Time Projection Chamber "HypTPC" for the high rate beams at J-PARC

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J-PARC can provide secondary beams with the world's highest intensities such as kaon. The high intensity beam enables us to search for new exotic states such as a H-dibaryon with high statistics, and the study of new exotic states helps deepen understanding of low-energy nonperturbative phenomena in QCD.

In recent years, the hadron group in ASRC has strongly contributed to develop a Hyperon Spectrometer (HS) by collaborating with Korea University and so on. The HS consists of a superconducting magnet, a time projection chamber called as a "HypTPC", and a time-of-flight system. HypTPC is the central tracker of HS. It measures the tracks of multiple charged particles in three dimensions as a bubble chamber with excellent momentum and special resolution, and large acceptance.

The design challenges of HypTPC are to make beam particles with about 1M cps (counts per second) pass perpendicularly to the TPC drift axis and make them hit an experimental target installed inside the TPC drift volume as shown in Fig.1. Thereby, HypTPC should have a capability for the high-particle rate, so that we adopted a triple GEM (Gas Electron Multiplier) amplification for signal detection and the gating-wire grid to suppress the ion backflow. The GEM is more stable against discharge compared with wire chambers under the high particle rates. Moreover, the P-10 (Ar : CH_4 = (90:10)) gas, whose maximum drift velocity is 5.3 cm/μs, is selected for the high particle-rate capability. This faster drift velocity has an advantage for the high rate operation to reduce the accidental track rate.

By using this powerful spectrometer, we propose three experiments at J-PARC to search for new exotic states. The E42 experiment, which aims to search for H-dibaryon, a multi-quark baryonic states with 6-quark (*uuddss*) configuration. The E45 experiment, for investigating baryon excited states, such as N* and Δ*, in (π, 2π) reactions. The E72 experiment, to search for a narrow Λ* resonance by using p(K^-, Λ) reaction. In addition, we have recently submitted a Letter of Intent to propose a new experiment to search for the double kaonic nucleus, which is a quasi-bound state of $\bar{K}$ and nucleus, K^-K^-pp. Since the HS is a multi-purpose large acceptance spectrometer, not only the proposed experiments but also new experiments in the near future, it is expected to lead the hadron physics at J-PARC facility.

We have constructed the HypTPC detectors and carried out a beam test at the Heavy-Ion Medical Accelerator Complex (HIMAC) by using 230 MeV protons with beam rates up to 1 MHz in order to confirm the basic performance and test the high rate capability of the HypTPC. This test experiment was carried out without a magnetic field. A photograph of the experimental setup of this experiment is displayed in Fig. 2. The result of the HIMAC data analysis is described in detail in Ref. [1].

The spatial resolutions on the pad plane without a magnetic field were measured to be 400 – 700 μm, depending on the drift length. The measured resolution corresponds to be 200 – 300 μm in a magnetic field of 1 T, which is consistent with our design value.

Even at the 1 M cps beam rate, the track candidates can be selected correctly by using a Hough transformation method. The measured pad efficiency of about 98% was almost unchanged up to 1M cps beam rate. Moreover, we observed no significant change in the transverse and longitudinal spatial resolutions under the high rate condition. We concluded that the HypTPC achieved the sufficient performance to carry out the actual experiments at J-PARC. The E42 experiment, which is the first physics experiment employing the HS, is planned to be carried out in June 2021.

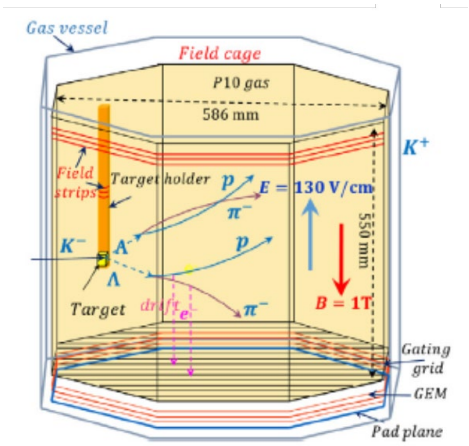

Fig1. Schematic view of HypTPC

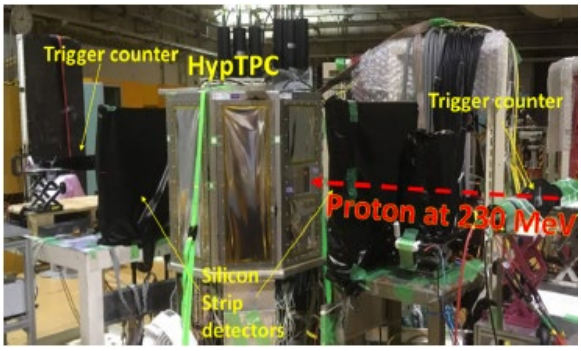

Fig2. Photograph of experimental setup at HIMAC. The plastic scintillators are installed both upstream and downstream of HypTPC as trigger counters. The silicon strip detectors are also installed both upstream and downstream of HypTPC as position reference detectors.

References

[1] S.H. Kim, Y. Ichikawa, H. Sako, et al., Nucl. Instrum. Methods Phys. Res. A **940**, 359 (2019).