The Strip Detector of the PANDA MVD

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on behalf of the PANDA MVD Group

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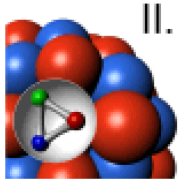


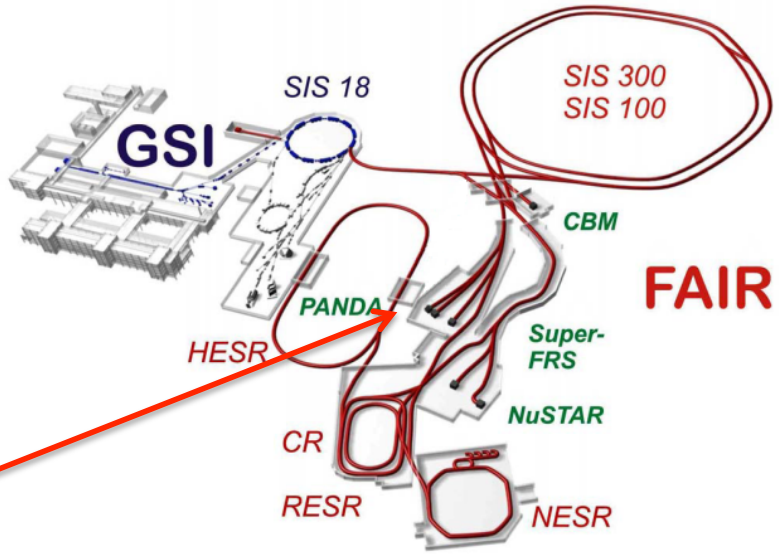
Outline

1. **Design of the PANDA MVD**
   - The PANDA Experiment
   - Disk and Barrel Parts of the Detector
   - Mechanical Integration of the Barrels
   - Powering Concept
2. **Hardware developments**
   - Front-end ASIC
   - Double-sided Silicon Strip Sensors
   - Sensor Irradiations
   - Hybrid Bus

Design of the PANDA MVD

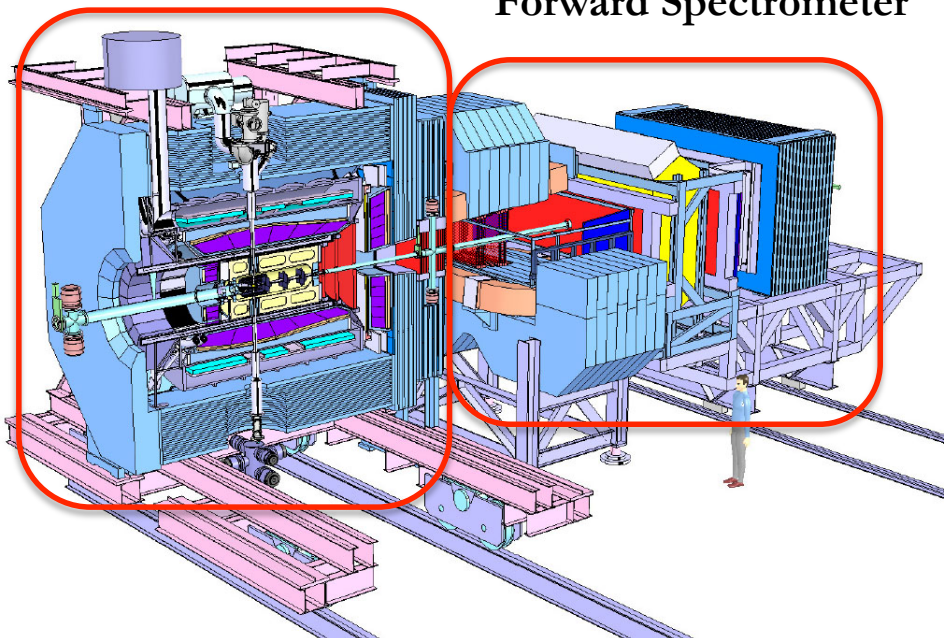
The PANDA Experiment

- Fixed target experiment at FAIR, Darmstadt
- Antiproton beam with p = 1.5 – 15 Gev/c and hydrogen or nuclear target
- Maximum luminosity $2 \cdot 10^{32}$ cm^{-2} s^{-1}; interaction rate $2 \cdot 10^{7}$ s^{-1}
- Continuous, triggerless readout



Target Spectrometer

Forward Spectrometer

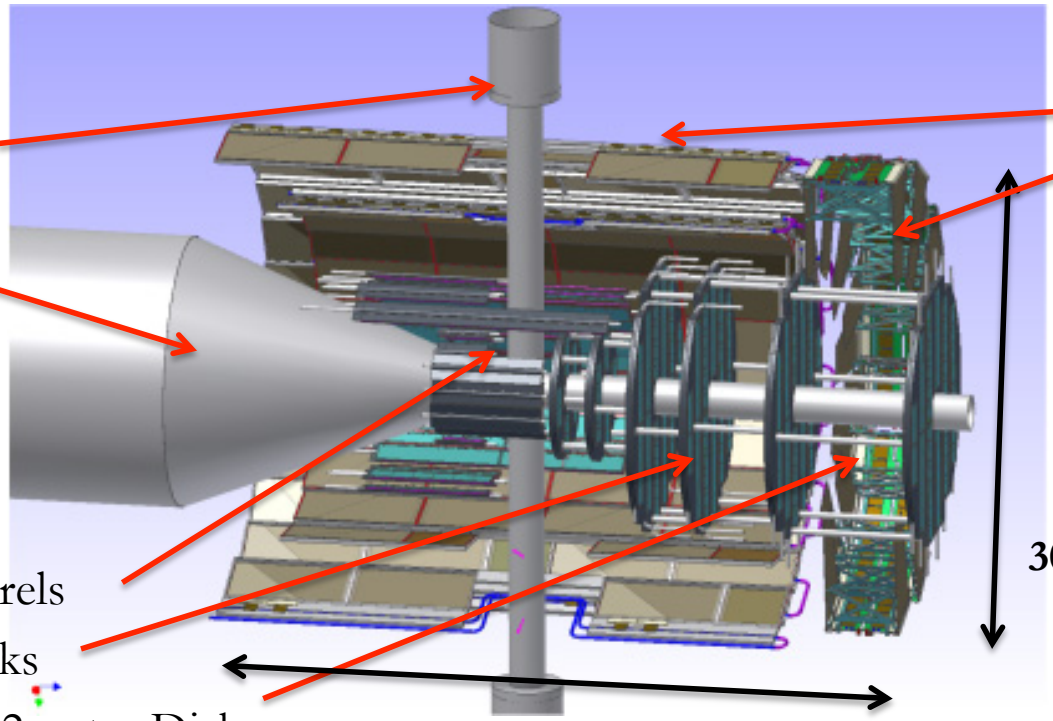


Physics program:

- High precision charmonium spectroscopy
- Search for hybrids and glueballs
- Study of exotic states (X, Y, Z)
- Nucleon structure
- Hyper-nuclear physics

The Micro Vertex Detector

- High resolution (<100 μm) vertexing; good time resolution (<6 ns)
- Radiation tolerance up to ~$4 \cdot 10^{14}$ $n_{1MeV\ eq}$ /cm^2
- High rate capability ($2 \cdot 10^7$ pbar-p annihilations/s) and triggerless readout
- Low material budget (<10% radiation length overall)



Double-sided Strip Part:

- 2 Outer Barrels
- Part of the 2 outer Disks

~ $2 \cdot 10^5$ channels,
0.5 m^2 silicon area

Hybrid Pixels Part:

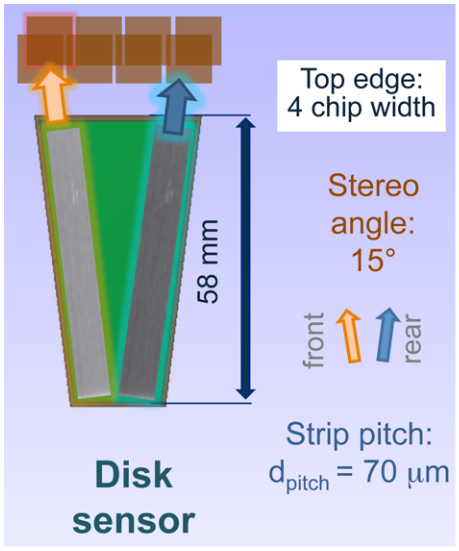
- 2 Inner Barrels
- 4 Inner Disks
- Part of the 2 outer Disks

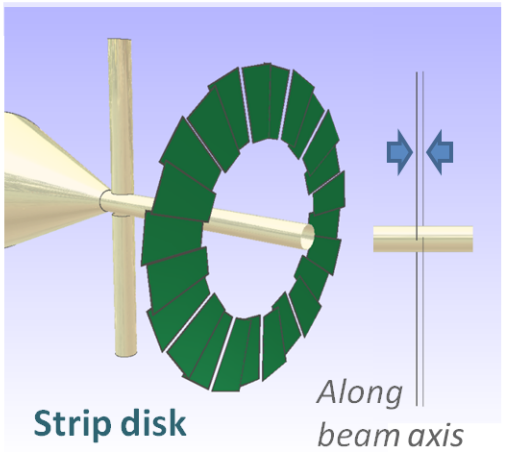
~ 10.5 $\cdot 10^6$ channels, 0.1 m^2 silicon area

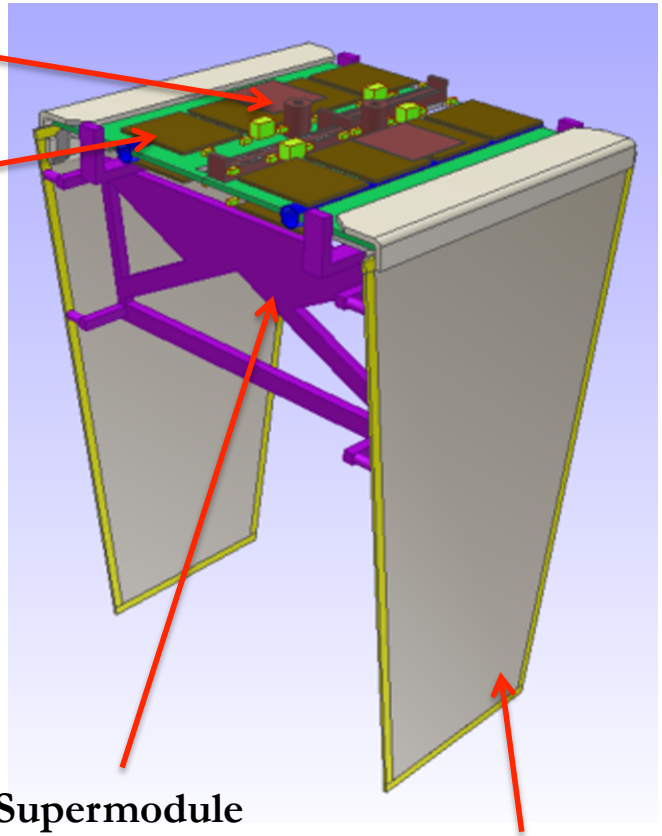
Strip Disks

Disk part:

- Trapezoidal sensors
- Stereo angle: 15°
- Strip pitch: 67.5 μm
- 512 channels per side
- Supermodule: two corresponding sensors on the two disks
- 2 disks at z = 155 and 215 mm, 24 sensors per disk



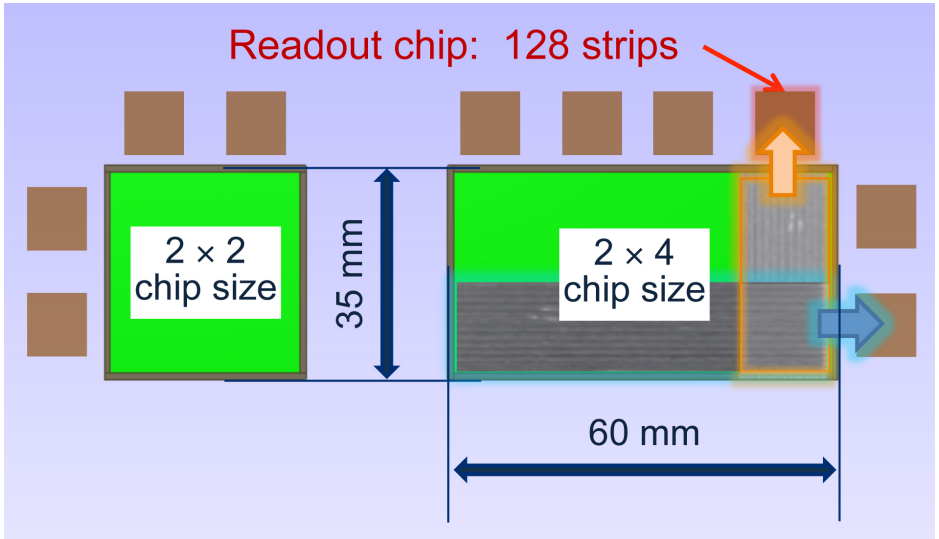


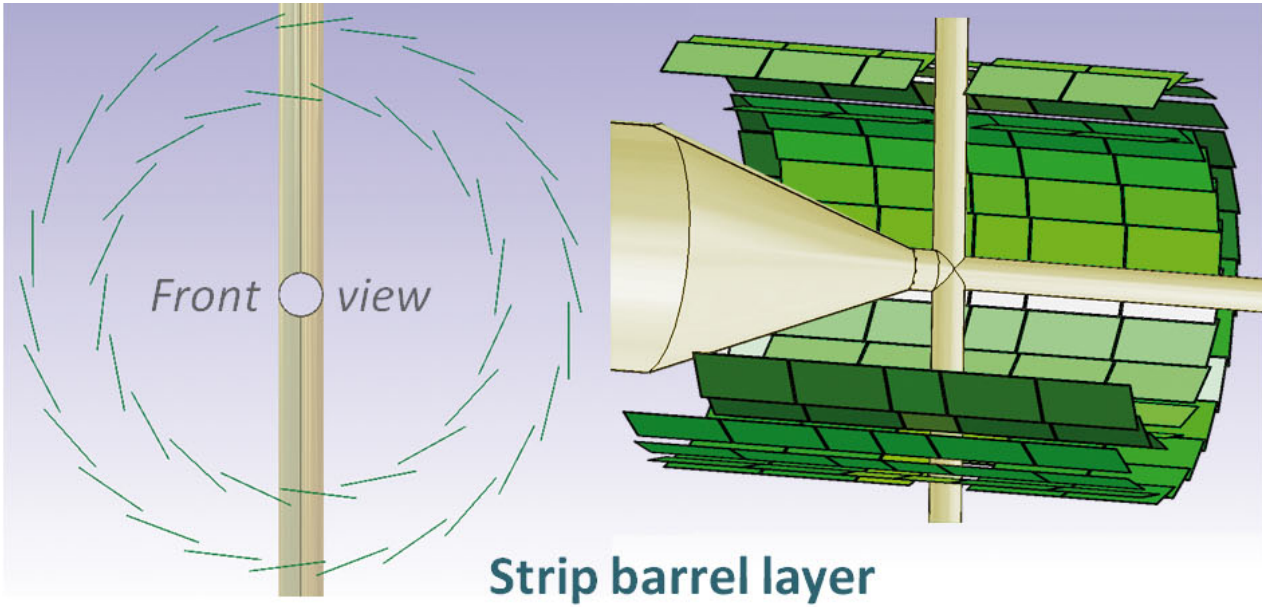


Strip Barrels

Barrel part:

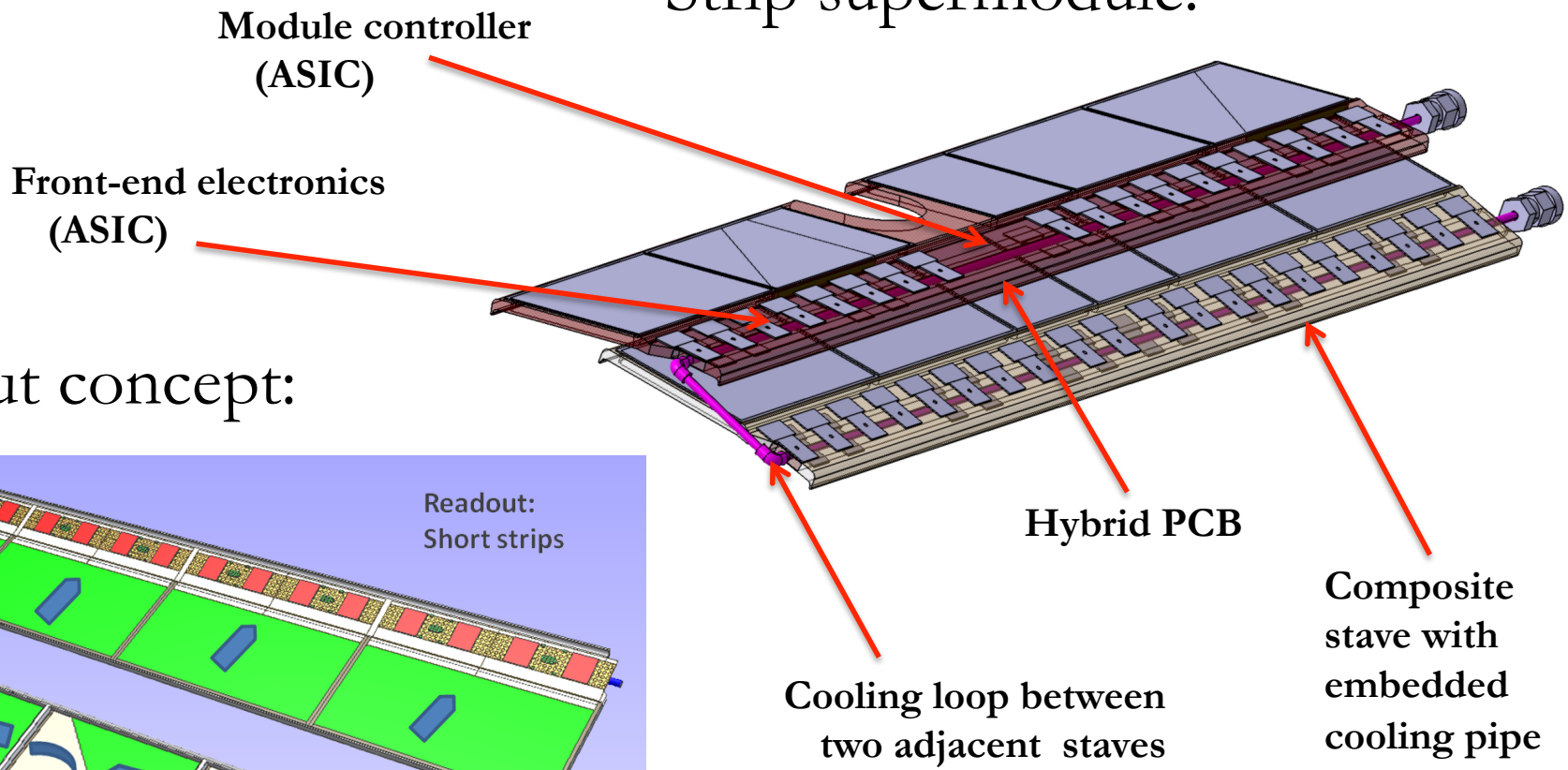
- Rectangular (512 × 896 channels) and squared (512 × 512 channels) sensors
- Stereo angle: 90°, strip pitch 65 μm
- Two barrels at r = 92 and 125 mm
- 4 – 6 sensors on each of the 46 staves (248 sensors in total)



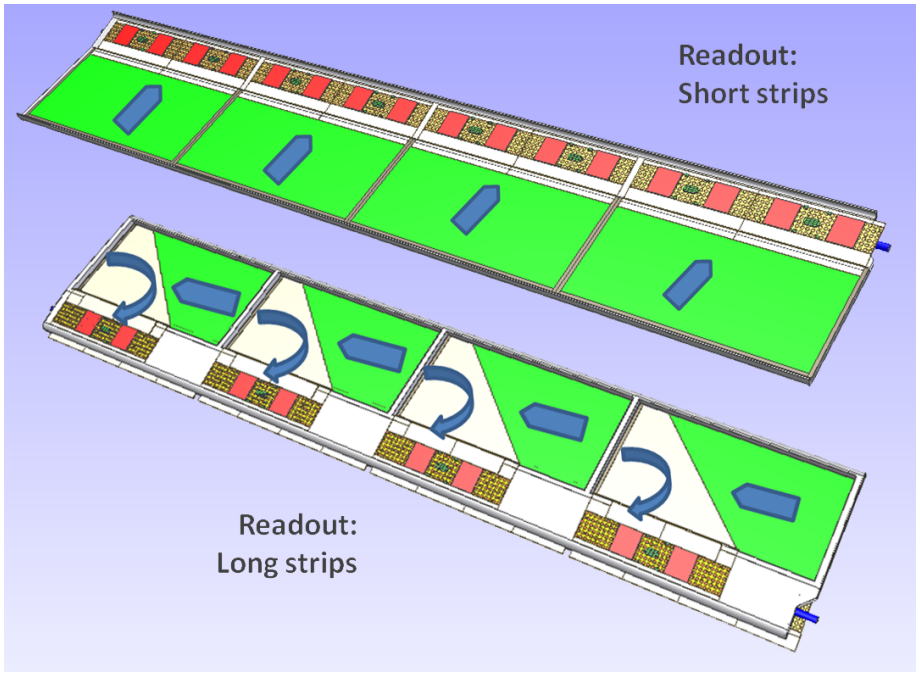


Strip Barrels – Stave Design I

Strip supermodule:

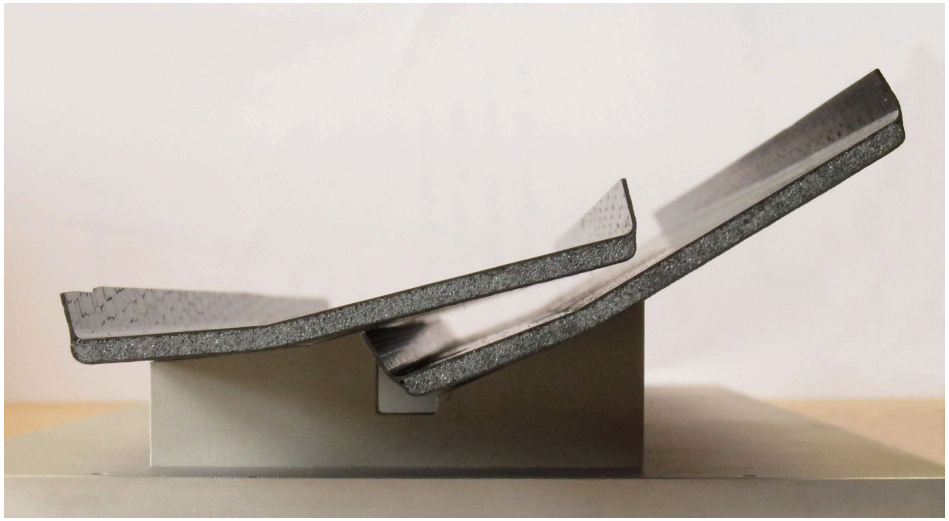


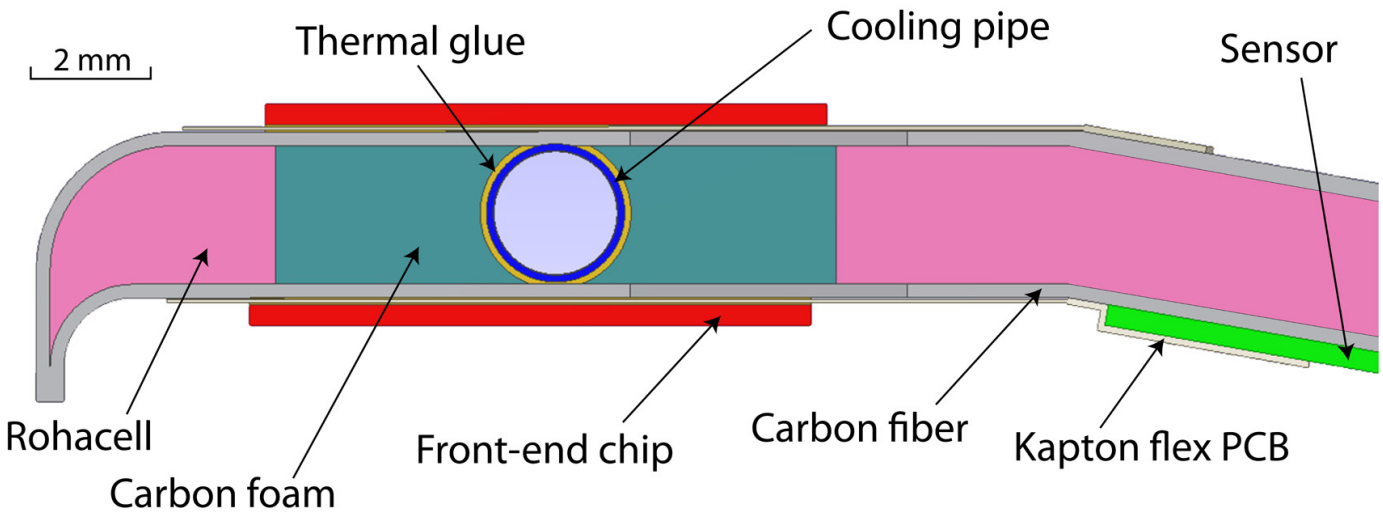
Readout concept:



Strip Barrels – Stave Design II

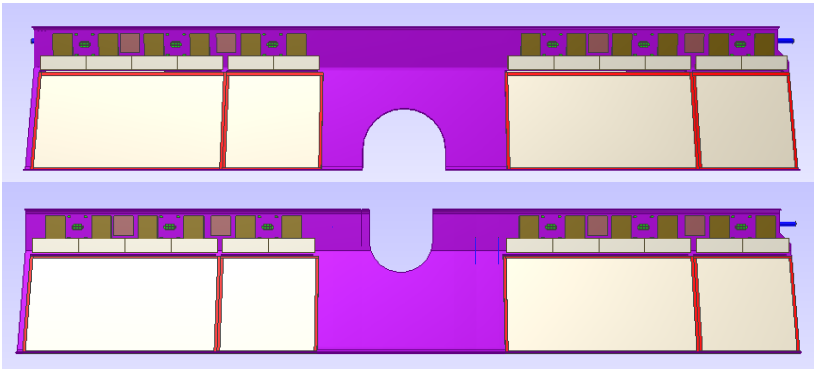
- Sandwich structure of carbon fiber (200 μm) and foam (2 mm)
- Up to 18 W dissipated on one stave → active water cooling
- Embedded cooling pipe in nickel-cobalt alloy (2 mm diameter, 80 μm wall thickness)
- Carbon foam (POCO HTC) in the area around the cooling pipe



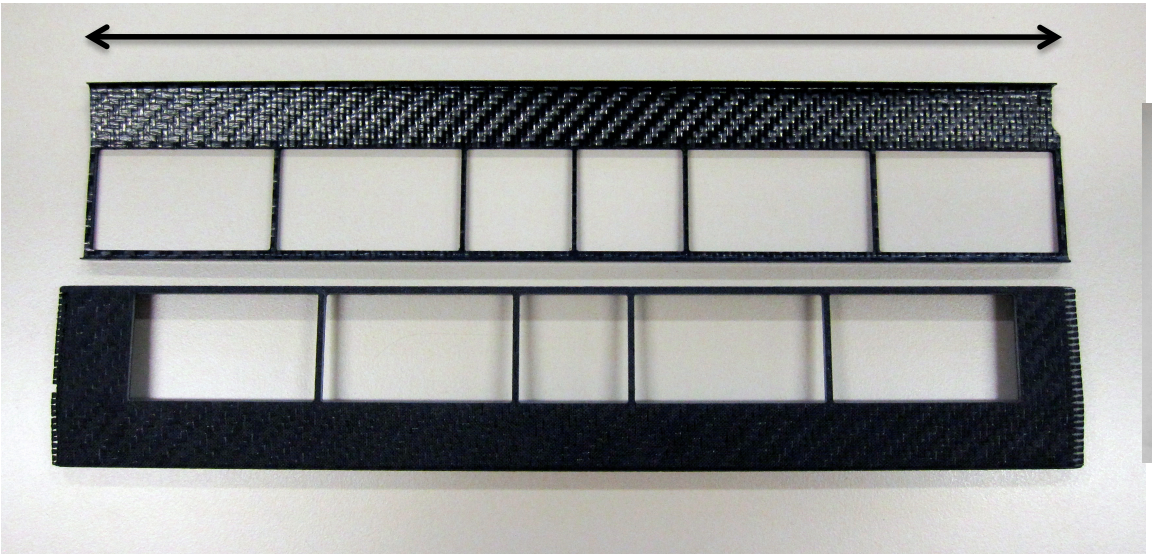


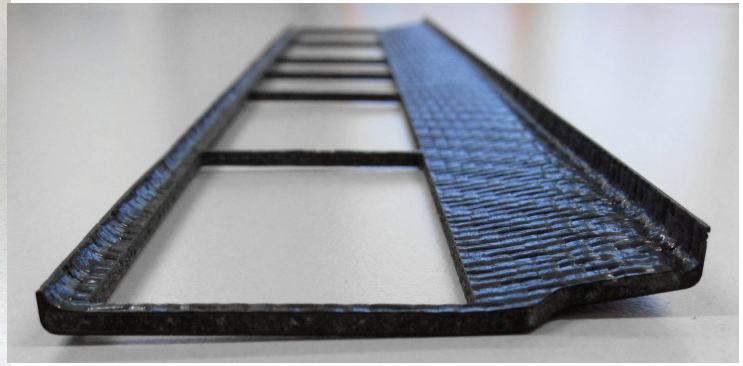
Strip Barrels – Stave Design III

- Large cutouts for the sensors
- Special design for top/bottom staves around the target pipe
- 6 different designs in total



31.3 cm

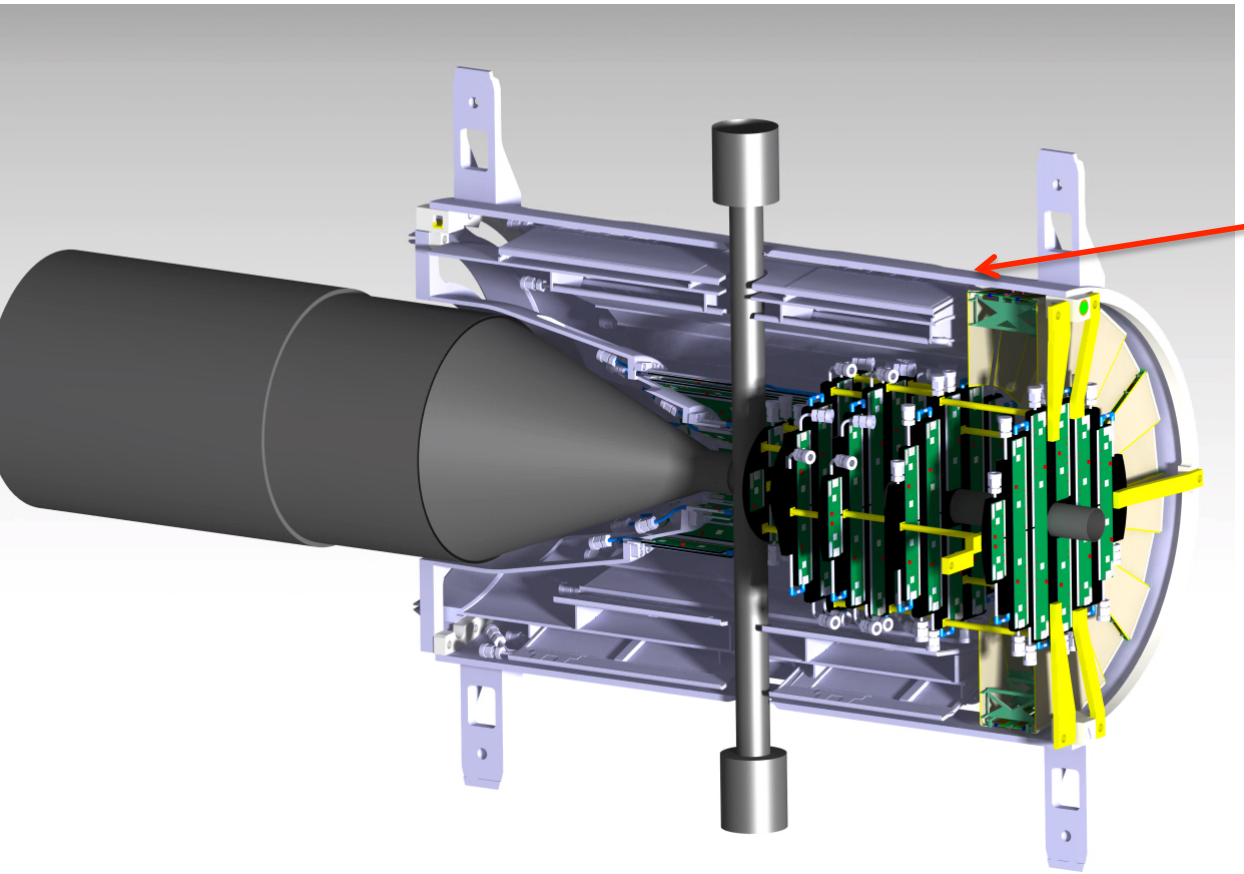




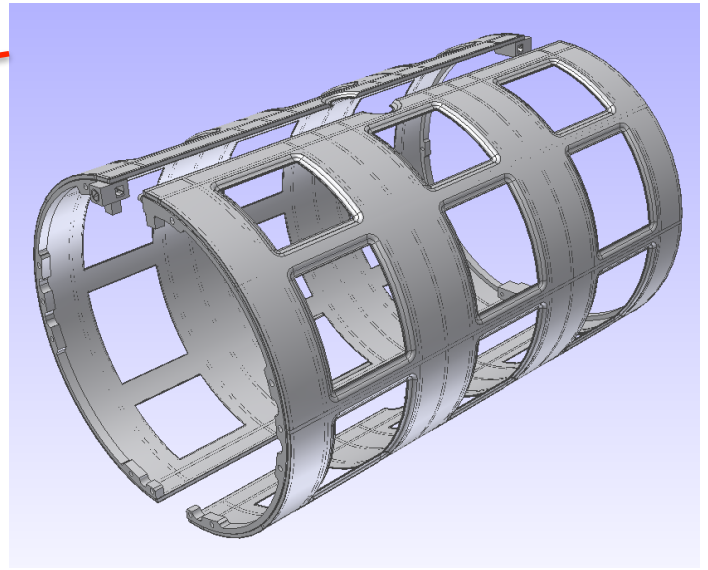
~6 cm

- Waiting for a prototype complete with cooling pipe to perform thermal tests

Mechanical Integration

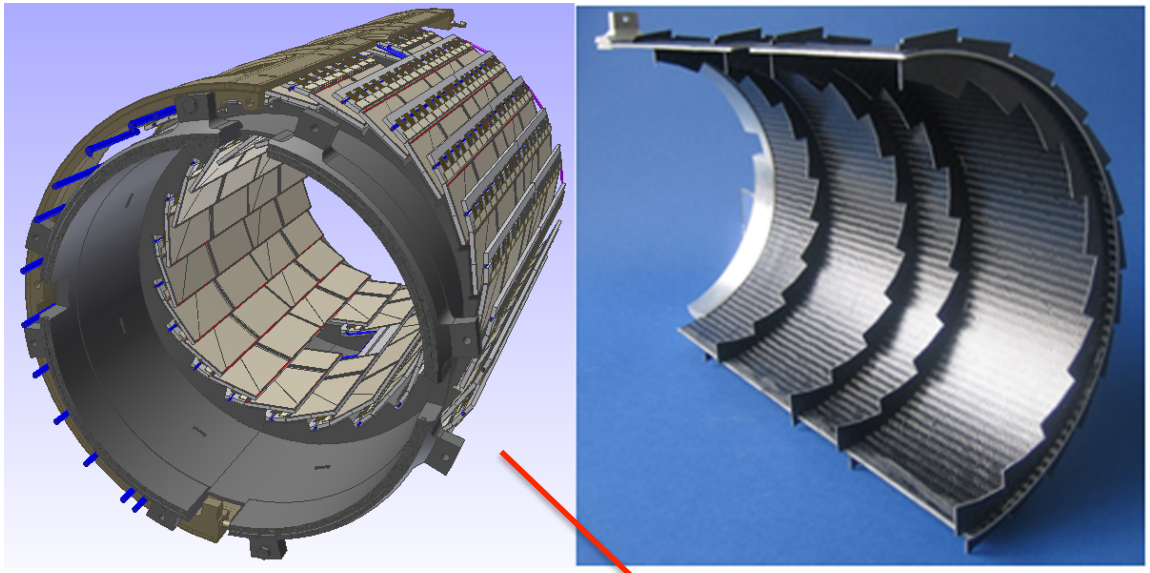


Complete half-detector

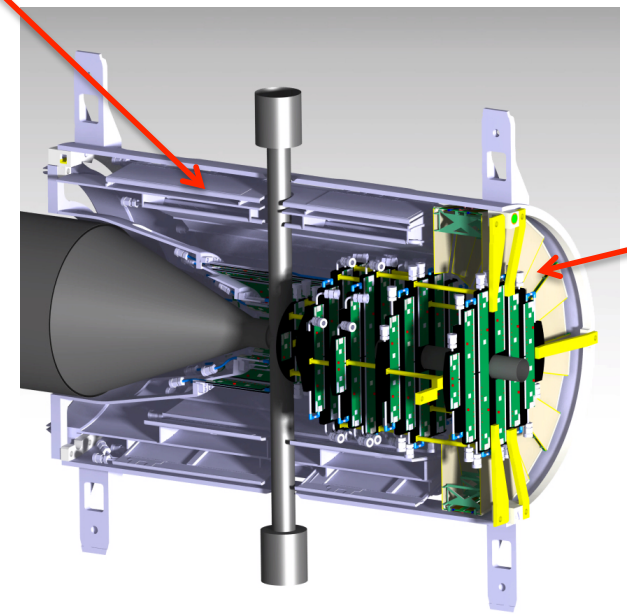


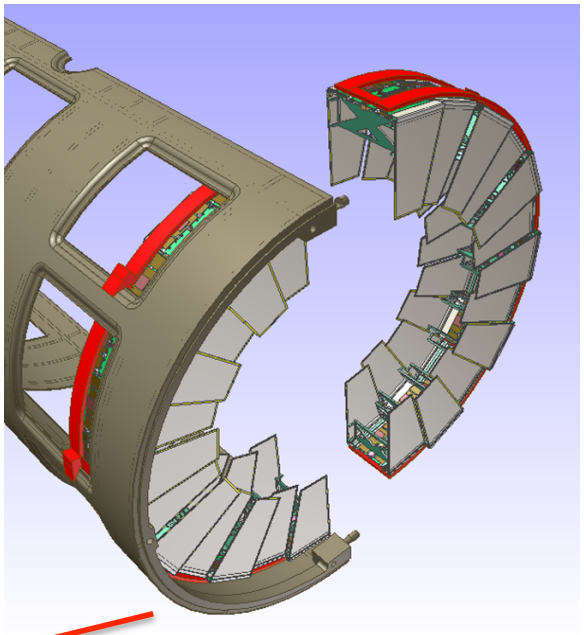
Global frame

Mechanical Integration – Strips



Barrel part

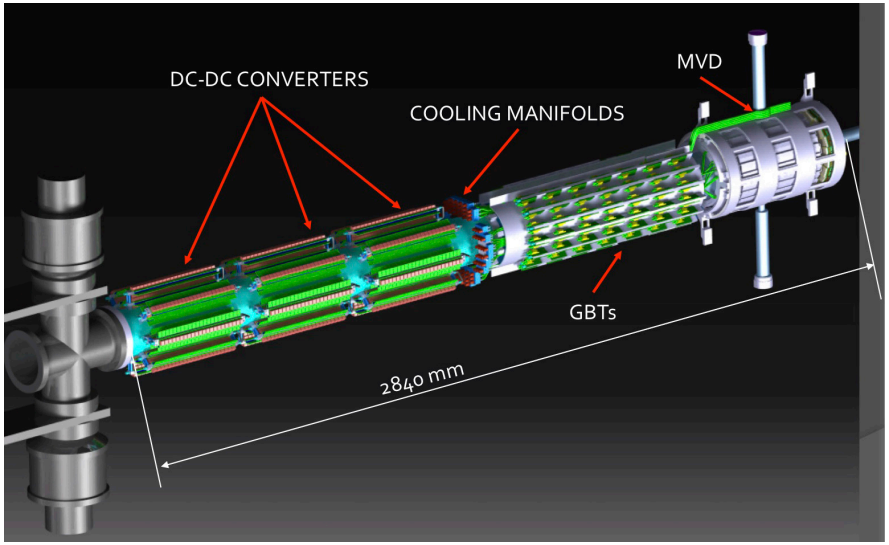


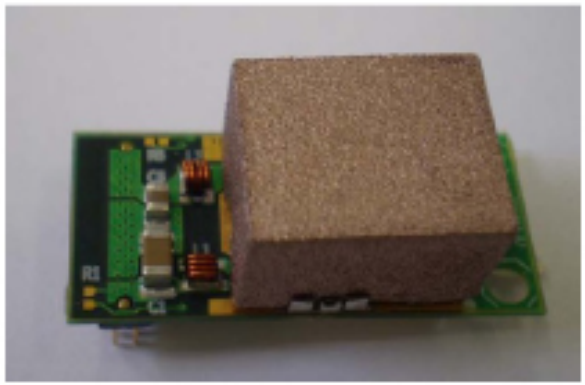


Disk part

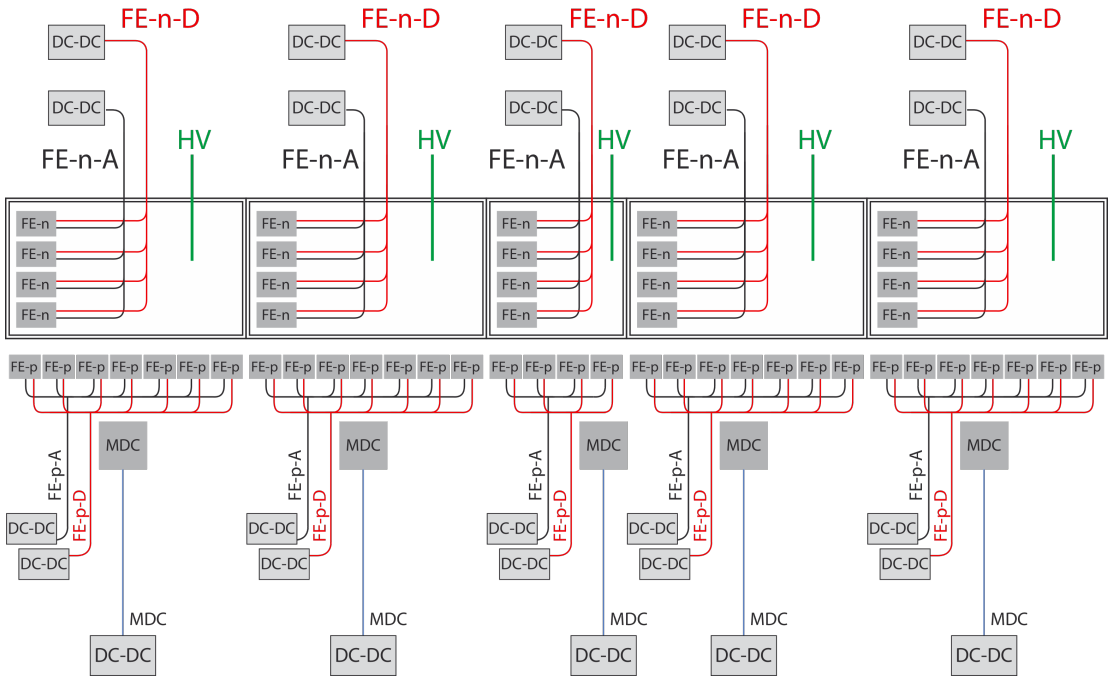
Strip Stave Powering

- DC-DC powering operating in B=2T
- 5 power domains per sensor
- up to 60 power supply cables per strip barrel stave (up to 4 m long)
- ~1500 converters for barrels + disks (+600 for pixel detector)
- MVD services routing is a crucial issue





SM01C converter (CERN development)



Hardware development

Front-end ASIC – I

Requirements to the strip front-end:

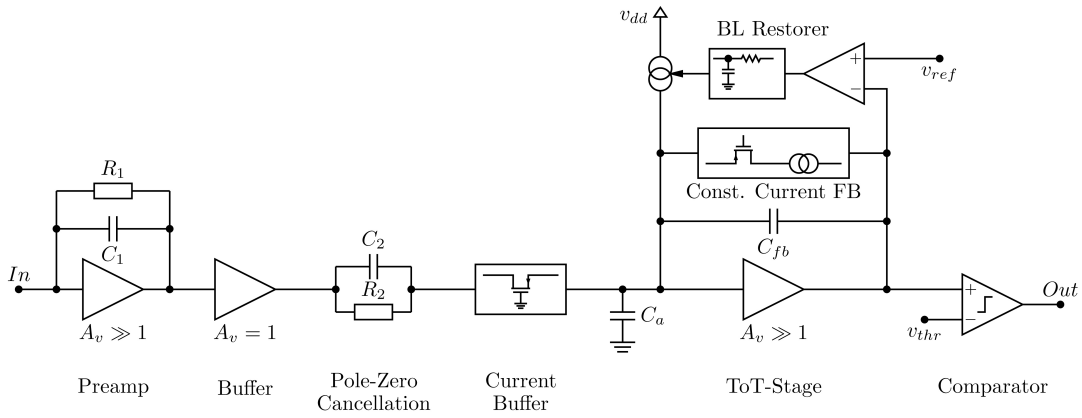
- Self-triggering
- Radiation hard up to 10 Mrad
- Power budget 1W/cm^2
- Charge measurement
- Input rate up to 40 kHz
- Noise <1500 e$^-$
- Fully digital outputs
- Sensor capacitance at the input ~20 pF

→ no chip available on the market which satisfies all these requirements

Front-end ASIC – II

New strip ASIC:

- Developed by INFN Torino with JLU Gießen and FZ Jülich
- Front-end adapted from ToPix (modified for larger input capacitance)
- Amplitude measurement with the Time-over-Threshold technique
- High resolution (~100 ps) time digitization with TDCs adapted from TOFPET
- Clock frequency 155.52 MHz
- Power budget: ~4 mW / ch



First submission expected in some months

Sensor Characterization – Prototypes

Wafer properties:

- Fabricated at CiS, Germany
- FZ Si, 4” wafer
- Thickness: 285 ± 10 µm
- Resistivity: 2.3 … 5 kΩ · cm
- Biasing: punch-through
- n-side insulation: p-spray

S1 (PANDA rectangular)

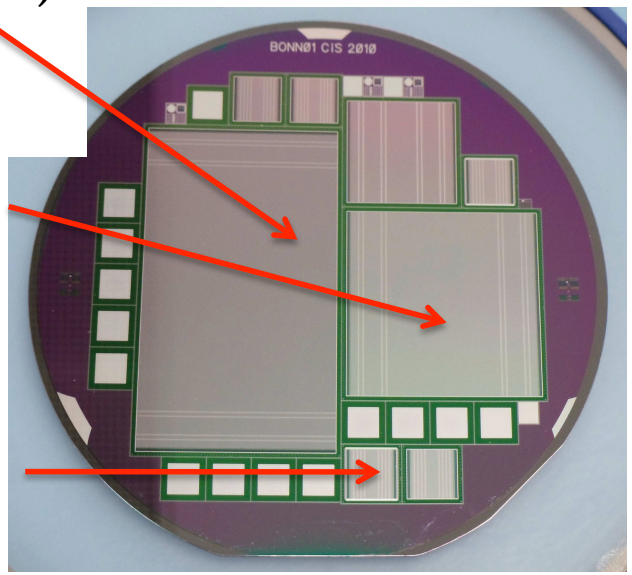
- 896 × 512 channels
- 58.3 × 33.3 mm^2

S2 (PANDA squared)

- 512 × 512 channels
- 33.3 × 33.3 mm^2

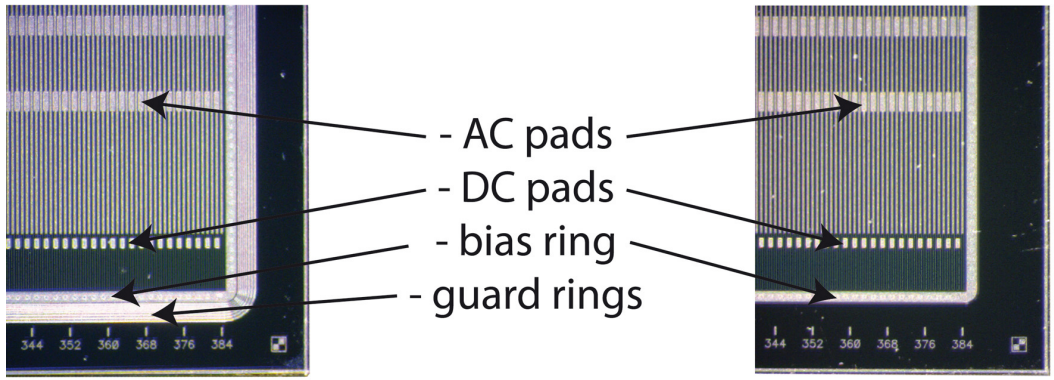
S4 (“Baby”)

- 128 × 128 channels
- 8.4 × 8.4 mm^2



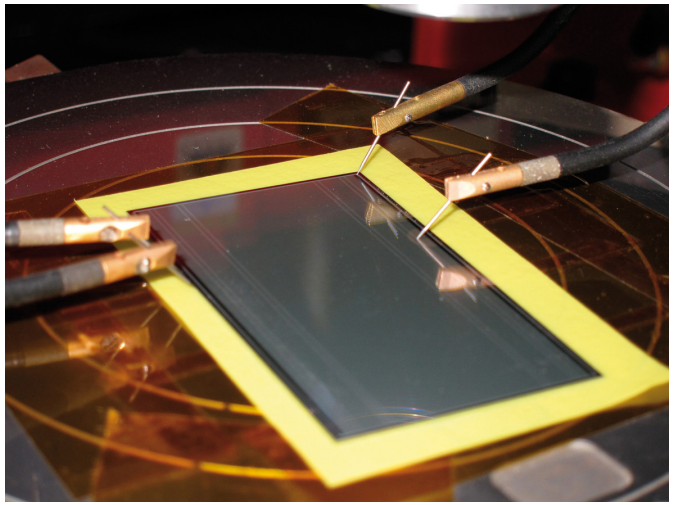
General sensor properties:

- Stereo angle: 90°
- Guard rings: 8
- Pitch: 65 µm or 50 µm
- Readout: 1 DC pad and
  4 AC pads per strip

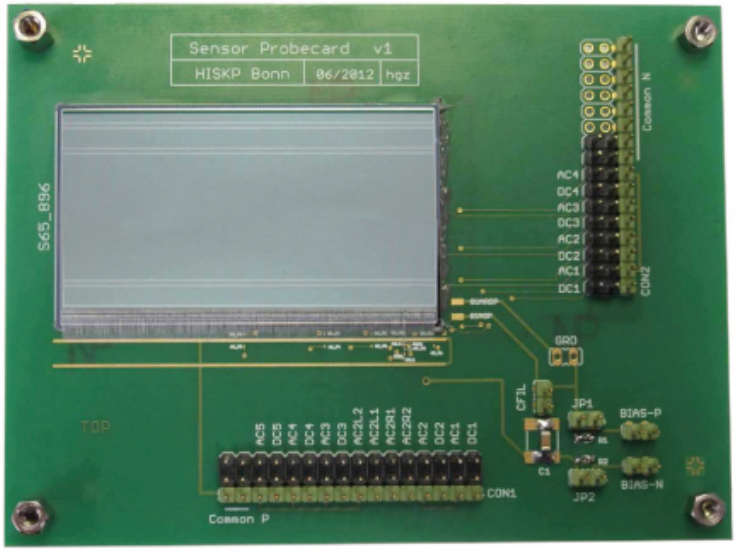


See T. Quagli et al., IEEE NSS CR N14(219) (2012) 1365-1369

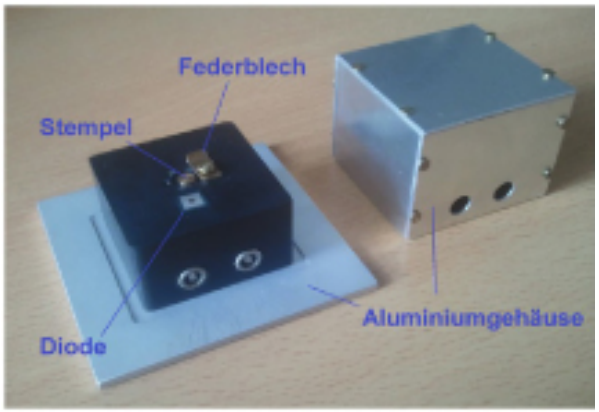
Sensor Characterization – Setup



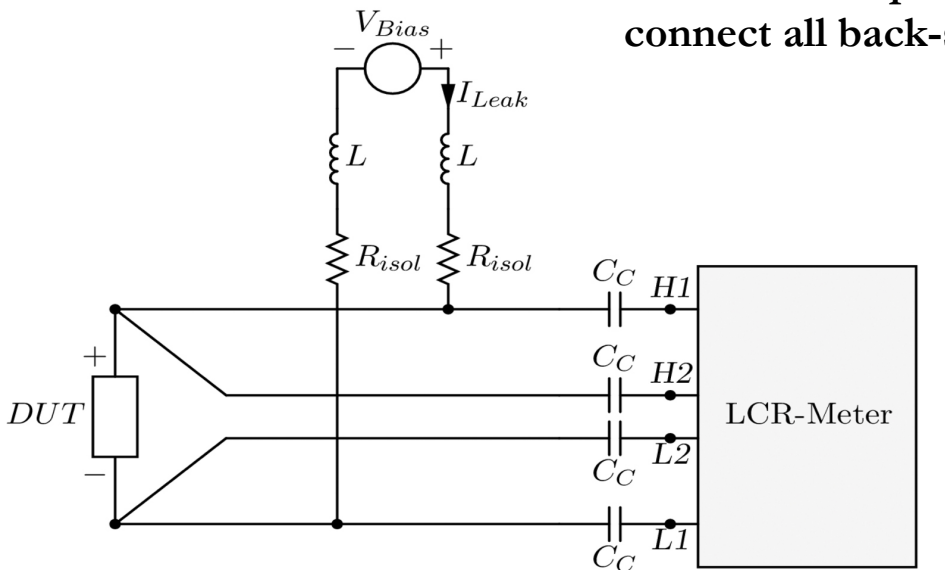
Probe station



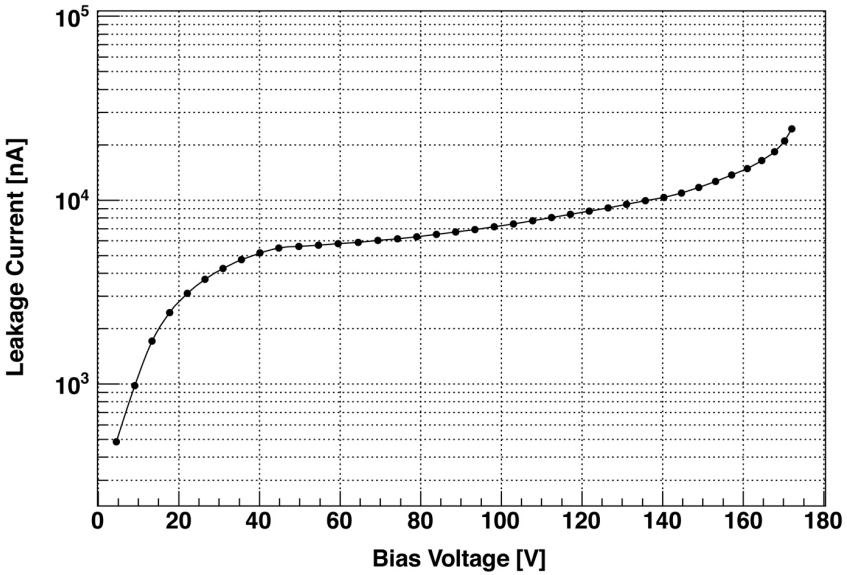
Fixed contact probe-card to connect all back-side strips



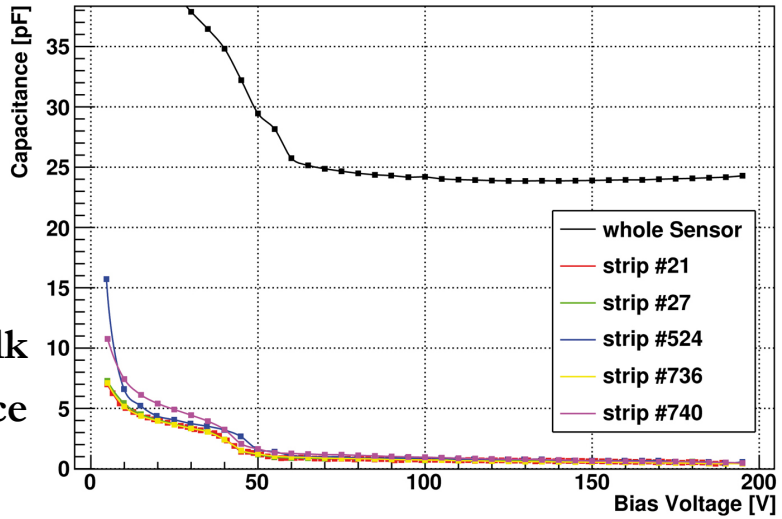
Test enclosure for connection of diodes



Sensor Characterization – S1 Sensor

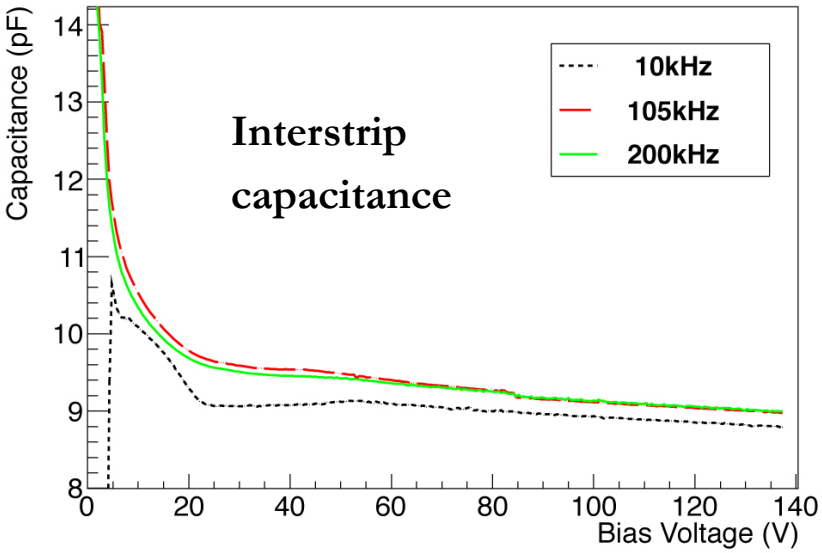


Leakage current



Strip-to-bulk capacitance

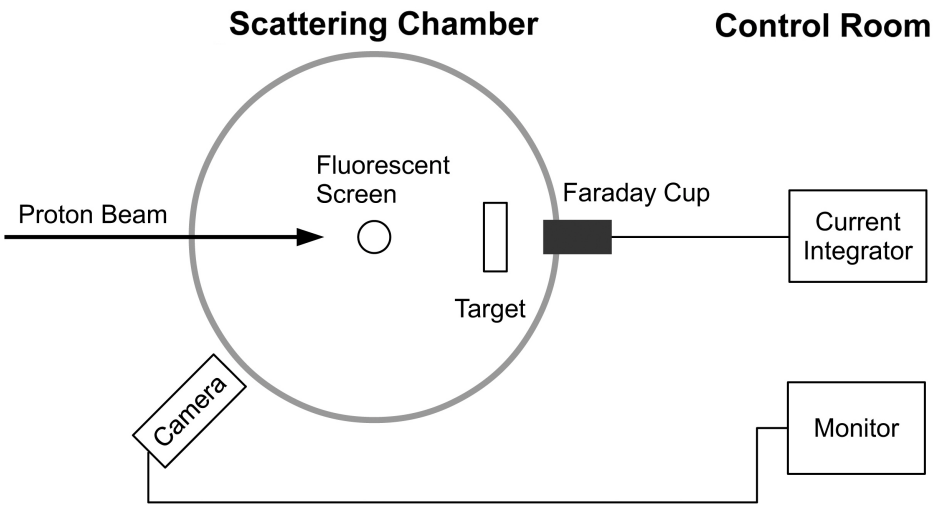
Parameter	Measurement
Full depletion voltage	~ 55 V
Leakage current	~ 6μA @ 50 V
Bulk capacitance	680 pF
Interstrip capacitance	~ 10 pF @ 50 V
Coupling capacitance	> 45 pF/cm
C_{input}	9.8 ± 0.2 pF (p-side) 17.1 ± 0.4 pF (n-side)

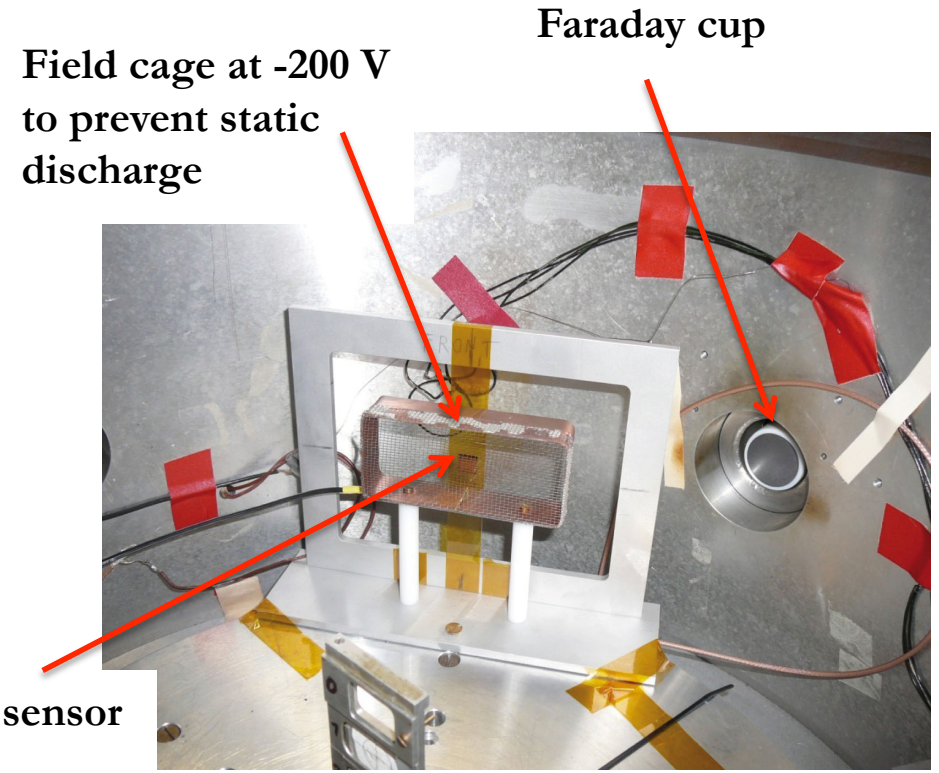


Sensor Irradiations – I

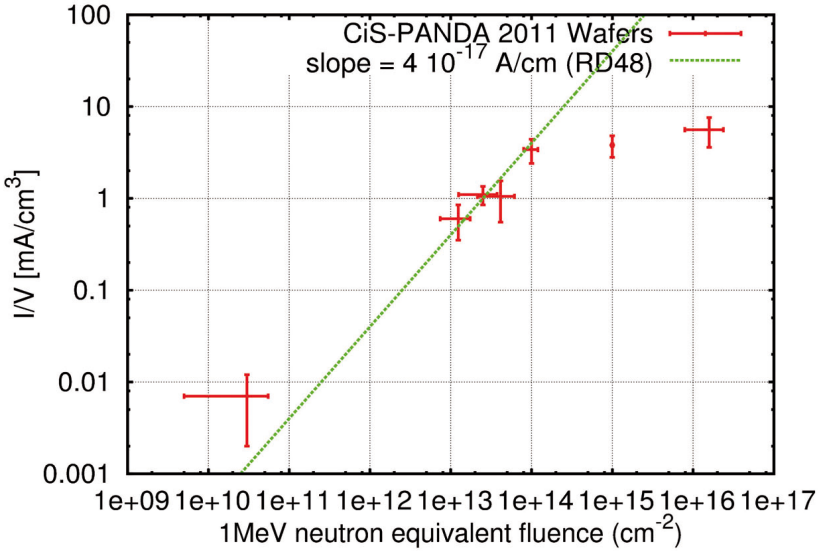
Irradiation studies on S4 ("Baby") sensors

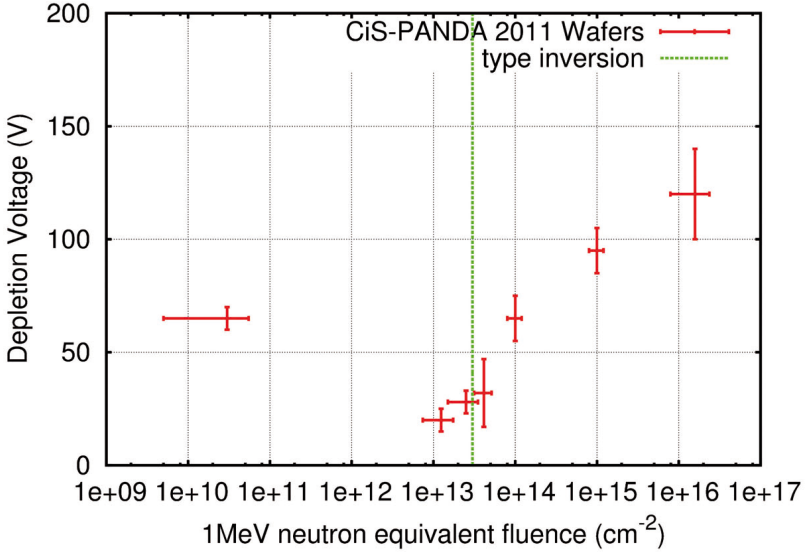
- Proton irradiations at the Bonn Isochronous Cyclotron
  → fluence between 10^{13} and 10^{15} n 1MeV eq /cm^2
- Neutron low-fluence ($3 \cdot 10^{10}$ n 1MeV eq /cm^2) irradiation with Am-Be source
- Neutron high-fluence ($1.6 \cdot 10^{16}$ n 1MeV eq /cm^2) irradiation at research reactor in Delft
- Annealing phase (80 minutes at 60°C)



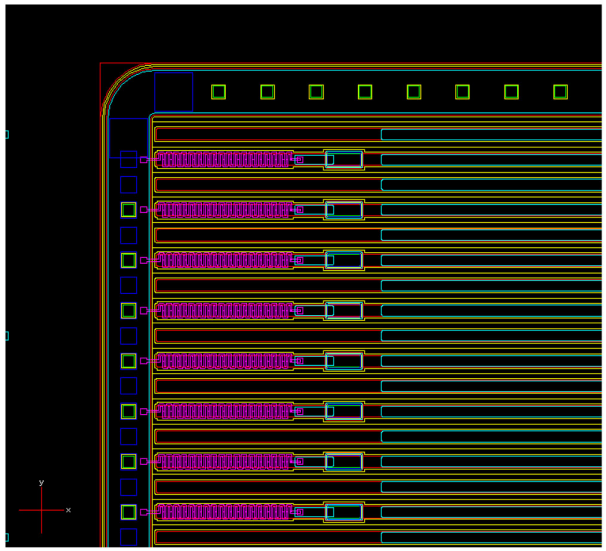


Sensor Irradiations – II

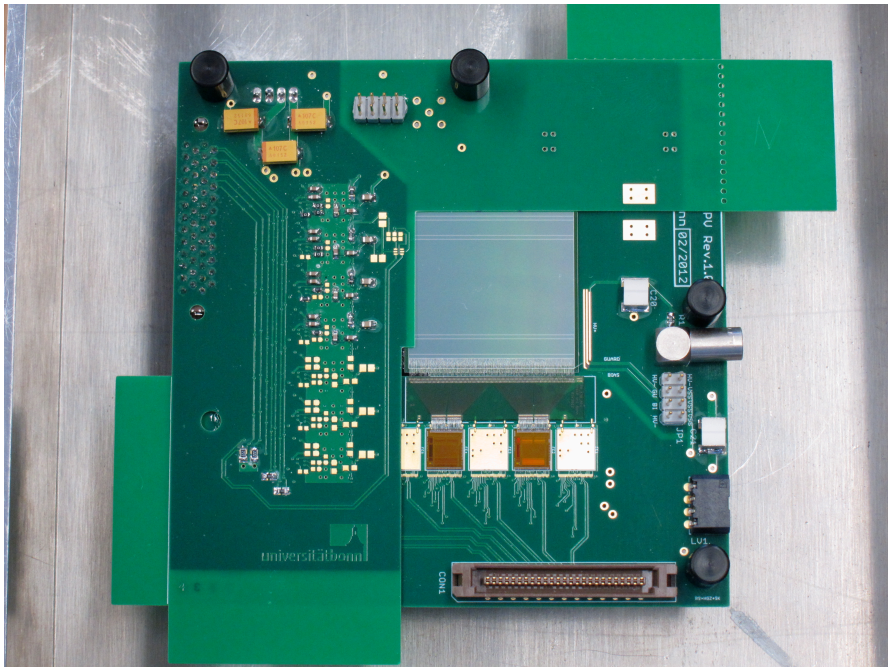




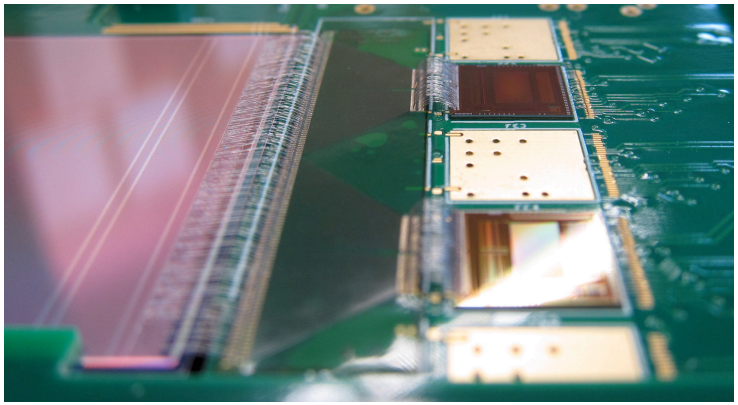
- Full depletion voltage remains below 100 V at end of PANDA lifetime
- New sensor batch with polysilicon biasing is coming soon

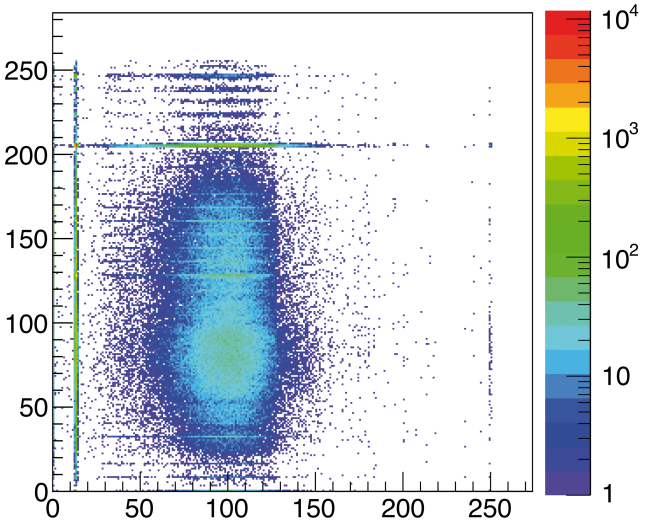


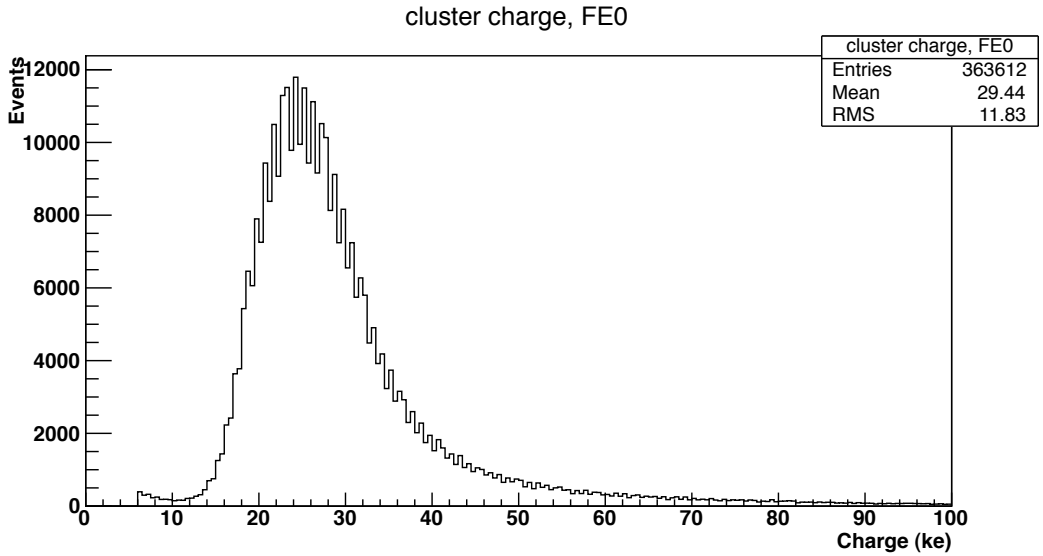
Sensor Characterization – Beam Test



Squared sensor assembled on a test board and successfully tested at SPS, CERN (September 2012)

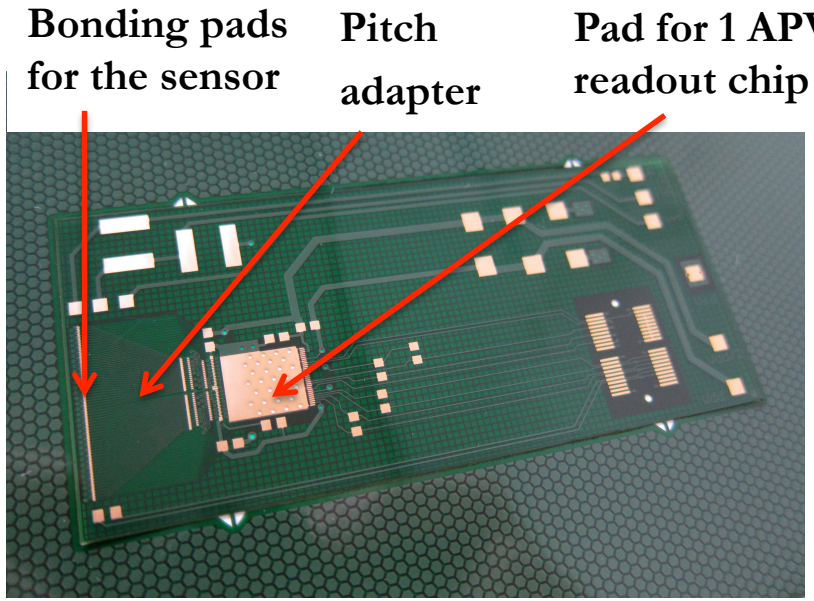


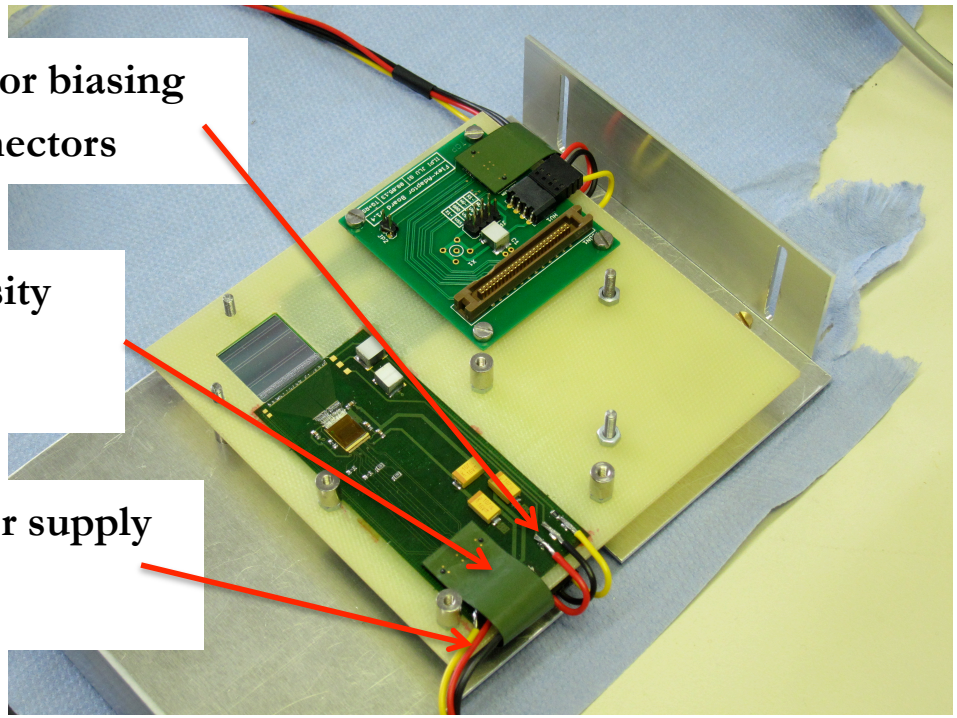




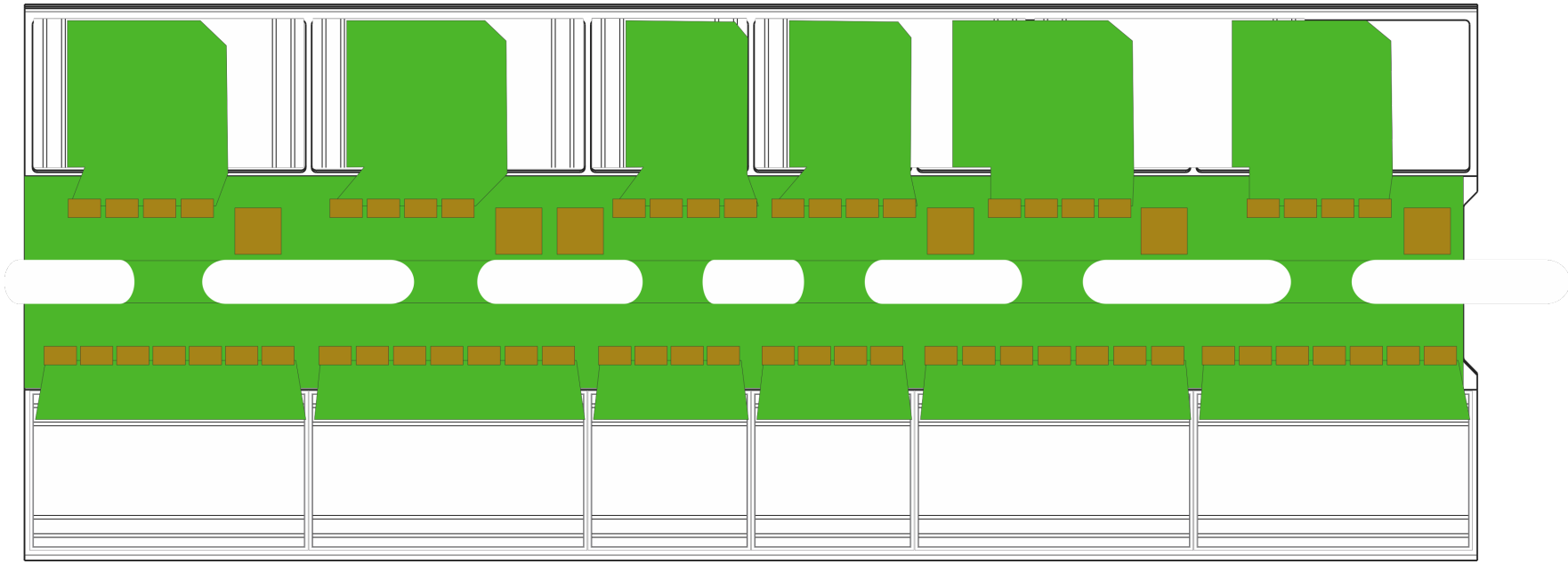
Strip Barrels – Hybrid Bus

- Connects the sensor and the front-end chips, adapting the pitch
- Distributes I/O signals (and possibly power) to the chips
- Reduced-scale prototype with APV25 readout chip produced



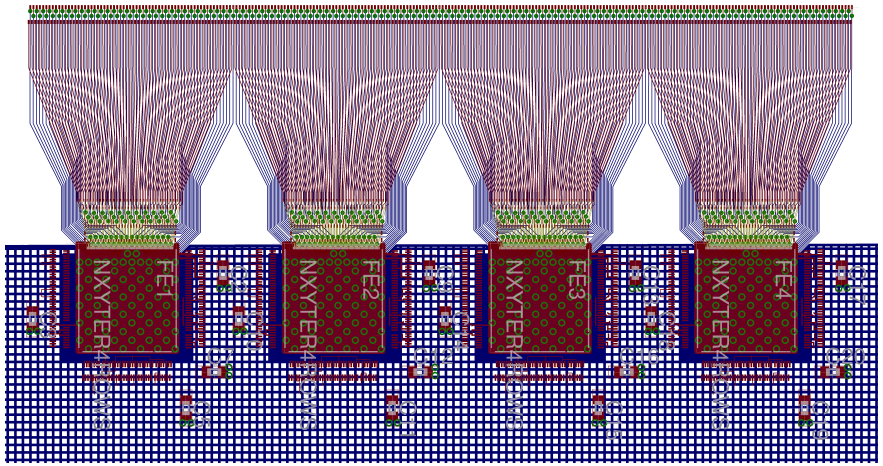


Strip Barrels – Hybrid Bus II



Proposal for the full hybrid layout

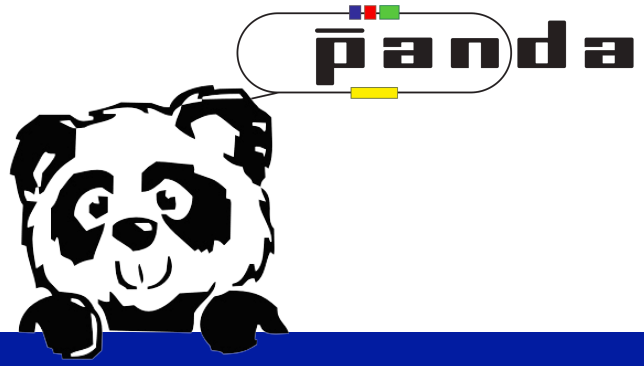
Chips-sensor fanout structure



Conclusions and Outlook

- **The general design of the PANDA MVD is finalized.**
- **Development and validation of components is ongoing:**
  - Front-end electronics under design;
  - First batch of sensors fully characterized;
  - Reduced-scale hybrid produced and under test.

- **Some future steps:**
  - Development of the readout chip;
  - Characterization of the new sensor technology;
  - Design and test of a full-scale hybrid;
  - Validation of the stave cooling system.



Thank you for your attention!

GEFÖRDERT VOM

Bundesministerium
für Bildung
und Forschung

HGS-HIRe for FAIR
Helmholtz Graduate School for Hadron and Ion Research

FAIR

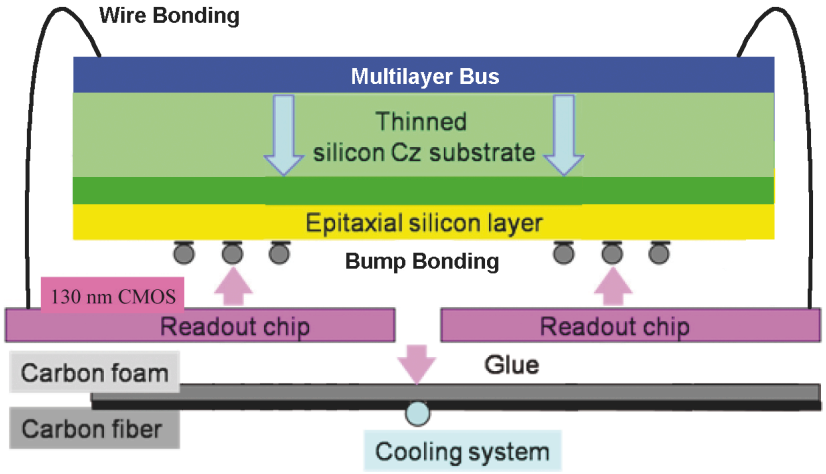
MVD
panda

JUSTUS-LIEBIG-
UNIVERSITÄT
GIESSEN

II. Physikalisches
Institut

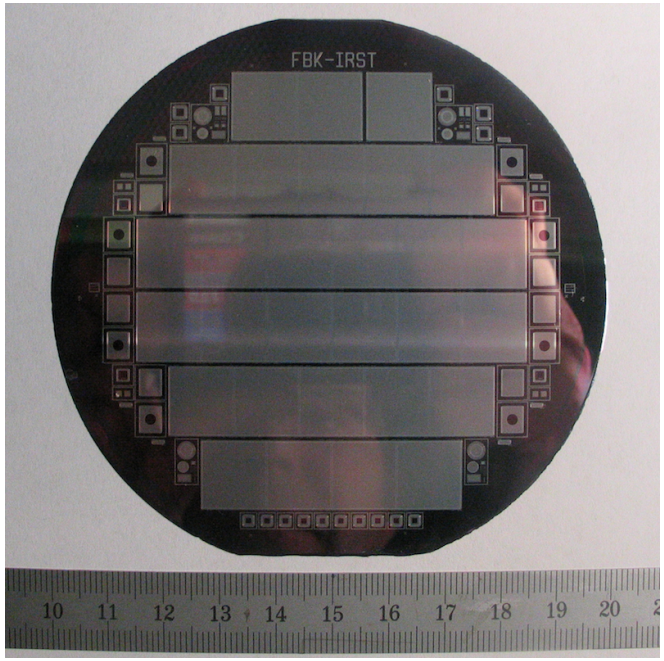
Backup slides

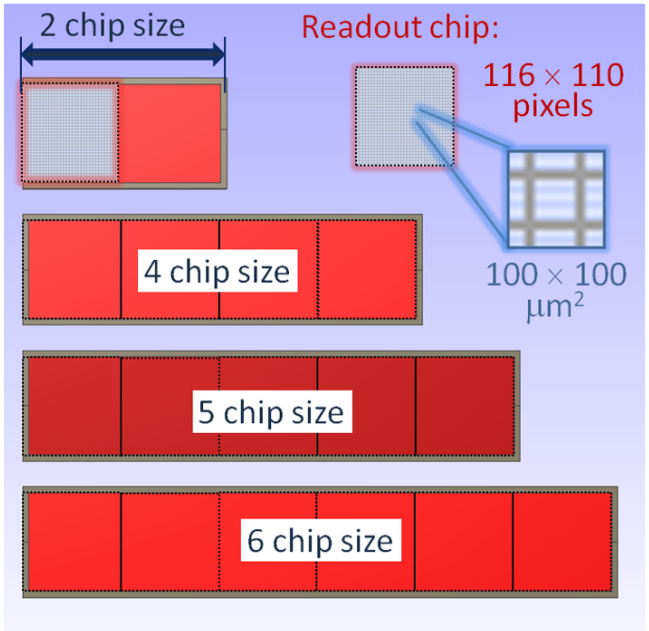
Pixel Detectors

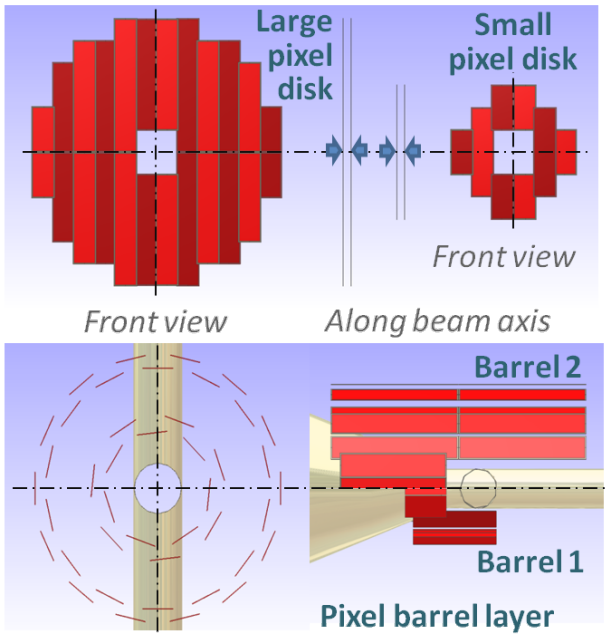


Sandwich structure:

- Bus
- Sensor
- Read-out chips
- Mechanical support with embedded cooling

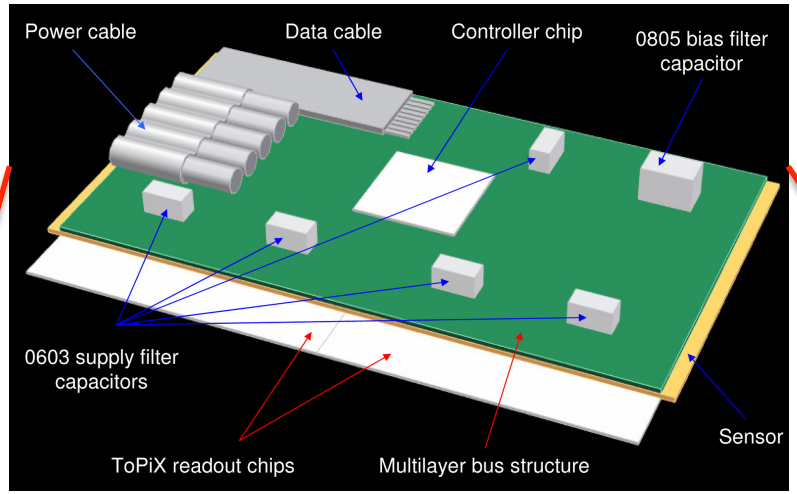


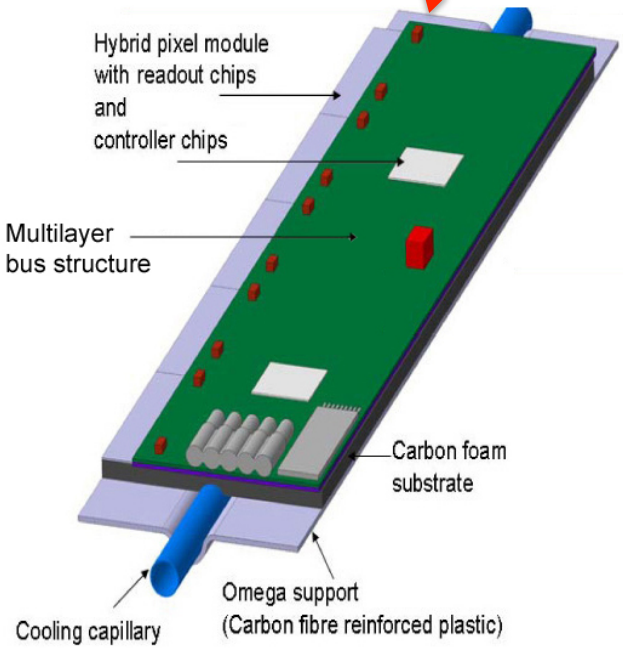




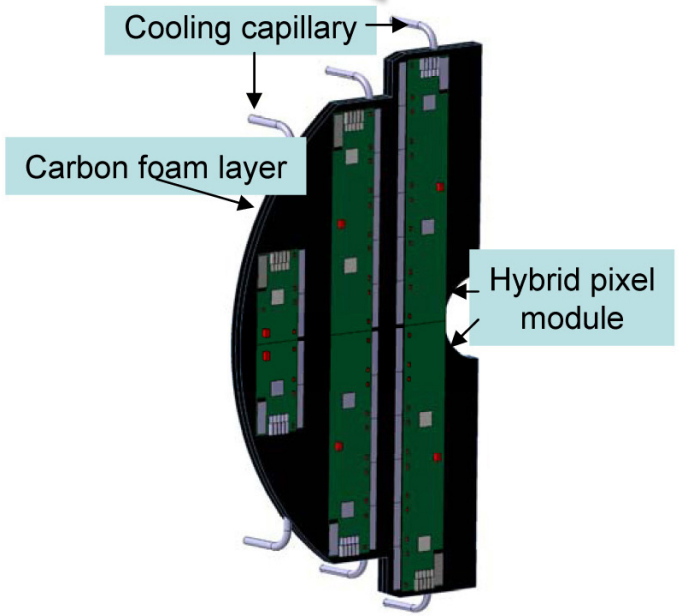
Pixel Detectors – II

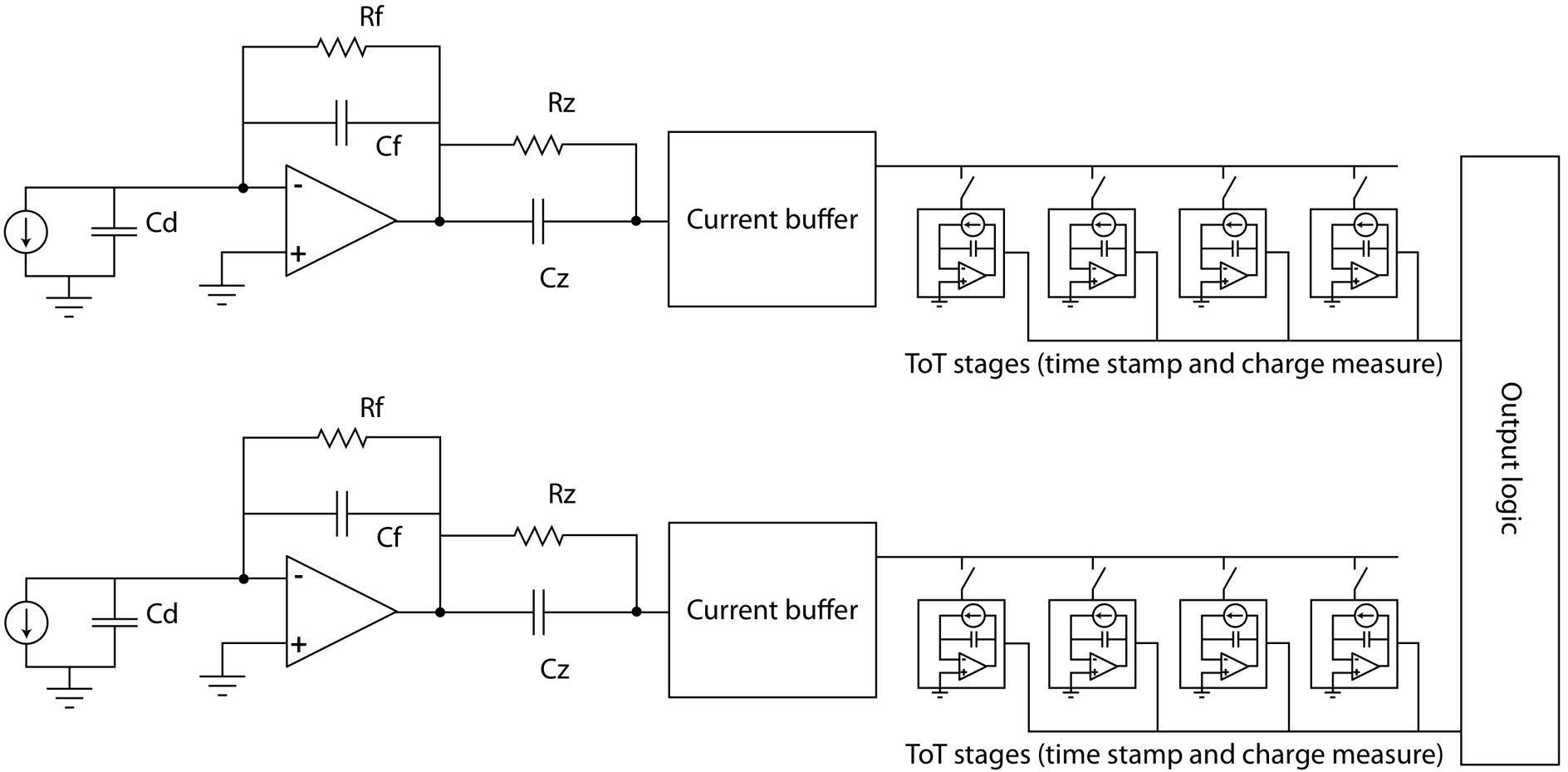
Linear barrel stave

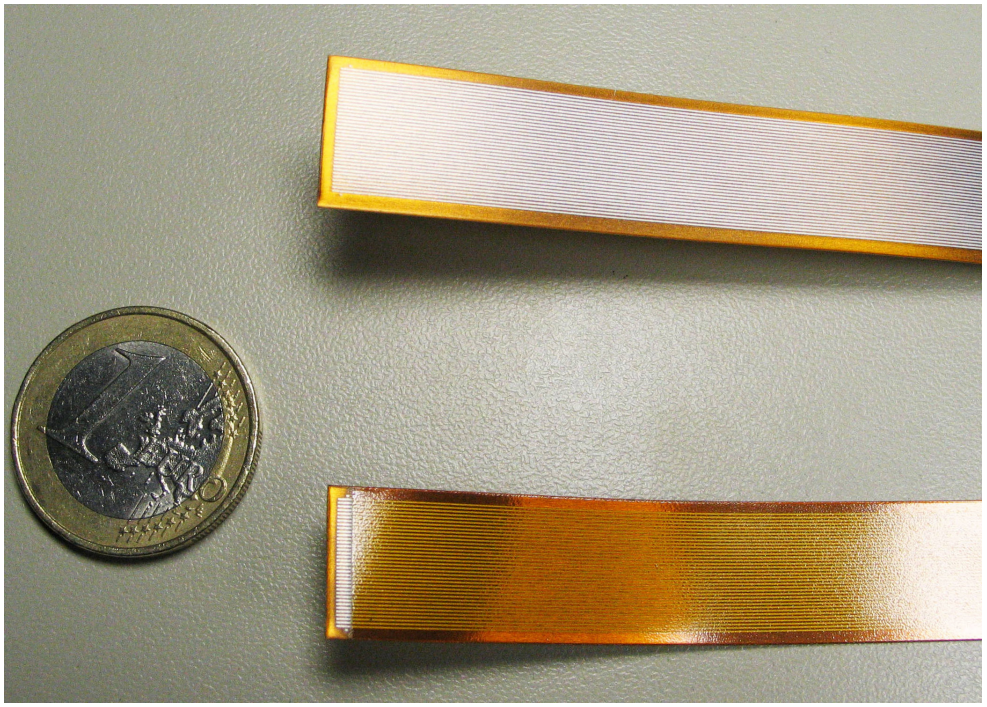


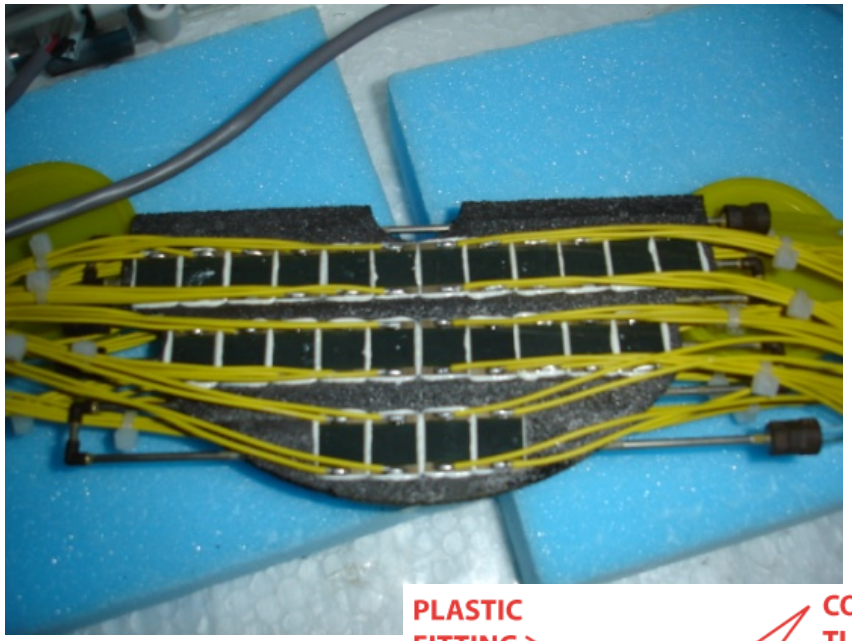


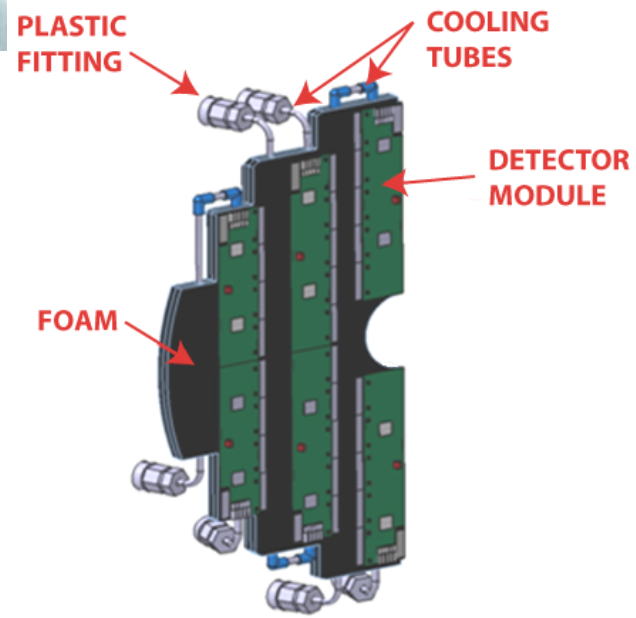
Half disk

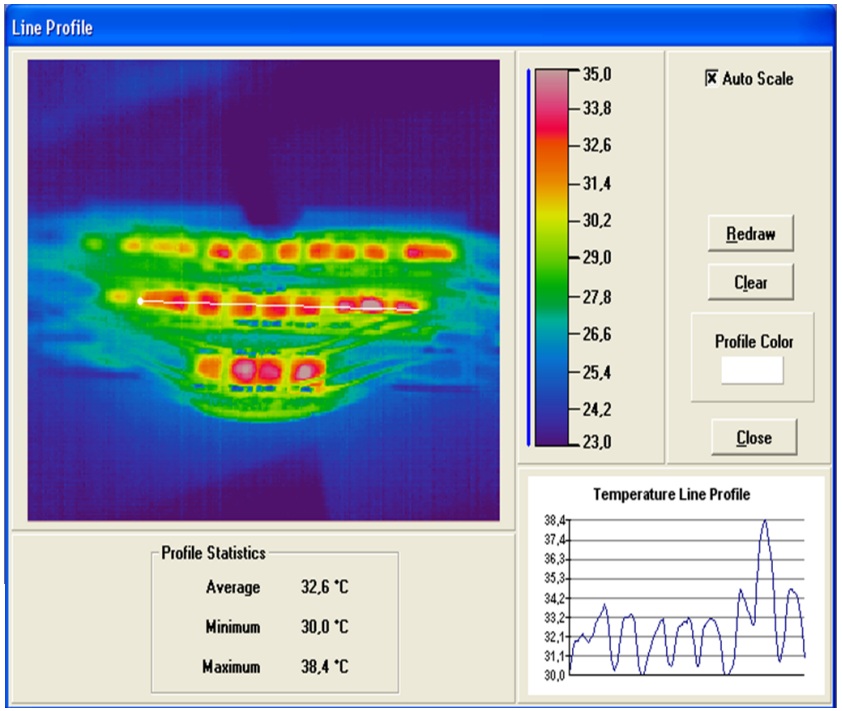



Rf
Cf
Rz
Cd
Cz
Current buffer
ToT stages (time stamp and charge measure)
Rf
Cf
Rz
Cd
Cz
Current buffer
ToT stages (time stamp and charge measure)
Output logic






PLASTIC
FITTING
COOLING
TUBES
DETECTOR
MODULE
FOAM


Line Profile
35,0
33,8
32,6
31,4
30,2
29,0
27,8
26,6
25,4
24,2
23,0
Auto Scale
Redraw
Clear
Profile Color
Close
Temperature Line Profile
38,4
37,4
36,3
35,3
34,2
33,2
32,1
31,1
30,0
Profile Statistics
Average 32,6 °C
Minimum 30,0 °C
Maximum 38,4 °C