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

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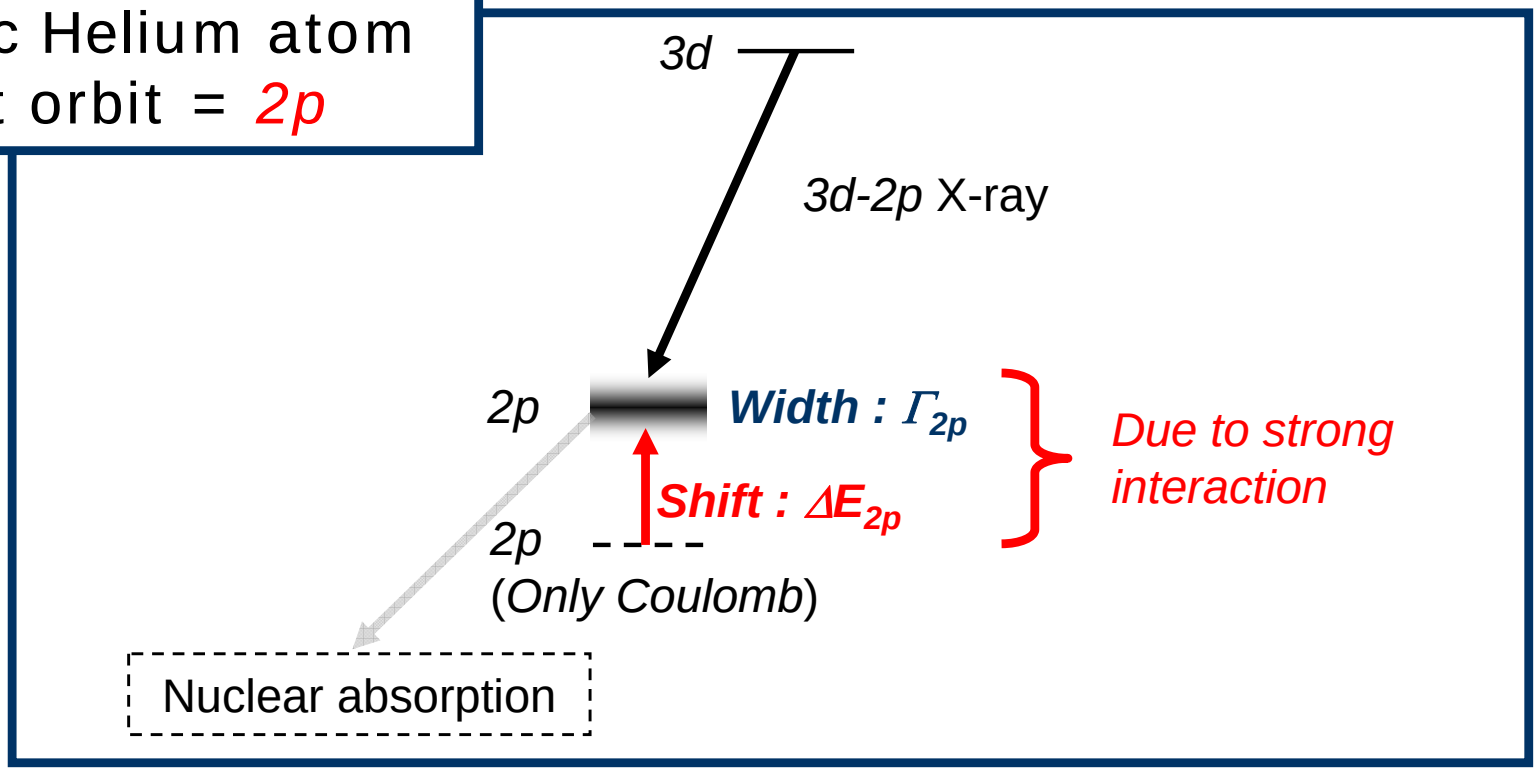
Introduction

Last orbit level shift of Kaonic atom

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

Kaonic Helium atom
→ last orbit = *2p*



precisely determine the $\overline{K}$-nucleus strong interaction at vanishing relative energy
→ many experiments have been done (from Helium to Uranium)

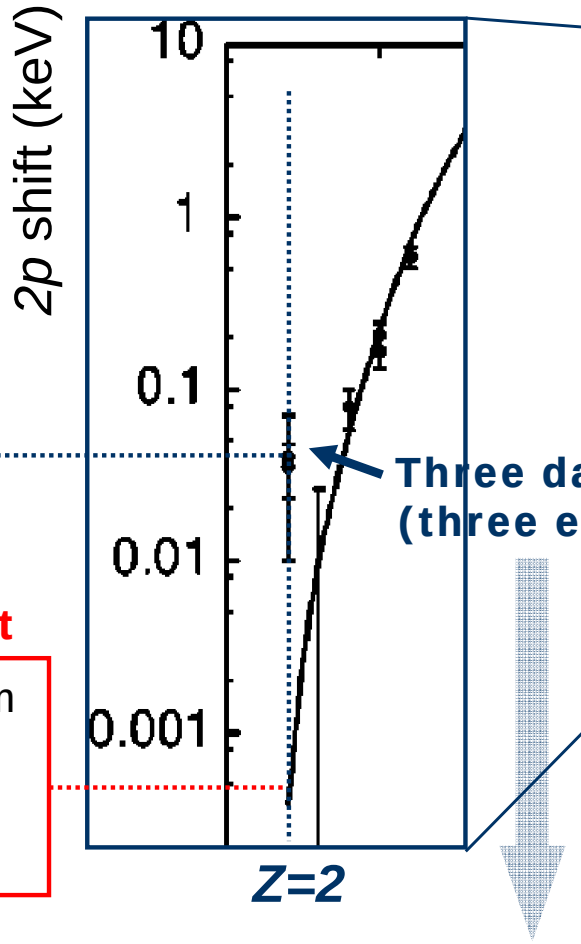
The Kaonic Helium Puzzle

Very large repulsive shift

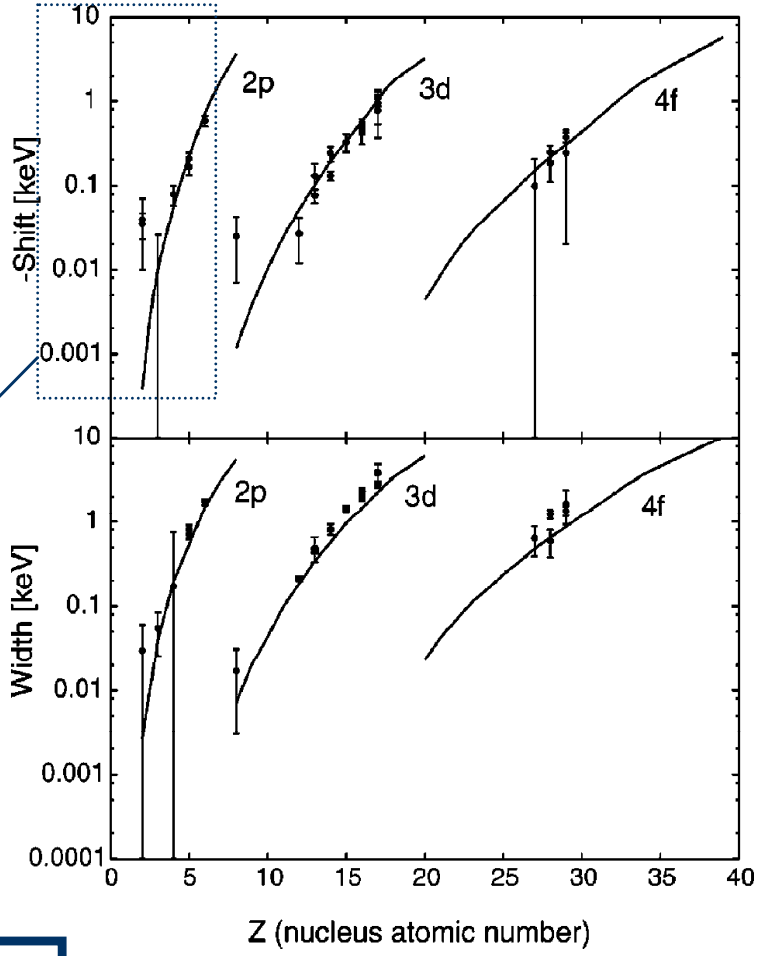
Exp.
~40eV

Very small shift

Calculation from chiral unitary+ optical model:
~0.2eV



Last orbit energy level shift and width of kaonic atoms



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 (Akaishi-Yamazaki model)

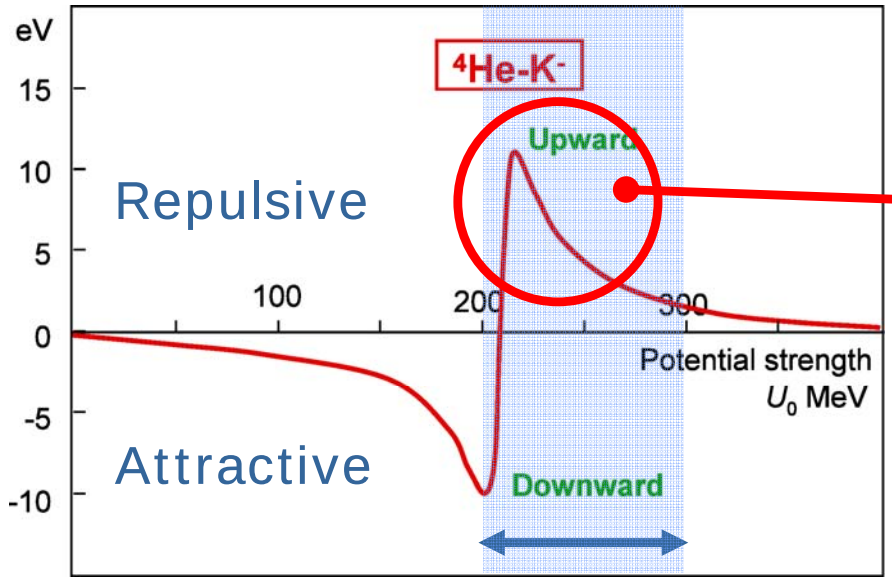
- $\overline{K}$-N scattering lengths
- The binding energy and width of kaonic hydrogen atom
- Treating $\Lambda(1405)$ as a K-N bound state

⇒ *Deep $\overline{K}$-nucleus potential*

⇓

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 early experiments

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

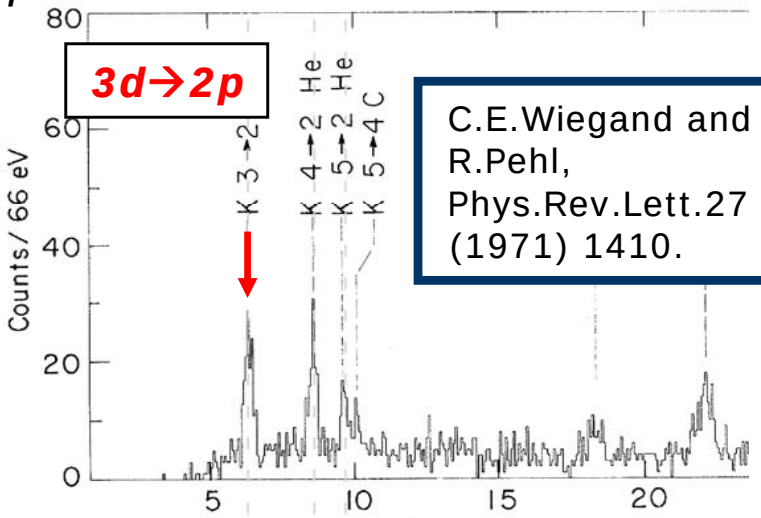
Exp.

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

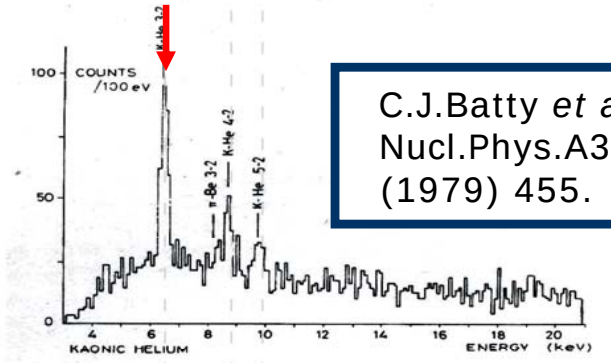
- ✓ X-ray detector : Si(Li)
  Energy resolution ... FWHM=300eV @6.4keV
- ✓ Large background
- ✓ No in-beam energy calibration

Present experiment (KEK-PS E570)

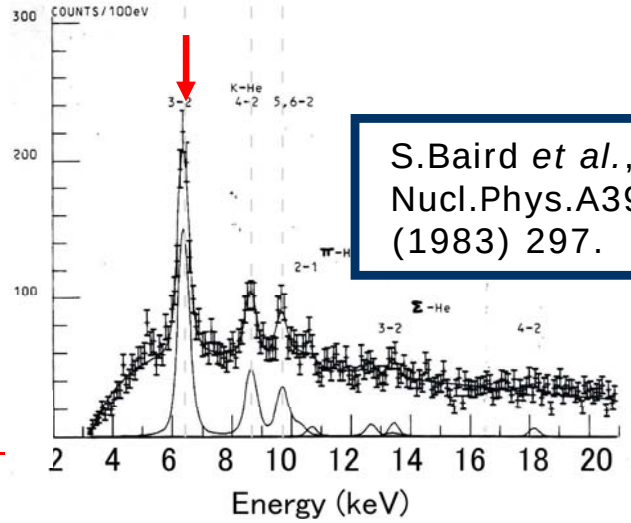
measure the shift with a precision <u>better than 2 eV.</u>



C.E.Wiegand and R.Pehl, Phys.Rev.Lett.27 (1971) 1410.



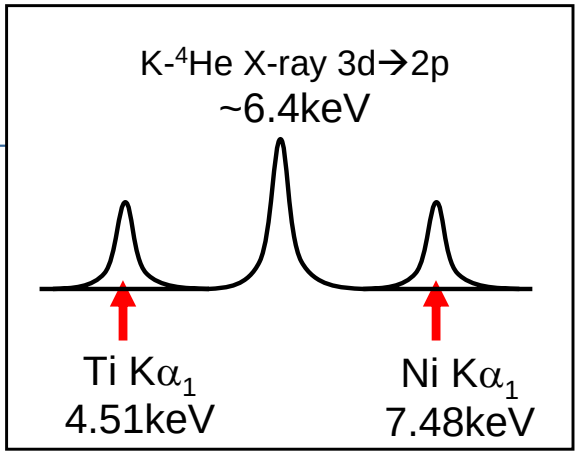
C.J.Batty *et al.*, Nucl.Phys.A326 (1979) 455.



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

Experiment

KEK-PS E570 experiment



3) Fiducial volume cut
Reconstruction of the reaction vertex

2) In-beam energy calibration

Secondary charged particle

K^- beam

π^- (or K^-)

X-ray

Characteristic X-rays from Ti and Ni foils

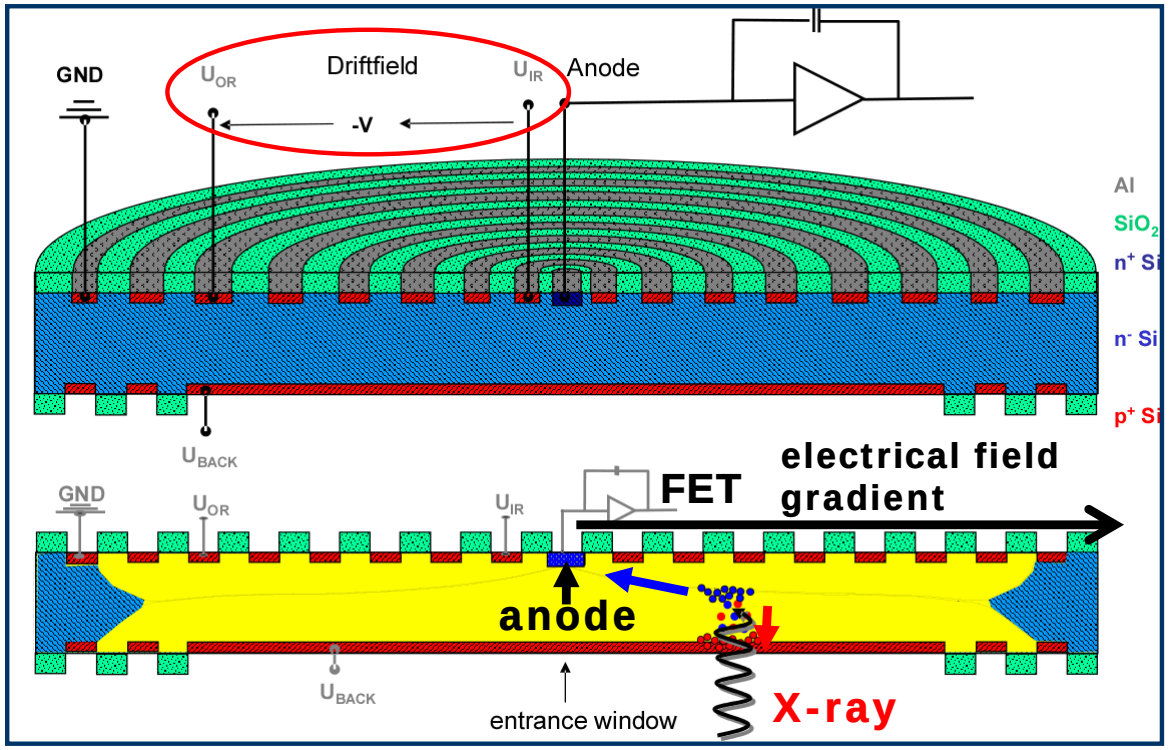
Liq. Helium target

10 cm

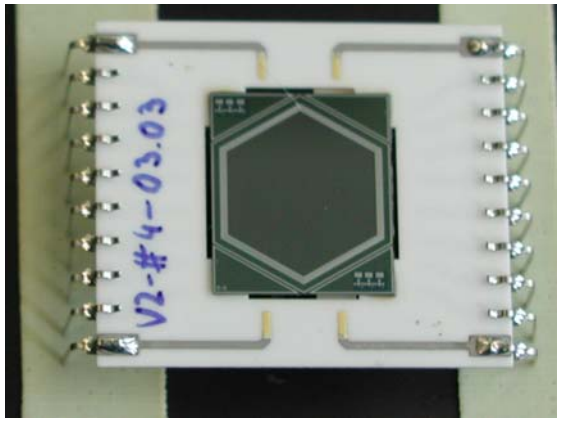
1) High resolution X-ray detector
Silicon Drift Detector "**SDD**" (8個)

SDD (Silicon Drift Detector)

Schematic drawing of a SDD



$$C = \varepsilon_0 S / d$$



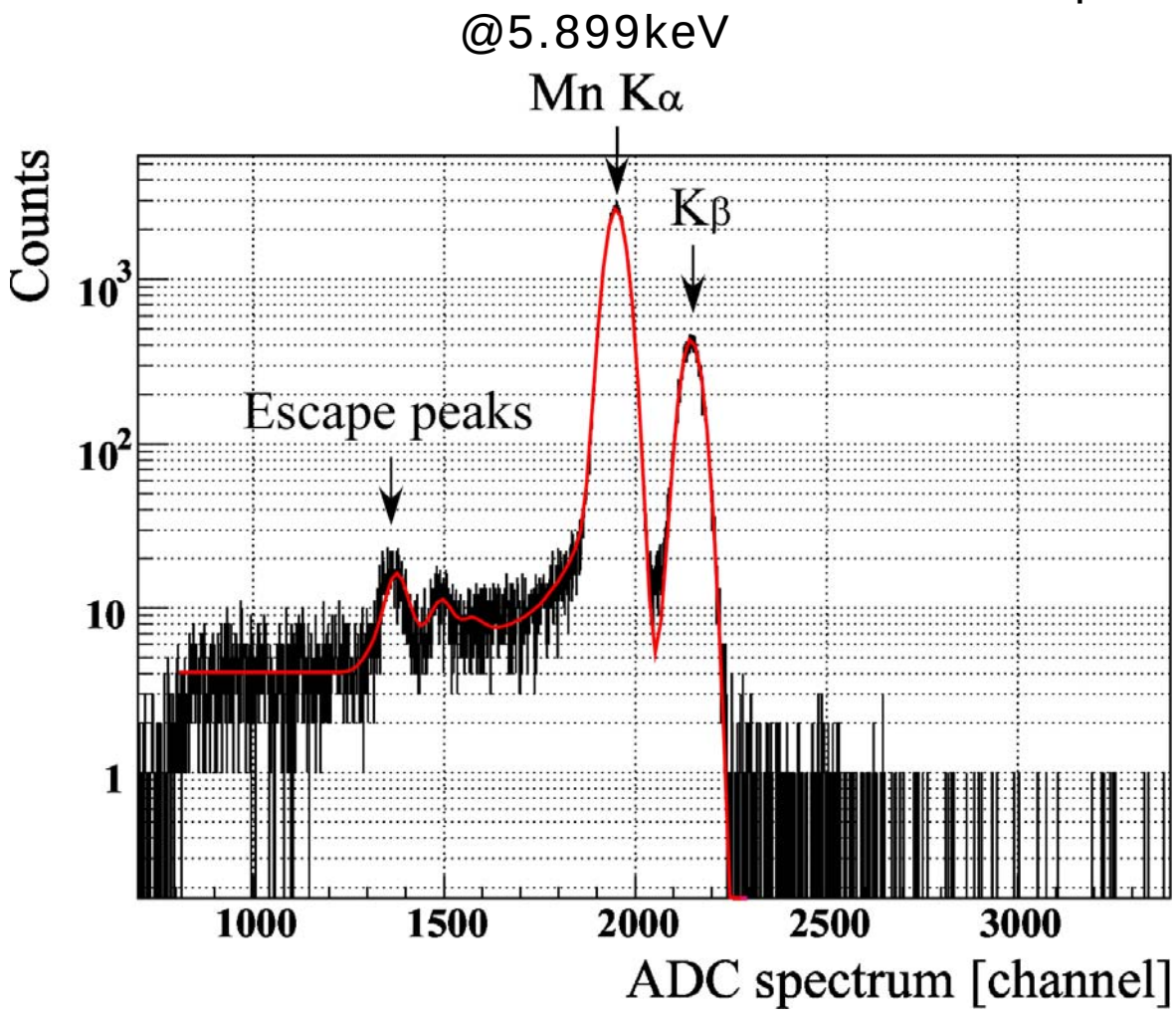
KETEK 100mm² SDD

- "**Small anode = Small capacitance**" with Large effective area (100mm²)
  - **Good energy resolution**
  - **Thin active layer** (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



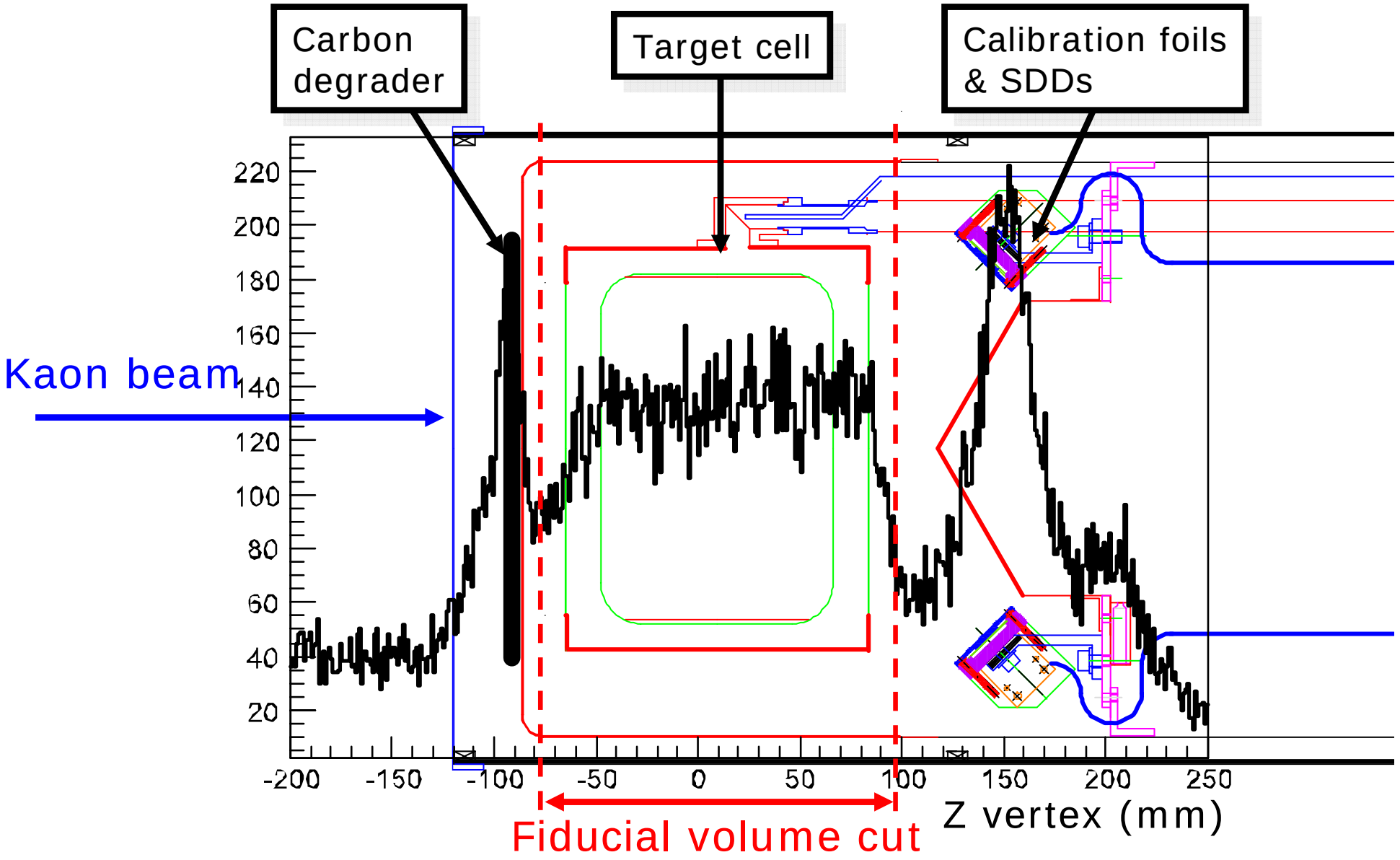
FWHM
= 181.8+0.41eV
@MnKα_1=5.899keV

185eV@6.5keV

(past exp:
~300eV @6.5keV)

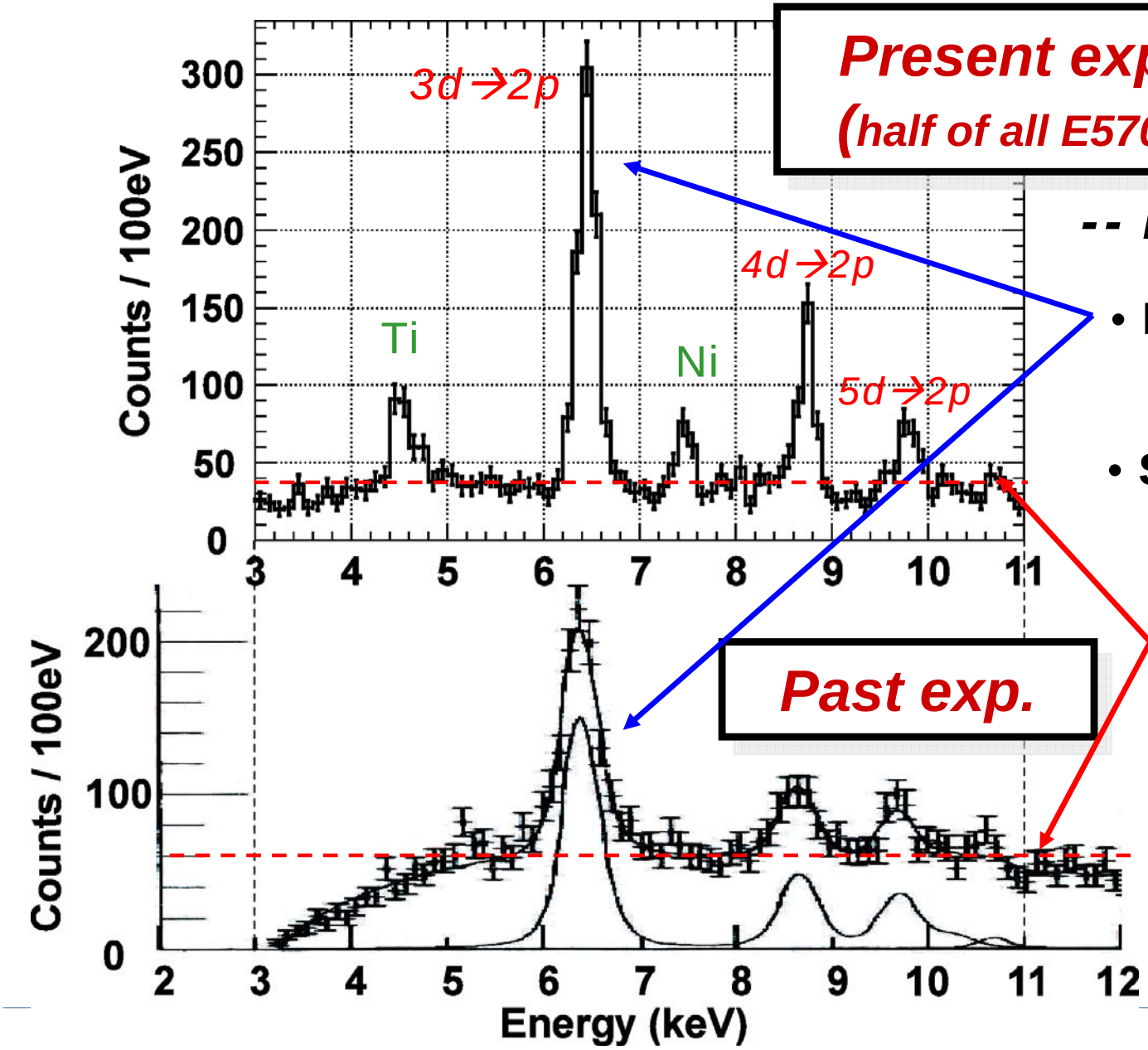
Preliminary result

Target image and fiducual volume cut



Preliminary spectrum

(Comparison with a past experiment)



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

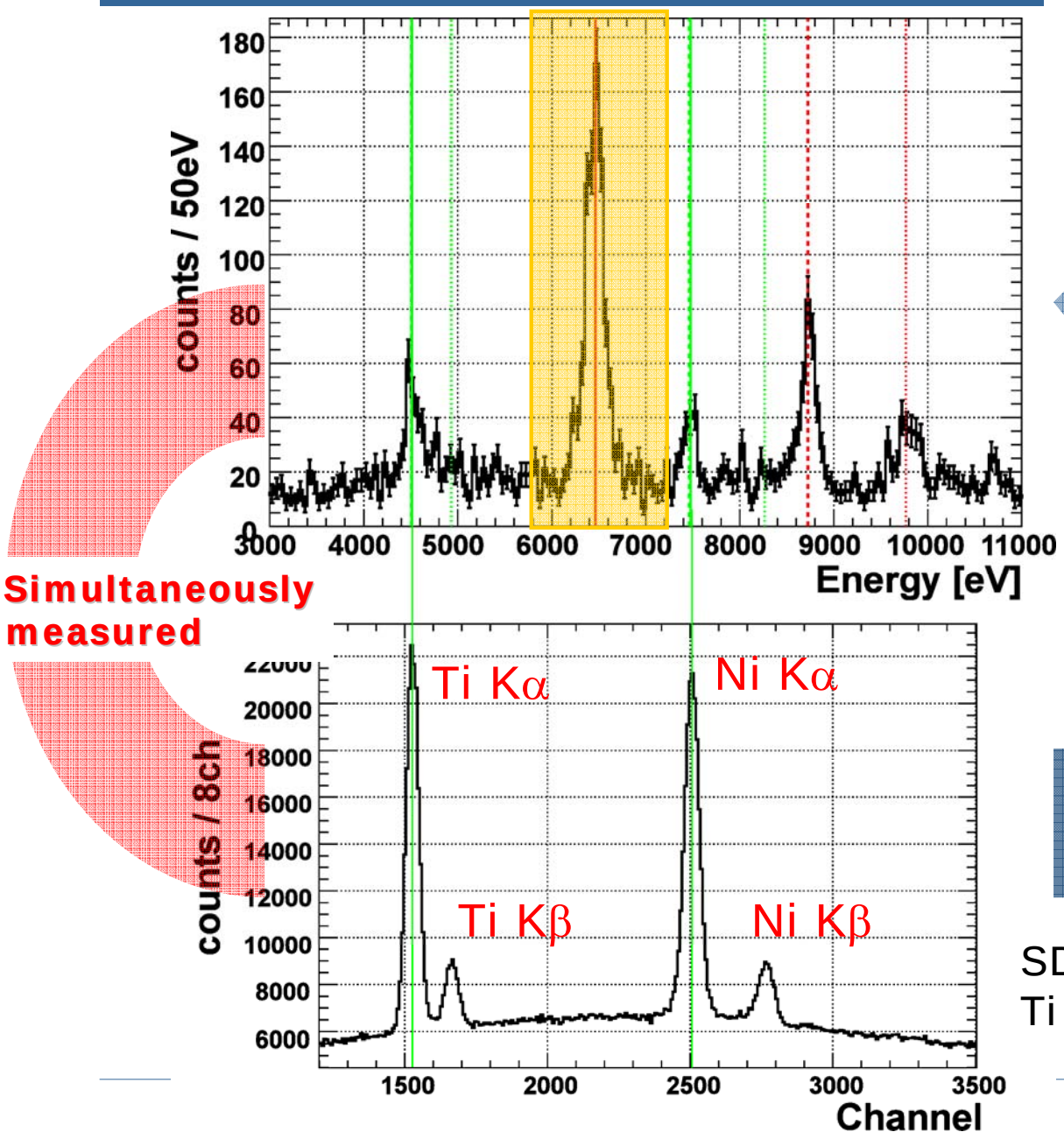
Past exp.

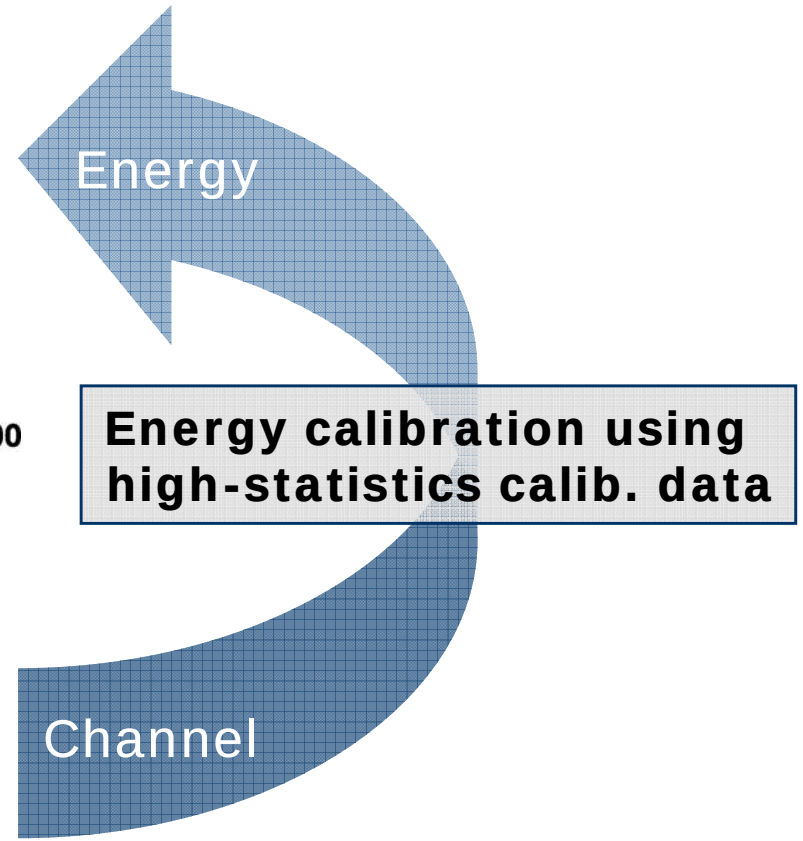
-- improvement --

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

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

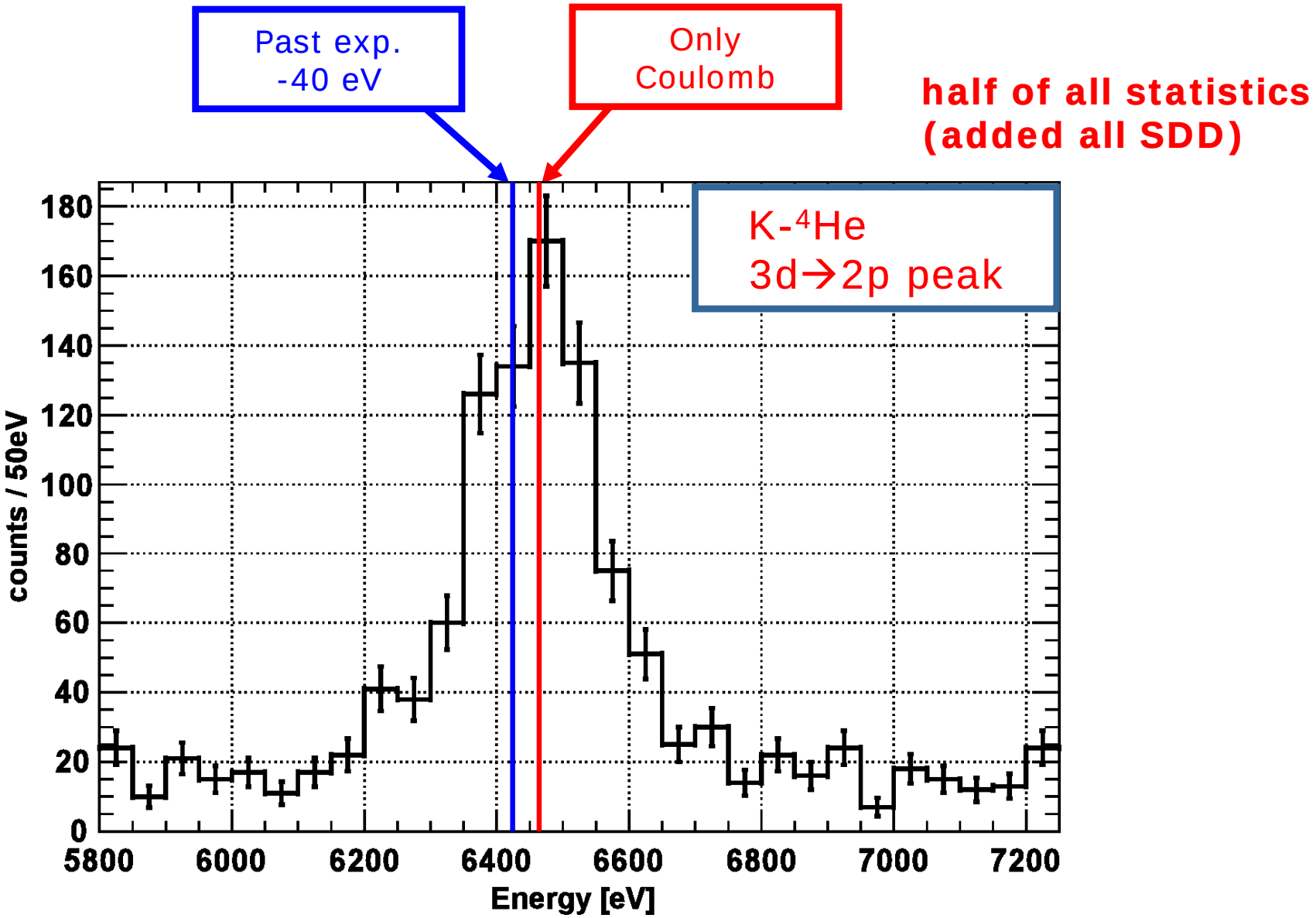
Energy calibration (high-statistics calib. data)





SDD calibration (Self) trigger events
Ti Ka1: 15k events/SDD/8hours

-40eV shift is very clearly rejected



Summary

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