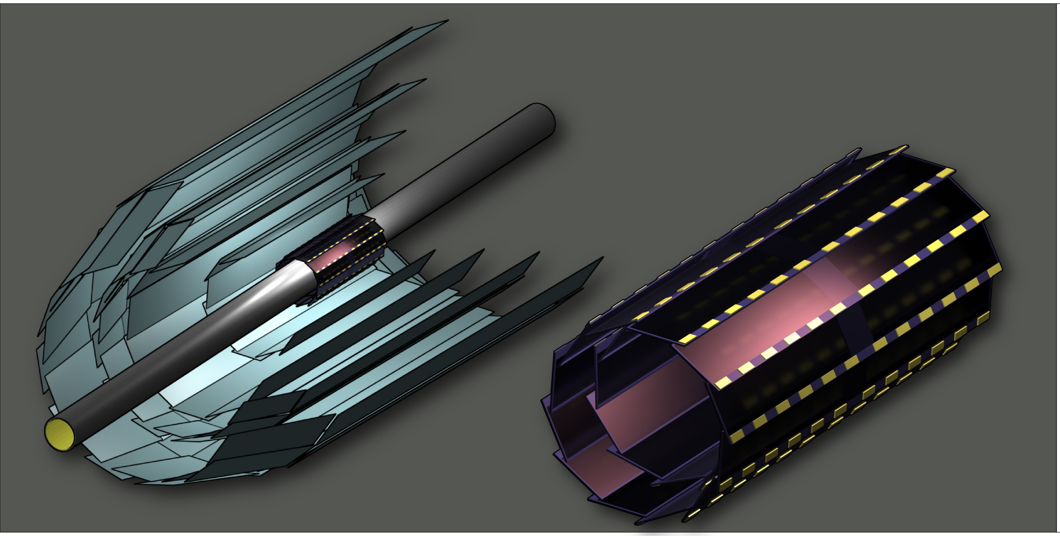
Optimization Studies with Single Tracks



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DEPFET Detectors and Applications
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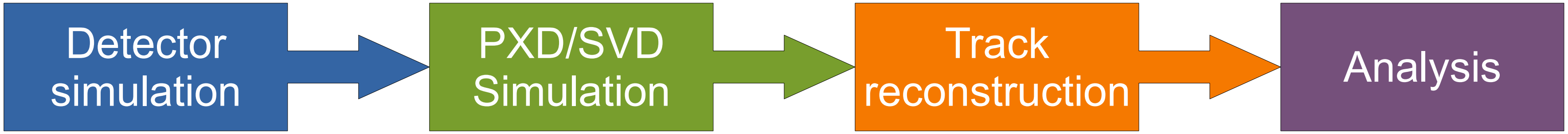
Excellence Cluster Universe

Max-Planck-Institut für Physik
(Werner-Heisenberg-Institut)

- Detector/Sensor simulation and track reconstruction
- Different methods to get the resolution of the impact parameter
- Detector models studied
- Analysis procedure
- Results

Study optimization of PXD using single tracks and impact parameters

Optimization chain



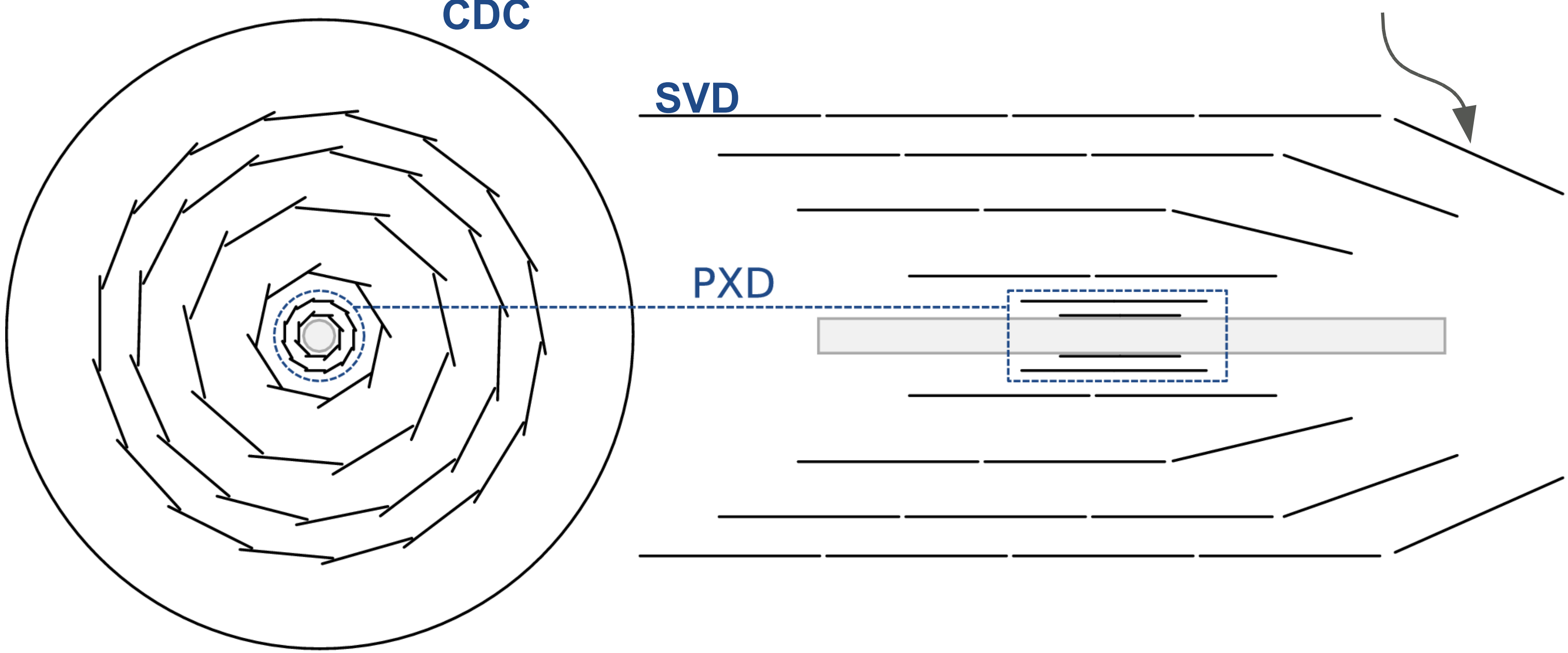
Detector simulation → PXD/SVD Simulation → Track reconstruction → Analysis

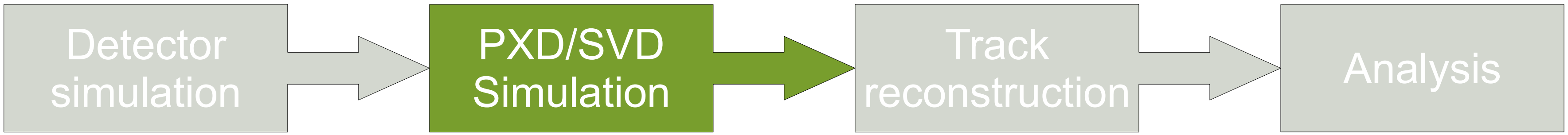
Single muons, **no background**

Detector simulation software: **Mokka** (geant4 based, ILC framework)

Belle II detector geometry:

Slanted parts not in simulation





Detailed simulation of DEPFET sensor signal:

- Global to **local reference system** transformation performed
- **Ionization points** generated (energy loss fluctuation added + electron-hole pairs created)
- **Signal points** generated:
    - drift of electron-hole pairs
    - drift path calculated
    - Lorentz shift in magnetic field + diffusion sigma calculated
- **Signal redistributed** according to diffusion, cell ID calculated
- **Hits produced** (pixels with signal above threshold (2xnoise) found + position calculated)
- Local to global reference system transformation

Clustering built into the digitizer
(performed on the hit level)

Landau energy deposit not taken from geant4
instead parameter from MIP used.

Detector simulation → **PXD/SVD Simulation** → Track reconstruction → Analysis

1 Digitization procedure:

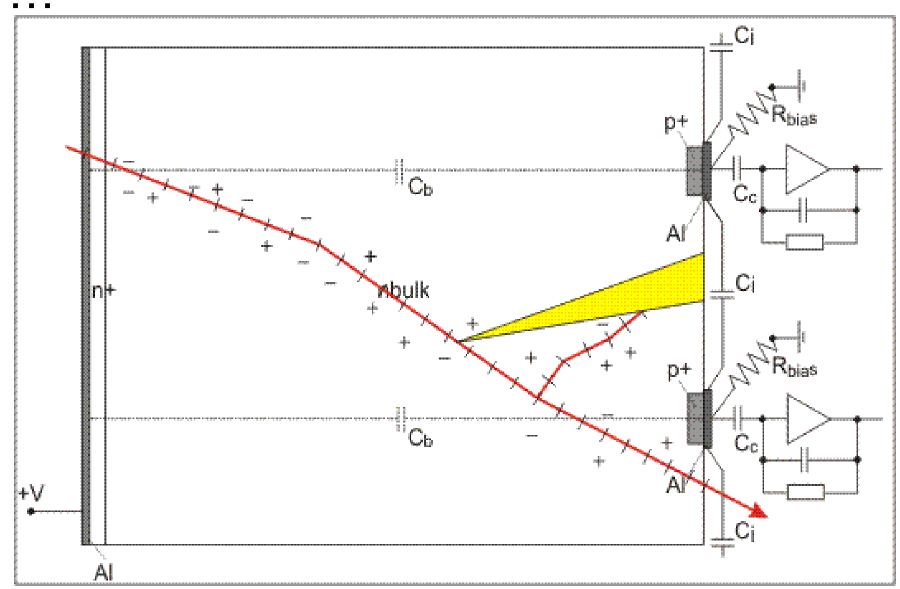
- Generation of **electron-hole pairs** along the path
- **Drift** of electron-hole pairs in the electric field
- **Diffusion** of electron-hole pairs due to multiple collisions
- **Lorentz shift** of electron-hole pairs in the magnetic field
- Calculation of mutual **micro-strip crosstalk** (missing: intermediate strips)
- Generation of **gaussian-type noise**: electronics …

Landau energy deposit taken from geant4

2 Clustering step:

- Seeds + neighbouring strips found based on S/N cut (separately in Z & R-Phi)
- Hit position calculated based on **COG** algorithm

all possible candidates in Z & R-Phi merged to 2D hit (ghosts produced)



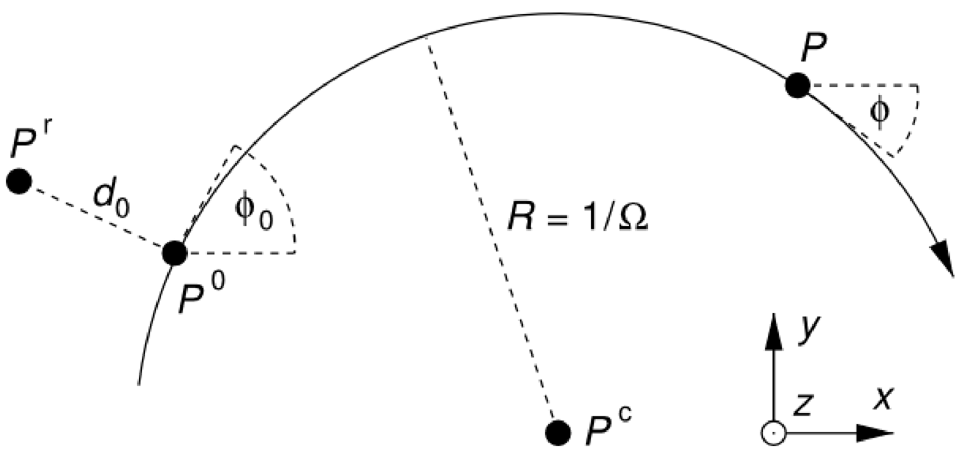
Detector simulation → PXD/SVD Simulation → **Track reconstruction** → Analysis

Tracking performed in **Marlin** (ILC framework)

- Silicon (PXD, SVD) tracking + CDC tracking → Merge Silicon and CDC tracks
- Tracks with impact parameters (+ its errors)

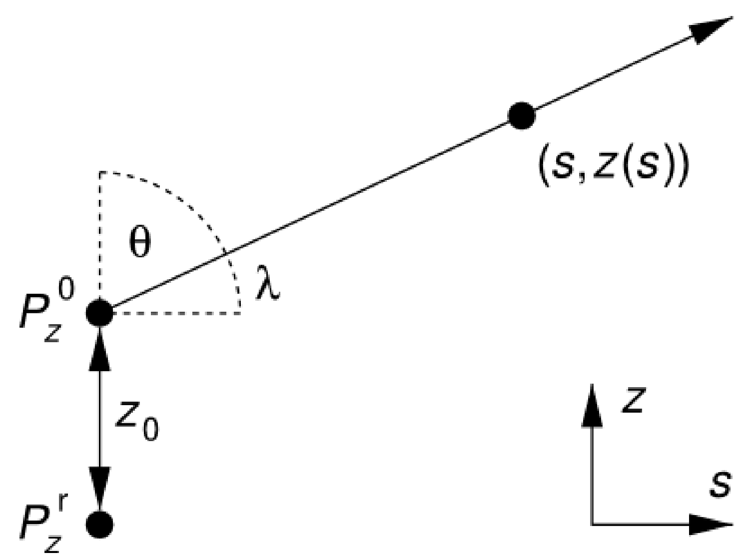
Definition impact parameter:

d0

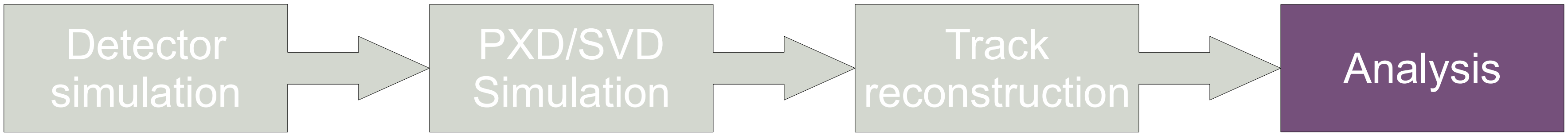


r-phi projection

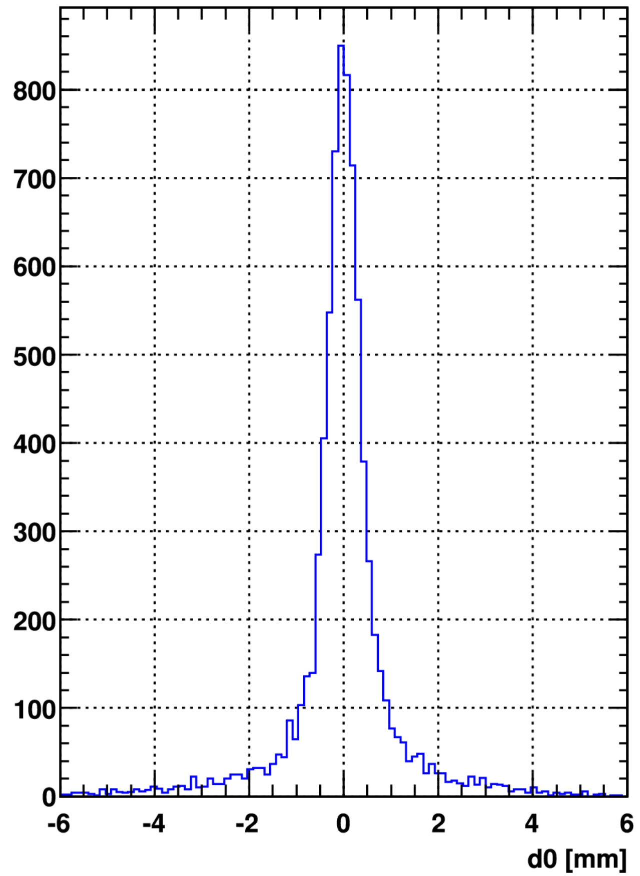
z0



arclength-z projection



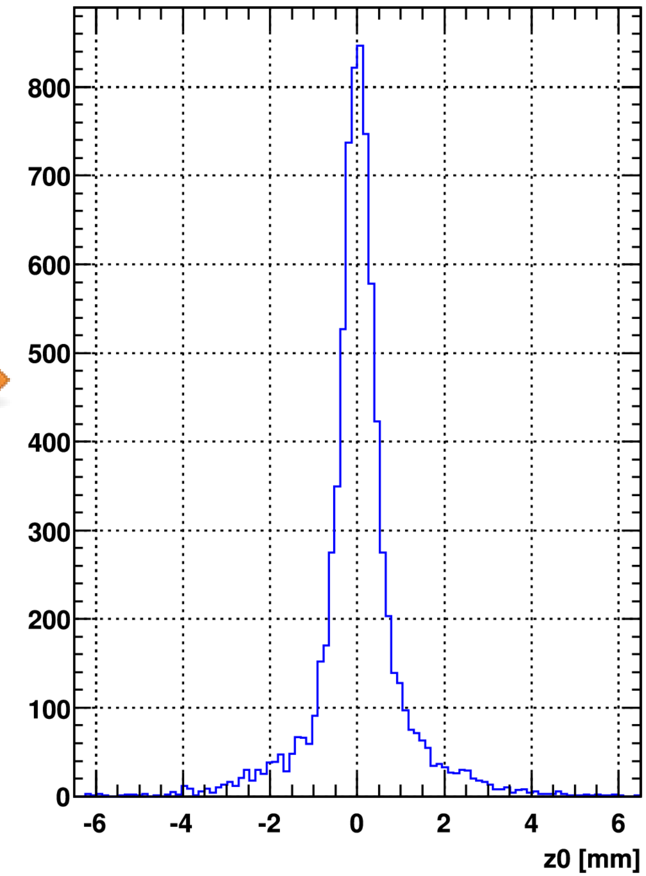
D0 :: 0.1 GeV :: 55 degree



p = 100 MeV
θ = 55 degree

Nano beam option

Z0 :: 0.1 GeV :: 55 degree



Resolution defined as width of peak (Signal)

Different possibilities: **RMS**, **RMS 90**, **Gauss fit**, **double Gauss fit** ...

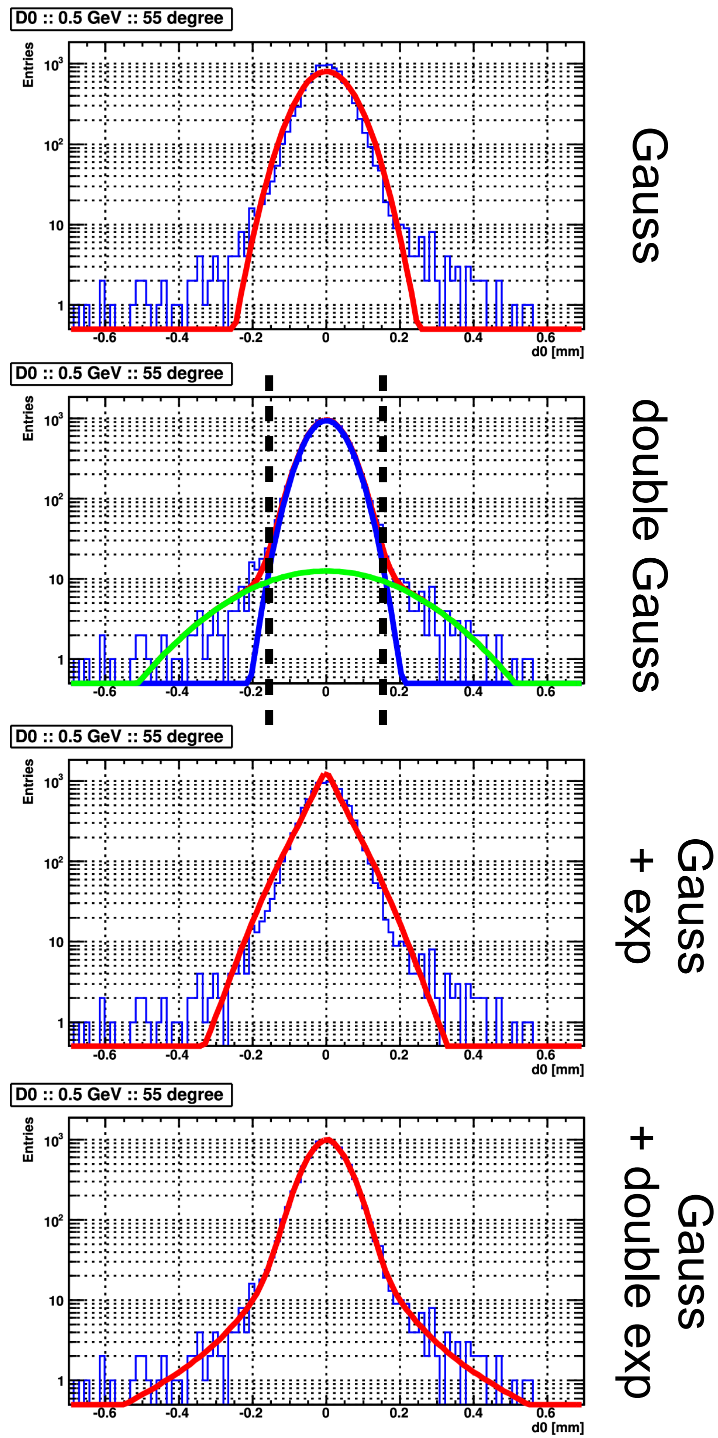
In order to study tails → Use fit of distribution

Different fitting methods were tested:

- Gauss
- double Gauss ← stable and reliable fit
- triple Gauss
- Gauss + exponential
- Gauss + double exponential

Fitting method:

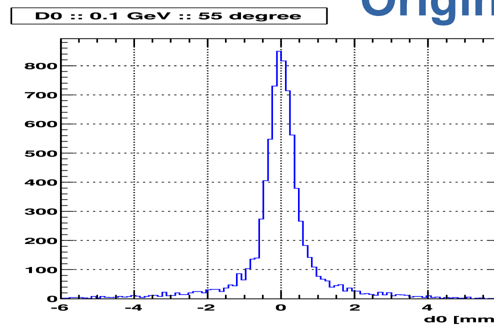
1. Pre-fit using Gauss
2. Values from pre-fit as start values for double Gauss fit
3. Smaller sigma of the two Gauss functions is taken
4. Intersection of the two Gauss functions separates signal region from tails



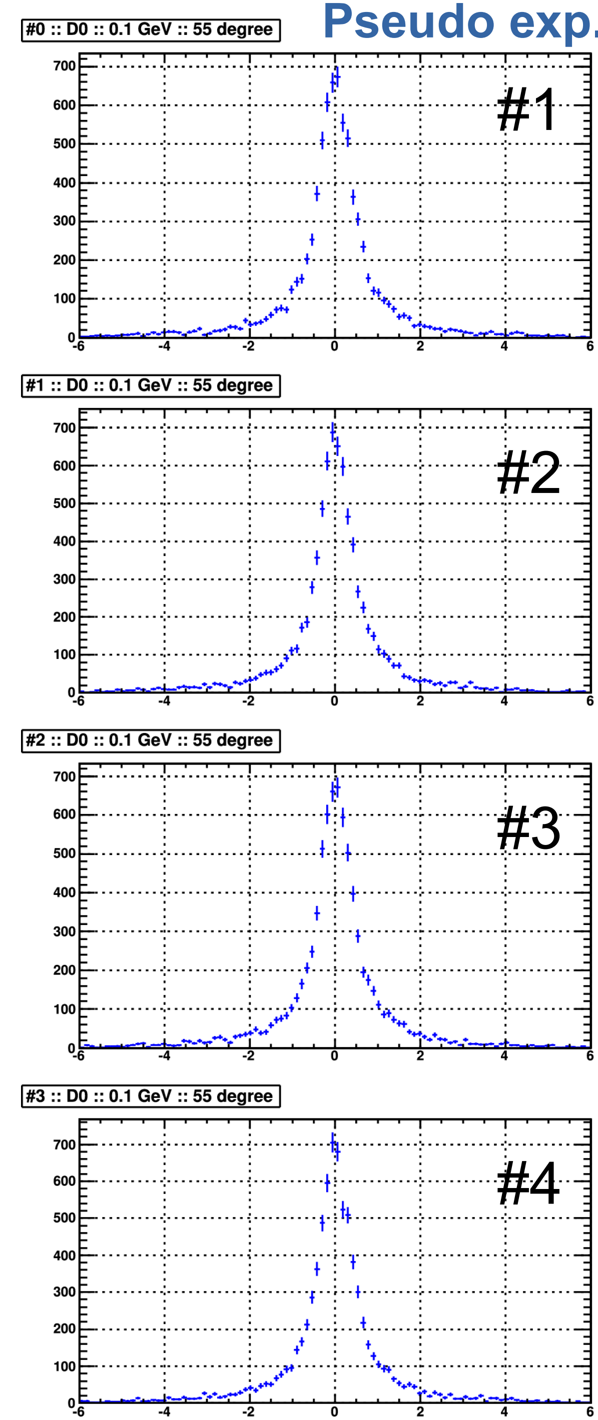
For each d0/z0 value **200**

new values of d0/z0 are calculated:

Original



Pseudo exp.



$$d0_{new} = d0 + RandomGauss(\overbrace{0}^{\text{Mean}}, \overbrace{Error_{d0}}^{\text{Sigma}})$$

The new values are filled into 200 histograms

- Mean of histogram “sigma” is resolution
- 2 sigma range defines asymmetric error of resolution (quantile function used)

Detector models

Constant pixel size, 1600 pixels, Pixel size: 1. layer: **50 x 47.7 µm**
2. layer: **50 x 73.4 µm**

	thickness	rad 1. layer	rad 2. layer	BP outer rad	BP Au
50um_HC	50 µm	18 mm	22 mm	16.5 mm	✓
50um_NB	50 µm	13 mm	22 mm	10.0 mm	✓
50um_NBnoAu	50 µm	13 mm	22 mm	10.0 mm	✗
75um_NB	75 µm	13 mm	22 mm	10.0 mm	✓
75um_NBnoAu	75 µm	13 mm	22 mm	10.0 mm	✗
100um_NB	100 µm	13 mm	22 mm	10.0 mm	✓
100um_NBnoAu	100 µm	13 mm	22 mm	10.0 mm	✗

Base line

Momentum (GeV)

0.1 slow pion
0.3
0.5 average hadron momentum
1.5 J/Psi
5.0 mu/mu

Angles (degree) + 1 degree smearing

35.0 forward region
55.0
80.0 central region

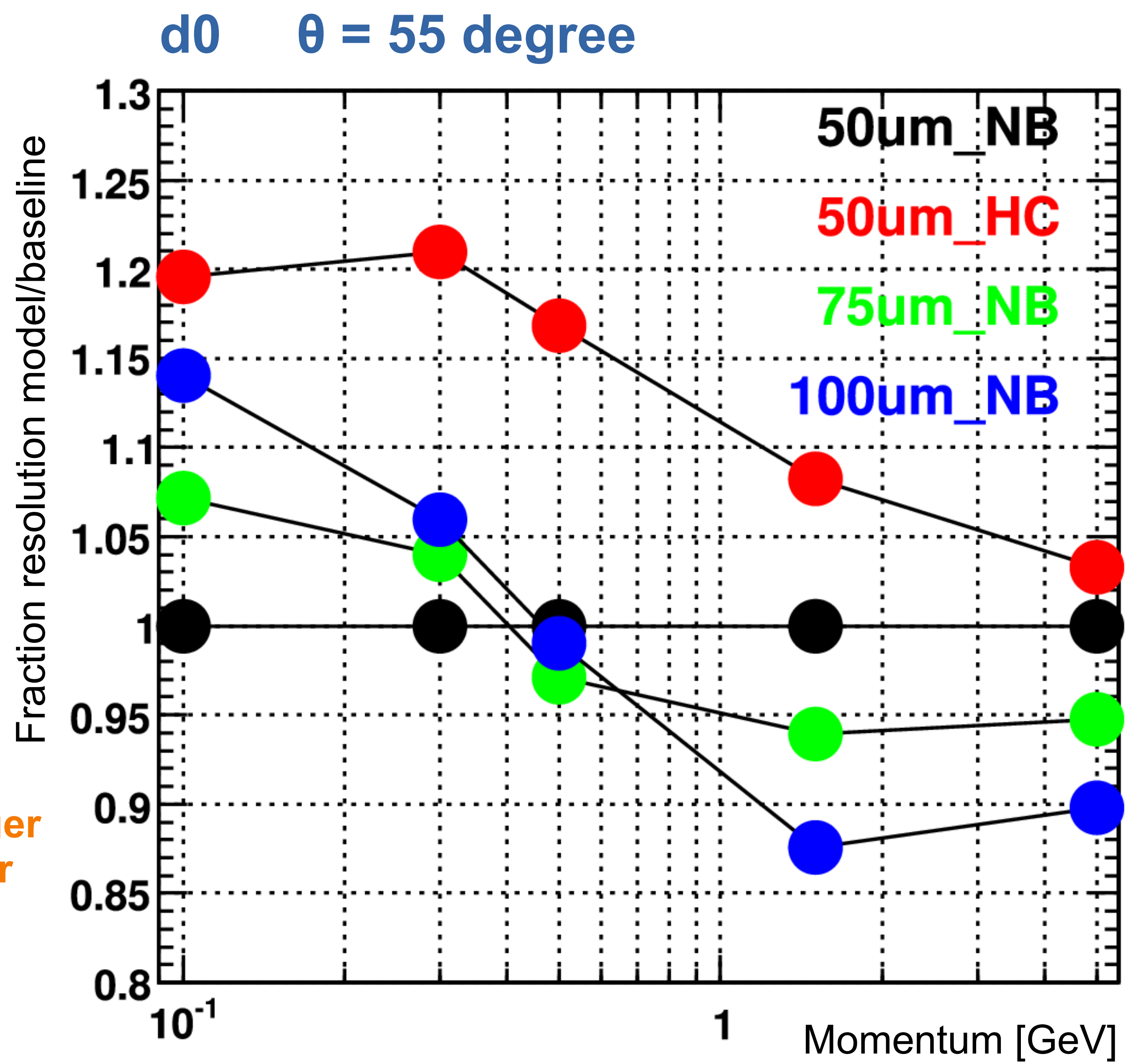
Normalized to baseline

$$y = \frac{resolution_{model}}{resolution_{baseline}}$$

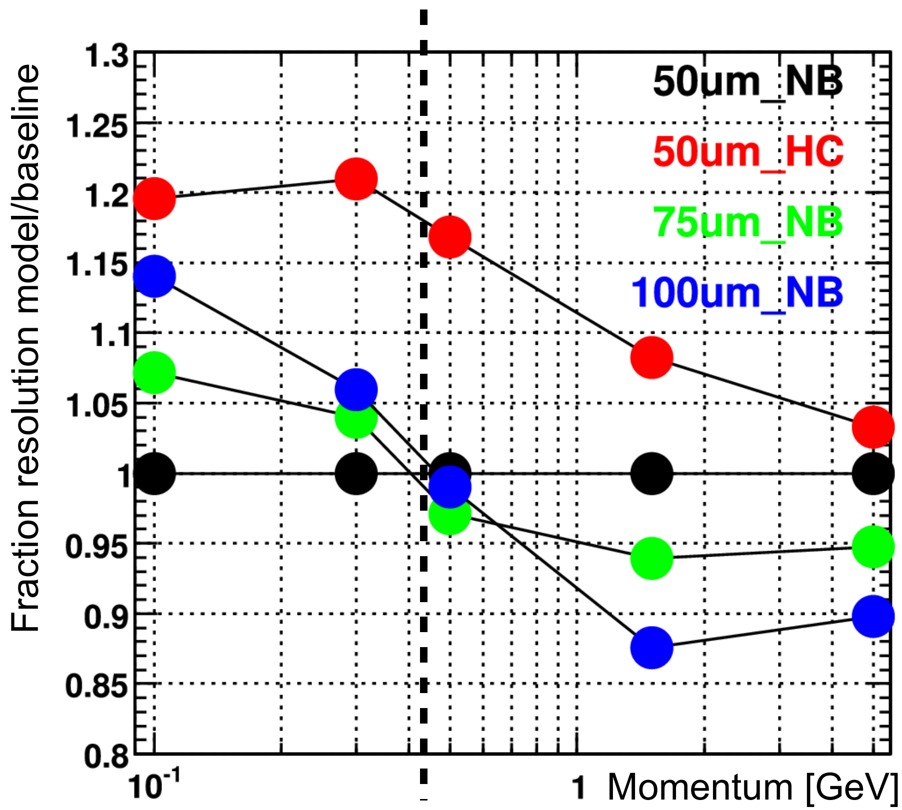
➡ momentum > 450 MeV

resolution seems to improve for thicker sensors

➡ **higher signal and bigger clusters dominate over multiple scattering**

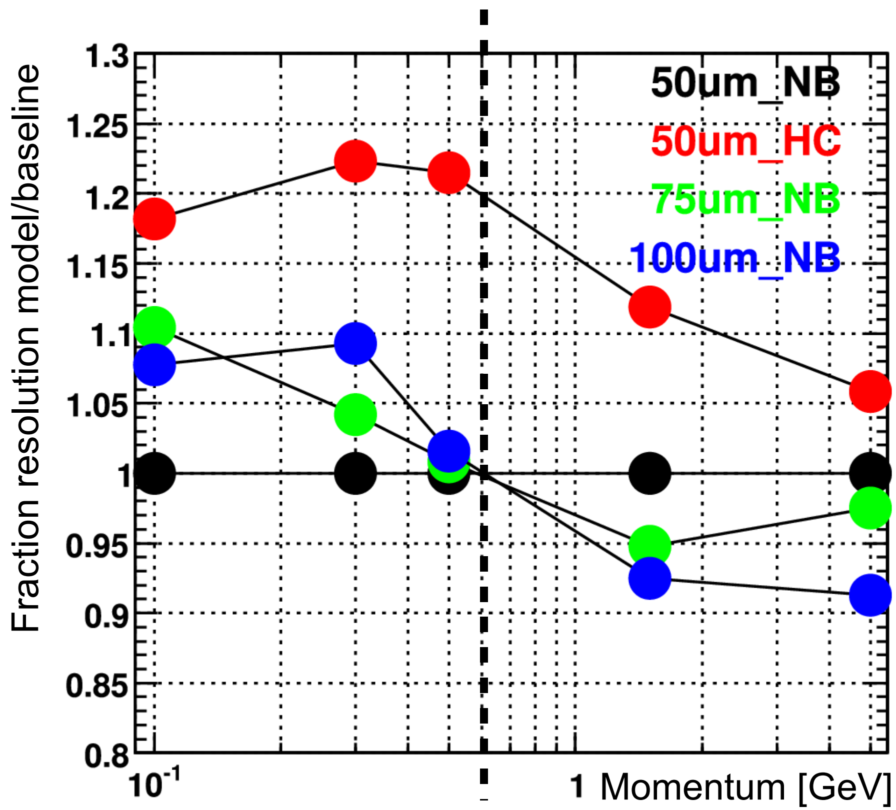


d0 θ = 55 degree



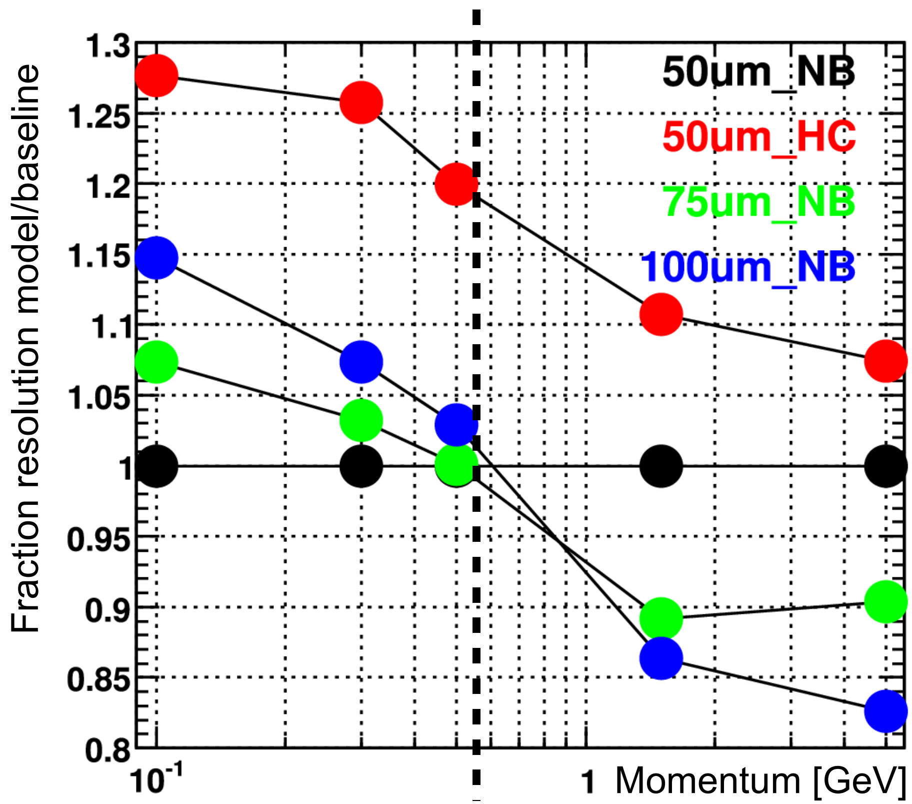
crossing point
~450 MeV

d0 θ = 35 degree



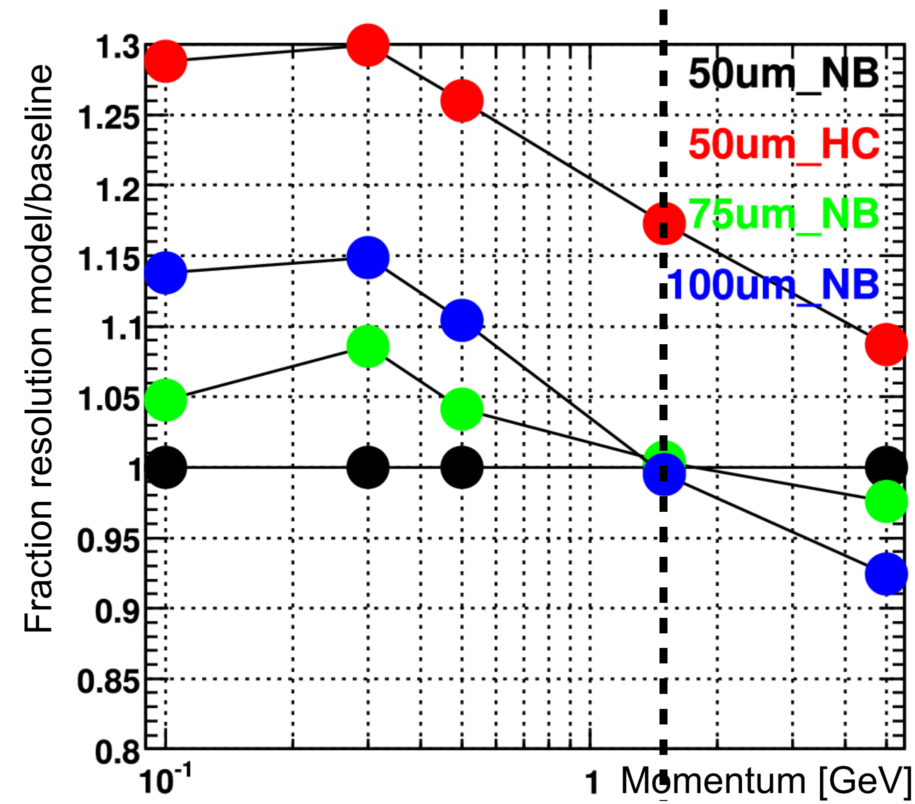
crossing point
~600 MeV

z0 θ = 55 degree



crossing point
~550 MeV

z0 θ = 35 degree



crossing point
~1500 MeV

effect of multiple scattering bigger, because path in sensor is longer for smaller angles.

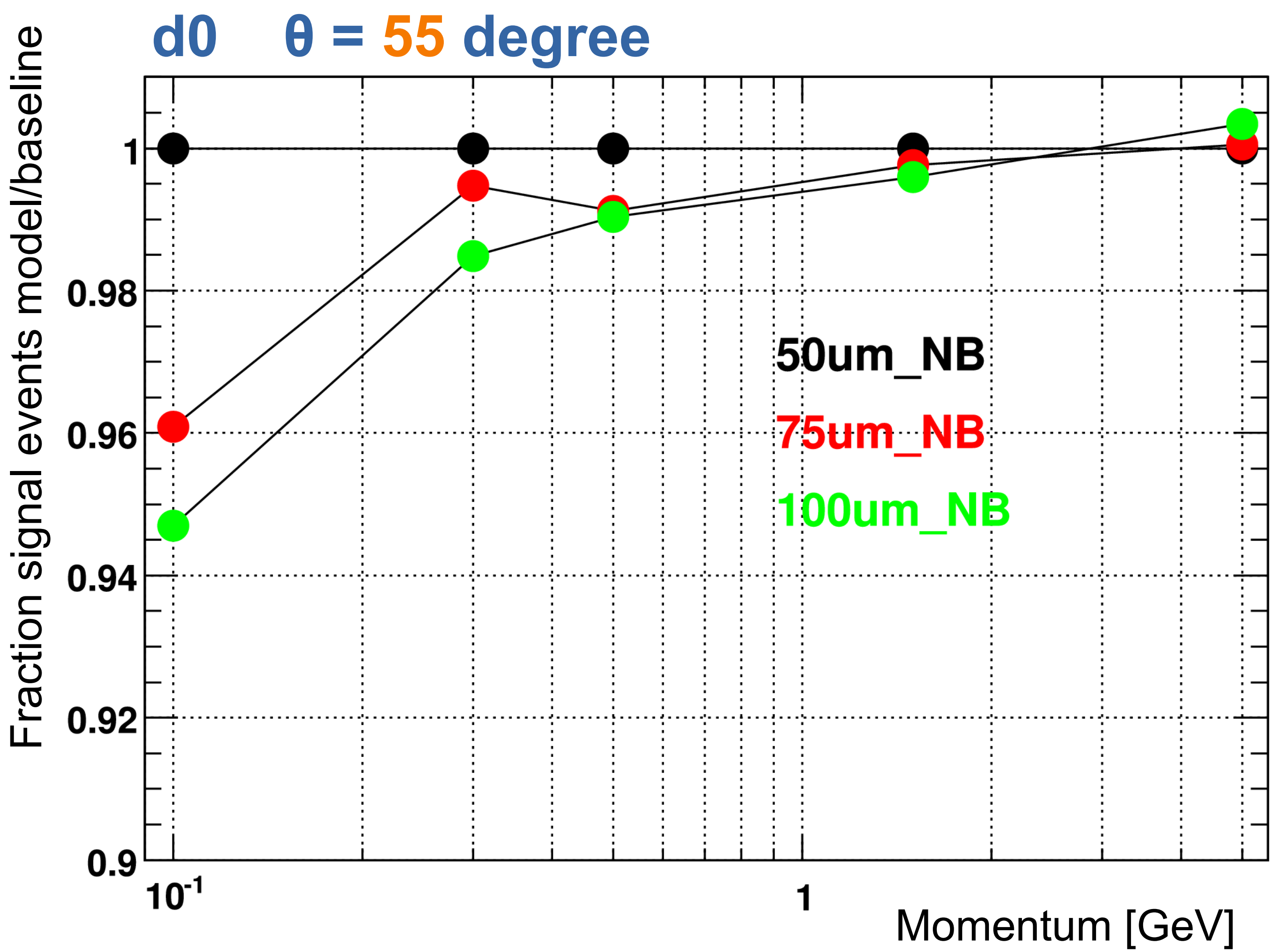
Normalized to baseline

$$f = \frac{\#Evt_{signal}}{\#Evt_{signal} + \#Evt_{tail}}$$

$$y = \frac{f_{model}}{f_{baseline}}$$

momentum > 3 GeV

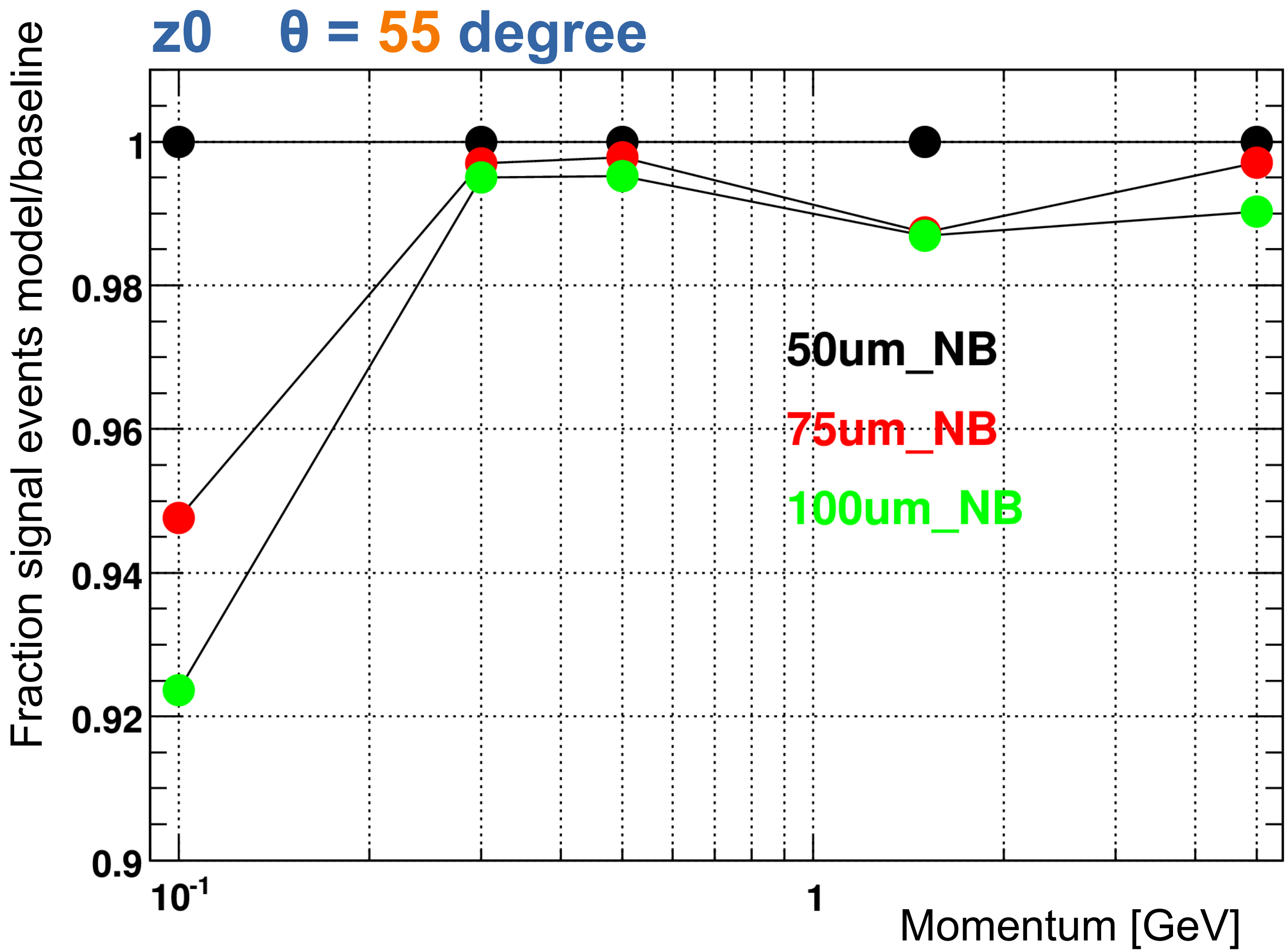
Signal fraction seems to improve for thicker sensors (effect is very small)



Normalized to baseline

$$f = \frac{\# Evt_{signal}}{\# Evt_{signal} + \# Evt_{tail}}$$

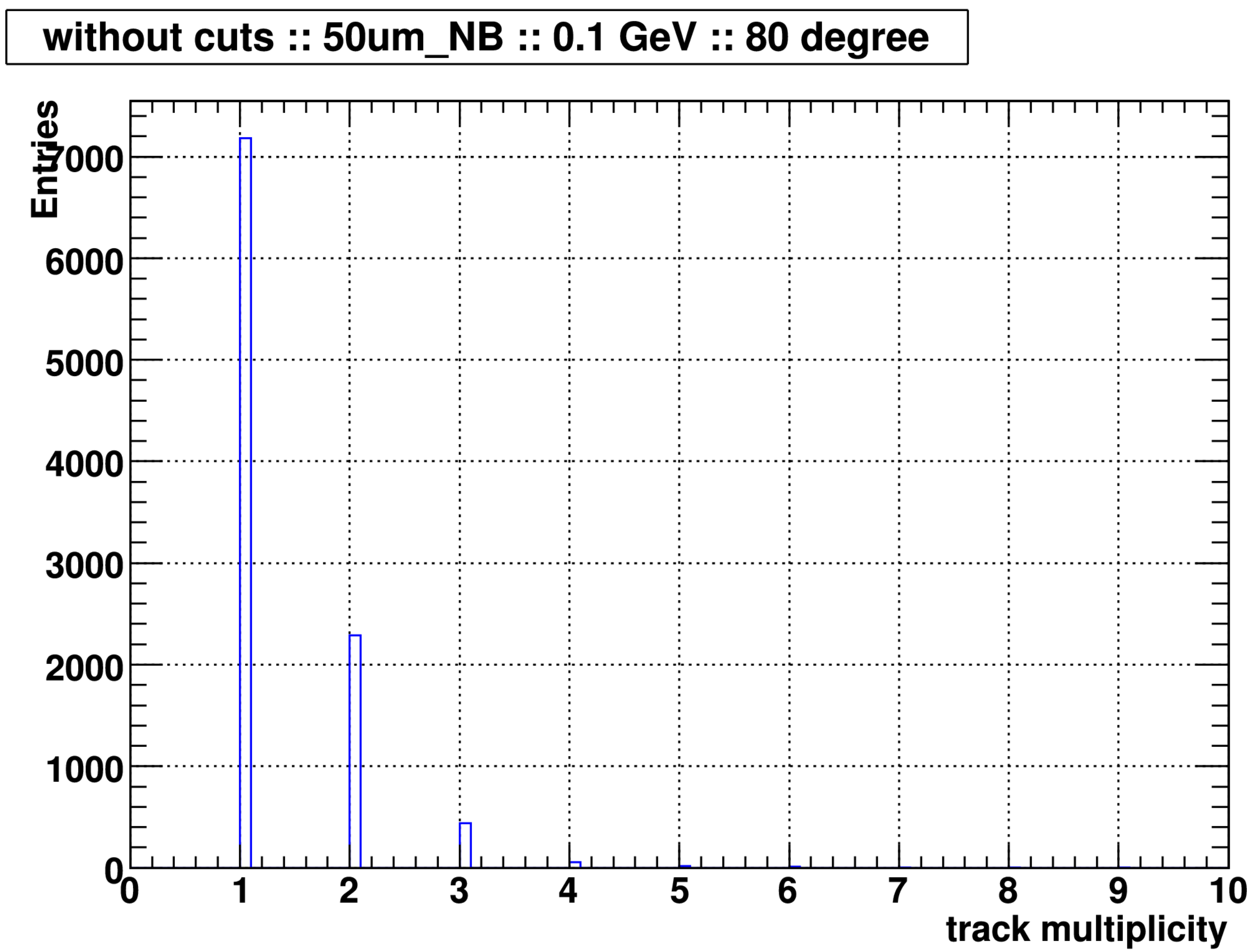
$$y = \frac{f_{model}}{f_{baseline}}$$



Tails are non Gaussian and contain contributions from

- multiple scattering
- pattern recognition, track fitting (tracking)

Example: **track multiplicity**



- Detailed simulation of PXD and SVD response is implemented
- Detailed studies on resolution and tail extraction started
- Optimization chain for single tracks works
- Preliminary result: **thin detector help**

Problems found:

- Resolution distribution shows core gaussian peak with non gaussian tails
- Size of tails is considered to be important for optimization
- Sources of non gaussian tails: **multiple scattering** (to be optimized)
  tracking
- Studies at present are not able to disentangle both effects
- Pattern recognition not optimized for low momentum (< 1GeV) particles

Next steps:

- Monte Carlo based pattern recognition for optimization studies
- Develop simple model for background simulation