Towards Upgrade of the J-PARC Hadron Experimental Facility
- Summary of a related RCNP workshop -

H. Noumi, RCNP Osaka U. on behalf of the WS organizers

NP08, 5 March, 2008 in Mito

J-PARC ハドロン実験施設のビームライン整備拡充に向けて
日 時：2007 年 11 月 11 日（日）- 11 月 12 日（月）
場 所：大阪大学核物理研究センター 4 階講義室

Slides are available on:
http://www.rcnp.osaka-u.ac.jp/Divisions/plan/kokusai/ws071111.html

Organizers:
K. Nakazawa(Gifu), H. Outa(Riken), N. Sasao(Kyoto), S. Sawada(KEK),
H. Tamura(Tohoku), T. Nagae(Kyoto), T. Nakano(Osaka), T. Yamanaka(Osaka),
K. H. Tanaka(KEK), S. Ajimura(Osaka), H. Noumi(Osaka)

Organized by HUA Executive Committee Members + α
The Workshop was held at RCNP on 11-12 November, 2007.

Charges of the Workshop were:

- To review the construction status and plan of the Hadron Hall and Beam lines, what was the original plan (before J-PARC approval) by K. H. Tanaka (Hadron Beam Line Group Leader)

- To trigger to dig up experimental ideas: physics interest/motivation, experimental methods, requests for beams ...

- To trigger to discuss how to accommodate experiments, how to develop apparatus/setups, how to construct beam lines, and equipments ...

with more than 60 participants of potential users for the Hadron Hall
Basic Design

- Main Stream
  - Cascade Targeting
- Short Beam
  - For Neutral Kaons

- Multi Purpose
  - For Primary Beams and High p Secondaries
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The WORKSHOP summary is available on the WEB page:


First 2 pages of the WS summary are shown, followed by experimental overviews of 22 presentations.
Category

1. Hypernuclear Physics
2. Hadron Spectroscopy
3. Chiral Restoration of Hadrons in Nuclear Medium
4. Quark-Gluon Distribution in Hadron and Hadron System
5. Physics beyond the Standard Model in Kaon Decays and Muon-Electron Conversion Process
<table>
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<tr>
<th>Beam Line</th>
<th>p (GeV/c)</th>
<th>particle</th>
<th>Intensity ×10^6 ppp</th>
<th>Apparatus</th>
<th>Physics</th>
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</table>
| K1.8      | 1.5–2    | K⁻       | 10                  | SKSplus, SKS, FEREST(γ detector) | S= 2 Nuclear Spectroscopy(E05/+)
|           | 1.2–1.5  | K⁺       | 10                  |           | Θ⁺ Nucleus, K⁺ in Nucleus |
|           | ~2       | π⁺       | 10                  | Neutron Spec., γ detector | ο Nucleus Spectroscopy (could be done at High P) |
| K1.8BR    | 1        | K⁻       | 1                   | KURAMA/CDC | K Nucleus Spectroscopy (E15/E17/+, to be done at K1.1) |
| K1.1      | 1.1      | K⁻       | 10                  | Hyperball J, SKS or SKS II | S= 1 γ ray Nuclear Spectroscopy |
|           | 0.78     | π⁺       | 10                  | π² Spec., Scifi MPDC | YN scattering |
|           |          |          |                     | Neutron Spec. | η Nucleus Spectroscopy (LoI) |
| K1.1BR    | 0.8      | K⁺       | 1                   | TROIDAL | T violation (E06) |
|           |          | K⁺       | 1                   | E910 spec. | Θ⁺ Spectroscopy (P00/LoI) |
|           |          |          |                     | SPE5 II | Σ Hypernuclei in A=3 |
| HIHR      | 1–2      | π⁺, π⁻   | 1000               | High Resolution Spec. | S= 1 Nuclear Spectroscopy (E10/+)
|           |          | p, p, K⁺, K⁻ | 10 | Ks Spec. | Hypernuclear Weak Decay (E22/+)
|           |          |          |                     | (KK) Spec., Neutron Spec. | Θ⁺ Spectroscopy |
| High P    | 30–50    | p        | 10000              | φ̄ spec. | φ chiral restoration (E16) |
|           |          | p/pol. p | 10                  | HP spec. (E906-spec.) | Q G Distribution (P04/+)
|           | ~2       | π⁺, K⁺, K⁻ | 10 | Neutron Spec., γ detector | Μ Nucleus Spectroscopy (could be done at K1.8) |
|           | 5–10     |          |                     | Emulsion | Charmed Hypernuclei |
| KL        | <2.1>    | K⁺       | 8                   | KL Spec. | K^0→π^0νν̄bar (E14/+)
| KL 2nd Phase | <5.4> |          |                     | i.e. BL from Tx at 5 deg. | |
| Muon      | ~0.04>   | µ⁻       | >100000             | COMET | μ e conversion(LoI) |
| Neutrino  | ~0.5     | ν, ν̄bar | Dual Liq. Sci. Tracker | Δs in nucleon (could be parasitic on T2K) |
I DO NOT fully cover
presented experimental ideas and discussions.

Fortunately, the discussions are connected to NP08.
## Hypernuclear Physics

<table>
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<th>Project Description</th>
<th>Institution</th>
<th>Principal Investigator(s)</th>
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<td>Reaction Spectroscopy for S=-2 Hypernuclear Systems</td>
<td>KEK</td>
<td>Toshiyuki Takahashi</td>
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<td>→ Strangeness, Tanida</td>
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<tr>
<td>Search for Θ hypernuclei using (K⁺,p) reaction</td>
<td>Kyoto Univ.</td>
<td>Kiyoshi Tanida</td>
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<td></td>
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<td>→ Hadron, KT</td>
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<td>Hypernuclear experiments at K1.1 in future</td>
<td>Tohoku Univ.</td>
<td>Hirokazu Tamura</td>
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<td>Hyperon nucleon scattering experiment using a Scifi and MPPC system</td>
<td>Tohoku Univ.</td>
<td>Koji Miwa</td>
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<td>Hypernuclear γ-ray spectroscopy via the (K⁺,π⁰) reaction</td>
<td>Tohoku Univ.</td>
<td>Kotarou Shirotori</td>
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<td>Experiments for Studies on Neutron-Rich Hypernuclei</td>
<td>Osaka Univ.</td>
<td>Atsushi Sakaguchi</td>
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<td>→ Strangeness, AS</td>
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<td>Measurement of nonmesonic weak decay from 4-body Λ hypernuclei at the high intensity and high resolution beam line</td>
<td>RCNP</td>
<td>Shuhei Ajimura</td>
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<td>→ Strangeness, SA</td>
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<tr>
<td>Precision spectroscopy on Hypernuclear and Hadron Physics using High Intensity, High Resolution Beam Line</td>
<td>RCNP</td>
<td>Hiroyuki Nouni</td>
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<td>→ Strangeness, HN</td>
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<td>Prospects of Searching for Charmed Nuclei</td>
<td>Kyoto Univ.</td>
<td>Toshinao Tsunemi</td>
</tr>
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<td>→ Strangeness, TT</td>
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</tbody>
</table>
**Potential and Impact on Neutron Stars**

- Strange hadrons appear in the core of neutron star...
- What kind of hadrons? / How much density?
  - depends on mass, charge, and interaction
  - Negative baryons are favored.
- $\Sigma^-$ was supposed to be important. However its interaction with neutron matter is found to be strongly repulsive.
- $\Xi^-$ and its interaction should be important.

E03, K. Tanida  
E05, T. Nagae  
E07, K. Nakazawa
Weak Decay in A=4 hypernuclei (E22+...), by S. Ajimura
Fig. 1: An example of layout plan of High Intensity, High Resolution (HIHR) Beam Line connected to the T2 target in the extended Hadron Experimental Hall.
Spin-flip M1 transitions

$\Gamma \propto B(M1) \propto |\langle \downarrow \mu | \uparrow \rangle|^2$ is sensitive to w.f.

Spin-flip of $u/d$ quarks – large medium effect?

Spin-flip of $s$ quark – small medium effect?
Hyperon nucleon scattering experiment using a Scifi and MPPC system by K. Miwa
Search for $\Theta^+$ Hypernuclei using (K$^+\cdot$p) Reaction by K. Tanida

- 素過程: d(K$^+$,p)Θ
- 運動量移行: 前方ではほぼ0にできる。
  - Magic momentum: $p_K \sim 600$ MeV/c
  - $p_K \sim 1$GeV/c くらいでも $\sim 120$ MeV/c

- 高分解能測定が可能
- 素過程の断面積は？
  - 保坂さん、永廣さんにお願いして計算
  - [nucl-th/0705.3965] には0.1-0.5 mbとあるが、根拠は不明
Charmed Hypernuclei with Emulsion Technique
by T. Tsunemi

Magic momentum to produce $\Lambda^+_c$ at rest

$p(D^+, \pi^+)\Lambda^+_c \ @ \theta_\pi = 0^\circ$

Fig. 2.3. The momentum $q_y$ transferred to the hyperon $Y$ as a function of the projectile momentum $p_{proj} = p_a$ in the reaction $aN \rightarrow Yb$ at $\theta_{a, L} = 0^\circ$. 
# Hadron Spectroscopy

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<tr>
<th>Study Description</th>
<th>Institution 1</th>
<th>Institution 2</th>
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<td>$\Theta^+$ study with Low Energy $K^+$ Beam</td>
<td>RCNP</td>
<td>Norihito Muramatsu</td>
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<tr>
<td>Measurement of $\Theta^+$ width via high resolution ($\pi^-,K^-$) reaction</td>
<td>Kyoto Univ.</td>
<td>Kiyoshi Tanida</td>
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<td></td>
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<td>$\Rightarrow$ Hadron, KT</td>
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</table>
Basic Concepts

- Resonance formation reaction:
  \[ K^+ n \rightarrow \Theta^+ \rightarrow K_S^0 p \rightarrow \pi^+ \pi^- p \]
  \[-P(K^+) = 417 \text{ (442)} \text{ MeV/c} \]
  \[\text{for } M = 1.53 \text{ (1.54) GeV/c}^2\]
- \( \pi^+, \pi^-, \text{ & proton detection} \)
  by 4\( \pi \) spectrometer
  \[M(\pi^+ \pi^-) = M(K_S^0) \Rightarrow M(K_S^0 p) = M(\Theta^+)\]
- Originally considered at BNL-E949
  Similar but optimized experiment is possible at J-PARC.

\( \Theta^+ \text{ study with Low Energy } K^+ \text{ Beam} \)
by N. Muramatsu
## Chiral Restoration of Hadrons in Nuclear Medium

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<th>Description</th>
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<th>Authors</th>
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<td>RIKEN</td>
<td>Satoshi Yokkaichi</td>
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<td>A new approach to study in-medium $\phi(1020)$-meson mass</td>
<td>RIKEN</td>
<td>Hiroaki Ohnishi</td>
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<td>In medium $N^*(1535)$ Spectroscopy</td>
<td>RIKEN</td>
<td>Kenta Itahashi</td>
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<td>Combined measurements of nuclear $\omega$ bound state and $\omega$ mass modification in $p(\pi, n)\omega$ reaction</td>
<td>Univ. Tokyo</td>
<td>Kyoichiro Ozawa</td>
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<td>Rough idea of $K^+ + A \rightarrow K^* + X$ experiments</td>
<td>Tohoku Univ.</td>
<td>Masashi Kaneta</td>
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<td>Plan of kaonic nuclei and kaonic atom experiments at K1.1 beamline</td>
<td>RIKEN</td>
<td>Haruhiko Outa</td>
</tr>
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</table>
Meson in Nuclear Medium (Hadron)

\[ p, \pi^- \to K^+, \phi, \omega \]

\[ K^* \to e^-, \gamma \]

\[ \omega : K. Ozawa \]

\[ K^* : M. Kaneta \]

\[ p\bar{p}, \pi^- \to \phi, \eta(N^*) \]

\[ \eta(N^*) : K. Itahashi \]

\[ \phi : H. Ohnishi \]
A New Approach to study in-medium $\phi(1020)$-meson mass by A. Ohnishi

$p\bar{p} + p \rightarrow \phi + \phi$

- **Conventional**
  - LEPS like setup
  - But large dipole magnet behind solenoid magnet to maintain large forward angle acceptance

- **Challenging setup**
  - Everything inside large solenoid magnet (~3m long, 1m diameter)
Quark-Gluon Distribution in Hadron and Hadron System

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<th>High Momentum Beam Line at J-PARC</th>
<th>KEK</th>
<th>Shinya Sawada</th>
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<td>Polarized structure measurement of the nucleon with dimuon production at J-PARC</td>
<td>RIKEN BNL</td>
<td>Yuji Goto</td>
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<td>Measurement of strange quark spin component of the proton spin using neutrino-nucleon elastic scattering</td>
<td>Tokyo I. Tech.</td>
<td>Yoshiyuki Miyachi</td>
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Issues at J-PARC: Drell-Yan ↔ DIS vBeam
Physics with High-Mass Dimuons at J-PARC

Drell-Yan (at 50 GeV):
- \( \bar{d} / \bar{u} \) flavor asymmetry at large \( x \)
- Antiquark distributions in nuclei
- Quark energy loss in nuclei

\( J / \Psi \) Production (at 30 or 50 GeV):
- \( J / \Psi \) nuclear dependence
- \( \bar{d} / \bar{u} \) via \( J / \Psi \) production

Spin physics with dimuons (mostly with polarized beam/target):
- Drell-Yan with polarized beam/target
  (Sea-quark polarizations, transversity, Sivers function)
- \( J / \Psi \) with polarized beam/target
  (Quark polarization, transversity, Sivers function)
- Unpolarized Drell-Yan decay angular distributions
  (Boer-Mulder's distribution function)
Dual SciBath configuration

SciBath1  MRD1  SciBath2  MRD2

5 m

BC501A  BC533

WLS readout

Fiducial volume:
3x3x3 m³

Geant4 data
v: 500 MeV
p: 270 MeV

NC elastic vp scattering

/12@RCNP

RCNP研究会  Yoshiyuki Miyachi, Tokyo Tech
Physics beyond the Standard Model in Kaon Decays and Muon-Electron Conversion Process

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<td>KEK</td>
<td>Takeshi Komatsubara</td>
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<td>$\rightarrow$ Kaon, $TK + \ldots$</td>
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<td>K1.1-BR beam optics optimized for K0.8 and E06 (TREK) experiment</td>
<td>KEK</td>
<td>Jun Imazato</td>
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<td>$\rightarrow$ Kaon, $Jl$</td>
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<td>An Experimental Search for Lepton Flavor Violating $\mu^-$-$e^-$ Conversion at Sensitivity of 10$^{-16}$ with a Slow-Extracted Bunched Proton Beam</td>
<td>Osaka Univ.</td>
<td>Akira Sato</td>
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K1.1-BR beam optics optimized for K0.8 and E06(TREK) experiment by J. Imazato

K1.1-BR beam optics optimized for K0.8 and E06(TREK) experiment by J. Imazato

第1期での K0.8 の可能性

• T1 標的の最大限有効利用

Beam line for $K^+ \rightarrow \pi^0\mu^+\nu$ Exp.
The PAC heard a report from the “Task Force on E14” associated with the beamline interferences. The main issue is to mitigate the effects due to the interference with the K1.1 beam line which are two-fold. On the one side, the presence of the K1.1 beamline components reduces by almost a factor of two the yield of neutral kaons per incoming protons. On the other hand, according to a simulation, the ratio of halo-neutrons to kaons increases by a factor of more than three. To reduce this interference, E14 has simulated a modified K1.1 layout that seems to be able to preserve the kaon flux per proton and to limit the worsening of the ratio of the halo-neutron to kaon ratio to about 60%. A beam survey seems to be an important step in order to match the beam line needs to the experiment. According to the current schedule, the beam survey can take place in the fall of 2009 and, given the small amount of slowly extracted proton expected by that date, does not require expensive shielding. The purpose of the survey is to 1) understand the effects related to the beam position stability in the presence of an extended target, 2) to study the $K^0_L$ yield and 3) to measure the neutron fluxes.

The “Task Force on E14” concluded that E14 addresses a very important physics goal, although without a large safety margin. It also concluded that the beam line should be optimized in terms of $K^0_L$ yield, detector acceptance and neutron-induced backgrounds.

**The PAC endorses the conclusions of the task force and recommends that the modified layout of the K1.1 beam line be considered as a new baseline design and be studied in detail. A detailed plan for the beam survey should be reported at the next PAC meeting.**
next to E14
for the B.R. measurement

- Optimized beamline with 5deg angle for
  
  - higher KL momentum $<P_K> = 5.2\text{GeV}/c$
  
  - higher yield: $4.4 \times 10^7/2\mu\text{srr}/3 \times 10^4 \text{pot}$

Example
Experimental Search for Flavor Violating $\mu^- - e^-$ conversion by A. Sato

Overview of the New Experiment: COMET

The beamline design is very important to reduce the beam intrinsic B.G.

ID signals B.G. reduction hit rate reduction
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  with more than 60 participants of potential users for the Hadron Hall.
Discussion of the “Grand Plan” for future J-PARC in J-PARC User Steering Committee

Discussion towards Upgrade of the Hadron Exp. Hall
• Extension of the Hall is strongly desired to accommodate proposed beam lines/facility/setups...
  → This would be understood.
  → Physics in the Extended Hall be asked. Need an Ace Experiment?
• Strategy:
  More proposals
  Road maps for the Beam lines

Continue Discussion at NP08@Mito
• form collaboration towards proposals
ビームダンプを50m下流に引越！

・ ダンプの総重量は1000ton
・ 移動は1日（8時間）以内に完了する！
・ さらなる拡張も、もちろん可能！！
Fin.