

# The PANDA Micro-Vertex-Detector

## Group report / DPG EuNPC 2009

12. März 2009

| Tobias Stockmanns for the PANDA Collaboration | HK 40.1

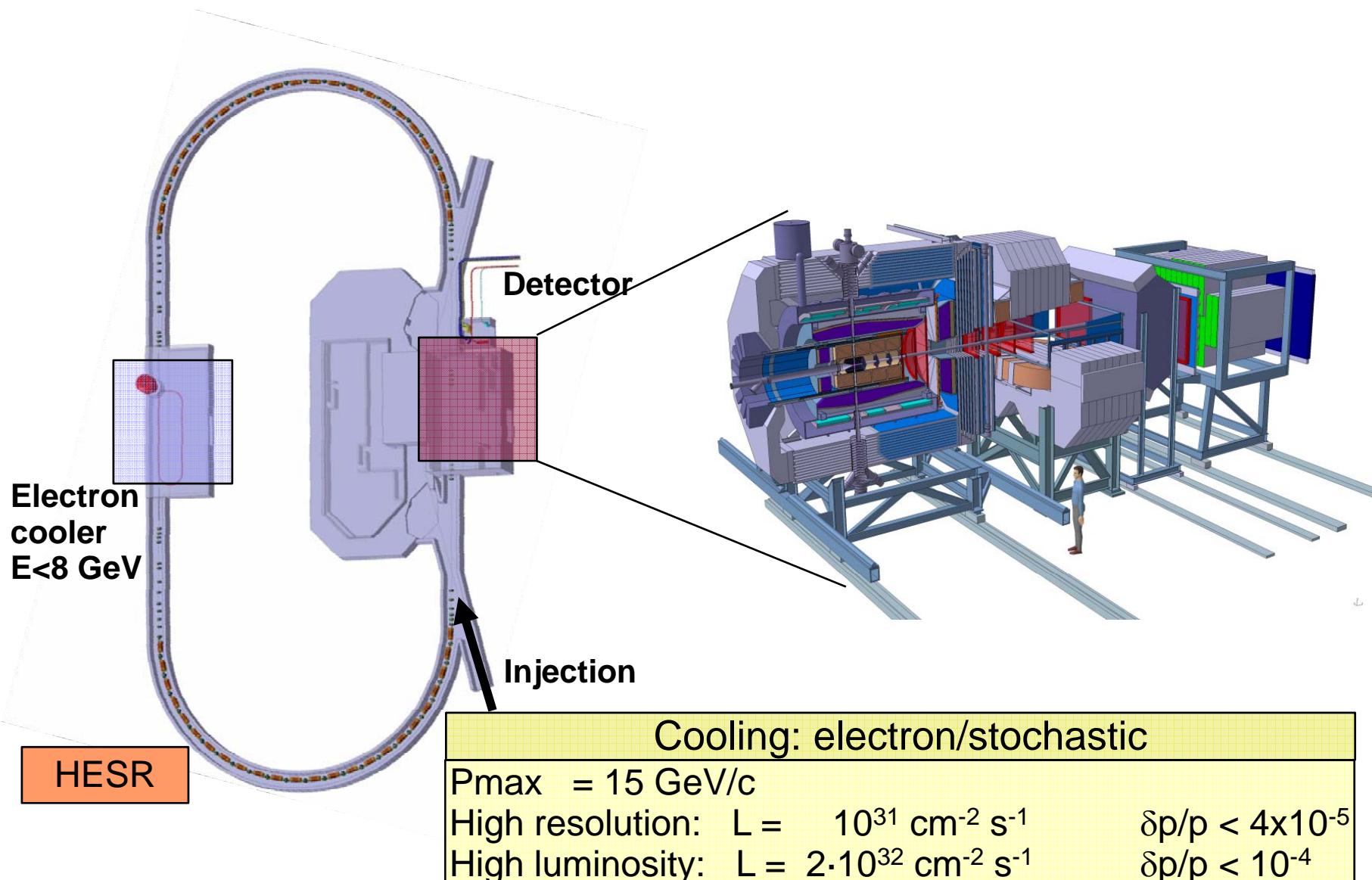
# Content

- Introduction to the PANDA physics program
- The PANDA detector at HESR
- The Micro-Vertex-Detector of PANDA
  - Requirements
  - Setup of the MVD
  - Technical Developments
  - Simulation Results
- Summary / Outlook

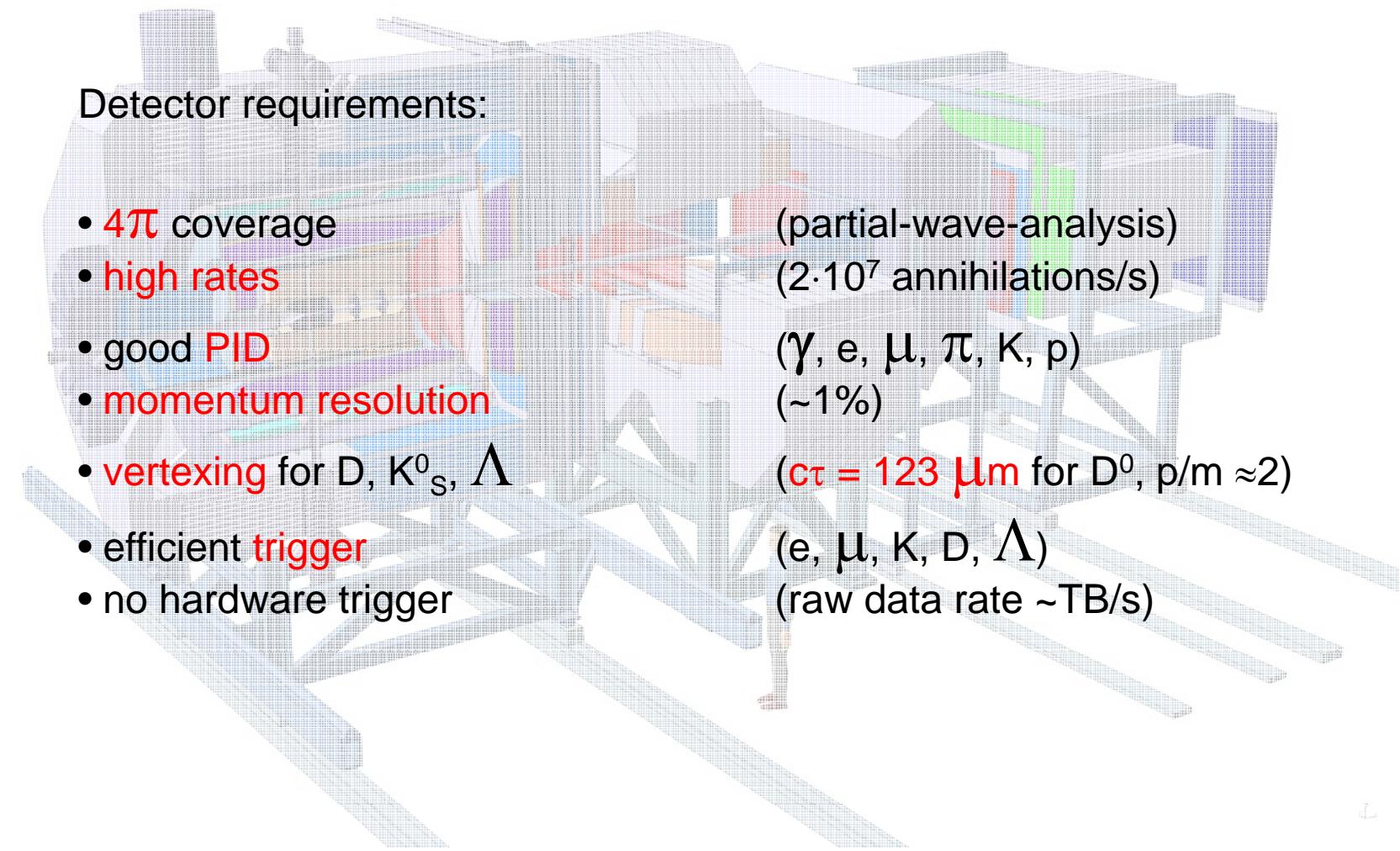
## PANDA – AntiProton Annihilations at Darmstadt

- qq potential in the charmonium system
  - precision measurements of cc-states (not only  $J^{PC} = 1^{--}$ )
  - cc above DD-threshold → measurement of D-mesons
- Search for Hybrids qqq and/or Glueballs gg
- Spectroscopy of new charm states
- Charmed and multi-strange baryon spectroscopy
- Electromagnetic processes ( $pp \rightarrow e^+e^-$ ,  $pp \rightarrow \gamma\gamma$ , Drell-Yan)
- Properties of single and double hypernuclei
- Properties of hadrons in nuclear matter

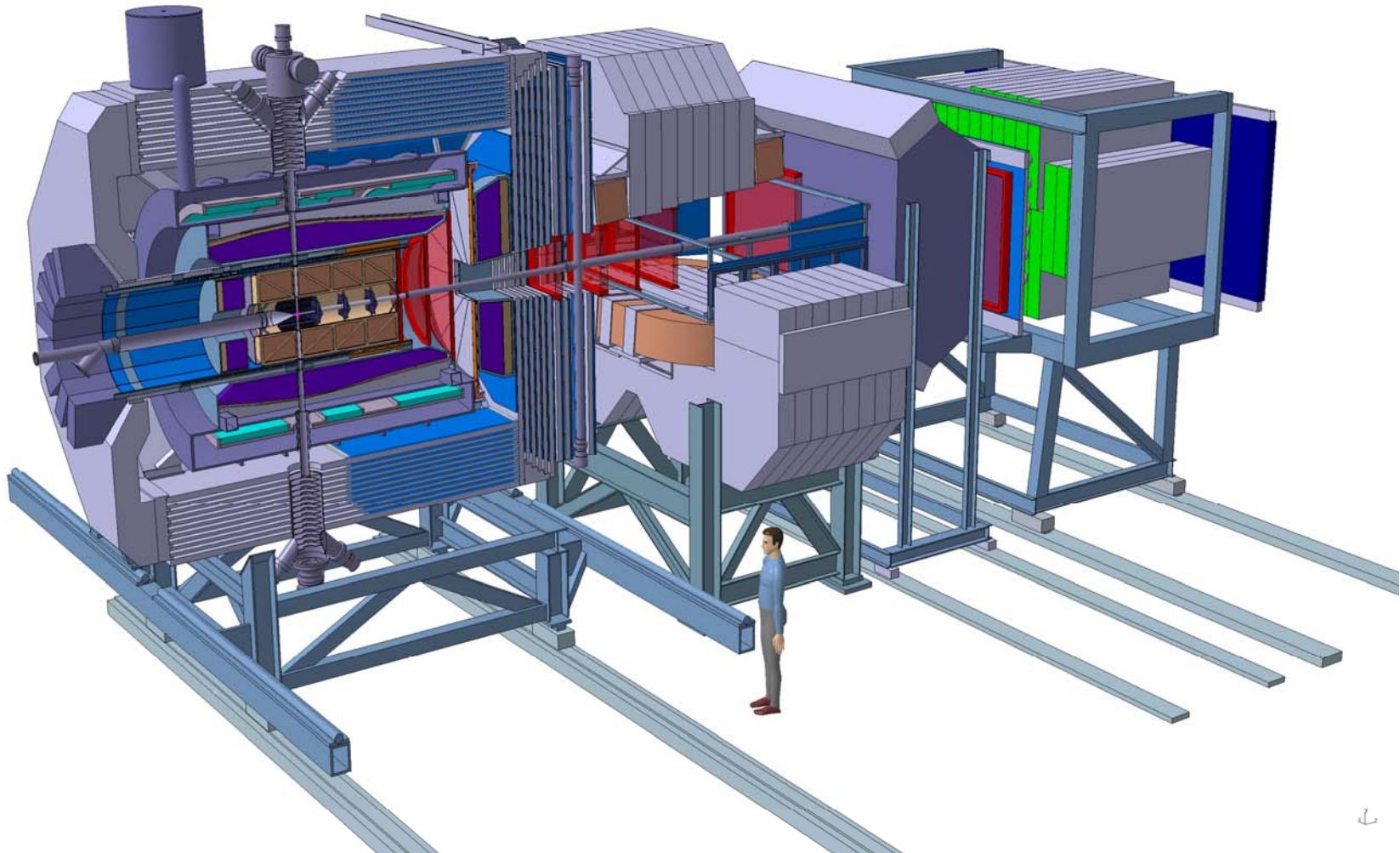
# High Energy Storage Ring



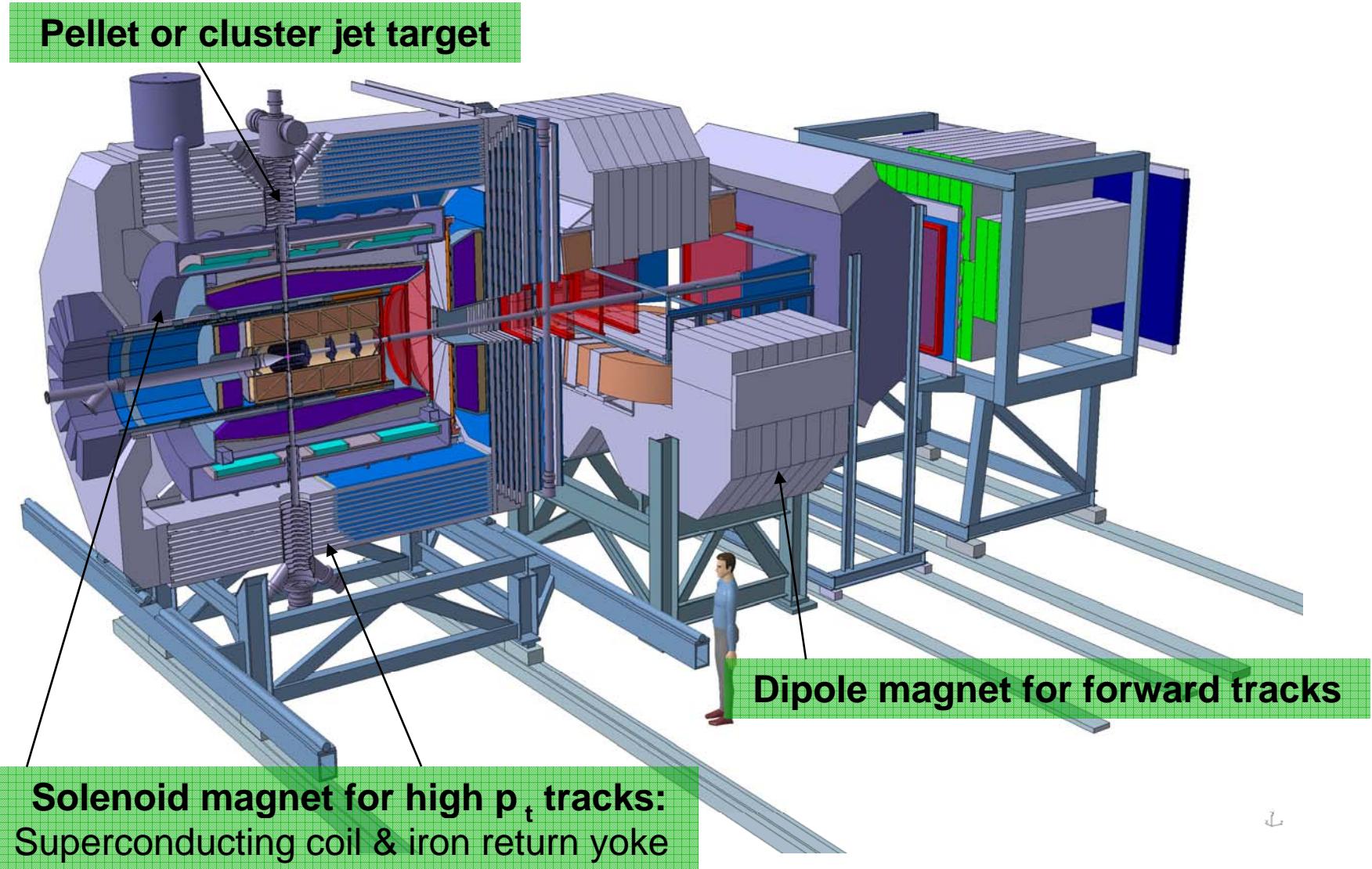
# PANDA Spectrometer



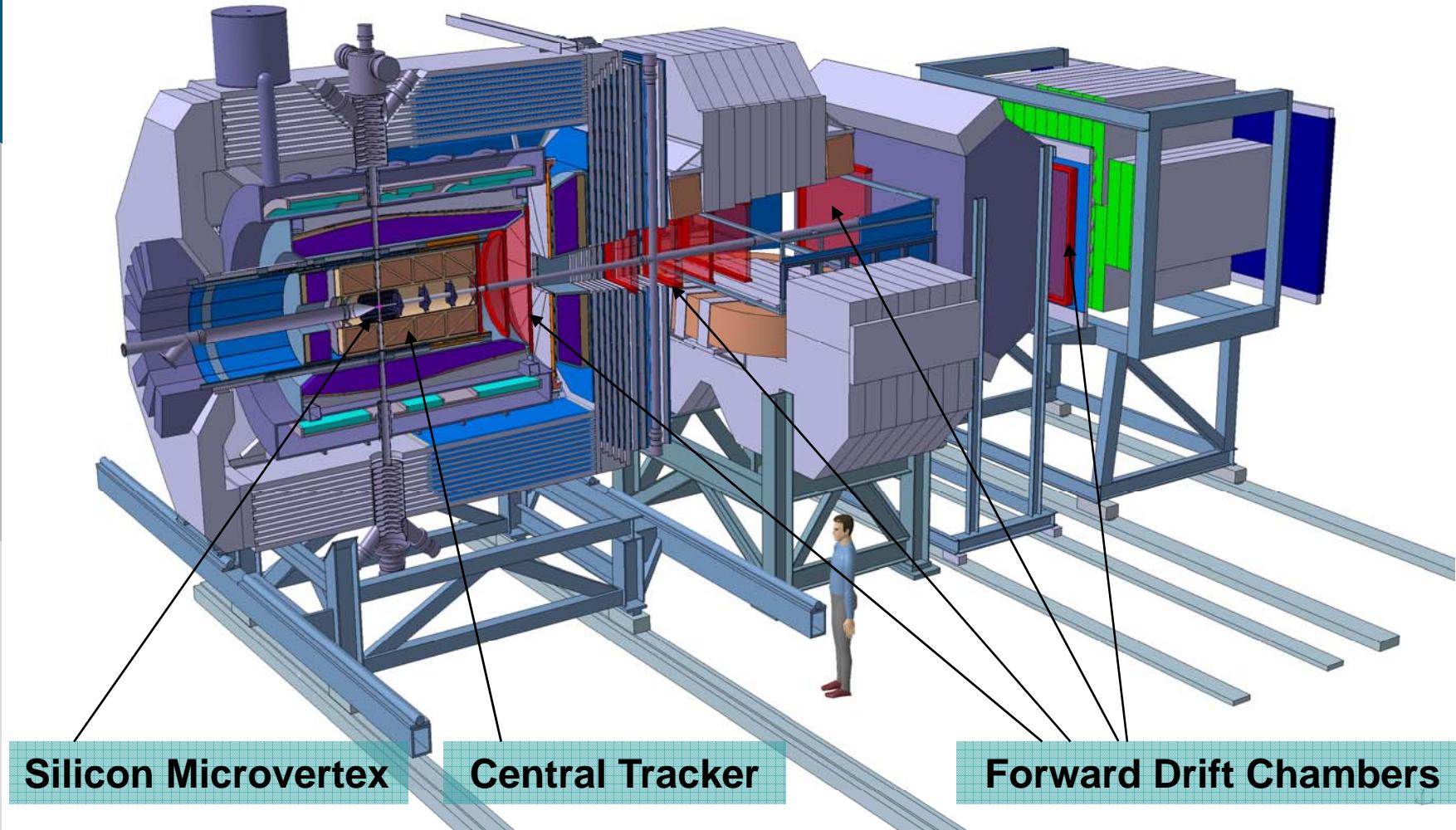
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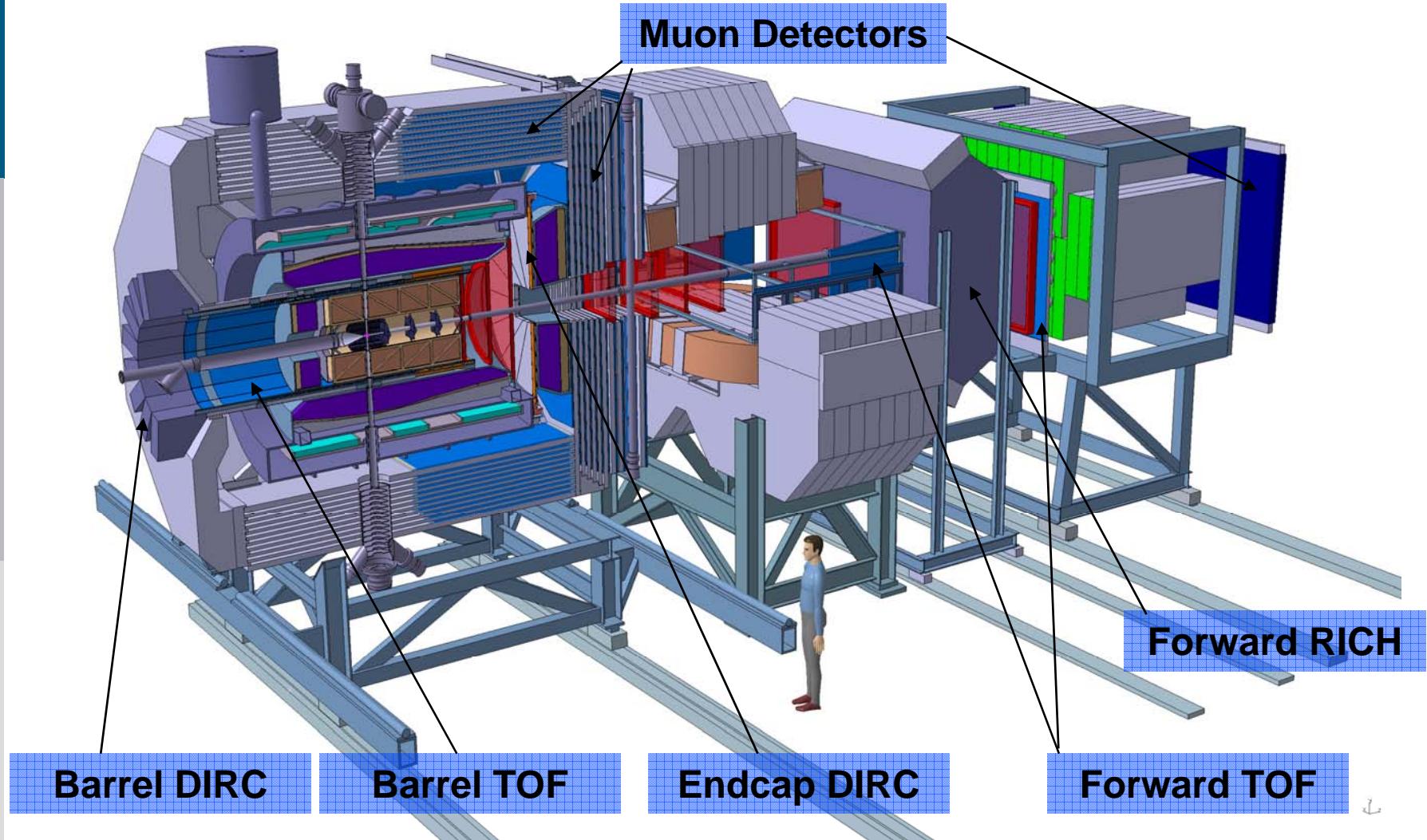
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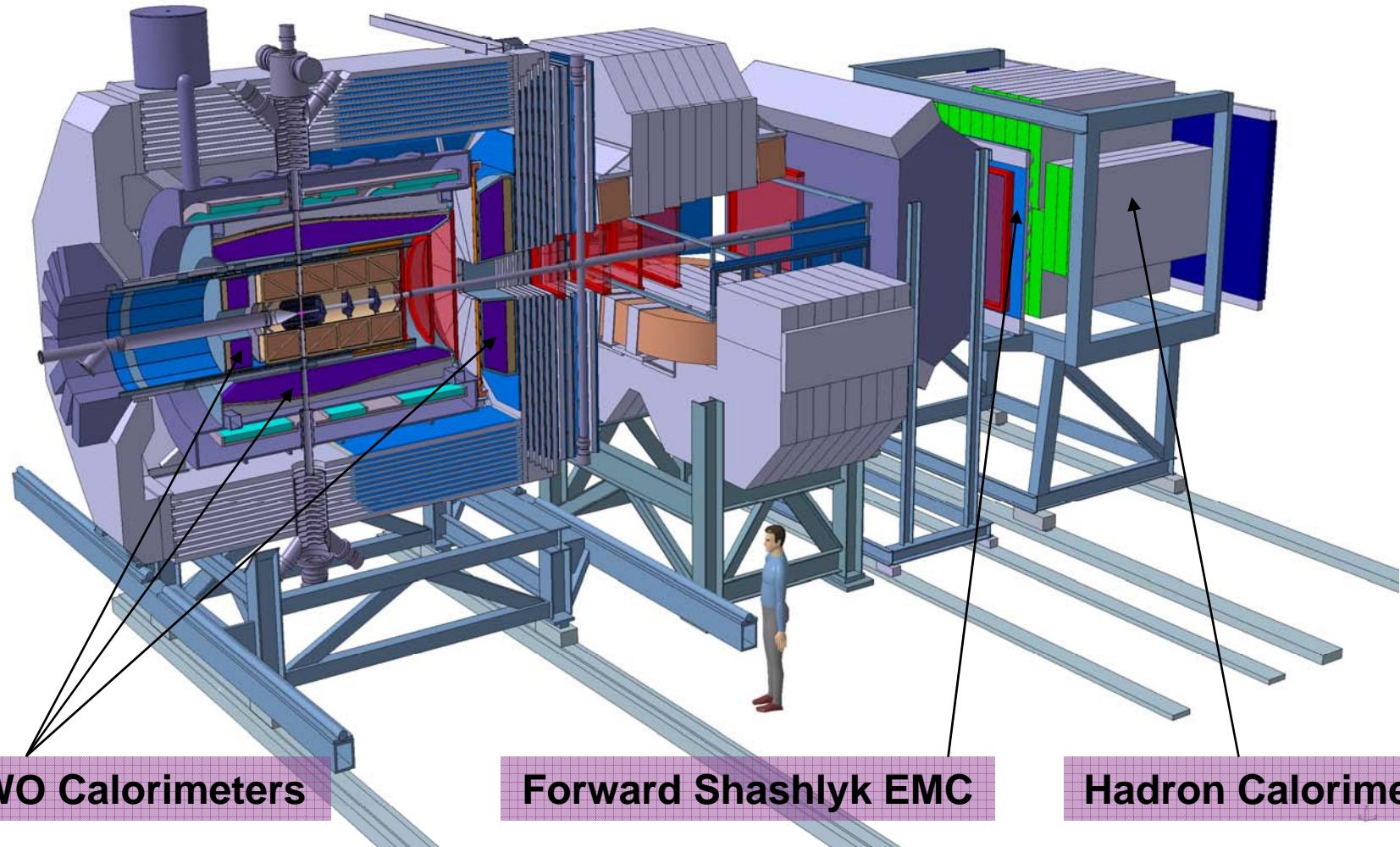
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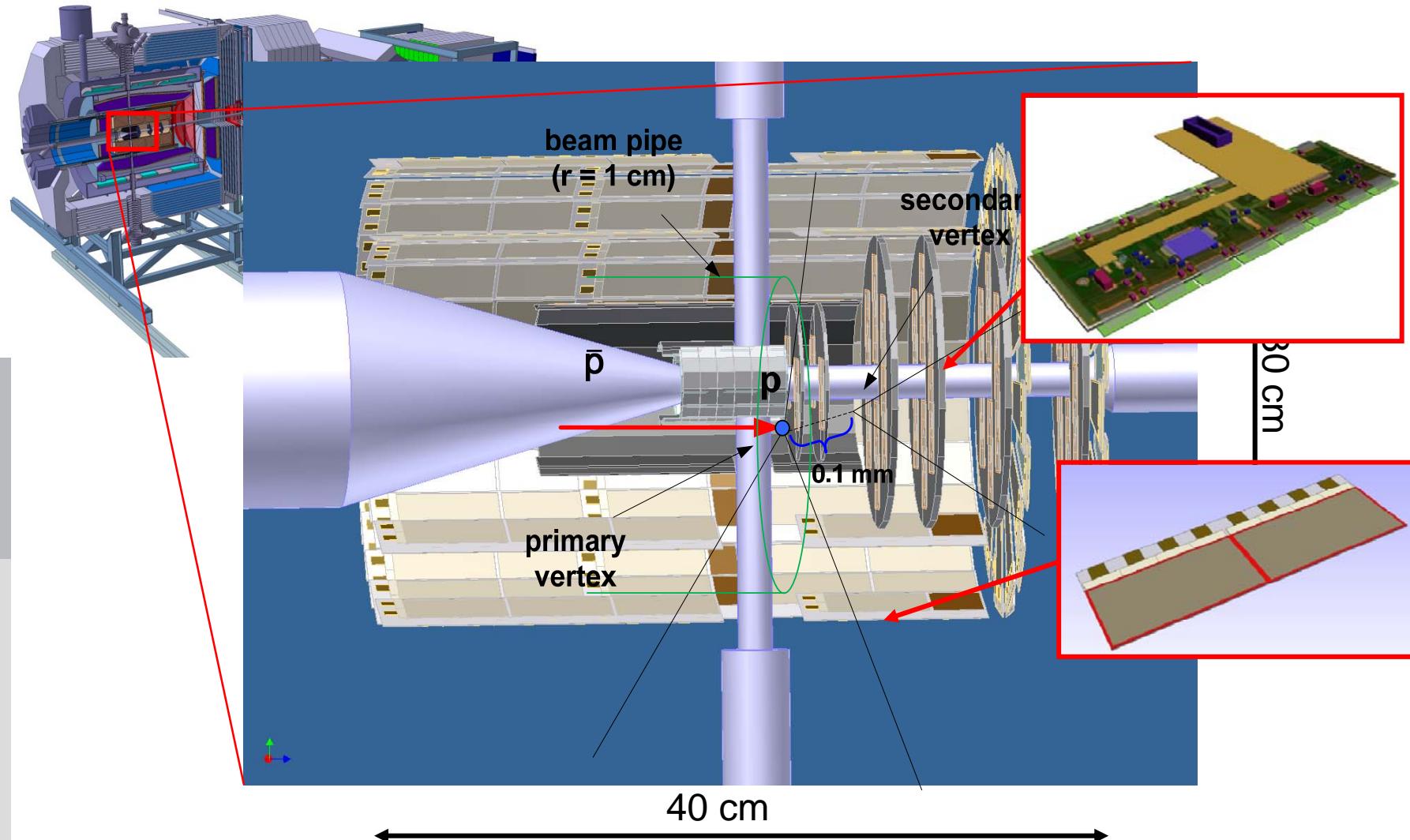
# PANDA Spectrometer



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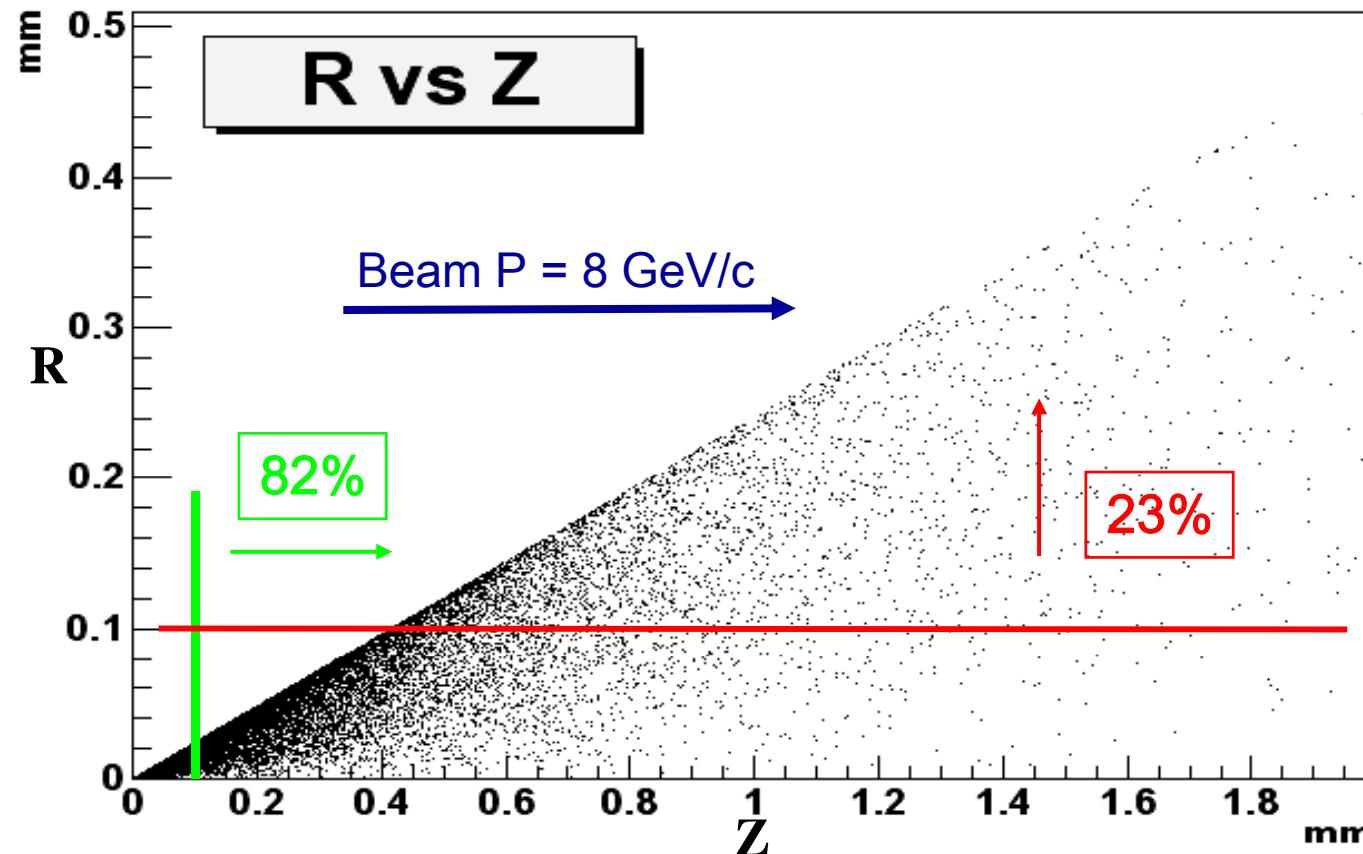
# Micro-Vertex-Detector



# Requirements MVD

- Good spatial resolution in r-phi → momentum measurement of soft pions from D\* decays
- Good spatial resolution specially in z → vertexing, D-tagging

## D-Meson decays



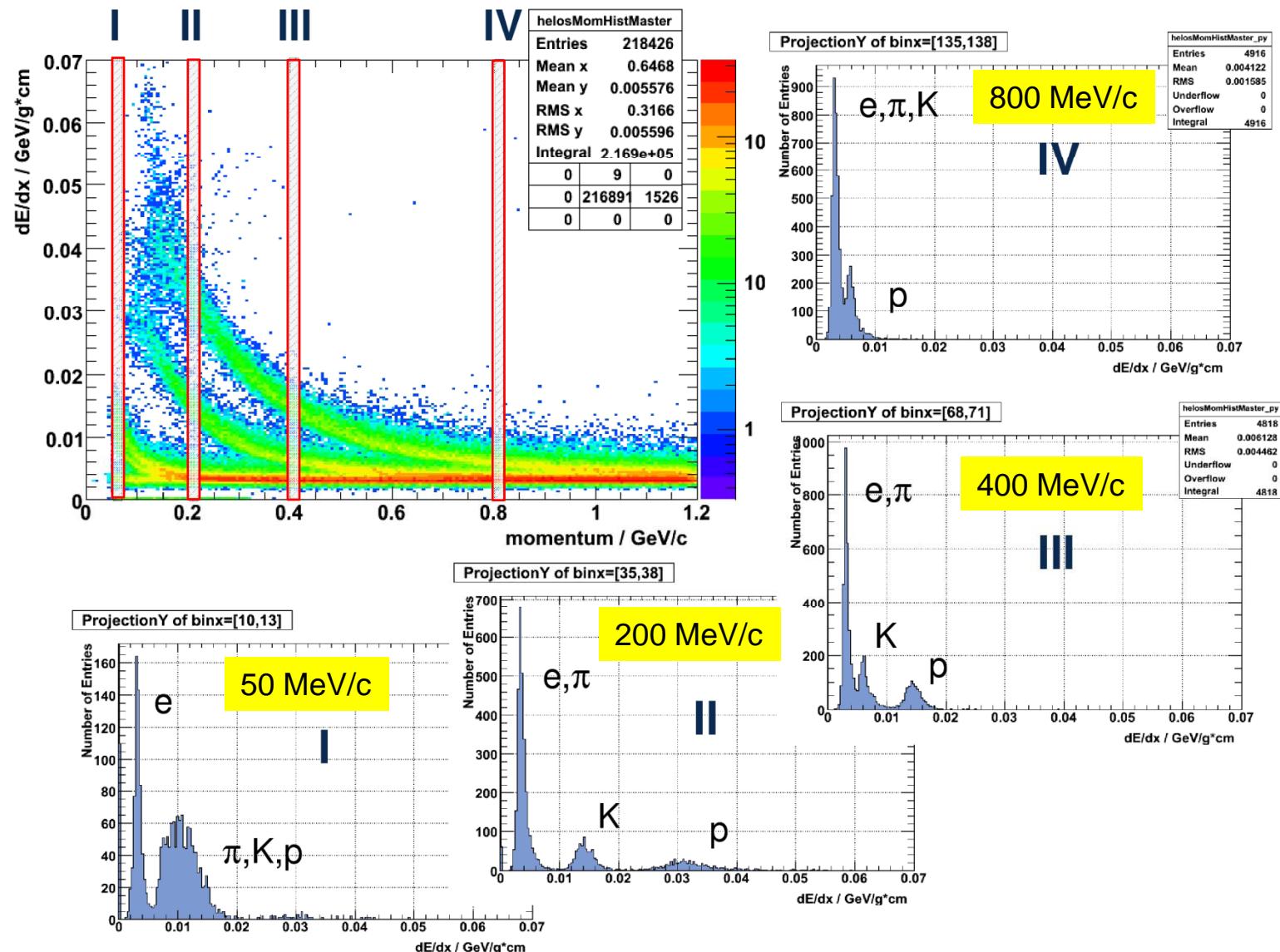
Distribution of secondary vertex from D-meson decays for a beam kinetic energy 8 GeV/c.

→ Need to optimize resolution in the Z direction!

# Requirements MVD

- Good spatial resolution in r-phi → momentum measurement of soft pions from D\* decays
- Good spatial resolution specially in z → vertexing, D-tagging
- Good time resolution ( $O(20 \text{ ns})$ ) → 'DC'-beam ( $2 \cdot 10^7$  events/s)
- Amplitude measurement → improvement of resolution  $dE/dx$  to improve particle ID

# Particle Identification with MVD

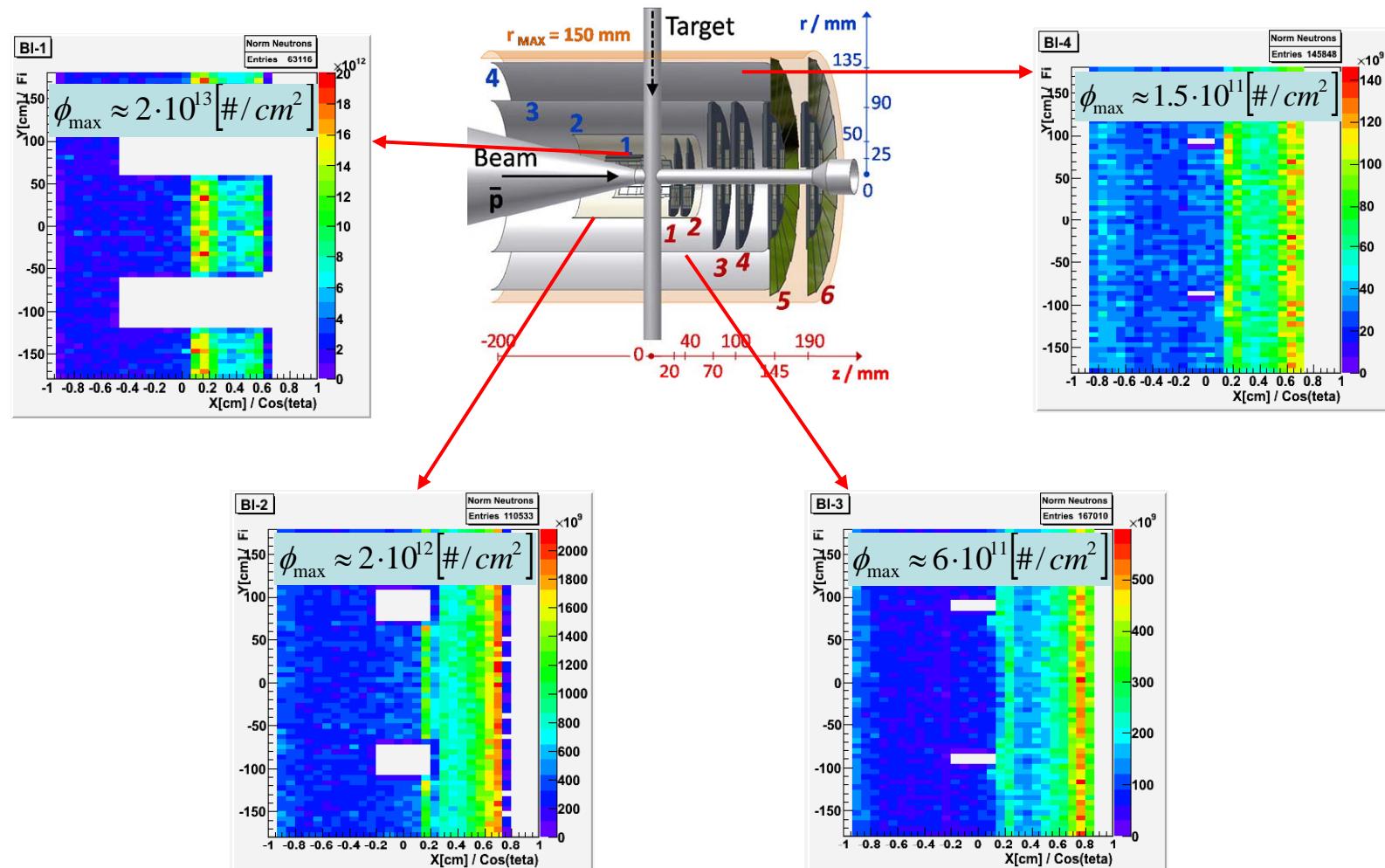


# Requirements MVD

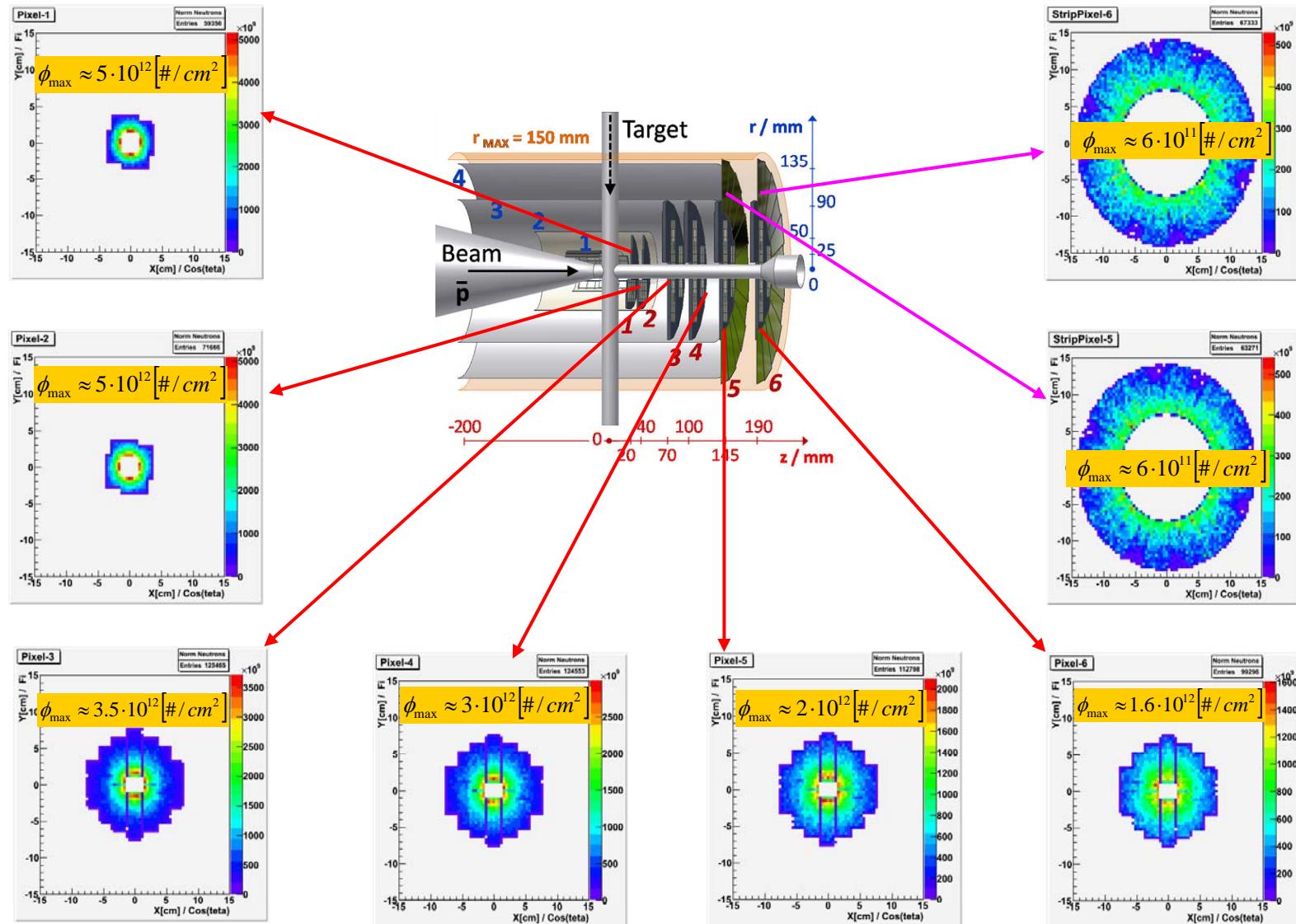
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- Amplitude measurement → improvement of resolution dE/dx to improve particle ID
- Modest radiation hardness ( $O(10^{14} \text{ n}_{\text{eq}} / \text{cm}^2)$ ) → depends on target material

# Radiation Damage Pixel Barrel

pp @ 5 GeV/c for one year operation



# Radiation Damage Disks

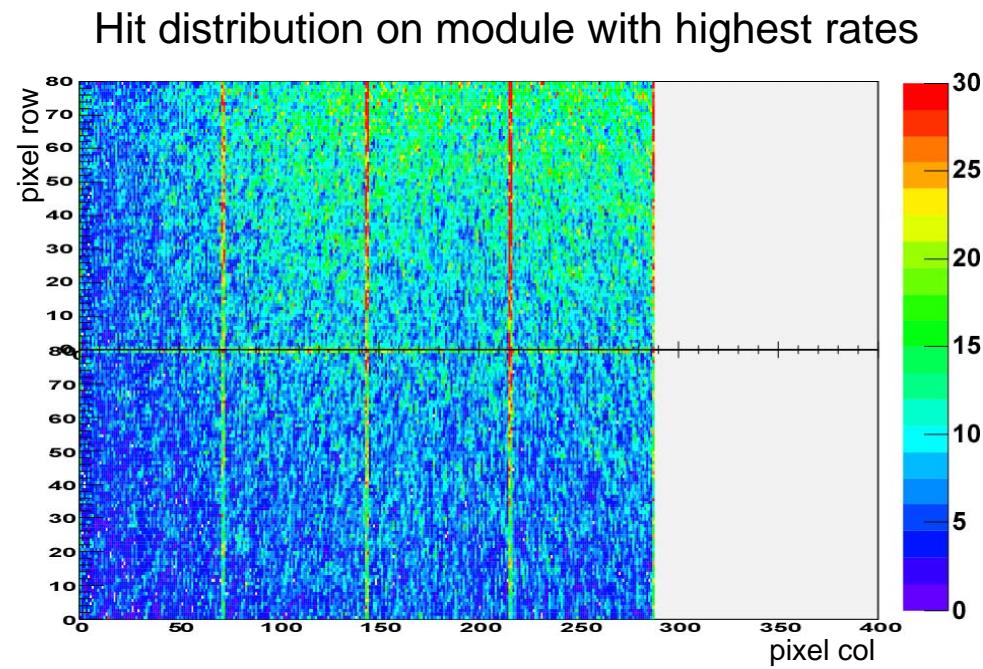
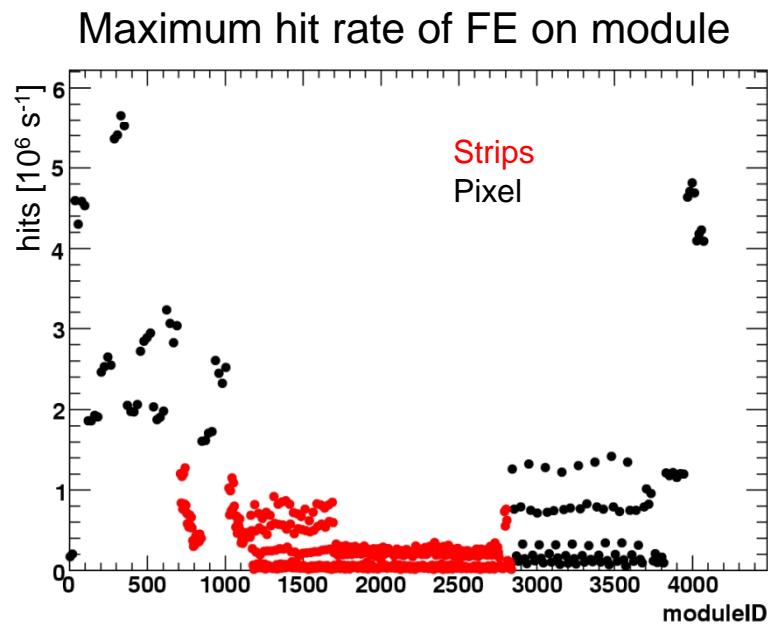


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- Modest radiation hardness ( $O(10^{14} n_{\text{eq}} / \text{cm}^2)$ ) → depends on target material
- Triggerless readout → no first level hardware trigger

# Simulated maximum data rate

- Simulated maximum data rate for 4 GeV/c p on Cu:
  - Pixel module (12 cm<sup>2</sup>):  $32 \cdot 10^6 \text{ s}^{-1} \rightarrow 1.3 \text{ Gbit/s}$
  - Front-End chip (1 cm<sup>2</sup>):  $5.5 \cdot 10^6 \text{ s}^{-1} \rightarrow 220 \text{ Mbit/s}$   
(assuming 40 bit/hit)

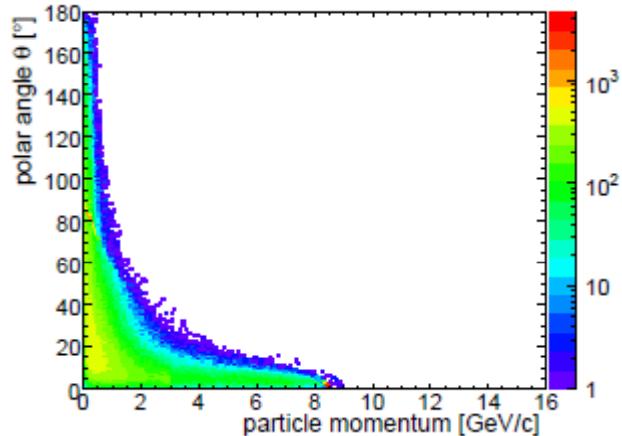


# Requirements MVD

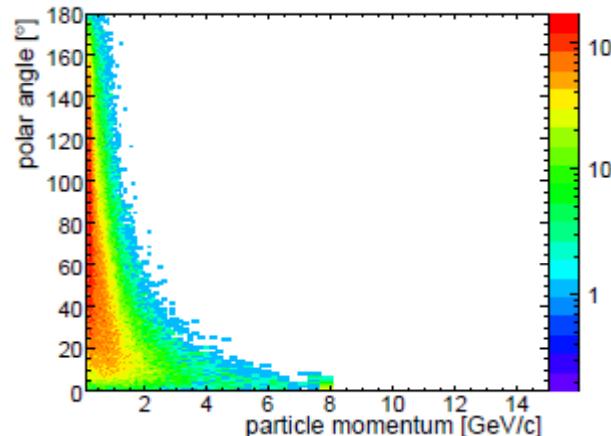
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- Low material budget → low momentum particles energy resolution calorimeter

# Momentum distribution and multiple scattering

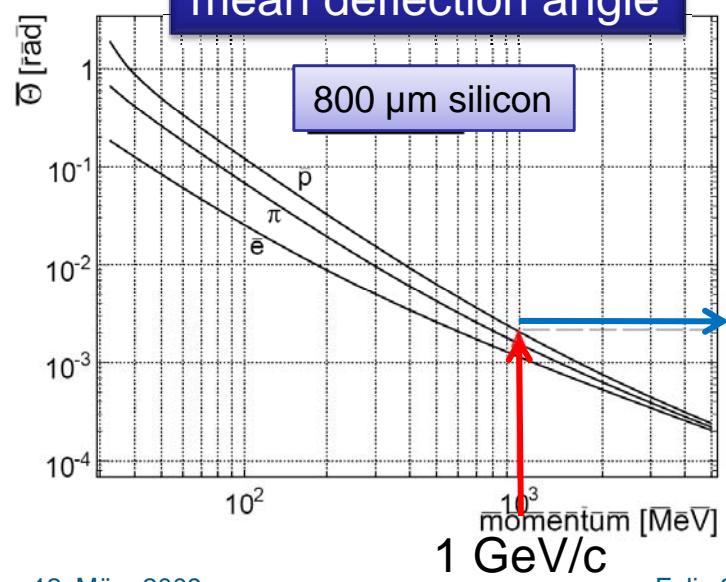
pp @ 8 GeV/c



pAu @ 8 GeV/c



mean deflection angle



2 mrad  $\rightarrow$  20  $\mu$ m error / cm path

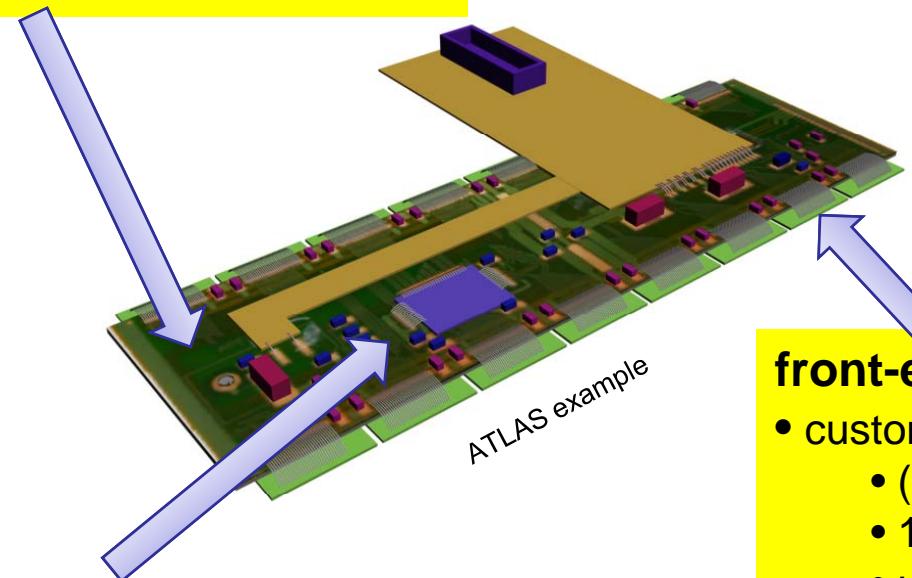
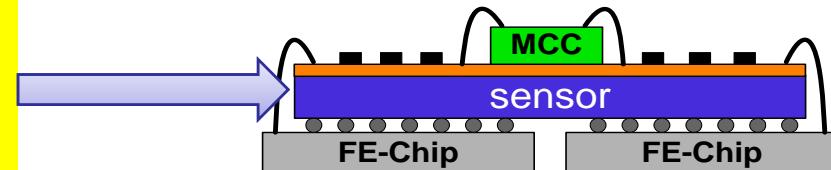
Multiple scattering dominates resolution for low momentum particles

# TECHNICAL DEVELOPMENTS

# Hybrid Pixel Module

## sensor:

- epi-Silicon
  - 50, 75, 100 µm thick epi-Layer on CZ substrate
  - thinned down to 75 – 150 µm
- alt. oxygen enriched silicon
  - thinned down to 150 – 200 µm



## readout:

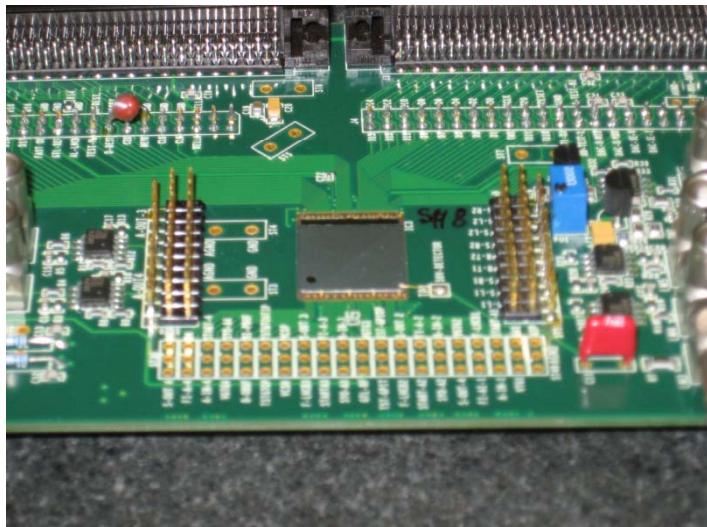
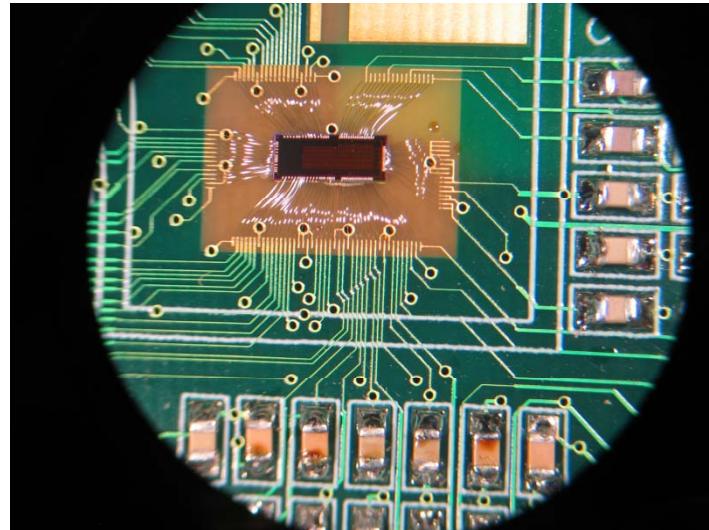
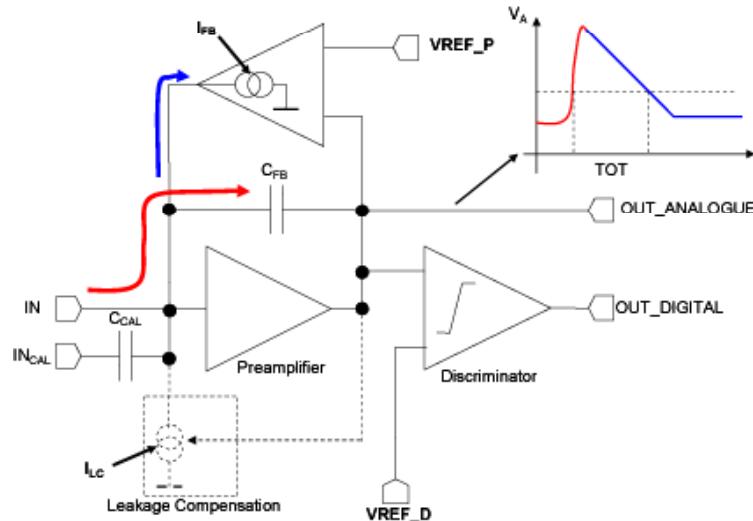
- Module Controller Chip?

## front-end chip:

- custom development (ToPix)
  - $(100 \mu\text{m})^2$  pixels
  - 100 x 100 pixel matrix
  - untriggered readout
  - 130 nm IBM process

→ D. Calvo HK40.2

# ToPix Development



## ToPix2

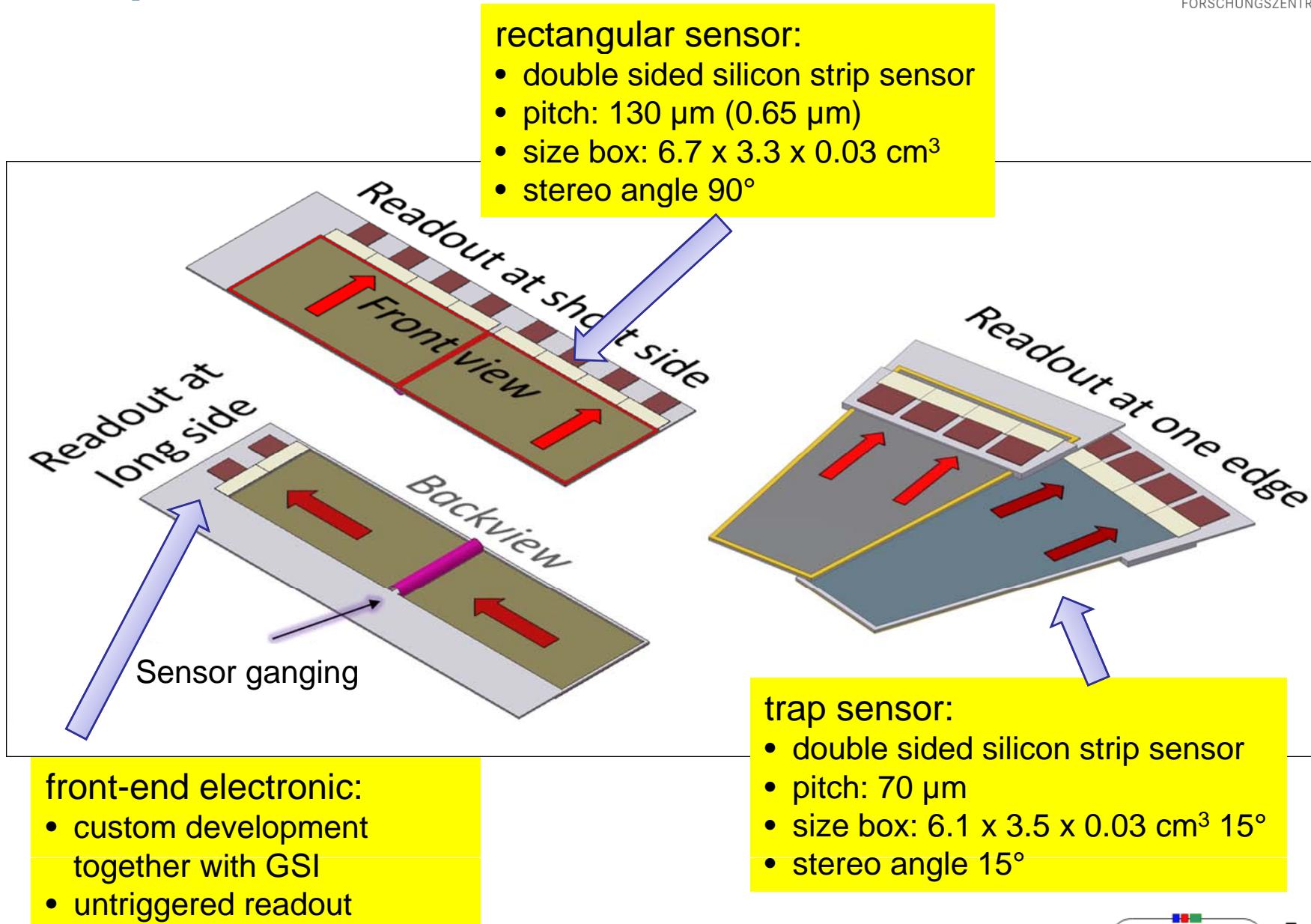
- 320 readout cells ( $100 \mu\text{m}$ ) $^2$
- $5 \times 2 \text{ mm}^2$  size
- analogue + digital circuit

## Epi-pixel sensor

- bump bonded on ALICE FE
- thinned down to:
  - $100 \mu\text{m}$  ( $49 \mu\text{m}$ )
  - $120 \mu\text{m}$  ( $75 \mu\text{m}$ )
  - $150 \mu\text{m}$  ( $98 \mu\text{m}$ )

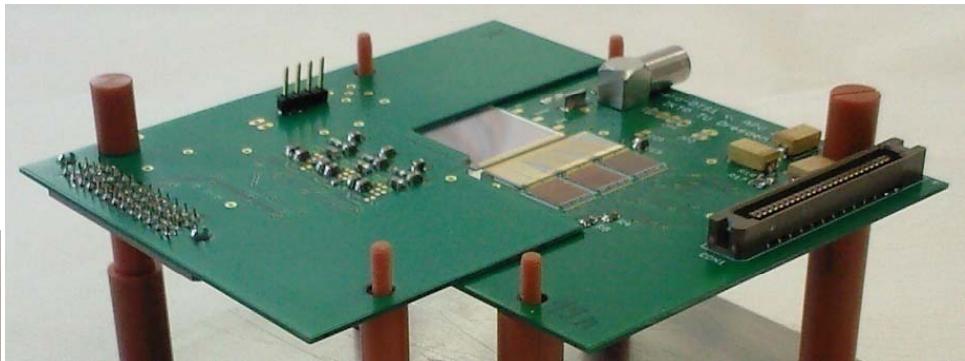
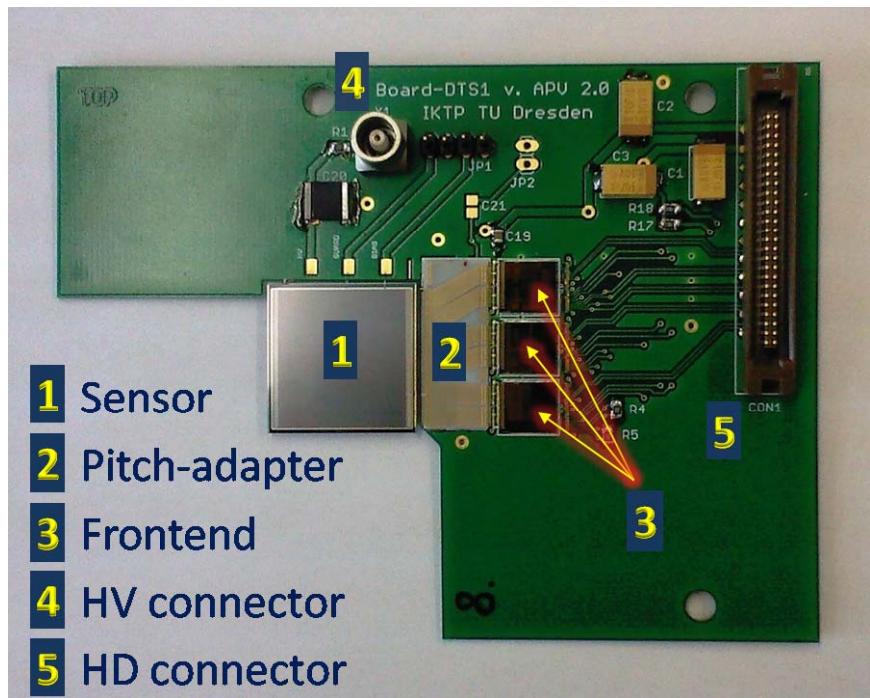
Tobias Stockmanns

# Strip Detector

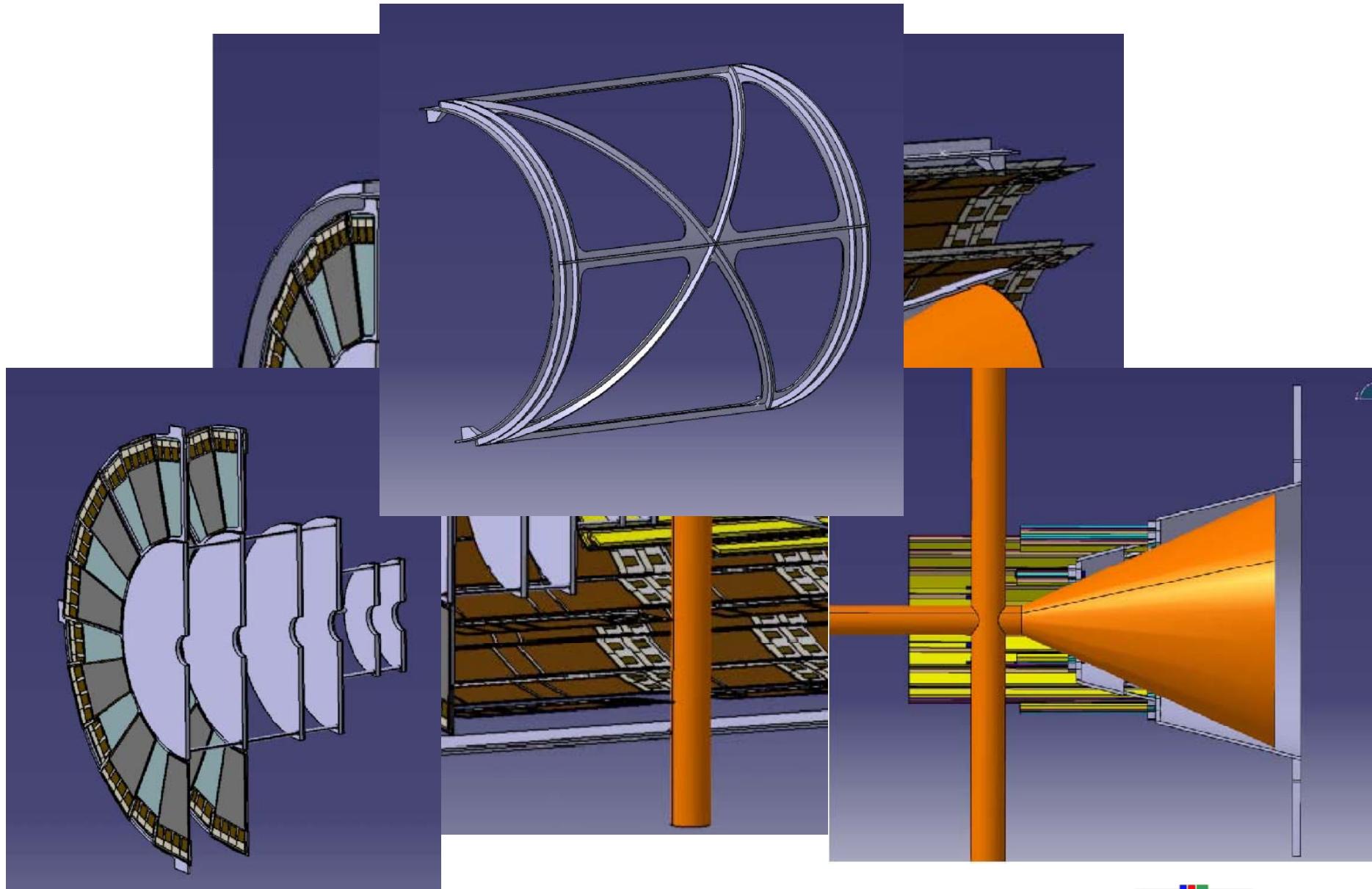


# Hardware development

First small sensor prototype with APV readout

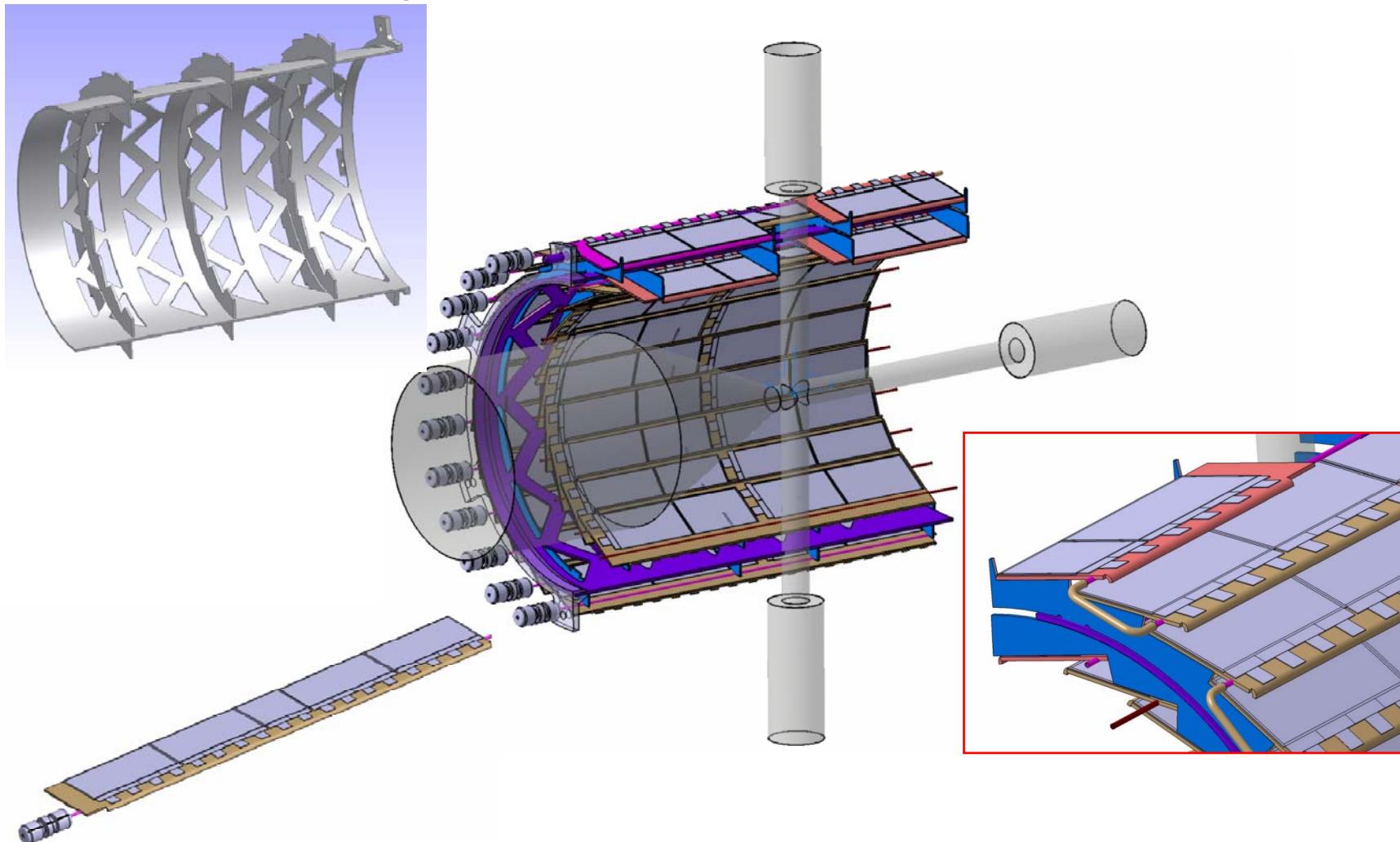


# Pixel support structures



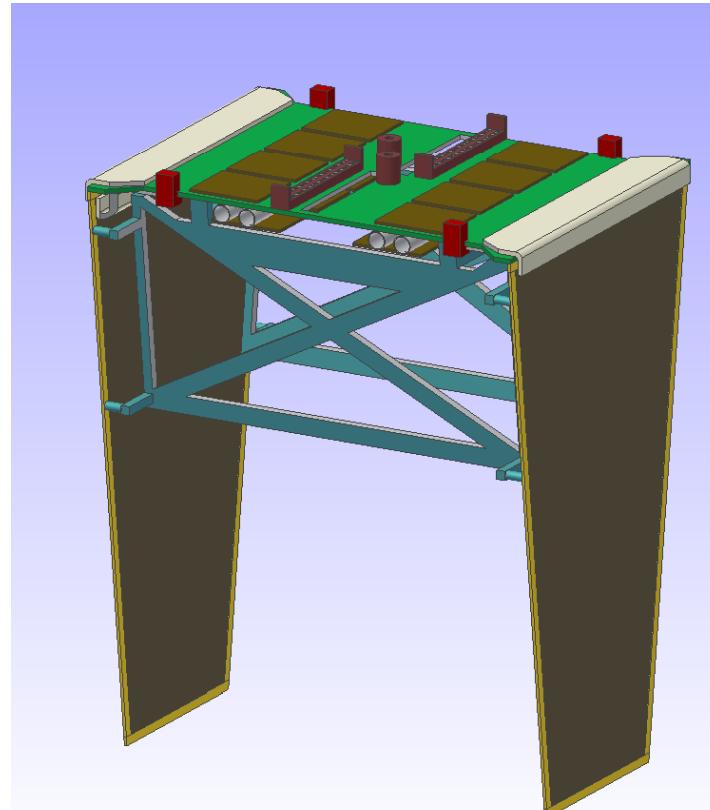
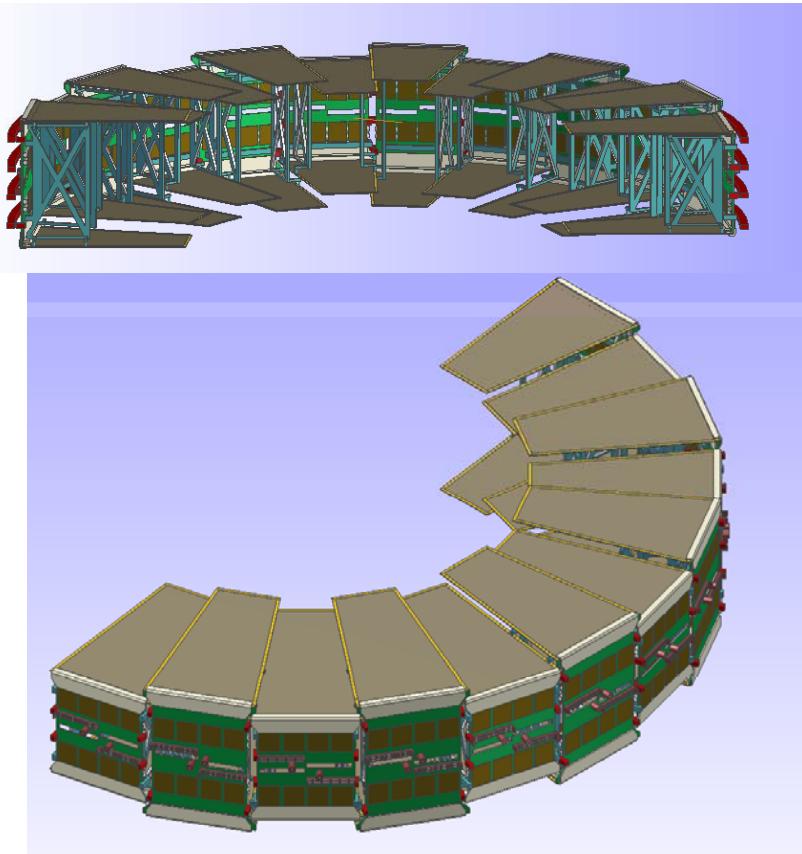
# Support Structures Strips

- Strip barrel design



# Concept for strip disks

Disk layer / Forward part

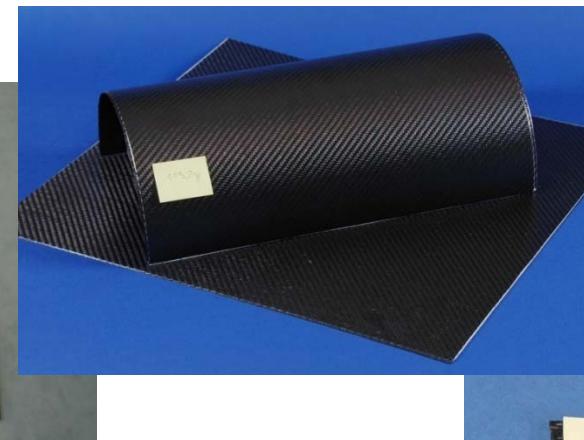
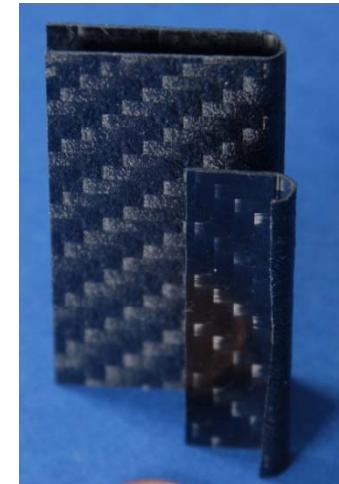
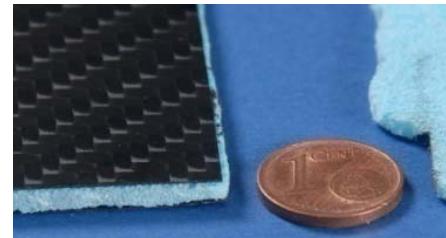


→ T. Würschig HK 40.3

Tobias Stockmanns

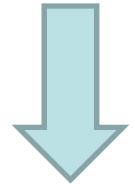
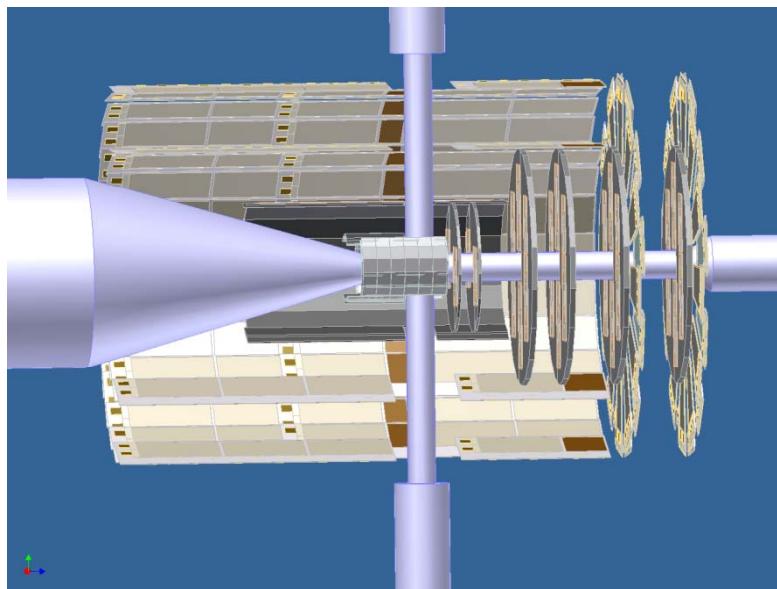
# Use of carbon sandwich structure

- Stave support: Sandwich structure  
(Carbon – Rohacell – Carbon)
- Barrel support: Half-shell and saw-tooth support
- Carbon foam with high thermal conductivity



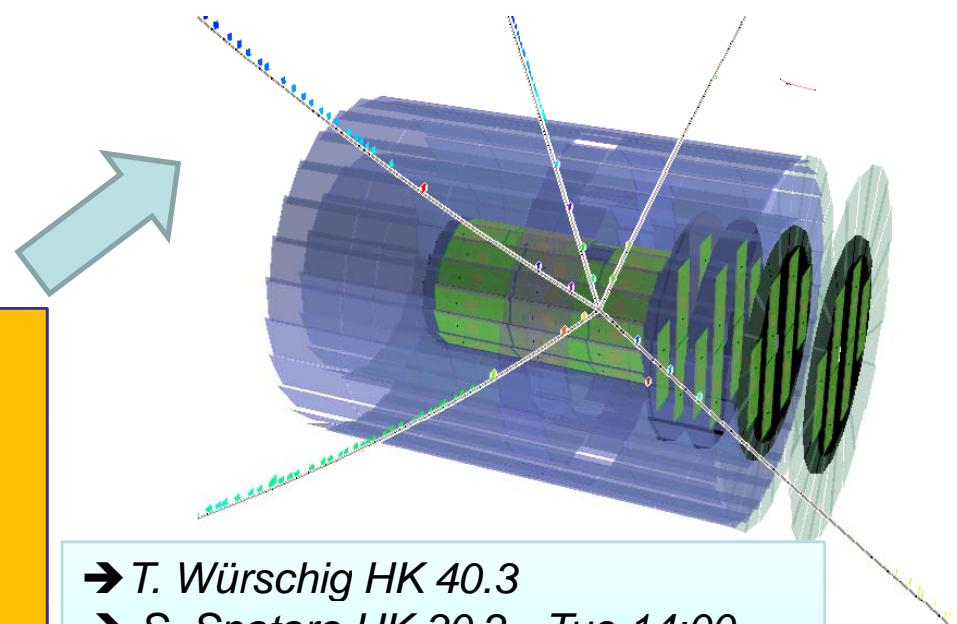
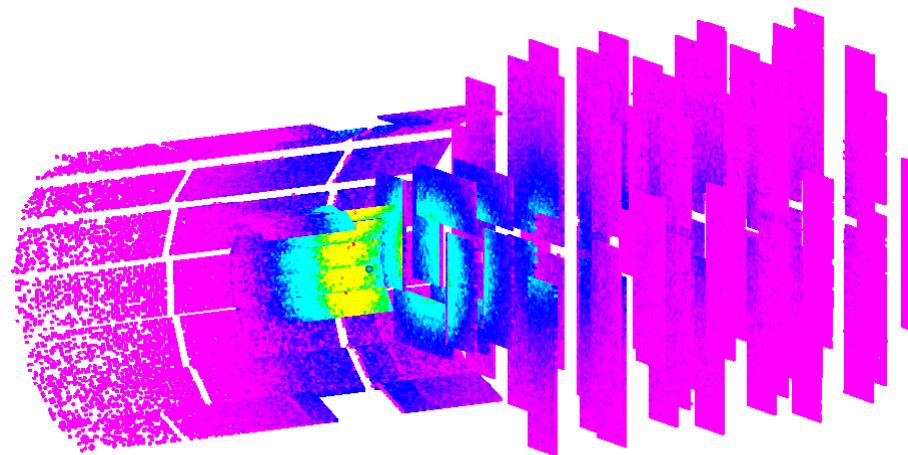
# SIMULATION PROGRAM

# Simulation Studies of Mechanical Design



## CAD Converter

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

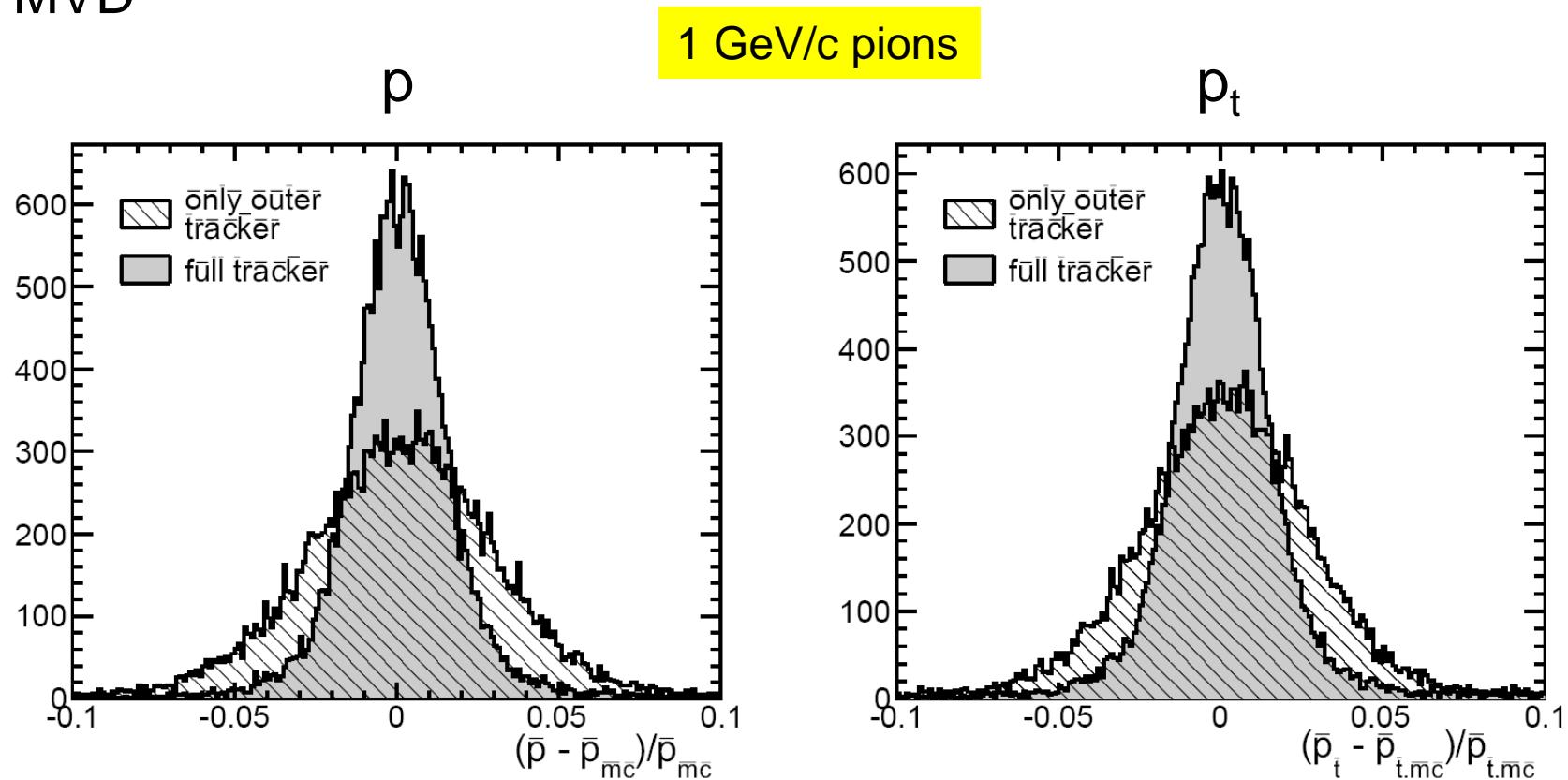


- T. Würschig HK 40.3
- S. Spataro HK 30.2 - Tue 14:00
- M. Al-Turany HK 53.5 – Wed 15:00

Tobias Stockmanns

# Performance of MVD

Momentum resolution of PANDA detector with and without MVD



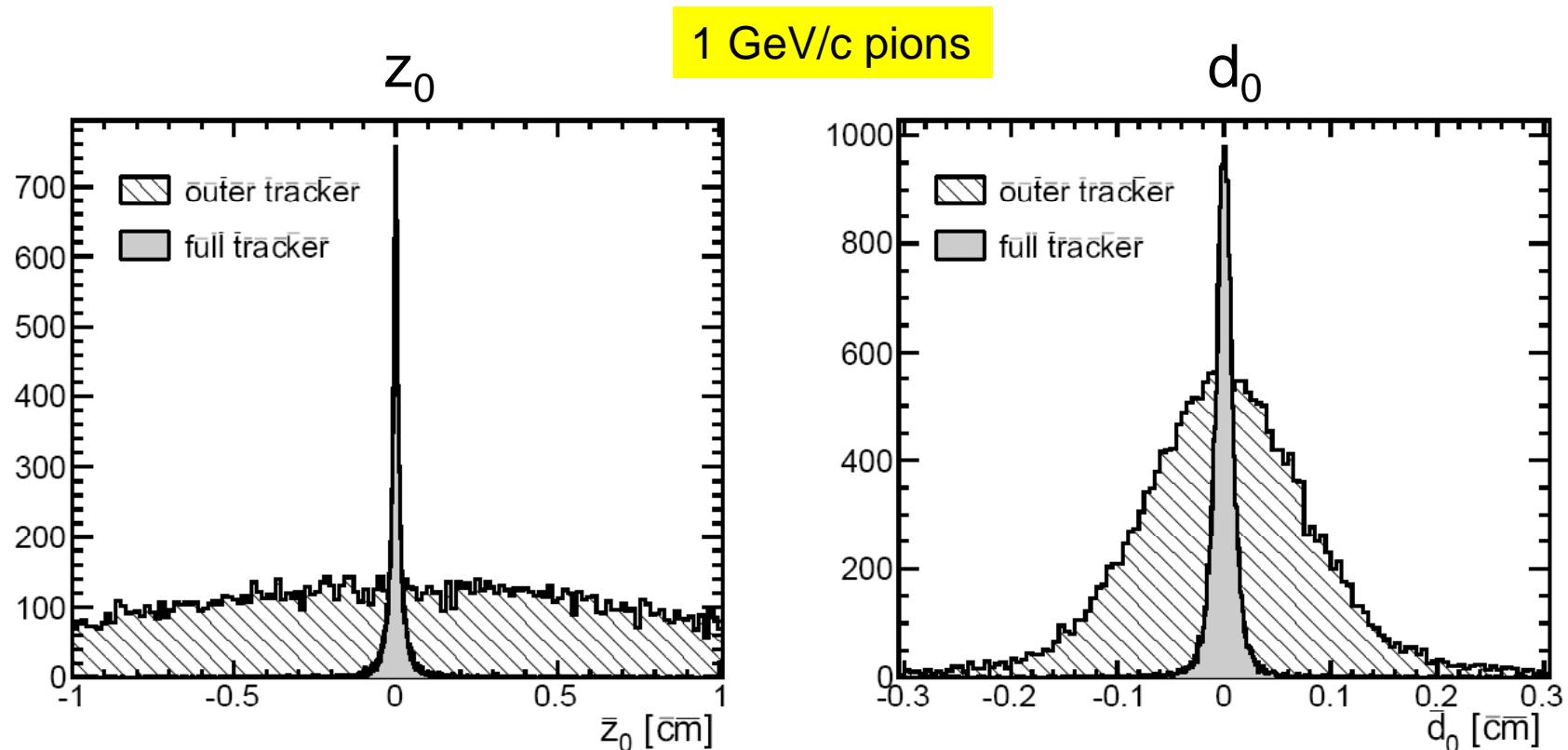
$$\sigma(p) [1\text{GeV}/c \pi] \text{ without MVD} = 2.6 \%$$

$$\sigma(p) [1\text{GeV}/c \pi] \text{ with MVD} = 1.4 \%$$

R. Jäkel PhD thesis in preparation

# Performance of MVD

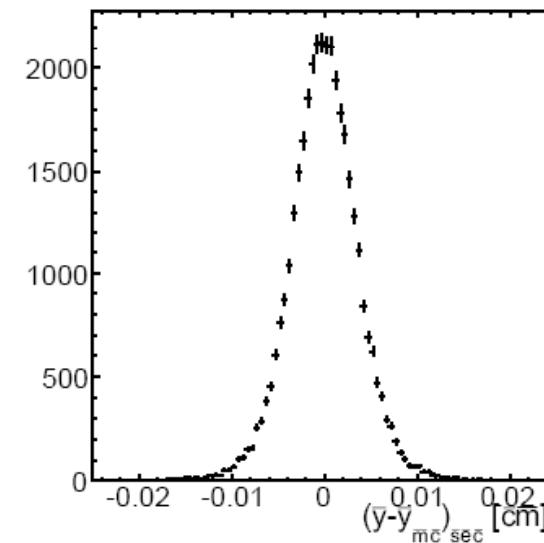
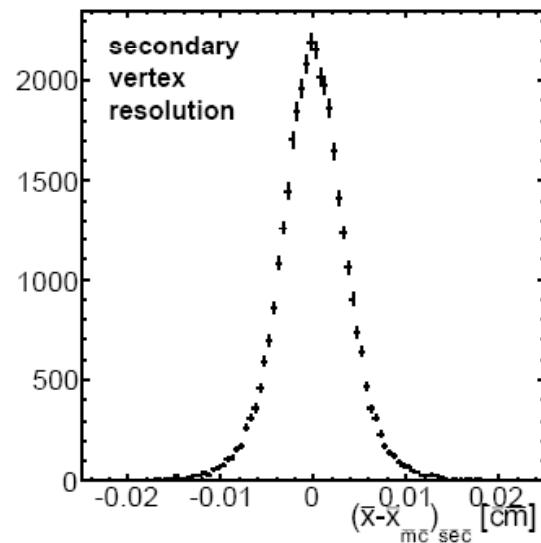
Track parameter resolution with and without MVD



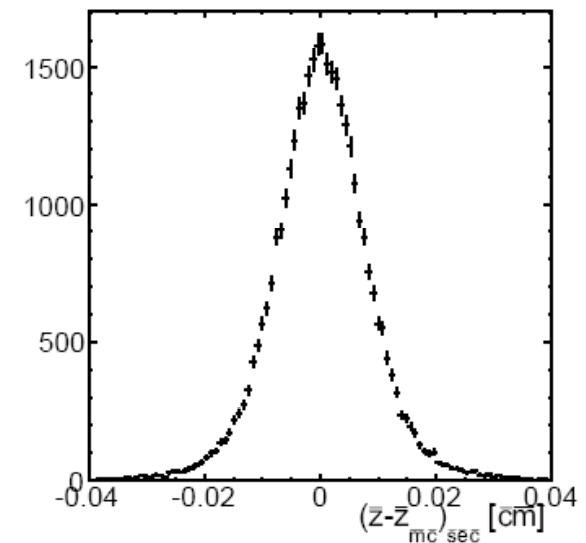
R. Jäkel PhD thesis in preparation

# Secondary vertex resolution

$pp \rightarrow D^+D^-$



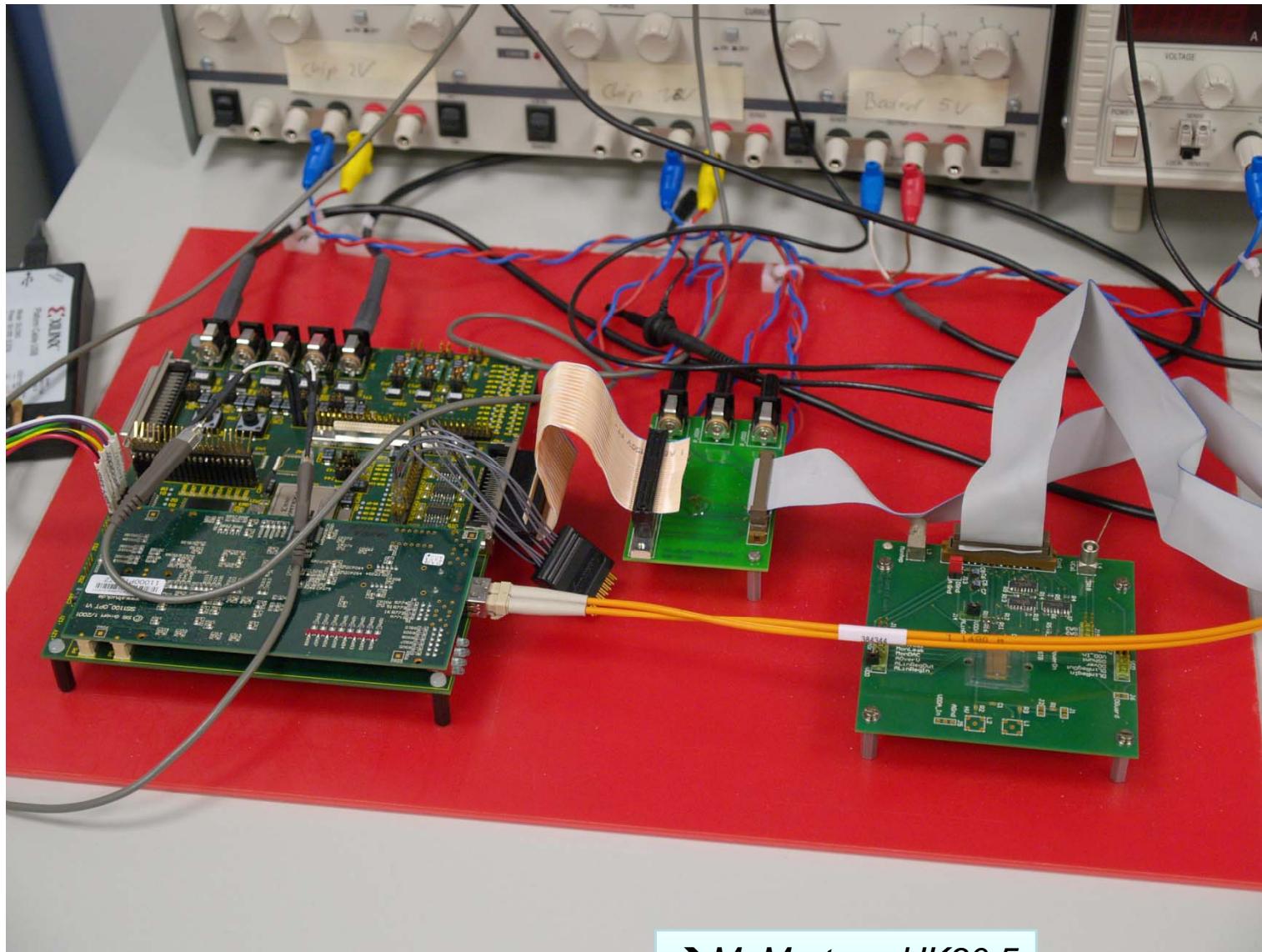
R. Jäkel PhD thesis in preparation



- Fully reconstructed  $D^+D^-$  pairs
- Vertex resolution:
  - 35  $\mu$ m in x and y
  - 77  $\mu$ m in z (at 6.57 GeV/c beam momentum)

# TEST SYSTEMS

# Test systems

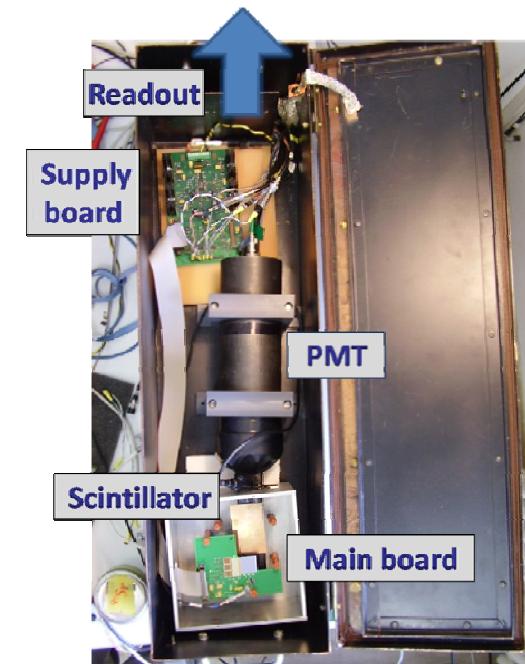
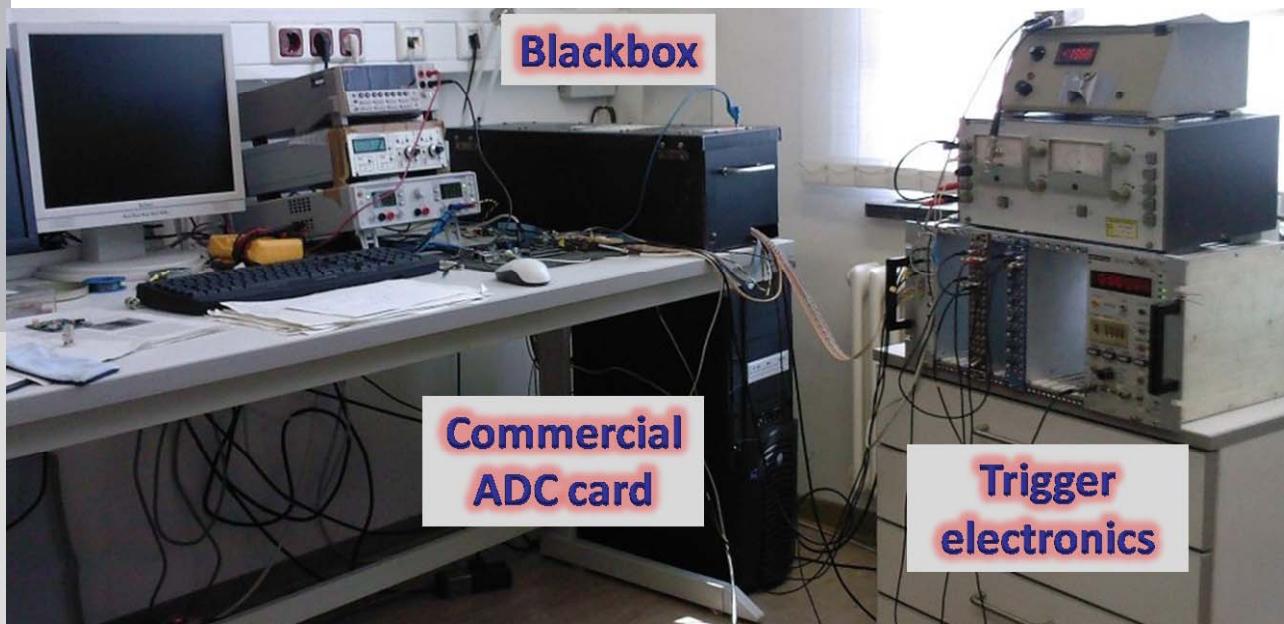


→ M. Mertens HK30.5

# Strip Test Station Bonn/Dresden

Test station: DTS1 (Lab setup)

- Evaluation of silicon strip sensors
- Modular setup allowing further prototype testing



→ F. Krüger HK 40.4

# Beam Telescope Bonn

Test-beam setup in Bonn



# Summary

- The Micro-Vertex-Detector is one of the most challenging subdetectors within PANDA
- It faces the highest radiation load, highest hit rates, very stringent requirements on the radiation length and by far the highest number of readout channels
- In the course of the PANDA project a very sophisticated simulation software was (and is still) developed which allows us to optimize all different design parameters of the detector and do realistic simulations of the physics performance
- The hardware development is on a good track and we think that we have the necessary technologies at hand which allows us to build this detector. Nevertheless there is still a lot of work ahead of us