E14 (KOTO) Status

T. Nomura (KEK/IPNS)

- Beamline
- Beam Survey
- Detector Preparation
Beamline

- Finalize design
- Fabrication status
- Installation plan
T1 target

Sweeping magnet

Pb $\gamma$ absorber

1st collimator

2nd collimator
Finalize beamline design

Progress since last PAC meeting

- Decide beam shape
  → rectangular

- Optimize collimator design further
  → reduce halo neutrons by a factor of 3

- Purchase collimators
  → collimators will be delivered in this JFY
Categorization of neutrons

- 0^{th} order
directly from the target $\leftarrow$ Core
- 1^{st} order
scattered once $\leftarrow$ Core-like
- 2^{nd} order
scattered twice $\leftarrow$ candidate to be halo n
Scattering points

- Related to generation of halo neutrons
  - Cu collimator (bore)
  - K1.1 components (mainly bore)
  - Pb $\gamma$ absorber (in the core)
  - KL collimators (bore and edge)
Step 1

1. Determine the size of “core-like” beam at the KOTO detector

Line between
\( \gamma \) absorber
(scatterer in beam)
and
KOTO beam hole

\[ \rightarrow \text{Fix midpoint of } 2^{\text{nd}} \text{ col.} \]

Independent of beam shape:
circular or rectangular
Step 2

2. Considering $\gamma$ absorber as main scatterer, hide the surface of 2nd collimator

Line between
midpoint of 2nd col.
and
center of $\gamma$ absorber

Sort of compromise!

$\Rightarrow$ Fix the upstream
gradient of 2nd col.

Common to circular and rectangular

Reduce 2nd order
(T $\rightarrow$ Pb $\rightarrow$ C2U)
Step 3

3. Hide upstream edge of 2\textsuperscript{nd} col. from target by 1\textsuperscript{st} collimator

Line between ups edge of 2\textsuperscript{nd} col. and target image

\(\rightarrow\) Fix the size / gradient of 1\textsuperscript{st} collimator

Core beam size is defined in this step
Step 4

4. Trim downstream half of 2\textsuperscript{nd} col. not to be seen from hottest points in 1\textsuperscript{st} col.

Line between narrowest point in 1st col. and midpoint of 2nd col.

\rightarrow Fix downstream half of 2\textsuperscript{nd} collimator

Avoid 2\textsuperscript{nd} order (T \rightarrow C1 \rightarrow C2D)

(T \rightarrow Pb \rightarrow C2D) also eliminated
Step 5

5. Optimize materials

Edge $\rightarrow$ tungsten (W) stopping power is important

Other part $\rightarrow$ steel (Fe) dominated by surface scattering

Stop particles entering from front surface

Chance to reduce $T \rightarrow Pb \rightarrow C2U \rightarrow C2D$
Results of optimization

Here, optimization basically means from Step 2 to 4

**GEANT3**

<table>
<thead>
<tr>
<th>Category</th>
<th>Condition</th>
<th>&quot;fixed design&quot;</th>
<th>&quot;trimmed square&quot;</th>
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<tr>
<td>$K_L$</td>
<td>K.E. &gt; 0.1GeV</td>
<td>$(1.46 \pm 0.08) \times 10^7$</td>
<td>$(1.64 \pm 0.08) \times 10^7$</td>
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<tr>
<td><strong>halo-$n$</strong></td>
<td>$</td>
<td>P</td>
<td>\geq 0.78\text{GeV}/c$</td>
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<tr>
<td>ratio to $K_L$</td>
<td></td>
<td>$(6.99 \pm 0.47) \times 10^{-4}$</td>
<td>$(1.79 \pm 0.10) \times 10^{-3}$</td>
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<tr>
<td><strong>hit-$n$ at liner CV</strong></td>
<td>K.E. &gt; 0.1GeV</td>
<td>$(1.32 \pm 0.69) \times 10^5$</td>
<td>$(1.15 \pm 0.64) \times 10^5$</td>
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<tr>
<td>ratio to $K_L$</td>
<td></td>
<td>$(9.04 \pm 4.73) \times 10^{-3}$</td>
<td>$(7.01 \pm 3.92) \times 10^{-3}$</td>
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</table>

**Improved factor 3**
Drawing of 1st collimator
Collimator fabrication

material

crude process

groove cutting

finished (lower half)

dimensional inspection
For survey 2009

No K1.1 components

Shields around collimators

KOTO area for survey

Small impact on core particles: -5%
Some impact on halo neutron: +60%
Construction schedule

KL Beam line construction schedule and expected crane usage

Remove shield (-Apr)  Installation (May-July)  Shielding up (Aug-early Oct)

Remove KL shielding blocks

- Confirm the beam line for construction
- Shielding block up to FL+1.5m
- Upstream collimator installation (3days + 1day)
- Bending Mg Installation (2 days)
- Beam Plug installation (2 days)
- Downstream collimator installation (3 days + 1 day)
- Vacuum connection

Shielding up to FL3

Shielding up to FL9
Toward Beam Survey 2009

- Method and preparation status
- 0th survey in Feb 2009
Beam survey 2009

1. Measure KL yield / spectrum
   - Fix number of KL
     (A factor of 3 variation between GEANT4/G3/FLUKA)

2. Measure core neutron
   - Confirm n/K ratio

3. Measure halo neutron
   - Confirm halo-n/K ratio

We need same target as in real experiment
Facility and Beam

• Experimental facility
  ✓ KL beamline and area for beam survey
    (no K1.1 components)
  ✓ Services (electricity / cooling water, interlock, ...)

• Beam
  • Intensity ~1% of FULL (3kW eq.)
  • “Moderate” stability (position, time structure)
  ✓ Beam monitor information (intensity, size/position)
    → Residual Gas Profile Monitor just in front of the target

Scheduled (or discussed)
Assumption
Comments on beam issues

• If intensity becomes higher/lower …
  → Just a running time issue for KL measurement
  → May cause high-rate problem in core n measurement

• If proton beam position is unstable (~mm) …
  → Small impact on KL measurement (~2%/mm)
  → Large impact on halo n meas. (~3 times when shifted 3mm)

• If extracted proton beam has time structure …
  (For ex., 1msec-width beam every 10msec,
   instantaneous rate becomes x10 higher than expected)
  → Can handle higher rate in KL measurement
    (at least up-to FULL intensity equivalent)
(0) Beam profile

[ Confirmation of collimator alignment ]

Example of profile counter (used in E391a)
(1) KL measurement

[ KL → π⁺π⁻π⁰ measurement with tracker + mini-calorimeter ]

• Tracker
  – 1cm Scinti bar + WLSF
  – X/Y plane, 2 stations, 2 banks
  – 400 ch in total
  – MAPMT+DAQ used for SciBar detector in K2K/KEK→SciBooNE/FNAL

• Mini-calorimeter
  – 7x7x30cm CsI crystal
  – 5x5 array, 2 banks
  – CsI crystal used in KEK-E391a
KL measurement

No magnet
No chamber
Method

i. Measure direction of $\pi^+ / \pi^-$ (tracker) and energy and position of $2\gamma$ (calorimeter)

ii. Calculate decay $Z$ (on beam axis) from $2\gamma$ information assuming $\pi^0$ mass

iii. Solve 2 equations of momentum balance (x,y) and determine $P_{\pi^+}$ and $P_{\pi^-}$

iv. Qualify data by requiring $K_L$ mass
Expected performance

Reconstructed $K_L$ mass

$K_L$ Momentum resolution:
\[
\frac{P(\text{Recons}) - P(\text{True})}{P(\text{True})}
\]

Event/day $\sim 500$
(after mass cut)

$\frac{\Delta p}{p}$ $\sim 13\%$
Further consideration (I)

• What is a tail in higher mass region?
  → Events with a certain geometry make a tail

When $\pi^+ / \pi^-$ go back-to-back in the transverse plane and $\pi^0$ happens to get $P_T$ in other direction (due to resolution or assumption of $K_L P_T = 0$), resultant $P_{\pi^+} / P_{\pi^-}$ become large to compensate fake $\pi^0 P_T$

Result from fast simulation with smearing by resolution
Further consideration (II)

• What happens if there are extra hits?
  – Hit rate / station = K: 500kHz, n: 150kHz
    when assuming FULL intensity
  – Thus, N(extra hits) / station / $\mu$s may become \( \sim O(1) \)

→ Improve analysis method to allow extra hits
  – Vertex determined by tracker info (multi combinations)
  – Choose one with which 2\( \gamma \) mass is closest to \( \pi^0 \) mass
  – Estimate performance with extra K decay randomly overlaid
    → 20% signal loss

→ Prepare additional hodoscope with better timing
  – Granularity could be coarse
Further consideration (III)

- What will happen when we use a tracker with better resolution? (say, 0.1mm)
  - Of course, we can expect better performance

  - Vertex can be well reconstructed by tracker info
  - $N(KL)$ becomes $x1.4$ (when $2\sigma$ cuts on the mass)
  - Momentum resolution becomes $\sim6\%$ (was 13%)
Further consideration (IV)

- Chambers as a tracker?
  Concerns are …
  - Operation in newly built, unknown environment
    • Slow neutrons, X-rays (Need keV level threshold for chamber)
  - Efficiency well controllable?
    ➔ Continue consideration, but as an option

- Other methods?
  ➔ Spectrometer option is being discussed
    with an existing magnet and existing chambers
Preparation status

• Beam test @ LNS/Tohoku (600 MeV e⁺)
  ➞ Select scintillator and WLSF
  Scinti.: ELJEN-EJ230
  WLSF: Kuraray-B2

• SciBar-DAQ, being tested at Kyoto U
(2) Core n measurement

[ using EM / hadron calorimeter ]

“Cerbelus” calorimeter (used in E391a)
Preparation status

- Tested with cosmic ray → DONE
- Beam test @ LNS/Tohoku (300-800 MeV e+)

\[ \sigma/E \sim 13\%/\sqrt{E} \]
(3) Halo n measurement

[ using PWO-CsI hybrid ]

At the same time, this is a prototype of upgraded collar counter (NCC)

Reduction of K decay contribution is the key issue

Need a beam pipe to avoid core n interaction
Preparation status

• CsI + WLSF (Kuraray-B1 or PMP) readout
  – Necessary when segmented in 3D
  – Test for NCC

• Beam test @ LNS/Tohoku
  – Check light yield, timing

• Continue optimization of WLSF
0th survey in Feb 2009

Though KL line is not yet there …
0th survey in Feb 2009

• Area survey
  – Thermal neutron
    • LiI(Eu) crystal, …
  – Muon
    • Simple telescope
      (coincidence of 2 scinti.)
As of Feb 2009

- MR intensity $\sim 2 \times 10^{11}$ ppp (when 0.17Hz continuous operation)
- Loss at extraction $\sim 10\%$
0th survey in Feb 2009

- We did see “the beam” !!
  - Muons
    - ~30 / burst / 256cm²
    - probably come from SX point
      → We don’t think it will be x10³ in real experiment
         since SX loss can only increase 10 times at most…

- No evidence of thermal neutron

So far so good
Observed muon in 0th survey

Angle scan
Detector Preparation

- Focus on CsI calorimeter
Cut away view of vacuum part

illustrated by Masuda (Kyoto U)
Transfer of KTeV CsI crystal

Unstacking finished in December
KTeV crystals to shine again

JPARC graduate students work to pack crystals from Fermilab's former KTEV experiment for shipment. JPARC will use the crystals in an experiment that will look for ultra-rare kaon decays.

From 1997 to 1999, scientists at Fermilab conducted an experiment using the most accurate energy-measuring device ever built for high-energy physics.

Then researchers carefully stored the experiment, KTeV. Until now.

Graduate students from the Japan Proton Accelerator Research Complex, or JPARC, arrived last Wednesday.
CsI / PMT test @ Osaka U

- Uniformity test using cosmic ray
  - 100 crystals at one time
  - 2 days / 1 set
CW base (Kyoto U + Matsusada)

- 2nd Prototype
  - CW circuit
  - Preamp in
  \(\rightarrow\) Performance test
  - Linearity
  - Rate
  - Operation in vac.
  - Noise
  \(\rightarrow\) 3rd prototype early next JFY

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Consideration of CsI backside

To design arrangement of CW-base, fiber, cable, etc.

KOTO endcap

Making a mockup @ Osaka U
Summary

• KL Beamline reaches a stage of construction
  • Collimator will be delivered by the end of this JFY
  • Construction in next FY is on the menu

• Beam survey preparation proceeds smoothly
  • Method is being examined to be more robust
  • Detectors are being prepared

• KOTO detector preparation also goes at a good rate