Spectroscopy of pionic atoms in tin isotopes by (d, ^{3}He) reactions

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We performed systematic spectroscopy measurements of pionic tin isotopes by (d, ^{3}He) reactions. We measured the masses of the reaction products, *i.e.*, pionic atoms, by missing mass spectroscopy. The incident deuteron beam energy was chosen as 500 MeV to enhance the formation cross-sections of the pionic atoms. We installed $A = 112, 115, 117, 119, 122$, and 124 tin isotopes at F0.

^{3}He emitted by an energy of ~360 MeV was momentum-analyzed by using the BigRIPS. We installed two low-pressure multi-wire drift chambers[1)] (MWDCs) at F5, and measured ^{3}He tracks. The MWDCs were operated with 30 kPa isobutane and had sufficient efficiency. We installed plastic scintillators at F5 and F7 for time-of-flight measurements. Combining the time-of-flight information with the measured energy loss at each scintillator, ^{3}He particles were identified.

One of the largest sources of resolution is the momentum spread of the primary beam, which was determined as $\delta p/p = 0.03\%$ (σ). We constructed dispersion matching optics by analyzing the beam momentum at F0 to have a dispersion of 44.6 mm/%. We developed a novel method of tuning the optical condition, called "trace-back method."[2)] In this method, the particle tracks at F3 and F5 are measured and the matrix elements in F0-F3-F5 are evaluated. Finally the trajectories are traced back to F0, and the phase distributions are deduced.

Figure 1 shows the position spectra of $p(d, ^{3}\mathrm{He})\pi^{0}$ reactions at F5 using a CH_2 target. The spectra were measured by placing the target at horizontal positions −3, 0, and +6 mm from the beam center. The beam spot size was enlarged to approximately 15 mm (σ) for the very large dispersion of 44.6 mm/% at the target. Without the dispersion matching conditions, the displacement of 3.0 mm at the target position causes a 5.5-mm shift at the F5 focal plane and severe deterioration of the energy resolution. In the spectra, we observe similar position distributions for the three target positions, which suggesting a nearly perfect realization of the dispersion matching conditions.

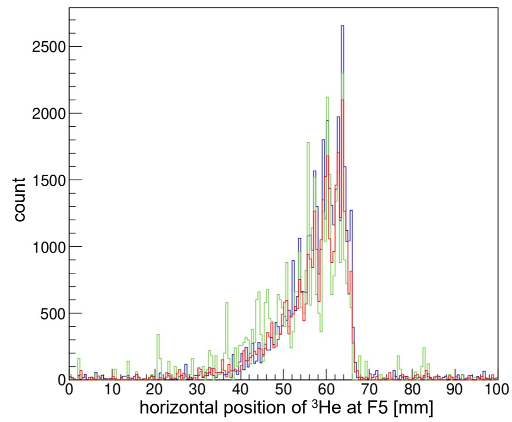

Fig. 1. Position distribution observed by $p(d, ^{3}\mathrm{He})\pi^{0}$ reactions. Blue, red and green lines represent data with CH_2 target at −3, 0, and +6 mm from beam center, respectively.

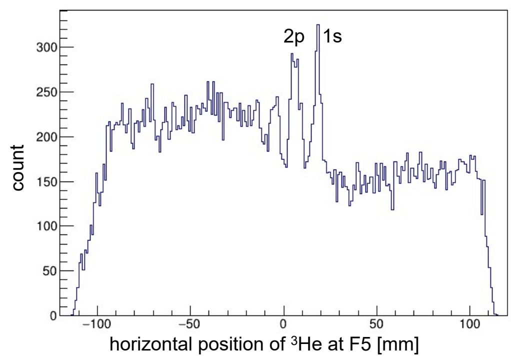

Fig. 2. Position spectrum measured using ^{124}Sn target.

Figure 2 shows a typical position spectrum observed in the production setting. We employed an ^{124}Sn target with a width of 6 mm and accumulated the data for approximately 50 min. Pionic atoms in 1s and 2p states are noticeable as peak structures.

We will continue the data analysis in terms of energy calibration, resolution improvement, and other factors.

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