Summary of International Workshop on Physics at the Extended Hadron Experimental Facility of J-PARC

March 5–6, 2016, Tokai, Japan

Opening & Introductory Session:

Prof. Tadashi Koseki, deputy director of J-PARC Center gave a greeting address, showing the status of the recent J-PARC facility and activities.

Prof. Shinya Sawada showed the current plan of the extension of Hadron Experimental Facility, based on the plan submitted to Master Plan 2014 of large scale projects two years ago. In this project new physics beyond standard model can be searched by measuring kaon rare decays in Particle Physics research field. In the nuclear physics, we will investigate how the matter in the Universe has been made from only several kinds of quarks. In the current plan, hadron experimental hall is extended 105m downstream and two production targets are installed. Several beam lines are newly build; Separated beam lines for low momentum kaons, K1.1 (~1.1 GeV/c) and K1.1BR (~0.8 GeV/c) and for high momentum kaons and anti-proton, K10 (6 - 10 GeV/c) from the second target (T2). High-intensity high-resolution (HIHR) beam line and new KL beam line with the extraction angle of 5 degree from the third target (T3).

He also report the recent developments; KEK roadmap, Research plan committee of IPNS, etc..

Dr. Kei Yamamoto gave an overview of particle physics related to the extension of the hadron experimental facility of J-PARC. Several observables of kaon physics including the branching ratio of $K_L \to \pi^0 \nu\nu$ are sensitive to new physics in much higher energy scale compared to direct searches in LHC. Correlations between them are strong tools to reveal nature of new physics. As an example, she showed her original study in correlations between such observables under SUSY contribution. Finally, she discussed SUSY contribution to the transverse polarization of muon from $K^+ \to \pi^0 \mu^+ \nu$ taking account of current bounds on SUSY.

Prof. Makoto Oka presents global view of nuclear hadron physics. It is well known that hadron is indeed elementary excitation modes of QCD vacuum. Therefore, understandings of hadrons will lead us to reveal the structure of QCD vacuum. One of ultimate goals for hadron physics that pointed out in his talk is “the symmetry and structure of vacuum at zero and finite temperature and density”.

To date, ground states of hadrons are very well understood by QCD and also QCD motivated models. However, sufficient interpretations are not given on the excited state baryons. Moreover, the reason why multi-quark states are rarely produced is also not known. To understand all pictures consistently, we may need clear connection between quarks-gluons to hadrons. He expressed this missing piece as “residence on second floor”, quarks-gluons and hadrons are stayed on first and third floor, respectively. Various possibilities are proposed as “second floor residence”, such as constituent quark, constituent gluon, di-quarks and so forth. Those are called as effective degree of freedom.

He also pointed out that heavy quark might help us to disentangle the effective degrees of freedom in hadron excitations, which will be reachable at J-PARC.

Strangeness Nuclear Physics Session

Prof. Josef Pochodzalla gave a keynote talk. Inducing the recent discovery of the gravitational wave and neutron stars, he reviewed topics on precision studies on Λ hypernuclei, neutron-rich hypernuclei, and S=–2 and –3 systems. He also pointed out the importance of co-operation among laboratories in the world to extend our knowledge and develop research activities in this field.

Prof. Hiroyuki Noumi showed the current design and expected performance of K1.1/K1.1BR for low-momentum kaon beam line and HIHR with dispersion-matching technique.

Possible experiments were presented with importance and great interests by the following speakers.

Dr. Shinji Okada presented the experiments on kaonic atom with stopped K^- beam at K1.1BR in order to study $K^{bar}N$ interaction.

Dr. Koji Miwa showed hyperon – proton scattering experiments at K1.1. Short-range properties in the baryon-baryon interaction and its origin are particular important to understand nuclear force.

Prof. Elena Botta proposed the precise measurements of lifetime of ${}^3_\Lambda H$ and ${}^4_\Lambda H$ at K1.1. The (π^+, K^0) reaction is used to identify hypernuclear production by detecting high-energy π^- in forward direction with SKS and π^+ with range counter system from $K^0 \to \pi^+ \pi^-$ decay.

Dr. Alessandro Feliciello presented measurements of weak decay widths of mirror p-shell hypernuclei at

K1.1

Prof. Satoshi N Nakamura proposed high-resolution reaction spectroscopy of Λ hypernuclei at HIHR such as measurement of $^{4}_{\Lambda}$He mass in terms of charge symmetry breaking of ΛN interaction, spectroscopy of neutron-rich Λ hypernuclei and medium-heavy Λ hypernuclei in terms of Equation of State (EOS) of nuclear (quark) matter and neutron-star. Λ single-particle energies may be very sensitive to the 3-body force and density-dependence of the interaction which can resolve Hyperon-Puzzle in neutron stars.

Dr. Hiroyuki Fujioka showed studies on η- and η'- mesic nuclei and meson-nucleon interaction at HIHR. Study of tetra-neutrons by the (π^-, π^+) reaction is also proposed.

Particle Physics Session

Dr. Hajime Nanjo gave a presentation about current status of the KOTO experiment to search for the rare kaon decay, $K_L \rightarrow \pi^0 \nu \nu^{bar}$. The KOTO step-2 experiment planned in the future extended hadron experimental facility (HEF) was also presented. The step-2 detector is designed to be built behind the dump of the primary beam.

Shorter length between the T3 target and the KOTO step-2 detector is preferable in order to gain the K_L yield. Length between the T3 target and the dump is needed to defocus the primary beam to the dump. Some discussion was made to clarify such situation. It should be further considered with primary beamline experts.

A "0-degree" experiment was suggested to gain the K_L yield, but it is not preferable because of more rapid increase of neutron flux compared to the K_L flux.

What is important for feedbacks from KOTO to KOTO step 2? To check background at sensitivity of the branching ratio of 10^{-11} order is highly important. KOTO already found new background mechanism made by halo neutron directly hitting the calorimeter to form two clusters. Reduction of the background is important.

Another point is to measure radiation behind the dump, flux of neutron, muon, and so on. For the KOTO experiment, additional radiation from the primary beam increases the detector rate. Further discussion to evaluate the flux behind the dump with the current beam dump was encouraged.

Another question concerning the primary beam with multiple targets was raised. Is there any realistic simulation for the transportation of primary beam? What is the estimate of the proton intensity at each target? Such simulation was made before with roughly 30% loss at each target. Realistic case study should be considered.

Dr. Suguru Shimizu gave a presentation about the TREK experiment to search for new source of T-violation. T-odd quantity of the transverse polarization of muon from the $K^+ \rightarrow \pi^0 \mu^+ \nu$ decay is used. The TREK spectrometer with a toroidal magnet was already used in the E36 experiment at the K1.1BR beamline at the current HEF to search for the violation of the lepton universality.

Do you have some experience to reflect it to the design of new K1.1BR beamline at the extended HEF? Or do you have some potential danger to move to new beamline? The design of new K1.1BR beamline is the same as in the current K1.1BR without any request of modification, and with no potential danger to move to new beamline.

Is there some update for the new physics models related to the transverse polarization? The literature was old and some new physics models or parameters might be already excluded. They will try to update.

The similar decay, $K_L \rightarrow \pi^- \mu^+ \nu$, is discussed to use it for the T-violation search. It is not preferable because stronger final state interaction between π^- and μ^+ can make a spurious muon transverse polarization.

Hadron Nuclear Physics Session

In this session, we discussed hadron physics to be carried out at J-PARC.

Dr. Hiroaki Ohnishi pointed out two important questions, which should be answered in the extended hadron hall.

(1) What is the effective degrees of freedom to describe hadron?

(2) How does the property of the hadron change when it is placed in a different environmental condition?

Little is known about multi-strange baryons, Ξ* and Ω*, thus spectroscopic studies of them in addition to charmed baryons are strongly desired to attack the question (1).

Open charmed meson can be a unique probe to see response of light and heavy quarks (anti-quarks) in nuclear medium.

Prof. Hitoshi Takahashi reported current design of K10. Intense kaon and p^{bar} beam at a level of 10^7 every 5.52 seconds for 50 kW primary beam on a 50% loss target. Reasonable particle separations will be achieved: K^-/π^-=1.1 at 4 GeV/c and p^{bar}/π^-=1 / 3.4 at 6 GeV/c in use of 27 m electrostatic separator, while $p^{bar}/K^-/\pi^-$ = 3.3 / 1 / 0.79 at 10 GeV/c in the case of RF separator. He presented study of the ΩN interaction and it could open S=–3 nuclear system.

Prof. Megumi Naruki presented cascade baryon spectroscopy with medium-energy, separated kaon beams, from which we could learn correlations of two heavy quarks are responsible to cascade baryon structure. Some of excited Ξ* close to particle threshold may be so-called exotic and is worthy to investigate their structure.
Prof. Wen-Chen Chang proposed that the Drell-Yan measurements with K/p^{bar} beams at K10 can provide very unique information on the hadron structures.
Dr. Or Hen requested high-momentum intense proton beams to study short-range two nucleon correlation in nuclei.
Dr. Hiroyuki Sako presented a future experimental plan for highly dense nuclear matter with heavy ion beam at J-PARC.

Discussion toward the Next Step

After a short presentation on what we should do by Prof. Takashi Komatsuba, intensive discussions were stimulated. Comments (C), requests (R), questions (Q), and answers (A) are listed below.

R: Continue the activities of this International WS, through video
Q: Were there new inputs on strange/Kdecay/hadron in this workshop?
  A: No brand-new beam-line request nor proposal was presented.
  R: Shorter beam line is desirable for higher flux.
Q: Who is a contact person for questions/requests on the beam quality of K1.1 BL?
  A: Toshiyuki Takahashi)
C: Documentation in English, in this year.
C: Authorization (by PAC?) is needed to proceed to the budget request.
  C: Written in the report of IPNS-RPC is the construction budget from 2018. (The beam stop would be 3 years from the start.)
  Q: Is it timely?
    A: Nuclear/Hadron community welcome at any time.
    A: For KOTO (100kWx3years), the design preparation would be ready.
    C: The secondary-target design strategy would be related to it.
Q: How is the MEXT's view on the Joint budget request?
C: International support: increasing the collaborations.
R: Limited beam time of the current Hall is a problem.
R: The beam share between NU and HD should be reconsidered.
  C: IPNS's long-or-midterm plan, with the prospects for the beam time, is based on the guideline of "5 : 4 for NU : HD" (Kobayashi).
R: Joint work for the R&D of more efficient data acquisition (trigger-less DAQ system?) should be encouraged.
  C: HUA would host the activities.
  C: University-based development activities
  C: Request more resources (budgets and positions) to KEK for the R&D.
  C: Establish a support division at KEK or J-PARC to be the core of the activity
    - Uchida-san (KEK-IPNS E-Sys group) is at Tokai, for Open-It activities.
Q: What is the functionality of Hadron Experimental Facility?
  A: HIHR, K10, newKL in the extended hall. K1.1 is dedicated to hyperon factory.
  Q: What is the minimum set of beam lines (and detectors) ?
C: We will make a combined **LOI for the Hadron Hall Extension,** including beam lines and physics to convince people outside.
C: We should also start to write LoI and proposal of each experiment.

Workshop was hosted by Hadron Hall Users Association (HUA)
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Workshop participants: 62 (13 from abroad)