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MID-TERM REPORT - STATUS AND NEEDS – SYNTHESIS OF RESULTS OF FIRST WORKSHOPS

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LIST OF ACRONYMS AND ABBREVIATIONS

ScC	Scientific Committee
SC	Steering Committee
WG	Working Group
NUSPRASEN	Nuclear Structure Physics, Reactions, Astrophysics and Superheavy Elements Network
NA	Networking Activity

EXECUTIVE SUMMARY

This is the mid-term report and summary of the works performed in the framework of the ENSAR2-WP2: NUSPRASEN. It includes the activities and workshops organised or supported by it within the first 24 months of the project, i.e. between March 1, 2016 and February 28, 2018. This is explicitly about the setup of organisms of NA2, the setup of its website and its working rules. Then, we report on the NUSPRASEN workshop 1 (organised at CERN ISOLDE on December 6, 2016), workshop 2 (held at Warsaw from January 22 to 24, 2018) and the ENNAS nuclear astrophysics schools, which were co-financed. The latter include the 13th Russbach School on Nuclear Astrophysics (Russbach, Austria, March 2016), the 27th Carpathian Summer School of Physics (Sinaia, Romania, June26 – July 9, 2016), the 14th Russbach School on Nuclear Astrophysics (Russbach, Austria, March 12 – 18, 2017), and the 9th European School on Experimental Nuclear Astrophysics (St. Tecla, Italy, Sep. 17 – 24, 2017). Finally, we also report on additional events, which were co-organised and co-financed in the NUSPRASEN context, as a consequence of a bottom-up "call for proposals", which is described below. In this period, this concerns the SPES-NUSPRASEN Workshop entitled "Probing Fundamental Symmetries and Interactions by low-energy excitations with RIBs", which was held February 1 and 2, 2018, in Pisa.

INTRODUCTION

The ENSAR2 start on March 1, 2016 found the NUSPRASEN workgroup with an agenda partly fixed and partly to be updated and agreed upon. The participants had to work on adapting the initial agenda to the current timing. They took into account new developments, needs and ideas, which were collected by a bottom-up approach, where the ENSAR2 community was widely involved. Furthermore, the first months were dedicated to setting up the working committees, their roles and the rules to follow in taking decisions. Several workshops were held. Some activities and results were already reported within Deliverable D2.1; these are only briefly mentioned here, while emphasis is given to the new aspects and recent workshops, which will be reported in more detail here.

SECTION 1 START-UP ACTIVITIES, STEERING COMMITTEE AND ADJUSTED WORKSHOP PLAN

Steering Committee:

The Steering Committee (SC) was set up. It comprises the following members: Angela Bonaccorso (INFN Pisa, Italy), Maria Borge (CERN, Switzerland), Peter Dendooven (KVI-CART, The Netherlands), Zsolt Fülöp (Atomki, Hungary), Rodi Herzberg (U. Liverpool, UK), Ari Jokinen (U. Jyväskylä, Finland), Denis Lacroix (IPN-Orsay, France), Silvia Lenzi (U. Padova, Italy), Adam Maj (IFJ-PAN Cracow, Poland), Christoph Scheidenberger (JLU Giessen), and Livius Trache (IFIN-HH, Romania). The SC aims at coordinating and organising the different activities and tasks, in particular it prepares the organisation of the meetings and workshops as outlined in the Grant Agreement. The SC oversees and steers the whole networking activity as such. The SC sets up individual Scientific Committees (ScCs) for every planned event; these ScCs will comprise experts of the topical focus of the individual event and some NUSPRASEN SC members as liaison persons. The SC has launched a "call for proposals" and evaluated the feedback from the community; this results in an updated and extended schedule of NUSPRASEN events.

Adjusted workshop plan:

Based on a suggestion of the ENSAR2 PCC and the recent, very positive experience with the first NUSPRASEN workshop that was organised as a satellite workshop at ISOLDE (held in December 2017), a call for workshop proposals was launched in January 2017 by the NUSPRASEN SC. This format (i.e. the combination of a NUSPRASEN workshop with a facility event, like, e.g., a collaboration meeting or facility user meeting) was considered very beneficial and useful by the

participants, organisers and the local groups. It raises many synergies between both events, enhances participation, reduces travel time and costs of the participants, and increases interaction within the ENSAR2 community and related activities.
Therefore, in order to put the future NUSPRASEN workshops on a still broader basis within ENSAR2, in order to obtain a better overview of the needs of the community, and finally in order to update the activity, this "call for workshop proposals" was launched and distributed to the ENSAR2 work-package representatives, and in particular to all ENSAR2 access facilities. They were asked for comments and suggestions on how and where to organise the future meetings. Feedback was requested with respect to the topical focus of possible workshops, to which (TA facility) event the workshop could be connected, to the format and possible keynote speakers. Six new suggestions were received. They were distributed to and analysed in detail by the NUSPRASEN SC; five of them were considered useful in the context of the already existing NUSPRASEN workshop schedule. They are listed in the following:

1. 1 day, late 2017, early 2018, e.g., at Pisa: "Low-E RIB for fundamental symmetries, theory, experiment, instruments", to be held in connection with a SPES workshop
2. 3 days, Sept. 2018, e.g., at Atomki, Debrecen: "Nuclear Physics in Stellar Explosions"
3. a workshop in fall 2018, in connection with GANIL-Spiral-2 week, format to be determined
4. 3.5 days, e.g., at IPN-O, ECT*, or GSI: "New avenues in nuclear physics: what is the way forward?", creating special links to the ENSAR2 work packages TheoS, TecHIBA and all TA-facilities
5. a 3-day workshop, spring 2019, Bucharest: "Science opportunities at ELI-NP", to attract and shape new user group(s).

Criteria for the discussion were the relevance of the topical focus of the proposals, the estimated usefulness for the ENSAR2 community with emphasis on the urgent needs/expected benefits of the TA facilities, and timing/date of the planned events in view of the overall schedule and the already planned NUSPRASEN workshops. The budget distribution was not touched, while it is clear that the contributions to these "new" workshops must be small and require some reduction of the other NUSPRASEN workshop budgets (on the level of ~10% each). The budget assignments were discussed and agreed by the SC in one of its telephone meetings.

The NUSPRASEN networking activity provides platforms for the ENSAR2 community to bring up, discuss, plan and coordinate research topics, exchange recent results and future directions, experimental methods for use and sharing of equipment and related activities. In particular, the workshops and meetings create or enhance the exchange between the TA user groups, the JRA participants of ENSAR2 and theoreticians of the field. Therefore, the NUSPRASEN network promotes the communication and coherent actions of the whole user community in Europe. The NUSPRASEN network activity is fully implemented and is proceeding successfully. Its milestones have been reached (with the exception of M-NA2-3: "Workshop on Nuclear Reactions", which was planned for month 15 but was shifted to month 23 of the project) and all deliverables due have been produced.

The complete, adjusted and updated schedule of all NUSPRASEN workshops looks as follows.
Past events:

- 13th **Russbach School** on Nuclear Astrophysics, March 6-12, 2016, Russbach, Austria (60 participants, 33 lectures and 22 short contributions by students)
- **Carpathian Summer School** of Physics 2016, June 26 – July 9, 2016, Sinaia, Romania *"Exotic Nuclei and Nuclear/Particle Astrophysics (VI). Physics with small accelerators"* (126 participants; 53 lectures and 23 communications)

- **Workshop on Nuclear Structure**, December 6, 2016, Geneva, Switzerland (~50 participants, 10 speakers), preceding the annual ISOLDE Collaboration Meeting
- 14th **Russbach School on Nuclear Astrophysics**, March 12-18, 2017, Russbach, Austria (56 participants, 22 lectures and 13 short contributions by students)
- **9th European School on Experimental Nuclear Astrophysics**, September 17-24, 2017, **St. Tecla**, Italy (92 participants, 34 lectures, 25 student contributions)
- **EURISOL-DF**, Nov. 15-16, 2017, Lisbon (Portugal), 54 participants
- **Workshop on Nuclear Reactions – Theory and Experiment,** January 22-24, 2018, Warsaw, Poland, 80 participants, 30 invited speakers, 50 oral contributions, 11 posters
- 15th **Russbach School on Nuclear Astrophysics**, March 18-24, 2018, Russbach, Austria (60 participants, 27 lectures and 23 short contributions by students)
- **SPES "Workshop on Low-Energy RIBs for fundamental symmetries"**, February 1-2, 2018, Pisa (Italy)

Planned future events:

- **Carpathian Summer School of Physics 2018**, July 1-14, 2018, Sinaia, Romania
- **EURISOL Town Meeting**, July 2-4, 2018, Pisa (Italy)
- **Workshop on Explosive Nucleosynthesis**, Debrecen, Hungary; Sept. 12-14, 2018
- **Workshop on current and future experiments at GANIL**, Caen, France, Oct. 8-12, 2018
- **ECT* "Workshop on Indirect Methods in Nuclear Astrophysics"**, Trento, Italy, November 5-9, 2018
- **16th Russbach school on Nuclear Astrophysics**, Russbach, Austria, in March 2019
- **Workshop Superheavy elements**, Darmstadt, tentative date: March 2019)
- **Workshop "Cross-combining elements (theory, instrumentation, computing, applications...)"** (place to be determined, date: early 2019)
- **Workshop "New avenues in nuclear physics: ways forward"** (place and date: to be determined)
- **Workshop on "New science opportunities at ELI-NP"**, Bucharest, early 2019
- **10th European School on Experimental Nuclear Astrophysics**, St. Tecla, Italy, September 2019

All effects and consequences with respect to the work plan that were caused by the delayed start of the ENSAR2 project, are overcome and all NUSPRASEN activities are well underway and in line with this adjusted schedule.

Website and logo:
An activity website was created, where basic information on NUSPRASEN is displayed (activity goals, past and future events, organisation, integration in ENSAR2), and an activity logo was prepared. Both, NUSPRASEN website and logo can be found at http://www.uni-giessen.de/fbz/fb07/fachgebiete/physik/einrichtungen/2pi/ag/ag-scheidenberger/NUSPRASEN

SECTION 2 THE NUSPRASEN WORKSHOP 1 AT CERN ISOLDE (DECEMBER 6, 2016)

NUSPRASEN workshop 1 has taken place at CERN in the Council Chamber, on **6 December 2016**, as a satellite meeting of the annual ISOLDE workshop. This has ensured minimal extra organisational effort and maximal attendance. Number of participants was 50-60 and all presentations were invited on topics agreed by the Scientific Committee of the event: 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, an 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.

Joaquin Gomez Camacho: Theory, astrophysics and small accelerators for ENSAR2

The EPM (Equivalent Photon Method) can be used in different time-scales and excitation energies at various energy regimes (e.g., HIE-ISOLDE, GANIL, GSI). In general, this allows tuning the strength (scattering angle) and time scales (energies). From a theory point of view, the EPM cannot describe low-energy Coulex experiments properly, as higher-order couplings are very important and a multi-channel calculation is required: EPM underestimates B(E2) values obtained at HIE-ISOLDE energies, (X)CDCC calculations should be used to analyse the data.

Opportunity: study electric susceptibility of nuclear media as a function of collision time.

Inclusive Coulomb break-up as a tool for astrophysics: can one directly measure astrophysical reaction rates? Measurements of inclusive Coulomb breakup at energies below the barrier and at forward angles should allow to estimate stellar temperatures. The region down to 2 GK can be probed with this method.

Small-scale facilities in ENSAR2: solid He targets for experiments with exotic beams are mentioned as an opportunity. Various target techniques are presented. Example of (^{4}He,^{6}He) to check long-range *n*-*n* correlations is given.

Alex Murphy: Direct and resonant reaction studies for nuclear astrophysics at HIE-ISOLDE

REX-ISOLDE capabilities are well matched to the needs of nuclear astrophysics, and presently there are more topics in reach. Several examples are given:

1) for the study of thermonuclear runaways in Novae and X-ray bursters: specific nuclear reactions can affect explosion onset, ejecta abundances, etc., e.g., the reaction ^{14}O(□,*p*)^{17}F, which may trigger break-out from the hot CNO cycles, is expected to be dominated by a single 1^{-}- resonance. Set up is CD system with MINIBALL array.

2) CC-Supernovae: general interest in these exciting events, many nuclear observables needed for understanding and modelling.

3) ^{44}Ti yield is consistently larger than predicted by models; with respect to nu-p process: ^{59}Cu(*p*,□) is presently unmeasured. IS-554 is an approved ISOLDE proposal to address the cosmological lithium problem (^{7}Li does not match observation).

Aurora Tumino: Trojan horse method for resonant reactions in nuclear astrophysics including recent results

Basic features of Trojan horse method, its application to resonant reactions, and two examples are presented: ^{18}F(*p*,□)^{15}O (= first Trojan Horse reaction with radioactive beam), experiments performed at RIKEN and TAMU; ^{12}C(^{12}C,□)^{20}Ne, S-factor needs to be extrapolated over 3 orders of magnitude, and further uncertainties arise from resonances known in this region; further measurements down to 1 MeV will be important. In resonant reactions, the standard R-matrix approach cannot be applied to extract resonance parameters: instead, modified R-matrix is introduced. Advantages: measure down to zero energy, not affected by electron screening, calculation is consistent with S(E)-factors.

Livius Trache: Recent results and future opportunities in laboratory nuclear astrophysics

Current directions comprise "direct measurements" (like direct or inverse reactions) and "indirect methods" (like Trojan horse or reactions with RIBs in "inverse kinematics").

Installations: various opportunities at different facilities are outlined; the complementarity of different instrumental approaches for the interdisciplinary field of nuclear astrophysics and the large variety of needed nuclear physics input is stressed. Reliable theories are essential and provide valuable input to network calculations.

Planned NA activities in NUSPRASEN were presented.

Gabriel Martinez-Pinedo: Exotic nuclei in supernova evolution and r-process nucleosynthesis

Electron-capture rates in CC supernova, challenging for theory, especially beyond N=40 (where EC transitions are suppressed, but correlations and finite temperatures counteract). Most relevant are nuclei around N=50. Various sites for r-process nucleosynthesis are discussed (CC supernova, n-star mergers, black-hole accretion disks).Fission yields play an important role in determining the final abundance pattern of dynamical ejecta.

Frederic Nowacki: Shell model far from stability: islands of inversion mergers

"Islands of inversion" (n-rich isotopes around N=20...28 and N=40...50) are important to study, as in both cases the established islands of inversion (around N=20 and N=40) extend further up to the next magic neutron numbers. Particular interest on ^{78}Ni. Excitation energies (E_2^{+}), BE2 values, binding energies are needed in the whole area to understand the development of collectivity. The physics around these magic or semi-magic closures depends on subtle balances between spherical mean field and the very large correlation energies of the open-shell configurations.

Gerda Neyens: Nuclear structure studies by the measurement of nuclear spins, moments and charge radii via collinear laser spectroscopy: results and perspectives

Collinear laser spectroscopy is a powerful technique that can deliver nuclear moments, spins and mean-square charge radii (relative to absolutely known ones) even for weak ion beams (intensities of several 10's of ions per second). Various complementary measurement schemes exist (collinear, in cell, in jet, ISCOOL, etc., each adapted to production method/sensitivity/resolution/etc.). Experimental campaigns in last 15 years at ISOLDE yielded a wealth of nuclear structure physics results: shape coexistence/deformation, shell evolution (N=50 to beyond N=82), shell structure around Z=20/N=32 and close to ^{78}Ni and ^{100}Sn.

Future plans aim at transition regions between/towards closed shells, exotic doubly-magic nuclei, neutron-deficient proton emitters. Generally speaking, other probes are needed to complement the physics interpretation, as each observable probes different aspects of the nuclear structure: Coulex and transfer reactions, masses, decay spectroscopy, lifetime measurements, and moments of excited states.

Sophie Peru: Mean field description on collective modes up to octupole in deformed nuclei

No further comments or observations.

Alejandro Algora: Shape effects from total absorption measurements

Shapes, nuclear moments, radii and gamma-ray spectroscopy yield very important nuclear structure information. Beta decay provides additional information and the strength distribution in the daughter nucleus depends on the shape of the parent. Total absorption spectrometers are highly efficient devices and avoid (largely) the incomplete solid-angle coverage of germanium detectors, and thus the problem of beta-feeding (Pandemonium effect). Several examples are discussed: n-deficient Kr, Hg and Pb isotopes have been studied experimentally. Challenge: neutron-rich nuclei, where the neutron emission competes with (or even can exceed) gamma-ray de-excitation; this requires additional neutron detection via 4π neutron counters and/or ToF spectrometers for neutrons (as for instance BRIKEN setup for beta-delayed neutron measurements at BigRIPS)

Magdalena Zielinska: Recent achievements and future developments in Coulomb-excitation studies

Coulomb excitation (Coulex), the population of excited states via purely electromagnetic interaction, is a well-established and widely used method to study transition probabilities, quadrupole moments and non-yrast states in exotic nuclei. Many nuclei/cases have been studied at HIE-ISOLDE already. Recent examples are presented (shape coexistence around N=60/^{100}Zr, deformation of ^{96}Sr, quadrupole moments and transition probabilities in ^{98}Sr, and several others)

Future developments and possibilities with HIE-ISOLDE and new detectors are addressed: a) the emission of conversion electrons can become very strong for E2 and M1 transitions in heavy nuclei; a new detector system for in-beam measurements (SPEDE) has been commissioned recently; b) a segmented silicon detector for Coulex experiments at SPES was commissioned at ISOLDE in July 2016.

Conclusion

In the general wrap-up discussion at the end, this workshop was considered very useful. New ideas for proposals were brought up, appreciated by the community, and the format (satellite of a facility or annual user group meeting) is very synergetic, efficient and useful. The mixing of communities and with different ENSAR2-activities is important and stimulating. In addition, the "short but complete" format (with few, but high-level talks, theory-experiment, structure-astrophysics-reactions) was received as very positive! It was unanimously accepted that further workshops of this format shall be held and the connection to facility/user group meetings shall be further developed and more frequently be used.

SECTION 3 THE NUSPRASEN WORKSHOP 2 ON "NUCLEAR REACTIONS – THEORY AND EXPERIMENT", HELD IN WARSAW, POLAND (JANUARY 22-24, 2018)

NUSPRASEN workshop 2: This workshop is one of the milestone workshops of WP2 NUSPRASEN. The Organising Committee is 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 below):

- 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.

Detailed results, analysis and findings:

Exotic nuclei and radioactive nuclear beams, which are the focus of nuclear physics in the last decades, are also produced by nuclear reactions. As such, it is difficult to overstate the importance of nuclear reactions and of the understanding of their dynamics. This was obviously the motivation behind choosing the title of this NUSPRASEN workshop: "Nuclear Reactions (Experiment and Theory)". It turns out that nuclear reactions are an approach to a diverse and rich field of phenomena, and implicitly an important asset of the facilities used in Europe for such studies, and of the theories needed to describe and understand them. The workshop was conceived as consisting of a number of invited talks on subjects chosen or suggested by the organisers, interspersed with talks chosen from the proposals of the participants. It turned out that this was a good combination: while the former were more of review in their nature, the latter were presenting progresses in nuclear facilities in Europe, in instrumentation, in theories and were reporting new data.

A large number of the experiments performed in the laboratory make use of different reaction mechanisms. Depending on the combination of the beam energy, impact parameter and nature of the projectile and target, these studies are dedicated to gain information on the structure of the nuclei involved, on the dynamics and reaction mechanism description; they provide relevant information of astrophysical interest or for different and important applications. On the experimental side, there is a permanent effort to improve the amount and quality of the data

recorded in experiments, but in general, the experiments need the joint effort of experimentalists and theoreticians to support and exploit the data recorded.
One important goal of the workshop was to treat nuclear reactions as an avenue to produce secondary beams, the key to our research field. The study of direct reactions at low, intermediate and high beam energy was also included in the presentations, as they are very powerful spectroscopic tools (for the determination of spins and parities, spectroscopic factors, dependence of the quenching factor R on separation energies, the role of pairing, etc.). Many of the presentations indicate the strong interplay between nuclear structure and reaction theories to interpret correctly the results. Interesting results on multi-nucleon removal, fragmentation, nucleus-nucleus collisions and fission remind us of the relevance of the dynamical aspects to understand the reaction mechanisms.
A few topics deserve a more detailed summary in the following: the emerging field of hypernuclei, the multi-disciplinary field of nuclear astrophysics, reaction theory, applications, and the role and impact of the so-called "small-scale" facilities.

Hypernuclei

Heavy-ion collisions at relativistic energies are copious source of strange mesons and baryons. When hyperons are captured by nuclei, hypernuclei are formed, some of which may be rather exotic. At high relative incident momenta, which exceed the Fermi momentum many times over, spectator regions and a participants' zone are formed in non-overlapping collisions between two heavy ions. To describe this initial stage of such reactions, various transport models can be applied. In a second stage, the observable fragments are formed. Spectator and participant regions have very distinct properties giving rise to very different mechanisms for the hyper-fragment formation. In the central region, a rather hot hadron gas is created - possibly preceded by the formation of a quark-gluon plasma - which undergoes expansion and cooling. In such a system, fragment formation can be described by statistical/thermal models or by coalescence processes. In order to study more baryon-rich systems around the critical point of nuclear matter, several future heavy ion experiments are planned around the world: at ALICE (LHC), at STAR (RHIC), at NICA (NUCLOTRON), and at CBM (FAIR). At GSI, a new avenue in the field of exotic nuclei is opened by the exploration of hypernuclei in projectile fragmentation reactions at the FRS (and later at SuperFRS at FAIR) using the excellent momentum resolution, yielding a significant improvement of the invariant mass resolution. This will allow to address the question of the existence of the neutral nn□ system, for which ahint was observed by the HypHI Collaboration. In the next decade, the unique combination of rare-isotope beams with the SuperFRS detection system may pave the way for exploring the limits of stability of hypernuclei by detecting very neutron-rich hypernuclei in the projectile fragmentation regime.

Nuclear astrophysics

Nuclear reactions are a main tool used to study the nuclear structure and nuclear interactions and to obtain data to understand the origin of the chemical elements and of the energy production in the Universe. This is the link to the interdisciplinary field of nuclear astrophysics (NA); a topic that has been already in the focus of the previous NUSPRASEN workshop at CERN ISOLDE in December 2016. At the present workshop, several talks were reporting on the NA efforts at laboratories across Europe, which included direct methods. One talk (L Trache) was "a list and review of the problems in indirect methods for nuclear astrophysics" in preparation of a dedicated workshop on this subject to be held at ECT* on November 5-9, 2018. That workshop is a milestone on the NUSPRASEN agenda. The talk of prof. Aurora Tumino (LNS Catania and Univ. di Enna, Sicily) reviewed briefly the Trojan Horse Method (THM) developed and used for two decades by now by the Catania group and reported an important result on the sub-barrier resonances found in the $^{12}C+^{12}C$ reaction, at energies relevant for explosive stellar phenomena. This reaction is indeed one of the crucial reactions in nuclear astrophysics, it is studied for decades and progress through

direct measurements has been and remains slow. The present result by THM, an indirect method, offers a glimpse of the complexity of the excitation function at energies in the Gamow window. The use of transfer reactions with radioactive nuclear beams and dedicated instrumentation was touched upon in a few talks, in particular that of prof. W. Catford (Surrey). On the theory side, it was noted that efforts are made with the *ab-initio* structure calculations for low-mass nuclei, with potential use in the description of reactions of importance for NA. More importantly, the need of increased accuracy of reaction theories and codes for the description of nuclear reactions that could be used to extract data useful for NA were noted.

Reaction theory

During the workshop, state-of-the-art of theories that are nowadays developed to describe various nuclear reaction mechanisms from very low to very high beam energy have been presented by experts in the field. The beam energy range covered was from below the Coulomb barrier, including experiments of nuclear astrophysical interest to several GeV/u where pions and hypernuclei can be produced. The discussions have led to a clear view of the advantages and drawbacks of each theoretical approach. Presentations on theory were made back to back to associated experiments leading to a clear view of the potentialities for comparison between theories and experiments. Several important remarks/conclusions have been made:

- For all areas of nuclear physics, it appears that a strong support for theory is needed both to interpret the observation and to propose new ideas. In some cases, it was stressed that the interpretation cannot be made without this strong support. Some difficulties to respond to the demand from experimentalists often stem from the limited manpower in theory.
- Theory plays also an important role to clarify the uncertainty on some properties deduced with specific experimental techniques. Typical examples are the Asymptotic Normalisation Coefficients (ANC), spectroscopic factors, and nuclear astrophysics experiments.
- The breakthrough of ab-initio methods has been pointed out in particular to provide less empirical ingredients in theory. It was, however, discussed that ab-initio methods are nowadays mainly focusing on nuclear structure properties and that efforts should be made also for nuclear reactions in the future.
- The different reactions (fission, quasi-fission and multi-nucleon transfer) used to produce super-heavy nuclei, neutron-rich or neutron-poor nuclei have been discussed. The theoretical understanding of these nuclear phenomena is an important guidance for producing new elements. New theories allowing for the microscopic description have been reviewed as well as their future developments.
- The impact of nuclear models and in particular their usefulness in hadron-therapy or space irradiation has been extensively discussed.
- Another important aspect of the workshop was the diversity of phenomena that was discussed. As a direct consequence, this allowed different communities to meet together, exchange ideas and eventually cross-fertilise. The workshop was very successful in that respect too.

Applications of reaction theory and experiments in space and medicine

Applications of nuclear techniques or data, for the benefit of the society or the community at large, are of particular interest for the ENSAR2 integrating activity. Therefore, a dedicated session was devoted to this topic. While many applications exist, it was considered to focus on two areas, which are emerging and as such rapidly developing, i.e. space-radiation research and therapy with ion beams.

Space: The motivation comes from effects of space radiation on the human body, which are considered to be one of the major risks for manned long-term missions in deep space or permanent planetary habitats, e.g., on Moon or Mars. Realistic space-radiation risk assessment as well as

mitigation techniques are, therefore, a necessity. Passive shielding using bulk materials is the only feasible countermeasure for the foreseeable future. The problem that needs to be treated is the generally complex space-radiation environment interacting with complicated geometries such as Solar particle events (mainly protons with energies up to some hundred MeV), and Galactic cosmic rays (wide variety of heavy ions, most prominently protons, helium and iron, with energies up to some GeV/u). There are further complexities due to space weather, "Forbush decrease" effect, etc. and due to practical constraints coming from spacecrafts (such as complex materials and geometries, payload restrictions, and others). The current approach is a combination of space-based and accelerator-based experiments in combination with Monte-Carlo simulations. As far as nuclear physics is concerned, Monte-Carlo models are being improved and cross-section measurements are needed for benchmarking the Monte-Carlo codes. Connections to other activities and funding projects like, e.g., ESA-IBER help for a cross-fertilisation of different fields.

Therapy: The prime goals is to improve the knowledge about the effects of currently used ions and to prepare additional ion species for particle therapy, e.g., helium and oxygen, to reduce side effects and offer novel treatment modalities. Due to the diverse and applied nature of particle therapy, close collaboration between highly specialised fields (e.g., medical physics and nuclear physics) is an absolute necessity. In the nuclear physics involvement, the following key points need improvement: Monte-Carlo modelling and cross-section measurements for benchmarking, fast beam-monitoring detectors and readout systems to improve dose delivery systems (R&D), an online monitoring of the beams (using prompt radiation) for fast gating and quality assurance. In this context, it is important to exploit additional beam-time possibilities at medical accelerators, e.g., MIT calls.

Impact and role of the so-called "small-scale facilities" in ENSAR2

The importance of the "small facilities" for the ENSAR2 community for educational aspects, applications, industry cooperation and cooperation between different ENSAR2 work packages was elaborated and is summarised here.

The ENSAR2 project is based on basic nuclear physics research activities of several large-scale facilities, for which ENSAR2 provides Trans-National Access funds. These are the Trans-National Access, or TNA facilities. Besides this, there is a Networking Activity of smaller facilities, which support and contribute strongly to the overall goals of ENSAR2. They are coordinated in the ENSAF network; it includes the following facilities: RBI, Zagreb, Croatia; NPI, Řež, Czech Republic; ATOMKI, Debrecen, Hungary; IST, Lisboa, Portugal; JSI, Ljubljana, Slovenia; CMAM, Madrid, Spain; RUBION, Bochum, Germany; Fysisk Institutt, Oslo, Norway; CRSD, Athens, Greece (Coordinator: Sotirios Harissopulos); INFN, Legnaro, Italy; CNA, Sevilla, Spain (Deputy Coordinator: Joaquin Gómez-Camacho). The research topics of ENSAF facilities are very wide and cover most of the applications of nuclear physics and accelerator techniques, and also some aspects related to atomic-nuclear reactions. Two aspects have been identified as especially relevant for the purposes of ENSAR2:

Radiation hardness tests in detectors: Several facilities had a relevant contribution to reaction-induced radiation tests in different detectors. In particular, the IBIC (Ion-Beam-Induced Charge) was found very interesting for the future of small facilities.

Participation in the testing of detector arrays of large facilities: The Madrid and Lisbon facilities contributed to the testing of the CALIFA detector array, which will be installed in the reaction experiment R3B at FAIR. Synergies between the Řež facility and the Czech contributions to SPIRAL and FAIR were outlined.

European cooperation

Overall, the workshop was very useful to identify the need for theory development in some specific areas of nuclear physics, as well as some deficiencies of current approaches to describe properly certain aspects of a nuclear reaction. Large discussions were devoted to the possibility to further improve the organisation of theory at the European level as well as possible ways to facilitate the

collaboration between experimentalists and theoreticians. The key role of the workshop centre ECT* has been pointed out. A discussion on the limited manpower in both nuclear theory and experiment has been made as well as on the possibility to better identify and pursue priorities at the European level. One difficulty that was pointed out was the eventual absence of coherence between national decisions for science and priorities decided at the European level.

Section 4 The NUSPRASEN workshop at SPES on "Probing Fundamental Symmetries and Interactions by low-energy excitations with RIBs", Held in Pisa, Italy (February 1-2, 2018)

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 title "Probing Fundamental Symmetries and Interactions by low-energy excitations with RIBs". 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 7 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 INFL-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 detailed topics were:

1. Implementation of effective, low-energy approximations to QCD
2. Interaction models, ab-initio approaches and energy-density functional calculations
3. Universal aspects and effective description of nuclear clustering
4. Radioactive decays, decay correlations and related processes
5. Neutrino-less double-beta decay, CP/T violation and limits of existence of Electric Dipole Moment, neutrino-nucleus interaction and related processes
6. Exotic coupling, symmetries and energy scale separation
7. Instrumentation

Invited speakers for keynote presentations were as follows:

C. Agodi (INFN-LNS, Italy)
A. Andrighetto (INFN LNL, Italy)
P. Butler (University of Liverpool, U.K.)
Ch. Enss (MPKI Heidelberg, Germany)
N. Itaco (University of Campania, Italy)
A. Knecht (PSI, Switzerland)
A. Lombardi (INFN LNL, Italy)
E. Mariotti (DSFTA,University of Siena, Italy)
D. Mengoni (University of Padova, Italy)
A. Nannini (INFN Firenze, Italy)
A. Pisent (INFN LNL, Italy)

G. Prete (INFN LNL, Italy)
F. Recchia (EDM and SPES, University of Padova, Italy)
D. Santonocito (INFN LNS, Italy)
B. Seiferle (University of Munich, Germany)
N. Severijns (University of Leuven, Belgium)
M. Viviani (INFN Pisa, Italy)
The main results of the discussions can be 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.

Conclusions

The scheme applied here followed that one utilised in the ISOLDE workshop. It was clearly noticed that such joint organisation helps to raise synergies among different ENSAR2 partners, stimulates information exchange between the users connected to the facility and allows for the development of SPES beams and instrumentation 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).

SECTION 5 THE EUROPEAN NETWORK OF NUCLEAR ASTROPHYSICS SCHOOLS CO-SPONSORED IN 2016-2018

The European Network of Nuclear Astrophysics Schools (ENNAS) exists since 2012 and is based on an understanding between the organisers of three schools in Europe to associate in order:

- "To correlate the topics of the schools such that we assure best coverage and avoid unnecessary overlaps, while keeping their characteristics. Will set a network advisory committee to assist with this task;
- To correlate the timing of the schools such as they better serve the communities of scientists and of physics and astronomy students;
- To correlate the efforts to obtain seed money to fund these schools, by lobbying the EPS, EC funding sources, the national funding agencies, own institutions and any other sources, such that these schools will become regular and well-established staples of the scientific environment in Europe and in the world." (citations from the MoU signed)
- To collaborate for providing the community with a coherent good coverage of nuclear astrophysics science: from the structure of exotic nuclei, to experimental and theoretical nuclear physics for astrophysics, Cosmo-chemistry, nucleosynthesis and star-evolution modelling.

- To attract not only the best speakers, but be attractive for students and caring for their formation as the future generation of scientists in the field.

The ENNAS Memorandum of Understanding was signed in June 2012 by representatives of 7 institutions. The current members of ENNAS are:

- the **Russbach School on Nuclear Astrophysics, RSNA** (Russbach am Pass Gschütt, Austria)
- the **Carpathian Summer School of Physics, CSSP** (Sinaia, Romania)
- the **European Summer School on Experimental Nuclear Astrophysics, ESSENA** (Santa Tecla, Italy).

ENSAR2 supports these schools through NUSPRASEN, as co-sponsor. In the first 2 years of operation of ENSAR2, five such schools were supported (partially, with seed money for student support):

- *the 13th Russbach School on Nuclear Astrophysics in Russbach, Austria, March 2016*
- *the 27th Carpathian Summer School of Physics in Sinaia, Romania, in June – July 2016*
- *the 14th Russbach School on Nuclear Astrophysics in Russbach, Austria, March 2017*
- *the 10th European Summer School on Experimental Nuclear Astrophysics, Santa Tecla, Italy, Sept. 2017*
- *the 15th Russbach School on Nuclear Astrophysics in Russbach, Austria, March 2018*

We enclose below the reports of their organisers on schools' proceedings and results.

Report to ENSAR2 – ENNAS - 13th Russbach School on Nuclear Astrophysics

From March 06 (arrival) to March 12 (departure), the "13th Russbach School on Nuclear Astrophysics" took place in Austria, region Dachstein West, at the village of Russbach am Pass Gschütt. 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 broadened so that its organisation now also directly includes GANIL (O. Sorlin) and the Technische Universität München & Universe Excellence Cluster (S. Bishop).

In keeping its tradition, the 13th Russbach school has again brought together specialists from various sub-fields of "nuclear astrophysics", i.e. experimental and theoretical astronomy, astrophysics, nuclear physics and Cosmo-chemistry, with the aim to raise mutual interest and to teach under- and postgraduate students, young postdocs, as well as senior scientists who want to be introduced to this interdisciplinary research field.

Apart from ENSAR2 (starting this year; 4000 Euro), from 2007 on the Russbach school has been sponsored by the University of Basel (5000 Euro), the Excellence Cluster of TUM & LMU at Munich (4000 Euro), GANIL (4000 Euro) and IN2P3 (2000 Euro). The funds were predominantly used 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, a limited number of accommodation grants to senior scientists from distant countries, e.g., USA, Japan and Australia was given. No travel costs were reimbursed.

The school was hosted at the two hotels "Ausswinkl" (accommodation, breakfast, dinner) and "Waldwirt" (accommodation, breakfast, coffee breaks, rent of lecture room).

This year, there were in **total ~60 participants** from 4 continents (from altogether 20 countries – from China, Japan and Iran to USA, and from Australia to Italy, France and Germany). Twenty-five invited scientists gave **33 lectures** of 45 to 60 min each, and 22 PhD students and young postdocs presented a total of **22 shorter contributions** of 20 to 40 min, respectively.

By tradition of the Russbach School, there will be no proceedings. However, the voluntarily handed in pdf-files of the contributions will soon be available at the conference website:

http://www.universe-cluster.de/russbach2016. In addition, the 2015 site with programme and lecture repository can also be seen at: http://www.universe-cluster.de/russbach2015.
The sponsors of the event are acknowledged below.

ENSAR2 has contributed with 4,000 euros to the event financing, through NUSPRASEN.
Prof. Karl-Ludwig Kratz
Dr. Olivier Sorlin
Prof. Shawn Bishop
Schools' co-directors
April 2016

Report on the Carpathian Summer School of Physics 2016
This edition of the Carpathian schools was held on June 26 – July 9, 2016, in Sinaia, Romania. It was the 27th edition of a tradition that begun in 1964. This year the title of the event was:
"Exotic Nuclei and Nuclear/Particle Astrophysics (VI). Physics with small accelerators"
and was the **6th** in the latest series with the same title organised in Mamaia (2005) and Sinaia (2007, 2010, 2012 and 2014). This school is part of the European Network of Nuclear Astrophysics Schools (ENNAS), together with the **European Summer School on Experimental Nuclear Astrophysics, ESSENA** (Santa Tecla, Italy) and the **Russbach School on Nuclear Astrophysics, RSNA** (Russbach am Pass Gschütt, Austria). ENNAS is endorsed by the Nuclear Physics Board of EPS and is supported by ENSAR2, a project of the European Horizon 2020 programme. These schools' organisers have created an established and recognised network of periodic events that responds to the need of preparing and educating the younger generations of physicists in the cross-disciplinary fields of nuclear physics and astrophysics. Through consultations and somewhat overlapping International Advisory Committees, we correlate and complement the topics of the schools, while keeping the specifics each has/had. As such, students from across Europe, and many times from other continents, can count on finding regular events to use in their preparation for scientific careers. Moreover, the settings of this school, and of the other two, offer the opportunities for a good and direct dialogue between generations, in many cases better and more diverse than those of the classrooms, or established campuses.
This year we added additional flavour to the event through the explicit inclusion of subjects related to physics with small accelerators, fundamental or applied research subjects.
We remained faithful to the successful format of the latest editions: 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).
For this edition, **"Horia Hulubei" National Institute for Physics and Nuclear Engineering (IFIN-HH) Bucharest-Magurele** was the sole organiser of the school.
Topics announced were similar to the ones in 2014, but included accelerator applications explicitly:

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

Students from Romania, from the surrounding regions and all countries were invited to attend. A limited number of stipends (22) to cover the local expenses for students were available. In total, there were 126 participants:

- 53 invited lecturers
- 55 students, who presented 23 oral communications.

(If you wonder why the numbers do not sum up, is because some were short-term participants, who did not fit in either category). Two days (June 3 – July 1) have been reserved for the special sessions *"ELI-NP. Status and Perspectives"*. On Saturday, 2 July, we had the traditional outreach session of the school with the subject *"JINR Dubna at 60 and the internationalisation of science".* This was honoured by the participation of Prof. Mikhail Itkis, deputy director of JINR Dubna, Prof. B. Sharkov, scientific director of FAIR Darmstadt, Prof. K. Langanke, scientific director of GSI Darmstadt, prof. I.I. Ursu, vice-president of ANCSI, Bucharest, and other guests from Romanian academia, public and media representatives. The day was concluded with the traditional conference dinner, at a remote place in the mountains ("At Kingdom's Gate", Paraul Rece), where we found a nice sunset waiting for the buses who started from a rainy afternoon in Sinaia.
Between June 30 and July 2, a number of exhibits were open in the framework of the school: "JINR at 60" and exhibits from the 7 sponsors.
Sponsors of the school were *IFIN-HH as organising institution*, the *Romanian National Authority for Scientific Research and Innovation (ANCSI)*, ENSAR2 through *the NUSPRASEN network*, and the exhibitors CAEN Quantech Works; Canberra Packard; *eNformation*; RomTek ELECTRONICS, WIENER CORALGON Instruments, Iseg; SERTO, SAES group, PFEIFFER VACCUM; tryamm. The event was endorsed by the European Physical Society, through its Nuclear Physics Board. Moreover, most of the participants were supported by their respective institutions, a fact that contributed to existence and the success of the school and which makes these institutions be our sponsors too.
One sign of appreciation was that CSSP16 was a success, appreciated both for the quality of science and organisation. Participants recommended:

- To continue this school with a new edition in 2018
- To continue its affiliation with ENNAS
- The future editions to concentrate on physics at FAIR and ELI-NP.

The Proceedings of CSSP16 is being published again with the prestigious "AIP Conference Proceedings" series of the American Institute of Physics. With all the changes that the whole publishing environment goes through, due to the changes in the supporting media (from paper to electronic support) and to the changes in mores (fast and lots, competing with peer review), we could collect fewer articles (~50) than expected, especially from the young contributors. However, we believe that we could put together an interesting volume. The volume of the Proceedings starts

with the information about the event and after that, the actual content is divided in three main parts:

- Part I Lectures
- Part II Communications
- Part III Closing matter

The lectures were grouped in chapters according to their subjects, as much as possible, even if they did not follow the original placement in school's sessions. The communications were ordered alphabetically after the name of the first author. Two communications were moved to the ELI-NP chapter to round that chapter.

ENSAR2 has contributed with 6,000 euros to the event financing, through NUSPRASEN. The funds were used to award fellowships to students (local costs only, no transportation).
The Proceedings of CSSP16 were published with the American Institute of Physics. See:
https://aip.scitation.org/toc/apc/1852/1?size=all&expanded=1852 (Open Access)
Livius Trache – CSSP16 chair

Report on the 14th Russbach School on Nuclear Astrophysics in Russbach, Austria, March 2017

Report to ENSAR2 – ENNAS -

14th Russbach School on Nuclear Astrophysics

From March 12 (arrival) to March 18 (departure), the "14th Russbach School on Nuclear Astrophysics" took place in Austria, region Dachstein West, at the village of Russbach am Pass Gschütt. 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 broadened so that its organisation now also directly includes GANIL (O. Sorlin) and the Technische Universität München & Universe Excellence Cluster (S. Bishop).
In keeping its tradition, the 14th Russbach school has again brought together specialists from various sub-fields of "nuclear astrophysics", i.e. experimental and theoretical astronomy, astrophysics, nuclear physics and Cosmo-chemistry, with the aim to raise mutual interest and to teach under- and postgraduate students, young postdocs, as well as senior scientists who want to be introduced to this interdisciplinary research field.
Apart from ENSAR2 (this year; 3500 Euro), from 2007 on the Russbach school has been sponsored by the University of Basel (this year; 3000 Euro), the Excellence Cluster of TUM & LMU at Munich (this year; 3000 Euro), GANIL (this year; 4000 Euro) and IN2P3 (this year; 1500 Euro). With the retirement of F. -K. Thielemann, the financial support from the University of Basel will be lost.

Therefore, the contribution from ENSAR2 is essential to keep the viability of the school. The funds were used primarily 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, four accommodation grants to senior scientists were given. No travel costs were reimbursed.
The school was hosted at the two hotels "Ausswinkl" (accommodation, breakfast, dinner) and "Waldwirt" (accommodation, breakfast, coffee breaks, rent of lecture room).

This year, there were in **total 56 participants** from altogether 10 countries – from Japan, USA, Iran, to European countries as Italy, Germany, France, Romania, Hungary, and Slovenia. Twenty-two invited scientists gave **lectures** of 40 to 60 min each; and 13 PhD students presented **shorter contributions** of 25 min each. The full programme of the school is available on the website: http://www.universe-cluster.de/russbach2017.

By tradition of the Russbach School, there will be no proceedings. However, the voluntarily handed-in pdf-files of the contributions are available at the same website.

Dr. Olivier Sorlin
Prof. Karl-Ludwig Kratz,
Prof. Shawn Bishop
Schools' co-directors

Report on the 9th European Summer School on Experimental Nuclear Astrophysics, Santa Tecla, Italy, September 17-24, 2017

The present understanding of the Universe and its components needs input data from all the fields of Physics. This multidisciplinary research, involving nuclear and particle astrophysics, plasma physics, cosmology and atomic physics, attracts a growing number of young physicists. Many conferences and symposia take place covering those fields, but usually they are focused to experts, while the younger researchers and students need to understand the basics and the current exciting problems.
In order to cover this issue, the European Summer School on Experimental Nuclear Astrophysics has started in 2001 and marks in the present year its 9th edition. The school, which belongs to the European Network of Nuclear Astrophysics Schools (ENNAS), was held from 17 to 24 September 2017 at Santa Tecla, in Sicily, Italy. It was jointly organised by the INFN – Laboratori Nazionali del Sud and the Dipartimento di Fisica e Astronomia of the University of Catania (DFA). In addition, ENSAR2-NUSPRASEN WP has given the School financial support, which has been devoted for covering the local expenses (hotel accommodation + fee) of 3 senior lecturers and 3 young researchers.
The school, in this edition, was devoted to stellar evolution, primordial nucleosynthesis, cross-section measurements with direct and indirect methods, nucleosynthesis (quiescent and explosive), detectors and experimental facilities. The lectures were followed by presentations by the young researchers, devoted to give a state-of-the-art presentation of the current issues in nuclear astrophysics.
The school took place in Santa Tecla, a small seashore village 15 km North of Catania, at the Santa Tecla Palace Hotel located directly at the Ionian Sea, in a comfortable and spectacular environment. About 50 students and young researchers attended the school from 10 countries all over the world, including participants from less favoured regions.
The school was welcomed by the Director of INFN- LNS, the Director of DFA – University of Catania**,** the Director of INFN-Sezione di Catania and the Director of Scuola Superiore di Catania. The school

hosted 80 participants, including lecturers, young researchers and observers (undergraduate students of the Nuclear Astrophysics academic course at DFA).
The social programme included a visit to the baroque beauties of Catania, within the UNESCO world heritage. In addition, a number of events (welcome cocktail and dinner, Sicilian folk music, Social dinner) made the social aspect of the school very pleasant and stimulating for creating a unique atmosphere among the students and lecturers of the school.
The interest among the students and the lecturers of the school clearly demonstrated the need for continuing this school. Therefore, the International Scientific Committee of the school decided to fix the 10th edition to be held in September 2019 in Santa Tecla. The proceedings of the school will appear in European Journal Physics A: Web of Conference.
Claudio Spitaleri, Chair
For ESSENA 2017 organisers
The school proceedings will be published by EPJ web of conferences.

Events planned for 2018-2019
At the time of reporting, the list of events for 2018-2019 has been established:
1. **28th Carpathian Summer School of Physics 2018 (CSSP18)**, Sinaia, Romania, July 1-14, 2018
2. **Nuclear Physics in Stellar Explosions,** Atomki, Debrecen, September 12-14, 2018
3. **ECT* workshop "Indirect Methods in Nuclear Astrophysics"**, Trento, Italy, November 5-9, 2018
4. **16th Russbach School on Nuclear Astrophysics**, Russbach, Austria, March 2019
5. **10th European School on Experimental Nuclear Astrophysics**, St. Tecla, Italy**,** September 2019
The first three events (all in 2018) are in advanced states of preparation. CSSP18 has a full list of speakers and its final details are being solved now (http://cssp18.nipne.ro/). So is the status of the workshop in Debrecen in September 2018 (http://atomki.hu/astro2018/). The workshop "Indirect Methods in Nuclear Astrophysics" was proposed to the ECT* Scientific Board and approved by it in the summer of 2017 http://www.ectstar.eu/node/4228. The organisers have a preliminary list of participants of about 70, close to the maximum capacity of the hosting venue.
All the above have only partial support from NUSPRASEN.

Conclusion and Outlook

The NUSPRASEN activity is in full swing. Its SC monitors the ongoing activities and prepares the future events in due time. The complete work plan has been established, completed and is regularly updated. All ongoing activities are in line with the schedule and the spending is in line with the planned budgets. The network website is operational. Several workshop events, nine in total, have taken place, in particular those marked as milestones. Overall, all scheduled milestones have been reached and the one deliverable, which was due in the reporting period, was submitted and accepted. The close interaction with facility/collaboration meetings is useful and increases synergies among the ENSAR2 work packages. More positive effects on community-facility interaction and user-group formation can be expected.