Kaonic Atoms at DaΦne
the SIDDHARTA Experiment

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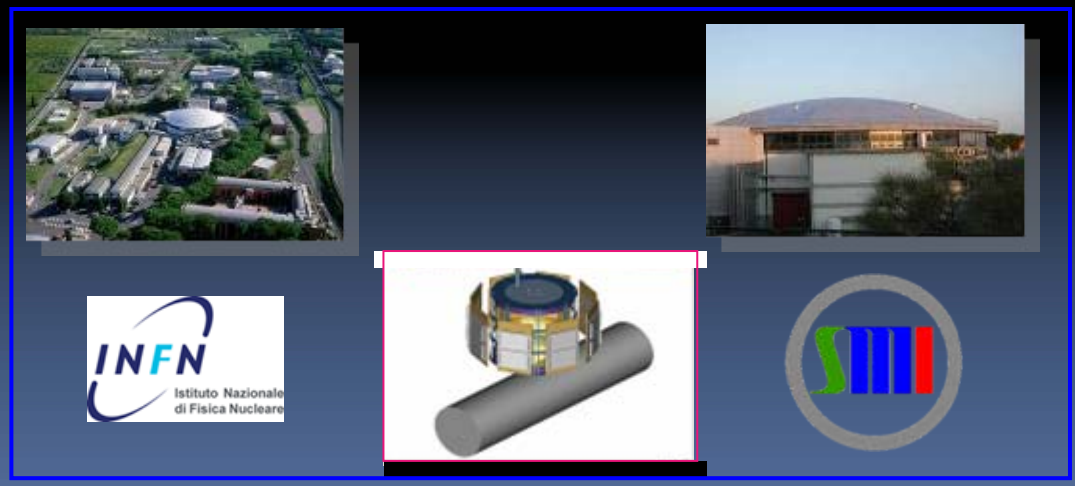

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- Kaonic atoms at DaΦne
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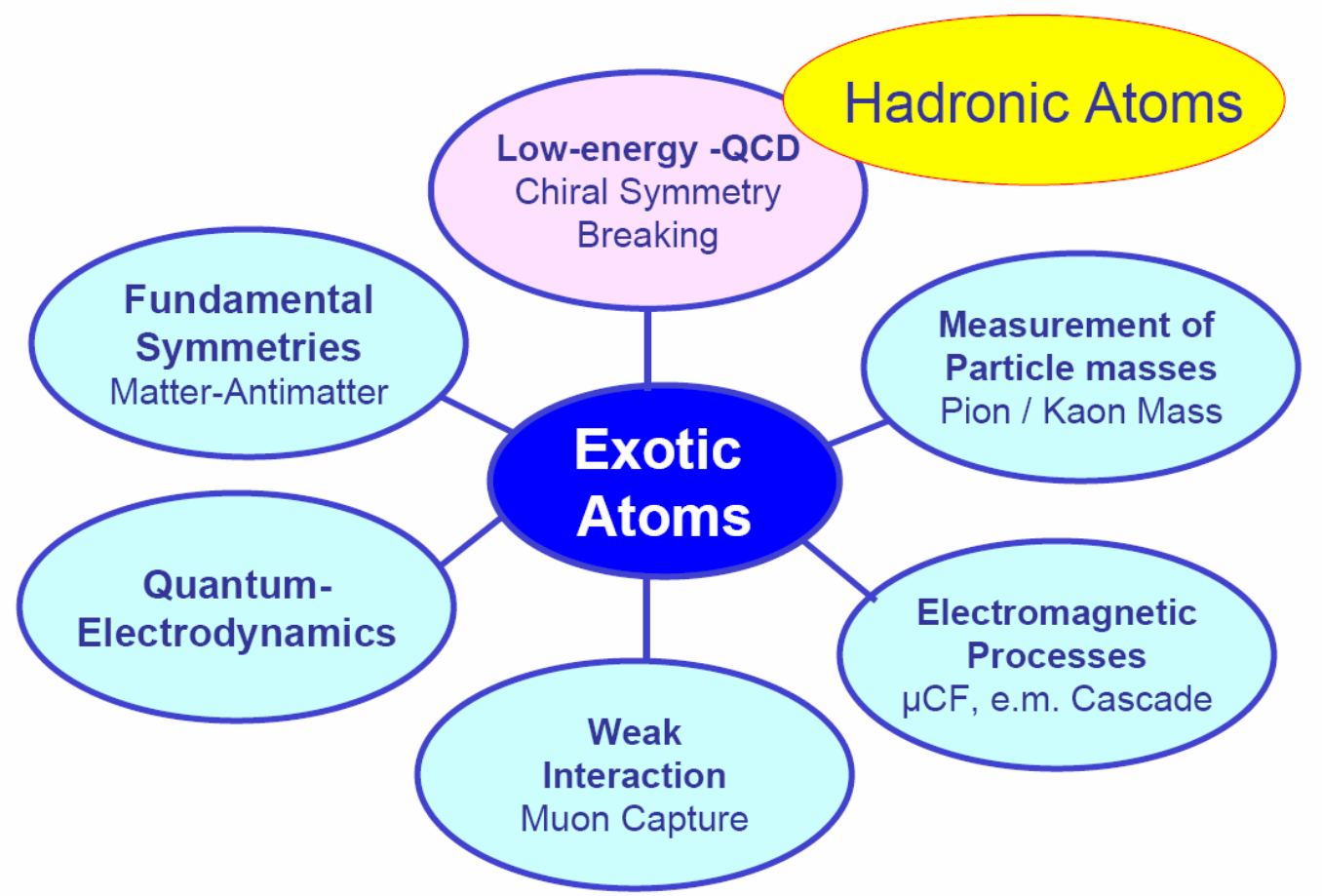
- Summary and Outlook

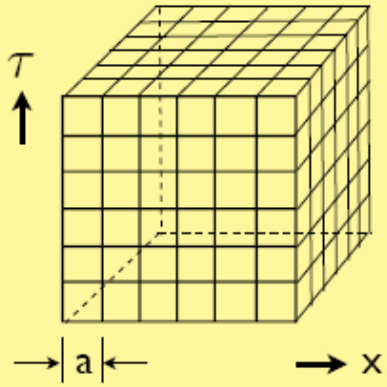

Hadronic Atoms
Low-energy -QCD
Chiral Symmetry
Breaking
Fundamental
Symmetries
Matter-Antimatter
Measurement of
Particle masses
Pion / Kaon Mass
Exotic
Atoms
Quantum-
Electrodynamics
Electromagnetic
Processes
μCF, e.m. Cascade
Weak
Interaction
Muon Capture

QCD
BASIC CONCEPTS and STRATEGIES

- "**HIGH - Q**" (> several GeV) ↔ **SHORT DISTANCE** (< 0.1 fm)
  - ⇨ Theory of WEAKLY INTERACTING QUARKS and GLUONS (Perturbative QCD)

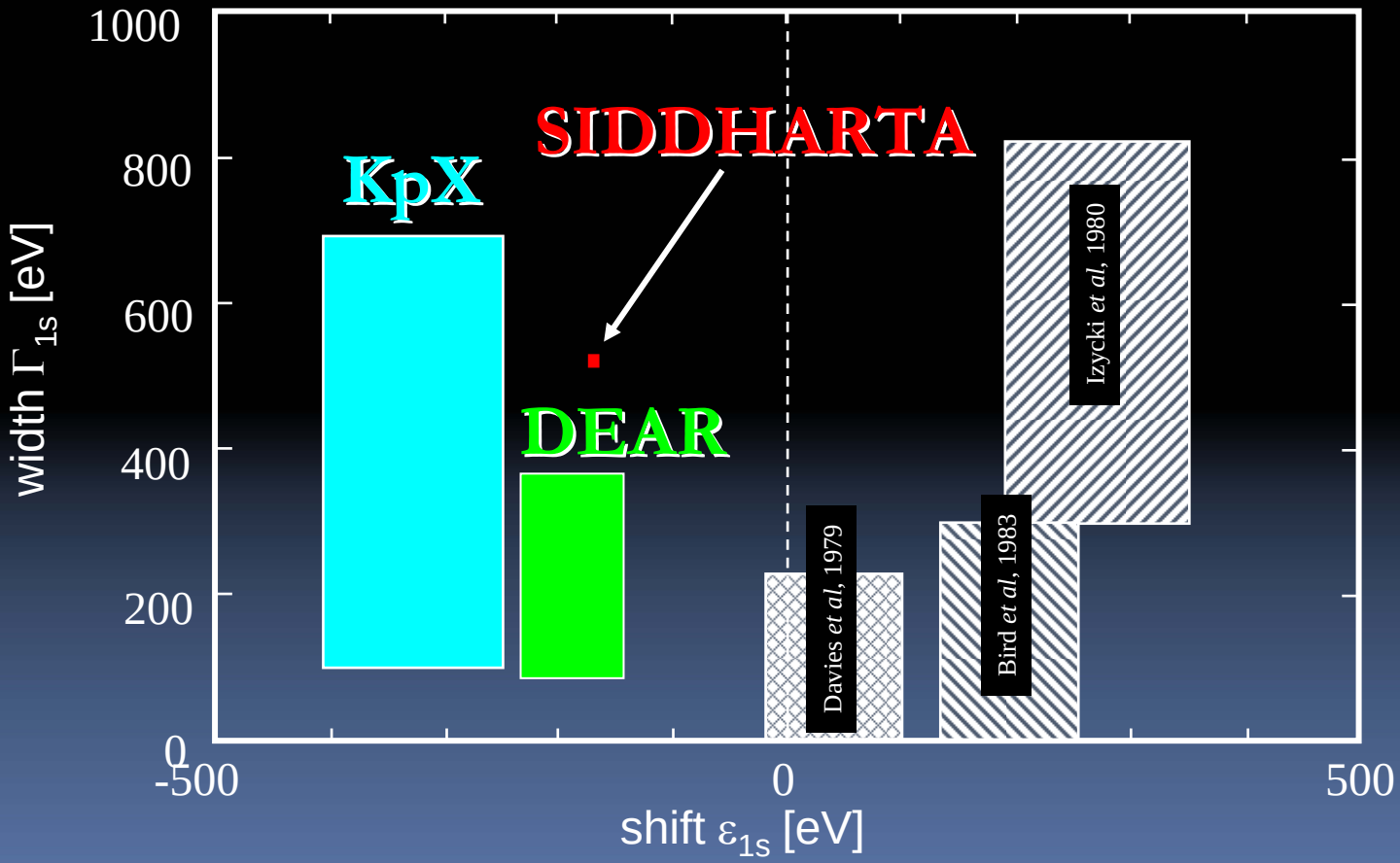
- "**LOW - Q**" (<< 1 GeV) ↔ **LONG DISTANCE** (> 1 fm)
  - ⇨ SPONTANEOUS (CHIRAL) SYMMETRY BREAKING
  - ⇨ Effective Field Theory of WEAKLY INTERACTING GOLDSTONE BOSONS (Pions)

- **LATTICE QCD**
  - ⇨ Large-scale computer simulations on EUCLIDEAN SPACE-TIME Lattices



SIDDHARTA Goal

Measurement of strong interaction induced shift and width of kaonic hydrogen with an accuracy of a few eV and a first measurement of kaonic deuterium.



Motivation

- Kaonic hydrogen atoms are ideally suited to study strong interaction with strangeness
  - strong interaction shift ε_{1s} and width Γ_{1s} directly observable by X-ray spectroscopy

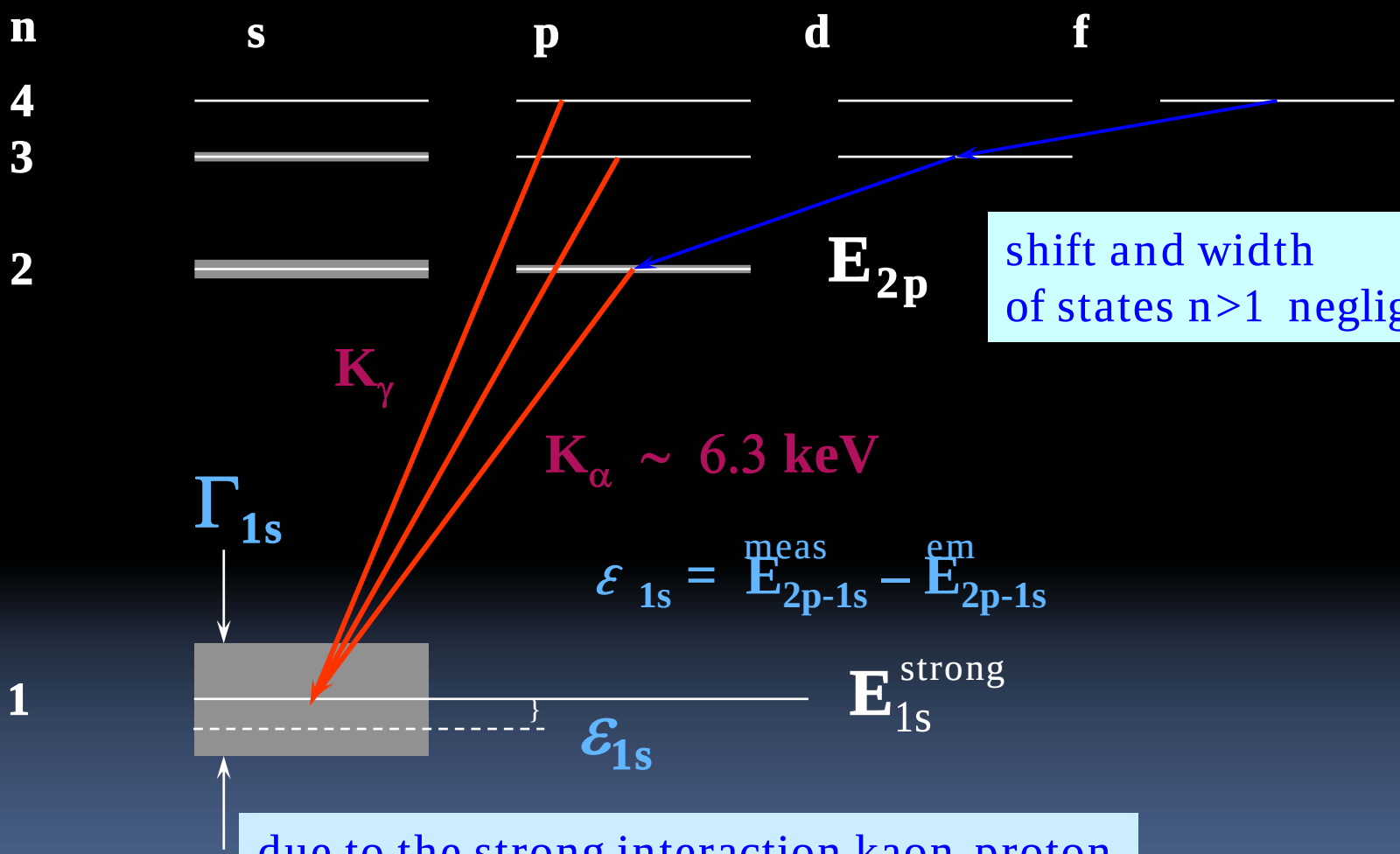
- Kaonic hydrogen: DEAR and KpX

  but: precision data missing

- Kaonic deuterium never measured before

  $\rightarrow$ extraction of isospin dependent scattering lenghts

Kaonic hydrogen X-rays



Kaonic hydrogen X-rays

Relation of strong interaction shift and width to the complex K^-p scattering length

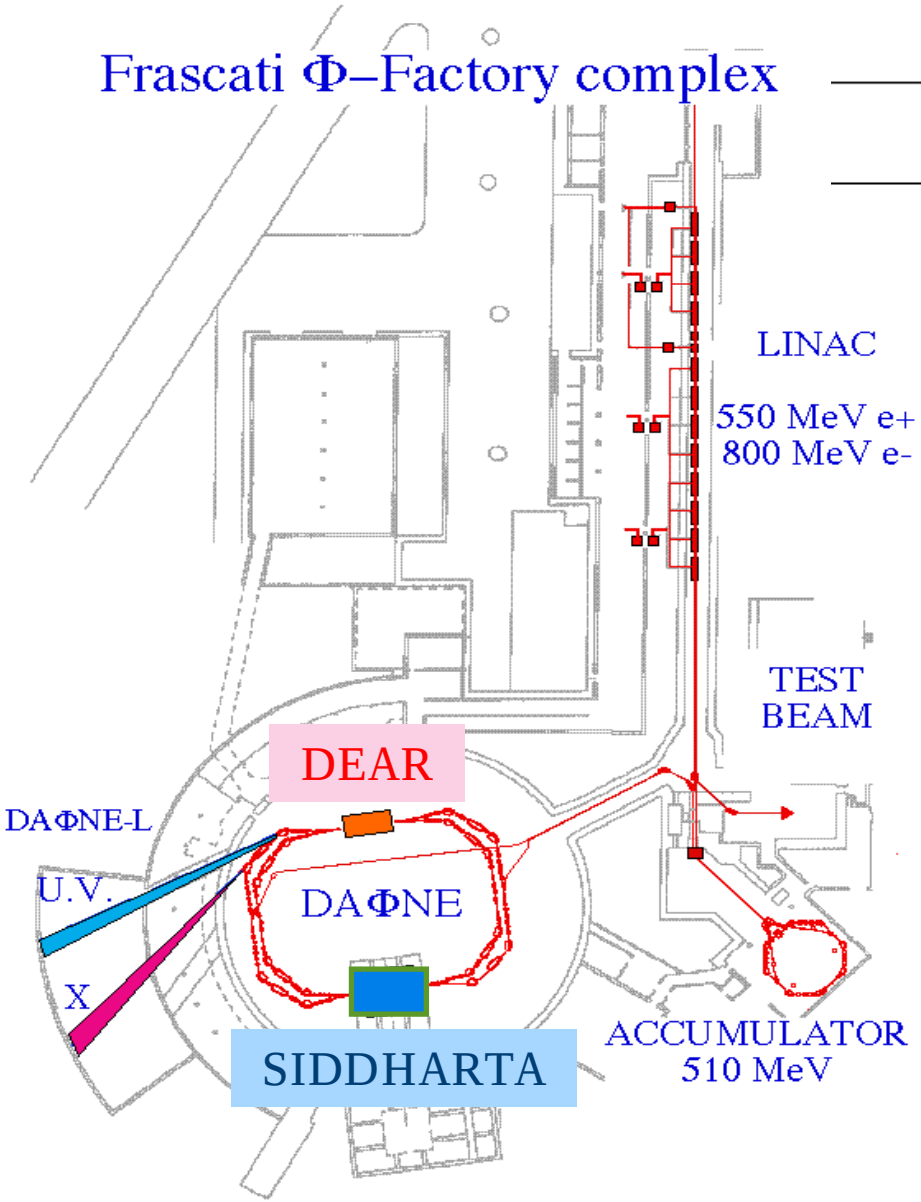
$$\varepsilon + i\frac{\Gamma}{2} = \frac{2\pi}{\mu}\left|\psi_{1s}(0)\right|^2 a_{K^-p} = 2\alpha^3\mu^2 a_{K^-p} = 412\ fm^{-1}\cdot eV\cdot a_{K^-p}$$

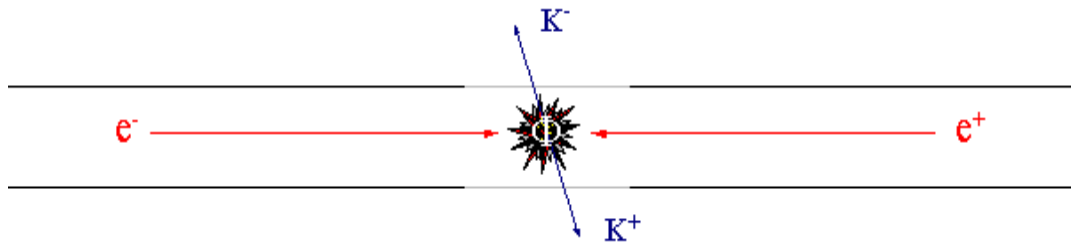
$$(Deser - Goldberger - Baumann - Thirring)$$

- for the determination of the isospin dependent scattering lengths a_0 and a_1 the hadronic shift and width of kaonic hydrogen ***and*** kaonic deuterium are necessary

$$a_{K^-p} = (a_0 + a_1)/2 \qquad a_{K^-n} = a_1$$

DAΦNE @ LNF

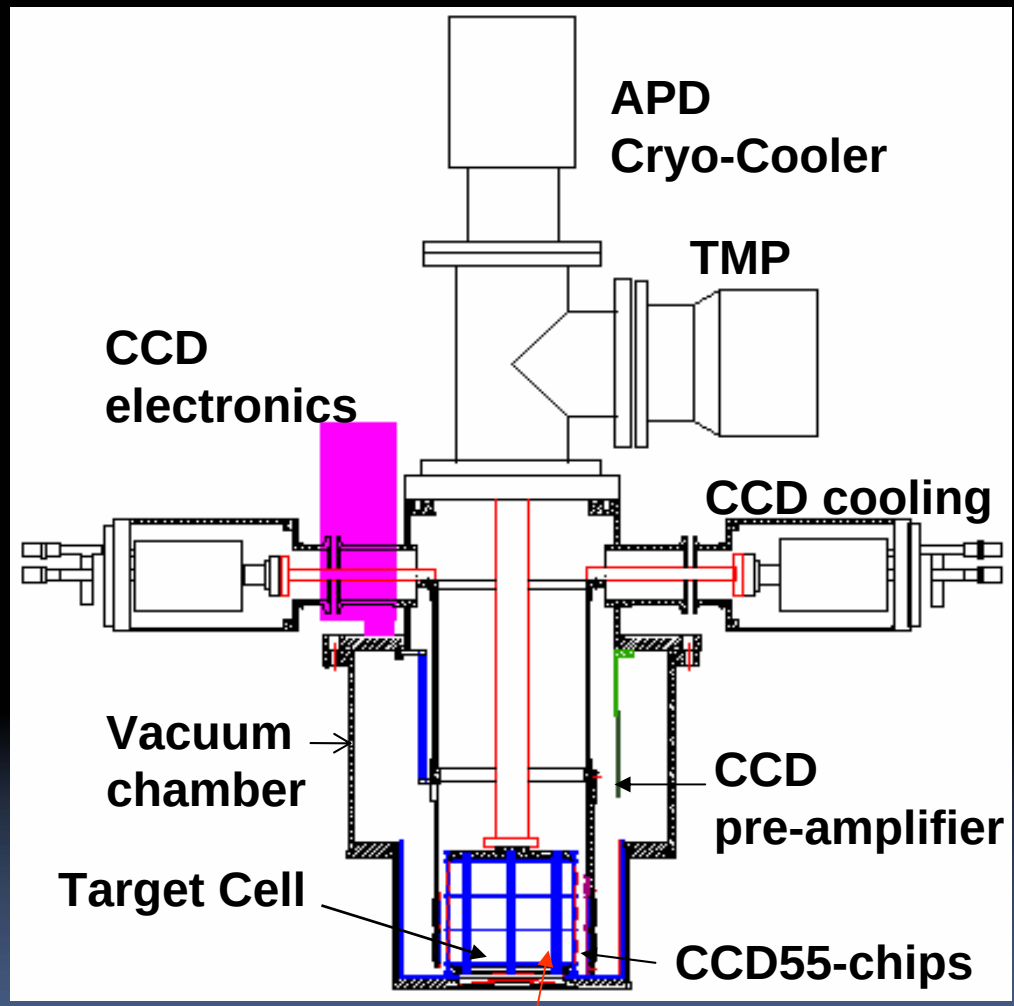




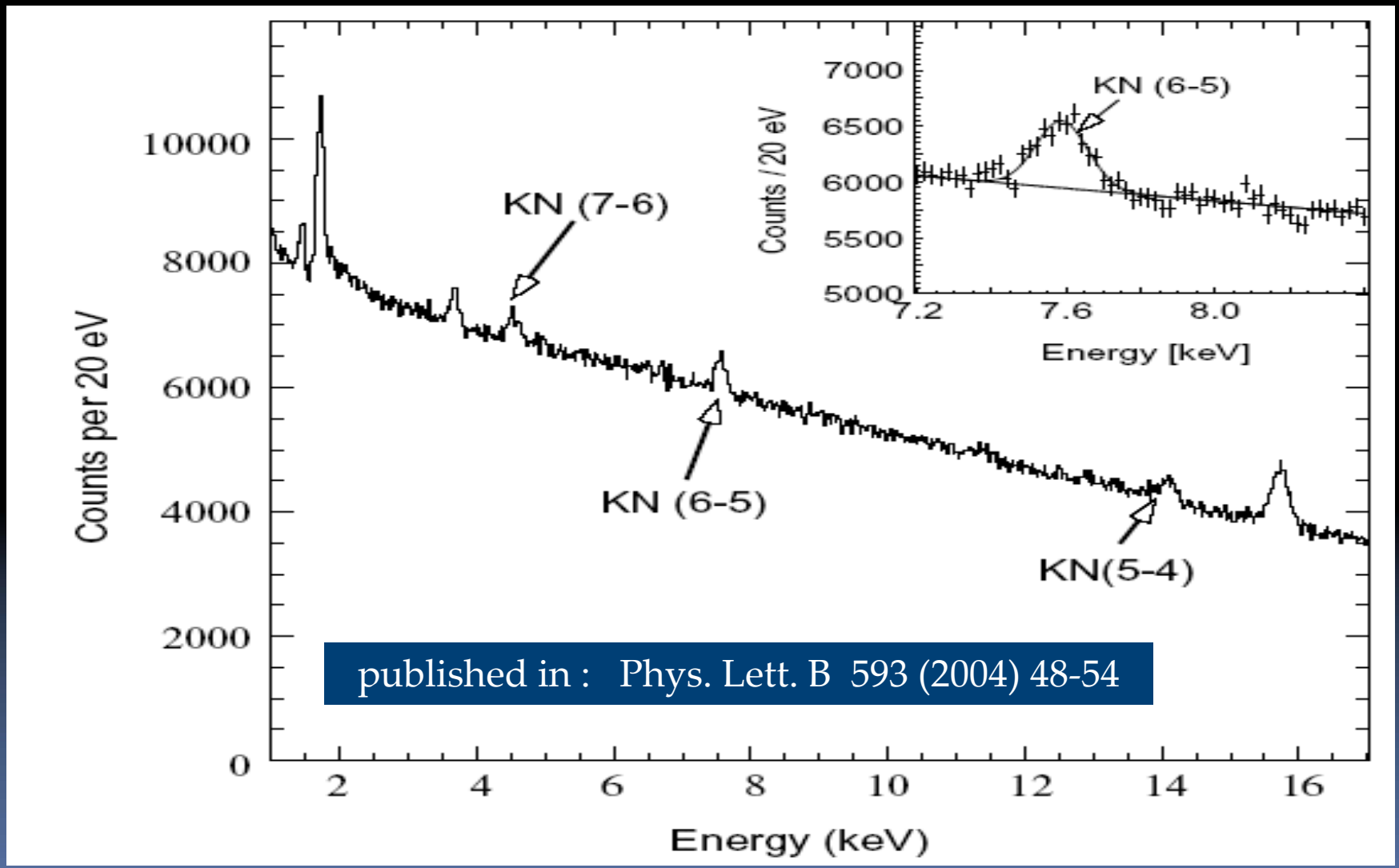
electron – positron collider

collision energy tuned to the Φ resonance at 1.02 GeV

Kaonic X-rays with DEAR



Kaonic nitrogen X-rays



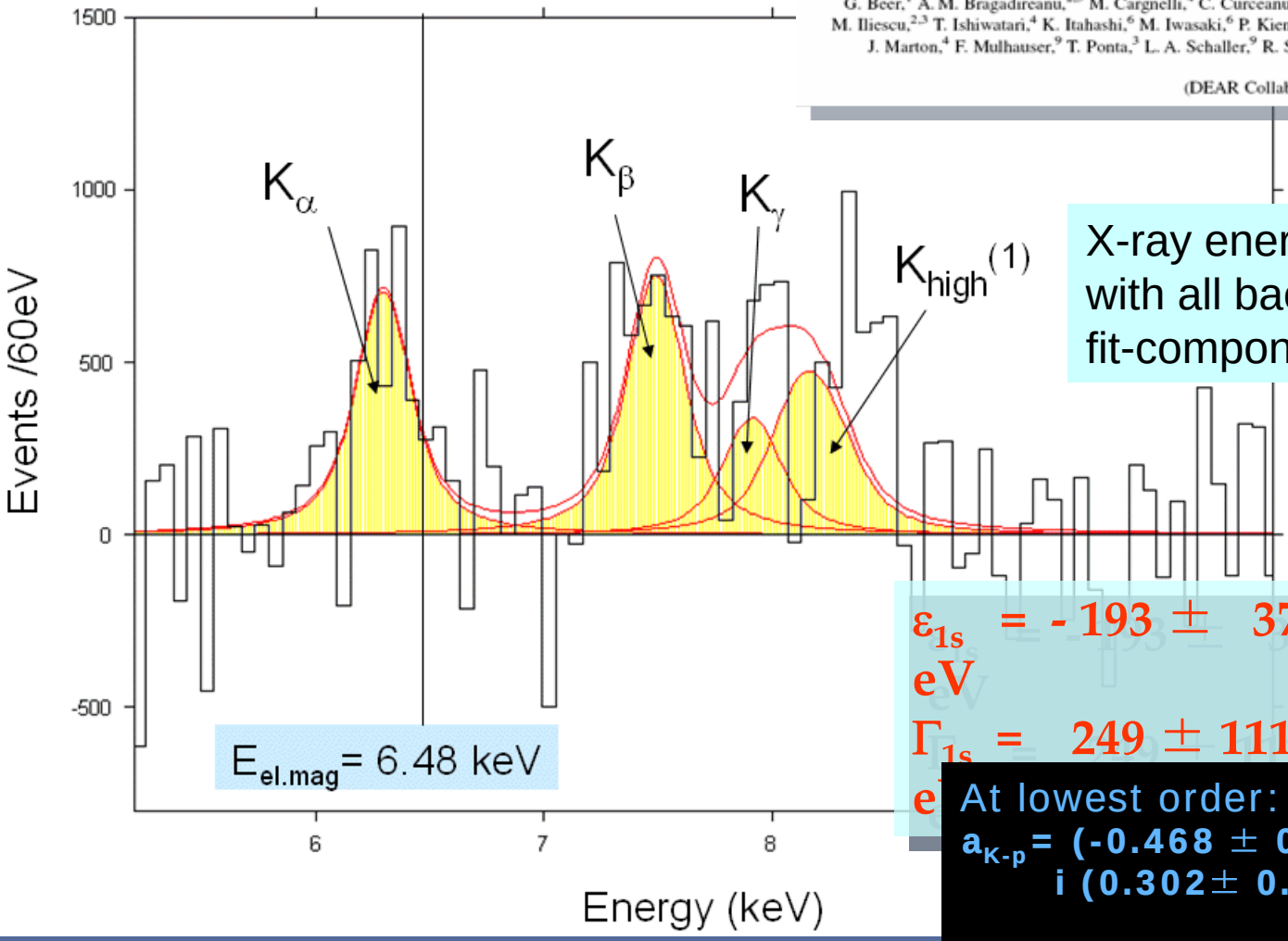
Kaonic hydrogen X-rays

PRL 94, 212302 (2005) PHYSICAL REVIEW LETTERS week ending 3 JUNE 2005

Measurement of the Kaonic Hydrogen X-Ray Spectrum

G. Beer,[1] A. M. Bragadireanu,[2,3] M. Cargnelli,[4] C. Curceanu-Petrascu,[2] J.-P. Egger,[5] H. Fuhrmann,[4] C. Guaraldo,[2] M. Iliescu,[2,3] T. Ishiwatari,[4] K. Itahashi,[6] M. Iwasaki,[6] P. Kienle,[4,7] T. Koike,[6] B. Lauss,[8] V. Lucherini,[2] L. Ludhova,[9] J. Marton,[4] F. Mulhauser,[9] T. Ponta,[3] L. A. Schaller,[9] R. Seki,[10,11] D.L. Sirghi,[2,3] F. Sirghi,[2] and J. Zmeskal[4]

(DEAR Collaboration)



X-ray energy spectrum with all background fit-components subtracted

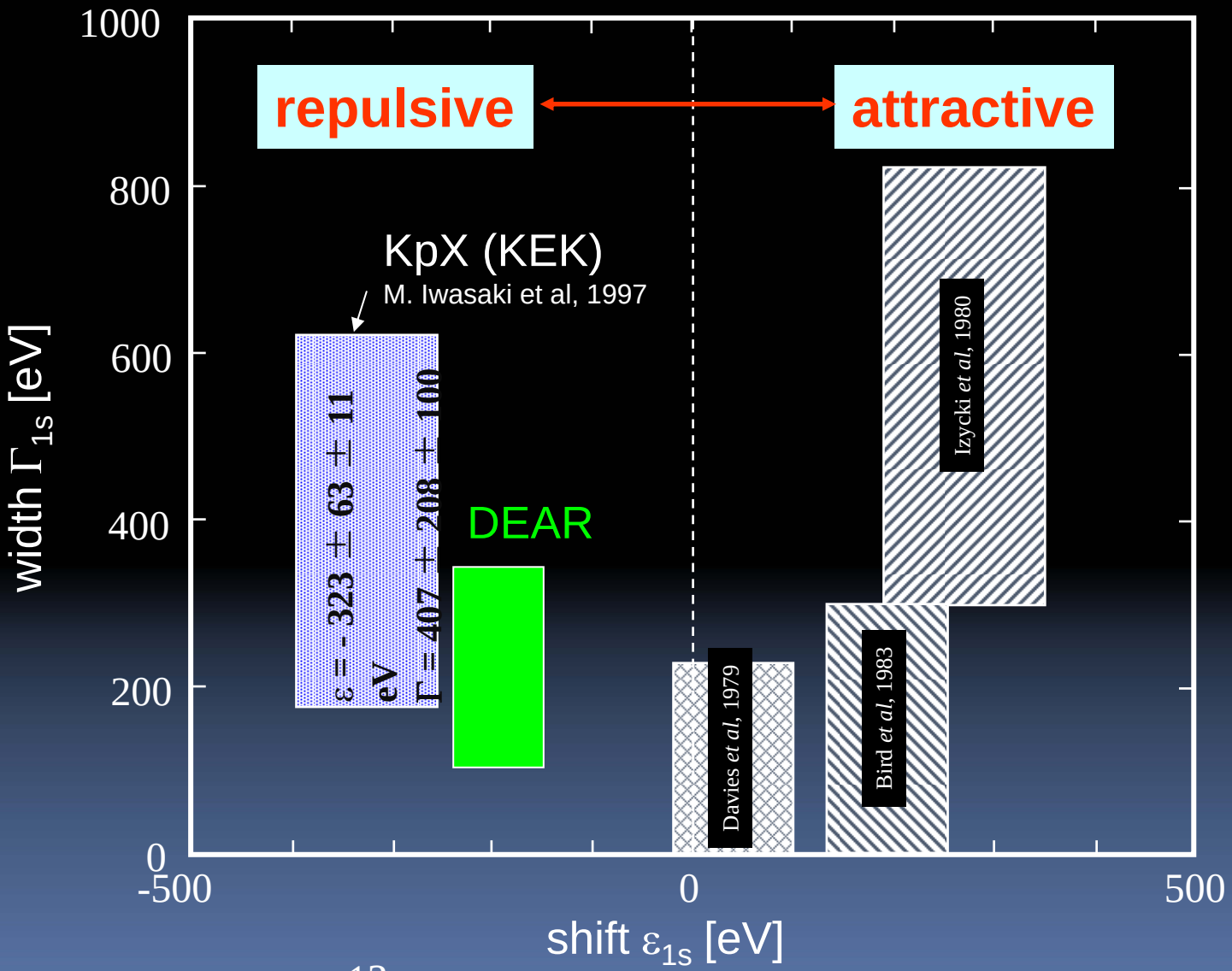
ε_{1s} = - 193 ± 37 (stat.) ± 6 (syst.) eV

Γ_{1s} = 249 ± 111 (stat.) ± 30 (syst.) e

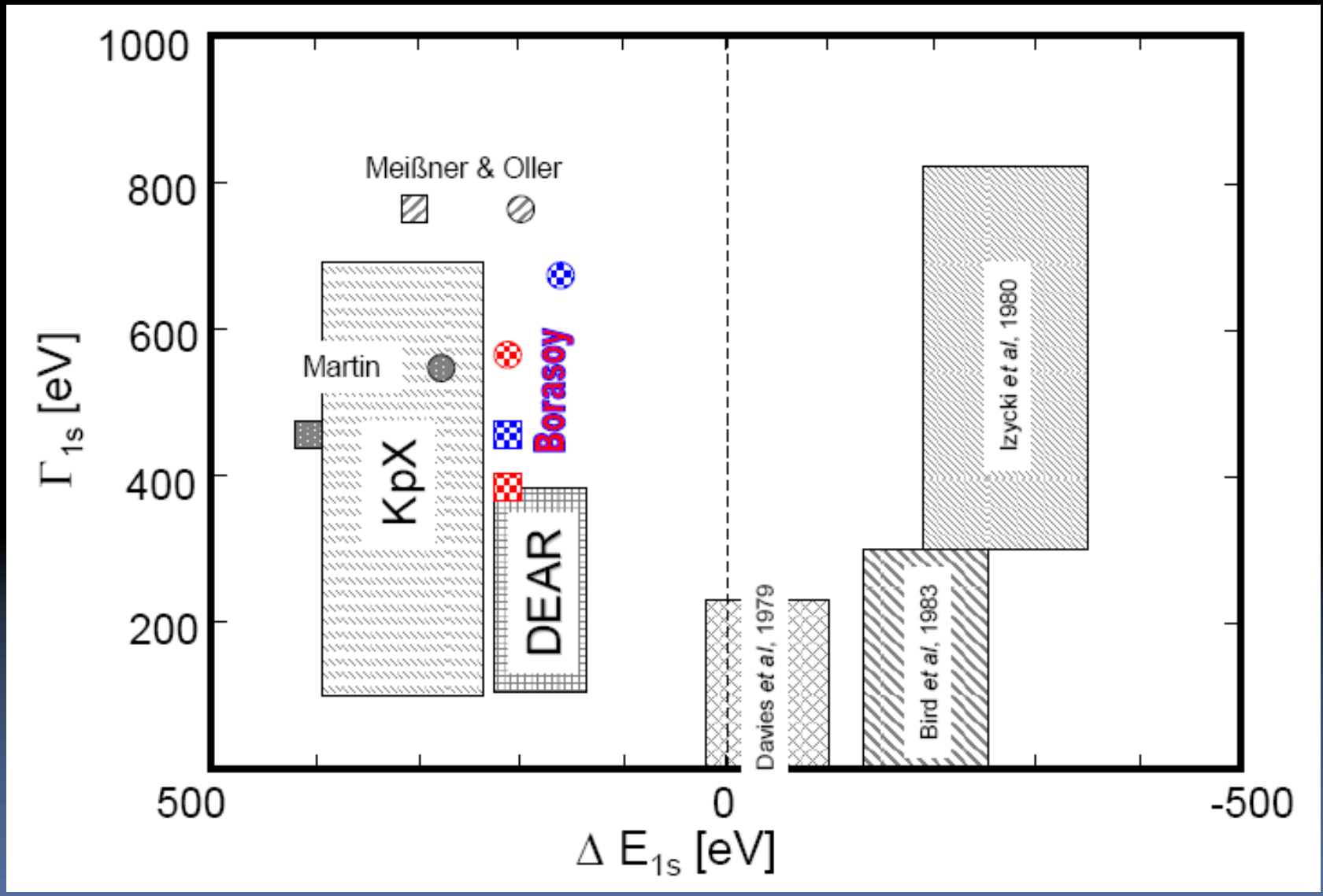
At lowest order:

$a_{K\text{-}p}$ = (-0.468 ± 0.090stat± 0.015syst) + i (0.302± 0.135stat± 0.036syst) fm

DEAR result

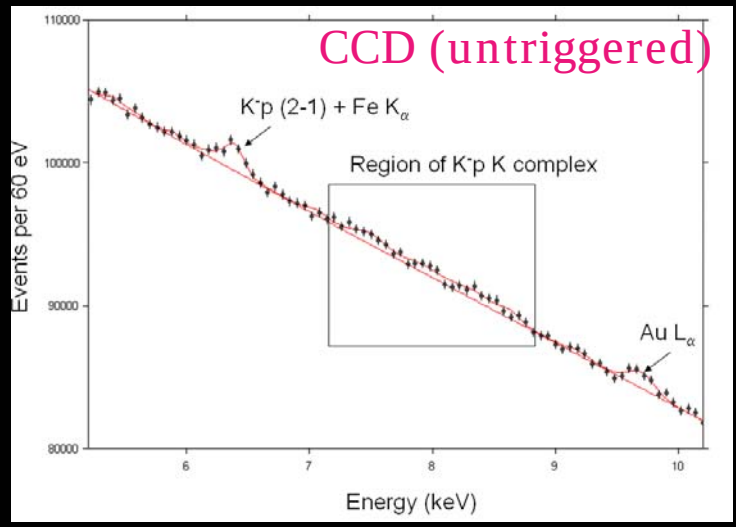

repulsive
attractive
KpX (KEK)
M. Iwasaki et al, 1997
ε = - 323 ± 63 ± 11 eV
Γ = 407 ± 208 ± 100
DEAR
Izycki et al, 1980
Davies et al, 1979
Bird et al, 1983
width Γ1s [eV]
shift ε1s [eV]
1000
800
600
400
200
0
-500
0
500

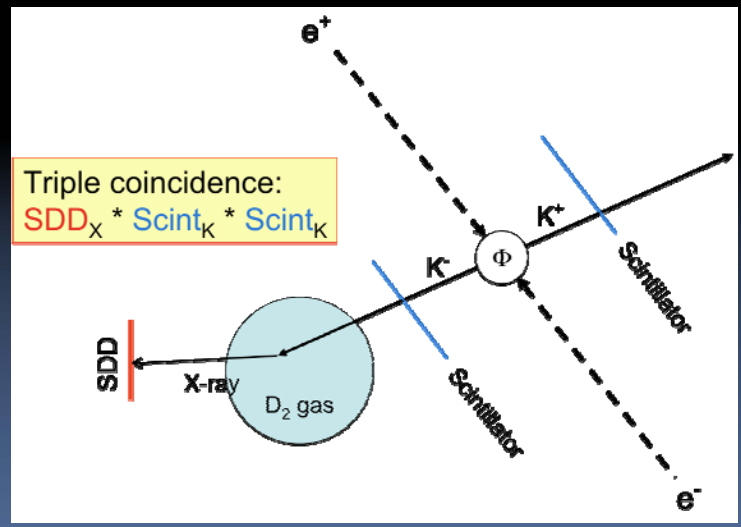
Comparison with theory



Why SIDDHARTA

- Precision of the DEAR result limited by high X-ray background (S/B~1:70)
- Next step:
  background reduction by using kaon – X-ray time correlation;
  expected background suppression ~ 3 orders of magnitude → S/B ~ 10:1 for kaonic hydrogen)





SIDDHARTA

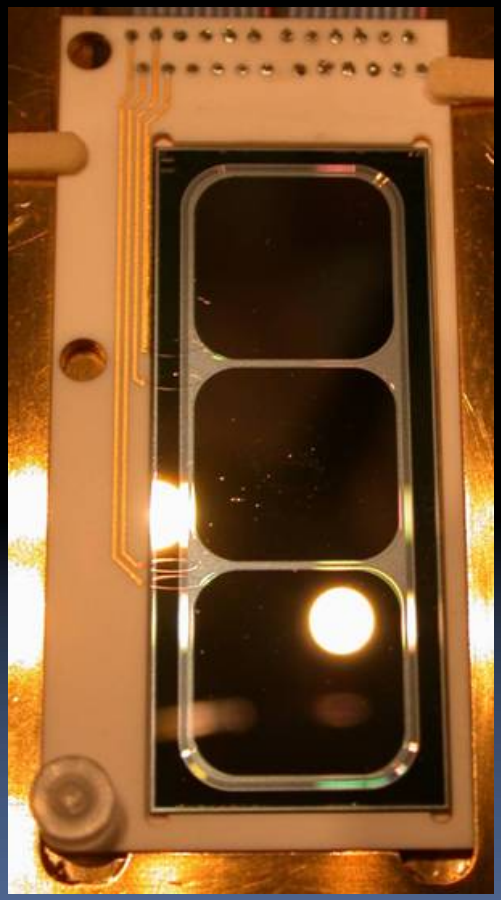
Goal: High precision X-ray spectroscopy using kaonic atoms

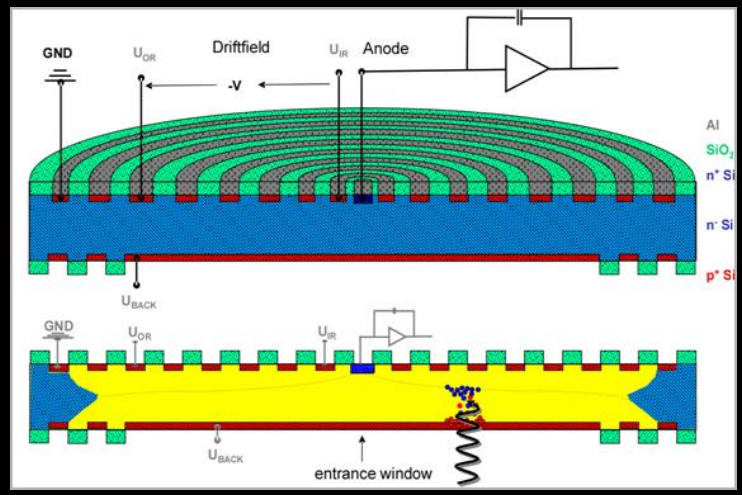
- improvement on kaonic hydrogen
- first measurement of kaonic deuterium
- Precise determination of kaonic helium (L-lines)

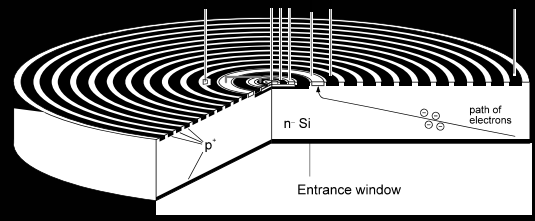
→ New X-ray detectors SDDs: JRA in I3HP (FP6)
cooperation of LNF, MPI-Halbleiterlabor, PNSensor, Politecnico Milano, IFIN-HH and SMI

- timing capability → background suppression by using the kaon - X ray time correlation
- excellent energy resolution
- high efficiency, large solid angle
- compact versatile design

Large Area SDDs





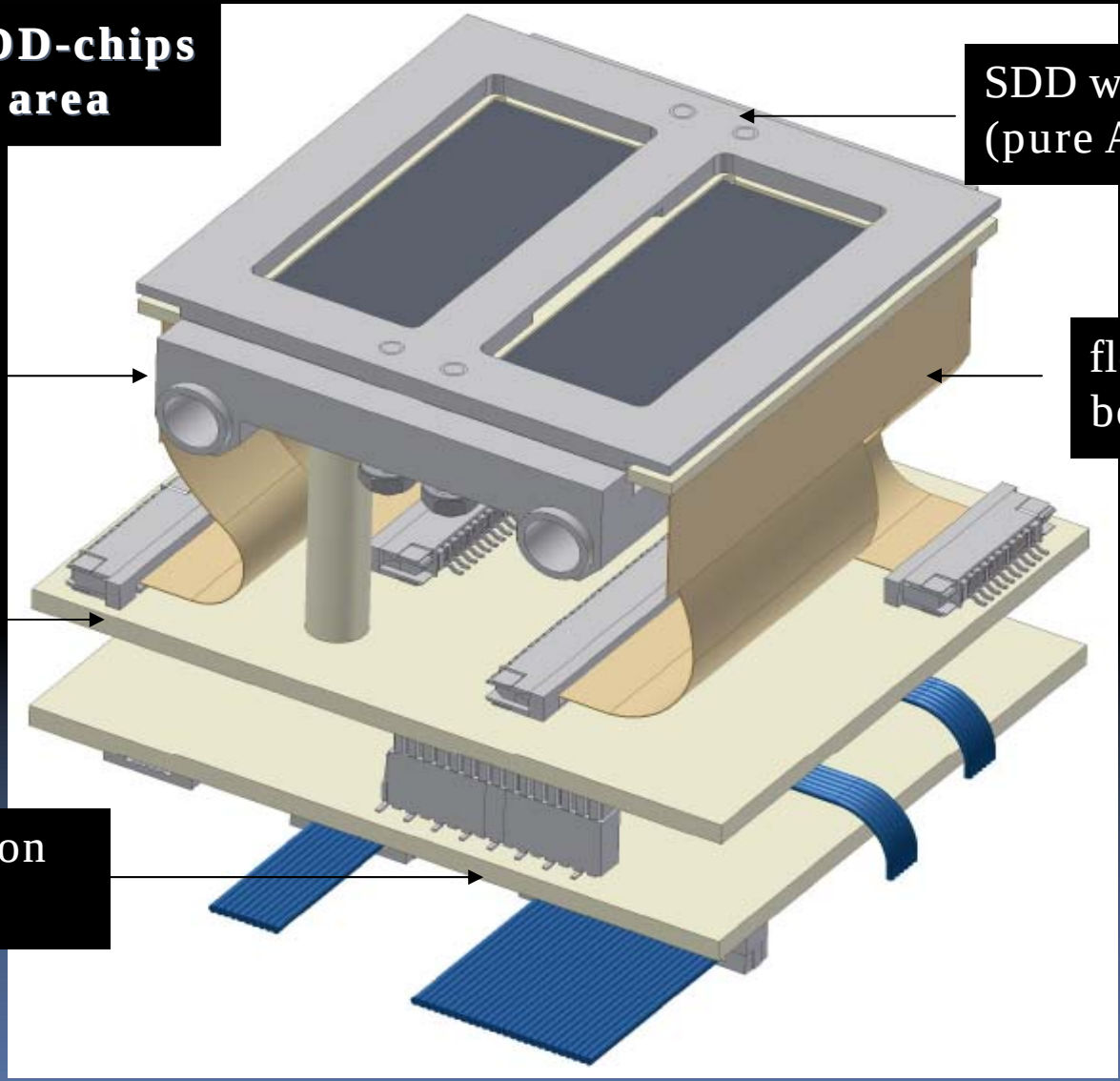


SDD with JFET

- SDD has small capacitance → low noise
- Good energy resolution (150 eV @ 6 keV) comparable with CCD
- and good timing capability ($\Delta t < 0.5$ μs)

SDD – Silicon Drift Detector

unit for 2 CDD-chips
6 cm² active area



SDD window frame (pure Al 99.999%)

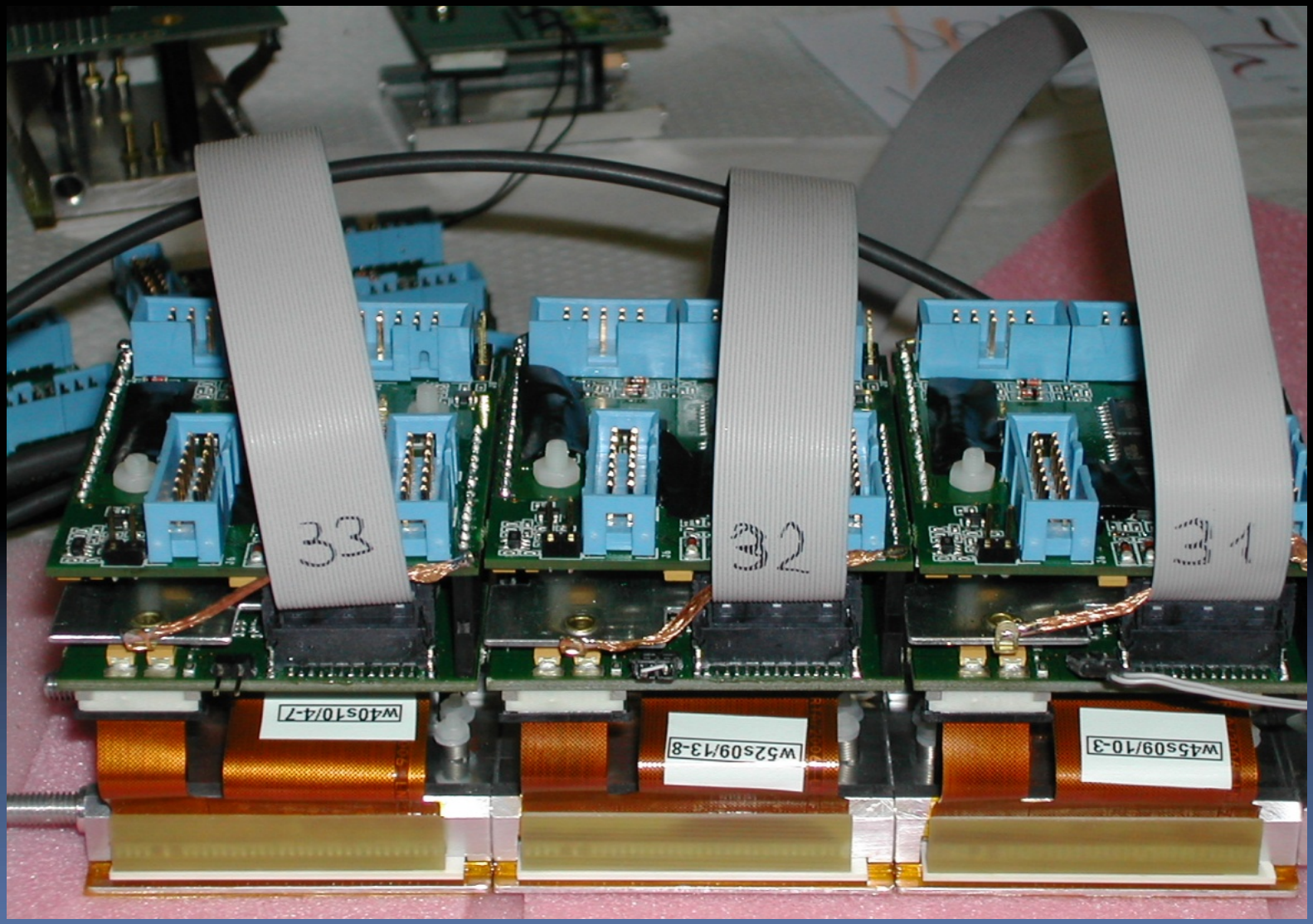
cooling back-plane

flexible Kapton boards

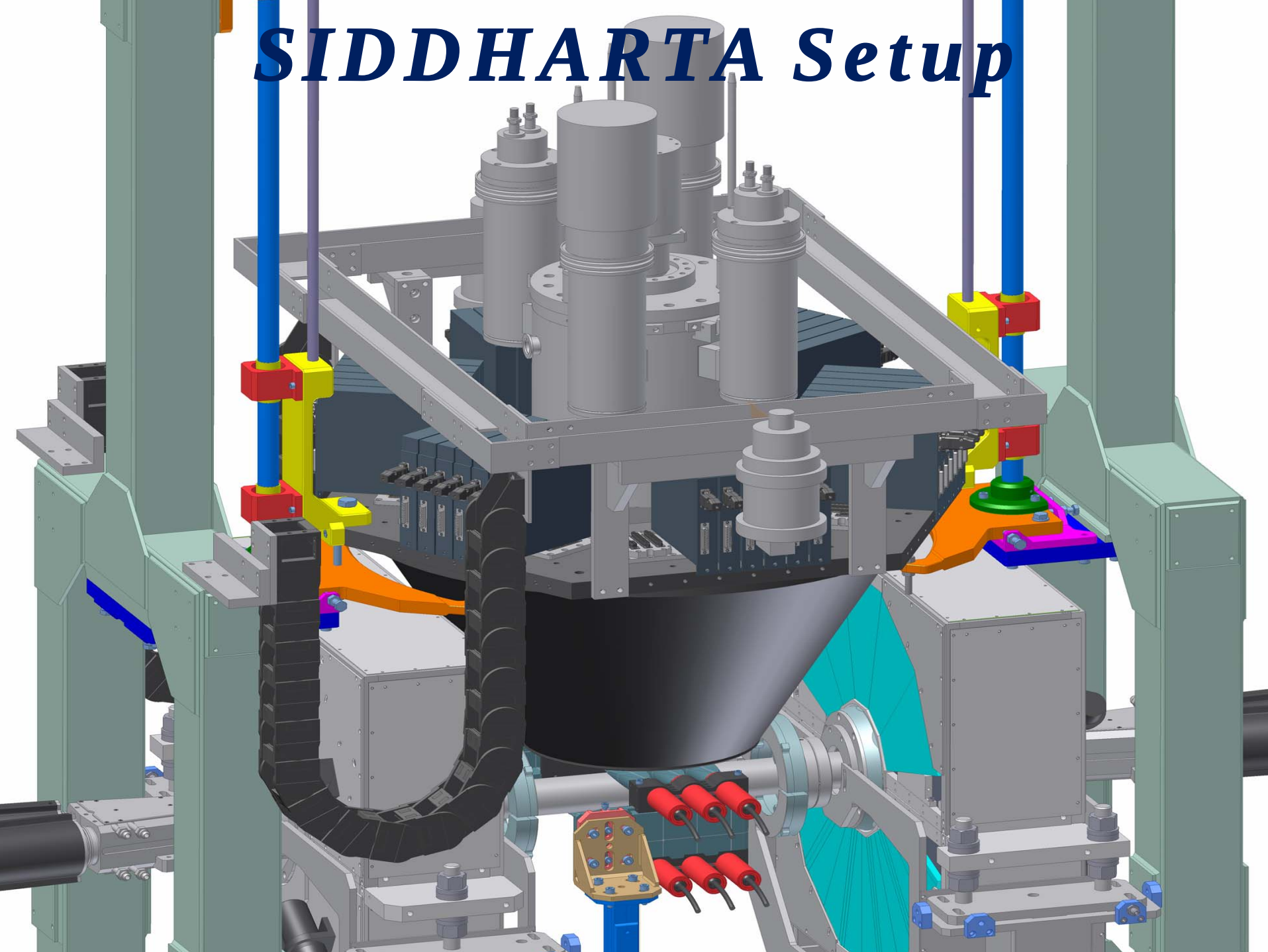
pre-amplifier board

HV+LV distribution board

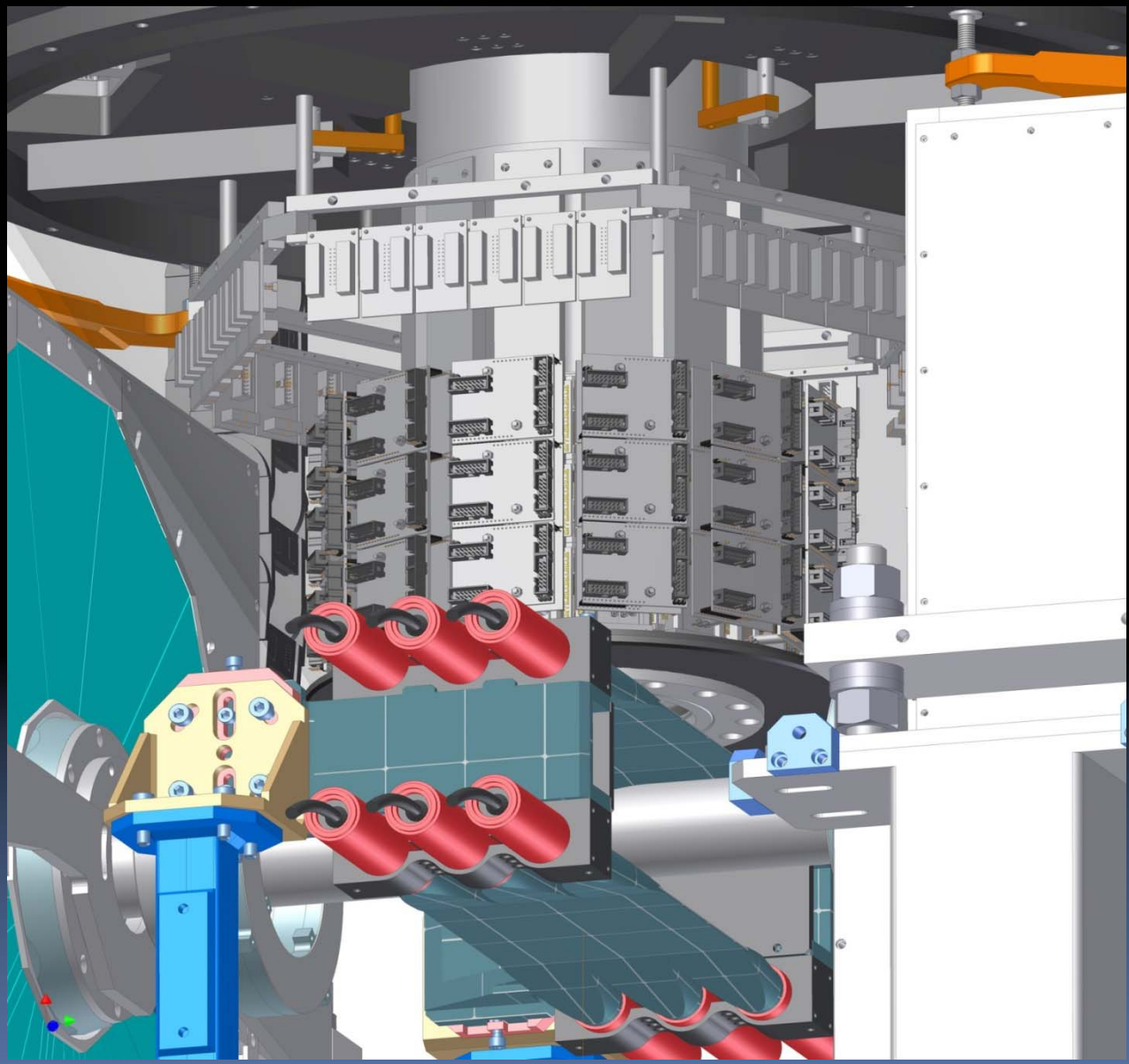
SDD sub-system



SIDDHARTA Setup

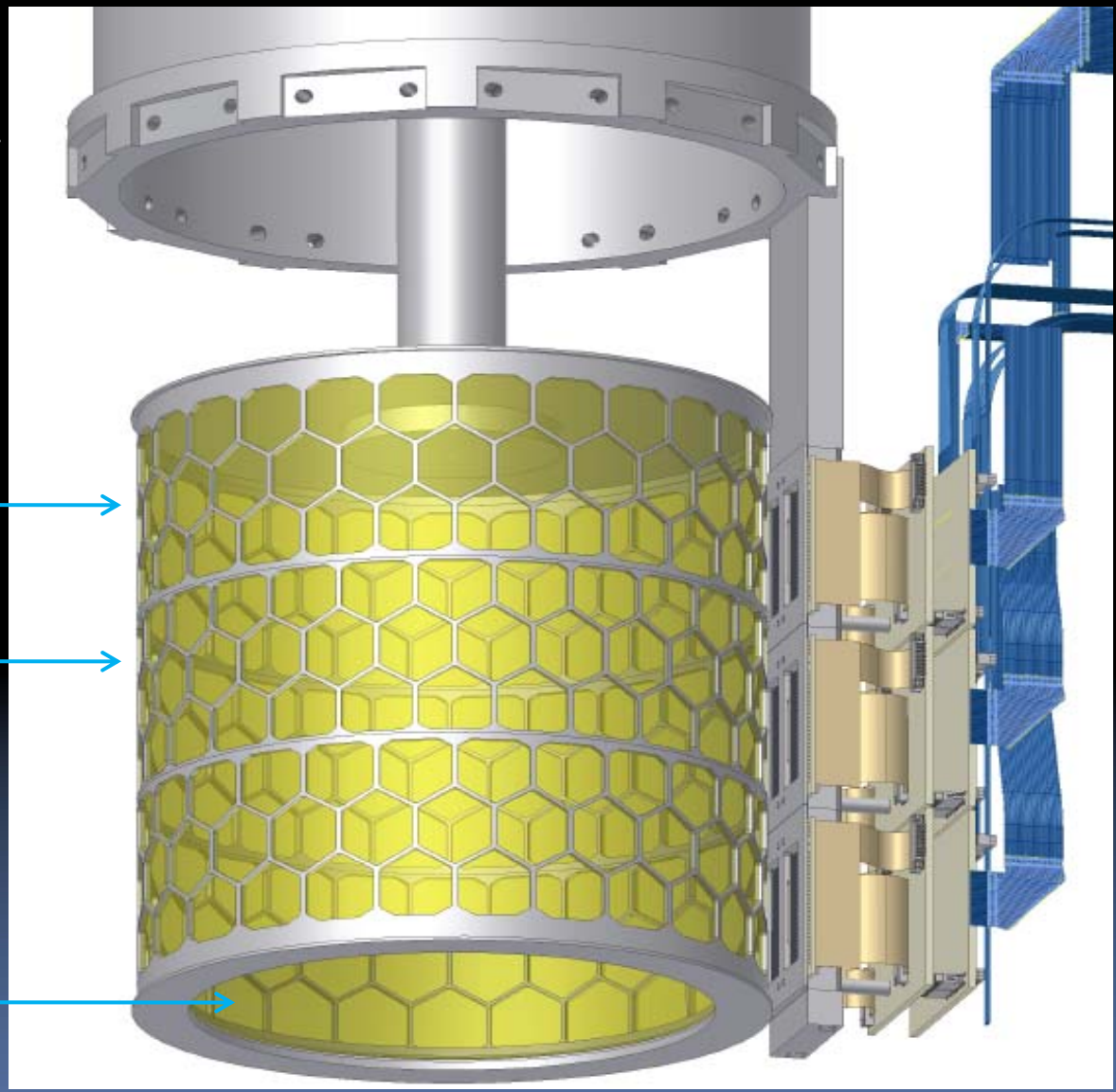


SIDDHARTA Setup - Inside



Cryogenic target cell

Working T 22 K
Working P 2.5 bar

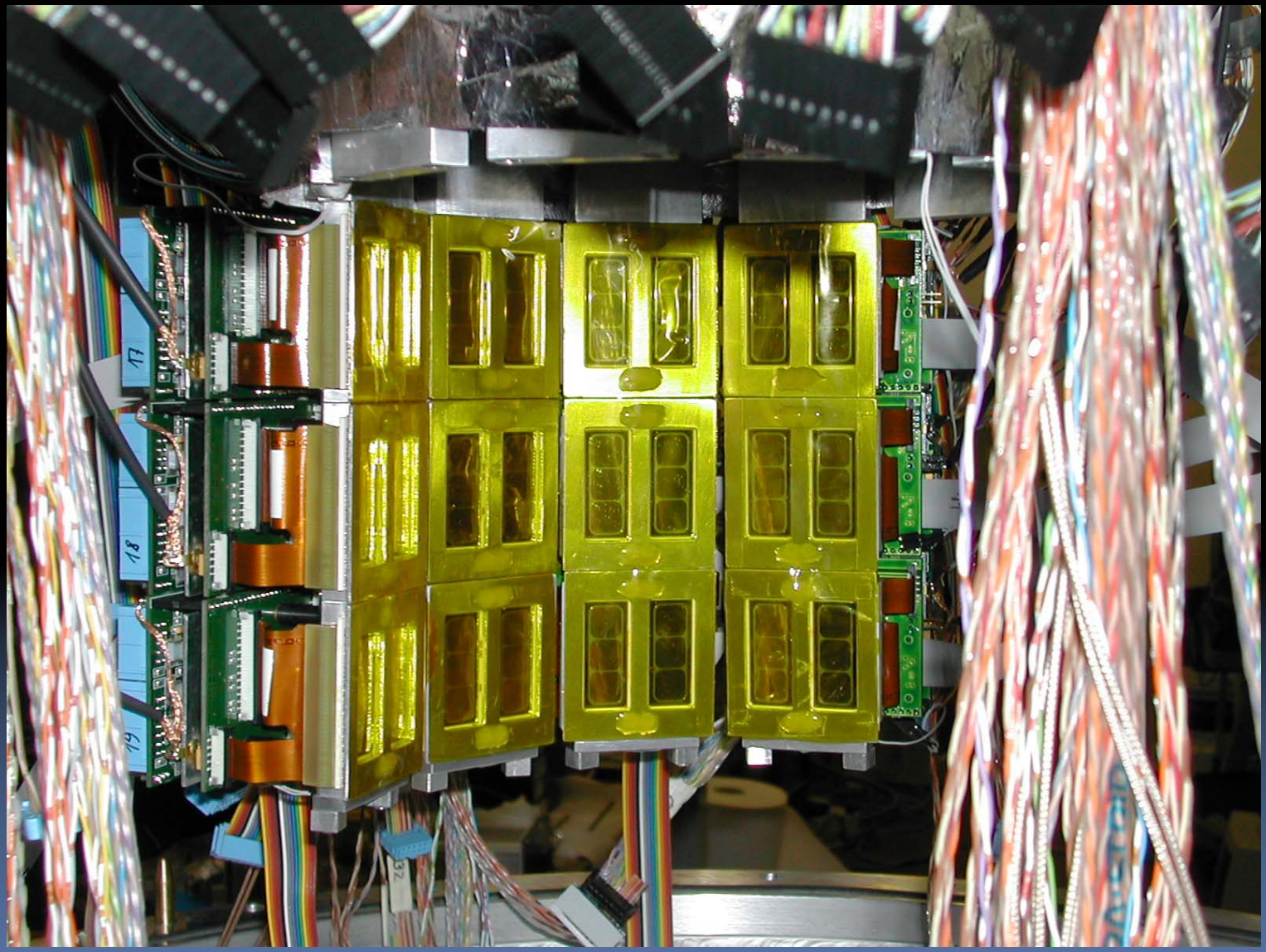


Alu-grid

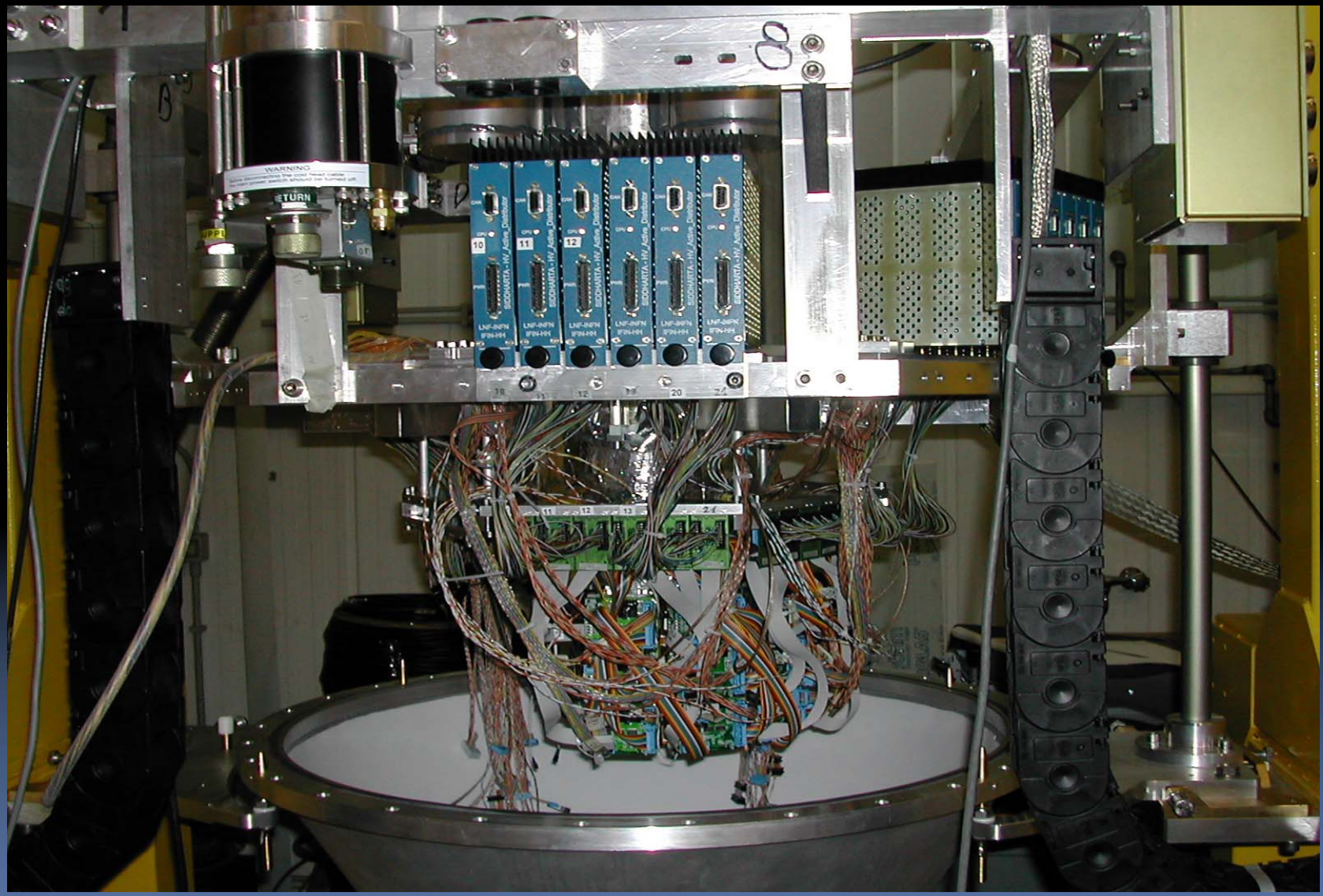
Side wall:
Kapton 50 μm

Kaon entrance
Window:
Kapton 50 μm

Assembly of SDDs

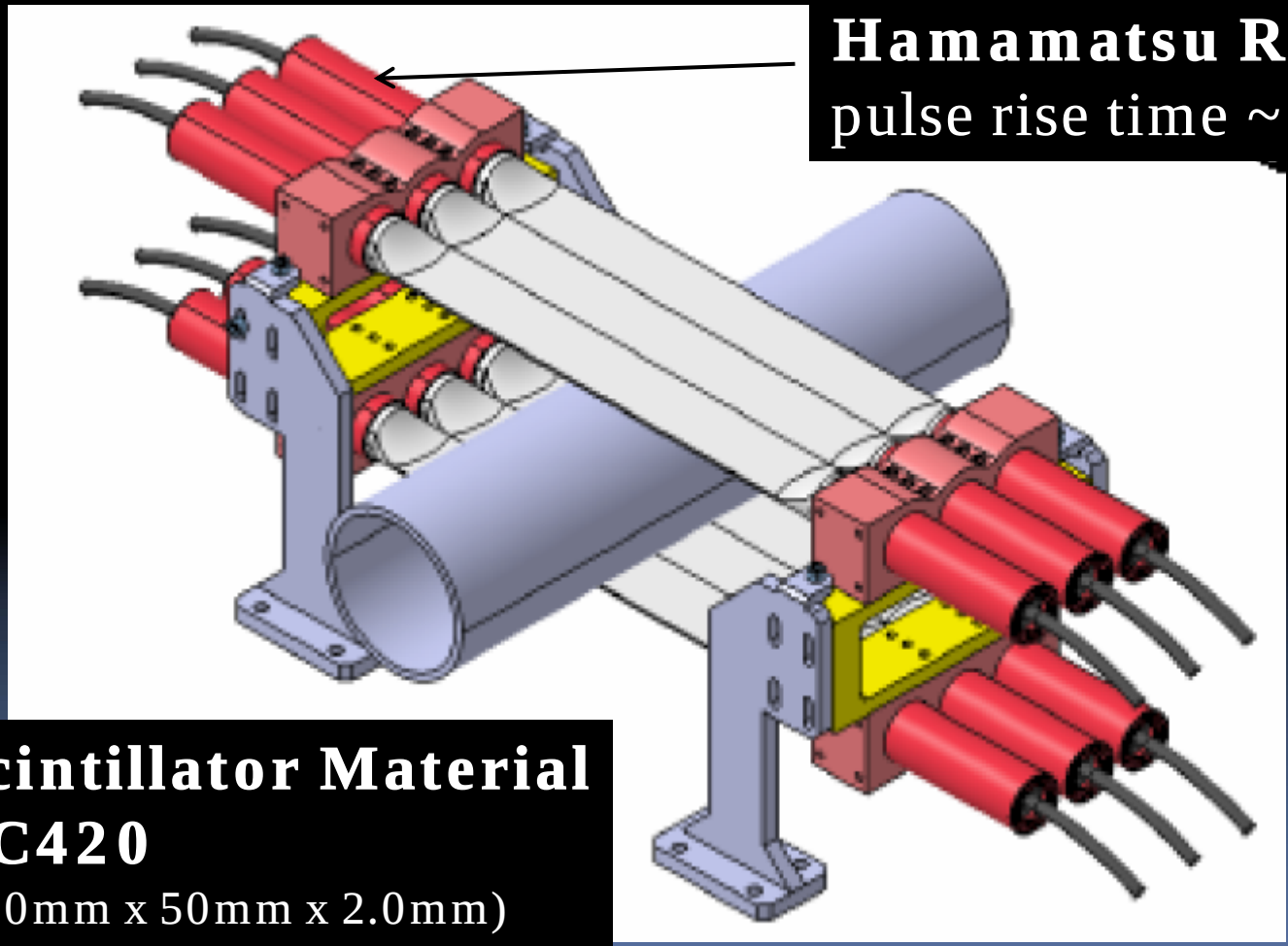


Assembly of SIDDHARTA



Kaon trigger

- Kaon trigger installed at interaction region
- Kaon trigger used as luminosity monitor

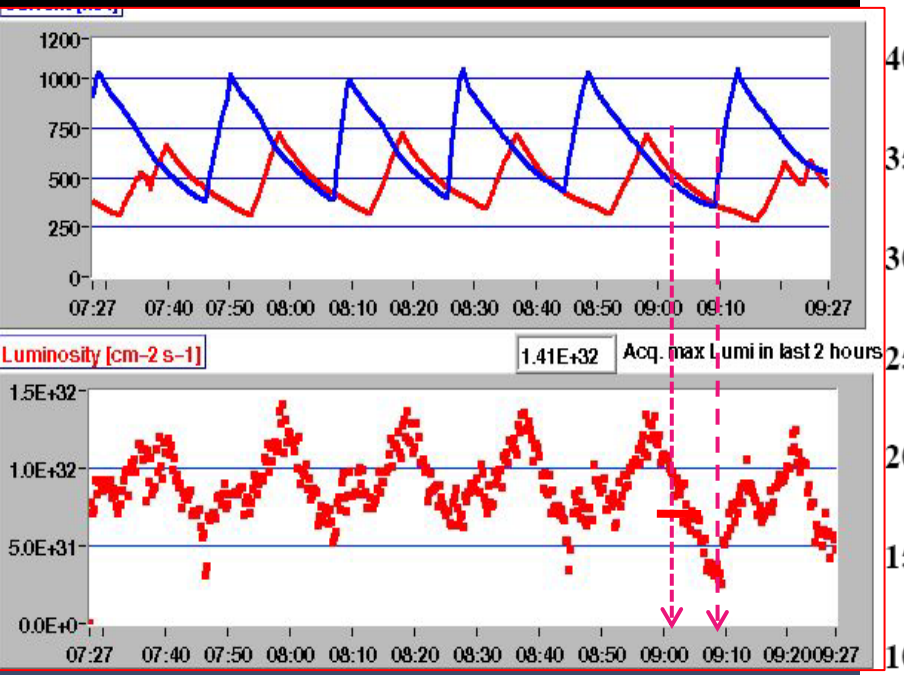


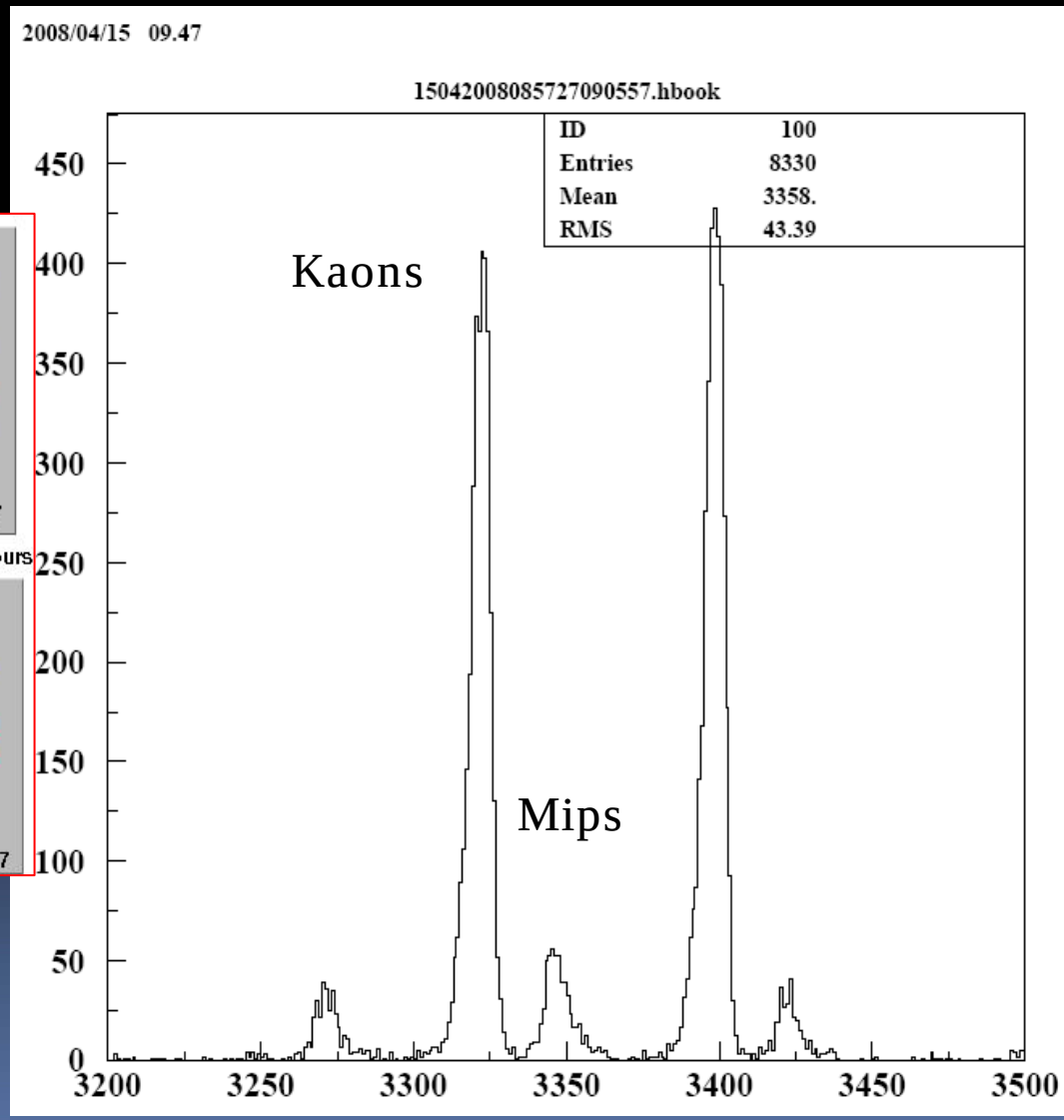
Hamamatsu R4998
pulse rise time ~ 0.7 ns

Scintillator Material
BC420
(150mm x 50mm x 2.0mm)

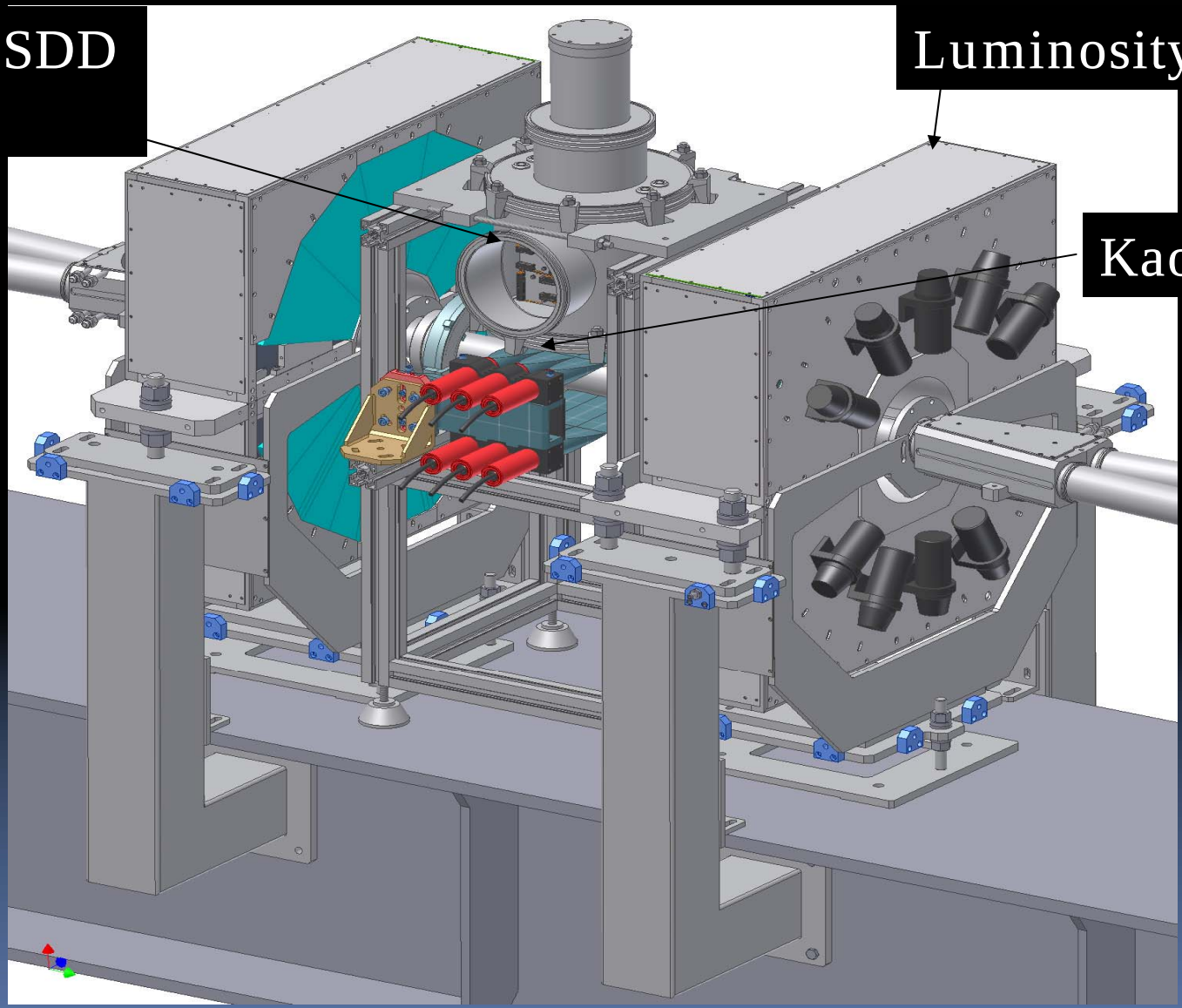
Kaon trigger

April 15, 2008
Kaons/mips ~ 8:1

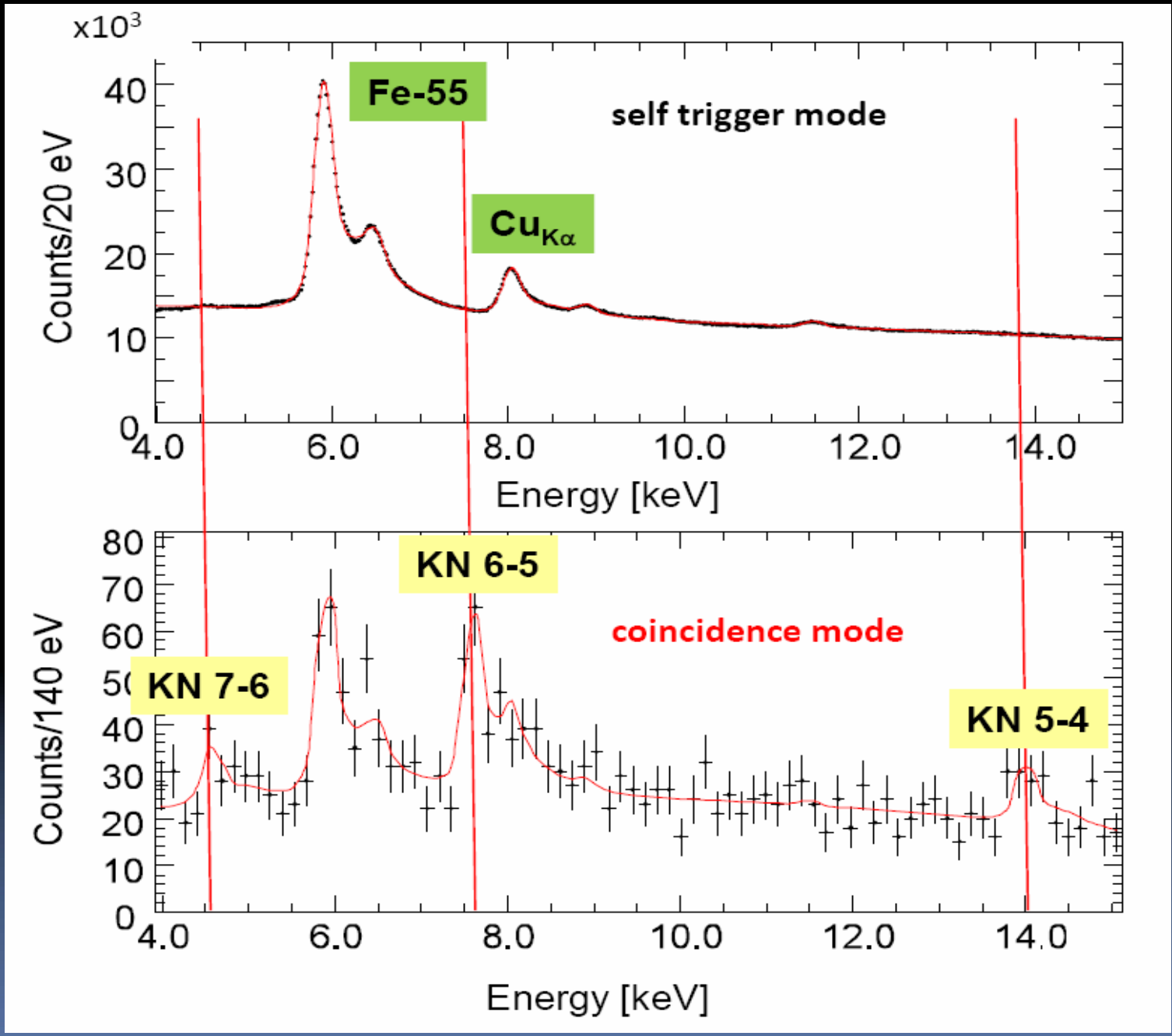




Day-One setup

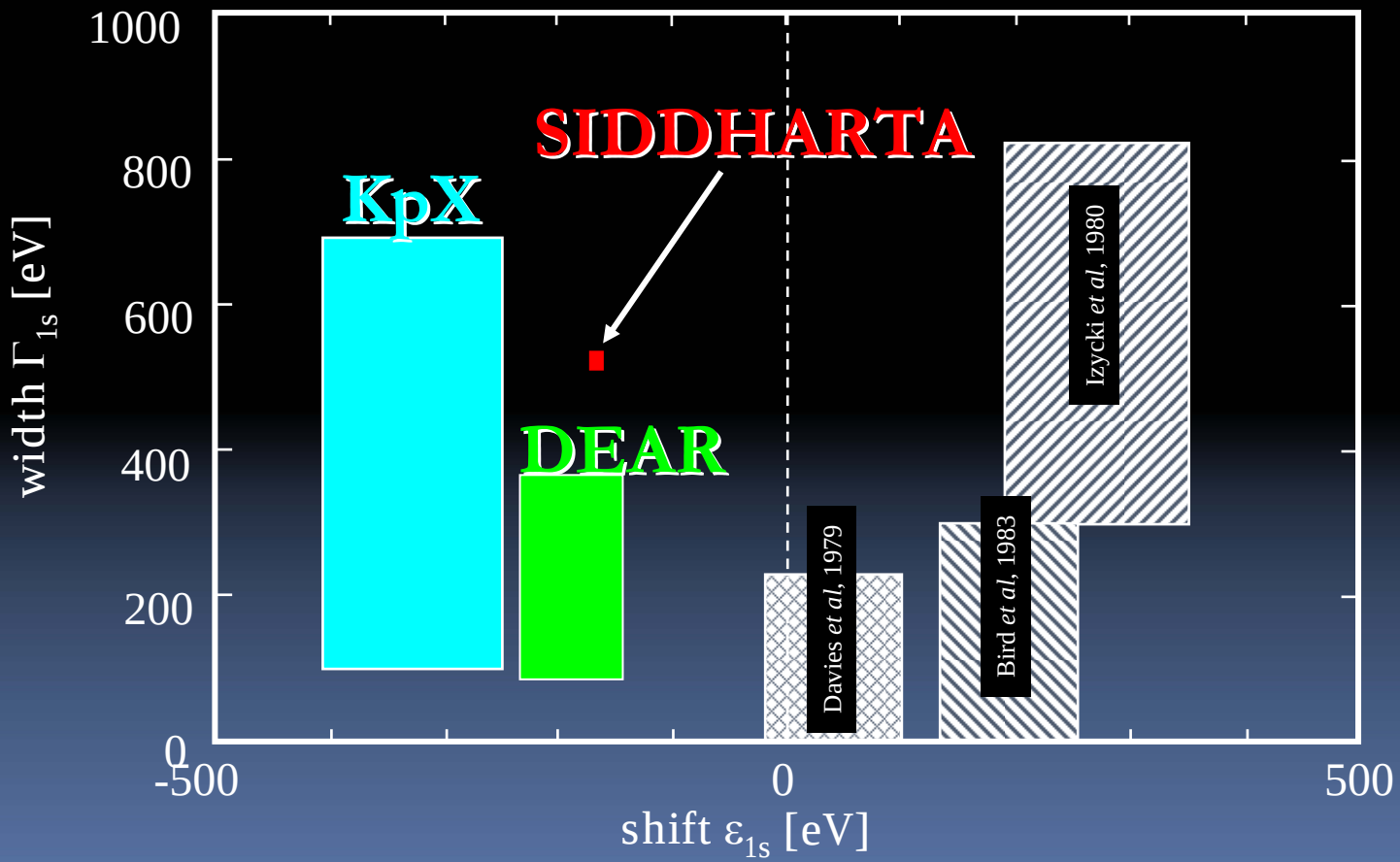


First kaonic nitrogen lines

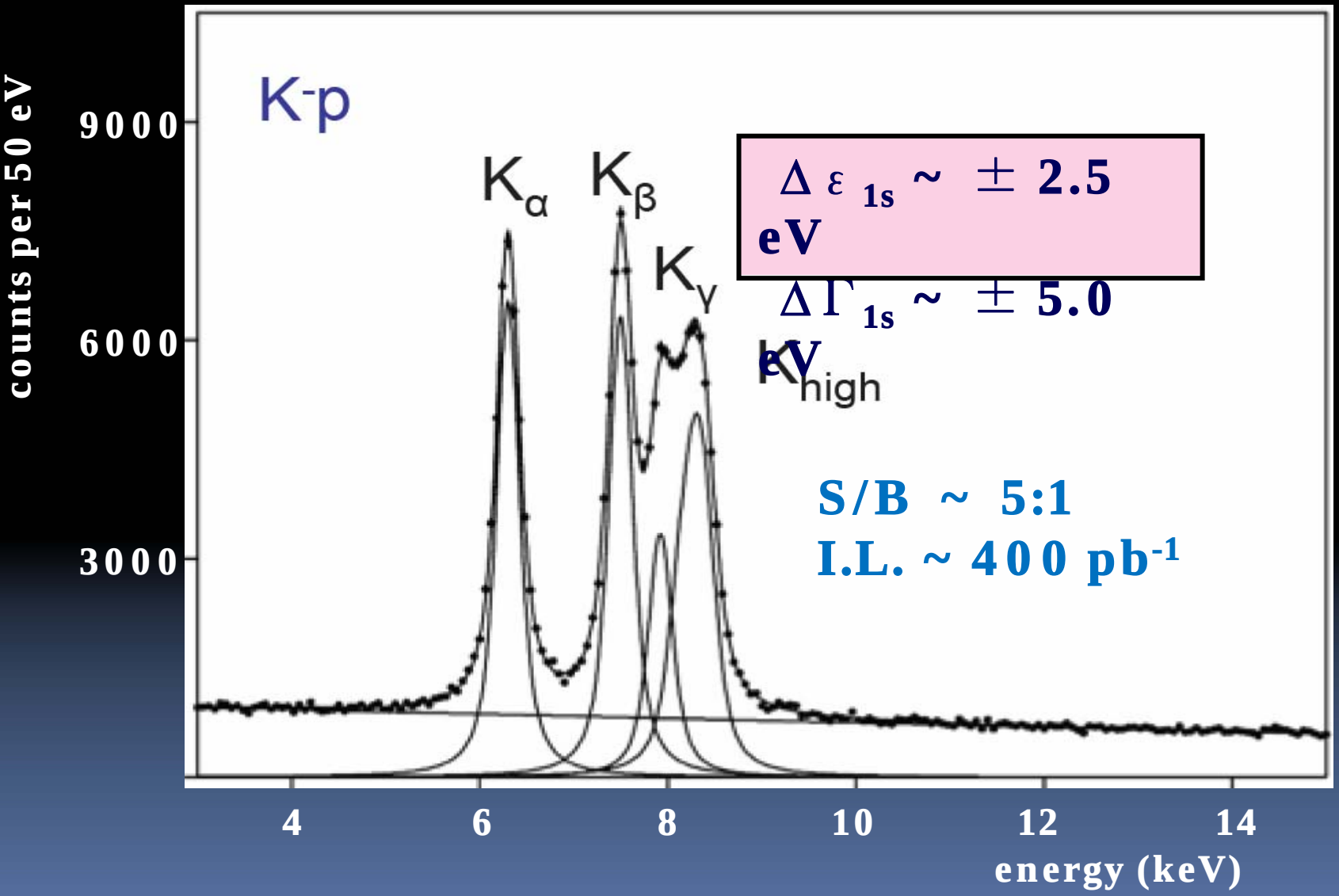


SIDDHARTA Programme

- **Measurement of strong interaction induced shift and width of kaonic hydrogen with an accuracy of a few eV and a first measurement of kaonic deuterium.**

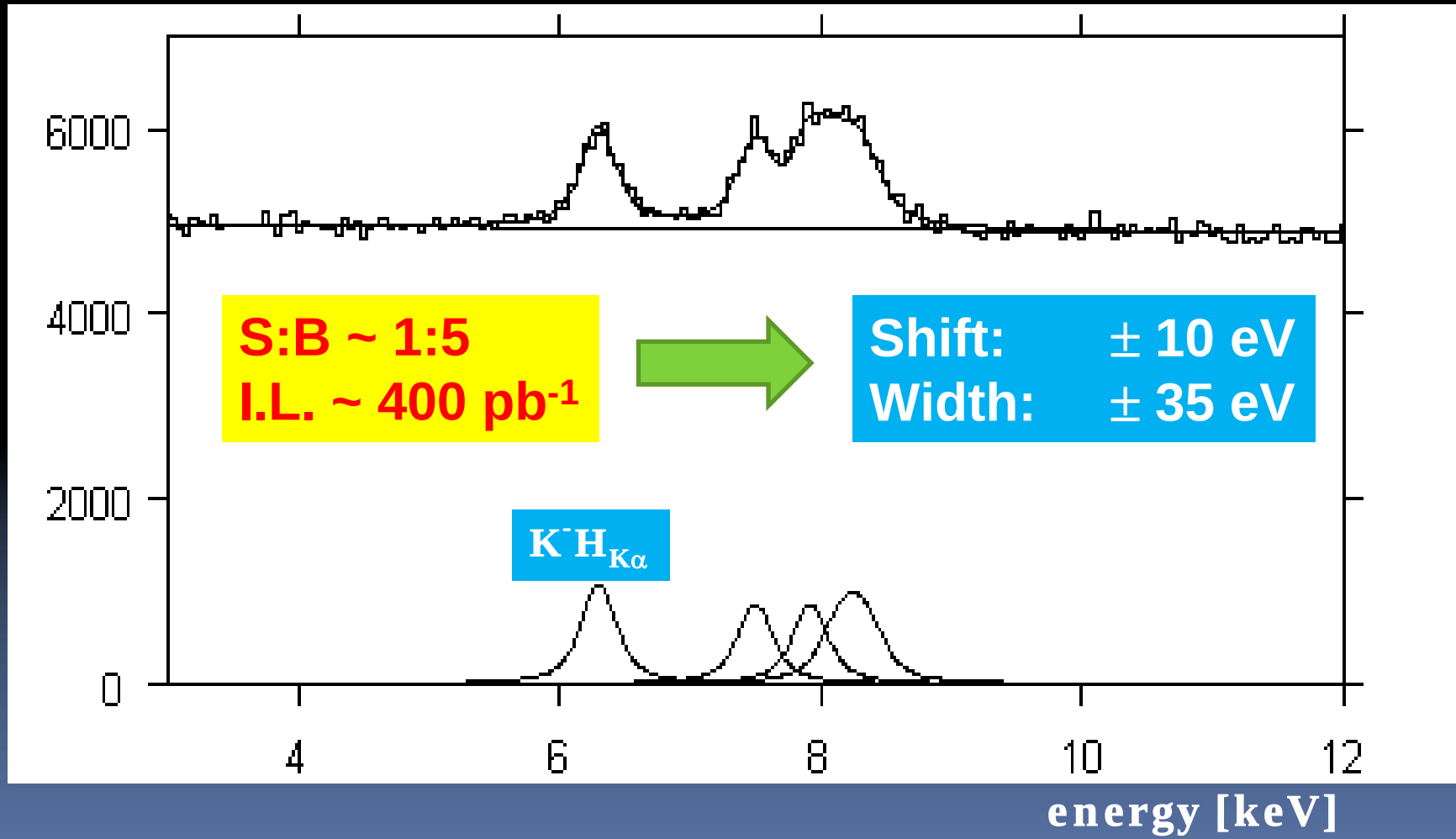


MC of kaonic hydrogen



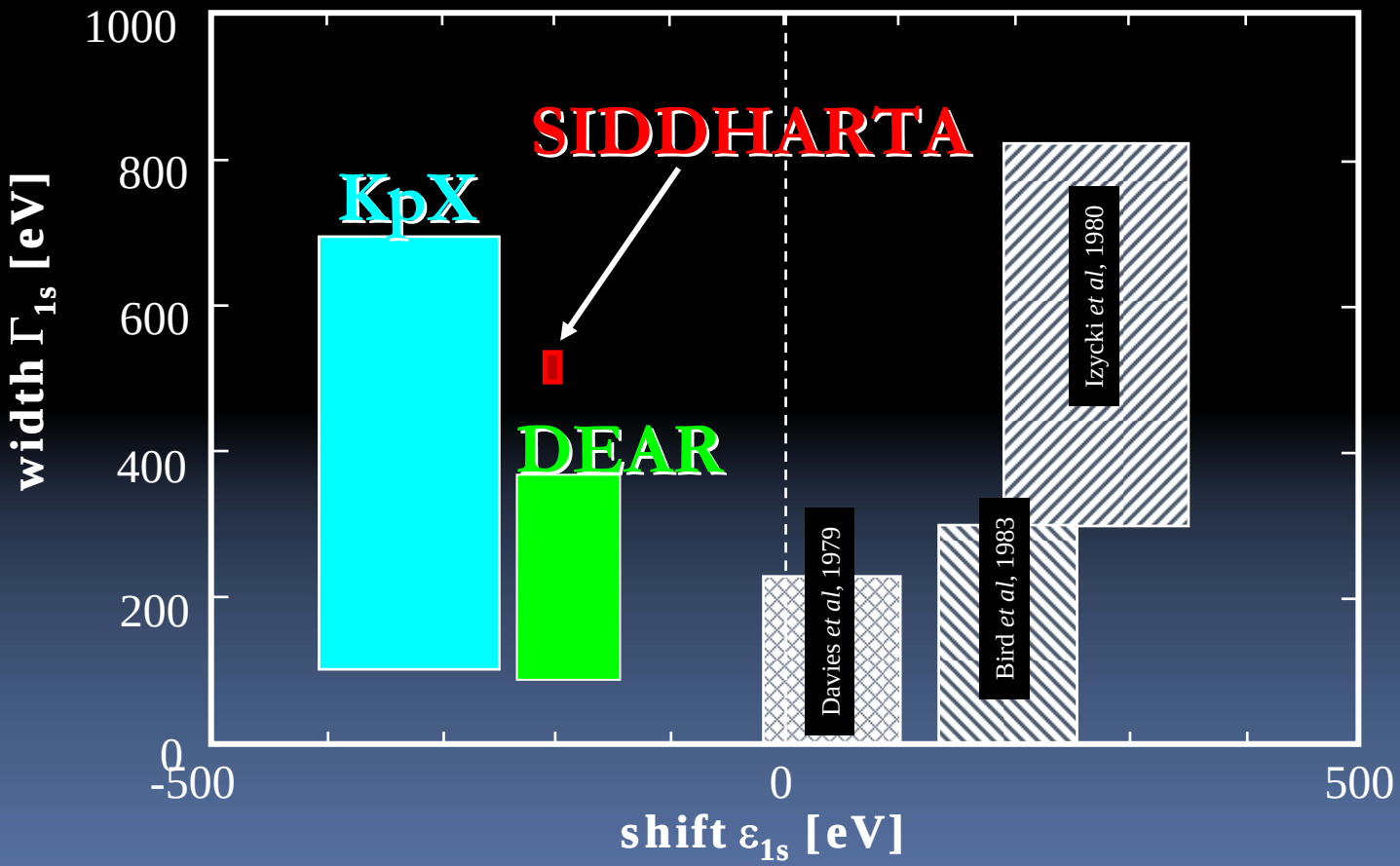
MC of kaonic hydrogen

background situation today



SIDDHARTA result

- Kaonic hydrogen with Day-One BG conditions
  - error in shift ~ ± 10 eV
  - error in width ~ ± 35 eV



Conclusions

- **Day-one setup successfully running**
  First test of SDDs under beam conditions
  background tests performed
- **Final setup to be installed begin of June**
  with improved shielding
  under improved stable beam conditions
- **Kaonic hydrogen measurement possible**
- **Kaonic deuterium measurement needs further improvements**
  further optimization of the beam optic
  improved vacuum condition (to reduce beam gas interaction)
  additional shielding