Research Group for Hadron Physics

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The objectives of Research Group for Hadron Physics are: 1) experimental study of exotic hadrons and nuclei with strangeness and charm at J-PARC and BNL-RHIC, 2) research and development of new high rate particle detectors such as a silicon strip detector, a scintillation fiber tracker and a time projection chamber, 3) theoretical study of nuclear matter at high and low densities and the role of strangeness in nuclear matter and neutron stars. Through these topics, we study many-body problems of quarks and hadrons in relation with QCD.

Hadron physics experiments at J-PARC.

In 2013, we started an experiment on γ-spectroscopy of hypernuclei (E13) in May. During the commissioning of the experiment, a gold target was melt because of unexpected intense pulsed proton beam, and radioactive isotopes were released to the Hadron Hall and environment. The experiments at J-PARC are, unfortunately, postponed to the next year due to the investigation of the accident and the construction of additional safety mechanism and shielding for the target, beam line and the Hadron Hall. We have contributed to these works.

The data analyses of the two experiments, search for ${}^{6}_{\Lambda}$H hypernucleus (E10) and search for $K^{-}pp$ state (E27), have been performed. The result of E10 was published [1] and is described as a research highlight in this annual report. Figure 1 shows a preliminary result of E27 suggesting a possible evidence of the $K^{-}pp$ state which was reported at Hadron2013 conference [2].

Detector R&D and Time Projection Chamber (TPC)

We have carried out R&D of a silicon strip detector (SSD), scintillating fiber tracker and time projection chamber (TPC) for hadron experiments with high intensity beams at J-PARC. A key word of the R&D is high rate capability. The SSDs and fiber trackers were successfully used at the rate of more than 10^{7}pions/spill in the E10 experiment. The study of the SSD is summarized recently [3]. Intensive studies of the TPC were performed with prototype TPC [4]. We have confirmed the TPC can be operated at the rate of more than 10^{6} particles/sec. Based on the studies, we have started the construction of the full size TPC (sensitive volume of 50 cm in diameter and 50 cm high). It has 3 layers of GEM (Gas Electron Multiplier) sheet and about 6000 readout pads of which width is 2.5 mm. It is designed to detect short-life hyperons as well as other charged particles emitted from the target. It will be used for H-dibaryon search experiment (E42) and others at J-PARC.

High energy heavy ion physics at RHIC and J-PARC

We took a part in the data taking of polarized proton-proton collisions and Au-Au collisions at RHIC to study phase diagram of hadron-quark matter, and contributed to the installation and commissioning of vertex detectors in PHENIX.

We led a working group to study possible scheme of the acceleration of heavy ions at J-PARC and its physics possibility. Uranium beams at maximum energy at J-PARC can create nuclear matter with the highest baryon density achievable with heavy ion collisions. Phase transition to quark-gluon matter at high baryon density is now a hot topic since the quark-gluon phase was confirmed at high temperature and very low baryon density at RHIC and LHC. For further discussion, we organized an international workshop on J-PARC heavy ion program. The goal of the current works is to write a proposal of J-PARC heavy ion physics.

Theoretical study of nuclear matter

In our study of inhomogeneous structures of liquid-gas mixed phase of nuclear matter relevant to the neutron star crusts, we have employed our fully three-dimensional mean-field model [5]. By using the deformation energy of the ground state of matter obtained in our new framework, we calculated the shear moduli of crystals of nuclear droplets in neutron gas, which indicates the mechanical strength of neutron star crusts. As a preliminary result, we pointed out that the shear modulus obtained in our full calculation is smaller than that of the conventional simplified calculation, due to the Coulomb screening and finite-size effects.

The properties of collective excitations of an inhomogeneous chiral phase whose appearance is suggested in quark matter at finite baryon densities have also been studied. We have found that some excitation modes, on the exotic ground state with spiral and wavy geometries, have an anisotropic dispersion relation.

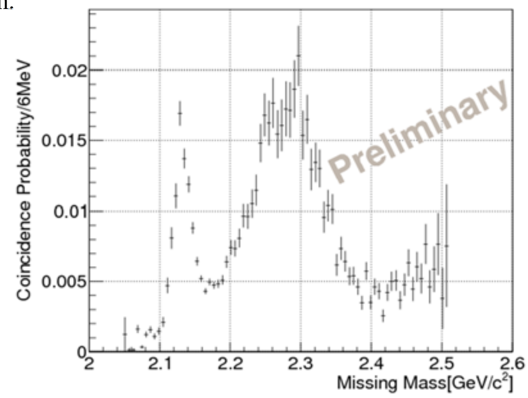

Fig.1 Missing mass spectrum for $d(\pi^{+},K^{+})$ reaction at 1.7GeV$/c$ shown as a ratio of the spectrum with proton detection and that without protons (proton coincidence probability). A possible origin of a peak around 2.3GeV$/c^2$ is the $K^{-}pp$ bound state. A sharp peak at 2.13GeV$/c^2$ is well known ΣN-ΛN cusp.

References

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