Development of multiwire drift chambers and the readout system for focal-plane tracking detectors in BigRIPS

S. Y. Matsumoto,[*1,*2] H. Fujioka,[*1,*2] K. Itahashi,[*1] T. Kawabata,[*2] T. Nishi,[*1] A. Sakaue,[*1,*2] M. Takaki,[*3] Y. K. Tanaka,[*1,*5] T. Uesaka,[*1] Y. N. Watanabe,[*1,*4] K. Yako,[*3] and J. Zenihiro[*1]

We are developing a new focal-plane detector and readout system, aiming at searching for double Gamow–Teller giant resonance (DGTGR) via the $\left(^{12}\mathrm{C}, ^{12}\mathrm{Be}\left(0_2^+\right)\right)$ reaction and systematic high-precision spectroscopy of pionic atoms (piAF) via the Sn $\left(d, ^3\mathrm{He}\right)$ reaction.

Both experiments use the same detector configuration for missing-mass spectroscopy. The particles emitted in the nuclear reactions are momentum-analyzed in F0–F5 of BigRIPS and detected at the F5 dispersive focal plane. The tracking detector at F5 (i) should detect light ions and (ii) should work under high rate background conditions (on the order of megahertz for tritons in the DGTGR experiment and protons in the piAF experiment). In order to satisfy these conditions, we adopt multiwire drift chambers (MWDCs) instead of the standard tracking detector, PPACs.

We decided to develop low-pressure MWDCs that can be operated in vacuum[1)]. In the preceding experiment of pionic atom spectroscopy in 2014, MWDCs with a gas pressure of 1 atm were operated in air. A vacuum window (50-μm-thick stainless) located upstream caused multiple scattering. While the intrinsic tracking resolution was found to be $\sim$ 0.1 mm (FWHM), the effect of multiple scattering resulted in the deterioration of the position resolution up to 4.1 mm (FWHM) at maximum. This deterioration is suppressed by using the low-pressure MWDC.

Our new MWDCs have configurations with sets of 1/3-cell staggered three-layer structures, (XX'X"(0°), UU'U"(+30°), VV'V"(−30°)), as schematically shown in Fig. 1. The previous MWDCs had sets of 1/2-cell staggered two-layer structures and showed a nonnegligible inhomogeneity in the spectra originating in an analytic bias in the proximity of both the sense and potential wires. The asymmetric probability distribution of the estimated drift length near the wires due to the boundary condition (0 ≤ drift length ≤ wire interval) caused a bias for the reconstructed track, disfavoring the close proximity of the wires. This effect is expected to be exhibited even with an exactly known drift-time-to-length conversion with a finite resolution, as demonstrated by a simple Monte Carlo simulation[2)] and becomes prominent in extremely high-statistics data. For each set of layers in the new MWDCs, we use the drift length information of two of the three layers by neglecting the data of the layer where the trajectory is closest to a wire. On the basis of the previous experiment, we expect a high-rate capability (0.1–1MHz) and sufficient plane resolution (0.3 mm (FWHM)) for the detector.

An upgrade of the readout system for the new MWDCs is necessary to realize high-speed data handling. As for the hardware of the system, we are developing a new all-in-one board[3)] that handles a higher triggering rate (∼10kHz). The board reads 64 channels of MWDC analog signals and amplifies, discriminates, and digitizes them by FADC and TDC. The board also receives trigger tag information from an event tagging system and transfers data by an SiTCP[4)] network processor implemented by an FPGA. There are two modes for reading data, raw and suppress modes. The raw mode is an option for recording all of the data of FADC, and the suppress mode, which is used in our experiments, is prepared for lowering the data size by collecting the data of channels with more than one TDC hit. We have been working on building a DAQ system with eight boards and combining this system with the standard RIBF DAQ[5)].

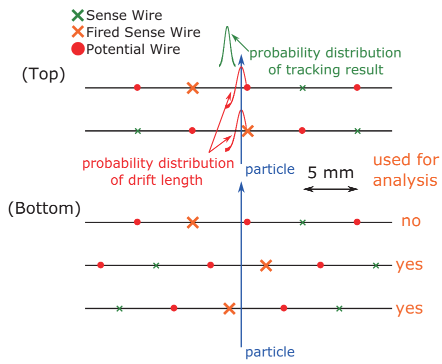

Fig. 1. Schematics of the old (top) and new (bottom) MWDC wire configurations. The new (old) MWDC has sets of 1/3-cell (1/2-cell) staggered three(two)-layer structures. The new MWDC has a redundant design to avoid the analytical bias originating from the asymmetric probability density distribution of the estimated drift length in the proximity of the wires.

References
1) H. Miya *et al.*, Nucl. Instr. Meth. B **317**, 701 (2013).
2) Y. K. Tanaka: Ph. D. thesis, Univ. Tokyo (2016).
3) H. Yamakami: Master's thesis, Kyoto Univ. (2015).
4) T. Uchida, IEEE Trans. Nucl. Sci. **55**, 3, 1631 (2008).
5) H. Baba *et al.*, Nucl. Instr. Meth. A **616**, 65 (2010).

*1 RIKEN Nishina Center
*2 Department of Physics, Kyoto University
*3 Center for Nuclear Study, University of Tokyo
*4 Department of Physics, University of Tokyo
*5 GSI Helmholtzzentrum für Schwerionenforschung GmbH