ÖAW AUSTRIAN ACADEMY OF SCIENCES

SMI – STEFAN MEYER INSTITUTE

SIDDHARTA - 2
STATUS REPORT

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for the SIDDHARTA-2 Collaboration

53nd LNF-INFN SCIENTIFIC COMMITTEE
May 9, 2017

WWW.OEAW.AC.AT/SMI

SIDDHARTA-2 Collaboration

SIlicon Drift Detector for Hadronic Atom Research by Timing Applications

HadronPhysics2
Study of Strongly Interacting Matter

HadronPhysics I3
Study of Strongly Interacting Matter

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
CNRS, Paris, France
Indian Inst. of Science, Bangalore, India

FWF Der Wissenschaftsfonds.

Ministero degli Affari Esteri e della Cooperazione Internazionale

StrangeMatter

CONTENT

Scientific Motivation

SIDDHARTA-2 apparatus – status with time lines

- Mounting frame
- Beam pipe
- Luminosity monitor
- Kaon trigger
- Cooling system
- Vacuum chamber
- Cryogenic target
- SDD X-ray detector
- Veto system

Overall time schedule

The scientific goal of SIDDHARTA-2

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

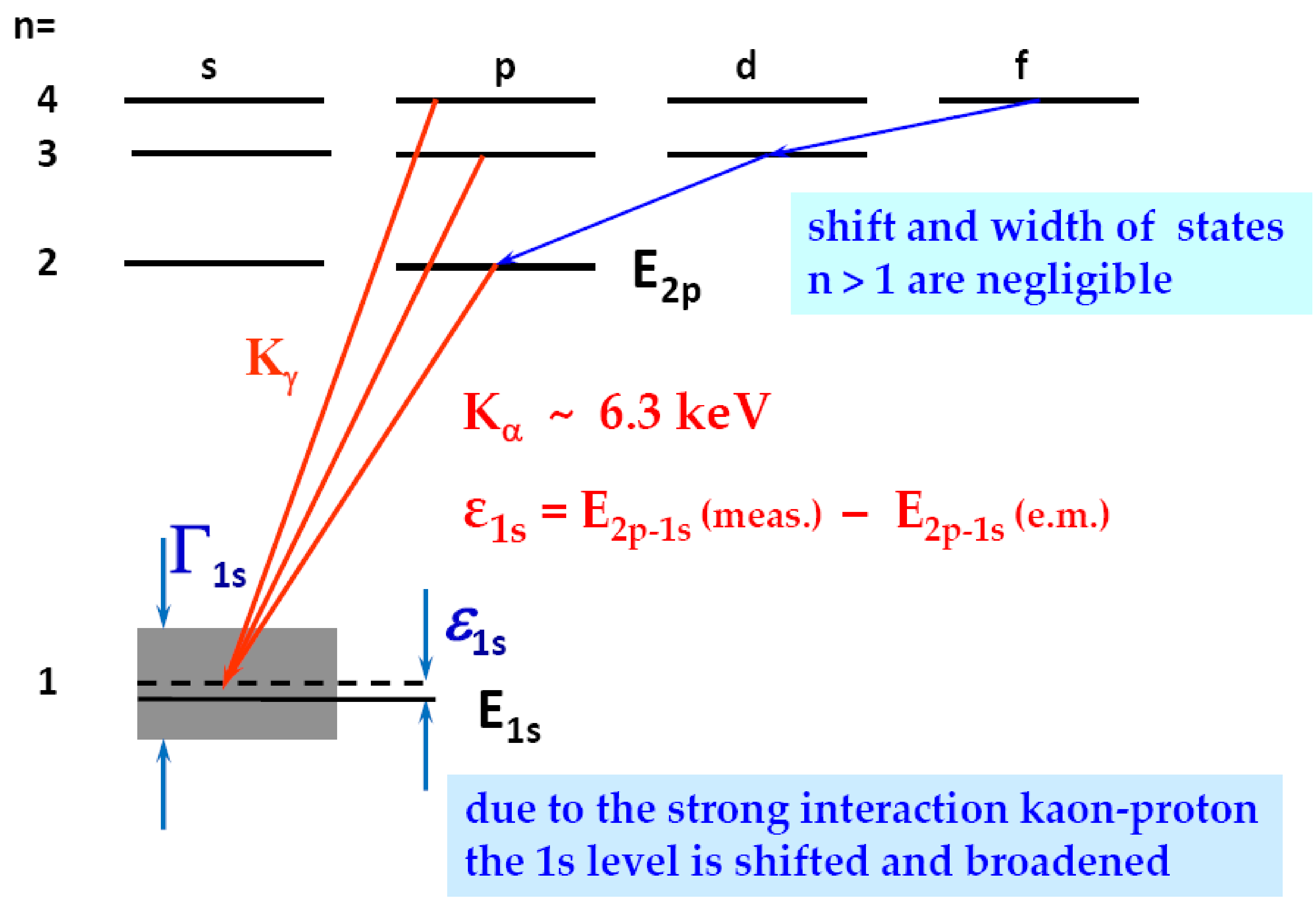
Starting with the precision measurement ***of shift*** and ***width***

- **first measurement of kaonic deuterium**

to extract the antikaon-nucleon isospin dependent scattering lengths

- chiral symmetry breaking, EOS for neutron stars

X-RAY TRANSITIONS TO THE 1s STATE

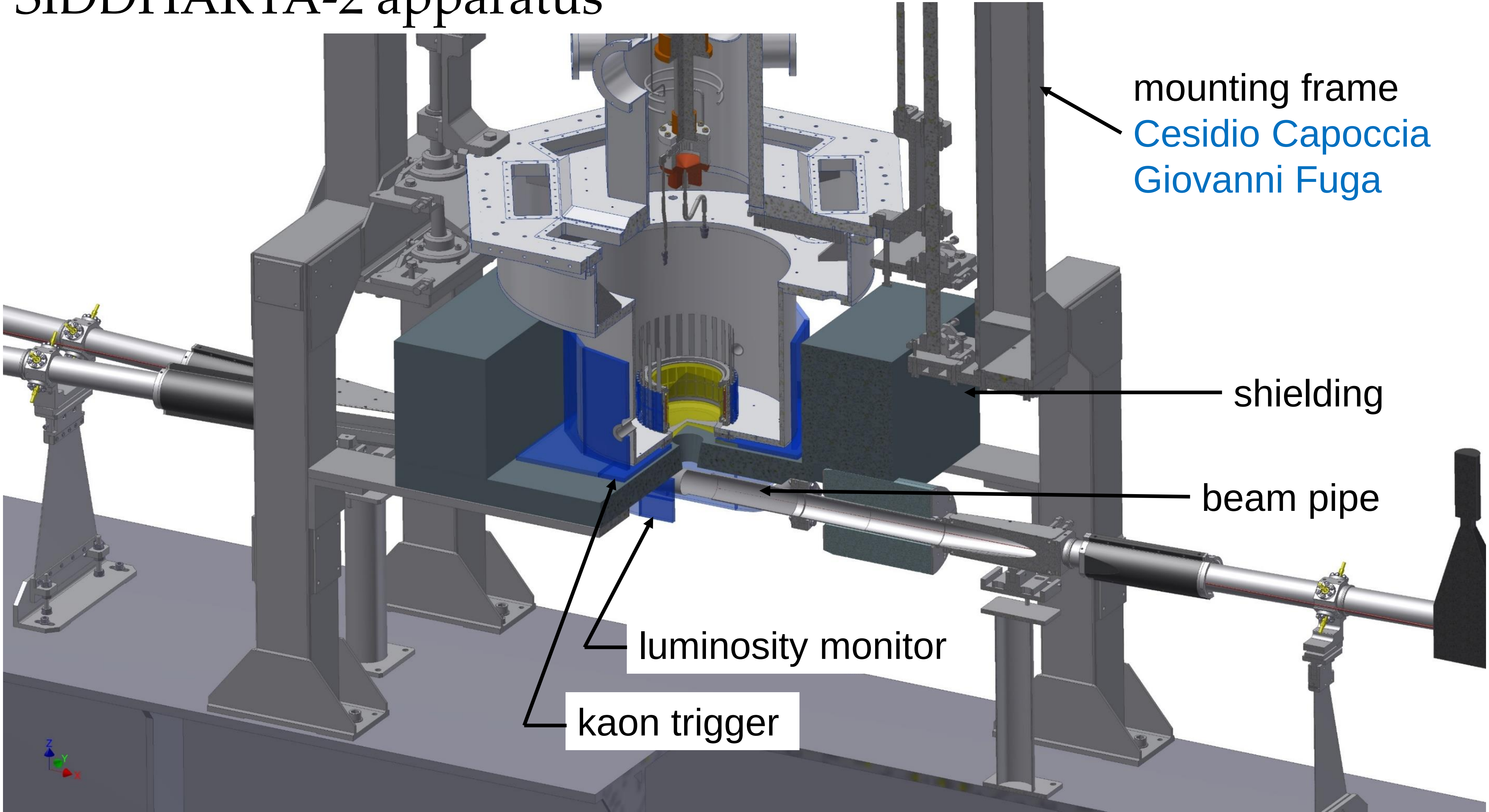


SIDDHARTA-2 setup

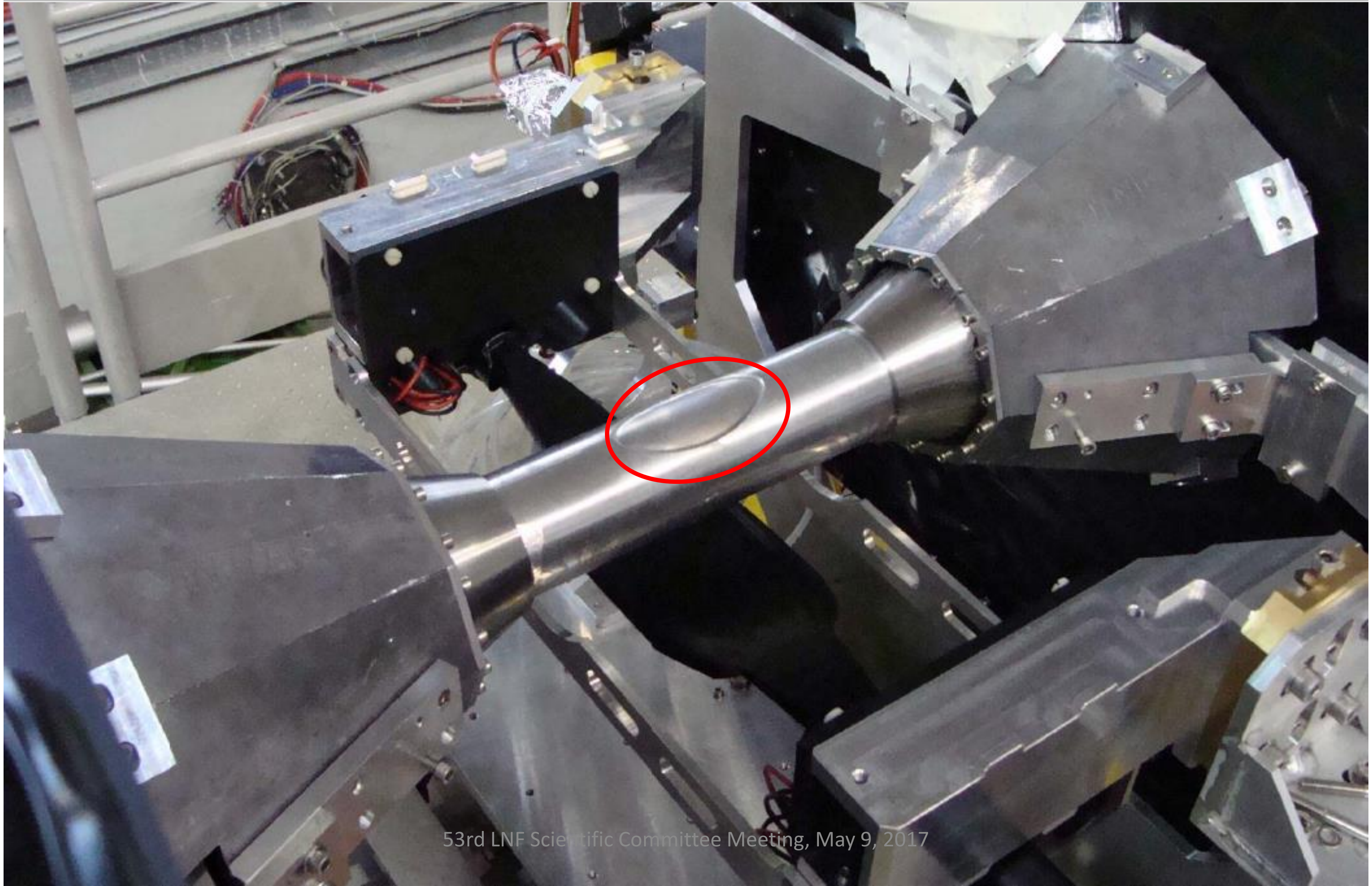
- Mounting frame
- Beam pipe
- Luminosity monitor
- Kaon trigger

- Platform

SIDDHARTA-2 apparatus



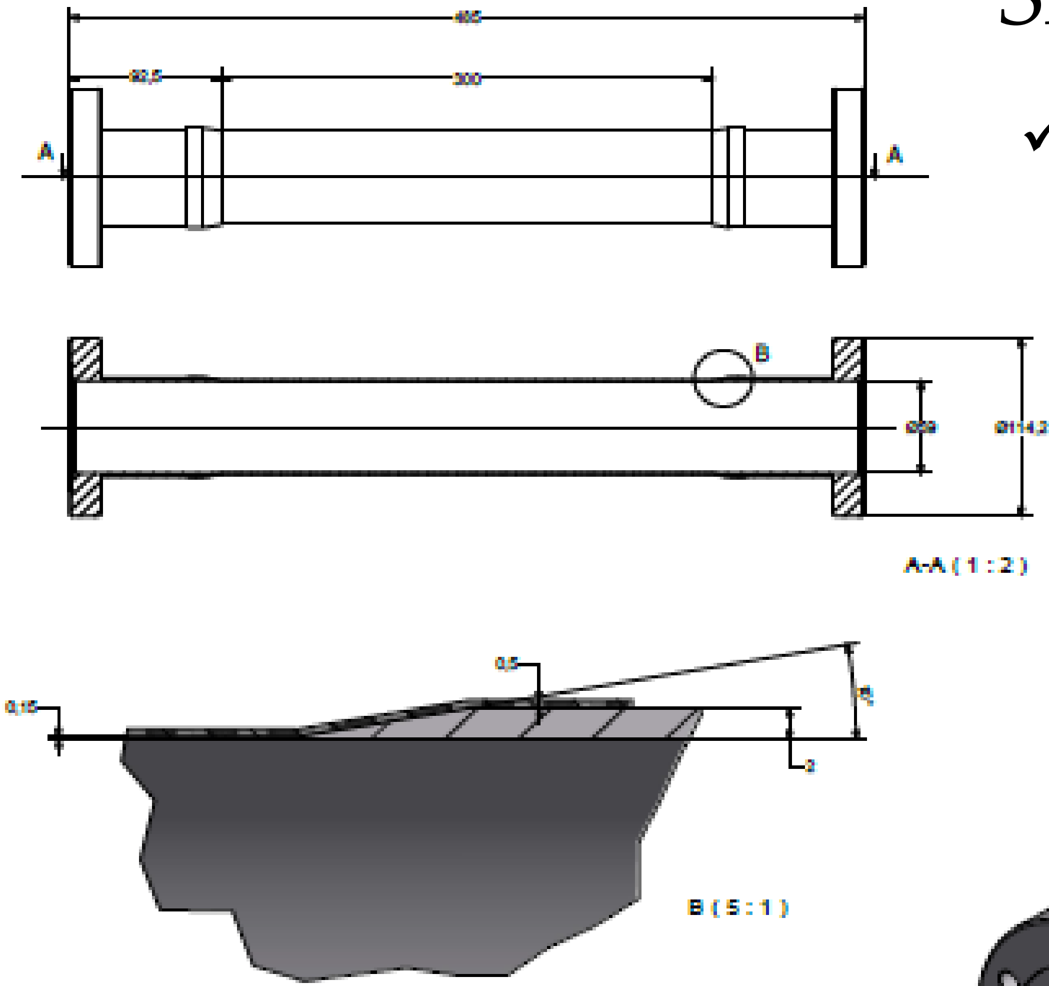
SIDDHARTA – beam pipe

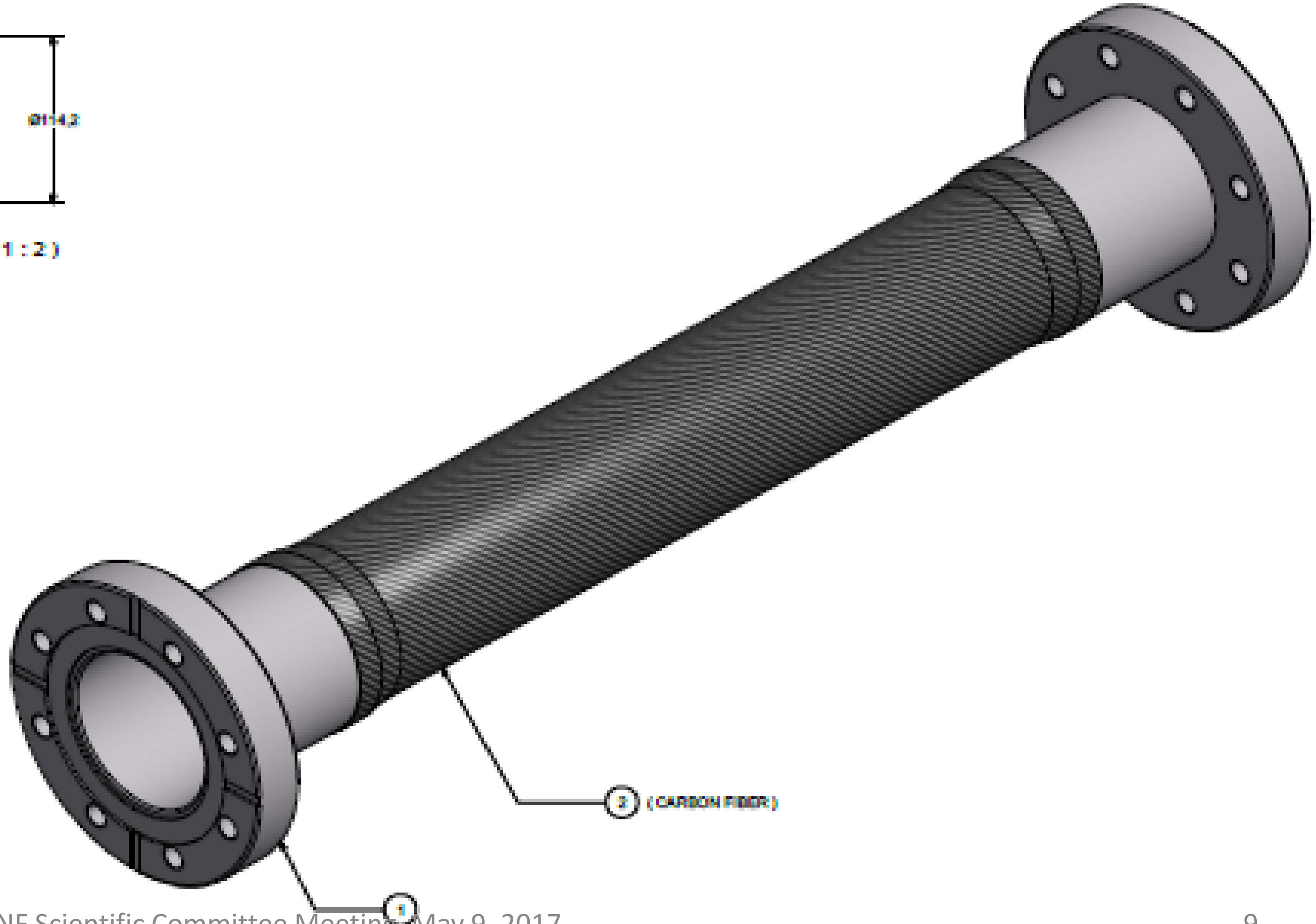


SIDDHARTA-2 beam pipe

✓ design / quotation

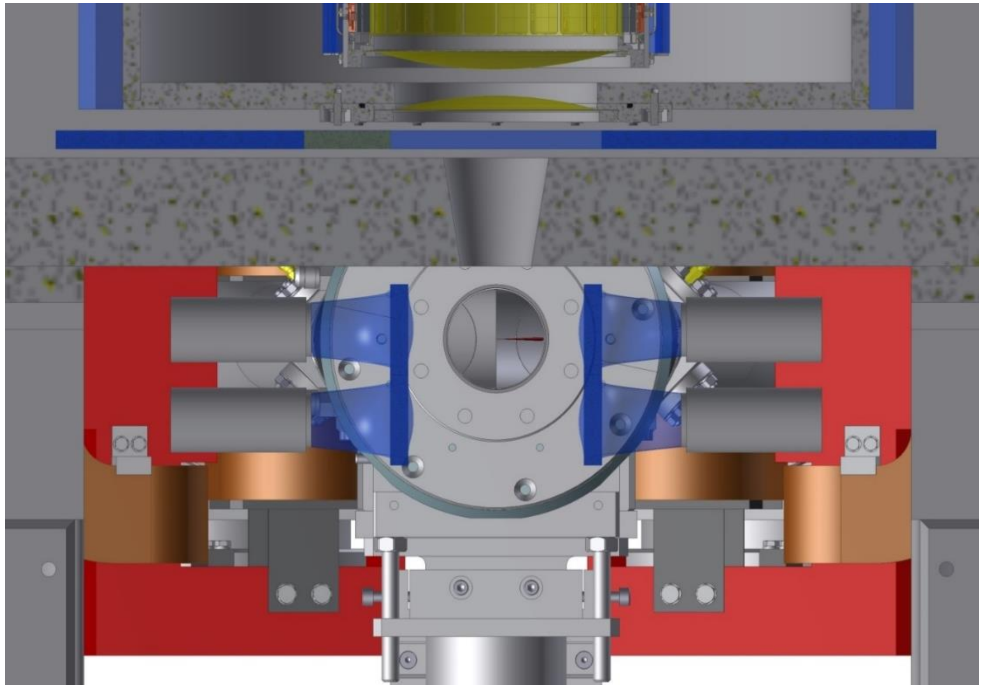
➢ final diameter to be decided





SIDDHARTA-2 - Luminosity monitor (based on kaons)

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



- prototype under construction, BTF timing test summer 2017

➢ **Coincidence rate:**

25.7 % per charged kaon pair
single rate at the boost side: 42.7 %
single rate at the anti-boost side: 32.3 %

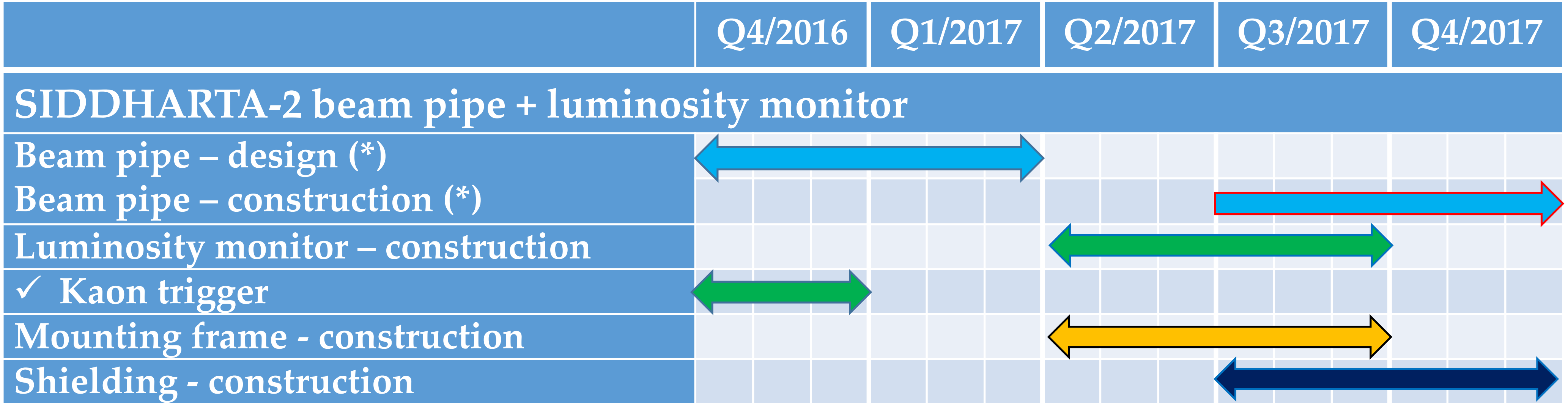
With a luminosity *L* = 10^{32}

→ 37 Hz (coincidence) / 62 Hz (on boost-side)

in 5 seconds:

185 counts (7%) / 310 counts (5.7%)

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



(*) Beam pipe – final diameter has to be fixed, depending on the final IR for SIDDHARTA-2

SIDDHARTA-2 setup

- Cooling systems
- Vacuum chamber + feedthroughs
- Cryogenic target

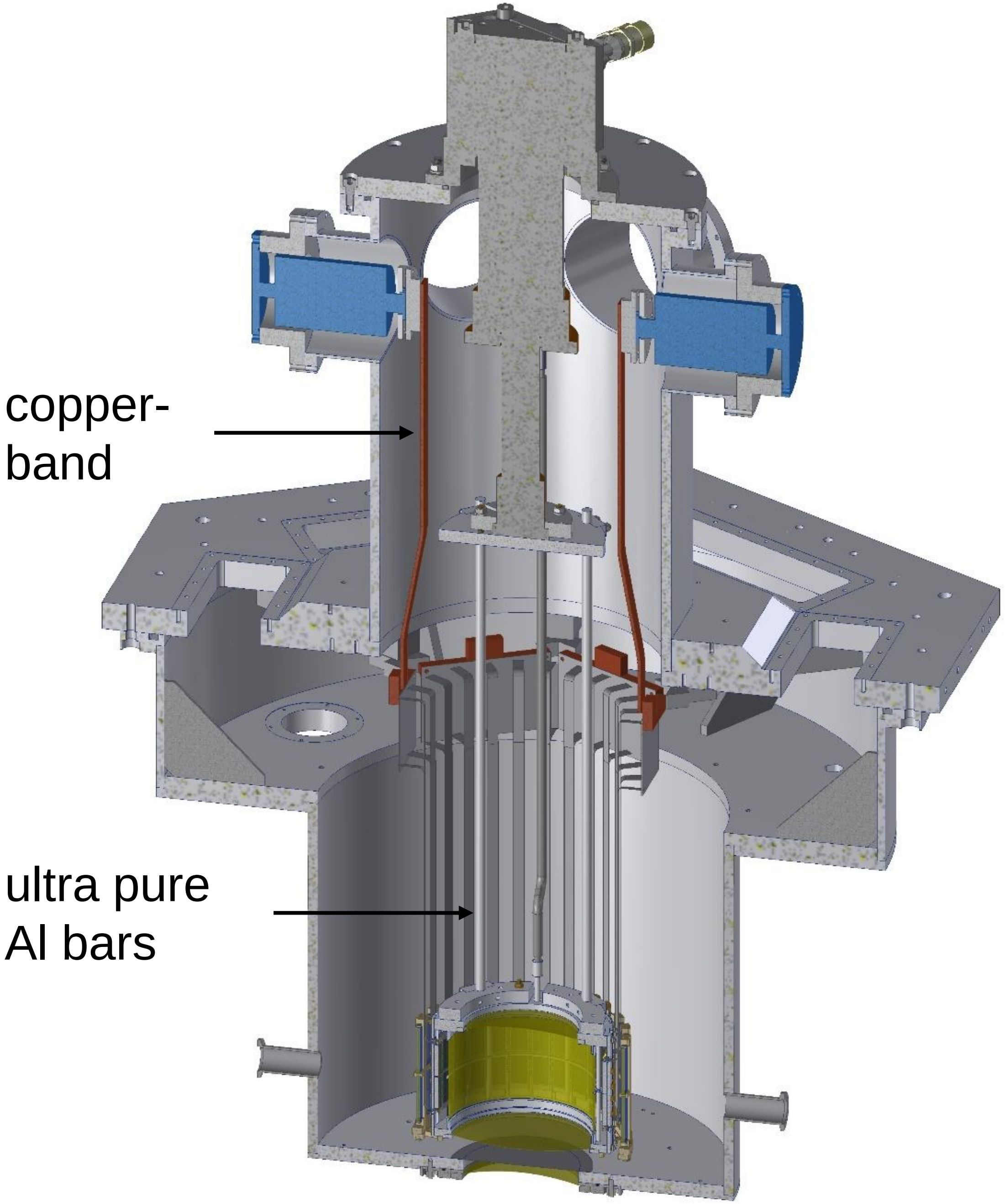
SIDDHARTA-2 cooling

✓ Target + SDD cooling:

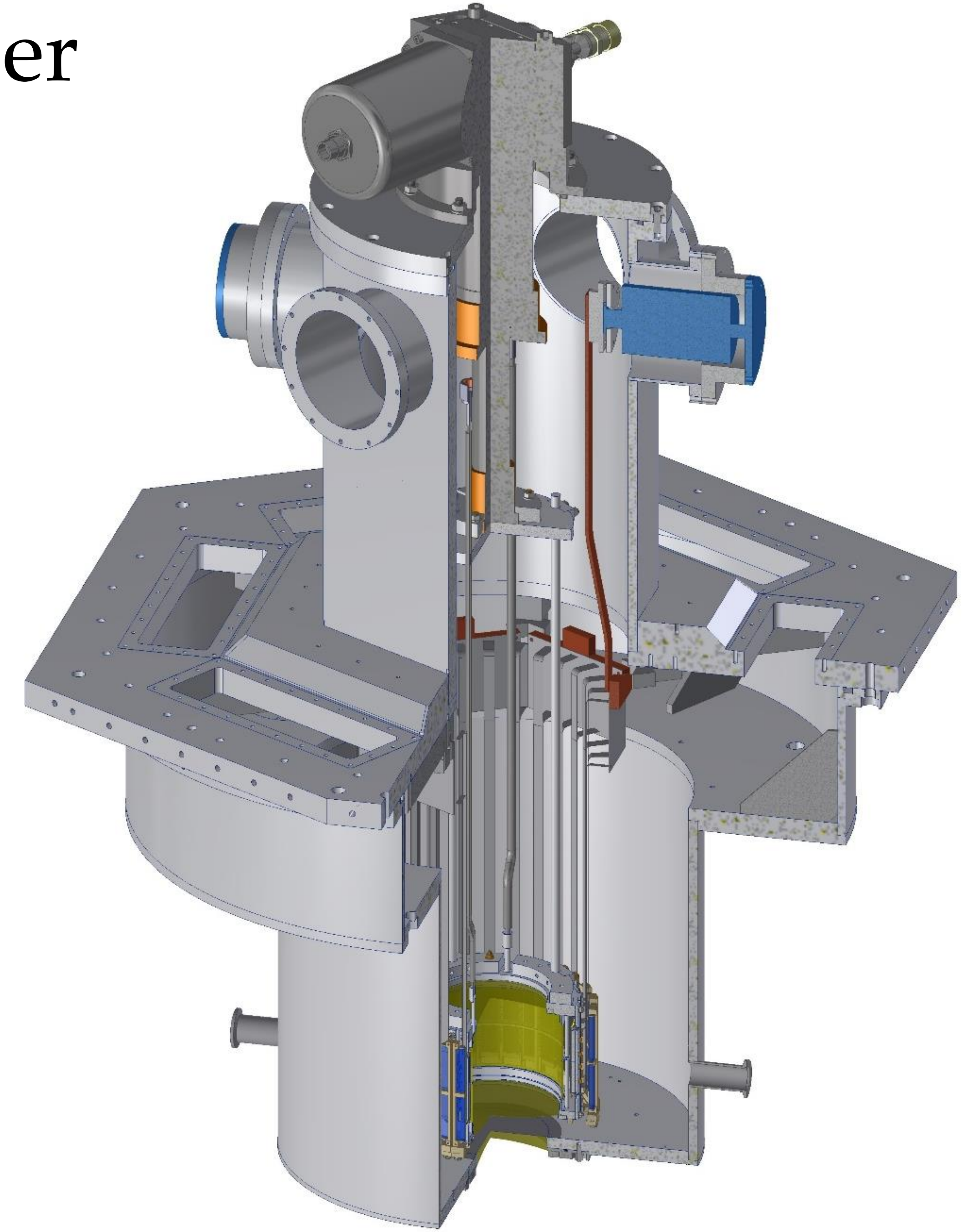
1 Leybold MD10 – 16 W @ 20 K
target cell and SDDs will be cooled via ultra pure aluminum bars
T_{TC} = 30 K
T_{SDD} = 50 K

✓ Line driver boards:

2 CryoTiger – 30 W @ 120 K
copper-band cooling lines
T_{LD} = 120 K

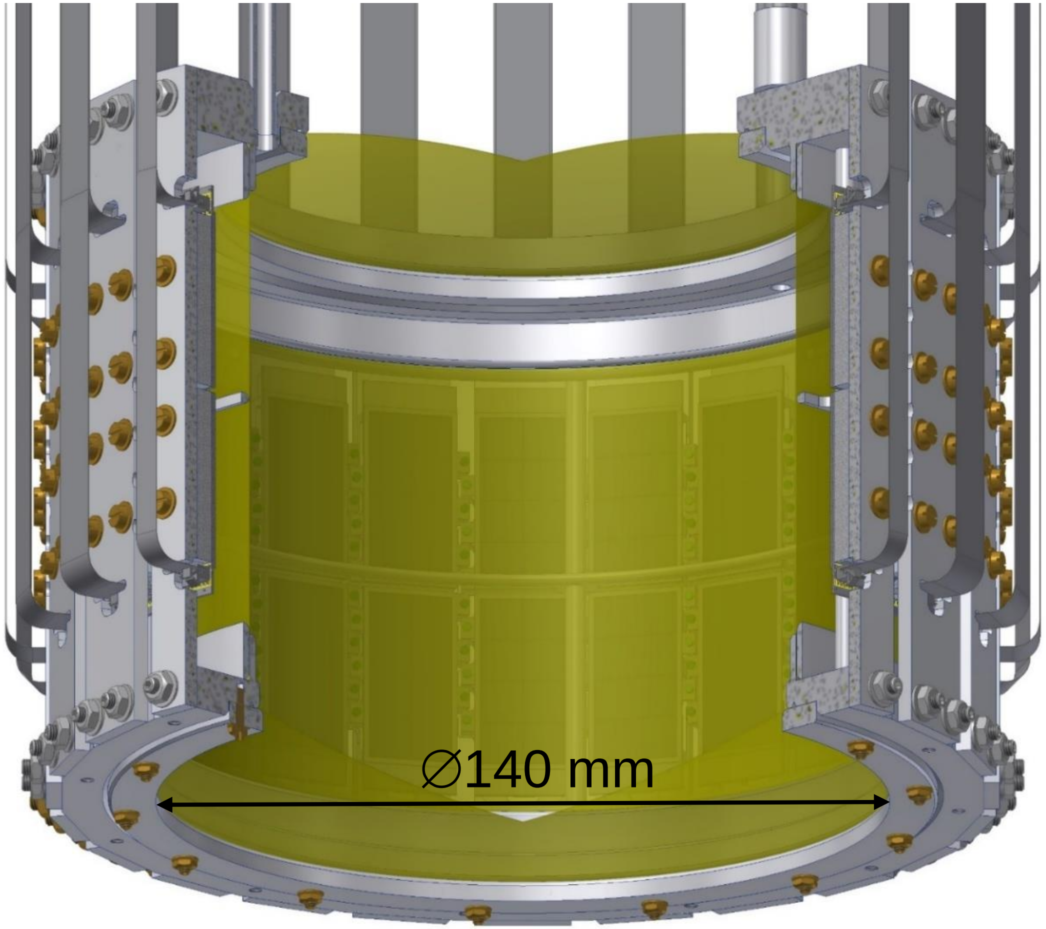


SIDDHARTA-2 vacuum chamber



SIDDHARTA-2 cryogenic target

Working temperature: 30 K
Working pressure : 0.3 MPa



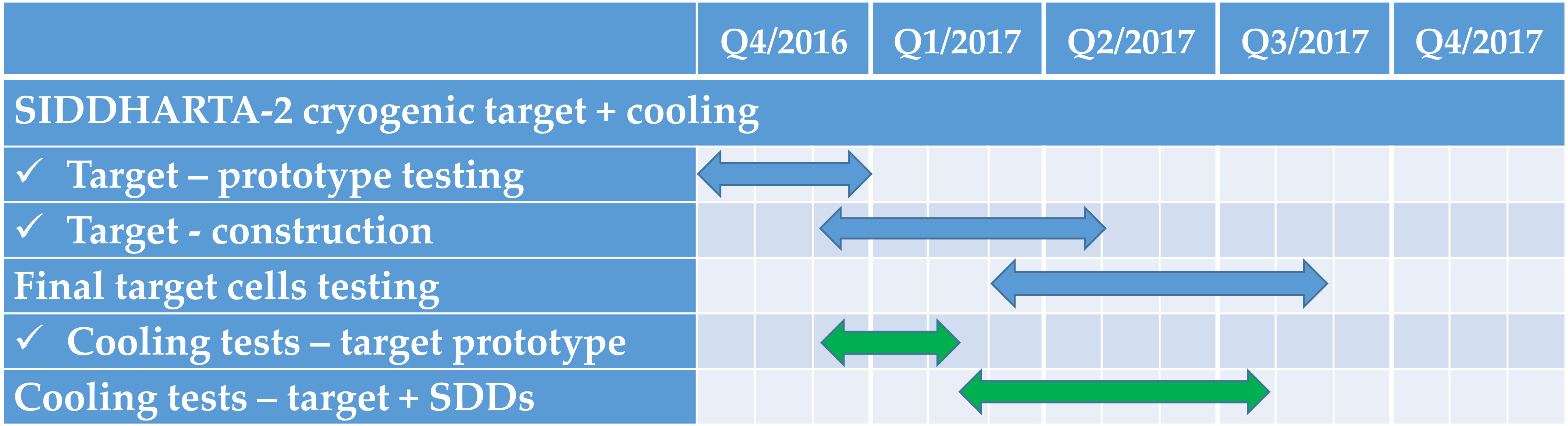
Pressurised for 16 days with P = 0.3 MPa (overP)

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)

Gantt chart SIDDHARTA-2: target



SIDDHARTA-2 setup

- SDD X-ray detector

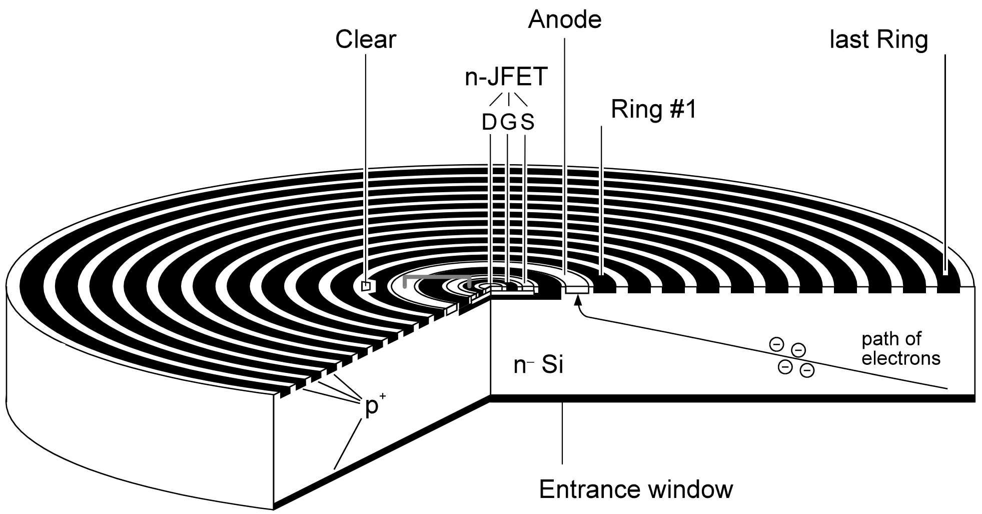
The "new" Silicon Drift Detector

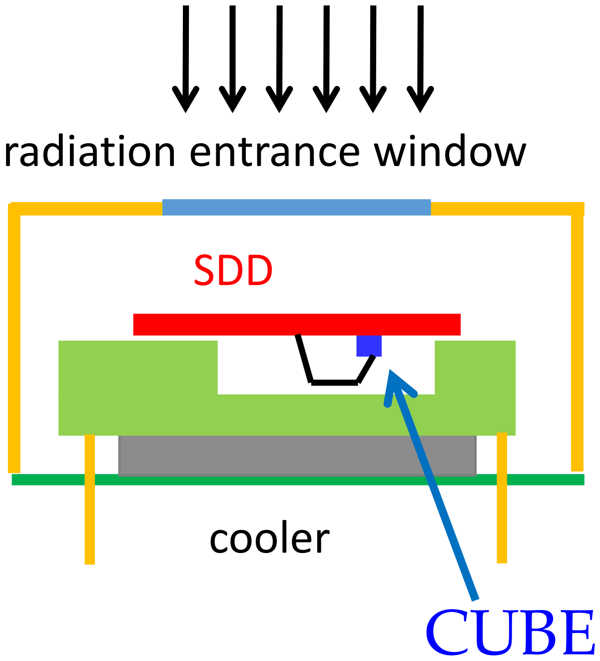
➢ **SIDDHARTA**

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

➢ **SIDDHARTA-2**

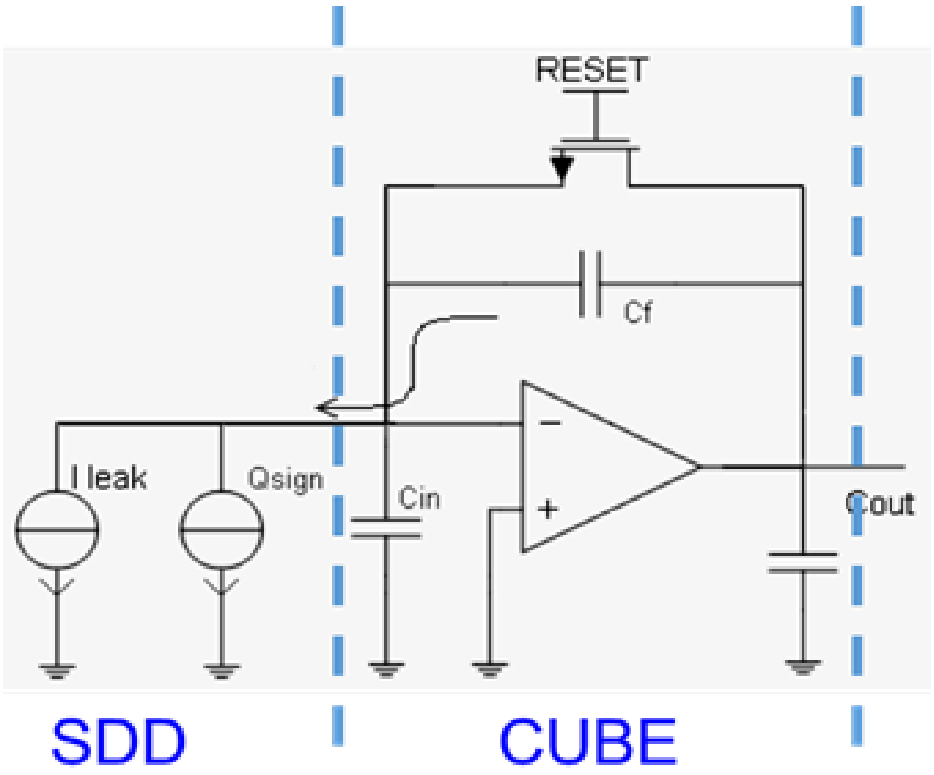
- external CUBE preamplifier (MOSFET input transistor)
- larger total anode capacitance
- better than FET performances
- standard SDD technology

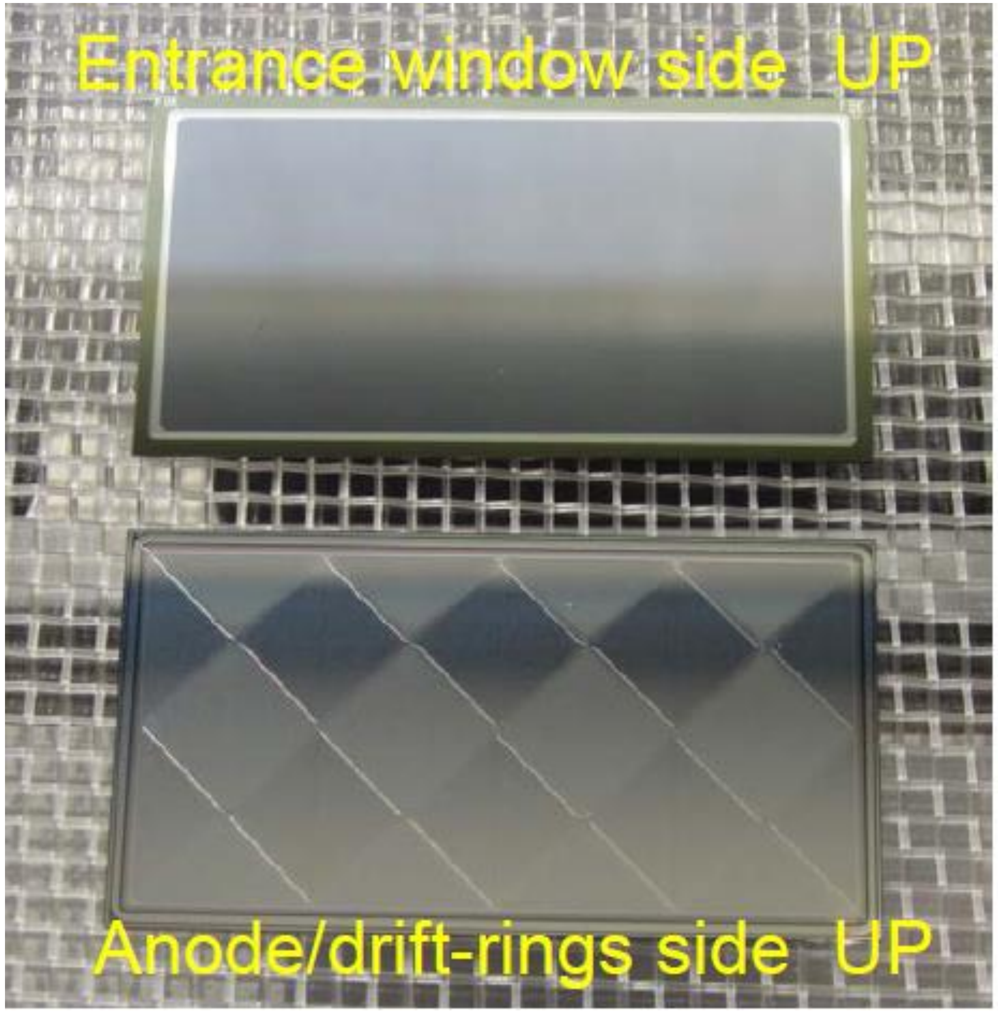




The CUBE preamplifier

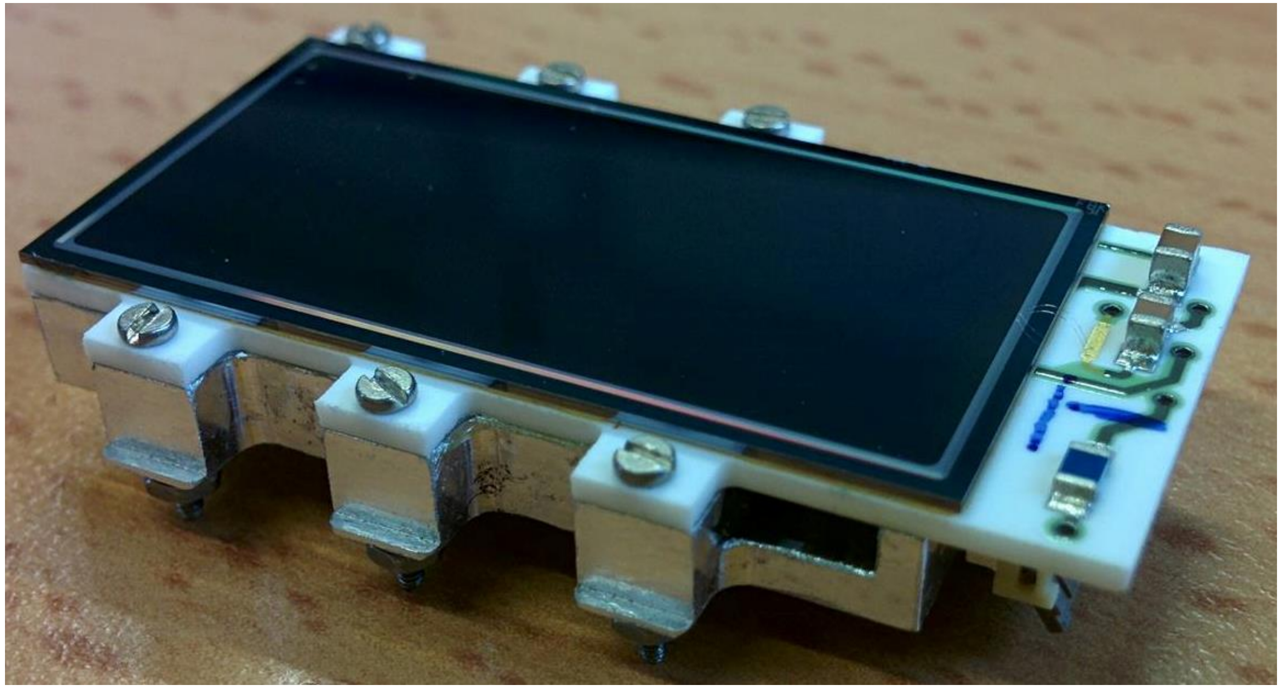
- A full CMOS preamplifier is mounted on ceramic board - connected via bonding
- The CUBE replaces the JFET, which was direct implanted on the anode side on the SIDDHARTA type SDDs
- Short bonding lines from CUBE to SDD, no difference in the detector performance
- Advantage, the preamplifier is connected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





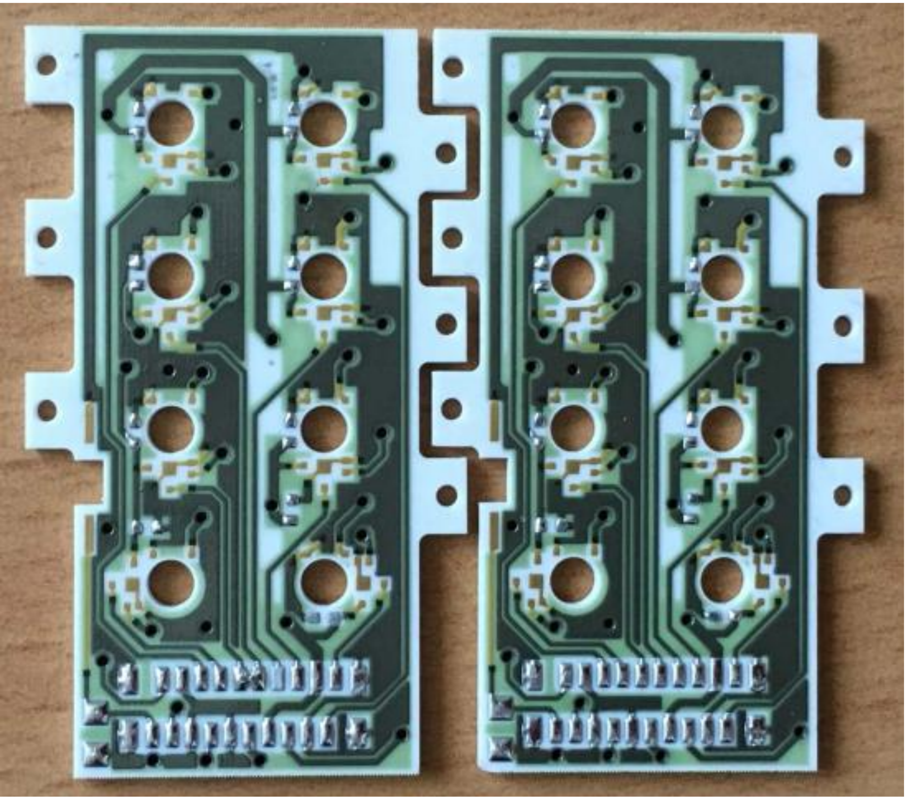
Shipping package

4x2 SDD array - single unit

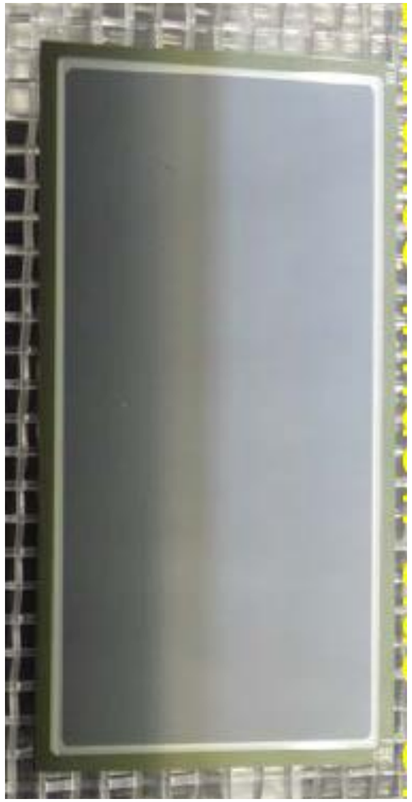


SDD mounting / bonding

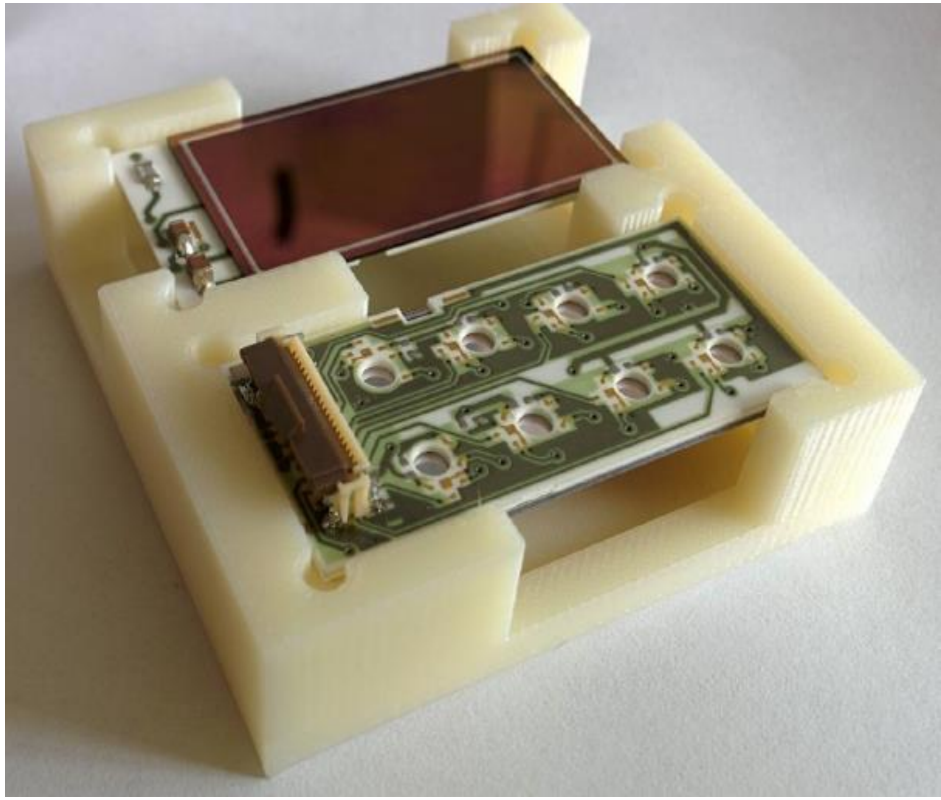
ceramic boards



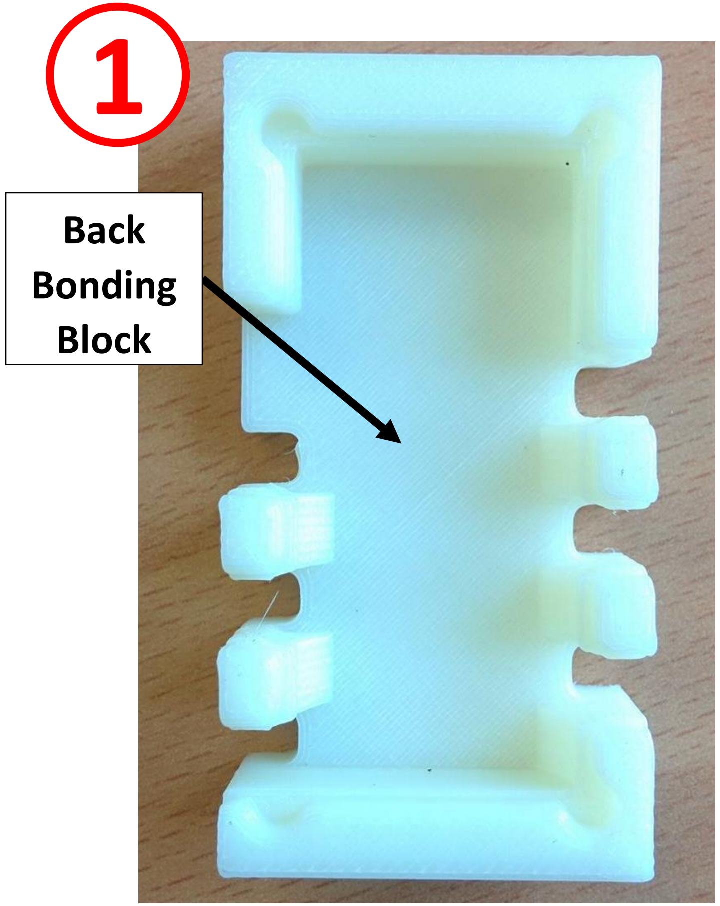
4x2 SDD chip



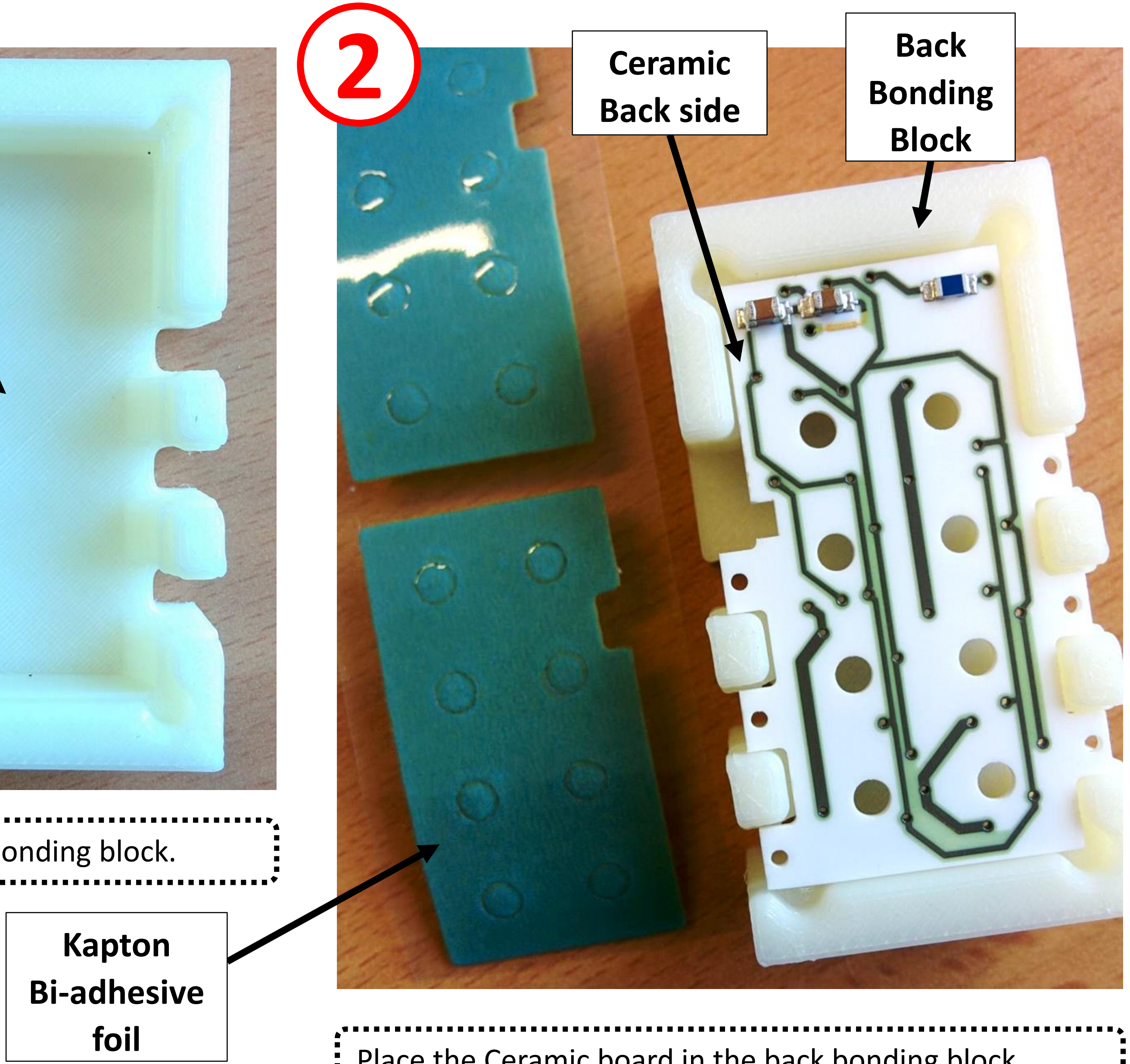
device for gluing and bonding



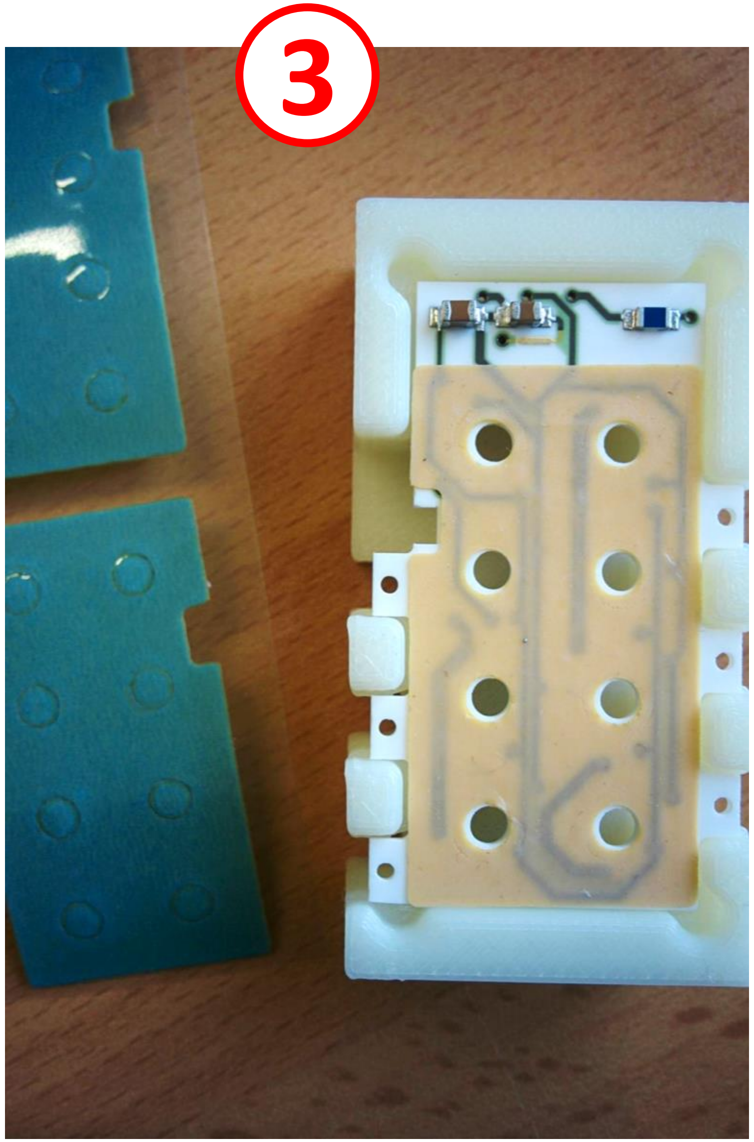
- mounting and bonding process under control



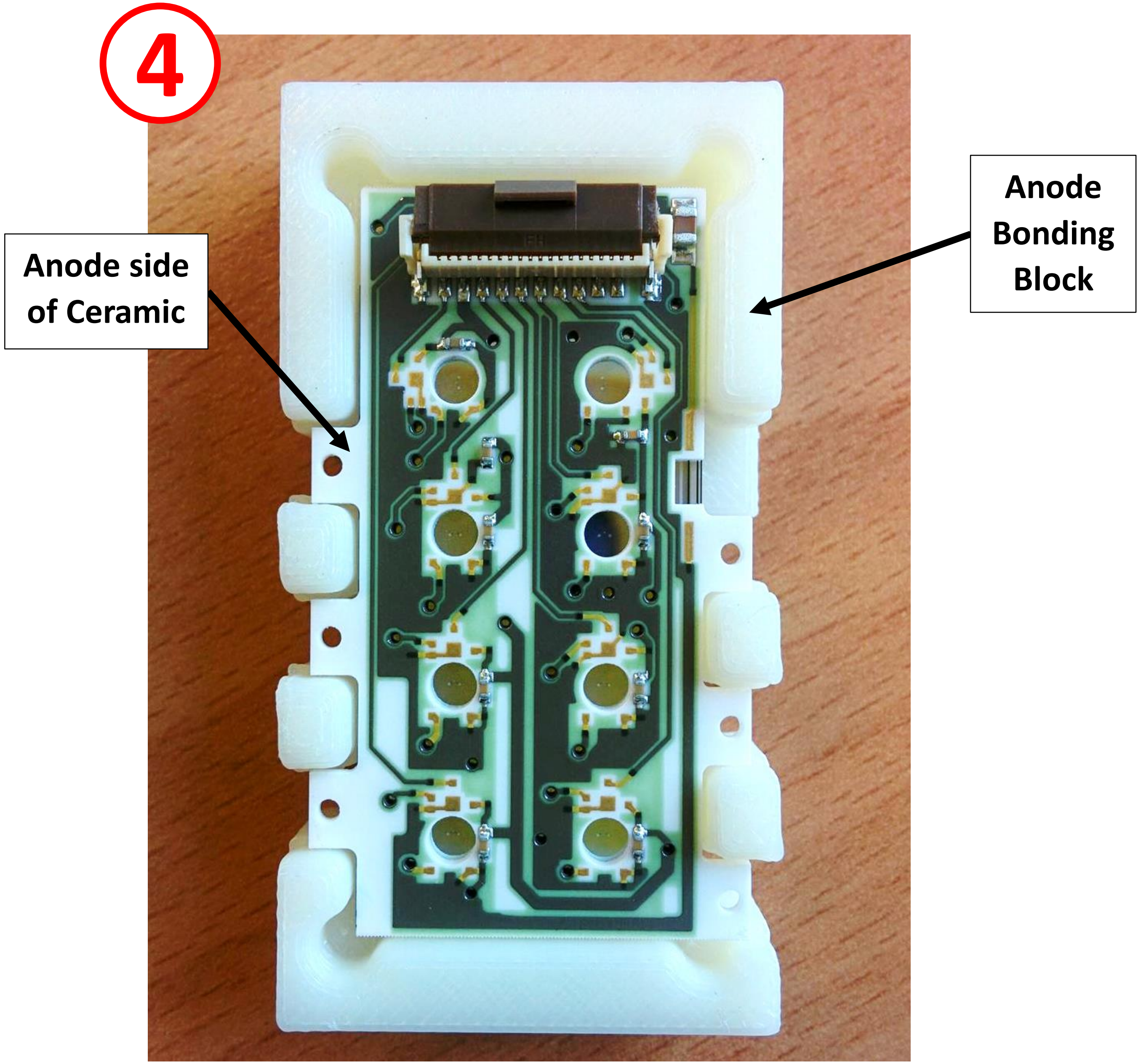
Take the Back bonding block.



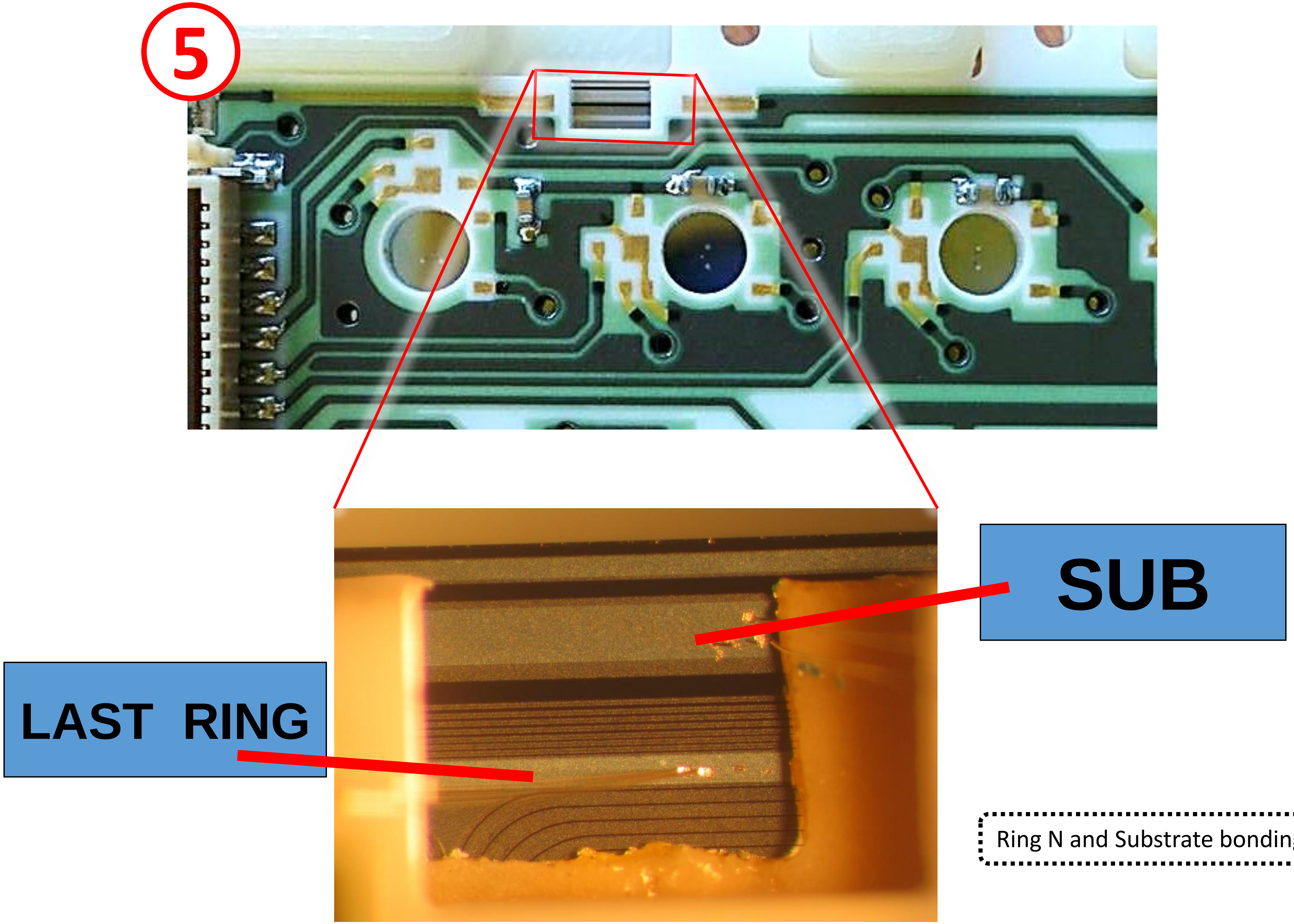
Place the Ceramic board in the back bonding block.



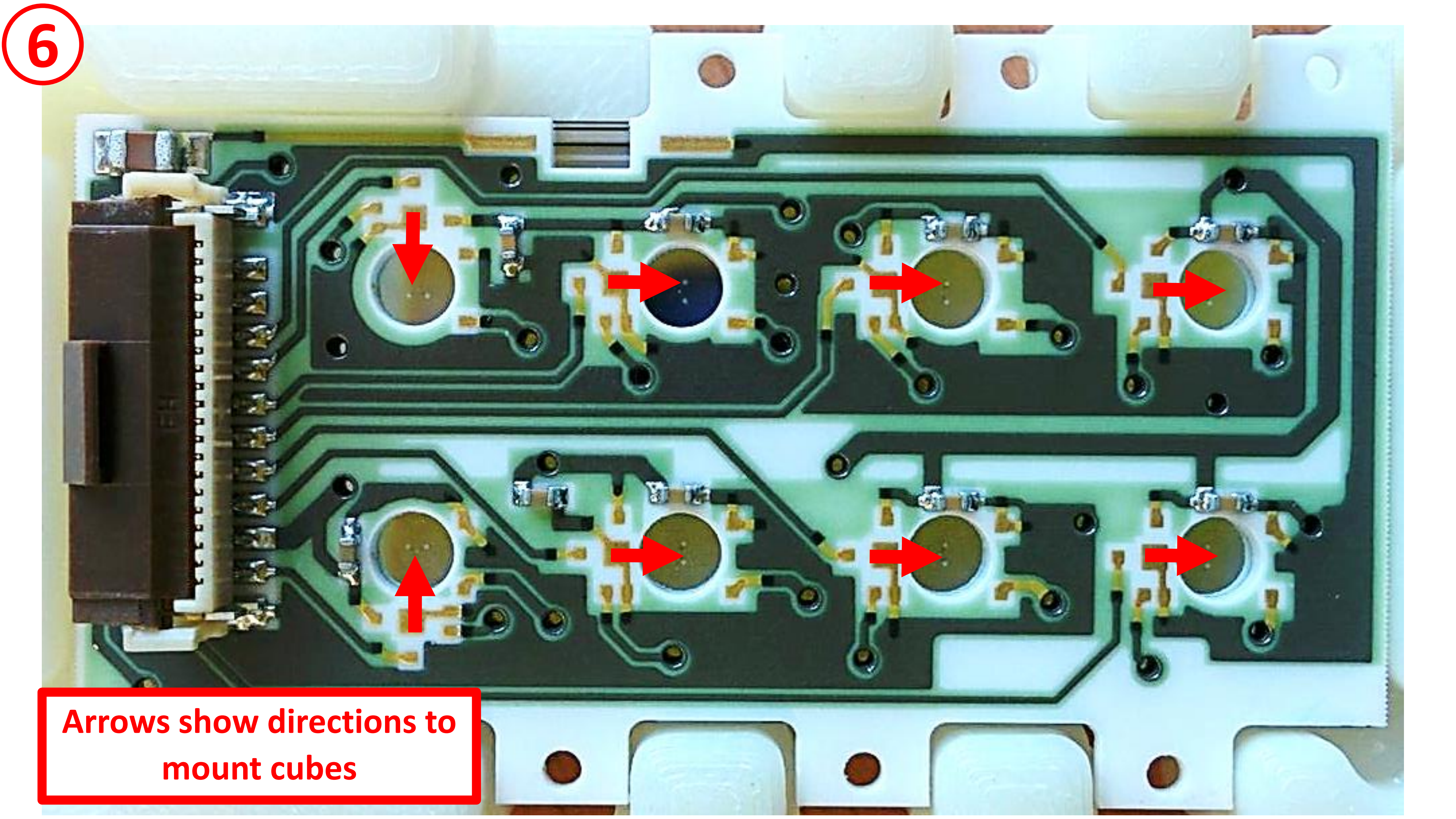
Place the Kapton bi-adhesive correctly on the ceramic back side.



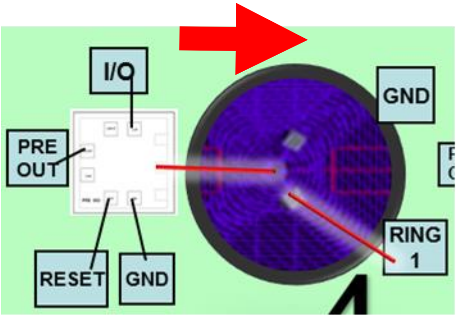
Place the ceramic of step 3 onto the SDD array present in the anode bonding block.



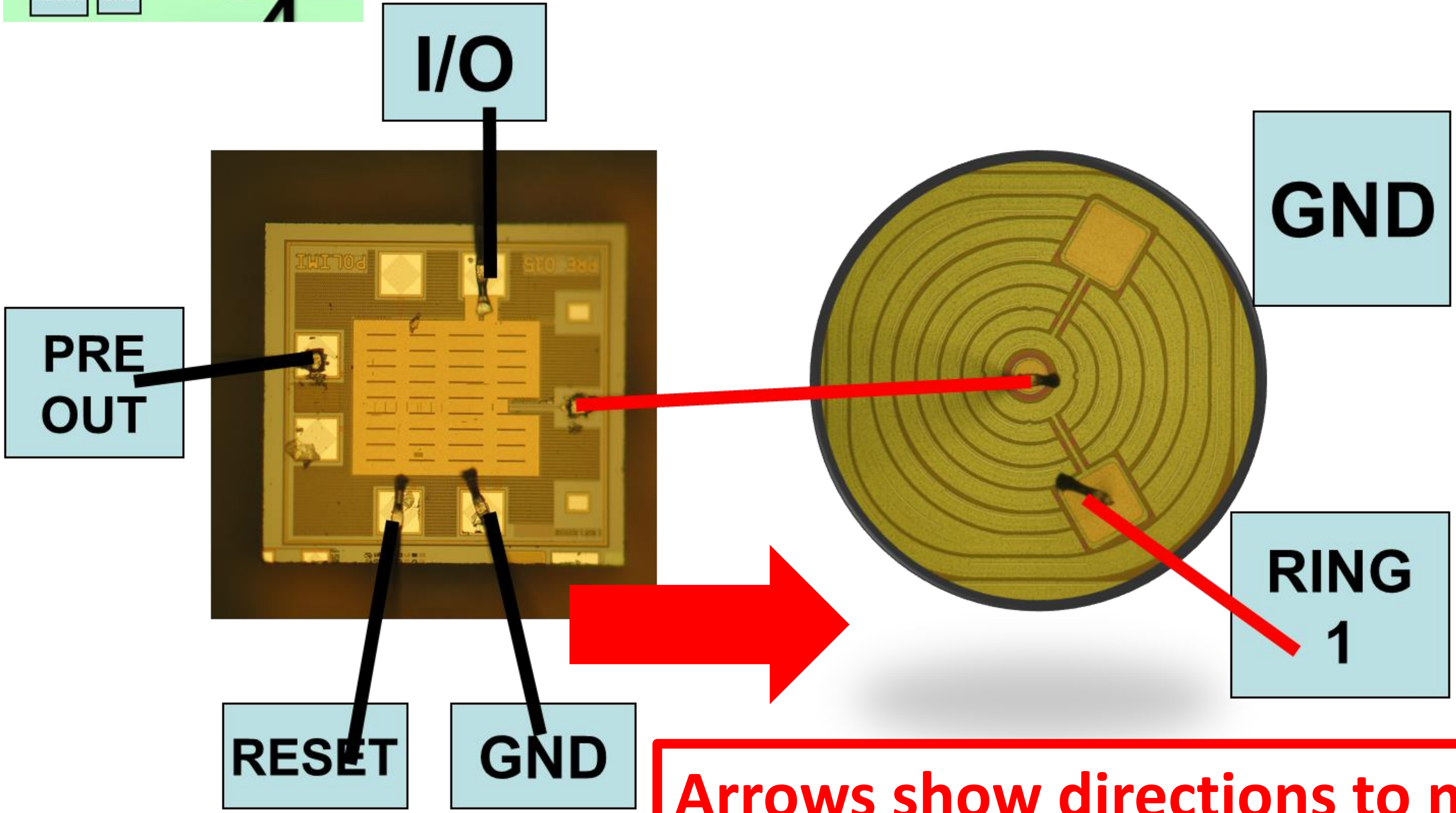
Ring N and Substrate bonding


6
Arrows show directions to mount cubes

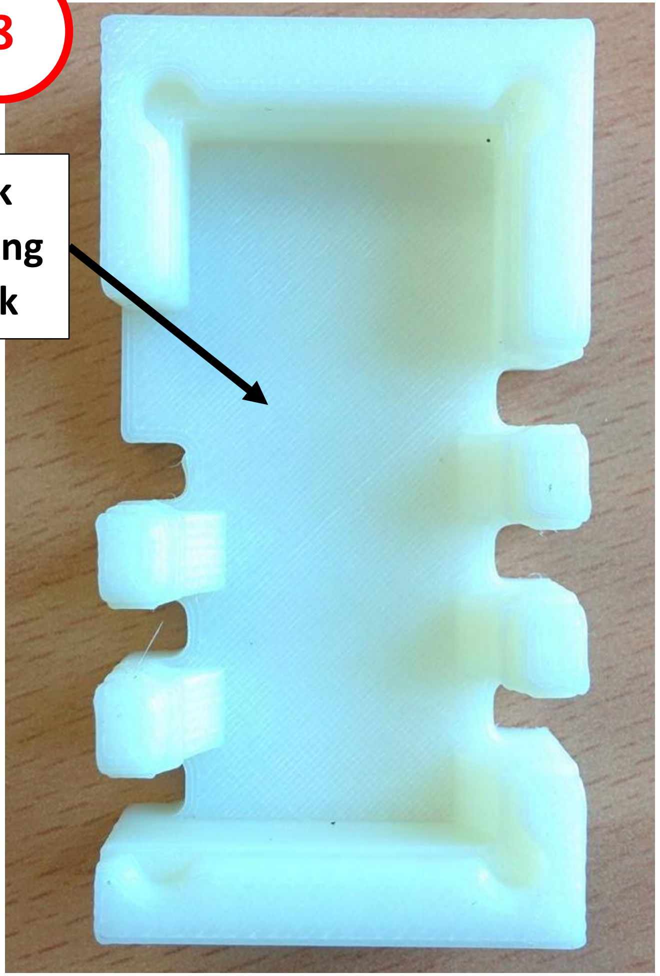
⑦



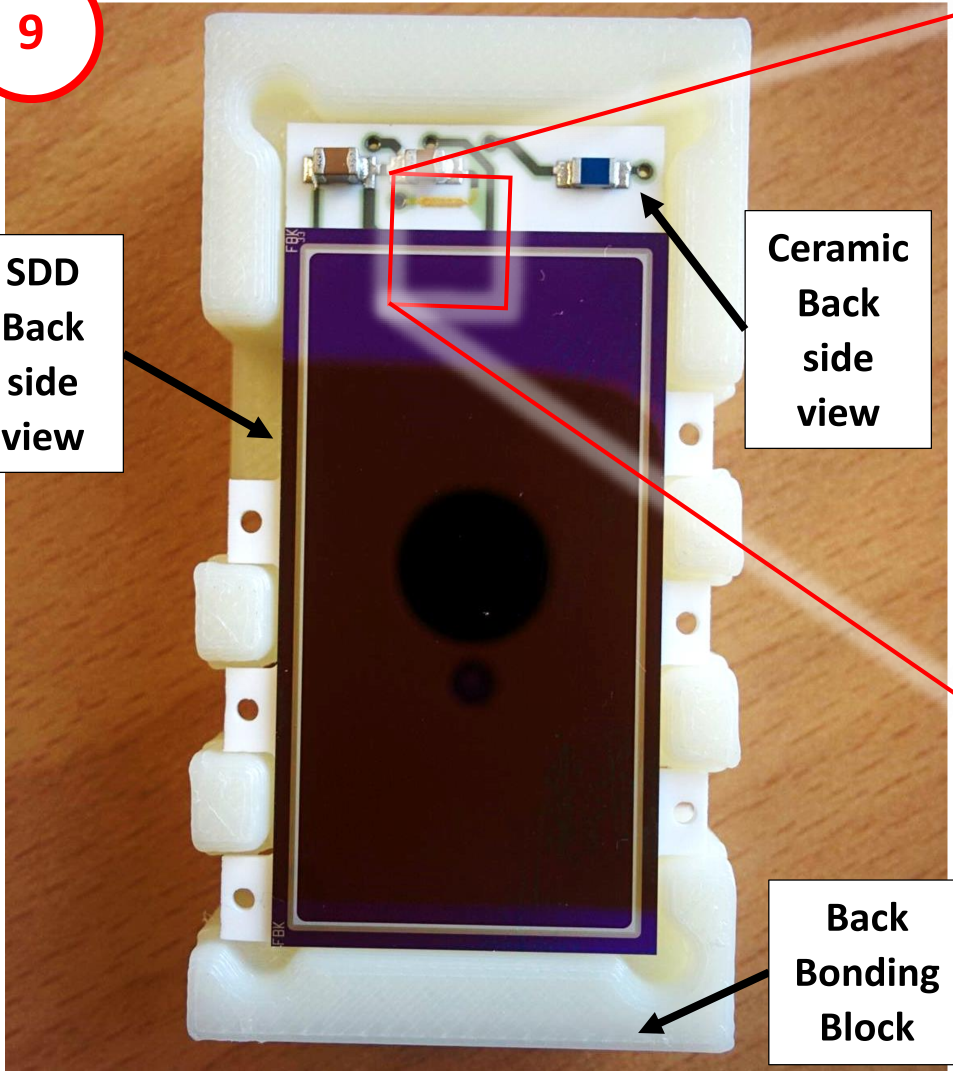
Complete working channel bonding



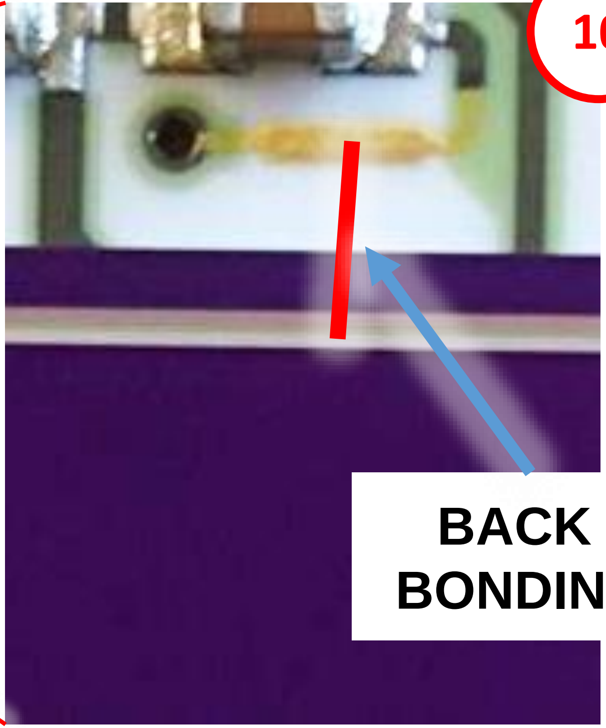
Arrows show directions to mount cubes



Take the Back bonding block.

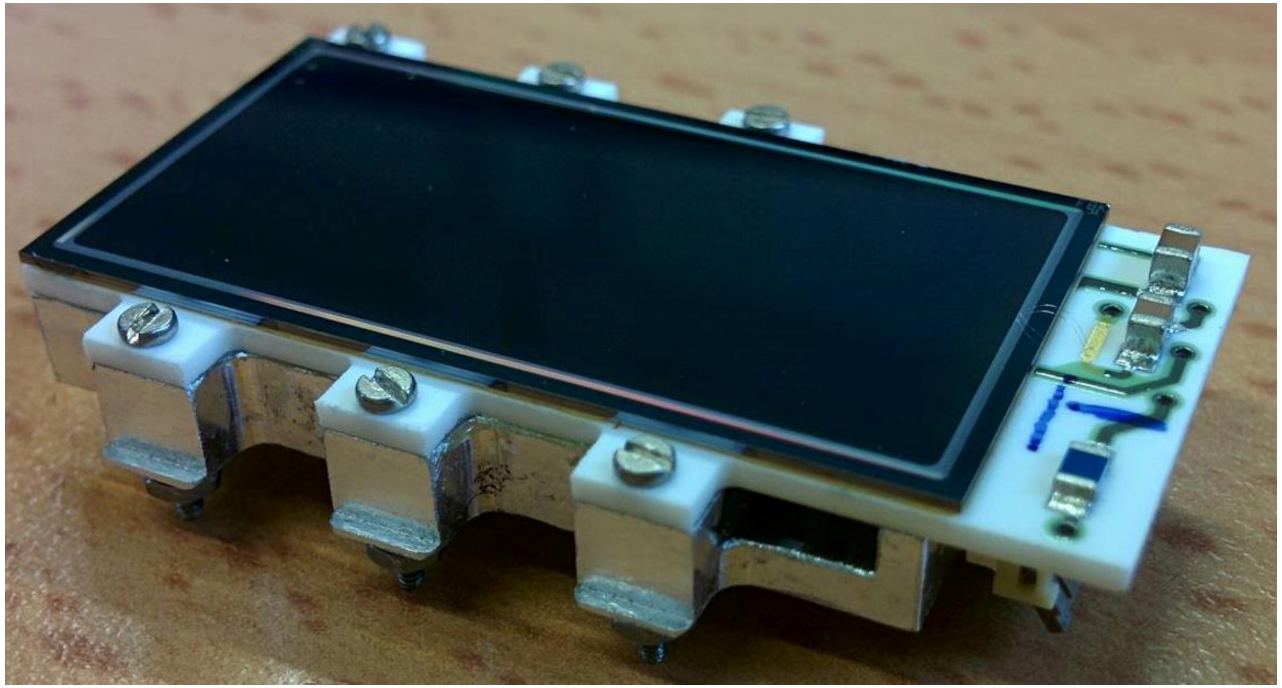


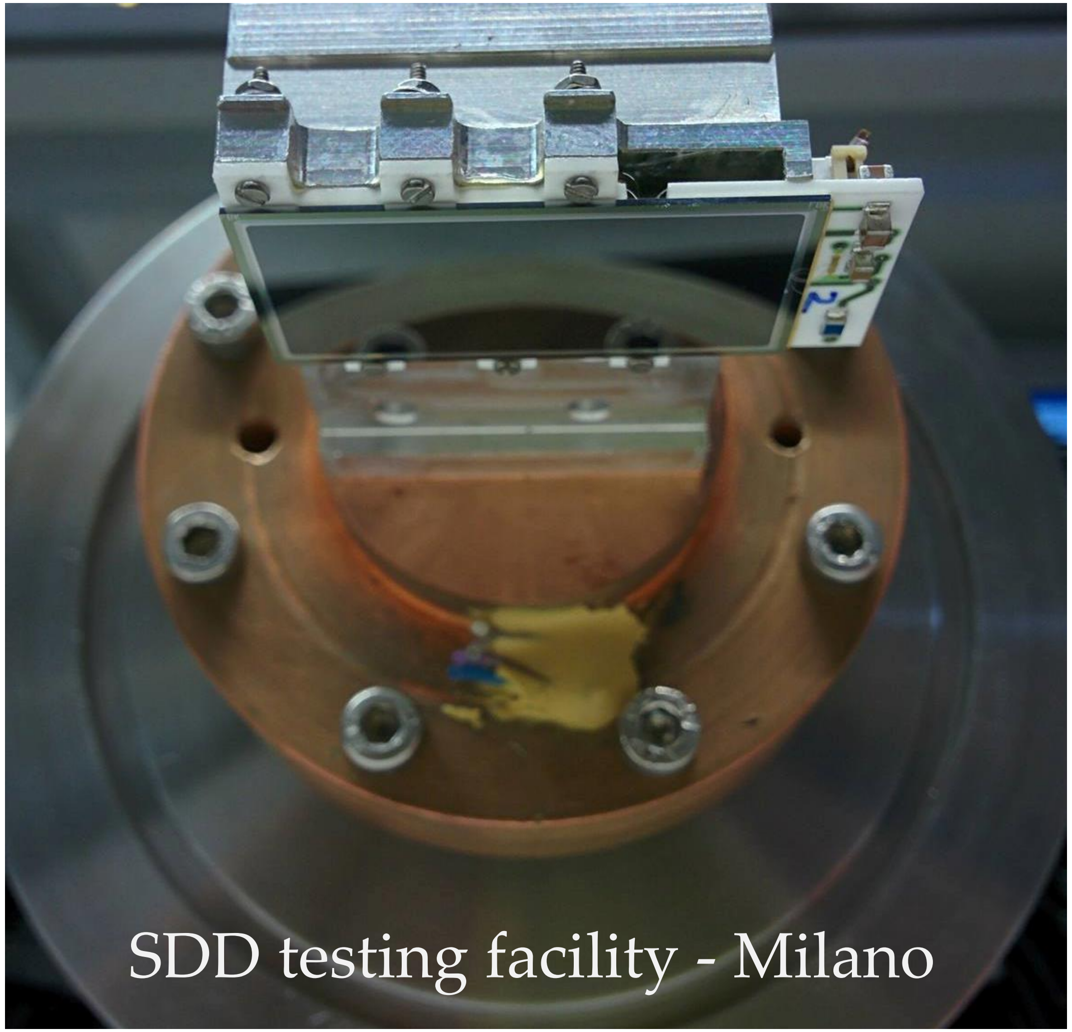
Place the ceramic board with SDD Back side up on the Back bonding block.



Perform back bonding.

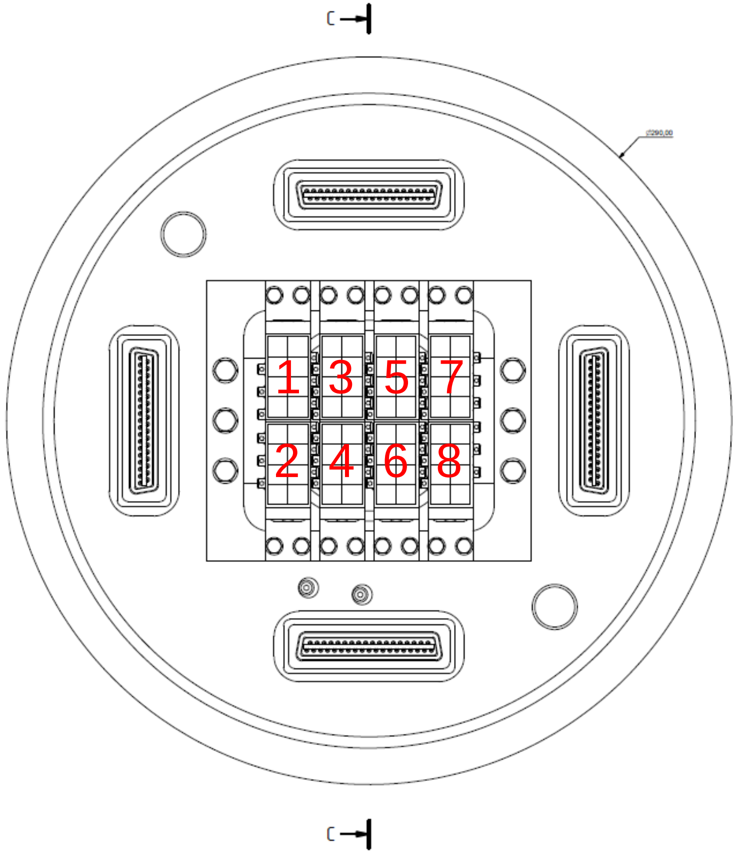
4 x 2 matrix SDD chip - testing

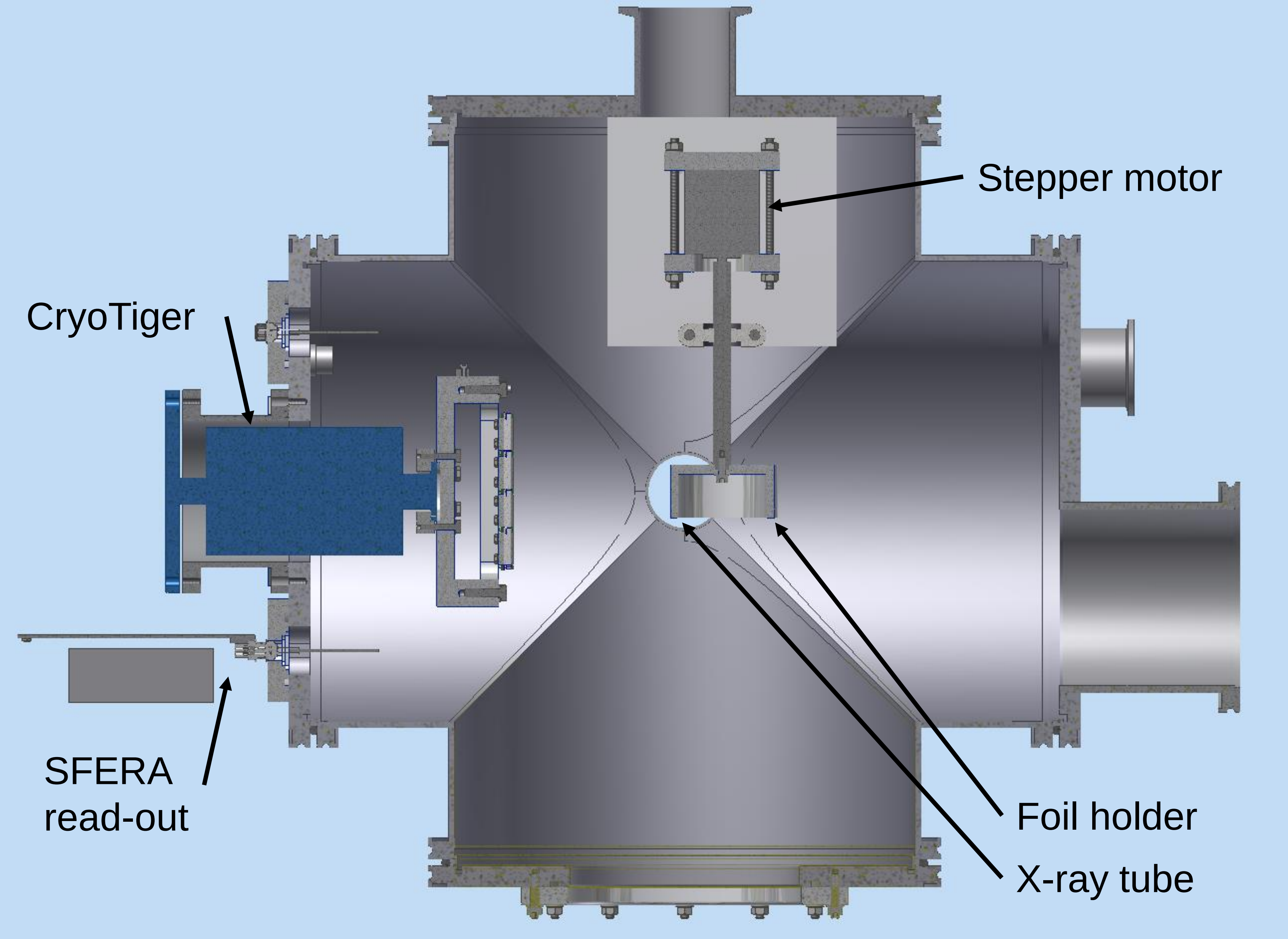




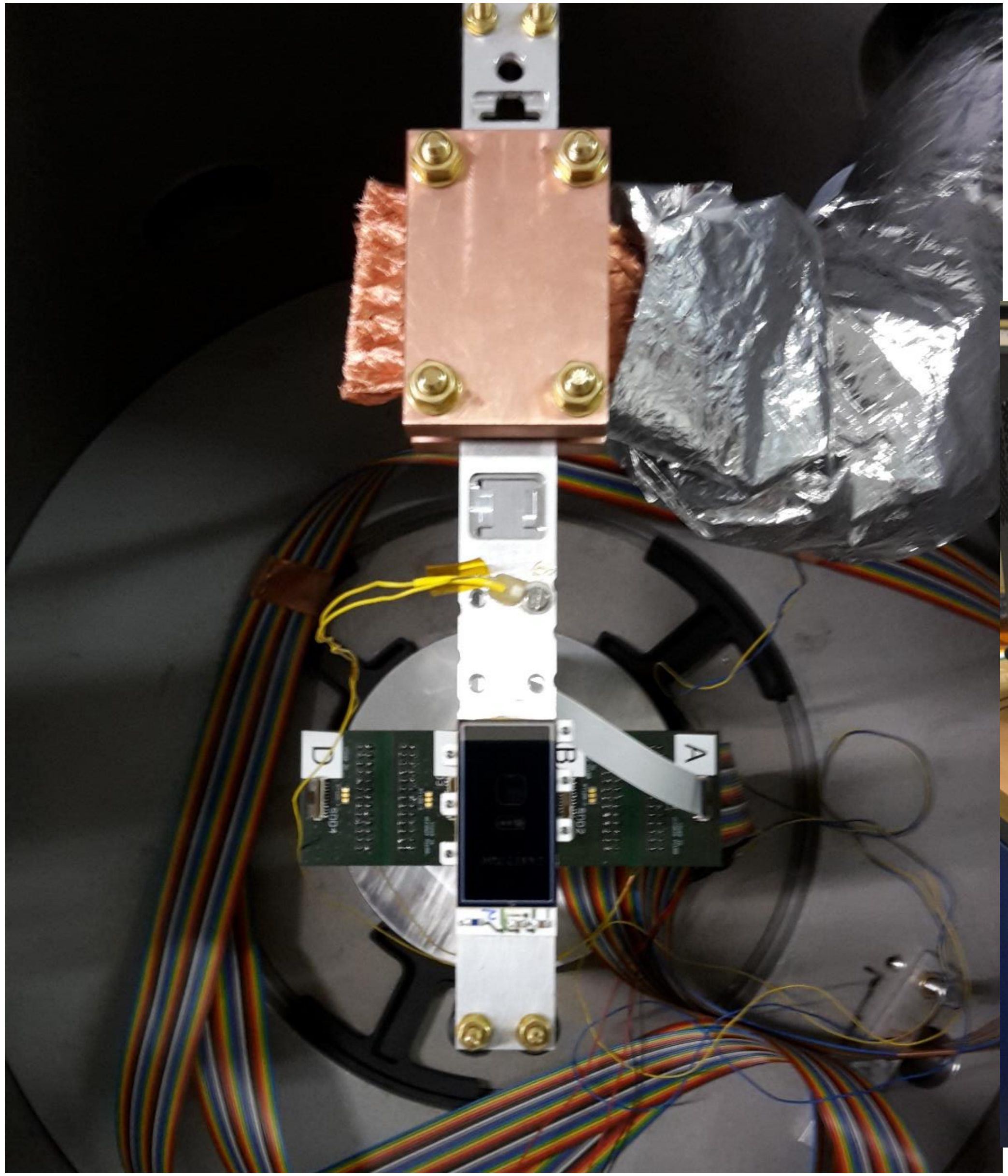
New SDD testing facility - LNF

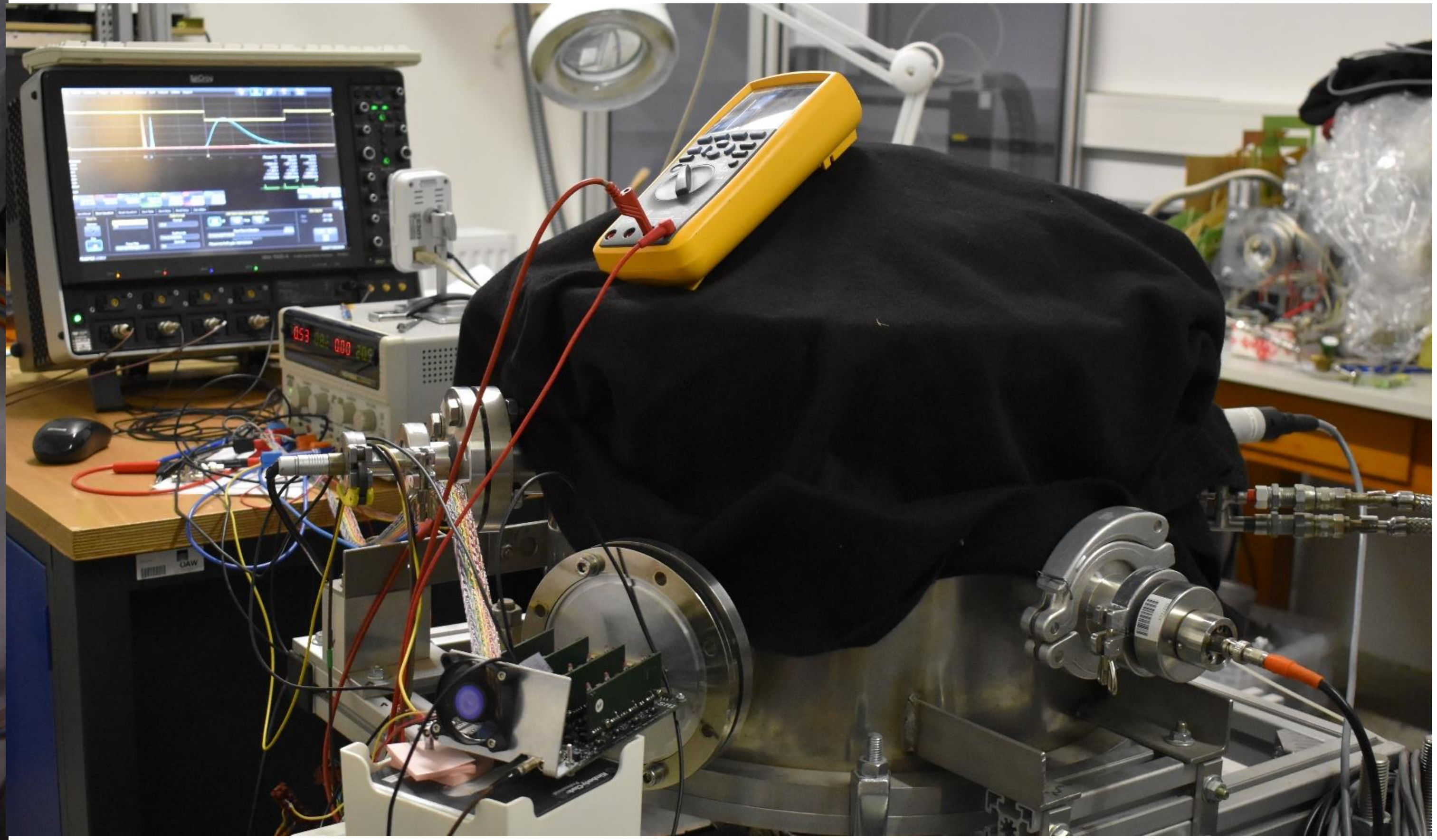
Mounting device for
8 SDD units



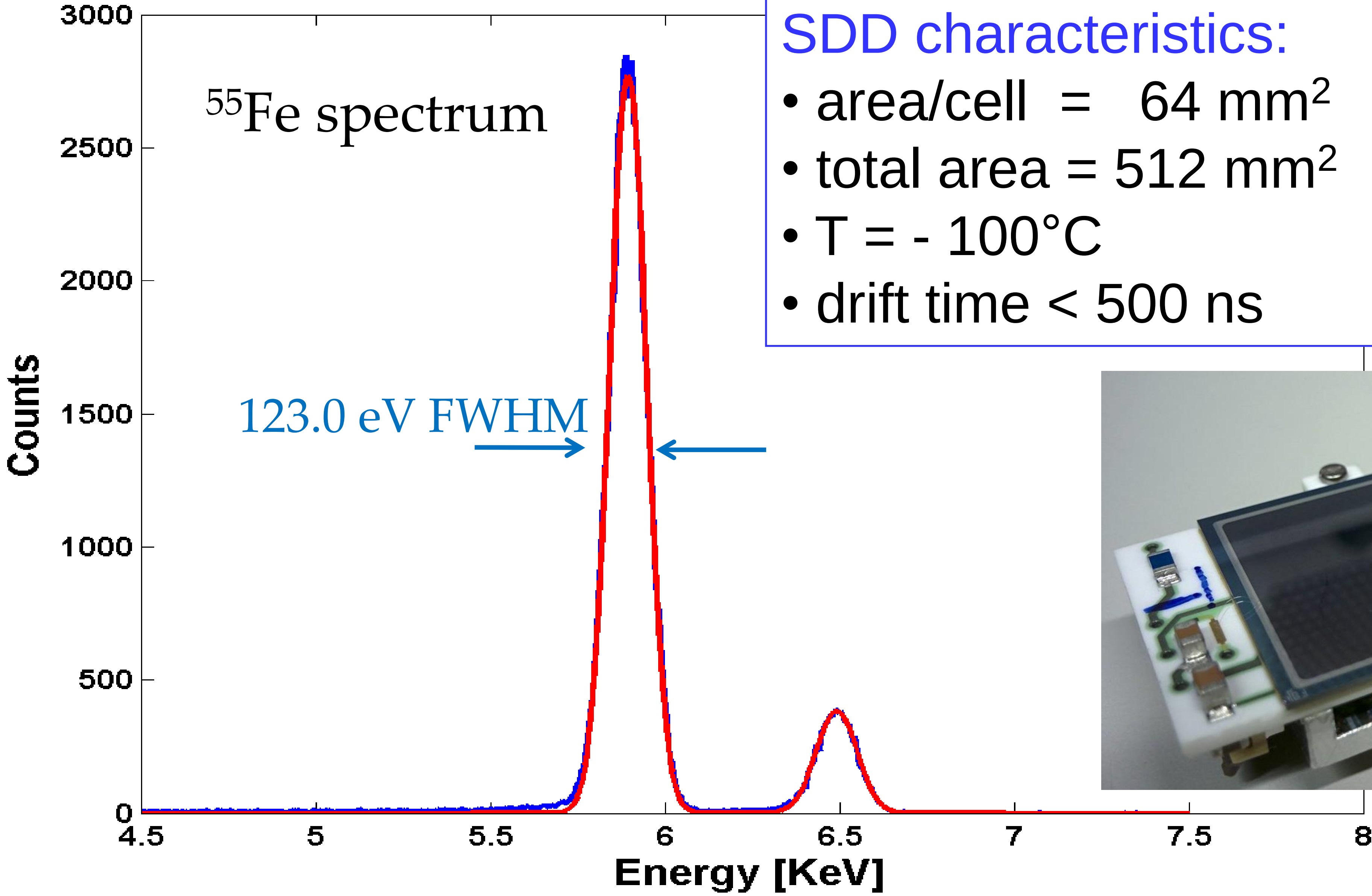


SDD testing facility - SMI



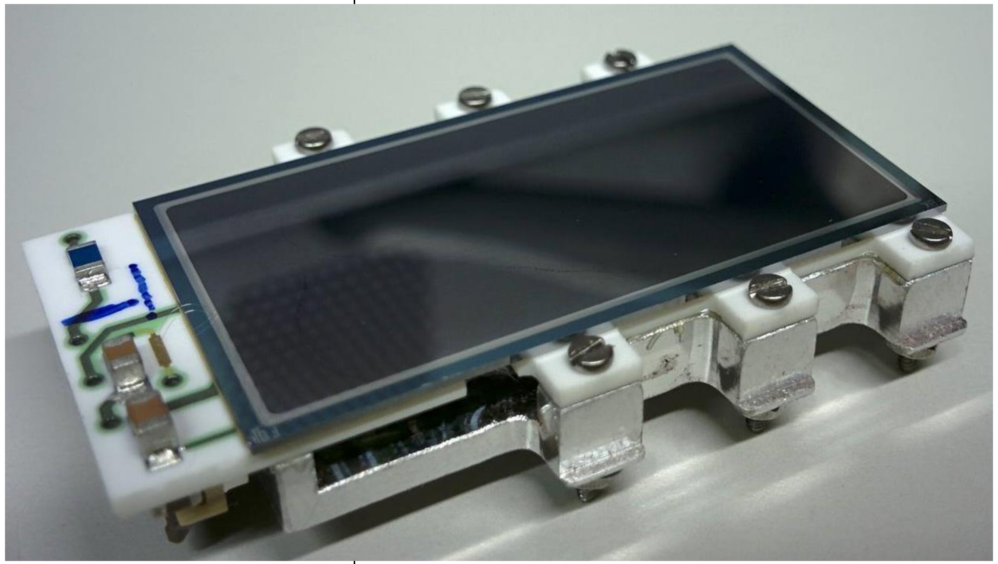


New SDD technology: CUBE preamplifier

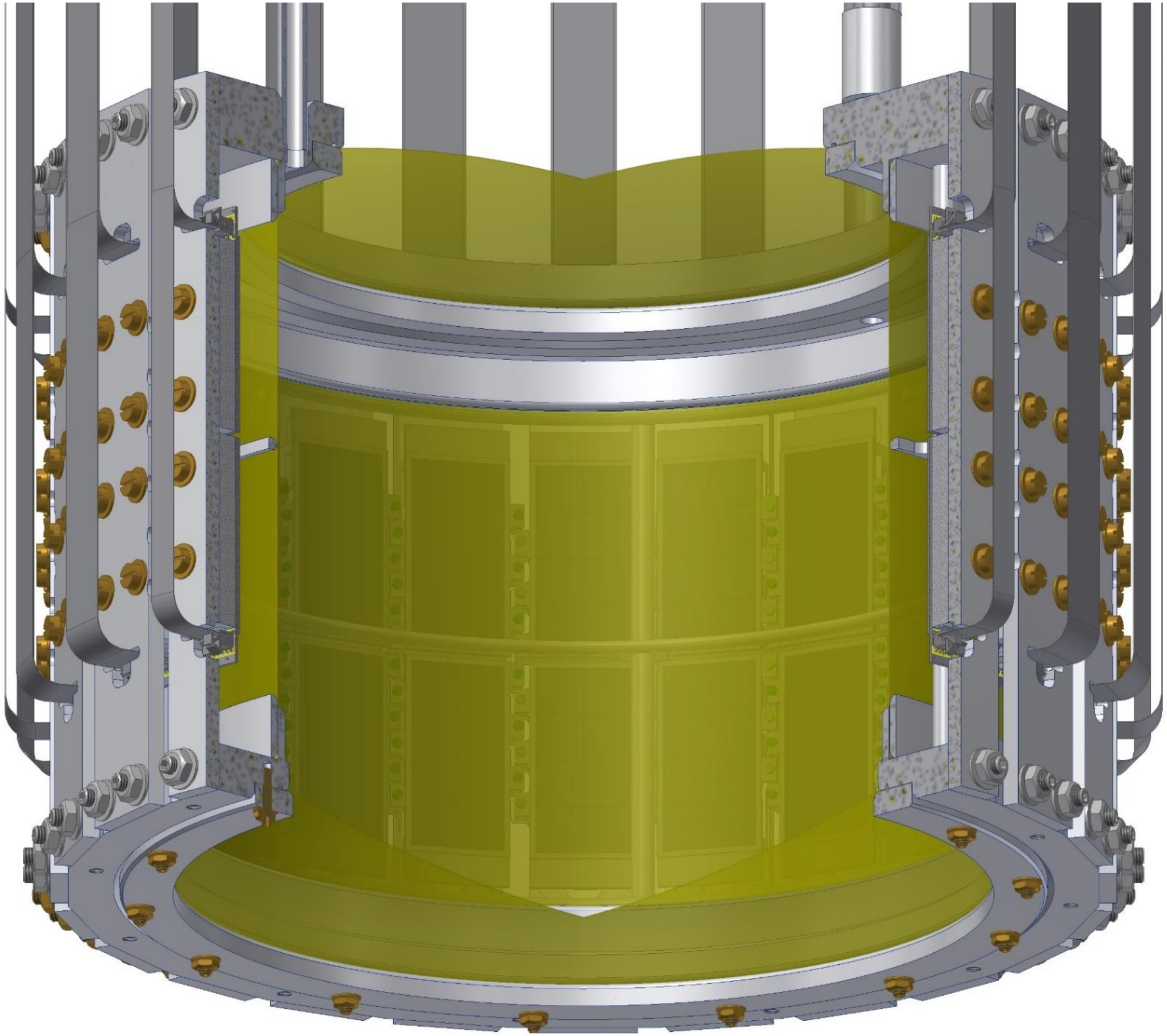


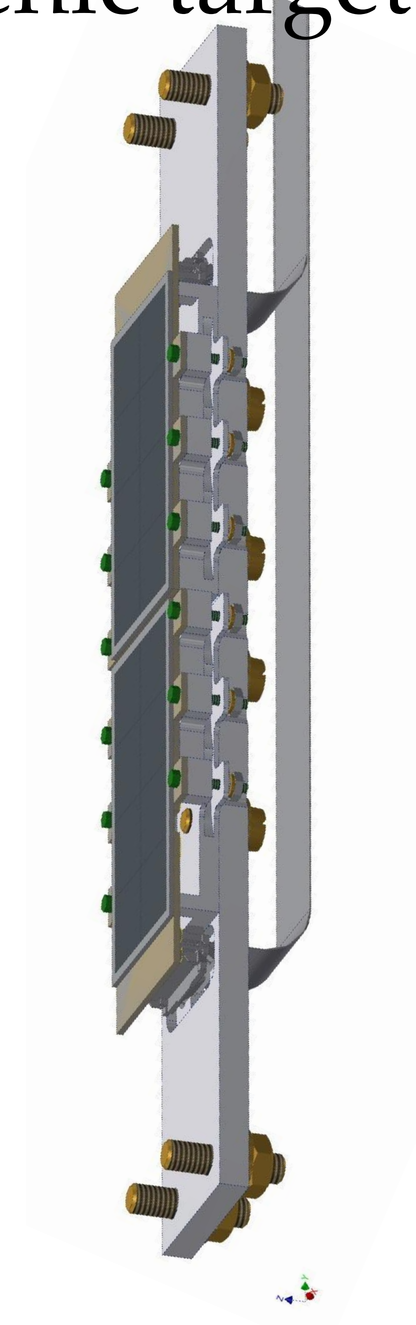
SDD characteristics:

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



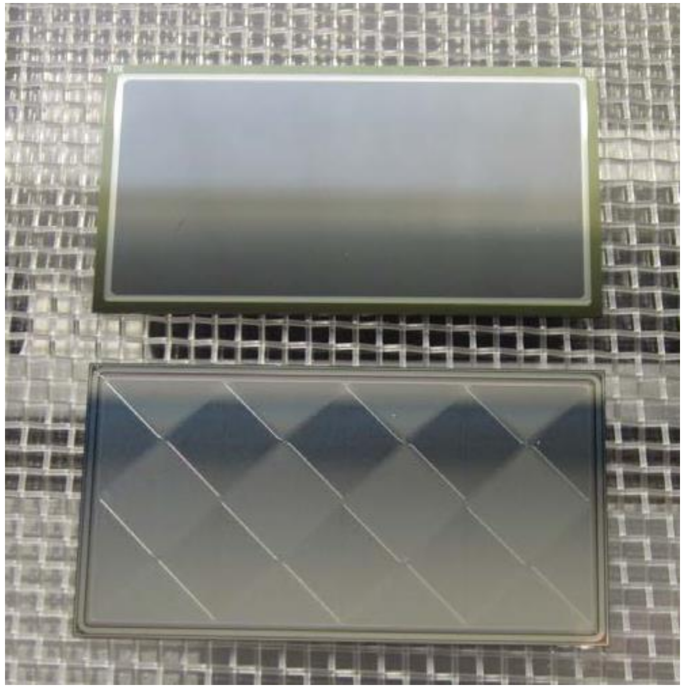
4x2 SDD arrays around the cryogenic target





In total 48 SDDs
will be used

SDD arrays, delivery and qualification



48 SDDs arrays needed

Delivery status:
52 arrays received

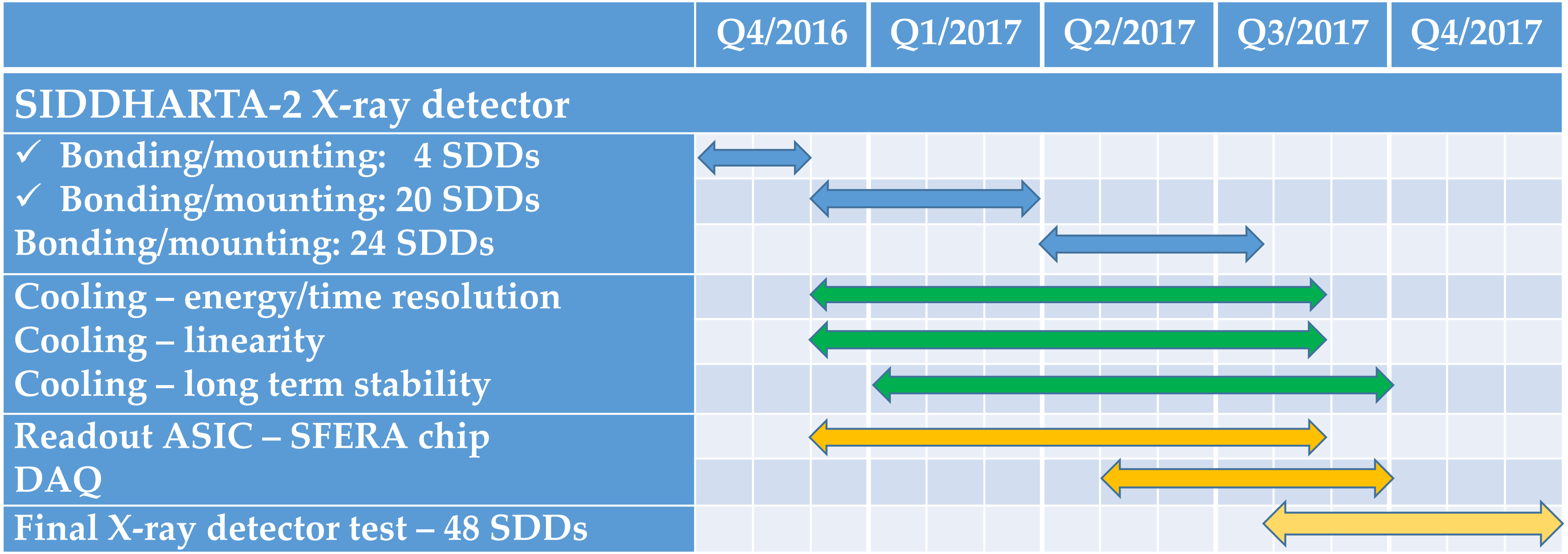
Batch	Wafer	Matrix	Q-index
SIDDHARTA1b	W01	1,2	8.080
SIDDHARTA1b	W01	2,1	8.080
SIDDHARTA1b	W01	3,2	8.080
SIDDHARTA1b	W01	3,3	8.530
SIDDHARTA1b	W02	1,4	8.161
SIDDHARTA1b	W02	3,1	8.800
SIDDHARTA1b	W02	3,3	8.530
SIDDHARTA1c	W12	2,1	8.440
SIDDHARTA1c	W17	1,1	8.080

Batch	Wafer	Matrix	Q-index
SIDDHARTA1b	W03	1,4	8.080
SIDDHARTA1b	W03	1,1	8.620
SIDDHARTA1b	W04	3,2	8.260
SIDDHARTA1b	W04	2,1	8.611
SIDDHARTA1b	W04	1,2	8.710
SIDDHARTA1b	W05	3,4	8.710
SIDDHARTA1d	W14	3,1	8.080
SIDDHARTA1d	W14	3,2	8.440
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/cm²)
D = number of "diamond" channels
(with J_{anode} < 80pA/cm²)
G = number of "gold" channels
(with J_{anode} < 250pA/cm²)
S = number of "silver" channels
(with J_{anode} < 600pA/cm²)

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

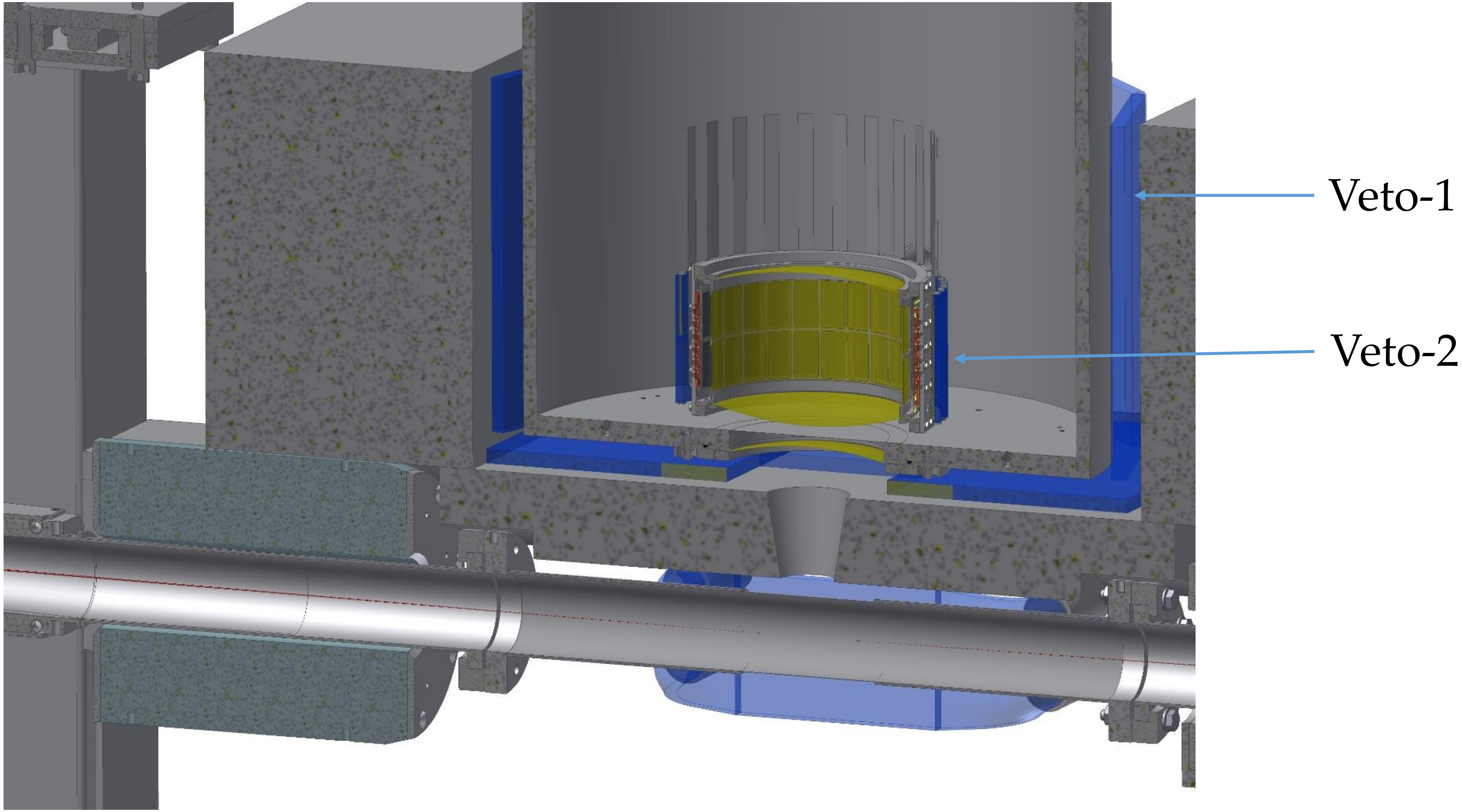
Gantt chart SIDDHARTA-2: X-ray detector



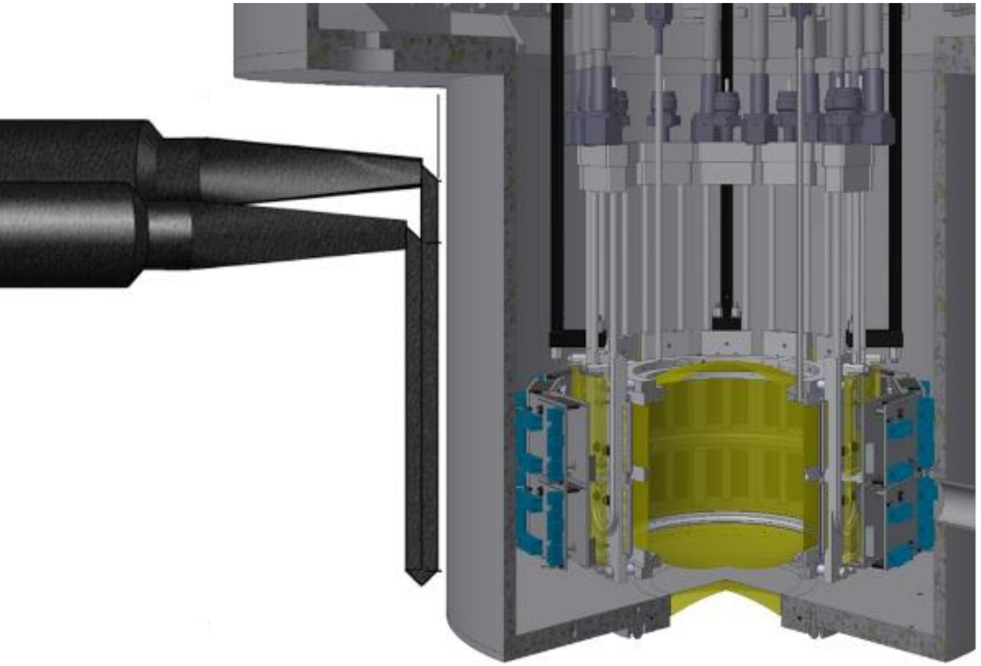
SIDDHARTA-2 setup

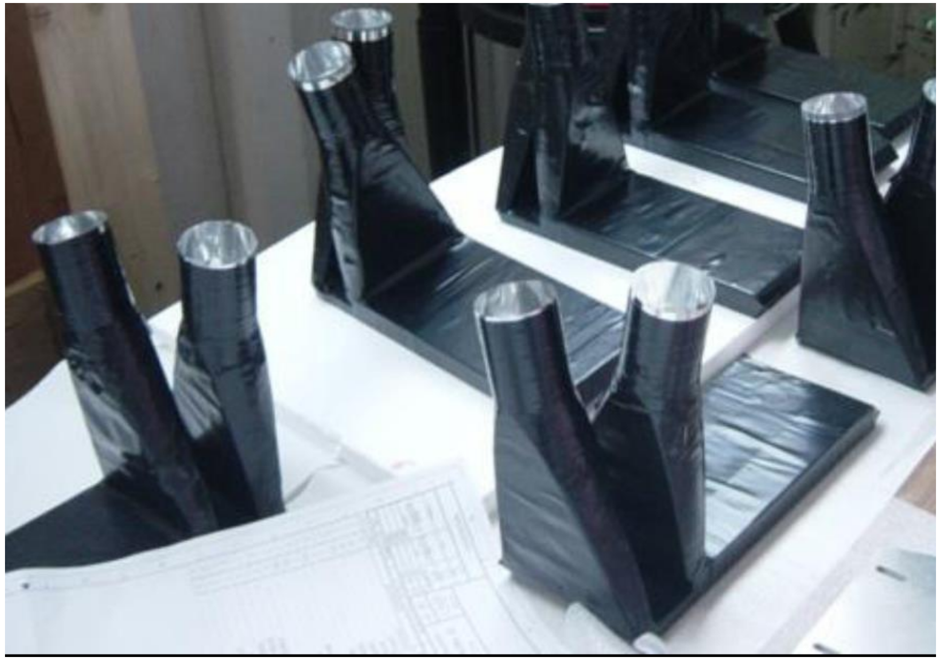
- the veto system

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



The veto-1 system

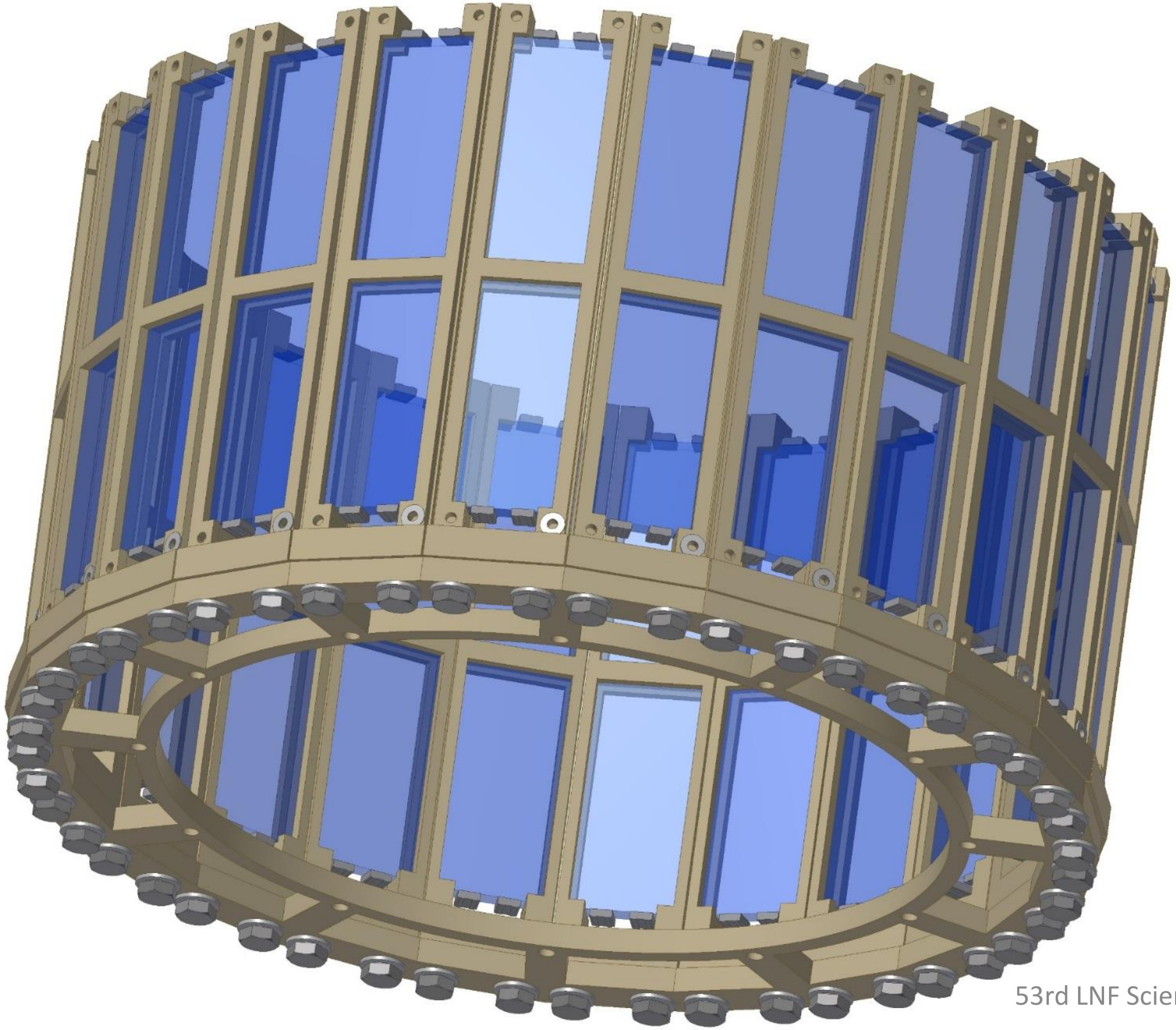


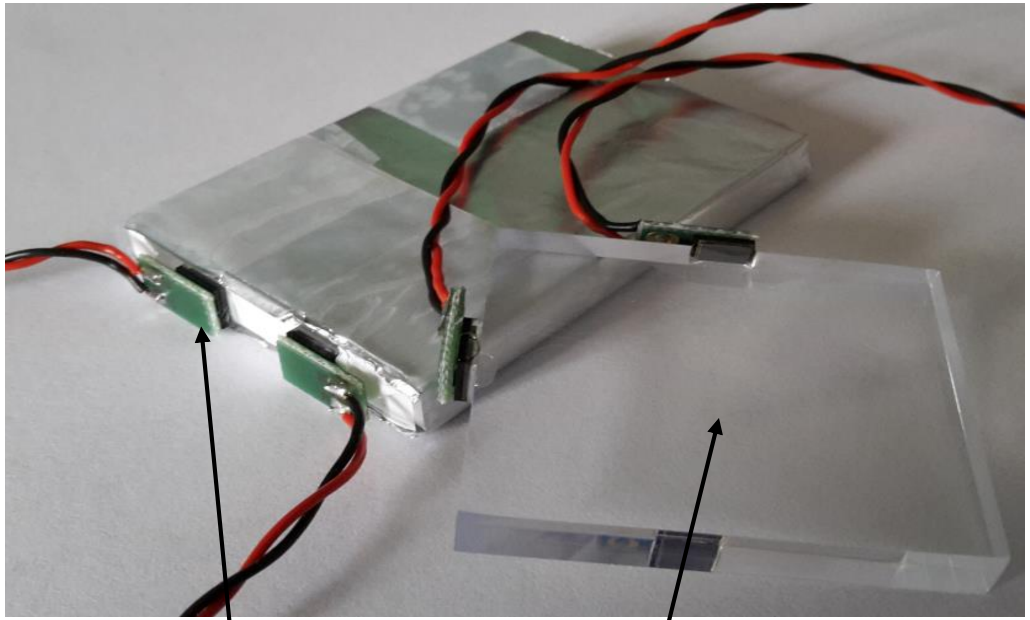


To achieve a good timing resolution, (independent of the "hit" position) < 600 ps (FWHM),the scintillator has to be read out on both side.
Because the available space is limited due to shielding material, the photomultiplier tubes have to be on the same side (a special light-guide mirror design was used).

The veto-2 system

Veto-2 arrangement



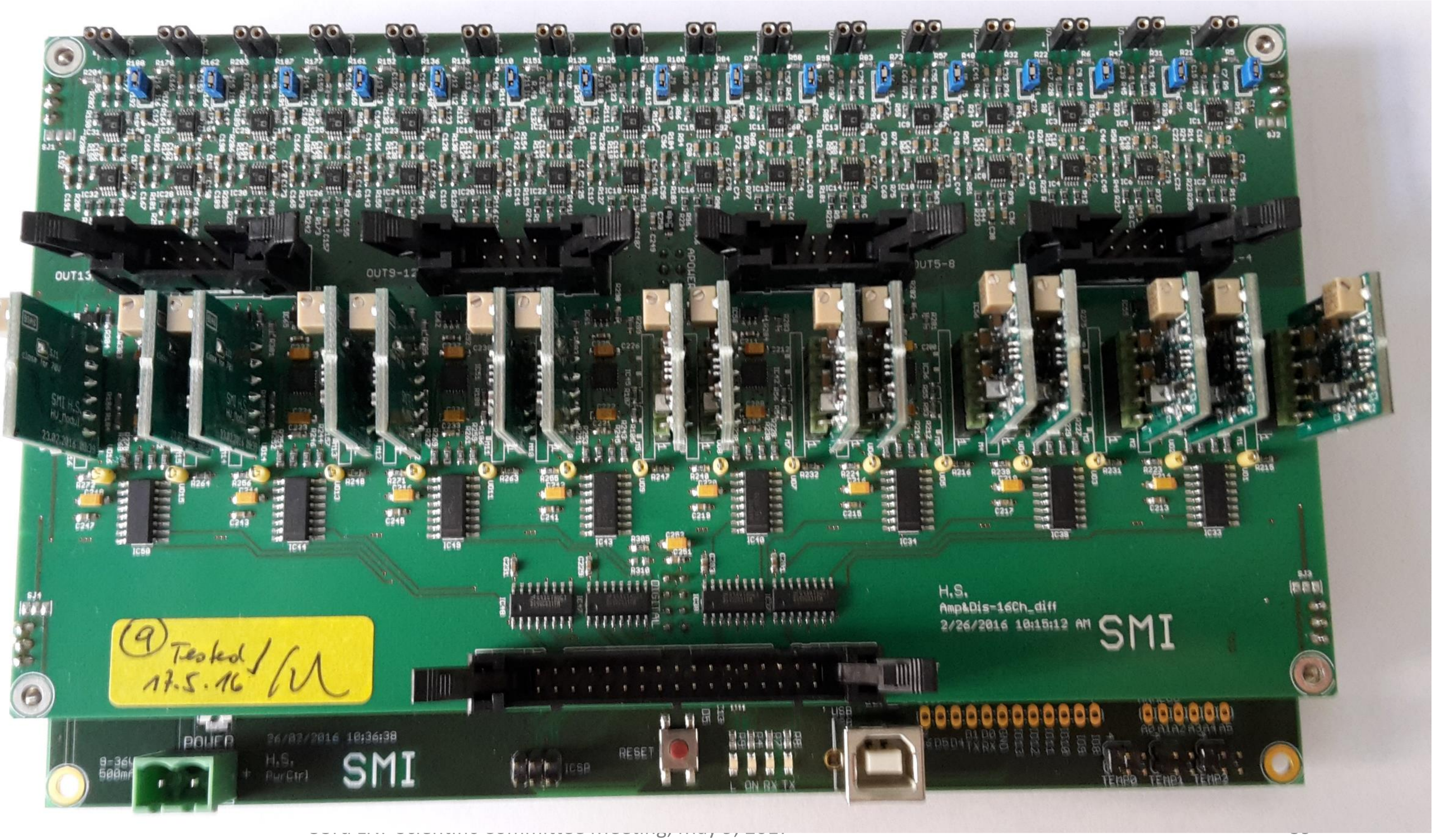


SiPM read-out: the 16-channel IFES board

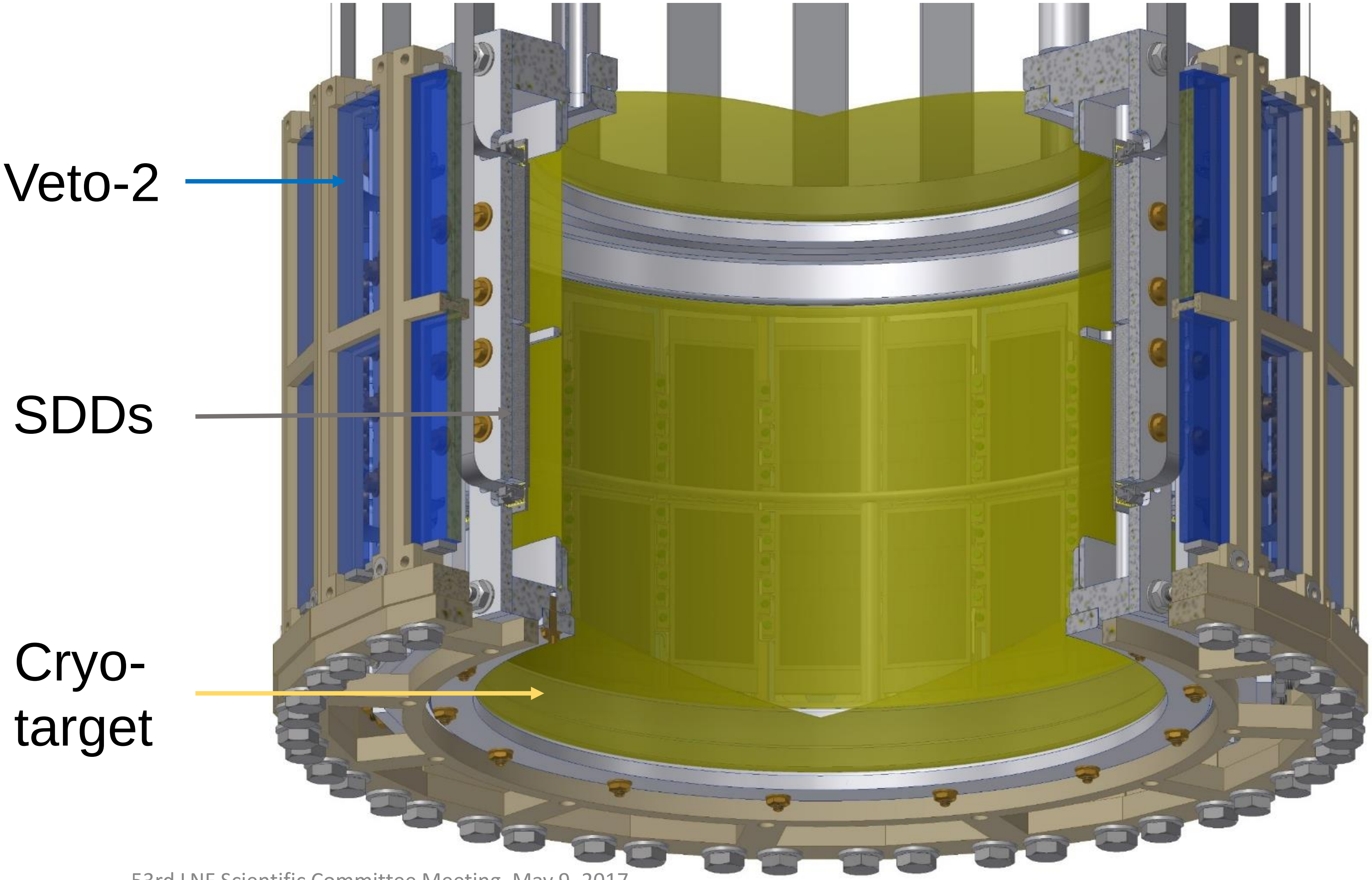
Analogue differential out

Bias voltage boards

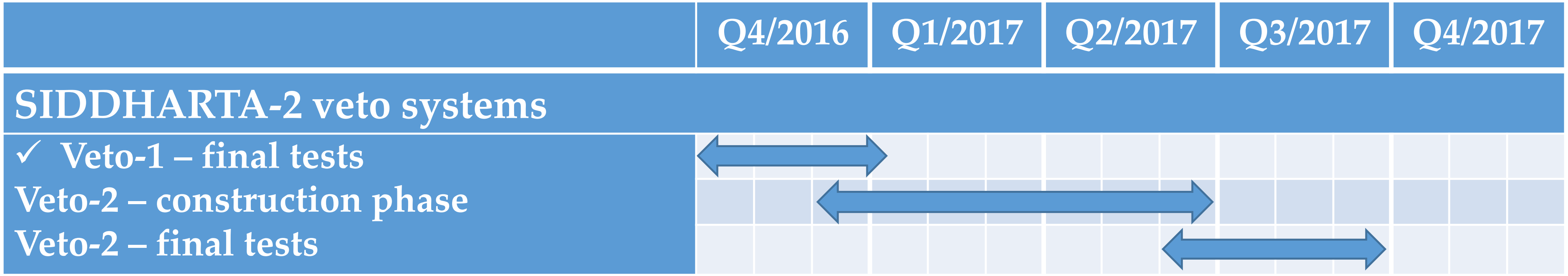
LVDS digital ToT output



Cryogenic target – SDDs – veto-2 arrangement



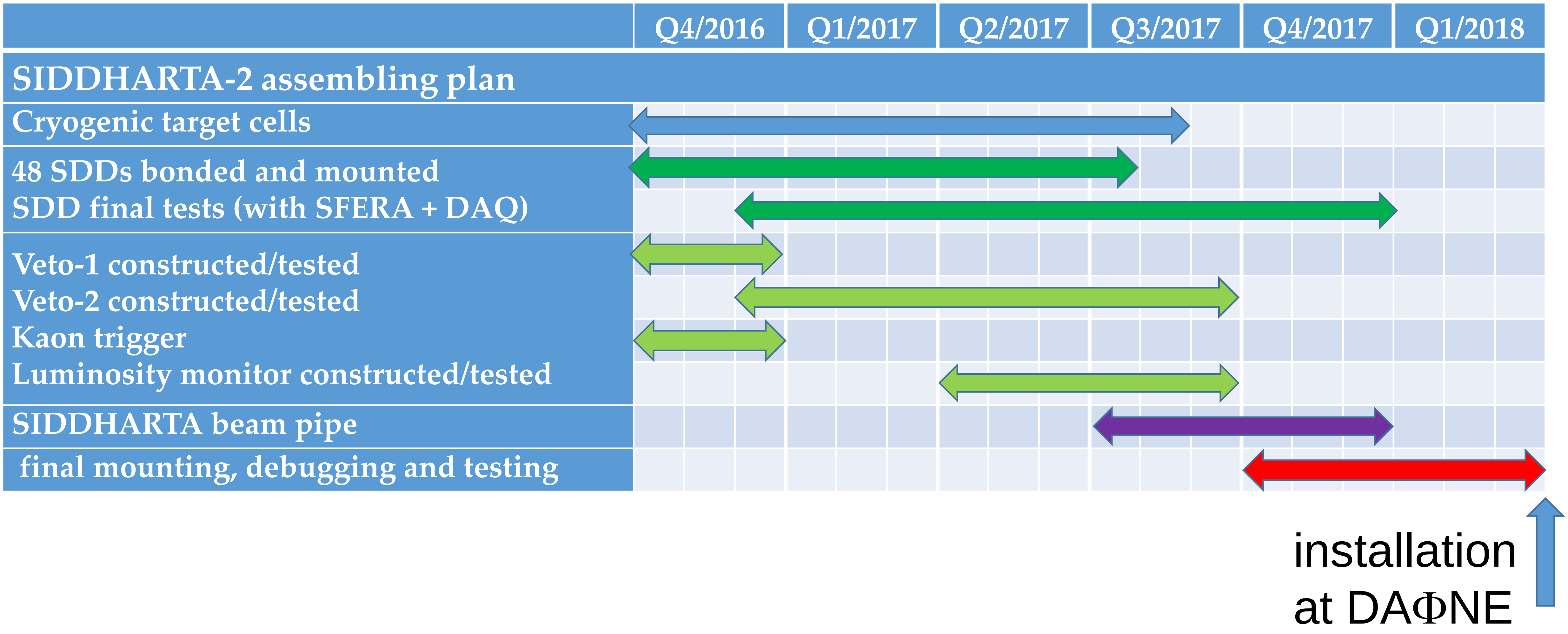
Gantt chart SIDDHARTA-2: Veto systems



SIDDHARTA-2 setup

- Assembling plan
- Installation at DAΦNE

Gantt chart SIDDHARTA-2:

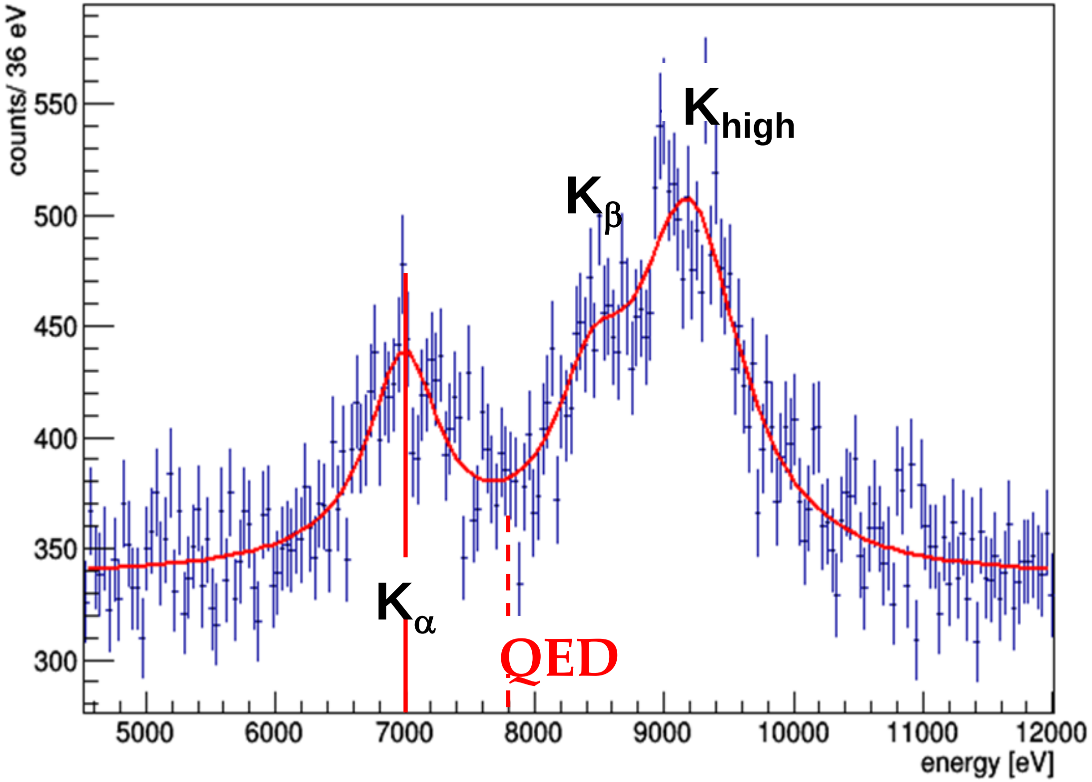


SIDDHARTA-2 plan for the K-d measurement

200 pb^{-1}, to debug and optimize the SIDDHARTA-2 apparatus

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

achievable precision:
shift: 30 eV
width: 75 eV



Plans to secure personal for beam time and analysis is under discussion!

SIDDHARTA-2 future programme and perspectives

- **Other light kaonic atoms (K^-O, K^-C,…)**
- **Heavier kaonic atoms (K^-Si, K^-Pb…)**
- **Kaonic helium transitions to the 1s level**
- **Kaon mass - precision measurement at a level < 7 keV**

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

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

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Thank you !

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