Atomic-number identification of heavy RI beams using the energy loss in a Xe-based gas

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Radioactive isotope (RI) beams produced at RIBF are tagged event-by-event with the atomic number Z and mass-to-charge ratio A/Q determined using beam-line detectors. For heavy RI beams, particle identification (PID) becomes difficult owing to the change in Q inside the beam-line detectors because Z is determined from the energy loss depending on Q^2. Blobs in the PID plot were clearly visible for the ^{208}Rn case[1)] but not for the ^{220}Th case.[2)] The relative Z resolutions were 0.45% and 0.69% (1σ) for the 185-MeV/nucleon ^{208}Rn beam and 315-MeV/nucleon ^{220}Th beam, respectively. The worse resolution was considered to be due to the energy-loss straggling caused by charge-state fluctuation in the gas of the ionization chamber. The difference between these two cases indicates the impact of the energy dependence of the charge-state fluctuation.

In this paper, the difference in the Z resolutions is discussed in regards to the energy dependence of the cross section of the change in Q in the gas using the GLOBAL code.[3)] Figure 1 shows the energy dependence of the partial mean free path length L, given a change in $Z-Q$ from 1 to 2 or from 2 to 1. The energy dependence of L is mainly for the electron-pickup reaction. In the ^{208}Rn case, the mean value of the equilibrium charge-state distribution $\langle Q\rangle$ is 84.5 at 185 MeV/nucleon. Since $\langle Q\rangle$ is a decimal, the charge state must change multiple times in the ionization chamber to make the effective Q in a single event closer to 84.5. L ($Z{-}Q = 1{\to}2$) is roughly 1/2 of the effective length of the ionization chamber, as indicated by the dotted line in Fig. 1. Thus, even if $Z-Q$ changes from 2 to 1, it could be back. In contrast, L ($Z{-}Q = 1{\to}2$) is longer than the effective length at 315 MeV/nucleon. $Z-Q$ might not change to 2 once it becomes 1. This is mainly the nature of Ar gas, which accounts for 90% of the P10 gas. Figure 1 also shows L

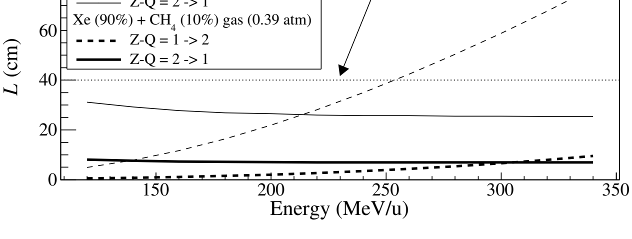

Fig. 1. Partial mean free path length of the change in the charge state in the ionization chamber as a function of the energy of the ^{208}Rn beam.

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of a Xe-based mixed gas (Xe 90% + CH_4 10%). The gas pressure was determined so that the energy deposit at 300 MeV/nucleon is same as that of the P10 gas. Even at 300 MeV/nucleon, L is shorter than that of P10 at 185 MeV/nucleon, indicating a better Z resolution.

The energy loss in the ionization chamber was simulated by using the energy-loss code ATIMA[4)] and GLOBAL. The fluctuation in Q was taken into account by the Monte Carlo method. The Z resolution of the 180-MeV/nucleon $^{210}_{85}$At beam was simulated to be 0.46%, which is consistent with the experimental value of 0.45%. Figure 2 shows the energy deposit of the 300-MeV/nucleon ^{208}Rn and ^{206}Ac beams into the effective region of the ionization chamber. The Z resolution is improved from 0.60% for the P10 gas to 0.39% for the Xe-based gas. This result is consistent with the discussion of Fig. 1.

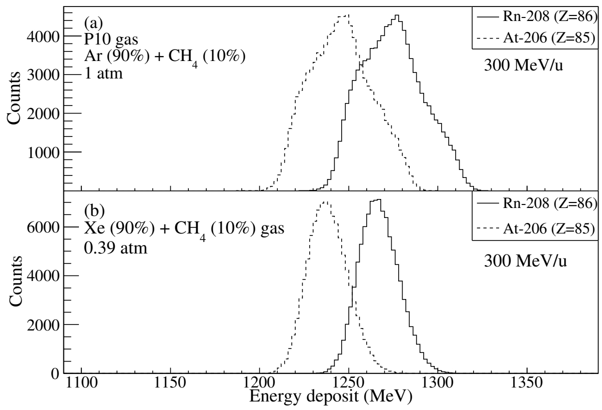

Fig. 2. Monte Carlo simulation of the energy deposit in the ionization chamber. Half of the energy-loss straggling in ATIMA was applied for the energy deposit.[5)]

An experimental study of PID using a Xe-based gas was already conducted, and a good Z resolution was obtained.[6,7)]

References

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