E17 Status Report

K⁻⁻³He 3d→2p x-rays

Ryugo S. Hayano, Tokyo

for J-PARC E17 Collaboration
J-PARC E17 collaboration


SNU¹, SMI², LNF³, RCNP⁴, Kyoto Univ.⁵, Univ. of Tokyo⁶, RIKEN⁷, KEK/J-PARC⁸, Tokyo Tech⁹, Tech. Munich Univ.¹⁰
E17 : K⁻-³He 3d→2p x-rays

(stopped K⁻ in liquid ³He target)

ΔE_{2p} Precision Goal: ± 2 eV (stat) ± 2 eV (syst)
Proposed in 2006

3d-2p X-ray (~ 6.2 keV)

Width : Γ_{2p}
Shift : ΔE_{2p}

(Coulomb-only)

Strong interaction

Nuclear Absorption

8 x SDDs
(silicon drift detectors)
~150 eV FWHM
E17 has been ready to run
but meanwhile...
SIDDHARTA main goals:
\( \Phi \rightarrow K^+K^-, K^-p, K^-d \) in gas, using 144 SDDs

Energy spectrum of the kaonic helium L\( _\alpha \) line is seen at 6.4 keV. The X-ray peaks in the energy spectrum were fitted with the additional Voigt function, where energy resolution evaluated from calibration data was 151\( \pm 8 \) eV (FWHM). The X-ray energy of the Kaonic helium L\( _\alpha \) line is determined to be 6.463 ± 0.008 eV (FWHM). The X-ray energy of the strong interaction shift of the kaonic helium 2\( ^p \) state in kaonic helium is negligibly small, we use the value of 3\( \pm 2 \) (syst). The systematic error is 2\( \pm 2 \) eV (FWHM). The natural width \( \Gamma \) was found to be below the measurement limit within our statistics.

K- 4He 2p shift (eV)

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<table>
<thead>
<tr>
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<tbody>
<tr>
<td>old average</td>
<td>-43 ± 8</td>
</tr>
<tr>
<td>KEK E570</td>
<td>+2 ± 2 ± 2</td>
</tr>
<tr>
<td>SIDDHARTA</td>
<td>0 ± 6 ± 2</td>
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</table>

(confirmation of E570)

And ALSO took data on K-^3He

The kaonic $^3$He $3d\rightarrow2p$ transition is seen at 6.2 keV. Together with this peak, small peaks are seen, which are the kaonic atom X-ray lines produced by kaons stopping in the target window made of Kapton (polyimide). The Ti Kα line at 4.5 keV is also visible.

The kaonic helium Lα peak was fitted with a Voigt function, which is a convolution of a Gaussian and a Lorentzian. The fit lines are shown in the figures. The energy resolution of the peak is consistent with the value obtained from the noncoincidence data (about 0.5 keV FWHM) at 6.2 keV.

SIDDHARTA Collaboration, arXiv:1010.4631
SIDDHARTA K$^{-3}$He & K$^{-4}$He

taken under condition similar to K$^{-3}$He (different from PLB 681)

Fit result:
Large 2p shift in K$^{-3}$He?
SIDDHARTA K^{-3}He & K^{-4}He

+6 eV correction due to rate-dependent gain shift

Fit

Systematic uncertainty in the gain shift correction
SIDDHARTA K\(^{-3}\)He & K\(^{-4}\)He

\[ \Delta E_{2p} [\text{eV}] \]

-6 eV correction due to rate-dependent gain shift

**SIDDHARTA**

<table>
<thead>
<tr>
<th></th>
<th>K(^{-3})He</th>
<th>K(^{-4})He (new)</th>
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<tr>
<td></td>
<td>-2 ± 2 ± 4</td>
<td>5 ± 3 ± 4</td>
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All results consistent with small (~0 eV) shift, BUT

arXiv:1010.4631

Systematic uncertainty in the gain shift correction

- Fit
All results consistent with small (~0 eV) shift, BUT is this an indication of “finite isotope shift” of 7 ± 3.6 eV ? (~2 σ) (\(^3\)He-\(^4\)He difference - less affected by systematic errors)

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<td>K(^{-4})He (new)</td>
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+6 eV correction due to rate-dependent gain shift

Systematic uncertainty in the gain shift correction
7 eV shift - interpreted à la Akaishi

Akaishi, 2005

isotope shift

K'He 2p shift (eV)

Potential (MeV)

siddharta isotope shift?

3He

4He

Akaishi, 2005
The (slightly) modified E17 goals

<table>
<thead>
<tr>
<th>quantity</th>
<th>Uncertainty (eV)</th>
</tr>
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<tbody>
<tr>
<td>$K^{-3}\text{He}$ 2p shift</td>
<td>± 1 (stat.)</td>
</tr>
<tr>
<td>$K^{-4}\text{He}$ 2p shift</td>
<td>± 1 (stat.)</td>
</tr>
<tr>
<td>isotope shift</td>
<td>± 1.5 (stat.)</td>
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The (slightly) modified E17 goals

$\Delta E_{2p}$ [eV]
Beam Requirements (for Physics Run)

Expected $L_x$ x-ray yield, in comparison with KEK E570 result (dashed quantities):

\[ Y(3d \rightarrow 2p) = \frac{N_{\text{stop}K^-} \cdot \varepsilon_{\text{DAQ}} \cdot \varepsilon_X \cdot \varepsilon_C}{N'_{\text{stop}K^-} \cdot \varepsilon'_{\text{DAQ}} \cdot \varepsilon'_X \cdot \varepsilon'_C} \times Y'(3d \rightarrow 2p) \]

$\Delta E_{\text{stat}} \approx 2$ eV (E17 proposal)

$Y(3d \rightarrow 2p) = Y'(3d \rightarrow 2p) = 2 \times 10^3$ events ($\Delta E_{\text{stat}} \approx \sigma_{E=6.2\text{ keV}}/\sqrt{Y}$)

$N_{\text{stop}K^-} = N'_{\text{stop}K^-} / 15.4 \approx 6 \times 10^6$ ($N'_{\text{stop}K^-} \approx 90M$)

Expected $K^-$ beam intensity at 750 MeV/c = 1.5 k/s (1kW - 0.167Hz, Ni)

Stopping Efficiency of $K^-$: 0.4% -> Number of stopped $K^- = 6$ /spill.

$\Rightarrow$ Required spill number: $6 \times 10^6 / 6 = 1 \times 10^6$ (208 shifts ~ 10 weeks)

We require **10 kW•week** to achieve the precision goal.

<table>
<thead>
<tr>
<th>$\rho \sim 0.08 \text{ g/cm}^3$</th>
<th>Ni target old tuning</th>
<th>Pt target (x 1.8) new tuning (x 2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$K^{-3}\text{He}$ $\pm 1\text{eV(stat)}$</td>
<td>40 kW•week</td>
<td>12 kW•week</td>
</tr>
<tr>
<td>$K^{-4}\text{He}$ $\pm 1\text{eV(stat)}$</td>
<td>30 kW•week</td>
<td>8 kW•week</td>
</tr>
<tr>
<td>total</td>
<td>70 kW•week</td>
<td>20 kW•week</td>
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</table>
SDD commissioning with beam

- Run 36 (Nov. 7 ~ Nov. 10, 2.9~3.5 kW, 900 MeV/c)

- SDD operation under beam condition
- Confirmation of yield and S/N ratio of calibration peaks

Successfully operated all SDDs with good energy resolution (ΔE ~150 eV @ 6.2 keV)

Yield of calibration peaks can be controlled well with good S/N.

X-ray spectrum (sum of 8 SDDs)
Liquid $^3$He Target System

The target system was installed in K1.8BR area in the summer of 2010.

After beam time of November, the cryogenic system was tested w/o SDDs.

- Time for target material changes from $^4$He to $^3$He is enough in half day.
- Estimated Heat Load is allowable for E17 (KEK-E570: 1.5K, 95L/day, 0.48W).
- By complete setting of E17, cooling test will be performed from Feb. to Mar. 2011.

Date: Dec. 2010 @K1.8BR

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<thead>
<tr>
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<th>E15 (measurement)</th>
<th>E17 (estimation)</th>
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<tbody>
<tr>
<td>Temperature in the Target Cell</td>
<td>1.3 K</td>
<td>1.4 K</td>
</tr>
<tr>
<td>Liq. $^4$He Consumption</td>
<td>54 L/day</td>
<td>77 L/day</td>
</tr>
<tr>
<td>Heat Load to the 1K Parts</td>
<td>0.22 W</td>
<td>0.38 W</td>
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The E17 target will be ready by end of Mar. 2011.
E17 MUST refute/confirm the 7 eV SHIDDHARTA isotope shift

- In addition to $K^{-3}\text{He}$, we need to take $K^{-4}\text{He}$ data
- This can be achieved with 20 kW-weeks
- “stop-K” tuning will be done in the spring (~3-days)