Kaonic Helium Atoms

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THE UNIVERSITY OF TOKYO

MESON2008

①	E570	K$^-$ ^{4}He	KEK	Data taken	Tatsuno (details, June 7A)
②	E17	K$^-$ ^{3}He	J-PARC	“Day-1” (2009)	Iwasaki (E15, June 10)

① K$^-$ ^{4}He

recently published

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Precision measurement of the $3d \to 2p$ x-ray energy in kaonic ^{4}He

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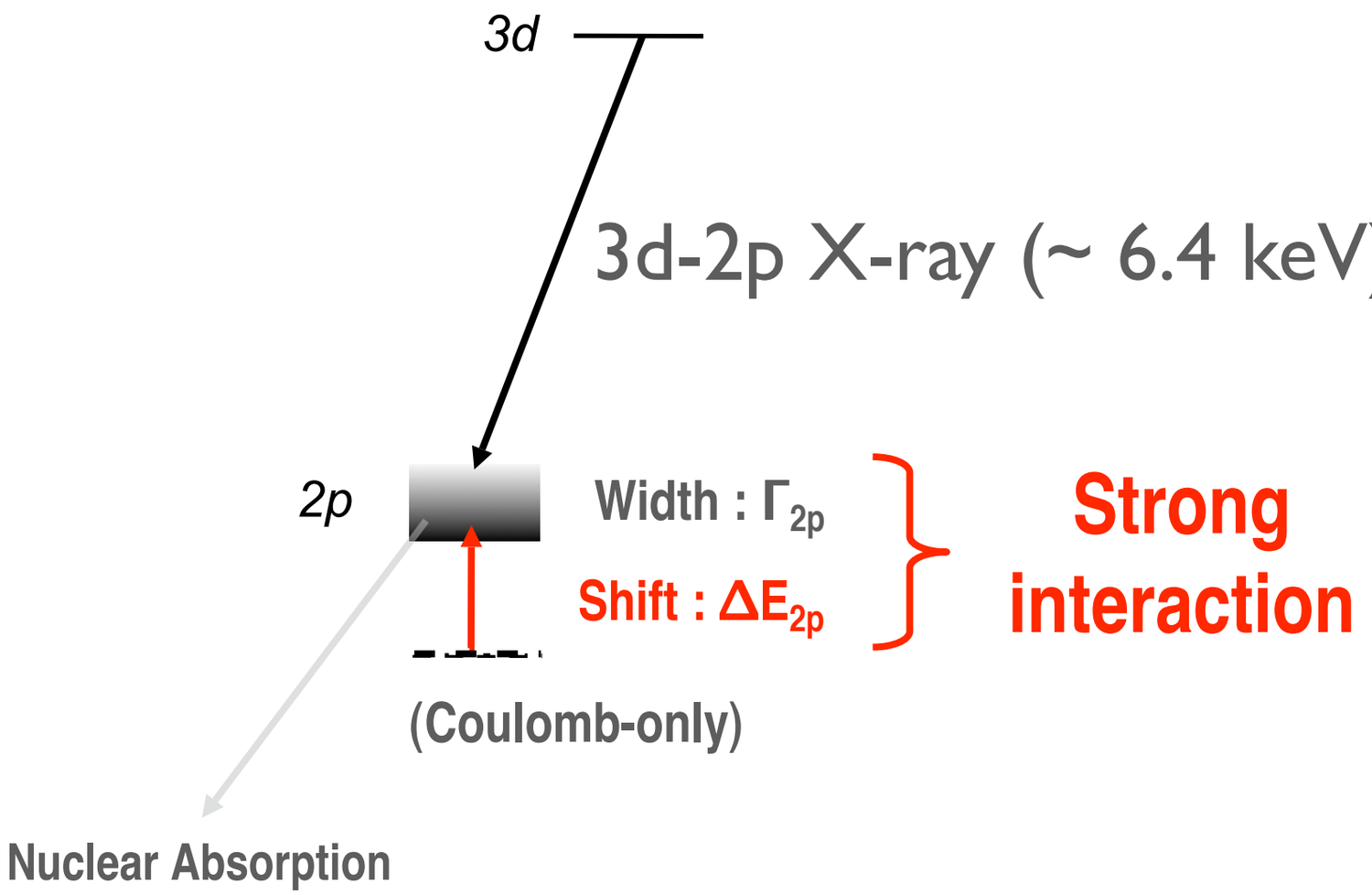
謎

What has been the problem?

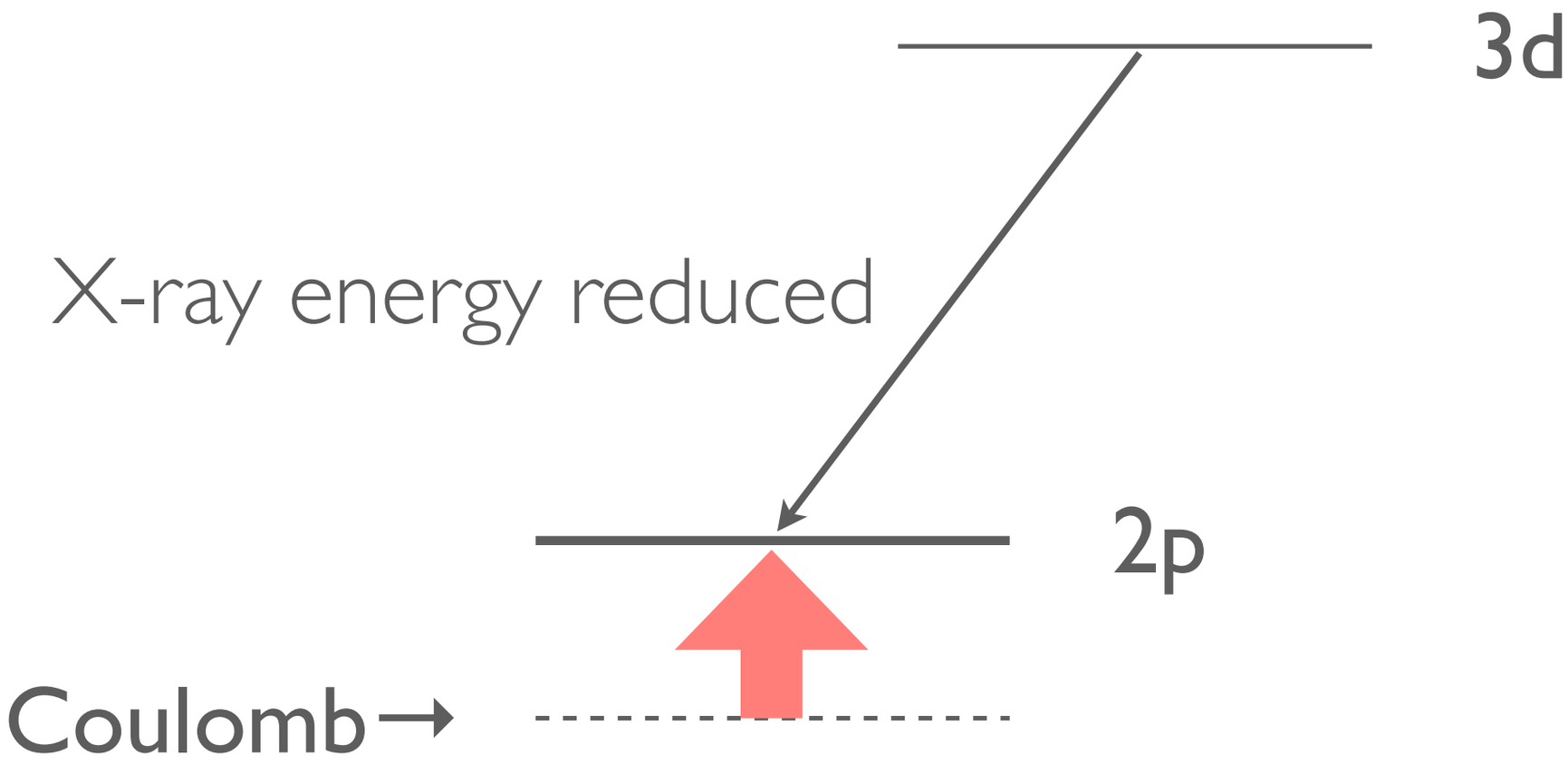
K^- He atom 3d-2p X-ray Energy

Strong-interaction shift (and width)



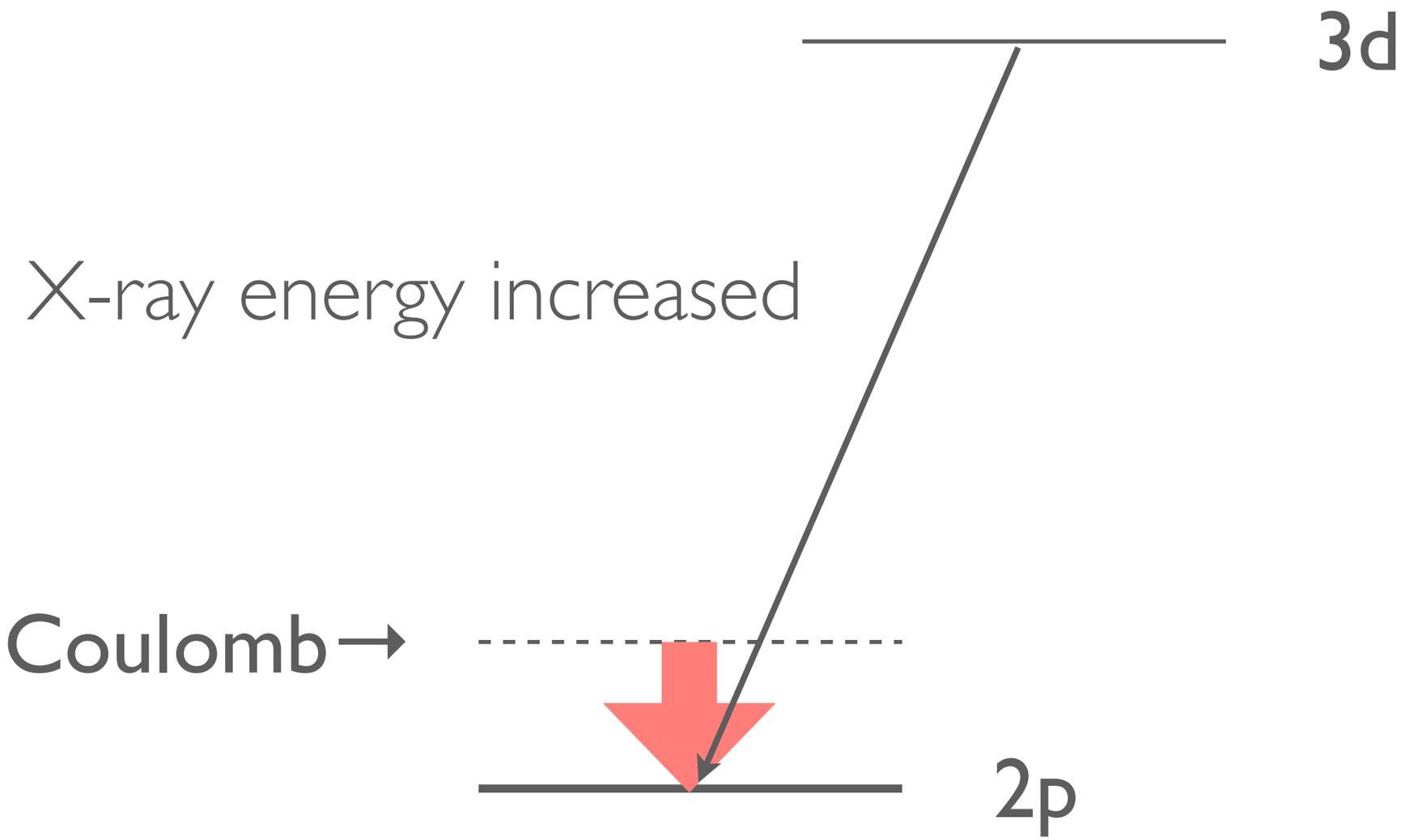
negative shift

(repulsive)



positive shift

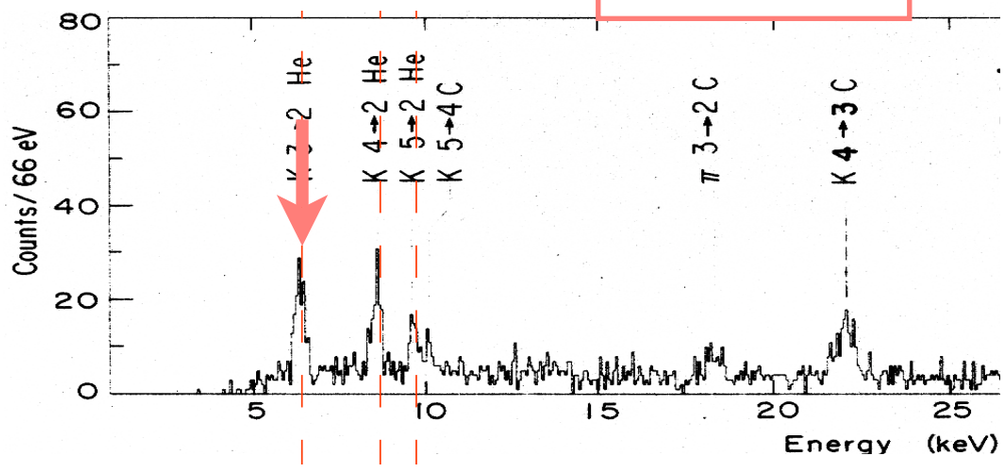
(attractive)



3 past experiments

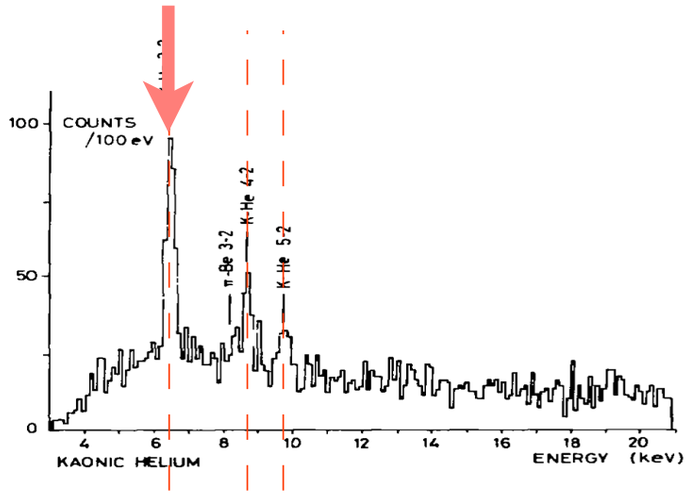
same-scale comparison

1971



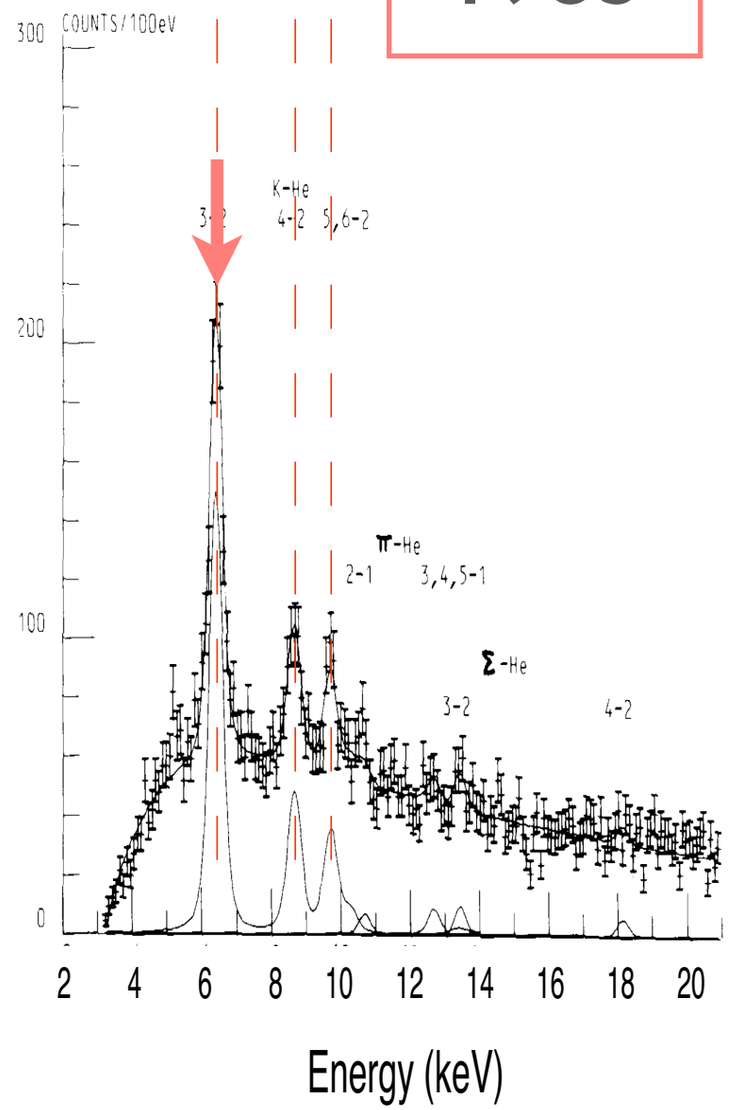
C.Wiegand and R. Pehl,
Phys. Rev. Lett. 27, 1410 (1971)

1979



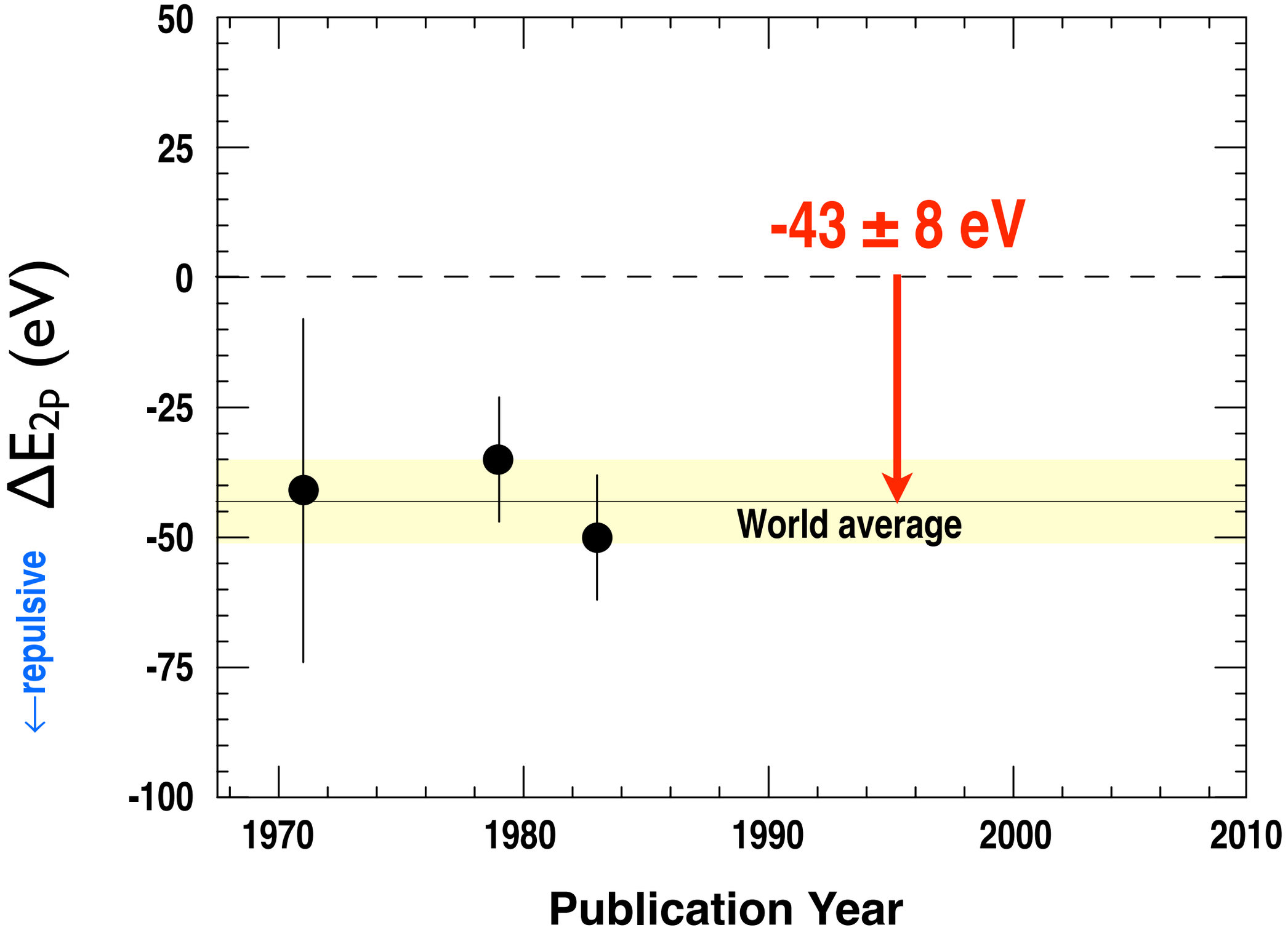
C. Batty et al.,
Nucl. Phys. A326, 455 (1979)

1983



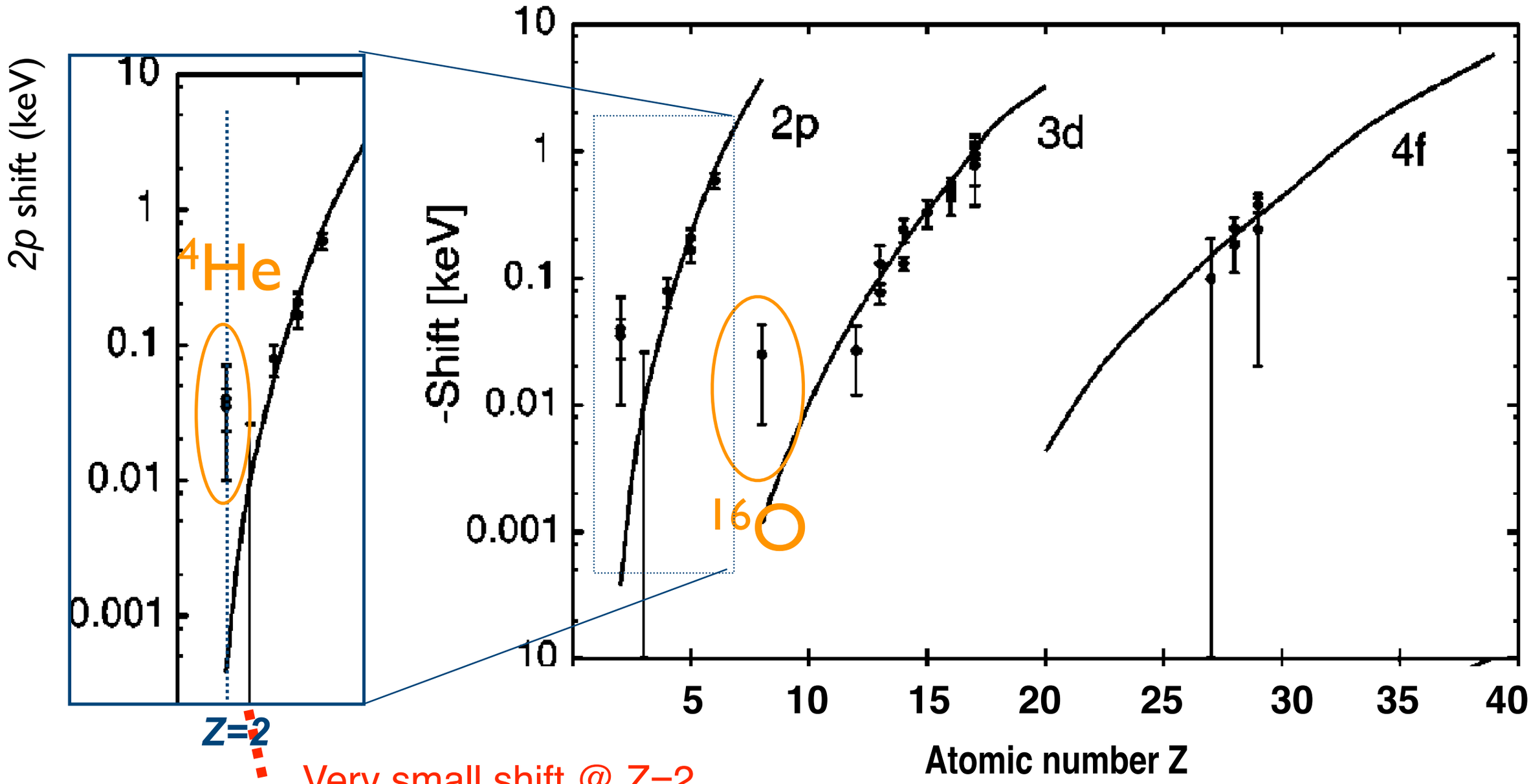
S. Baird et al.,
Nucl. Phys. A392, 297 (1983)

Kaonic Helium X-ray Spectroscopy



but theory...

optical model



Very small shift @ Z=2

(chiral unitary+ optical model):

~0.2eV

Batty (1990),
Hirenzaki et al (2000),
Friedman (2007)

then came Akaishi's coupled-channel model calculation

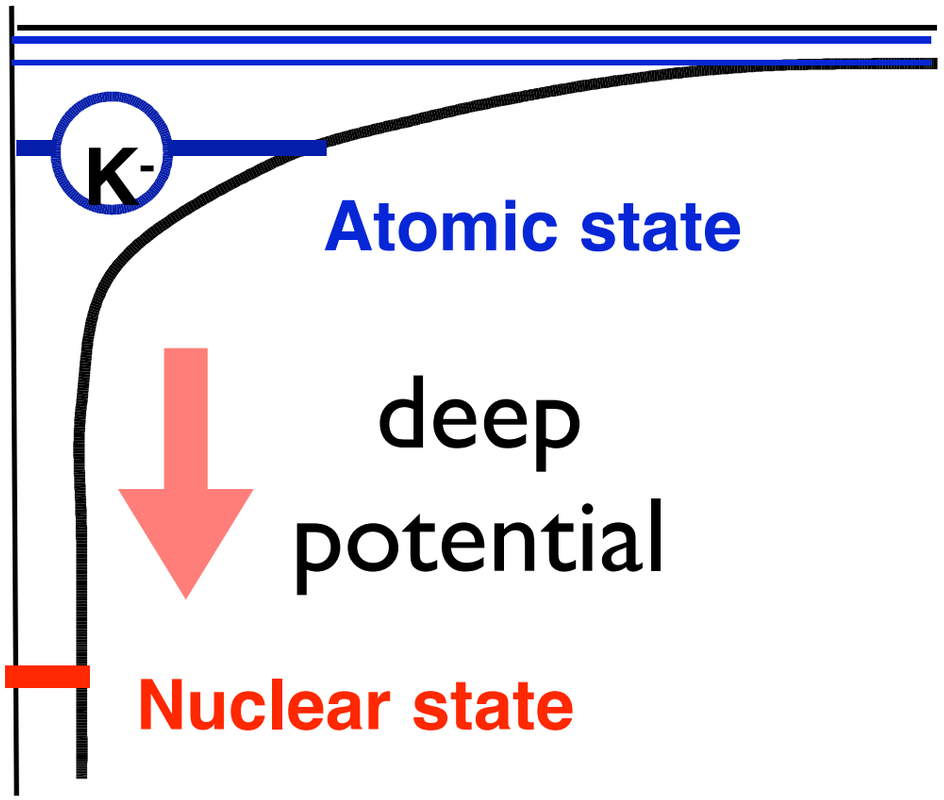
coupling to the $\pi^- + {}^4_\Sigma\mathrm{He}$ channel

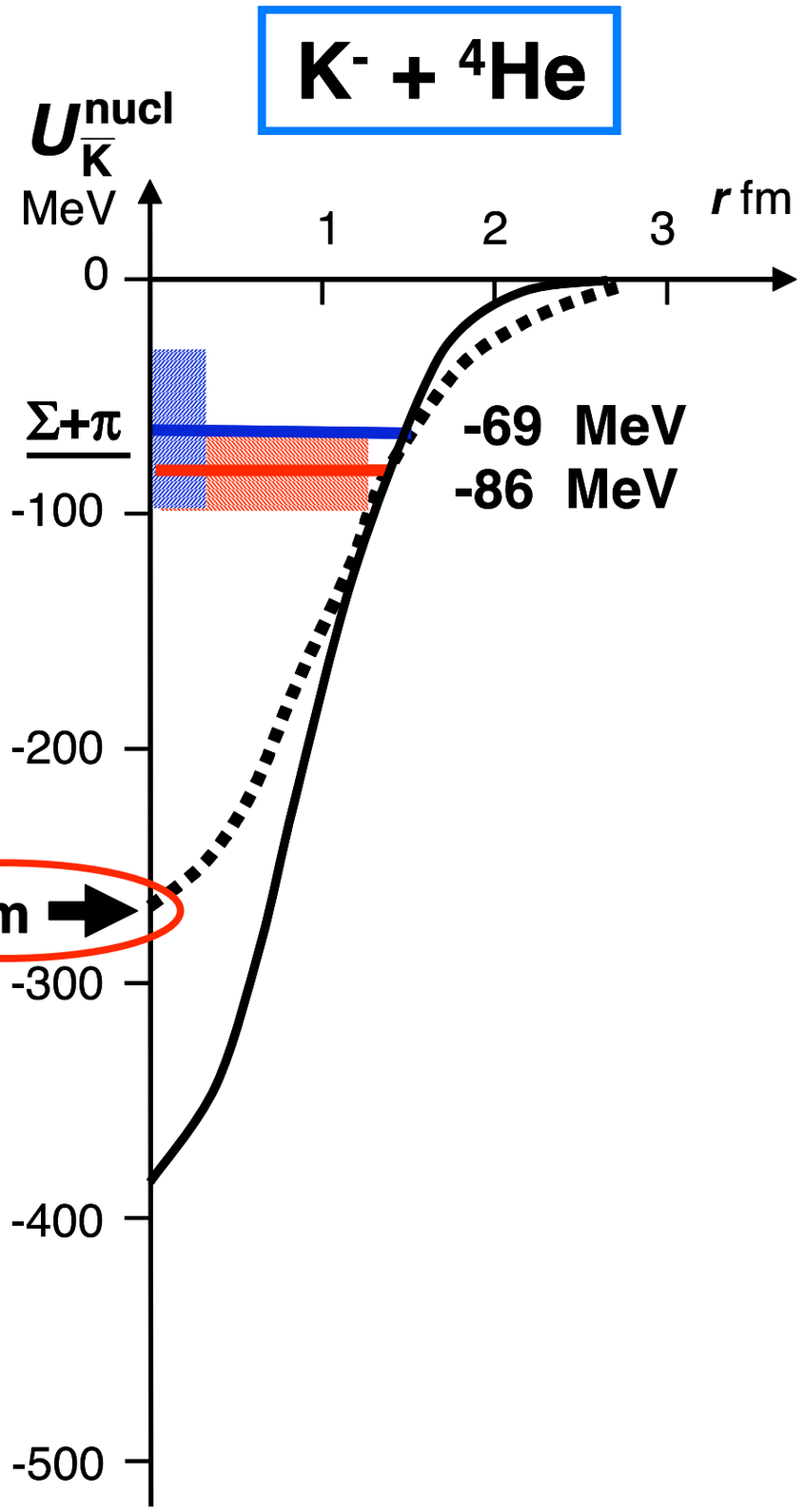
$$\text{diagonal: } U_D = -U_0 F(r)$$
$$\text{coupling: } U_C = U_{\mathrm{coupl}} F(r)$$

$$\left\{-\vec{\nabla}^2 + 2\mu(V_c + U_D - \epsilon) - (V_c - \epsilon)^2\right\}\Psi + 2\,\mu U_C \Phi = 0$$

$$\left\{-\vec{\nabla}^2 + 2\mu'(Q - \epsilon) - (Q - \epsilon)^2\right\}\Phi + 2\,\mu' U_C \Psi = 0$$

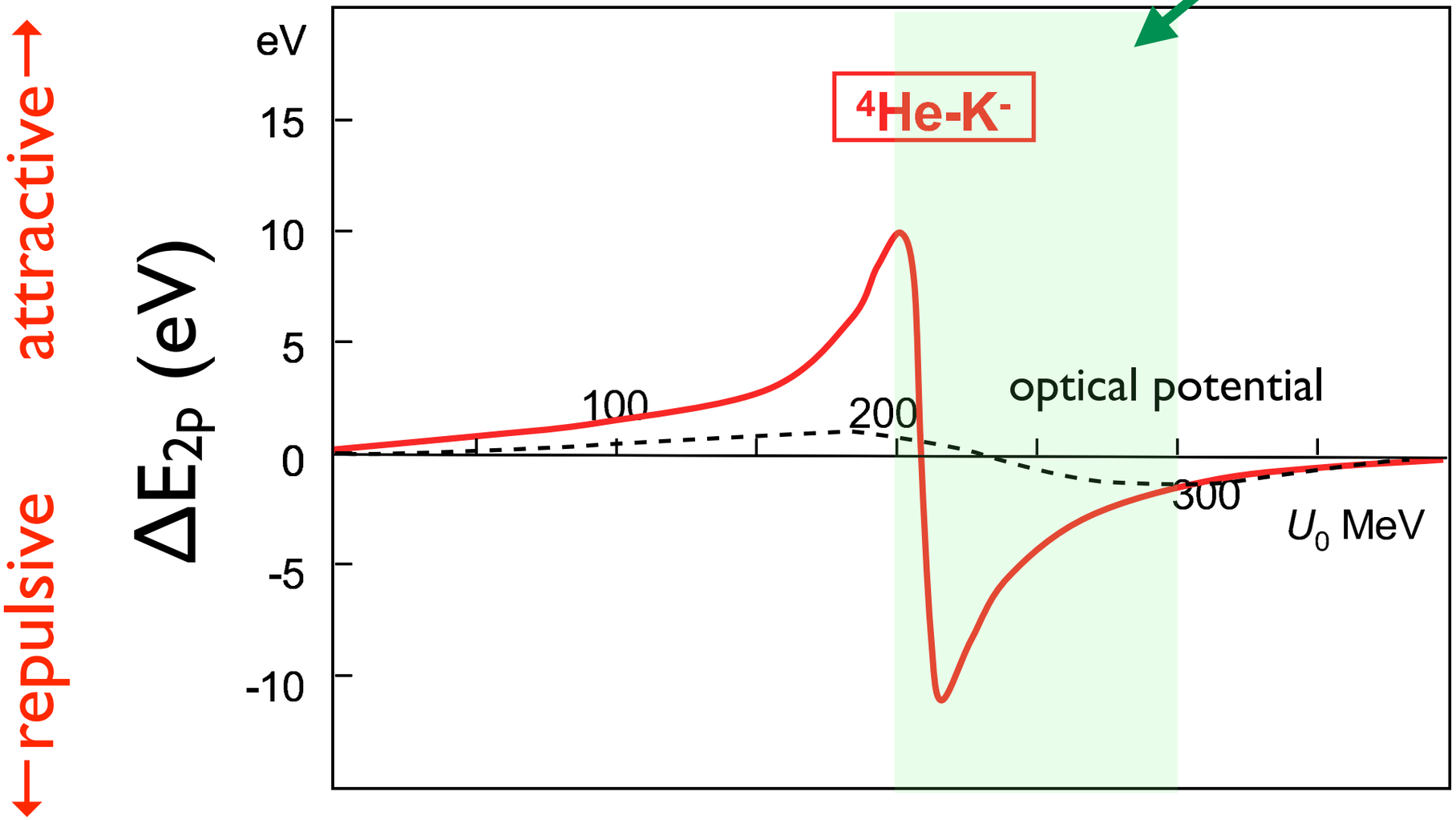
$$Q \equiv M_{{}^4_\Sigma\mathrm{He}} + m_{\pi^-} - M_{{}^4\mathrm{He}} - m_{K^-}$$


K-
Atomic state
deep
potential
Nuclear state


K- + 4He
$U_{\bar{K}}^{nucl}$
MeV
r fm
1
2
3
0
Σ+π
-100
-69 MeV
-86 MeV
-200
Atom
-300
-400
-500

Akaishi

(accommodates kaonic nuclear states)



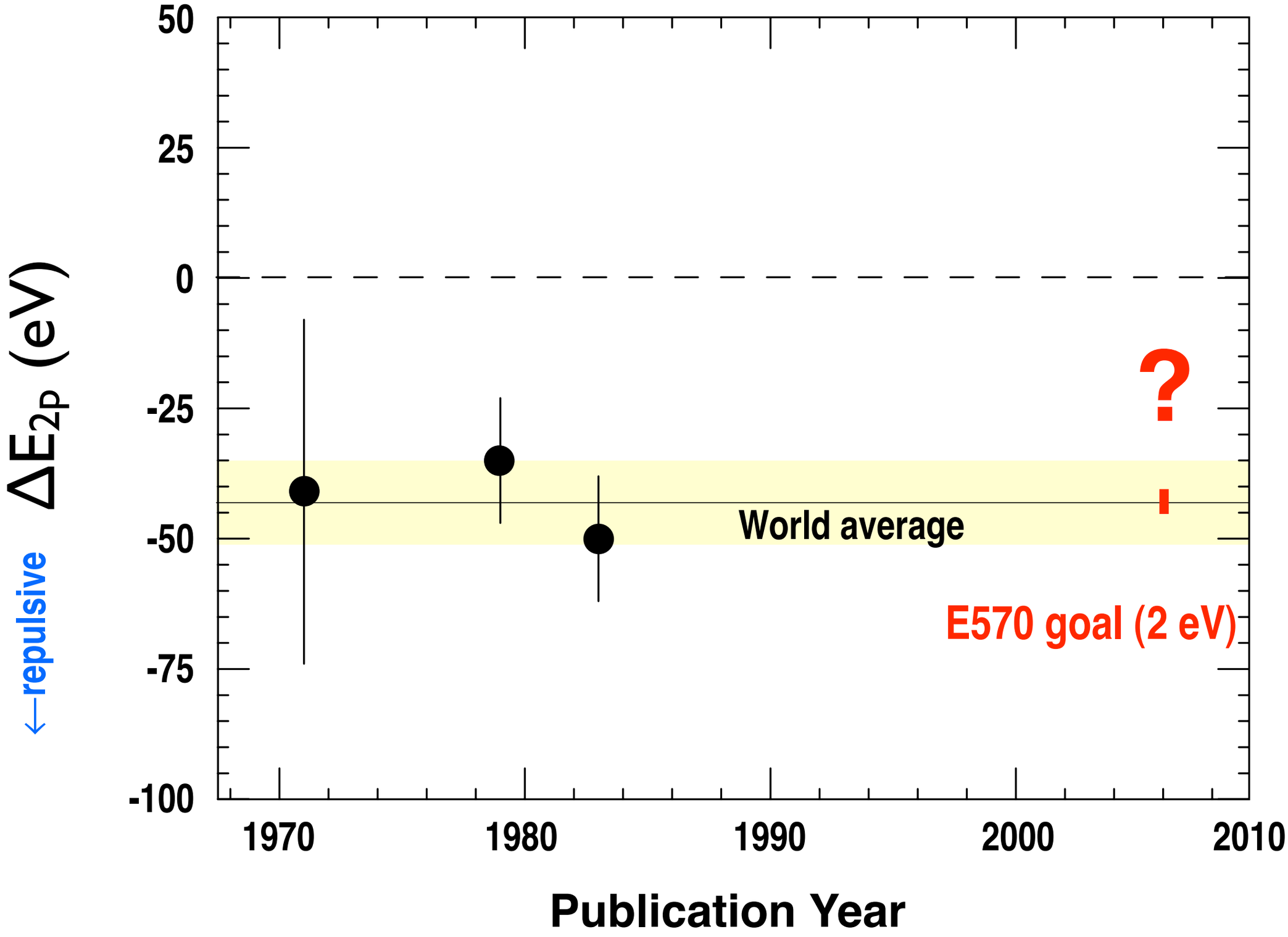
U_c fixed to 120 MeV, U_0 varied

Akaishi EXA05

興味

Akaishi-Yamazaki prediction motivated us
to re-measure K^- ^{4}He

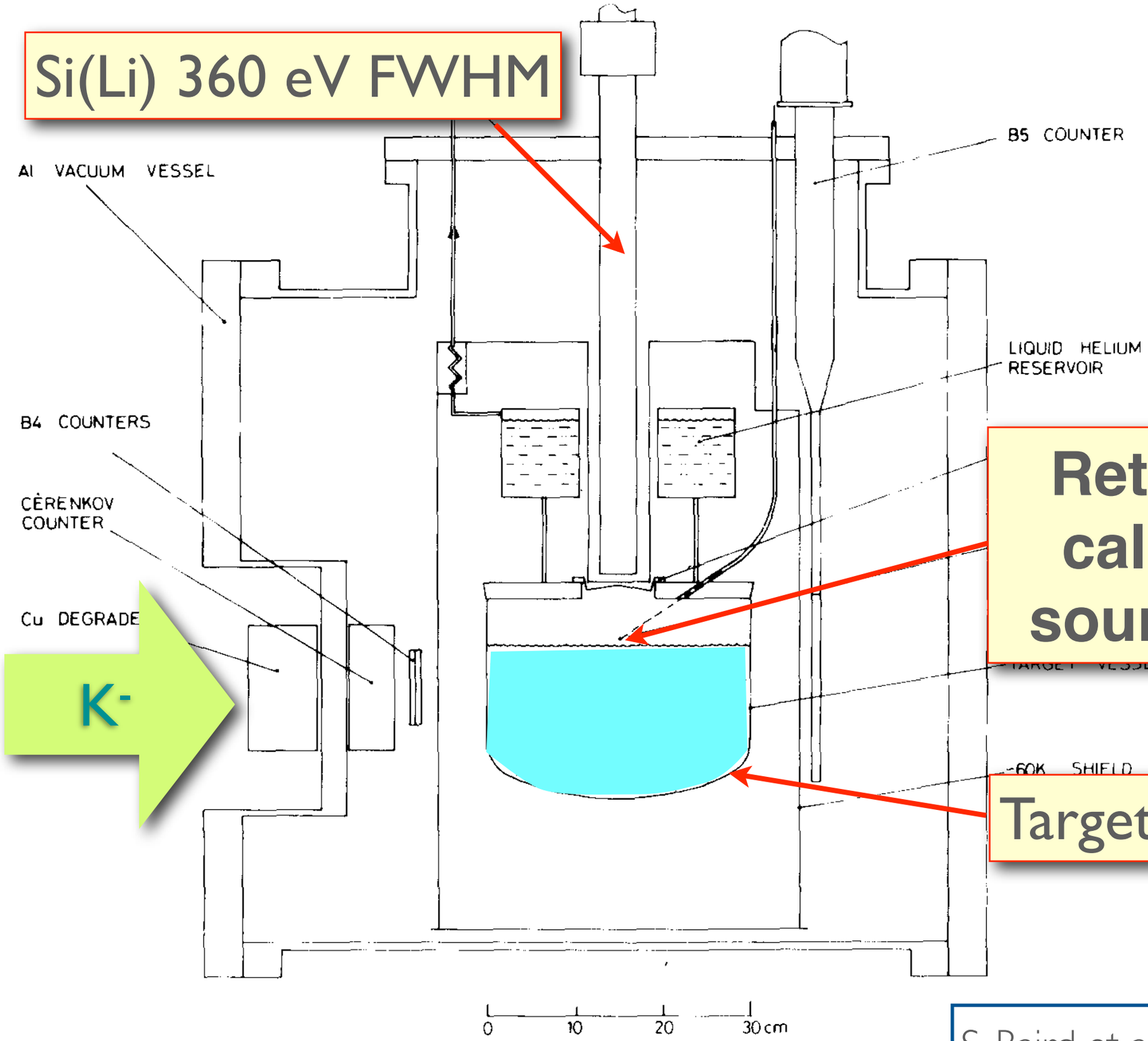
Kaonic Helium X-ray Spectroscopy



方法

how it was done in the past

Si(Li) 360 eV FWHM



Retractable calibration source (^{55}Fe)

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

方法

how E570 did it

❶ resolution

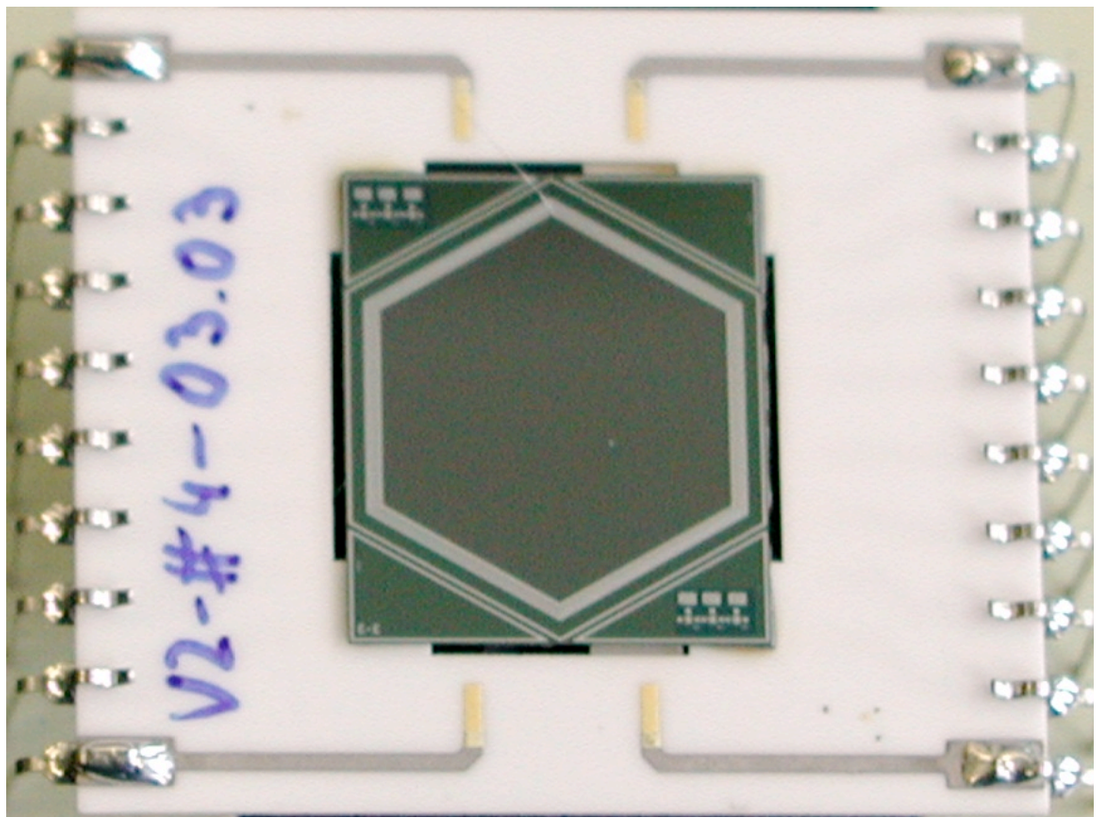
❷ S/N (and statistics)

❸ calibration

❹ line shape

❶ x2 better resolution

SDD (silicon drift detector)



Produced by KETEK GmbH

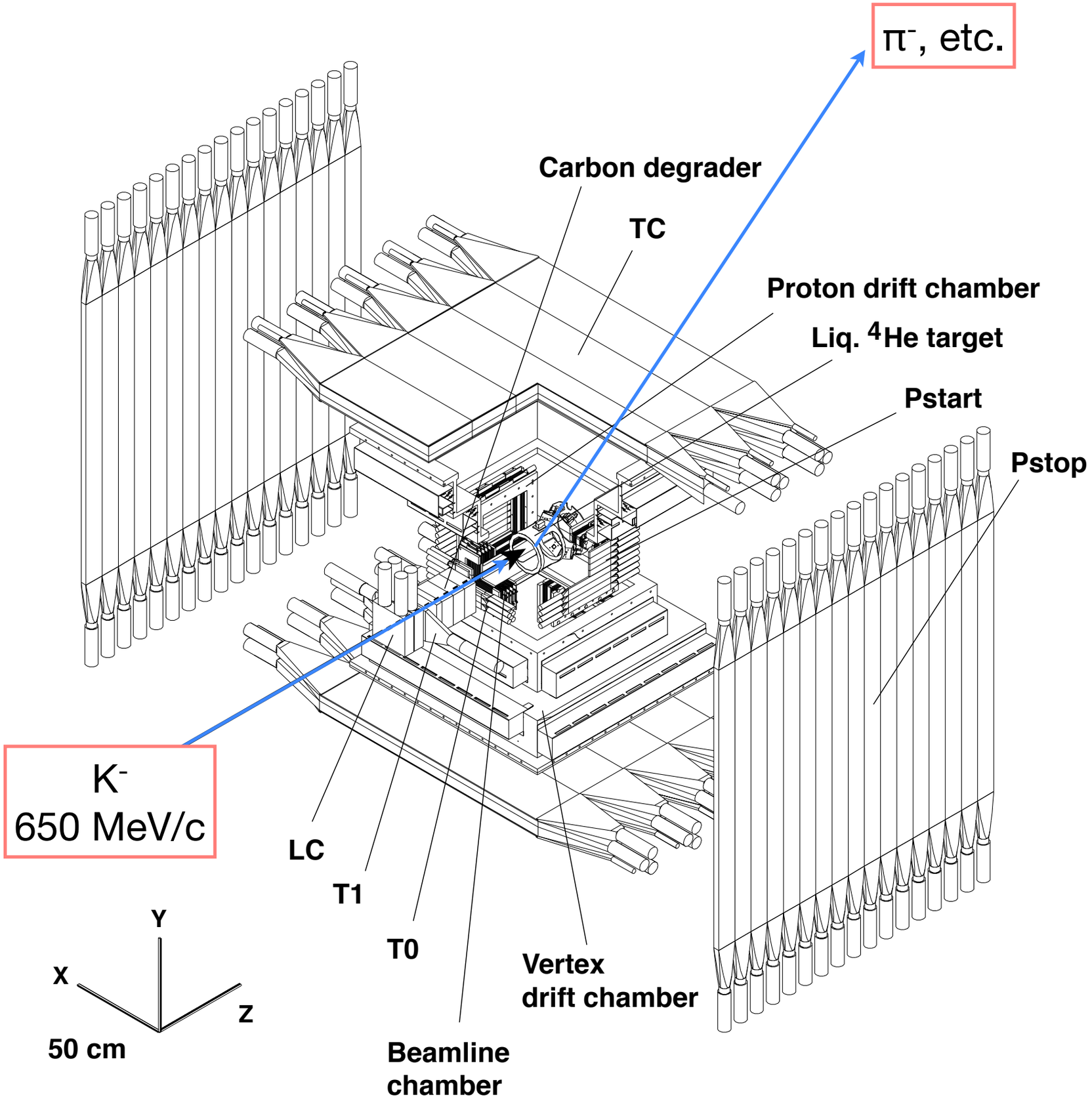
electrons drift to a small anode (small capacitance)

high resolution
(185 eV FWHM @ 6.4 keV),
despite large area (100 mm^2)

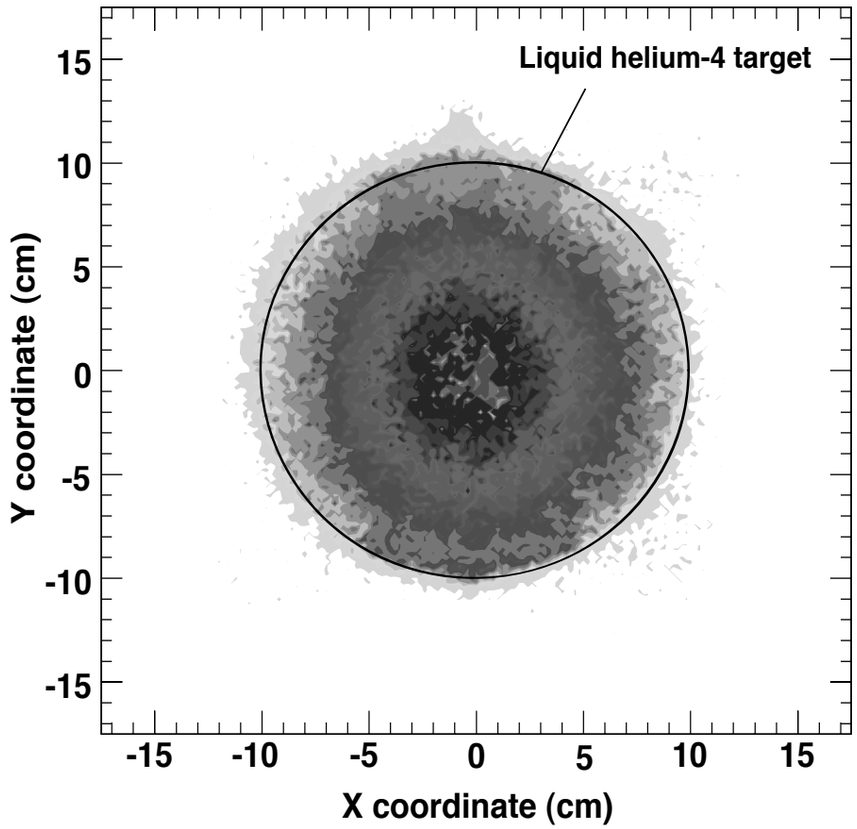
8 such SDDs used in E570

❷ x6 better S/N

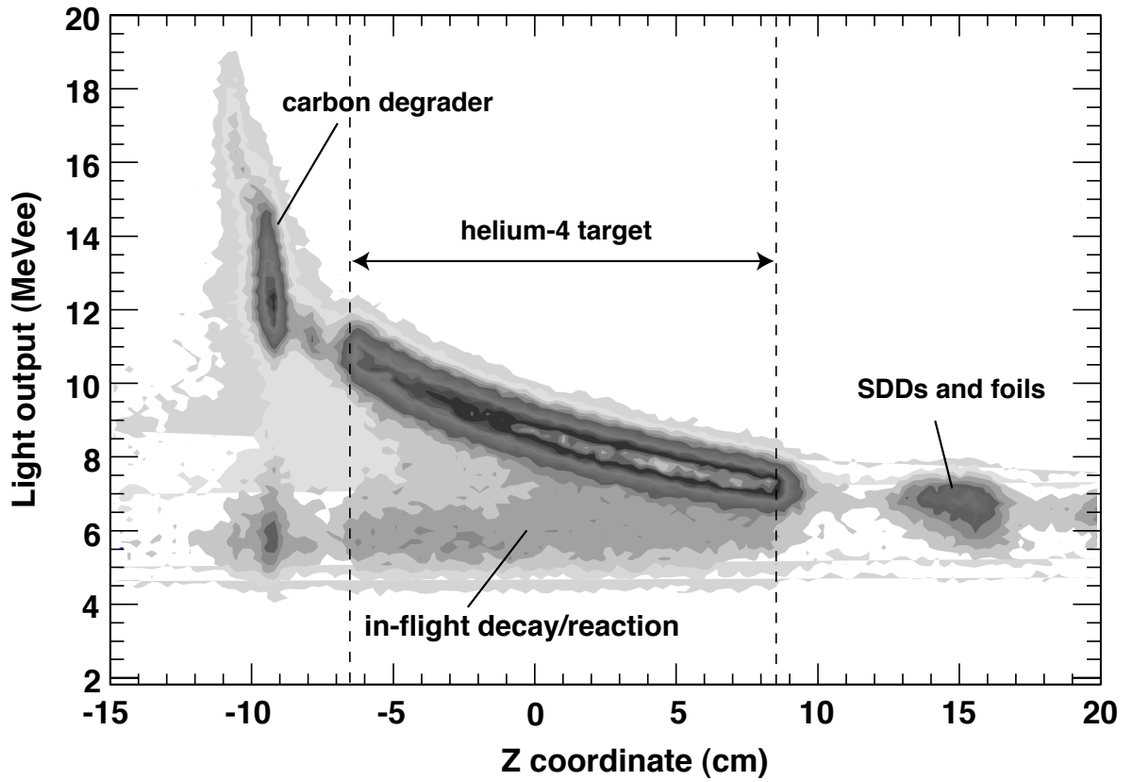
K^- stop vertex



Fiducial selection

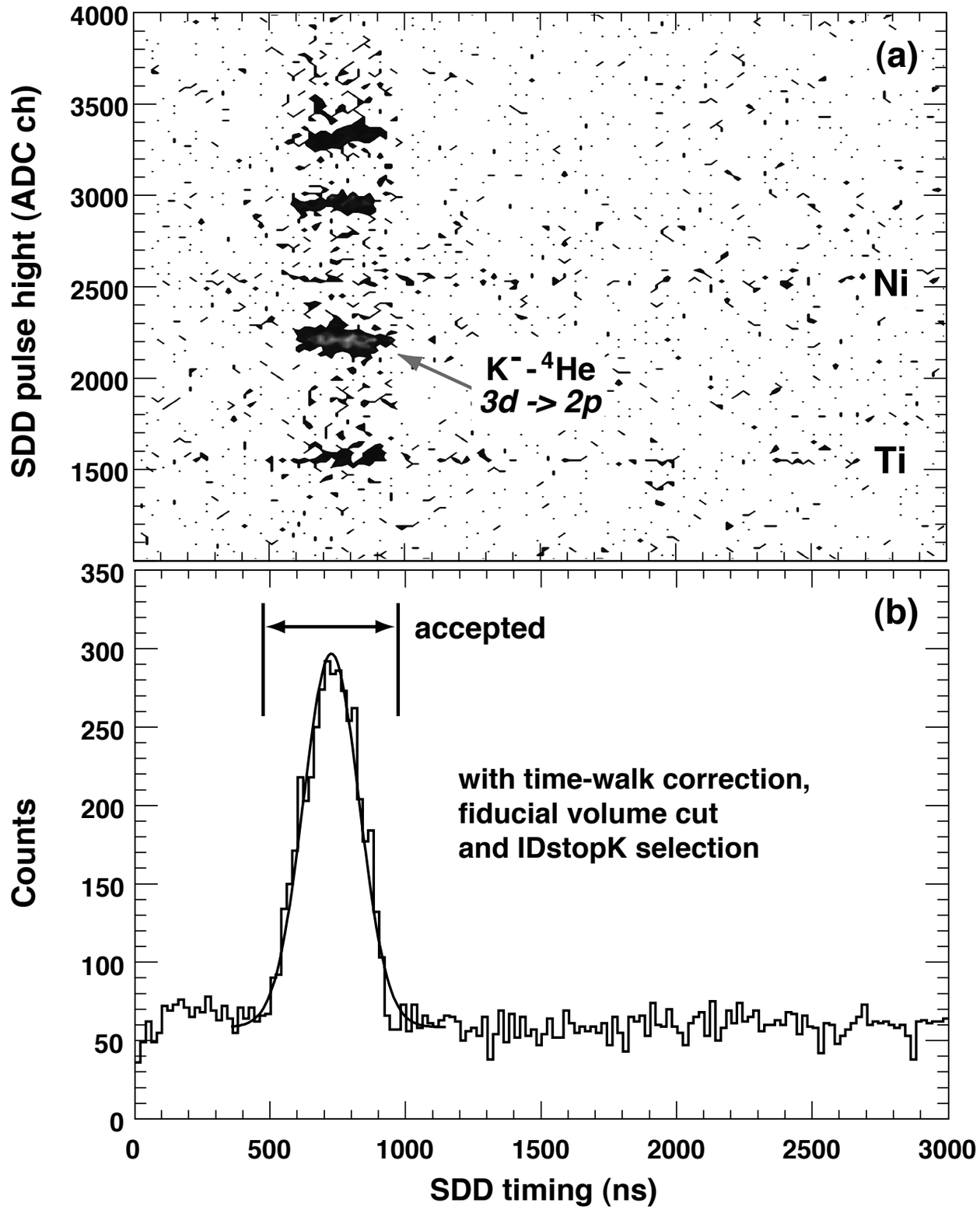


front view



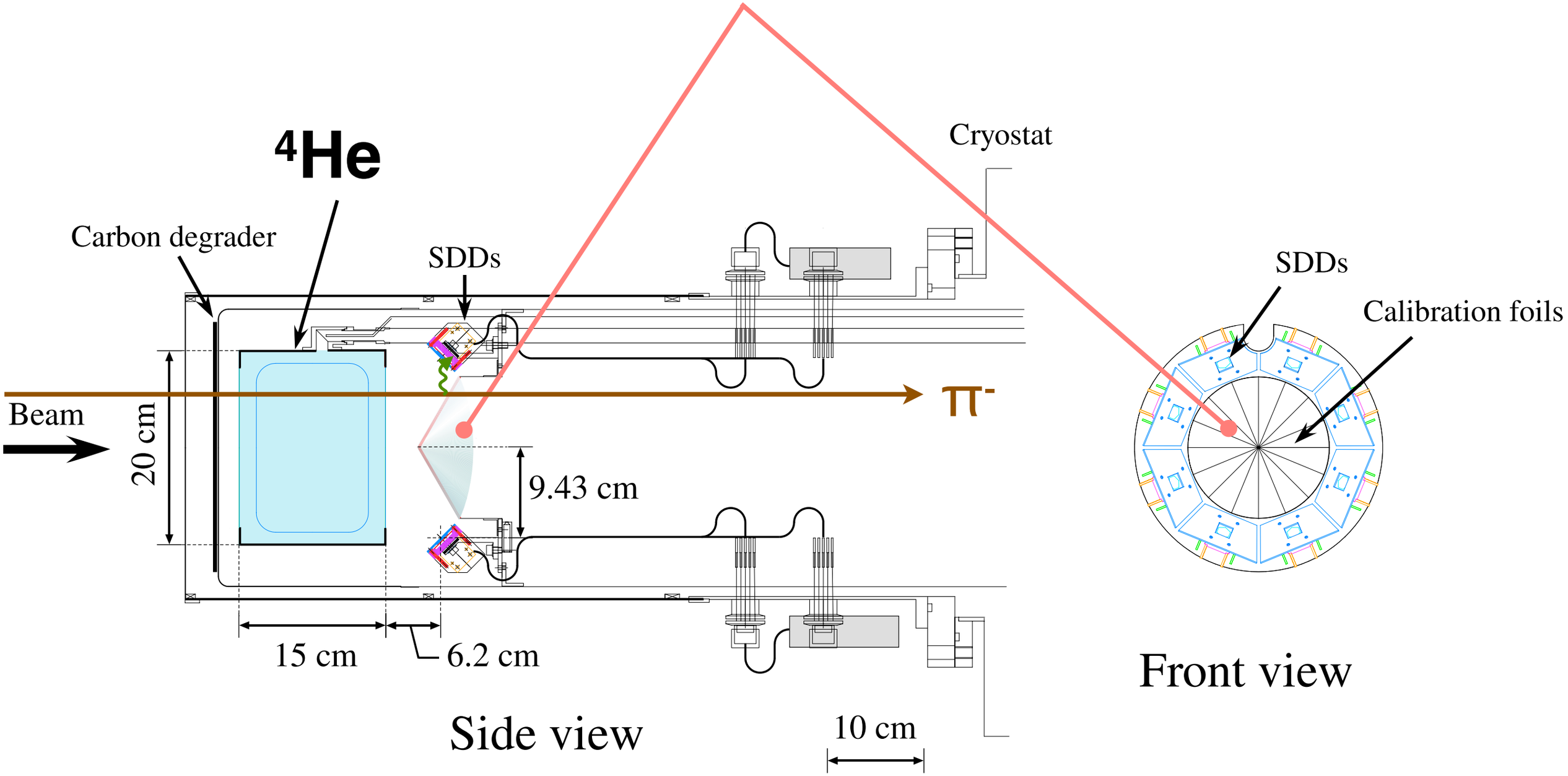
side view

Timing selection

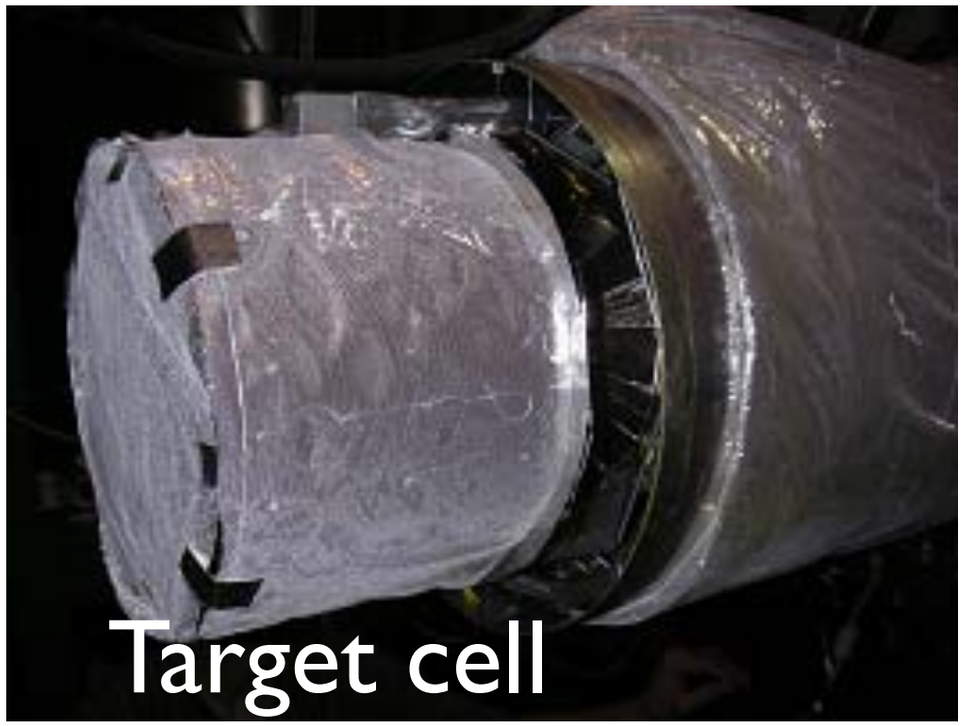


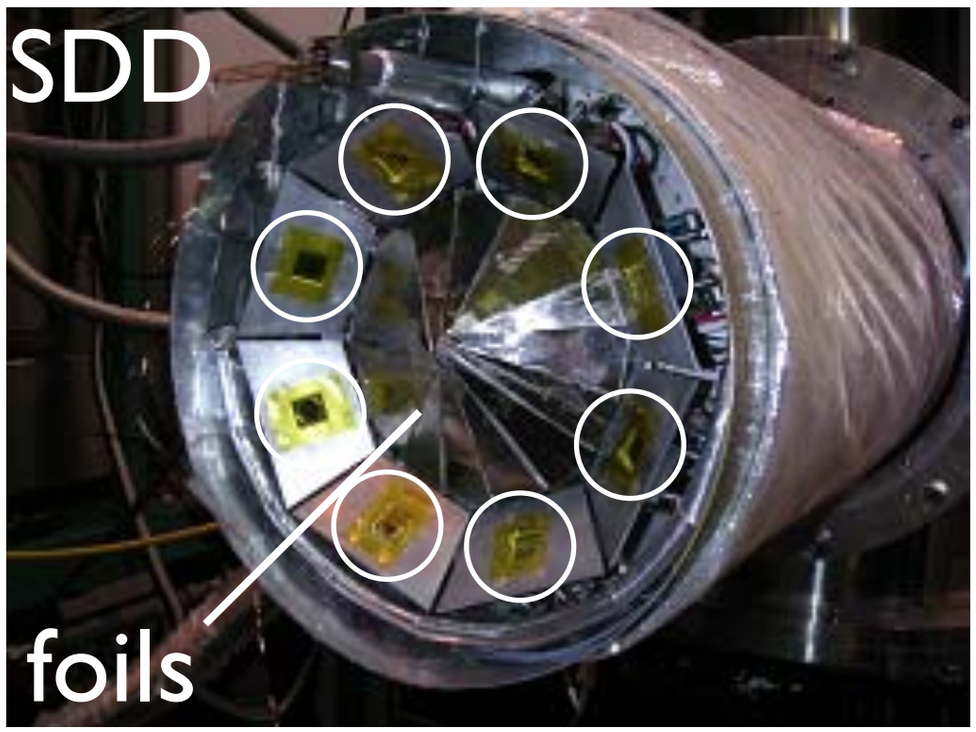
❸ in-situ calibration

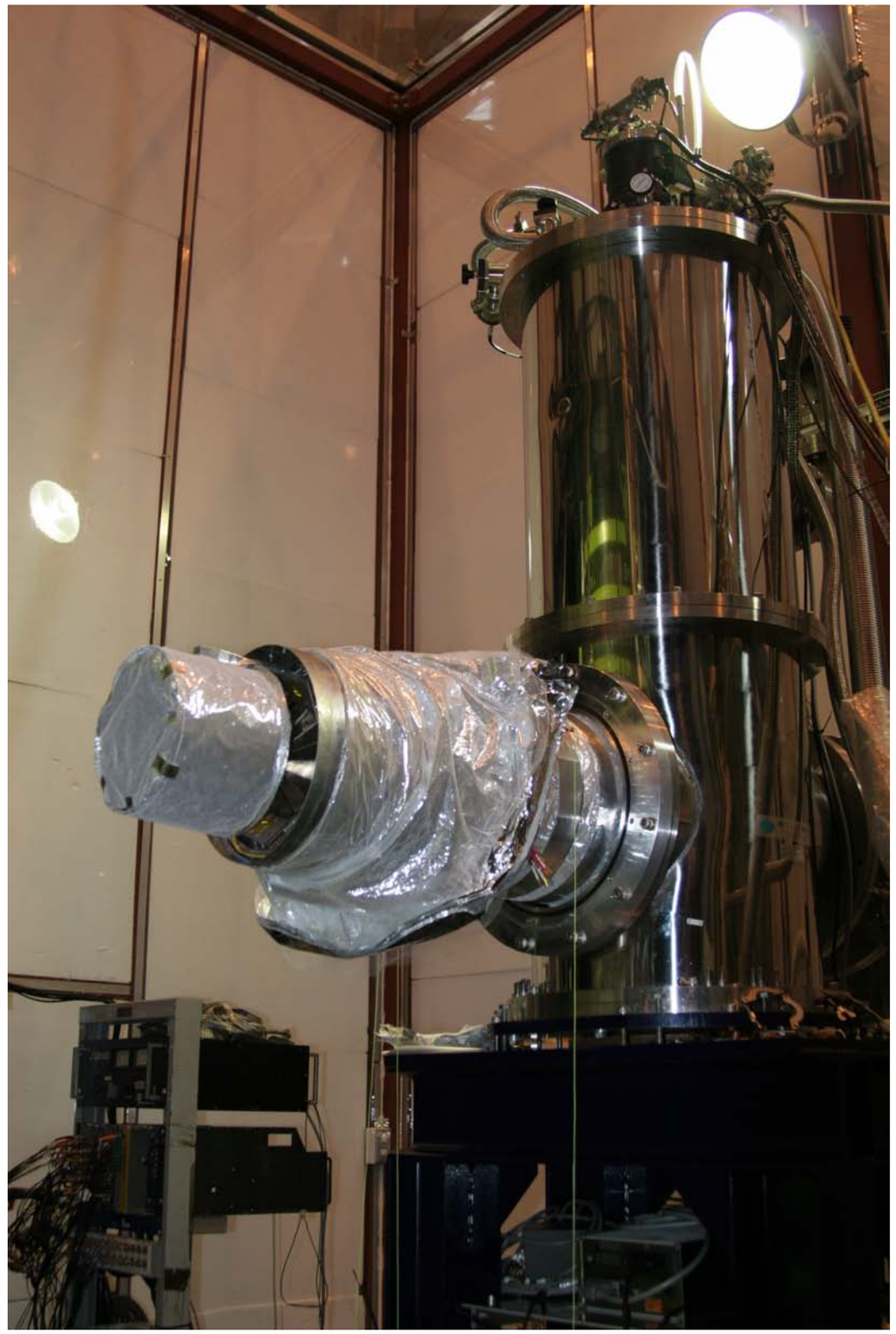
Ti & Ni foils

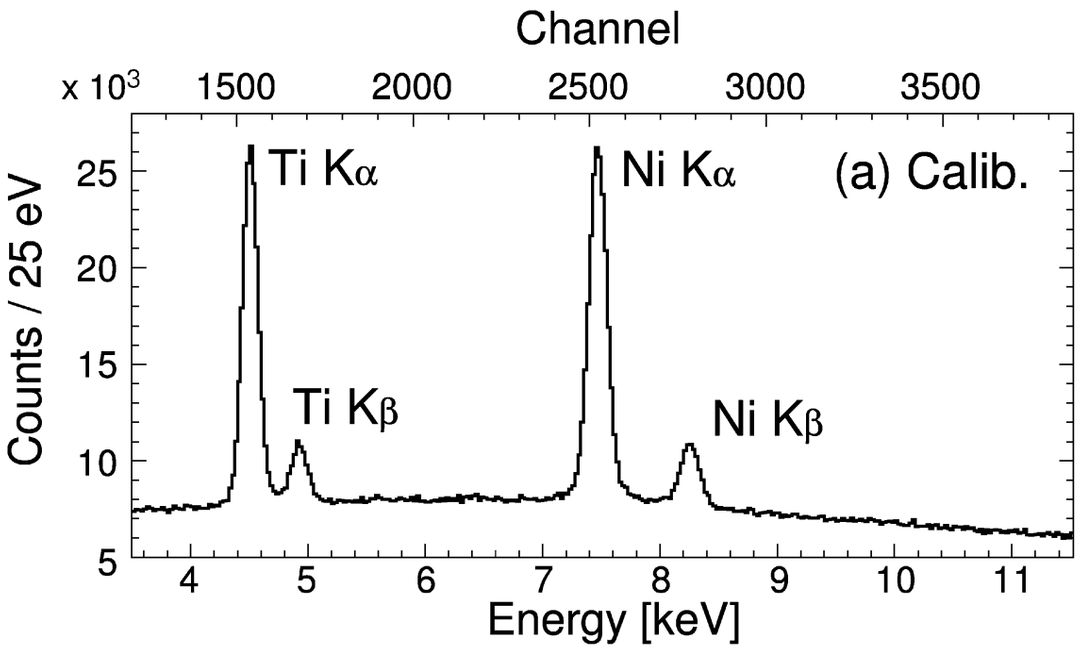

4He
Carbon degrader
SDDs
Cryostat
Beam
π-
20 cm
9.43 cm
15 cm
6.2 cm
10 cm
Side view
SDDs
Calibration foils
Front view

E570 target & X-ray detectors

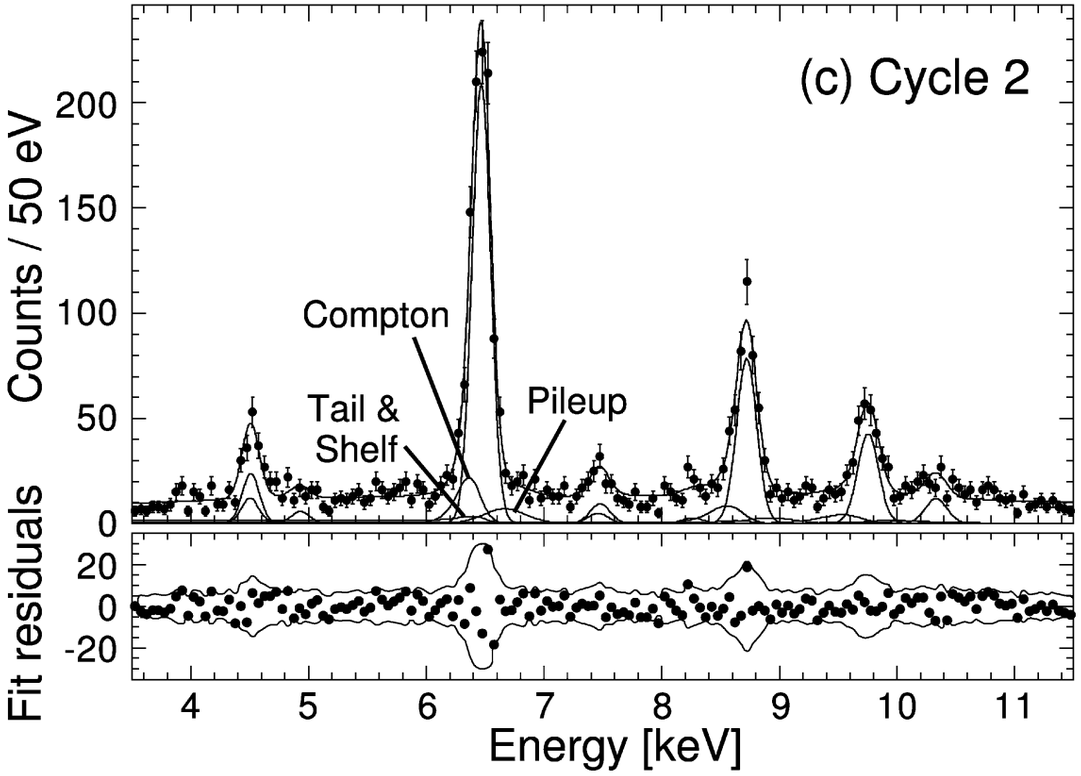








SDD Self trigger

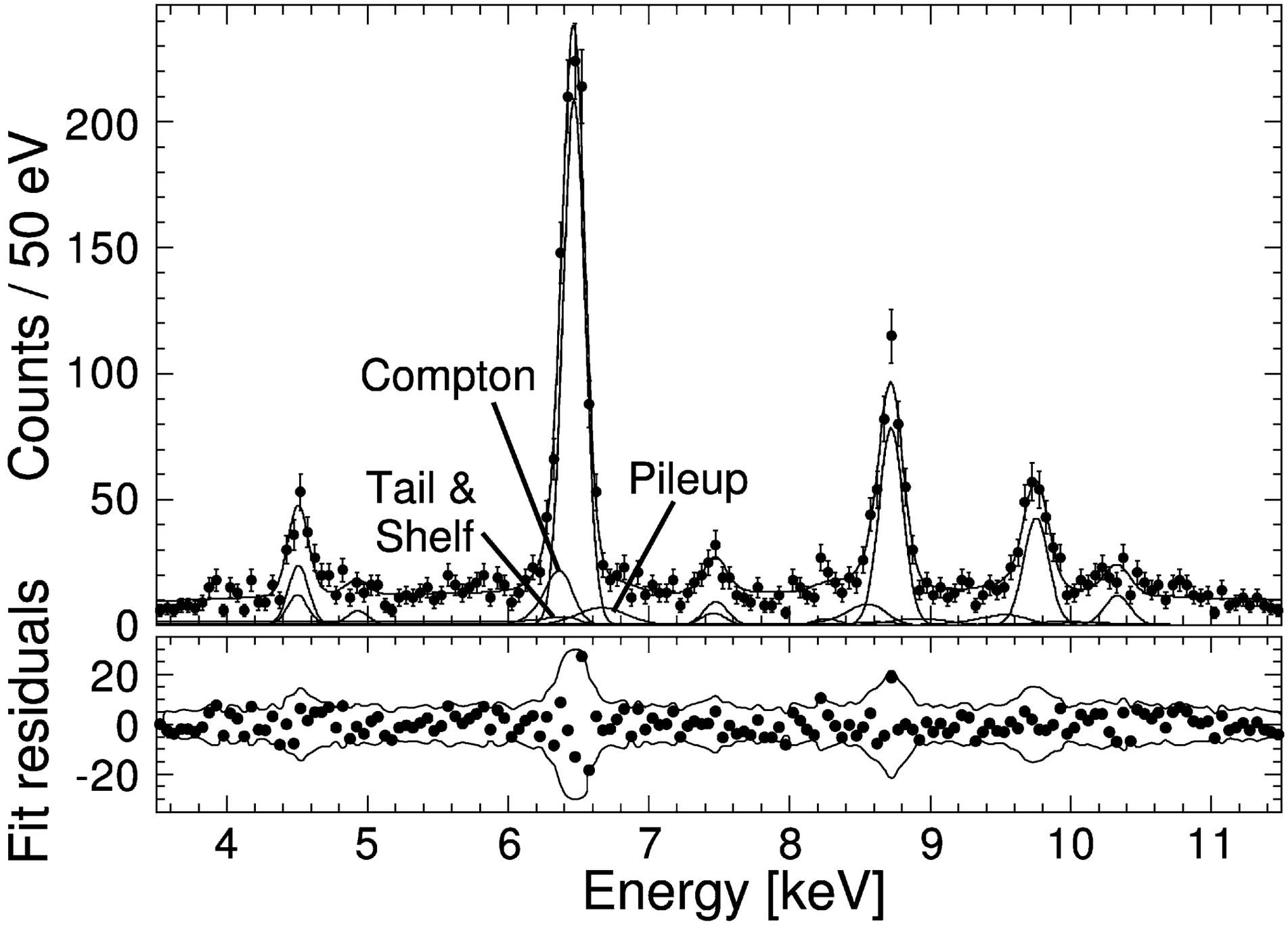


Kaon trigger, fiducial & timing cut

Okada et al., PLB 653 (2007) 387

❹ line shape

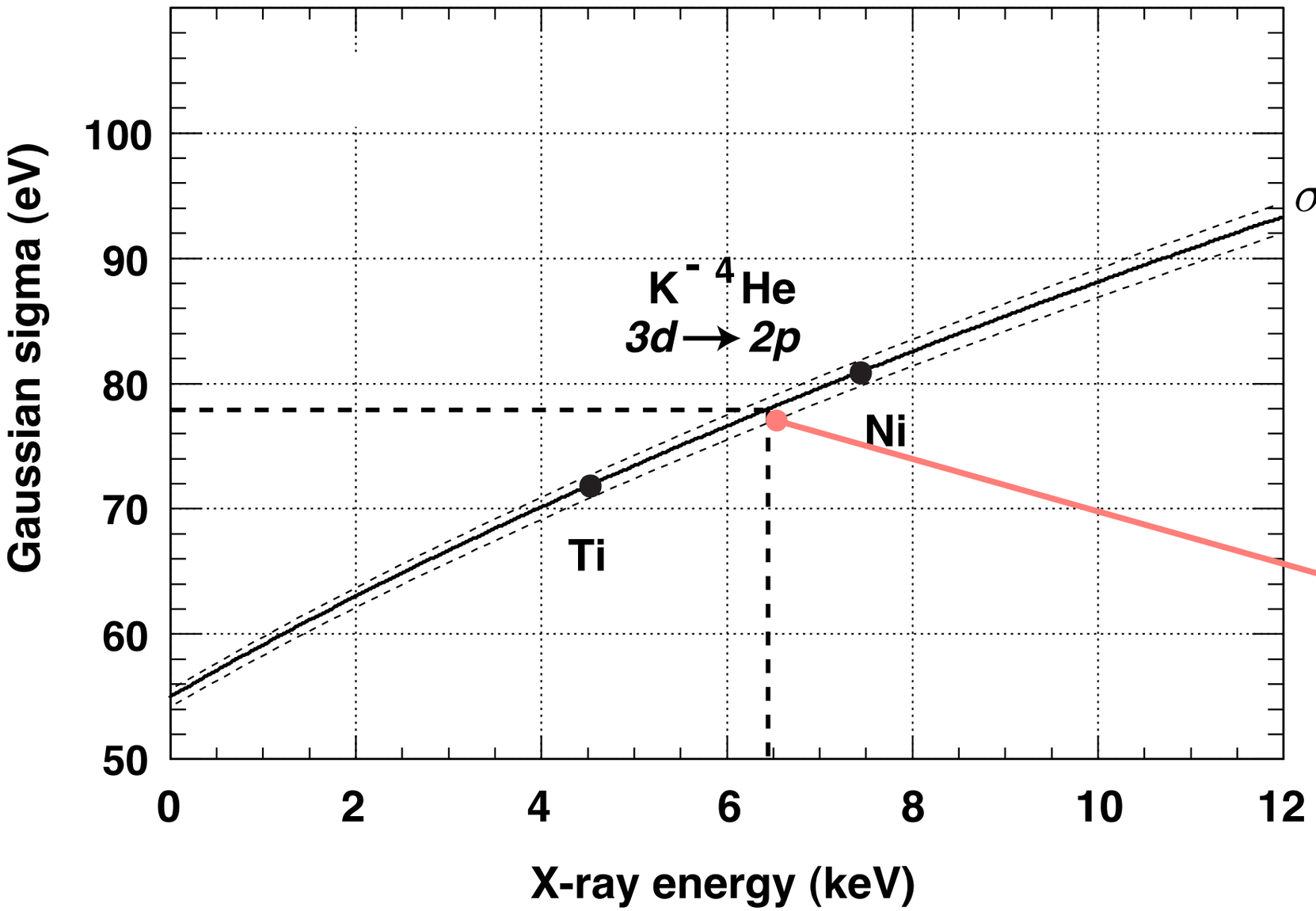
the fit



Okada et al., PLB 653 (2007) 387

Resolution @ 6.4 keV

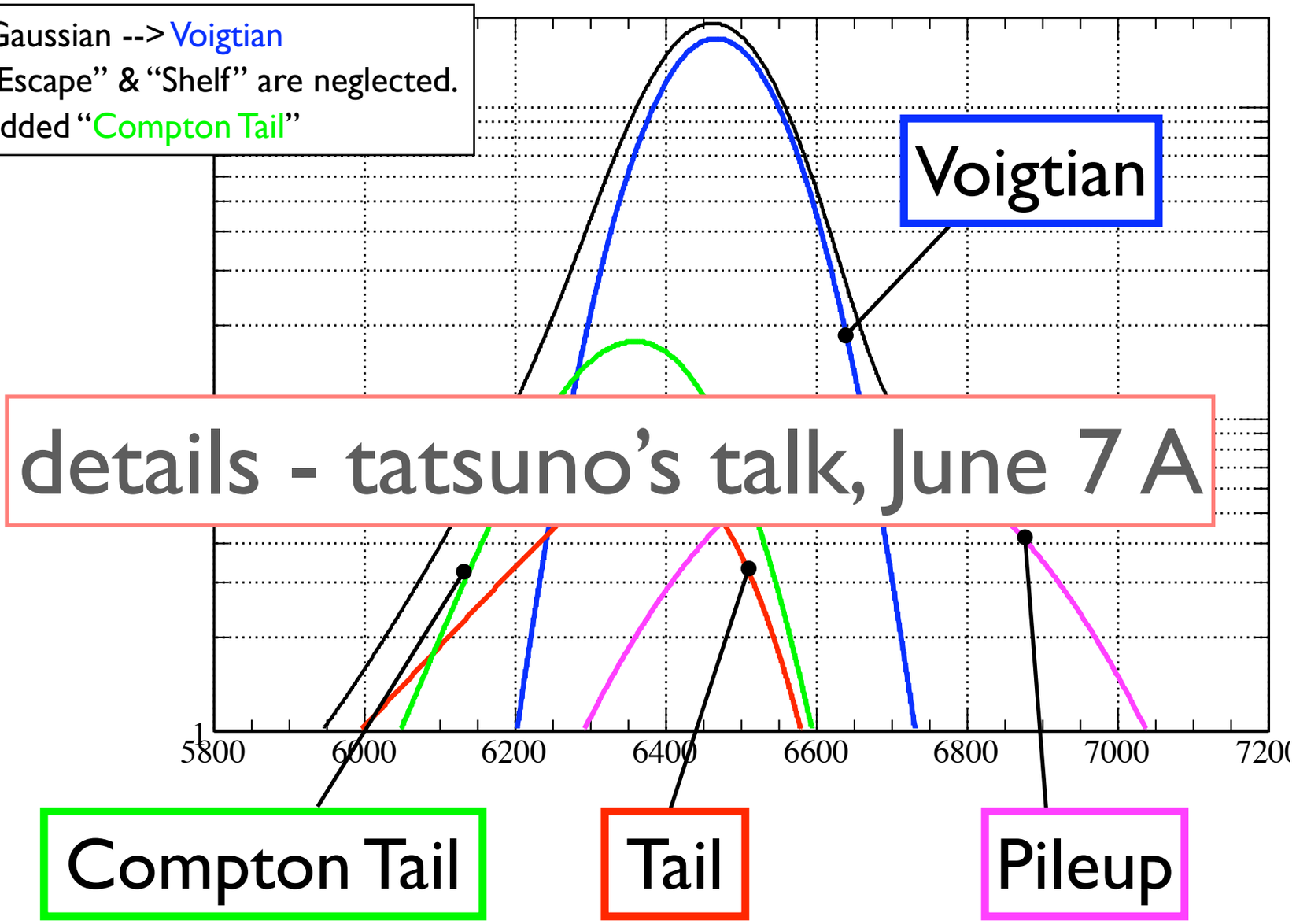
obtained from the in-situ calibration peaks



$$\sigma(E) = \omega\sqrt{W_N^2 + FE/\omega}$$

σ=77.9±0.6eV
@ 6.463 keV

- Gaussian --> Voigtian
- "Escape" & "Shelf" are neglected.
- added "Compton Tail"



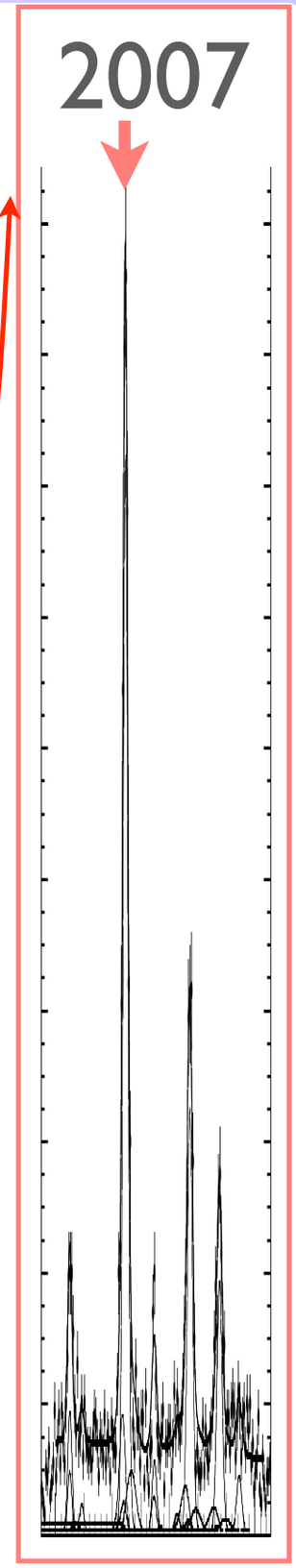
details - tatsuno's talk, June 7 A

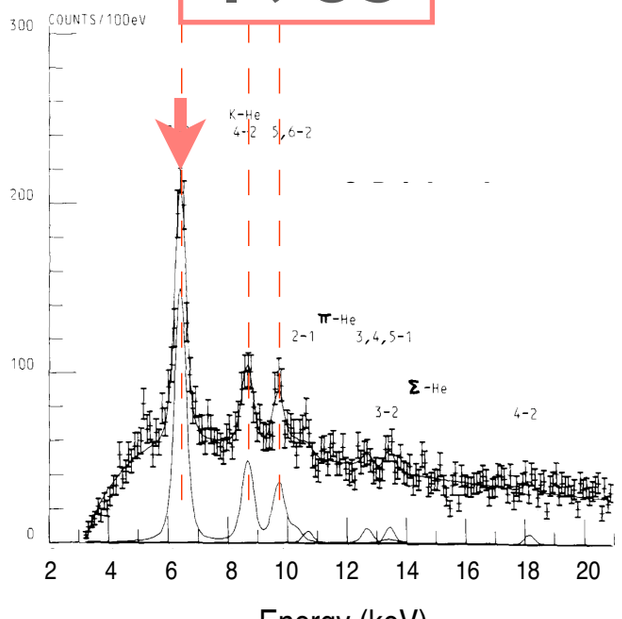
結果

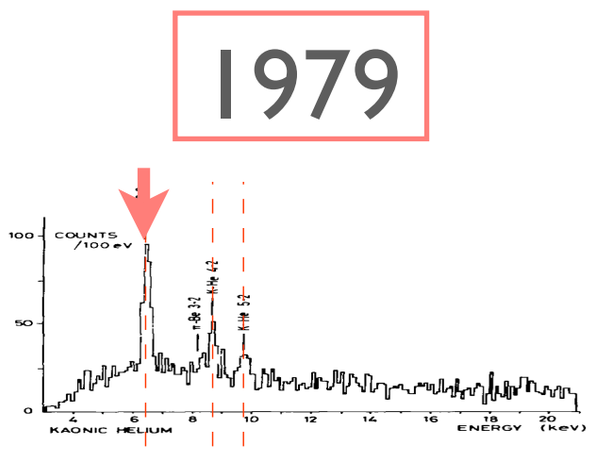
Results

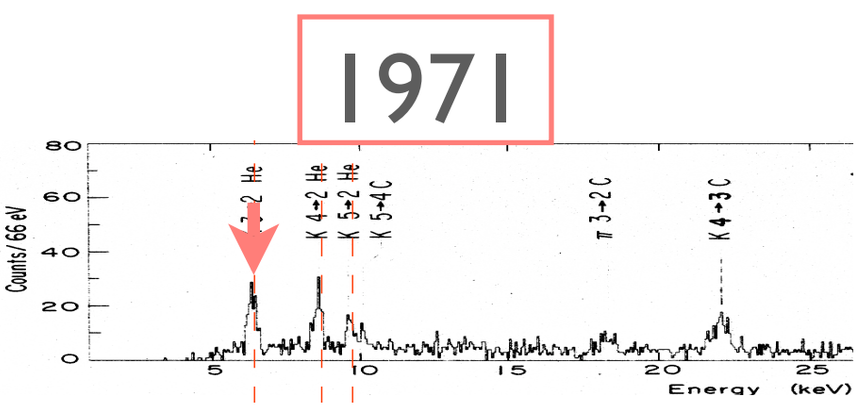
Same-scale comparison

statistics	x3
S/N ratio	x6
resolution	x2





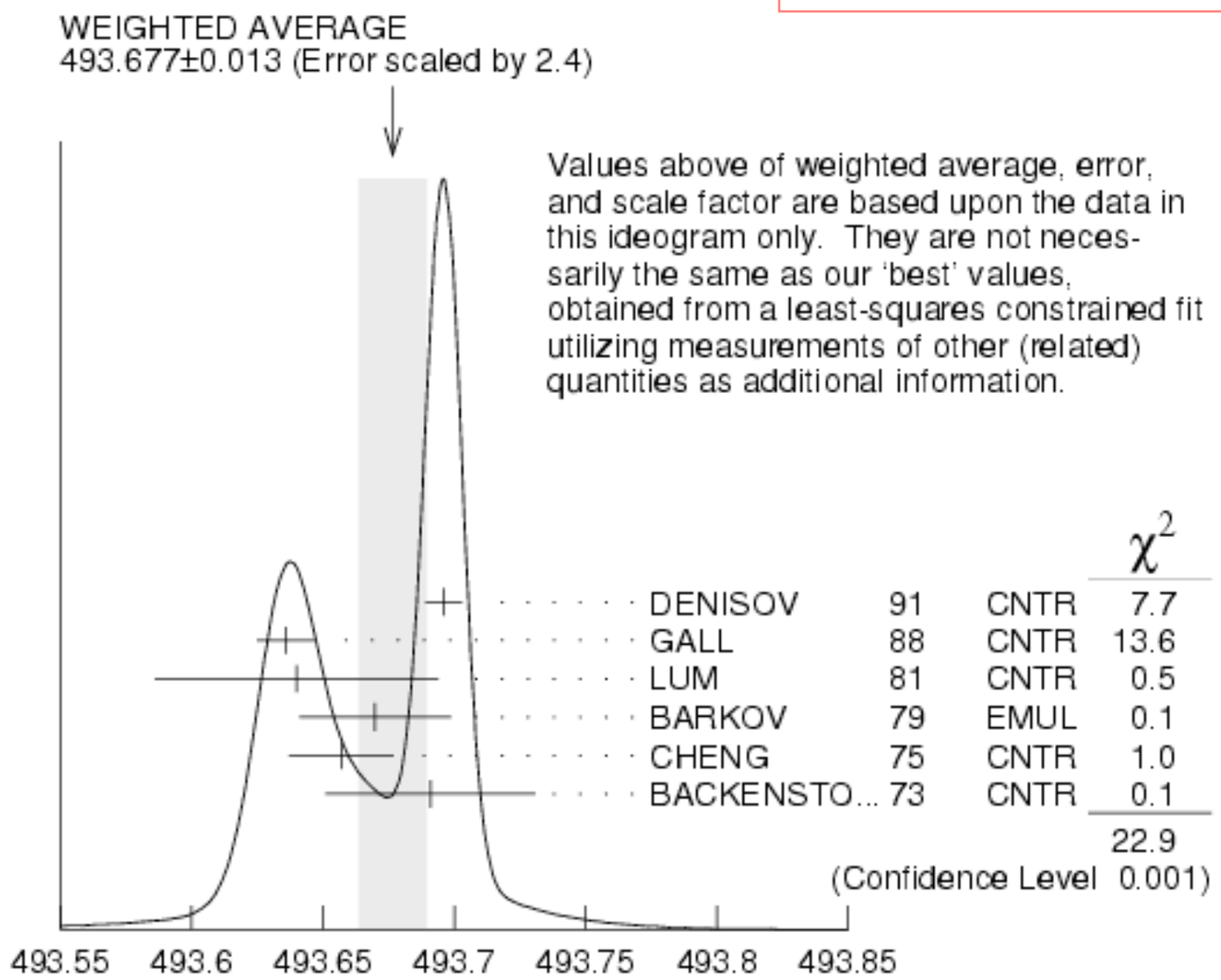




shift = E^{exp} - E^{EM}

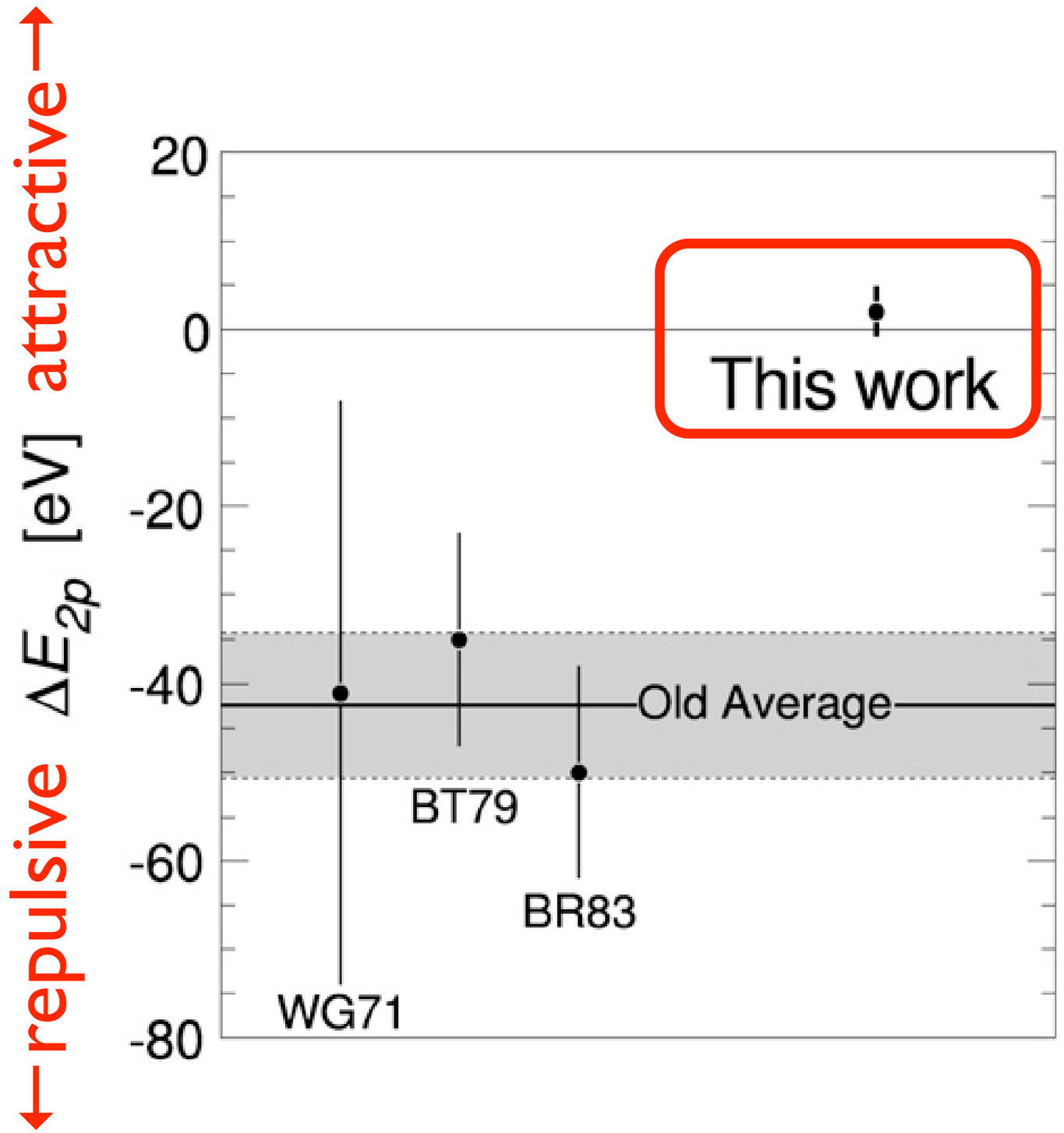
E_{EM}(eV) 6463.46 ± 0.15 (Koike)

due to the K mass error



corresponds to ±1 eV in X-ray energy

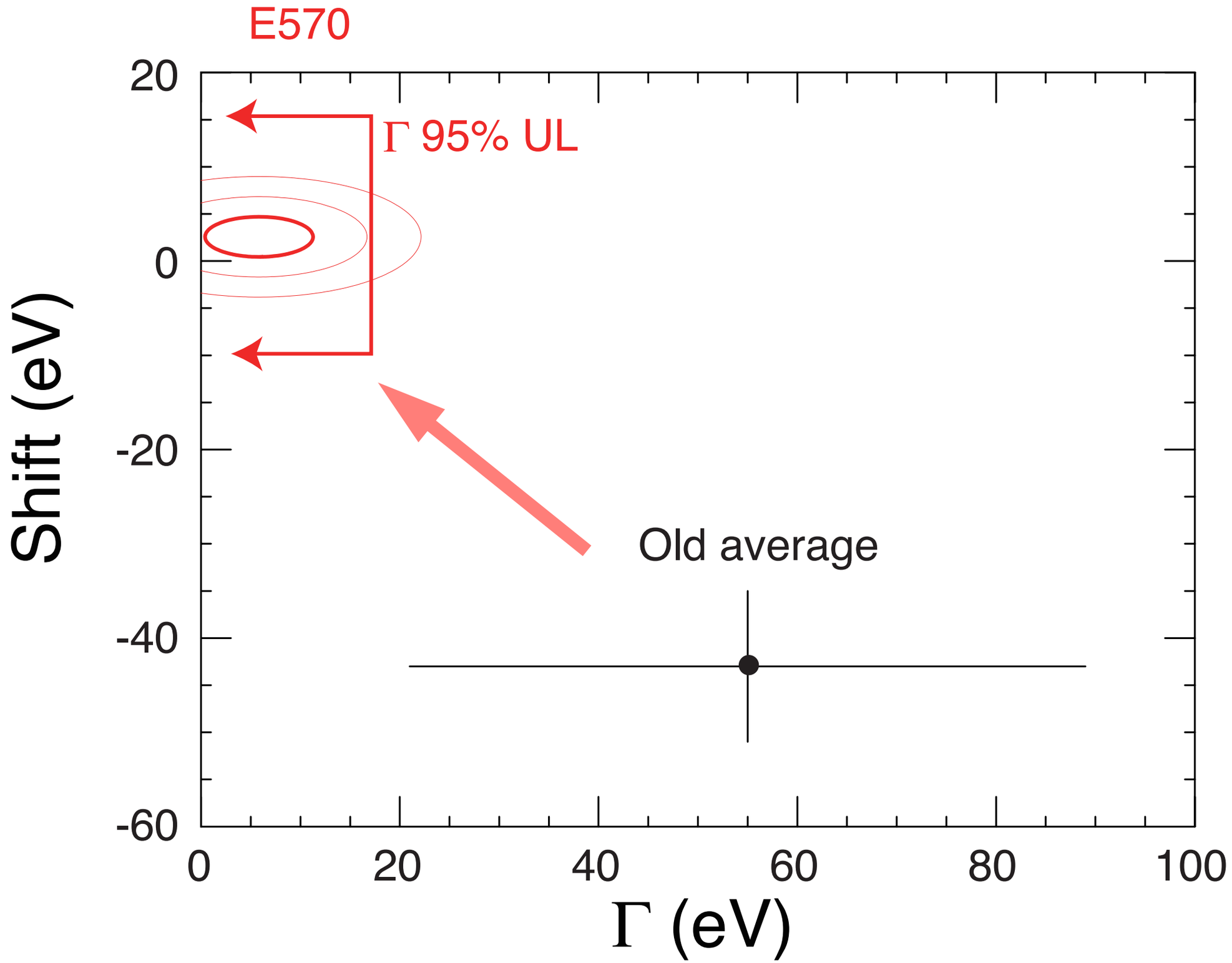
$\Delta E2p = 2 \pm 2(stat) \pm 2(sys)$ eV



Okada et al., PLB 653 (2007) 387

what about the width?

Γ_{2p}<17 eV (95%)

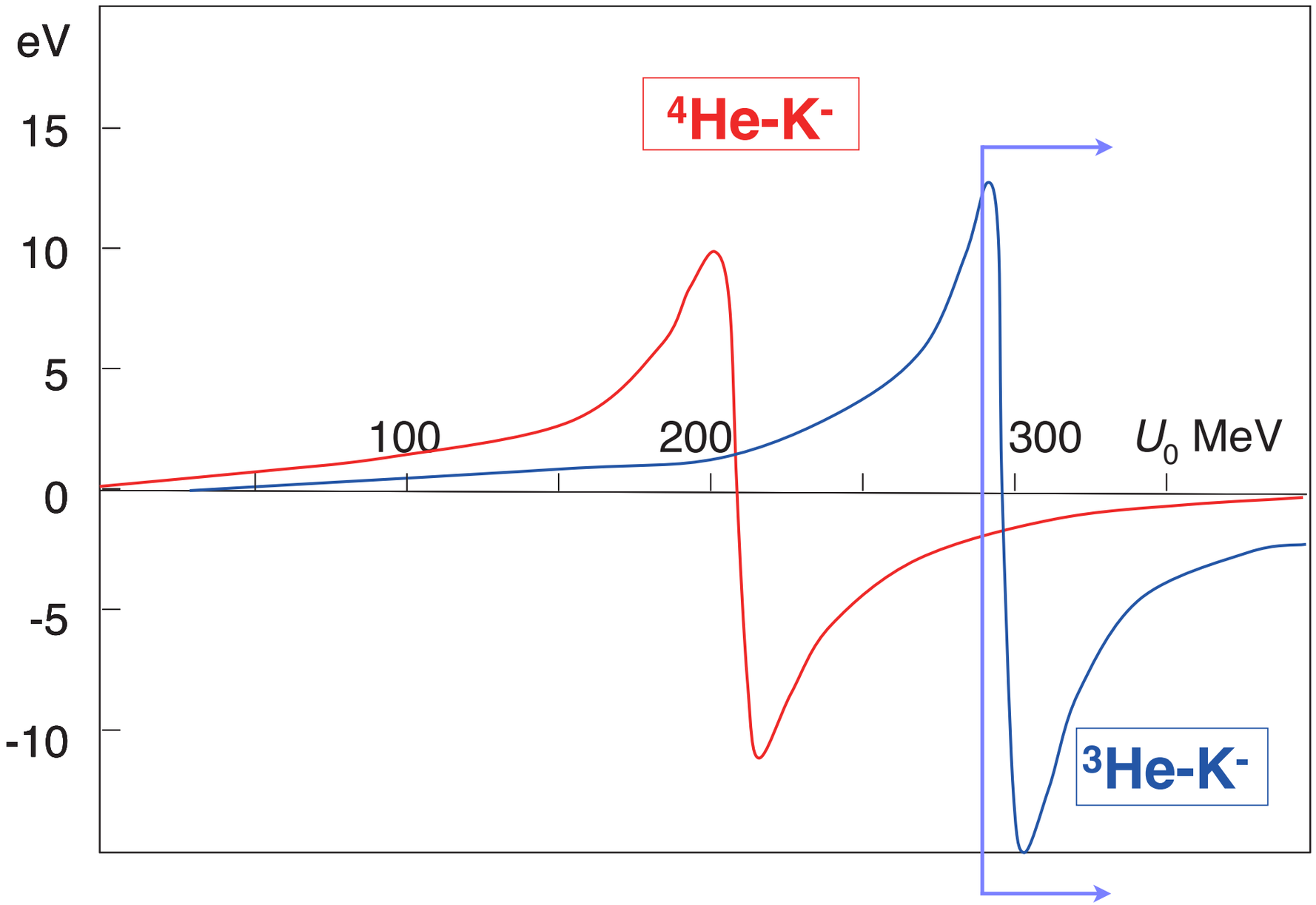


② K$^-$ ^{3}He

E17: the “day-1” experiment @ J-PARC

E17 will measure K^- ^{3}He (J-PARC Day-1)

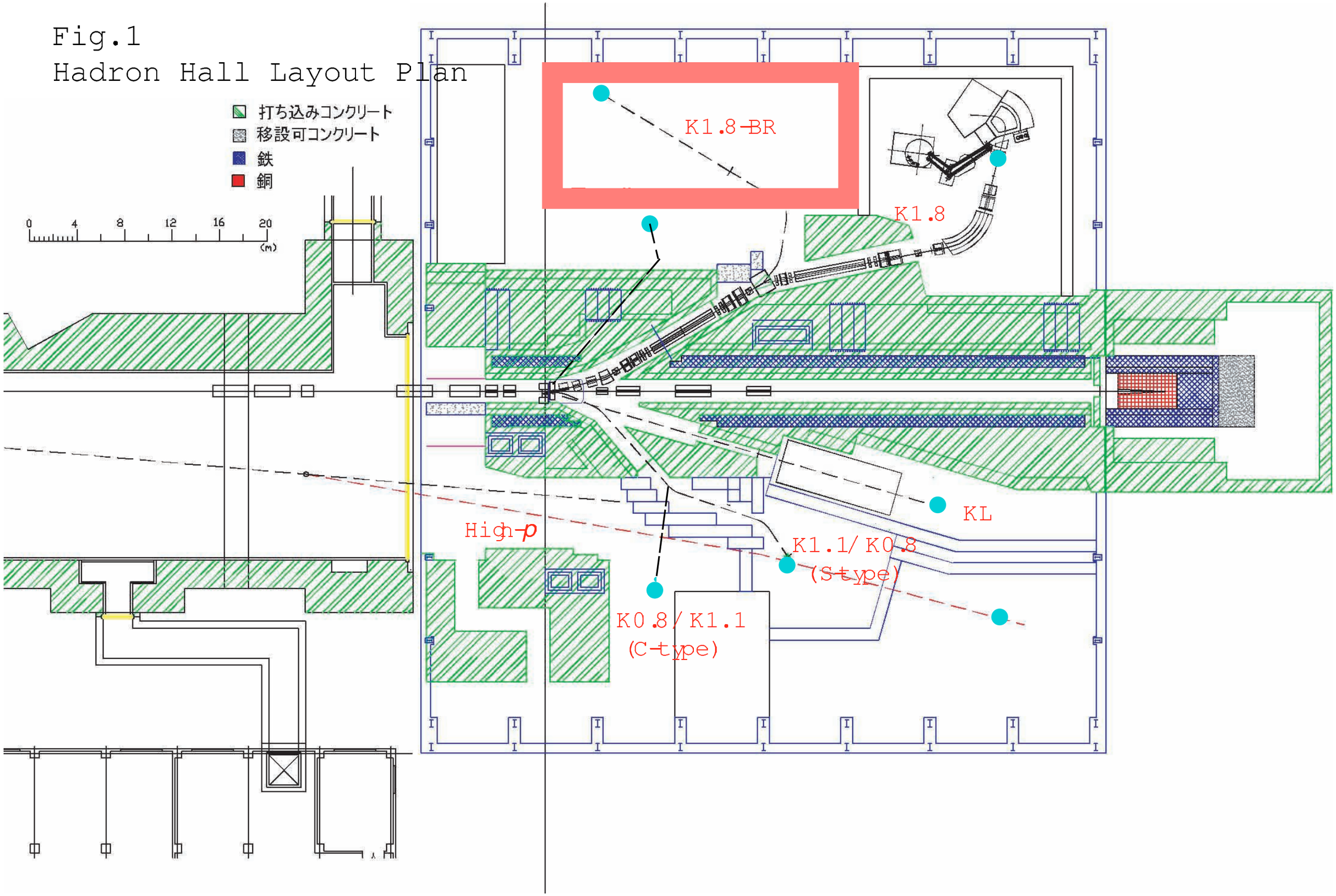
no data available



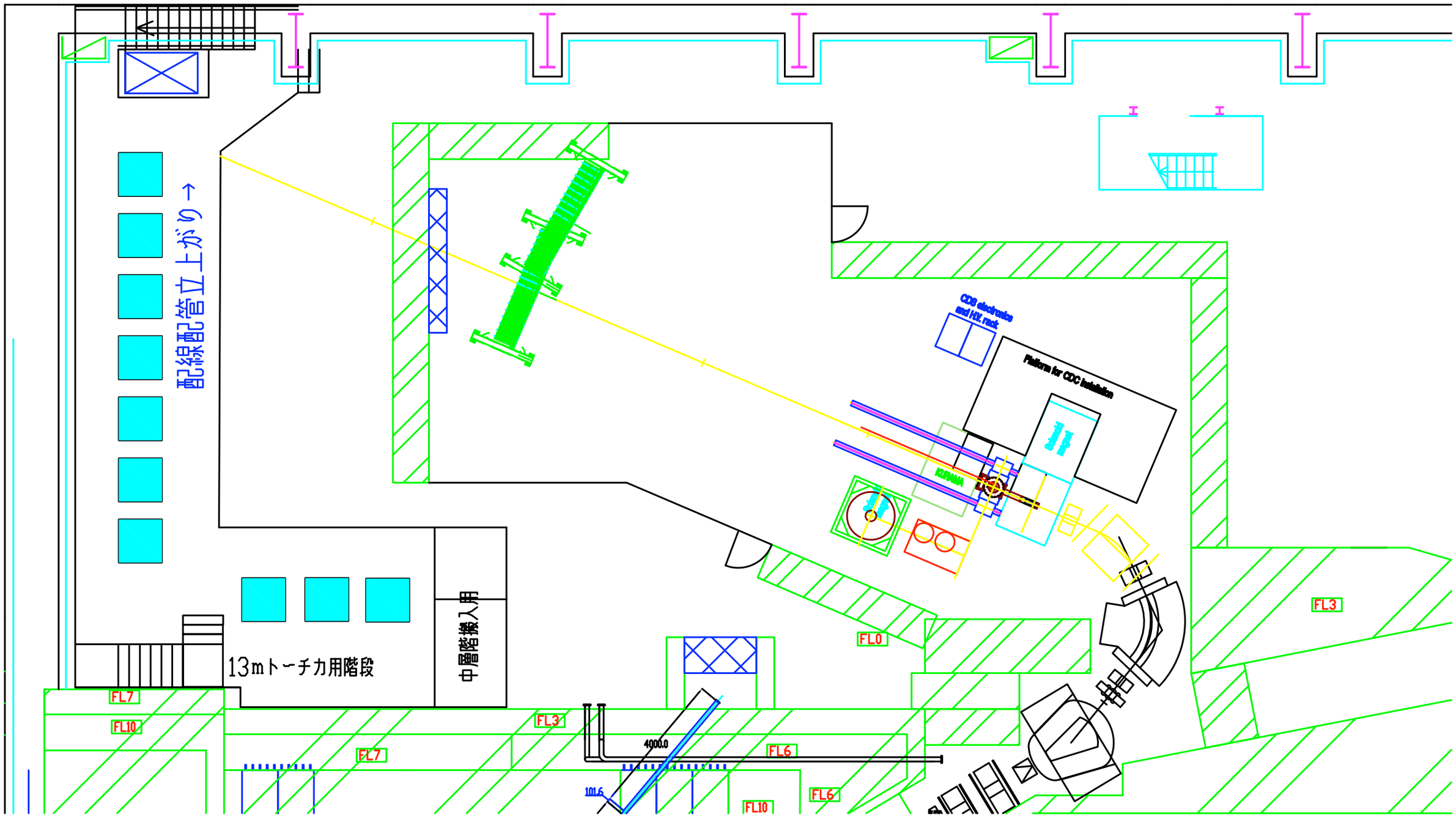

Hadron hall

Hadron hall

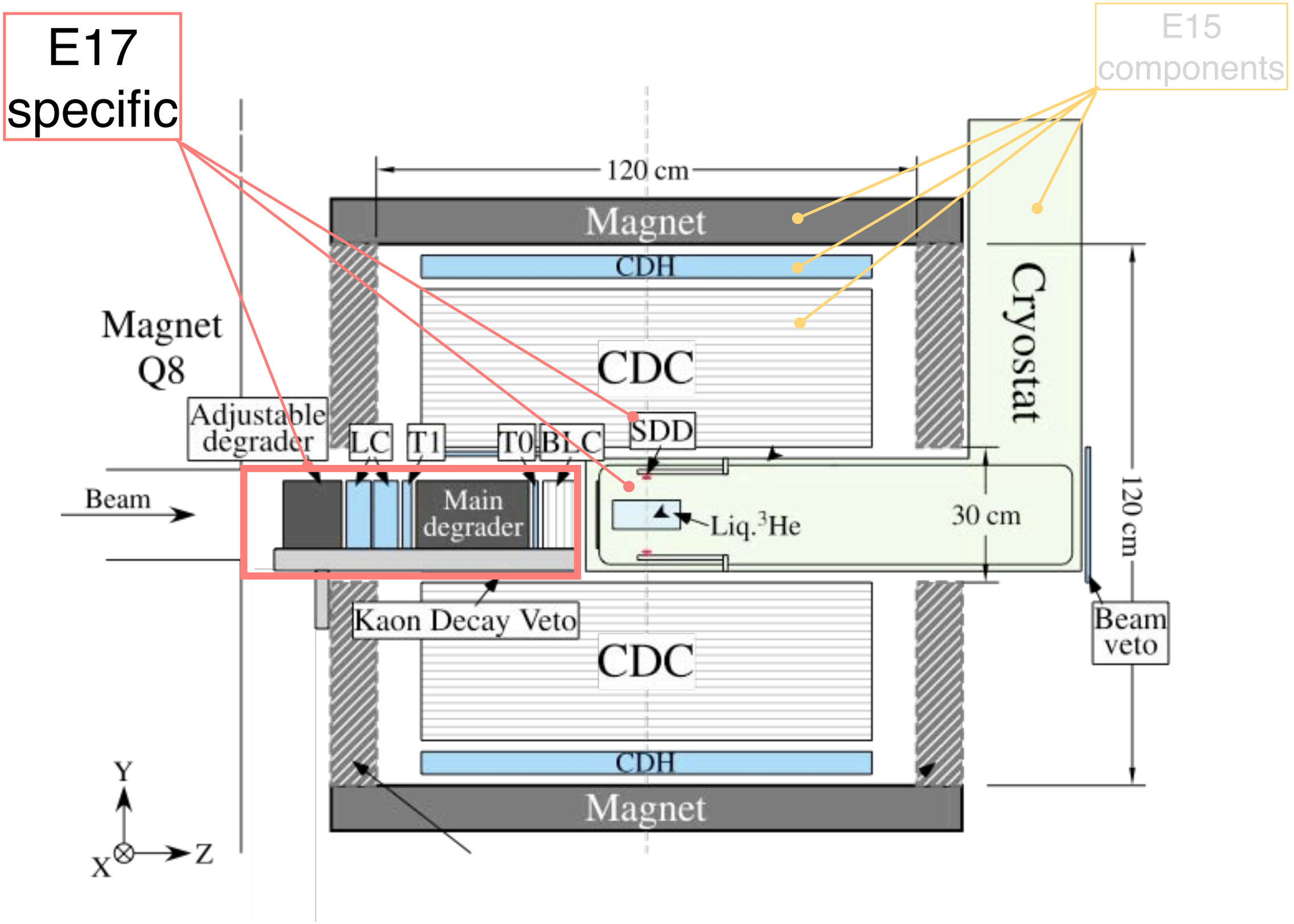
Fig.1
Hadron Hall Layout Plan



K1.8BR


配線配管立上がり→
13mトーチカ用階段
中層階搬入用
FL7
FL10
FL7
FL3
4000.0
FL6
101.6
FL10
FL6
FL0
FL3
CDS electronics and HV. rack
Platform for CDC installation
KURAMA

E17(15) setup

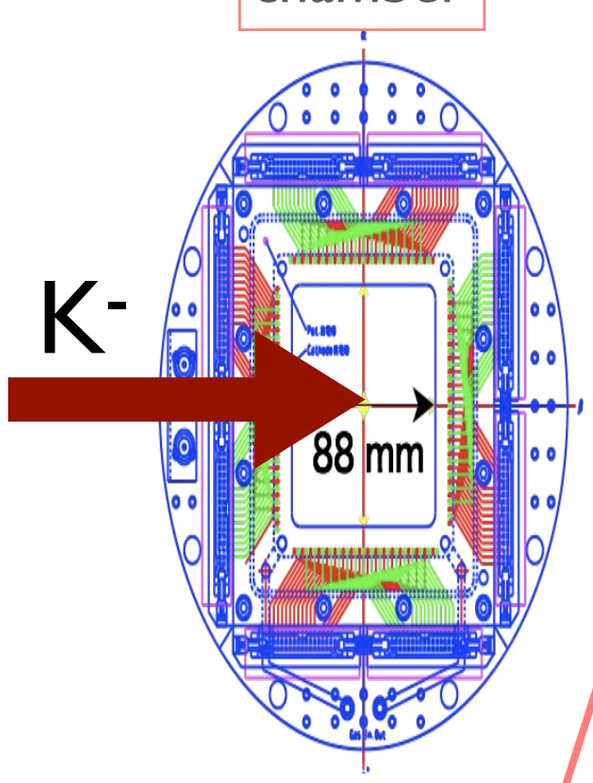

E17
specific
E15
components
120 cm
Magnet
CDH
CDC
Cryostat
Magnet
Q8
Adjustable
degrader
LC
T1
T0
BLC
SDD
Beam
Main
degrader
Liq.^{3}He
30 cm
120 cm
Kaon Decay Veto
Beam
veto
CDC
CDH
Magnet
Y
X
Z

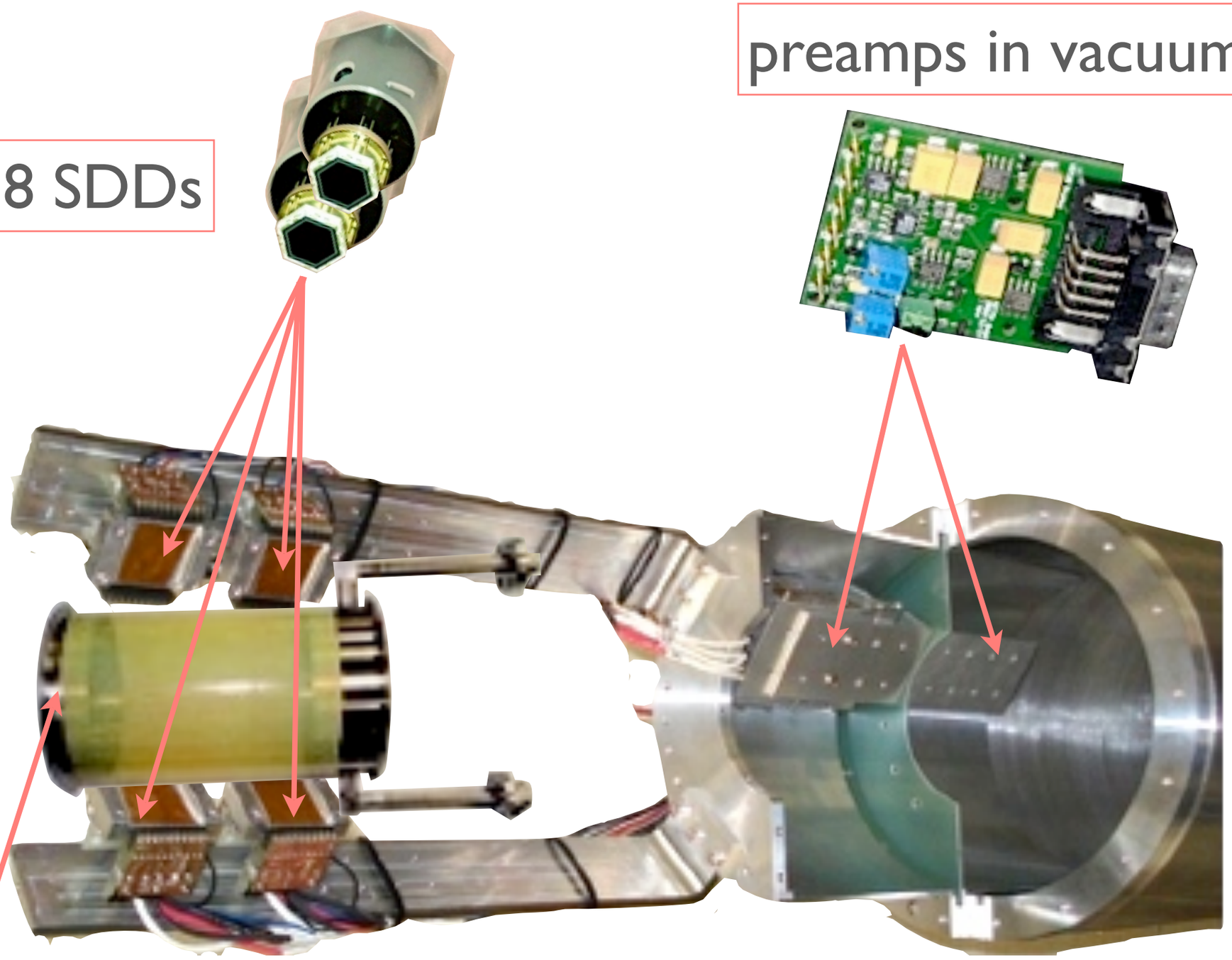
Getting ready

preamps in vacuum

8 SDDs

beamline chamber





target (^{3}He ~500 cm^3, liquified in the heat exchanger)

結論

Summary

- ✓ Now the K-^{4}He $2p$ shift is consistent with all theory calculations
- ✓ No more Kaonic Helium puzzle
- ✓ Width also appears to be small
- ✓ E17 J-PARC Day-1 experiment will measure K-^{3}He

The E570 collaboration

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The E15/E17 collaboration

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