

## Research Group for Hadron Nuclear Physics

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The research objectives of the Hadron Nuclear Physics Group are experimental studies of 1) exotic hadrons and nuclei with strange and charm quarks and 2) hot and dense partonic/hadronic matter at J-PARC, BNL-RHIC, and Belle (II). Through these topics, we investigate many-body problems of quarks and hadrons in relation to Quantum Chromo Dynamics (QCD).

### Hadron experimental studies at J-PARC

We completed the J-PARC E03 experiment (X-ray spectroscopy with  $\Xi^-$  atom) in Apr. 2021 [1]. We collected 95 billion  $K^-$  irradiated events, which correspond to 95% of the planned statistics. The analysis of the X-ray spectrum is underway.

We also completed the first experiment E42 (Search for H-dibaryon) to use the Hyperon Spectrometer in June 2021, with 175 billion  $K^-$  irradiated events. The Time Projection Chamber (TPC) has been stably operated with good 3-dimensional tracking performance as shown in Fig. 1. The efficiency of 94% is achieved. Calibration of the TPC such as the baseline correction and the drift time correction is being performed.

We analyzed the E40 (Study of  $\Sigma^+p$  scattering) data, and published two papers for  $\Sigma^+p$  elastic [1] and  $\Sigma^+p \rightarrow \Lambda n$  inelastic [2] scatterings. A press release is also published for the former result. For details, refer to the research highlight article in this volume.

The Transition Edge Sensor detector developed for the X-ray spectroscopy for Kaonic atoms at K1.8 beamline was applied for muonic atoms and detailed deexcitation processes were unveiled [3]. We issued a press release for this result.

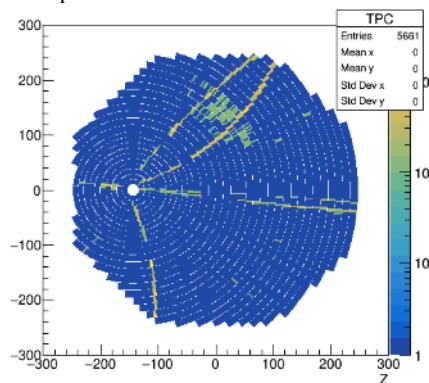


Fig.1: An interaction event of the TPC at J-PARC E42 experiment.

J-PARC E16 aims at studying in-medium modification of the  $\phi$  meson spectrum through  $\phi$  decay into  $e^+e^-$  inside the nucleus. A commissioning run of E16 was performed in May-June 2021. We evaluated the electron identification and pion rejection performance of Hadron Blind Detectors and Lead Glass Calorimeters. We also tested time-of-flight measurements with prototype Multi-gap Resistive Plate Chamber (MRPC) and a start

timing counter for charged hadron identification for the  $\phi \rightarrow K^+K^-$  experiment (P88 below). We also developed a high-rate capable MRPC by heating glass sheets and confirmed improvement of the timing resolution by increasing temperature at LEPS2. We submitted a proposal for the  $\phi \rightarrow K^+K^-$  measurement to J-PARC Program Advisory Committee (PAC) in June 2021, and two reviews were held in July 2021 and Jan. 2022. The proposal (P88) is going to be approved for Stage-I status (physics importance) in early JFY 2022.

### Other research activities

We propose a future heavy-ion beam program at J-PARC (J-PARC-HI) to create dense baryonic matter to search for a phase boundary and the QCD critical point in the QCD phase diagram. We submitted the first experimental proposal (P89) to J-PARC PAC in July 2021, which aims to measure the temperature of thermal photons with  $e^+e^-$  pairs at the J-PARC E16 spectrometer with detector upgraded for heavy-ion collisions to search for the phase transition. The proposal submission accelerated the discussions for J-PARC-HI in J-PARC center and JAEA.

We also studied exotic hadrons at Belle and Belle II experiments, and studied high-density matter at the STAR experiment and developed silicon-strip detectors for sPHENIX experiment at RHIC.

### Reimei research programs

The Reimei research program “Systems with two strange quarks at FAIR and J-PARC” continued since JFY 2020 to strengthen the cooperation between scientists working at J-PARC and FAIR, the only two facilities in the world for the two-strange quark systems, through an international collaboration with Prof. J. Pochodzalla (Univ. of Mainz). We continued weekly seminars between our Reimei research program and the THEIA program funded by EU, including discussions on research plans to search for X-rays from heavy hyperatoms for the PANDA experiment at FAIR and J-PARC experiments.

We proposed another Reimei program “Collaborative research to evaluate QCD vacuum properties at high density from  $\phi$  meson decay inside the nucleus”. In this program, we collaborate with theorists led by S. H. Lee (Yonsei Univ.) and experimentalists at J-PARC to study  $\phi$  properties inside the nucleus. We developed theoretical model for J-PARC P88 to support the review. We held a Reimei Workshop “Hadrons in dense matter at J-PARC” online with about 100 participants in Feb. 2022.

### References

- [1] K. Miwa *et al.*, Phys. Rev. C **104**, 045204 (2021).
- [2] K. Miwa *et al.*, Phys. Rev. Lett. **128**, 072501 (2022).
- [3] T. Okumura *et al.*, Phys. Rev. Lett. **125**, 053001 (2021).