ENSAR-2 NUSPRASEN Workshop

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CERN

Book of Abstracts

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Theory, astrophysics and small accelerators for ENSAR2

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Nuclear reactions can be understood as exposing nuclei to external fields, Coulomb or nuclear. ENSAR-2 exotic beam facilities (ISOLDE, GANIL and GSI-FAIR) provide different time scales for the external fields, associated to the collision time. The complementarity of these measurements will be discussed. Astrophysically relevant reaction rates in stellar environments imply averages over Maxwellian energy distributions, which are governed by the temperature of the stars. On the other hand, Coulomb-dominated inclusive break-up cross sections imply energy averages, which are governed by the collision time. This opens the possibility of relating experimentally mesured inclusive break-up cross sections, with the proper collision time, with astrophysical reaction rates, at the proper temperature. Recent instrumentation develomments carried out at the small facilities within ENSAR-2, relevant to the large exotic beam facilities, will be presented.

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

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.The capabilities of HIE-ISOLDE are well matched to a broad range of experimental nuclear astrophysics studies. In this talk I will review recent works relevant to x-ray bursts and core collapse supernovae, and will present some of the proposals in these and other areas presently awaiting beam time.

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

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.Understanding energy production and nucleosynthesis in stars requires a precise knowledge of the nuclear reaction rates at the energies of interest. To overcome the experimental difficulties arising from the small cross sections at those energies and from the presence of the electron screening,

the Trojan Horse Method has been introduced. The method represents one of the most powerful tools for experimental nuclear astrophysics because of its advantage to measure unscreened low-energy cross sections of reactions between charged particles, and to retrieve information on the electron screening potential when ultra-low energy direct measurements are available. This is done by selecting the quasi-free (QF) contribution of an appropriate three-body reaction A + a ⊠ c + C + s, where $ is described in terms of clusters x +s. The QF reaction is performed at energies well above the Coulomb barrier, such that cluster x is brought already in the nuclear field of A, leaving s as spectator to the A+x interaction. The THM has been successfully applied to several reactions connected with fundamental astrophysical problems as well as with industrial energy production. I will recall the basic ideas of the THM focussing on resonant reactions and show some recent results.

Session 1 / **6**

Recent results and future opportunities in laboratory nuclear astrophysics

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.Some of the questions in nuclear physics for astrophysics and the news on methods we use in the laboratory to answer them will be reviewed, with emphasis on what the new large experimental facilities can bring.

Also will discuss about NUSPRASEN's planned activities for nuclear astrophysics.

Session 1 / **7**

Exotic nuclei in supernova evolution and r-process nucleosynthesis

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.Exotic nuclei play an important role in many astrophysical environments, in particular the collase of massive stars and r-proccess nucleosynthesis. During the collapse, the composition of the core is dominated by intermediate mass neutron-rich nuclei. Due to the high temperatures and densities, electrons can be captured on nuclei removing the major source of pressure support and accelerating the collapse. Particularly important are electron capture rates around the N=40 and N=50 and regions where there is experimental evidence of large correlations across the shell closures. A proper account of these correlations together with finite temperature effects is fundamental to determine the relevant electron capture rates.

Compact binary mergers are currently considered the best candidate for the main r-process site. These events are expected to produce gravitational waves, likely to be observed by the LIGO collaboration, and eject large amounts of neutron-rich material where the r process operates. I will discuss the important role of nuclear

physics to determine the r-process yields from compact binary mergers. In addition to neutron captures and beta decay, fission rates and yields of superheavy neutron-rich nuclei are fundamental to understand the r-process dynamics and nucleosynthesis. Mergers constitute also ideal candidates to directly observe the r-process via an electromagnetic transient due to the radioactive decay of r-process material. This type of event, known as kilonova, may have already been observed associated with the gamma-ray burst GRB 130603B.

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Shell model far from stability: Islands of Inversion mergers

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In this presentation, I will expose some of the last developmentsin microscopic nuclear structure calculations for exotic nuclei far from stabilitity [1].
In a first part, I will expose recent study on the development of collectivity in neutron-rich nuclei around N=40, where recent experimental evidence suggest a rapid change from the spherical to rotational regime, in analogy to the island of inversion known at N=20 [2,3] and extension of the island of collectivity towards N=50 [4].
Our recent algebraic Nilsson SU3 self-consistent model will be used to describe the intruder relative evolution in the vicinity of 78Ni [5].
Then new theoretical calculations for the very region of 78Ni will be presented for the first time within the interacting shell
model framework using an enlarged model space outside a 60Ca core comprising pf shell for the protons and sdg
orbits for neutrons. Besides, the surprising spectrum of 78Ni, we predict development of deformation below 78Ni for iron and chromium isotopes, leading to the idea of merging islands of collectivity from N=40 to N=50, as already observed from N=20 to N=28 [2]. Core excitations and their impact on moments in Cu and Zn isotopic chains will be discussed.
Finally, discussion of the underlying mecanism in terms of Spin-Tensor components will be exposed and compared to other neutron-rich regions of the nuclear chart.

[1] F. Nowacki, A. Poves, Phys. Rev. Lett. in print
[2] E. Caurier, F. Nowacki, A. Poves, Phys. Rev. C 90, 014302 (2014)
[3] S. Lenzi et al., Phys. Rev. C 82, 054301 (2010)
[4] C. Santamaria et al., Phys. Rev. Lett. C 115, 192501 (2015)
[5] A. P. Zuker et al., Phys. Rev. C 92, 024320 (2015)

Session 2 / **9**

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

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.High resolution laser spectroscopy gives access to properties of nuclear ground states and long-lived (> 5ms) isomeric states of radioactive nuclei far from stability, such as nuclear spins, nuclear magnetic and quadruple moments and charge radii [1]. These fundamental properties of exotic nuclei provide important information for the investigation of the nuclear structure in different regions of nuclear chart. Currently, two complementary collinear laser spectroscopy set-ups are available at ISOLDE, Collinear Laser Spectroscopy (COLLAPS) [2] and Collinear Resonant Ionization Spectroscopy (CRIS) [3].

Combining these two techniques, the nuclear structure in several key regions of the nuclear chart can be investigated. Results from studies in the Ca and Ni regions will be presented and an outlook to future opportunities will be presented.

References:
[1] P. Campbell et al., Progress in Particle and Nuclear Physics 86, 127 (2016).
[2] http://collaps.web.cern.ch/
[3] http://isolde-cris.web.cern.ch/isolde-cris/

Session 2 / **10**

Mean field theory on octupole deformed nuclei

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.The QRPA approach, well known to be adapted for giant resonance description, is also a good formalism to describe low energy vibrational states for all multipolarities and parities with the same accuracy. We will present selected recent successful results obtained within the QRPA approach using the Gogny interaction.
First, we will compare the first 2+ collective state obtained in QRPA and in 5DCH (a GCM-like method, including rotation) in tin (Z=50), N=16 isotones, and in the Nickel isotopic chain, from drip line to drip line [1]. Concerning octupolar modes, predictions for first 3- states (energies and transition probabilities) in the tin isotopic chain will be discussed, before presenting the low energy spectra obtained in super heavy nuclei such as Cm, Cf and Fm.
Secondly low energy dipole resonances in light nuclei and giant resonances in doubly magic exotic nuclei [3] will be addressed, enlightening the role of the intrinsic deformation [4]. The first fully coherent microscopic description of the multipolar spectrum of the heavy deformed nucleus 238U [5] will be used to summarize our know-how. On the basis of all these satisfactorily results, large-scale calculations of dipole responses, both electric [6] and magnetic [7], for all nuclei for which data exist have been undertaken. A strategy for an application to odd-A and odd-odd nuclei will be discussed with few examples.
Finally, we present the generalization of QRPA to the charge-exchange nuclear excitation (pnQRPA) [8] namely the Isobaric Analog and Gamow-Teller resonances which play a crucial role in several fields of physics (nuclear physics, astrophysics and particle physics). A comparison of the results with existing experimental data on Fermi and Gamow-Teller strength distributions is presented and the role of nuclear deformation analyzed. A special attention is paid to the reproduction of β-decay half-lives as well as for the specific N = 82 isotonic chain relevant for the r-process nucleosynthesis [9]. For these charge-exchange modes possible extension to odd systems will be presented too.

REFERENCES
[1] S. Péru and M. Martini, Eur. Phys. J. A (2014) 50: 88 ;
[2] M. Martini, S. Péru and M. Dupuis, Phys. Rev. C 83, 034309 (2011) ;
[3] S. Péru, JF. Berger, PF. Bortignon, Eur. Phys. J. A 26, 25-32, (2005) ;
[4] S. Péru, H. Goutte, Phys. Rev. C 77, 044313, (2008);
[5] S. Péru, G. Gosselin, M. Martini, M. Dupuis, S. Hilaire and J. -C. Devaux, Phys. Rev. C 83, 014314 (2011) ;
[6] M. Martini, S. Péru, S. Hilaire, S. Goriely, F. Lechaftois, Phys. Rev. C 94, 014304 (2016) ;

[7] S. Goriely, S. Hilaire, S. Péru, M. Martini, I. Deloncle, F. Lechaftois, Phys. Rev. C 94, 044306 (2016) ;
[8] M. Martini, Péru and S. Goriely, PRC89, 044306 (2014) ;
[9] M. Arnould, S. Goriely and T. Takahashi, Phys. Rep. 450, 97 (2007).

Session 2 / **11**

Shape effects from total absorption measurements

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.The concept of nuclear shape plays an important role in our present understanding of nuclear structure. For that reason it is important to have methods to infer the shape of a nucleus in any state of excitation or in particular in its ground state. In this talk I will describe how a proper measurement of the beta strength in beta decay studies can provide in particular cases information about the prolate, oblate or spherical character of the decaying parent state. For the measurements the appropriate technique, the total absorption technique, is needed in order to avoid the so-called Pandemonium effect. I will cover the measurements performed at ISOLDE(CERN), discuss some examples of measurements performed at IGISOL, Univ. of Jyväskylä, and present future ideas for more exotic regions of the nuclide chart where a combination of techniques might be needed.

Session 2 / **12**

Recent achievements and future developments in Coulomb excitation studies

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.Coulomb excitation is one of the rare methods available to obtain information on static electromagnetic moments of short-lived excited nuclear states, including collective non-yrast levels. In the scattering of two nuclei, the electromagnetic field that acts between them causes their excitation. The process selectively populates low-lying collective states and is therefore ideally suited to study nuclear collectivity and deformation. Historically, these experiments were limited to stable isotopes, however the advent of new facilities, providing intense beams of short-lived radioactive species, has opened the possibility to apply this powerful technique to a much wider range of nuclei.

I will present some recent examples of complex Coulomb excitation studies at ISOLDE and elsewhere that demonstrate how this method can be used to investigate phenomena such as shape coexistence and development of exotic deformation (superdeformed, triaxial or octupole shapes). Possible synergies with other European RIB facilities will also be discussed.

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Discussion and Conclusion