# Degrader system for ZD-MRTOF

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After the successful experience with gas-cell techniques and the multi-reflection time-of-flight mass spectrograph (MRTOF-MS) at SLOWRI and GARIS-II, parasite experiments for commissioning the cryogenic He gas cell and MRTOF-MS using the ZeroDegree spectrometer have been proposed. A gutter RF carpet gas cell will be installed at the downstream side of F11 to stop heavy ions and extract them to the MRTOF-MS. Since the maximum stopping power of the gas cell is ∼0.7 MeV/nucleon[1] ions dumped from ZeroDegree that have an energy higher than 100 MeV/nucleon need to be slowed down before entering the gas cell. A degrader system will be installed. Additionally, as the commissioning will be run symbiotically with other ZeroDegree experiments, an independent data acquisition (DAQ) system for particle identification (PID) should be developed.

A movable flat Pb-glass degrader with a thickness of 7.1 mm was combined with a step motor rotating in the vertical direction from 0° to 90°, which is mounted in front of the gas-cell window. The step motor has a high resolution of 0.0072° per step enabling the fine tuning of the effective degrader thickness. The maximum effective thickness of the degrader is 10.04 mm when the degrader rotates to 45°, while there is no degrader at 90°. An online PID DAQ system with shared beam signals from ZeroDegree is developed independently for the BigRIPS DAQ, which will not be in conflict to other experiments. The PID could be performed by the $\Delta E$-$\Delta E$ method using a multi-samping ion chamber at F11 and Si detectors. Moreover, the $\Delta E$-TOF-$B\rho$ method for PID could be applied using the multi-samping ion chamber at F11, time of flight from F8 to F11 and F10 PPAC position information. With the selection of specified ions, the degarder angle can be optimized by measuring beam energy loss in the Si array. After fixing the angle of the degarder, the Si array will be removed and ions will be transported to the gas-cell.

The degrader system has been tested in an online experiment. A $^{238}$U primary beam with an energy of 345 MeV/nucleon was incident on a 4-mm thick $^{9}$Be target. Fragmentation around $^{80}$Zn was produced and selected by BigRIPS and ZeroDegree spectrometers, where a wedge-shaped degrader at F10 was utilized so as to mono-energetically focus particles on F11 by adopting the LAA-monoionic optical mode. The PID has been performed by the $\Delta E$-$\Delta E$, as shown in Fig. 1(a), with a reasonable resolution. By scanning the degrader angle $\theta$ from 0° to 90° and gating on $^{81}$Ga, the energy loss in Si as a function $\theta$ was obtained as shown in Fig. 1(b). By fine tuning of $\theta$ from 39° to 40°, $^{81}$Ga was expected to be caught by the gas cell. This result is consistent with LISE++ calculation.

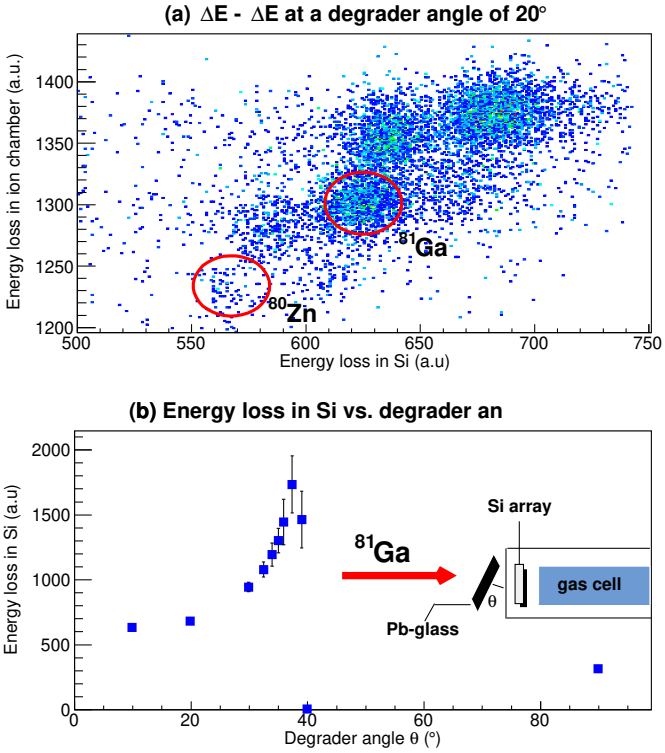


Fig. 1. (a) Particle identification using the $\Delta E$-$\Delta E$ method by a multi-sampling ion chamber at F11 and Si detector; (b) energy loss in the Si detector as a function of the degrader angle

A real-time PID trigger is under construction within the PID DAQ system, and it can be possible to stop a single ion in the gas cell. With selected particle information from the DAQ, a pulse will be generated to turn off the DC field in the gas cell for a half life of the selected ion. In such a condition, the $\beta$-delayed neutron emission probability of the ion can be determined by counting daughter nuclei distinguished using MRTOF-MS.

Reference

1) M. Wada *et al.*, Nucl. Instrum. Methods Phys. Res. B **204**, 570–581 (2003)

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