Research Group for Hadron Physics

Group Leader : Ken-ichi Imai

Members : Toshiki Maruyama, Hiroyuki Sako, Susumu Sato, Shoichi Hasegawa, Kotaro Shirotori, Hitoshi Sugimura, Minoru Okamoto, Yudai Ichikawa, Sanghoon Hwang, Ryuta Kiuchi, Shoji Nagamiya

The objectives of Research Group for Hadron Physics are experimental study of hypernuclei and hadrons including strangeness, utilizing the high intensity K and π beams at J-PARC, and related theoretical studies on nuclear matter in compact stars, nuclei, and hadrons. All of the studies are motivated by unknown aspects of nuclear matter under extreme conditions and strange hadrons such as interaction between hyperons. More general hadron physics through both experimental and theoretical approaches is also in our scope.

Search for a pentaquark Θ^+ (E19)

As the first hadron physics experiment at J-PARC, we have searched for a pentaquark Θ^+ by $\pi^- p \rightarrow K^- X$ reaction at 1.92 and 2.0 GeV/c. We used the K1.8 high resolution beam line and SKS spectrometer which provided a very good mass resolution (1.4 MeV/c^2 FWHM). The sensitivity to a possible pentaquark production was improved by an order of magnitude from the previous experiment at KEK-PS. No peak was found in the missing mass spectrum and an upper limit of the production cross section (0.26μb/sr) was provided [1]. This result gives a very severe constraint on the existence of the pentaquark Θ^+.

Search for kaonic nuclei (K^-pp state) (E27)

We have performed the first stage measurement of J-PARC E27 to establish the existence of kaonic nuclei, especially K^-pp bound state. A possible existence of the kaonic nuclei and the K^-pp state has been a controversial issue both theoretically and experimentally. Decisive experiments at J-PARC have been awaited. This state was searched by $\pi^+ d \rightarrow K^+ X$ reaction at P_{π^-}=1.7 GeV/c in E27. We have employed range counters surrounding a liquid deuterium target in addition to the K1.8 beam line and SKS spectrometers. The range counters can enhance the signal of the state which is expected to emit two energetic protons. The observed missing mass spectrum is compared to a simulation using past data for proton and neutron Fermi-motion in a deuteron (Fig.1). The spectrum at the low mass region is well reproduced by quasi-free Λ and Σ productions except the well-known ΣN threshold cusp region. In the high mass region, however, a large discrepancy between data and the simulation based on Λ(1405) and Σ(1385) quasi-free productions was found [2]. It may suggest a large modification of Λ(1405) in the final state. Further analysis has been underway.

Detector R&D for experiments at J-PARC

We carried out R&D and construction of several detectors for coming experiments with high intensity π and K beams at J-PARC. Scintillation fiber trackers with MPPC readout were constructed for a good position resolution (180μm) and high rate capability (50MHz). They were successfully operated together with silicon strip detectors for E10 (Search for neutron rich hypernuclei $^6H_\Lambda$ [3]). A lot of efforts on R&D of TPC and a full simulation for experiments with TPC have been made. As the result, E42 (Search for H-dibaryon) and E45 (Extensive spectroscopy of nucleon resonances) were approved by J-PARC PAC, and full-size proto-type TPC was designed and constructed.

Structures and properties of nuclear matter in the neutron star crust

We numerically explored structures and properties of low-density nuclear matter where inhomogeneous structures "pasta" might appear as ground states. We have employed a fully three-dimensional calculation without any assumption on the geometry of the matter structure [4]. This fiscal year, we have focused on beta-equilibrated nuclear matter relevant to the crust of neutron stars. In the low-density region, it has been believed that spherical nuclei form a crystal of body-centered cubic (bcc) lattice so as to minimize the Coulomb energy. On the contrary, we have found that a face-centered cubic (fcc) lattice can appear near the density where the structure of matter transits from spherical nuclei to cylindrical rods (Fig.2.). This is due to the differences in nuclear size and in proton fraction for bcc and fcc lattices, showing the importance of proper treatment of the density distribution in low-density nuclear matter [4,5].

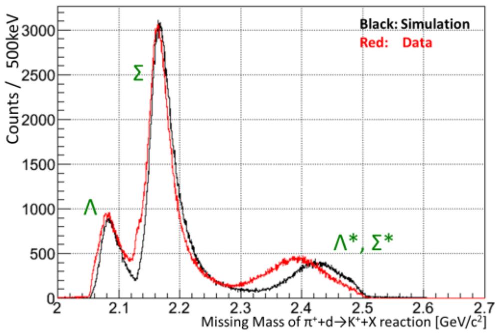

Fig.1 Missing mass spectrum for $\pi^+ d \rightarrow K^+ X$ reaction obtained by E27. Red and black points are present data and simulation, respectively.

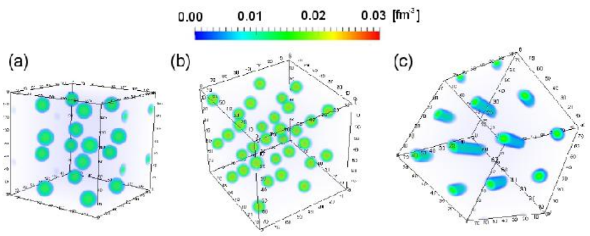

Fig.2 Proton density distribution are shown; (a) spherical nuclei in bcc at ρ_B = 0.01fm^{-3}, (b) spherical nuclei in fcc at ρ_B = 0.03fm^{-3}, (c) cylindrical rods in honeycomb at ρ_B = 0.056 fm^{-3}. This figure was taken from Ref. [5].

References

[1] K. Shirotori *et al.*, Phys. Rev. Lett. **109** 132002 (2012).
[2] Y. Ichikawa *et al.*, Few Body Systems, in press.
[3] H. Sugimura *et al.*, Few Body Systems, in press.
[4] M.Okamoto *et al.*, Phys. Lett. B**713** 284 (2012).
[5] M.Okamoto *et al.*, Proc. of Sci. (NIC XII) 218 (2012).