Ion-optical simulations for the Inelastic Reaction Isotope Separator IRiS

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Introduction

An impressive advancement in investigation of superheavy elements (SHE) was achieved in the past 25 years. The heaviest currently reported superheavy element contains 118 protons and novel challenging experiments pursuing the synthesis of elements 119 and 120 are under preparation. Yet all of these heaviest currently claimed elements were synthesized in nuclear fusion reactions, which can yield only neutron deficient products. Neutron-rich isotopes of the heaviest elements, which are of special interest e.g. in the context of nuclear chemistry and nuclear astrophysics, cannot be produced this way. The only viable production mechanism for neutron-rich nuclides is through multi-nucleon transfer reactions (MNTR), the application of which will give access to tens of new neutron-rich isotopes of the heaviest elements. Currently available separators are optimized for fusion products emitted under 0° and are poorly suited for MNTR studies due to their limited angular acceptance.

A new Inelastic Reaction Isotope Separator (IRiS) [1], dedicated to the investigation of neutron-rich isotopes of the heaviest elements produced in MNTR, will be constructed and set-up at the GSI in a joint effort of an international collaboration, headed by the Johannes Guttenberg University Mainz, the Helmholtz Institute Mainz, and the GSI Helmholtzzentrum für Schwerionenforschung Darmstadt. The main design goal of the IRiS is the ability to separate the heavy products formed in MNTR and deliver them to a focal plane. Here ion implantation and decay is detected in focal plane detector. To perform (i) chemical studies, (ii) mass measurements, and (iii) nuclear and atomic spectroscopy of the heavy ions separated in the IRiS, the detector setup will be retracted and allow the separated products to enter a gas cell, where they will be stopped and extracted for further investigation. A conceptual design scheme is shown in Fig. 1.

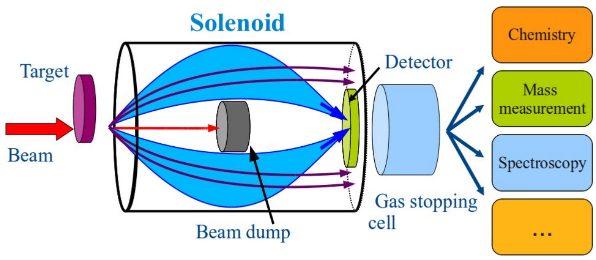

Figure 1: Schematic drawing of the IRiS design concept. Products are separated in a gas-filled solenoid magnet according to their magnetic rigidity. A beam dump stops the beam particles as well as 0° products.

Simulations

An essential part of the IRiS design process is the development of a computer simulation for the IRiS ion-optics. Due to the availability of theoretical predictions, the following two nuclear reactions were chosen as input for the simulation: ^{48}Ca+^{248}Cm at E_{CM}=209 MeV [2], and ^{238}U+^{248}Cm at E_{CM}=750 MeV [3]. The simulation code using the ROOT [4] framework is already highly advanced and includes: (i) Simulation of unreacted projectiles and products of elastic and inelastic scattering including MNTR; (ii) energy loss and straggling in the target; (iii) ion interaction with gas molecules and (iv) ion tracking in a realistic solenoidal magnetic field.

Simulation results

Simulations showed that relatively strong magnetic fields are necessary to achieve acceptable separation in a gas-filled solenoid. While several solenoid dimensions and magnetic field strengths were successfully tested, a stored energy of about 10 MJ was necessary in all cases. In symmetric ion-optical geometries, as shown in Fig. 2, efficiencies of typically about 20% for collecting the heaviest products (Z ≥ 102) in the detector area were reached, while the detector count-rate due to background was estimated to about few kHz. Although not optimal for the identification of products in a focal plane detector, these conditions are well suited for use of a gas cell.

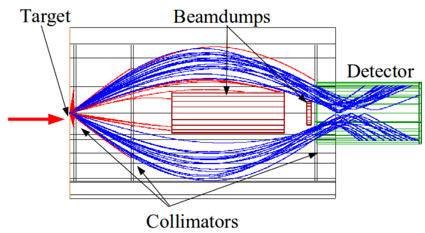

Figure 2: Trajectories of the heaviest products (Z ≥102) produced in the reaction ^{48}Ca + ^{248}Cm.

Acknowledgements

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References

[1] J. Dvorak *et al.*, NIMA in press *http://dx.doi.org/10.1016/j.nima.2010.08.124*
[2] G.G. Adamian and N.V. Antonenko, private comm.
[3] V. Zagrebaev, private comm.
[4] ROOT- *http://root.cern.ch*