Development of new ionization chamber specialized in high-Z beam

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An ionization chamber (IC) is an essential detector to identify particles in flight in the BigRIPS separator and ZeroDegree spectrometer.[1)] Generally, the atomic number (Z) is deduced from the energy deposit (ΔE) in the IC. However, so far, the Z resolution of particles with $Z > 80$ emitted from the fragmentation of ^{238}U primary beam on a production target is insufficient for the clear particle identification. Here, we report on the construction and data acquisition of a new IC for high-Z beam with an effective diameter of 60 mm.

The deterioration in the Z resolution is caused by the δ-rays[2,3)] and the fluctuation of the ionic charge state. The δ-rays bring about a long tail at the higher energy side of the ΔE distribution. The Z resolution can be enhanced if the IC does not collect the electron-ion pairs from the δ-rays. Accordingly, smaller electrodes were employed for the new IC. The outer diameter of the electrodes that form the electric fields was reduced from 280 mm for the conventional F7 IC to 80 mm for the new IC. Consequently, the change reduces the effective electrode diameter from 232 mm to 60 mm. The electrode size effects will be tested in the future.

The charge state fluctuation of heavy ions in matter is a well-known phenomenon.[4)] The ΔE is proportional to the square of the charge state, instead of the Z of the particle. Therefore, the charge state fluctuation by the filled gas and other materials in the IC affects the ΔE distribution and the Z resolution. Accordingly, the materials in front of the first electrode should be reduced to measure the charge state incident on the F7 chamber with the IC. Therefore, the thickness of the upstream vacuum separation window was reduced from 150 μm to 77 μm, and the length of the dead gas from the vacuum separation window to the first electrode was reduced from 89 mm to 16 mm. Furthermore, we also adopted the methane gas with a smaller cross section of the charge state changing, compared to the P10 (argon 90% + methane 10%) gas. The P10 and methane pressures were 620 Torr. The distance between the electrodes is 20 mm and the effective gas thickness is 480 mm, as shown in Fig. 1. Six signals each from four gas cells were digitized.

The response of the new IC to the gas species was measured at F7 using ^{238}U^{90+} beam with 320 MeV/nucleon. The trigger rates at the F7 were approximately one kcps. The geometrical averages for the six ADC values of the P10 and the methane gas are shown in Fig. 2.

To understand these distributions, the charge state distributions in the IC were simulated with the GLOBAL code.[5)] On the one hand, the charge states at the first→last electrode in the P10 is 76→37% for 90+ and 19→45% for 91+. On the other hand, those in methane are 79→68% for 90+ and 16→24% for 91+. The average number of charge state changes from 90+ to 91+ is 0.9 times for P10 and 0.2 times for methane. According to the simulation, the asymmetric energy distribution with the P10 was formed by the mixture of charge 90+ and 91+. In contrast to the P10, the energy distribution with methane has two peaks. The first narrow peak was formed by charge 90+ and the second peak was formed by 91+. Consequently, 0.9 times of the charge state changes in the P10 appears to be small to average different charge states and large for separating ΔE of each charge state. If a gas with a large cross section of the charge state changing is used, the distribution will be narrowed because the mixture of multiple charge states is well averaged.

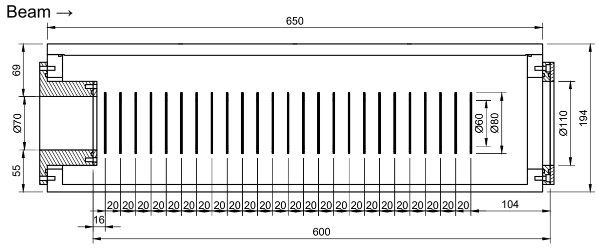

Fig. 1. Cross sectional view of the new IC. The electrode foil is aluminized (both sides) Mylar sheet with 2.5 μm thickness.

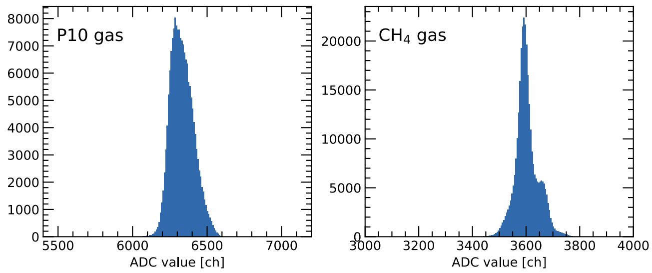

Fig. 2. Energy distributions for ^{238}U^{90+} beam at 320 MeV/nucleon directed onto the new IC with the P10 gas (left) and the methane gas (right).

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