JUSTUS-LIEBIG-UNIVERSITÄT GIESSEN

Particle Identification with Disc DIRC at PANDA

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PANDA Collaboration Meeting 17/2

HIC for FAIR
Helmholtz International Center

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HGS-HIRe for FAIR
Helmholtz Graduate School for Hadron and Ion Research

Outline

1. Detector Concept
2. Detector Performance
3. DESY Testbeam 2016

Motivation: Deeper Discussion about TDR results of chapter 5

$\bar{\text{P}}$ANDA Spectrometer

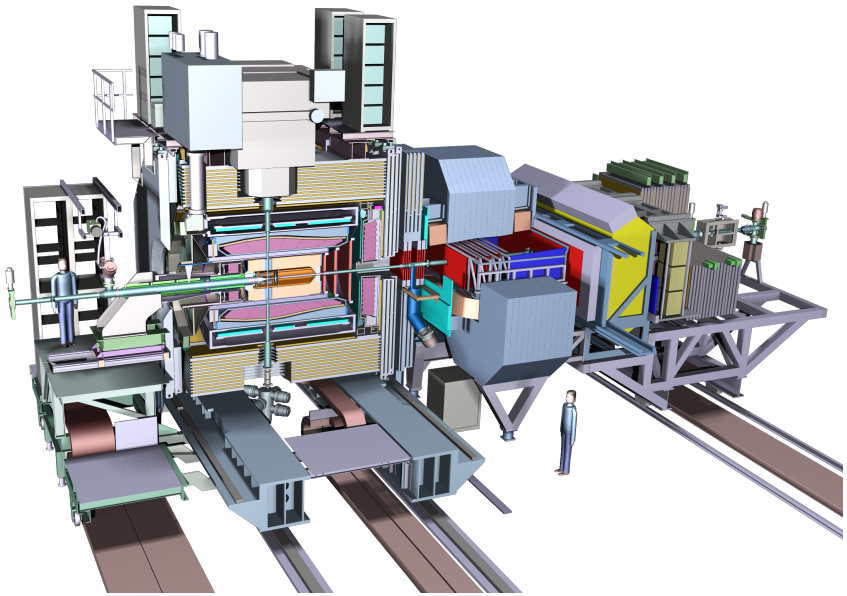
FAIR

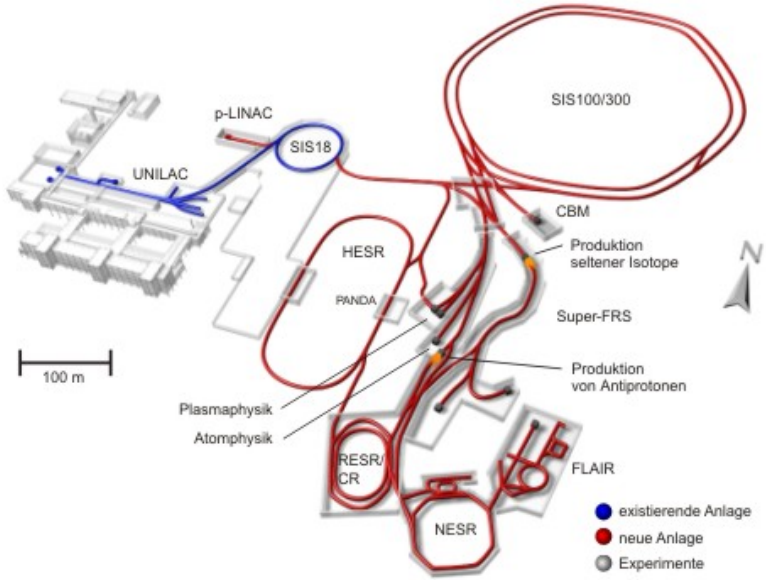
- Antiprotons $\bar{p}$ from HESR
- High luminosity mode:

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

- Average interaction rate:

$$\dot{N} = 2 \cdot 10^{7}\,\mathrm{s}^{-1}$$





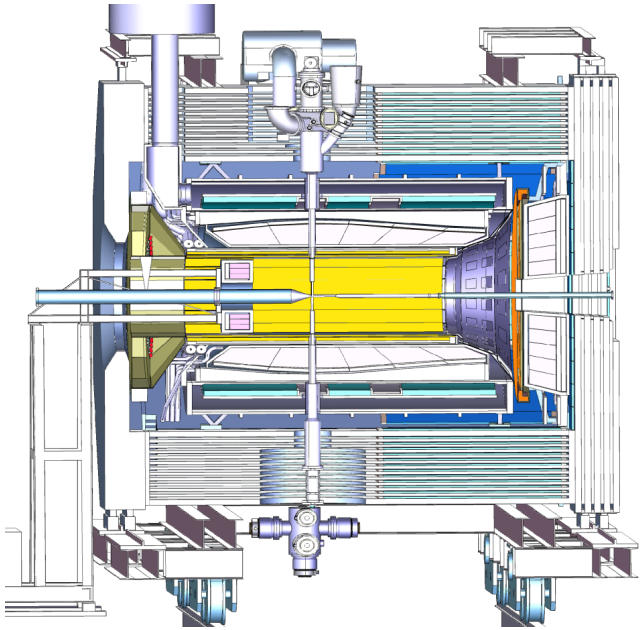
PANDA

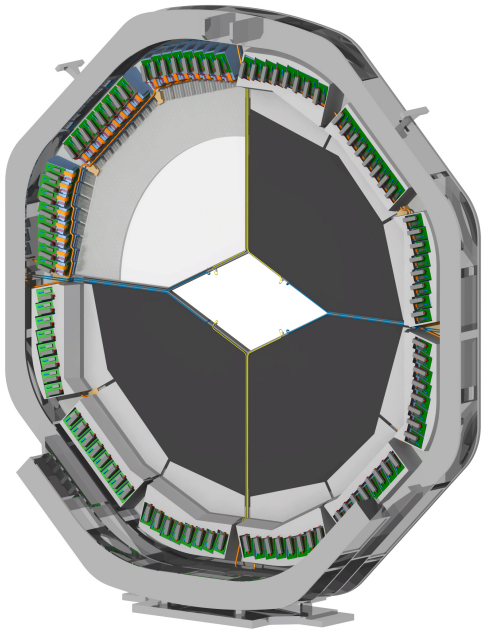
- $p\bar{p}$ collisions with hydrogen target
- Created particles with forward boost in z-direction
- Excellent PID necessary to fullfill physics program goals

Detector Concept

Particle Identification

- Two Cherenkov PID detectors in target spectrometer: Barrel & Disc DIRC
- Large area of kaon phase space covered with both detectors





Disc DIRC

- Only 2 cm thickness in z-direction
- Radiator disk consisting of 4 independent fused silica quadrants
- 98 multi channel plates photomultipliers (MCP-PMT)
- 218 focusing elemts

Detector Overview

Opening angle of Cherenkov Cone:

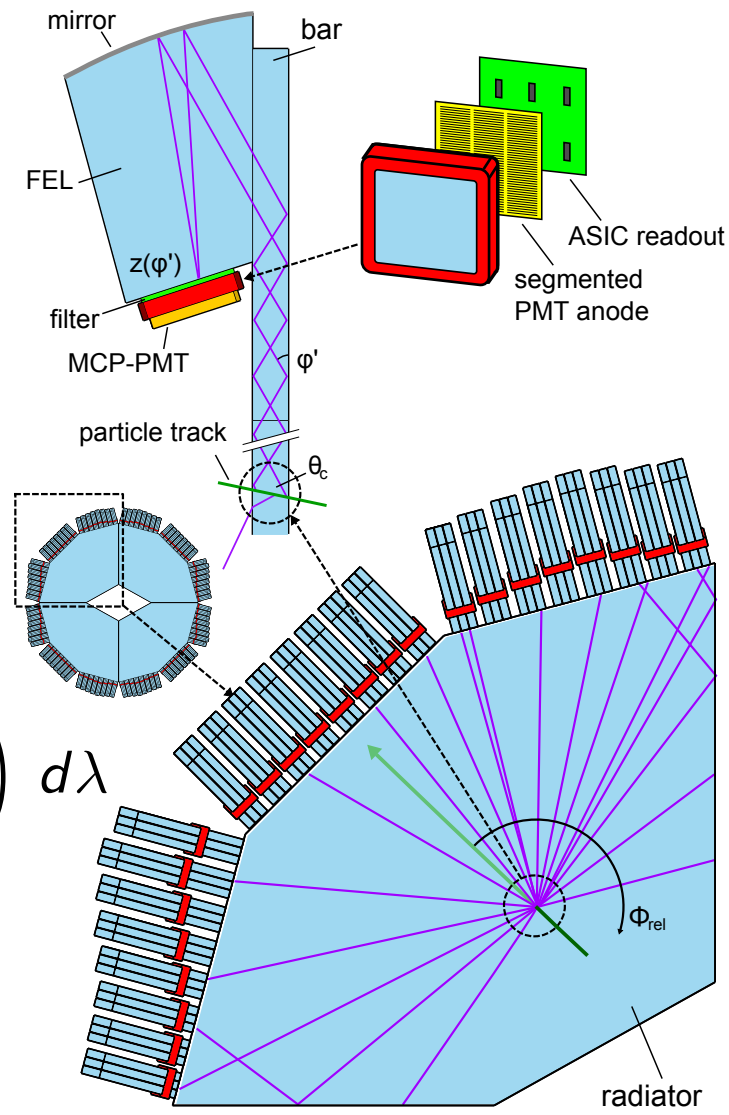
$$\theta_C = \arccos\left(\frac{1}{n(\lambda)\beta}\right)$$

with $\beta = p/(m_0^2 + p^2)$.

Number of photons per track length according to Frank-Tamm-Formula:

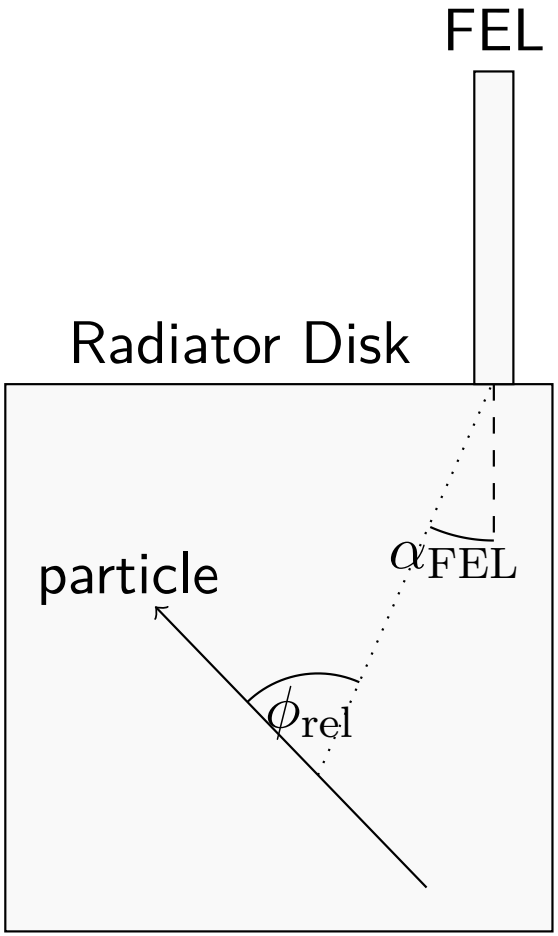
$$\frac{dN}{dx} = 2\pi\alpha z^2 \int_{\lambda_1}^{\lambda_2} \left(\frac{1}{\lambda^2} - \frac{1}{n^2(\lambda)\beta^2\lambda^2}\right) d\lambda$$

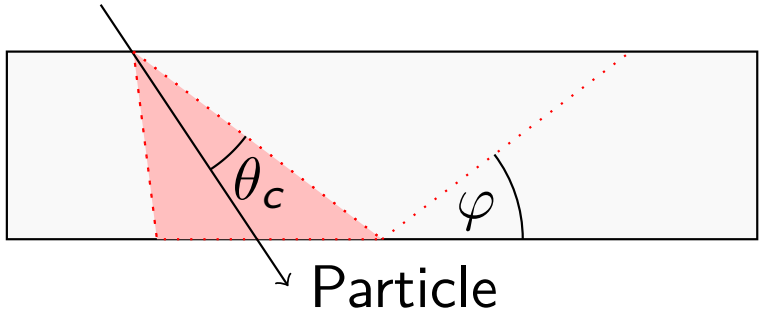
$$\approx 1000\,\text{Photons/Event for } \pi^{\pm} \text{ with } 4\,\text{GeV/c momentum}$$



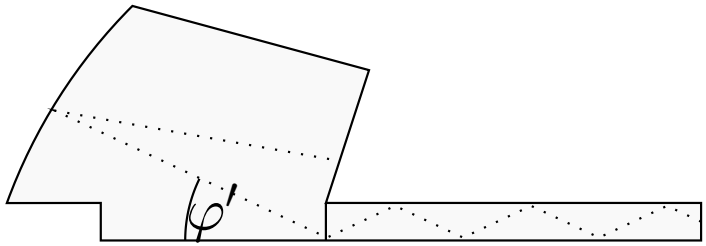
Geometrical Model for Reconstruction

Taking particle position $\vec{x}$ and momentum $\vec{p}$ from tracking:



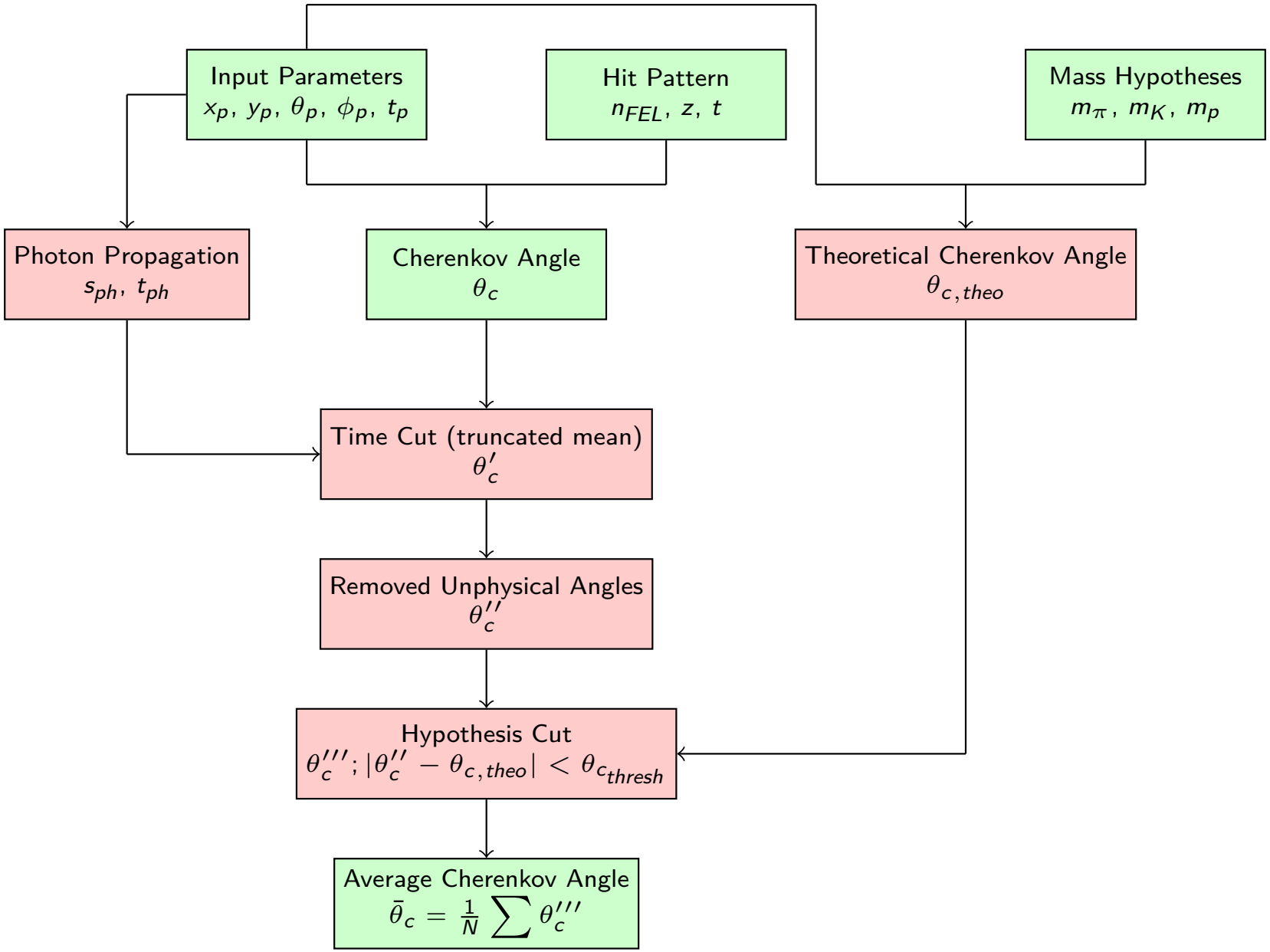


$$\tan\varphi' = \frac{\tan\varphi}{\tan\alpha_{FEL}}$$



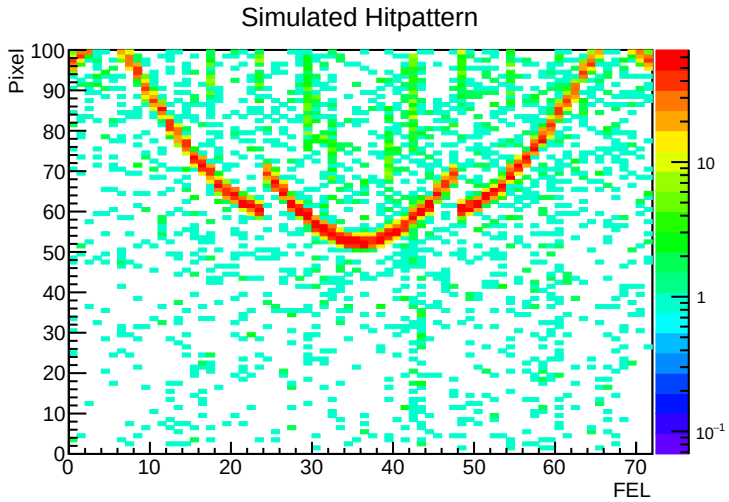
$$\theta_c = \arccos(\sin\theta_p \cos\phi_{rel} \cos\varphi + \cos\theta_p \sin\varphi)$$

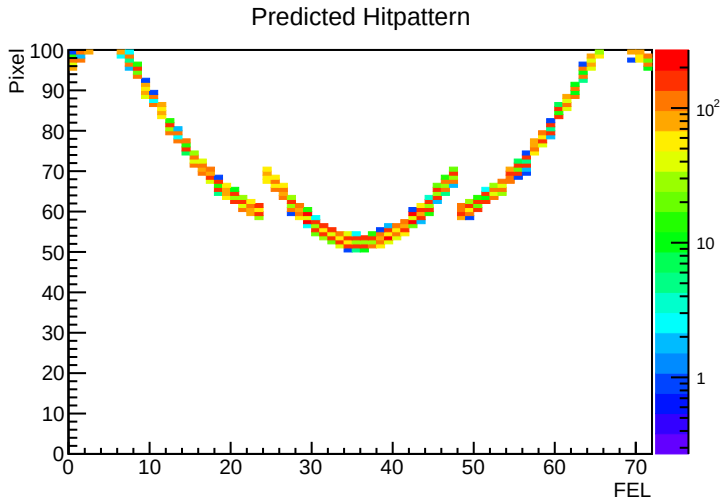
Backward Reconstruction Algorithm



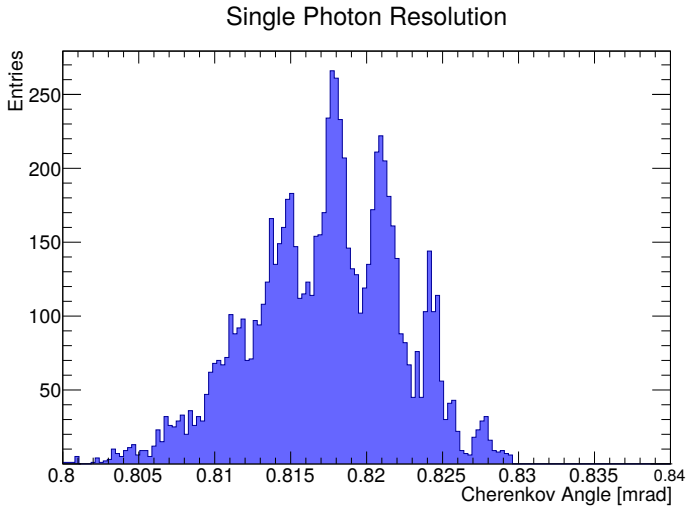
Cherenkov Angle Resolution

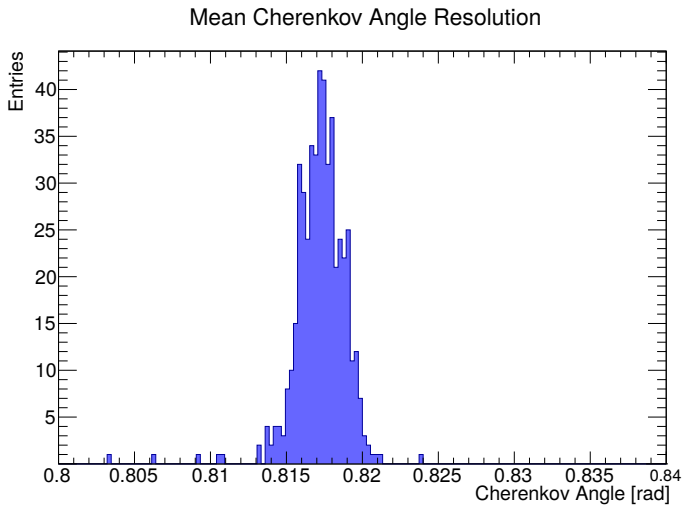
Hit pattern with new geometry:





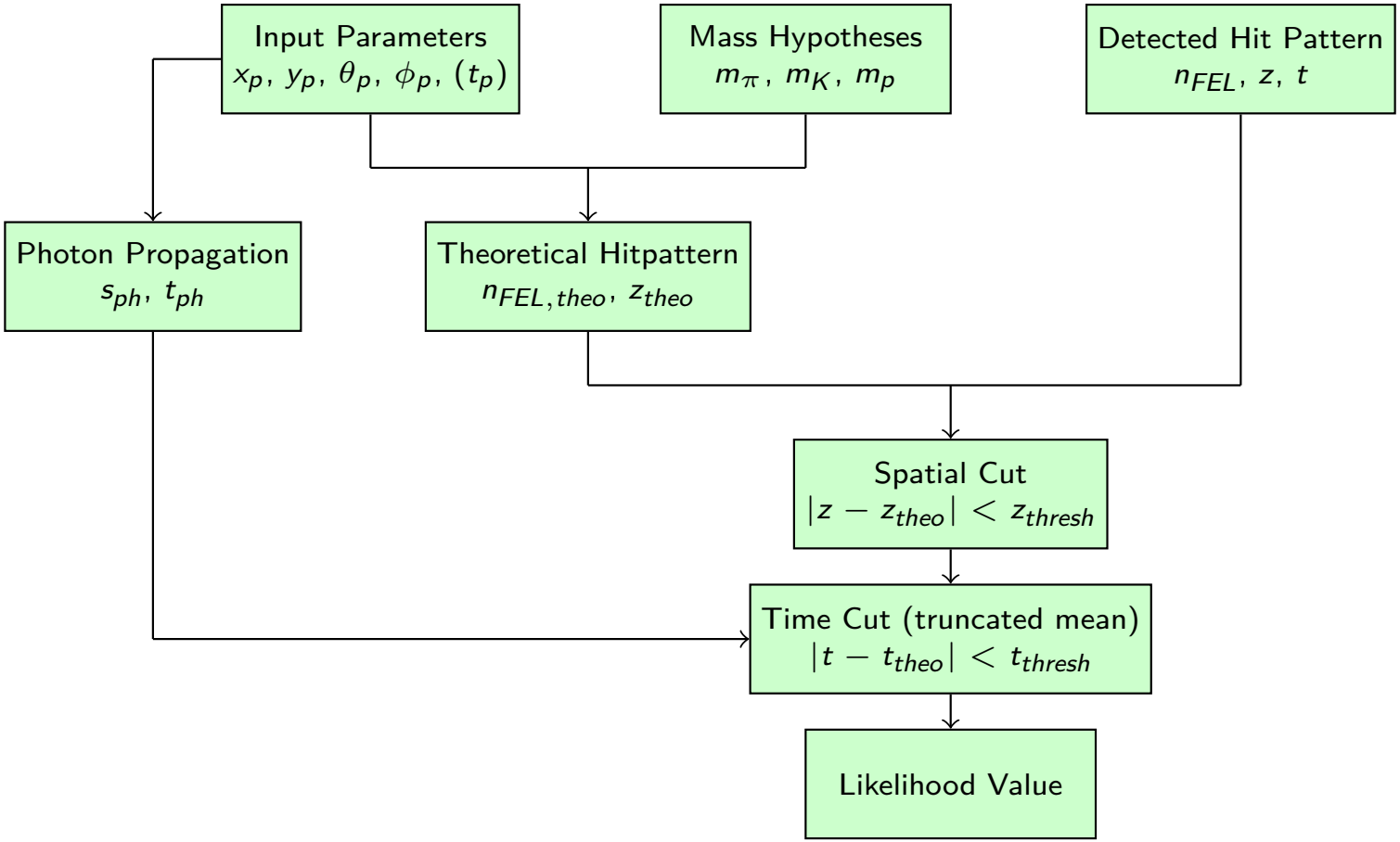
Single photon resolution and detector resolution:





Foward Reconstruction Algorithm

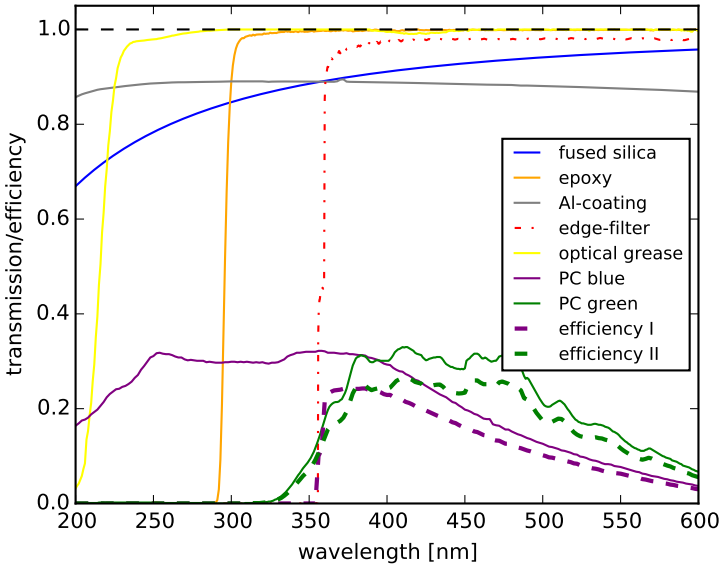
More calculation steps $\rightarrow$ offline reconstruction



Pseudo likelihood function for accepted hits:

$$\ln \mathcal{L} = \sum_{i=0}^{N} \left(\ln \mathcal{G}(z_i | z_{pred,i}; \sigma_z) + \ln \mathcal{G}(t_i | t_{pred,i}; \sigma_t) \right) \qquad (1)$$

Monte-Carlo Parameters



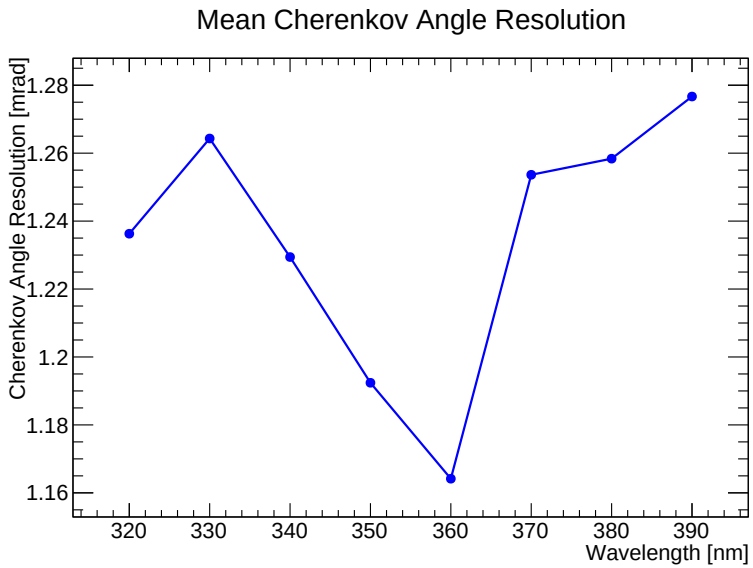
Inserted parameters in PandaRoot:

- Mirror reflectivity of focusing elements
- MCP detection efficiency (Two photo cathodes)
- Transmission coefficiencies of epoxy, optical grease, fused silica and filter

- Detector resolution::

$$\sigma_\theta^2 = \frac{\sigma_{ph}^2}{N} + \sigma_{track}^2$$

- σ_{ph} containing chromatic error
- Using longpass filter with minimum wavelength

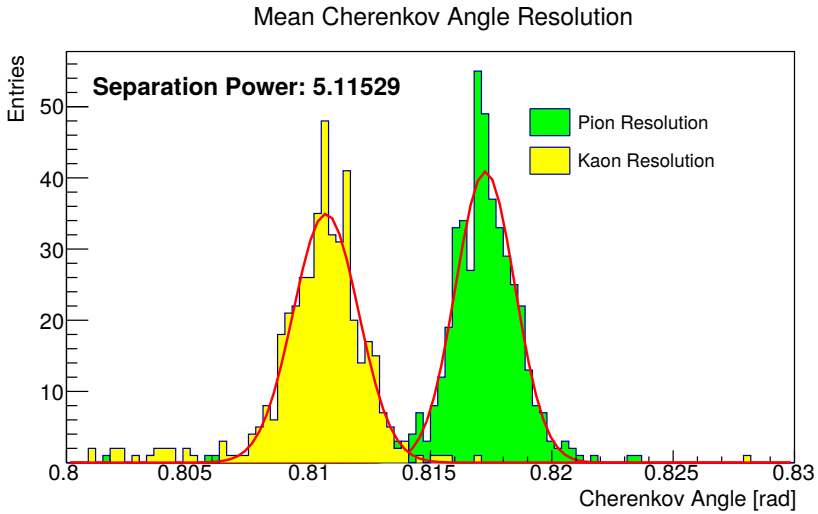


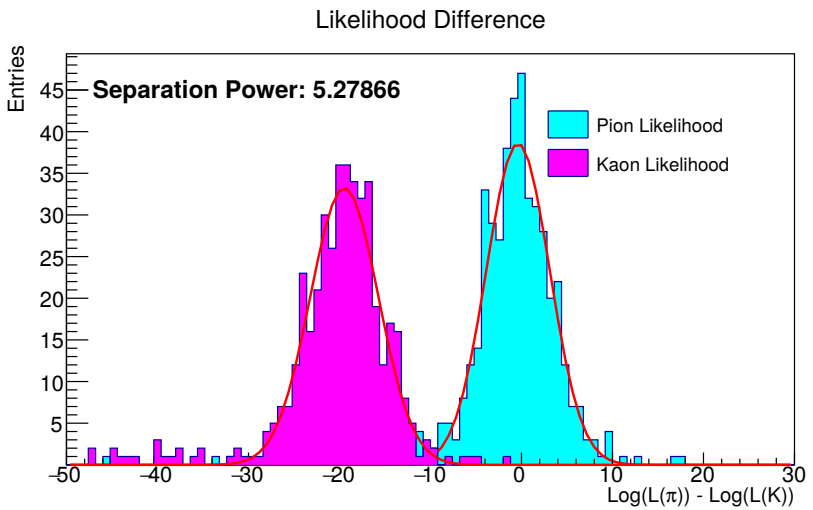
Algorithm Comparisons

- Comparison between backward and forward algorithm
- 1000 events with π^+ and K^+
- Momentum: 4 GeV/c
- Theta: 12°
- Phi: 45°
- Calculation of separation power:

$$n_\sigma = \frac{\mu_K - \mu_\pi}{\frac{1}{2}(\sigma_K + \sigma_\pi)}$$

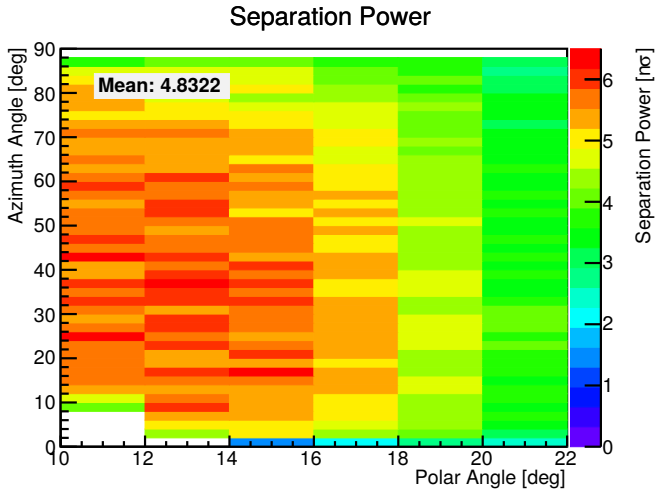
- Both results almost identical

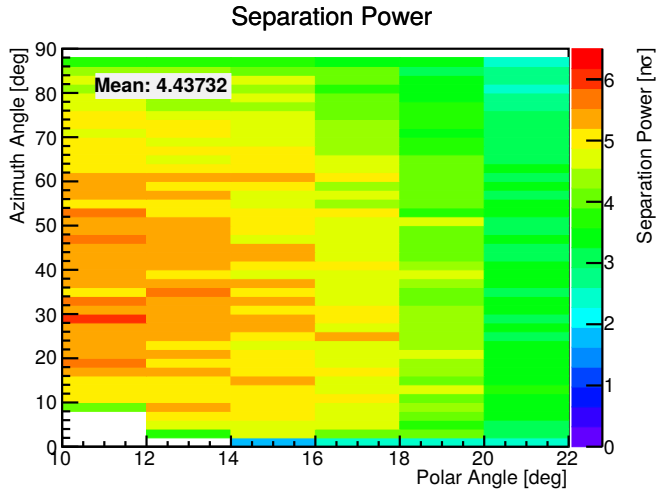




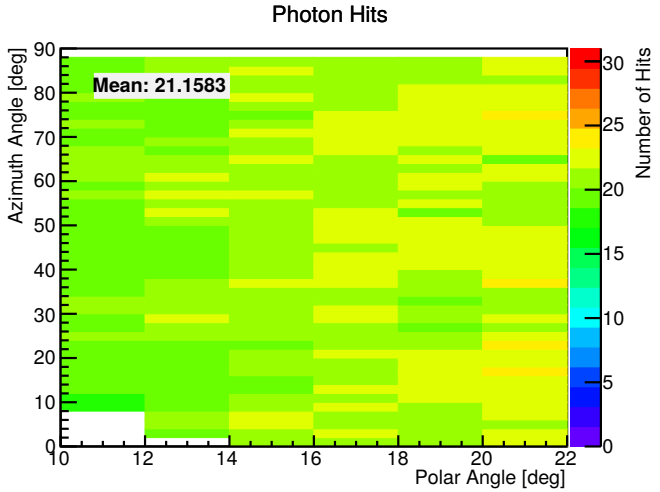
Performance Studies

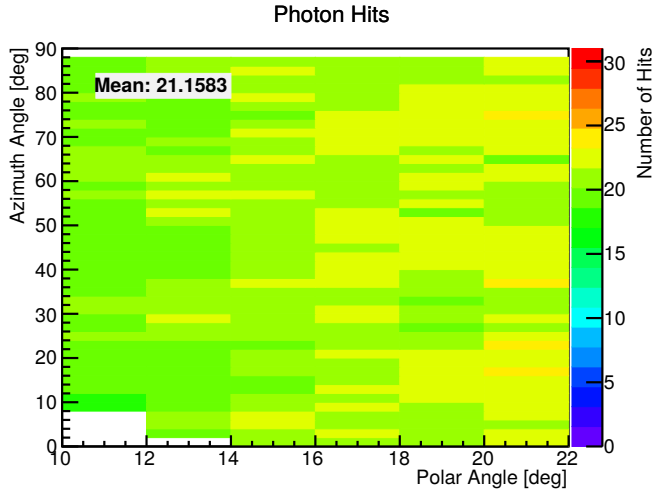
Separation power blue/green photo cathode:





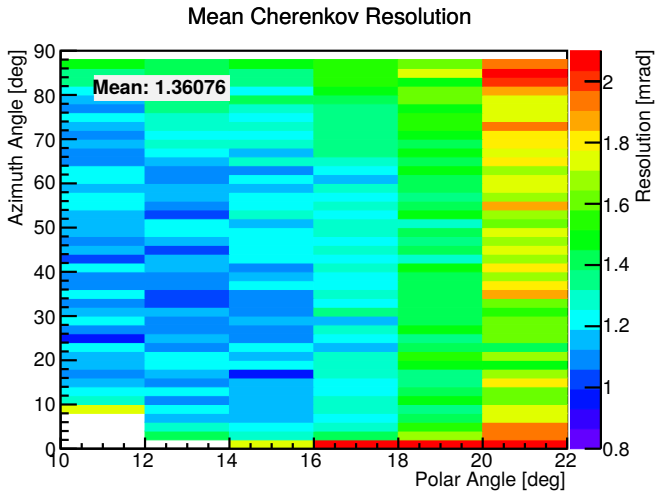
Photon hits blue/green photo cathode:

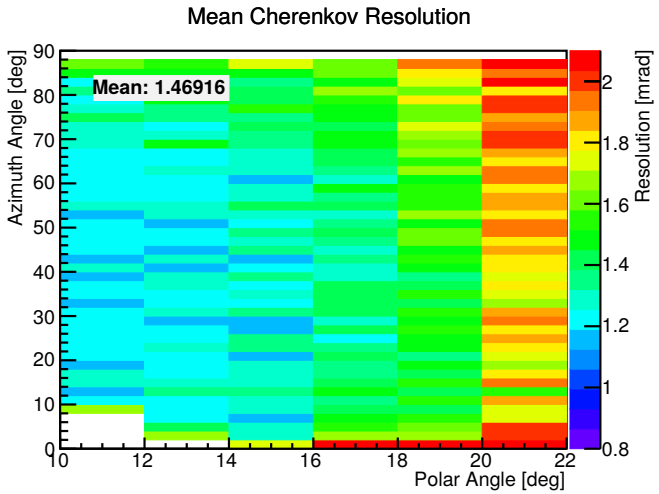




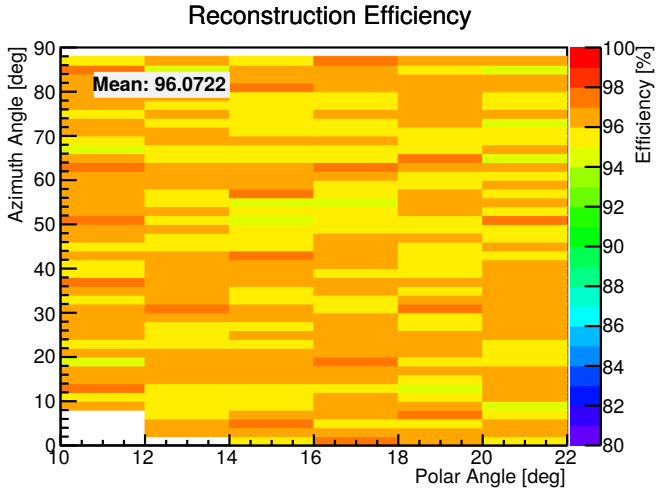
Performance Studies

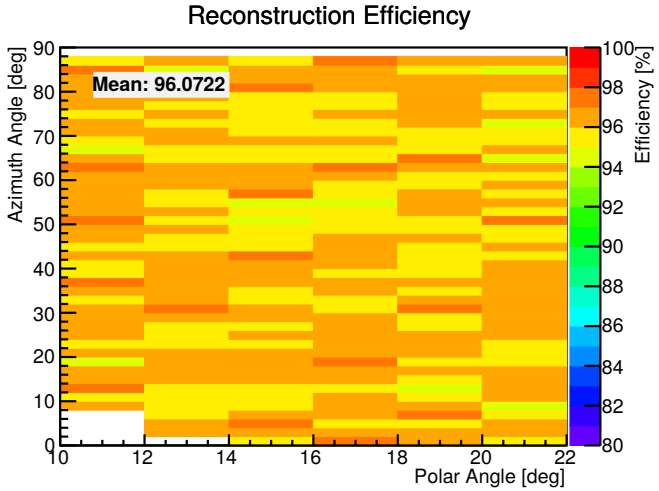
Detector Resolution blue/green photo cathode:





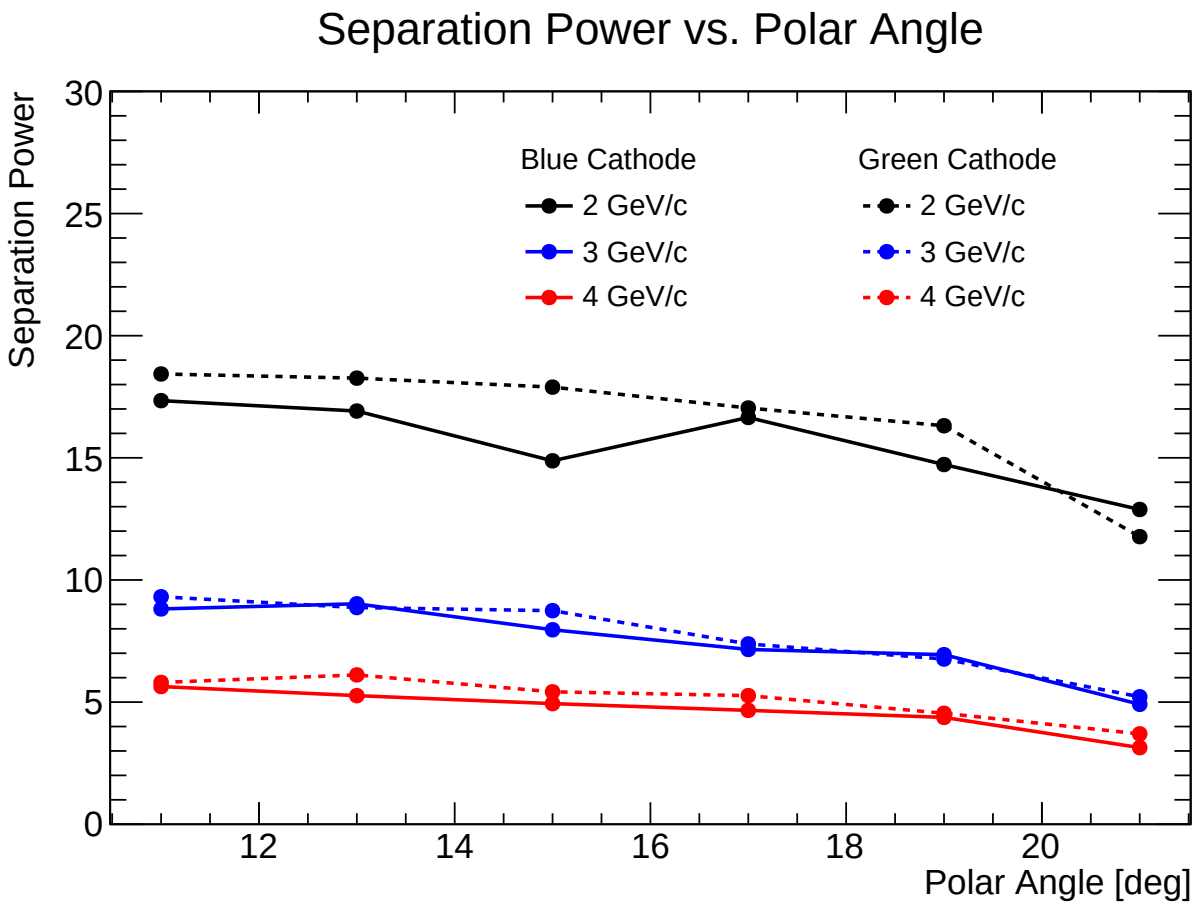
Reconstruction Efficiency blue/green photo cathode:





Separation Power

Separation Power for different momenta as function of polar angle:

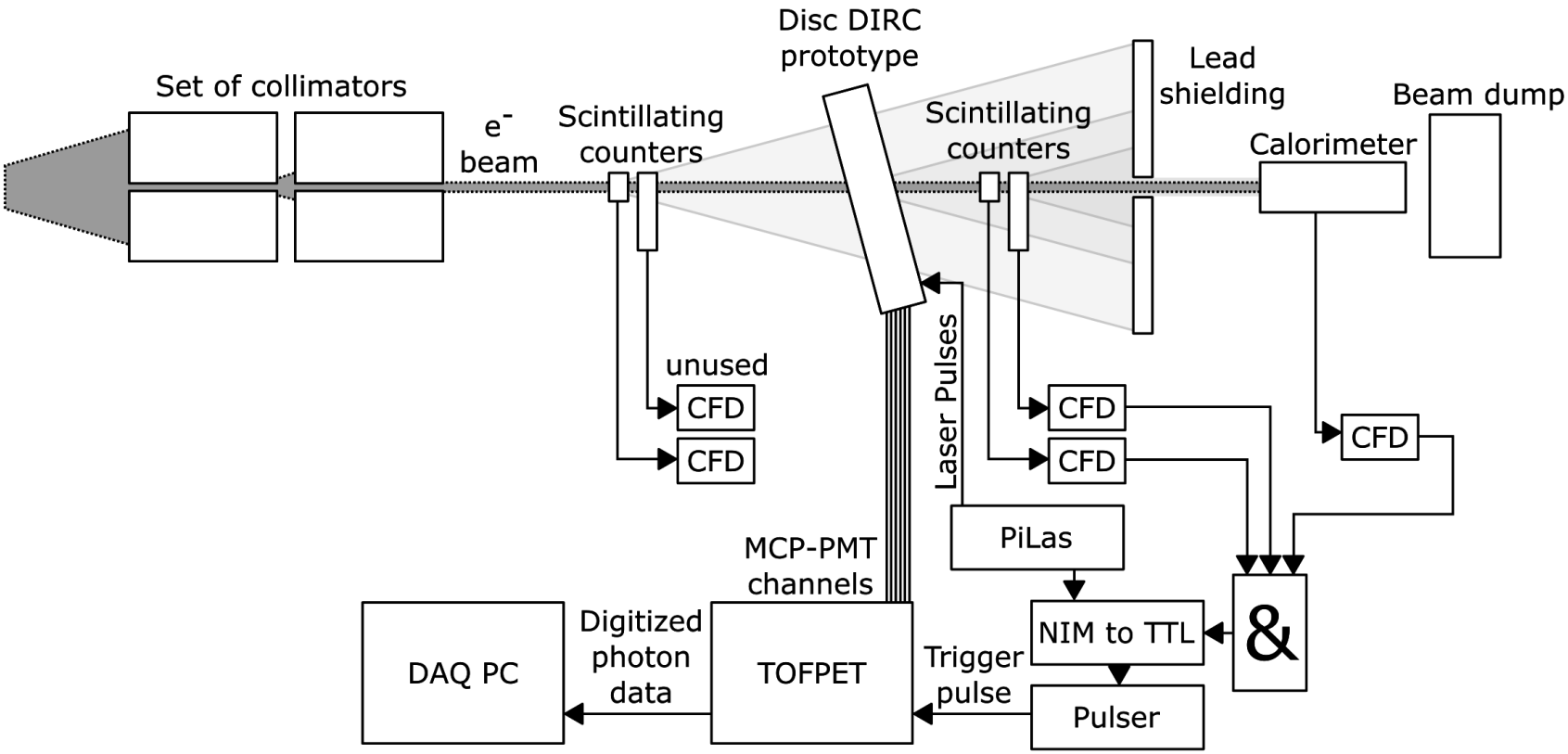


Important Results:

- Small difference between photo cathodes
- Worse resolution for larger polar angles

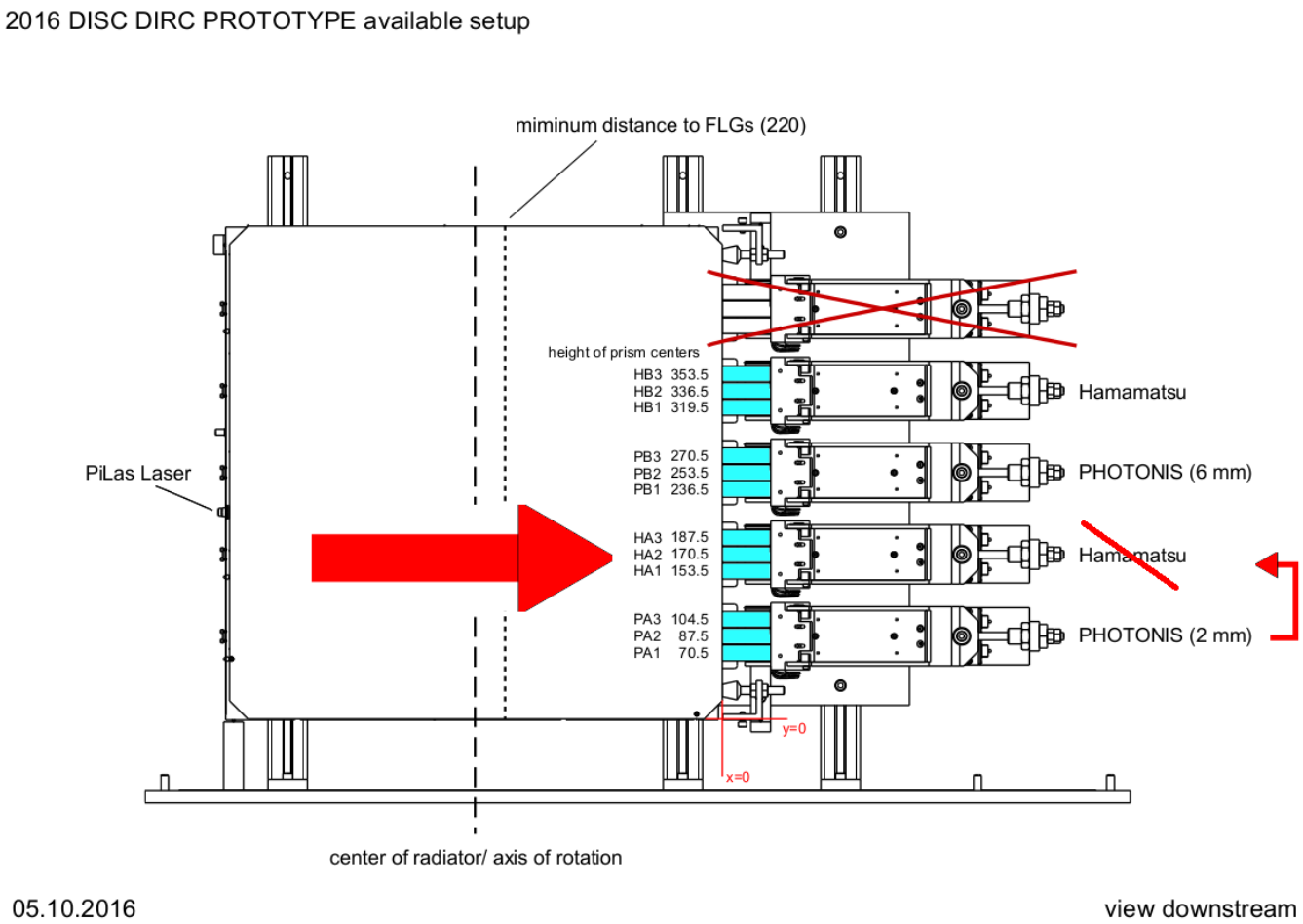
Testbeam Setup

DESY testbeam setup for T24/1 hall:



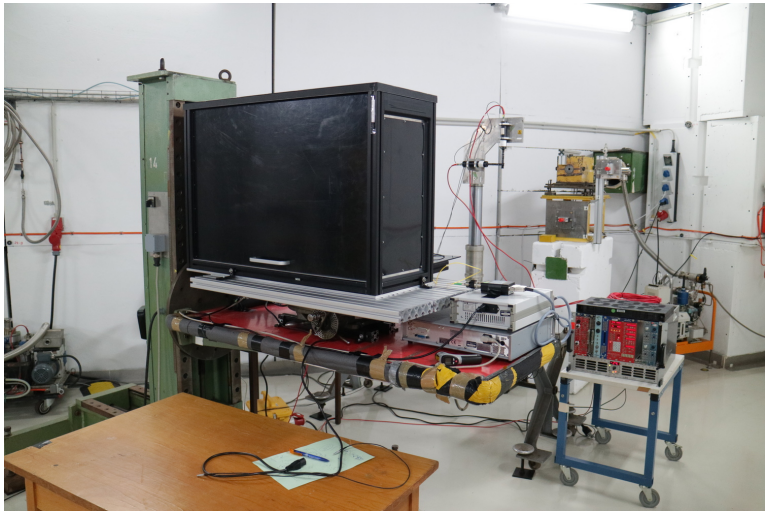
TOFPET: Free running readout device with 50 ps time resolution

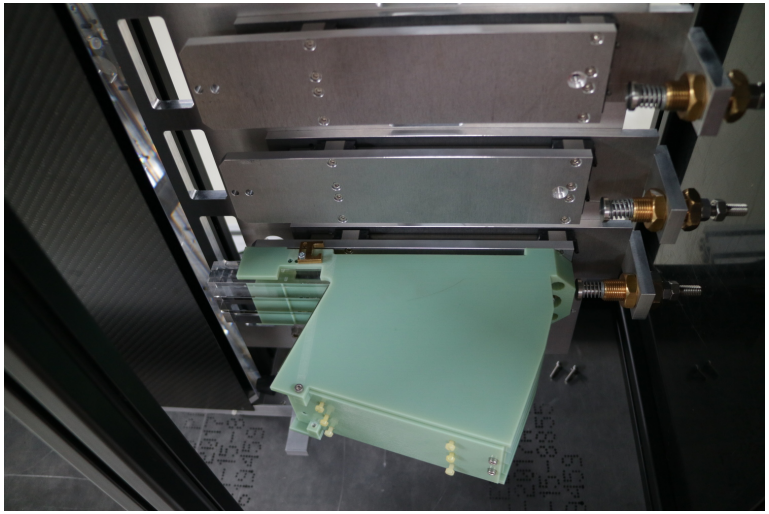
Radiator Setup

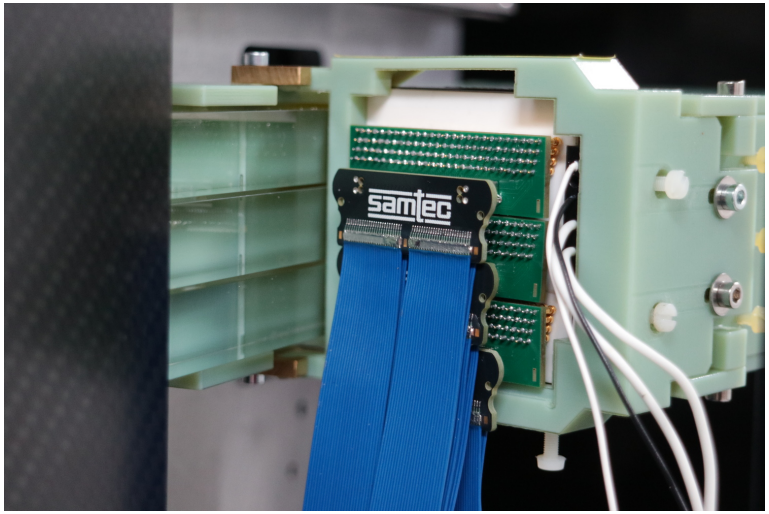


Testbeam radiator: Fused silica plate ($50\,\mathrm{cm} \times 50\,\mathrm{cm}$ fused silica plate with 1 nm surface roughness)

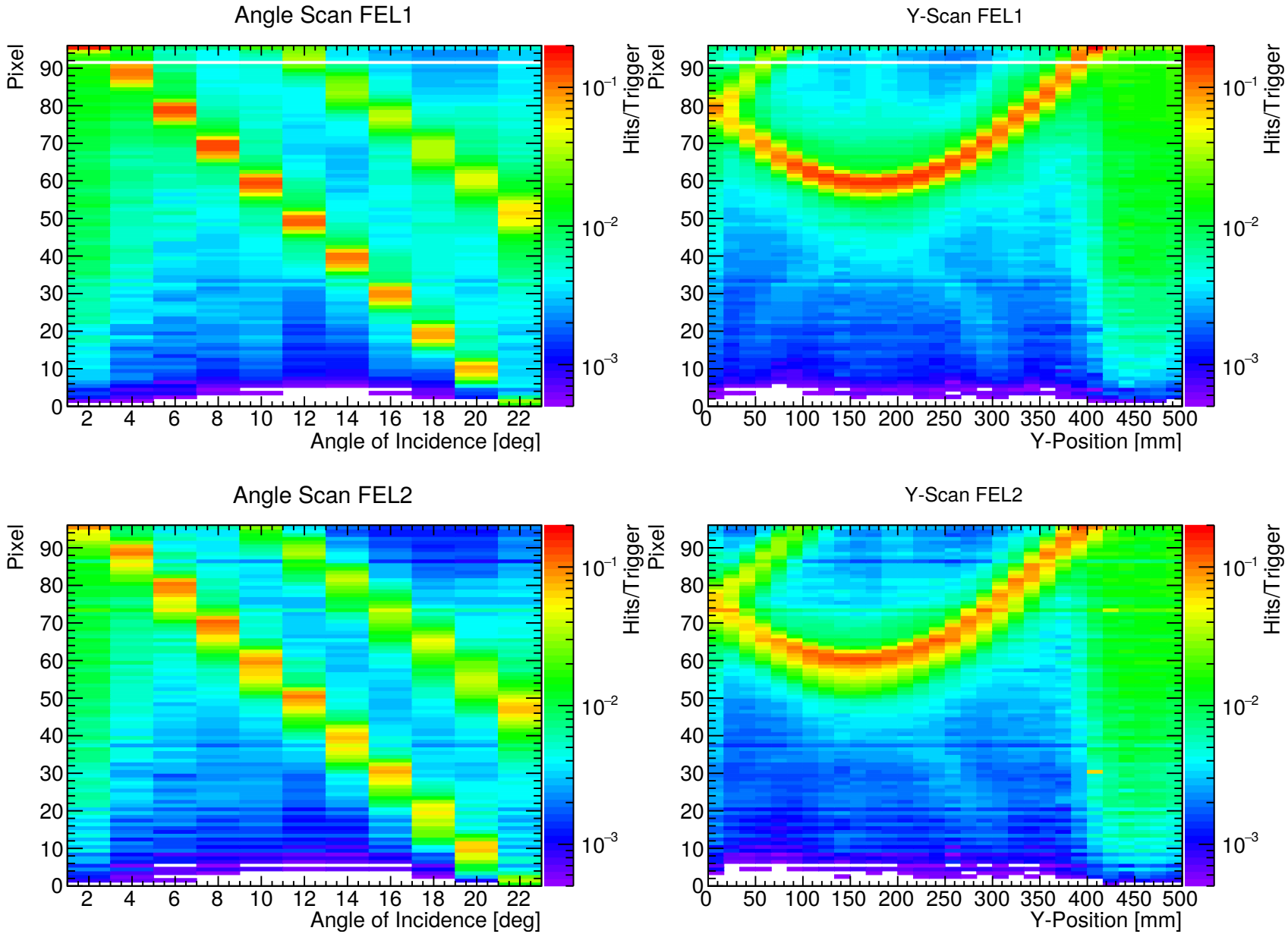
Testbeam Fotos





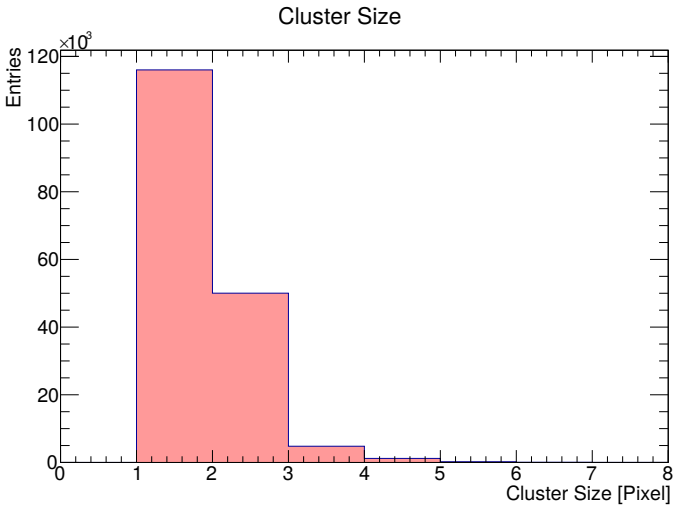


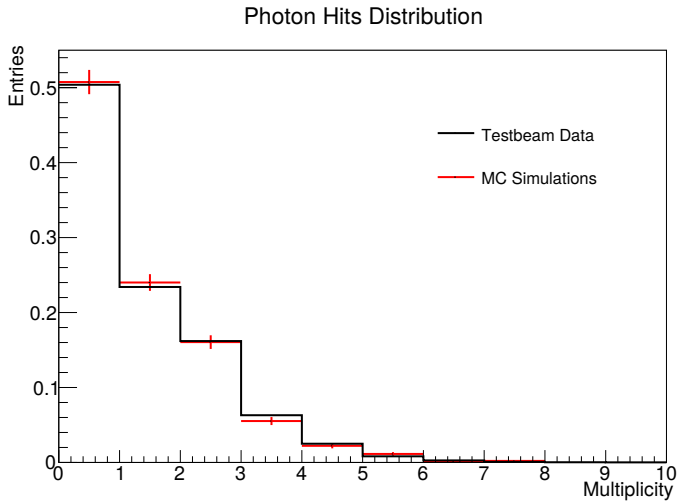
Measured Hitpattern



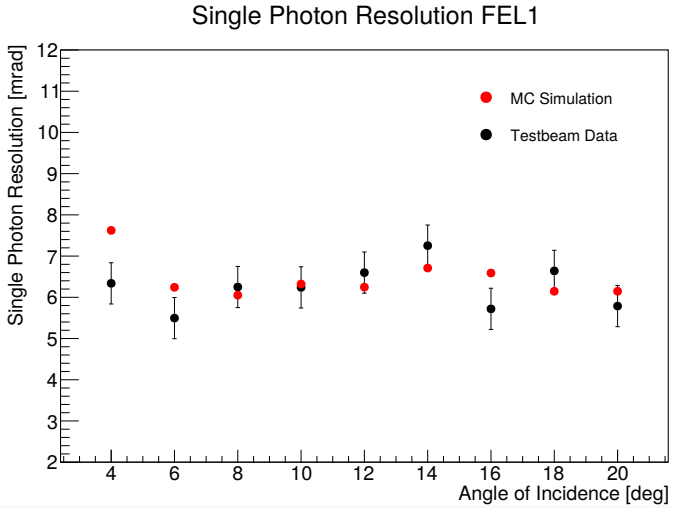
Testbeam Results

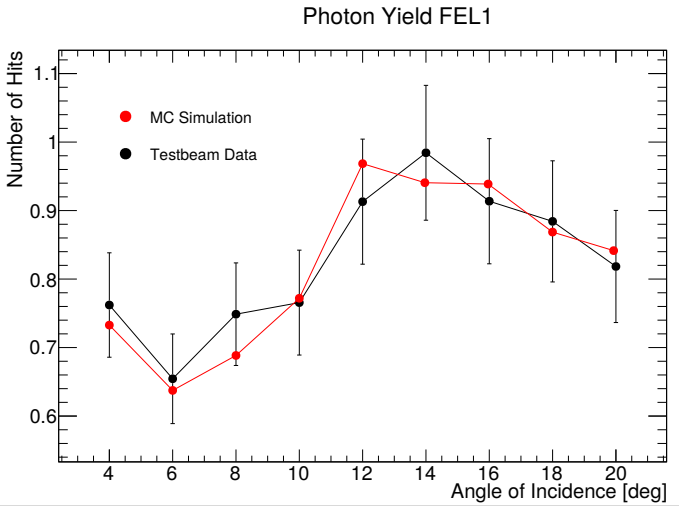
Estimating charge sharing from cluster size ($\approx 30\%$):



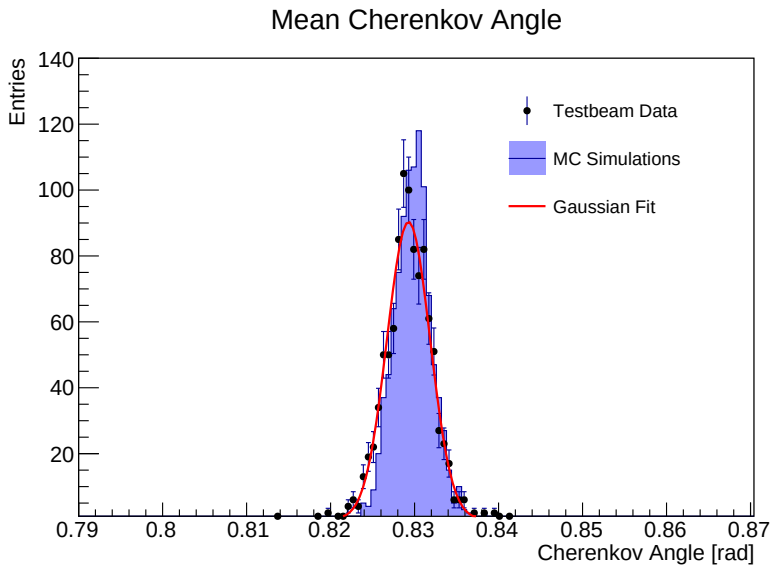


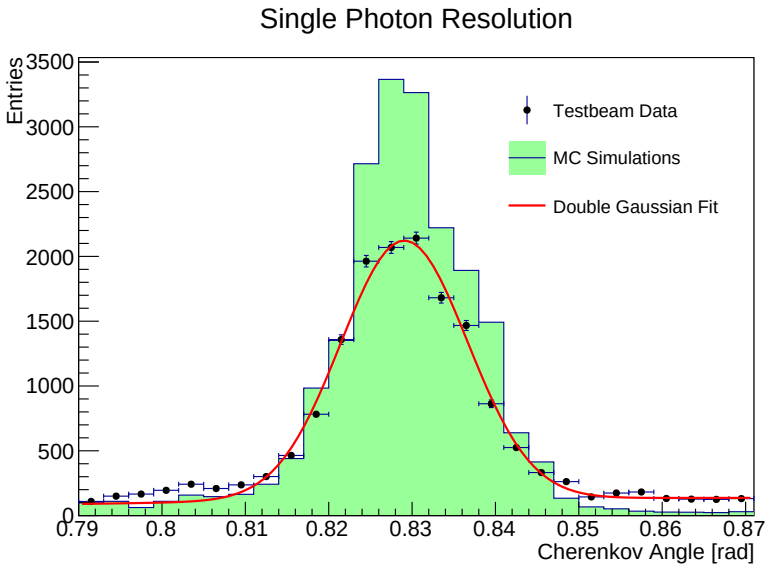
Single photon resolution and photon yield:

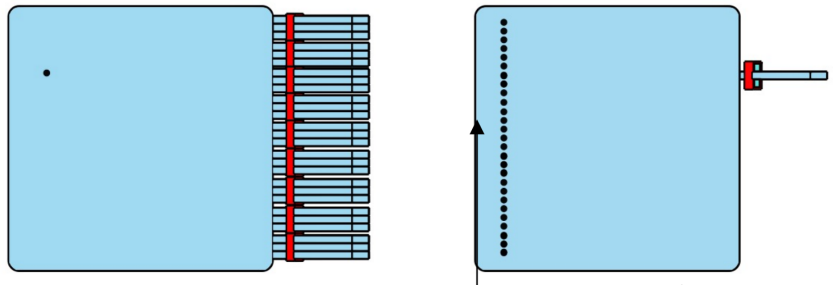




Event Combination

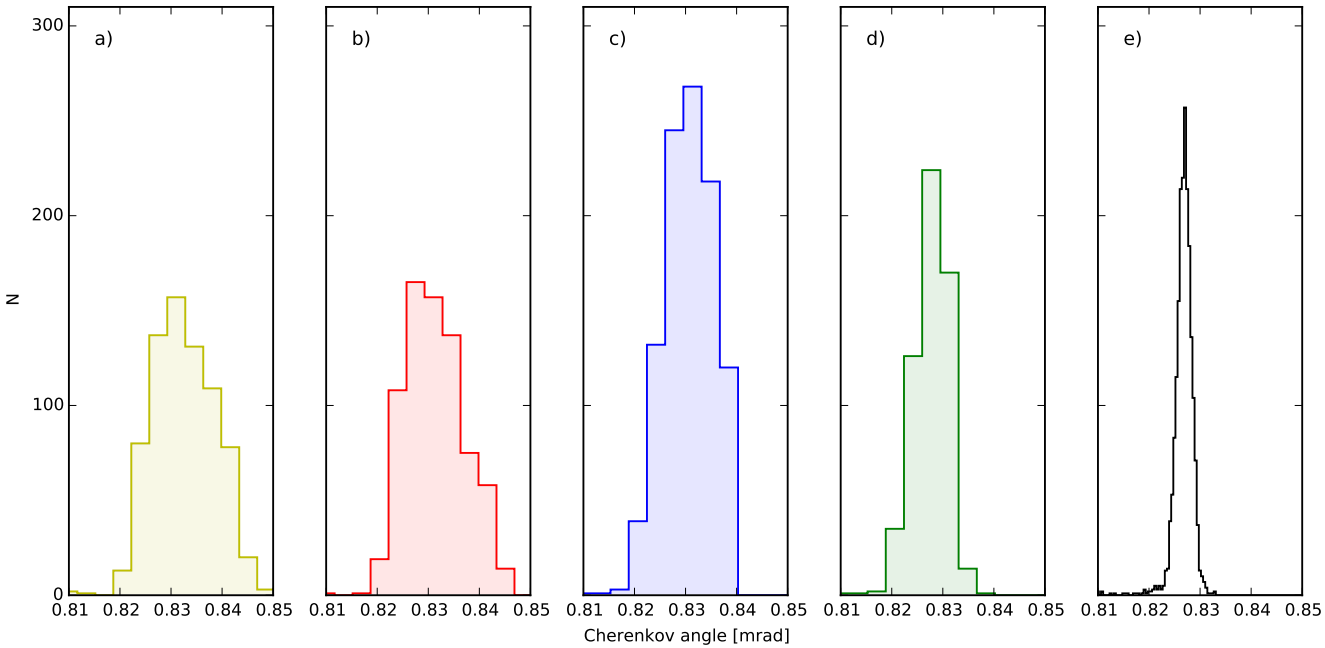






- Combining each event from every position to one new event
- Making a coarse time cut according to photon propagation time
- Reduction of background with truncated mean of pixel hits
- Obtained resolutions:
  $\sigma_\theta = 7.75\,\text{mrad}$
  $\sigma_{\bar{\theta}} = 2.52\,\text{mrad}$

Result Extrapolation



radiator	particle	filter	#FEL	single photon resolution
prototype	e	-	1	6.06 mrad
prototype	π	-	1	5.95 mrad
PANDA	π	-	1	4.80 mrad
PANDA	π	LP	1	3.45 mrad
PANDA	π	LP	24	1.80 mrad

Thank you very much for your attention!