PROCEEDINGS OF SCIENCE

Development of a GEM-based TPC for H-dibaryon Search at J-PARC

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We developed a TPC using GEMs and a gating grid to search for the H-dibaryon at J-PARC with high rate hadron beams up to 10^6 count per second (cps) / cm^2. The TPC consists of an octagonal-shape drift cage filled with Ar-CH_4 (90:10) gas, and an end cap detector consisting of a gating grid, a triple GEM stack, and readout pads. The TPC is operated in the magnetic field of 1 T. We built a small prototype TPC and performed tests. The hit position shift due to ion backflow was suppressed within 0.2 mm at the beam rate up to 5×10^5 cps/cm^2. The hit detection efficiency was better than 90% up to the beam rate of 3×10^6 cps/cm^2. The horizontal position resolution was improved by 40 – 50% in the magnetic field from 0 to 0.68 T at a laser test.

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1. Introduction

We developed a TPC to search for H-dibaryon in ^{12}C(K^-,K^+)$\Lambda\Lambda X$ reaction (the J-PARC E42 experiment [1]). Figure 1 shows a schematic view of the E42 TPC (HypTPC) [2]. The drift cage has an octagonal-prism shape of 58 cm diameter and the drift length (vertical) of 55 cm, where the magnetic field of 1 T is applied in parallel to the drift field. The diamond target is positioned inside the drift volume with a cylindrical target holder. The end-cap detector consists of a gating grid and three-layer GEMs [3] (two GEMs with 50 μm thickness and a GEM with 100 μm thickness in the bottom). The configuration is adopted to suppress the ion backflow as much as possible to cope with field distortion. A high rate K^- beam of 10^6 cps is injected directly into the drift volume, and two π^-s and 2 protons are reconstructed. The $\Lambda\Lambda$ invariant mass resolution is required to be better than 2 MeV/c^2. The hit position distortion due to ion backflow should be less than 1 mm in order not to deteriorate position resolution.

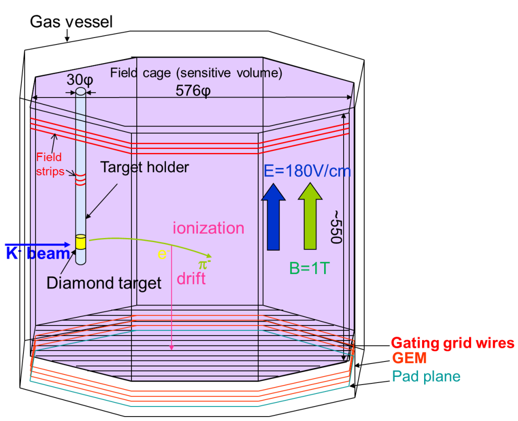

Figure 1: A schematic view of the E42 TPC (HypTPC) design.

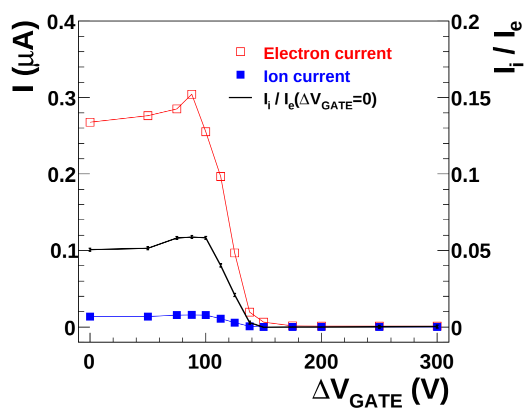

Figure 2: The electron current (open squares) (μA), the positive ion current (filled squares) (μA), and the ion backflow fraction (thick line) as a function the gate voltage in V, where the voltage of the 50 μm GEM is kept to 325 V

2. Performance evaluation of the prototype TPC

In order to evaluate performance required for E42, we built a small TPC with the transverse dimension of 10×10 cm^2 with the drift length of 20 cm.

2.1 Backflow measurement

We measured the ion backflow using a ^{90}Sr source. Figure 2 shows the electron current and the ion current as a function of the gate voltage. At the gate voltage of 0, the ion backflow fraction to the electron current is 4.5 ± 0.2% at the GEM voltages of 325 V and 488 V for the 50 μm GEMs and the 100 μm GEM, respectively. The gain was 1.7×10^4. By applying the gate voltage, the ion backflow is suppressed further, and the ion backflow fraction at the gate voltage of $150-300$ V is measured to be $0.00 \pm 0.04\%$.

2.2 Beam test

In order to evaluate performances at high rates, we performed a test using a 400 MeV proton beam. The horizontal resolution was measured to be $0.19-0.46$ mm using TPC tracks at the drift length of $5-20$ cm with 4-mm wide pads without the magnetic field. The expected horizontal position resolution at E42 with 1 T magnetic field is better than 0.3 mm, which fulfills the requirement. Efficiency better than 90% was obtained at the beam rate up to 3×10^6 cps/cm^2.

We measured the hit position distortion using external trackers as shown in Fig. 3. With the gate open, we observed the horizontal position shifts of ± 1.3 mm at the beam rate of 9.1×10^3 cps, while in the gate operation, it is suppressed within ± 0.2 mm at the beam rates up to 5×10^4 cps. The vertical distortion with and without the gate operation was within ± 0.2 mm. The expected distortion at E42 was estimated using the measured data and the measured ion backflow, assuming linear dependence of the distortion on the ion current, to be 0.3 ± 0.2 mm both in the horizontal and vertical directions.

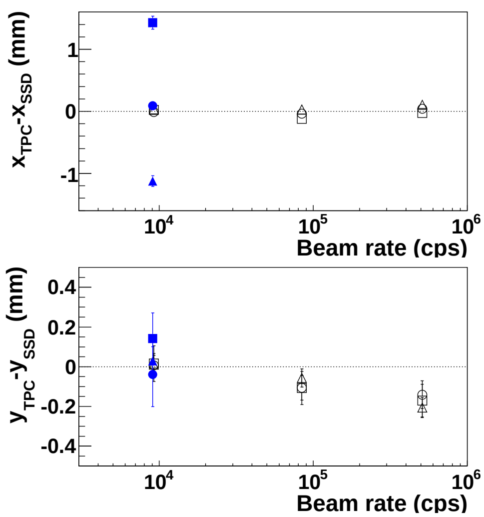

Figure 3: Horizontal (top) and vertical (bottom) cluster position distortion (mm) with respect to those at a low beam rate (6.58×10^3 cps) with the gate voltage of 150 V as a function of the beam rate for P-10. In the top (bottom) plots, circles, squares, and triangles are at 0, -4 mm, and +4 mm with respect to the beam center horizontal (vertical) position of 19.8 mm (143.3 mm), respectively. Open symbols are at the gate voltage of 150 V and filled symbols are at 0 V.

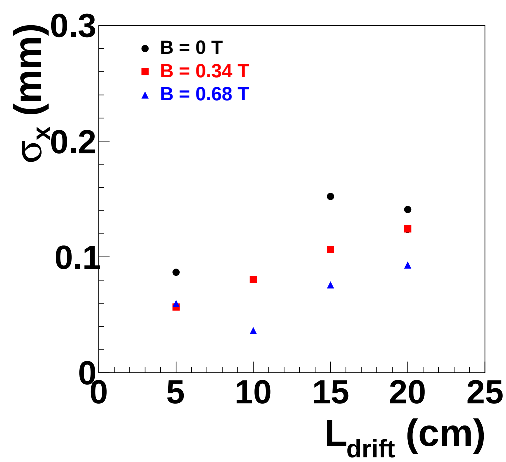

Figure 4: The horizontal resolution as a function of the drift length with the 3-mm wide pads at the magnetic fields of 0 T, 0.34 T, and 0.68 T.

2.3 Laser test with the magnetic field

We performed a test in the magnetic field using a UV laser. We injected a horizontal YAG laser beam of 266 nm wavelength through quartz windows on the gas vessel. Fig. 4 shows the horizontal position resolution as a function of the drift length. We observed the reduction of the resolution by $40-50\%$ at the magnetic field from 0 to 0.68 T. Note that the resolution is smaller by 60 % compared to that for a minimum ionizing particle due to a much larger number of ionized electrons.

3. Conclusions

In summary, we built a prototype TPC and evaluated performance required for the E42 experiment. We measured the backflow fraction of 5% with only the GEMs, and less than $\pm 0.04\%$ also with the gating grid. The hit position distortion for E42 was estimated to be 0.3 ± 0.2 mm, within the requirement of 1 mm. The efficiency was better than 90% at the beam rate up to 3×10^6 cps/cm^2. The horizontal position resolution for E42 with 1 T magnetic field was estimated to be better than 0.3 mm from the measured resolution without the magnetic field. The horizontal position resolution was improved by $40-50\%$ in the magnetic field of 0.68 T at the laser test. These prototype performance fulfil the requirements of E42. The E42 TPC has been designed based on the test results, and is currently under construction.

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