DIRC Options for Super Charm Tau Factory

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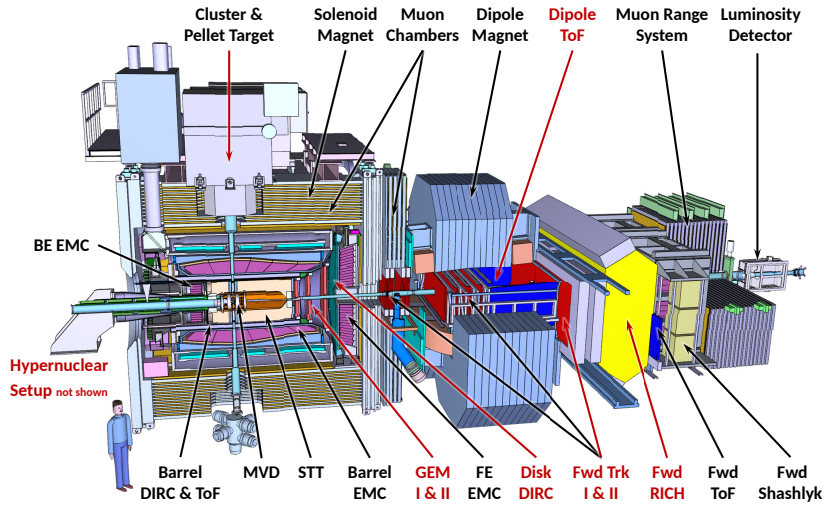
PANDA vs SCTF

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

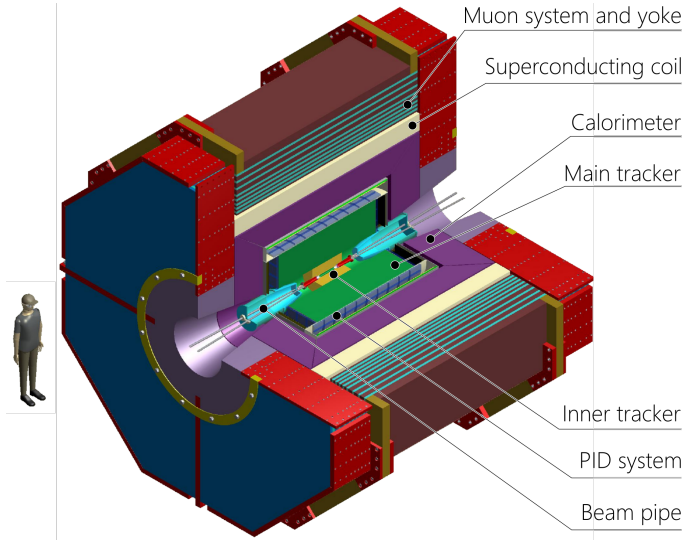


SCTF

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

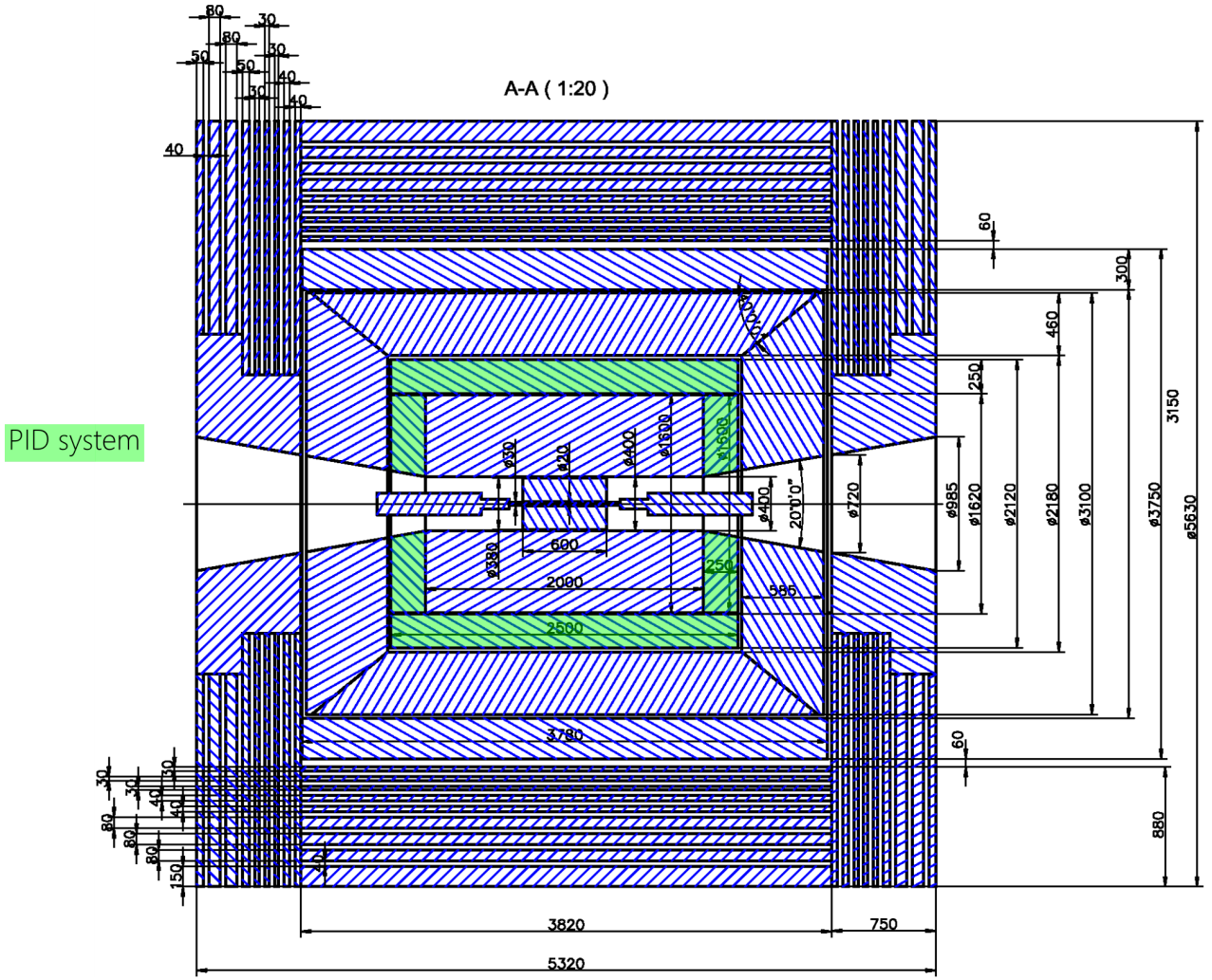
$$\mathcal{L} \approx 10^{35}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$$

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



SCTF Detector Geometry

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



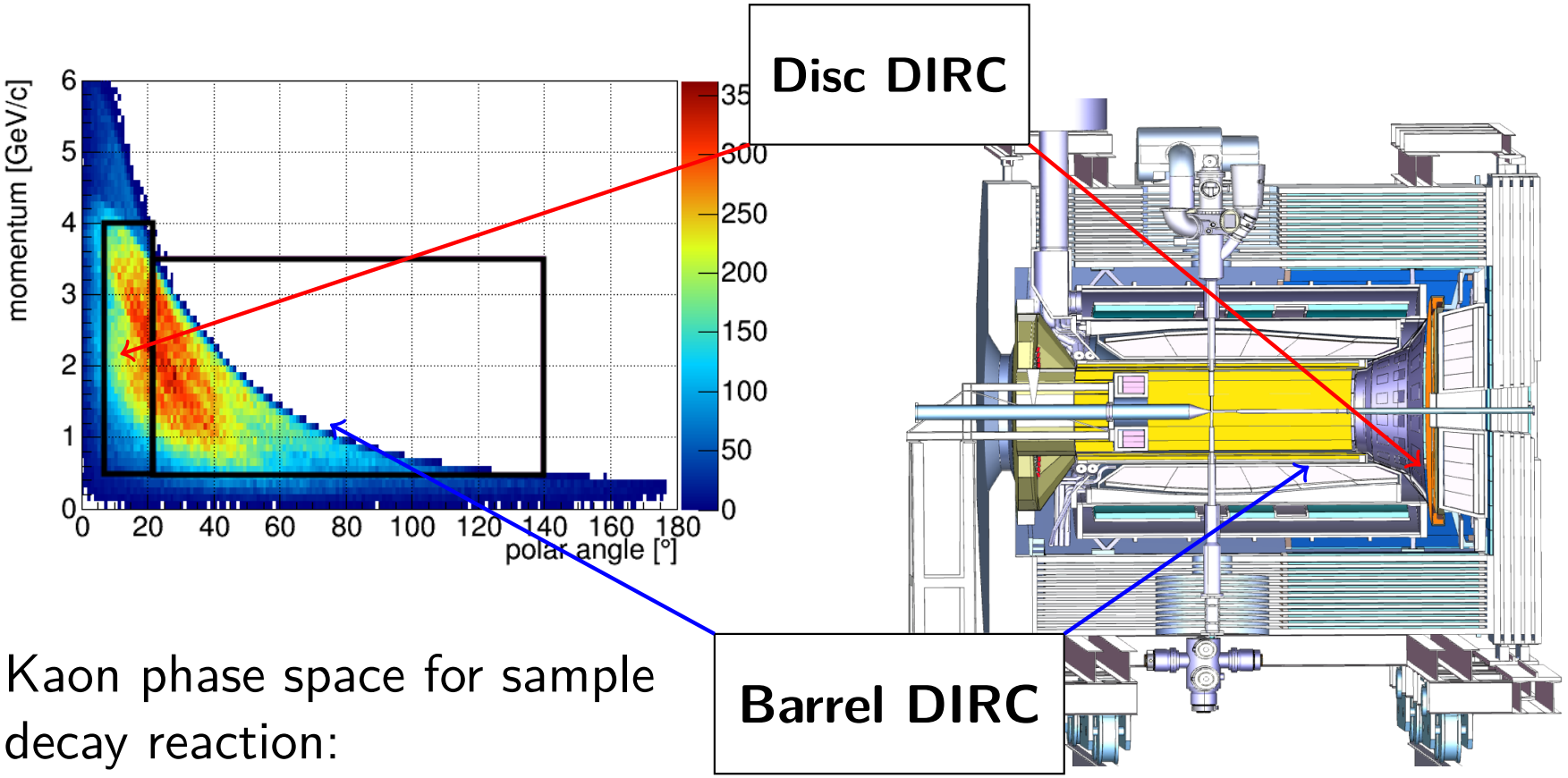
Detector design to be revised for DIRC options

PID in PANDA

No hadronic calorimeter in PANDA

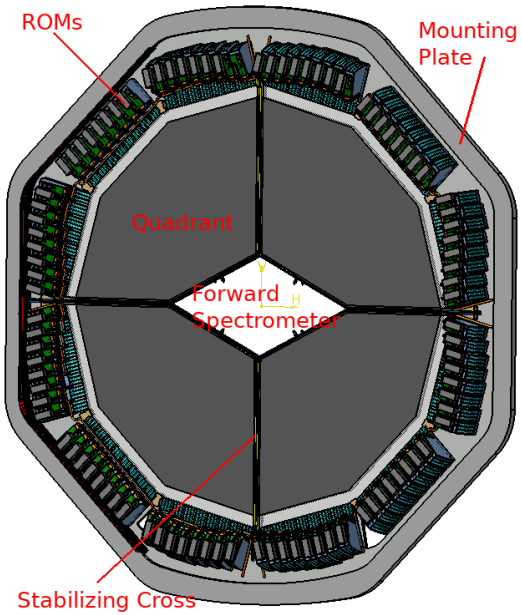
Two DIRC detectors for PID in target spectrometer

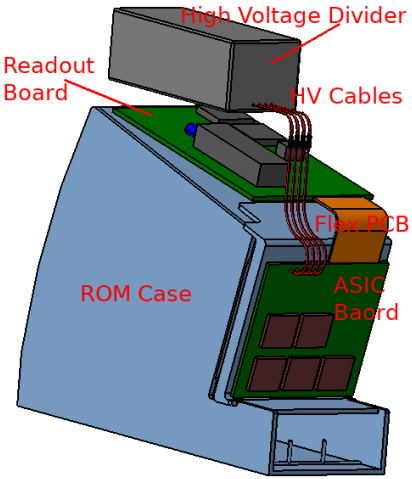
DIRC: Detection of Internally Reflected Cherenkov Light



Kaon phase space for sample decay reaction:
$J/\Psi \rightarrow K^+K^-\gamma$ @ 6.5 GeV/c

PANDA EDD Specifications



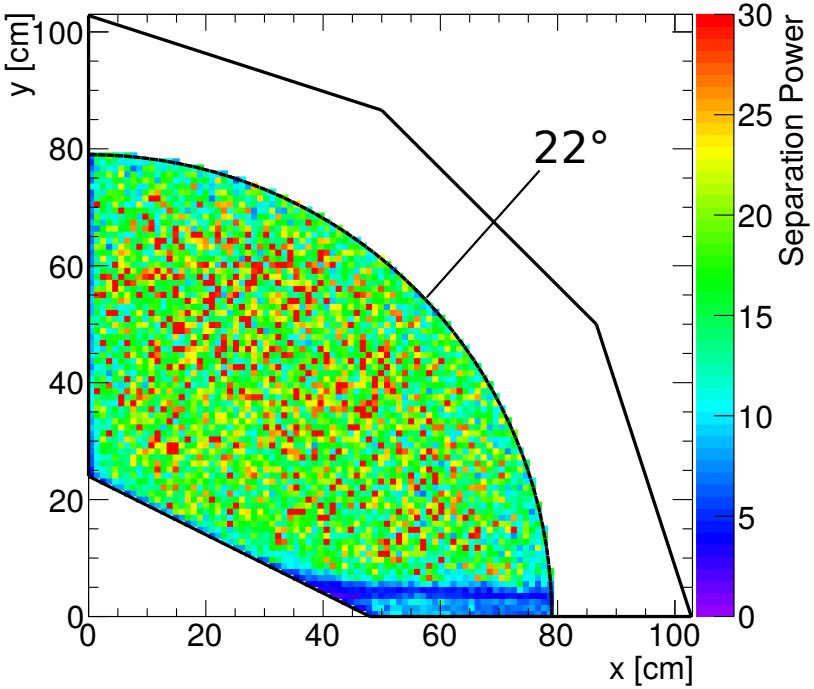


- 8 Readout Modules (ROMs) per side $\Rightarrow$ 96 ROMs in total
- Readout: PETsys TOFPET ASICs with 30 ps LSB
- 5 ASICs with 64 channels per ROM
- 300 pixels per MCP-PMTs $\Rightarrow$ 28,800 readout channels
- Approx. 1 charged track per collision (22 photon hits per track)
- Hit frequency per channel: 60 kHz in high luminosity mode
- Connection to PANDA DAQ system
- Using SODAnet for time synchronisation

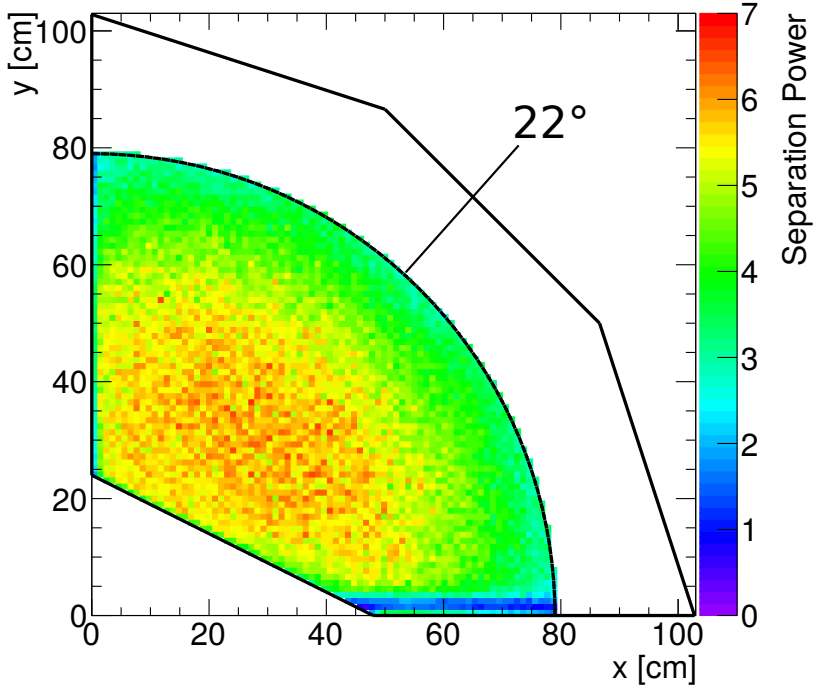
High Resolution Simulations for PANDA EDD

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

Momentum 2 GeV/c

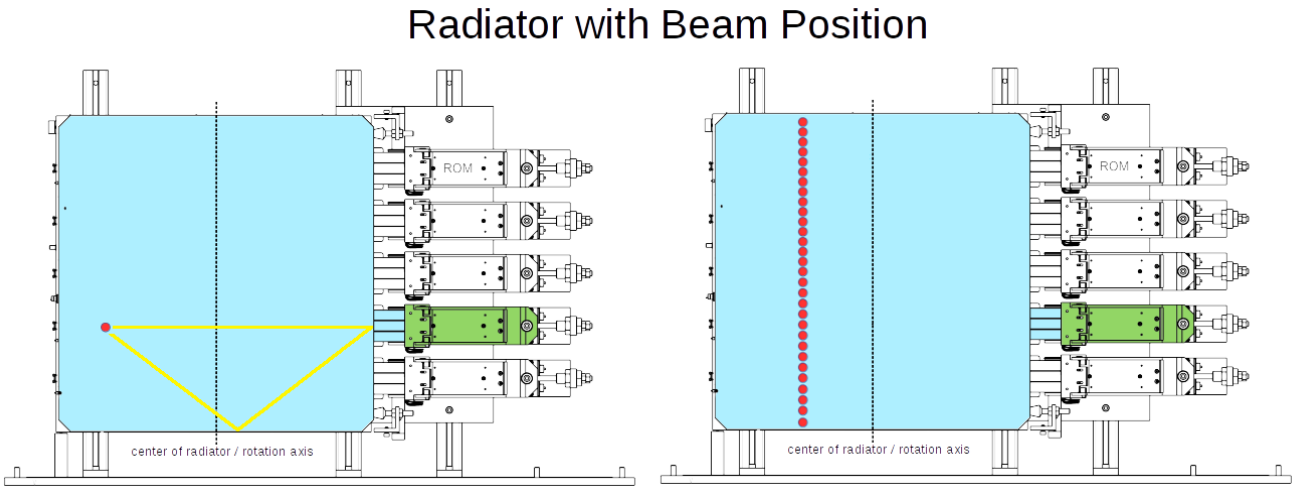


Momentum 4 GeV/c

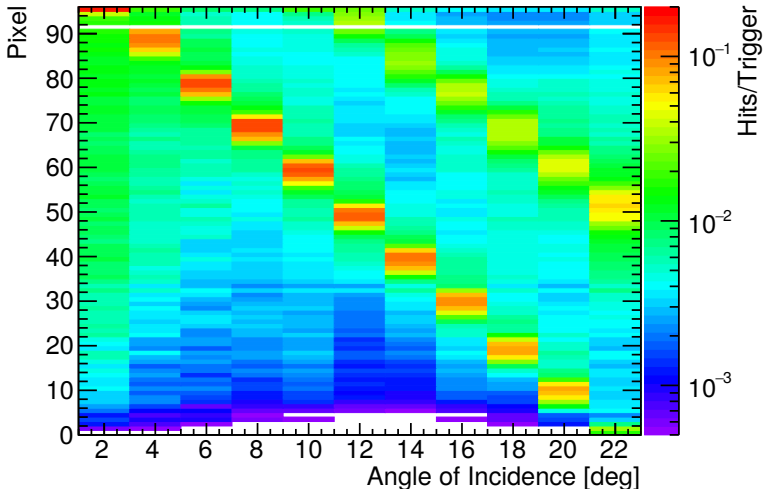


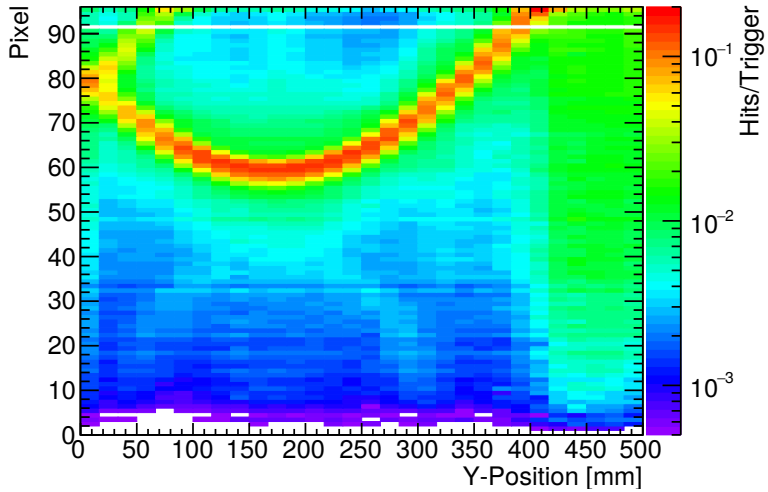
EDD DESY Testbeam 2016

Hit patterns including vertical position and angle scan

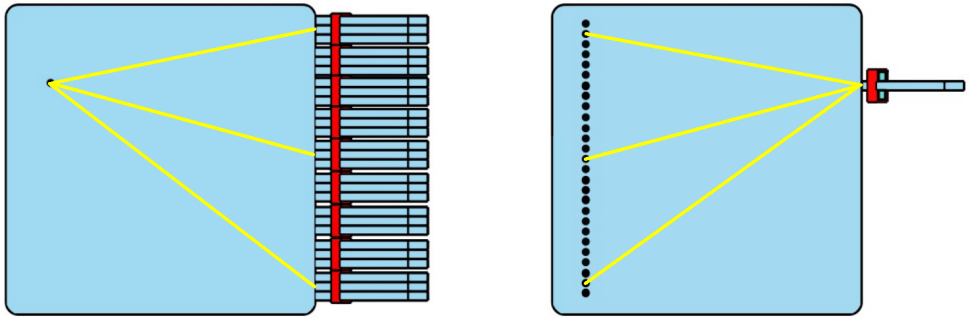


Hit pattern from the central FEL inside highlighted ROM



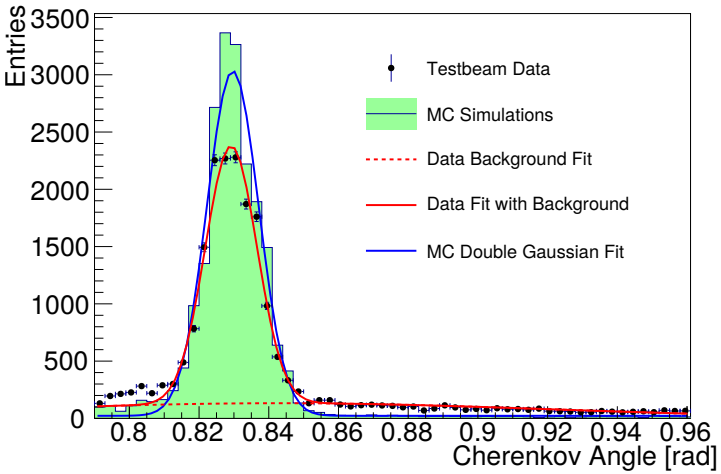


Event Combination DESY 2016

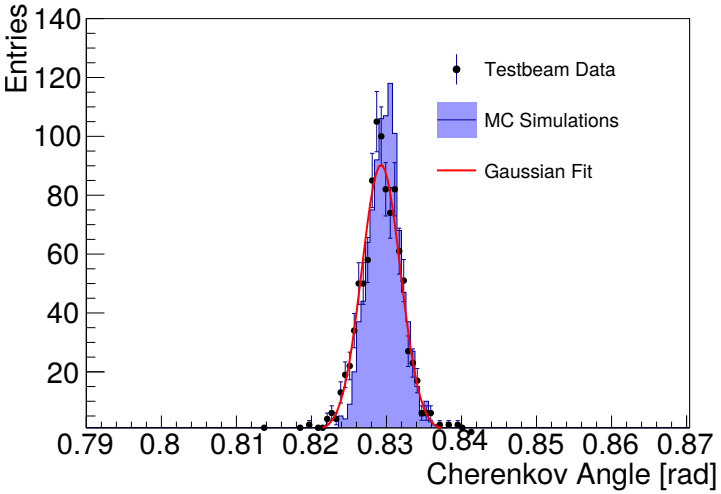


- Combining each event from every position to one new event
- Making a coarse time cut according to photon propagation time
- Reduction of background with truncated mean of pixel hits
- Obtained resolutions:
  $\sigma_\theta = 7.4\,\text{mrad}$ (single photon)
  $\sigma_{\bar{\theta}} = 2.5\,\text{mrad}$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

Single Photon Distribution

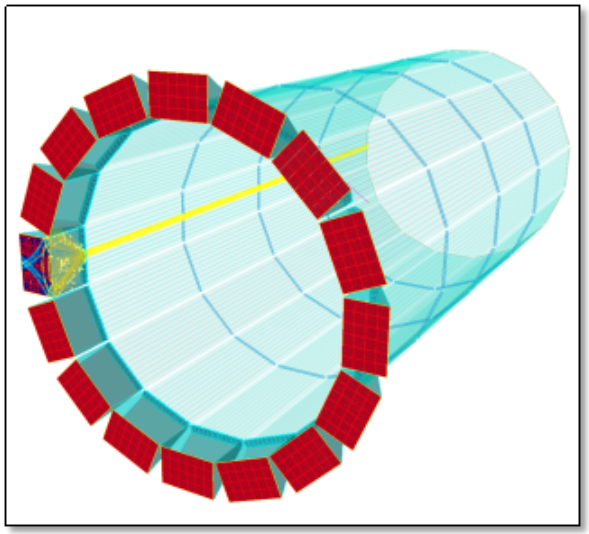


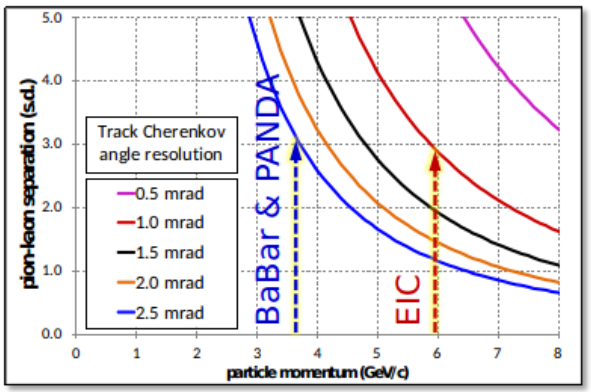
Event Mean Distribution



HP-DIRC Specifications

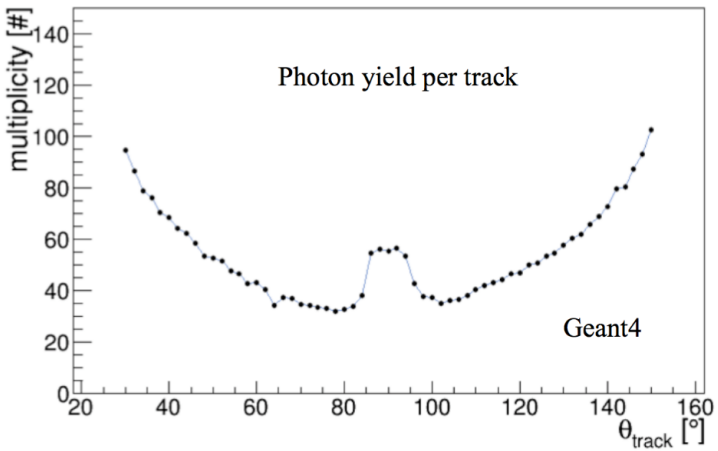
- Inspired by design elements from BaBar, SuperB, Belle II, and PANDA
- 176 radiator bars (11 per sector), synthetic fused silica ($17\,\text{mm}\,(\text{T}) \times 35\text{mm}\,(\text{W}) \times 4200\text{mm}\,(\text{L})$)
- Focusing optics: innovative rad-hard 3-layer spherical lens
- Compact photon camera: 30-cm-deep solid fused silica prisms as expansion volumes, lifetime-enhanced MCP-PMTs with $3 \times 3\,\text{mm}^2$ pixels, fast readout electronics ($\approx 100,000$ channels, $\leq 100\,\text{ps}$ single photon timing)



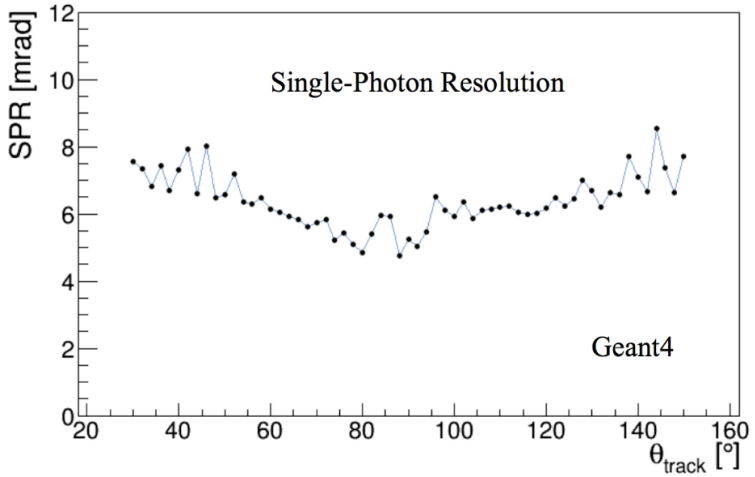


Simulations for HP-DIRC

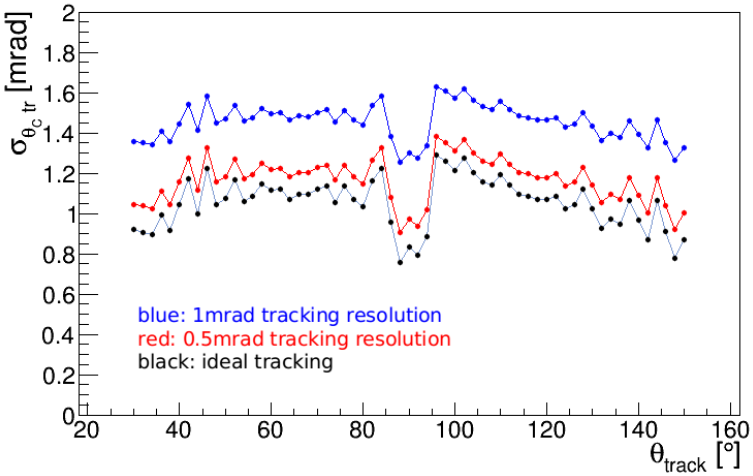
Photon Yield per Particle



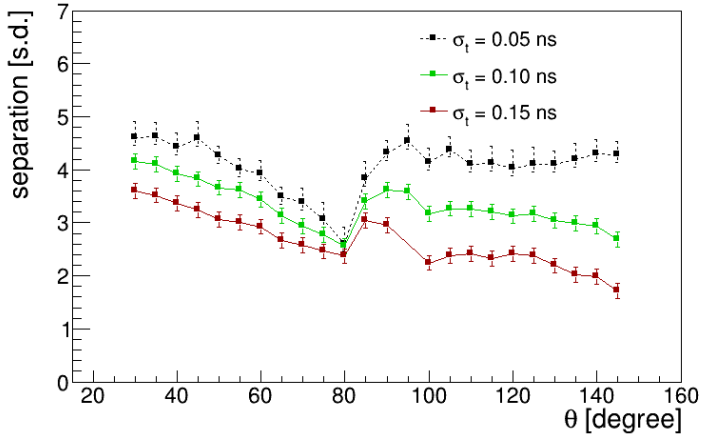
Single Photon Resolution (SPR)



Detector Resolution

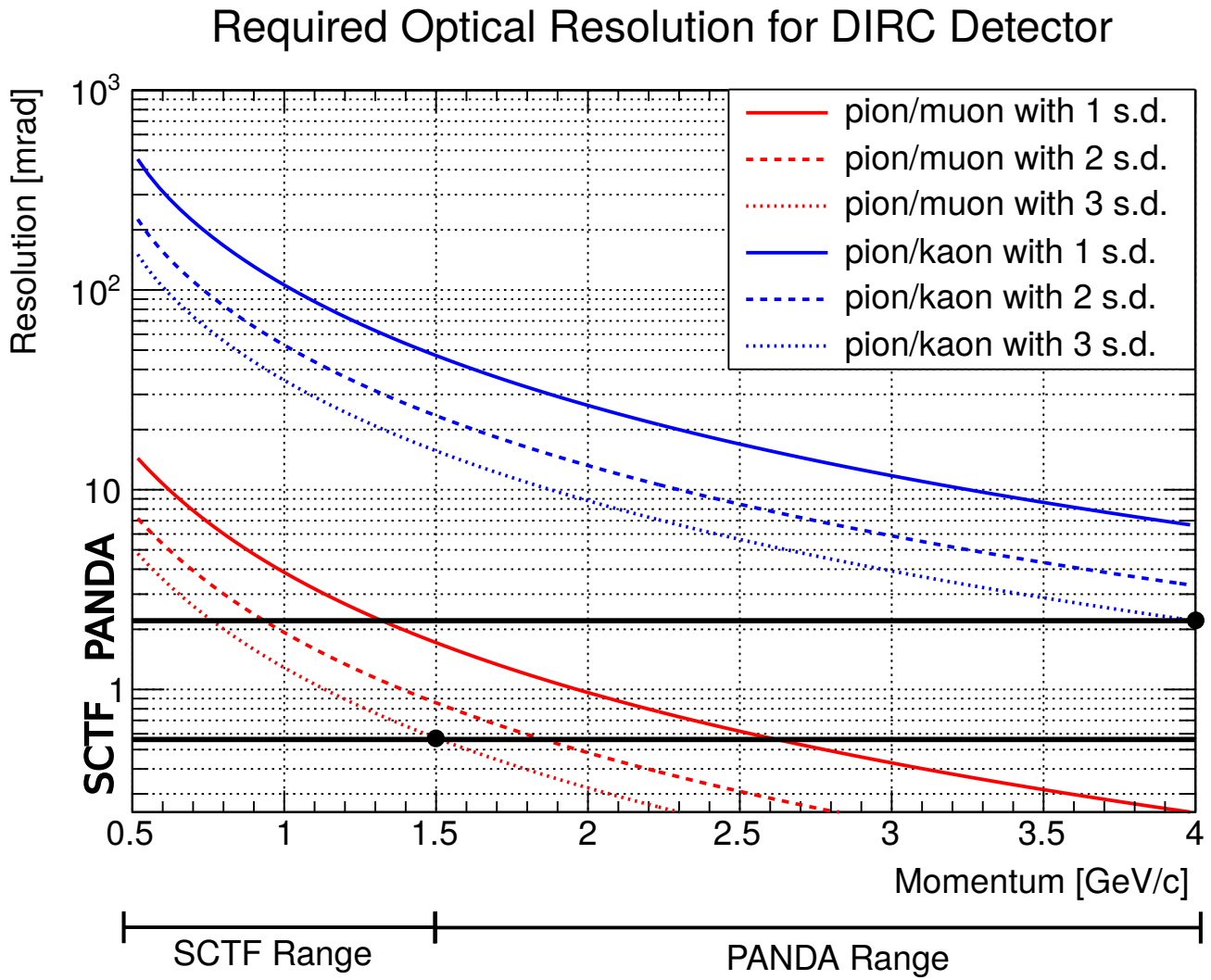


π/K Separation @6 GeV/c



Required Resolution for Muon/Pion Separation

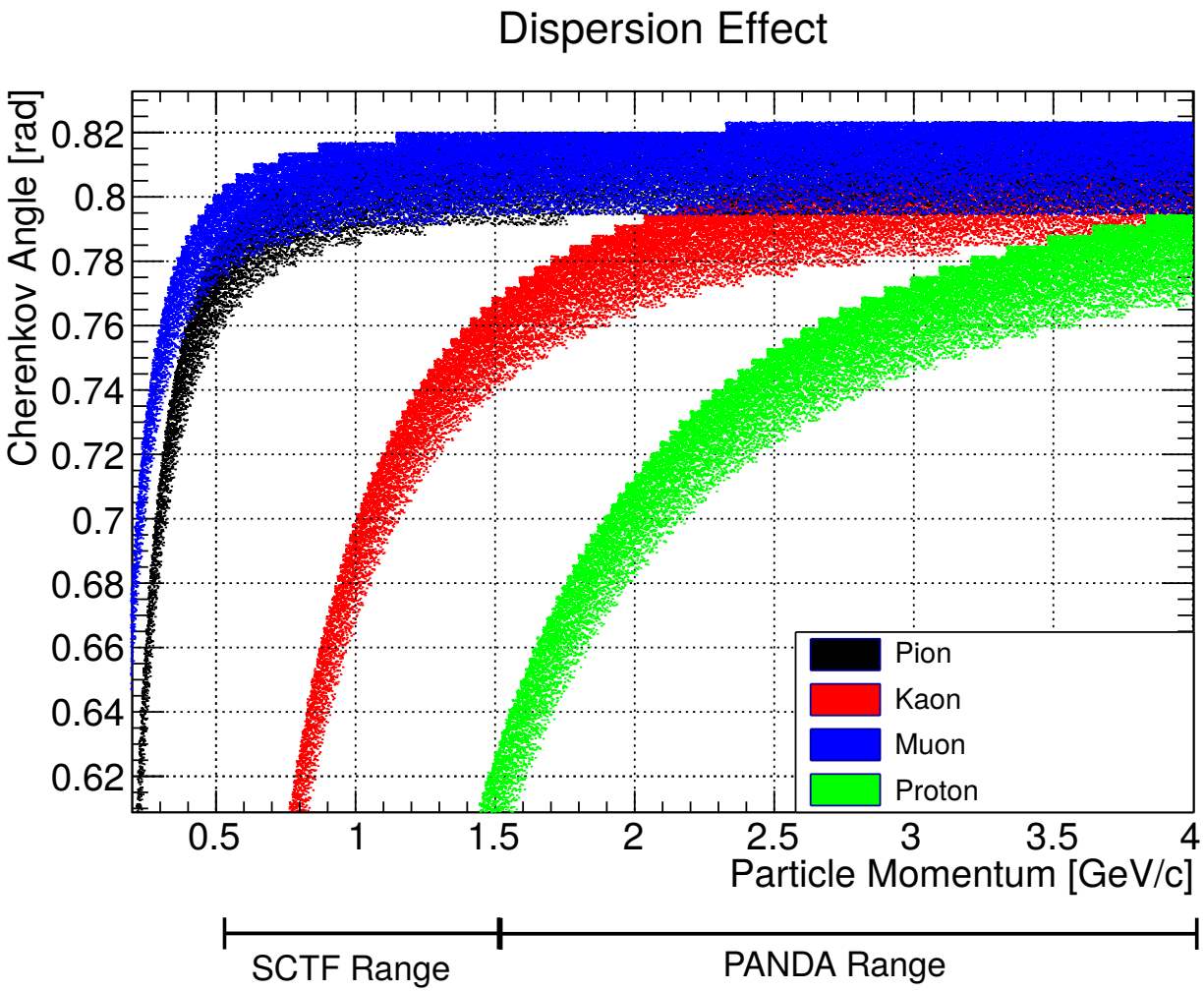
PANDA: Pion/Kaon ≈ 2.1 mrad for 3 s.d. @4 GeV/c
SCTF: Muon/Pion ≈ 0.7 mrad for 3 s.d. @1.5 GeV/c



Dispersion Bands

Largest effect from dispersion and similar rest masses

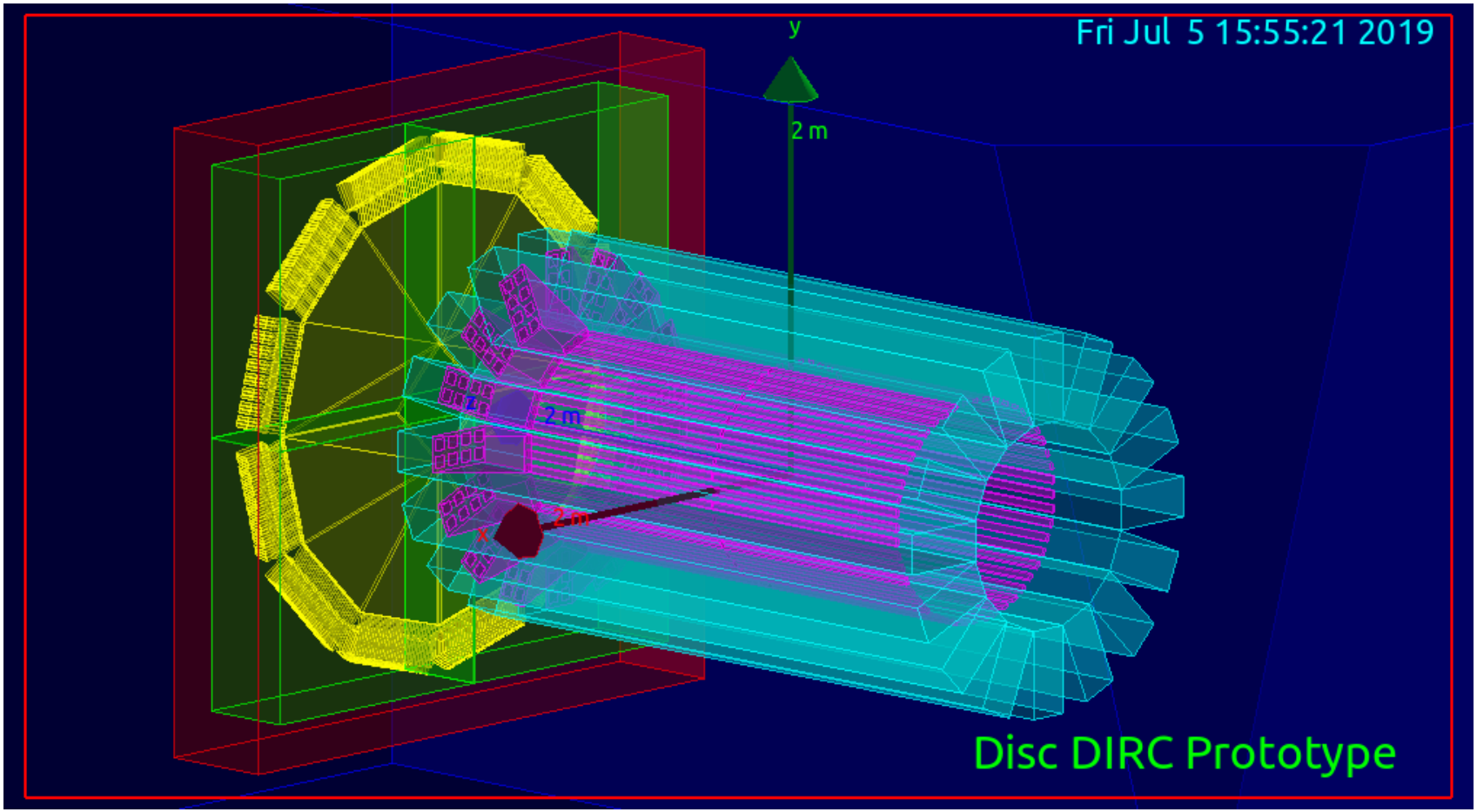
Wavelength interval: $300 \leq \lambda \leq 700\,\text{nm}$



Reducing dispersion band: More photons or better wavelength cuts

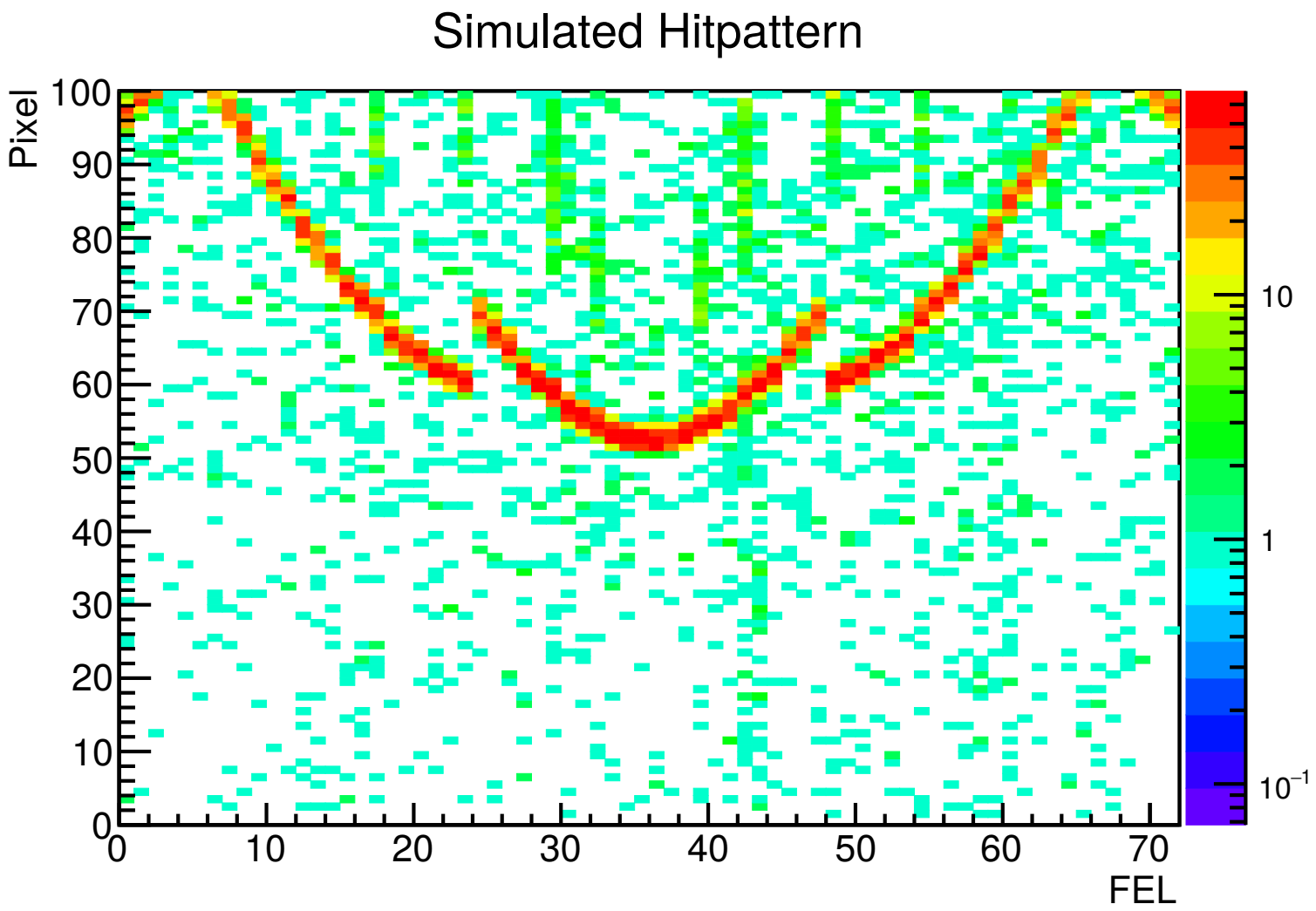
Geant4 Simulations

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



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

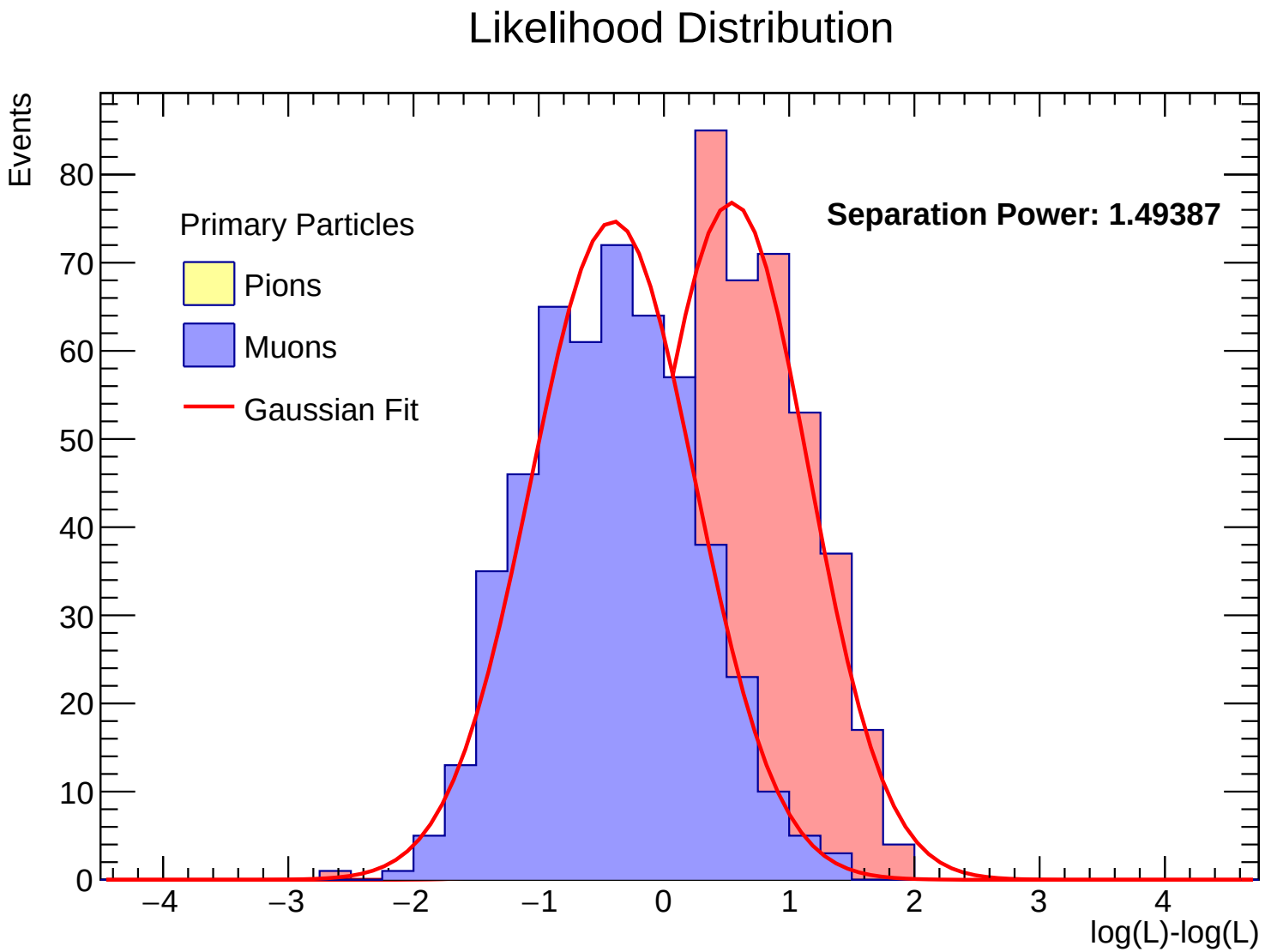
PANDA Disc DIRC Hit Pattern



Geant4 MC simulated hit pattern for 1000 muon/pion tracks

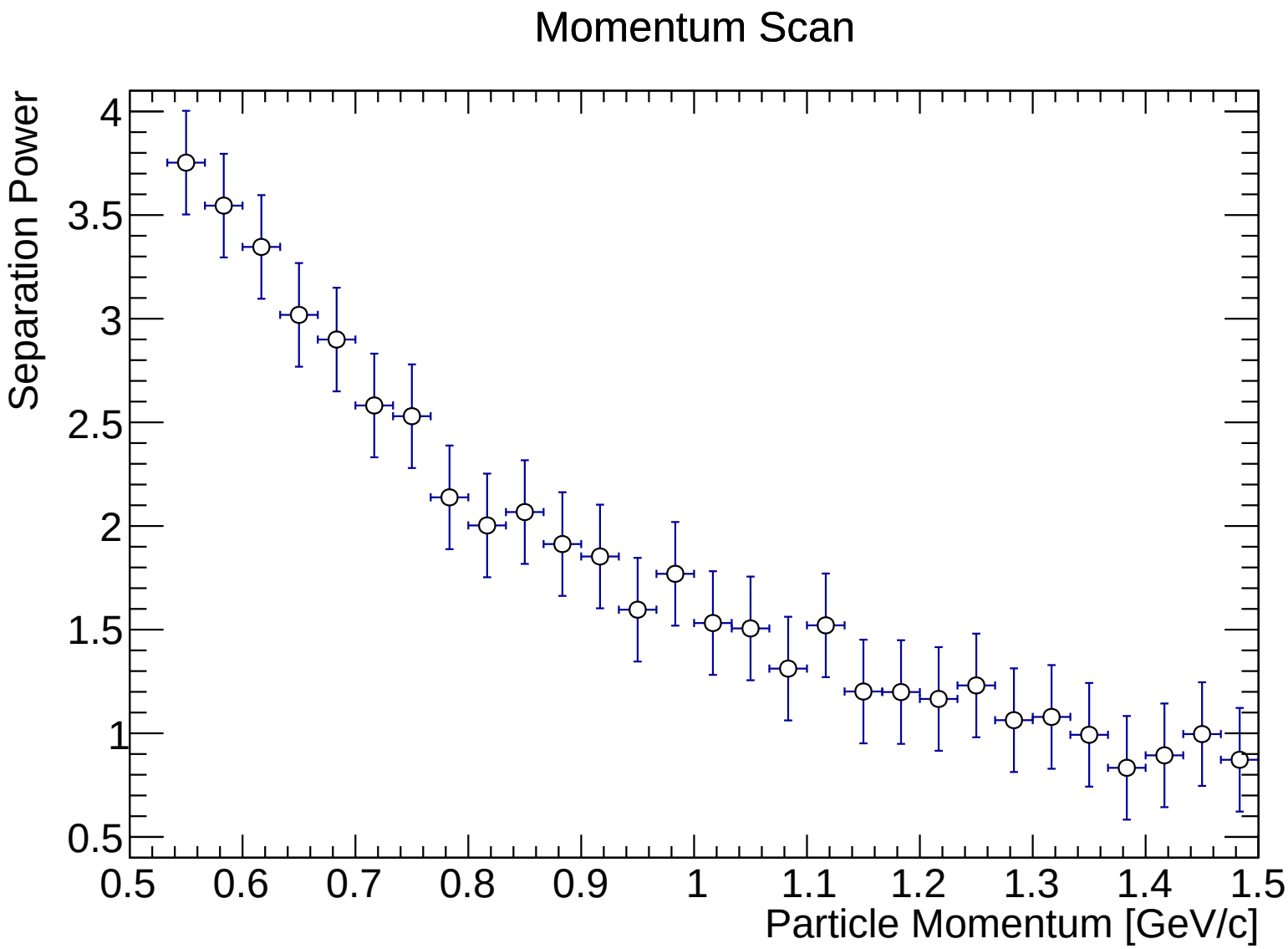
Muon/Pion Separation

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



Momentum scan

Momentum scan for μ/π separation with PANDA setup:



Possible Improvements

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

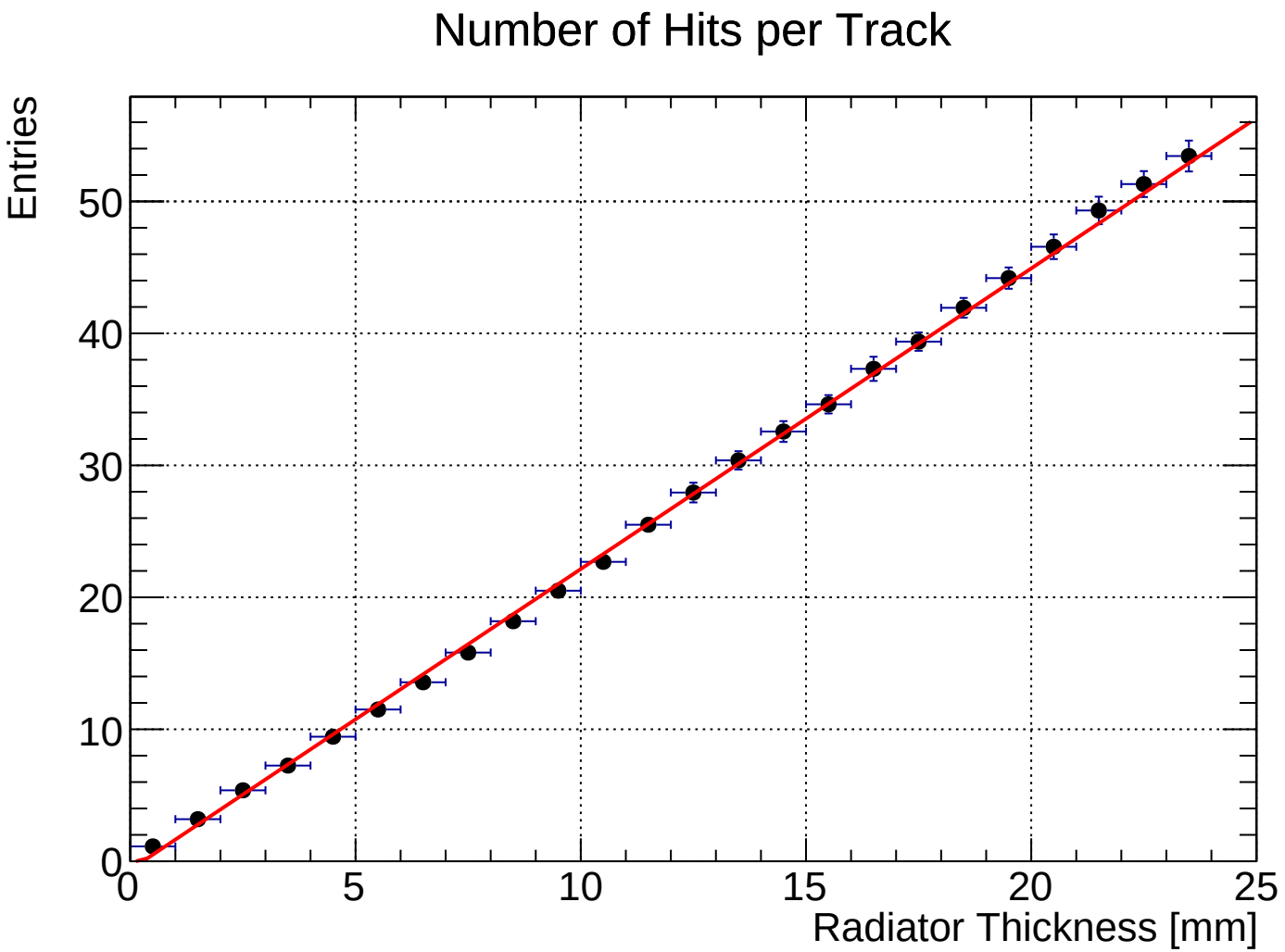
How can the performance be increased?

Possible optimizations for the Disc DIRC:

- Radiator optimizations (mainly thickness)
- Bar width optimization
- Increasing pixel resolution
- Different sensor types (MCP-PMTs or SiPMs)
- Optimizations for focusing optics
- Optimization in quantum efficiency and wavelength filter
- Dispersion corrections (3D DIRC)

Radiator Optimization

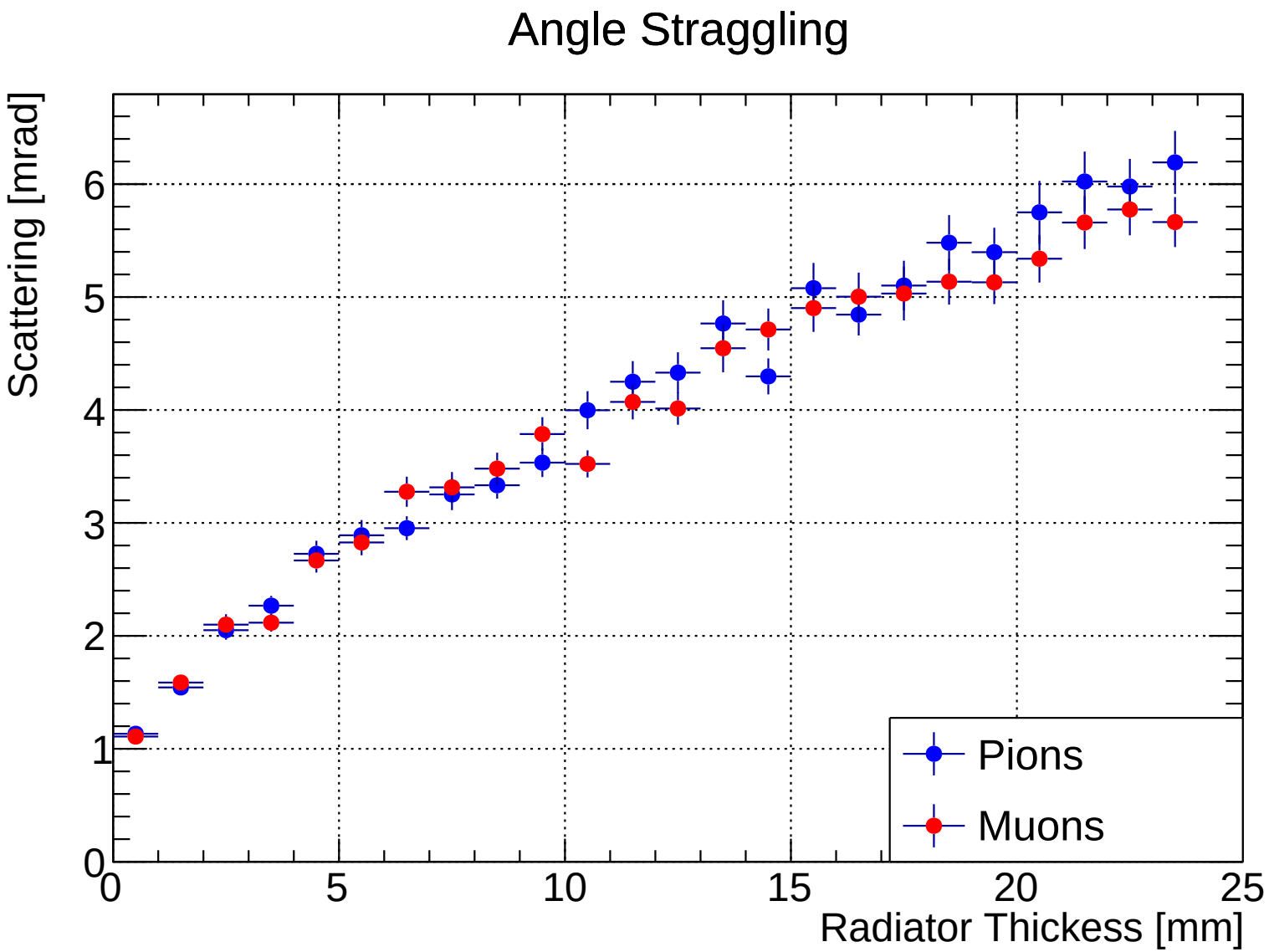
Studying resolution as function of radiator thickness (Disc DIRC)



Almost linear increase of detected photons (as expected)

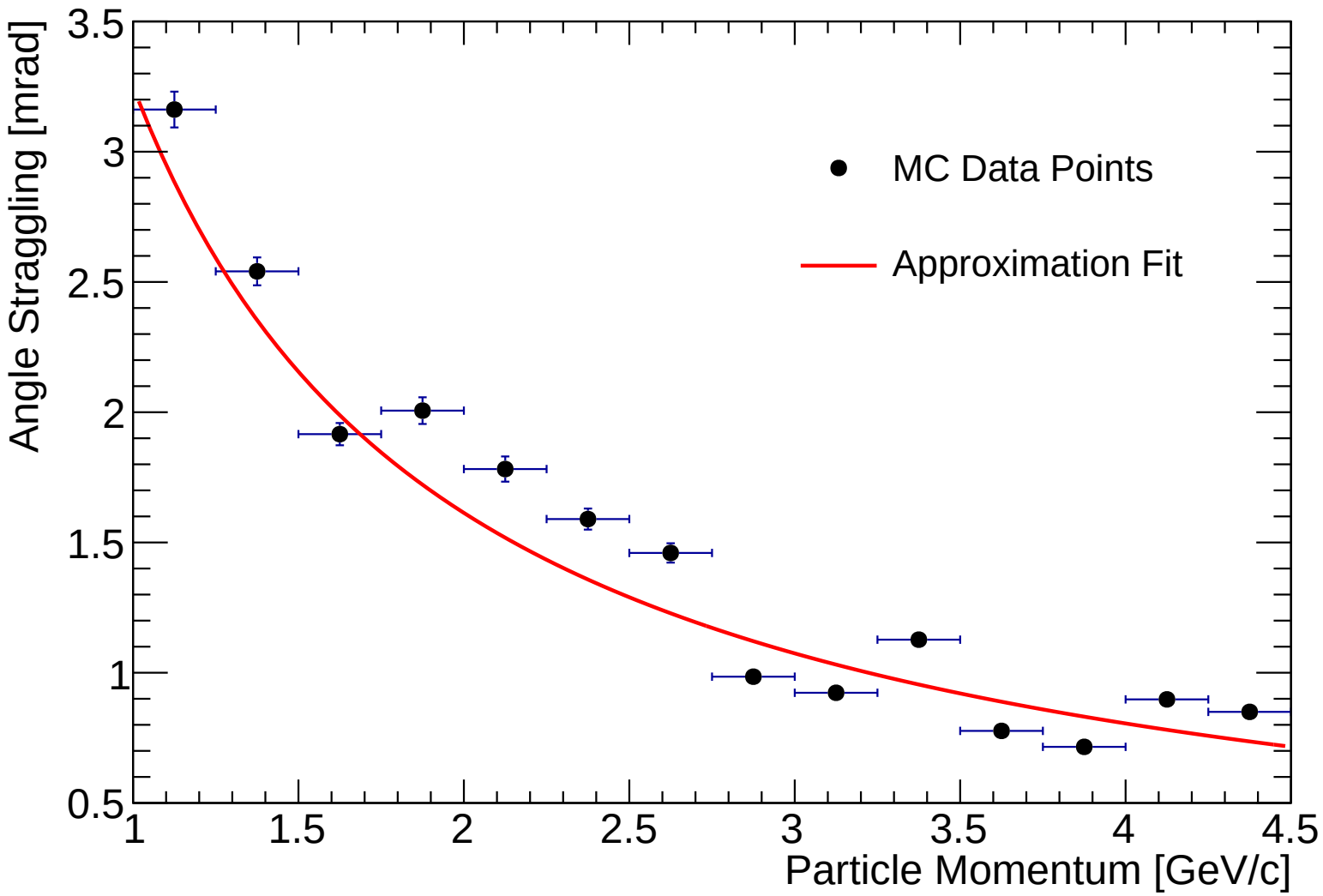
Angle Straggling

Multiple Coulomb Scattering of pions in radiator plate



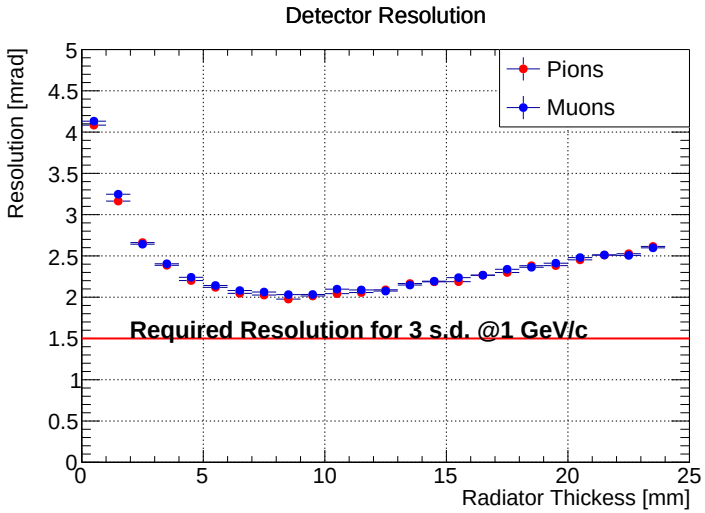
Momentum Dependency

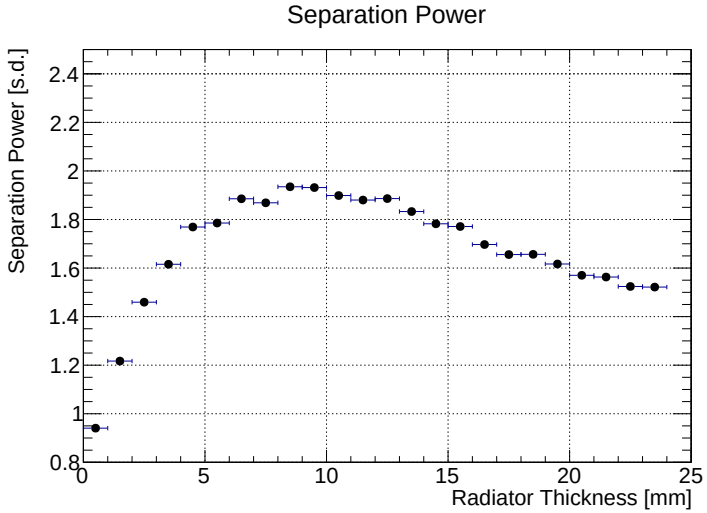
Angle straggling as function of momentum (10 mm thickness)



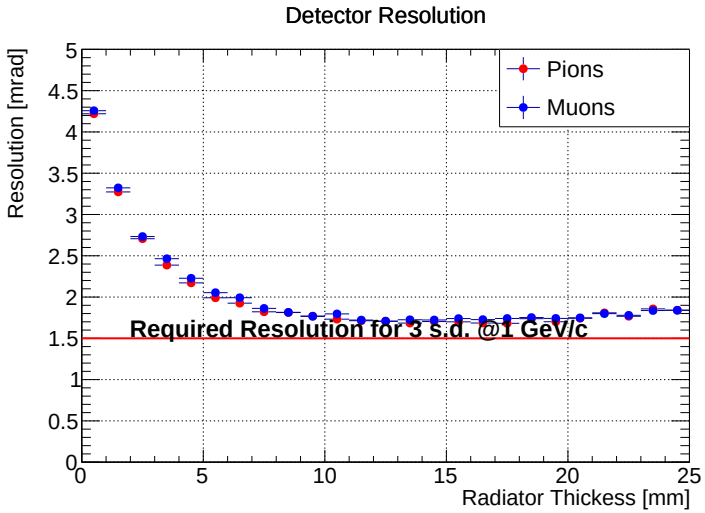
Radiator Optimization

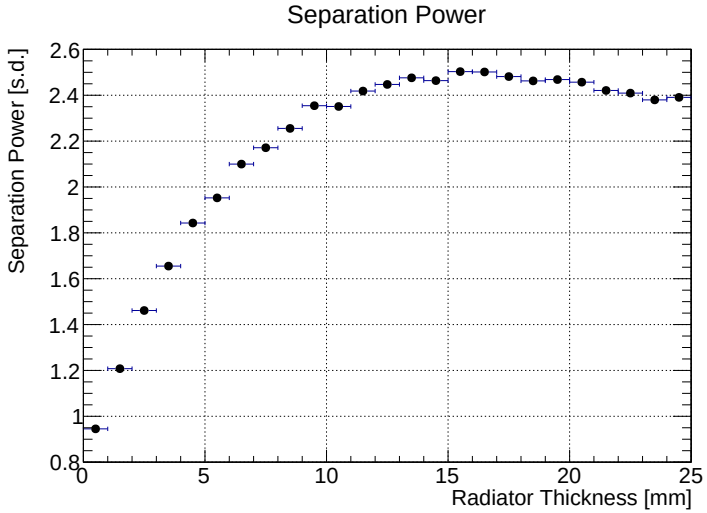
Simulation Results with Original Configuration





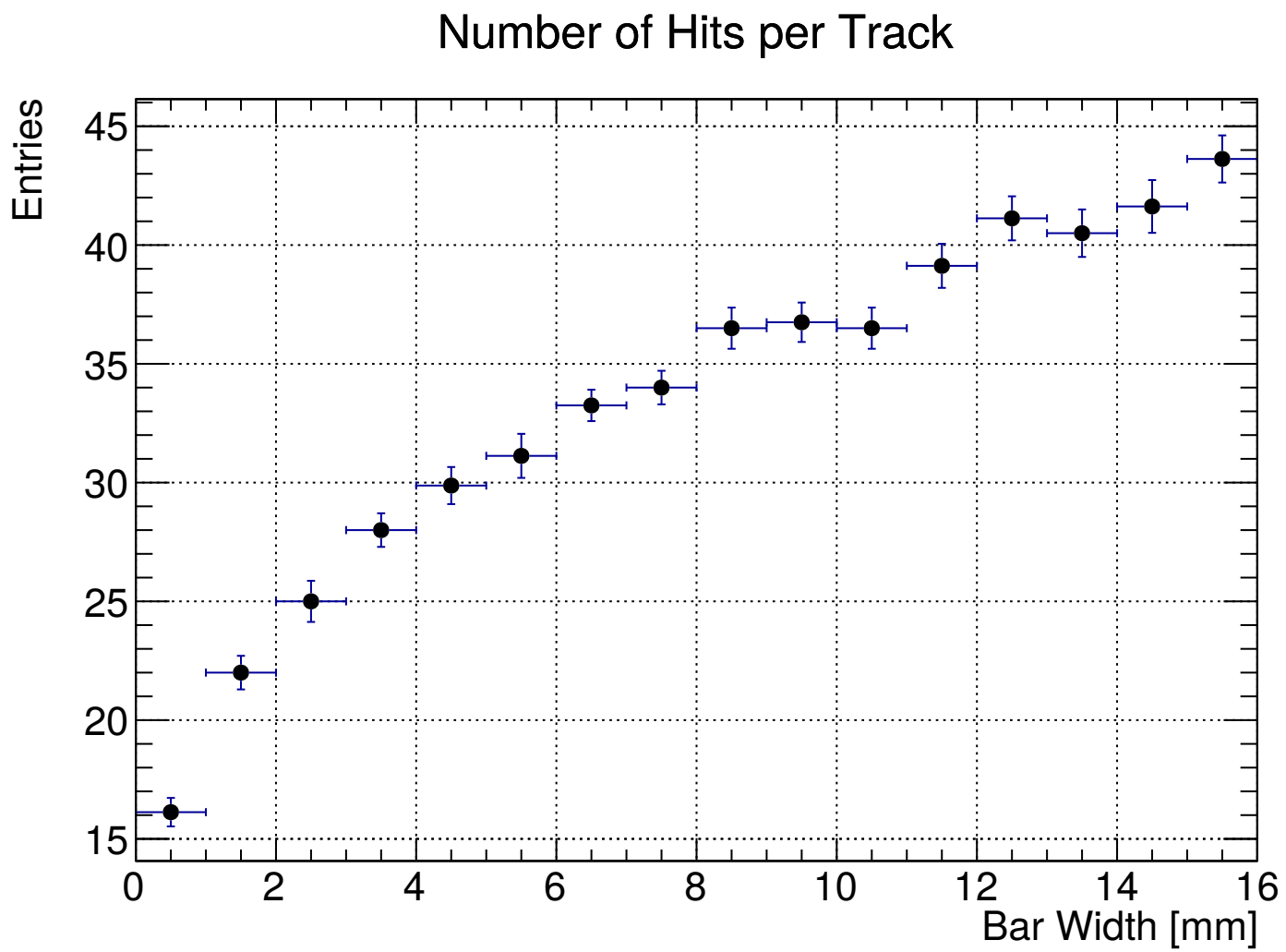
Simulation Results with Additional Tracking





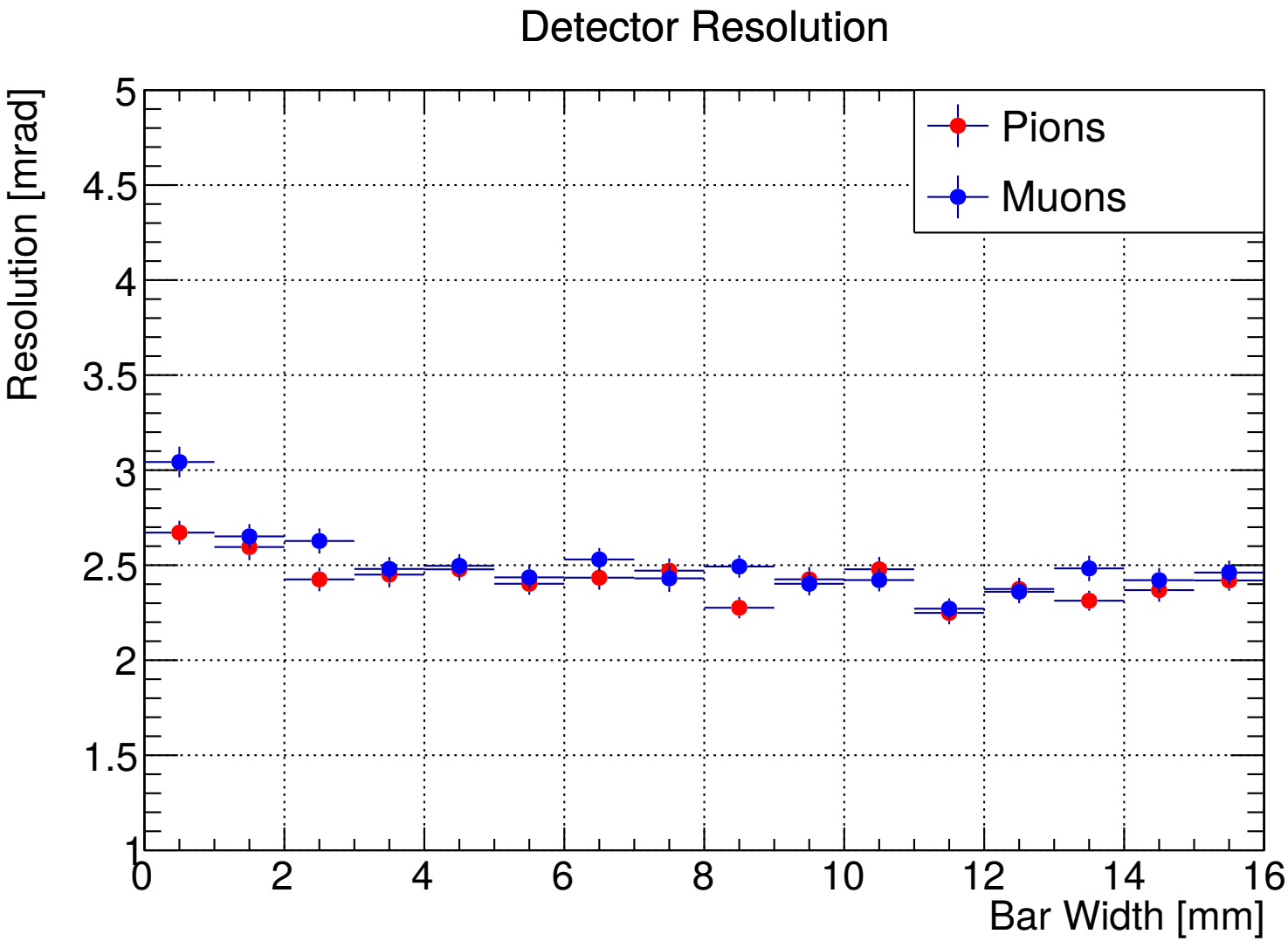
Bar Width Optimization

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



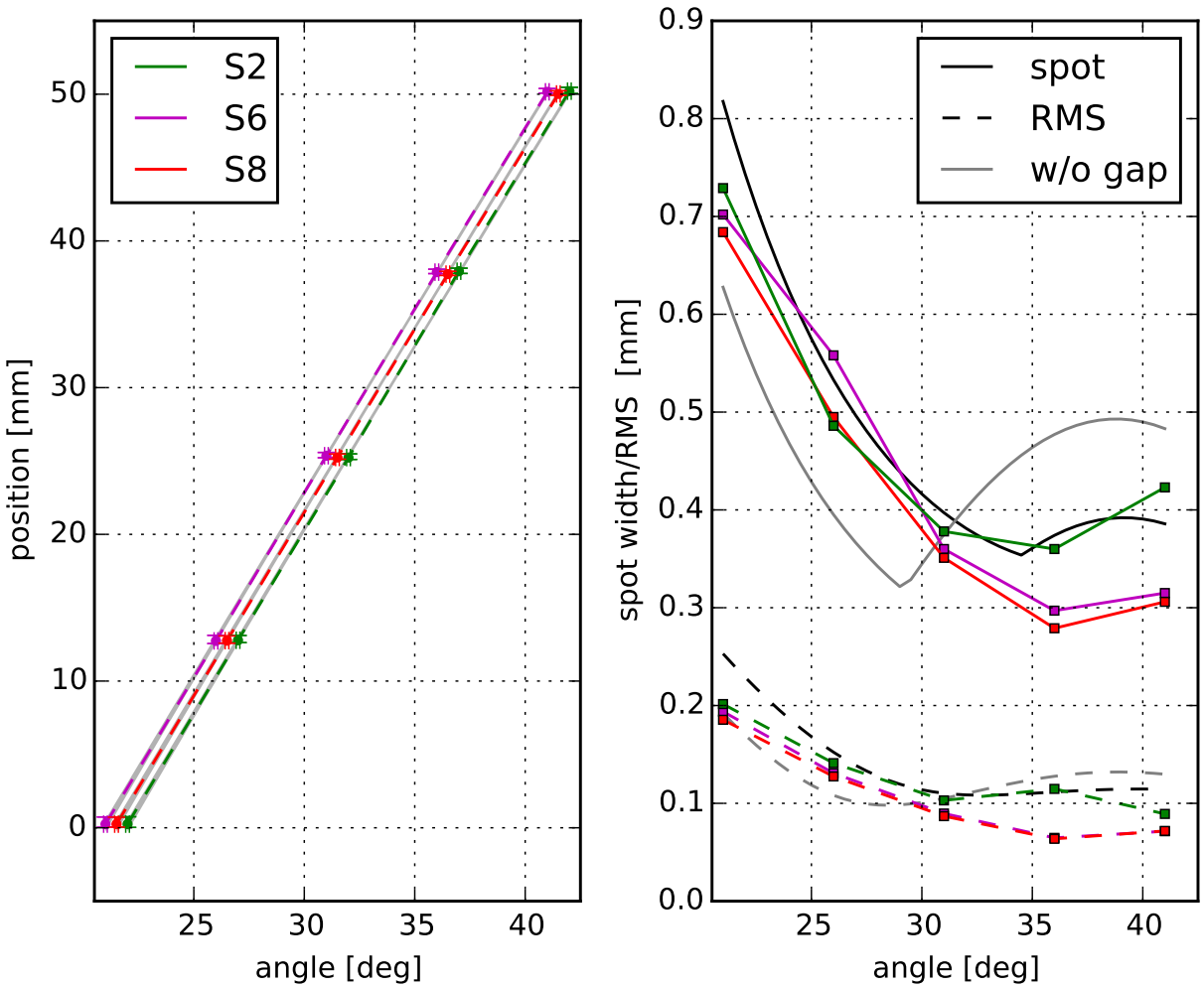
Bar Width Optimization

Resolution does not change with varying bar widths



Cylindrical Optics

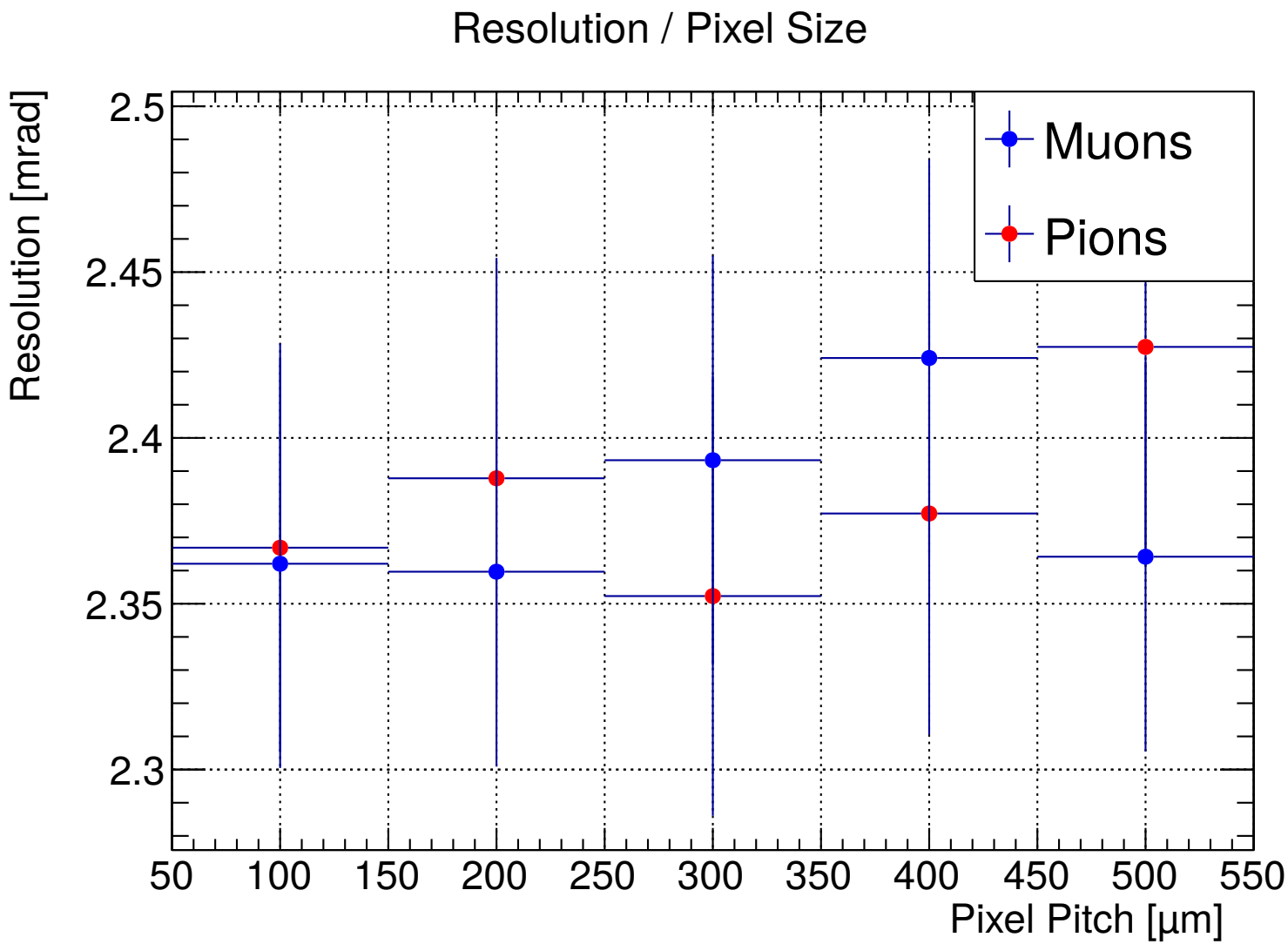
Spot width between 0.3 and 0.7 mm (current pixel size 0.5 mm)



Measurments from 2015 (TDR) by E. Etzelmüller

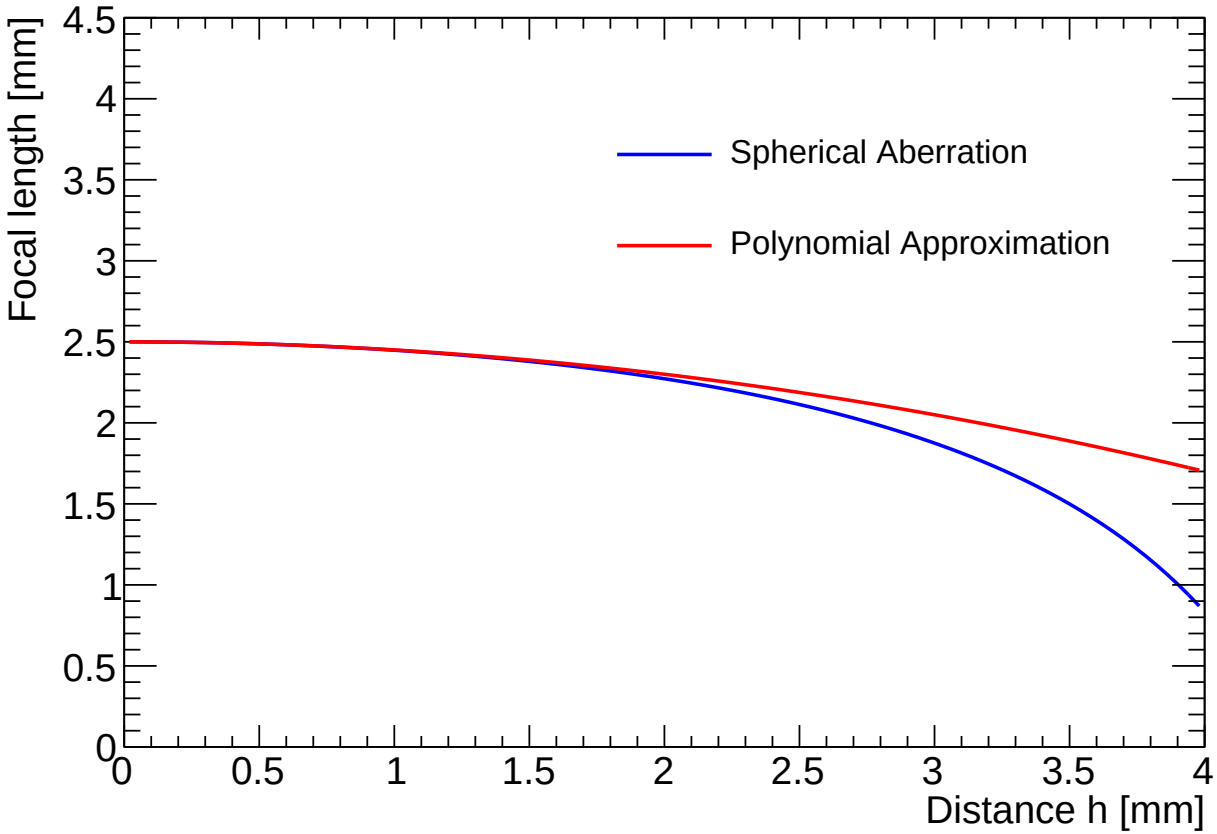
Pixel Pitch Optimizations

Resolution almost independent of pixel resolution (current optics)



Focusing Optics

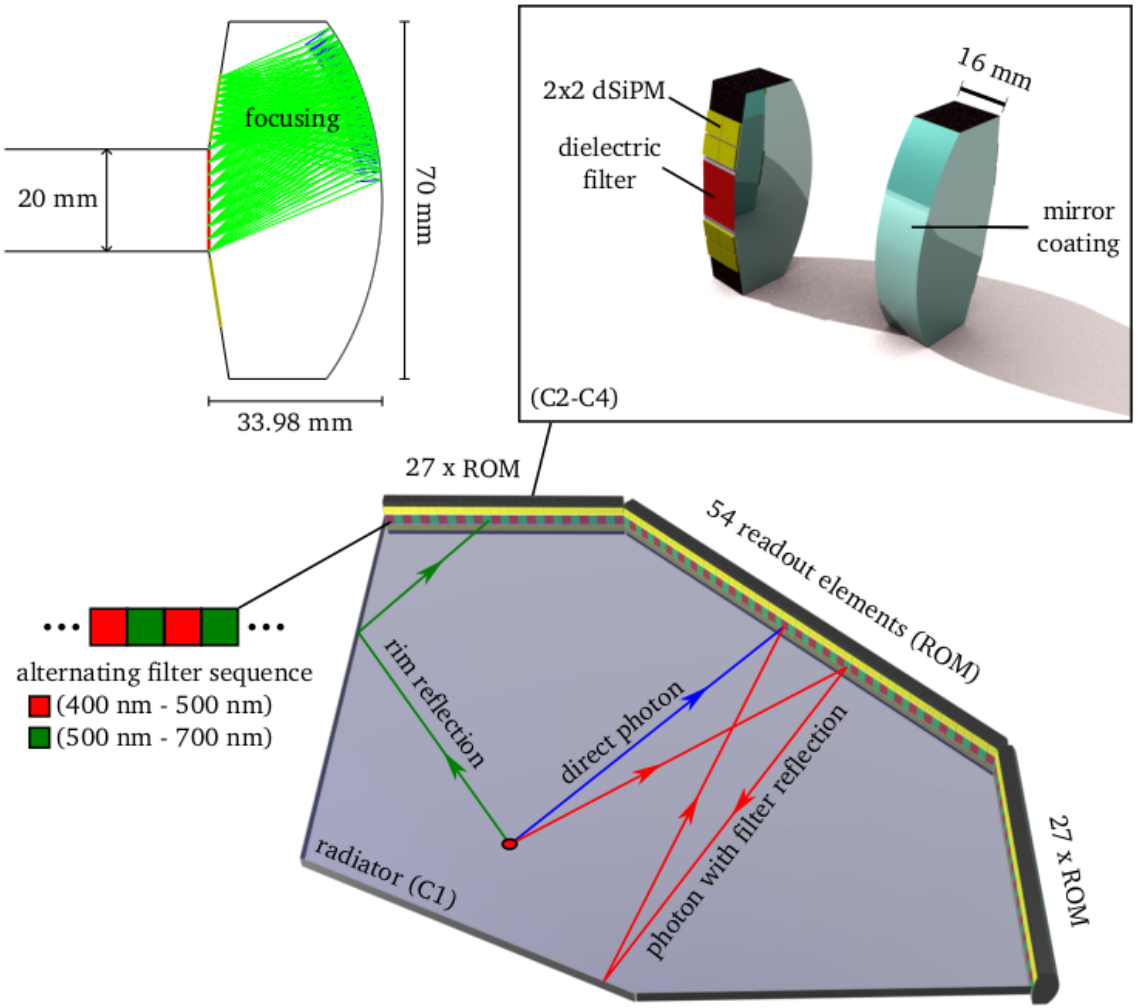
Geometrical aberration for cylindrical mirrors
(alternatives to be studied)



Possibility to use aspheric shape for FELs (production expensive)

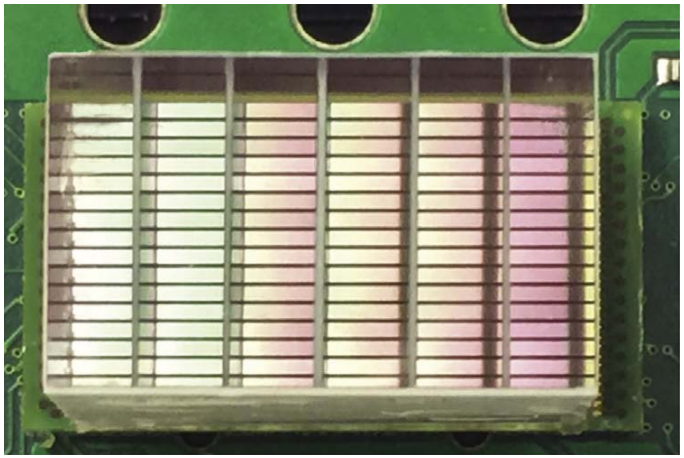
Optics Opmization Possibilities

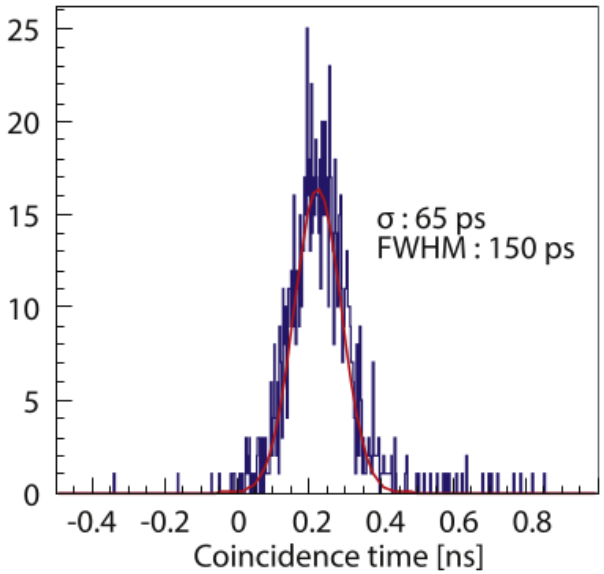
Ongoing studies with dSiPM readout and smaller symmetric FELs



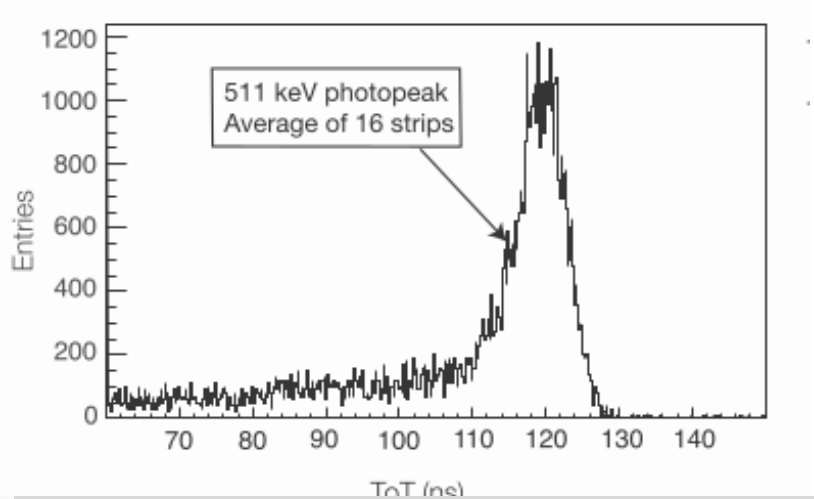
Optimization process ongoing

Analog Silicon PMs





- New development at CERN: Multi Pixel Photon Counters (MPPCs) with analog SiPMs
- Active area: $11 \times 15\,\mathrm{mm}^2$
- 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 smaller SiPMs with strip readout instead of MCP-PMTs for better resolution (possible problem: radiation hardness)
- Barrel DIRC or Belle-2-like ToP counter for large polar angles also under consideration

Thank you very much for your attention!