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DIRC Options for Super Charm Tau Factory

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(Castle Rauischholzhausen)

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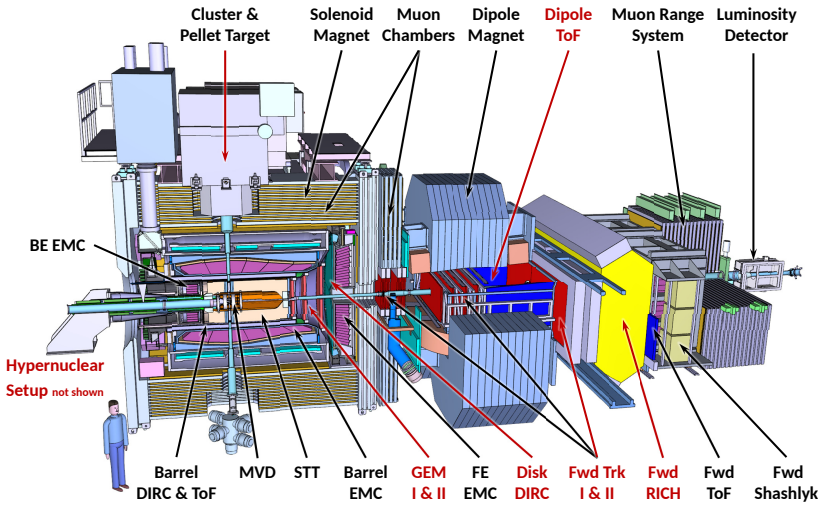
Super Charm Tau Factory

PANDA

- Fixed target $\bar{p}p$ collisions
- Beam momentum:
  $p = 1.5 \ldots 15\,\mathrm{GeV/c}$
- High luminosity mode:

$$\mathcal{L} = 2 \cdot 10^{32}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$$

- PID: π/K separation

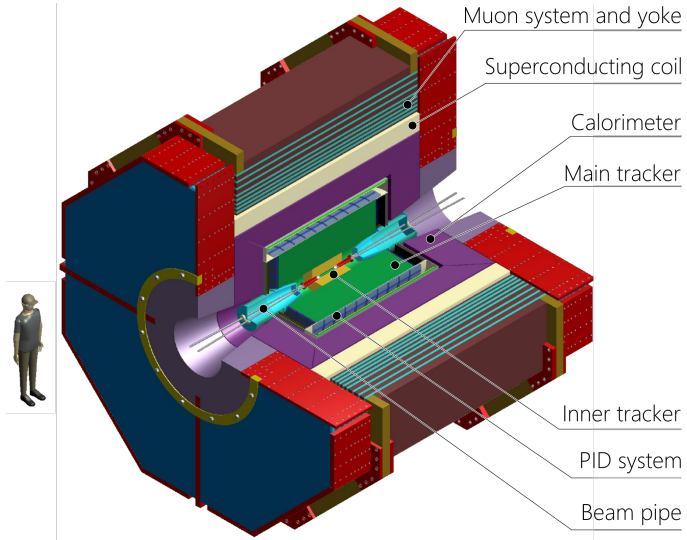


SCTF

- Symmetric e^+e^- collider
- Energy: $E_{CMS} = 2 \ldots 6\,\mathrm{GeV}$
- Achievable luminosity:

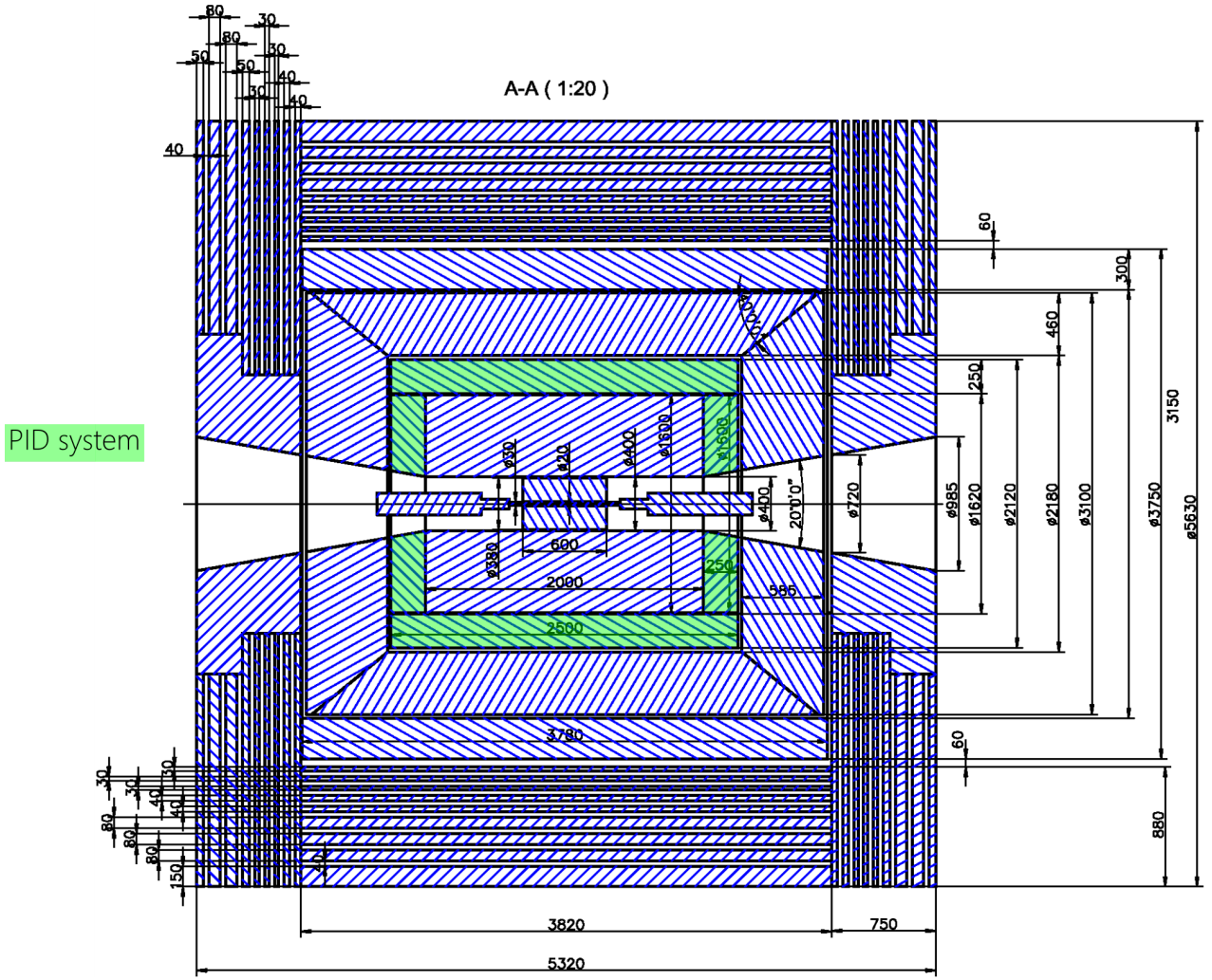
$$\mathcal{L} \approx 10^{35}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$$

- PID: $\boxed{\mu/\pi}/K$ separation



SCTF Detector

DIRC detectors in the green area (Barrel and Disc DIRC)

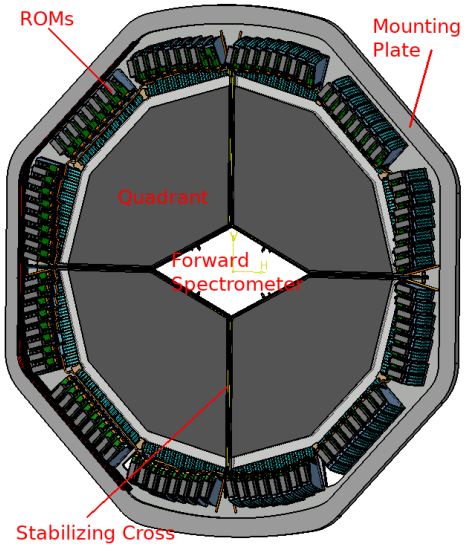


Detector design to be revised for DIRC options

PANDA DIRC Detectors

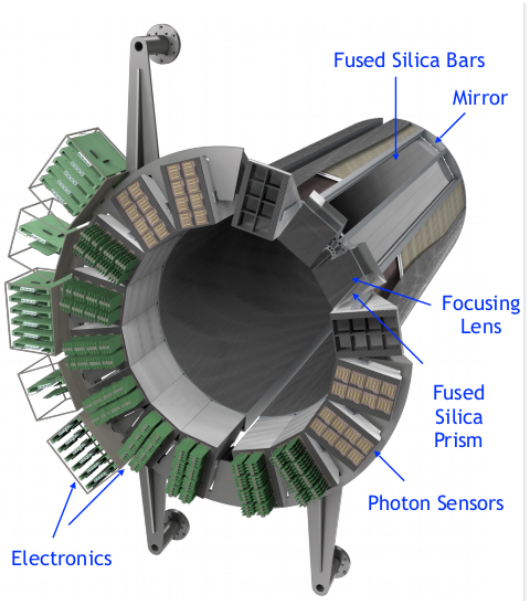
Disc DIRC

- 4 independent radiator quadrants with 96 readout modules (ROMs)
- Mainly pion/kaon separation
- Momentum range: 1.5 – 4.0 GeV/c
- Polar angle range: 5° – 22°



Barrel DIRC

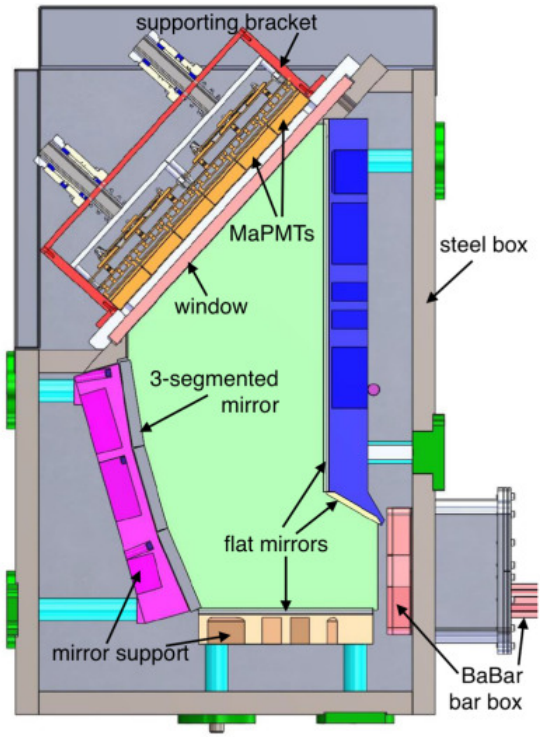
- BaBar-like design
- Mainly pion/kaon separation
- Momentum range: 1.5 – 3.5 GeV/c
- Polar angle range: 22° – 140°



Other DIRCs

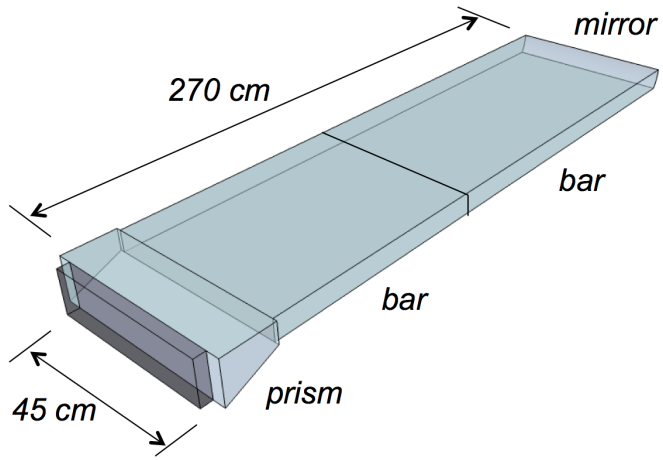
GlueX DIRC

- Horizontally placed BaBar boxes containing 48 fused silica bars in total
- Mainly pion/kaon separation
- Up to 4 GeV/c particle momentum
- Polar angle range: up to approx. 11°



Belle II ToP

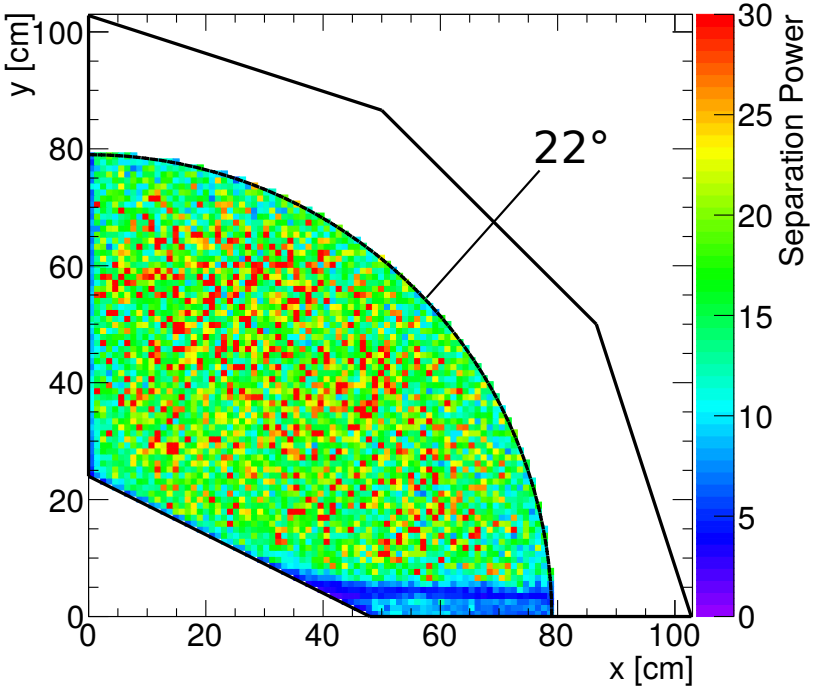
- Large Plates in barrel shape around interaction point
- Mainly pion/kaon separation
- Up to 5 GeV/c particle momentum
- Polar angle range: 32° – 120°



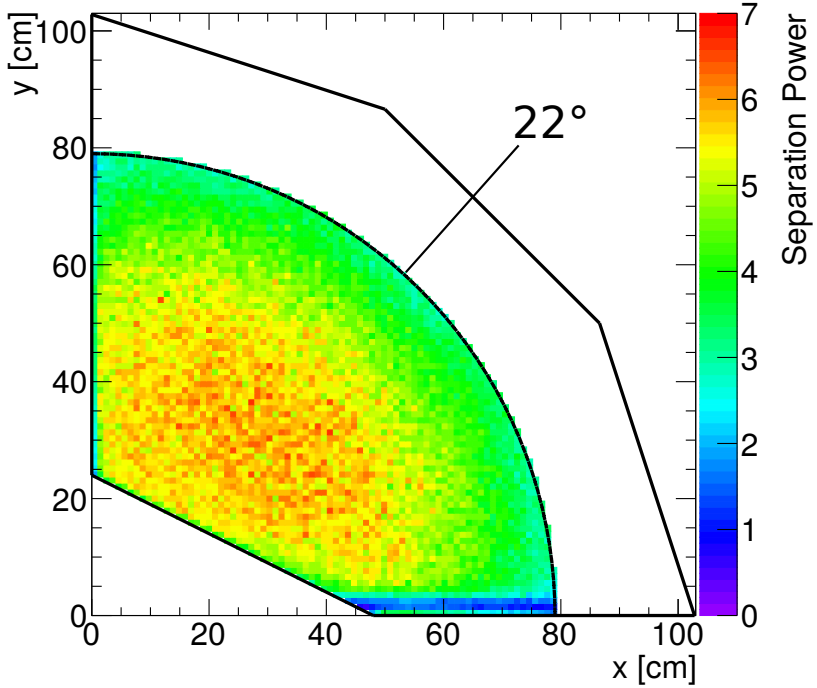
High Resolution Simulations for PANDA

Simulated scan with high resolution for π^+/K^+ for full radiator quadrant including solenoid field of target spectrometer:

Momentum 2 GeV/c

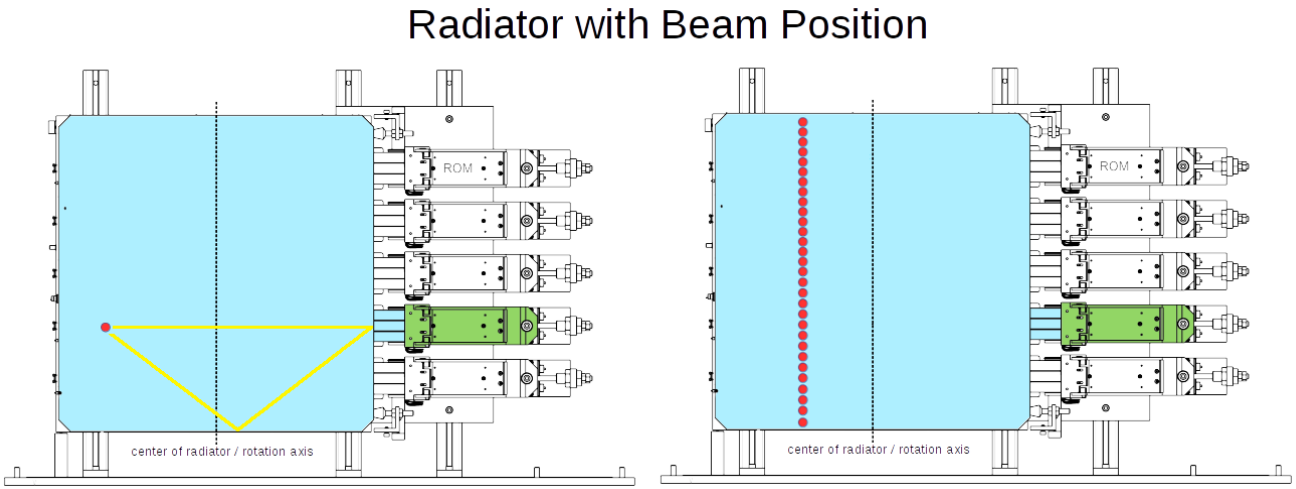


Momentum 4 GeV/c

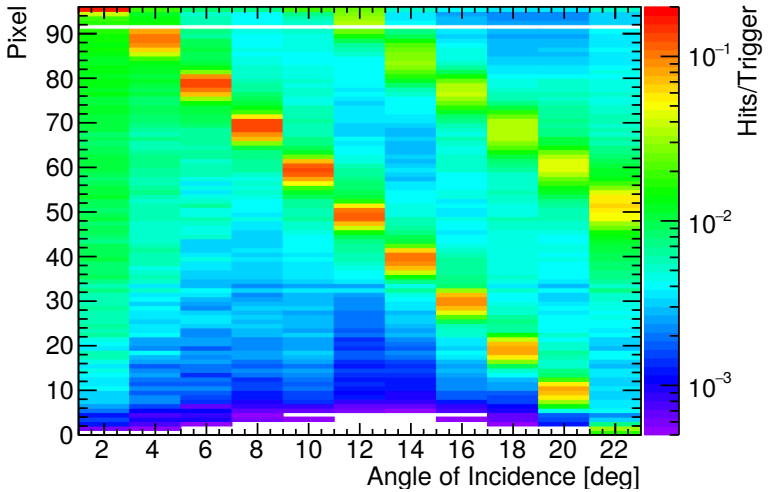


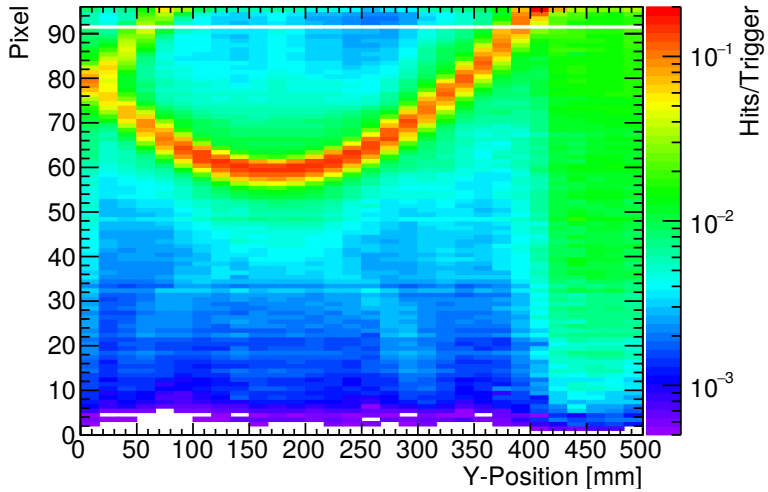
Testbeam Scans 2016

Hit patterns including vertical position and angle scan

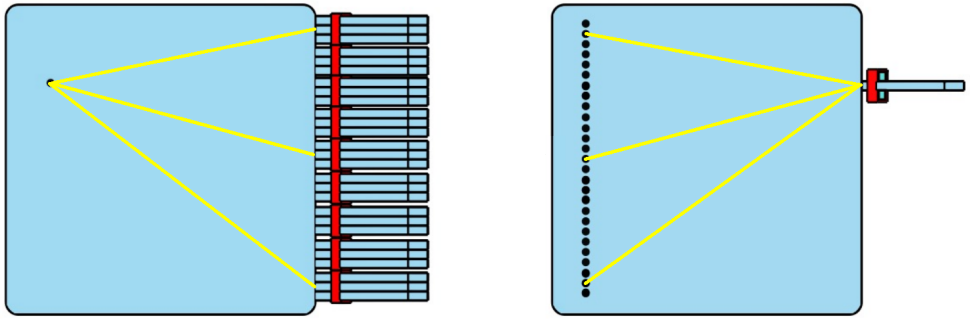


Hit pattern from the central FEL inside highlighted ROM



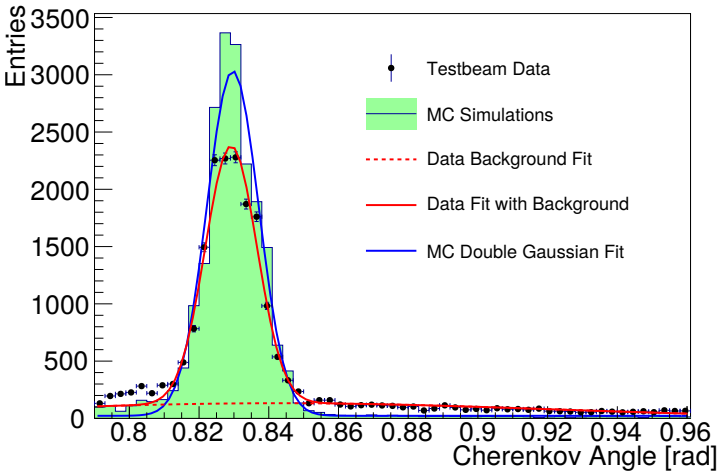


Event Combination 2016

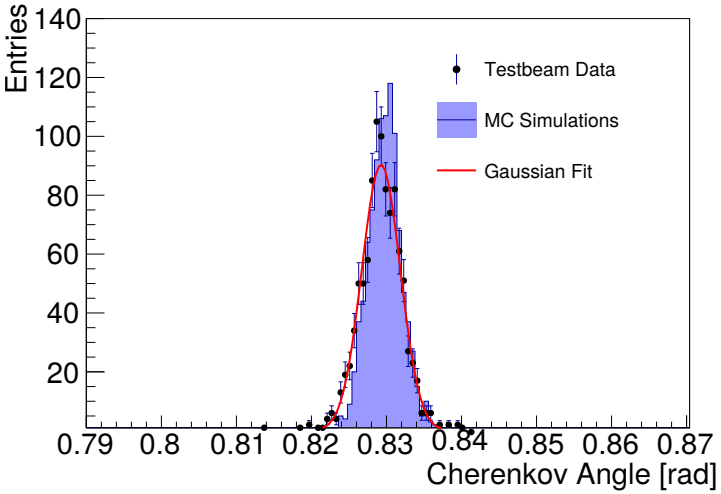


- Combining each event from every position to one new event
- Making a coarse time cut according to photon propagation time
- Reduction of background with truncated mean of pixel hits
- Obtained resolutions:
  $\sigma_\theta = 7.4\,\text{mrad}$ (single photon)
  $\sigma_{\bar{\theta}} = 2.5\,\text{mrad}$ (average)

Single Photon Distribution

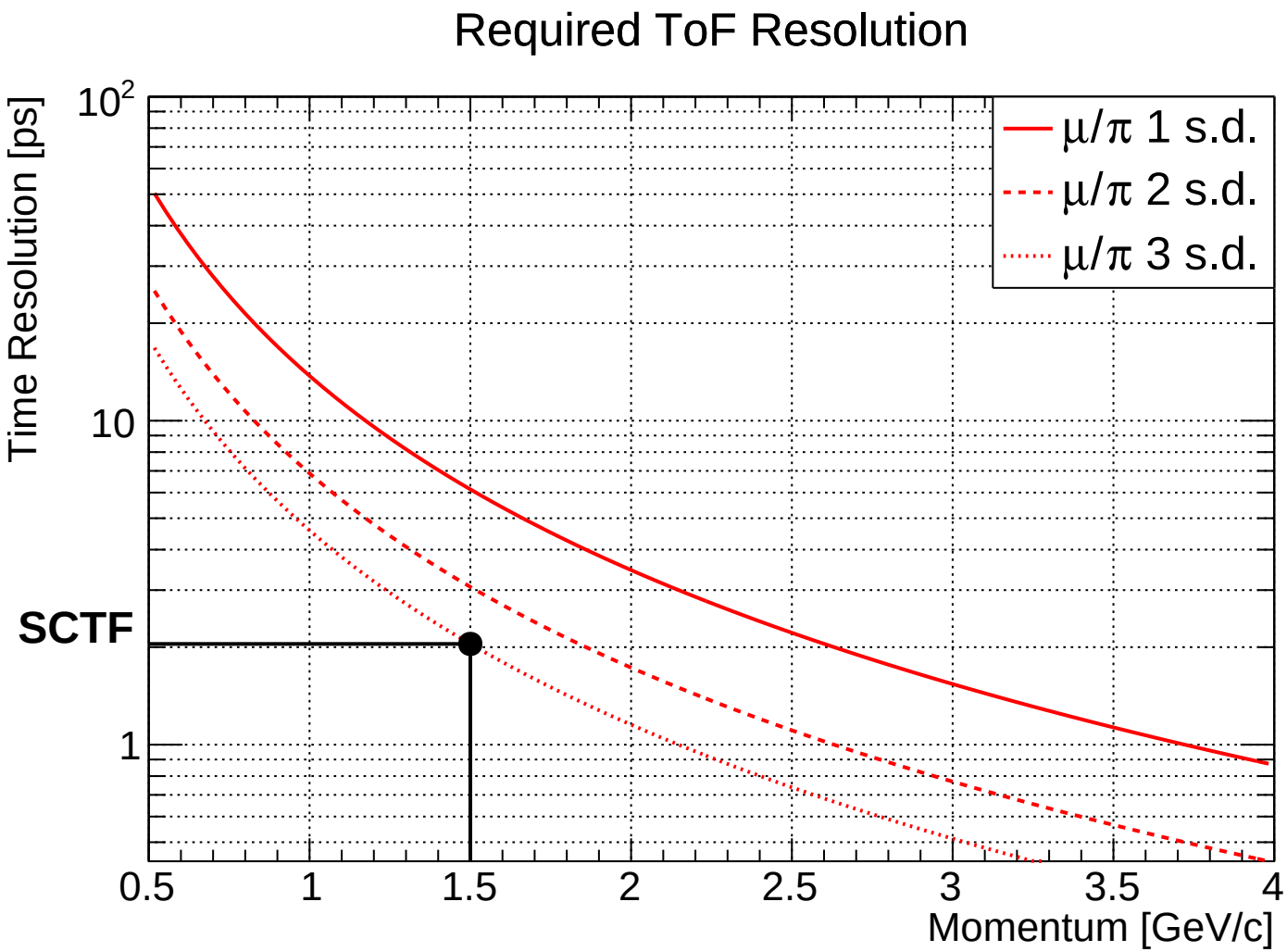


Event Mean Distribution



Time of Flight

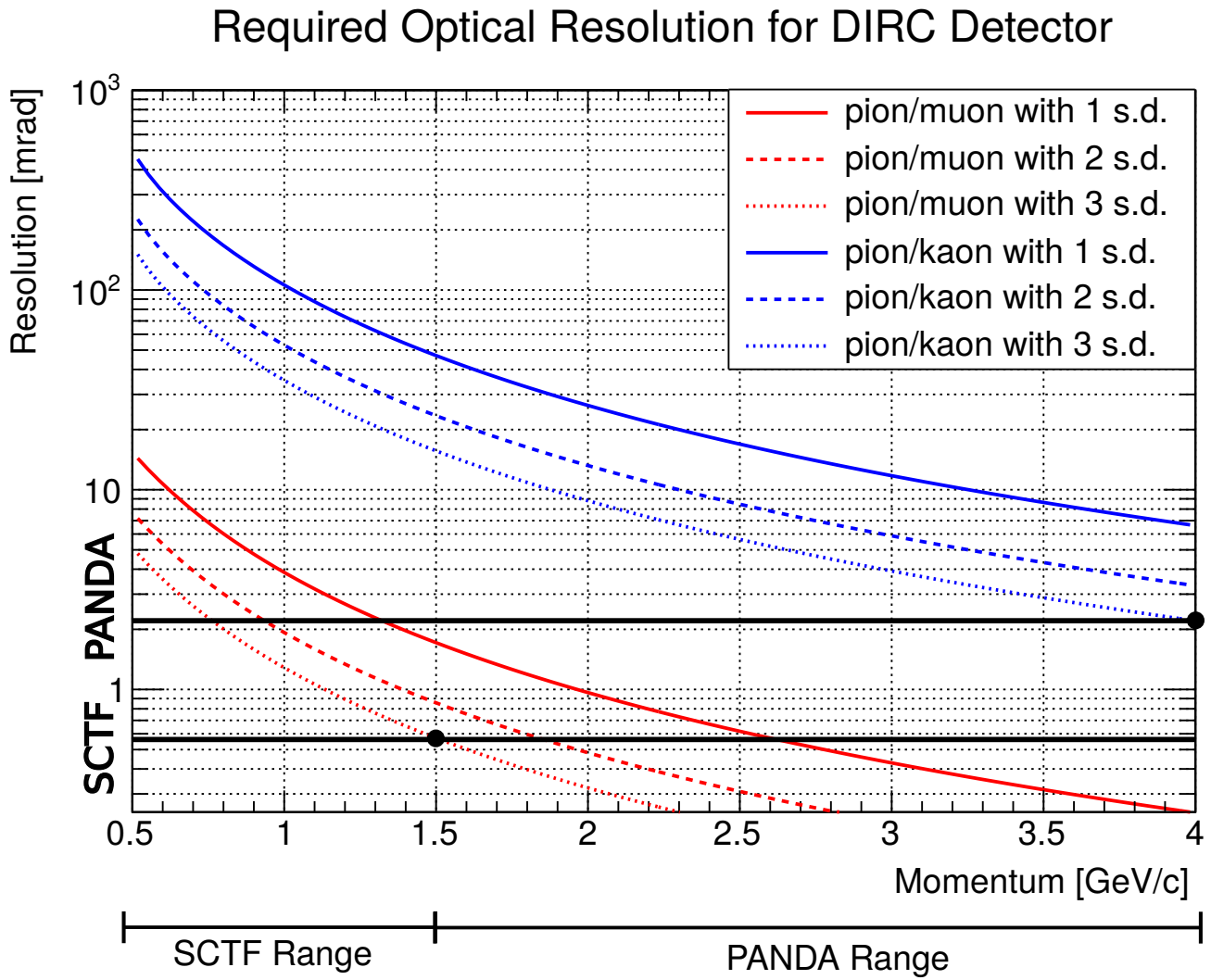
Why not using ToF system?



Estimated distance: $L = 1\,\text{m} \Rightarrow$ Time resolution: $\sigma_t \approx 2\,\text{ps}$

Required Resolution

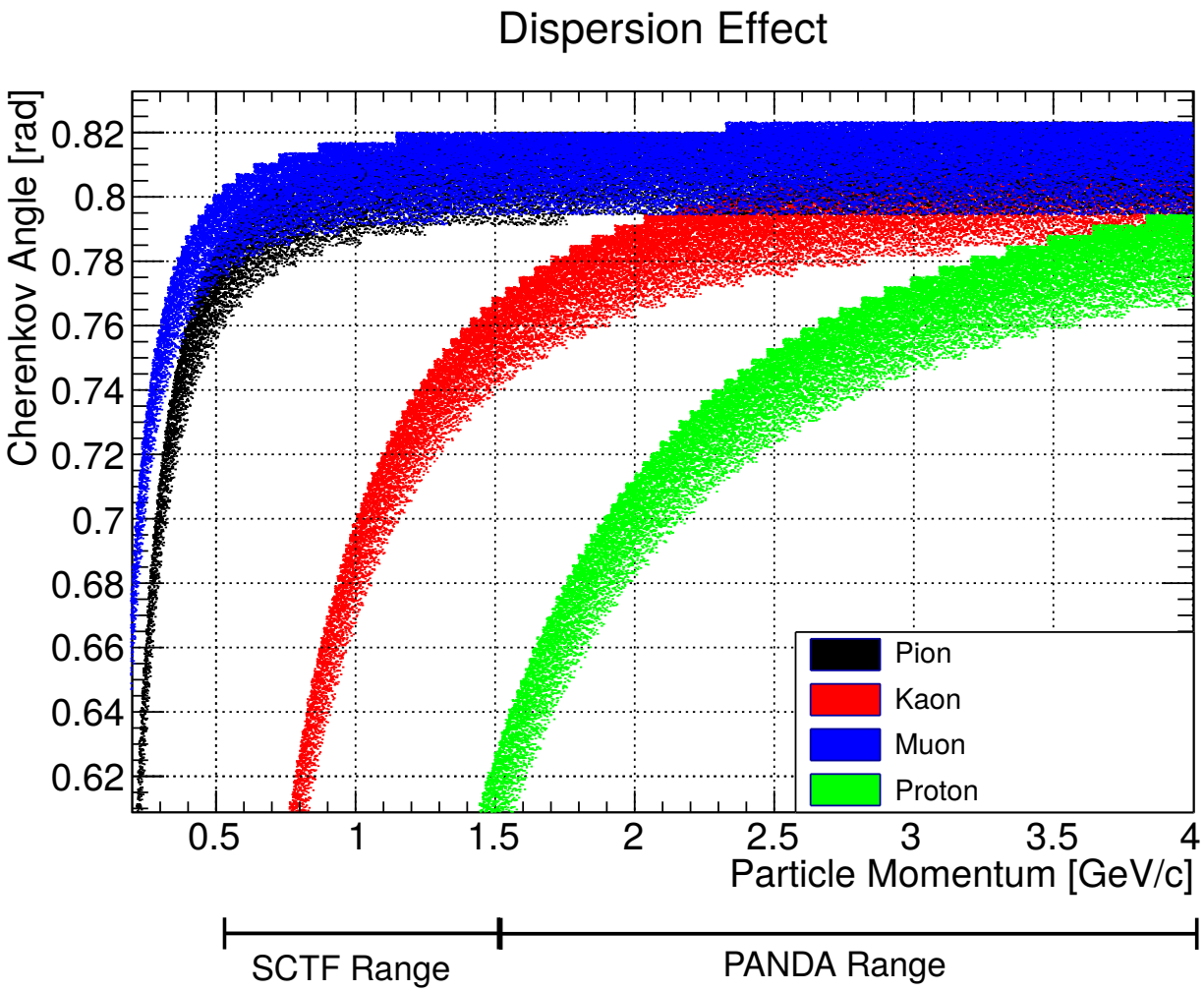
PANDA: Pion/Kaon ≈ 2.1 mrad for 3 s.d. @4 GeV/c
SCTF: Muon/Pion ≈ 0.7 mrad for 3 s.d. @1.5 GeV/c



Dispersion Bands

Largest effect from dispersion and similar rest masses

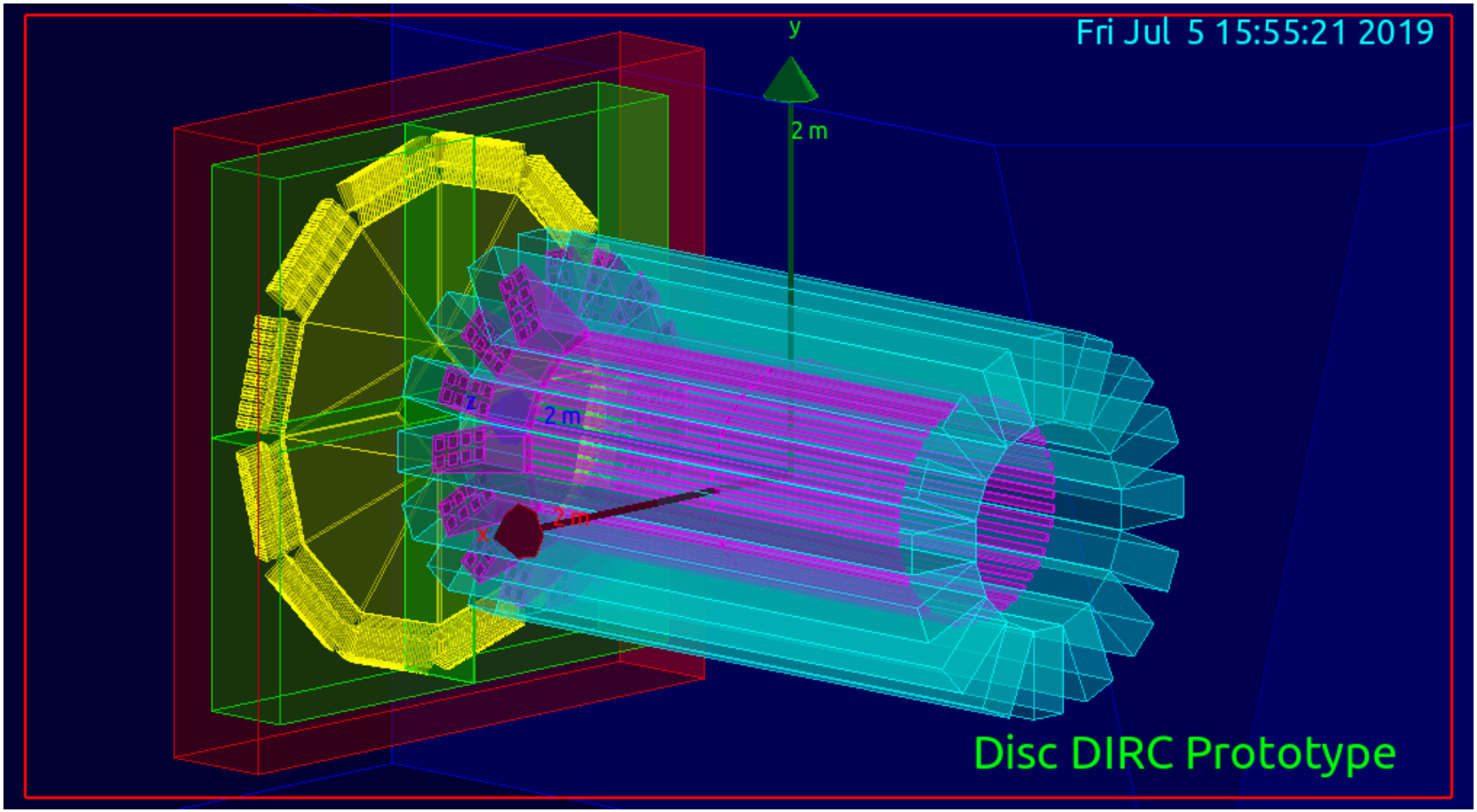
Wavelength interval: $300 \leq \lambda \leq 700\,\text{nm}$



Reducing dispersion band: More photons or better wavelength cuts

Geant4 Simulations

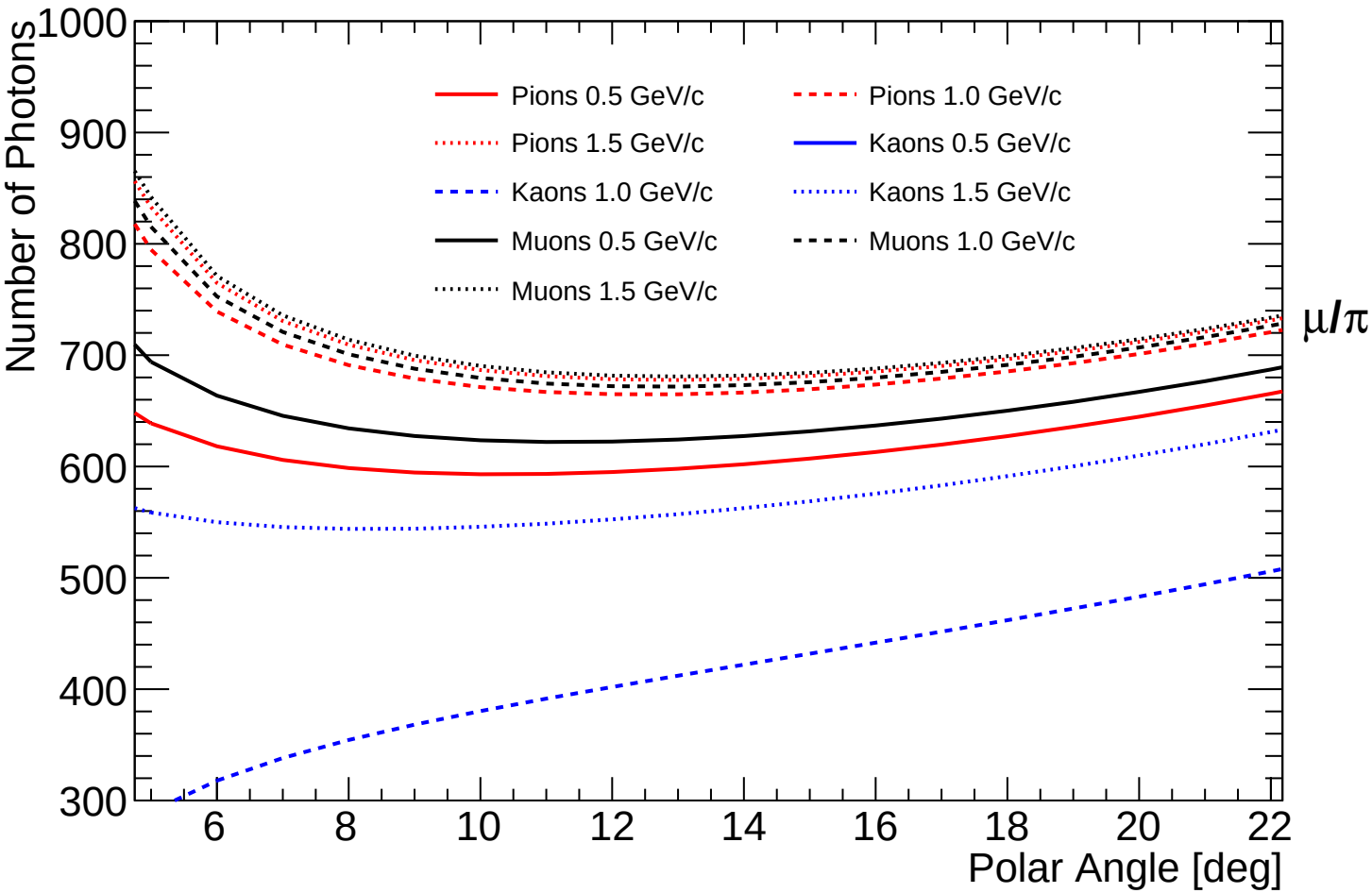
All detector components recently implemented in standalone Geant4 framework according to actual SCTF geometry



All simulation studies performed for 12° polar angle and 1 GeV/c particle momentum

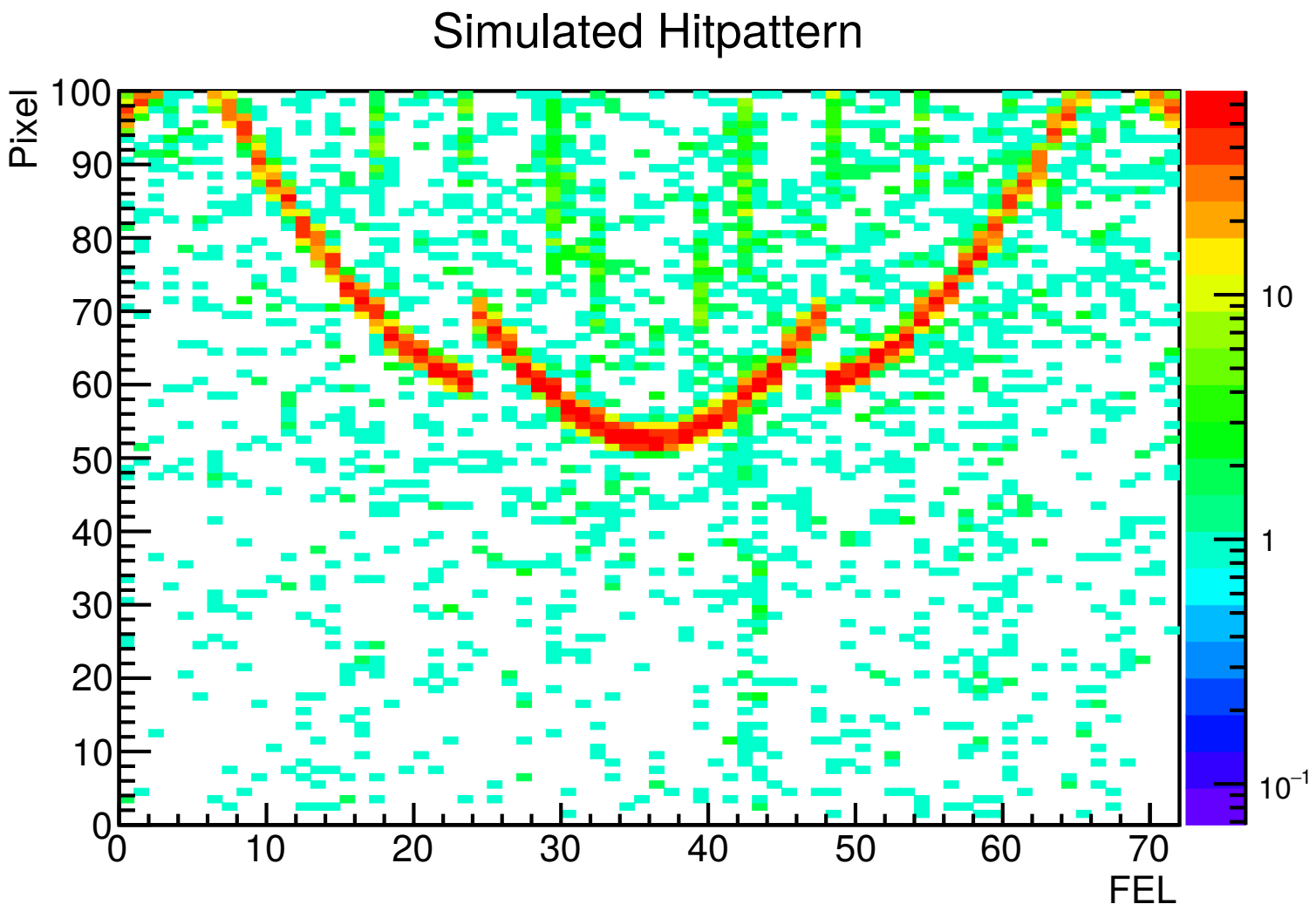
Photon Trapping for Endcap DIRC

Approx. 1000 photons created in 2 cm fused silica radiator



Results for muons and pions almost identical

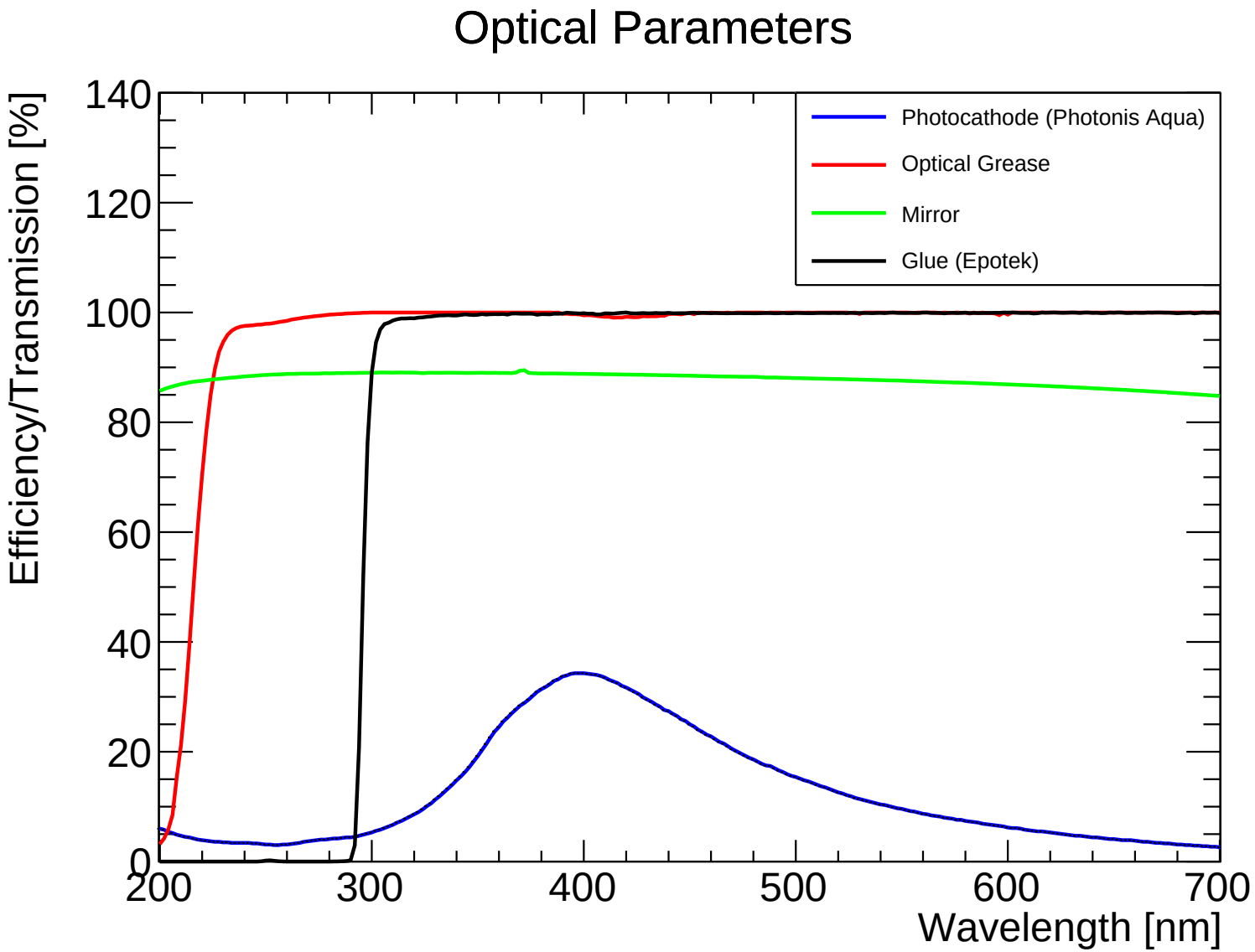
PANDA Disc DIRC Hit Pattern



Geant4 MC simulated hit pattern for 1000 muon/pion tracks

Simulation Parameters

All relevant optical parameters included in Monte-Carlo Simulations



Possible Improvements

Separation of μ/π not working "out of the box"

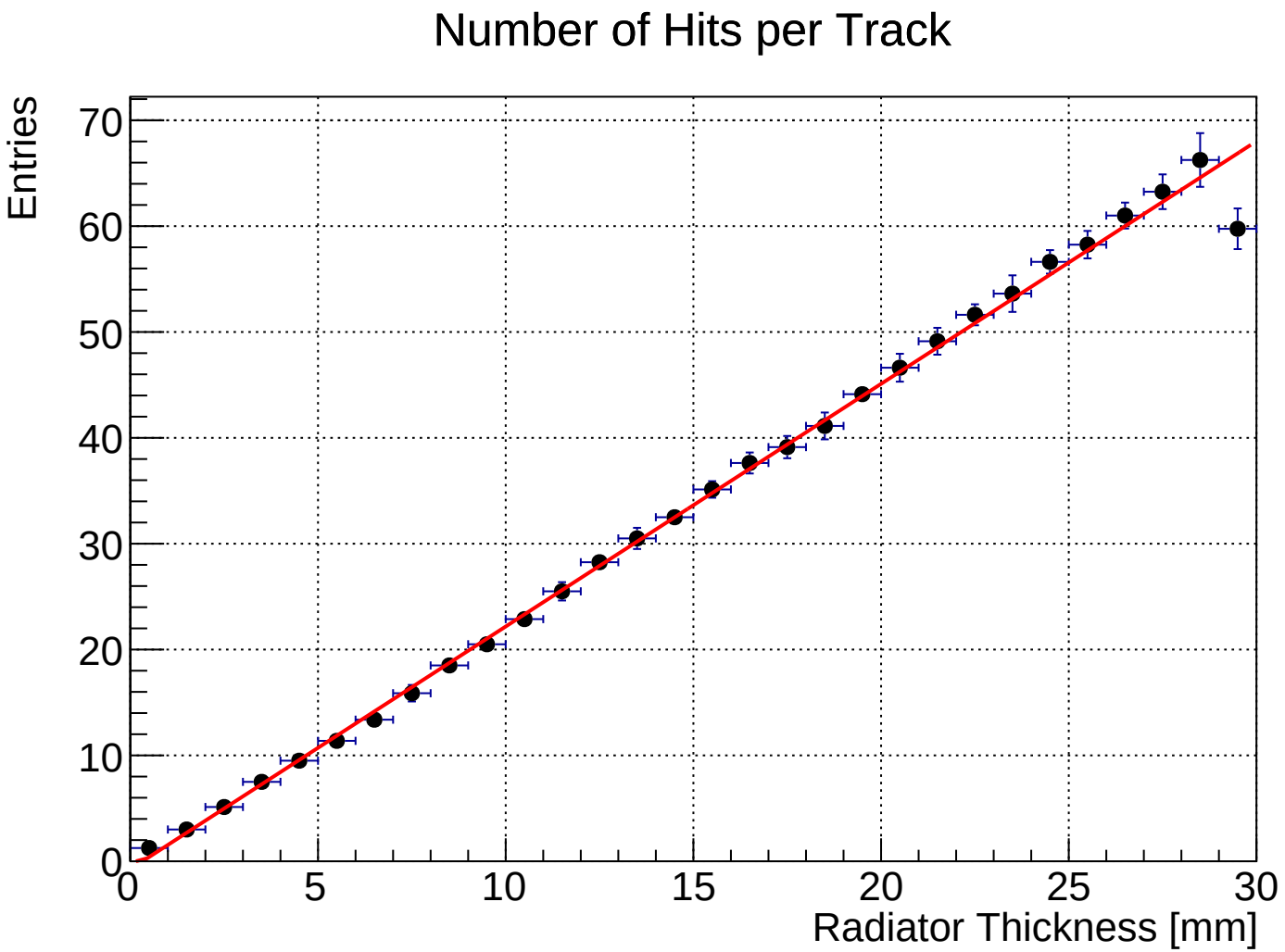
How does the performance can be increased?

Possible optimizations for the Disc DIRC:

- Radiator optimizations (mainly thickness)
- Bar width optimization
- Increasing pixel resolution
- Choosing different sensor types (MCP-PMTs or SiPMs)
- Optimizations for focusing optics
- Dispersion corrections (3D DIRC)

Radiator Optimization

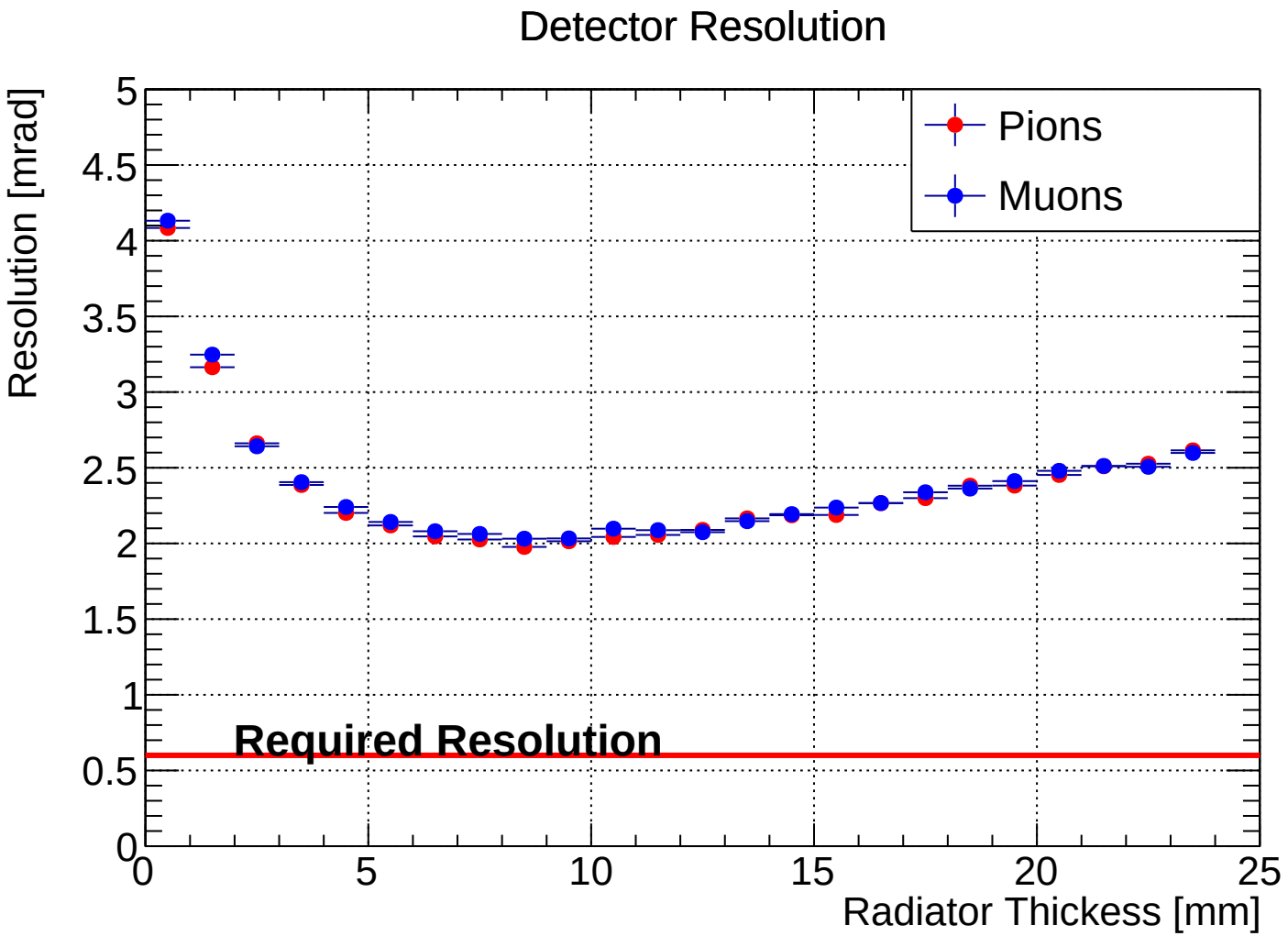
Studying resolution as function of radiator thickness (Disc DIRC)



Almost linear increase of detected photons (as expected)

Radiator Optimization

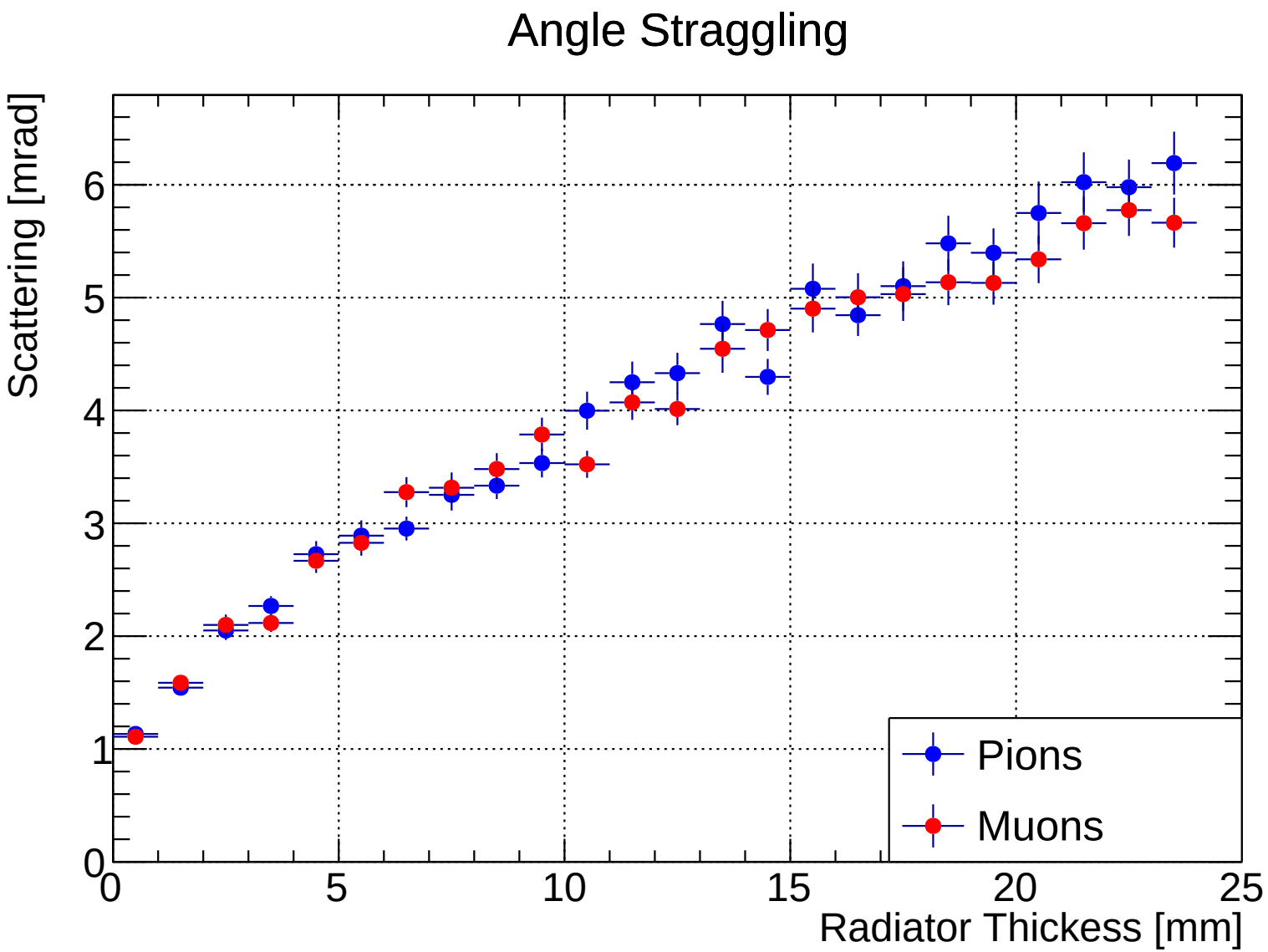
Non-linear dependency of final detector resolution



Effects of angle straggling and energy loss to be studied

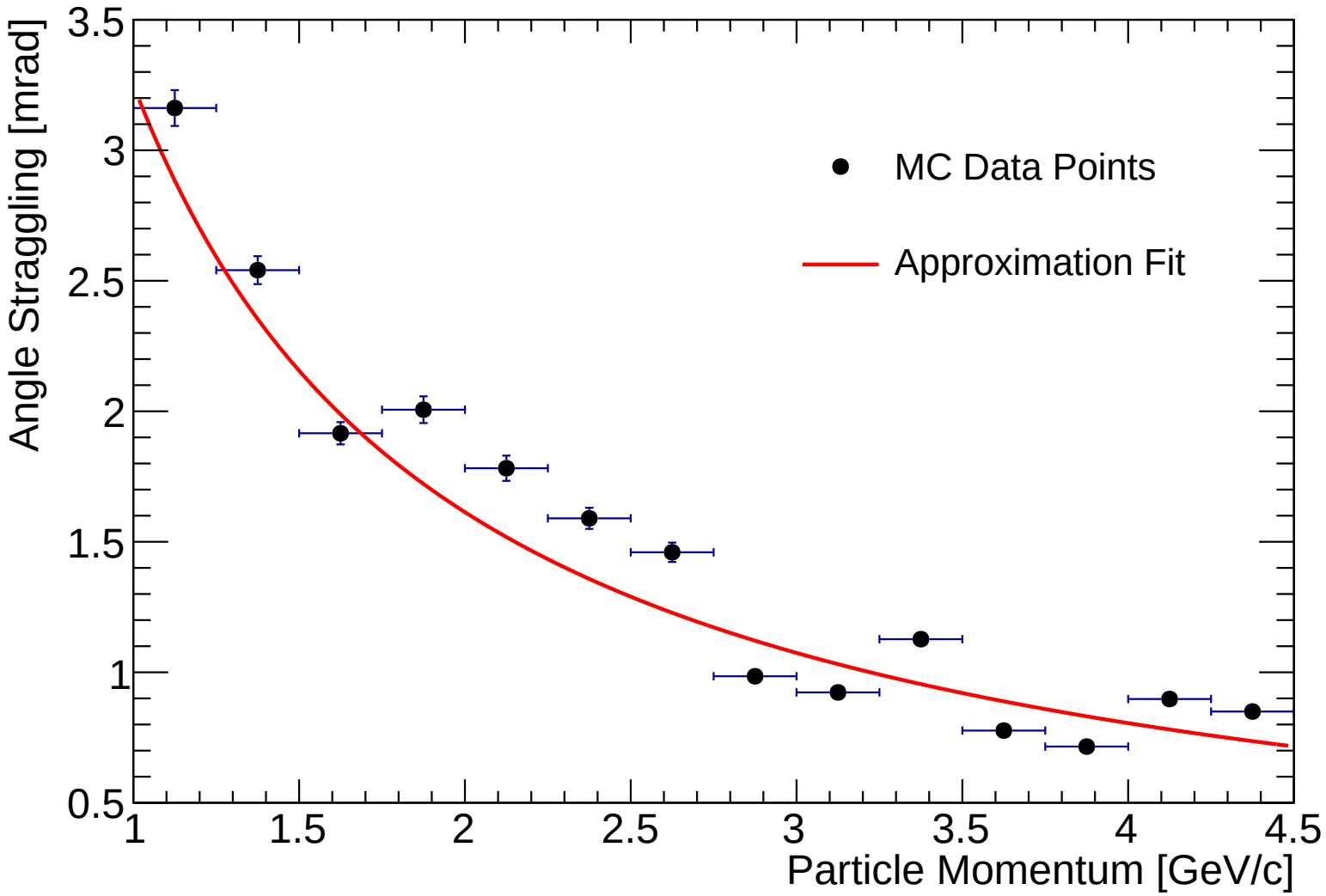
Interaction with Radiator

Multiple Coloumb Scattering of pions in radiator plate



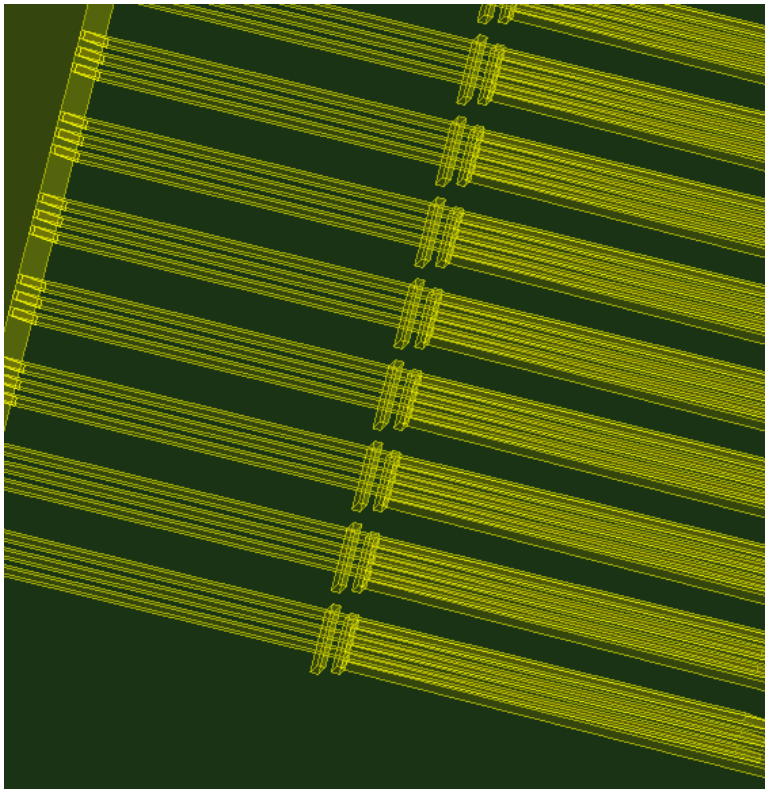
Momentum Dependency of Angle Straggling

Angle straggling as function of momentum (10 mm thickness)

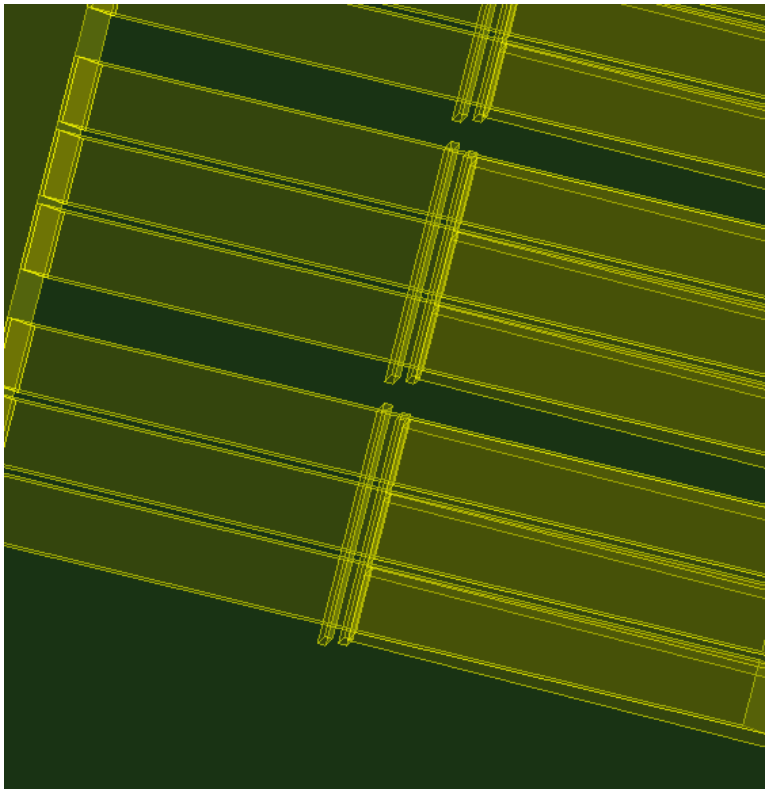


Bar Width Optimization

Bar width scan in Geant4 MC simulations:



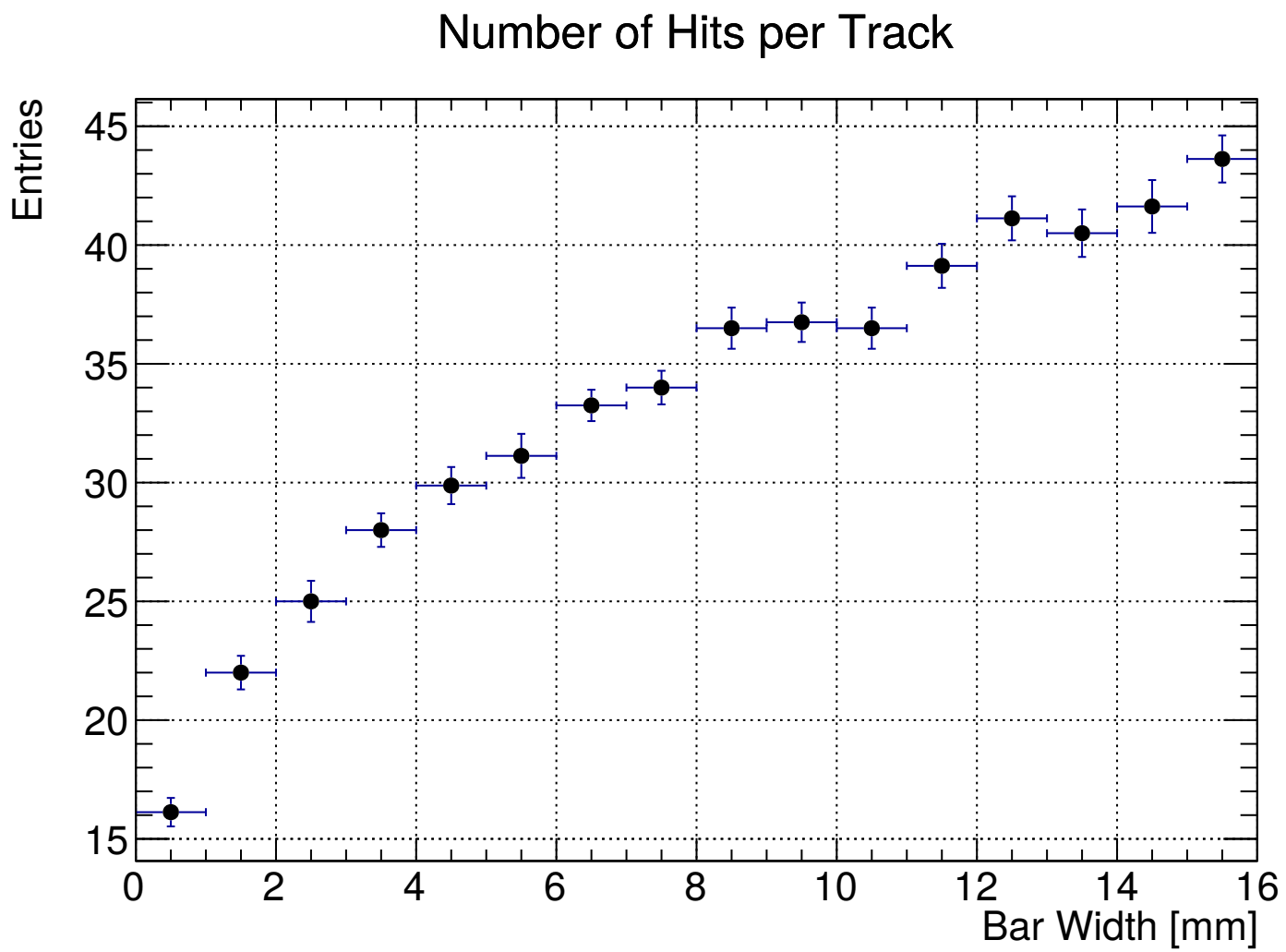
Bar width: 2 mm



Bar width: 16 mm

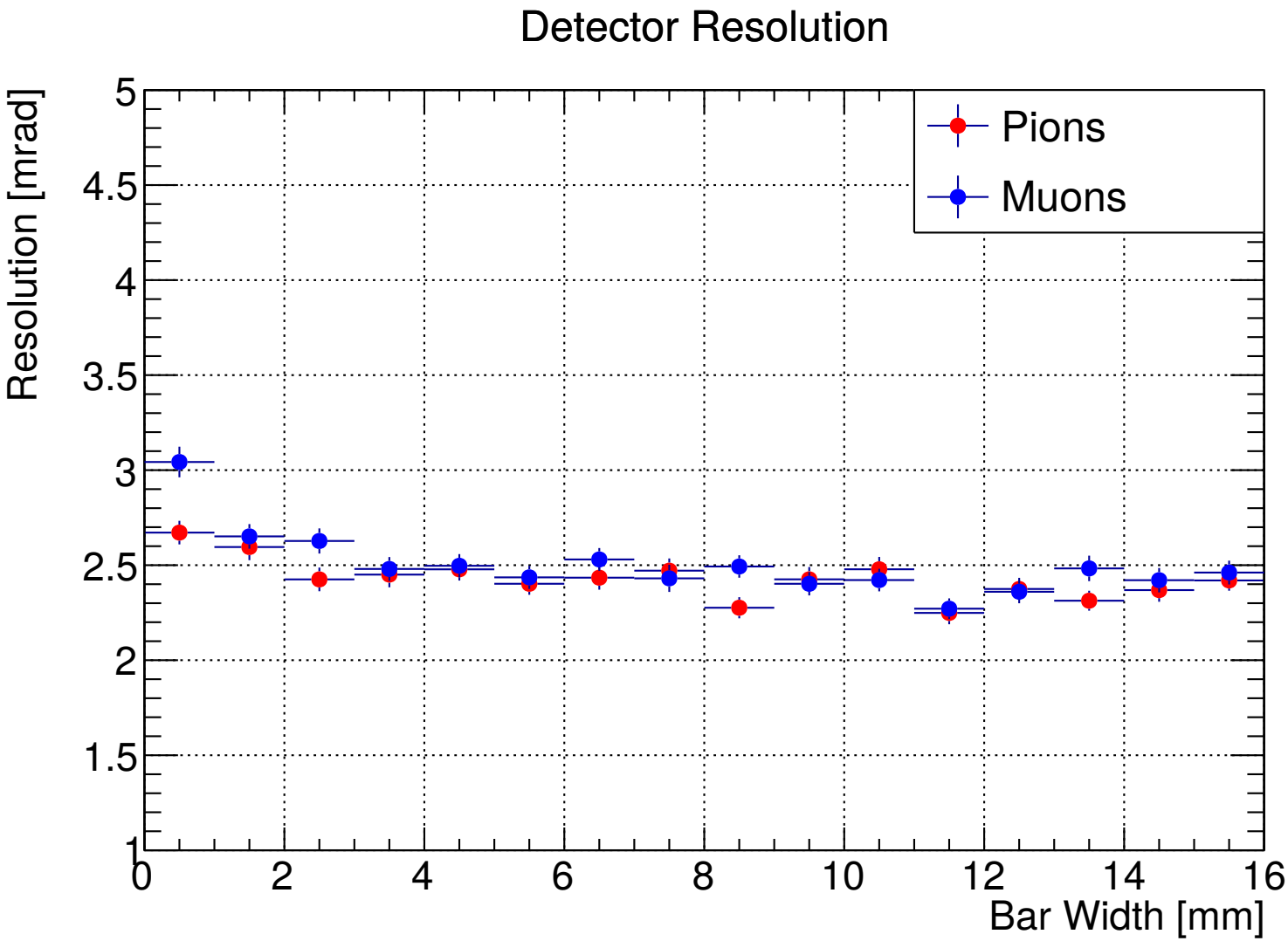
Bar Width Optimization

Smaller photon yield for thinner bars (effective area decreases):



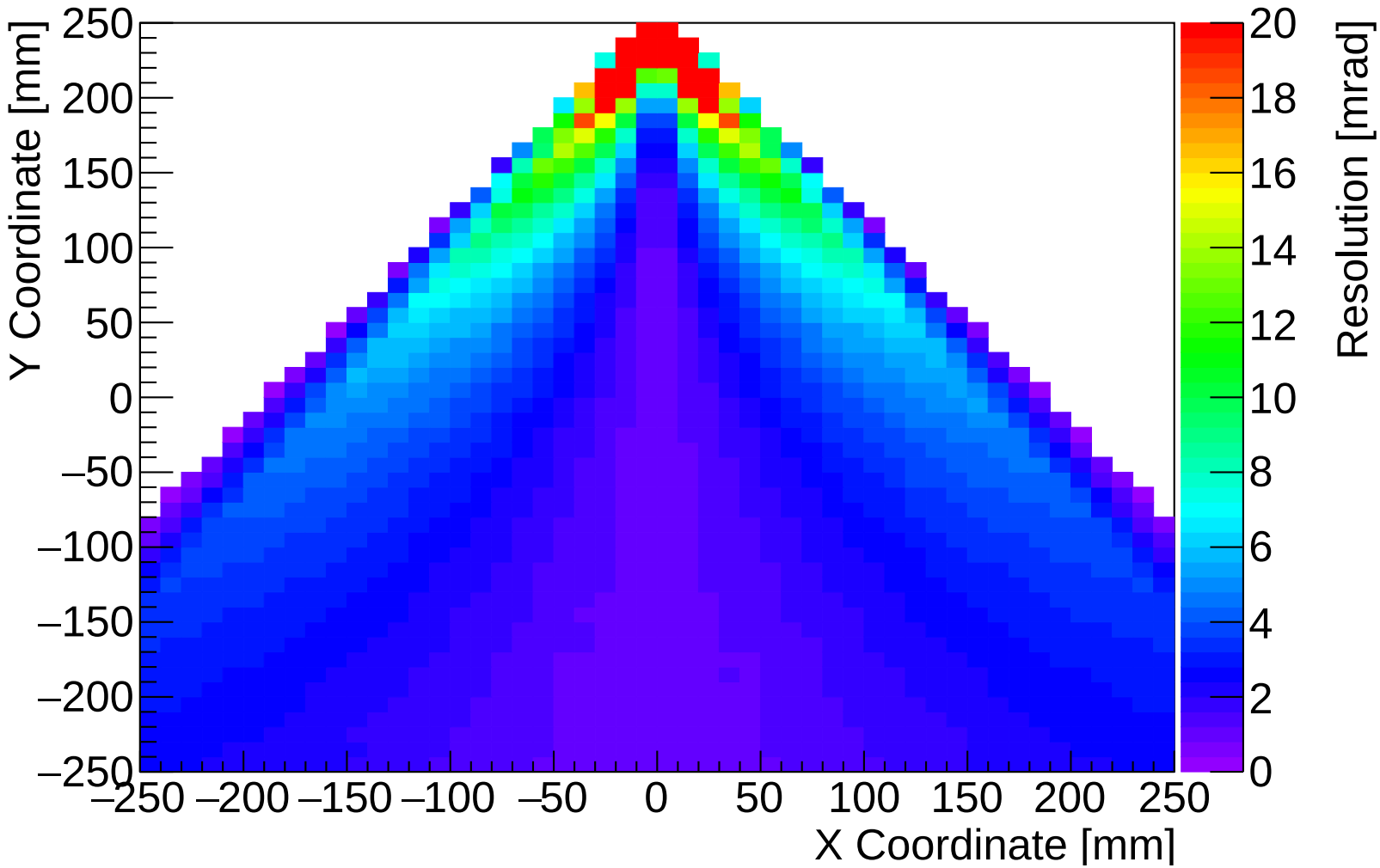
Bar Width Optimization

Resolution does not change with varying bar widths



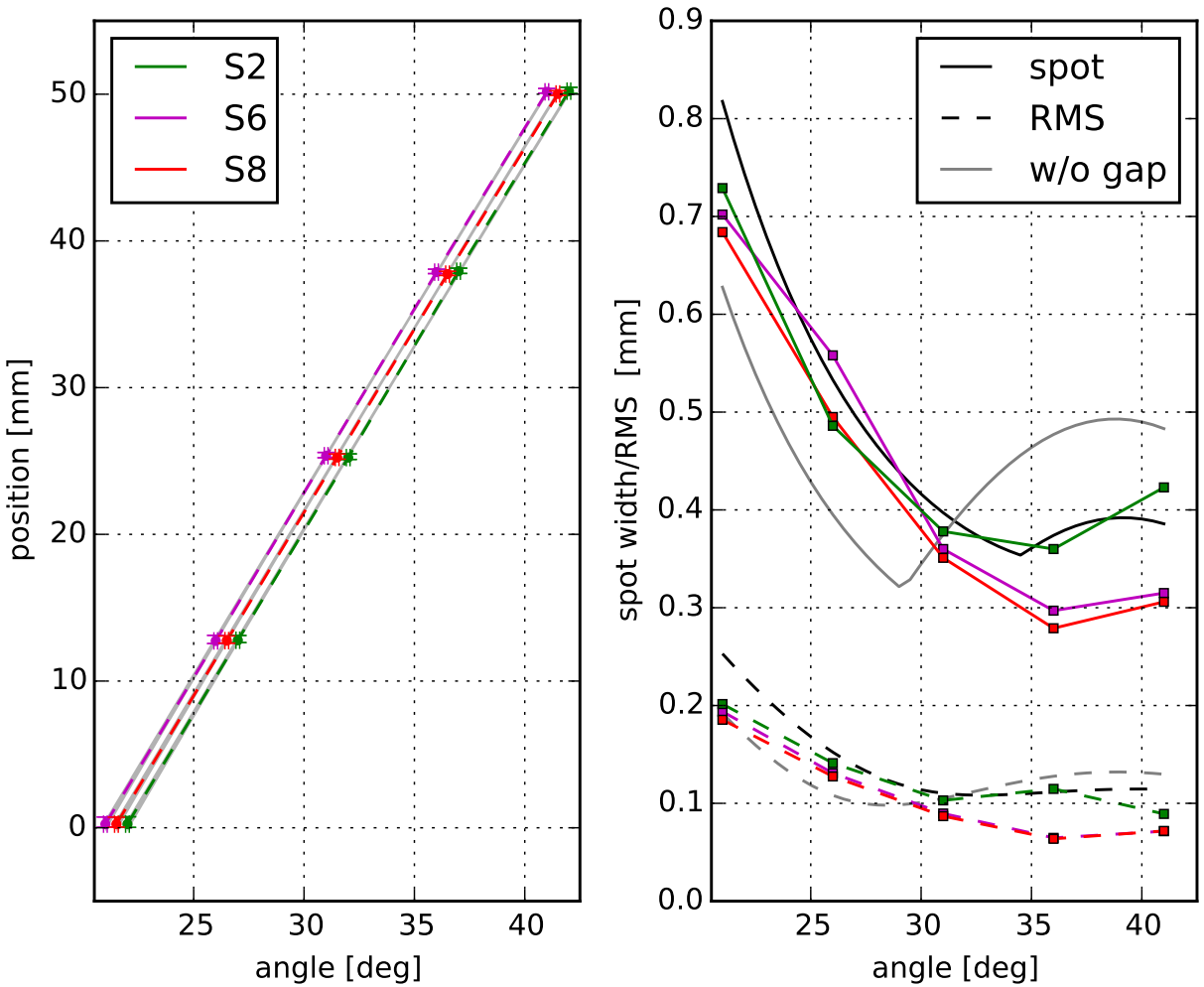
Theoretical Resolution

Toy MC simulations for different x and y coordinates: bar width effect only for larger polar angles



Cylindrical Optics

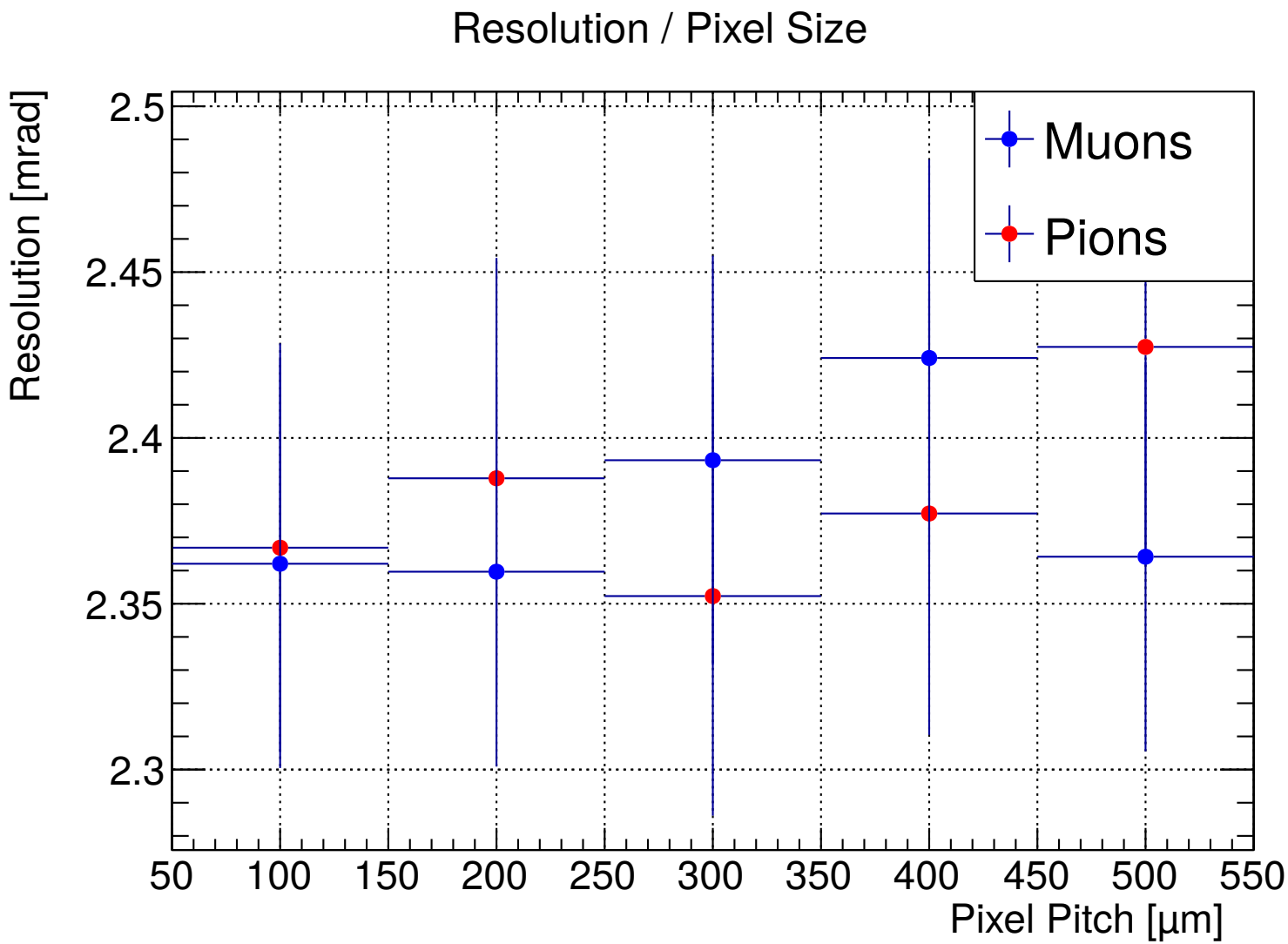
Spot width between 0.3 and 0.7 mm (current pixel size 0.5 mm)



Measurments from 2015 (TDR) by E. Etzelmüller

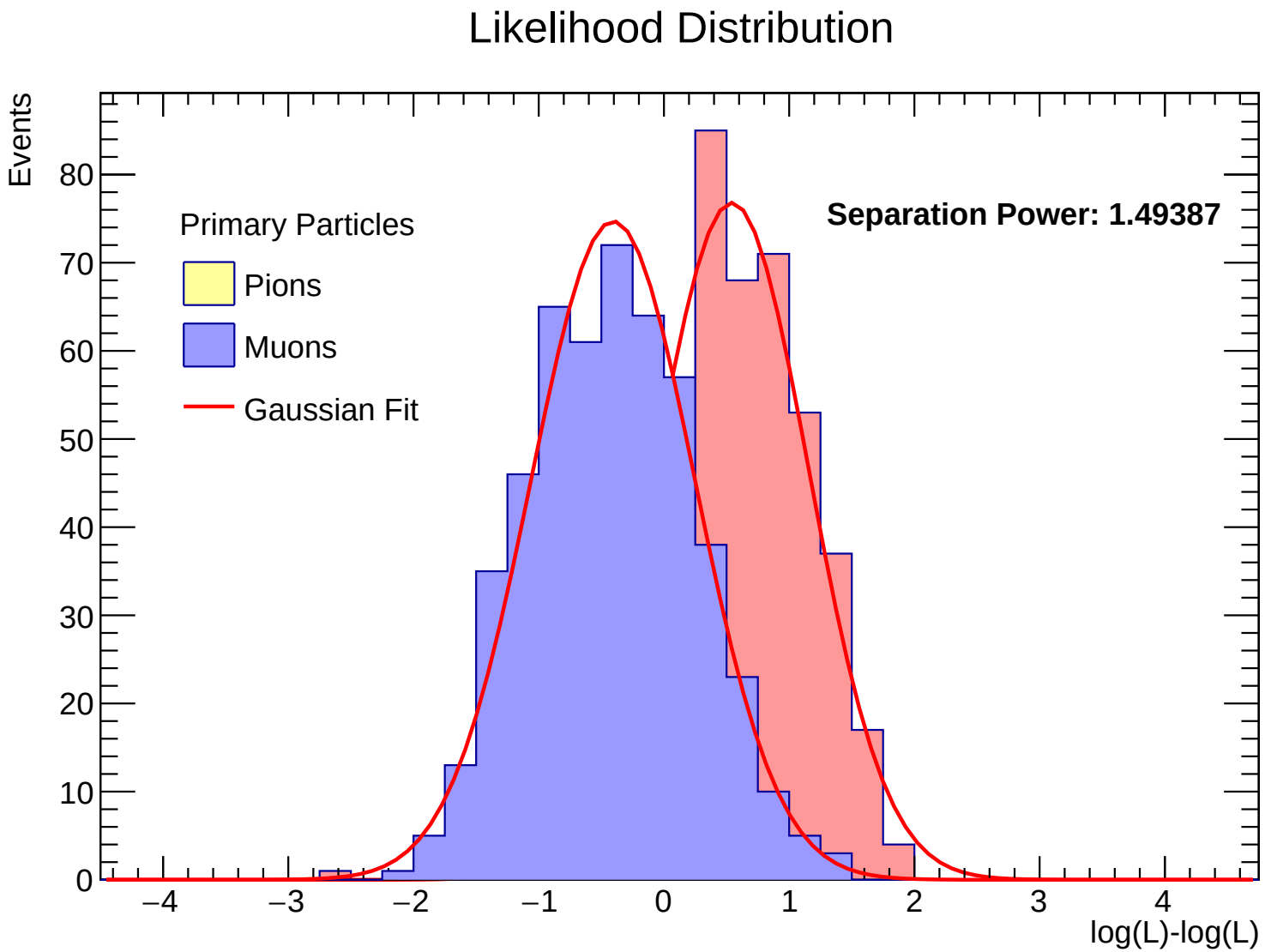
Pixel Pitch Optimizations

Resolution almost independent of pixel resolution (current optics)



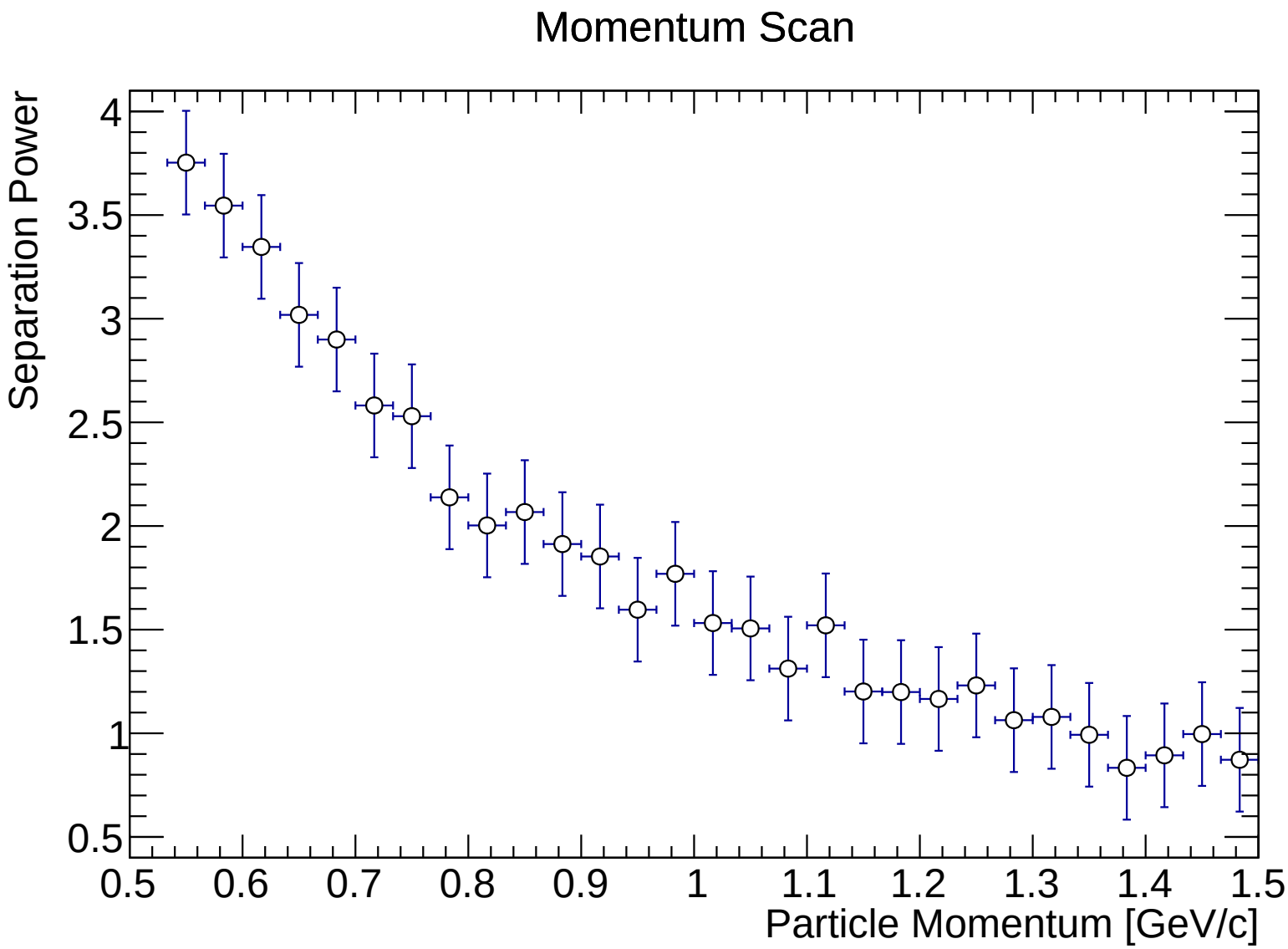
Muon/Pion Separation

Separation power for μ/π at 1 GeV/c momentum:



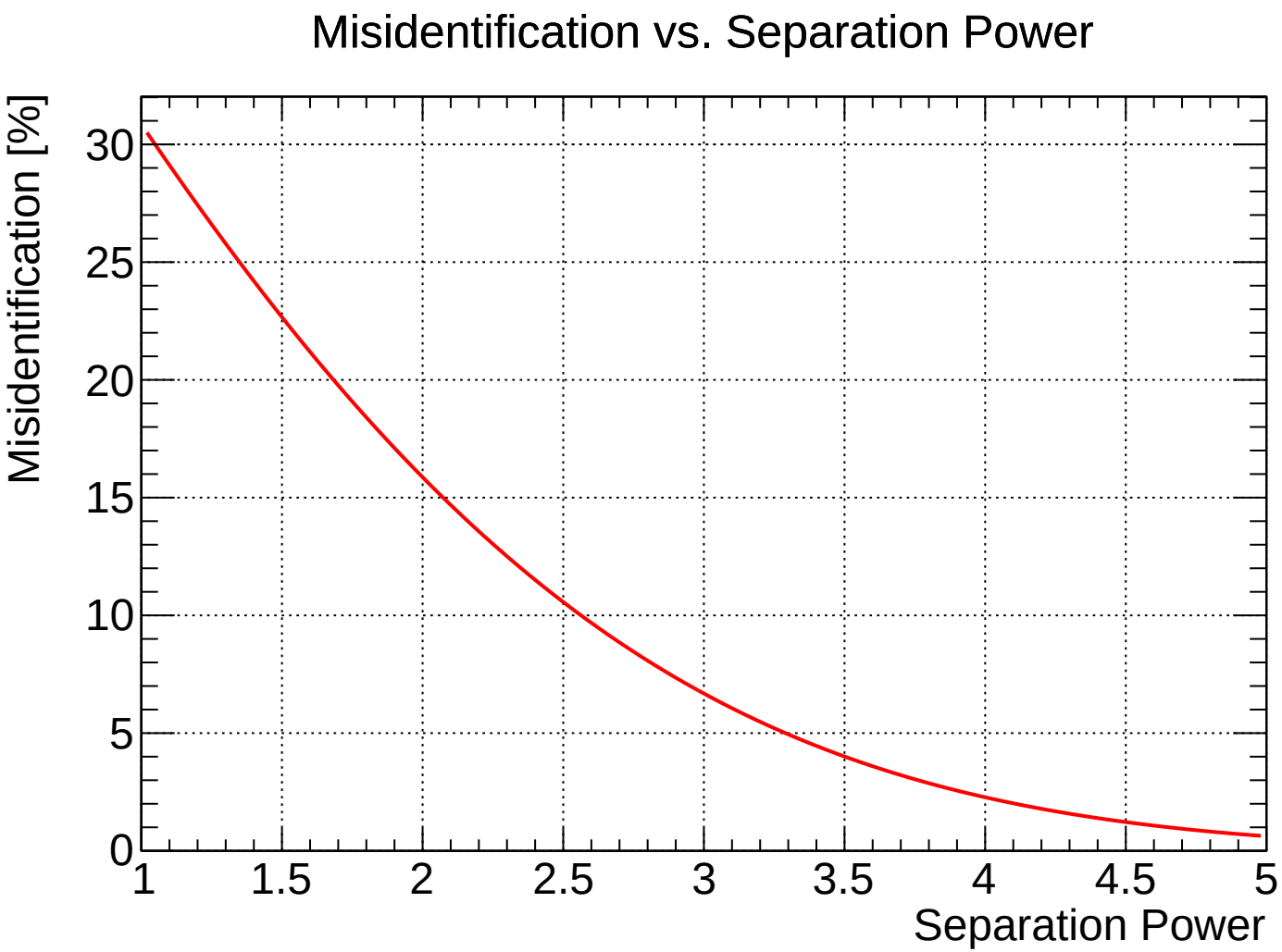
Momentum scan

Momentum scan for μ/π separation with PANDA setup:



Misidentification

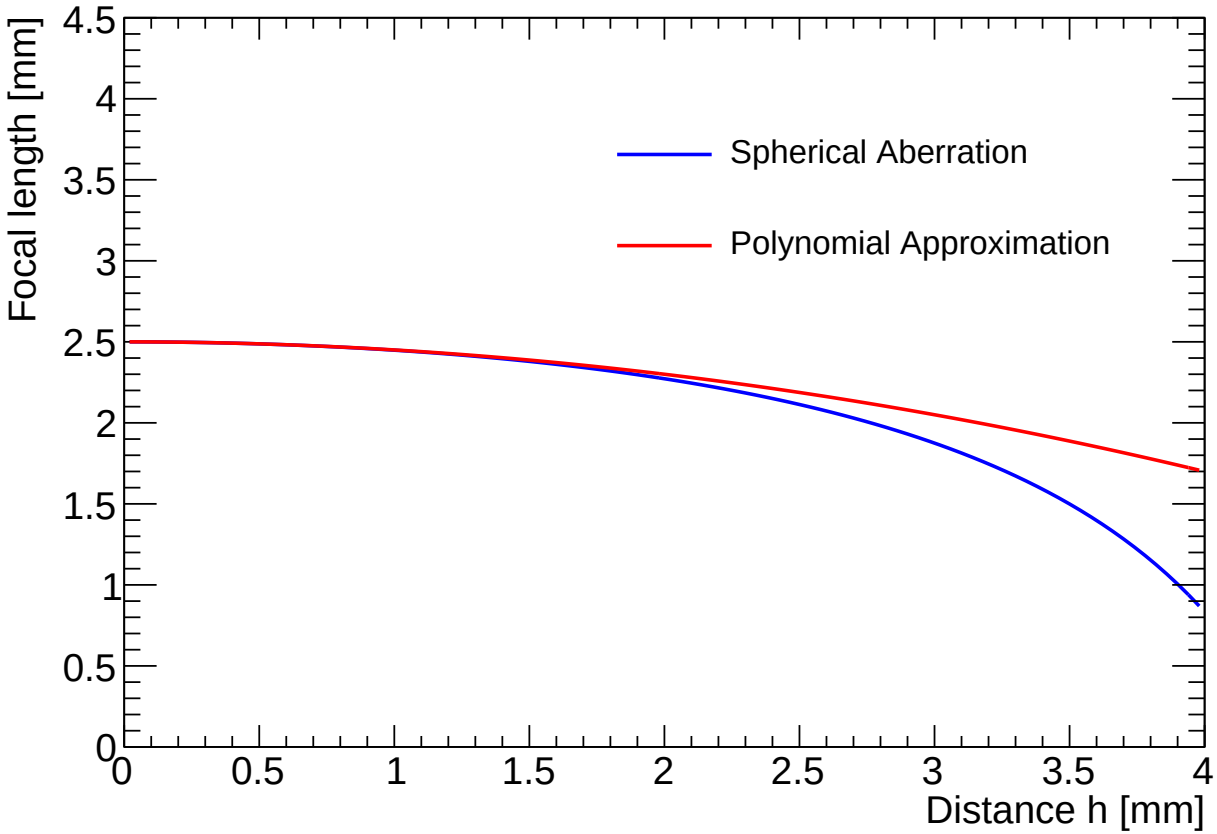
Expected misidentification for given sep. power (equal fluxes):



Required separation power: 3 s.d. sep. power for 1 GeV/c muons

Focusing Optics

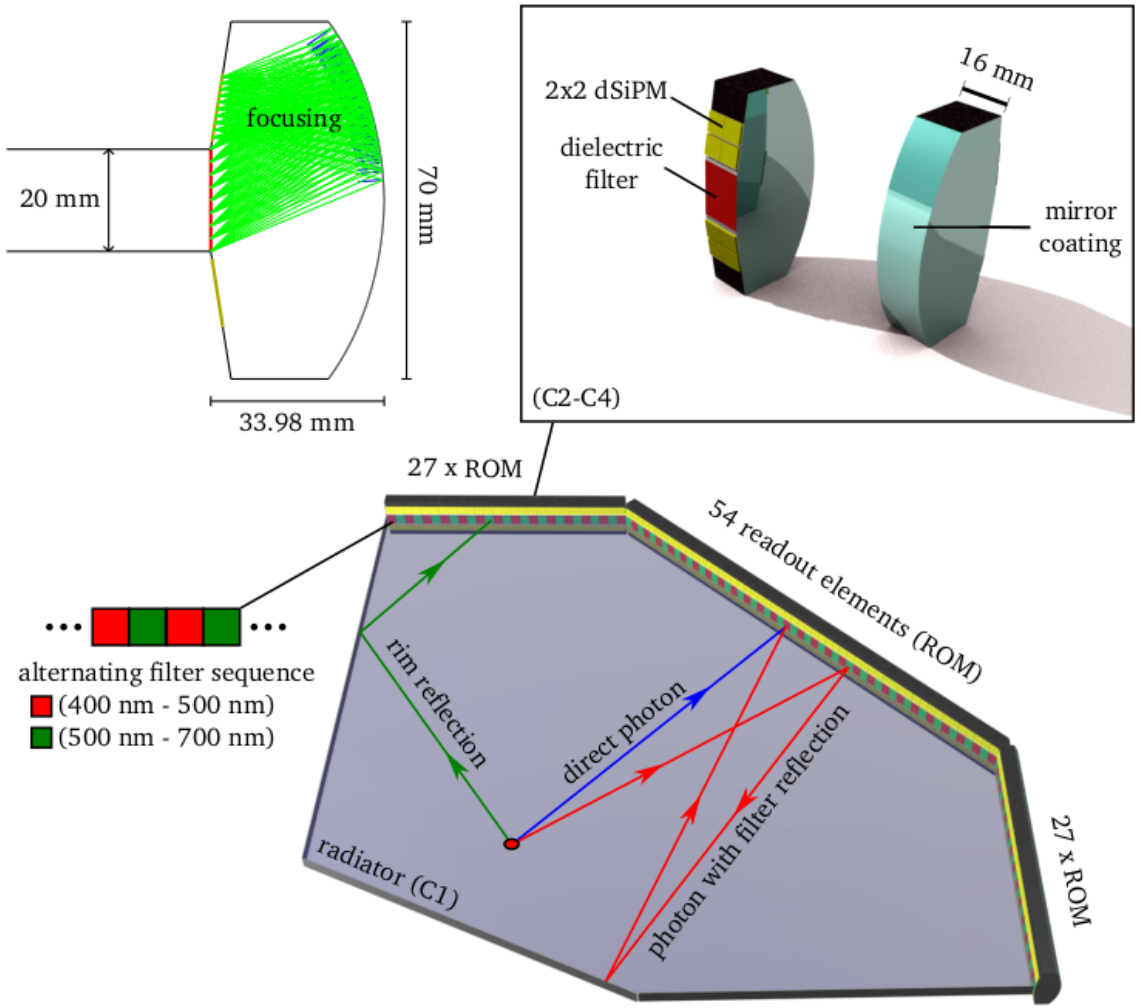
Geometrical aberration for cylindrical mirrors
(alternatives to be studied)



Possibility to use aspheric shape for FELs (production expensive)

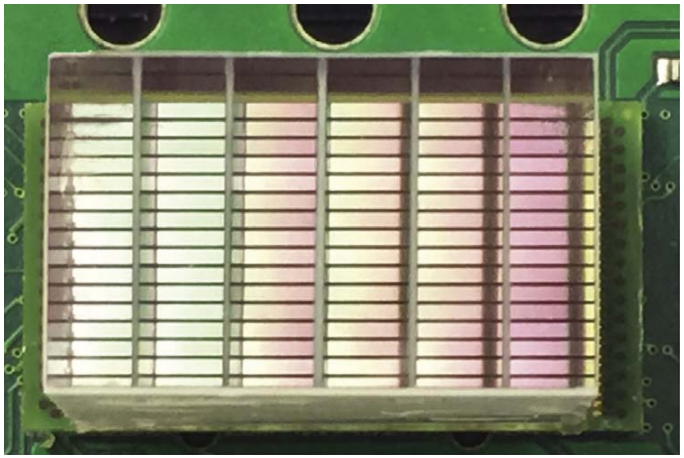
Optics Opmization Possibilities

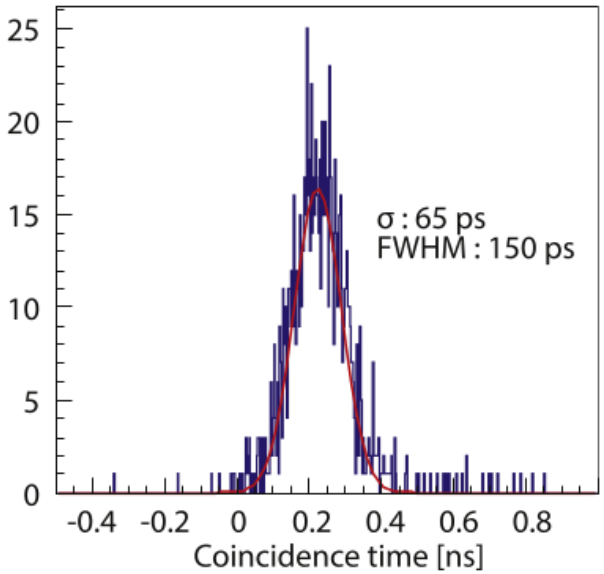
Ongoing studies with dSiPM readout and smaller symmetric FELs



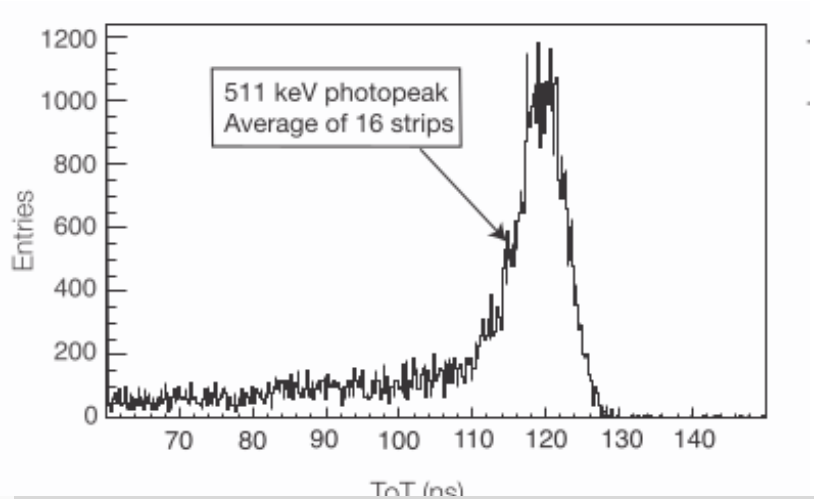
Optimization process ongoing

Analog Silicon PMs





- New development at CERN: Multi Pixel Photon Counters (MPPCs) with analog SiPMs
- Active area: $11 \times 15\,\mathrm{mm}^3$
- Tested MPPC board with 16 strips with LFS crystals (strip pitch: $\approx 0.68\,\mathrm{mm}$)
- Obtained time resolution: 65 ps with Gaussian fit



Summary & Outlook

- DIRC options for SCTF currently under investigation
- Separation of muons and pions more difficult than pion/kaon separation
  $\Rightarrow$ Optimization for required misidentification very important
- Different options (optics, sensors etc.) in optimization phase
- Using SiPMs with strip readout instead of MCP-PMTs for better resolution
- Barrel DIRC or Belle-2-like ToP counter for large polar angles also under consideration

Thank you very much for your attention!