SIDDHARTA-2
Status of the upgrade

Catalina Curceanu

On behalf of the SIDDHARTA-2 Collaboration

47th LNF-SC 14 November 2013

SIDDHARTA-2

SIlicon Drift Detector for Hadronic Atom Research by Timing Applications

- **LNF- INFN, Frascati, Italy**
- **SMI- ÖAW, Vienna, Austria**
- **IFIN – HH, Bucharest, Romania**
- **INFN and Politecnico, Milano, Italy**
- **TUM, Munchen, Germany, Germany**
- **RIKEN, Japan**
- **Univ. Tokyo, Japan**
- **Victoria Univ., Canada**
- **Univ. Zagreb, Croatia**

The scientific aim of SIDDHARTA and SIDDHARTA-2

To perform precision measurement of kaonic atoms X-ray transitions -> unique info about the QCD in non-perturbative regime in the strangeness sector not obtainable otherwise with implications from particle and nuclear physics to astrophysics

Precision *measurement of the shift* and *of the width* of the 1s level of **kaonic hydrogen** and the of **kaonic deuterium**

and of other types of kaonic atoms (kaonic helium3, 4)

ECT*

EUROPEAN CENTRE FOR THEORETICAL STUDIES
IN NUCLEAR PHYSICS AND RELATED AREAS

TRENTO, ITALY

Institutional Member of the ESF Expert Committee NuPECC

Strangeness in the Universe?
Theoretical and experimental progress and challenges
October 21-25, 2013

SIDDHARTA main results:

- Kaonic Hydrogen: 400pb^{-1}, most precise measurement ever,Phys. Lett. B 704 (2011) 113, Nucl. Phys. A881 (2012) 88; Ph D

- Kaonic deuterium: 100 pb^{-1}, as an exploratory first measurement ever, published in Nucl. Phys. A907 (2013) 69; Ph D

- Kaonic helium 4 – first measurement ever in gaseous target; published in Phys. Lett. B 681 (2009) 310; NIM A628 (2011) 264 and Phys. Lett. B 697 (2011); PhD

- Kaonic helium 3 – 10 pb^{-1}, first measurement in the world, published in Phys. Lett. B 697 (2011) 199; Ph D

- Widths and yields of KHe3 and KHe4 - Phys. Lett. B714 (2012) 40; ongoing: KH yields; kaonic kapton yields: Nucl. Phys. A 916(2013) 30

SIDDHARTA – important TRAINING for young researchers

SIDDHARTAT(-2) papers in 2013:

1) The SIDDHARTA(-2) and the AMADEUS experiments at the DAFNE collider, **Nuclear Physics A 914 (2013) 215**
2) Strong-interaction shifts and widths of kaonic helium isotopes, **Nuclear Physics A 914 (2013) 305**
3) Kaon-Nucleon Strong Interaction in Kaonic Atoms: The SIDDHARTA Program**, Few Body Syst. 54 (2013) 1123-1126**
4) X-ray transition yields of low-Z kaonicatoms produced in Kapton, e-Print: arXiv:1306.5912 [nucl-ex], **Nuclear Physics A 916 (2013) 30**
5) Preliminary study of kaonic deuterium X-rays by the SIDDHARTA experiment at DAFNE, **Nucl. Phys. A907 (2013) 69-77**

SIDDHARTA(-2) papers 2013 and more

6) The yield of kaonic hydrogen X-rays in SIDDHARTA experiment, to appear in **EPJ**

7) Unveiling the strangeness secrets: low-energy kaon-nucleon/nuclei interactions studies at DAFNE, to appear in **EPJ**

8) C. Fiorini et al**,** Silicon Drift Detectors for Readout of Scintillators in Gamma-Ray Spectroscopy, IEEE 60 (2013) 2923

Kaonic hydrogen paper in Phys Lett B 704 (2011) – cited more than 50 times

PhD in 2013: D. Sirghi; HeXi Shi

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SIDDHARTA2 strategy – phases

1) Kaonic deuterium measurement - a document signed by many theoreticians about the importance of the measurement

2) Kaonic hydrogen at eV precision

3) Kaonic helium transitions to the 1s level – 2nd measurement, R&D

3) Other light kaonic atoms (KO, KC,…)

4) Heavier kaonic atoms measurement (Si, Pb…)

5) Kaon radiative capture – Λ(1405) study

6) Investigate the possibility of the measurement of other types of hadronic exotic atoms (sigmonic hydrogen ?)

7) Kaon mass precision measurement at the level of <10 keV

Antikaon-nucleon scattering lengths

Once the shift and width of the 1s level for kaonic hydrogen and deuterium are measured -) scattering lengths

(isospin breaking corrections):

$$\varepsilon + i\,\Gamma/2 \Rightarrow a_{K^-p}\ eV\ fm^{-1}$$

$$\varepsilon + i\,\Gamma/2 \Rightarrow a_{K^-d}\ eV\ fm^{-1}$$

one can obtain the isospin dependent antikaon-nucleon scattering lengths

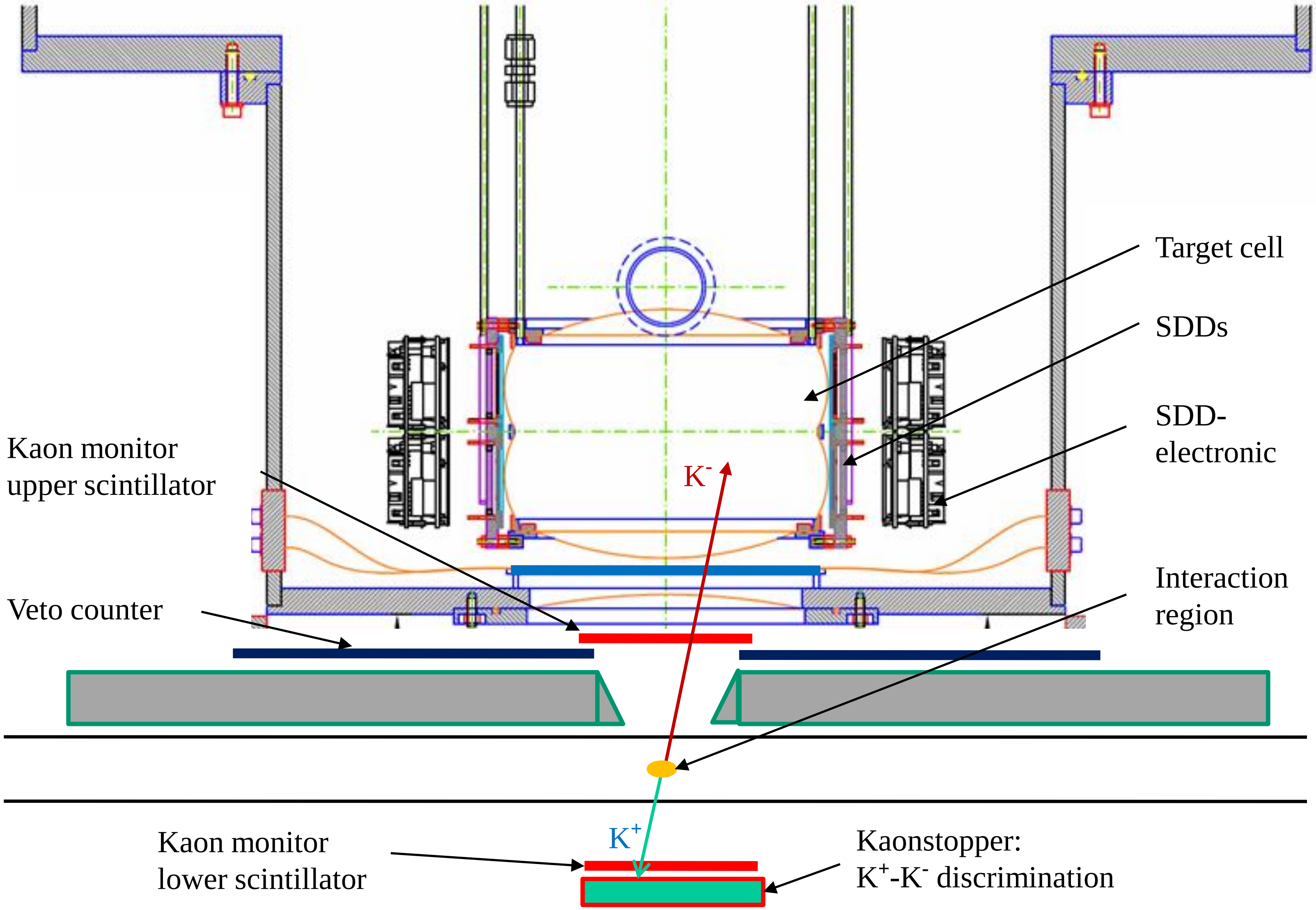
$$a_{K^-p} = (a_0 + a_1)/2$$

$$a_{K^-n} = a_1$$

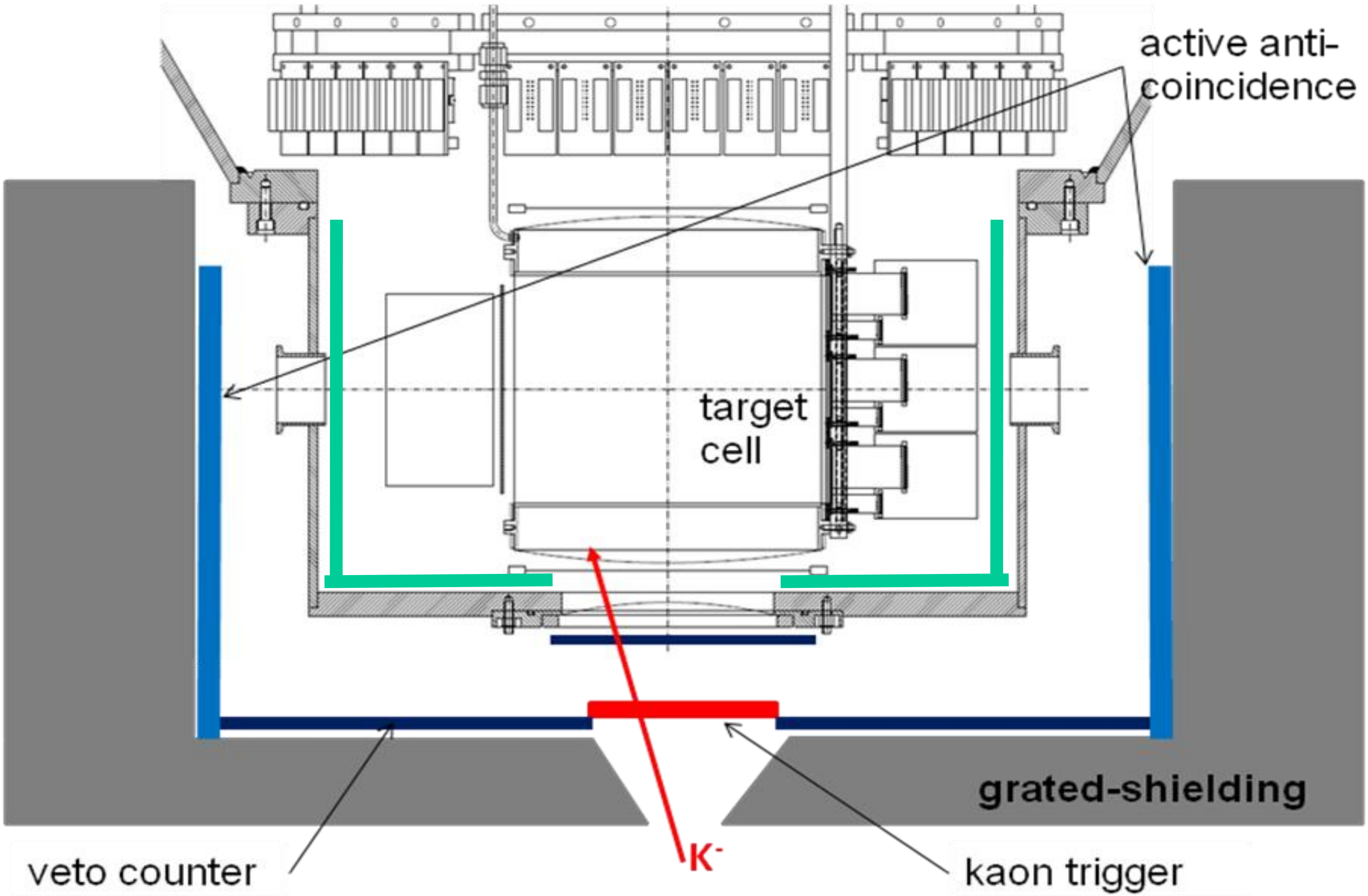
***Breakthrough in the low-energy QCD* in the strangeness sector, with implications from particle and nuclear physics to astrophysics**

The SIDDHARTA-2 setup, essential improvements

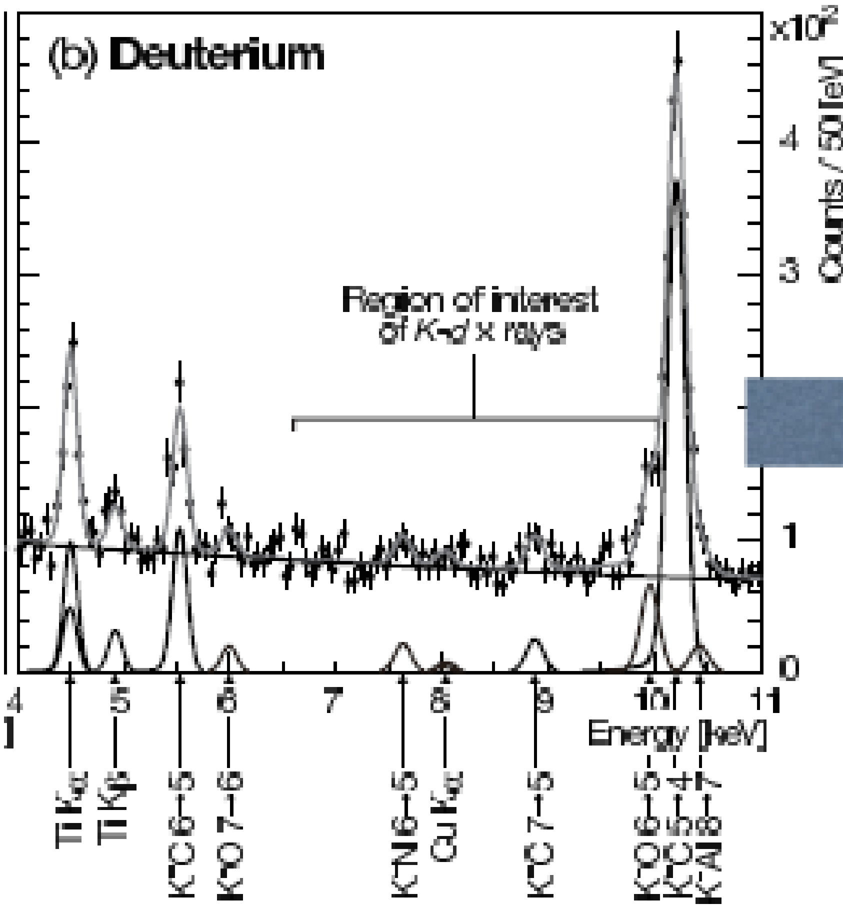
- new target final tests
- new SDD arrangement
- vacuum chamber final tests
- more cooling power
- improved trigger scheme
- shielding and anti-coincidence (veto)
- Assembly and tests



Target cell
SDDs
SDD-
electronic
Kaon monitor
upper scintillator
K^-
Veto counter
Interaction
region
K^+
Kaon monitor
lower scintillator
Kaonstopper:
K^+-K^- discrimination

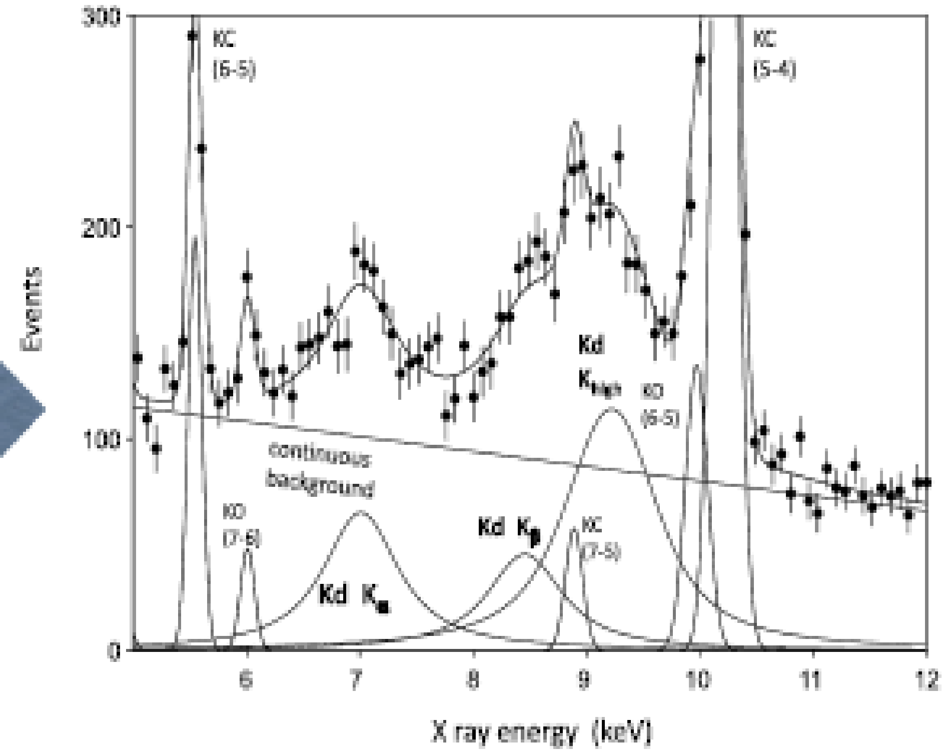

active anti-coincidence
target cell
grated-shielding
veto counter
K-
kaon trigger

SIDDHARTA(2009)



~100 pb^{-1}

SIDDHARTA2
(expected spectrum)



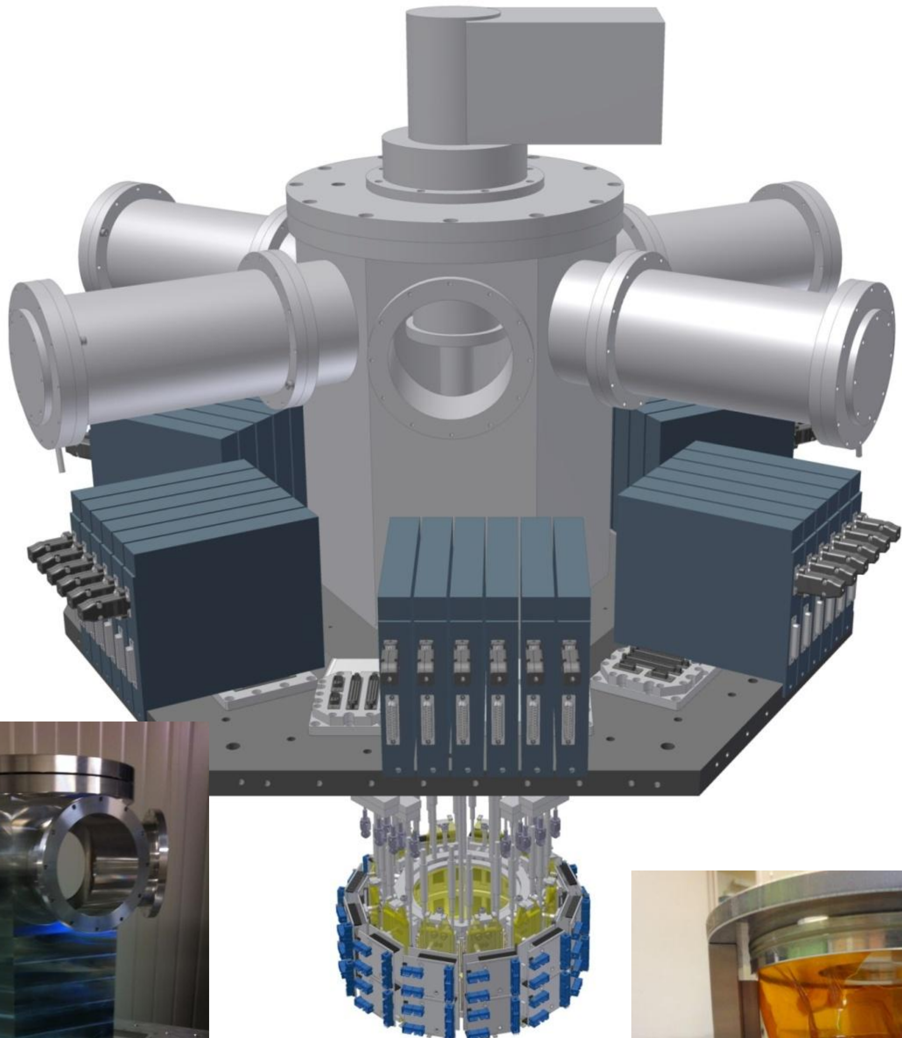
assuming

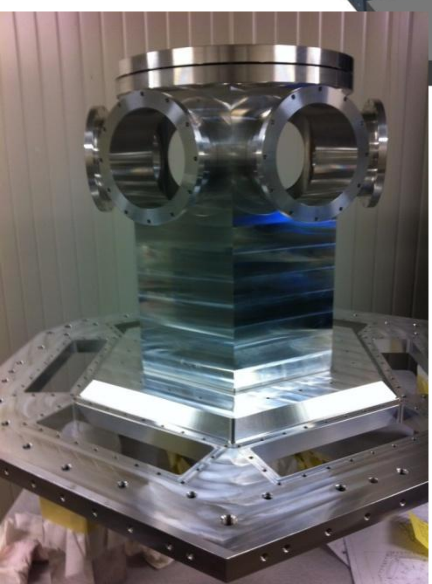
0.1% yield (1/10 of Kp)

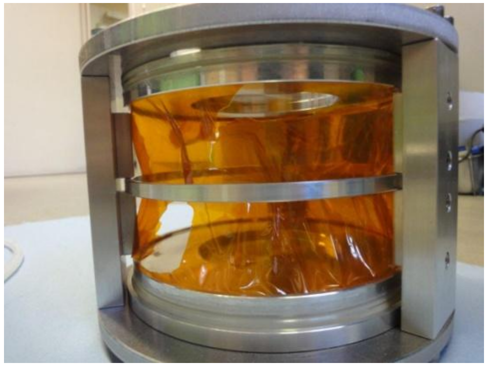
800 pb^{-1}

fit result (all intensities free) sample 1
shift = -556+-86 eV width= 1284+-145 eV

SIDDHARTA-2: Status in 2013

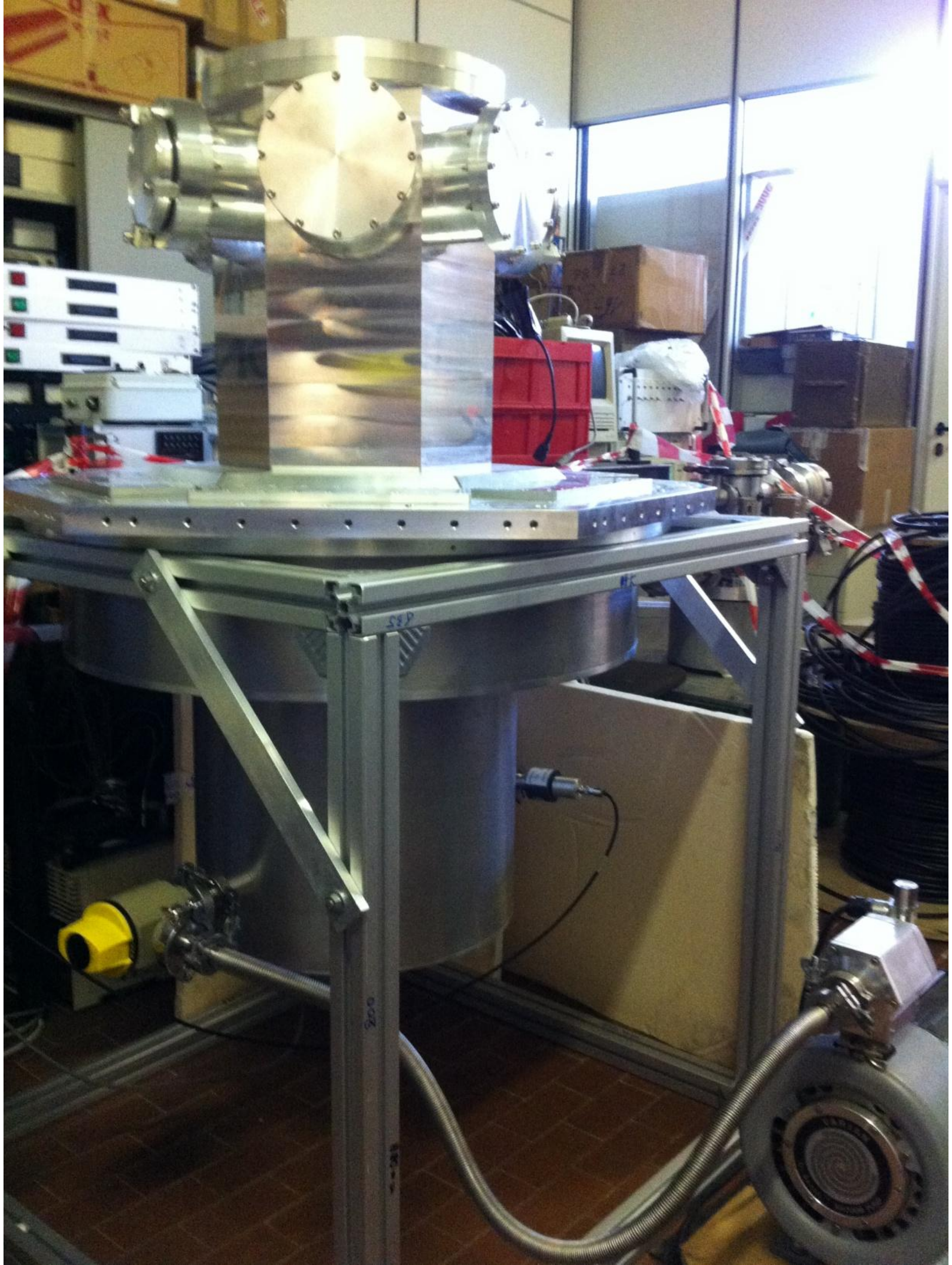






- **Vacuum chamber**
  ready and tested
- **Cryogenic target**
  ready and first cooling tests successfully
- **SDD cooling unit**
  prototype tested, components under construction

SIDDHARTA-2 new vacuum chamber test:

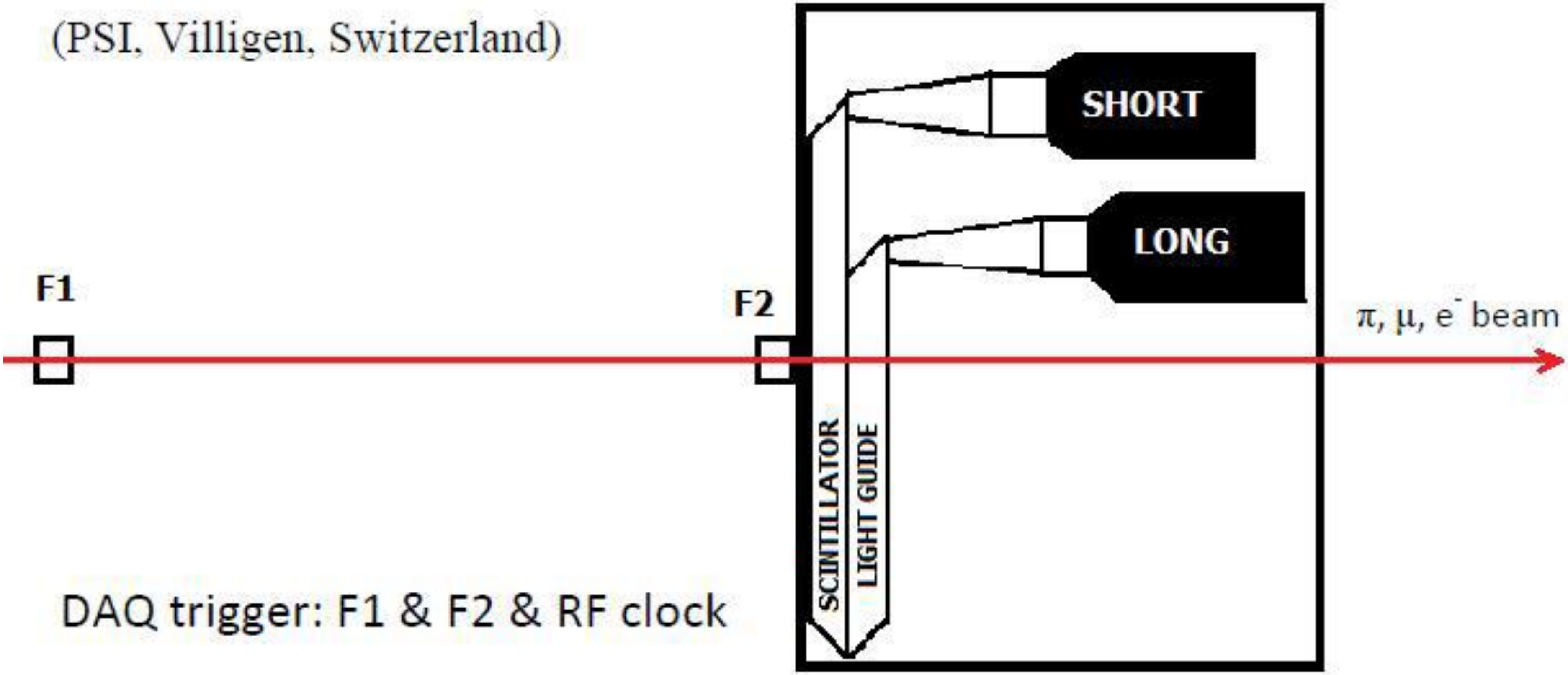


Veto system: construction and tests (PSI)

Paper in JINST – just accepted:

Characterization of the second level trigger detector based on a prism reflector lightguide scintillator for the SIDDHARTA-2 experiment

πM-1 beam at Paul Scherrer Institute
(PSI, Villigen, Switzerland)



DAQ trigger: F1 & F2 & RF clock

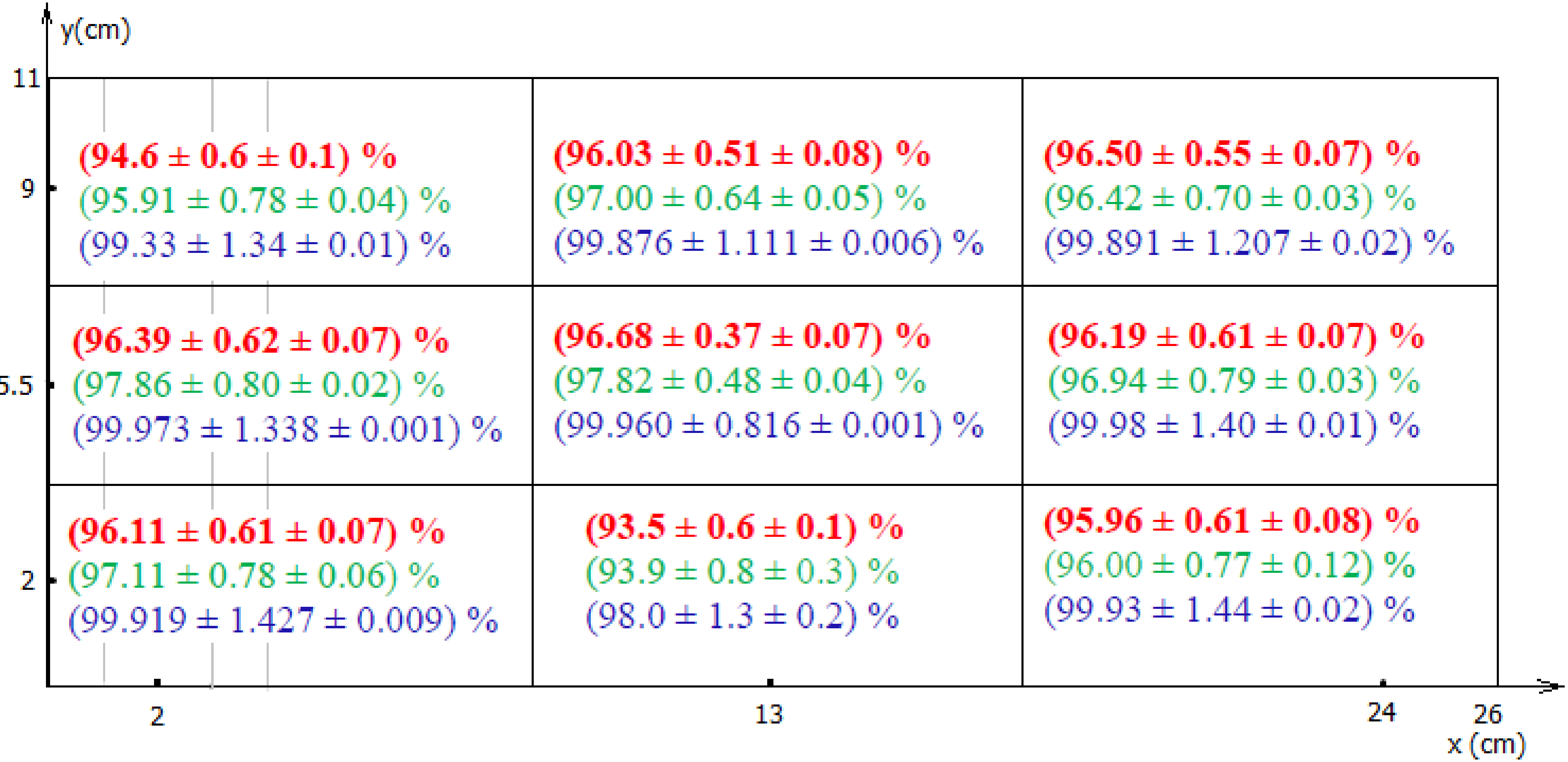


Figure 9. Measured efficiencies (MT) for the 170 MeV/c momentum pions (red) muons (green) and electrons (blue).

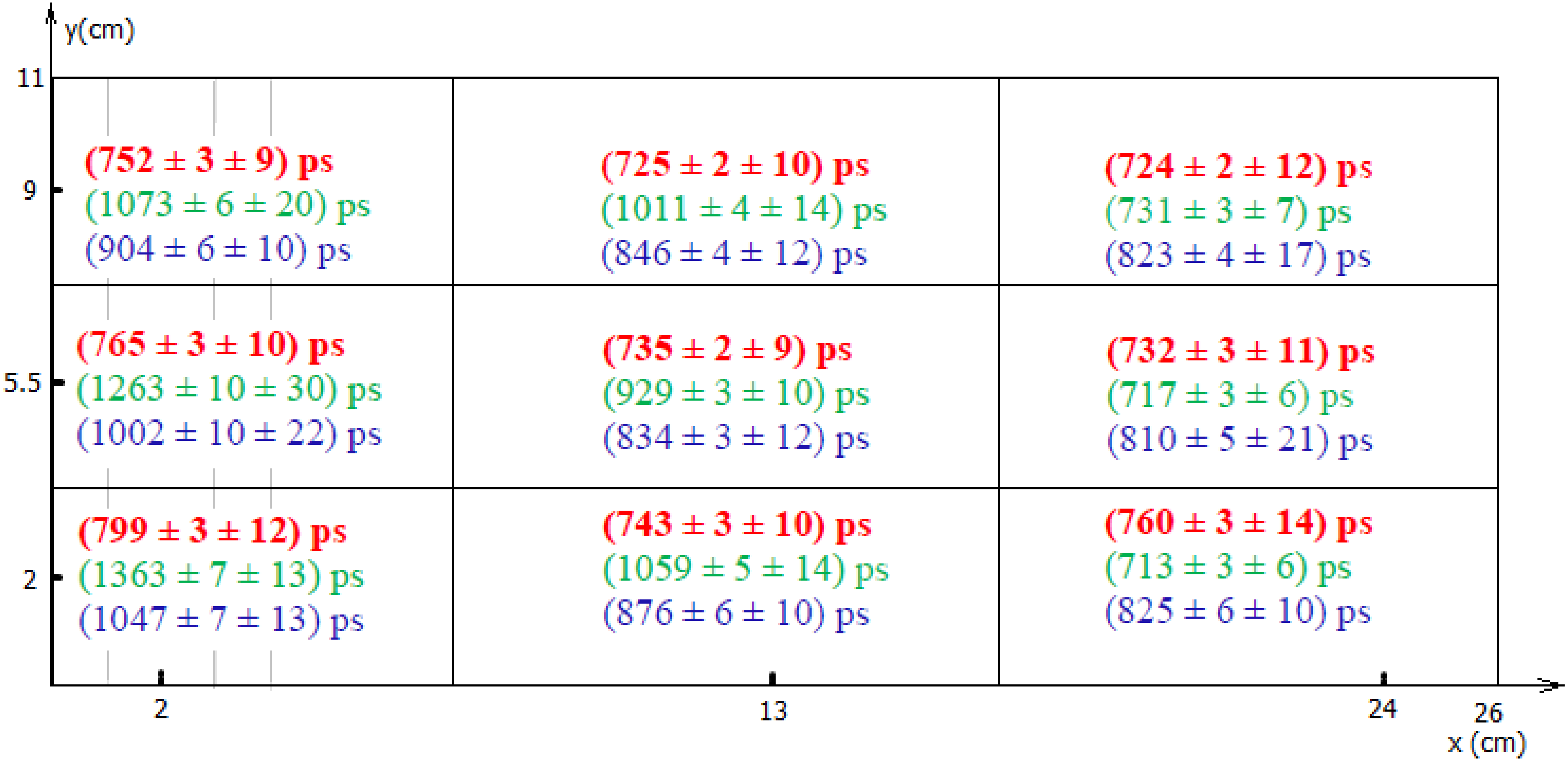


Figure 7. Measured mean time resolutions (FWHM) for 170 MeV/c momentum pions (red), muons (green) and electrons (blue).

Kd measurement:

SIDDHARTA-2 setup is going to be ready within 2014

We are confident that with an integrated luminosity of ***600-800 pb^{-1},*** SIDDHARTA-2 will be able to perform the measurement of the strong interaction parameters in kaonic deuterium- **the energy displacement and the width of the kaonic deuterium ground state, a fundamental measurement in low-energy strangeness QCD.**

In SIDDHARTA-like conditions this measurement would take about 4 months

Where to install SIDDHARTA-2? A realistic possible scenario:

To (re)open the second IP with or without crab waist scheme

While awaiting to enter on DAFNE:

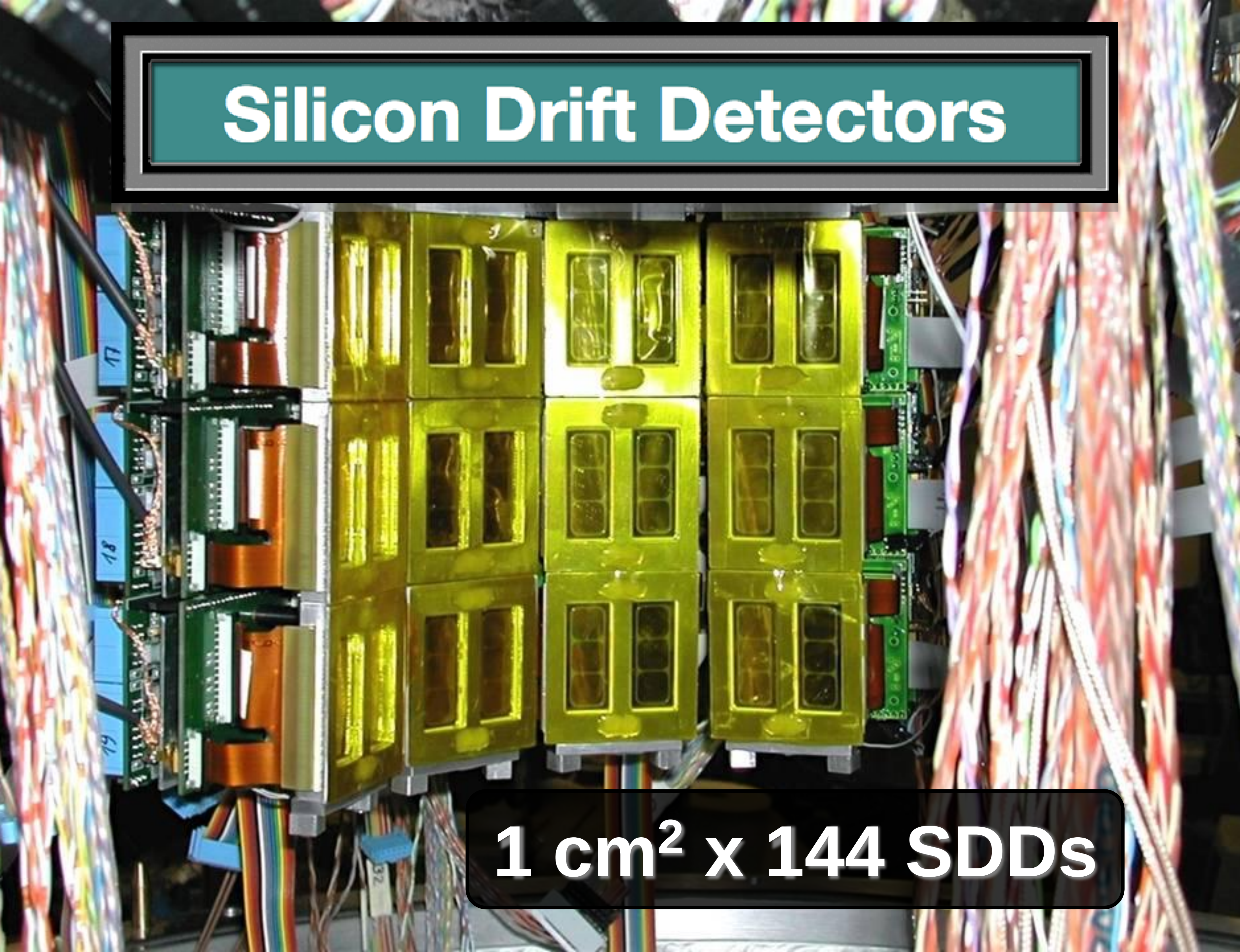
In 2013 - New SDDs – FBK were tested:

To replace the 10-years old SIDDHARTA SDDs (financed by INFN – gr 3 for about 40%)

The SIDDHARTA-2 setup further improvement

- new target final tests
- new SDD arrangement
- vacuum chamber final tests
- more cooling power
- improved trigger scheme
- shielding and anti-coincidence (veto)
- Assembly and tests
- **Use of new SDD detectors**

Silicon Drift Detectors



1 cm^2 x 144 SDDs

The new SDDs and electronics – work done (Milano and Frascati)

New development of SDDs by Politecnico & FBK

- **Started in 2011 within a project supported by ESA**
- **Considered very suitable for the upgrade of the Siddharta-2 apparatus, with preliminary evaluation on prototypes in 2012/2013**

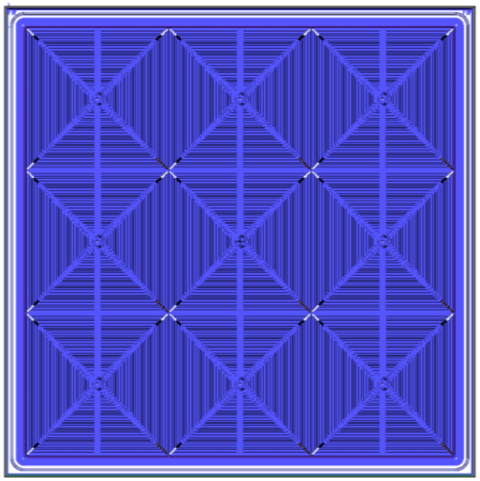
- **Key features of the proposed technological approach:**

1) **process of SDD detectors WITHOUT JFET integrated on the SDD itself (as used on current SIDDHARTA apparatus).**
   advantages:
   - simplicity
   - much lower production costs (much less techn. steps)
   - faster production times (3-4 months vs. one year)
   - much lower dependence of settings/performances on bias voltages than with the present detectors
   - less sensitivity to latch-up during beam injection

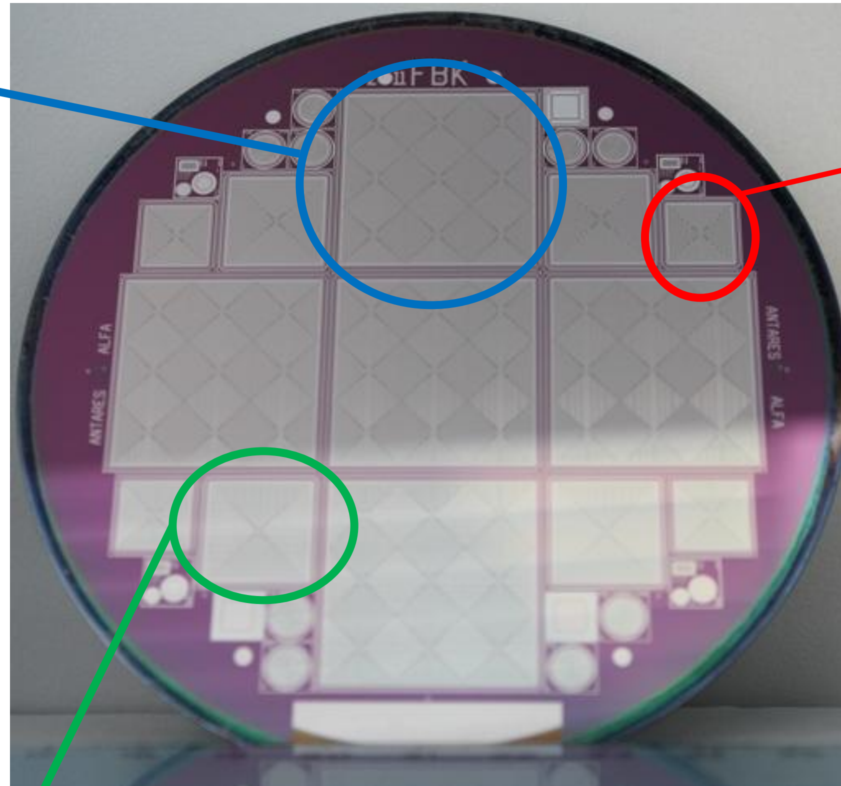
2) **SDD readout based on a new charge preamplifier "Cube" (recently developed at Politecnico di Milano):**
   - allows high performances in X-ray spectroscopy still using 'conventional' SDD technology (W/O integrated JFET)

Present layouts of SDDs developed in the Polimi-FBK collaboration

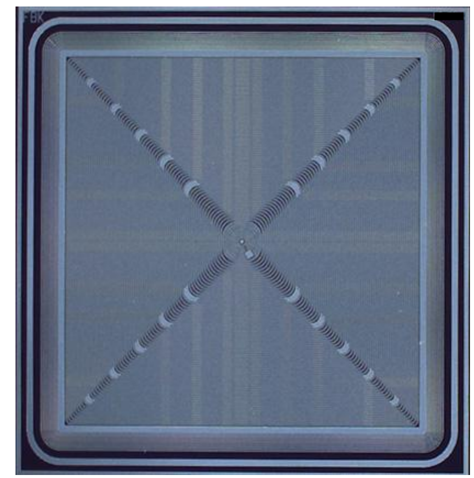
Array: 9 SDDs (8 x 8 mm^2 each)



26mm



8 x 8 mm^2 single SDD



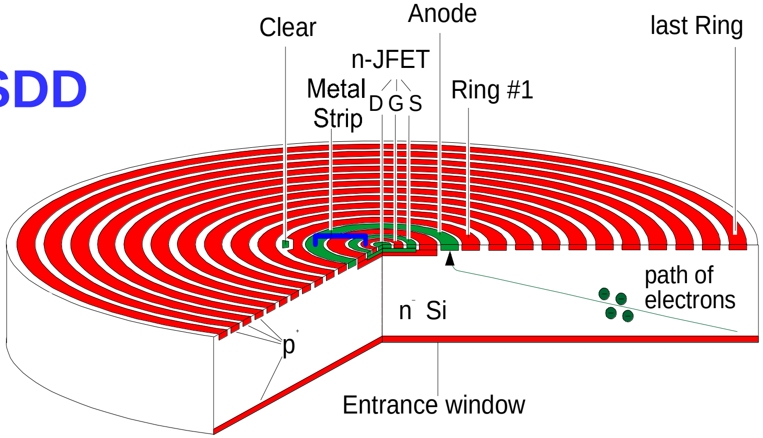
12 x 12 mm single SDD

FBK production:

- **4” wafer**
- **6” wafer upgrade just finished**

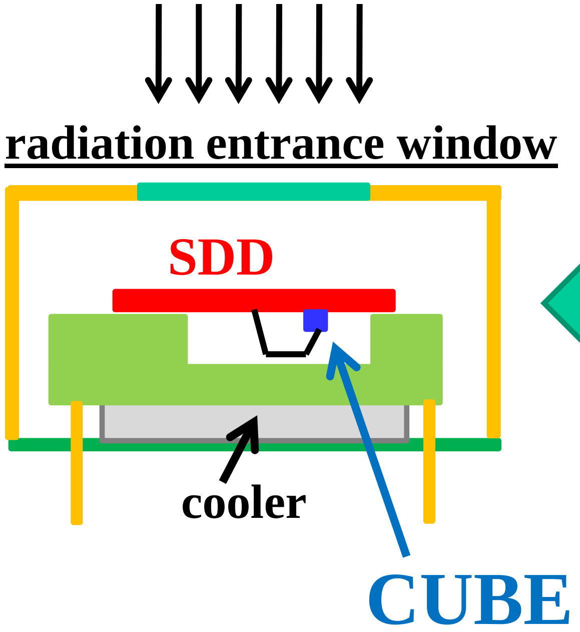
Front-end readout strategy

- **JFET integrated on the SDD**
  - **lowest total anode capacitance**
  - **limited JFET performances (gm, 1/f)**
  - **sophisticated SDD+JFET technology**



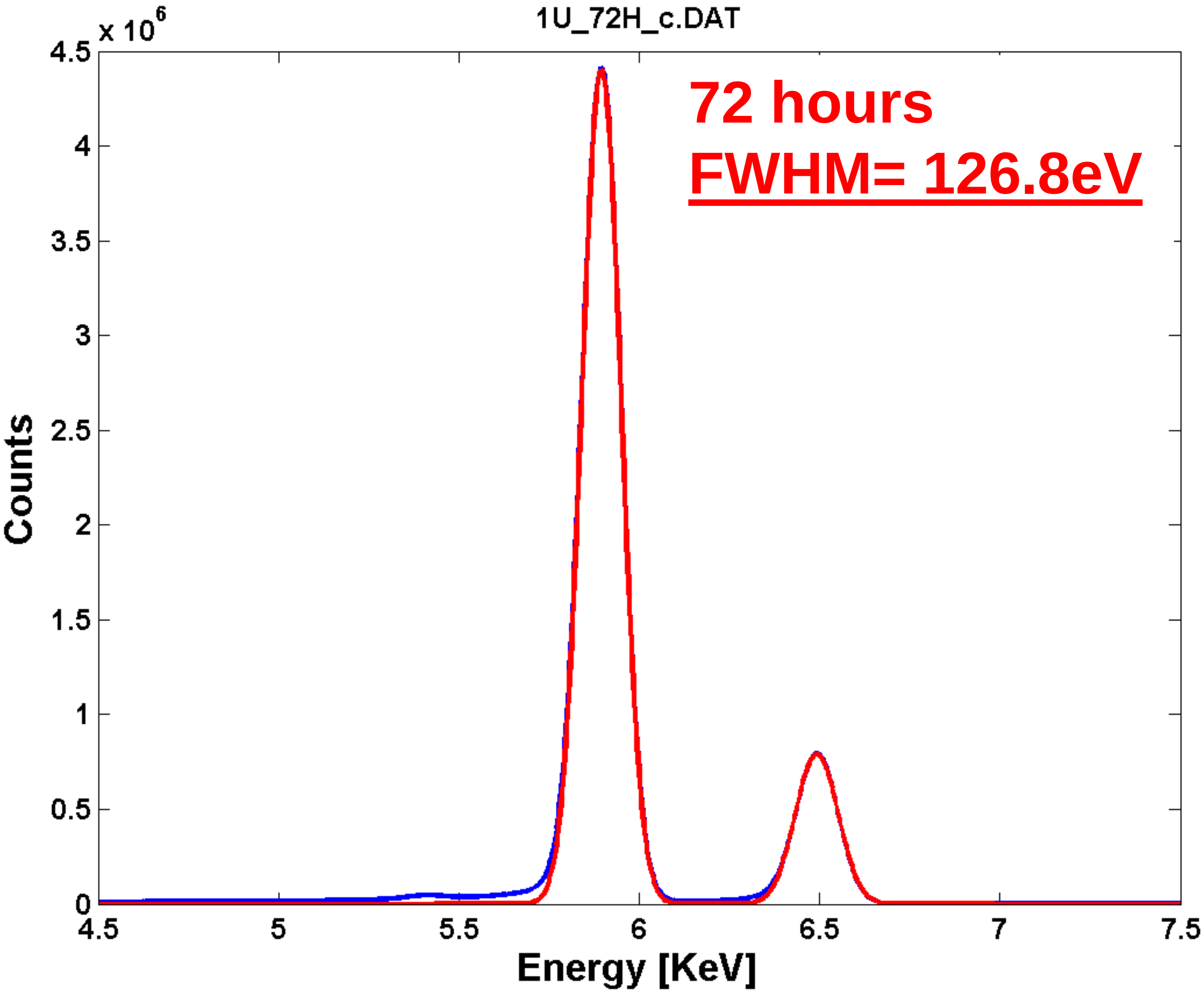
Now in Siddharta

- **external CUBE preamplifier (MOSFET input transistor)**
  - **larger total anode capacitance**
  - **better FET performances**
  - **standard SDD technology**



Proposed for Siddharta-2

Stability tests (in Milano, other tests were made in Frascati)



square SDD: 64 mm^2
meas. time: 72 hours
T= 100 K
Rate: 1.1 kcps
Vacuum chamber set-up.

(following slides courtesy of M.Iliescu)

SDD characterization at LNF

Stability tests:

-long term monitoring of the gain and offset

-stability under small temperature variations

-gain stability at different X-ray rates

-gain stability at different ionizing particle rates (ongoing)

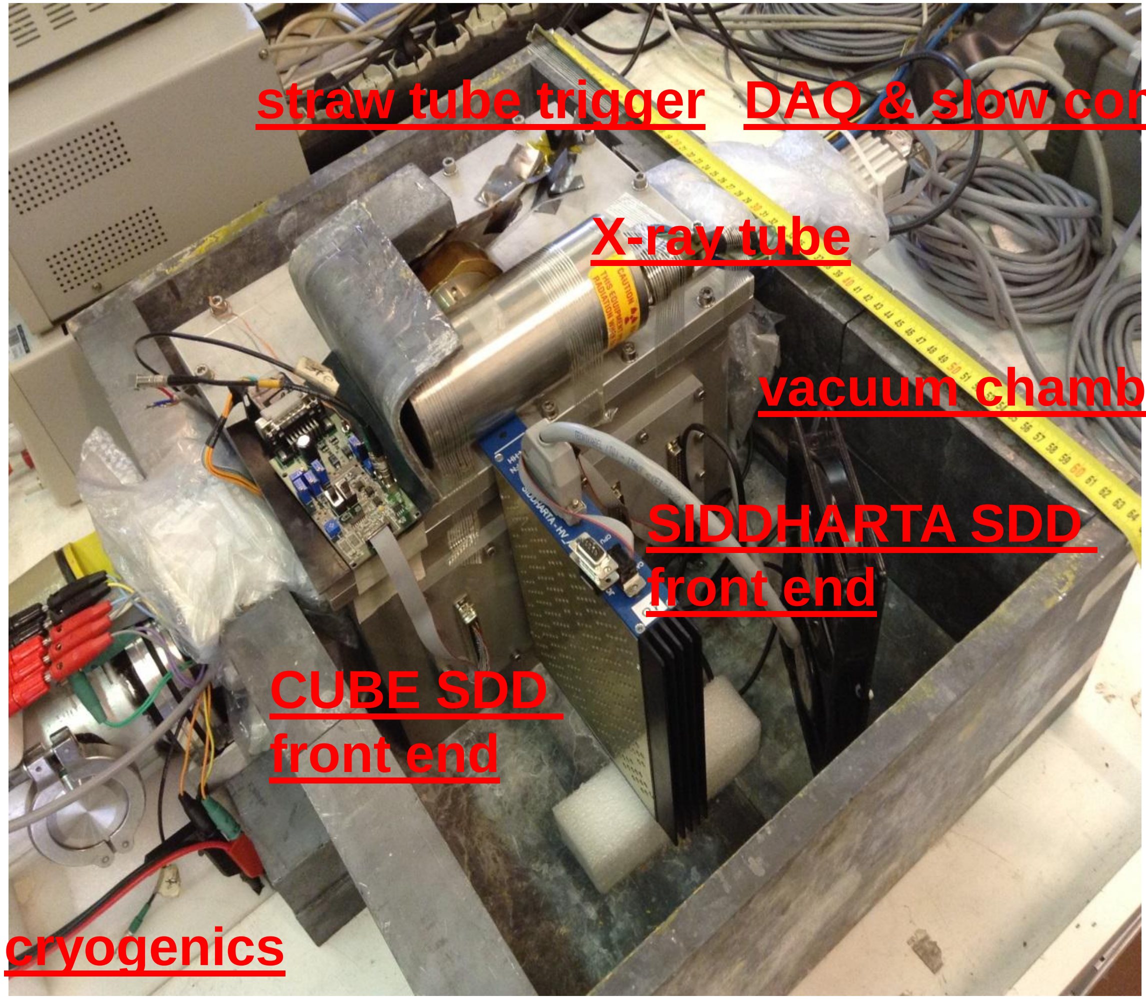
Linearity measurements

SDD time response at various temperatures

Testing the radiation hardness

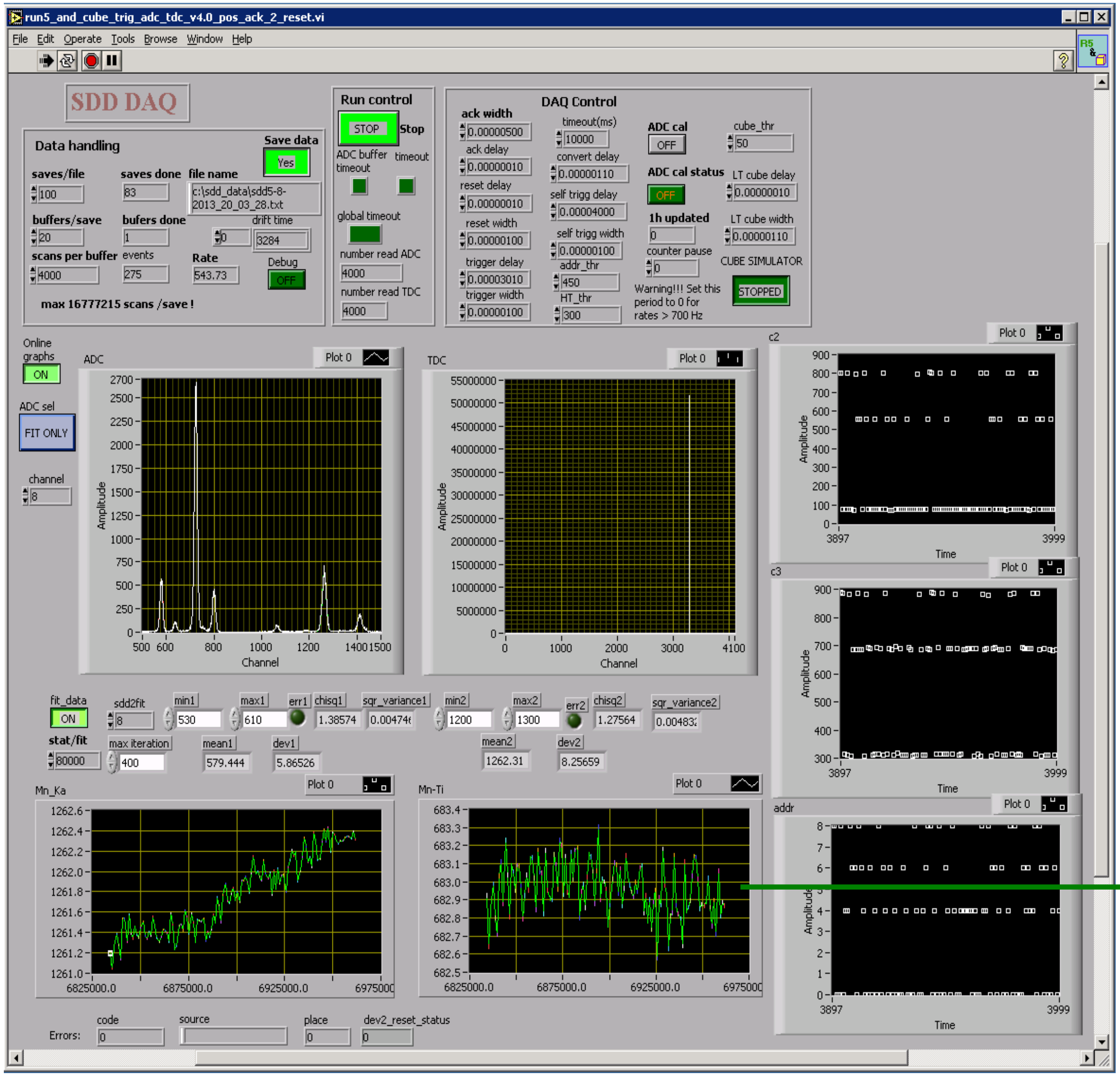
SDD functioning at very low temperatures (~ 20 K)

Status of SIDDHARTA 2 preparation

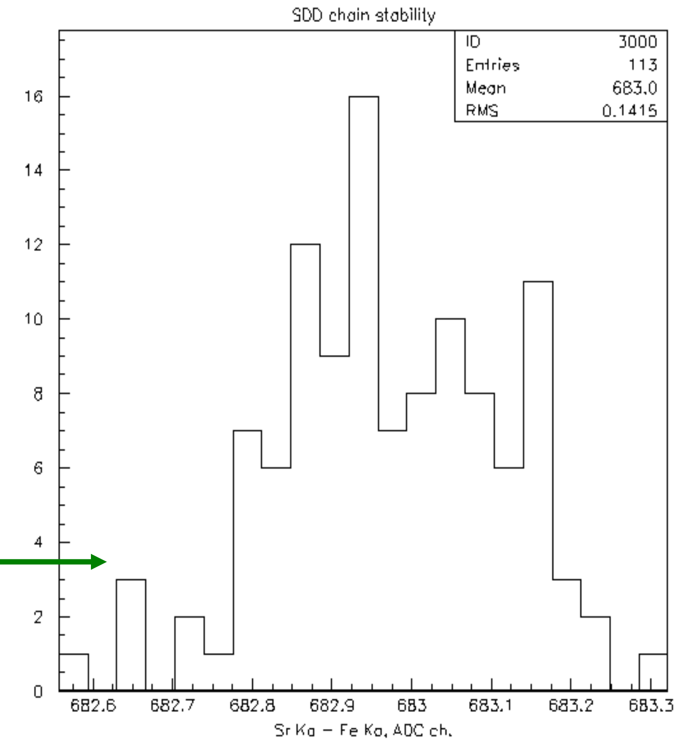


Test setup for SIDDHARTA 2 electronics and new SDDs (Trento) equipped with Milano CUBE reset amplifier

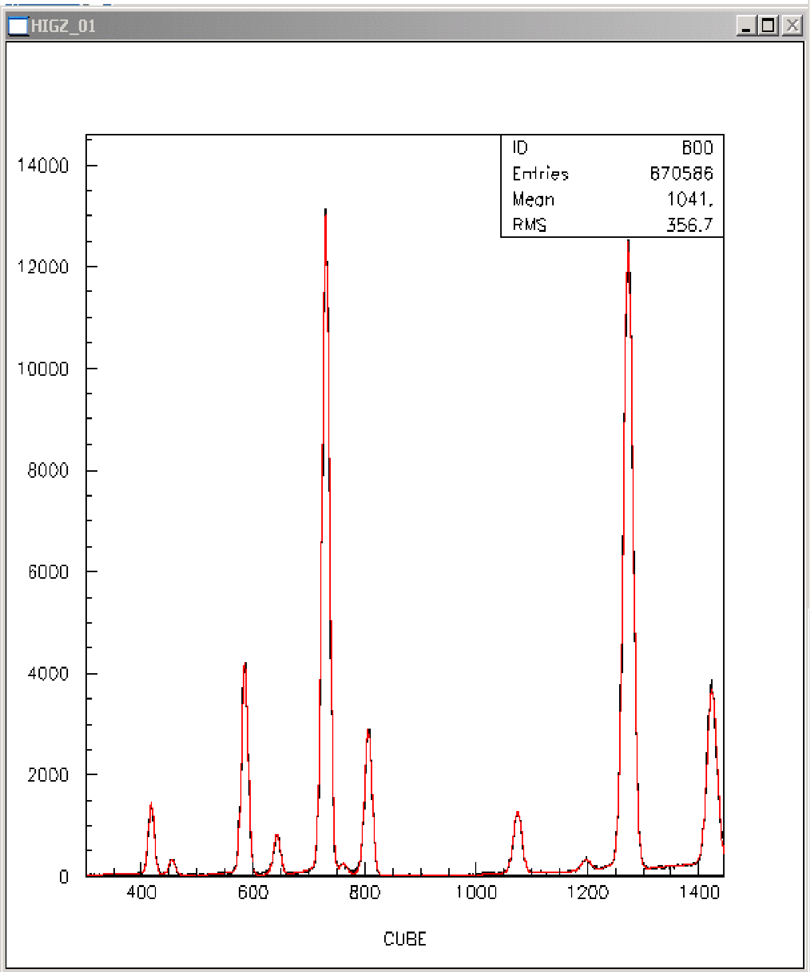
Gain stability tests for the new SDDs equipped with CUBE reset amplifier

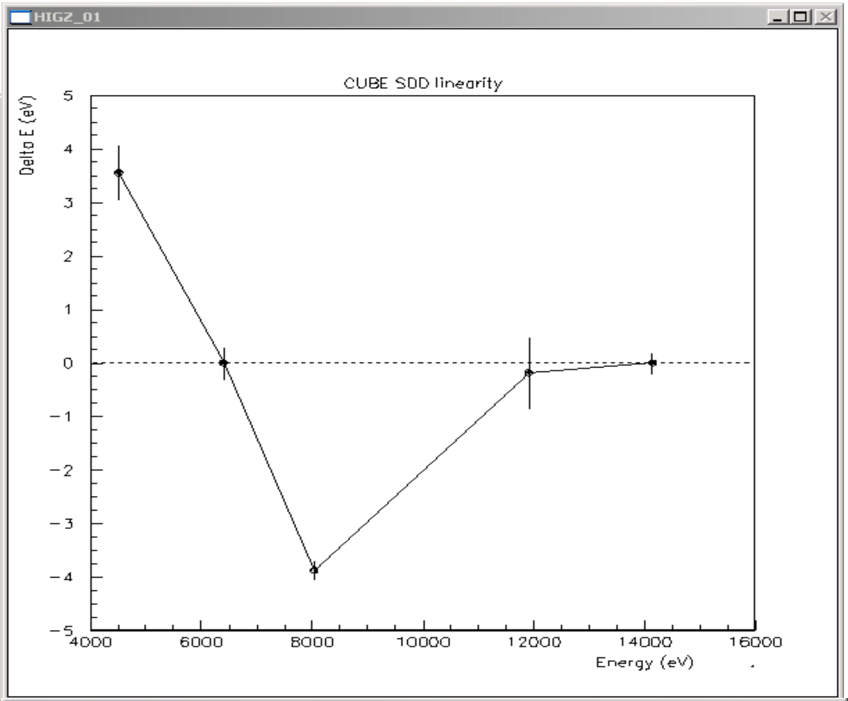


Gain fluctuations (Sr Kα- Fe Kα):
0.14 ADC ch/ 683 ch = 2 x 10^{-4},
compatible with the NIM bench quality
Fe Kα resolution: 152 eV FWHM
Offset fluctuations ~10^{-3}, still under study

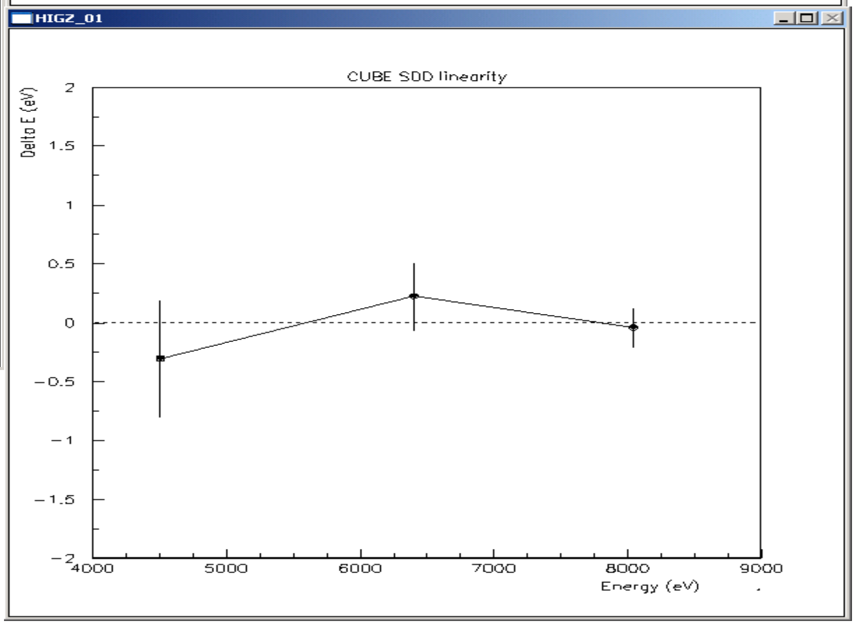


Linearity of the new SDDs equipped with CUBE reset amplifier



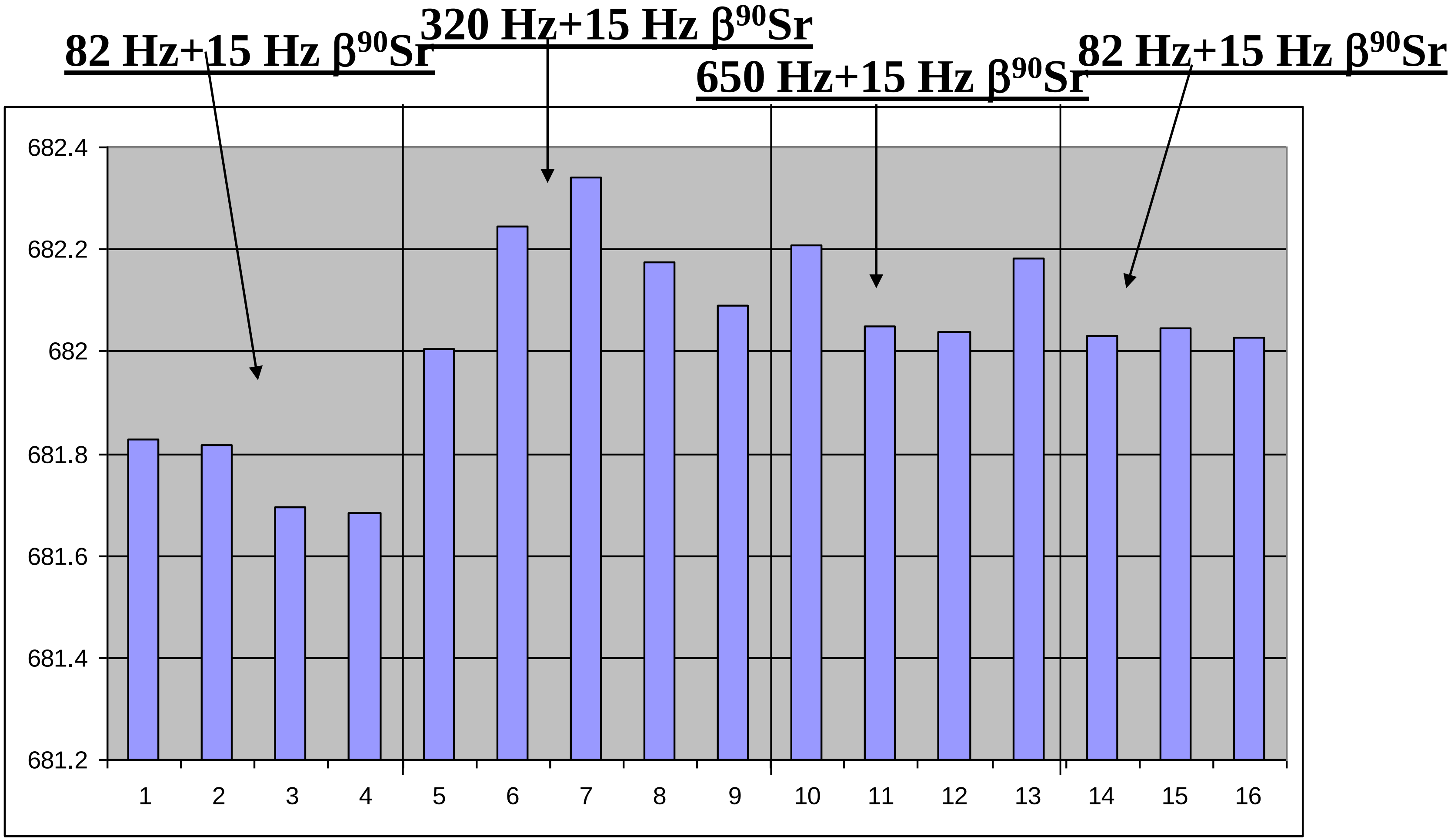


Full range: linearity deviation below 4 eV equivalent

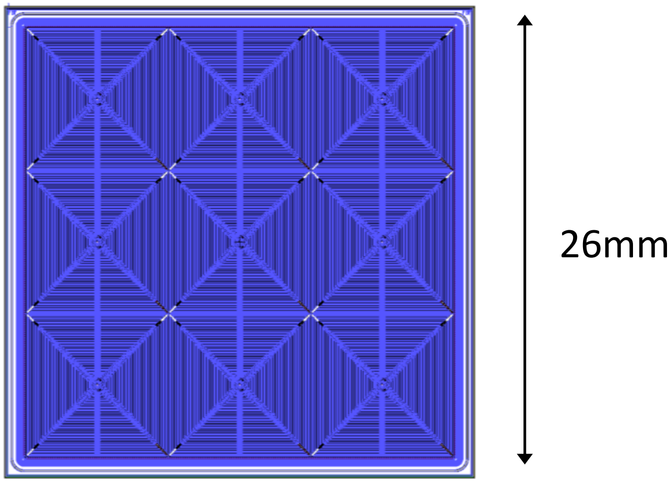


4-8 keV: linearity deviation below .5 eV equivalent

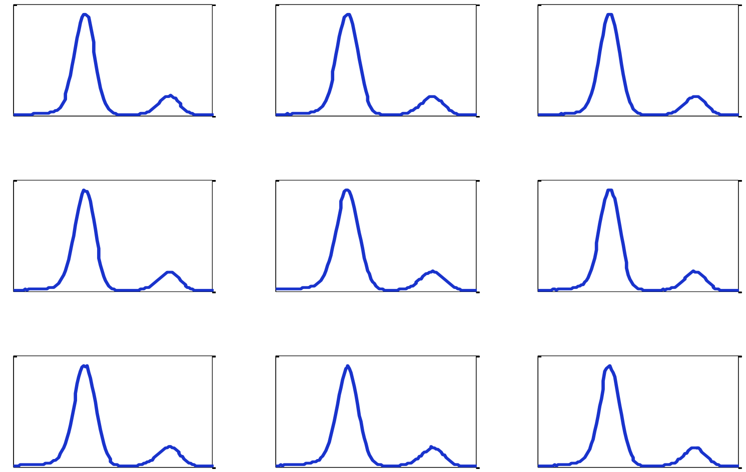
Gain stability of the SDD/CUBE chain under various incident X-ray rates



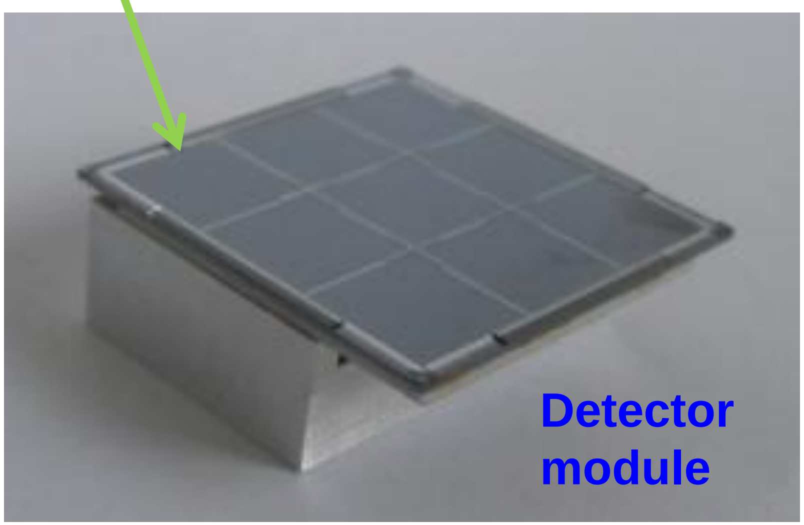
Monolithic array of 3x3 SDDs: an ideal detector for Siddharta-2 upgrade

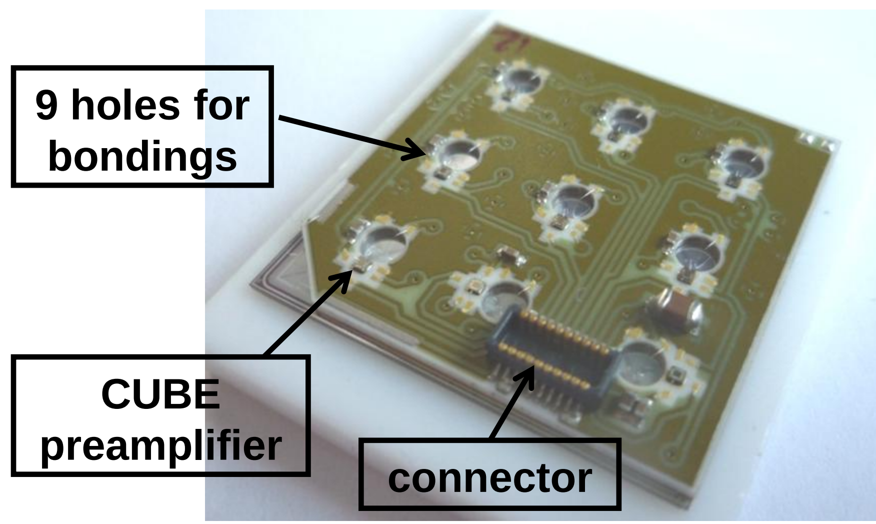


1mm dead space on each side: **85% active area**



- ^{55}**Fe spectra**
- **T=-20°C**





Ceramic carrier

What we gain with 200 cm2 new SDDs?**
(can be placed instead of present ones...)

Kaonic hydrogen at ~eV with 100 pb – very important (Weise, Meissner)

Kaonic deuterium at about 30 eV with 600 pb

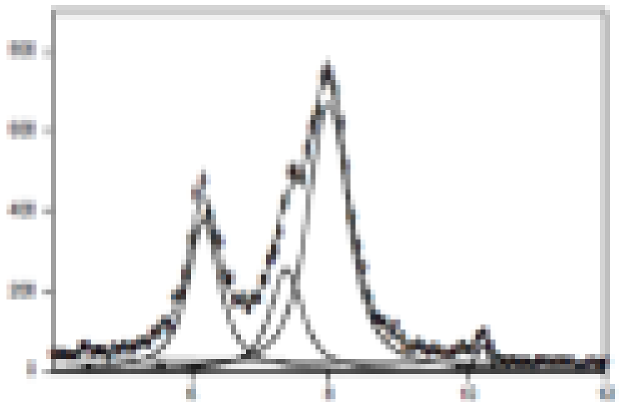
Kaonic helium 2p at < 1 eV with 50 pb

Kaonic helium 1s – 150 events?

- total background 1/1

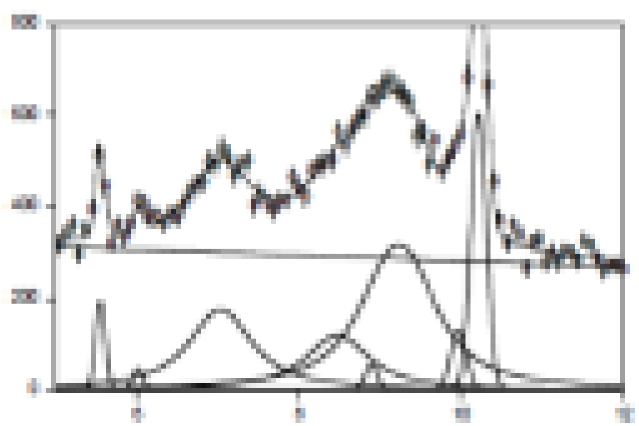
100 pb^{-1} hydrogen

K_α peak 4000 events
S/B 14:1
sigma(shift) = 7 eV sigma(width) = 13 eV

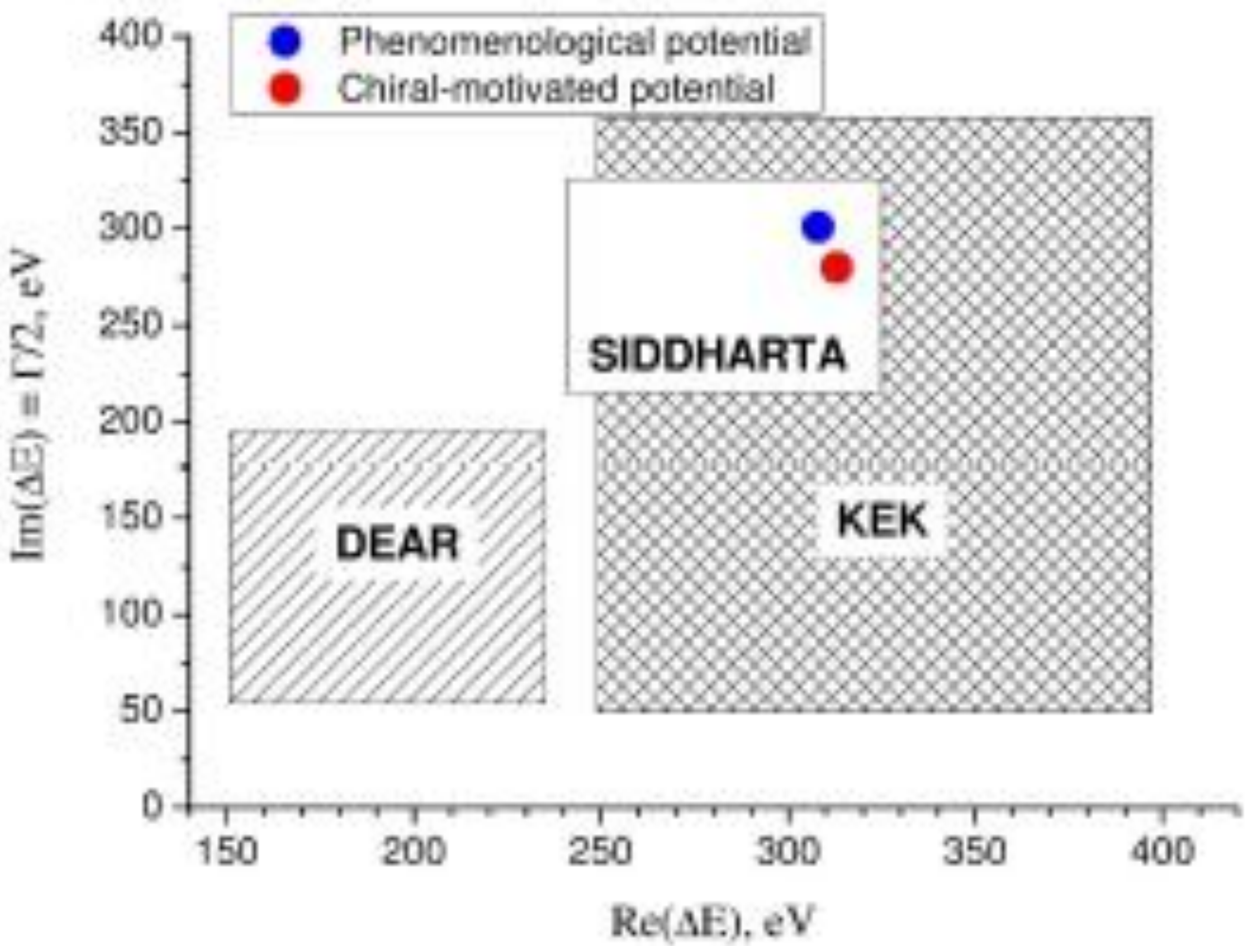


800 pb^{-1} deuterium

K_α peak 3000 events
S/B 1:1.5
sigma(shift) = 27 eV sigma(width) = 72 eV



Experimental and theoretical $1s$ level shifts and widths of kaonic hydrogen



Shevcenko, ECT* October 2013

Requests (same as 45th and 46th SC)

-to be **considered in the planning of LNF-INFN activities** (this includes support for fellowships and postdocs)

- a **concrete time schedule** for the installation of SIDDHARTA-2 at DAΦNE and for the data taking ***not only for Kaonic Deuterium but for all the measurements contained in the SIDDHARTA-2 programme***

-With **effective steps** to be performed in this direction (otherwise problems to get financing……)


DAFNE represents an unique
opportunity to unveil the
secrets of the kaon-nucleon/nuclei
interaction at low energy

45th SC Reco:

The SC recommends producing a study of the luminosity and background in IP2 when separating the beams in IP1 and an estimation of the time needed for replacing the beam-pipe and installing SIDDHARTA in IP2 and an estimation of the

The SC recommends that the soon after the DAΦNE start-up attention is put to produce an assessment of the achievable level of luminosity and an official schedule including the running of the two experiments. The goal is to have the schedule six months after the start-up.

46th SC Reco:

Furthermore, it was our impression that the issue of a second interaction point, that would allow them to run simultaneously with KLOE, is still perceived by the SIDDHARTA-2 Collaboration as a major issue for which the Accelerator Department could have done more to find a satisfactory solution.
We reiterate that the K-d SIDDHARTA-2 experiment is a forefront experiment that should be done with high priority at DAΦNE.

46th SC Reco:

The SC recommends producing by the next SC meeting a study of the luminosity and background in IP2 when separating the beams in IP1 and an estimation of the time needed for replacing the beam-pipe and installing SIDDHARTA in IP2 and an estimation of the running time of SIDDHARTA in IP2 to collect 600 pb-1.