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*REFERENCES AND APPLICABLE DOCUMENTS**LIST OF ACRONYMS AND ABBREVIATIONS*

ScC	Scientific Committee
SC	Steering Committee
WG	Working Group
NUSPRASEN	N uclear S tructure P hysics, R eactions, A strophysics and S uperheavy E lements N etwork
NA	Networking Activity

EXECUTIVE SUMMARY

This is the final report on the activities on NA02 NUSPRASEN: the events, workshops, town meetings and scientific schools, planned and performed in the framework of the above named ENSAR2-WP2 in the period March 1, 2016 – February 2020. NUSPRASEN was designed as the Network Activity encompassing all physics subjects of the ENSAR2 project, therefore, the topics of the events were quite different. Nine workshops on precise topics, one EURISOL town meeting, and eight periodic nuclear astrophysics school events (part of the existing European Network of Nuclear Astrophysics Schools) were organised and supported in this time interval. We report briefly on each and on the general conclusions of them and those at the latest workshop in Helsinki, Nov. 25-27, 2019. During the latter and later at the GA in Athens, Feb. 10-14, 2020, extended discussions were devoted to the future directions of the ENSAR2 community inside the INFRAIA Research Infrastructures projects of the EU. The EURISOL Town Meeting on July 2018, Pisa, Italy, concerned a similarly important topic for the future of the European nuclear physics at low and intermediate energies community.

SECTION 1 INTRODUCTION

NUSPRASEN is the Networking Activity summarising the scientific goals of the ENSAR2 project – it has acted accordingly in the past four years, achieving a large representation in its working bodies, meeting subjects and participation.

In the ENSAR2 proposal NUSPRASEN was meant to:

- organise and support workshops on nuclear structure, nuclear reactions, nuclear astrophysics and superheavy elements, plus applications
- raise synergies of the ENSAR2 work packages and the ENSAR2 access facilities
- coordinate related activities and
- disseminate its results
- educate and form future generations of specialists.

The proposal set 7 milestones and 5 deliverables for this work package. All milestones and 4 deliverables were achieved and reported in time, this report is deliverable D2.5.

All events covered were scientific events and inherently the report contains not only organisational aspects, but also scientific ones, insisting on those that relate to the specific functions of NUSPRASEN in ENSAR2. Detailed reports on the events in M1-M34 were presented in D2.1, D2.2 and D2.4 and on the EURISOL town meeting in D2.3, therefore reports on those events will be shorter, and we will insist on the new events occurring between M35 and M48. For each event websites were setup, they are still available and contain further details. Due to the extension of the project for 6 months in 2020, NUSPRASEN plans and supports 3 more events using its manpower and remaining funds. These will be mentioned at the end of the report.

Risks – no important risks were/are foreseen, other than for timing, in some cases, where the actual timing of the planned events depended on factors not under our control: the later start of the whole project, the dependence on approvals of the scientific bodies of the collaborating institutions, etc.

No major difficulties, except for when we had to schedule some events at times different than those in the original proposal.

Gender equality: we did and do strive for a good representation of women among the participants and speakers at events. In addition, a LoI was signed with the European project GENERA (Gender Equality Network in European Research Area) to join its dedicated network.

SECTION 2 STARTUP ACTIVITIES, STEERING COMMITTEE AND ADJUSTED WORKSHOP PLAN

The NUSPRASEN workgroup set its agenda in the first months of the ENSAR2 project. It was described in the midterm report, deliverable D2.2. The set-up activities envisioned were to establish:

- a **Steering Committee**
- an **activity website**, and **logo**
- an **adjusted workshop plan** – defined by community.

The **NUSPRASEN Steering Committee** was selected and is composed of the following members:

- Angela Bonaccorso (U.Pisa, Italy)
- Maria Borge (CSIC-Madrid, Spain)
- Peter Dendooven (KVI-CART, The Netherlands)
- Zsolt Fulop (Atomki, Hungary)
- Rodi Herzberg (U.Liverpool, UK)
- Ari Jokinen (U.Jyväskylä, Finland)
- Denis Lacroix (IPN-Orsay, France)
- Silvia Lenzi (U.Padova, Italy)
- Adam Maj (U.Cracow, Poland)
- Christoph Scheidenberger (GSI, Germany) – WP coordinator
- Livius Trache (IFIN-HH, Romania) – WP deputy coordinator

The Steering Committee had regular and as-needed meetings by teleconference and further communications by email.

The NUSPRASEN **website**, where basic information on NUSPRASEN to be displayed (activity goals, past and future events, organisation, integration in ENSAR-2), and an activity **logo** were prepared. They are at <http://www.nusprasen.net/>

The logo is displayed in Figure 1, below.



Figure 1. The logo for NA02 NUSPRASEN, part of ENSAR2.

The main events of the **workshop plan** were organised as in the original proposal plus those that were agreed upon after the consultations that NUSPRASEN SC opened in January 2017 through a “**Call for workshop proposals**” (Jan – March 2017), which resulted in a modified meeting schedule, which was realised fully by now. A few events were added later, due to newly occurring needs and possibilities (also decided by the SC).

Below is the **list of Workshops** on nuclear structure, nuclear reactions, nuclear astrophysics & SHE, in chronologic order. The EURISOL Town Meeting is included also:

- **WS Nuclear Structure (M-NA2-2)** Dec. 6, 2016, CERN in Geneva (Switzerland) directly preceding the annual **ISOLDE User Meeting**. 10 invited speakers, ~50 participants
- **EURISOL-DF workshop**, Nov. 15-16, 2017, Lisbon (Portugal), 54 participants.
- **Workshop on Nuclear Reactions – Theory and Experiment (M-NA2-3)**, January 22-24, 2018, Warsaw, Poland, 77 participants, 30 invited speakers, 48 oral contributions, 11 posters.
- **SPES “Workshop on Low-Energy RIBs for fundamental symmetries”**, February 1-2, 2018, Pisa (Italy). Organised by INFN.
- **EURISOL Town Meeting (M-NA2-5)**, held in Pisa, Italy, on July 2-4, 2018.
- **WS Nuclear Physics in Stellar Explosions** Atomki, Debrecen, Sep.12-14, 2018. Co-sponsored by the COST Action 16117 ChETEC. 2.5 days, 44 talks. Organised by ATOMKI.
- **WS on current and future experiments at GANIL**, Caen, France, Oct. 8-12, 2018.
- **Indirect Methods in Nuclear Astrophysics (IMNA) (M-NA2-4)** - a workshop at ECT* Trento, Italy, Nov. 5-9, 2018. It was organised at ECT* (TNA10 in ENSAR2) and it was a successful cooperation between these two WP of ENSAR2. Organised by IFIN-HH.
- **WS Superheavy Element Research (M-NA2-6)** held on February 25-27, 2019 at GSI Darmstadt (Germany), 112 participants from 34 institutes in 18 countries.
- **Workshop Nuclear Science Applications (M-NA2-7), Helsinki**, Nov. 25-27, 2019 (topic/title changed), about 70 participants from 28 countries.

As said above, the recently approved extension of the ENSARA2 project allowed to include two other workshops and two editions of the nuclear astrophysics schools, see further:

- **WS on “New science opportunities at ELI-NP”**, Bucharest-Magurele, moved to June 2020
- **ECT* workshop KRINA “Key reactions in nuclear astrophysics”**, ECT* Trento, June 22-26, 2020.

SECTION 3 TOPICAL WORKSHOPS

3.1 WS Nuclear structure

NUSPRASEN workshop 1 has taken place at CERN in the Council Chamber, on 6 Dec. 2016, as a satellite meeting of the annual ISOLDE workshop. This has ensured minimal extra organisational effort and maximal attendance. The number of participants was 50-60 and all presentations were invited on topics agreed by the Scientific Committee of the event. The Scientific Committee consisted of the following members: Maria J. Garcia Borge, Zsolt Fülöp, Silvia Lenzi, Riccardo Raabe, Christoph Scheidenberger, Livius Trache, and Jennifer Weterings. Several presentations were made (10), followed by discussions. At the suggestion of the committee members at this workshop, extra attention was given to nuclear astrophysics.

The website of the meeting was available in advance for the information of the participants, for registration and further details: <https://indico.cern.ch/event/577013/overview> . It also includes the “Book of Abstracts”.

The event was chaired by C. Scheidenberger. The notes below describe in detail the scientific points treated and the opinions of the participants. The event was a success, in form and substance. Details in D2.1.

3.2 Workshop on Nuclear reactions – Theory and Experiment

NUSPRASEN workshop 2: This was one of the milestone workshops of WP2 NUSPRASEN. It was held in Warsaw, Poland, Jan. 22-24, 2018. The Organising Committee was composed of the following members: Angela Bonaccorso, **Denis Lacroix (Chair)**, Adam Maj, Paweł Napiorkowski, Krzysztof Rusek (Co-Chair), Christoph Scheidenberger (Co-Chair), and Livius Trache. There were **30 invited speakers, 48 talks, 11 posters, 77 participants. The main topics were:**

- 1) Fragment production, fusion and fission
- 2) Direct reactions with light exotic beams including ab-initio calculations and nuclear astrophysics
- 3) Deep inelastic reactions, multi-nucleon transfer and superfluidity including very heavy elements
- 4) High-energy beams and experiments in high-energy storage rings at GSI and FAIR
- 5) Reactions with hypernuclei
- 6) ELI-NP, small facilities
- 7) Applications: Biophysics and hadron therapy, Space radiation research

More details can be found at the workshop website <http://slcj.uw.edu.pl/en/nusprasen>

In short, the summary, outcome and conclusions are as follows (detailed description in D2.2):

- The number of participants reflects the high interest in nuclear reactions
- A complete overview of the many facets of nuclear reactions has been given by experts in the different sub-fields; one success was the cross-fertilisation (experiment or theory) between different sub-fields that usually do not meet each other.
- The workshop gave many opportunities for dedicated discussions on the current interest in experimental programmes and the current need for theory; the need for more precise theoretical estimates was underlined
- Some missing theories for future programmes have been identified; the necessity to identify selected “key experiments” to constrain reactions theories was mentioned
- The impact of reactions on societal applications has also been discussed and illustrated.

It is mandatory to further improve the exchange between experimentalists and theoreticians, and to identify ways to reach this goal (e.g., funds for dedicated workshops, exchange of people, closer collaborations, etc.), especially at the European level; the issue of limited manpower in the field of nuclear reactions and possible solutions to this problem have been largely discussed.

3.3 SPES “Workshop on Low-Energy RIBs for fundamental symmetries”

The SPES-NUSPRASEN Workshop was held at INFN in Pisa (Italy) on 1-2 February 2018 in the framework of the annual SPES 1-day user group meetings. Its topical focus is reflected in the workshop. Workshop chairs were Angela Bonaccorso, Alejandro Kievsky and Giacomo De Angelis. The NUSPRASEN-SC members Silvia Lenzi, Ari Jokinen, and Christoph Scheidenberger joined the Scientific Committee. Overall, 42 participants from seven countries were registered.

The SPES project at Legnaro is one of the important pillars of the nuclear science community in Europe; it is located at the INFN-LNL in Legnaro, Italy. Parallel to the operation of the existing accelerator facilities, the construction work is progressing and new instrumentation is under development. This collaboration workshop is the 6th in a series and part of the roadmap towards the experimental programme at SPES; therefore, it is an important event for the user groups of the present facility. The workshop was

jointly organised with NUSPRASEN and the topical focus was on fundamental interactions. The general goal was to discuss new topics, related instrumentation, collaborations, and to come up with new LoIs and proposals for new experiments. There were two main blocks, one illustrating the status of the SPES project (time line, available beams etc., and with two keynote speakers elucidating the potentiality of RIB beams for the proposed research), the other with the proposed experiments, new ideas and proposed instrumentation. A roundtable discussion in the evening of February 1st rounded up the overall workshop programme. The workshop website is located at

<https://agenda.infn.it/internalPage.py?pageId=1&confId=13891>

The main results of the discussions were summarised as follows:

- Fundamental interactions are a very appealing topic and may have impact on various aspects of BSM physics on the low-energy scale. EDM and beta-decay experiments are considered.
- Fundamental interactions need long-term effort and commitment (resources, many people, time, beam time, etc.)
- Beam development is needed (for heavy beams, medium-heavy beams like Ba are in reach at LNL from fission fragments).
- Theory involvement (e.g., from groups in Pisa) can be an important asset of such activity
- Overall, to initiate such a programme requires a dedicated decision and coherent effort of laboratory, user groups, theorists, the allocation of resources and long-term commitment.
- On the European level, coordination will be useful to identify, assess and evaluate important future directions, to take strategic decisions for a complementary science programme of the laboratories, to align efforts and assignments accordingly with the goal of best exploitation of efforts and investments of facilities and scientists, to maximise the scientific impact and output.

Further details in D2.2.

3.4 EURISOL-Distributed Facility workshop

Nov. 15-16, 2017, Lisbon (Portugal), 54 participants

The EURISOL facility is a project of the European community of nuclear physics that was many years in the planning. It is supposed to be the solution of this community to the needs of modern nuclear physics, which implies the availability of radioactive ion beams (RIB). Of the two major ways of producing RIBs for research, EURISOL was envisioned as the facility of ISOL-type beams of higher quality, intensity and tunable energies. The project went through different phases. Most recently a Distributed Facility EURISOL DF was considered. The workshop in Pisa dealt with this proposal. It produced the idea of having an EURISOL Town Meeting in 2018. That took place in Pisa as well, in July 2018 (see below).

3.5 The workshop “Nuclear Physics in Stellar Explosions”

The workshop was organised in Sept. 12-14, 2018 at the Atomki institute, Debrecen, Hungary. Website: <http://w3.atomki.hu/astro2018/>. The motivation behind this workshop is simple: about 50% of the isotopes heavier than iron are synthesised in explosive nucleosynthesis scenarios. Namely, most probably the astrophysical r-process – which is probably still the least known nucleosynthesis scenario – takes place either in merging neutron stars or during the supernova explosion of massive stars. Furthermore, according to our current knowledge the stable proton-rich – so-called p-isotopes – are formed by photodisintegration reactions in X-ray bursts. Nowadays, a large fraction of the isotopes involved into these nucleosynthesis

scenarios can be produced in radioactive isotope beam facilities like RIKEN Nishina Center, FRIB, or at FAIR/GSI. Furthermore, in order to study their properties, the development of cutting-edge detection systems is necessary. Therefore, the aim of the workshop was to review our knowledge on these nucleosynthesis processes and to discuss the current results in detector development and possible cooperation with high tech industry.

In 2.5 days of invited talks and presentations the workshop's topics were covered by 44 talks. About 60 students, researchers and representatives from companies and research centers have attended the workshop from 10 European countries (including Croatia, Finland, France, Germany, Hungary, Romania, Spain, Swiss, Turkey and UK). With the permission of the authors more than 80% of presentations are available at the webpage of the event (<http://w3.atomki.hu/astro2018/#schedule>). Furthermore, on the afternoon of Thursday the workshop participants visited the National Instruments factory and development center, located at Debrecen. This workshop was also supported logistically and financially by the COST action 016117 ChETEC "Chemical Elements as Tracers of the Evolution of Cosmos".

3.6 WS on current and future experiments at GANIL

Website: <https://gcm2018.sciencesconf.org/>

The workshop was organised in Caen, France on October 8th-12th, 2018. This event was the first edition of a series of workshop that replaced the "Spiral2 week" meetings, and will be organised by GANIL. The purpose of the meeting was to bring together the whole low-energy nuclear physics community working with GANIL (TA in ENSAR2) or similar facilities in Europe to discuss and define coherently future research programmes. An important effort was made by the organisers to reach out to the international users of the GANIL installations. The scientific programme was organised around reviewing the state-of-the-art of the user research fields and the physics programmes that they may develop in the upcoming 5-year time period at GANIL. The status of the infrastructures (accelerators, spectrometers and instrumentation) was reviewed to disseminate to the conveners the progress of upgrade phase of GANIL.

The NUSPRASEN sponsorship has enhanced the internationalisation of the theory keynote speakers (43% non-FR of which 66% EU members) and by calling on the sponsored conveners to write a short scientific report based on their presentation, which will serve in a second step for the long-range plan of GANIL in the EU context. A major impact of this initiative is to contribute to the upcoming GANIL perspective for the next decade. Another positive benefit of the present initiative concerns fostering science.

3.7 ECT* "Workshop on Indirect Methods in Nuclear Astrophysics"

Website: <https://indico.ectstar.eu/event/27/overview>

The workshop was organised in Nov. 4-9, 2018 at the European Centre for Theoretical Studies in Nuclear Physics and Related Areas ECT*, Trento, Italy. ECT* is TNA10 in ENSAR2. The activity was proposed by an international group in May 2017 and approved by the ECT* Board in July, the same year. It 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. 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. Similarly, we wanted to review the importance of nuclear physics in cosmology and stellar evolution was another important objective.

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 programmes, were included. New directions were touched upon.

Over 30 participants registered for this event. 26 presentations of over 45 min each were given. The participants were mostly from Europe, but we had a reasonably large number of participants from the USA, and from Japan and China. Three late cancellations were motivated by personal problems of the registrants (one each from China, Spain and USA). Two of their talks were successfully covered by other participants. The participants were mostly senior level scientists, but we had also 4 young students, of which 2 have presented communications of 20 min each. Among the participants 7 were female.

The website of the event <https://indico.ectstar.eu/event/27/overview> was open in time by the ECT* staff and completed by our colleague dr. Alexandra Spiridon (IFIN-HH). Most of the lectures were posted online during the workshop <https://indico.ectstar.eu/event/27/timetable/#20181105.detailed> and will be completed with the materials that the authors agree to be made public.

Scientifically the most important achievements are presented above. The most important one, we stress again, was that specialists in various subjects met and talked. As the realm of nuclear astrophysics gets richer now, it is of paramount importance that we cooperate closely and that new connections are being formed among the specialists in its different sub-fields. Same importance has the fact that also theoreticians and experimentalists were talking to each other.

Another important consequence may be considered that at the end of the workshop the participants decided to have another proposal for an ECT* workshop on key reactions in nuclear astrophysics and that a group of initiative was setup already. 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.

3.8 Workshop Superheavy Element Research

Website: <https://indico.gsi.de/event/7760/>

The workshop **Superheavy Element Research (M-NA2-6 and subject of Subtask 2.4: Superheavy elements)** was held on February 25-27, 2019 at GSI Darmstadt (Germany), integrated in the format of the NUSTAR Annual Meeting 2019. It was organised by the workshop Scientific Committee:

Michael Block (GSI-Darmstadt and HIM-Mainz)

Christoph E. Duellmann (GSI-Darmstadt, HIM-Mainz and JG-Universität Mainz)

Rolf-Dietmar Herzberg (JYFL and U.Liverpool; member of the NUSPRASEN Steering Comm.)

Wolfram Korten (CEA Saclay, Chair of the NUSTAR Board of Representatives)

Bettina Lommel (GSI-Darmstadt, Head of Target Laboratories)

Christoph Scheidenberger (GSI and JLU-Giessen; leader of NUSPRASEN work package)

The workshop's declared main goals were to:

- Update ongoing activities in Europe, stimulate cooperation among European laboratories, through presentations by PhD students, postdocs and early career researchers
- Provide support and development of next-generation researchers in the field
- Review all aspects of target developments for next generation SHE experiments using high intensity beams of upgraded facilities
- Produce an overview of recent highlight results and achievements world-wide

31 invited speakers and a total of 112 participants from 34 institutes in 18 countries were present.

3.9 NUSPRASEN Workshop on Nuclear Science Applications»

This NUSPRASEN milestone “Workshop on Nuclear Science Applications” was held in Helsinki (Finland) in the period 25-27 November 2019. This milestone was originally planned for Month 42; however, due to the modified start date of ENSAR2, this month turned out to become August 2019, but a workshop in August does not make sense due to holiday season and the absence of many people. Consequently, the workshop needed to be shifted: September is very difficult because it is the “classical” month of many conferences and workshops in our field (e.g. Mazurian Lakes, Collaboration meetings like NUSTAR-Week, etc.), October sees many conflicting events that touch the ENSAR2 community (for instance: the final MediNet meeting was held on October 6-8 and therefore it is very difficult for the MediNet community to attract their members as participants for another, somewhat similar workshop in October), therefore November was the earliest possible useful month, where the workshop could take place. It is important to note that this shift by 3 months does neither affect the NUSPRASEN work plan nor the overall ENSAR2 activity.

The workshop was organised by a Scientific Committee with the following members: Daniel Bemmerer (HZDR, Dresden), Peter Dendooven (Univ. Groningen & Univ. Helsinki), Zsolt Fülöp (Atomki, Debrecen), Paul Greenless (Univ. Jyväskylä), Ari Jokinen (Univ. Jyväskylä), Giulio Magrin (MedAustron, Wiener Neustadt), Timo Sajavaara (Univ. Jyväskylä), Christoph Scheidenberger (GSI, Darmstadt), Mihai Straticiuc (IFIN-HH, Bucharest), Peter Thirolf (LMU Munich), Livius Trache (IFIN-HH, Bucharest), Giuseppe Verde (INFN, Catania). In addition, Timo Sajavaara (Univ. Jyväskylä) served the Local Organising Committee.

Half-a-day sessions on applications in the following fields were held:

- medical field (2 sessions)
- heritage science
- nuclear safety, security and safeguards
- collaboration with and the needs of industry

The most important issues the organisers had in mind were inter-disciplinary connections. Contacts and discussions with people working in adjacent fields that use techniques, methods and instruments initiated by nuclear physics. In each session, two invited speakers setup the stage, followed by contributed presentations selected from the abstracts submitted before. The invited speakers were carefully selected and in general from outside ENSAR2: from IAEA, from the medical community, from industry, from outside Europe. In addition, a discussion on future collaborations in nuclear science applications was organised. Details of the programme can be found at <https://indico.gsi.de/event/9181/overview>. Overall, 90 people from 28 countries and 3 continents registered for the workshop (but 20 of these did not show up: several did not obtain a visa from the Finnish authorities, but most of them gave no reason).

The workshop has resulted in a better understanding and appreciation between communities working on different applications of nuclear science and the people directly from the ENSAR2 community, who are more academically oriented. It became clear, as was the purpose of the workshop, what some of the major scientific questions and technological needs in the various fields are. There were lively discussions during the presentation sessions as well as outside of these.

Many interesting points of view and issues related to a next "ENSAR2-like" activity were put forward and discussed. The document summarising this discussion will remain valuable as reference. Many participants expressed that they had very much enjoyed the workshop; it can thus be considered a great success.

SECTION 4 THE EURISOL TOWN MEETING

EURISOL Town Meeting, Pisa, Italy, July 2-4, 2018

Website: <https://agenda.infn.it/conferenceDisplay.py?ovw=True&confId=14402>

This was a unique type of event organised by NUPRASEN. It dealt with a crucial aspect of the future plans of the whole ENSAR2 community: where does Europe go in the not-so-immediate future, how to keep Europe competitive in the field of nuclear physics with radioactive beams at energies below those provided by other facilities (like FAIR in Darmstadt, Germany). The meeting took place in Pisa on July 2-4, 2018 with the goal to discuss and disseminate the recent progress, the ongoing physics and instrumentation developments, as well as the specific needs and plans of the EURISOL community. These were recently expressed also by the EURISOL Distributed Facility initiative. The town meeting was the subject of a detailed report D2.3 submitted in February 2019 (M36). We shall not repeat those details here, will only mention the main lines and results as the advancement of the EURISOL concept with the long-term goal of building a dedicated facility is of importance for the European nuclear physics community and, therefore, needs special attention. The organisers and the participants appreciated that it requires activities to continuously update the scientific case, shape the community, and strengthen the synergies with other facilities. A JRA EURISOL work package exists in ENSAR2 and the EURISOL networking activities were included in the NUSPRASEN network. The meeting was attended by 45 participants from 10 countries and consisted of 30 invited talks, several contributed posters and a round table.

All slides presented at the meeting can be found at the EURISOL TM Web site <https://agenda.infn.it/conferenceDisplay.py?ovw=True&confId=14402>. After the meeting every speaker

was asked to submit a short-written report on his/her contribution. These reports are included in the overall report from EURISOL TM, with D2.3.

SECTION 5 EDUCATION AND FORMATION OF NEXT GENERATIONS: THE EUROPEAN NETWORK OF NUCLEAR ASTROPHYSICS SCHOOLS

Task 2.3 of the ENSAR2 proposal stipulated to “support ENNAS (European Network Nuclear Astrophysics Schools)”.

The European Network of Nuclear Astrophysics Schools (ENNAS) exists since 2012 and consists of an understanding between the organisers of three schools of tradition in Europe to associate in order “to correlate the topics and timings of the schools such that these schools become regular and well-established staples of the scientific environment in Europe and in the world” (citations from the MoU signed).

Eight editions of the three ENNAS schools took place in the reporting period.

- the 13th, 14th, 15th and 16th **Russbach School on Nuclear Astrophysics**, Russbach, Austria, March 2016, 2017, 2018, 2019; typically, 65 participants, 27 lectures, 23 short contributions by students. Organised jointly by GANIL, Caen, France and TU Muenchen, Germany
- the 9th and 10th **European Summer Schools on Experimental Nuclear Astrophysics** (ESSENA 2017), St. Tecla, Italy, Sep. 17-24, 2017; 92 participants, 34 lectures, 25 student contributions, respectively ESSENA 2019, Catania, June 16-23, 2019. Organised by LNS and University of Catania, Italy..
- the 27th and 28th **Carpathian Summer School of Physics** “Exotic nuclei and Nuclear/Particle Astrophysics (VI/VII). Physics with small accelerators” (CSSP16 and CSSP18), Sinaia, Romania, July 2016 and 2018; 110, 92 participants, ~70 lectures, 23-18 student communications. Organised by IFIN-HH Bucharest-Magurele, Romania.

More on ENNAS was in the previous reports D2.2 and D2.4. ENSAR2 supported these schools through NUSPRASEN, as co-sponsor, providing what the Organisers call “seed money”. This helped the Organisers to call for and obtain the support of other sponsors. The schools are regular: the yearly Russbach school and the biennial Catania and Carpathian schools (in odd, respectively even years) and offered for more than a decade reliable events that helped the education and formation of newer generations of specialists in nuclear physics, with emphasis on nuclear astrophysics. We enclose below excerpts from the reports of their organisers on schools’ proceedings and results.

Publications. The ESSENA (Catania) and the Carpathian (Sinaia, Romania) schools, by tradition, publish their proceedings with some of the best publishing houses in our field of physics. Four volumes were published in this period:

- ESSENA 2017 in C. Spitaleri, L. Lamia, R.G. Pizzone, G. Rapisarda and M.L. Sergi (Eds.), EPJ Web of Conferences, Volume 184 (2018), *9th European Summer School on Experimental Nuclear Astrophysics, Santa Tecla, Catania, Italy, September 17-24, 2017*. <https://www.epj-conferences.org/articles/epjconf/abs/2018/19/contents/contents.html> ;
- CSSP16 in L. Trache and D.G. Ghita (eds.), “*Exotic nuclei and Nuclear/Particle Astrophysics (VI). Physics with small accelerators*”, American Institute of Physics Conference Proceedings, vol. 1852, NY 2017. ISBN 978-0-7354-1526-3; ISSN 0094-243X, and is available online at <http://www.proceedings.aip.org> (Open Access).

- CSSP18 in L. Trache and A. Spiridon (eds.), “*Exotic nuclei and Nuclear/Particle Astrophysics (VII). Physics with small accelerators*”, AIP Conference Proceedings, vol. 2076, ISBN 978-0-7354-1804-2; ISSN 0094-243X. <https://aip.scitation.org/toc/apc/2076/1?expanded=2076> (perpetual Open Access). NUSPRASEN has paid the publication fee for this volume!
- ESSENA 2019 was published this month in C. Spitaleri, L. Lamia et al (eds.), *Proceedings of the 10th European Summer School on Experimental Nuclear Astrophysics*, EPJ Web of Conferences **227**, 010 (2020).

It is to be underlined here that in these cases the volumes contain both longer articles from distinguished lecturers and the shorter communications of the students, as presented orally at the schools. The organisers and editors consider this in itself another contribution to the education and formation of the new generations of scientists.

5.1 Russbach Schools on Nuclear Astrophysics in Russbach

The winter schools of nuclear astrophysics are being organised annually in Russbach, Austria in a friendly and not so expensive rural mountain setting. It reached 17 editions with the one coming in a few weeks in March 2020. NUSPRASEN helped so far financing four editions from 2016 to 2019. Apart from ENSAR2, the Excellence Cluster of TUM & LMU at Munich, GANIL and IN2P3 were sponsoring the school. After the loss last year of the support from the University of Basel due the retirement of Prof. Thielemann, *the contribution from ENSAR2 was absolutely essential to keep the viability of the school*. The funds were used in priority to support all undergraduate and PhD students, as well as most of the young(er) postdocs for their twin-room accommodation, half board (breakfast & dinner) and the coffee breaks. In addition, one accommodation grant to senior scientist was given. No travel costs were reimbursed.

Website <https://indico.ph.tum.de/event/3845/>

It was organised in 2018 by a group from three institutions: GANIL, Caen, France, Universität Mainz and Technische Universität München, Germany. This winter / spring school was started in 2004 within the Helmholtz "Virtual Institute of Nuclear Structure and Astrophysics" (VISTARS; Director K.-L. Kratz)). Since 2014, it is endorsed by the European Physical Society through its Nuclear Physics Board as part of the "European Network of Nuclear Astrophysics Schools" (ENNAS). In the intervening time, the school has successfully grown and broaden so that its organisation now also directly includes GANIL (O. Sorlin) and the Technische Universität München & Universe Excellence Cluster (S. Bishop).

Just as an example: in 2018, there were in **total 63 participants** from altogether 10 countries – from Japan, USA, Iran to European countries as Italy, Germany, France, Romania, Hungary, Slovenia & Germany. 23 invited scientists gave **lectures** of 40 to 60 min, each; and 24 PhD students presented a total of **shorter contributions** of 15 min, each. Two lecturers cancelled at the very last moment.

By tradition of the Russbach school, there was no proceedings. However, volunteers handed in pdf-files of the contributions that are available at the school's website <https://indico.ph.tum.de/event/3845/> . Similar numbers were valid for all four editions sponsored by NUSPRASEN. Details for each one in D2.1, D2.2 and D2.3

5.2 European Summer Schools on Experimental Nuclear Astrophysics (ESSENA)

These are summer schools, organised by the nuclear astrophysics group of prof. Claudio Spitaleri. As a rule, they were/are organised every two years in the odd years (2017 and 2019 in this case) and have reached 10 editions so far. The LNS and University of Catania group are well known for their innovative indirect method in nuclear astrophysics called the Trojan Horse Method. They are also known for the good number of younger scientists that grew in this group and are populating now position at Sicilian universities and even abroad.

The two editions we are talking about were hosted in St. Tecla (2017) and in Catania proper, in the LNS facilities. The number of participants and the details about the two volumes of Proceedings were given before.

5.3 Carpathian Summer Schools of Physics (CSSP)

Websites: <http://cssp16.nipne.ro>, <http://cssp18.nipne.ro/>

The **Carpathian Summer School of Physics 2016 (CSSP16) and 2018 (CSSP18)** was held July 2016, 2018, in Sinaia, Romania, with “**Horia Hulubei**” **National Institute for Physics and Nuclear Engineering (IFIN-HH) Bucharest-Magurele** the sole institutional organiser of the school. These consist of longer courses, two weeks each, biennially organised, in the even years. They were the 27th and 28th editions of an event that has a long tradition. The title of the event was: “**Exotic Nuclei and Nuclear/Particle Astrophysics (VI/VII). Physics with small accelerators**” and were the 6th and 7th in the latest series with the same title organised 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 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 through 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 week, 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.

Students from Romania, from the surrounding regions and all countries were invited to attend. A limited number of stipends to cover the local expenses for students were available. In 2016 there were 112 participants, while in 2018 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 Saturdays in the middle 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.

Sponsors of the school were *IFIN-HH as organising institution*, the *Romanian Ministry for Research and Innovation (MCI)*, ENSAR2 through *the NUSPRASEN network*, and the industrial private exhibitors *CAEN, Wiener, Canberra, Coralgon, Pfeiffer, BSI, Bruker, Total Spectrum, iseg, Quantech Works*.

See the website for the closing remarks:

<http://www.nipne.ro/indico/getFile.py/access?sessionId=95&resId=0&materialId=0&confId=368>

The volumes of the Proceedings of CSSP18 were published (see above).

SECTION 6. FURTHER ACTIVITIES: EVENTS PLANNED FOR 2020

In 2020 we have more events planned:

- The **17th Russbach School on Nuclear Astrophysics**, March 15-21, 2020, Russbach, Austria.
- The workshop “**New science opportunities at ELI-NP. Users Group setup**”, at IFIN-HH Bucharest-Magurele, June 2020. In collaboration with TA9 IFIN-HH/ELI-NP.
- The ECT* workshop “**Key reactions in Nuclear Astrophysics**” (**KRINA 2020**), June 22-26, ECT* Trento, Italy. In collaboration with TA10 ECT*.
- The **28th Carpathian Summer School of Physics “Exotic nuclei and Nuclear/Particle Astrophysics (VIII). Physics with small accelerators” (CSSP20)**, Sinaia, Romania, June 28 - July 11, 2020.

This was only possible due to the extension by six month of the ENSAR2 project. The titles of the events are telling by themselves where they place in the NUSPRASEN assembly. All of the above will have only partial support (seed money) from NUSPRASEN. The two workshops are being organised in close collaboration and co-financing with two TA’s of ENSAR2.

SECTION 7. CONCLUSION AND OUTLOOK

The NUSPRASEN activity was in full swing in the whole period reported here. Its SC monitored and monitors the ongoing activities and prepares a few future events in due time. The complete workplan has been established, completed and is updated if the need occurs. All activities were in line with the schedule and the spending is in line with the planned budgets. The network website remains operational. Several workshop events, nine in total, one town meeting and eight schools have taken place. All events were well organised, well attended and very much appreciated by the participants. A few images from four events, randomly chosen, are shown in Figure 2, part of a report presented at the General Assembly meeting in Athens, Greece, in February 2020.

Overall, the scheduled milestones have been reached, as were the previous four deliverables, and they were submitted and accepted. The close interaction with facility/collaboration meetings was useful and increased synergies among the ENSAR2 work packages. More positive effects on community-facility interaction and user-group formation can be expected given that we will have three more events in the closing six months of the project.

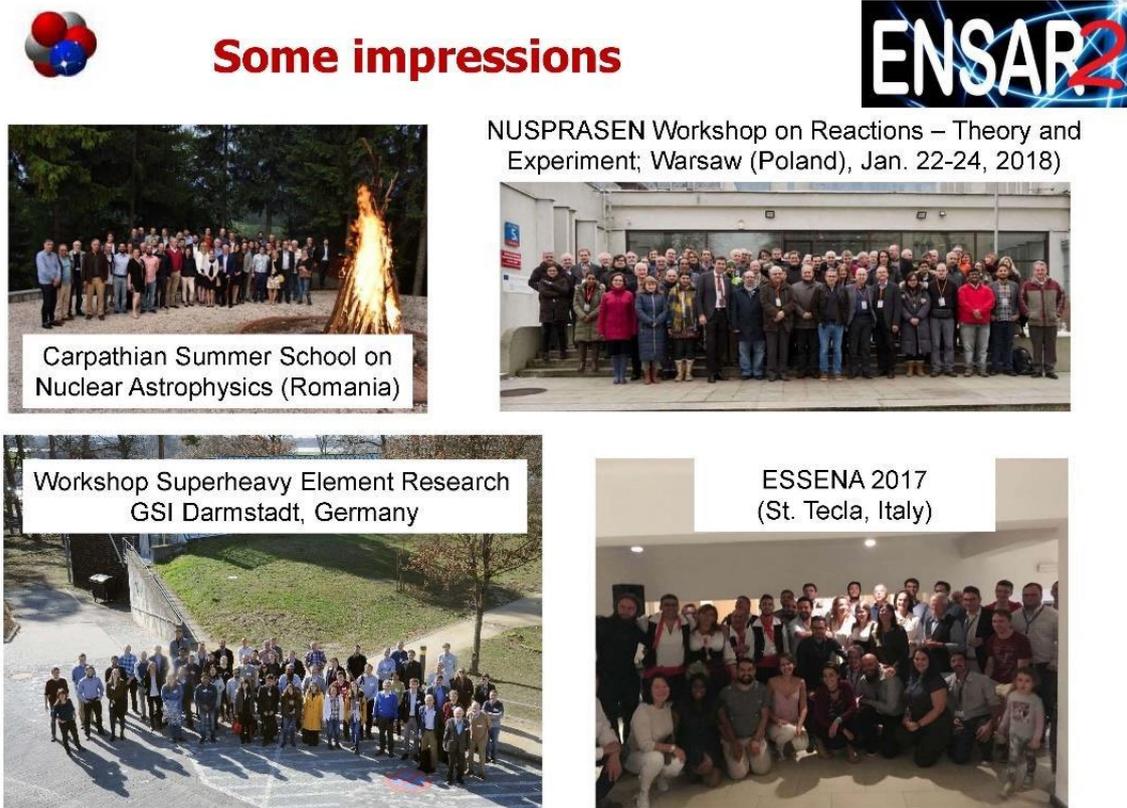


Figure 2. Images from four events organised under NUSPRASEN.

The scheme applied by NUSPRASEN in several of its organised events followed the one utilised in the first workshop (ISOLDE workshop). It was clearly noticed that jointly organisation of our workshops with regular events of the large partners (like Users Meetings of CERN, GANIL, GSI, INFN, etc....) helps to raise synergies among different ENSAR2 partners, stimulates information exchange between the users connected to the facility and allows for the developments in line with the requests and needs of the community linked to the ENSAR2 facilities. Moreover, the joint organisation helps in the development of research programmes built among ENSAR2 partners to make use of the potential of the different institutions and helps to avoid unnecessary duplications, in line with the aims of the EURISOL Distributed Facility (EURISOL-DF). Simultaneously it helps reducing travel costs.