ÖAW AUSTRIAN ACADEMY OF SCIENCES

SMI – STEFAN MEYER INSTITUTE

SIDDHARTA - 2
STATUS REPORT

Johann Zmeskal
for the SIDDHARTA-2 Collaboration

54th LNF-INFN SCIENTIFIC COMMITTEE
November 13, 2017

CONTENT

Scientific Motivation

SIDDHARTA-2 apparatus

- Platform
- Mounting frame
- Beam pipe
- Luminosity monitor

- Cooling system
- Vacuum chamber
- Cryogenic target

- SDD X-ray detector
- SDD testing facilities

- Veto system

Overall time schedule

SIDDHARTA-2 Collaboration

SIlicon Drift Detector for Hadronic Atom Research by Timing Applications

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

The scientific goal

To perform precision measurements of kaonic atoms X-ray transitions

- unique information about QCD in the non-perturbative regime in the strangeness sector not obtainable otherwise

Started with the precision measurement of ***shift*** and ***width*** of ***kaonic hydrogen***

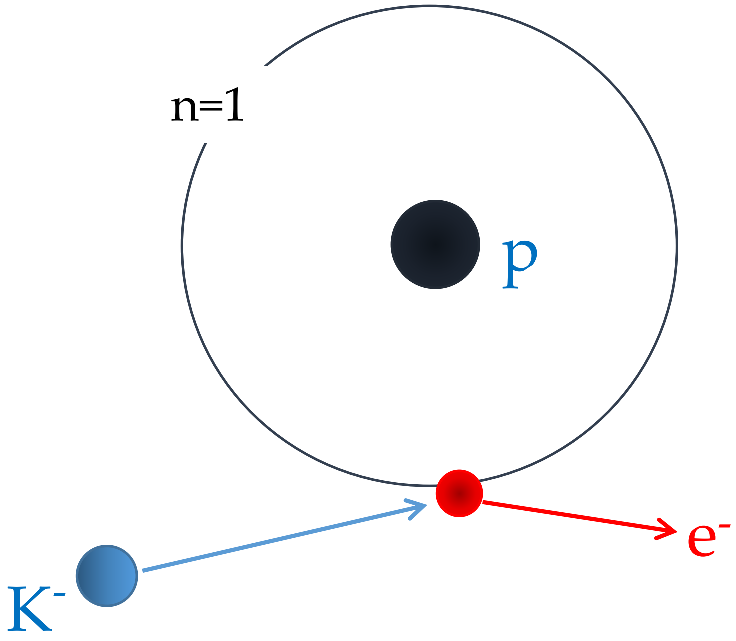
- NOW **first measurement of kaonic deuterium**

to extract the antikaon-nucleon isospin dependent scattering lengths

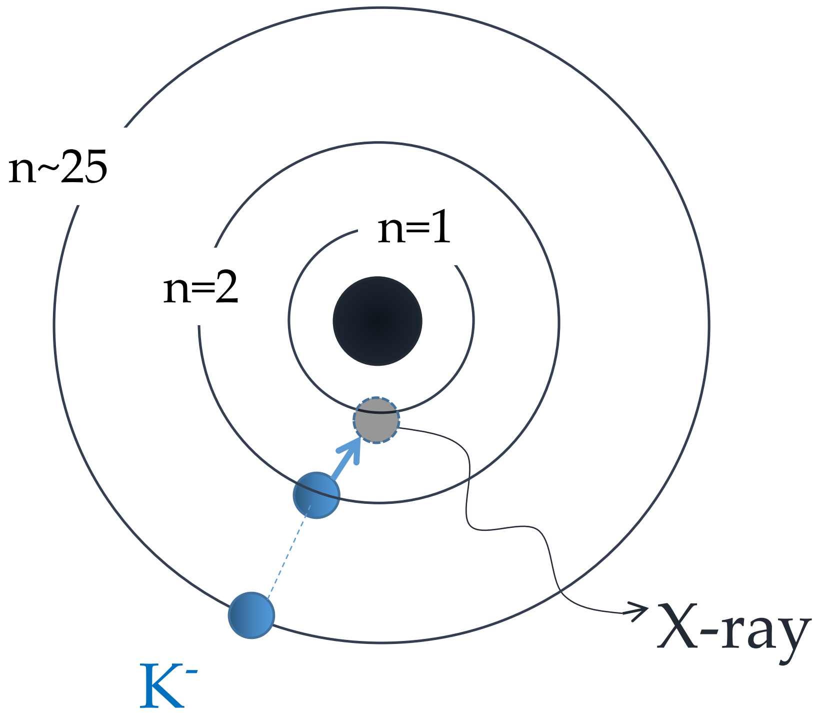
- chiral symmetry breaking (mass problem), EOS for neutron stars

FORMING "EXOTIC" ATOMS

"normal" hydrogen



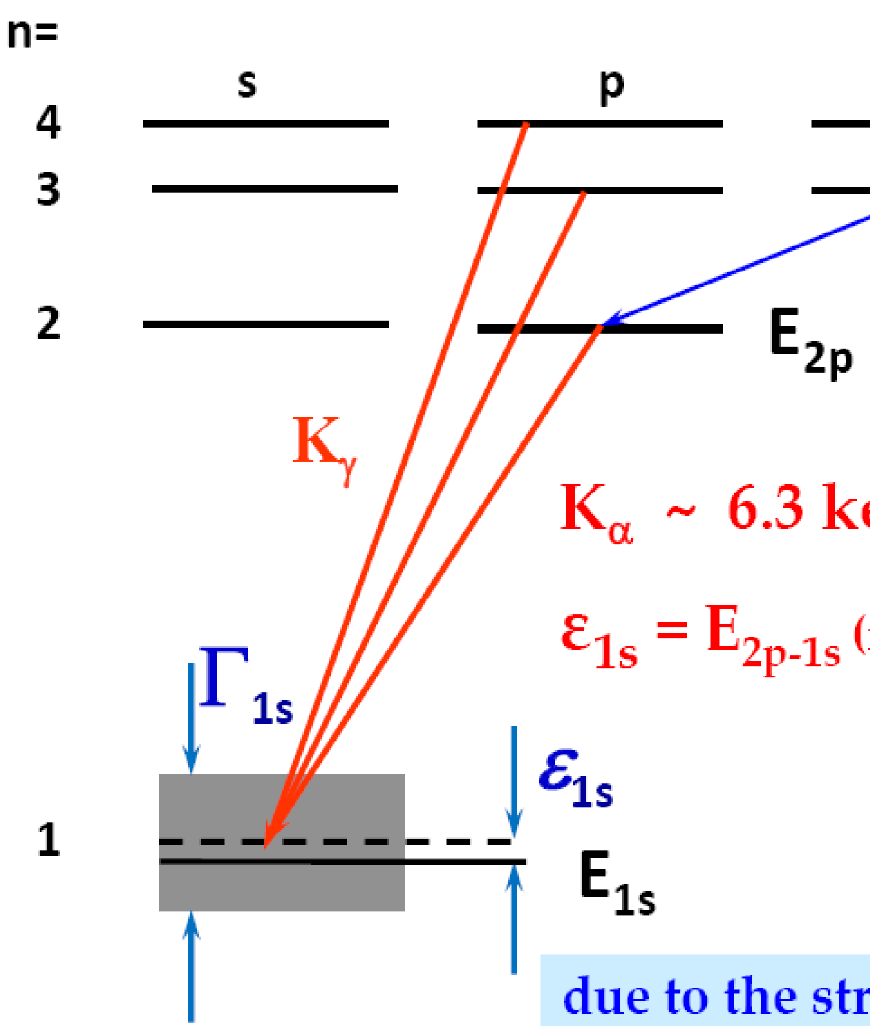
"exotic" (kaonic) hydrogen



$$n \approx \sqrt{\frac{m_{\rm red}}{m_e}} \cdot n_e$$

2p → 1s
K_α transition

X-RAY TRANSITIONS TO THE 1s STATE



shift and width of states
n > 1 are negligible

K_α ~ 6.3 keV

$\varepsilon_{1s} = E_{2p\text{-}1s}\,(\text{meas.}) - E_{2p\text{-}1s}\,(\text{e.m.})$

due to the strong interaction kaon-proton
the 1s level is shifted and broadened

SCATTERING LENGTHS

Deser-type relation connects shift ε_{1s} and width Γ_{1s} to the real and imaginary part of a $_{K\text{-}p}$

$$\varepsilon_{1s} - \frac{i}{2}\Gamma_{1s} = -2\alpha^3 \mu_c^2 a_{K^-p} \left(1 - 2\alpha\mu_c (\ln\alpha - 1) a_{K^-p}\right)$$

(μ_C reduced mass of the K^-p system, α fine-structure constant)

U.-G. Meißner, U.Raha, A.Rusetsky, Eur. phys. J. C35 (2004) 349
next-to-leading order, including isospin breaking

$$a_{K^-p} = \frac{1}{2}[a_0 + a_1]$$

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

$$a_{K^-d} = \frac{k}{2}\left[a_{K^-p} + a_{K^-n}\right] + C = \frac{k}{4}[a_0 + 3a_1] + C$$

$$k = \frac{4[m_n + m_K]}{[2m_n + m_K]}$$

Physical Review C96 (2017) 045204
arXiv:1705.06857v1 [nucl-th] 19 May 2017

Constraining the $\bar{K}N$ interaction from the $1S$ level shift of kaonic deuterium

Tsubasa Hoshino,[1] Shota Ohnishi,[1] Wataru Horiuchi,[1] Tetsuo Hyodo,[2] and Wolfram Weise[2,3]

[1] *Department of Physics, Hokkaido University, Sapporo 060-0810, Japan*
[2] *Yukawa Institute for Theoretical Physics, Kyoto University, Kyoto 606-8502, Japan*
[3] *Physik-Department, Technische Universität München, 85748 Garching, Germany*

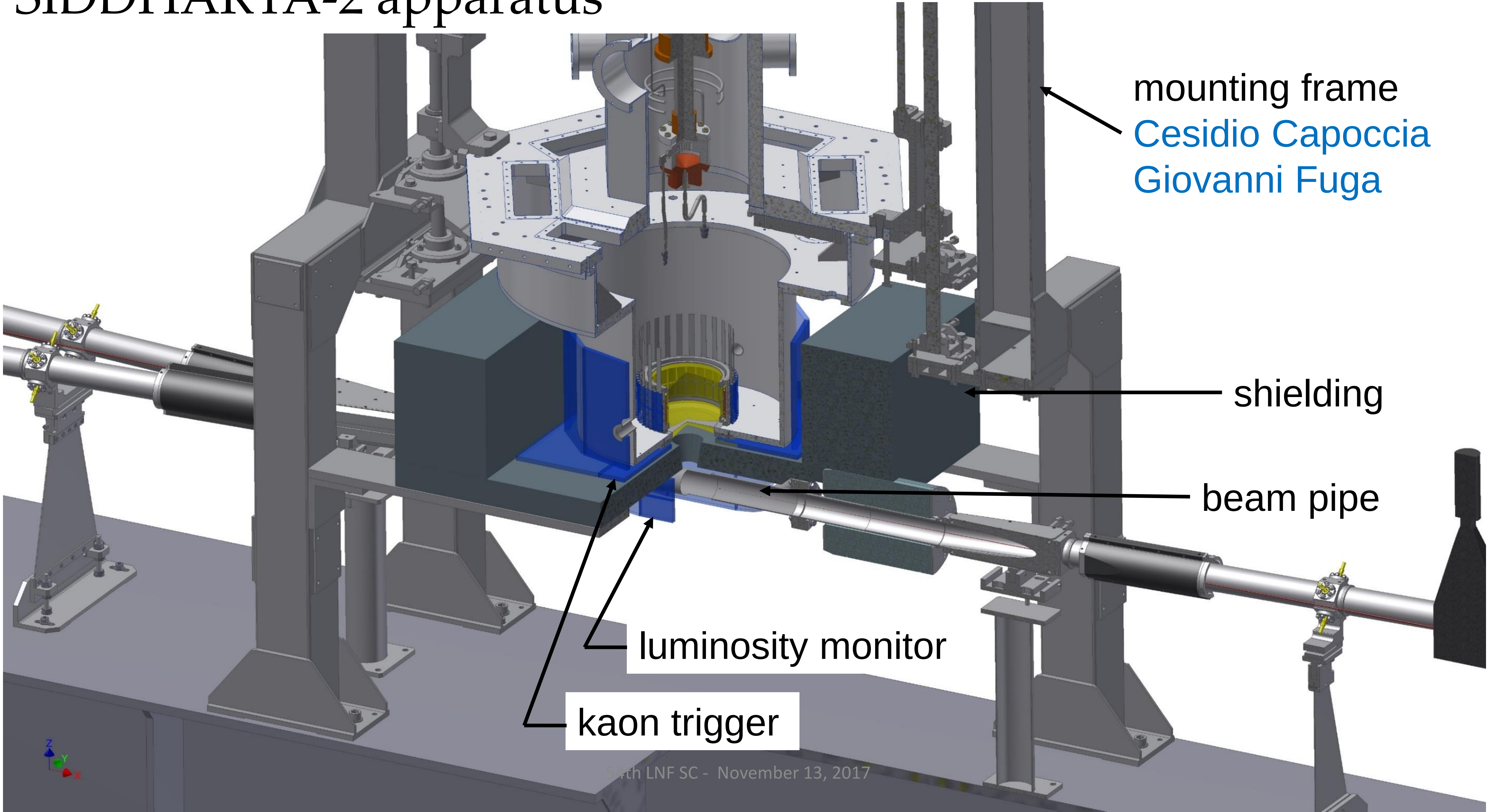
Motivated by the precise measurement of the $1S$ level shift of kaonic hydrogen, we perform accurate three-body calculations for the spectrum of kaonic deuterium using a realistic antikaon-nucleon ($\bar{K}N$) interaction. In order to describe both short- and long-range behavior of the kaonic atomic states, we solve the three-body Schrödinger equation with a superposition of a large number of correlated Gaussian basis functions covering distances up to several hundreds of fm. Transition energies between $1S$, $2P$ and $2S$ states are determined with high precision. The complex energy shift of the $1S$ level of kaonic deuterium is found to be $\Delta E - i\Gamma/2 = (670 - i\,508)$ eV. The sensitivity of this level shift with respect to the isospin $I = 1$ component of the $\bar{K}N$ interaction is examined. It is pointed out that an experimental determination of the kaonic deuterium level shift within an uncertainty of 25 % will provide a constraint for the $I = 1$ component of the $\bar{K}N$ interaction significantly stronger than that from kaonic hydrogen.

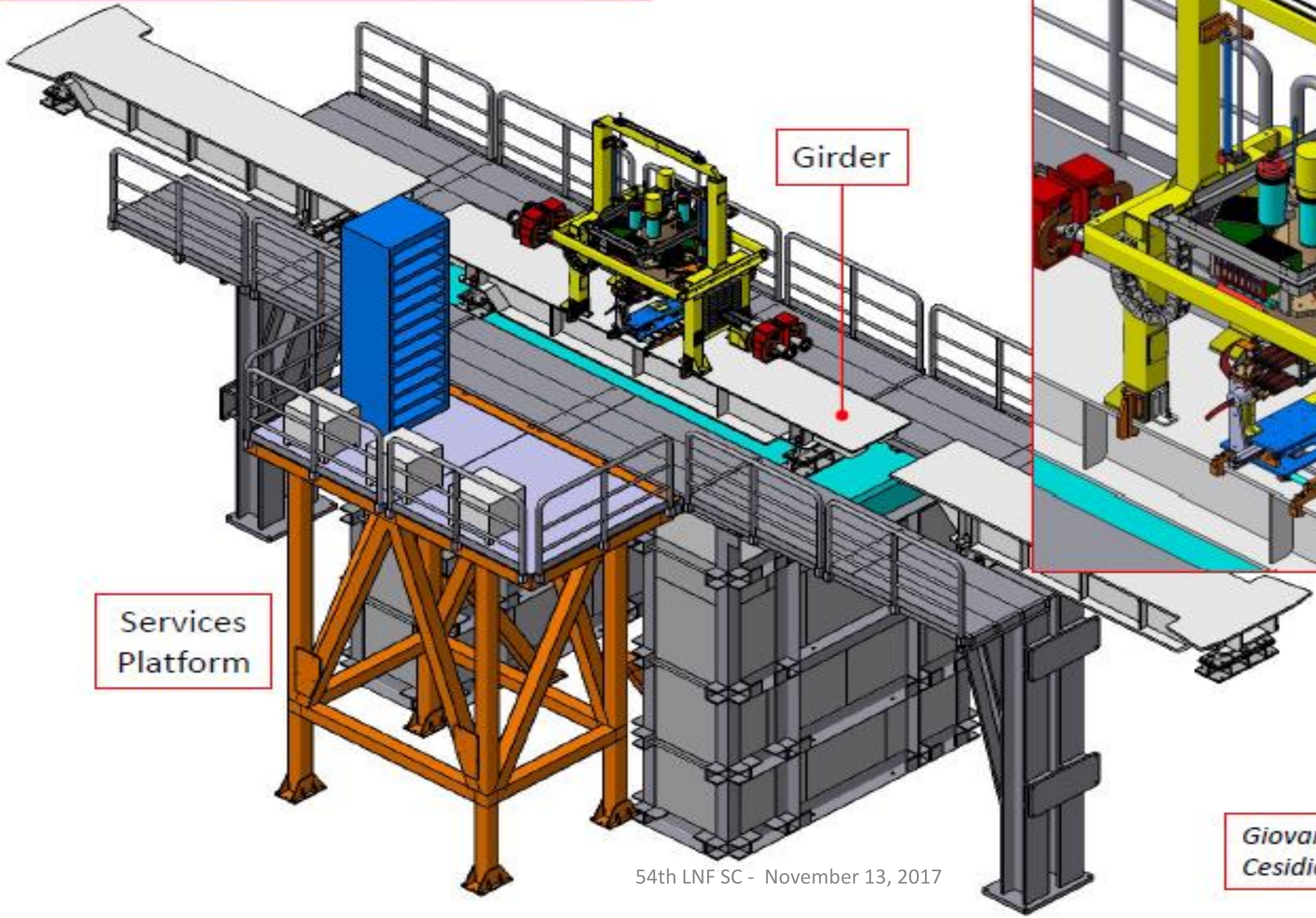
- **Hot topic: Neutron star, strangeness content - EOS**

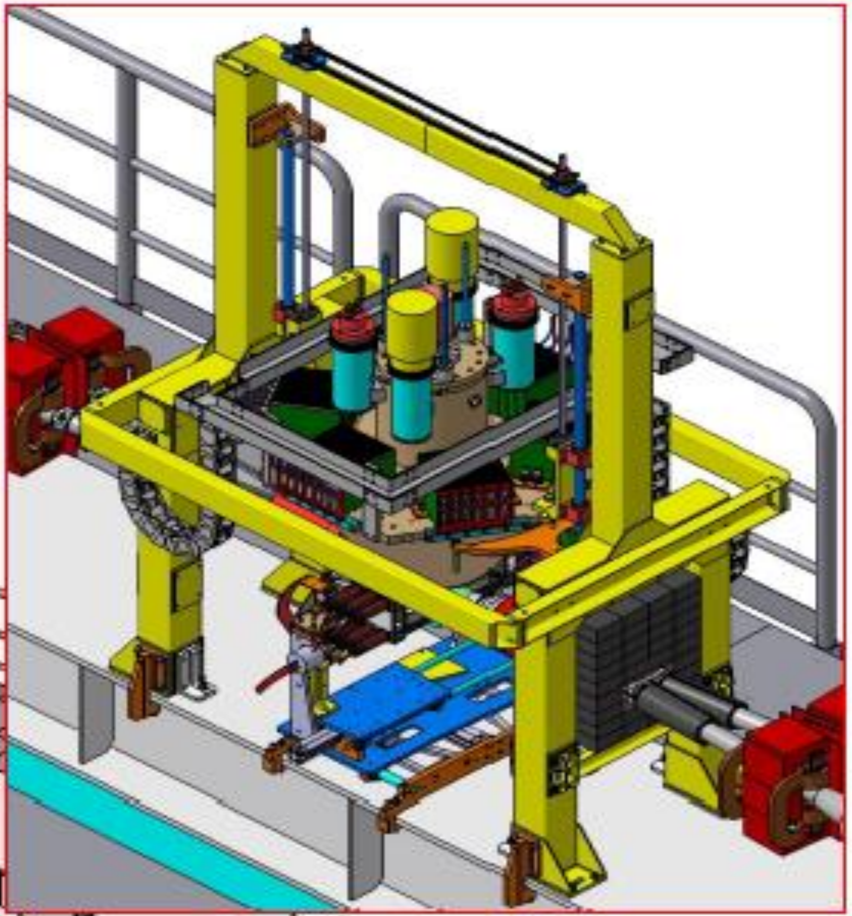
SIDDHARTA-2 setup

- Platform / mounting frame
- Beam pipe
- Luminosity monitor

SIDDHARTA-2 apparatus







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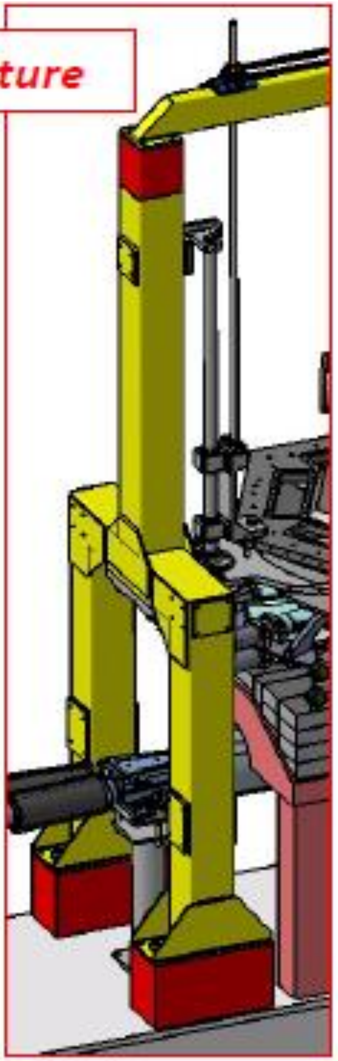
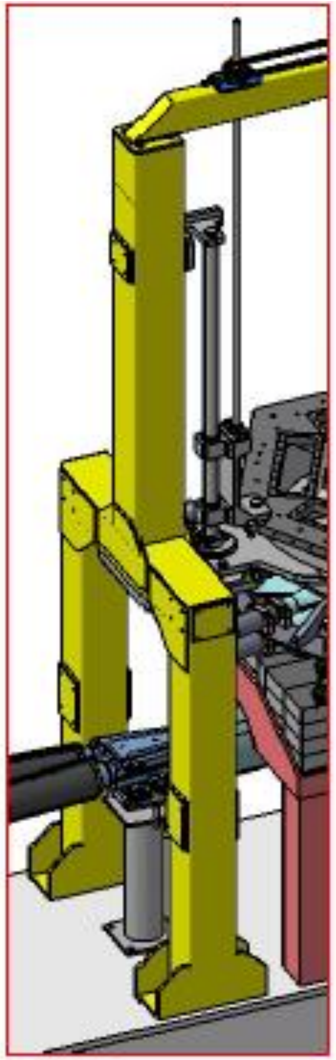
Cesidio.Capoccia@lnf.infn.it

2) Support Structure

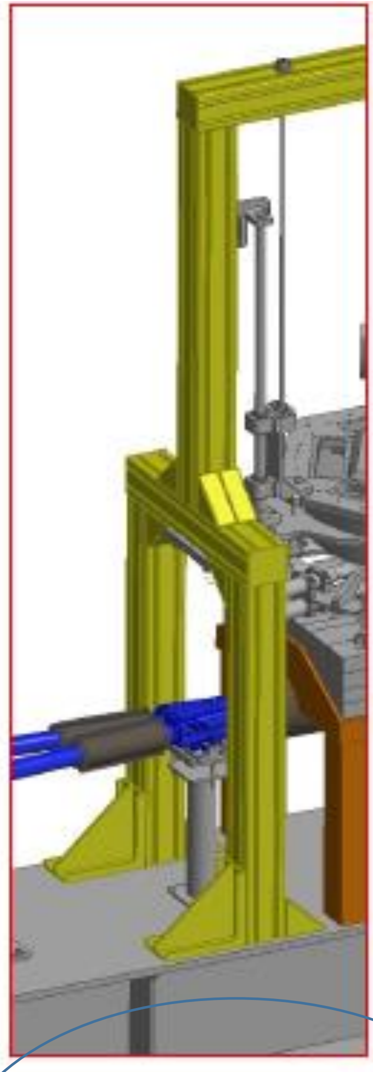
The new envelope of Siddharta needs more vertical space, than it's necessary to modify the support structure



A) *Refurbishing of old structure with some extensions (red parts)*



B) *New one, same drawing, with new dimensions*



C) *New structure done with Bosch (or similar) aluminum profiles*

ordered

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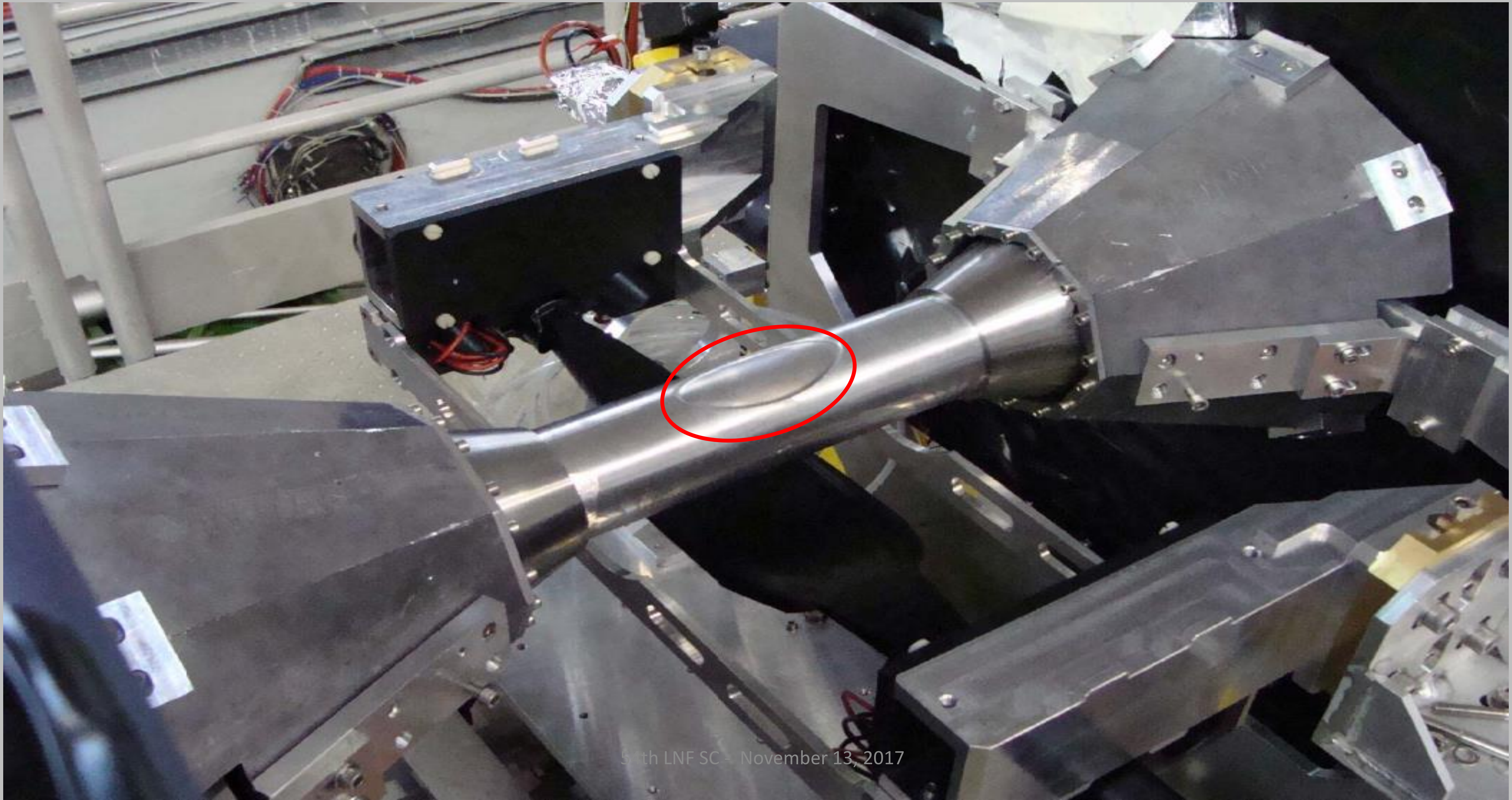
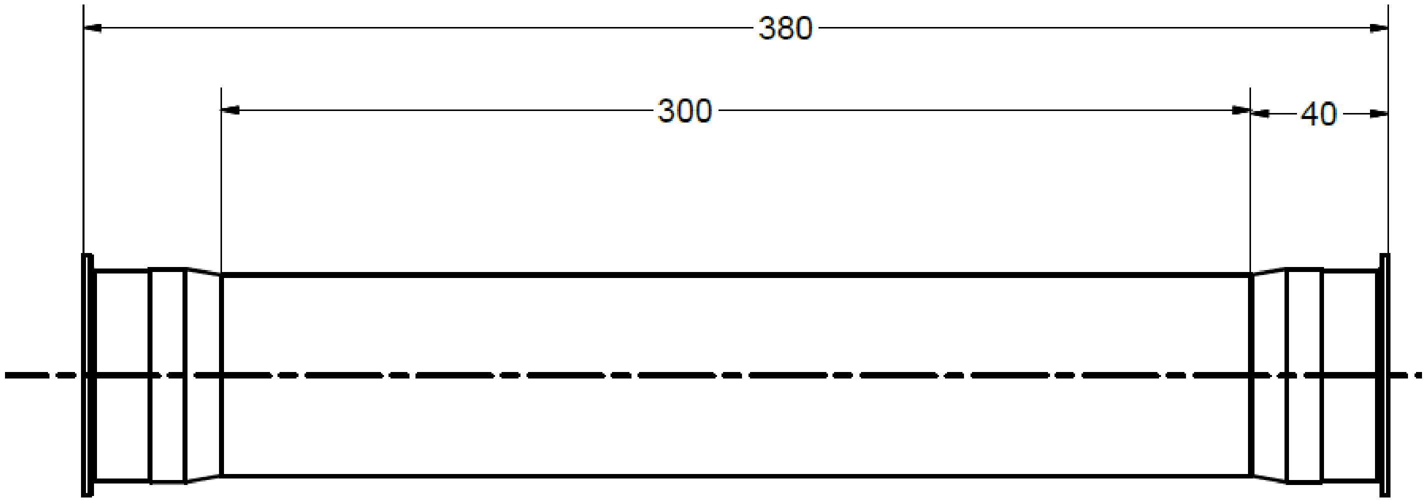
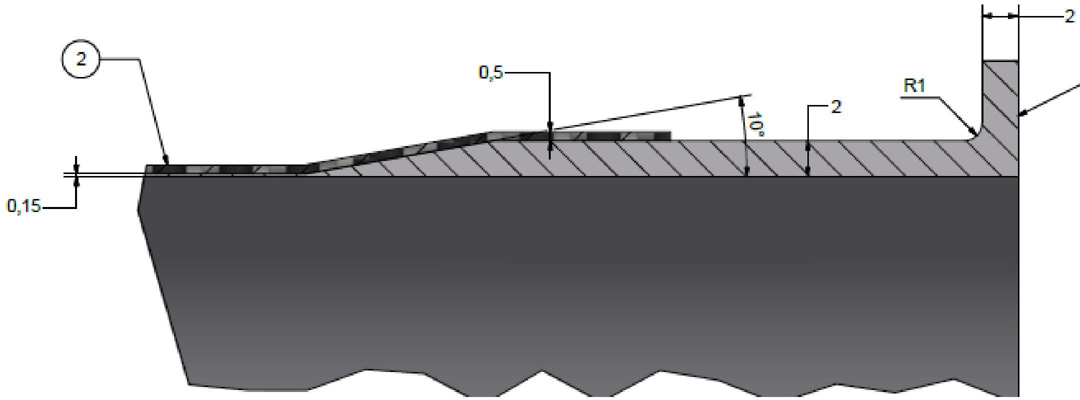
SIDDHARTA – beam pipe



SIDDHARTA-2 beam pipe





- ✓ design / quotation / ordered
  - ➢ final inner diameter 57 mm
  - ➢ Alu thickness 150 µm
  - ➢ Carbon fibre reinforcement 500µm

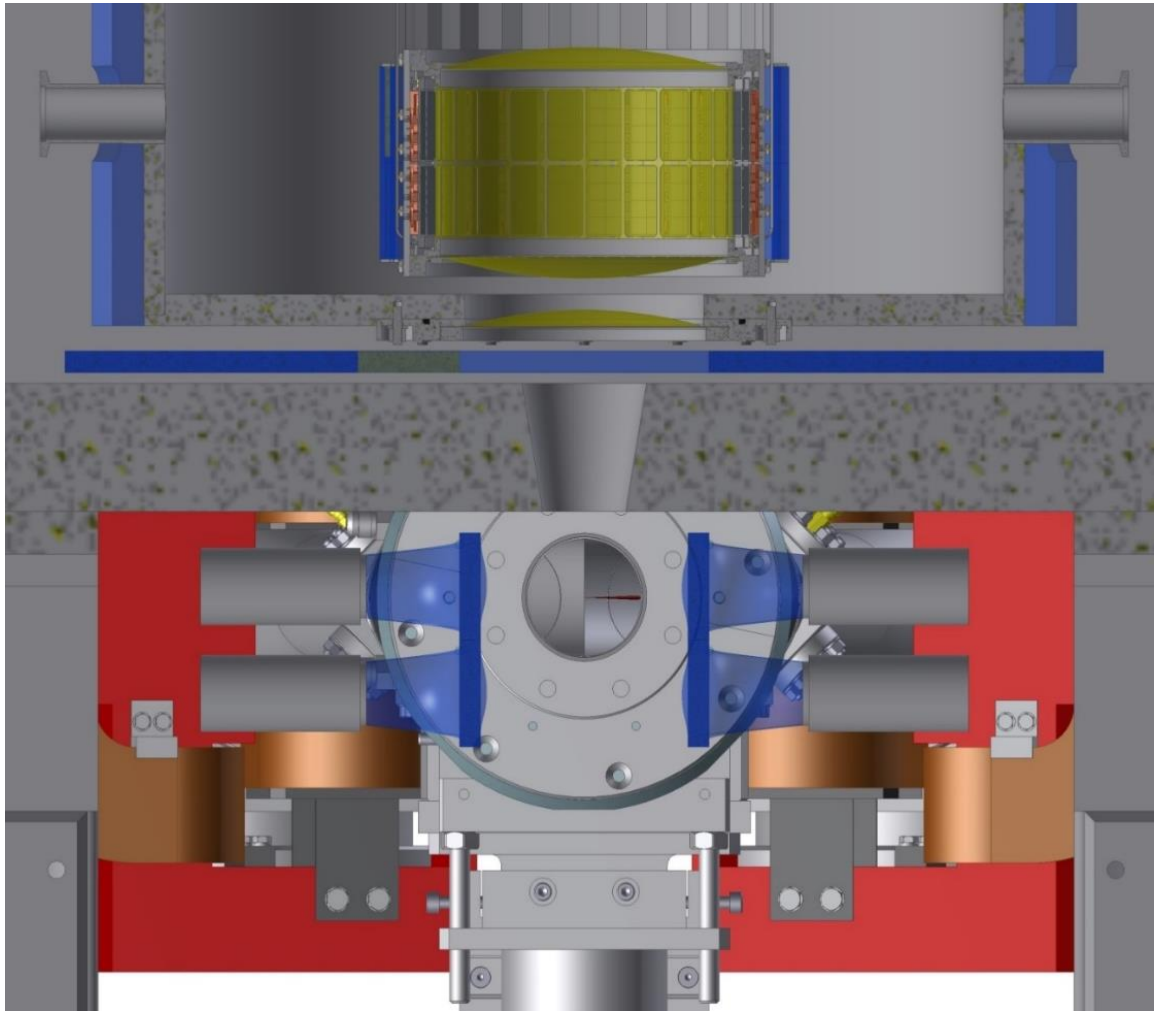
SIDDHARTA-2 - Luminosity monitor (based on kaons)

Size: 8 x 8 cm^2, on both sides of the beam pipe, made of 2 pieces 8 x 4 cm^2
thickness = 2 mm
distance y = ± 4 cm off beam

To be realized in early 2018

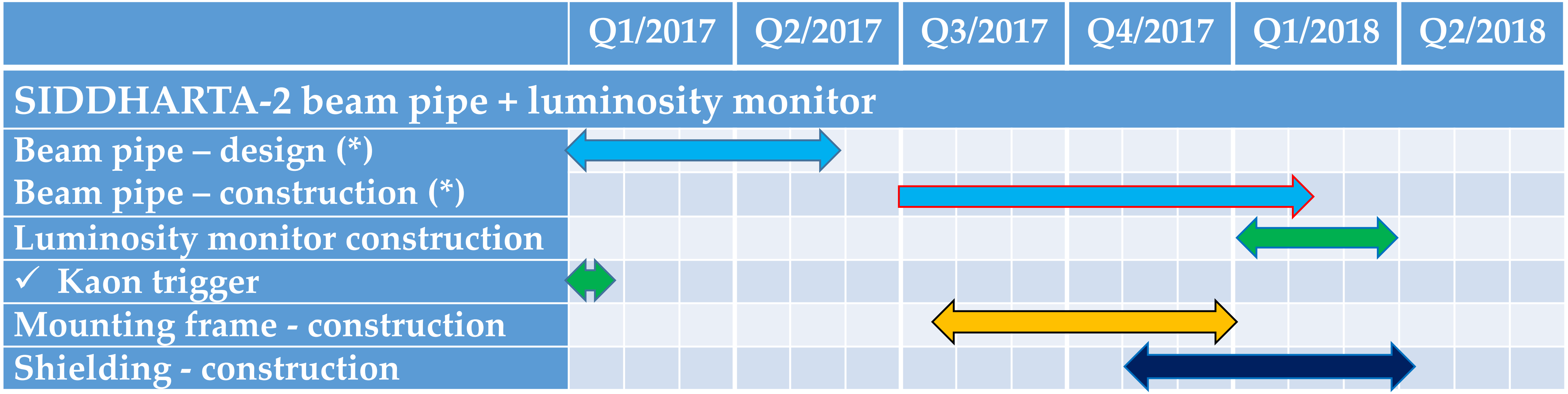
- **coincidence rate: 25.7 %**
- **single rate at the boost side: 42.7 %**

with a luminosity $L = 10^{32}$
62 Hz (on boost-side),
in 5 seconds: 310 counts (5.7%)



- prototype under test

Gantt chart SIDDHARTA-2:
beam pipe + luminosity monitor + mounting frame



(*) Beam pipe – final diameter was fixed begin of Oct. 2017

SIDDHARTA-2 setup

- Cooling systems
- Vacuum chamber
- Cryogenic target

SIDDHARTA-2 cooling

✓ **Target + SDD cooling:**

1 Leybold MD10 – 16 W @ 20 K
target cell and SDDs will be cooled via ultra pure aluminum bars

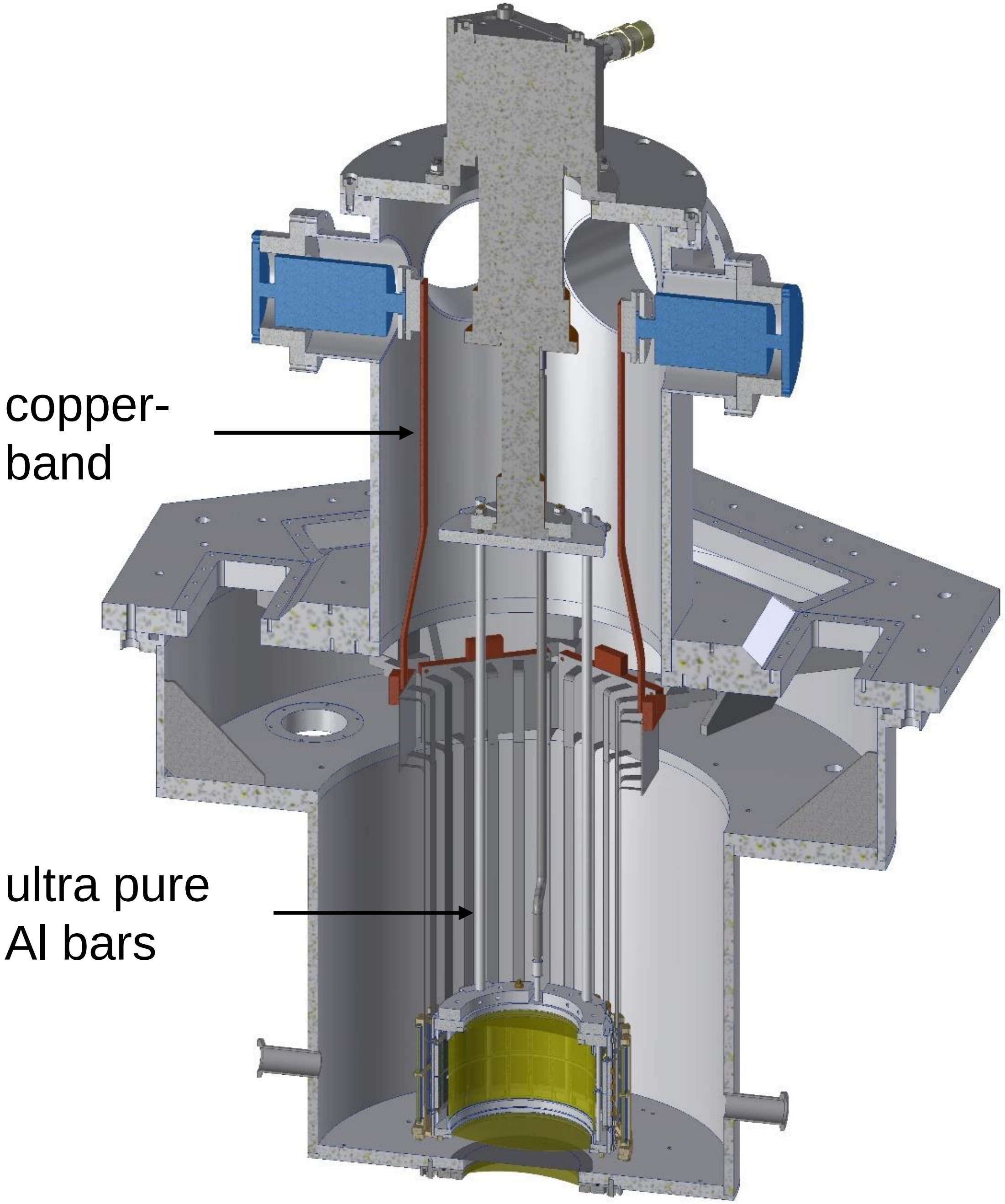
$T_{TC} = 30$ K

$T_{SDD} = 50$ K

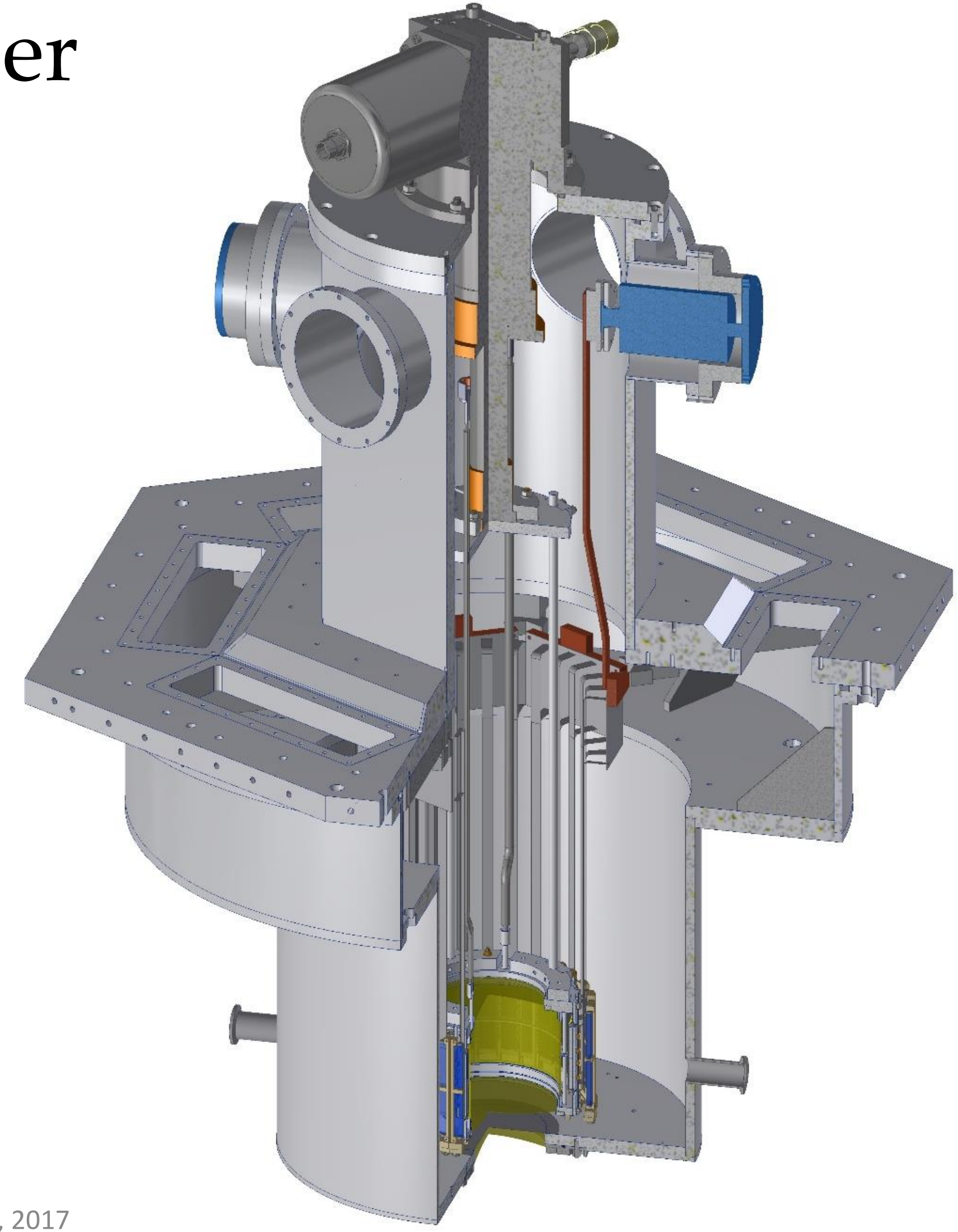
✓ **Line driver boards:**

2 CryoTiger – 30 W @ 120 K
copper-band cooling lines

$T_{LD} = 120$ K

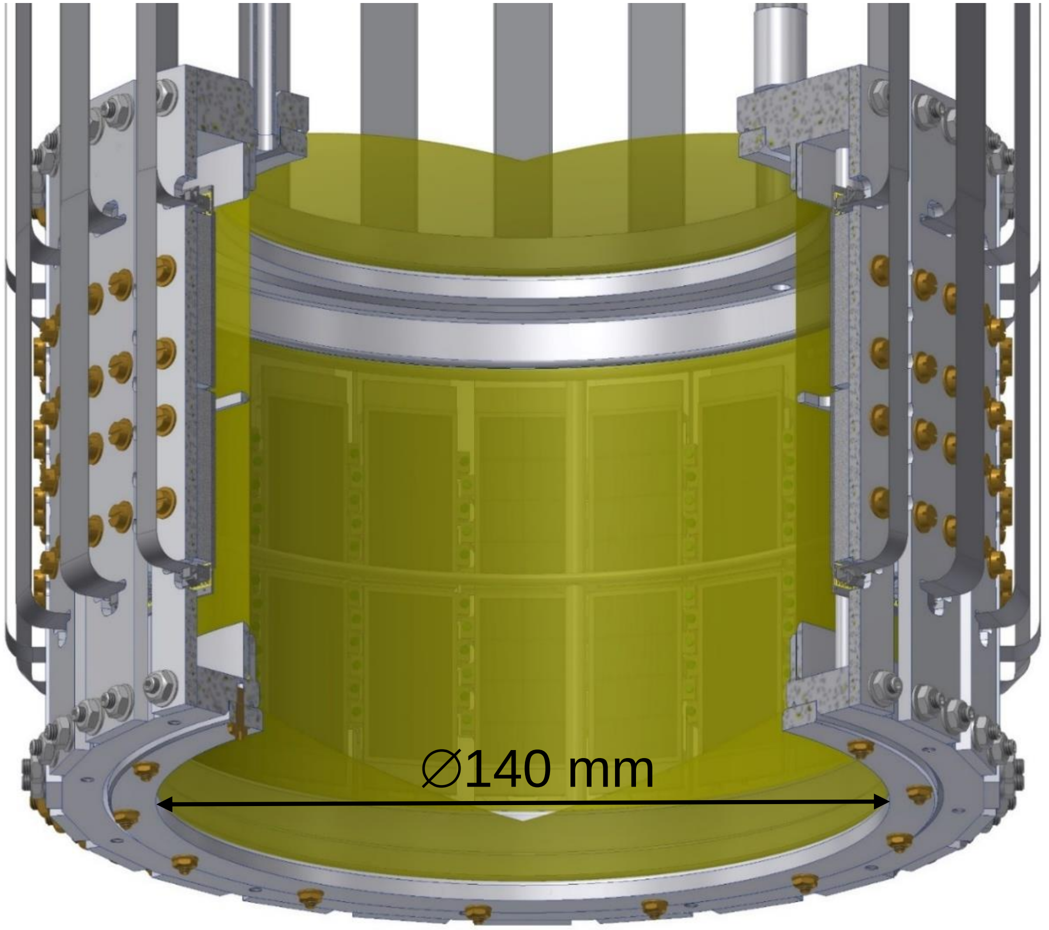


SIDDHARTA-2 vacuum chamber



SIDDHARTA-2 cryogenic target

Working temperature: 30 K
Working pressure :   0.3 MPa



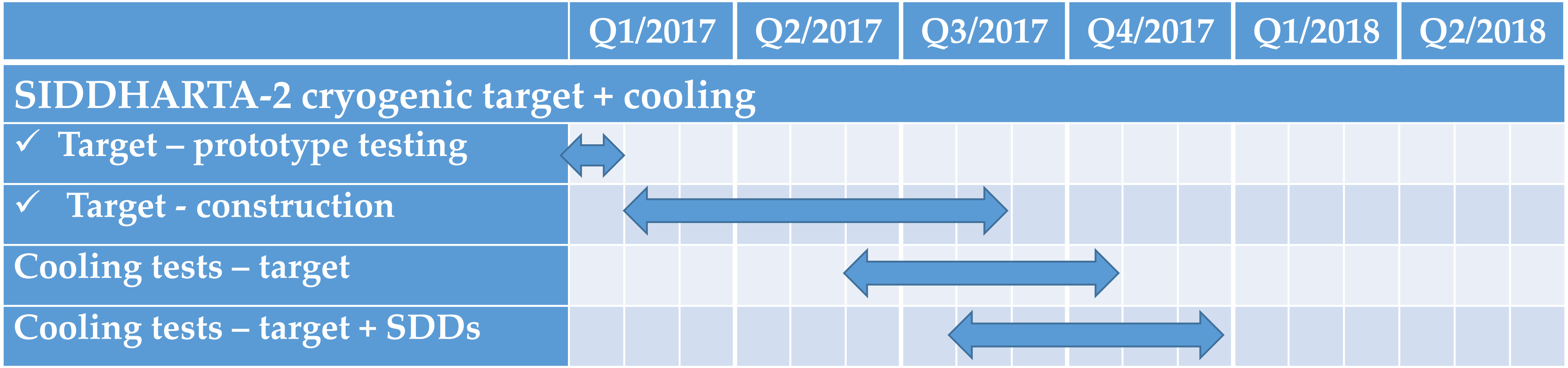
Final test during summer 2017:
Pressurised for 16 days
with P = 0.3 MPa (overP)

Cooling/pressure test
- 2.5 weeks 30 K / 0.19 MPa
- 3.5 days   30 K / 0.31 MPa

➢ Target cell wall is made of a 2-Kapton layer structure (25 μm + 25 μm + Araldit < 100 μm)

➢ **HPH Deuterium generator**

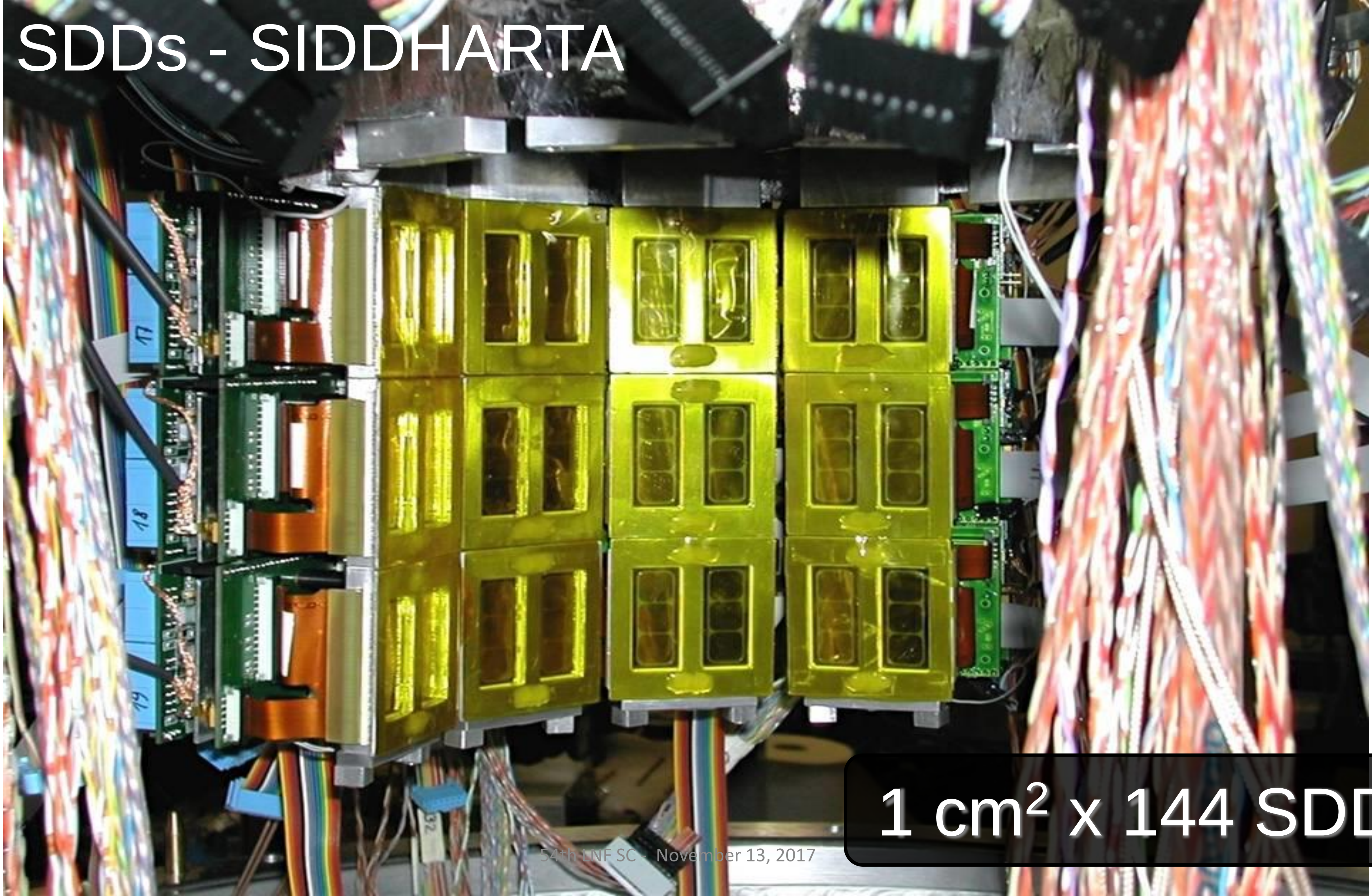
Gantt chart SIDDHARTA-2: target



SIDDHARTA-2 setup

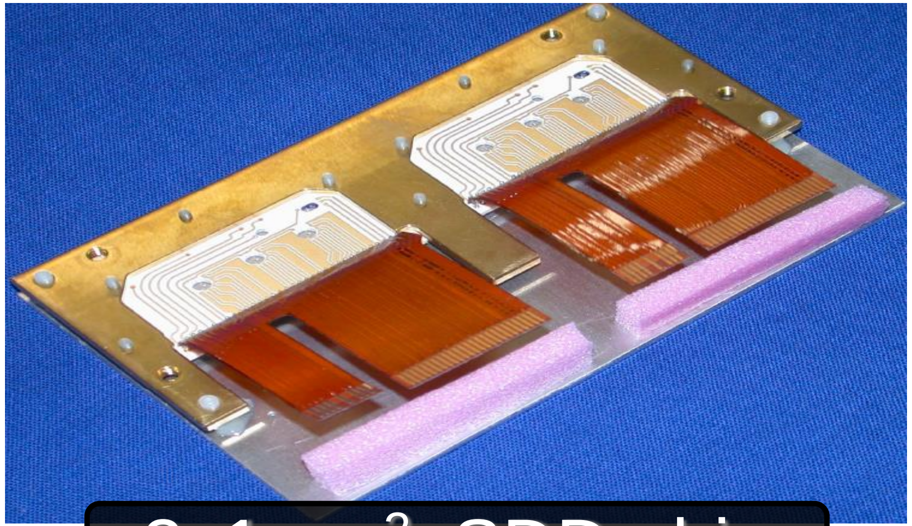
- SDD X-ray detector

SDDs - SIDDHARTA

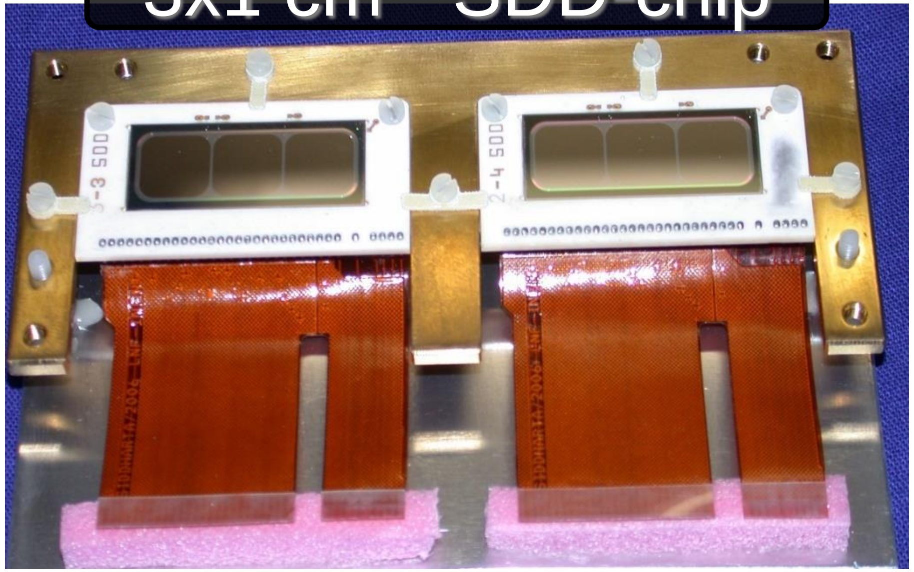


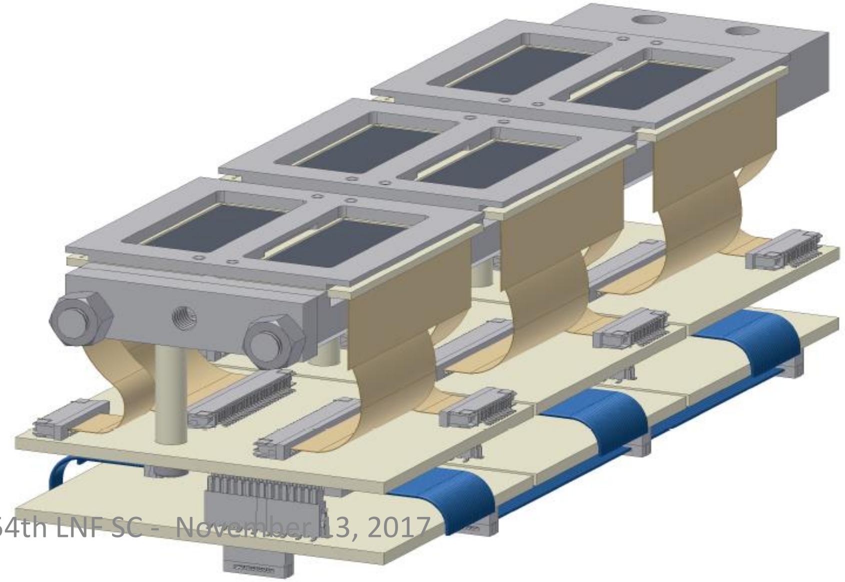
1 cm^2 x 144 SDDs

SDDs developed for SIDDHARTA



3x1 cm^2 SDD-chip





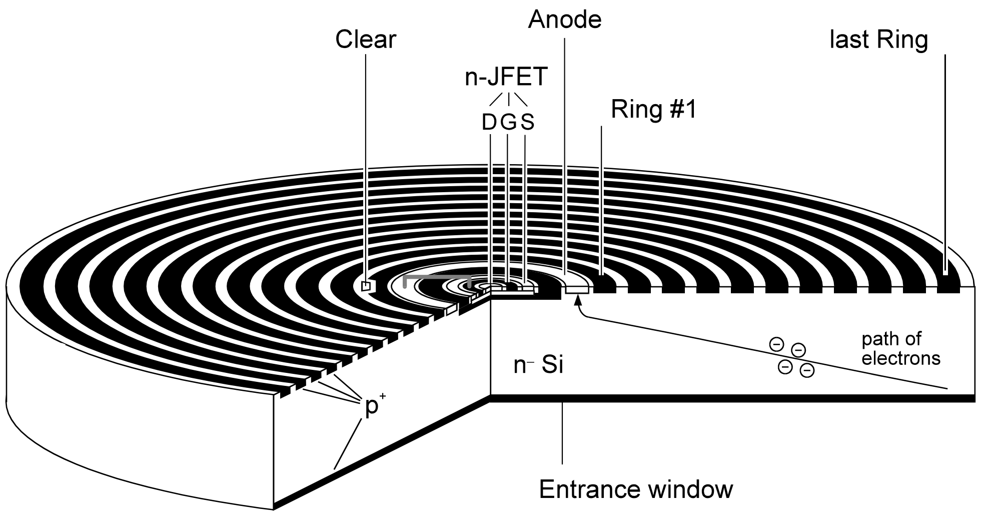
18 cm^2 sub-module

- **total 144 cm^2**

The "new" Silicon Drift Detector

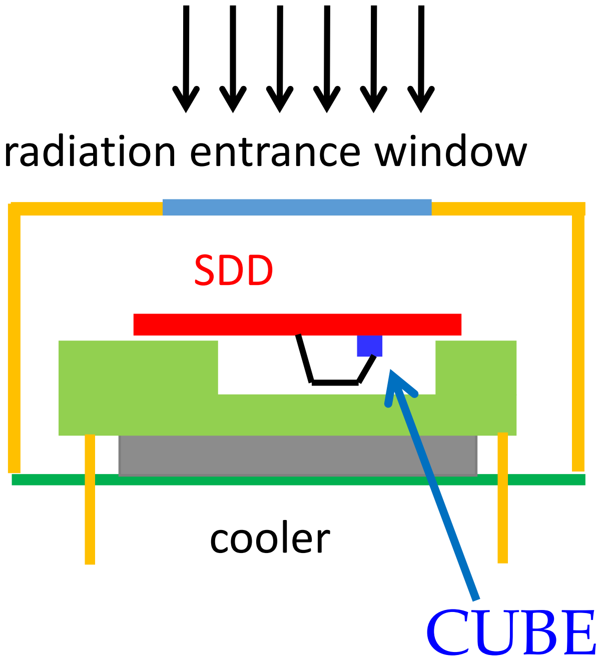
➢ **SIDDHARTA**

- JFET integrated on SDD
- lowest total anode capacitance
- limited JFET performance
- sophisticated SDD+JFET technology



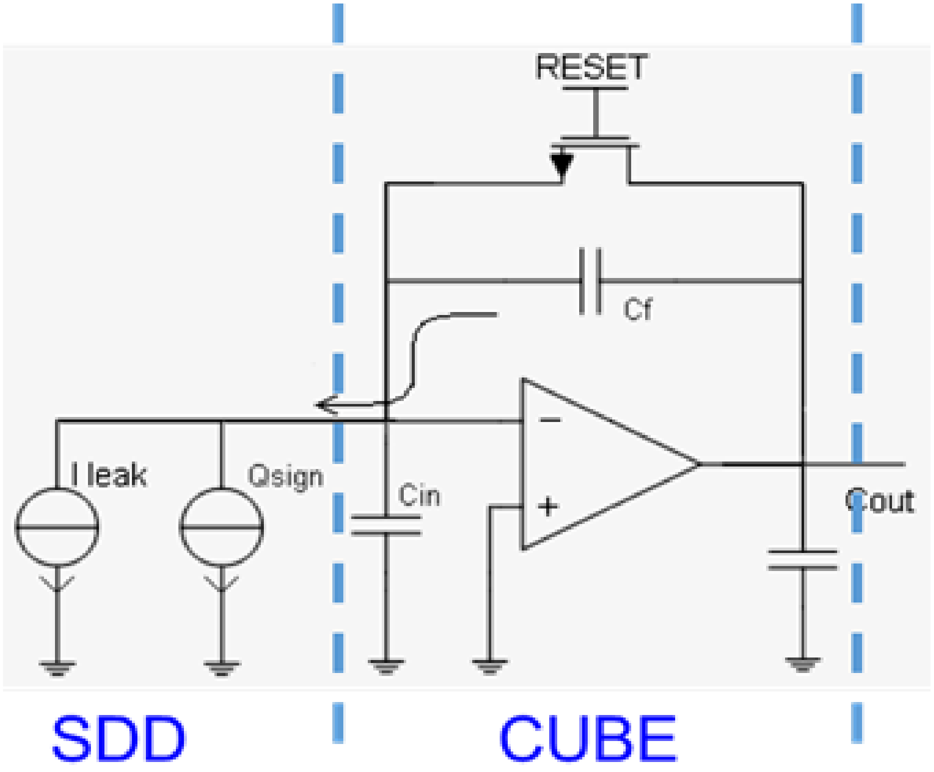
➢ **SIDDHARTA-2**

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

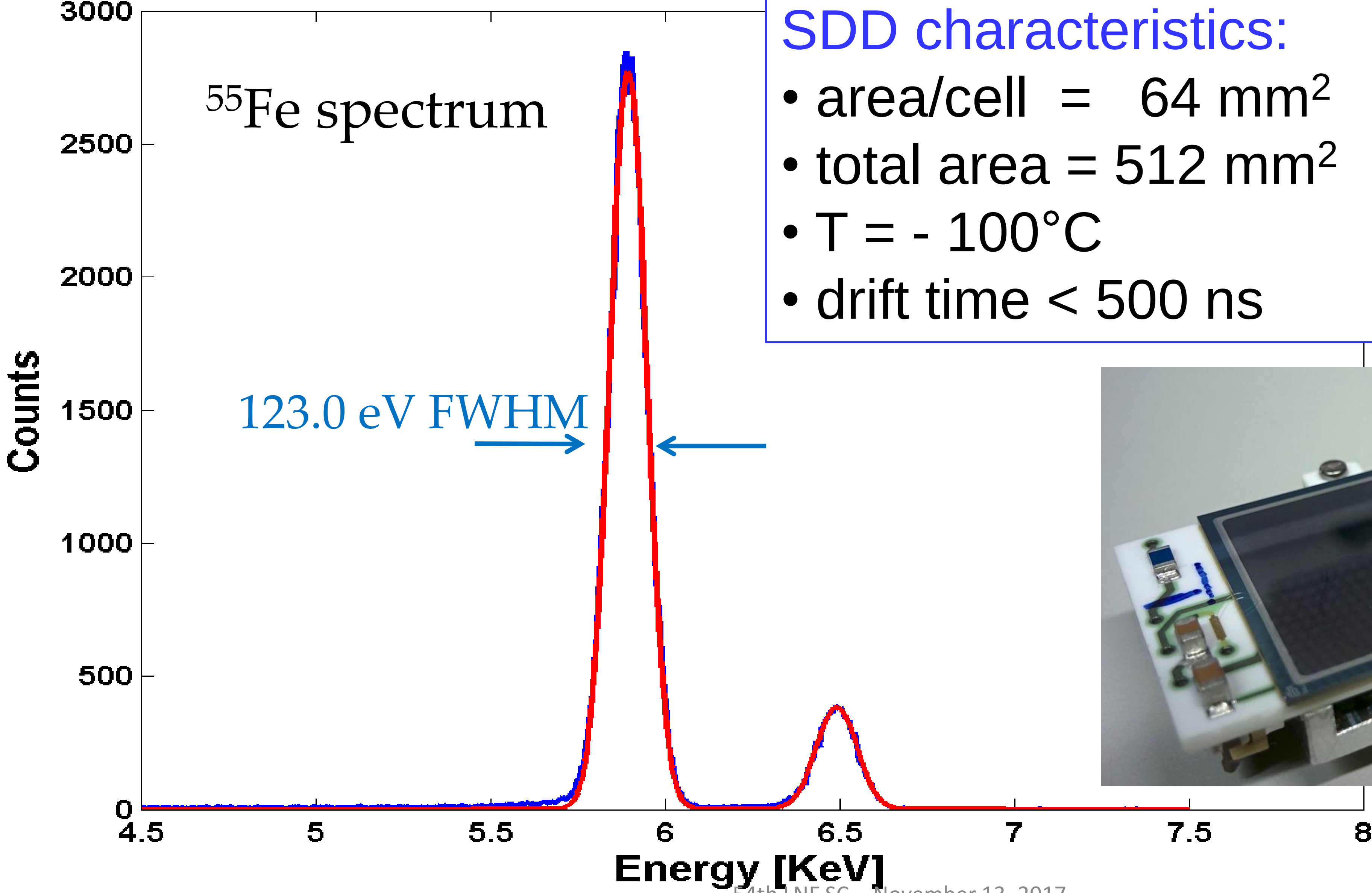


The CUBE preamplifier

- A full CMOS preamplifier is mounted on ceramic board - connected via bonding
- The CUBE replaces the JFET, which was direct implanted on the anode side on the SIDDHARTA type SDDs
- Short bonding lines from CUBE to SDD, no difference in the detector performance
- Advantage, the preamplifier is connected close to the SDD and not only the FET → ASIC of analogue processing can be placed relatively up to ~100 cm away

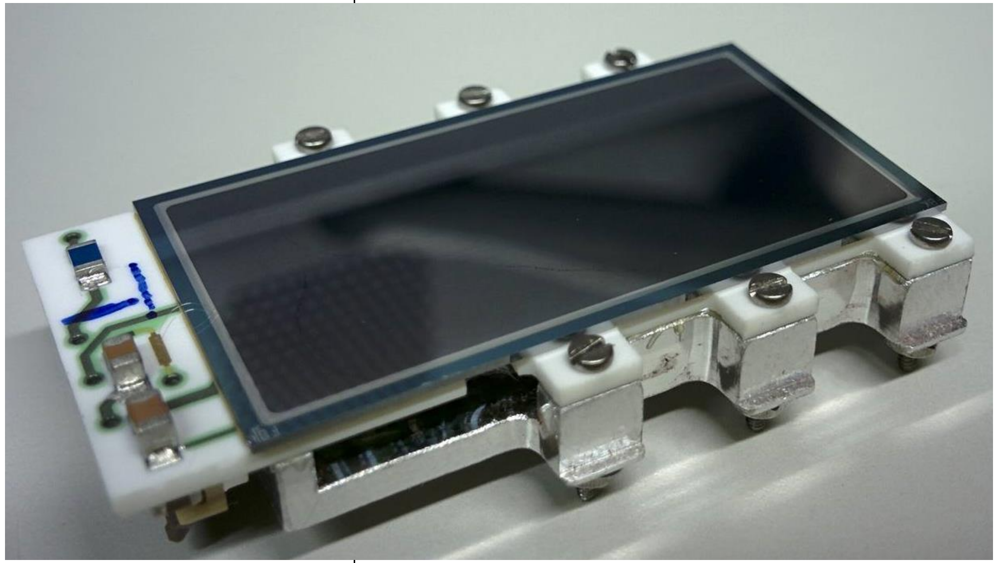


New SDD technology: CUBE preamplifier

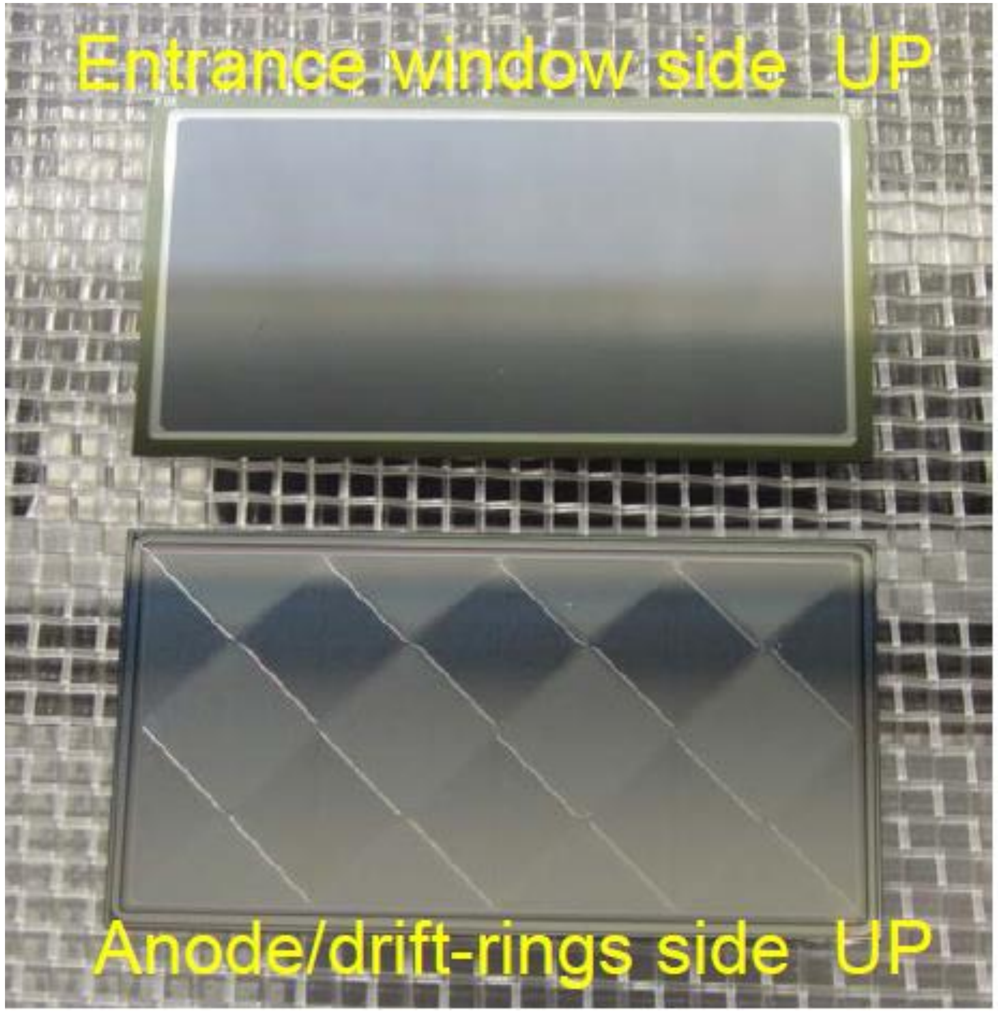


SDD characteristics:

- area/cell = 64 mm^2
- total area = 512 mm^2
- T = - 100°C
- drift time < 500 ns

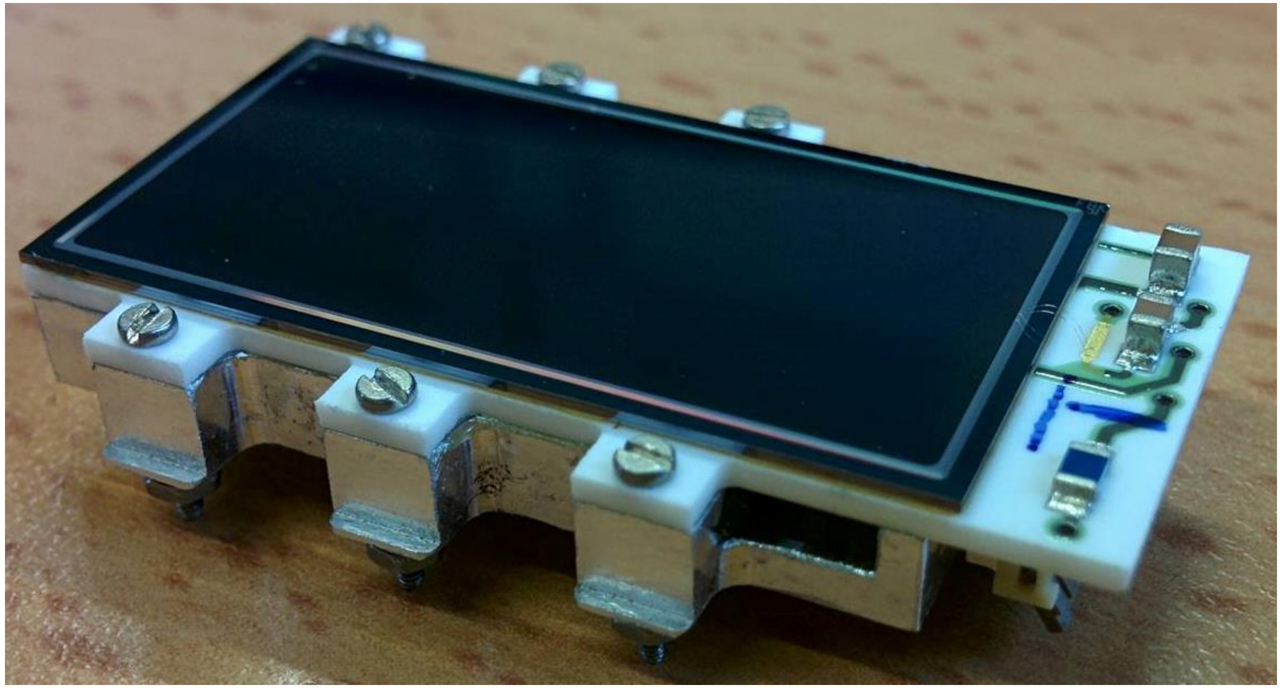


SDD delivery → SDD bonded + mounted

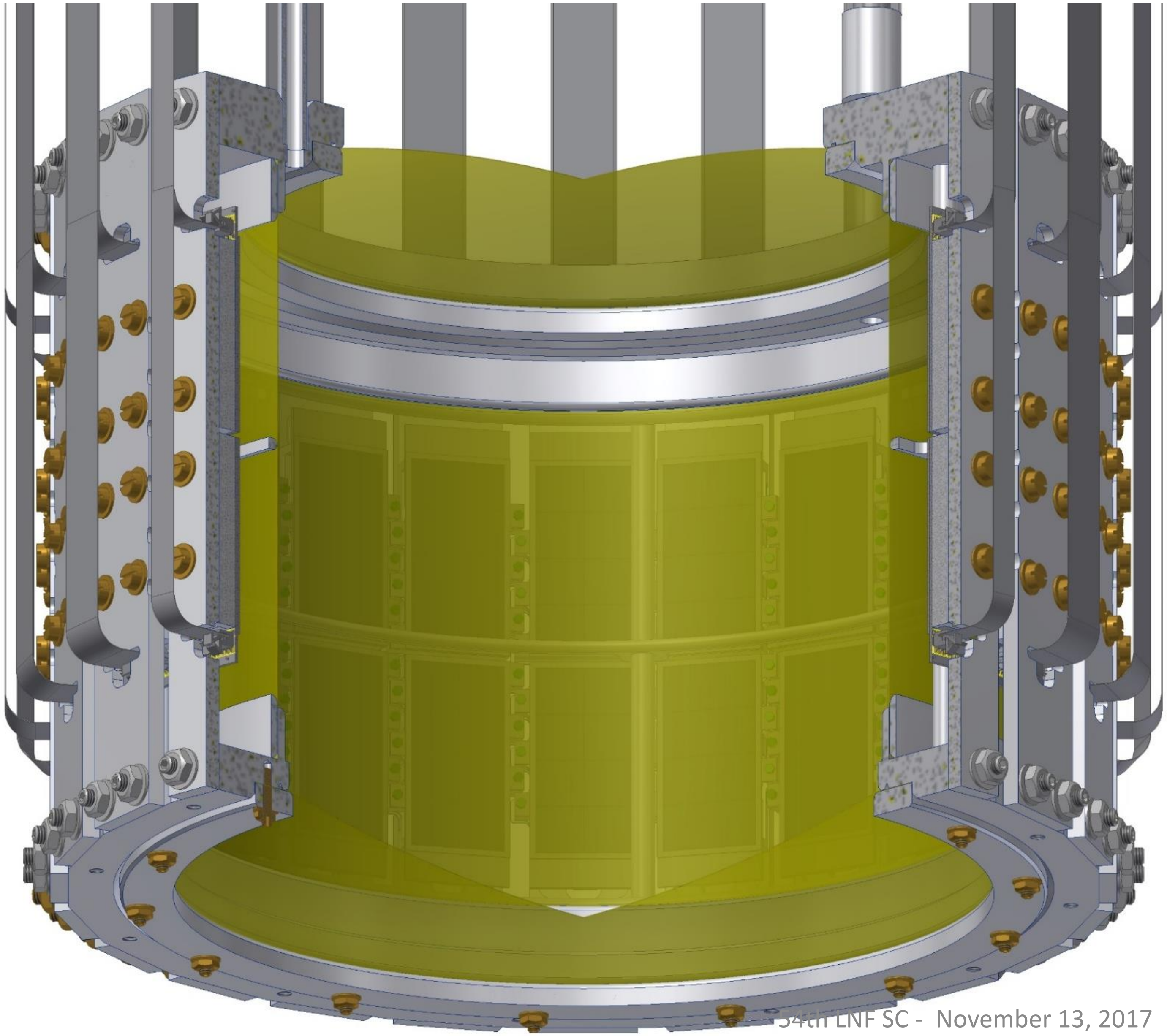


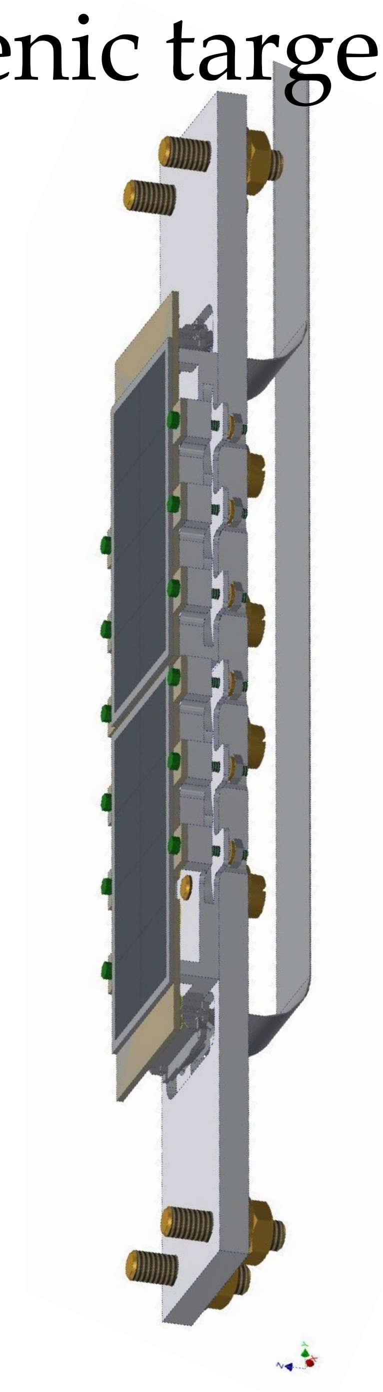
Shipping package

4x2 SDD array - single unit



4x2 SDD arrays around the cryogenic target

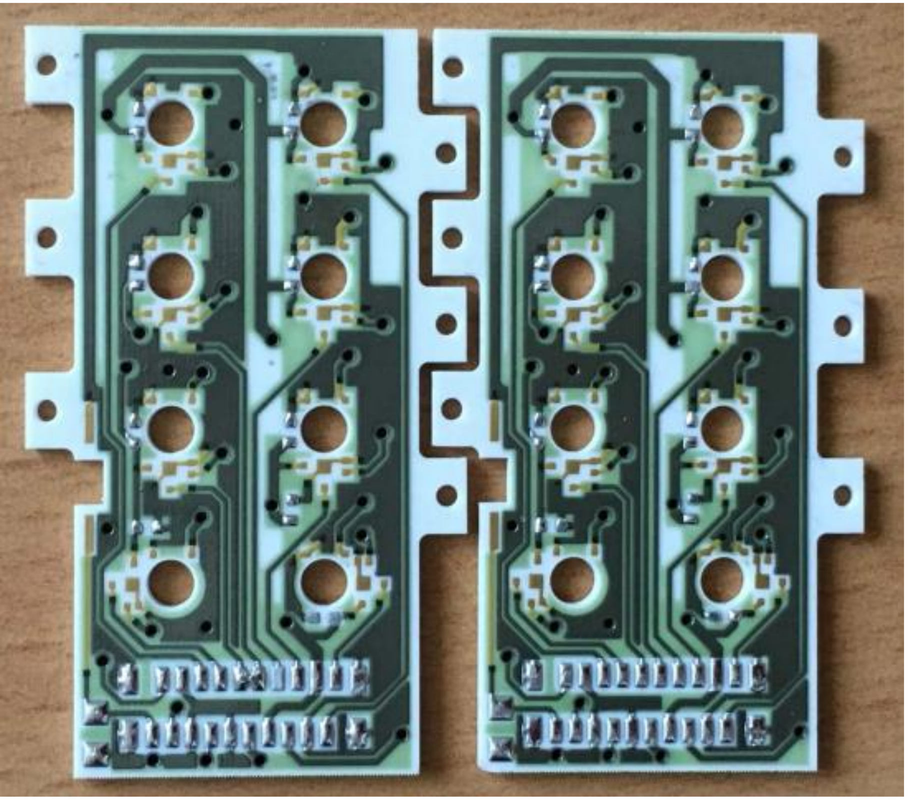




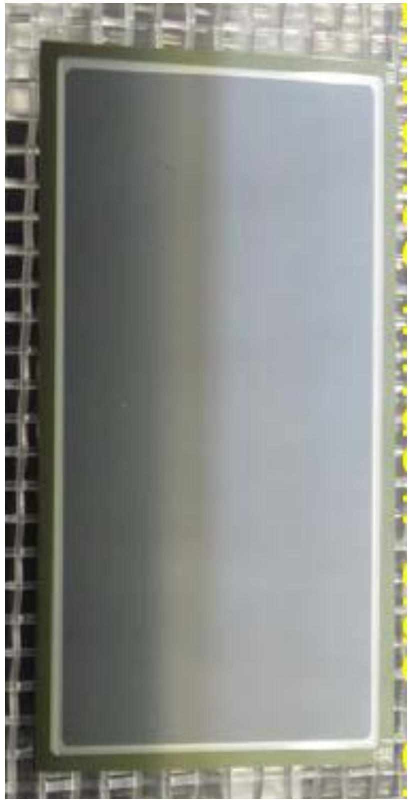
In total 48 SDDs will be used

SDD mounting / bonding

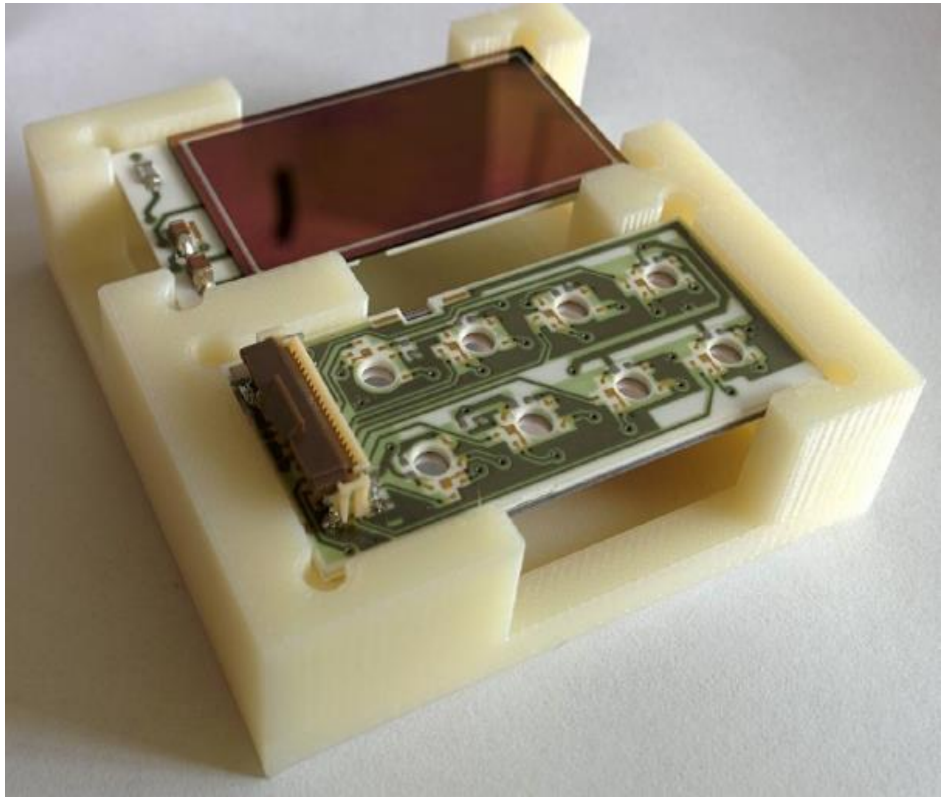
ceramic boards



4x2 SDD chip

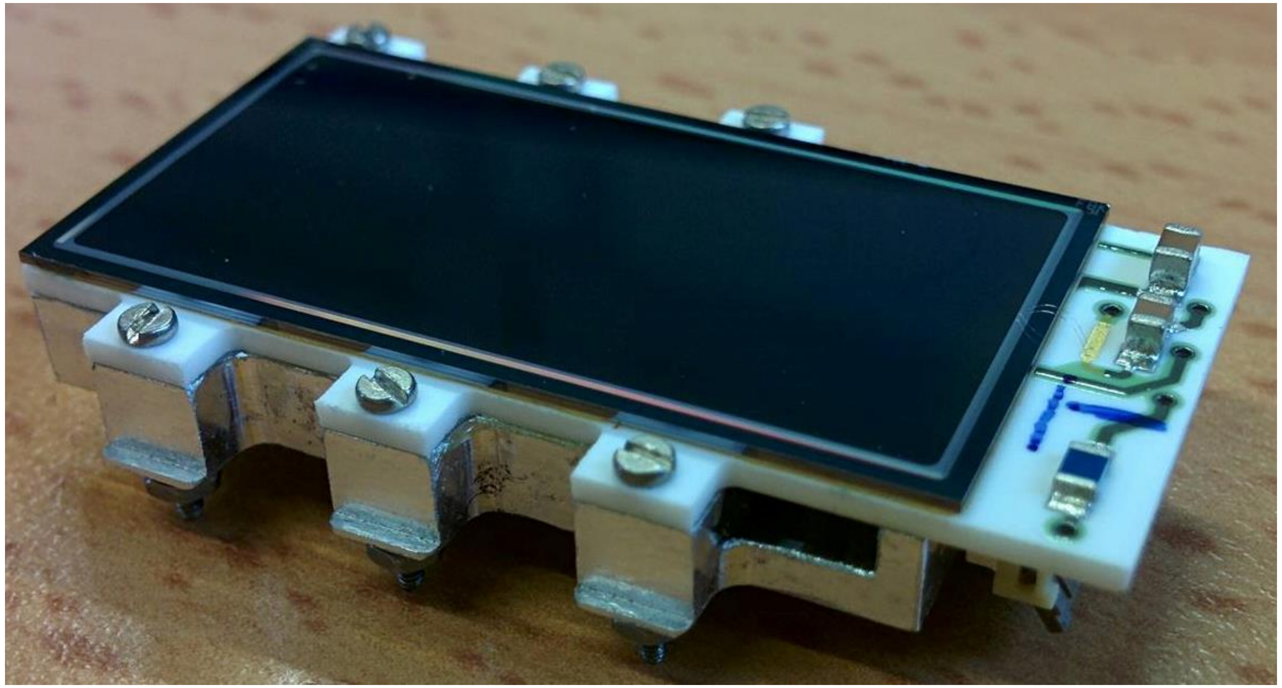


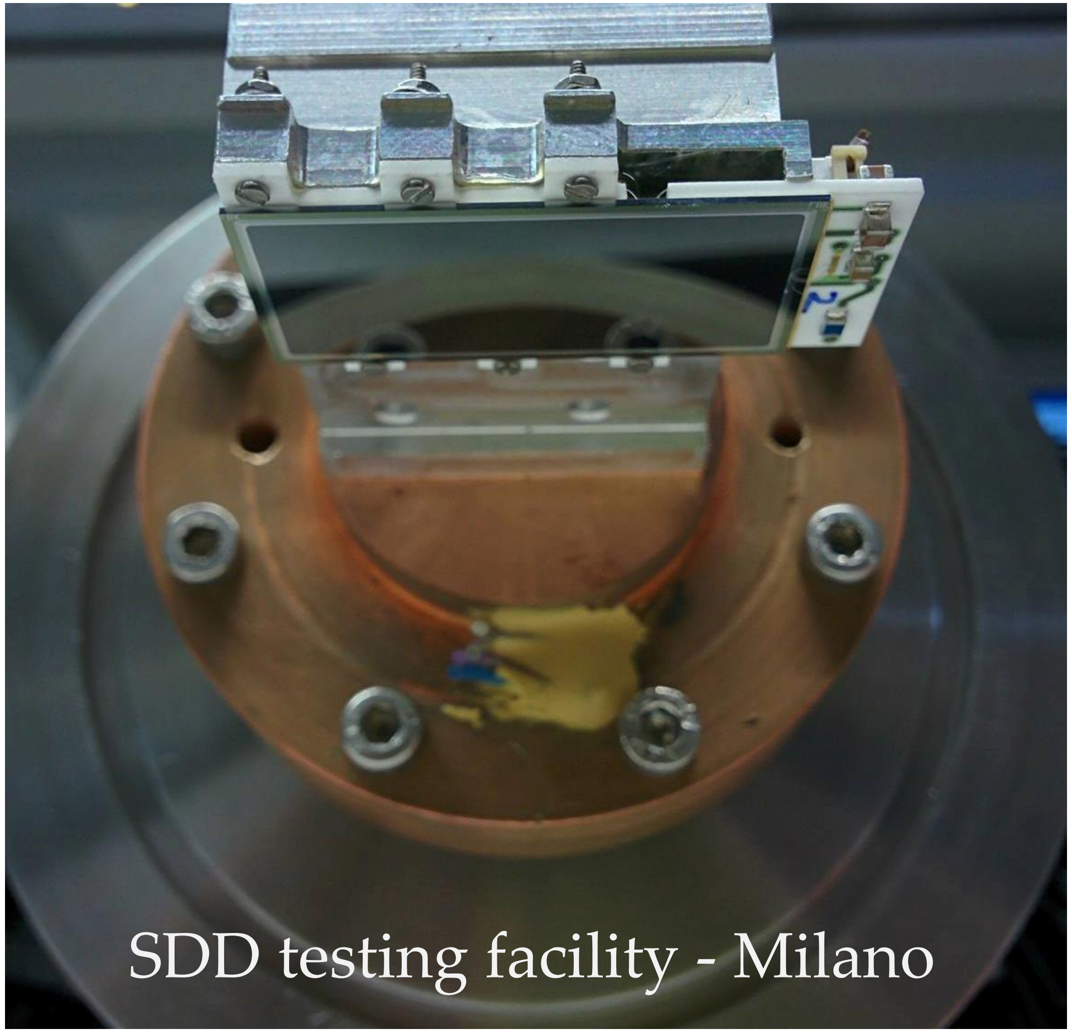
device for gluing and bonding



- mounting and bonding process under control

4 x 2 matrix SDD chip - testing

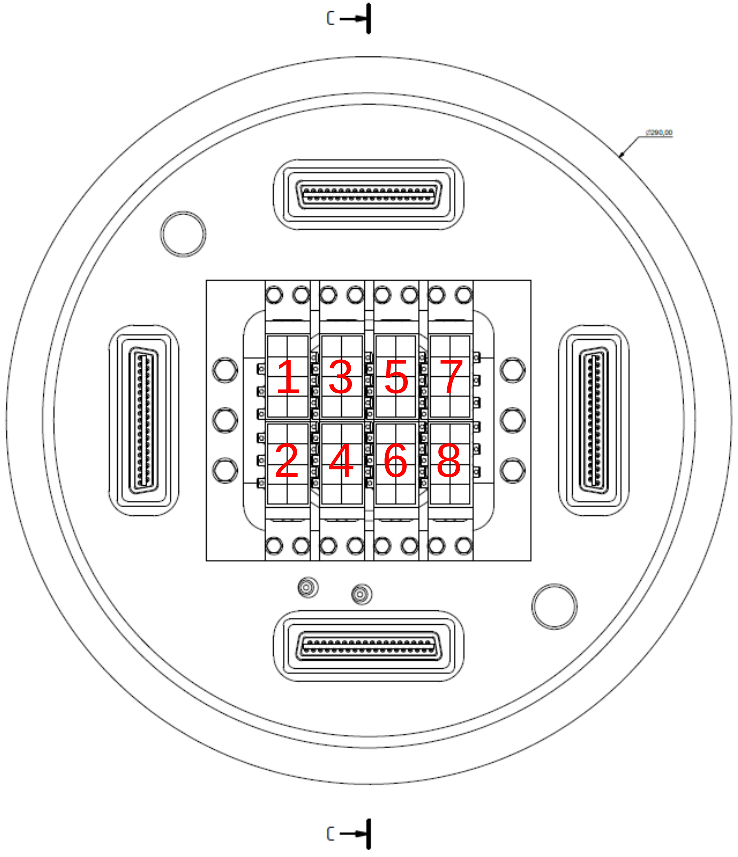


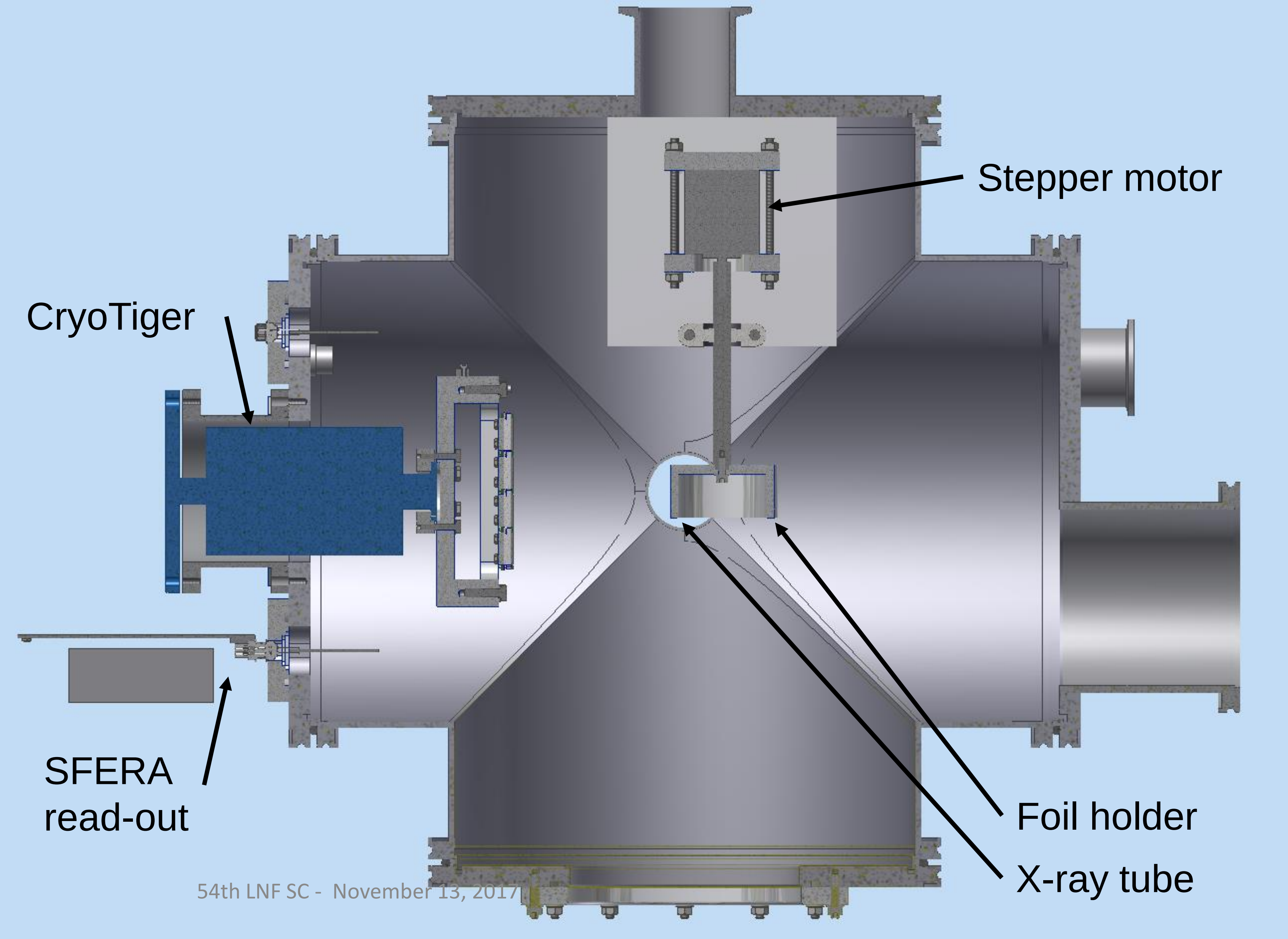


SDD testing facility - Milano

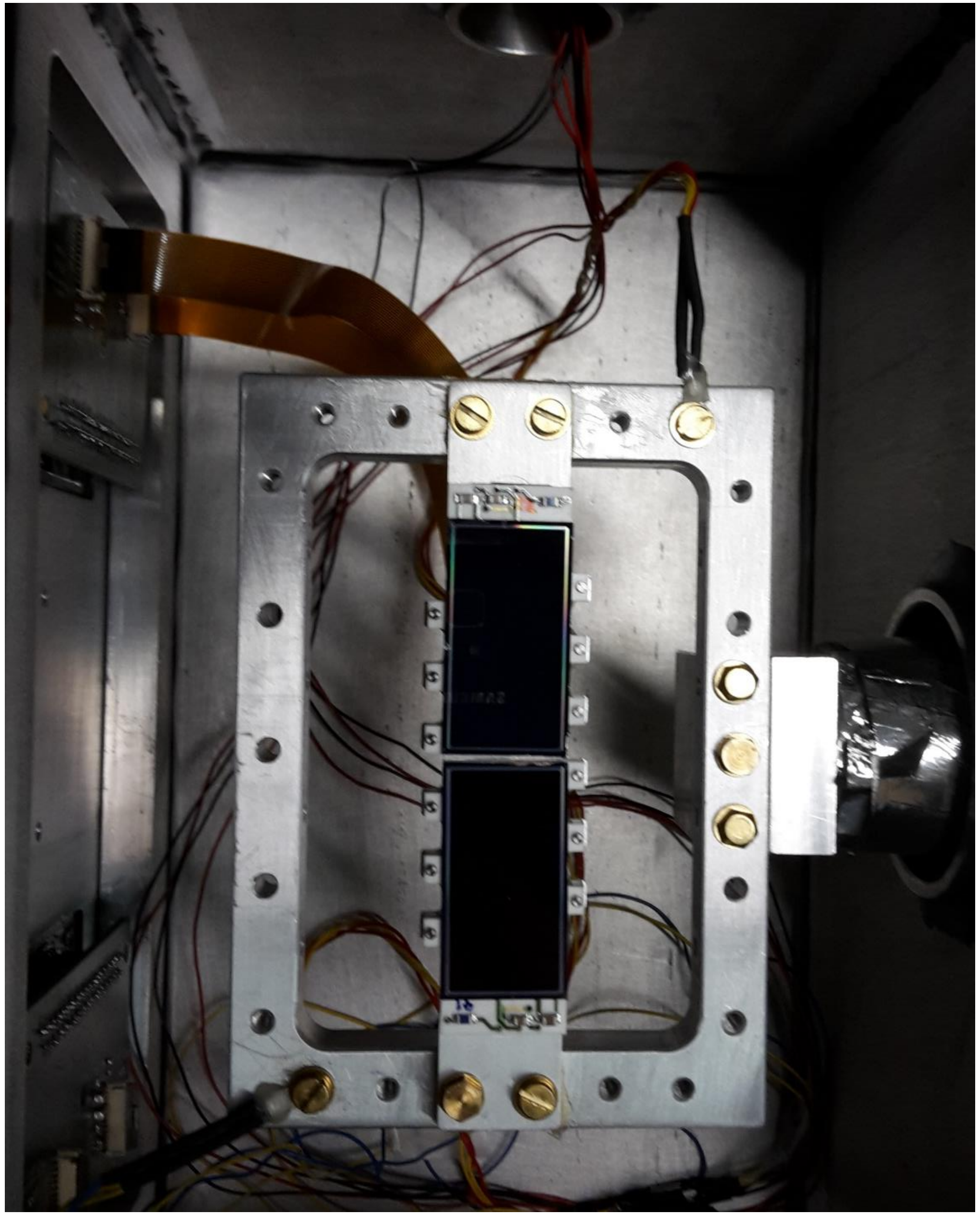
New SDD testing facility - LNF

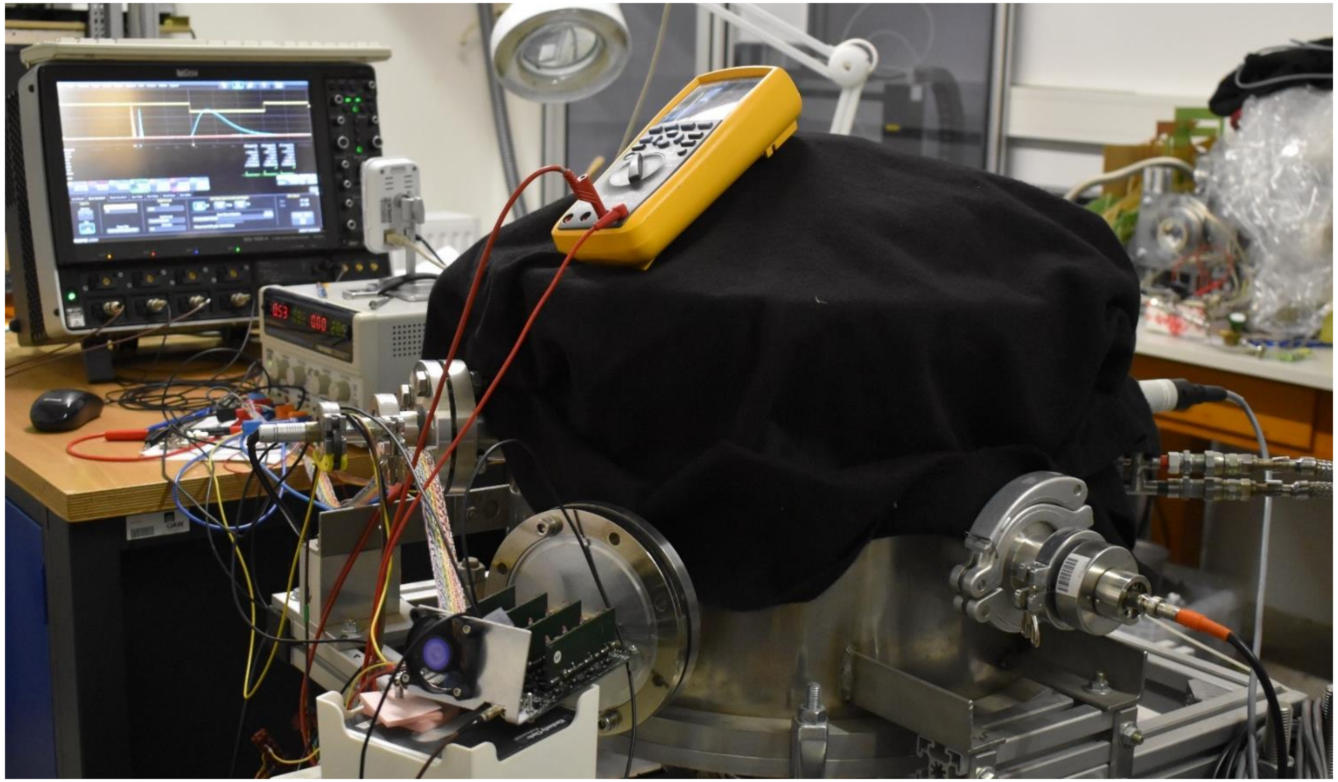
Mounting device for
8 SDD units



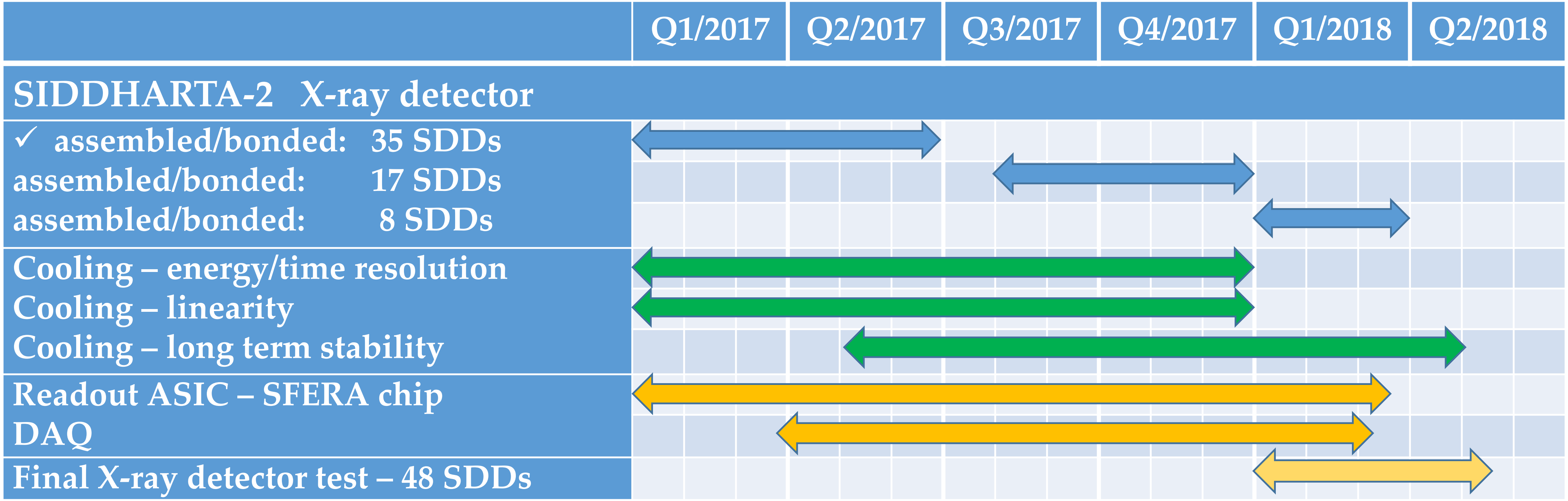


SDD testing facility - SMI





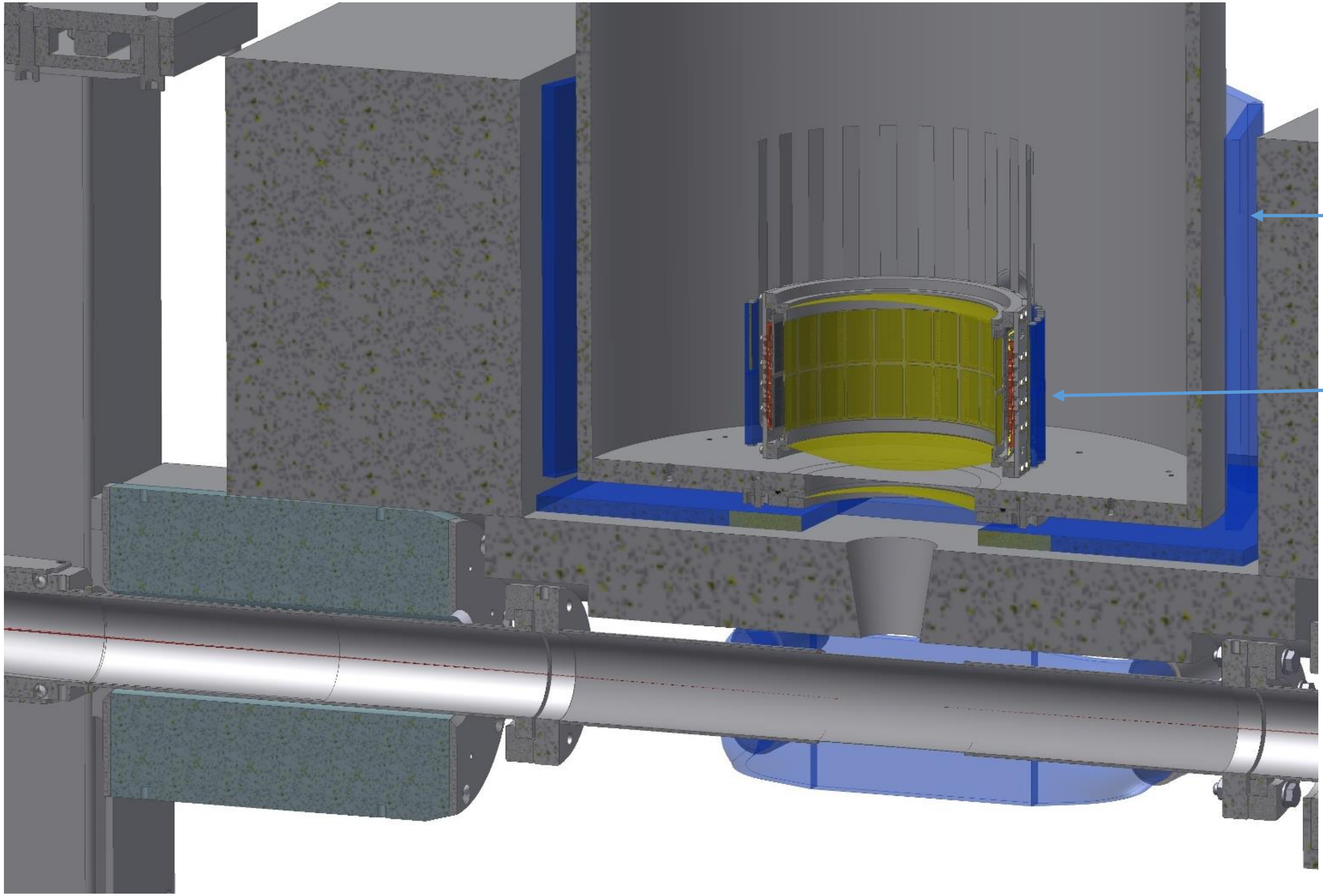
Gantt chart SIDDHARTA-2: X-ray detector



SIDDHARTA-2 setup

- the veto system

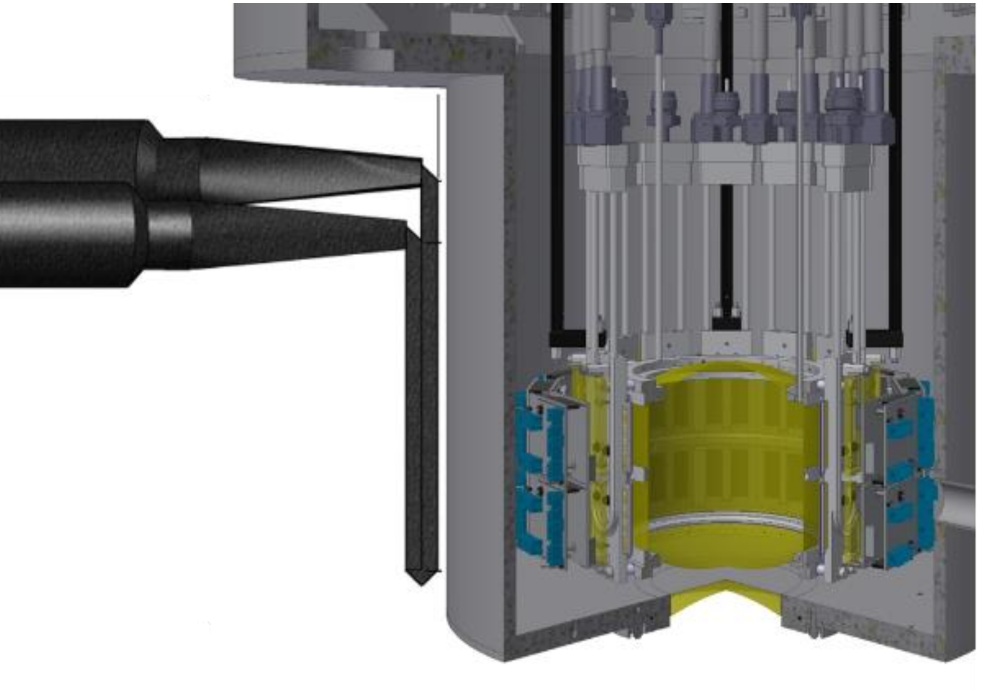
SIDDHARTA-2 setup: Veto-1 + Veto-2

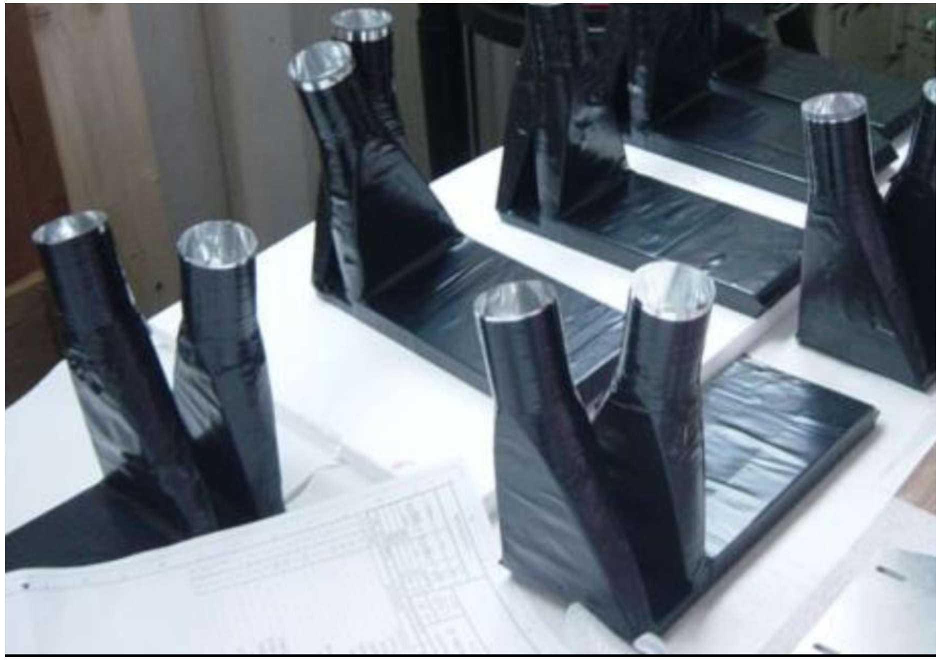


Veto-1

Veto-2

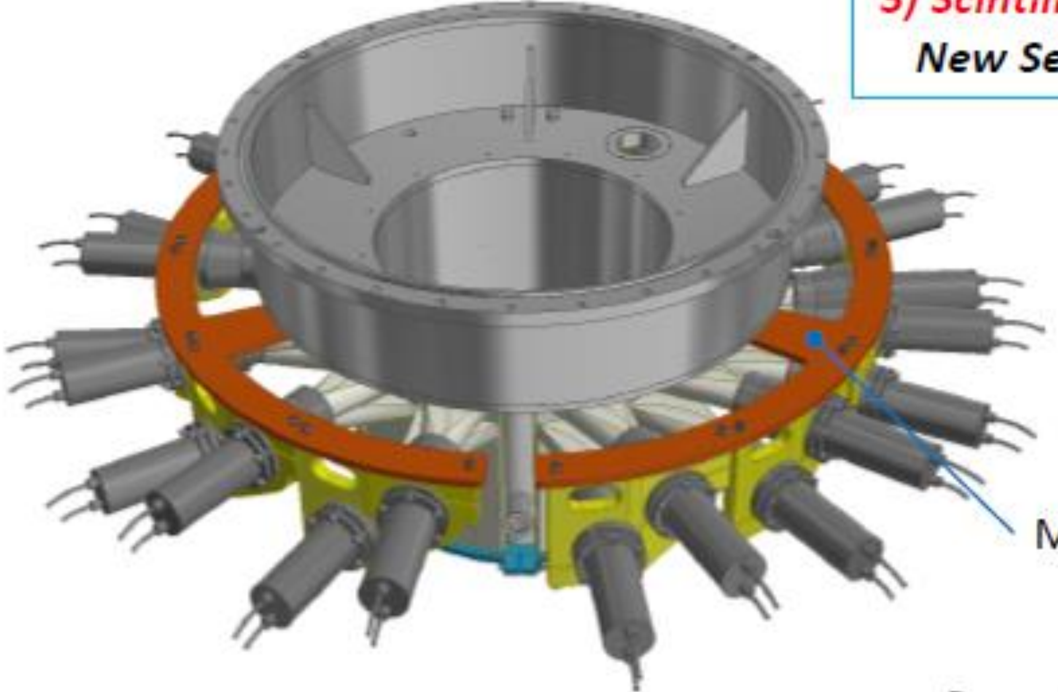
The veto-1 system

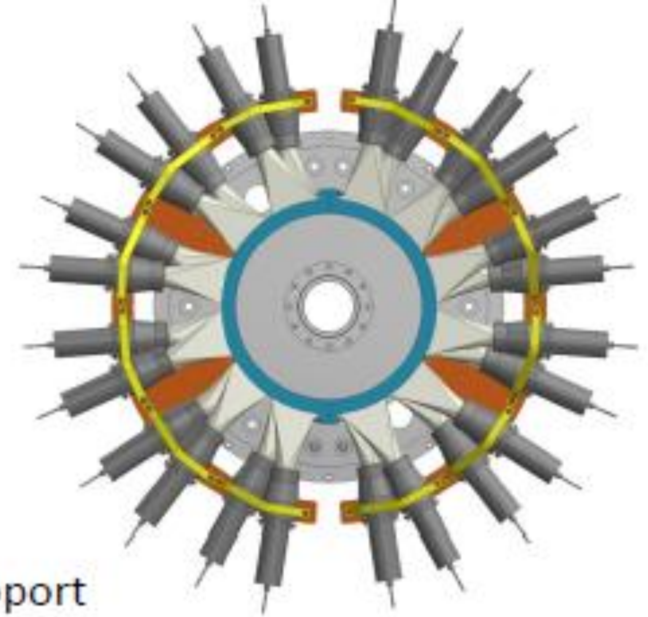




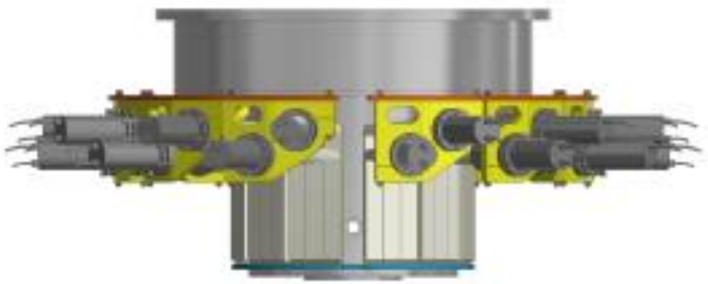
To achieve a good timing resolution, (independent of the "hit" position) < 600 ps (FWHM),the scintillator has to be read out on both side.
Because the available space is limited due to shielding material, the photomultiplier tubes have to be on the same side (a special light-guide mirror design was used).
PAPER

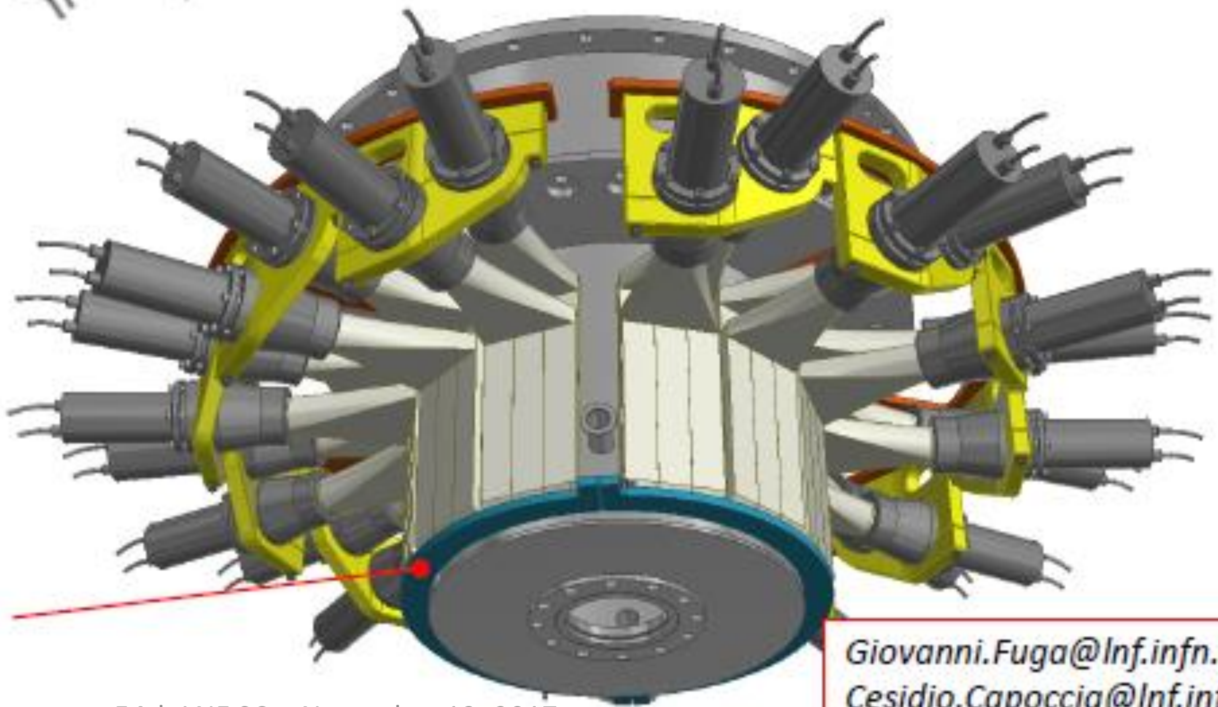
3) Scintillators
New Setup





- Under realisation





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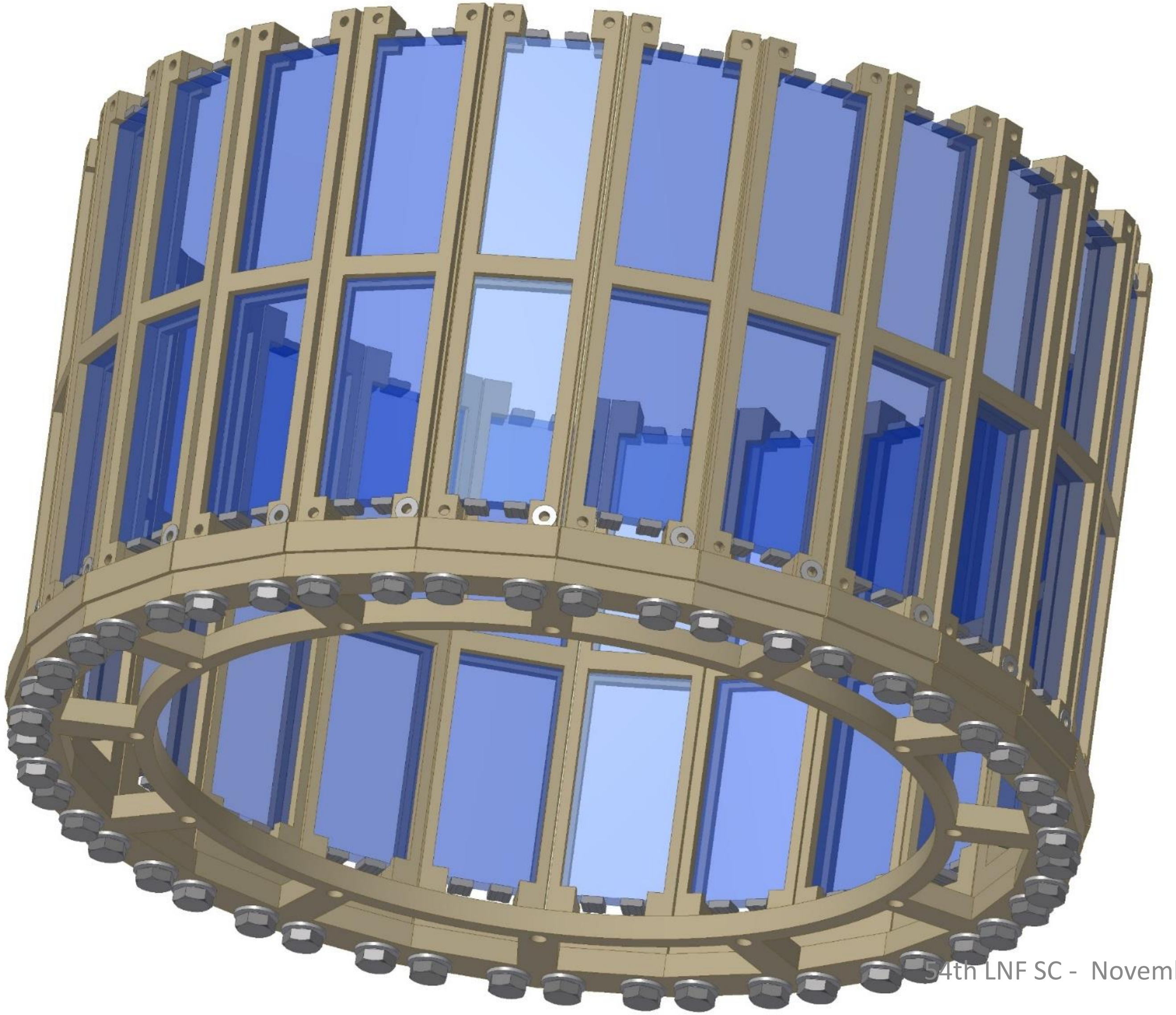
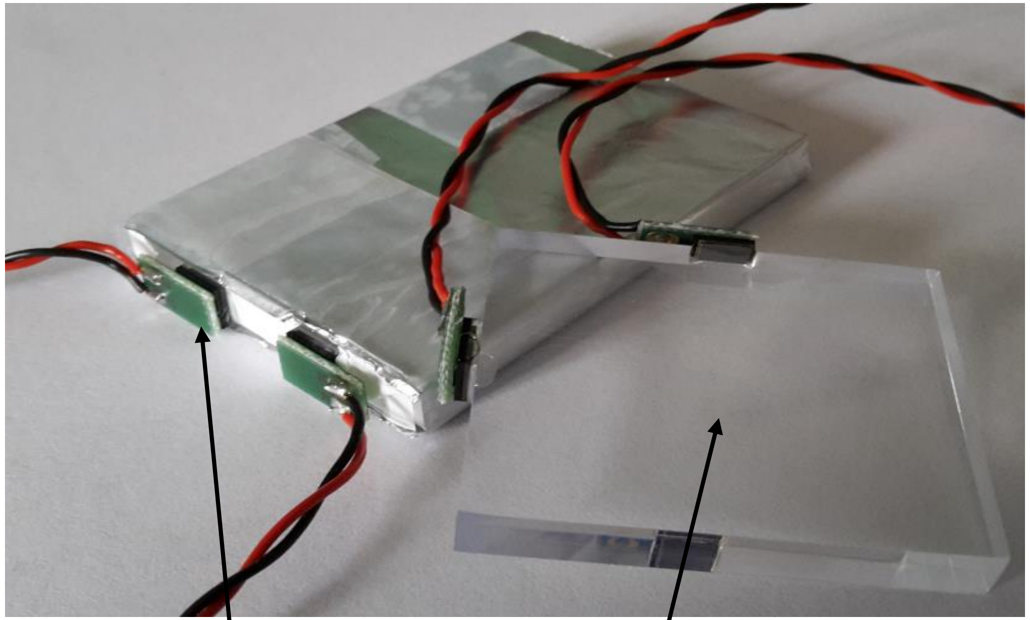
Cesidio.Capoccia@lnf.infn.it

The veto-2 system

Veto-2 arrangement



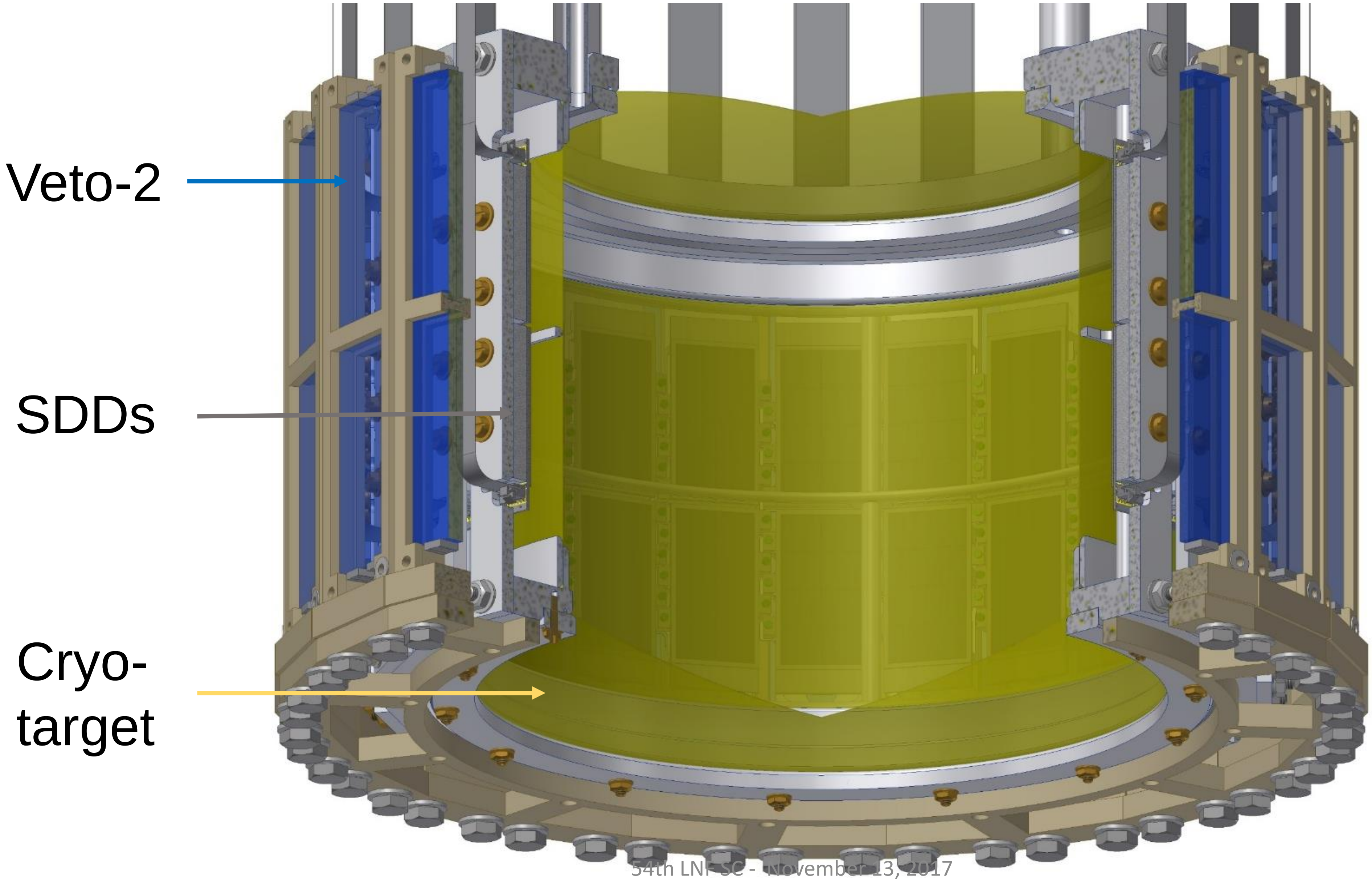


SiPM – 4x4
NUV-Trento

BC-408
scintillator tile

➢ Under realisation

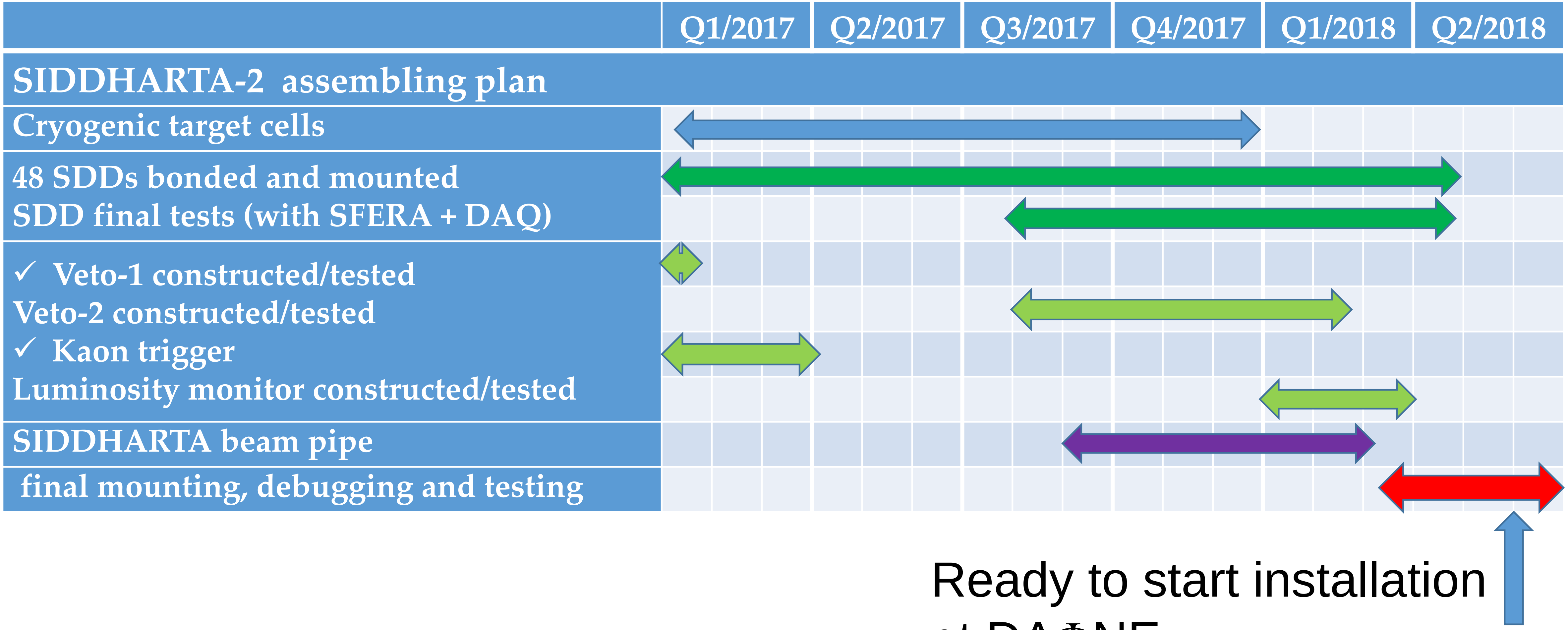
Cryogenic target – SDDs – veto-2 arrangement



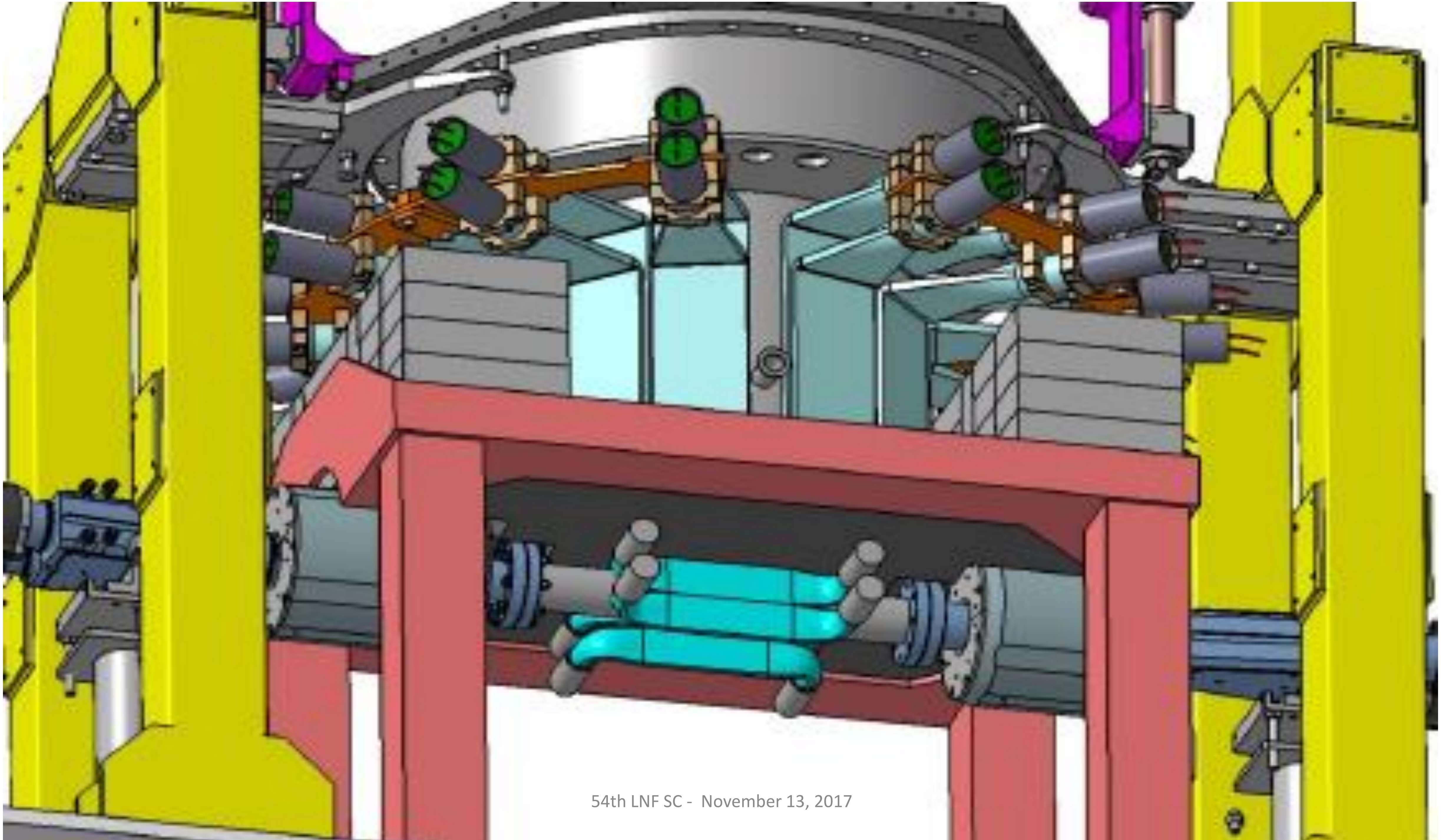
SIDDHARTA-2 setup

- Assembling plan
- Installation at DAΦNE

Gantt chart SIDDHARTA-2 setup



Ready to start installation
at DAΦNE



SIDDHARTA-2 plan for the K-d measurement

KLOE2: ends data taking 31 March 2018

- *DAFNE; new IR and new Quadrupoles; preparation within summer 2018 (new optics!)*

Installation on DAFNE starting summer 2018

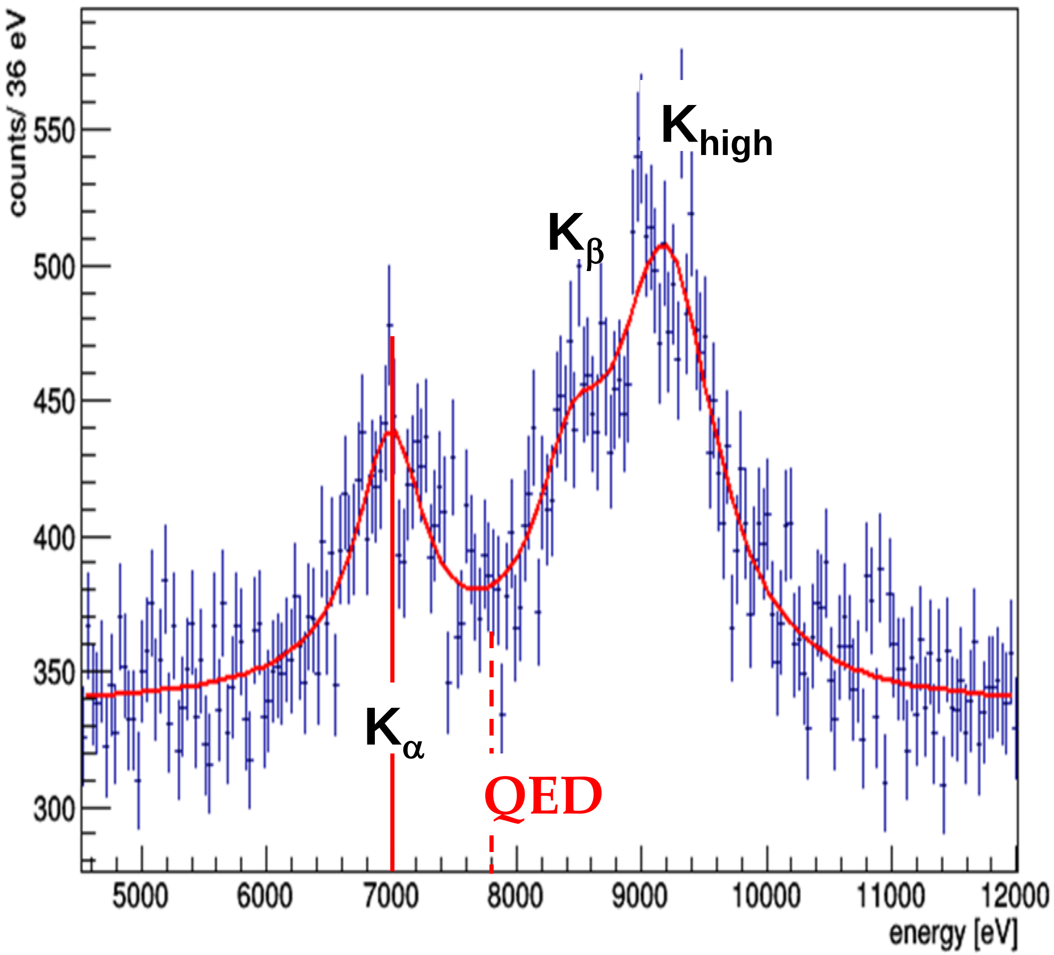
Technical run in 2018

Kaonic deuterium run in 2019:

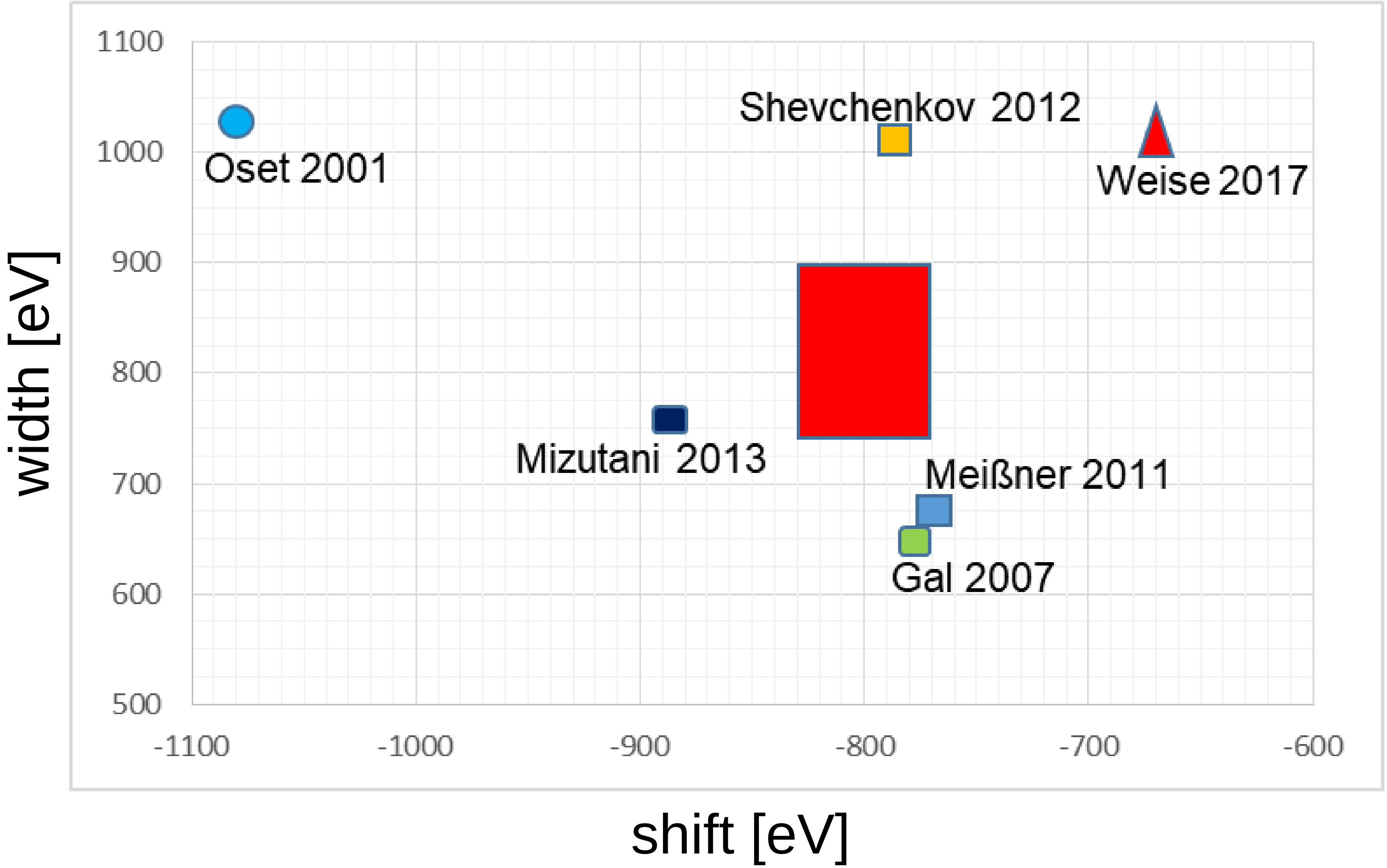
200 pb^{-1} to debug and optimize the apparatus

800 pb^{-1} to perform the first measurement of the strong interaction induced energy shift and width of the kaonic deuterium ground state (similar precision as $K^{-}p$) !

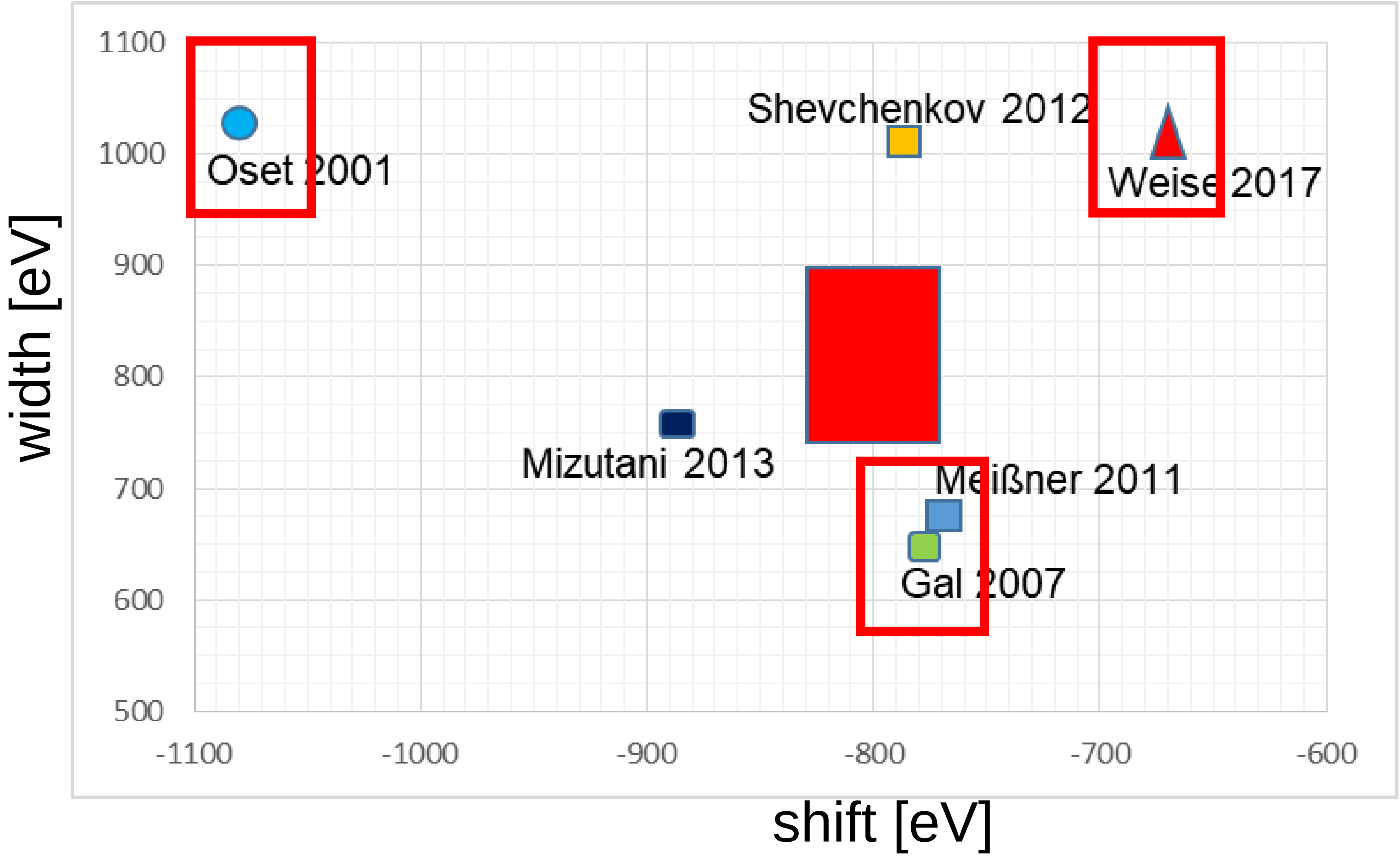
achievable precision:
shift: 30 eV
width: 75 eV



Theory – SIDDHARTA-2

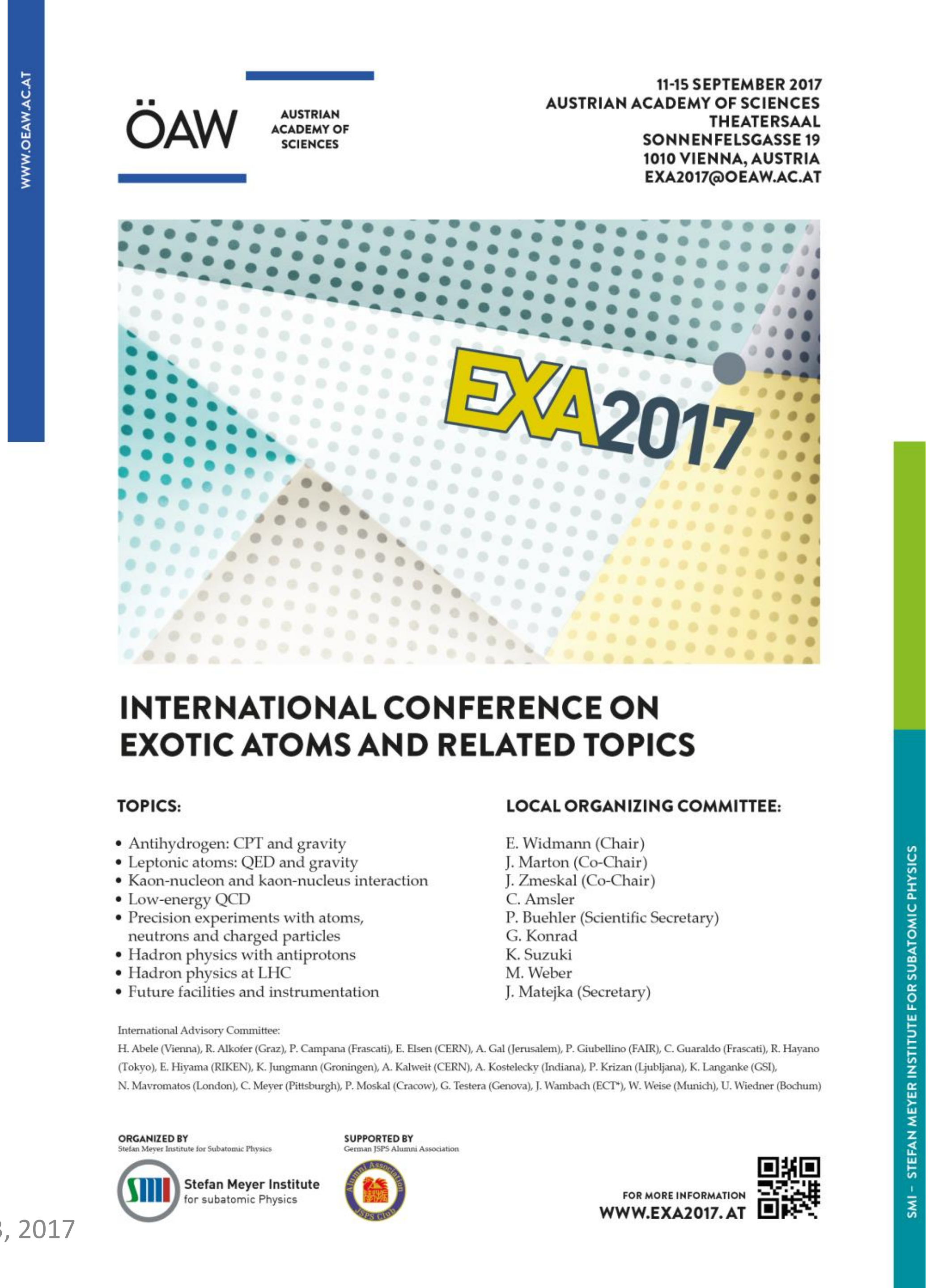


Theory – SIDDHARTA-2



11-15 SEPTEMBER 2017
AUSTRIAN ACADEMY OF SCIENCES
THEATERSAAL
SONNENFELSGASSE 19
1010 VIENNA, AUSTRIA
EXA2017@OEAW.AC.AT

~ 150 participants



Ministero degli Affari Esteri
e della Cooperazione Internazionale

Organizers:
Catalina Curceanu, LNF-INFN (Chair)
Kenta Itahashi, RIKEN (Japan)
Masahiko Iwasaki, RIKEN (Japan)
Fuminori Sakuma, RIKEN (Japan)
Alessandro Scordo, LNF-INFN (Italy)
Johann Zmeskal, SMI-Vienna (Austria)

Strange and non-strange mesons induced processes studies at DAFNE, J-PARC and RIKEN: present and future

Laboratori Nazionali di Frascati INFN
Room: Aula Touschek
Dates: 10 - 11 July 2017

ASTRA: Advances and open problems in low-energy nuclear and hadronic STRAngeness physics

Trento, October 23-27, 2017

Main Topics

Theoretical aspects on the low-energy strange nuclear and hadronic strangeness physics
Hypernuclear and hyperatom spectroscopy
Kaonic deuterium status and new ultra-high precision experiments
Kaons in strongly interacting systems
The Lambda(1405) structure: experimental and theoretical
Strangeness in neutron stars

Key participants

P. Achenbach (*Johannes Gutenberg-University, Germany*), M. Barabanov (*JINR, Russian Federation*), I. Bombaci (*Univ. and INFN Pisa, Italy*), A. Cieply (*Rez. Prague, Czech Republic*), B. Doenigus (*Johannes Gutenberg-University, Germany*), L. Fabbietti (*TUM, Muenchen, Germany*), E. Friedman (*The Hebrew Univ. Jerusalem, Israel*), A. Gal (*The Hebrew Univ. Jerusalem, Israel*), C. Guaraldo (*LNF-INFN, Italy*), H. Lenske (*JLU Giessen, Germany*), J. Mares (*Rez. Prague, Czech Republic*), K. Nakazawa (*Gifu University, Japan*), S.N. Nakamura (*Tohoku University, Japan*), F. Pederiva (*University of Trento, Italy*), K. Piscicchia (*LNF-INFN Frascati, Italy*), H.-J. Schulze (*INFN, Italy*), L. Tang (*Hampton University, USA*), W. Weise (*TUM, Muenchen, Germany*), J. Zmeskal (*SMI-Vienna, Austria*)

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Isaac Vidaña - INFN Catania (Italy)

Director of the ECT*: Professor Jochen Wambach (ECT*)

The ECT* is sponsored by the "Fondazione Bruno Kessler" in collaboration with the "Assessorato alla Cultura" (Provincia Autonoma di Trento), funding agencies of EU Member and Associated States and has the support of the Department of Physics of the University of Trento.

Future programme and perspectives

- **Kaon mass - precision measurement at a level < 7 keV**
- **Kaonic helium transitions to the 1s level**

- **Other light kaonic atoms (K^-O, K^-C,…)**
- **Heavier kaonic atoms (K^-Si, K^-Pb…)**

  - **Radiative kaon capture – Λ(1405) study**
  - **Investigate the possibility of the measurement of other types of hadronic exotic atoms (sigmonic hydrogen ?)**

Special thanks to the accelerator division,
to the DAΦNE and to the BTF staffs,
to the LNF Director and to the responsible
of the LNF Research Division
and to the KLOE-2 collaboration

The EPS Emmy Noether Distinction for Women in Physics 2017 (Spring/Summer) was given to ***Dr. Catalina Curceanu***

for *her substantial contributions to a better understanding of low-energy QCD in the non-perturbative regime, and for her pioneering research in foundational issues. With her strong scientific record, and a rich scope of successful outreach and education activities, Dr. Curceanu is an outstanding role model for women researchers.*

Thank you !