Development of new ionization chamber specialized for high Z beam (II)

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Ionization chambers (ICs) are detectors used to determine the energy deposit (ΔE) of the ions with sufficient accuracy to distinguish the atomic number (Z) in the BigRIPS separator and ZeroDegree spectrometer. A new IC has been developed to improve the Z resolution of heavy ions with $Z > 80$ and the energy of 200–300 MeV/nucleon,[1)] for which experimental proposals are on the rise. The difficulty in Z determination is because of the change in the charge state,[2)] which is more pronounced for higher Z beams. To overcome this effect, previous studies suggested the replacement of the commonly used P-10 with a gas with a smaller or larger Z.[1,3)]

We conducted machine studies (MS-EXP21-10, -11) on the gas dependence of the IC at RIKEN RIBF. The IC setup has been described in a previous study.[1)] We used three gas species, P-10 gas (Ar 90% + CH_4 10%), methane gas (CH_4 100%) with a smaller cross section of the charge state changing, and xenon-based gas (Xe 70% + CH_4 30%) with a larger cross section of the charge state changing. The ICs with these gases were operated at 620 Torr in the F7 vacuum chamber.

The ΔE in the IC was measured with $^{238}U^{90+,91+}$ ions at 344 MeV/nucleon. Figure 1 shows the ΔE distributions for the three gas species. The shape for the CH_4 gas differed significantly between 90+ and 91+. The lowest energy peak corresponds to 90+ passing through the IC without charge state changing and the second-lowest peak corresponds to 91+.

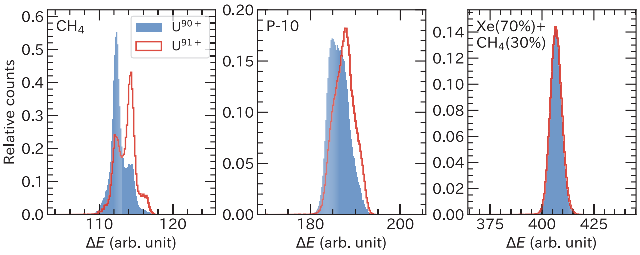

Fig. 1. Energy deposit (ΔE) distributions of the IC in methane, P-10, and xenon-based gases irradiated with 344 MeV/nucleon $^{238}U^{90+}$ (blue area) and $^{238}U^{91+}$ (red line).

The shape difference for the P-10 gas was smaller than that for the CH_4 gas. However, the mean fitted with a normal distribution changed by 0.56% depending on the charge states. When multiple charge states are transmitted, the mean shift adversely affects particle identification (PID). The energy resolution of 90+ and 91+ was 1.1%, which was worse than the 0.7% energy resolution required to achieve the 3σ separation at $Z = 92$ from $Z = 91$ isotopes. In contrast to the CH_4 and P-10 gases, the xenon-based gas yielded almost identical shapes for 90+ and 91+. The difference between the means was only 0.03%. This is because a charge-state equilibrium was reached immediately after the injection into the IC. The energy resolution was obtained to be 0.69%, which is sufficient for the 3σ separation in Z. Hence, the xenon-based gas was demonstrated to be suitable for the IC specialized for high Z beams.

We injected the high-Z secondary beam at approximately $A/Q = 2.5$ into the xenon-based gas IC. The secondary beam was produced from the 345 MeV/nucleon ^{238}U primary beam impinging on a 4 mm-thick Be target. The magnetic rigidity of the first dipole was 6.3 Tm and no degraders were used in the separator. The PID was performed using the TOF-$B\rho$-ΔE method, as shown in Fig. 2. Further, the beam energy at F7 was typically 264 MeV/nucleon at $Z = 80 - 92$. Although the blobs for He-like and H-like ions are dense, the different ion species were well separated and identified. The averaged Z resolution of $Z = 81–91$ was 0.34 (1σ). The resolution is approximately twice better than that by the P-10 gas IC.[4)]

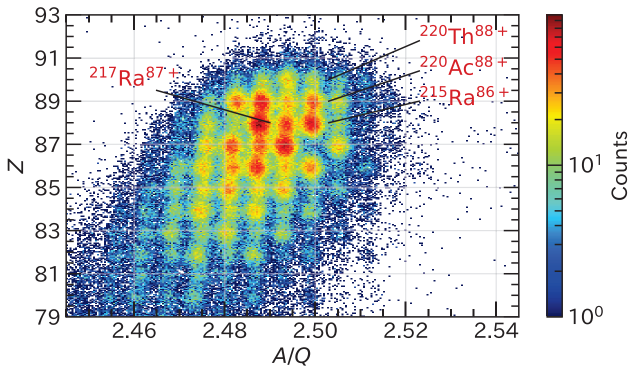

Fig. 2. PID plot of Z versus A/Q obtained with the xenon-based gas IC. The typical energy is 264 MeV/nucleon.

In conclusion, the xenon-based gas IC achieved the 3σ separation in Z, and rendered the PID for the secondary beams with $Z > 80$ at approximately 260 MeV/nucleon practical for all experimental groups.

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References
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