3rd International Conference on
Frontiers in Nuclear Structure, Astrophysics and Reactions

FINUSTAR3

Rodos Palace Hotel, Rhodes, Greece
August 23-27, 2010

Organized by:
Tandem Accelerator Laboratory, Institute of Nuclear Physics,
NCSR "Demokritos", Aghia Paraskevi, Athens, Greece
and
Accelerator Laboratory, Department of Physics,
University of Jyväskylä, Jyväskylä, Finland

Funded by the EC
(FP7/REGPOT/LIBRA – Grant 230123)

Abstracts
Participants

FINUSTAR 3

Rhodes, Greece, August 23-27, 2010

LIBRA

REGPOT/Grant 230123

SEVENTH FRAMEWORK PROGRAMME

EDITED BY

P. Demetriou (Institute of Nuclear Physics, NCSR "Demokritos")

T. J. Mertzimekis (Tandem Accelerator Lab., Institute of Nuclear Physics, NCSR "Demokritos")

S. V. Harissopulos (Tandem Accelerator Lab., Institute of Nuclear Physics, NCSR "Demokritos")

AUGUST 2010

FINUSTAR 3rd International Conference on
Frontiers in Nuclear Structure, Astrophysics and Reactions
23-27 August 2010, Rhodos, Greece

Chairs

Rauno Julin (JYFL, Jyväskylä)
Sotirios Harissopulos (NCSR "Demokritos", Athens)

Scientific Secretary

Paraskevi Demetriou (NCSR "Demokritos", Athens)

Organizing Committee

Theo J. Mertzimekis (NCSR "Demokritos", Athens)
Anastasios Lagoyannis (NCSR "Demokritos", Athens)
Michael Axiotis (NCSR "Demokritos", Athens)
Miltiades Andrianis (NCSR "Demokritos", Athens)
Stephen F. Ashley (NCSR "Demokritos", Athens)
Iain D. Moore (JYFL, Jyväskylä)
Panu Rakhila (JYFL, Jyväskylä)

International Advisory Committee

Ken Amos (U. Melbourne)
Dimiter Balabanski (INRNE, Sofia)
Jonathan Billowes (U. Manchester)
Bertram Blank (CENBG, Bordeaux)
Yorick Blumenfeld (ISOLDE/CERN)
Angela Bonaccorso (INFN Pisa)
Maria Borge (CSIC, Madrid)
Mark Chadwick (LANL, Los Alamos)
Jacek Dobaczewski (JYFL, Jyväskylä)
Yussef El Masri (UCL, Louvain-la-Neuve)
Lidia Ferreira (CFIF, IST, Lisbon)
Mamoru Fujiwara (RCNP, Osaka)
Hans Fynbo (U. Aarhus)
Sydney Gales (GANIL, Caen)
Paul Garrett (U. Guelph)
Stephane Goriely (ULB, Brussels)
Magne Guttormsen (U. Oslo)
Muhsin Harakeh (RUG, Groningen)
Jordi José (UPC, Barcelona)
Reiner Krücken (TU Munich)
Silvia Lenzi (U. Padova & INFN)
Bradley Meyer (U. Clemson)
Bill Lynch (MSU, East Lansing)
Takaharu Otsuka (U. Tokyo)
Claus Rolfs (RU Bochum)
Christoph Scheidenberger (GSI, Darmstadt)
Olivier Sorlin (GANIL, Caen)
Claudio Spitaleri (LNS, Catania)
Alejandro Szanto de Toledo (U. Sao Paolo)
Hiroaki Utsunomiya (Konan U., Kobe)
Roza Vlastou (NTUA, Athens)
Alan Wuosmaa (WMU, Kalamazoo)
Andreas Zilges (U. Cologne)

Email: finustar3@inp.demokritos.gr

Website: http://www.inp.demokritos.gr/~finustar3

A few words about FINUSTAR 3 and LIBRA

FINUSTAR 3 is the 3rd in a series of international conferences previously held in 2005[1] in the isle of Kos, Greece and in 2007[2] in Agios Nikolaos, Crete, Greece. Just like the previous ones, this conference aims at covering a wide spectrum of research activities in nuclear structure, nuclear astrophysics and nuclear reactions that due to common instrumentation and research facilities have been overlapping strongly over the last years. FINUSTAR 3 covers the following topics, both experimental and theoretical:

- Nuclear structure at the extremes.
- Collective phenomena and phase transitions in nuclei.
- Exotic excitations.
- Synthesis and structure of the heaviest elements.
- Nuclear masses and ground state properties.
- Ab-initio calculations and the shell model.
- Mean field theories, cluster models and molecular dynamics.
- Scattering and reaction dynamics at low and intermediate energies.
- Nuclear reactions off stability and indirect methods.
- Neutrinos in nuclear astrophysics and astroparticle physics.
- Nuclear astrophysics (Big-Bang, s-, r- and p-process nucleosynthesis).
- Radioactive and exotic relativistic beams.
- Facilities and instrumentation for the future.

FINUSTAR 3 is supported by the EC through the project entitled *Center of Excellence in Low-energy Ion-Beam Research and Applications – LIBRA*[3] which is funded within the CAPACITIES/ REGPOT program of FP7. This allows us to hold the conference in one of the best equipped convention centres in the Mediterranean, the 5-star Rodos Palace Hotel.

The Center of Excellence in **L**ow-Energy **I**on-**B**eam **R**esearch and **A**pplications (LIBRA) runs since January 1, 2009. The LIBRA project was funded by the European Commission within the "Research Potential" (REGPOT) scheme of the FP7-Capacities program. The objectives of LIBRA is to unlock and develop further the research potential of the Tandem Accelerator Laboratory of the Institute of Nuclear Physics (INP) of the National Centre for Scientific Research "Demokritos" and to strengthen the capacity of the INP's research group by: a) Increasing the personnel of the INP group, b) Facilitating the transfer of know-how and expertise in forefront research areas and technological developments from certain European institutions (Partner Institutions) with leading roles in ion-beam based scientific research to INP, c) Enabling an active participation of the INP group in R&D activities at EU level, d) Upgrading and extending the existing infrastructure of the Tandem Accelerator Laboratory of INP improving this way its response to the socio-economic needs of the country as well as of the whole Southeast European and Mediterranean region, e) Promoting the existing research and training capacity of INP and enhancing its international reputation and visibility. LIBRA targets three different research directions: Nuclear Astrophysics, Nuclear Structure, and Ion-Beam Applications.

---

[1] http://www.inp.demokritos.gr/~finustar
[2] http://www.inp.demokritos.gr/~finustar2
[3] http://libra.inp.demokritos.gr

Contents

pages

INVITED SPEAKERS

	Speaker	Talk Title
1	**A. Algora** *(IFIC Valencia, Spain)*	*TAS measurements for reactor physics and nuclear structure*
2	**J. Aÿstö** *(University of Jyväskylä, Finland)*	*Penning Trap Mass Spectrometry of Exotic Nuclei*
3	**F. de Oliveira Santos** *(GANIL, Caen, France)*	*Nuclear astrophysics with light nuclei at GANIL*
4	**A. Di Pietro** *(LNS & INFN, Catania, Italy)*	*Elastic Scattering of Beryllium isotopes at the Coulomb barrier*
5	**A. Diaz-Torres** *(U. Surrey, UK)*	*Coupled-channel density-matrix approach to reaction dynamics*
6	**P. Fallon** (*LBL, Berkeley, USA)*	*Lifetime Measurement of the 2^+ State in ^{16}C and ^{20}C: Electromagnetic Transition Rates*
7	**K. Flanagan** *(U. Manchester, UK)*	*Laser Spectroscopy: Present and Future at ISOLDE*
8	**A. Gadea** *(IFIC Valencia, Spain)*	*Highly Retarded GT decay to the quasi-deuteron 1^+ state in odd-odd ^{62}Ga: absence of proton-neutron T=0 condensate in the N=Z, A=62 Nucleus*
9	**G. Hagen** *(ORNL, Oak Ridge, USA)*	*Coupled Cluster Approach to Medium Mass and Neutron Rich Nuclei*
10	**R. Herzberg** *(U. Liverpool, UK)*	*In-beam and Decay Spectroscopy of Superheavy Nuclei*
11	**S. Hilaire** *(ICEA, DAM, DIF, Arpajon, France)*	*Nuclear ingredients for cross section calculation of exotic nuclei*
12	**N. Kalantar-Nayestanaki** *(KVI, Univ. of Groningen, The Netherlands)*	*The EXL experiment @ FAIR and plans with the ESR @ GSI*
13	**J. Kurcewicz** *(GSI, Darmstadt, Germany)*	*New isotope production around the 3rd r-process peak*

14	**K.-H. Langanke** *(GSI, Darmstadt, Germany)*	*The FAIR Chance for Nuclear Astrophysics*
15	**A. C. Larsen** *(U. Oslo, Norway)*	*Gamma-ray strength at low energies-review of experiments*
16	**A. Parikh** *(TU München, Germany)*	*Improving the $^{33}S(p,\gamma)^{34}Cl$ reaction-rate for classical nova explosions*
17	**S. Romano** *(LNS-INFN & U. Catania, Italy)*	*The Trojan Horse Method and its Applications in Nuclear Astrophysics and in Nuclear Physics: Recent Results.*
18	**H. Sakai** *(RIKEN & U. Tokyo, Japan)*	*First charge-exchange measurements with SHARAQ*
19	**H. Sakurai** *(RIKEN, Japan)*	*New Generation of Physics with Exotic Nuclei at RIBF*
20	**H. Simon** *(GSI, Darmstadt, Germany)*	*Light exotic systems at relativistic Velocities*
21	**F. Strieder** *(U. Bochum, Germany)*	*Key Reactions in Nuclear Astrophysics: $^{12}C(\alpha,\gamma)^{16}O$ and $^{12}C+^{12}C$ Fusion*

TAS measurements for reactor physics and nuclear structure

A. Algora

IFIC (CSIC-Univ. Valencia), Valencia, Spain

In this contribution we will present recent total absorption measurements of the beta decay of neutron-rich nuclei performed at the IGISOL facility of the Univ. of Jyväskylä. In these measurements the JYFL Penning Trap was used as a very high resolution isobaric separator. The total absorption technique will be described and the impact of recent results in the fields of reactor physics (decay heat calculations) and nuclear structure will be discussed.

Penning Trap Mass Spectrometry of Exotic Nuclei *

Juha Äystö
and the JYFLTRAP Collaboration

Department of Physics, P.O. Box 35 (YFL), FI-40014 University of Jyväskylä, Finland

Manipulation of radioactive isotopes with ion traps has opened new opportunities in atomic and nuclear spectrometry. The applications employed so far include high-precision mass measurements as well as studies by laser and decay spectroscopy where high sensitivity and purity is obtained through ion manipulation in Penning and Paul traps. In my talk I will discuss recent precision mass measurements using the JYFLTRAP setup at the IGISOL facility. These experiments are related to probing the nuclear structure effects in binding energies and the fine structure of the nuclear mass surface near the doubly magic ^{78}Ni, ^{100}Sn and ^{132}Sn nuclei as well as to nucleosynthesis via the rapid proton- and neutron capture processes [1,2].

* This work is supported by the Academy of Finland.

[1] J. Hakala et al., Phys. Rev. Lett. 101 (2008) 052502
[2] V. Elomaa et al., Phys. Rev. Lett., 102 (2009) 252501

Nuclear astrophysics with light nuclei at GANIL

François de Oliveira Santos

GANIL Grand Accélérateur National d'Ions Lourds B.P. 5027 F-14076 Caen Cedex, France

The astrophysical phenomena such as Novae, Supernovae or X-ray bursts are among the most fascinating subjects. With the advent in our laboratories of accelerated radioactive beams, new opportunities of studies open up. Several examples of studies related to this field and performed at GANIL with radioactive nuclei will be presented. In particular, the measurement of radiative alpha capture reactions is of prime importance in the understanding of the origin of the p-nuclei. Exploratory experimental studies will be presented. The role of simultaneous two-proton capture reactions in extremely dense and hot environments is discussed. Other competing exotic reaction mechanisms, e.g. the reaction (p,γβ), will be presented. With the objective to better understand the effects of the continuum, measurements of the properties of the unbound nuclei ^{19}Na, ^{16}F, ^{18}Na were performed. Electron screening effects in nuclear reactions and in the lifetime of nuclei is a subject of debate. A new experiment and new ideas will be presented.

Elastic scattering of Beryllium isotopes at the Coulomb barrier

A. Di Pietro

INFN-Laboratori Nazionali del Sud and Sezione di Catania, Italy

Elastic scattering and reaction mechanisms around the barrier, in reaction induced by halo nuclei, has been the object of many publications in the last years (see e.g. [1-3] and ref. therein). In collisions induced by halo nuclei, direct reactions, as for instance transfer or break-up, may be favored owing to the low binding energy, the extended tail of the matter distribution and the large Q-value for selected transfer channels. Moreover, the effects of the coupling to the continuum on the fusion cross-section are not fully understood.

Experimentally, almost all elastic scattering and reaction mechanism studies around the barrier with halo nuclei have been performed with 2n halo nucleus ^{6}He and only few experiments have been performed with 1n halo ^{11}Be [4,5]. In this contribution new results concerning different reaction channels for the collisions ^{9,10,11}Be+^{64}Zn at the same center of mass energy, close to the Coulomb barrier, will be presented. The analysis of elastic scattering shows a damped elastic angular distribution for the collision induced by the ^{11}Be halo nucleus when compared to the ones induced by ^{9,10}Be. Correspondingly, the total reaction cross-section extracted for ^{11}Be +^{64}Zn is more than a factor of two larger than for the other two systems. It will be shown that such an enhancement of the total reaction cross-section with ^{11}Be is due to the presence of strong transfer/break-up channels.

[1] L.F. Canto et al., Phys. Rep. 424, 1 (2006).
[2] N. Keeey et al., Prog. Part. and Nucl. Phys. 59, 579 (2007).
[3] N. Keeey et al., Prog. Part. and Nucl. Phys. 63, 396 (2009).
[4] M. Mazzocco et al., Eur. Phys. J. A 28, 295 (2006).
[5] L. Acosta et al., Eur. Phys. J. A 42, 461 (2009).

Coupled-Channels Density-Matrix Approach to Reaction Dynamics

Alexis Diaz-Torres

Department of Physics, University of Surrey, GU2 7XH, United Kingdom

Coupled-channels approaches have been very successful in explaining several collision observables. However, problems remain. Foremost is the inability to describe elastic scattering and fusion measurements simultaneously and, related, the more recent failure to describe in a physically consistent way the below-barrier quantum tunneling and above barrier fusion yields [1].

These problems may be caused by the neglect of important physical processes (e.g., deep-inelastic) which cannot be treated within (standard) coupled-channels models. Measurements [2] have shown that deep-inelastic processes occur even at sub-barrier incident energies, in competition with the process of quantum tunneling, and thus fusion.

The understanding of this complex interplay, at near- and below barrier energies, requires a dynamical model which can describe coupling assisted tunneling with dissipation. I will present a novel coupled-channels density-matrix approach [3] that overcomes these difficulties. The coupled-channels description is formulated with the Lindblad equation for a reduced density matrix. It describes the time evolution of the reduced system (comprising the relative motion of the nuclei plus selected, intrinsic collective excitations) that irreversibly interacts with an “environment” of complex excitations.

The development provides a significant step towards an improved theoretical understanding of low-energy collision dynamics, as model calculations exhibit both quantum decoherence and energy dissipation. These cannot be treated within standard coupled channels approaches [4]. Effects of decoherence and dissipation on reaction dynamics can be manifested outside the fusion barrier radius, changing the quantum tunneling probability (fusion) and scattering observables.

[1] M. Dasgupta *et al.*, Phys. Rev. Lett. **99**, 192701 (2007), and references therein.
[2] D.J. Hinde *et al*., Nucl. Phys. **A834**, 117c (2010).
[3] A. Diaz-Torres *et al.*, Phys. Rev. **C78**, 064604 (2008).
[4] A. Diaz-Torres, Phys. Rev. **C81**, 041603(R) (2010).

Lifetime Measurement of the 2^+ State in ^{16}C and ^{20}C: Electromagnetic Transition Rates at the Limit of Stability*

Paul Fallon

Lawrence Berkeley National Laboratory, Berkeley CA 94720, USA

The search for new phenomena and nuclear structure effects due to weak nucleon binding and "de-coupling" of neutrons and protons is of great interest. Examples of such decoupled behavior include neutron halo nuclei and low-energy dipole modes such as "pygmy" resonances. Information on the coupling between the valence neutrons and the core, and on the effects of weak binding can also be obtained from measurements of the electric quadrupole transition strength B(E2) - particularly where the low lying 2^+ state has a predominant neutron excitation. Neutron-rich carbon isotopes have received a great deal of attention recently, both experimental and theoretical, in regards to the question of spatially extended (halo-like) and possibly decoupled valence neutrons. The observation of low B(E2: 2^+->0^+) values is cited as one of the main pieces of experimental evidence for a reduced coupling in these nuclei.

This talk will focus on data from a direct lifetime measurement of the 2^+ state in ^{16}C and ^{20}C obtained in experiments carried out at the NSCL (Michigan State University) using the recoil distance method. This is the first measurement of the ^{20}C 2^+ state lifetime and provides an important data point at the limit of stability. We find the B(E2: 2^+->0^+) value for ^{16}C to be consistent with recent measurements. The data for ^{20}C indicates an increasing B(E2) relative to $^{16,18}C$. We interpret this in terms of an increased proton amplitude in the ^{20}C 2^+ state due to a weakening of proton $p_{3/2}$-$p_{1/2}$ spin-orbit splitting with increasing neutron number, caused by the interaction between valence neutrons and protons. The $^{16,18,20}C$ B(E2) values are reproduced by shell model calculations using a *p-sd* model space and with smoothly decreasing polarization charges following an approximate 1/A dependence.

* This work was supported in part by the DOE Office of Nuclear Physics under contract No.DEAC02-05CH11231.

Laser spectroscopy - present and future at ISOLDE

K. Flanagan

U. Manchester, UK

Laser spectroscopy experiments at the ISOLDE facility already have a venerable history now spanning more than 30 years. This period has seen the development of a remarkable variety of laser techniques in order to study rare isotopes far from stability, which include in-source, collinear and β-NMR/β-NQR laser spectroscopy to name but a few. These innovative ideas reflect the demands placed on laser spectroscopy by not only the element under study, but also the mechanism by which it is produced. The propensity for innovation in laser spectroscopy at ISOLDE has continued in the last two years, helped in part by synergies with laboratories across Europe. This has been crucial for the successful application of bunched-beam spectroscopy being successfully applied to study the Cu and Ga isotope chains. The introduction of the frequency comb has allowed absolute frequency measurements to be made on the Be isotope chain, permitting the charge radii to be determined for the one-neutron halo nucleus, ^{11}Be. New ionization schemes have been developed for the Po atom, which allowed in-source spectroscopy to be performed down to ^{191}Po, which was detected with a rate of approximately 0.1 atoms/second.

The future HIE-ISOLDE facility will provide experimentalists with improved ion-beam quality, increased yields and a larger number of accessible elements. Several new experiments are now in preparation to maximise the reach of laser spectroscopy at HIE-ISOLDE, which include collinear resonance ionization spectroscopy, in-cooler optical pumping and ion- resonance ionization spectroscopy. This talk will present a review of the recent laser spectroscopy experiments at ISOLDE and the future prospects at the HIE-ISOLDE facility.

Highly Retarded GT decay to the quasi-deuteron 1^+ state in odd-odd ^{62}Ga: absence of proton-neutron T=0 condensate in the N=Z, A=62 Nucleus

A. Gadea

Instituto de Física Corpuscular, CSIC-Universidad de Valencia, Spain
Laboratori Nazionali di Legnaro, INFN, Legnaro, Italy

It is well known that in the atomic nucleus, alike nucleons (neutrons or protons) in time reverse orbits, couple in pairs giving rise to nuclear superfluidity, with very significant impact in the structure as well as in the collective properties of the nucleus. In addition, nuclei consist of a combination of two fermionic fluids (neutrons and protons) and as a consequence of the isospin (T) degree of freedom, four types of pairs, the triplet with T=1, J=0 and the singlet T=0 J>0, are expected. It has been shown that T=0 pairs will be only relevant in the vicinity of N=Z nuclei [1,2]

In medium mass N=Z nuclei, the existence of T=0 pairing has been studied searching for the absence of Coriolis Anti-Pairing effects at high angular momentum in rotational bands [1,2,3]. Nevertheless no clear-cut signature has been found. It has been suggested that enhanced Gamow-Teller (GT) b-decay rates between the ground state of an even-even N+2=Z nucleus and the lowest I=1 state of its odd -odd N=Z daughter nucleus can be the fingerprint of T=0 pairing. The role played in β-decay by proton-neutron coherent pairs (bosons) have been extensively discussed by F. Iachello [4,5] in the framework of the proton-neutron boson scheme (IBM-4).

While in light nuclei strong GT transitions to low lying states result from the presence of approximate SU(4) symmetry, the existence of strong spin-orbit splitting, in heavier nuclei, suppresses the symmetry. The GT strength can then be fragmented over many final states resulting in a reduced B(GT) for the low lying ones [6,7,8].

The Gamow-Teller β-decay of the ^{62}Ge T=1 0^+ g.s. into excited states of the odd-odd N=Z ^{62}Ga have been studied for the first time at the GSI laboratory with the Fragment Separator (FRS) and the RISING Ge-array coupled to an active implantation setup.

The aim of the present was to seek for an enhancement of the B(GT) as fingerprint of the proton-neutron T=0 condensate in the odd-odd N=Z nuclei. Contrary to expected, a diminish B(GT)=0.07±17 $g_A^2/4p$ has been observed for the transition to the first 1^+ state lying at 571 keV excitation energy. A lifetime of t =119.6 ±20 ms has been measured for the ^{62}Ge ground state.

[1] W. Satula and R. Wyss, Phys Lett. B 393 (1997) 1
[2] S. Frauendorf , J. Sheikh Nucl. Phys. A 645 (1999) 509
[3] G.de Angelis et al., Phys. Lett. B 415 (1997) 217
[4] F.Iachello, Proc. Int. Conf. on Perspectives for the IBM, Padova Italy, (1994) p.1.
[5] F.Iachello, Yale University preprint YCTP-N13-88 (1988).
[6] P.Van Isaker, Rep. Prog. Phys. 62 (1999) 1661.
[7] A.F. Lisetskiy, et al., Eur. Phys. J. A 26 (2005) 51.
[8] I. Petermann, et al., Eur. Phys. J. A 34 (2007) 319.

Coupled Cluster Approach to Medium Mass and Neutron Rich Nuclei

G. Hagen[1], T. Papenbrock[1,2], D. J. Dean[1] and M. Hjorth-Jensen[3]

[1]*Physics Division, Oak Ridge National Laboratory, Oak Ridge, TN 37831, USA*
[2]*Dept. of Physics and Astronomy, University of Tennessee, Knoxville, TN 37996, USA*
[3]*Dept.of Physics and Center of Mathematics for Applications, University of Oslo, N-0316 Oslo, Norway*

The nuclear many-body problem is a challenging undertaking, and coupled-cluster theory is a very promising candidate for pushing the *ab initio* nuclear structure program into regions of medium mass and neutron rich nuclei. With coupled-cluster theory, it is our goal to address the two frontiers in the nuclear physics community; *What is the role of threenucleon forces in medium mass and neutron rich nuclei? What is the role of the scattering continuum on the evolution of nuclear shell structure and location of driplines?*

Recently we reformulated coupled-cluster theory in a spherical formulation, and this allowed us to treat model space sizes of 20, or more, major oscillator shells. With these enormous model space sizes we could study the saturation of ``bare'' chiral NN interactions in medium mass nuclei [1,2] and in the neutron rich oxygen isotopes ^{16,22,24,28}O [3]. In particular, we found that ^{16}O and ^{48}Ca are under bound by about 400keV per particle while ^{40}Ca is slightly over bound with respect to experiment. We have also developed spherical equation-of-motion theory for the description of ground- and excited states in the odd mass A±1 neighbours of a closed shell nucleus with mass A. With the spherical formulation we can handle the enormous model space sizes required to take the coupling with the scattering continuum into account. In Ref. [5] we presented the first *ab initio* calculation of the $1/2^+$ halo state in ^{17}F and the $3/2^+$ resonances in ^{17}F and ^{17}O using equation-of-motion coupled-cluster theory and chiral NN interactions. We found that the coupling with the continuum gives a significant amount of additional binding for the low-lying $1/2^+$, $3/2^+$, and $5/2^+$ states in ^{17}F and ^{17}O. Our calculation of the $1/2^+$ state in ^{17}F agree remarkably well with experiment, and we argue that this state is insensitive to short ranged three-nucleon forces. The calculated energies of the $3/2^+$ resonances in ^{17}F and ^{17}O are in rather good agreement with experiment, but the ($3/2^+$ - $5/2^+$) spin-orbit splitting are too compressed due to the lack of three-nucleon forces.

[1] G. Hagen, T. Papenbrock, D.J. Dean, and M. Hjorth-Jensen, Phys. Rev. Lett. **101,** 092502 (2008).
[2] G. Hagen, T. Papenbrock, D.J. Dean, M. Hjorth-Jensen, submitted to Phys. Rev. C (2010), arXiv:1005.2627
[3] G. Hagen, T. Papenbrock, D.J. Dean, M. Hjorth-Jensen, and B. Velamur Asokan, Phys. Rev. C **80**, 021306 (2009).
[4] G. Hagen, T. Papenbrock, and D.J. Dean, Phys. Rev. Lett. **103**, 062503 (2009).
[5] G. Hagen, T. Papenbrock, and M. Hjorth-Jensen, Phys. Rev. Lett. **104**, 182501 (2010).

Spectroscopy of superheavy nuclei *

R.-D. Herzberg

Department of Physics, University of Liverpool Liverpool, L69 7ZE, UK

A growing number of experiments is currently opening up the transfermium region of nuclei for detailed spectroscopic investigations [1,2]. In the deformed nuclei in the nobelium region this allows identification and mapping of single particle orbitals closest to the top end of the nuclear chart.

Initial in-beam measurements in the region focused on γ-ray spectroscopy of even-even nuclei (e.g. ^{252,254}No, ^{250}Fm), studying the ground-state yrast bands and allowing extraction of parameters such as the moments of inertia, and proving the deformed nature of these nuclei. More recently, attention has switched to odd-mass nuclei such as ^{253}No, ^{251}Md and ^{255}Lr, the latter being the heaviest nucleus so far studied in-beam. Rotational bands have been observed in all these nuclei. Non-yrast and K-isomeric states have recently been observed in ^{252,254}No and ^{250}Fm through the use of both in-beam and focal plane decay spectroscopy. The studies employed a calorimetric technique, whereby the summed energy from a cascade of conversion electrons is detected in a DSSSD detector and used as a "tag" for γ-rays detected in the various germanium detectors. These experiments have yielded data which can be used to determine the excitation energies and configurations of two quasiparticle states in the region, and compared to the predictions of various theories. These comparisons show that reasonable agreement is obtained with Woods-Saxon approaches but discrepancies are observed with the predictions of HFB calculations with SLy4 or Gogny interactions. Such observations highlight the need for such detailed spectroscopic data in order to improve the interactions used in these modern approaches.

An overview of the most recent results and the experimental techniques used will be presented and new experimental developments such as the SAGE spectrometer coming online in Jyvaskyla and the new TASISpec setup at will be discussed.

* This work is supported by the UK STFC.

[1] R.-D. Herzberg, J. Phys. G 30, R123 (2004).
[2] R.-D. Herzberg, P.T. Greenlees, Prog. Part. Nucl. Phys. 61, 674 (2008).

Nuclear ingredients for cross section calculation of exotic nuclei

S. Hilaire[1], S. Goriely[2], A. Koning[3], M. Girod[1]

[1]*ICEA, DAM, DIF, F-91297 Arpajon, France.*
[2]*Institut d'Astronomie et d'Astrophysique, Université Libre de Bruxelles, Campus de la Plaine, CP 226, B-1050 Brussels, Belgium.*
[3]*Nuclear Research and Consultancy Group, P.O. Box 25, NL-1755 ZG Petten, The Netherlands.*

The increasing need for cross sections far from the valley of stability, especially for applications such as nuclear astrophysics, poses a challenge for nuclear reaction models. So far, predictions of cross sections have relied on more or less phenomenological approaches, depending on parameters adjusted to available experimental data or deduced from systematic relations. While such predictions are expected to be reliable for nuclei not too far from the experimentally known regions, it is clearly preferable to use more fundamental approaches, based on sound physical bases, when dealing with very exotic nuclei.

Thanks to the high computer power available today, all major ingredients required to model a nuclear reaction can now be (and have been) microscopically (or semi-microscopically) determined starting from the information provided by a nucleon-nucleon effective interaction. We have implemented all these microscopic ingredients in the latest version of the TALYS nuclear reaction code [1], and we are now able to perform fully microscopic cross section calculations.

We will discuss both the quality of these ingredients and the impact of using them instead of the usually adopted phenomenological parameters. We will also discuss the foreseen evolutions of the models and of the ingredients on which they rely.

[1] http://www.talys.eu

The EXL experiment @ FAIR and plans with the ESR @ GSI

Nasser Kalantar-Nayestanaki

KVI, University of Groningen, Groningen, The Netherlands

The upcoming FAIR facility in Darmstadt, Germany, will produce intense high energy beams of exotic nuclei, which will be used to explore the properties of new regions of the chart of nuclides of key importance for both nuclear structure and nuclear astrophysics. Since the nucleus under study is the one which is produced in the process of in-flight fragmentation, one has to deal with inverse kinematics in which the hadronic probe, generally a light nucleus, is the target being bombarded by the heavy nucleus. The inverse kinematics will impose particular conditions on the design of detection systems. In the EXL project, heavy ion beams are first cooled in the New Experimental Storage Ring (NESR) and then used to induce reactions on windowless thin Hydrogen, deuterium and Helium gas targets in the ring. High luminosities can be achieved because the beam circulates a couple of million times in the ring. The EXL system will be ideal for high resolution reaction studies at low momentum transfers, for example the study of nuclear sizes using protons, giant resonance properties using inelastic light-ion scattering – such studies provide unique insights into the asymmetry energy in the nuclear equation of state and the properties of neutron stars. The design of the detector system considered is universal in the sense that it should allow the use of a large variety of nuclear reactions, addressing numerous physics questions. The detector system provides the capability of fully exclusive kinematical measurements, with target recoil detectors, fast ejectile forward detectors and an in-ring heavy-ion spectrometer. Technologically, the requirement that the detectors should be placed in the ultra-high vacuum of the ring is most demanding and requires non-standard solutions of the detector design.

The physics case and detector design considerations for EXL will be presented in this talk along with experimental plans with the present ESR at GSI.

New isotope production around the third r-process peak

J. Kurcewicz[1], S. Pietri[1], F. Farinon[1,2], H. Geissel[1,2], C. Nociforo[1], A. Prochazka[1,2], H. Weick[1], P. Allegro[3], J. Benlliure[4], G. Benzoni[5], M. Bunce[6], M. Bowry[6], P. Boutachkov[1], J.Gerl[1], M.Górska[1], A. Gottardo[7], N. Gregor[1], R. Janik[8], R. Knöbel[1], I. Kojouharov[1], T. Kubo[9], Yu. A. Litvinov[1,10], E. Merchan[1], I. Mukha[1], F. Naqvi[1,11], B. Pfeiffer[1], M. Pfützner[12], W. Plaß[2], M. Pomorski[12], Zs. Podolyak[6], P. Regan[6], B. Riese[1], M.V. Ricciardi[1], H. Schaffner[1], C. Scheidenberger[1,2], B. Sitar[8], P. Spiller[1], J. Stadlmann[1], P. Strmen[8], B. Sun[2,13], I. Szarka[8], H. Takeda[9], I. Tanihata[14], S. Terashima[9], J.J. Valiente-Dobón[7], J.S. Winfield[1], M. Winkler[1], H.-J. Wollersheim[1], Ph. Woods[15]

[1]GSI, Darmstadt, Germany; [2]JLU Giessen, Germany, [3]USP, Sao Paulo, Brazil; [4]USC, Santiago de Compostela, Spain; [5]INFN-Universita di Milano, Italy; [6]University of Surrey, Guildford, UK; [7]LNL-INFN Legnaro, Italy; [8]Comenius University, Bratislava, Slovakia; [9]RIKEN Nishina Center, Wako, Japan; [10]MPI-K, Heidelberg, Germany; [11]IKP, Köln, Germany; [12]IEP, Warsaw, Poland; [13]Beijing University, China; [14]Osaka University, Japan; [15]University of Edinburgh, UK.

The development of the numerous Radioactive Ion Beams facilities in the last 20 years, has contributed to a better understanding of the synthesis of the elements in the stars with new measurements of crucial nuclear data including half-lives, masses and neutron-pairing energies of the most exotic nuclei.

In particular relativistic projectile fragmentation reactions represent a unique and powerful method for the production of heavy neutron-rich nuclei near and at the shell closures of N=82 and N=126. In this contribution we discuss the results of an experiment performed at the SIS synchrotron of GSI Darmstadt, which delivered a 1 A GeV ^{238}U beam impinging on a 1.6 g/cm2 thick beryllium target placed at the entrance to the projectile Fragment Separator (FRS) [1]. The primary beam intensity was about $2*10^9$ ions/spill. The reaction products were separated by the FRS operated in the standard achromatic mode. The implantation point located at the final focal plane was surrounded by the RISING germanium detector setup [2]. The isomer tagging technique was applied in order to facilitate the identification of the reaction products. Several *B*r settings of the FRS were used yielding optimum beam intensities for neutron rich Dy, Os, Hf, Pt and At isotopes. We report on the discovery of heaviest neutron-rich isotopes with Z<92. The measured production yields of the studied neutron-rich isotopes will be discussed. Lifetime and mass measurements at N=126 will be the next steps in this experimental campaign.

[1] H. Geissel et al. NIM B 70, (1992) 286
[2] S. Pietri et al. NIM B 261, (2007) 1079

The FAIR Chance for Supernovae

K. Langanke

GSI Helmholtzzentrum für Schwerionenforschung, Planckstr. 1, D-64291 Darmstadt, Germany
and
Institut für Kernphysik, Technische Universität Darmstadt, D-64289 Darmstadt, Germany

In October the convention for the construction of FAIR, the Facility for Antiproton and Ion Research, to be built in Darmstadt will be signed by the international partners. This facility will start a new era in nuclear astrophysics allowing for the experimental determination of crucial nuclear physics input for the simulations of core-collapse supernovae and their associated explosive nucleosynthesis. The talk will highlight recent progress in the understanding of this research topic and will outline the opportunities offered by FAIR.

Gamma-ray strength functions and their relation to astrophysics*

A.C. Larsen[1], S. Goriely[2], A. Bürger[1], M. Guttormsen[1], A. Görgen[1,3], H. T. Nyhus[1], A. Schiller[4], S. Siem[1], H.K. Toft[1], G.M. Tveten[1], and A. Voinov[4]

[1]*Department of Physics, University of Oslo, N-0316 Oslo, Norway*
[2]*Institut d'Astronomie et d'Astrophysique, Université Libre de Bruxelles, CP 226, 1050 Brussels, Belgium.*
[3]*Dapnia/SPhN, CEA-Saclay, France*
[4]*Department of Physics and Astronomy, Ohio University, Athens, Ohio 45701, USA.*

One of the most challenging topics within nuclear astrophysics today is the description of the observed element abundances in our solar system and the universe. The reaction mechanisms that are called for to describe the stellar nucleosynthesis include rapid neutron capture, slow neutron capture, and photodisintegration. However, as of today, the scientific community is far from having a complete picture of the nucleosynthesis. One reason for this is that the astrophysical site for the rapid neutron capture process is still not firmly established; another is due to the wealth of required nuclear information.

Two indispensable quantities that enter the reaction codes are the nuclear level density and the γ-ray strength function, where the latter one is particularly important for neutron-capture cross sections. The -ray strength function gives information on the average electromagnetic decay properties of the nucleus, and is dominated by the Giant Electric Dipole Resonance (GEDR). However, soft resonances in the γ-ray strength function close to the neutron threshold may have a large impact on the neutron-capture cross sections and consequently on the astrophysical reaction rates relevant for the r-process [1,2].

Experimental data on γ-ray strength functions measured at the Oslo Cyclotron Laboratory (OCL) will be presented, as well as calculated neutron-capture cross sections for some key cases where the input model for the -ray strength function is modified to fit the data. Also the impact on the astrophysical rates will be demonstrated.

* This work is financed by the Research Council of Norway.

[1] S. Goriely, Phys. Lett. B436, 10 (1998).
[2] A. C. Larsen and S. Goriely, submitted to Phys. Rev. C.

Improving the $^{33}S(p,\gamma)^{34}Cl$ reaction-rate for classical nova explosions

A. Parikh, T. Faestermann, R. Krücken, V. Bildstein, S. Bishop, K. Eppinger, C. Herlitzius, O. Lepyoshkina, P. Maierbeck, D. Seiler, K. Wimmer
TU-München, Garching, Germany
R. Hertenberger, H.-F. Wirth
LMU- München, Garching, Germany
C. Ruiz, J. Fallis, U. Hager, D. A. Hutcheon, D. Ottewell
(TRIUMF, Vancouver, Canada)
C. Wrede, B. Freeman, A. García, B. Delbridge, A. Knecht, A. Sallaska
(Univ. Washington, Seattle, USA)
P. Bertone, J. A. Clark
(Argonne, USA)
C. Deibel
(Joint Institute of Nuclear Astrophysics, USA; Argonne, USA)
A. A. Chen
(Excellence Cluster Universe, Garching, Germany; McMaster Univ., Hamilton,Canada)
K. Setoodehnia
(McMaster Univ., Hamilton, Canada)
U. Greife
(Colorado School of Mines, Golden, USA)
P. D. Parker
(Yale Univ., New Haven, USA)
B. Guo, Z. Li, E. Li, G. Lian, Y. Wang
(China Institute of Atomic Energy, Beijing, China)

The analysis of microscopic grains within primitive meteorites has revealed isotopic ratios largely characteristic of the conditions thought to prevail in various astrophysical environments. A large ^{33}S abundance may suggest a grain of nova origin: nucleosynthesis calculations predict as much as 150x the solar abundance of ^{33}S in the ejecta of oxygen-neon novae. This overproduction factor may, however, vary by several orders of magnitude because of uncertainties in the $^{33}S(p,\gamma)^{34}Cl$ reaction-rate over nova temperatures. In addition, better knowledge of this rate would help with the interpretation of nova observations over the S-Ca mass region, and contribute towards the firm establishment of a nucleosynthetic endpoint in these phenomena. Finally, constraining this rate may help to confirm or rule out the decay of a metastable state of ^{34}Cl (Ex=146 keV, $t_{1/2}$=32 m) as a source for observable gamma-rays from novae.

Direct examinations of the $^{33}S(p,\gamma)^{34}Cl$ reaction in the past have only identified resonances down to ER=434 keV. At nova temperatures, lower-lying resonances could certainly play a dominant role. We discuss several recent, complementary studies dedicated to improving our knowledge of the $^{33}S(p,\gamma)^{34}Cl$ rate, using both indirect methods (measurement of the $^{34}S(^{3}He,t)^{34}Cl$ and $^{33}S(^{3}He,d)^{34}Cl$ reactions with the Munich Q3D spectrograph) and direct methods (in normal kinematics at CENPA, θniversity of Washington, and in inverse kinematics with the DRAGON recoil mass separator at TRIUMF). Other indirect studies using the Munich Q3D spectrograph, relevant to improving the nuclear physics input to nova models, will also be discussed.

The Trojan Horse Method and its applications in nuclear astrophysics and in nuclear physics: recent results

S. Romano

Laboratori Nazionali del Sud – INFN and University of Catania

In the last two decades the Trojan Horse Method (THM) has been applied to several nuclear reaction involved in different astrophysical scenarios. The method allows to extract information on the astrophysical S(E)–factor in the energy regions where the direct measurements are strongly restricted [1-3].

The THM is based on the quasi-free break-up mechanism. A suitable three-body reaction is selected as a mean to investigate the two-body reaction of astrophysical interest. In the process it is assumed that the interaction between a projectile and the Trojan Horse particle, which may be described as made up by two clusters, involves only one cluster (participant) leaving the other one as a spectator. If the break-up of the target occurs in the nuclear interaction field, the hindering Coulomb Barrier is overcome. Appropriate kinematic conditions allow one to select the interacting energies as close as possible to the relevant Gamow energy. Finally, because of the three-body nature of the process, a continuous two body energy range can be explored in a single measurement.

Thus the THM can be applied to determine the energy dependence of the bare nucleus astrophysical $S_b(E)$-factor, without the Coulomb suppression as well as the electron screening effect.

Today, the method is recognized as the only technique to investigate nuclear effects at ultra low energies.

Recently, the same technique has been applied to reactions in which the participant to the process is a neutron. In these cases, of course, there are not coulomb effects. Thus the main advantage is the possible investigation of neutron induced reaction and its application both in nuclear and astrophysical scenarios.

The application of the method will be presented together with recent results. In particular a new result concerning the first experimental study of the 10 keV resonance in the ^{10}B + p interaction will be discussed. The 10B(p,α)7Be represents one of the most important reactions for the boron destruction in stellar atmospheres, and the bare nucleus S(E)-factor measurement can give useful hints for non-standard transport processes discrimination in stars [4].

[1] C. Spitaleri et al., Phys. Rev., **C60**, 055802 (1999);
[2] A. Tumino et al., Phys. Rev. **C67**(2003)065803;
[3] C. Spitaleri et al. Phys. Rev. **C69** (2004)055806;
[4] A.M. Boesgaard , *"The Light Elements: Lithium, Beryllium and Boron", Carnegie Observatories Astrophysics Series*, **Vol.4**: 2004.

First Charge-Exchange Measurements with SHARAQ*

K. Miki[1], H. Sakai[1,2] and NP0811-SHARAQ72 Collaboration

[1]*Dept. of Physics, University of Tokyo, Hongo 7-3-1, Bunkyo, Tokyo 113-0033, Japan*
[2]*RIKEN Nishina Center, RIKEN, Hirosawa 2-1, Wako, Saitama 351-0198, Japan.*

Spin-isospin responses are one of the most important fundamental collective modes in nuclei. The exothermic Heavy-Ion Charge-Exchange (HICE) reaction employing radioactive projectiles having a large positive reaction Q-value allows us to access the so far unexplored ω>q region (time-like region) in spin-isospin responses. Note that the HICE reactions with conventional stable beams can access only the ω<q region (space-like region). Here ω and q are the excitation energy and momentum transfer, respectively. In order to realize the study of spin isospin responses in ω>q, we have constructed the high resolution magnetic spectrometer SHARAQ under the ICHOR project1 (Isospin-spin responses in CHarge-exchange exothermic Reactions) and installed the SHARAQ in the experimental hall of the Radio-Isotope Beam Facility (RIBF) in RIKEN Nishina Center, taking an advantage of strong RI beam intensities of RIBF. The photograph of SHARAQ taken in spring of 2008 is shown below.

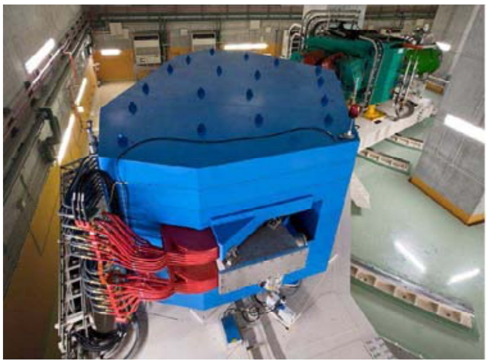


Fig. 1: The high resolution magnetic spectrometer as of spring 2008.

Among various kinds of spin-isospin responses, the isovector spin monopole resonance (IVSMR) attracts significant interest. Since the IVSMR is a breathing mode with spin and isospin flips, it can be related to the nuclear matter compressibility with spin and isospin degrees of freedom. Despite of the importance of the IVSMR, only few experiments are reported on IVSMR for the β^- channel and none for the β^+ channel. In order to establish the IVSMR(β^+), we carried out the measurement on the (t,^{3}He) reactions at 300 MeV/u. The triton beam of 300 MeV/u was produced by the fragmentation of the ^{4}He beam of 320MeV/u, and was bombarded on the secondary targets with an intensity of 1×10^7 pps. Produced ^{3}He particles were momentum-analyzed by the SHARAQ spectrometer. This is the first physics measurement utilizing SHARAQ. The double differential cross section spectra for the ^{208}Pb,^{90}Zr(t,^{3}He) reactions are obtained for $0<E_x<70$ MeV excitation energy and $0^o< \theta_{lab} <3^o$ scattering angles. In this talk, the SHARAQ construction and the obtained signatures of the IVSMR(β^+) will be presented.

* This work is supported in part by the Grant-in-Aid for Specially Promoted Research from the Japan Ministry of Education, Sports, Culture, Science, and Technology, No. 17002003.

New generation of physics with exotic nuclei at RIBF

H. Sakurai

RIKEN Nishina Center for Accelerator-Based Science, 2-1 Hirosawa, Wako, Saitama 351-0198, Japan

I would illustrate the new facility of RIBF through introducing heavy-ion experimental programs at several experimental devices.

RIBF is the world-class radioactive-isotope beam (RIB) facility, which is based on a new high-power heavy-ion accelerator complex [1] and a new in-flight fragment separator BigRIPS [2]. In 2007, RIBF started to deliver radioactive isotope beams. High performances and potentialities of this facility have been demonstrated by discovery of two new isotopes [3] in 2008 and of 45 new isotopes in 2010 [4].

The accelerator system has been upgraded since 2007. Additional beam monitors have been installed to strengthen a beam diagnostic and to improve a transmission-efficiency. In 2009, an 18GHz SC-ECR ion source was installed to increase heavy-beam intensities. Maximum intensities achieved for ^{48}Ca and ^{238}U beams at 345 A.MeV are 230pnA and 0.8pnA, respectively.

Based on the powerful ^{48}Ca beam, the first spectroscopy experiments at BigRIPS and ZeroDegree Spectrometer (ZDS) [5] were performed for the island-of-inversion region as a DayOne experiment campaign in December, 2008 [6,7]. In this year, missing mass spectroscopy with the state-of-art detector MUST2 made in France was organized to investigate exotic structure of ^{24}O. By using the U beam, the first decay spectroscopy was performed at the end of last year.

Concerning the other devices, a high resolution spectrometer SHARAQ [8] has been served for charge-exchange programs since 2009. A large acceptance spectrometer SAMURAI [9], which is dedicated for exclusive measurements, will be ready in 2011. A system to achieve electron scattering with unstable nuclei SCRIT [10] will be constructed in 2011. An rf ion-guide gas-catcher system SLOWRI [11], Rare-RI Ring dedicated for mass measurement [12] are to be funded in near future.

[1] Y. Yano, Nucl. Instr. Meth. B 261, 1009 (2007).
[2] T. Kubo, Nucl. Instrum. Methods B204 (2003) 97.
[3] T. Onishi et al., J. Phys. Soc. Japan 77 (2008) 083201.
[4] T. Onishi et al., J. Phys. Soc. Japan 79 (2010) 073201.
[5] H. Sakurai, Nucl. Phys. A 805 (2008) 526c-532c.
[6] P. Doornenbal, H. Scheit, N. Aoi et al., Phys. Rev. Lett. 103, 032501 (2009)
[7] T. Nakamura et al., Phys. Rev. Lett. 103 262501 (2009).
[8] T. Uesaka et al., Nucl. Instrum. Methods B266 (2008) 4218-4222.
[9] Technical information on experimental devices are found in: http://rarfaxp.riken.go.jp/RIBF-TAC05/
[10] M. Wakasugi, et al., Phys. Rev. Lett. 100 (2008) 164801.
[11] M. Wada et al., Hyperfine Interactions 173 (2006) 153-163
[12] Y. Yamaguchi et al., Nucl. Instrum. Methods B266 (2008) 4575-4578

Light exotic systems at relativistic Velocities

Haik Simon

GSI Helmoltzzentrum für Schwerionenforschung, Planckstr. 1, 64291 Darmstadt, Germany

Light nuclei far from stability [1] provide a fertile testing ground for nuclear structure models and the underlying forces. A series of experiments has been performed in order to study extremely neutron rich nuclei at and beyond the driplines, where the neutron separation energy vanishes, by using breakup reactions. Beams with large neutron excess were produced in flight at several 100 MeV/nucleus and directed to a versatile reaction setup. The relativistic kinematics allows describing the reaction process cleanly and the internal motion of the valence nuclei is slow compared to the interaction time. Experimentally the forward focusing of the reaction products enables covering practically the full solid angle with high detection efficiency. As result of the dissociation typically 2 to 3 fragments interact in the exit channel of the reaction and form even more asymmetric nuclear systems like e.g. ^{5}H. They can be characterized by studying their kinematic correlations in the continuum. Selected findings in the outskirt of the nuclear landscape will be shown and discussed together with the underlying structure of the bound exotic projectiles leading to their formation.

[1] B. Jonson, Phys. Rep. 389, 1 (2004)

Key Reactions in Nuclear Astrophysics: $^{12}C(\alpha,\gamma)^{16}O$ and $^{12}C+^{12}C$ Fusion*

Frank Strieder

Institut für Experimentalphysik, Ruhr-Universität Bochum, Bochum, Germany.

The capture reaction $^{12}C(\alpha,\gamma)^{16}O$ takes place in the helium burning of Red Giants and is generally accepted to be a key process of nuclear astrophysics. The reaction rate at the relevant Gamow energy ($E \approx 300$ keV at $T \approx 2\times10^{8}$ K) determines - together with the convection mechanism at the edge of the stellar core - the $^{12}C/^{16}O$ ratio at the end of helium burning. This, in turn, influences not only the nucleosynthesis of elements up to the iron region but also the subsequent evolution of massive stars, the dynamics of a supernova, and the kind of remnant after a supernova explosion. For these reasons, the cross section should be known with a precision of at least 10%. However, the radiative capture cross section at the astrophysical energies is too small to be measured directly and in spite of tremendous experimental efforts in measuring the cross section over nearly 40 years, one is still far from the needed precision since higher energy data have to be extrapolated down to 300 keV. Contributions from E1 and E2 ground state transitions have to be taken into account, as well as cascade transitions. The presence of subthreshold levels further complicates the extrapolation. Our current knowledge of the extrapolated cross section is mostly based on R-matrix analyses of γ-ray capture and elastic scattering data. The β-delayed α-decay of ^{16}N provides information on the properties of the subthreshold 1^{-} level. A general overview is given on the current experimental data basis for $^{12}C(\alpha,\gamma)^{16}O$ with a focus on the direct measurements of the last years.

The fusion reactions $^{12}C(^{12}C,\alpha)^{20}Ne$ (Q=4.62 MeV) and $^{12}C(^{12}C,p)^{23}Na$ (Q=2.24 MeV) are referred to as carbon burning in stars. In massive stars the ashes produced during helium burning become the fuel for further nuclear-burning processes, leading to the synthesis of most elements with mass numbers larger than 20. As helium burning progress, a core develops composed primarily of carbon and oxygen. Since the Coulomb barrier is lowest for the carbon nuclei, these will be the first to interact, resulting in the formation of neon, sodium and magnesium. Consequently, these $^{12}C+^{12}C$ fusion reactions represent key processes since they influence not only the nucleosynthesis but also the subsequent evolution of a star. However, at the astrophysical relevant energies the reaction rate of these fusion reactions is not very well known and provided only by extrapolations of high energy data. These fusion reactions have now been studied from E = 1.9 to 4.75 MeV by γ-ray and particle spectroscopy using thick carbon targets with ultra-low hydrogen contamination. The data reveal new information down to the range of the Gamow peak for carbon burning in massive stars, which takes place at temperatures $T \approx (5-10)\times10^{8}$ K. The possible impacts of the results on various astrophysical sites, e.g. supernovae progenitor stars, will be discussed.

* This work is supported by the Deutsche Forschungsgemeinschaft.

INVITED ORAL CONTRIBUTIONS

Listed in alphabetical order of the first author name

	Author(s)	Title
1	**R. Dressler** *et al.* *(PSI, Villingen, Switzerland)*	*Chemical investigation of element 114: indication for a massive relativistic effect in chemistry*
2	**M. Fujiwara** *et al* *(RCNP, Osaka Univ., Japan)*	*Measurements of ISGMR in Sn, Cd, and Pb isotopes and the asymmetry of nuclear matter incompressibility*
3	**S. Goriely** *(IAA-ULB, Brussels, Belgium)*	*The r-process nucleosynthesis during the decompression of cold neutronised matter*
4	**M. N. Harakeh** *(GSI, Darmstadt, Germany & KVI, U. Groningen, The Netherlands)*	*Scope of Integrating Activity: European Nuclear Science and Applications Research (ENSAR)*
5	**T. Kajino** *(NAO, U. Tokyo, Japan)*	*Nuclear Weak Interactions and Supernova Neutrino- and R-Processes*
6	**E. Lanza** *et al.* *(INFN & U. Catania, Italy)*	*On the Nature of the Pygmy Dipole Resonance*
7	**P. Milazzo** *et al.* *(INFN-Trieste, Italy)*	*Nuclear Astrophysics at CERN n_TOF facility*
8	**E. Moya De Guerra** *et al.* *(U. Complutense de Madrid, Spain)*	*Selected Topics on Nuclear Structure in Electroweak Processes*
9	**T. Otsuka** *(U. Tokyo, Japan)*	*Shell Evolution in Exotic Nuclei*
10	**P. Thirolf** *et al.* *(LMU München, Germany)*	*Fission-Fusion: a new Reaction Mechanism for Nuclear Astrophysics based on Laser-Ion Acceleration*

Chemical investigation of element 114: indication for a massive relativistic effect in chemistry

R.Dressler[1]
for a PSI-University of Bern-FLNR-LLNL collaboration*

[1]*Laboratory for Radiochemistry and Environmental Chemistry, Paul Scherrer Institute, CH-5232 Villigen, Switzerland.*

The systematic order of the periodic table places element 114 into group 14 together with carbon, silicon, germanium, tin, and lead. The enhancing metallic character with increasing atomic number Z is a typical trend observed along the main groups 13-17 of the periodic table [1]. However, relativistic calculations of the electronic structure of super heavy elements suggest an increased chemical stability of the elemental atomic state for element 114, having an electronic ground state configuration of Rn: $5f^{14}6d^{10}$ $7s^{2}7p_{1/2}^{2}$ [2-7]. Therefore, a high volatility and a rather chemical inertness were postulated as a result of the contraction of the outermost s- and p-electron orbital. Modern relativistic calculation models predict atomic properties for element 114, representing a higher chemical inertness but still similarity to the lighter group 14 metal lead [8-10]. Recently, element 112 adsorption on gold was investigated using thermochromatography [11,12]. During these experiments in the irradiation of ^{242}Pu with ^{48}Ca (details see [12]) a decay chain was observed, which is unambiguously attributed to the primary product of the nuclear reaction – the isotope $^{287}114$ ($T_{1/2}$=0.5 s). Even more exciting was the observation of this decay chain on detector 19 held at a temperature of -88°C. The lighter group 14 homologues C, Si, Ge, Sn, and Pb are not at all transported at these experimental conditions in their elemental state to the detector.

This spectacular first chemical observation of element 114 was confirmed switching to the projectile target combination ^{48}Ca and ^{244}Pu. The production of $^{288}114$ ($T_{1/2}$=0.8 s) and $^{289}114$ ($T_{1/2}$=2.4 s) are reported in the nuclear reactions $^{244}Pu(^{48}Ca,4n)$ and $^{244}Pu(^{48}Ca,3n)$, respectively [13]. Indeed, two more decay chains unambiguously attributed to the isotope 288114 were observed, fully confirming the first observation. A kinetic Monte-Carlo based model of gas adsorption chromatography [14] assesses the adsorption enthalpy ($-\Delta H_{ads}^{Au}$) from the observed deposition pattern of element 114 on the gold surface in the Cryo On-Line Detector. This approach reveals an adsorption enthalpy as $-\Delta H_{ads}^{Au}(E114)=35^{+19}_{-3}$ kJ/mol (68% c.i.). Recent relativistic density functional calculations predict a higher reactivity for element 114 compared to element 112 and the formation of a metallic bond between element 114 and gold [10]. A rather rough estimation yields an interval for $-\Delta H_{ads}^{Au}(E114)$ between 100-150 kJ/mol corresponding to a deposition temperature of element 114 on gold of about 150-300°C at the current experimental conditions. A semi-empirical macroscopic metal-metal adsorption model [15,16] predicts an even higher adsorption enthalpy of a metal-like element 114 on gold of $-\Delta H_{ads}^{Au}(E114)$=183 kJ/mol. The adsorption enthalpy of a noble-gas like element 114 on gold surfaces was estimated to $-\Delta H_{ads}^{Au}(E112)=42\pm5$ kJ/mol [17].

The comparison between these theoretical values and our experimental result concludes the formation of a noble-gas like weak physisorption bond between atomic 114 and a gold surface in contrast to the expectations from the relativistic models and from empirical predictions. Element 114 reveals a substantially increased stability of the elemental state compared to its homologues in group 14, which might be explained only with a closed shell electronic structure, as predicted in [2-7] revealing for the first time indication for massive relativistic effects acting on the outermost s- and p-electrons.

[1] Eichler, B. *Kernenergie* **19,** 307-311 (1976) (*in German)*.
[2] Fricke, B. *Structure and bonding* **21,** 90-144 (1975).
[3] Pitzer, K. S.*J. Chem. Phys.* **63(2),** 1032 (1975).
[4] Pyykkö, P. et al. *Acc. Chem. Res.* **12,** 276-281 (1979).
[5] Schwerdtfeger, P. et al. In *Encyclopaedia of Computational Chemistry,* Vol. 4, 2480-2499 (Wiley, New York, 1998).
[6] Landau, A. et al. *J. Chem. Phys.* **114,** 2977-2980 (2001).
[7] Liu, W. et al. *Adv. Quant. Chem.* **39,** 325-355 (2001).
[8] Nash, C. *J. Phys. Chem. A* **109,** 3493-3500 (2005).
[9] Seth M. et al. *Angew. Chem. Int. Ed.* **37,** 2493-2496 (1998).
[10] Pershina, V. et al. *J. Chem. Phys.* **127,** 134310 (2007).
[11] Eichler, R. et al. *Nature* **447,** 72-75 (2002).
[12] Eichler, R. et al. *Angew.Chem. Int. Ed.*, **47(17),** 3262 (2008).
[13]Oganessian, Yu. Ts. *et al. Phys. Rev.C* **70**, 064609 (2004).
[14] Zvara I. *Radiochim. Acta* **38**, 95-101 (1985).
[15] Eichler, B. et al. *Radiochim. Acta* **33,** 121-125 (1983).
[16] Eichler, B. Metal chemistry of transactinides.
PSI Report 00-09, Villigen (2000), Volatilization properties of transactinides from metal surfaces and melts (thermochemical calculation). In *PSI Report 03-01*, Villigen (2002).
[17] Eichler, R. et al. *J. Phys.Chem. B* **106,** 5413-5420 (2002).

* PSI-University of Bern-FLNR-LLNL collaboration:
R. Eichler[1,2], F.Sh. Abdullin[3], N.V. Aksenov[3], A.V. Belozerov[3], G.A. Bozhikov[3], V.I. Chepigin[3], R. Dressler[1], S.N. Dmitriev[3], H.W. Gäggeler[1,2], V.A. Gorshkov[3], R.A. Henderson[4], M.G. Itkis[3], A.M. Johnsen[4], J.M. Kenneally[4], V.Ya. Lebedev[3], Yu.V. Lobanov[3], O.N. Malyshev[3], K.J. Moody[4], Yu.Ts. Oganessian[3], O.V. Petrushkin[3], D. Piguet[1], A.N. Polyakov[3], A.G. Popeko[3], P. Rasmussen[1], R.N. Sagaidak[3], A. Serov[1,2], D.A. Shaughnessy[4], I.V. Shirokovsky[3], S.V. Shishkin[3], A.V. Shutov[3], M.A. Stoyer[4], N.J. Stoyer[4], A.I. Svirikhin[3], E.E. Tereshatov[3], Yu.S. Tsyganov[3], G.K. Vostokin[3], V.K. Utyonkov[3], M. Wegrzecki[5], P.A. Wilk[4], A.V. Yeremin[3]

[2]*Departement für Chemie und Biochemie, Universität Bern, CH-3012 Bern, Switzerland*
[3]*Flerov Laboratory of Nuclear Reactions, Joint Institute for Nuclear Research, 141980 Dubna, Russia*
[4]*Lawrence Livermore National Laboratory, University of California, 94551 Livermore, USA*
[5]*Insitute of Electron Technology, 02-668 Warsaw, Poland*

Measurements of ISGMR in Sn, Cd, and Pb isotopes and the asymmetry of nuclear matter incompressibility

M. Fujiwara[1], T. Li[2], D. Patel[2], U. Garg[2], G.P.A. Berg[2], Y. Liu[2], R. Marks[2], J. Matta[2], B. K. Nayak[2], P. V. Madhusudhana-Rao[2], A. Long[2], K. Sault[2], R. Talwar[2], H. Hashimoto[1], K. Nakanishi[1], S. Okumura[1], M. Yosoi[1], M. Ichikawa[3], M. Itoh[3], R. Matsuo[3], T. Terazono[3], M. Uchida[4], Y. Iwao[5], T. Kawabata[5], T. Murakami[5], H. Sakaguchi[5], S. Terashima[5], Y. Yasuda[5], J. Zenihiro[5], H. Akimune[6], C. Iwamoto[6], A. Okamoto[6], K. Kawase[7], T. Adachi[8], and M.N. Harakeh[8,9]

[1]Research Center for Nuclear Physics, Osaka Univ., Osaka 567-0047, Japan; [2]JINA and Physics Dept., University of Notre Dame, Notre Dame, Indiana, USA, [3]Cyclotron and Radioisotope Center, Tohoku Univ., Sendai 980-8578, Japan; [4]Tokyo Institute of Technology, 2-12-1 O-Okayama, Tokyo 152-8550, Japan; [5]Dept. of Physics, Kyoto Univ., Kyoto 606-8502, Japan; [6]Dept. of Physics, Konan University, Hyogo 658-8501, Japan; [7]Advanced Photon Research Center, JAEA, Kyoto 619-0215, Japan; [8]KVI, University of Groningen, Groningen, The Netherlands; [9]GSI, Darmstadt, Germany

The compression-mode isoscalar giant monopole resonance (ISGMR) has been studied in the Sn, Cd and Pb isotopes using inelastic scattering of 400 MeV a-particles at extreme forward angles, including. We have obtained completely ``background-free'' inelastic-scattering spectra for the Sn, Cd, and Pb isotopes for a wide angular and excitation-energy range. The various giant resonances excited with different transferred angular momenta were extracted by a multipole-decomposition analysis (MDA). It was found that the centroid energies of the ISGMR in Sn isotopes are significantly lower than the theoretical predictions. The Kt in the empirical expression for the nuclear incompressibility has been determined to be MeV from the moment ratios [1]. The extracted value for the Cd isotopes is MeV. These numbers are consistent with values of MeV obtained from an analysis of the isotopic transport ratios in medium-energy heavy-ion reactions [2], MeV obtained from constraints placed by neutron-skin data from anti-protonic atoms across the mass table [3], and MeV obtained from theoretical calculations using different Skyrme interactions and relativistic mean field (RMF) Lagrangians [4].

Stringent constraints on interactions employed in nuclear structure calculations are obtained on the basis of the experimentally determined values for K_∞ and K_τ. These parameters constrain as well the equation of state (EOS) of nuclear matter. However, a significant discrepancy still remains. The ISGMR positions in Sn and Cd isotopes are systematically lower than the predictions obtained on basis of determined from the ISGMR in ^{208}Pb. This raises the question “why are Sn and Cd nuclei so soft?”, an important problem that has to be solved [5]. For a clue to solve the problem, the exact positions of the ISGMR in $^{204,\,206,\,208}$Pb have to be measured [6]. In this talk, we will review the current status of the experimental studies on the compression mode giant resonances, and the possible implications for astrophysics and physics with exotic nuclei.

[1] T. Li *et al.*, Phys. Rev. Lett. 99, 162503 (2007), and Phys. Rev. C 81, 034309 (2010).
[2] Lie-Wen Chen *et al.*, Phys. Rev. C 80, 014322 (2009).
[3] M. Centelles *et al.,* Phys. Rev. Lett. 102, 122502 (2009).
[4] H. Sagawa *et al.*, Phys. Rev. C 76, 034327 (2007).
[5] J. Piekarewicz, J. Phys. G: Nucl. Part. Phys. 37, 064038 (2010).
[6] E. Khan, Phys. Rev. C 80, 011307 (2009).

The r-process nucleosynthesis during the decompression of cold neutronised matter

S. Goriely

Institut d'Astronomie et d'Astrophysique, Université Libre de Bruxelles, Campus de la Plaine CP226, 1050 Brussels, Belgium

The rapid neutron-capture process, or r-process, is known to be of fundamental importance for explaining the origin of approximately half of the A > 60 stable nuclei observed in nature. In recent years nuclear astrophysicists have developed more and more sophisticated r-process models, eagerly trying to add new astrophysical or nuclear physics ingredients to explain the solar system composition in a satisfactory way. The r-process remains the most complex nucleosynthetic process to model from the astrophysics as well as nuclear-physics points of view. The identification of the astrophysical site for the r-process remains clearly and by far the most unsatisfactorily understood facet of the r-process modeling.

The present contribution emphasizes some important future challenges faced by nuclear physics in this problem, particularly in the determination of the radiative neutron capture rates by exotic nuclei close to the neutron drip line and the fission probabilities of heavy neutron-rich nuclei. These quantities are particularly relevant to determine the composition of the matter resulting from the decompression of initially cold neutron star matter. New detailed r-process calculations are performed and the final composition of ejected inner and outer neutron star crust material is estimated. We discuss the impact of the many uncertainties in the astrophysics and nuclear physics on the final composition of the ejected matter.

Scope of Integrating Activity *European Nuclear Science and Applications Research* (ENSAR)

Muhsin N. Harakeh

GSI Helmholtzzentrum für Schwerionenforschung GmbH, Planckstraße 1, 64291 Darmstadt, Germany
Kernfysisch Versneller Instituut, University of Groningen, Zernikelaan 25, NL-9747 AA Groningen, The Netherlands

ENSAR is the Integrating Activity of Nuclear Scientists from almost all European countries reflecting the community at large and within an equal opportunity structure. It has been established through a bottom-up approach under the auspices of NuPECC, which assured a global view on the needs for development of Nuclear Physics within Europe. It comprises a coherent and complementary ensemble of Networking, Transnational Access and Joint Research Activities, which will ensure within the funding period starting from September 2010 a qualitative and quantitative improvement of the services and access provided by seven large-scale infrastructures (GSI, GANIL, JYFL, LNL&LNS, KVI, ISOLDE, and ALTO). The novel and innovative developments that will be achieved by the RTD activities will also assure state-of-the-art technology needed for the new European large-scale projects. In addition to the seven Transnational Access Facilities, ENSAR incorporates 7 Joint Research Activities and six Networking Activities including the management network.

The presentation aims at providing an overview of the ENSAR structure, activities, deliverables, and time schedule.

Nuclear Weak Interactions and Supernova Neutrino- and r-Processes

Taka Kajino

Division of Theoretical Astronomy, National Astronomical Observatory
Department of Astronomy, Graduate School of Science, University of Tokyo
2-21-1 Osawa, Mitaka, Tokyo 181-8588, Japan

Recent progress in nuclear structure physics is expected to contribute to the understanding of explosive nucleosyntheses in Supernovae (SNe). Accumulated knowledge on the nuclear structure of weak transitions (i.e. GT, spin-dipole and higher mutipole transitions) provides critical information to understand neutrino-process nucleosynthesis in core-collapse SNe. The advancement of radioactive nuclear beam physics also helps understand still unknown astrophysical origin of r-process nucleosynthesis.

We first discuss our recent theoretical studies of nuclear weak-interactions and neutrino-nucleus cross sections on ^{4}He, ^{12}C, ^{40}Ar, ^{56}Fe, ^{56}Ni, ^{138}La, ^{180}Ta, and others. We then discuss application to neutrino-process nucleosynthesis in SNe. The light element (LiBeB isotopes) synthesis in carbon-rich He-layer is strongly affected by the MSW matter-effect of neutrino oscillation, while the heavier element (FeCoNi isotopes, ^{138}La, ^{180}Ta, etc.) synthesis in the inner Si- and ONeMg-layers are almost free from the MSW effect but subject to the flavor-mixing effect due to the neutrino self-interactions. We present how to determine the unknown neutrino-oscillation parameters from nucleosynthetic studies of the observed light-to-heavy element abundances in neutrino-process by taking account of both MSW- and self-interaction effects on SN neutrinos. We also discuss nuclear physics uncertainties.

We secondly discuss r-process nucleosynthesis in different models of explosion mechanisms, i.e. neutrino-heated supernova winds, binary neutron-star mergers, and magneto-hydrodynamic explosion of gamma-ray bursts (GRBs). In particular among them, we discuss GRB r-process. Very peculiar abundance pattern has recently been discovered in most metal-deficient oldest halo stars HE 1327-2326 and HE 0107-5240 with [Fe/H] = -5.4 and -5.3, respectively. We will show that our GRB nucleosynthesis model of black hole forming Hypernovae which are associated with accretion disks can explain the peculiar abundance pattern including r-process elements.

On the Nature of the Pygmy Dipole Resonance

E. G. Lanza[1], M. V. Andrés[2], F. Catara[1], D. Gambacurta[1], A. Vitturi[3]

[1] *INFN and Dipartimento di Fisica e Astronomia, Catania, Italy.*
[2] *Departamento de FAMN, Facultad de Física, Sevilla, Spain*
[3] *Dipartimento di Fisica and INFN, Padova, Italy*

In the last years the properties of collective states in neutron-rich nuclei have been studied with special attention to the presence of dipole strength at low excitation energy. This strength has been often associated to the possible existence of a new collective mode of new nature: Pygmy Dipole Resonance (PDR).

From a theoretical point of view the presence of this low-lying strength is predicted by almost all microscopic models, ranging from Hartree-Fock plus RPA with Skyrme interactions to relativistic Hartree-Bogoliubov plus relativistic quasiparticle RPA. All these approaches predict similar amounts of strength, but often disagree on the collective (or not) nature of these states, on their fragmentation and on their isoscalar/isovector contents.

We will use the results obtained in the simplest discrete non-relativistic RPA approach with Skyrme interactions, consistently used both at the level of mean-field Hartree-Fock and of RPA. We have performed calculations for several Sn isotopes.

One important question is how much collective are these dipole states. One measure of the collectivity is the number of particle-hole components entering in the RPA wave-function with an appreciable weight. Such criterion does not take into account the other fundamental concept that underlies collectivity that is coherence. Both aspects have to be taken into account in order to establish whether the state under study is collective or not. From our novel analysis, it emerges that the low lying structures are related to the co-operative, although not coherent, effect of several p-h excitations.

More precise information on the specific nature of the states is contained in their transition densities. For the PDR state the neutron and proton components oscillate in phase in the interior region, while in the external region only the neutrons give a contribution to both isoscalar and isovector transition densities which have the same magnitude. Such behaviour, which has been found also in all the other microscopic approaches, can be taken as a sort of definition of PDR.

This brings in the question of the interpretation of this state, macroscopically described as the oscillation of the neutron skin with respect to the proton-neutron cores. Calculations done along these lines show that, although some similarities are present, a full interpretation of the state in the above macroscopic terms is not obvious. It should be noted that the macroscopic picture should also involve a collective nature of the state, which was not found to be fulfilled at least in our calculations.

From an experimental point of view the evidence for these states has come from Coulomb excitation processes. As known, these can only provide values of the multipole B(Eλ) transition rates. Much more information, like wave function and transition densities, can be obtained by resorting to reactions where the nuclear part of the interaction is involved. This can be done because of the strong isoscalar component of the PDR state. By tuning the projectile mass, charge, bombarding energy and scattering angle one can alter the relative role of the nuclear and Coulomb components, as well as of the isoscalar and isovector contributions.

Our calculations show that valuable information on the nature of the PDR can be obtained by excitation processes involving the nuclear part of the interaction. The use of different bombarding energies, of different combinations of colliding nuclei involving different mixture of isoscalar/isovector components, together with the mandatory use of microscopically constructed form-factors, can provide the clue to reveal the characteristic features of these states.

Nuclear Astrophysics at CERN n_TOF facility

Paolo Maria Milazzo

INFN-Trieste, Trieste, Italy

Nuclear astrophysics presents many cases that require neutron capture reaction data with high precision. In particular, refined data are needed for the stellar s-process nucleosynthesis.

The neutron time of flight (n_TOF) facility at CERN is a neutron spallation source; its white neutron energy spectrum ranges from thermal to hundreds of MeV, covering the full energy range of interest for nuclear astrophysics. The low repetition rate of the proton beam, the high instantaneous neutron flux, and the favourable background conditions in the experimental area make this facility unique for high resolution time-of-flight measurements of neutron induced reaction cross sections. The n_TOF collaboration is presently operating two different capture experimental set-ups. The first consists of two low-neutron sensitivity C_6D_6 detectors with the analysis relying on the Pulse Height Weighting technique. In addition, a Total Absorption Calorimeter, consisting of 40 BaF_2 crystals covering the whole solid angle, was used.

This contribution gives an overview on the astrophysical program performed at n_TOF facility. The results and the implications will be reported.

Selected Topics on Nuclear Structure in Electroweak Processes

E. Moya de Guerra[1], **O. Moreno**[1], **P. Sarriguren**[2]

[1] *Depto. Física Atómica, Molecular y Nuclear, Facultad de Ciencias Físicas, Universidad Complutense de Madrid, Ciudad Universitaria, E-28040 Madrid, Spain.*
[2] *Instituto de Estructura de la Materia, Consejo Superior de Investigaciones Científicas, Serrano 123, E-28006 Madrid, Spain.*

We study electroweak processes in complex nuclei within the framework of self-consistent mean field theories including pairing and RPA correlations. We review the adiabatic time dependent Hartree-Fock theory and its ability to simultaneously handle large and small amplitude modes. We apply the formalism to the study of single and double beta decay as normal modes of the system, allowing for collective deformation, using Skyrme density dependent two body interactions. We also apply the formalism to the study of parity violating electron scattering.

We first discuss results on single beta decay half lives of several isotopic chains, including waiting point nuclei of astrophysical interest. Results on two neutrino double beta decay are also discussed along with Gamow Teller strengths of the single beta branches in parent and daughter nuclei. The dependence on deformation is analyzed and comparison with experiment and with other theoretical results is presented. Preliminary results on the double beta decay of ^{150}Nd matrix element for the zero neutrino case will also be discussed. We also give particular attention to the double-beta decay matrix elements in the A=76 system, where recently spectroscopic factors have been accurately measured. In the later case, we first review the Skyrme interaction as introduced by Vautherin and Brink in the Hartree-Fock formalism to construct the energy density functional and, more specifically, the two-body spin-orbit term. Keeping in mind that problems with this term were already pointed out by Skyrme, we discuss possible options that allow for more flexibility in the spin-orbit dependent terms of the energy density functional and of the self-consistent mean field potential. Focusing in particular on the recently measured spectroscopic factors in germanium and selenium isotopes, we show that using different neutron and proton spin-orbit coupling constants, together with pairing and deformation, greatly improves the agreement with experiment [1]. Results on spectroscopic factors, rms radii and other collective and single particle properties of germanium and selenium isotopes obtained with the new and old parametrizations of the constrained HF(Sk3)+BCS potential will be shown, in addition to results on the two-neutrino double-beta decay matrix element for ^{76}Ge going to ^{76}Se.

Concerning parity-violating elastic electron scattering [2] we discuss its potential as a tool for precise determination of neutron densities in nuclei. We study nuclear isovector and isoscalar densities for N>Z and for N=Z stable nuclei obtained within the self-consistent mean field approximation. We compare the values of the parity-violating asymmetry (PVA) at low and intermediate q-values for different N/Z and A values. Distorted wave calculations of PVA are shown and are compared to plane wave impulse approximation. We discuss how to extract the ratio between neutron and proton rms radii and monopole form factors from theoretical and experimental asymmetries. We focus on several N=Z cases to study the influence of nuclear isospin mixing in PVA. The effect of strangeness content of the nucleon on the PVA is also taken into account.

[1] O. Moreno, E. Moya de Guerra, P. Sarriguren and Amand Faessler, Phys. Rev. C 81, 041303(R) (2010).
[2] O. Moreno, P. Sarriguren, E. Moya de Guerra and J. M. Udias, J. Phys. G: Nucl. Part. Phys. 37, (2010) 064019; O. Moreno, P. Sarriguren, E. Moya de Guerra, J. M. Udias, T. W. Donnelly and I. Sick, Nucl. Phys. A 828 306 (2009).

Shell Evolution in Exotic Nuclei

Takaharu Otsuka

Department of Physics and Center for Nuclear Study, University of Tokyo

In recent years, the understanding of the shell evolution in exotic nuclei has been advanced considerably. I will present an overview on the shell evolution in exotic nuclei due to 2- and 3-body nuclear force, with perspectives over the future directions. The shell evolution due to the proton-neutron interaction has the major origin in the central and tensor forces. The indispensable role of the tensor force has been established not only from the comparison to experimental data but also from modern microscopic theories on the hard-core effects and in-medium corrections. Renormalization process is shown not to change the monopole part of the tensor force, and the bare tensor force obtained from one-pion and one-rho-meson exchanges is a good approximation, explaining/predicting changes of the spin-orbit splitting in a robust and well-defined quantitative manner. The central force is, at present stage, more phenomenological as it is changed largely through the renormalization. On the other hand, the resultant central force appears, at least in its monopole part, with a very simple form with Gaussian range of 1 fm. By using such a proton-neutron monopole interaction, one can describe or predict many phenomena by a single fixed interaction: transition from the N=20 island of inversion to normal structure at ^{40}Ca, breaking of Z=28 around N=50, transition from ^{90}Zr to ^{100}Sn structures with very different single particle orderings, with more interesting cases over the periodic table [PRL 104, 012501].

The interaction between valence neutrons has been clarified more recently with additional new aspects. The bare 3-body interaction, particularly the one originating in Delta particle excitation (Fujita-Miyazawa (FM) force), induces an effective interaction between valence neutrons. This interaction between two neutrons is due to the third nucleon in the core, and its monopole part is shown to be robustly repulsive. This repulsive contribution solves a long-standing problem in the shell-model interaction: the origin of repulsive modification to the T=1 monopole part. This 3-body-induced 2-body interaction, combined with an effective interaction from bare 2-body force, indeed reproduces many properties which are otherwise open questions. This interaction is related to and consistent with neutron matter/star. The dripline and magic structure of oxygen isotopes are an example. The dripline can be predicted naturally, and the new magic numbers N=14 and 16 arise. The major ingredients of such a 3-body-induced 2-body interaction will be discussed with perspectives over unexpected structures of exotic nuclei. [arXiv nucl-th: 0908.2607]

Fission-Fusion: a new Reaction Mechanism for Nuclear Astrophysics based on Laser-Ion Acceleration *

P. G. Thirolf[1], D. Habs[1,2], M. Gross[1], J. Schreiber[2]

[1] *Ludwig-Maximilians-Universität München, Am Coulombwall 1, D-85748 Garching, Germany*
[2] *Max-Planck-Institut f. Quantenoptik, Garching, Germany*

High power short-pulse lasers with peak powers presently reaching hundreds of Terawatts and even Petawatt levels routinely reach focal intensities of 10^{18}-10^{21} W/cm^2. These lasers are able to produce a wide array of secondary radiation, from relativistic electrons to multi-MeV/nucleon ion beams [1]. Compared to ion beams generated by conventional accelerators, laser-accelerated ion bunches can reach ultra-high densities around solid-state density, exceeding classical ion beams by up to 15 orders of magnitude. These unprecedented properties will soon allow to investigate a new reaction mechanism, fission-fusion, opening the perspective to generate extremely neutron-rich fusion products e.g. towards the N=126 waiting point of the r-process path. Laser-accelerated ^{232}Th ions (ca. 7 MeV/u) from a first target foil pass through a second Th foil, where target-like and beam-like Th nuclei will disintegrate into heavy and light fission fragments. Due to the very high beam density subsequent fusion between two light (neutron-rich) fission fragments can occur, resulting in a very neutron rich fusion product. A new EU-funded large-scale research infrastructure ELI (Extreme Light Infrastructure [2]) will be built until 2015, with its pillar in Bucharest being exclusively devoted to high-power laser-based nuclear physics. With this new facility the intensity limit of high-power lasers will be pushed by about three orders of magnitude to yet unprecedented 10^{24} W/cm^2. It will be one of the experimental goals pursued there to develop the new fission-fusion reaction mechanism.

* This work is supported by the DFG Cluster of Excellence MAP (Munich-Centre for Advanced Photonics).

[1] A. Henig et al., Phys. Rev. Lett. 103, 245003 (2009).
[2] http://www.extreme-light-infrastructure.eu/

ORAL CONTRIBUTIONS

Listed in alphabetical order of the first author name

	Author(s)	Title
1	**H. Akimune** *et al.* *(Konan University, Kobe, Japan)*	*M1 and E1 Cross Sections near Threshold in Photodisintegration of Deuteron*
2	**A. Andreyev** *et al.* *(U. West of Scotland, Paisley, UK)*	*Beta-delayed Fission of ^{180}Tl*
3	**L. Audirac** *et al.* *(CENBG, Gradignan, France)*	*Experimental Studies of an Exotic Decay Mode at the Proton Drip-line: the Two-proton Radioactivity*
4	**E. Běták** *et al.* *(Slovak Academy of Sciences, Bratislava, Slovakia)*	*Influence of Strange Matter Admixtures on Macroscopic Properties of Neutron Star*
5	**M. Cavallaro** *et al.* *(INFN-LNS, Catania, Italy)*	*Two-Neutron Excitations in Light Neutron Rich Nuclei Studied via the (^{18}O,^{16}O) Reaction at 84 MeV*
6	**P. Chowdhury** *et al.* *(Univ. of Massachusetts Lowell, Lowell, MA, USA)*	*Spectroscopy of Neutron-rich Plutonium Nuclei*
7	**A. Corsi** *et al.* *(Univ. Milano & INFN Italy)*	*Measurement of isospin mixing in ^{80}Zr at finite temperature*
8	**A. Cowley** *et al.* *(Stellenbosch University, Matieland, South Africa)*	*Incident-energy Dependent Quenching of the Analyzing Power in Pre-equilibrium Composite Particle Emission*
9	**J. Cseh** *(ATOMKI, Debrecen, Hungary)*	*Exotic shapes and exotic clusterization*
10	**D. Cullen** *(U. Manchester, UK)*	*DPUNS - A Differential-Plunger for Lifetime measurements of Tagged Exotic- and Unbound nuclear states*
11	**P. Demetriou** *et al.*, presented by **Y. El Masri** *(UCL, Louvain-la-Neuve, Belgium)*	*Fission properties of actinide nuclei at energies 26.5 and 62.9 MeV*
12	**J. Endres** *et al.* *(IKP, U. Köln, Germany)*	*Splitting of the Pygmy Dipole Resonance*
13	**Lidia S. Ferreira** *et al.* *(CFIF/IST, Lisbon, Portugal)*	*Assigning γ deformation from fine structure in exotic nuclei*

14	**N. Fotiades** *et al.* *(LANL, Los Alamos, USA)*	*Study of near-stability nuclei populated as fission fragments in heavy-ion fusion reactions*
15	**C. Fransen** *et al.* *(IKP, U. Köln, Germany)*	*Measurement of absolute E2 transition strengths in ^{176}W: Signatures for a rapid shape change*
16	**E. Ganioğlu** *et al.* *(Istanbul University, Turkey)*	*Gamow-Teller Transitions Starting from T_z = +3/2 Nucleus ^{47}Ti*
17	**P. Garrett** *(U. Guelph, Ontario, Canada)*	*Mapping Quadrupole Collectivity in the Cd Isotopes: The Breakdown of Spherical Vibrational Motion*
18	**P. R. S. Gomes** *et al.* *(U. Federal Fluminense, Niteroi, RJ, Brazil)*	*Fusion Enhancement/Suppression and Irreversibility in Reactions Induced by Weakly Bound Nuclei*
19	**C. Gustavino** *INFN Sezione di Roma, Roma, Italy)*	*The Impact of LUNA Results on Astroparticle Physics*
20	**M. Itkis** *et al.* *(JINR Dubna, Russia)*	*The Entrance Channel Effects in Fusion-fission and Quasi-fission*
21	**S. Karataglidis** *et al.* *(U. Johannesburg, South Africa)*	*Recent Advances in Multi-Channel Algebraic Scattering*
22	**M. Krtička** *et al.* *(Charles University, Prague, Czech Republic)*	*Photon Strength Functions at the Low-Energy Tail of the GEDR Obtained from Different Reaction*
23	**J. Kvasil** *et al.* *(Charles University, Prague, Czech Republic)*	*Electric, Magnetic and Vorticity Strengths in Heavier Nuclei*
24	**M. La Cognata** *et al.* *(INFN-LNS & U. Catania, Italy)*	*High Accuracy ^{18}O(p,a)^{15}N Reaction Rate in the 8 ×10^6 - 5×10^9 K Temperature Range*
25	**J. Lubian Rios** *et al.* *(U. Federal Fluminense, Niteroi, RJ, Brazil)*	*Study of the Interplay Between the ^{8}B Breakup and Other Reaction Mechanisms by Means of the CDCC Method*
26	**I. Martel** *et al.* *(U. Huelva, Spain)*	*Sub-barrier fusion and breakup of light halo nuclei*
27	**D. Mücher** *et al.* *(TU München, Germany)*	*Monopole-effects on symmetric and antisymmetric couplings of protons and neutrons*
28	**I. Mukha** *et al.* *(GSI Darmstadt, Germany)*	*Studies of Nuclei Beyond the Proton Drip Line by Tracking Technique*

29	**V. O. Nesterenko** *et al.* *(JINR Dubna, Russia)*	*Description of Magnetic Giant Resonances with Skyrme Forces*
30	**M. Niikura** *et al.* *(IPN Orsay, France)*	*Lifetime Measurements of Low-lying States in Neutron-rich Zn Isotopes by the Plunger Technique*
31	**C. Nociforo** *et al.* *(GSI Darmstadt, Germany)*	*1n-removal reactions around N=20 shell closure*
32	**N. Paar** *et al.* *(U. Zagreb, Croatia)*	*Exotic Modes of Excitation and Weak Interaction Rates at Finite Temperature*
33	**P. Rahkila** *et al.*, presented by **J. Pakarinen** *(U. Liverpool, UK and CERN/ISOLDE, Switzerland)*	*Gamma-ray Spectroscopy at the Extremes; In-beam Study of ^{180}Pb*
34	**S. Panebianco** *et al.* *(CEA Saclay, IRFU, Gif-sur-Yvette, France)*	*Development of a Micromegas TPC for Low Energy Heavy Ions Measurement for Nuclear Fission and Astrophysics Applications*
35	**J. Piot** *et al.* *(Institut Pluridisciplinaire Hubert Curien, Strasbourg, France)*	*Investigation of ^{246}Fm: In-beam Spectroscopy at the Limits*
36	**C. Qi** *et al.* *(KTH, Stockholm, Sweden)*	*Abrupt Changes in Alpha Decay Systematics as a Manifestation of Collective Nuclear Modes*
37	**E. Rapisarda** *et al.* *(INFN - Sezione di Catania, Italy)*	*^{2}He Decay from ^{18}Ne Excited States: Status and Perspectives*
38	**F. Recchia** *et al.* presented by **S. Lunardi** *(U. Padova and INFN, Italy)*	*A new island of inversion far from stability*
39	**R. Rodríguez-Guzmán** *et al.* *(IEM/CSIC, Madrid, Spain)*	*Charge radii and structural evolution in Sr, Zr and Mo isotopes*
40	**W. Rother** *et al.* *(IKP, U. Köln, Germany)*	*Neutron-rich ^{62,64,66}Fe show enhanced Collectivity: The Washout of N=40 in Terms of Experiment, Valence Proton Symmetry and Shell Model*
41	**P. Sarriguren** *(IEM/CSIC, Madrid, Spain)*	*Weak Decay Rates for Neutron Deficient Medium-Mass Isotopes Relevant for the rp-Processes*
42	**D. Schumann** *(PSI, Villigen, Switzerland)*	*Extraction of Radionuclides from Accelerator Waste at PSI*
43	**M. M. Sharma** ***et al.*** *(Kuwait University, Kuwait)*	*Exotic structures near the drip lines*

44	**J. Sharpey-Schafer** *(University of Western Cape, Bellville, South Africa)*	*The Structure of Excited 0^+ States in Nuclei and the Effect of the γ Degree of Freedom*
45	**B. Sulignano** *et al.* *(CEA Saclay, IRFU/SPhN, Gif-sur-Yvette, France)*	*MUSETT and the Spectroscopy of Heavy Elements at GANIL*
46	**T. Suzuki** *et al.* *(Nihon University, Tokyo, Japan)*	*Electron Capture Reactions and Beta Decays in Steller Environments*
47	**O. Tengblad** *et al.* *(IEM-CSIC Madrid, Spain)*	*^{12}C formation: A Classical Quest in New Light*
48	**P. Ujic** *et al.* *(GANIL, France)* presented by **A. Lagoyannis** *(INP, NCSR “Demokritos”, Athens)*	*Alpha-particle capture reactions in inverse kinematics relevant to p-process nucleosynthesis*
49	**H. Utsunomiya** *et al.* *(Konan University, Kobe, Japan)*	*The γ-ray Strength Function Method*

M1 and E1 Cross Sections near Threshold in Photodisintegration of Deuteron

H. Akimune[1], C. Iwamoto[1], H. Utsunomiya[1], T. Kondo[1], T. Yamagata[1], H. Toyokawa[2], K. Yamada[2], H. Harada[3], F. Kitatani[3], S. Goko[4], A. Makinaga[4], Y.-W. Lui[5]

[1]*Department of Physics, Konan University, Kobe 658-8501-1, Japan*
[2]*National Inst. of Advanced Industrial Science and Technology, Tsukuba 305-8568, Japan*
[3]*Japan Atomic Energy Agency, Tokai 319-1195, Japan*
[4]*Department of Engineering, Hokkaido University, Sapporo 060-8628, Japan*
[5]*Cyclotron Institute, Texas A&M University, Texas 77843, USA*

Photodisintegration of deuteron is one of the most fundamental reactions to investigate nuclear interactions. In addition, an accurate determination of the photodisintegration cross section near breakup threshold is desired from the viewpoint of big-bang nucleosynthesis of deuterium. Further, M1 strength in ^{2}H(γ,n)p is related to the Gerasimov-Drell-Hearn sum rule, which is a fundamental law that governs the nucleon spin.

Total photodisintegration cross sections were measured by Hara *et al*. with Laser-Compton scattering (LCS) γ rays [1]. The photon analyzing power was measured by Ahmed *et al*. [2] with LCS γ rays from a free-electron laser to determine the cross section ratio, σ(*M*1)/(σ(*M*1)+σ(*E*1)). Further, M1 cross sections were deduced by Ryezayeva *et al*. in the (*e*,*e*') reaction at 180° [3].

We measured M1 and E1 cross sections in photodisintegration of deuteron, ^{2}H(γ,n)p with linearly-polarized LCS γ rays at four energies near photodisintegration threshold. Figure 1 shows results of the measurement in comparison with total and partial cross sections previously reported for deuteron as a function of γ-ray energy.

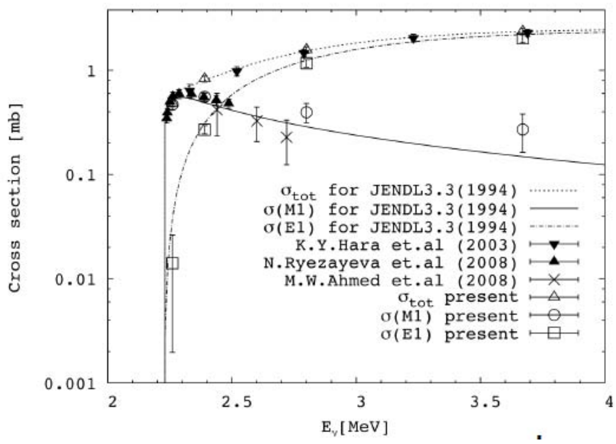


Fig. 1: Present M1 and E1 cross sections determined in the ^{2}H(γ,n)p reaction; σ(M1) (open circles), σ(E1) (open squares), and sum cross sections σ_{total} (open triangles).

[1] K. Y. Hara *et al*., Phys. Rev. D 68, 072001 (2003)
[2] W. Tornow *et al*., Phys. Lett. B574, 8 (2003); M.W. Ahmed *et al*., Phys. Rev. C 77, 044005 (2008)
[3] N. Ryezayeva *et al*., Phys. Rev. Lett. 100, 172501 (2008)

Beta-delayed Fission of ^{180}Tl

Andrei Andreyev
on behalf of the IS466 Collaboration and ISOLDE collaboration
University of the West of Scotland, Paisley, UK and IKS, KU Leuven, Belgium

Detailed studies of three decay modes (α, β^+ and beta-delayed fission) of an extremely neutron-deficient isotope ^{180}Tl were performed at the mass separator ISOLDE (CERN). A novelty and key feature of this work was the production of a pure source of ^{180}Tl using Resonance Ionization Laser Ion Source (RILIS) of ISOLDE.

In total, approximately 1.4×10^6 alpha decays of ^{180}Tl were detected, which represents approximately 6% alpha-decay branch of this nucleus. Due to high statistics, detailed fine-structure alpha decay studies of ^{176}Au (a daughter of ^{180}Tl after α decay) and of excited states in ^{180}Hg, populated in the β^+/EC decay of ^{180}Tl, were also performed.

The most surprising result of the experiment is the observation of the asymmetric fission fragments mass distribution of exotic nucleus ^{180}Hg (N/Z=1.25), produced after β^+/EC decay of ^{180}Tl (see Figure). Interpretation of this interesting phenomenon will be presented based on the recently-developed 5-dimentional approach to fission by P. Möller et al [1].

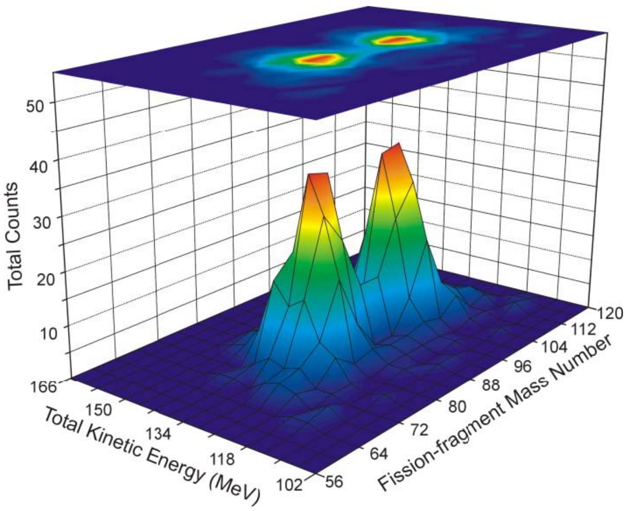


Fig. 1: The derived fission-fragment distribution of ^{180}Hg as a function of the fragment mass and the total kinetic energy.

[1] P. Möller et al., Nature 409, 785 (2001)

Experimental studies of an exotic decay mode at the proton drip-line: the two-proton radioactivity

L. Audirac[1], N. Adimi[1], P. Ascher[1], B. Blank[1], C. Borcea[1], G. Canchel[1], C. E. Demonchy[1], F. de Oliveira Santos[2], C. Dossat[3], J. Giovinazzo[1], S. Grevy[2], L. Hay[1], J. Huikari[1], T. Kurtukian-Nieto[1], S. Leblanc[1], I. Matea[1], J.-L. Pedroza[1], L. Perrot[2], J. Pibernat[1], L. Serani[1], C. Stodel[2], J.-C. Thomas[2]

[1]CENBG, Chemin du Solarium, BP 120, F-33175 Gradignan Cedex, France
[2]GANIL, Bvd Henri Becquerel, BP 55027, F-14076 Caen Cedex 5, France
[3]DAPNIA, CEA Saclay, F-91191 Gif-sur-Yvette Cedex, France

Two-proton radioactivity for long-lived ground-state emitters was predicted by Goldanskii in 1960. This decay mode concerns proton-rich nuclei at the proton drip-line with even number Z, where only the emission of two protons is possible and emission of one proton is forbidden. Possible candidates are in the mass 50 region. This decay mode was first observed for ^{45}Fe in 2002, although no direct observation of the two protons was possible [1]. The heavy ions were implanted in a silicon detector. Therefore the total decay energy and the half-life could only be measured, since the two protons could not escape from the detector. A similar experiment for the study of the decay of ^{54}Zn was achieved in 2004 [2]. The 2-proton radioactivity of ^{54}Zn was clearly observed. In order to determine the mechanism of emission, it is necessary to observe directly the two protons emitted, especially to determine the energetic and angular correlations between the protons.

For this purpose, a new detector was developed at CENBG, consisting in a Time Projection Chamber (TPC). The active volume is made of P10 gas into which the heavy ions are implanted and the correlated decays are visualized. The detection setup consists in a two dimensional matrix of two orthogonal sets of 768 strips, each one giving energy and time information with respect to the energy and the arrival time of the signal on the considered strip.

A first experiment was performed at the LISE3 separator of GANIL with the TPC in September 2006 for the study of ^{45}Fe. The total decay energy and the life-time were confirmed and the direct observation of the two protons emitted has been achieved for the first time [3]. Since the proton tracks could be reconstructed, the sharing of the decay energy and the relative angle between the two protons were especially determined. Moreover this experiment allowed to confirm the β-2p emission of ^{43}Cr and to compare the results obtained with ^{45}Fe.

A second experiment was performed at the LISE3 separator in July 2008. The direct visualization of 2-proton decay of ^{54}Zn was observed. In the same way, the sharing of the total decay energy and the relative angle between the protons could be studied.

[1] J. Giovinazzo *et al.*, Phys. Rev. Lett. **89**, 102501 (2002)
[2] B. Blank *et al.*, Phys. Rev. Lett. **94**, 232501 (2005)
[3] B. Blank *et al.*, Nucl. Instr. and Meth. in Phys. Res. **A613**, 1 (2010)

Influence of strange matter admixtures on macroscopic properties of neutron stars*

Martin Urbanec[1], Emil Běták[1,2], Zdeněk Stuchlík[1]

[1]*Institute of Physics, Silesian University, 74601 Opava, Czech Republic*
[2]*Institute of Physics, Slovak Academy of Sciences, 84511 Bratislava, Slovakia*

We used the equations of state of dense nuclear matter to construct the macroscopic properties of neutron stars and test them using available observational results. The Dirac-Brueckner-Hartree-Fock mean field calculations (see e.g. [1]) approximated by their parameterized form [2] are the basis of our calculations. Their formulation envisages also the presence of hyperons in addition to neutrons and protons usually considered in the core of a neutron star. For the outer regions, we used the classical EoS's, and Tolman-Oppenheimer-Volkoff equation [3] was employed to follow the variables from the surface to the centre of the star. We calculated the central pressure and density and correspondingly the possible radius and mass without allowance for hyperons first, and compared these results with recent astronomical observations (e.g. [4-8]). The astronomical data imposed constraints on the considered EoS's, and they can be used to exclude some of them. Finally, we studied the influence of hyperon admixture to the nucleon matter on the macroscopic properties of the neutron stars, and compared these calculations to those without hyperon inclusion.

* This work is supported by grants MSM 4781305903, LC 06014 and VEGA 2/0029/10.

[1] J.D. Walecka, Theoretical Nucl. and Subnucl. Phys., 2nd Ed. (Imper. Coll. & World Sci., 2004)
[2] J. Kotulič Bunta, Š. Gmuca, Phys. Rev. C68, 054318 (2003)
[3] R. Tolman, Phys. Rev. 55, 364 (1939); J. Oppenheimer, G. Volkoff, ibid., 374 (1939)
[4] J. Lattimer, M. Prakash, Phys. Rep. 442, 109 (2007)
[5] T. Klähn et al., Phys. Rev. C74, 035802 (2006)
[6] T. Belloni et al., Mon. Not. Royal Astron. Soc. 376, 1133 (2007)
[7] A.W. Steiner et al., arXiv:1005.0811v1 (2010)
[8] M. Boutelier et al., Mon. Not. Royal Astron. Soc. 401, 1290 (2010)

Two-Neutron Excitations in Light Neutron Rich Nuclei Studied via the (^{18}O,^{16}O) Reaction at 84 MeV

M. Cavallaro[1] , F. Cappuzzello[1,2], D. Carbone[1,2], A. Cunsolo[1,2], A. Foti[2,3], M. Bondì[1,2], G. Santagati[1,2], G. Taranto[1,2], C. Ruofu[1], R. Linares[1], F. Azaiez[4], S. Franchoo[4], M. Niikura[4], J. Scarpaci[4]

[1]Istituto Nazionale di Fisica Nucleare - LNS, Catania, Italy.
[2]Dipartimento di Fisica e Astronomia, Università di Catania, Catania, Italy.
[3]Istituto Nazionale di Fisica Nucleare - Sezione di Catania, Catania, Italy.
[4]CNRS - IN2P3 - Institut de Physique Nucléaire d'Orsay, Orsay, France.

A study of two-neutron excitations in ^{11}Be and ^{13}B has been done by the (^{18}O,^{16}O) transfer reaction at 84 MeV incident energy. This corresponds to about 10 times the Coulomb barrier and is safely low to reduce the influence of deep inelastic mechanism. In such conditions detailed information about nuclear structure can be cleanly accessed. In particular the (^{18}O,^{16}O) reaction has been used to study the dynamical effects of pairing correlations in nuclei. Recently, the study of the ^{13}C(^{18}O,^{16}O)^{15}C reaction at 84 MeV has shown the appearance of striking phenomena in the energy spectra of ^{15}C connected with the transfer of the neutron pair. In the experiment performed at INFN-LNS (Italy) the ^{16}O ejectiles has been momentum analyzed by the MAGNEX magnetic spectrometer. The achieved energy resolution (80 keV) has allowed to identify several known excited states in the reaction products. Thanks to the MAGNEX large energy acceptance (± 20%), excitation energy spectra has been produced for the first time up to 20 MeV. Angular distributions for the transitions to several states have been measured allowing to draw interesting conclusions on the role of pairing in the structure of ^{11}Be and ^{13}B.

Spectroscopy of Neutron-rich Plutonium Nuclei*

P. Chowdhury[1], S. Hota[1], S. Lakshmi[1], S. K. Tandel[1], T. Harrington[1], E. Jackson[1], K. Moran[1], U. Shirwadkar[1], I. Ahmad[2], M. P. Carpenter[2], C. J. Chiara[2,3], J. Greene[2], C. R. Hoffman[2], R. V. F. Janssens[2], T. L. Khoo[2], F. G. Kondev[2], T. Lauritsen[2], C. J. Lister[2], E. A. McCutchan, D. Seweryniak[2], I. Stefanescu[2], and S. Zhu[2]

[1]*University of Massachusetts Lowell, Lowell, MA 01854, USA*
[2]*Argonne National Laboratory, Argonne, IL 60439, USA*
[3]*University of Maryland, College Park, MD 20742, USA*

Spectroscopic studies of nuclei in the A≈250, Z≈100 region provide critical input to theoretical models that attempt to describe the structure and stability of the heaviest elements. In addition to single-particle energies, the availability of low-lying high-K configurations in this region allows additional parameters, such as pair gaps and spin-spin residual interactions, to be deduced experimentally, through the population and decay of K-isomers. We report here on new spectroscopic observations in the N=150,151 nuclei ^{244,245}Pu (Z=94). This continues our exploration of specific high-K configurations observed in the heavier neutron-rich $^{246\text{-}249}$Cm (Z=96) and $^{247\text{-}249}$Cf (Z=98) nuclei using deep-inelastic and transfer reactions [1], which complement physics results obtained from fusion-evaporation studies [2] of Z ≥ 100 nuclei (see Fig.1).

High-spin states in ^{244,245}Pu were populated via inelastic and transfer reactions using ^{47}Ti and ^{208}Pb beams incident on a ^{244}Pu target. Delayed and prompt gamma rays were detected with Gammasphere. A new K-isomer in ^{244}Pu, with energy and decay similar to 2quasineutron 8^-isomers in heavier N=150 neighbors, has been identified, and its half-life measured. A new 2-qp rotational band structure, with properties consistent of being built on top of this isomer, has also been identified, along with other new rotational band structures in ^{244,245}Pu. The new results will be discussed in the larger context of emerging data [3] and theoretical expectations in neutron-rich N ≥ 150 nuclei.

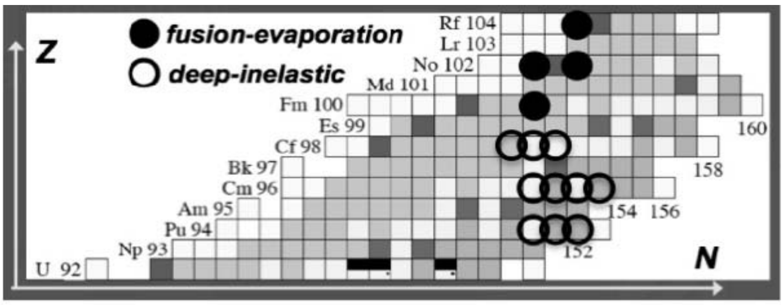


Fig. 1: Neutron-rich A≈250 nuclei investigated via inelastic and transfer reactions in this work.

*Supported by USDOE Grants DE-FG02-94ER40848 and DE-AC02-06CH11357.

[1] U. Shirwadkar, Ph.D. Thesis, U. Massachusetts Lowell, 2009.
[2] S. K. Tandel et al., Phys. Rev. Lett. **97**, 082502 (2006).
[3] R.-D. Herzberg and P. T. Greenlees, Prog. Part. & Nucl. Phys. **61**, 674 (2008).

Measurement of isospin mixing in $^{80}Zr^*$ at finite temperature

A. Corsi[1], A. Bracco[1], F. Camera[1], O. Wieland[7], S. Barlini[2], V. L. Kravchuk[3], G. Baiocco[5], L. Bardelli[2], G. Benzoni[7], M. Bini[2], N. Blasi[7], S. Brambilla[7], M. Bruno[5], G. Casini[2], M. Ciemala[4], M. Cinausero[3], M. Chiari[2], F. C. L. Crespi[1], M. D'Agostino[5], M. Degerlier[3], A. Giaz[1], F. Gramegna[3], M. Kmiecik[4], S. Leoni[1], A. Maj[4], T. Marchi[3], K. Mazurek[4], W. Meczynski[4], B. Million[7], D. Montanari[6], L. Morelli[5], A. Nannini[2], R. Nicolini[1], G. Pasquali[2], S. Piantelli[2], A. Ordine[8], G. Poggi[2], V. Rizzi[3], V. Vandone[1], G. Vannini[5]

[1]*Dipartimento di Fisica, Università di Milano and INFN Sezione di Milano, Italy.*
[2]*Dipartimento di Fisica, Università di Firenze and INFN Sezione di Firenze, Italy.*
[3]*INFN Laboratori Nazionali di Legnaro, Italy.*
[4]*The Henryk Niewodniczański Institute of Nuclear Physics, Krakow, Poland.*
[5]*Dipartimento di Fisica, Università di Bologna and INFN Sezione di Bologna, Italy.*
[6]*Dipartimento di Fisica, Università di Padova and INFN Sezione di Padova, Italy.*
[7]*INFN Sezione di Milano, Italy.*
[8]*INFN Sezione di Napoli, Italy.*

The issue of isospin mixing in N≈Z nuclei, related to the breaking of isospin symmetry due to Coulomb interaction, as well as other isospin-related phenomena has been subject of renewed interest in recent years [1]. It has been predicted that isospin mixing probability should increase with nuclear mass and temperature [2]. It is expected that the mixing increases up to T≈1-2 MeV and then decreases because the excited compound nucleus lifetime is too short for the relatively weak Coulomb interaction [2]. This prediction has been confirmed by several measurements of isospin mixing at finite temperature, limited up to now to the A=26-60 mass region [3].

A useful tool to study the degree of isospin purity of a state is to observe an isospin forbidden transition, as for example the E1 gamma decay from a compound nucleus populated in the I=0 channel where gamma decay is allowed only due to isospin mixing. In order to isolate isospin effects, statistical decay of two compound nuclei with the same mass and temperature but I≠0 and I=0 should be studied and compared. In addition, the measurement of the Giant Dipole Resonance decay of the compound nucleus is now the only available tool to study I=0 nuclei with A>60, since these nuclei close to the proton drip line are difficult to populate at zero temperature. The results obtained at finite temperature can then be extrapolated to the ground state.

Two reactions populating a compound nucleus of mass A≈80 with I≠0 and I=0 entrance channel have been performed at Laboratori Nazionali di Legnaro (Italy) with the combination of HECTOR (array of 8 BaF2 scintillators), GARFIELD (apparatus of 96 E-ΔE telescopes) and 32 PHOSWICH (plastic scintillators combined with CsI) detectors.

Results of the statistical model analysis for the reference reaction, ^{37}Cl+^{44}Ca, will be presented. These results have been used in the analysis of ^{40}Ca+^{40}Ca statistical decay where isospin effects inhibit the E1 Giant Dipole Resonance decay.

[1] D.D.Warner *et al.*, Nature Phys. 2, 311 (2006)
[2] H.L Harney *et al.*, Rev.Mod.Phys 58, 607 (1986)
[3] M.Kicinska-Habior, Acta.Phys.Pol B, 36 (2005), 1133 and references therein.

Incident-energy Dependent Quenching of the Analyzing Power in Pre-equilibrium Composite Particle Emission*

A. A. Cowley[1,2] **and J. J. van Zyl**[1]

[1]*Dept. of Physics, Stellenbosch University, Private Bag X1, Matieland 7602, South Africa*
[2]*iThemba Lab. for Accelerator Based Sciences, P. O. Box 722, Somerset West 7129, South Africa*

The analyzing power experimental observable proves to be a very sensitive quantity to investigate the multi-step character of the reaction process of proton-induced pre-equilibrium composite ejectile emission.

Recently we have shown [1-3] that the (p,^{3}He) reaction in the incident energy range of 100 to 160 MeV on two representative target nuclei, ^{59}Co and ^{93}Nb, can be understood reasonably well in terms of a multistep reaction process. The initial nucleon-nucleon collisions appear to be followed by a final step in which a proton-neutron pair is picked up from the target system. Of particular interest is the reproduction of the evolution of the characteristic features of the analyzing power distributions as a function of incident energy. A general trend is that the average magnitude of the analyzing power decreases towards higher incident energy. Unfortunately, due to the convoluted nature of the theoretical calculations, it is not obvious whether the observed incident energy-dependent quenching of the analyzing power is a consequence of fortuitous conspiracy of pickup from the various states available to the reaction process, or something more fundamental.

A similar study of the (p,α) reaction at the same incident energies and target nuclei suggests an analogous mechanism, with perhaps, based on dynamical considerations, knockout of pre-formed or induced α-clusters from the target more likely for the final step in the multistep chain.

We will discuss calculations for the (p,α) reaction in a kinematic range which should preferentially favour a one-step knockout of pre-formed cluster. Results will be evaluated in terms of consistency with the known small a-cluster occupation available in the ground state of targets in the same mass range.

*This work is supported by the South African National Research Foundation (NRF)

[1] A. A. Cowley, J. Bezuidenhout, S. S. Dimitrova, P. E. Hodgson, S. V. Förtsch, G. C. Hillhouse, M. Jacobs, R. Neveling, F. D. Smit, J. A. Stander, G. F. Steyn, and J. J. van Zyl. Phys. Rev. C **75** (2007) 054617.
[2] A. A. Cowley, J. Bezuidenhout, E. Z. Buthelezi, S. S. Dimitrova, S. V. Förtsch, G. C. Hillhouse, E. Hodgson, N. M. Jacobs, R. Neveling, F. D. Smit, J. A. Stander, G. F. Steyn, and J. J. van Zyl. Proceedings of the 23rd International Nuclear Physics Conference INPC2007 (Tokyo, Japan) 3-8 June 2007. (Editors: S. Nagamiya, T. Motobayashi, M. Oka, R.S. Hayano and T. Nagae). Publisher: Elsevier, Amsterdam (2008) Volume 2, p. 473 – 475.
[3] J. J. van Zyl. MSc thesis, University of Stellenbosch, 2008 (unpublished).

Exotic shapes and exotic clusterization*

J. Cseh

MTA ATOMKI, Debrecen Pf.51. Hungary-4001

The study of the possible clusterizations of extremely deformed nuclear states (e.g. superdeformed (SD) and hyperdeformed (HD)) is important from two aspects. On one hand they contribute to the understanding of the structure. On the other hand they can guide us in selecting the reactions which can populate these shape isomers. Recently we have applied symmetry-adopted methods for investigating different aspects of this problem.

The early chapters of the history of the HD state of the ^{36}Ar illustrate the efficiency of this approach. i) The first prediction for the HD state came from an alpha-cluster calculation [1]. ii) The possible binary cluster configurations of this state (i.e. the reaction channels to populate it) were investigated systematically in[2]. The preferred ones turned out to be the ^{24}Mg+^{12}C and ^{20}Ne+^{16} O channels. iii) The recent analysis of experimental data revealed the existence of small-spin resonances in the ^{24} Mg+^{12}C scattering [3]. Together with higher-spin ^{20}Ne+^{16}O resonances [4] they seem to form a rotational band. Its moment of inertia is in a good agreement with that of the predicted HD state. iv) The possible elongated shape isomers of the ^{36} Ar nucleus were determined from Nilsson-model +quasi-dynamical symmetry calculations [5]. This search gave the SD state in line with the other theoretical studies (at 4ħω excitation). It also gave a HD state which has a moment of inertia in agreement with the α-cluster model and experimental observation, and furthermore, it has the same U(3) symmetry, as suggested by the Brink-model.

The combination of arguments i-iv) makes the ^{36}Ar a good candidate for showing evidence for the ground, superdeformed and hyperdeformed states in a single nucleus. Work is in progress in order to find other favourable reactions (including gamma-decay) for the observation of the HD state. Applications of the method to other nuclei are also mentioned.

*This work is supported by the OTKA (Grant No.K72357).

[1] W.D.M. Rae, A. Merchant, Phys. Lett. B 279 (1992)207.
[2] J. Cseh, A. Algora, J. Darai, P. O. Hess, Phys. Rev. C 70 (2004)034311.
[3] W. Sciani et al, Phys. Rev. C 80 (2009)034319.
[4] Shimizu et al., Phys. Lett. B112 (1982)323; Gai et al, Phys. Rev. C 30 (1984)925;
Miao et al, Phys. Rev. C 53 (1996)815.
[5] J. Cseh, J. Darai, et al, Phys. Rev. C 80 (2009)034320.

DPUNS - A Differential-Plunger for Lifetime measurements of Tagged Exotic- and Unbound nuclear states*

D. M. Cullen

[1] *Schuster Laboratory, School of Physics and Astronomy, University of Manchester, Manchester, M13 9PL, United Kingdom.*

This talk will discuss the development of a new Differential-Plunger for lifetime measurements of tagged unbound nuclear states, DPUNS, at the University of Manchester (See Fig. 1). DPUNS will be used in conjunction with the existing GREAT spectrometer at the University of Jyvaskyla to preferentially select weak nuclear channels ($\sigma \approx \mu b$) by the detection of recoils, isomeric states or proton/alpha decays at the focal plane of the RITU gas-filled separator. The low-background environment produced by these sensitive tagging techniques allows the lifetimes of the states above these isomers and alpha- or proton unbound states to be measured for the first time. Such lifetime information provides crucial information about the deformation and underlying configuration of the isomer-, alpha-, proton-decaying state which is often required in theoretical tunnelling calculations. One aim of this work is to study the effect of the triaxiality on proton-decay tunnelling rates. As an example, the results of the first isomer-tagged differential-plunger measurement (using an existing Koln plunger) to determine the lifetimes of the unbound states above a low-spin shape isomer in ^{144}Ho will be discussed [1,2] in terms of the development of triaxiality and Critical-Point symmetries in nuclei [3] near the proton drip line in the mass 140 region.

DPUNS has been optimised to work within the RITU gas, removing the windows required with the Koln differential plunger, and thereby reducing the additional scattering of beam and recoils. DPUNS makes use of the Lyrtec digital electronics from the SAGE and LISA projects producing a more efficient setup which will be able to study lifetimes and deformations in nuclei with smaller production cross sections than is presently possible.

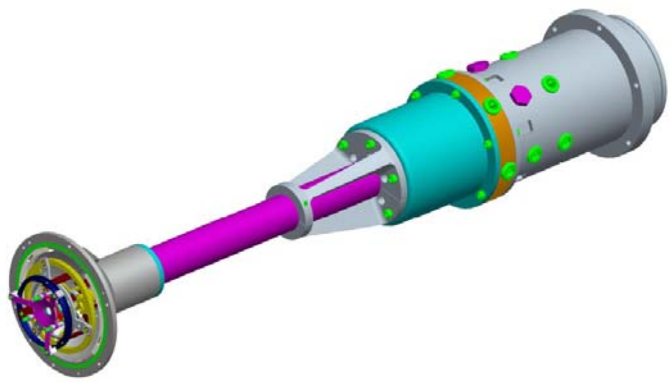


Fig. 1: DPUNS – a differential-plunger for unbound nuclear states.

* This work is supported by the UK STFC under contract number ST/G008787/1.

[1] P.J.R. Mason, D.M. Cullen *et al*., Phys. Lett. **B683**, 17 (2009)
[2] P.J.R. Mason, D.M. Cullen *et al*., Phys. Rev. **C79**, 024318 (2009)
[3] M. Procter, D.M. Cullen *et al*., to be published.

Fission properties of actinide nuclei at energies 26.5 and 62.9 MeV

P. Demetriou[a),]Th. Keutgen[b)], R. Prieels[b)] and Y. El Masri[b)]

[a)] *Institute of Nuclear Physics, NCSR "Demokritos", 153.10 Aghia Paraskevi, Athens, Greece*
[b)] *FNRS and Institut de Physique Nucléaire, Université catholique de Louvain, B-1348 Louvain-la-Neuve, Belgium*

Fission properties of proton-induced fission on ^{232}Th, ^{237}Np, ^{238}U, ^{239}Pu and ^{241}Am targets, measured at the Louvain-la-Neuve cyclotron facility at proton energies of 26.5 and 62.9 MeV, are compared with the predictions of the state-of-the-art nuclear reaction code TALYS. The code couples the multi-modal random neck rupture model with the pre-equilibrium "exciton" and statistical models to predict fission fragment mass yields, pre- and post-scission neutron multiplicities and total fission cross sections in a consistent approach.

The experimental results are presented and the sensitivity of the calculations to the input parameters of the code and possible improvements are discussed in detail.

Splitting of the Pygmy Dipole Resonance

J. Endres[1], A. Zilges[1], N. Pietralla[2], V. Yu. Ponomarev[2], D. Savran[2], K. Sonnabend[2], M. N. Harakeh[3,4], E. Litvinova[3,5,6], V. I. Stoica[4], H.J. Wörtche[4,7], L. Popescu[8], P. Butler[9], R.-D. Herzberg[9], M. Scheck[9], S. Harissopulos[10], A. Lagoyannis[10], R. Krücken[11], P. Ring[11]

[1] *Institut für Kernphysik, Universität zu Köln, Zülpicher Straße 77, D-50937 Köln, Germany*
[2] *Institut für Kernphysik, TU Darmstadt, Schlossgartenstraße 9, D-64289 Darmstadt, Germany*
[3] *GSI Helmholtzzentrum für Schwerionenforschung, D-64291 Darmstadt, Germany*
[4] *KVI, University of Groningen, 9747 AA Groningen, The Netherlands*
[5] *FIAS, Universität Frankfurt, D-60438 Frankfurt amMain, Germany*
[6] *Institute of Physics and Power Engineering, RU-249033 Obninsk, Russia*
[7] *INCAS3, Dr. Nassaulaan 9, 9401 HJ Assen, The Netherlands*
[8] *Belgian Nuclear Research Centre SCK*CEN, Boeretang 200, B-2400 Mol, Belgium*
[9] *Oliver Lodge Laboratory, University of Liverpool, L69 7ZE, United Kingdom*
[10] *Institute of Nuclear Physics, NCSR "Demokritos", GR-15310 Aghia Paraskevi, Athens, Greece*
[11] *Physik Department, TU München, D-85748 Garching, Germany*

In recent years investigations have been made to study the electric Pygmy Dipole Resonance (PDR) systematically, mainly in semi-magic nuclei. For this purpose the well understood high resolution (γ,γ′) photon scattering method is used [1]. In (α,α′γ) coincidence experiments at E_α=136 MeV a similar energy resolution and a high selectivity to E1 transitions can be obtained at the Big-Bite Spectrometer (BBS) at KVI, Groningen. In comparison to the (γ,γ′) method a structural splitting of the PDR could be observed in the N=82 nuclei ^{138}Ba and ^{140}Ce and in the Z=50 isotope ^{124}Sn [2,3,4]. There is a low energy part which could be excited in (γ,γ′) as well as in (α,α′γ) and there is a high energy part which could only be observed in (γ,γ′). The experimental results and theoretical QPM and RQTBA calculations on ^{124}Sn will be presented which are able to reproduce the splitting of the PDR. The low-lying group of $J^\pi=1^-$ states seem to represent the more isoscalar neutron-skin oscillation of the PDR while the energetically higher lying states seemingly belong to the tail of the isovector Giant Dipole Resonance (GDR).

* This work is supported by the DFG (ZI 510/4-1 and SFB 634), by the LOEWE program of the State of Hesse (HIC for FAIR), the DFG cluster of excellence Origin and Structure of the Universe, and by the EU under EURONS Contract No. RII3-CT-2005-506065.

[1] D. Savran et al., Phys. Rev. Lett. 100, 232501 (2008).
[2] D. Savran et al., Phys. Rev. Lett. 97, 172502 (2006).
[3] J. Endres et al., Phys. Rev. C. 80, 034302 (2009).
[4] J. Endres et al., submitted to Phys. Rev. Lett.

Assigning γ deformation from fine structure in exotic nuclei*

Lidia S. Ferreira[1], **Enrico Maglione[2] and P. Arumugam**

[1] *Centro de Fisica das Interaccoes Fundamentais, and Departamento de Fisica, Instituto Superior Tecnico, Avenida Rovisco Pais, P1049-001 Lisbon, Portugal*
[2] *Dipartimento di Fisica ``G. Galilei'', Via Marzolo 8, I-35131 Padova, Italy and Istituto Nazionale di Fisica Nucleare, Padova, Italy*

The nonadiabatic quasiparticle model for triaxial shapes is used to perform calculations for decay of ^{141}Ho, the only known odd-Z even-N deformed nucleus for which fine structure in proton emission from both ground and isomeric states has been observed. All experimental data corresponding to this unique case namely, the rotational spectra of parent and daughter nuclei, decay widths and branching ratios for ground and isomeric states, could be well explained with a strong triaxial deformation $\gamma \sim 20^\circ$. The recent experimental observation of fine structure decay from the isomeric state, can be explained only with an assignment of $I = 3/2^+$ as the decaying state, in contradiction with the previous assignment, of $I=1/2^+$, based on adiabatic calculations.

This study reveals that proton emission measurements could be a precise tool to probe triaxial deformations and other structural properties of exotic nuclei beyond the proton dripline.

* This work is supported by "Fundacao para a Ciencia e a Tecnologia (FCT) Portugal", Project: PTDC/FIS/68340/2006.

Study of near-stability nuclei populated as fission fragments in heavy-ion fusion reactions

N. Fotiades[1], J. A. Cizewski[2], R. O. Nelson[1], M. Devlin[1], R. Krücken[3], R. M. Clark[4], P. Fallon[4], I. Y. Lee[4], A. O. Macchiavelli[4], J. A. Becker[5], W. Younes[5]

[1] *Los Alamos National Laboratory, Los Alamos, New Mexico 87545, USA.*
[2] *Department of Physics and Astronomy, Rutgers University, New Brunswick, New Jersey 08903, USA.*
[3] *Physik Department E12, Technische Universität München, D-85748 Garching, Germany.*
[4] *Nuclear Science Division, Lawrence Berkeley National Laboratory, Berkeley, California 94720, USA.*
[5] *Lawrence Livermore National Laboratory, Livermore, California 94550, USA.*

There is a long history of studies of nuclear structure by identifying the prompt discrete lines from fission fragments, a technique used frequently in the study of neutron-rich and near-stability nuclei that cannot be studied as evaporation residues in heavy-ion fusion reactions since they cannot be populated with stable beam-target combinations in such reactions. Especially useful is the complementary fission fragment technique that enables assigning of γ-rays and high-spin states to neutron-rich and near-stability fission fragments for which no high-spin spectroscopic information exists by establishing - coincidences between these γ-rays and previously known γ-rays of one or more complementary fission fragments.

Examples will be presented to illustrate the power of prompt γ-ray spectroscopy of fission fragments from compound nuclei with A≈200 formed in fusion-evaporation reactions in experiments using the Gammasphere Ge-detector array. Complementary methods, such as Coulomb excitation and deep-inelastic processes, have also been used in some cases. In other cases we have also developed a technique that uses (n,xnγ) reactions on stable isotopes to complement assignments of γ-rays. This technique is based on establishing of neutron excitation functions for γ-rays using a pulsed "white"-neutron source, like the one at the Los Alamos Neutron Science Center facility, coupled to a high-energy-resolution germanium-detector array (see, for instance, the assignment of transitions to ^{135}Xe in Ref. [1] using the GEANIE Ge-detector array). Results from all these methods will be discussed.

The observation of high spin states in all these complementary methods bridges the gaps in the systematics between the neutron-deficient and neutron-rich nuclei. Moreover, several nuclei studied in these methods are located near shell or sub-shell closures where the experimental results can be easily compared with predictions from shell-model calculations.

[1] N. Fotiades et al., Phys. Rev. C 75 054322 (2007); and references therein.

Measurement of absolute E2 transition strengths in ^{176}W: Signatures for a rapid shape change *

Christoph Fransen[1], Alfred Dewald[1], Gunnar Friessner[1], Matthias Hackstein[1], Jan Jolie[1], Oliver Möller[2], Thomas Pissulla[1], Wolfram Rother[1], Karl-Oskar Zell[1]

[1] Institut für Kernphysik, Universität zu Köln, Zülpicher Straße 77, 50937 Cologne, Germany
[2] Institut für Kernphysik, Technische Universität Darmstadt, Schlossgartenstraße 9, 64289 Darmstadt, Germany

The X(5) symmetry describes nuclei at the critical point of the shape phase transition from axially deformed rotor nuclei to spherical vibrators [1]. ^{150}Nd, ^{152}Sm, and ^{154}Gd were the first nuclei where the predicted characteristics of the X(5) symmetry were observed (see, e.g., [2]). Later it was shown that also ^{176,178,180}Os can be successfully described with the X(5) symmetry [3].

In the close vicinity of shape phase transitions one expects strongly changing nuclear shapes. In the X(5) region around A=150 this was observed for nuclei with different neutron numbers, whereas in the X(5) region around A=180 this is to be expected for different proton numbers.

The aim of the work presented here is the confirmation of a rapid shape change for nuclei close to ^{178}Os. Besides the knowledge on the level scheme of the nuclei of interest, especially absolute E2 transition strengths are crucial for the interpretation of nuclear structure. Prolate deformation is expected for ^{176}W. Thus we performed a recoil distance Doppler shift (RDDS) measurement on ^{176}W to measure E2 transition strengths from level lifetimes. The experiment was performed at the Cologne FN Tandem accelerator with the Cologne coincidence plunger with the reaction ^{169}Dy(^{16}O,4n)^{176}W and a beam energy of 80 MeV. We will present our experimental results and relate them to data on the neighboring nuclei ^{178}Os and ^{182}Pt. The results will be discussed in the framework of nuclear shape transitions in this mass region and compared to calculations with both the Interacting Boson Model (IBM) and the GCM.

* This work is supported by the Deutsche Forschungsgemeinschaft, grant No. De 1516/-1

[1] F. Iachello, Phys. Rev. Lett. 87, 052502 (2001).
[2] E.A. McCutchan, N.V. Zamfir, R. F. Casten, Phys. Rev. C 71, 034309 (2005).
[3] A. Dewald et al., J. Phys. (London) G 31, S1427 (2005).

Gamow-Teller Transitions Starting from T_z = +3/2 Nucleus ^{47}Ti

E. Ganioğlu[1], H. Fujita[2], Y. Fujita[2], T. Adachi[3], A. Algora[4], M. Csatlos[5], J. Deaven[6], E. Estevez[4], C. Guess[6], J. Gulyás[5], K. Hatanaka[3], K. Hirota[3], D. Ishikawa[3], A. Krasznahorkay[5], H. Matsubara[3], R. Meharchand[6], F. Molina[4], H. Okamura[3], Y. Oktem[1], H.J. Ong[3], G. Perdikakis[6], B. Rubio[4], C. Scholl[7], G. Susoy[1], T. Suzuki[3], A. Tamii[3], J. Thies[8], R.G.T. Zegers[6], J. Zenihiro[3]

[1] *Department of Physics, Istanbul University, Istanbul 34134, Turkey*
[2] *Department of Physics, Osaka University, Toyonaka, Osaka 560-0043, Japan*
[3] *Research Center for Nuclear Physics, Osaka University, Ibaraki, Osaka 567-0047, Japan*
[4] *Instituto de Física Corpuscular, CSIC-Universidad de Valencia, E-46071 Valencia, Spain*
[5] *ATOMKI, P.O.Box 51, H-4001 Debrecen, Hungary*
[6] *NSCL, Michigan State University, East Lansing, Michigan 48824-1321, USA*
[7] *Institut für Kernphysik, Universität zu Köln, 50937 Köln, Germany*
[8] *Institut für Kernphysik, Westfälische Wilhelms-Universität, D-48149 Münster, Germany*

Gamow-Teller (GT) transition, caused by the $\sigma\tau$-type interaction, is the most popular weak process in nuclei. It is of interest not only in nuclear physics, but also in astrophysics. A high energy-resolution (^{3}He,*t*) experiment at Reseach Center for Nuclear Physics (RCNP), Osaka [1-4] was performed on the T_z = +3/2 nucleus ^{47}Ti at 0° and at an intermediate incident energy of 140 MeV/nucleon in order to study the precise GT transition strengths to the final T_z = +1/2 nucleus ^{47}V. Owing to the energy resolution of 20 keV achieved in the ^{47}V spectrum, individual GT transitions were observed [5]. It is known that the strength of each of these transitions is proportional to the GT transition strength *B*(GT) in the (^{3}He,*t*) reaction[6]. Since the "standard *B*(GT) value" was available from the β decay study of ^{47}V, *B*(GT) values were reliably derived up to higher excitations.

[1] T. Adachi *et al.*, Phys. Rev. C 73, 024311 (2006).
[2] Y. Fujita, *et al.*, Phys. Rev. Lett. 95, 212501 (2005).
[3] H. Fujita *et al.*, Phys. Rev. C 75, 034310 (2007).
[4] L. Popescu *et al.*, Phys. Rev. C 79, 064312 (2009).
[5] http://www.rcnp.osaka-u.ac.jp
[6] Y. Fujita, *et al.*, Phys. Rev. C 75, 057305 (2007).

Mapping quadrupole collectivity in the Cd isotopes: The breakdown of spherical vibrational motion

P. E. Garrett

Department. of Physics, University of Guelph, Guelph, Ontario, Canada N1G2W1

The nuclear structures of the even-even Cd isotopes near stability, especially $^{110\text{-}116}$Cd, were long thought to be prime examples of low-lying vibrational motion. Their level schemes display a nearly harmonic spacing of one, two, and three-phonon levels. Due to their importance as paradigms of vibrational motion, their structures were previously investigated by a variety of reactions, such as a series of (α,2n) reactions and (n,n'g) reactions. While these reactions were essential for establishing the location of levels and their main decay branches, and in most cases their lifetimes, they did not have the sensitivity to probe the weak low-energy branches that are necessary to assess the degree of collectivity possessed by low-spin states at high excitation energy.

In order to complement the data used to test the collectivity present in the Cd isotopes, we have initiated a programme of extensive beta-decay experiments using the 8π spectrometer at the TRIUMF radioactive-beam facility. The goal of these experiments is to achieve a sufficient sensitivity to weak, low-energy branches amongst the multi-phonon levels so that the collective branches would either be observed, or very stringent upper limits set. Thus far, we have examined the decay of ^{110}In to ^{110}Cd, and ^{112}In/^{112}Ag to ^{112}Cd. These experiments have allowed a nearly complete mapping of the *E2* strength in low-spin levels up to ~3 MeV, and have revealed that the individual low-spin multi-phonon states do not decay in the expected manner. Further, and much more surprising, the missing *E2* strength is not due to fragmentation (i.e., mixing) amongst the levels below ~3 MeV. This lack of the *E2* strength has forced a re-evaluation of the structure, suggesting a more rotational picture rather than vibrational. This also raises the issue that if our long-standing paradigms of vibrations can no longer be considered as vibrational nuclei, are there any spherical vibrational nuclei?

Fusion enhancement/suppression and irreversibility in reactions induced by weakly bound nuclei.

P. R. S. Gomes[1], L. F. Canto[2], J. Lubian[1], E. Crema[3], L. C. Chamon[3], M. S. Hussein[3]

[1] Instituto de Física, Universidade Federal Fluminense, Niterói, 24210-340 Brazil.

[2] Instituto de Física, Universidade Federal do Rio de Janeiro,Rio de Janeiro, Brazil.

[3] Instituto de Física, Universidade de São Paulo, São Paulo, Brazil.

The effect of breakup of weakly bound nuclei, especially halo nuclei, on the fusion cross section has been widely investigated [1] but not yet fully understood. One can distinguish effects of two kinds. First, there are the static effects associated with the longer tail of the nuclear density, arising from the halo nucleons. This tail gives rise to a more diffuse potential, with a lower barrier. We will show strong sub-barrier fusion enhancements for the ^{6}H +^{209}Bi and ^{238}U systems, owing to the static halo properties of ^{6}He, in opposition to what was claimed by Raabe et al. [2], who compared data with calculations using realistic double folding potential and therefore were not able to observe static halo effects. Secondly, there are dynamical effects associated with the strong coupling between the elastic and the breakup channels. The consequences of this coupling are more difficult to assess. To investigate the role of weak binding in the fusion process, it is important to compare fusion cross sections for different systems and to have a benchmark to which the data have to be compared. Recently we have developed a new method [3] to investigate systematical trends in the fusion of weakly bound nuclei, through dimensionless fusion functions and energy variable quantity, and we were able to disentangle static from dynamic effects of the breakup on fusion. By comparing data with a benchmark curve, called Universal Fusion Function [3] we observe a general trend of fusion suppression above the barrier. This fusion suppression is clearly observed when, performing CDCC calculations, continuum-continuum couplings (CCC) are considered. We will present results of CDCC calculations for complete fusion, breakup and elastic scattering, and comparisons with data, in order to investigate the role of breakup and the feeding of continuum states in reaction mechanisms [4]. We will show that the suppression of complete fusion does not come from some kind of irreversibility of the transition to the continuum, but rather the inclusion of CCC makes the real part of the polarization potential more repulsive, so that the incident current has to cross a higher barrier to produce fusion.

[1] L.F. Canto, P.R.S. Gomes, R. Donangelo, M.S. Hussein; Phys. Rep. **424**, 1 (2006).

[2] R. Raabe *et a.l*, Nature **431**, 823 (2004)

[3] L.F. Canto, P.R.S. Gomes, J. Lubian, L.C. Chamon, E. Crema; J. Phys. G **36,** 015109 (2009); Nucl. Phys. A **821**, 51 (2009).

[4] L.F. Canto, J. Lubian, P.R.S. Gomes, M.S. Hussein, Phys. Rev. C **80**, 047601 (2009)

The Impact of LUNA Results on Astroparticle Physics

Carlo Gustavino
for the LUNA Collaboration

INFN Sezione di Roma, I-00185 Roma, Italy

LUNA (Laboratory for Underground Nuclear Astrophysics) is devoted to measure nuclear cross sections relevant in astroparticle physics. The LUNA facility operates underground, at the "Laboratori Nazionali del Gran Sasso" (LNGS), where the measurement of nuclear cross sections at very low energies is possible due to the fact that the Gran Sasso mountain provides a huge reduction of the background induced by cosmic rays. LUNA yields a solid experimental base for the Standard Solar Model that is of primary importance in the study of the Sun and in the neutrino physics. Many reactions studied by LUNA are very important to study other celestial bodies and their evolution. Finally, LUNA provides the measurement of cross sections of several leading processes in the Big Bang Nucleosynthesis. The comparison between the direct observation of light isotopes and their calculated abundance, allows an important test for the BBN theory, for the Standard Model and for the evolution of the universe. The results obtained by LUNA in the past and the future measurements are discussed.

The Entrance Channel Effects in Fusion-fission and Quasi-fission

M. G. Itkis, and G.N. Knyazheva

Joint Institute for Nuclear Research, 141980 Dubna, Russia

The existence of the island of stability in the region of nuclei with Z=114 and N=184 predicted theoretically has induced an extensive experimental investigation in the field of superheavy element synthesis. A considerable success was achieved in reactions of actinides with a double magic ^{48}Ca beam at FLNR where the synthesis of with atomic number z up to 118 has been claimed. Experimental data confirm the theoretical prediction of the increase of the half-lives following the increase of the neutron number of the compound nucleus. Unfortunately, the isotopes of superheavy elements formed these ^{48}Ca induced reactions cannot reach the neutron closed shell with N=184 due to the lack of 7-9 neutrons. Nuclei with Z>118 cannot be synthesized in ^{48}Ca induced reactions since 249Cf is the heaviest target material available for these purposes. A possible alternative pathway is represented by the complete fusion of actinide nuclei with heavier projectiles such as ^{58}Fe or ^{64}Ni leading to the formation of compound nuclei with Z=118-124 and N=178-188. Since at energies near the Coulomb barrier the fusion reactions between two heavy nuclei are strongly hindered by the competing quasi-fission and deep-inelastic reactions, more detailed experimental studies of the reaction mechanism are required to provide realistic estimates of the probability of producing compound nuclei in such reactions, especially in connection with the entrance channel properties.

Mass-energy distributions as well as capture cross sections of fission-like fragments have been measured for a wide range of composite systems with Z=82-122 formed in the reactions with ^{22}Ne, ^{26}Mg, ^{48}Ca, ^{58}Fe and ^{86}Kr ions at energies around the Coulomb barrier. The experiments were carried out using a double-arm time-of-flight spectrometer of binary reaction products CORSET. The main peculiarities of mass and energy distributions of fusion-fission and quasi-fission fragments will be discussed. The results of the experimental investigations of the influence of the entrance channel properties on the competition between fusion-fission and quasi-fission for the “warm” and “cold” fusion reactions will be reported.

Recent advances in Multi-Channel Algebraic Scattering*

S. Karataglidis[1], P. Fraser[2], K. Amos[3], L. Canton[4], J. P. Svenne[5], and D. van der Knijff[3]

[1] *Dept. of Physics, University of Johannesburg, P.O. Box 524, Auckland Park, 2006, South Africa.*
[2] *Instituto de Ciencias Nucleares, Universidad Nacional Autnoma de México, 04510 México, D.F., Mexico.*
[3] *School of Physics, University of Melbourne, Victoria, 3010, Australia.*
[4] *Istituto Nazionale di Fisica Nucleare, Sezione di Padova, I-35131, Italy*
[5] *Dept.of Physics and Astronomy, Univ.of Manitoba, Winnipeg, Manitoba, Canada, R3T 2N2.*

With the rush to build new radioactive-ion-beam (RIB) facilities, notably FRIB, the descriptions of weakly-bound systems, and the scattering therefrom, are becoming increasingly important. A central aspect of this, particularly in coupled-channels approaches to scattering, is the need to include target excited states that are unbound, with particle-emission widths that are significantly different from zero. One question which arises is how the particle-emission widths affect the formation of compound states, as well as the scattering cross sections. This is explored within the framework of the Multi-Channel Algebraic Scattering (MCAS) method.

We consider a range of light-mass, particle unstable targets, and compare the results with, and without, the inclusion of the target resonance widths. We find that the compound spectra and evaluated cross sections vary markedly with the resonance character of the target. A proper description of the energy dependence of the decay widths is needed, to ensure a correct specification of both the sub-threshold bound and scattering states.

* This work is supported by the National Research Foundation, South Africa, the Instituto de Ciencias Nucleares, UNAM, Natural Sciences and Engineering Research Council, Canada, INFN, and the Australian Academy of Science.

Photon Strength Functions at the Low-Energy Tail of the GEDR Obtained from Different Reactions

M. Krtička[1], F. Bečvár[1]

[1] *Faculty of Mathematics and Physics, Charles University, V Holešovičkách 2, 182 00 Prague, Czech Republic*

The photon strength functions (PSFs) for different multipolarities are the key entities describing the statistical -decay, being at the same time related to the photoabsorption cross sections. It is well known that PSFs and photoabsorption cross sections at energies above the threshold for particle emission are well described by the Lorentzian giant electric dipole resonance (GEDR) with the maximum near 15 MeV and a width of about 5 MeV. On the other hand, shapes of PSFs at the low-energy tail of GEDR are known rather poorly.

In this contribution the main difficulties with the extraction of the PSFs from different experiments at -ray energies below the particle emission will be emphasized. A special attention will be paid to a mutual comparison of PSFs deduced from (n,γ), (γ,γ_0') and 3He-induced reactions. It will be shown that with the available techniques for extracting the data on PSFs the different reactions yield inconsistent results. At present, it is thus very difficult to make a reliable comparison of experimental data on these quantities with theoretical predictions.

* This work is supported by the Czech Research Plans MSM-021620859 and INGO-LA08015.

Electric, Magnetic and Vorticity Strengths in Heavier Nuclei

J. Kvašil[1], V. O. Nesterenko[2], W. Kleinig[2,4], P. Veselý[1,3] and P.-G. Reinhard[5]

[1]*Institute of Particle and Nuclear Physics, Charles University, CZ-18000, Prague, Czech Republic*
[2]*Laboratory of Theoretical Physics, Joint Institute for Nuclear Research, Dubna 141980, Moscow region, Russia*
[3]*Department of Physics, P.O. Box 35 (YFL), University of Jyväskylä, 40014 Jyväskylä, Finland*
[4]*Technical University, D-01062, Dresden, Germany*
[5]*University of Erlangen, D-91058, Erlangen, Germany*

The separable RPA method [1,2] starting from the Skyrme functional is applied for the analyses of E1 and M1 giant resonances in rare-earth and actinide spherical and deformed isotopes. A special attention is paid to the role of the time-odd currents in the Skyrme functional and to their influence on the GR properties [1,2]. We discuss the influence of Skyrme parameterizations with different effective masses on the description of the photoabsorption cross section, E1 sum rule, and M1 resonance [3,4]. The main contributions to the resonance width (deformation splitting, Landau fragmentation, etc) are analysed.

The low-energy E1 strength near the particle emission thresholds is known to be important for astrophysical problems. We inspect influence of the deformation on this strength for particular isotopic chains [3]. The impact is shown negligible near and below the thresholds. At the same time, it increases the E1 strength near the E1 GR.

The irrotationality of the nuclear matter is analysed using the strength function of the dipole vorticity operator derived from the long wave expansion of the electric E1 transition operator [5]. Vorticity strength is compared with the E1 and dipole toroidal strength especially in the excitation energy interval characteristic for the Pigmy mode.

[1] V.O. Nesterenko, J. Kvasil, and P.-G. Reinhard, Phys. Rev. C, 66, 044307 (2002);
V.O. Nesterenko, W. Kleinig, J. Kvasil, P.-G. Reinhard, and P. Vesely, Phys. Rev. C, 74, 054306 (2006);
W. Kleinig, V.O. Nesterenko, J. Kvasil, P.-G. Reinhard and P. Vesely, Phys. Rev. C 78, 044313 (2008).
[2] P. Vesely, J. Kvasil, V.O. Nesterenko, W. Kleinig, P.-G. Reinhard, and V.Yu. Ponomarev, Phys. Rev. C. 80, 031302(R) (2009).
[3] J. Kvasil, P. Vesely, V.O. Nesterenko, W. Kleinig, P.-G. Reinhard, S. Frauendorf, Int. J. Mod. Phys. E 18(4), 975 (2009).
[4] V.O. Nesterenko, J. Kvasil, P. Vesely, W. Kleinig, P.-G. Reinhard, and V.Yu. Pomomarev, J. Phys. G: Nucl. Part. Phys. 37, 064034 (2010).
[5] J. Kvasil, V.O. Nesterenko, W. Kleinig, P.-G. Reinhard, P. Vesely, to be published.

High accuracy $^{18}O(p,\alpha)^{15}N$ reaction rate in the 8×10^6 – 5×10^9 K temperature range

M. La Cognata[1,2], C. Spitaleri[1,2], A. Mukhamedzhanov[3], A. Banu[3], S. Cherubini[1,2], A. Coc[4], V. Crucillà[1,2], V. Goldberg[3], M. Gulino[1], B. Irgaziev[5], G. G. Kiss[1,2], L. Lamia[1,2], J. Mrazek[6], R. G. Pizzone[1,2], S. M. R. Puglia[1,2], G. G. Rapisarda[1,2], S. Romano[1,2], M. L. Sergi[1,2], G. Tabacaru[3], L. Trache[3], R. E. Tribble[3], W. Trzaska[7], and A. Tumino[1,8]

[1] *INFN – Laboratori Nazionali del Sud*
[2] *DMFCI – Università di Catania, Catania, Italy*
[3] *Cyclotron Institute – Texas A&M University, College Station, TX, USA*
[4] *CSNSM CNRS/IN2P3, Université Paris Sud, Orsay, France*
[5] *GIK – Institute of Engineering Sciences and Technology, Topi District, Pakistan*
[6] *Nuclear Physics Institute of ASCR, Rez near Prague, Czech Republic*
[7] *Physics Department, University of Jyvaskyla, Finland*
[8] *Università degli studi di Enna "Kore," Enna, Italy*

The $^{18}O(p,\alpha)^{15}N$ reaction is of great importance in several astrophysical scenarios, as it influences the production of key isotopes such as ^{19}F, ^{18}O and ^{15}N. Fluorine is synthesized in the intershell region of asymptotic giant branch stars, together with s-elements, by radiative capture on ^{15}N, which in turn is produced in the ^{18}O proton-induced destruction [1].

Peculiar ^{18}O abundances are observed in R-Coronae Borealis stars, having $^{16}O/^{18}O$ <1, hundreds of times smaller than the galactic value. In the framework of the double degenerate scenario, a quantitative account of such abundances can be provided if H-rich material is ingested and the $^{18}O(p,\alpha)^{15}N\,(p,\alpha)^{12}C$ chain is activated, thus reducing ^{18}O overproduction [2]. Finally, there is no explanation of the $^{14}N/^{15}N$ ratio in presolar grains formed in the outer layers of asymptotic giant branch stars. Again, such an isotopic ratio is influenced by the $^{18}O(p,\alpha)^{15}N$ reaction that might increase the ^{15}N yield during non-convective mixing episodes [3].

In this work, a high accuracy $^{18}O(p,\alpha)^{15}N$ reaction rate is proposed, based on the simultaneous fit of direct measurements and the results of a new Trojan horse experiment (see [4] for a description of the method). Indeed, current determinations are uncertain because of the poor knowledge of the resonance parameters of key levels of ^{19}F. A key role is played by the 20 keV resonance in the $^{18}O(p,\alpha)^{15}N$ cross section, whose strength has been recently determined in a novel THM approach [5]. Moreover, we focus on the study of the broad 660 keV $1/2^+$ resonance corresponding to the 8.65 MeV level of ^{19}F. Since Γ=100-300 keV, it determines the low-energy tail of the resonant contribution to the cross section and dominates the cross section at higher energies. Here we provide a factor 2 larger reaction rate above T=0.5 10^9 K based over our new improved determination of its resonance parameters, which could strongly influence present-day astrophysical model predictions [6].

[1] M. Lugaro *et al.*, Astrophys. J. **615**, 934 (2004)
[2] G.C. Clayton *et al.*, Astrophys. J. **662**, 1220 (2007)
[3] K.M. Nollett *et al.*, Astrophys. J. **582**, 1036 (2003)
[4] C. Spitaleri *et al.*, Phys. Rev. C **69**, 055806 (2004)
[5] M. La Cognata *et al.*, Astrophys. J. **708**, 796 (2010)
[6] M. La Cognata *et al.*, submitted to the Astrophysical Journal

Study of the interplay between the ^{8}B breakup and other reaction mechanisms by means of the CDCC method *

J. Lubian[1], T. Correa[1], P. R. S. Gomes[1], L. F. Canto[2]

[1]*Instituto de Física, Universidade Federal Fluminense, Gragoatá, Niterói, R.J., 24210-340, Brazil.*
[2]*Instituto de Física, Universidade Federal do Rio de Janeiro, 21941-972 Rio de Janeiro, Brazil.*

Recently it has been shown that the standard ways of determining polarization potentials are not useful to describe the breakup cross section in terms of a one-step process. Because the continuum couplings are strongly non-local the complexity of coupled channel methods may well be unavoidable [1].

In the present work the effect of the breakup process on the fusion induced by proton halo projectiles is investigated through the behavior of the quasi elastic barrier distribution (QEBD) of the system ^{8}B+^{58}Ni. The competition between the breakup channel and inelastic excitations and the behavior of their corresponding polarization potentials are studied by means of CDCC calculations. We performed several calculations including couplings with channels associated with ^{8}B breakup and ^{58}Ni collective states. Switching on and of the couplings with each kind of channel, we determined their separate influence on the QEBD. While the breakup coupling shifts the barrier distribution to higher energies, reduces slightly its maximum and makes the distribution broader, the coupling to inelastic channels shifts the distribution to lower energies and leads to a second maximum at higher energies. When both couplings are considered, the shifts toward opposite directions cancel and the barrier remains close to its nominal value. This fact is interpreted as: the repulsive polarization potential associated with breakup cancels the attractive one resulting from the coupling with the target collective states [2].

We have used the CDCC method to investigate the effects of breakup coupling on ^{8}B+^{58}Ni elastic scattering. Our results were compared with the recent data of Aguilera et al. [3]. The results of our calculations were in excellent agreement with the experimental results. The effect of inelastic excitations and of continuum-continuum couplings on the angular distributions has been also investigated. We found that inelastic excitations do not have an appreciable influence while continuum-continuum couplings are of utmost importance. It has been shown that the multipole expansion of the coupling interaction is dominated by monopole, dipole and quadrupole terms. Higher multipoles can be neglected. The relative importance of Coulomb and nuclear breakups and their interference were also investigated. For this purpose, we perform CDCC calculations switching of each of these interactions, and comparing the results with the ones obtained with the full couplings. The repulsive character of the polarization potential associated with Coulomb breakup was found in the barrier region. On the other hand, the results for purely nuclear breakup coupling fall slightly below the results of the single-channel calculation. When both nuclear and Coulomb breakup couplings are taken into account, there is a destructive interference between the two amplitudes and the angular distribution lies slightly above the no-coupling results.

* This work is supported by the CNPq and FAPERJ.

[1] J. Lubian and F. M. Nunes, J. Phys. G: Nucl. Part. Phys. **34**, 513 (2007).
[2] J. Lubian, T. Correa, P. R. S. Gomes and L.F. Canto, Phys. Rev. **C** , (2008).
[3] E. F. Aguilera et al, Phys. Rev. C 79, 021601(R) (2009).

Sub-barrier fusion and breakup of light halo nuclei *

I. Martel[1], R. Wolski[2], L. Standylo[3], L. Acosta[1], J. L. Aguado[1], C. Angulo[4], R. Berjillos[1], J. P. Bolíivar[1], J. A. Dueñas[1], M. S. Golovkov[5], T. Keutgen[6], M. Mazzocco[7], A. Padilla[1], A. M. Sánchez-Benítez[1], C. Signorini[7], M. Romoli[8], and K. Rusek[9]

[1] *Departamento de Física Aplicada, Universidad de Huelva, E-21071 Huelva, Spain*
[2] *Henryk Niewodniczanski Institute of Nuclear Physics PAS, Cracow, Poland*
[3] *Andrzej Soltan Institute for Nuclear Studies, PL-00681Warsaw, Poland*
[4] *Tractebel Engineering S.A., Avenue Ariane 7, B-1200 Brussels, Belgium*
[5] *Flerov Laboratory of Nuclear Reaction, JINR, Dubna, Russia*
[6] *Centre de Recherche du Cyclotron, UCL, B-1348, Louvain-la-Neuve, Belgium*
[7] *Physics Department and INFN, I-35131 Padova, Italy*
[8] *INFN Sezione di Napoli, Napoli, Italy*
[9] *Heavy Ion Laboratory, University of Warsaw, PL02093Warsaw, Poland*

Sub-barrier fusion of heavy ions has been historically a very dedicated subject of research. It is very important for the understanding of the quantum mechanical problem of tunnelling and the interplay between static and dynamical degrees of freedom. Halo nuclei provide a natural workbench to study collective excitation effects and the role of valence nucleons in the process of sub-barrier fusion [1,2]. At collision energies around the Coulomb barrier the coupling between fusion, transfer and breakup reaction channels has been found to be of un-precedent importance [3,4]. During the scattering process the halo wave function is distorted leading to dipole oscillations and strong couplings to the continuum. In this scenario an enhancement of the fusion cross section is often observed as a result of a reduction of the fusion barrier and the strong coupling to breakup and transfer channels [5,6,7].

In this work we present new data for the sub-barrier fusion of the system ^{6}He+^{206}Pb obtained at the radioactive facility at the Centre de Recherche du Cyclotron, Louvain-la-Neuve, Belgium [8]. The cross-sections for the evaporation residue ^{210}Po have been measured in the energy range 14-18 MeV, down to a level of 1 mb. The interplay between fusion, break and transfer reaction channels will be discussed on the basis of previous results obtained at GANIL (Caen, France) [9] and at the Flerov Laboratory of Nuclear Reaction (Dubna, Russia) [7,10].

* This work was partially supported by the Spanish Ministry of Science under contract FPA 2007-63074 and by the European Commission under contract No. HPRI-CT-1999- 00110

[1] J. F. Liang and C. Signorini, Int. Jour. Mod. Phy. E 8 (2005) 1121
[2] L.F. Canto et al., Physics Reports 424 (2006) 1
[3] C.H. Dasso, L. Guisado, S.M. Lenzi, A. Vitturi. NPA 597 (1996) 473
[4] V.I. Zagrebaev, Phys. Rev. C 67 (2003) 061601
[5] D. Escrig et al., Nucl. Phys. A 792, (2007) 2
[6] R. Raabe et al., Nature 431, 823
[7] Y.E. Penionzhkevich et al., Phys.Rev.Lett. 96 (2006) 162701
[8] R. Wolski and I. Martel. Proposal PH-238 to the PAC of the CRC (LLN, Belgium), 2007.
[9] A. Lemasson et al., Phys. Rev. Lett. 103 (2009) 232701
[10] S.M. Lukyanov et al., Phys.Lett. B 670 (2009) 321

Monopole-effects on symmetric and antisymmetric couplings of protons and neutrons

D. Mücher[1], **E. Elhami**[2], **M. T. McEllistrem**[2], **C. Fransen**[3], **M. Gorska**[4], **S. Heinze**[3], **J. Jolie**[3], **R. Krücken**[3], **A. Linnemann**[3], **S. Mukhopadhyay**[2], **M. Scheck**[5], **S. W. Yates**[2]

[1]*Physics Department E12, TU Munich, James Frank Str., 85748 Garching, Germany*
[2]*Department of Chemistry and Department of Physics and Astronomy, University of Kentucky, Lexington, Kentucky 40506 - 0055 USA*
[3]*Institute for Nuclear Physics, Cologne University, Zülpicher Str. 77, 50937 Köln, Germany*
[4]*Gesellschaft für Schwerionenforschung, Planckstr. 1, 64291 Darmstadt, Germany*
[5]*Oliver Lodge Laboratory, University of Liverpool, Liverpool L69 7ZE, United Kingdom*

As a general feature of two-fluid quantum systems, excited states in atomic nuclei can be constructed in a proton-neutron symmetric or mixed-symmetric way. In near vibrational nuclei the building block of mixed-symmetric states is the one-phonon quadrupole-collective isovector valence-shell excitation $2^+_{1,ms}$ [1]. In a most simple picture, such states can be understood to be generated by mixing unperturbed proton and neutron phonons via the residual proton-neutron interaction [2]. Therefore the study of mixed-symmetric states delivers direct information on the residual proton-neutron interaction in the valence shell and provides a tool to explore the evolution of the residual interaction towards e.g. extreme values of isospin.

In the framework of the generalized seniority scheme we present a simple expression for the valence proton-neutron interaction Vpn in atomic nuclei near closed shells consisting of a monopole and a quadrupole term. The monopole component of the residual interaction is approximated by double differences of binding energies only. We show that the energetic splitting between the lowest lying $J^\pi=2^+$ states of symmetric and mixed-symmetric character in even-A nuclei is well reproduced in almost all experimentally known cases (see Fig. 1 for one example), including nuclei where the effective number of valence particles is put to zero at subshells. The only free parameter, the quadrupole strength parameter κ turns out to be surprisingly constant in the mass region A=50 to A=150, yielding a good approximation for absolute values of V_{pn} near closed shells. We show applications on new data from neutron scattering with monoenergetic neutrons on the nuclei ^{68,70}Zn where an unusual abrupt drop in the excitation energy of the mixed-symmetric components is found towards the possible subshell at N=40. We draw conclusions on the minimal repelling of the lowest-lying symmetric and mixed-symmetric 2^+_1 states in even-A nuclear systems.

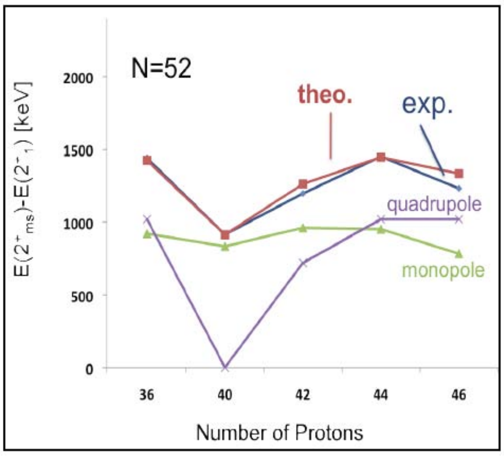


Fig. 1 Energy differences of the lowest lying 2^+ states of symmetric and mixed-symmetric character for N=52 isotones from experiment and theory, together with the contribution of monopole and quadrupole part of Vpn .

[1] N.Pietralla, P.von Brentano, A. F. Lisetskiy, Prog. Part. Nucl. Phys. 60, 225 (2008)
[2] T. Ahn et al., Physics Letters B 679 (2009) 19–24

Studies of Nuclei Beyond the Proton Drip Line by Tracking Technique

I. Mukha[1,2] for the S271 Collaboration[2]

[1] *IFIC, Valencia, Spain;*

[2] *GSI, Darmstadt Germany; University of Sevilla, Spain; University of Huelva, Spain; Joint Institute of Nuclear Research, Dubna, Russia; Kurchatov Institute, Moscow Russia; IEP Warsaw University, Poland; University of Santiago de Compostela, Spain; University of Mainz, Germany; University of Edinburgh,UK, University of Surrey, Guilford, UK*

Extremely proton-rich nuclei with odd or even atomic numbers were predicted [1] to decay through one or two-proton radioactivity, respectively. Two-proton (2p) radioactivity, a spontaneous decay of an atomic nucleus by emission of two protons, is the most recently discovered nuclear disintegration mode. It has first been reported for ^{45}Fe with a half-life of about 4 ms [2], which is about 1000 times longer than the quasi-classical estimate of “di-proton” (or ^{2}He) cluster emission. Further observations of 2p radioactivity, e.g. reported for ^{94m}Ag [3] where first proton-proton correlations were observed, have confirmed unexpectedly large half-lives of 2p precursors. The recently-developed first quantummechanical theory of 2p radioactivity which uses a three-body “core”+p+p model [4] explains this observation due to considerable influence of the three-body Coulomb and centrifugal barriers, and it predicts the regular existence of long-lived 2p precursors.

Experiments investigating such exotic nuclear decays are usually based on implantation of the radioactive atoms and subsequent detection of their decay. For the first time in studies of radioactivity, we performed an in-flight-decay experiment in which trajectories of all fragments were precisely tracked. The distribution of 2p-decay vertices along a beam direction and the angular correlations of the decay products were deduced from the measured trajectories. In this way, we observed the 2pradioactivity of the previously unknown ^{19}Mg ground-state [5]. The trajectories of its decay products, ^{17}Ne+p+p, were measured by tracking with micro-strip detectors. The measured half-life of ^{19}Mg deduced from the decay vertex distribution is 4.0(15) ps, which is the pioneering result in studies of short-time radioactivity. The Q-value of the 2p-decay of the ^{19}Mg ground state is 0.75(5) MeV. The method of measuring 2p-decays in flight provides new specific observables, thus yielding valuable spectroscopic information. For example, proton-proton correlations were observed for the 2p decays of the ground states of ^{19}Mg and ^{16}Ne for the first time [6]. These data were used to reconstruct the angular correlations of fragments projected on planes transverse to the precursor momenta. The measured proton-proton correlations reflect a genuine three-body decay mechanism, in contrast to the quasiclassical “di-proton” model which fails to describe our observations. These correlations are sensitive to the structure of the parent nucleus. The comparison between experiment and theory yields evidence that in ^{16}Ne, the valence protons are equally distributed in the *s*- and *d*- shells. For ^{19}Mg, however, a dominating *d*-shell configuration is the preferred description which is also consistent with the lifetime information [6]. Using this technique, systematic studies of about dozen other 2p emitters predicted theoretically are foreseen.

Information about one-proton unbound nuclei, e.g., ^{16,16}F, ^{18,19}Na, was obtained as well [7]. This opened a new way for systematic studies of proton-rich exotic nuclei beyond the proton drip line. For example, the properties of the proton-unbound isotopes ^{69}Br and ^{73}Rb which are above the well-known “waiting point” nuclei ^{68}Se and ^{72}Kr are important for understanding the element abundance in nature, providing the input data for modeling of the astrophysical *rp*-process.

[1] V. I. Goldansky, Nucl. Phys. **19**, 482 (1960).
[2] M. Pfützner et al., Eur. Phys. J. A **14**, 279 (2002); J. Giovinazzo et al., Phys. Rev. Lett. **89**, 102501 (2002).
[3] I. Mukha et al., Nature (London) **439**, 298 (2006).
[4] L.V.Grigorenko et al., Phys.Rev.Lett. **85**, 22 (2000).
[5] I. Mukha et. al., Phys.Rev.Lett., **99**, 182501 (2007).
[6] I. Mukha et. al., Phys.Rev. C**77**, 061303(R) (2008).
[7] I. Mukha et. al., Phys.Rev. C**79**, 061301(R) (2009).

Description of Magnetic Giant Resonances with Skyrme Forces

V. O. Nesterenko[1], J. Kvasil[2], P. Vesely[2,3], W. Kleinig[1,4], and P.-G. Reinhard[5]

[1]*Laboratory of Theoretical Physics, Joint Institute for Nuclear Research, Dubna, 141980, Moscow region, Russia*
[2]*Institute of Particle and Nuclear Physics, Charles University, CZ-18000, Prague, Czech Republic*
[3]*Department of Physics, P.O. Box 35 (YFL), University of Jyväskylä, 40014 Jyväskylä, Finland*
[4]*Technical University, D-01062, Dresden, Germany*
[5]*University of Erlangen, D-91058, Erlangen, Germany*

Despite a great success of the time-dependent Skyrme Hartree-Fock (TDSHF) approach in exploration of nuclear dynamics, it is still poorly applied to magnetic excitations, in particular to spin-flip M1 and scissors M1 giant resonances (GR). At the same time the spin-flip M1 GR can be an important source of knowledge on spin correlations in the Skyrme functional. The resonance strongly depends on the spin-orbit splitting and so can serve as a robust test of the spin-orbit interaction. Besides, the spin-flip M1 GR is closely related to the Gamow-Teller (GT) resonance and its satisfactory treatment is relevant for the description of GT mode as well. The scissors M1 resonance is also of a great importance as a useful source of information on the nuclear deformation and orbital magnetism. Our recent studies have shown that TDSHF has serious troubles in description of the spin-flip M1 giant resonance [1,2]. The results for different Skyrme parameterizations are contradictory and poorly agree with the experiment. In particular, it is quite difficult to describe simultaneously the one-peak gross structure of M1 strength in doubly magic nuclei and two-peak structure in heavy deformed nuclei. The reason of this mismatch could lie in an unsatisfactory treatment of spin correlations and spin-orbit interaction. We review the present status of the problem and possible ways of its solution [1,2]. In particular, we inspect i) the interplay of the collective shift and spin-orbit splitting, ii) the isovector M1 response versus isospin-mixed responses, and iii) the role of tensor and isovector spin-orbit interaction. The analysis is done within the self-consistent separable Skyrme-RPA (SRPA) method which, being proved as a reliable theoretical tool for investigation of electric giant resonances [3], was recently specified for the magnetic excitations [1,2]. The exploration involves 8 Skyrme forces and various (light/heavy, spherical/deformed) nuclei. The results for the orbital scissors M1 mode are also presented [4]. General perspectives of TDSHF description of magnetic modes are discussed with the emphasis to the role of the tensor interaction.

[1] P. Vesely, J. Kvasil, V.O. Nesterenko, W. Kleinig, P.-G. Reinhard, and V.Yu. Ponomarev, Phys. Rev. **C80** (2009) 031302(R).
[2] V.O. Nesterenko, J. Kvasil, P. Vesely, W. Kleinig, P.-G. Reinhard, and V.Yu. Pomomarev, J. Phys. G: Nucl. Part. Phys. **37** (2010) 064034.
[3] V.O. Nesterenko, J. Kvasil, and P.-G. Reinhard, Phys. Rev. **C66**, (2002) 044307;
V.O. Nesterenko, W. Kleinig, J. Kvasil, P.-G. Reinhard, and P. Vesely, Phys. Rev. **C74** (2006) 054306;
W. Kleinig, V.O. Nesterenko, J. Kvasil, P.-G. Reinhard and P. Vesely, Phys. Rev. **C78** (2008) 044313.
[4] V.O. Nesterenko, J. Kvasil, P. Vesely, W. Kleinig, and P.-G. Reinhard, to be published in Int. J. Mod. Phys. (E); arXiv:0911.2410[nucl-th].

Lifetime measurements of low-lying states in neutron-rich Zn isotopes

M. Niikura[1], B. Mouginot[1], F. Azaiez[1], G. Angelis[2], M. Assie[3], P. Bednarczyk[4], C. Borcea[5], A. Burger[6], G. Burgunder[3], A. Buta[5], L. Caceres[3], M. Catalin[5], E. Clément[3], L. Coquard[7], G. De France[3], F. de Oliveira[3], A. Dewald[8], A. Dijon[3], Z. Dombradi[9], E. Fiori[10], S. Franchoo[1], C. Fransen[8], G. Friessner[8], L. Gaudefroy[11], G. Georgiev[10], S. Grevy[3], M. Hackstein[8], M. Harakeh[3], F. Ibrahim[1], R. Lozeva[10], A. Maj[4], I. Matea[1], O. Möller[7], S. Myalski[4], F. Negoita[5], D. Pantelica[5], L. Perrot[1], T. Pissula[8], F. Rotaru[5], W. Rother[8], J. A. Scarpaci[1], I. Stefan[1], C. Stodel[3], J. C. Thomas[3], P. Ujic[3], M. Umiecik[4], D. Verney[1]

[1] IPN Orsay IN2P3-CNRS, [2] LNL INFN, [3] GANIL, [4] IF PAN, [5] NIPNE, [6] University of Oslo, [7] IKP TU Darmstadt, [8] IKP Universität zu Köln, [9] ATOMKI,[10] CSNSM IN2P3-CNRS, [11] DAM CEA

One of the most critical ingredients in determining the disappearance or appearance of magicity in nuclei far from stability is the evolution of single-particle energies with increasing neutron or proton numbers when moving away from the valley of stability. The three known cases of disappearance of shell effects at N=8, 20 and 28 in neutron-rich nuclei are understood as due to the effect of the tensor part of the nucleon-nucleon interaction. The tensor force is held responsible for the strong attraction between a proton and a neutron in spin-flip partner orbits. A recent generalization of such mechanism foresees a similar behavior also for orbitals with non-identical orbital angular momenta. It is expected that orbitals with anti-parallel angular momenta attract each other and orbitals with parallel angular momenta repulse each other. In this context neutron-rich nuclei in the vicinity of ^{78}Ni are particularly interesting since they allow to search for anomalies when compared with shell-model predictions. It is predicted, for example, that the Z=28 gap for protons in the *pf*-shell becomes smaller when moving from N=40 to 50 as a consequence of the attraction between the proton $f_{5/2}$ and neutron $g_{9/2}$ orbits and the repulsion between the proton $f_{7/2}$ and the neutron $g_{9/2}$ states. The same argument would also predict a weakening of the N=50 shell gap when depleting the proton $f_{5/2}$ state upon approaching the ^{78}Ni nucleus, due to the diminished attraction between the neutron $f_{9/2}$ and the proton $f_{5/2}$ orbits and the reduced repulsion between the neutron $g_{9/2}$ and the proton $f_{5/2}$ states.

In order to investigate the shell evolution in the vicinity of ^{78}Ni we have performed lifetime measurements for low-lying states in $^{72\text{-}74}$Zn by the differential plunger technique. A cocktail beam of ^{73,74}Zn was produced by the projectile-fragmentation reaction of ^{76}Ge on a ^{9}Be target and separated by the first half of the LISE spectrometer at GANIL. The secondary beam with the energy of 34 MeV/nucleon was bombarding on a secondary CD_2 target to induce inelastic and transfer reactions, and outgoing particles were selected and identified by the second half of LISE. Gamma rays emitted from the reaction products were detected by 8 EXOGAM detectors, which were surrounding secondary target at 45 and 135 degrees relative to the beam direction. The differential plunger technique with ^{9}Be degrader was applied to measure lifetimes of excited states.

The first results of the lifetime measurement in low-lying states in ^{72,73,74}Zn will be Reported together with the comparison to results from Coulomb excitation experiments at REX-ISOLDE and GANIL. A picture of the low-energy structure in these isotopes towards the middle of the $\nu g_{9/2}$ orbital will be given via: i) identification of the levels populated with inelastic scattering reaction and ii) determination, in a model-independent way, of the transition probabilities of those levels towards the ground state.

1n-removal reactions around N=20 shell closure

C. Nociforo[1], A. Prochazka[1,2], R. Kanungo[3], B. A. Brown[4], T. Aumann[1], D. Boutin[2], D. Cortina-Gil[5], B. Davids[6], M. Diakaki[7], F. Farinon[1,2], H. Geissel[1], R. Gernhäuser[8], J. Gerl[1], R. Janik[9], B. Jonson[10], B. Kindler[1], R. Knöbel[1,2], R. Krücken[8], M. Lantz[10], H. Lenske[2], Yu. A. Litvinov[1], K. Mahata[1], P. Maeirbeck[8], A. Musumarra[11,12], T. Nilsson[10], T. Otsuka[13], C. Perro[3], C. Scheidenberger[1,2], B. Sitar[9], P. Strmen[9], B. Sun[2], I. Szarka[9], I. Tanihata[14], Y. Utsuno[15], H. Weick[1], M. Winkler[1].

[1]*GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt, Germany*
[2]*Justus-Liebig University, Gießen, Germany*
[3]*Astronomy and Physics Department, Saint Mary's University, Halifax, Canada*
[4]*NSCL, Michigan state University, East Lansing, USA*
[5]*Universidad de Santiago de Compostela, Santiago de Compostella, Spain*
[6]*TRIUMF, Vancouver, Canada*
[7]*National Technical University, Athens, Greece*
[8]*Physik Department E12, Technische Universität München, Garching, Germany*
[9]*Faculty of Mathematics and Physics, Comenius University, Bratislava, Slovakia*
[10]*Fundamental Physics, Chalmers University of Technology, Göteborg, Sweden*
[11]*Università di Catania, Catania, Italy*
[12]*INFN-Laboratori Nazionali del Sud, Catania, Italy*
[13]*Center for Nuclear Study, University of Tokyo, Saitama, Japan*
[14]*Research Center for Nuclear Physics, Osaka, Japan*
[15]*Japan Atomic Energy Agency, Tokai, Ibaraki, Japan.*

The evolution of the configuration mixing in the ground state of the pf shell Al isotopes as a function of the neutron number have been studied through the longitudinal momentum distribution analysis of the residues in 1n-removal reactions at relativistic energies. The experiment [1] was performed by using radioactive ion beams produced inflight at the Fragment Separator (FRS) of GSI in order to investigate a wide region of the nuclear chart overlapping with the so called Island of Inversion, around N=20. The new data presented here have been described within an eikonal model. Their interpretation will be discussed comparing the results of theoretical calculations in the *sd*-shell and *sdpf*-shell model spaces. Concerning the odd-mass Al isotopes (N=20,22), dominated by the unpaired $d_{5/2}$ proton, an influence of core polarization effects as a function of the neutron number is expected. For the even mass Al (N=21,23), information on the occupied orbital of the unpaired neutron can be extracted on the basis of shell model predictions.

[1] R. Kanungo, et al. Phys, Lett. **B685**, 253(2010).

Exotic modes of excitation and weak interaction rates at finite temperature

N. Paar[1], T. Marketin[1], D. Vretenar[1], Y. F. Niu[2], J. Meng[2,3], G. Colò[4], E. Khan[5]

[1] *Physics Department, Faculty of Science, University of Zagreb, Croatia*
[2] *State Key Laboratory for Nuclear Physics and Technology, School of Physics, Peking University, Beijing 100871, People's Republic of China*
[3] *School of Physics and Nuclear Energy Engineering, Beihang University, Beijing 100191,People's Republic of China*
[4] *Dipartimento di Fisica dell'Università degli Studi and INFN, Sezione di Milano, via Celoria 16, 20133 Milano, Italy*
[5]*Institut de Physique Nucléaire, IN2P3-CNRS/Université Paris-Sud, 91406 Orsay, France*

The interplay of isospin asymmetry and finite temperature in nuclei plays an important role in their exotic structure properties and nuclear weak interaction rates in stellar environment [1]. Recently a fully self-consistent microscopic framework, based on Skyrme energy density functionals, has been introduced for description of exotic excitations and weak-interaction rates at finite temperature [2]. The single-nucleon basis and the corresponding thermal occupation factors of the initial nuclear state are determined in the finite-temperature Hartree-Fock model, and charge-exchange transitions to excited states are obtained using the finite-temperature random phase approximation. On the other side, self-consistent framework involving nuclei at finite temperature has also been developed within relativistic mean field theory using effective Lagrangians with density dependent meson-nucleon vertex functions. Nuclear excitations are studied using finite temperature random phase approximation [2,3] for the range of temperatures T=0-2 MeV, as well as in nuclei far from stability. In the focus of research are the structure properties of exotic modes of excitation (e.g. pygmy dipole resonances) and charge-exchange modes (e.g. Gamow-Teller resonances and forbidden transitions). It is shown that finite temperature effects include novel low-energy multipole excitations and modifications of the Gamow-Teller transition spectra [2-4]. Using a representative set of Skyrme functionals, as well as covariant energy density functional with DD-ME2 parameterization, both theory frameworks have been applied in calculations of electron-capture cross sections and respective rates relevant in the stage of supernova precollapse. Recent self-consistent studies of weak interaction in nuclei also include description of neutrino-nucleus cross sections [5] and muon capture rates [6].

*This work was supported by UKF Grant No. 17/08, MZOS project No. 1191005-1010, Croatian National Foundation for Science, NSFC under Grant Nos. 10775004, 10875157, and 10975008, the Major State 973 Program 2007CB815000 of China.

[1] N. Paar, J. Phys. G: Nucl. Part. Phys. 37, 064014 (2010).
[2] N. Paar, G. Col_o, E. Khan, and D. Vretenar, Phys. Rev. C 80, 055801 (2009).
[3] Y. F. Niu, N. Paar, D. Vretenar, and J. Meng, Phys. Lett. B 681, 315 (2009).
[4] N. Paar, Y. F. Niu, D. Vretenar, and J. Meng, Phys. Rev. Lett. 103, 032502 (2009).
[5] N. Paar, D. Vretenar, T. Marketin, and P. Ring, Phys. Rev. C 77, 024608 (2008).
[6] T. Marketin, N. Paar, T. Niksic, and D. Vretenar, Phys. Rev. C 79, 054323 (2009).

Gamma-ray spectroscopy at the extremes; in-beam study of ^{180}Pb

P. Rahkila[1], D. G. Jenkins[2], J. Pakarinen[3,4], C. Gray-Jones[3], P. Greenlees[1], U. Jakobsson[1], P. Jones[1], R. Julin[1], S. Juutinen[1], S. Ketelhut[1], H. Koivisto[1], M. Leino[1], P. Nieminen[1], M. Nyman[1], P. Papadakis[3], S. Paschalis[3], M. Petri[3], P. Peura[1], O. J. Roberts[2], T. Ropponen[1], P. Ruotsalainen[1], J. Saren[1], C. Scholey[1], J. Sorri[1], A. G. Tuff[2], J. Uusitalo[1], R. Wadsworth[2], M. Bender[5] and P.-H. Heenen[6]

[1]Department of Physics, University of Jyväskylä, P.O.Box 35, 40014 Jyväskylä, Finland.
[2]Department of Physics, University of York, Heslington, York YO10 5DD, United Kingdom.
[3]Oliver Lodge Laboratory, University of Liverpool, Liverpool L69 7ZE, United Kingdom.
[4]CERN-ISOLDE, CH-1211 Geneva, Switzerland.
[5]Universite Bordeaux, CNRS/IN2P3, Centre d'Etudes Nucleaires de Bordeaux Gradignan, CENBG, Chemin du Solarium, BP120, F-33175 Gradignan, France.
[6]Service de Physique Nucleaire Theorique, Universite Libre de Bruxelles, B-1050 Bruxelles, Belgium.

A considerable body of both theoretical and experimental evidence has been gathered for coexisting configurations possessing different shapes in the very neutron-deficient lead isotopes [1,2]. This phenomenon becomes particularly apparent in lead isotopes in the vicinity of the N=104 neutron midshell, where the competing deformed structures intrude down to energies close to the spherical ground state. The intruder states have been associated with proton multiparticle-multihole excitations across the closed Z=82 shell. This picture is supported by hindrance factors obtained in α-decay fine-structure studies [3]. Mean-field calculations suggest that each intruder configuration can be associated with a different shape [4]. Together with the spherical ground state, they result in a unique triplet of shape-coexisting 0^+ states in ^{186}Pb [3].

Various spectroscopic techniques have been employed in order to understand the driving force and behaviour of the intruder states. This presentation focuses on in-beam γ-ray spectroscopy employing recoil-decay tagging. Although these studies possess a vast experimental challenge, as nuclei of interest are produced in the level of few particles per hour, it is the only feasible technique to access very neutron-deficient nuclei in the lead region.

Very recently, we have observed excited states in the extremely neutron-deficient nucleus ^{180}Pb [5]. This study lies at the limit of what is presently achievable with in-beam spectroscopy, with an estimated cross section of only 10 nb. Results shed light on the evolution of different shapes when moving further beyond the N=104 neutron midshell. The systematic behaviour of levels in the lead isotopic chain shows a continuation of the trend of what is observed in heavier 182Pb and 184Pb isotopes. A comparison with beyond meanfield calculations has been made. The interpretation of results will be discussed in more details.

[1] J.L. Wood *et al.*, Phys. Rep. **215**, 101, (1992).
[2] R. Julin, K. Helariutta and M. Muikku, J. Phys. G: Nucl. Part. Phys. **27**, R109, (2001).
[3] A.N. Andreyev *et al.*, Nature, Vol **405**, 430, (2000).
[4] F.R. May, V.V. Pashkevich and S. Frauendorf, Phys. Lett. **B68**, 113 (1977).
[5] P. Rahkila *et al.*, arXiv:1003.0452v1

Development of a Micromegas TPC for low energy heavy ions measurement for nuclear fission and astrophysics applications

Stefano Panebianco[1], Michail Axiotis[2], Diane Doré[1], George Fanourakis[2], Theodoros Geralis[2], Ioannis Giomataris[1], Sotirios Harissopulos[2], Anastasios Lagoyannis[2], Thomas Papaevangelou[1], Laetitia Vernoud[1]

[1]*CEA Saclay, Institut de Recherche sur les lois Fondamentales de l'Univers, 91191 Gif-sur-Yvette, France.*
[2]*Institute of Nuclear Physics, NCSR "Demokritos", 15310 Aghia Paraskevi, Athens, Greece.*

Time Projection Chambers are widely used since many years for tracking and identification of charged particles in high energy physics. We aim to present a new R&D project to investigate the feasibility of a Micromegas TPC for low energy heavy ionsdetection. Two physics cases are relevant for this project. The first is the study of the nuclear fission of actinides by measuring the fission fragments properties (mass, nuclear charge, kinetic energy). These measurements, which are important both for fundamental physics and for applications, will be performed at different installations and in particular at the NFS facility to be built in the framework of the SPIRAL2 project in GANIL. A second physics case is the study of heavy ion reactions, like (α,γ), (α,p), (α,n) and all the "inverse" reactions in the energy range between 1.5 and 3 AMeV using both stable and radioactive beams (SPIRAL2, ISOLDE, S-DALINAC). These reactions have a key role in p process in nuclear astrophysics to explain the synthesis of heavy proton-rich nuclei.

The project is in its initial stage and a large effort is devoted to Mont-Carlo simulations. In particular, we will present a detailed benchmark of different simulation codes (SRIM, GEANT4, LISE++) on the energy loss and ranges of heavy ions at low energy. A new approach for simulating the ion charge state evolution in GEANT4 will be also presented. Finally, preliminary results on the TPC simulation will be discussed, in comparison with experimental tests on prototypes.

Together with the simulation studies, we have made experimental tests using a prototype Micromegas TPC made in "Demokritos" to detect fragments from the spontaneous fission of a Cf source. The prototype is equipped with a digital Front End Electronics, called AFTER, and developed at CEA for the T2K neutrino experiment. We will present the results of these preliminary tests and we will discuss the following steps of the R&D, mainly a measurement campaign using 2D Micromegas TPC in a magnetic field (up to 8T).

Investigation of ^{246}Fm: in-beam spectroscopy at the limits

Piot J.[1], Gall B.JP.[1], Dorvaux O.[1], Greenlees P.T.[2], Rahkila P.[2], Andersson L.L.[3], Cox D.M.[3], Dechery F.[6], Hauschild K.[4*], Henning G.[4], Herzberg R.-D.[3], Hessberger F.[5], Jakobsson U.[2], Julin R.[2], Jungvall J.[6], Jones P.[2], Ketelhut S.[2], Khoo T.-L.[7], Leino M.[2], Lopez-Martens A.[4*], Papadakis P.[3], Parr E.[3], Peura P.[2], Ruotsalainen P.[2], Sandzelius M.[2], Sarén J.[2], Scholey C.[2], Sewernyniak D.[7], Sorri J.[2], Sulignano B.[6], Theisen C.[6], Uusitalo J.[2]

[1] Institut Pluridisciplinaire Hubert Curien, 23 rue du Loess, 67037 Strasbourg, France
[2] Department of Physics, University of Jyväskylä, P.O.Box 35, 40014 Jyväskylä, Finland.
[3] Department of Physics, Oliver Lodge Laboratory, University of Liverpool, Oxford Street, Liverpool L69 7ZE, United Kingdom.
[4] Centre National de Spectrométrie Nucléaire et de Spectrométrie de Masse, Bâtiments 104 et 108, 91405 Orsay Campus, France.
[5] GSI Helmholtzzentrum für Schwerionenforschung GmbH, Planckstr. 1, 64291 Darmstadt, Germany
[6] Commissariat à l'Energie Atomique / Saclay, 91191 Gif-sur-Yvette cedex, France.
[7] Argonne National Laboratory, 9700 S. Cass Avenue, Argonne, IL 60439, USA

The structure of ^{246}Fm has been investigated using in-beam γ-ray spectroscopy. The experiment was performed at the University of Jyväskylä using JUROGAM2 associated to RITU and GREAT. The ^{246}Fm Nuclei were produced using a beam of ^{40}Ar impinging on a target of ^{208}Pb at an energy of 186 MeV. JUROGAM 2 was fully instrumented with TNT2 digital acquisition cards. The use of digital acquisition cards and the rotating target allowed for unprecedented beam intensities up to 71 particle-nanoamperes. This permitted to overcome a record cross-section of 10 nanobarns for prompt spectroscopy of ^{246}Fm and revealed already online a series of transitions forming a rotational band. After discussing the use of digital electronics for in-beam γ-ray spectroscopy, the results of the analysis will be presented.

* On leave at Dept. of Physics, University of Jyväskylä, P.O.Box 35, 40014 Jyväskylä, Finland.

Abrupt changes in alpha decay systematics as a manifestation of collective nuclear modes *

Chong Qi[1], A.N. Andreyev[2;3], M. Huyse[2], R.J. Liotta[1], P. Van Duppen[2], R. Wyss[1]

[1] KTH, 10691 Stockholm, Sweden; [2] IKS, K.U. Leuven, B-3001 Leuven, Belgium;
[3] School of Engineering and Science, University of the West of Scotland, Paisley PA1 2BE, UK.

It is nearly a century ago that the Geiger-Nuttall law, which was to revolutionize physics by its implications, was formulated based on α decay systematic [1]. Indeed, its explanation by Gamow [2] and also by Gurney and Condon [3] required to accept the probabilistic interpretation of Quantum Mechanics. The Gamow theory reproduced the Geiger-Nuttall law nicely. One can assert that this is an effective theory, where concepts like “frequency of escape attempts" have to be introduced. Yet Gamow's theory is so successful that even today it is applied, with minor changes, in the studies of radioactive decays. One may then wonder why effective approaches have been so successful. The reason is that the _-particle formation probability usually varies from nucleus to nucleus much less than the penetrability. In the logarithm scale of the Geiger-Nuttall law the differences in the formation probabilities are usually small fluctuations along the straight lines predicted by that law for different isotopic chains. The importance of a proper treatment of _ decay was attested by a recent calculation which shows that the different lines can be merged in a single line. One thus obtained a generalization of the Geiger-Nuttall law which holds for all isotopic chains and all cluster radioactivities [4,5]. In this universal decay law (UDL) the penetrability is still a dominant quantity. By using three free parameters only, one finds that all known ground-state to ground-state radioactive decays are explained rather well. This good agreement is a consequence of the smooth transition in the nuclear structure that is often found when going from a nucleus to its neighboring nuclei. This is also the reason why, e.g., the BCS approximation works so well in many nuclear regions.

In this work we will show that, when a sudden transition occurs in a given chain of nuclei, departures from the UDL can be seen [6]. Perhaps even more important is that for most cases the UDL predicts the experimental values within a factor of three, except for N = 126, where the difference becomes about one order of magnitude. This is so distinct that one may even suspect that the difference in the values of formation amplitudes when going from one nucleus to its neighbors in the vicinity of N = 126 overruns the corresponding differences in the penetrability. The difference is explained as a sudden hindrance of the clustering of the nucleons that eventually form the _ particle. This is because the clustering induced by the pairing mode acting upon the four nucleons is inhibited if the configuration space does not allow a proper manifestation of the pairing collectivity.

* This work has been supported by the Swedish Research Council (VR), FWO-Vlaanderen (Belgium), GOA/2004/03 (BOF-K.U.Leuven), the IUAP-Belgian State-Belgian Science Policy-(BriX network P6/23), and by the European Commission within the Sixth Framework Programme through I3-EURONS (Contract RII3-CT-2004-506065).

[1] H. Geiger and J. M. Nuttall, Philos. Mag. 22, 613 (1911); H. Geiger, Z. Phys. 8, 45 (1922).
[2] G. Gamow, Z. Phys. 51, 204 (1928).
[3] R. W. Gurney and E. U. Condon, Nature 122, 439 (1928).
[4] C. Qi, F. R. Xu, R. J. Liotta, and R. Wyss, Phys. Rev. Lett. 103, 072501 (2009), arXiv:0909.4492.
[5] C. Qi, F. R. Xu, R. J. Liotta, R. Wyss, M. Y. Zhang, C. Asawatangtrakuldee, and D. Hu, Phys. Rev. C 80, 044326 (2009), arXiv: 0909.4495.
[6] C. Qi, A. N. Andreyev, M. Huyse, R. J. Liotta, P. Van Duppen, R. A. Wyss, Phys. Rev. C (in press), arXiv:1004.4523.

^{2}He Decay from ^{18}Ne Excited States: Status and Perspectives

Elisa Rapisarda[1,2], G. Cardella[2], M. De Napoli[4], F. Giacoppo[4], G. Raciti[3], C. Sfienti[2,3]

[1] *Centro Siciliano di Fisica Nucleare e Struttura della Materia, Via S. Sofia 64, Catania, Italy.*
[2] *INFN - Sezione di Catania, Via S. Sofia 64, Catania, Italy.*
[3] *Dipartimento di Fisica e Astronomia, Universit di Catania, Via S. Sofia 64, Catania, Italy.*
[4] *INFN - Laboratori Nazionali del Sud, Via S. Sofia 62, Catania, Italy.*

We will report on the first experimental evidence for diproton emission from the 6.15 MeV ^{18}Ne (1^-) level. The secondary ^{18}Ne beam was produced using the in-flight FRIBs facility of the Laboratori Nazionali del Sud in Catania. ^{18}Ne levels were populated by Coulomb excitation on a *nat*Pb target. Several levels were identified in the excitation energy spectrum built by kinematic reconstruction from the ^{17}F+p and ^{16}O+2p fully measured decay events. The study of the relative momentum and angle correlation of the two protons, analysed in the excitation energy window 5.9<E*<6.5 MeV, clearly disentangles the diproton and democratic or virtual sequential decay mechanisms contributions to the 2p emission. Moreover, in the ^{16}O+2p decay channel the population of high-lying known and unknown states in ^{18}Ne Coulomb excitation was observed [1]. New analysis on data obtained in a recent experiment seems to indicate the possibility that correlated two protons emission occurs in such states despite the predominant democratic or true sequential three-body mechanism. This observation provides new hints for the interpretation of the phenomenon.

[1] G. Raciti *et al.*, Phys. Rev. Lett. 100, 192503 (2008).

A new island of inversion far from stability

F. Recchia[1], S. M. Lenzi[1], S. Lunardi[1], D. Bazzacco[1], S. Beghini[1], G. Benzoni[3], A.Bracco[3], D. Bucurescu[6], F. Camera[3], L. Corradi[2], A. Deacon[5], G. de Angelis[2], F. Della Vedova[2], E. Farnea[1], E. Fioretto[2], S. J. Freeman[5], A. Gadea[2], B. Guiot[2], M. Ionescu-Bujor[6], A. Iordachescu[6], B. Kay[5], S. Leoni[3], N. Marginean[2], R. Marginean[1], P. Mason[1], R. Menegazzo[1], B. Million[3], G. Montagnoli[1], D. R. Napoli[2], R. Orlandi[2], P. Pavan[1], I. Pokrovsky[2], F. Scarlassara[1], J. F. Smith[5], A. M. Stefanini[2], D. Steppenbeck[5], S. Szilner[2], M. Trotta[4], C. A. Ur[1], J. J. Valiente Dobon[2], B. J. Varley[5], O. Wieland[3]

[1]*Department of Physics and INFN, Sezione di Padova, Padova, Italy*
[2]*INFN, Legnaro National Laboratories, Legnaro, Italy*
[3]*Department of Physics and INFN, Sezione di Milano, Milano, Italy*
[4]*INFN, Sezione di Napoli, Napoli, Italy*
[5]*University of Manchester, Manchester M13 9PL, UK*
[6]*NIPNE, Bucharest, Romania*

The study of neutron-rich isotopes of medium-mass nuclei is of current interest in modern nuclear physics. One of the principal interests in these studies comes from the fact that different theoretical calculations predict the disappearance of classical shell and subshell closures, such as N=28, 40 and 50, and the appearance of new ones, for example at N=16 and 32.

While the experimental information obtained for nuclear systems has been limited for decades to nuclei close to the stability line, the continuous experimental developments allow nowadays the study of exotic nuclei far from stability. Unexpected modifications to the shell structure have been already encountered and there is evidence that the usual magic numbers change when increasing the neutron number [1,2]. Responsible for these changes could be both the developments of a diffuse neutron surface that could fade the spin-orbit interaction as well as the proton-neutron monopole interaction that could reorder the single-particle orbits.

A neutron-rich region, where new magic numbers may appear and others disappear, is the one bounded by N=28–40 and Z=20–28. As a matter of fact, it has been shown that a new sub-shell closure is present at N = 32 but only for Z~20 [1]. The appearance of this new shell gap has been explained [2] in terms of a strong spin-flip $\pi 1f_{7/2}$–$\nu 1f_{5/2}$ proton–neutron monopole interaction. On the other side it has been predicted that in the middle of this region nuclear deformation sets in, and that the sub-shell closure at N=40 disappears. Near N=40, a new region of deformation is observed [3] due to changes in the shell structure in neutron-rich Cr and Fe isotopes. New experimental and theoretical results will be shown and discussed.

[1] J.I. Prisciandaro et al., *Phys. Lett.* B510, 17 (2001)
[2] T. Otsuka et al., *Phys. Rev. Lett.* 87, 082502 (2001)
[3] E. Caurier et al., *Eur. Phys. J.* A15, 145 (2002)

Charge radii and structural evolution in Sr, Zr and Mo isotopes

R. Rodríguez-Guzmán[1], P. Sarriguren[1] and L. M. Robledo[2]

[1] *Instituto de Estructura de la Materia, CSIC, Serrano 123, E-28006 Madrid, Spain.*
[2] *Departamento de Física Teórica C-XI, Universidad Autónoma de Madrid, 28049-Madrid, Spain*

The evolution of the ground-state nuclear shapes in neutron-rich Sr, Zr and Mo isotopes, including both even-even and odd-A nuclei, will be discussed within the self-consistent mean-field approximation based on the Gogny interaction. Calculations for neutron separation energies and charge radii will be presented and compared with available data. A correlation between s shape transition and a discontinuity in those observables is found within our microscopic framework. It is shown that, while in Sr and Zr isotopes the steep behavior observed in the isotopic dependence of the charge radii is a consequence of a sharp prolate-oblate transition, the smooth behavior found in Mo isotopes has its origin in an emergent region of triaxiality.

Neutron-rich $^{62,64,66}Fe$ show enhanced Collectivity: The Washout of N=40 in Terms of Experiment, Valence Proton Symmetry and Shell Model

W. Rother[1], A. Dewald[1], H. Iwasaki[2,3], S. Lenzi[4], K. Starosta[5], D. Bazin[2], T. Baugher[2,3], B. A. Brown[2,3], H. Crawford[2,3], C. Fransen[1], A. Gade[2,3], T. Ginter[2,3], T. Glasmacher[2,3], G. F. Grinyer[2], M. Hackstein[1], G. Ilie[6], J. Jolie[1], S. McDaniel[2,3], B. Melon[7], G. Pascovici[1], P. Petkov[1,8], Th. Pissulla[1], A. Ratkiewicz[2,3], C. A. Ur[4], P. Voss[2,3], K. Walsh[2,3], D. Weisshaar[2,3], and K.O. Zell[1]

[1]Institut fur Kernphysik der Universitat zu Koln, 50937 Koln, Germany
[2]NSCL, MSU, East Lansing, Michigan 48824, USA
[3]Department of Physics and Astronomy, MSU, East Lansing, Michigan 48824, USA
[4]Dipartimento di Fisica dell' Universita and INFN, Sezione di Padova, Padova, Italy
[5]Department of Chemistry, Simon Fraser University, Burnaby BC V5A 1S6, Canada
[6]WNSL, Yale University, New Haven, Connecticut 06520, USA, and
National Institute of Physics and Nuclear Engineering, 76900 Bucharest, Romania
[7]Dipartimento di Fisica, Universita di Firenze and INFN, Sesto Fiorentino, 50019, Italy
[8]Institute for Nuclear Research and Nuclear Energy, BAS, 1784 Sofia, Bulgaria

Probing shell structure at a large neutron excess has been of particular interest in recent times. Neutron-rich nuclei between the proton shell closures Z=20 and Z=28 offer an exotic testing ground for shell evolution. The development of the N=40 gap between neutron fp and $1g_{9/2}$ shells gives rise to highly interesting variations of collectivity for nuclei in this region.

While ^{68}Ni shows doubly magic properties in level energies and transition strengths, this was not observed in neighbouring nuclei. Especially neutron-rich Fe isotopes proved particularly resistant to calculational approaches using the canonical valence space (*fpg*) resulting in important deviations of the predicted collectivity. Only an inclusion of the $d_{5/2}$-orbital could solve the problem [1]. Hitherto no transition strengths for ^{66}Fe have been reported.

We determined $B(E2;2^+_1\rightarrow0^+_1)$ values from lifetimes measured with the recoil distance Doppler-shift method using the Cologne plunger for radioactive beams at National Superconducting Cyclotron Laboratory at Michigan State University. Excited states were populated by projectile Coulomb excitation for $^{62,64,66}Fe$.

The data show a rise in collectivity for Fe isotopes toward N=40. Results are interpreted by means of a modified version of the Valence Proton Symmetry [2] and compared to scale shell model calculations using a new effective interaction recently developed for the *fpgd* valence space.

[1] E. Caurier *et al.*, Eur. Phys. J **A15**, 145 (2002)
[2] A. Dewald *et al.*, Phys. Rev. C 78, 051302(R) (2008).

Weak Decay Rates for Neutron Deficient Medium-Mass Isotopes Relevant for the rp-Process *

P. Sarriguren

Instituto de Estructura de la Materia, CSIC, Serrano 123, E-28006 Madrid, Spain

Weak interaction rates are studied in neutron-deficient medium-mass waiting-point isotopes in ranges of densities and temperatures relevant for the *rp* process [1]. The nuclear structure involved in the process is described within a deformed quasiparticle random phase approximation based on a self-consistent mean field obtained from Skyrme Hartree-Fock+BCS. This microscopic model has been shown to reproduce [2] not only the experimental half-lives but also the more demanding Gamow-Teller strength distributions that have been measured with high accuracy from β-decay experiments in the whole Q-energy window [3,4]. Although the decay properties may be different at the high temperatures and densities characteristic of the *rp*-process scenarios, success in their description under terrestrial conditions is a requirement for a reliable calculation of the weak decay rates in more general conditions.

In this work we analyze the ingredients needed to describe the rates in a reliable way, as well as the various sensitivities of the decay rates to both density and temperature [5]. In particular, in a first step we study the contributions to the decay rates coming from excited states in the parent nucleus, which are populated as the temperature increases. In agreement with previous studies [6], it is found that, in general, below T=3 GK their effect can be safely neglected, and thus, the decay from the ground state is already a good approximation for *rp*-processes. Nevertheless, special attention should be paid to the cases where the 2^+ excited states are particularly low in energy, because their contributions can be competitive at these temperatures. We then study the continuum electron capture rates, whose origin is related to the fact that atoms in *rp* scenarios are completely ionized and the electrons are no longer bound to the nuclei, but forming a degenerate plasma obeying a Fermi-Dirac distribution. It is found that its effect is enhanced as the temperature and density increase and becomes comparable to the β^+ decay rates at *rp* peak conditions. At slightly larger values of temperatures and densities continuum electron capture dominates over β^+ decay. This point is important because these contributions have been usually neglected in earlier evaluations of weak decay rates at *rp* conditions [1].

* This work was supported by Ministerio de Ciencia e Innovación (Spain) under Contract No. FIS2008–01301.

[1] H. Schatz *et al.*, Phys. Rep. 294, 167 (1998).
[2] P. Sarriguren, Phys. Rev. C 79, 044315 (2009).
[3] E. Poirier *et al.*, Phys. Rev. C 69, 034307 (2004).
[4] E. N´acher *et al.*, Phys. Rev. Lett. 92, 232501 (2004).
[5] P. Sarriguren, Phys. Lett. B (2009).
[6] K. Langanke and G. Martinez-Pinedo, Nucl. Phys. A 673, 481 (2000).

Extraction of radionuclides from accelerator waste at PSI

Dorothea Schumann

Paul Scherrer Institute, CH-5232 Villigen PSI, Switzerland

PSI operates the most powerful proton accelerator world-wide. With 590 MeV and a beam current of 2.5 mA it serves as the proton feeder for the Swiss neutron spallation source SINQ. Components in the surrounding of this instrument are highly activated by high energetic protons and secondary particles. Since spallation reactions induce the production of isotopes with masses up to one mass unit higher than the target mass, the spectrum of elements produced cover nearly the entire periodic table. Therefore, some of these activated components represent valuable archives for exotic and rare isotopes, which are urgently needed for experiments in several scientific fields. One of these research areas is nuclear physics, and especially nuclear astrophysics.

1. Separation of ^{44}Ti: Core collapse supernovae are remarkable astrophysical sites, representing one of the most extreme physics laboratories in Nature. Without them, the diversity and abundances of the chemical elements around us would be radically different, and yet the details of the core collapse phenomenon are still poorly known. One of the important diagnostic tools to help understand these processes is the isotope ^{44}Ti. Moreover, due to its nuclear properties (b^{+} radiation, convenient half-life) the short-lived daughter nuclide ^{44}Sc ($T_{1/2}$=3.92h) is believed to be a potential PET (Positron Emission Tomography) nuclide. For model studies, about 4 MBq ^{44}Ti were separated from a copper beam dump irradiated with 590 MeV protons at PSI by use of ion exchange from HF containing aqueous solution [1].

2. Preparation of ^{60}Fe samples for the determination of the neutron capture cross section at stellar energies and the re-measurement of the half-life: The long-lived radionuclide ^{60}Fe plays a key role in tracing the history of the Early Solar System (ESS). Attempts at reconstructing the inventory of radioactivity between Fe and Pb require, among others, the exact knowledge of the half-life and experiments aimed to determine the neutron capture cross section. Two ^{60}Fe samples were prepared from the copper beam dump mentioned above using liquid-liquid extraction, precipitation and ion exchange. The experiments were successfully performed in 2007 and 2008 [2,3].

3. ^{7}Be separation from the SINQ cooling water: ^{7}Be is a key radionuclide for investigations of astrophysical processes and phenomena like the study of the solar neutrino flux, in particular the reaction ^{7}Be(p,γ)^{8}B [4]. Highly-active ^{7}Be targets in the range of several 100 GBq are required for such studies. ^{7}Be is produced in considerable amounts in the cooling water (D_2O) of the SINQ facility at PSI by spallation reactions on ^{16}O with the generated fast neutrons. By use of a mixed-bed ion exchanger the separation of ^{7}Be samples with an activity in the TBq range is possible.

[1] D. Schumann, J. Neuhausen, J. Phys. G 35 (2008) 014046

[2] E. Uberseder, R. Reifarth, D. Schumann, I. Dillmann, C. Domingo Pardo, J. Görres, M. Heil, F. Käppeler, J. Marganiec, J. Neuhausen, M. Pignatari, F. Voss, S. Walter, and M. Wiescher, PRL 102, 151101 (2009)

[3] G. Rugel, T. Faestermann, K. Knie, G. Korschinek, M. Poutivtsev, D. Schumann, N. Kivel, I. Gunther-Leopold, R. Weinreich, M. Wohlmuther, On the Half-Life of ^{60}Fe, PRL (2009), submitted.

[4] L. T.Baby, C. Bordeanu, G. Goldring, M. Hass, L. Weissman, V. N. Fedoseyev, U. Koster, Y. Nir-El, G. Haquin, H. W. Gaggeler, and R. Weinreich, PRL 90, 022501 (2003)

Exotic structures near the drip lines

M. M. Sharma[1], J. K. Sharma[2], A. A. Saldanha[1]

[1]*Physics Department, Kuwait University, Kuwait 13060.*
[2]*Physics Department, St. John's College, Agra-282002, India*

I will discuss surprising results of our study of nuclei in the rp-process region. It will be shown that due to presence of large shell gaps in deformed space, we have uncovered the existence of double magicity of both protons and neutrons in several N=Z nuclei near the rp-process path [1]. These nuclei are known to contribute to large abundances in the rp-process nucleosynthesis and have been shown to be waiting-point nuclei in this process. I will also discuss the emergence of stability of nuclei beyond the neutron drip line in our recent study of the r-process region near N=126. Interesting features on exotic structures of nuclei near the drip lines will be presented [2].

[1] M. M. Sharma and J. K. Sharma, AIP Proceedings, Vol. 1224 (2010) p. 175.
[2] M. M. Sharma and A. A. Saldanha, submitted (2010).

The Structure of Excited 0+ States in Nuclei and the Effect of the γ Degree of Freedom*

J. F. Sharpey-Schafer

University of Western Cape, Department of Physics, P/B X17, Bellville, ZA-7535 South Africa.

The comprehensive review of Garrett [1] demonstrates that most first excited 0^+ states in nuclei do not have the characteristics of β-vibrations. We have conclusively shown [2] that in N=88 and 90 nuclei these 0_2^+ states are a second vacuum formed by the combination of the quadrupole pairing force and the low density of oblate orbitals near the Fermi surface. This is confirmed by the blocking of this collective 0_2^+ mode in the even-even nuclei from coupling to the [505]11/2$^-$ single-particle quasi-neutron orbital in the neighbouring odd neutron nuclei. The fact that these 0_2^+ states are 2p-2h neutron states demonstrates the futility of attempts to describe them [3,4] using non-microscopic models that use the Bohr Hamiltonian and alleged β-softness in transitional nuclei and/or various variants of the IBA. Even the most sophisticated models [5,6], that do not include 2p-2h configurations, do not have the crucial physics and cannot expect to get good agreement with the experimental data on 0_2^+ bands. The structure of 0_2^+ and 0_n^+ states, in various regions of the nuclear chart, will also be discussed.

Recently K=2$^+$ "γ-vibrational" bands have been observed up to 17$^+$ in $^{154}Gd_{90}$ [2] and to 28$^+$ in $^{156}Dy_{90}$ [7]. These bands "track" the ground state band up to their highest spins. Positive parity bands have also been observed that decay to second vacuum states based on the 0_2^+ levels in both these nuclei. These bands "track" the band based on 0_2^+ and have the characteristics of the second vacuum K=2$^+$ "γ-vibrational" band.

Starting with the Bohr Hamiltonian, the rotation-vibration model gives [8], in an obvious notation;

$$E_x(n_\beta n_\gamma IK) = \hbar\omega_\beta(n_\beta + ½) + \hbar\omega_\gamma(2n_\gamma + ½|K| + 1) + [I(I+1) - K2]\,\hbar^2/2I$$

so that the traditional K=2$^+$ γ-band is not a band containing a quantum in the γ direction but has $n_\gamma = 0$ and a bandhead energy given by $E_x = \hbar\omega_\gamma + \hbar^2/I$. In the rotation-vibration model there is a strong coupling between rotations and γ-vibrations, physically expressing the fact that rotations with non-vanishing K become possible only in the presence of dynamical triaxiality [8]. Any model having the γ degree of freedom will have zero-point fluctuations and a similar origin for K=2$^+$ bands. The systematics of known γ-bands and candidates for K=4$^+$, $n\gamma = 0$ bands will be discussed.

* This work is supported by the Joyce Frances Adlard Cultural Fund.

[1] P. E. Garrett, J. Phys. **G** (London) **27**, R1 (2001)
[2] J. F. Sharpey-Schafer *et al.,* Nucl. Phys. **A834**, 45c (2010)
[3] F. Iachello, Phys. Rev. Lett. **85**, 3580 (2000) and **87**, 052502 (2001)
[4] R. F. Casten and N. V. Zamfir, Phys. Rev. Lett. **87,** 052503 (2001)
[5] S. Y. Chu et al, Phys. Rev. **C52**, 1407 (1995)
[6] J.-P. Delaroche *et al.,* Phys. Rev. **C81,** 014303 (2010).
[7] S. N. T. Majola *et al.,* this conference, poster.
[8] W. Greiner and J. A. Maruhn, *Nuclear Models (Springer 1996)* p158/9

MUSETT and the spectroscopy of heavy elements at GANIL

B. Sulignano[1]
for the MUSETT Collaboration
[1]*CEA Saclay, IRFU/SPhN, 91191 Gif/Yvette Cedex, France.*

Over the past years, one of the most fascinating topics in nuclear structure physics research has been the synthesis and spectroscopy of heavy nuclei in the direction of the predicted super-heavy island of stability. Detailed information has been obtained on the collective properties and single-particle structures using both prompt and decay spectroscopy techniques. However, very little data are available for neutron-rich heavy elements. These isotopes can only be populated in very asymmetric reactions using light ion beams and actinide targets. Hence the recoil nuclei produced have a very large angular distribution and very low kinetic energy. The transmission of separators or spectrometers is usually very small for such reactions.

The VAMOS spectrometer has a larger transmission for very asymmetric reactions than any other spectrometer coupled to a Germanium detector array and is therefore the ideal choice for doing in-beam spectroscopy after such reactions. For this purpose VAMOS has been equipped with a new silicon detector array MUSETT ("Mur de Silicium pour l'Etude des Transfermiens par Tagging") which has been developed for implantation and identification of fusion-evaporation residues through alpha-decay tagging. This new detector consists of 4 double-sided silicon strip detectors (128 strips on each side) having a total active area of 40x10 cm^2. The huge number of high-resolution channels requires the use of a new front-end electronics which assures the compactness of the system. An ASIC's chip (36mm2), known as ATHED and a new data acquisition system have been developed. Recoil-decay tagging was used to unambiguously identify evaporation residues in the dominant backgrounds of unwanted reaction channels, and EXOGAM provided a large efficiency for the detection of prompt gamma-ray cascades.

In this contribution, we will first give an overview of our experimental program on transfermium and transactinides elements studies. We will then describe the new MUSETT silicon wall and the new NARVAL-based data acquisition system. We will then show the results of the first commissioning experiment using very asymmetric reactions and the VAMOS Wien filter mode. A new gas-filled operation mode has been recently implemented at VAMOS. Examples of nuclear structure and reaction dynamics studies using this new mode and MUSETT will be given. In a near future the Super Separator Spectrometer S3 and the ultra-high intensities of the LINAG linear accelerator will provide fantastic opportunities for decay-spectroscopy studies. We will show how the S3 focal plane detection will benefit from the MUSETT developments and give examples of first-day experiments foreseen with S3 in 2013.

Electron Capture Reactions and Beta Decays in Stellar Environments

Toshio Suzuki[1], **Michio Honma**[2], **Takashi Yoshida**[3], **Toshitaka Kajino**[3,4], **Takaharu Otsuka**[5,6]

[1] *Dept. of Physics, Nihon University, Sakurajosui, Setagaya-ku, Tokyo 156-8550, Japan.*
[2] *Center for Mathematical Sciences, Univ. of Aizu, Aizu-Wakamatsu, Fukushima, Japan.*
[3] *Department of Astronomy, Graduate School of Science, University of Tokyo, Bunkyo-ku, Hongo, Tokyo 113-0033, Japan.*
[4] *National Astronomical Observatory of Japan, Mitaka, Tokyo 181-8588, Japan.*
[5] *Department of Physics, University of Tokyo, Hongo, Bunkyo-ku, Tokyo 113-0033, Japan.*
[6] *Center for Nuclear Study, University of Tokyo, Hongo, Bunkyo-ku, Tokyo 113-0033, and RIKEN, Hirosawa, Wako-shi, Saitama 351-0198, Japan.*

Gamow-Teller transition strengths in fp-shell nuclei are studied by shell model calculations with the use of new shell model Hamiltonians, GXPF1 [1]. The distributions of the strengths are found to be generally more fragmented compared to those obtained by KB3G [2]. The difference of the distribution of the strength leads to different reaction cross sections or rates in stars, for example, the enhancement of the neutrino-induced ^{56}Ni (ν,ν'p) ^{55}Co reaction cross section and production rate of ^{55}Mn in population III stars [3].

Electron capture reactions on Ni, Fe and Co isotopes are investigated by shell model calculations in steller environments. The capture rates depend sensitively on the distribution of the GT strength. The rates are found to be smaller for GXPF1 compared to KB3G in many of Fe and Ni isotopes such as ^{58}Ni and ^{52,54,56}Fe at temperatures T=(3∼10) $\times 10^9$ K and densities rYe $\simeq 10^7 \sim 10^9$ mole/cm^3. In particular, for ^{58}Ni, this reduction of the capture rates is found to be consistent with the rates obtained from experimental GT strength in ^{58}Ni [4]. In case of ^{60}Ni, the capture rates increase for GXPF1 compared to KB3G due to the existence of the GT strength at a low excitation energy, E_x =0.7 MeV for GXPF1. This is consistent with the observed large GT strength, B(GT$^+$) =0.95±0.15 at E_x=0.65 MeV [5].

Beta decays of the N=126 isotones are studied by shell model calculations taking into account both the GT and first-forbidden (FF) transitions. The FF transitions are found to be important to reduce the half-lives by twice to several times of those by the GT contributions only [6]. Implications of the short half-lives of the waiting point nuclei on the r-process nucleosynthesis will be discussed for various astrophysical conditions.

[1] M. Honma et al., Phys. Rev. C 65, 061301 (2002); Phys. Rev. C 69, 034335 (2004).
[2] A. Poves et al, Nucl. Phys. A694, 157 (2001); E. Caurier et al, Rev. Mod. Phys. 77, 427 (2005).
[3] T. Suzuki et al., Phys. Rev. C 79, 061603(R) (2009).
[4] M. Hagemann et al., Phys. Lett. B579, 251 (2004).
[5] N. Anantaraman et al., Phys. Rev. C 78, 065803 (2008).
[6] K. Langanke and G. Martinez-Pinedo, Rev. Mod. Phys. 75, 819 (2003).

^{12}C formation: A classical quest in new Light *

O. Tengblad[1]
for the MAGISOL collaboration
[1]*Instituto de Estructura de la Materia, CSIC, ES-28006 Madrid, Spain*

Hans Bethe was the first to establish the concept of nucleon synthesis in stars [1] proposing the CNO cycle and the PP chain, but was unsuccessful in solving the ^{12}C formation mechanism. Not until the introduction of the Hoyle state [2] in 1953 one was getting close to a solution. However, still 50 years later the 12C break-up is still not fully solved and the quest for learning more about the reaction rates in stars by studying the triple-alpha process is continuing.

In this work we have studied the break-up of ^{12}C following the reactions $^{10}B(^{3}He,paaa)$ and $^{11}B(^{3}He,daaa)$. The study was performed at the 5MV tandem accelerator at the *Centro de Micro Analysis de Materials* (CMAM) [3] at the *Universidad de Autónoma de Madrid*.

The break-up give us information on excited states in ^{12}C from the famous Hoyle state up to energy of almost 18 MeV.

Using a highly segmented experimental set-up the simultaneous detection of thethree alpha particles in coincidence with a proton or deuteron respectively made possible a full kinematic reconstruction of the break-up. On the basis of the energies of the three alpha particles and their angular correlations it has been possible to separate the branching of the break-up through the *ground state* and the first excited 2^+ state in ^{8}Be, as well as to determine the spin and parity of states for cases in which the assignment has been doubtful.

Some of these levels will also de-excite via electromagnetic emission. The comparison between the energy of proton that populate a state of ^{12}C and the sum of the energies of the 3α emitted from the same state makes possible to determine the presence of electromagnetic disintegration (γ) to lower states within ^{12}C followed by the 3α break-up. This technique permits to identify γ-emissions between states where the gamma radiation emitted does not correspond to a peak [4]. In this contribution we will discuss the experimental set-up followed by a detailed description of the analysis method to reach the results obtained.

* This work was supported by the CICYT via contract FPA2007-62170.

[1] H.A. Bethe, Energy production in stars, Phys. Rev. 55(1939)434
[2] F. Hoyle et al., Phys. Rev. 92(1953)1095
[3] http://www.cmam.uam.es/
[4] O. S. Kirsebom, et al., Phys. Let. B680(2009)44

Alpha-particle capture reactions in inverse kinematics relevant to p-process nucleosynthesis

Predrag Ujić[1], Anastasios Lagoyannis[2], Th. J. Mertzimekis[2], Francois de Oliveira Santos[1], Sotirios Harissopulos[2], Artemis Spyrou[3], Luc Perrot[4], Christelle Stodel[1], Marie-Genevieve Saint-Laurent[1], Omar Kamalou[1], Anne Lefebvre-Schuhl[5], Stephane Grevy[1], Lucia Caceres[1], Marek Lewitowicz[1]

[1]GANIL, Bd. Henri Becquerel, Caen, France
[2]Tandem Accelerator Lab., Inst. of Nuclear Physics, NCSR "Demokritos", Athens, Greece
[3]NSCL/MSU, East Lansing, Michigan, USA
[4]IPN Orsay (IN2P3-CNRS) F-91406 Orsay, France
[5]CSNSM, Orsay, France

The synthesis of the so-called p-nuclei requires a special mechanism known as p-process [1]. This process occurs in stellar environments of very high temperatures where the preexisting more neutron-rich nuclei are involved in sequences of (γ,n), (γ,p) and (γ,α) reactions, whereby, in some scenaria, certain (p,γ) and (α,γ) reactions are also included. In order to perform abundance calculations, the reaction rates of more than 20000 nuclear reactions on about 2000 nuclei are needed. Consequently, all extended network calculations have to rely almost completely on cross sections predicted by the Hauser-Feshbach (HF) theory. However, some of the very few (α,γ) data show that the phenomenological alpha-particle optical potentials, used in these calculations, can be wrong by a factor of ten or more. Hence, systematic cross-section measurements of α-particle capture reactions at energies between 1 and 3.5 MeV/u are necessary. Such measurements are proposed to be carried out mainly in the A=80÷140 and A=170÷200 mass regions [2]. The measurement of these reactions in inverse kinematics is the only possible solution, when the radioactive nuclei are involved. Nevertheless, this was not ever performed for the medium-mass nuclei due to the small mass-difference between the beam particles and the recoils which sets tight experimental conditions for their separation.

For the first time we performed the inverse kinematics experiment with the medium mass nuclei - ^{78}Kr(α,γ)^{82}Sr reaction. The aim was to prove feasibility of this type of experiment. The energy of the reaction was E(CM)=6.5 MeV and respective velocity of ^{78}Kr and ^{82}Sr were 1.8290 ± 0.0311 cm/ns and 1.7349 ± 0.0951 cm/ns, which is about of 5% difference. Beam intensity was around 10 nA (7.8×10^{9} pps). The target consisted of 10^{17} atoms of helium (approximately 1 μg/cm^2) embedded in aluminum foil of 50 μg/cm^2. LISE3 spectrometer which includes 12m long Wien Filter was used for the separation of the ^{82}Sr from the primary beam – ^{78}Kr.

Considering very small difference of velocities – about 5%, between the primary beam and compound nucleus, very good rejection factor was achieved – more than 10^{9}. Unfortunately high intensity of the ions, at that time of unknown origin, completely masked the expected position of our ion of interest. It was hard to explain that these ions are scattered primary beam since they had too big difference in energy and too high intensity which could not be explained by the energy loss in the target with so high probability. The very probable explanation for the origin of this pollutant could be the microscopic dust deposited on the surface of the target.

The conclusion of the experiment is that the cross section measurement of the (α,γ) reactions is feasible regarding high rejection rate of the primary beam of factor >10^9, however the use of gas-jet target instead of solid one is compulsory.

[1] M. Arnould and S. Goriely, Phys. Rep. **384**, 1 (2003)
[2] P. Demetriou *et al.* , Nucl. Phys. **A707**, 253 (2002)

The γ-ray Strength Function Method*

H. Utsunomiya[1], S. Goriely[2], H. Akimune[1], T. Yamagata[1], T. Kondo[1], C. Iwamoto[1], A. Okamoto[1], H. Harada[3], F. Kitatani[3], S. Goko[4], H. Toyokawa[5], K. Yamada[5], Y.-W. Lui[6], S. Hilaire[7], and A.J. Koning[8]

[1]Dept. of Physics, Konan University, Okamoto 8-9-1, Higashinada, Kobe 658-8501, Japan
[2]Institut d'Astronomie et d'Astrophysique, Université Libre de Bruxelles, Belgium
[3]Japan Atomic Energy Agency, Tokai-mura, Naka, Ibaraki 319-1195, Japan
[4]Department of Engineering, Hokkaido University, Sapporo 060-8628, Japan.
[5]National Institute of Advanced Industrial Science and Technology, Tsukuba 305-8568, Japan
[6]Cyclotron Institute, Texas A&M University, College Station, Texas 77843, USA
[7]CEA, DAM, DIF, F-91297 Arpajon, France
[8]Nuclear Research and Consultancy Group, P.O. Box 25, NL-1755 ZG Petten, The Netherlands

Radiative neutron capture cross sections for unstable nuclei are of direct relevance to nucleosynthesis of heavy elements referred to as the s- and r-process in nuclear astrophysics and to nuclear data in nuclear engineering. The surrogate reaction method is proposed and currently in active utilization in the latter field. We propose an alternative and less model-dependent method based on the γ-ray strength function (γSF) which is a nuclear statistical ingredient common to *(γ,n)* and *(n,*γ*)* reactions. The validity of this method is demonstrated in its application to zirconium, tin and palladium isotopes, predicting (n,γ) cross sections for unstable nuclei ^{93}Zr ($T_{1/2}$=1.6×10^{6} y), ^{95}Zr (64 d) and ^{107}Pd (6.5×10^{6} y). The source of uncertainties of this method, the nuclear level density and low-lying strength, is discussed quantitatively.

The γSF is best probed above neutron threshold by a measurement of photoneutron cross sections for stable nuclei including those with low neutron separations energies (6-8 MeV) and justified by reproducing experimental *(n,*γ*)* cross sections for stable nuclei that are sensitive to γSF below neutron threshold. Thus, the method requires both (γ,*n*) and (*n*,γ) cross sections for stable isotopes as systematic as possible. Laser-Compton scattering γ-ray beams at AIST, Duke-HIGS, and NewSUBARU and pulsed-spallation neutron beams at CERN, LANSCE, and J-Parc could contribute to providing the required data.

Some important cases to be studied with the γSF method are discussed along with experimental techniques. For a versatile application of the γSF method, the fundamental structure of the γSF needs to be understood in terms of extra strengths of pigmy E1, giant M1 and other multipolarity on top of the low-energy tail of GDR. Especially, nuclear physics study of the systematics of pygmy E1 strength, which is valid throughout the chart of nuclides, and a persistent improvement of nuclear physics models of γSF are indispensable.

* The present study includes the result of "Study on nuclear data by using a high intensity pulsed neutron source for advanced nuclear system" entrusted to Hokkaido University by the Ministry of Education, Culture, Sports, Science and Technology of Japan (MEXT). This work is partly supported by the Japan Private School Promotion Foundation and the Konan-ULB bilateral project. S.G. acknowledges support from FNRS.

Poster Contributions

Listed in alphabetical order of the first author name

	Author(s)	Title
1	**N. Adimi** *et al.* *(CENBG, Gradignan, France)*	*The Spectroscopic study of ^{33}Ar*
2	**K. G. Balasi** *et al.* *(U. Ioannina, Greece)*	*Nuclear structure calculations of the even-even Mo isotopes in the context of QRPA method*
3	**Ch. Borgmann** *et al.* *(Max-Plank-Insitut für Kernphysik, Heidelberg, Germany)*	*Mass Measurements for Nuclear Structure Studies of Kr and Ag at ISOLTRAP*
4	**P. Capel** *et al.* presented by **M. De Napoli** *(INFN-LNS, Catania, Italy)*	*^{17}F Breakup Reactions: a Touchstone for Indirect Measurements*
5	**F. Cappuzzello** *et al.* *(INFN-LNS Catania & Università di Catania, Italy)*	*The role of pairing in the via the ^{13}C(^{18}O,^{16}O)^{15}C reaction at 84 MeV*
6	**E. Crema** *et al.* *(U. São Paulo, Brazil)*	*Testing nuclear diffuseness with quasi-elastic barrier distribution*
7	**M. Cubero** *et al.* *(IEM-CSIC, Madrid, Spain)*	*Scattering Studies of the Halo Nucleus ^{11}Li and its Core ^{9}Li on ^{208}Pb near the Coulomb Barrier, Scattering and Reaction Dynamics*
8	**John Daoutidis** *et al.* *(IAA-ULB, Brussels, Belgium)*	*Improved Relativistic QRPA calculations of the γ-ray strength*
9	**J. Darai** *et al.* *(U. Debrecen, Hungary)*	*Clusterization and phase-transitions in atomic nuclei*
10	**N.A. Demekhina** *et al.* presented by **T. Chuvilskaya** *(INP, Moscow State Univ., Russia)*	*Yields of Radioactive Products of Transfer Reactions Induced by ^{6}He Ions on ^{197}Au Target.*
11	**M. De Rydt** *et al.* presented by **Th. Mertzimekis** *(INP, NCSR “Demokritos”, Athens)*	*The ground-state g factor of ^{44}Cl: a probe for the reduced gaps at Z=16 and N=28*
12	**M. Fisichella** *et al.* *(INFN-LNS Catania & U. Messina, Italy)*	*Fusion cross section in ^{4,6}He+^{64}Zn collision around and below the Coulomb barrier*
13	**S. Fujimoto** *et al.* *(Kumamoto National College of Technology, Goshi 861-1102, Japan)*	*Nucleosynthesis in neutrino-driven, aspherical supernova explosion of massive stars*

14	**S. Goriely** *et al.* *(IAA-ULB, Brussels, Belgium)*	*Latest development of the combinatorial model of nuclear level densities*
15	**S. Goriely** *et al.* presented by **S. Hilaire** *(CEA/DAM/DIF, Arpajon, France)*	*Gogny HFB prediction of nuclear structure properties*
16	**A. Herzáň** *et al.* *(U. Jyväskylä, Finland)*	*Spectroscopy of Neutron-Deficient Francium Isotopes*
17	**O. Itoh** *et al.* presented by **H. Utsunomiya** *(Konan Univ., Kobe, Japan)*	*Photoneutron Cross Sections for Au*
18	**Y. Iwata** *et al.* *(GSI Darmstadt, Germany)*	*Momentum-dependent Nuclear Potential and its Applications*
19	**Jacob S. Johansen** *(Aarhus Univ., Denmark)*	*Transfer Reactions Using a Low-energy ^{11}Be Beam*
20	**P. Jones** *et al.* *(U. Jyväskylä, Finland)*	*Advances in In-beam Spectroscopy with the JUROGAM II Spectrometer*
21	**D. Kanjilal** *et al.* *(Saha Institute of Nuclear Physics, Kolkata, India)*	*Investigation of high spin states and isomeric decays in doubly odd ^{208,210}Fr*
22	**V. A. Karnaukhov** *et al.* *(JINR Dubna, Russia)*	*Hot Nuclei and Phase Transitions*
23	**J. Kroll** *et al.* *(Charles Univ., Prague, Czech Republic)*	*Evidence for the Scissors Mode in ^{160}Tb from the Two-Step Gamma Cascade Measurement*
24	**J. J. Lawrie** *et al.* *(iThemba LABS, Somerset West, South Africa)*	*Dipole Bands in ^{196}Hg*
25	**O. Shirinda** *et al.* presented by **E. A. Lawrie** *(iThemba LABS, South Africa)*	*B(M1) Staggering in Two-quasiparticle Chiral Bands*
26	**John Leckey** *et al.* *(College of William & Mary, Williamsburg VA, USA)*	*Qweak – A Search for New Physics*
27	**M. Lipoglavšek** *et al.* *(Jozef Stefan Institute, Ljubljana, Slovenia)*	*Electron Screening in Metals*
28	**J. Ljungvall** *et al.* *(CSNSM Orsay, France)*	*Onset of collectivity in Neutron-Rich iron isotopes: Toward a new island of inversion?*

29	**H. Makii** *et al.* *(ASRC, JAEA, Ibaraki, Japan)*	*Preparation for the Measurement of the $^{12}C(\alpha,\gamma)^{16}O$ Reaction at TRIAC*
30	**T. Maruyama** *et al.* *(Nihon Univ., Tokyo)*, presented by **T. Kajino** *(NAO, Tokyo, Japan)*	*Asymmetric Neutrino Reaction from Magnetized Proto-Neutron Stars in fully Relativistic Framework including Hyperons*
31	**P. L. Masiteng** *et al.* presented by **E. A. Lawrie** *(iThemba LABS, South Africa)*	*Possible Chiral Bands in ^{194}Tl*
32	**S. Mohammadi** *(Payame Noor University, Mashad, Iran)*	*Symmetric and Non-symmetric Muonic Atoms-Molecules Studies*
33	**D. Montanari** *et al.* *(U. Milano & INFN-Milano, Italy)*	*Reaction Dynamics and Nuclear Structure Studies via Deep Inelastic Collisions with Heavy-ions: Search for Particle-vibration Couplings in ^{49}Ca*
34	**H. R. Moshfegh** *et al.* *(University of Tehran, Iran)*	*Cold Hybrid Star Properties*
35	**H. Nakada** *(Chiba University, Chiba, Japan)*	*Nuclear Shell Structure in Semi-Realistic Mean-Field Approach*
36	**M. Ono** *et al.* *(Kyushu University, Fukuoka, Japan)*	*Heavy-element Nucleosynthesis in Magnetohydrodynamical Jets from Collapsars*
37	**S. Palmerini** *et al.* *(U. Perugia & INFN-Perugia, Italy)*	*p-capture nucleosynthesis in Low Mass Stars: effects of new reaction rates*
38	**P. Ruotsalainen** *et al.* *(U. Jyväskylä, Finland)*	*A Recoil-Beta Tagging Study of N=Z Nucleus ^{66}As*
39	**M. Saruwatari** *et al.* *(Kyushu University, Fukuoka, Japan)*	*R-process Nucleosynthesis during the MHD Explosions of a Massive Star*
40	**A. Sauerwein** *et al.* presented by **A. Zilges** *(IKP, U. Köln, Germany)*	*Experiments on proton- and alpha-induced reactions of particular relevance for the p process*
41	**V. Scuderi** *et al.* *(Università di Catania and INFN-LNS Catania, Italy)*	*Elastic scattering and fusion of ^{6}Li on ^{64}Zn at near-barrier*
42	**O. Shirinda** *et al.* *(iThemba LABS, Somerset West, South Africa)*	*Reaching degeneracy in two-quasiparticle chiral bands*
43	**R. Silvestri** *et al.* *(U. Napoli & INFN-Napoli, Italy)*	*Dynamical Dipole Mode in Fusion heavy-Ion Reactions by Using Stable and Radioactive Beams*

44	**G. Susoy** *et al.* *(Istanbul University, Turkey)*	*High Resolution Study of Gamow-Teller Transitions in ^{45}Sc nucleus*
45	**T. Suzuki** *et al.* *(Nihon University, Tokyo, Japan)*	*Structure of Neutron-rich Calcium Isotopes and Roles of Three-body Interaction*
46	**T. P. D. Swan** *et al.* *(U. Surrey, UK)*	*High-K Structures in the ^{164}Er Region*
47	**Yu. M. Tschuvil'sky** *(Moscow State Univ., Russia)*	*Microscopic Description of the Alpha-Clustering Phenomenon in (2s-1d)-Shell Nuclei*
48	**D. Torresi** *et al.* *(U. Catania & INFN-LNS, Italy)*	*Search for Li-α cluster state in ^{12}B using Inverse Kinematics Thick Target Scattering*
49	**H. Utsunomiya** *et al.* *(Konan University, Kobe, Japan)*	*Application of the γSF Method to Palladium*
50	**H. Utsunomiya** *et al.* *(Konan University, Kobe, Japan)*	*Striking Behaviour of Photoneutron Cross Sections for ^{90}Zr near Threshold*
51	**A. Vancraeyenest** *et al.* *(IPNL, U. Lyon, France)*	*γ Spectroscopy of Positive Parity Bands ^{156}Gd*
52	**P. Veselý** *et al.* *(U. Jyväskylä, Finland)*	*Finite-range Separable Pairing Interaction within New N3LO DFT Approach*
53	**D. Karadimos** *et al.*, presented by **R. Vlastou** *(NTUA, Athens, Greece)*	*The ^{237}Np(n,f) cross section at the CERN n-TOF facility*
54	**A. Wendt** *et al.* *(IKP, U. Köln, Germany)*	*Commissioning of LYCCA - a HISPEC-device*
55	**Y. Xu** *et al.* *(IAA-ULB, Brussels, Belgium)*	*Update and Extension of the Nuclear Astrophysics Compilation of Reaction Rates (NACRE): Charged-Particle Thermonuclear Rates with A<16*

The Spectroscopic study of ^{33}Ar

N.Adimi[1,2], R.Dominguez-Reyes[3], M. Alcorta[3], A. Bey[1], B. Blank[1], M. J. G. Borge[3], F.de Oliveira Santos[4], C. Dossat[1], H. O. U.Fynbo[5], J. Giovinazzo[1], H. H. Knudsen[5], M. Madurga[4], I. Matea[1], A. Perea[3], K. Sümmerer[6], O. Tengblad[3] and J. C. Thomas[4]

[1]*Centre d'Etudes Nucléaires de Bordeaux Gradignan, Université Bordeaux 1, UMR 5797 CNRS / IN2P3, Chemin du Solarium, BP 120, F-33175 Gradignan, France*
[2]*Faculté de Physique, USTHB, B.P.32, El Alia, 16111 Bab Ezzouar, Alger, Algeria*
[3]*Instituto de Estructura de la Materia, CSIC, Serrano 113bis, E-28006-Madrid, Spain*
[4]*Grand Accélérateur National d'Ions Lourds, B.P. 55027, F-14076 Caen Cedex 05, France*
[5]*Department of Physics and Astronomy, University of Aarhus, Ny Munkegade 1520, DK-8000 Aarhus C, Denmark*
[6]*Gesellschaft für Schwerionenforschung, Planckstrasse 1, D-64291 Darmstadt, Germany*

The proton-rich nucleus ^{33}Ar has been produced at the low-energy facility of SPIRAL at GANIL. Spectroscopic studies of gamma and p emission of this nucleus were performed with the “Silicon Cube” detection system. The analysis of proton and gamma singles and coincidence spectra allowed to establish a complete decay scheme of this nucleus. The comparison of the Gamow-Teller strength distribution deduced from our experiment and the theoretical one obtained with the Shell Model permitted the determination of a quenching factor for the Gamow-Teller strength.

Nuclear structure calculations of the even-even Mo isotopes in the context of QRPA method

K. G. Balasi[1], **E. Ydrefors**[2], **J. Suhonen**[2]

[1]*Department of Physics, The University of Ioannina, 45110 Ioannina Greece.*
[2]*Department of Physics, University of Jyväskylä, P.O.Box 35, 40014 Jyväskylä, Finland.*

The even-even Mo isotopes play a significant role in supernova evolution phenomena and are used as targets in the MOON neutrino experiment in Japan. A systematic study of the nuclear structure of the aforementioned isotopes is presented and discussed. The nuclear wave functions for the initial and final nuclear states are constructed in the context of the quasi-particle random phase approximation (QRPA) tested on the reproducibility of the low-lying energy spectrum (up to about 5 MeV) of the studied nuclei. The response of these detectors to supernova neutrino is also studied, by exploiting the above results and utilizing the folding procedure assuming a two parameter Fermi-Dirac distribution for the supernova neutrino energy-spectra.

Mass Measurements for Nuclear Structure Studies of Kr and Ag at Isoltrap*

Ch. Borgmann[1], G. Audi[2], D. Beck[3], K. Blaum[1], Ch. Böhm[1], M. Breitenfeldt[4], D. Fink[1], S. George[1], F. Herfurth[3], A. Herlert[5], M. Kowalska[5], S. Kreim[1], D. Lunney[2], S. Naimi[2], D. Neidherr[6], M. Rosenbusch[4], S. Schwarz[7], L. Schweikhard[4]

[1]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, D-69117 Heidelberg, Germany.
[2]CSNSM-IN2P3-CNRS, Université de Paris Sud, F-91405 Orsay, France.
[3]GSI Helmholtzzentrum für Schwerionenforschung, Planckstr. 1, D-64291 Darmstadt, Germany.
[4]Institut für Physik, Ernst-Moritz-Arndt-Universität, D-17487 Greifswald, Germany.
[5]CERN, Physics Department, 1211 Geneva 23, Switzerland.
[6]Institut für Physik, Johannes Gutenberg-Universität, D-55128 Mainz, Germany.
[7]NSCL, Department of Physics and Astronomy, MSU, Michigan 48824, East Lansing, USA.

With the Penning trap mass spectrometer Isoltrap, located at the isotope separator ISOLDE at CERN, masses of short-lived radionuclides can be measured with relative uncertainties down to 10^{-8}. In 2009, the masses and thus the nuclear binding energies of ^{96,97}Kr and $^{122-124}$Ag were measured. These measurements serve nuclear structure studies as well as tests of the predictive power of mass models.

The determination of the neutron-rich silver masses clarified the previously observed, unexpected behaviour of the two-neutron separation energies (S_{2n}) of this isotopic chain. Now, the S_{2n} values follow the trend expected for spherical nuclei. The masses of ^{96,97}Kr were measured for the first time and indicate a critical point of a quantum phase transition region: For higher Z, a sudden deformation occurs around N=60. With our newly measured masses, however, there is no deformation visible for krypton from the two-neutron separation energies. This identifies the krypton chain as the border of the region of deformation.

In this contribution, the experimental setup, the measurement principle, as well as the abovementioned results will be presented and discussed.

* This work was supported by the German Federal Ministry for Education and Research (BMBF) through grants 06GF151 and 06MZ215, the Max-Planck Society, the French In2p3, the EU FP6 Program (MEIF-CT-2006-042114) and the Helmholtz Association for National Research Centers (VH-NG-037).

^{17}F breakup reactions: a touchstone for indirect measurements

P. Capel[1], M. De Napoli[2], F. Giacoppo[2,3], C. Mazzocchi[4], G. Raciti[5,6], E. Rapisarda[6,7], C. Sfienti[5,6]

[1]National Superconducting Cyclotron Laboratory, MSU, East Lansing, MI, USA.
[2]INFN-Laboratori Nazionali del Sud, I-95123 Catania, Italy.
[3]Dipartimento di Fisica, University of Messina, I-98166 Messina, Italy.
[4]INFN-Sezione di Milano and University of Milano, I-20133, Milano Italy.
[5]Dipartimento di Fisica e Astronomia, University of Catania, I-95123, Catania, Italy.
[6]INFN-Sezione di Catania, I-95123, Catania, Italy.
[7]Centro Siciliano di Fisica Nucleare e Struttura della Materia, I-95125 Catania, Italy.

Dissociation has become an essential tool in several domains of nuclear physics. It provides useful information about the structure of halo nuclei [1], and Coulomb breakup can be used as an indirect method to measure radiative-capture cross sections at stellar energies [2]. Indeed, Coulomb breakup, simulated as the exchange of virtual photons between the projectile and the target, can be seen as its time-reversed reaction. The radiative-capture cross section can thus be obtained from the Coulomb-dissociation cross section via a detailed balance [2]. Though simple it may seem, this indirect technique relies on peculiar assumptions. Recent theoretical analyses of the Coulomb breakup of ^{8}B (e.g. [3]) have shown that these assumptions are not all satisfied. This may explain the discrepancy found between direct and indirect methods of measuring the cross section of the ^{7}Be(p,γ)^{8}B reaction. Whereas many experimental investigations on such a phenomenon have been conducted on ^{8}B, the case of ^{17}F has been poorly addressed up to now. Yet the Coulomb dissociation of ^{17}F is the ideal test case to study the accuracy of the indirect technique [2]. An exclusive study of ^{17}F breakup reactions has thus been performed at the FRIBs facility of the Laboratori Nazionali del Sud, Catania (Italy). This facility produces, since a few years, Radioactive Ion Beams (RIBs) at intermediate energies, by projectile fragmentation [4]. In order to discriminate the number of nuclei at the exit of the fragment separator, the leading idea of FRIBs is to apply the tagging technique: namely, the identification, on an event-by-event basis, of each nucleus of the secondary beam cocktail, before it impinges on the secondary target. A primary beam of 45 AMeV ^{20}Ne interacting with a ^{9}Be production target has lead to the formation of a radioactive cocktail containing ^{17}F of about 40 AMeV. The experimental setup and the detector systems allowed the measurement, event-by-event, of the X-Y coordinates of the interaction point on the target as well as the momenta and angles of all outgoing decay particles in a solid angle of 0.34 str around zero degree with a geometrical efficiency of 72% and a resolution of approximately 300 keV. The first results and preliminary model comparison will be presented.

[1] I. Tanihata, J. Phys. **G22**, 157 (1996)
[2] G. Baur and H. Rebel, Annu. Rev. Nucl. Part. Sci. **46**, 321 (1996)
[3] G. Goldstein, P. Capel and D. Baye, Phys. Rev. **C76**, 024608 (2007)
[4] G. Raciti *et al.*, Nucl. Inst. Meth. **B266**, 4632 (2008)

The role of pairing in the via the $^{13}C(^{18}O,^{16}O)^{15}C$ reaction at 84 MeV

F. Cappuzzello[1,2], **D. Carbone**[1,2], **M. Cavallaro**[1,2], **A. Cunsolo**[1,2], **A. Foti**[1,3], **M. Bondì**[1,2], **G. Santagati**[1,2], **G. Taranto**[1,2]

[1] *Dipartimento di Fisica e Astronomia, Università degli Studi di Catania, Italy*
[2] *Istituto Nazionale di Fisica Nucleare – Laboratori Nazionali del Sud, Italy*
[3] *Istituto Nazionale di Fisica Nucleare – Sezione Catania, Italy*

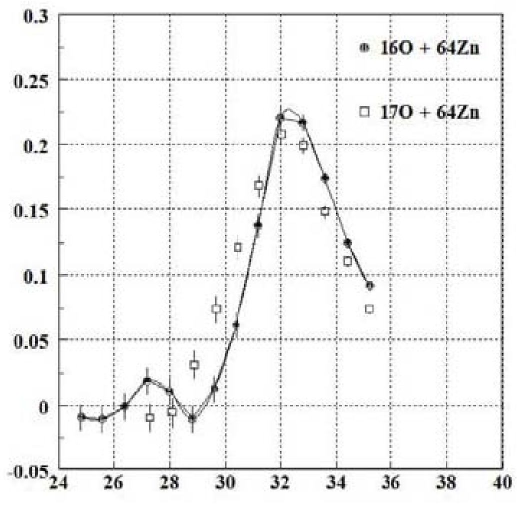
A study of the ^{15}C states was pursued at the Catania INFN-LNS laboratory by the $^{13}C(^{18}O,^{16}O)^{15}C$ reaction at 84 MeV incident energy. The ^{16}O ejectiles were detected at forward angles by the MAGNEX magnetic spectrometer. Thanks to an innovative technique the ejectiles were identified without the need of time of flight measurements. Exploiting the large momentum acceptance (20%) and solid angle (50 msr) of the spectrometer, the ^{15}C energy spectra were obtained with a relevant yield up to about 25 MeV excitation energy. The application of the powerful technique of the trajectory reconstruction did allow to get an energy resolution of about 80 keV FWHM. The spectra show several known low lying states up to about 7 MeV as well as an unknown resonant structure at about 13 MeV. The strong population of these latter together with the measured width of about 5 MeV FWHM reveals the excitation of a collective mode. In addition the measured angular distribution seems to indicate a transfer of a correlated neutron pair in L = 0 configuration, compatible with the Giant Pairing Vibration mode. The analysis is on the way and preliminary results will be presented at the Conference

Testing nuclear diffuseness with quasi-elastic barrier distribution

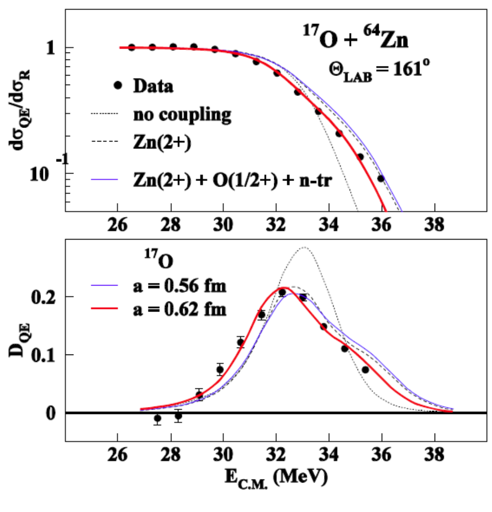
E. Crema[1], J. F. P. Huiza[1], D. S. Monteiro[1], J. M. B. Shorto[1], R. F. Simões[1], P.R. S. Gomes[2]

[1] *Departamento de Física Nuclear, Instituto de Física da Universidade de São Paulo, SP, Brazil.*
[2] *Instituto de Física, Universidade Federal Fluminense, RJ, Brazil.*

Quasi-elastic excitation function for the ^{17}O+ ^{64}Zn system was measured at energies near and below the Coulomb barrier, and θ_{lab}=161°. The corresponding quasi-elastic barrier distribution was derived, which has a particular shape, despite the low mass of the projectile and target. The excitation functions for the alpha particle and neutron stripping reactions were also measured, at the same angle and energies, and the experimental values of the spectroscopy factors were deduced by fitting data with theoretical calculations of the code FRESCO. A good agreement was obtained in the comparison of the experimental quasi-elastic barrier distribution with coupled channel calculations including a very large number of channels. Among these channels investigated, three of them dominated the coupling matrix: two inelastic channels, $^{64}Zn(2_1^+)$ and $^{17}O(1/2^+)$, and one-neutron transfer channel. Besides, this analysis shows that a good agreement between data and calculation is only obtained if is used a larger nuclear diffuseness for the ^{17}O nucleus, compared to ^{16}O. The figures below show the comparison of the experimental quasi-elastic barrier distributions of the ^{16}O+^{64}Zn with ^{17}O+^{64}Zn systems (left), and the coupled channel analysis of the ^{17}O+^{64}Zn system (right), where is showed that the barrier distribution was able to evidence the larger nuclear diffuseness of the ^{17}O nuclei, compared to the ^{16}O one.



E_{cm} (MeV)



E_{cm} (MeV)

Scattering studies of the halo nucleus ^{11}Li and its core ^{9}Li on ^{208}Pb near the Coulomb barrier, Scattering and Reaction dynamics

M. Cubero[1], M. J. G. Borge[1], L. Acosta[2], M. Alcorta[1], M. A. G. Alvarez[5,6], C. Diget[3], D. Galaviz[4], J. P. Fernández-García[5], J. Gomez-Camacho[5,6], J. A. Lay[5], M. Madurga[1], I. Martel[2], A. M. Moro[5], I. Mukha[5], A. M. Sánchez-Benítez[2], A. Shotter[7], O. Tengblad[1], P. Walden[7]

[1]*Inst. Estructura de la Materia, CSIC, Serrano 113bis, E28006 Madrid, Spain.*
[2]*Departamento de Física Aplicada, Universidad de Huelva, E-21071, Huelva, España*
[3]*Department of Physics, University of York, York, UK*
[4]*CFNUL, Universidade de Lisboa, Av. Prof. Gama Pinto 2, 1649-003, Lisboa, Portugal*
[5]*Departamento de FAMN, Universidad de Sevilla, E-41080 Sevilla, España*
[6]*Centro Nacional de Aceleradores, Av. Thomas A. Edison, 41092 Sevilla, España*
[7]*TRIUMF, Vancouver, British Columbia, Canada, V6T 2A3*

The scattering of ^{11}Li on a high-Z target at energies near and below the Coulomb barrier can unveil new features of halo nuclei. The nucleus ^{11}Li has a halo structure of two neutrons with very low binding energy due to its loosely bound structure (S_{2n}=369.15 (65) keV[1]), one expects that collisions with heavy targets at energies around the Coulomb barrier will depart from Rutherford. And this deviation can shed light on the nuclear halo as well as on the scattering process and how this process depends on coupling to the continuum. In particular, the effect of dipole polarizability is known to affect strongly the elastic scattering of halo nuclei on heavy targets, even at energies below the Coulomb barrier, where nuclear forces should not be dominant. Two effects are noticeable: First, Coulomb break-up reduces the elastic cross sections. Second, the distortion of the wave function generated by the displacement of the charged core with respect to the center of mass of the nucleus reduces the Coulomb repulsion, and with it the elastic cross sections.

We report here on the experiment, performed in 2008 at the ISAC-II facility at TRIUMF, where the break-up and elastic differential cross section of ^{11}Li on ^{208}Pb at laboratory energies of 2.2 and 2.7 MeV/u was measured. For comparison and in order to decouple the behaviour of the core, ^{9}Li, from the system, ^{11}Li, the scattering of its core ^{9}Li at the same CM energies was also measured. Furthermore to characterize the Optical Potential (OP) for the ^{9}Li+^{208}Pb system, scattering of ^{9}Li at 3.67 MeV/u was also measured. We used a set of four telescopes with DSSSD, SSSD and PAD silicon detectors in order to clearly identify all fragments in the angular range relevant for this study, from 10 to 140 degrees.

It has been found that the measured ^{11}Li+^{208}Pb elastic cross sections show significant deviations from Rutherford even at energies below the Coulomb barrier. The ratio between the breakup and elastic cross section of ^{11}Li on ^{208}Pb at 24 and 29 MeV as well as the experimental energy distribution of the breakup products from ^{11}Li scattering at forward angles are according with CDCC energy calculations of di-neutron model assuming direct breakup.

In this contribution we will present the preliminary results, the optimum OP parameterization able to describe the elastic cross section, the comparison with different models and the main conclusions achieved.

[1] Phys. Rev. Lett. 101, 202501 (2008).

Improved Relativistic QRPA calculations of the γ-ray strength

John Daoutidis[1], **Stephane Goriely**[1], **D. Pena Arteaga**[2]

[1] *Institut d'Astronomie et d'Astrophysique, ULB, CP226, 1050 Bruxelles, Belgium*
[2] *Institut de Physique Nucléaire, IN2P3, CNRS, 91406 Orsay, France*

Microscopic treatment of nuclear excitations capable to describe observed gamma-ray strength distribution of nuclear reactions as well as resonance widths in neutron rich nuclei, requires approaches which account for the exact coupling to the positive energy continuum as well as proper treatment of the nuclear deformation. Although both improvements are particularly complicated, their importance in extreme nuclei is unambiguous. For that purpose, we have formulated the Quasiparticle Continuum Random Phase Approximation (QCRPA) and the Quasiparticle Deformed RPA (QDRPA) respectively.

The first method is based on the Relativistic Mean Field theory plus BCS, where point coupling phenomenological parameters are used. It has been found that when the coupling to the continuum is treated properly, it does extremely well in reproducing the E1 spectrum with one order of magnitude less numerical effort. The second method, uses the Relativistic Hartree Bogoliubov with density-dependent forces for the static spectrum and can be applied to deformed nuclei.

Both developments, i.e. a proper account of the continuum and of the deformation effects, have been applied separately to the calculation of the E1 strength distribution of stable and exotic neutron rich nuclei. The impact of these effects on the neutron-capture cross sections of astrophysical relevance has been studied.

Clusterization and phase-transitions in atomic nuclei *

J. Darai[1], **J. Cseh**[2]

[1] *Institute of Experimental Physics, University of Debrecen, Pf.105. Hungary-4010.*
[2] *MTA ATOMKI, Debrecen Pf.51. Hungary-4001.*

Atomic nuclei show evidence for different kind of phase transitions. Some of them are very similar to those of the classical thermodynamics, apart from the finite size effects, e.g. the liquid-gas transition in nucleonic matter. Others have different nature, e.g. they take place at zero temperature, yet they show many similarities to the well-known phase transitions. The latter ones are called shape-phase transitions or quantum phase transitions. Much work has been devoted to the study of this phenomenon in relation with the quadrupole collectivity of atomic nuclei [1].

Recently we have started to investigate the phases and phase transitions of the clusterized nuclei in a similar manner [2]. In the present contribution we plan to present some results concerning the large N limit (where N is the number of particles) of the algebraic cluster models. These include the vibron model [3], the semimicroscopical [4], and the phenomenological [5] algebraic cluster models (these latter two have the same group structure, and interactions, but their model space are different from the viewpoint of the exclusion principle). Various interactions are applied [6]. Furthermore, numerical studies are presented, concerning the survival of the quasi-dynamical U(3) symmetry [5], as well as for obtaining realistic spectra in comparison with experimental data [7].

* This work is supported by the OTKA (Grant No. K72357).

[1] See e.g. D. J. Rowe, Nucl. Phys. A745 (2004) 47; D. J. Rowe et al, Phys. Rev. Lett. 93 (2004) 232502; M. Caprio et al, Ann. Phys. NY 323 (2008) 1106; P. Cejnar, J. Jolie, Progr. Part. Nucl. Phys. 62 (2009) 211; and references therein.
[2] J. Cseh et al, J. Phys. Conf. Ser. 111 (2008) 012043; J. Cseh et al, Int. J. Mod. Phys. E17 (2008) 2296; J. Cseh, J. Phys. Conf. Ser. 205 (2010) 012021.
[3] F. Iachello, Phys. Rev. C 23 (1981) 2778.
[4] J. Cseh, Phys. Lett. B281; J. Cseh and G. L´evai, Ann. Phys. (NY) 230 (1994) 165.
[5] H. Yepez-Martinez et al, Phys. Rev. C 74 (2006) 024319.
[6] H. Yepez-Martinez et al, in press.
[7] J. Darai et al, in preparation.

Yields of Radioactive Products of Transfer Reactions Induced by ^{6}He Ions on ^{197}Au Target

N. A. Demekhina[1], A. A. Kulko[1], T. V. Chuvilskaya[2], Yu. E. Penionzhkevich[1], N. K. Skobelev[1], A. A. Shirokova[2]

[1] *Joint Institute for Nuclear Research, 141980, Dubna, Russia.*
[2] *Skobeltsyn Institute of Nuclear Physics, Moscow State University, 119991, Moscow, Russia.*

The investigation and the analysis of the excitation functions of the ground and the isomeric states obtained in the reactions ^{197}Au(^{6}He,xn)$^{200-198}$Tl and ^{197}Au(^{6}He,^{4}He xn)$^{198;196;194}$Au at the projectile energy 15-60 MeV [1] is performed. The experimental results are compared with the ones calculated using the code EMPIRE-2.18 [2]. To calculate the branching ratio of production of an isomeric and a ground state in a residual nucleus (isomeric ratio) probabilities of the population of known discrete levels of the nucleus in a gamma-cascade are taken into account. It is shown that projectile break-up processes play an essential role in the production of the discussed nuclides along with the statistical, multi-step compound, and multi-step direct transfer reactions.

[1] Yu.E. Penionzhkevich et al., Preprint JINR E7-2006-75. Dubna, 20 pp. (2006).
[2] M. Herman, www.nds.iaea.org/empire/.

The ground-state g factor of ^{44}Cl: a probe for the reduced gaps at Z=16 and N=28

M. De Rydt[1], J. M. Daugas[2], F. de Oliveira Santos[3], S. Grévy[3], D. Kameda[4], V. Kumar[5], R. Lozeva[1,6], P. Morel[2], T. J. Mertzimekis[7], T. Nagatomo[4], G. Neyens[1], L. Perrot[8], O. Sorlin[3], C. Stödel[3], J. C. Thomas[3], N. Vermeulen[1], P. Vingerhoets[1]

[1] *IKS, K.U. Leuven, Belgium,*
[2] *CEA, DAM, DIF, France,*
[3] *GANIL, France,*
[4] *RIKEN, Japan,*
[5] *Weizmann Institute of Science, Israel,*
[6] *CSNSM, Orsay, France,*
[7] *INP, NSCR "Demokritos", Athens, Greece,*
[8] *IPN, Orsay, France*

The *g* factor of the ^{44}Cl ground state is measured at the LISE fragment separator at the Grand Accélérateur National d'Ions Lourds (GANIL) using the β nuclear magnetic resonance technique, resulting in $g(^{44}Cl)=(-)0.2749(2)$. An analysis of the *g* factor value and of the theoretical level scheme in the shell-model framework reveals the presence of odd-proton $s_{1/2}$ configurations and neutron excitation across the N=28 shell gap in the ground state of ^{44}Cl. In addition, the measured g factor strongly supports a 2^- spin assignment for the ^{44}Cl ground state.

Fusion cross section in $^{4,6}He+^{64}Zn$ collision around and below the Coulomb barrier

M. Fisichella[1,2], A. Di Pietro[2], P. Figuera[2], F. Amorini[2,3], C. Angulo[4], G. Cardella[2], E. Casarejos[4], C. Marchetta[2], M. Milin[6], A. Musumarra[2,3], A. Ninane[4], M. Papa[2], M. G. Pellegriti[2,3], R. Raabe[5], F. Rizzo[2,3], V. Scuderi[2,3], N. Skukan[6], D. Torresi[2,3], M. Zadro[6].

[1]Dipartimento di Fisica, Universita di Messina, Messina, Italy
[2]INFN- Laboratori Nazionali del Sud and sezione di Catania, Catania, Italy
[3]Dipartimento di Fisica ed Astronomia, Universita di Catania, Catania, Italy
[4]Centre de Recherches du Cyclotron, Louvain-la-Neuve, Belgium
[5]Instituut voor Kern-en-Stralingsfysica, University of Leuven, Leuven, Belgium
[6]Ruđer Bošković Institute, Zagreb, Croatia

A lot of experimental (see e.g. [1,2] and ref therein) and theoretical work (see e.g. [3-4]) has been performed, in recent years, in order to understand the effect of the projectile structure on the fusion mechanisms in collisions induced by light halo and/or weakly bound nuclei. It is expected that the properties of the halo nuclei would play a role in the fusion mechanism at energies around and below the Coulomb barrier.

New results concerning the measurement of fusion cross section of $^{4,6}He+^{64}Zn$ collision will be presented. The ^{6}He nucleus is a halo nuclei and is known to have an extended two neutron distribution. The study of the reaction induced by the stable well bound isotope, ^{4}He allows understanding the role of the two neutrons halo in the ^{6}He. The fusion cross section was measured by using an activation technique where the radioactive evaporation residues produced in the reaction were identified by the X-ray emission which follows their electron capture decay.

Comparing the two systems, we observe an enhancement on the fusion cross section in the reaction induced by ^{6}He, at energy below the Coulomb barrier.

[1] Canto et al., Phys.Rep. (2006) 424, 1
[2] Dasgupta, Hinde Ann.Rev. Nucl. Part. Sci (1998) 48, 401
[3] Takigawa et al., Phys.Lett. B (1991) 265, 23
[4] Ito et al., Phys.Lett. B (2006) 637, 53

Nucleosynthesis in neutrino-driven, aspherical supernova explosion of massive stars

Shin-ichiro Fujimoto[1], Masa-aki Hashimoto[2], Masaomi Ono[2], Kei Kotake[3], Naofumi Ohnishi[4]

[1] Kumamoto National College of Technology, 2659-2 Suya, Goshi 861-1102, Japan
[2] Kyushu University, Fukuoka 810-8560, Japan
[3] National Astronomical Observatory, 2-21-1, Osawa, Mitaka, Tokyo, 181-8588, Japan
[4] Tohoku University, 6-6-01 Aramaki-Aza-Aoba, Aoba-ku, Sendai, 980-8579, Japan

Explosion mechanism of core collapse supernovae (SNe) is still not clearly understood. Multidimensional effects are recognized to be important for the explosion, in particular for a progenitor heavier than about $11M_{\odot}$ in its main sequence phase [1,2]. Standing accretion shock instability (SASI) is a reliable candidate to initiate bipolar oscillations of a stalled shock. The oscillations trigger strong convection, which pushes the shock to larger radii and leads to longer neutrino exposure and therefore more effective neutrino heating to the postshock gas. Recent two-dimensional simulations of stellar core collapse show that the delayed neutrino-driven mechanism for the SN explosion aided by SASI is likely to cause aspherical explosion of massive stars [3].

We examine explosive nucleosynthesis during neutrino-driven, aspherical SN explosion aided by SASI, based on two-dimensional hydrodynamic simulations of the explosion of a $15M_{\odot}$ star. We find that masses of the ejecta and ^{56}Ni correlate with the neutrino luminosity, and ^{56}Ni mass is comparable to that observed in SN 1987A. We find that abundance pattern of the supernova ejecta is similar to that of the solar system, for cases with high explosion energies of $\approx 10^{51}$ ergs, which is comparable to the energy observed in SN1987A and Cas A. We also find that *p*-nuclei are abundantly produced in the ejecta via *γ-process*, or the photodisintegration of seed nuclei, as in spherical models [4,5,6]. Underproduced nuclei in the spherical model, such as ^{92}Mo, ^{94}Mo, ^{96}Ru, and ^{98}Ru, are also underabundant in our aspherical models. We discuss abundance change via neutrino interactions and denpendence of abundances on nuclear reaction rates.

[1] Kitaura, F. S., Janka, H.-T., & Hillebrandt, W. 2006, A&A 450, 345
[2] Buras, R., Janka, H.-T., Rampp, M., & Kifonidis, K. 2006, A&A457, 281
[3] Marek, A., & Janka, H.-T.2009, ApJ 694, 664
[4] Hashimoto, M. 1995, Prog. Theor. Phys. 94, 663.
[5] Woosley, S. E., & Weaver, T. A. 1995, ApJS101, 181
[6] Rauscher, T., Heger, A., Hoffman, R. D., & Woosley, S. E. 2002, ApJ576, 323

Latest development of the combinatorial model of nuclear level densities

S. Goriely[1], **S. Hilaire**[2], **M. Girod**[2]

[1] *Institut d'Astronomie et d'Astrophysique, Université Libre de Bruxelles, Campus de la Plaine CP226, 1050 Brussels, Belgium*
[2] *CEA, DAM, DIF,F-91297 Arpajon, France*

The combinatorial model of nuclear level densities has now reached a level of accuracy comparable to that of the best global analytical expressions without suffering from the limits imposed by the statistical hypothesis on which the latter expressions rely. In particular, it provides naturally, non gaussian spin distribution as well as non equipartition of parities which are known to have a significant impact on cross section predictions at low energies [1,2]. Our first global model developed in Ref. [1] suffered from deficiencies, in particular in the way the collective effects - both vibrational and rotational - were treated. We have recently improved this treatment using simultaneously the single particle levels and collective properties predicted by a newly derived Gogny interaction [3], therefore enabling a microscopic description of energy-dependent shell, pairing and deformation effects. In addition for deformed nuclei, the transition to sphericity is coherently taken into account on the basis of a temperature-dependent Hartree-Fock calculation which provides at each temperature the structure properties needed to build the level densities. This new method is described and shown to give promising preliminary results with respect to available experimental data.

[1] S. Goriely, S. Hilaire, and A. J. Koning, "Improved microscopic nuclear level densities within the Hartree-Fock-Bogoliubov plus combinatorial method", Phys. Rev. C, 78, 064307 (2008).
[2] S. Goko et al., "Partial photoneutron cross sections for the isomeric state $^{180}Ta^{m}$" Phys. Rev. Lett., 96, 192501 (2006).
[3] S. Goriely et al., "First Gogny-Hartree-Fock-Bogoliubov Nuclear Mass Model," Phys. Rev. Lett., 102, 242501 (2009).

Gogny HFB prediction of nuclear structure properties

S. Goriely[1], S. Hilaire[2], M. Girod[2]

[1] *Institut d'Astronomie et d'Astrophysique, Université Libre de Bruxelles, Campus de la Plaine CP226, 1050 Brussels, Belgium*

[2] *CEA, DAM, DIF,F-91297 Arpajon, France*

The increasing need for nuclear data far from the valley of stability requires information on nuclei which cannot be accessed experimentally or for which almost no experimental data is known. In this case, the use of microscopic approaches to predict properties of such poorly known nuclei is necessary. Within this context, large scale mean field calculations from proton to neutron drip lines have been performed using the Hartree-Fock-Bogoliubov method based on the Gogny nucleon-nucleon effective interaction. This extensive study has shown the ability of the method to reproduce bulk nuclear structure data available experimentally. This includes nuclear masses, radii, matter densities, deformations, moment of inertia as well as collective mode (low energy and giant resonances). In particular, the first mass table based on a Gogny-Hartree-Fock-Bogolyubov calculation including an explicit and coherent account of all the quadrupole correlation energies is presented. The rms deviation with respect to essentially all the available mass data is 798 keV. Nearly 8000 nuclei have been studied under the axial symmetry hypothesis and going beyond the mean-field approach. The corresponding properties are made available to the nuclear scientific community on an internet web site for every individual nucleus. The content and original feature of this nuclear data library is also presented.

Spectroscopy of Neutron-Deficient Francium Isotopes

A. Herzáň[1]
On behalf of Darmstadt-Bratislava-Leuven-Liverpool-Paisley-Orsay collaboration
[1] *Dept. of Physics, University of Jyväskylä, P. O. Box 35, Jyväskylä FI-40014, Finland*

In neutron-deficient nuclei around Z=82, shape coexistence phenomena induced by proton excitations across the shell gap play a major role [1, 2]. In many cases in this region of nuclei, this results in nuclear isomerism, when two or even three closely-lying configurations have a large spin difference. Some of the studied cases are for example, odd-A Bi (Z=83) isotopes, in which an $1/2^+$ 2p-1h intruder state ($\pi 3s^{-1}_{1/2} \otimes 1h^2_{9/2}$ configuration) coexists at low energy with the $9/2^-$ 1p-0h ground state. These configurations can be efficiently investigated by combination of α- and γ-decay spectroscopy.

Shape coexistence also occurs in the neutron-deficient isotopes of Fr (Z=87); a recent study at RITU in Jyväskylä, Finland [3] identified an α-decaying $1/2^+$ intruder state in ^{201}Fr.

In our work, we investigated the shape coexistence phenomena in very neutron-deficient francium isotopes ^{200,201,202}Fr (Z=87). These isotopes were studied in the complete fusion - evaporation reaction ^{149}Sm(^{56}Fe,pxn)$^{205-(x+1)}$Fr at the velocity filter SHIP in GSI Darmstadt, Germany.

Besides significantly improved knowledge of the decay properties of these isotopes, the most interesting is the evidence of new microsecond isomeric state in ^{201}Fr. Based on the preliminary analysis, the most probable candidate spin-parity assignment for this state would be ($13/2^+$). The main part of this work is concentrated on the study of its decay properties. This is important for systematic of low-lying excited levels in this region as the excitation energy for the $13/2^+$ level in francium isotopes has been known for N=126 only [3]. It will be shown why the nuclear isomerism might be important for the nuclear structure studies near the closed shells as well as description of the basic techniques used for probing of this kind of nuclear phenomena.

[1] J.L. Wood, K. Heyde, W. Nazarewicz, M. Huyse, P. Van Duppen, Phys. Rep. 215, (1992) 101.
[2] R. Julin, K. Helariutta, M. Muikku, J. Phys. G 27, (2001) R109.
[3] J. Uusitalo et al., Phys. Rev. C71 (2005) 024306-6.

Photoneutron Cross Sections for Au*

O. Itoh[1], H. Utsunomiya[1], H. Akimune[1], T. Kondo[1], M. Kamata[1], T. Yamagata[1], H. Toyokawa[2], H. Harada[3], F. Kitatani[3], S. Goko[3], C. Nair[4], and Y.-W. Lui[5]

[1] *Department of Physics, Konan University, Okamoto 8-9-1, Higashinada, Kobe 658-8501, Japan*
[2] *National Institute of Advanced Industrial Science and Technology, Tsukuba 305-8568, Japan*
[3] *Japan Atomic Energy Agency, Tokai-mura, Naka, Ibaraki 319-1195, Japan*
[4] *Institut für Strahlenphysik, Forschungszentrum Dresden-Rossendorf, D-01314 Dresden, Germany*
[5] *Cyclotron Institute, Texas A&M University, College Station, Texas 77843, USA*

Photoneutron cross sections for Au are regarded as one of the basic data in nuclear physics cited in the classical literature [1]. The cross section was measured with γ rays produced in positron annihilation in flight (PAIF) at LLNL and Saclay [2-4]. Direct neutron counting was carried out with a neutron detector consisting of BF_3 counters embedded in a paraffin moderator at LLNL[2,4] and with a Ga-doped liquid scintillator at Saclay [3]. While the data show rather good agreement near neutron threshold, they show serious discrepancies above 10 MeV toward the peak of GDR. Photoneutron cross sections near neutron threshold also serve a standard for photoactivation measurements in the study of the p-process nucleosynthesis. The photoactivation data near threshold [5] is consistent with the direct neutron-counting data. Recently, photoactivation measurements for Au have been extended from the threshold region to the peak energy region of GDR [6]. Photoneutron cross sections for Au were previously measured with laser Compton-scattering (LCS) γ rays [7]. However, a data reduction with the photon difference method has ended up with large uncertainties.

We measured photoneutron cross sections for Au in the entire energy range of the (γ,n) channel with the LCS γ rays based on a direct neutron-counting technique with a high efficiency neutron detector consisting of three rings of 4, 8, and 8 ^{3}He proportional counters embedded in a polyethylene moderator. A least-squares method was employed in data deduction to provide photoneutron cross sections at thirty average energies of the LCS γ-ray beam from 8.08 MeV to 13.13 MeV. Results are compared with the past direct neutroncounting data taken with the PAIF γ rays and the photoactivation data taken with bremsstrahlung.

* This work is supported by the Japan Private School Promotion Foundation and the Konan-ULB bilateral project.

[1] A. Bohr and B.R. Mottelson, Nuclear Structure, Vol. II, p. 475 (1975).
[2] S.C. Fultz, R.I. Bramblett, T.J. Caldwell, N.A. Kerr, Phys. Rev. 127 (1962) 1273.
[3] A. Veyssiere, H. Beil, R. Bergere, P. Carlos, A. Leprettre, Nucl. Phys. A159, 561 (1970).
[4] B.L. Berman, R.E. Pywell, S.S. Dietrich, M.N. Thomppson, K.G. McNeill, J.W. Jury, Phys. Rev. C36, 1286 (1987).
[5] K. Vogt, P. Moh *et al.*, Nucl. Phys. A707, 241-252 (2002).
[6] C. Nair *et al.*, Phys. Rev. C78, 055802-1:9 (2008).
[7] K.Y. Hara *et al.*, J. Nucl. Sci. Technol. 44, 938-945 (2007).

Momentum-dependent nuclear potential and its applications

Yoritaka Iwata and **Hans Feldmeier**

GSI Helmholtz Centre for Heavy-Ion Research

Charge equilibration, which is a rapid process taking about 10^{-22} s, is decisive in determining the final products of heavy-ion collisions [1]. Indeed, fusion does not take place without attaining the charge equilibrium. Nowadays, three-dimensional time-dependent Hartree-Fock (TDHF) calculations are feasible equipped with full Skyrme interactions, where modern TDHF calculations have been shown to agree with experiments (e.g., see [2]), even in terms of the number of transferred nucleons [3]. In this paper, based on H. Feldmeier [4] and H. Feldmeier and P. Buck [5], we propose a rather accurate method of extracting nuclear potentials from the collision dynamics (TDHF calculations). This method is advantageous enough to allow us to obtain potentials microscopically and momentum-dependently. First, in the context of nuclear potential structure, we show that the spin-orbit force play a crucial role in charge equilibration. Next, the relation between spin-orbit force and spin-polarization is discussed (for the preceding studies on spin-polarization, e.g., see [6, 7, 8]). Eventually, momentum-dependence and the isovector dependence of spin-oribt/nuclear potential is clarified, and the mechanisms of charge equilibration, spin-polarization, and dissipation are understood in such a microscopic manner.

[1] Y. Iwata, T. Otsuka, J. A. Maruhn and N. Itagaki, Phys. Rev. Lett., in press; arXiv1001.0850 [nucl-th].
[2] Y. Iwata, T. Otsuka, J. A. Maruhn and N. Itagaki, Nucl. Phys A 803 (2010) 108.
[3] H. Feldmeier, Rep. Prog. Phys. 50 (1987) 915.
[4] H. Feldmeier and P. Buck in the Lecture Notes in Physics: K. Goeke and P. -G. Reinhard, Time-dependent Hartree-Fock and Beyond, Springer-Verlag (1982) 111.
[5] Y. Iwata, T. Otsuka, J. A. Maruhn and N. Itagaki, Euro. Phys. J. A 42 (2009) 613.
[6] J. A. Maruhn *et. al.*, Phys. Rev. C 74 (2006) 027601.
[7] Y. Iwata, N. Itagaki, J. A. Maruhn and T. Otsuka, Int. J. Mod. Phys. E 17 (2008) 1660.
[8] Y. Iwata, T. Otsuka, J. A. Maruhn and N. Itagaki, to appear in Euro. Phys. J. W. "IWM2009".

Transfer reactions using a low-energy ^{11}Be beam

Jacob S. Johansen[1]
on behalf of the IS430 collaboration

[1] *Department of Physics and Astronomy, Aarhus University, Denmark*

The bound states of ^{10}Be and ^{12}Be have been studied through transfer reactions using a low-energy ^{11}Be incident on a deuteron target. Scattering of ^{11}Be on deuterons has been observed as well, and the effect of the halo structure of ^{11}Be has been studied both for (d,d) and (p,p). Beryllium isotopes close to ^{11}Be have been studied intensively both theoretically and experimentally. The inversion of states has been identified in ^{11}Be and ^{12}Be leading to the breaking of the N=8 magic number in ^{12}Be. The experimental approaches have so far been limited to high energy reactions. The first results from a low-energy study of ^{12}Be, including spectroscopic factors for the bound states, were published in 2009 [1]. On the theoretical site the structure of ^{12}Be has been studied in several different approaches. One of them [2] describes ^{12}Be as a three particle cluster of ^{10}Be and two neutrons. The model describes the bound states in ^{12}Be as single particle excitations of the two neutrons.

Two experiments were performed at the REX-ISOLDE facility at CERN, first in 2005 and again in October 2009. ISOLDE is the ISOL facility with the largest range of beams, and with the REX post accelerator it is possible to produce bunches of exotic nuclei with kinetic energy up to 3 MeV per nucleon. The experiment in 2005 was a short run designed to gain information about possible reaction channels, and two double sided silicon strip detectors were used for particle detection. The resolution was too low to separate levels with small separation energy and the setup was improved for the 2009 experiment where germanium detectors (the MINIBALL array) were used to detect gamma decays. Cross sections have been determined from the 2005 data and are compared to optical model calculations in order to determine spectroscopic factors. The results from the 2005 experiment will be presented along with preliminary results from the 2009 experiment.

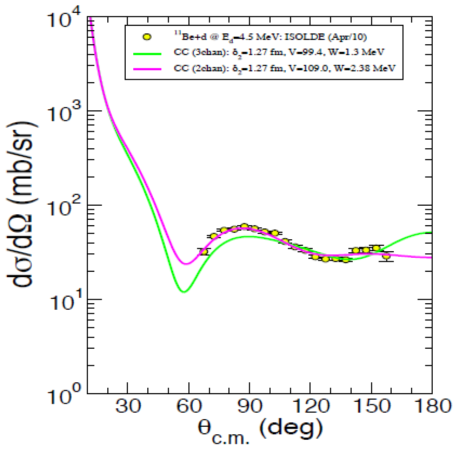


Fig. 1: Experimentally determined cross section for ^{11}Be(d,d)^{11}Be (dots) compared to two coupled channel calculations. The coupled channels are calculated using a modified optical potential from ^{11}B.

[1] R. Kanungo et al., Phys. Lett. B 682, 391-395 (2010).
[2] C. Romero-Redondo et al., Phys. Rev. C 77, 054313 (2008).

Advances in in-beam spectroscopy with the JUROGAM II spectrometer

P. Jones[1]
on behalf of the JUROGAM collaboration

[1]*Department of Physics, University of Jyväskylä, P.O.Box 35, 40014 Jyväskylä, Finland*

The JUROGAM II gamma-ray spectrometer is the latest in a series of detector systems to study many aspects of the nuclear landscape from N=Z nuclei, nuclei near the proton drip line to superheavy elements. JUROGAM II has an absolute efficiency of ~6.2% and is used in conjunction with the RITU gas-filled separator and the GREAT focal plane spectrometer.

In order to extend the bounds of spectroscopy new means of instrumentation have been commissioned. These include the commissioning and complete instrumentation with new digital electronics for the increased number of channels for 24 four-fold Clover detectors and 15 Tapered detectors and associated anti-Compton suppression shields. The new instrumentation allows for increased count-rate performance of the detectors and this increased beam intensities to be used.

JUROGAM II has been designed with other complementary detectors to be integrated at the target position. These include devices for in-beam conversion electron spectroscopy and for light-ion identification. Two such devices have been recently commissioned and first results obtained.

An overview of the project, achievements and recent highlights presented.

Investigation of high spin states and isomeric decays in doubly odd ^{208,210}Fr

D. Kanjilal[1], S. Bhattacharya[1], A. Goswami[1], R. Kshetri[1], R. Raut[1], S. Saha[1], R. K. Bhowmik[2], J. Gehlot[2], S. Muralithar[2], R. P. Singh[2], G. Mukherjee[3], B. Mukherjee[4]

[1] *Saha Institute of Nuclear Physics, Kolkata 700064, India*
[2] *Inter University Accelerator Centre, New Delhi 110067, India*
[3] *Variable Energy Cyclotron Centre, Kolkata 700064, India*
[4] *Department of Physics, Visva Bharati, Santiniketan 731235, India*

The nuclei near the doubly magic ^{208}Pb are predicted to exhibit various interesting structural phenomena. However, little experimental data are available in Z>82, N≤126 mass region till date. Recently a few spectroscopic investigations on the proton rich lighter Francium (Z=87) isotopes (A=206 to 209) have been made [1-4]. Wealth of nuclear phenomena from core excitation populated single particle states to the existence of shears band in these extreme proton rich heavy nuclei were observed. Although our experiment was aimed at exploring the nuclear structure of 208Fr [4], the yield of ^{210}Fr at 88 MeV was found to be significant to establish its level scheme. Relevant details of our experiment have been reported in ref. [4].

Based on the earlier observation [5] of a couple of low lying transitions connecting the 6^+ ground state of ^{210}Fr, and a few strong transitions [3], which could not be assigned to other Fr isotopes, the excitation function studies of ^{210}Fr at three different energies are done, and found to be in good agreement with similar studies made from independent offline decay analysis reported earlier [4]. Based on our results, a preliminary level scheme for ^{210}Fr is established for the first time as shown in the Fig. 1. From our γγΔT correlation analysis, we could find only one isomeric transition with 41.4 ± 2.1 ns half life. Further refinement of analysis, interpretation of the results based on nuclear structure calculations is currently undertaken.

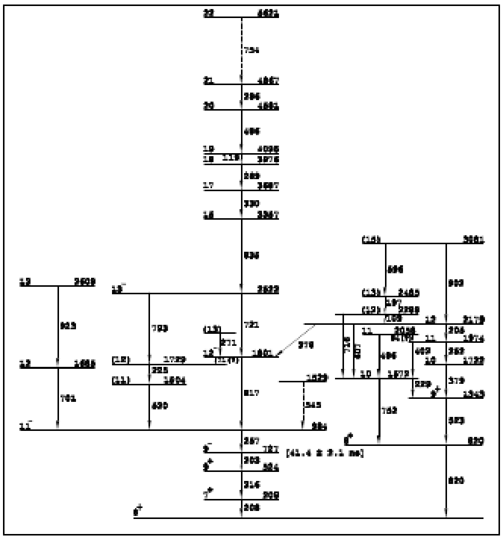


Fig. 1: Tentative Level Scheme of ^{210}Fr

[1] D.J. Hartley et al, Phys. Rev. C 78, 054319 (2008).
[2] G.D. Dracoulis et al., Eur. Phys. J A 40, 127 (2009).
[3] G.D. Dracoulis et al., Phys. Rev. C 79, 054313 (2009).
[4] D.Kanjilal et al., Nucl. Phys. A 842, 1 (2010).
[5] P.Kuusiniemi et al., Eur. Phys. J A 22, 429 (2004).

Hot nuclei and phase transitions

V. A. Karnaukhov[1]
for FASA collaboration*

[1] *Joint Institute for Nuclear Research, Dubna, Russia*

The nuclear phase diagram includes the liquid phase, spinodal region of liquid-gas mixture, hadron gas and quark-gluon plasma (QGP). There are two critical temperatures: T_c for the liquid-gas phase transition and Hagedorn temperature T_H related to the quark-gluon plasma. Very exhausting search for the signals of QGP in nucleus-nucleus collisions failed. Note that this phase is very short-lived: after ~10fm/*c* it is transformed into the nucleonic system. So, QGP is some kind of transition state like a compound nucleus. Study of the nuclear properties inside the spinodal region was more successful. The main tool here is fragmentation process, which is the multibody decay of hot nucleus. The final state is the nuclear fog consisting of droplets (IMF, 2<Z<20) and gas interspersed between fragments. We call it the liquid-fog phase transition. The hot nucleus expands due to thermal pressure, enters the spinodal region, where baryon density is less than normal one, ρ_o, and temperature is below T_c. Figure 1 is obtained by the FASA collaboration (for p+Au collisions at relativistic energy). Two characteristic densities were found: ρ_t,, which corresponds to the “chemical” freeze-out at the top of fragmentation barrier, and ρ_f, which is related to the “kinetic” freeze-out point, when fragments become free. The values of T_c and the fragment emission time were also measured. The experimental study of hot nuclear system dynamics is in progress now.

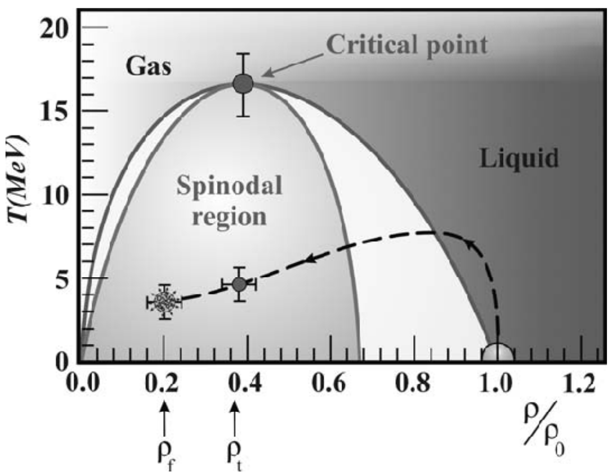


Fig. 1

*FASA collaboration: S. P. Avdeyev, A. S. Botvina, A. Budzanowski, V. A. Karnaukhov, W. Karcz, V. V. Kirakosyan, E. Norbeck, H. Oeschler, P. A. Rukoyatkin

Evidence for the Scissors Mode in ^{160}Tb from the Two-Step Gamma Cascade Measurement *

J. Kroll[1], F. Bečvár[1], M. Krtička[1], I. Tomandl[2]

[1] *Faculty of Mathematics and Physics, Charles University, V HolečovičKách 2, 182 00 Prague, Czech Republic*
[2] *Nuclear Physics Institute of the Czech Academy of Sciences, 250 68 Řež near Prague, Czech Republic*

Spectra of two-step cascades (TSCs) following the neutron capture in ^{159}Tb were measured by sum-coincidence technique with a two-HPGe-detector facility installed at a pure sub-thermal neutron beam of the 15 MW light-water research reactor at Řež.

In order to obtain information about the quantities governing the decay of ^{160}Tb levels - the photon strength functions (PSFs) and the level density (LD) - experimental TSC spectra were compared with the output of simulations of the -cascade decay based on the validity of the extreme statistical model. These simulations were performed with the aid of the dicebox algorithm [2] assuming various combinations of the LD and PSFs.

The results obtained lead to an inescapable conclusion that the scissors mode plays a marked role in the cascade decay of the product nucleus 160Tb. This finding represents the first evidence for the existence of this mode in an odd-odd deformed nucleus.

* Work supported by the Czech Research Plans MSM-021620859 and grants INGO-LA08015 and SVV-2010-261 309.

[1] J. Honzátko et al., Nucl. Instr. Meth. A376 (1996) 434
[2] F. Bečvár, Nucl. Instr. Meth. A417, (1998) 434

Dipole Bands in ^{196}Hg

J. J. Lawrie[1], E. A. Lawrie[1], B. Msezane[1,2], M. Benatar[1,3], M. Federke[3], G. K. Mabala[1,3], S. M. Mullins[1], K. P. Mutshena[1,3], N. J. Ncapayi[1,4], R. T. Newman[1], J.F. Sharpey-Schafer[1], F. D. Smit[1], P. Vymers[1,4]

[1] *iThemba LABS, PO Box 722, Somerset West 7129, South Africa*
[2] *Department of Physics and Engineering, University of Zululand, Private Bag X1001, Kwadlangezwa 3886, South Africa*
[3] *Physics Department, University of Cape Town, Rondebosch 7700, South Africa*
[4] *Department of Physics, University of the Western Cape, Private Bag X17, Bellville 7535, South Africa*

In previous studies dipole bands were observed in a number of even Hg isotopes, Including 196Hg where one dipole band was found [1]. In an experiment at iThemba LABS we observed both this and a second dipole band in ^{196}Hg and could make an unambiguous spin and parity assignments from DCO and polarization measurements.

The experiment was performed using the AFRODITE array that consisted of 7 suppressed clover detectors and 7 segmented planar Ge detectors. ^{196}Hg was populated in the ^{194}Pt(α,6n) reaction at 65 MeV using a thin (0.2 mg/cm2) target. The decay scheme obtained from a study of γ-γ coincidences generally confirms and extends the level scheme reported by Mehta et al. [2]. We extended the even spin negative parity structure beyond the band crossing and up to spin 24^-. We also observed the dipole band reported by Cederwall et al [1], and managed to establish two decay paths out of this band, both to negative parity bands, thereby fixing the excitation energy, spin and parity (-) of this dipole band. In addition we observe a second dipole band that extends both above and below previously observed levels at 5351, 5617 and 5860 keV [2]. DCO and polarization measurements on the transitions that depopulate this band towards a negative parity band fix the spin and parity (+). A discussion on possible configurations as well as a comparison with dipole bands in ^{192,194}Hg will be presented.

[1] B. Cederwall *et al*., Phys. Rev. C 7, R2443 (1993).
[2] D. Mehta *et al*., *Z. Phys. A* 339, 317 (1991).

B(M1) staggering in two-quasiparticle chiral bands *

O. Shirinda[1,2], E. A. Lawrie[1]

[1]*Department of Nuclear Physics, iThemba LABS, P.O. Box 722, Somerset West 7129, South Africa*
[2]*Department of Physics, University of the Western Cape, Private Bag X17, Bellville 7535, South Africa*

Strongly broken chirality is suggested to exhibit a pair of degenerate ΔI = 1 rotational bands [1,2]. In order to form a chiral system, an aplanar orientation of the total angular momentum is required [1,2]. However, such an aplanar orientation is insufficient to ensure perfect degeneracy in chiral partner bands, rather strictly orthogonal individual angular momenta are required [3]. Such perfect orthogonality seems unlikely to occur in real nuclei. However, chiral degeneracy corresponding to a strongly broken chiral system, can be obtained in theoretical calculations, (by restricting the configuration to a pure particle/hole at the bottom/top of a high-j shell within the particle-rotor model [3]). Since the calculations can describe both a strongly broken as well as a weakly broken chiral system, one has a useful tool to study other fingerprints of chirality too. It had been previously suggested that large staggering of the B(M1) intra- and inter-band transition probabilities indicates strongly broken chirality for the symmetric $\pi h_{11/2} \otimes \nu h_{11/2}^{-1}$ configuration [4,5]. We have examined the staggering in the B(M1) reduced transition probabilities, using the two-quasiparticle-plus-triaxial-rotor model codes of P.B. Semmes and I. Ragnarsson [6], for both strongly broken and weakly broken chiral systems. Furthermore we investigated such systems built on symmetric ($\pi h_{11/2} \otimes \nu h_{11/2}^{-1}$) and also on asymmetric ($\pi g_{9/2}^{-1} \otimes \nu h_{11/2}$ and $\pi h_{9/2} \otimes \nu i_{13/2}^{-1}$) configurations. Our results show that the staggering in the B(M1) probabilities does have largest amplitude for the optimal for chirality g deformation. However, we have also found that equally strong or even stronger B(M1) staggering may occur for some weakly broken chiral systems too. Results on the B(M1) staggering for the 100, 130 and 190 mass regions will be discussed.

* This work is supported by the National Research Foundation, South Africa.

[1] S. Frauendorf and J. Meng, Nucl. Phys. **A 617**, 131 (1997)
[2] S. Frauendorf, Rev. Mod. Phys. 73, **463** (2001)
[3] E.A. Lawrie and O. Shirinda, Phys. Lett. B **689**, 66-71 (2010)
[4] T. Koike, et al., Phys. Rev. Lett. **93**, 172502 (2004)
[5] B. Qi, et al., Phys. Rev. C **79**, 041302(R) (2009)
[6] P.B. Semmes and I. Ragnarsson, AIP Conf. Proc. **259**, 566 (1992)

Qweak – A Search for New Physics *

John Leckey[1]
for the Qweak Collaboration

[1]*Physics Department, College of William and Mary, Williamsburg VA, 23188 USA*

Qweak is a currently running experiment at the Thomas Jefferson National Accelerator Lab that will use parity-violating elastic electron-proton scattering to measure the weak charge of the proton (Q^P_{weak}). This experiment will be a sensitive test for physics beyond the Standard Model, as Q^P_{weak} is well predicted in the Standard Model. Longitudinally polarized electrons scatter off a liquid hydrogen target and pass through a toroidal-field magnetic spectrometer. In order to perform a 4 % measurement of Q^P_{weak}, we will need to measure the momentum transfer (Q^2) to 0.5 %. The Q^2 will be measured using a tracking system consisting of two gas electron multipliers (GEM), four horizontal drift chambers (HDC), and four vertical drift chambers (VDC). In this talk I will outline the design of the full apparatus and discuss the details of the Q^2 and Q^P_{weak} measurements that will be complete in 2012 and present any results thus far in the experiment's progress.

* This work is supported by the National Science Foundation, the Department of Energy, and the Natural Sciences and Engineering Research Council of Canada.

Electron Screening in Metals

M. Lipoglavšek and **U. Mikac**

Jožef Stefan Institute, Jamova cesta 39, 1000 Ljubljana, Slovenia.

Electron screening enhances cross sections for nuclear reactions at low energies. Exceptionally large electron screening has recently been observed when the reactants were implanted in various metals. We have studied the $^{1}H(^{7}Li,\alpha)^{4}He$ reaction in inverse kinematics and observed large electron screening only when the metallic targets were under tensile stress [1]. Hydrogen was loaded into Pd and PdAg alloy foils from gas phase and concentrations reached about 0.6 protons per metallic atom. Mechanical pressure creates stress induced states in the metal. Without pressure hydrogen occupies octahedral interstitial positions in the fcc Pd lattice. Under stress some protons move to dislocated octahedral (dis-O) sites in the lattice [2]. Incidentally, these dis-O sites may be the same as those, where hydrogen ends up after implantation [2]. As opposed to our experiment almost all previous electron screening studies in metals have been performed on implanted targets (see [1] and refs. therein). We believe that the magnitude of screening in various metals depends on the electron density on dis-O sites in case of fcc lattices or dislocated tetrahedral sites in bcc metals. In case of gas loading of hydrogen, the fitted value of the screening potential also depends on the portion of protons occupying the dislocated sites. We are currently trying to confirm the above claims by determining the electron density at the sites occupied by protons via the measurement of proton Knight`s shift with ^{1}H nuclear magnetic resonance technique and by calculating spatial distribution of electrons in the crystal.

[1] M. Lipoglavsek *et al.*, Eur. Phys. J. **A44**, 71 (2010).
[2] Y. Fukai, The Metal-Hydrogen System, Springer, Berlin, Germany, 2005.

Onset of collectivity in Neutron-Rich iron isotopes: Toward a new island of inversion?

J. Ljungvall[1,2,3], A. Görgen[1], A. Obertelli[1], W. Korten[1], E. Clément[2], G. de France[2], A. Bürger[4], J.-P. Delaroche[5], A. Dewald[6], A. Gadea[7], L. Gaudefroy[5], M. Girod[5], M. Hackstein[6], J. Libert[8], D. Mengoni[9], F. Nowacki[10], T. Pissulla[6], A. Poves[11], F. Recchia[12], M. Rejmund[2], W. Rother[6], E. Sahin[12], C. Schmitt[2], A. Shrivastava[2], K. Sieja[10], J. J. Valiente-Dobón[12], K.O. Zell[6], M. Zielińska[13]

[1]CEA Saclay, IRFU/SPhN, F-91191 Gif-sur-Yvette, France; [2]GANIL, Bd Henri Becquerel, BP 55027, F-14076 Caen, France; [3]CSNSM, F-91405 Orsay, France; [4]Dept. of Physics, University of Oslo, PO Box 1048 Blindern, N-0316 Oslo, Norway; [5]CEA, DAM, DIF, F-91297 Arpajon, France; [6]Institut für Kernphysik, Universität zu Köln, D-50937 Köln, Germany; [7]Instituto de Fisica Corpuscular, CSIC-Universidad de Valencia, E-46071 Valencia, Spain; [8]Institut de Physique Nucléaire, CNRS/IN2P3-Université Paris-Sud, F-91406 Orsay, France; [9]Dipartimento di Fisica dell'Università and INFN Sezione di Padova, I-35131 Padova, Italy; [10]IPHC, CNRS/IN2P3 and Université Louis Pasteur, F-67037 Strasbourg, France; [11]Depart. de Física Teórica, IFT-AM/CSIC, Universidad Autónoma, E-28049 Madrid,Spain; [12]INFN, Laboratori Nazionali di Legnaro, I-35020 Legnaro, Italy; [13]Heavy Ion Laboratory, Warsaw University, Warsaw, PL-02097, Poland

The lifetimes of the first excited 2^+ states in ^{62}Fe and ^{64}Fe have been measured for the first time using the recoil-distance Doppler shift technique. A ^{238}U beam of 6.5 AMeV impinged on ^{64}Ni target, and the target like products were slowed down by degrader foil positioned at micrometer distance downstream of the target and identified in the VAMOS spectrometer on an event-by-event basis. The lifetimes were then determined from the intensities of the degraded and fully Doppler shifted components of the 2^+-> 0+ transition detected in EXOGAM detectors positioned at backward angles. The resulting lifetimes show a steep increase of the B(E2) values of the first excited 2^+ state from ^{62}Fe to ^{64}Fe. A comparison with shell model calculations shows that the onset of collectivity is related to the occupation of neutron intruder orbitals. The large B(E2) value for ^{64}Fe is only reproduced if the valence space includes both the neutron $g_{9/2}$ and $d_{5/2}$ orbitals. The transition from spherical ^{68}Ni to more proton-deficient N 40 isotones has some similarity with the island of inversion around ^{32}Mg. The developing quadrupole collectivity can in both cases be related to the occupation of neutron intruder orbitals which are at the same time quasi-SU(3) partners: ($f_{7/2}$, $p_{3/2}$) for ^{32}Mg and ($g_{9/2}$, $d_{5/2}$) for the neutron-rich Fe.

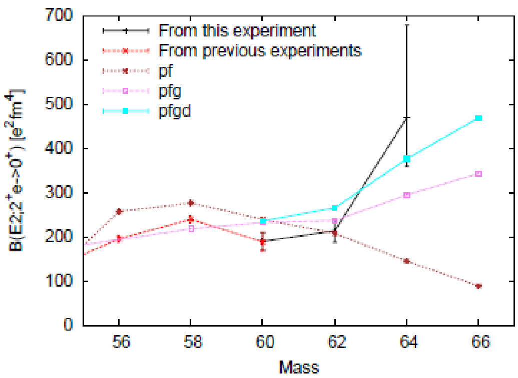


Fig. 1: B(E2; 2^+_1->0^+_1) values for neutron-rich iron isotopes. Values from this work are shown in black. New shell-model calculations clearly show the importance of the $g_{9/2}$ intruder orbital and its $d_{5/2}$ quadrupole partner.

Preparation for the measurement of the $^{12}C(\alpha,\gamma)^{16}O$ reaction at TRIAC*

H. Makii[1], **H. Miyatake**[2], **Y. X. Watanabe**[2], **N. Imai**[2], **H. Ishiyama**[2], **Y. Hirayama**[2], **K. Niki**[2], **M. Okada**[2], **S.C. Jeong**[2], **S. Chiba**[1], **S.Mitsuoka**[1], **K. Nishio**[1], **Y. Wakabayashi**[1]

[1] *Advanced Science Research Center, JAEA, Shirakata Shirane 2-4, Tokai, Ibaraki 319-1195, Japan.*
[2] *Institute of Particle and Nuclear Studies, High Energy Accelerator Research Organization (KEK), Oho 1-1, Tsukuba, Ibaraki 305-0801, Japan.*

The $^{12}C(\alpha,\gamma)^{16}O$ reaction plays an important role in stellar evolution at the stage of helium-burning. Its reaction cross section determines the mass fraction of ^{12}C and ^{16}O, the abundance distribution of the elements between oxygen and iron, and the iron-core mass before the supernova explosion [1]. Therefore, it is quite important to accurately determine the cross section at center-of-mass energy $E_{cm.}$=0.3 MeV. The direct measurement of the cross section at $E_{cm.}$=0.3 MeV, however, is not possible using current experimental technique, because the cross section is too small, around 10^{-17} barn. Hence, one has to derive the cross section by extrapolating a measured cross section at $E_{cm} \geq 1.0$ MeV into the range of stellar temperature. However, the estimated cross section at E_{cm}=0.3 MeV still has a large uncertainty mainly due to the poor determination of the ratio of $E2$ cross section to $E1$ one, σ_{E2}/σ_{E1}.

Recently, we have succeeded in determining the σ_{E2}/σ_{E1} with small statistical and systematic uncertainties by using high efficiency anti-Compton NaI(Tl) spectrometers to detect a γ–ray from the reaction with a large S/N ratio, intense pulsed α-beams to discriminate true events from background events due to neutron from $^{13}C(\alpha,n)^{16}O$ reaction with a time-of-ight (TOF) method, and monitoring system of target thickness [2, 3]. In order to provide a stringent constraint to extrapolation down to E_{cm}=0.3 MeV additional data is crucial. Hence we are now preparing a new measurement at TRIAC (Tokai Radioactive Ion Accelerator Complex). TRIAC can accelerate heavy ions (q=A>1/10) from 2 keV/u to 1.1 MeV/u with 26 MHz Split Coaxial RFQ (SCRFQ) and 52 MHz Interdigital-H (IH) linac. Since the SCRFQ has a radio frequency of 26 MHz, the bunch interval becomes 38.5 ns. On the other hand, the bunch interval is required to be that of 250 ns or more for removing background events due to neutrons with the TOF method. Therefore we have installed the pre-buncher, coupled to a multilayer chopper, with a variable frequency of 2-4 MHz upstream of the SCRFQ. In this presentation we will report the results of the beam test using α beam and the plan for new experiment on $^{12}C(\alpha,\gamma)^{16}O$ reaction.

* This work is supported by Grant-in-Aid for Scientific Research from the Japan Ministry of Education, Calture, Sports, Science, and Technology.

[1] T.A. Weaver and S.E. Woosley, Phys. Rep. **227**, 65 (1993).
[2] H. Makii *et al*., Nucl. Instr. and Meth. **A547**, 411 (2005).
[3] H. Makii *et al*., Phys. Rev. C **80**, 065802 (2009).

Asymmetric Neutrino Reaction from Magnetized Proto-Neutron Stars in fully Relativisitc Framework including Hyperons

T. Maruyama[a], N. Yasutake[b], T. Kajino[b], M. K. Cheoun[c] and C. Y. Ryu[c]

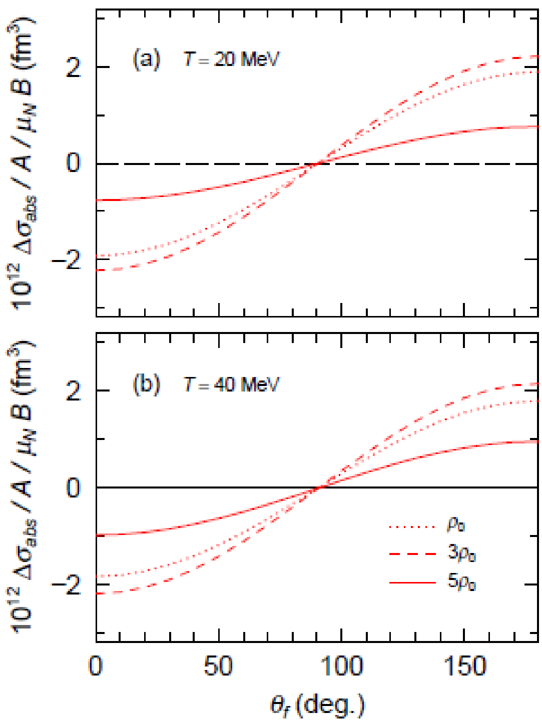
[a] *College of Bioresouce Sciences, Nihon University, Japan*
[b] *National Astronomical Observatory, 2-21-1 Osawa, Mitaka, Tokyo 181-8588, Japan*
[c] *Department of Physics, Soongsil University, Seoul, 156-743, Korea*

A new type of neutron star, called magnetar, which is associated with a super strong magnetic field has been discovered. It is therefore requisite to improve models of hot and dense hadronic matter which is presumed to manifest in the neutron star under strong magnetic field [2]. Neutrino emission as well as GW is the unique observable that provides signals of the change of internal structure of the neutron star [3]. In this paper we show, for the first time, our calculated scattering and absorptive neutrino cross sections in the hot and dense hadronic matter with hyperons under strong magnetic field [1].

Here we assume that there is uniform magnetic field along *z*-direction as *B* = *B*ˆ*z*. Even astronomically strong magnetic filed is still weaker than the strong interaction order: √*eB* ≪_*a*, where _*a* is the chemical potential of the particle *a*. We therefore treat the magnetic field in the perturbative way, ignore the contribution from the conventional current, and thus consider only the spin-interaction. In this approximation the crosss ection is given as

$$\sigma = \sigma_0 + \Delta\sigma \quad (1)$$

where σ_0 is independent of *B*, and $\Delta\sigma$ is proportional to *B*. Figure shows Δ_ of the neutrino absorption part ($\nu_e \rightarrow e-$) as a function of the incident neutrino angle ϑ_i, where the initial neutrino energy is taken to be the chemical potential. We found that the absorption cross-section is minimum at $\vartheta_i = 0^\circ$ and maximum at $\vartheta_i = 180^\circ$, leading to very interesting phenomena that in the strong poloidal magnetic field, the neutrinos are strongly absorbed in the antarctic areas of the proton neutron stars. This result implies that the strong magnetic field could influence the pulser-kick and the cooling process of proto neutron stars. Furthermore, it is also expected to affect the spin-down of the proto neutron star under the toroidal magnetic field.



[1] T. Maruyama et al., in preparation.
[2] S. Reddy, M. Prakash and J.M. Lattimer, Phys. ReV. D58, 013009 (1998).
[3] P. Arras and D. Lai, Phys. Rev. D 60 (1999) 043001.

Possible chiral bands in ^{194}Tl *

P. L. Masiteng[1,2], E. A. Lawrie[1], T. M. Ramashidzha[1,2], J. J. Lawrie[1], R. A. Bark[1], J. Kau[1,4], F. Komati[1,4], S. M. Maliage[1,2], I. Matamba[5], S. M. Mullins[1], P. Mutshena[1,5], S. H. T. Murray[1,3], J. F. Sharpey-Shafer[1], P. Vymers[1,2], Y. Zhang[1,3]

[1] *iThemba LABS, PO Box 722, 7129 South Africa*
[2] *University of the Western Cape, Private Bag X17, 7535 Bellville, South Africa*
[3] *University of Cape Town, Private Bag, 7701 Rondebosch, South Africa*
[4] *University of North West, Private Bag X2046, 2735 Mmabatho, South Africa*
[5] *University of Venda for science and technology, Thohoyandou, South Africa*

High spin states in ^{194}Tl, excited through the ^{181}Ta(^{18}O, 5n) heavy-ion fusion evaporation reaction were studied using the AFRODITE array at iThemba LABS. The γ-γ coincidences, DCO ratios and linear polarization measurements were carried out and the previously known level scheme of ^{194}Tl was significantly extended. The yrast band built on the 8- isomeric state has the $\pi h_{9/2}\ n\ i_{13/2}^{-1}$ configuration suitable for a chiral system. One of the new bands built on the 10^- level has the same parity and close excitation energy to that of the yrast band [1]. This band is linked to the yrast band by several M1/E2 transitions which indicates similar configuration. These negative parity bands were observed through a band crossing caused by the excitation of a $\nu i_{13/2}$ pair. Above the band crossing the excitation energies of these 2 bands remain close, suggesting that chirality may persist for the 4qp configuration too. In addition, these bands have very similar properties such as quasiparticle alignments, moments of inertia, B(M1)/B(E2) reduced transition probabilities especially above the band crossing and the same band crossing frequencies. They however have different energy staggering patterns. Particle-rotor model, in which two and four particles are coupled to a triaxial core with and without residual proton-neutron interaction included was employed for the negative parity bands. In this contribution the results of the gamma spectroscopy, the theoretical calculations and the possibility of these bands being chiral will be discussed.

* This work is supported by the South African National Research Foundation (NRF).

[1] P. L. Masiteng *et al.*, Acta Phys. Pol. **B40**, 657 (2009)

Symmetric and non-symmetric muonic atoms-molecules studies

S. Mohammadi
Physics Department, Payame Noor University, Mashad 91735, IRAN

The muonic helium atom ($^3He^{+2}\mu^-e^-$ or $^4He^{+2}\mu^-e^-$) is the simplest example of a three body atomic system with bound particles of widely different masses. This simple system can provide a sensitive test for the three-body Schrodinger wave function determination of the magnetic moment of the μ- as a test of CPT (Charge conjugation-Parity-Time reversal) invariance. The atom is produced in the reaction of capture of the negative muon by the positive helium ion. It is one of the products in the process of muon catalyzed fusion, and its spectroscopic properties have to be therefore studied carefully to understand the fusion reactions property

In this system, the negative muon is bound closely to the nucleus in the ground state of the atom; the orbital radius of the muon is about 400 times smaller than that of the electron due to their mass ratio and different charge screenings Therefore, in the simplest approximation, the muonic helium atom can be considered to be hydrogen like with a pseudo nucleus $(\mu^3He)^+$ or $(\mu^4He)^+$. Also the hyperfine structure interval Δν for the muonic helium atom provides interesting and unusual case of atomic hyperfine structure [1]. The major difference in the hyperfine structure of the ground state of the muonic ^{3}He and ^{4}He atoms arises from the spin and associated magnetic moment of the 3He nucleus. The ^{3}He nucleus (I = 1/2) and μ^- (I = 1/2) have a total spin F_1 = 1 or 0, which interacts magnetically with the electron spin (J = 1/2) to yield hyperfine levels with different total angular momenta $\mathbf{F} = \mathbf{F_1} + \mathbf{J}$

For the mentioned systems, the calculation of the hyperfine splitting and other properties has been developed from many approaches with varying degrees of sophistication and accuracy [2]. These calculations are generally based on the variational approach with a large number of variational parameters. However it is considerable to develop wave functions which illustrate some of the local properties, such as the behavior of the wave function when two particles are close to each other, or when they are far away from each other. These local properties have been found to be very useful in developing simple wave functions and also provide a deeper .understanding of the structure of system.

In this work, we concentrate on the computation of the lowest order hyperfine splitting and other properties of muonic helium atoms ($^3He^{+2}\mu^-e^-$ and $^4He^{+2}\mu^-e^-$) in the ground state, with use of some local properties of the wave functions. We use a wave function which satisfies boundary conditions, such as when the two particles are close to each other or far away from each other

[1] K.N. Huang and V.W. Hughes, *Phys. Rev.* **A21** (1980) 1071
[2] A.M. Frolov, *Phys. Rev.* **A61** (2000) 022509; *Phys. Rev.* **E62** (2000) 8740

Reaction dynamics and nuclear structure studies via deep inelastic collisions with heavy-ions: Search for particle-vibration couplings in ^{49}Ca.

D. Montanari[1], S. Leoni [1], G. Benzoni [1], N. Blasi [1], A. Bracco [1], S. Brambilla [1], F. Camera [1], A. Corsi [1], F. C. L. Crespi [1], B. Million [1], R. Nicolini [1], O. Wieland [1], L. Corradi[2], G. de Angelis[2], F. Della Vedova[2], E. Fioretto[2], A. Gadea[2,3], B. Guiot[2], D. R. Napoli[2], R. Orlandi[2,†], F. Recchia[2], R. Silvestri[2], A. M. Stefanini[2], R. P. Singh[2], S. Szilner[2,4], J. J.Valiente-Dobon[2], D. Bazzacco[5], E. Farnea[5], S. M. Lenzi[5], S. Lunardi[5], P. Mason[5], D. Mengon[5], G. Montagnoli[5], F. Scarlassara[5], C. Ur[5], G. Lo Bianco[6], A. Zucchiatti[7], M. Kmiecik[8], A. Maj[8], W. Meczynski[8], G.Pollarolo[9]

[1]Dipartimento di Fisica and INFN, Sezione di Milano, Milano, Italy
[2] Laboratori Nazionali di Legnaro,Padova, Italy
[3] IFIC, CSIC-University of Valencia, Spain
[4] RBI, Zagreb, Croatia
[5] Dipartimento di Fisica and INFN Sezione di Padova, Padova, Italy
[6] Università di Camerino and INFN Sezione di Perugia, Camerino (Pg), Italy
[7] INFN Sezione di Genova, Genova, Italy
[8] The Niewodniczanski Institute of Nuclear Physics, PAN, Krakow, Poland
[9] Dipartimento di Fisca Teorica and INFN Sezione di Torino, Torino

The population and gamma decay of neutron rich nuclei around ^{48}Ca was measured at LNL with the PRISMA-CLARA setup, using deep-inelastic collisions (DIC) on ^{64}Ni, at an energy ~2.5 times above the Coulomb barrier. The reaction properties of the main products will be presented, focusing on total cross sections and angular distributions energy integrated and associated to the population of specific excited states. The analysis provides information on basic physical quantities, such as potentials, spectroscopic factors, and pair transfer. Gamma spectroscopy studies based for the first time on angular distributions and polarization measurements will be also shown, allowing a firm spin and parity assignments for a number of excited states of one and two nucleons transfer channels. Special emphasis will be given to candidates for particle-vibration coupling in ^{49}Ca, for which lifetimes measurements are also performed. The excitation of these states provides a further test to the role of low lying collective states in the reaction dynamics. Both reaction and gamma spectroscopy studies therefore demonstrate the relevance of DIC with heavy ions for the investigation of neutron rich systems.

Cold Hybrid Star Properties

H. R. Moshfegh, and M. Daremoradi

Department of Physics, University of Tehran, North Karegar, 14399-55961, Tehran, Iran.

We examine the matter inside the neutron stars, strange stars and neutron stars with quark core (Hybrid stars). Such dense objects are good candidate for testing the equation of state of baryonic matter both zero and finite temperature. In hybrid stars we study the hadron-quark phase transition in the interior of star. We have used MIT bag model with constant and density dependent bag parameter, B(ρ), for quark phase. We have calculated the equation of state of hadronic matter part of star using two model, first we use statistical Thomas-Fermi approach by employing Myers-Swiatecki density dependent potential [1] and then by using the lowest order constraint variational (LOCV) method [2] by employing AV18 and Reid93 channel dependent potential. The mass-radius relation of various types of these compact objects is obtained. We have found that in hybrid stars the maximum mass fall in relatively narrow interval in compare to regular pure neutron stars. The maximum mass of star is highly dependent to choice of interaction. Finally we have compared our calculated results with other methods and interactions.

[1] H. R. Moshfegh, IJMP E 15, 1127 (2006).
[2] M. Modarres, T. Pourmirjafari, H.R. Moshfegh, Nucl. Phys. A 819, 27 (2009).

Nuclear Shell Structure in Semi-Realistic Mean-Field Approach

H. Nakada

Department of Physics, Graduate School of Science, Chiba University,
Inage, Chiba 263-8522, Japan.

As typically manifested in magic numbers, the shell structure is one of the fundamental concepts in the nuclear structure physics. The experimental data in unstable nuclei have clarified [1] that the shell structure may depend on Z or N more strongly than expected from most conventional theories, and this discovery has stimulated to reexamine and refine theories relevant to the nuclear shell structure. As the new experimental facilities [2] are expected to access heavier unstable nuclei in coming years, it is desired to give predictions on the shell structure from the refined theories, which could be a good guidance to new experiments and will eventually be tested by them.

Concerning the Z or N dependence of the shell structure, two mechanisms have been argued: the absent or low centrifugal barrier in low-ℓ orbits near the drip lines, and influence of specific ingredients of the *NN* interaction; *e.g.* the tensor force. For full understanding of the shell structure in unstable nuclei, we should take both possibilities into account. The mean-field (MF) theories are a good tool to study the nuclear shell structure from the nucleonic degrees of freedom. The author has recently developed semi-realistic *NN* interactions [3], and numerical methods for the MF and RPA calculations [4]. The semi-realistic interactions are obtained by modifying the M3Y interaction [5] so as to describe basic observed properties such as the saturation and the ℓs splitting. The numerical methods are applicable to finite-range interactions including the semi-realistic ones, and well take account of spatial extension of wave functions in drip-line nuclei. By applying the MF calculations with the newly developed methods and interactions, shell structure of the neutron-rich Ca and Ni nuclei has been investigated [6], with paying special attention to the magicity of N=32,34,40 and 58. After surveying the results for these nuclei, I plan to present extensive investigation in other unstable medium-mass nuclei in this paper, particularly focusing on the (possible) magic numbers; *e.g.* N = 28 and Z = 40.

[1] O. Sorlin and M.-G. Porquet, Prog. Part. Nucl. Phys. **61**, 602 (2008).
[2] T. Aumann, Prog. Part. Nucl. Phys. **59**, 3 (2007); S. Gales, *ibid.* **59**, 22 (2007);
T. Motobayashi, *ibid.* **59**, 32 (2007).
[3] H. Nakada, Phys. Rev. C **68**, 014316 (2003); **78**, 054301 (2008); **81**, 027301 (2010).
[4] H. Nakada and M. Sato, Nucl. Phys. A **699**, 511 (2002); H. Nakada, *ibid.* **764**, 117 (2006); **808**, 47 (2008);
H. Nakada, K. Mizuyama, M. Yamagami and M. Matsuo, *ibid.* **828**, 283 (2009).
[5] N. Anantaraman, H. Toki and G.F. Bertsch, Nucl. Phys. A **398**, 269 (1983).
[6] H. Nakada, Phys. Rev. C **81**, 051302 (2010).

Heavy-element Nucleosynthesis in Magnetohydrodynamical Jets from Collapsars

Masaomi Ono[1], **Masa-aki Hashimoto**[1], **Shin-ichiro Fujimoto**[2], **Kei Kotake**[3], **Shoichi Yamada**[4]

[1] Department of Physics, Kyushu University, Fukuoka 812-8581, Japan.
[2] Kumamoto National College of Technology, Kumamoto 861-1102, Japan.
[3] Division of Theoretical Astronomy/Center for Computational Astrophysics, National Astronomical Observatory of Japan, Tokyo 181-8588, Japan.
[4] Advanced Research Institute for Science and Engineering, Waseda University, Tokyo 169-8555, Japan.

Massive stars larger than 8 $M_\odot$ evolve to form the core composed of iron-group nuclei (Fe core). The core grows and eventually begins to collapse, which will lead to a supernova explosion. The origin of most elements heavier than carbon in the universe is attributed to the supernova explosions. The nucleosynthesis during the hydrostatic evolution of a massive star and its supernova explosion may involve s, p, r-process. Therefore, supernova explosions are important phenomena in both astrophysics and nuclear physics aspects. We investigate the heavy-element nucleosynthesis of a massive star whose mass in the main sequence stage is $M_{\rm ms}$ = 70 $M_\odot$. Numerical calculations of the nucleosynthesis are performed during the stage of hydrostatic stellar evolution until the Fe core begins to collapse. As a supernova explosion model, a collapsar model is constructed whose jets are driven by magnetohydrodynamical effects of a differentially rotating core by two-dimensional magnetohydrodynamical simulations. The heavy-element nucleosynthesis inside the jet is followed along the trajectories of stream lines of the jet. We calculate the heavy-element nucleosynthesis by using a large nuclear reaction network which includes r-elements (about 4000 nuclei) and its involving reactions. We combine the results of both detailed hydrostatic and heavy-element nucleosyntheses to compare with the solar abundances. We also investigate the effects of different mass formulae on the produced abundance pattern. As shown in Figure 1, neutron-rich elements of 70 < A < 160 and weak s-elements of 70 < A < 90 are highly overproduced to the solar abundances. Therefore, we conclude that this explosion model should correspond to rare events and other underproduced elements would be produced in different type supernova explosions.

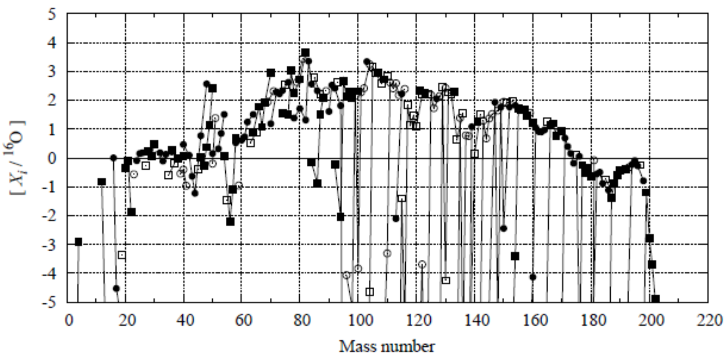


Fig. 1: Normalized overproduction [$Xi/^{16}$O] against the mass number of nuclei ejected by the jet. [$X_i/^{16}$O] ≡ $\log_{10}[(X(i)=X(^{16}\mathrm{O}))]-\log_{10}[(X(i)=X(^{16}\mathrm{O}))_\odot]$, where X and i denote the mass fraction and i-th nuclei, respectively. Filled (open) symbols connected to each other indicate the isotopes with the even (odd) atomic numbers.

p-capture nucleosynthesis in Low Mass Stars: effects of new reaction rates

S. Palmerini[1], M. Busso[1], M. La Cognata[2], S. Cristallo[3,4], E. Maiorca[1]

[1] *Dipartimento di Fisica, Università degli Studi di Perugia & INFN sezione di Perugia, Italy*
[2] *Dipartimento di Metodologie Chimiche e Fisiche per l'Ingegneria,*
Università di Catania & Laboratori Nazionali del Sud – INFN, Catania, Italy
[3] *INAF Osservatorio Astronomico di Collurania, Teramo, Italy*
[4] *Departamento de Fisica Teorica y del Cosmos, Universidad de Granada, Spain*

Evolved low and intermediate mass stars are important sites for the production of heavy nuclei (through slow n-captures) and of light and intermediate-mass isotopes (through p-captures). This was revealed by spectroscopy of evolved stars as well as by the chemical analysis of presolar grains of circumstellar origins. The observational basis for these issues has grown considerably over the years, confirming peculiar abundances of ^{3}He, ^{7}Li, CNO isotopes, ^{19}F and ^{26}Al. Many studies have been presented in the last thirty years suggesting that the above evidence can be accounted for by non-convective transport mechanisms (sometimes called deep mixing) that link the stellar envelope with the region where proton captures take place, during the red giant phases. Nucleosynthesis in deep mixing episodes is made uncertain by two series of problems. On one side one has to identify the physical mechanism for the transport (thermohaline diffusion, rotational shear, gravitational waves, magnetic buoyancy). On the other, several reaction rates adopted in the calculations are still uncertain, mainly because hydrogen burning takes place in red giants at typical Gamow-Peak energies of a few tens of keV, where experimental measurements are extremely difficult. Most results present in the literature were obtained using reaction rates from either the [1] or the [2] compilations. Here we want to discuss the effects of upgrades in the nuclear physics inputs occurred recently [3,4] on p-capture nucleosynthesis during extended mixing. We show how the use of more accurate reaction rates from new experiments induces considerable differences in the results as compared to previous studies. Among the most remarkable novelties we mention a possible higher production of ^{26}Al, changes in the 14N/15N ratio in stellar envelopes and an extremely precise account of the oxygen isotopic ratios in oxide grains, from which even the mass of the parent AGB stars can be unambiguously derived.

[1] Caughlan, G.R. & Fowler, W. A., ADNDT, 40 283 (1998).
[2] Angulo, C. et al., Nu.Ph.A. , 656, 3 (1999).
[3] Adelberger et al., 2010 arXiv1004.2318A.
[4] Iliadis et al., NuPhA, 841 31 (2010).

A Recoil-Beta Tagging Study of N=Z Nucleus ^{66}As

P. Ruotsalainen[a], C. Scholey[a], B. S. Nara Singh[b], R. Wadsworth[b], D. G. Jenkins[b], C. J. Barton[b], M. A. Bentley[b], L. Bianco[c], J. E. Brown[b], P. J. Davies[b], P. T. Greenlees[a], U. Jakobsson, P. Jones[a], D. T. Joss[c], R. Julin[a], S. Juutinen[a], S. Ketelhut[a], M. Leino[a], M. Nyman[a], R. D. Page[c], P. Peura[a], P. Rahkila[a], P. Sapple[c], J. Sarén[a], J. Sorri[a], M. J. Taylor[b], J. Uusitalo[a]

[a]Department of Physics, University of Jyväskylä, P. O. Box 35 (YFL), FI-40014, Finland
[b]Department of Physics, University of York, Heslington, York YO10 5DD, UK
[c]Oliver Lodge Laboratory, University of Liverpool, Liverpool L69 7ZE, UK

A Recoil-Beta Tagging (RBT) experiment was recently performed in order to identify T=1 excited states in the medium-heavy N=Z=33 nucleus 66As. The aim of this study was to yield information especially on the Coulomb energy differences (CED) between the T=1 isobaric analogue states of ^{66}As and ^{66}Ge. The CED can reveal various nuclear phenomena such as nucleon-nucleon pairing effects and shape co-existence. In the case of mirror nuclei, where the nuclei have inverse neutron and proton numbers the CED can be used to extract information about the proton-neutron (p-n) pairing interaction. The possible changes in the p-n pairing strength also have an influence on nuclear shapes. This leads to the concept of shape co-existence where the same nucleus can have either spherical, oblate or prolate shapes depending on the configuration of valence nucleons. In addition the information gained for excited states in the neutron deficient A≈70 mass region, adds to our understanding of the astrophysical rp-process.

The experiment was carried out at the University of Jyväskylä accelerator laboratory utilizing the JUROGAM II -ray spectrometer in conjunction with the gas-filled recoil separator RITU and the GREAT focal plane spectrometer system. The 66As-nuclei were produced via ^{28}Si(^{40}Ca,pn)^{66}As reaction at a beam energy of 75 MeV. This experiment was successful due to the technical developments in the measurement set-up. New 50 µm thick Mylar windows were installed for the multi-wire proportional counter, which allowed a higher gas pressure to be used in RITU, thereby improving the separation between the recoils of interest and beam like projectiles. The planar germanium detector was used to detect the beta particles as well as -rays.

A tentative level scheme for 66As was reported by Grzywacz et al [1], [2]. The data obtained from this experiment reveals some discrepancies with the previous work. This presentation will discuss the most recent results regarding the 66As, lightest nucleus ever studied at RITU.

[1] R. Grzywacz et al., Nucl. Phys. A 682 41 (2001)
[2] R. Grzywacz et al., Phys. Lett. B 429, 247 (1998)

R-process Nucleosynthesis during the MHD Explosions of a Massive Star

M. Saruwatari[1], M. Hashimoto[1], K. Kotake[2], S. Yamada[3]

[1] *Department of Physics, Kyusyu University, Fukuoka, 812-8581, Japan.*
[2] *National Astronomical Observatory of Japan, Tokyo, 181-8588, Japan.*
[3] *Waseda University Faculty of Science and Engineering, Tokyo, 169-8555, Japan*

The study of collapse-driven supernovae is crucial for the understanding of astrophysical relevance, such as nucleosynthesis of heavy elements and chemical evolutions in the universe, radiations of neutrinos and gravitational waves, and possibly gamma-ray bursts and hypernovae (Arnett 1996, Raffelt 2002, Andersson 2003, MacFadyen & Woosley 1999). However, the explosion mechanism has not been clarified yet (Liebendorfer 1998). On the other hand, it has been considered that the origin of heavy neutron-rich elements like uranium is mainly due to the r-process nucleosynthesis that occurs during the supernova explosions (Nishimura et al.2006). The main issue concerning the r-process research is to reproduce the three peaks in the abundance pattern for the r-elements in the solar system.

We investigate the possibility of the r-process during the magnetohydrohynamical explosion of supernova in a massive star of 13 solar mass with the effects of neutrinos induced. We adopt five kinds of initial models which include properties of rotation and the toroidal component of the magnetic field. The simulations which succeed the explosions are limited to a concentrated magnetic field and strong differential rotation. Low Y_e ejecta produce heavy elements and the third peak can be reproduced. However, the second peak is low because Y_e distribution as a function of radius is steep and ejecta corresponding to middle Ye is very few.

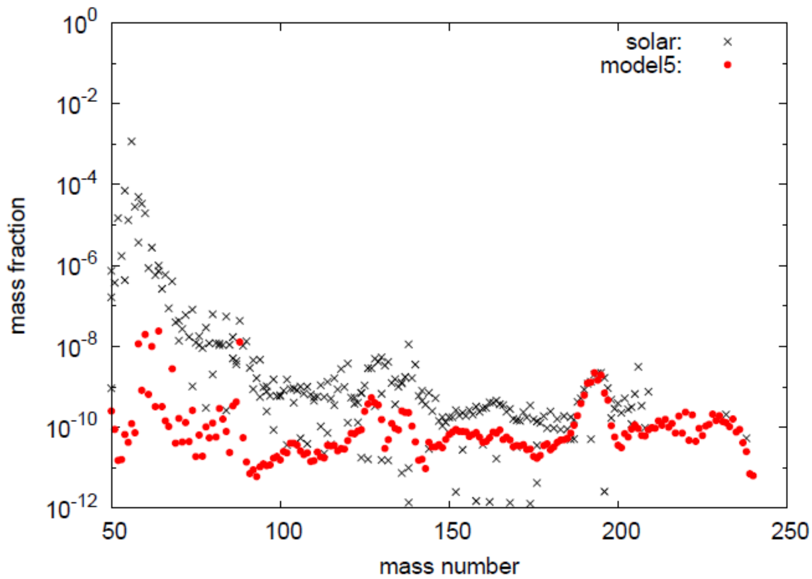


Fig. 1: Mass fractions as a function of the mass number.

Experiments on proton- and α- induced reactions of particular relevance for the p process *

Anne Sauerwein[1,γ], Janis Endres[1], Jens Hasper[1], Andreas Hennig[1,γ], Lars Netterdon[1], Andreas Zilges[1]

[1] *Institut für Kernphysik, Universität zu Köln, Zülpischer Str. 77, 50937 Köln, Germany.*

Most nuclei heavier than iron are synthesized by the s and r processes via neutron-capture reactions [1]. 35 proton-rich nuclei are bypassed by these processes. These nuclei, referred to as p nuclei, are believed to be synthesized by the p process in the explosive scenario of supernovae type II [2]. At this astrophysical site, the p nuclei can be produced by a sequence of photodisintegration reactions, i.e. (γ,n), (γ,p), and (γ,α) reactions. In total, the p process involves an extensive reaction network consisting of about twenty thousand reactions on approximately two thousand nuclei. Due to the absence of experimental data, network calculations for the p process are based almost completely on theoretically predicted reaction rates stemming from Hauser-Feshbach statistical model calculations. The accuracy of these predictions depends on the adopted nuclear models for optical-model potentials, photon-strength functions and nuclear level densities. Comprehensive experimental data for astrophysically relevant reactions are mandatory to derive reliable global nuclear models for the reaction codes, but so far the experimental data base is not sufficient for this purpose.

The 10 MV ion Tandem accelerator of the University of Cologne provides unique opportunities to improve the experimental situation for proton- and α-induced reactions of relevance for the p process. This facility allows to perform both in-beam experiments using the highly-efficient HPGe detector array HORUS and activation experiments using a low-background counting setup which employs two large-volume HPGe Clover detectors. In addition, a new 6 MV Tandem accelerator for Accelerator Mass Spectrometry (AMS) [3] is currently being commissioned at the University of Cologne which can be used to detect smallest amounts of long-lived radionuclides being produced either by cosmic events or in the laboratory.

The combination of this variety of experimental approaches gives access to a large number of astrophysically relevant reactions and allows detailed investigations of some key reactions within the p-process network [4,5], which so far could not be studied in the laboratory. In this contribution we will present first results of recent measurements and report on experiments planned in the near future.

* This work is supported by the DFG (ZI 510/5-1).
[γ] Member of the Bonn-Cologne Graduate School.

[1] G. Wallerstein et al., Reviews of Modern Physics 69 (1997) 995.
[2] D. Lambert, The Astronomy and Astrophysics Review 3 (1992) 201.
[3] A. Dewald, J. Jolie, and A. Zilges, Nuclear Physics News 18 (2008) 26.
[4] W. Rapp et al., Astrophysical Journal 653 (2006) 474.
[5] T. Rauscher, Physical Review C 73 (2006) 015804.

Elastic scattering and fusion of ^{6}Li on ^{64}Zn at near-barrier

V. Scuderi[1,2], F. Amorini[1,2], A. Di Pietro[2], P. Figuera[2], M. Fisichella[2], O. Goryunov[3], C. Maiolino[2], M. Lattuada[1,2], A. Musumarra[1,2], V. Ostashko[3], M. Papa[4], M. G. Pellegriti[1,2], F. Rizzo[1,2], D. Santonocito[2], D. Torresi[1,2] and M. Zadro[5]

[1]*Università di Catania, via S. Sofia 64, I-95123 Catania, Italy*
[2]*INFN, Laboratori Nazionali del Sud, via S. Sofia 62, I-95123 Catania, Italy*
[3]*Kiev Institut for Nuclear Research, Kiev, Ukraine*
[4]*INFN, Sezione di Catania, via S. Sofia 64, I-95123 Catania, Italy*
[5]*Rudjer Boskovic Institute, Bijenicka 54, HR-10000 Zagreb, Croatia*

In the last years a lot of work has been performed, both experimentally and theoretically (see ref. [1] and references therein), to study the effects of the breakup channel on the fusion and elastic scattering in collisions induced by light, unstable and stable, weakly bound nuclei at energies around the Coulomb barrier. Recently, much work has been devoted particularly to the study of the threshold anomaly (TA) in elastic scattering of weakly bound nuclei, such as ^{6}Li and ^{7}Li. For these projectiles the breakup channel is expected to be important even at energies below the Coulomb barrier and the usual TA may disappear.

In this contribution results concerning different reaction channels for the collision $^{6}Li+^{64}Zn$ at energies around the Coulomb barrier will be presented. Elastic scattering angular distributions were measured at eight beam energies from below to above the Coulomb barrier, $12.0 \leq E_{lab} \leq 22.0$ MeV. The experimental data were analyzed within the optical model in order to study the energy dependence of the interaction potential and to obtain total reaction cross-sections. The energy dependence of the real and imaginary parts of the potential shows that no usual TA is present for the $^{6}Li+^{64}Zn$ system.

Moreover, in order to further investigate on the influence of the breakup on the fusion channel, we have also extended to sub-barrier energies the fusion excitation function for the ^{6}Li on ^{64}Zn, previously measured by Gomes *et al.* [2] at energies close and above the barrier. The fusion cross-section was measured using an activation technique detecting off-line the delayed X-rays activity emitted by the evaporation residues and the energy range explored is E_{cm}= 9−37 MeV. Comparison of the deduced reaction cross-section and total fusion cross-section in [2,3] showed a reaction cross-section larger than the total fusion one at energies around the barrier and the authors concluded that the elastic break-up has significant cross-section at these energies. However, there are indications [4] that there may have been problems with the $^{6}Li+^{64}Zn$ fusion data in [2] and this could change this conclusion. Actually, from our new preliminary results the large difference between the reaction and the total fusion cross sections, observed by Gomes *et al.* [2,3], is reduced.

[1] L. F. Canto, P. R. S. Gomes, R. Donangelo, and M. S. Hussein, Phys. Rep. **424**, 1 (2006).
[2] P. R. S. Gomes *et al.*, Phys. Rev. **C 71**, 034608 (2005).
[3] I. Padron *et al.*, Phys. Rev. **C 66**, 044608 (2002).
[4] P. R. S. Gomes, J. Lubian and L. F. Canto Phys. Rev. **C 79**, 027606 (2009).

Reaching degeneracy in two-quasiparticle chiral bands *

O. Shirinda[1,2], **E.A. Lawrie**[1]

[1]*Department of Nuclear Physics, iThemba LABS, P.O. Box 722, Somerset West 7129, South Africa*
[2]*Department of Physics, University of the Western Cape, Private Bag X17, Bellville 7535, South Africa*

Nuclear chiral symmetry is suggested to occur in the angular momentum space. The necessary condition for such a system to form is an aplanar orientation of the total angular momentum, i.e. the total angular momentum should point out of the planes defined by any two of the major nuclear axes [1,2]. For a two quasiparticle configuration an aplanar orientation of the total angular momentum could be achieved if the nuclear shape is triaxial and if one of the quasiparticles has a predominant particle nature, while the second one – a predominant hole nature. In that case the angular momentum of the particle will be oriented along the short nuclear axis, that of the hole – along the long nuclear axis, and the angular momentum of the rotating core – along the intermediate axis. We have examined the properties of such systems using the two-quasiparticle-plus-triaxial-rotor model codes of P.B. Semmes and I. Ragnarsson [3].

We found that degeneracy in all properties of the chiral bands can be reached. However, it occurs only if the nucleon configuration is restricted to a pure particle and a pure hole occupying the highest and the lowest orbitals of a high-j shell. In real nuclei such a restriction on the nucleon configuration is unlikely. These results, obtained for a symmetric nucleon configuration in the 130 mass region, with both the proton and neutron occupying $h_{11/2}$ orbitals, were reported in Ref. [4].

In this contribution we will discuss: (i) conditions for reaching degeneracy in chiral bands not only in the 130, but also in the 100 and 190 mass regions, where the nucleon configuration is asymmetric, (ii) the impact of the change of the proton and neutron Fermi levels, and (iii) the effect of changing the nuclear g deformation.

In summary it seems that degeneracy in two-quasiparticle chiral bands can be reached only for pure particle-hole configurations, for which the particle (hole) occupy the lowest (highest) orbitals in the high-j shell, and for which the individual angular momenta are strictly mutually perpendicular. Furthermore we found that the optimal conditions for chirality may require g deformation slightly different from 30^{o}.

* This work is supported by the National Research Foundation, South Africa.

[1] S. Frauendorf and J. Meng, Nucl. Phys. **A 617**, 131 (1997)
[2] S. Frauendorf, Rev. Mod. Phys. 73, **463** (2001)
[3] P.B. Semmes and I. Ragnarsson, AIP Conf. Proc. **259**, 566 (1992)
[4] E.A. Lawrie and O. Shirinda, Phys. Lett. B **689**, 66-71 (2010)

Dynamical Dipole Mode in Fusion heavy-Ion Reactions by Using Stable and Radioactive Beams

R. Silvestri[1,2], D. Pierroutsakou[2], C. Parascandolo[2], C. Agodi[3], R. Alba[3], A. Boiano[1], R. Coniglione[3], E. De Filippo[4], A. Del Zoppo[3], U. Emanuele[5], F. Farinon[6], A. Guglielmetti[7], G. Inglima[2], M. La Commara[1,2], C. Maiolino[3], B. Martin[1], C. Mazzocchi[6], M. Mazzocco[8], M. Romoli[2], M. Sandoli[1,2], D. Santonocito[3], C. Signorini[8], A. Trifirò[5] and M. Trimarchi[5].

[1]Università degli Studi di Napoli "Federico II", via Cintia, 80126 Napoli, Italy; [2]INFN - Sezione di Napoli, via Cintia, 80126 Napoli, Italy; [3]INFN - LNS, via Santa Sofia 62, 95125 Catania, Italy; [4]INFN-Sezione di Catania, 95123, Catania, Italy; [5]INFN, Gruppo Coll. di Messina and Dip. di Fisica, Università di Messina, Messina, Italy; [6]GSI, Planckstr.1, 64291, Darmstadt, Germany; [7]Dip. di Fisica and INFN, Università di Milano, via Celoria 16, 20133 Milano, Italy; [8]Dip. di Fisica and INFN, Università di Padova, via F. Marzolo 8, 35131 Padova, Italy

An experimental overview [1-6] on an interesting feature of dipole excitation in heavy-ion collisions, the dynamical dipole mode, predicted to occur between interacting ions with a large charge asymmetry will be presented. In a campaign of experiments where the same compound nucleus in the ^{132}Ce region was probed through different charge asymmetry entrance channels, a larger g γ-ray emission from the more charge asymmetric channel was evidenced, in the Giant Dipole Resonance energy range. The beam energy dependence of this extra g yield was extracted by comparing the results obtained at different beam energies [2-5]. The first angular distribution data taken at E_{lab}= 16 MeV/nucleon support its prompt dynamical nature [2,3]. Our data [2-5] are compared with theoretical calculations performed within a BNV transport model and based on a collective bremsstrahlung analysis of the entrance channel reaction dynamics [7] and with recent data [6] obtained for compound nuclei in the same mass region but formed from entrance channel with a lower charge asymmetry.

Using the prompt dipole radiation as a probe and employing radioactive beams, new possibilities for the investigation of the symmetry energy at sub-saturation density are foreseen and will be discussed [5].

As a fast cooling mechanism on the fusion path, the prompt dipole radiation could be of interest for the synthesis of superheavy elements through hot fusion reactions. The entrance channel charge asymmetry could provide a way to cool down the hot fusion paths, so ending up with a larger survival probability. To shed light in this direction and to study if pre-equilibrium effects survive in heavier systems, we extended our study to the ^{192}Pb compound nucleus, formed at an excitation energy of 232 MeV, by using the ^{40}Ca+^{152}Sm and ^{48}Ca+^{144}Sm reactions at E_{lab}=440 MeV and 485 MeV, respectively. Preliminary results of this measurement, done with the aim to search for the dynamical dipole mode in both fusion evaporation and fusion-fission events for the first time in this mass region, will be presented.

[1] S. Flibotte et al., Phys. Rev. C77 (1996)1448
[2] D. Pierroutsakou et al, Eur. Phys. J. A17. (2003) 71
[3] D. Pierroutsakou et al., Phys. Rev. C71 (2005) 054605
[4] B. Martin et al., Phys. Lett. B664 (2008) 47
[5] D. Pierroutsakou et al., Phys. Rev. C 80 (2009) 024612
[6] A. Corsi et al., Phys. Lett. B 679 (2008) 197
[7]V. Baran et al., Phys.Rev.Lett. 87(2001)182501
[8] V. Baran et al., Phys. Rev. C79 (2009) 021603(R).

High resolution study of Gamow-Teller transitions in ^{45}Sc nucleus

G. Susoy[1], H. Fujita[2], T. Adachi[3], Y. Fujita[2], E. Ganioğlu[1], A. Algora[4], M. Csatlos[5], J. Deaven[6], E. Estevez[4], C. Guess[6], J. Guly'as[5], K. Hatanaka[3], K. Hirota[3], D. Ishikawa[3], A. Krasznahorkay[5], H. Matsubara[3], R. Meharchand[6], F. Molina[4], H. Okamura[3], Y. Oktem[1], H.J. Ong[3], G. Perdikakis[6], B. Rubio[4], C. Scholl[7], T. Suzuki[3], A. Tamii[3], J. Thies[8], R. G. T. Zegers[6], J. Zenihiro[3]

[1]*Department of Physics, Istanbul University, Istanbul 34134, Turkey*
[2]*Department of Physics, Osaka University, Toyonaka, Osaka 560-0043, Japan*
[3]*Research Center for Nuclear Physics, Osaka University, Ibaraki, Osaka 567-0047, Japan*
[4]*Instituto de Fisica Corpuscular, CSIC-Universidad de Valencia, E-46071 Valencia, Spain*
[5]*Institute of Nuclear Research of the Hungarian Academy of Sciences, P.O.Box 51, H-4001 Debrecen, Hungary*
[6]*NSCL, Michigan State University, East Lansing, Michigan 48824-1321, USA*
[7]*Institut für Kernphysik, Universität zu Köln, 50937 Köln, Germany*
[8]*Institut für Kernphysik, Westfalische Wilhelms-Universität, D-48149 Munster, Germany*

In the early stage of the core collapse of supernovae, studying the weak nuclear response, especially the Gamow-Teller (GT) transitions of pf-shell nuclei is one of the key issues in nuclear and astronuclear physics [1]. Therefore, electron capture and β decay of pf shell nuclei that mainly proceed by GT transitions play important roles [2].

In order to study the detail of the GT transition strengths starting from one of the T_z=3/2 pf-shell nucleus ^{45}Sc, where T_z= (1/2)(N-Z), performed a 0° experiment at an intermediate energies of 140 MeV/nucleon at the Research Center for Nuclear Physics (RCNP) in Osaka [3-4] by using the magnetic spectrometer Grand Raiden (GR) [5] and applied the dispersion-matching techniques for the beam transportation in order to achieve high resolution. In $_{45}$Ti spectra energy resolution of ~35 keV was achieved and the discrete states were observed up to 8.5 MeV [6].

By using high resolution (3He,t) reactions, the project to obtain $B(GT_-)$ distributions in pf-shell nuclei is in progress. It is expected that they can be used for the understanding of various astrophysical phenomena.

[1] K. Langanke and G. Martinez-Pinedo, Rev. Mod. Phys. 75, 819 (2003).
[2] G. M. Pinedo, Nuclear Physics A, 805, 478c–485c (2008).
[3] Y.Fujita, et all., Phys. Rew. Lett. 95, 212501 (2005).
[4] L. Popescu, et all., Phys. Rew. C 79, 064312 (2009).
[5] M. Fujiwara, et all., Nucl. Instrum. Methods A, 422, 484., (1999).
[6] http://www.rcnp.osaka-u.ac.jp

Structure of Neutron-rich Calcium Isotopes and Roles of Three-body Interaction

Toshio Suzuki[1], **Takaharu Otsuka**[2,3]

[1] *Department of Physics, Nihon University, Sakurajosui, Setagaya-ku, Tokyo 156-8550, Japan.*
[2] *Department of Physics, University of Tokyo, Hongo, Bunkyo-ku, Tokyo 113-0033, Japan.*
[3] *Center for Nuclear Study, University of Tokyo, Hongo, Bunkyo-ku, Tokyo 113-0033, and RIKEN, Hirosawa, Wako-shi, Saitama 351-0198, Japan.*

Structure of neutron-rich calcium isotopes are studied by shell model calculations with the use of microscopic two-body and three-body interactions. Microscopic G-matrix elements with core polarization effects [1] are used for the two-nucleon interaction. The Fujita-Miyazawa force [2] induced by Δ-isobar-hole excitations is included as the dominant part of the three-nucleon interaction. We found the following important roles of the three-body force on the structure of exotic nuclei. The three-body interaction can solve several serious problems in nuclear structure inherent in the microscopic two-body interactions.

The three-body force induces repulsive contributions to the monopole terms of the valence neutron-neutron interaction. The need for the repulsive components in the isospin T=1 monopole terms in phenomenological interactions such as GXPF1 [3] in the pf-shell can be naturally explained.

Ground state energies of the isotopes, which have deviations from the experimental values near drip-lines only with the two-body interaction, are found to be well reproduced up to the observed ones when the three-body interaction is included. This is quite similar to the case of oxygen isotopes, where the three-body interaction is found to be important to explain why the drip-line of oxygen isotopes is ^{24}O and the isotopes with neutron number N≥17 do not exist [4].

Besides the monopoles, we further investigate the effects of the contributions of the three-body force to the multipole terms of the valence two-nucleon matrix elements. We discuss the effects on the energy levels of the Ca isotopes as well as the O isotopes. We discuss also the excitation energies of the 2^+_1 states in Ca isotopes, and show that those in ^{48}Ca and ^{54}Ca are enhanced with the inclusion of the three-body interaction. The three-body force thus plays a key role for the magicity of ^{48}Ca and ^{54}Ca. Similar results are obtained with the use of microscopic V_{lowk} two-nucleon interaction and chiral 3N nucleon interaction [5].

The magnetic dipole (M1) strength in ^{48}Ca is fragmented in case with the microscopic two-body interaction only. The strength is found to be concentrated and pushed up to higher excitation energy when the three-body interaction is included. An important role of the multipole components is pointed out for the concentration of the strength. The single-particle structure of ^{48}Ca is reproduced with the inclusion of the three-body interaction.

We will also show that the three-body interaction improves the agreement of the calculated ground state energies of helium isotopes with the observation.

[1] M. H. Jensen, T.T.S. Kuo and E. Osnes, Phys. Rept. 261, 125 (1995).
[2] J. Fujita and H. Miyazawa, Prog. Theor. Phys. 17, 360 (1957).
[3] M. Honma et al., Phys. Rev. C 65, 061301 (2002); Phys. Rev. C 69, 034335 (2004).
[4] T. Otsuka, T. Suzuki, J. D. Holt, A. Schwenk and Y. Akaishi, to be published.
[5] J. D. Holt, T. Otsuka, A. Schwenk and T. Suzuki, in preparation.

High-K Structures in the ^{164}Er Region

T. P. D. Swan[1], P. M. Walker[1], Zs. Podolyak[1], M. W. Reed[1], G. D. Dracoulis[2], G. J. Lane[2], T. Kibèdi[2], M. L. Smith[2]

[1]Physics Department, University of Surrey, Guildford, Surrey, GU27XH, United Kingdom.
[2]Department of Nuclear Physics, Australian National University, Canberra, ACT 0200, Australia.

Several multi-quasiparticle isomers have been observed for the first time in a gammaspectroscopy experiment performed at the Australian National University Heavy Ion Accelerator Facility.

A fusion-evaporation reaction using a 57 MeV, pulsed, ^{9}Be beam incident on a ^{160}Gd enriched target was used to populate nuclei in the vicinity of ^{164}Er. Of specific interest was a known four quasi-particle isomer in ^{164}Er with an uncertain half-life [1]. The bunched andchopped beam provided ideal conditions for the half-life measurement of all gamma decaying levels observed using the CAESAR array [2], which consists of nine HPGe detectors and two LEPS detectors.

Twelve different isotopes with observable gamma ray transitions were detected in the experiment, many produced by the incomplete fusion channel. Of these, three were observed to possess new multi-quasiparticle isomers: ^{162}Dy, ^{163}Ho and ^{165}Er. A precise measurement of the ^{164}Er, K=12^{+} isomer's half-life was made that greatly improved upon earlier estimates [1]. Half-life measurements up to several micro-seconds will be presented along with structural assignments for all of the new isomers.

An analysis which yields an estimate for the K value of the s-bands in ^{164}Er and ^{162}Dy will be presented. The same method has been applied to other nuclei in the region by Walker [3], elucidating the relationship between neutron number and s-band K value. The surprisingly high K values obtained provide an explanation for the existence of highly forbidden transitions from K-isomers to the ground-state bands of nuclei in the region.

* This work is supported by the STFC (UK) and the EPSRC (UK).

[1] R. Bark *et al.*, Z. Phys A359, 5 (1997)
[2] G. D. Dracoulis and A. P. Byrne, Department of Nuclear Physics Annual Report No. ANUP/1052 (1989) (unpublished)
[3] P. M. Walker, J Phys G34, 123 (2007)

Microscopic Description of the Alpha-Clustering Phenomenon in (2s-1d)-Shell Nuclei

Yu. M. Tchuvil'sky

Skobeltsyn Institute of Nuclear Physics, Moscow State University, 119991, Moscow, Russia

As it is shown in [1], the generalized Elliott model based on the microscopic (i. e. expressed in terms of nucleon variables) Hamiltonian of the broken *SU(3)* symmetry is a valuable research tool in studying of various clustering phenomena. In the present work the multi alpha-particle states of the (2s-1d)-shell nuclei are studied by these means. The discussed Hamiltonian can be presented in the form:

$$\hat{H}=\hat{H}_{osc}+F\,(L^2, p, \hat{g}_2, \hat{g}_3, \Omega), \quad (1)$$

where $\hat{H}_{osc}$ is the oscillator Hamiltonian, p is the operator of parity, L is the angular momentum operator, $\hat{g}_2$ and $\hat{g}_3$ are Casimir operators of the *SU(3)* group, Ω is Bargman operator and F is an arbitrary function of the arguments. The use of the Hamiltonian makes it possible to classify of alpha-particle states of the discussed nuclei and to calculate very complicated spectra. For example dense spectrum of alpha-cluster states in ^{32}S nucleus containing more than 80 levels with identified spin, which is experimentally studied in [2], is calculated using six-parameter linear Hamiltonian (1).

The results of the calculations are in a rather good agreement with the experimental data. In the energy regions where, according to [2], the levels with certain value of the spin J^{π} are observed (the widths of these regions are about 2–3 MeV) theoretical calculations result in trifle over numbers of such levels which may be unobservable because of limited resolution power of the experimental set. The sole exclusion is related to 6^+ levels – 11 levels are observed whereas there are 9 theoretical ones in the respective region. The energies of lower lying levels are slightly overestimated by the calculations.

The alpha-particle spectra of other *N=Z*-even nuclei are studied. A lot of α-particle states of these nuclei are predicted.

[1] I. A. Gnilozub, S. D. Kurgalin, Yu. M. Tchuvil'sky, Phys. At. Nucl. **69**, 1014. (2006).
[2] K.–M. Kallman, M. Brenner, V. Z. Goldberg *et.al.*, Eur. Phys. J. **A 16**, 159 (2003).

Search for Li-α cluster state in ^{12}B using Inverse Kinematics Thick Target Scattering

D. Torresi[1,2], L. Cosentino[1], A. Di Pietro[1], C. Ducoin[3], M. Lattuada[1,2], T. Lonnroth[4], P. Figuera[1], M. Fisichella[1,5], C. Maiolino[1], A. Musumarra[1,6], M. Papa[1,3], M.G.Pellegriti[1,7], M. Rovituso[2], V. Scuderi[1,2], G. Scalia[1,2], D. Santonocito[1], M. Zadro[8]

[1] *INFN Laboratori Nazionali del Sud, Catania, Italy.*
[2] *Dipartimento di fisica ed Astronomia, Universitàdi Catania, Italy*
[3] *INFN, Sezione di Catania, Italy*
[4] *Åbo Academy, Turku, Finland*
[5] *Dipartimento di Fisica, Universit`a Messina, Italy*
[6] *Dipartimento di Metodologie Fisiche e Chimiche per l'Ingegneria, Università di Catania, Italy*
[7] *CSFNSM, Catania, Italy*
[8] *Ruder Boskovic Institute, Zagreb, Croatia*

The study of exotic clustering in light n-rich nuclei is one of the possible applications of radioactive ion beams. We performed an experiment aimed at the search for ^{8}Li−α cluster configurations in ^{12}B using the radioactive ^{8}Li provided by the Laboratori Nazionali del Sud radioactive facility EXCYT. Cluster states associated to the ^{8}Li−α configurations located just above the α decay threshold were already predicted by using Resonating Group Method [1].

The ^{8}Li+^{4}He elastic scattering excitation function was measured by using the inverse kinematic thick target method [2]. The ^{8}Li beam at an energy of 30 MeV and was delivered in a large scattering chamber filled with ^{4}He gas at a pressure of 700 mbar. The ^{4}He gas acts as target and as degrader at the same time, reducing the incident particle energy from the initial value down to zero and allowing measuring the excitation function at angles around 180^{o} in CM system in a wide range of energies using a single beam energy.

Thanks to the large difference in the stopping power of helium for ^{8}Li and for ^{4}He, the beam is stopped inside the target while the recoiling ^{4}He particles can reach the detectors placed at the end of the chamber. The detection system was made by 4 silicon telescopes, each one consisting in a four quadrant thin silicon detector and a thick Double Sided Silicon Strip Detector. A Micro Channel Plate was used to measure the number of incident particles as well as the time difference between the entrance of the projectile in the chamber and the arrival of the recoil α on one of the detectors. This allows discrimination between elastic and inelastic scattering.

The setup and the experimental technique will be described in details and preliminary results will be shown and discussed.

[1] P. Descouvemont, Nucl. Phys. A596 (1996) 285.
[2] V. Z. Goldberg et al., Phys. Rev. C 69 (2004) 024602

Application of the γSF Method to Palladium*

H. Utsunomiya[1], S. Goriely[2], I. Daoutidis[2], H. Akimune[1], T. Yamagata[1], T. Kondo[1], C. Iwamoto[1], M. Kamata[1], O. Itoh[1], H. Harada[3], F. Kitatani[3], S. Goko[4], H. Toyokawa[5], K. Yamada[5], Y.-W. Lui[6], S. Hilaire[7], and A.J. Koning[8]

[1]*Dept. of Physics, Konan University, Okamoto 8-9-1, Higashinada, Kobe 658-8501, Japan*
[2]*Institut d'Astronomie et d'Astrophysique, Universite´ Libre de Bruxelles, Campus de la Plaine, CP-226, 1050 Brussels, Belgium*
[3]*Japan Atomic Energy Agency, Tokai-mura, Naka, Ibaraki 319-1195, Japan*
[4]*Department of Engineering, Hokkaido University, Sapporo 060-8628, Japan*
[5]*National Institute of Advanced Industrial Science and Technology, Tsukuba 305-8568, Japan*
[6]*Cyclotron Institute, Texas A&M University, College Station, Texas 77843, USA*
[7]*CEA, DAM, DIF, F-91297 Arpajon, France*
[8]*Nuclear Research and Consultancy Group, P.O. Box 25, NL-1755 ZG Petten, The Netherlands*

The γ-ray strength function (γSF) method [1] is applied to palladium isotopes with a focus on indirect determination of radiative neutron capture cross sections for a radioactive nucleus ^{107}Pd with $T_{1/2} = 6.5\times10^{6}$ y. Photoneutron cross sections were measured near neutron threshold for ^{108,106,105}Pd nuclei with laser Compton scattering γ rays at the National Institute of Advanced Industrial Science and Technology. The experimental cross section is compared with the statistical model calculations based on the TALYS code making use of different E1 γ-ray strength prescriptions including the Hybrid model [2] and two versions of the mean field plus QRPA model, namely the non-relativistic HFB plus QRPA calculation of [3] and the relativistic mean field plus continuum QRPA (RMF+cQRPA) calculation of [4]. We compare the model predictions from different γSF models for ^{108}Pd(γ,n)^{107}Pd and ^{107}Pd(n,γ)^{108}Pd cross section with experimental data. A recommendation is given to predictions with the Hybrid and RMF+cQRPA models of the γSF in an application of the γSF method to ^{108,106,105}Pd.

*The present study includes the result of "Study on nuclear data by using a high intensity pulsed neutron source for advanced nuclear system" entrusted to Hokkaido University by the Ministry of Education, Culture, Sports, Science and Technology of Japan (MEXT). This work is partly supported by the Japan Private School Promotion Foundation and the Konan-ULB bilateral project. S.G. acknowledges support from FNRS.

[1] H. Utsunomiya et al., this conference.
[2] S. Goriely, Phys. Lett. B436, 10 (1998).
[3] S. Goriely, E. Khan, and M. Samyn, Nucl. Phys. A739, 331 (2004).
[4] J. Daoutidis, P. Ring, Phys. Rev. C 80, 024309 (2009).

Striking Behaviour of Photoneutron Cross Sections for ^{90}Zr near Threshold*

H. Utsunomiya[1], S. Goriely[2], H. Akimune[1], T. Yamagata[1], T. Kondo[1], C. Iwamoto[1], O. Itoh[1], M. Kamata[1], M. Io[1], K. Kususe[1], H. Harada[3], F. Kitatani[3], S. Goko[4], H. Toyokawa[5], K. Yamada[5], Y.-W. Lui[6]

[1]*Dept. of Physics, Konan University, Okamoto 8-9-1, Higashinada, Kobe 658-8501, Japan*
[2]*Institut d'Astronomie et d'Astrophysique, Universite´ Libre de Bruxelles, Campus de la Plaine, CP-226, 1050 Brussels, Belgium*
[3]*Japan Atomic Energy Agency, Tokai-mura, Naka, Ibaraki 319-1195, Japan*
[4]*Department of Engineering, Hokkaido University, Sapporo 060-8628, Japan*
[5]*National Institute of Advanced Industrial Science and Technology,Tsukuba 305-8568, Japan*
[6]*Cyclotron Institute, Texas A&M University, College Station, Texas 77843, USA*

A photon difference technique was employed to examine a minute behaviour of photoneutron cross sections for ^{90}Zr near neutron threshold with laser Compton scattering (LCS) γ-ray beams at the National Institute of Advanced Industrial Science and Technology. The maximum energy of the LCS γ-ray beam was changed in 50-200 keV steps from 12135 to 12890 keV near threshold at 11970 keV. Figure 1 shows the present data of photoneutron cross sections for ^{90}Zr in comparison with the previous data [1,2]. The cross sections above 12300 keV are in good agreement with the data of Ref. [1], while the data of Ref. [2] do not show such a rapid fall. A striking feature is that there is a significant strength just above the neutron threshold, suggesting the presence of resonance states. They are possibly $3P_{3/2}$ wave neutron resonances that predominantly manifest themselves around A = 90, as predicted by the valence model [3].

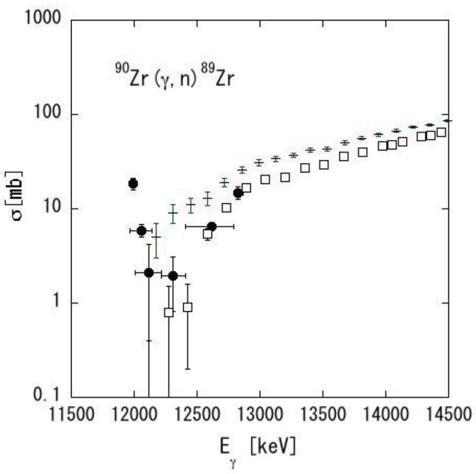


Fig. 1: Photoneutron cross sections for ^{90}Zr

*This work is supported by the Japan Private School Promotion Foundation and the Konan-ULB bilateral project. S.G. acknowledges support from FNRS.

[1] B.L. Berman *et al.*, Phys. Rev. 162, 1098 (1967).
[2] A. Lepretre *et al.*, Nucl. Phys. A175, 609 (1971).
[3] J.E. Lynn, *The Theory of Neutron Resonance Reactions* (Clarendon, Oxford, 1968).

Spectroscopy of Positive Parity Bands ^{156}Gd

A. Vancraeyenest[1], D. Guinet[1], D. Curien[2], O. Stezowski[1], Q.T. Doan[1], N. Redon[1], P. T. Greenlees[3], P. Jones[3], et al.

[1] IPNL, Université de Lyon, Université Lyon 1, CNRS/IN2P3, 4 rue E. Fermi, 69622 Villeurbanne cedex, France
[2] IPHC-DRS, ULP, IN2P3-CNRS, 67037 Strasbourg, France
[3] Department of Physics, University of Jyväskylä, 40014 Jyväskylä, Finland

An experiment was realized in September 2007 at Jyväskylä laboratory involving a 27 MeV α beam on a ^{154}Sm thick target. Gamma spectroscopy was performed using the JUROGAM array which was composed by 43 segmented HPGe detector. First aim of this experiment was the search for fingerprints of tetrahedral symmetry in negative parity bands. However the high quantity of triple coincidence events obtained allowed us to manage a more detailed spectroscopy of ^{156}Gd nucleus. Since the negative parity bands have already been discussed in previous work [1], we will present here experimental results concerning positive parity bands. Indeed, ^{156}Gd level scheme was enriched with more than ten new transitions, essentially between the two bands. Moreover, our study revealed an additional level in the new band proposed by Sugawara et al. [2].

Work is in progress concerning interpretation of new transitions find out in the study and possible spin assignation of level which wasn't determined by Sugawara et al. [2] because of lake of statistics.

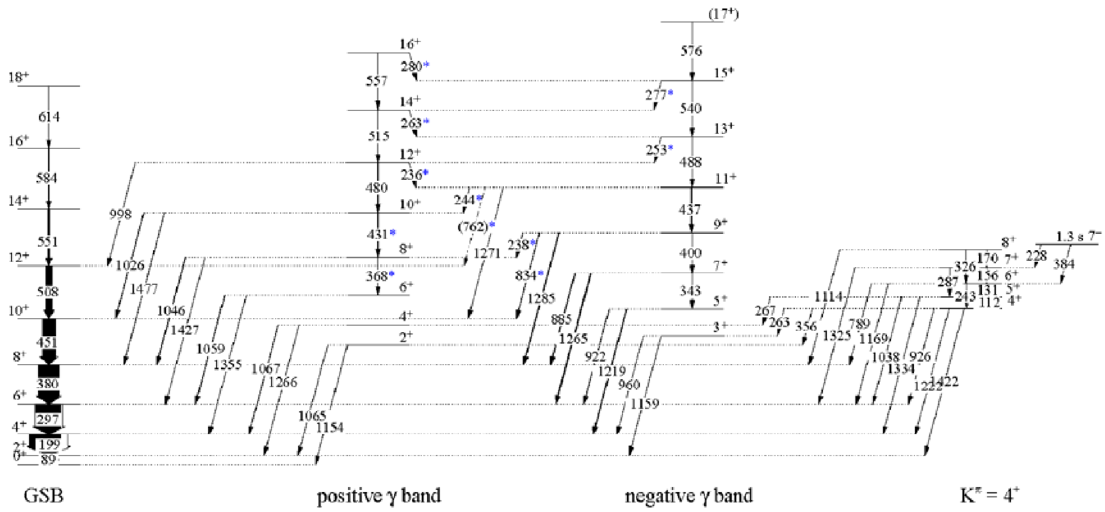


Fig. 1: Partial level scheme of positive parity band in ^{156}Gd. New transitions in and between bands are marked with star.

[1] Q.T. Doan et al., Acta Phys. Pol. B 40, 725 (2009).
[2] M. Sugawara et al., Nucl. Phys. A 686, 29-40 (2001).

Finite-Range Separable Pairing Interaction within New N^{3}LO DFT Approach

P. Veselý[1], B. G. Carlsson[1], J. Dobaczewski[1,2], N. Michel[1], A. Pastore[1], F. Raimondi[1], J. Toivanen[1] and P. Toivanen[1]

[1] Department of Physics, P.O. Box 35 (YFL), University of Jyväskylä, FI-40014, Finland
[2] Institute of Theoretical Physics, University of Warsaw, ul. Hoza 69, 00-681 Warsaw, Poland

For over four decades, the Skyrme functional within various parametrizations has been used to calculate nuclear properties. In the last few years there was a number of attempts to improve its performance and introduce generalized forms. In particular, the most general phenomenological quasi-local energy density functional, which contains all combinations of density, spin-density, and their derivatives up to the sixth order (N^{3}LO), was proposed in reference [1]. Since in the phenomenological functional approaches the particle-particle (pp) interaction channel is treated independently from the particle-hole (ph) channel, there remains a question of what pairing interaction is suitable to use within the N^{3}LO energy functional. In our study, we use the separable, finite-range, translationally invariant form given in [2], which we generalize to the arbitrary angular momentum channel. We discuss the application of this pairing interaction within the N^{3}LO energy functional.

[1] B. G. Carlsson, J. Dobaczewski, M. Kortelainen, Phys. Rev. C 78, 044326 (2008)
[2] Y. Tian, Z.Y. Ma, P. Ring, Phys. Lett. B 676, 44 (2009)

The $^{237}Np(n,f)$ cross section at the CERN n-TOF facility

D. Karadimos, R. Vlastou, L. Audouin, C. Guerrero, U. Abbondanno, G. Aerts, H. Alvarez, F. Alvarez-Velarde, S. Andriamonje, J. Andrzejewski, P. Assimakopoulos†, G. Badurek, P. Baumann, F. Becvar, F. Belloni, E. Berthoumieux, F. Calvino, M. Calviani, D. Cano-Ott, R. Capote, C. Carrapi¸ P. Cennini, V. Chepel, E. Chiaveri, N. Colonna, G. Cortes, A. Couture, J. Cox, M. Dahlfors, S. David, I. Dillmann, C. Domingo-Pardo, W. Dridi, I. Duran, C. Eleftheriadis, L. Ferrant†, A. Ferrari, R. Ferreira-Marques, K. Fujii, W. Furman, S. Galanopoulos, I. F. Goncalves, E. Gonzalez-Romero, F. Gramegna, F. Gunsing, B. Haas, R. Haight, M. Heil, A. Herrera-Martinez, M. Igashira, E. Jericha, F. Käppeler, Y. Kadi, D. Karamanis, M. Kerveno, P. Koehler, V. Konovalov, E. Kossionides, M. Krticka, C. Lampoudis, C. Lederer, H. Leeb, A. Lindote, I. Lopes, M. Lozano, S. Lukic, J. Marganiec, S. Marrone, T. Martınez, C. Massimi, P. Mastinu, E. Mendoza, A. Mengoni, P.M. Milazzo, C. Moreau, M. Mosconi, F. Neves, H. Oberhummer, S. O'Brien, J. Pancin, C. Papadopoulos, C. Paradela, A. Pavlik, P. Pavlopoulos, G. Perdikakis, L. Perrot, M. T. Pigni, R. Plag, A. Plompen, A. Plukis, A. Poch, J. Praena, C. Pretel, J. Quesada, T. Rauscher, R. Reifarth, M. Rosetti, C. Rubbia, G. Rudolf, P. Rullhusen, L. Sarchiapone, R. Sarmento, I. Savvidis, C. Stephan, G. Tagliente, J. L. Tain, L. Tassan-Got, L. Tavora, R. Terlizzi, G. Vannini, P. Vaz, A. Ventura, D. Villamarin, V. Vlachoudis, F. Voss, S. Walter, M. Wiescher and K. Wisshak

(The n TOF Collaboration, http://www.cern.ch/ntof)

The investigation of neutron-induced reactions is of considerable importance in several fields of fundamental and applied Nuclear Physics. The main technological applications are related to the design of innovative Accelerator Driven Systems (ADS) for the future production of clean and safe nuclear energy as well as for nuclear waste incineration [1,2]. Neptunium-237 is the most important actinide in the problem of spent fuel transmutation and the existing (n,f) data in literature present many discrepancies.

$^{237}Np(n,f)$ cross sections have been measured relative to ^{235}U and ^{238}U fission cross sections, at the n-TOF facility, a spallation neutron source built at CERN with a high intensity flux and an extensive neutron energy range (from eV to GeV) and an excellent time resolution. A fast ionization chamber (FIC) was used as a fission fragment detector with registration efficiency of not less than 97% [3]. The ionization detector was equipped with fast electronics including time-digital converters (TDC) and Flash Analog to Digital Converters (FADC). TDC were used for neutron energy range from 0.1 eV to 1 MeV, while FADC have been used for measurements above 20 KeV. An adapted analysis procedure has been developed to obtain the relative fission cross sections of the measured actinides [4]. Reliable $^{237}Np(n,f)$ cross section measurements, from a preliminary analysis of the row data, have been deduced in the energy range 20 keV to ≈10 MeV and will be presented along with data from literature.

[1] C. Rubbia et al., CERN/AT/95-44, CERN, 1995.
[2] C.D. Bowman, Ann. Rev. Nucl. Part. Sci. 48 (1998)505.
[3] M.Calviani, et al., Nucl. Instr. Meth. A 594 (2008) 220.
[4] D.Karadimos, R.Vlastou et al. Nucl.Instr.Meth. B(2010) , in press

Commissioning of LYCCA - a HISPEC-device*

A. Wendt[1] , M. Bentley[4], P. Boutachkov[3], J. Gerl[3], Ch. Goergen[1], P. Golubev[2], R. Hoischen[2], E. Merchan[3], G. Pascovici[1], S. Pietri[3], P. Reiter[1], D. Rudolph[2], H. Schaffner[3], Taprogge[1], M. Taylor[4]

[1]*IKP, University of Cologne, Zulpicher Str. 77, 50937 Cologne, Germany.*
[2]*Division of Nuclear Physics, Lund University, Professorsgatan 1, 22363 Lund, Sweden.*
[3]*GSI, Plankstr. 1, 64291 Darmstadt, Germany.*
[4]*Department of Physics, University of York, YO10 5DD, United Kingdom*

The Lund-York-Cologne Calorimeter Array LYCCA will be employed for future PRESPEC and HISPEC γ-ray spectroscopy experiments at the GSI/FAIR accelerator facility. Reaction product identification after a secondary target at the focal plan of the FRS/SUPERFRS is based on a TOF-ΔE-E measurement.

The modular array will comprise for the individual telescope module a 32x32 double-sided Si strip detectors and 9 CsI scintillators. Plastic or diamond detectors are used for TOF measurement.

Several in-beam test experiments were performed first with low energetic protons at 18 MeV and second with a secondary fragmentation beam of ions around ^{48}Ca with energy of 600 MeV/u. The presentation summarizes the results of these LYCCA commissioning experiments.

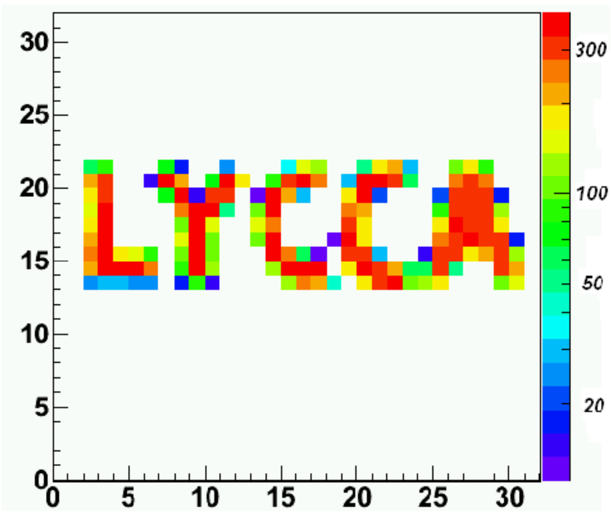


Fig. 1: Hit pattern of a LYCCA-DSSD through a mask.

* This work is supported by the German BMBF (06KY205I).

Update and Extension of the Nuclear Astrophysics Compilation of Reaction Rates (NACRE): Charged-Particle Thermonuclear Rates with A<16 *

Yi Xu[1], Kohji Takahashi[2], Stephane Goriely[1], Marcel Arnould[1]

[1] *Institut d'Astronomie et d'Astrophysique, Université Libre de Bruxelles, Bruxelles, Belgium.*
[2] *GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt, Germany.*

A library of easily accessible state-of-the-art nuclear reaction rates is essential to the study of nucleosynthesis and stellar evolution. In this presentation, we report a new evaluation of reaction rates for 21 capture and 15 transfer reactions on stable targets with mass numbers A<16. At low energies where no experimental data is available, the astrophysical S-factors, together with their uncertainties, are evaluated on the basis of the potential model (PM) for capture reactions and the distorted wave Born approximation (DWBA) for transfer reactions. The model parameters are obtained from a fit to the available experimental data. The extrapolated S-factors from PM and DWBA evaluation are utilized to calculate the reaction rates and corresponding uncertainties. At high energies, whenever available, experimental cross sections (and astrophysical S-factors) as well as their errors are used to compute the reaction rates and corresponding uncertainties. A new evaluation of reaction rates is provided as numerical tables and compared with the NACRE compilation. The new reaction rates are believed to be more reliable than those previously determined due to the physical models adopted to extrapolate the S-factors at low energies and the updated sets of experimental data considered.

*This work has been carried out within the framework of the Konan-ULB convention.

LIST OF PARTICIPANTS

		Participant	Affiliation	Email
1	Ms.	**Adimi** Nassima	CENBG, Chemin du Solarium, Le Haut Vigneau, BP 120, F-33175 Gradignan, France	adimi@cenbg.in2p3.fr
2	Dr.	**Akimune** Hidetoshi	Department of Physics, Konan University, Kobe 658-8501, Japan	akimune@konan-u.ac.jp
3	Prof.	**Akkus** Baki	Istanbul University, Science Faculty, Physics Department, 34134 Vezneciler - Istanbul - Turkey	akkus@istanbul.edu.tr
4	Dr.	**Algora** Alejandro	Instituto de Fvsica Corpuscular, CSIC-Universidad de Valencia, Spain	algora@ific.uv.es
5	Mr.	**Andrianis** Miltiades	Tandem Accelerator Laboratory, Institute of Nuclear Physics, NCSR "Demokritos", 15310 Aghia Paraskevi, Athens, Greece	mandrian@inp.demokritos.gr
6	Dr.	**Andreyev** Andrei	School of Engineering and Science, University of the West of Scotland, Paisley Campus, High Street, Paisley, Renfrewshire, PA12BE, Scotland, UK	Andrei.Andreyev@uws.ac.uk
7	Dr.	**Ashley** Steven	Tandem Accelerator Laboratory, Institute of Nuclear Physics, NCSR "Demokritos", 15310 Aghia Paraskevi, Athens, Greece	sfashley@inp.demokritos.gr
8	Mr.	**Audirac** Laurent	CENBG, Chemin du Solarium, BP 120, F-33175 Gradignan Cedex, France	audirac@cenbg.in2p3.fr
9	Dr.	**Axiotis** Michael	Tandem Accelerator Laboratory, Institute of Nuclear Physics, NCSR "Demokritos", 15310 Aghia Paraskevi, Athens, Greece	axiotis@inp.demokritos.gr
10	Prof.	**Aÿstö** Juha	Dept. of Physics, Univ. of Jyvaskyla, P.O. Box 35 (YFL), 40014 Jyvaskyla, Finland	juha.aysto@jyu.fi
11	Ms.	**Balasi** Konstantia	University of Ioannina, Ionanina, Greece	dbalasi@hotmail.com
12	Dr.	**Becker** Hans Werner	Dynamitron Tandem Labor – RUBION, Ruhr-Universität Bochum, Bochum, Germany	Hans-Werner.Becker@rub.de
13	Prof.	**Billowes** Jonathan	Shuster Laboratory, School of Physics and Astronomy, University of Manchester, Manchester M13 9PL, UK	j.billowes@manchester.ac.uk
14	Dr.	**Běták** Emil	Institute of Physics, Slovak Academy of Sciences, 84511 Bratislava, Slovakia	betak@savba.sk

15	Prof.	**Borge** Maria	Instituto de Estructura de la Materia, CSIC, Serrano 113 bis, E-28006 Madrid, Spain	borge@iem.cfmac.csic.es
16	Dr.	**Borgmann** Christopher	Max-Planck-Institut f ur Kernphysik, Saupfercheckweg 1, D-69117 Heidelberg, Germany	christopher.borgmann@cern.ch
17	Dr.	**Cappuzzello** Francesco	Dipartimento di Fisica, Università di Catania and INFN-LNS, Catania	cappuzzello@lns.infn.it
18	Dr.	**Cavallaro** Manuela	INFN - LNS, via S. Sofia 62, 95125, Catania, Italy	manuela@lns.infn.it
19	Prof.	**Chowdhury** Partha	Department of Physics, Univ. of Massachusetts Lowell, Lowell, MA 01854, USA	partha_chowdhury@uml.edu
20	Dr.	**Chuvilskaya** Tatiana	Institut of Nuclear Physics Moscow State University 119991 Moscow Russia	tatchuv@anna19.sinp.msu.ru
21	Dr.	**Corsi** Anna	Universita degli Studi and INFN Milano, via Celoria 16, I-20133 Milano, Italy	anna.corsi@mi.infn.it
22	Prof.	**Cowley** Anthony A.	Department of Physics, Stellenbosch University, Private Bag X1, Matieland 7602, South Africa	aac@sun.ac.za
23	Prof.	**Crema** Edilson	Departamento de Física Nuclear, Instituto de Física da Universidade de São Paulo, SP, Brazil	crema@dfn.if.usp.br
24	Dr.	**Cseh** Jozsef	MTA ATOMKI, Bem ter 18/C, Debrecen, Hungary 4026	cseh@atomki.hu
25	Mr.	**Cubero** Mario	IEM-CSIC, c/Serrano 113 bis, Madrid, Spain	mcubero@iem.cfmac.csic.es
26	Dr.	**Cullen** David	Shuster Laboratory, School of Physics and Astronomy, University of Manchester, Manchester M13 9PL, UK	dave.cullen@manchester.ac.uk
27	Dr.	**Daoutidis** John	Universite Libre de Bruxelles	idaoutid@ulb.ac.be
28	Dr.	**Darai** Judit	Institute of Experimental Phys., University of Debrecen, Debrecen, Bem ter 18/a, Hungary 4026	darai@namafia.atomki.hu
29	Dr.	**Demetriou** Paraskevi	Institute of Nuclear Physics, NCSR "Demokritos", 15310 Aghia Paraskevi, Athens, Greece	vivian@inp.demokritos.gr
30	Dr.	**De Napoli** Marzio	INFN - Laboratori Nazionali del Sud, Via S. Sofia 62, 95125 Catania, ITALY	denapoli@lns.infn.it

31	Dr.	**De Oliveira Santos** Francois	GANIL, Bd H. Becquerel, 14000 Caen, France	oliveira@ganil.fr
32	Dr.	**Di Pietro** Alessia	INFN-LNS and INFN Sezione di Catania, via S.Sofia 64, I-95125 Catania	dipietro@lns.infn.it
33	Prof.	**Diaz-Torres** Alexis	Department of Physics, University of Surrey, GU2 7XH, United Kingdom	A.Diaztorres@surrey.ac.uk
34	Prof.	**Dobaczewski** Jacek	University of Jyväskylä, P.O. Box 35 (YFL),Survontie 9, FI-40014 University of Jyväskylä, Finland	dobaczew@jyu.fi
35	Dr.	**Dressler** Rugard	Laboratory for Radiochemistry and Environmental Chemistry, Paul Scherrer Institute, CH-5232 Villigen, Switzerland.	rugard.dressler@psi.ch
36	Prof.	**El Masri** Youssef	Institute of Nuclear Physics, Universit? catholique de Louvain, Chemin du Cyclotron, 2, B-1348 Louvain-la-Neuve, Belgium	youssef.elmasri@uclouvain.be
37	Dr.	**Endres** Janis	Institut für Kernphysik, Universität zu Köln, Zülpicher Straße 77, D-50937 Köln, Germany	endres@ikp.uni-koeln.de
38	Dr.	**Fallon** Paul	Lawrence Berkeley National Laboratory, Berkeley CA 94720, USA	pfallon@lbl.gov
39	Prof.	**Ferreira** Lidia	Centro de Fisica das Interaccoes Fundamentais (CFIF), Instituto Superior T?cnico (IST), Avenida Rovisco Pais, P1049-001 Lisbon, Portugal	flidia@ist.utl.pt
40	Ms.	**Fisichella** Maria	Università degli Studi di Messina / LNS-INFN, Via S.Sofia 62, 95126 Catania, Italy	fisichella@lns.infn.it
41	Dr.	**Flanagan** Kieran	U. Manchester, School of Physics and Astronomy, Manchester, M13 9PL, UK	flanagan@cern.ch
42	Dr.	**Fotiades** Nikolaos	LANL, Los Alamos, NM 87544, USA	fotia@lanl.gov
43	Ms.	**Foteinou** Varvara	Tandem Accelerator Laboratory, Institute of Nuclear Physics, NCSR "Demokritos", 15310 Aghia Paraskevi, Athens, Greece	foteinou@inp.demokritos.gr
44	Dr.	**Fransen** Christoph	Institut für Kernphysik, Universität zu Köln, Zülpicher Straße 77, D-50937 Köln, Germany	fransen@ikp.uni-koeln.de
45	Asst. Prof.	**Fujimoto** Shin-ichiro	Kumamoto National College of Technology, 2659-2 Suya, Goshi 861-1102, Japan	fujimoto@ec.knct.ac.jp
46	Prof.	**Fujiwara** Mamoru	Research Center for Nuclear Phsyics, Osaka University, Mihogaoka 10-1, Ibaraki 567-0047. Osaka Japan	fujiwara@rcnp.osaka-u.ac.jp

47	Prof.	**Fynbo** Hans	Department of physics and astronomy, Aarhus University, Ny Munkegade 120, 8200 Aarhus C, Denmark	fynbo@phys.au.dk
48	Dr.	**Gadea** Andres	Instituto de Física Corpuscular, CSIC-Universidad de Valencia, Spain	Andres.Gadea@ific.uv.es
49	Prof	**Gales** Sydney	GANIL, Bd H. Becquerel, 14000 Caen, France	gales@ganil.fr
50	Ass. Prof.	**Ganioğlu** Ela	Istanbul University, Science Faculty, Physics Department, 34134 Vezneciler-Istanbul, Turkey	ganioglu@istanbul.edu.tr
51	Prof.	**Garrett** Paul	Dept. of Physics, University of Guelph, Guelph, Ontario, Canada N1G2W1	pgarrett@physics.uoguelph.ca
52	Prof.	**Gomes** Paulo	Instituto de Fisica, Universidade Federal Fluminense, Niteroi, Rio de Janeiro, Brazil	paulogom@if.uff.br
53	Dr.	**Goriely** Stephane	Institut d'Astronomie et d'Astrophysique, ULB, Campus de la Plaine CP226, 1050 Brussels, Belgium	sgoriely@astro.ulb.ac.be
54	Dr.	**Gustavino** Carlo	INFN-LNGS, Laboratori Nazionali del Gran Sasso, Aquila, Italy	carlo.gustavino@lngs.infn.it
55	Prof.	**Guttormsen** Magne	Department of Physics/SAFE, P.O.Box 1048 Blindern, N-0316 Oslo, Norway	m.s.guttormsen@fys.uio.no
56	Dr.	**Hagen** Gaute	ORNL, Physics Division, P.O. Box 2008, Bldg. 6025, M.S. 6373, Oak Ridge, TN 37831-6373, USA	hageng@ornl.gov
57	Prof.	**Harakeh** Muhsin	GSI, Darmstadt, Germany & KVI, University of Groningen, The Netherlands	m.n.harakeh@kvi.nl
58	Dr.	**Harissopulos** Sotirios	Tandem Accelerator Laboratory, Institute of Nuclear Physics, NCSR "Demokritos", 15310 Aghia Paraskevi, Athens, Greece	sharisop@inp.demokritos.gr
59	Mr	**Herzáň** Andrej	University of Jyväskylä, P.O. Box 35 (YFL),Survontie 9, FI-40014 University of Jyväskylä, Finland	anherzan@jyu.fi
60	Prof.	**Herzberg** Rodi	University of Liverpool, Oliver Lodge Laboratory, Oxford Street, Liverpool L69 7ZE, UK	rdh@ns.ph.liv.ac.uk
61	Dr.	**Hilaire** Stephane	ICEA, DAM, DIF, F-91297 Arpajon, France	stephane.hilaire@cea.fr
62	Prof.	**Itkis** Mikhail	Joint Institute for Nuclear Research - JINR, 141980 Dubna, Russia	itkis@jinr.ru

63	Dr.	**Iwata** Yoritaka	GSI Helmholtz Center, Darmstadt	y.iwata@gsi.de
64	Mr.	**Johansen** Jacob	Department of physics and astronomy, Aarhus University, Ny Munkegade 120, 8200 Aarhus C, Denmark	jacobsj@phys.au.dk
65	Dr.	**Jones** Pete	University of Jyväskylä, P.O. Box 35 (YFL),Survontie 9, FI-40014 University of Jyväskylä, Finland	pete.jones@phys.jyu.fi
66	Prof.	**Julin** Rauno	University of Jyväskylä, P.O. Box 35 (YFL),Survontie 9, FI-40014 University of Jyväskylä, Finland	julin@phys.jyu.fi
67	Dr.	**Kahane** Sylvian	Physica Dept, NRCN, P.O.Box 9001, Beer Sheva, Israel, 84190	skahane@bgu.ac.il
68	Prof.	**Kajino** Taka	National Astronomical Observatory, University of Tokyo, 2-21-1 Osawa, Mitaka, Tokyo 181-8588, Japan	kajino@nao.ac.jp
69	Prof.	**Kalantar-Nayestanaki** Nasser	KVI, University of Groningen, Groningen, The Netherlands	nasser@kvi.nl
70	Ms.	**Kanjilal** Debasmita	Saha Institute of Nuclear Physics, Sector-1, Block-AF, Kolkata-700064, India	debasmita.kanjilal@saha.ac.in
71	Prof.	**Karataglidis** Steven	Department of Physics, University of Johannesburg, P.O. Box 524, Auckland Park, 2006, South Africa	stevenka@uj.ac.za
72	Prof.	**Karnaukhov** Victor	Joint Institute for Nuclear Research, Dubna,Moscow Region, 141980, Russia	karna@jinr.ru
73	Dr.	**Koerner** Gabrielle - Elisabeth	NUPECC	Sissy.Koerner@ph.tum.de
74	Mr.	**Konstantinopoulos** Theodore	Tandem Accelerator Laboratory, Institute of Nuclear Physics, NCSR "Demokritos", 15310 Aghia Paraskevi, Athens, Greece	theodorkon@inp.demokritos.gr
75	Mr.	**Kroll** Jiri	Charles University, Prague, V Holesovickach 2, 18200, Prague, Czech Republic	kroll@ipnp.troja.mff.cuni.cz
76	Dr.	**Krtička** Milan	Charles University, Prague, V Holesovickach 2, 182 00 Prague, Czech Republic	krticka@ipnp.troja.mff.cuni.cz
77	Dr.	**Kurcewicz** Jan	GSI, Planckstr. 1, 64291 Darmstadt, Germany	J.Kurcewicz@gsi.de
78	Prof.	**Kvasil** Jan	Institute of Particle and Nuclear Physics MFF UK, Charles University, V Holesovickach 2, 18000 Prague 8, Czech Republic	kvasil@ipnp.troja.mff.cuni.cz

79	Dr	**La Cognata** Marco	INFN-LNS & University of Catania, Via S. Sofia 62, I-95123 Catania, Italy	lacognata@lns.infn.it
80	Dr.	**Lagoyannis** Anastasios	Tandem Accelerator Laboratory, Institute of Nuclear Physics, NCSR "Demokritos", 15310 Aghia Paraskevi, Athens, Greece	lagoya@inp.demokritos.gr
81	Prof.	**Langanke** Karl Heinz	GSI, Planckstr. 1, 64291 Darmstadt & TU Darmstadt, Schlossgartenstr.9, 64289 Darmstadt, Germany	K.Langanke@gsi.de
82	Dr.	**Lanza** Edoardo G.	INFN and Dipartimento di Fisica e Astronomia, Catania, Italy.	lanza@ct.infn.it
83	Dr.	**Larsen** Ann-Cecilie	Department of Physics/SAFE, P.O.Box 1048 Blindern, N-0316 Oslo, Norway	a.c.larsen@fys.uio.no
84	Dr.	**Lawrie** Kobus	iThemba LABS, PO Box 722, Somerset West 7129, South Africa	lawrie@tlabs.ac.za
85	Dr.	**Lawrie** Elena	iThemba LABS, South Africa	elena@tlabs.ac.za
86	Mr.	**Leckey** John	Department of Physics, College of William & Mary, P.O. Box 8795, Williamsburg, VA 23187-8795 USA	jleck5zc@gmail.com
87	Dr.	**Lefebvre-Schuhl** Anne	CSNSM, CNRS/IN2P3, Université Paris-Sud 11, Bât 104, F-91405 Orsay Campus, France,	lefebvre@csnsm.in2p3.fr
88	Dr.	**Lipoglavsek** Matej	Jozef Stefan Institute, Ljubljana, Slovenia	matej.lipoglavsek@ijs.si
89	Dr	**Ljungvall** Joa	CSNSM, CNRS/IN2P3, F-91405 Orsay, France	ljungvall@csnsm.in2p3.fr
90	Prof.	**Lunardi** Santo	INFN and Dipartimento di Fisica, Universita di Padova, Via Marzolo 8, 35131 Padova, Italy	lunardi@pd.infn.it
91	Dr.	**Lubian Rios** Jesus	Federal Fluminense University, Instituto de Fisica, Av. Litornea, s/n, Gragoat?, Niterei, Rio de Janeiro, Brazil, 24210-340	lubian@if.uff.br
92	Dr.	**Madeira Szanto** Eloisa	University of Sao Paulo, Brazil	szanto@if.usp.br
93	Prof.	**Maglione** Enrico	INFN and Dipartimento di Fisica, Universita di Padova, Via Marzolo 8, 35131 Padova, Italy	maglione@pd.infn.it
94	Dr.	**Makii** Hiroyuki	Advanced Science Research Center, Japan Atomic Energy Agency(JAEA), Shirakata Shirane 2-4, Tokai, Ibaraki 319-1195, Japan	makii.hiroyuki@jaea.go.jp

95	Dr.	**Marques** Miguel	LPC-Caen, France	marques@lpccaen.in2p3.fr
96	Dr	**Martel** Ismael	University of Huelva, E-21071 Huelva, Spain	imartel@uhu.es
97	Dr.	**Mertzimekis** Theo J.	Tandem Accelerator Laboratory, Institute of Nuclear Physics, NCSR "Demokritos", 15310 Aghia Paraskevi, Athens, Greece	tmertzi@inp.demokritos.gr
98	Dr.	**Milazzo** Paolo Maria	INFN-Trieste, Trieste, Italy	paolo.milazzo@ts.infn.it
99	Prof.	**Morrissey** David	NCSL, Michigan State University, East Lansing, MI 48824, USA	morrissey@nscl.msu.edu
100	Dr.	**Mohammadi** Saeed	Physics Department, Payame Noor University, Mashad 91735-433, Iran	mohammadi@pnu.ac.ir
101	Dr.	**Montanari** Daniele	University of Milano and INFN Milano	daniele.montanari@pd.infn.it
102	Prof.	**Moshfegh** Hamid Reza	Department of Physics, University of Tehran, North Karegar, Tehran, 1439955961, Iran	hmoshfegh@ut.ac.ir
103	Prof.	**Moya De Guerra** Elvira	Depto. Física Atómica, Molecular y Nuclear,Universidad Complutense de Madrid, Ciudad Universitaria, E-28040 Madrid, Spain.	emoyaval@fis.ucm.es
104	Dr.	**Mücher** Dennis	Technische Universität München, James Franck Str, D-85748 Garching, Germany	dennis.muecher@ph.tum.de
105	Dr.	**Mukha** Ivan	GSI Helmholtz Center, Darmstadt, Germany	I.Mukha@gsi.de
106	Prof.	**Nakada** Hitoshi	Department of Physics, Graduate School of Science, Chiba University, Inage, Chiba 263-8522, JAPAN	nakada@faculty.chiba-u.jp
107	Prof.	**Nesterenko** Valentin	Laboratory of Theoretical Physics, JINR, Dubna, 141980, Moscow region, Russia	nester@theor.jinr.ru
108	Dr	**Niikura** Megumi	IPN Orsay, F-91406 Orsay Cedex, France	niikura@ipno.in2p3.fr
109	Dr.	**Nociforo** Chiara	GSI, Planckstr. 1, 64291 Darmstadt, Germany	c.nociforo@gsi.de
110	Ass. Prof.	**Oktem** Yim	Istanbul University, Science Faculty, Physics Department, 34134 Vezneciler - Istanbul - Turkey	

111	Mr.	**Ono** Masaomi	Department of Physics, Kyushu University, Fukuoka 812-8581, Japan	ono@phys.kyushu-u.ac.jp
112	Prof.	**Otsuka** Takaharu	Department of Physics, University of Tokyo, Hongo, Bunkyo-ku, Tokyo 113-0033, Japan	otsuka@phys.s.u-tokyo.ac.jp
113	Prof.	**Paar** Nils	Physics Department, University of Zagreb, Bijenicka 32, 10000 Zagreb, Croatia	npaar@phy.hr
114	Dr.	**Pakarinen** Janne	CERN-ISOLDE, Building 26, 1-013, CH-1211 Geneva 23, Switzerland	janne.pakarinen@cern.ch
115	Dr.	**Palmerini** Sara	Dipartimento di Fisica, Università degli Studi di Perugia & INFN sezione di Perugia,via Pascoli, I-06123 Perugia, Italy	sara.palmerini@fisica.unipg.it
116	Dr.	**Panebianco** Stefano	CEA Saclay, IRFU/SPhN, F-91191 Gif-sur-Yvette Cedex, France	stefano.panebianco@cea.fr
117	Dr.	**Parikh** Anuj	Physik Dept. E12, TU München, James-Franck-Str., D-85748 Garching, Germany	anuj.parikh@ph.tum.de
118	Dr.	**Piiparinen** Matti	University of Jyväskylä, P.O. Box 35 (YFL),Survontie 9, FI-40014 University of Jyväskylä, Finland	matti.piiparinen@phys.jyu.fi
119	Mr.	**Piot** Julien	IPHC/DRS, 23 rue du Loess, F-67037 Strasbourg, France	julien.piot@ires.in2p3.fr
120	Mr.	**Provatas** George	Tandem Accelerator Laboratory, Institute of Nuclear Physics, NCSR "Demokritos", 15310 Aghia Paraskevi, Athens, Greece	provatas@inp.demokritos.gr
121	Dr.	**Qi** Chong	Royal Institute of Technology (KTH), Alba Nova University Center, 10691 Stockholm, Sweden	chongq@kth.se
122	Dr.	**Rapisarda** Elisa	INFN-LNS, Via S. Sofia 62, I-95123 Catania, Italy	rapisarda@lns.infn.it
123	Dr.	**Rodríguez-Guzmán** Ryner Roberto	Instituto de Estructura de la Materia (IEM), CSIC, Madrid, Spain	rayner@iem.cfmac.csic.es
124	Dr.	**Romano** Stefano	Laboratori Nazionali del Sud - INFN and University of Catania	romano@lns.infn.it
125	Mr.	**Rother** Wolfram	Institute for Nuclear Physics, University of Cologne, Zuelpicher Str. 77, D-50937 Koeln	wrother@ikp.uni-koeln.de
126	Mr.	**Ruotsalainen** Panu	University of Jyväskylä, P.O. Box 35 (YFL),Survontie 9, FI-40014 University of Jyväskylä, Finland	panu.ruotsalainen@jyu.fi

127	Prof.	**Sakai** Hideyuki	RIKEN Nishina Centr, Hirosawa 2-1, Wako, Saitama 351-0198, Japan	hsakai@ribf.riken.jp
128	Prof.	**Sakurai** Hiroyoshi	RIKEN Nishina Centr, Hirosawa 2-1, Wako, Saitama 351-0198, Japan	sakurai@ribf.riken.jp
129	Prof.	**Sarriguren** Pedro	Instituto de Estructura de la Materia, CSIC, Serrano 123, E-28006 Madrid, Spain	sarriguren@iem.cfmac.csic.es
130	Mr.	**Saruwatari** Motoaki	Department of Physics, Kyusyu University, Fukuoka, 812-8581, Japan	saruwatari@phys.kyushu-u.ac.jp
131	Dr.	**Schumann** Dorothea	Paul Scherrer Institute, CH-5232 Villigen PSI, Switzerland	dorothea.schumann@psi.ch
132	Dr.	**Scuderi** Valentina	INFN-Laboratori Nazionali del Sud, via S. Sofia 62, 95123, Catania, Italy	scuderiv@lns.infn.it
133	Prof.	**Sharma** Madan M.	Physics Department, Kuwait University, Kuwait 13060.	sharma@kuc01.kuniv.edu.kw
134	Prof.	**Sharpey-Schafer** John	University of Western Cape, P/B X17 Belleville, ZA-7535 South Africa	jfss@tlabs.ac.za
135	Mr.	**Shirinda** Obed	iThemba LABS, PO Box 722, Somerset West 7129, South Africa	obed@tlabs.ac.za
136	Dr.	**Silvestri** Rosetta	Università degli Studi di Napoli "Federico II" & INFN - Sezione di Napoli, via Cintia, I-80126 Napoli, Italy	rosetta.silvestri@na.infn.it
137	Dr.	**Simon** Haik	GSI, Planckstr. 1, 64291 Darmstadt, Germany	H.Simon@gsi.de
138	Prof.	**Strieder** Frank	Institut für Experimentalphysik, Ruhr-Universität Bochum, Bochum, Germany	strieder@ep3.rub.de
139	Dr.	**Sulignano** Barbara	CEA Saclay, IRFU/SPhN, 91191 Gif/Yvette Cedex, France	barbara.sulignano@cea.fr
140	Ms.	**Susoy** Gulfem	Istanbul University,Faculty of Science, Physics Department, 34134 Vezneciler, Istanbul, Turkey	glfmsusoy972@gmail.com
141	Prof.	**Suzuki** Toshio	Nihon University, Dept. of Physics, College of Humanities and Sciences, Sakurajosui 3-25-40, Setagaya-ku, Tokyo 156-8550, Japan	suzuki@chs.nihon-u.ac.jp
142	Mr.	**Swan** Thomas	University of Surrey, Department of Physics, Guildford, Surrey, GU27XH, United Kingdom	T.Swan@surrey.ac.uk

143	Prof	**Szanto de Toledo** Alejandro	Universidade de Sao Paulo	szanto@dfn.if.usp.br
144	Prof.	**Tchuvil'sky** Yury	Skobeltsyn Institute of Nuclear Physics, Moscow State University, 119991, Moscow, Russia	tchuvl@nucl-th.sinp.msu.ru
145	Prof.	**Tengblad** Olof	Instituto de Estructura de la Materia, CSIC, Serrano 113 bis, E-28006 Madrid, Spain	olof@iem.cfmac.csic.es
146	Prof.	**Thirolf** Peter	Ludwig-Maximilians-Universitaet Muenchen, Am Coulombwall 1, D-85748 Garching	Peter.Thirolf@physik.uni-muenchen.de
147	Mr.	**Torresi** Domenico	Università di Catania & INFN - Laboratori Nazionali del Sud, via S.Sofia 62, 95125 Catania, ITALY	domenico.torresi@lns.infn.it
148	Prof.	**Utsunomiya** Hiroaki	Konan University, 8-9-1 Okamoto, Higashinada, Kobe 658-8501, Japan	hiro@center.konan-u.ac.jp
149	Ms.	**Vancraeyenest** Aurelie	Institut de Physique Nucléaire de Lyon, Université de Lyon, 4 rue Enrico Fermi 69622 Villeurbanne CEDEX FRANCE	a.vancraeyenest@ipnl.in2p3.fr
150	Dr.	**Vesely** Petr	University of Jyväskylä, P.O. Box 35 (YFL),Survontie 9, FI-40014 University of Jyväskylä, Finland	vesely@ipnp.troja.mff.cuni.cz
151	Prof.	**Vlastou** Roza	National Technical University of Athens, Zografou Campus, 15780 Zografou, Greece	vlastou@central.ntua.gr
152	Mr.	**Wendt** Andreas	Institute for Nuclear Physics, University of Cologne, Zuelpicher Str. 77, D-50937 Koeln	a.wendt@ikp.uni-koeln.de
153	Dr.	**Xu** Yi	Institut d'Astronomie et d'Astrophysique, ULB, Campus de la Plaine CP226, 1050 Brussels, Belgium	xuyi@ulb.ac.be
154	Prof.	**Zilges** Andreas	Institute for Nuclear Physics, University of Cologne, Zuelpicher Str. 77, D-50937 Koeln	zilges@ikp.uni-koeln.de