Precision spectroscopy of kaonic helium x-rays

For KEK-PS E570 collaboration

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KEK-PS E570 collaboration

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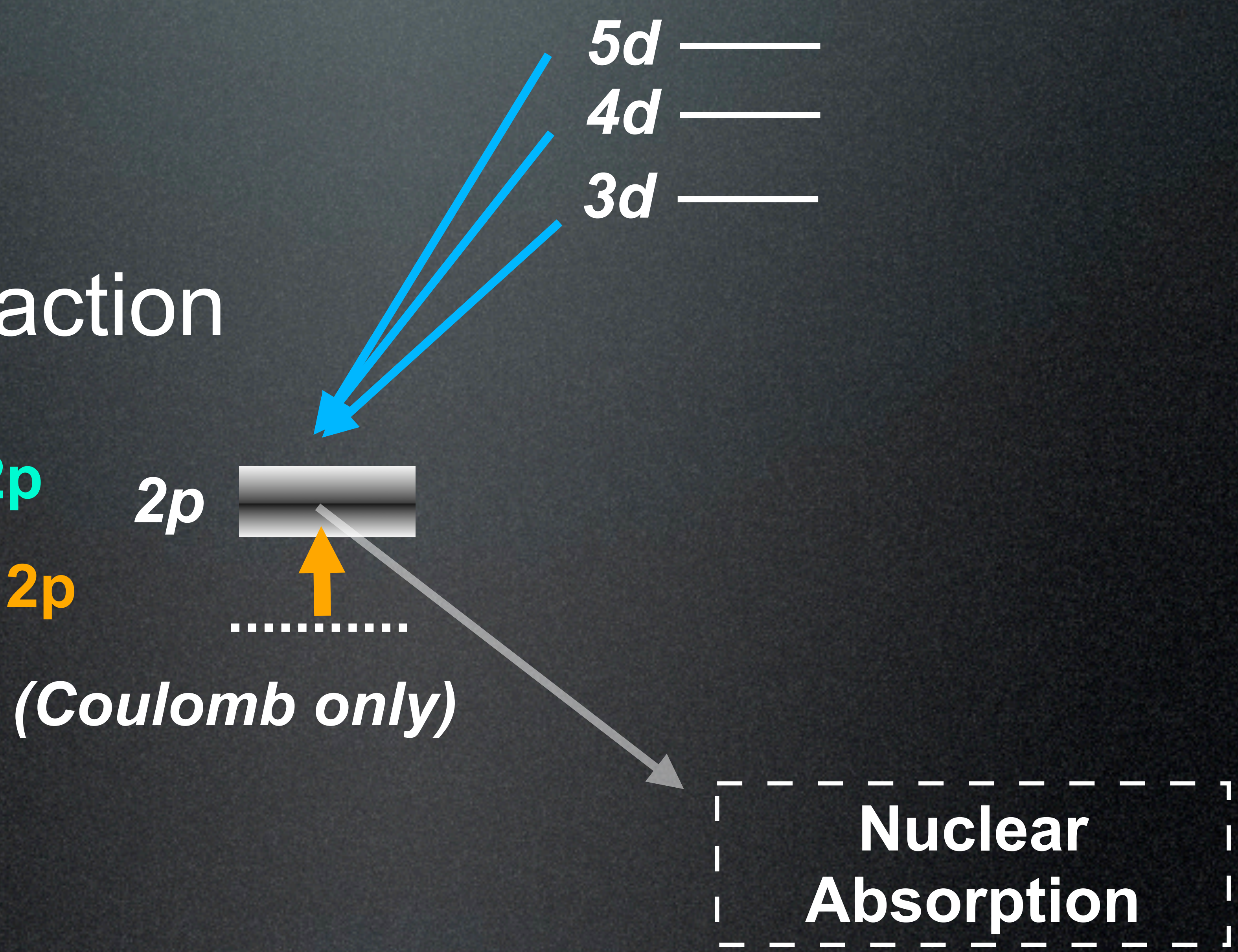
Goal of E570

determine the strong-interaction shift with a precision of 2 eV

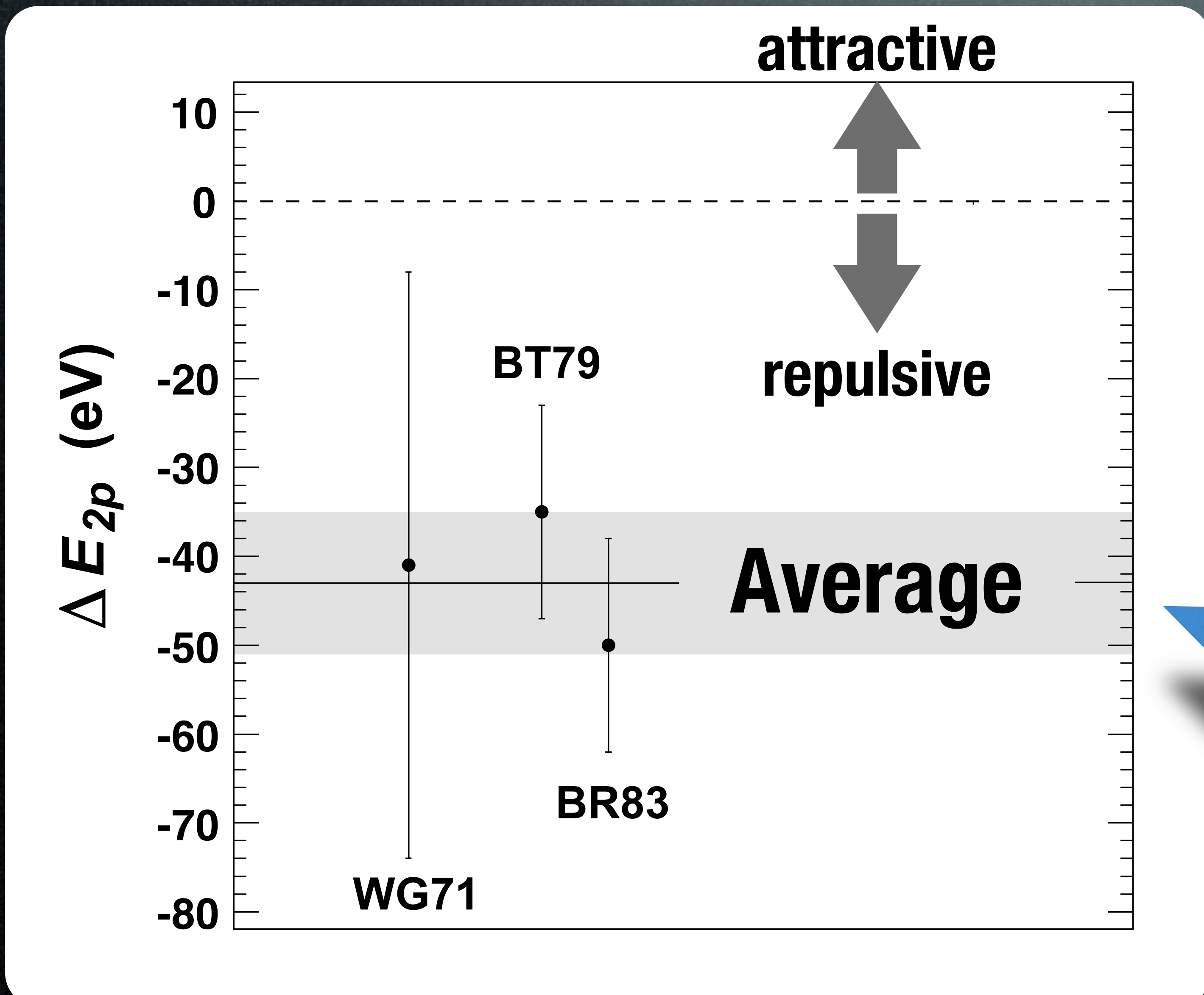
strong-interaction

width : Γ_{2p}

shift : ΔE_{2p}



Kaonic helium puzzle



Theories

~0 eV

S. Hirenzaki et al, PRC61, 055205 (2000)

C.J. Batty, NPA508, 89 (1990)

E.Friedman (2007)

Experiments

–41 ± 8 eV

1. C.E. Wiegand and R.H. Pehl PRL27, 1410 (1971)
2. C.J. Batty et al, NPA326, 455 (1979)
3. S. Baird et al, NPA392, 297 (1983)

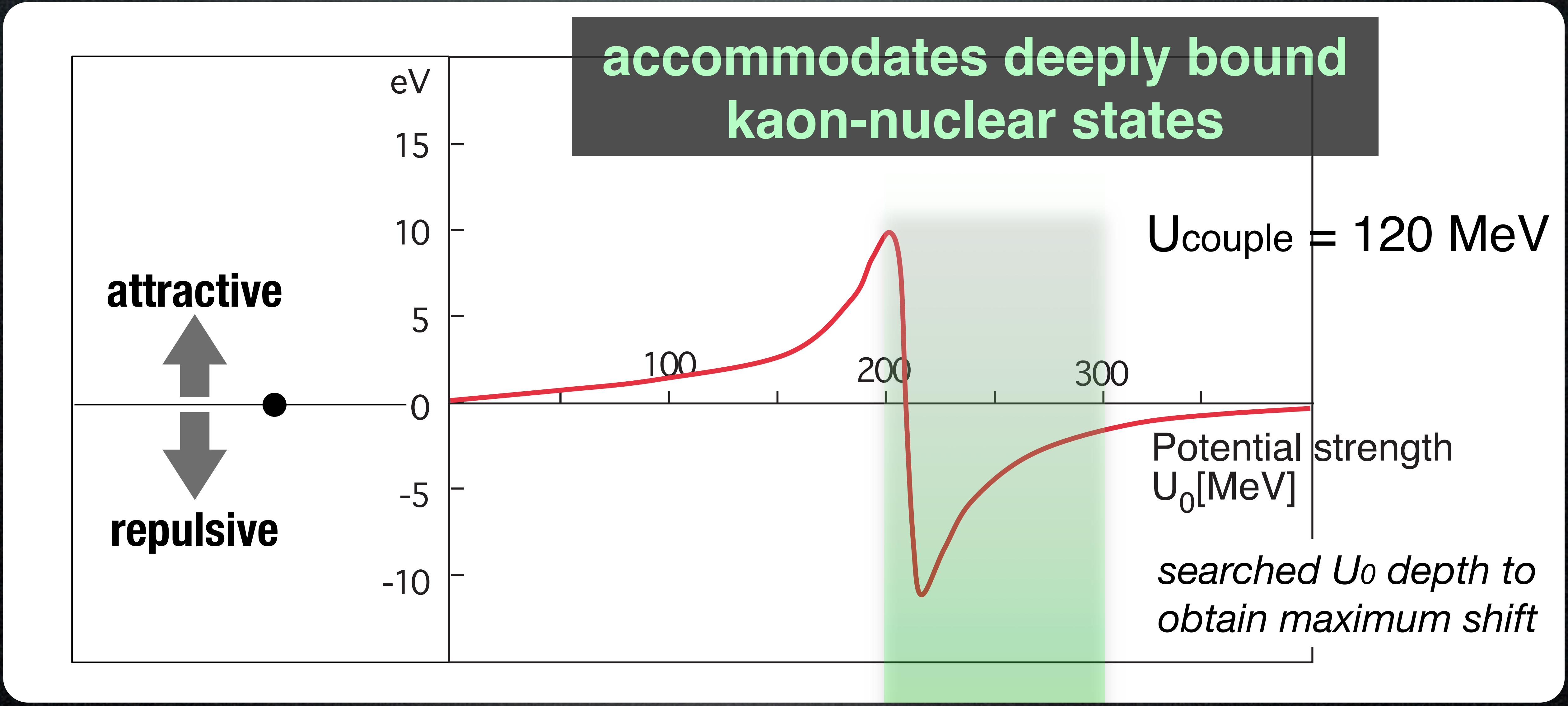
Possible large shift

optical model

SU(3) chiral unitary model

coupled $\Sigma\pi$-channel model

Y. Akaishi, EXA05, p45 (2005)



Possible large shift

optical model
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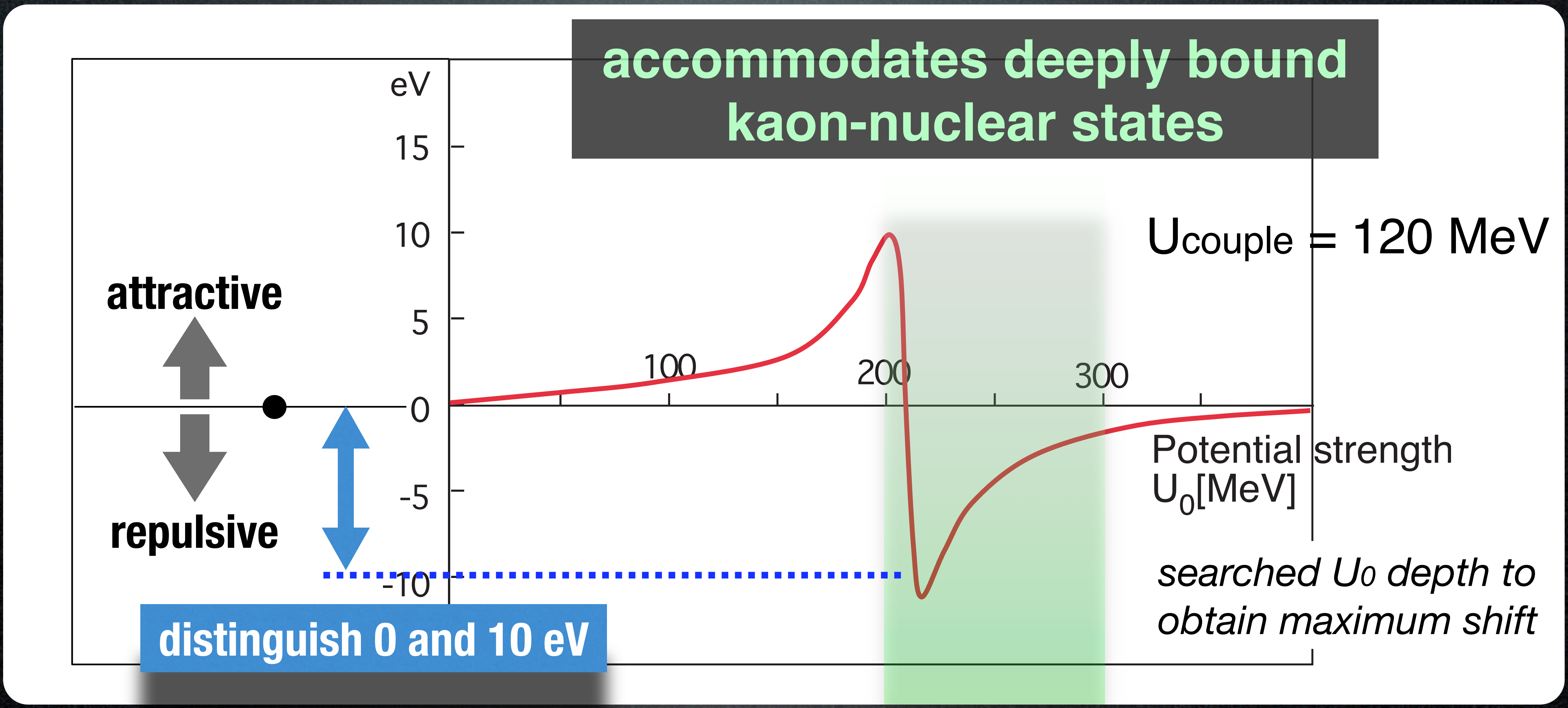
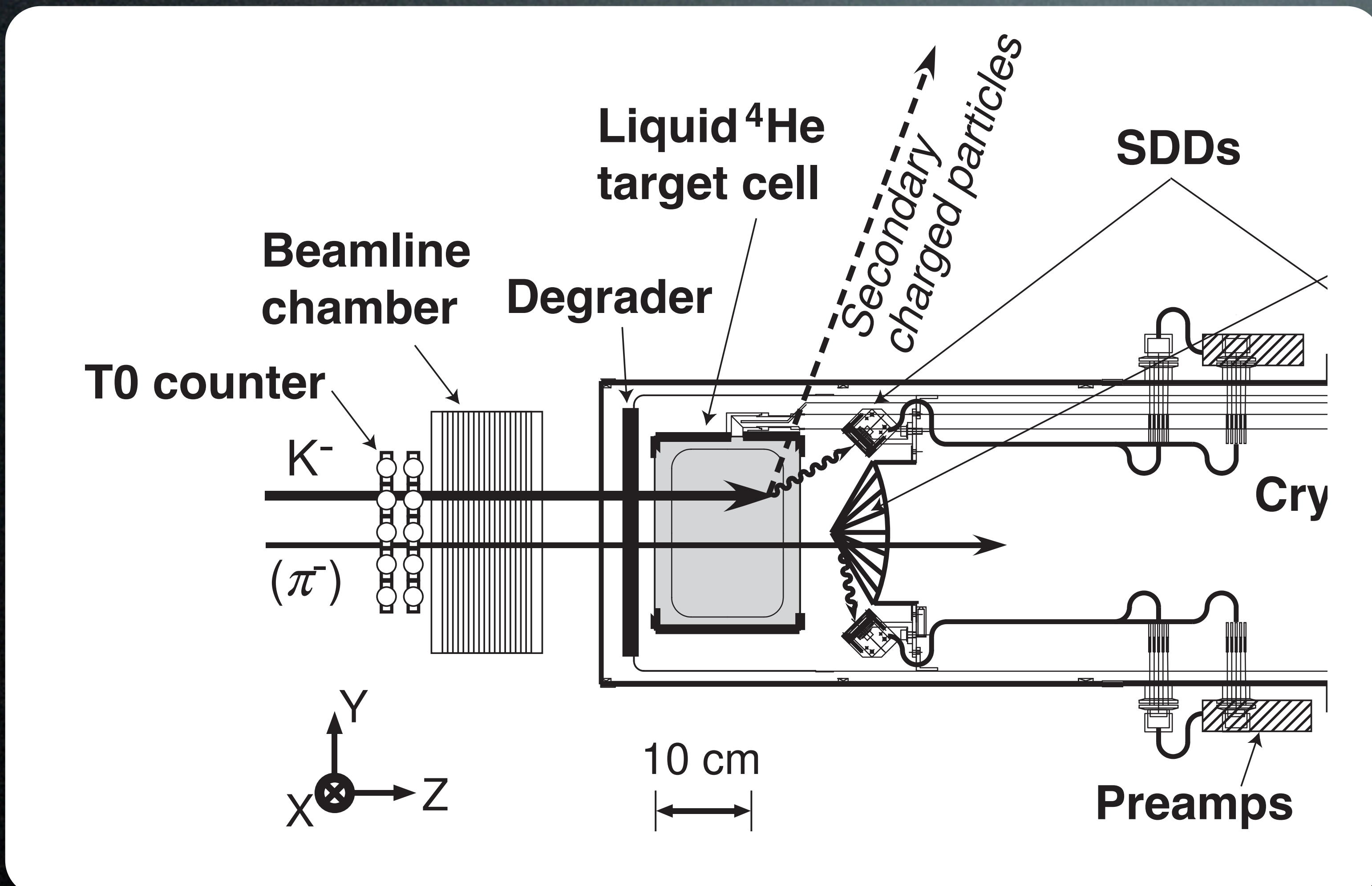


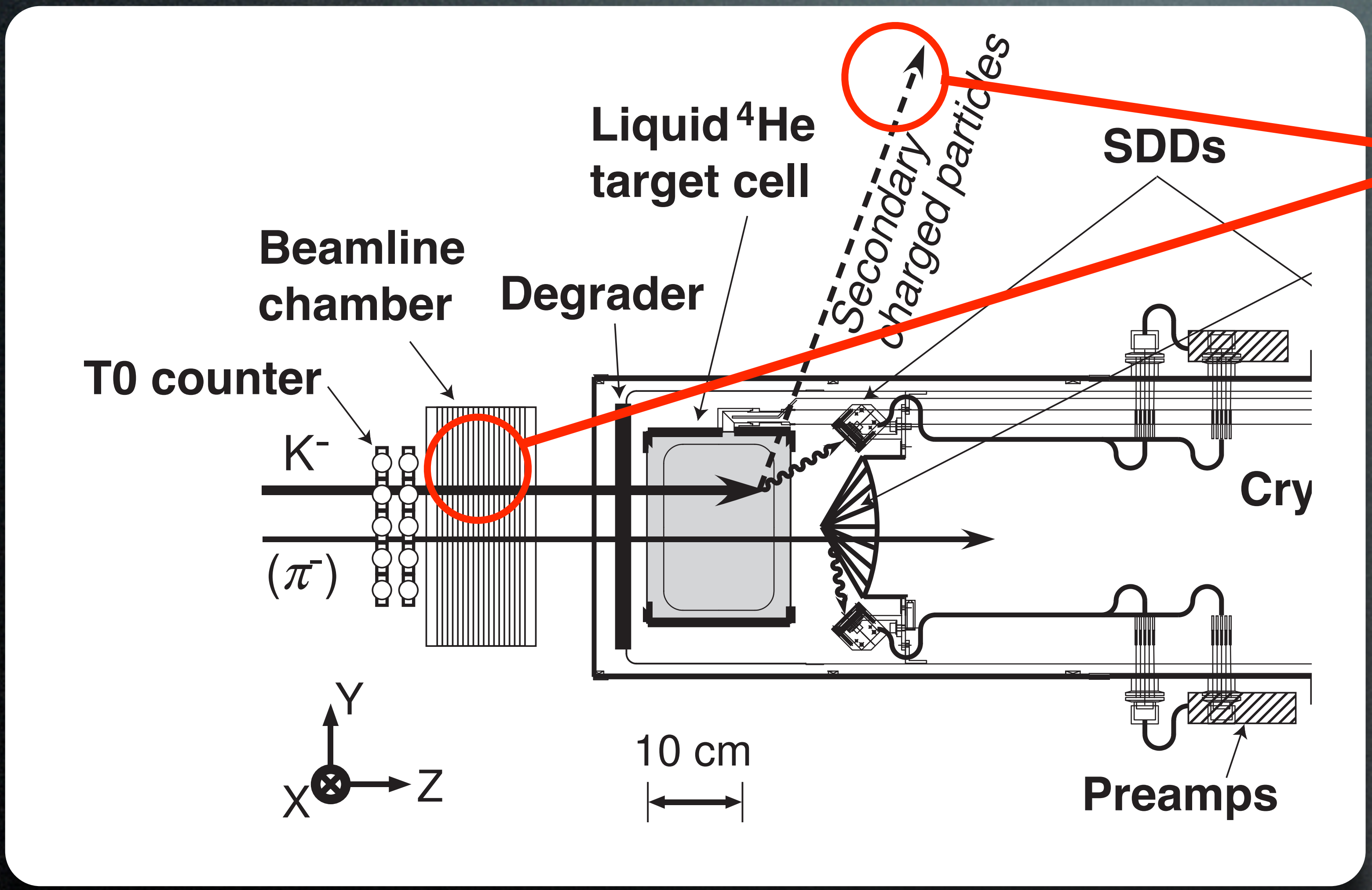
E570 experiment

1. high resolution (silicon drift detector)
2. low background (high S/N)
3. *in-situ* energy calibration

2. low background : stopped-kaon selection

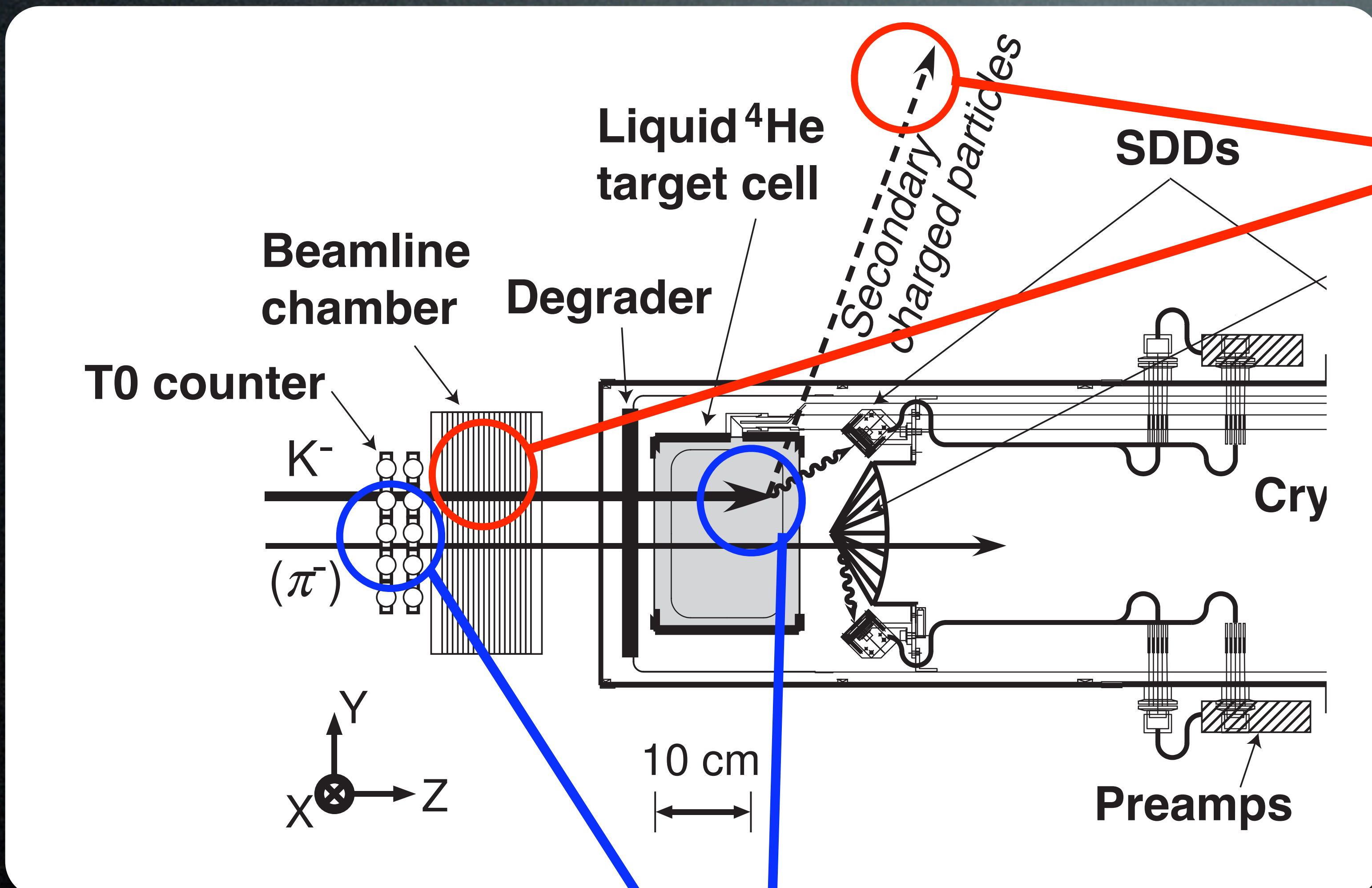


2. low background : stopped-kaon selection



reaction vertex reconstruction

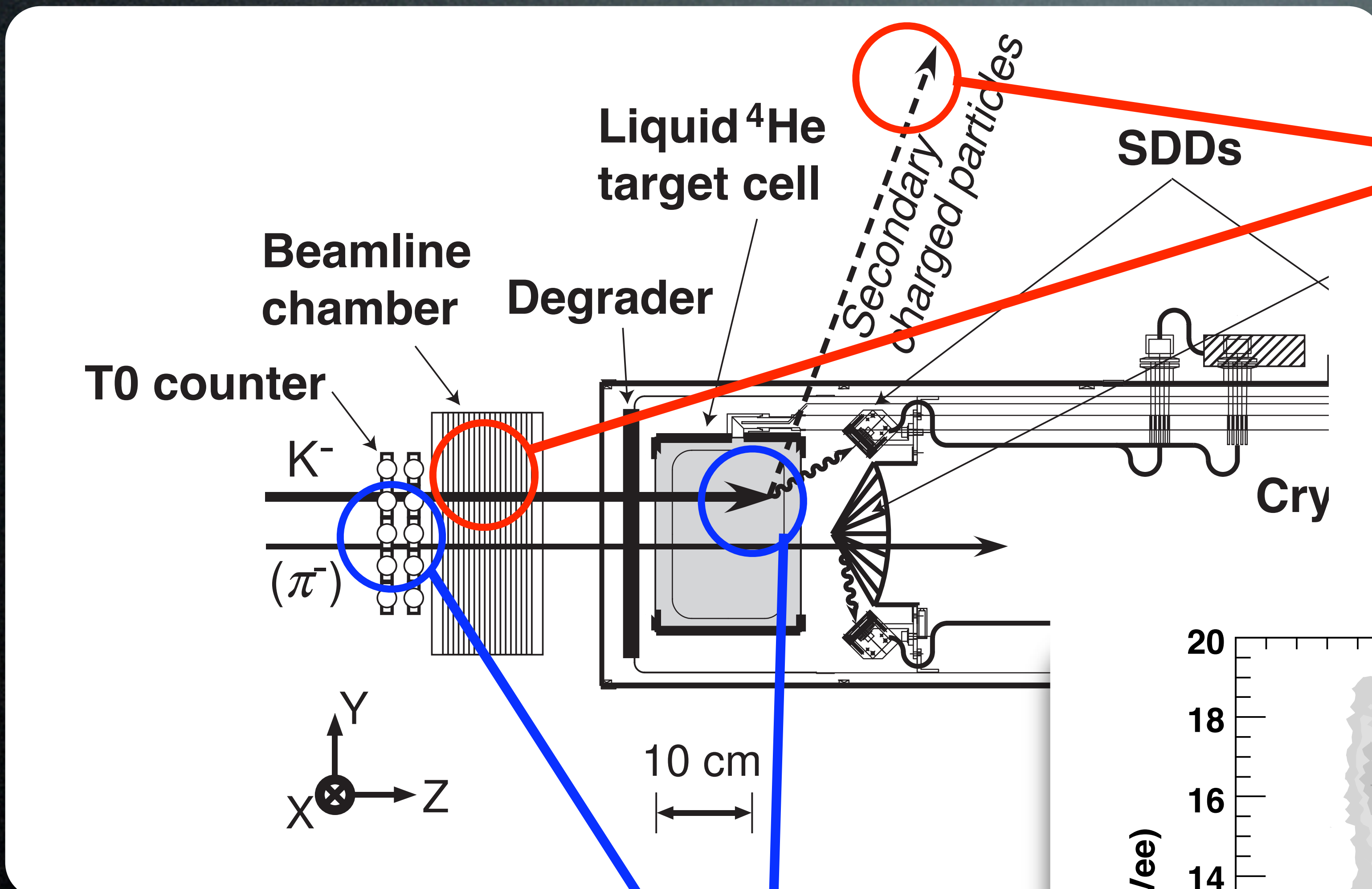
2. low background : stopped-kaon selection



reaction vertex reconstruction

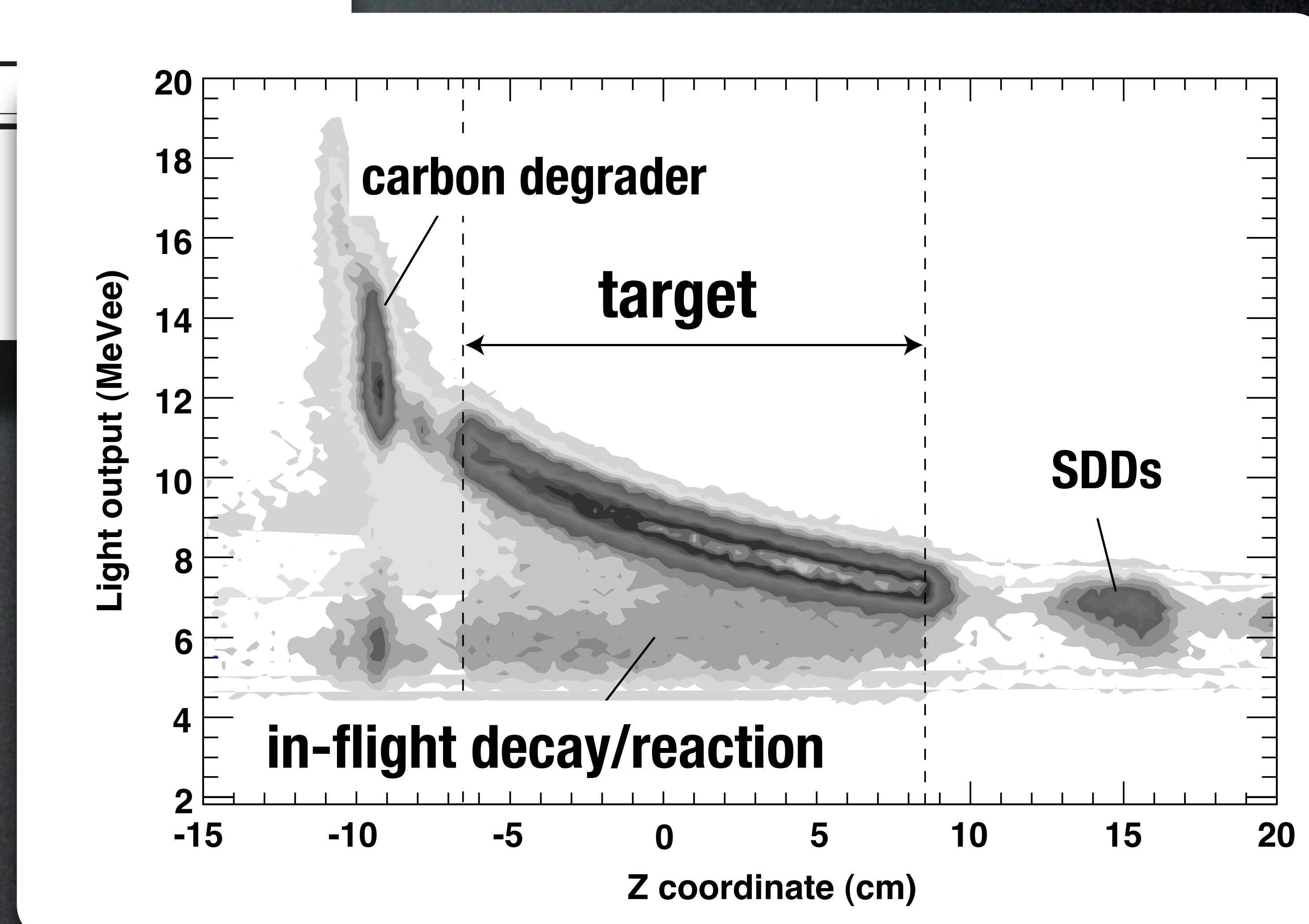
stopped kaon selection

2. low background : stopped-kaon selection



reaction vertex reconstruction

stopped kaon selection



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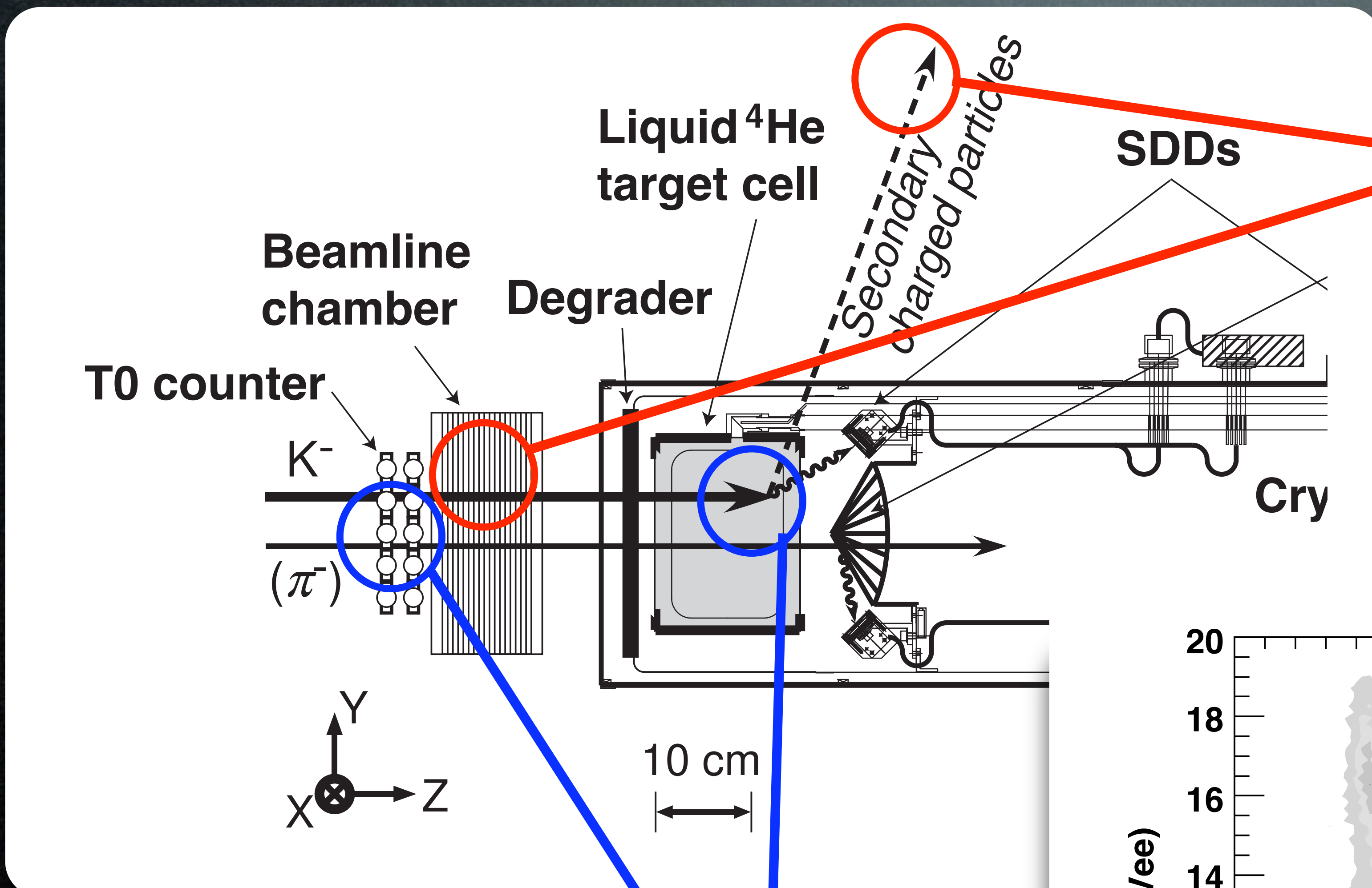
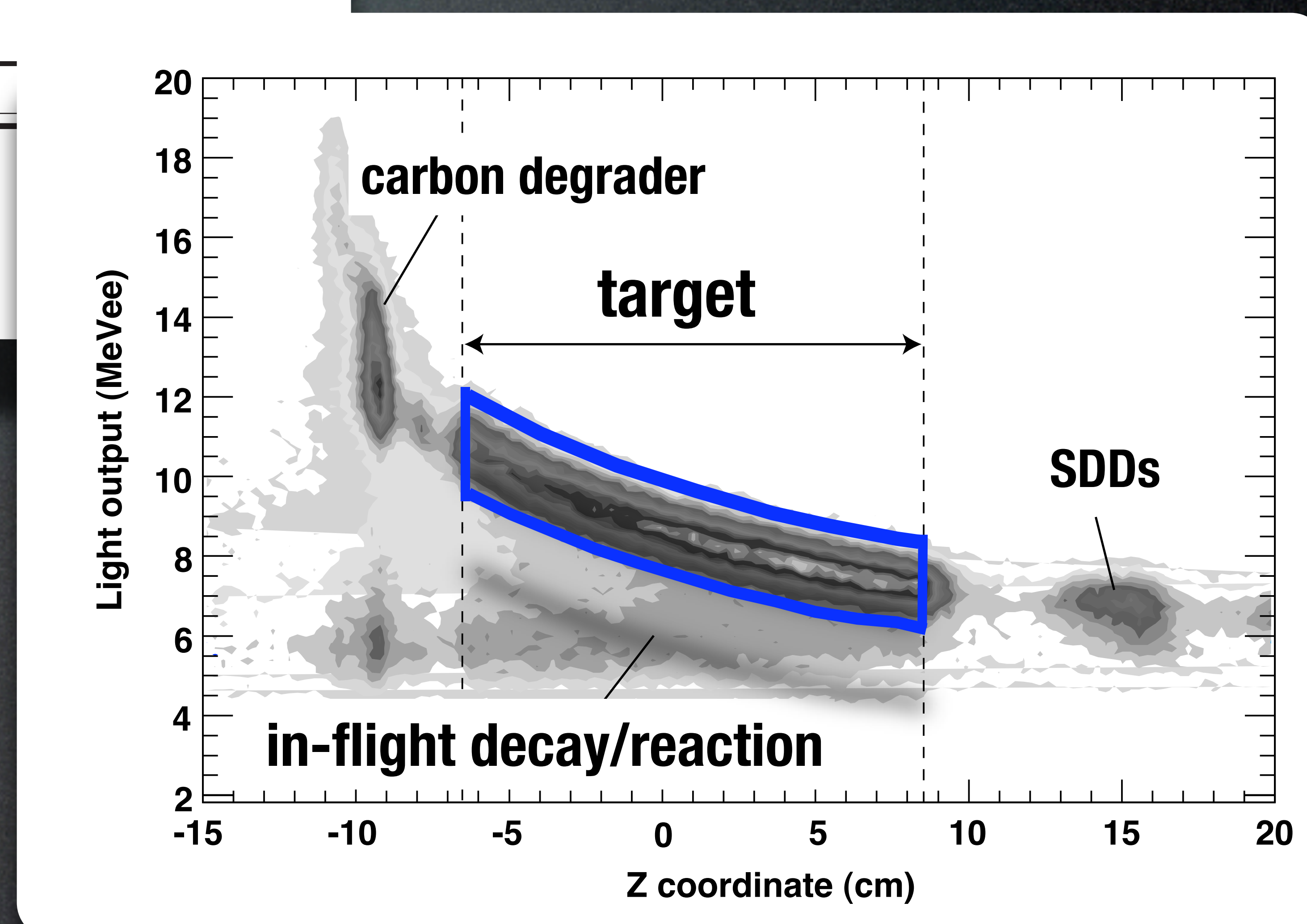


reaction vertex reconstruction



stopped kaon selection

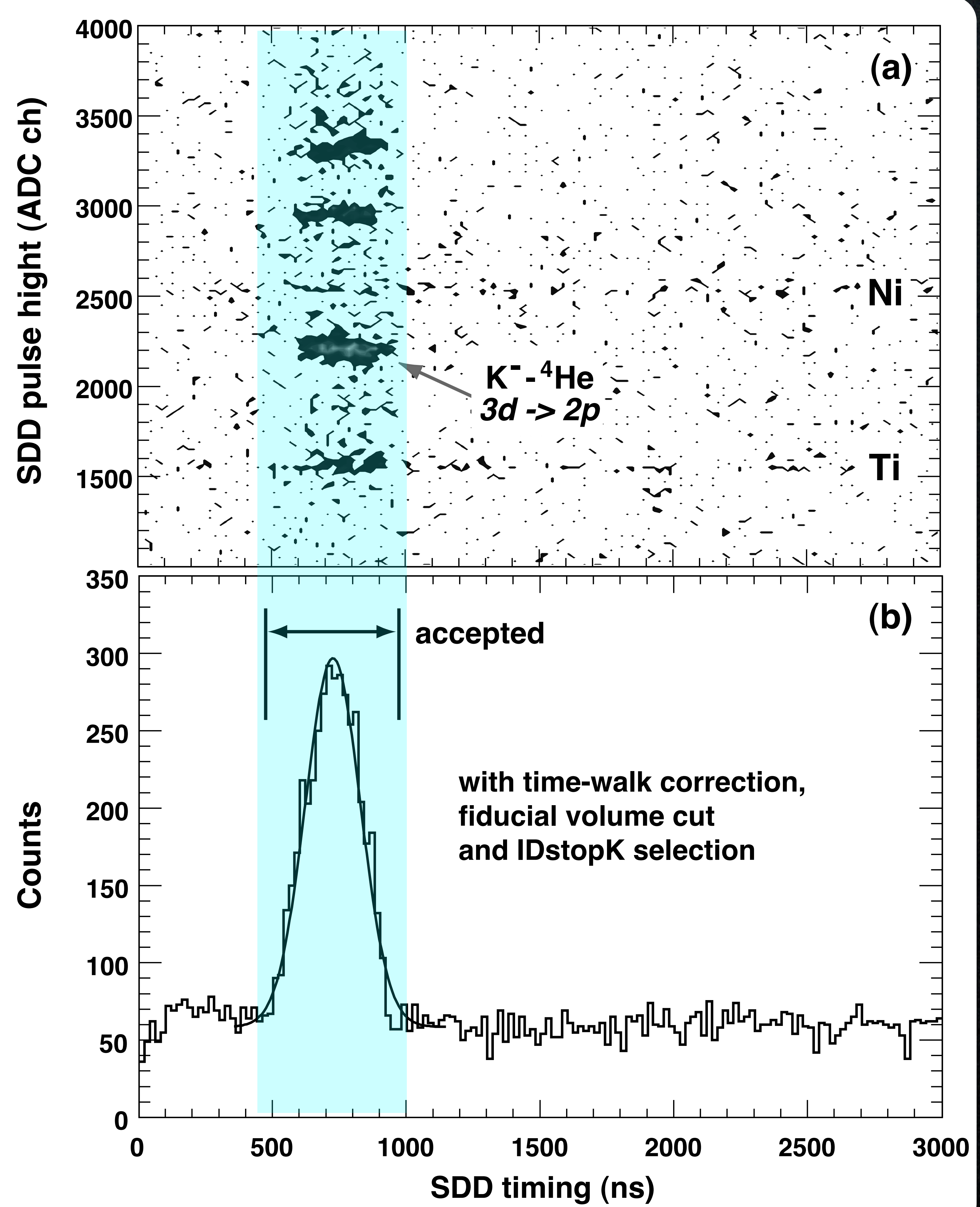
2. low background

kaon timing selection

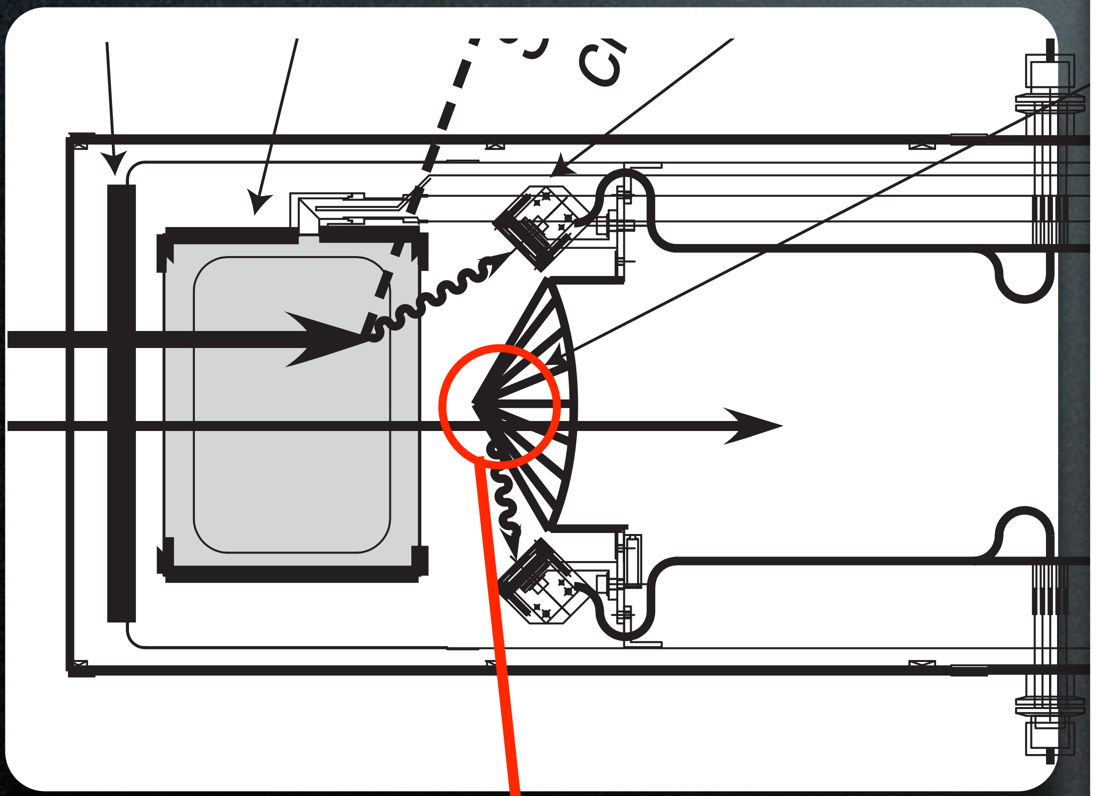
coincidence events with SDDs

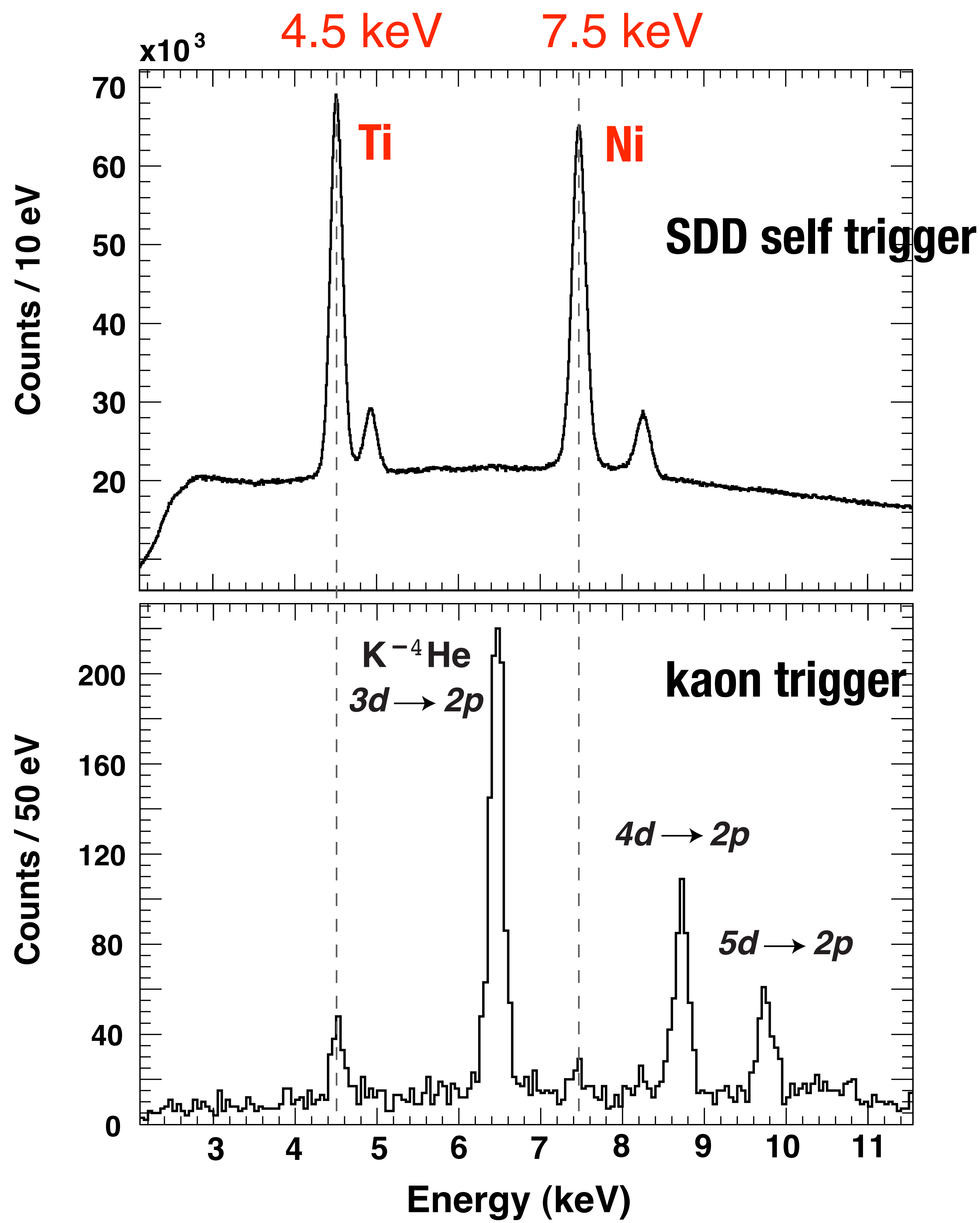
time resolution

σ = 130 ns



3. energy calibration





Ti and Ni *Kα* lines induced by the beam

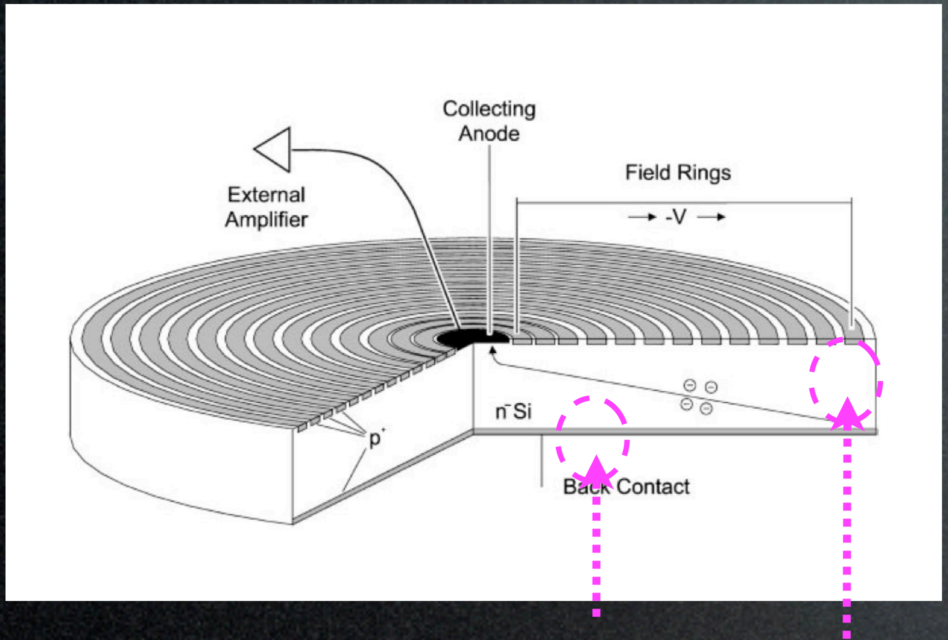
To achieve a few eV precision

Fit functions

(1) response function of the SDD
(2) Compton scattering in the target
(3) pileup

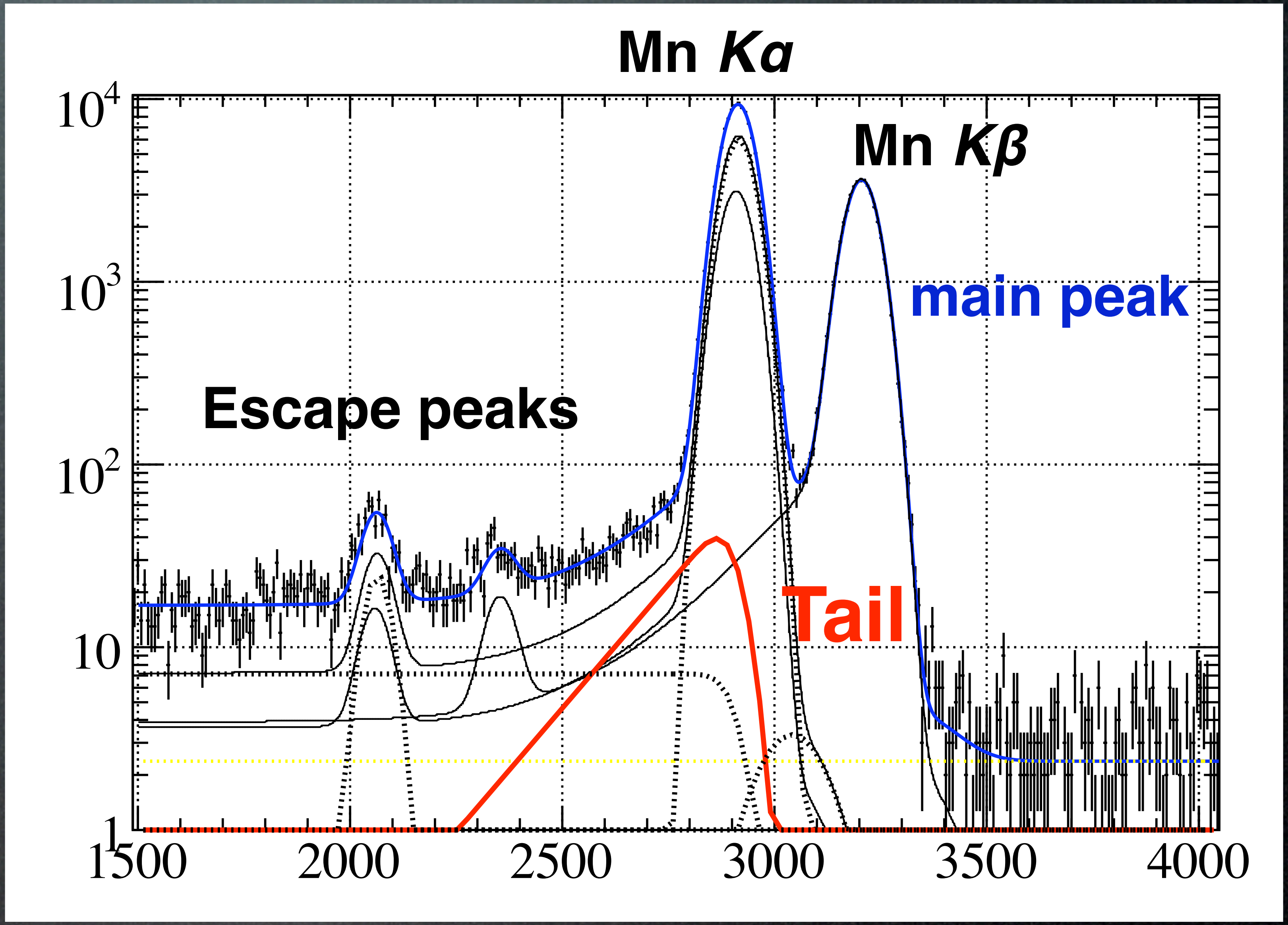
Response function

SDD



incomplete charge collection

Fe55 source measurement



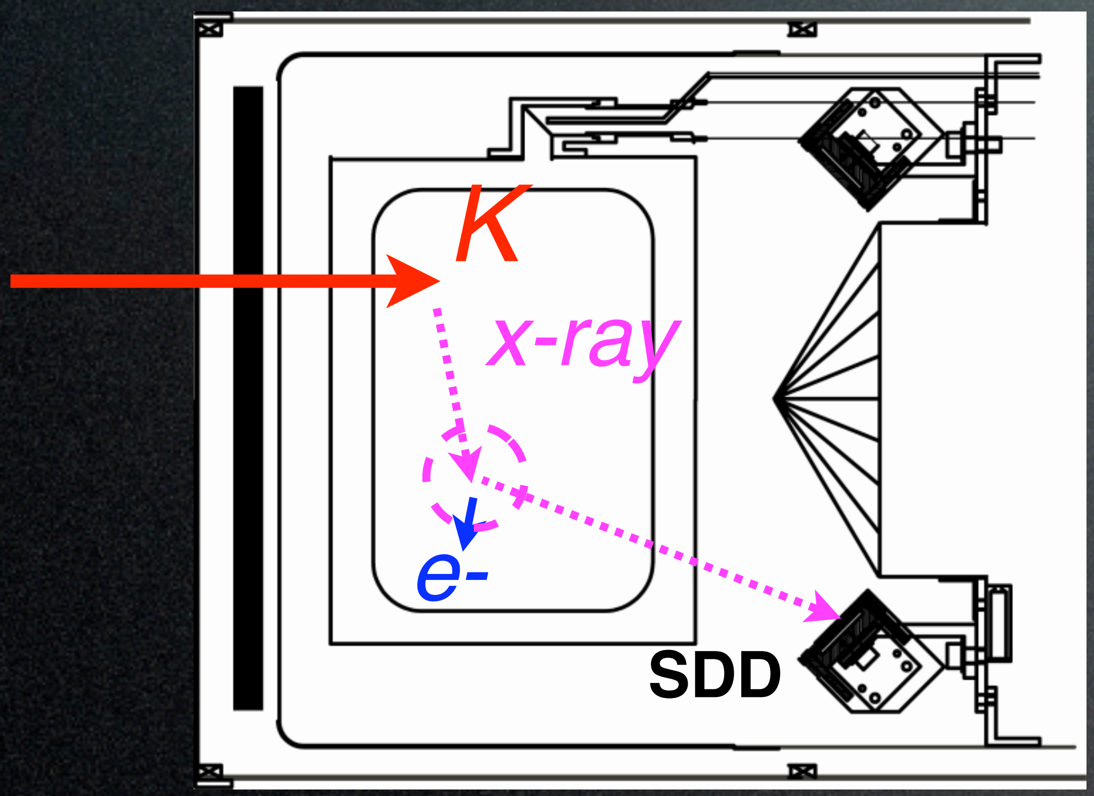
low-energy tail + flat component

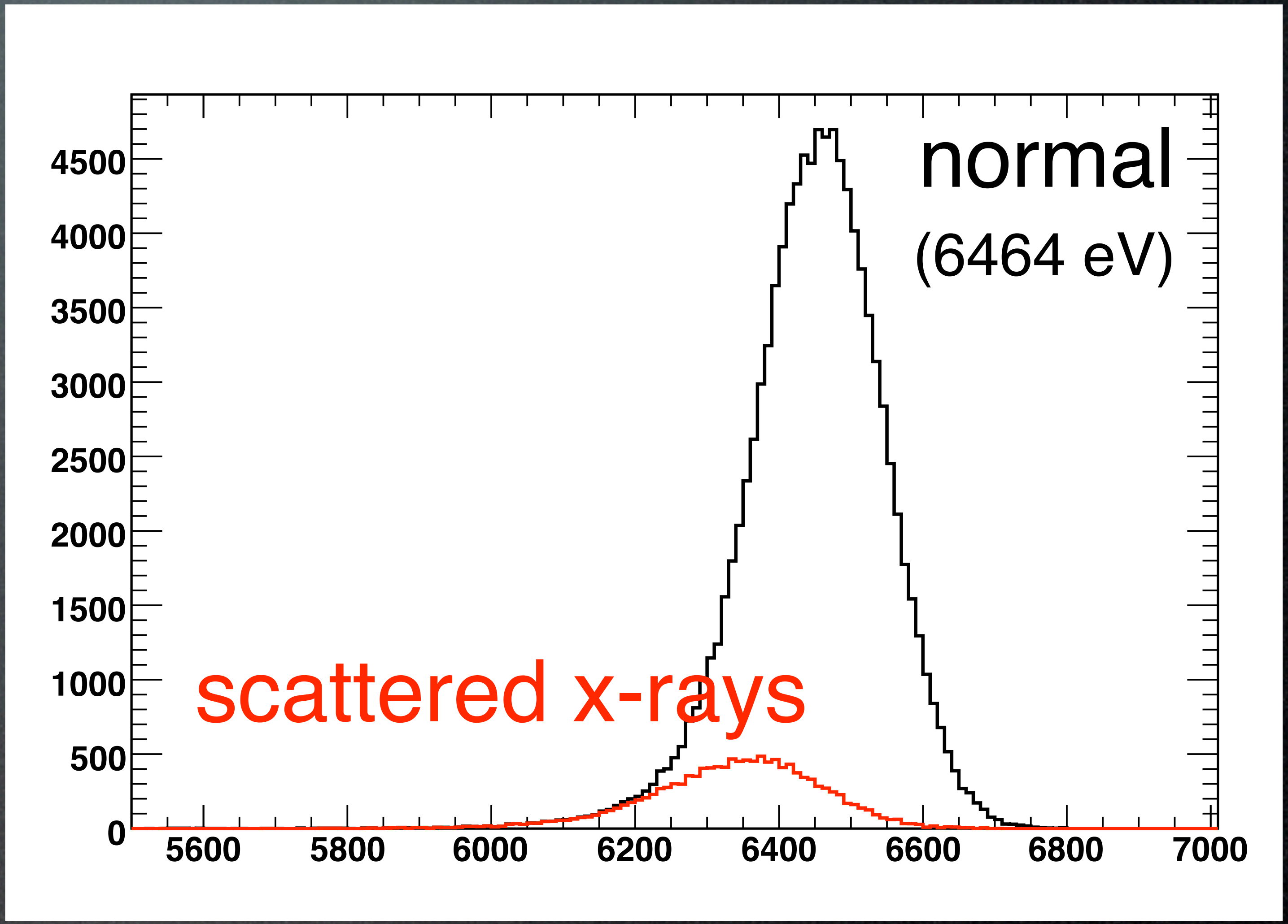
fraction ~3%

Compton scattering in the target

GEANT4 simulation
low-energy Compton scattering package

0.145 g/cm3 liquid helium





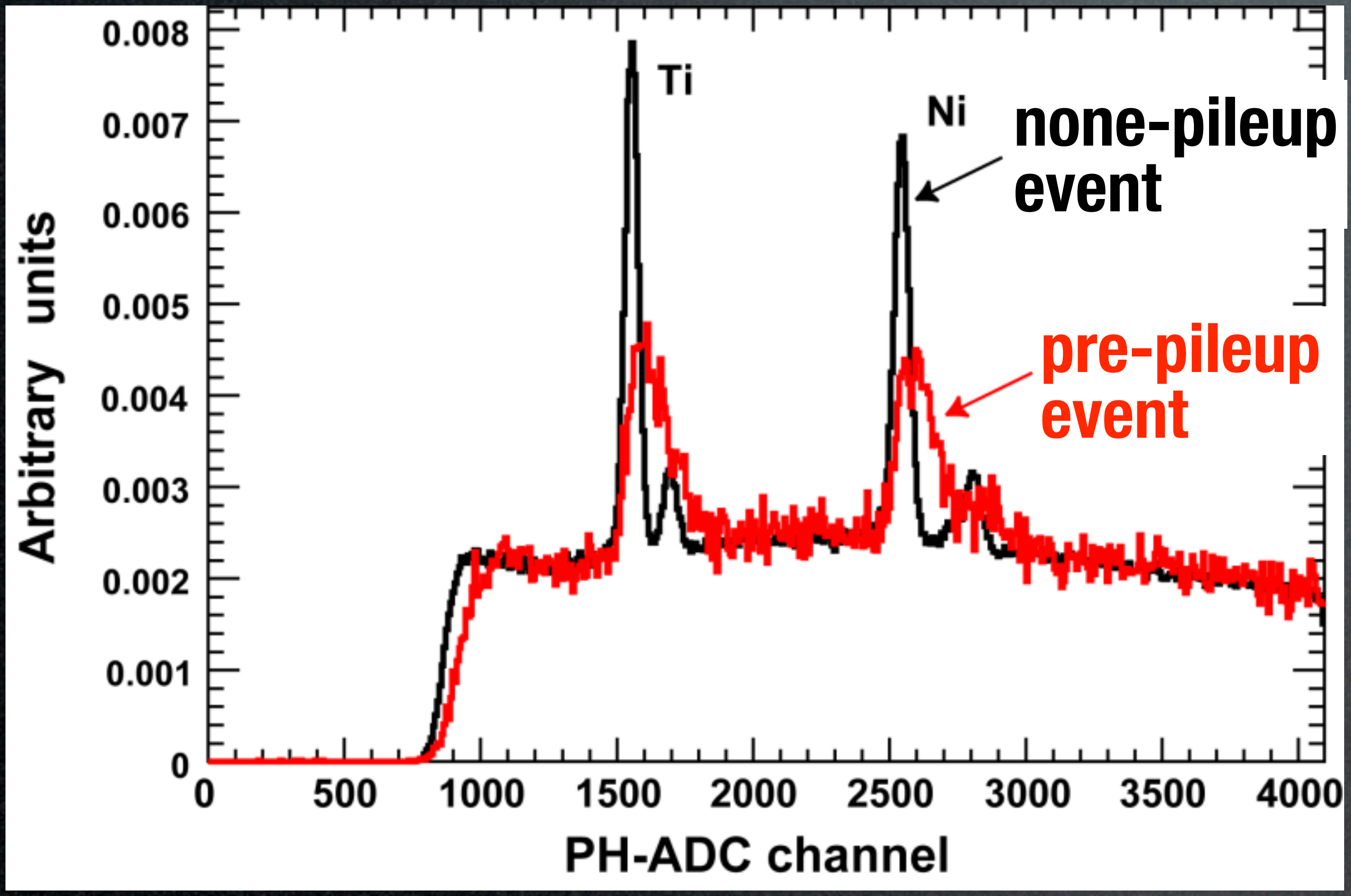
low-energy tail

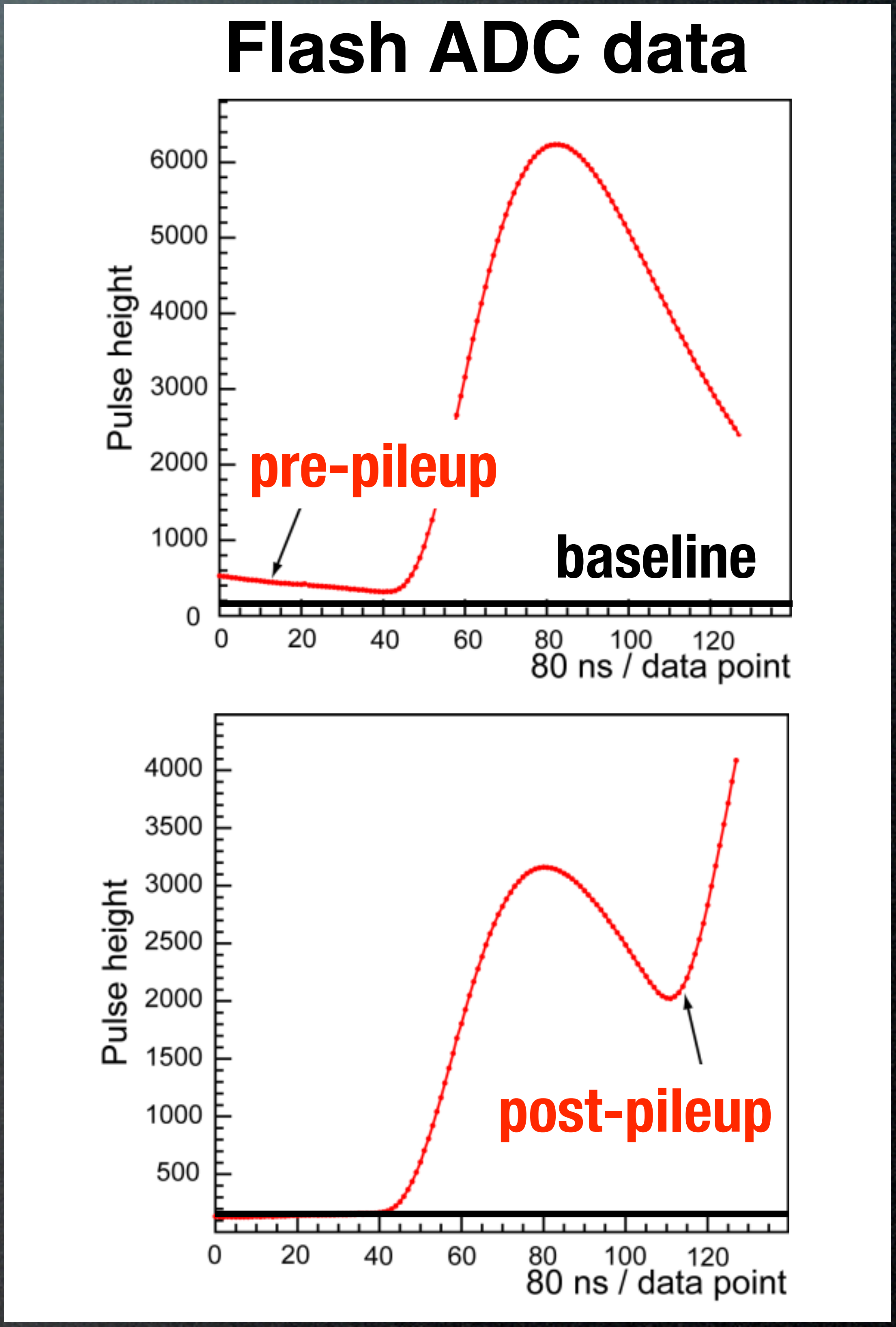
fraction ~11% !

Pileup

high-energy tail

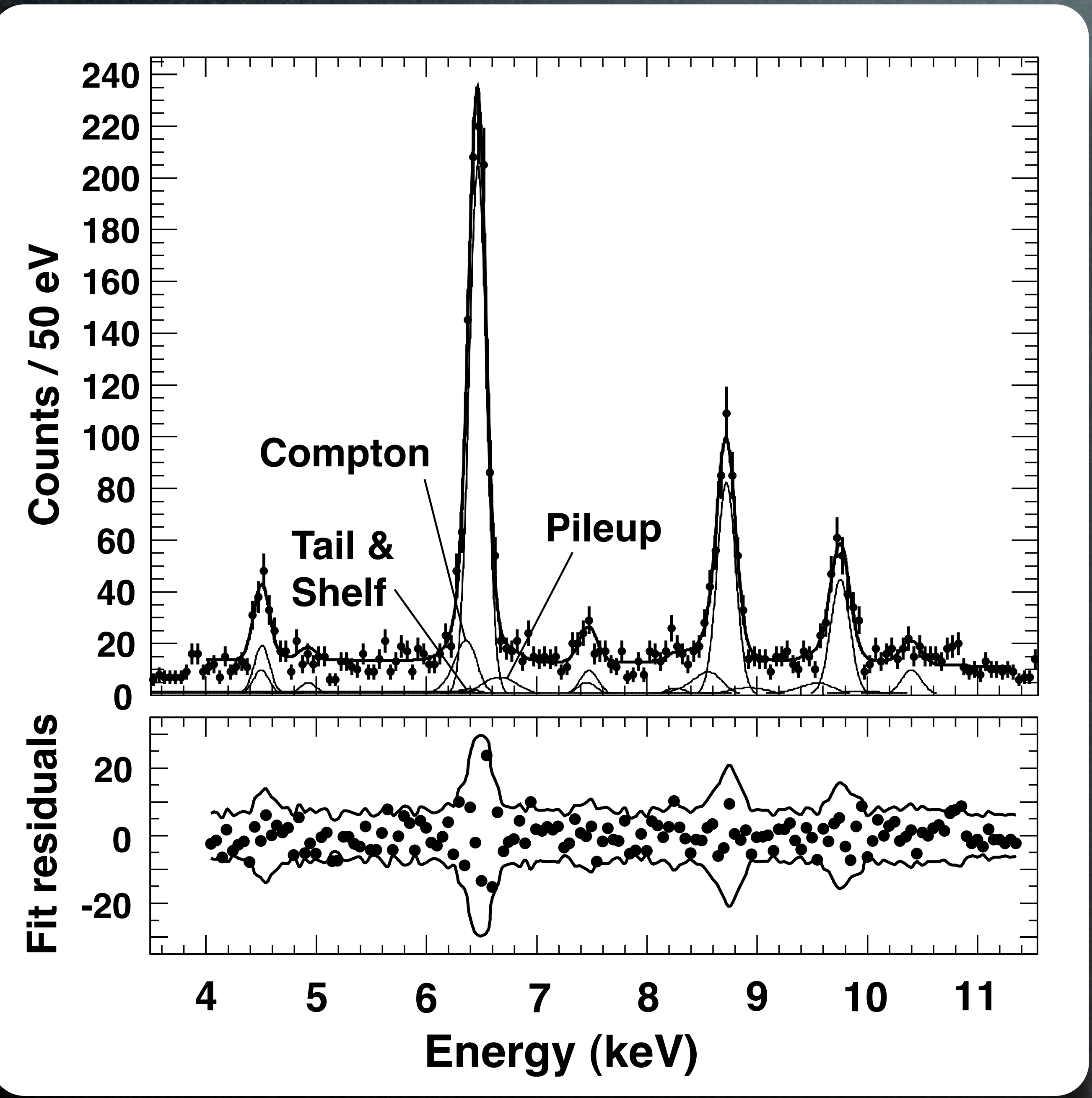
fraction ~7%





Results

Shift



transition	3d->2p	4d->2p	5d->2p
exp. (eV)	6466.7±2.5	8723.3±4.6	9760.1±7.7
calculation (eV)	6463.46±0.15	8721.73±0.20	9766.78±0.23

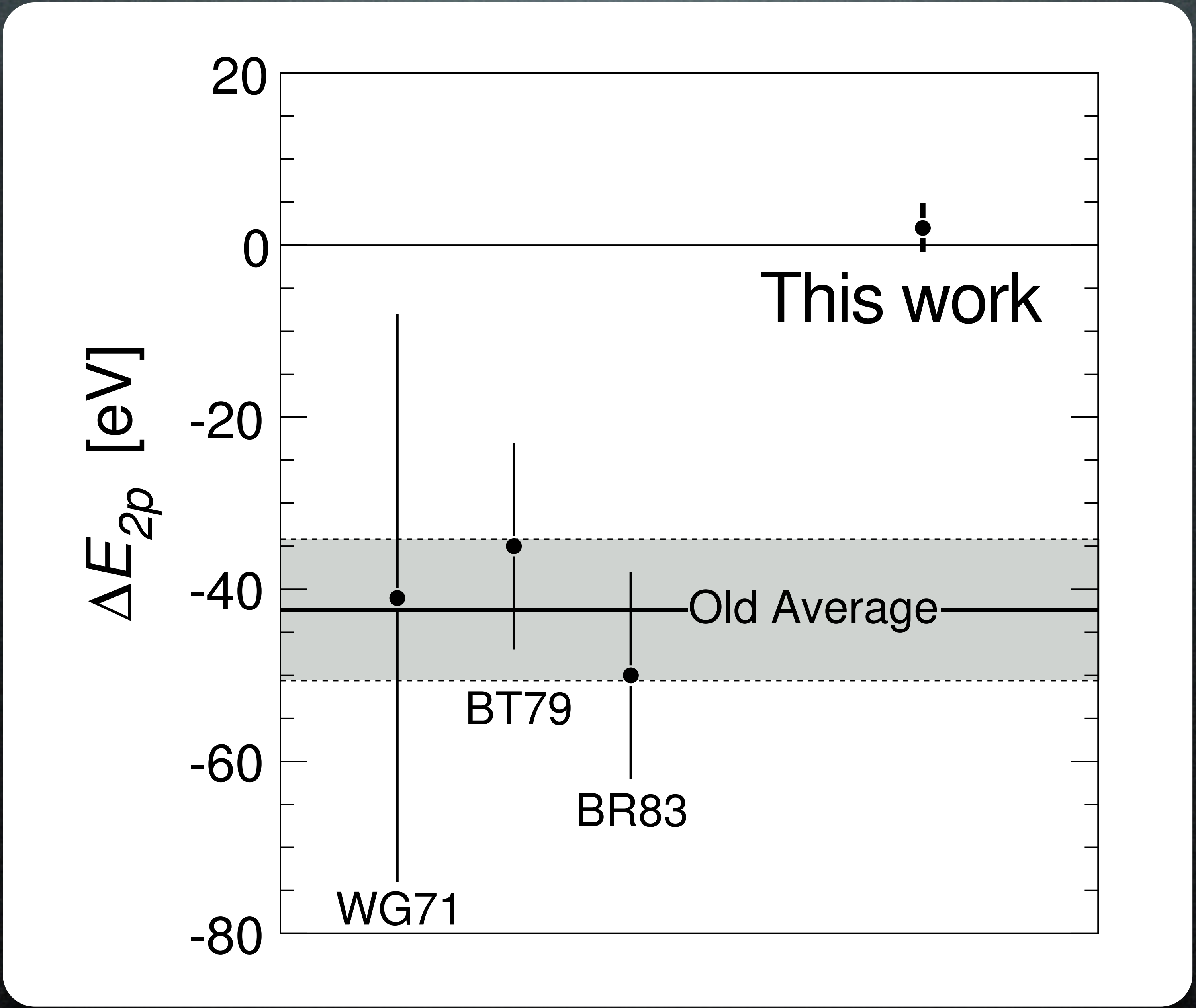
calculated by T.Koike (2007)

Result

Shift = 2 ± 2(stat) ± 2(syst) eV

S.Okada et al, PLB 653, 387, (2008)

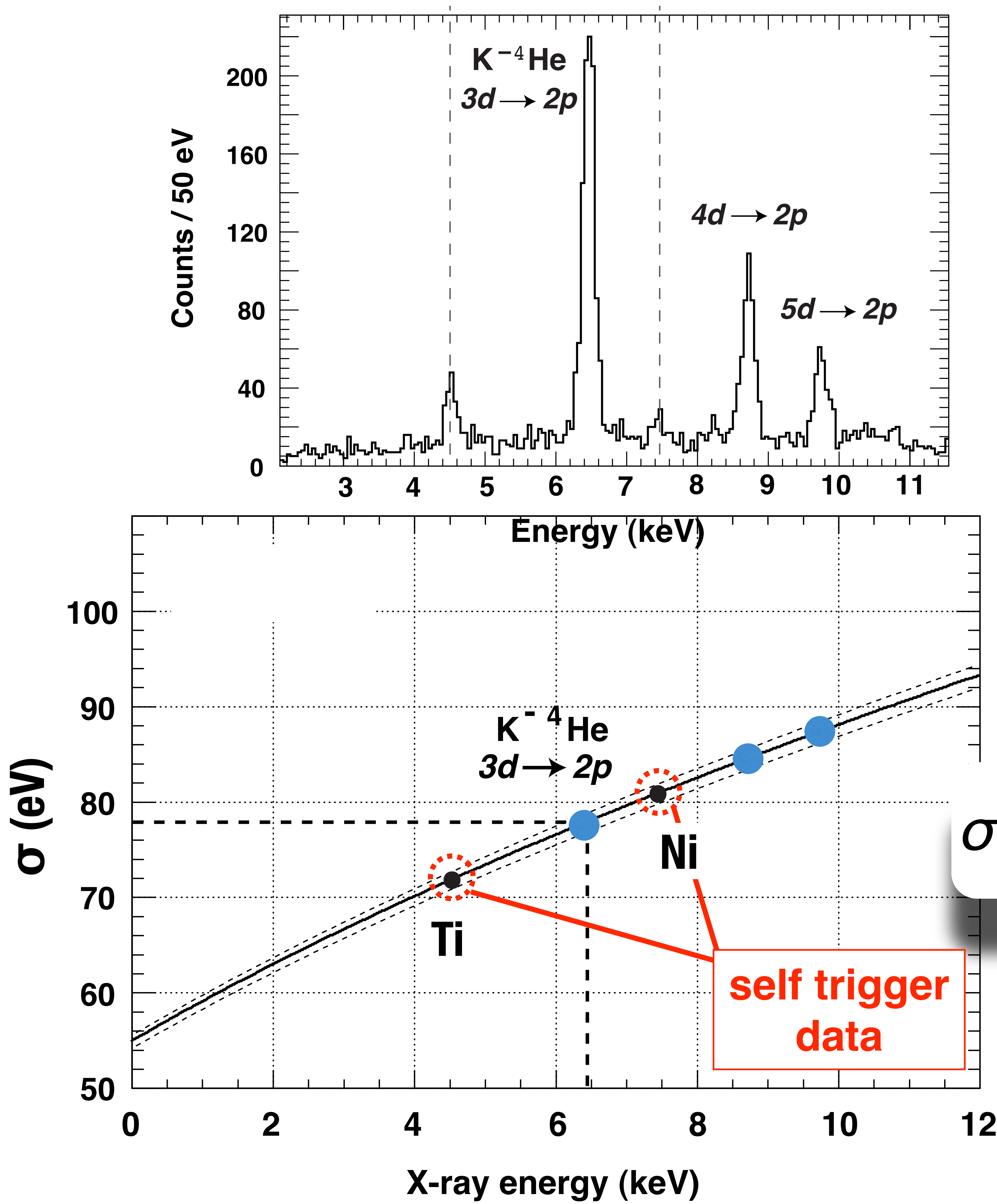
Shift



S.Okada et al, PLB 653, 387, (2008)

The kaonic helium puzzle was resolved

To fit the width



Voigt function
Breit-Wigner*Gaussian

Gaussian sigma fixed

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

σ(6.4 keV)=77.9±0.6 eV

Width

preparing

Preliminary result

upper limit

17 eV at 95% CL

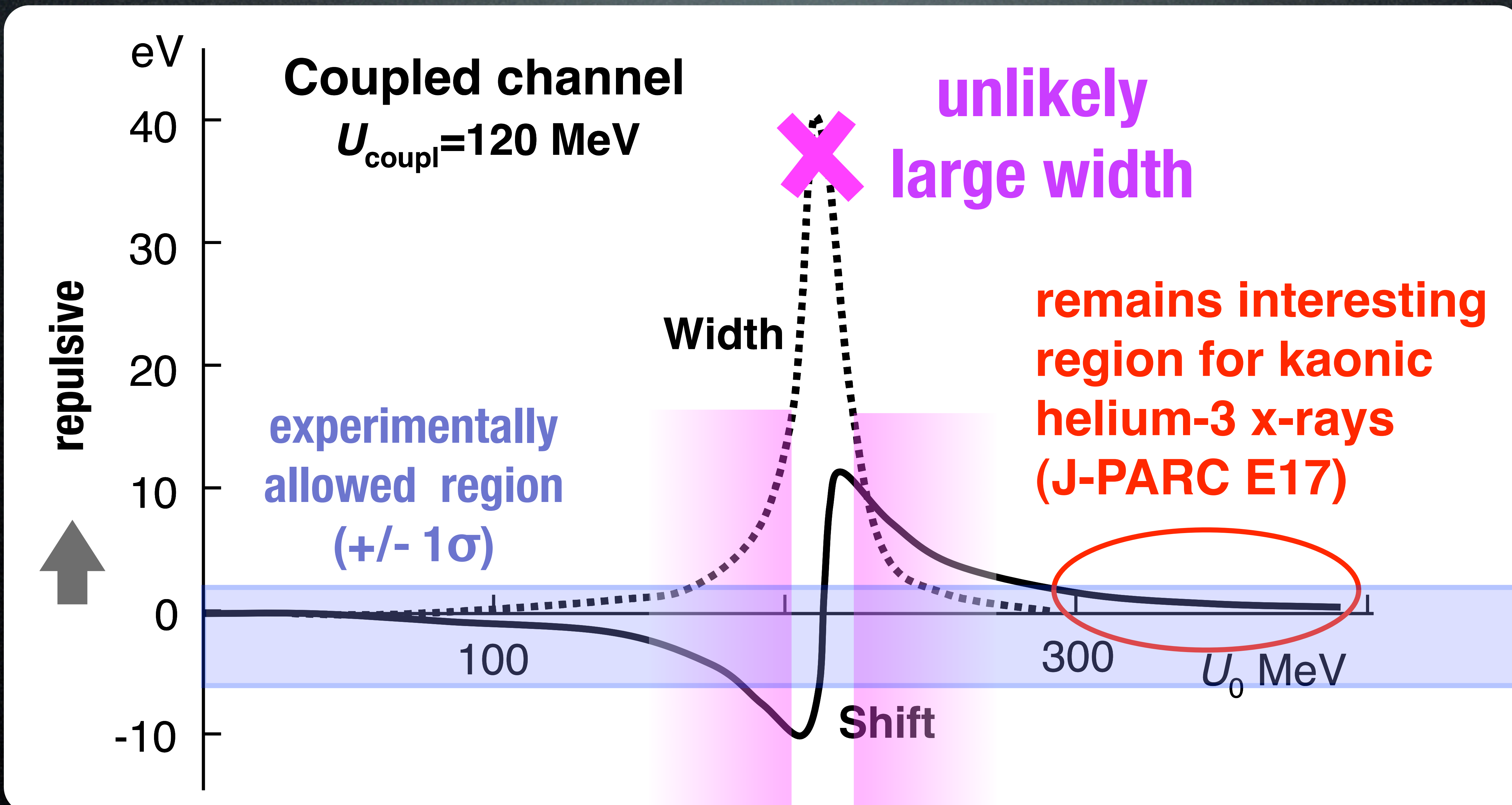
Theories

~2 eV

C.J. Batty, NPA508, 89 (1990)

E.Friedman (2007)

Comparison with Akaishi's prediction



Summary

E570 results are consistent with
all theoretical calculations

Kaonic helium puzzle was resolved

Unlikely large width
-> remains deep potential possibility (~300 MeV)
to investigate kaon-nuclear states

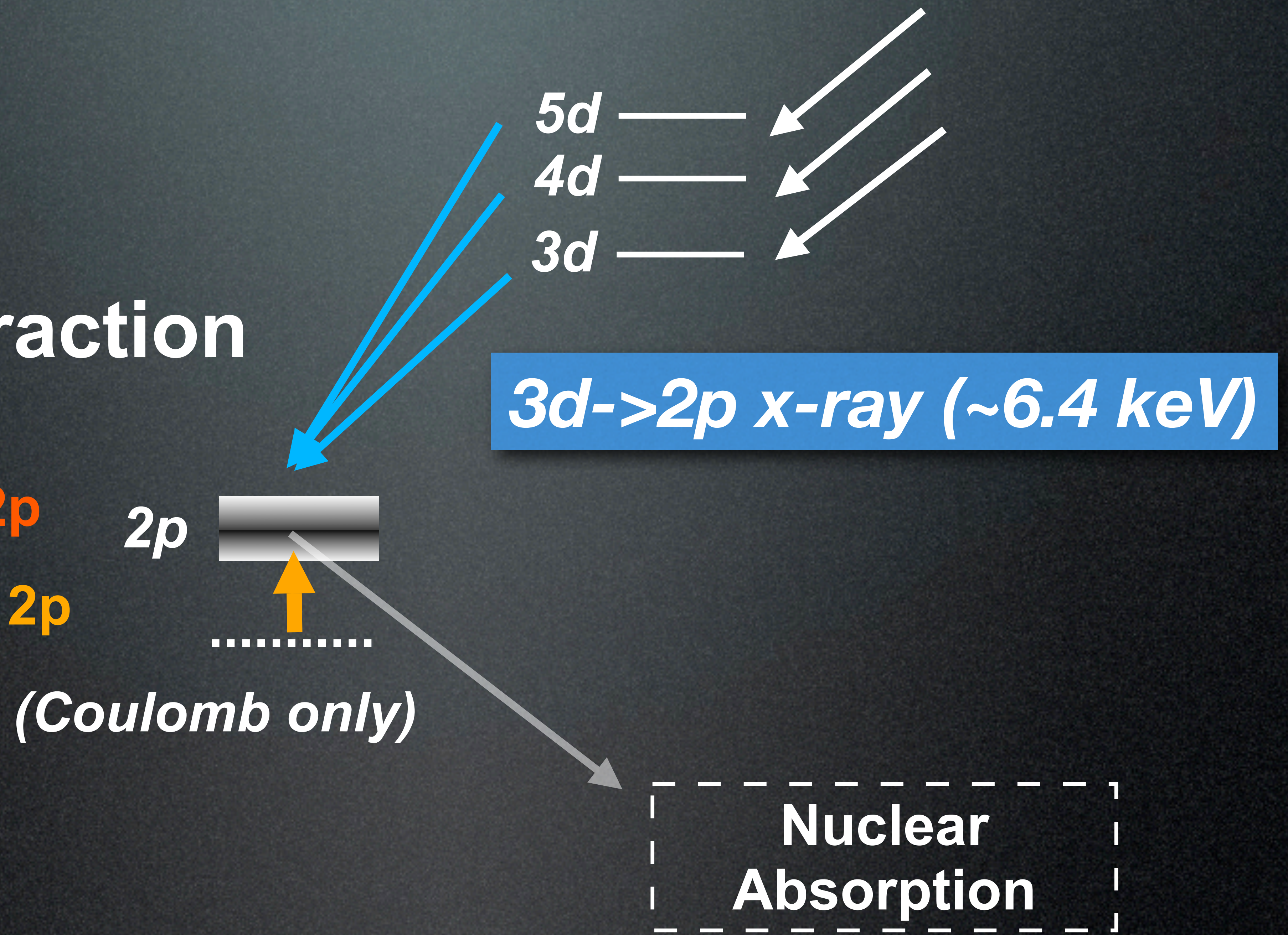
Backup

Kaonic helium x-rays

strong-interaction

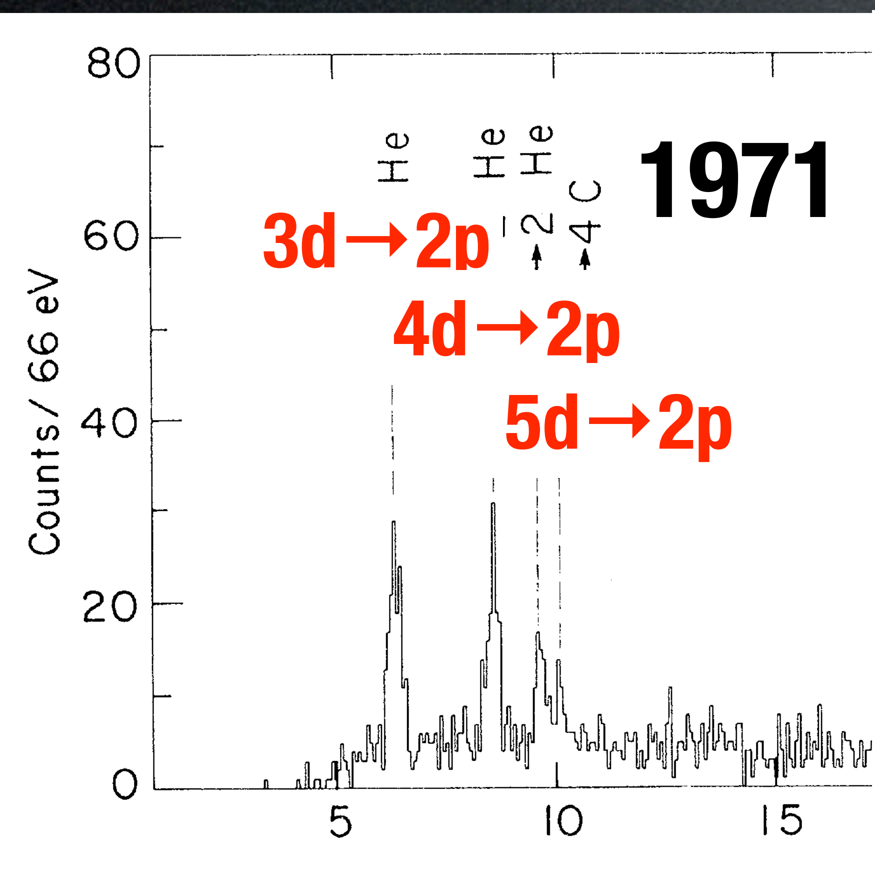
width : Γ_{2p}

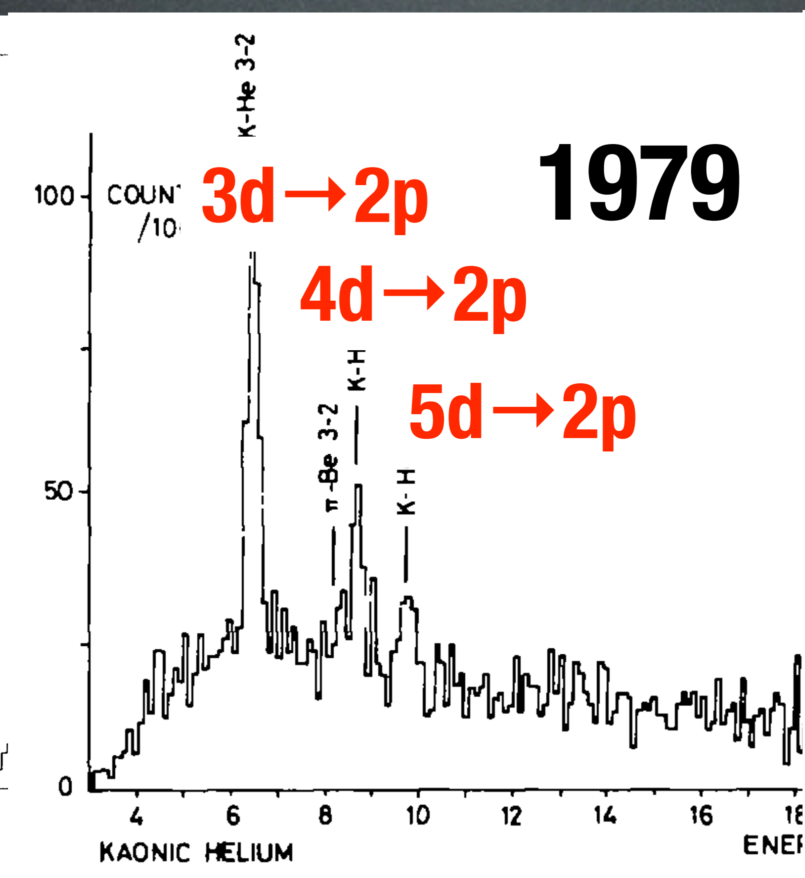
shift : ΔE_{2p}

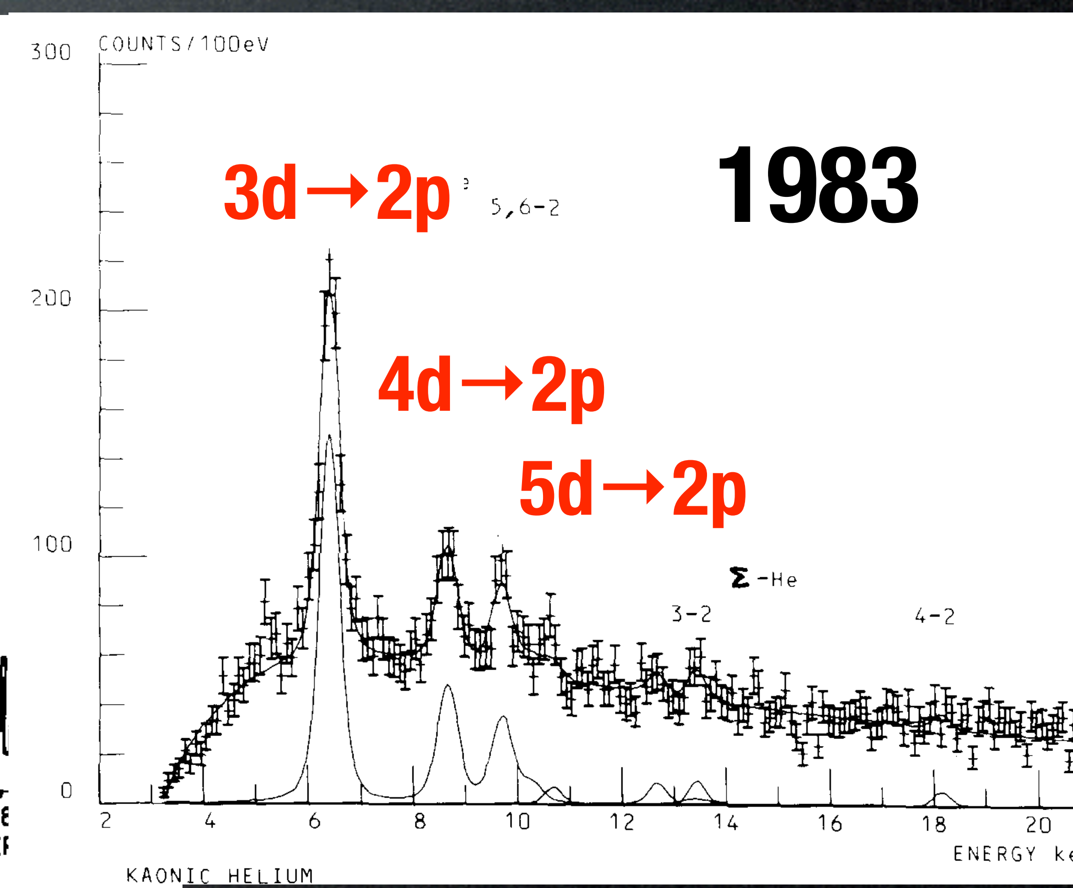


Past experiments

1. C.E. Wiegand and R.H. Pehl (1971) **PRL27, 1410**
2. C.J. Batty *et al* (1979) **NPA326, 455**
3. S. Baird *et al* (1983) **NPA392, 297**



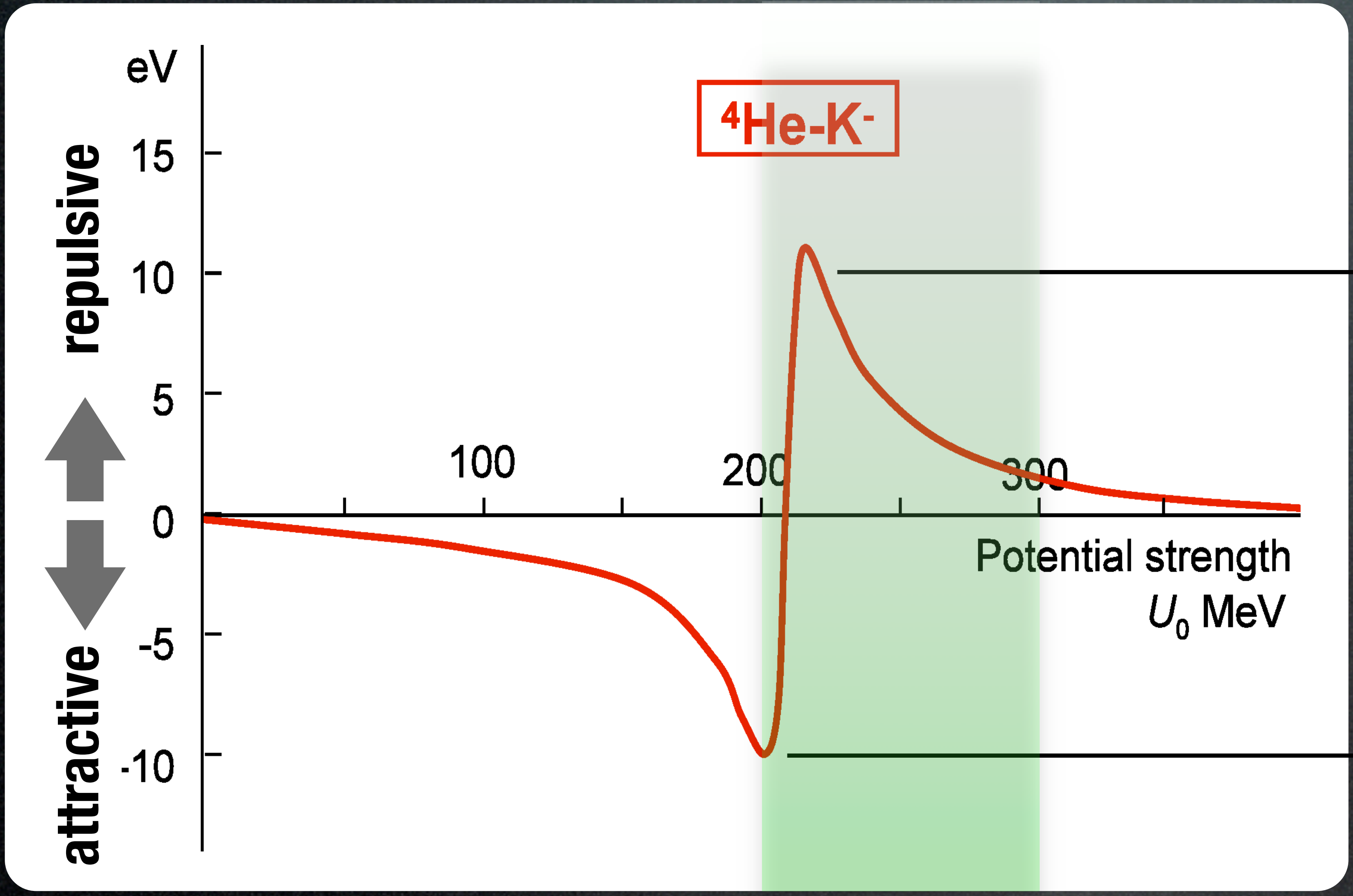




Possible large shift

Akaishi's prediction : coupled $\Sigma\pi$-channel model

accommodates **deeply bound kaon-nuclear states**



Y. Akaishi, EXA05, p45 (2005)

U_{couple} = 120 MeV, searched U_0 depth to obtain maximum shift

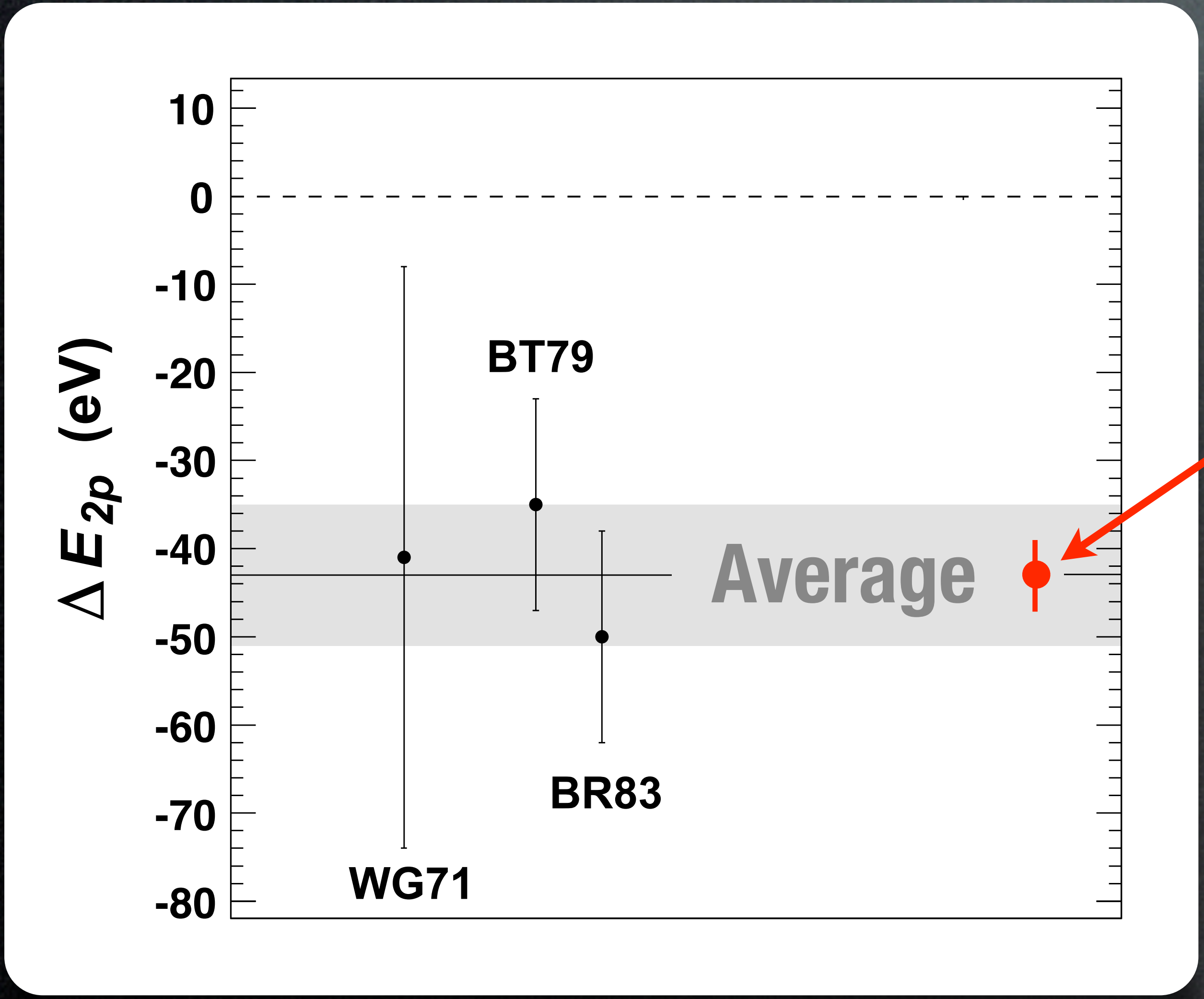
$|\Delta E_{2p}|$ up to ~10 eV

Experiment KEK-PS E570

Goal

determine the strong-interaction shift

with a precision of 2 eV

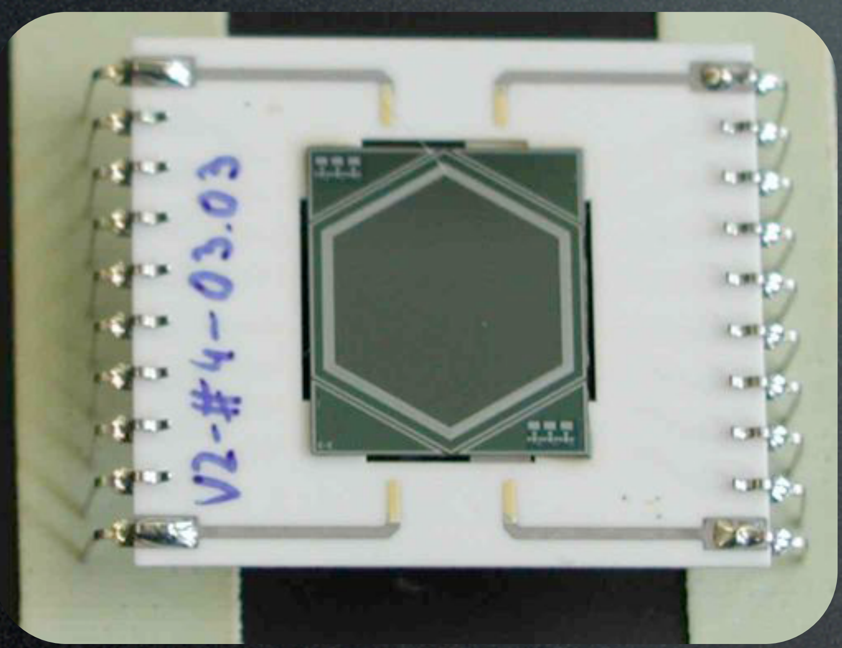


E570 goal

to distinguish 0 eV with 10 eV

1. high resolution

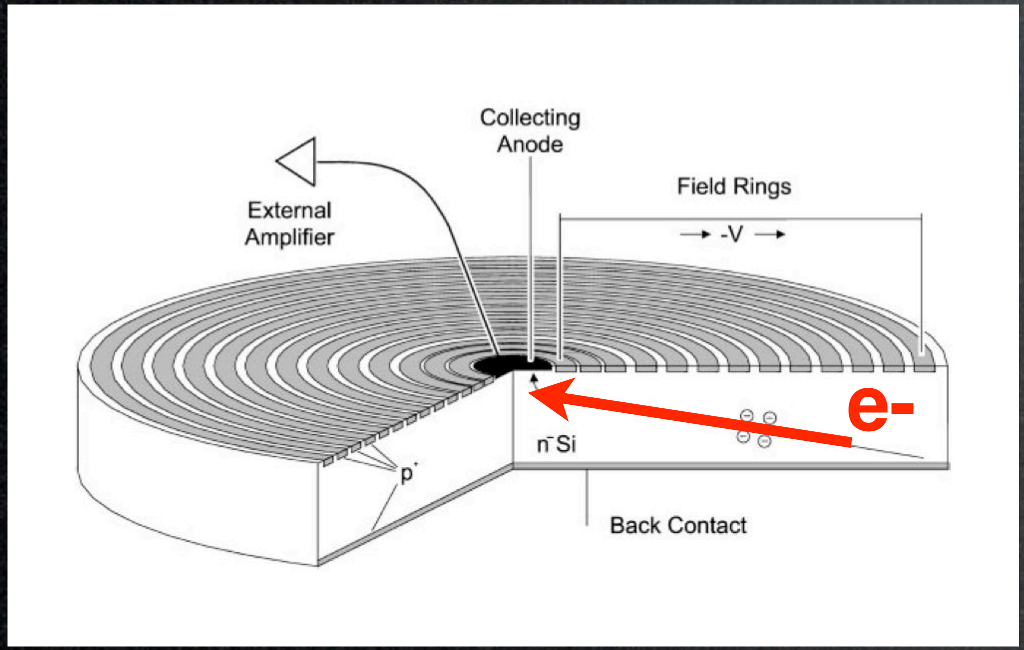
Silicon Drift Detectors (SDDs)



produced by KETEK GmbH

small anode → small detector capacitance

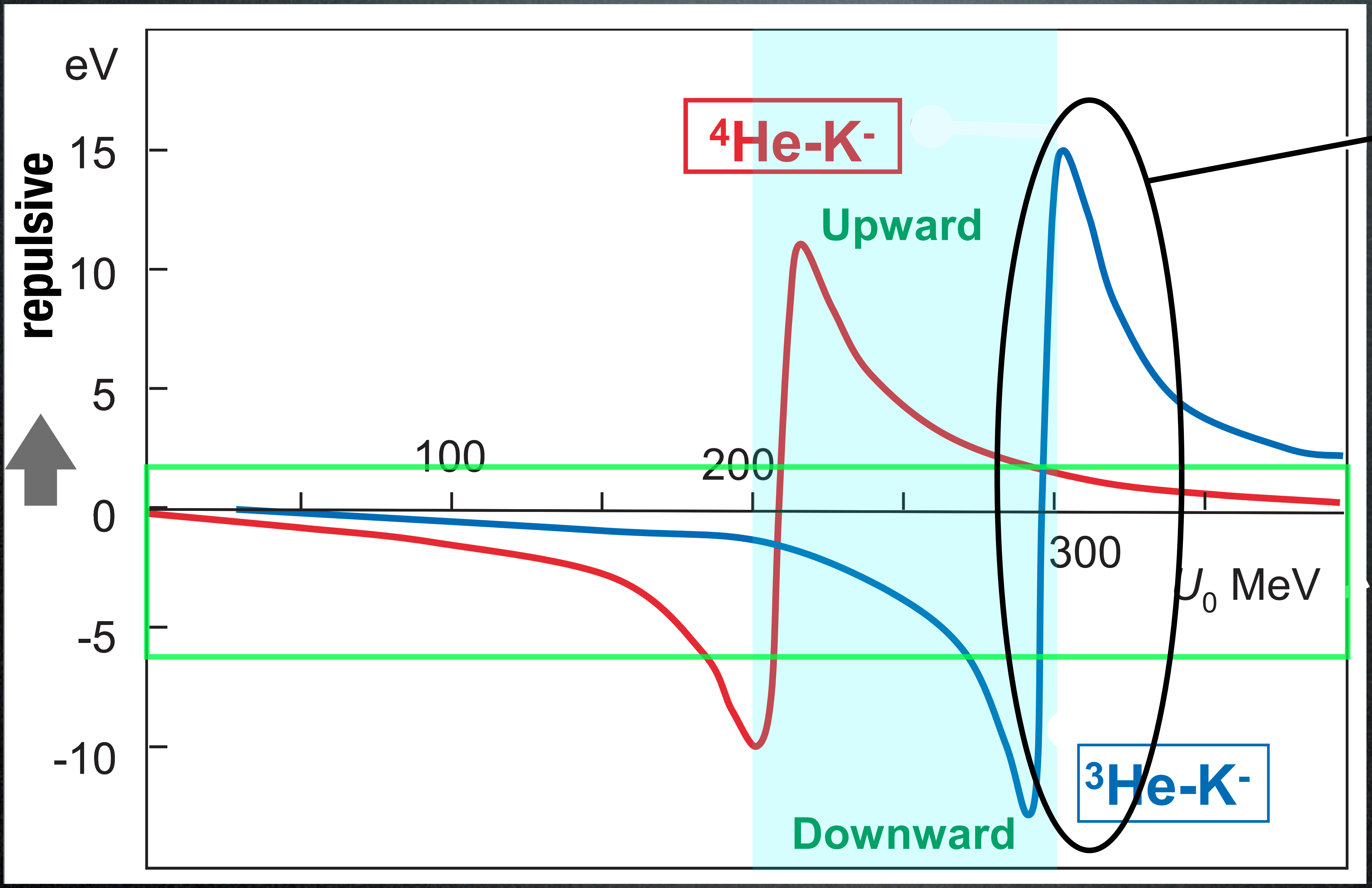
high resolution : 185 eV FWHM at 6.4 keV



large effective area : 100 mm^2

thin detector : 0.26 mm

Outlook



possible large shift

eV precision is essential again !

kaonic helium-3 x-rays @ J-PARC E17