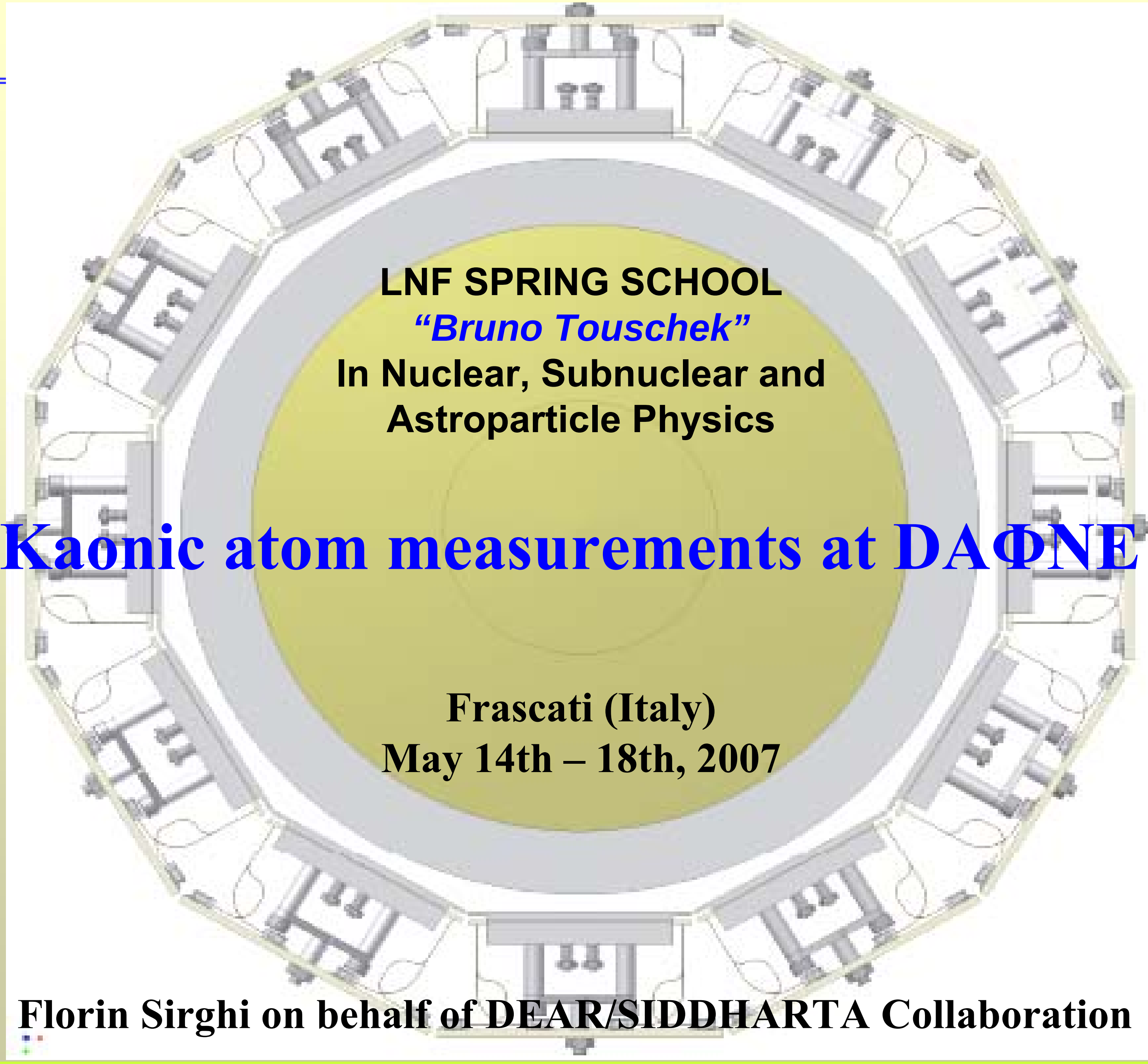


LNF SPRING SCHOOL

“Bruno Touschek”

In Nuclear, Subnuclear and Astroparticle Physics

Kaonic atom measurements at DAΦNE

Frascati (Italy)

May 14th – 18th, 2007

Florin Sirghi on behalf of DEAR/SIDDHARTA Collaboration

SIDDHARTA

***SI**licon **D**rift **D**etector for **H**adronic **A**tom **R**esearch*
*by **T**iming **A**pplications*

represents the natural development, from scientific and technical point of view, of the

DEAR

DAFNE Exotic Atom Research

along the line of research dedicated to exotic atoms at DAFNE

DEAR/SIDDHARTA Collaboration

LNF- INFN, Frascati, Italy

Politecnico, Milano, Italy

Stefan Meyer Institut, Vienna, Austria

IFIN–HH, Bucharest, Romania

Univ. Tokyo, Japan

RIKEN, Japan

Victoria University, Canada

PNSensor GmbH, Munich, Germany

Max-Planck-Institute for Extraterrestrial Physics, Garching, Germany

The scientific aim

the determination of the ***isospin dependent***
$\bar{K}N$ scattering lengths through a

~ eV measurement of the shift
and *of the width*

of the K_α line of **kaonic hydrogen**

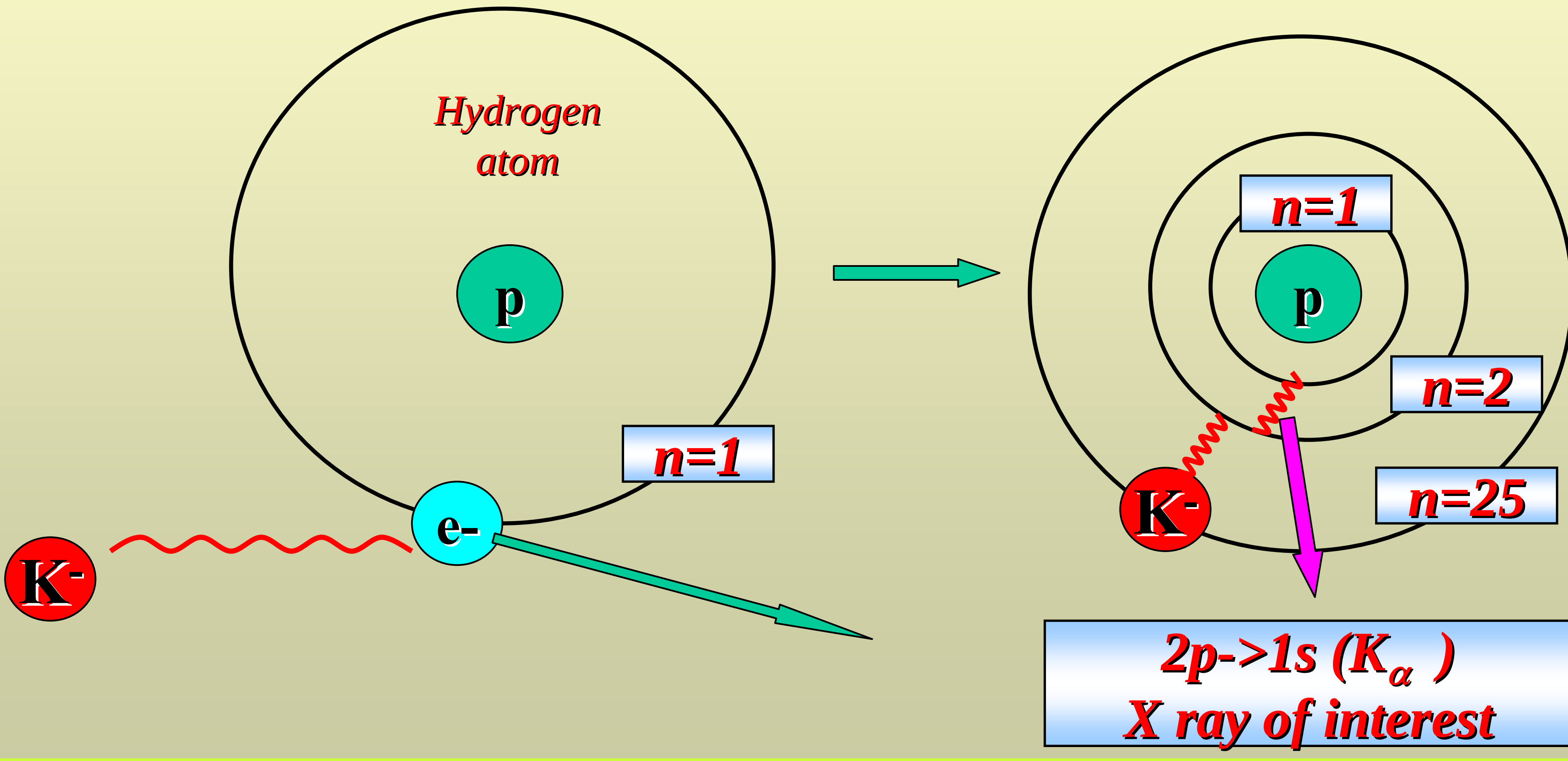
and

the *first (similar) measurement* of **kaonic deuterium**

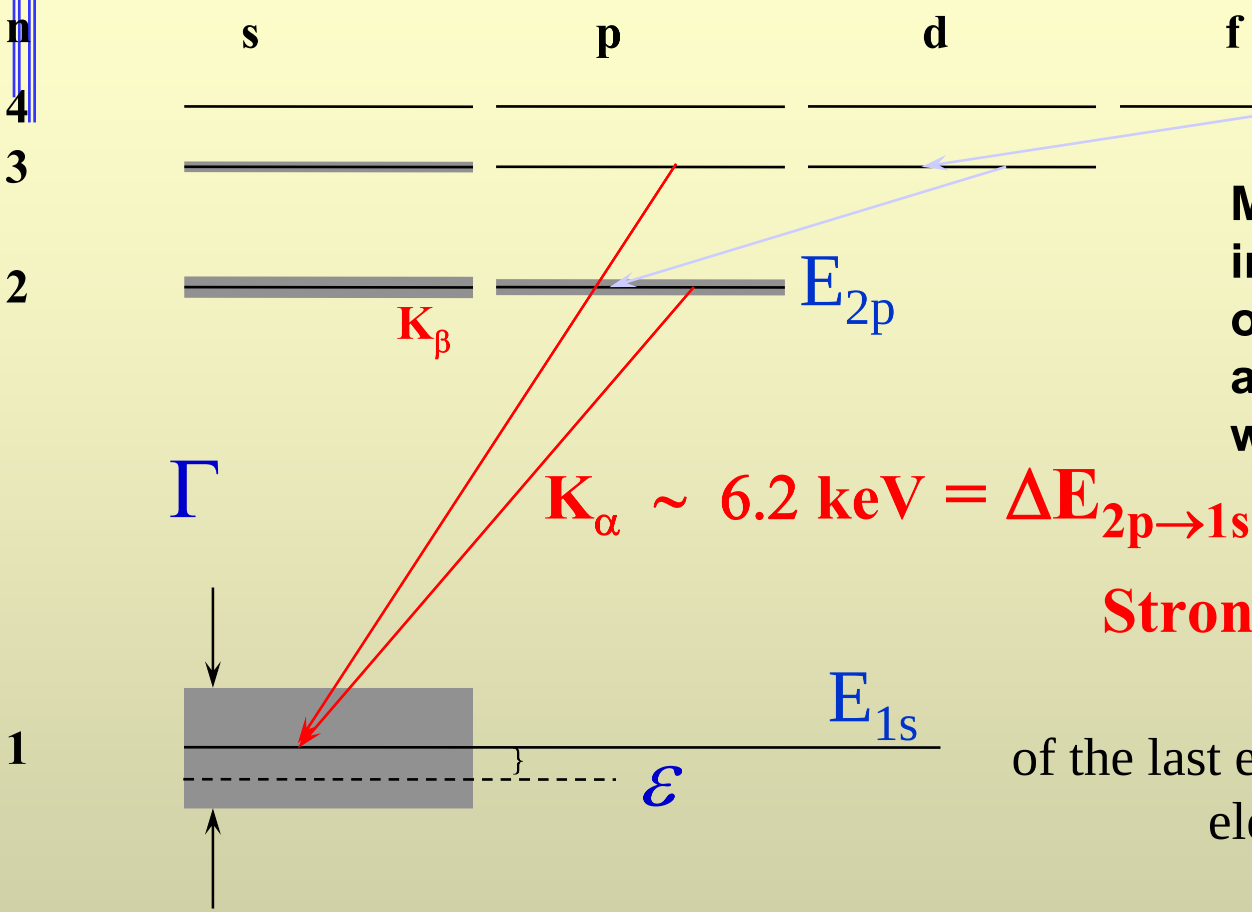
Exotic Atom

Hydrogen atom

Kaonic hydrogen



Kaonic cascade and the strong interaction



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

Strong Interaction causes:

energy shift ε

of the last energy levels form their purely electromagnetic values

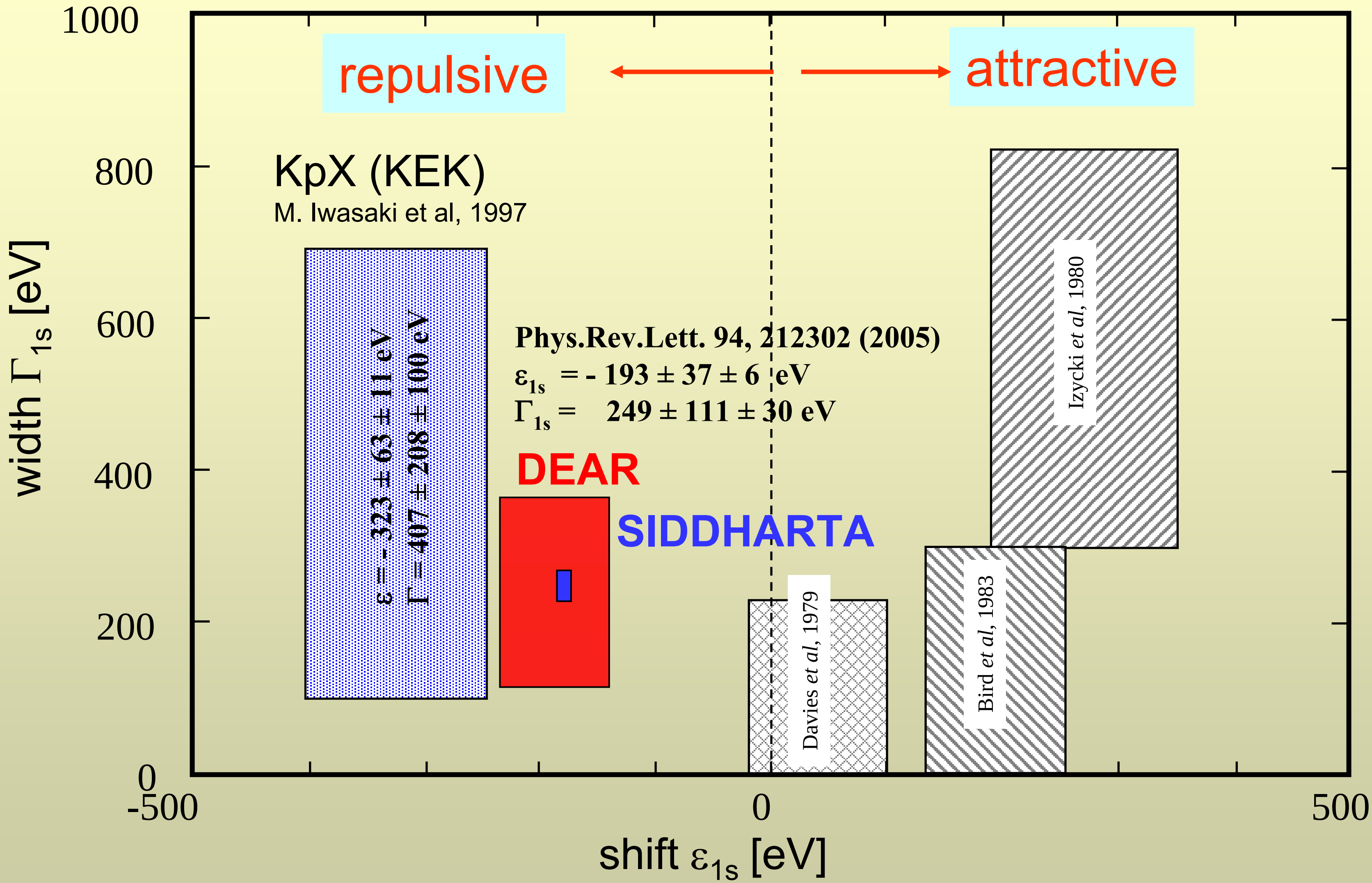
AND

level width Γ

finite lifetime of the state corresponding to an increase in the observed level width

$$\varepsilon = E2p\text{-}1s(\text{meas.}) - E2p\text{-}1s(\text{e.m.})$$

Results on Kaonic Hydrogen

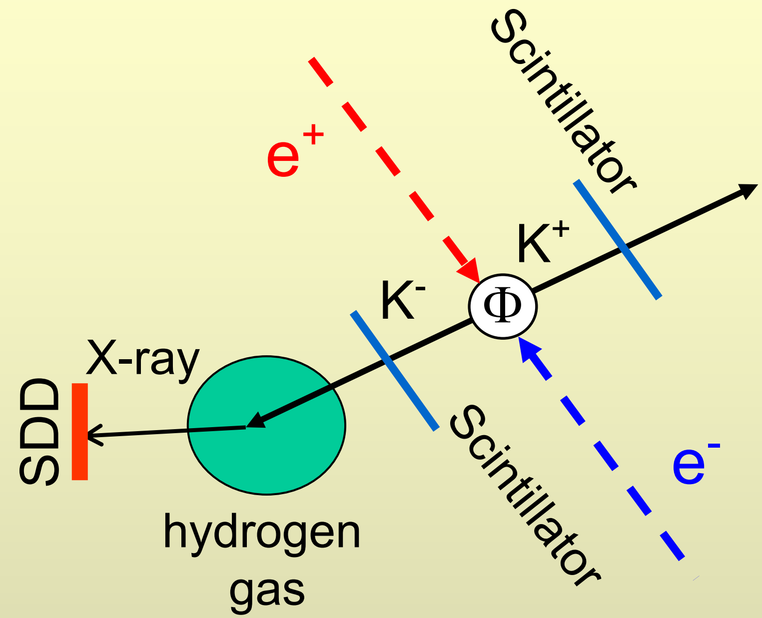


A strong motivation for the community working on the low-energy kaon-nucleon interactions

Experimental requirements

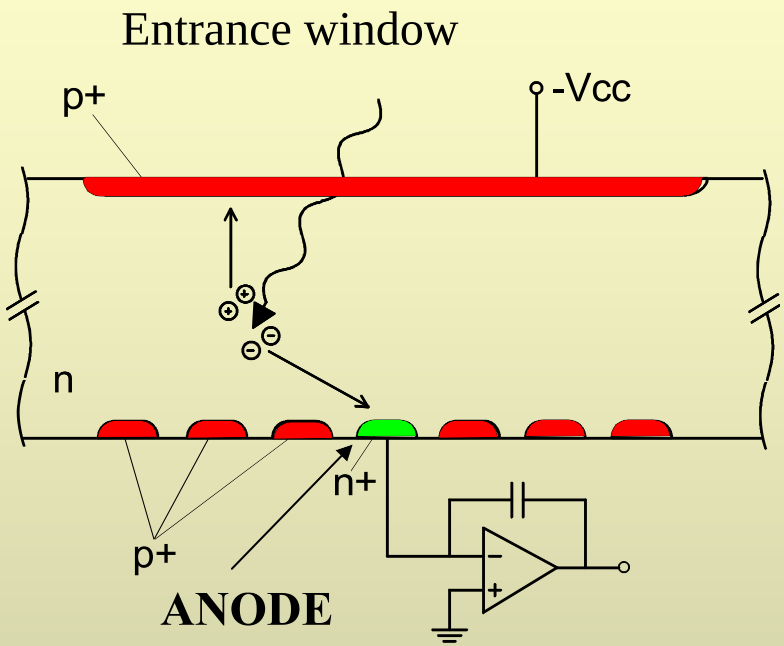
- **Kaon Beam at DAΦNE with unique performance**
  - ✓ Slow, nearly monochromatic kaons (E~16 MeV)
  - ✓ Kaon pair emitted back-to-back
  - ✓ Low hadronic background
- **Target System**
  - ✓ Cryogenic gas target, pure hydrogen gas
  - ✓ Thin windows, light-weight construction
- **X-ray Detector**
  - ✓ Large active area
  - ✓ Superior energy resolution
  - ✓ Background suppression capability
- **Calibration**
  - ✓ “online“ calbration – fluorescence lines

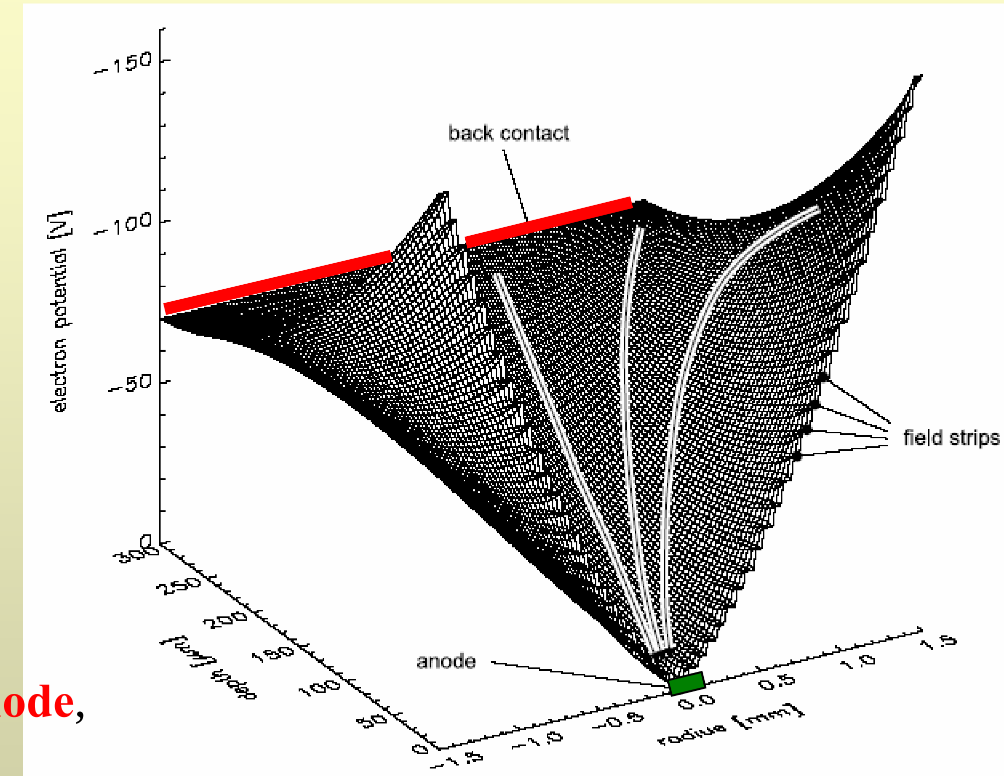
The choice of the detector



- A good X-ray detector, which preserves all good features of the CCD (no timing)
  - ✓ large active area
  - ✓ quantum efficiency
  - ✓ energy resolution
  - ✓ linearity and stability
  - ✓ performance in accelerator environment
- Trigger capability (fast shaping times – 1μs) for background rejection by using the kaon - X ray time correlation

Principle of the Semiconductor Drift Detector

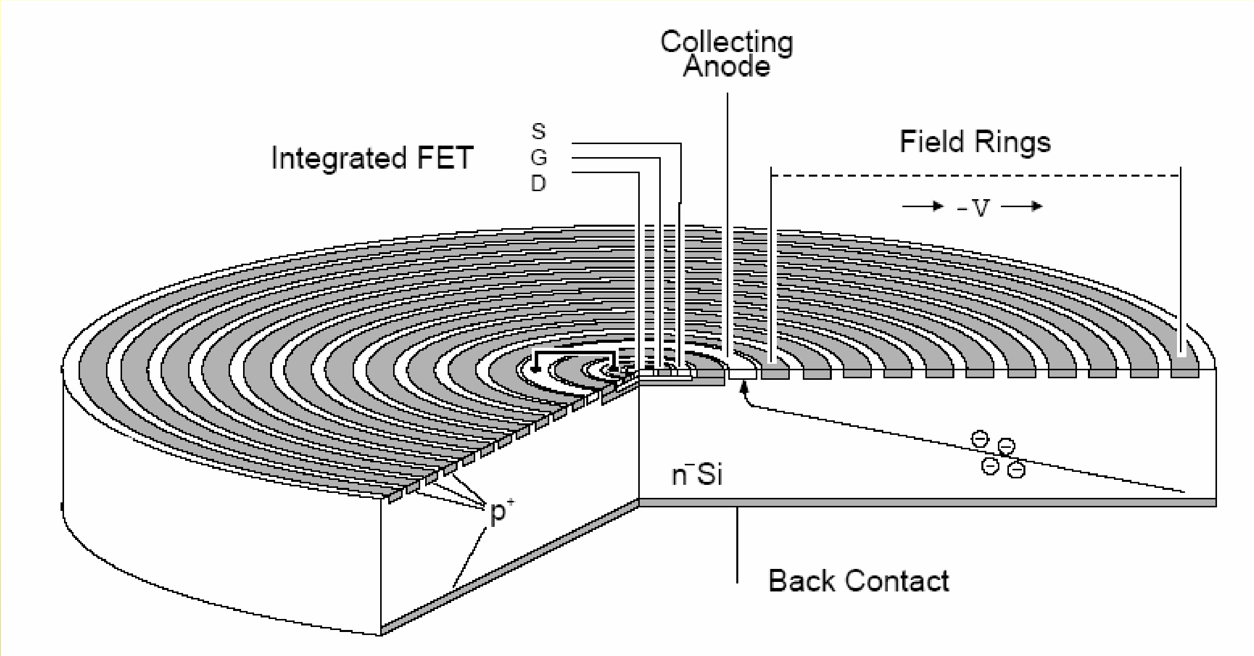


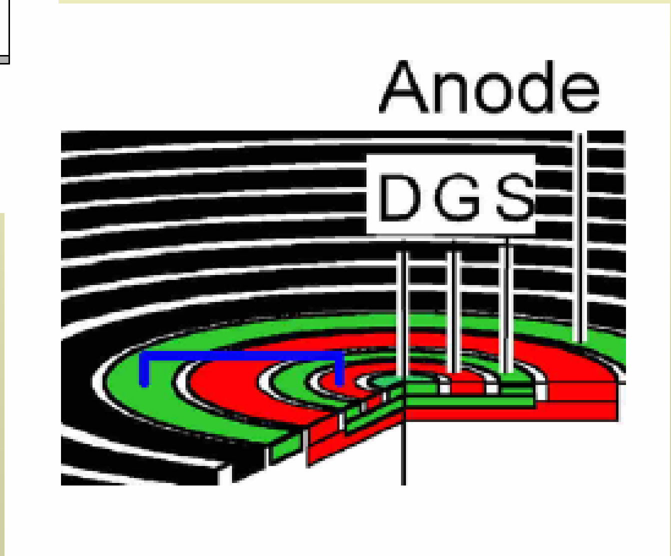


The electrons are collected by the **small anode**, characterized by a low output capacitance.

Advantages: **very high energy resolution at fast shaping times**, due to the small anode capacitance, independent of the active area of the detector

The Silicon Drift Detector with on-chip JFET

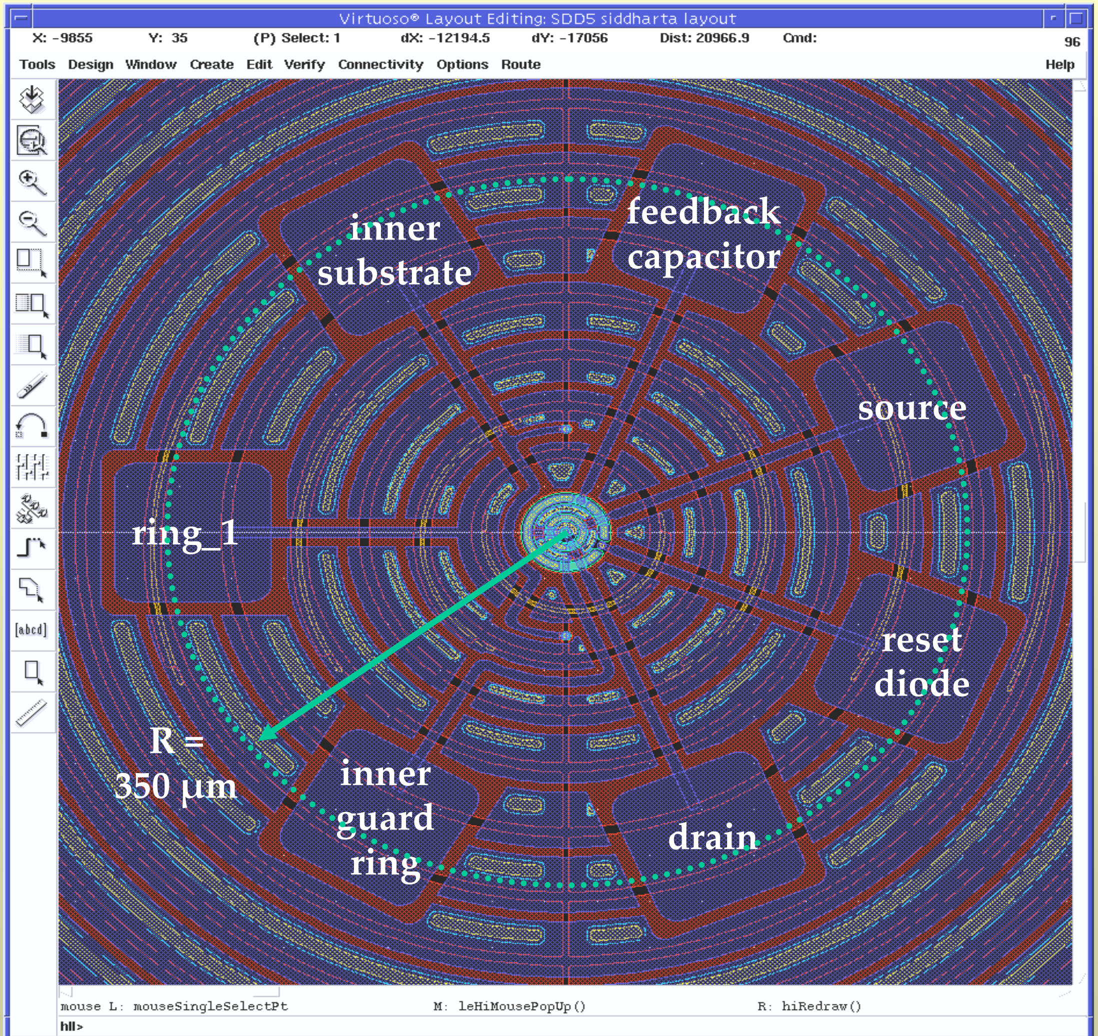




JFET integrated on the detector

- capacitive **'matching'**: **$C_{gate} = C_{detector}$**
- minimization of the **parasitic capacitances**
- reduction of the **microphonic noise**
- **simple solution** for the connection detector-electronics in monolithic **arrays of several units**

SDD readout side, cell center



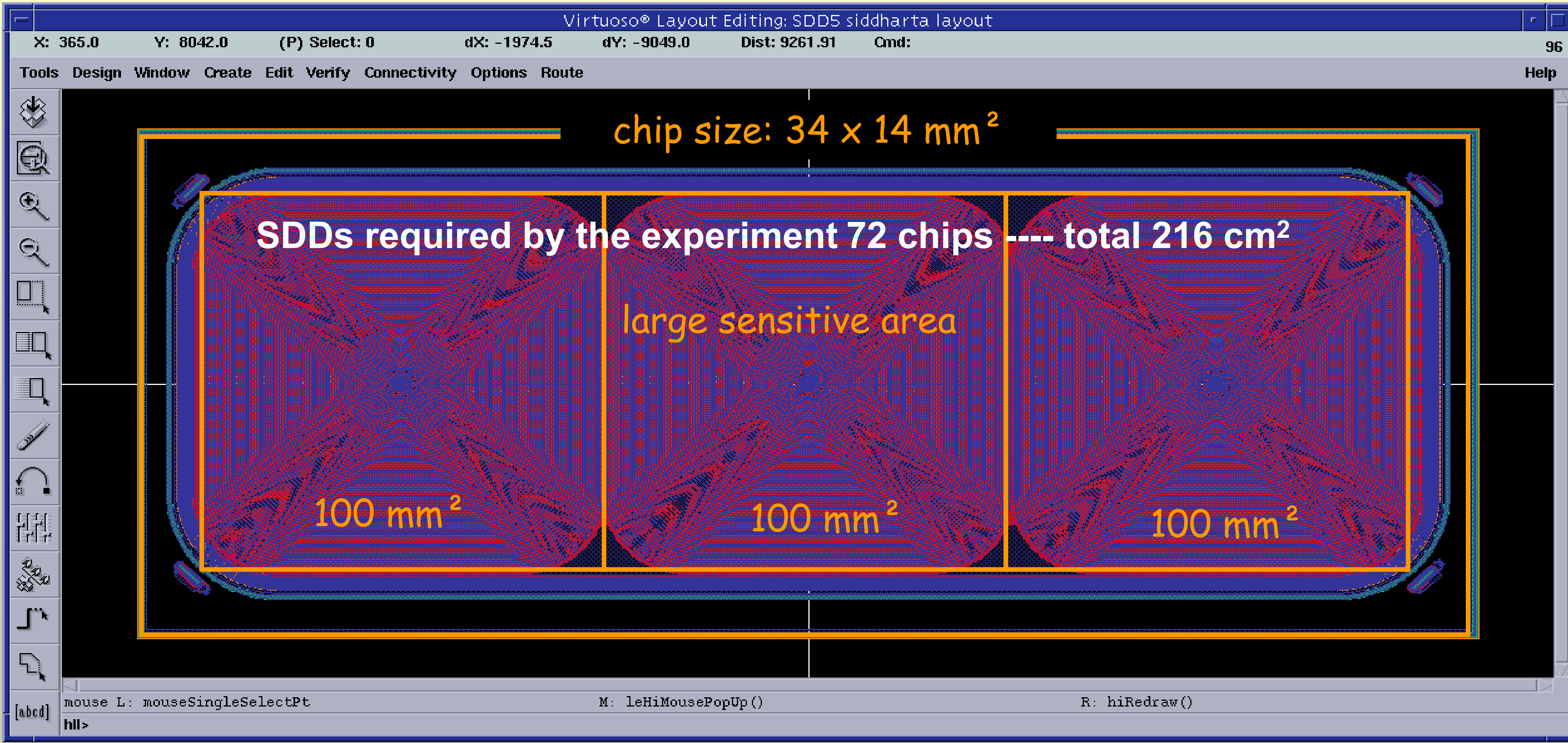
bond pads

150µm x 150µm

7 internal contacts

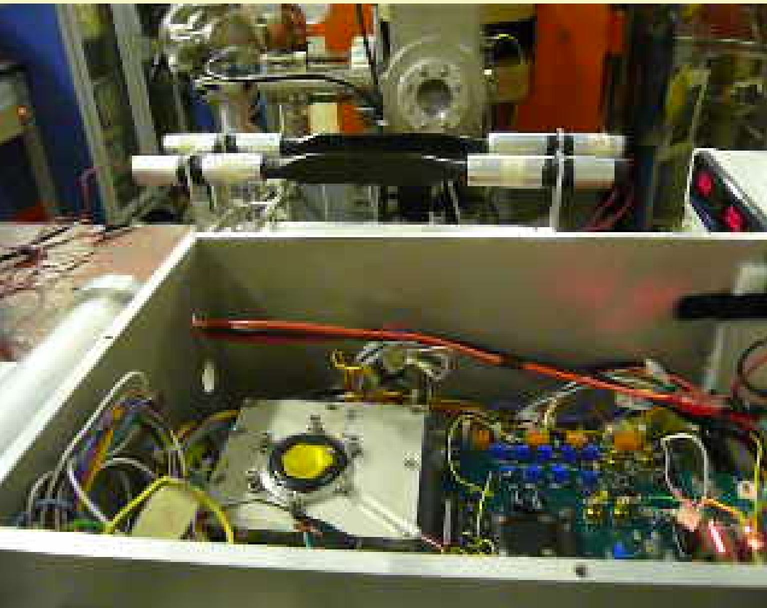
- **source**
- **drain**
- **ring_1**
- **inner guard ring**
- **inner substrate**
- **reset diode**

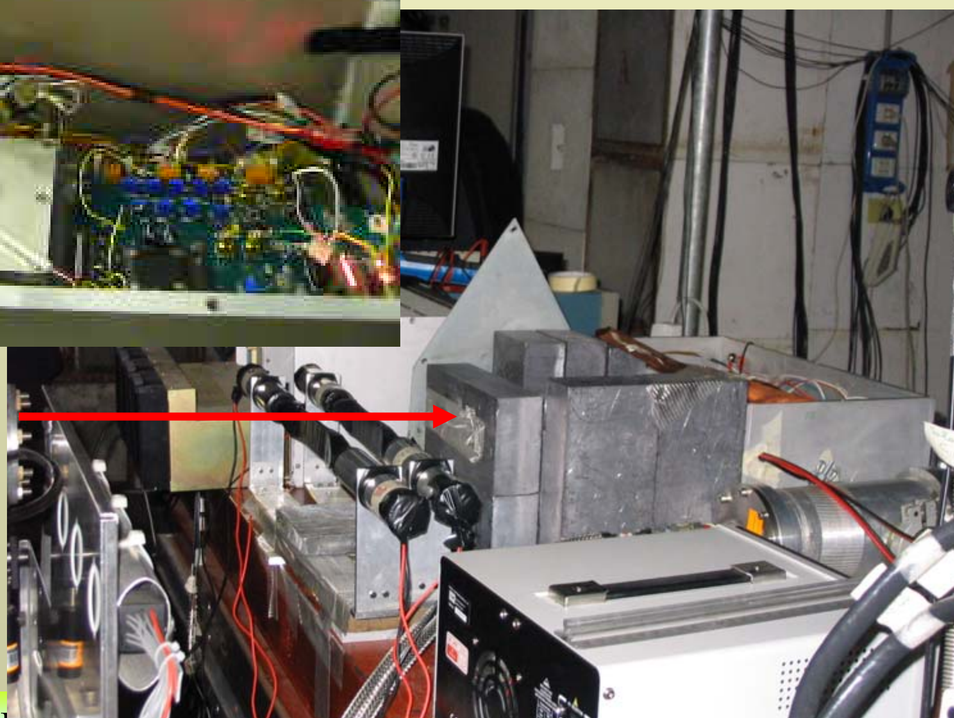
Special chip design for SIDDHARTA

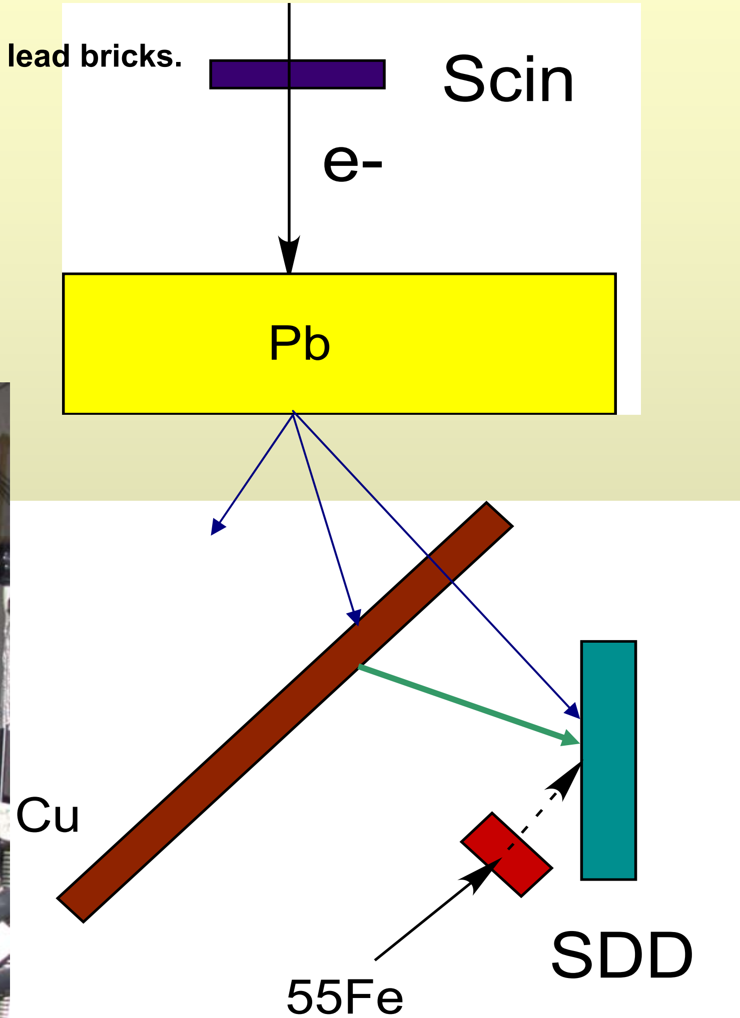


BTF test setup March 2007

Using electron beam from BTF (beam test facility) at DAFNE, SDD tests are performed.
BTF Electron beams = 500 MeV electrons with 50 Hz.
High-energy gamma-rays/electrons are produced by 500-MeV electron beam and lead bricks.

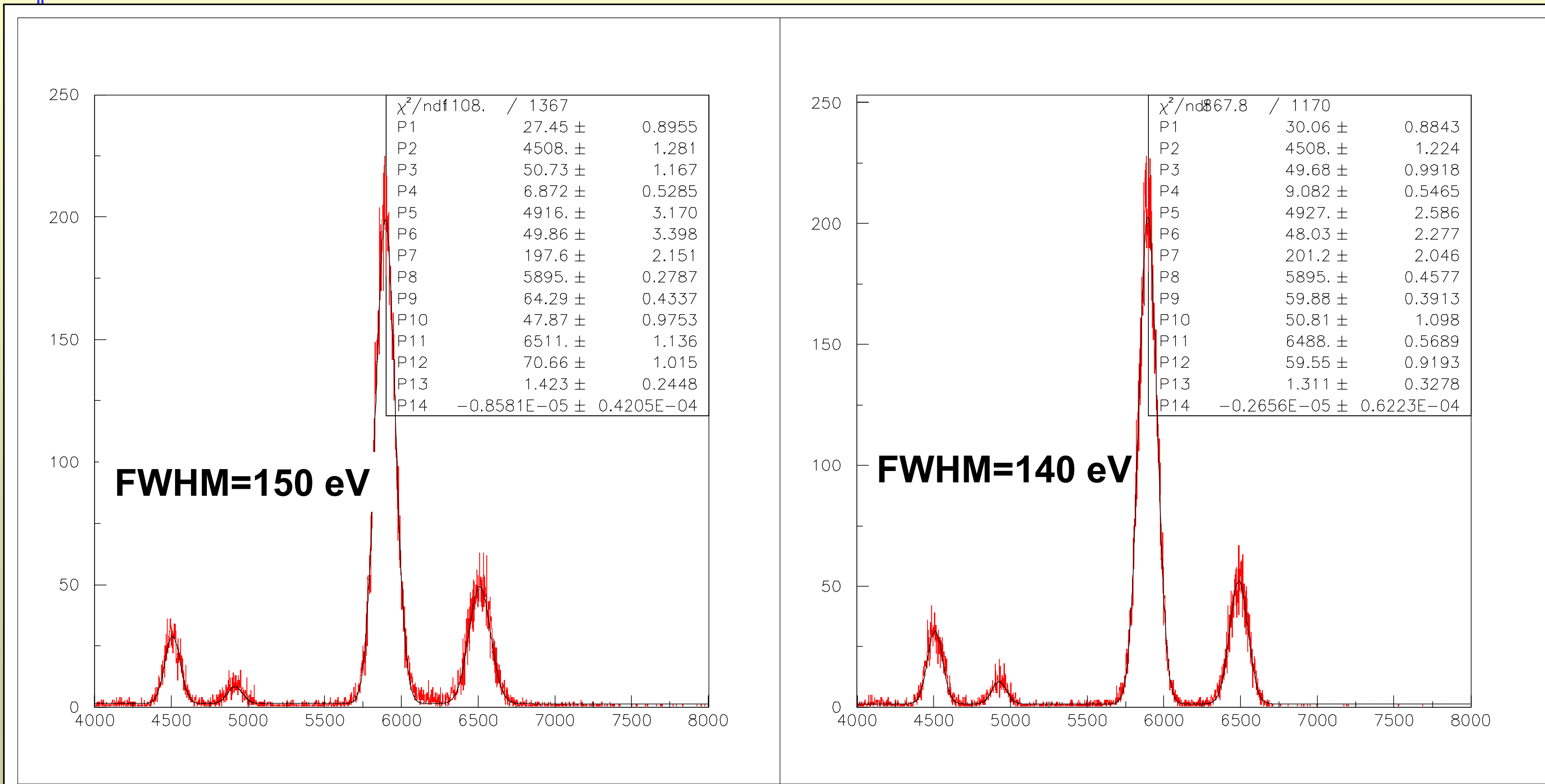




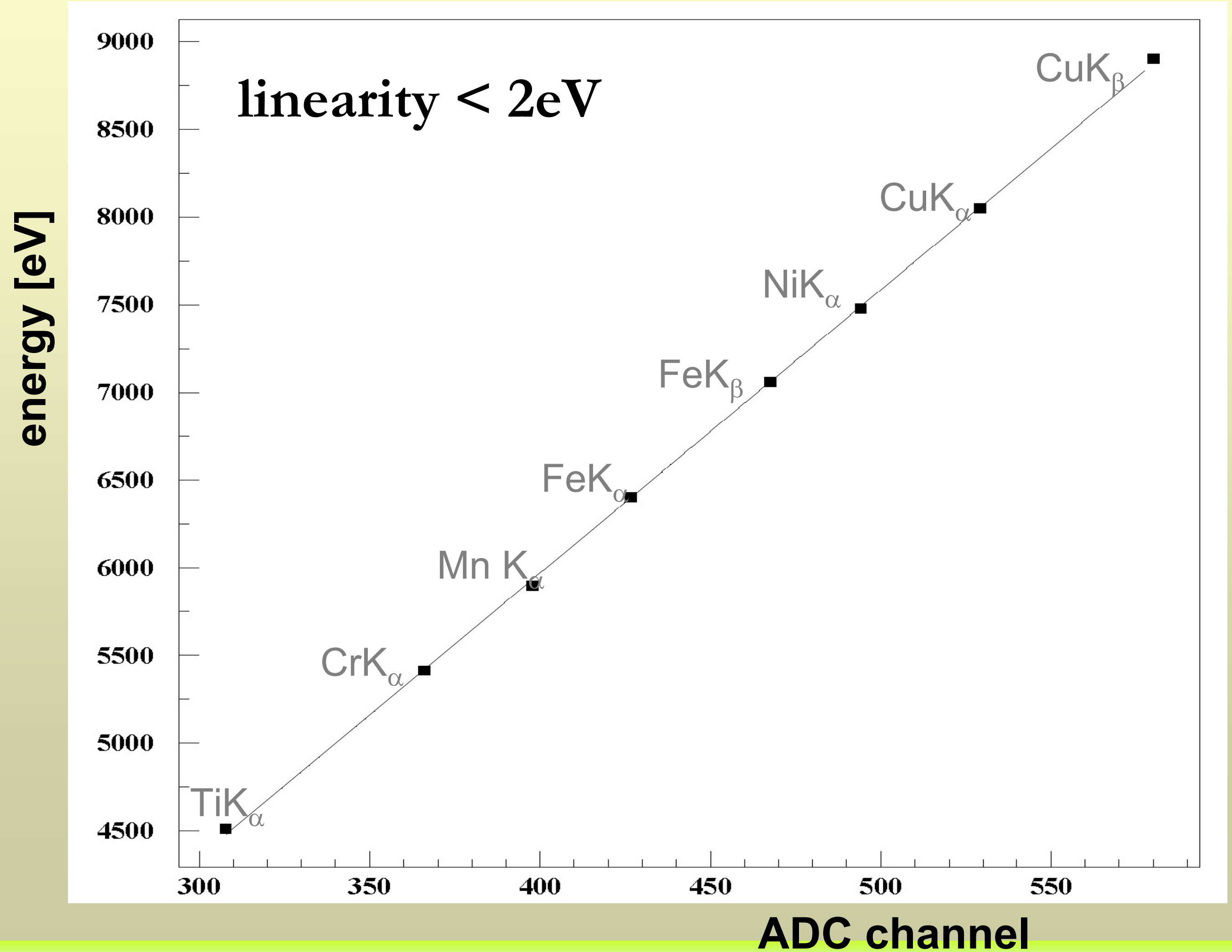


SDD energy resolution

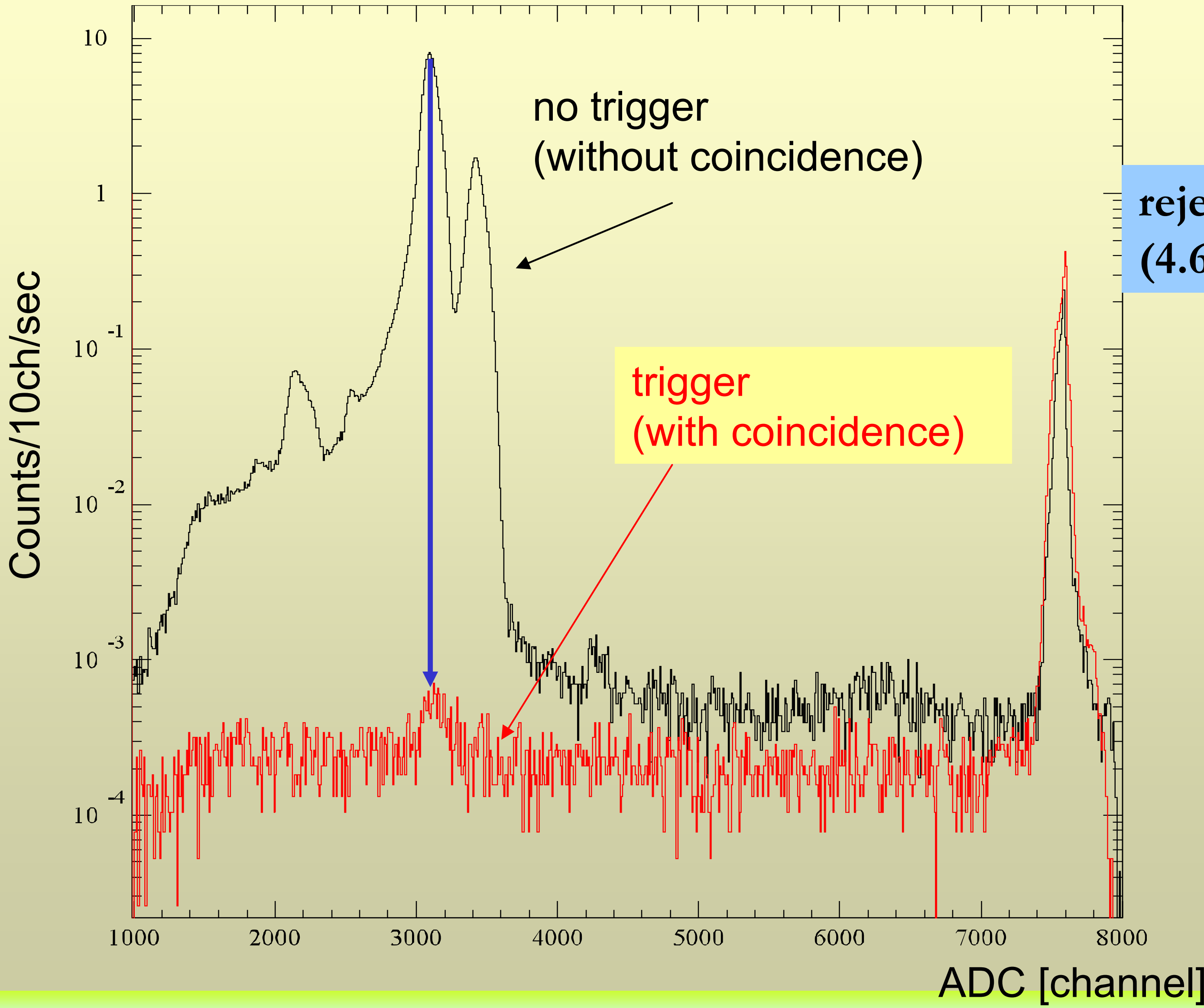
W49S06 cell3 **W01S01 cell1**



SDD linearity test

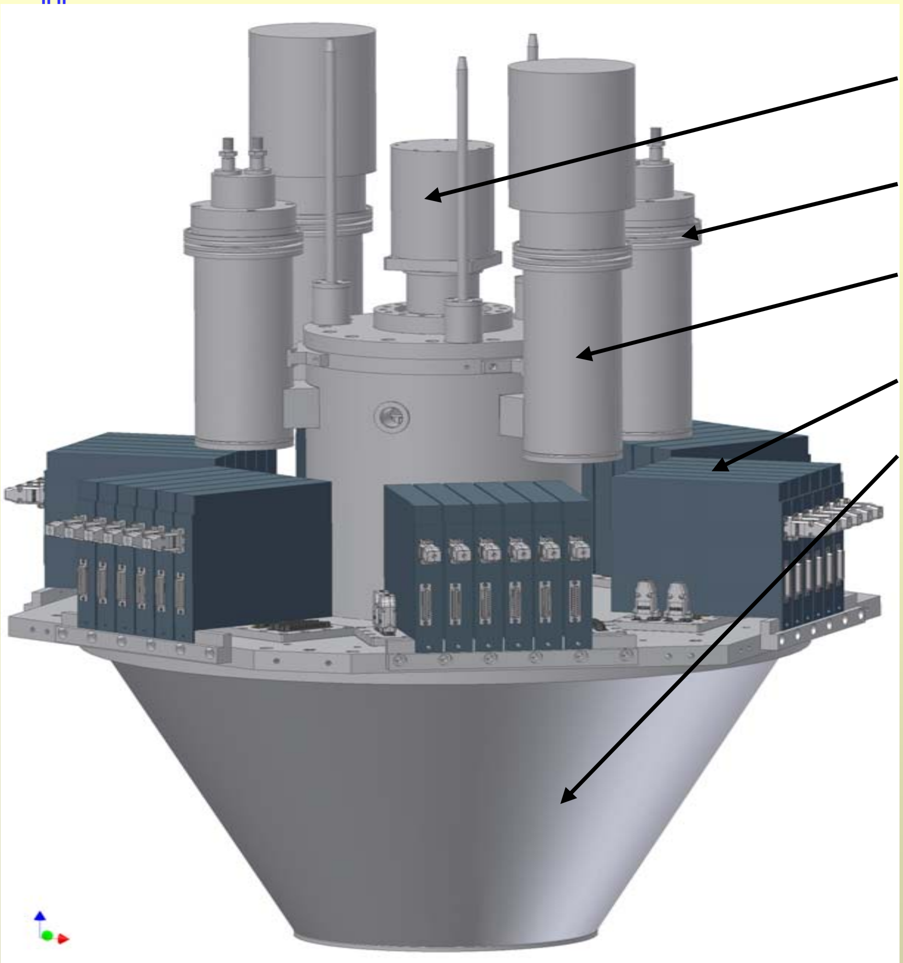


Background rejection

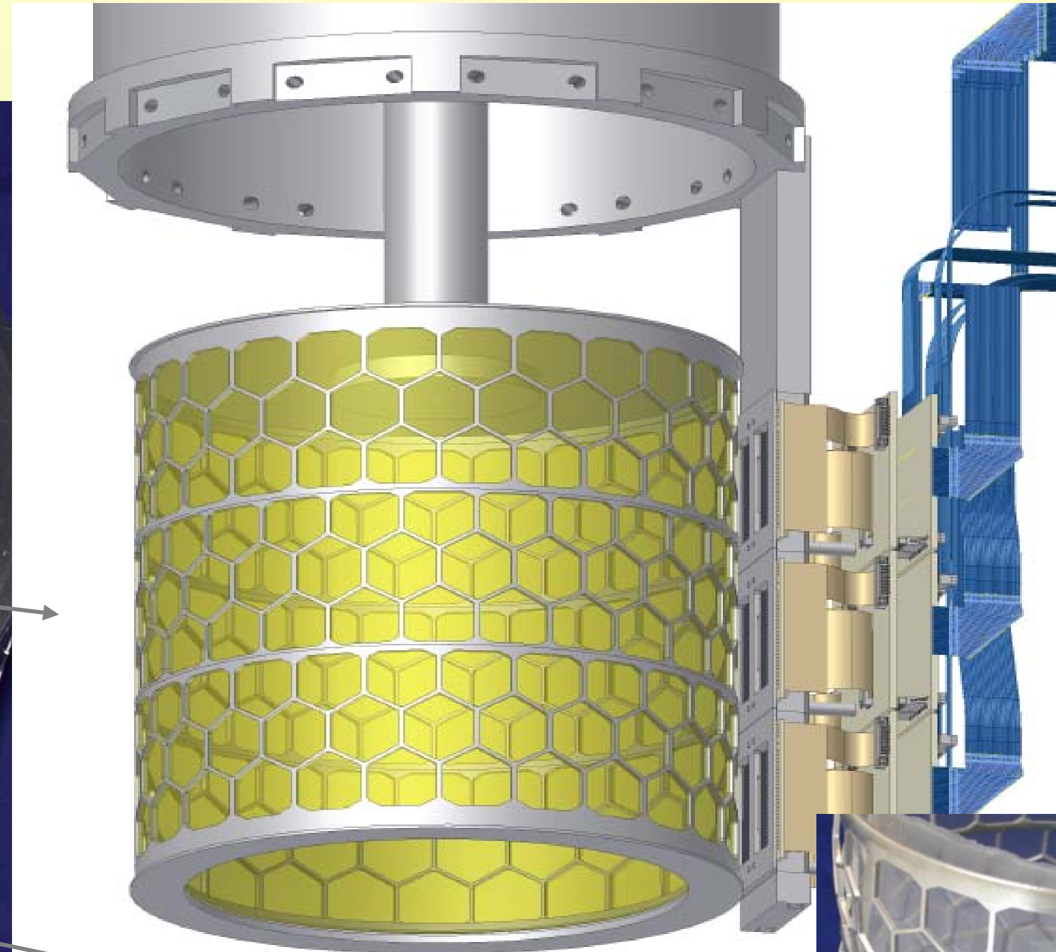


rejection factor
$(4.6 \pm 0.5).10^{-5}$

The SIDDHARTA Setup

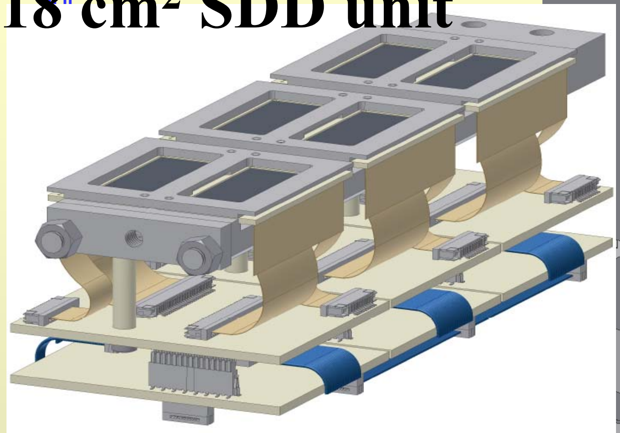


Cryogenic target cell

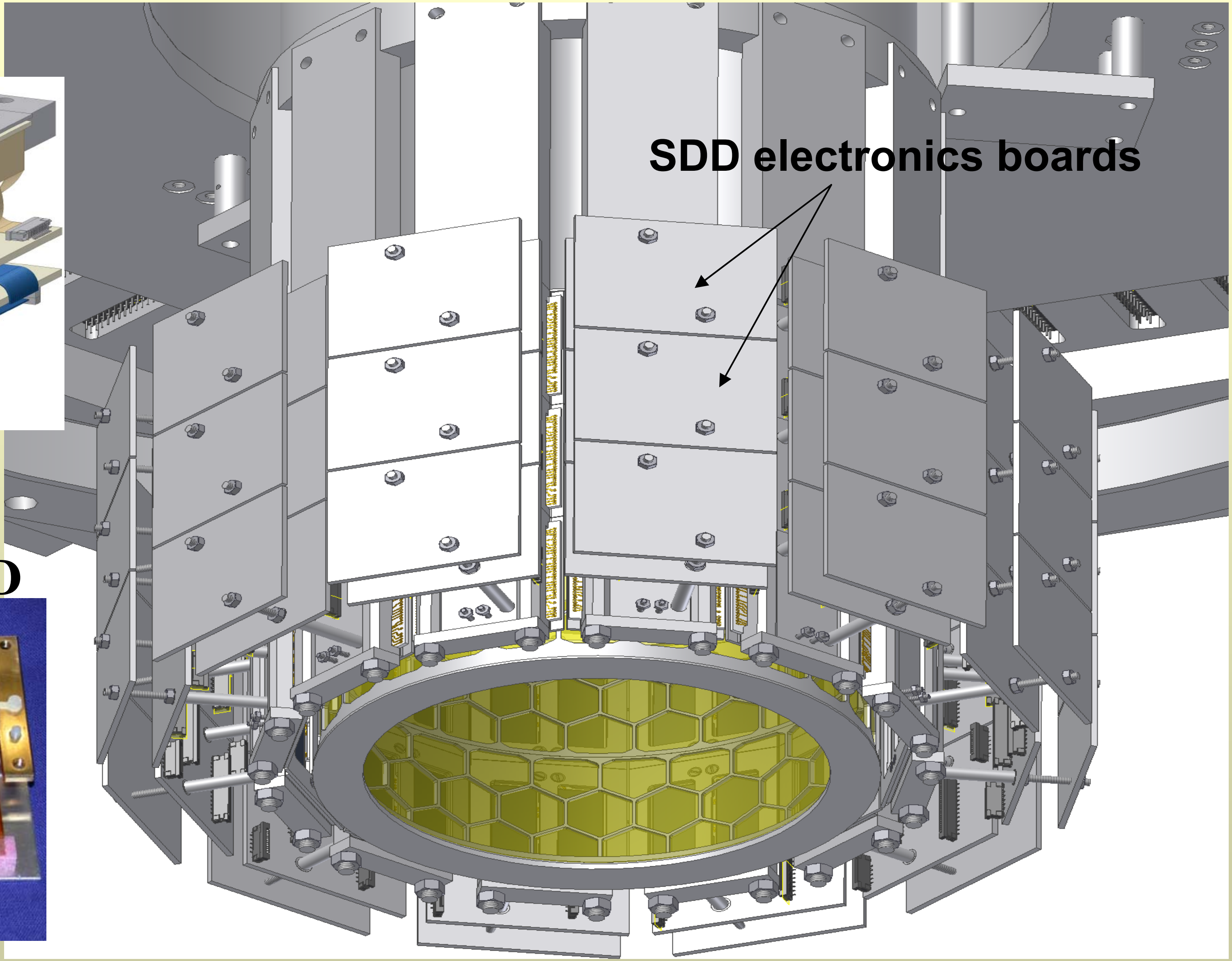


SDD arrangement

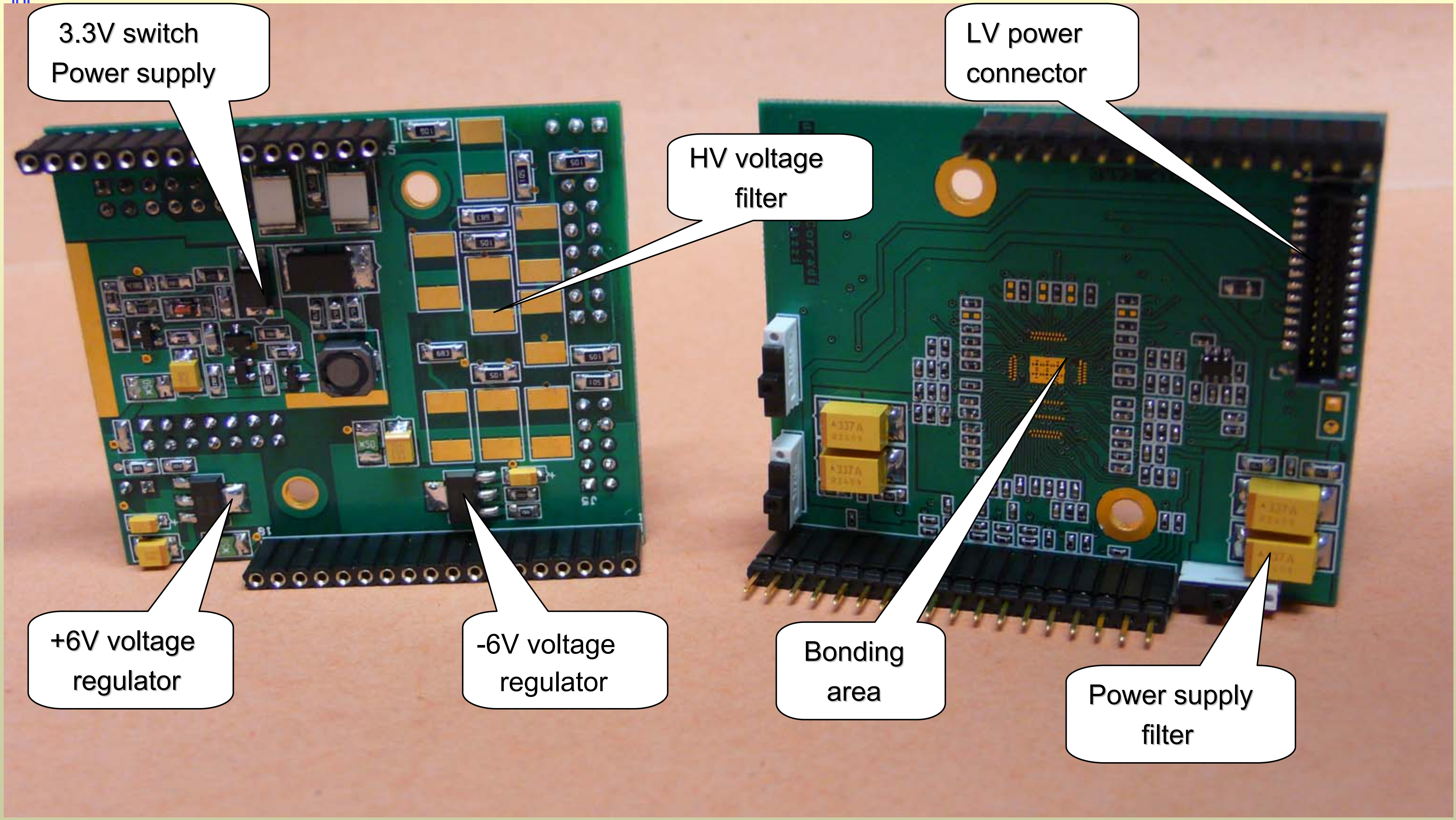
18 cm^2 SDD unit



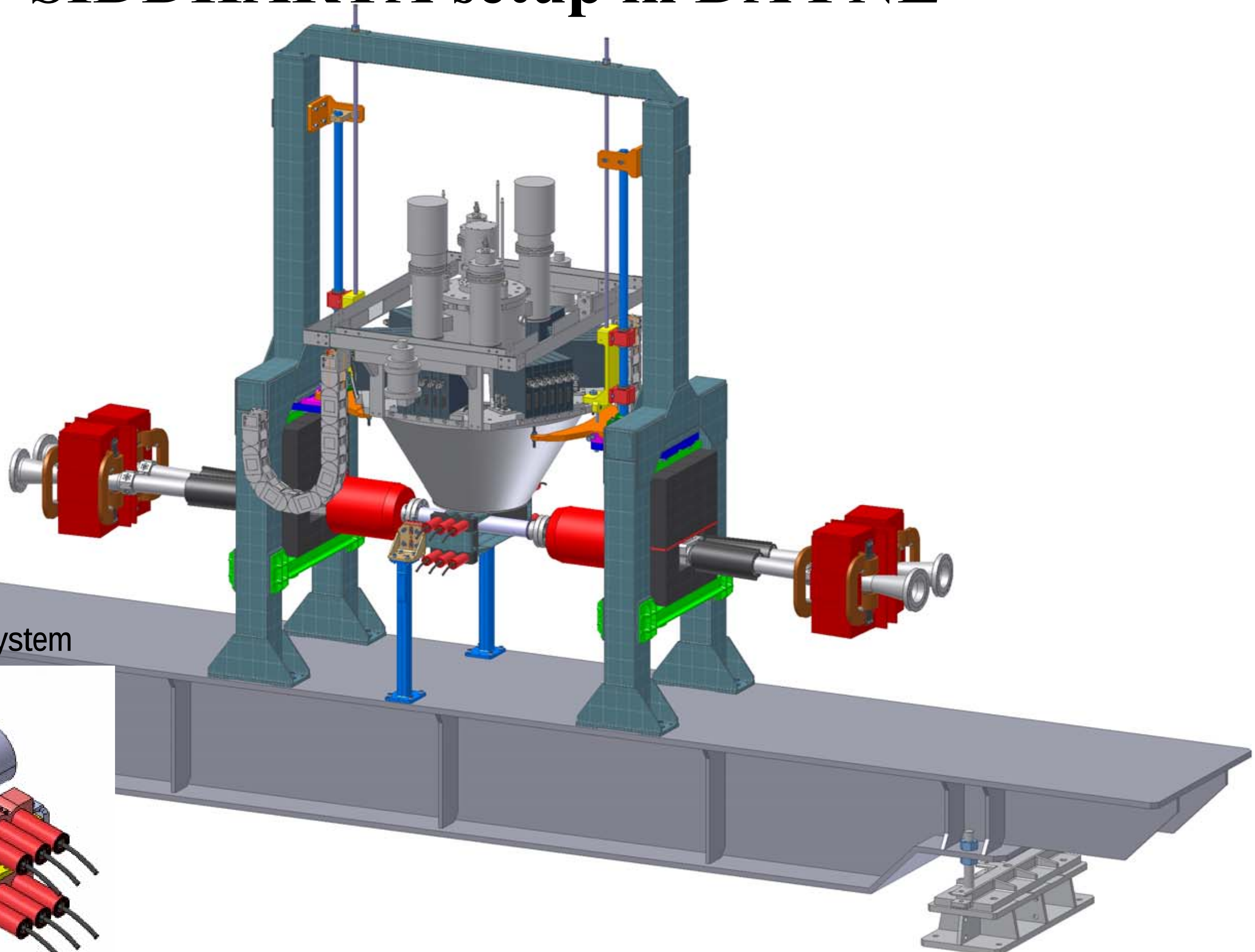
2 array of 3cm^2 SDD



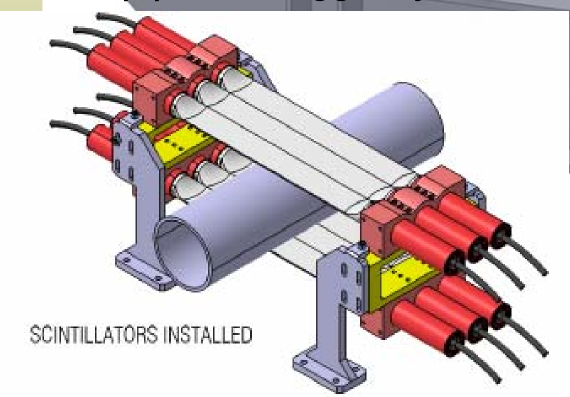
CHIP card & transfer card



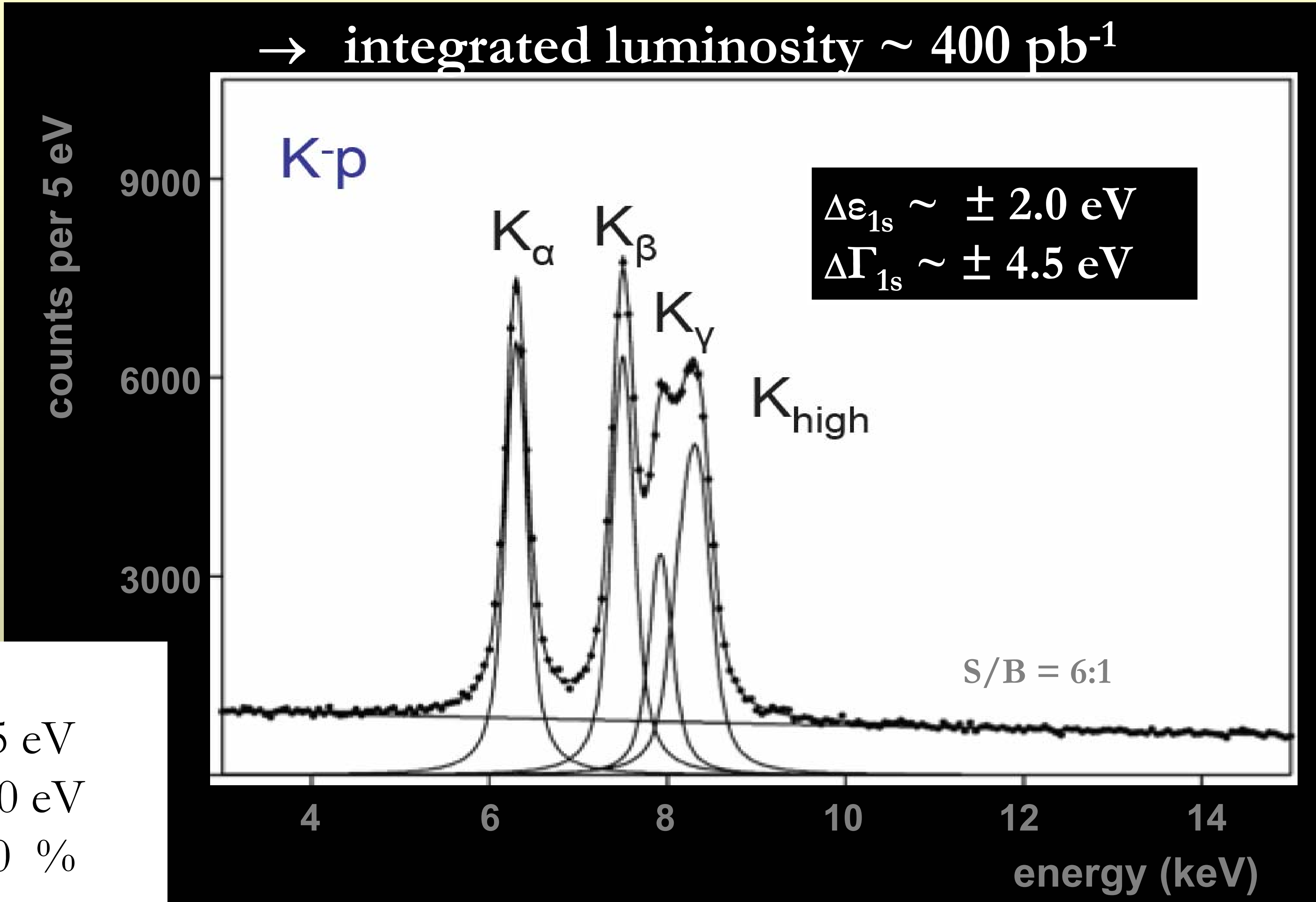
SIDDHARTA setup in DAΦNE



Beam pipe and trigger system



Expected results for $K^{-}p$



Input:

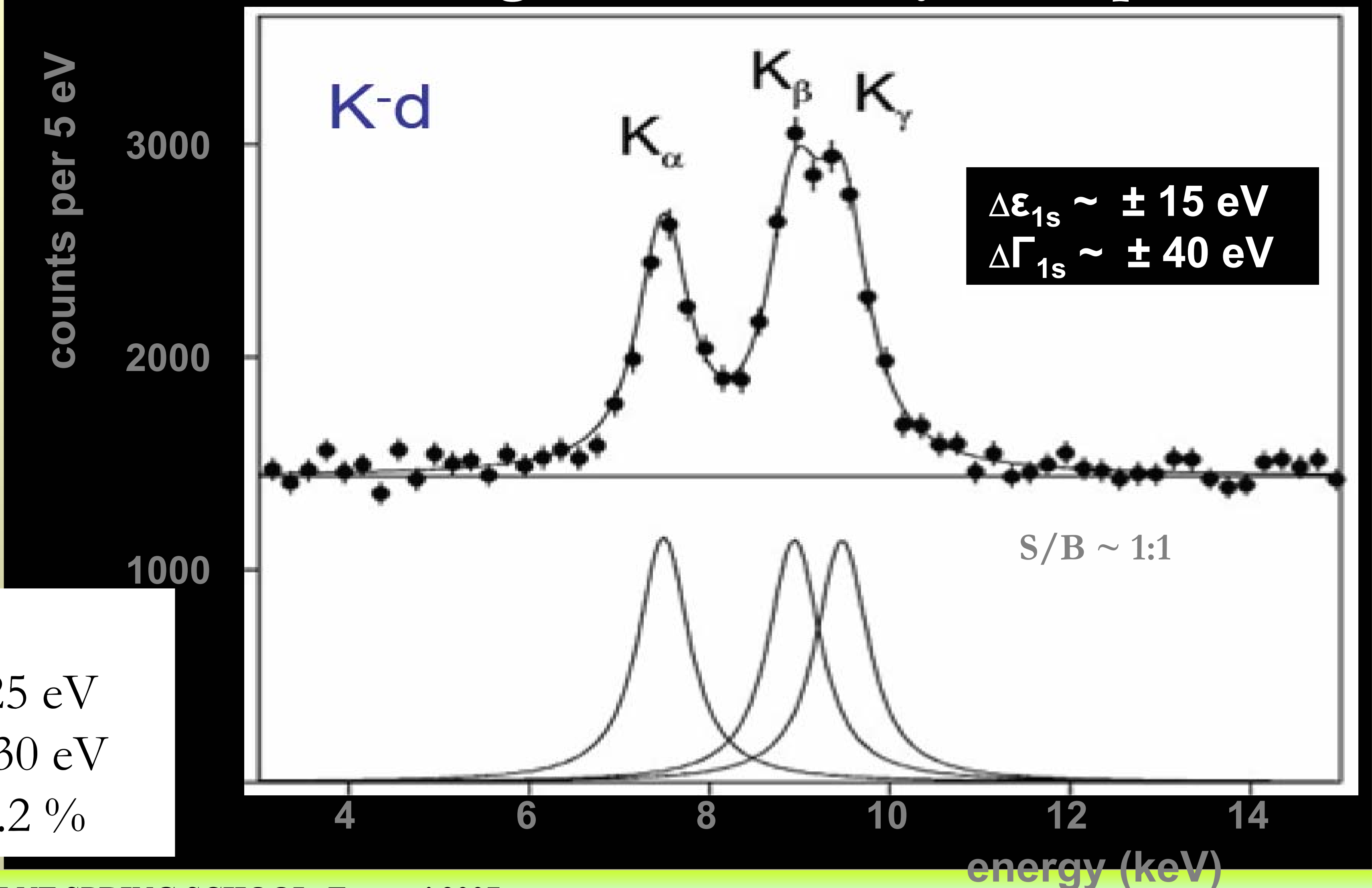
$\varepsilon_{1s} = 195$ eV

$\Gamma_{1s} = 250$ eV

$Y_{K\alpha} = 2.0$ %

Expected results for K$^-$d

→ integrated luminosity ~ 600 pb^{-1}



Input:

ε_{1s} = 325 eV

Γ_{1s} = 630 eV

$Y_{K\alpha}$ = 0.2 %

Summary

- Tests of all subsystems done

  - characterization of large area SDDs under beam conditions
  - front-end electronics production
  - data acquisition production
  - construction of the experimental setup
  - slow-controls system

- The assembling at LNF in progress

- ready for installation at DAΦNE fall of 2007

SIDDHARTA future plans

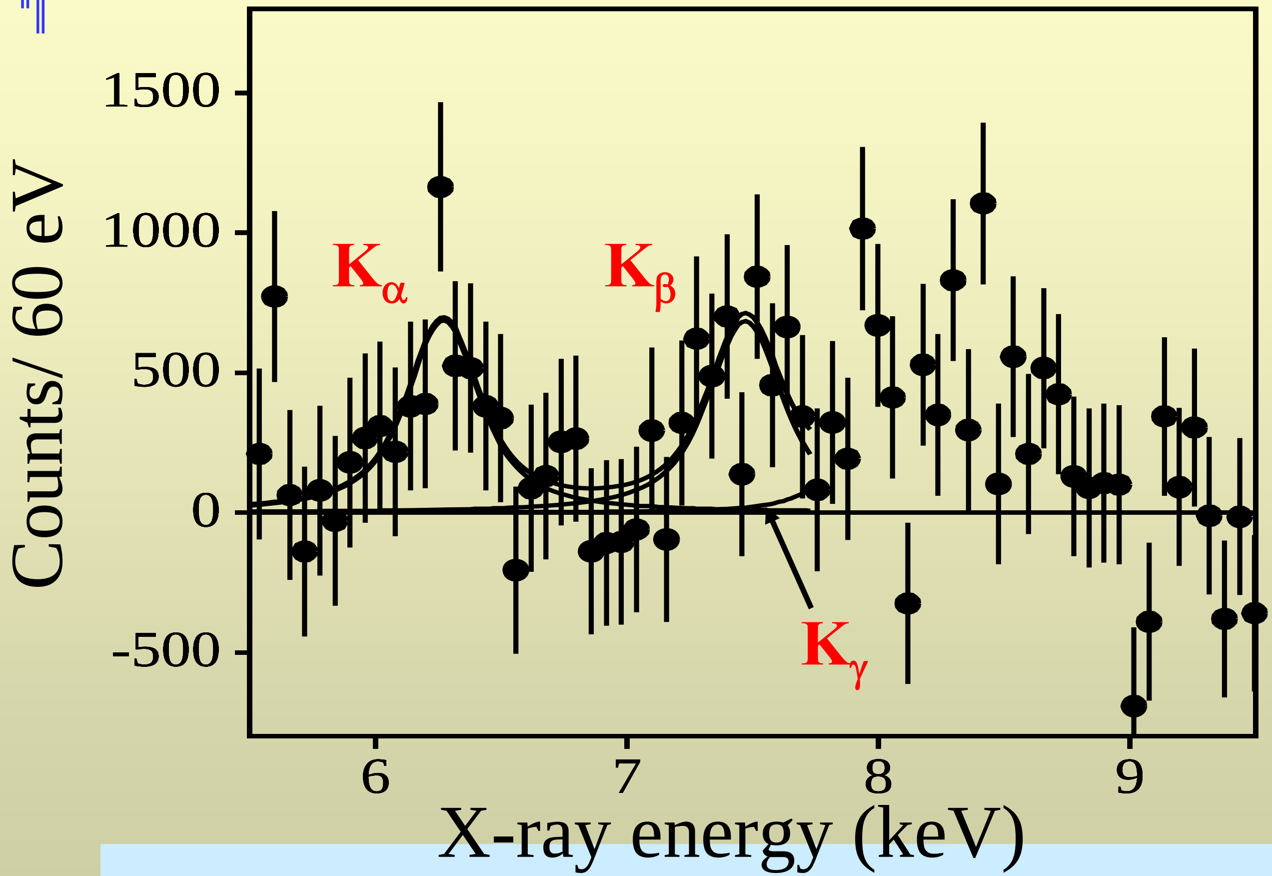
Kaonic helium measurement towards the study of deeply bound nuclear kaonic state.

Other light kaonic atoms measurement (Li, Be…).

Investigate the possibility of the measurement of other types of hadronic exotic atoms (sigmonic atoms).

Charged kaon mass precision measurement.

DEAR results on the shift and width for kaonic hydrogen



represents the **best measurement performed on Kaonic Hydrogen up to now**

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

Width: Γ_{1s} = 249 ± 111 (stat.) ± 30 (syst.) eV

Motivation

- Exotic (kaonic) atoms – probes for strong interaction
  - hadronic shift ε_{1s} and width Γ_{1s} directly observable
  - experimental study of low energy QCD
- Kaonic hydrogen
  - K^-p simplest exotic atom with strangeness
  - kaonic hydrogen „puzzle“ solved – but still: precision data missing
  - kaonic deuterium never measured before
- Information on $\Lambda(1405)$ sub-threshold resonance
  - important for research on deeply bound kaonic states
- Determination of the isospin dependent $K\bar{N}$ scattering lengths