IRiS - Feasibility Calculations

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The design for a new Inelastic Reactions Isotope Separator (IRiS) [1] to be installed at the GSI Darmstadt has been developed in a joint effort of an international collaboration, headed by the University Mainz, the Helmholtz Institute Mainz, and the GSI. This separator will be dedicated to the investigation of neutron-rich isotopes of heavy and superheavy elements, which can be produced exclusively in multi-nucleon transfer reactions. So far, experimental studies of transfer products with recoil separators have focused on light isotopes not far from stability for a number of reasons. These include low efficiencies for multi-nucleon transfer reactions of recoil separators that are optimized for fusion-evaporation reactions. Here, we present developments toward a dedicated facility featuring an extra-large angular acceptance separator IRiS, which will make the study of heavy neutron-rich transfer reaction products feasible.

The task of IRiS is to separate reaction products of interest from the primary beam and unwanted byproducts. The separated products will be delivered either into a detector setup or alternatively to auxiliary setups for identification and further investigation of the species of interest. For internal detection in a Si stop detector, maximum acceptable count rates are on the order of 1 kHz. For detection in auxiliary systems like a gas stopping chamber for coupling to external experimental setups, count rates up to 100 kHz appear acceptable.

In our feasibility calculations, two particular nuclear reactions were studied in detail: the reaction ^{48}Ca + ^{248}Cm at a center-of-mass beam energy E_{CM} = 209 MeV, and the reaction ^{238}U + ^{248}Cm at E_{CM} = 750 MeV. Predictions for the multi-nucleon transfer channels from theoretical models of V. Zagrebaev [2] and G. Adamian and N. Antonenko [3] were used for these studies. An ion-optical simulation was developed in framework of this study to test the performance of various potential IRiS setups for the two selected reactions. Besides the heavy n-rich products of interest, other reaction byproducts were simulated as well as they will be the major source of background.

Due to large differences in the properties (e.g., velocity, energy, angular emittance) of the studied heavy transfer products when produced in different reactions, the optimal setup differs for either of the reactions. The most versatile setup was found to be one based on a superconducting solenoid magnet as the main component, with a stored energy of E ~ 10 MJ. In the simulations, a solenoid magnet with a maximum magnetic field strength of B_{max}=4.3 T and dimensions of 2 m length and 90 cm inner diameter was used. The target is located on axis at the entrance of the solenoid. A beam dump blocking central ions is placed axially at the exit of the solenoid and the detector is located further downstream from the solenoid, see Fig. 1. Ion-optical simulations of the identified optimal setups resulted in efficiencies of roughly 20% for separation of the heaviest (Z ≥ 102) transfer products, while keeping the background rate well below 100 kHz. For the reaction ^{238}U + ^{248}Cm, the background is predicted to be below 1 kHz, when using a 500-µg/cm^2 thick target. Using thicker targets resulted in increased background. For the reaction ^{48}Ca + ^{248}Cm two setups were investigated. The setup tuned for detection of the heaviest (Z ≥ 102) transfer products resulted in background below 1 kHz and the possibility to roughly identify A and Z of the ions. When the setup was adjusted for the detection of Fm isotopes, the background increased to ~ 10 kHz.

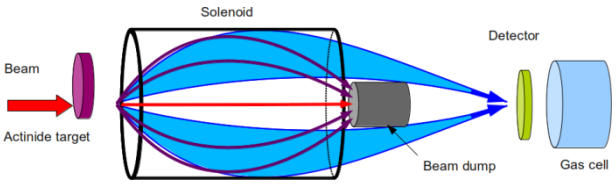

Figure 1: Schematic drawing of a solenoid-based IRiS design in an asymmetric mode. A thin actinide target is bombarded with a heavy-ion beam. A beam dump located on axis behind the solenoid stops both, beam ions, which pass through the target without undergoing nuclear reactions (red arrow) as well as light products of transfer reaction channels (violet). Heavy transfer reaction products (blue) are focused on a disk-like detector at the exit of the solenoid. In the separator mode, the detector is removed, and the products pass through a thin window into the gas-filled stopping cell, where they are available for transport to ancillary setups.

We conclude that the optimal identified setups perform better than expected for the reactions of choice. These setups will most probably not only allow for delivery of separated products into a gas stopping cell, which is the main design requirement, but also enable on-line detection in internal Si detectors. The above described setups offer enough space for inserting of multiple gas-filled detectors for precise TOF measurement and ideally also for a rough Z identification.

References

[1] J. Dvorak et al., Nucl. Instrum. Meth. A 652 (2011) 687.

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