First Results from the DEAR Experiment

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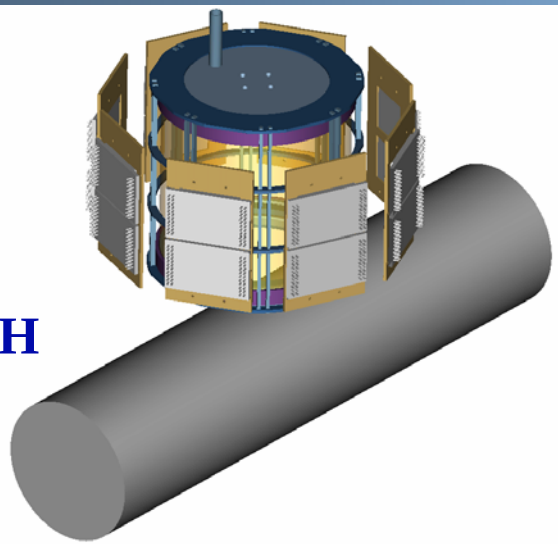
for the DEAR collaboration

LNF - IMEP - INFN Trieste - Univ. Fribourg - Univ. Neuchâtel
RIKEN - Univ. Tokyo - Univ. Victoria

DAFNE
EXOTIC
ATOM
RESEARCH



Goal of DEAR

is the precise determination

of the isospin dependent

antikaon-nucleon scattering lengths,

through a percent level measurement

of the K_α line shift and broadening,

due to strong interaction,

in kaonic hydrogen

and

in kaonic deuterium

Motivation

- **Kaonic hydrogen**
  → simplest exotic atom with strangeness
  → kaonic hydrogen „puzzle“ solved – but precision data missing
  → first measurement in kaonic deuterium

- **Determination of the isospin dependent $\bar{K}N$ scattering lengths**

- **Information on $\Lambda(1405)$ sub-threshold resonance**
  → important for research on deeply bound kaonic states

- ***Testing chiral symmetry breaking in systems with strangeness***

Scattering Lengths

Relation of hadronic shift and width to the complex $\bar{K}p$ scattering length

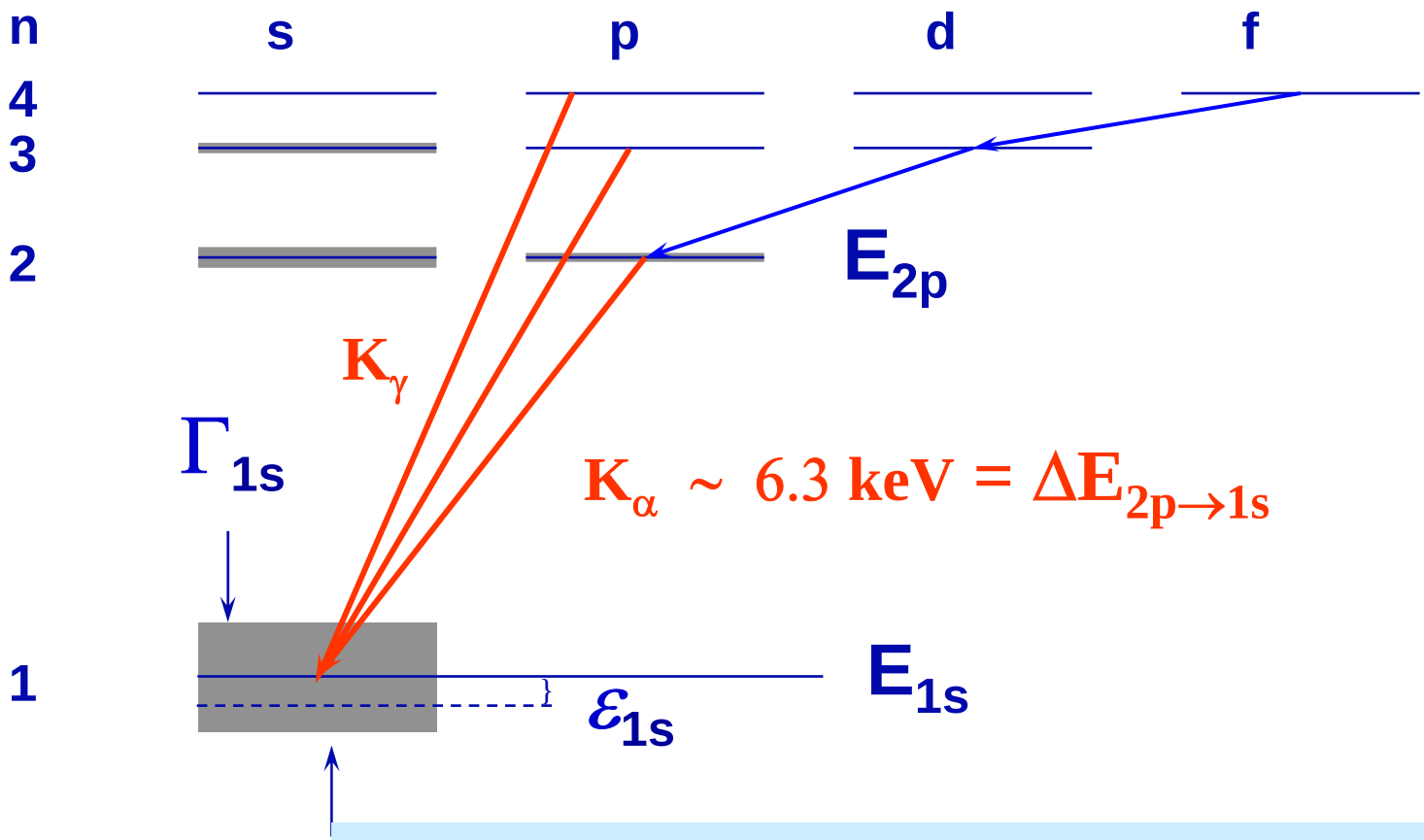
$$\varepsilon + i\frac{\Gamma}{2} = 2\alpha^3 \mu^2 a_{K^- p} = 412\, fm^{-1} \cdot a_{K^- p}$$

$$(Deser - Trueman)$$

For the determination of the ***isospin dependent scattering lengths*** the hadronic shift and width of kaonic hydrogen ***and*** kaonic deuterium are necessary

Production of Kaonic Atoms

Negative kaons stopped in H_2 → initial capture → cascade processes → X-ray transitions



As the kaon interacts strongly with the nucleus, the 1s energy level is both shifted and broadened

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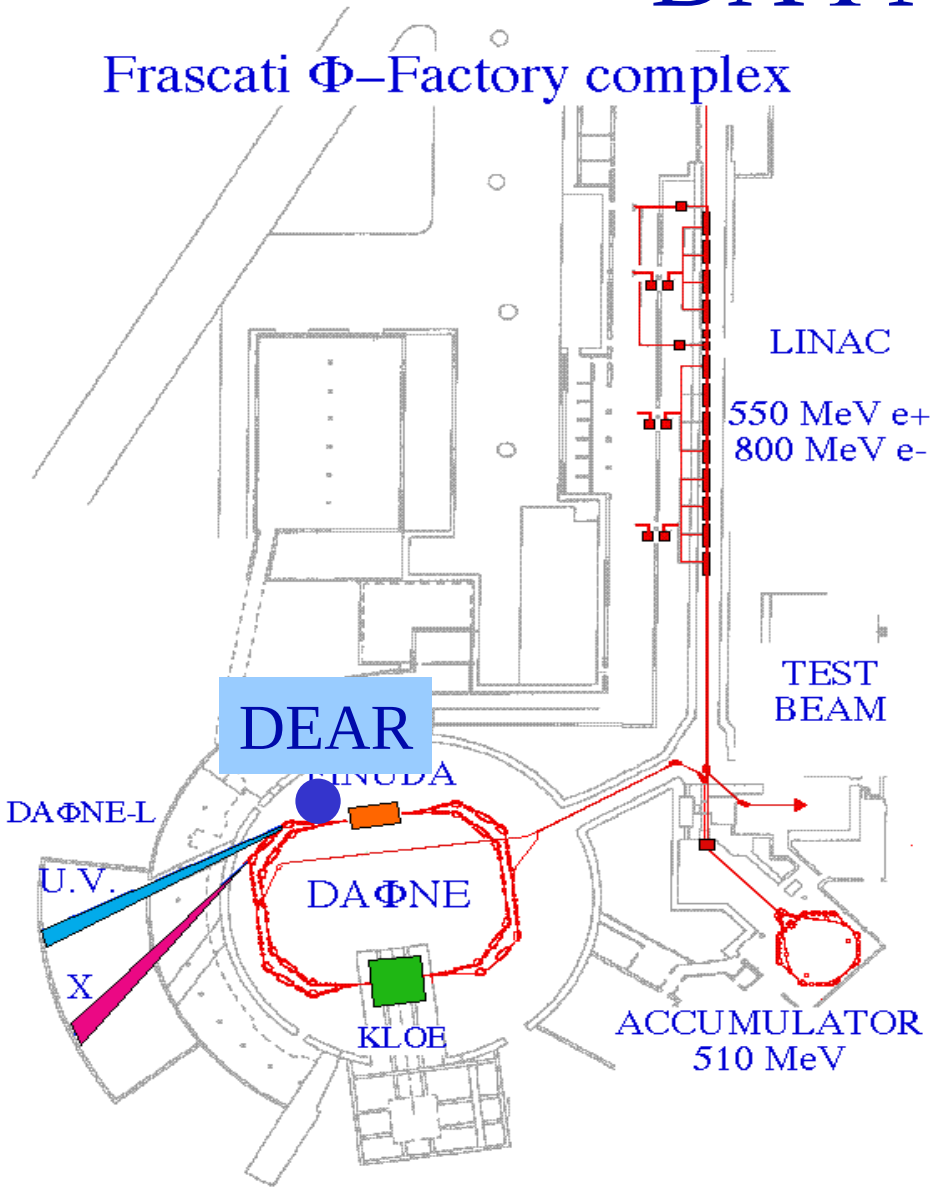


Electron – Positron collider with collision energy tuned to the Φ resonance at 1.02 GeV

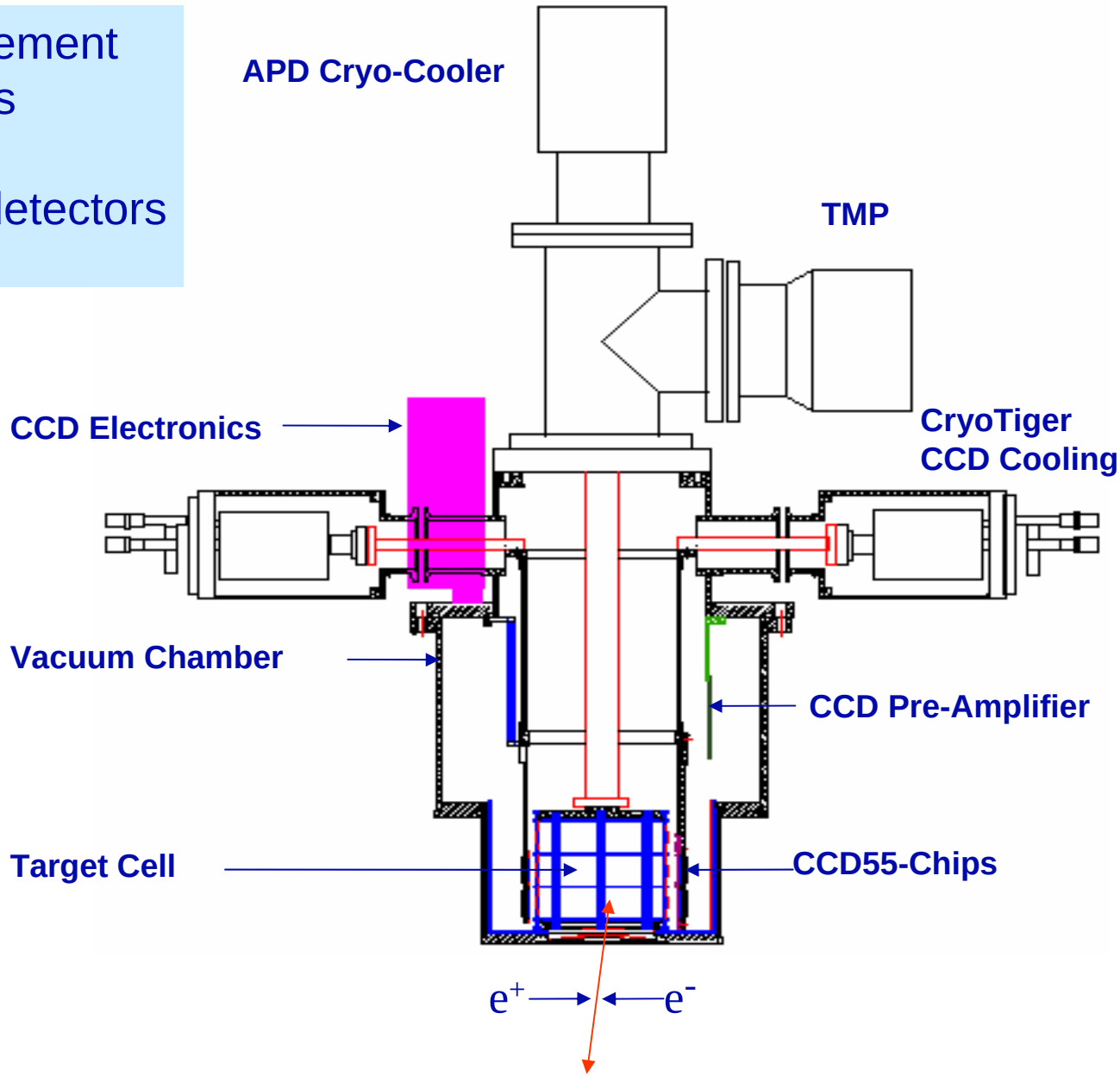
Φ production ~ 3000nb

Int.luminosity ~ $2pb^{-1}$ /day

=> ~ 3×10^{6} K^{-}

Experimental Set-up

Energy measurement
of kaonic K-lines
with an array of
16 CCD X-ray detectors
(~100 cm^2 area)



Cryogenic Target Cell

volume: 1150 cm^3
side wall: 75 µm Kapton
Window: 125 µm Kapton

grid structure:
glass fiber reinforced epoxy

working conditions:
temperature: 23 K
pressure: 1.9 bar

hydrogen gas density:
3.1 % (LHD)
2.2 g/l

Features

- Nearly monoenergetic kaons from Φ decay
  (pion induced background suppressed)
- Light weight target for low X-ray background
- Carefully chosen structure materials
  (checked by different analysis methods)
- Optimized target density for high X-ray yield
- CCDs as X-ray detectors
  (large area, pixel analysis for background reduction, excellent resolution)
- Shielding for background reduction

Data 2002

Kaonic Nitrogen A: 3.04.-29.04.2002 9000 × 16 files (**160GB**)
14.2 pb^{-1} => 20.5 × 10^6 K^-

Kaonic Nitrogen B: 6.10.-28.10.2002 7000 × 16 files (**112GB**)
17.4 pb^{-1} => 25.1 × 10^6 K^-

Kaonic Hydrogen: 30.10.-16.12.2002 18000 × 16 files (**288GB**)
58.4 pb^{-1} => 84.1 × 10^6 K^-

Hydrogen, NoColl: 16.12.-23.12.2002 2600 × 16 files (**42GB**)
No Collisions no kaons produced,
scrapers removed to produce high background

Data Analysis Procedure

Extraction of kaonic X-rays spectra requires

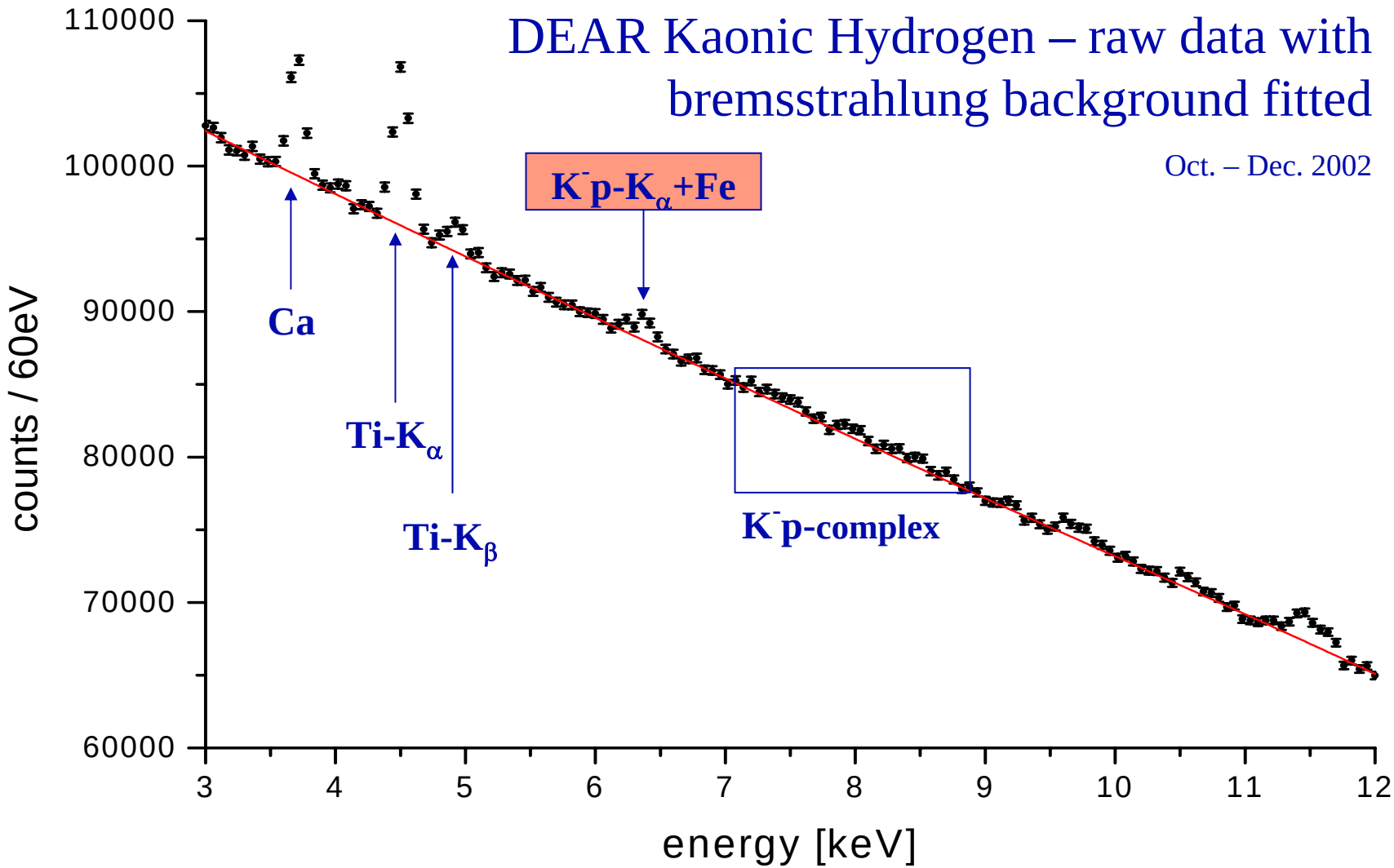
- Selection of single and double pixel events
- Frames with large noise peak width rejected
- Frames with very high occupancy rejected
- Energy calibration
- Determine detector resolution

The same procedure was applied on

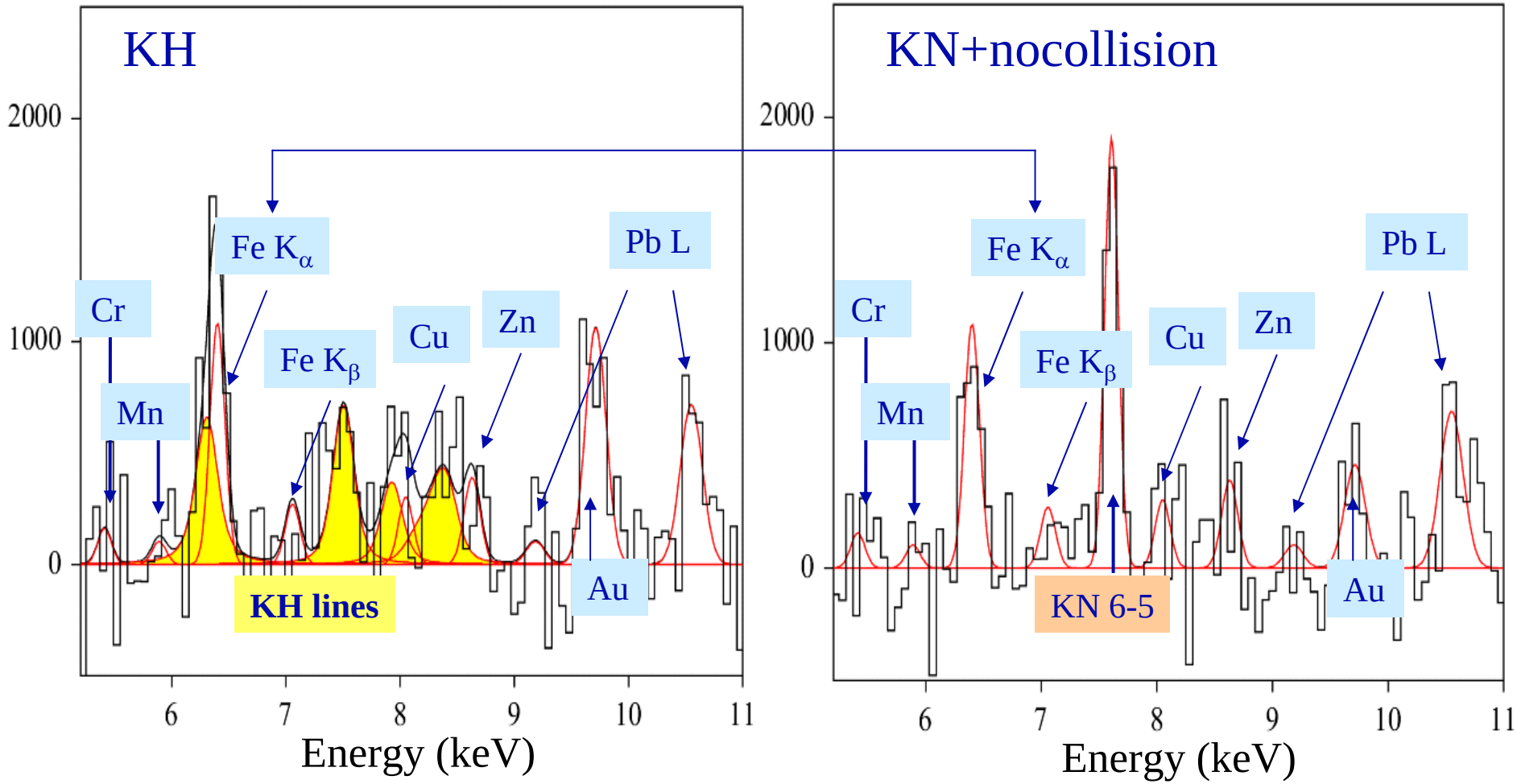
- Data from hydrogen with collisions (KH)
- Background data: measurement in nitrogen with collisions (KN) and in hydrogen without collisions (nocoll)

Determine normalization of KH vs. KN+nocoll.

X-ray spectrum (K^-p)

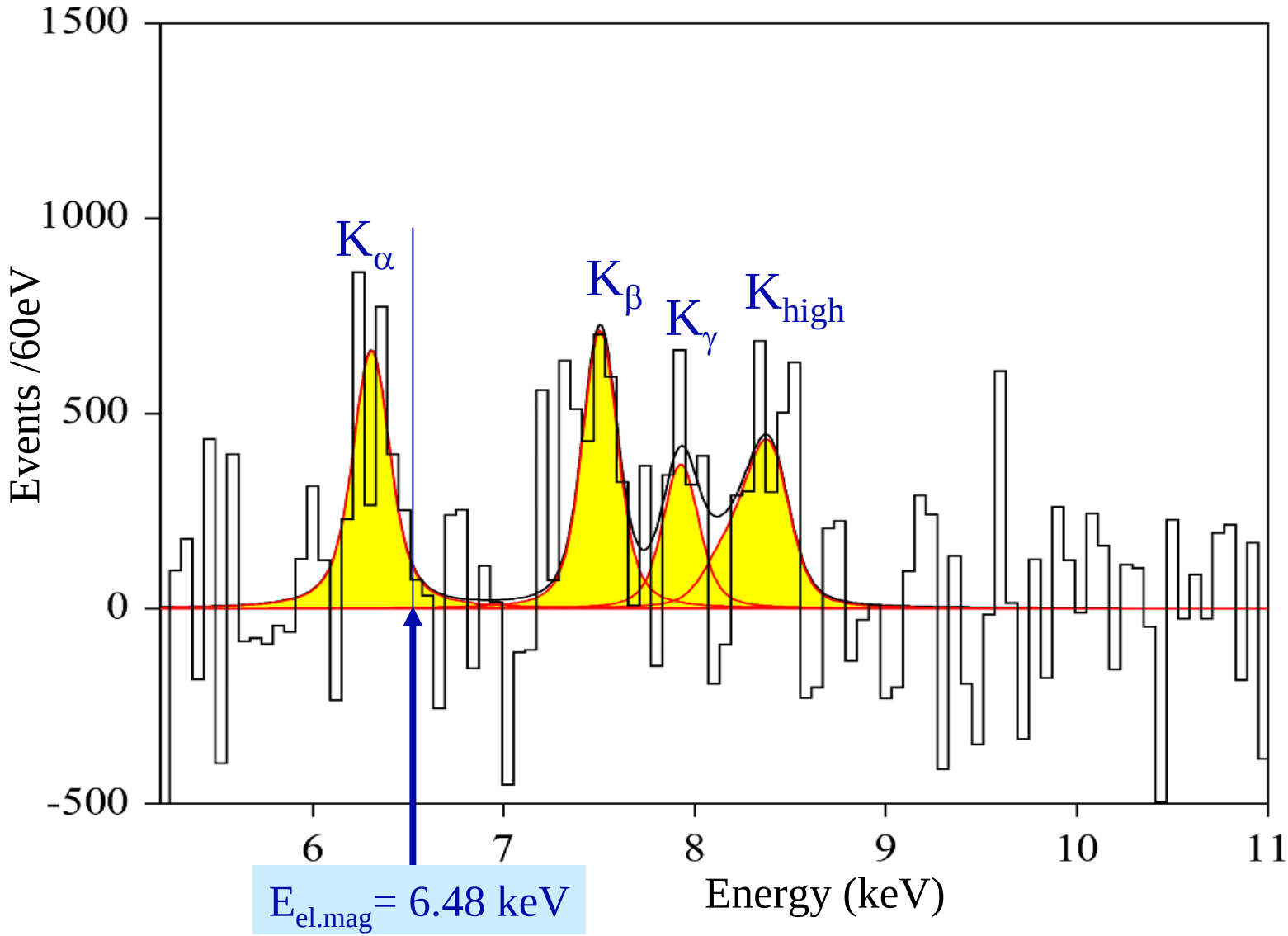


Simultaneous fit of KH and KN+nocollision spectra



Resulting K^-p spectrum

(continuous AND fluorescence background subtracted)



Status of Analysis on Hadronic Shift and Width

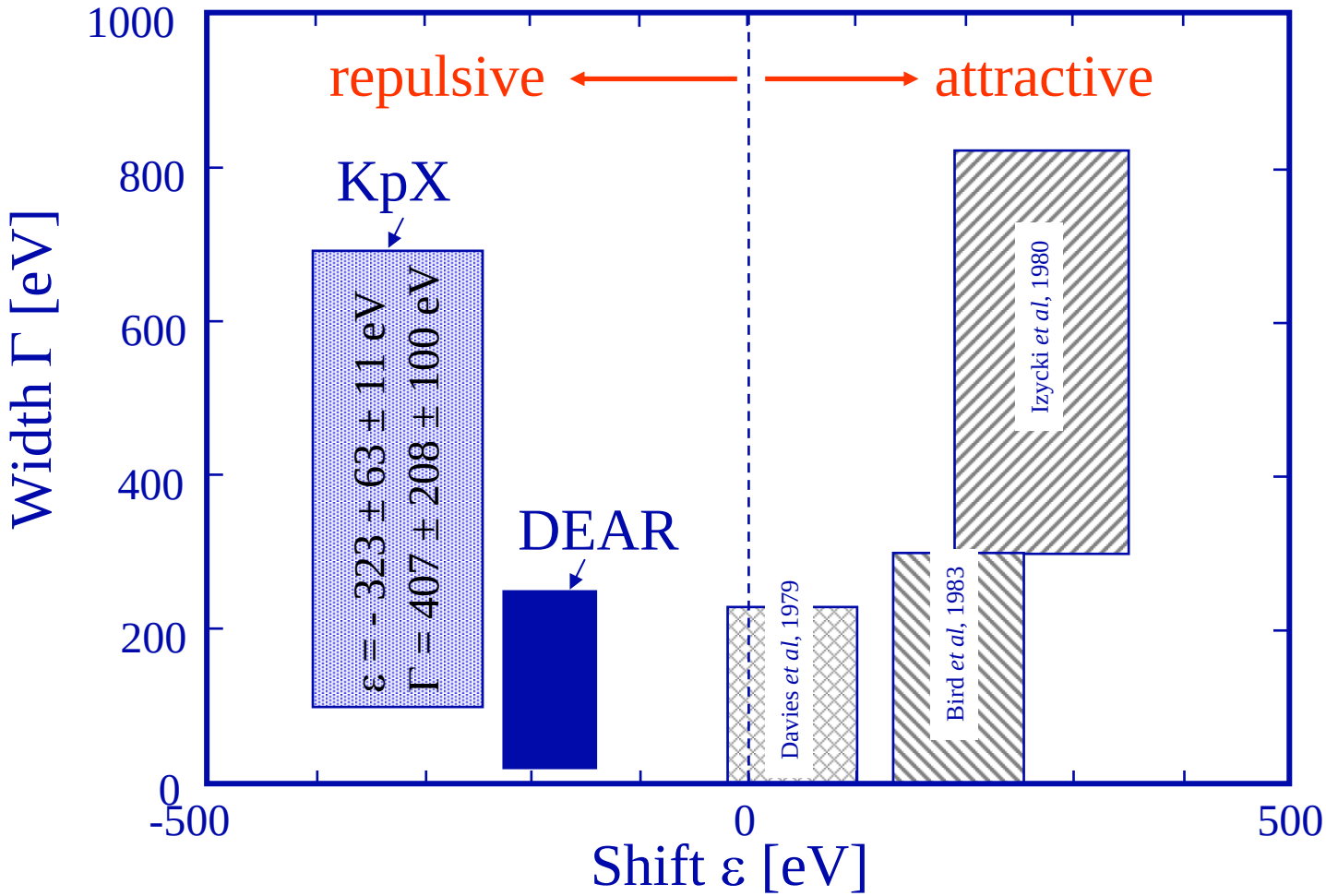
From simultaneous fit we get
the ***preliminary results***

Shift: $\varepsilon_{1s} = -175 \pm 26 \pm 15$ eV

Width: $\Gamma_{1s} = 120 \pm 90 \pm 15$ eV

Repulsive shift verified

Preliminary results



Next Steps

New X-ray detector development

- timing capability → background suppression by using the kaon - X ray time correlation
- excellent energy resolution (170eV @ 6 KeV)

→ SDD (silicon drift detectors)
I3 Hadron Physics – Joint Research Project
cooperation: LNF, MPI, PNSensor, Politec.Milan and IMEP-Vienna

→ First test measurements at BTF / LNF

- SDD timing relative to beam scintillation counter
- Accidental suppression tested (applying coincidence with beam counter)

With DEAR II we expect (for kaonic hydrogen)

signal vs. background 5 : 1

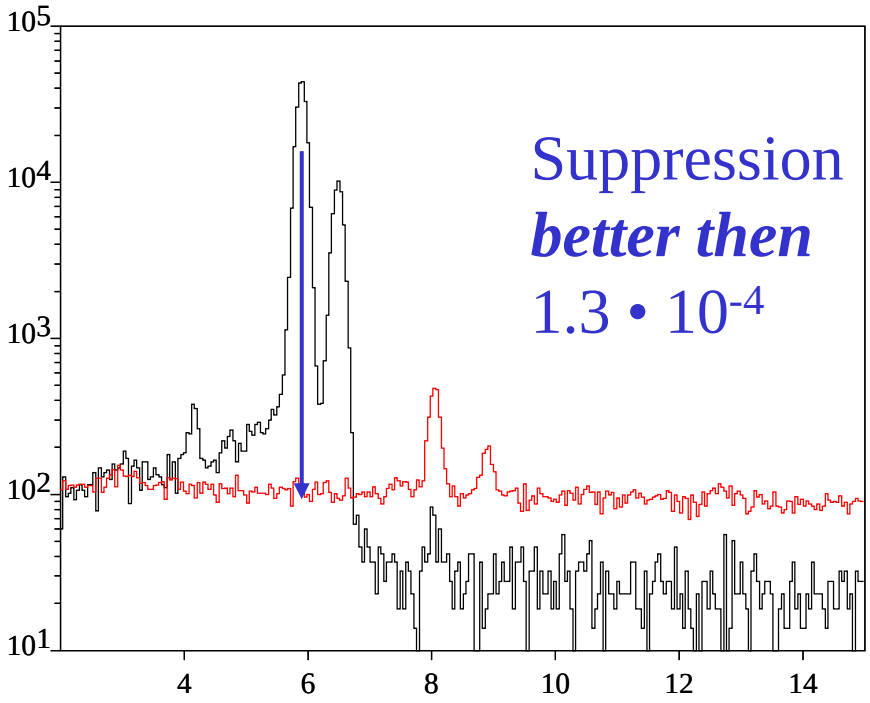
Results from the SDD tests July 2003

400 MeV e^- from LNF linac, tagged with a scintillator

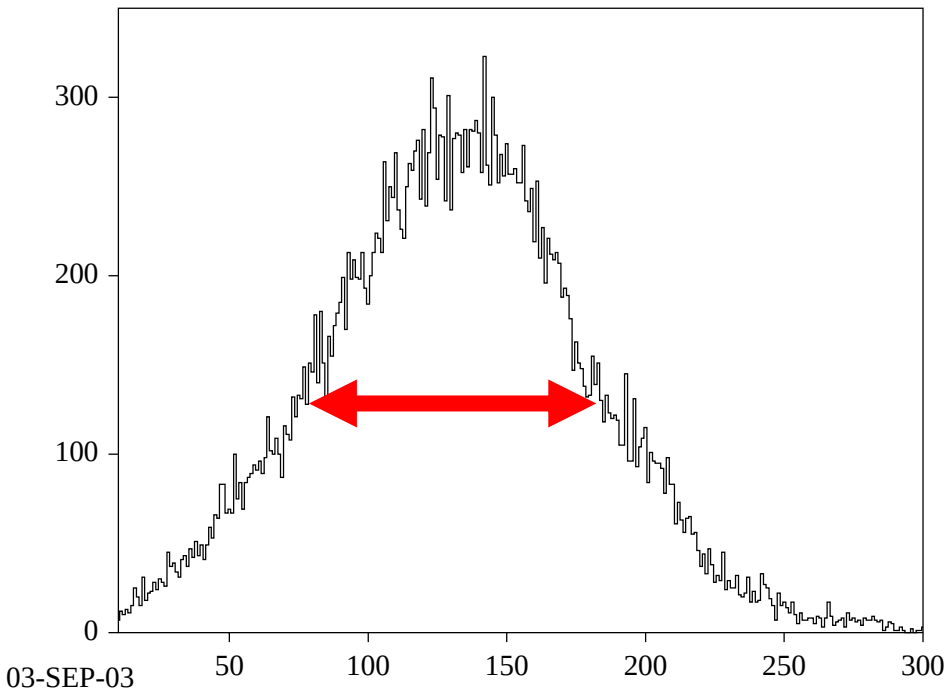
10 mm^2 SDD

- Accidentals produced by Fe 55 source
- Beam correlated bremsstrahlung, Cu XRF

Time correlation
FWHM: 194 ns



Energy (keV)



TDC channels (2ns/ch)

Summary

Preliminary results on hadronic shift and width:

- repulsive hadronic shift in K^-p verified
- smaller values for shift and width, with better precision as in the KpX experiment

Potential for future high precision measurements using new triggered SDD detectors was demonstrated by test measurements at LNF

Outlook

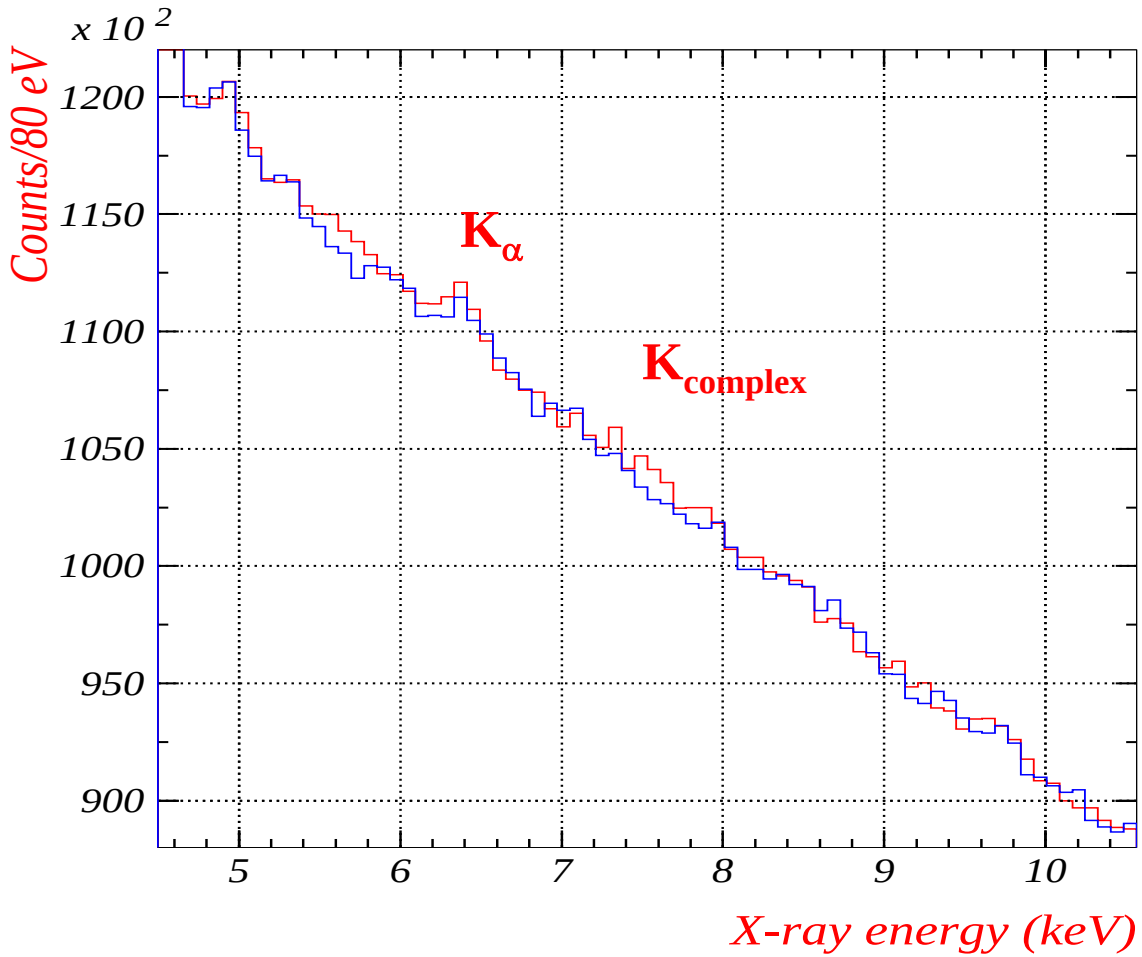
- ***Precison measurement*** of kaonic hydrogen
  with the new SDD detector system
  precision on shift <2%, width <10%

- Measurement of ***kaonic deuterium***

- ***Long range perspectives:***
  Precision measurement of kaon mass
  Study of other kaonic atoms

Method II

Normalized background spectrum subtracted



Fit of the ***subtracted spectrum*** → ε = -162 ± 40 eV

Γ = 200 ± 100 eV