Development of the gaseous Xe scintillation detector for heavy RI beams

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In this contribution, we briefly report on the performance test of the gaseous Xe scintillation detector installed in the F7 vacuum chamber of BigRIPS. In this test, we use the detector for the particle identification of heavy RI beams up to the atomic number $Z \sim 90$ for the first time. At present, RIBF is the best facility for the generation of high-intensity and high-energy RI beams in the world. However, the use of high-intensity RI beams is now limited because of radiation damage and/or the slow responses of the standard detectors of BigRIPS.[1)] As machine time is also limited because of the hogh cost of electric power, failure to use the high-intensity RI beams would be a significant loss.

Therefore, we proposed a new detector using scintillation photons from Xe gas. Because the average energy expended per scintillation photon is very small (<20 eV) and its lifetime is relatively short (5 ns and 100 ns),[2)] the detector is expected to have a good energy resolution and a fast response time. The Xe detector is promising for the ΔE measurements of high-intensity RI beams (>100 kcps), where the ion chamber (IC) cannot work because of the slow response. To replace the IC with the Xe detector, we must first compare its energy resolution to that of the IC. A prototype of the detector was tested using a cocktail secondary beam at 300 MeV/nucleon up to $Z = 55$ at HIMAC, QST in Chiba. An rms resolution of $\Delta Z = 0.2$ around $Z = 55$ in sigma was achieved.[3)] However, it is difficult to install the prototype in the vacuum chambers at the focal planes in the BigRIPS beamline owing to the thick detector material, which consists of 4-atm and 12-cm-thick Xe gas and 2-mm-thick Al windows. We recently built a new version of the Xe detector with 2-atm and 9-cm-thick Xe gas and 125-μm-thick Kapton windows, as shown in Fig. 1. The material thickness is approximately 100 mg/cm^2, which is comparable to that of the IC.

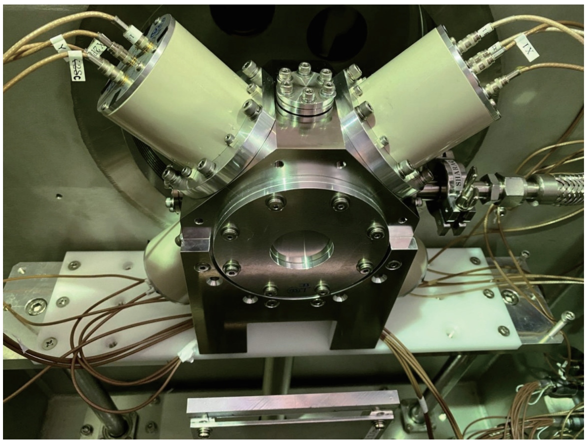

Fig. 1. Photograph of the new version of the gaseous Xe scintillation detector. Four 2-inch-ϕ PMTs (Hamamatsu, R6041-406) were attached to the corners.

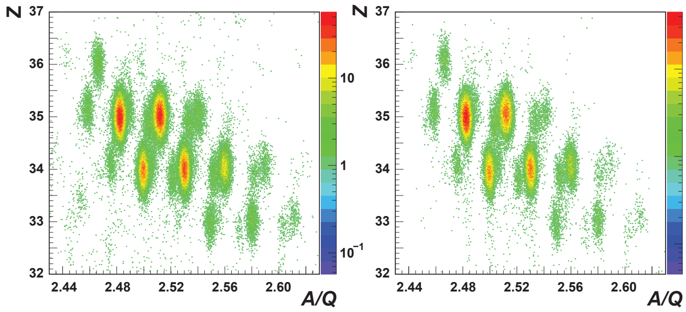

Fig. 2. Z obtained using the IC (left) and the Xe detector (right) vs. A/Q spectra with the Ge setting.

In November 2020, we installed the new detector in the F7 vacuum chamber for the first time and performed a test experiment by using several heavy RI and primary beam settings such as Ge, Sb, Er, Th, and U. We successfully acquired data of particles of different Z and different beam intensities. For the readout circuits, flash ADC (CAEN V1730) have been used in addition to the conventional QDC and TDC modules to check the high-rate torelance. Figure 2 shows the obtained two-dimensional PI spectra with the Ge setting. To deduce Z and A/Q values, the energy loss ΔE of the IC and the Xe detector as well as time of flight between the F3 and F7 plastic scintillators are used. The rms resolution of $\Delta Z \sim 0.22$ determined from the ΔE in the Xe detector is very close to that of the IC. Although the analysis is ongoing, the preliminary spectra show that the Xe detector will be helpful under high-intensity beam conditions.

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