The Micro-Vertex-Detector of the PANDA Experiment

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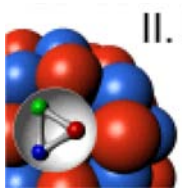
DPG Frühjahrstagung
Darmstadt, March 15th, 2016



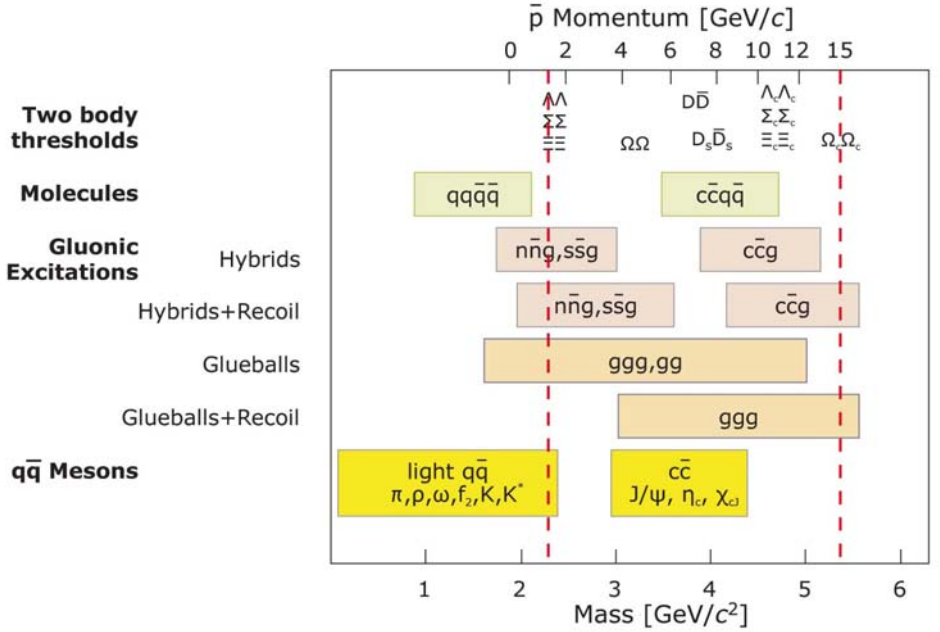
II. Physikalisches Institut

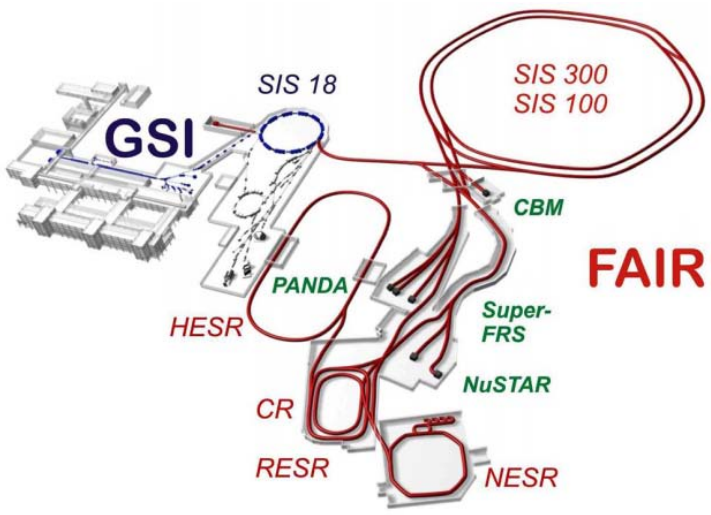
Outline

- **The PANDA Experiment: Physics Motivation and Experimental Setup**
- **The Micro Vertex Detector**
  - **Hybrid Pixel Detector**
  - **Double Sided Silicon Strip Detector**

The PANDA Experiment

- **QCD in non-perturbative regime**
  - Charmonium spectroscopy
  - Search for hybrids and glueballs
  - Study of exotic states (X, Y, Z)
- **In-medium effects**
- **Nucleon form factor**
- **Hypernuclear physics**

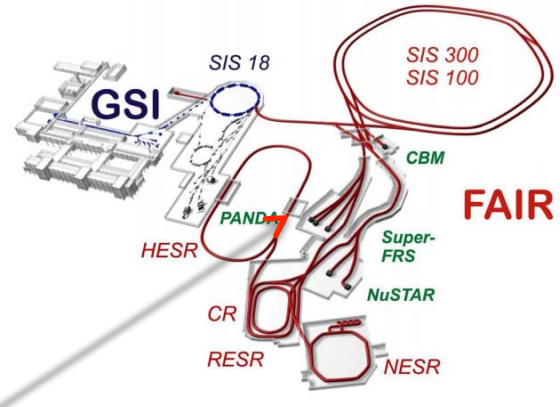




- Fixed target experiment at FAIR, Darmstadt
- Antiproton beam with p = 1.5 – 15 GeV/c and hydrogen or nuclear target
- Located at the High Energy Storage Ring (HESR)

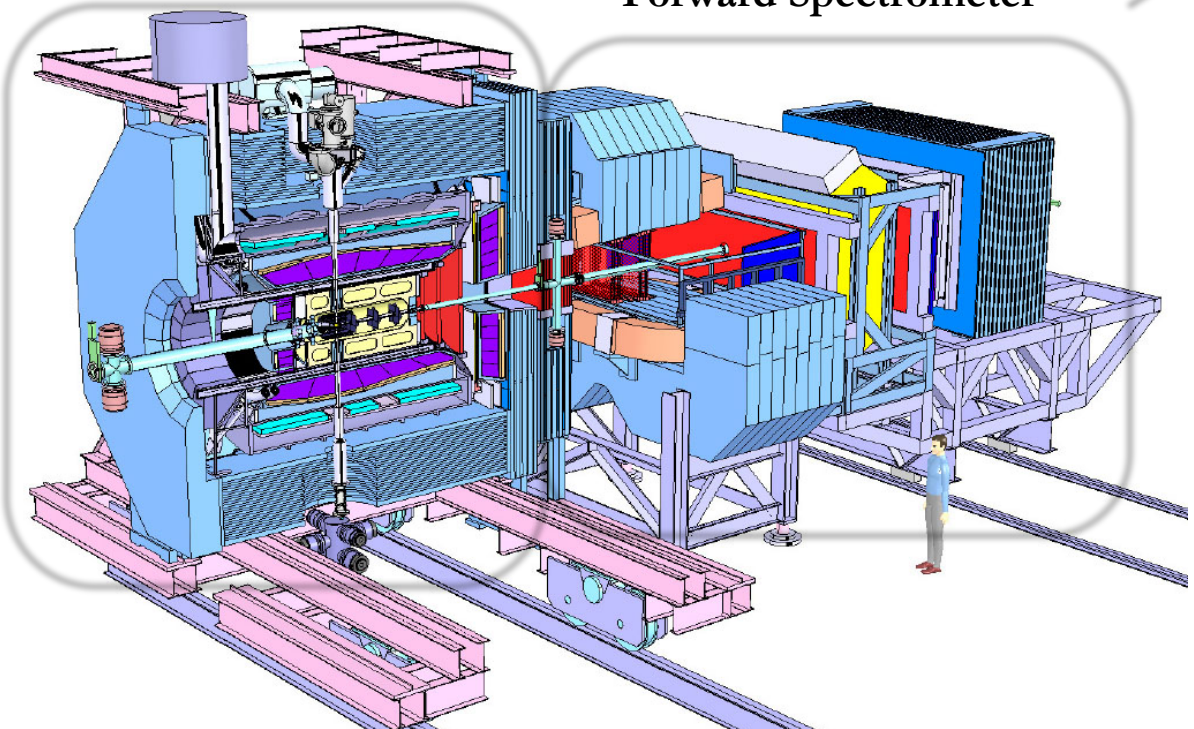
The PANDA Detector

- 4π acceptance
- Electromagnetic Calorimetry
- Tracking for Charged Particles (MVD, STT, GEM, FTS)
- Particle Identification (DIRC, SciTil, RICH)
- Continuous, triggerless readout



Target Spectrometer

Forward Spectrometer



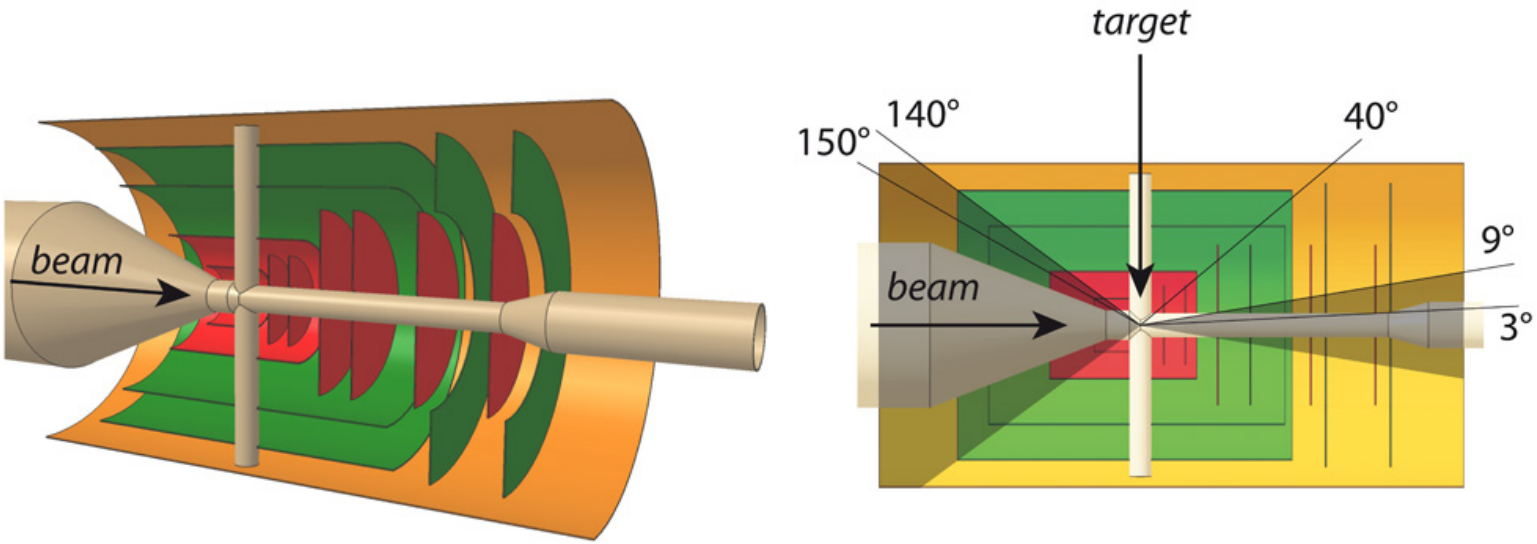
Target Spectrometer:
solenoid superconducting magnet (2T field)

Forward Spectrometer:
dipole magnet (2Tm field)

The Micro Vertex Detector

The Micro Vertex Detector (MVD)

- High resolution (<100 μm) vertex reconstruction; good time resolution (<6 ns)
- Radiation tolerance up to ~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)



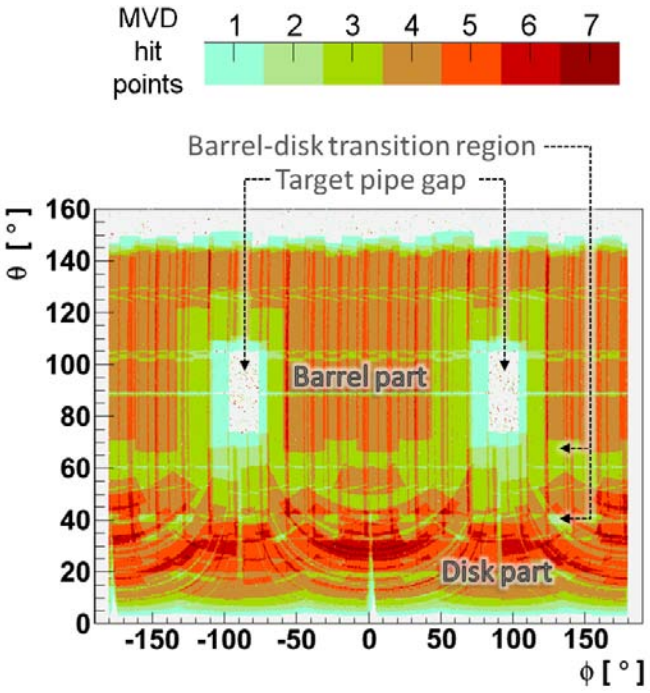
4 barrels surrounding the interaction point and 6 disks in the forward direction

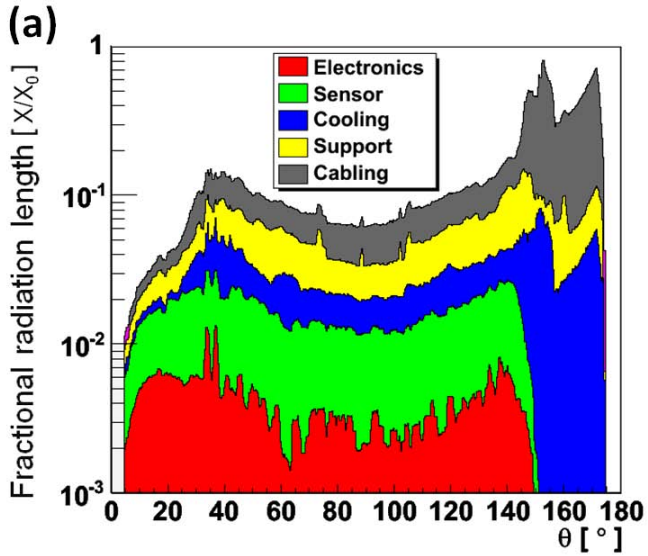
Two technologies:

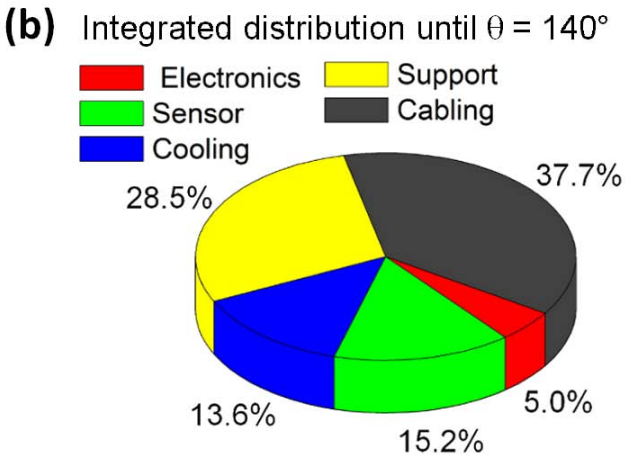
- Hybrid Pixel Detectors
- Double-sided Silicon Strip Detectors

MVD Simulations

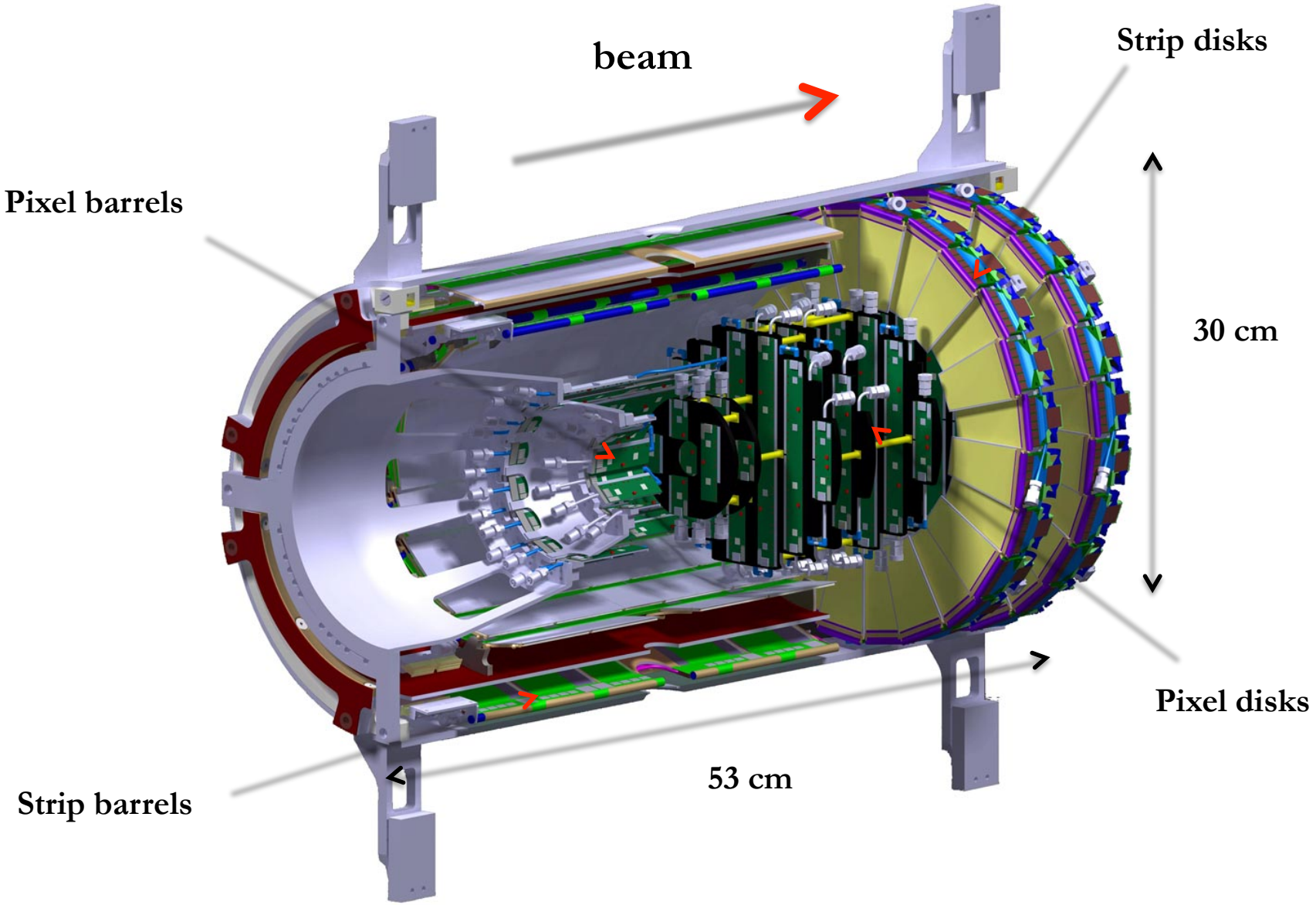
- Mechanical detector model imported in PandaRoot with the CAD Converter
- Extensive detector simulations to optimize the design, e.g.
  - Detector coverage
  - Material budget



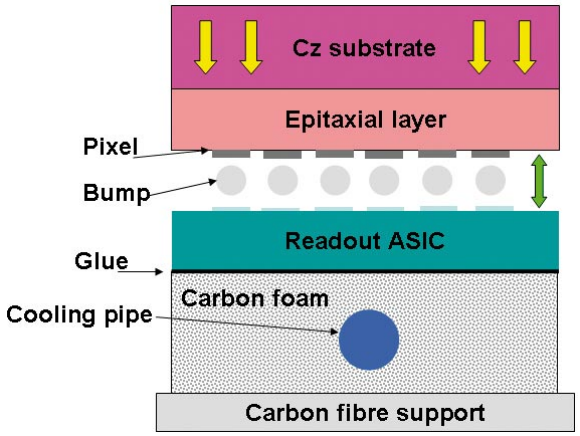


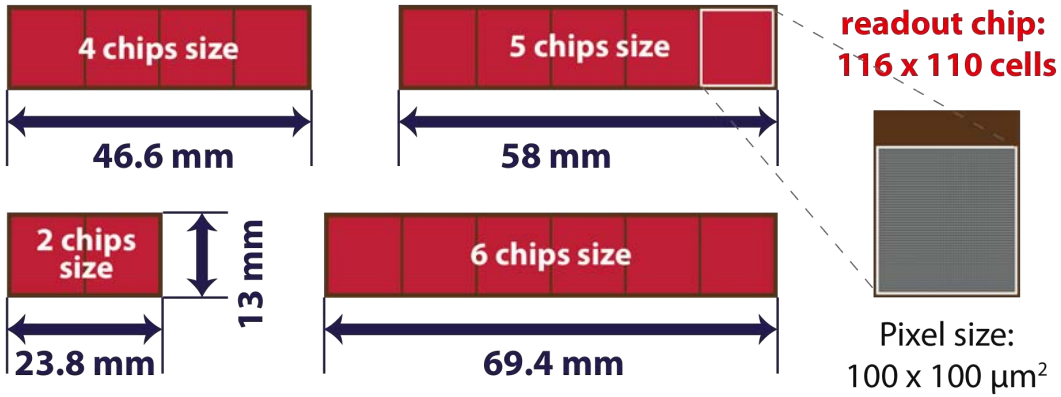


The Micro Vertex Detector



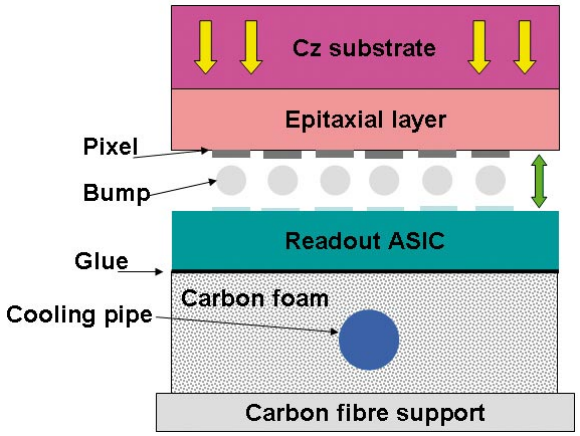
MVD – Pixel Part

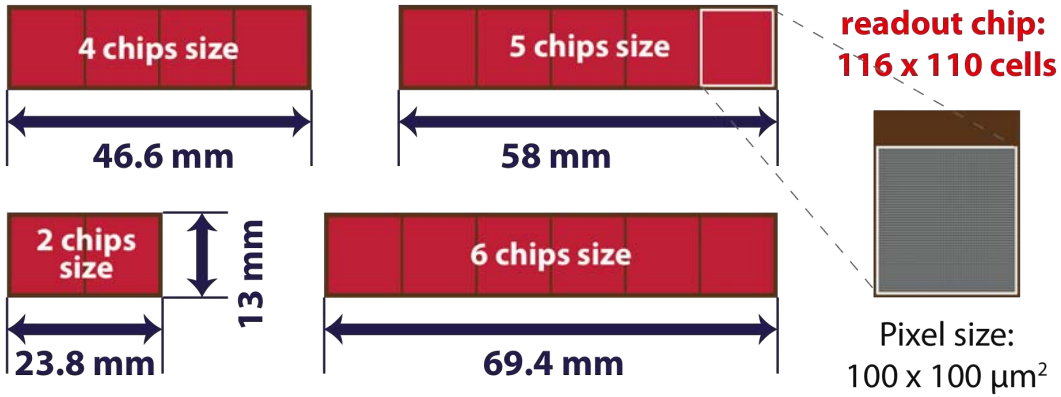




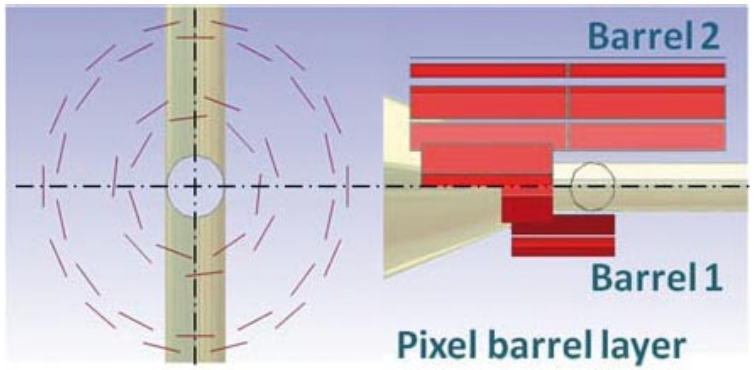
- 100 µm rectangular epitaxial silicon sensors
- Readout electronics bump-bonded to the sensor

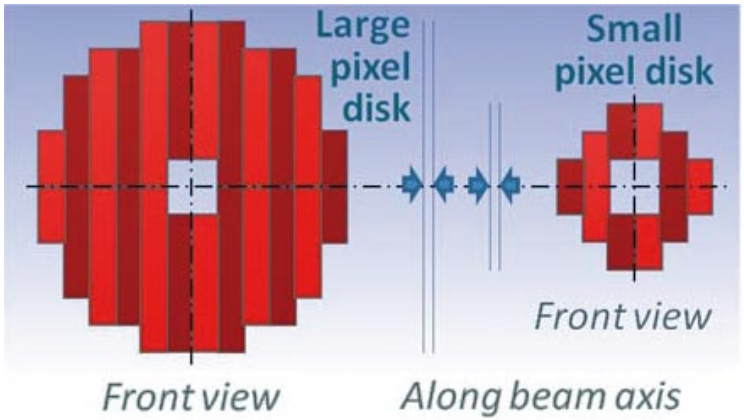
MVD – Pixel Part





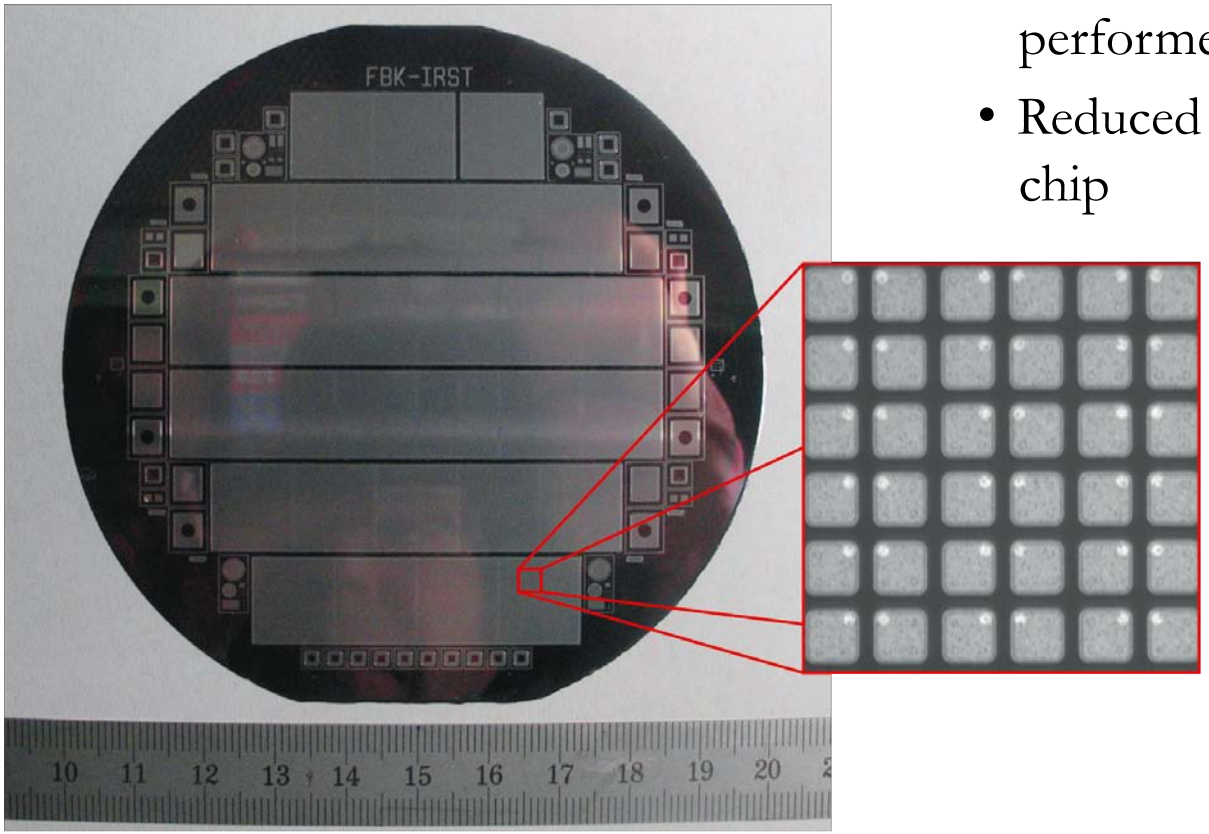
- 100 µm rectangular epitaxial silicon sensors
- Readout electronics bump-bonded to the sensor
- Two barrels and six disks
- 10.4M channels on 176 sensors



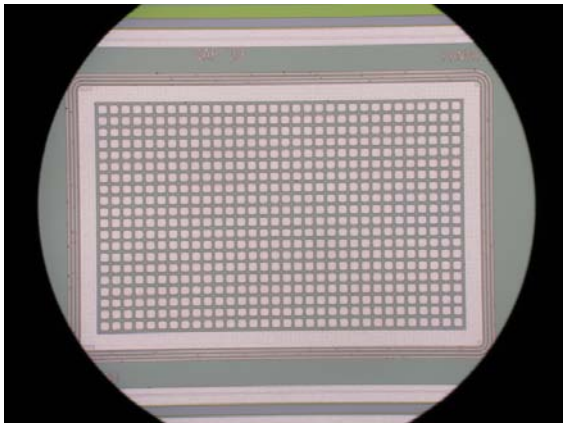


Pixel Sensors

- Epitaxial silicon pixel sensors
  - Epitaxial layer 100 μm thick
  - Cz substrate thinned to ~20 μm
  - $\rho_{epi} \sim 1500\ \Omega \cdot cm$

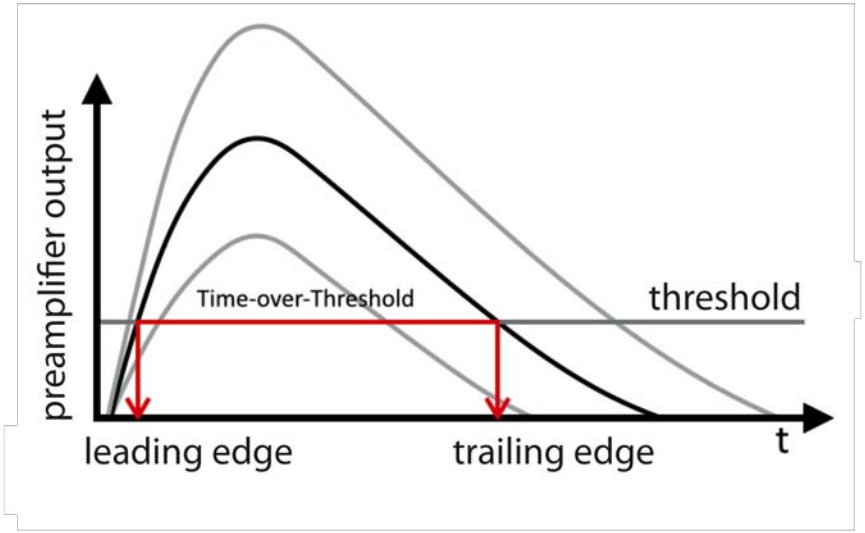


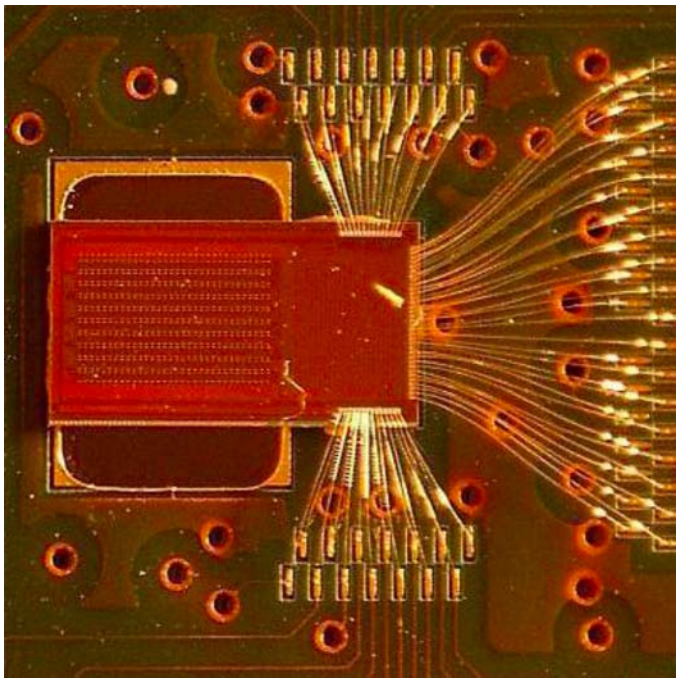
- Matrix of 100 × 100 μm^2 pixels
- Connection to electronics through Sn-Pb bump bonds
- Pixel fabricated at FBK, Trento
- Cz thinning and bump bonding performed at IZM, Berlin
- Reduced scale sensors bonded to chip



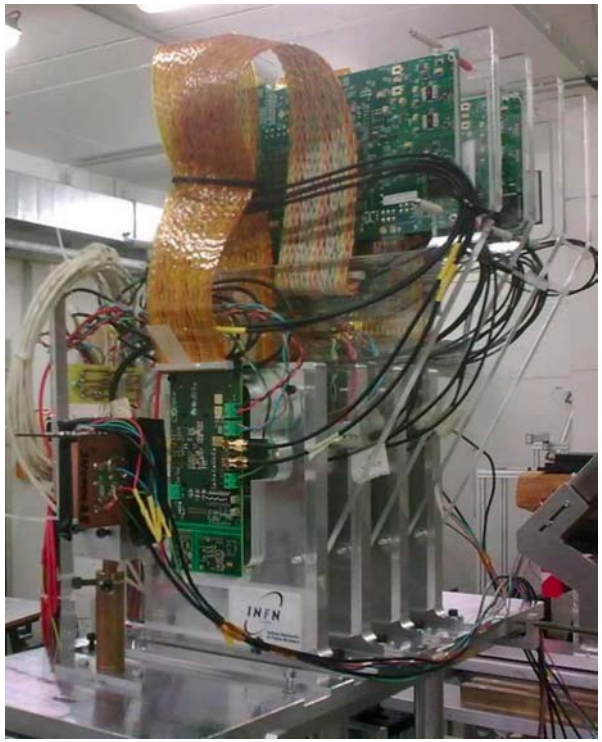
Pixel Electronics: ToPix

- Energy measurement through Time-over-Threshold (ToT) technique
- Radiation hard design
- Clock frequency 160 MHz
- ToPix_4 reduced size prototype:
  - Matrix of 640 pixels
  - CMOS 130 nm technology
  - 3 × 6 mm^2 chip size



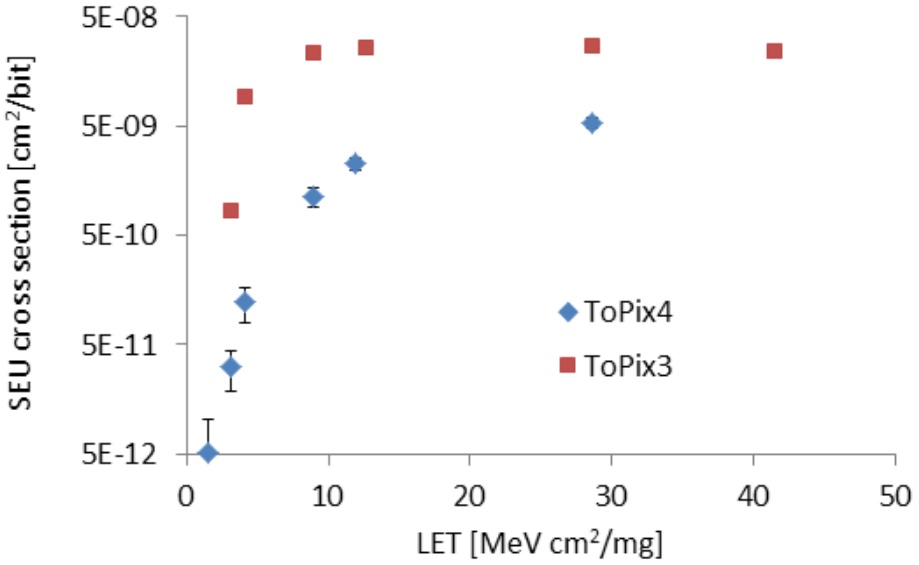


Pixel Electronics: ToPix

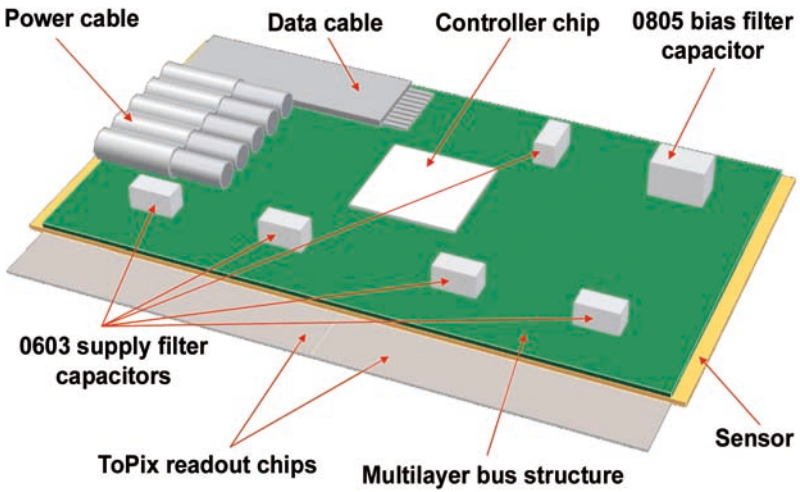


- Pixel tracking station (four pixel layers)
- Beam test at Jülich (2.9 GeV/c protons) combined with strip tracking station

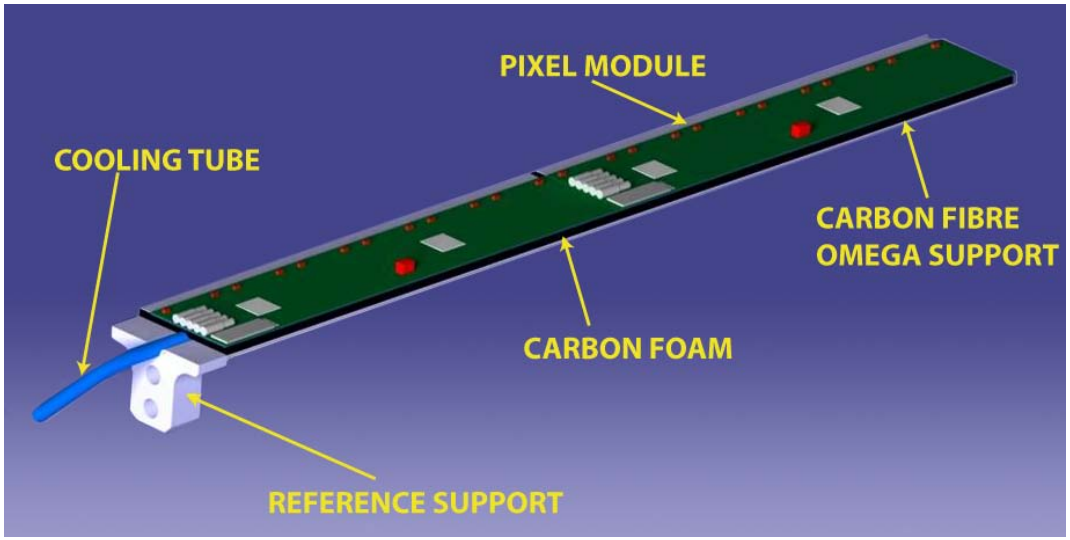
- Single Event Upset (SEU) radiation tolerance studies
- Significant improvement from ToPix3 (latches circuits) to ToPix4 (D-type flip flops and Hamming encoding)

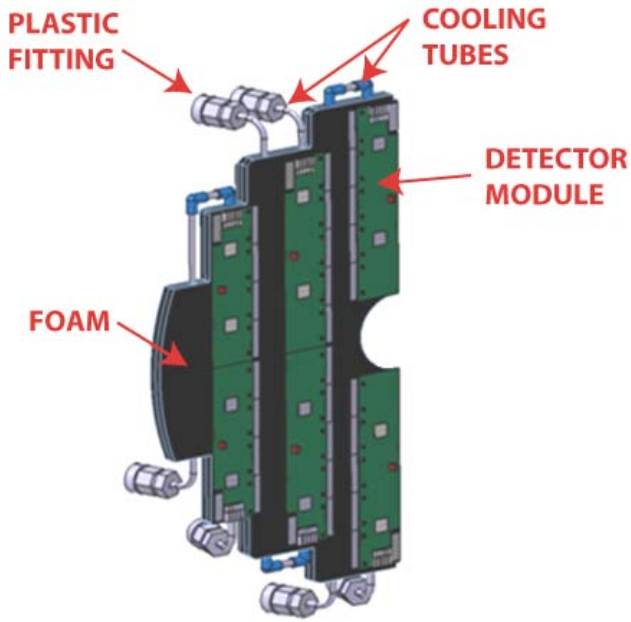


Pixel Modules

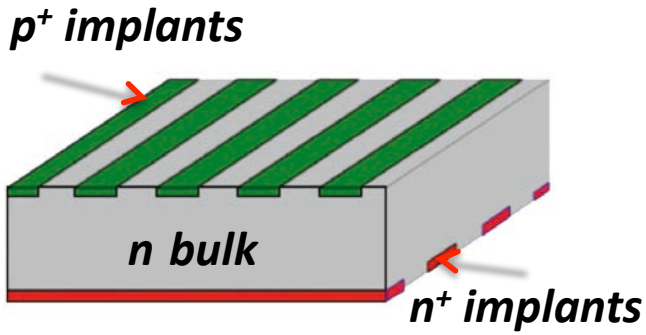


- Sensor module composition:
  - one sensor
  - 2 – 6 ToPix chips
  - multilayer bus
- 42 carbon fiber staves on the barrels
- 12 carbon foam half-disks

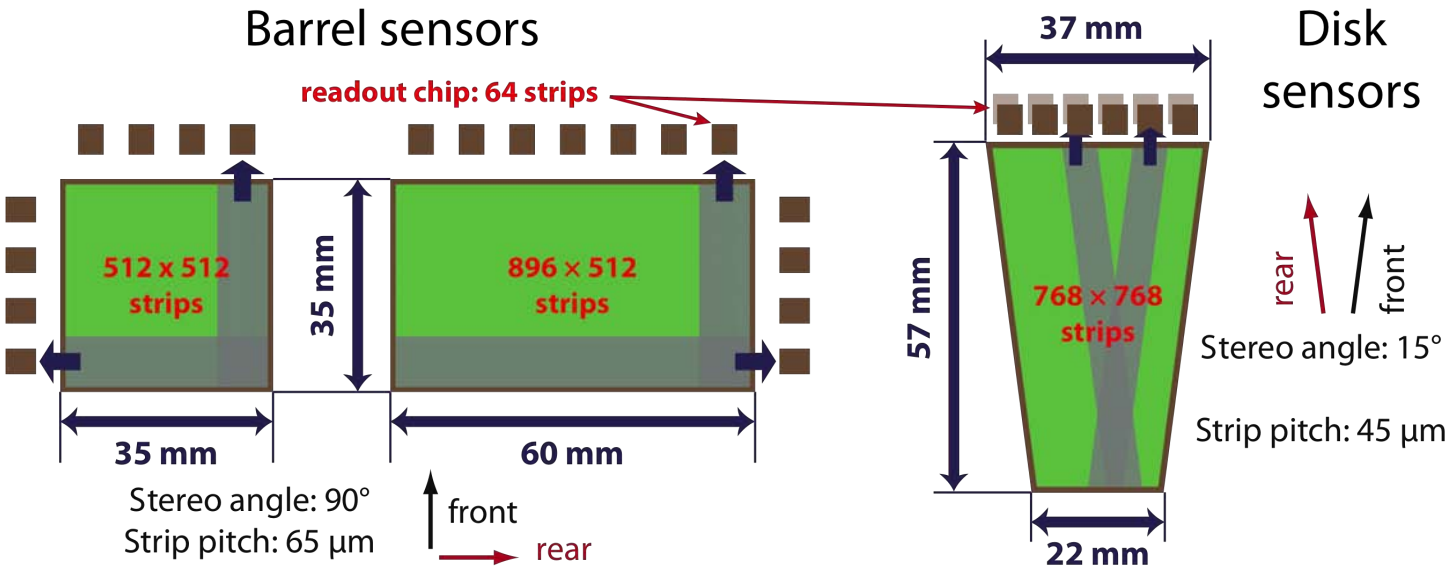




MVD – Strip Part



- Rectangular, square and trapezoidal sensors



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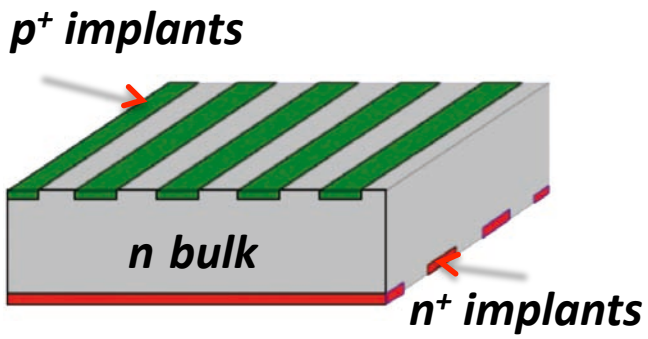
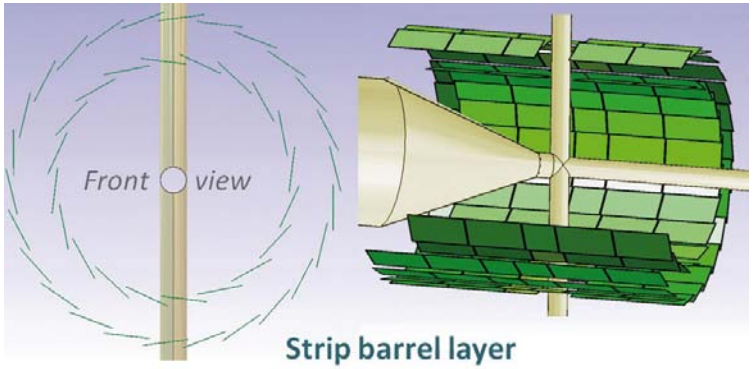
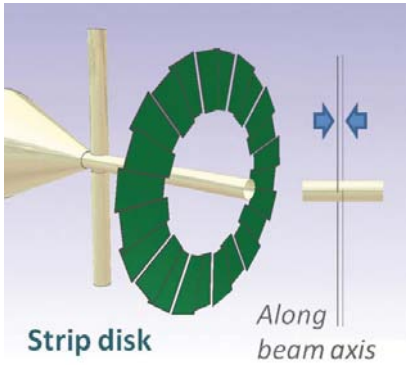
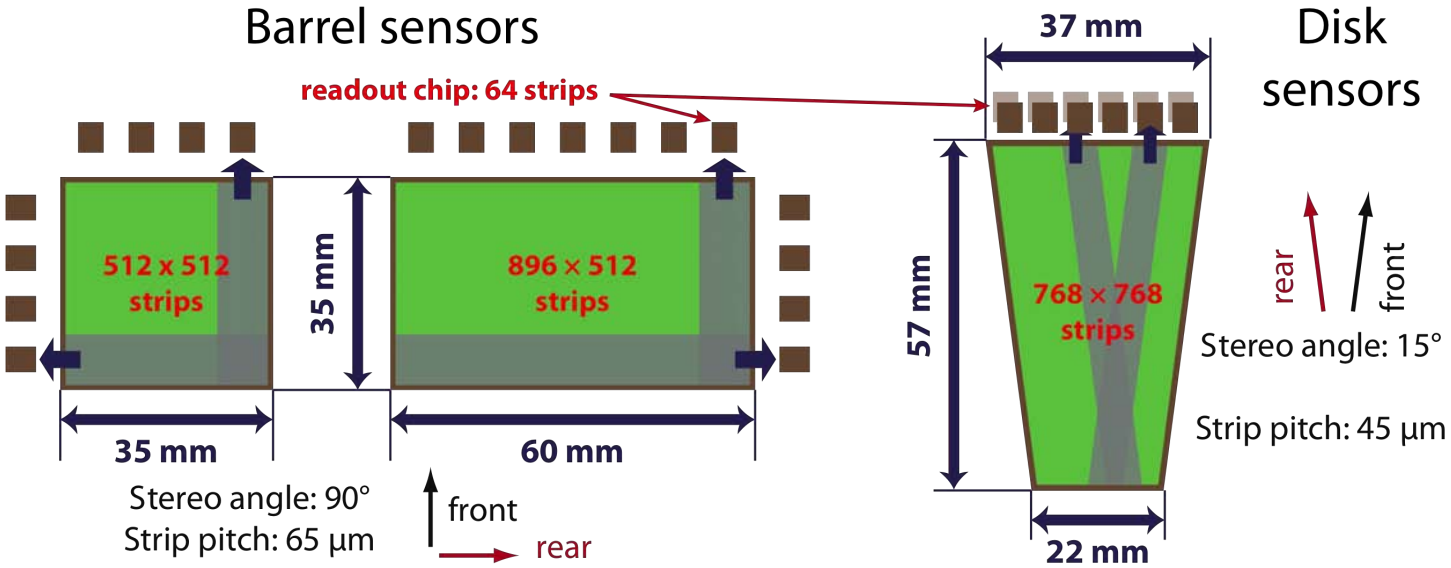




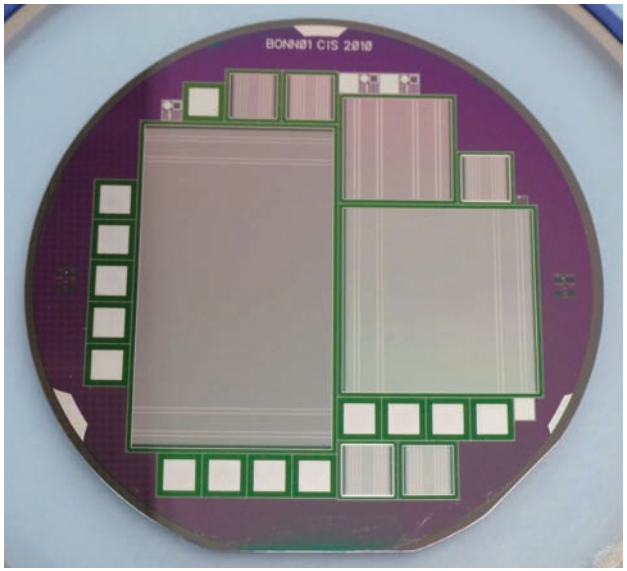


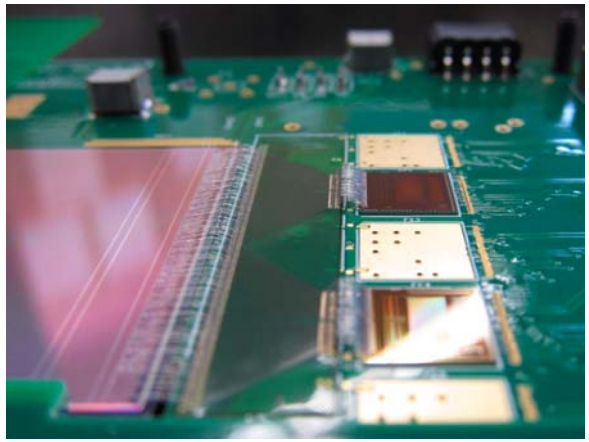
- Rectangular, square and trapezoidal sensors
- Two barrels and two rings around the last disks
- 200k channels on 296 sensors

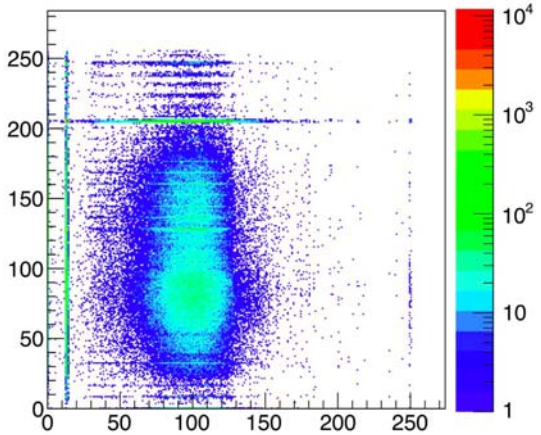


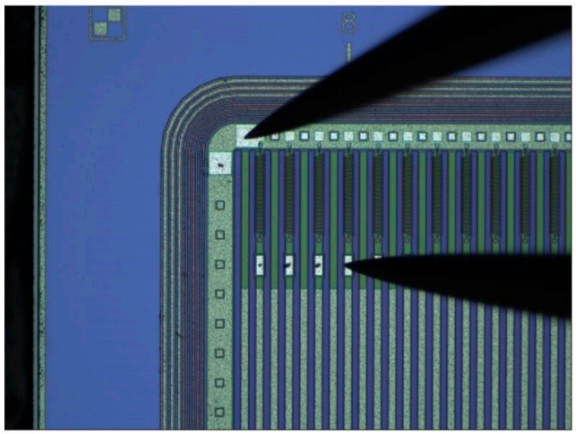
Strip Sensors

- Two prototype runs at CiS GmbH, Erfurt
  - 1st run: punch-through biasing
  - 2nd run: polysilicon biasing
- Extensive characterization and screening in Giessen:
  - Probe station and probe card measurements
  - Irradiation tests
  - Detector modules
- See R. Schnell (HK 45.66)









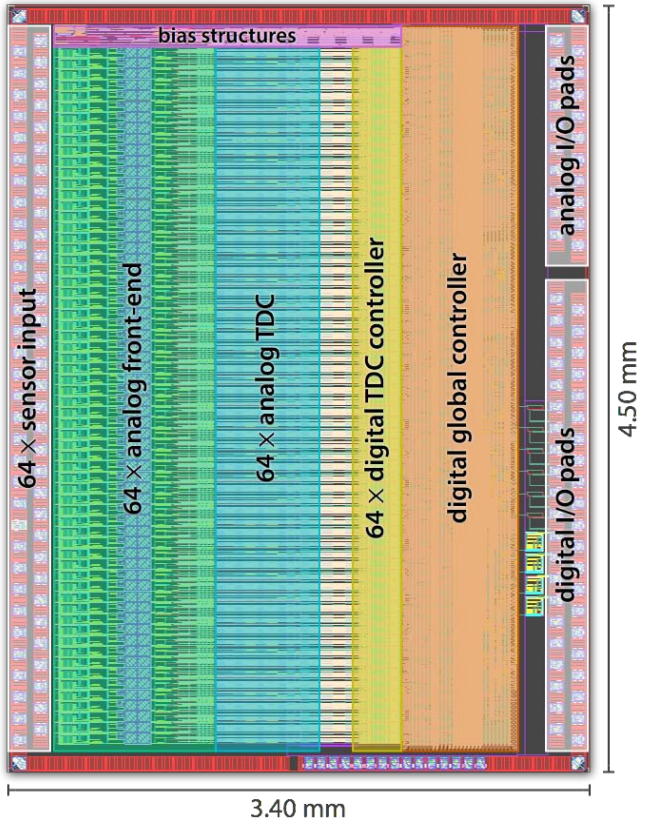
Strip Electronics – PASTA

- **PA**NDA **S**trip **A**SIC
- Free-running readout chip
- ToT-based readout with precise timestamp

Key features

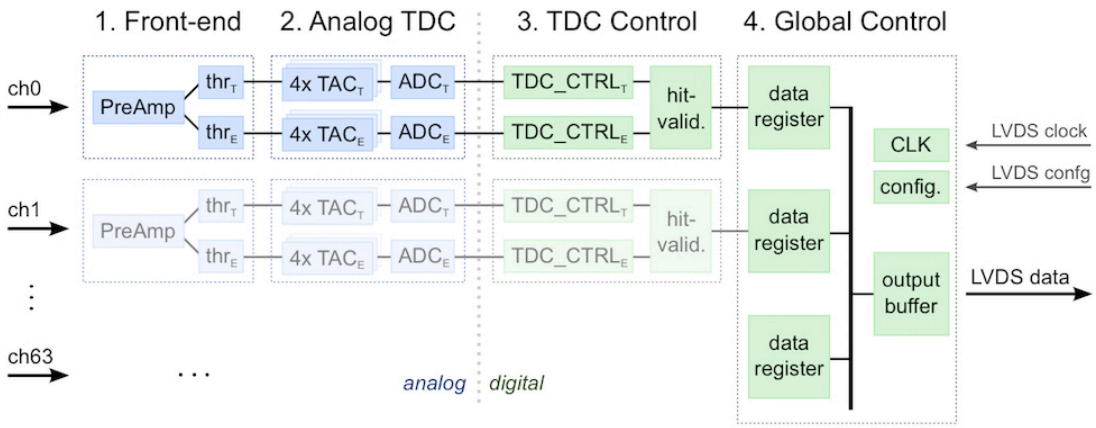
Channels	64
Input pitch	63 µm
Rate capability	100 kHz/channel
Power consumption	< 4 mW/channel
Front-end noise	< 600 e^-
Time bin width	50 - 400 ps
Charge resolution	8 bit (dyn. range) *
Radiation tolerance	100 kGy *

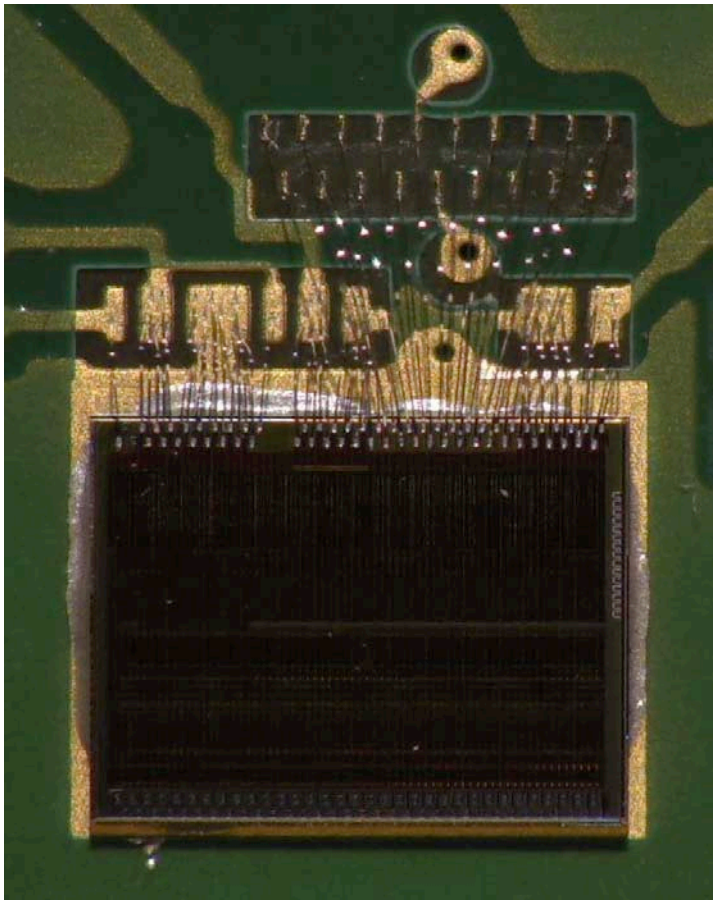
* Design goal



- Joint project Uni Gießen – INFN Torino – FZ Jülich
- See A. Riccardi (HK 7.2)

Strip Electronics – PASTA

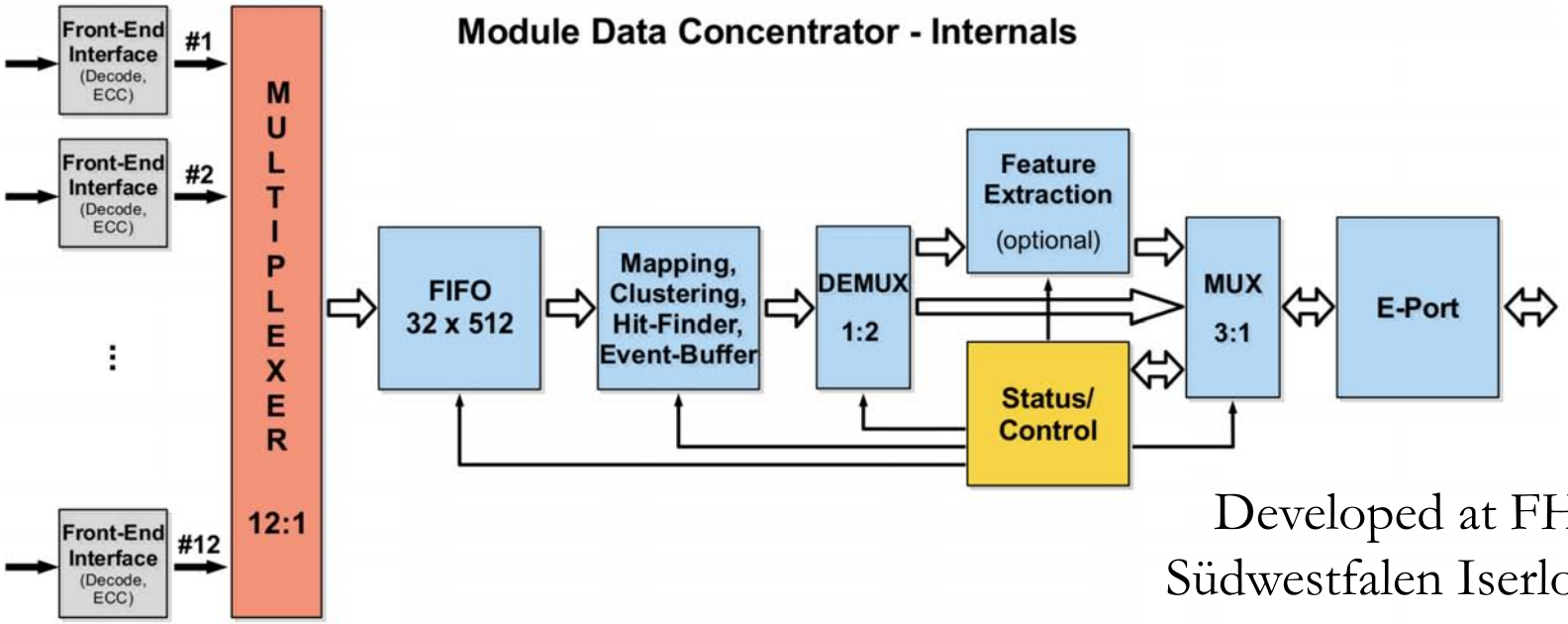




- Prototypes fabricated in 2015 (Multi Project Wafer run)
- 110 nm commercial CMOS technology
- Readout system in preparation (see A. Lai, HK 29.3)

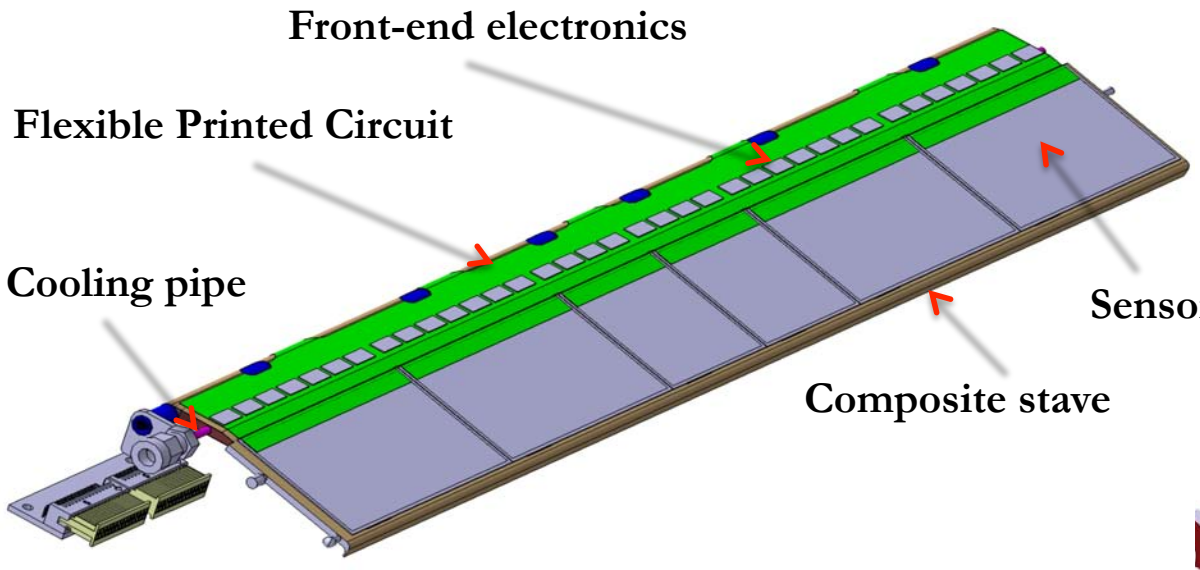
Strip Electronics – MDC

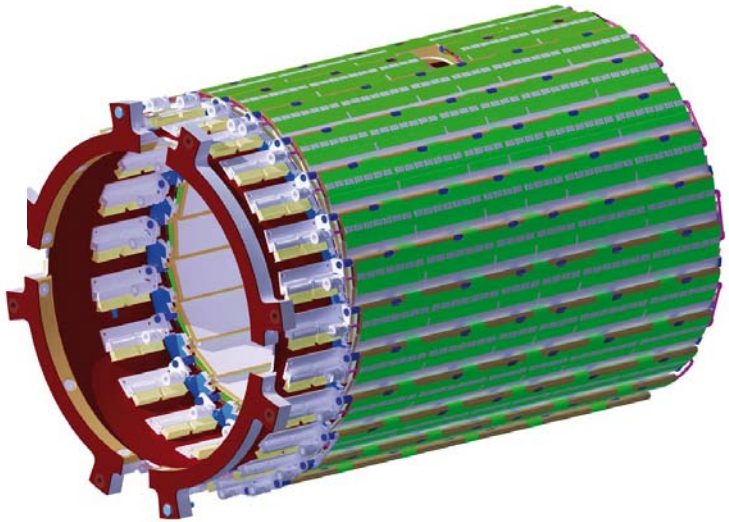
- **M**odule **D**ata **C**oncentrator
- Multiplexing of all FEs of one sensor (up to 12 inputs)
- Feature extraction: cluster finding, cluster correlation
- Interface to the out-of-detector electronics:
  - Slow-control and calibration of all attached FEs
  - Fast GBT e-link for data and configuration I/O

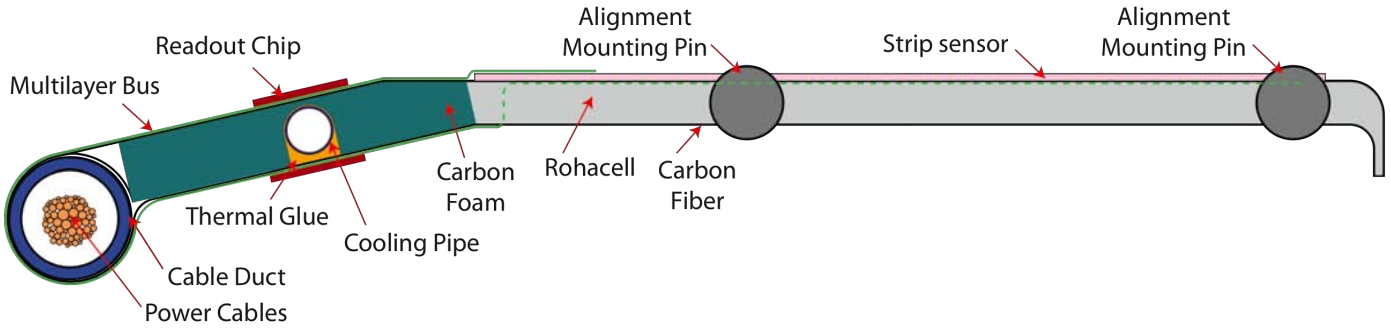


Developed at FH Südwestfalen Iserlohn

Strip Modules – Barrels



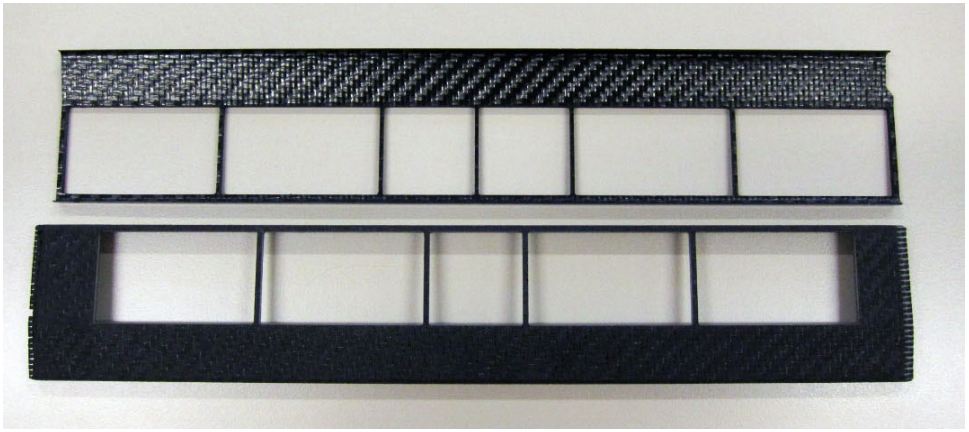




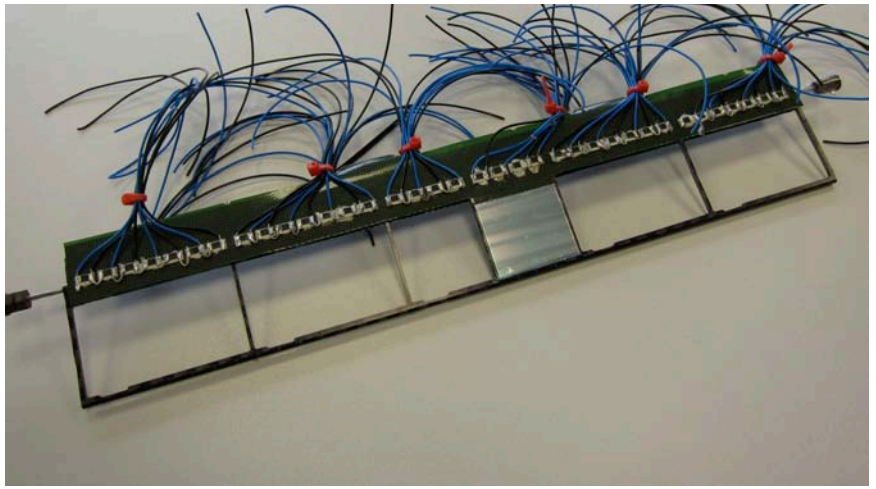
Strip Modules – Barrels

Staves at various manufacturing stages:

Staves with the sensor cutouts, without cooling or cables

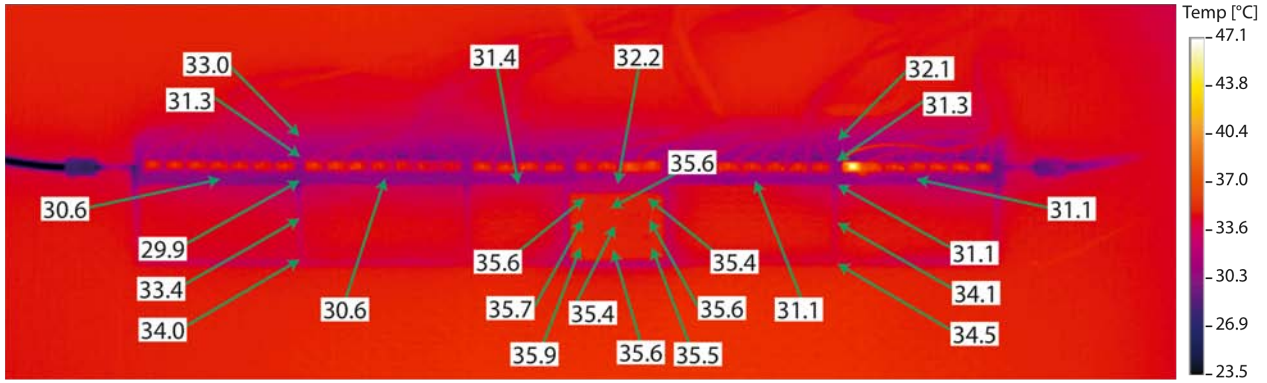


Full size prototype for cooling studies

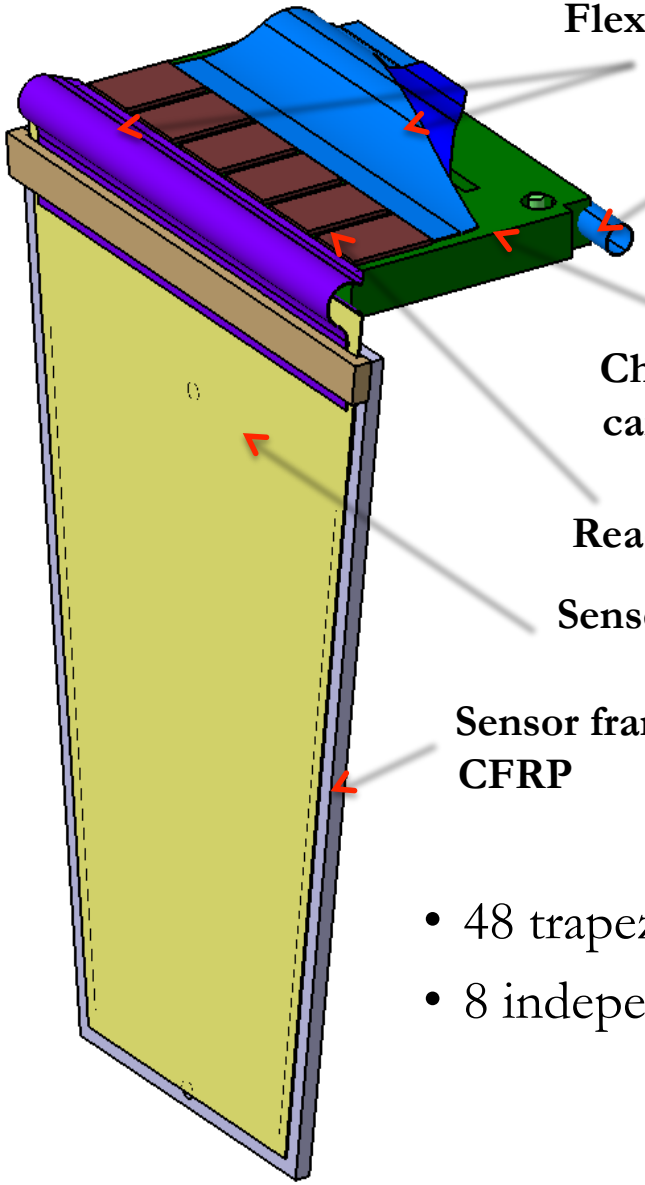


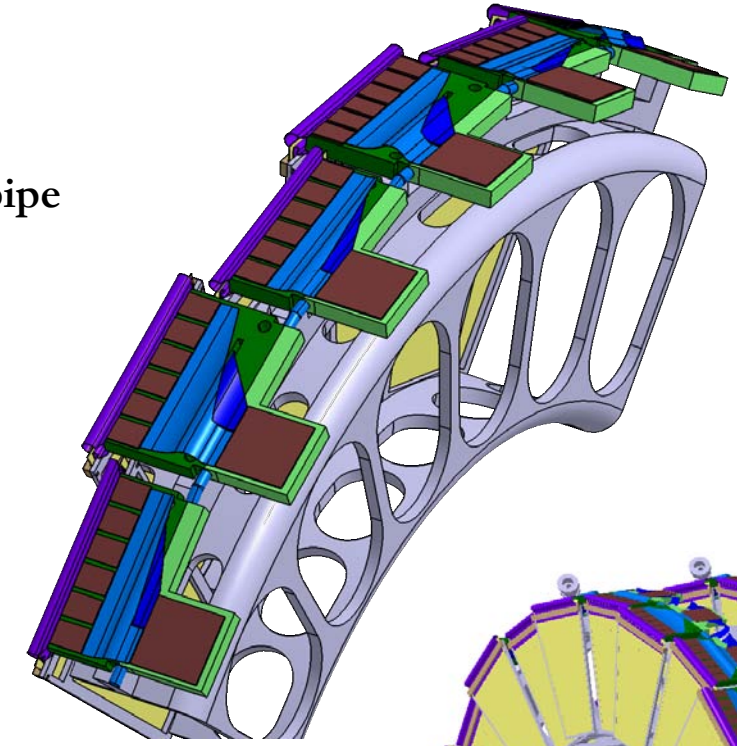
Stave cooling system: carbon foam and metal pipe

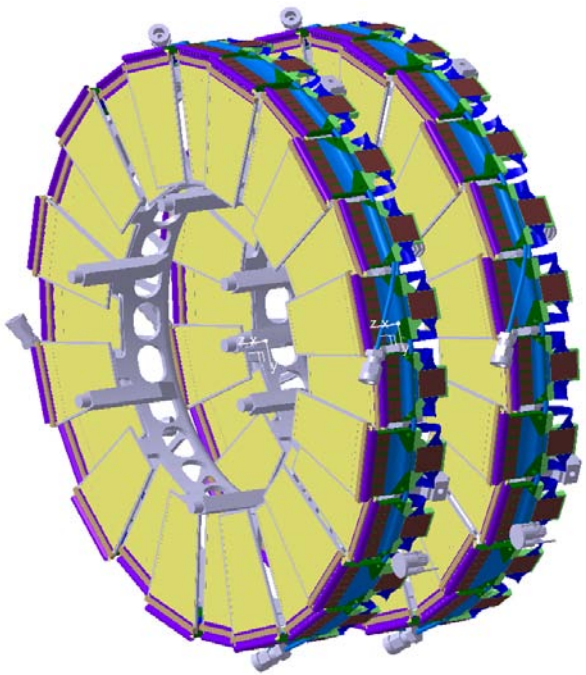
IR camera measurements of stave temperature



Strip Modules – Disks

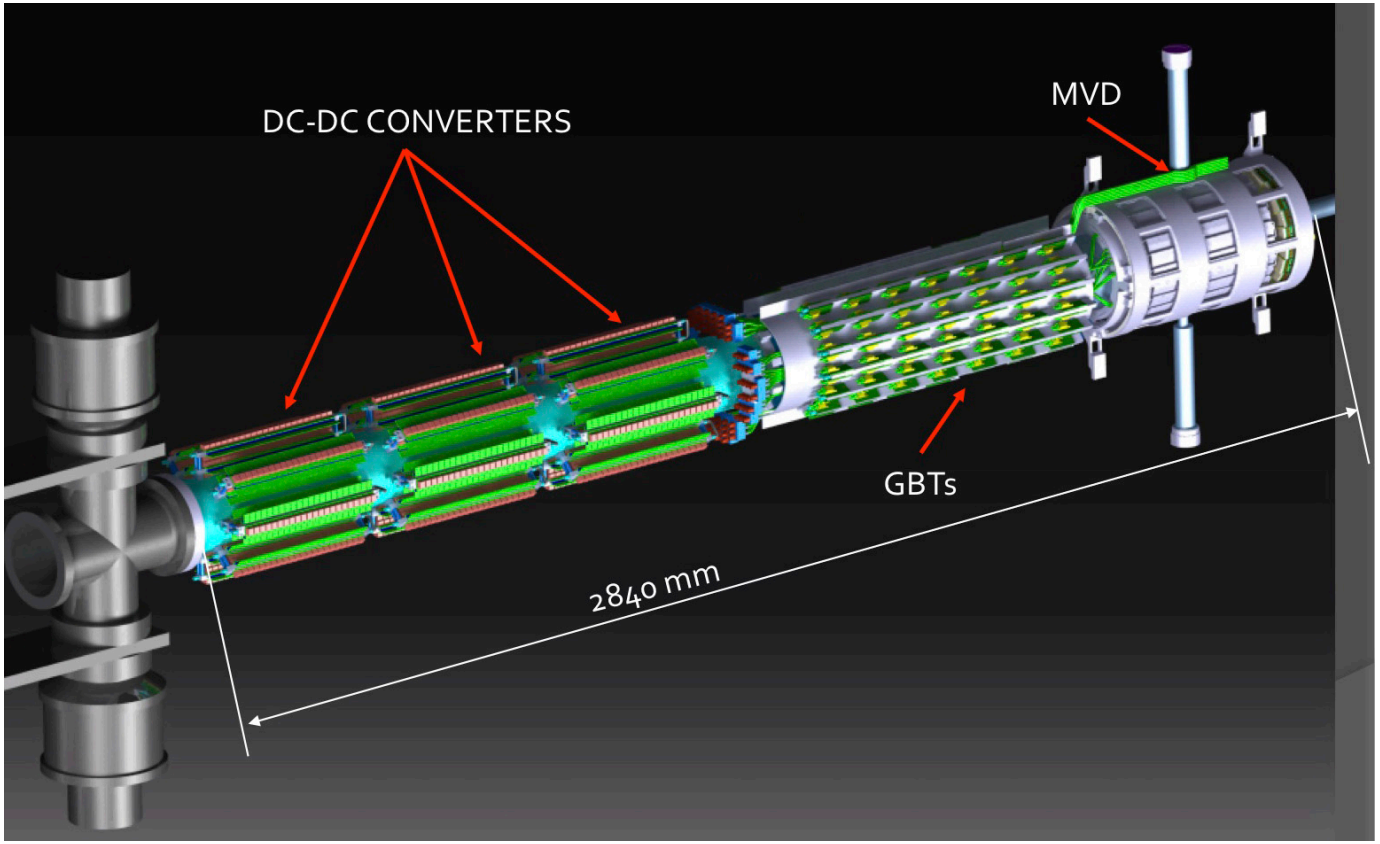






- 48 trapezoidal sensors
- 8 independent disk quarters on 2 disks

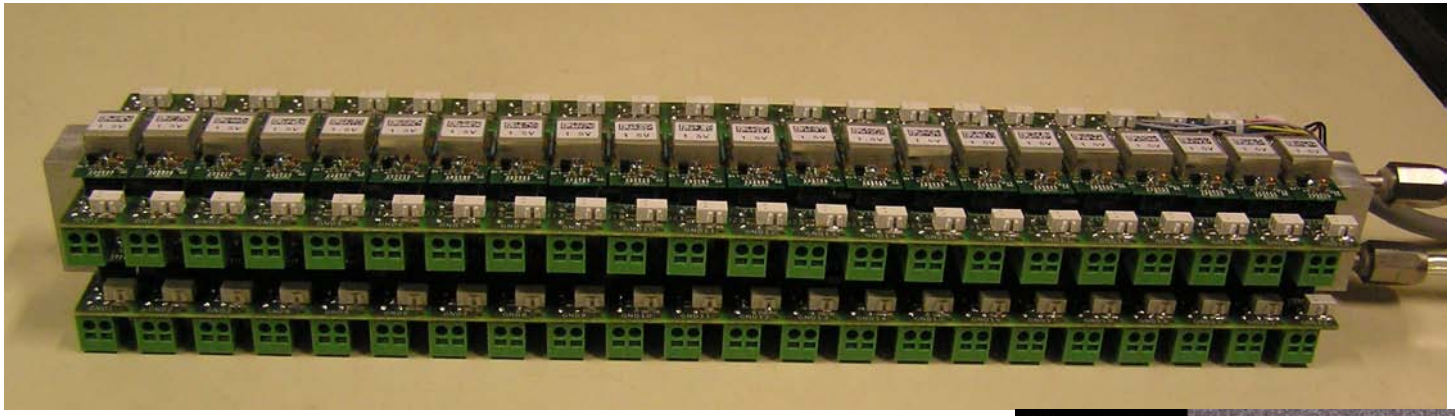
MVD Services

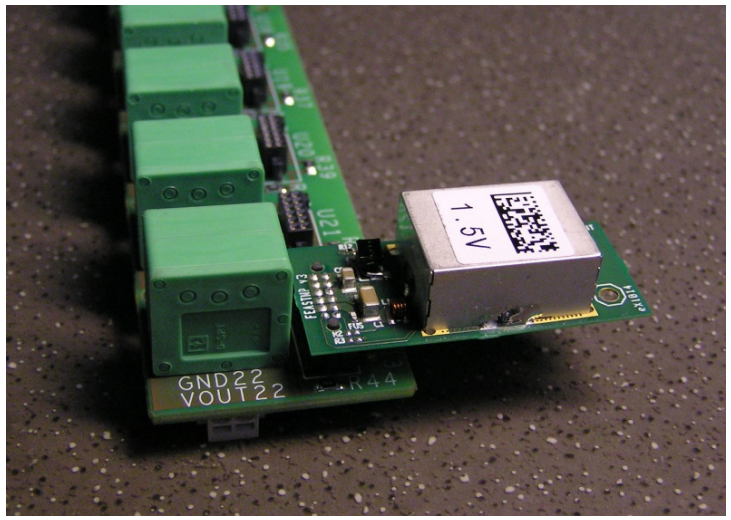


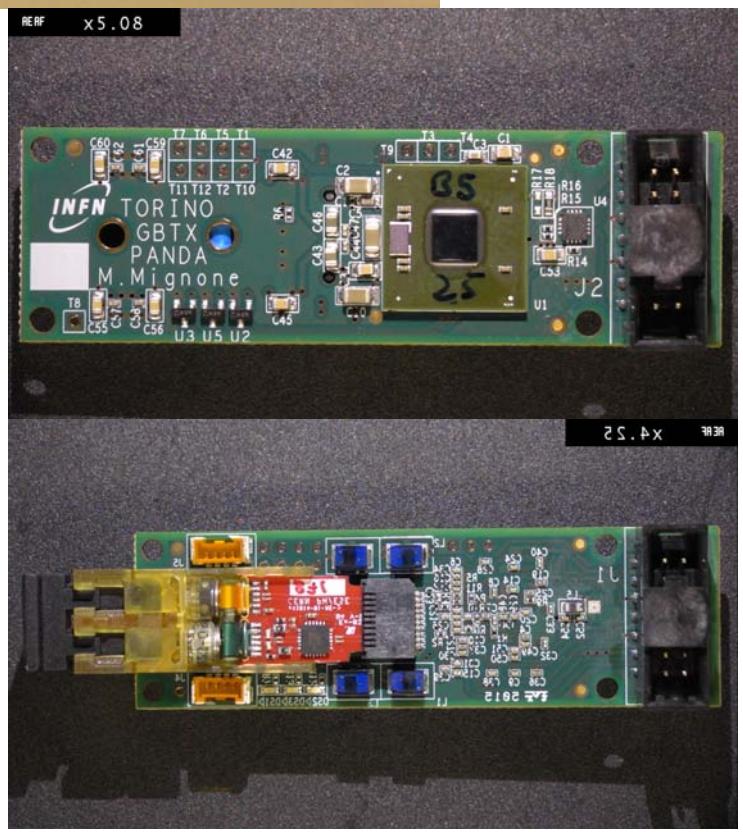
Services arranged around the beam pipe:

- DC-DC powering operating in B=2T → approx. 2100 DC-DC converters
- ~200 GBT boards for electro-optical conversion of signals
- Critical arrangement of cables

MVD Services







- Prototypes of DC-DC and GBT modules currently under test

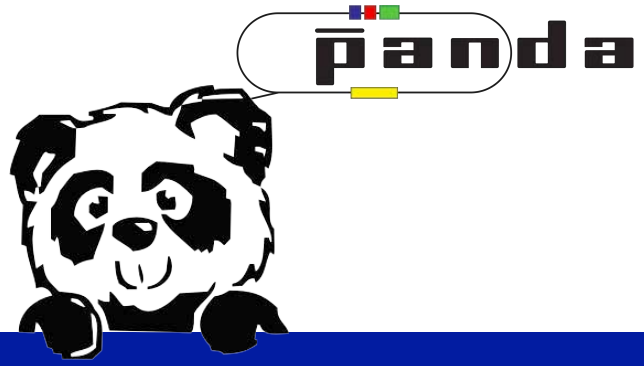
Conclusions

- **The design of the PANDA MVD is in an advanced stage, but…**

Conclusions

- **The design of the PANDA MVD is in an advanced stage, but…**

- **Many details are missing: lot of work to do!**



Thank you for your attention!

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HIC for FAIR
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MVD panda

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