Energy resolution of a gas ionization chamber for high-energy heavy ions†

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Gas ionization chambers are used for the BigRIPS spectrometer to identify the atomic number of the flight particles by using the energy deposition.[1,2] Since the key parameter of the detector in this application is its energy resolution for heavy ions, an understanding of the energy resolution behavior of high-energy heavy ions is essential in discussing the particle identification performance. We report the energy resolution of the gas ionization chamber for heavy ions from the atomic number Z=31 up to Z=52 at low counting rates below 1 kcps, and which have an energy of nearly 340 MeV/nucleon.

The ionization chamber is installed at the F7 focal plane of the BigRIPS[1] spectrometer, which is operated using a counting gas mixture of Ar(90%)+CH_4(10%) at approximately 760 Torr. The effective gas thickness of 48 cm is divided into six segments, and energy spectra can be obtained for every 8 cm of gas thickness.[2] The dependence of energy resolution on the gas thickness is plotted in Fig. 1. As an example, we show the analysis results for ions Z=38 and Z=51. With the horizontal axis scaled as the inverse-square-root of the gas thickness, $L^{-1/2}$, a linear relationship is observed, as shown by the solid linear-fitting result lines; this observation is in good agreement with the experimental data. We conclude that the energy resolution is linearly dependent on $L^{-1/2}$. These results indicate that the energy resolution, $\Omega/\Delta E$, is expressed by statistical fluctuations in the energy loss, i.e., the energy straggling of heavy ions, Ω, and the mean energy deposition within the gas, ΔE, which are explained by the Bohr expression ($\Omega \propto ZL^{1/2}$) and the Bethe-Bloch formula ($\Delta E \propto Z^2L$), respectively.[3,4)]

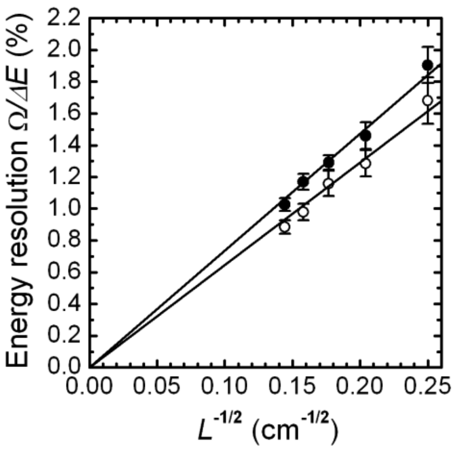

Fig. 1. Dependence of energy resolution on gas thickness obtained for heavy ions Z=38 (solid circles) and Z=51 (open circles). The solid lines are the results of linear fitting, which show the linear dependence on $L^{-1/2}$.

In Fig. 2, we plot the energy resolution as a function of the heavy ion atomic number for the cases of L = 24 cm ≡ L_1 (open circles) and L = 48 cm ≡ L_2 (solid circles). According to the Bohr expression Ω is also proportional to the incident ion atomic number, Z. Therefore, the energy resolution, $\Omega/\Delta E$, should be proportional to Z^{-1} because $\Delta E \propto Z^2$. The solid and dotted lines show the fitting results of CZ^{-1}, where C is the fitting parameter. The best-fit parameters were found to be C_1 = 61.2±1.2 and C_2 = 43.5±1.0 for L_1 and L_2, respectively. The ratio of these values is C_1/C_2 = 1.41±0.04, which shows excellent agreement with the value of $(L_1/L_2)^{-1/2} \approx 1.41$. This result is consistent with the above discussion, $\Omega/\Delta E \propto L^{-1/2}$.

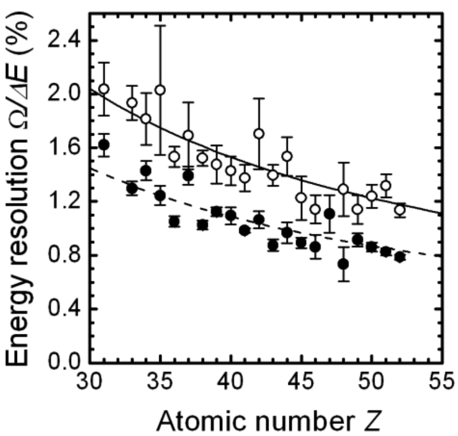

Fig. 2. Energy resolution as a function of the atomic number of fragment heavy ions produced from the in-flight fission of ^{238}U at 345 MeV/nucleon. Open and solid circles represent the cases with L=24 cm and L=48 cm, respectively. The solid and dotted lines are the results of the fitting of Z^{-1}.

In future works, the experimental energy resolution data for heavier ions up to uranium (Z=92) are required to discuss the performance of the ionization chamber for the identification of these heavy ions. In addition, the performance at high counting rates up to 1 Mcps is still unclear and requires further investigation.

References

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