HEAVY ELEMENTS

2nd Workshop on

Inelastic Reaction Isotope Separator for Heavy Elements

November 19, 2010, GSI, Darmstadt, Germany

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Program & Abstracts

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14:30	**Coffee Break**		
15:00	**Next Steps – Panel Discussion** • Choice: solenoid vs. QD • If needed: next steps other WGs? • General discussion	**Chair:**	
16:00	**End**		

The length of all presentations will be 15 minutes + 5 minutes discussion time, except * (→ 25 min. + 5 min. discussion time)

KEK isotope separation system for β-decay spectroscopy of r-process nuclei

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Neutron-rich isotones with neutron number *N*=126 on the r-process path are supposed to be progenitors which form the third peak (*A*~195) in the r-abundance element distribution. Their β-decay properties are considered to play critical roles for better understanding where the heavy elements such as gold and platinum were made in the universe. We are now getting to work on a project to study β-decay properties and nuclear structures of neutron-rich nuclei around *N*=126 experimentally.

Those isotopes could be obtained via multi-nucleon transfer reactions induced by low-energy intense neutron-rich radioactive ion beams, such as ^{140}Xe and/or ^{144}Xe generated by facilities based on the ISOL and post-acceleration scheme. Since there has not been such facilities in the world yet, as the first step, we are going to produce ^{200}Os~^{204}Pt (*Z*=74~78, *N*=126), which have not been produced in any other facilities, by using the multi-nucleon transfer reactions in ^{136}Xe (stable beam) + ^{198}Pt (target) system.

In order to study the products of rare reaction channels, it is essential to select the element (atomic number *Z*) and mass number (*A*). Therefore, we will adopt the gas catcher for collecting all reaction products efficiently, the laser resonance ionization technique for selecting the atomic number of the collected nuclei and electromagnetic separator system, which allows us to measure their β-decays by multi-layered plastic scintillation detectors and germanium detectors.

Laser resonance ionization system has been constructed at RIKEN, and as a system performance test, stable nickel element has been successfully ionized in vacuum using two frequency-tunable dye lasers pumped by excimer lasers. The search for the ionization scheme of stable elements for *Z*=68~78 is in progress.

Mass measurements of rare isotopes with the Penning trap mass spectrometer SHIPTRAP

M. Block for the SHIPTRAP collaboration
GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt, Germany

The quest for the island of stability is at the forefront of nuclear physics and chemistry. The region of superheavy elements (SHE) is a prime testing ground for nuclear structure theories since SHE owe their very existence to shell effects. Direct mass measurements with Penning traps give experimental access to the binding energy and thus allow studying the nuclear shell structure.
However, mass measurements of the heaviest elements are hampered by their very low production rates. The Penning trap mass spectrometer SHIPTRAP at GSI was the first to perform direct mass measurements of rare isotopes above uranium. Recently, the masses of several nobelium and lawrencium isotopes with yields as low as about one particle per minute have been measured with high precision. The accurate mass values provide new and reliable anchor points in the region of the heaviest elements. Moreover, the experiments have paved the way to access superheavy elements in the near future.

Design of a Large Acceptance Spectrometer for Deep-Inelastic Scattering with re-accelerated Radioactive Beams

G.A. Souliotis
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and
Texas A&M University, College Station, USA

A large acceptance ray-tracing spectrometer has been designed in order to fully exploit the research opportunities that will be offered by reaccelerated radioactive beams in the energy range 6-15MeV/nucleon from the proposed Facility for Rare Isotope Beams (FRIB) in the USA and other similar facilities. The preliminary design of the spectrometer has been benefitted by several similar instruments in Europe (e.g. VAMOS, PRISMA, MAGNEX). The design is of QQD type (quadrupole-quadrupole-dipole) with two large-bore quadrupoles and a large-gap 70^{o} bending magnet offering an angular acceptancearound 50 msr and a momentum acceptance of 10%. The focal plane dimensions are 60cm X 20cm and can accommodate two X-Y position sensitive detectors, a multi-segmented ionization chamber and a Si detector wall. The maximum magnetic ridigity is 2.5 Tesla-meter, providing a range appropriate for the most neutron-rich products expected from binary reactions with reaccelerated radioactive beams.
The spectrometer will be mounted on a platform allowing rotation around the target in a wide angular range. It is envisioned that the spectrometer will play an important role in the rich research directions in nuclear structure and reaction studies, combined with gamma-ray and particle arrays around the target.

Large-bore Solenoid Collector (*BigSol*) for Isotope and Heavy-Element Production

F. Becchetti
University of Michigan, Ann Arbor, USA

A large-bore (40 cm), super-conducting solenoid reaction-product collector (*BigSol*; B=7T) was developed at UM and used for several years at the MSU-NSCL heavy-ion facility for production and study of interesting nuclear species including reactions with a short-lived gamma-tagged isomer beam (18Fm, t=200 nsec) and production of heavy isotopes near mass 70 (several newly identified at the time). The latter used a long flight-path ToF configuration with tracking detectors which provided exceptional isotope identification without extensive pre-gating of rare events. This could have applications at GSI for SHE production and studies. Some of the limitations of such a device will be presented along with possible improvements. Recently, the magnet has been in use at the TAMU cyclotron, again as the main element in a long-flight-path TOF spectrometer for heavy element production, including an experiment testing the feasibility of such a device for SHE production.

Near barrier collisions of transactinides: excitation functions and angular distributions of transfer reaction products

Valery Zagrebaev
Flerov Laboratory of Nuclear Reactions, JINR, Dubna, Russia

Multi-nucleon transfer process in near barrier collisions of heavy (and very heavy, U-like) ions seems to be the only reaction mechanism allowing us to produce and explore the nuclei located at the north-east part of the nuclear map including those on the island of stability. In addition to our previous predictions for the cross sections of such the processes, we have also analyzed the angular and energy distributions of primary and survived reaction products in the laboratory frame. These results as well as predicted excitation functions for the yields of neutron-rich superheavy isotopes might be useful for design of appropriate experimental equipment and carrying out experiments of such kind.

Reaction Properties

Jan Dvorak
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Understanding reaction properties is crucial for designing IRiS. The nuclear reactions between various projectiles on actinide targets at energies in the region of 100-110% of Coulomb Barrier were chosen for deeper analysis during the last IRiS workshop. Here we present properties of these reactions relevant for IRiS simulation and design. A special attention will be given to reactions ^{48}Ca + ^{248}Cm and ^{238}U + ^{248}Cm at bombarding energies of 209 and 750 MeV in lab system, respectively. Parsing properties of these two reactions will illuminate behavior of other projectile-target combinations at similar energies.

Concepts for separation and detection of heavy transfer products

S. Heinz
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Transfer products from deep inelastic reactions have broad distributions of kinematic parameters like energy and scattering angle. Unlike in fusion reactions they overlap in a wide range with the parameters of background events. For the identification of events on cross-section levels of picobarn and below, the setup must consider strong background suppression and high total efficiency.

Possible concepts will be presented, whereby special emphasis will be put on required techniques and their present limitations.

Solenoid design

Jan Dvorak
Helmholz-Institute Mainz, Mainz, Germany

Solenoid magnet acts as an ion-optical lens with a chromatic aberration, focusing ions emitted from one side of the solenoid to an image point on the other side. Dispersion in momentum and charge can be beneficial for ion separation inside the solenoid. A solenoid-based recoil separator would have an extraordinary angular acceptance, making it ideal for collection of transfer-reaction products. We have investigated the possibility of using a solenoid for separation of products of multi-nucleon transfer reactions ^{48}Ca,^{238}U + ^{248}Cm. Here we will discuss results of our simulations.

A gas stopping station for IRIS

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In recent years experiments on rare isotopes at low energy have flourished resulting in several high-precision measurements of different ground state properties. The combination of advanced ion-beam manipulation techniques with gas stopping has extended the reach of such experiments to more exotic radionuclides far away from stability. The stopping of reaction products from fusion-evaporation reactions as well as from fast-beam fragmentation in helium or argon gas provides access to practically all elements including refractory elements and even the elements above uranium. In combination with radiofrequency quadrupole ion-beam coolers low-energy radioactive beams with excellent beam quality can be prepared for numerous applications such as high-precision mass measurements and laser spectroscopy. Therefore, a gas stopping station is also foreseen at the new IRIS separator. Considerations about the layout of such a system will be presented.

Nuclear structure of SHE: current developments

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Any detector system for IRiS has to fulfill a few basic requirements, namely the identification of products, the study of their decay, and the identification of good signals over the background. A close interplay between detector and separator is important as the channels of interest are produced at only a small fraction of the total cross section and a good pre-separation of beam and unwanted reaction products is required before the detection stage. Thus the work on a detection system is highly interlinked with that of separator design.

In the talk several options for the detection system will be discussed.