

Activities at J-PARC

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Among research activities of the J-PARC group in 2018, we highlight the following topics.

- I.a Development of a scintillation fiber tracker for measuring high-intensity beams [1]
- I.b Development of a beam timing detector for the charmed baryon spectroscopy [2]
- I.c Development of prototype for the streaming data acquisition system of the charmed baryon spectroscopy at J-PARC [3]
- II.a Measurement of the $\pi^0\Sigma^0$ missing mass spectrum [4]
- II.b Study of $\bar{K}NN$ bound state via ${}^3\text{He}(K^-, \Lambda p)n$ reaction at J-PARC [5]

Here, we introduce each topic digestly. More detailed descriptions can also be found in Refs [1]-[5] (to be found in this site, except [4])

I. Charmed Baryon Spectroscopy at the J-PARC High-Momentum Beam Line

We are conducting a new platform of hadron physics under the MoU between RCNP, IPNS, and J-PARC at the J-PARC High-momentum Beam Line. We are preparing for an experiment on charmed baryon spectroscopy via the $p(\pi^-, D^{*-})$ reaction (E50) [6]. We report progress on some detector developments for the E50 spectrometer achieved in 2018.

a. Development of a scintillation fiber tracker for measuring high-intensity beams [1]

Scintillating fiber trackers plays an essential role in E50, which is expected to work at a high beam rate greater than 1 MHz/mm. We developed a prototype of the scintillation fiber tracker for beam tracking in E50. Two sets of X, U, V fiber sheets are aligned at a distance of 317 mm. The X, U, and V sheets are tilted 0, +30, and -30 degrees to the vertical line, respectively. Each sheet has a width of 6 mm. Each sheet comprises two layers. Six fibers of 1 mm in diameter each are aligned in each layer. The second layer is staggered 3 mm to the first one. Although the prototype tracker covers limited area, it was enough to see the spatial resolution, timing response, and tracking efficiency at various beam conditions.

We carried out a test experiment [7] with high-intensity electron/positron beams at the Research Center for Electron Photon Science (ELPH) in Tokoku University. We demonstrate satisfactory performances of 160 μm in spatial resolution, ~ 1 ns in time resolution, and 97% of a layer efficiency at an expected beam rate of 1 MHz/mm in E50. Details are described in Ref. [1].

b. Development of a beam timing detector for the charmed baryon spectroscopy [2]

A cherenkov counter with an X-shape of an acrylic (Polymethyl Methacrylate, PMMA) radiator have been developed as a time zero counter used in E50, as shown in Fig. 1. A beam particle intercepts the radiator twice. At the first intercept, cherenkov light emitted along the radiator will be propagated diagonally downward to one photon sensor (MPPC). At the second intercept, emitted cherenkov light will be propagated diagonally upward to the other photon sensor. Compared with a single tilted acrylic bar type configuration, the X-shaped configuration reduces a time jitter depending on the beam position in height by taking a mean time of the two signals, and the time resolution is improved by detecting double photons.

Performance test of the time zero counter was done under high-intensity electron beams at ELPH [7]. We demonstrated that the time resolution is ~ 54 ps at a beam rate of 2~3 MHz. We found that the resolution becomes worse as the beam intensity increases because a ringing tail of the previous signal is piled up by the signal and affects the time resolution. Further improvement of the time resolution will be achievable by improving signal shape of the preamplifier. Details are described in Ref. [2].

c. Development of prototype for the streaming data acquisition system of the charmed baryon spectroscopy at J-PARC [3]

A streaming DAQ system is a so-called dead-time-less data acquisition system, which is a key technology for E50 to handle a number of event data due to a high interaction rate of greater than 3 MHz caused by an

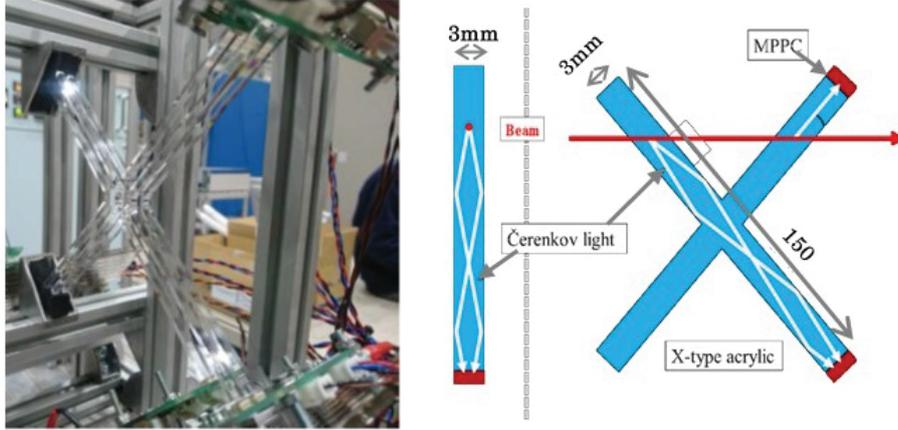


Figure 1: X-shaped acrylic Cherenkov counter for the time zero counter in E50

intense pion beam of 30 MHz. The concept of the streaming DAQ system are as follows. Each digitizer module connected to detectors records event data with a global time stamps in an internal memory. The data are read out by a corresponding process in a CPU via a network link. Then, a data stream is formed module by module. Since each data stream contains number of event hits from a corresponding module in a time order, event data scattered in different data streams are reconstructed by referring time stamps in the next process. In this step, data traffic among the processes becomes very complicate and load balance of employed processes are taken into account. Once event data are reconstructed, the data are recorded on the data storage devices. Before the data storage, one can insert a filtering process to reduce the data size to record, where preliminary analysis can be done to discard unwanted events. Technical details are described in [3].

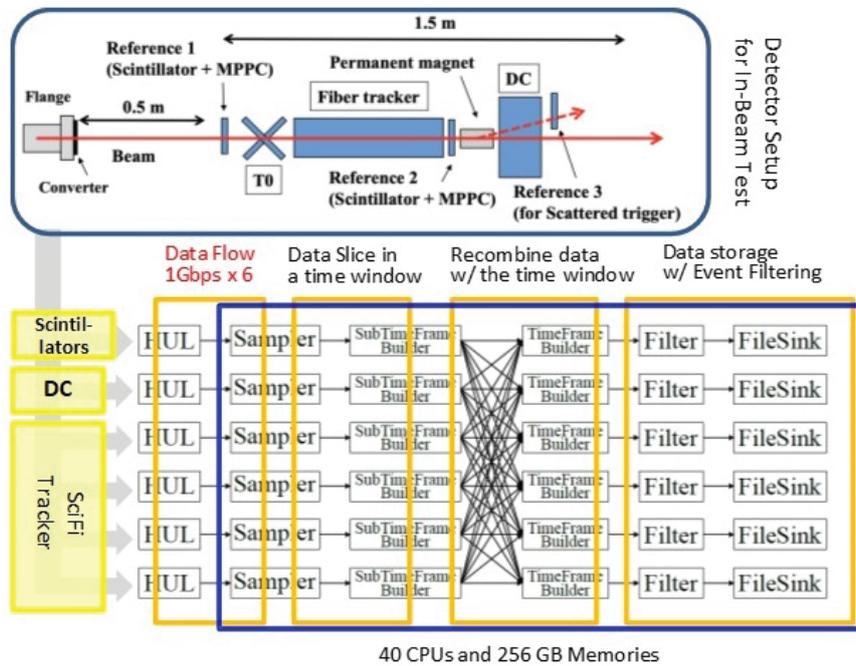


Figure 2: Setups of a beam test for prototype of the streaming DAQ system at ELPH.

We successfully demonstrated a scheme of the streaming DAQ system with a detector complex under a high intensity electron beam at ELPH [7]. A schematic drawing of the detector set up and data flow in the streaming DAQ system is illustrated in Fig. 2. Six FPGA-based streaming TDC modules developed in the Hadron Universal Logic modules [8] are used as digitizers for 14 channels of scintillation counters, 30 channels

of a drift chamber, and 128 channels of a scintillation fiber tracker. The DAQ system could record without significant data loss up to a data rate of 6 Gbps, which is limited by a maximum speed of the network link (1 GbE×6). This is an epoch-making demonstration for the streaming DAQ system. Since the data size in E50 is expected to be about 100 times more than that in the present test, we will be able to manage in principle by simply increasing parallel processing on the system of proportionally scaled CPUs, memories, and network links.

II. Study of Hyperon Resonances below $\bar{K}N$ threshold via the $d(K^-, n)$ reaction and related topics

a. Measurement of the $\pi^0\Sigma^0$ missing mass spectrum

The J-PARC E31 experiment [9] aims at investigating the so-called double pole structure of $\Lambda(1405)$ [10] via the (K^-, n) reaction on a deuteron target.

Since we carried out the second physics run in January and February, 2018. We have accumulated 3 times more data compared with those taken in the first physics run in 2016.

As already reported in Refs. [11, 12], we successfully identified the $d(K^-, n)X_{\pi^0\Sigma^0}$ reaction and observed the $\pi^0\Sigma^0$ missing mass spectrum. We obtained the missing mass spectrum of $\pi^0\Sigma^0$ with good statistics in the second run, as shown in Fig. 3. We confirm the characteristic line shape below and above the $\bar{K}N$ mass threshold, which carries direct information on the $\bar{K}N \rightarrow \pi\Sigma$ scattering amplitude in the isospin = 0 channel below and above the $\bar{K}N$ mass threshold. We expect that the pole information can be extracted in the $\bar{K}N$ scattering amplitude.

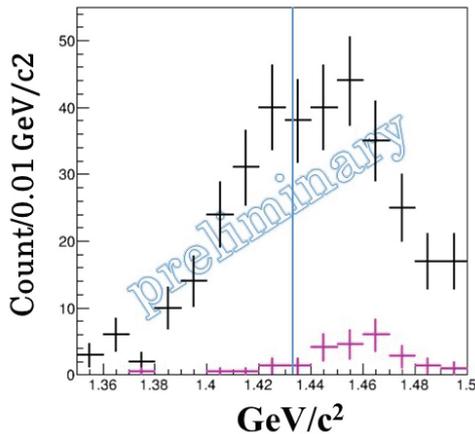


Figure 3: Missing mass spectrum of $d(K^-, n)\pi^0\Sigma^0$ (black crosses) and estimated background spectrum (magenta crosses). A blue vertical line indicates the K^-p mass threshold. Acceptance correction has yet to be done.

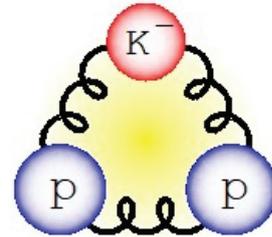


Figure 4: Schematic illustration of the K^-pp bound system

b. Study of $\bar{K}NN$ bound state via ${}^3\text{He}(K^-, \Lambda p)n$ reaction at J-PARC [5]

As for a topic related to the E31 experiment, we report a remarkable result of the J-PARC E15 experiment [13]. The E15 collaboration reported a hitherto-unknown state below the K^-pp mass threshold. The state is regarded as a bound state comprises a kaon and two protons, the so-called K^-pp bound state (Fig. 4). The binding energy and the width are found to be as deep as 47 MeV and as wide as 115 MeV, respectively. This work was published as the dissertation of doctor of philosophy in Osaka University [14] and in Physics Letters B [15]. Compared with the fact that the binding energy of a nucleon in nucleus is less than 1% of the nucleon mass, the binding energy of the K^-pp state is as large as 10% of the kaon mass. More details are described in Ref. [5]. After the state is found, new questions arise, such as what is the spatial size/quantum state of it, how deep a kaon is bound in nuclei/nuclear matter, and so on. A new aspect on the studies of the kaon-nucleon interaction is open.

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