

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

In J-PARC E07 experiment (studies of double Λ hypernuclei), we observed an event for Ξ^- nucleus bound system ($\Xi^- + {}^{14}\text{N} \rightarrow \Xi^- {}^{15}\text{C}$) named “IBUKI-event” as shown in Fig. 1 [1]. The event was uniquely interpreted as a ${}^{15}\text{C}$ hypernucleus decaying into ${}^{10}\text{Be}$ and ${}^5\text{He}$. The binding energy of Ξ^- was obtained to be 1.27 ± 0.21 MeV, suggesting a Ξ^- bound in the nuclear 1p state. This is the first precise determination of the Ξ^- binding energy of Ξ hypernuclei. For details, refer to the research highlight article in this volume.

In preparation for the Hyperon Spectrometer for E42 (H-dibaryon search), E45 (baryon spectroscopy with $\pi\text{N} \rightarrow \pi\pi\text{N}$ reactions), and E72 (search for a new Λ resonance), commissioning runs for the water Cherenkov counter (WC) and HypTPC were performed at J-PARC K1.8 experimental area during E40 beam time in June 2020 and Feb. 2021. As a result, the efficiencies of π , K, p with WC were evaluated to fulfil the requirement of E42. HypTPC also had good track reconstruction performance. E42 beam time is scheduled in June-July 2021.

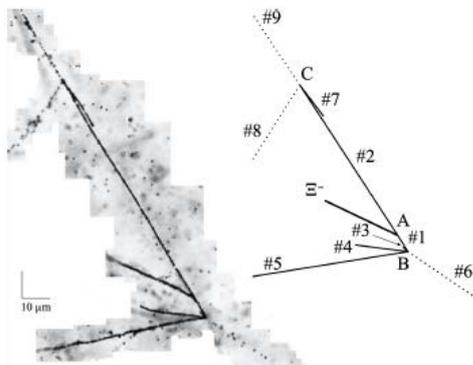


Fig.1: A hypernuclear event of $\Xi^- + {}^{14}\text{N} \rightarrow \Xi^- {}^{15}\text{C}$.

For J-PARC E03 (Ξ atom X-ray spectroscopy), we tuned the secondary kaon beamline (K1.8) in June 2020 and finished the detector installation and tuning in Dec. 2020. We started the physical run in Dec. 2020 but it was suspended in Feb. 2021 due to a trouble in J-PARC Main Ring synchrotron. The experiment will be resumed in Apr. 2021 to complete the data taking.

J-PARC E16 aims at studying in-medium modification of the ϕ meson spectrum through ϕ decay into e^+e^- inside the nucleus. The first and second commissioning runs of E16 were performed in June 2020 and Feb. 2021, with the proton beams transported in the newly-constructed high-momentum beamline. We confirmed performance of the proton beams such as the beam profiles. We also successfully operated the tracking detectors (GEM Trackers and Silicon Strip Detectors) and electron identification detectors (Hadron Blind Detectors and Lead Glass Calorimeters). In addition, we tested prototype detectors for charged hadron identification with the time-of-flight measurement: a high timing resolution chamber (Multi-gap Resistive Plate Chamber) and start timing counters for $\phi \rightarrow K^+K^-$ measurement, and good timing resolution of ~ 70 ps was obtained in the time-of-flight measurements between these detectors. A Letter-of-Intent for the $\phi \rightarrow K^+K^-$ measurement was submitted to J-PARC Program Advisory Committee (PAC) in Dec. 2020.

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 organized the J-PARC-HI Working Group to aim at submitting the first experimental proposal to J-PARC PAC.

We found a large left-right asymmetry of neutral pions at very forward angles in polarized proton-proton collisions at the RHICf experiment, which will change theoretical interpretation of the particle production mechanism [2]. We also participate in Belle and Belle II experiments to study hadrons with heavy quarks. Belle II achieved the world's highest luminosity in June 2020.

Reimei research programs

The Reimei research program “Systems with two strange quarks at FAIR and J-PARC” was proposed 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), organized by Mainz Univ. Helmholtz Lab., JAEA, Tohoku Univ., and Kyoto Univ. We held 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 PANDA experiments at FAIR and the J-PARC experiments E03, E42, E45, and E70.

References

- [1] S. H. Hayakawa, et al, Phys. Rev. Lett. 126, 062501 (2021).
- [2] M. H. Kim, et al, Phys. Rev. Lett. 124, 252501 (2020).