Development of the gaseous Xe scintillation detector

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RIKEN 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 (∼20 eV), approximately 175 nm. 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 ~ 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 ∼ 100 k particles/spill) was delivered to the Xe detector through the SB2 beam line. 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.

The energy resolutions at 1 and 4 atm for the 132 Xe primary beam are approximately 1.2% and 0.8%, respectively. 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.

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.

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.

References

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