ANEXA 1.A

Annual Summary Document

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

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

2nd intermediate report –

1. Cover Page (1 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-Ionela CHILUG, PhD student, Research Assistent
  4. Dana TUDOR, PhD student, Research Assistent
  5. Alexandra SPIRIDON, PhD student, Research Assistent
  6. Ionut-Catalin STEFANESCU, PhD student, Physicist
  7. Valentin BALANICA, Physicist
  8. Gherghina STAN, staff, Economist

- **Specific scientific focus of group (state physics of subfield of focus and group's role)**

The focus of the group is **nuclear physics for astrophysics**. In particular the use of **indirect methods with radioactive beams for nuclear astrophysics**.
We proposed 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**.

- **Summary of accomplishments during the reporting period** (Nov. 2016 – Nov. 2017)

The proton breakup experiments of the SAMURAI HI-p collaboration, including NP1412-SAMURAI29R that we lead, were re-scheduled for the spring 2018 campaign of Radioactive Ion Beam Facility of RIKEN, Wako, Japan. Preparations are being finalized. A student is on an IPA fellowship of 5 months at RIKEN now. A test experiment at the HIMAC accelerator in Chiba, Japan is scheduled for Dec. 2017.
Two experiments were carried out at Texas A&M University to study **beta-delayed proton-decay** of ^{31}Cl and ^{35}K.
We participated at a number of international schools and conferences, with talks or invited lectures.
One PhD student graduated at Texas A&M University, two PhD students at the University of Bucharest passed their qualifying exams, two new students were admitted in PhD programs.

2. Scientific accomplishments (max. 3 pages) – Results obtained during the reporting period.

1. Introduction

In the application, I said explicitly:

"… the Nuclear Astrophysics Group (NAG) at IFIN-HH proposes a number of preparatory steps for future FAIR experiments:

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 members of the group.

… motivated by nuclear astrophysics and using radioactive ion beams" (Form B2_EN, page 6).

As the research activity is a continuous one, not necessarily divided clearly per year, other than for reporting purposes, and as in particular some of this grant activities depend on factors we cannot easily control, like beamtime schedules at international facilities, changings and/or fluctuations in acquisitions and financing, the report may reflect changes from the original proposal written in May 2016. However, continuous progress was achieved in 2017 on all three types of steps enumerated above. In short:

a) While RIKEN did not schedule the NP1412-SAMURAI29R and three other experiments named together "SAMURAI HI-p" (proton breakup experiments at SAMURAI) with which we collaborate, serious work was done for it in 2017. A student of my group (Alexandra Chilug) applied and obtained through competition an IPA fellowship of 5 months at RIKEN for July – Dec. 2017. She was and is working on simulations and setup for this experiment. A test experiment at the HIMAC accelerator is scheduled for Dec. 1-10, 2017, and 4 members of NAG will participate.
   Instead, we had two experiments at Texas A&M University (TAMU), Cyclotron Institute, for experiments with ASTROBOX2. Also, same student (A. Chilug) participated at an in-flight decay experiment at NSCL, MSU in May 2017, with the Washington University group of prof. Lee G Sobotka.
b) The setup for the experiments at RIBF is finalized. The HIMAC experiment in Dec. 2017 will determine the last unknowns in the associated electronics.
   Design was completed for ASTROBOX2E and the detector is planned to be finalized before the end of the year. The setup of the identical detector ASTROBOX2 worked well in 3 experiments at Texas A&M University (for ^{23}Al, ^{31}Cl and ^{35}K decay experiments).
c) Training of the young members of the group progressed really well:
   - Alexandra Spiridon, a student I had at TAMU, has joined the group in Feb. 2017, finalized her PhD thesis while in Bucharest and defended it successfully at Texas A&M University in Oct. this year.
   - Alexandra Chilug and Dana Tudor were admitted in the PhD program of the University of Bucharest in Sept 2016 and passed their PhD qualifying exams by Sept. 2017.
   - Ionut Stefanescu was admitted in the PhD program of the University of Bucharest in Sept. 2017.
   - Iuliana Madalina Stanciu is a new member of NAG. She has obtained her master degree from the University Politechnica Bucharest in July and is admitted in a PhD program at Technische Universitaet Muenchen on a subject related to using Accelerator Mass Spectrometry (AMS) to detect traces of supernovae explosion(s) in

Earth sediments, research to be done in cooperation (she is not financed from this project).

- All students had work stages or collaboration trips at reputable laboratories or universities on 3 continents:
  - A. Chilug at Washington University in St. Louis, MI for an experiment at NSCL, Michigan State University, and a 5 months fellowship in RIKEN, Wako, Japan;
  - A. Spiridon and I. Stefanescu at TAMU, USA;
  - D. Tudor at IMP Lanzhou, China (not financed by this project);
  - I. Stanciu at TUM, Germany;
  - D. Tudor, I Stefanescu and myself will join A. Chilug for the test experiment at HIMAC, Japan in December;
- One undergraduate student, Madalina Ravar, started working with us in continuation of her summer internship.

Meanwhile, we continued working on projects we started before: with dr. Florin Carstoiu we completed in 2016 the 3 papers started earlier on optical potentials for nucleus-nucleus collisions and with him and A. Spiridon on her thesis data (elastic and transfer obtained at the MDM spectrometer of TAMU). We continue to work on NA subjects with outside collaborators, some not yet published.

Our work or our plans were also presented at international conferences and schools.

In June 2017 I (LT) submitted a proposal to organize an ECT* workshop with the topic "Indirect Methods for Nuclear Astrophysics", chair: L. Trache, co-organizers C. Bertulani (TAMUC), A. Bonaccorso (INFN Pisa), T. Motobayshi (RIKEN, Wako) and Zs. Fulop (ATOMKI Debrecen) . It was approved in July and is scheduled to take place on Nov. 5-9, 2018 in Trento, Italy.

2. General report

*The **experiments of the SAMURAI HI-p collaboration**.*

Progress was made on the preparation of the setup. Our students completed simulations of the experimental setup and of the experiment itself using GEANT4 for complete simulations. Scheduling constraints and simulations' results made us reconsider the geometry of the SAMURAI: we will work with the spectrometer at 30^0. This geometry is shown in Figure 1, below.

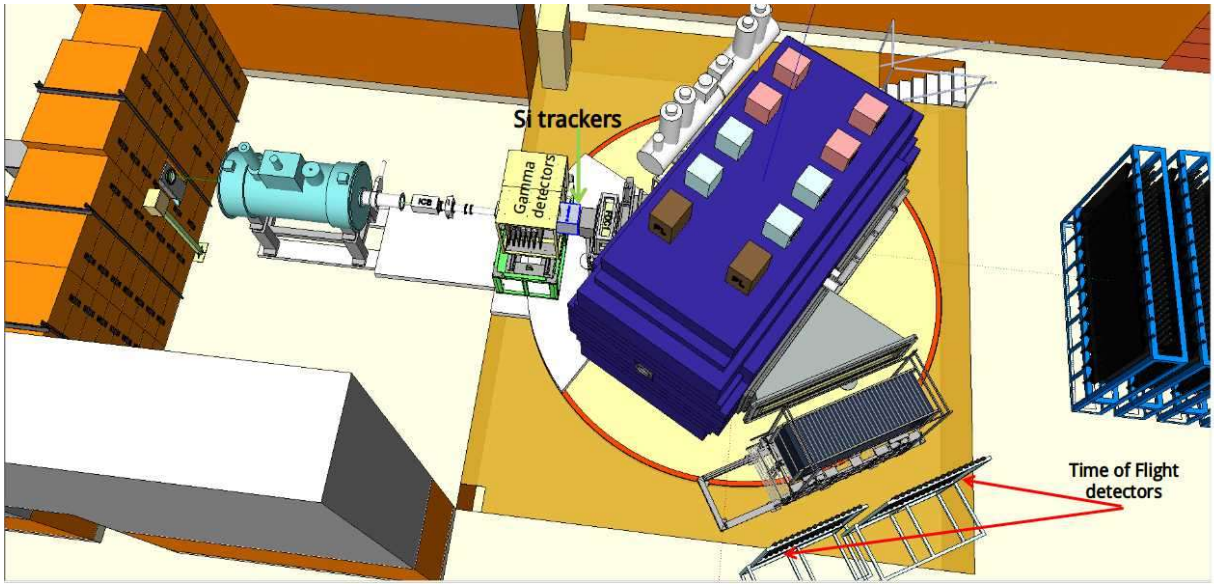

Figure 1. General view of the experimental setup. The SAMURAI spectrometer will be placed at 30º.

Decay spectroscopy experiments at Texas A&M University

Another line of research we have followed this year was that of using decay spectroscopy tools to find resonances important in various radiative proton capture reactions of importance in nuclear astrophysics. I started a program of measurements about a decade ago at the Cyclotron Institute, Texas A&M University, using the excellent conditions given by the primary beams from the superconducting cyclotron K500 and the MARS recoil separator. The program addresses a number of missing data on resonances important in H-burning in novae. It continues and did evolve not only in the direction of measuring more nuclei, but also in changing the equipment, including more efficient and more sensitive detectors. During the years:

a. Implantation detectors were evolving:
    i. very thin DSSSD (Double Sided Silicon Strip Detectors) W1-110, W1-65 and BB2-45 (105, 65 and 45 mm, thick respectively)
    ii. gas detector ASTROBOX1
    iii. gas detector ASTROBOX2
b. the nuclei studied were: ^{23}Al, ^{31}Cl, ^{27}P (with thin Si detectors and HPGe detectors for gammas) and ^{23}Al, ^{31}Cl and ^{35}K with gas detectors (ASTROBOX1 and 2)
c. the external collaborators at TAMU experiments were from the University of Jyvaskyla, University of Edinburgh, CEA/IRFU Saclay, CERN, IFIN-HH, …

In the latest campaigns we have measured using ASTROBOX2, an upgraded version of the first gas detector developed with dr. E. Pollacco of CEA/IRFU Saclay and dr. Ruiz and CERN collaborators. It was commissioned in an experiment in April 2015 (^{23}Al) and used successfully for the further study of ^{31}Cl (Oct. 2016) and ^{35}K (July 2017 and Oct 2017). I only include below a spectrum showing a beautiful proton peak at E_p=260 keV, a long sought after resonance in the ^{30}P(p,γ)^{31}S reaction (Figure 5).

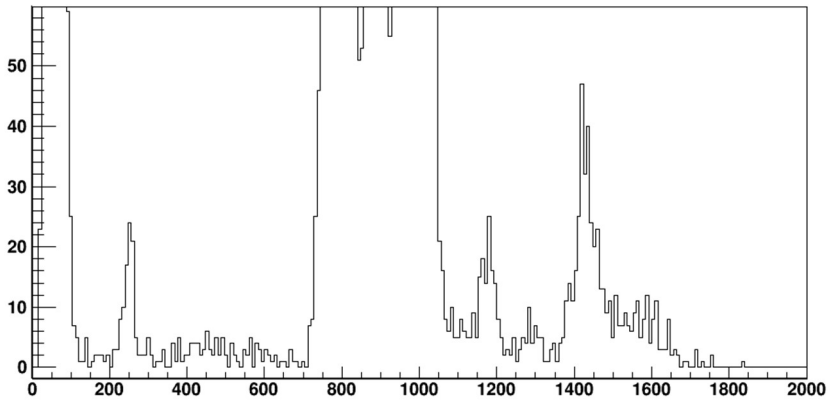

Figure 2. Proton spectrum from the βp-decay of 31Cl. The horizontal axis is in keV.

One development to note here is that the TAMU partners accepted in Oct. 2017 our proposal to measure the decay of ^{27}P with ASTROBOX2 in College Station, next year (2018). This measurement will be NAG's responsibility and part of the thesis data of I. Stefanescu. ^{27}P was measured before with lower resolution using implantation in Si detectors.

3. Group members (table):

- List each member, his/her role in project and the Full Time Equivalent (FTE) time in project. The FTE formula to be used is: FTE = Total number of worked hours /Total number of hours per reporting period*;

Nr. Crt	Name and Surname	Role in project	Full Time Equivalent (FTE)
1	Livius TRACHE	Project director	50%
2	Florin CARSTOIU	Senior researcher	
3	Alexandra-Ionela CHILUG	Team member	100%
4	Dana TUDOR	Team member	100%
5	Ionut-Catalin STEFANESCU	Team member	100%
6	Alexandra SPIRIDON	Team member	100%
7	Valentin BALANICA	Team member	25%
8	Gherghina STAN	Team member	5%

- **List PhD/Master students and current position/job in the institution.**
  1) Alexandra SPIRIDON, PhD student, Research Associate
  2) Alexandra-Ionela CHILUG, PhD student, Research Associate
  3) Dana TUDOR, PhD student, Research Associate
  4) Ionut-Catalin STEFANESCU, master student -> PhD student, Physicist
  5) Iuliana STANCIU, master student -> PhD student, Engineer

4. Deliverables in the last year related to the project:

- List of papers (journal or conference proceeding):
  - In 2016 we completed the publication of a series of 3 papers on optical model potentials between nuclei:
    Heavy Ion Orbiting and Regge Poles (I, II, III)
    F. Carstoiu, M. Lassaut, L. Trache, V. Balanica, **Rom. J. Phys. 61**, 400-412, 857-874, and 1180-1197 (2016)
  - *Simultaneous measurement of β-delayed proton and γ decay of 27P,* E. McCleskey, A. Banu, M. McCleskey, T. Davinson, D. T. Doherty, G. Lotay, B. T. Roeder, A. Saastamoinen, A. Spiridon, L. Trache, J. P. Wallace, P. J. Woods, and R. E. Tribble, **Phys. Rev. C 94**, 065806 (2016) - Published 27 December 2016
  - "*In-beam measurements of $^{13}C+^{12}C$ fusion reaction cross section at energies around and below Coulomb barrier"*, I. Stefanescu et al, in Proc. CSSP16, AIP Conf Proc., vol. 1852, p. 080011 (2017)
  - *"Activation measurements of 13C+12C fusion cross section at deep sub-barrier energies in IFIN-HH*", D. Tudor et al., in Proc. CSSP16, AIP Conf Proc., vol. 1852, p. 080012 (2017)
  - *Other indirect methods for nuclear astrophysics,* L. Trache, in Eur. Phys. Web of Conf, Proc. NPA8 Conference, Catania, June 18-23, 2016; accepted (2017)
  - *Uncovering the resonant behavior of $^{12}C+^{12}C$ fusion at astrophysical energies,* A. Tumino, C. Spitaleri, M. La Cognata, S. Cherubini, G.L. Guardo, M. Gulino, S.

* Total number of hours (for a certain period) = 170 average monthly hours x number of months (e.g., for a full year: 170 hours/month x 12 months = 2040 hours)

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 – submitted to Nature, Aug. 2017

- List of talks of group members (title, conference or meeting, date)
  - L. Trache, *Recent results and future opportunities in laboratory nuclear astrophysics,* at ENSAR2 NUSPRASEN Workshop, CERN Geneva, Dec. 6th, 2016
  - L. Trache: *Nuclear Astrophysics at IFIN-HH Bucharest,* at the 14th Russbach School on Nuclear Astrophysics, Russbach, Austria, March 12-18, 2017
  - A. Chilug, *Measurement of the ^{58}Ni (α, γ) ^{62}Zn fusion reaction cross section at deep sub-barrier energies relevant for nuclear astrophysics,* at the 14th Russbach School on Nuclear Astrophysics, Russbach, Austria, March 12-18, 2017
  - D. Tudor, *Experimental study of the $^{64}Zn(\alpha, p)^{67}Ga$ fusion reaction at deep sub-barrier energies,* at the 14th Russbach School on Nuclear Astrophysics, Russbach, Austria, March 12-18, 2017
  - L. Trache: *Other indirect methods for nuclear astrophysics*, invited talk, Nuclear Physics for Astrophysics VIII (NPA8) Conference, Catania, June 18-32, 2017.
  - L. Trache: *Advances in nuclear astrophysics with direct and indirect methods at IFIN-HH*, at the 9th European School on Experimental Nuclear Astrophysics, St. Tecla, Sept. 17-24, 2017
- Other deliverables (patents, books etc.).
  - *"Exotic Nuclei and Nuclear/Particle Astrophysics (VI). Physics with Small Accelerators"*, L. Trache and D.G. Ghita (eds), AIP Conference Proceedings, vol. 1852, Melville, New York 2017 and http://aip.scitation.org/toc/apc/1852/1?expanded=1852

5. **Further group activities (max. 1 page):**

- Collaborations, education, outreach.

The NA Group is involved in 4 experiments at RIBF of RIKEN, Japan and other collaborations at TAMU (Texas) and FAIR/GSI (Germany).
The Project Director, Livius Trache is also member in other projects (7 in 2017), having leading functions:

-Program Director of the PN 16 42 program of the whole IFIN-HH, which includes 14 projects (Feb 2016 – Aug. 31, 2017)

- Project Director of the project PN 16 42 03 02 with the title: "Structuring a Center for the study and preservation of cultural heritage"

- Deputy Group Leader of Work Group NUSPRASEN of ENSAR2, an European H2020 project

- Vice Chair of the Governing Board of the European project GENERA, part of H2020.

Also the activity of the NA Group has an outreach component focused on the "Scoala Altfel" program and on the Busteni Summer school for the finalists at the Physics Olympiad (3rd edition in July 2017).
We have a fresh web page of the NAGroup: http://www.nipne.ro/research/departments/dfn.php

6. Financial Report (budget usage) for the reporting period (see the Annex).

7. Research plan and goals for the next year (max. 1 page).

According with the Project Proposal, the next stage of this project will have two main purposes:
- the proton breakup experiments (of ^{9}C foremost) at RIBF of RIKEN, Japan, and

- experiment(s) on beta-delayed proton decay of ^{27}P at Texas A&M University using the ASTROBOX2 detector. An European version of it is under construction, will be finalized and tested.
- publication of results from the last 2-3 years will be accelerated.

ANEXA 1.B Indicatori de realizare intermediară

Tip indicator	Număr	Scurtă descriere (dacă este cazul)
Număr de articole ştiinţifice în reviste şi volume indexate	5+1	5 published, 1 submitted
Număr co-publicaţii	2	1 published + 1 submitted
Număr articole publicate în top 10% cele mai citate publicaţii	1+1	1 published + 1 submitted
Număr de brevete obţinute la nivel naţional şi internaţional		
Număr de brevete în curs de obţinere la nivel naţional şi internaţional		
Numărul altor forme de DPI solicitate: desene, mărci în domeniul strategic.		
Număr de tehnologii elaborate/transferate		
Număr de modele experimentale/prototitpuri		
Numărul de posturi de cercetatori echivalent normă întreagă (ENI) susţinute *	28.74	
Numărul de cercetători cu doctorat susţinuţi *	2	
Numărul de ingineri susţinuţi *		
Numărul de tehnicieni susţinuţi *		
Numărul personalului economic/administrativ susţinut *	1	
Numărul de doctoranzi susţinuţi *	4	
Număr de masteranzi susţinuţi *	1	
Număr de conferinţe organizate *		
Număr de participări la Conferinţe Internaţionale*	8	
Număr de prezentări la Conferinţe Internaţionale	7	
Număr de postere prezentate la Conferinţe Internaţionale*		
Număr de participanţi la Workshopuri*	4	
Număr de prezentări orale la Workshopuri	1	
Număr de postere prezentate la Workshopuri		
Numarul participantilor la intruniri FAIR –din cadrul Colaborarilor (Collaboration Meetings)	3	
Numărul de proiecte Orizont 2020 (inclusiv cele ale partenerilor dacă este cazul)	2	
Numărul de evenimente de comunicare şi popularizare a ştiinţei susţinute *	2	
Număr de cursuri de instruire sau perfecţionare realizate		
Altele (specificaţi)		

*) din Fondurile Programului

Bucharest-Magurele
Date: Nov. 6, 2017

Director de proiect,
Dr. Livius Trache

ANEXA 1.A

Annual Summary Document Template[1]

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

Titlu proiect: "Astrofizica Nucleara cu Metode Indirecte si Fascicule de Ioni Radioactivi/ NAIRIB"

2nd intermediate report –

1. Cover Page (1 page):

- Echipa de proiect a fost compusa din următorii membri:
    1. Livius TRACHE, Director de Proiect, CS I
    2. Florin CARSTOIU, Cercetător Senior, CS I
    3. Alexandra-Ionela CHILUG, Student PhD, Asistent Cercetare
    4. Dana TUDOR, Student PhD, Asistent Cercetare
    5. Alexandra SPIRIDON, Student PhD, Asistent Cercetare
    6. Ionut-Catalin STEFANESCU, Student PhD, Fizician
    7. Valentin BALANICA, Fizician
    8. Gherghina STAN, Economist

- Domeniul de interes al grupului este **fizica nucleara pentru astrofizica** si in special, **utilizarea metodelor indirecte cu fasicule radioactive pentru astrofizica nucleara**. Am propus experimente folosind **metoda de separare nucleara si Coulumbiană a unui proton** pentru determinarea ratelor de reactie de captura radiativa de protoni. **Spectroscopia de rezonante pentru astrofizica nucleara** este de asemenea un punct de interes al proiectului. In prezent, ne concentram pe **dezintegrari protonice intarziate beta**.

- **Rezumat al realizarilor din perioada de raportare** (Nov. 2016 – Nov. 2017)

Experimentele de separare a unui proton ce sunt parte din colaborarea SAMURAI HI-p, inclusiv NP1412-SAMURAI29R condusa de grupul nostru, au fost reprogramate in orarul de primavara al anului 2018 al facilitatii RIBF (Radioactive Ion Beam Facility) de la RIKEN, Wako, Japonia. Pregatirile pentru aceste experimente sunt in curs de finalizare. Unul dintre studentii grupului este in prezent la RIKEN printr-o bursa de 5 luni de la IPA. Un experiment de testare a echipamentului va avea loc la acceleratorul HIMAC in Chiba, Japonia in luna decembrie 2017.
Doua experimente au avut loc la Universitatea Texas A&M cu scopul de a studia **dezintegrarea protonica intarziata beta** a nucleelor ^{31}Cl si ^{35}K.
Am participat la un numar de scoli si conferinte internationale cu prezentari sau lectii invitate.
Un student PhD a incheiat studiile doctorale la Universitatea Texas A&M, 2 studenti PhD de la Universitatea Bucuresti au luat examenele de calificare si doi studenti noi au fost admisi la studii doctorale.

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2. Rezultate stiintifice obtinute in perioada raportarii.

1. Introducere

In lucrarea de aplicatie, am mentionat clar:
"… Grupul de Astrofizica Nucleara (NAG) de la IFIN-HH propune un numar de pasi pregatitori pentru viitoare experimente la FAIR:

a) Lucrul la facilitati RIB, cu scopul de a testa metodele, detectorii si teoria folosite in experimente
b) Planificarea si realizarea ansamblelor experimentale de detecție
c) Nu in ultimul rând, educarea si pregătirea membrilor tineri ai grupului.

… motivate de astrofizica nucleara si utilizarea fasciculelor de ion instabili" (Form B2_EN, page 6).

Luand in considerare faptul ca cercetarea este o activitate continua, care nu poate fi intotdeauna impartita clar pe ani in afara necesarelor raportari, si in particular pentru ca anumite activitati din acest grant depind de factori mai greu de controlat, precum programarile de fascicol de la facilitati internationale, schimbari si/sau fluctuatii in achizitii si finantare, este posibil ca acest raport sa prezinte diferente fata de propunerea originala scrisa in Mai 2016. Totusi, in 2017 a fost realizat un continuu progres la toti cei trei pasi descrisi mai sus. In rezumat:

a) Desi RIKEN nu a programat experimentul NP1412-SAMURAI29R si celelalte 3 experimente denumite impreuna "SAMURAI HI-p" (experimente de separare de un proton la SAMURAI) in care suntem colaboratori, s-a facut o munca considerabila de pregatire pentru el in 2017. O studenta din grupul meu (Alexandra Chilug) a aplicat si obtinut o bursa IPA de 5 luni la RIKEN pentru perioada Iulie – Dec. 2017. E a lucrat si lucreaza in continuare la simulari pentru acest experiment. Un test pregatitor pentru acest experiment este planificat la acceleratorul HIMAC in perioada Dec. 1-10, 2017, si 4 membri al grupului NAG vor participa.
   In schimb, am avut 2 experimente la Texas A&M University (TAMU), Cyclotron Institute, pentru proiectul ASTROBOX2. De asemenea, aceeasi studenta (A. Chilug) a participat la un experiment de dezintegrare in zbor la NSCL, MSU in Mai 2017, cu grupul de la Universitatea Washington al prof. Lee G Sobotka.
b) Ansamblul de detectie pentru experimentele de la RIBF a fost finalizat. Testul de la HIMAC din Dec. 2017 va determina ultimele necunoscute in partea de electronica a ansamblului.
   Planul de constructie pentru ASTROBOX2E a fost terminat urmand ca detectorul sa fie finalizat inainte de sfarsitul anului. Ansamblul identic de detectie ASTROBOX2 a functionat foarte bine in 3 experimente la Universitatea Texas A&M (pentru studii de dezintegrare a ^{23}Al, ^{31}Cl si ^{35}K).
c) Pregatirea educationala a membrilor tineri ai grupului a progresat foarte bine:
   - Alexandra Spiridon, o studenta pe care am avut-o la TAMU, s-a alaturat grupului in Feb. 2017, si-a terminat de scris teza de Doctorat in Bucuresti si a sustinut cu succes lucrarea la Universitatea Texas A&M in Oct. anul acesta.
   - Alexandra Chilug si Dana Tudor au fost admise in programul de Doctorat al Universitatii din Bucuresti in Sept 2016 si au luat cu succes examenele doctorale de calificare pana in Sept. 2017.
   - Ionut Stefanescu a fost admis in programul de Doctorat al Universitatii din Bucuresti in Sept. 2017.

- Iuliana Madalina Stanciu este un membru nou al grupului NAG. Ea si-a obtinut diploma de Masterat de la Universitatea Politechnica din Bucuresti in Iulie si a fost recent admisa in programul de Doctorat al Technische Universitaet Muenchen, Germania si va avea o tematica de studiu legata de utilizarea metodei Accelerator Mass Spectrometry (AMS) pentru a detecta urme ale exploziilor din supernove in sedimente terestre, cercetare ce va fi efectuata in colaborare cu grupul nostru (ea nu este finanata din acest proiect).
- Toti studentii au avut stagii de lucru sau colaborare la laboratoare sau universitati de renume pe 3 continente:
    - A. Chilug la Washington University in St. Louis, MI pentru un experiment la NSCL, Michigan State University, si o bursa de 5 luni in RIKEN, Wako, Japan;
    - A. Spiridon and I. Stefanescu la TAMU, USA;
    - D. Tudor la IMP Lanzhou, China (nefinantata din acest project);
    - I. Stanciu la TUM, Germany;
    - D. Tudor, I Stefanescu si cu mine ne vom alatura Alexandrei Chilug pentru experimentul de test de la HIMAC, Japan in Decembrie;
- O studenta de licenta, Madalina Ravar, a inceput sa lucreze cu noi dupa incheierea stagiului de vara pe care l-a avut cu grupul nostru.

In acelasi timp, am continuat sa lucram la proiecte incepute in trecut: cu dr. Florin Carstoiu am incheiat in 2016 cele 3 articole incepute mai inainte despre potentiale optice pentru ciocniri nucleu-nucleu; si cu el si A. Spiridon am lucrat la datele ei de teza (sectiuni elastice si de transfer obtinute cu spectrometrul MDM de la TAMU). Continuam sa lucram pe subiecte NA cu colaboratori externi, multe in prezent nepublicate.

Activitatile si planurile noastre au fost de-asemenea prezentate la conferinte si scoli internationale.

In Iunie 2017 eu (LT) am depus o propunere pentru a organiza un workshop ECT* pe tematica “Indirect Methods for Nuclear Astrophysics”, presedinte: L. Trache, co-organizatori: C. Bertulani (TAMUC), A. Bonaccorso (INFN Pisa), T. Motobayshi (RIKEN, Wako) and Zs. Fulop (ATOMKI Debrecen). A fost aprobata in Iulie si va avea loc in perioada Nov. 5-9, 2018 in Trento, Italy.

2. Raport general

Experimentele din colaborare SAMURAI HI-p.
A fost facut progres in pregatirea ansamblului de detectie. Studentii din grupul nostru au efectuat simulari ale ansamblului experimental si ale experimentului propriu-zis folosind GEANT4 pentru a obtine simulari complete. In urma unor constrangeri ale timpului de fascicol acordat si ale rezultatelor de la simulari, am decis sa modificam geometria de la SAMURAI: vom lucra cu spectrometrul la 30^0. Aceasta geometrie este arătată in Figura 1, mai jos.

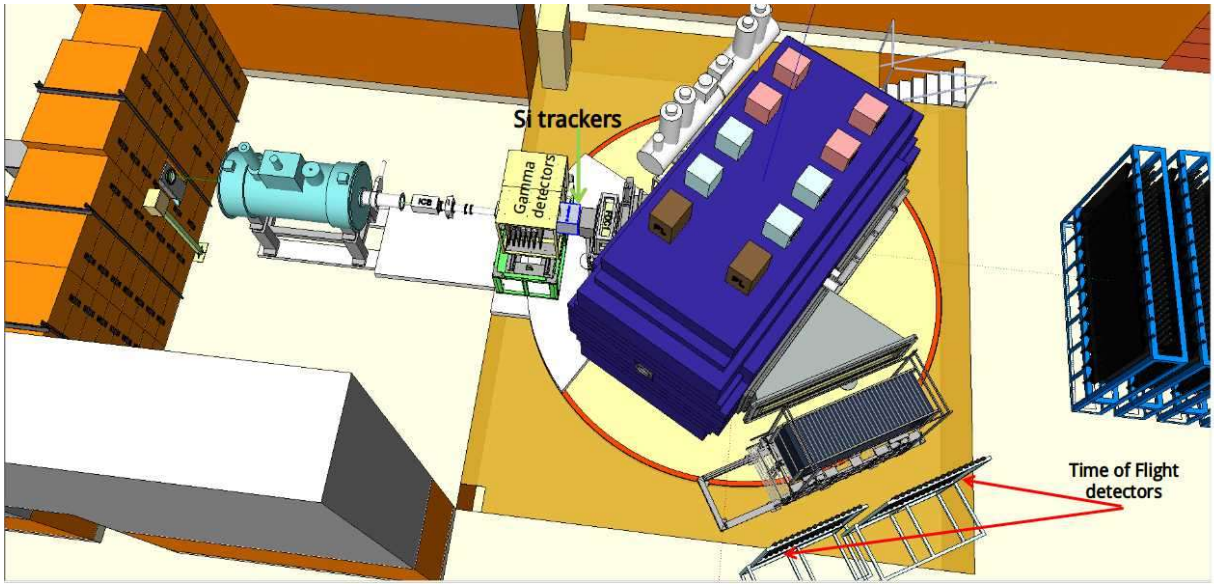

Figura 1. Perspectiva generala a ansamblului experimental. Spectrometrul SAMURAI va fi plasat la 30°.

Experimente de spectroscopie de dezintegrari la Texas A&M University

O alta tematica de cercetare pe care ne-am concentrat anul acesta a fost utilizarea spectroscopiei de dezintegrare pentru a studia rezonante importante in diferite reactii de captura radioactiva de protoni, reactii importante in astrofizica nucleara. Acum 10 ani la Cyclotron Institute, Texas A&M University, am implementat un plan de masuratori ce se folosesc de conditiile experimentale excelente produse de fasciculele primare de la ciclotronul superconductor K500 si spectrometrul MARS. Acest plan adreseaza absenta de date experimentale pentru rezonante importante in procesul de ardere a hidrogenului in novae. Planul a continuat si continua sa evolueze nu numai din punct de vedere al numarului crescut de nuclee măsurate, ci si in directia schimbarilor de ansamblu experimental, utilizand detectori din ce in ce mai sensibili si mai eficienti. De-a lungul anilor:

a. Detectorii de implantare au evoluat:
   i. detectori foarte subtiri DSSSD (Double Sided Silicon Strip Detectors) de tip W1-110, W1-65 and BB2-45 (respectiv 105, 65 si 45 mm grosime)
   ii. detector cu gas ASTROBOX1
   iii. detector cu gas ASTROBOX2
b. nucleele studiate pana acum sunt: ^{23}Al, ^{31}Cl, ^{27}P (cu detectori subtiri de Si si detectori HPGe pentru raze gamma) si ^{23}Al, ^{31}Cl si ^{35}K cu detectori de gaz (ASTROBOX1 si 2)
c. colaboratorii externi la experimentele TAMU au fost de la University of Jyvaskyla, University of Edinburgh, CEA/IRFU Saclay, CERN, IFIN-HH, …

In cele mai recente experimente, am facut masuratori cu ASTROBOX2, o versiune mult imbunatatita a primului detector de gas construit cu ajutorul dr. E. Pollacco de la CEA/IRFU Saclay, a dr. Ruiz si a colaboratorilor de la CERN. Detectorul ASTROBOX2 a fost inaugurat intr-un experiment in Aprilie 2015 (^{23}Al) si utilizat cu succes pentru studii aditionale ale nucleelor ^{31}Cl (Oct. 2016) si ^{35}K (iulie 2017 si octombrie 2017). Includ mai jos doar un spectru de protoni care arata varful de la E_p=260 keV, o resonanta foarte mult cautata din reactia ^{30}P(p,γ)^{31}S (Figura 2).

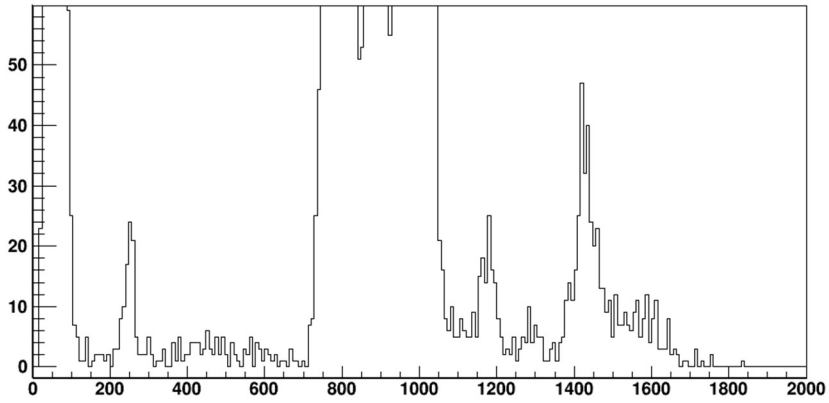

Figura 2. Spectru de protoni obtinut din dezintegrarea γp a nucleului 31Cl. Axa orizontala este in keV.

Trebuie mentionat aici ca partenerii de la TAMU au aprobat in Oct. 2017 propunerea noastra de a masura dezintegrarea nucleului ^{27}P cu detectorul ASTROBOX2 in College Station anul viitor (2018). Grupul NAG va fi responsabil de acest experiment si datele obtinute vor fi parte din teza de doctorat a lui I. Stefanescu. ^{27}P a fost masurat in trecut cu rezolutie slaba folosind implantare in detectori de Si.

3. Membrii grupului (tabel):

- Se include fiecare membru, rolul lui/ei in proiect si contributia de timp Full Time Equivalent (FTE) in proiect. Calcularea contributiei FTE se face astfel: FTE = Numar total de ore lucrate /Numar total de ore in perioada de raportare[2];

Nr. Crt	Prenume si Nume	Rol in proiect	Full Time Equivalent (FTE)
1	Livius TRACHE	Director Proiect	50%
2	Florin CARSTOIU	Cercetator Senior	
3	Alexandra-Ionela CHILUG	Membru grup	100%
4	Dana TUDOR	Membru grup	100%
5	Ionut-Catalin STEFANESCU	Membru grup	100%
6	Alexandra SPIRIDON	Membru grup	100%
7	Valentin BALANICA	Membru grup	25%
8	Gherghina STAN	Membru grup	5%

- **Lista de studenți PhD/Master si poziția curenta in institut.**
  1) Alexandra SPIRIDON, student PhD, Asistent Cercetare
  2) Alexandra-Ionela CHILUG, student PhD, Asistent Cercetare
  3) Dana TUDOR, student PhD, Asistent Cercetare
  4) Ionut-Catalin STEFANESCU, student master -> PhD, Fizician
  5) Iuliana STANCIU, student master -> PhD, Inginer

4. Alte rezultate din ultimul an legate de proiect:

- Lista de articole (journal or conference proceeding):
  - In 2016 am finalizat publicarea unei serii de 3 articole despre potentiale optice intre nuclei:
    Heavy Ion Orbiting and Regge Poles (I, II, III)
    F. Carstoiu, M. Lassaut, L. Trache, V. Balanica, **Rom. J. Phys. 61**, 400-412, 857-874, and 1180-1197 (2016)
  - *Simultaneous measurement of β-delayed proton and γ decay of 27P,* E. McCleskey, A. Banu, M. McCleskey, T. Davinson, D. T. Doherty, G. Lotay, B. T. Roeder, A. Saastamoinen, A. Spiridon, L. Trache, J. P. Wallace, P. J. Woods, and R. E. Tribble, **Phys. Rev. C 94**, 065806 (2016) - Published 27 December 2016
  - "*In-beam measurements of $^{13}C+^{12}C$ fusion reaction cross section at energies around and below Coulomb barrier"*, I. Stefanescu et al, in Proc. CSSP16, AIP Conf Proc., vol. 1852, p. 080011 (2017)
  - *"Activation measurements of 13C+12C fusion cross section at deep sub-barrier energies in IFIN-HH*", D. Tudor et al., in Proc. CSSP16, AIP Conf Proc., vol. 1852, p. 080012 (2017)
  - *Other indirect methods for nuclear astrophysics,* L. Trache, in Eur. Phys. Web of Conf, Proc. NPA8 Conference, Catania, June 18-23, 2016; accepted (2017)
  - *Uncovering the resonant behavior of $^{12}C+^{12}C$ fusion at astrophysical energies,* A. Tumino, C. Spitaleri, M. La Cognata, S. Cherubini, G.L. Guardo, M. Gulino, S.

[2] Total number of hours (for a certain period) = 170 average monthly hours x number of months (e.g., for a full year: 170 hours/month x 12 months = 2040 hours)

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 – submitted to *Nature*, Aug. 2017

- Lista de prezentari tinute de membrii grupului (titlu, data conferintei)
  - L. Trache, *Recent results and future opportunities in laboratory nuclear astrophysics,* at ENSAR2 NUSPRASEN Workshop, CERN Geneva, Dec. 6th, 2016
  - L. Trache: *Nuclear Astrophysics at IFIN-HH Bucharest,* at the 14th Russbach School on Nuclear Astrophysics, Russbach, Austria, March 12-18, 2017
  - A. Chilug, *Measurement of the ^{58}Ni (α, γ) ^{62}Zn fusion reaction cross section at deep sub-barrier energies relevant for nuclear astrophysics,* at the 14th Russbach School on Nuclear Astrophysics, Russbach, Austria, March 12-18, 2017
  - D. Tudor, *Experimental study of the ^{64}Zn(α, p)^{67}Ga fusion reaction at deep sub-barrier energies,* at the 14th Russbach School on Nuclear Astrophysics, Russbach, Austria, March 12-18, 2017
  - L. Trache: *Other indirect methods for nuclear astrophysics*, invited talk, Nuclear Physics for Astrophysics VIII (NPA8) Conference, Catania, June 18-32, 2017.
  - L. Trache: *Advances in nuclear astrophysics with direct and indirect methods at IFIN-HH*, at the 9th European School on Experimental Nuclear Astrophysics, St. Tecla, Sept. 17-24, 2017
- Alte publicatii.
  - *"Exotic Nuclei and Nuclear/Particle Astrophysics (VI). Physics with Small Accelerators"*, L. Trache and D.G. Ghita (eds), AIP Conference Proceedings, vol. 1852, Melville, New York 2017 and http://aip.scitation.org/toc/apc/1852/1?expanded=1852

5. **Alte activitati de grup (max. 1 page):**

- Colaborari, educatie, outreach.

Grupul NA este implicat in 4 experimente la RIBF in RIKEN, Japan si in alte colaborari la TAMU (Texas) si FAIR/GSI (Germany).
Directorul de Proiect, Livius Trache a fost de asemenea membru in alte proiecte (7 in 2017), in roluri de conducere:

- Director de Program al programului PN 16 42 pe tot institutul IFIN-HH, acesta incluzand 14 proiecte (Feb 2016 – Aug. 31, 2017)
- Director de Proiect al proiectului PN 16 42 03 02 cu titlul: "Structurarea Centrului de studiul si conservarea patrimoniului cultural"
- Conducator Adjunct de grup al Work Group NUSPRASEN of ENSAR2, un proiect European H2020
- Vicepresedinte al Consiliului de Administratie al proiectului European GENERA, parte din H2020.

De-asemenea, activitatea Grupului NA are o componenta de outreach centrata pe programul "Scoala Altfel" si pe scoala de vara Busteni pentru finalistii de la Olimpiada de Fizica (a 3-a editie in Iulie 2017).
Avem si o pagina web noua a grupului NAG: http://www.nipne.ro/research/departments/dfn.php

6. Raport Financiar (budget usage) pe perioada de raportare (in Anexa).

7. Plan de cercetare si tinte pentru anul urmator (max. 1 page).
Conform Propunerii de Proiect, urmatoarea etapa va avea doua scopuri principale:
- experimentele de separare de protoni (^{9}C in primul rand) la RIBF din RIKEN, Japan, si

- experimentul(ele) de dezintegrare beta-proton a nucleului ^{27}P la Universitatea Texas A&M, folosind detectorul ASTROBOX2. O versiune Europeana a acestui detector, care este in constructie in prezent, va fi finalizata si testata.
- publicarea rezultatelor din ultimii 2-3 years va fi accelerata.

ANEXA 1.B Indicatori de realizare intermediară

Tip indicator	**Număr**	**Scurtă descriere (dacă este cazul)**
Număr de articole ştiinţifice în reviste şi volume indexate	5+1	5 published, 1 submitted
Număr co-publicaţii	2	1 published + 1 submitted
Număr articole publicate în top 10% cele mai citate publicaţii	1+1	1 published + 1 submitted
Număr de brevete obţinute la nivel naţional şi internaţional		
Număr de brevete în curs de obţinere la nivel naţional şi internaţional		
Numărul altor forme de DPI solicitate: desene, mărci în domeniul strategic.		
Număr de tehnologii elaborate/transferate		
Număr de modele experimentale/prototitpuri		
Numărul de posturi de cercetatori echivalent normă întreagă (ENI) susţinute *	28.2	
Numărul de cercetători cu doctorat susţinuţi *	2	
Numărul de ingineri susţinuţi *		
Numărul de tehnicieni susţinuţi *		
Numărul personalului economic/administrativ susţinut *	1	
Numărul de doctoranzi susţinuţi *	4	
Număr de masteranzi susţinuţi *	1	
Număr de conferinţe organizate *		
Număr de participări la Conferinţe Internaţionale*	8	
Număr de prezentări la Conferinţe Internaţionale	7	
Număr de postere prezentate la Conferinţe Internaţionale*		
Număr de participanţi la Workshopuri*	4	
Număr de prezentări orale la Workshopuri	1	
Număr de postere prezentate la Workshopuri		
Numarul participantilor la intruniri FAIR –din cadrul Colaborarilor (Collaboration Meetings)	3	
Numărul de proiecte Orizont 2020 (inclusiv cele ale partenerilor dacă este cazul)	2	
Numărul de evenimente de comunicare şi popularizare a ştiinţei susţinute *	2	
Număr de cursuri de instruire sau perfecţionare realizate		
Altele (specificaţi)		

*) din Fondurile Programului

Bucharest-Magurele
Date: Nov. 6, 2017
Director de proiect,
Dr. Livius Trache