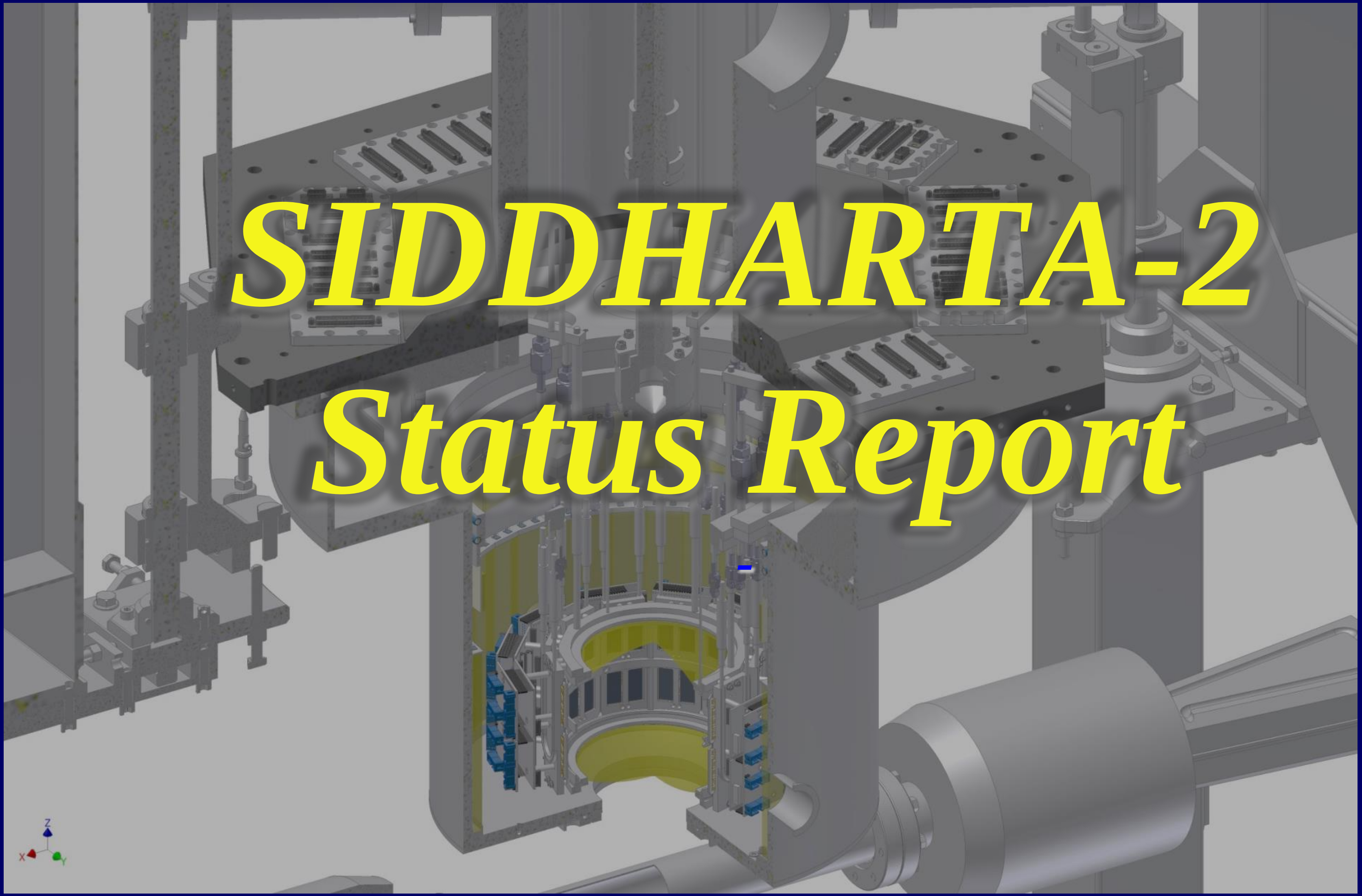
SIDDHARTA-2 Status Report



Catalina Curceanu, LNF-INFN

On behalf of the SIDDHARTA-2 Collaboration

LNF-INFN, SC, 23rd May2016

SIDDHARTA-2

SIlicon Drift Detector for Hadronic Atom Research by Timing Applications

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

HadronPhysicsHorizon
HP2020

Content

- *SIDDHARTA & AMADEUS recent results (->[publications])*
- *Status of the SIDDHARTA-2 experiment*
- *Monte Carlo simulations*
- *Interaction with DAΦNE (start planning)*
- *Requests to the SC-LNF*
- *Future perspectives*

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Nuclear Physics A ••• (••••) •••–•••

NUCLEAR PHYSICS A

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K-series X-ray yield measurement of kaonic hydrogen atoms in a gaseous target

M. Bazzi [a], G. Beer [b], G. Bellotti [c,d], C. Berucci [e,a], A.M. Bragadireanu [f,a], D. Bosnar [g], M. Cargnelli [e], C. Curceanu [a], A.D. Butt [c,d], A. d'Uffizi [a], C. Fiorini [c,d], F. Ghio [h], C. Guaraldo [a], R.S. Hayano [i], M. Iliescu [a], T. Ishiwatari [e], M. Iwasaki [j], P. Levi Sandri [a], J. Marton [e], S. Okada [j], D. Pietreanu [f,a], K. Piscicchia [a,k], A. Romero Vidal [l], E. Sbardella [a], A. Scordo [a], H. Shi [a,*], D.L. Sirghi [a,f], F. Sirghi [a,f], H. Tatsuno [m,n], O. Vazquez Doce [o], E. Widmann [e], J. Zmeskal [e]

DOI: 10.1016/j.nuclphysa.2016.03.047

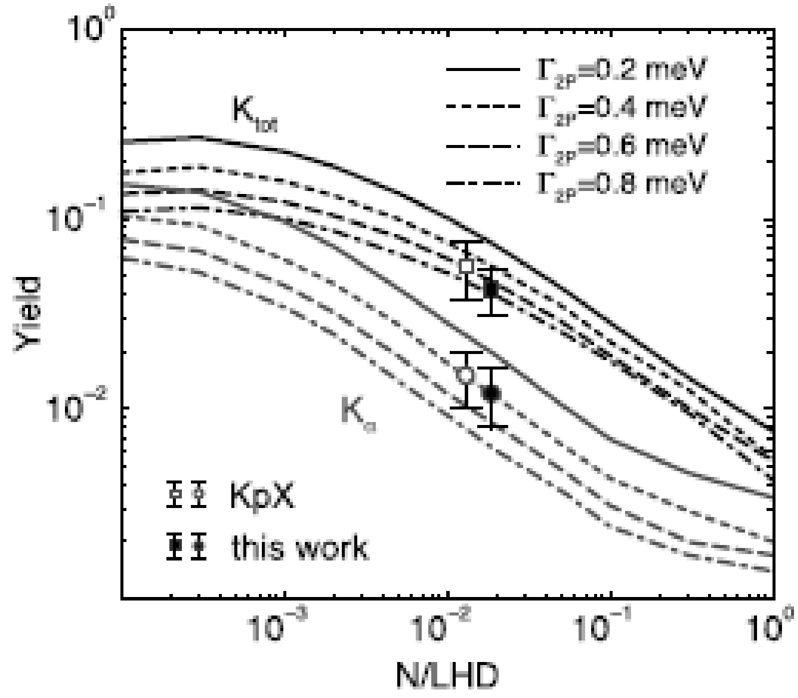


Fig. 5. The results on the yields of $K^- p$ X-rays from two experiments using a gaseous target: this work (filled dots) and the KpX experiment [6] (hollow dots). The theoretical curves are from the cascade calculation by Jensen and others [16,17], using different $2p$ widths as an input parameter. The horizontal scale is density as a fraction of liquid hydrogen density.

DOI: 10.1016/j.nuclphysa.2016.03.047

AMADEUS-related papers

(in collaboration with members of KLOE2):

K^- absorption on two nucleons and ppK^- bound state search in the Σ^0p final state

O. Vázquez Doce[1,2], L. Fabbietti[1,2], M. Cargnelli[3], C. Curceanu[4], J. Marton[3], K. Piscicchia[4,5], A. Scordo[4], D. Sirghi[4], I. Tucakovic[4], S. Wycech[6], J. Zmeskal[3], A. Anastasi[4,7], F. Curciarello[7,8,9], E. Czerwinski[10], W. Krzemien[6], G. Mandaglio[7,11], M. Martini[4,12], P. Moskal[10], V. Patera[13,14], E. Pérez del Rio[4] and M. Silarski[4].

Accepted for pub. in Phys. Lett. B; DOI: 10.1016/j.physletb.2016.05.001

On the $K^- \, ^4\text{He} \rightarrow \Lambda\pi^- \, ^3\text{He}$ resonant and non-resonant processes

K. Piscicchia[1]

S. Wycech[2]

C. Curceanu[3]

Accepted for pub. in Nucl. Phys. A

Status of the

SIDDHARTA-2 experiment

The scientific aim of SIDDHARTA & SIDDHARTA-2

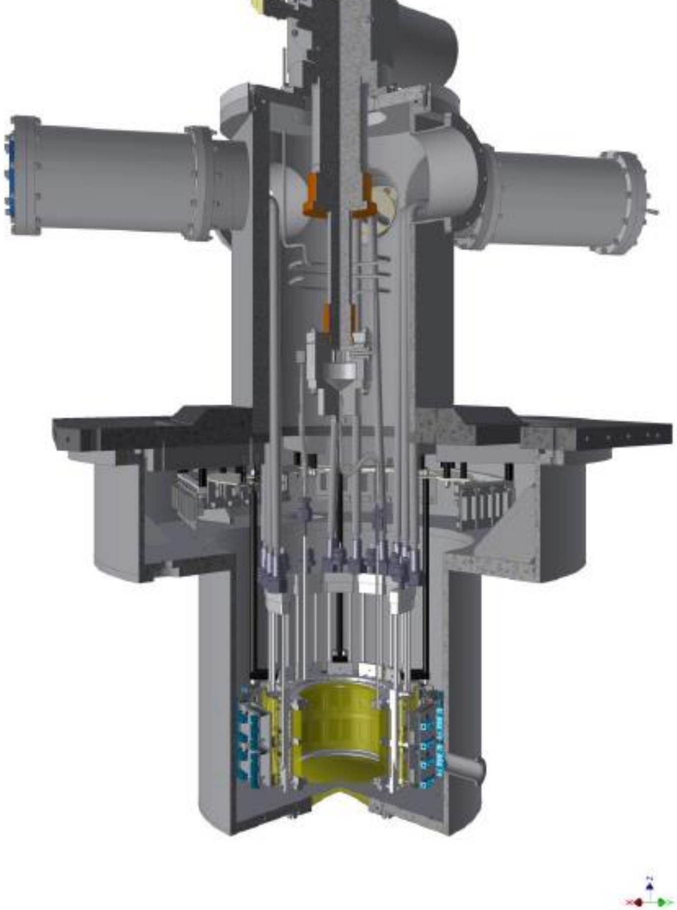
To perform precision measurements of kaonic atoms X-ray transitions -> unique info about the QCD in non-perturbative regime in the strangeness sector not obtainable otherwise

Precision *measurement of the shift* and *of the width*

-> of the 1s level of **kaonic hydrogen (SIDDHARTA)** and

-> the *first measurement* of **kaonic deuterium (SIDDHARTA-2)**

to extract the antikaon-nucleon isospin dependent scattering lengths (-> low-energy QCD – *see also Annex of Gal & Colangelo 42nd SC – 2011*)



TECHNICAL REPORT

SIDDHARTA-2 – kaonic deuterium measurement

May 2016

The SIDDHARTA-2 Collaboration:

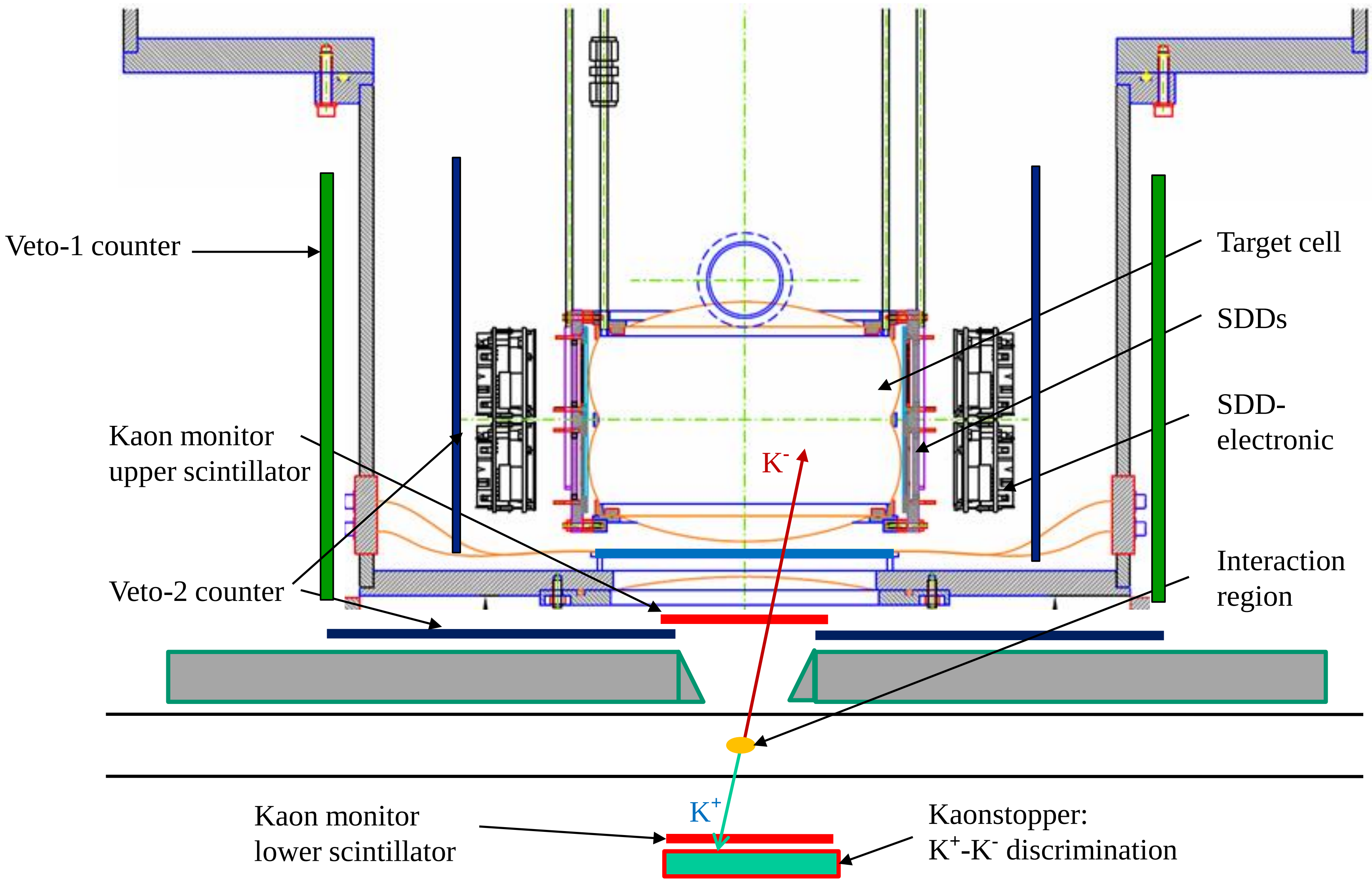
LNF- INFN, Frascati, Italy; SMI- ÖAW, Vienna, Austria; IFIN – HH, Bucharest, Romania; Politecnico and INFN, Milano, Italy; TUM Muenchen, Germany; RIKEN, Japan; Univ. Tokyo, Japan; Victoria Univ., Canada; Univ. Zagreb, Croatia

Contents

The SIDDHARTA-2 setup

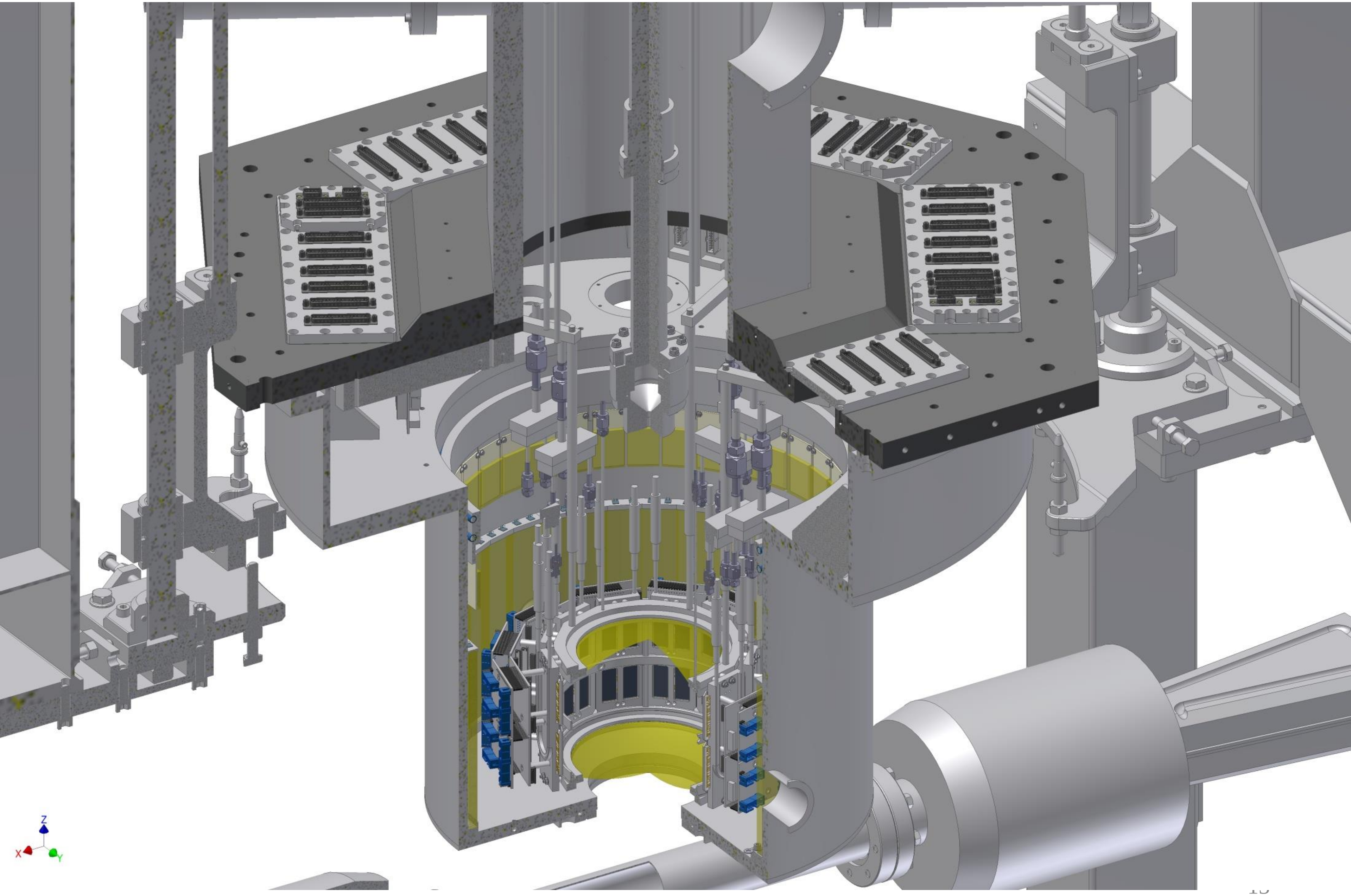
- new target cell
- new vacuum chamber
- new cooling system
- new kaon monitor/trigger
- two veto systems
- K^+ induced backg. discriminator
- new shielding structure
- new SDD detectors

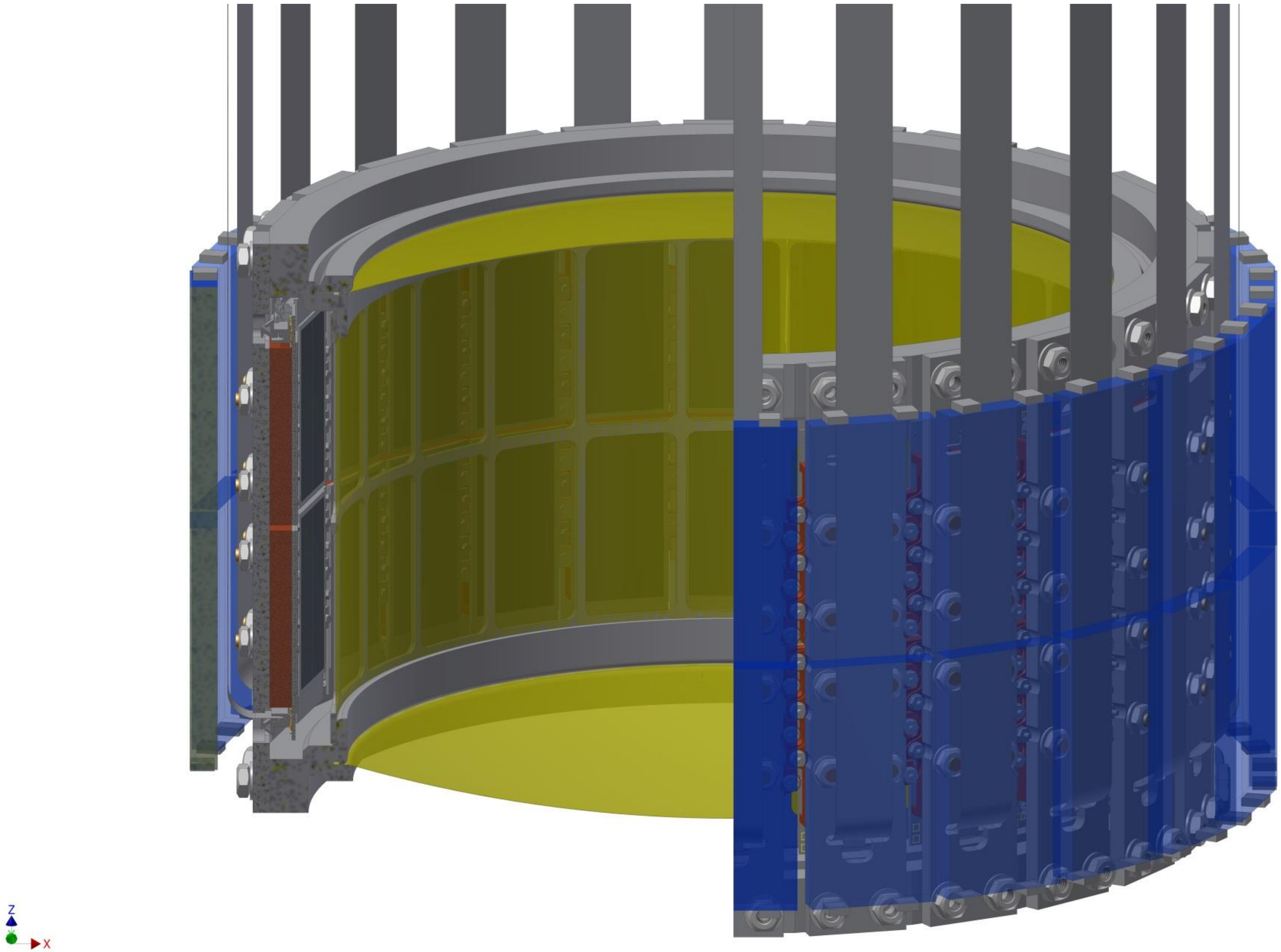
(support of INFN – letter of referees + other institutes)



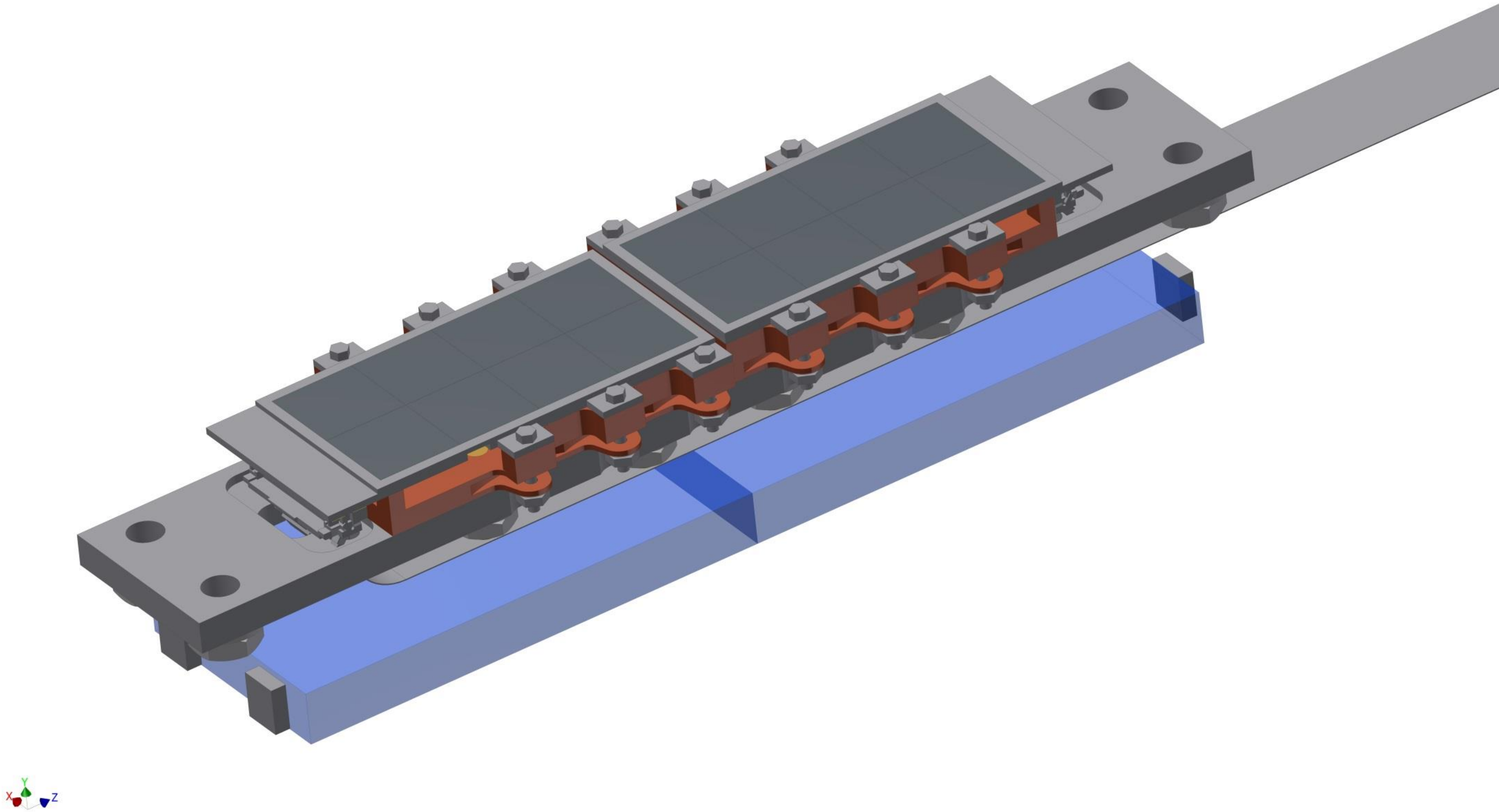
Veto-1 counter
Target cell
SDDs
SDD-
electronic
Kaon monitor
upper scintillator
K-
Veto-2 counter
Interaction
region
K+
Kaon monitor
lower scintillator
Kaonstopper:
K+-K- discrimination

SIDDHARTA-2 setup

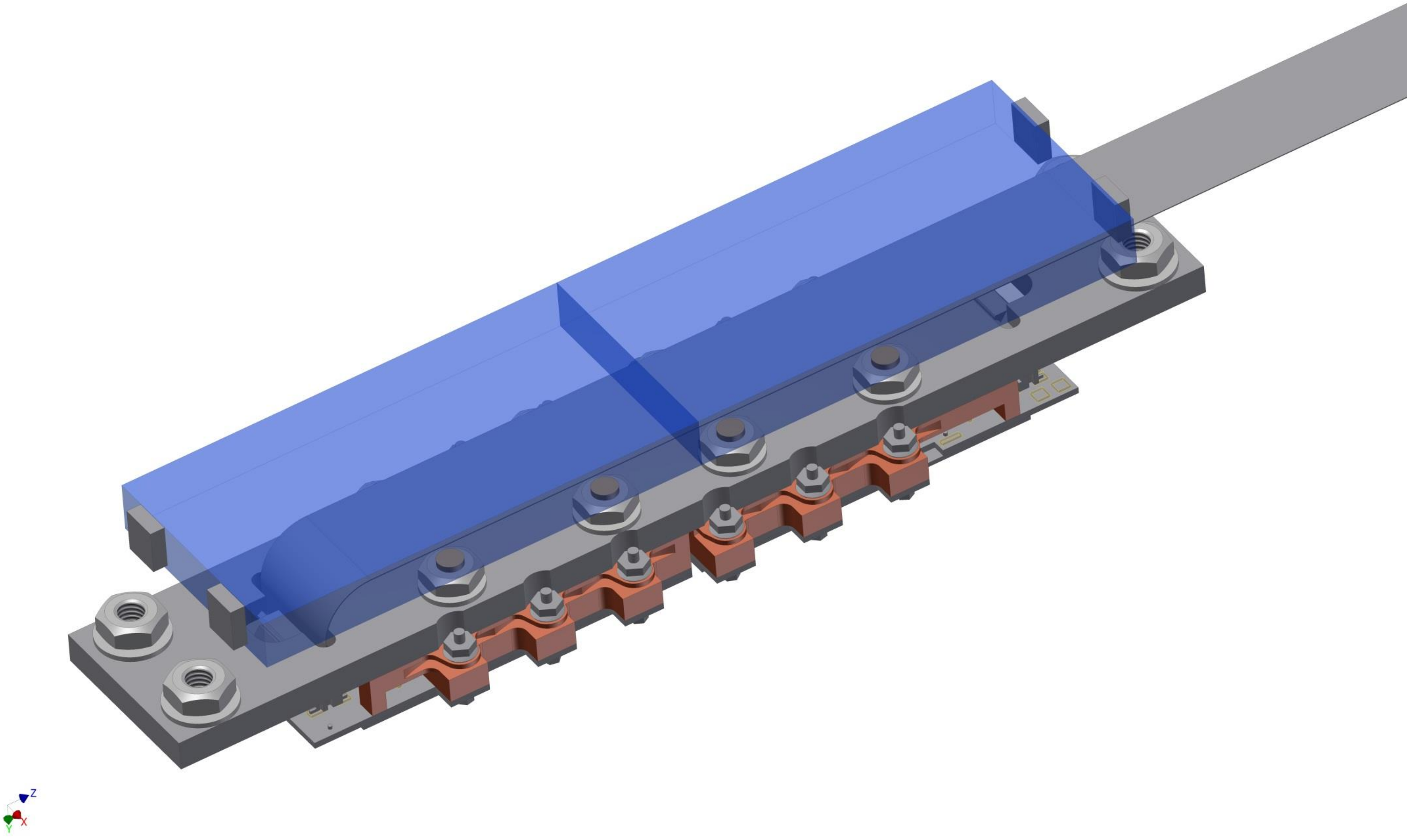




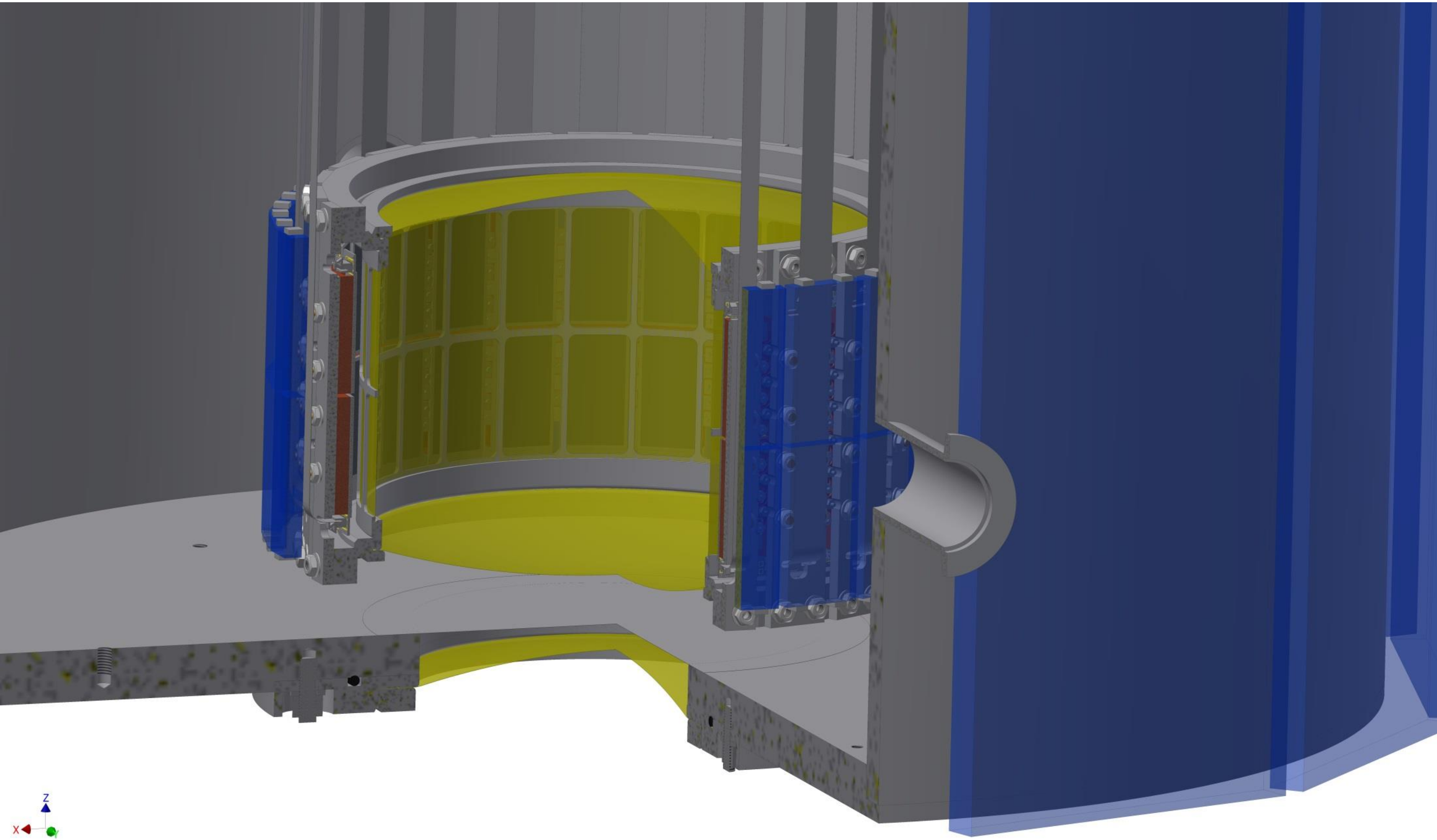
SIDDHARTA-2 target and SDD detectors (detail)



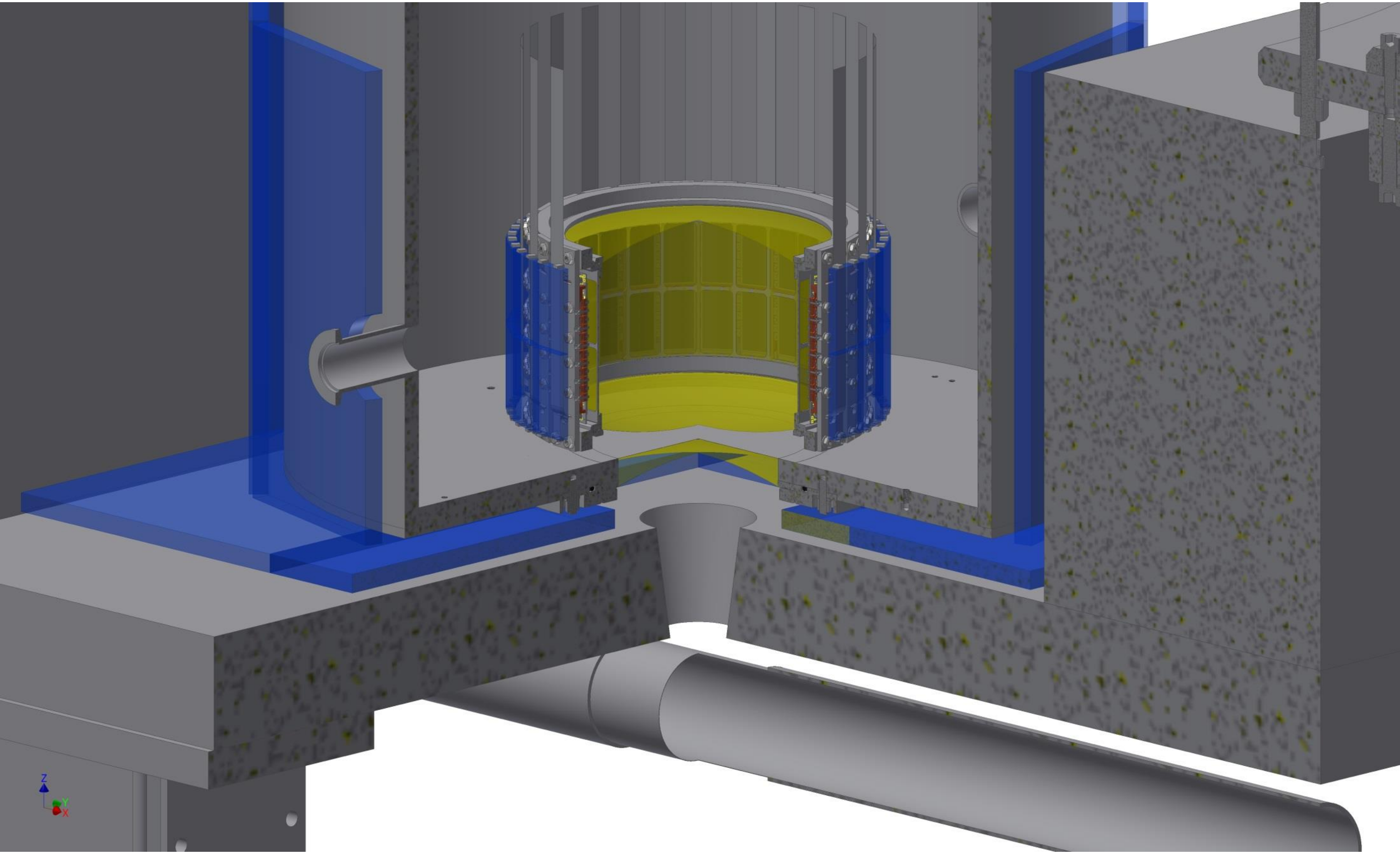
SIDDHARTA-2 SDD unit (2 SDD arrays) - detail



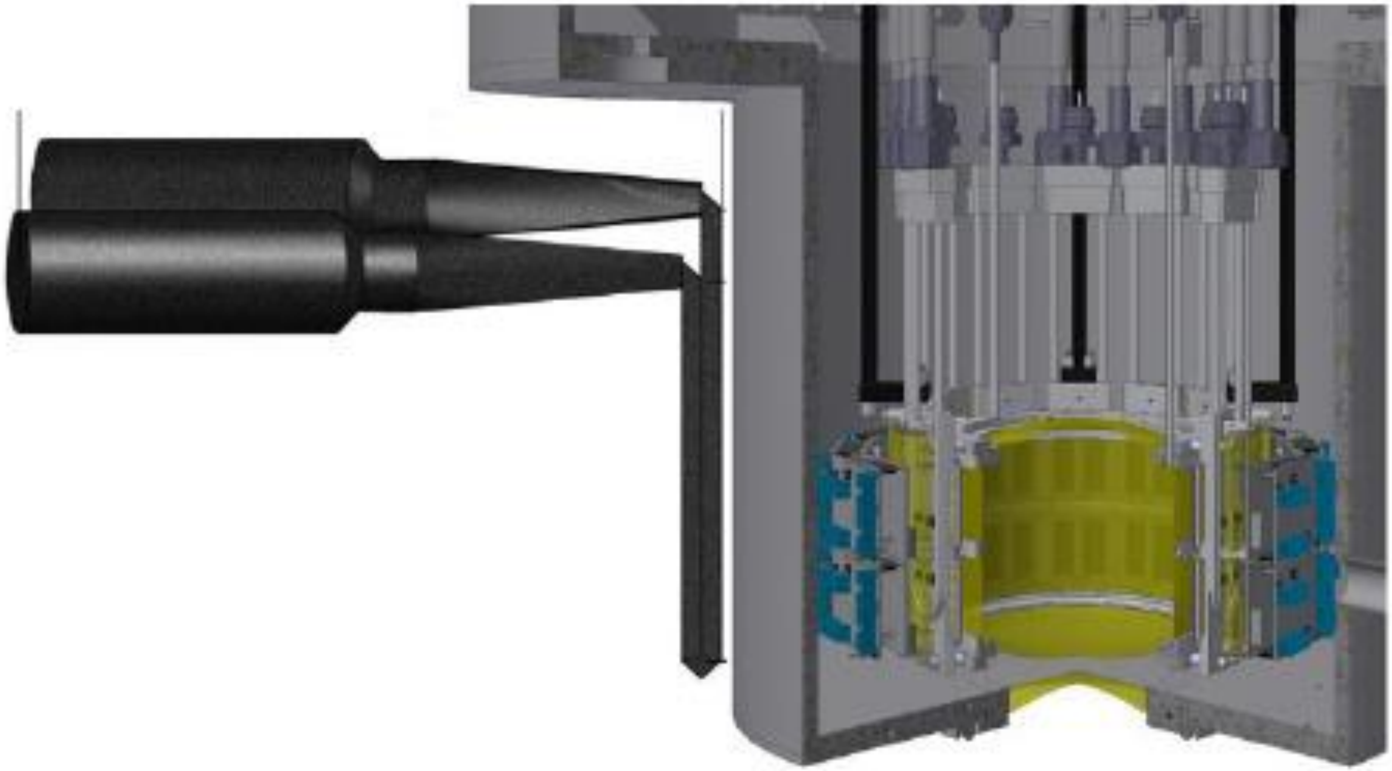
SIDDHARTA-2 veto2 system



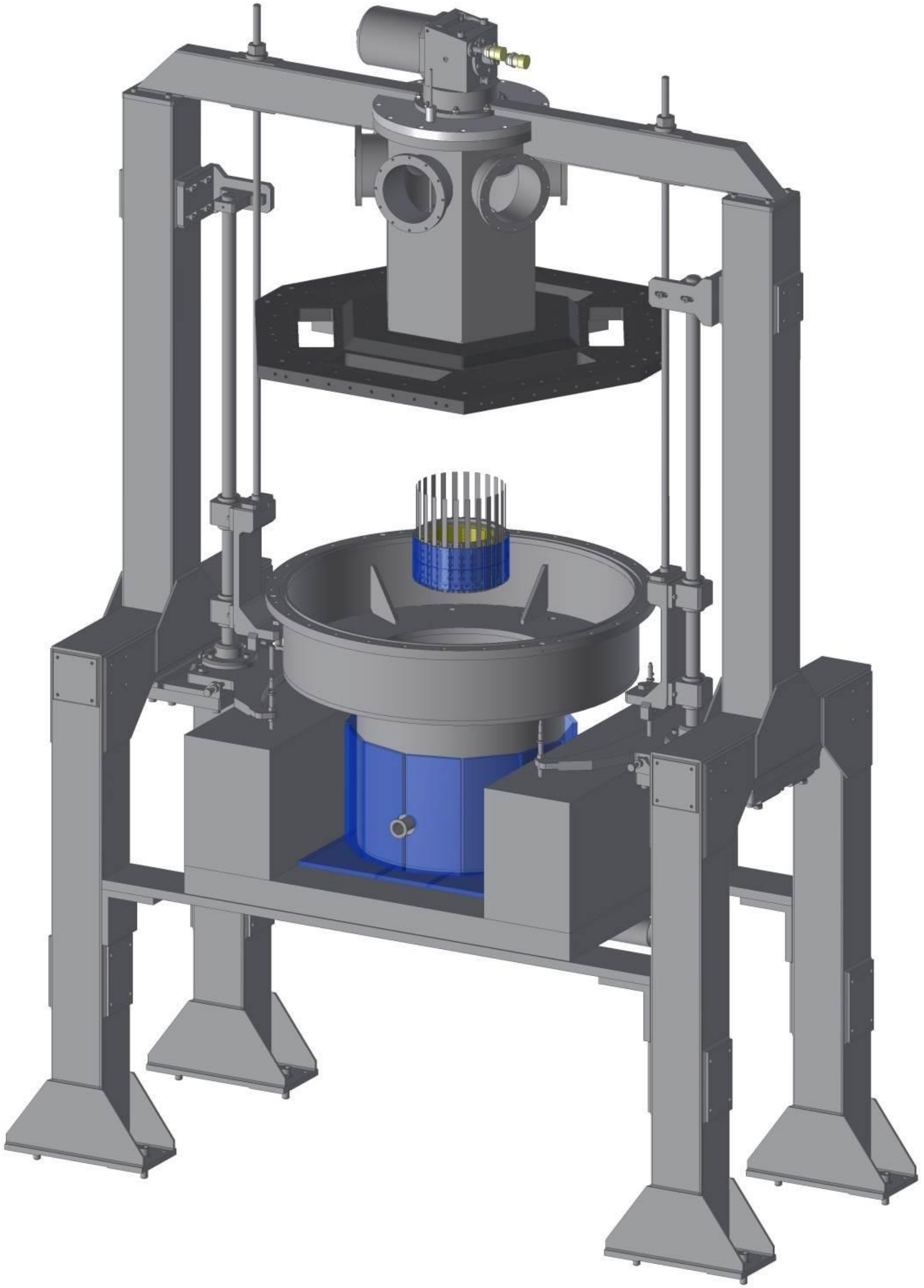
SIDDHARTA-2 target , SDD detectors, vacuum chamber, veto (detail)



SIDDHARTA-2 setup (detail)



SIDDHARTA-2 – detail with veto system

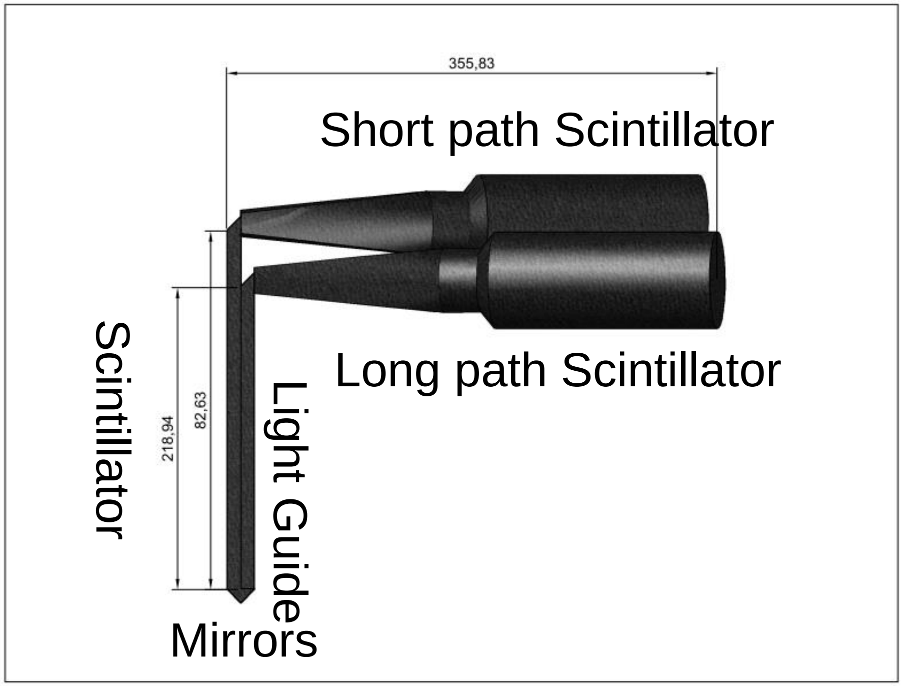


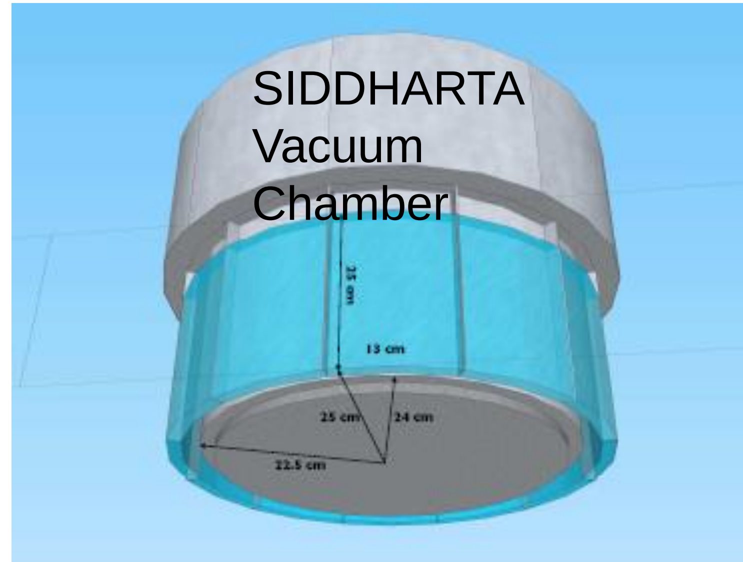
SIDDHARTA-2 setup

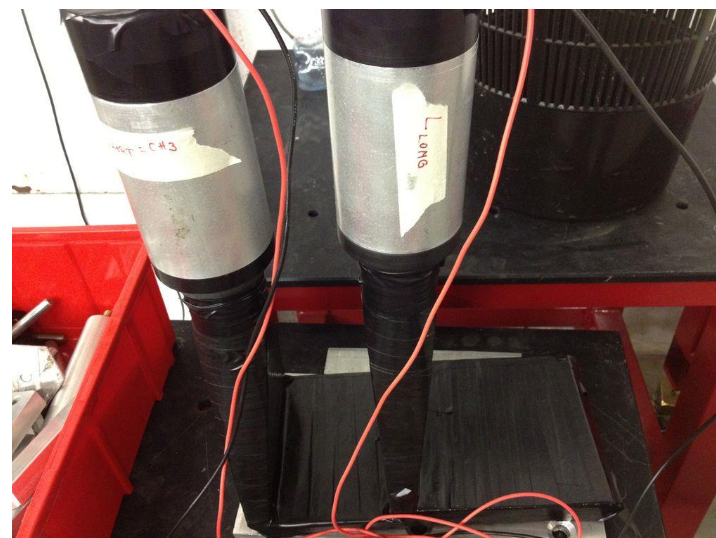
- **Vacuum chamber**
  ready and tested

- **Cryogenic target**
  tests were successful

A multi – reflection Scintillator for the VETO system of the SIDDHARTA experiment







Ready and tested

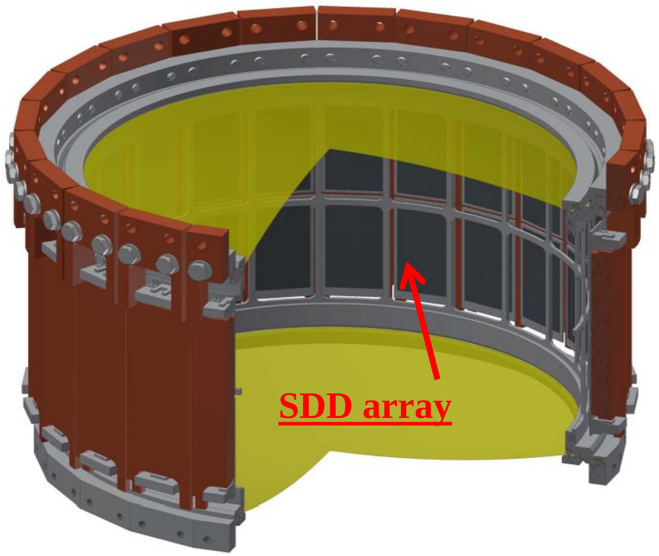
JINST
PUBLISHED BY IOP PUBLISHING FOR SISSA MEDIALAB
RECEIVED: *September 6, 2013*
ACCEPTED: *November 1, 2013*
PUBLISHED: *November 15, 2013*

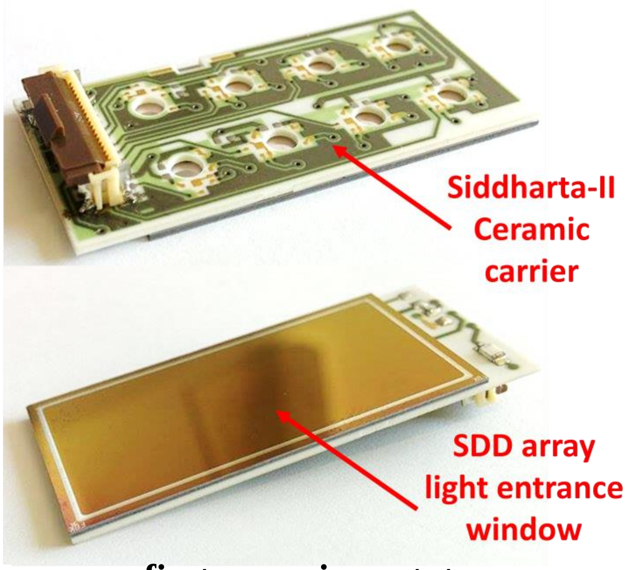
TECHNICAL REPORT

Characterization of the SIDDHARTA-2 second level trigger detector prototype based on scintillators coupled to a prism reflector light guide

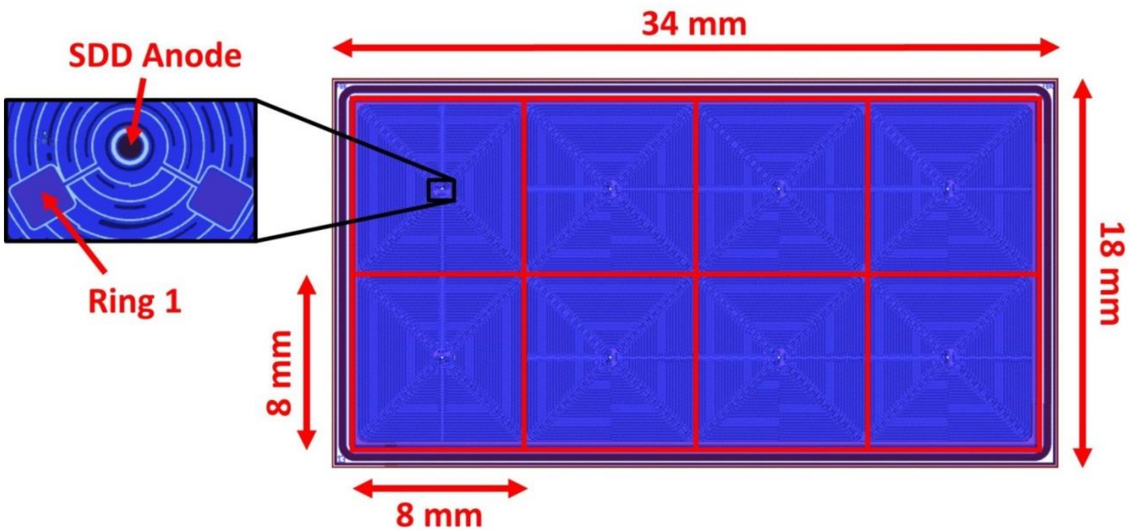
SIDDHARTA-2 new SDD detectors

Upgrade the apparatus with new SDD detectors

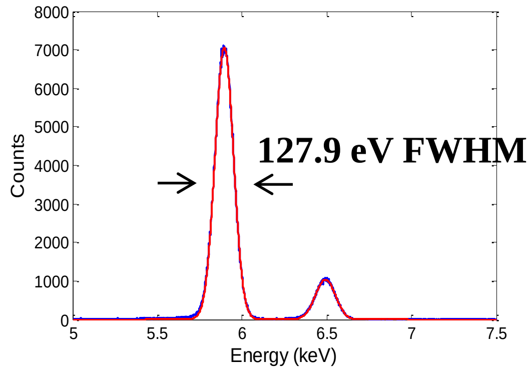




first ceramic prototype
(final design in production)



Siddharta-II SDD array (Average $I_{Leakage}$ 200 pA/cm^2 @room temperature)



- single SDD
- T= -35°C
- T_{sh}=2μs

Study on the temperature dependence of the SDD drift time and energy resolution
BTF 16~21 June 2015

Test Setup on the BTF-LNF beam line (thanks BTF and DAFNE staff!)

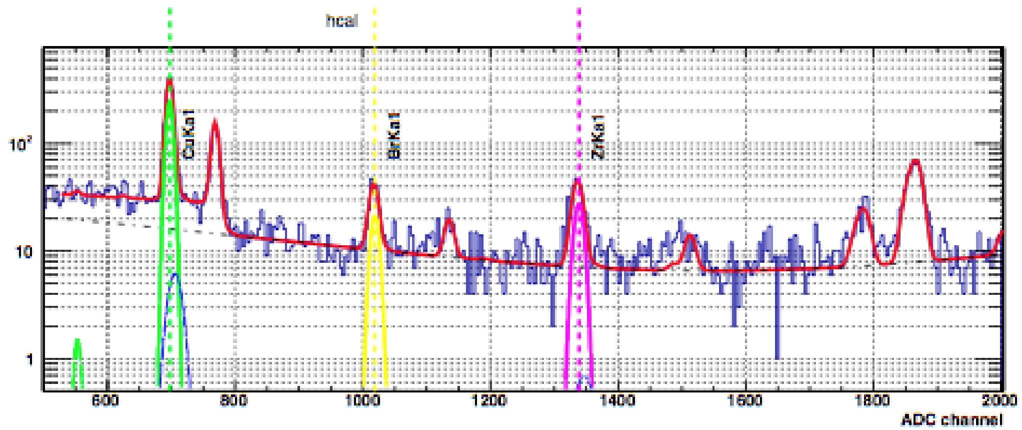
Test Setup on the BTF-LNF beam line

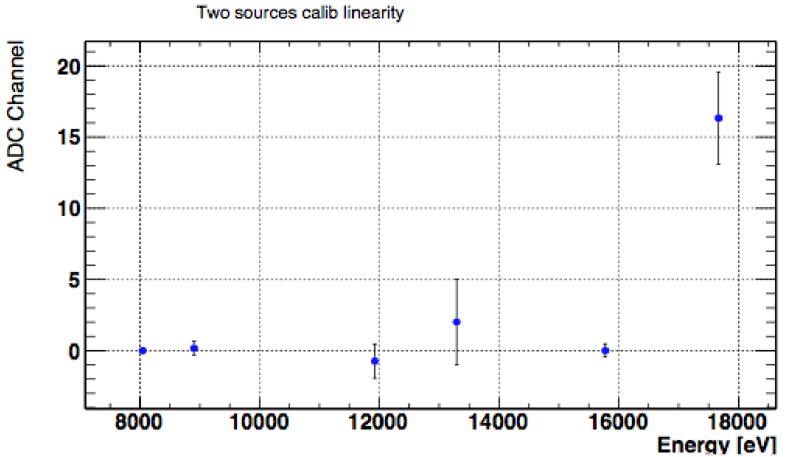
Energy calibration

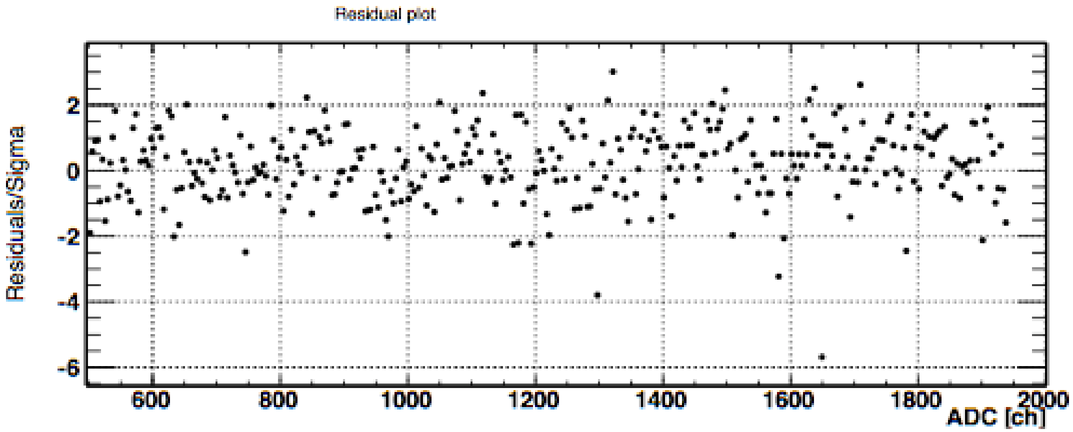
sdd1-11-2015_02_19_29.txt

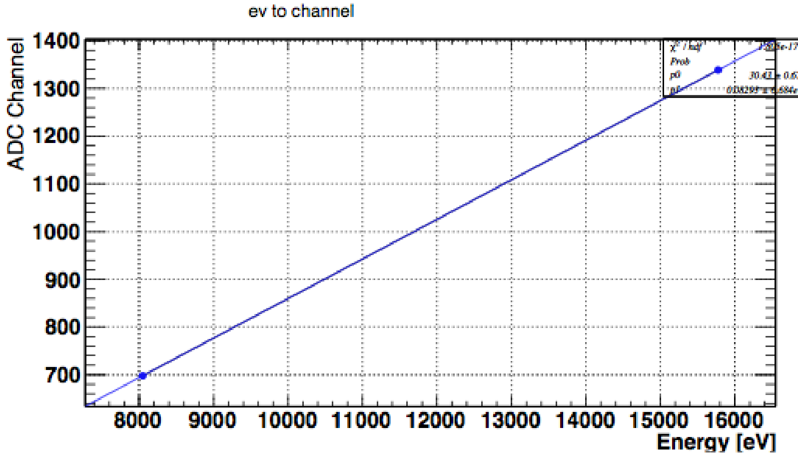
- 165 ℃

FWHM @ 6 keV: 131 eV



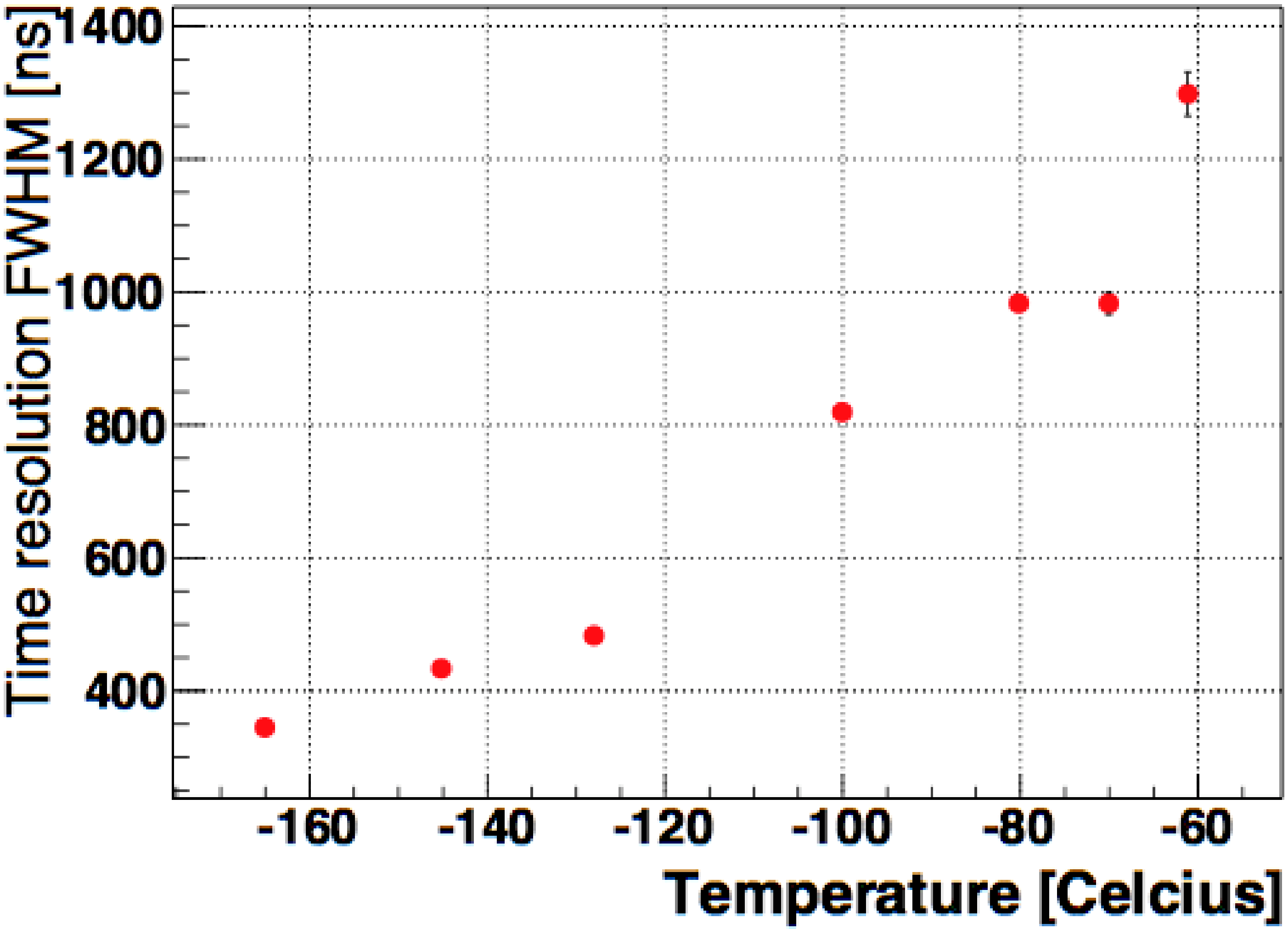






Temperature dependence of timing resolution

2015 BTF



BTF beam test: 20-25 June 2016

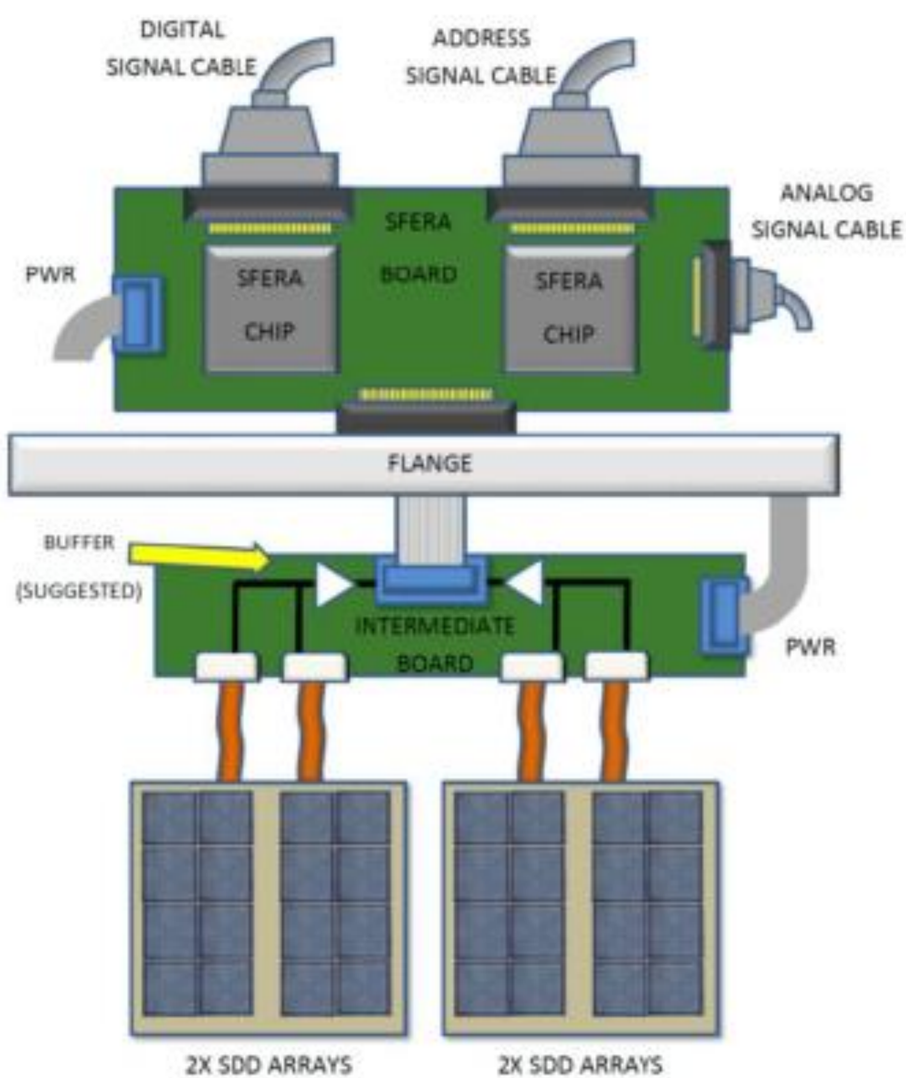
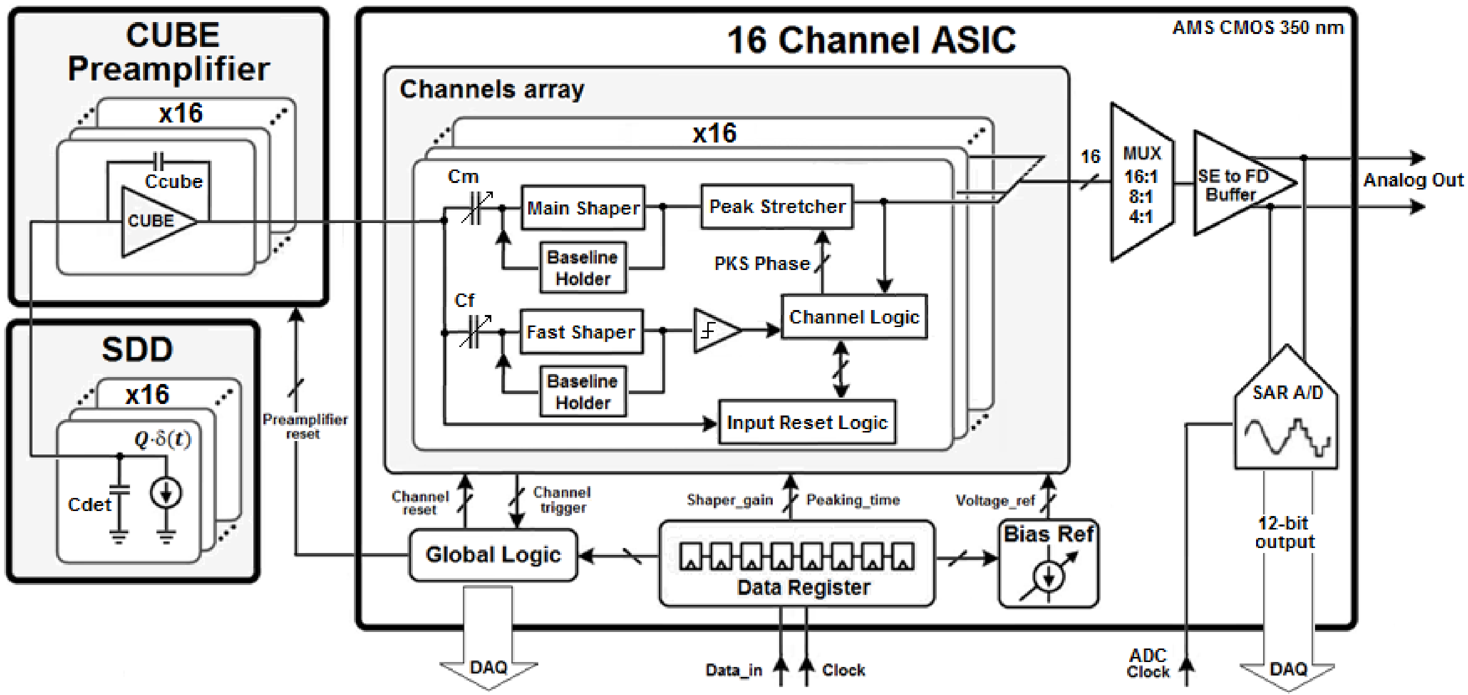


Figure 16: SFERA chip arrangement

Readout electronics: the SFERA ASIC

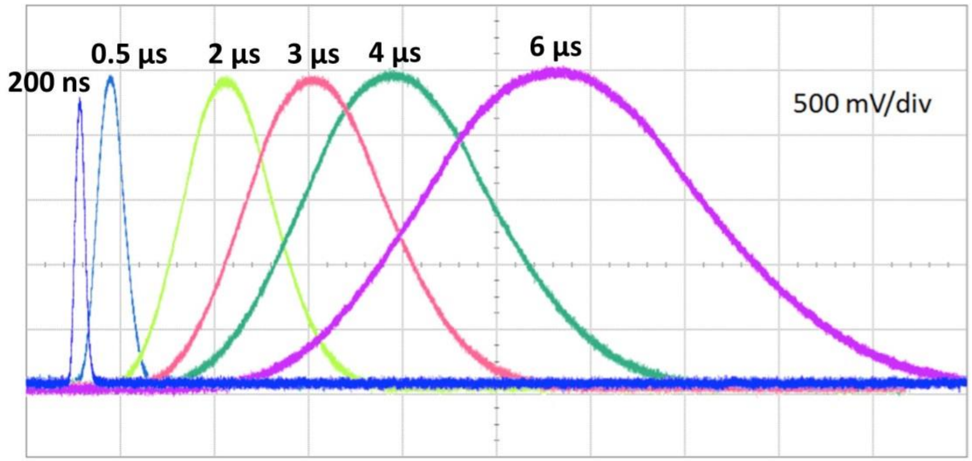
SFERA (Silicon-Drift-Detectors Front-End Readout ASIC)

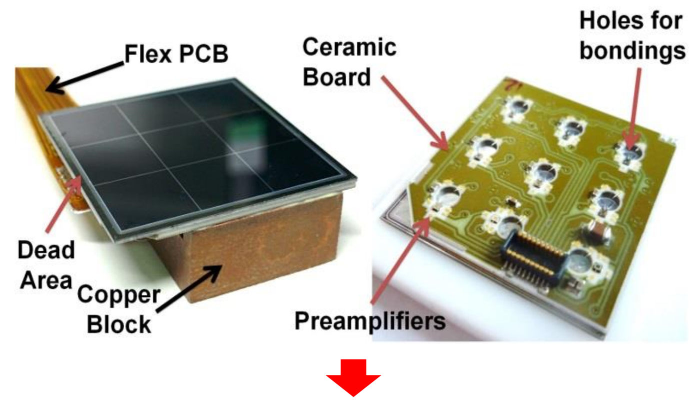


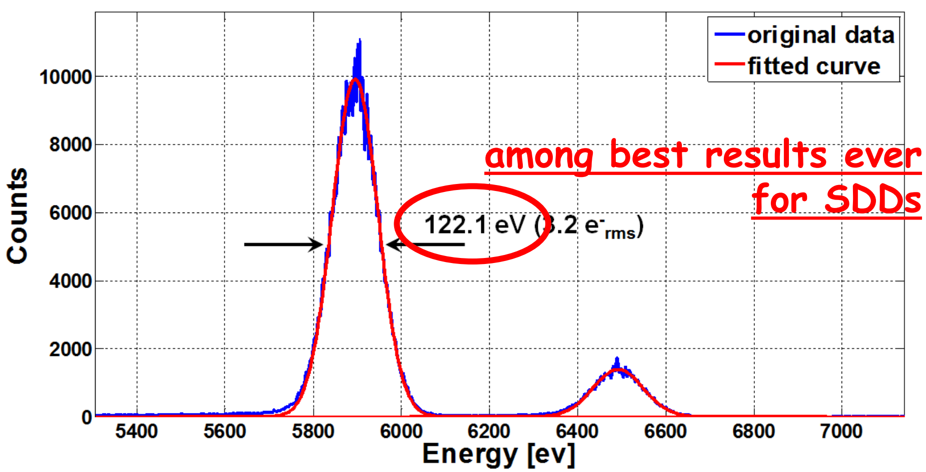
- 16 analog channels
- Shaper with selectable gain and peaking times (9^{th} order complex poles)
- Fast shaper (9^{th} order complex poles)

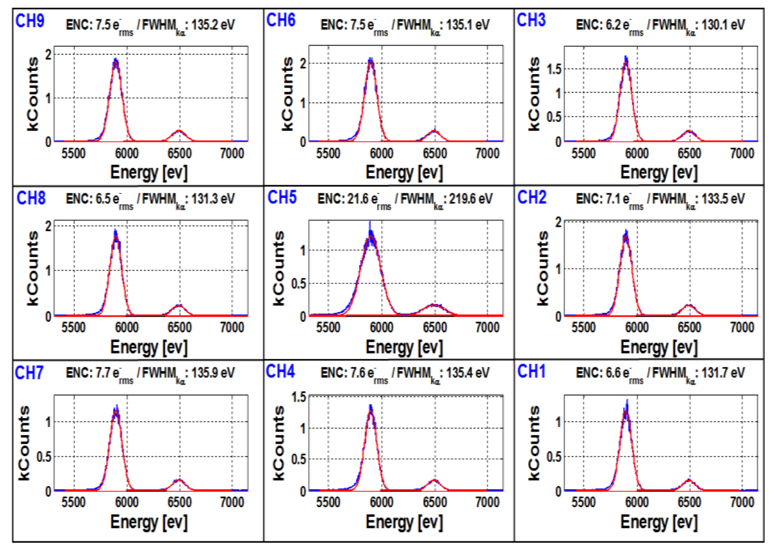
- Pile-up rejector
- Integrated 12-bit ADC
- SPI programming
- Polling and sparse MUX options

Experimental results of SFERA







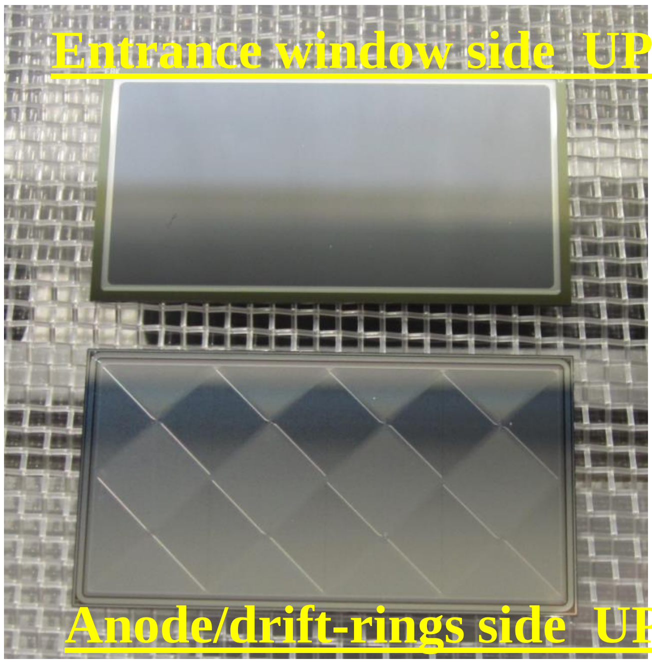


^{55}Fe source spectra with 10mm^2 SDD at -35 °C coupled with SFERA (4 μs peaking time).

^{55}Fe source spectra with 3x3 SDD array (8x8mm^2 area single unit) at -35 °C (4 μs peaking time).

SDD arrays delivery and qualification (FBK)

- **Wafers are diced in FBK to get single arrays**
- **Isolated arrays are delivered in gel-pak (vacuum release) chip trays**
- **Classification of SDD arrays by means of I/V measurements**



Batch	Wafer	Matrix	Q-index	Batch	Wafer	Matrix	Q-index
SIDDHARTA1b	W01	1,2	8.080	SIDDHARTA1b	W03	1,4	8.080
SIDDHARTA1b	W01	2,1	8.080	SIDDHARTA1b	W03	1,1	8.620
SIDDHARTA1b	W01	3,2	8.080	SIDDHARTA1b	W04	3,2	8.260
SIDDHARTA1b	W01	3,3	8.530	SIDDHARTA1b	W04	2,1	8.611
SIDDHARTA1b	W02	1,4	8.161	SIDDHARTA1b	W04	1,2	8.710
SIDDHARTA1b	W02	3,1	8.800	SIDDHARTA1b	W05	3,4	8.710
SIDDHARTA1b	W02	3,3	8.530	SIDDHARTA1d	W14	3,1	8.080
SIDDHARTA1c	W12	2,1	8.440	SIDDHARTA1d	W14	3,2	8.440
SIDDHARTA1c	W17	1,1	8.080	SIDDHARTA1d	W14	2,1	8.521
				SIDDHARTA1d	W14	3,3	8.620
				SIDDHARTA1d	W15	3,4	8.170
				SIDDHARTA1d	W15	3,1	8.251
				SIDDHARTA1d	W15	3,3	8.260
				SIDDHARTA1d	W15	2,1	8.440
				SIDDHARTA1d	W19	1,2	8.260
				SIDDHARTA1d	W19	3,1	8.260
				SIDDHARTA1d	W19	1,1	8.350
				SIDDHARTA1d	W19	1,4	8.350

Q-index: N.DGS

N = number of functioning channels (with $J_{anode} < 2nA/cm^2$)

D = number of "diamond" channels (with $J_{anode} < 80pA/cm^2$)

G = number of "gold" channels (with $J_{anode} < 250pA/cm^2$)

S = number of "silver" channels (with $J_{anode} < 600pA/cm^2$)

Table 1: Q-index classification based on anode leakage current density

X-ray tests on 2x4 array

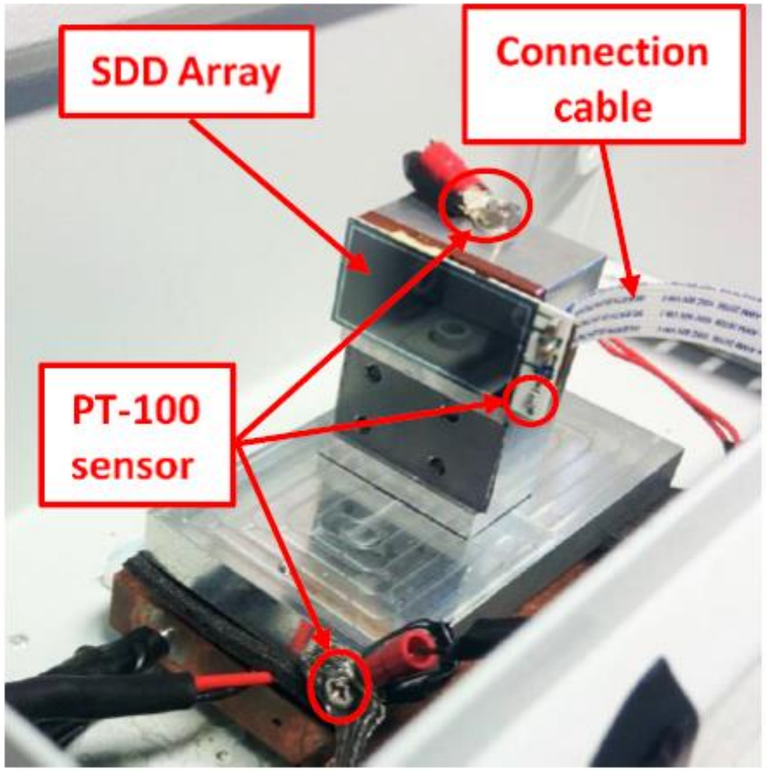


Fig. 4. Experimental setup employing thermoelectric (Peltier) cooling stage to characterize Siddharta-II arrays at a temperature of -30 °C.

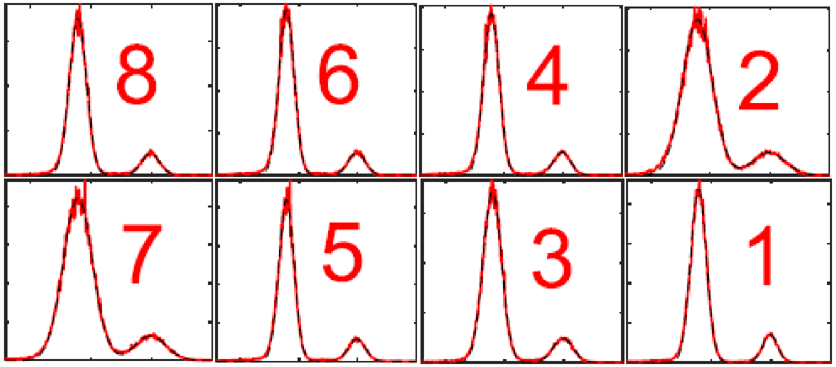


Fig. 5. Eight X-ray spectra acquired by irradiating a 2×4 SDD array with an un-collimated ^{55}Fe X-ray source at a temperature of -30 °C with 3 μs shaping time using.

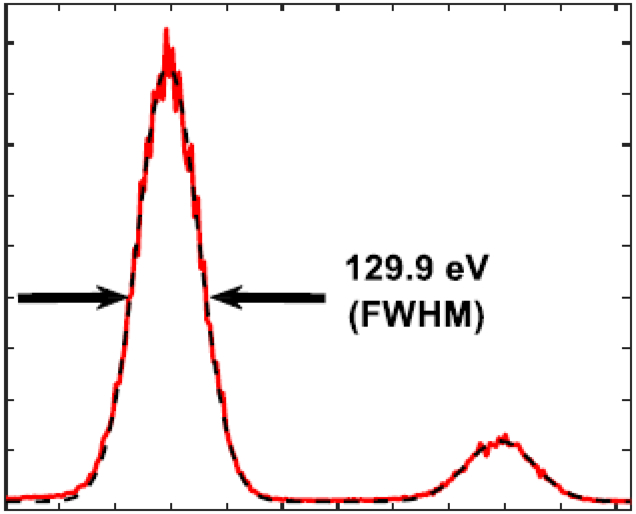


Fig. 6. Best X-ray spectrum acquired using 2×4 SDD array and SFERA. An energy resolution of ~130 eV FWHM measured for Mn-Kα peak at -27 °C with 6 μs shaping time.

SDDHARTA-2 setup status and plans:

- The vacuum chamber was built and tested and is ready for use

- The two subgroups of the active anticoincidence detector are realized, tested and ready for use

- A prototype of the target cell was built and successfully tested; the final target cell (once decided the setup should be installed on DAΦNE) can be built in 2 months

SDDHARTA-2 setup status and plans:

- The new SDDs will be ready by Summer 2016 (27 arrays already delivered)
- Mounting and bonding of the new SDDs: end of 2016
- New readout electronics will be ready by end of 2016
- Assembly and test of new SDDs: by Spring 2017
- The new veto system (veto-2) will be ready by Spring 2017

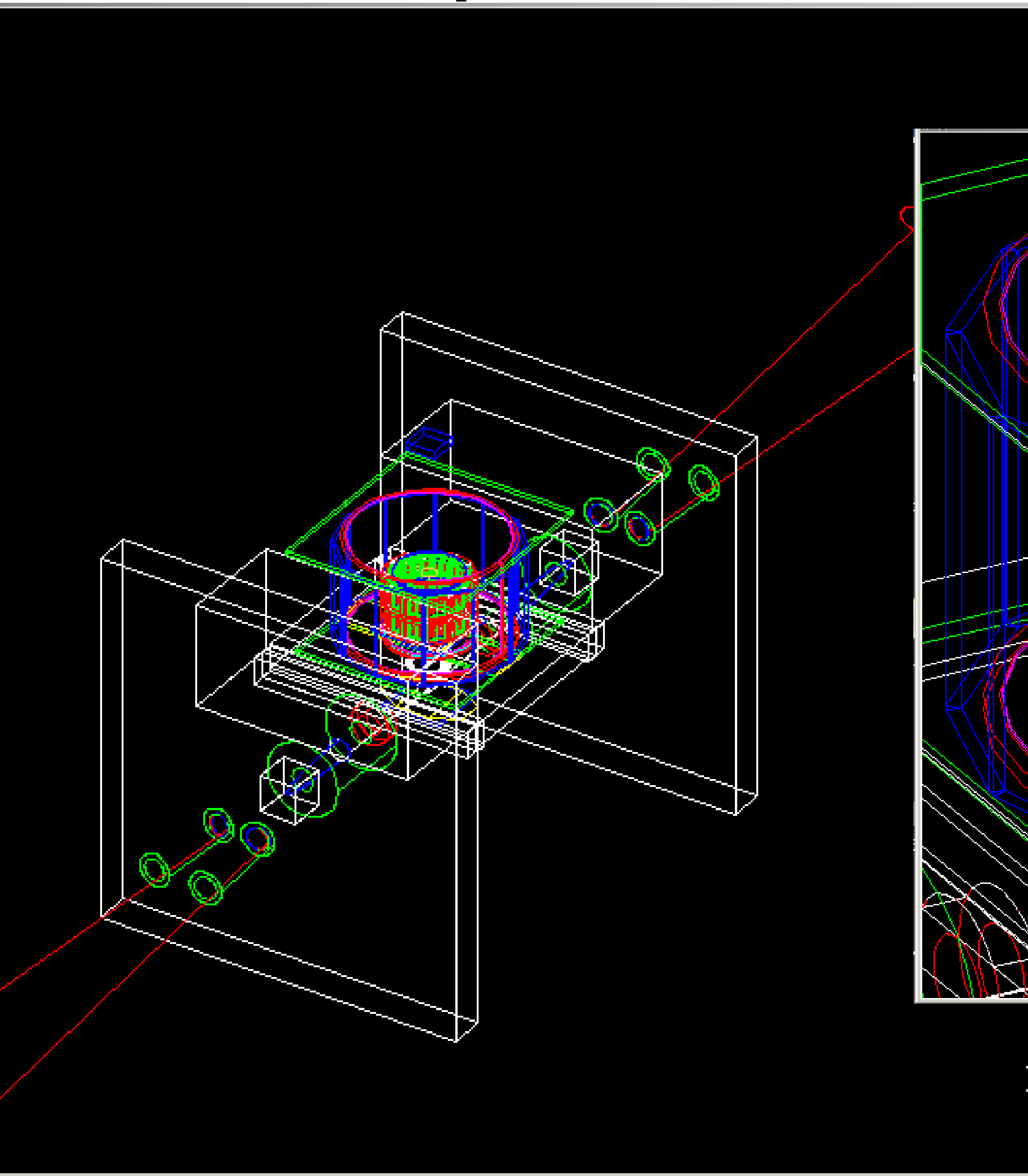
SDDHARTA-2 setup status and plans:

- **SIDDHARTA-2 setup with new SDDs will be mounted and tested by Summer 2017**

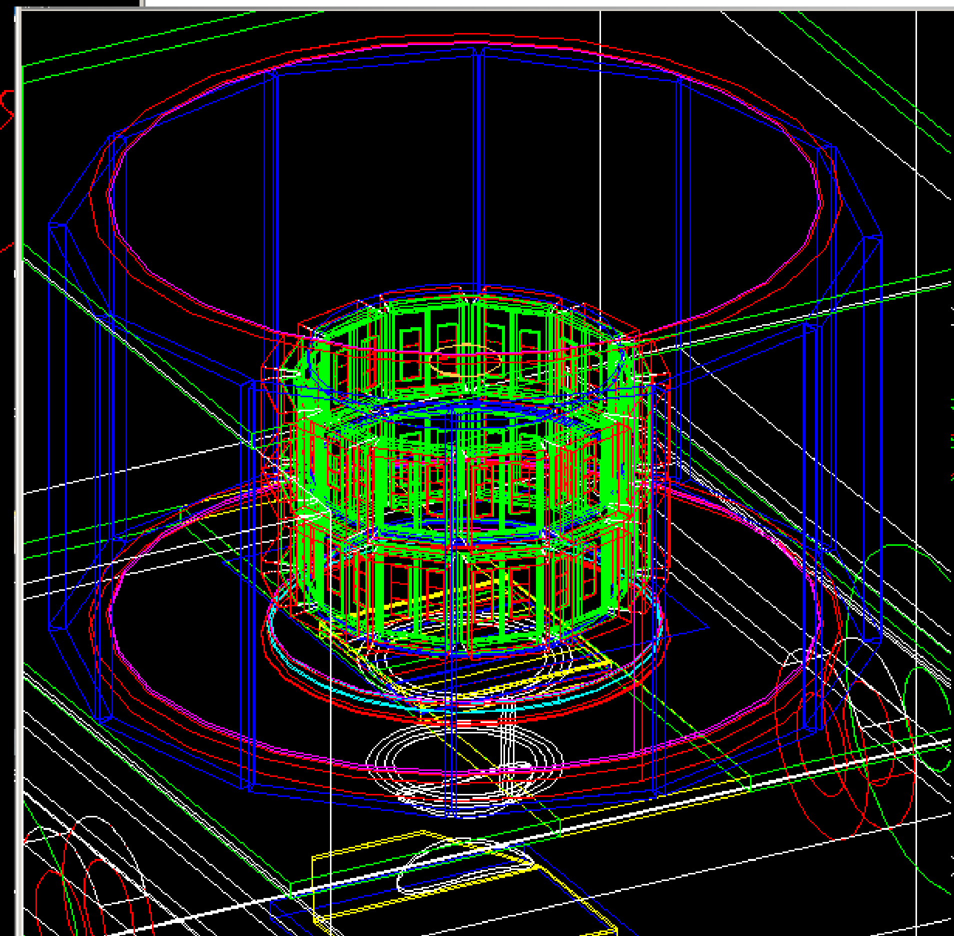
- **SIDDHARTA-2 setup ready to be installed on DAΦNE in Summer 2017.**

SIDDHARTA 2 (GEANT4 MC, M. Iliescu & C. Berucci)

SIDDHARTA2 setup

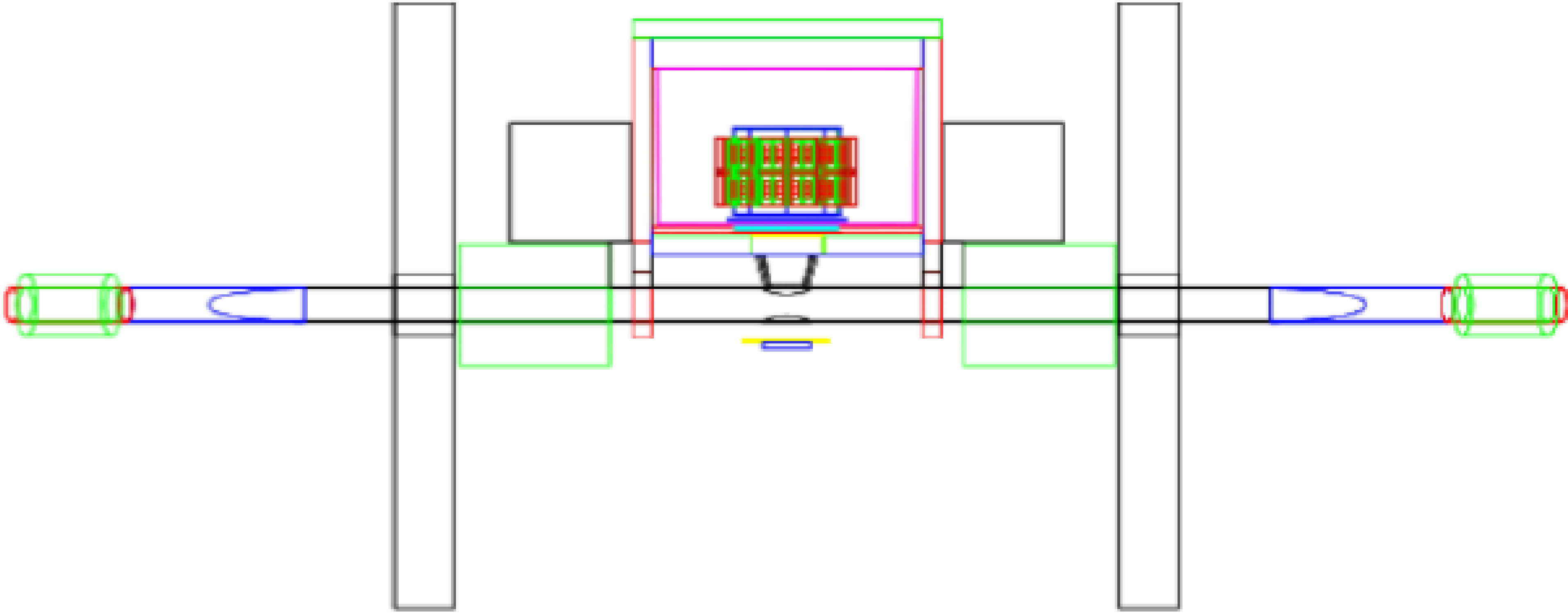


Setup detail



SIDDHARTA 2 (GEANT4 MC, M. Iliescu & C. Berucci)

Tested on SIDDHARTA – we have full control on simulation



	signal	hadronic BG	machine BG	S/B	K_α events
SIDDHARTA	1.00	1.00	1.00	1:40	
IP - target	1.38	1.33		1:11	
3% LHD	1.64	1.08			6075
geometry	1.25	0.56	0.25		
Trigger 1	0.71	0.48		1:7.6	4320
Trigger 2	0.79	0.59	0.33	1:5.7	3415
Trigger 3	0.98	0.73		1:4.2	3350
K+ discrimination	0.70	0.78		1:3.3	2345
drift time 400ns			0.49	1:3.0	2345
SIDDHARTA-2	**1.09**	**0.12**	**0.04**	**1:3**	**2345**

Table 2: The main results of the GEANT4 MC simulation for the SIDDHARTA-2 setup

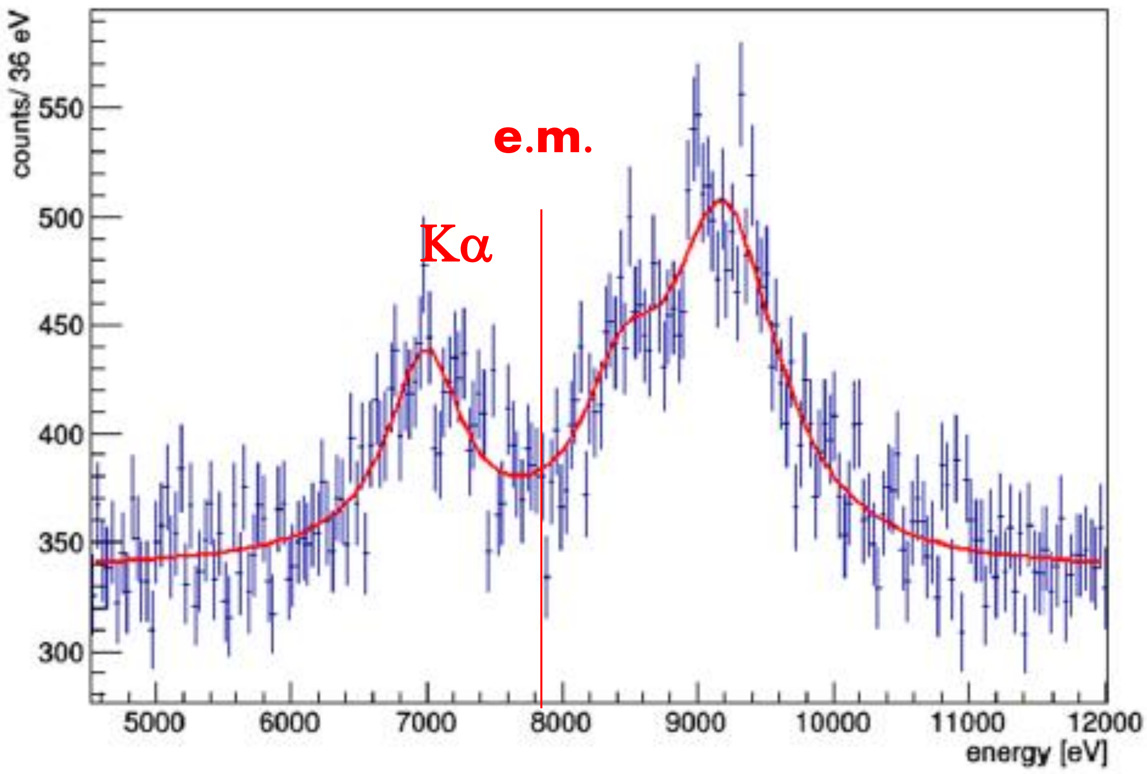


Figure 21: The simulated spectrum of K^-d for SIDDHARTA-2 for 800 pb^{-1} (the K_α line is at 7 keV, while from 8 to 10 keV there is the K-complex)

$\Delta\varepsilon(1s)$ = 30 eV and $\Delta\Gamma(1s)$ = 70 eV

DAFNE – SIDDHARTA-2 meeting

- **installation of the SIDDHARTA-2 in the actual KLOE region (same as SIDDHARTA)**
- **DAFNE team will check the existence of beam pipe elements and of platform of SIDDHARTA**
- **beam pipe: explore possibility to realise a new beam pipe (carbon fiber)**
- **study feasibility of rolling out KLOE2 as a block – new quadrupole magnets**
- **other technical items , including 3D SDDHARTA-2 setup -> DAFNE team**

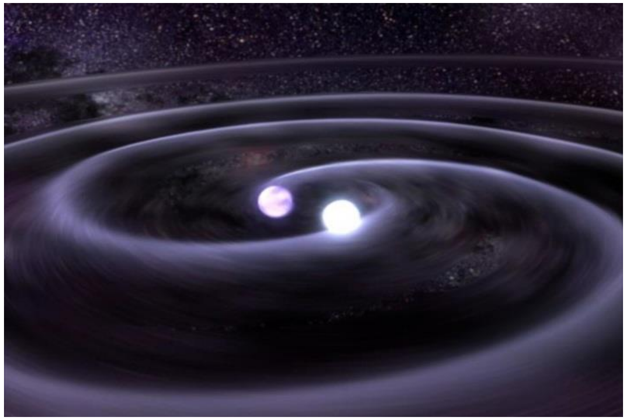
SIDDHARTA-2 - Kd request:

We require an integrated luminosity of *900 pb^{-1}* *(100 for tuning of the apparatus)* to perform the first measurement of the strong interaction induced parameters - the energy displacement and the width - for the kaonic deuterium ground state, which is a fundamental measurement in low-energy strangeness physics (QCD).

We are ready to install starting with second half of 2017.

We request a *clear schedule for the installation and run*.

Together with the results of the kaonic hydrogen measurement performed by SIDDHARTA, the kaonic deuterium measurement will allow to extract for the first time the isospin-dependent antikaon-nucleon scattering lengths, fundamental quantities to understand low-energy QCD in the strangeness sector, which in turn is important for studies in particle and nuclear physics, as well as in astrophysics, including the emergent sector of gravitational waves emitted by binary (neutron) stars and the dark matter (primordial strongly inter. DM)



ONE DAY MEETING

Strangeness, Gravitational waves and neutron stars

10 June 2016
INFN-LNF
Aula di Direzione (Ed. 1)

Organizers: Catalina Oana Curceanu, Maria Paola Lombardo

Speakers include:

Omar Benhar (INFN Sapienza), Ignazio Bombaci (Univ. e INFN Pisa), Alessandro Drago (Univ. e INFN Ferrara, Italy) Viviana Fafone (ToV), Alessandra Feo (Univ. Perugia), Massimo Mannarelli (LNGS), Cristian Piscicchia (LNF-INFN e Centro Fermi, Roma), Jacobus Verbaarschot (SUNY)

http://agenda.infn.it/event/strangeness

SIDDHARTA2 future perspectives

1) Kaonic deuterium measurement - 1st measurement: and R&D for other measurements

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

3) Other light kaonic atoms (KO, KC,…) -> HPGe

4) Heavier kaonic atoms measurement (Si, Pb…) -> HPGe

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 <7 keV (kaon mass puzzle) – TES, VOXES

Helmholtz Mainz: HPGe detectors

Kaonic atoms measurements

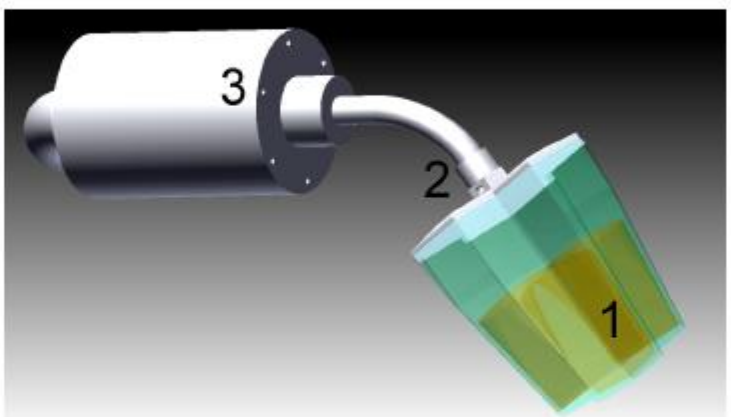


Fig. 2 Drawing of one HPGe detector system assembled to an X-Cooler II device. Three encapsulat coaxial HPGe crystals (1) are arranged in one capsule. The flexible section of the thick cold finger (enables the placement of the cluster at the restricted space inside the $\overline{\text{P}}$ANDA spectrometer. The X-Cooler II (3) replaces the standard liquid nitrogen cooling devices.

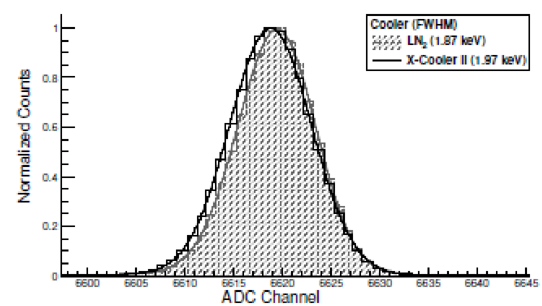
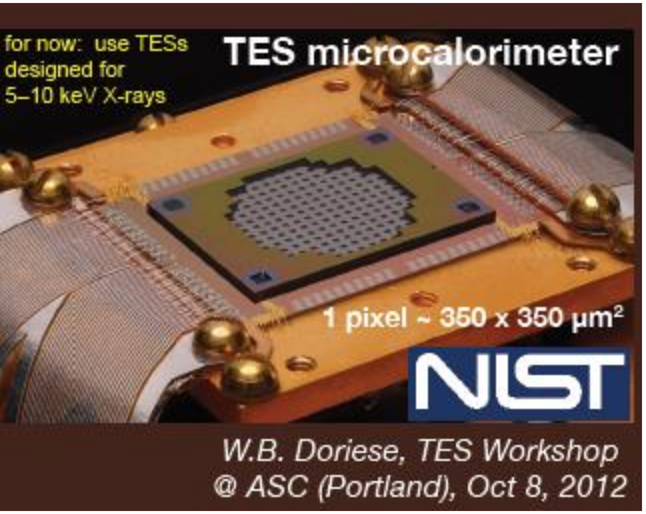


Fig. 3 Measured energy spectra of the 1.332 keV line of a ^{60}Co calibration source taken with two different cooling devices. For the dashed spectrum with a line width of FWHM = 1.97 keV the HPGe crystal was cooled electromechanically, for the solid spectrum with a line width of FWHM = 1.87 keV a liquid nitrogen cooling system was used [5].

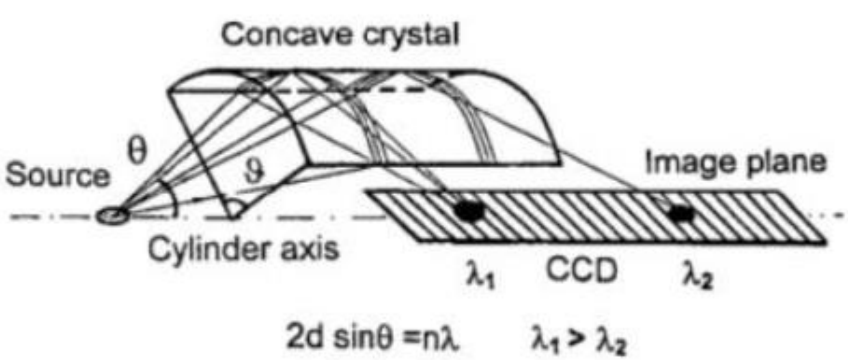


- 1 pixel : 300 x 320 μm^2
- 240 array : total ~ **23 mm^2**
- **2~3 eV (FWHM)** @ 6 keV

well established system!

TES: RIKEN, Japan
VOXES: LNF-INFN

Extreme precision meas.:
Kaon mass (K-)



There is no exquisite

beauty without

some STRANGENESS

in the proportion.

Edgar Allan Poe