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Design Optimisation for (the Silicon Micro-Strip Part of) the PANDA Micro-Vertex-Detector *

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on behalf of the PANDA MVD group

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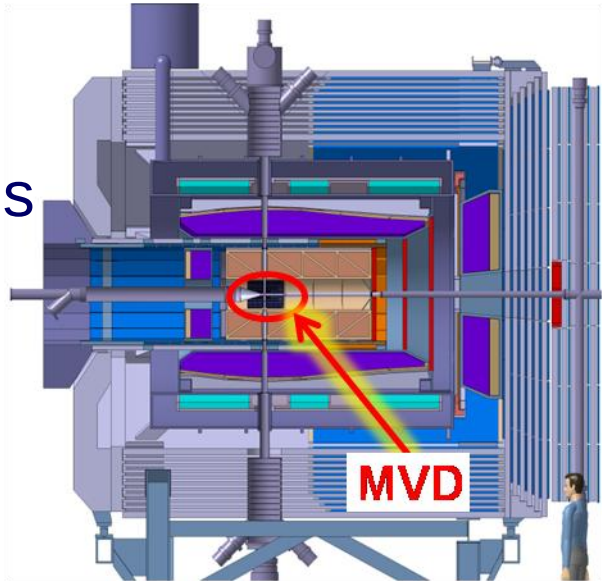
Introduction

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

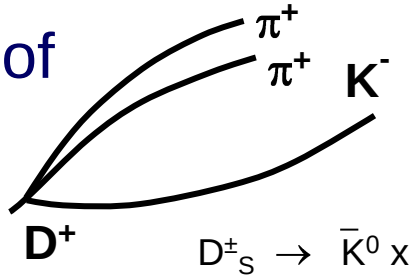
(1) Improvement of momentum resolution

(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



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

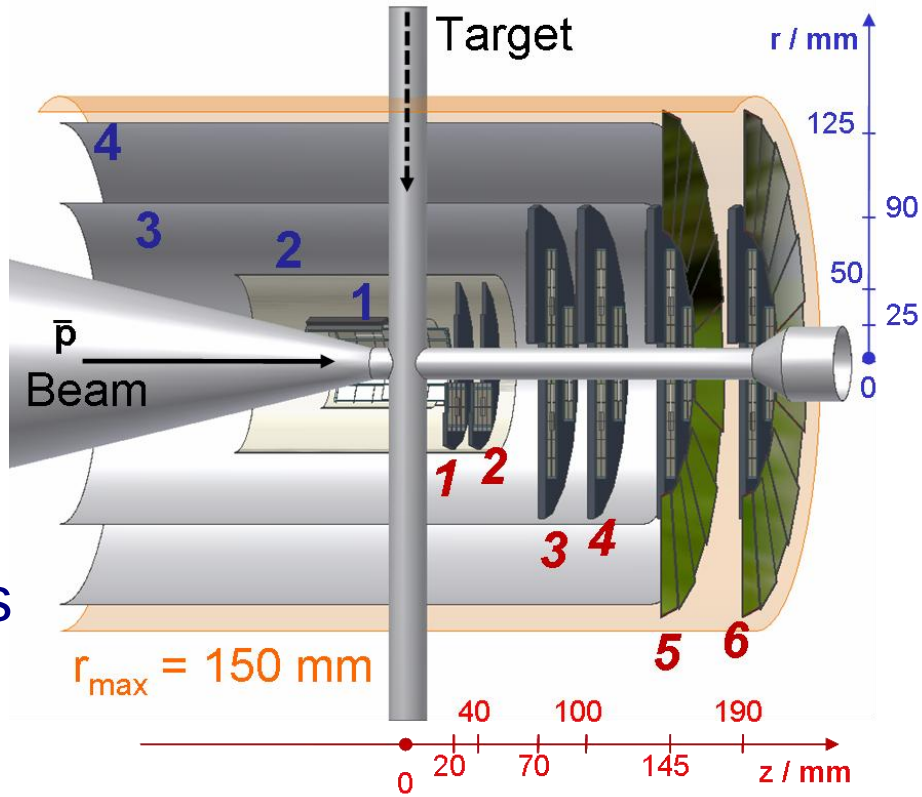
$c\tau = 312\ \mu m$

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

$c\tau = 147\ \mu m$

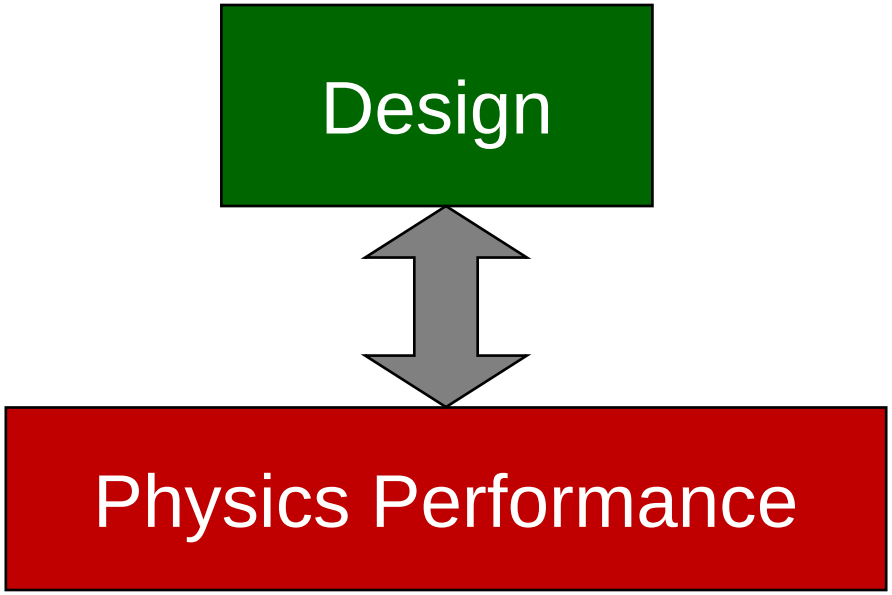
Motivation

- General MVD layout fixed
  - Number of layers
  - Detector type
  - Overall geometry
- Detailed implementation
  - Detector: shape, dimensions
  - Hybridisation
  - Support structure
  - Cooling, cabling and routing concept
  - Alignment … integration / interplay with other subsystems



Motivation

Extraction of **design parameters** in order to **qualify** dedicated concepts in terms of **physics performance**



Design parameters enable **optimisation** of the detector

Design parameters

a **Innermost detector** in PANDA:

- Low material budget, notably in forward direction
  - → Material mapping
  - → Radiation lengths
  - → Scattering effects

b **Tracking** detector:

- Maximum spatial coverage
- Sufficient number of hit points
  - → Number of hit points / track
    - Design goal: 4 points per track
    - 1st point close to vertex
    - Last point close to outer tracker

Design parameters

c Vertex resolution:

- Number and position of track points (w.r.t. vertex)
- Spatial resolution of single track points

  → Size of readout structure

  → Sensor arrangement …

d Additional input for PID:

- Analogue information for single hit points

  → Energy deposition

  (→ Calculation of hit position … see above)

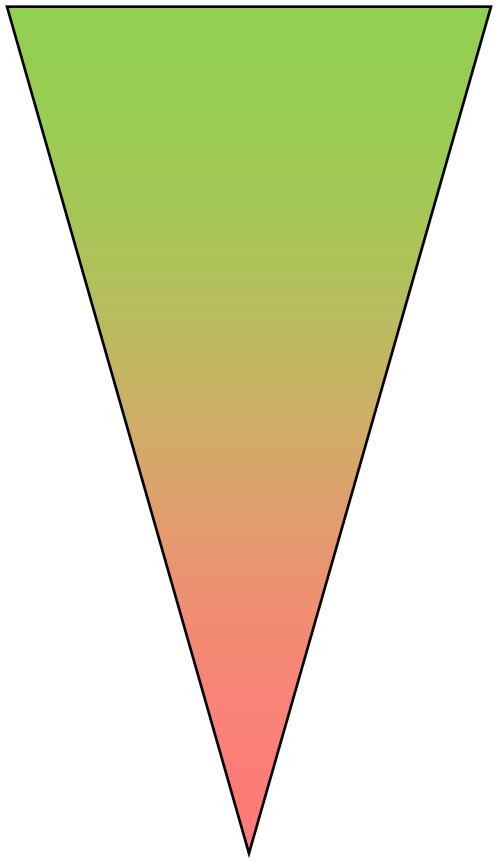
  → Resolution

  → d_{eff} (sensor thickness, incident angle of track)

  → Signal-to-Noise as function of d_{eff} …

Design parameters

Basic Parameters



Physics Results

→ Number of hit points / track ($N_{trk\text{-}pt}$)
→ Spatial distribution of ($N_{trk\text{-}pt}$ / track)

→ Spatial distribution of material load
→ Mapping of scattering effects

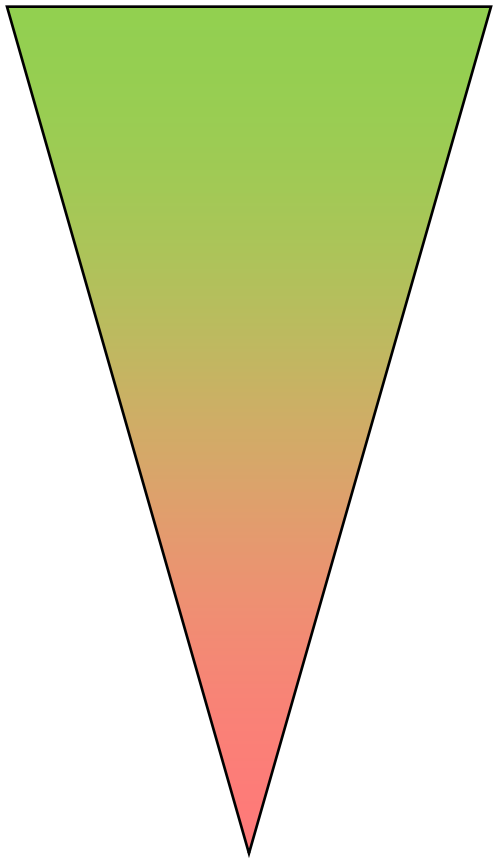
→ Count rate studies
→ Single hit resolution

… …

→ Track resolution
→ Vertex resolution
→ Simulation of physics channels
(*R. Jäkel*, HK 25.7)

Design parameters

Basic Parameters



Physics Results

→ Number of hit points / track (N_{trk-pt})

→ Spatial distribution of (N_{trk-} / track)

→ pad

→

→ Vertex resolution

→ Simulation of physics channels

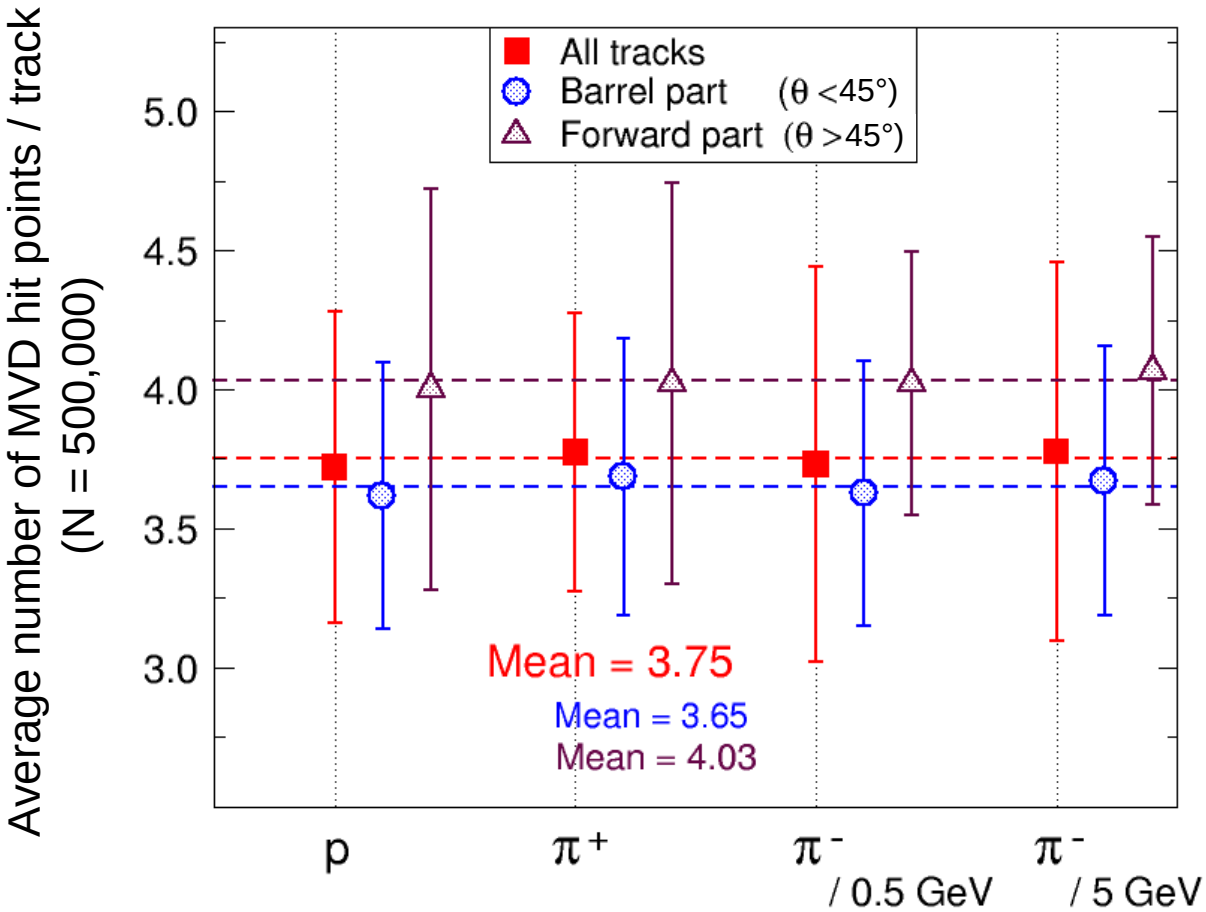
(*R. Jäkel*, HK 25.7)

Set of complementary parameters, interdependent w.r.t. optimisation

… no parameter can be studied independently … !

Track-point studies

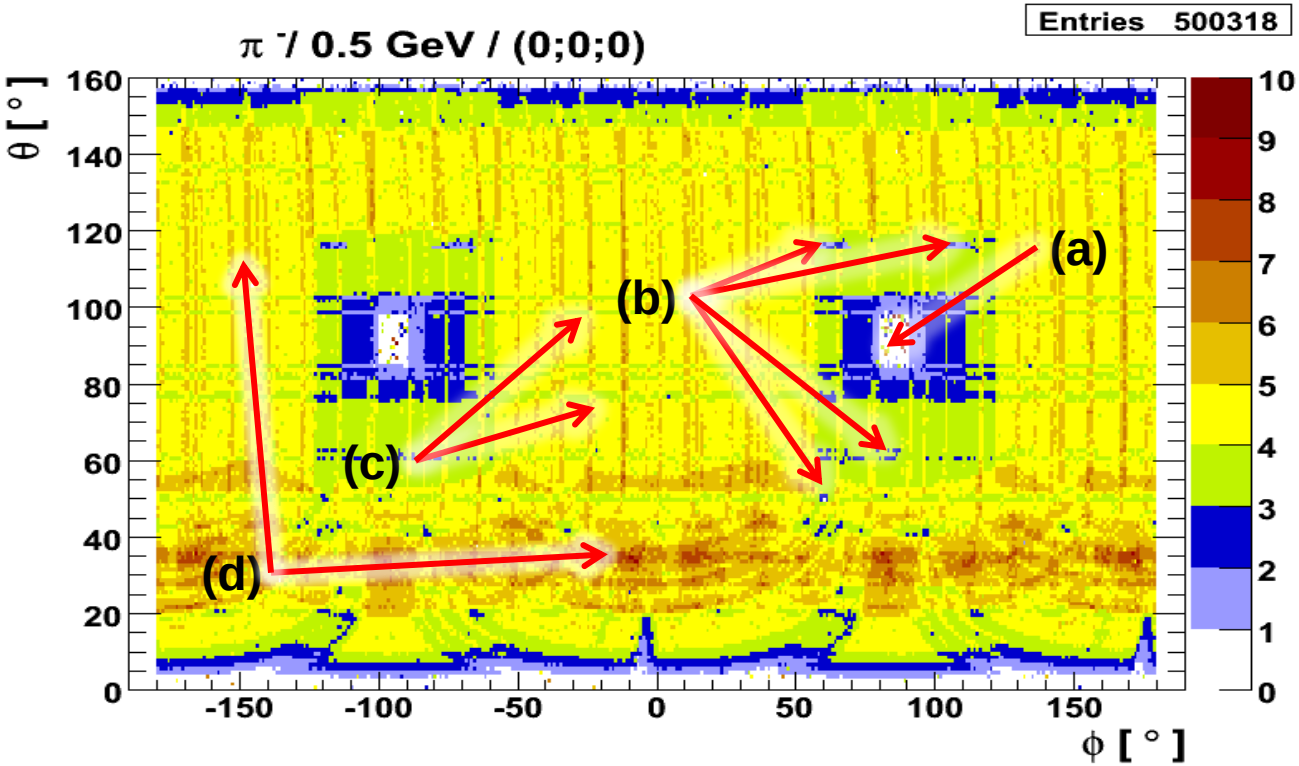
- Comparison for different particles and excess energy



- Implementation of realistic CAD model
- Simulation includes:
  - ✓ Full material budget
  - ✓ Magnetic field

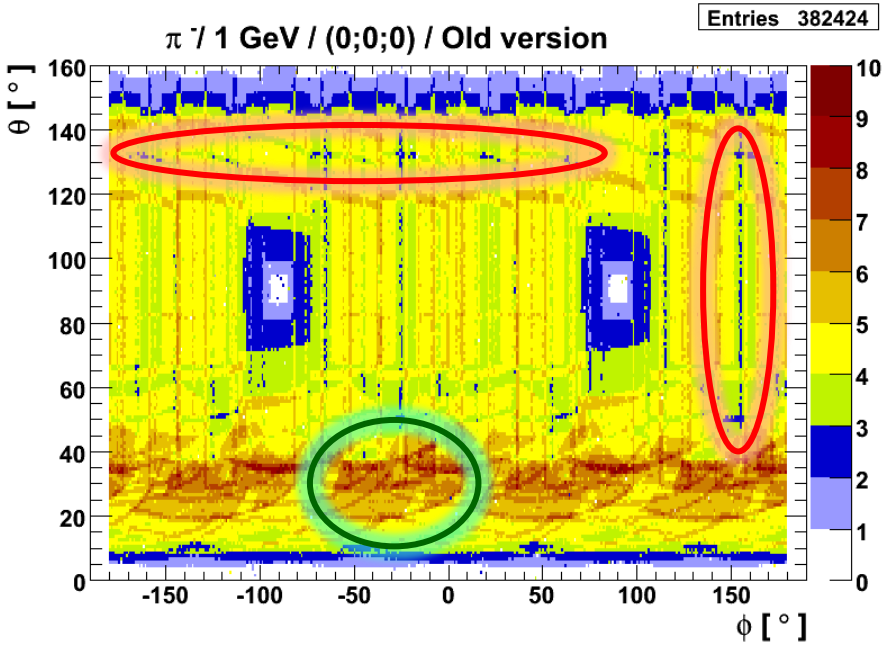
Track-point studies

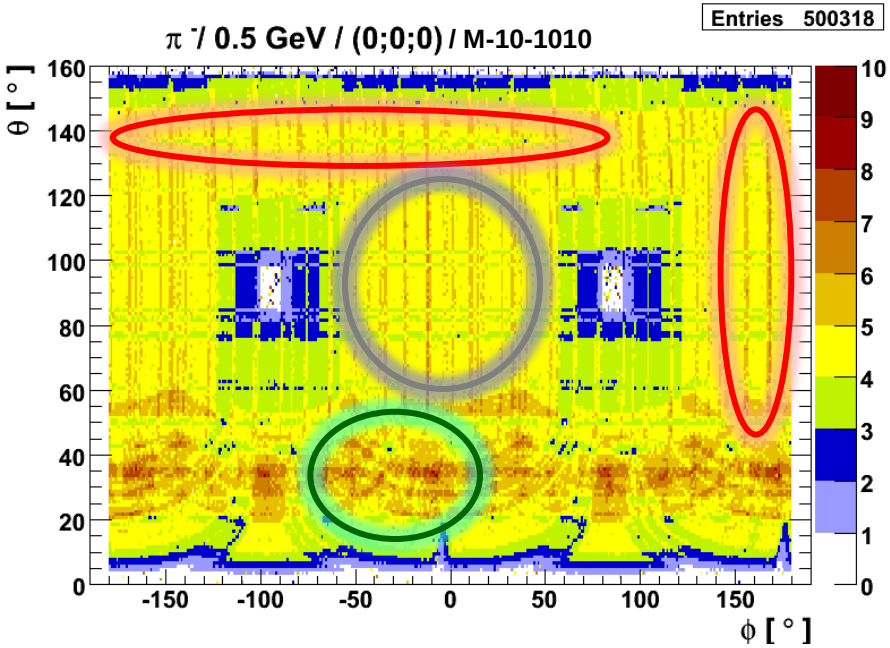
- Spatial distribution of MVD points / track
  - Inhomogeneities: (a) Target pipe, (b) module positioning, (c) strip-sensor gap in barrel layers, (d) sensor overlap, ...



Track-point studies

- Detector optimisation:
  Comparison of different implementations



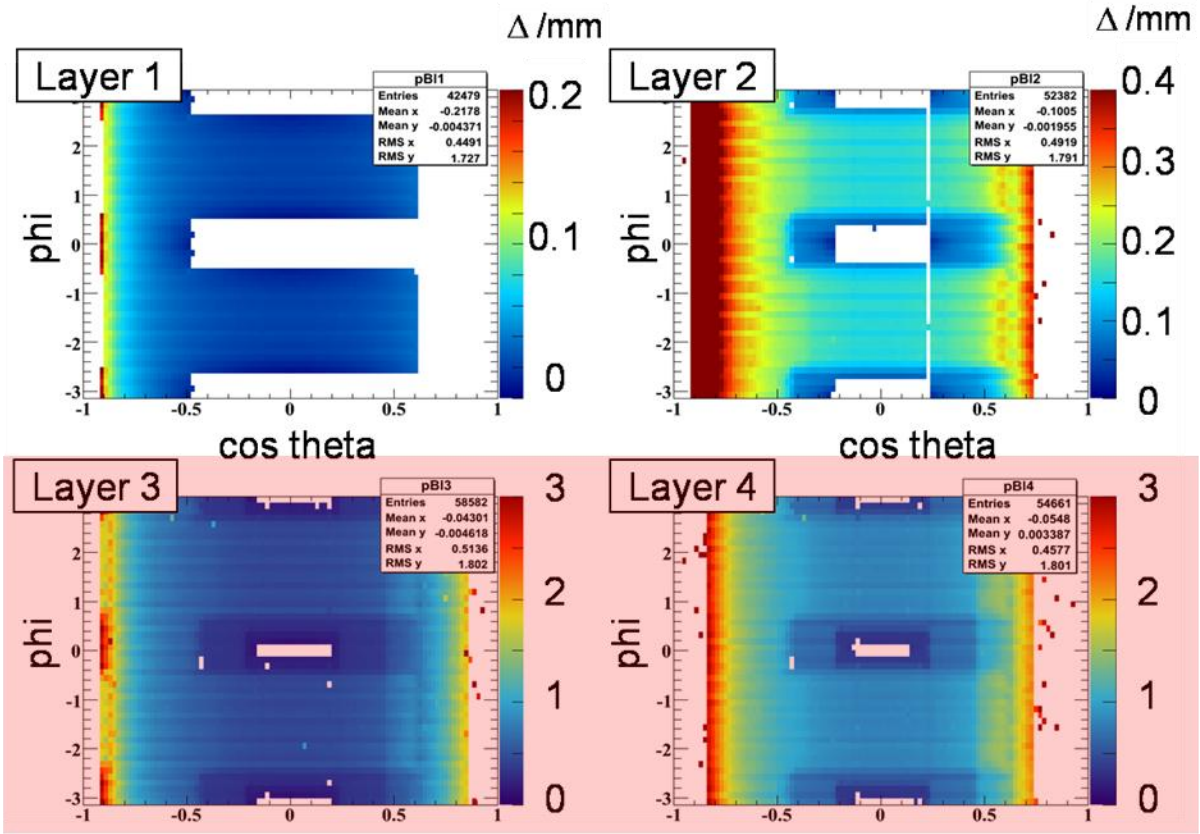


- Visualisation and correction of gaps
- Reduction of material: Limitation of track points
- Homogenous distribution in the barrel part

MVD layer: Point resolution

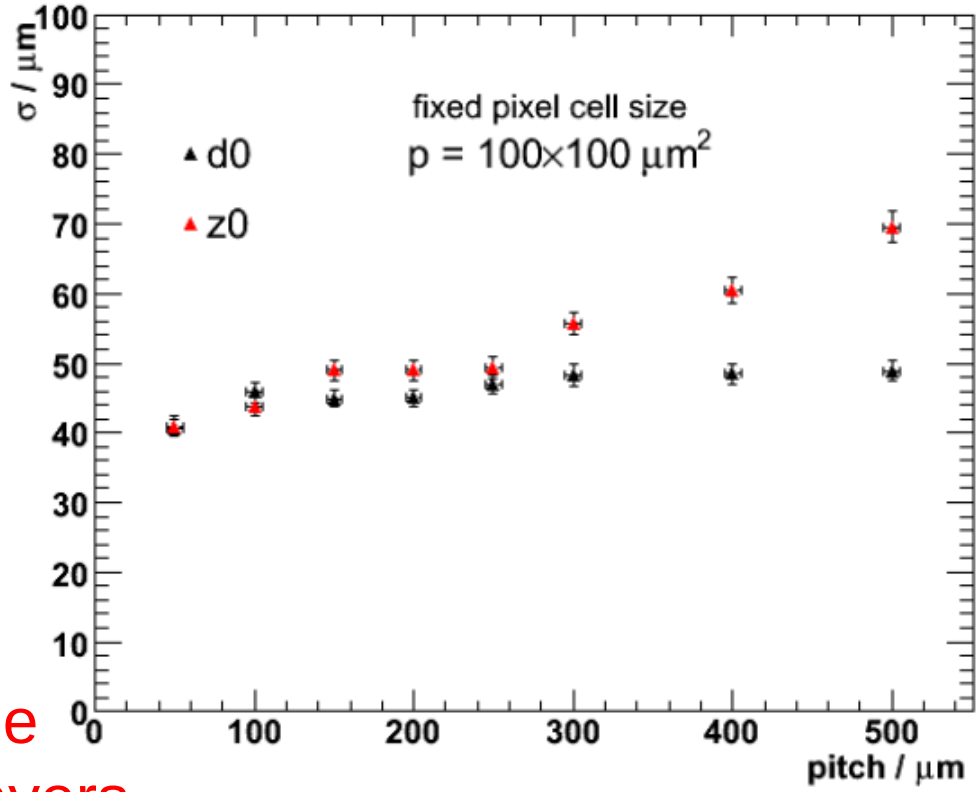
- Study of multiple scattering with particle propagator
  - *Geane* (based on *Geant3*)
  - Example:
    π^+, 0.5 GeV / c
    → Barrel layer
  - Plotting the deviation due to scattering (Δ)

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



Vertex resolution studies

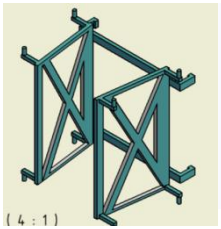
- Single track vertex resolution for different readout structures (pixel cell size/ strip pitch)
  - Example:
    π^-, (0.2 … 3) GeV / c
    → Fixed pixel cell size
    → Variation of strip pitch
  - Analysis:
    → Vertex resolution parameters (d_0, z_0)

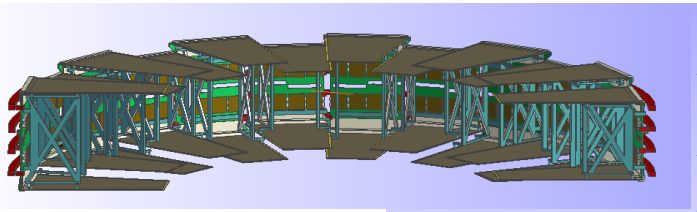


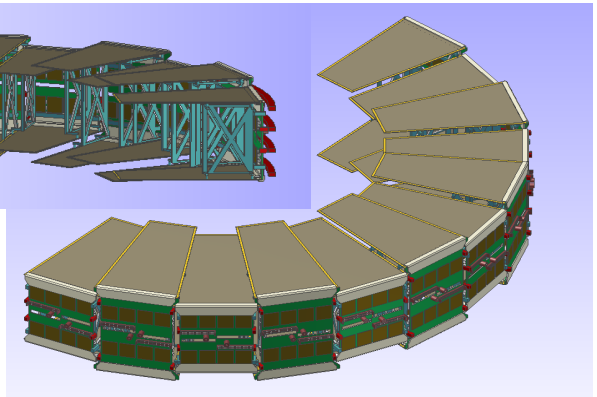
No significant improvement below 250 μm strip pitch due to scattering in precedent layers

Impact on MVD strip part

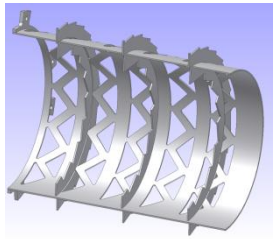
- Validation of sensor size and readout pitch
  - Barrel part:
    - ✓ Rectangular shape, stereo angle 90°, pitch: 130 μm
  - Forward part:
    - ✓ Trapezoidal shape, stereo angle 15°, pitch: 70 μm
- Disk concept

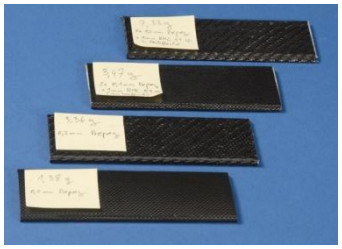


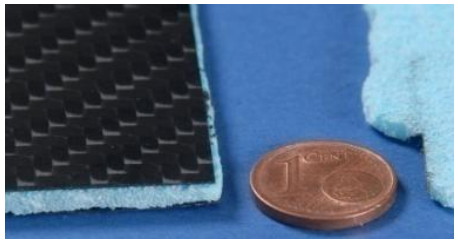




- Barrel support







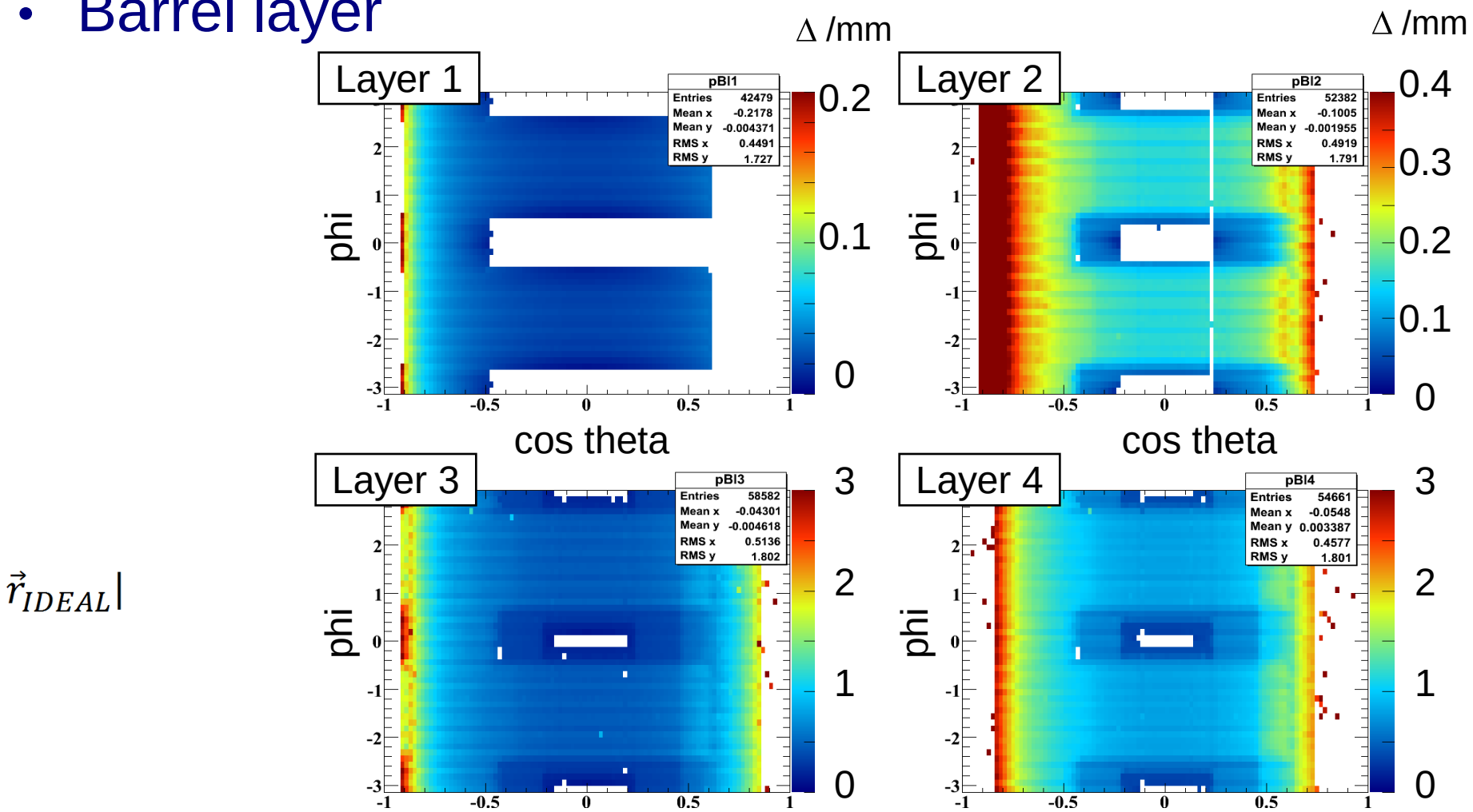
Summary

- Overall MVD layout fixed
- Work on detailed implementation started
- Design parameters to verify physics performance of detector → Detector optimisation
- Tools for studies and analysis available (Physics and engineering simulations)
  → Set of input parameters must be chosen carefully

Physics guidance of engineering implementation ensure an optimised detector development

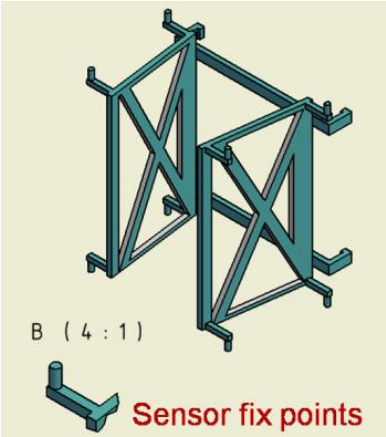
MVD layer: Point resolution

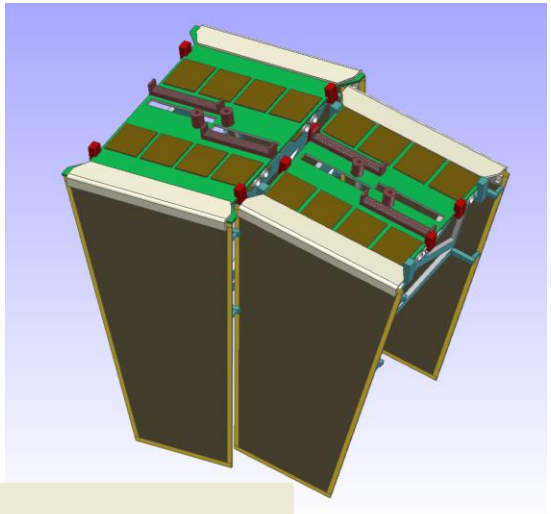
- Barrel layer

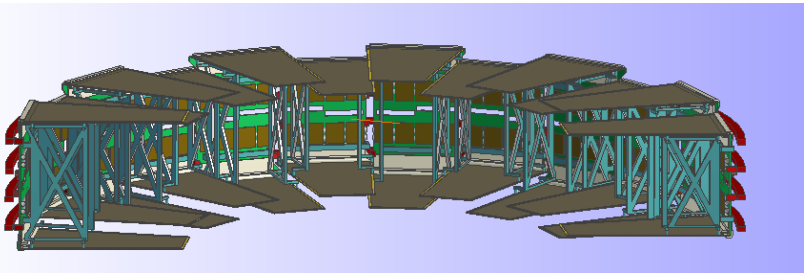


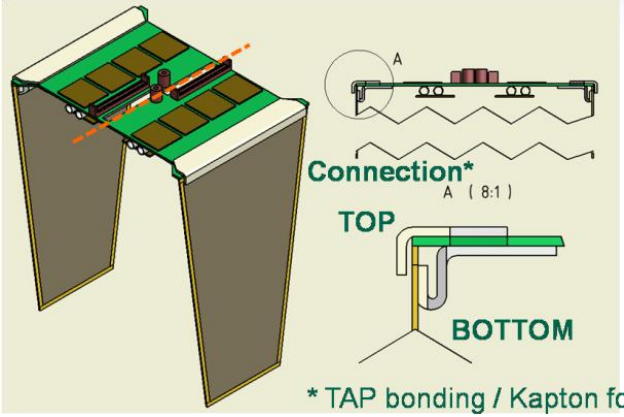
Impact on MVD strip part

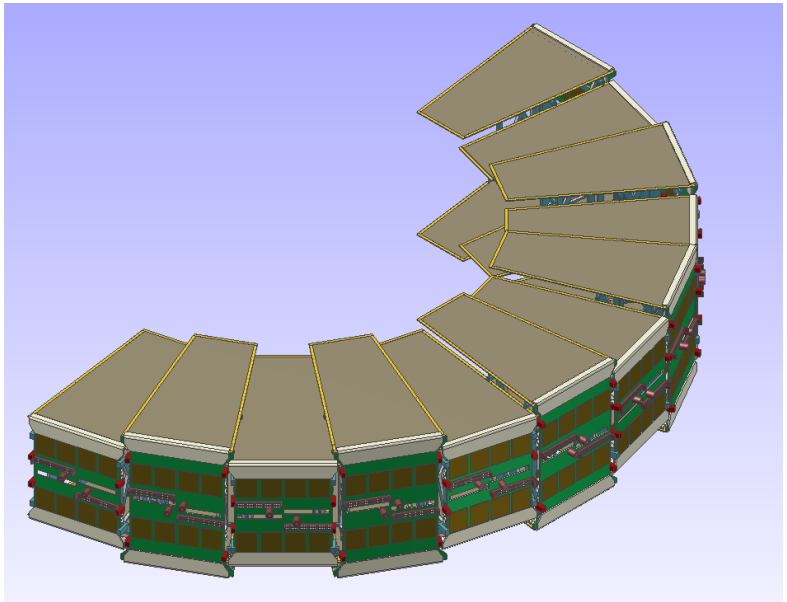
- Modified concept for forward strip disks





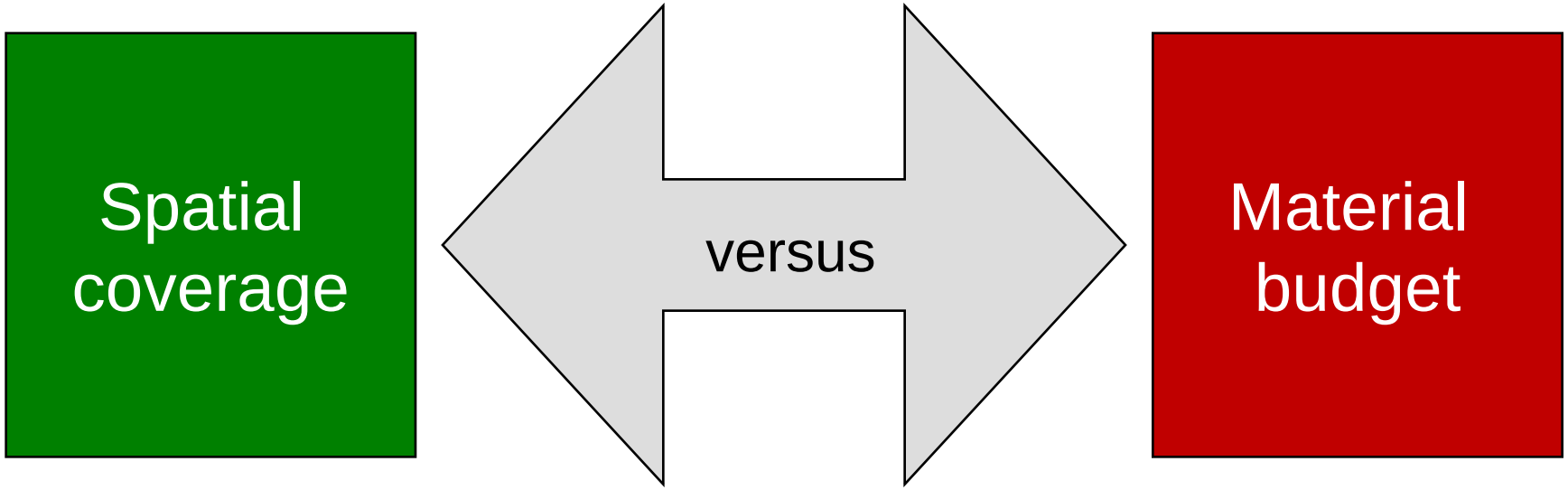




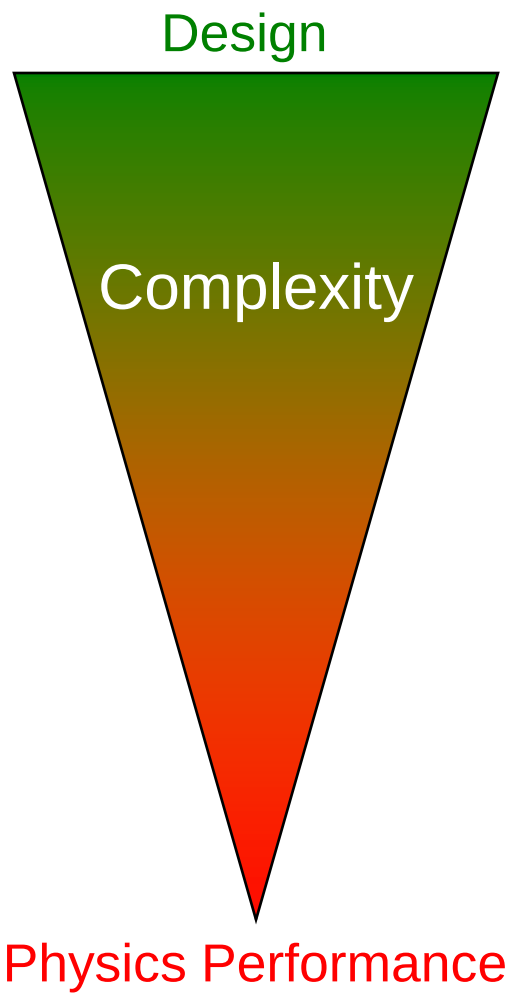


Design parameters

- Most typical example for optimisation…



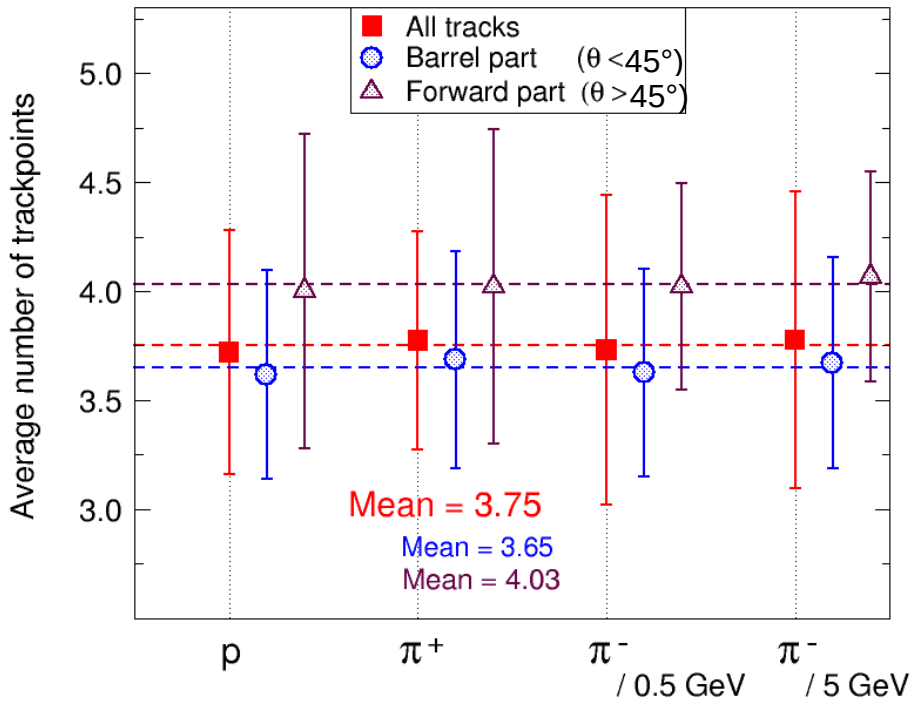
Design parameters

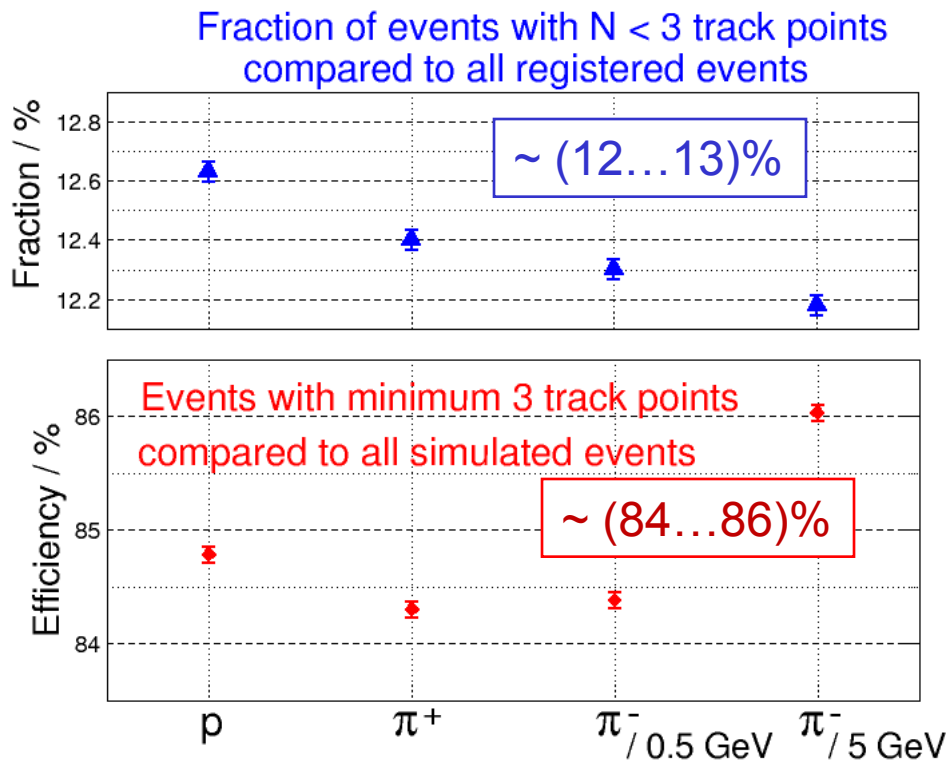


- → Number of hit points / track ($N_{trk\text{-}pt}$)
- → Spatial distribution of ($N_{trk\text{-}pt}$ / track)
- → Spatial distribution of material load
- → Mapping of scattering effects:
  Point resolution in MVD detector layers
- → Count rate studies
- → Resulting temperature on sensors
- → Single hit resolution
- → Track resolution
- → Vertex resolution: *f* (readout structure)

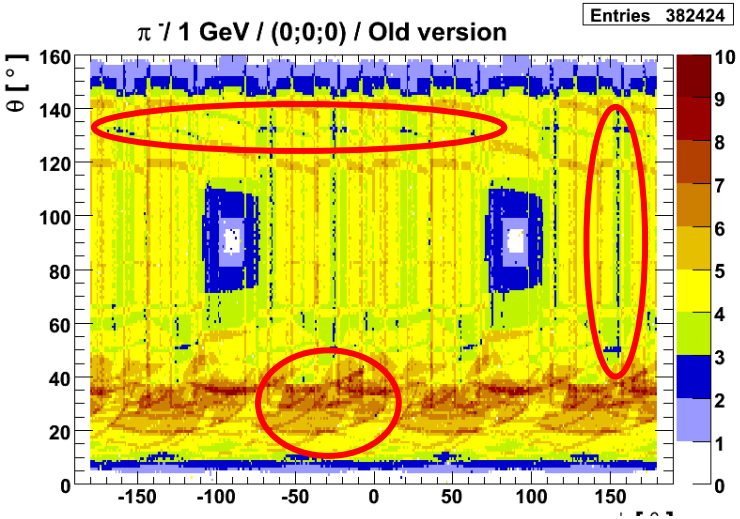
Track-point studies

- **Comparison for different particles and energy**
  - No severe changing, in particular no asymmetry for charge conjugated particles



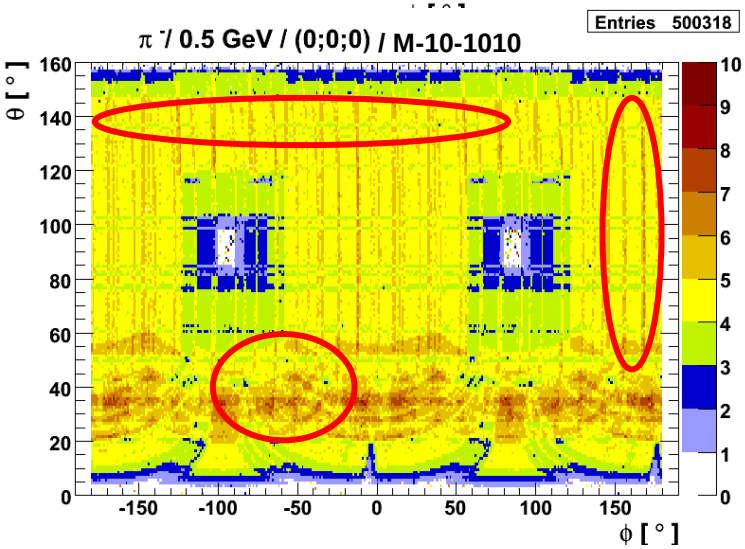


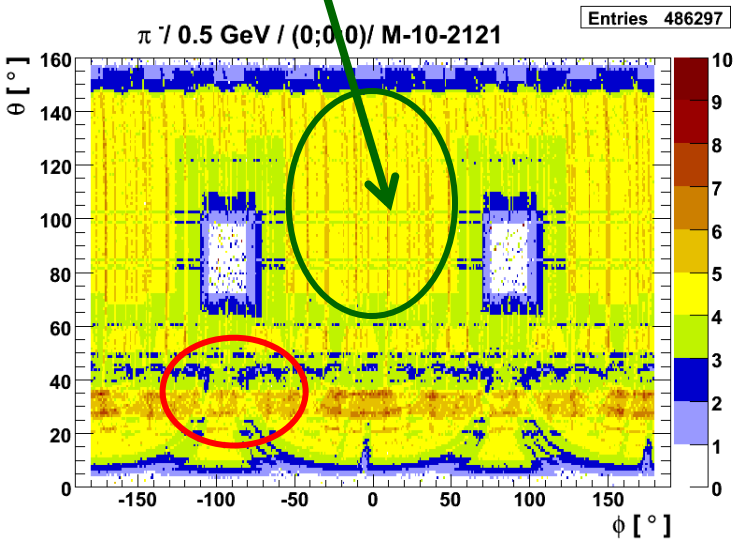
Track-point studies



Results: **Optimisation process for different CAD models**

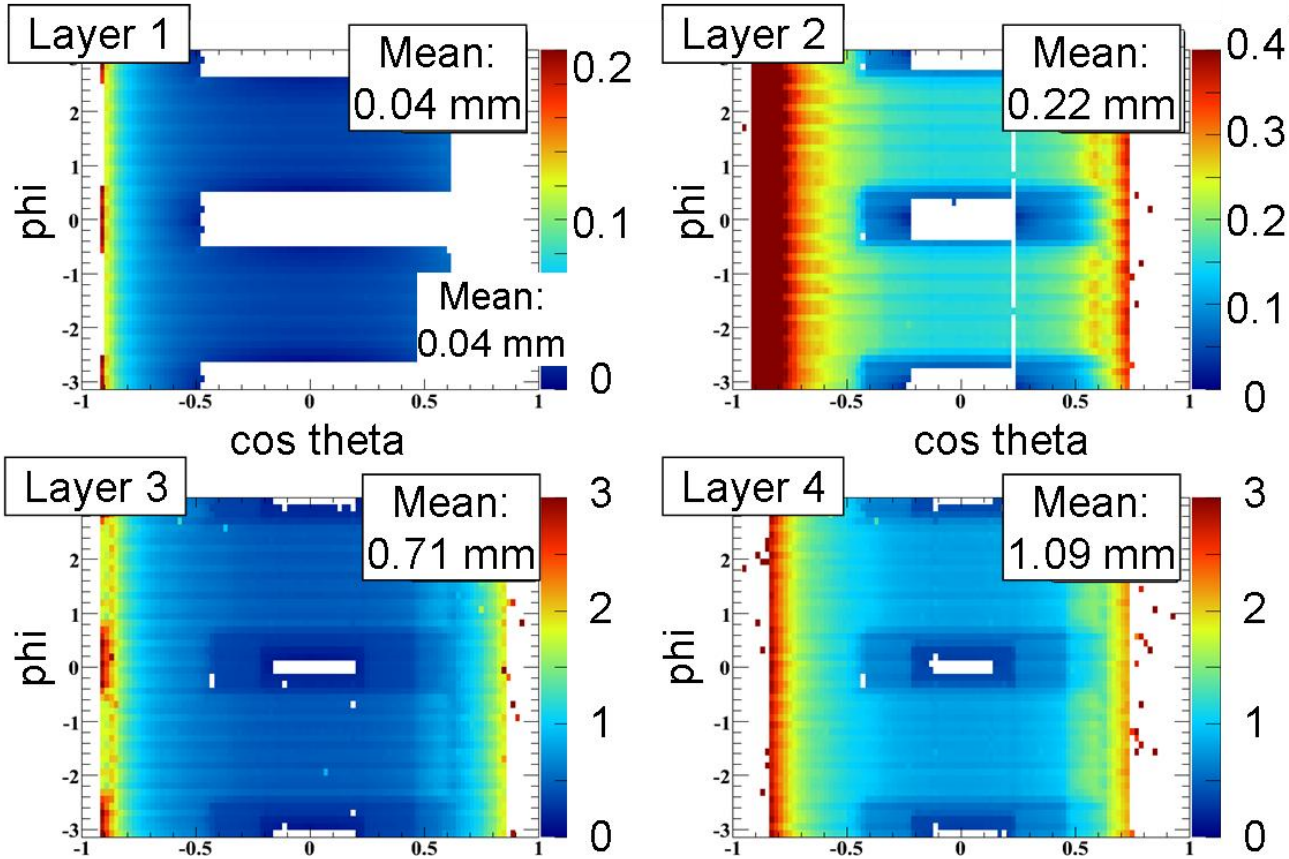
- Visualization of appearing or corrected gaps and overlaps
- Homogenous distribution with $N_{trk\text{-}pt} > 3$ in the barrel part





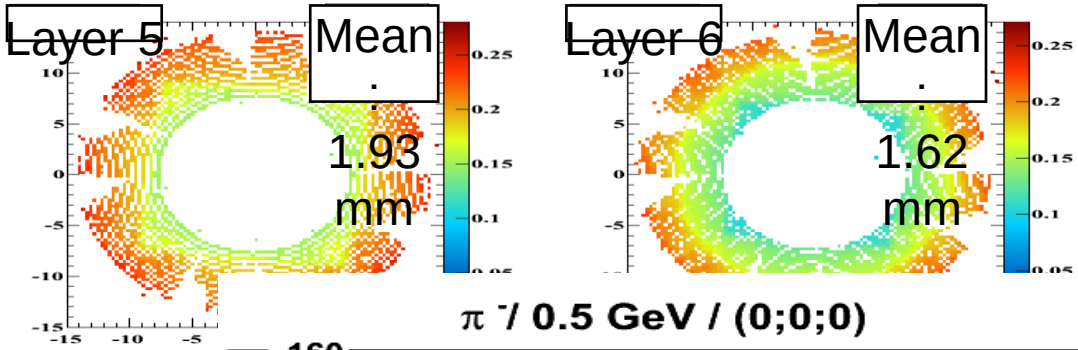
MVD layer: Point resolution

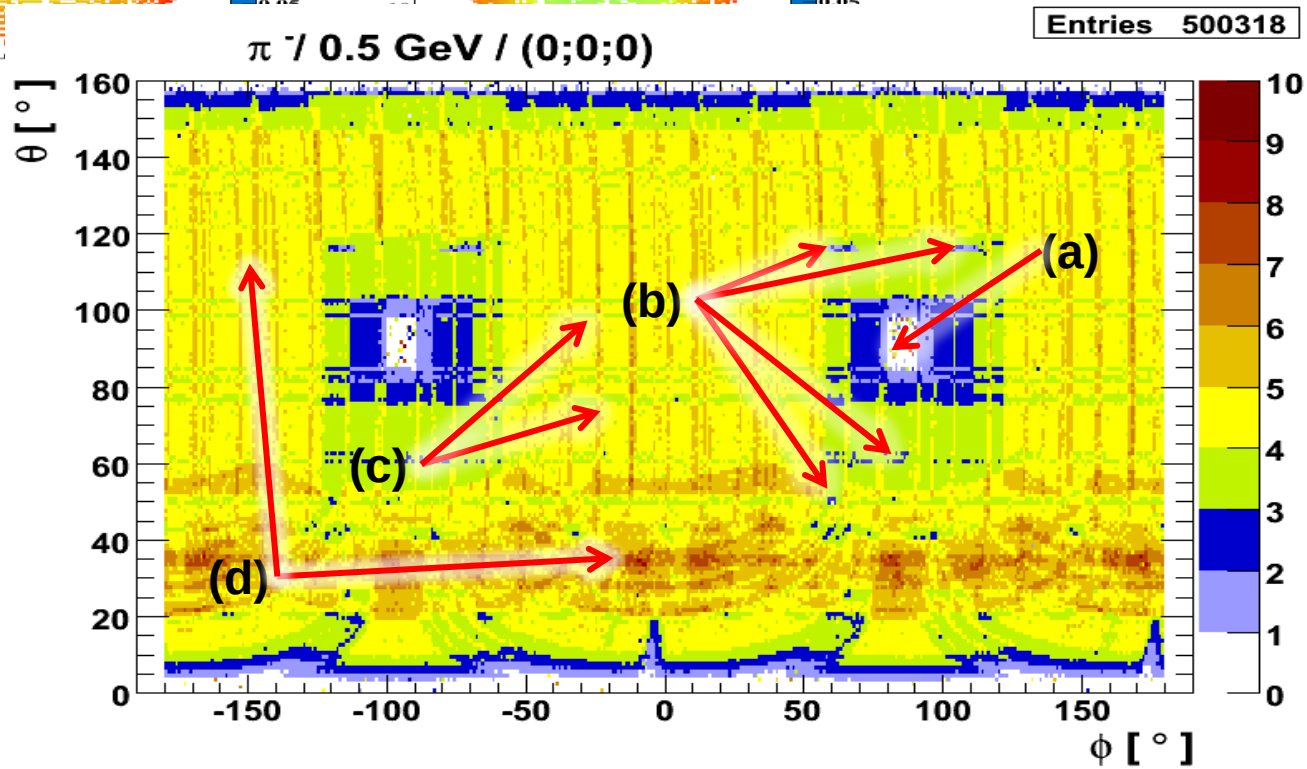
- Results: Barrel layer (π^+, 0.5 GeV / c)



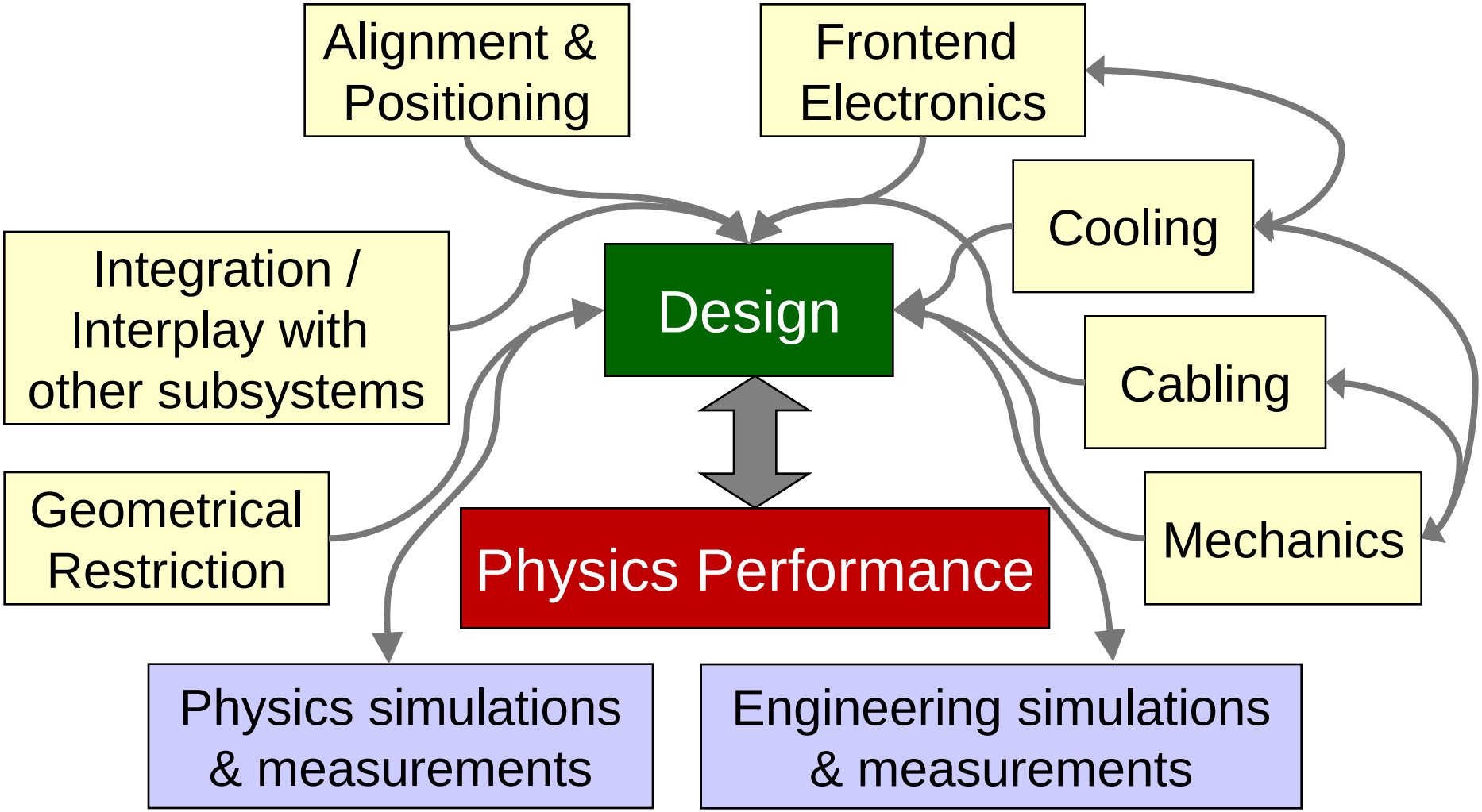
Scattering effect in outer strip barrel layers reaches 1 mm (r.m.s.)

MVD layer: Point resolution

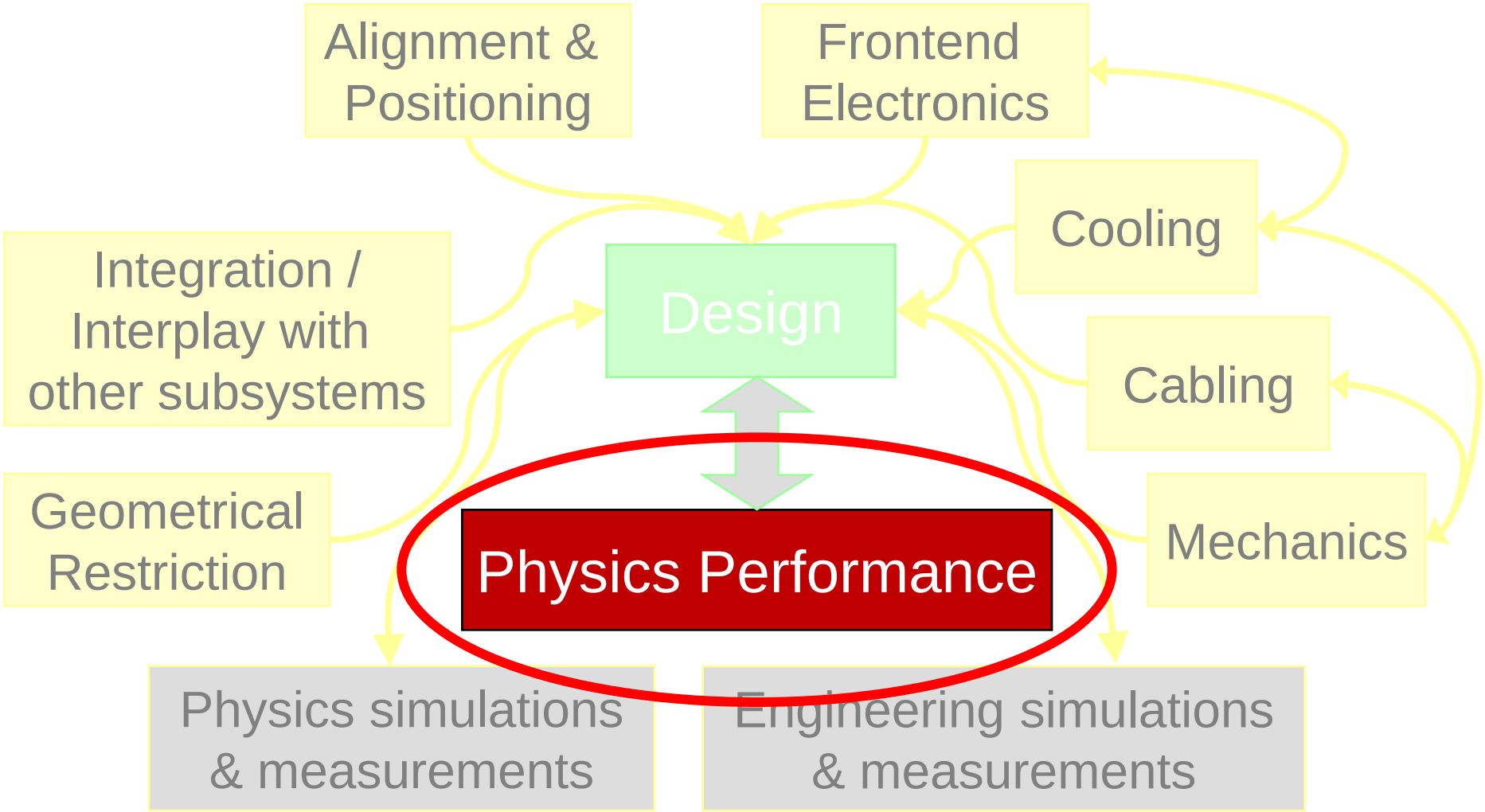




Detector optimisation



Detector optimisation



Impact on MVD strip part

- Concept of carbon support structure for barrel part