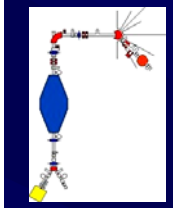


Experimental Nuclear Physics at the Institute of Nuclear Physics of the National Center for Scientific Research "Demokritos" (2/2006)

The INP is one of the 8 institutes of the National Centre for Scientific Research "Demokritos". It was established in 1987 by merging the Nuclear with the Particle Physics groups. The Nuclear Physics group was already formed in the late sixties around a 5 MV Tandem Accelerator Lab. The Tandem delivered the first beams in 1973.

Research Directions

- Nuclear Astrophysics and Reactions
- Nuclear Structure
- Ion-Beam interactions with matter
- X-ray Physics

Scientific Outcome (last 5 years)

- 108 papers in refereed journals
- 9 Ph.D. theses

Current Scientific Personnel

- 4 senior researchers
- 2 postdocs
- 5 Ph.D. students, 4 undergraduates

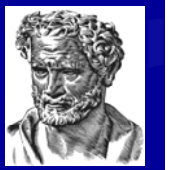
3 retirements (not yet replaced)

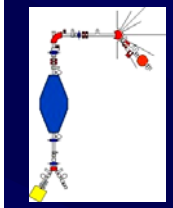
Collaborators in Greece

NTU Athens, NKU Athens, Univ. of Ioannina, Aristotle Univ. Thessaloniki, Univ. Crete
Inst. of Material Science/NCSR "Demokritos"

International Collaborations with

GSI, U. Cologne, U. Bochum, U. Stuttgart, BESSY-II, Fz-Rossendorf, TU-Berlin, JYFL, LN-Legnaro, LNS-Catania, CSNSM-Orsay, ULB-Brussels, CRC/Louvain-la-Neuve, CFNUL-Lisboa, VINCA-Belgrade, Jozef Stefan Inst.-Ljubljana





The 5.5 MV VdG Tandem Accelerator Facility @ INP/NCSR "Demokritos"

The existing laboratory is the successor of a small accelerator lab. established in 1962 around a 400 kV VdG accelerator donated by the IAEA. The first papers published in Nuclear Physics in 1964 came from this lab. The 5.5 MV VdG Tandem delivered the first beams in 1973.


Sources, 30° inflector and LE tube


Tank (HV Generator)


HE tube and Analyzer magnet

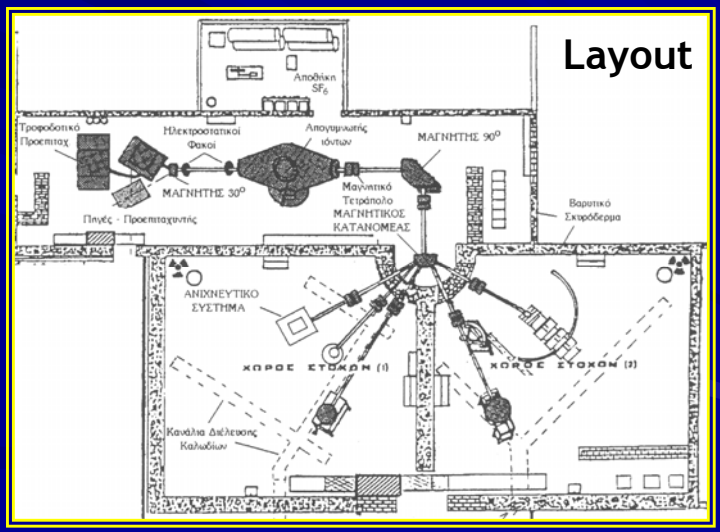
Sources: Sputter & Duoplasmatron

Accelerated beams	Source Current (max)
p	40 μA
d	20 μA
^{4}He	1 μA
Li	1 μA
C	15 μA
O	15 μA
F	1 μA
Ti, V, .. Os	0.5 μA

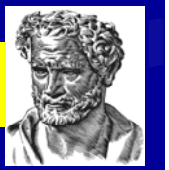
Operation (no PAC)
2500 hrs/year, 65% external users

Basic Research (60%)
Nuclear Astrophysics
Neutron Physics
Nuclear Reactions on light systems

Applied Research (40%)
Materials, Archaeometry,
Environmental studies

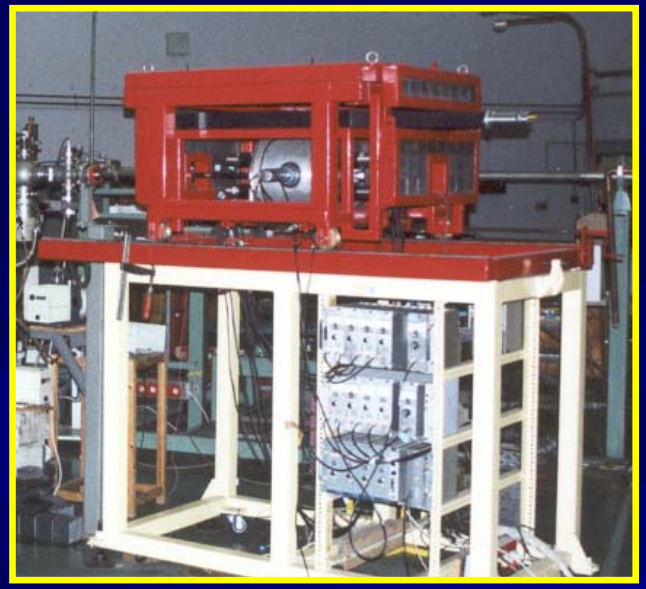


THE ONLY ACCELERATOR FACILITY EXISTING IN GREECE

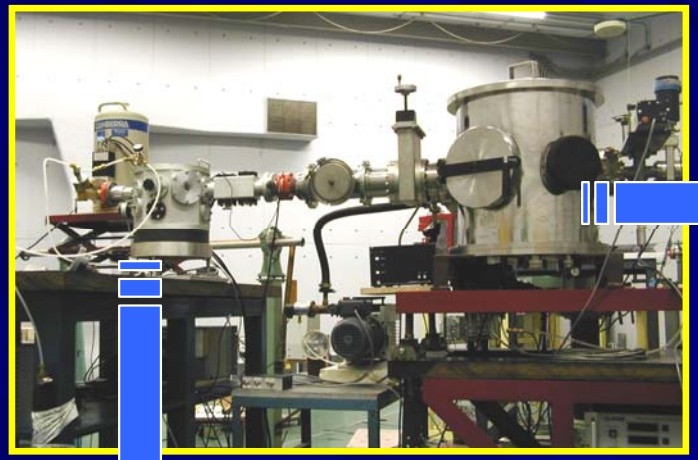


The 5.5 MV VdG Tandem Accelerator Facility @ INP/NCSR "Demokritos"

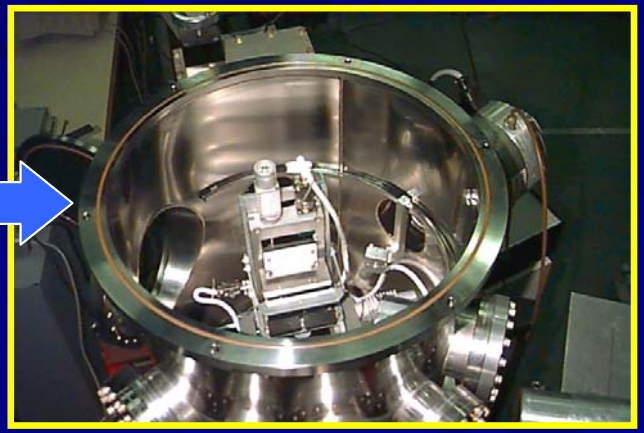
BASIC EXPERIMENTAL TOOLS



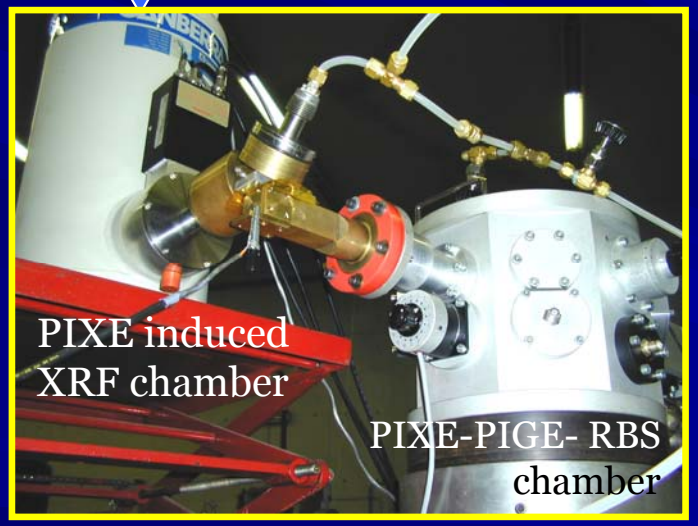
PTOLEMEOS: A 4π NaI calorimeter
(12" × 12" 8-fold segmented crystal)
(Nuclear Astrophysics, ^{15}N profiling)



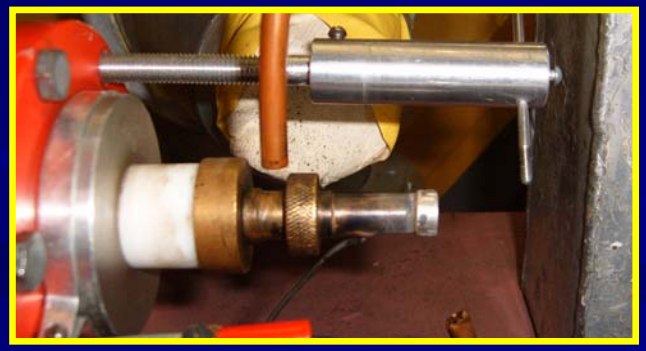
Station for analytical methods



4-axis Goniometer : Accuracy of 0.01° in detector and target positioning
(RBS, Channelling, NRA)

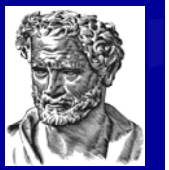


Multipurpose Scattering Chamber
(Particle Spectroscopy, Irradiations)



GAS CELL : monoenergetic neutrons
E_n (MeV) = 0.1 ÷ 0.65 [$^{7}Li(p,n)^{7}Be$]
E_n (MeV) = 4.0 ÷ 12.0 [$^{2}H(d,n)^{3}He$]
$\Phi_n \approx 5 \times 10^6$ n/cm²sec

Particle detectors: Surface barrier det. of various thicknesses
γ-ray detectors: 4 HPGe (80%, 60%, 30%, 20%),
various small-size NaI crystals (3"×3" and 6"×6")



The X-Ray Physics Laboratory @ INP/NCSR “Demokritos”

X-ray sources:

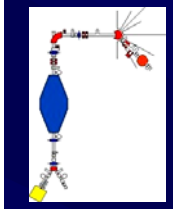
- ✓ Diffraction Mo anode tube 3kW
- ✓ Rh air-cooled low power tube (50 W)
- ✓ Radioactive annular/point sources (^{241}Am, ^{109}Cd)

X-ray detectors:

- ✓ Si(Li) detectors
- ✓ SWTU Si(Li) detector
- ✓ Peltier cooled PIN diodes

Experimental set-ups:

- ✓ Secondary target XRF set-up
- ✓ Total Reflection XRF module
- ✓ Radioisotope Induced XRF set-up
- ✓ Portable XRF spectrometers



Nuclear Astrophysics @ INP/NCSR "Demokritos" *(PREVIOUS WORKS)*

The Nuclear Astrophysics research program was launched in the early nineties. Since then the group has carried out measurements at the Tandem accelerator of "Demokritos" as well as at facilities abroad in collaboration with well-established nuclear astrophysics groups.

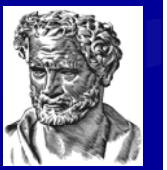
In the first years, the group studied key nuclear reactions relevant to inhomogeneous big-bang nucleosynthesis as well as to the CNO and MgAl cycles.

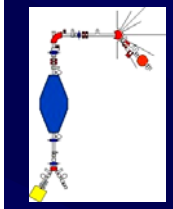
In the mid-nineties, the group actively contributed to the installation of a 250 kV high current accelerator (PAPAP) for nuclear astrophysics applications at CSNSM-Orsay, France.

Until 2000, the group participated in two large Nuclear Astrophysics Networks

a) NATO SCIENCE Network Program SC1-0065 (1990-1993)
b) The NACRE Network supported by the Human Capital and Mobility Programme (1995-1999)
   The latter network produced the famous NACRE Compilation of charged-particle induced thermonuclear reaction rates published in Nuclear Physics A (Vol. 656, 1999, pp. 3-183) and is now a reference work for every nuclear astrophysicist.

1999-2001: Experimental studies of the $^{12}C(\alpha,\gamma)^{16}O$ key reaction in stellar helium burning: Realized at the Dynamitron accelerator of the University of Stuttgart, Germany, within a wide European collaboration (CSNSM, IReS, Stuttgart, Tübingen, Demokritos, KVI, Budapest).
=> First implementation of a multi-detector array (EUROGAM) in Nuclear Astrophysics.





Nuclear Astrophysics @ INP/NCSR "Demokritos"

(RECENT WORK)

RAPID COMMUNICATIONS

PHYSICAL REVIEW C **72**, 062801(R) (2005)

Cross section of the $^{13}C(\alpha, n)^{16}O$ reaction: A background for the measurement of geo-neutrinos

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[2]*Dynamitron-Tandem-Laboratorium, Ruhr-Universität Bochum, D-44801 Bochum, Germany*

[3]*Institut für Strahlenphysik, Universität Stuttgart, D-70569 Stuttgart, Germany*

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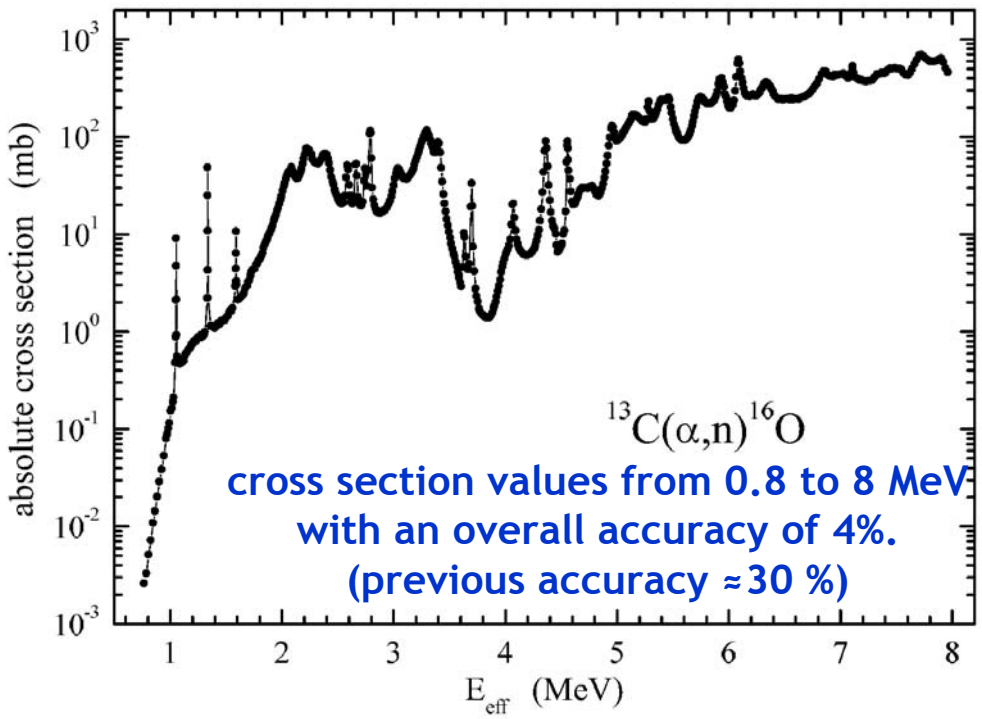
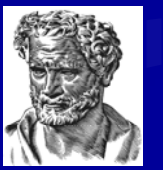
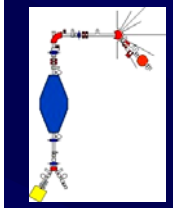
(Received 24 April 2005; published 22 December 2005)



CONCLUSION

With an overall accuracy of 4% for the absolute cross section of $^{13}C(a,n)^{16}O$ one can subtract reliably this background in KamLAND and thus the discovery of geo-neutrinos appears achievable





p-process nucleosynthesis

(PROGRAM RUNNING SINCE 1998)

Motivation: Investigation of nuclear physics uncertainties affecting the modelling of the p process. The large discrepancies between observed and calculated p-nuclei abundances could be the result of unreliable cross-section predictions.

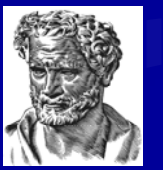
Task: Systematic cross-section measurements of proton and α-capture reactions at sub-Coulomb energies in the Gamow window, to test the reliability of the statistical-model calculations at astrophysics-relevant energies. Improve existing models of nuclear properties entering the statistical model, i.e. Nuclear Level Densities (NLD) and Optical Potentials (OP).

Goal: Derive global (microscopic) models of NLD and OP for large-scale abundance calculations.

In collaboration with:

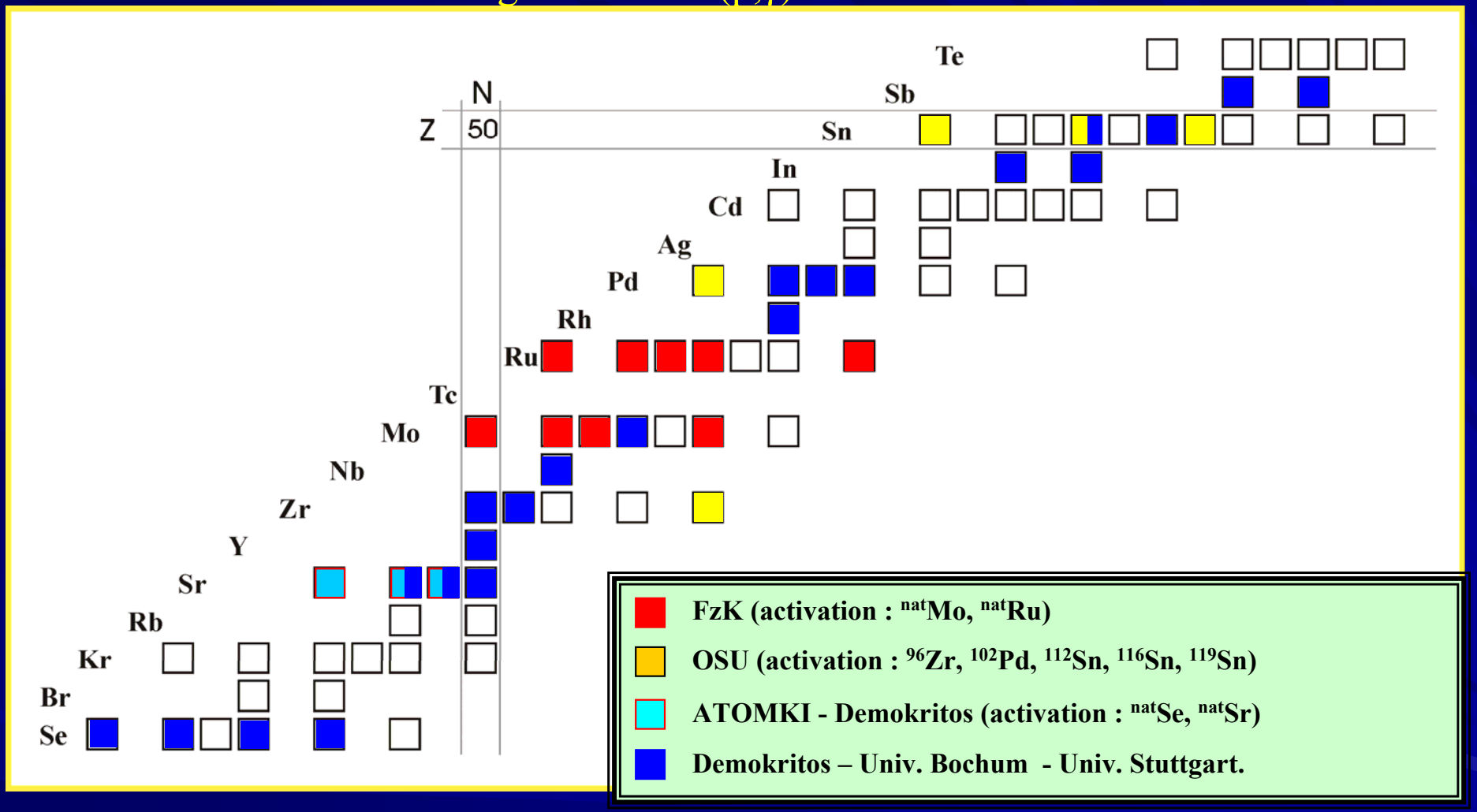
Bochum (C. Rolfs), IAA/ULB (M. Arnould, S. Goriely) and the theory group of INP-Demokritos (P. Demetriou)

Previous collaborators: Stuttgart (W. Hammer), Debrecen (E. Somorjai)

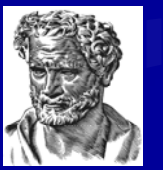


Nuclear Astrophysics @ INP/NCSR "Demokritos"

stable target-nuclei in (p,γ) reactions studied so far

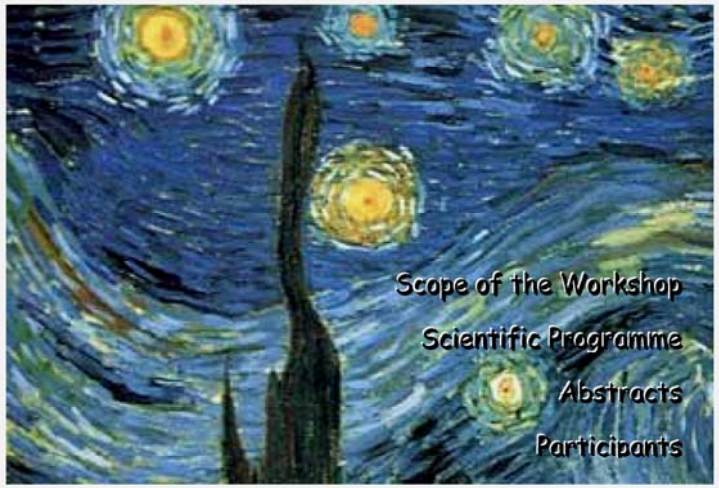


25 (p,γ) and 8 (α,γ) reactions were investigated by the Nuclear Astro*Group of "Demokritos".



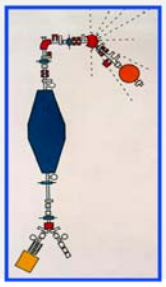
Nuclear Astrophysics @ INP/NCSR "Demokritos"

ESF/PESC Exploratory Workshop on
p-Process Nucleosynthesis
Vravron, Attika, Greece, April 18-21, 2002



CONVENOR
Dr. Sotirios V. Harissopulos
ORGANIZING COMMITTEE
Dr. Paraskevi Demetriou
Dr. Michael Kokkoris

Nuclear Astro*Group, Institute of Nuclear Physics,
National Centre for Scientific Research "Demokritos"
15310 Aghia Paraskevi, Athens, Greece
E-mail: nuastro@inp.demokritos.gr



http://www.esf.org/generic/1362/EW0121PReport.pdf

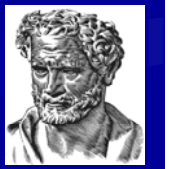
30 Experts from 10 Countries

Belgium – France – Germany
Greece – Hungary – Japan – Italy
Norway – Portugal – Switzerland

16 Institutions – 13 young scientists

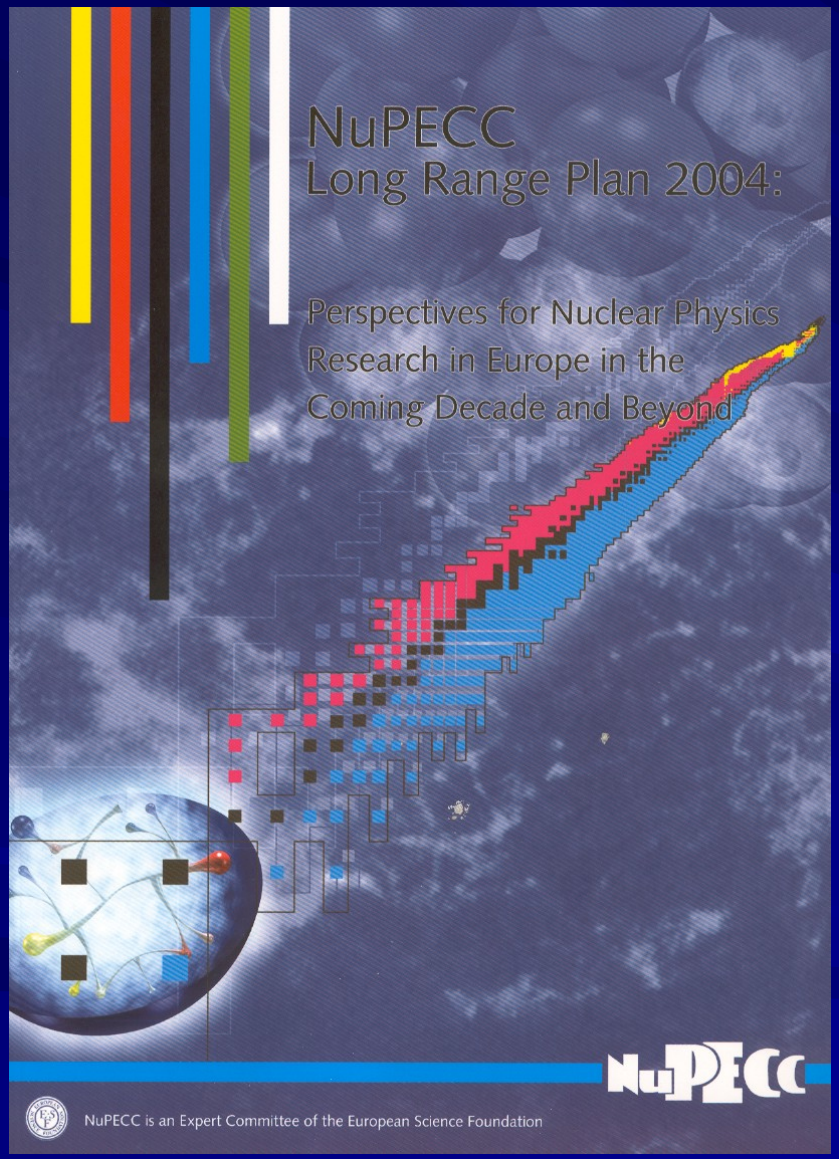
At the end of the round–table discussion the participants concluded that although the European teams working in the scientific domain of heavy-element nucleosynthesis are recognized by the international Nuclear Astrophysics community to have the leading role in this field, the support given so far by the European Community to the European nuclear astrophysics community is in comparison with other scientific communities negligible.

THERE IS A STRONG NEED TO PROCEED WITH A SCIENTIFIC NETWORK AIMING AT COORDINATED REASERCH IN THE FIELD OF HEAVY-ELEMENT NUCLEO-SYNTHESIS



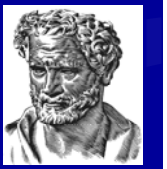
Nuclear Astrophysics @ INP/NCSR "Demokritos"

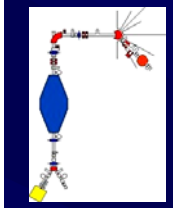
NuPECC Long Range Plan 2004



7. Nuclei in the Universe page 129

Experimental data for charged-particle induced reactions of p-process interest used to be scarce. This situation is largely due to the smallness of the related reaction cross sections at the sub-Coulomb energies of astrophysical interest. However, an important effort has recently been devoted to the measurement of a series of (p,γ) reaction cross sections on medium mass nuclei with $34 \leq Z \leq 51$ at low enough energies to be of astrophysical relevance. These experiments conducted principally at small facilities (Demokritos, Stuttgart) make use of two techniques, the activation method and the in-beam measurements. So far, data are available only for stable targets up to about Sb. A compilation of the present data, as well as an extension of the experimental efforts towards heavier ($Z > 50$) targets would be most valuable in order to better constrain and improve global reaction models (Section 7.7).

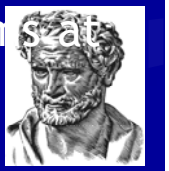


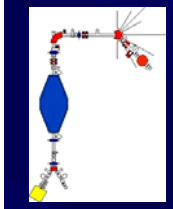


Nuclear Reactions @ INP/NCSR "Demokritos"

Until the late eighties, research was mainly focussed on cross-section measurements of fusion reactions of light ions, like $^{16}O+^{13}C$, as well as on experimental studies on the competition between different exit channels leading to the same residual nucleus in heavy-ion reactions. In the nineties, monochromatic neutron beams were extracted by means of the $D(d,n)^3He$ reaction, which were then used to induce reactions of interest mainly in nuclear astrophysics. In the period 2001-2004, the group participated in the CERN n-TOF collaboration with the aim to provide a reliable cross-section database of (n,f), (n,γ) and (n,xn) reactions. These are necessary for the design of Accelerator Driven Systems (ADS) for the future production of clean and safe nuclear energy as well as for the incineration of nuclear waste. In the framework of n-TOF, the group of INP has performed cross-section measurements on ^{232}Th and ^{241}Am reactions at the Tandem accelerator of "Demokritos" using the activation technique in close collaboration with the National Technical University of Athens.

Since 2004, the latter program has been extended to measurements of isomeric cross section ratios. These ratios are of particular interest as they are governed by the spins of the levels in consideration and theoretical calculations depend strongly on the spin distribution of the nuclear level densities involved. In addition, there is an intense collaboration with the University of Ioannina, Greece, to study the elastic scattering of ^6Li and ^7Li on ^{28}Si. The relevant measurements are performed at the Tandem accelerator of "Demokritos" and aim at mapping the real and imaginary part of the optical potential to probe the so-called threshold anomaly, a phenomenon observed in weakly bound systems at energies around the barrier.



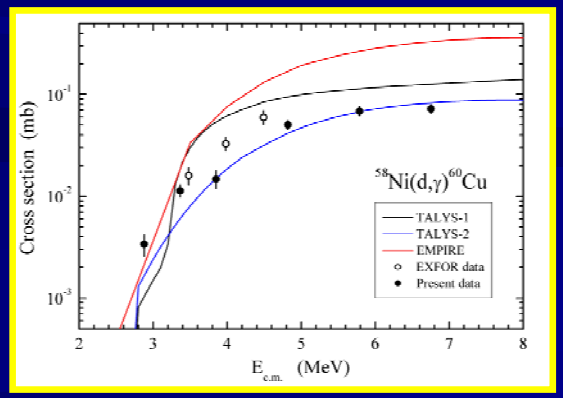


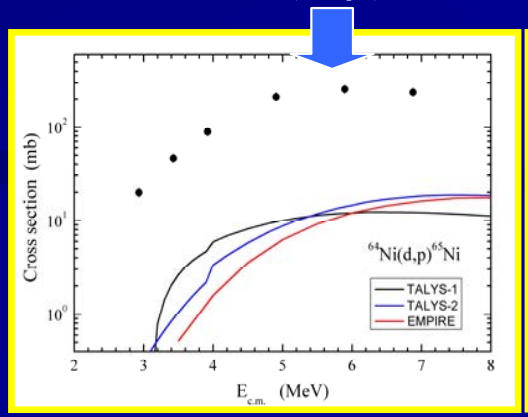
Nuclear Reactions @ INP/NCSR "Demokritos"

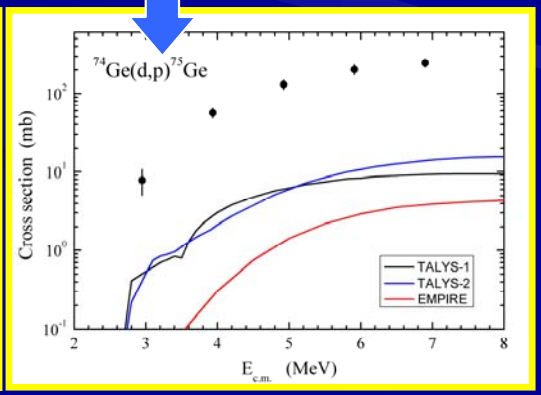
Recently the research activities have included cross-section measurements of deuteron-induced reactions at sub-Coulomb energies.

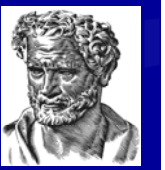
Reactions with light complex particles in the entrance/exit channels have long been recognized as difficult to describe since they involve different reaction mechanisms depending on the energy, such as direct nucleon transfer, knockout, inelastic processes with clusters, and projectile breakup. Although contributions from these processes are expected to become significant at incident energies above a few tens of MeV, in the case of deuteron-induced reactions this is not so. I.e., due to the small binding energy, deuteron breakup effects could be important even at low incident energies.

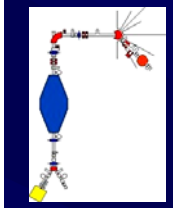
A comparison of the results of the measured (d,γ) and (d,p) cross sections with statistical-model calculations already indicate the possible influence of reaction mechanisms other than the well-understood evaporation process. The agreement between theory and experiment observed in the (d,γ) reaction is in sharp contrast with the discrepancy of almost one order of magnitude obtained in the (d,p) reaction.







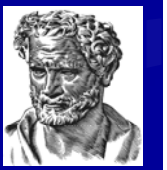


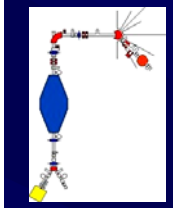


Nuclear Structure @ INP/NCSR "Demokritos" *(PREVIOUS WORKS)*

The first nuclear structure experiments were carried out at "Demokritos" in 1973, following the commissioning of the Tandem VdG accelerator. In the mid-eighties, the nuclear spectroscopy group participated in the first experiments at Daresbury, UK, employing the first γ arrays (TESSA-3, ESSA30). The group continued its high-spin physics activities within various European collaborations using first the EUROGAM and later the EUROBALL multi-detector arrays installed at different large scale facilities (IRES-Strasbourg, France, and later at LNL-Legnaro, Italy). These activities have been jointly carried out with the nuclear spectroscopy group of NTU Athens.

In the period 1999-2003, the group focussed its activities on beta decay studies of N≈Z nuclei around ^{100}Sn, which were carried out at the UNILAC facility of GSI, Germany in collab. with Prof. E. Roeckl. This research program aimed at the study of of the residual proton-neutron interaction in identical orbits ($\pi\nu$-pairing) and the role of core excitations. The mass region around ^{100}Sn provides the best conditions for studying these phenomena that give rise to, e.g . ß-decaying high-spin isomers often referred to as spin-gap isomers, and hence for testing shell-model predictions. The relevant calculations have been provided by L. Skouras (INP).





Nuclear Structure @ INP/NCSR "Demokritos" *(RUNNING ACTIVITIES)*

Search for critical-point (dynamical) symmetries in nuclear structure.

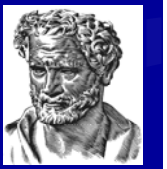
Recently, a new class of dynamical symmetries, the so-called E(5) and X(5) critical-point symmetries were introduced by F. Iachello. These symmetries describe (nuclear) systems that undergo shape-phase transitions. As phase transitions between stable structural limits serve as benchmarks for nuclear structure, their empirical proof is an important and challenging task. The fingerprints of these symmetries can be found in the excitation spectra of candidate nuclei. Transition probabilities offer a more sensitive check. This check is carried out by means of lifetime measurements using the plunger apparatus of the University of Cologne.

Nuclear structure studies @ REX-ISOLDE (since summer 2005).

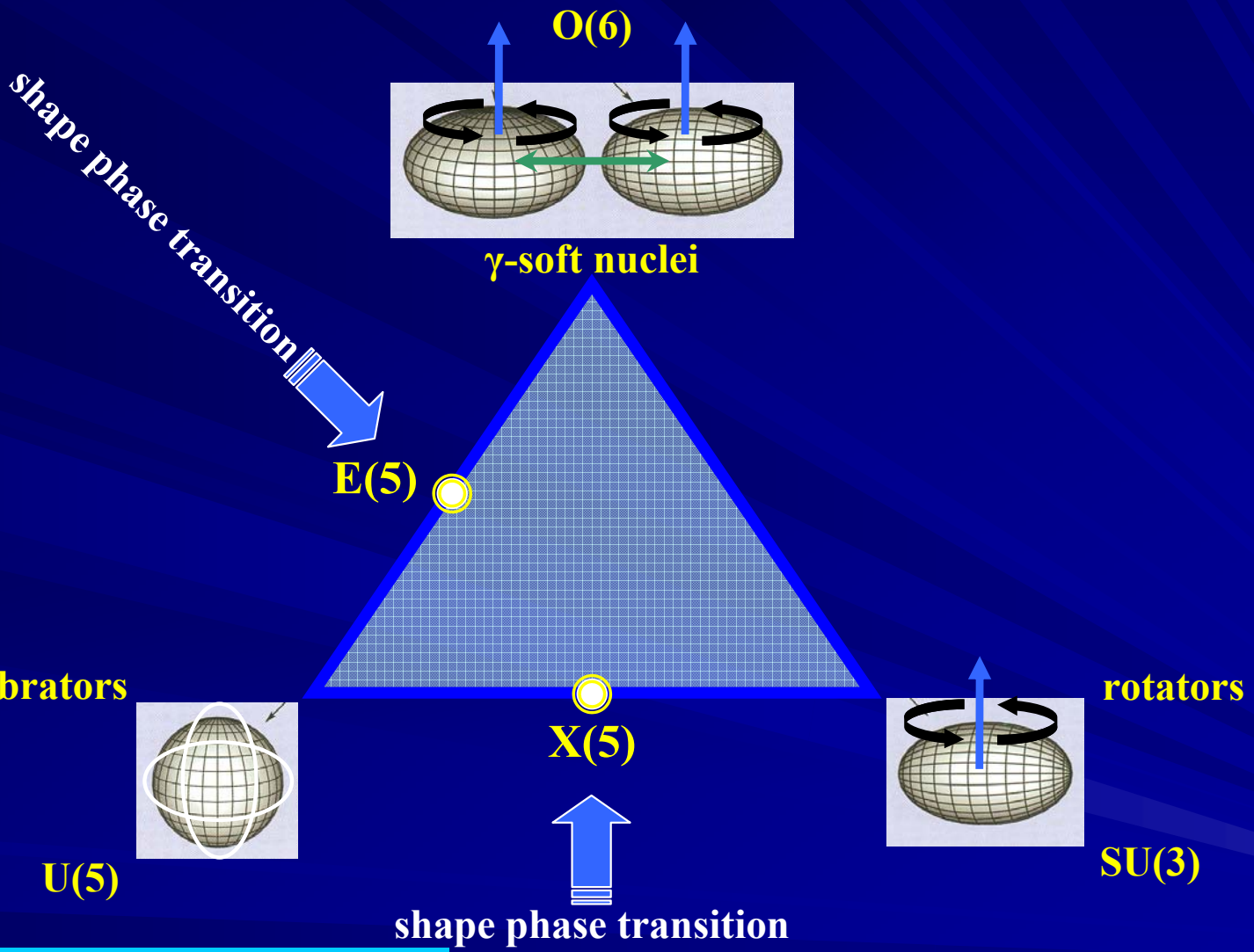
Participation in recent Coulomb excitation measurements of odd-mass and odd-odd Cu isotopes aiming at the determination of proton and neutron effective charges in the N≈40 region using the MINIBALL detector array.

In collaboration with:
Cologne (A. Dewald), JYFL (R. Julin), LNL (G. de Angelis), U-Camerino/Sofia (D. Balabanski), NTU-Athens (R. Vlastou), the nuclear theory group of INP-"Demokritos" (Dr. D. Bonatsos) and KU-Leuven (P. van Duppen) and the MINIBALL collaboration.

2 PhD theses in progress

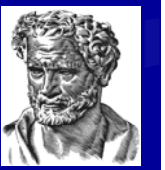


Nuclear Structure @ INP/NCSR "Demokritos" *(RECENT WORK)*



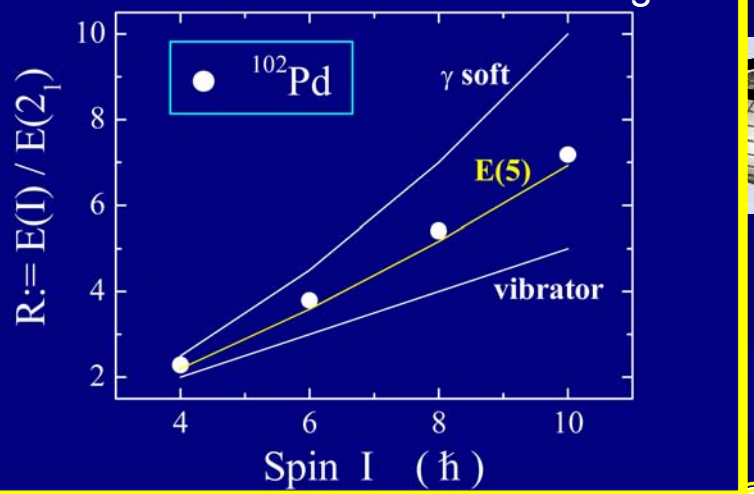
Demokritos-Cologne-LNL-Padova-
NTU Athens-Camerino

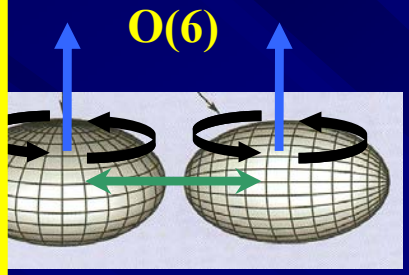
G. Kalyva : Ph.D thesis



Nuclear Structure @ INP/NCSR "Demokritos" *(RECENT WORK)*

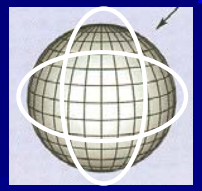
Ground state band: excitation energies





γ-soft nuclei

vibrators



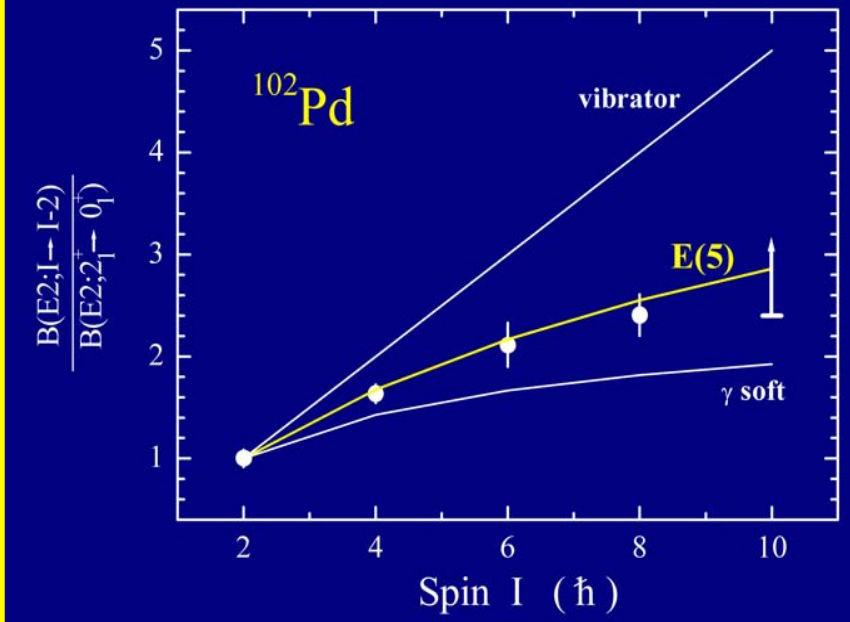
U(5)

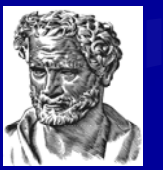
sha

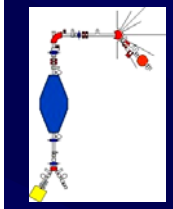
Demokritos-Cologne-LNL-Padova-NTU Athens-Camerino

G. Kalyva : Ph.D thesis

B(E2) Results: Plunger expm. @ GASP - LNL







Experimental Nuclear Physics Research at INP/ NCSR "Demokritos"
(FUTURE ACTIVITIES)

Refurbishing & Upgrade of the TANDEM Accelerator

- New ion sources with PC-based remote control, upgrade of beam lines and installation of 2 new lines,
- Refurbishing of vacuum system, upgrade of Data Acquisition System.

Nuclear Astrophysics & Reactions

Continuation of running activities with emphasis on the α-capture reactions

- Direct measurements of (α,γ) reactions @ INP/Demokritos, Bochum, Cologne.
- Capture reactions in inverse kinematics using stable as well as radioactive ion beams (feasible @ LNL, ISOLDE, CRC Louvain-la-Neuve)

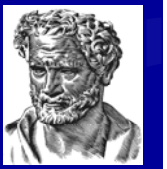
Nuclear Structure

Continuation of running activities @ Large Scale Facilities

on the basis of PAC-approved proposals (next experiment at JYFL, Sept. 2006).

Involvement at FAIR, GSI (MoU signed by Greece)

planned activities within the NUSTAR/HISPEC Collaboration.



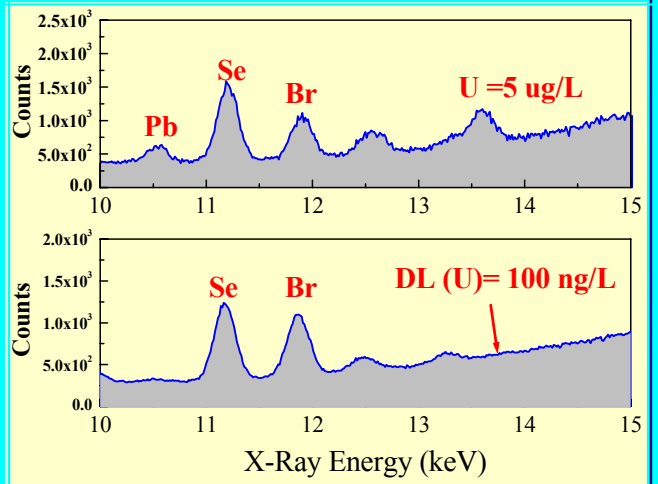
Applications of Nuclear Science @ INP/NCSR "Demokritos" - 1

Biomedicine

Development of novel analytical methodologies for the determination of trace elements in human tissues or fluids using X-Ray fluorescence (XRF) or Ion Beam methods.

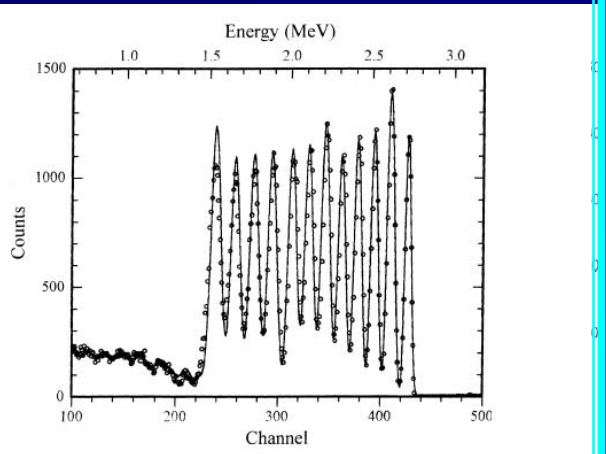
- New method for measuring Uranium in humans in the ppt region !
- Fluorine analysis in human teeth (PIGE)
- Trace metal analysis in human body fluids.
- Monitoring of Pt traces in the blood circulation of mice

Uranium detection in human



Collaborators: Centro de Fisica Atomica, Lisboa – Athens Univ. Med. School – Pharmaceutical Lab. of Univ. of Patras NTU Athens, Univ. Ioannina, IMS/Demokritos, TU Munich, Fz-Rossendorf, Aristotle Univ. Thessaloniki

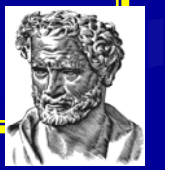
α - RBS spectrum of a UV filter



Materials Analysis and Characterization

Application of standard analytical methods and development of advanced characterization techniques using ion beams.

- Smart glasses
- Superconducting thin films
- Radiation damage in semi-conducting crystals
- Optical filters



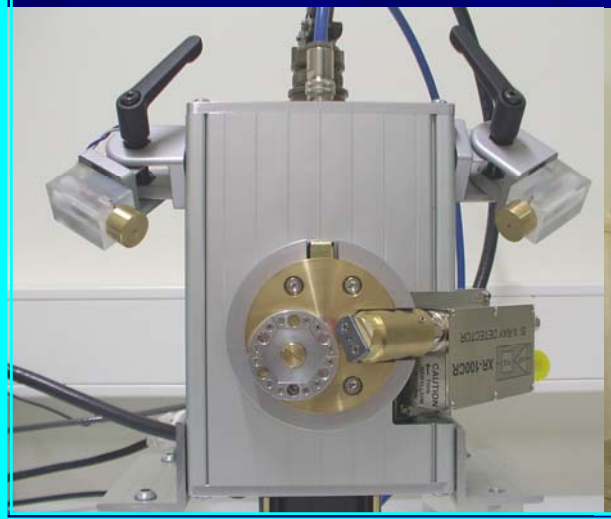
Applications of Nuclear Science @ INP/NCSR "Demokritos" - 2

Archaeometry

Development and application of portable XRF and Ion Beam methods for the non-destructive analysis and characterization of cultural heritage materials.

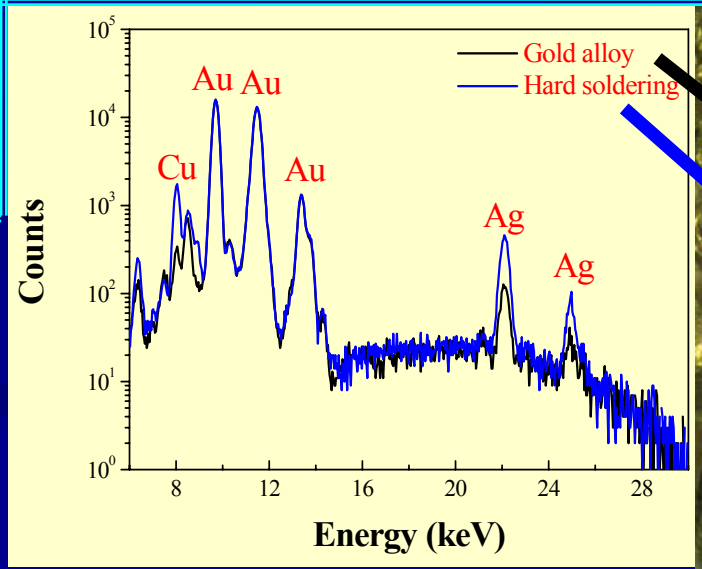
- Development and evaluation of novel portable XRF spectrometers
- Development of analytical methodologies that enhance and optimize the comple-mentary role of various recently developed portable techniques (XRF, XRD, α-PIXE) in archaeometrical and conservation research.
- Ion beam and X-ray methods to assess the laser cleaning efficiency on ancient metals

Development of a portable milli-beam XRF spectrometer

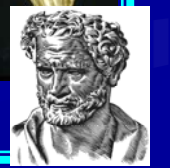


…. identifying traces of pigments on marble statues

Development of a portable semi-μXRF spectrometer

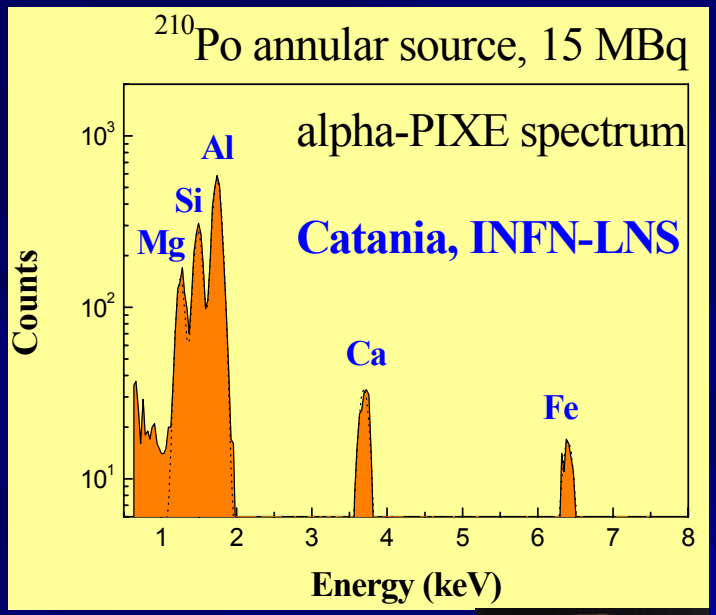


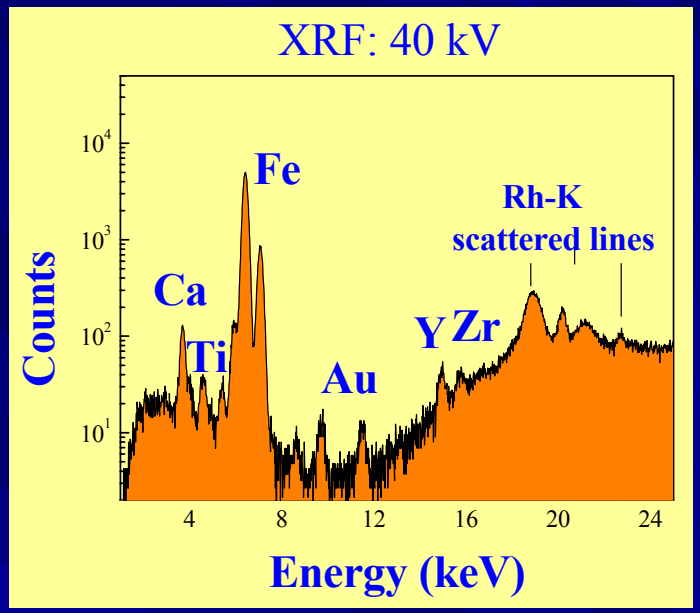
… for identifying ancient soldering techniques



Applications of Nuclear Science @ INP/NCSR "Demokritos" - 3

In-situ combined XRF/α-PIXE analysis of gemstones on ancient jewelry - Benaki musuem

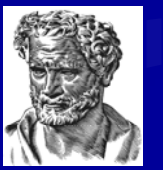


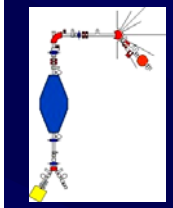


Mg rich garnet Rhodolite

Collaborators in Archaeometry:

Centre de Recherché et de Rastauration des Musees de France, Paris – LNS Catania – Univ. of Waseda, Tokyo TU Berlin – NTU Athens – Dept. of Conservation of Antiquities & Works of Art, T.E.I, Athens – Foreign Archaeological Schools in Athens (French, Italian, American) - Cultural Foundations – Public & Private Museums





Applications of Nuclear Science @ INP/NCSR "Demokritos" - 4

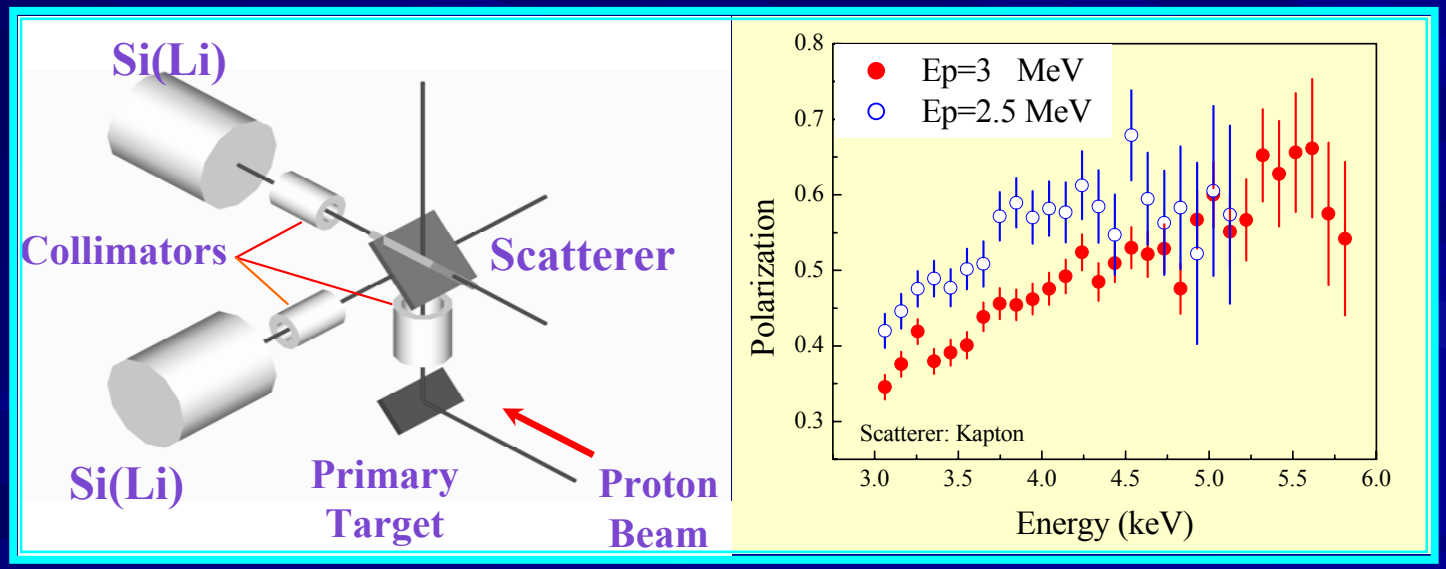
Basic research related to applications

Ion-beam interactions with mater

- Channeling parameters
- Focusing in thin crystals
- Polarization properties of PIXE Bremstrahlung

X-ray interactions with mater

- Secondary Photo-electron Excitation processes
- Resonant Raman Scattering



Collaborators: National Metrology Institute of Germany (PTB, BESSY II) Berlin – VINCA Belgrade
Jozef Stefan Inst. Ljubljana –TU Munich – NTU Athens – Aristotle University of Thessaloniki
Fz-Rossendorf, Germany