Annual Summary Document

Project: PNIII/P5/P5.2 nr. 02/FAIR-RO

Project title: "Nuclear Astrophysics with Indirect-methods and Rare Ion Beams/ NAIRIB"

3rd intermediate report – Jan- Dec 2018
"Evaluation experiments. Carpathian Summer School of Physics 2018"

1. Cover Page

- **Group list (physicists, staff, postdocs, students);**
  The project team was composed by the following members:
  1. Livius TRACHE, Project Director, CS I
  2. Florin CARSTOIU, senior researcher, CS I
  3. Alexandra SPIRIDON, PhD, Research Scientist
  4. Alexandra-Ionela CHILUG, PhD student, Research Assistant
  5. Dana TUDOR, PhD student, Research Assistant
  6. Ionut-Catalin STEFANESCU, PhD student
  7. Iuliana STANCIU, PhD student, Research Assistant
  8. Valentin BALANICA, Fizician
  9. Andreea SUVAILA, financial resp.

- **Specific scientific focus of group**

The focus of the group is **nuclear physics for astrophysics**. In particular, the use of **indirect methods with radioactive beams for nuclear astrophysics** is funded through this project.
We conducted experiments using **nuclear and Coulomb proton breakup** to determine astrophysical reaction rates for radiative proton capture.
Resonance spectroscopy for nuclear astrophysics is another focus of the project. We concentrate now on **beta-delayed proton-decay** and on **gamma-ray spectroscopy**.

Summary of accomplishments during the reporting period

1) The experiment NP1412-SAMURAI29R1, proposed and approved by RIBF PAC in Dec. 2014, took place at RIKEN, Wako, in Japan, between June 1-3, 2018.
2) Early efforts to carry out indirect measurements using the Trojan Horse method for the 12C+12C reaction, was published in the prestigious journal ***Nature*** [1].
3) The experiment "Complete spectroscopy of ^{31}S for nuclear astrophysics", approved by the IFIN-HH PAC in Oct. 2017, was carried out in the last 12 days (Nov. 15-26, 2018) at the Bucharest 9 MV tandem.
4) An experiment proposed for the study the beta-delayed proton-decay of ^{27}P was accepted by our partners and the management at the Cyclotron Institute, Texas A&M University. It is tentatively scheduled for the spring of 2019.
5) Four international meetings were organized by the PD and his NAG group (3 in Romania and 1 in Italy).

2. Scientific accomplishments

This report combines the organizational, personnel, financial and scientific aspects of our work in this year (2018) under this project. In many cases a clear separation between work under this project and other projects or sources of financing is not possible, and I will mention those specifically, where possible.

In 2018, in fact immediately after the previous report, the Nuclear Astrophysics Group (NAG) from the Department of Nuclear Physics (DFN) of IFIN-HH continued its research activities motivated by nuclear astrophysics. The project team was essentially the same as for the 2017 part of this project. Some of the positions of the young members of the group have changed, however, due to progress in their careers. As such:

- Alexandra Spiridon graduated and has obtained her PhD at Texas A&M University, College Station, TX, USA. Following a competition in the summer of 2018 she was promoted to Research Scientist in DFN.
- Ionut STEFANESCU is a PhD student at the Physics Doctoral School of the University of Bucharest.
- Iuliana STANCIU is currently a PhD Student at the Technical University Munich, Germany.
- In 2018, ec. Gherghina STAN has retired and is replaced by ec. Andreea SUVAILA.

NAG continued to work in 2018 in nuclear physics for astrophysics (NPA) **research** and **education and formation.** These were stated in the original proposal as:

a) Work at existing RIB facilities, to test the methods, setups and theories involved
b) Design and realization of experimental setups
c) Not in the last and least, the training of young group members

Research (items a) and b) above) concentrated on (1) the use of **direct measurements** for nuclear astrophysics, conducted at IFIN-HH facilities but not financed by this project and (2) on the use of **indirect methods** with experiments carried out at international facilities and financed mostly through this project. While these may seem formally different, group's activities remained closely intertwined, with their goals well and consistently followed through. The most important achievement of the year was for sure the successful experiment NP1412-SAMURAI29R1 which was conducted in June at RIBF, RIKEN in Wako, Japan. Another is the completion of ASTROBOX2E, a special equipment to study beta-delayed proton emission of exotic nuclei (described last year).

Education and formation (item c) were also in the focus of the project director (PD) of this project and of the group (as per its proposal) and consisted of the continuous formation of its younger members, as well as from activities targeting a broader, international audience. The younger members were or are part in PhD programs, 3 at the Physics Doctoral School of the University of Bucharest and 2 at abroad universities (USA and Germany). As for the broader audience, the PD has organized, with the help of NAG members, four important events in 2018, of which three with wide international participation:

- The ChETEC training school that our group was organizing on April 10-20, 2018, in Magurele. [ChETEC (Chemical Elements as Tracers of the Evolution of Cosmos) is a COST Action (http://www.cost.eu) CA16117 aiming to increase networking of specialists in nuclear astrophysics, star dynamics, nucleosynthesis and observational

astronomy – http://chetec.eu. Participants are from 29 countries. The Project Director was a co-proposer and is a member of its Management Committee; the action was approved by the European program COST in November 2016 and was started in March 2017.] The training school at IFIN-HH was attended by 15 trainees (from master students to post-docs) from across Europe, as intended. Them and 3 international trainers and 2 local trainers were fully supported by ChETEC for an event that got very good grades from all involved. It consisted of lectures and a hands-on experiment at the 3 MV tandetron accelerator and the MicroBequerel laboratory that IFIN-HH has in the Slănic-Prahova salt mine.

- The **Carpathian Summer School of Physics 2018**, Sinaia, July 1-14, 2018 (http://cssp18.nipne.ro/). This event is a periodic one, continuing a tradition of over 50 years. This year's 28th edition had the title: *"Exotic Nuclei and Nuclear/Particle Astrophysics (VII). Physics with small accelerators"*. The PD and 2 of NAG members were the main and most effective of the Organizing Committee. Was attended by close to 100 participants from 4 continents. It was considered an important success. For it we have obtained partial support from the Romanian Ministry of Research and Innovation (MCI), from ENSAR2 NuSPRASEN and from private sponsors. Its Proceedings are being prepared by us for publication with the Conference Series of the American Institute of Physics, one of the most prestigious publishers in our field. On Nov. 28, 2018, we submit the volume to the Publisher and will appear in early 2019.
- The **ECT*workshop "Indirect Methods in Nuclear Astrophysics"**, proposed and organized by the PD at the European Center for Theoretical Studies in Nuclear Physics and Related Areas, Trento, Italy, only a few weeks ago: Nov. 5-9, 2018 (see the webpage https://indico.ectstar.eu/event/27/overview). It was similarly considered a success. ENSAR2 and ECT* were the sponsors of the event.
- The (national) Summer School for Physics Olympics, July 18-6, 2018 in Busteni (http://www.nipne.ro/indico/conferenceDisplay.py?confId=365). This was the 4th yearly edition of this event well appreciated by the about 25 high school students, best in their senior classes, selected from the finalists of the Physics Olympiads. Note: given that at every edition about 5 of the participants were already students accepted at the most prestigious universities of the world (Oxford, Cambridge, Princeton, etc...), these could be considered international events, too!

Note that none of these events were directly financed from this NAIRIB project (except for the partial support for the participation of some group members to some of them), because funds were not available or came from other sources, but they cannot be separated from the activities of the group in the research direction financed by it. They were in the research area financed by this project (and its sister project NUCASTRO2 of UEFISCDI), we both made efforts and benefited from them and as such cannot be ignored in this report. **CSSP18** was in the plans of this project (repeat: no funds were used for its support). The **ECT* workshop** was exactly about the subject of this project. These two events will be described more in detail below. Reports are attached in Appendices.

2. Data evaluation RIBF RIKEN experiment. Carpathian Summer School of Physics 2018/ Evaluare experimente. Scoala de vara CSSP18.

2.1 Data evaluation of RIBF RIKEN experiment. Experiment proposal/ Analiza date experiment la RIBF RIKEN. Propunere experiment la ISOLDE (sau GANIL)

The year 2018 was a good one for the NAG group, with 4 notable achievements listed on Cover page, in addition to the scientific events mentioned above and smaller ones (as for example invitations to lecture or communicate at conferences).
I will only refer briefly to the first two. The latter two are in too early of stages to be described here in detail.

2.1.1 The experiment NP1412-SAMURAI29R1

The experiment was proposed and approved by RIBF PAC in Dec. 2014. Those who know how difficult it is to have an experiment approved at RIBF and then actually carried on, can appreciate this. It took place between June 6-8, 2018 with the participation of the whole group.

The motivation for it was to determine the astrophysical S-factor $S_{18}(0)$ for the radiative proton capture reaction $^{8}B(p,\gamma)^{9}C$ using both nuclear and Coulomb breakup (two different and complementary methods).

I need to mention here, because it was crucial for the success of the experiment, the help NAG has received from the Nishina Center for Accelerator Based Science of RIKEN. Namely, two of the students in NAG have obtained IPA fellowships consisting of support for longer stays at RIKEN:

- Drd. Alexandra Chilug for 6 + 3 months (6 in 2017, 3 in 2018)
- Drd. Dana Tudor for 3 months in 2018.

This was a valuable help, as the students had the opportunity and the time to learn much, to get accustomed to the complex experimental setup around the SAMURAI spectrometer and to work on the equipment that we had to add in order to adapt the setup for this experiment. It was also an important financial support, which allowed for the rest of the group (2 students and me) to go to Japan for about 3 weeks, before, during and after the experiment per se. The travel was supported from this NAIRIB project.

The setup was described in detail in past year's (2017) report in Fig. 1 and 2.. The data analysis is in initial phase: the setup of the analysis environment. A full analysis may take more than a year. I will, therefore, include here only a few details about the results we have so far.

It is worth noting that this was the first run with a proton-rich secondary beam from RIBF. Three other experiments approved in a package known as "HI-p experiments" will be carried out later (probably in 2019), after the results from this first one. Moreover, the proton-rich beam of 9C was obtained from a neutron rich primary beam of ^{18}O at 230 MeV/nucleon (460pnA beam current, very stable). It was very important for us to run this experiment at this time, therefore we accepted the changed conditions (we had proposed 16O as primary beam) and we worked intensely with the RIBF crew to get the best conditions for the secondary beam. In the end we got a stable secondary beam of about 3.7 10^4 pps, with ~91% purity of 9C at 160 MeV/u. Impurities; 8B and 7Be. Specific for these proton-rich experiments is the SSD system: four Silicon Strip detectors with 128 strips each, in pairs of 2 at 35 cm distance, covering 10cm

x 10 cm areas between the target and the SAMURAI spectrometer. They were set at zero degrees, in the beam, and had to measure the core-proton pair. An ASIC based system of Dual Gain Preamplifiers followed by another ASIC based system of shaper-amplifiers HINP16 gave 1024 electronic signals that were added to a few thousands more of the general SAMURAI setup. The system worked. In Figure 1 below it is photographed on the bench (detector and electronics).

Figure 1. The Silicon Strip Detectors system.

The results can be summarized:

- The SSD system worked. We could identify signals from the heavy ions ^{9}C, ^{8}B, ^{7}Be and from the protons.
- We could identify the main channels of ^{9}C breakup: ^{8}B+p and ^{7}Be +2p
- We measured nuclear breakup of ^{9}C on a C target for 5 hours.
- We measured 46 hours of Coulomb breakup of ^{9}C on a Pb target. An exclusive measurement was done.

These are exemplified in Figure 2 below.

At the same time, we are working with the theoreticians who are part of the project Florin Carstoiu (IFIN-HH), Carlos Bertulani (Texas A&M Commerce) and Angela Bonaccorso (INFN Pisa) on the description of these breakup phenomena.

Of valuable importance for the success of the experiment was the support from prof. Tohru Motobayashi (RIKEN) and dr. Valerii Panin (then at RIKEN, now at IRFU Saclay).

Short communications about the experiments were presented by my student Alexandra Chilug at CSSP18 (presentation of the simulations made in preparation of the experiment) and at the ECT* workshop on Indirect Methods in Nuclear Astrophysics, Trento, at the beginning of November. The ^{9}C breakup is a subject part of her thesis.
A communication was selected for oral presentation at the upcoming Nucleus-Nucleus 2018 Conference to be held Dec. 4-8 in Omiya, Japan. It will be presented by Alexandra C. as well.

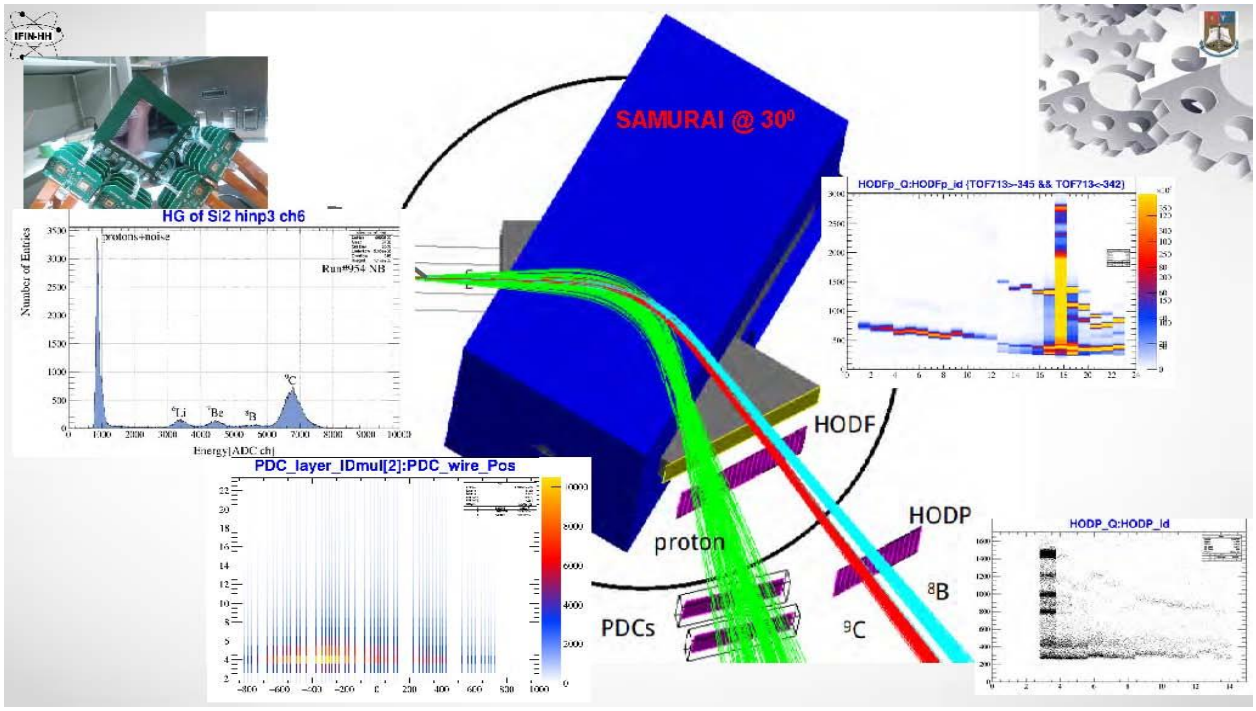

Figure 2. The SAMURAI setup with characteristic spectra from its main components.

2.1.2 Trojan Horse Method for the ^{12}C+^{12}C reaction

^{12}C+^{12}C is a crucial reaction in nuclear astrophysics, one of the most important. Carbon burning influences the fate of massive stars and super-bursts from accreting neutron stars. There is a rich literature of attempts to measure or evaluate the fusion cross section at low energies, which turns out to be dominated by resonances. Most of the direct measurements stop above the Gamow window (however, new attempts are being made). Indirect methods were also used. The Nuclear Astrophysics Group (NAG) at IFIN-HH participated in two of the most recent attempts:

- The study of an adjacent reaction: ^{13}C+^{12}C to evaluate the reaction mechanism at deep sub-barrier energies. This was a substantial joint effort with a group at IMP Lanzhou, China, with experiments at the 3 MV tandetron of IFIN-HH and activity measurements in our ultra-low background laboratory in the Slănic-Prahova salt mine. A paper was submitted to Phys. Rev. Lett. in Sept 2018.
- The use of Trojan Horse Method (THM) to find the resonances involved, down to about E_{cm}=1 MeV, therefore covering the Gamow window for temperatures 1 GK and higher. This project lasted a few years and was conducted with our collaborators from LNS Catania, who are the specialists of THM

Early efforts to carry out indirect measurements using the Trojan Horse Method for the $^{12}C+^{12}C$ reaction started in Bucharest, at the 9 MV tandem. It turned out that the reaction chosen at that time $^{16}O+^{12}C\rightarrow {}^{12}C+^{12}C+\alpha$ was not good for THM: ^{16}O has not a good cluster structure ($^{12}C+\alpha$) in its ground state. The same team used the ^{14}N beam at the Catania tandem accelerator and the result was positive. The ground state of ^{14}N has a cluster structure $^{14}N=^{12}C+d$ and was appropriate for THM. The results are of outmost importance for nuclear astrophysics, discovering several sub-barrier resonances that affect the reaction rate at temperatures of a few GK. The *Nature* paper is in the Appendices at the end of this report.

2.1.3 Complete spectroscopy of 31S

The reaction $^{28}Si(\alpha,n\gamma)^{31}S^*$ was studied at the 9 MeV tandem of IFIN-HH, using a E=22 MeV beam, the ROSPHERE Gamma-ray array with 20 Ge detectors and 5 neutron detectors. These latter are the novelty in this setup and the early analysis make us believe that the experiment was successful. From what we could analyze online, we will have results, and the offline analysis will start soon. This is a resonance spectroscopy subject.

2.1.4 An ASTROBOX2 experiment at Texas A&M University

The success in building and commissioning the ASTROBOX2 detector capable to measure very low-energy protons following beta-delayed proton-decay of exotic nuclei at the MARS separator of the Cyclotron Institute, Texas A&M University (^{23}Al, ^{31}Cl, ^{35}K), allowed us to propose an experiment to measure the decay of ^{27}P. This was measured before with very thin Si detectors [2], which are no sufficiently sensitive at the very low energies important for nuclear astrophysics. No experiments could be proposed now at ISOLDE or GANIL as they are not in operation.

References

[1] A. Tumino et al. **Nature 557**, 687 (2018).

[2] E. McCleskey et al. **Phys. Rev. C 94**, 065806 (2016)

2.2 Carpathian Summer School of Physics 2018

2.2.1 Report on the Carpathian Summer School of Physics 2018

The **Carpathian Summer School of Physics 2018** (http://cssp18.nipne.ro/) was held July 1st - 14th, 2018, in Sinaia, Romania. A full report is presented in Appendix 2. The school was the 28th edition of a long tradition. This year the title of the event was: **"Exotic Nuclei and Nuclear/Particle Astrophysics (VII). Physics with small accelerators"** and was the **7th** in the latest series with the same title organized in Mamaia (2005) and Sinaia (2007, 2010, 2012, 2014 and 2016) and keeping the topic "Physics with small accelerators", which was added in 2016. The school is part of the **European Network of Nuclear Astrophysics Schools (ENNAS)**, together with the **European Summer School on Experimental Nuclear Astrophysics, ESSENA** (Santa Tecla, Italy) and the **Russbach School on Nuclear Astrophysics, RSNA** (Russbach am Pass Gschütt, Austria). ENNAS is endorsed by the Nuclear Physics Board of EPS and is supported by ENSAR2, a project of the European Horizon 2020 program, through NUSPRASEN. The additional flavor brought by the explicit inclusion of subjects related to physics with small accelerators (fundamental or applied research) turned out to be a plus again, because of the exchange of ideas that was facilitated thru the presence of people, experts or beginners, with different competences and interests.

The format of the latest editions was kept: the **first week** of the event was closer to a school-like format defined by a series of courses up to 2 hours each, aimed at graduate students, post-docs and young researchers. The **second week** had a conference-like format, with 1 hour invited lectures. Students and young researchers gave 20 min. short communications (distributed over both weeks). The first day (July 2nd) was dedicated to introductory lectures. Most of the topics related to applications were concentrated in the first week, which included also two days (July 5-6) reserved for the special sessions *"ELI-NP. Status and Perspectives"*. On this occasion many laser specialists from ELI-NP and from outside Romania, have joined the school.

Topics announced were like the ones in past years, including accelerator applications explicitly:

- **Exotic nuclei**
- **Nuclear physics with RIBs**
- **Nuclear physics for astrophysics**
- **Stellar evolution. Neutron stars and supernovae**
- **Astroparticle physics**
- **Stellar and laser induced plasmas**
- **Physics at ELI-NP**
- **Applications at small accelerators**
- **Nuclear astrophysics with small accelerators**
- **Instrumentation**
- **Accelerators for medical treatments, radioisotope production and industrial applications**

The **"Horia Hulubei" National Institute for Physics and Nuclear Engineering (IFIN-HH) Bucharest-Magurele** was the sole institutional organizer of the school.

Organizing Committee:

Livius Trache *and* Ovidiu Tesileanu*: chairs*

Mihai Straticiuc *and* Tiberiu Sava*: scientific secretaries*

Ion Burducea, Alexandra Spiridon, Ionut Stefanescu, Doru Pacesila *and* Dan Ghita

The **International Advisory Committee** established at the end of 2017 was made of reputable scientists and academics, many of which have joined us to present lectures, talk with students and among themselves.

Students from Romania, from the surrounding regions and all countries were invited to attend. A limited number of stipends (8 full + 4 partial) to cover the local expenses for students were available. In total there were 92 participants:

- 58 from Romanian institutions: 4 institutes, 2 universities and 2 companies
- 34 from institutions outside the country: 12 institutes and 21 universities

who presented 70 lectures and 18 student communications (oral, 20 minutes each).

On Saturday July 7 we had the traditional outreach session of the school with the subject: ***"How one prepares the next generation of scientists in the age of instant communication"*** where we invited guests from Romanian academia and media representatives.

One sign of appreciation was that CSSP18 was declared a success by all participants, considering both the quality of science and organization. Participants recommended during the discussions in the Closing session, on Friday, July 14th:

- To continue this school with a new edition in 2020
- To continue its affiliation with ENNAS

See the website for details of the school, including the program, list of participants, lecturers, their presentations and the closing remarks at the indico website: http://www.nipne.ro/indico/getFile.py/access?sessionId=95&resId=0&materialId=0&confId=368 Most of this work was done by members of the NAG group.

Sponsors of the school were *IFIN-HH as organizing institutions*, the *Romanian Ministry for Research and Innovation (MCI)* and ENSAR2 through *the NUSPRASEN network.* Very important for the school and the participants of many students was the fact that we attracted private sponsors: *CAEN, Wiener, Canberra, Coralgon, Pfeiffer, BSI, Bruker, Total SpectruM, iseg, Quantech Works* (logos below). Moreover, most of the participants were supported by their respective institutions, a fact which contributed to existence and the success of the school and which makes these institutions be our sponsors too.

The Proceedings of CSSP18 will be published again with the prestigious "AIP Conference Proceedings" series of the American Institute of Physics AIP Conference Proceedings, in Open Access. Our NAG group has 4 articles accepted in this publication, which is ISI listed.

2.2.2 ECT*workshop "Indirect Methods in Nuclear Astrophysics"

This event was not included in the initial proposal of this project and was not explicitly supported financially by it. However, its subject was exactly that of the project and the PD as Organizer-Coordinator and one of group members (Alex Spiridon) were instrumental in its organization and success. We include a brief report on it here. Full report in Appendix 3.

Objectives

The workshop proposed to bring together physicists working in various fields of, or close to, nuclear astrophysics. Theoreticians and experimentalists were to meet with the purpose of identifying stellar scenarios needing nuclear reaction data that make sizable difference in stellar

evolution and the optimal methods to obtain them, to identify the most promising indirect methods in nuclear astrophysics, to discuss their specifics and to assess their reliability. We wanted a broad discussion to review the existing indirect methods, assess the problems with their accuracy and emphasize the need for modern codes and assess the sets of parameters to use in calculations. Such discussions are crucial for reliably using indirect methods for nuclear astrophysics and even to validate the very existence of many Rare Isotope Beams facilities which rely on them as one of as their main areas of research. To review the importance of nuclear physics in cosmology and stellar evolution was another important objective.

Achievements

The meeting succeeded in its major intention: to reunite scientists working in nuclear astrophysics, a research domain that now consists or is close to: nuclear physics for astrophysics, stellar dynamics, nucleosynthesis modeling, specific astronomy observations, cosmology. Talks were given to review the status of different subjects of common interest, as well as talks on detailed specific cases encountered in the use of indirect methods for nuclear astrophysics. There were talks on: nuclear astrophysics for practitioners, nuclear data needs, stellar dynamics, nucleosynthesis modeling, observations. Existing indirect methods in nuclear astrophysics were discussed: “the list” of indirect methods, their specifics, assessment of problems with their use, importance of calculated absolute values, codes, etc. Review of experimental methods, equipment and specifics as well as new facilities, including RIB facilities, and their nuclear astrophysics programs, were included. New directions were touched upon.

The assistance from the local support staff of ECT* was excellent.

The support under ENSAR2 Networking Activity NuSPRASEN and TNA10 ECT* was an important contribution to the success of the workshop.

3. Group members

Project NAIRIB

Nr.	Name	Position in project	Professional rank	Profession	FTE
1	Livius TRACHE	Project Director	CS1	physicist	0.8
2	Florin CARSTOIU	senior researcher	CS1	physicist	0.2
3	Alexandra SPIRIDON	Team member	CS, PhD.	physicist	1
4	Alexandra CHILUG	Team member	AC	physicist	1
5	Dana TUDOR	Team member	AC	physicist	1
6	Ionut STEFANESCU	Team member	AC	physicist	1
7	Iuliana STANCIU	Team member	AC	physicist	0.2
8	Valentin BALANICA	Team member	physicist	physicist	0.7
9	Andreea SUVAILA	Team member	Ec.	economist	0.1

AC = Research Assistant
CS1 = Senior Researcher 1

Group members who are students:

Four students, all graduated their master studies and are PhD students now and during whole 2018 year

1. Alexandra-Ionela CHILUG, PhD student, Research Assistant
2. Dana TUDOR, PhD student, Research Assistant
3. Ionut-Catalin STEFANESCU, PhD student, Research Assistant
4. Iuliana STANCIU, PhD student, Research Assistant

As of Nov. 2018

4. List of new publications and conference presentations

4.1 Publications

I include here papers published in 2018 (till Nov. 29) and papers shown on Web of Science webpage http://apps.webofknowledge.com as published after the previous year's report.

1. A. Tumino, C. Spitaleri, M. La Cognata, S. Cherubini, G. L. Guardo, M. Gulino, S. Hayakawa, I. Indelicato, L. Lamia, H. Petrascu, R. G. Pizzone, S. M. R. Puglia, G. G. Rapisarda, S. Romano, M. L. Sergi, R. Spartá & L. Trache, **Nature 557** Issue: 7707 Pages: 687 (2018) **https://doi.org/10.1038/s41586-018-0149-4**
   An increase in the C-12+C-12 fusion rate from resonances at astrophysical energies
2. N. Zhang, … D. Tudor, A.I. Chilug, I.C. Stefanescu, M. Straticiuc, I. Burducea, D.G. Ghita, R. Margineanu, C. Gomoiu, A. Pantelica, D. Chesneanu, and L. Trache et al, submitted to **Phys Rev Lett**. Sept 2018.
   Constraining the 12C+12C astrophysical S-factors with the 13C+12C measurements at very low energies
3. I.C. Stefanescu, A. Spiridon, L. Trache, E. Pollacco, A. Saastamoinen, B. Roeder, J. Phys.: Conf. Ser. 1024, 012007 (2018)
   AstroBox2E: a detection system for very low energy β-delayed proton decay
4. Trache, Livius, in Conference: 8th International Conference on Nuclear Physics in Astrophysics)NPA) Location: Lab Nazionali Sud, Catania, ITALY Date: JUN 18-23, 2017, NUCLEAR PHYSICS IN ASTROPHYSICS VIII (NPA8 2017) Book Series: EPJ Web of Conferences Volume: 165 Article Number: UNSP 02007
   "Other" indirect methods for nuclear astrophysics
5. Burjan, V.; Hons, Z.; Kroha, V.; L. Trache et al., in Proc. 8th International Conference on Nuclear Physics in Astrophysics NPA8, Lab Nazionali Sud, Catania, Italy, JUN 18-23, 2017. NUCLEAR PHYSICS IN ASTROPHYSICS VIII (NPA8 2017) Book Series: **EPJ Web of Conferences** Volume: **165**, Article Number: UNSP 01007
   The astrophysical S-factor of the direct O-18(p, gamma)F-19 capture by the ANC method
6. B. Fernández-Domínguez, L. Trache et al., **Phys. Lett. B 779**, 124-129 (2018)
   Re-examining the transition into the N=20 island of inversion: Structure of Mg-30
7. B. Fernández-Domínguez, … L. Trache et al., **Journal of Physics Conference Series** Volume: **966** Article Number: UNSP 012020 Published: 2018
   How sharp is the transition into the N=20 island of inversion for the Mg isotopes ?
8. Dana Tudor, A.I. Chilug, I.C. Stefanescu, A. Spiridon, M. Straticiuc, I. Burducea, L. Trache, R. Margineanu, in "Exotic Nuclei and Nuclear/Particle Astrophysics (VIII). Physics with small accelerators", Proceedings CSSP18, AIP Publishing, Melville, NY, accepted Nov. 2018
   Experimental study of the α+ 64Zn reaction in the Gamow region
9. Alexandra Spiridon et al – in "Exotic Nuclei and Nuclear/Particle Astrophysics (VIII). Physics with small accelerators", Proceedings CSSP18, AIP Publishing, Melville, NY, accepted Nov. 2018
   Elastic studies with the upgraded TAMU-MDM detector

10. Alexandra Chilug et al – in "Exotic Nuclei and Nuclear/Particle Astrophysics (VIII). Physics with small accelerators", Proceedings CSSP18, AIP Publishing, Melville, NY, accepted Nov. 2018
    Study of the ^{9}C breakup through the NP1412-SAMURAI29R1 experiment
11. Ionut Stefanescu – in "Exotic Nuclei and Nuclear/Particle Astrophysics (VIII). Physics with small accelerators", Proceedings CSSP18, AIP Publishing, Melville, NY, accepted Nov. 2018
    AstroBox2E: A detection system for very low energy beta-delayed proton decay

We include pdf copies of articles 1, 3 and 4 at the end of the report, in Appendices.

4.2 Conference participations and presentations

1. L. Trache – NuSPRASEN workshop on nuclear reactions, Warsaw, Jan. 2018: Invited talk *Indirect methods in Nuclear Astrophysics*
2. L. Trache, 15th Russbach Winter school on nuclear astrophysics, in Russbach, Austria. March 18-24, 2018. Invited lecture *Nuclear Astrophysics at IFIN-HH.*
3. A. Spiridon, 15th Russbach Winter school on nuclear astrophysics, in Russbach, Austria. March 18-24, 2018. Communication. Supported by ChETEC.
4. A. Chilug, 15th Russbach Winter school on nuclear astrophysics, in Russbach, Austria. March 18-24, 2018. Communication. Supported by ChETEC.
5. D. Tudor, 15th Russbach Winter school on nuclear astrophysics, in Russbach, Austria. March 18-24, 2018. Communication. Supported by ChETEC.
6. I. Stefanescu, 15th Russbach Winter school on nuclear astrophysics, in Russbach, Austria. March 18-24, 2018. Communication. Supported by ChETEC
7. A. Spiridon, CSSP18, Sinaia, July 1-14, 2018. Communication *Elastic studies with the upgraded TAMU-MDM detector*.
8. A. Chilug, CSSP18, Sinaia, July 1-14, 2018. Communication *Study of the ^{9}C breakup through the NP1412-SAMURAI29R1 experiment*
9. D. Tudor, CSSP18, Sinaia, July 1-14, 2018. Communication *Experimental study of the α+ 64Zn reaction in the Gamow region*
10. I. Stefanescu, CSSP18, Sinaia, July 1-14, 2018. Communication *AstroBox2E: A detection system for very low energy beta-delayed proton decay*
11. L. Trache, Debrecen workshop, Sept. 2018. Invited talk *Nuclear Astrophysics at IFIN-HH*. Supported by ChETEC
12. A. Chilug, Debrecen workshop, Sept. 2018. Supported by ChETEC
13. D. Tudor, Debrecen workshop, Sept. 2018. Supported by ChETEC
14. L. Trache, ECT* workshop. Organizer. Supported by ENSAR2
15. A. Spiridon, ECT* workshop. Organizer. Communication. Supported by ENSAR2
16. A. Chilug, ECT* workshop. Communication. Supported by ENSAR2.
17. A. Chilug, Nucleus-Nucleus Conference 2018, Omiya, Tokyo, Japan, Dec. 4-8, 2018. Oral presentation *Nuclear breakup and Coulomb dissociation of 9C nucleus studied at RIBF RIKEN*
18. L. Trache, Nucleus-Nucleus Conference 2018, Omiya, Tokyo, Japan, Dec. 4-8, 2018. Oral presentation

5. List of Appendices

Appendix 1: reports on the formation and education events:
ChETEC training school, CSSP18, ECT* IMNA and CRR2.
Appendix 2: papers published in 2018 or submitted for publication
Papers # 1, 3, 4

Consideram ca obiectivele fazei au fost pe deplin indeplinite.

Director de proiect,
Dr. Livius Trache