12th HANUC Lecture Week
Student seminar
Torino, March 26, 2009

Thomas Würschig

The PANDA Micro-Vertex-Detector (MVD)

universität bonn

Introduction

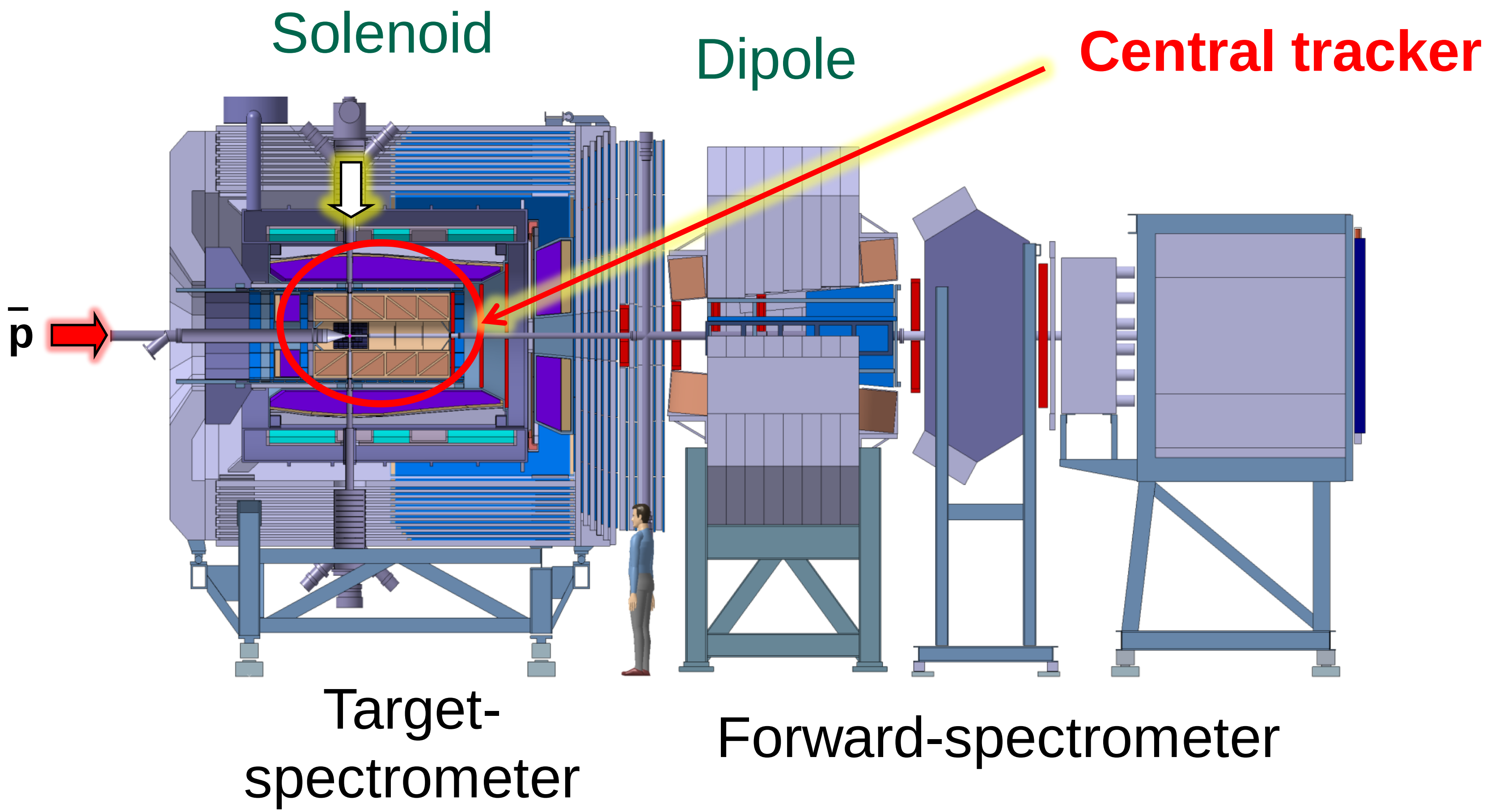
- PANDA - Experiment
  - Fixed target experiment @ HESR
  - Frozen hydrogen and heavier nuclear targets (e.g. Gold)
  - Pellet target / Cluster-jet target
  - Design parameters
    a) High Luminosity: $L = 2 \cdot 10^{32}\ cm^{-2} s^{-1} \Leftrightarrow \Delta p/p < 10^{-4}$
    b) High resolution: $L = 10^{31}\ cm^{-2} s^{-1} \Leftrightarrow \Delta p/p < 4 \cdot 10^{-5}$
    Beam momentum: (2 ... 15) GeV / c

→ Interaction rate: 10^7 events / s

→ **Non ordered time structure**

Setup

- PANDA - Spectrometer

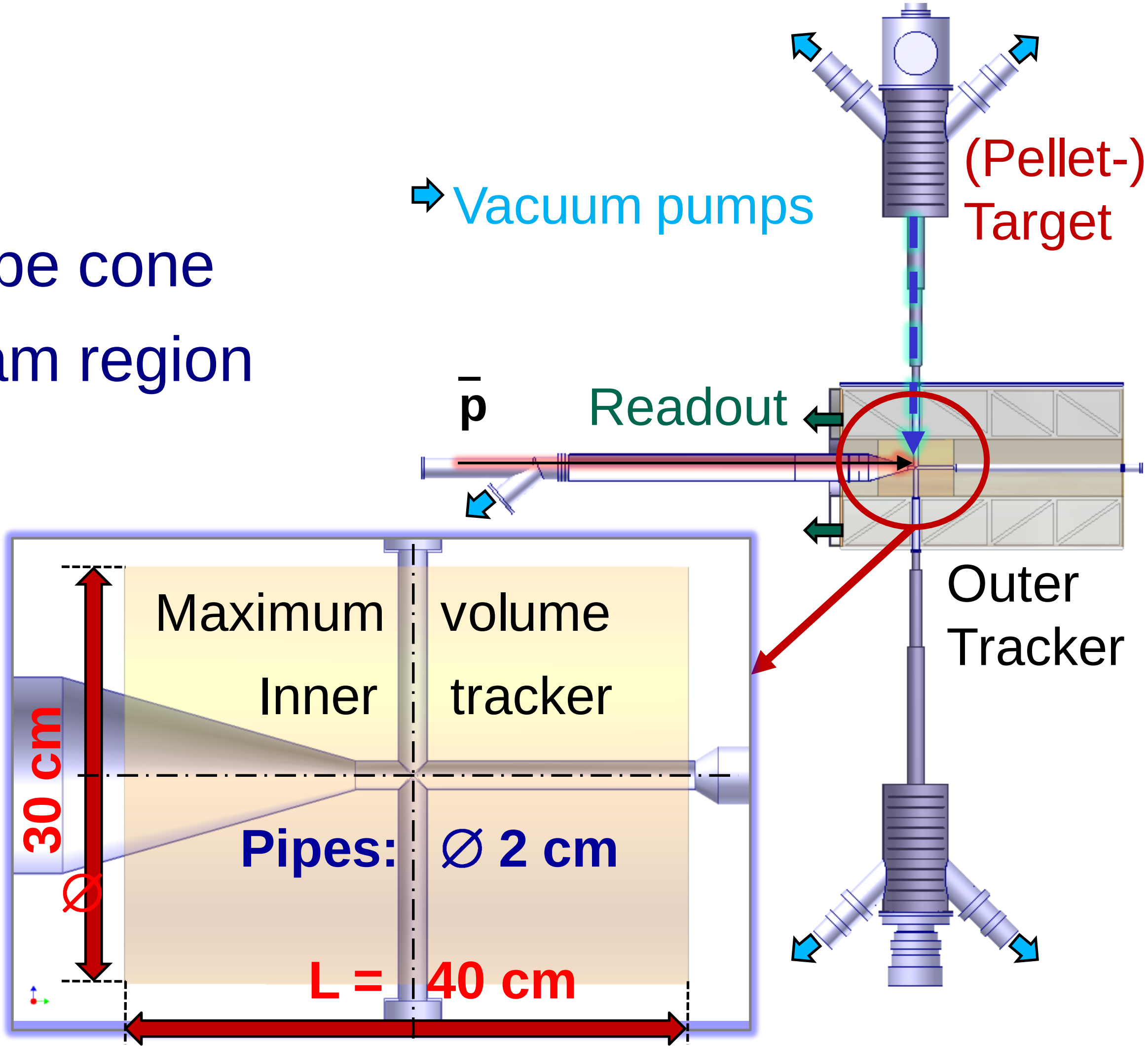


Setup

- Vertex-Geometry
  - Beam-target cross
  - Upstream beam pipe cone
  - Readout in upstream region

→ Implications for inner tracker

  - Geometrical constraints
  - Broken symmetry
  - Limited space



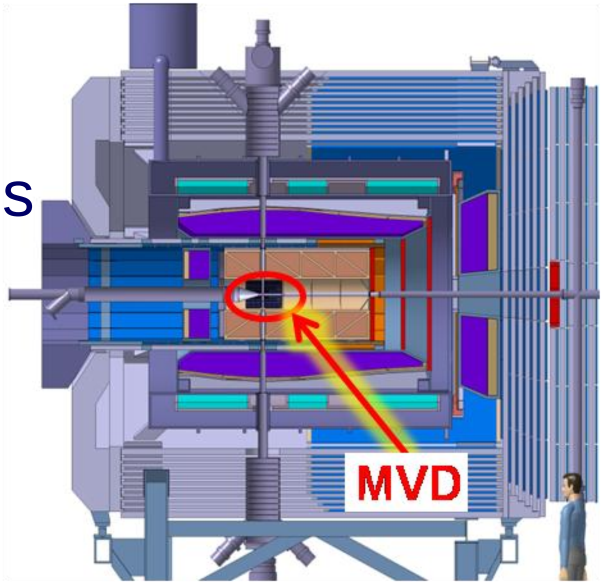
General description

- Micro-Vertex-Detector (MVD)
  - **Tracking detector** for charged particles
  - **Innermost** detector in PANDA
  - ***Main tasks***

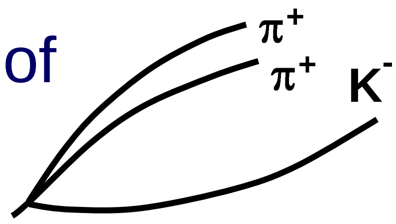
(1) Improvement of momentum resolution

(2) High vertex resolution for primary interaction vertex and secondary vertices of short lived particles and delayed decays

(3) Additional input for particle-ID



Target spectrometer



$D^{\pm}_{S} \rightarrow \bar{K}^0 x + K^0 y$

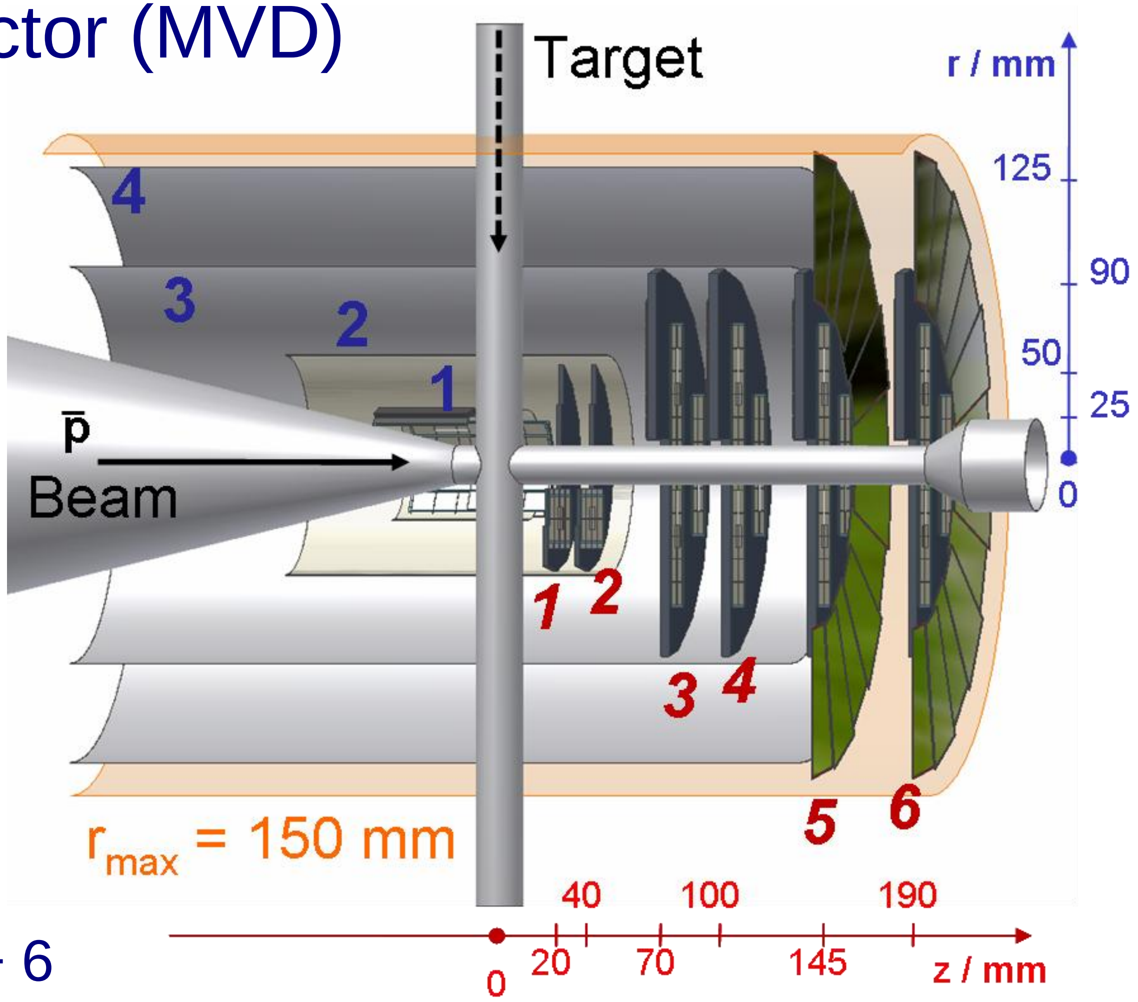
$c\tau = 147\ \mu m$

$D^{\pm} \rightarrow \bar{K}^0 x + K^0 y$

$c\tau = 312\ \mu m$

General layout

- Micro-Vertex-Detector (MVD)
  - Four barrel layer
  - Six disk layer
  - Detector types:
    - ✓ Pixel sensors
    - ✓ Double-sided microstrip sensors
  - Strip sensors:
    - ✓ Barrel layer 3 + 4
    - ✓ Outer radii disk 5 + 6

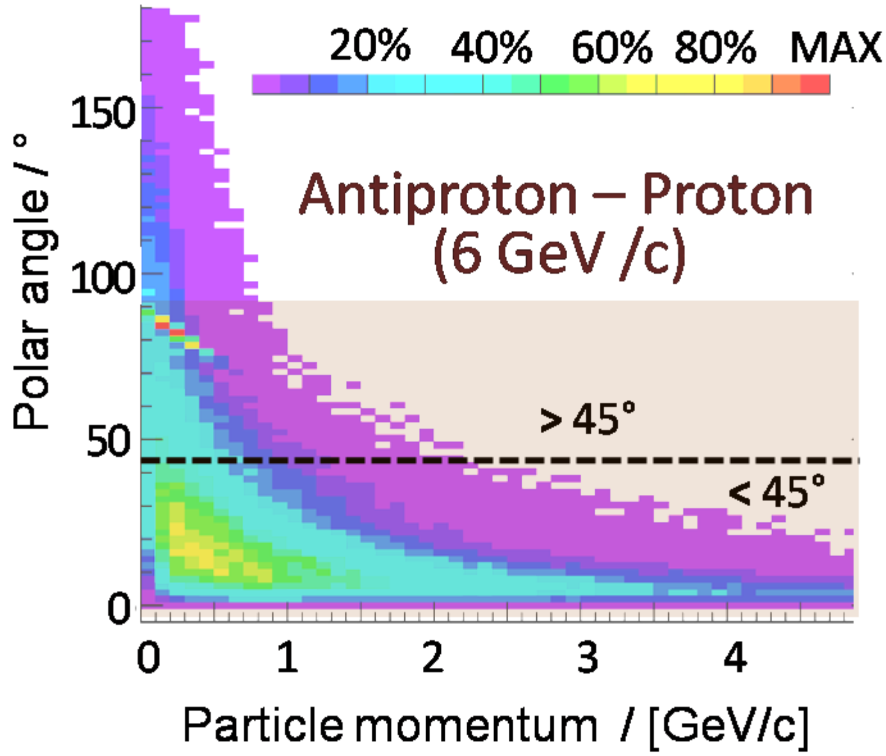


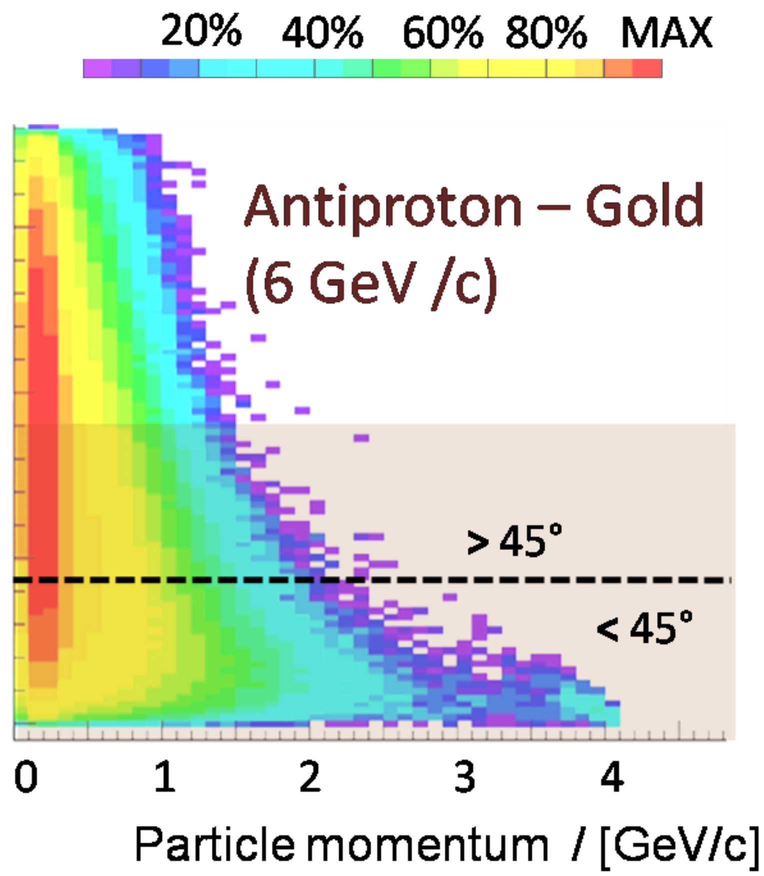
Requirements

- **Good spatial resolution and high spatial coverage**
  - r-phi → Momentum measurement (e.g. soft pions D* decay)
  - z → Vertexing, D-tagging
- **Good time resolution** (~20ns) → Quasi continuous beam
- **Amplitude** measurements → Improvement of spatial solution and PID
- Modest **radiation hardness** (~10^{14} $n_{eq}cm^{-2}$)
- **Triggerless readout** → no first level trigger hardware
- **Low material budget**

Experimental conditions

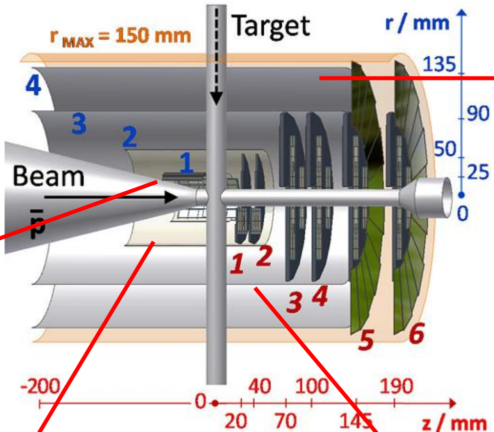
- Track density



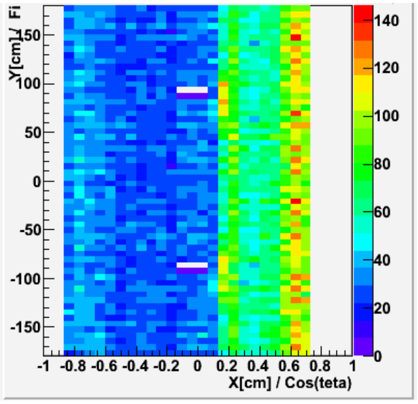


Experimental conditions

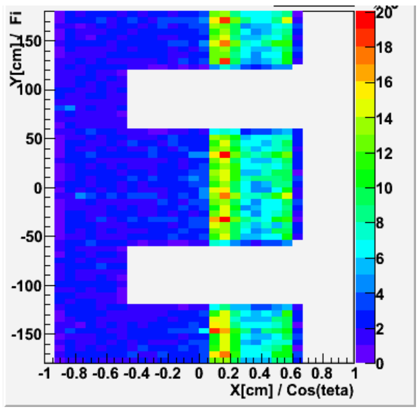
- Radiation load



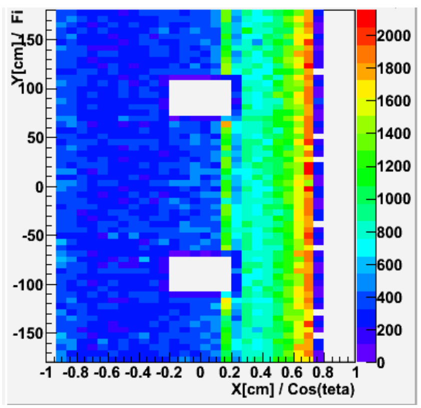
$\varphi_{max} \approx 1.5 \cdot 10^{11}\ n_{eq}/cm^2$

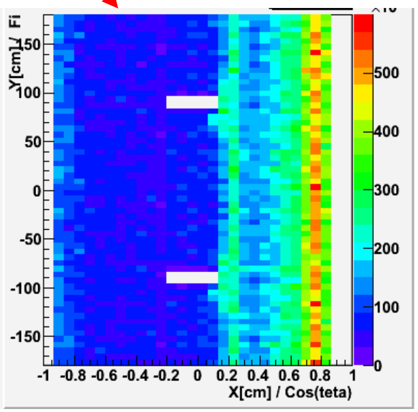


$\varphi_{max} \approx 2 \cdot 10^{13}\ n_{eq}/cm^2$



$\varphi_{max} \approx 2 \cdot 10^{12}\ n_{eq}/cm^2$

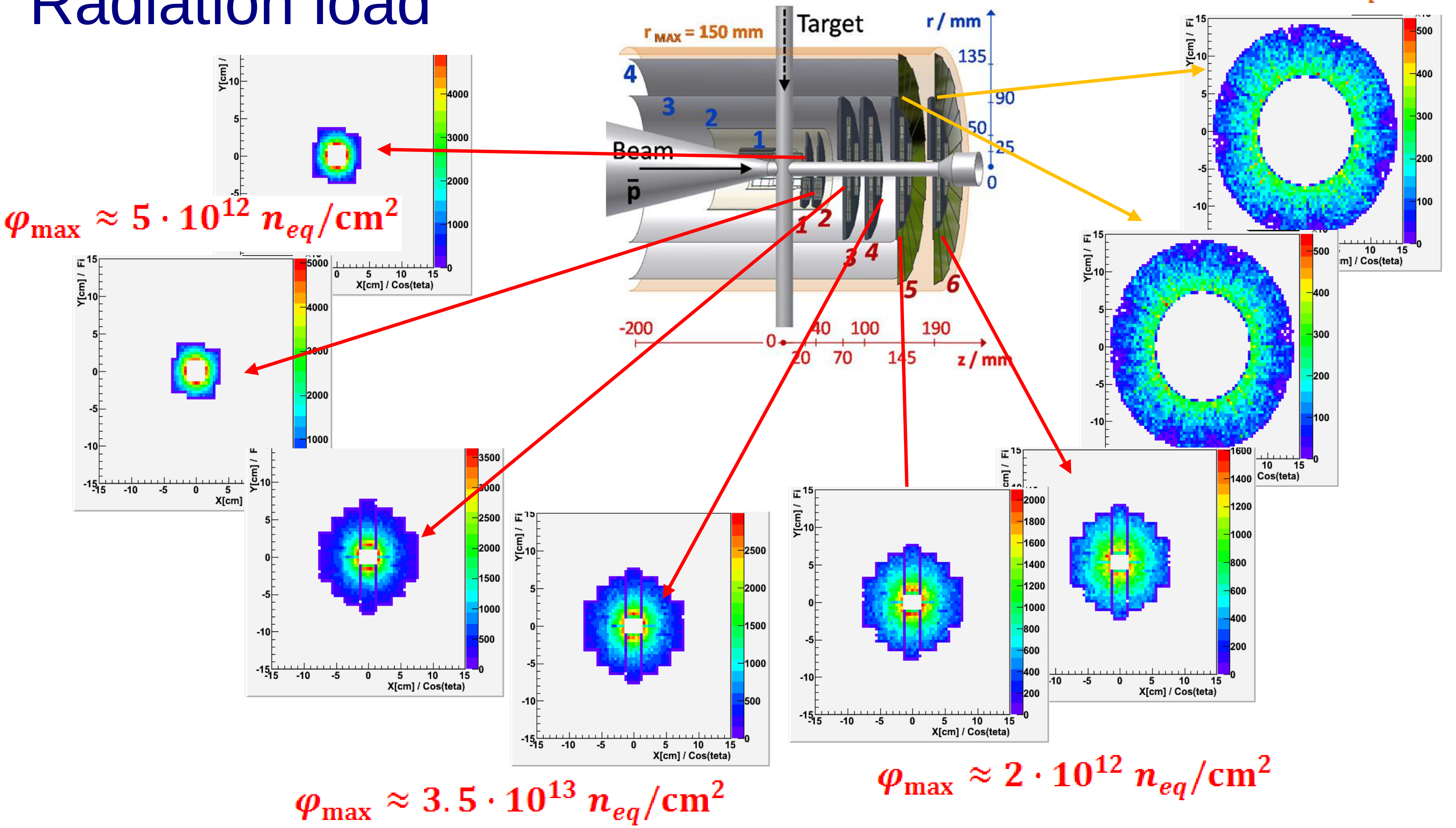




$\varphi_{max} \approx 6 \cdot 10^{11}\ n_{eq}/cm^2$

Experimental conditions

- Radiation load

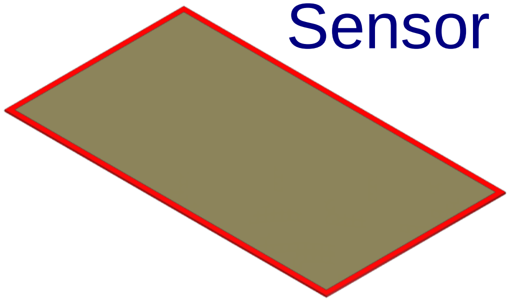


Implementation

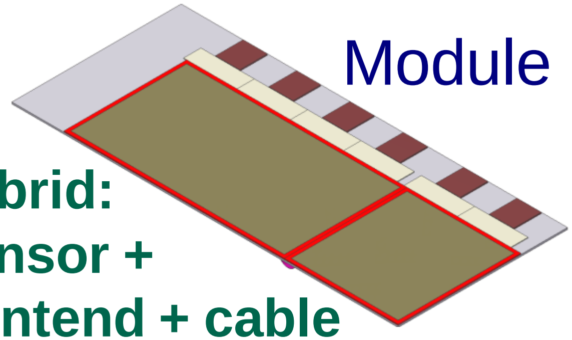
- Definition of sensor size and shape
  - Pixel: Rectangular
  - Strip: Rectangular (barrel), trapezoidal (disk)
- Definition of size for readout structure
  - Pixel size: 100 x 100 μm^2
  - Readout pitch and stereo angel:
    - ✓ 130 μm / 90° (barrel), 70 μm / 15° (strip)
- Sensor arrangement
- Hybridisation including frontend electronics
- Mechanics: cooling, cabling, support, alignment, integration

Implementation

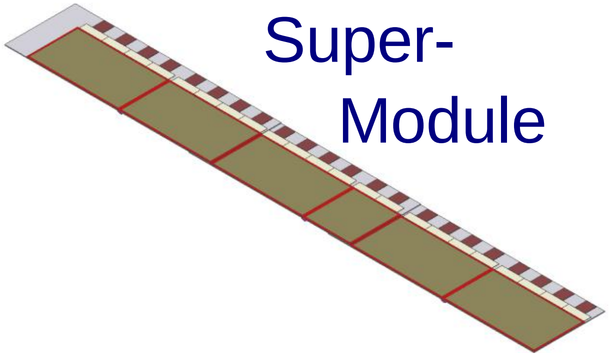
Sensor



Module

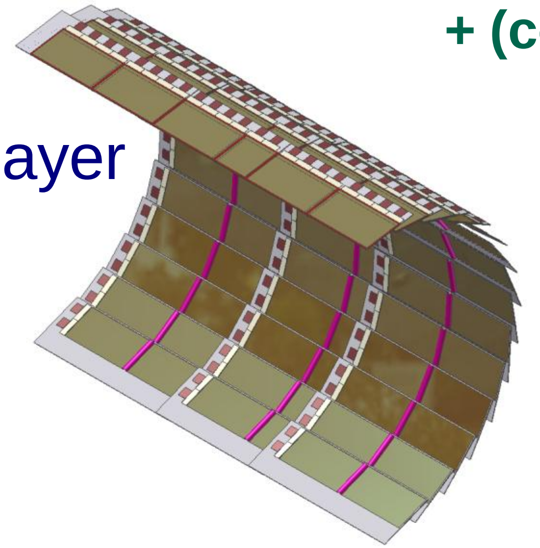


Super-Module



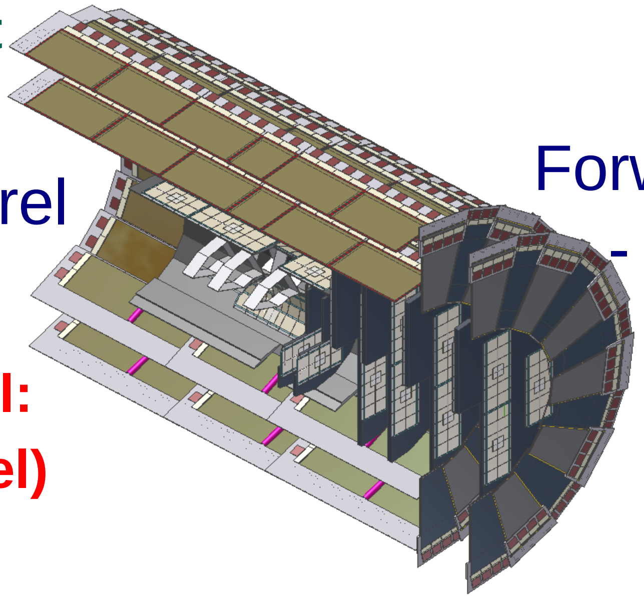
Hybrid:
Sensor + frontend + cable + (cooling) + support

Layer



Half-barrel

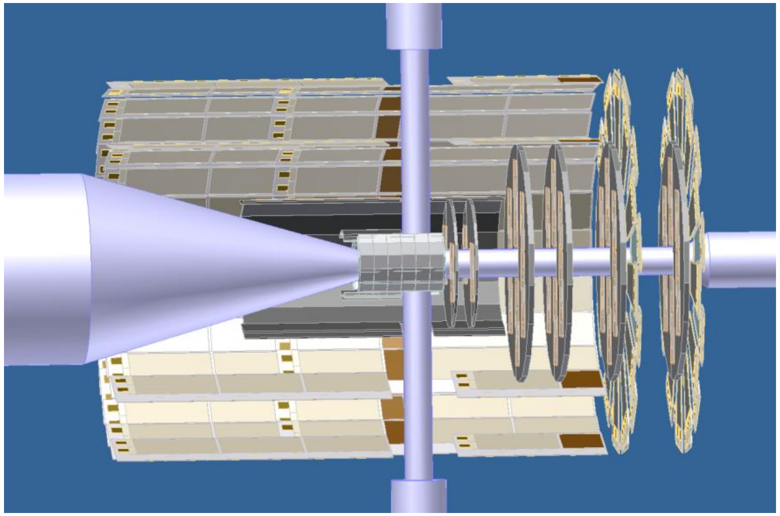
Forward - part

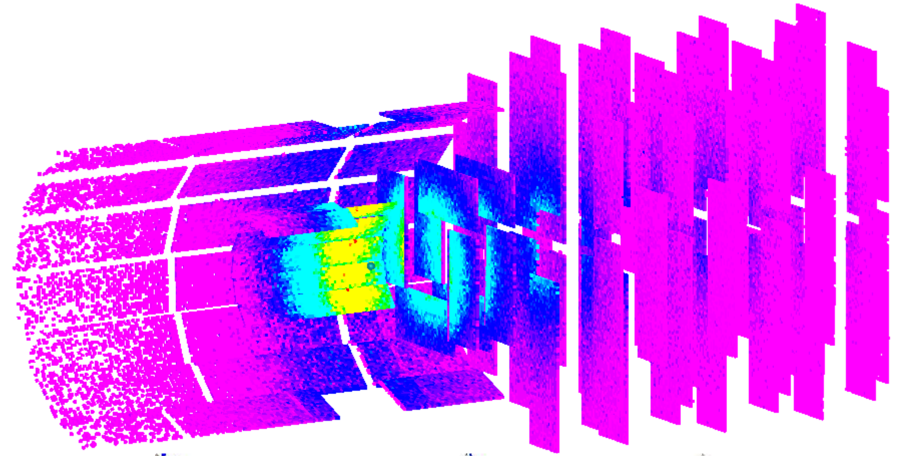


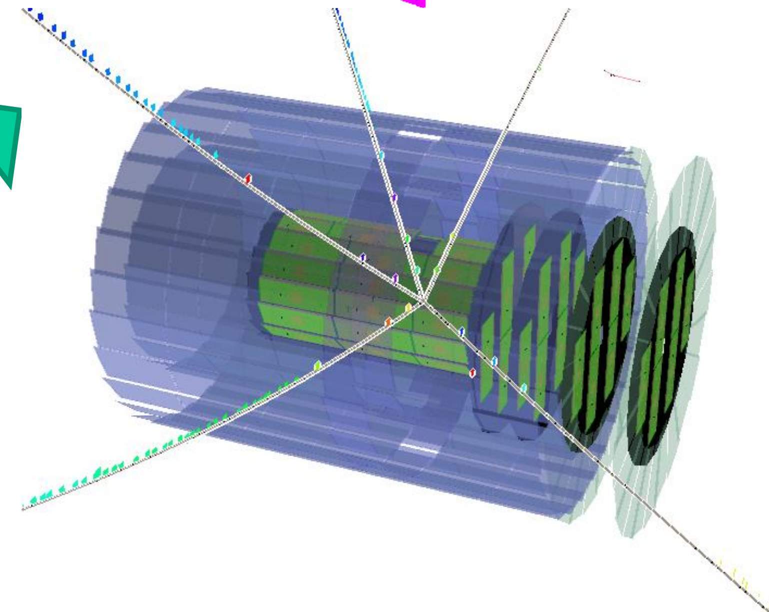
Readout channel:
~ 12 million (pixel)
~ 200.000 (strip)

Low power dissipation for frontend electronics !!!

Implementation



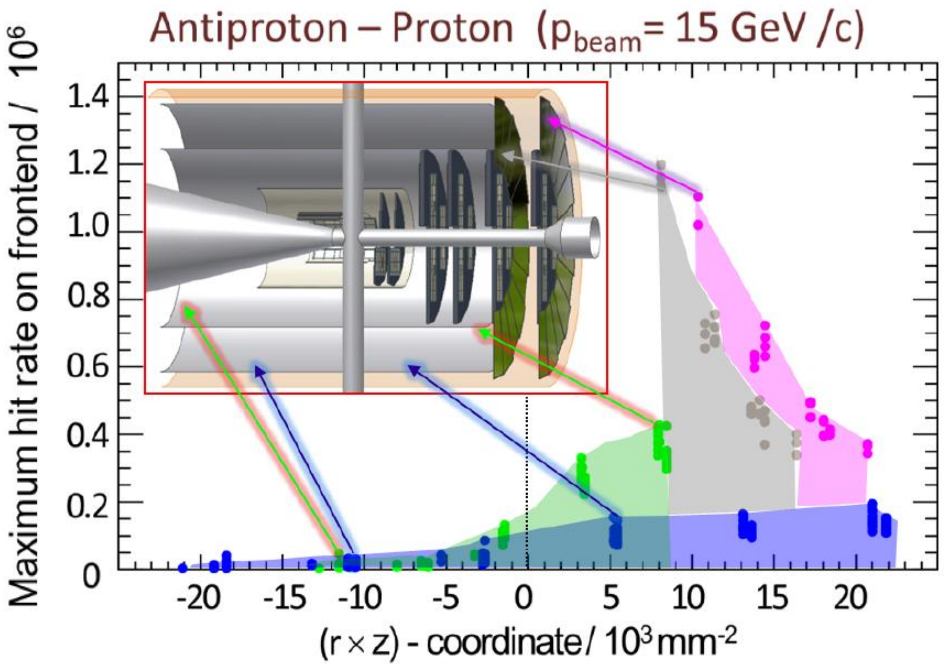




CAD Converter
translates CAD drawings (STEP-files) into ROOT geometries ➔ access to full pandaROOT simulation with realistic detector design

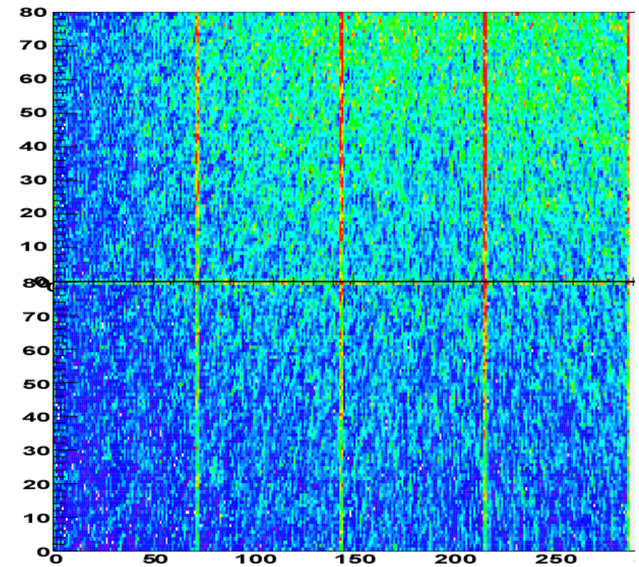
Simulation

- Maximum count rates



- ➢ Max. Rate / frontend: ~ **1 MEvts / s**
- ➢ Max. Rate / channel: ~ **10 kEvts / s**

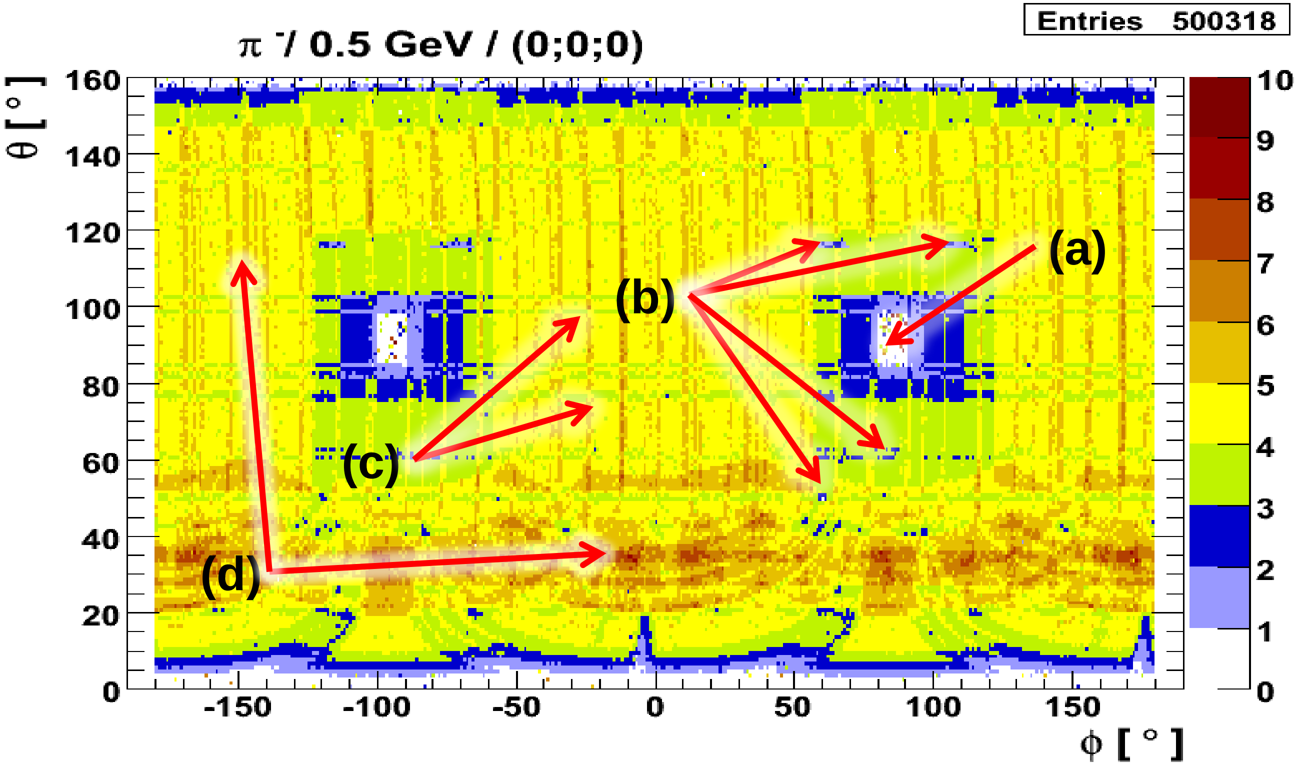
- ➢ Highly anisotropic
- ➢ Pixel: Variations for channels on frontend



Hit distribution on pixel module with highest rates

Simulation

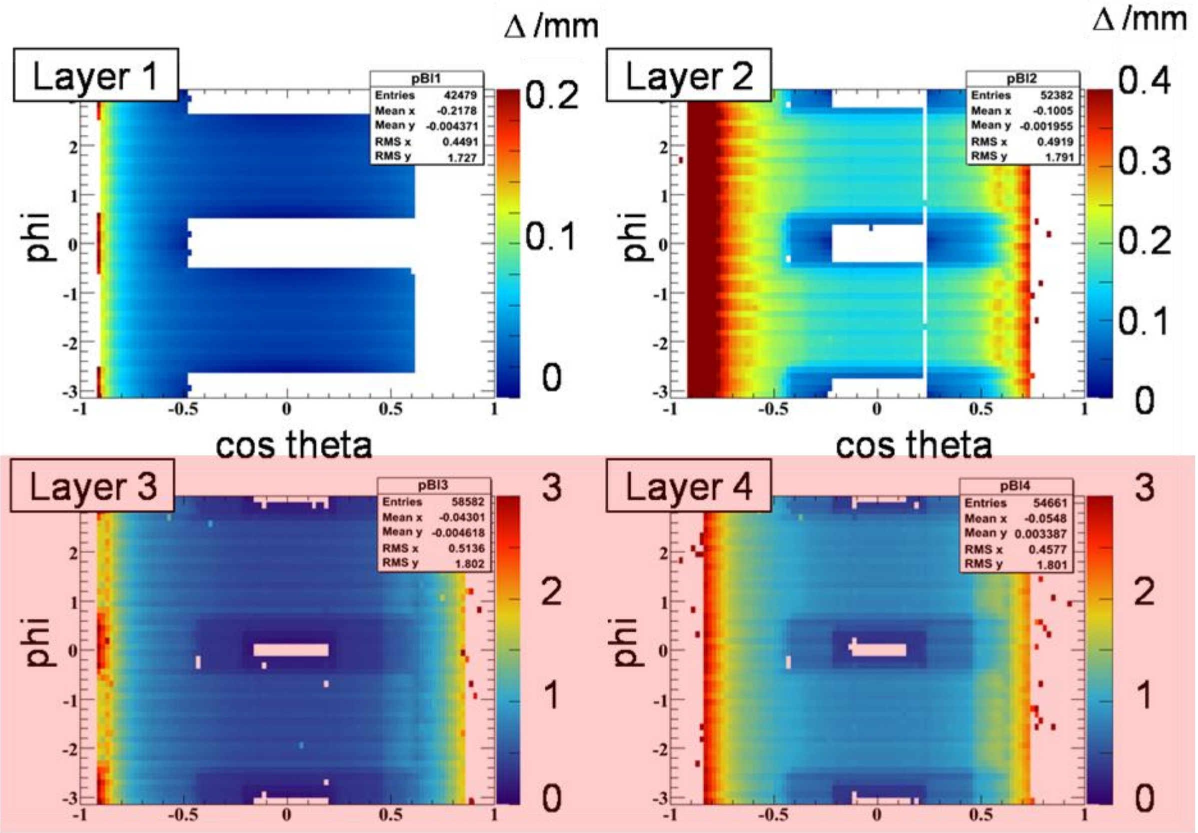
- Spatial distribution of MVD points / track
  - Inhomogeneities: (a) Target pipe, (b) module positioning, (c) strip-sensor gap in barrel layers, (d) sensor overlap, ...



Simulation

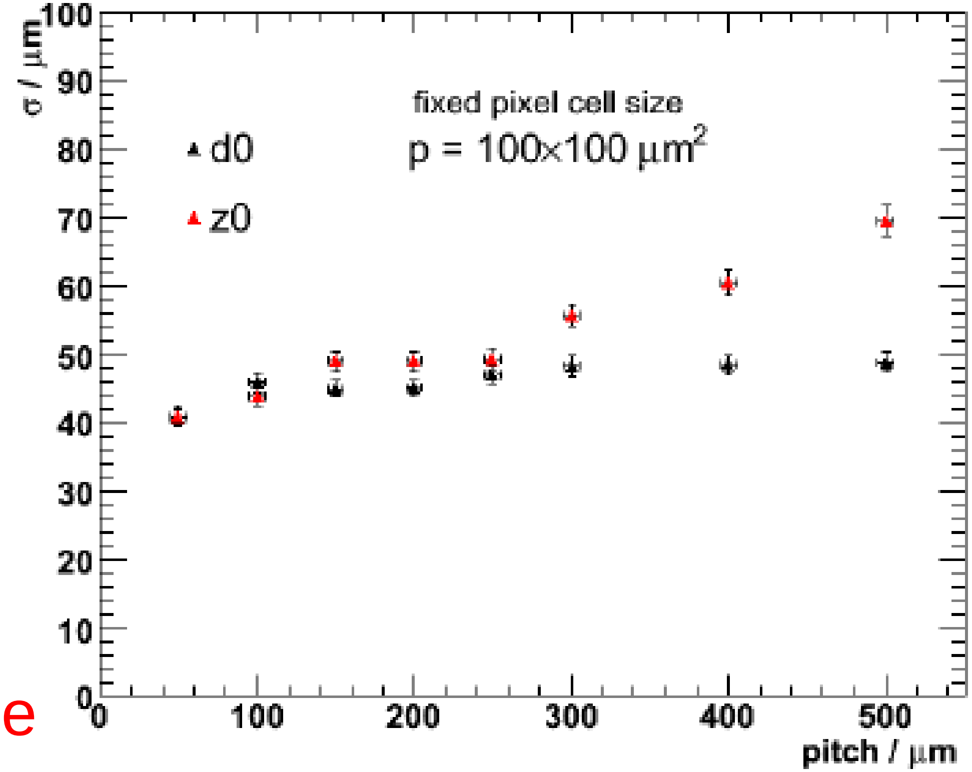
- Study of multiple scattering with particle propagator
  - *Geane* (based on *Geant3*)
  - Example:
    π^+, 0.5 GeV / c
    → Barrel layer
  - Plotting the deviation due to scattering (Δ)

$$\Delta = |\vec{r}_{SIM} - \vec{r}_{IDEAL}|$$



Simulation

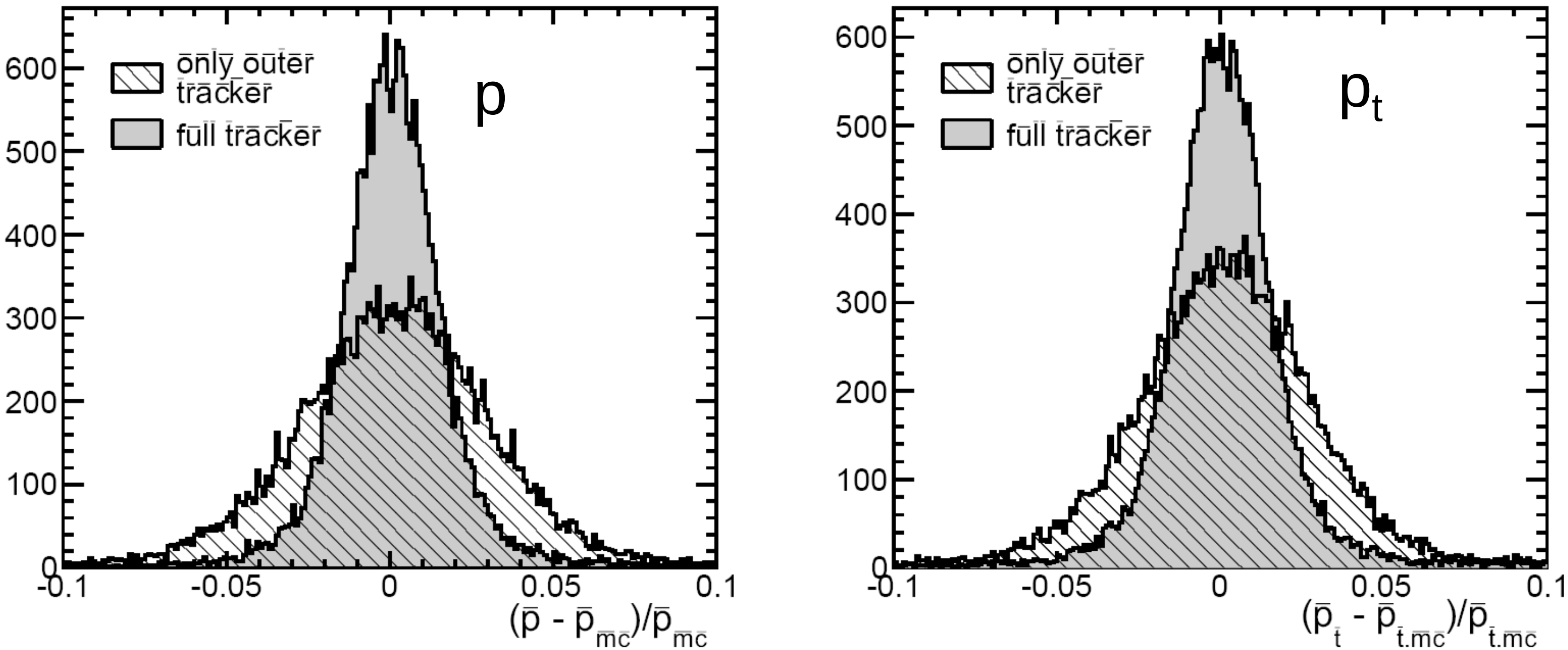
- Single track vertex resolution for different readout structures (pixel cell size/ strip pitch)
  - Example:
    π^-, (0.2 … 3) GeV / c
    → Fixed pixel cell size
    → Variation of strip pitch
  - Analysis:
    → Vertex resolution parameters (d_0, z_0)



No significant improvement below 250 µm strip pitch due to scattering in precedent layers

Performance

- Momentum resolution



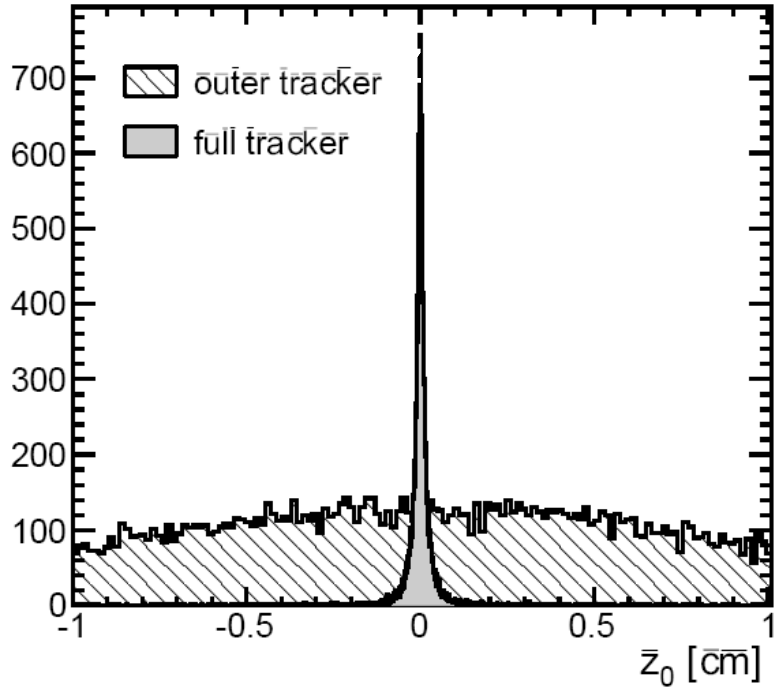
σ(p) [1GeV/c π] without MVD = 2.6 %

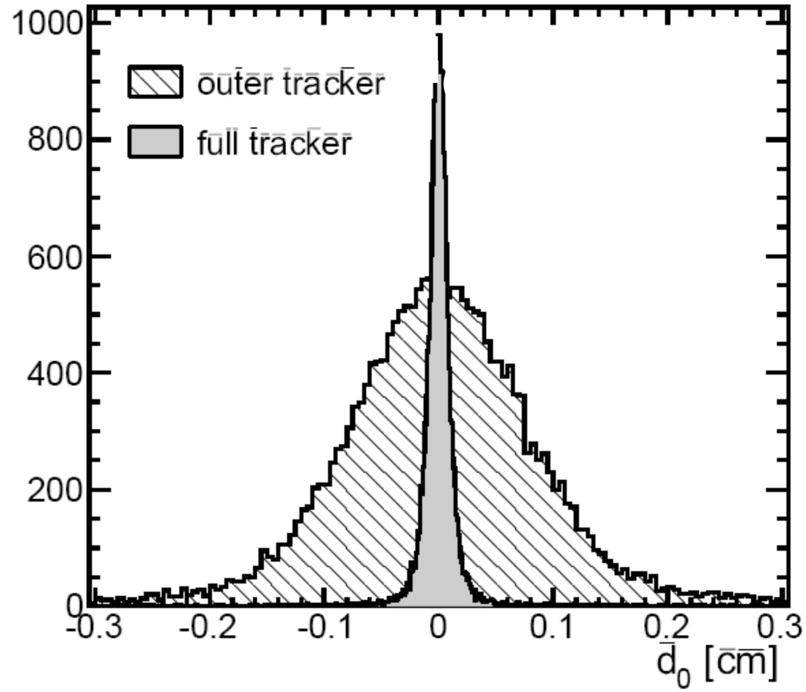
σ(p) [1GeV/c π] with MVD = 1.4 %

1 GeV/c pions

Performance

- Track parameter resolution





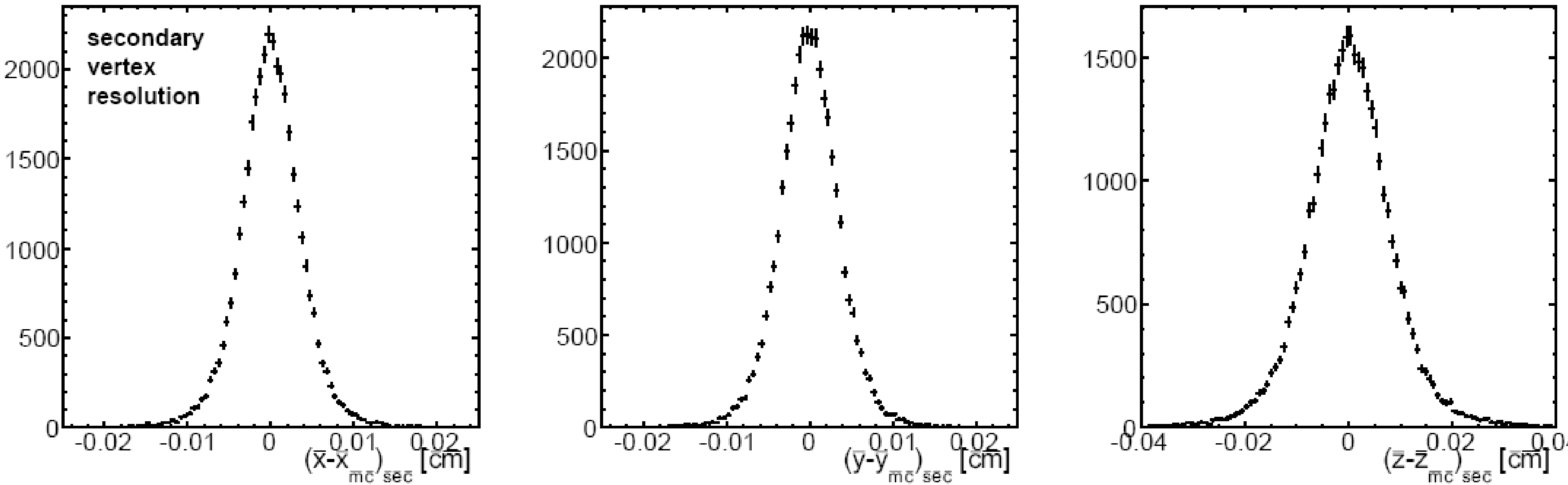
1 GeV/c pions

R. Jäkel PhD thesis in preparation

Performance

- Secondary vertex resolution

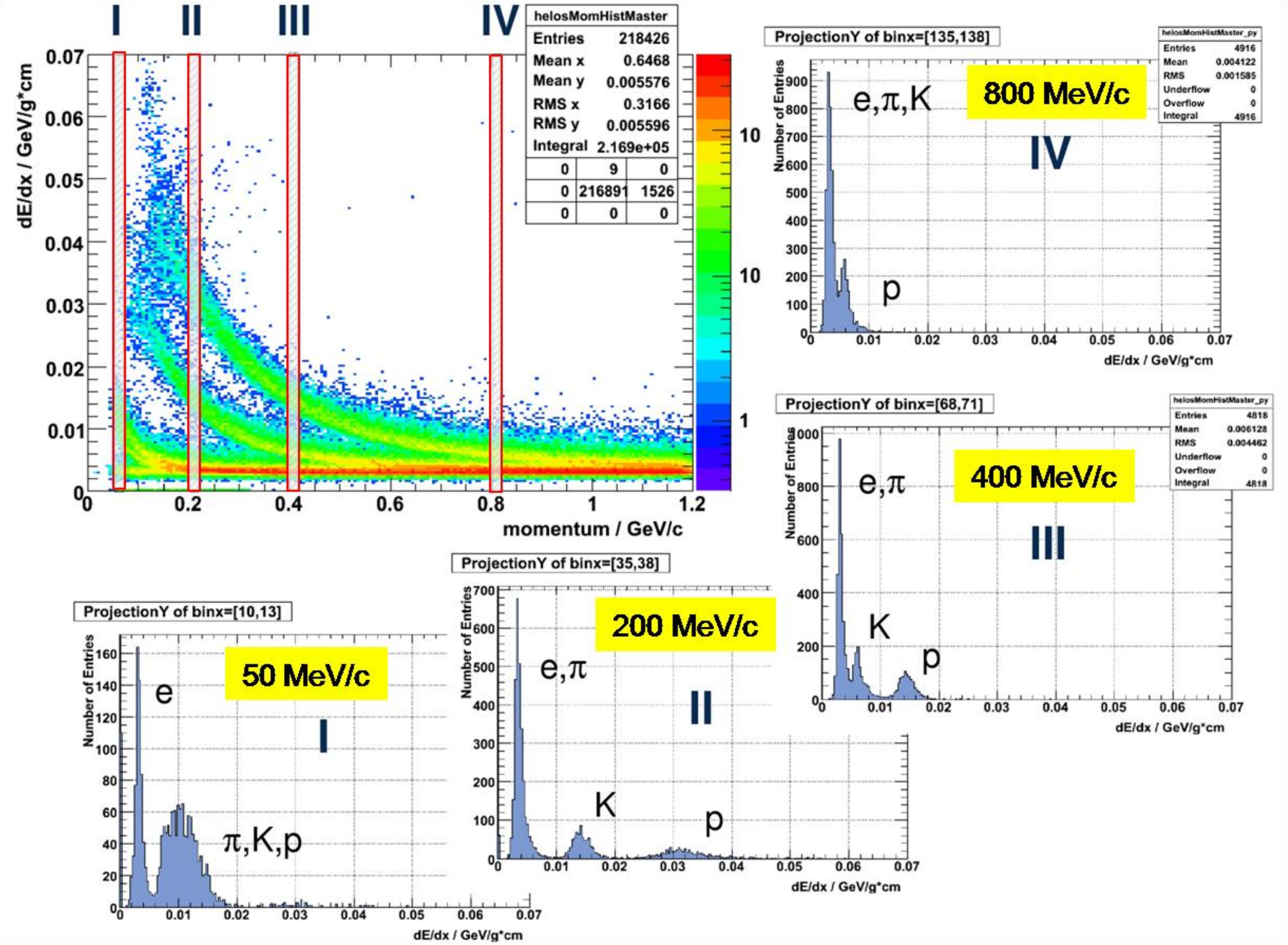
ppbar → D^+D^-



R. Jäkel PhD thesis in preparation

- Fully reconstructed D^+D^- pairs
- Vertex resolution (at 6.57 GeV/c):
  35 µm in x and y ; 77 µm in z

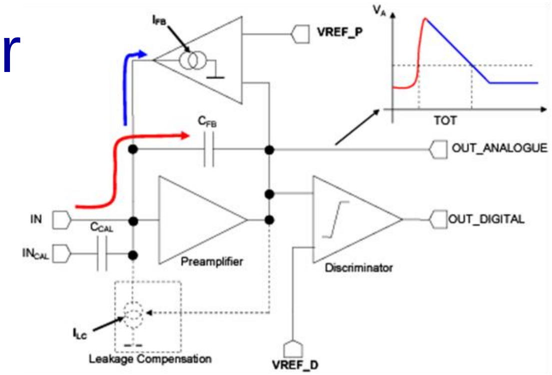
- PID

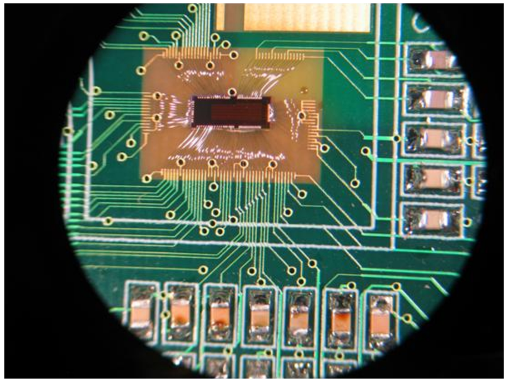


I
II
III
IV
helosMomHistMaster
Entries 218426
Mean x 0.6468
Mean y 0.005576
RMS x 0.3166
RMS y 0.005596
Integral 2.169e+05
dE/dx / GeV/g*cm
momentum / GeV/c
ProjectionY of binx=[135,138]
e,π,K
p
800 MeV/c
IV
ProjectionY of binx=[68,71]
e,π
K
p
400 MeV/c
III
ProjectionY of binx=[35,38]
e,π
K
p
200 MeV/c
II
ProjectionY of binx=[10,13]
e
π,K,p
50 MeV/c
I
Number of Entries

Development

- Frontend electronics
  - TOPIX chip for pixel sensors

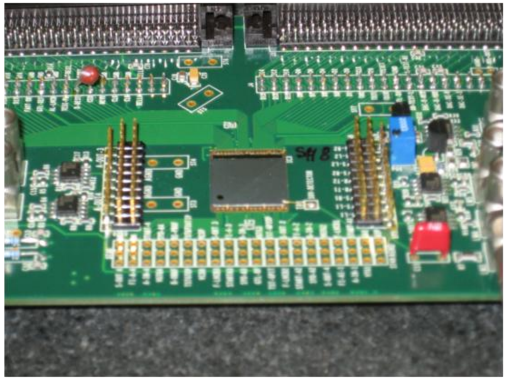




ToPix2
- 320 readout cells (100 µm)²
- 5x2 mm² size
- analogue + digital circuit

… more in next talk:

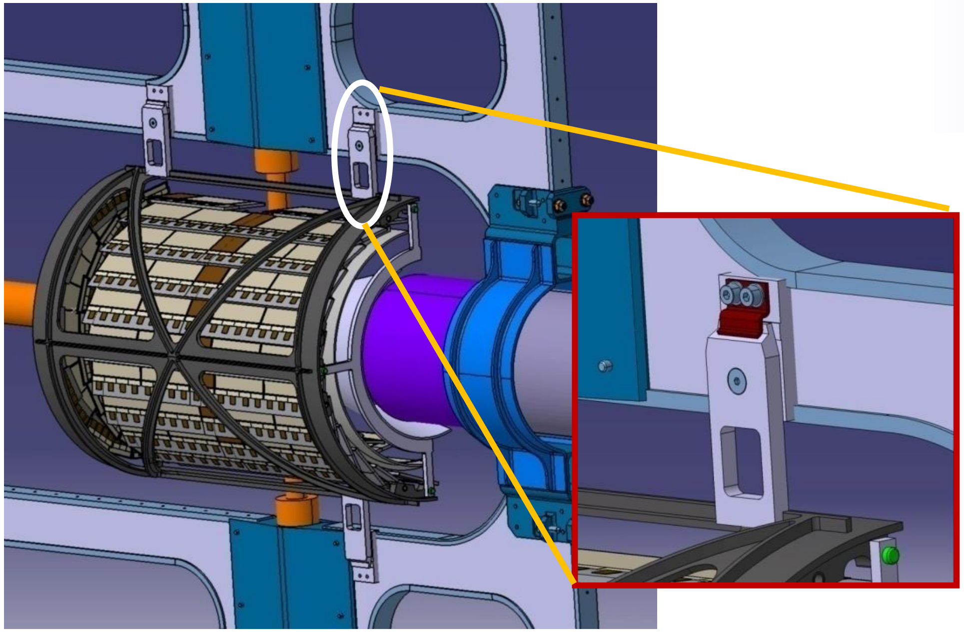
T. Kugathasan

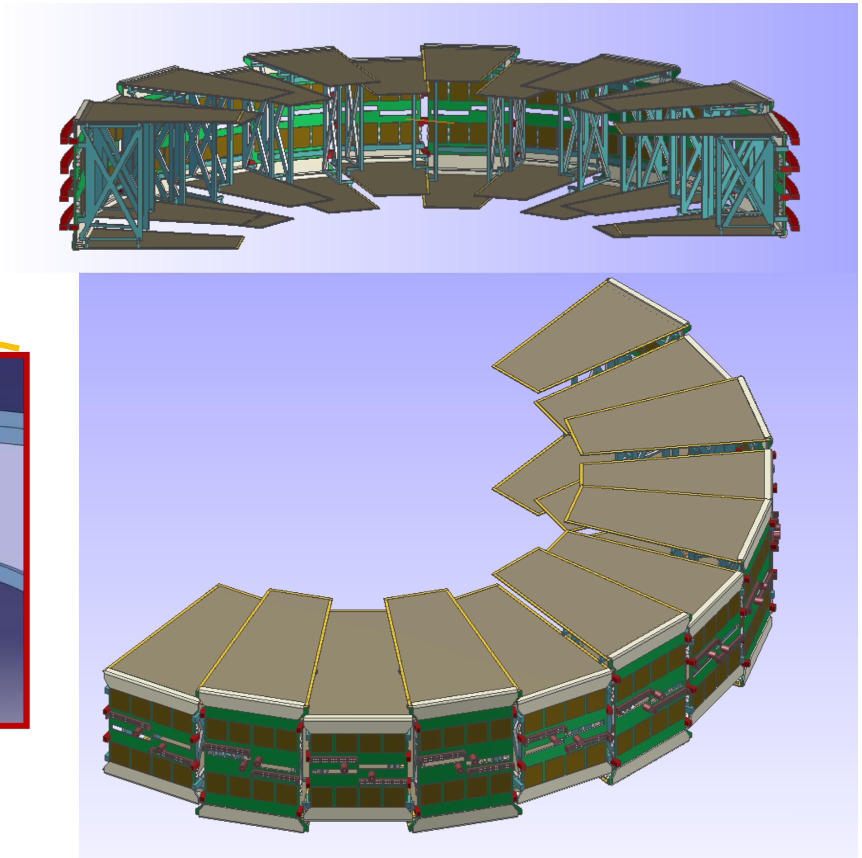


Epi-pixel sensor
- bump bonded on ALICE FE
- thinned down to:
  - 100 µm (49 µm)
  - 120 µm (75 µm)
  - 150 µm (98 µm)

Development

- CAD development: integration

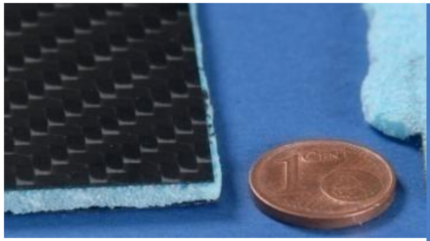
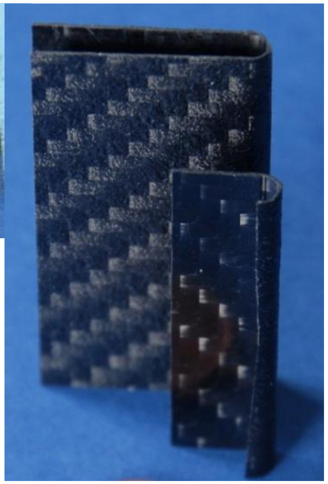
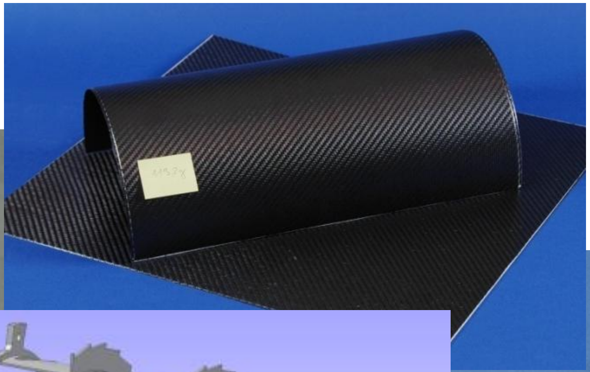
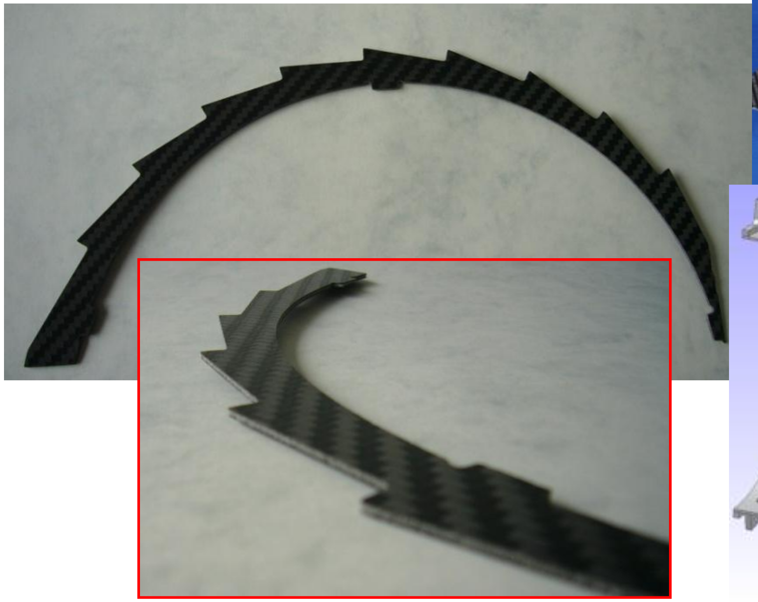
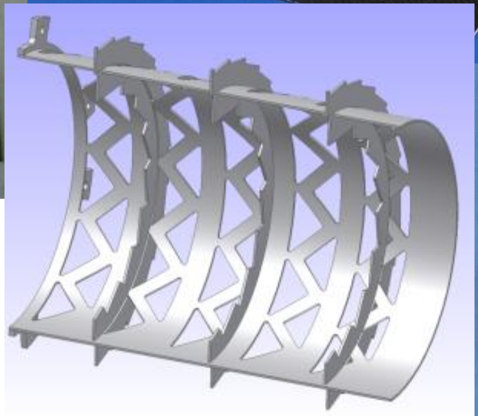
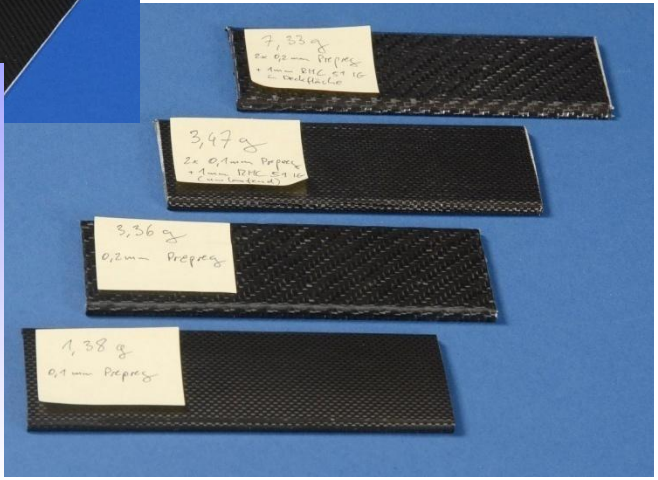




Development

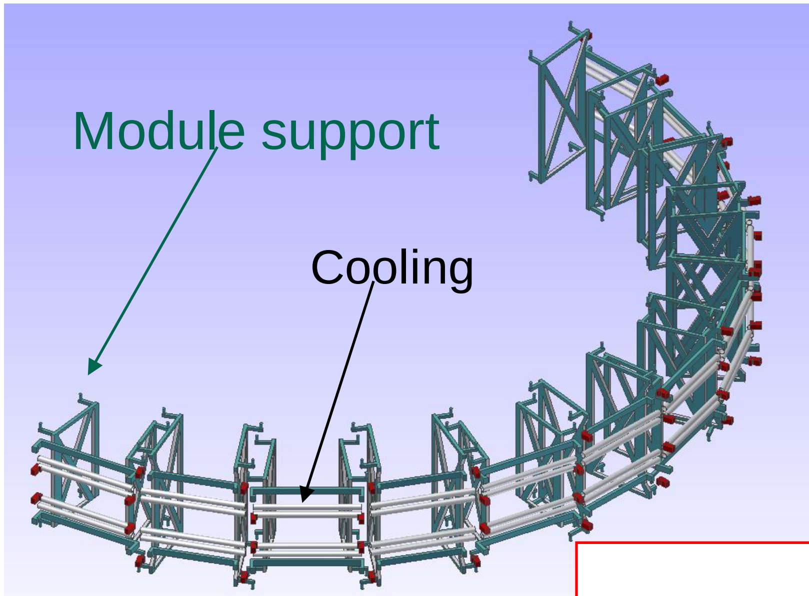
- Mechanics: Carbon structures
  - Sandwich structure

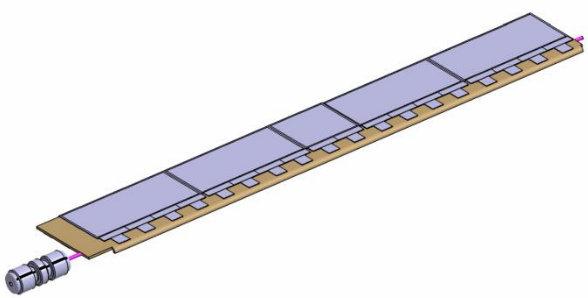
    (Carbon – Foam – Carbon)
  - Barrel support

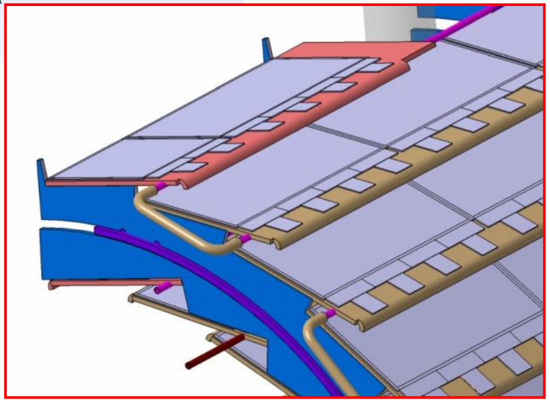







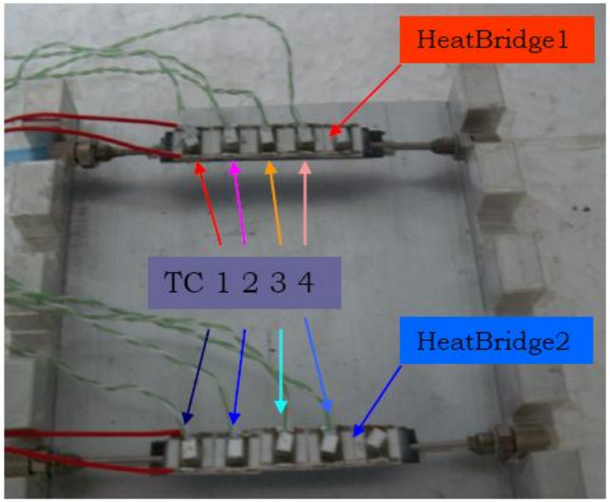
Development

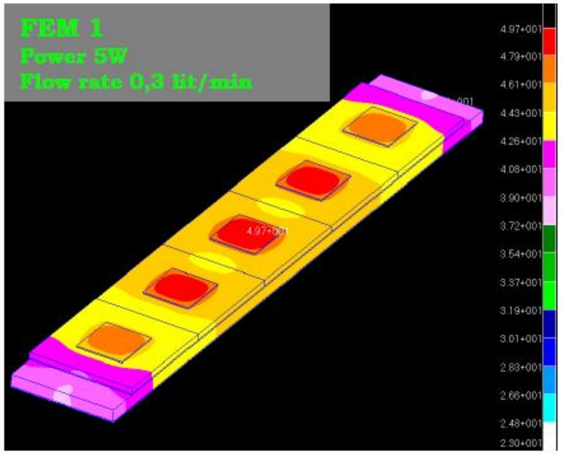
- Mechanics: Cooling system





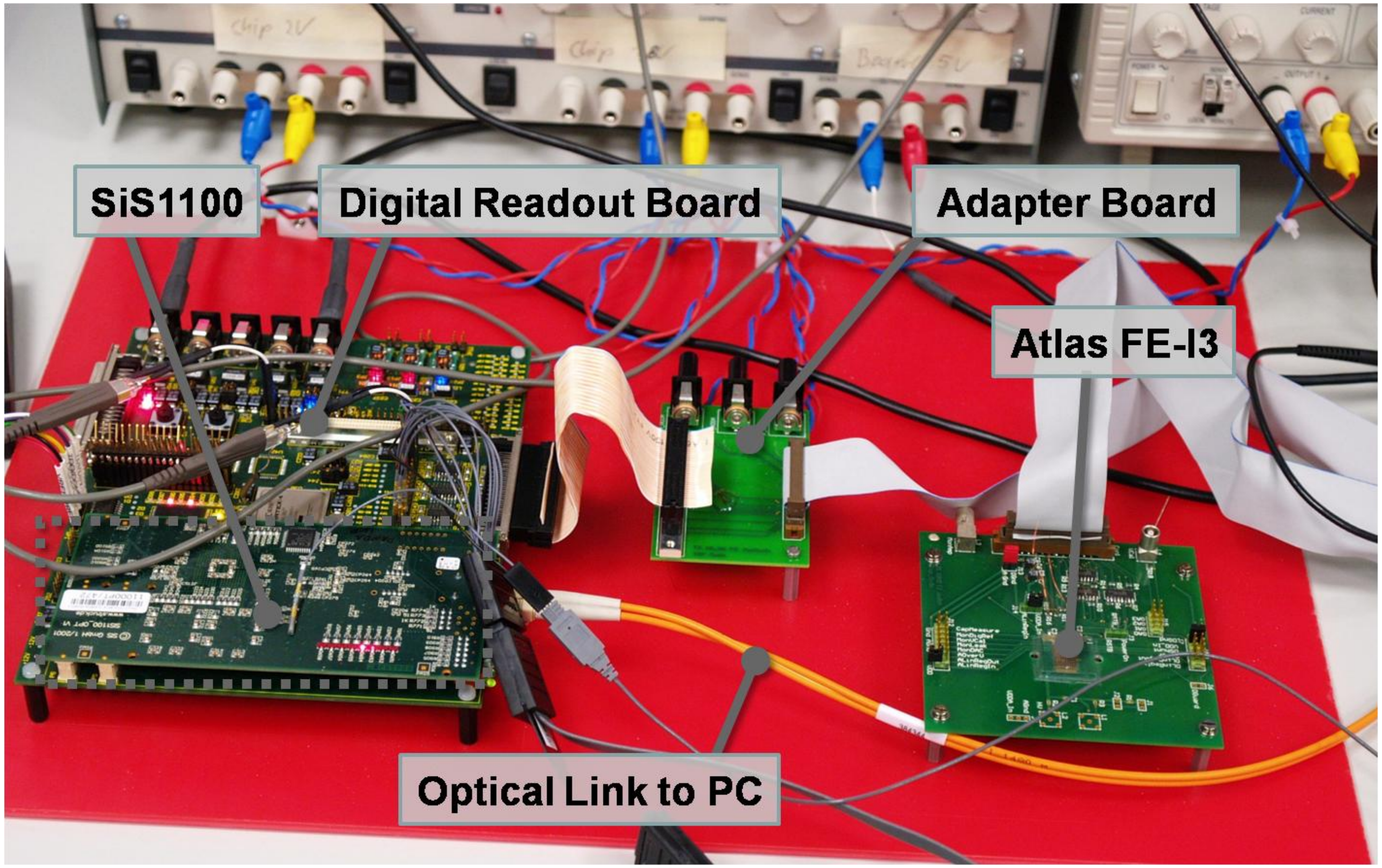






Development

- Test system for pixels

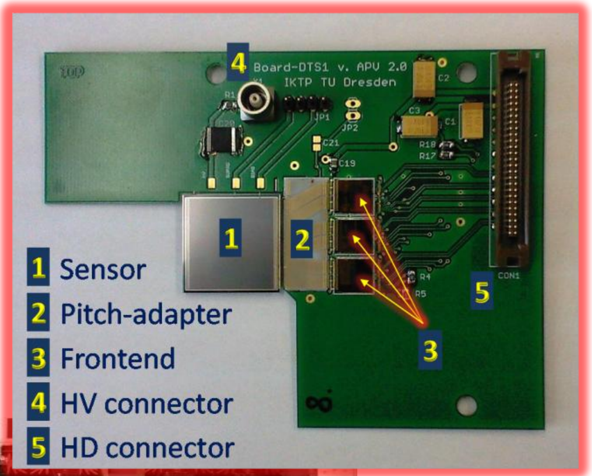


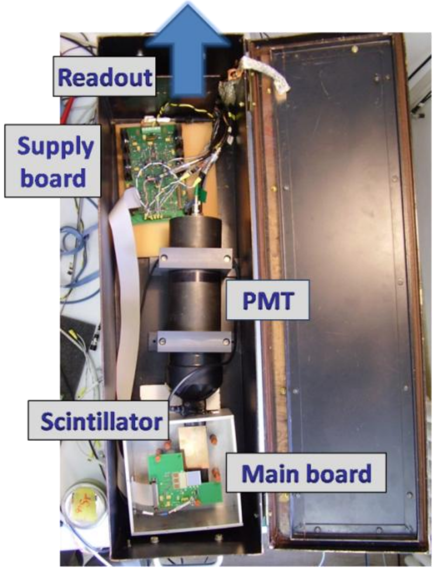
Development

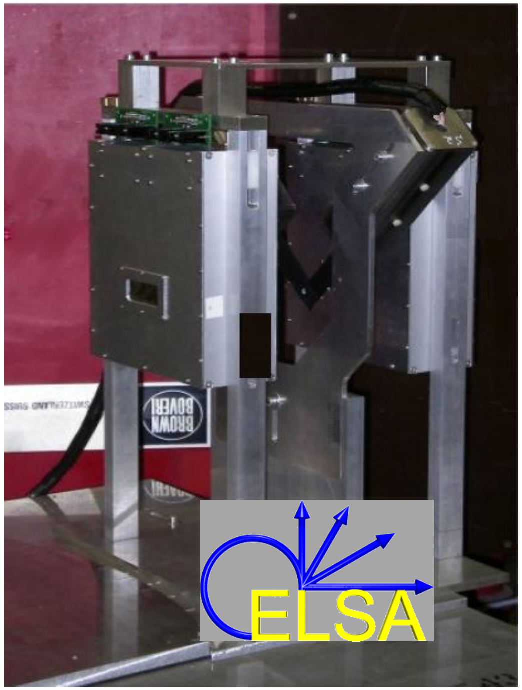
- Test system for strip sensors

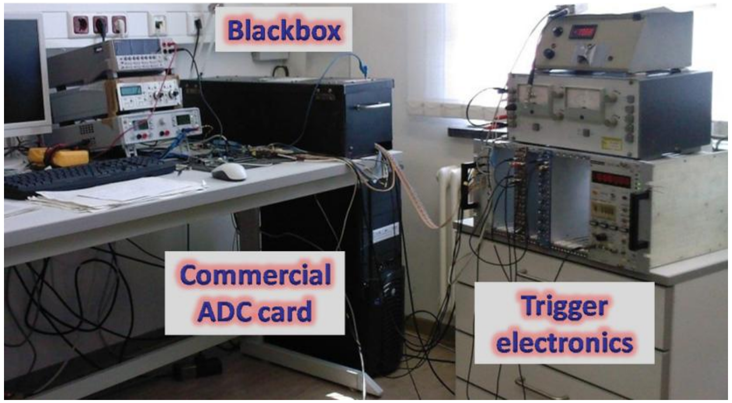
  Lab-system /

  Beam telescope

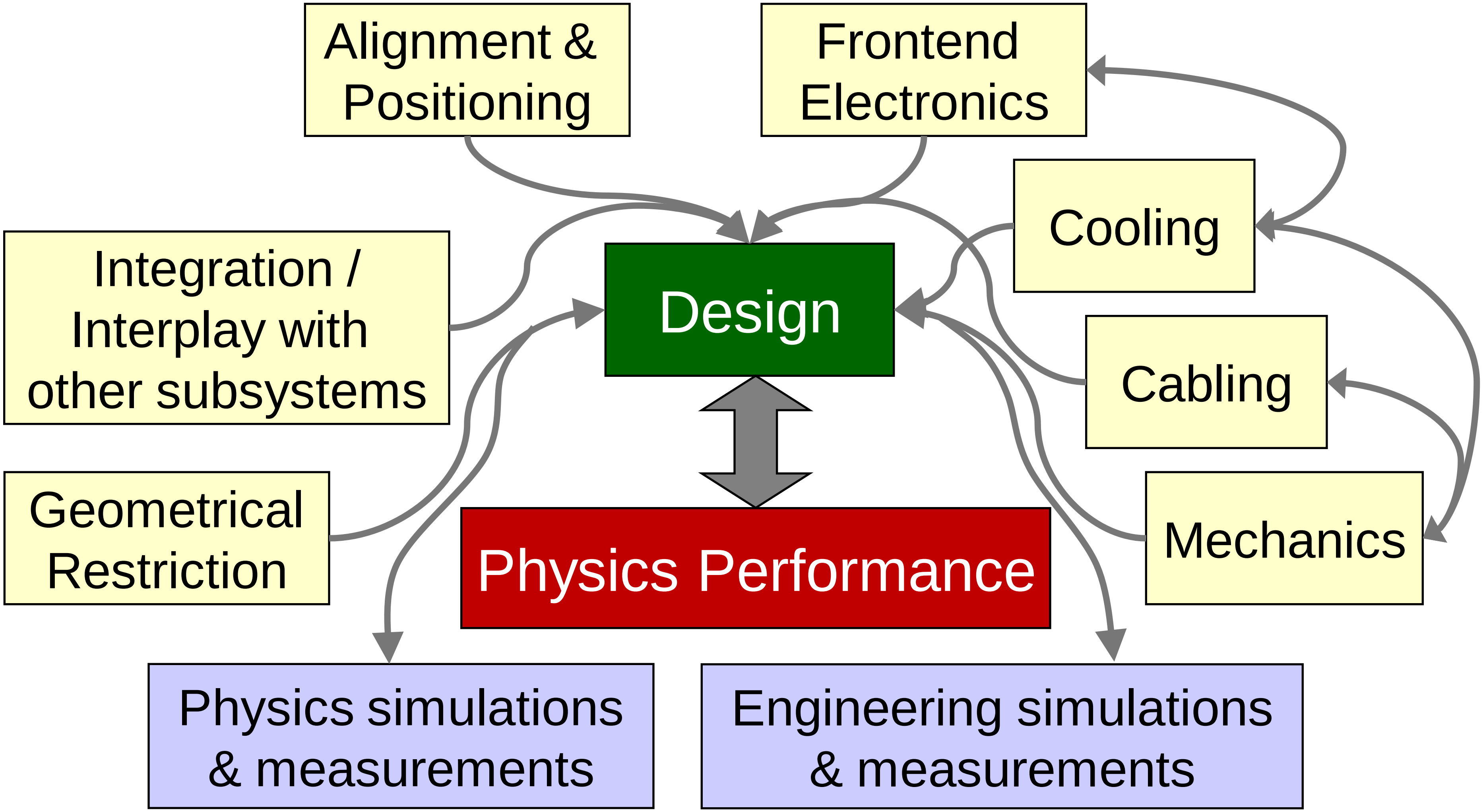








Detector optimisation



Summary

- MVD plays important role to exploit PANDA physics program
- General MVD layout fixed
- Work on detailed implementation started
  → Detector optimisation
- Simulation and hardware tools available

Physics guidance of engineering implementation ensure an optimised detector development

Finally ...

> 0.5

+

< 0.5