Charmed-baryon Experiment E50

H. Noumi for E50, RCNP, Osaka University/IPNS, KEK

- Quick Introduction
- High-p Collaboration
  - R&D for “Multipurpose” Spectrometer
  - Towards construction of the 2ndary Beam Line
High-res., High-momentum Beam Line

- High-intensity secondary Pion beam (unseparated)
  - $1.0 \times 10^7$ pions/sec @ 20 GeV/c
- High-resolution beam: $\Delta p/p \sim 0.1\%$
- High-res. Spectrometer: $\Delta p/p \sim 0.2\%$ at ~5 GeV/c

30 GeV proton beam

Production Target

Pion Beam Up to 20 GeV/c

Spectrometer

H$_2$ TGT

Fiber Tracker

2m

Dipole mag

DC

DC

TOF

DC

RICH

$K^+$

decay

$p(p^+)$

T1

$\pi$
Charmed Baryon Spectroscopy Using Missing Mass Techniques

- Production and Decay reflect [qq] correlation in Excited Charmed Baryons
- C.S. DOES NOT go down at higher $L$ when $q_{eff} > 1 \text{ GeV/c.}$
Missing Mass Spectrum (Sim.)

- $\sim 1000 \, Y_c^*/nb/100$ days
- Sensitivity: $\sigma \sim 0.1$ nb for $Y_c^*$ w/ $\Gamma = 100$ MeV

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* LS partner (HQS doublet)
* LS partner? (HQS doublet?)
Spectrometer Design

20 GeV/c
Beam $\pi^-$
Spectrometer Design

Large acceptance ~ 60% (for $D^*$), ~85% (for decay $\pi^+$)
Good resolution: $\Delta p/p \sim 0.2\%$ at ~5 GeV/c
From the 20th PAC minutes

At the same time, the collaboration has started to investigate a possible extension of its physics program joining forces with other experimental groups interested in related activities on the high-P beamline at J-PARC. Particularly interesting could be the possibility of studying the formation of the recently discovered pentaquark state, via an appropriately modified experimental set-up aimed at precise identification of di-muon resonances (J/ψπsi, etc…).

The PAC strongly encourages this and other extensions of the physics program of E50, as well as the extension of the original experimental set-up toward a “multi-purpose” detector. A systematic analysis of possible realistic options along these lines should be pursued.

Concerns on safety aspects of the high-P beam-line for E50 have been raised by the FIFC. In view of this potentially serious impact, the PAC suggests that IPNS further investigate this issue in detail.
Muon ID for Exclusive DY Exp.

Nucleon Structure via Exclusive DY

• $\pi^- p \rightarrow \mu^+ \mu^-' n$


~7 pb
$P_c(4380), P_c(4450)$ at High-\(p\)

- Is $P_c^+$ the N* with a hidden c-cbar?
- $P_c^0$ can be excited on its mass with 10 GeV/c pion beam at J-PARC.
- Its decay modes to $Y_c + \bar{D}$.
- Its family?

How large is the CS?
High-p Collaboration

- Cooperative works of activities at High-p BL
  - E50+E16+J-PARC-HI+Potential Users+Facility Group

- Detectors
  - Large Strip RPC for LEPS2
  - Fine grained Trackers to be installed for E16
  - Muon ID: \(J/\psi\), dimuon

- High Speed DAQ/Electronics
  - ALICE O2 as associate members (approved recently)
  - Pipelined High Resolution TDC (\(~20\)ps)

- Facility
  - Production TGT, BSO, Magnets, Radiation Safety, etc.

→ Joint Effort under the High-p Collaboration
High-rate detectors

* High-rate beam
  - \(6 \times 10^7\) /spill
    (30 MHz @ 2 sec spill)

- Focal plane detector
  - Focal plane region
  - Beam momentum analysis
    • Position and angle

- Beam tracker
  - At the target upstream
  - Size: 100 mm × 100 mm

- Scattered particle tracker
  - At the target downstream
  - 600 mm × 800 mm

- Time zero counter
  - At the target upstream
  - Reference timing for TOF
Prototype beam tracker: in preparation

- 2 XUV units
- "Position fixing frame" (L-type frame)
- MPPC boards attached to sockets

• Design can be used for actual one.
Beam Test at ELPH

Timing counter: T0

Fiber test

150-mm scintillator + MPPC

1 mm, 0.5 mm 0.25 mm fiber
T0: □ 3mmx150mm + MPPC + Preamp

- Time Resolution for MIP: ~70 ps
- Photoelectron: ~100
- Overshot Pulse to be reduced

Sample wave form:
- ~60 ns Overshoot
- 20 mV, 10 ns
## Fiber x MPPC: Based on Beam Test

<table>
<thead>
<tr>
<th>φ [mm]</th>
<th>MPPC [μm]</th>
<th>PDE [%]</th>
<th>P.E. [Single]</th>
<th>Resol. [Single] [ps(rms)]</th>
<th>P.E. [Both/OR]</th>
<th>Resol. [Both] [ps(rms)]</th>
<th>Comments</th>
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<td>1.00</td>
<td>PMT</td>
<td>25</td>
<td>12</td>
<td>420</td>
<td>24</td>
<td>300</td>
<td></td>
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<tr>
<td>1.00</td>
<td>25</td>
<td>30</td>
<td>15</td>
<td>380</td>
<td>30</td>
<td>270</td>
<td>Better</td>
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<tr>
<td>1.00</td>
<td>50</td>
<td>50</td>
<td>30</td>
<td>270</td>
<td>60</td>
<td>190</td>
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<td>25</td>
<td>30</td>
<td>7</td>
<td>650</td>
<td>14</td>
<td>460</td>
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<tr>
<td>0.50</td>
<td>50</td>
<td>50</td>
<td>14</td>
<td>460</td>
<td>28</td>
<td>330</td>
<td>Less Material</td>
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<td>0.25</td>
<td>25</td>
<td>30</td>
<td>3</td>
<td>1000</td>
<td>6</td>
<td>700</td>
<td>Low eff.</td>
</tr>
<tr>
<td>0.25</td>
<td>50</td>
<td>50</td>
<td>6</td>
<td>700</td>
<td>12</td>
<td>500</td>
<td></td>
</tr>
</tbody>
</table>

- Acceptable combination of Fiber and MPPC
  - φ1.00 mm ⇒ 25/50 μm MPPC + Single edge
  - φ0.50 mm ⇒ 50 μm MPPC + Single edge
  - φ0.25 mm ⇒ 50 μm MPPC + Both edge (OR readout)
Large Strip RPC

By N. Tomida (RCNP)

• 2m Long RPC for LEPS2
  – Signal reflection caused by Impedance Mis-Matching
  – Dispersion during Signal Propagation
  – Transmission Line Theory (D. Gonzalez-Diaz)

Change Materials to minimize dispersion during Signal Propagation, changing coupling C to control Signal Propagation Speed
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Before (res. ~ 70 ps)  
After (res. to be improved)

Now Testing at SPring-8
High-speed DAQ system for E50

Frontend modules
* Signal digitalization
  – Pipelined system

Buffer PCs
* Data accumulation
  – Several 10 GB memories

* High-speed data link (Local)

Filter PCs
* Event reconstruction
  – 100–200 CPUs

~50 GB/spill

<0.5 GB/spill

Storage
  – Local storage
  – Transferred to KEKCC/RCNP

Streaming DAQ (~50 GB/spill)
ALICE O2 Hardware Facility

Software R&D (Sako)  Load Balancing/Data Flow Regulation R&D (Ma)
LEPS/J-PARC joint R&D
FPGA-based HR-TDC Test Board

- DRS4
- AD9637 (ADC 12bit, 40MSPS)
- FPGA
  - Spartan-6
  - LX150
- OPamp
- comparator
- comparator out (LVDS)
  - 16 ch
- analog input (single-end)
  - 16 ch
- User I/O (NIM)
- 100BASE-T
- DAC (for bias, threshold)

\[ \sigma_t \approx 20 \text{ps} \left(= \frac{28}{\sqrt{2}} \text{ps} \right) \]
with Clock Pulse
→ Test at LEPS

By T.N. Takahashi (RCNP)
High-res., High-momentum Beam Line

- High-intensity secondary Pion beam (unseparated)
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30 GeV proton beam

Production Target

Prod. Angle = 0 deg. (Neg.)

Spectrometer

Sanford-Wang
15 kW Loss on Pt
Acceptance: 1.5 msr%, 133.2 m
Facility: Beam Line Issues

• High-p/COMET Line Construction Status
  – SY: Magnets have been installed. Lambertson, Collimators, and monitors will be installed in next summer.
  – HD: Magnets are ready to be installed in 2017~2018.

• Design for Secondary Beams at the High-p BL
  – A PD has been hired at RCNP (OU J-PARC Br.)
Issues for 2ndary BL

• Production Target: essentially same as current T1 system
  – Au/Cu indirect water-cooling system
  – Air-tight Chamber with He-gas circulating radiation monitor
  – Beam Window: Ti for current system, Be under developing

• Radiation Shielding:
  – Soil activation limit: 15kW Loss@SM
  – 0.5uSv/h at a border of Radiation Controlled Area
  – Activation around the Target Station (for Maintenance)

• Beam Swinger Optical elements:
  – by which the branching magnets (Lambertson/septum mags) will be replaced
  – Swinger magnets will be made with Mineral Insulation Cable (MIC)
  – Beam Piping: cooling system if necessary

• Vacuum System
  – Pillow Seal at BSO
  – Vacuum Pump: Storage tank for exhaust gas and valve control system
π20 beam extraction - New

beam swinger optics optimized for 20GeV/c π⁻ beam production

Proton angle:
-0.20° (tot.-0.19°) +0.01° (tot.+1.93°) +2.12° (tot.+1.93°) -1.99° (tot.-0.06°) -0.21° (tot.-0.27°) +0.27° (tot.0°)

Production angle:
π⁻ angle: +0° (tot.+1.93°) +3.07° (tot.+5°)

20 GeV/c π⁻

※production angle of other charge/momentum:
20GeV/c π⁺: 3.9°
15GeV/c π⁻: 0.5°
Current Hadron Target

- Up to 50 kW beam
- Indirectly water-cooled
- Gold was chosen due to the good thermal conductivity and thermal expansion coefficient close to that of copper
- Involved in airtight chamber and He gas is circulated to monitor the target soundness

Gold (6-divided)

Proton beam

Cooling water

Copper

Stainless-steel

*Gold, copper, and stainless-steel are bonded by HIP (Hot Isostatic Pressing)

Cross-sectional view

IAC, 2016
Target

He gas

Cooling Water

Thermocouple connection

He gas system be newly constructed.

Au target

66mm (6 parts)

Proton beam

Cooling water

Cu block

Target driver

He gas

IAC, 2016
Radiation Level estimated by MARS
by Y. Komatsu

To be <0.5uSv/h at a border

Just put a 15kW loss target in the Current Shielding Structure
Safety Issue

• Monitoring system
  – Target temperature
  – He-gas circulating radiation monitor
    • Piping route: SY to M1
  – Radiation Monitor
    • Beam Intensity, Beam Profile, Beam Loss
    • Area Monitor (Air-dust sampling monitor)
    • Air-born radio-activities in SY

• Maintenance Scenario
  – Radiation Shielding in opening the target station
  – (Semi-)remote handling system
    • quick and remote connection/disconnection of power/signal lines, water cooling/vacuum pipes, and so on
    • Remote alignment system

• Safety Simulation for Severe Accident
  – Short pulse extraction->Target melt down, Beam window broken
  – Magnet failure -> Beam Displacement -> Protection against unexpected beam irradiation to BL elements
  – ...
Cooling Water and Helium Gas

H. Takahashi, Dec., 2015

- Share cooling water with magnets
- He gas piping (1way ~ 125m)
- Buffer tank
- 1st machine bldg.
- He circulation system
Helium circulation system

- Blower (or pump)
- 3-way valve
- Filter
- 3/8"
- Vacuum pump
- Radiation monitors
- Exhaust stack of M2
- M2 sub tunnel
- Service space
- 40A
- 5m³/hour
- Tank
- Heat exchange
- Buffer tank
- Emergency He tank (Vacuum in normal operation)
- Exhaust stack of M2
- Helium gas is circulated at negative pressure, -1kPa.
Summary

• We have many items to be developed.
  – Spectrometer System for “multipurpose”
  – Beam line facility
• Cooperative works among the High-p collaboration are indispensable.
  – We need your contributions.