An idea of a GARIS-type pre-separator for MNT reactions

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The multi-nucleon transfer (MNT) reaction is crucial for generating neutron-rich nuclides, particularly contributing to neutron-rich actinide production. Access to r-process nuclides for uranium synthesis primarily relies on this reaction. However, handling MNT reactions is challenging due to their low energy, high multiplicity, large angle, and velocity distribution. KEK's KISS device is the sole ISOL facility capable of supplying neutron-rich isotopes of refractory elements via MNT reactions.[1)] KISS captures reaction products in an argon gas cell, selectively ionizes elements through laser resonance ionization of neutralized atoms, and obtains high-purity RI beams by mass separation using an isotope separator.

Despite its capabilities, KISS faces limitations in primary beam intensity, capture/separation efficiency, and measurement multiplicity, leading to the development of the KISS-II project.[2)] KISS-II aims to enhance these aspects and achieve a 10,000-fold improvement in overall performance. The KISS-II plan involves using a large-diameter gas-filled superconducting solenoid as a pre-separator to separate the primary beam from the reaction products. However, significant costs and inherent restrictions on primary beam intensity persist due to stopping the primary beam within the magnet.

This report explores the use of a GARIS-type separator as a pre-separator. GARIS exhibits high-efficiency capture for reaction products concentrated in forward regions, such as superheavy element generation through fusion reactions.[3)] However, there is nearly zero yield in the forward region in MNT reactions, making GARIS directly inapplicable. The angle distribution for the ^{238}U + ^{238}U → ^{250}U reaction, as calculated by Grazing, is illustrated in Fig. 1a), exhibiting a peak at approximately 54 degrees that decreases with increasing energy. To capture ions in this distribution efficiently, a configuration with a tilted beam axis at 54 degrees is considered (Fig. 2). In this setup, the primary beam can be dumped before entering the separator. Placing the target position 10-cm downstream provides an acceptance of H: ±70 mrad, V: ±180 mrad (Fig. 3). While capturing a portion of the horn-shaped angle distribution (Figs. 1c), d)), the transmission rate at this acceptance is found to be 3%, which corresponds to 1/10th of KISS-II's solenoid, and is sufficiently practical; detailed evaluations are in progress.

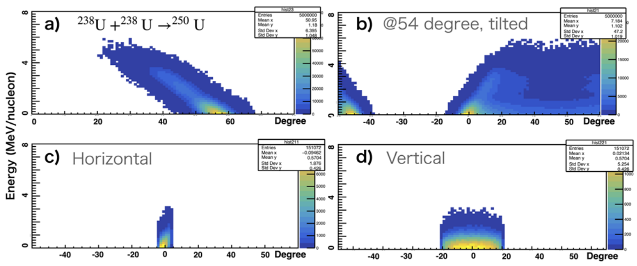

Fig. 1. Energy vs. angular distributions in ^{238}U + ^{238}U →^{250} U reaction. a) raw distribution, b) with 54 degree titled axis, and accepted portion in a ellipse in ±70 mrad, V: ±180 mrad, c) for horizontal and d) for vertical.

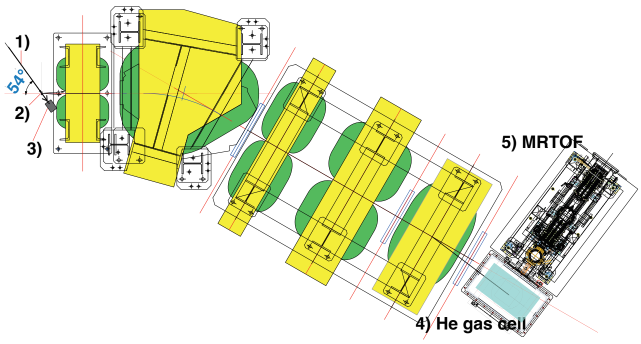

Fig. 2. Tilted GARIS-II configuration for MNT. 1) primary beam, 2) target, 3) beam dump, 4) gas cell, and 5) MRTOF-MS.

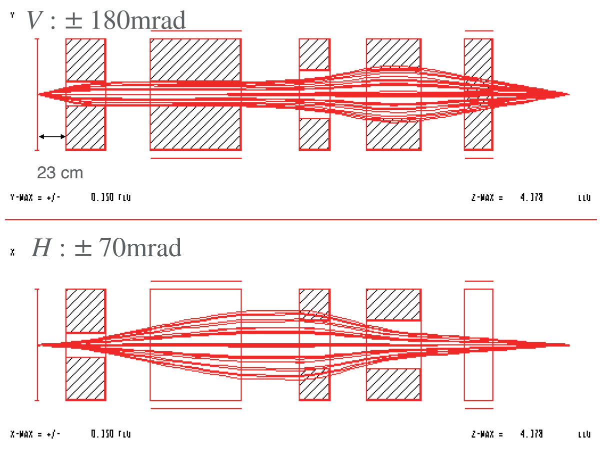

Fig. 3. Beam envelop of GARIS-II with the shifted target position.

References

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