

**TEMPLATE**  
**Questionnaire for the preparation**  
**of the EURONS East-West-Outreach Network Activity (EWON)**  
**Report on:**

**“Research Activities of Southeast and Northeast European Nuclear  
Physics Groups at the European Large Scale Facilities: Status and  
Future Possibilities”**

**1. Information about the research group –**

Niewodniczanski Institute of Nuclear Physics PAN, Krakow, Poland  
Prof. dr hab. Rafał Broda (group leader), dr hab. Bogdan Fornal, dr. Wojciech Królas,  
dr Tomasz Pawlat, dr Jacek Wrzesiński  
Nuclear structure and heavy-ion reactions

**2. Collaboration with LSF - INFN LNL Legnaro**

**3. Earlier history of collaboration**

The close collaboration of the INP Krakow spectroscopy groups with the LNL Legnaro physicists developed in earlier common research work in other European laboratories (predominantly in the IKP der KFA Juelich). Since 1978 the direct collaboration started with sequential long term visits (above 2 years) of five young researchers at the LNL Legnaro. Since 1992 our group comes frequently for short visits to Legnaro to perform experiments at the Tandem and ALPI Linac accelerator beams using laboratories experimental facilities. Until 2005 the collaboration was sponsored by the INFN LNL Legnaro funds and Polish Scientific Committee grants. Since 2006 the EURONS funds provide additional support for the continuous collaboration.

**4. Brief summary of the research activity performed by the group within this collaboration since 1996 –**

The research activity was focused on the spectroscopy studies of neutron-rich nuclei using deep-inelastic heavy-ion reactions. Following the earlier (since 1992) investigation of neutron-rich Ni and Te isotopes and high-spin states in nuclei of the  $^{208}\text{Pb}$  region, since 1996 the research was concentrated on yrast structures of nuclei in the region of doubly-magic  $^{48}\text{Ca}$ . In a series of thick target experiments yrast state structures were established in the  $^{48}\text{Ca}$  and all of its closest neighbors, as well as in a number of more neutron-rich nuclei in the region. This investigations were additionally supported by the data from parallel experiments performed with the Gammasphere array at the Argonne NL. The obtained results serve to improve the shell model description in the region and to study the evolution of nuclear structure with increasing neutron-richness. The essential information on the N=32 subshell closure was obtained and recently on the reordering of single particle states which got a new impulse with the new identifications obtained in most recent experiments using the PRISMA-CLARA spectrometer. In parallel analysis of the thick target data the

high-spin states in the neutron-rich Zr, Y and Sr isotopes arising in fusion evaporation reaction are also investigated.

All experimental projects were initiated by our Krakow group and in a more limited scale some of our group members participated in other nuclear spectroscopy projects initiated by others at the LNL Legnaro.

## 5. Experimental facilities used

Tandem and ALPI Linac accelerators, GASP, EUROBALL, PRISMA-CLARA

## 6. Statistical information

- a. number of the group's publications and conference presentations (published in proceedings) resulting from this research collaboration

	1996-2000	2001-2005	2006-
publications	20	18	2
conference presentations	16	18	2

- b. number of experiments performed, estimate of a total amount of beam time, estimate total duration of visits (person/day)

	1996-2000	2001-2005	2006-
experiments	4	2	2
beam time (days)	22	12	8
duration of visits	180	140	100

- c. number of PhD degrees obtained based on research at the given LSF  
none

## 7. Participation in the R&D activity – participation in Joint Research Activities or in any other activity improving the LSFs infrastructure, as well as gains of the EWON groups from LSFs in improving their own laboratories infrastructure

Our group essentially did not participate in the R&D activity and concentrated solely on research using the laboratories infrastructure. One of us (JW) participated in the final stage of efforts starting the PRISMA-CLARA spectrometer operation.

## 8. Additional relevant information

R.Broda – LNL Legnaro User Selection Panel member

## 9. Most important achievements of your group research at the:

### LNL Legnaro

The further development of the method using deep-inelastic heavy-ion reactions for spectroscopy of nuclei not accessible in fusion evaporation reactions

Identification of high-spin states and isomers in  $^{207,208}\text{Pb}$  isotopes

Identification of the effect of the N=32 subshell closure in Ti isotopes

Identification of yrast states in closest neighbors to  $^{48}\text{Ca}$

Establishing the yrast structures of N=30  $^{50}\text{Ca}$  and  $^{51}\text{Sc}$  isotopes

Identification of the structure of neutron-rich  $^{48,49}\text{K}$ ,  $^{51}\text{Ca}$  and  $^{52}\text{Sc}$  isotopes (as the most recent result it is suggested to be selected for presentation in the Report)

## 10. Free remarks on the present organization of this research collaboration and suggestions for the future.

Our fruitful collaboration was based on the mutual scientific interest developed in many years of personal contacts with the INFN LNL Legnaro/Padova University physicists and common research work elsewhere. The very positive approach of the laboratories directors, administration and technical staff was supportive through all years of the collaboration. In this sense the recent years development assigning to the LNL Legnaro the status of the Large Scale Facility, and including it into the funding within European projects, allows to continue our research with better established financial support for the access to perform experiments. The perspectives of enriching the laboratories infrastructure, specifically the further development of the PRISMA-CLARA spectrometer, full operation of the PIAVE Ion-source and future installment of the AGATA detector makes the future collaboration with LNL Legnaro even more attractive.

### **Important remark !**

*In order to place the collaboration with various LSF's in context of all research activity, the report will also include brief outline of the research performed by the NEEN/SEEN groups in other European laboratories and outside Europe. Therefore the groups which are involved in such activity are kindly requested to provide on a separate page the brief information on this, relevant to make the summary of this activity.*

## **Information on collaboration with laboratories other than LSF**

### **Information about the research group –**

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**Prof. dr hab. Rafał Broda (group leader), dr hab. Bogdan Fornal, dr. Wojciech Królas, dr Tomasz Pawlat, dr Jacek Wrzesiński**

**Nuclear structure and heavy-ion reactions**

### **European laboratories**

**Before 1996 the group performed several experiments in JYFL and GSI. Since 1996 the groups research collaboration in Europe was limited exclusively to INFN LNL.**

### **Laboratories outside Europe**

**In the period 1996-2007 the group intensely collaborated with the following US laboratories:**

**Purdue University – extended research visits of 2 scientists (in all 10 month/person)**

**Argonne National Laboratory – 4 experiments with Gammasphere and 1 with Fragment Mass Analyser and Gammasphere and extended measurement of gamma-coincidences with the  $^{248}\text{Cm}$  SF source**

**SLSC Michigan State University – 2 experiments**

**Sponsored by DOE Grants and Polish Scientific Committee grants**

**The research program concentrated on spectroscopy of neutron-rich nuclei not accessible via fusion evaporation reactions. Essentially the thick target technique of deep-inelastic heavy ion reactions was used with the Gammasphere detector array. At the MSU the fragmentation and knock-out reactions were used.**

**Within 1996-2007 scientific results were published in total number of 29 publications (apart from these publications which were counted within the INFN LNL Legnaro collaboration, although involved also results obtained in US experiments)**