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Precision spectroscopy of Kaonic Helium *3d*→*2p* X-rays

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for KEK-PS E570 collaboration

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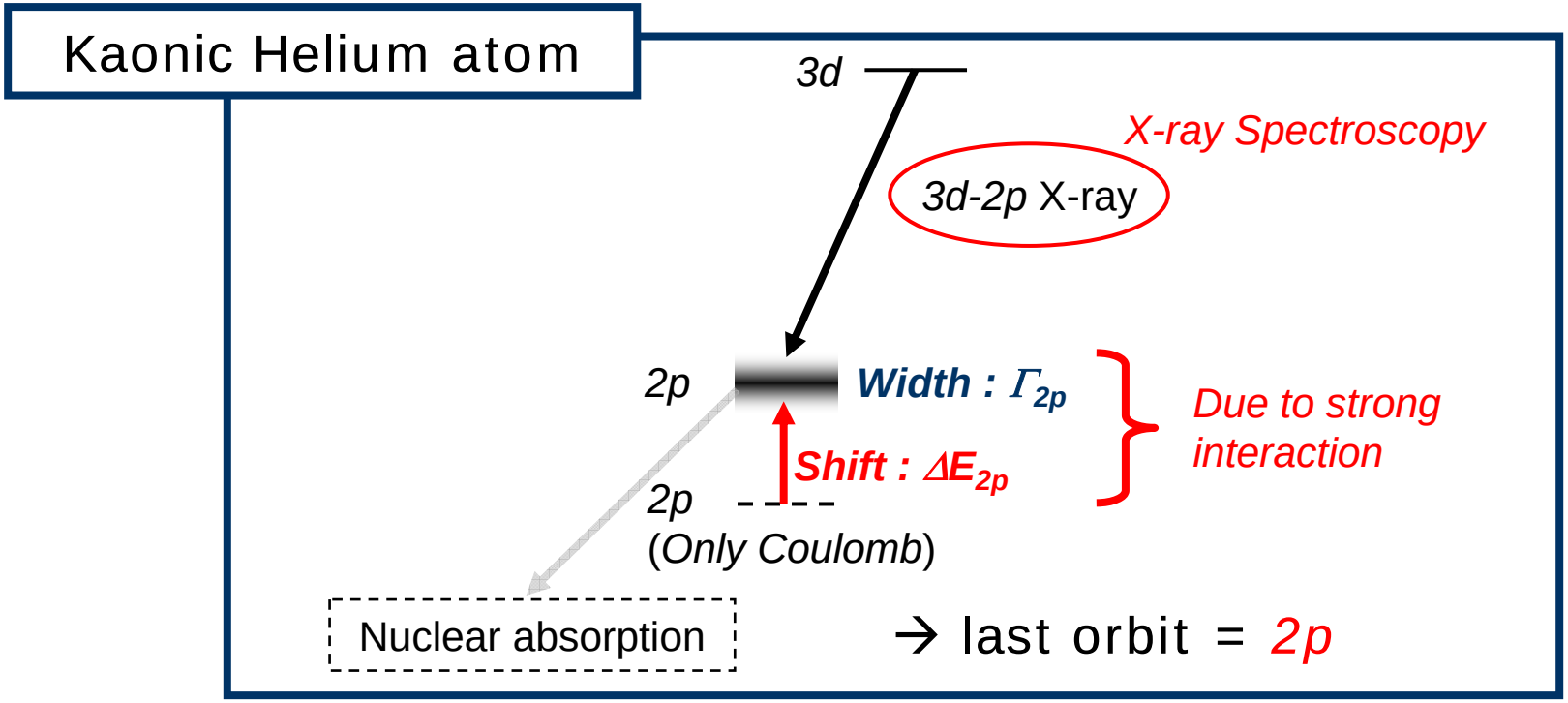
Introduction

Last orbit level shift of Kaonic atom

Last orbit level shift of Kaonic atom is sensitive to **K-nucleus strong interaction**.

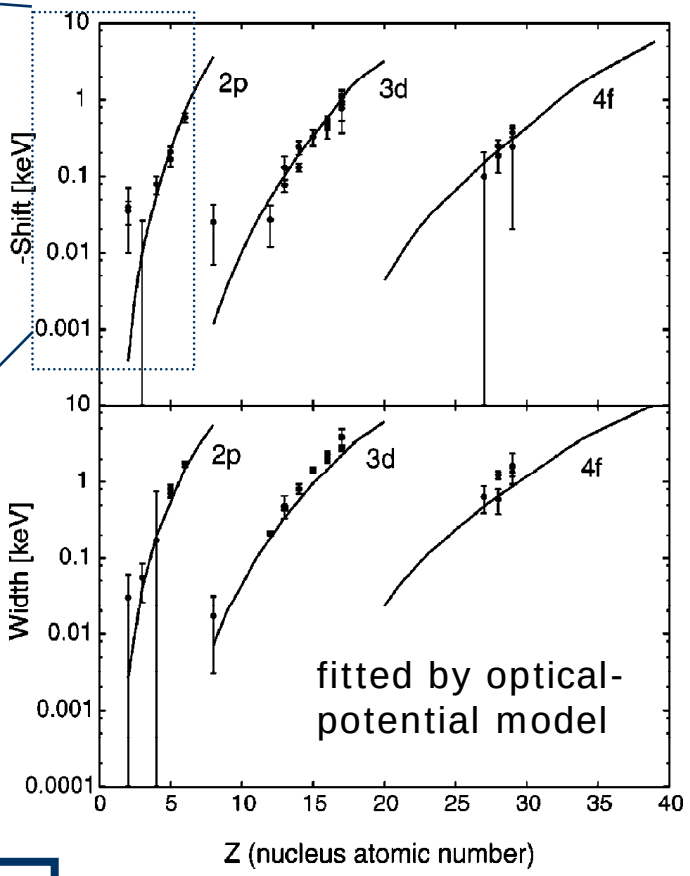


precisely determine the $\overline{K}$-nucleus strong interaction at vanishing relative energy

→ many experiments have been done (from Helium to Uranium)

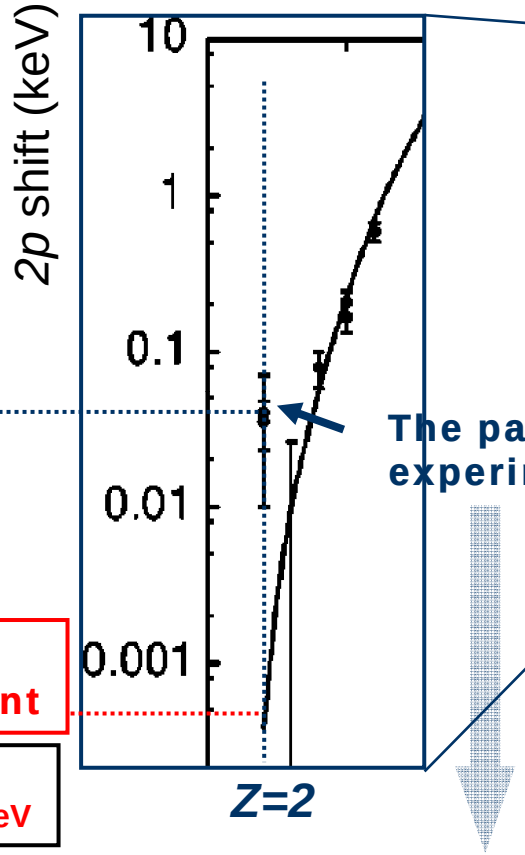
The Kaonic Helium Puzzle

Last orbit energy level shift and width of kaonic atoms



Very large repulsive shift

Exp.
~40eV



The past three experiments

theoretical calc.
→ **zero consistent**

ex) chiral unitary+ optical model : **~0.2eV**

No theory can reproduce such a large shift (~40eV) !

S.Hirenzaki, Y.Okumura, H.Toki, E.Oset, and A.Ramos
Phys. Rev. C 61 055205

A possible **large repulsive shift !**

Akaishi-Yamazaki prediction of “deeply-bound kanoic nuclei” ➡ **Strange multibaryon candidates** (KEK, DAFNE, BNL)

a bare $\overline{K}$-N potential so as to simultaneously reproduce

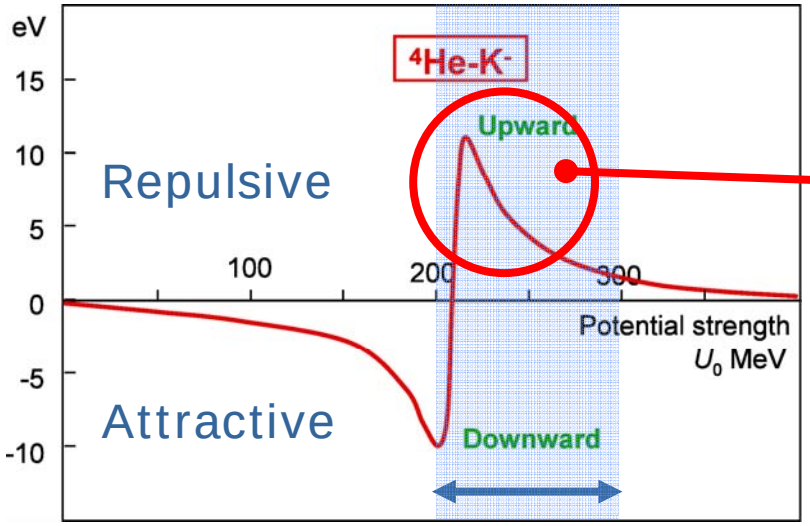
- $\overline{K}$-N scattering lengths
- The binding energy and width of kaonic hydrogen atom
- Treating $\Lambda(1405)$ as a K-N bound state

G-matrix calc. ⇒ *Deep $\overline{K}$-nucleus potential*

applied to kaonic atom ⇓

Large repulsive shift is acceptable
~-10 eV at maximum

***2p* level shifts of the K^--^{4}He atom**



200~300MeV
Predicted region

Y.Akaishi, EXA05 proceedings (2005)

Three past experiments

Exp.

ΔE_{2p} (eV)	Γ_{2p} (eV)
-41 ± 33	$-$
-35 ± 12	30 ± 30
-50 ± 12	100 ± 40
Average -43 ± 8eV	55 ± 34eV
Shift	Width

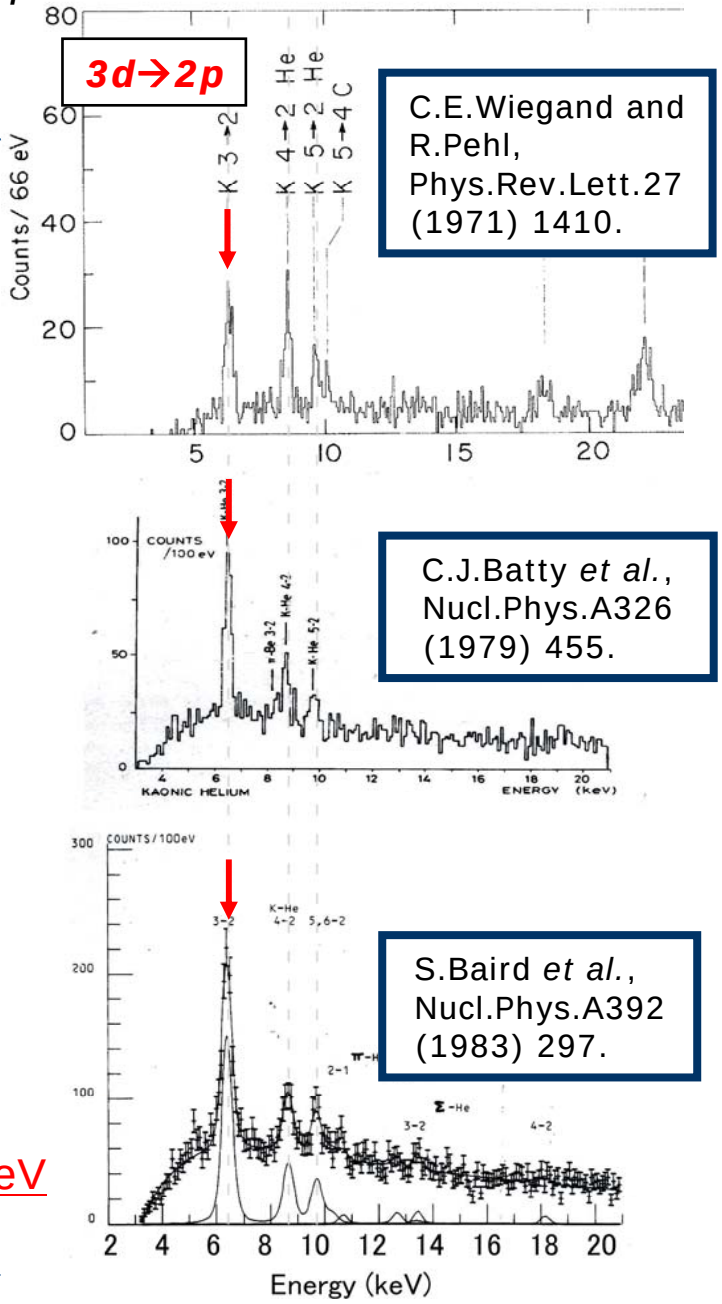
- ✓ X-ray detector : Si(Li)
  Energy resolution … FWHM=300eV @6.4keV
- ✓ Large background
- ✓ Absolute energies w/o in-beam calib.

Present experiment (KEK-PS E570)

measure the shift with a precision <u>better than 2 eV</u>

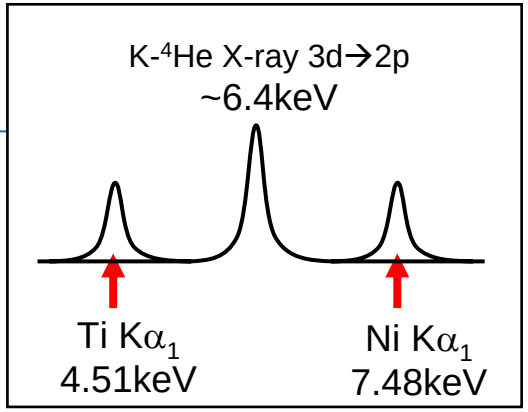
by improved experimental method.

2p level shifts of the K^--^{4}He atom



Experiment

Experimental setup and features



provide accurate in-situ calib!

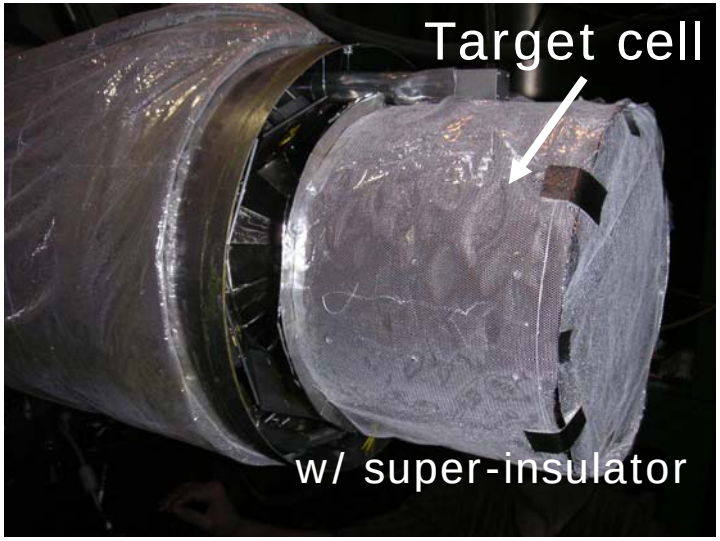
continuum background
events → reduced

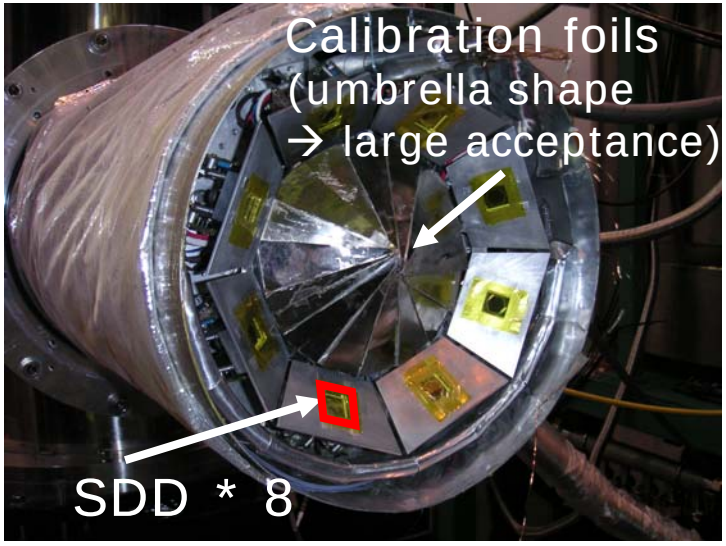
3) Fiducial volume cut
reaction vertex is within the liq. He volume

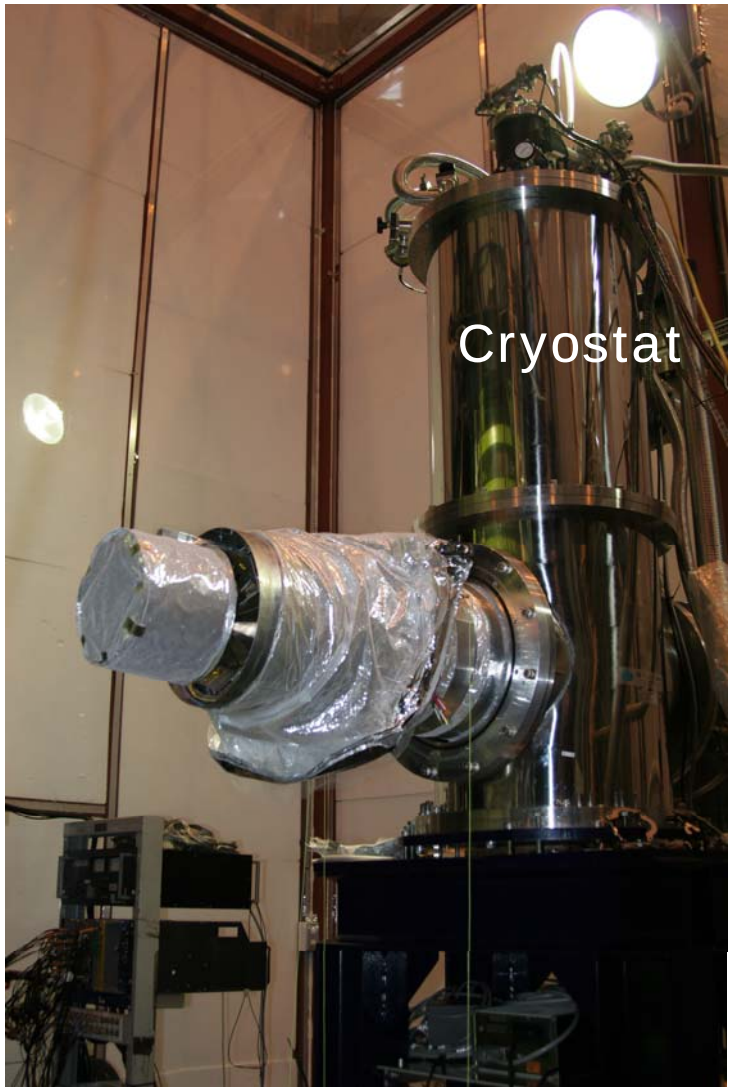
2) In-beam energy calibration

1) High resolution X-ray detector
Silicon Drift Detector "SDD" (8個)

Setup pictures



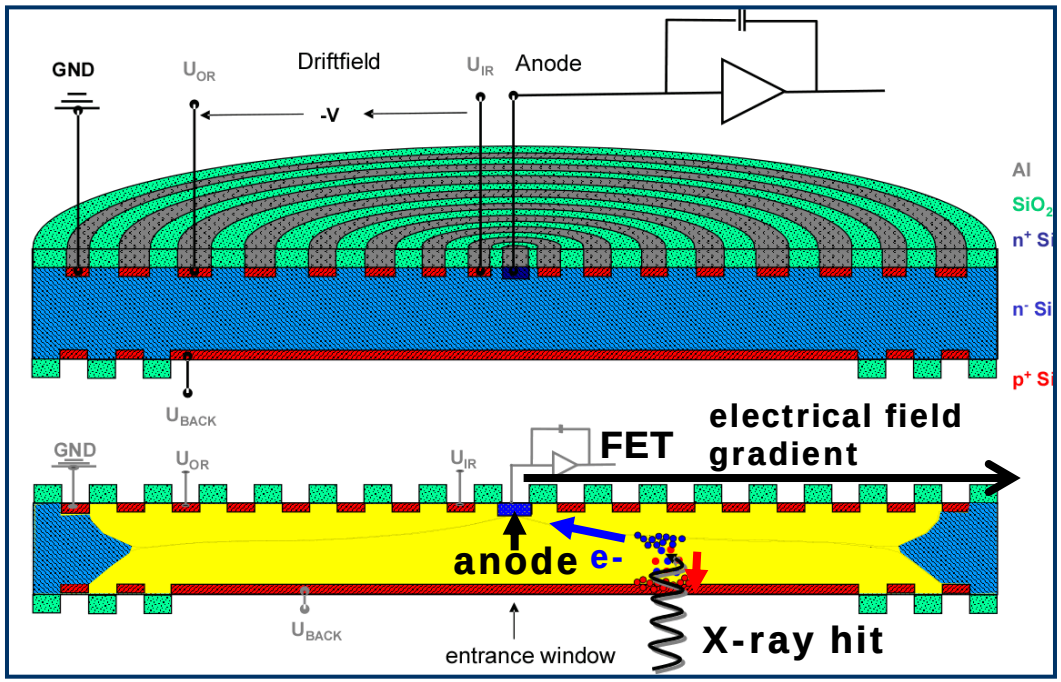


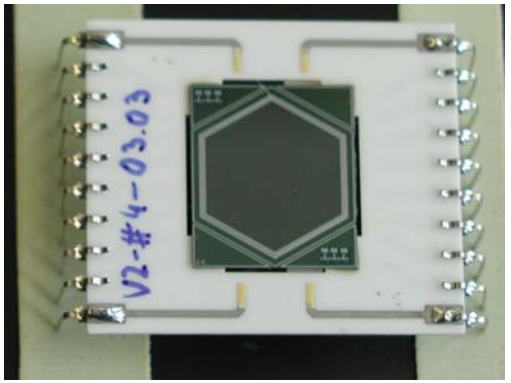


SDD (Silicon Drift Detector)

conventional Si(Li) → SDD

Schematic drawing of a SDD





KETEK 100mm^2 SDD

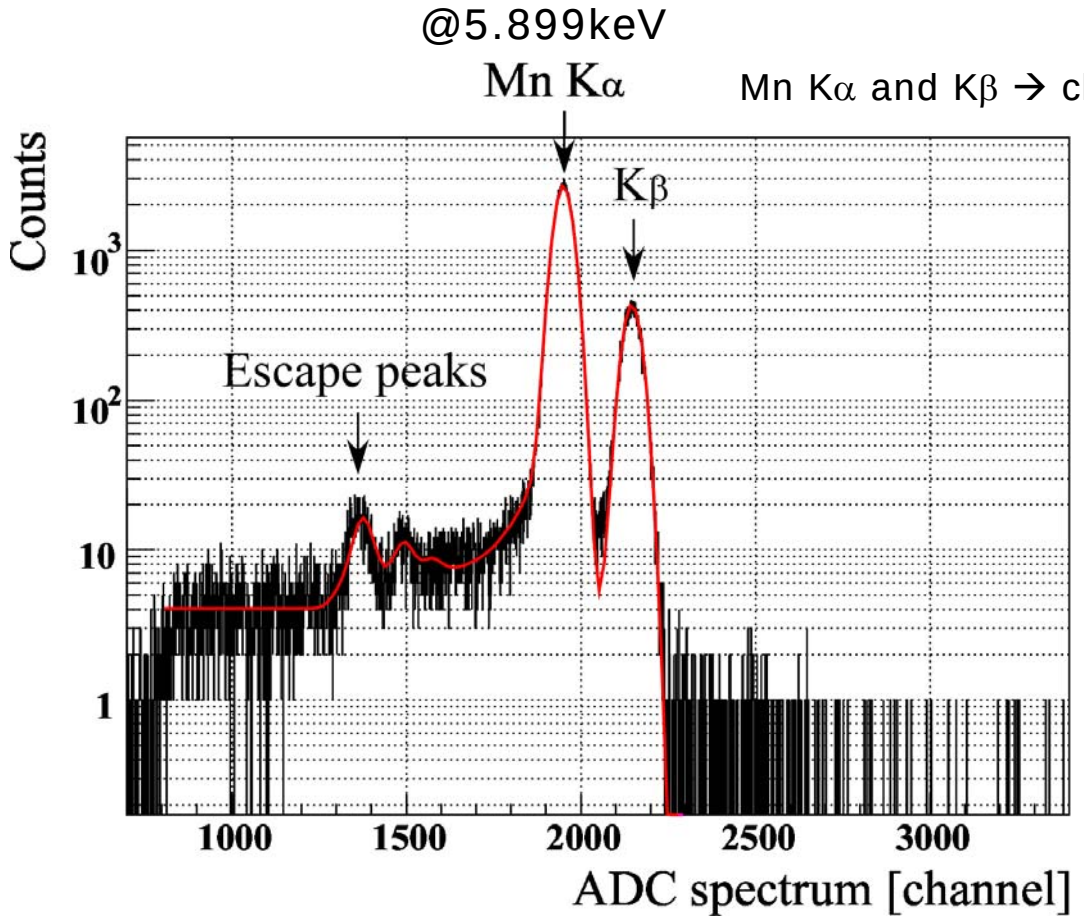
$C = \varepsilon_0 S / d$

- **Anode size (capacitance) kept small** independent of the detector area.
  - **Good energy resolution** with large effective area (100mm^2)
  - **Small anode → reduce the thickness** (0.26mm<<4mm in previous exp.)

  → reduce continuum background caused by the soft-Compton process.

Typical resolution (with ^{55}Fe source)

- Same experimental setup with that of E570
- SDD temperature : 85K



Mn Kα and Kβ → clearly observed

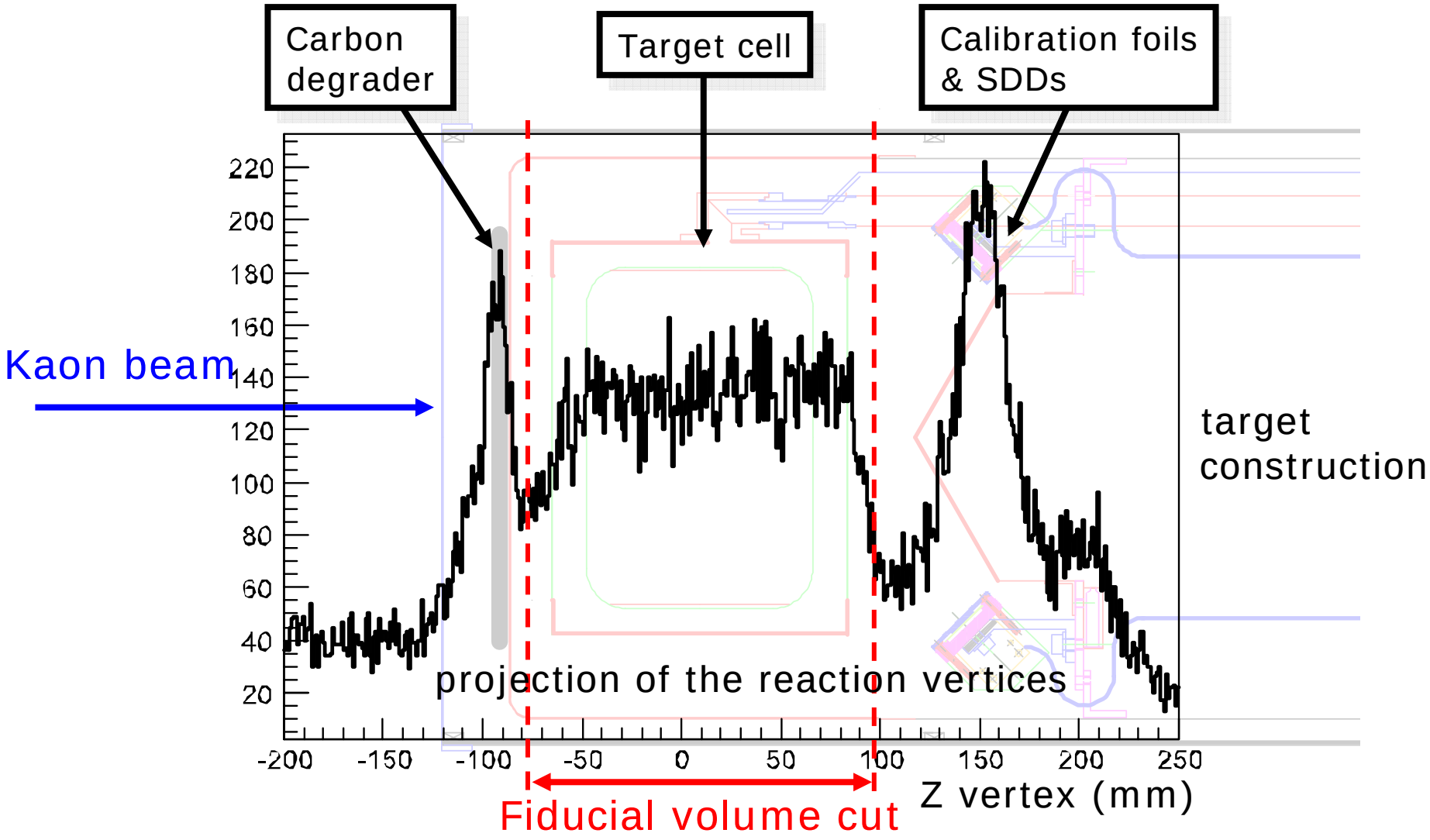
FWHM
= 181.8+0.41eV
@MnKα$_1$=5.899keV

185eV@6.5keV

(past exp:
~300eV @6.5keV)

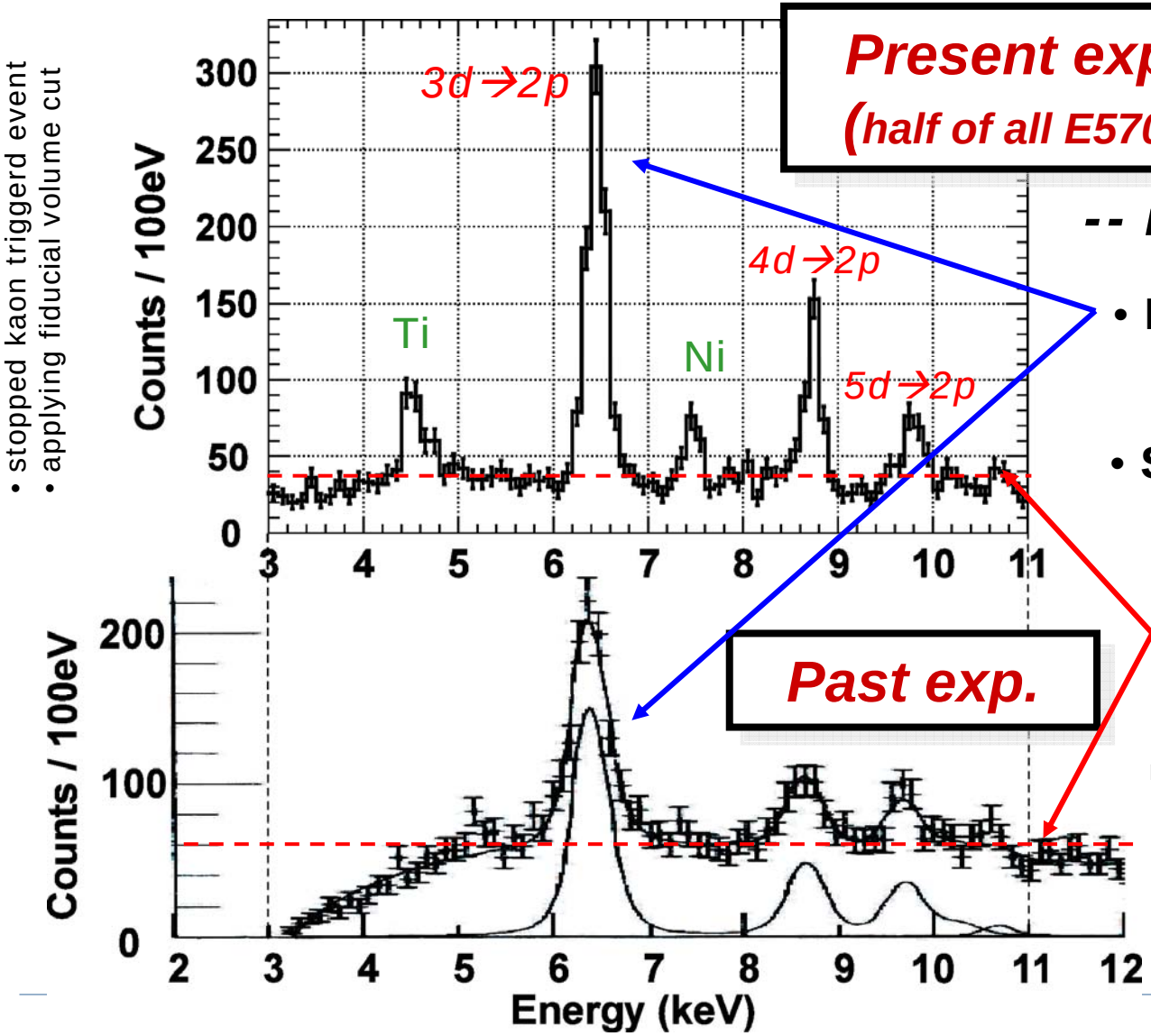
Preliminary result

Target image and fiducual volume cut



Preliminary spectrum

(Comparison with a past experiment)



Present exp. (E570)
(half of all E570 statistics)

Past exp.

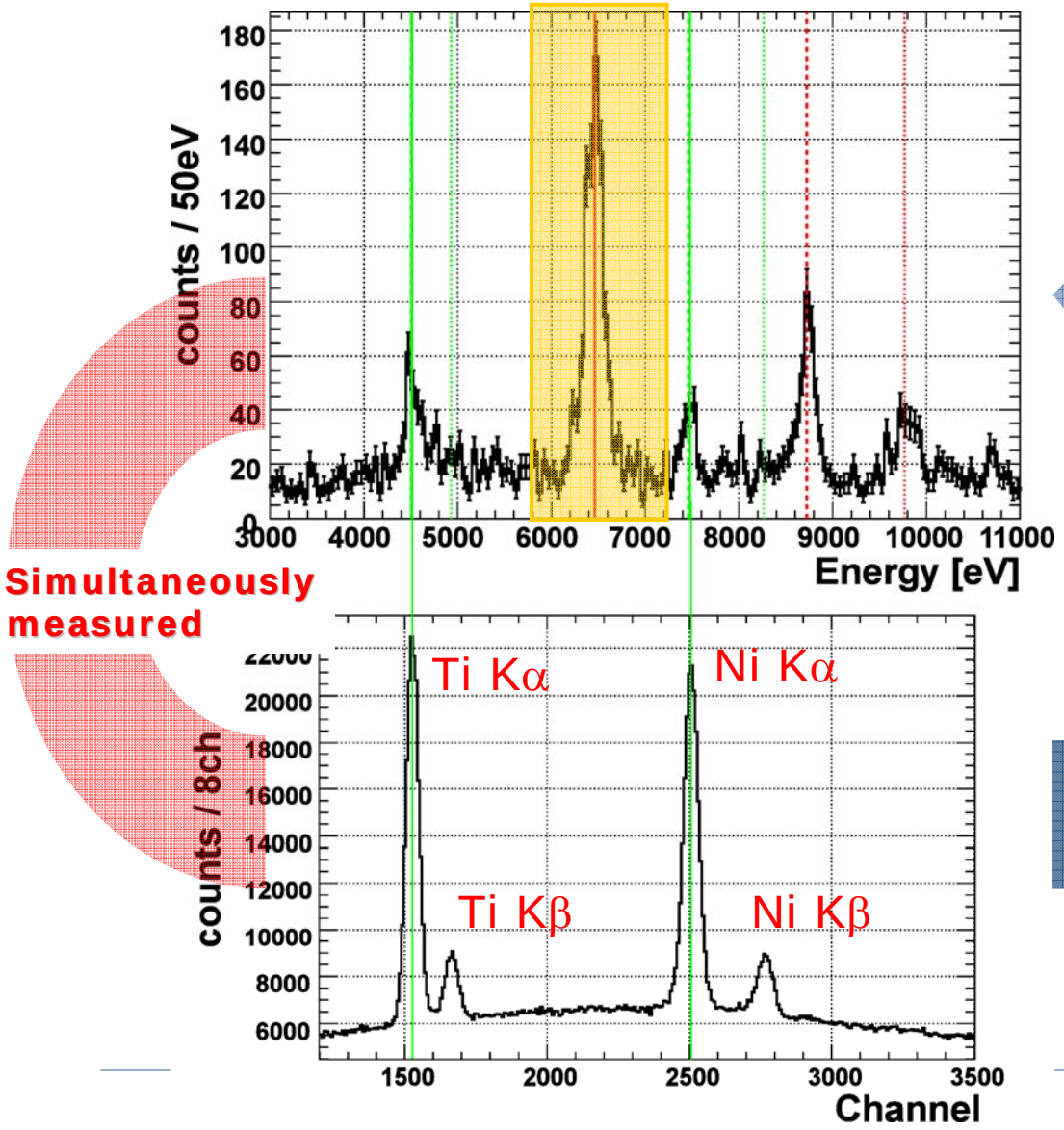
-- improvement --

- **Resolution : x ~1.5**
  (300eV→185eV)
- **Statistics : x ~2.5**
  (3d→2p all statistics: ~1500 events)
- **S/N ratio : x ~5**
  (0.8 → 4)

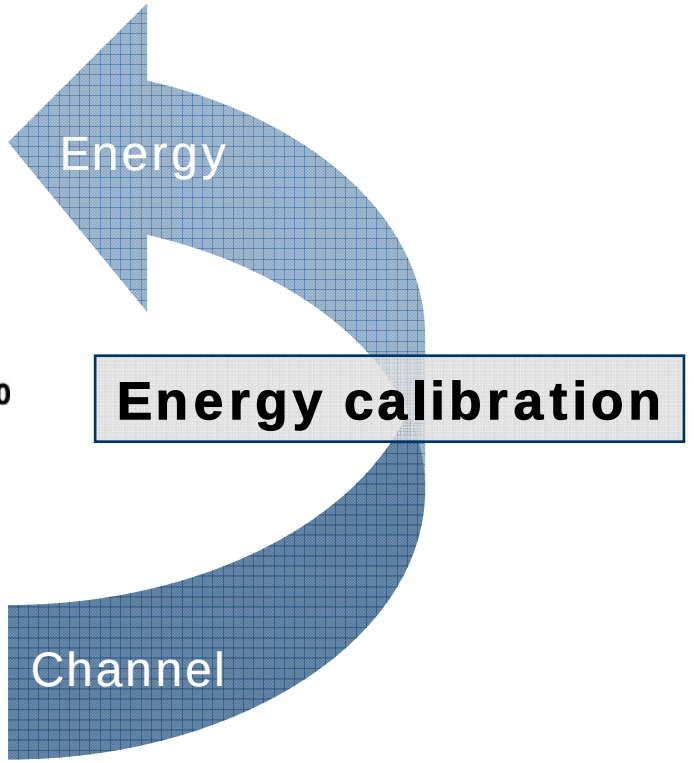
most resent exp.

S.Baird *et al.*, Nucl.Phys.A392 (1983) 297.

Energy calibration (high-statistics calib. data)

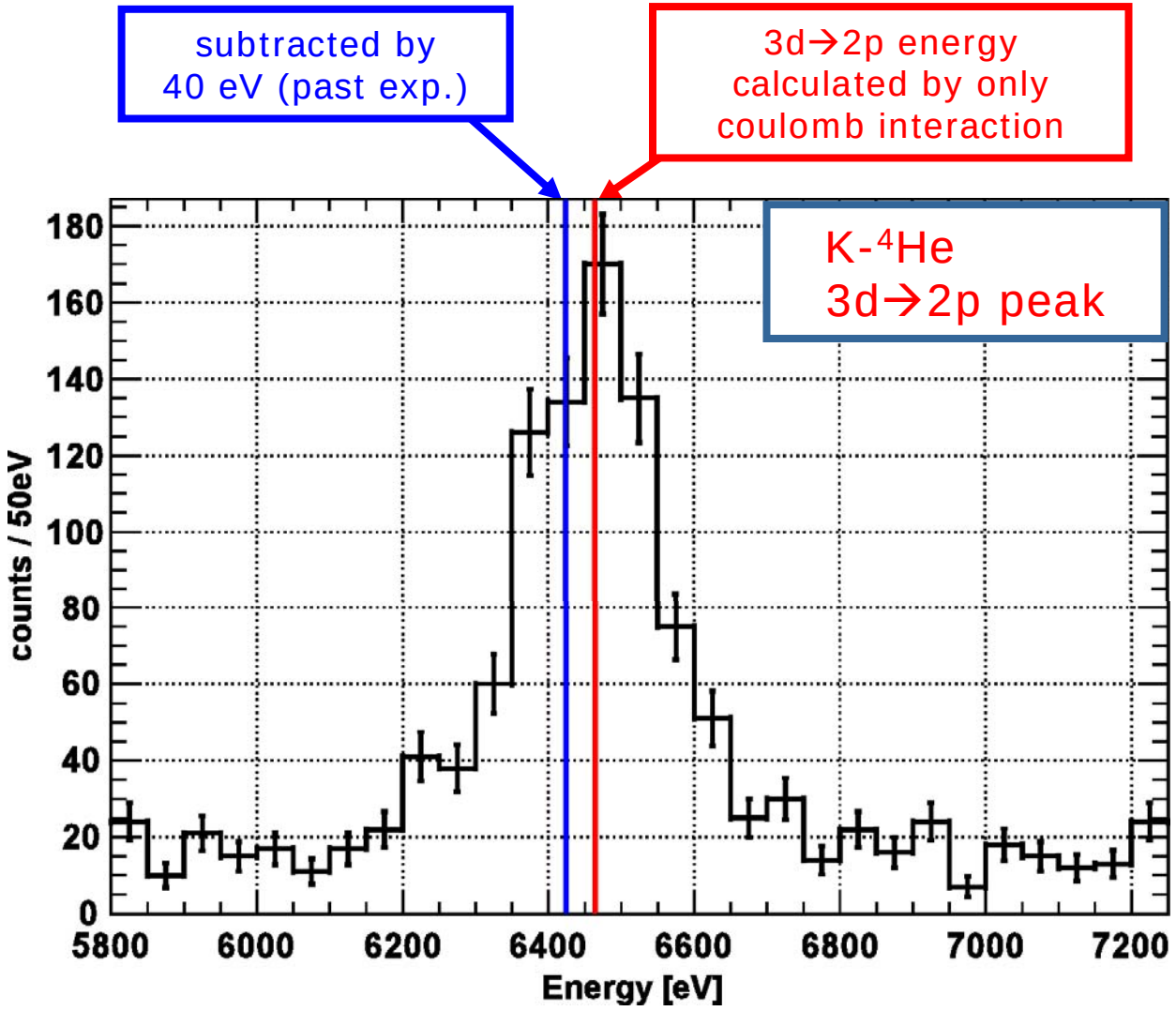


Kaonic atom x-ray spectrum



High statistics calib. spectrum
(self triggered event)
Ti Ka1: 15k events/SDD/8hours

-40eV shift is very clearly rejected



half of all statistics
(added all SDD)

Error estimations

mean value of the 3d→2p x-ray's peak

- Estimated statistical error : ~2 eV

  (1500 events for 3d→2p x-ray)

$$\frac{\sigma}{\sqrt{N}} \sim \frac{185/2.355}{\sqrt{1500}} = 2.03$$

- Systematic errors ... Now in progress
  - Energy calibration & gain adjustment
  - Not sure that pion induced (~500MeV/c) characteristic x-ray energy =~ photon induced (x-ray data booklet).

  ... At this moment, we are using x-ray data booklet energies as the calibration energies of Ti & Ni's x-rays in our energy calibration.

  ... To be sure this matter, we have already performed a test experiment to measure the pion-induced x-ray spectra with calibration sources. (This experiment has been performed just until one week before at PSI. ...This analysis is now in progress.)

  - SDD response function study etc.

Summary

- Accurately measured K^--^{4}He *3d*→*2p* X-ray energy spectrum
  - High energy resolution : 185 eV @6.5keV
  - Good S/N ratio : applying fiducial volume cut (~6)
  - Energy calibration was successfully done by using characteristic X-rays from Ti and Ni foils
- Cleary rejected -40eV (repulsive) shift reported in the three past experiments.

Now we are still analyzing these data including systematic error estimation.