Q-value resolution improvements in the spectroscopy of deeply bound pionic atoms using BigRIPS


In June 2014, we performed missing-mass spectroscopy on the deeply bound pionic atoms to measure their binding energies and widths.1,2) The Q values of the $^{122,117}$Sn($d,^3$He) reactions were measured using BigRIPS near the $\pi^-$ emission threshold. We succeeded in accumulating a sufficient number of events and achieved the best Q-value resolution in the spectroscopy of the $^{90}$Sr/$^{90}$Y source.

In our present experiment, we used a low-background environment because of the low production rate of the nuclei of interest. To efficiently count low-energy $\beta^-$ particles and form the third peak of the elemental abundance, we measured to be 5 cps. The origins of the background ground of $\gamma$ rays from the $^{90}$Sr/$^{90}$Y source.

The veto counter reduced the previous background rate by 2.4 cps. Finally, by raising the momentum spread of 0.04% (x) and achieved the best Q-value resolution in the spectroscopy of the $^{90}$Sr/$^{90}$Y source.

The emittance and momentum spread were monitored using the beam position and angle at the achromatic focal plane F3 and the dispersive focal plane F5 in BigRIPS. According to these measurements, the voltage and phase of the flat top cavity of SRC, the phase of the RF of RRC, and the voltage of the re-buncher were optimized. We also optimized the phase slit inside and the double slits downstream of the AVF cyclotron. After optimization, we achieved an emittance of 0.2 x 2.0 $\mu$m-$\text{mrad}$ (horizontal) and a momentum spread of 0.027% (x), which are dramatic improvements from those achieved in the pilot experiment: an emittance of 0.7 x 3.0 $\mu$m-$\text{mrad}$ and momentum spread of 0.04% (x).

To adjust the dispersion at F0, a new method was developed using position information at the F3 and F5 focal planes. In our experiment, we developed new ion optics with finite dispersion at F0 to realize the dispersion-matching condition.3) However, there are no high-precision position/angle detectors in the beam-transfer line to tune the optics. In the new method, the momentum deviation of the particle and the position at F0 can be deduced through position measurements at F3 and F5 using the following equations:

$$x_0 = x_3/(x|x)\alpha_3,$$
$$\delta = (x_5 - (x|x)\alpha_3)/(x|x)\beta_3.$$

Here, x0, x3, and x5 are the positions at the F0, F3, and F5 focal planes in BigRIPS, respectively. (x|x)\alpha_3 and (x|x)\beta_3 are the magnifications from F0 to F3 and from F3 to F5, respectively. (x|x)\beta_3 represents dispersion. Because of achromatic transport from F0 to F3, (x|x)\beta_3 is assumed to be 0. These transfer matrix elements of BigRIPS were measured in advance by setting the optics of the beam-transfer line to the standard mode, in which the F0 focal plane was achromatic. Figure 1 shows the 2D plot of the deduced $\delta$ and $x_0$ by using this method, we could measure and improve the new optics in the beam-transfer line.

As a result, we succeeded in improving the Q-value resolution. The peaks in the online spectrum of the present experiment were clearly narrower than those of similar past experiments. The precise analysis is in progress.

References