

EURORIB 2010

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Village de Vacances de Lamoura

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Book of Abstracts

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Introduction

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Welcome the participants

Are you a student, postdoc or an attendee from an “emerging” country and would like to apply for financial support?:

no

Shell structure Far From Stability I / 1

Pygmy Resonances in Exotic Nuclei

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The progress of the new generation of experimental facilities on radioactive ion beams opens the opportunity to investigate unknown regions of exotic nuclei, far from the valley of beta-stability. One of the most interesting findings, was the observation of enhanced, resonance-like, low-energy, dipole strength, as a common feature of stable and unstable nuclei with neutron excess. This clustering of strong dipole transitions was named Pygmy Dipole Resonance (PDR). It was suggested that the PDR is due to an oscillation of a small portion of neutron-rich nuclear matter relative to the rest of the nucleus. Here, we present systematic investigations based on self-consistent HFB and QPM theory on dipole and other multipole excitations in several isotonic and isotopic chains of nuclei, particularly exploring their connection to the thickness of the neutron or proton skin, respectively [1-3]. From the analysis of the structure of low-energy electric dipole and quadrupole states and the corresponding neutron and proton transition densities a Pygmy Dipole [1,3] and a Pygmy Quadrupole Resonances (PQR) [2] are identified as a distinct and unique excitation, different from giant resonances and low-energy collective quadrupole states, respectively. The total PDR and PQR strengths are found to be related to the neutron skin thickness.

In addition, it has been suggested that the pygmy resonances are independent of the type of nucleon excess (neutron or proton) [1,2].

Furthermore, recent calculations of low-energy E1 and spin-flip M1 excitations in N=82 nuclei are presented in comparison with experimental data [3]. These investigations allow to decompose the dipole strength below the GDR to elastic E1 component, related to skin oscillations and PDR, and background component composed of elastic and inelastic E1 and M1 transitions, respectively. The obtained information reveals new aspects in the isospin dynamics of the nucleus.

References:

- [1] N. Tsoneva, H. Lenske, Phys. Rev. C 77, 024321 (2008), and refs. therein.
 [2] N. Tsoneva, H. Lenske, Phys. Lett. B submitted, arXiv:0910.3487 [nucl-th].
 [3] A. P. Tonchev, S. L. Hammond, J. H. Kelley, E. Kwan, H. Lenske, G. Rusev, W. Tornow, and N. Tsoneva, Phys. Rev. Lett., accepted, and refs. therein.

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yes

Shell Structure Far From Stability III / 2

Masses and Structure in Exotic Nuclei

Author: Richard Casten¹

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The measurement of nuclear masses takes on enhanced importance in exotic nuclei far from stability where spectroscopic data will often be sparse. Masses and binding energies are integral quantities reflecting all nucleonic interactions. However, various differences and double differences of binding energies can isolate particular physics or specific interactions. There has been enormous progress in mass measurements in recent years, in particular with Penning traps and storage rings. This has spawned significant advances in understanding the relationship between masses and structure and, thereby, using measured masses to study structural evolution in nuclei, underlying shell structure, the development of collectivity, quantum phase transitions, and the microscopic interactions that drive this evolution. This talk will focus on a few of these recent developments, in particular using two nucleon separation energies and proton-neutron interaction strengths deduced from nuclear masses. Work supported by U.S. DOE Grant No. DE-FG02-91ER-40609.

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No

Poster Prize Talks - Board: 25 / 3

Introduction to Laser Spectroscopy at the TRIGA-SPEC Facility

Author: Christopher Geppert¹

Co-authors: Andreas Krieger¹; Bastian Sieber¹; Jörg Krämer¹; Klaus Blaum²; Klaus Eberhardt¹; Micheal Hammen¹; Rodolfo Sanchez³; Wilfried Nörtershäuser¹; _ TRIGA-SPEC collaboration⁴

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⁴ _

On-line laser spectroscopy allows us to study the nuclear ground-state properties of short-lived exotic isotopes by measuring their hyperfine structure and isotope shifts. The properties that can be

extracted from this are the nuclear spin, the magnetic moment, the spectroscopic nuclear quadrupole moment, and the change in the mean-square nuclear charge radii between isotopes. Experimental data can be determined with high precision and the nuclear parameters can be extracted in a nuclear-model free way. Collinear laser spectroscopy has played an important role in obtaining hyperfine structures and isotope shifts of short-lived isotopes and is still a versatile tool for the exploration of long isotopic chains reaching far from the valley of nuclear stability.

At the TRIGA research reactor at the University of Mainz a collinear laser spectroscopy experiment is currently being installed, which will allow us to study short-lived fission products created by neutron induced fission of, e.g., ^{249}Cf near the reactor core. A gas-jet transport system will be employed to guide the nuclei from the production site close to the nuclear reactor core to an ECR ion source, where ion beams of a large variety of elements including refractory elements will then be produced and after mass separation be guided to the TRIGA-Laser experiment. We will present the technical outline of the experiment, show the results of first beam line performance tests with a surface ion source and report on first specification measurements by laser spectroscopy on a fast beam of stable Rb atoms.

Would you prefer your contribution to be a poster presentation? (please answer yes or no):

no

Would you prefer your contribution to be an oral presentation? (please answer yes or no):

yes

New Modes of Radioactivity / 4

Two proton radioactivity: status and perspectives

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Two-proton radioactivity is the latest nuclear decay mode discovered. It consists of the emission of a pair of protons from a nuclear ground state. According to the definition by V. Goldanskii who was the first to discuss this new type of radioactivity extensively, one-proton radioactivity is not allowed to be an open decay channel for two-proton radioactivity (2p) candidates.

In pioneering experiments at GANIL and GSI, this new radioactivity was discovered in 2002 and meanwhile ^{45}Fe and ^{54}Zn are established 2p emitters, with a possible third nucleus, ^{48}Ni , for which one event was most likely observed. These results allowed a detailed comparison with the theoretical models available and showed that, at the level of precision of the experimental data and of the predictive power of the models, nice agreement was obtained.

The latest step in the investigation of 2p radioactivity was the use of time-projection chambers to study the decay dynamics via measurements of the individual proton energies and the relative proton-proton emission angle. A first experiment at GANIL and a high-statistics experiment performed at MSU on ^{45}Fe allowed to gain first insides into the decay characteristics by comparison with a three-body model. Meanwhile, ^{54}Zn has also been studied with a TPC at GANIL.

The present talk will review the experimental results on ground-state two-proton radioactivity and compare these results with theoretical predictions. Future studies and the possible discovery of new 2p emitters will be discussed.

Production of High-Intensity Rare Isotope Beams at SPES with the Multi-foil direct target

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The SPES Project at Laboratori Nazionali INFN di Legnaro now is entering in its construction phase. The SPES is a ISOL type RIB facility concentrating on the production of neutron-rich radioactive nuclei by the Uranium fission at a rate of 1013 fission/s. The most critical element of the SPES project is the direct production target. The Rare Ion Beam (RIB) indeed, will be produced by proton induced fission on a UCx multi foil direct target. Up to day the proposed target, represents an innovation in term of capability to sustain the primary beam power. The design is carefully oriented to optimise the radiative cooling taking advantage of the high operating temperature of 2000oC. In the present talk will be presented recent developments dedicated to production, ionization and acceleration of RIB exceeding by more than one order of magnitude the currently available beam intensities. Design and tests of target chamber element, results on production and characterization of UCx target discs, and simulations of the ion sources performances will be discussed. The manipulation of very high intensity (up to 109 pps) RIB implicates advanced solutions for the safety and radioprotection issues. A preliminary design of the RIB production area will be presented

Board: 8 / 6

Possibility of production of new superheavy nuclei in complete fusion reactions

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Using available experimental data, the survival probabilities of excited superheavies are extracted. Their increase beyond $Z = 114$ indicates the next proton shell closure at Z between 120 and 126.

The perspectives of the production of new superheavy nuclei ($Z \geq 114$) in complete fusion reactions were investigated. The possible way to synthesize new superheavies is the use of the actinide-based reactions with projectiles heavier than ^{48}Ca . At present, there are theoretical shell model calculations which predict a stability island close to the element $Z=114$ or 120, or 126 and $N=184$. Using these predictions of properties of superheavy nuclei and the dinuclear system fusion model, the production cross sections in the hot fusion reactions $^{48}\text{Ca}, ^{50}\text{Ti}, ^{54}\text{Cr}, ^{58}\text{Fe}, ^{64}\text{Ni} + ^{238}\text{U}, ^{244}\text{Pu}, ^{248}\text{Cm}, ^{249}\text{Cf}$ were calculated. It was shown that the cross sections are much larger with mass tables which predict the next double magic nucleus $^{310}126$ beyond ^{208}Pb . In this case there are possibilities to synthesize new superheavy elements with the present experimental setups.

The excitation functions of superheavy nuclei in hot fusion reactions $^{32,34,36,38}\text{S} + ^{233-238}\text{U} \rightarrow ^{108}$ and $^{40,44,48}\text{Ca} + ^{238}\text{U} \rightarrow ^{112}$, were predicted using the available predictions of nuclear properties.

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yes

Board: 15 / 7

Sysmatics of charged-particle radioactivities and implications on nuclear structure effect

Author: Chong Qi¹

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Starting from the R-matrix description of the charged-particle emission, we found a generalization of the Geiger-Nuttall law in alpha radioactivity[1]. It relates the half-lives of monopole radioactive decays with the Q values of the outgoing particles as well as the masses and charges of the nuclei involved in the decay[1,2]. The new formula explains well all known cluster emissions, ranging from proton to heavier cluster radioactive decays. It may help us in the searching new cluster decay modes and detecting alpha decays of superheavy nuclei.

In a few proton and alpha decay cases, significant differences are seen between experimental decay half-lives and predictions of the formula. We found that this can be related to the sudden change in the underlying nuclear structure[3]. This large variation makes cluster decay a powerful tool to study the structure of decaying nuclei.

[1]C. Qi, F. R. Xu, R. J. Liotta, and R. Wyss, *Phys. Rev. Lett.* 103, 072501 (2009).

[2]C. Qi, F. R. Xu, R. J. Liotta, R. Wyss, M. Y. Zhang, C. Asawatangtrakuldee, and D. Hu, *Phys. Rev. C* 80, 044326 (2009).

[3]C. Qi, R.J. Liotta, P. Van Duppen, and R.A. Wyss, to be published.

Is this an invited talk? (please answer yes or no):

no

Would you prefer your contribution to be an oral presentation? (please answer yes or no):

yes

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yes, i am a postdoc

Board: 23 / 8

DELAYED MULTIPLE NEUTRON EMISSION FROM PHOTOFISSION FRAGMENTS. NEUTRON MEASUREMENTS AT ALTO: TRIAL EXPERIMENT, FIRST RESULTS.

Author: Dmitry Testov¹

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Delayed-neutron emission probabilities (P_n) and half-lives ($T_{1/2}$) are among the easiest measurable gross β -decay properties of neutron-rich nuclei far from stability. Not only are they importance for reactor applications, but also they play huge role in the context of studying nuclear structure features and astrophysical scenarios. Correlations between neutrons emitted can provide with valuable information inaccessible otherwise about the pairing of nucleons inside the atomic nucleus since neutrons are not disturbed by the Coulomb barrier and correlation should be observable outside the nucleus.

Up to now there are a lot of experimental data about multiple (up to 4 neutrons) neutron emission has been obtained in light nuclei range [1] and only double neutron emission for $^{98,100}\text{Rb}$ [2] in ranges of medium and heavy nuclei.

Measuring the β -delayed neutron emission probability along the chains of very neutron-rich isotopes in the ^{132}Sn region predicted effects possibly to be observed are –irregularities in the A -dependence of the P_{total} –values and suppression of the delayed neutron emission probability [3,4]. A favorable situation for dedicated studies can be found in the region of the Sn isotopes with the neutron numbers $N > 82$ where typically $Q_{\beta-2n} = 2-5$ MeV.

The unique experimental detection system created with at ALTO [5] (IPN Orsay) consisted of three kinds of the detectors were constructed. 90 ^3He counters were used together with a detector of gammas and beta. The ^3He detector has been created at FLNR (Dubna) and has high, constant in broad range of energy, efficiency; are free from “cross talk” effect and also has easy changing geometry. The detailed description of the detector is given in [6]. Three-partial coincidence trial experiment was carried out at a mass separated beam ($A = 136$). The P_n probability for ^{136}Te was measured and compared with the table one. Due to low statistics the result obtained has quite big errors however it proves availability of the unique system created for direct measurements of delayed multi neutron emissions from neutron rich fission fragments. The experiment for measurements P_{2n} of ^{136}Sb is scheduled.

Is this an invited talk? (please answer yes or no):

no

Would you prefer your contribution to be a poster presentation? (please answer yes or no):

yes

Would you prefer your contribution to be an oral presentation? (please answer yes or no):

yes

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Yes, I am PhD student, so I would appreciate any financial support.

Board: 26 / 10

Ion beam preparation at the new TRIGA-SPEC facility

Author: Thomas Beyer¹

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The TRIGA-TRAP mass spectrometer and the TRIGA-LASER laser spectroscopy setup, forming the TRIGA-SPEC experiment, were recently installed at the research reactor TRIGA Mainz. The new facility aims for high-precision measurements of the ground state properties of short-lived neutron-rich radionuclides in the mass range $80 < A < 150$. The radionuclides are produced by thermal neutron-induced fission of an actinoid sample inside the reactor and extracted by a gas-jet system. Their ionization takes place in an ECR ion source. The ions of interest will subsequently be mass-separated in a 90° dipole magnet prior injecting into a radiofrequency ion beam cooler and buncher in order to reduce the ion beam's emittance. After ejection a pulsed drift tube will decelerate the ions for the TRIGA-TRAP part of the experiment where a double Penning-trap system for mass spectrometry is already operational. The TRIGA-LASER experiment will use ions of high energy for collinear laser spectroscopy. A switchyard will distribute the ions among both setups. The status of the ECR source, the mass separator and the ion beam cooler and buncher as well as recent results from TRIGA-SPEC will be presented.

Is this an invited talk? (please answer yes or no):

no

Would you prefer your contribution to be a poster presentation? (please answer yes or no):

no

Would you prefer your contribution to be an oral presentation? (please answer yes or no):

yes

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no

Board: 16 / 12

Towards bunched-beam laser spectroscopy on Cadmium at ISOLDE/CERN

Author: Kim Kreim¹

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Collinear laser spectroscopy is a well established tool for measuring model-independent properties of nuclear ground and isomeric states. With this spins, electromagnetic moments and root mean square charge radii can be extracted. These quantities probe nuclear structure with a high sensitivity - and by this the nuclear wave function - as well as macroscopic properties such as size or shape. In particular, the experimental input is of crucial importance near closed shells to improve nuclear models. We plan to study the chain of cadmium between the

N=50 and N=82 shell closures with high-resolution laser spectroscopy for the first time. These data will contribute to a better understanding of the nuclear structure in the vicinity of the doubly-magic ^{100}Sn and ^{132}Sn . On the neutron-rich side this is expected to shed light on a shell-quenching hypothesis and consequently on the duration of the r-process along the waiting-point nuclei below ^{130}Cd . The physics motivation will be presented in detail along with the experimental techniques needed to resolve the exotic species of cadmium.

Is this an invited talk? (please answer yes or no):

no

Would you prefer your contribution to be a poster presentation? (please answer yes or no):

yes

Would you prefer your contribution to be an oral presentation? (please answer yes or no):

no

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Student, yes

Board: 13 / 13

Towards a radioactive-beam trapping experiments in Israel

Authors: Michael Hass¹; Sergey Vaintraub¹

Co-authors: Dan Berkovits²; Israel Mardor²; Oded Heber¹; Ofer Aviv¹; Tsviki Hirsh¹

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The standard model of particle physics provides a good description of almost all known particle physics processes. Despite its successes, the standard model is known to be incomplete since, for example, some of its parameters are arbitrary and are derived from experiment rather than a priori. New physics beyond the standard model tests becomes one of the major interests in recent years. Lately, most known experiments to test for physics beyond the standard model are being developed in the ultra-high energy regime (e.g. LHC), which probes directly new physics processes. A second class of experiments searches for the effects of new physics at lower energies by performing precise measurements of observables, which are calculable from the standard model, and attributing any variation to new physics. Recent years have seen a plethora of such experimental proposals in general, that make use of existing accelerator facilities (e.g., the JLab Qweak and PREx proposals) as well as experiments which borrow techniques from Nuclear, Atomic, Molecular, and Optical (AMO) physics. The present work is in the context of measurements of correlation coefficients in the beta decay of radioactive nuclei.

We discuss the plans of performing such high precision measurements at the Weizmann Institute, using a high-flux d+t neutron generator to produce ^6He and ^8Li by (α, n) reactions. This in turn will lead to experiments at the upcoming 40 MeV, 2 mA, proton and deuteron SARAF accelerator in Israel. The SARAF accelerator will provide record yields of light radioactive beams (such as ^8Li and ^6He), of $O(10^{12})$ atoms/sec. The talk will address the present R&D efforts toward this goal and discuss possible collaborations with ongoing RIB trapping programs. Of particular emphasis is the novel use of an Electrostatic Ion Beam Trap (EIBT) for such measurements. These traps were first built and used at the Weizmann Institute and are currently being extensively used in atomic and molecular physics experiments, but have not yet been utilized for trapping of radioactive ions. The proposed scheme may offer numerous advantages over other techniques.

In this talk we present the conceptual design of such a scheme and preliminary simulations.

Would you prefer your contribution to be a poster presentation? (please answer yes or no):

no

Would you prefer your contribution to be an oral presentation? (please answer yes or no):

yes

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Student

Future RIB Facilities / 16

The new intermediate energy in flight facility ACCULINNA-2

Author: A.S. Fomichev¹

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The new project of the in-flight fragment separator ACCULINNA-2 [1] at U-400M cyclotron in Flerov Laboratory of Nuclear Reaction, JINR is proposed as the third generation of the Dubna Radioactive Ions Beams (DRIBs-1) complex [2]. It is expected to be a more universal and powerful instrument in comparison with existing separator ACCULINNA [3]. The beam intensity should be increased by factor 10-15, the beam quality greatly improved and the range of the accessible secondary radioactive beams broadened up to Z^{20} . The new separator will provide RIBs in the broad range of energies 5÷50 AMeV –the lowest energy range which is attainable for in-flight separators. Extensive research program which could be carried out at this facility and its operating principle are described. The new ACCULINNA-2 separator is planned to be constructed during the years 2010-2016.

Is this an invited talk? (please answer yes or no):

no

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Working Group - Synergies in Instrumentation / 17

MUSETT and the spectroscopy of heavy elements at GANIL

Author: christophe theisen¹

¹ CEA Saclay

Corresponding Author: christophe.theisen@cea.fr

Ch. THEISEN for the MUSETT collaboration

In the last few years, an impressive amount of new information has been obtained in the region of the heaviest elements. Detailed information has been obtained on the collective properties and single-particle structure using both prompt and decay spectroscopy techniques.

However, very little data are available for nuclei located on the less neutron-deficient side of this region of the nuclear chart. Indeed, these isotopes can only be populated in very-asymmetric hot fusion-evaporations reactions using light-ion beams and actinide targets with the consequence that the recoiling nuclei have a very large angular distribution and a very low kinetic energy. The transmission of separators or spectrometers is usually poor for such reactions. With its very large acceptance providing a high transmission, VAMOS is well adapted to these studies; recoils are detected in the new MUSETT silicon detector array (“Mur de Silicium pour l’Etude des Transfermiens par Tagging”), which has been developed for the detection of the very heavy and very slow fusion-evaporation residues and for alpha-decay tagging. MUSETT is made of 4 segmented double-sided silicon detectors (128 strips on each side) assembled in a wall having a total size of 40x10 cm² covering the VAMOS focal plane. Given the very large number of strips a new highly integrated ASIC based electronics and data acquisition system have been developed. Recoil-decay tagging will be used to unambiguously identify evaporation residues in the dominant backgrounds of unwanted reaction channels, while EXOGAM will provide a large efficiency for the detection of prompt gamma-ray cascades.

In this contribution, we will first give an overview of our experimental program on transfermium and transactinides elements studies. We will then describe the new MUSETT silicon wall and show the results of the first commissioning experiment. A new gas-filled operation mode has been recently implemented at VAMOS, which extends the capability of the spectrometer in symmetric and inverse kinematics fusion-evaporation reactions. Examples of nuclear structure and reaction dynamics studies using this new mode and MUSETT will be given. In a near future the Super Separator Spectrometer S3 and the ultra-high intensities of the LINAG linear accelerator will provide fantastic opportunities for decay-spectroscopy studies. We will show how the S3 focal plane detection will benefit from the MUSETT developments and give examples of first-day experiments foreseen with S3 in 2013.

Is this an invited talk? (please answer yes or no):

no

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Board: 39 / 18

Recent mass measurements at ISOLTRAP

Author: Susanne Kreim¹

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Corresponding Author: susanne.waltraud.kreim@cern.ch

Precision mass measurements are performed at the mass spectrometer ISOLTRAP which is located at the isotope separator ISOLDE/CERN. The time-of-flight method is employed to determine the frequency of an ion stored in a Penning trap from which the mass can be extracted. Of special interest are exotic nuclei whose mass can be determined with a relative uncertainty of down to 10⁻⁸. These values help to examine nuclear structure effects, revising mass models or are incorporated into nucleo-synthesis calculations. In the past year, ISOLTRAP delivered precious data to some of these applications: Determining the two neutron separation energy of 64-66Mn allowing for ruling out a possible shell closure at N=40. The nucleus 66Mn with a half-life of only 64ms is thereby the shortest-lived nuclei ever to be measured at ISOLTRAP. In addition, the masses of 96,97Kr disproved the assumption of some mass models –such as e.g. HFB17 –that a region of deformed nuclei existed around N=60. Nuclei lying far from stability can furthermore be used to test mass models, thus shedding light on the r-process; one of them being the masses of 122-124Ag. Finally, the determination of the mass of 194Hg allows for improving the reachable limit for the electron neutrino mass to about 20eV.

Is this an invited talk? (please answer yes or no):

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Applications in other fields / 20

Applications of radioactive beams

Author: Ulli Köster¹

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Advances in nuclear spectroscopy and nuclear reaction studies far from stability are more and more driven by the availability of intense and pure radioactive beams. However, also other disciplines profit of such beams, e.g. nuclear astrophysics, nuclear solid state physics, materials sciences and medical applications. The particular requirements to the radioactive beam properties will be discussed via some practical examples and future perspectives will be given.

Is this an invited talk? (please answer yes or no):

yes

Shell Structure Far From Stability III / 21

Testing fundamental symmetries with Ra isotopes

Author: Lorenz Willmann¹

Co-authors: Bodhaditya Santra²; Gouri S. Giri²; Hans W. Wilschut²; Klaus Jungmann²; Oscar O. Versolato²; Praveen Shidling²; Umakanth Dammalapati²

¹ *University of Groningen/NL*

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Radium isotopes are of interest because they have advantageous properties searching for new physics beyond the Standard Model of particle physics. At KVI we are developing experiments to measure Atomic Parity Violation (APV) and Time Reversal Violation (TRV) using Ra ions and atoms, respectively. The APV measurements aim to improve on the accuracy of weak charge measurements. The sensitivity scales faster than the atomic number of the atom and therefore Ra ions may improve on the current best accuracy obtained with Cs. Limits on TRV can be obtained by searching for a permanent Electric Dipole Moment (EDM) also here Ra is orders of magnitude more sensitive than the current best limit on the EDM using Hg atoms. Current focus is on measuring atomic properties of Ra ions and atoms. We describe the production and trapping of Ra atoms and ions and the first measurements, such as isotope shifts and hyperfine interactions of excited states, which address the accuracy of theoretical calculations. The latter will be essential for the interpretation of the fundamental experiments.

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Production and Manipulation of RIB / 22

Secondary neutrons as the main source of the neutron rich fission residues production after the bombardment of a thick U target by 1 GeV protons: experimental evidences for Cs isotopes

Author: Anatolij Barzakh¹

Co-authors: Dmitry Fedorov ¹; Fedor Moroz ¹; Gerard Lhersonneau ²; Konstantin Mezilev ¹; Luigi Tecchio ³; Marina Tonezzer ³; Oleg Alyakrinskiy ³; Pavel Molkanov ¹; Stanislav Orlov ¹; Viktor Ivanov ¹; Vladimir Panteleev ¹; Yury Volkov ¹

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To predict isotope yields in the future ISOL installations it is of crucial importance to understand properly the mechanism of isotope production in thick target. The present work seems to be a step toward this understanding.

Experimental yields of the mass separated Cs isotopes produced by 1 GeV proton beam in thick U targets (with the thicknesses 6.5, 91 and 146 g/cm²) have been analyzed in the framework of diffusion-effusion model. The applicability of the model has been shown by the analysis of the Fr isotopes yields. Comparison of the neutron rich and neutron deficient Cs isotopes production efficiencies allows to divide contributions from the direct reaction (p+238U) and secondary reaction ((secondary n)+238U) in the neutron rich Cs isotopes production. For 146Cs, for example, the secondary neutron contribution is greater than the direct reaction contribution from 10 to 40 times depending on the thickness and geometry of a target material. Simple calculation of the “neutron contribution” with the known secondary neutron multiplicity and the isotope production cross-sections in the reaction (n14MeV+238U) describes these data fairly well.

Is this an invited talk? (please answer yes or no):

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no

Applications in other fields / 23

Use of RIB facilities for producing isotopes for cancer treatment by D α RT

Author: Itzhak Kelson¹

¹ *School of Physics and Astronomy, Tel Aviv University, Tel Aviv, Israel*

Alpha particles are well known for their effectiveness against cancer cells. A few alpha particles passing through the cell DNA are sufficient to destroy it or to stop its multiplication. However, the short range (less than 0.1 mm) of naturally available alpha particles has so far prohibited their use as a practical therapeutic agent. Diffusing Alpha-emitters Radiation Therapy (D α RT) is a new modality for utilizing alpha particles for treating solid tumors which overcomes this limitation. Instead of inserting into a tumor a source emitting alpha particles, one inserts a source which releases short-lived alpha emitters. These disperse in the tumor by diffusion and by convection, emitting their alpha particles at a therapeutically significant distance (a few mm) from the source. Specifically, the parent isotope on the D α RT source is 224Ra (3.7 days half-life), which releases a sizable fraction of its progeny by its own alpha-decay induced recoil. 224Ra itself is being collected electrostatically onto

the source after recoiling from a surface ^{228}Th (1.9 years half-life) generator. An optimal method of producing such generators is through the collection of ^{228}Fr , which results in a practical, longer lived ^{228}Th generator fed by the intermediate isotope ^{228}Ra (5.7 years half-life).

Working Group - Synergies in Instrumentation / 24

The CHyMENE project for a windowless solid hydrogen thin target

Author: A. Gillibert¹

Co-authors: A. Obertelli¹; C. Louchart¹; E.C. Pollacco¹; L. Nalpas¹; V. Lapoux¹

¹ DSM/IRFU/SPhN

Corresponding Author: alain.gillibert@cea.fr

Nuclear reactions on hydrogen CH₂ or CD₂ targets in inverse kinematics are extensively used with radioactive beams. This is the case, for example, for transfer reactions or resonant elastic scattering. Cryogenic targets may be used to improve the luminosity and remove the contribution of C atoms. However, for low incident beam energies, the thickness of the cryogenic target is a crucial parameter to achieve the detection of the reaction products. The aim of the CHyMENE project is first to produce a thin target in the 50-100 μm range by a continuous extrusion technique. A film of solid hydrogen flows in a given plane (perpendicular to the beam axis in our case) and will be evacuated after irradiation. No additional Mylar-type window will be used.

Is this an invited talk? (please answer yes or no):

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Shell structure Far From Stability I / 25

Onset of collectivity in neutron-rich Fe isotopes

Authors: Andreas G \ddot{o} rger¹; Joa Ljungvall²

Co-authors: Alahari Navin³; Alexander B \ddot{u} rger⁴; Alexandre Obertelli¹; Alfred Dewald⁵; Alfredo Poves⁶; Andres Gadea⁷; Aradhana Shrivastava³; Christelle Schmitt³; Daniele Mengoni⁸; Eda Sahin⁹; Emmanuel Cl \acute{e} ment³; Francesco Recchia⁹; Frederic Nowacki¹⁰; Gilles de France³; Jean-Paul Delaroche¹¹; Jose Javier Valiente-Dobon⁹; K.O. Zell⁵; Kamila Sieja¹⁰; Laurent Gaudefroy¹¹; Magdalena Zielinska¹²; Matthias Hackstein⁵; Maurycy Rejmund³; Michel Girod¹¹; Thomas Pissulla⁵; Wolfram Korten¹; Wolfram Rother⁵

¹ CEA Saclay, IRFU / SPhN

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⁴ *Univ. Oslo*⁵ *Univ. Köln*⁶ *Univ. Autonoma Madrid*⁷ *CSIC Valencia*⁸ *INFN Padova*⁹ *INFN Legnaro*¹⁰ *IPHC Strasbourg*¹¹ *CEA / DAM*¹² *Univ. Warsaw***Corresponding Author:** agoergen@cea.fr

The lifetimes of the first excited 2+ states in ⁶²Fe and ⁶⁴Fe have been measured in an experiment at GANIL using the Recoil-Distance Doppler Shift technique. The iron nuclei were populated in multi-nucleon transfer reactions between a ²³⁸U beam at 6.5MeV/A and a ⁶⁴Ni target. A degrader foil at micrometer distances from the target was used to slow the reaction products before entering the VAMOS spectrometer for identification. The Doppler shift of the gamma rays emitted before and after the degrader foil was measured with the EXOGAM germanium detector array.

The lifetimes give evidence for a strong increase in collectivity from ⁶²Fe to ⁶⁴Fe. The results are compared to new large-scale shell model calculations and HFB-based configuration mixing calculations. The large B(E2) value in ⁶⁴Fe can be related to the occupation of the neutron g_{9/2} and d_{5/2} orbitals. Many parallels are found between the neutron-rich Fe isotopes below ⁶⁸Ni and the so-called 'island of inversion' around ³²Mg.

Is this an invited talk? (please answer yes or no):

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At and Beyond the Dripline / 26

FIRST RESULTS OF REACTIONS INDUCED WITH EXOTIC BEAMS IN THE REGION OF ¹¹Be WITH CHIMERA ARRAY

Author: L. Grassi¹

Co-authors: A. Anzalone²; A. Pagano³; A. Trifirò³; C. Maiolino²; D. Loria³; E. De Filippo⁴; E. Geraci⁵; E. La Guidara⁶; E. Rosato⁷; F. Amorini²; F. Porto⁸; F. Rizzo⁸; G. Cardella⁴; G. Lanzalone⁹; G. Politi¹; G. Verde⁴; I. Lombardo⁸; J. Han²; L. Auditore³; L. Zetta¹⁰; M. Papa⁴; M. Trimarchi³; M. Vigilante⁷; M.B. Chatterjee¹¹; P. Guazzoni¹⁰; P. Russotto⁸; S. Lo Nigro⁸; S. Pirrone⁴

¹ *INFN sez CT- Università degli Studi di Catania*² *INFN LNS Catania*³ *INFN gruppo collegato di Messina*⁴ *INFN sez Catania*

⁵ INFN sez CT- Università degli studi di Catania

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¹¹ Saha Institute of Nuclear Physics, Kolkata

Corresponding Author: laura.grassi@ct.infn.it

Nowadays our understanding of atomic nuclei is strongly oriented to the study of exotic nuclei. The availability of energetic beams of short-lived nuclei, referred to as radioactive ion beams (RIBs), has opened the way to the study of the structure and dynamics of new nuclear species, and to investigate nuclear matter under extreme conditions.

In Catania, at Laboratory Nazionali del Sud is available a facility that produces radioactive beams at Fermi energies through in flight separation technique of projectile fragmentation products. With these beams and the CHIMERA multidetector, we have performed two experiments by using ^{13}C and ^{18}O as primary beams at 55 MeV/A impinging on ^9Be target and measuring reactions induced by various exotic beams as $^{10,11,12}\text{Be}$, $^{12,13,14}\text{B}$ and $^{16,17}\text{C}$. We report preliminary results obtained on the reactions $^{11}\text{Be}(p,d)^{10}\text{Be}$ and $^{10}\text{Be}(d,p)^{11}\text{Be}$: the two reactions allow to study ^{11}Be nuclear halo structure.

Is this an invited talk? (please answer yes or no):

no

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PhD Student

Working Group - Synergies in Instrumentation / 27

MINOS: a new active target for in-beam gamma spectroscopy

Author: Alexandre Obertelli¹

¹ CEA Saclay

Corresponding Author: alexandre.obertelli@cea.fr

In-flight gamma spectroscopy of rare isotopes is known to be one of the most efficient tools to investigate shell effects in exotic nuclei. In this presentation, we present MINOS, a project for a new active target dedicated to hydrogen-induced reactions and in-beam gamma spectroscopy at relativistic energies. When coupled to AGATA, the improvement in sensitivity is to reach a factor of several hundreds compared to today's capabilities. In the future, it will take advantage of the most exotic neutron-rich beams produced at the FAIR facility, coupled to the new-generation gamma array AGATA spectrometer.

Is this an invited talk? (please answer yes or no):

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yes

Shell Structure Far From Stability II / 28

Single particle states in ^{67}Ni

Author: Jan Diriken¹

Co-authors: Andrei Andreyev²; Athena Pakou³; Dennis Muecher⁴; Georgi Georgiev⁵; Iain Gerard Darby¹; Jytte Elseviers¹; Kathrin Wimmer⁶; Mark Huuse¹; Michael Seidlitz⁴; Nikolaos Patronis³; Piet Van Duppen¹; Riccardo Raabe¹; Thomas Roger¹; Vinzenz Bildstein⁶

¹ *Katholieke Universiteit Leuven*

² *University of West-Scotland*

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The interest in the structure of nuclei around ^{68}Ni has been triggered long ago by the observation of the high excitation energy of the first $2+$ in this nucleus [1]. Combining this observation with the fact that a minimum is reached in the systematic of $B(E2;2+ \rightarrow 0+)$ -values at $N=40$ in the neutron rich nickel chain has lead to interpretations in terms of a harmonic oscillator subshell closure resulting in extensive theoretical studies [2]. The excitation spectrum of odd mass nuclei in the direct neighborhood of closed shells is usually governed by single particle excitations. One-neutron transfer reactions are a useful tool to fix spins and parities of excited states and determine spectroscopic factors which can be compared to shell model predictions. Recent large scale shell model calculations have shown the sensitivity of certain nuclear parameters in this region to the size of the $N=40$ and $N=50$ shell gaps [3]. By measuring effective single-particle energies these shell gaps can be fixed in order to further update the existing nuclear models.

In this case the excitation spectrum of ^{67}Ni was studied by performing the $^{66}\text{Ni}(d,p)^{67}\text{Ni}$ reaction in inverse kinematics with an energy of 3 MeV/u at the REX-ISOLDE radioactive ion beam facility in CERN using the MINIBALL setup in combination with the T-REX particle detection array [3]. The extracted angular distributions of the protons can be compared to DWBA calculations in order to determine spin and parity of the excited states as well as spectroscopic factors. Population of levels with excitation energy up to 6 MeV have been observed, probably above $N=50$.

Preliminary results of the analysis will be presented.

[1] R. Broda et al. Phys.Lett.B 113, 279 (1982)

[2] O. Sorlin et al. Phys.Rev.Lett. 88, 092501 (2002)

[3] K. Langanke et al. Phys.Rev.C 67, 044314 (2003)

[4] V. Bildstein et al. Prog.Part.Nucl.Phys 59, 386 (2007)

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Board: 21 / 29

New laser setup for the selective isotope production and investigation in a laser ion source at the IRIS facility

Authors: Anatoly Barzakh¹; Pavel Molkanov¹

Co-authors: Dmitry Fedorov¹; Viktor Ivanov¹; Vladimir Pantelev¹

¹ *Petersburg Nuclear Physics Institute, 188300 Gatchina, Russia*

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New laser installation for the resonance ionization spectroscopy in a laser ion source and for rare isotope production has been recently built and put into operation at the IRIS facility (PNPI, Gatchina). This is a significant improvement of a target-laser ion source device of the IRIS mass-separator, working on-line with 1 GeV proton beam of PNPI synchrocyclotron. It makes us possible to get the isobarically clean radioactive isotope beams of a number of chemical elements. New laser setup should provide the two- or three- resonance step ionization in the range of wavelength of 200 – 850 nm. Two narrowband scanning dye lasers will be applied for the laser spectroscopy inside the target-ion source device of the IRIS mass-separator. The first off-line and on-line tests of the laser setup for Tl and In stable and radioactive isotopes have been carried out at IRIS facility.

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no

Fusion Reactions and Synthesis of Heavy and Superheavy Nuclei / 30

Sub-barrier fusion of $^6\text{He} + ^{208}\text{Pb}$

Authors: Angel Sanchez-Benitez¹; Antonio Padilla¹; Carmen Angulo²; Cosimo Signorini³; Ismael Martel Bravo¹; Jose Duenas¹; Juan Pedro Bolivar¹; Krzysztof Rusek⁴; Luis Acosta¹; Lukasz Standylo⁵; Marco Mazzocco³; Mauro Romoli⁶; Mikail Golovkov⁵; Rafael Berjillos¹; Roman Wolski⁵; Thomas Keutgen²

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During the last years there have been an increasing interest in understanding the process of sub-barrier fusion induced by halo nuclei. The fusion probability is largely affected by two main features, the extended density distribution and the weak binding energy of these exotic systems. In addition to this, one and two neutron transfer can also play an important role in the dynamics of the fusion process. Sub-barrier fusion of ${}^6\text{He}$ was studied in [1, 2, 3] but no clear signature of fusion enhancement was found. This picture is consistent with the observation of large yields of alpha particles [4] which could be attributed only to neutron transfer (incomplete fusion) and projectile breakup. However in a recent measurement [5], a large enhancement of the fusion channel was observed in the scattering of ${}^6\text{He}+{}^{206}\text{Pb}$ at deep sub-barrier energies. The authors explained their finding using a sequential neutron transfer mechanism [6] that increases the fusion probability and is able to reproduce the data. To clarify the situation we have performed a new measurement of the fusion cross-sections for the system ${}^6\text{He} + {}^{206}\text{Pb}$, in the range of energies 14-18 MeV (Lab) using the target activation technique. The experiment was performed at the RIB facility of the Cyclotron Research Center (UCL) at Louvain-la Neuve (Belgium). The irradiated targets were analyzed in the Detector Laboratory at the University of Huelva (Spain). The details of the experimental method and the new fusion data will be presented and discussed.

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- [6] V.I. Zagrebaev, Phys. Rev. C 67, (2003) 061601.

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Yes

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Board: 27 / 31

An off-line laboratory for laser photoionization studies

Authors: Alessandra Tomaselli¹; Daniele Scarpa²; Piero Benetti¹

Co-authors: Alberto Andrighetto ³; Gianfranco Prete ³; Jesus Vasquez ³; Lisa Biassetto ³; Mattia Manzi ³; Michele Bruschi ⁴; Stefano Corradetti ³

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In Pavia a collaboration started on in support of Laser photoionization activities within SPES Project. Three tunable dye laser will be used to investigate the photoionization pathways for elements of interest of the Project. The available wavelength range spans from UV to near IR and operation are for now limited to 10 Hz repetition rate.

The overall yield of photoionization will be measured by means of a reflectron time of flight mass spectrometer, whilst the intermediate optical steps are monitored with fluorescence techniques.

Some measurements are also performed using a hollow cathode lamp as atomic reservoir and observing the laser interaction, photoionization included, by means of an optogalvanic technique. This system turns out to be a simple and effective tool for preliminary photoionization studies.

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NO

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YES

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Board: 37 / 32

Shape coexistence in the neutron-deficient lead region

Author: Nick Bree¹

Co-author: Andrew Petts²

¹ *Inst. voor Kern- en Stralingsfysica - Katholieke Universiteit Le*

² *Oliver Lodge Laboratory - University of Liverpool*

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Since isotope shift measurements [1] first observed a sharp shape transition in the ground states of light odd-mass mercury isotopes, shape coexistence has been an actively studied phenomenon by means of in-beam spectroscopy. In light even mass mercury isotopes a weakly deformed oblate ground state band ($\beta_2 \approx -0.15$) is found to coexist with a more deformed ($\beta_2 \approx 0.25$) prolate band. The prolate states are associated with the excitation of four protons across the $Z=82$ shell gap into the $h_{9/2}$ and $f_{7/2}$ ($\pi(4p-6h)$) configuration) while oblate states are associated with the $\pi(0p-2h)$ configuration [2,3]. There now exists a large body of evidence supporting the coexistence of different shapes at low excitation energies in mercury isotopes.

Coulomb excitation at safe energies serves as a vigorous technique to investigate the magnitude of transitions between low-lying states, revealing information on the mixing of the different bands.

Pure beams of $^{182,184,186,188}\text{Hg}$ were delivered by the ISOLDE radioactive beam facility to a stable Cd target (^{112}Cd or ^{114}Cd) placed in the middle of the MINIBALL gamma spectrometer to induce Coulomb excitation. The isotopes of interest were produced with 1.4 GeV protons from the PS booster impinging upon a molten lead target. The nuclei were charge bred in EBIS to charge states of $44+$ ($^{182,184,186}\text{Hg}$) and $45+$ (^{188}Hg). The intensities at the cadmium target were 4.9×10^3 pps (^{182}Hg), 1.0×10^5 pps (^{184}Hg), 2.5×10^5 pps (^{186}Hg) and 3.1×10^5 pps (^{188}Hg). These intensities were sufficient for the detection of low-lying, low-spin states. Observed deexcitation rates, together with known lifetimes [4-6] enable the transitional quadrupole matrix elements connecting different states to be extracted. Also the sign of the diagonal matrix element of the first excited $2+$ state, containing the information about the nuclear quadrupole deformation, will experimentally be determined. In addition to the decay of the first $2+$ state, transitions from the second $2+$ state and from the first $4+$ state have been observed during the experiment.

Analysis is in progress to measure the E2 matrix elements for the lower states in these nuclei. An experiment aiming at measuring lifetimes very precisely in $^{184,186,188}\text{Hg}$ has been approved and scheduled at Argonne National Laboratory. Also an experiment at JYFL will attempt to measure E0 matrix elements in the nuclei of interest. The evolution of band mixing and deformation throughout the $^{184,186,188}\text{Hg}$ isotope chain will be investigated to enhance our understanding about the shape coexistence phenomenon in this part of the nuclear landscape.

- [1] J. Bonn et al., Phys. Lett. B 38 (1972) 308.
- [2] W. Nazarewicz, Phys. Lett. B 305 (1993) 195.
- [3] R. Julin et al., J. Phys. G 27 (2001) R109.
- [4] W.C Ma et al., Phys. Lett. 167 (1986) 277.
- [5] Proetel et al., Phys. Lett. 48 (1974) 102.
- [6] Joshi et al., Int. J. Mod. Phys. E 3 (1994) 757.

Is this an invited talk? (please answer yes or no):

No

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Yes

Board: 38 / 34

Nuclear structural evolution and average proton-neutron interactions on Xe and Rn from precision mass measurements

Authors: D. Neidherr¹; R. B. Cakirli²

Co-authors: A. Herlert³; A. Kellerbauer⁴; Ch. Böhm⁵; D. Beck⁶; D. Lunney⁷; E. Minaya-Ramirez⁷; E. Noah⁸; F. Herfurth⁶; G. Audi⁷; K. Blaum⁵; L. Penescu⁸; L. Schweikhard⁹; M. Breitenfeldt¹⁰; M. Kowalska³; M. Rosenbusch⁹; R. F. Casten¹¹; S. George⁵; S. Naimi⁷; S. Schwarz¹²; T. Stora⁸

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¹² NSCL, Michigan State University, East Lansing, Michigan 48824-1321, USA

Corresponding Author: burcu@wnsl.physics.yale.edu

The evolution of nuclear structure will be discussed with a direct approach based on plots of 2-dimensional contours of various observables. This approach offers a new way visualizing and extrapolating the systematics of nuclei, especially far from stability. In addition, different regions will be examined, including those addressed from recent mass measurements of Xe [1] and Rn [2] with the double Penning trap mass spectrometer ISOLTRAP at CERN-ISOLDE. The average proton-neutron interaction, dV_{pn} , extracted from double differences of masses, is studied using these new mass results for the Ra and Ba nuclei. A new pattern was observed for both $N \sim 90$ and $N \sim 134$ regions. Finally, these experimental dV_{pn} results will be compared with recent microscopic density functional theory results.

[1] D. Neidherr, R. B. Cakirli, G. Audi, D. Beck, K. Blaum, et al., Phys. Rev. C 80, 044323 (2009).

[2] D. Neidherr, G. Audi, D. Beck, K. Blaum, Ch. Böhm, et al., Phys. Rev. Lett. 102, 112501 (2009).

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Would you prefer your contribution to be a poster presentation? (please answer yes or no):

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Shell Structure Far From Stability II / 35

Laser spectroscopy of gallium isotopes using ISCOOL

Author: Bradley Cheal¹

Co-authors: Alex Brown²; Andreas Krieger³; Ari Jokinen⁴; Christopher Geppert⁵; David Forest⁶; Deyan Yordanov⁷; Ernesto Mane¹; Frances Charlwood¹; Gerda Neyens⁸; Henry Stroke⁹; Iain Moore⁴; Jonathan Billowes¹; Jorg Kramer³; Kieran Flanagan¹; Klaus Blaum¹⁰; Magda Kowalska⁷; Mark Bissell⁸; Michael Schug¹⁰; Michio Honma¹¹; Monica Zakova³; Pieter Vingerhoets⁸; Rainer Neugart³; Wilfried Nortershauser³

¹ The University of Manchester, UK

² NSCL and Dept. Physics and Astronomy, MSU, USA

³ Mainz, Germany

⁴ JYFL, Jyväskylä, Finland

⁵ GSI, Darmstadt, Germany

⁶ University of Birmingham, UK

⁷ CERN, Switzerland

⁸ IKS, KU Leuven, Belgium

⁹ New York University, USA

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¹¹ University of Aizu, Fukushima, Japan

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Laser spectroscopy performed at ISOLDE, CERN has been revolutionised by the installation of an ion beam cooler, ISCOOL. This device, a gas-filled linear RFQ, serves not only to improve the beam quality but also delivers a bunched ion beam. Recent measurements on isotopes of gallium ($Z=31$) are presented which illustrate the improvement. The phenomenon of monopole migration is the primary physics motivation in these studies - specifically the movement of proton states as the $g_{9/2}$ neutron orbit is filled. The nuclear spin, magnetic moment, quadrupole moment and mean-square charge radius are complementary probes and all are obtainable from optical spectroscopy. Anomalous ground state spins have been measured for $A=73$ and $A=81$, and these, together with the moments, are compared with theoretical calculations.

Is this an invited talk? (please answer yes or no):

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yes

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postdoc

At and Beyond the Dripline / 36

Beta decay directly to continuum

Author: Karsten Riisager¹

¹ Department of Physics and Astronomy, Aarhus University

Corresponding Author: karsten.riisager@cern.ch

The beta-delayed deuteron decay of the halo nucleus ${}^6\text{He}$ is thought of as proceeding directly to continuum states, and it appears that the corresponding decay of ${}^{11}\text{Li}$ behaves in the same manner [1]. The present contribution discusses evidence that beta decays directly into continuum states may happen more generally. Experimental indications come from extended R-matrix fits to beta-delayed alpha decays of ${}^{12}\text{N}$ [2] and ${}^8\text{B}$ [3] measured at JYFL and KVI. In both cases acceptable fits with a moderate number of resonances only occur for unrealistic parameter values of the resonances. I shall - after presenting the experimental data - argue that transitions directly into the continuum should be considered as an alternative decay route, explain how this conceptually ties in with the R-matrix fits and illustrate this via simplified model calculations.

[1] R. Raabe et al, Phys.Rev.Lett. 101 (2008) 212501.

[2] S. Hyldegaard et al, Phys. Rev. C81 (2010) 024303.

[3] O. Kirsebom, S. Hyldegaard et al, in preparation.

Is this an invited talk? (please answer yes or no):

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No

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Yes

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Facility Talks II / 37

EURISOL –European ISOL facility for high-intensity exotic beams

Author: Juha Aysto¹

¹ *University of Jyväskylä*

Recently completed Design Study for EURISOL [1] –a European isotope-separation-on-line (ISOL) facility –aims at the construction of an accelerator-based ISOL system for producing exotic radioactive ion beams (RIBs) with intensities several orders of magnitude greater than those available today. EURISOL is intended to be complementary to FAIR –the Facility for Antiproton and Ion Research, currently planned in Germany. With high-power beams of protons producing highest intensities for a range of radioactive and exotic isotopes, EURISOL will provide a unique facility for European scientists. In this talk the main features of the planned facility and its potential impact on nuclear science and its applications will be reviewed.

1. <http://www.eurisol.org/site02/index.php>

Is this an invited talk? (please answer yes or no):

yes

Would you prefer your contribution to be a poster presentation? (please answer yes or no):

no

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Poster Prize Talks - Board: 35 / 38

β -decay and Coulomb excitation of neutron-rich Mn and Fe isotopes at ISOLDE

Author: Jarno Van de Walle¹

Co-authors: Bruce Marsh ²; Deyan Radulov ³; Didier Voulot ²; Dieter Pauwels ³; Fredrik Wenander ²; Hilde De Witte ³; Iain Darby ³; Jan Diriken ³; Joakim Cederkall ⁴; Kathrin Wimmer ⁵; Luis Mario Fraille ⁶; Mark Huyse ³; Nick Bree ³; Nigel Warr ⁷; Paul Van den Bergh ³; Pierre Delahaye ⁸; Piet Van Duppen ³; Reiner Kruecken ⁵; Roman Gernhauser ⁵; Thorsten Kroell ⁵; Ulli Koester ⁹; Valentin Fedosseev ²; Vinzenz Bildstein ⁵; William Bill Walters ¹⁰; Yuri Kudryavtsev ³

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⁴ Lund University, Sweden

⁵ E12, TUM, Munich, Germany

⁶ Universidad Complutense, Madrid, Spain

⁷ IKP, Universitat Koln, Germany

⁸ GANIL, Caen, France

⁹ ILL, Grenoble, France

¹⁰ University of Maryland, USA

The first hint for onset of deformation south of ^{68}Ni came from a beta decay experiment on $^{64,66}\text{Mn}$ at ISOLDE back in 1999 [1]. This experiment was possible thanks to the availability of the selective Resonance Ionization Laser Ion Source. In the ten years since then, much structural information has been obtained on radioactive neutron rich isotopes in this region. In this contribution a short summary will be given of recent discoveries south of ^{68}Ni .

Now, 10 years later, a beta decay experiment was performed at ISOLDE on $^{60-68}\text{Mn}$ with the LISOL tape station. Some of the high quality spectra will be shown and first results will be presented. A comparison will be made with recently obtained spectra from in-flight facilities.

It will be shown that online a factor ten increase in yield could be achieved by further optimizing the laser ionization scheme of the neutron rich Mn isotopes with $A \geq 65$.

The $A=62$ and 63 Mn beams were also post-accelerated at REX-ISOLDE and Coulomb excitation has been induced on $^{62,63}\text{Mn}$ and ^{62}Fe at the MINIBALL setup. The latter was possible by making use of the in-trap decay of the short lived ^{62}Mn isotope. The combined results from Coulomb excitation and beta decay of the pure and intense ^{62}Mn beam will be shown.

[1] M. Hannawald et al., PRL 82, 1391 (1999)

Is this an invited talk? (please answer yes or no):

No

Would you prefer your contribution to be a poster presentation? (please answer yes or no):

No

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Board: 7 / 39

High precision measurement of the final-state distribution in 8B decay

Authors: J. Büscher¹; R. Raabe¹; T. Roger¹

Co-authors: A. Perea²; A. Saastamoinen³; B. Bastin¹; B. Santra⁴; D. Galaviz²; D.J. Van der Hoek⁵; E. Traykov¹; G.S. Giri⁵; H.O.U. Fynbo⁶; H.W. Wilschut⁵; J. Cruz⁷; J. Äystö³; K. Jungmann⁵; K. Riisager⁶; L. Fraile⁸; L.R. Gasques⁹; M. Alcorta²; M. Carmona-Gallardo²; M. Huyse¹; M. Lantz⁹; M. Sohani⁵; M.J.G. Borge²; O. Kirsebom⁶; O. Tengblad²; O.O. Versolato⁵; P. Dendooven⁵; P. Van Duppen¹; P.D. Shidling⁵; S. Hyldegaard⁶; T. Cocolios¹; W.L. Kruithof⁵

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² *Instituto de Estructura de la Materia, CSIC, Madrid, Spain*

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⁴ *KVI Groningen Kernfysisch Versneller Instituut, Rijksuniversiteit Groningen, The Netherlands*

⁵ *Kernfysisch Versneller Instituut, Rijksuniversiteit Groningen, The Netherlands*

⁶ *Department of Physics and Astronomy, University of Aarhus, Denmark*

⁷ *Dep. Fisica, FCT, Universidade Nova de Lisboa, Portugal*

⁸ *Departamento Fisica Atomica, Universidad Complutense, Madrid, Spain*

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The measurement of the undistorted spectrum of 8B neutrinos is necessary to extract information on the neutrino oscillation parameters from the solar neutrino spectrum observed on Earth.

Several experiments aiming at determining this intrinsic spectrum have been performed using different techniques. The latest results of Bhattacharya et al. [1] and Winter et al. [2] show large disagreement with the measurement of Ortiz et al. [3].

We have measured with a high precision the 8B beta final state distribution, reducing the systematic uncertainties. For this purpose, a 18.7 MeV 8B beam from the TRIUMF separator at KVI was implanted in a 75 μm thick double-sided stripped silicon detector [4,5]. The detection of the two alpha particles resulting from the decay of the first excited 2+ state in 8Be, together with a full beta-summing GEANT4 simulation, enabled us to reconstruct the final state distribution with a precision of about 5 keV down to 350 keV excitation energy.

The R-matrix fit of this distribution will be presented, and the obtained neutrino distribution will be compared with the previously obtained results.

[1] M. Bhattacharya et al., Phys. Rev. C73, 055802 (2006)

[2] W.T. Winter et al., Phys. Rev. Lett. 91, 252501 (2003)

[3] C.E. Ortiz et al., Phys. Rev. Lett. 85, 2909 (2000)

[4] D. Smirnov et al., Nucl. Instr. and Meth. A547, 480 (2005)

[5] J. Büscher et al., Nucl. Instr. and Meth. B266, 4652 (2008)

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yes

Radioactive Ion Beams in Nuclear Astrophysics / 40

Perspectives for nuclear astrophysics using ultra-dense ion beams and highly brilliant gamma beams

Author: Peter Thirolf¹

Co-author: Dietrich Habs ¹

¹ *Fakultät für Physik-Ludwig-Maximilians-Univ. München*

Corresponding Author: peter.thirolf@physik.uni-muenchen.de

Along with the availability of high power, short pulse lasers arises the perspective of generating ultra-dense, laser-accelerated ion beams, which is one of the most active fields of research in virtually all major high-power laser laboratories world-wide. We plan to apply the new Radiation Pressure Acceleration (RPA) mechanism for ion acceleration, which was recently observed [1,2,3]. We are exploring the possibility to establish a new nuclear reaction mechanism, fission-fusion, where in a first step bunches of solid state density of e.g. ^{232}Th with about 10 MeV/u will be produced (thus exceeding the density of ion bunches from classical accelerators by about 15 orders of magnitude), which then pass through a second Th foil where they desintegrate into light and heavy fission fragments. A strongly reduced atomic stopping power is expected in the interaction of the very dense ion bunches via collective effects, which is important to obtain intense fission fragment beams.

The high density of the projectile and target ions furthermore leads to a reasonable subsequent fusion yield between neutron-rich light fission fragments. This may grant access to the production of extremely neutron-rich nuclei in the region of the astrophysical r-process near the waiting point $N=126$. Moreover, highly brilliant gamma-beams with MeV energies can be produced via Compton-backscattering of laser photons (ca. 1 eV) off brilliant electron bunches from conventional accelerators (storage ring or energy recovery linac). High-resolution spectroscopy ($\Delta E_{\text{gamma}}/E_{\text{gamma}} \sim 10^{-4}$) using nuclear the resonance fluorescence technique can be applied to shed new light on short-lived neutron-deficient nuclei relevant for the astrophysical p- or rp nucleosynthesis processes. Ultra-dense laser ion acceleration as well as a brilliant gamma source based on the above concept is presently under study for the nuclear physics pillar of the European ELI (Extreme Light Infrastructure) large scale research facility to be built within the next 5 years in Bucharest [4].

[1] A. Henig et al., Phys. Rev. Lett. 103, 245003 (2009).

[2] T. Tajima, D. Habs, X. Yan; Laser Acceleration of Ions for Radiation Therapy, RAST 2, 221 (2009).

[3] S. Steinke et al., 'Efficient ion acceleration by collective laser-driven electron dynamics with ultra-thin foils', submitted to Phys. Rev. Lett. (2009), arXiv:0909.2334v1 [physics.plasm-ph]

[4] <http://www.extreme-light-infrastructure.eu/>

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Board: 22 / 41

Microstrip Metal Detector For Radioactive Ion Beam Diagnostics

Author: Oleksii Kovalchuk¹

Co-author: Valery Pugatch ²

¹ *Institute for Nuclear Research NASU (Ukraine)*

² *Institute for Nuclear Research NASU*

Corresponding Author: lexxkov@kinr.kiev.ua

Microstrip Metal Detectors (MMD) are discussed as detectors of radioactive ions, charged particles and X-ray beams. A nearly transparent sensor (~1 micron) makes MMD the thinnest detector ever made for the particles registration. Other advantages of the MMD such as high radiation tolerance (10-100 MGy); perfect spatial resolution (5 –25 microns); unique, well advanced production technology are discussed too.

MMD applications:

-RIB profile monitoring

-Detectors at the focal plane of mass-spectrometers and electron microscopes

-Imaging sensors for X-ray and charged particle applications

-Precise dose distribution measurements for micro-biology, medicine etc.

Currently available Microstrip Metal Detector (a row of 1024 nickel strips (2 micron thick, 40 micron width, 60 micron pitch) read-out via thin polyimide cable by 128-channel ASIC preamplifiers VA_SCM3) is characterized as a device for the RIB diagnostics.

Would you prefer your contribution to be a poster presentation? (please answer yes or no):

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Board: 1 / 42

Study of the β -delayed particle emission of ^{17}Ne

Author: Ricardo Domínguez-Reyes¹

Co-authors: A. Jokinen ²; A. Saastamoinen ³; B. Jonson ⁴; G. Nyman ⁴; H. Jepsen ⁵; H. O. U. Fynbo ⁵; J. López Herraiz ⁶; J. M. Udías ⁶; J. Äystö ³; K. Riisager ⁵; L. M. Fraile ⁶; M. J. G. Borge ¹; O. Kirsebom ⁵; O. Tengblad ¹; R. Schueber ⁷; S. España Palomares ⁶; T. Nilsson ⁸

¹ *IEM, CSIC, Madrid, Spain*

² *Helsinki Institute of Physics, FIN-40014, University of Jyväskylä, Finland*

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⁵ *Institut for Fysik og Astronomi, Aarhus, Denmark*

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Beta delayed particle emission provides a very useful way of studying nuclear structure near the drip lines. With this aim we have performed an experiment at ISOLDE to investigate the β -delayed proton and alpha emitter ^{17}Ne , the lightest bound neon isotope. We wanted to study the β -delayed proton decay branches and in particular those unstable to α decay.

One of the main interests on ^{17}Ne is the population by β -delayed proton decay of states in ^{16}O of astrophysical importance. The width of the 7.117 and 6.917 MeV states in ^{16}O affects the strength

of the E1 and E2 components of the capture reaction $^{12}\text{C}(\alpha,\gamma)^{16}\text{O}$ of the CNO cycle after the triple- α process. The ratio of these two processes determines the amount of ^{12}C and ^{16}O after helium burning, which in turn influences the amount of heavier nuclei that are created starting from each of these two.

To achieve a better understanding of that process, we have studied the β -delayed charged particles channels using ISOLDE's Si-Ball along with a DSSSD+Si-PAD. The Time-of-Flight technique and telescope event selection

were used to separate the proton and alpha channels in order to obtain branching ratios and β feeding to the levels of interest. We have investigated the particle coincidence channels ($\beta p\alpha$ and $\beta\alpha p$). Furthermore we have performed advanced R-Matrix fits to the data in order to reproduce the shape of the spectrum including interference. We have been able to determine the spin-parity and widths of most of the levels relevant to the particle emission process from the excited states of ^{17}F .

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No

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Yes

New Modes of Radioactivity / 43

Study of exotic beta-decays of light nuclei with an implantation technique

Author: Riccardo Raabe¹

¹ *Instituut voor Kern- en Stralingsfysica, K.U. Leuven*

Corresponding Author: raabe@kuleuven.be

Thanks to its well-established theory, beta-decay is a useful tool to study the peculiar features present in light exotic nuclei, such as halos and cluster structures. In such systems, beta decay is characterised by large Q -values and low breakup thresholds in the daughter nuclei, so that feeding to continuum states and delayed emission of nucleons and light ions become possible. To study these exotic decays we used a technique where the radioactive nuclei are implanted in a finely segmented detector, and the decay channels are identified through the time and position correlation between the implanted nuclei and subsequent parent and daughter decays. This method ensures a high efficiency and an accurate normalisation of the branching ratios. We will illustrate the results obtained for the study of various systems: The deuteron-emission decay channel of the nuclei ^6He and ^{11}Li , and the implications concerning their halo structure; The decays of ^{12}B and ^{12}N to alpha-unbound channels in ^{12}C ; The measurements of the decay of ^8B and ^{11}Be .

Is this an invited talk? (please answer yes or no):

no

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Board: 20 / 44

Micropixel Detector Timepix For Measuring And Imaging Radioactive Ion Beams

Author: Andrii Chaus¹

Co-authors: Oleksii Kovalchuk¹; Valery Pugatch²

¹ *Institute for Nuclear Research NASU (Ukraine)*

² *Institute for Nuclear Research NASU*

Corresponding Author: lexkov@kinr.kiev.ua

We have carried out the first studies of TimePix - hybrid pixel detector installed at the focal plane of a laser mass-spectrometer operating with a wide range of ions accelerated from 3 to 25 keV. The results of the first test of the TimePix as a metal detector of low energy ions in a focal plane of the laser mass-spectrometer are presented too. The TimePix detector provides two-dimensional imaging of ion beams and their charge/mass distribution allowing for tuning mass spectrometer 'on-line' (focusing, alignment etc.). The 2D-data allow also to improve mass resolution by projecting mass-data from isotope's loci. The possibility to apply the TimePix detector for Radioactive Ion Beam diagnostics is discussed.

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I am a PhD student and I would like to apply for financial support

Working Group - Synergies in Instrumentation / 46

Prototyping of DSSD detectors for the EXL project

Author: Branislav Streicher¹

Co-authors: Bjorn Riese¹; Catherine Rigollet²; Helmut Weick¹; Jens Volker Kratz³; Manfred Mutterer¹; Morko von Schmid⁴; Nasser Kalantar²; Peter Egelhof¹; Philip Woods⁵; Ruud Borger²; Thomas Davinson⁵; Thorsten Kroell⁴; Vladimir Eremin⁶; Xuan Chung Le¹

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⁴ *TU Darmstadt*

⁵ *The University of Edinburgh*

⁶ *PTI St. Petersburg*

Corresponding Author: b.streicher@gsi.de

The EXL1) experiment as part of the future FAIR facility will provide the means for studying numerous physics phenomena in unstable exotic nuclei. Reactions will be performed in inverse kinematics using new storage-ring techniques and an universal detector system providing high resolution and large solid angle coverage for kinematically complete measurements. The present work focuses on prototyping and testing double-sided silicon strip detectors (DSSDs) produced in PTI St. Petersburg (Russia) as a part of the EXL's Silicon Particle Array (ESPA).

The spectroscopic properties and tracking performance of DSSDs with 16x16 and 64x64(16) strips were studied using 241Am alpha source, with special emphasis on the interstrip characteristics using particle implantation from either the junction or the ohmic side.

These detectors were also used in telescope-like configurations in two test experiments with proton beams of 50 and 100 MeV performed at KVI Groningen and GSI Darmstadt, respectively, aimed at the total energy reconstruction. Another experiment with these detectors was performed at TU München aimed at separating protons and alpha particles using pulse shape discrimination. Special ceramic PCBs along with support flanges were constructed and tested at GSI Darmstadt to examine the possibility of using the first layer of EXL's DSSDs as an active vacuum barrier separating storage ring ultra-high vacuum from moderate vacuum housing all the subsequent detectors and the necessary cabling and electronics.

The talk will cover spectroscopic performance of DSSDs as well as the results of the aforementioned experiments. The second part will address the mechanical solutions for the ESPA in conjunction with the vacuum prototype using DSSDs as a vacuum barrier.

1) <http://www.rug.nl/kvi/Research/hnp/Research/EXL/index>

Is this an invited talk? (please answer yes or no):

no

Would you prefer your contribution to be a poster presentation? (please answer yes or no):

no

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yes

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yes

Board: 30 / 47

Charge radii of magnesium isotopes: the island of inversion investigated by dedicated laser-spectroscopy methods

Author: D. T. Yordanov¹

Co-authors: A. Krieger²; C. Geppert³; G. Neyens⁴; J. Krämer²; K. Blaum⁵; K. Kreim⁵; M. Bissell⁴; M. Hammen²; M. Kowalska⁶; P. Lievens⁷; P. Vingerhoets⁴; R. Neugart²; W. Nörtershäuser³

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The island of inversion is commonly regarded as an island of deformation. Yet, the transition to a deformed configuration in the isotopes of magnesium is not well understood. This problem cannot be addressed by quadrupole-moment measurements due to nuclear spin 0 or 1/2 of most key isotopes. Experimental evidence from reaction studies as well as the spins and magnetic moments of ^{31,33}Mg are consistent with considerable prolate deformation. However, in order to obtain a continuous picture of the evolution of the nuclear shape along the magnesium chain one has to measure a quantity accessible for all isotopes (odd and even) with the same experimental technique. Accordingly, a measurement of the rms charge radii of the neutron-rich magnesium isotopes will be presented for the first time.

This work was undertaken with the collinear laser spectroscopy setup at ISOLDE-CERN. The isotope shifts of ²⁴⁻³²Mg were measured using different detection methods for increased sensitivity to the exotic nuclei in the island of inversion. Classical fluorescence detection was used for the intense beams of ²⁴⁻²⁹Mg. Beta detection was applied on the odd isotopes ²⁹Mg and ³¹Mg and used for isotope-shift measurements for the first time. The application of this technique was justified after a recent development of computer simulations of the beta-asymmetry produced by optical pumping. This approach is essential for extracting the small nuclear-volume effect contributing to the isotope shifts of light atomic systems. The equivalence of optical and beta detection is investigated on the basis of ²⁹Mg, which is accessible with both methods, and thus used as a proof of principle. Fluorescence spectra of ³⁰Mg were recorded by gating on the short release from the ISOLDE target. The case of ³²Mg was investigated with the use of photon-ion coincidence.

The measurements on the rms charge radii of the neutron-rich magnesium isotopes will be presented with emphasis on the novel methodology for extracting accurate isotope shifts from beta-detection spectra. The results will be discussed in terms of deformation in light nuclei near N=20 and in the context of evolution of the shell structure away from stability.

Is this an invited talk? (please answer yes or no):

No

Would you prefer your contribution to be a poster presentation? (please answer yes or no):

No

Would you prefer your contribution to be an oral presentation? (please answer yes or no):

Yes

Shell Structure Far From Stability II Cont'd / 49

The EXL experiment at FAIR

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¹ *University of Groningen*

Corresponding Author: nasser@kvi.nl

The upcoming FAIR facility in Darmstadt, Germany, will produce intense high energy beams of exotic nuclei, which will be used to explore the properties of new regions of the chart of nuclides of key importance for both nuclear structure and nuclear astrophysics. Since the nucleus under study is the one which is produced in the process of in-flight fragmentation, one has to deal with inverse kinematics in which the hadronic probe, generally a light nucleus, is the target being bombarded by the heavy nucleus. The inverse kinematics will impose particular conditions on the design of detection systems. In the EXL project, heavy ion beams are first cooled in the New Experimental

Storage Ring (NESR) and then used to induce reactions on windowless thin hydrogen, deuterium and Helium gas targets in the ring. High luminosities can be achieved because the beam circulates a couple of million times in the ring. The EXL system will be ideal for high resolution reaction studies at low momentum transfers, for example the study of nuclear sizes using protons, giant resonance properties using inelastic light-ion scattering –such studies provide unique insights into the asymmetry energy in the nuclear equation of state and the properties of neutron stars. The design of the detector system considered is universal in the sense that it should allow the use of a large variety of nuclear reactions, addressing numerous physics questions. The detector system provides the capability of fully exclusive kinematical measurements, with target recoil detectors, fast ejectile forward detectors and an in-ring heavy-ion spectrometer. Technologically, the requirement that the detectors should be placed in the ultra-high vacuum of the ring is most demanding and requires non-standard solutions of the detector design.

The physics case and detector design considerations for EXL along with tests experiments performed at KVI and GSI, paving the way to the full EXL detection system, will be presented.

Is this an invited talk? (please answer yes or no):

No

Would you prefer your contribution to be a poster presentation? (please answer yes or no):

No

Would you prefer your contribution to be an oral presentation? (please answer yes or no):

Yes

Are you a student, postdoc or an attendee from an “emerging” country and would like to apply for financial support?:

No

Board: 14 / 50

Spectrometer studies for HIE-ISOLDE

Author: Gry Tveten¹

Co-author: Joakim Cederkäll²

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² *Lund University*

Corresponding Author: gry.tveten@cern.ch

The planned High Intensity and Energy (HIE) upgrade of the radioactive beam facility ISOLDE will enable postacceleration of radioactive beams up to an energy of about 10 MeV/u in the final stage of the upgrade, thus opening the door to nuclear reaction studies. In the case of transfer reactions in inverse kinematics a recoil separator is often well suited or even needed to tell recoils and beam apart and to select the exit channel or to do spectroscopic studies. Two different types of spectrometer designs are being considered for HIE-ISOLDE, namely a recoil mass separator or a raytracing type of spectrometer. A set of nuclear transfer reactions in inverse kinematics have been simulated using realistic parameters for HIE-ISOLDE.

The performance of the two types of spectrometer designs is compared and their scientific possibilities and limitations discussed based on the simulation results. To evaluate the validity of the simulations a data set from PRISMA at LNL is compared with simulation results and a comparison between simulations and these data will be presented.

Is this an invited talk? (please answer yes or no):

no

Would you prefer your contribution to be a poster presentation? (please answer yes or no):

yes

Would you prefer your contribution to be an oral presentation? (please answer yes or no):

no

Are you a student, postdoc or an attendee from an “emerging” country and would like to apply for financial support?:

no

Dynamics and Thermodynamics / 51

Testing the behavior of neutron-rich systems away from normal density

Author: Maria Colonna¹

Co-author: Massimo Di Toro¹

¹ INFN-LNS

Corresponding Author: colonna@lns.infn.it

Heavy Ion Collisions (HIC) represent a unique tool to probe the in-medium nuclear interaction in regions away from saturation. We present a selection of new reaction observables in dissipative collisions (10-50 MeV/u) particularly sensitive to the low-density part of the symmetry term of the nuclear Equation of State (Iso-EoS). In particular, we will discuss the Isospin Equilibration Dynamics. At low energies this manifests via the recently observed Dynamical Dipole Radiation, due to a collective neutron-proton oscillation with the symmetry term acting as a restoring force. At higher beam energies Iso-EoS effects will manifest through isospin diffusion between projectile and target and Imbalance Ratio Measurements, in particular in correlation with the total kinetic energy loss.

At higher beam energies (above 100 MeV/u) suitable observables, such as the isotopic content of particle and meson emission and collective flows, allow one to test the Iso-EoS at high density.

Are you a student, postdoc or an attendee from an “emerging” country and would like to apply for financial support?:

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Is this an invited talk? (please answer yes or no):

no

Would you prefer your contribution to be a poster presentation? (please answer yes or no):

no

Would you prefer your contribution to be an oral presentation? (please answer yes or no):

yes

Shell Structure Far From Stability II / 52

Spectroscopy of neutron-rich lead nuclei

Author: giovanna benzoni¹

Co-authors: Ajay Deo ²; Alejandro Algora ³; Alison Bruce ⁴; Ana Denis-Bacelar ⁴; Andrea Gottardo ⁵; Andres Gadea ³; Angela Bracco ⁶; Anjali Sharma ⁷; Anna Corsi ⁸; Anrej Prochazka ⁷; Benedicte Million ⁶; Cesar Domingo-Pardo ⁷; Chiara Nociforo ⁷; Daniel Napoli ⁵; Daniele Mengoni ⁹; Davinder Siwal ¹⁰; Dirk Rudolph ¹¹; Eda Sahin ⁵; Elionora Gregor ⁷; Enrique Casarejos ¹²; Fabio Crespi ⁶; Fabio Farinon ⁷; Farheen Navqi ¹³; Francesco Recchia ¹⁴; Franco Camera ⁶; Gregory Farrelly ²; Hans Geissel ⁷; Hans-Jurgen Wollersheim ⁷; Helmut Weick ⁷; Henning Schaffner ⁷; Ivan Kojouharov ⁷; Jan Szarka ¹⁵; Jerzy Grebosz ⁷; Jose Benlliure ¹²; Jose Javier Valiente-Dobon ⁵; Juan Alcantara Nunez ¹²; Jurgen Gerl ⁷; Katrin Eppinger ¹⁶; Konrad Steger ¹⁶; Magdalena Gorska ⁷; Marek Pfutzner ¹⁷; Maria Doncel ¹⁸; Matthew Reed ²; Mike Bowry ²; Mike Bunce ²; Namita Goel ⁷; Nasser Alkhomeishi ²; Nawras Al-Dahan ²; Nik Kurz ⁷; Oliver Wieland ⁶; Patrick Regan ²; Paula Allegro ¹⁹; Philip Walker ²; Plamen Boutachkov ⁷; Robert Hoiscen ¹¹; Roberto Menegazzo ²⁰; Roberto Nicolini ⁶; Roberto Ribas ¹⁹; Samit Mandal ¹⁰; Santo Lunardi ²⁰; Silvia Leoni ⁶; Stephane Pietri ⁷; Stephanie Klupp ¹⁶; Thomas Pissulla ¹³; Thomas Swan ²; Wawrzyniec Prokopowicz ⁷; Yassid Ayyad ¹²; Zsolt Dombradi ²¹; Zsolt Podolyak ²; liliana cortes ⁷

¹ INFN sezione di Milano

² University of Surrey, Guildford, UK

³ IFIC, Valencia, E

⁴ Univ. Of Brighton, Brighton, UK

⁵ INFN-LNL, Legnaro (Pd), I

⁶ Universita' degli Studi e INFN sezione di Milano, Milano, I

⁷ GSI, Darmstadt, D

⁸ Universita degli Studi e INFN sezione di Milano, Milano, I

⁹ Universita' di Padova e INFN sezione di Padova, Padova, I; University of the West of Scotland, Paisley, UK

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¹¹ Lund University, Lund, S

¹² University of Santiago de Compostela, Santiago de Compostela, E

¹³ IKP Koeln, Koeln, D

¹⁴ Universita' di Padova e INFN sezione di Padova, Padova, I

¹⁵ Comenius University, Bratislava, S

¹⁶ TU Munich, Munich, D

¹⁷ University of Warsaw, Warsaw, PL

¹⁸ Univ. Of Salamanca, Salamanca, E

¹⁹ Univ. Of Sao Paulo, Sao Paulo, Br

²⁰ Universita' di Padova e INFN sezione di Padova, Padova, I

²¹ ATOMKI, Debrecen, H

Corresponding Author: giovanna.benzoni@mi.infn.it

The neutron-rich lead region is of exceptional interest to trace the evolution of single-particle levels and the residual proton-neutron interaction beyond the doubly magic 208Pb. While 208Pb is well understood in terms of the shell model, experimental data on the heavier isotopes are very scarce [1,2].

Another crucial aspect that calls for further experimental information is the evaluation of beta-decay half lives for neutron-rich nuclei with $A > 215$. These half lives are particularly needed for r-process calculations as an essential test to validate the nuclear and beta-decay models away from stability [3].

In this talk results from a recent RISING experiment aiming at studying neutron-rich lead isotopes with $A > 210$ will be reported.

The experiment employed the active stopper configuration of the RISING array in order to study both isomeric gamma decay of long-lived states and the beta decay of heavy lead and bismuth isotopes.

The nuclei of interest were populated by relativistic fragmentation of 238U at 1 GeV/u on a Be target. The ions of interest were transported in the GSI FRS separator [4] and implanted in an active catcher consisting of 9 Silicon DSSSD. The gamma decay after implantation was measured by the 15 Cluster HPGe detectors of the RISING array [5,6].

New isomers have been identified in the populated Pb, Bi and Tl isotopes, and their lifetime and isomeric ratios are being evaluated. Comparison with shell model calculations will be presented.

- [1]M. Pfutzner et al., Phys. Lett. B 444 (1998) 32-37.
- [2]Zs. Podolyak, Acta Physica Polonica B36 (2005) 1269.
- [3]I.N. Borzov. Phys. Rev. C67 (2004) 025802.
- [4]H. Geissel et al., Nucl. Instr. Meth. B70 (1992) 286.
- [5]S. Pietri et al., Nucl. Instr. Meth. B 261 (2007)1079.
- [6]R. Kumar et al., Nucl. Instr. Meth. A 598 (2009) 754.

Is this an invited talk? (please answer yes or no):

no

Would you prefer your contribution to be a poster presentation? (please answer yes or no):

no

Would you prefer your contribution to be an oral presentation? (please answer yes or no):

yes

Production and Manipulation of RIB / 53

A novel method for isomeric beam production

Author: Kieran Flanagan¹

Co-authors: Bradley Cheal¹; Gerda Neyens²; Jonathan Billowes¹; Klaus Wendt³; Mark Bissell²; Masaki Hori⁴; Pieter VINGERHOETS²; Ryugo Hayano⁵; Takumi KOBAYASHI⁵; Thomas Proctor¹; Wannes VANDERHEIJDEN²

¹ *The University of Manchester*

² *K.U. Leuven*

³ *The University of Mainz*

⁴ *Max-Planck-Institut für Quantenoptik*

⁵ *The University of Tokyo*

Corresponding Author: kieran.flanagan@cern.ch

We report a new innovation in laser spectroscopy: Collinear Resonant Ionization Spectroscopy (CRIS), which aims to study the rarest isotopes produced at ISOLDE. CRIS relies on the new RFQ ion cooler and trap (ISCOOL) to remove the duty cycle losses that previously prevented effective realization of this technique. This method will produce ultra-clean isomeric beams, which can be studied independently of the ground state, with yields below 1 atom per second. Therefore CRIS could be applied at future RIB facilities for beam cleaning and isomer selection. This would open up the possibility of preparing pure isomeric beams for reacceleration and decay spectroscopy. This talk will discuss the status of the CRIS project at ISOLDE and the application of this technique at current and future RIB facilities.

Is this an invited talk? (please answer yes or no):

No

Would you prefer your contribution to be a poster presentation? (please answer yes or no):

No

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Yes

Are you a student, postdoc or an attendee from an “emerging” country and would like to apply for financial support?:

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Fundamental Interactions / 54

Limits on tensor-type weak currents obtained with beta-asymmetry measurements in nuclear decays.

Author: Frederik Wauters¹

Co-authors: Dalibor Zakoucky²; Emil Traykov¹; Gergelj Soti¹; Ian Towner³; Ilya Kraev¹; Michael Tandecki¹; Nathal Severijns¹; Simon Van Gorp¹; Veronique De Leebeek¹

¹ *Katholieke Universiteit Leuven*

² *Nuclear Physics Institute Rez*

³ *Queens University, Kingston, Ontario*

Corresponding Author: frederik.wauters@fys.kuleuven.be

Precision beta decay experiments are a powerful tool to probe the structure of the weak interaction at low energies 1). For example, the beta-asymmetry parameter A for pure Gamov-Teller nuclear decays is sensitive to a possible tensor component in the weak interaction if determined at the 1 % precision level. Here we will present two measurements of this parameter. Our results are competitive with the best results available in literature and contain information on tensor type charged weak currents.

The low temperature nuclear orientation technique is used to create a polarized ensemble of radioactive nuclei by cooling them down to a few millikelvin in a strong magnetic field that is created either by hyperfine interactions or by an external magnet. The beta-particles are observed by semiconductor detectors operating at a temperature of about 10 K and facing directly to the sample. In previous measurements the accuracy of such an experiment was usually limited to several percent by the scattering of beta particles and the deflection of their trajectories by the magnetic field. We have developed a method based on GEANT4 Monte-Carlo simulations to gain control over these effects. The code was extensively tested by comparing simulations to experimental data taken under various well-controlled experimental conditions 2).

First results were obtained with the isotopes ^{114}In and ^{60}Co with a precision at the 1,5 % level; which is better than the current literature values 3). An extensive study of the recoil corrections on the Standard Model prediction value was done to interpret our results in terms of exotic currents.

The method is further being improved to push the precision and new data is under analysis. Our goal is to reach the 1% level or better, which would improve the sensitivity to tensor type weak currents by a factor of 2 to 3 compared to previous experiments in beta decay.

1) N. Severijns, M. Beck, and O. Naviliat-Cuncic, *Rev.Mod. Phys.* 78, 991 (2006).

2) F. Wauters et al., *Nucl. Instrum. Methods A* 609, 156 (2009).

3) F. Wauters et al., *Phys. Rev. C* 80, 062501 (2009).

Is this an invited talk? (please answer yes or no):

no

Would you prefer your contribution to be a poster presentation? (please answer yes or no):

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postdoc

Fusion Reactions and Synthesis of Heavy and Superheavy Nuclei / 55

Heavy and superheavy nuclei in covariant density functional theory

Author: Anatoli Afanasjev¹

Co-authors: Elena Litvinova²; George Lalazissis³; Hazem Abusara¹; Peter Ring⁴; Sheeren Shawaqfeh¹

¹ *Mississippi State University, USA*

² *GSI, Germany*

³ *Aristotle University of Thessaloniki, Greece*

⁴ *Technical University of Munich, Germany*

Corresponding Author: aa242@msstate.edu

The questions of the existence limits and the properties of shell-stabilized superheavy nuclei have been a driving force behind experimental and theoretical efforts to investigate such nuclei. Unfortunately, theoretical predictions for superheavy nuclei differ considerably. In such a situation, heavy nuclei of actinide region play a role of testing ground for many theoretical approaches. Systematic study of these nuclei allows to put the error bars on theoretical description of the properties of superheavy nuclei. The present status of our understanding of heavy and superheavy nuclei within covariant density functional theory will be presented. I will concentrate on several aspects which define the shell structure and the stability of superheavy nuclei, such as (i) single-particle degrees of freedom, (ii) role of pairing, and (iii) the fission barriers.

Single-particle degrees of freedom define the shell structure. Thus, the differences in model description of the single-particle energies are important when extrapolating to superheavy nuclei. Following our initial analysis of the single-particle spectra in a few actinide nuclei [1], the systematic analysis of

the accuracy of the description of the energies of deformed quasiparticle states has been carried out in relativistic Hartree-Bogolubov (RHB) approach in rare-earth and actinide regions [2] with the goal to better understand the accuracy of the extrapolation of single-particle energies to superheavy nuclei. Impact of particle-vibration coupling on the single-particle structure of superheavy nuclei [3] will also be discussed. Special attention will be paid to self-consistency effects [4].

The fission barriers play an important role in the physics of heavy and superheavy nuclei; they are intimately connected with the existence and stability of superheavy nuclei. The role of treatment of pairing on the fission barriers has been investigated and new results were obtained [5]. The RHB and RMF+BCS calculations show that calculated fission barrier heights substantially depend on employed pairing force and treatment of pairing window even in the case when the pairing strengths are adjusted to the same value of the pairing gap at the ground state. The consequences of a different treatment of pairing for the stability of superheavy nuclei will be discussed. In addition, we performed systematic study of the impact of triaxiality on the fission barrier height [6]; in many cases it substantially decreases the fission barrier.

This work has been supported by the U.S. Department of Energy under the grant DE-FG02-07ER41459

[1] A.V.Afanasjev, T.L.Khoo, S.Frauendorf, G.A.Lalazissis, and I.Ahmad, *Phys. Rev. C* 67, 024309 (2003).

[2] S.A. Shawaqfeh and A.V.Afanasjev, in preparation

[3] E. Litvinova and A.V. Afanasjev, in preparation

[4] A.V. Afanasjev and S.Frauendorf, *Phys. Rev. C* 71, 024308 (2005).

[5] S. Karatzikos, A.V. Afanasjev, G.A. Lalazissis, and P.Ring, submitted to Physics Letters B and arXiv: 0909.1233[nucl-th]

[6] H. Abusara and A.V.Afanasjev, in preparation

Is this an invited talk? (please answer yes or no):

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no

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yes

Board: 28 / 56

Collinear Laser Spectroscopy of Cu Isotopes: Progress and Potential

Author: Mark Bissell¹

Co-authors: Andreas Krieger²; Bradley Cheal³; Christopher Geppert²; Dave Forest⁴; Deyan Yordanov⁵; Garry Tungate⁴; Gerda Neyens¹; Henry Stroke⁶; Jon Billowes³; Jorg Krämer²; Kieran Flanagan³; Klaus Blaum⁷; Magda Kowalska⁷; Marieke De Rydt¹; Paul Campbell³; Peter Lievens⁸; Pieter Vingerhoets⁹; Rainer Neugart²; Wilfried Nörtershäuser²

¹ *Inst. voor Kern- en Stralingsfysica-Katholieke Universiteit Leuven, B-3001 Leuven, Belgium*

² *Institut für Kernchemie, Johannes Gutenberg-Universität Mainz, D-55099 Mainz, Germany*

³ *School of Physics and Astronomy, The University of Manchester, Manchester, M13 9PL, United Kingdom*

⁴ *School of Physics and Astronomy, The University of Birmingham, Birmingham, B15 2TT, United Kingdom*

⁵ *CERN European Organization for Nuclear Research, Physics Department, CH-1211 Geneva 23, Switzerland*

⁶ *Department of Physics, New York University, New York, New York 10003, USA*

⁷ *Max-Planck-Institut für Kernphysik, D-69117 Heidelberg, Germany*

⁸ *Laboratorium voor Vaste-Stoffysica en Magnetisme, Katholieke Universiteit Leuven, B-3001 Leuven, Belgium*

⁹ *Inst. voor Kern- en Stralingsfysica-Katholieke Universiteit Leuven, B-3001 Leuven, Belgium*

Corresponding Author: mark.lloyd.bissell@cern.ch

As a probe of nuclear ground-state properties, laser spectroscopy remains unrivalled in its ability to simultaneously shed light on multiple observables. The nuclear spin, magnetic-dipole, electric-quadrupole and Seltzer moments may all be obtained with complete nuclear model independence. Undoubtedly, such observables constitute keen tests of our understanding of nuclear structure.

This technique has been brought to bear on the isotopic chain of Cu in order to address three questions of considerable contemporary interest: Does the monopole migration of the $\pi 1f_{5/2}$ orbital result in an inversion of ground-state spins by ^{75}Cu ? Is the $N = 28$ shell closure significantly weakened in the region of the $Z = 28$ shell closure? Additionally, does ^{72}Cu have a ground-state spin of $I\pi = (2+)$, as indicated by β -decay spectroscopy, but in direct contradiction to both shell-model calculations and in-source atomic spectroscopy?

The measurements of the hyperfine structures of the neutron rich Cu isotopes have now been performed. These results have provided unequivocal evidence for the spin inversion at ^{75}Cu and a ground state with $I\pi = 2(-)$ in ^{72}Cu . Such conclusions will be reviewed and the implications examined.

Preparations have now begun for the continuation of this experimental campaign towards the neutron deficient isotopes, addressing the issue of the $N = 28$ shell closure. The challenges and anticipated outcomes of this work will be considered.

Is this an invited talk? (please answer yes or no):

no

Would you prefer your contribution to be a poster presentation? (please answer yes or no):

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Would you prefer your contribution to be an oral presentation? (please answer yes or no):

yes

Are you a student, postdoc or an attendee from an “emerging” country and would like to apply for financial support?:

postdoc

Board: 40 / 57

Low energy structure of neutron rich 71-73Ni isotopes studied via beta-decay

Author: Mustafa Rajabali¹

¹ *Katholieke Universiteit Leuven*

Corresponding Author: mustafa.moiz.rajabali@cern.ch

A decay spectroscopy experiment was conducted at the NSCL to measure low energy excited states in 71–75Ni populated via the beta-decay of 71–75Co isotopes. Results from the data analysis of this experiment have revealed a possible beta-decaying isomer in 71Ni which was previously observed in 69Ni. Level schemes for 71,73Ni have been constructed with reference to shell model (SM) calculations using the NR78 residual interaction. These level schemes show increasing energy of the 5/2– level (attributed to $\nu f5/2$ single particle state) with increase in neutron number. This appears to agree with theoretical predictions. We have also reinvestigated the decay of 72Co, where improved data has revealed the presence of a new state tentatively interpreted as a 4+ seniority $\nu=2$ member of the ground state band. This observation is a significant step forward in understanding the disappearance of 8+ microsecond-isomers in 72Ni and 74Ni and is also in agreement with the SM calculations using the NR78 interaction.

Is this an invited talk? (please answer yes or no):

no

Would you prefer your contribution to be a poster presentation? (please answer yes or no):

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yes

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postdoc, Kenyan

Future RIB Facilities / 58

The ALTO facility for the production of rare nuclei

Author: Fadi IBRAHIM¹

¹ *IPN Orsay*

Corresponding Author: ibrahim@ipno.in2p3.fr

The ALTO facility (Accélérateur Linéaire et Tandem d'Orsay) at Institut de Physique Nucléaire d'Orsay is ready for operation. The aim of this facility is to provide neutron rich isotope beams for both nuclear physics study (away from the valley of stability) and developments dedicated to next generation facilities such as SPIRAL2. The neutron rich isotopes are produced by photofission of ²³⁸U induced by the 50 MeV electrons from the linear accelerator. The isotopes coming out of the fission target effuse towards an ion source to form a beam that is analyzed through the on line separator PARRNe. Additional experimental beam lines are currently under construction. First experimental results will be presented.

Is this an invited talk? (please answer yes or no):

no

Would you prefer your contribution to be a poster presentation? (please answer yes or no):

no

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yes

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Board: 34 / 59

Study of the N=50 major shell effect towards ⁷⁸Ni : contribution from beta-decay studies at IPN Orsay

Author: David Verney¹

¹ *IPN IN2P3-CNRS/Université Paris Sud 11*

Corresponding Author: verney@ipno.in2p3.fr

The PARRNe ISOL device has been operating at IPN Orsay since 10 years. Originally conceived as a test bench for R&D studies in the framework of SPIRAL2, the performance of the setup has proven suitable to undertake a physics research program on the evolution of N=50 towards ⁷⁸Ni by beta-decay studies. During the past decade, several experiments were realized using either the Tandem as a deuteron driver or ALTO as an electron driver. Physics results from these experiments will be presented as well as the way they connect to other results obtained elsewhere (and for other observables) in this mass region. Most of the data obtained were largely pioneering at their time and a parallel effort on the theoretical side had to be undertaken in order to provide a correct description and global understanding.

Is this an invited talk? (please answer yes or no):

no

Would you prefer your contribution to be a poster presentation? (please answer yes or no):

no

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yes

Are you a student, postdoc or an attendee from an “emerging” country and would like to apply for financial support?:

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Board: 29 / 60

Changes in the mean-square charge radii of polonium at CERN-ISOLDE

Authors: Maxim D Seliverstov¹; Thomas Elias Cocolios¹; Wim Dexters¹

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The region of the nuclear chart around the neutron-deficient lead isotopes is famous for the coexistence of different shapes at low energy. The lead isotopes ($Z=82$), however, remain spherical in their ground state. With two protons outside the lead closed core, the polonium isotopes ($Z=84$) also exhibit shape coexistence for the most neutron-deficient isotopes with intruding deformed bands. We investigated the influence of those intruding configurations on the ground state of the polonium isotopes by means of in-source resonant ionization laser spectroscopy.

Polonium isotopes and long-lived isomers from ^{191}Po up to ^{218}Po have been studied over two campaigns at the CERN-ISOLDE facility using the RILIS laser ion source. The isotope shift between all the isotopes have been extracted. Large-scale atomic calculations using the GRASP code and the RATIP package have been used to determine the electronic parameters necessary to deduce changes in the mean-square radii. The comparison between two transitions for the isotopes $^{200,202,204,206-210}\text{Po}$ is used to assert the reliability of those calculations. A very large departure in the changes in $\langle r^2 \rangle$ from sphericity is observed for $A < 200$ together with a reversal of the odd-even staggering below $A = 196$. The magnitude of the departure is much stronger than in the Hg ($Z = 80$) and Pt ($A = 78$) isotones, showing the

The analysis of the hyperfine structure of the odd- A isotopes has been performed and electromagnetic moments have been extracted. The magnetic dipole moments are consistent with a large mixing in the configuration of the ground state of the most neutron-deficient isotopes.

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yes

Shell Structure Far From Stability III / 61

In-gas-cell laser spectroscopy of neutron-deficient 57-59Cu isotopes at LISOL

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With a single proton outside the $Z=28$ shell closure and spanning the nuclear chart across several magic or quasi-magic neutron shells ($N=20,28,40,50$), the copper isotopes are ideal to study the evolution of magicity. Of particular interest is the isotope ^{57}Cu with a single proton outside the controversial doubly-magic, $N=Z=28$, nucleus ^{56}Ni . The earlier measurement of the magnetic moment of ^{57}Cu by beta-NMR pointed towards a large breaking of the ^{56}Ni core but attempts to confirm this measurement with the in-source laser spectroscopy technique at a hot-target ISOL facility has been unsuccessful.

In a recent campaign, in-gas-cell laser ionization spectroscopy coupled to mass separation and nuclear decay identification has been performed for the first time at the LISOL facility (Belgium). The magnetic dipole moments of $^{58-59}\text{Cu}$ was confirmed but that of ^{57}Cu shows a large discrepancy from the published value. The new proposed value is in good agreement with empirical and theoretical predictions, supporting the magic nature of the ^{56}Ni core in the ground state of ^{57}Cu . The g-factor of the odd-odd ^{58}Cu isotope is compared to empirical g-factors and points similarly to a configuration consistent with a magic ^{56}Ni core.

The success of this measurement opens also new possibilities for future gas-catcher facilities such as S3 at GANIL.

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no

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possibly

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yes

Board: 9 / 62

Fast neutron converter for light RIB production with 5 MeV deuterons beam of SARAF phase I

Author: Tsviki Y Hirsh¹

Co-authors: Dan Berkovits²; Ido Silverman²; Kuljeet Singh³; Markus Lauscher⁴; Michael Hass³; Vivek Kumar³

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Intense neutron sources based on high current deuterons impinging a thick beryllium, lithium or carbon targets are the basis for most of SARAF (Soreq, Israel) and SPIRAL2 (GANIL, France) future applications. Both facilities will use a 40 MeV and few mA of deuterons, resulting with $\sim 10^{15}$ fast n/sec sources.

SARAF phase I linear accelerator consists of a RFQ and one superconducting module. During the 2009 commissioning, the linac delivered high power proton beams and accelerated deuterons. By the end of 2010 a high power 5 MeV deuteron beam is expected to be available for limited experiments. This relatively low energy beam can already produce an intense fast neutron source. The spectra and total yield of fast neutrons depend on the choice of the converter material. We found that a target made from LiF maximizes the energy and yield of fast neutrons, and is also capable of holding ~ 10 kW beam power.

We introduce the concept of LiFTiT - LiF Thick Target, thermally coupled to a micro-channel water cooled copper backing. Simulations suggest a total yield of 1013 fast n/sec with neutron energies of up to 20 MeV. The high neutron yield and spectral similarity makes LiFTiT a good experimental tool for verifying isotope production schemes planned for SARAF phase II or SPIRAL2.

We present a unique experiment of ^8Li production and extraction using fast neutrons from LiFTiT. The secondary production target is a 65% porous B4C in which ^8Li is produced via the $^{11}\text{B}(n,\alpha)^8\text{Li}$ reaction channel. The B4C target will be mounted inside a high temperature furnace for fast extraction of the short-lived isotopes. According to simulations, up to 10^9 $^8\text{Li}/\text{sec}$ are expected in this experiment.

As a results of this proposed experiment at SARAF-I, better production and extraction schemes of light RIB, of great interest in various nuclear and astrophysics related measurements, may become possible .

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Yes, Student

Board: 17 / 63

The ISOLTRAP system for decay spectroscopy studies

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Penning traps are ideal tools not only for high-precision mass measurements on short-lived nuclides, but also for isobaric and even isomeric beam purification. A system for beta- and gamma-spectroscopy installed behind the Penning trap can be used for both performing decay spectroscopy on pure samples in regions where contamination hampers standard measurements, as well as for assisting mass measurements by decay-identification of the trapped species.

The installation of such a system at the ISOLTRAP Penning trap mass spectrometer located at ISOLDE/CERN is very challenging. The main reasons are a limited space, ultra-high vacuum required for mass measurements, a small number of ions which can be purified efficiently in the trap, and the need to reaccelerate the ions to kV energies for a reliable implantation avoiding ion losses during decay observation. In spite of these obstacles, in autumn 2009 the first successful tests using 80Rb beam were performed.

In this contribution, we discuss the technical details of the setup, the results of the commissioning beamtime, and future prospects.

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Dynamics and Thermodynamics / 64

DYNAMICAL DIPOLE MODE IN FUSION HEAVY-ION REACTIONS

Author: Rosetta Silvestri¹

Co-authors: A Boiano²; A Guglielmetti³; A. Del Zoppo⁴; A. Trifirò⁵; B Martin²; C Agodi⁴; C. Maiolino⁶; C. Mazzocchi⁷; C. Parascandolo²; C. Signorini⁸; D Pierroutsakou⁹; D. Santonocito⁴; E. De Filippo⁶; F Farinon⁷; G Inghima²; M. La Commara²; M. Mazzocco⁸; M. Romoli²; M. Sandoli²; M. Trimarchi⁵; R Alba⁴; R Coniglione⁴; U Emanuele⁵

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An experimental overview [1-6] on an interesting feature of dipole excitation in heavy-ion collisions, the dynamical dipole mode, predicted to occur between interacting ions with a large charge asymmetry will be presented. In a campaign of experiments where the same compound nucleus in the ^{132}Ce region was probed through different charge asymmetry entrance channels, a larger gamma-ray emission from the more charge asymmetric channel was evidenced, in the Giant Dipole Resonance energy range. The beam energy dependence of this extra gamma yield was extracted by comparing the results obtained at different beam energies [2-5]. The first angular distribution data taken at $E_{\text{lab}} = 16$ MeV/nucleon support its prompt dynamical nature [2,3]. Our data [2-5] are compared with theoretical calculations performed within a BNV transport model and based on a collective bremsstrahlung analysis of the entrance channel reaction dynamics [7] and with recent data [6] obtained for compound nuclei in the same mass region but formed through smaller entrance channel charge asymmetry.

Using the prompt dipole radiation as a probe and employing radioactive beams, new possibilities for the investigation of the symmetry energy at sub-saturation density are foreseen and will be discussed [5].

As a fast cooling mechanism on the fusion path, the prompt dipole radiation could be of interest for the synthesis of superheavy elements through hot fusion reactions. The entrance channel charge asymmetry could provide a way to cool down the hot fusion paths, so ending up with a larger survival probability. To shed light in this direction and to study if pre-equilibrium effects survive in heavier systems, we extended our study to the ^{192}Pb compound nucleus, formed at an excitation energy of 232 MeV, by using the $^{40}\text{Ca} + ^{152}\text{Sm}$ and $^{48}\text{Ca} + ^{144}\text{Sm}$ reactions at $E_{\text{lab}} = 440$ MeV and 485 MeV, respectively. Preliminary results of this measurement, done with the aim to search for the dynamical dipole mode in both fusion-evaporation and fusion-fission events for the first time in this mass region, will be presented.

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- [7] V. Baran et al., Phys.Rev.Lett. 87(2001)182501
- [8] V. Baran et al., Phys. Rev. C79 (2009) 021603(R).

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no

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Yes, I'm postdoc.

Board: 19 / 65

Coulomb excitation as a probe of nuclear polarization

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Co-author: Christophe Sotty²

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The orientation of nuclear spin ensembles is an important ingredient in nuclear physics experiments. Spin polarization can provide indispensable information in e.g. nuclear transfer reactions, Coulomb excitation etc. Therefore, obtaining a beam of polarized nuclei is of very high interest both for nuclear reactions and structure studies.

A test of spin polarization, using the tilted foils (TF) method, has been carried out with the Miniball experimental setup at ISOLDE. A stable beam of ^{21}Ne , $I\pi = 3/2^+$, was subject to Coulomb excitation after passing through a set of tilted foils. The de-excitation gamma rays were observed in the Miniball Ge detectors in coincidence with the ^{21}Ne particles detected in position sensitive Si detectors. The asymmetry of the angular distribution of particles can serve as a probe for the degree of the nuclear spin polarization. The difficulties of the present test originate in the contradictory requirements of obtaining a reasonable degree of nuclear polarization by the TF method (very low beam energy) and the Coulomb excitation (higher beam energies for higher excitation probabilities). The preliminary results of the ^{21}Ne test will be presented.

Tilted foils polarization is a simple technique applicable to a wide range of isotopes with predictable direction of the polarization. The atomic spin polarization occurring at the boundary of the foils is transferred to the nuclei via hyperfine interactions. Any isotope with nonzero ground state nuclear spin can be polarized in flight and the foils are easily introduced into a beam line. This experiment is the first in a series aiming to establish optimal conditions for spin-polarization at REX-ISOLDE.

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Board: 18 / 66

A beta-NMR setup for REX-ISOLDE

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The beta-NMR is a highly sensitive technique used for studies of nuclei as well as properties of condensed matter (Solid-State Physics, Biophysics etc). The first requirement for performing a beta-NMR measurement is to obtain an ensemble of polarized nuclei. There are several techniques that can be used for this purpose. However, one of the least demanding ones, provided a reliable control of its application is gained, is the tilted foils (TF) technique. The TF method is based on the transfer of the atomic polarization, obtained by the passage of the ions through foils at oblique angles, to the nuclear spins.

An experimental setup utilizing the beta-NMR technique is currently being assembled after the REX-ISOLDE accelerator. The setup has been previously used at HMI, Berlin. A stack of tilted foils will be used for the spin polarization, with beam energies from REX varying between 0.3 and 3 MeV/u (with HIE-ISOLDE up to 10 MeV/u). The initial experimental runs will investigate the polarization of the beta-decaying isotopes ⁸Li and ²⁷Na, used in earlier polarization experiments. The tilted foils will be introduced in the immediate vicinity of the beta-NMR apparatus and the beam will be implanted into a suitable host for observation of the beta decay asymmetry. An external RF-field, applied in direction perpendicular to the holding magnetic field B, will be used to destroy the nuclear polarization at the NMR position, thus giving a measure of the degree of the initial spin polarization.

As a first stage of the program we are planning to gain broad knowledge on the process of TF polarization in different energy regimes. This should allow for better control and production of a larger variety of polarized nuclear species both at low energies and, eventually, post accelerated polarized beams. The present status of the setup and the perspectives of the program will be presented.

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Board: 6 / 67

WITCH, status and perspectives

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The WITCH set-up (Weak Interaction Trap for Charged Particles) that has been installed at ISOLDE/CERN combines a double Penning trap system to prepare and confine radioactive ions and a retardation spectrometer to probe the energy distribution of the daughter recoil ions [1]. The latter leads to the beta-neutrino angular correlation coefficient a , which contains information of the presence of scalar or tensor interactions in nuclear beta decay. The setup is now operational and the first recoil ion spectra have been measured in the decay of ^{124}In . Although statistics were not sufficient and systematic effects have not yet been addressed in sufficient detail to extract weak interaction information, the charge state distribution of the recoiling ^{124}Sn daughter ions could be determined in this experiment [2]. The setup has been upgraded (better vacuum, buffer gas purification, electro-polished electrodes) and further optimized to allow for measurements on ^{35}Ar . A first such measurement has been performed and allowed the investigation of systematic and unwanted effects in the system. At present these data are being analyzed to collect information in preparation of longer measurements on ^{35}Ar where useful physics information can be obtained.

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Shell structure Far From Stability I / 68

Isomer spectroscopy of ^{127}Cd and ^{125}Cd

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The isomeric decays in ^{127}Cd and ^{125}Cd having two proton holes and three and five neutron holes respectively in the doubly magic ^{132}Sn core have been studied. To date even mass heavy Cd isotopes have been investigated in detail [1,2]. The obtained systematics exhibits evolution of single particle energies and addresses the onset of deformation when removing particles from the core nucleus. The experiment was performed at GSI, Darmstadt to investigate the structure of excited states in odd mass neutron rich Cd isotopes. Isomeric decays in the nuclei of interest were observed in the fragmentation reaction of a ^{136}Xe beam at energy 750MeV/u on a ^9Be target of 4g/cm² thickness. The Cd ions were selected using the standard $B\rho-\Delta E-B\rho$ method in the FRagment Separator (FRS). Event by event identification of the particles in terms of their mass A and charge Z was provided by the standard FRS detectors. Isomers populated in the reaction were implanted in a plastic catcher surrounded by 15 Ge cluster detectors from RISING array [3] to detect the γ decays. In ^{127}Cd , excited states with pure neutron ν ($h_{11/2}^{-2} d_{3/2}^{-1}$) character analogous to ^{129}Sn have been observed, whereas in ^{125}Cd apart from the previously observed $(19/2)^+$ isomer reported in Ref. [4], a new isomeric state has been detected. The level schemes of these nuclei have been established based on the obtained intensity balance and life time information. The new experimental information provides vital input for the shell model description of the evolution of neutron hole energies in neutron-rich nuclei in the $N=82$, $Z=50$ region. Comparison of the experimental results with shell model calculations will be discussed.

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Fusion Reactions and Synthesis of Heavy and Superheavy Nuclei / 69

Temperature evolution of the GDR width and Jacobi shape transitions in hot rotating 88Mo nuclei

Author: Michał Ciemala¹

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³ *Dipartimento di Fisica, Università di Firenze and INFN sezione di Firenze*

⁴ *University of York, UK*

⁵ *IPN Orsay, France*

⁶ *Laboratori Nazionali di Legnaro, Legnaro*

⁷ *Dipartimento di Fisica, Università di Bologna and INFN sezione di Bologna*

⁸ *Tata Institute of Fundamental Research, Mumbai, India*

⁹ *Institut Pluridisciplinaire Hubert Curien, Strasbourg, France*

¹⁰ *GANIL, Caen, France*

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The study of the properties of the giant dipole resonance (GDR) at high temperature and angular momentum is one of the central topics in nuclear structure as it provides insight into the behavior of nuclei under extreme conditions. The wealth of experimental data on this subject covers in most cases an interval of temperatures up to 2.5 MeV and is mainly based on the study of the GDR gamma-decay from fusion-evaporation reactions. These data have been shown to provide an important testing ground for the theoretical models. In particular, the change of the GDR width with angular momentum and temperature reflects the role played by quantal and thermal fluctuations in the damping of the giant vibrations.

Certain nuclei are expected to exhibit very exotic behavior –the Jacobi shape transition. This phenomenon is predicted as an abrupt change from an oblate shape at the so called critical value of spin to triaxial and to more elongated shapes, and finally undergoes scission.

First results from the experiment performed in LNL Legnaro aiming at investigating the spin and temperature evolution of the 88Mo nucleus as well as the GDR width at high temperature will be presented. The 48Ti beam at 300, 450 and 600 MeV bombarded 40Ca target producing 88Mo compound nucleus at temperatures 3, 3.8 and 4.5 MeV respectively. The coupled GARFIELD and HECTOR detector arrays were used, which allowed to measure high-energy gamma rays, charged particles, evaporation residua and fission fragments.

Is this an invited talk? (please answer yes or no):

No.

Would you prefer your contribution to be a poster presentation? (please answer yes or no):

No.

Would you prefer your contribution to be an oral presentation? (please answer yes or no):

Yes.

Are you a student, postdoc or an attendee from an “emerging” country and would like to apply for financial support?:

I'm PhD student. If it is possible financial support would be welcome.

Facility Talks II / 70

THE TRIUMF-ISAC RADIOACTIVE ION BEAM (RIB) FACILITY: RECENT HIGHLIGHTS AND FUTURE PLANS

Author: Gordon Ball¹

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The availability of a wide variety of intense beams of exotic nuclei from the next generation of radioactive ion beam facilities such as the Isotope Separator and Accelerator (ISAC) facility at TRIUMF provides an unprecedented opportunity to address key questions of current interest in nuclear astrophysics, nuclear structure physics, fundamental symmetries and molecular and material science. The short-lived isotopes are produced at ISAC by the ISOL (on-line isotope separation) method using a beam of up to 100uA of 500 MeV protons from the TRIUMF H- cyclotron to bombard thick production targets. The targets can be coupled to a wide variety of ion sources including: surface, laser (TRILIS) and plasma (FEBIAD) sources, to produce the worlds most intense RIB beams for certain isotopes such as ^{11}Li .

Low-energy (<60 keV) RIBs have been available at ISAC since 1999, and over the past decade a large number of state of the art experimental facilities have been developed. Recent research highlights include: high precision mass measurements of halo nuclei using the TITAN ion trap, measurements of the ground state quadrupole moments of $^{8,9,11}\text{Li}$ using βNQR , implications for neutrinoless double electron capture via β -decay studies of ^{112}Ag and ^{112}In using the 8π gamma-ray spectrometer, and microscopic investigations by βNMR of proximity effects in metal- superconductor bilayers. Fundamental symmetry studies including the search for a permanent EDM in odd A radon isotopes and PNC in francium isotopes using RIBs from a UC2 production target are under development.

An RFQ and variable energy DTL provide reaccelerated radioactive beams in the energy range from 0.15-1.8 A MeV for nuclear reaction studies of importance in explosive nucleosynthesis environments such as Novae and X-ray bursts. Most recently the DRAGON recoil separator was used to study the $^{23}\text{Mg}(p,\gamma)^{24}\text{Al}$ reaction, of critical importance in the transition between the Ne-Na and Mg-Al cycles.

Since January 2007 the new Superconducting LINAC installed at ISAC-II has made nuclear reaction studies possible with radioactive beams at energies up to 5 A MeV for $A < 30$. The initial studies using exotic beams of halo nuclei included: a measurement of the two-halo neutron transfer reaction $^1\text{H}(^{11}\text{Li}, ^9\text{Li}) ^3\text{H}$ at 3 A MeV carried out using the active target detector MAYA brought to TRIUMF from GANIL, a study of halo effects in the scattering of ^{11}Li on ^{208}Pb at energies near the Coulomb barrier, and a study of the halo structure of ^{12}Be studied via the $^{11}\text{Be}(d,p)$ reaction. In 2009, the TUDA particle detector array was move to ISAC-II for astrophysically motivated studies of the $^{18}\text{F}(p,\alpha)^{15}\text{O}$ and $^{21}\text{Na}(p,\alpha)^{18}\text{Ne}$ reactions.

The gamma-ray spectroscopy program at ISAC-II is centered on TIGRESS, a next generation array of high-efficiency segmented HPGe detectors with digital signal processing that is specifically designed to meet the challenges of experiments with high-energy radioactive ion beams. A number of auxiliary detectors are also under development for use with TIGRESS including: a DSSSD barrel for detecting charged particles SHARC, an array of neutron detectors DESCANT, and a recoil mass spectrometer EMMA. During the past year, the experimental studies included: the Coulomb excitation of ^{10}Be and the first experiment with SHARC, a measurement of the $^{25}\text{Na}(d,p)^{26}\text{Na}$ reaction as part of a program to follow the evolution of shell structure of neutron-rich sd-shell nuclei.

The potential for nuclear structure studies at ISAC-II will be greatly enhanced during the coming year with the installation of high-beta cavities and a charge state booster to provide radioactive beams up to 7 A MeV for $A < 150$.

Recent highlights from the research programs at ISAC I and ISAC II will be presented together with

an overview of future plans which include the construction of a 50 MeV, 500 kW superconducting e-linac to provide intense beams of neutron-rich nuclei via the photo-fission of actinide targets.

Is this an invited talk? (please answer yes or no):

yes

Board: 31 / 71

New magic number for neutron rich Sn isotopes

Authors: Maitreyee Saha Sarkar¹; Sukhendusekhar Sarkar²

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Due to scarcity of experimental data the variation of 2^+_{-1} energies for heavier Sn isotopes ($A \geq 136$) is still a topic for serious theoretical endeavours by different groups. Large basis untruncated shell model calculations have been done in the $p(gdsh) + n(hfpi)$ valence space above the ^{132}Sn core using both realistic and empirical (1+2) - body Hamiltonians. A new shell closure for neutron rich Sn isotopes has been predicted from these calculations using empirical SMPN interaction that works successfully in this neutron rich domain. Calculations with realistic two-body interaction CWG also predict this shell closure provided a three-body force contribution is included in it. The calculated $E(2^+_{-1})$ values for $^{134-140}\text{Sn}$ fits nicely in the systematics and shows dramatic resemblance with the trends shown by even-even $^{18-22}\text{O}$ and $^{42-48}\text{Ca}$.

Is this an invited talk? (please answer yes or no):

No

Would you prefer your contribution to be a poster presentation? (please answer yes or no):

NO

Would you prefer your contribution to be an oral presentation? (please answer yes or no):

YES

Are you a student, postdoc or an attendee from an “emerging” country and would like to apply for financial support?:

I am a participant from India. Some financial support may be helpful.

Board: 5 / 73

Nuclear Structure and Reaction dynamics in neutron-rich nuclei around ^{48}Ca with deep inelastic collisions

Author: Daniele Montanari¹

Co-authors: Adam Maj²; Alberto Marino Stefanini³; Alessandro Zucchiatti⁴; Andres Gadea⁵; Angela Bracco⁶; Ann Corsi⁶; Benoit Guiot³; Bénédicte Million⁶; Calin Ur⁷; Daniel R. Napoli³; Daniele Mengoni⁷; Dino Bazzacco⁷; Enrico Farnea⁷; Enrico Fioretto³; Fabio Celso Luigi Crespi⁶; Fernando Scarlassara⁷; Francesco Recchia³; Franco Camera⁶; Giacomo de Angleis³; Giovanna Benzoni⁶; Giovanna Montagnoli⁷; Giovanni Pollarolo⁸; José Javier Valinete-Dobon³; Lorenzo Corradi³; Nives Blasi⁶; Oliver Wieland⁶; Paolo Mason⁷; Rajesh Pratap Singh³; Riccardo

Orlandi ³; Roberto Nicolini ⁶; Santo Lunardi ⁷; Sergio Brambilla ⁶; Silvia Leoni ⁶; Silvia M. Lenzi ⁷; Suzana Szilner ⁹; Witold Meczynski ²

¹ *University of Milano and INFN Padova*

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³ *Laboratori Nazionali di Legnaro, Padova*

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⁸ *Università e INFN sezione Torino*

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The population and gamma-decay of n-rich nuclei around ^{48}Ca was measured at LNL using deep-inelastic collisions (DIC) on ^{64}Ni , at an energy ~ 2.5 times above the Coulomb barrier. The experimental setup consisted of the CLARA Ge array coupled to the PRISMA magnetic spectrometer. DIC are proved to be a powerful tool to study nuclear properties far from stability and a starting point for extracting nuclear structure information is the study of the reaction dynamics. In this contribution we present a detailed investigation of the reaction properties, such as total cross sections and energy integrated angular distributions of the most relevant transfer channels, taking into account a detailed study of the response of the PRISMA magnetic spectrometer. The experimental results are compared with predictions from the semiclassical multi-nucleon transfer model of ref. [1], which is found to well reproduce the data corresponding mainly to one nucleon transfer.

For the first time with heavy ions, angular distributions of reaction channels leading to specific excited states have been measured, and the experimental results are interpreted in terms of DWBA calculations, providing structure information on $B(E2)$'s, spectroscopic factors and particle-vibration coupling. A similar analysis has also being performed in neutron rich Ne isotopes, giving further support to the importance of DIC in the study of basic nuclear structure properties also in connection with more exotic nuclei.

[1] A. Winther, Nucl. Phys. A594, 203(1995).

Is this an invited talk? (please answer yes or no):

no

Would you prefer your contribution to be an oral presentation? (please answer yes or no):

yes

New Modes of Radioactivity / 74

Observation of gamma-delayed three-alpha breakup in ^{12}C : a complete kinematics approach to study multi-particle final state reactions

Author: Olof Tengblad¹

Co-authors: Angel Perea ¹; Björn Jonson ²; Göran Nyman ²; Hans Fynbo ³; Karsten Riisager ³; Maria Borge ¹; Martin Alcorta ¹; Oliver Kirsebom ³; Thomas Nilsson ²

¹ *Consejo Sup. de Investigac. Cientif (CSIC)*

² *Chalmers University of Technology*

³ *University of Aarhus*

Corresponding Author: olof.tengblad@cern.ch

Hans Bethe was the first to establish the concept of nucleon synthesis in stars [1] proposing the CNO cycle and the PP chain, but was unsuccessful in solving the ^{12}C formation mechanism. Not until the introduction of the Hoyle state [2] in 1953 one was getting close to a solution. However, 50 years later the ^{12}C break-up is still not fully solved and the quest for learning more about the reaction rates in stars by studying the triple-alpha process is continuing.

In this work we have studied the break-up of ^{12}C following the reactions $^{10}\text{B}(3\text{He}, p\alpha\alpha\alpha)$ and $^{11}\text{B}(3\text{He}, d\alpha\alpha\alpha)$. The study was performed at the 5MV tandem accelerator at the Centro de Micro Analisis de Materiales (CMAM) [3] at the Universidad Autónoma de Madrid. The break-up give us information on excited states in ^{12}C from the famous Hoyle state up to an energy of almost 18 MeV. Using a highly segmented experimental set-up the simultaneous detection of the three alpha particles in coincidence with a proton or a deuteron, respectively, made possible a full kinematic reconstruction of the break-up. On the basis of the energies of the three alpha particles and their angular correlations it has been possible to separate the branching of the break-up through the ground state and the first excited $2+$ state in ^8Be , as well as to determine the spin and parity of states for cases where the assignment have been doubtful.

Some of these levels will also de-excite via electromagnetic emission. The comparison between the energy of the proton (or deuteron) that populate a state of ^{12}C and the sum of the energies of the 3α emitted from the same state makes possible to determine the presence of electromagnetic disintegration (γ) to lower states within ^{12}C followed by the 3α break-up. This technique permits to identify γ -emissions between states where the gamma radiation emitted does not correspond to a peak [4].

In this contribution we will discuss the experimental set-up followed by a detailed description of the analysis method to reach the results obtained.

[1] H.A. Bethe, Energy production in stars, Phys. Rev. 55(1939)434

[2] F. Hoyle et al., Phys. Rev. 92(1953)1095

[3] <http://www.cmam.uam.es/>

Is this an invited talk? (please answer yes or no):

no

Would you prefer your contribution to be a poster presentation? (please answer yes or no):

no

Would you prefer your contribution to be an oral presentation? (please answer yes or no):

yes

Production and Manipulation of RIB / 75

The ISOLDE RILIS laser upgrade program

Author: Bruce Marsh¹

Co-authors: Dima Fedorov²; Klaus Wendt³; Lars-Erik Berg⁴; Marica Sjodin¹; Maxim Seliverstov⁵; Roberto Losito¹; Sebastian Rothe³; Valentin Fedosseev¹

¹ CERN

² PNPI, Gatchina

³ University of Mainz

⁴ KTH, Stockholm

⁵ Instituut voor Kern- en Stralingsfysica, Leuven

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For many ISOLDE users, the isobaric purity of the ion beam is a critical factor. The Resonance Ionization Laser Ion Source (RILIS) is the only ion source capable of achieving high ionization efficiency combined with chemical selectivity for many different elements. By using up to three broadly tunable dye lasers with optional second or third harmonic generation, ionization schemes for 27 elements have been successfully applied for ion beam production. Until 2008, the RILIS relied on copper vapor lasers (CVLs) to pump tunable dye lasers and to ionize highly excited atoms. The maintenance and operation of the CVLs manufactured almost 20 years ago required substantial efforts. A new CERN, KTH (Stockholm) collaboration funded by a grant from the Knut and Alice Wallenberg foundation was established with the goal of improving the RILIS performance through a series of upgrade steps. The first of these, the replacement of the CVLs with a commercial Nd:YAG laser, began in 2008 and by 2009 the new laser was fully integrated into the RILIS setup and the CVLs were no longer required. An improvement in RILIS performance in terms of ionization efficiency, as well as overall stability and reliability has been achieved. The second phase of the RILIS upgrade is underway and involves the replacement of the dye lasers. The three new dye lasers are adapted to take advantage of the availability of a 355 nm output of the Nd:YAG pump laser, extending the fundamental tuning range into the blue part of the spectrum to bridge the gap in the spectral coverage offered by the dye laser fundamental and second harmonic beams of the 532 nm pumped system. One laser has a motorized intra-cavity etalon which reduces its linewidth to 1 GHz. This is necessary for precision tuning to hyperfine components of an electron energy level to perform an isomer separation with RILIS, or for high resolution scanning during in-source resonance ionization spectroscopy studies. The third RILIS upgrade task is the installation of a complementary, all solid state RILIS system of Nd:YAG pumped Titanium Sapphire lasers, alongside the existing setup. The construction of this system, which is being carried out in collaboration with the University of Mainz, began in 2009 and its progressive installation during 2010/2011 is planned.

Is this an invited talk? (please answer yes or no):

No

Would you prefer your contribution to be a poster presentation? (please answer yes or no):

no

Would you prefer your contribution to be an oral presentation? (please answer yes or no):

yes

Are you a student, postdoc or an attendee from an “emerging” country and would like to apply for financial support?:

No

Shell Structure Far From Stability II / 76

Shell structure far from stability

Author: Silvia Lenzi¹

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Corresponding Author: lenzi@pd.infn.it

Far from the valley of beta stability, the nuclear shell structure undergoes important and substantial modifications. In medium-light nuclei, interesting changes have been observed such as the appearance of new magic numbers, and the development of new regions of deformation around nucleon numbers that are magic near stability. The observed changes help to shed light on specific terms of the effective nucleon-nucleon interaction and to improve our knowledge of the nuclear structure evolution towards the drip lines. In particular, it has been shown that the monopole part of the tensor force of the proton-neutron interaction gives the main contribution to the shell evolution. The

possibility of having a good theoretical description of these phenomena is essential to allow a deep insight into the nuclear effective interaction, to interpret the structure of nuclei far from stability, to predict the position of the drip-lines and to understand the nucleosynthesis pathways.

In the last few years, particular effort has been put on studying light and medium-mass neutron-rich nuclei where these effects manifest more dramatically. Detailed nuclear structure information is becoming available both with stable and radioactive beams nowadays and deeper insight on nuclei approaching the drip line is foreseen with the future radioactive beams facilities. The status of the present scenario and future perspectives will be discussed.

Is this an invited talk? (please answer yes or no):

yes

Board: 2 / 77

11Li+208Pb at energies near to the coulomb barrier

Author: Mario Cubero¹

Co-authors: Antonio Moro²; Christian Diget³; Daniel Galaviz⁴; H.O.U Fynbo⁵; Ismael Martel⁶; Joaquín Gómez-Camacho⁷; Juan Pablo Fernández⁸; M.J.G. Borge¹; Marcos Alvaréz⁹; Olof Tengblad¹; Patrick Wolden¹⁰

¹ IEM-CSIC

² Univerisidad de Sevilla

³ Department of Physics - University of York

⁴ Centro da Física Nuclear da Universidade de Lisboa

⁵ Department of physics and Astronomy, University of Aarhus

⁶ Universidad de Huelva

⁷ CNA - Universidad de Sevilla

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⁹ CNA - Universidad de Sevilla

¹⁰ TRIUMF - University of British Columbia

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The scattering of ^{11}Li on a high-Z target at energies near and below the Coulomb barrier can unveil new features of halo nuclei. Due to the halo structure one expects departures from Rutherford scattering and this deviation can shed light on the nuclear halo. In particular, the effect of dipole polarizability is known to affect strongly the elastic scattering of halo nuclei on heavy targets, even at energies below the Coulomb barrier, where nuclear forces should not be dominant. Two effects are noticeable: First, Coulomb break-up reduces the elastic cross sections. Second, the distortion of the wave function generated by the displacement of the charged core with respect to the center of mass of the nucleus reduces the Coulomb repulsion, and with it the elastic cross sections.

We report here on an experiment, performed in 2008 at the ISAC-II facility at TRIUMF, where we measured the break-up and elastic differential cross section of ^{11}Li on ^{208}Pb at laboratory energies of 2.2 and 2.7 MeV/u and the scattering of its core ^9Li at the same CM energies. We used a set of four telescopes with DSSSD, SSSD and PAD silicon detectors in order to clearly identify all fragments in the full detection angles covering 10-140 degrees.

It has been found that the measured $^{11}\text{Li}+^{208}\text{Pb}$ elastic cross sections show significant deviations from Rutherford cross sections even at energies below the Coulomb barrier. The break-up probabilities are important, even when the distance from projectile to target is very large. When break-up probabilities are properly scaled, and plotted versus the collision time, the reduced break-up probability becomes independent on the collision energy. In this contribution we will present the preliminary results and the comparison with theory and the main conclusions achieved.

Is this an invited talk? (please answer yes or no):

no

Would you prefer your contribution to be a poster presentation? (please answer yes or no):

no

Would you prefer your contribution to be an oral presentation? (please answer yes or no):

yes

Are you a student, postdoc or an attendee from an “emerging” country and would like to apply for financial support?:

I'm student, I like to apply for financial support

Working Group - Synergies in Instrumentation / 79

Active target ACTAR for the low-energy short-lived radioactive SPIRAL2 beams

Author: Laurent Nalpas¹

Co-authors: Emanuel Pollacco¹; Riccardo Raabe²; and the ACTAR-GET collaborations

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The active targets (AT) are promising tools for the study of low-energy short-lived radioactive beams available in the next decade at SPIRAL2, HIE-ISOLDE, NSCL and RIKEN. They are based on a gaseous ionization detector for the measurement of the incoming radioactive ions and their particle decay stopping in the volume. Alternatively, the nuclei of the gas can interact as a target with the beam to study induced direct reaction in inverse kinematics. The active targets provide high efficiency, low detection threshold and ion tracking capabilities allowing angular distribution and energy measurements. The validity of the method has been demonstrated with the first generation of detection set-ups developed at Bordeaux [1] and Ganil [2-3]. The ACTAR (Active TARget) collaboration aims to build a new active target, working as a time-projection chamber (TPC), able to record the 3D-tracks of ionizing particles passing through the gas volume and to work with medium-mass high-intensity radioactive beams. The ACTAR joint research initiative has promoted an R&D program gathering 9 European laboratories led by Ganil to define the characteristics of ACTAR [4], namely a highly segmented cathode (25 pads/cm²) representing more than 10'000 electronic channels, having a large dynamic range (both in energy and time), self-triggering and high-data rate capabilities. A specific R&D program called GET (General Electronics for TPC) has been started by IRFU/Saclay, CENBG/Bordeaux, GANIL/Caen and NSCL/MSU to build in a 4-year plan a generic front-end electronics for AT-TPC. The French ANR and US agencies have already funded the project. It will be a modular scale-free system able to read various AT-TPC within the ACTAR specifications.

[1] J. Giovinazzo et al., Phys. Rev. Lett. 99 (2007) 102501

[2] C. Demonchy et al., Nucl. Instrum. Methods A 583 (2007) 341.

[3] I. Tanihata et al., Phys. Rev. Lett 100 (2008) 192502.

[4] H. Alvarez Pol, ActarSim, <http://fpsalmon.usc.es/r3b/ActarSimACTAR.shtml>

This work has been partly financed by the FP6 European contract.

Is this an invited talk? (please answer yes or no):

no

Would you prefer your contribution to be a poster presentation? (please answer yes or no):

no

Would you prefer your contribution to be an oral presentation? (please answer yes or no):

yes

Are you a student, postdoc or an attendee from an “emerging” country and would like to apply for financial support?:

no

Facility Talks I / 80

HIE-ISOLDE: Status Report of the Project and Highlights

Author: Yacine Kadi¹

Co-authors: Matteo Pasini¹; Richard Catherall¹

¹ CERN

Corresponding Author: yacine.kadi@cern.ch

The research with radioactive beams has strengthened the link between technical developments and physics output. The study of radioactive beams allows us to follow the evolution of nuclear structure over extended regions in the nuclear chart. ISOLDE has nowadays a vast variety of species produced, more than 1000 nuclei from almost 70 elements, the largest number by far of the existing ISOL-facilities. A key feature of the REX-ISOLDE complex is that essentially all isotopes produced can be charge bred and accelerated further up to 3 MeV/u. The present energy range limits the experimental program to Coulomb excitation of light and intermediate mass nuclei and to transfer reaction for the lightest species.

The ISOLDE facility has been expanded several times in order to continue being a reference facility. Improvement of beam quality, increase in intensity and availability of new radioactive beams will boost decay experiments as well as the study of ground state properties as, for instance, Penning trap mass measurements that continuously refine our understanding of the nuclear mass surface. An energy upgrade will make all produce nuclei available for reactions up to and above the Coulomb barrier opening new avenues from the physics point of view. The enlarged dynamic range, first to 5.5 MeV/u and in a later stage to 10 MeV/u, will allow the optimization in each case with respect to cross section and reaction channel opening.

A major upgrade of the present facility, High Intensity and Energy ISOLDE (HIE-ISOLDE), is now approved to fully exploit the latest developments and significantly increase the ISOLDE scope. The HIE-ISOLDE project proposes a staged upgrade in three main categories: beam intensity, beam energy and beam quality. In this talk the present status of the project, and the future plans will be presented.

Is this an invited talk? (please answer yes or no):

no

Would you prefer your contribution to be a poster presentation? (please answer yes or no):

no

Would you prefer your contribution to be an oral presentation? (please answer yes or no):

yes

Are you a student, postdoc or an attendee from an “emerging” country and would like to apply for financial support?:

no

Radioactive Ion Beams in Nuclear Astrophysics / 81**beta-decay half lives of nuclei approaching the r-process path near the 126-neutron shell closure****Author:** Anabel Morales López¹**Co-authors:** "for the RISING collaboration"; Hans Juergen Wollersheim²; Jose Benlliure³; Juergen Gerl²; Karl-Heinz Schmidt²; Magda Gorska²; Patrick Regan⁴; Shashi Verma³; Stephane Pietri²; Zsolt Podolyak⁴¹ USC² *Department Gesellschaft für Schwerionenforschung, GSI*³ *University of Santiago de Compostela, USC*⁴ *University of Surrey, Guildford***Corresponding Author:** anaisabel.morales@rai.usc.es

The decay properties of neutron-rich nuclei around $N=126$ are very important not only because they will provide valuable information about nuclear models far from stability, but also because these nuclei approach the astrophysical rapid-neutron capture [1] path near the waiting-point $A \sim 195$. Particularly, the beta-decay half lives provide a noteworthy understanding of the r-process time-scales, and hence of the atomic abundances in the Universe. The use of projectile fragmentation at relativistic energies has opened up the possibility to produce these nuclei via the "cold-fragmentation" reaction channels [2]. Isomer spectroscopy using passive stoppers with a germanium array [3] and time correlations for beta-decays with an active stopper [4,5] have provide the first structural information on some of them.

In a previous experiment the half-lives of 198-199-200Ir, 199-200Os and 194-195Re were measured from time-position correlations between implanted ions and subsequent beta-decays using double side silicon strip detectors (DSSSD) [4]. In this work we benefit from the last developments using beta-delayed gamma-ray spectroscopy to measure the beta-decay half lives of other nuclei at the current limits of experimental synthesis. The present experiment was performed at GSI where the Fragment Separator (FRS) was used to identify and select heavy neutron-rich nuclei produced in the reaction $208\text{Pb}+\text{Be}$ at 1 AGeV. The nuclei were then slowed down and implanted in three DSSSD detectors acting as active stopper [6], recording the position and time of implantations and decays. Additionally, the RISING gamma-ray array [7] enclosed the active stopper in order to register the characteristic transitions from daughter nuclei. The event-by-event position and time correlations between implantations and gamma-labelled radioactive electrons allowed for the measurement of the beta-decay half lives of 204Au , $204\text{-}203\text{Pt}$ and $200\text{-}202\text{Ir}$ with improved background conditions. The new measurements allow to validate the numerical technique previously proposed for the analysis of beta-decay half lives under complex background conditions [4], and confirm the conclusions on the beta-decay of nuclei in this region of the Segrè chart. Indeed, the comparison of all our measurements with theoretical predictions [8,9] indicates the importance of FF transitions in the beta-process picture of this region. Moreover, the fact that beta-decay models used in standard r-process calculations do not consider FF transitions suggests that the r-process matter flow across $N=126$ is faster than expected.

[1] E.M. Burbidge et al., *Rev. Mod. Phys.* 29 (1957) 547[2] J. Benlliure et al., *Nucl. Phys. A* 660 (1999) 87[3] P.H.Regan et al. *Nucl. Phys. A* 787 (2007) 491c[4] T. Kurtukian, J. Benlliure and K.H.Schmidt, *Nucl. Instr. and Methods A* 589 (2008) 472[5] N.Alkhomashi et al., *Phys. Rev. C* 80 (2009) 064308[6] R. Kumar et al., *Nucl. Instr. Meth. A* 598 (2009) 754[7] S. Pietri et al., *Nucl. Inst. Meth. B* 261(2007) 1079[8] P. Möller et al., *Phys. Rev. C* 67 (2003) 055802[9] I.N. Borzov, *Phys. Rev. C* 67 (2003) 025802**Is this an invited talk? (please answer yes or no):**

no

Would you prefer your contribution to be a poster presentation? (please answer yes or no):

no

Would you prefer your contribution to be an oral presentation? (please answer yes or no):

yes

Are you a student, postdoc or an attendee from an “emerging” country and would like to apply for financial support?:

no

Future RIB Facilities / 82

SPIRAL 1 upgrade: status and perspectives for physics

Author: Pierre Delahaye¹

Co-authors: Alexandre Pichard¹; Bertrand Jacquot¹; Emmanuel Clement¹; François De Oliveira¹; Hanna Franberg¹; Jean Charles Thomas¹; Jean Yves Pacquet¹; Laurent Maunoury¹; Marek Lewitowicz¹; Marie-Geneviève Saint Laurent¹; Mickael Dubois¹; Navin Alahari¹; Olivier Bajeat¹; Pascal Jardin¹; Patricia Roussel-Chomaz¹; Patrick Leherissier¹; Sydney Gales¹

¹ *GANIL*

Since 2001, SPIRAL at GANIL has been delivering radioactive ion beams of unique intensity and purity for physics experiments. Using projectile fragmentation on a graphite target and ionization in an ECR ion source via a cold transfer passage, mostly isotopes of gases lighter than Xe and fragments of volatile molecules such as O and F were post-accelerated. During the past year, a project was formed to upgrade the present facility with a 1+ to n+ charge breeding system, thus permitting the use of more versatile 1+ sources for extending the range of elements available for post-acceleration. Numerous physics projects based on the potential new capabilities of SPIRAL 1 were recently formulated in the form of letter of intents, attesting of the scientific relevance of such upgrade.

This contribution will present the status of the upgrade, its positioning with respect to the SPIRAL 2 production capabilities and physics objectives.

Is this an invited talk? (please answer yes or no):

no

Would you prefer your contribution to be a poster presentation? (please answer yes or no):

no

Would you prefer your contribution to be an oral presentation? (please answer yes or no):

yes

Board: 4 / 83

The role of isospin in fusion-evaporation reactions

Author: Antonio Di Nitto¹

Co-authors: Alfonso Boiano¹; Antonio Ordine¹; Augusto Brondi¹; Emanuele Vardaci¹; Francesco Lucarelli²; Gianfranco Prete³; Giovanni La Rana¹; Marco Cinausero³; Nicla Gelli²; Pavel Nadtochy¹; Renata Moro¹; Valentina Rizzi³

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Isospin may play an important role in light particle evaporation from hot composite nuclei. On the basis of the statistical model, isospin effects on the evaporative process are expected through two physical quantities: i) the isospin distribution and ii) the symmetry energy. The first one is related to the level density parameter a , while the second one affects the binding energy of the evaporated particles. Statistical model calculations have been carried out in order to explore to what extent these isospin effects can be observed experimentally, by measuring spectral shapes, angular correlations and multiplicities of light particles as well as evaporation residue distributions. We found that these observables are sensitive to the isospin, allowing to study the level density of exotic nuclei. We also report the results of a first experiment aimed at searching for isospin effects in the decay of ^{139}Eu composite nuclei produced by a stable beam at $E_x=90$ MeV.

Is this an invited talk? (please answer yes or no):

No

Would you prefer your contribution to be a poster presentation? (please answer yes or no):

No

Would you prefer your contribution to be an oral presentation? (please answer yes or no):

Yes

Are you a student, postdoc or an attendee from an “emerging” country and would like to apply for financial support?:

Yes

Facility Talks III / 84**A plan to construct a rare isotope accelerator facility in Korea****Author:** Seung-Woo Hong¹¹ *Sungkyunkwan University***Corresponding Author:** swhong@skku.ac.kr

The Korean government announced in January 2009 a preliminary plan to construct a heavy ion accelerator facility for producing radioactive ion beams in the framework of a mega project called the International Science & Business Belt. Since then, a planning work for the construction of a heavy ion accelerator is underway supported by the government. The construction of this facility will be a cornerstone for basic science research in Korea. This facility which is tentatively referred to as KoRIA (Korea Rare Isotope Accelerator) is to be used for multipurpose research, including nuclear science, atomic, material & energy sciences, and bio-medical sciences. To produce the radioactive ion beams, both ISOL and In-flight fragmentation methods are being considered. Post-acceleration of the radioactive ion beams may be done up to unprecedentedly high energies. The conceptual design study is expected to start soon, and the present status of the planning will be presented.

Is this an invited talk? (please answer yes or no):

Yes.

Would you prefer your contribution to be a poster presentation? (please answer yes or no):

No.

Would you prefer your contribution to be an oral presentation? (please answer yes or no):

Yes.

Are you a student, postdoc or an attendee from an “emerging” country and would like to apply for financial support?:

No.

Future RIB Facilities / 85

THE MYRRHA ADS PROGRAMME IN BELGIUM

Authors: Didier De Bruyn¹; Dieter Pauwels²; Dirk Vandeplassche¹; Hamid Ait Abderrahim¹; Jan Heyse¹; Jan Wagemans¹; Lucia Popescu¹; Mark Huysse²; Paul Schuurmans¹; Peter Baeten¹; Piet Van Duppen²; Riccardo Raabe²

¹ *Centre d'Etude de l'Energie Nucl. (SCK-CEN)*

² *University of Leuven (K.U.Leuven)*

Since 1995, SCK•CEN has been studying the coupling of a proton accelerator, a windowless liquid Lead-Bismuth spallation target and a Lead-Bismuth cooled, sub-critical fast core. The study was first performed in collaboration with Ion Beam Applications (IBA, Louvain-la-Neuve) in the frame of the ADONIS project (1995-1997). ADONIS was a small irradiation facility, based on the ADS concept, having a dedicated objective to produce radioisotopes for medical purposes and more particularly ⁹⁹Mo as a fission product from highly enriched ²³⁵U fissile targets. The ad-hoc scientific advisory committee recommended extending the purpose of the ADONIS machine to become a Material Testing Reactor (MTR) for material and fuel research, to study the feasibility of transmutation of the minor actinides and to demonstrate at a reasonable power scale the principle of the ADS. The project, since 1998 named MYRRHA, has then evolved to a larger installation.

MYRRHA today is conceived as a flexible fast spectrum irradiation facility, able to work as an Accelerator Driven System (subcritical mode) and in critical mode. In this way, MYRRHA will allow fuel developments for innovative reactor systems, material developments for GEN IV systems, material developments for fusion reactors, radioisotope production for medical and industrial applications and industrial applications, such as Si-doping. MYRRHA will also demonstrate the ADS full concept by coupling the three components (accelerator, spallation target and subcritical reactor) at a reasonable power level to allow operation feedback, scalable to an industrial demonstrator and allow the study of efficient transmutation of high-level nuclear waste.

MYRRHA consists of a proton accelerator with a proton energy of 600 MeV and a design intensity of 4 mA, coupled to a liquid Lead-Bismuth Eutectic spallation neutron source. Apart from the experimental and irradiation possibilities in the subcritical reactor, the MYRRHA proton accelerator on its own can be used as a supply of proton beams for a number of experiments. In order to explore new research opportunities offered by the accelerator, a pre-study was initiated within the framework of the “Belgian Research Initiative on eXotic nuclei” (BriX) network of the Interuniversity Attraction Poles Programme of the Belgian State. This study is investigating unique possibilities for fundamental research using high-intensity proton beams with a fraction of the full beam during ADS operation (up to 200 μ A). An interesting approach for fundamental research using the 600-MeV proton accelerator is the installation of an Isotope Separator On-Line (ISOL@MYRRHA) facility with a ruggedized target-ion source system, which is able to provide intense low-energy Radioactive Ion Beams (RIB) for experiments requiring very long beam times (up to several months). This will open unique opportunities for RIB research in various scientific fields, which is complementary with the activities at other existing and future facilities. In a second phase, when the MYRRHA reactor will run as a stand-alone critical reactor, the full proton-beam intensity might be used for ISOL@MYRRHA or other applications.

MYRRHA is foreseen to be in full operation by 2024 and it will be operated in the first years as an ADS.

Is this an invited talk? (please answer yes or no):

no

Would you prefer your contribution to be a poster presentation? (please answer yes or no):

no

Would you prefer your contribution to be an oral presentation? (please answer yes or no):

yes

Are you a student, postdoc or an attendee from an “emerging” country and would like to apply for financial support?:

no

Poster Prize Talks - Board: 10 / 86

Radioactive ISOL beam production for SPIRAL 2

Author: Hanna Franberg-Delayahe¹

Co-authors: B. Blank²; C Lau³; E. Cottureau ; F Varenne¹; F. DeOliviera¹; J.C. Thomas⁴; L Serani²; L Tecchio⁵; M Fadil¹; M Lewitowicz¹; M.A. Pichard¹; M.G. Saint-Laurent¹; N. Necesne¹; O. Bajeat¹; P Delahaye ; P. Jardin¹; Quiclet¹; S. Essabaa³; Y Huguet¹

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The future facility SPIRAL 2 at GANIL aims at producing radioactive isotopes using not only neutron induced fission from high density UCx target, but from other nuclear reactions such as deep inelastic transfer, fusion evaporation, etc [1]. The different intensity estimates for some of the beam that should be available at the start of SPIRAL 2 and their extrapolation to nominal operation conditions will be presented during the meeting together with the method adopted for calculating the in-target yield estimates, for evaluating diffusion and effusion losses, ionization, charge breeding and post-acceleration efficiencies.

[1] White Book of SPIRAL 2

Facility Talks I / 87

SPES Project

Author: Gianfranco Prete¹

¹ INL-INFN

The SPES Project at INFN Laboratori Nazionali di Legnaro (LNL) is now entering its construction phase. SPES is a facility based on a two exit-port cyclotron as proton driver and the PIAVE-ALPI superconductive linac accelerator, to supply an ISOL facility for Rare Ion Beam (RIB) production

and reacceleration. The second proton beam is devoted to neutron production and applied physics research.

RIB's will be produced by proton induced fission on a UCx multi foil direct target with the goal to produce neutron-rich radioactive nuclei by the Uranium fission at a rate of 1013 fission/s. This is obtained developing a target able to operate with a proton beam of 8kW power (40MeV, 200µA). The unstable nuclei on experimental target are expected at a rate of 105-109 pps and energies up to 13 MeV/n in the mass region A=130. Special effort is also devoted to produce a high quality beam, well selected by a High Resolution Mass Spectrometer

The talk will present recent developments and the actual status of the project.

Shell Structure Far From Stability II / 88

Exploring life-time of low-lying states in neutron rich nuclei towards ^{78}Ni with the plunger technique at GANIL

Author: Batipste MOUGINOT¹

Co-authors: A. PONOMARENKO²; Adam MAJ³; Alexander BUEGER⁴; Alfred DEWALD⁵; Andres GADEA⁶; Christelle STODEL⁷; D. MENGONI⁶; David VERNEY⁸; Denis MUECHER⁵; Dimitar BALABANSKI⁹; Dorrottya SOHLER¹⁰; Eda SAHIN⁶; Enrico FIORI¹¹; Fadi IBRAHIM¹²; Façal AZAIEZ¹²; Fanny REJMUND⁷; Florin NEGOITO¹³; Francesca DELLA VEDONA⁶; Francesco RECCHIA⁶; François De Olivera Santos⁷; Geoffroy BURGUNDER⁷; Georgi GEORGIEV¹¹; Giacomo DE ANGELIS⁶; Gilles De France⁷; Hironi IWASAKI¹²; Iolanda MATEA¹⁴; Jan JOLIE⁵; Jean-Charles THOMAS⁷; Jose VALIENTE-DOBON⁶; Kalin GLANISHKI¹⁵; Laurent GAUDEFROY¹⁶; Lucia CACERES⁷; Lulian STEFAN¹²; Marlène ASSIE¹⁴; Matthias HACKSTEIN⁵; Megumi NIKURA¹⁴; Mihai STANOIU¹⁷; Norbert PIETRALLA²; Olivier MOELLER²; Olivier SORLIN⁷; Riccardo ORLANDI⁶; Santo LUNARDI¹⁸; Serge FRANCHOO¹²; Skymon MYALSKI³; Stéphane GREVY¹⁹; Thomas PISSULLA⁵; Wolfram ROTHER⁵; Yuri Erastovich PENIONZHKEVICH²⁰; Zsolt DOMBRADI¹⁰

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¹⁴ IPN Orsay in2p3

¹⁵ University of Sofia

¹⁶ CEA

¹⁷ GSI

¹⁸ INFN Padova

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One of the most critical ingredients in determining the disappearance or appearance of magicity in nuclei far from stability is the evolution of single-particle energies with increasing neutron or proton numbers when moving away from the valley of stability. The three known cases of disappearance of shell effects at N=8, 20 and 28 in neutron rich nuclei are understood as due to the effect of the

tensor part of the nucleon-nucleon interaction. The tensor force is held responsible for the strong attraction between a proton and a neutron in spin-flip partner orbits. A recent generalization of such mechanism foresees a similar behaviour also for orbitals with non-identical orbital angular momenta. It is expected that orbitals with anti-parallel angular momenta attract each other and orbitals with parallel angular momenta repulse each other. The change in shell structures based on this mechanism has recently been discussed for different mass regions of the nuclear chart.

In this context neutron-rich nuclei close to shell gaps are particularly interesting since they allow to search for anomalies when compared with shell-model predictions. It is predicted, for example, that the $Z=28$ gap for protons in the pf-shell becomes smaller when moving from ^{68}Ni to ^{78}Ni as a consequence of the attraction between the proton $f_{5/2}$ and neutron $g_{9/2}$ orbits and the repulsion between the proton $f_{7/2}$ and the neutron $g_{9/2}$ states. The same argument would also predict a weakening of the $N=50$ shell gap when depleting the proton $f_{5/2}$ state upon approaching the ^{78}Ni nucleus, due to the diminished attraction between the neutron $g_{9/2}$ and the proton $f_{5/2}$ orbits and the reduced repulsion between the neutron $g_{7/2}$ and the proton $f_{5/2}$ states.

Recently an experiment aiming at the study of the evolution of the structure of neutron rich Cu and Zn isotopes has been performed. This experiment uses the plunger technique in order to measure life time of gamma transition involved in the decay of excited states in these exotic nuclei. The studied nuclei have been populated using reactions induced by a cocktail beam composed of $^{73,74}\text{Zn}$ RIB's of 34MeV/u in a CD2 target. The cocktail beam is produced by the in-flight technique using the first half of the LISE separator. The second half is used for the selection and identification of the final products after interaction in the secondary CD2 target. The EXOGAM array and the differential Plunger technique provide information on the in-beam gamma spectroscopy and life time of the excited states in the picoseconds to tens of picoseconds

The first results obtained on the life time of excited states in $^{72,73,74}\text{Zn}$ will be reported together with the comparison to results from Coulomb excitation experiment at REX-ISOLDE. A picture of the low-energy structure in these isotopes towards the middle of the $g_{9/2}$ orbital will be given via: i) identification of the levels populated with inelastic scattering reaction and ii) determination, in a model-independent way, of the transition probabilities of those levels towards the ground state.

Facility Talks III / 90

The FAIR project

Author: Ingo AUGUSTIN¹

¹ GSI

This presentation outlines the current status of the Facility for Antiproton and Ion Research (FAIR). It is expected that the actual construction of the facility will commence in 2011 as the project has raised more than one billion euro in funding.

Outstanding research opportunities offered by the Modularized Start Version for all scientific FAIR communities from early on will allow to bridge the time until the completion of FAIR with a world-leading research program.

FAIR will provide intense secondary beams of unstable Isotopes across the entire nuclide chart. Beam intensities exceed those available at existing rare-Isotope-beam facilities by several orders of magnitude and beam energies are variable up to more than 1GeV/u . A superconducting in-flight separator (Super-FRS) serves external stations and coupled storage cooler rings and in a later stage also an electron-ion collider. The novel instruments and experimental opportunities have attracted a large community of nuclear physicists addressing a broad research spectrum covering nuclear structure physics, nuclear astrophysics and studies of fundamental interactions and symmetries. Altogether 9 experimental programs are currently planned at the three branches of the Super-FRS. These programs are organized in the NuSTAR collaboration (Nuclear Structure, Astrophysics, and Reactions) with more than 700 participating scientists. The presentation will put special emphasis on this scientific branch of FAIR.

Facility Talks I / 91

GANIL-SPIRAL2: a new era at the dawn of a new decadeAuthor: Sydney GALES¹¹ GANIL

GANIL-SPIRAL2: a new era at the dawn of a new decade

Abstract:

GANIL presently offers unique opportunities in nuclear physics and many other fields that arise from not only the provision of low-energy stable beams, fragmentation beams and re-accelerated radioactive species, but also from the availability of a wide range of state-of-the-art spectrometers and instrumentation. With the construction of SPIRAL2 over the next few years, GANIL is in a good position to retain its world-leading capability even though it faces strong competition from new and upgraded ISOL and fragmentation facilities.

As selected by the ESFRI committee, the next generation of ISOL facility in Europe is represented by the SPIRAL2 project to be built at GANIL (Caen, France). SPIRAL 2 is based on a high power, CW, superconducting LINAC, delivering 5 mA of deuteron beams at 40MeV (200KW) directed on a C converter+ Uranium target and producing therefore more 10¹³ fissions/s. The expected radioactive beams intensities in the mass range from A=60 to A=140, will surpass by two order of magnitude any existing facilities in the world. These unstable atoms will be available at energies between few KeV/n to 15 MeV/n. The same driver will accelerate high intensity (100A to 1 mA), heavier ions (Ar up to Xe) at maximum energy of 14 MeV/n.

In applied areas SPIRAL2 is considered as a powerful variable energy neutron source. The Neutrons For Science collaboration (NFS) is proposing a physics program on fission induced by fast neutrons as well as fusion studies on materials.

Under the 7FP program of European Union called Preparatory phase, the SPIRAL2 project has been granted a budget of about 4M€ to build up an international consortium around this new venture. The status of the construction of SPIRAL2 accelerator and associated physics instruments in collaboration with EU and International partners will be presented*

In addition, in order to ensure that the existing GANIL-SPIRAL1 facility makes best use of available resources, a study of the prospects for the laboratory has been undertaken, which will address its likely needs for the scientific programme up to 2015.

Facility Talks III / 92

Present Status and Perspectives of RIKEN RIBFAuthor: Hiro Sakurai¹¹ RIKEN Nishina Center for Accelerator-based Science

I show present status and perspectives of RIBF “RI Beam Factory (RIBF)” through demonstrating recent results obtained and discussing physics programs to be promoted.

RIBF is the world-class radioactive-isotope beam (RIB) facility, which is based on a new high-power heavy-ion accelerator complex [1] and a new in-flight fragment separator BigRIPS [2]. In 2007, RIBF started to deliver radioactive isotope beams. High performances and potentialities of this facility have been demonstrated by discovery of two new isotopes [3].

The accelerator system has been upgraded since 2007. Additional beam monitors have been installed to strengthen a beam diagnostic and to improve a transmission-efficiency. In 2008 maximum intensities achieved for 48Ca and 238U beams at 345A MeV were 175pnA and 0.3pnA, respectively. Based on the powerful 48Ca beam in 2008, the first spectroscopy experiments at BigRIPS/ZDS were performed for the island-of-inversion region as a DayOne experiment campaign in December, 2008.

In 2009, light ion beams such as (polarized) deuteron and nitrogen were successfully accelerated up to 250A MeV. At a DayTwo campaign at the end of last year, an intensity of 238U beam was achieved to be 0.8 pnA due to a newly installed 28 GHz SC-ECR ion source.

Concerning experimental devices, ZeroDegree Spectrometer (ZDS) [4] and SHARAQ spectrometer [5] have been served for scientific programs since 2008 and 2009, respectively. Other devices [6], SAMURAI spectrometer and SCRIT system [7], will be ready for experiments in 2011. An rf ion-guide gas-catcher system SLOWRI [8], Rare-RI Ring dedicated for mass measurement [9], IRC-to-RIPS BT line for multi-use capability [6] are to be funded in near future.

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Facility Talks III / 93

NSCL/FRIB - Michigan State University

Author: Konrad Gelbke¹

¹ *NSCL - Michigan State University*

Plans for FRIB at MSU
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 NSCL/FRIB Laboratory, Michigan State University,
 East Lansing, Michigan 48824-1321, USA

Michigan State University has been selected by the U.S. Department of Energy to design and establish the Facility for Rare Isotope Beams (FRIB), a cutting-edge research facility to advance understanding of rare nuclear isotopes and the evolution of the cosmos. In this talk I will provide a high-level summary of the envisioned science program, the facility layout, the FRIB project status, and the planned user interfaces.

Dynamics and Thermodynamics / 94

Even-odd effects in multifragmentation products

Author: Maria Valentina Ricciardi¹

¹ *GSI*

We discuss about the origin of the even-odd staggering observed in the yields of multifragmentation products. The observed fine structure agrees well with the fluctuations of the lowest particle threshold as a function of neutron and proton number. The structure is not consistent with the fluctuations of the binding energies. We take this experimental observation as an indication that primary fragments produced in multifragmentation are mostly found in excited states from which a sequential decay originates. The production of the finally observed cold intermediate-mass fragments directly in their ground state seems to be weak. Our study confirms the important role of the deexcitation process in almost all nuclear reactions. We focus our attention particularly on multifragmentation reactions, where sequential decay strongly influences the yields of light fragments, which are often used to extract information on the nature of hot nuclear matter.

Fundamental Interactions / 95**“Fundamental Interaction Studies with Radioactive Nuclei”****Author:** Nathal Severijns¹¹ *Kath. Univ. Leuven*

In the past few years significant progress was made in the study of weak interaction properties at low energies. Particle traps and GEANT based simulations have played a crucial role in this. Improved theoretical calculations and new measurements have verified the unitarity condition of the quark mixing matrix with high precision, leading to stringent limits on different types of physics beyond the standard model. Further, a series of new results from different types of correlation measurements in the beta decay of radioactive nuclei have recently become available. These provide new constraints on exotic, viz. scalar and tensor, charged weak currents. An overview of the status and prospects for the future of this field will be given.

Production and Manipulation of RIB / 96**Production and manipulation of relativistic exotic nuclei****Author:** Helmut Weick¹¹ *GSI*

Projectile fragmentation or fission in flight is a rich source of exotic nuclei. The production cross sections of the selected nuclides are crucial for a successful experiment, but also the production rates of all other nuclei is of importance as they define the level of separation that must be reached. With beam intensities exceeding 10^{10} primary beam ions a high reduction factor must be achieved.

The so called $B\rho - \Delta E - B\rho$ method has become the standard method for separation in fragment separators. World wide many dedicated devices have been built or existing beamlines have been modified to work in this technique. For new separators as BigRIPS or the planned Super-FRS a many stage separation scheme with more than only one degrader will be employed. This scheme can even be extended by an additional stage for bunching the energy-distribution for implantation into a gas catcher.

A formalism to calculate analytically the separation characteristics of these devices will be presented as well as numerical techniques of simulation. The description involves the combination of the ion-optical properties as well as the energy-loss of heavy ions in matter. The achievable resolution as well as limitations from ion-optical imperfections and the energy-loss and angular straggling in the degraders will be discussed.

The exact characteristics of separation depend on the velocity at which the separator is operated and strong differences even in the energy domain of 100-1000 MeV/u are the result. Ions of different charge states can confuse the particle identification and require special care for separation.

Another interesting possibility comes with the coupling to storage rings where after beam cooling much higher resolving powers can be achieved.

Fusion Reactions and Synthesis of Heavy and Superheavy Nuclei / 97**Present and future studies of Superheavy Nuclei****Author:** Paul GREENLEES¹¹ *University of Jyväskylä*

The production and spectroscopic study of the heaviest elements has always been a central theme of nuclear physics. In recent years, a wealth of new data has been produced, both in terms of new elements (up to $Z=118$ [1]) and in detailed spectroscopic studies of nuclei with masses above 240 [2]. Such studies provide data concerning nuclear parameters such as masses, decay modes, half-lives, moments of inertia, single-particle properties, etc., in systems with the highest possible number of protons. The main focus of current experiments is the search for the next closed proton- and neutron-shells beyond the doubly magic 208Pb.

This search can be made directly, by producing nuclei in the region of interest ($Z>112$ and $N>176$), or indirectly through the study of lighter deformed nuclei where the orbitals of interest at sphericity are active at the Fermi surface.

The advent of next-generation radioactive beam facilities will begin to provide reasonably intense beams of exotic nuclei. Whilst the intensities are not expected to be at the level used in current stable beam facilities, the beams still offer a opportunity to extend studies of superheavy nuclei. Neutron-rich beams will provide a method to populate isotopes not accessible by any other means. The use of more symmetric reactions will allow nuclei in the region of ^{254}No to be populated at higher spin and excitation energy than currently possible. New opportunities to study reaction dynamics with exotic neutron-rich beams will also provide interesting data. The use of deep inelastic collisions with neutron-rich beams may also be of interest.

Examples of recent highlights in heavy element studies with stable beams, along with the opportunities provided by future facilities to extend these studies will be presented.

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Production and Manipulation of RIB / 98

Production and Manipulation of Radioactive Ion Beams

Author: Iain D. Moore¹

¹ *Department of Physics, University of Jyväskylä, Finland.*

The preparation and subsequent manipulation of radioactive ion beams is a hot topic of interest for all facilities involved in the study of isotopes far from stability. With ever increasing primary beam intensities, the ability to handle unwanted secondary contaminants is of particular interest. The means to produce the secondary radioactive ion beams in a selective manner relies on novel technologies, often developed at smaller facilities. Complicated experiments often set stringent requirements on the temporal or spatial properties of the beams. Indeed, in the last two years since the previous EURORIB conference (2008), many of the new techniques introduced at that time have now matured and others are presently in the planning stage to be used at future Large Scale Facilities.

In this presentation I will present some of the recent advances and highlights in this important field including: ionization in a chemically selective manner, suppression of abundant contaminants in order to efficiently isolate the rare isotopes, novel techniques to provide high-precision mass separation on short timescales, preparation of low energy ion beams from an initial high energy primary or secondary beam, optical manipulation of ion beams for state-selective preparation and so forth.

Radioactive Ion Beams in Nuclear Astrophysics / 99

Radioactive ion beams in nuclear astrophysics

Author: Rene REIFARTH¹

¹ *GSI Darmstadt Germany*

The nucleosynthesis of elements beyond iron is dominated by neutron captures in the s and r processes. However, 32 so-called p-nuclei are thought to be produced in the p process, where proton-rich nuclei are made by sequences of photodisintegrations and (p,g) reactions and following decays on existing r- and s-seed nuclei.

Charged-particle induced cross section measurements in the astrophysically interesting energy range are already very challenging on stable nuclei. Only a minute part of the nuclei involved in p-process networks, however, is stable. The most promising approach to determine the desired reaction rates is to produce the isotopes in Radioactive Ion Beam facilities and to investigate the reactions in inverse kinematics. A pioneering experiment was recently performed at the Experimental Storage Ring (ESR) at GSI. Fully stripped ions of ⁹⁶Ru were injected into the storage ring and slowed down to a few MeV/nucleon. The reaction products were detected with different particle detectors.

Similarly photon-induced cross sections on radioactive nuclei can be measured in inverse kinematics applying the Coulomb-dissociation method. This can be done at the LAND/R3B setup at GSI. Recent examples applying this method to radioactive beams will be presented.

This project is supported by the HGF Young Investigators Project VH-NG-327.

Applications in other fields / 100

Applications of RIBs in other fields

Author: Giacomo Cuttone¹

¹ *INFN-LNS Catania*

Radioactive Ion Beams (RIBs) is becoming the most promising and challenging topic for nuclear physics in the next decade. The facilities under development are typically based on high intensity, high power particle accelerators. These are giving the opportunity to exploit the possibility to apply the production techniques even in other fields as the production of radioisotopes for advanced imaging and therapy in oncology and new radiopharmaceuticals. Moreover the study and cross section measurements for beta emitters production can be carried out. They can be of particular interest for the development of PET Online applications in hadrontherapy.

It is feasible to get neutron sources in the framework of future RIBs facilities. They can offer the opportunity to develop dedicated application in medicine (Boron Neutron Capture Therapy), cultural heritage, material science and electronics. Moreover the availability of high power, high energy proton beams can open the possibility to study their application in the field of nuclear power production and waste transmutation. These possibilities will be presented and discussed together with some examples now under development.

Board: 32 / 101

Shell closures far from the stability studied with the

Author: Tomas R. Rodriguez¹

¹ *GSI-Darmstadt/Universidad Autonoma de Madrid*

Self-consistent mean field approaches with effective phenomenological interactions (Skyrme, Gogny, Relativistic) have succeed in describing many bulk properties along the whole nuclear chart. This success is closely related to the spontaneous symmetry breaking mechanism that allows the inclusion of many correlations within a very simple product-type wave function

which describes the system. However, in some regions this picture fails in taking into account important correlations -pairing, deformation, shape coexistence...- and methods beyond the mean field approach have to be applied. Furthermore, it is mandatory to go beyond the mean field approximation in order to evaluate excitation energies or transition probabilities properly.

In this contribution I will present some recent advances and results obtained with the Gogny interaction applying methods beyond mean field -in this case, particle number and rotational symmetry restoration plus configuration mixing in the quadrupole moment. In particular, I will show calculations from shell to shell in Cd isotopes and also the study of possible shell closures far from the stability in Ca, Ti, Cr.

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Shell structure Far From Stability I / 102

Extended energy density functionals and ground-state correlations in nuclei

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In collaboration with the FIDIPRO team at the University of Jyväskylä: B.G. Carlsson, M. Kortelainen, N. Michel, A. Pastore, F. Raimondi, J. Toivanen, P. Toivanen, and P. Veselý

Reliable predictions of nuclear properties in exotic nuclei, with controlled theoretical errors, are essential for modelling many stellar processes. In medium heavy and heavy nuclei, the only available approach, able to provide global information on ground-state properties, is based on the one-body degrees of freedom, which in modern formulation takes the form of the energy density functional (EDF) theory. Over the years, methods based on such ideas have proved to be extremely efficient, however, the present-day status thereof is far from being complete. Two elements of the approach are currently intensely studied, namely, construction of schemes that would allow for systematic improvements of the precision and determination of theoretical errors and variances.

In Ref. [1], it was proposed to shift attention and focus of the EDF methods from ground-state bulk properties (e.g. total nuclear masses) to single-particle (s.p.) properties, and to look for a spectroscopic-quality EDFs that would correctly describe nuclear shell structure. Proper positions of s.p. levels are instrumental for good description of deformation, pairing, particle-core coupling, and rotational effects, and many other phenomena. Up to now, methods based on using EDFs, in any of its variants like local Skyrme, non-local Gogny, or relativistic-mean-field [2] approach, were mostly using adjustments to bulk nuclear properties. As a result, shell properties were described poorly. After so many years of investigations, a further increase in precision and predictability of all methods based on the EDFs may require extensions beyond forms currently in use [3,4]. Before this can be fully achieved, it was proposed to first take care of the s.p. properties, and come back to precise adjustment of bulk properties once these extensions are implemented.

Within the standard 12-parameter form of the Skyrme functional [2], an improvement of spectroscopic properties cannot be obtained [3], and extensions of this form seem to be mandatory. One possible way could be the inclusion of density dependence into all the 12 coupling constant of the standard functional [5]. Another one, which was recently proposed in Ref. [4], aims at including gradient corrections up to next-to-next-to-next-to-leading order (N3LO – sixth order). In this talk I describe recent progress and new ideas emerging in the EDF approaches, including the attempts of microscopic derivations from first principles.

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[2] M. Bender, P.-H. Heenen, and P.-G. Reinhard, *Rev. Mod. Phys.* 75, 121 (2003).

[3] M. Kortelainen, J. Dobaczewski, K. Mizuyama, and J. Toivanen, *Phys. Rev. C* 77, 064307 (2008).

[4] B.G. Carlsson, J. Dobaczewski, and M. Kortelainen, *Phys. Rev. C* 78, 044326 (2008).

[5] M. Kortelainen et al., to be published.

Nuclear Structure studies at the borders of stability

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We have performed theoretical calculations to describe the structure of nuclei at the extremes of stability, using the nonadiabatic quasiparticle approach. We reproduce the experimental half-life for proton radioactivity in ¹²¹Pr assuming $J = 7/2^-$ as decaying state, showing for the first time clear evidence for partial rotation alignment in a proton emitting nucleus¹.

Recent findings suggest the departure from axial deformation in the region of proton emitting nuclei. Our calculation for ¹⁴⁵Tm³, giving the energy spectra of parent and daughter nuclei, half-life and fine structure, confirmed a large triaxiality. Similarly, we have studied decay of ¹⁴¹Ho², the only known nucleus for which fine structure in proton emission from both ground and isomeric states was observed. The interpretation of the data pointed out to the breaking of axial symmetry in this emitter.

The present studies provide new theoretical tools to access nuclear structure properties far from the stability domain.

1 M. C. Lopes, E. Maglione, L. S. Ferreira, Phys. Lett.B 673(2009)15

2 P. Arumugam, L.S. Ferreira, and E. Maglione Phys. Rev. C78(2008) 041305

3 P. Arumugam, L.S. Ferreira, and E. Maglione Phys. Lett. B680(2009)443

Fundamental Interactions / 104

Time-Modulation of Two-Body Weak Decays with Massive Neutrinos

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Abstract:

In recent experiments at the GSI, Darmstadt, time-modulated orbital Electron Capture (EC) decays of H-like ¹⁴⁰Pr⁵⁸⁺, ¹⁴²Pm⁶⁰⁺, and ¹²²I⁵²⁺ ions with one electron in the K-shell, coasting in the ESR storage ring with velocity $\beta = 0.71$, were observed. The EC-branches show exponential decay curves time-modulated with period $T = 7.06(8)$ s and amplitude $a = 0.18(3)$ for ¹⁴⁰Pr decays, $T = 7.10(22)$ s and $a = 0.23(4)$ for ¹⁴²Pm decays, and $T = 6.04(6)$ s and $a = 0.19(3)$ for ¹²²I (preliminary) decays in the laboratory frame. The simultaneously measured β^+ branch of ¹⁴²Pm shows no modulation with $a < 0.03$. We discuss here as origin of the modulation neutrino quantum beats produced by the superposition of massive neutrino mass-Eigen states emitted in the entangled two body weak decay. From the modulation frequency a value for the difference of the quadratic mass values $\Delta m^2 = m^2_2 - m^2_1 = 2.22(3) \times 10^{-4} \text{ eV}^2$ is deduced, which is 2.75 times larger than the value derived by the KamLAND antineutrino oscillation experiment. Vacuum polarisation effects of lepton-W-boson loops in the Coulomb-field of heavy nuclei are proposed to explain the difference of Δm^2 for neutrinos and antineutrinos. The origin of the small modulation amplitudes is discussed as the result of a partial restoration of the interference terms which are expected to cancel for the usual assumed unitarity of the neutrino flavour mixing matrix.

Board: 33 / 105

High and low density behavior of coupling constants within different relativistic mean field models

Author: Kristian Petrik¹

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Numerous calculations have established that relativistic mean-field (RMF) models provide a reliable tool for realistic description of the bulk properties of finite nuclei and nuclear matter. In addition to this successful low-energy phenomenology, these models are often extrapolated into regimes of high density and temperature to extract the nuclear equation of state or calculate masses, radii and other properties of compact stars.

RMF theory is easily applicable, however not parameter free, therefore it is reasonable to retain the basic structure of this theory but provide a more direct access to many-body dynamics through adjustment of free parameters to the more fundamental Dirac-Brueckner-Hartree-Fock (DBHF) calculations. This is done to obtain coupling constants of the nonlinear RMF model, as well as of the density dependent RMF model. In the latter case new functional forms of density dependence are proposed in order to investigate their effects on the low and high density extrapolations of coupling constants. Results of the fit of all models to the DBHF data are compared with the aim to examine the reliability and justifiability of such extrapolations. This knowledge is very important for compact star structure calculations or for constraining the high density equation of state.

Fusion Reactions and Synthesis of Heavy and Superheavy Nuclei / 106

To fuse or not to fuse: That is the question

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Fusion reactions provide an avenue for extending the periodic table creating nuclei, powering the stars and in the near future, solution of the energy problem. The fusion of complex (composite) nuclei is governed by a delicate balance between the attractive nuclear and repulsive Coulomb interactions. Detailed experiments made in the last three decades have shown that the fusion process cannot be understood as a simple barrier penetration by a structureless object with a potential depending only on the distance between the centers of the colliding systems. The associated tunneling probability was shown to be extremely sensitive to the plasticity of the intrinsic structure that can evolve during the process and to the interplay of the many open and virtual channels, whose amplitudes may be tuned by varying the beam energy and/or choosing different projectile-target combinations. Thus the theoretical tool to conceptually understand the modification of barrier(s) towards fusion due the coupling of direct reactions to the elastic channel is a coupled channel approach. To obtain a complete understanding of fusion process necessitates also the investigation of the associated direct channels.

Short-lived Radioactive Ion Beams (RIB) with weak binding, unusual neutron/proton asymmetry and extended spatial distributions (halos) provide a new vista to probe such a multidimensional tunneling. The experimental conditions for measuring the fusion cross sections using low intensity RIB combined with the need to identify a complete amalgamation of project and target (complete fusion) made these measurements challenging. The role of exotic structures on the tunneling process and its interconnectivity with other open channels especially coupling to unbound states (breakup) and transfer channels have been pursued mainly using beams of ^6He , ^9Li , ^{11}Be . Such studies have focused mainly on light ion beams as they show a large variety of exotic structures as compared to heavier nuclei. The coupling to states in the continuum in such nuclei is also being used to study open quantum systems and the effect of dechorence to describe nuclear reactions. Studies of the tunneling of composite objects are also of fundamental interest in molecular processes and transport in nanodevices

In this talk after a brief historical overview of the major stepping stones of fusion with stable beams, we will review the recent status of the field and our present understanding of fusion with radioactive ion beams and discuss perspectives in this field.

Working Group - Synergies in Instrumentation / 107

Experiments with Exotic Nuclei applying a new Generation on In-Flight Separators and Spectrometers

Author: Hans Geissel¹

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The research potential with exotic nuclei is determined by fast, sensitive and highly efficient separation and high-resolution detection methods. Therefore, new separators and spectrometers are integrated parts in each rare-isotope facility worldwide. In this contribution novel developments of separators and spectrometers are briefly reviewed and compared. High-resolution experiments are often the key to extend the knowledge of nuclear physics. Present and future spectrometers for stored rare isotopes offer unique research opportunities at low and high kinetic energies.

Is this an invited talk? (please answer yes or no):

yes

Working Group - Synergies in Instrumentation / 108

Overview on large gamma arrays and complementary instrumentation

Author: Andres Gadea¹

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Gamma spectroscopy is a fundamental tool for the investigation of nuclear structure. Since the end of the EUROBALL deployment, very specialized large arrays as well as compact arrays optimized for the first generation of radioactive ion beam (RIB) facilities, have been extensively used by the Nuclear Physics community. Examples of former arrays are JUROGAM [1] and JUROGAM II coupled to RITU at JYFL, CLARA [2] coupled to PRISMA at INFN-LNL and RISING [3] installed at the focal plane of the Fragment Separator at GSI, while examples of the latter are EXOGAM [4], installed at GANIL and MINIBALL [5] at REX-ISOLDE.

Presently, Nuclear Physics is entering a new era with the construction of second generation RIB facilities as the in-flight FAIR-NUSTAR and the ISOL SPIRAL2 and SPES. The response of the gamma spectroscopy community to this challenge is being the construction of the Advanced Gamma Tracking Array (AGATA) [6] with superior sensibility and counting rate capabilities. In addition a number of the last generation compact gamma-arrays is being upgraded, improving again sensibility and rate capabilities, to cope with the necessities of a community with high demand of instrumental availability. Moreover, R&D is ongoing for a high-resolution spectroscopy array for decay spectroscopy after implantation in relativistic in-flight facilities.

Since long time it is well known that complementary instrumentation is of paramount importance to improve the sensibility of the large gamma-arrays as well as for particular type of experiments as lifetime measurements, or for the selection of the reaction channels. An overview of complementary

Is this an invited talk? (please answer yes or no):

yes

Board: 24 / 109

Implementation of a MR-ToF isobar separator at the on-line mass spectrometer ISOLTRAP

Author: Robert WOLF¹

¹ *PH-UIS*

A multi-reflection time-of-flight mass separator (MR-ToF-MS) was installed at the ISOLTRAP/CERN mass spectrometer for isobaric purification of rare isotope ensembles as a preparation for precision mass determinations. The MR-ToF-MS consists of two ion optical mirrors between which ions are oscillating and are separated by their mass-over-charge ratio m/q . Flight paths of several hundreds of meters are folded to an apparatus length of less than one meter. Previous tests resulted in a mass resolving power of up to $m/\Delta m \approx 10^5$ and the separation was demonstrated for the isobaric ions CO^+ and N_2^+ . In combination with a Bradbury-Nielsen beamgate, the MR-ToF-MS will support the existing purification methods of the setup to gain access to nuclides produced with high isobaric contamination yields at the ISOLDE facility. The modified ISOLTRAP setup and its performance will be presented.

Authors:

N. Robert Wolf[1], Klaus Blaum[2], Christopher Borgmann[2], Martin Breitenfeldt[1], Daniel Fink[2], Alexander Herlert[3], Magdalena Kowalska[3], Susanne Kreim[2], Dave Lunney[4], Gerrit Marx[1], Sarah Naimi[4], Marco Rosenbusch[1], Lutz Schweikhard[1]

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Board: 11 / 110

Liquid metal target prototypes for EURISOL Project: goals and future challenges

Author: Kalvis Kravalis¹

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Poster is dedicated to the concepts of the EURISOL multi megawatt liquid metal target. One of the possible versions could be windowless target concept. Windowless target concept has the ability to withstand the extremely high loads in the terms of hydraulic shocks, thermal loads, cavitations, reliable work and adequate lifetime of the target. Meantime this concept hasn't been studied much, which give scientific and technological challenge for the scientists and engineers to enforce it. Development of the windowless target concepts is overseen along with comparison with classical targets. Theoretical considerations and numerical simulations are viewed. Experimental developments and future concepts of low pressure crossflow targets are shown at the poster.

K. Kravalis, E. Platacis, A. Zik, O. Lielausis

Working Group - Synergies in Data Acquisition / 111

Front-end electronics and Controls as seen from the NUSTAR/FAIR perspective

Author: Haik Simon^{None}

The experimental program at FAIR requires a smooth transition from existing experiments as well as integrating a variety of old and new detector systems from different collaborations world-wide. We follow a flexible scheme where minimal functionalities of an associated electronics, readout and control are defined in order to make these complex systems work together. In my talk I will present these functionalities and associated implementations and prototypes, as well as the necessary back-end installations to be implemented at the FAIR facility. The issue of being able to monitor and judge on the quality of the data produced by an inhomogenous setup with large channel counts is discussed, especially in view of the necessary setup times. I will also outline in this context, how future instrumentation can be made compatible in the sense that they can be used flawlessly in different labs.

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ENSAR Presentation

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Discussion

At and Beyond the Dripline / 114

”Recent results from experiments at and beyond the dripline”

Author: Dolore Cortina Gil¹

¹ USC

Modern high-intensity accelerators provide access to new regions of the nuclear chart. This allows one to study the properties of extremely weakly bound or even unbound nuclei which spontaneously emit protons or neutrons. These nuclei have a huge imbalance in the proton/neutron ratio, adding a new degree of freedom - the isospin - and opening a large field of new experimental possibilities.

It has been observed that, in these systems, nuclear forces manifest themselves in different ways. This is interpreted presently as an isospin dependence, and is questioning our understanding of the behaviour of nuclear matter going from proton- rich to neutron-rich matter.

The light part of the nuclide chart offers a unique scenario where particle-bound and unbound nuclei mixed in the same isotopic chain, offering the possibility to follow how the structure develops as a function of increasing neutron number. In general, the isospin variations present in exotic nuclei are predicted to modify the nuclear mean-field picture together with the long and short-range correlation and are thus a key issue for the understanding of the evolution of the shell structure with isospin.

We will review in this talk a personal selection of recent experimental results obtained in different laboratories during the last years. The enormous quality and amount of data, are a clear sign of the dynamism and interest awoken by the investigation of nuclear species close to the dripline.

Working Group - Synergies in Data Acquisition / 115

INCAS

Author: H.J. WOERTCHE¹

¹ INCAS

I will present the organizational structure and the research program of INCAS3, a starting research institute focusing on the development of advanced sensor technology.

INCAS3 is co-financed by the Northern-Netherlands Provinces, the European Union, European Fund for Regional Development and the Dutch Ministry of Economic affairs. The mission of INCAS3 is to translate business and societal needs into research projects and to advance scientific and technological knowledge in the field of sensors and sensor systems, in collaboration with industry and the scientific community, leading to technological breakthroughs.

I will provide an overview of development lines relating to nuclear technologies: antineutrino detection, medical applications, environmental monitoring/geophysical exploration techniques and cognitive sensor (systems). I will further indicate the involvement of industrial partners and our approach to stimulate and to organize these collaborations.

Working Group - Synergies in Data Acquisition / 116

Trends of FEE instrumentations for Spiral2 detectors

Author: Michel TRIPON¹

¹ GANIL

Along with the implementation of SPIRAL2, the second generation of RIB accelerator of the GANIL laboratory, have emerged projects of new detectors and instrumentations which comply with new constraints brought by high intensities RIB, such as higher counting rates, higher number of channels, higher data readout rate, fast link connections between DAQ instrumentations, experimental cave accessibility. European and French laboratories have collaboration in nine projects of new instrumentations for the future SPIRAL2 detectors: Exogam2, DESIR, ACTAR, PARIS, AGATA, FAZIA, GASPARD, S3, and NEDA.

Representatives of these detectors instrumentations have met within the Electronic Group of the Instrumentation Coordination Committee (ICCEG) for the SPIRAL2 detectors. The ICCEG aims to find synergies in hardware, firmware and embedded software fields in order to share and to retrieve developments undertaken for these instruments, as well as to exchange knowledge on systems and technologies. Templates of specifications of these detectors and their respective instrumentations show a wide range of specifications: kinds of detectors (HPGe, Si, scintillators, and gas), number of channels (from 100 to 20000), counting rate (from 1 kHz to 300 kHz), total data rate (from 1Mb/s to 1 Gb/s), number of trigger levels (from triggerless to 2). Among the nine SPIRAL2 detector instrumentation projects, four projects are either in the demonstration phase (AGATA), either in early development phase (Exogam2, ACTAR, FAZIA). It is worth to notice:

- Two instrumentation architectures are emerging: one based on the implementation of analog ASICs which integrate filters and sampling memories (ACTAR) and one based on the implementation of flash ADC associated to digital processing.
- Fast serial communication protocols such as Gigabits Ethernet, PCIe and Aurora using copper or optical media are widely deployed; these links are managed in embedded software FPGA.
- The choice of the electronic standard is widely opened: customized racks, NIM, ATCA, μ TCA. Nevertheless, digital modules are mainly designed in the ATCA and μ TCA standards due to their resources in high speed communication and in high frequencies bandwidth signals transmissions.
- A system which provides a reference clock (200MHz), time stamps parameters and returns trigger decisions is required.

GANIL is involved in two projects. In the ACTAR one, GANIL has taken in charge the development of the trigger and local clock distribution system, so called MUTANT and BEM; both modules are in μ TCA standard. In the Exogam2 project, GANIL manages the collaboration of several labs for the design and the implementation of the instrumentation. Its architecture is based on the AGATA instrumentation one; it retrieves the GTS system but not the complex ATCA standard. The digitizer

is the key development. Synergies with NEDA, PARIS, and S3 have been pointed out during ICCEG and last SPIRAL2 week meetings. Thanks to the FADC mezzanines concept and the firmware flexibility, the EXOGAM2 digitizer will be made versatile enough for dealing with the different frequency bandwidth analog inputs and for running specific digital processing.

When coupling several detectors, the critical issue is how compliant are their instrumentations. The ICCEG had a meeting about what systems for clock distribution, time stamping and trigger. Three systems were examined: the TDR running at Jyvaskyla, the GTS implemented in AGATA and the BUTIS and White Rabbit under development at GSI. The GTS has been found a comprehensive system, having a possible connection to BUTIS. GANIL suggests deploying the GTS system in NIM form for the GTS fanin fanout levels and in μ TCA form for the trigger processor level. Thanks to the μ TCA resources, high speed signals and high level messages could be exchanged between various instrumentations and DAQ of detectors involved in an experiment.

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Front end electronics and Data acquisition of Fazia detector.

Author: Maurizio BINI¹

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The development of the Fazia FEE design will be presented, concerning the main problems that have been attacked. In order to minimize noise and signal distortion the solution of the digitizer back-to-back the preamplifier inside the vacuum chamber has been adopted. With the digitizing ADCs (6 for each telescope composed of two Silicon detectors of 300 and 500 micron followed by a CsI) each FEE board will host FPGAs to perform online trapezoidal shaping and to handle the communication through optical fibers with a system of regional cards outside the scattering chamber. The online fast shaped signals are aimed at generating fast logic signals to produce a global trigger validation. The high-speed bidirectional optical fibers (≥ 3 Gbit/s) will transmit both data for the acquisition and logic information to a common general device. It will include a programmable trigger unit which, following the experiment demands, will generate and send back to all telescope of the apparatus a fast trigger validation. The data to be acquired, when separated, are sent through an ethernet network to a PC farm for storage and online analysis.

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Discussion