ANEXA VII – Raport final de activitate

RAPORT FINAL DE ACTIVITATE

Denumirea proiectului	**"Nuclear Astrophysics with Indirect-methods and Rare Ion Beams/ NAIRIB"**
Numar de contract	C02 Project: PNIII/P5/P5.2 nr. 02/FAIR-RO
Conducator de proiect	Institutul de Fizica si Inginerie Nucleara "Horia Hulubei" (IFIN-HH)
Perioada raportata	16.09.2016 – 15.12. 2019
Numar total de pagini	

.

Raportul conține Secțiunea 1 – ***Raport științific final*** și Secțiunea 2 – ***Raport explicativ al cheltuielilor***. (La predare, Raportul se prezinta și pe suport electronic.)

Subsemnatul *Nicolae V. Zamfir* in calitate de reprezentant legal autorizat al *Institutului de Fizica si Inginerie Nucleara "Horia Hulubei" (IFIN-HH)*, declar, pe proprie raspundere, ca datele furnizate prin prezentul Raport de activitate sunt reale si ca toate cheltuielile s-au efectuat in mod exclusiv pentru realizarea si in conformitate cu prevederile contractului nr. C02 finantat prin PN III/Programul 5/Subprogramul 5.2/Modulul FAIR-RO

Reprezentant legal al Conducatorului de proiect,
Director General IFIN-HH
Acad. Nicolae V. Zamfir

Director Proiect,

Dr. Livius Trache

Data 12.12.2019

Director Economic,

ec. Alexandru Popescu

RAPORT ŞTIINŢIFIC FINAL

Raportul stiintific final va cuprinde urmatoarele documente:

1. Rezumat publicabil in limbile romana si engleza (maxim 3 pagini) din care sa rezulte principalele rezultate, activitati, gradul de noutate si impactul preconizat asupra mediului stiintific, tehnic, economic, social si didactic.
2. Indicatori de realizare finala, conform modelului din Anexa 1.B – reprezinta suma tuturor indicatorilor din rapoartele intermediare.
3. Protocol de finalizare a proiectului, conform modelului din Anexa 1.D.

C02 Project: PNIII/P5/P5.2 nr. 02/FAIR-RO

Final scientific report (English)

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

The focus of the Nuclear Astrophysics Group (NAG) at the Department of Nuclear Physics (DFN) from IFIN-HH is **nuclear physics for astrophysics.**

As per the proposal of 2016, the goals of the grant were three-fold:

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

Scientific accomplishements

Work at existing RIB facilities, to test the methods, setups and theories involved

While the group is using also direct measurements, the use of **indirect methods with radioactive beams for nuclear astrophysics** is mostly funded through this project.

So far different reactions were our focus. During the period covered by this grant we conducted experiments at existing RIB facilities using:

1. **nuclear and Coulomb proton breakup of $^{9}C \rightarrow {}^{8}B + p$** to determine astrophysical reaction rates for the reaction $^{8}B(p,\gamma)^{9}C$. This experiment was carried out at RIBF facility of RIKEN, Wako, Japan.
2. **resonance spectroscopy** for the reactions $^{30}P(p,\gamma)^{31}S$ and $^{26}Al(p,\gamma)^{27}Si$. We studied the spectroscopy of ^{31}S and ^{27}Si through the **beta-delayed proton-decay of ^{31}Cl and ^{27}P.** These experiments were carried out at the Cyclotron Institute, Texas A&M University (TAMU), in College Station, TX, USA.
3. **Trojan Horse Method (THM)** for the indirect study of $^{12}C+^{12}C$ and $^{12}C+^{16}O$ reactions at stellar relevant energies. While for the first reaction several papers were published, the experiment for the latter was only carried out in Oct. 2019. These were led by the THM Catania group, longtime collaborators, and the experiments were carried out at the LNS tandem accelerator.

Publications resulted in each of these 3 topics of experimental activities, some containing final results, some only preliminary or partial ones. All in collaboration, at outside radioactive beam facilities: for items 1) and 2), we were the leading experimenters, for 3) our LNS collaborators were the leaders. The publications ranged from those in volumes of proceedings of conferences (FAIRNESS 2017, ESSENA 2017 and 2019, CCSP18, Nucleus-Nucleus Collisions 2018, etc.), to those in regular nuclear physics journals, to one publication in the prestigious journal *Nature*. The NAG list of publications 2016-2019 is included at the end of the report.

In addition, NAG or its members participated in many other national and international activities - experiments, data analyses or meetings - related to the topic of this grant: nuclear astrophysics. In this time, internationally important meetings were organized by the Project Director (PD) and the NAG group, notable here inspite of not being financed thru this grant: a COST ChETEC CA16117 training school in April 2018, the Carpathian Summer School of Physics 2018, an ECT* workshop "Indirect Methods in Nuclear Astrophysics" in 2018, in Trento, Italy. Proposals for the next editions of each of these 3 events were prepared during the latter part of 2019 and are approved for 2020.

At the point "test methods and theories", we should include the work done in collaboration with prof. F. Carstoiu of DFT on theories to be used for the interpretation of the results of indirect methods, those 4 papers published on the topics of optical potentials (see list).

Design and realization of experimental setups

For topics 1) and 2) above, the actual experiments implied also the design and realization of instrumentation: a Silicon detection system for tracking reaction products in front of the SAMURAI spectrometer at RIBF and the realization of the ASTROBOX2 detector at TAMU, including an European version ASTROBOX2E. Both systems were realized and tested in satellite experiments, like those at the HIMAC accelerator in Chiba, Japan and at TAMU. They were described in the Annual Summary Documents.

Formation and Education. Outreach

At the start of this NAIRIB project the group was formed of two senior scientists and 5 students. Listing the status changes of them can best illustrate the work in the direction of education and formation. In the period covered by it:

- 4 of the initial students have obtained master's degrees
- All 4 were later admitted at the Doctoral School of Physics of the University of Bucharest and are in final stages of their thesis work (on group's topics)
- Alexandra Spiridon, a new member of the group since Feb. 2017, obtained here PhD at Texas A&M University in Dec. 2017 and
- In 2018 was appointed as post-doc and then as junior Research Scientist (CS) in the Department of Nuclear Physics (DFN) of IFIN-HH
- Madalina Ravar, a student at Faculty of Physics of the University of Bucharest (not financed in this grant) obtained her licence diploma with work in NAG and is currently a master student at the University of Cologne, Germany
- Iuliana Stanciu, a chemist, has joined the group after her master's degree in 2017 and is currently a PhD student at Technische Universitaet Muenchen, Germany (her experimental work is carried out in IFIN-HH).

The Project Director was consistently working that NAG young members complement their formal education thru participation in international conferences and schools, but most importantly thru work in other laboratories (RIKEN, TAMU, NSCL) for shorter or longer periods. An important help NAG has received from the Nishina Center for Accelerator Based Science of RIKEN, Japan. Namely, three of the students in NAG have obtained International Program Associate (IPA) fellowships consisting of support for longer stays at RIKEN:

- Drd. Alexandra Chilug for 6 + 3+1 months (6 in 2017, 3 in 2018, 1 month in spring 2019)
- Drd. Dana Tudor for 3 months in 2018.
- Drds. Alexandra Chilug and Ionut Stefanescu for 1 year each, beginning Nov. 1, 2019.

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 our 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 NP1412-SAMURAI29R1 per se (May-June 2018). The travel was supported from this NAIRIB project. This collaboration was the starting point of a proposal that the PD and prof. A. Petrovici at the request of RIKEN have intermediated a **Collaboration Agreement signed in 2019 between RIKEN, Japan and the Doctoral School of Physics of the University of Bucharest.** IFIN-HH is part of the Doctoral School of Physics of UB.

Beyond the boundaries of the NAG group, the PD and the members of the group initiated, organized and carried out several events with international participation that had the formation and education of new generation of scientists as their main goal:

- the ChETEC CA16117 training school in April 10-20 2018, Magurele „A hands-on nuclear astrophysics experiment at IFIN-HH". The training school was attended by 15 trainees (from master students to post-docs) from across Europe, as intended, and 3 European trainers..
- the Carpathian Summer School of Physics, July 1-14, 2018, Sinaia, Romania (CSSP18). This 28th edition had the title: *"Exotic Nuclei and Nuclear/Particle Astrophysics (VII). Physics with small accelerators"*. We had 92 participants, 70 lectures and 18 student communications.
- the ECT* workshop "Indirect Methods in Nuclear Astrophysics" in Nov. 5-9 2018, in Trento, Italy
- two volumes of the Proceedings of CSSP16 and CSSP18 were edited with considerable efforts and competence and published at the American Institute of Physics by group's members in 2017 and 2019, respectively.

As for the broader audience, the PD has organized, with the help of NAG members, the 3rd, 4th and 5th editions of the (national) Summer School for Physics Olympics, July 2017, 2018 and 2019, in Busteni in collaboration with the NGO Apex-Edu from Cluj-Napoca. They were well appreciated by the about 20-25 high school students, best in their senior classes, selected from the finalists of the Romanian Physics Olympiads. In addition to the PD who is the director of the scientific part of these schools, two young members of NAG were lecturing in Busteni. Dr. Alexandra Spiridon was talking about her experience as PhD student in USA, while drd. Alexandra Chilug was talking about her thesis work in IFIN-HH, centred on the experiment we had at RIBF RIKEN in Wako, Japan.

At this section on formation of the new generations of scientists I should include that one group member has proposed (Oct. 2019) a project in the new UEFISCDI competition for Post-Doctoral grants on the study of ion-ion fusion mechanism and that the NAG youngsters have 4 local beamtime proposals approved by the Nov. 2019 PAC session for 2020, and one external proposal accepted at Texas A&M University (and carried out very late in Nov 25 -Dec. 5, 2019).

The scientific results summarized above are original and can be considered at the top of their class – a statement supported by the publications and by the attendance and appreciations of the events organized.

Details of the above listed accomplishments were included in the annual reports of the project.

I consider that the goals of this project were fully accomplished,

Prof. Livius Trache
NAIRIB Project Director

Proiect C02: PNIII/P5/P5.2 nr. 02/FAIR-RO

Raport stiintific final (Romana)

"Astrofizica Nucleara cu metode indirecte si fascicule radioactive / NAIRIB »

Activitatea Grupului de Astrofizica Nucleara (NAG – Nuclear Astrophysics Group) din Departamentul de Fizica Nucleara (DFN) al IFIN-HH este **fizica nucleara pentru astrofizica**.

Conform propunerii din 2016, activitatile au fost concepute pe trei directii :

a) Experimente la instalatii existente de fascicule radioactive (RIB), pentru a testa metode, ansambluri expérimentale si teoriile implicate
b) proiectarea si realizarea de echipament experimental
c) nu in ultimul rand, formarea si educarea membrilor tineri ai grupului; promovarea domeniului.

Realizari stiintifice

Experimente la instalatii existente de fascicule radioactive (RIB); teste metode, ansambluri expérimentale si teorii implicate

Desi grupul NAG foloseste atat metode directe, cat si **metode indirecte de astrofizica nucleara**, in cadrul prezentului proiect acestea din urma au fost finantate cu precadere.

Pana acum, mai multe reactii au fost focusul nostru. In perioada acoperita de acest proiect am efectuat experimente la instalatii existente de fascicule radioactive din strainatate folosind :

1. **Disocierea Coulombiana si nucleara** a $^{9}C \rightarrow {}^{8}B+p$ pentru a determina ratele de reactie pentru reactia $^{8}B(p,\gamma)^{9}C$. Acest experiment a fost executat la instalatia RIBF a RIKEN in Wako, Japonia.
2. **Spectroscopia de rezonanta** pentru reactiile $^{30}P(p,\gamma)^{31}S$ si $^{26}Al(p,\gamma)^{27}Si$. Am studiat spectroscopia ^{31}S si ^{27}Si prin dezintegrarea protonica intarziata de beta a nucleelor radioactve ^{31}Cl si ^{27}P.Aceste experimente au fost efectuate la Cyclotron Institute, Texas A&M University (TAMU), in College Station, TX, SUA.
3. **Metoda calului troian (THM)** pentru studiul indirect al reactiilor $^{12}C+^{12}C$ si $^{12}C+^{16}O$ la energii stelare. In timp ce pentru prima reactie au fost deja publicate articole, experimentul pentru cea de-a doua a avut loc abia recent, in octombrie 2019. Aceste experimente au fost conduse de catre grupul THM din Catania, colaboratori vechi, iar experimentele au avut loc la acceleratorul tandem al LNS Catania.

Publicatii au rezultat in fiecare din aceste 3 subiecte experimentale, unele raportand rezultate finale, altele numai rezultate preliminare sau partiale. Toate 3 au fost efectuate in colaborare la instalatii cu fascicule RIB din afara tarii: pentru metodele 1) si 2) noi am fost grupul coordonator, pentru 3) colaboratorii de la LNS au fost liderii. Publicatiile au aparut intr-o diversitate de medii, de la articole in volumele de proceedings de la conferinte internationale (FAIRNESS 2017, ESSENA 2017 and 2019, CCSP18, Nucleus-Nucleus Collisions 2018, etc.), la articole in reviste de prima clasa de fizica nucleara, pana la o publicatie in prestigioasa revista *Nature*. Lista publicatiilor NAG 2016-2019 este inclusa la sfarsitul raportului.

La capitolul „unelte" pentru testare metode trebuie sa citam studiul facut in colaborare cu prof. F. Carstoiu de la DFT despre teorii de folosit in interpretarea rezultatelor metodelor indirecte, rezultand in cele 4 articole publicate pe subiectul potentialelor optice (a se vedea Lista de publicatii).

In plus, NAG si membrii sai au participat la multe alte activitati nationale si internationale – experimente, analize de date sau intruniri stiintifice – legate de subiectul acestui proiect: astrofizica nucleara. In aceasta periioada, importante evenimente internationale au fost organizate de care directorul de proiect (PD) si NAG, activitati notabile aici in ciuda faptului ca nu au fost finantate prin acest proiect: o scoala a COST ChETEC CA16117 in aprilie 2018, editia 2018 a Carpathian Summer School of Physics in Sinaia, iulie 2018, un workshop ECT* „Indirect Methods in Nuclear Astrophysics" in noiembrie 2018 la Trento, Italia. Propuneri pentru urmatoare editii ale acestor 3 evenimente au fost pregatite in ultima parte a 2019 si sunt aprobate pentru 2020.

Proiectarea si realizarea de echipament experimental

Pentru subiectele 1) si 2) din lista de mai sus, experimentele propriu-zise au implicat de asemeni proiectarea si realizarea de instrumentatie: un sistem de detectori de siliciu pentru urmarirea produsilor de reactie la intrarea in sepctrometrul magnetic supraconductor SAMURAI la RIBF si detectroul ASTROBOX2 la TAMU, inclusiv versiunea sa europeana ASTROBOX2E in IFIN-HH. Ambele sisteme au fost realizate si testate in experimente satelit cu au fost cele de la acceleratorul HIMAC, Chiba, Japonia si la TAMU. Ambele au fost descrise anterior in rapoartele anuale.

Formare si educare

La inceputul prezentului proiect NAIRIB grupul a fost format din doi cerectatori seniori (CS1) si 5 studenti. Enumerarea schimbarilor de status a membrilor juniori ilustreaza cel mai bine rezultatele in directia educatiei si formari. In perioada la care ne referim :

- 4 dintre studentii initiali si-au obtinut diplôme de master
- Toti 4 au fost admisi ulterior la Scoala Doctorala de Fizica a Universitatii din Bucuresti si se afla in stadii finale de efectuare a tezei
- Alexandra Spiridon, un membru nou al grupului din februarie 2017, a obtinut doctoratul la Texas A&M University in Dec. 2017 si
- In 2018 a fost promovata post-doc si apoi Cercetator Stiintific (CS) in DFN, la IFIN-HH
- Madalina Ravar, studenta a Facultatii de Fizica a Universitatii din Bucuresti (nefinantata in acest proeict) si-a obtinut in 2018 diploma de licenta cu tematica si activitate din NAG si este in prezent masterand al Universitatii din Koeln, Germania
- Iuliana Stanciu, chimist, a intrat in grup dupa obtinerea masteratului in 2017 si este in present doctoranda la Technische Universitaet Muenchen (TUM), Germania (partea experimentala a tezei o efectueaza in IFIN-HH).

Directorul de proiect a actionat consistent si constient ca membrii tineri ai grupului sa-si completeze educatia formala prin participarea la scoli si conferinte internationale, dar mai ales si mai important prin activitati in laboratoare internationale de prestigiu (RIKEN, TAMU, NSCL) pentru perioade scurte sau mai lungi. Un real si important ajutor NAG am primit de la Nishina Center for Accelerator Based Science al RIKEN, Wako, Japonia. Anume, trei studenti ai NAG au primit burse IPA (International Program Associates) constand din finantarea de sederi mai lungi la RIKEN:

- Drd. Alexandra Chilug pentru 6 + 3 + 1 months (6 in 2017, 3 in 2018, 1 in primavara 2019)
- Drd. Dana Tudor pentru 3 months in 2018.

- Drds. Alexandra Chilug si Ionut Stefanescu pentru 1 an fiecare, de la 1 noiembrie 2019.

Acesta a fost un ajutor deosebit, caci studentii au avut oportunitatea si timpul de a invata multe, de a deveni familiari cu aranjamentul experimental complex din jurul sectrometrului SAMURI si de a lucra cu echipamentul pe care noi l-am realizat si adaptat pentru experimentul nostru propriu-zis. A fost si un sprijin financiar important, care a permis restului grupului (2 alti studenti si eu) sa faca deplasarea in Japonia, inainte, in timpul si putin dupa experimentul NP1412-SAMURAI29R1 (mai-iunie 2018). Aceasta colaborare a fost si punctul de start al propunerii pe care RIKEN a adresat-o prin PD si prof. A. Petrovici sa intermediem un Acord de Colaborare intre RIKEN si Scoala Doctorala de Fizica a UB, acord deja semnat in Sept. 2019. IFIN-HH este parte a Scolii Doctorale de Fizica a UB.

Dincolo de limitele grupului, PD si membrii lui au initiat, organizat si desfasurat mai multe evenimente cu participare internationala care au avut formarea si educarea noilor generatii de cercetatori ca scop principal:

- Scoala ChETEC CA 16117 in Aprilie 10-20, 2018, la Magurele „A hands-on nuclear astrophysics experiment at IFIN-HH". La eveniment au participat 15 tineri (master students la post-doci) din toata Europa, asa cum a fost intentia si 3 lectori europeni invitati.
- Editia a 28-a a Carpathian Summer School of Physics, July 1-14, 2018, Sinaia, Romania (CSSP18) cu titlul: *"Exotic Nuclei and Nuclear/Particle Astrophysics (VII). Physics with small accelerators"*. Au fost 92 participanti, 70 lectii si 18 communicari ale studentilor.
- un workshop "Indirect Methods in Nuclear Astrophysics" in Nov. 5-9 2018, la ECT* Trento, Italia.
- Doua volume de Proceedings ale CSSP16 and CSSP18 au fost editate cu eforturi considerabile si competenta si publicate la American Institute of Physics de membri ai grupului in 2017 si respectiv 2019.

In ce priveste audienta mai larga, PD a organizat, cu sprijin din partea membrilor NAG, editiile cu numarul 3, 4 si 5 ale Scolii de vara pentru elevi olimpici de fizica, in iulie 2017, 2018 si respectiv 2019, in Busteni, in colaborare cu ONG Apex-Edu din Cluj-Napoca. Acest eveniment national a fost foarte apreciat de cei 20-25 elevi de liceu prezenti in fiecare an. Ei au fost selectati sa fie cei mai buni in clasele mari (XI si XII) dintre finalistii Olimpiadelor Nationale de Fizica. Pe langa PD care este directorul stiintific al acestor scoli, la ultimele doua editii au participat si doi tineri membri ai NAG. Dr. Alexandra Spiridon a vorbit despre experienta dansei ca student la doctorat in SUA, iar Alexandra Chilug despre munca ei la teza de doctorat in IFIN-HH, care se bazeaza pe un mare experiment la RIKEN, in Japonia.

As include la aceasta sectiune despre formarea tinerei generatii informatia ca unul din membrii grupului a inaintat in octombrie 2019 o propunere de proiect in cadrul competitiei UEFISCDI pentru granturi Post-Doctorale despre studiul mecanismului de fuziune ion-ion la energii sub-bariera si ca tinerii din NAG au inaintat 4 propuneri de experimente la sesiunea PAC a IFIN-HH din noiembrie 2019, care au fost acceptate pentru 2020 si o propunere externa aprobata la TAMU (care a si fost efectuata intre 25 nov. – 5 dec. 2019).

Toate rezultatele mentionate mai sus sunt originale si pot fi considerate de varf in clasa activitailor respective – afirmatie sustinuta de publicatii, cat si de participare internationala si aprecierile comunitatiii stiintifice.

Detalii despre realizarile listate aici au fost incluse in rapoartele Anuale ale proiectului.

Consider ca obiectivele proiectului au fost in intregime atinse.
Prof. Livius Trache / Director Proiect NAIRIB

List of Publications - Nuclear Astrophysics Group 2016-2019

On nuclear astrophysics – direct and indirect methods topics

1. F. Carstoiu, M. Lassault, L. Trache and V. Balanica, Rom. J. Phys. 61 (2016) 400
   Heavy ion orbiting and Regge poles (I)

2. F. Carstoiu, M. Lassault, L. Trache and V. Balanica, Rom. J. Phys. 61 (2016) 857
   Heavy ion orbiting and Regge poles (II)

3. F. Carstoiu, M. Lassault, L. Trache, V. Balanica, Rom. J. Phys. 61 (2016) 1180
   Heavy ion orbiting and Regge poles (III)

4. 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

5. 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

6. Trache, Livius, in Conference: 8th International Conference on Nuclear Physics in Astrophysics NPA8) 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

7. Gulino, Marisa; Cherubini, Silvio; Rapisarda, Giuseppe Gabriele; et al., Conference: 9th European Summer School on Experimental Nuclear Astrophysics Location: Catania, ITALY Date: SEP 17-24, 2017. 9TH EUROPEAN SUMMER SCHOOL ON EXPERIMENTAL NUCLEAR ASTROPHYSICS Book Series: **EPJ Web of Conferences** Volume: 184 Article Number: UNSP 01008 Published: 2018.
   Trojan Horse Method experiments with radioactive ion beams

8. Burjan, V.; Hons, Z.; Kroha, V.; et al., **EUROPEAN PHYSICAL JOURNAL A** Volume: **55**, Article Number: 114. Published: JUL 23, 2019.
   The determination of the astrophysical S-factor of the direct O-18(p, gamma)F-19 capture by the ANC method

9. Chilug, A. I.; Panin, V.; Tudor, D.; et al., Group Author(s): HI-p Collaboration EXOTIC NUCLEI AND NUCLEAR/PARTICLE ASTROPHYSICS (VII) – PHYSICS WITH SMALL ACCELERATORS Book Series: **AIP Conference Proceedings**, Volume: **2076**, Article Number: UNSP 060001. Published: 2019.
   Study of the C-9 Breakup Through NP1412-SAMURAI29R1 Experiment

10. Stefanescu, I. C.; Trache, L.; Chilug, A. I.; et al., EXOTIC NUCLEI AND NUCLEAR/PARTICLE ASTROPHYSICS (VII) – PHYSICS WITH SMALL ACCELERATORS, Book Series: **AIP Conference Proceedings**, Volume: **2076**, Article Number: UNSP 060008. Published: 2019.
Decay Spectroscopy As A Tool For Nuclear Astrophysics

11. Alexandra Spiridon et al – in EXOTIC NUCLEI AND NUCLEAR/PARTICLE ASTROPHYSICS (VII) – PHYSICS WITH SMALL ACCELERATORS, Book Series: **AIP Conference Proceedings** Volume: **2076** Article Number: UNSP 060007 Published: 2019.
Elastic studies with the upgraded TAMU-MDM detector

12. D. Tudor, L. Trache, Alexandra I. Chilug, Ionut C. Stefanescu, Alexandra Spiridon, Mihai Straticiuc, Ion Burducea, Ana Pantelica, Romulus Margineanu, Dan G. Ghita, Doru G. Pacesila, Radu F. Andrei, Claudia Gomoiu, Ning T. Zhang, Xiao D. Tang, **Nucl. Instr. & Meth. in Phys. Res. A 953** (2020) 163178.
A facility for direct measurements for nuclear astrophysics at IFIN-HH -- a 3 MV tandem accelerator and an ultra-low background laboratory

13. N. T. Zhang, X. Y. Wang, H. Chen, Z. J. Chen, W. P. Lin, W. Y. Xin, S. W. Xu, D. Tudor, A. I. Chilug, I. C. Stefanescu, M. Straticiuc, I. Burducea, D. G. Ghita, R. Margineanu, C. Gomoiu, A. Pantelica, D. Chesneanu, L. Trache, X. D. Tang, B. Bucher, L. R. Gasques, K. Hagino, S. Kubono, Y. J. Li, C. J. Lin , et al. **Phys. Lett. B 801** (2020) 135170.
Constraining the $^{12}C+^{12}C$ astrophysical S-factors with the $^{12}C+^{13}C$ measurements at very low energies

14. A. Chilug, D. Tudor, A. Spiridon, I. Stefanescu, L. Trache, …et al, in *Proc. Nucleus-Nucleus Collisions 2018, Saitama, Dec. 2018*, **Japan Phys. Soc. Conf. Ser.**, accepted July 2019.

15. L. Trache, in *Proc. ESSENA 2019*, **Eur. Phys. J. Conf. Ser.**, accepted Sep. 2019.
Nuclear astrophysics studies at NIPNE

16. A. Saastamoinen, E. Pollacco, B.T. Roeder, R. Chyzh, L. Trache, R.E. Tribble, **Nucl. Instr. & Meth. B,** accepted May 2019, in press.
Studies of systematic effects of the AstroBox2 detector in online conditions

17. A. Tumino, C. Spitaleri, M. La Cognata, S. Cherubini, 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. Serghi, R. Sparta and L. Trache, **Il Nuovo Cimento 42 C** (2019) 55.
Uncovering carbon burning in stars.

18. F. Carstoiu, M. Lassault and L. Trache, **Rom. J. Phys. 65** (2020) 301
Rainbow extinction, orbiting and Regge poles

19. Livius Trache and Florin Carstoiu, arXiv: http://arxiv.org/abs/1911.06077
Indirect methods in Nuclear Astrophysics

Books:

1. **Livius Trache and Dan Gabriel Ghita (eds.)** *Exotic nuclei and nuclear/particle astrophysics (VI) - Physics with small accelerators. Proceedings of the Carpathian Summer School of Physics 2016 (CSSP16).* Book Series: **American Institute of Physics Conference Proceedings**, Volume: 1852, Melville, New York, 2017.
   https://aip.scitation.org/toc/apc/1852/1

2. **Livius Trache and Alexandra Spiridon (eds.)**, *Exotic nuclei and nuclear/particle astrophysics (VII) - Physics with small accelerators. Proceedings of the Carpathian Summer School of Physics 2018 (CSSP18).* Book Series: **American Institute of Physics Conference Proceedings**, Volume: 2076, Melville, New York, 2019.

   https://aip.scitation.org/toc/apc/2076/1?expanded=2076