Silicon Drift Detectors for the kaonic atom X-ray measurements in the SIDDHARTA experiment

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SIDDHARTA Collaboration
Silicon Drift Detector for Hadronic Atom Research by Timing Applications

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Silicon Drift Detectors for the kaonic atom X-ray measurements in the SIDDHARTA experiment

1. Kaonic atom X-rays
2. Kaonic hydrogen with CCDs
   (DEAR, LNF)
3. Silicon Drift Detectors
4. Kaonic helium with SDDs
   (E570,KEK)
5. Kaonic hydrogen & deuterium with SDDs
   by Monte Carlo
   (SIDDHARTA, LNF)

Kaonic atom X-rays and KN scattering lengths

$$\varepsilon_{1s} + i\frac{\Gamma_{1s}}{2} = 2\alpha^3\mu^2 a$$

(*Deser Formula*)

Shift (ε) and width (Γ) of
K^-p and K^-d gives
isospin dependent
KN scattering lengths(***a_0*** and ***a_1***)

These scattering lengths provide
Low-energy SU(3) QCD:
SU(3) chiral symmetry, KN σ-term,
nature of Λ(1405),
S^0 (3115) S^+ (3140)

Difficulty

1. High-background in kaon beams

2.Small X-ray yields (a few% K-p, below 1% K-d)

3.Precise determination of X-ray energy and width

X-ray detector with

1. high background rejection,

2. large-area,

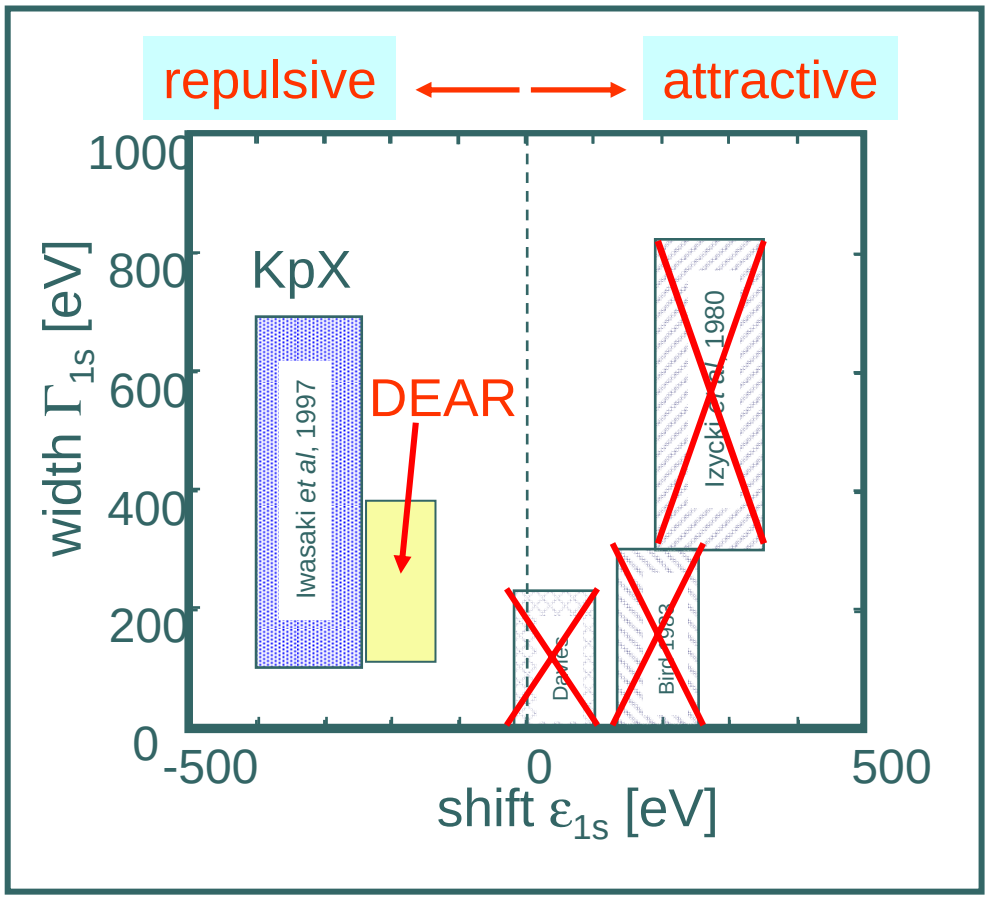
3. good resolution in energy and time

Experimental results of kaonic atoms

Katom	Old exp.	New exp.
^{1}H	Attractive shift	Repulsive shift
^{2}D	No data	No data
^{3}He	No data	No data
^{4}He	Large shift	Small shift

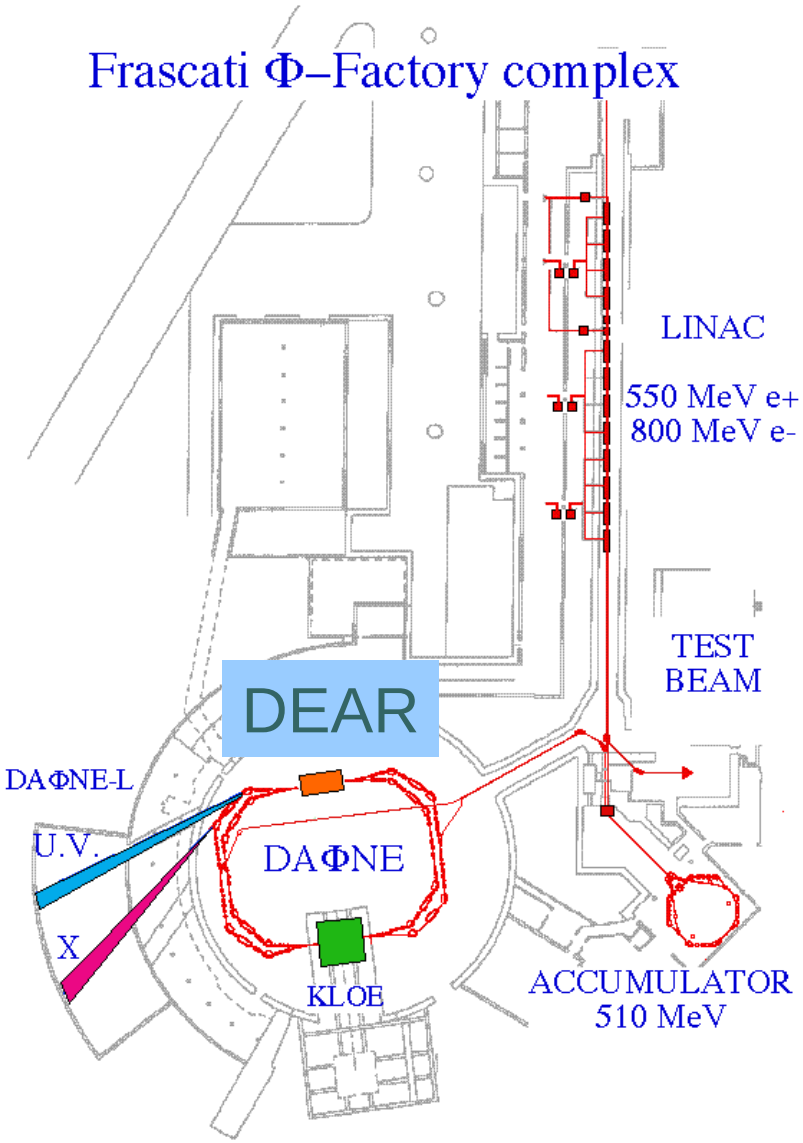
Accuracy for K^-p,
First for K^-d
(as well as 4He,3He)
are badly needed!

Results of kaonic hydrogen



Phys. Rev. Lett. **94**, 212302 (2005)

DEAR experiment at DAFNE



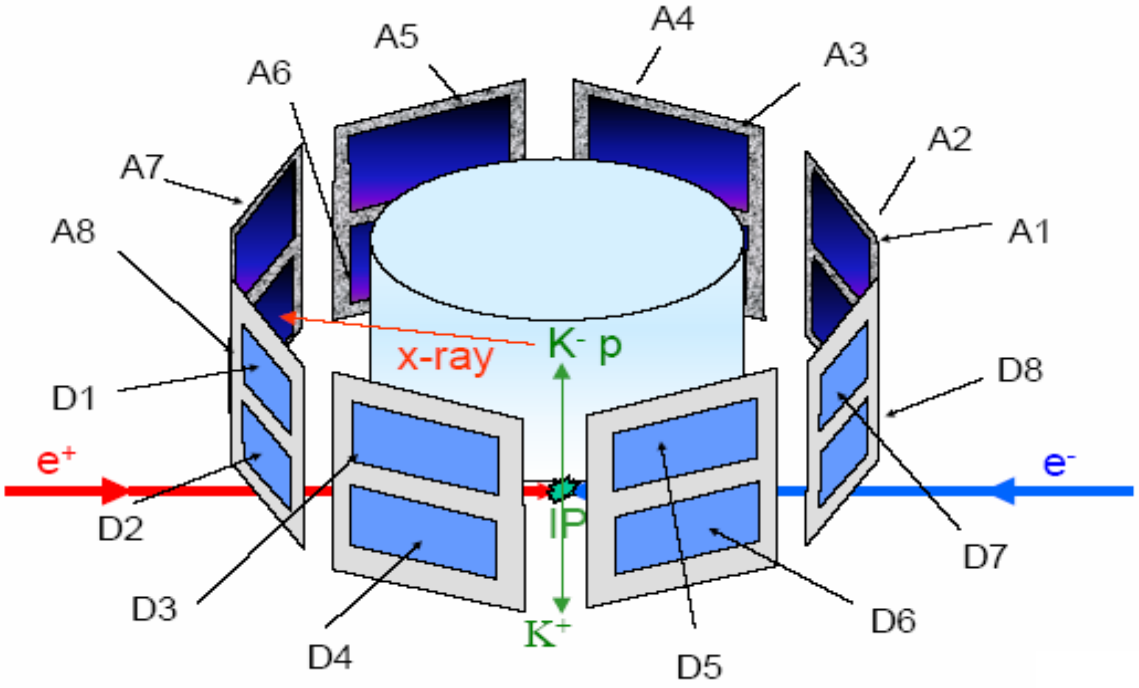
DAFNE e^+e^- collider
optimized to produce
ϕ-meson at rest (1.020 GeV)

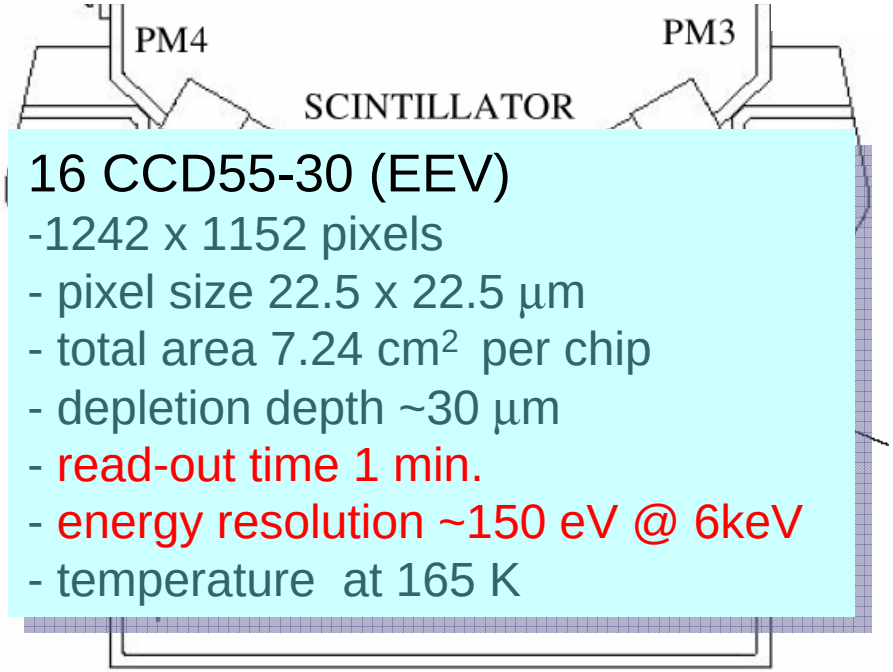
$$e^+ + e^- \rightarrow \phi \rightarrow K^+ + K^-$$

K^- beam at DAFNE
1. **Monochromatic**
2. **Low-energy**
3. **No hadronic background**

$$\sigma_{K^+K^-} \sim 3000\ nb,$$
$$\int L\,dt \sim 2\ pb^{-1}/\text{day}$$
$$\rightarrow \sim 3 \cdot 10^6\ K^-/\text{day}$$

D



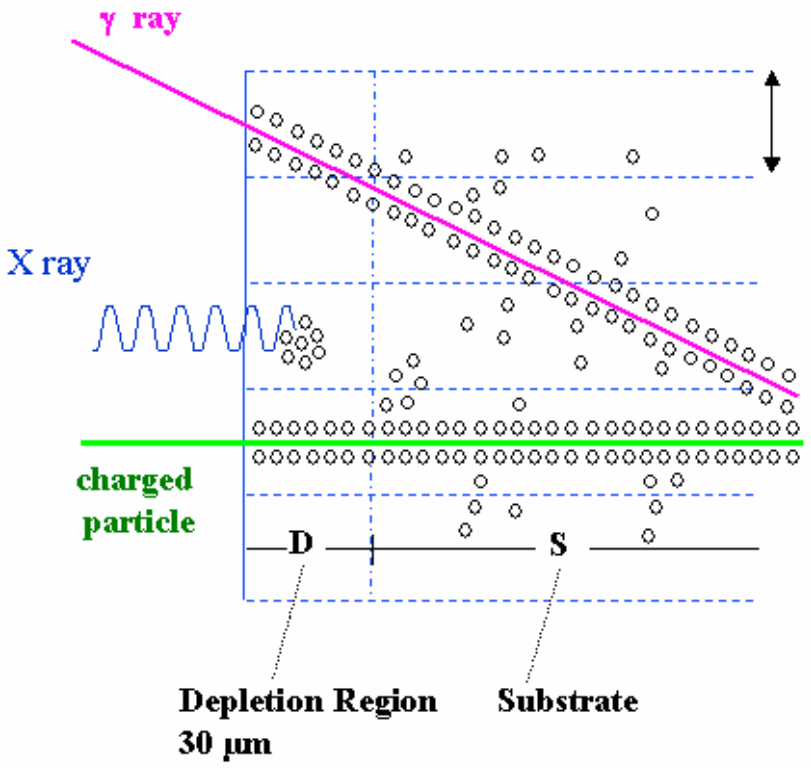


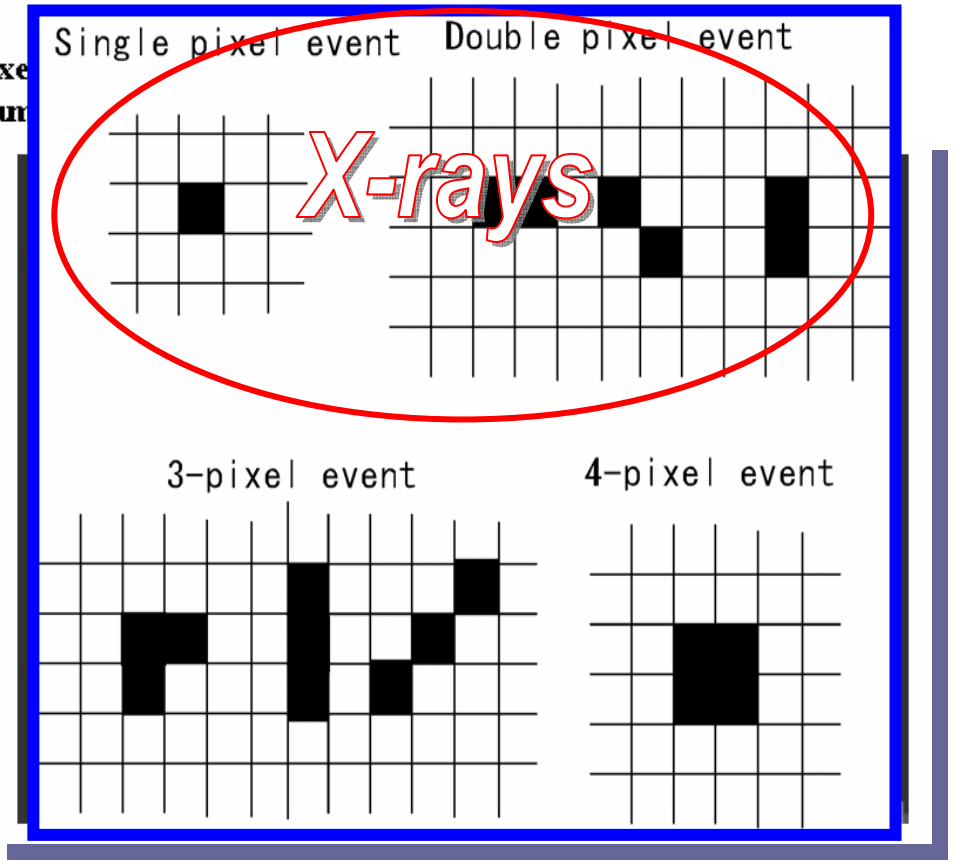
16 CCD55-30 (EEV)

-1242 x 1152 pixels
- pixel size 22.5 x 22.5 μm
- total area 7.24 cm^2 per chip
- depletion depth ~30 μm
- read-out time 1 min.
- energy resolution ~150 eV @ 6keV
- temperature at 165 K

CCD X-ray detector

X-ray events → 1 and 2 pixel events
Charged particles → large pixel events
background suppression by pixel analysis





K⁻p energy spectrum by DEAR CCDs

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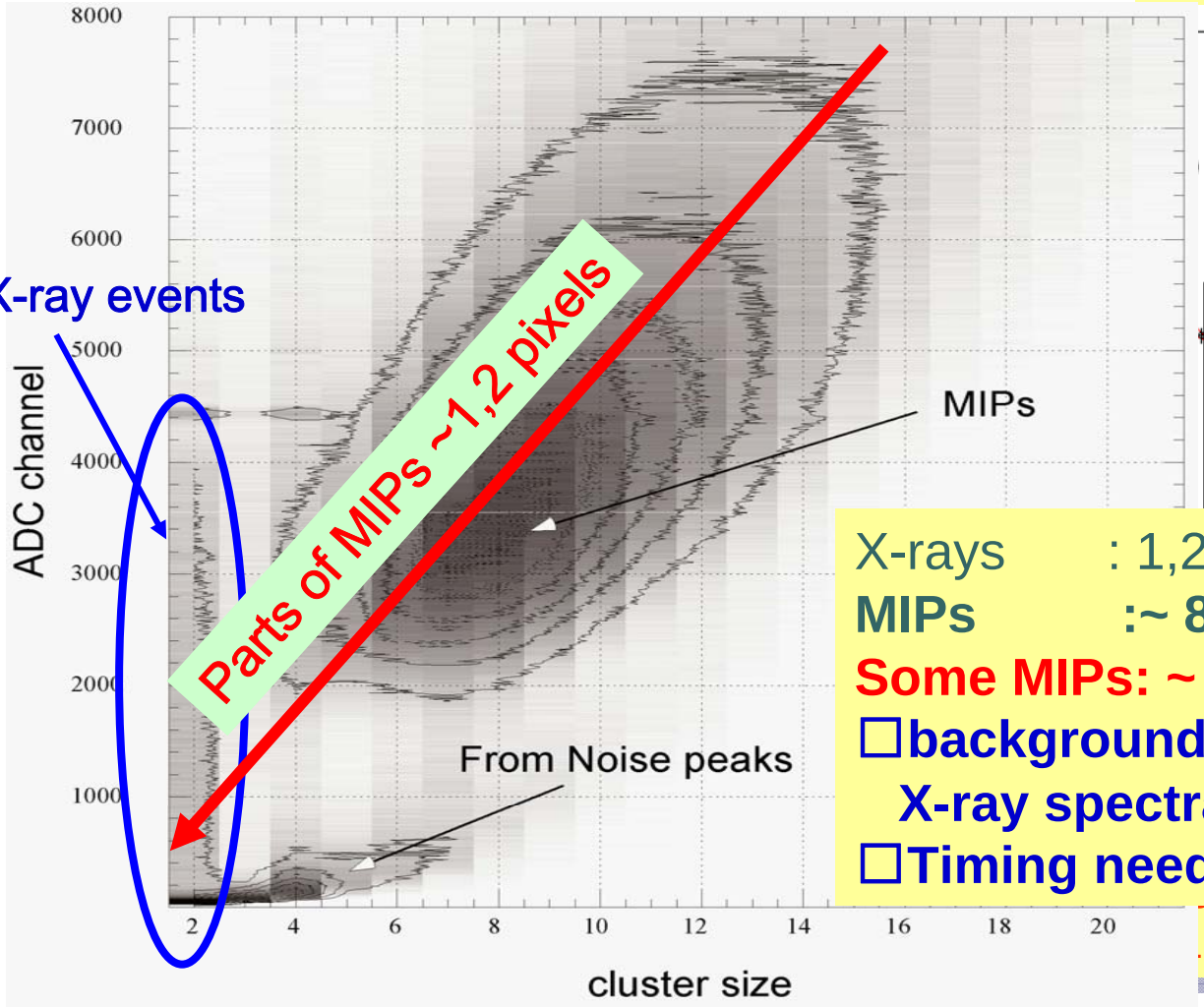
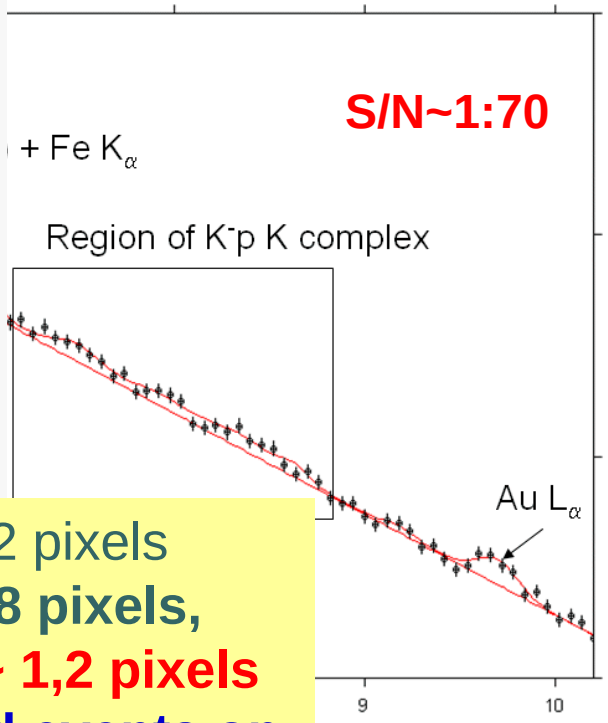
NIMA 556(2006)509

DEAR results





X-rays : 1,2 pixels

MIPs :~ 8 pixels,

Some MIPs: ~ 1,2 pixels

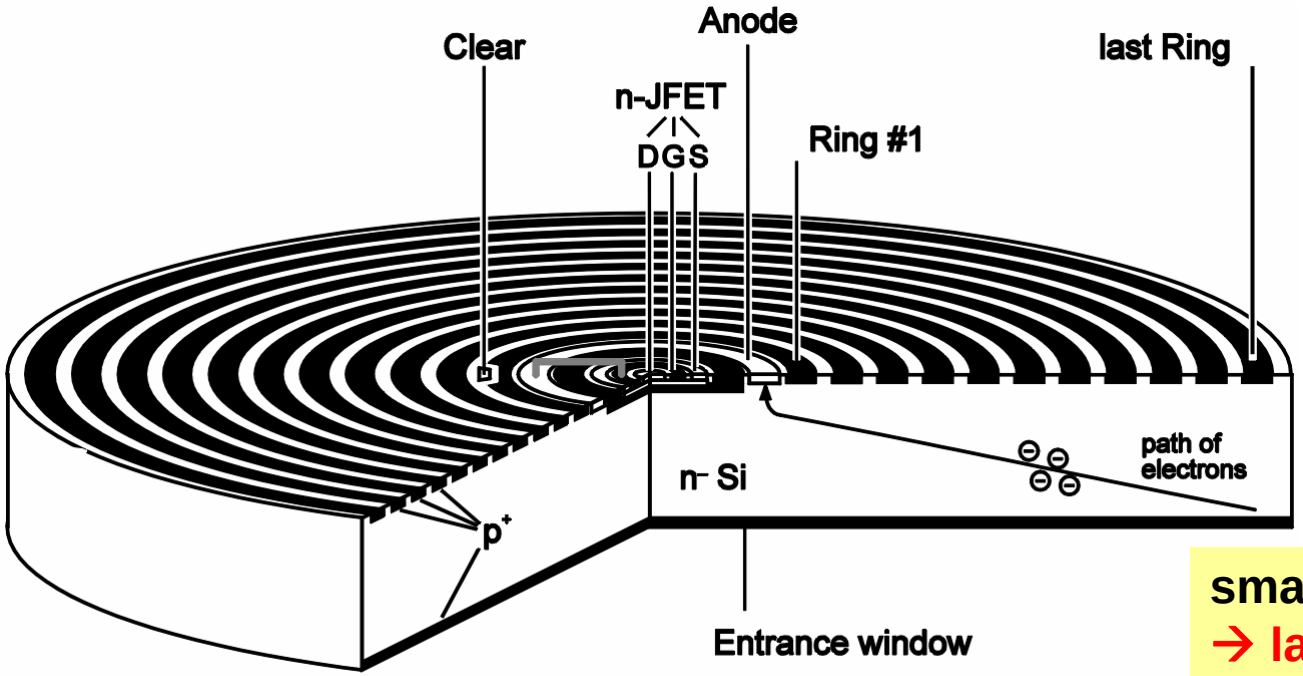
☐background events on X-ray spectra

☐Timing needed!

yst.) eV

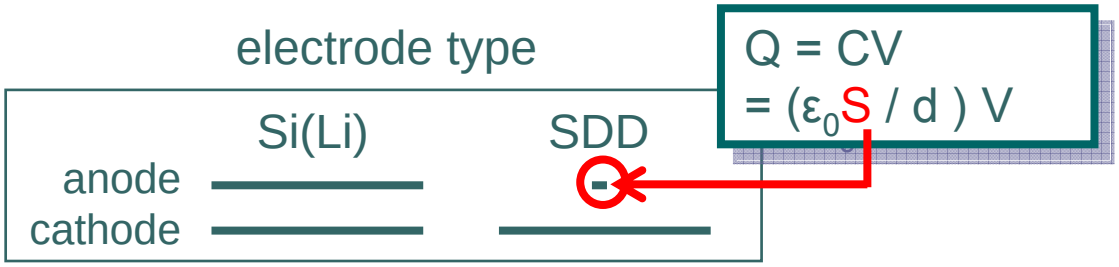
.1 (stat.) ± 30 (syst.) eV

SDD (Silicon Drift Detector) X-ray detector

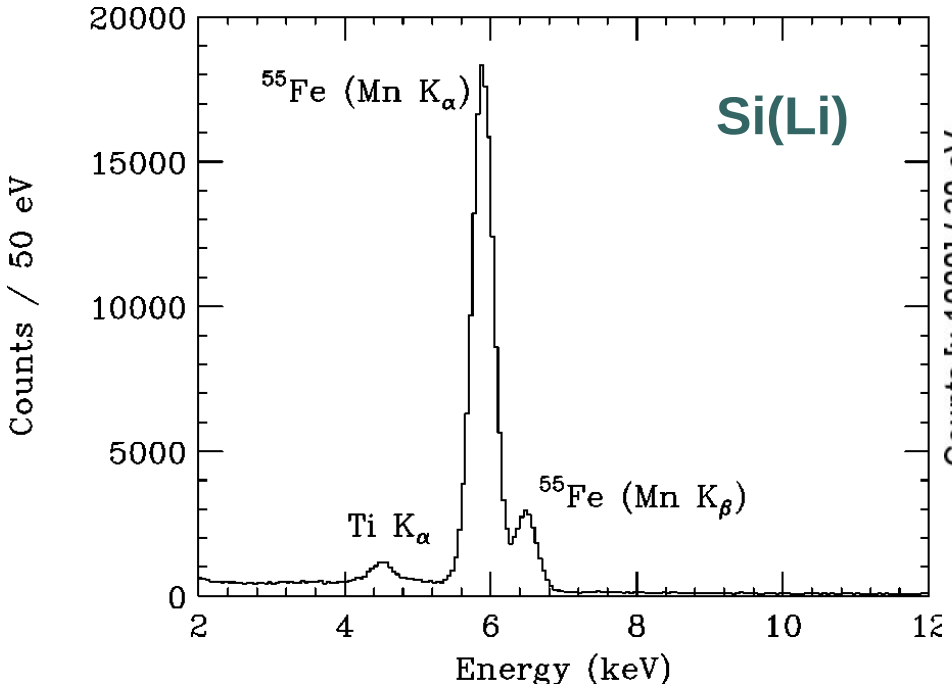


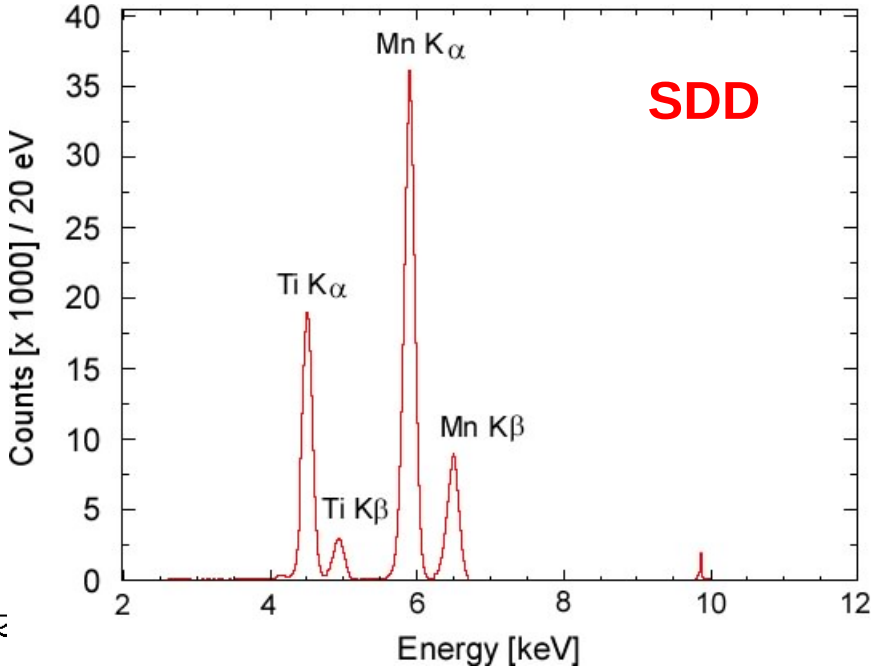
small anode
→ large-area,
high energy resolution,
Thin depletion
→ reduce background caused by electron/gamma

Low capacitance



Comparison of X-ray detectors used for kaonic X-ray experiments



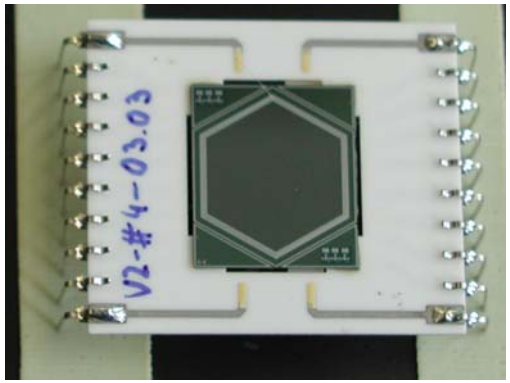


Detector		Si(Li)	CCD	SDD
Area	[mm2]	200	724	100
Thickness	[mm]	5	0.03	0.30
Δ E (FWHM)	[eV]	410	170	185
Δ t (FWHM)	[ns]	290	-	430

These values are obtained during the beam times.

Kaonic Helium X-rays with SDDs (E570, KEK)

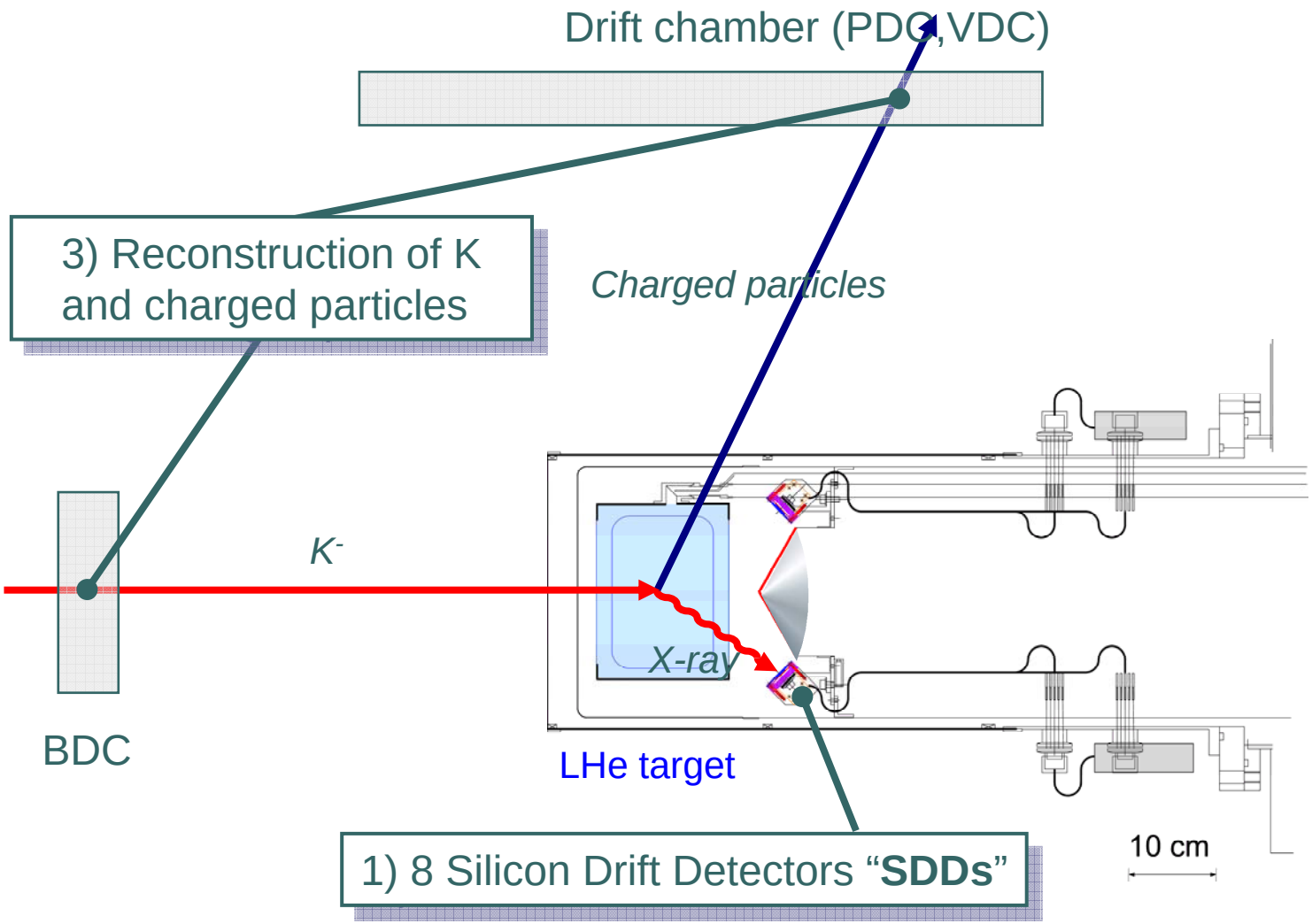
K-4He La X-rays



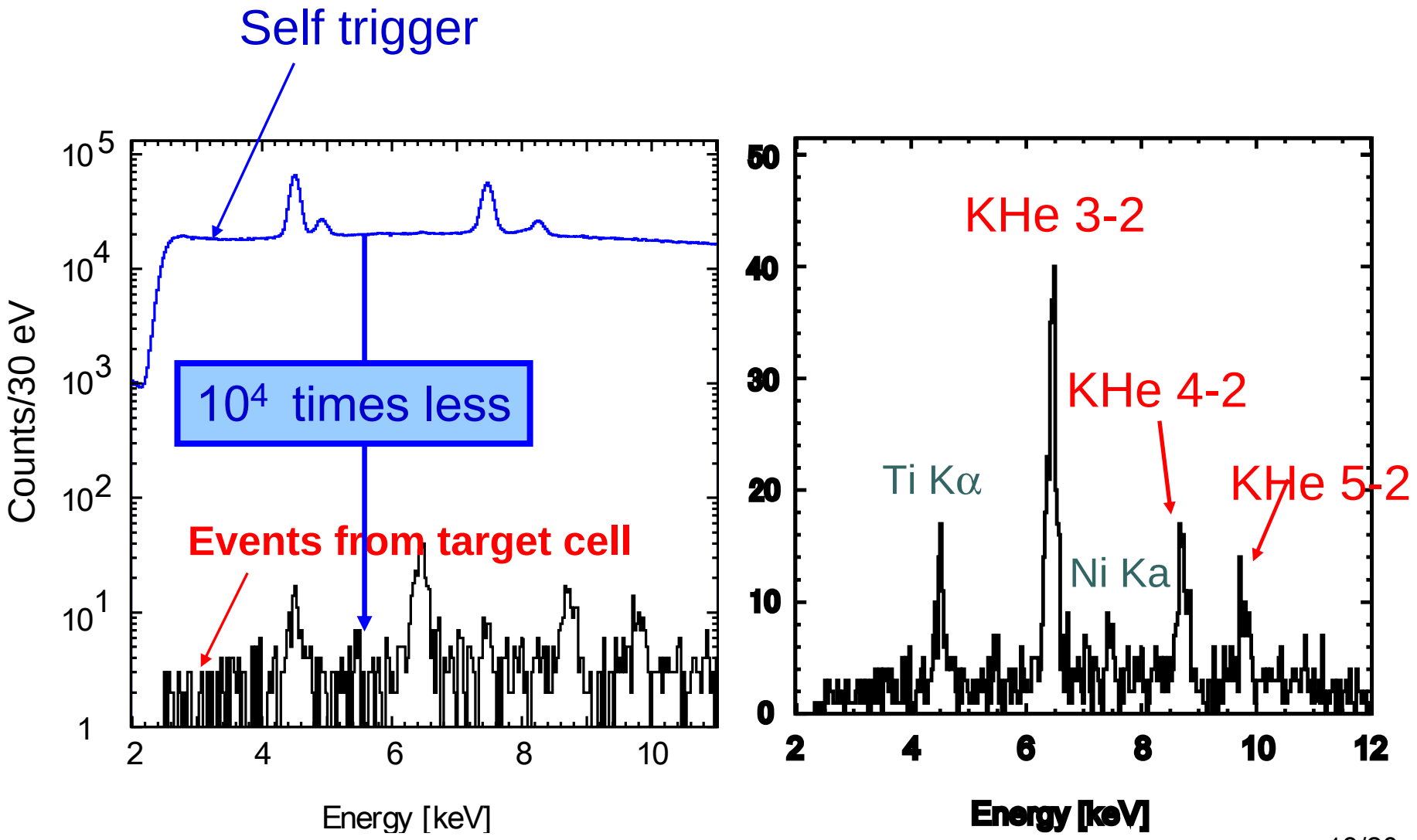
KETEK 1 cm^2 SDD

	E570
Energy resolution	~185 eV @ 6 keV
Effective Area	1cm^2 * 8 SDDs
Thickness	0.26 mm
Temperature	~85 K
Energy calibration	In-beam (Ti and Ni)
Fiducial volume cut	Yes

E570 experimental setup

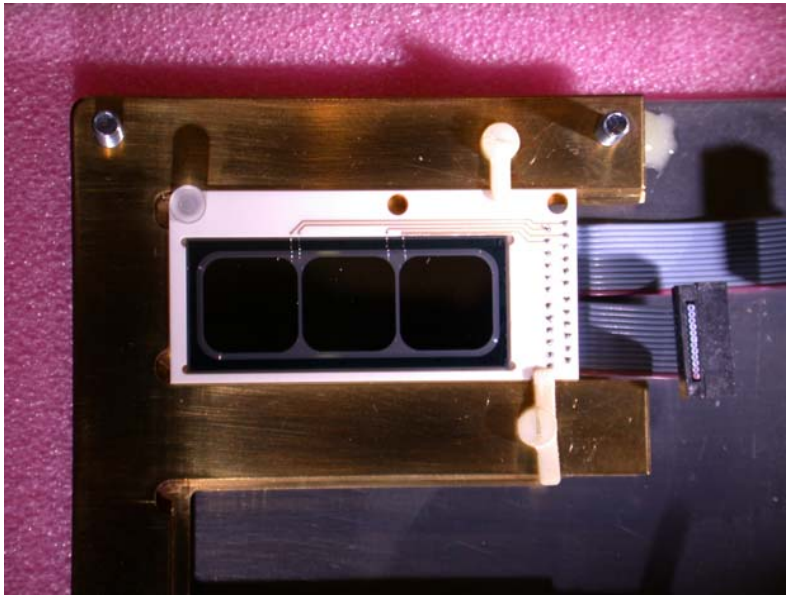


Kaonic 4He Energy spectra with SDDs



SIDDHARTA experiment (LNF, Italy)

Silicon **D**rift **D**etectors
for **H**adronic **A**tom **R**esearch
by **T**iming **A**pplication



HadronPhysics I3

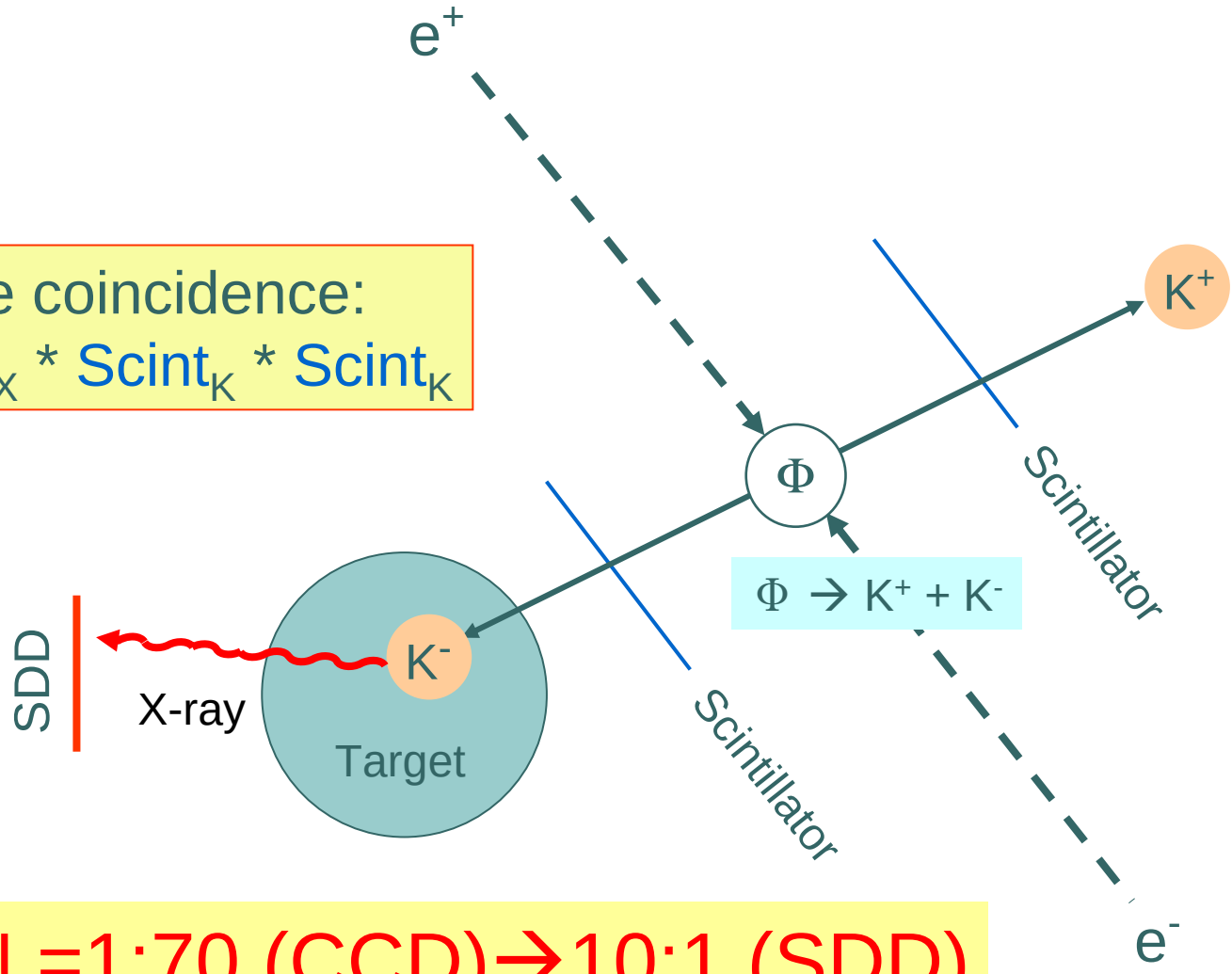
Study of Strongly Interacting Matter

New SDDs specially designed for SIDDHARTA

200 SDDs with 1cm² per SDD on-chip preamp

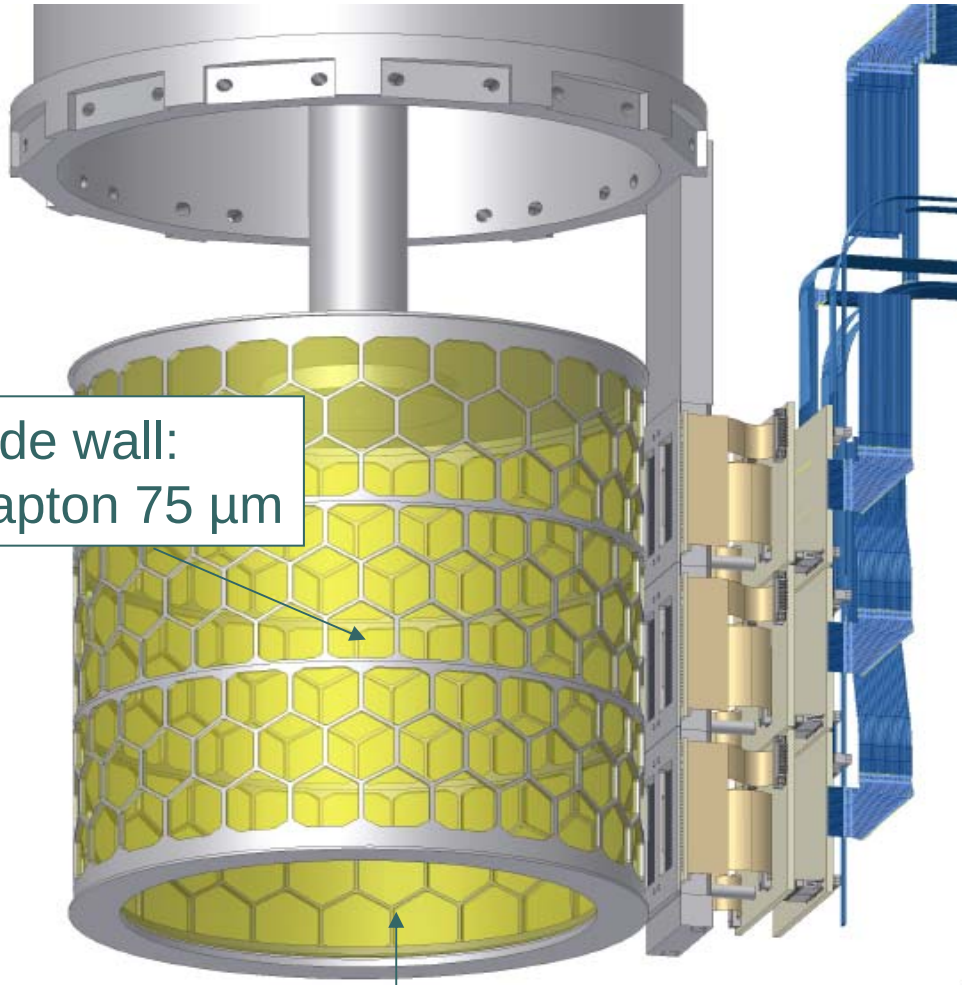
Triple coincidence technique

Triple coincidence:
SDD_X * $Scint_K$ * $Scint_K$

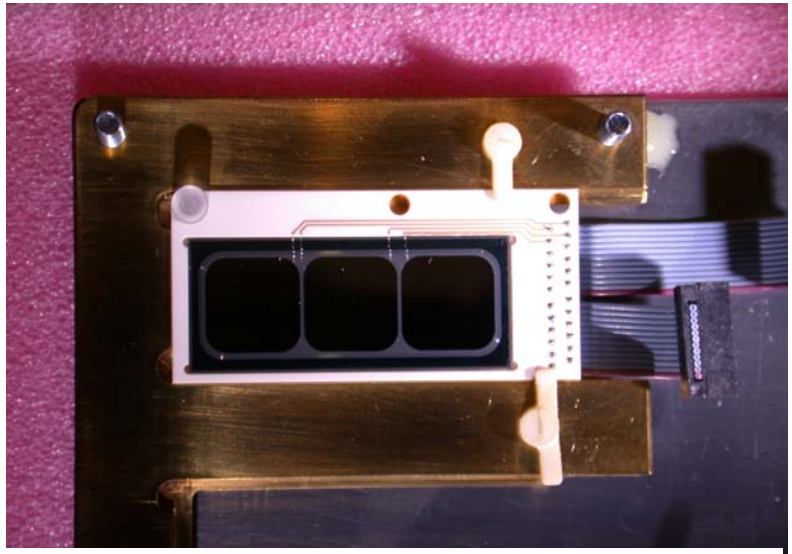


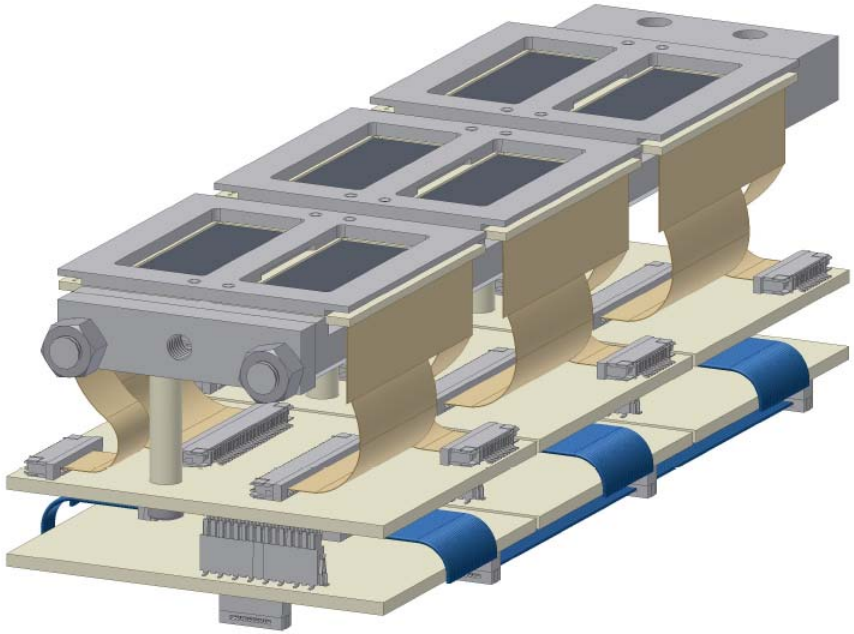
S/N =1:70 (CCD)→10:1 (SDD)
for kaonic Hydrogen

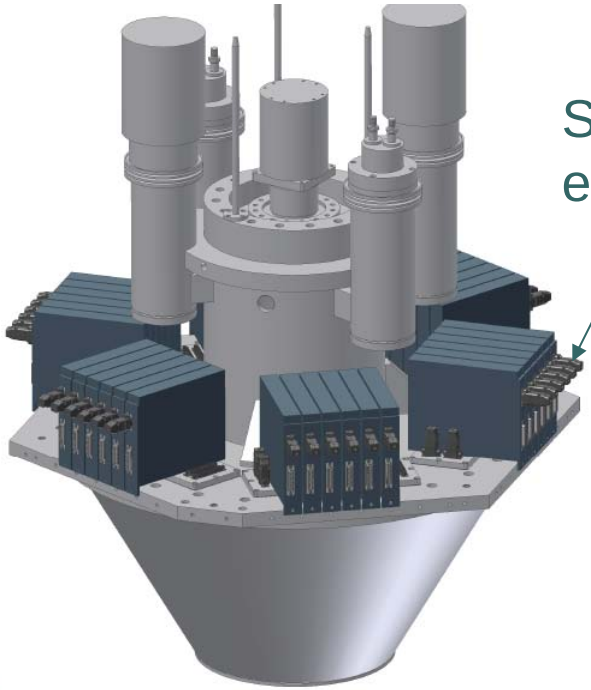
Temperature 22 K
Pressure max. 5 bar



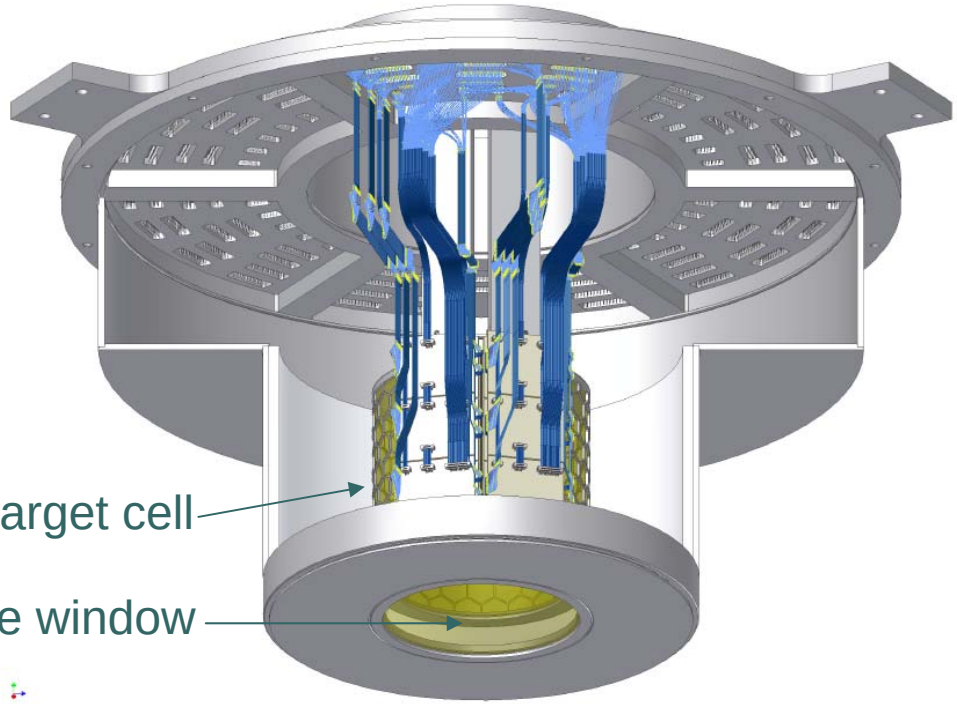
200 SDDs with 1cm² per SDD





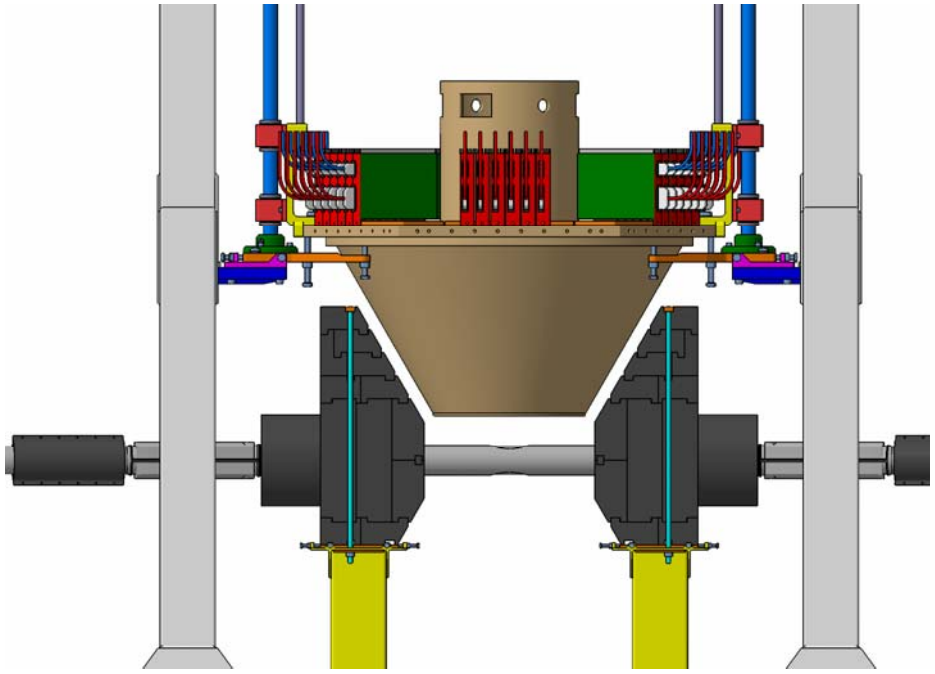


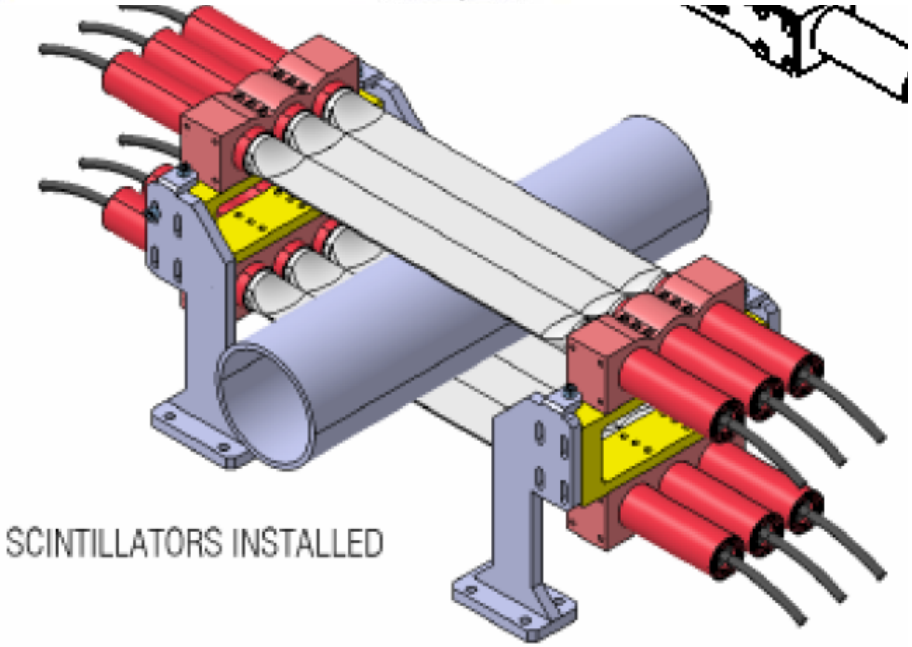
SDDs
electronics



Cryogenic target cell

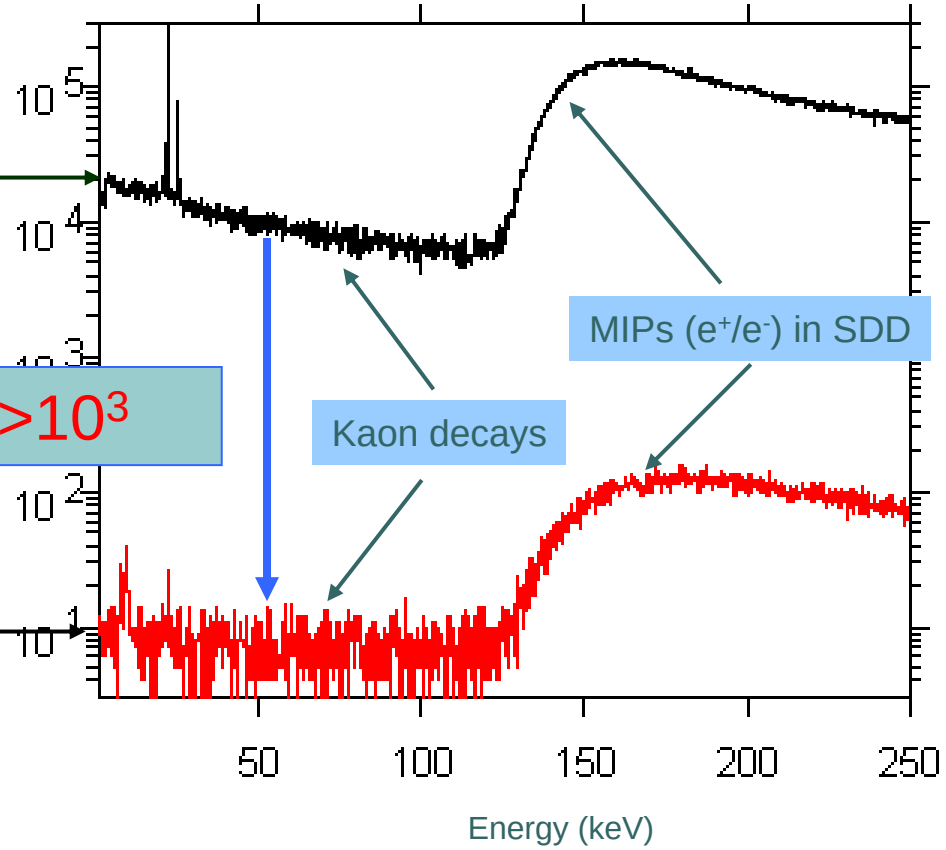
Kaon entrance window





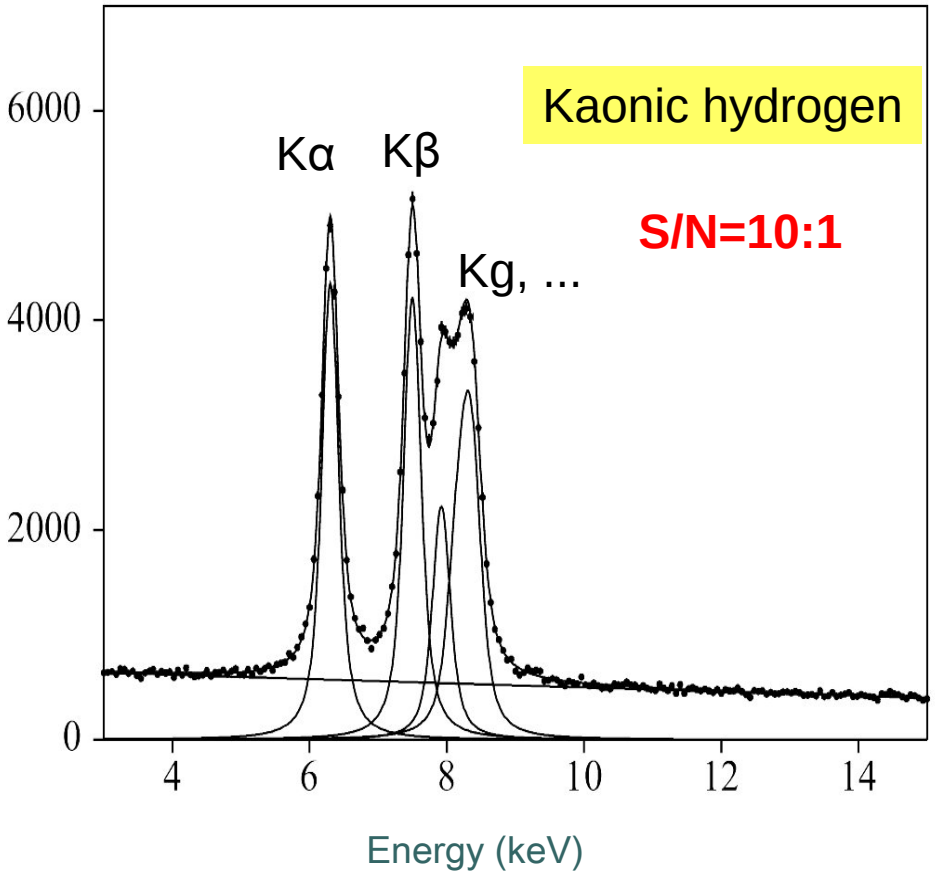
SCINTILLATORS INSTALLED

Monte Carlo for SIDDHARTA

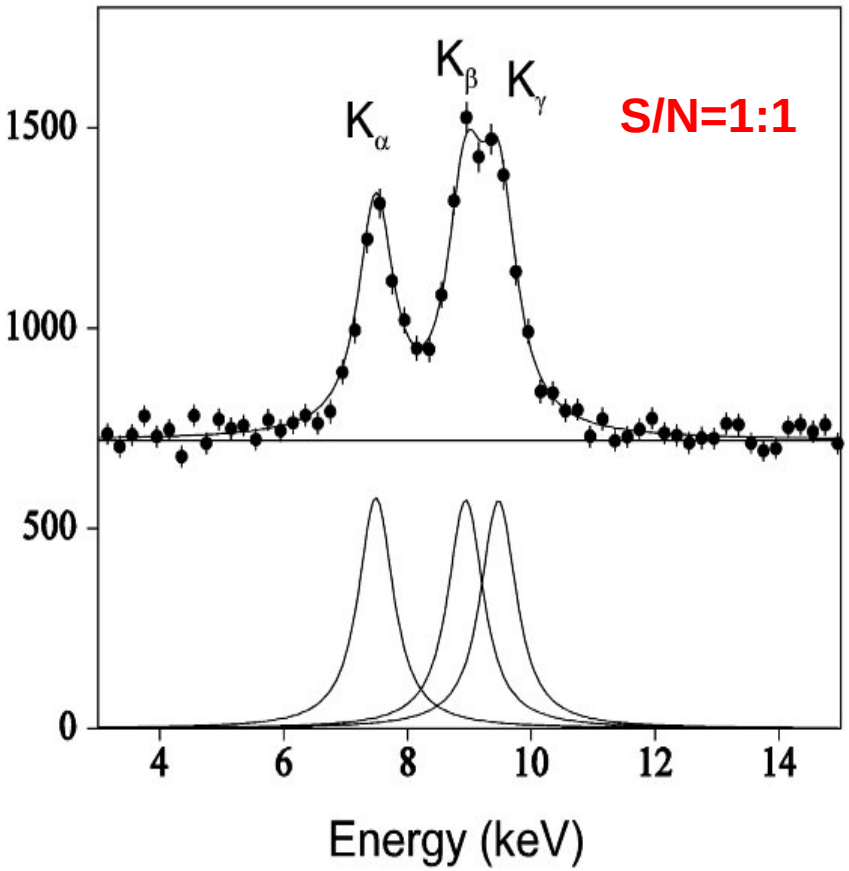


Signal rate ~ 2.2x10^{-3} /s
130 /d (duty cycle=2/3 of d.)

Energy spectra in SIDDHARTA (Monte Carlo)



Kaonic deutrium



K^-p: ε_{1s} = 193 eV, Γ_{1s} = 249 eV, Y(K_α)=2%
precision: ε_{1s} ± 3 eV Γ_{1s} ± 5 eV

K^-d: ε_{1s} = 325 eV, Γ_{1s} = 630 eV, Y(K_α)=0.2%
precision: ε_{1s} ± 18 eV Γ_{1s} ± 45 eV

Signal rate ~ 2.2×10^{-3} /s
130 /d (duty cycle=2/3 of d.)

30 days data taking

Summary

- Application of SDD X-ray detectors in the field of kaonic atoms is given.
- SDDs have good Energy resolution as well as good Time resolution.
- Prototype of Large-area SDDs are tested with a kaon beam at KEK successfully.
- High performance on Energy resolution, Time resolution, Background rejection capability was measured.
- We are now developing new type of Large-area SDDs specially designed for SIDDHARATA experiment.
- SIDDHATA will obtain
  - the most accurate for kaonic hydrogen X-rays,
  - and the first observation of kaonic deuterium X-rays.
- The physics runs start from 2007.

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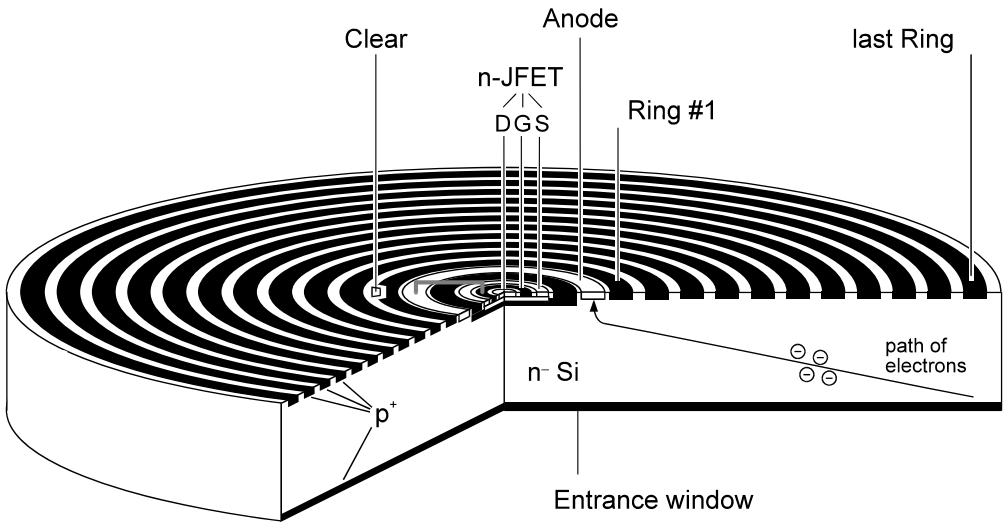
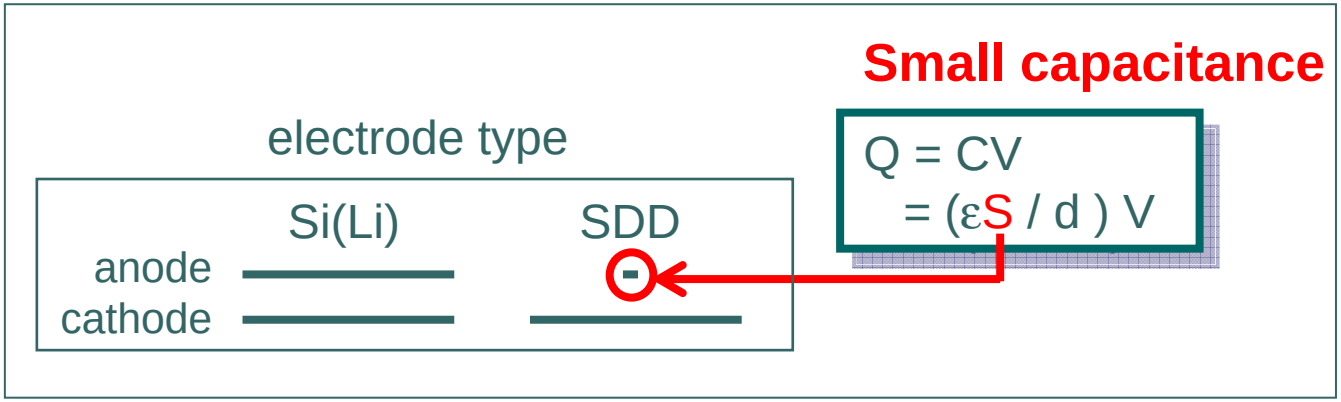
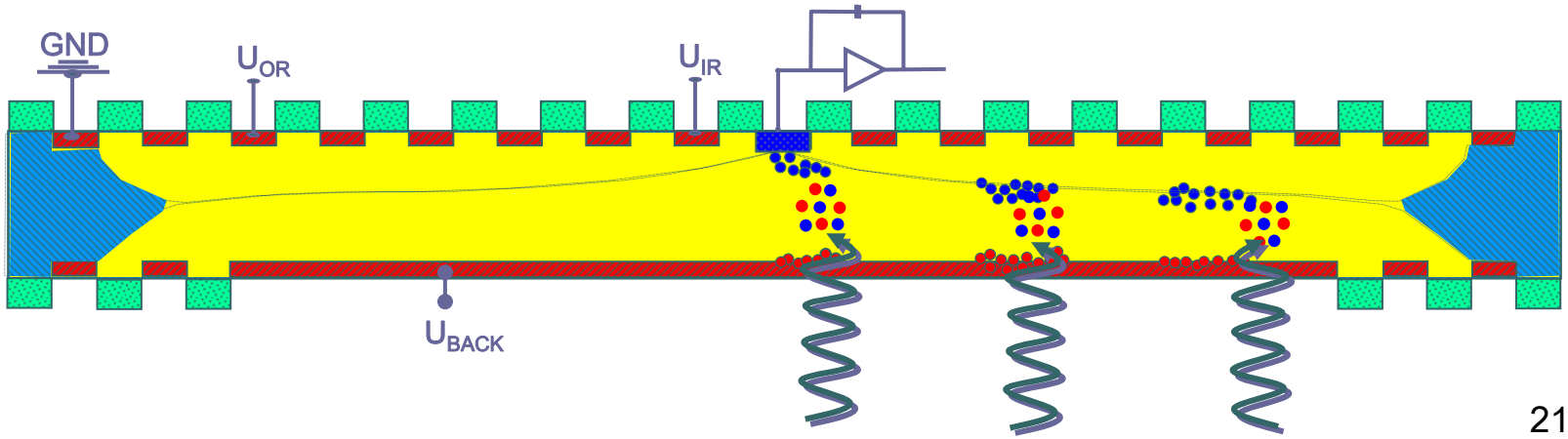
Silicon Drift Detector



high energy resolution at fast shaping times, due to the small anode capacitance

Small capacitance





E570 experimental setup