Research Group for Hadron Physics

Group Leader : Ken-ichi Imai
Members : Toshiki Maruyama, Hiroyuki Sako, Susumu Sato, Shoichi Hasegawa, Kotaro Shirotori, Ryuta Kiuchi, Kiyoshi Tanida, Hitoshi Sugimura, Yudai Ichikawa, Minoru Okamoto

The research objectives of Hadron Physics Research Group are: (i) empirical study of structure of nuclei and hadrons with strangeness, with use of high intensity $K(\pi)$-beams at J-PARC, and (ii) theoretical study of nuclear matter, hadrons with strangeness, and high density matter realized in neutron stars.

In JFY 2011, we have (1) searched for pentaquarks Θ^+ at J-PARC (E19) and established new upper limits, (2) proposed an experiment for H-dibaryon at J-PARC (P42), and (3) developed and installed vertex pixel detector for charm/bottom tagging at BNL−RHIC PHENIX experiment to study high energy heavy ion collisions. Also we have studied (4) high density matters in theoretical simulations, in which phase transitions of baryon density distribution has been found at the surface of the neutron star.

Experimental search for pentaquarks Θ^+

The Θ^+ baryon has been searched for via the $\pi^- p \rightarrow K^- X$ reaction using a 1.92 GeV/c π^- beam at the J-PARC−K1.8 beam line. The K1.8 beam line spectrometer and the SKS spectrometer shown in Fig. 1, both of which have an excellent momentum resolution, were used. In the missing mass spectrum, no prominent peak has been observed (Fig. 2) in the Θ^+ mass region [1]. The preliminary upper limit of the differential cross section averaged over the scattering angle from 2 to 15 degrees at the laboratory frame was less than 0.3 μb/sr at the 90% confidence level in the missing mass region of 1.51–1.55 GeV/c^2.

Study of the exotic state with strangeness; H-dibaryon

One of the exotic hadronic states, composed of 6 quarks, is H-dibaryon (“uuddss” quark state). In order to observe such a state, a large acceptance tracking spectrometer is indispensable. We have been doing R&D for a Time Projection Chamber (TPC), and Silicon Strip Detectors (SSDs) with Seoul National University and Scintillating Fiber trackers (SciFi) with Tohoku University as high-rate pion and kaon beam line trackers. A beam test has been performed at RCNP in Nov. 2011, and good performance (at 10^6 of incident beam rate) of these detectors was obtained (e.g., in TPC, a few 100s micrometer resolution was achieved). Design of the spectrometer is progressing in collaborating with Pusan National University.

Study of heavier flavour (charm/bottom) in heavy ion collision

We have developed and installed a vertex pixel detector in collaboration at BNL-RHIC PHENIX experiment, to extrapolate the signal from particle with charmed and/or bottom flavours. In 2011 and 2012, we have accumulated collision data of Au + Au and Cu + Au.

Numerical study of inhomogeneous structures in nuclear matter

We have numerically explored the pasta structures [3] and properties of low-density nuclear matter without any assumption on the geometry. We observed conventional pasta structures, while a mixture of the pasta structures appeared as a metastable state at some transient densities. Proton density distributions of the ground states of symmetric matter are shown in Fig. 3. Typical pasta structures were observed: (a) Spherical droplets at baryon density of 0.01 fm^{-3}. (b) Cylindrical rods with a honeycomb crystalline structure at 0.024 fm^{-3}. (c) Slabs at 0.05 fm^{-3}. (d) Cylindrical tubes with a honeycomb crystalline structure at 0.08 fm^{-3}. (e) Spherical bubbles at 0.09 fm^{-3}.

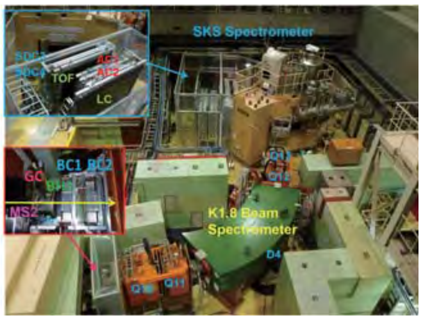

Fig. 1 K1.8 beam line spectrometer and the SKS spectrometer at J-PARC.

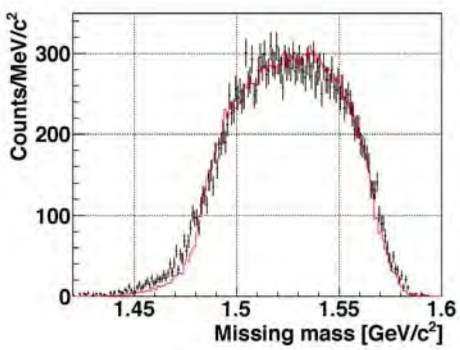

Fig. 2 Missing mass spectrum distribution via $\pi^- p \rightarrow K^- X$ reaction using a 1.92 GeV/c π^- beam. The red histogram shows corresponding background.

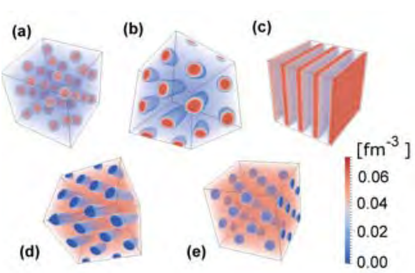

Fig. 3 Proton density distributions of the ground states of symmetric nuclear matter. For details, see the text.

References

[1] K. Shirotori *et al*., The Fifth Asia-Pacific Conference on Few-Body Problems in Physics, **APBF2011** (2011).
[2] Program Advisory Committee (PAC) for Nuclear and Particle Physics Experiments at the J-PARC 50 GeV Proton Synchrotron: http://j-parc.jp/researcher/Hadron/en/PAC_for_NuclPart_e.html, **J-PARC PAC** (2011).
[3] T. Maruyama and T. Tatsumi, J. Phys. Conf. Ser. **312**, 042015 (2011).