Degrader optimization for ZeroDegree gas cell

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Using a high-quality beam provided by BigRIPS and the ZeroDegree spectrometer, a system combining a gas cell and a multi-reflection time-of-flight (MRTOF) mass spectrograph was set up at F11 to study the masses of exotic nuclei.[1)] The first online commissioning was conducted in the winter of 2020 as parasitic experiments during the HiCARI campaign. To achieve the mass measurement in the MRTOF device, the radioactive beams received from ZeroDegree must be stopped in the gas cell, which is 500-mm long and filled with He gas. The typical beam energy behind ZeroDegree is 100–200 MeV/nucleon. To stop such high-energy beams in the He gas, a degrader is essential, and its thickness must be precisely adjusted. Therefore, a movable degrader system was introduced.

Figure 1 shows a sketch of the gas cell with the degrader system. The degrader system contains a rotational flat degrader placed in front of the gas cell and a downstream silicon detector array inside the outer chamber. The flat degrader was coupled to a step motor, which can rotate the degrader plate from 0° to 55° in steps of 0.0072°; therefore, it can finely adjust the effective thickness of the degrader. The downstream silicon detectors contain 15 Si PIN photodiods s3204-09, arranged in a 5×3 array to cover the full range of the beam spot. After losing most of its energy in the flat degrader, part of the beam is stopped in the He gas, while the rest deposits energy in the Si detectors. The signal from the Si detectors was acquired in coincidence with the beam-line detectors of ZeroDegree for particle identification; therefore, optimization can be performed for specific isotopes. The stopping in He gas can be optimized according to the beam energy loss measured by the Si detectors[2)] or simply using the beam rate from the Si detectors.

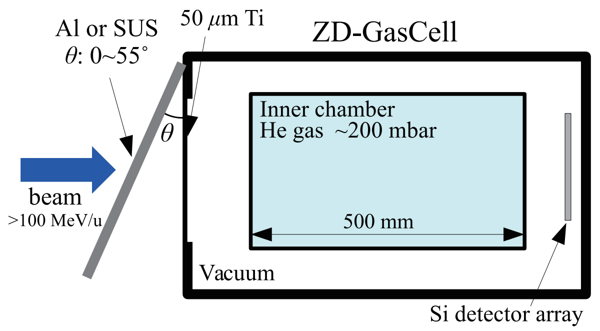

Fig. 1. Sketch of the ZeroDegree gas cell and degrader system.

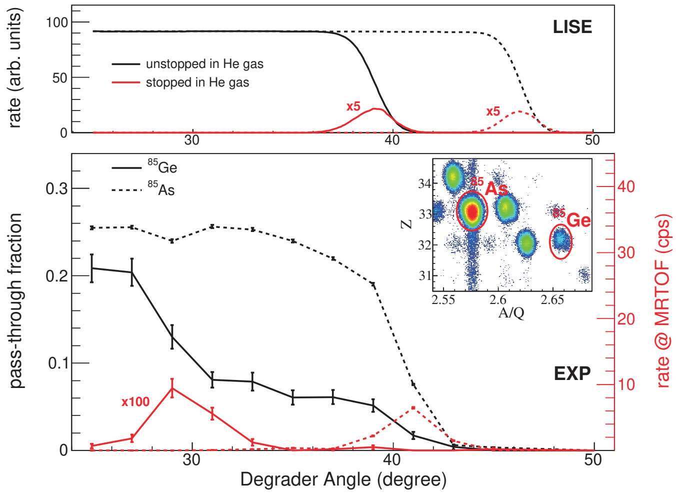

Fig. 2. Degrader optimization for ^{85}Ge (solid) and ^{85}As (dash). The black curve shows the ratio of the rate detected by an Si detector to the rate at F11. Only one Si detector was used in the analysis. The red curve is the rate of isotope identification in the mass spectrum. The inset shows the ZeroDegree particle identification. The upper panel displays the corresponding LISE calculations using the beam energy measured in ZeroDegree.

Figure 2 demonstrates the degrader optimization with a 2.5-mm-thick Al flat degrader for ^{85}Ge and ^{85}As during the commissioning run. The fractions (black), calculated as the beam rate detected in the Si detectors compared with the rate at F11, decrease with increasing degrader angle. The rates of isotopes observed in the MRTOF mass spectrum (red) show peak structures, from which we can determine the optimized degrader angle for each isotope. The LISE calculations well reproduce the measured pattern; however, discrepancies in the absolute angles are observed, which emphasize the importance of such direct measurement in experiments. For low-intensity isotopes (rate in MRTOF as low as 1 count/h), the direct measurement of the rate curve in MRTOF is not feasible. In this case, the fraction curve from Si can still be measured. Combined with the LISE calculation, the optimized degrader angle can be determined in future experiments.

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2) J. Liu, RIKEN Accel. Prog. Rep. **53**, 133 (2020).