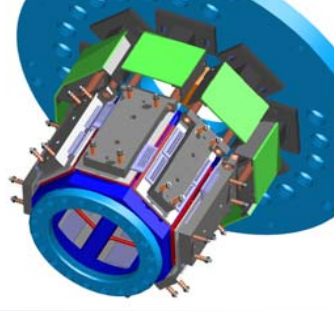
DAΦNE Exotic Atom Research Results and Future Perspectives

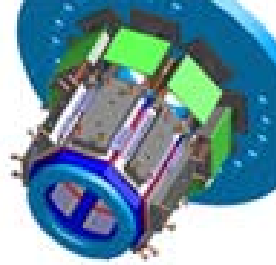
Johann Zmeskal for the DEAR Collaboration



The DEAR Collaboration

LNF-INFN, Frascati
IMEP-ÖAW, Vienna
IFIN – HH, Bucharest
INFN, Trieste
RIKEN
Univ. Fribourg
Univ. Neuchâtel
Univ. Tokyo
Univ. Victoria
Caltech

DAΦNE Exotic Atom Research Results and Future Perspectives



Contents

- Introduction
- DEAR Setup
- Kaonic Nitrogen
- Kaonic Hydrogen
- A New Detector Concept
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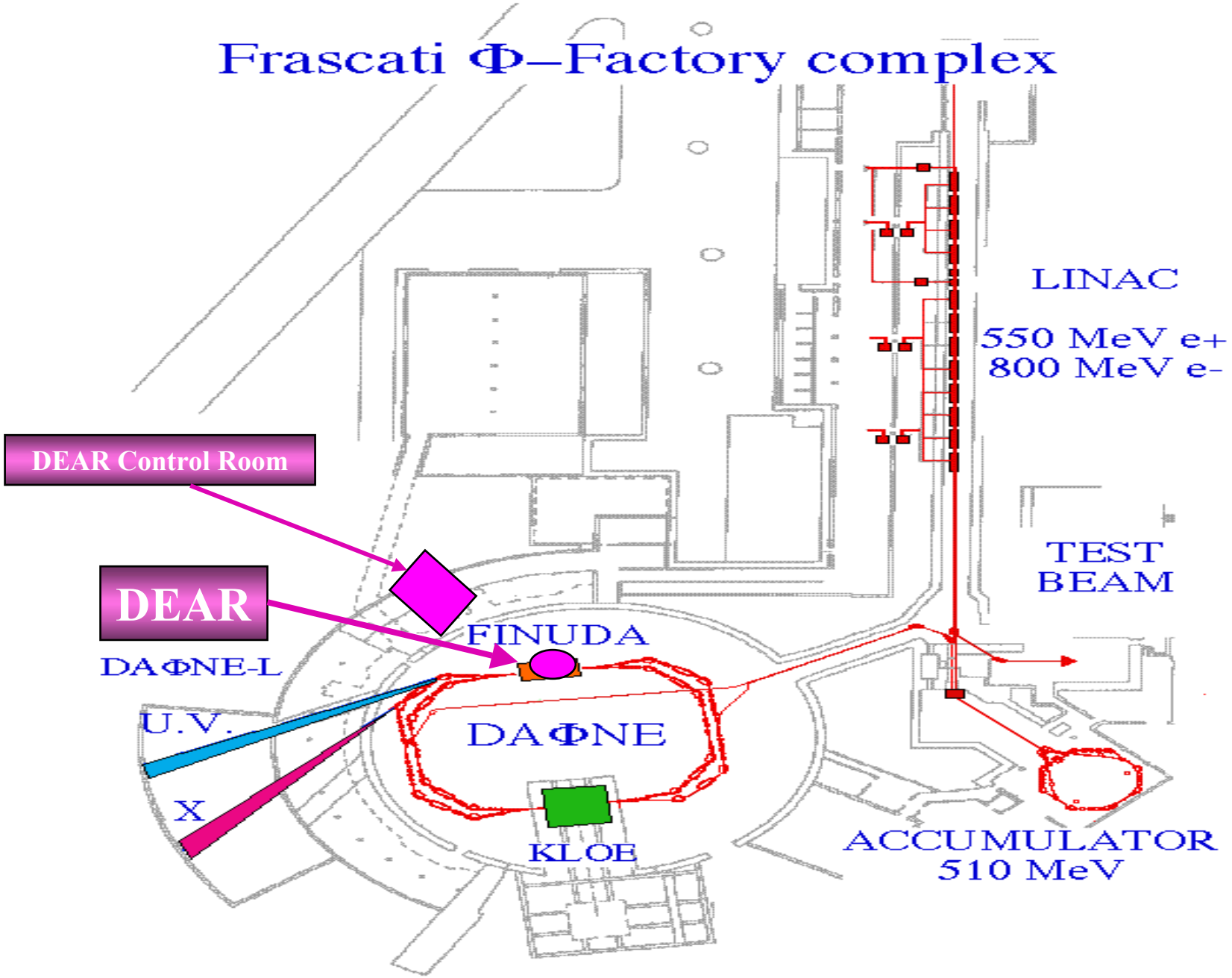
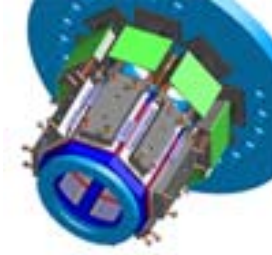
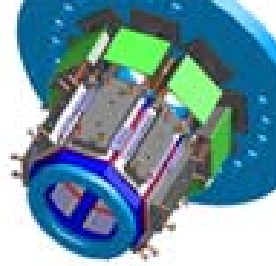

Frascati Φ–Factory complex
LINAC
550 MeV e+
800 MeV e-
DEAR Control Room
DEAR
TEST
BEAM
FINUDA
DAΦNE-L
U.V.
DAΦNE
X
KLOE
ACCUMULATOR
510 MeV

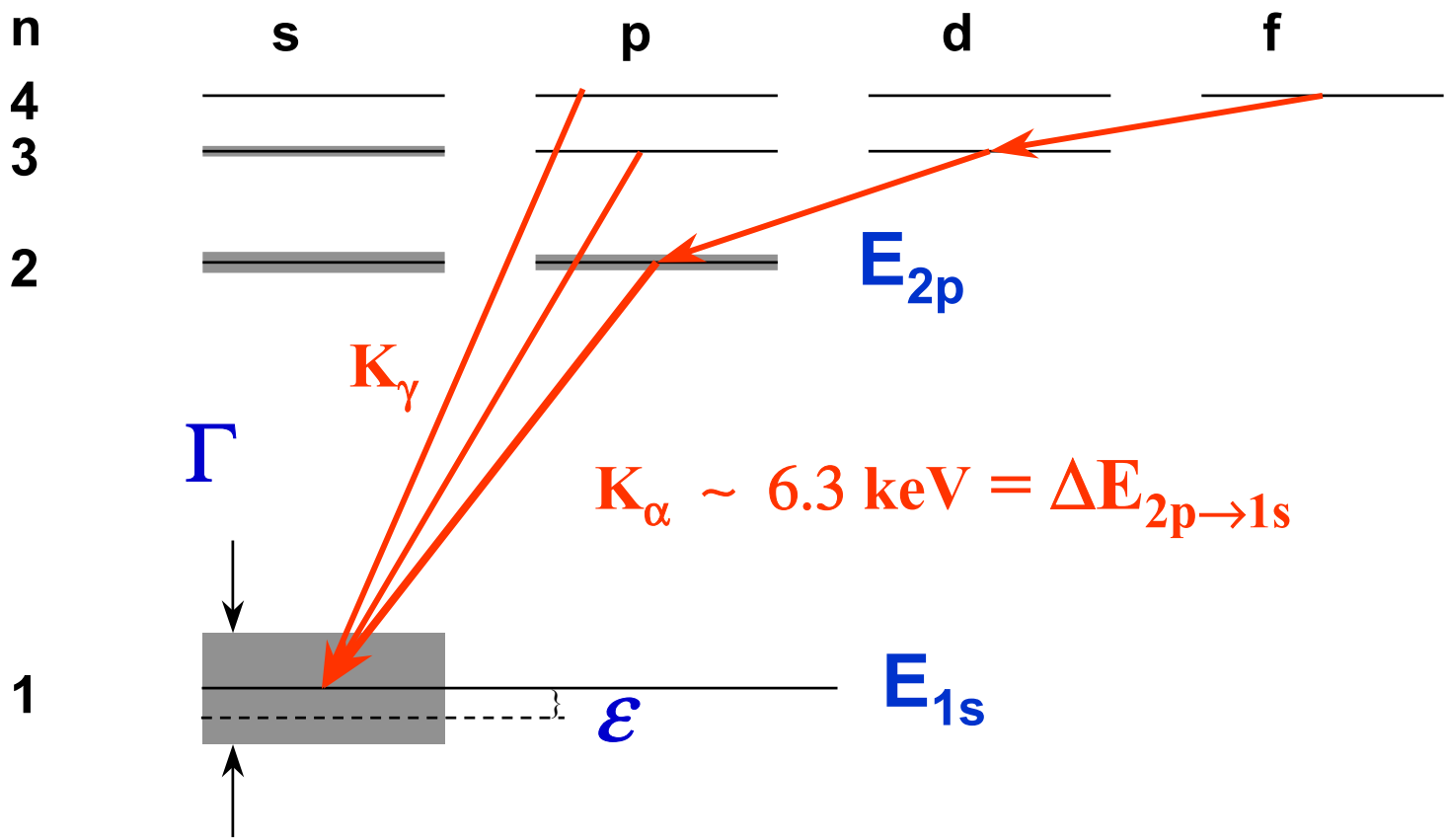
Goal of DEAR



A ~ 1% measurement of
the K_α line shift and
a ~ 5% measurement of the K_α line width
in kaonic hydrogen
and
the first measurement of
the K_α line shift
and width
in kaonic deuterium

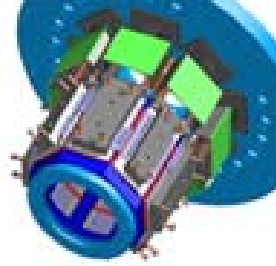
Kaonic Hydrogen - Cascade





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

Scattering Length



The energy shift ε and the width Γ of the 1s level can be directly related to the complex Kaon-proton scattering length through the

Deser-Trueman Formula

S.Deser et al., Phys.Rev.96 (1954) 774.

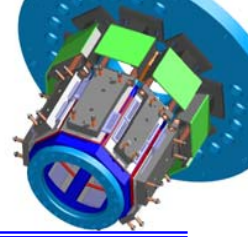
$$\varepsilon_{1s} + i/2\,\Gamma_{1s} = 2\,\alpha^3\mu^2\,a_{K^-p} = 412\;\; a_{K^-p}$$

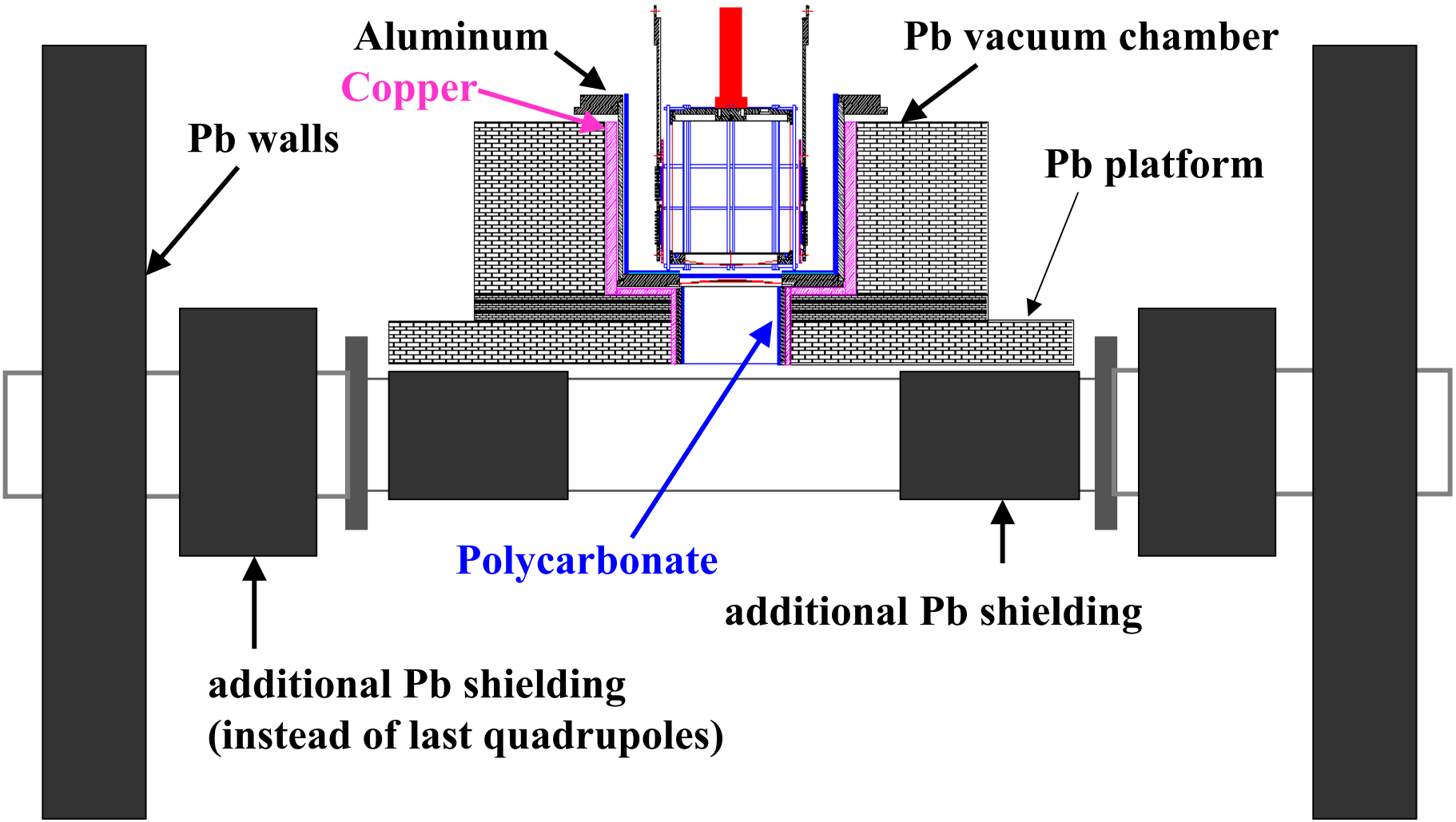
α = **fine structure constant**

μ = **reduced mass of K^-p**

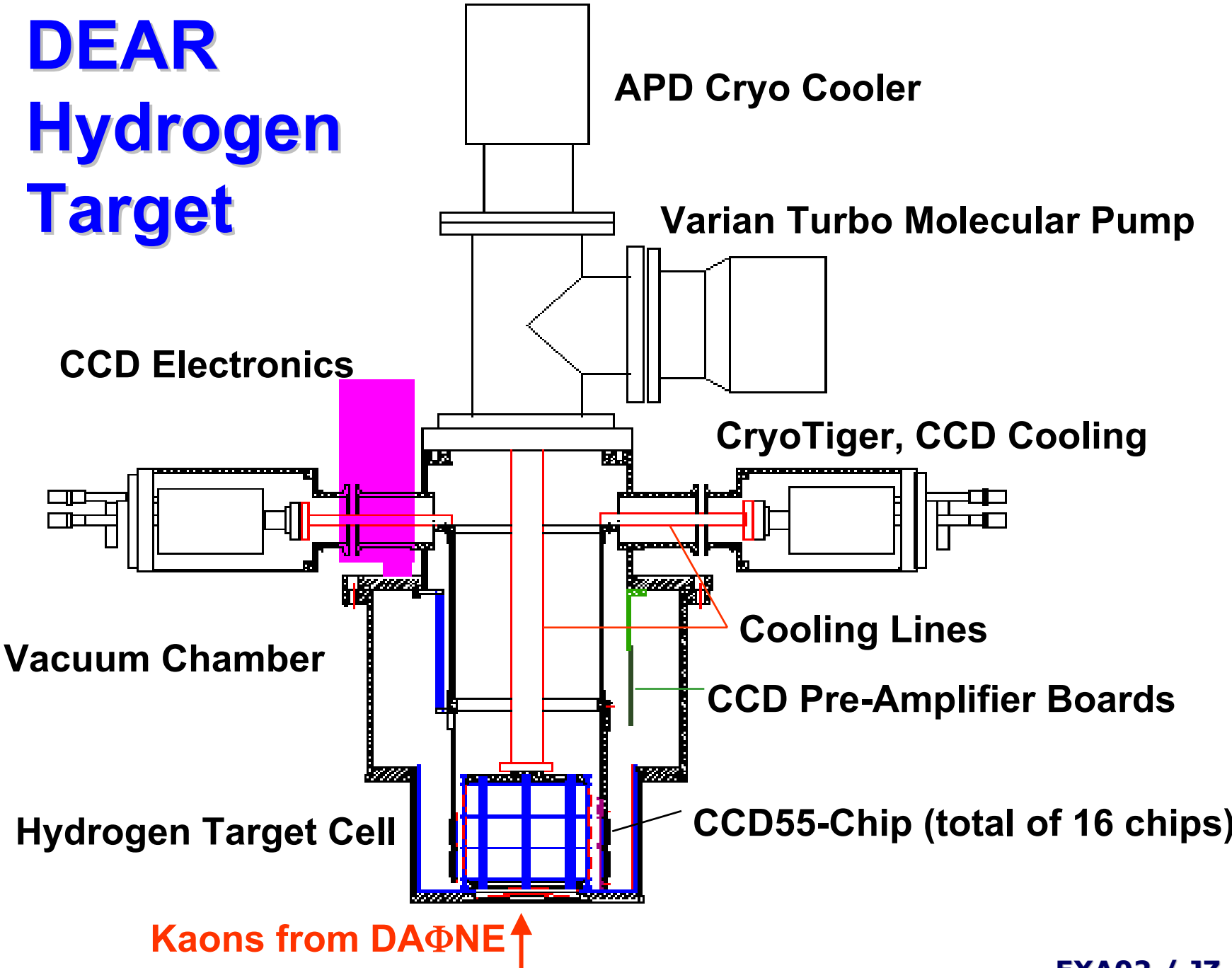
a_{K^-p} = **complex K^-p scattering length**

DEAR Setup - Shielding

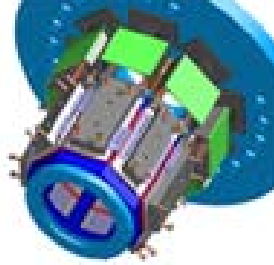




DEAR Hydrogen Target

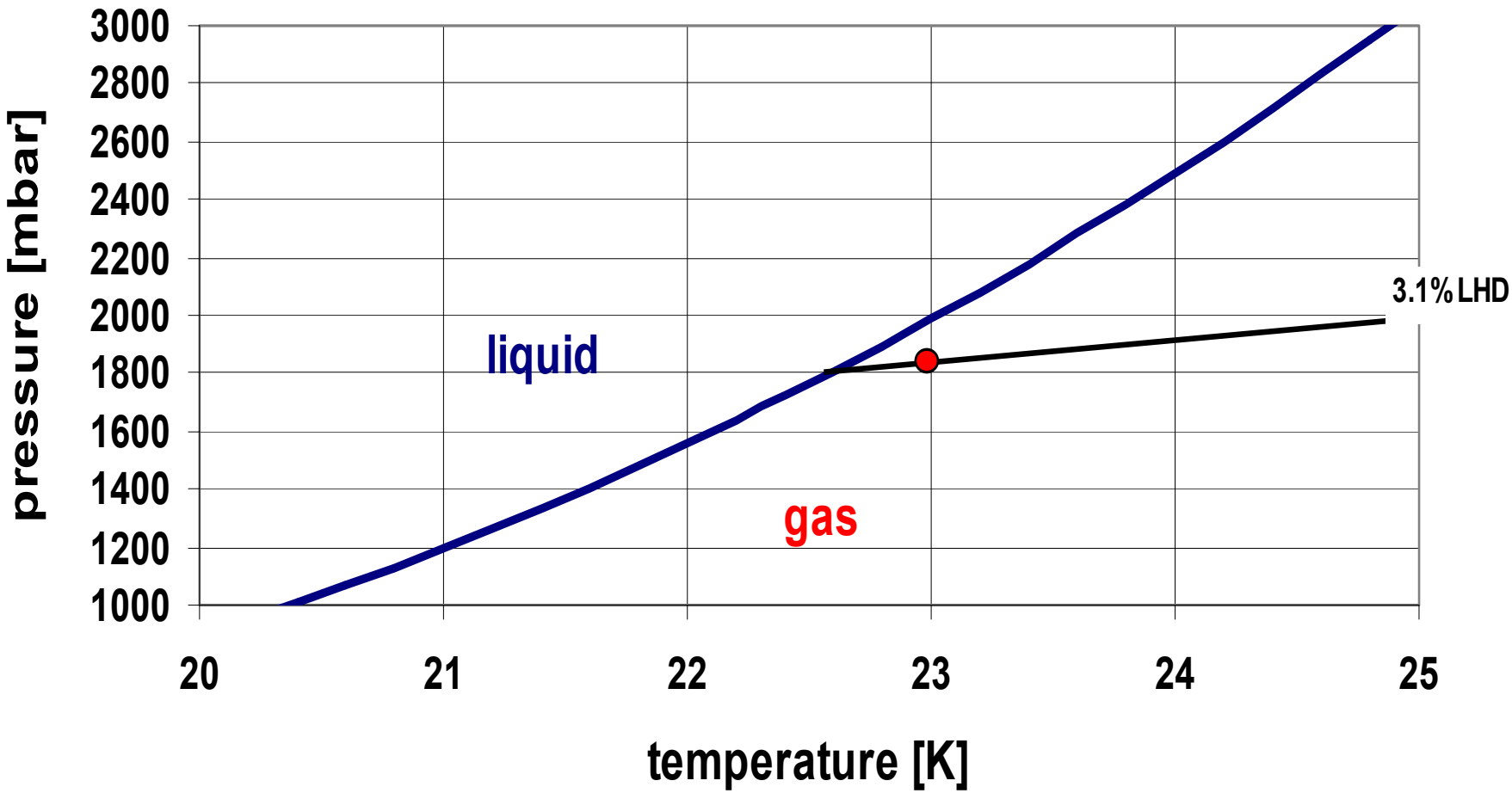


Cryogenic Hydrogen Target

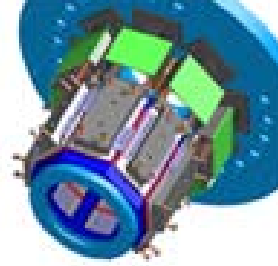


working point: T = 23 K, P = 1.82 bar

hydrogen density: 3.1% of LHD, 2.2 g/l



Cryogenic Hydrogen Target Cell



"low mass construction"

Volume: 1150 cm^3
Weight: 410 g

Materials:

side wall	75µm Kapton
entrance window	125µm Kapton
grid structure	glass fiber reinforced epoxy
mounting ring	aluminum
top plate	aluminum

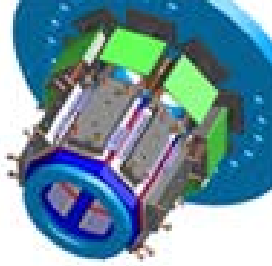
Permeation rates: hydrogen 5.10^{-5} mbar.l/s @ 295 K
nitrogen 1.10^{-6} mbar.l/s @ 295 K

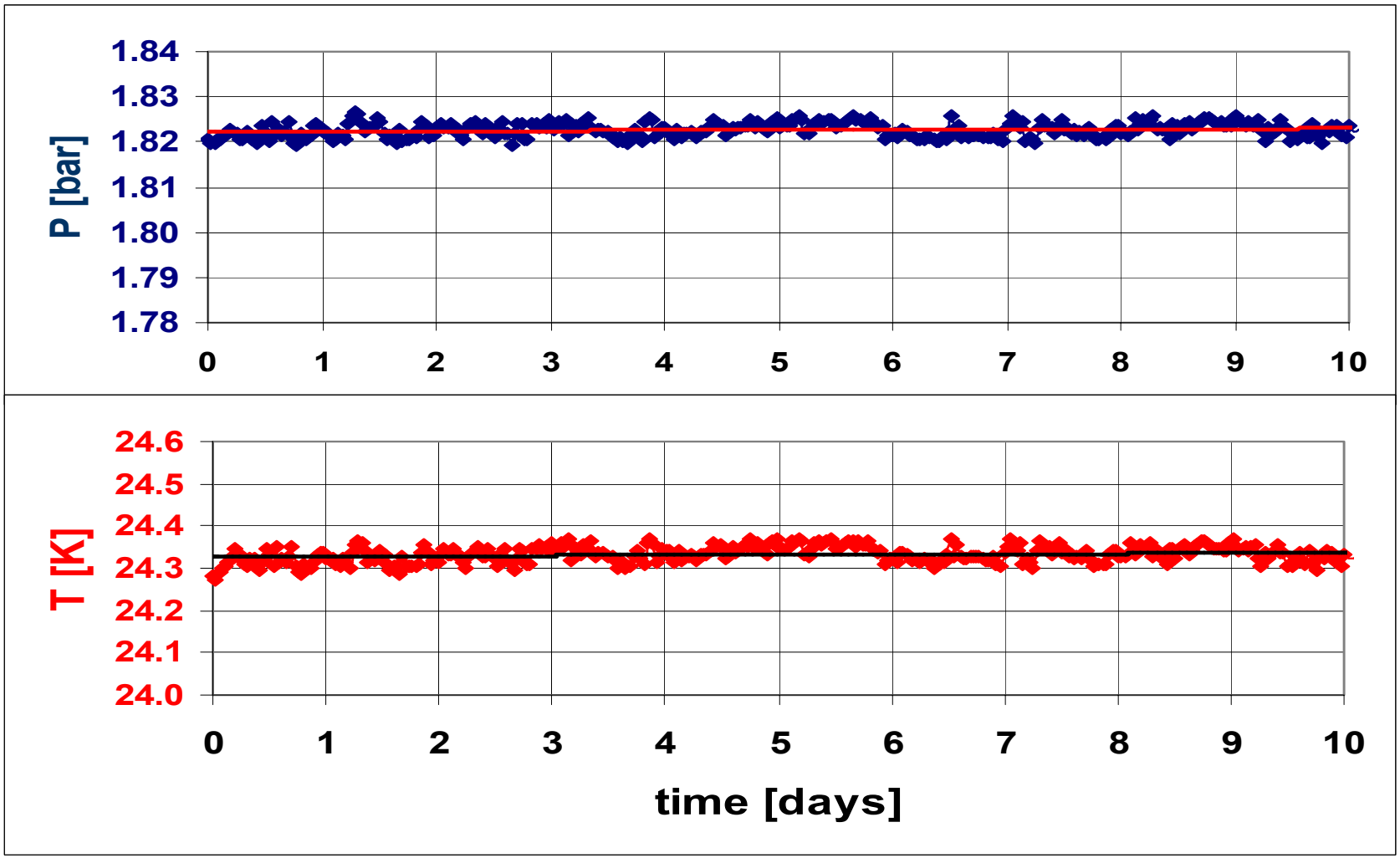
for T < 100 K: < 5.10^{-9} mbar.l/s (H_2, N_2)

DEAR Cryogenic Target Cell

DEAR Hydrogen Target

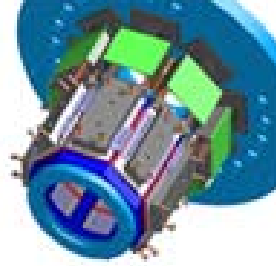
pressure, temperature stability Oct. 30 – Nov. 8, 2002





DEAR CCD Detector

16 CCD-chips with active area 100cm^2



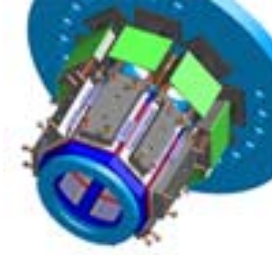
- Resolution:
  - thermal noise FWHM of about 15 eV
  - energy resolution at 5.9 keV (Mn Kα line) 136 eV
    (to be compared with silicon intrinsic Fano resolution of 128 eV, thermal noise included)

- Linearity: about 10^{-4}

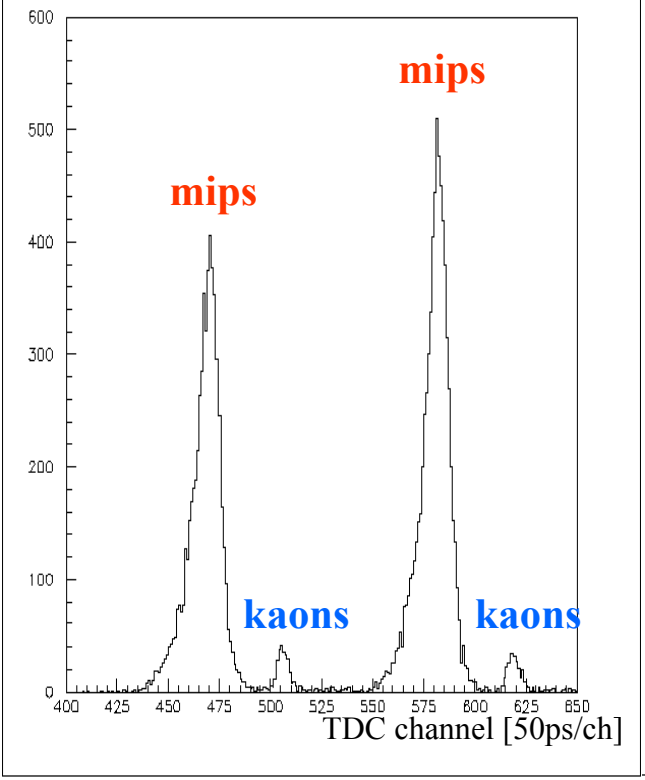
- Stability: fluctuations below 4 eV/month

- Charge transport inefficiency: ~10^{-6}

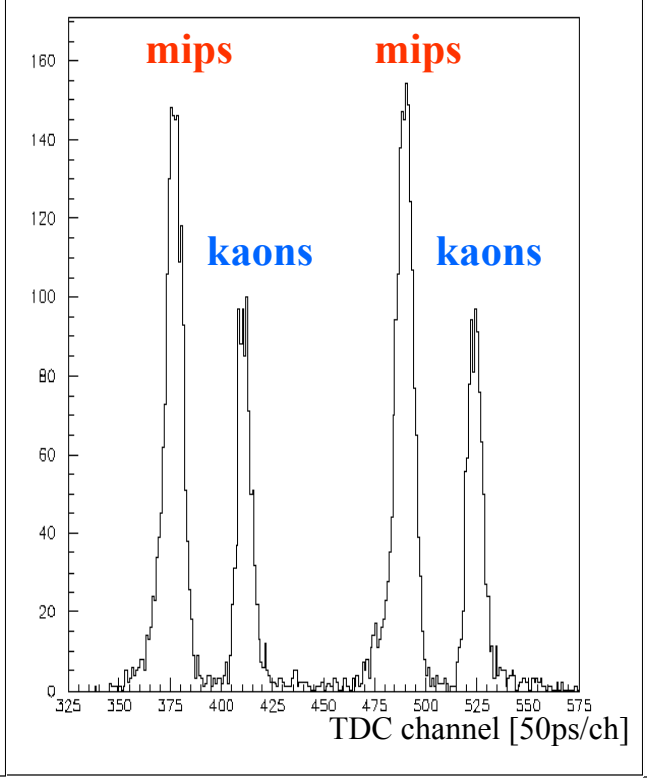
Kaon Monitor – beam conditions



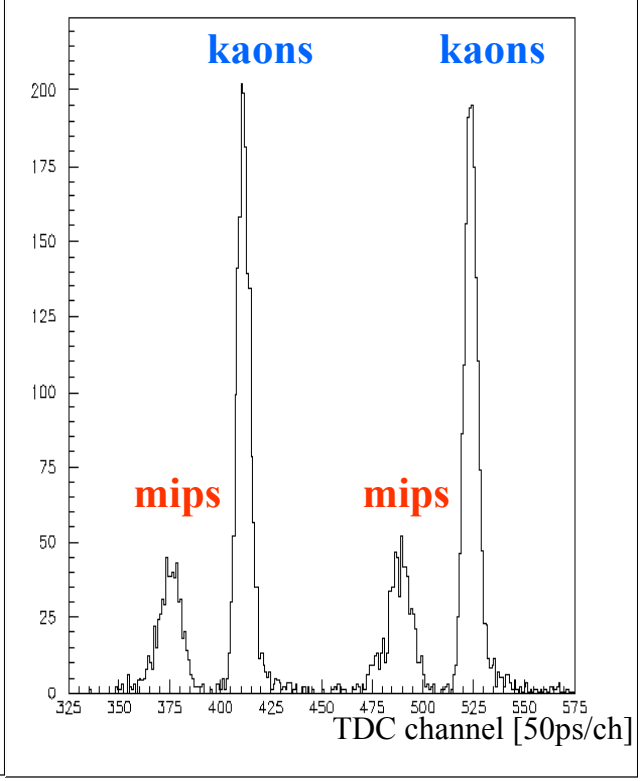
December 21, 2001



April 14, 2002



April 26, 2002



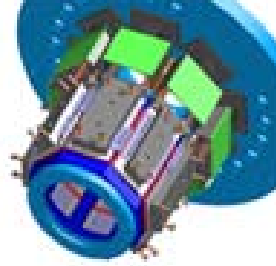
Kaons/mips = 0.034

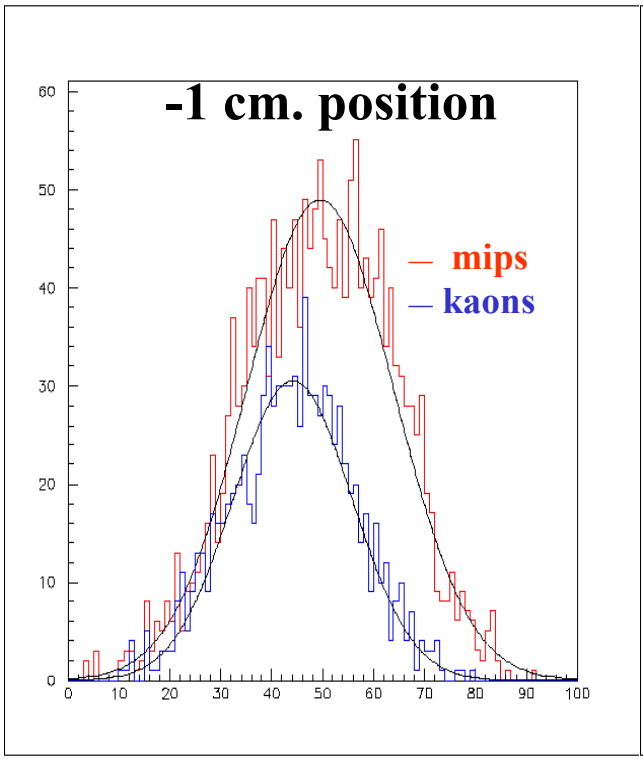
Kaons/mips = 0.47 (scrapers and KM shielding)

Kaons/mips = 2.28 (new optics)

Kaon Monitor – stability monitor

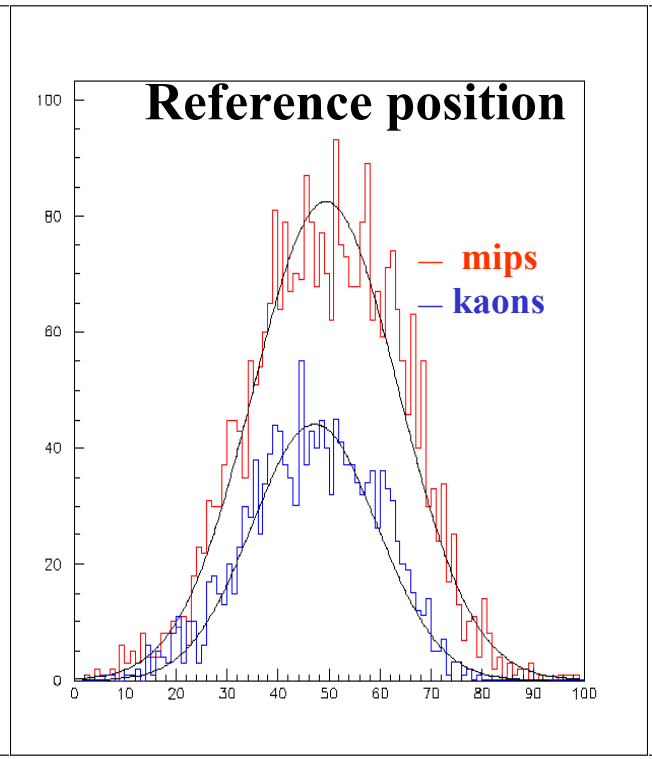
sensitivity to the I.P. shift in z





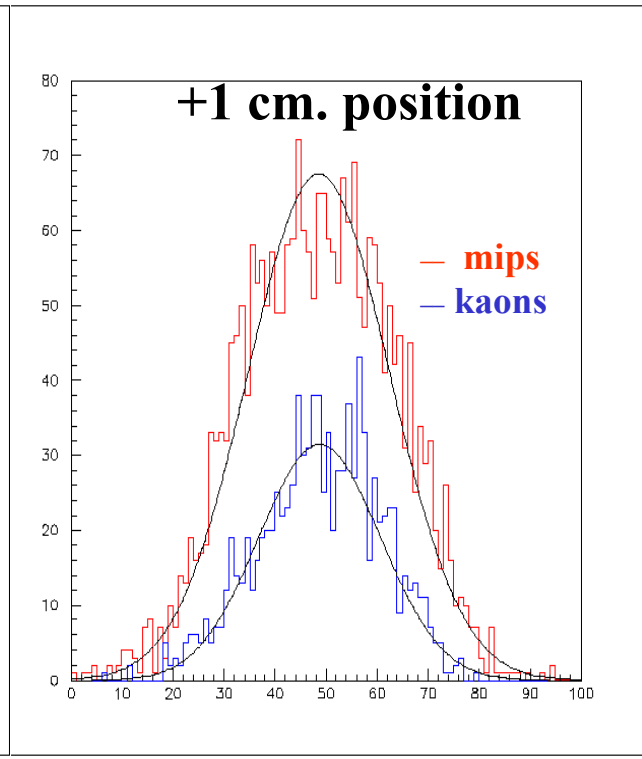
Mean = 49.50 ± 0.35

Mean = 44.12 ± 0.40



Mean = 49.35 ± 0.27

Mean = 47.15 ± 0.34



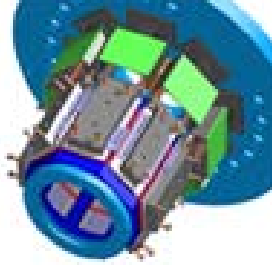
Mean = 49.50 ± 0.29

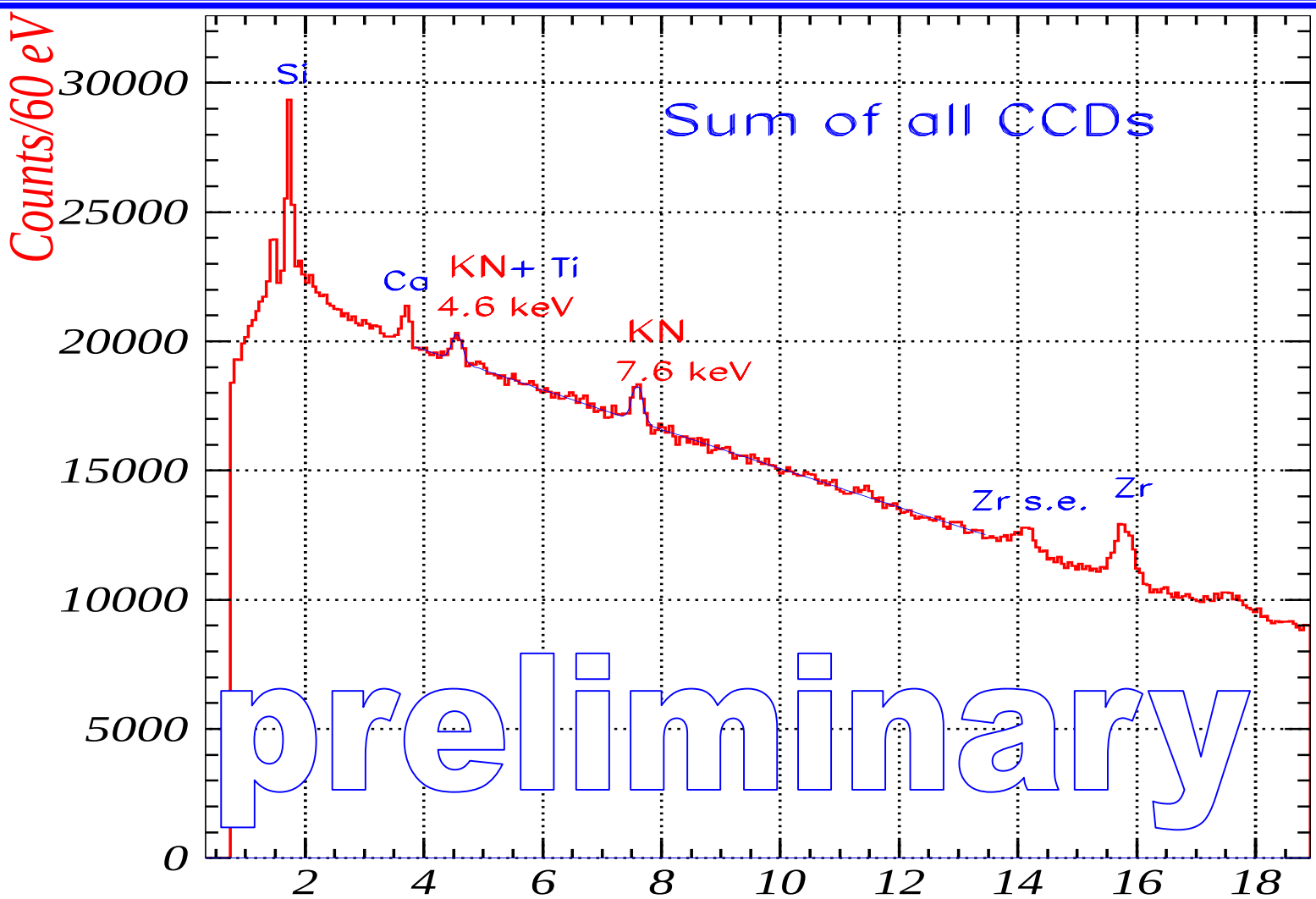
Mean = 49.55 ± 0.48

Kaonic Nitrogen

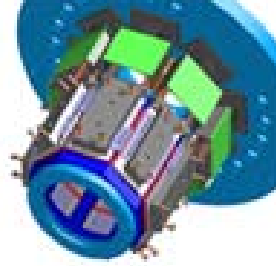
integrated luminosity 10 pb^{-1}

T = 85 K, P = 1.01 bar, density = 4.4 g/l

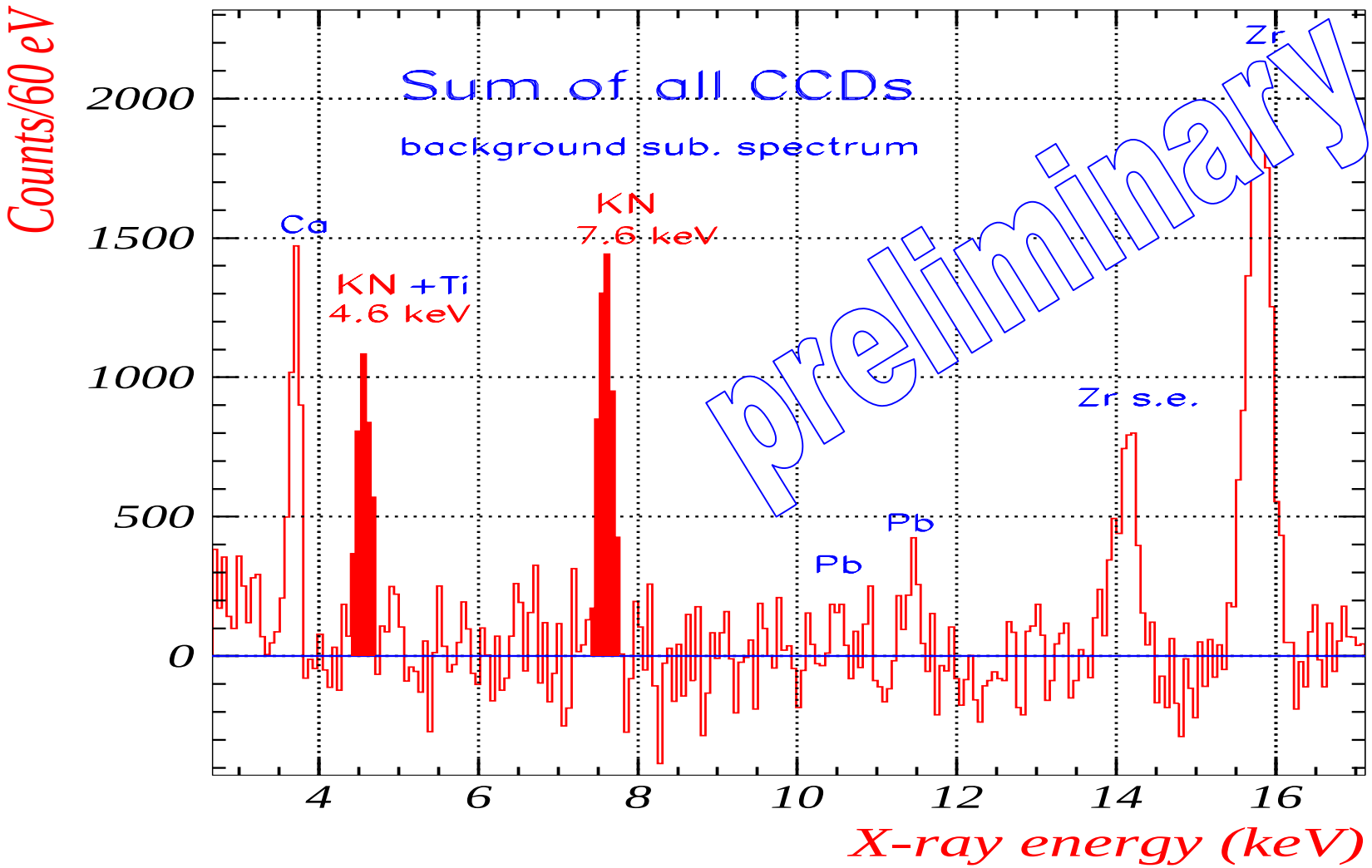




Kaonic Nitrogen, 10 pb^{-1}

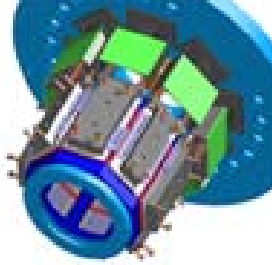


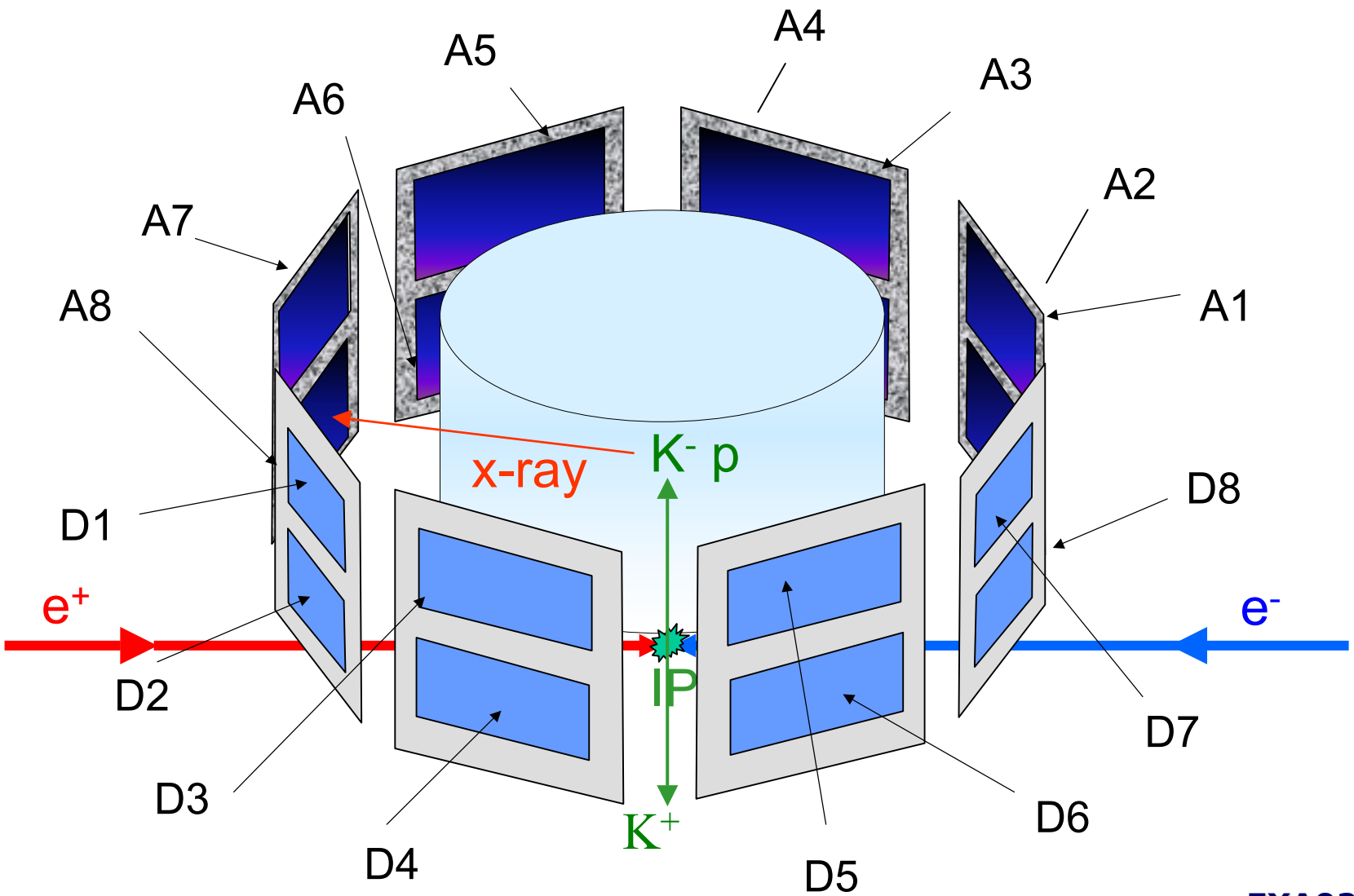
2200 events 4.6 keV **5200 events 7.6 keV**



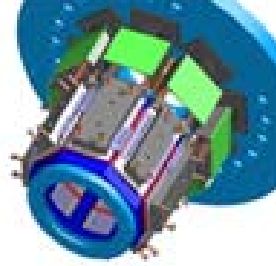
DEAR CCD Arrangement

Total of 16 CCD-55s, active area 100 cm^2

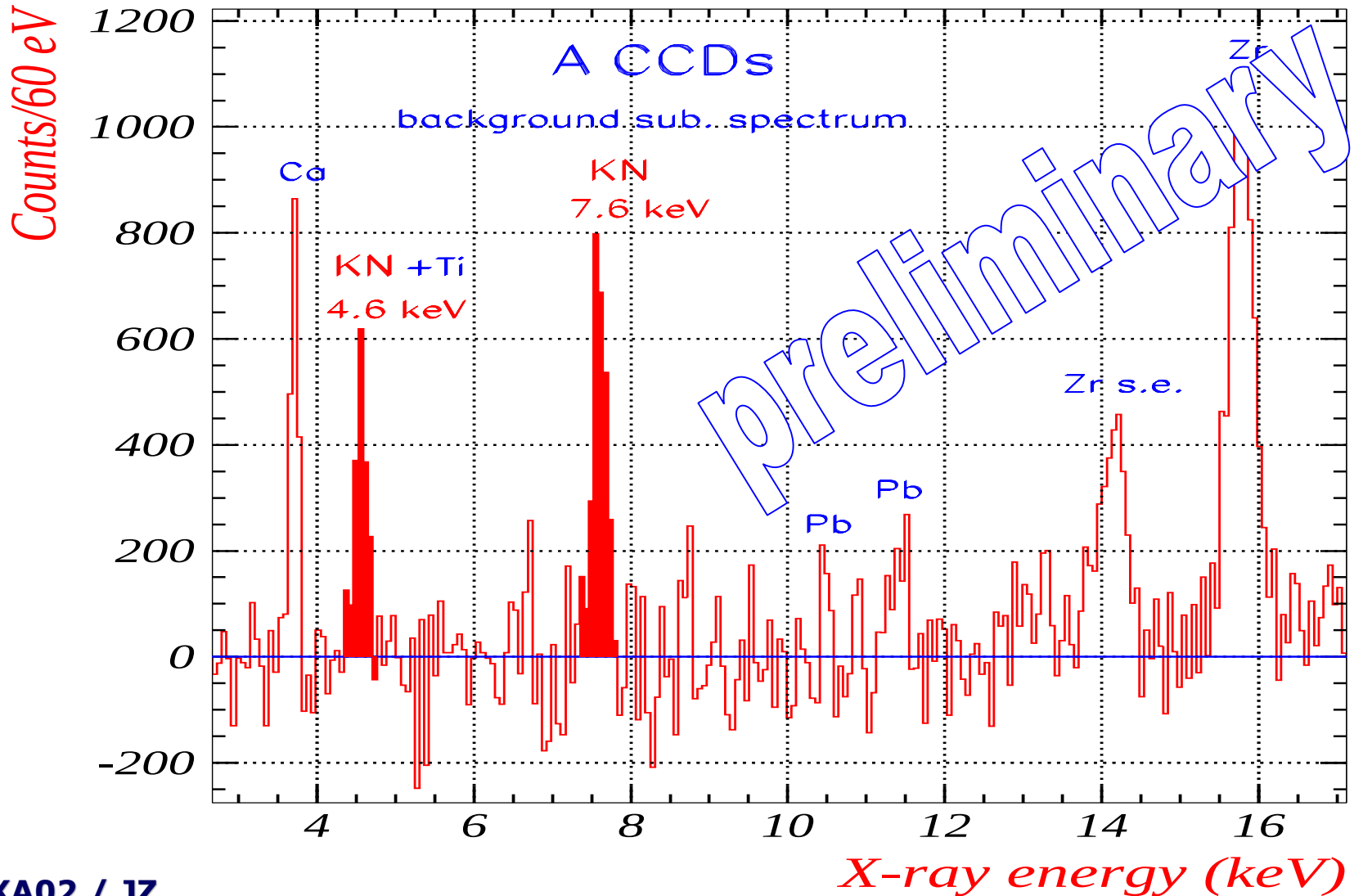


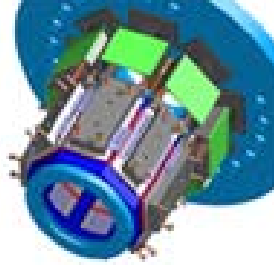


Kaonic Nitrogen; sum of A-CCDs



1200 events 4.6 keV **2800 events 7.6 keV**





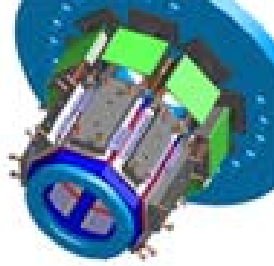
Kaonic Nitrogen,

comparison of different data sets for K^-N 4.6 keV / 7.6 keV

K^-N	4.6 keV	7.6 keV	
All	2200 +/- 320	5200 +/- 300	
A	1200 +/- 250	2800 +/- 240	
D	1000 +/- 250	2400 +/- 240	
UP	1400 +/- 270	3000 +/- 260	
DOWN	800 +/- 240	2200 +/- 230	(* two CCDs less)

- in good agreement with MC simulation

Kaonic Nitrogen Physics

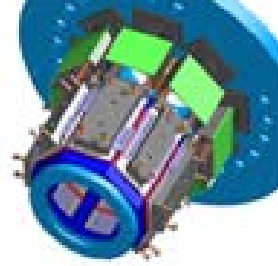


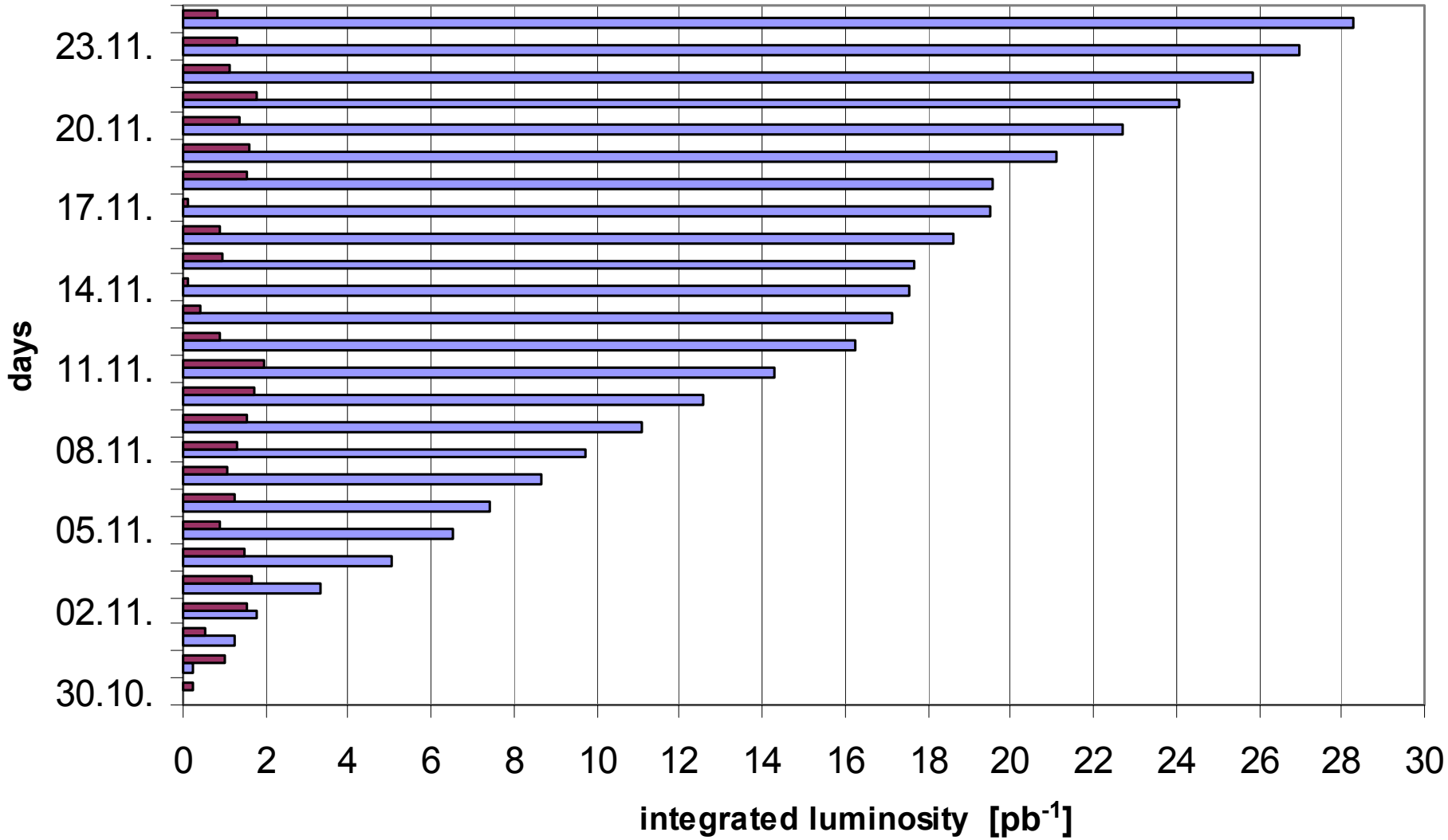
- **Background determination for kaonic hydrogen**
- **Determination of the yield of transitions with a precision better than 10%**
- **Mass of the kaon – as a test measurement – better than 200 keV**

Kaonic Hydrogen, Luminosity

integrated luminosity; total 29 pb^{-1}

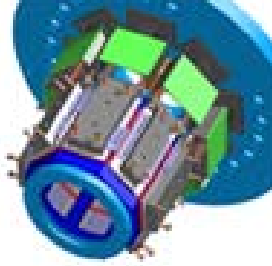
from Oct. 30 up to Nov. 23, 2002

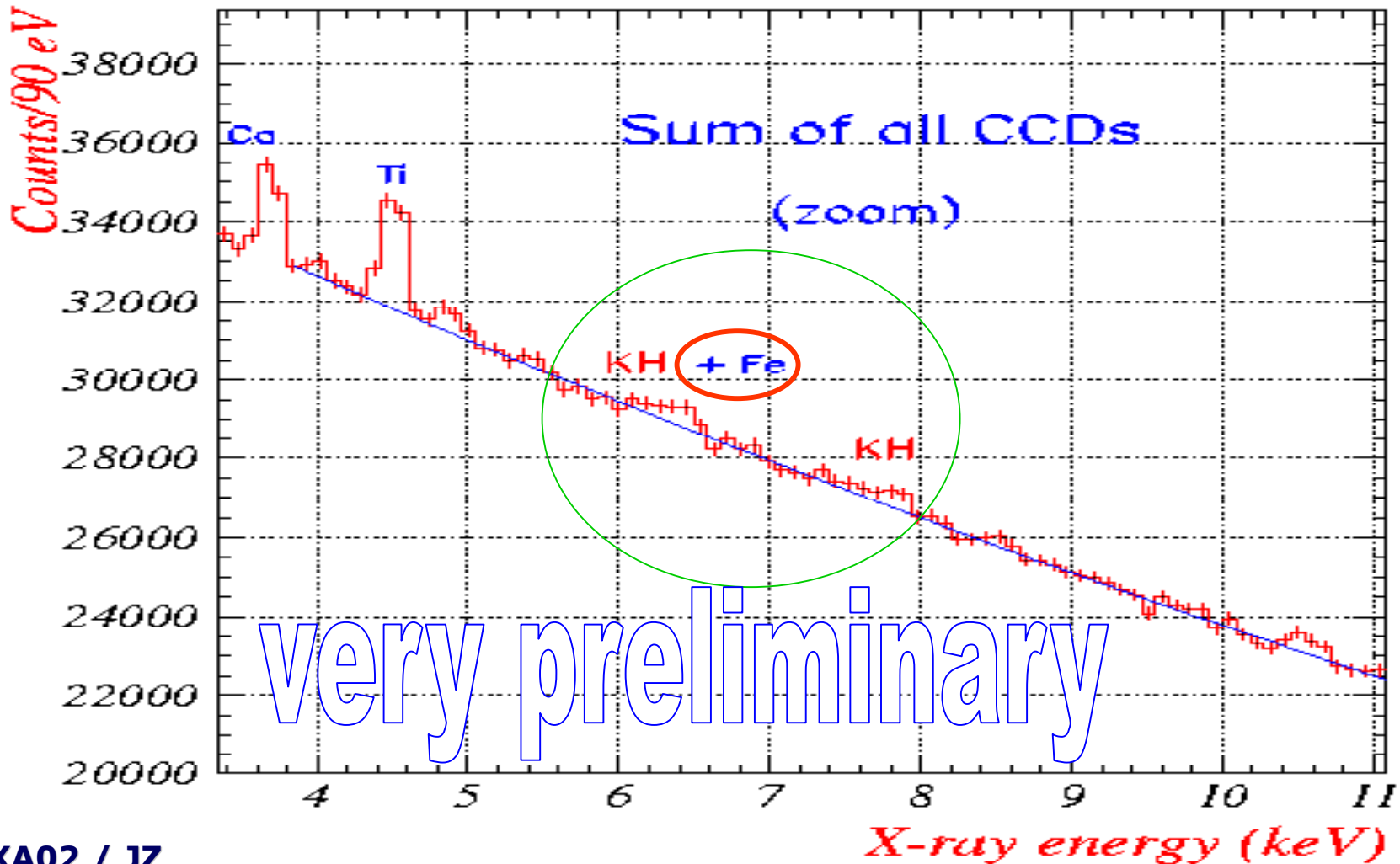




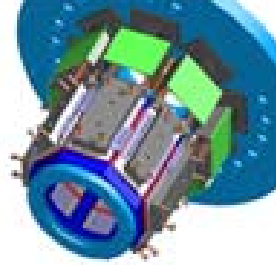
Kaonic Hydrogen

integrated luminosity: 20 pb^{-1}

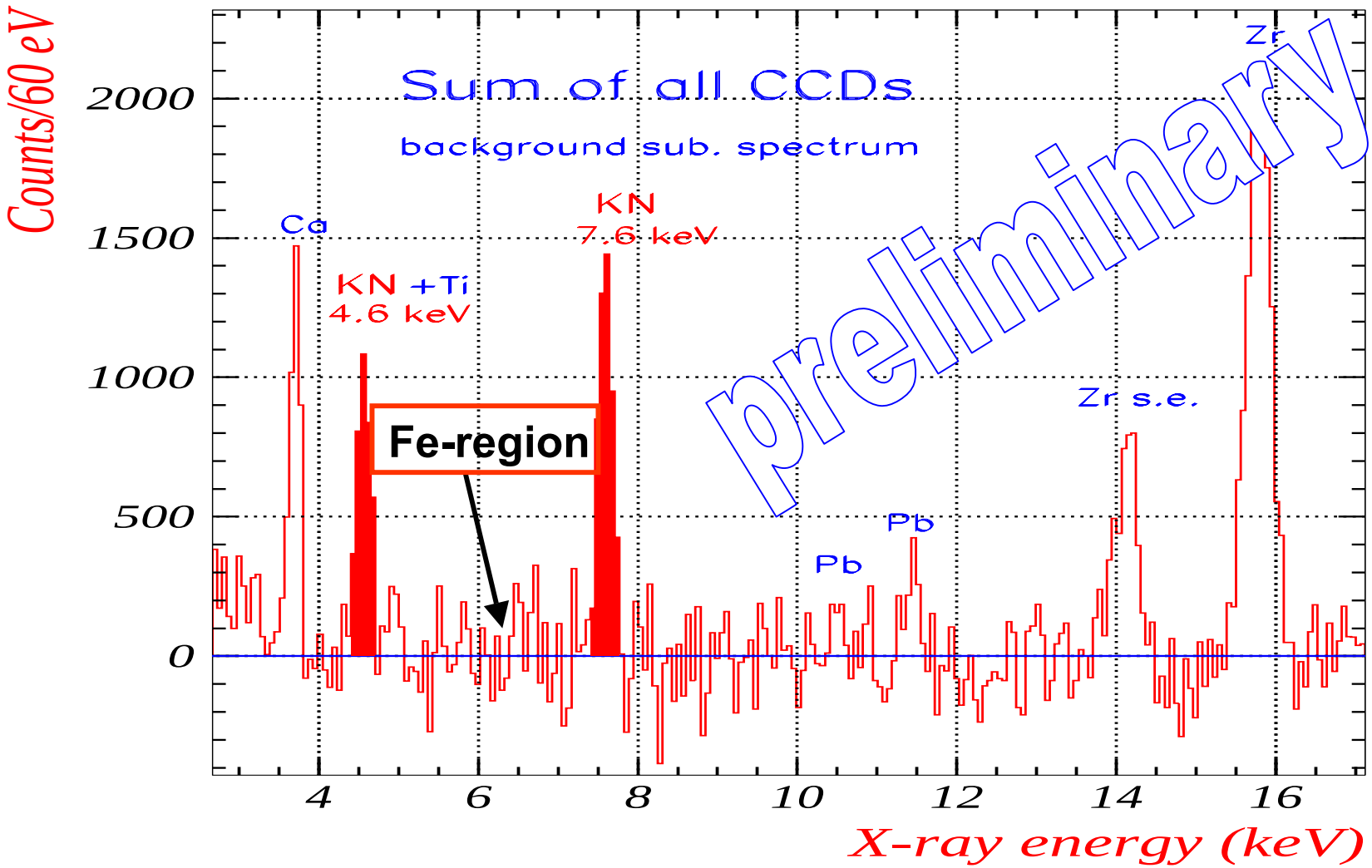




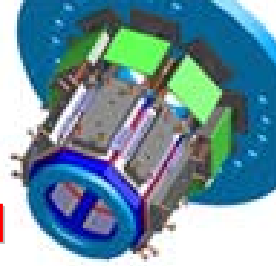
Kaonic Nitrogen, 10 pb^{-1}



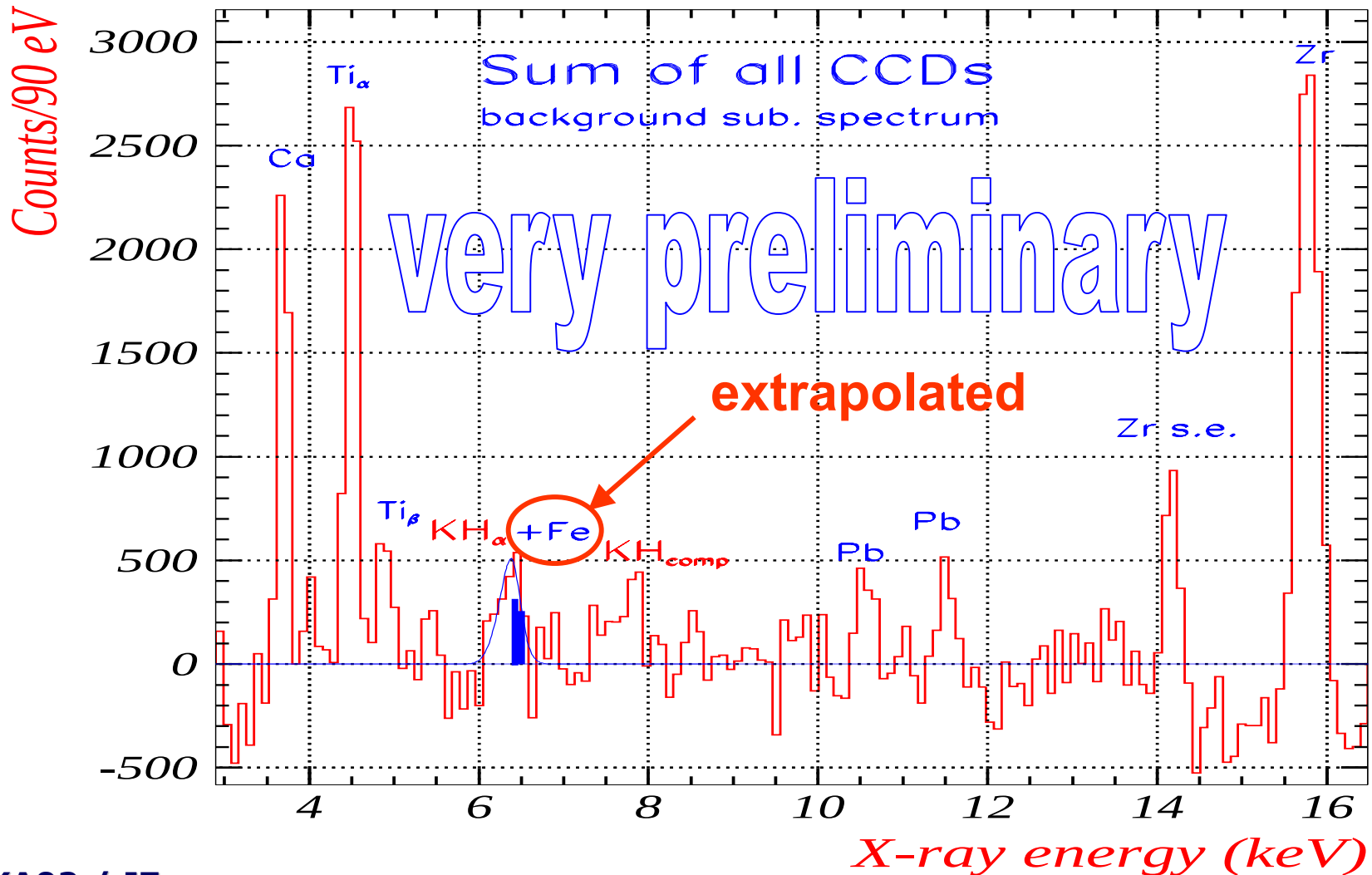
2200 events 4.6 keV **5200 events 7.6 keV**



Kaonic Hydrogen

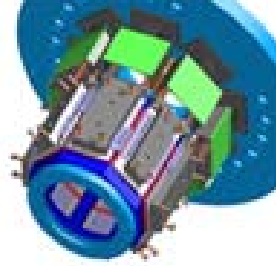


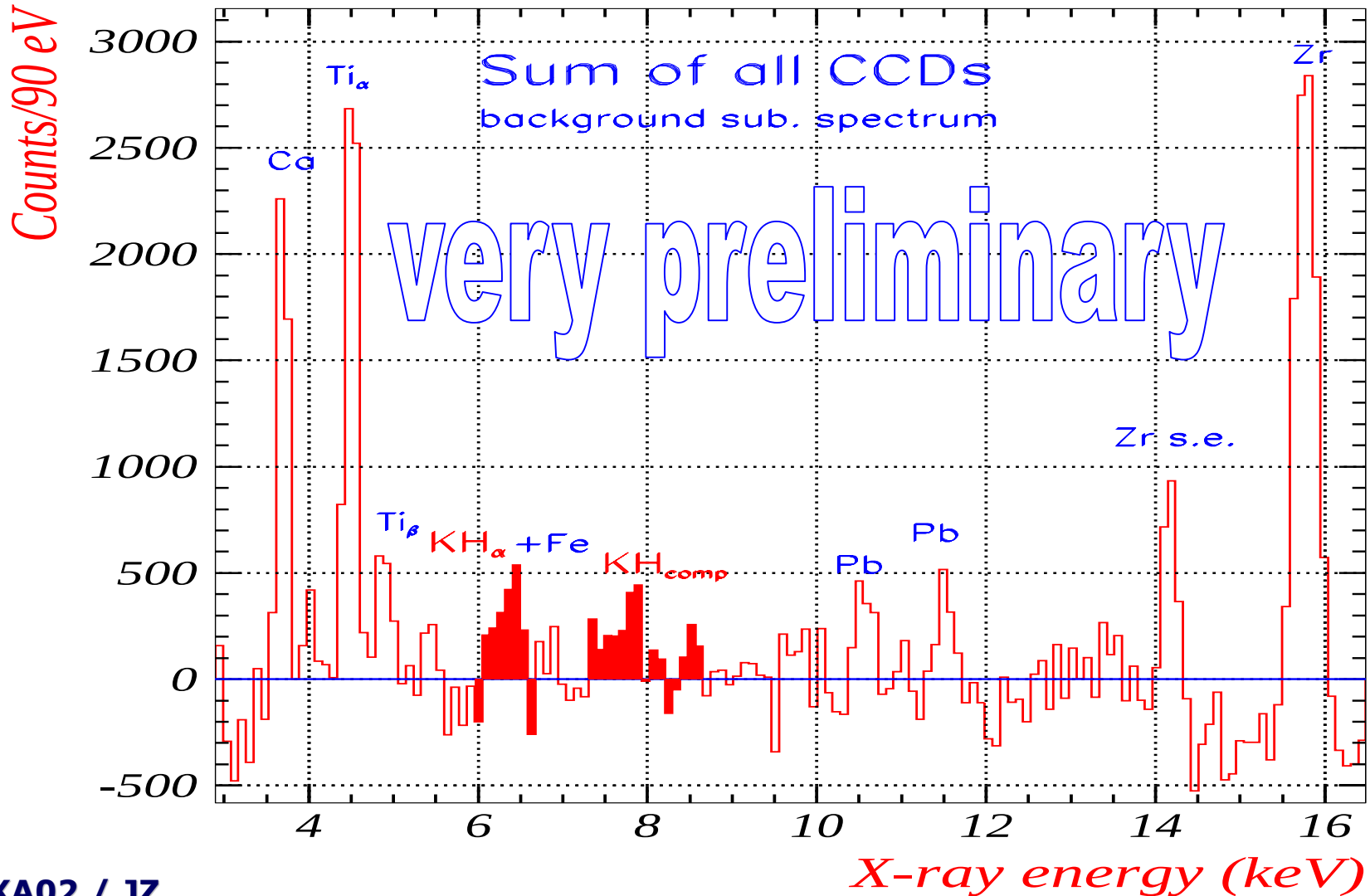
1800 events in 6.3 keV-region: 500 events Fe + 1300 events KH



Kaonic Hydrogen

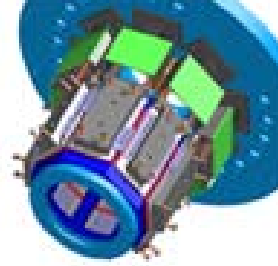
K_α-region: 1300 +/- 450 $K_{complex}$-region: 1800 +/- 600

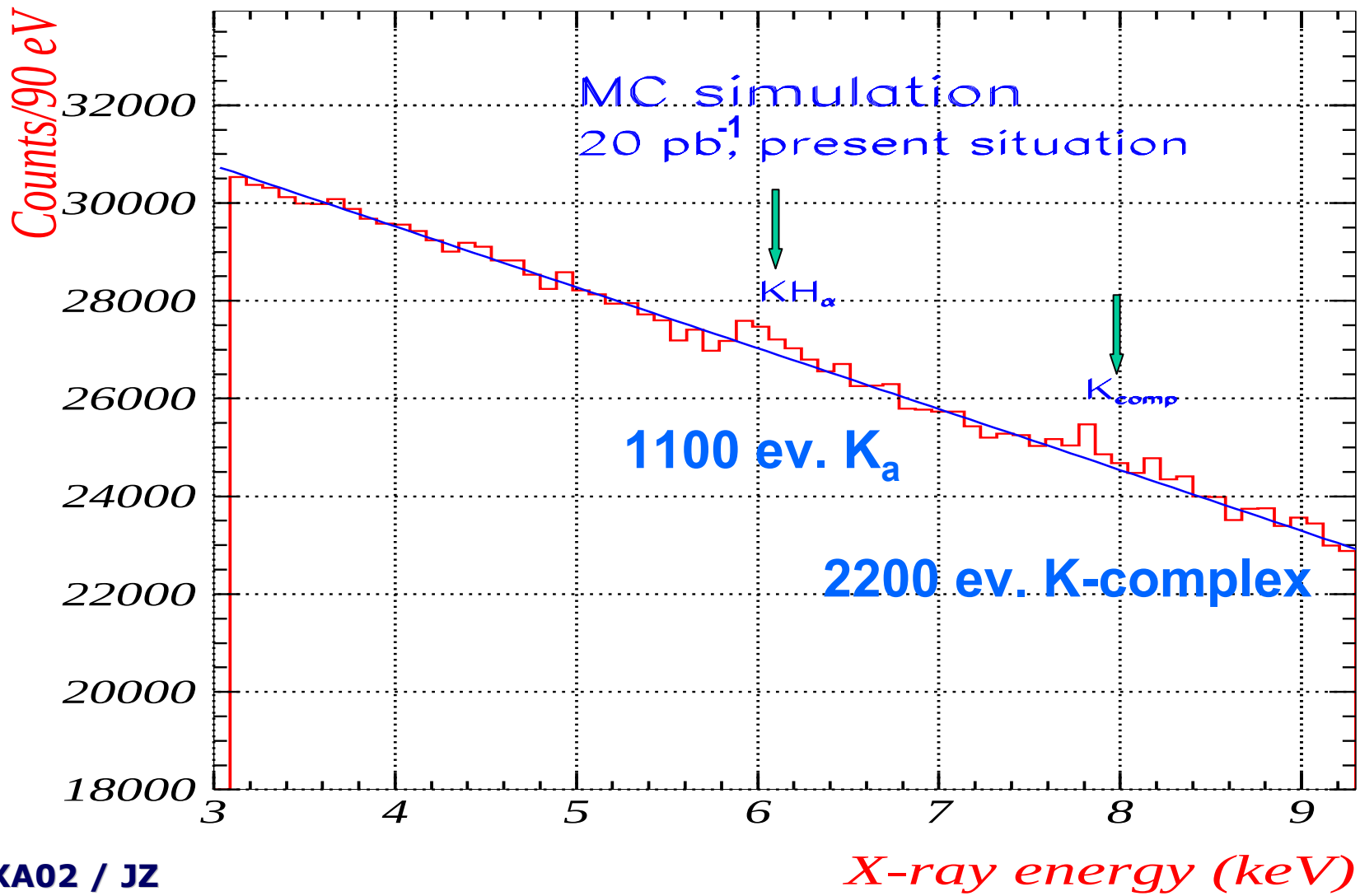




Kaonic Hydrogen, 20 pb^{-1}

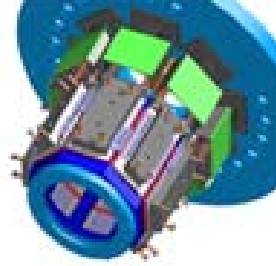
Monte Carlo simulated spectrum

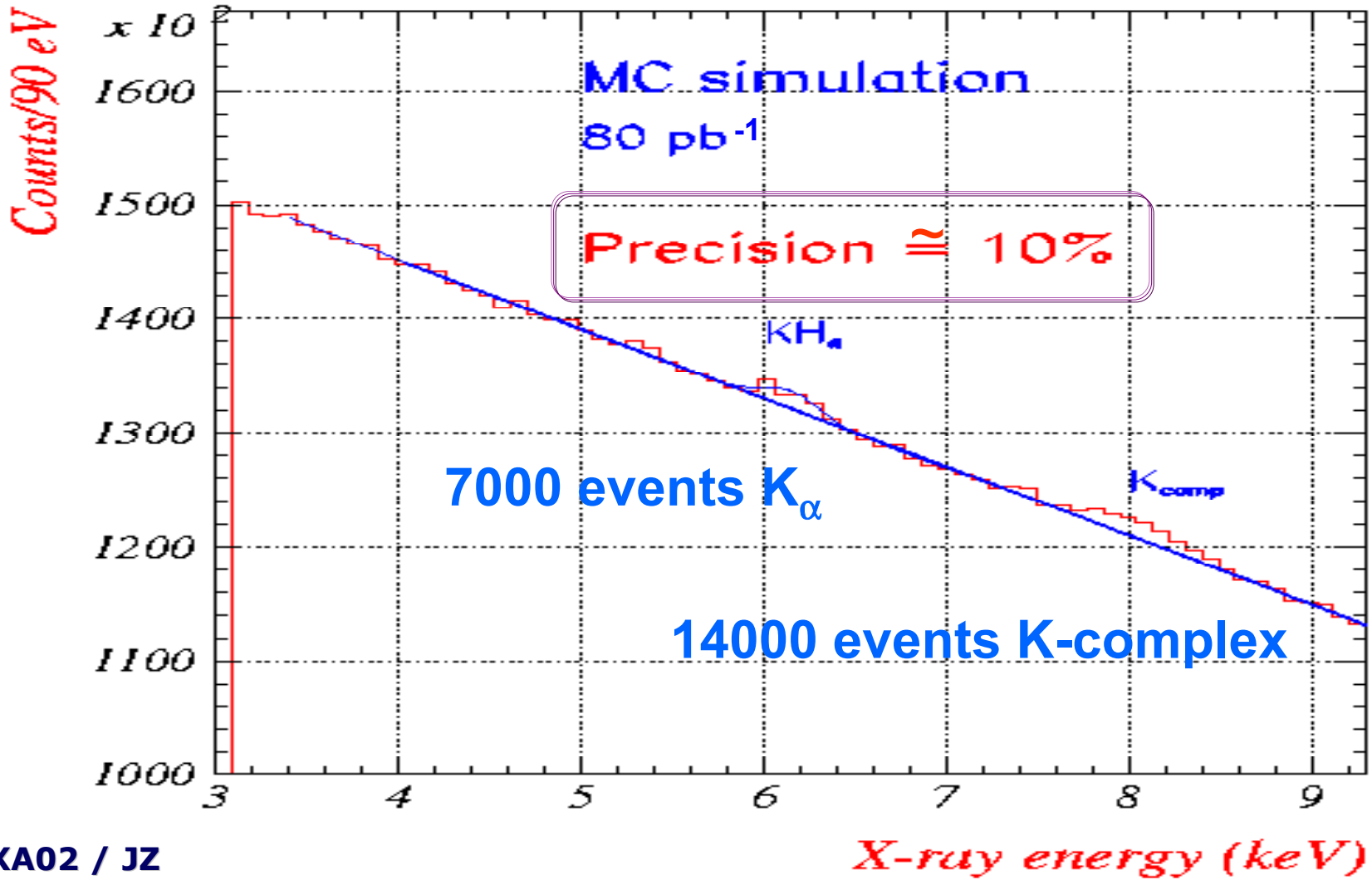




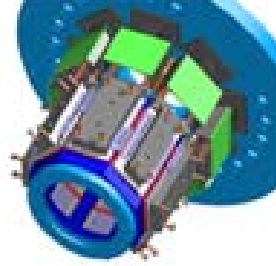
Kaonic Hydrogen, 80 pb^{-1}

Monte Carlo simulated spectrum





Next Steps of the DEAR Scientific Program



- a kaonic deuterium measurement
- a kaonic helium measurement
- to measure the kaon mass
- a JRP within FP6 will be started to develop a triggerable low energy x-ray detector

Kaon mass measurement