Development of the gaseous Xe scintillation detector

J. Zenihiro,[*1] T. Harada,[*1,*6] S. Terashima,[*1,*2] Y. Matsuda,[*1,*3] S. Ota,[*4] H. Sakaguchi,[*1,*5] K. Kawata,[*4] S. Ishida,[*1,*3] Y. Kasamatsu,[*1,*3] and E. Takada[*7]

RIBF can provide very intense RI beams, but we cannot fully utilize this ability because of the radiation damages of the existing detectors for particle identification. We need a new detector with a good radiation hardness as well as a good energy and/or timing resolution.

For this purpose, we proposed a Xe gas scintillation detector. Xe gas has a small work function ($\sim$ 20 eV), its time response for the scintillation process is relatively fast, and the wavelength of the scintillation photons is approximately 175 nm.[1)] The performance of the Xe gas scintillation for high-energy heavy-ion particles has not been fully measured so far.

The detector consists of an Al chamber filled with high-pressure (1 $\sim$ 5 atm) and pure (99.999%) Xe gas, two 5-mm-thick and 80-mm-ϕ synthetic silica glass windows, and two PMTs (Hamamatsu, R6041-406). Scintillation photons produced in the Xe gas go through the two silica glass windows on both sides of the chamber and finally reach the photo-cathode of the PMTs.

To study the performance of this new detector, we carried out a test experiment at HIMAC in November 2017 (H390). A secondary beam with a mass-to-charge ratio A/Z of approximately 2.28 at 300 MeV/nucleon was produced by the fragmentation of a primary ^{132}Xe beam at 400 MeV/nucleon with a 9-mm-thick Be target. The cocktail beam (1 k $\sim$ 100 k particles/spill) was delivered to the Xe detector through the SB2 beam line.[2)] In addition to the Xe detector, a 100-μm-thick plastic scintillator and a 300-μm-thick Si detector were used for reference.

Figure 1 shows the raw signals of the left (yellow) and right (green) PMTs from the Xe detector at 1 and 4 atm in the upper and lower panels, respectively. Two components were found in the scintillation process. We also checked the signals at 2, 3, and 5 atm, which shows that the ratio of the slow component decreases as a function of pressure.

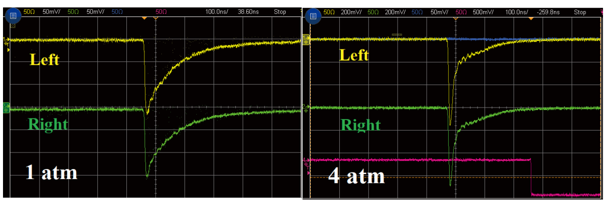

Fig. 1. Raw signals of the Xe detector monitored by an oscilloscope. The left panel shows the signals when the Xe gas pressure is 1 atm, while the right shows that at 4 atm. One division of the horizontal axis is 100 ns, and that of the vertical axis is 50 mV for the left and 200 mV for the right.

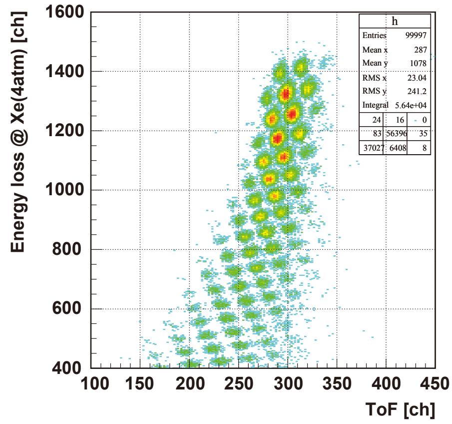

Fig. 2. Particle identification plot of the secondary beam. The x and y axes correspond to the energy loss for 4-atm Xe in QDC channels and the time of flight in TDC channels, respectively.

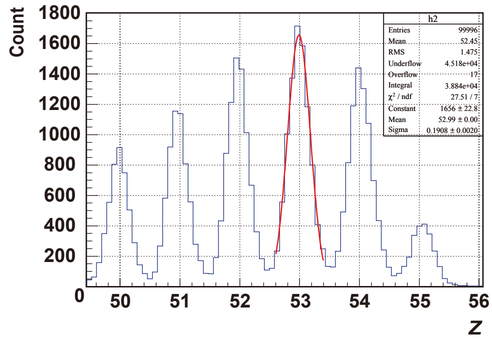

Fig. 3. Atomic number spectrum around 50 deduced from the energy-loss information of the Xe detector.

The energy resolutions at 1 and 4 atm for the ^{132}Xe primary beam are approximately 1.2% and 0.8%, respectivley. The timing resolution is approximately 100 ps in sigma and does not change between 1 and 4 atm. In Fig. 2, the correlation between the mean QDC value of the Xe detector at 4 atm and the time of flight is plotted. The secondary beam particles with Z up to 55 are clearly identified. The Z spectrum around 50 was deduced from the energy-loss information of the Xe detector, as shown in Fig. 3. The root-mean-square resolution of $\Delta Z = 0.2$ (5σ separation) is achieved.

These results are very promising for the high-intensity and heavy RI-beam experiments. A more detailed analysis is in progress.

*1 RIKEN Nishina Center
*2 School of Physics and Nuclear Energy Engineering, Beihang University
*3 CYRIC, Tohoku University
*4 Center for Nuclear Study, University of Tokyo
*5 RCNP, Osaka University
*6 Department of Physics, Toho University
*7 National Institute of Radiological Science

References

1) M. Mimura *et al.*, Jpn. J. Appl. Phys. **48**, 076501 (2009).
2) M. Kanazawa *et al.*, Nucl. Phys. **746**, 393c (2004).