JUSTUS-LIEBIG-UNIVERSITÄT GIESSEN

Particle Identification with Disc DIRC at PANDA

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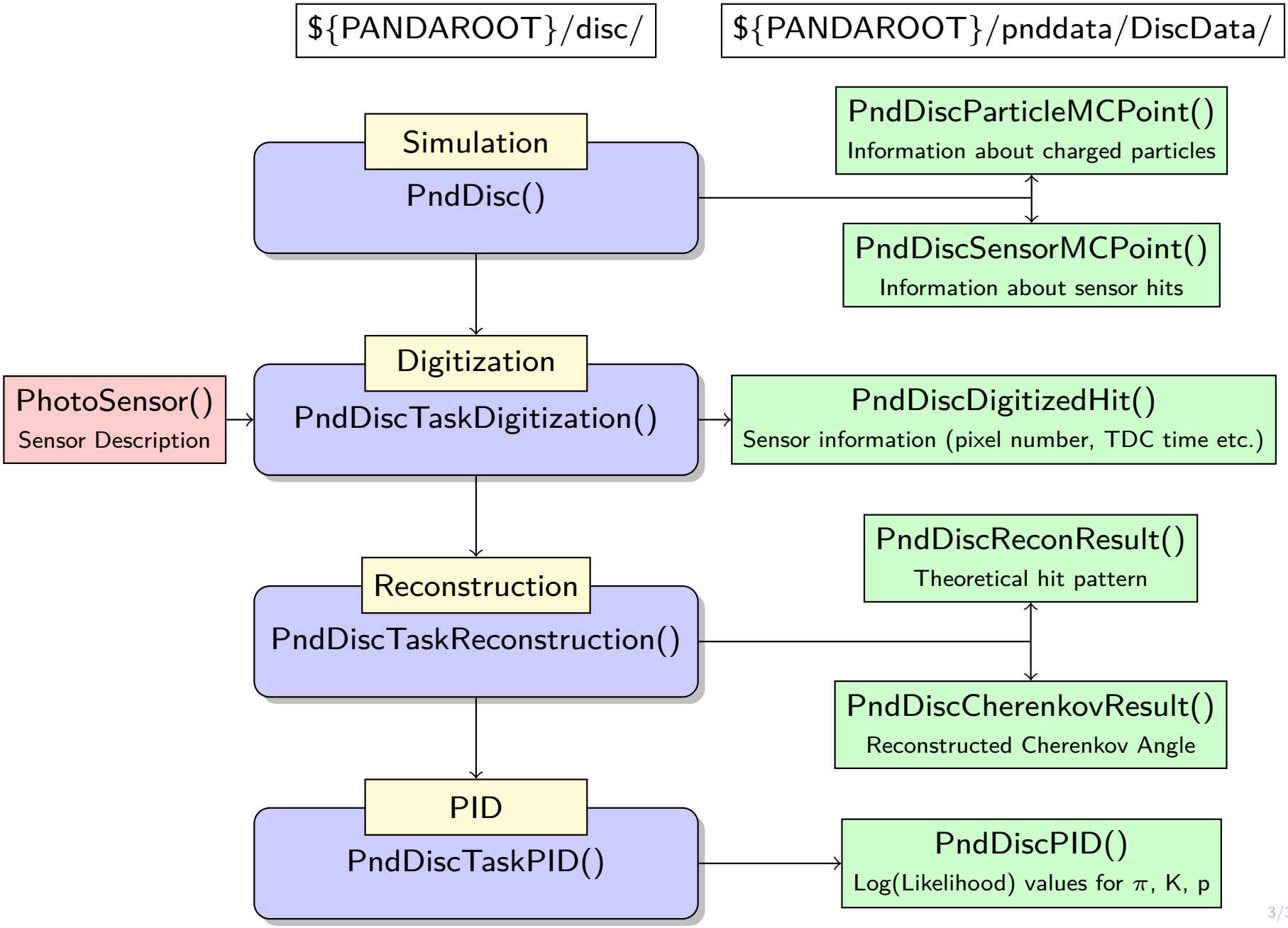
HGS-HIRe for FAIR
Helmholtz Graduate School for Hadron and Ion Research

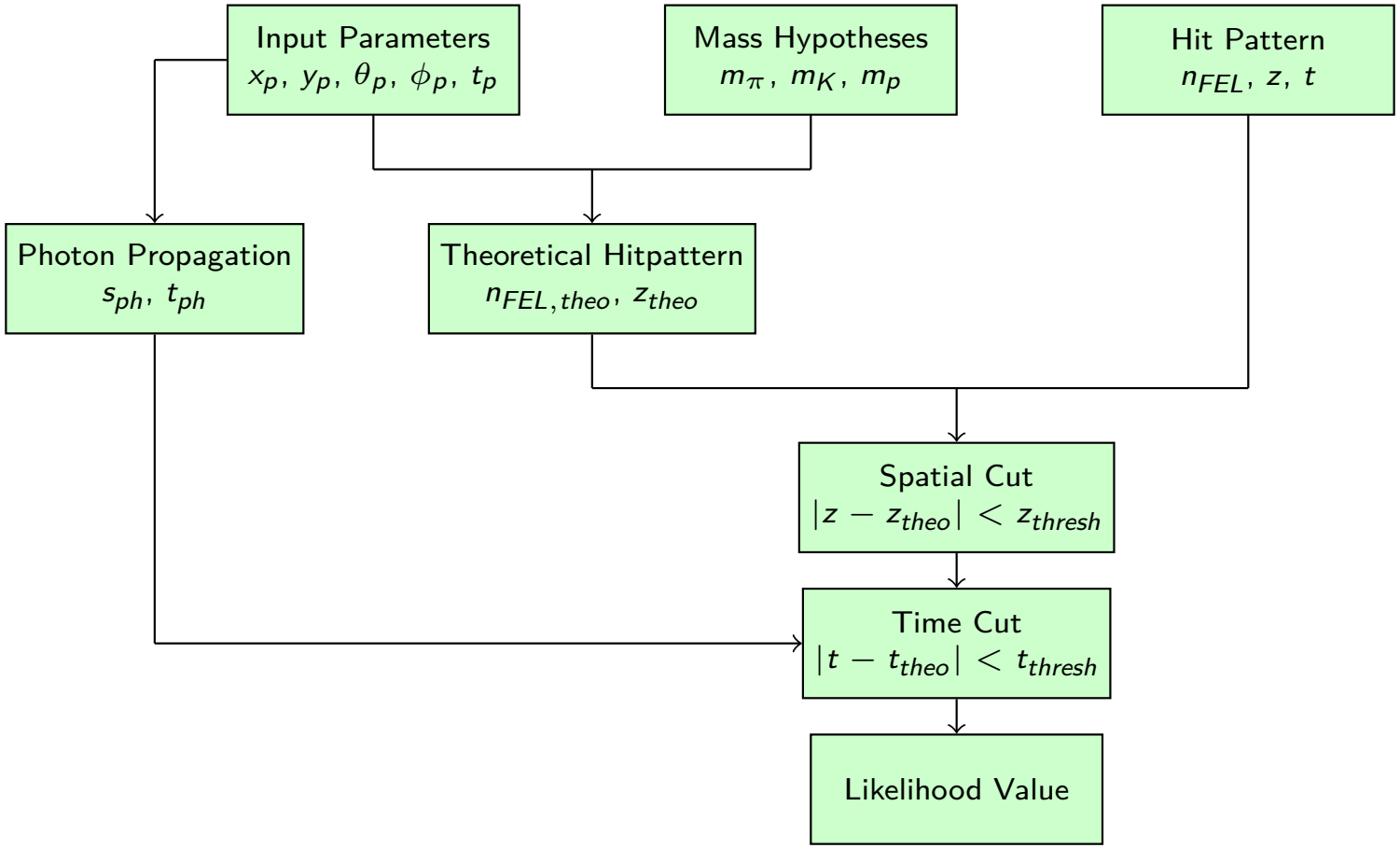
Outline

Reconstruction & PID

Full Simulation Chain

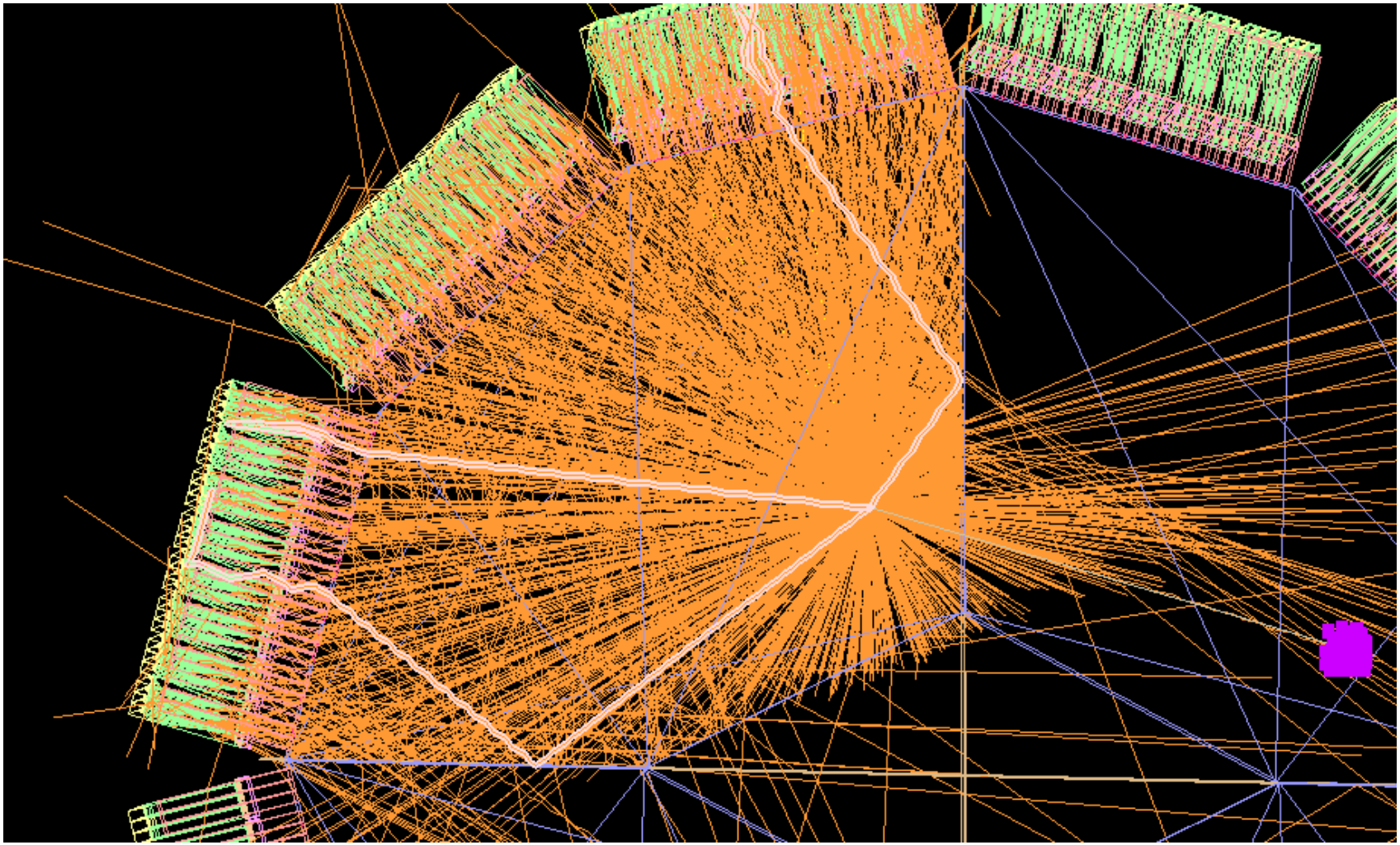


Hitpattern Matching



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

Event Display with Photon Reflections



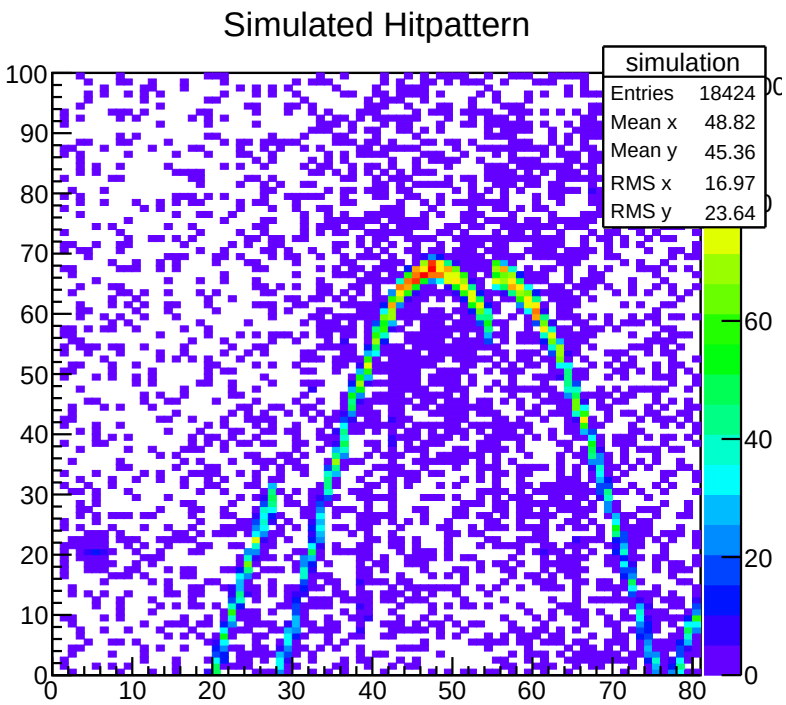
Simulation Parameters

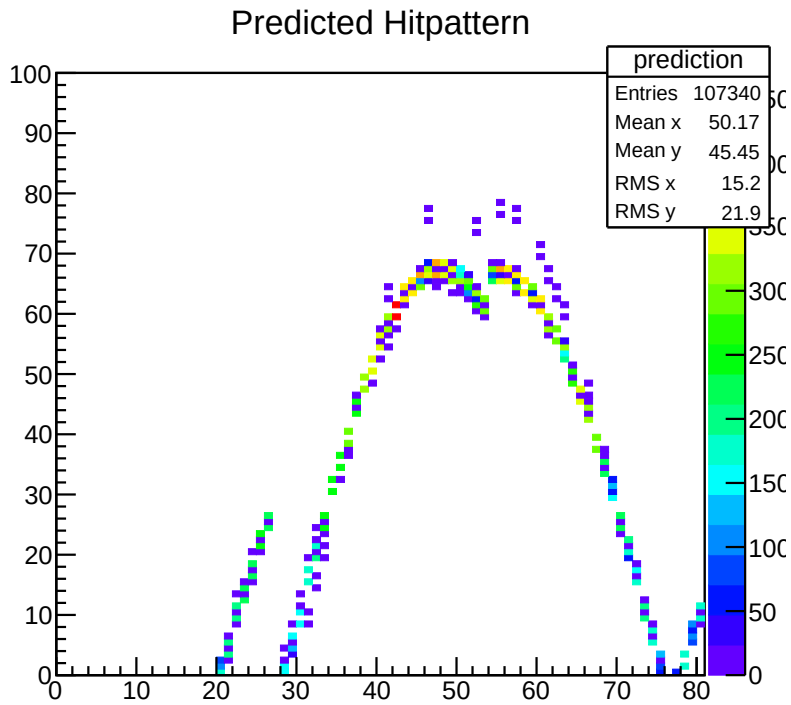
Assumed parameters for event based simulations:

- Surface roughness: $\sigma = 1.0\,\text{nm}$
- Time resolution: 21 ps
- Pixel dead time: 20 ns
- TDC binning: 50 ps
- Position resolution: $\sigma_{x,y} = 1.5\,\text{mm}$
- Momentum resolution: $\sigma_{p_x,p_y,p_z} = 10\,\text{MeV/c}$
- Spatial cut: $3\sigma_{\theta_C}$ (calculated SPR)
- Reconstruction time cut: 1.0 ns

Simulated and Reconstructed Hitpattern

Parameters: $\theta = 12°$, $\phi = 45°$, $p = 4\,\mathrm{GeV/c}$, 500 Pions and Kaons

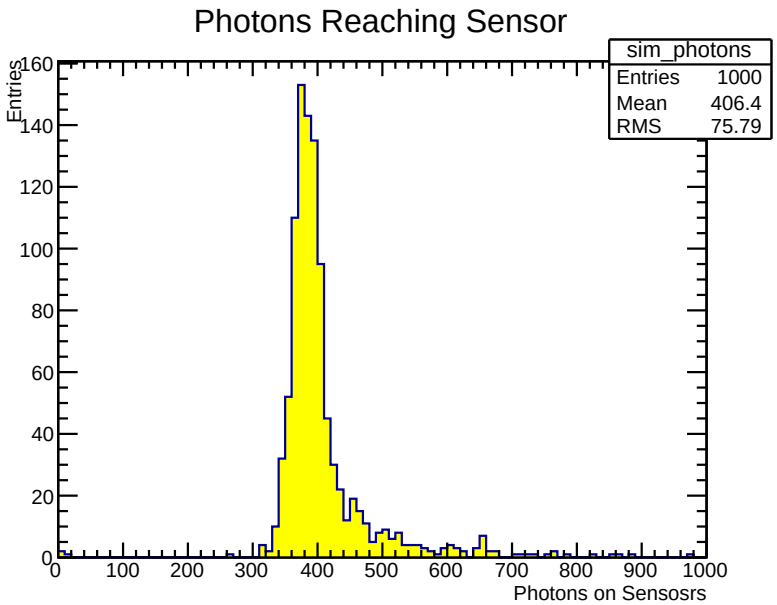


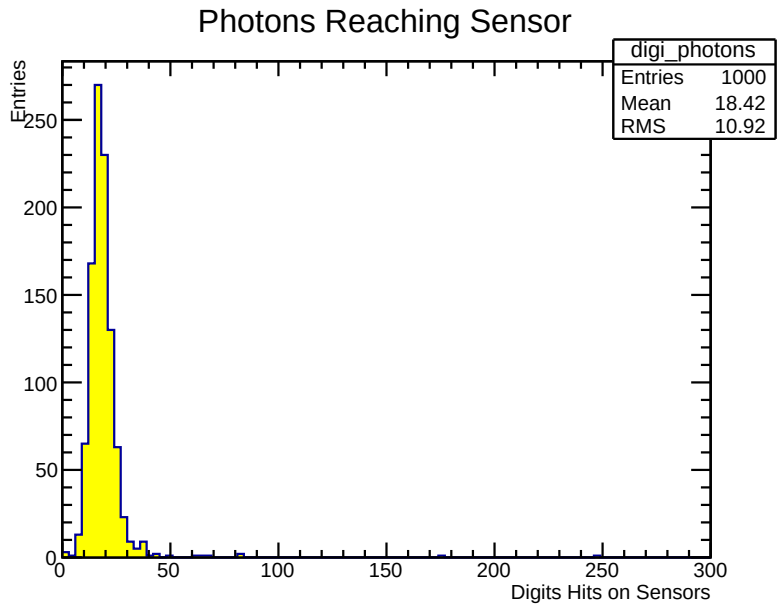


Blue photon cathode, air gap, no mirror, long-pass filter

Photon Yield

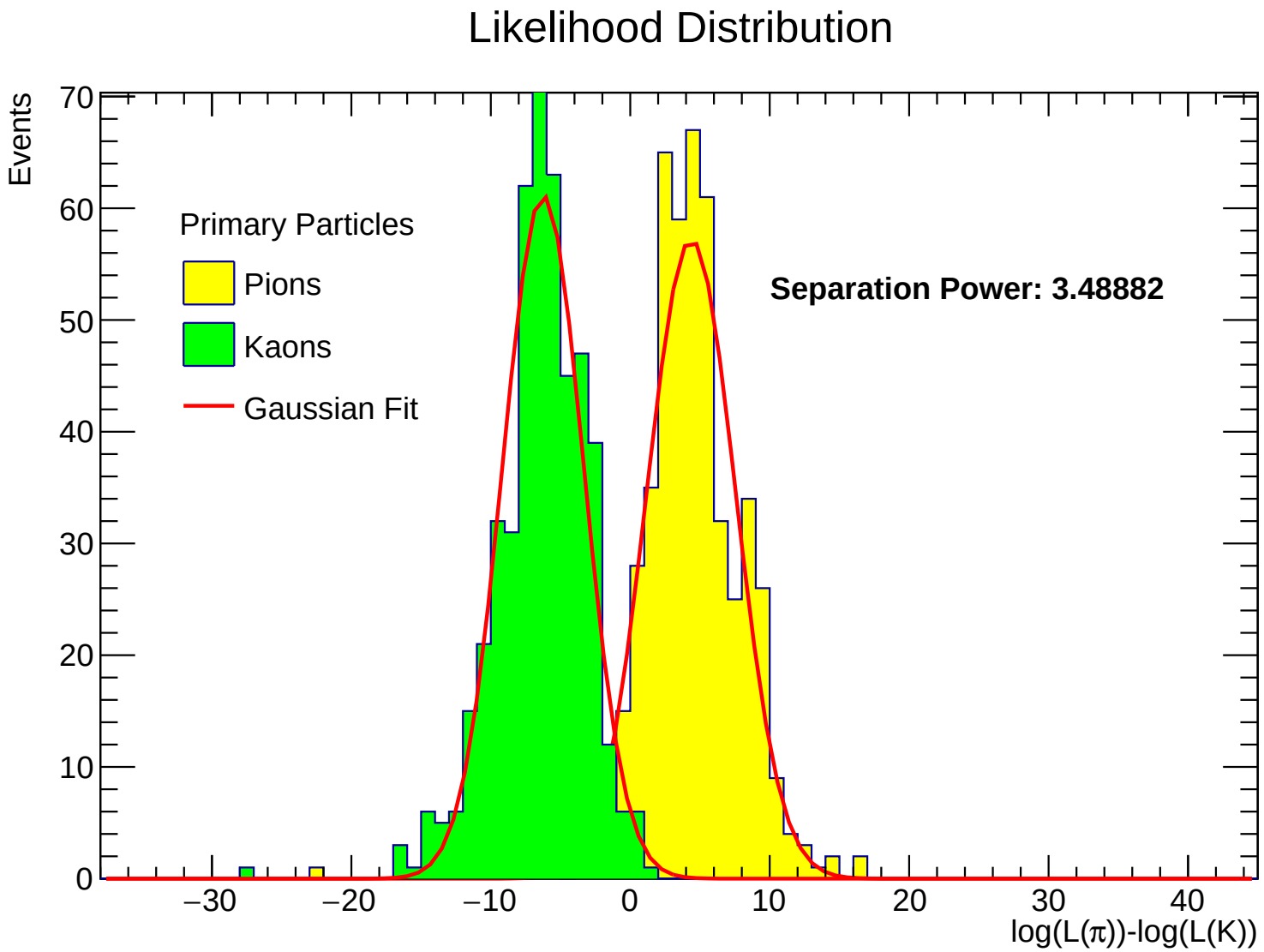
Photon yield of Monte-Carlo simulations before (left) and after (right) application of PDE:





Blue photo cathode with 80 % collection efficiency.

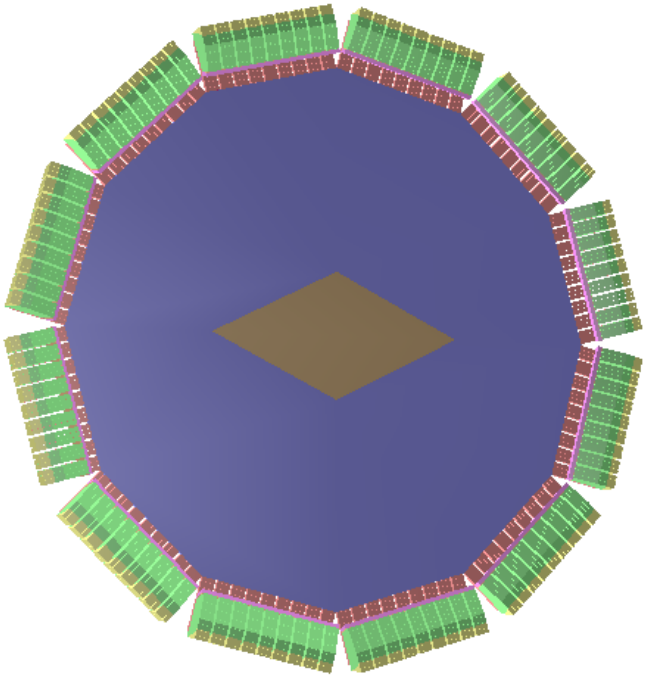
Performance

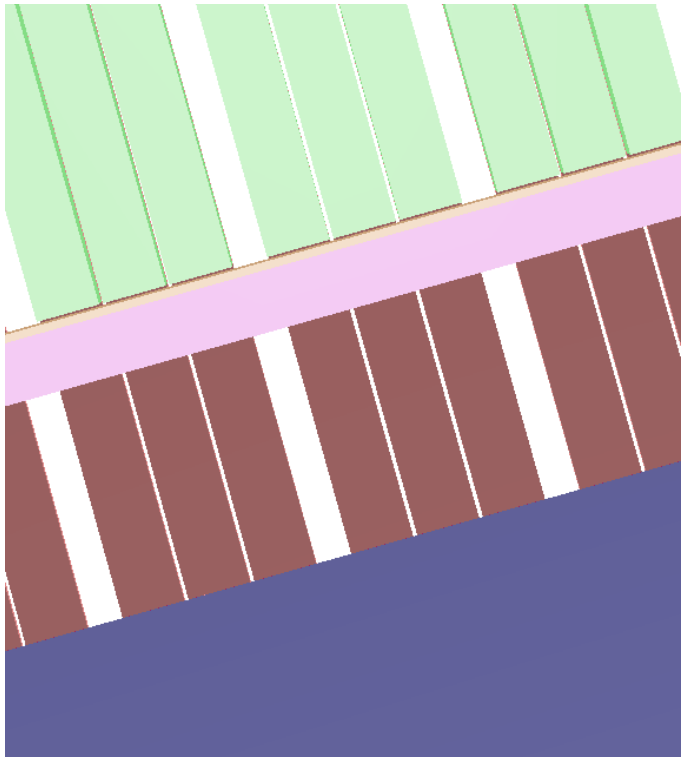


Geometry Studies

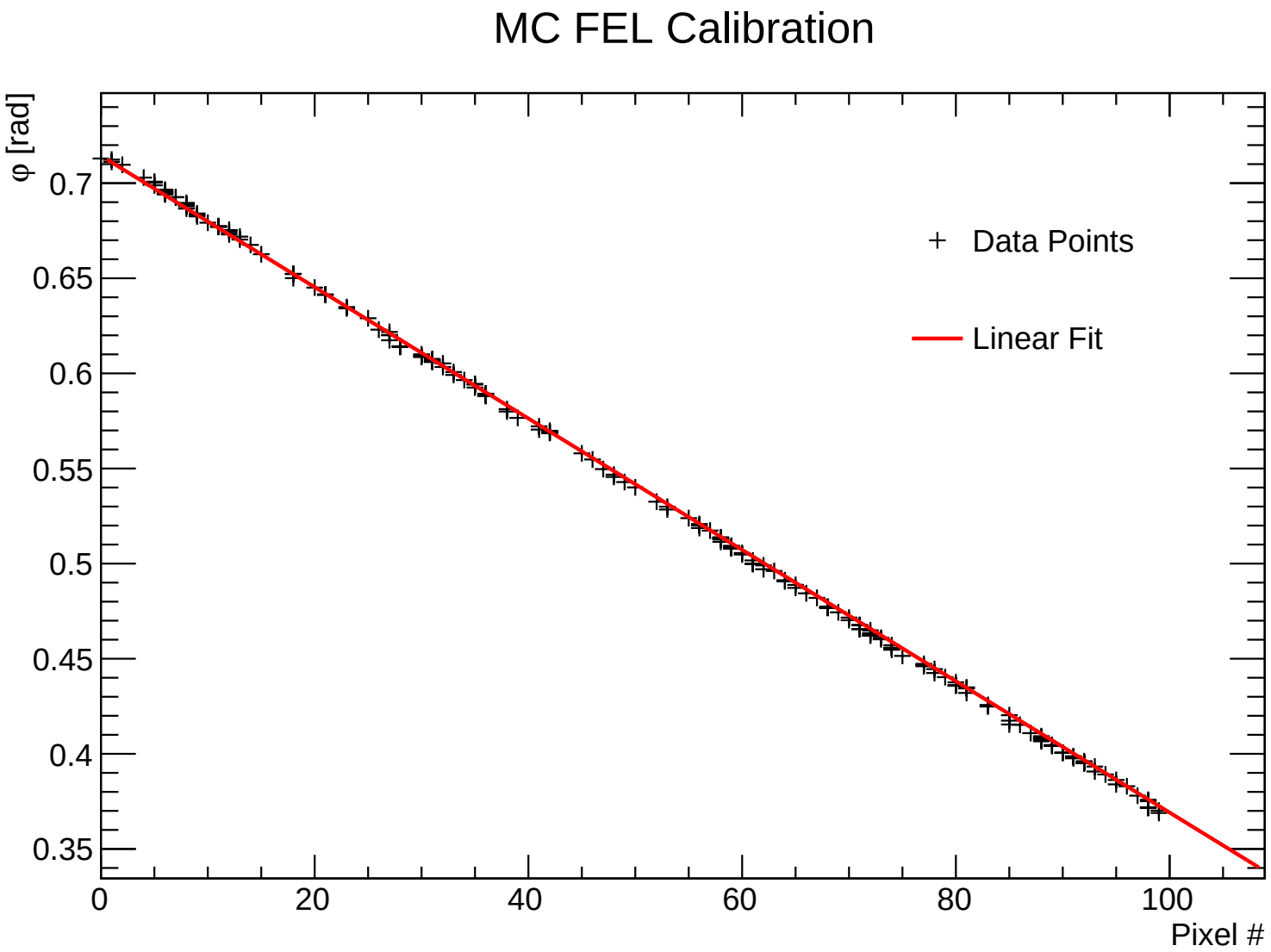
New Detector Geometry

New geometry script with parameterized design including optical grease and air gap

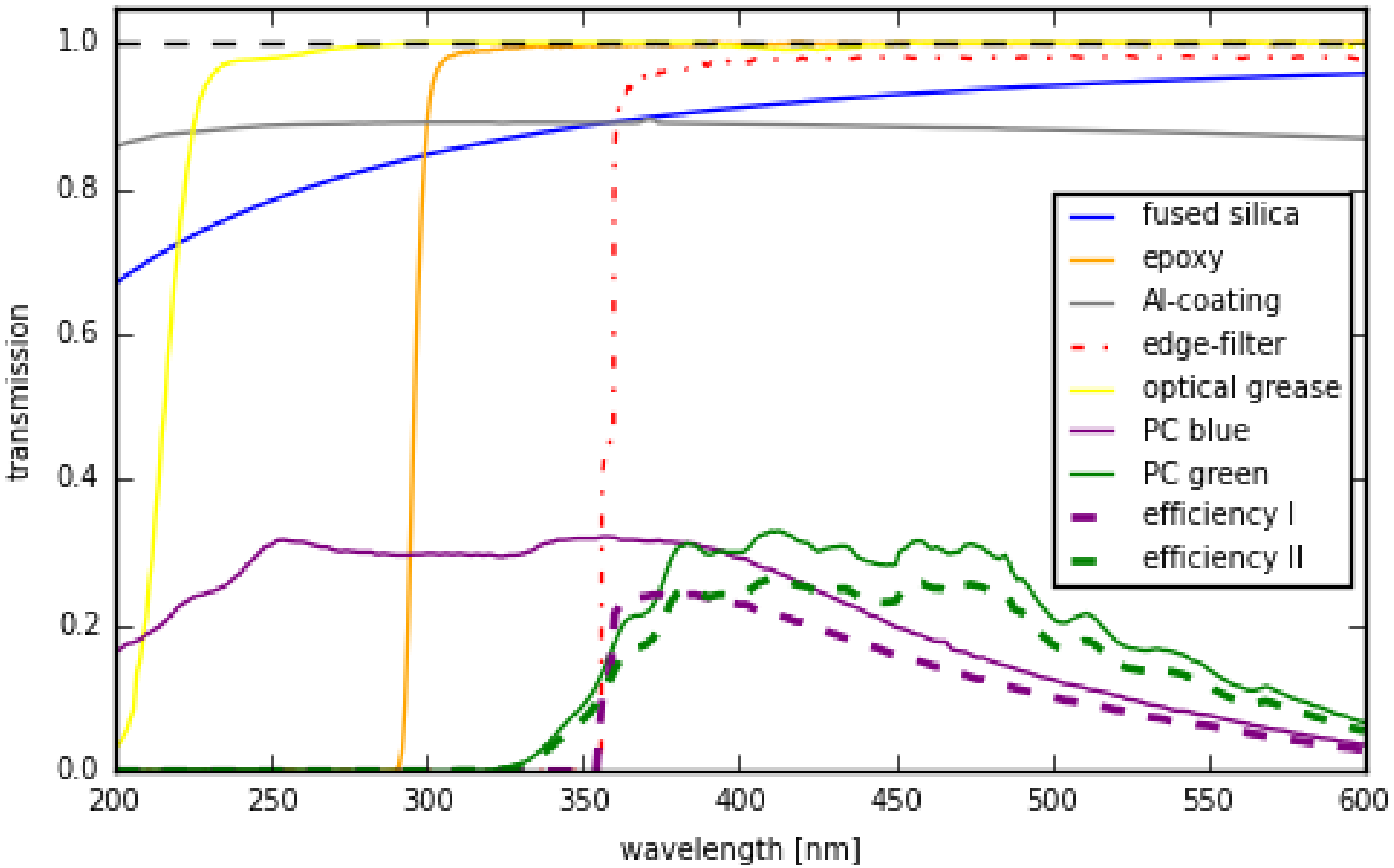




Simulated and Reconstructed Hitpattern



Analysis Summary



Preliminary Studies for TDR

Actual values for different geometries of Disc DIRC:

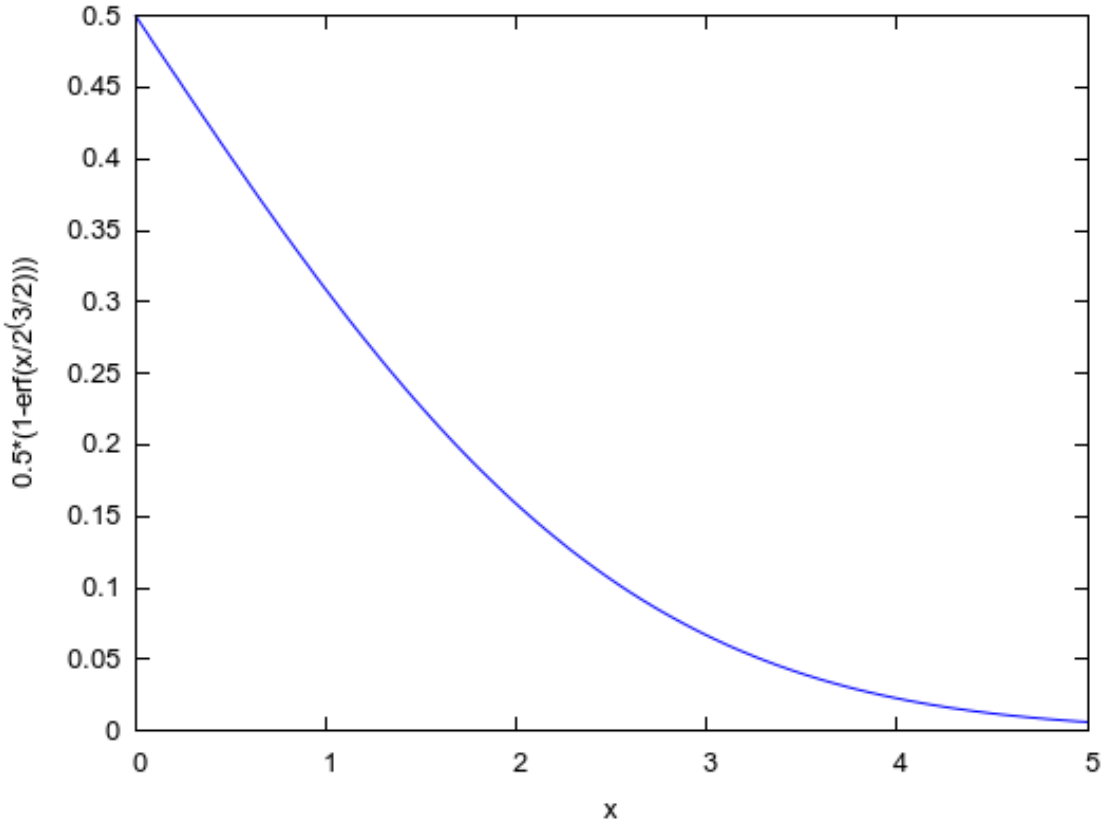
digitization ▼	Simulation ►		9 ROMs mirror	9 ROMs -	8 ROMs -	8 ROMs air gap
Blue-PC	365-460	80% CE	20,61 x 4,08			
	LP filter	65% CE	23,01 x 3,75	21,59 x 3,67	18,72 x 3,77	17,51 x 3,54
Green-PC	no filter	65% CE	32,40 x 4,04	30,9 x 3,99	26,78 x 4,09	24,59 x 3,88
	LP filter	65% CE	29,78 x 4,03	28,27 x 4,04	24,57 x 4,2	22,2 x 3,84
			n	s.p.		

Particle angle	*$\vartheta = 16°$, $\varphi = 45°$*
Generated Wavelengths	*300-800 nm*
Quantities	*Number of Photons*
	Separation Power

Misidentification

Probability for misidentification with separation power n:

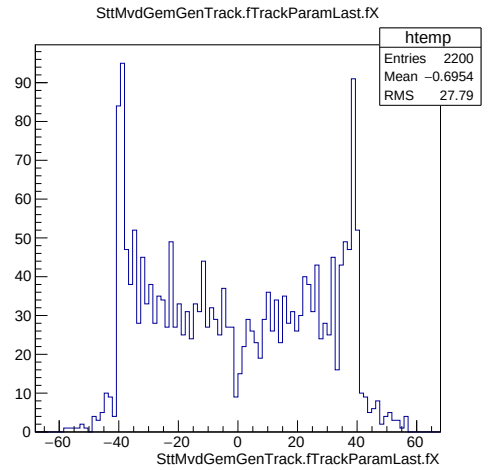
$$p(\pi|K) = \frac{1}{2}\left(1 - \mathrm{erf}\left(\frac{n}{2\sqrt{2}}\right)\right) \tag{2}$$

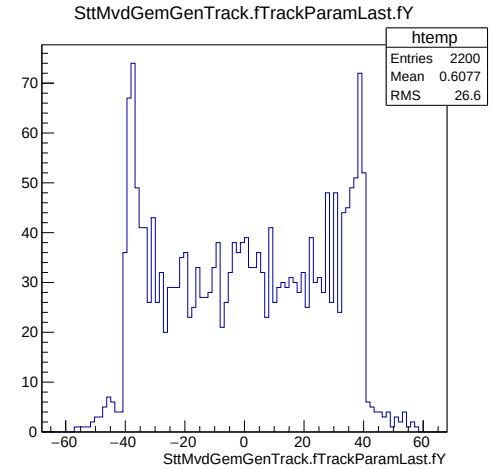


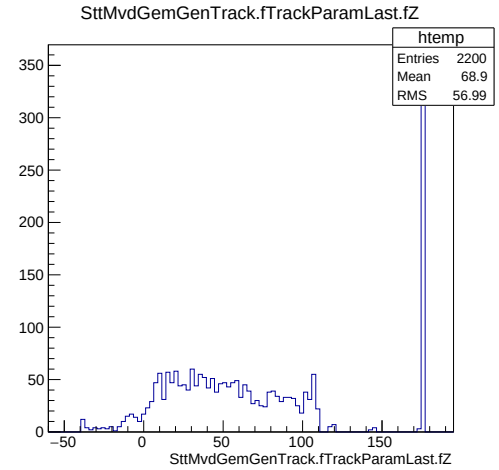
Track Reconstruction

Vertex Reconstruction

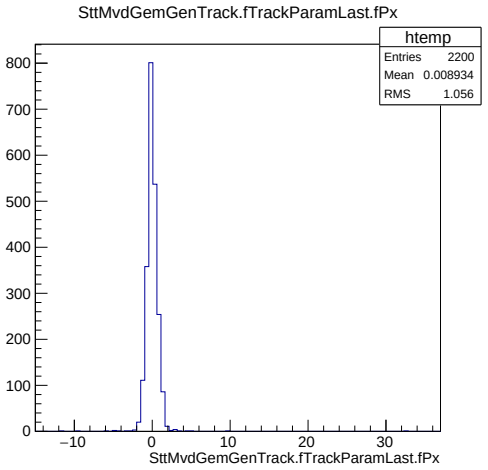
Position and momenta at last tracking vertex:

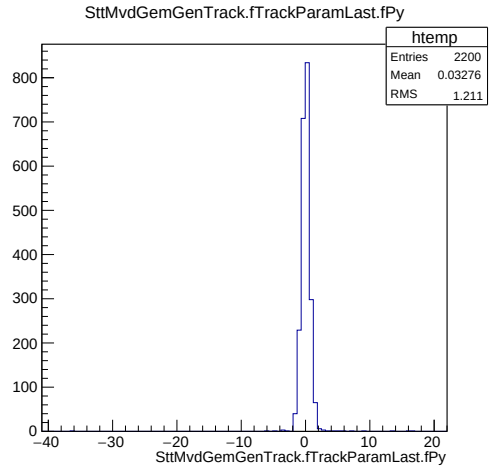


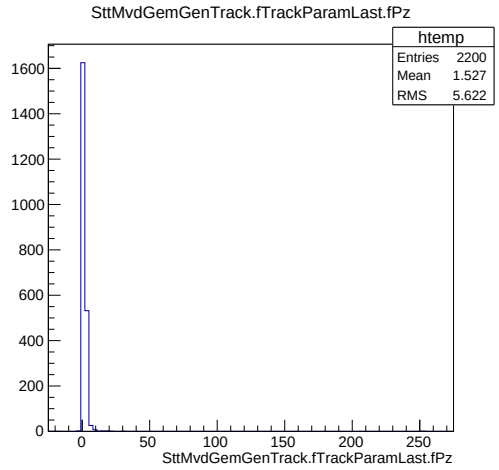




Momentum at last tracking vertex:



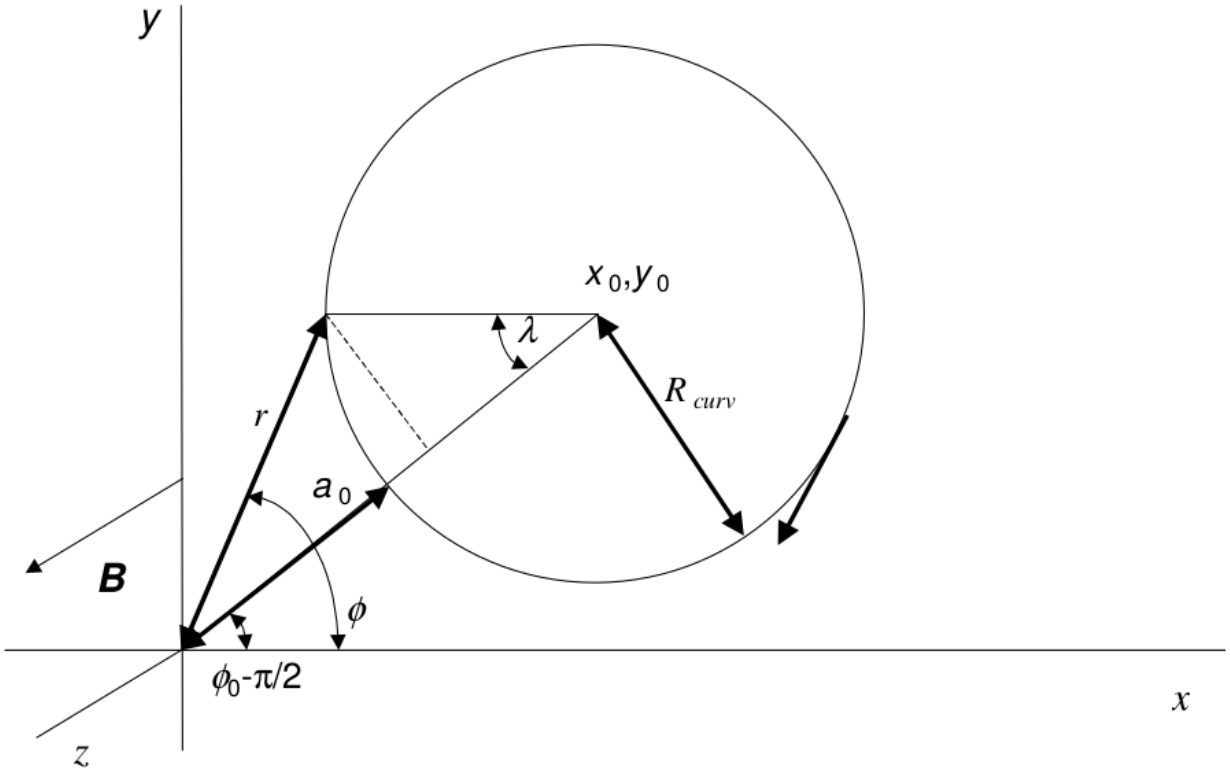




Helix Propagator

Important Helix Parameters:

- Helix center: x_0, y_0, z_0
- Helix radius: $\rho = R_{curv}$
- Impact parameter: a_0
- Helix phase: λ or ϕ



Position Reconstruction

Transverse momentum:

$$p_T = \sqrt{p_x^2 + p_y^2}$$

Calculation of curvature from magnetic field:

$$\rho[m] = \frac{p_T[\mathrm{GeV}]}{0.3B[\mathrm{T}]}$$

Center of helix:

$$x_0 = x + Q\rho\cos(\alpha - \tfrac{1}{2}Q\pi) = x + Q\rho\sin\alpha$$
$$y_0 = y + Q\rho\sin(\alpha - \tfrac{1}{2}Q\pi) = y - Q\rho\cos\alpha$$
$$z_0 = z - 2\rho\cot\theta\arcsin\left(\sqrt{\frac{x^2+y^2-a_0^2}{4\rho^2+4Qa_0\rho}}\right)$$

with

$$\cos\alpha = \frac{p_x}{p_T} \quad \text{and} \quad \sin\alpha = \frac{p_y}{p_T}$$

Position Reconstruction

Transverse impact parameter:

$$a_0 = Q\left(\sqrt{x_0^2 + x_0^2} - \rho\right)$$

Initial phase:

$$\phi_0 = \arctan\left(\frac{y_0}{x_0}\right) + \frac{1}{2}Q\pi$$

Calculation of phase λ:

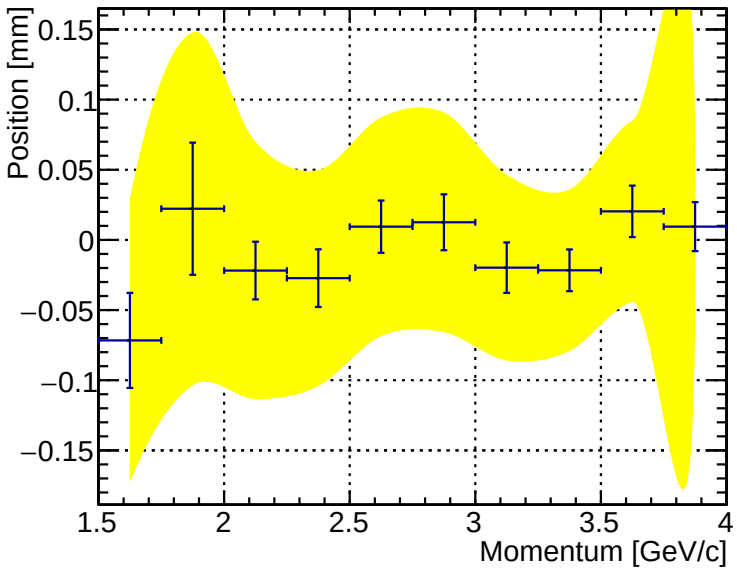
$$z(\lambda) = z_0 + \rho\lambda\cot\theta \Rightarrow \lambda = \frac{z(\lambda) - z_0}{\rho\lambda\cot\theta}$$

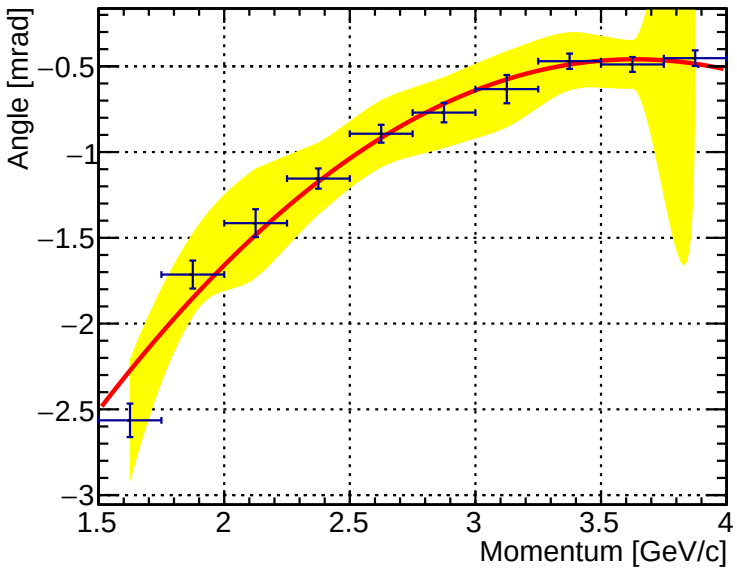
Propagating helix with equations of motion:

$$x'(\lambda) = x_0 + Q\rho\cos(Q\lambda - \phi_0)$$
$$y'(\lambda) = y_0 + Q\rho\sin(Q\lambda - \phi_0)$$

Reconstruction Results

Position and polar angle resolution on surface of raudiator disk as funciton of particle momentum for $\theta = 15°$ and $0° < \phi < 360°$:





Error bars: Error of mean value
Yellow band: Resolution
Offset calibration of polar angle with polynomal fit of 2nd degree

Benchmark Channel Analysis

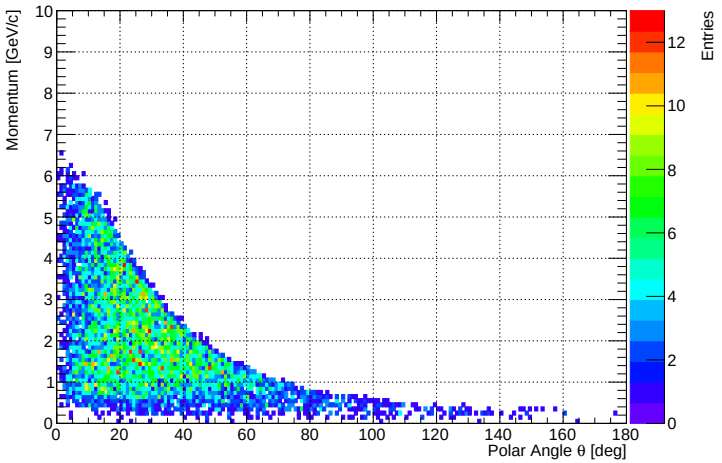
Decay of $f_0(1500)$ in EvtGen decay file:

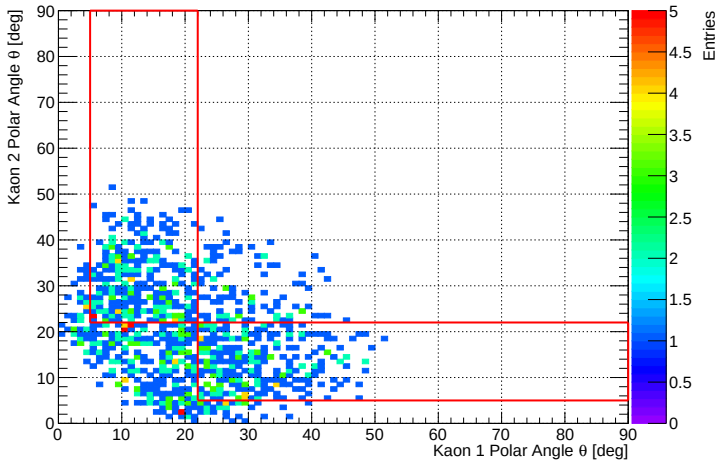
```
Decay f_0(1500)
0.019000000 eta      eta'
0.051000000 eta      eta
0.1410   pi0  pi0  pi0  pi0                    PHSP;
0.3540   pi+  pi-  pi+  pi-                    PHSP;
0.2330   pi+  pi-                             PHSP;
0.1160   pi0  pi0                             PHSP;
0.0430   K+   K-                              PHSP;
0.0215   K_S0  K_S0                           PHSP;
0.0215   K_L0  K_L0                           PHSP;
Enddecay
```

Benchmark Channel: $p\bar{p} \rightarrow f_0\pi^0 \rightarrow \pi^0 K^+ K_-$

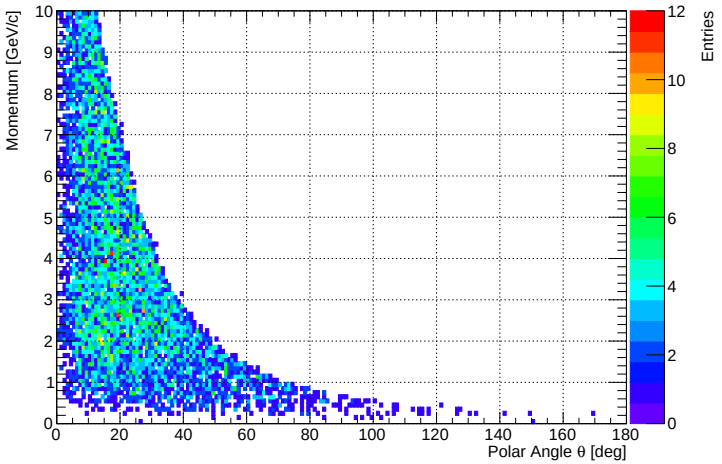
Glueball candidate $f_0(1500)$ decay into K^+K^-:

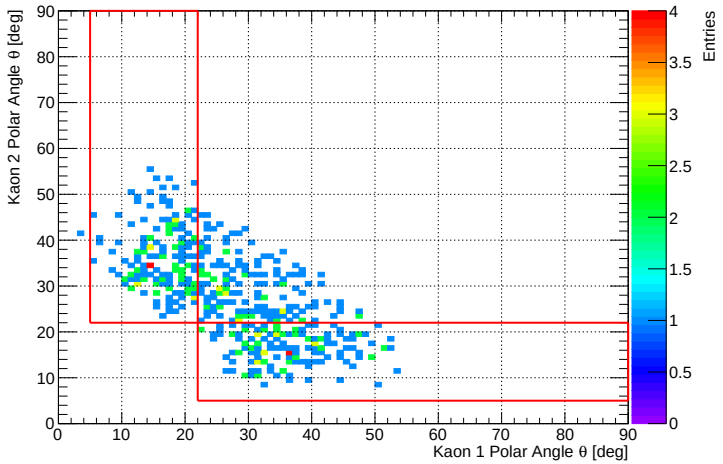
Beam Momentum: 6.5 GeV/c:





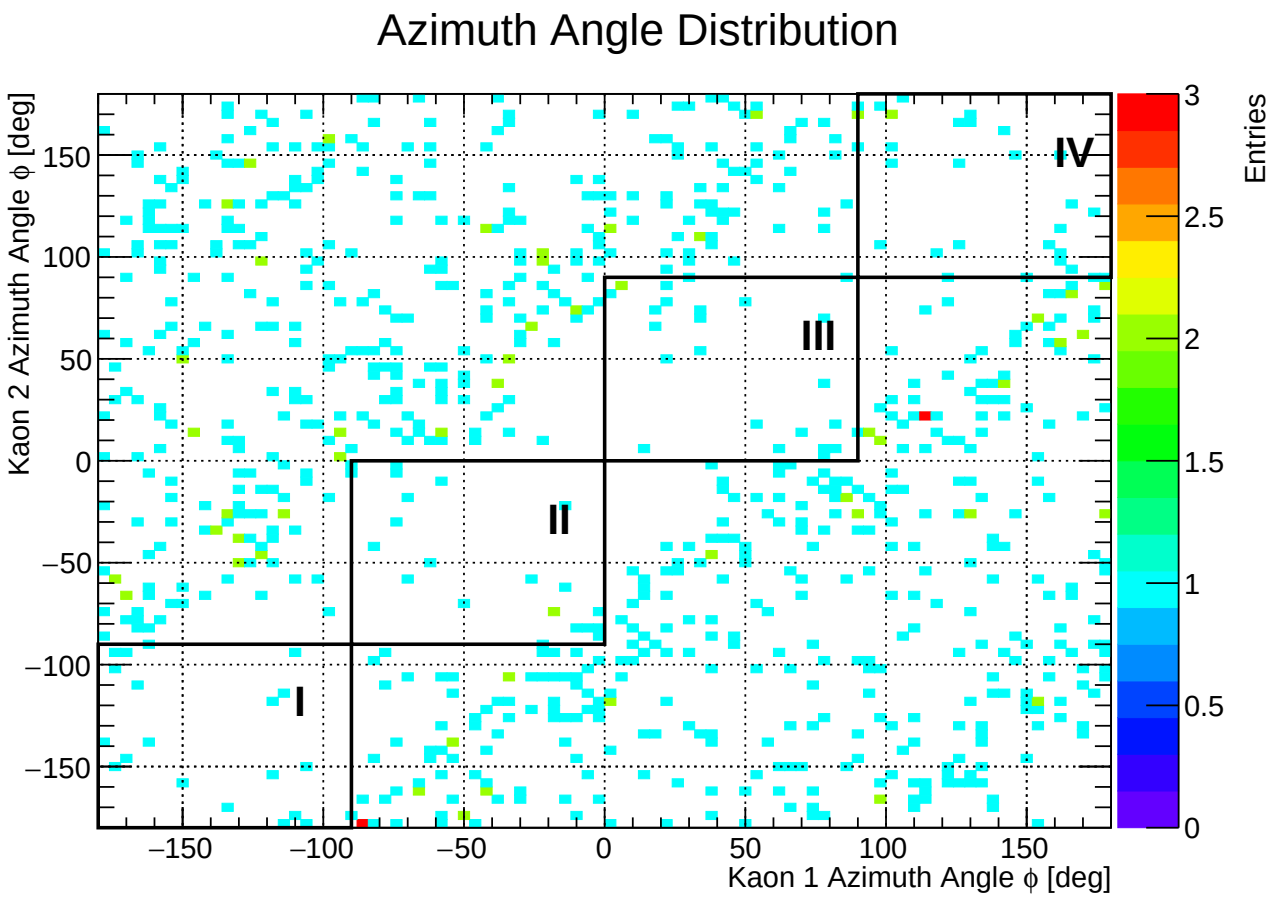
Beam Momentum: 15 GeV/c:





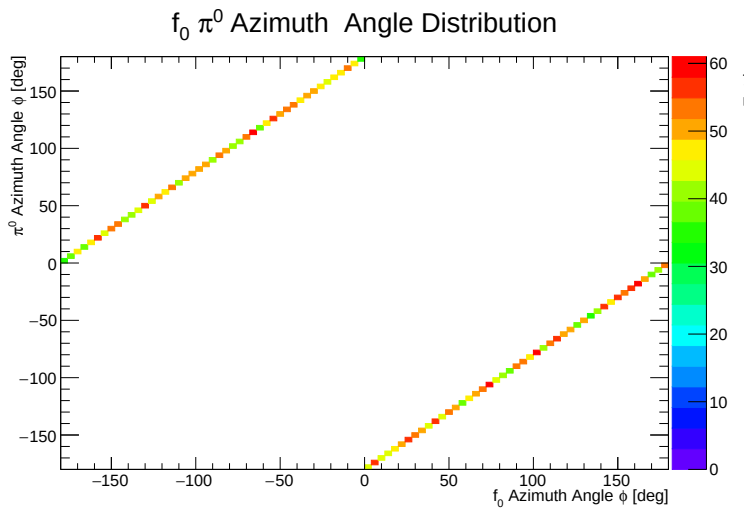
Azimuth Angle Distribution

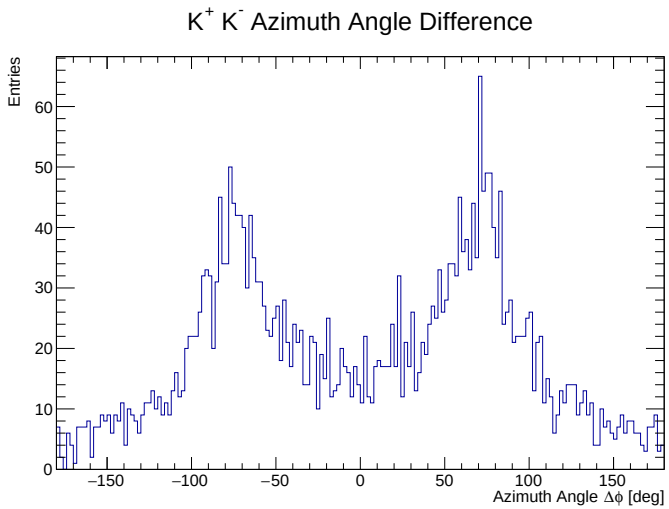
Beam momentum: 6.5 Gev/c, polar angle cut: $5^\circ < \theta < 22^\circ$



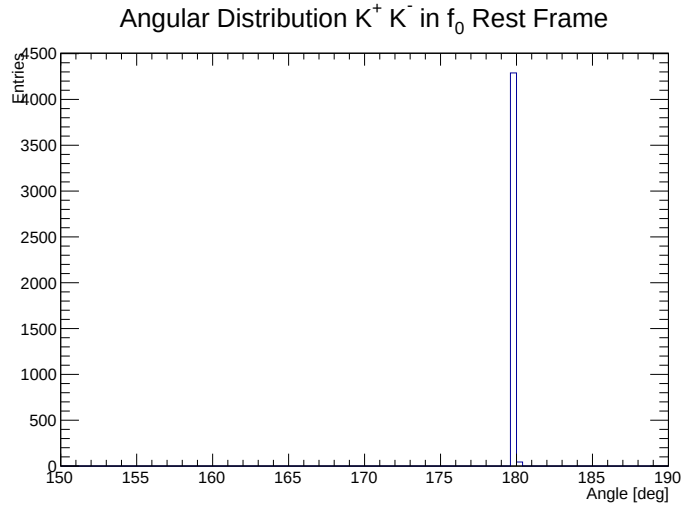
Very few events with pileup problems

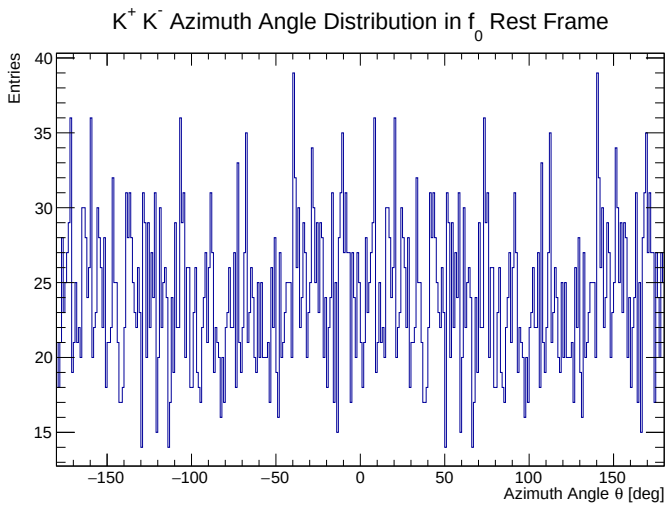
Azimuth Angle Distribution





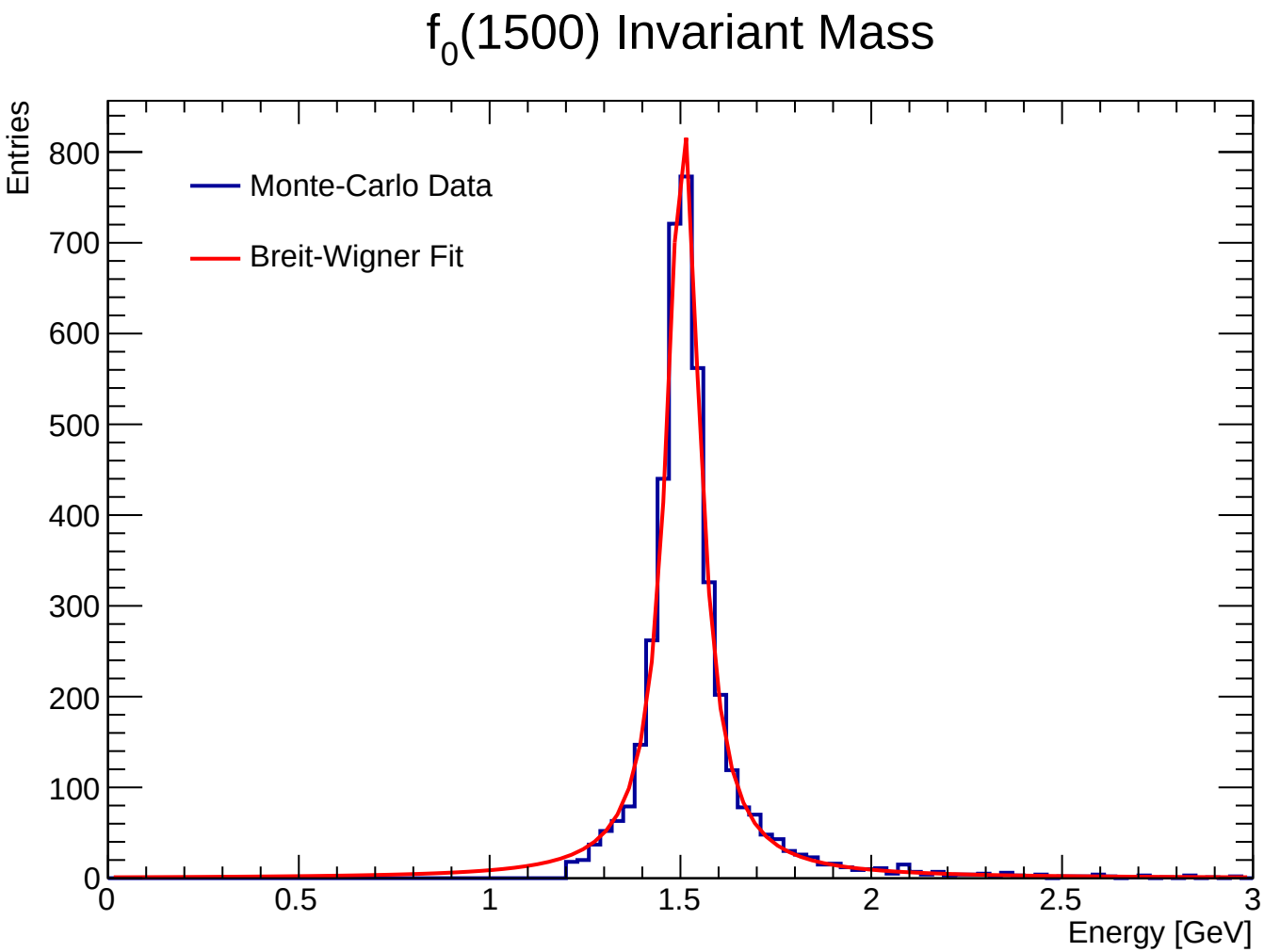
Azimuth angle distribution after Lorentz boost into rest frame:





Invariant Mass

Invariant mass calculated from Monte-Carlo truth data:



Statistics

- Likelihood value equal to value of PDF:

$$\mathcal{L}(\theta|x) = f(x;\theta) \tag{3}$$

- Bayesian Approach:

$$p(\theta|x) = \frac{\mathcal{L}(\theta|x)\pi(\theta)}{\int \mathcal{L}(\theta'|x)\pi(\theta')d\theta'} \tag{4}$$

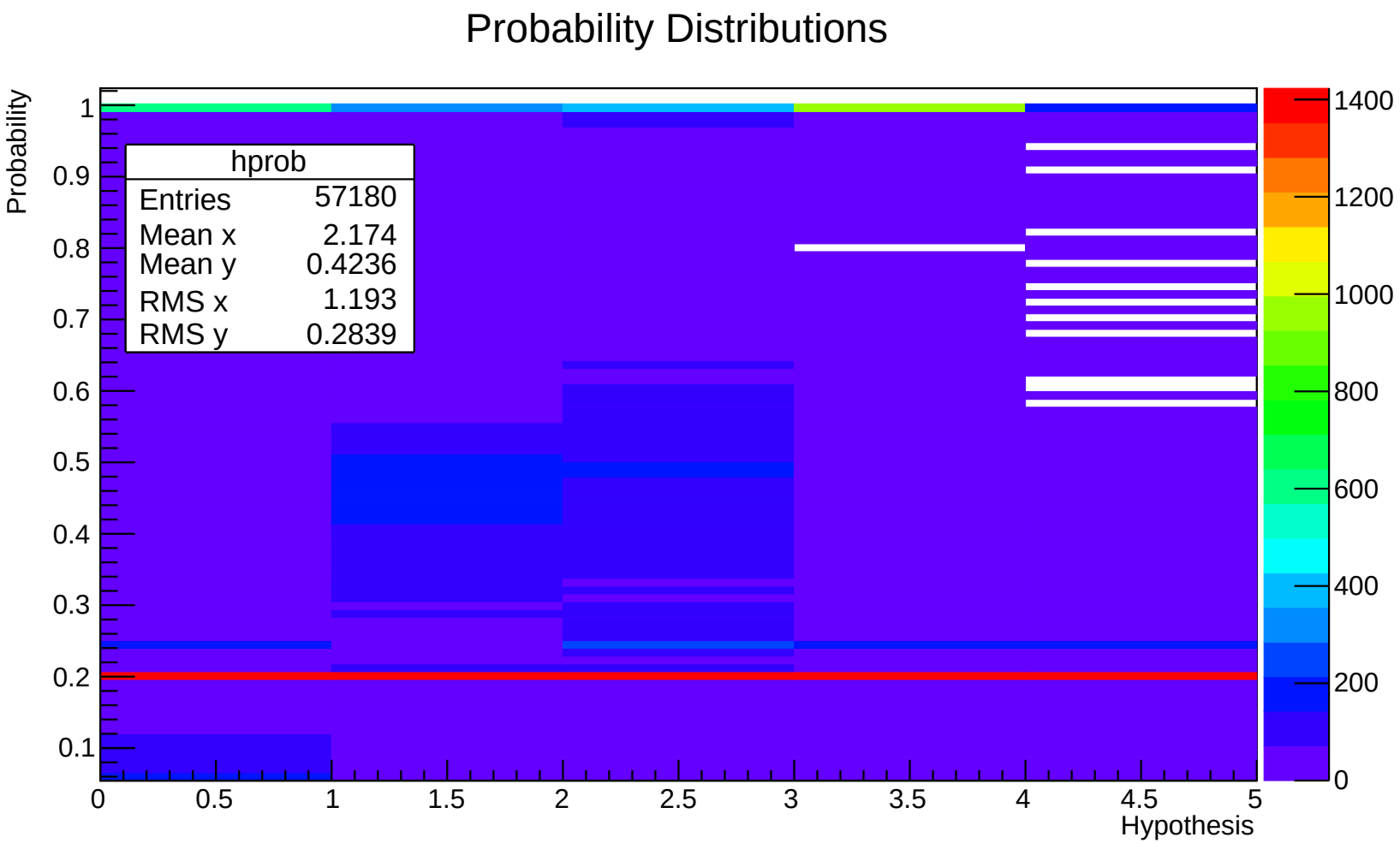
- Following the probability for finding particle k (a-priory propbability set to 1):

$$p(k) = \frac{\prod_i \mathcal{L}_i(k)}{\sum_j \prod_i \mathcal{L}_i(j)} \tag{5}$$

$i = 0 \ldots N$ for N subdetectors
$j = e, \mu, \pi, K, p$

Probability Distributions

Probability Distributions including for all detectors:



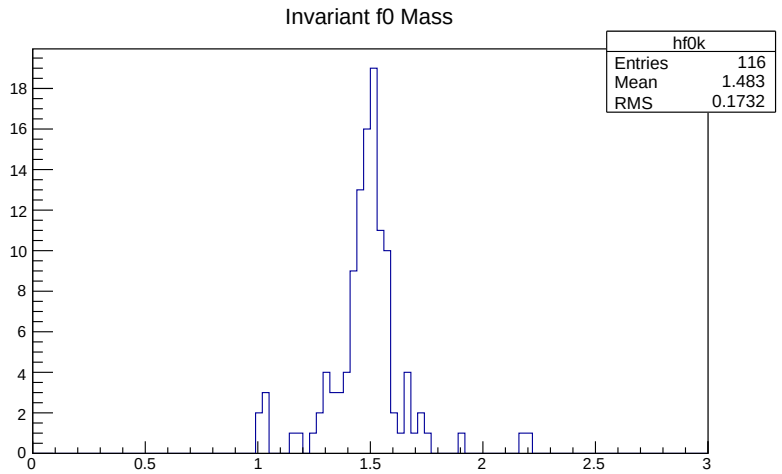
Analysis

Reconstructed mass from kinematics of K^+/K^- decay channel:

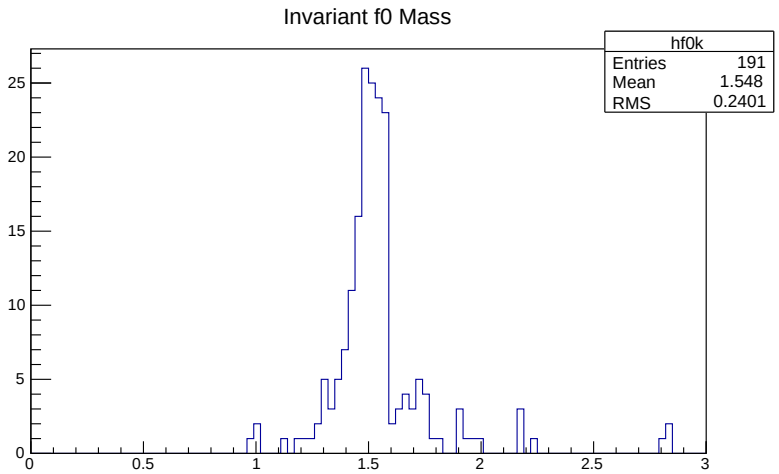
$$m_{f_0} = \sqrt{(E_{K^+} + E_{K^-})^2 + (\vec{p}_{K^+} + \vec{p}_{K^-})^2}$$

with combined likelihood value and PID cut at 50%:

Without Disc DIRC



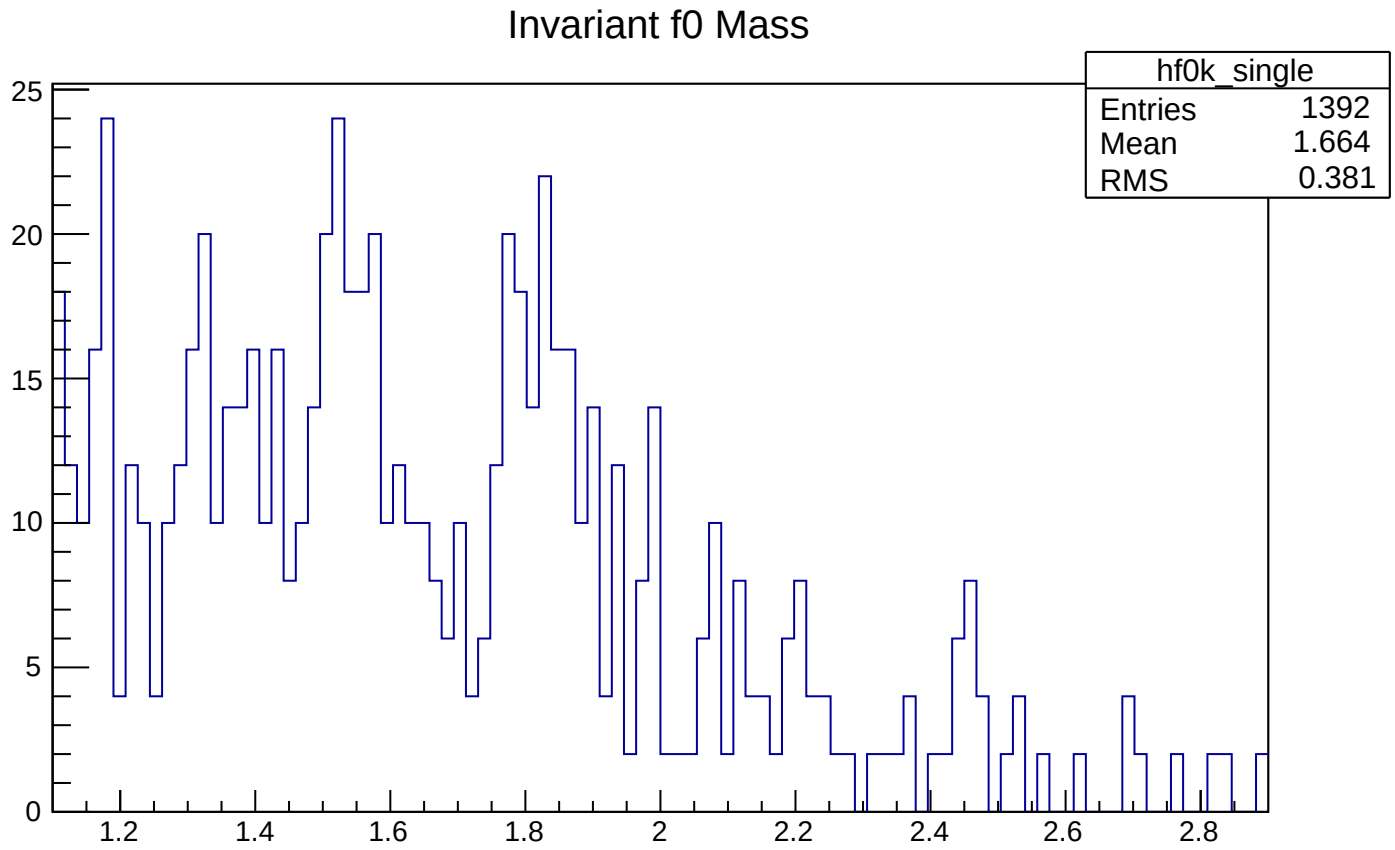
With Disc DIRC



Approx. factor 2 in reconstruction efficiency

Single Kaon Reconstruction

Mass reconstruction with signle Kaon in Disc DIRC

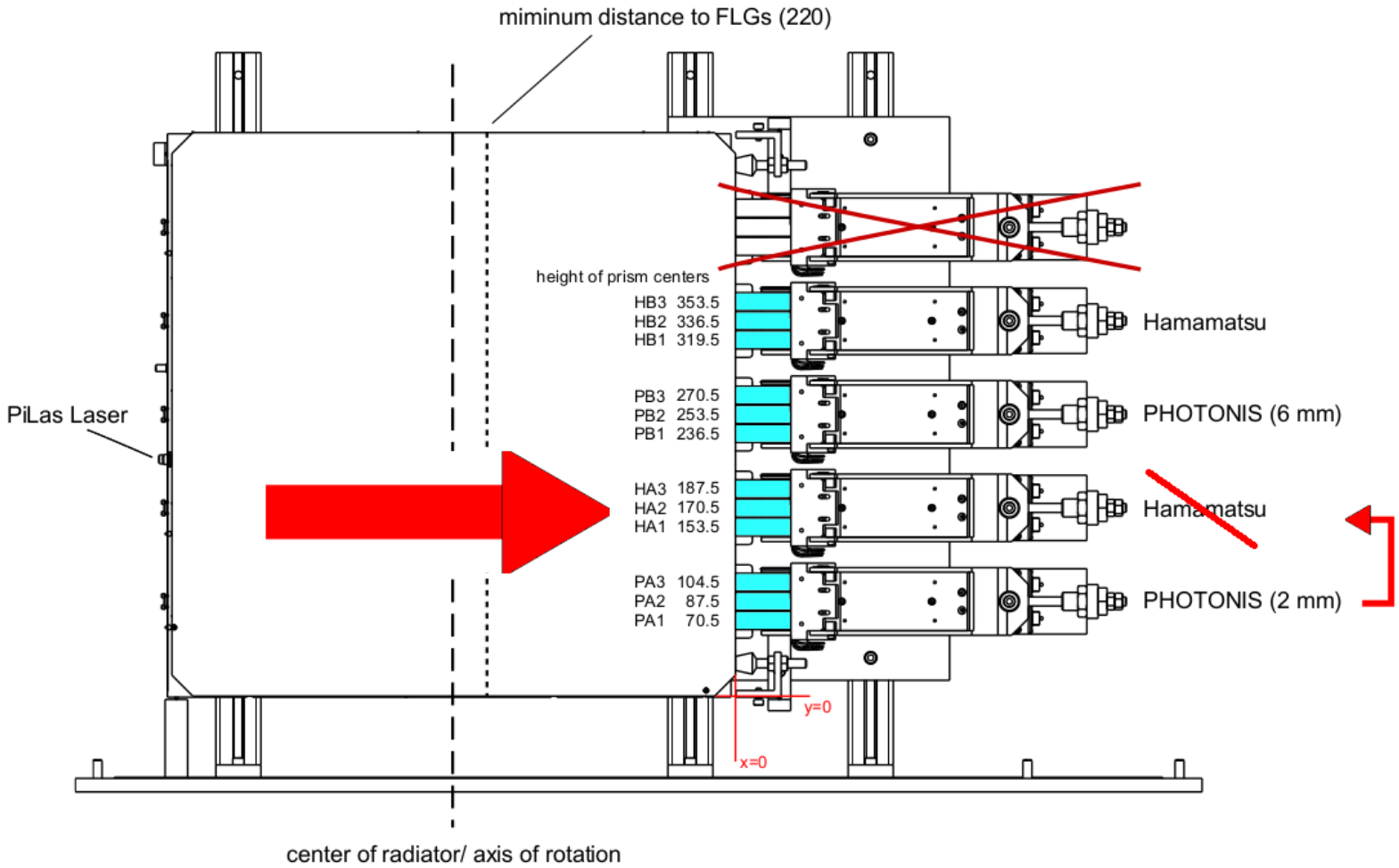


Higher statistics than events $\Rightarrow$ most likely ghost tracks

Testbeam Analysis

Radiator Setup

2016 DISC DIRC PROTOTYPE available setup

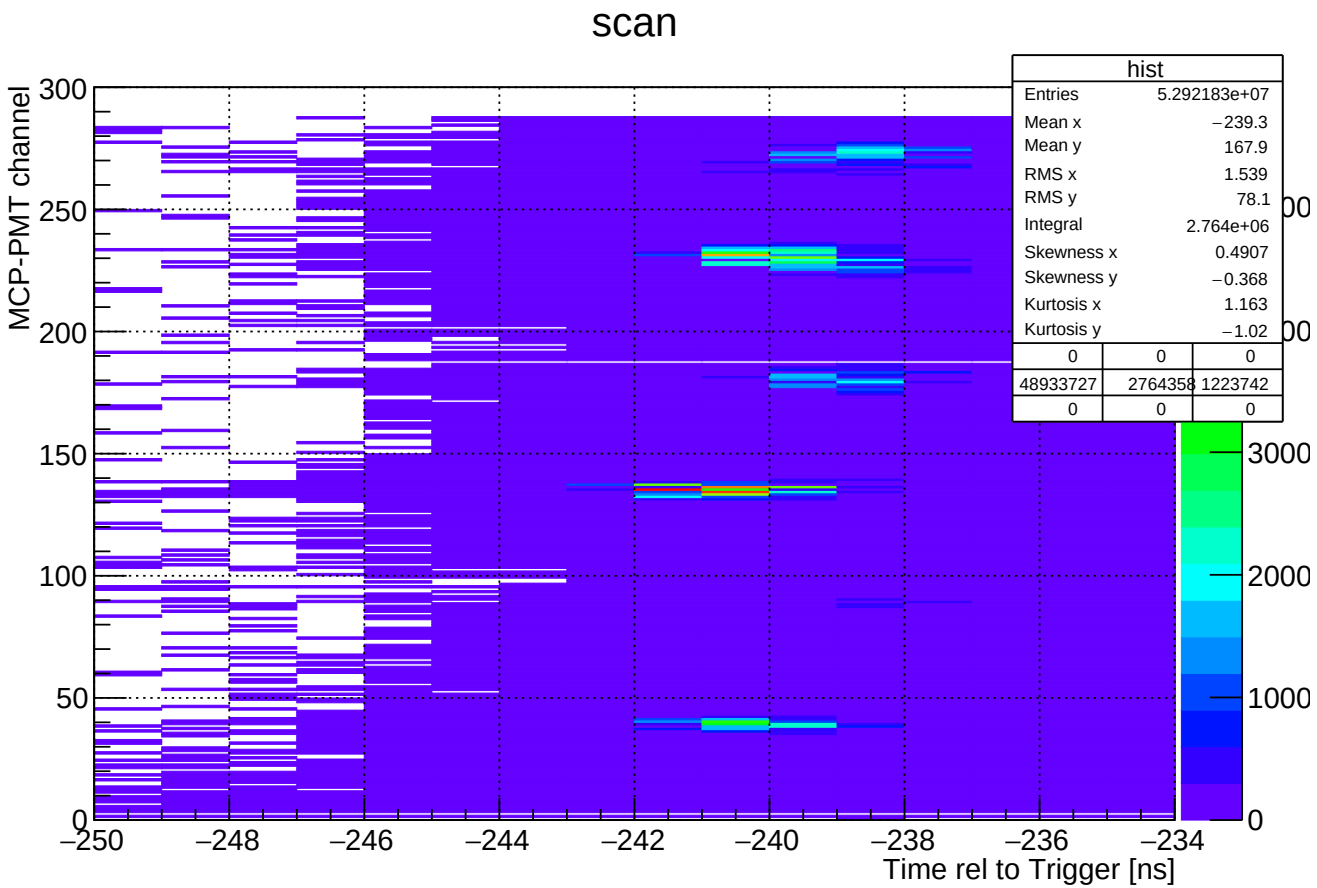


05.10.2016

view downstream

Time Spectrum

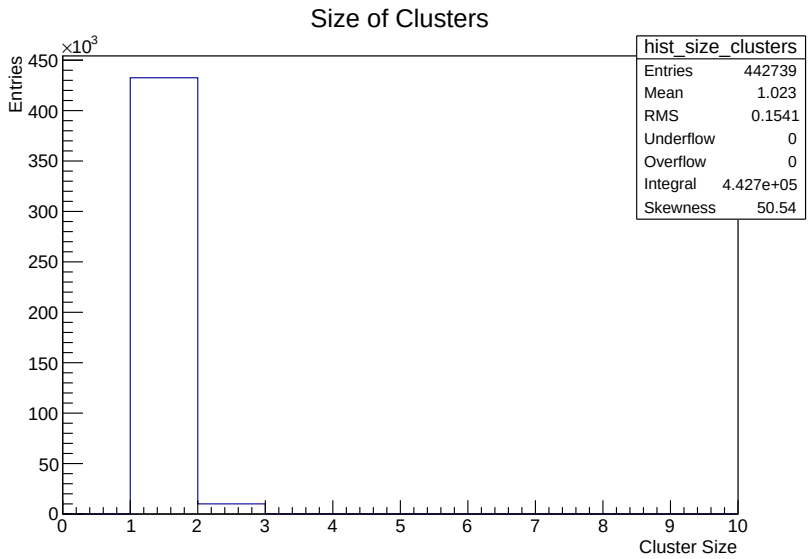
Time spectrum for all 3 FELs during one run

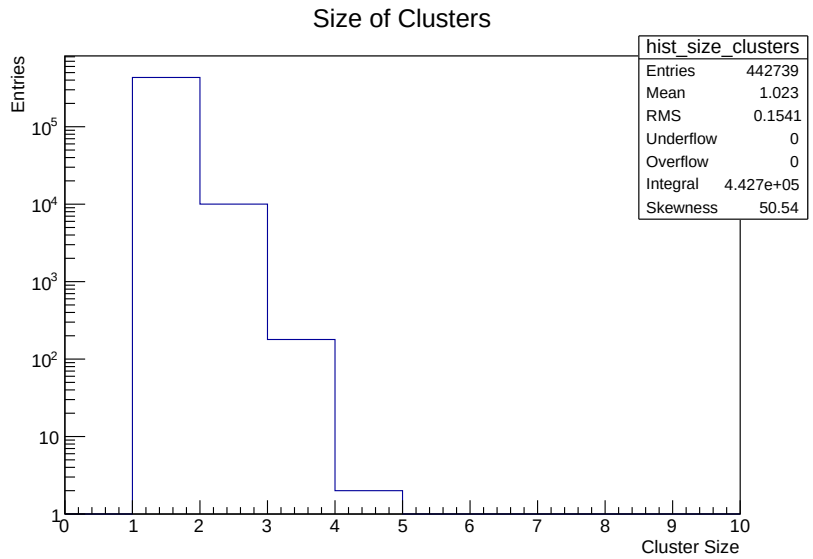


Time cut between 236 and 243 ns

Pixel Cluster Size

Assumption: 1 photon $\rightarrow$ approx 1.4 photo electrons
Cluster size cumulated for all events in one FEL with linear (left) and log scale (right):

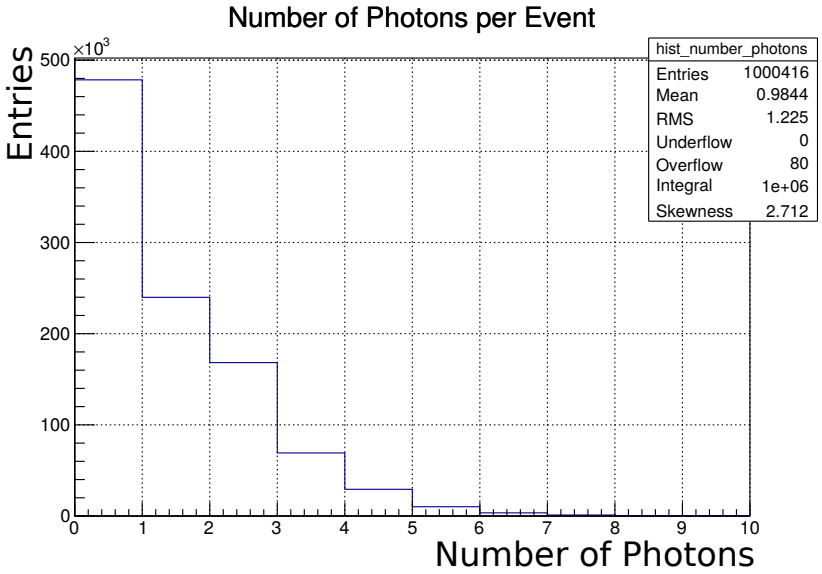


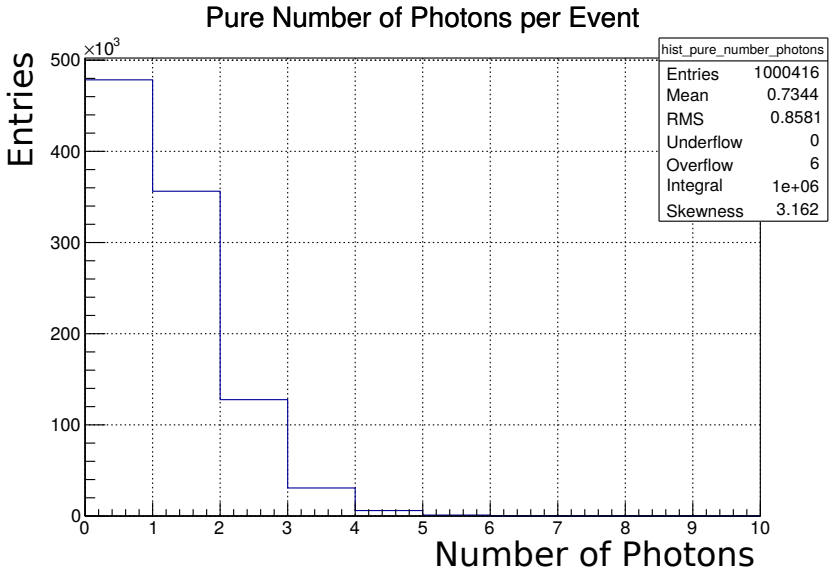


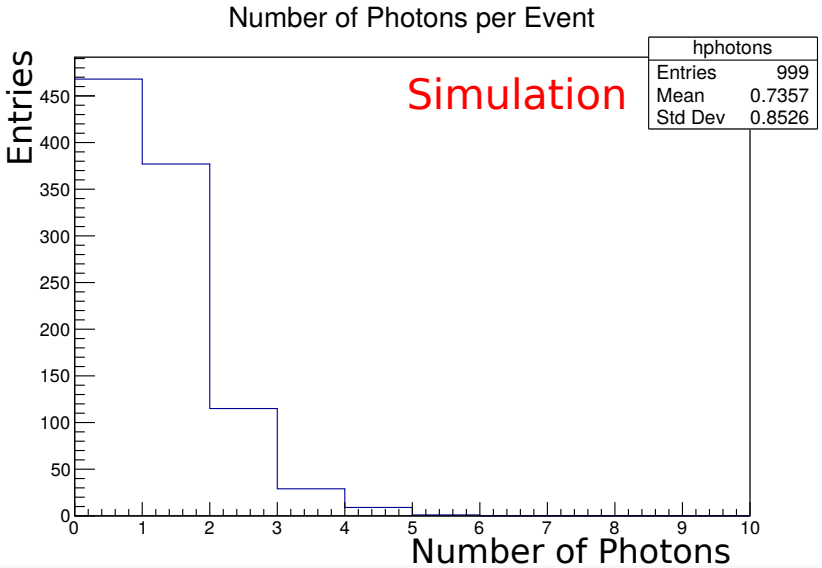
Status until now: Different result in testbeam analysis because of background and dark counts $\rightarrow$ Time cuts necessary

Photon Yield

Number of hits without (left) and with (right) rejecting neighbouring pixels:







Comparison of mean values:

Simulation: 0.7357
Testbeam data: 0.7344