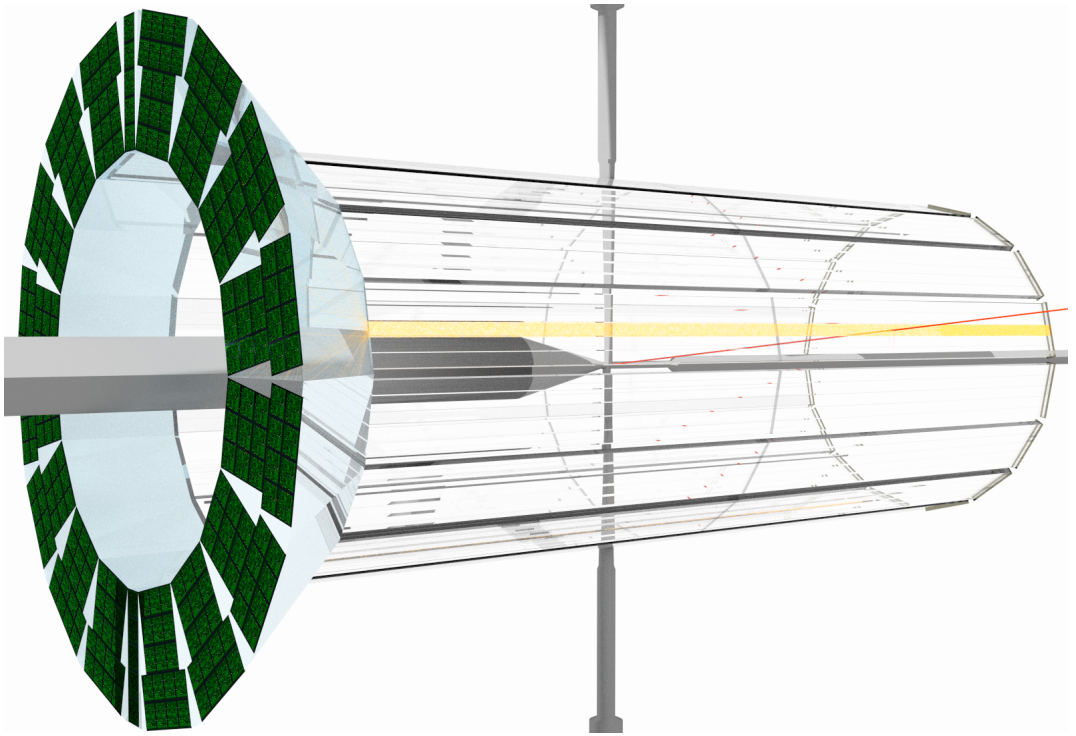
Simulation and Reconstruction of the PANDA Barrel DIRC



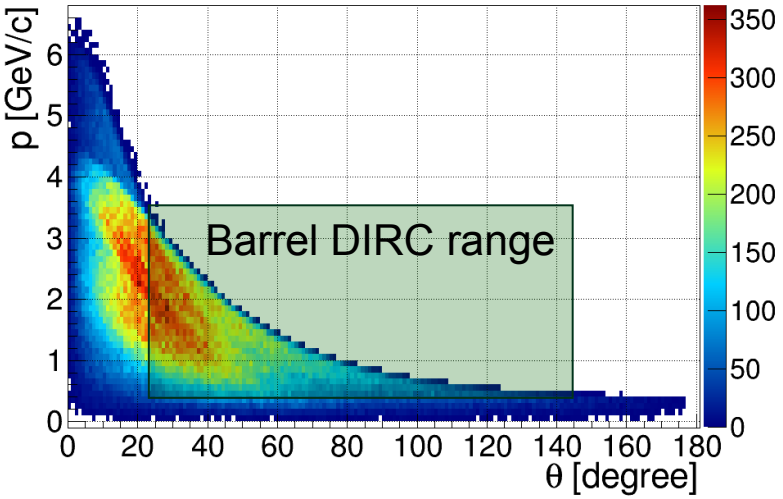
DIRC 2015 workshop

Roman Dzhygadlo
GSI, for the Panda Cherenkov Group

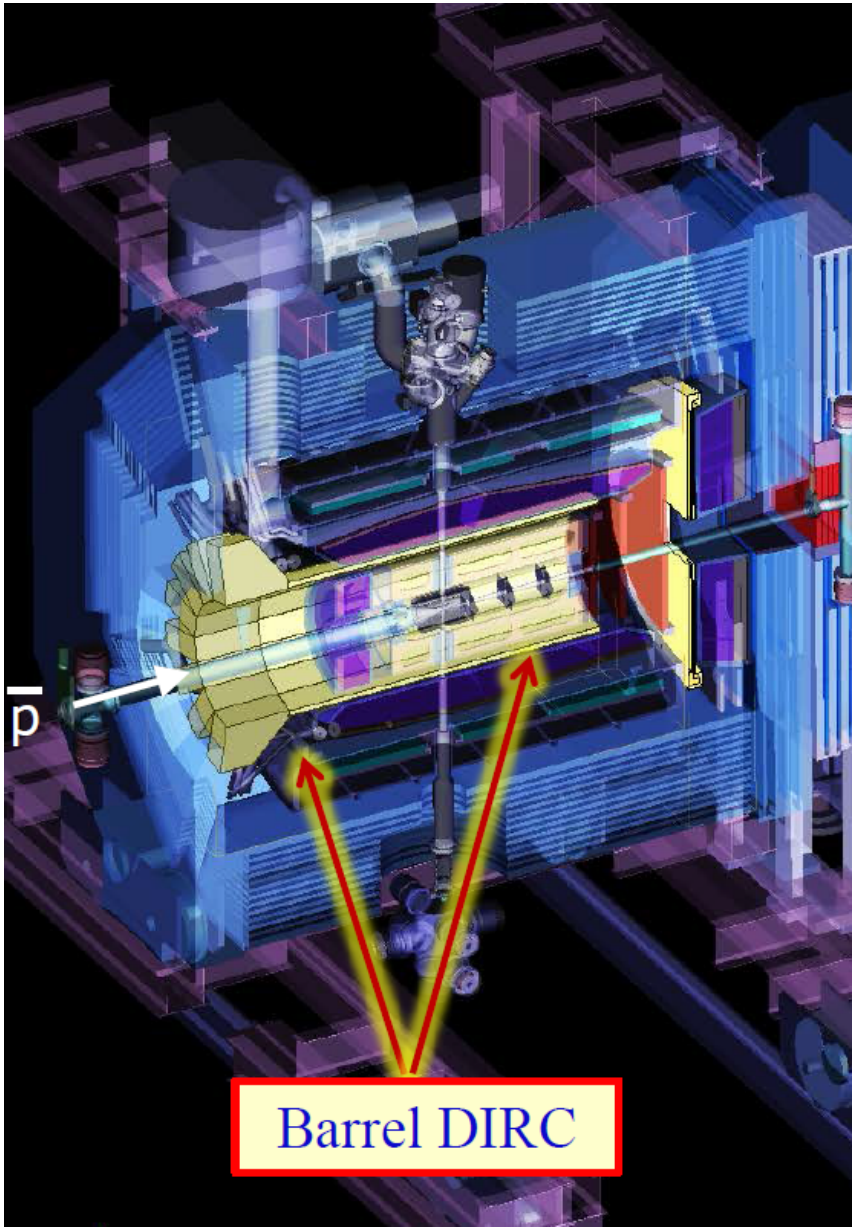
- Overview
- Simulation flow
- Reconstruction methods
- Time-based simulation
- Summary & Outlook

Overview of the PANDA Barrel DIRC

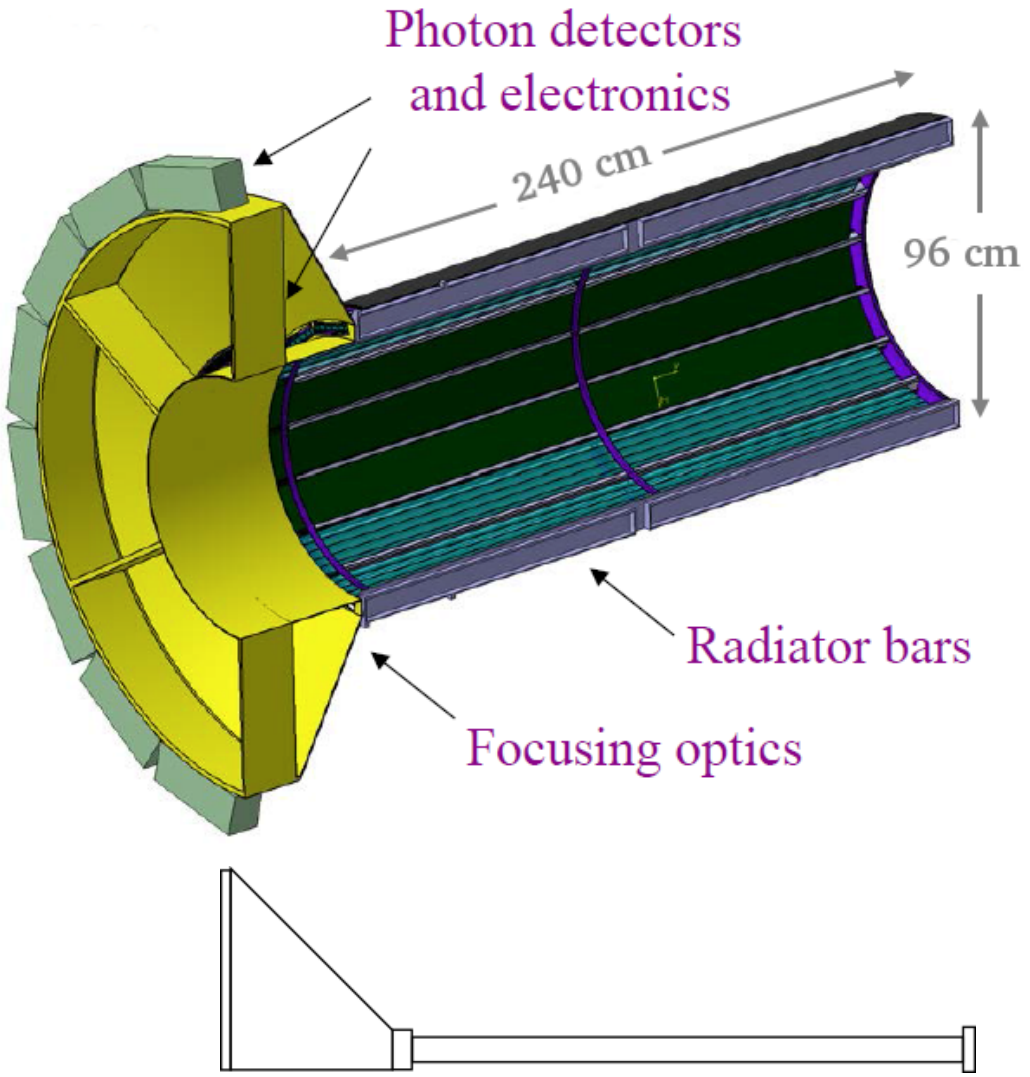
- Acceptance: 22-140 degree
- Momentum range: 0.5 - 3.5 GeV/c
- PID goal: 3σ π/K separation



Kaon momentum distribution of the major channels @ 6-15 GeV/c beam momentum.

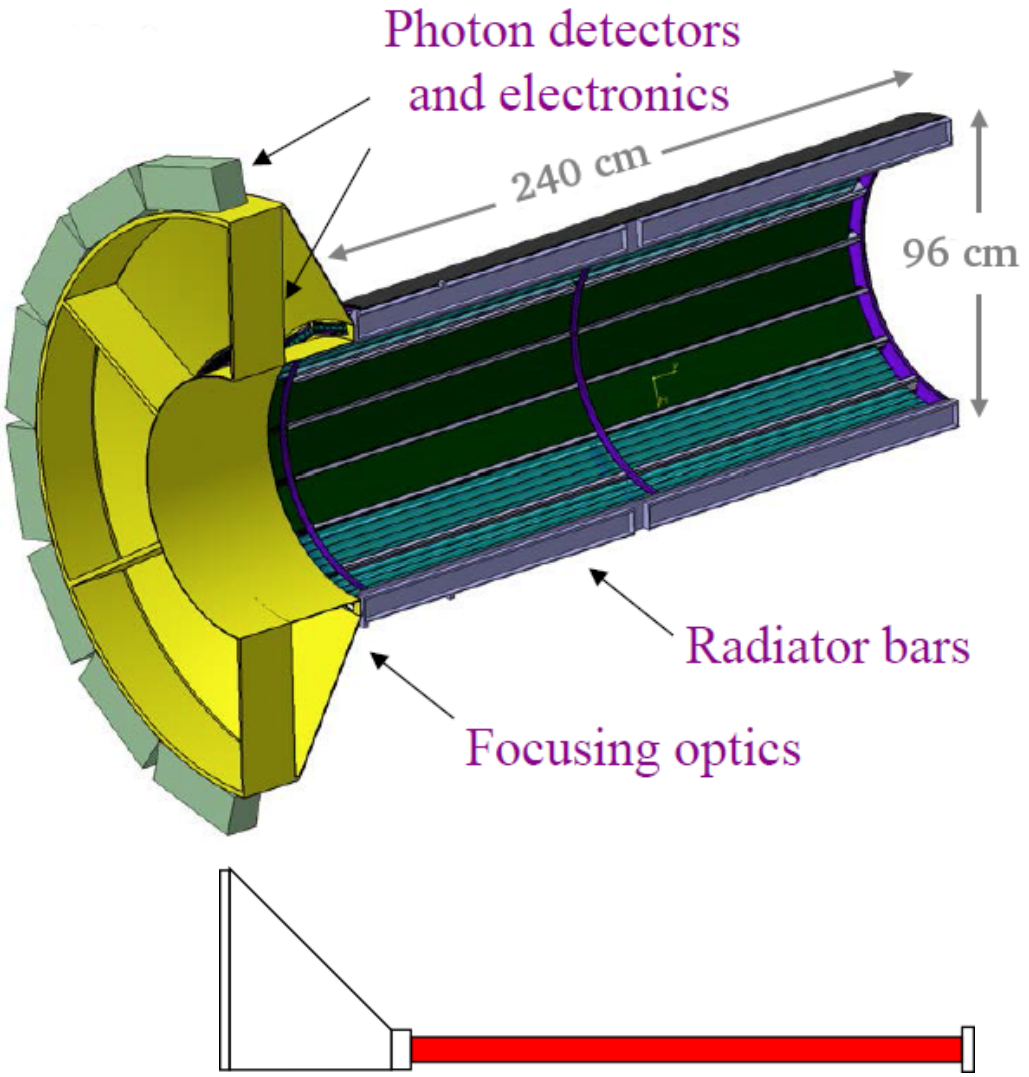


Components of the Panda Barrel DIRC



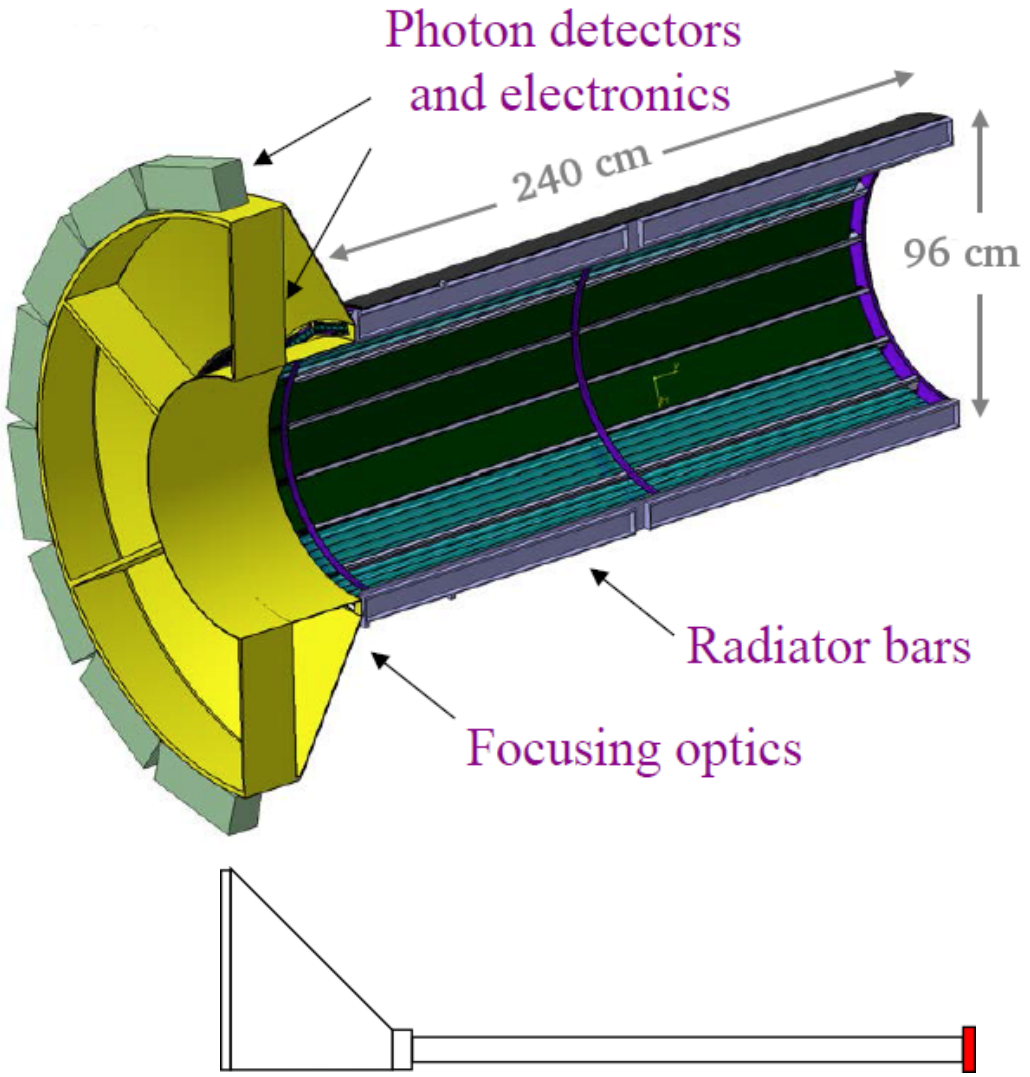
Components of the Panda Barrel DIRC

- Highly polished rectangular radiator.



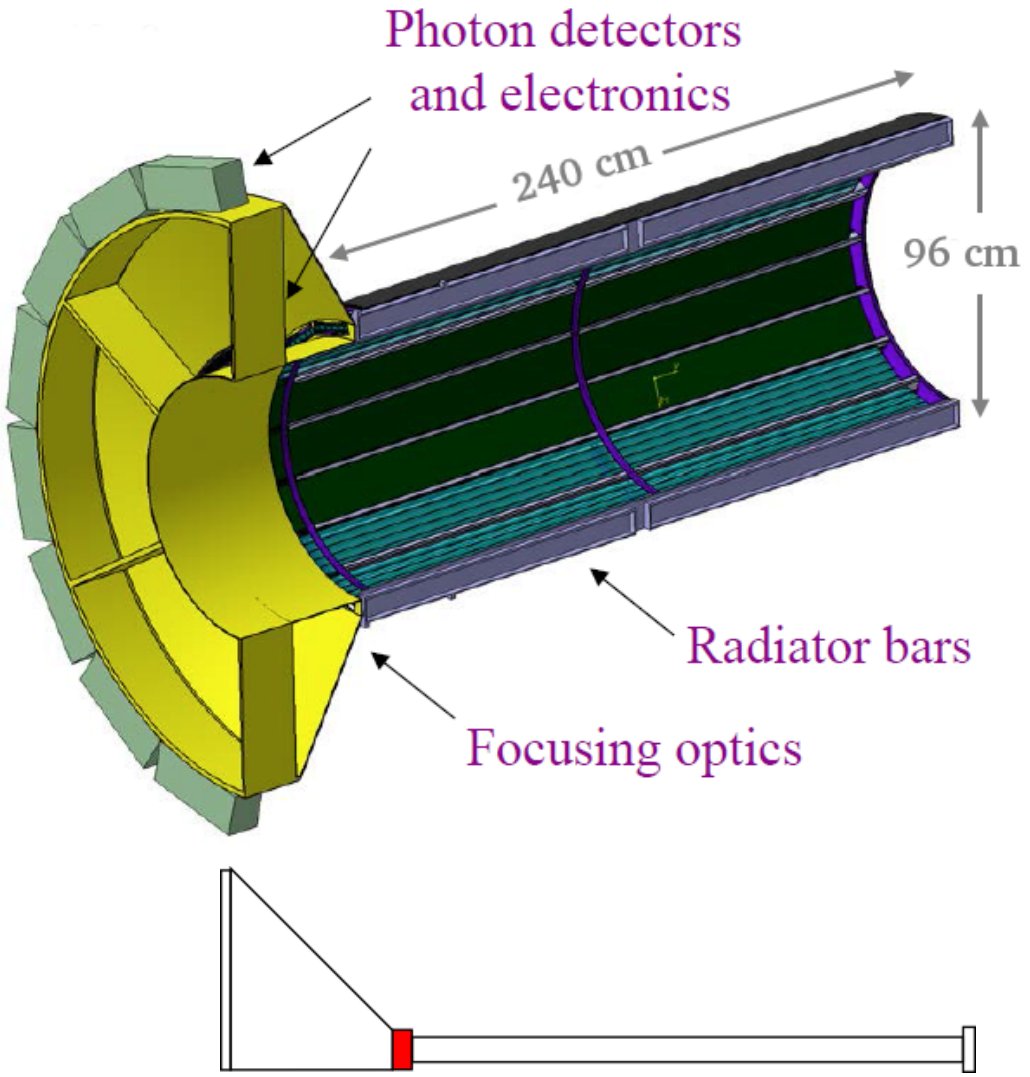
Components of the Panda Barrel DIRC

- Highly polished rectangular radiator.
- Mirror.



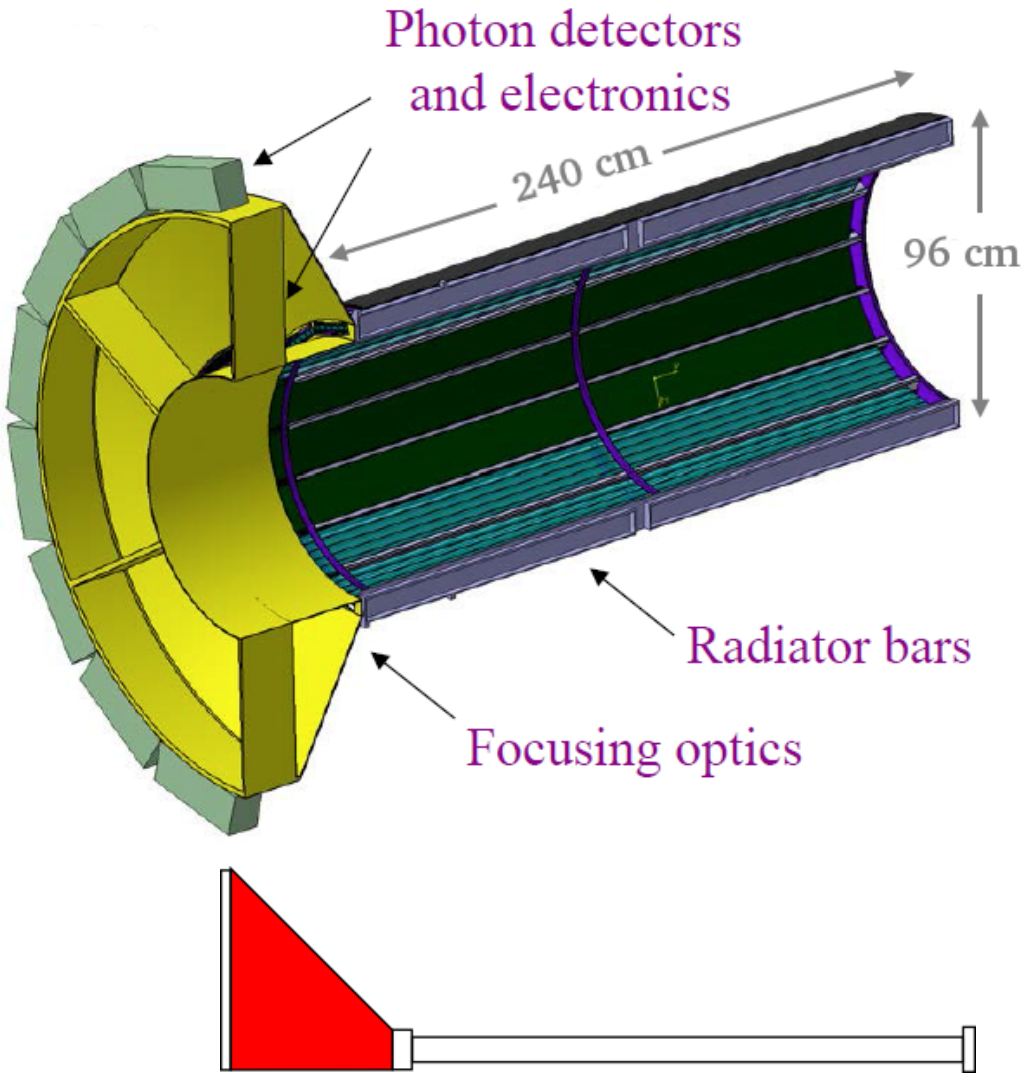
Components of the Panda Barrel DIRC

- Highly polished rectangular radiator.
- Mirror.
- Focusing optics.



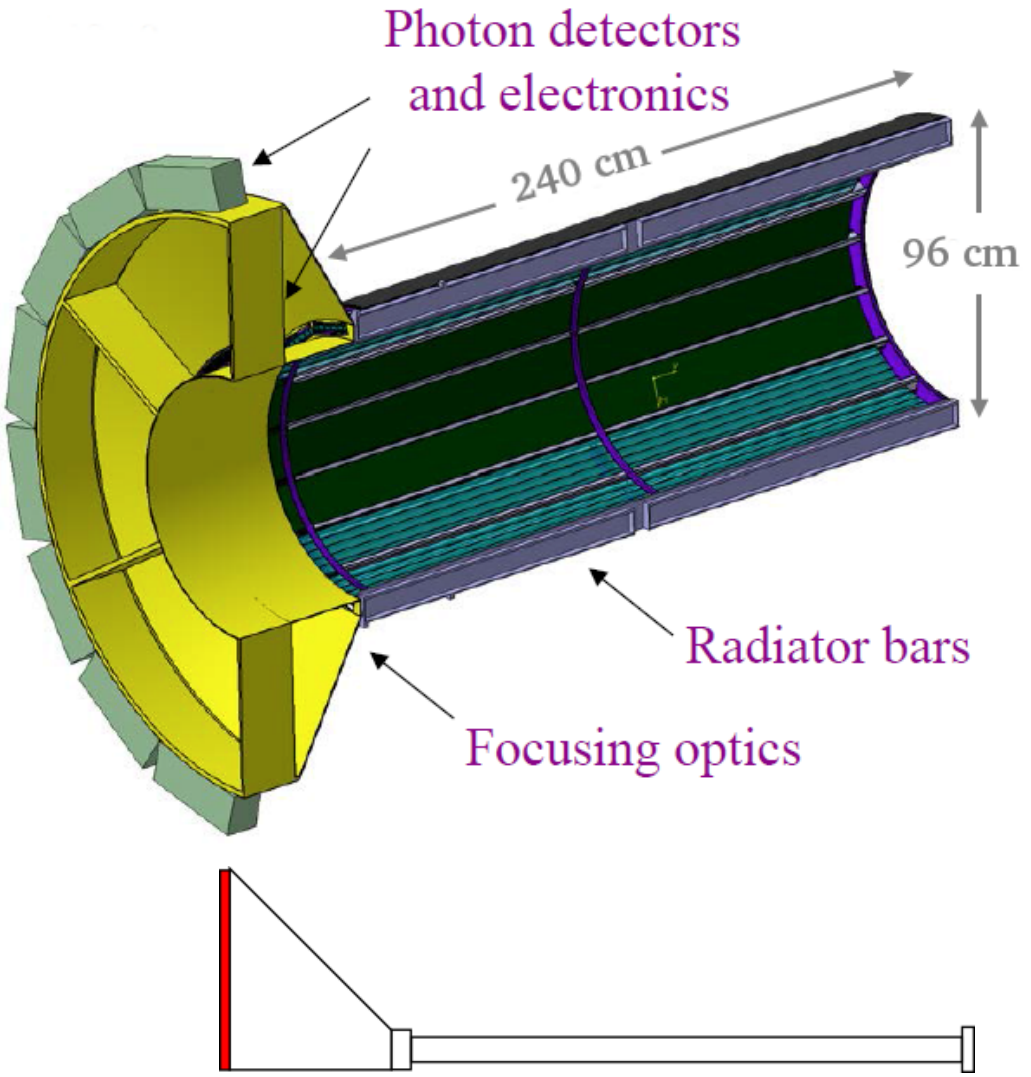
Components of the Panda Barrel DIRC

- Highly polished rectangular radiator.
- Mirror.
- Focusing optics.
- Compact expansion volume.



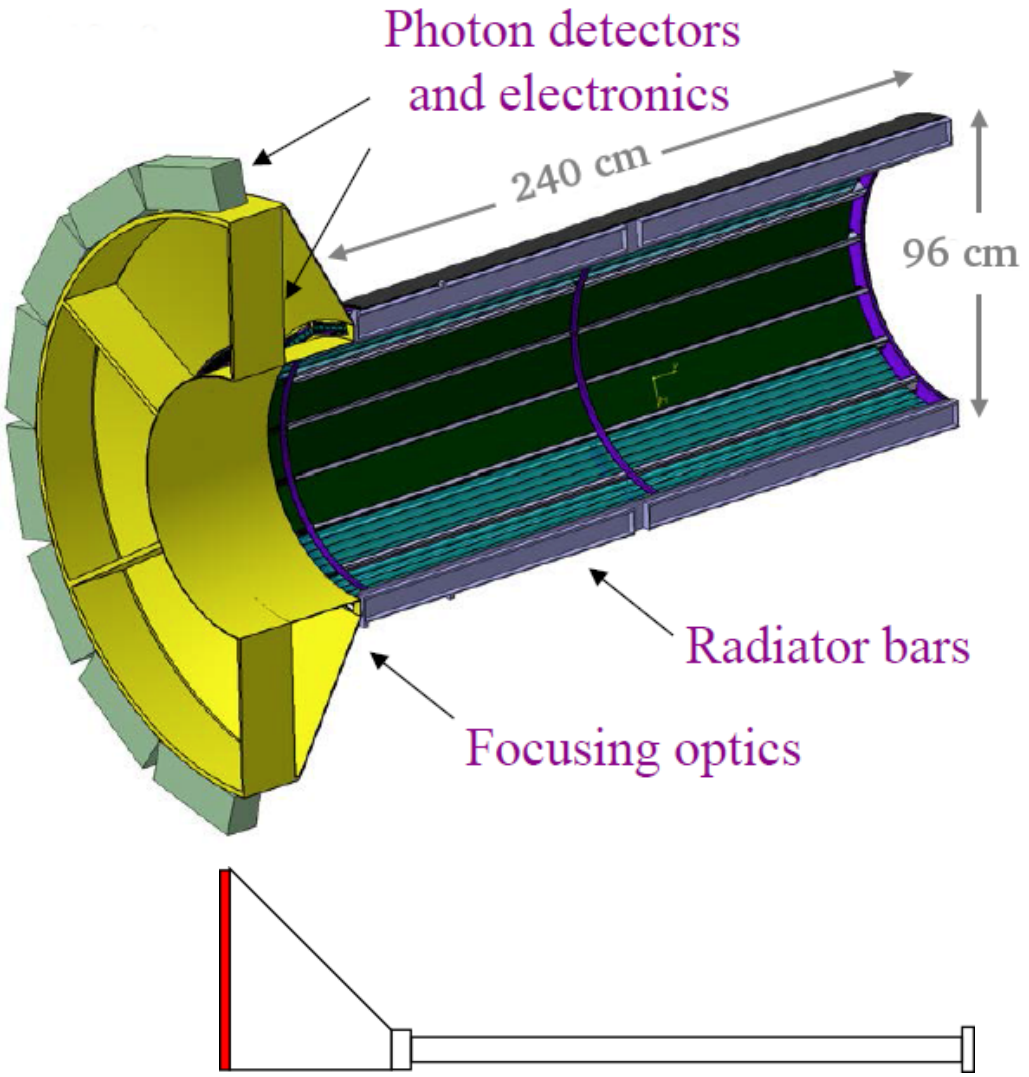
Components of the Panda Barrel DIRC

- Highly polished rectangular radiator.
- Mirror.
- Focusing optics.
- Compact expansion volume.
- Compact multi-anode photon detectors.



Components of the Panda Barrel DIRC

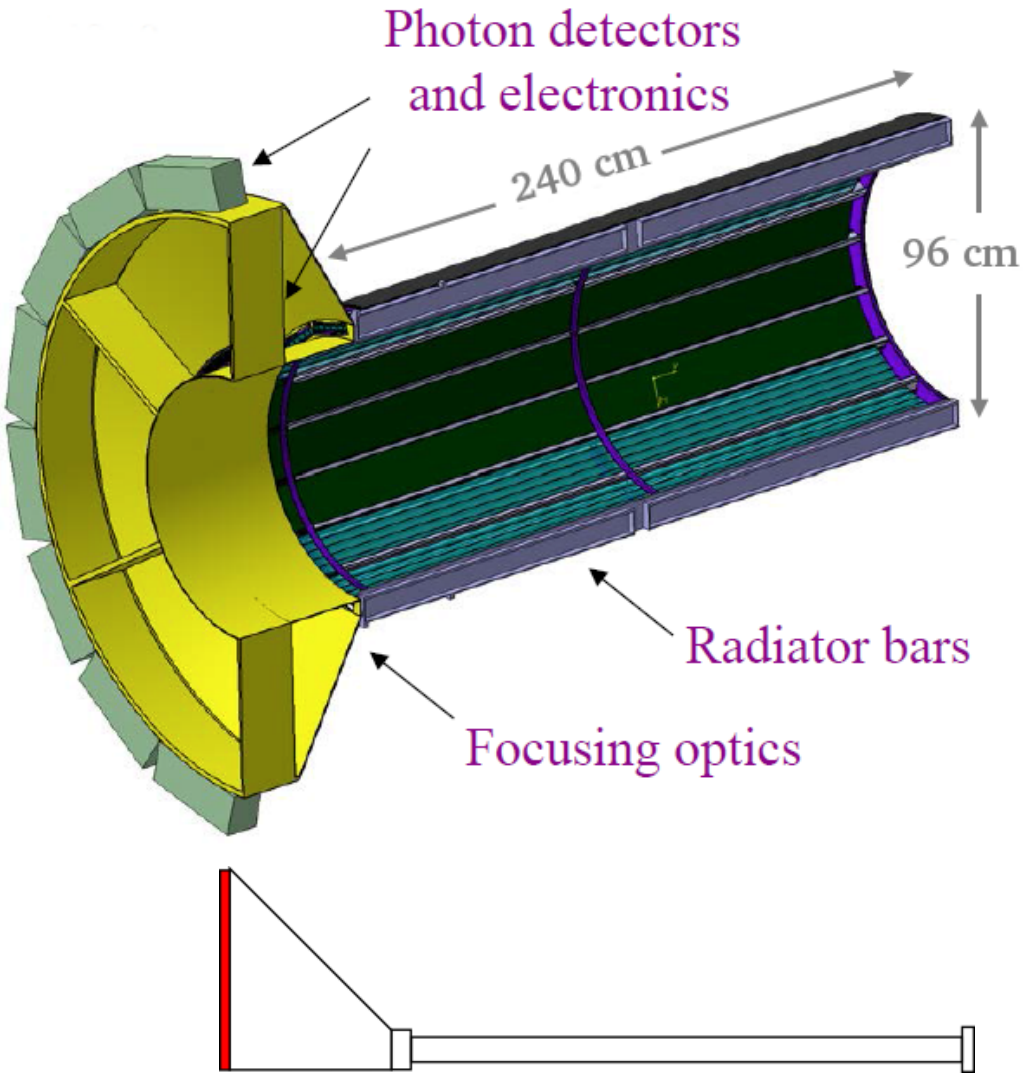
- Highly polished rectangular radiator.
- Mirror.
- Focusing optics.
- Compact expansion volume.
- Compact multi-anode photon detectors.
- Fast readout electronics.



Components of the Panda Barrel DIRC

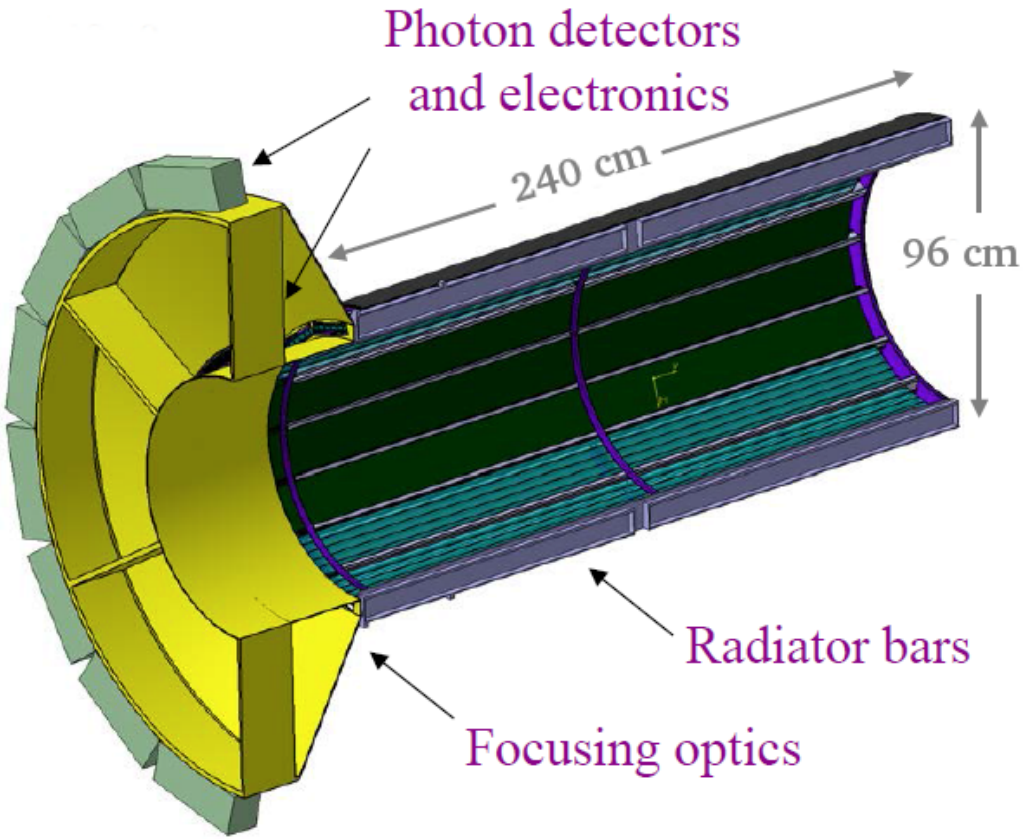
- Highly polished rectangular radiator.
- Mirror.
- Focusing optics.
- Compact expansion volume.
- Compact multi-anode photon detectors.
- Fast readout electronics.

Different options for the Expansion Volume, Focusing, Radiator.



Components of the Panda Barrel DIRC

- Highly polished rectangular radiator.
- Mirror.
- Focusing optics.
- Compact expansion volume.
- Compact multi-anode photon detectors.
- Fast readout electronics.

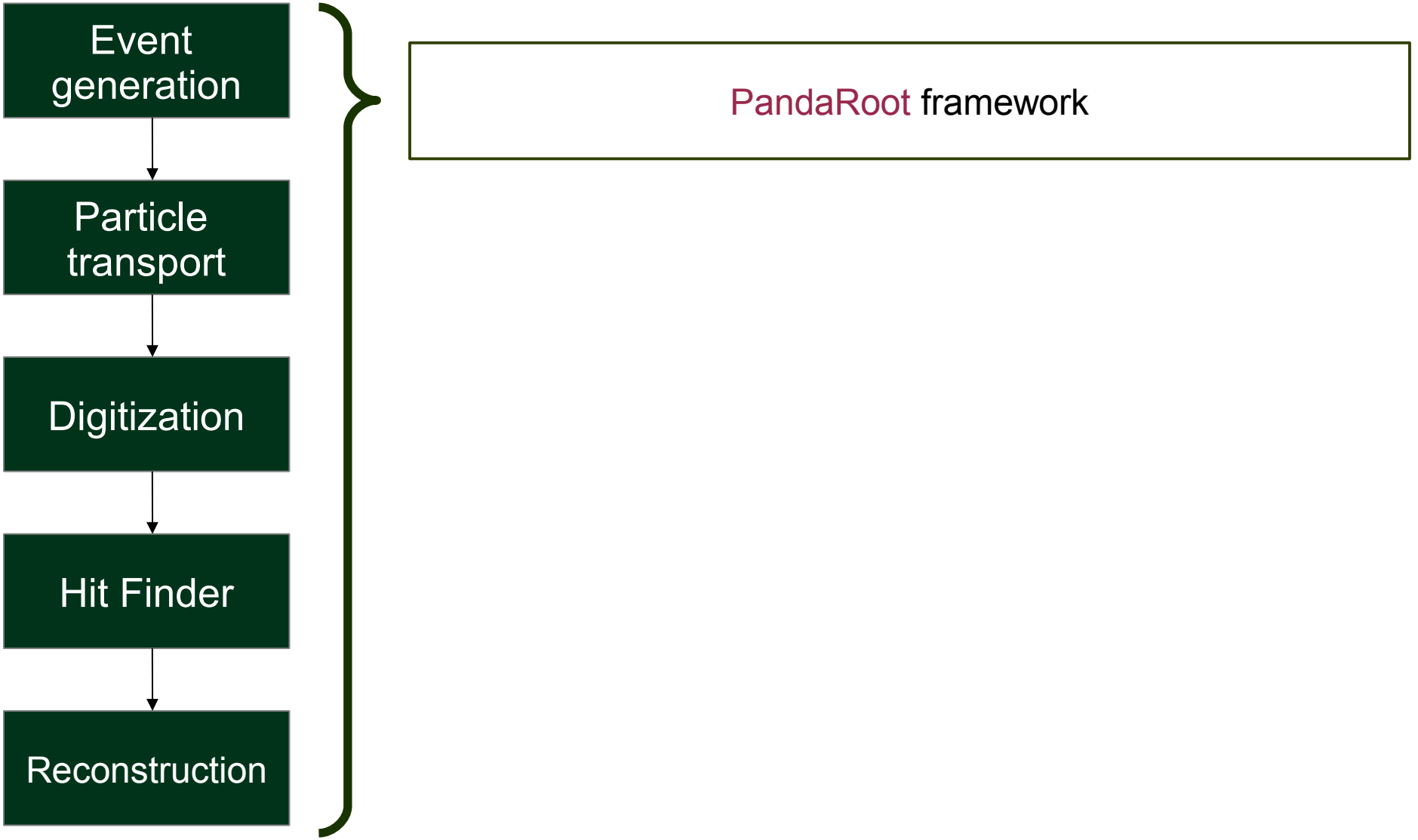


Different options for the Expansion Volume, Focusing, Radiator.

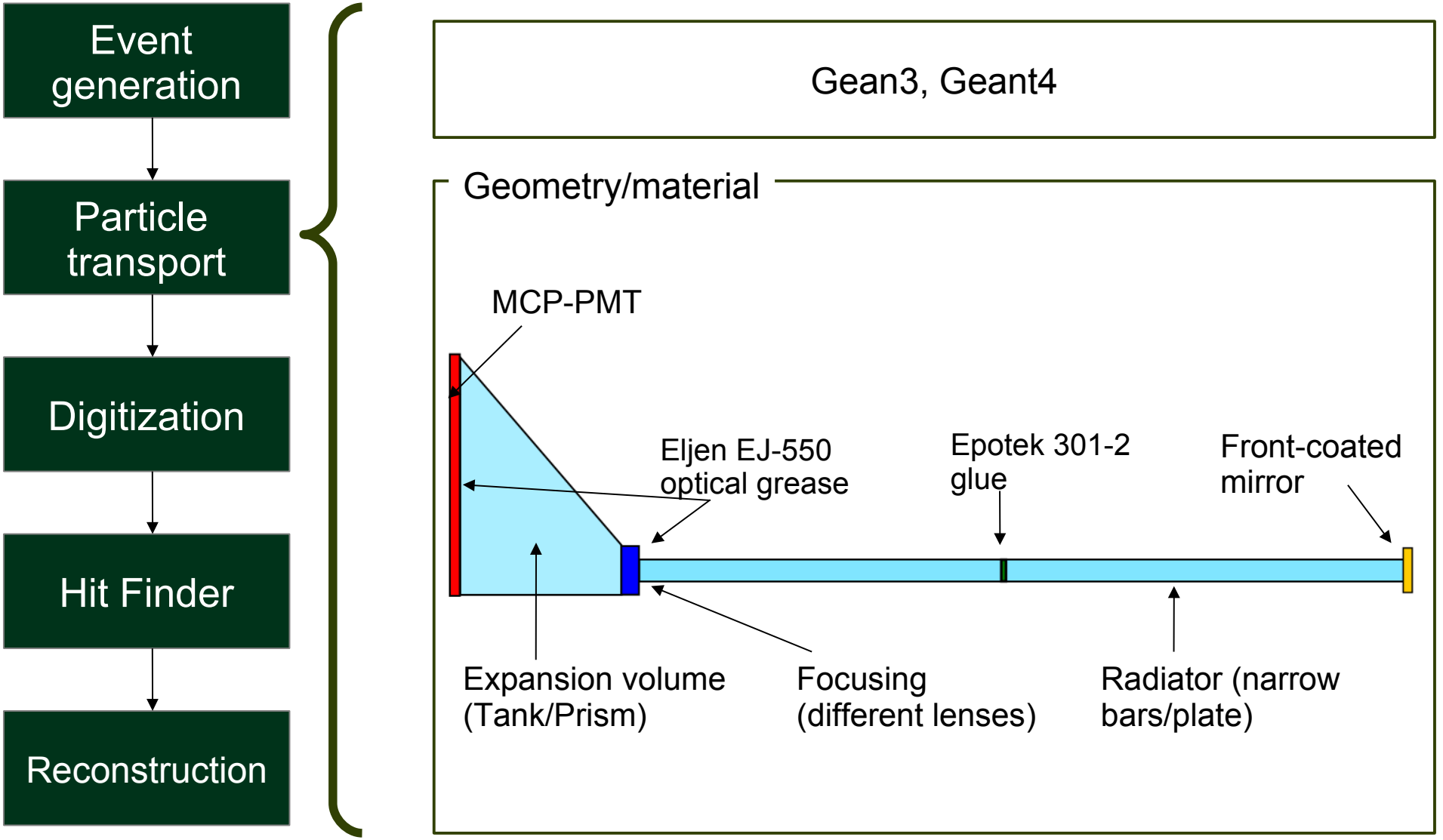
Expected performance of
3σ π/K separation requires:

- Single photon Cherenkov angle resolution: **8-10 mrad**.
- Number of detected photons for β≈1 track: **>15**.

Simulation and Reconstruction



Simulation and Reconstruction



Simulation and Reconstruction

Event generation

Particle transport

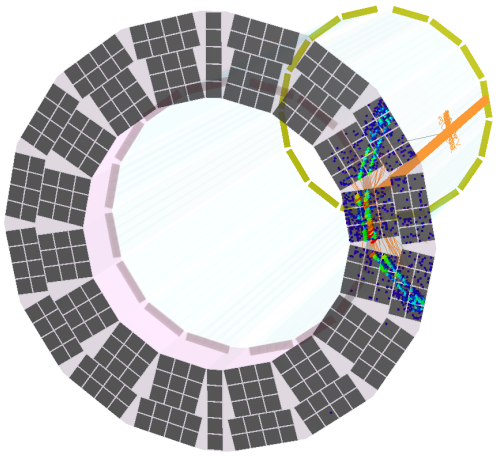
Digitization

Hit Finder

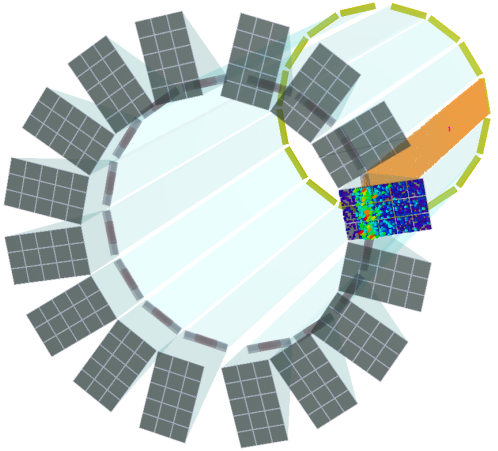
Reconstruction

Geometry examples

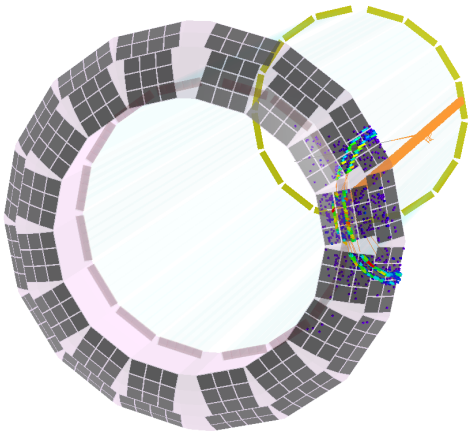
Tank/bar



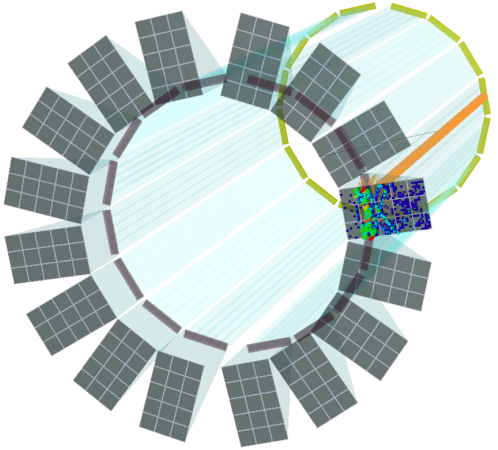
Prism/plate



Tank with curved FP/bar



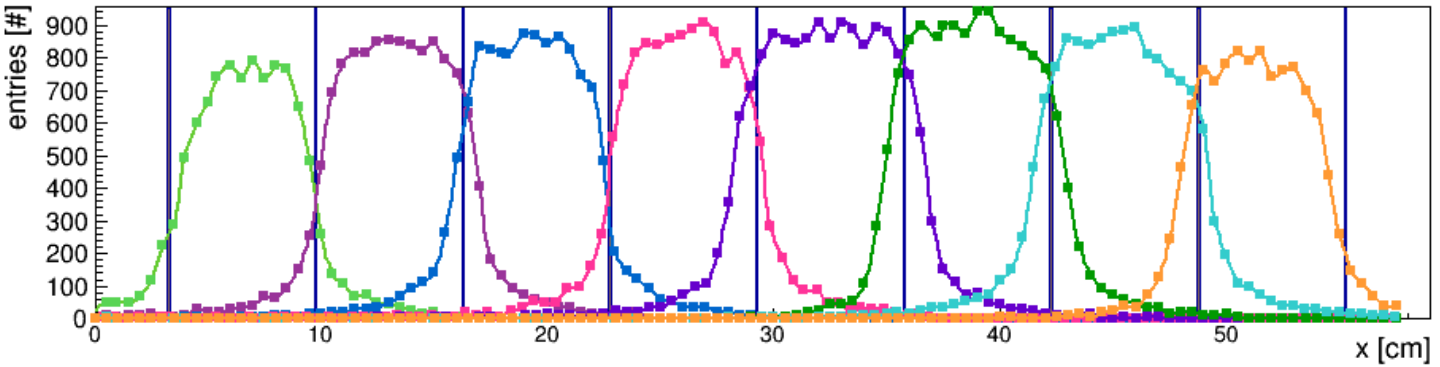
Prism/bar



Simulation and Reconstruction

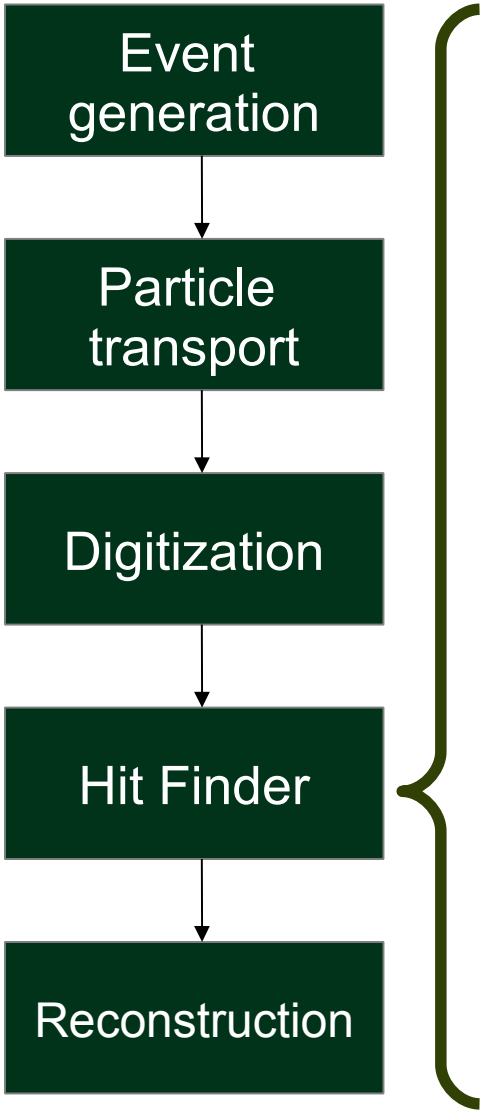
- Event generation
- Particle transport
- Digitization
- Hit Finder
- Reconstruction

- Charge sharing



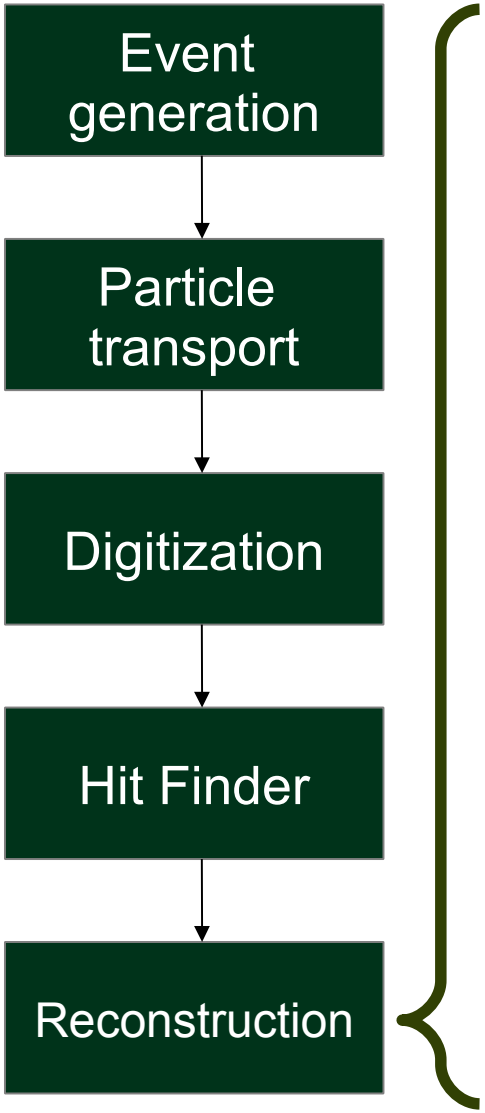
- Dark counts
- Single photon time resolution
- Collection efficiency
- Quantum efficiency

Simulation and Reconstruction



Assignment of hits to their tracks

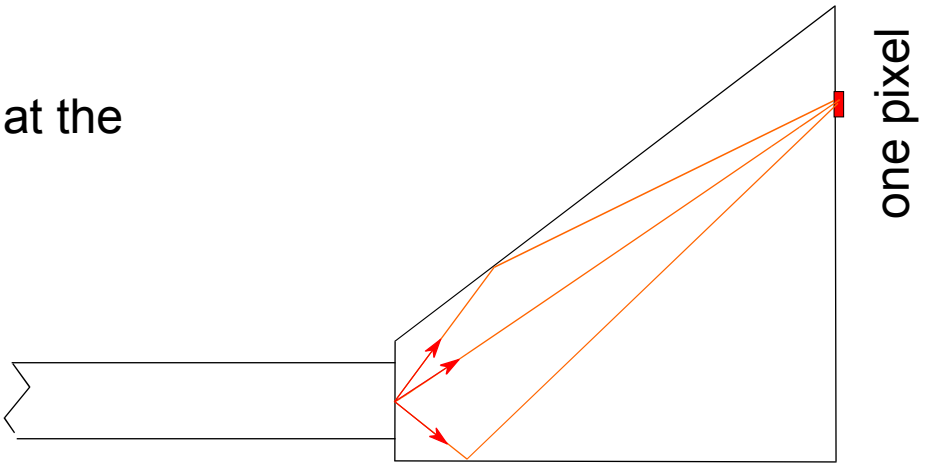
Simulation and Reconstruction



- Geometrical reconstruction
- Time Likelihood imaging

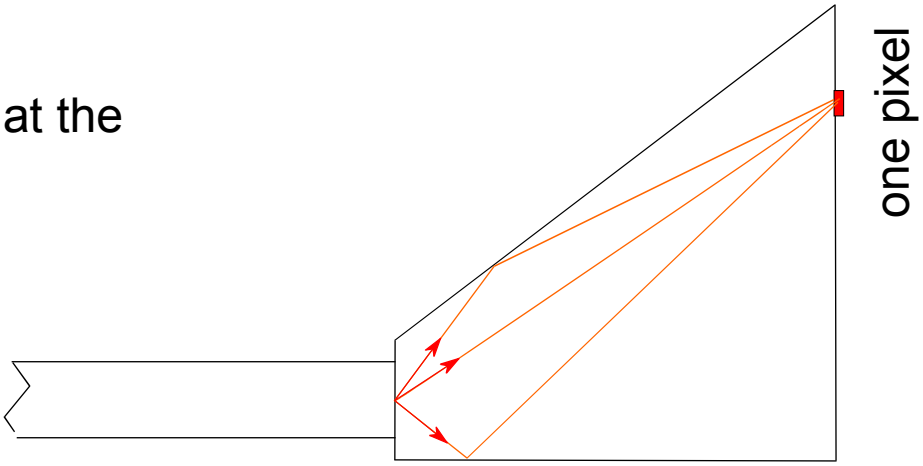
Geometrical Reconstruction

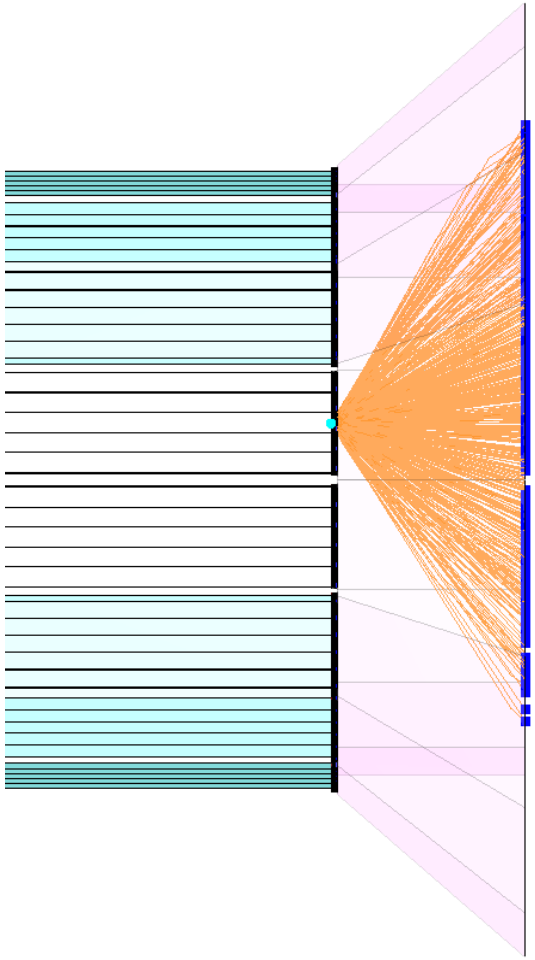
- BABAR-like reconstruction
- Look-Up Table creation: store direction at the end of the radiators for each hit pixel



Geometrical Reconstruction

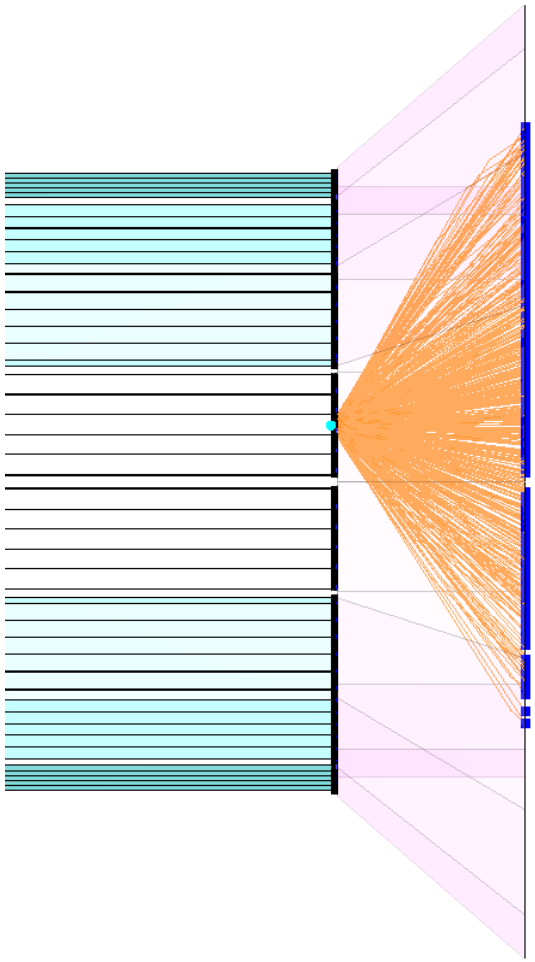
- BABAR-like reconstruction
- Look-Up Table creation: store direction at the end of the radiators for each hit pixel

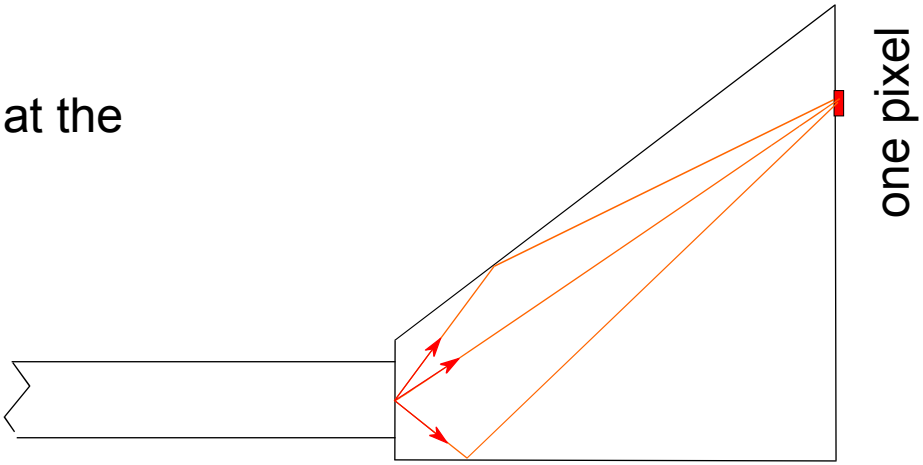


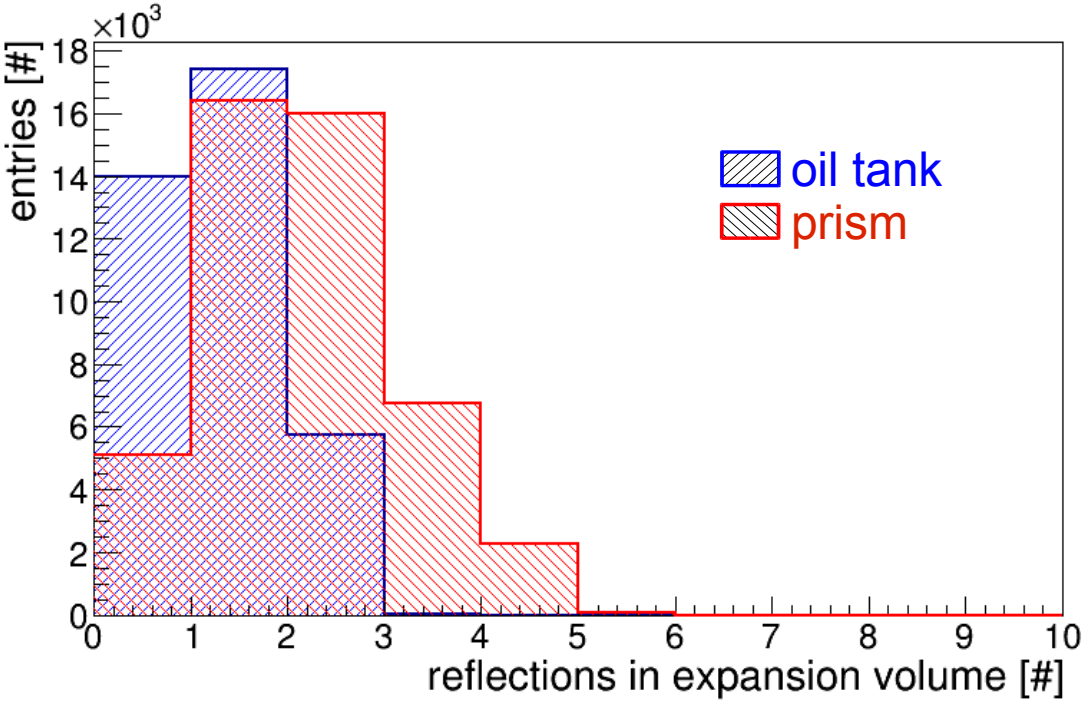


Geometrical Reconstruction

- BABAR-like reconstruction
- Look-Up Table creation: store direction at the end of the radiators for each hit pixel

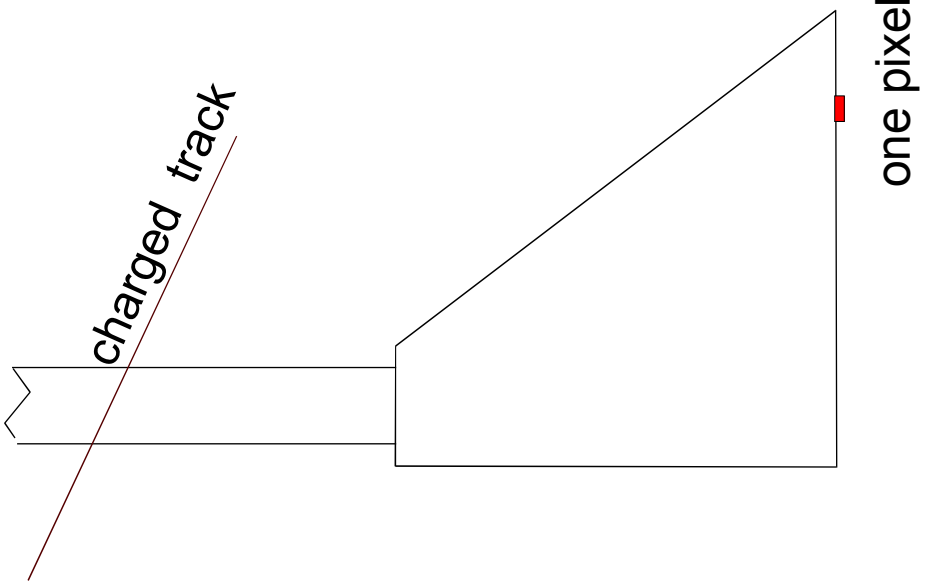






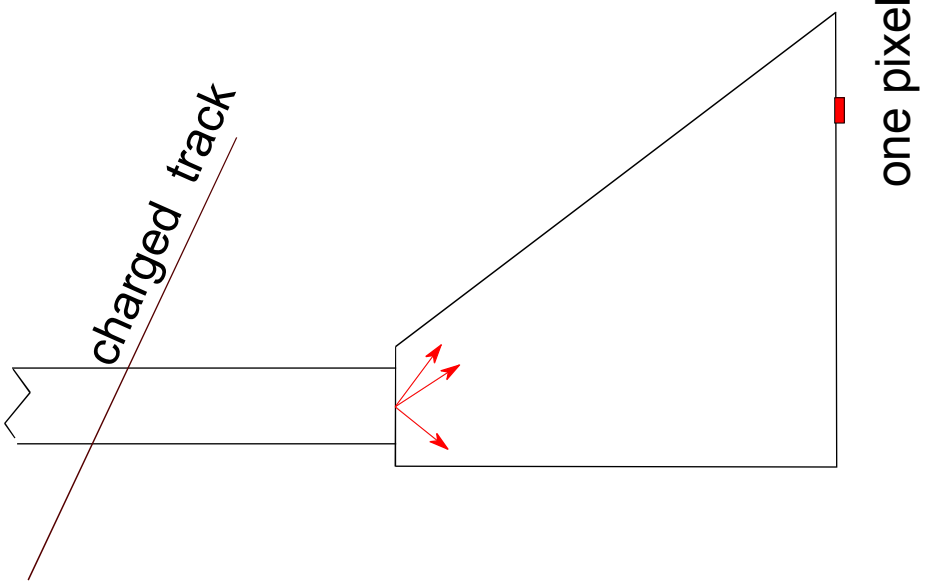
Geometrical Reconstruction

- Reconstruction: direction from LUT for hit pixels are combined with charge track direction



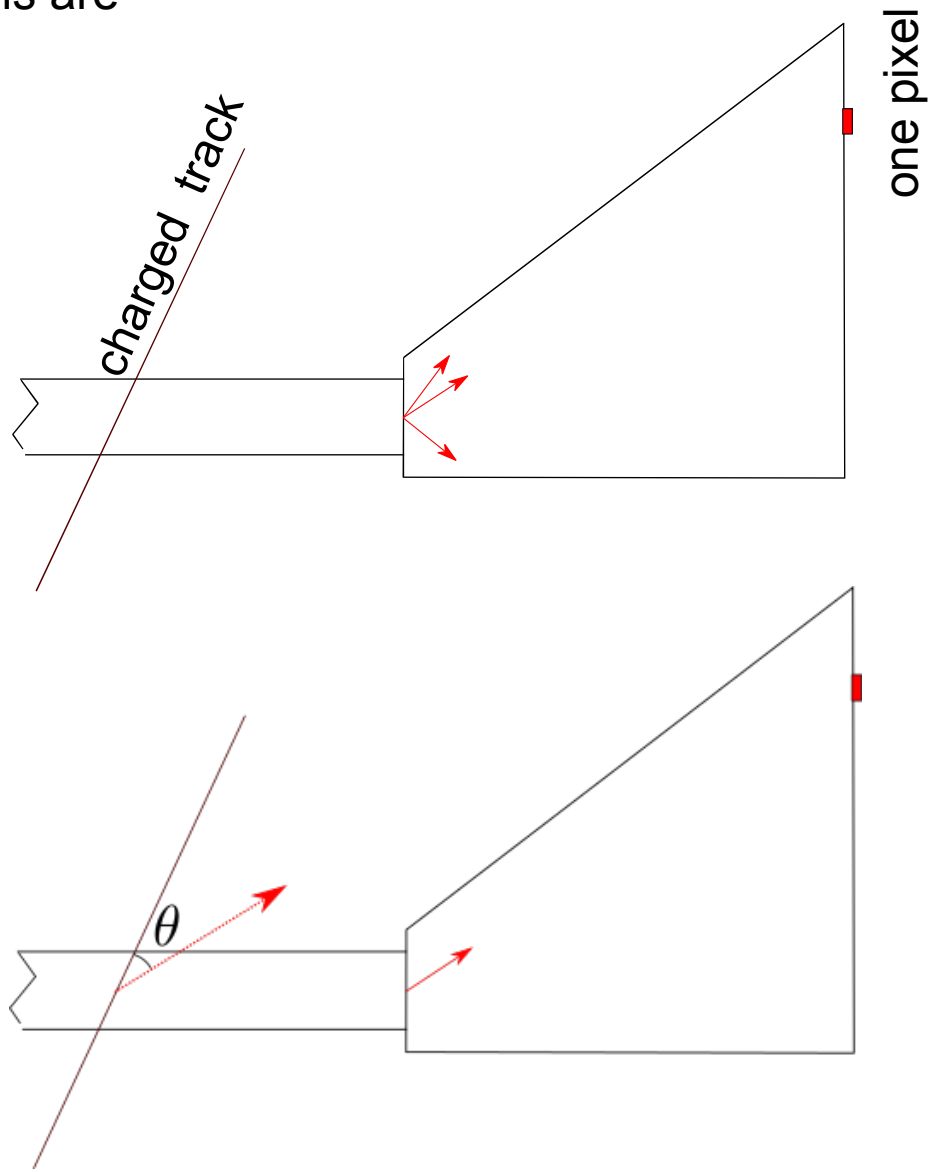
Geometrical Reconstruction

- Reconstruction: direction from LUT for hit pixels are combined with charge track direction



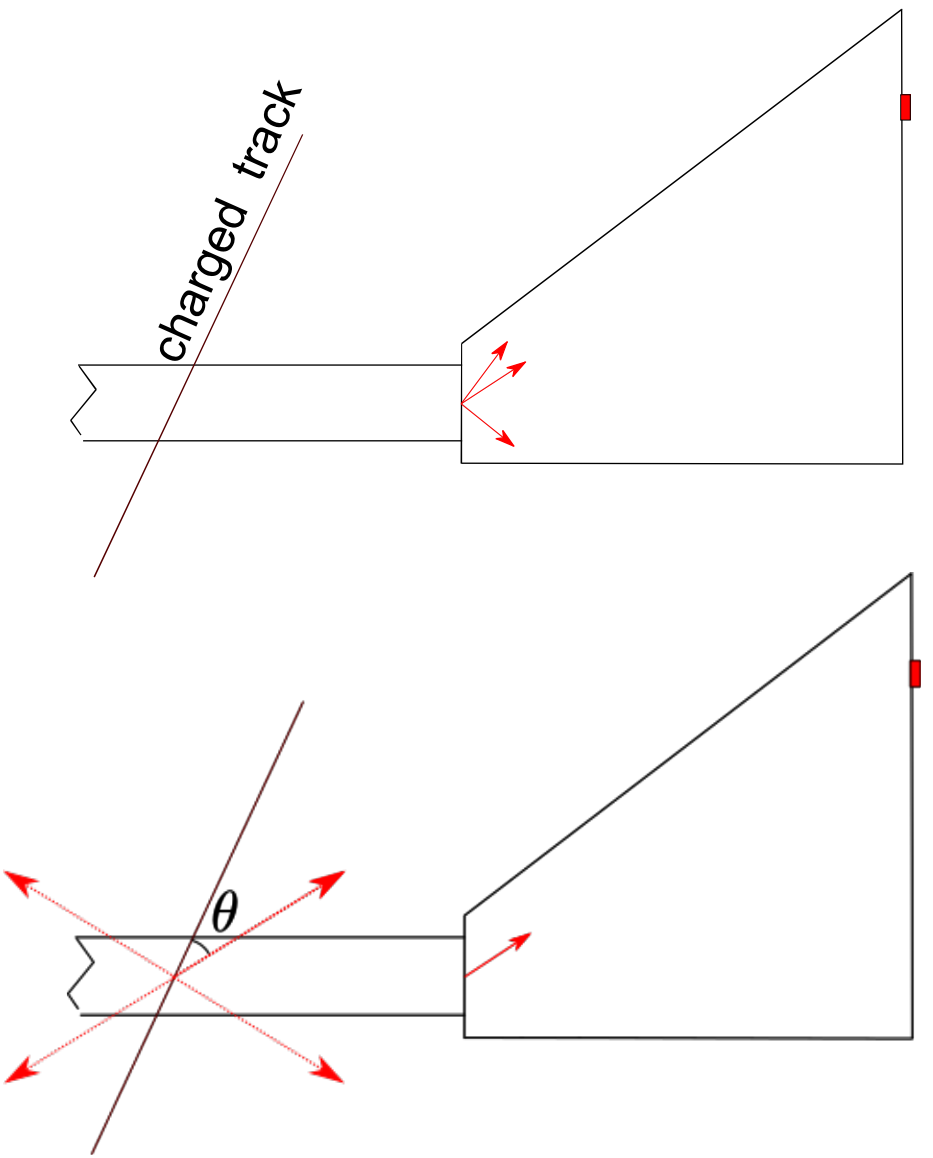
Geometrical Reconstruction

- Reconstruction: direction from LUT for hit pixels are combined with charge track direction



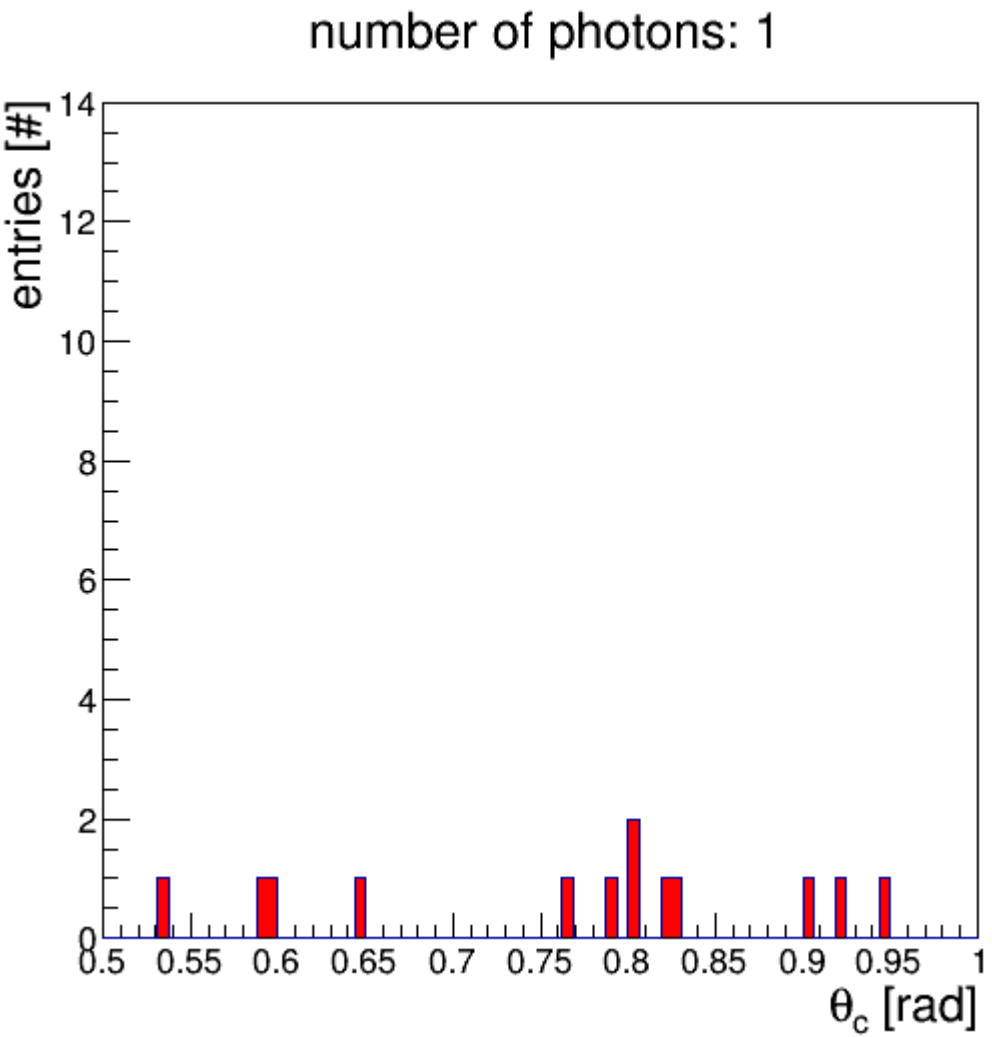
Geometrical Reconstruction

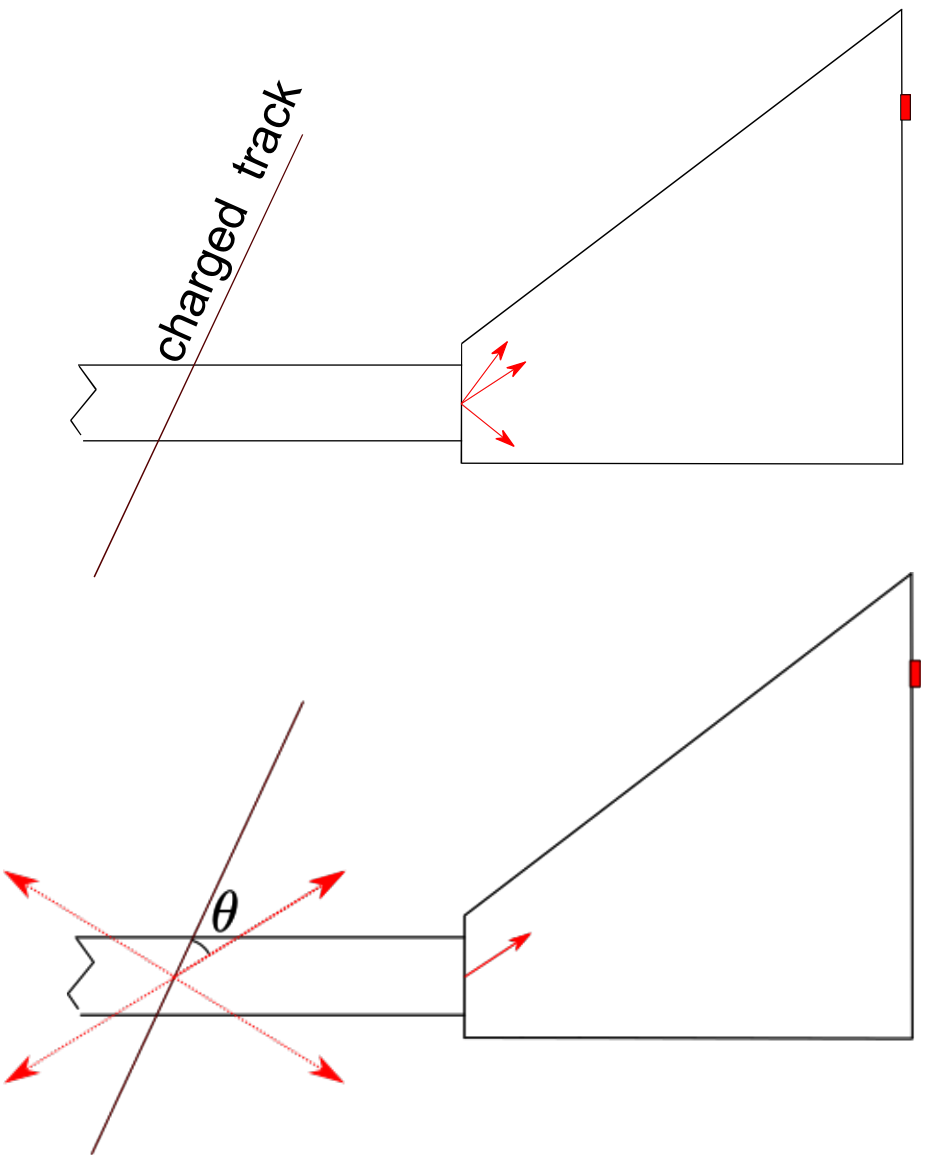
- Reconstruction: direction from LUT for hit pixels are combined with charge track direction



Geometrical Reconstruction

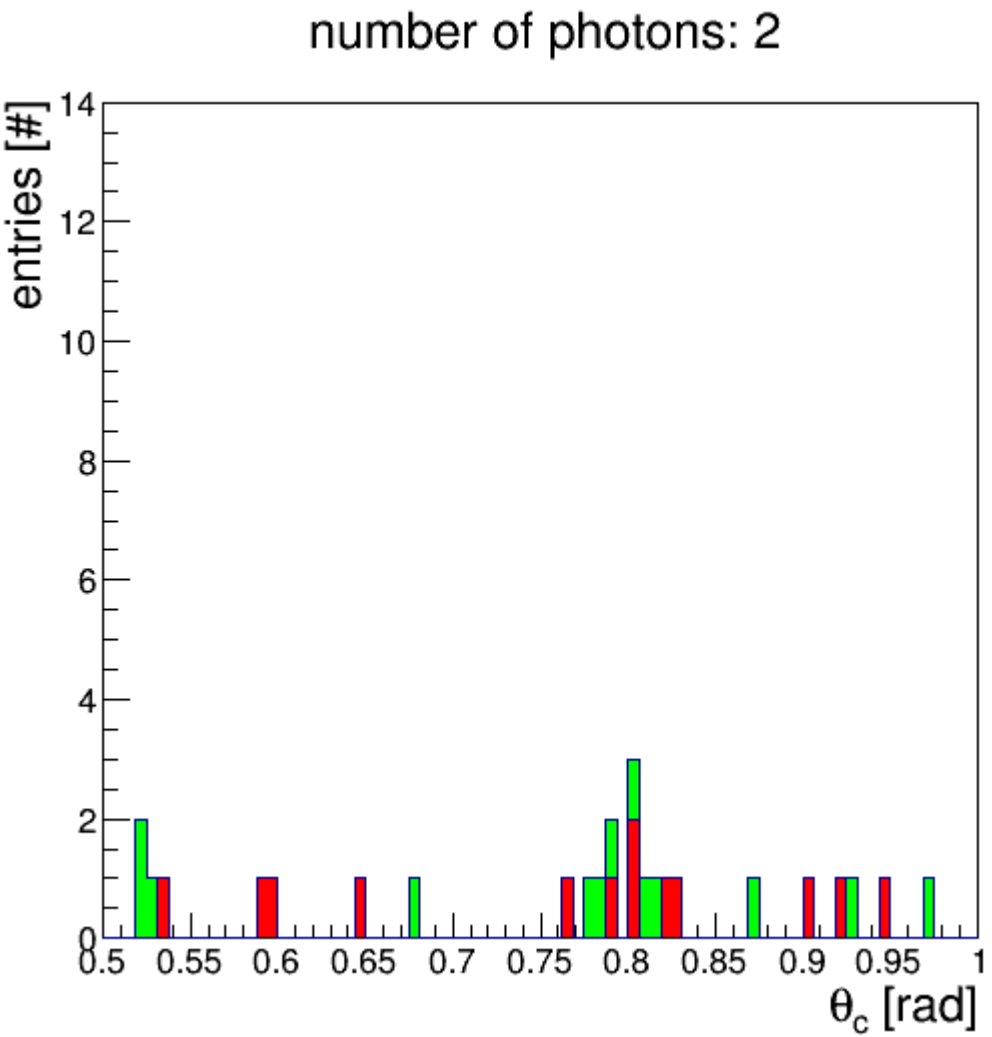
- Reconstruction: direction from LUT for hit pixels are combined with charge track direction

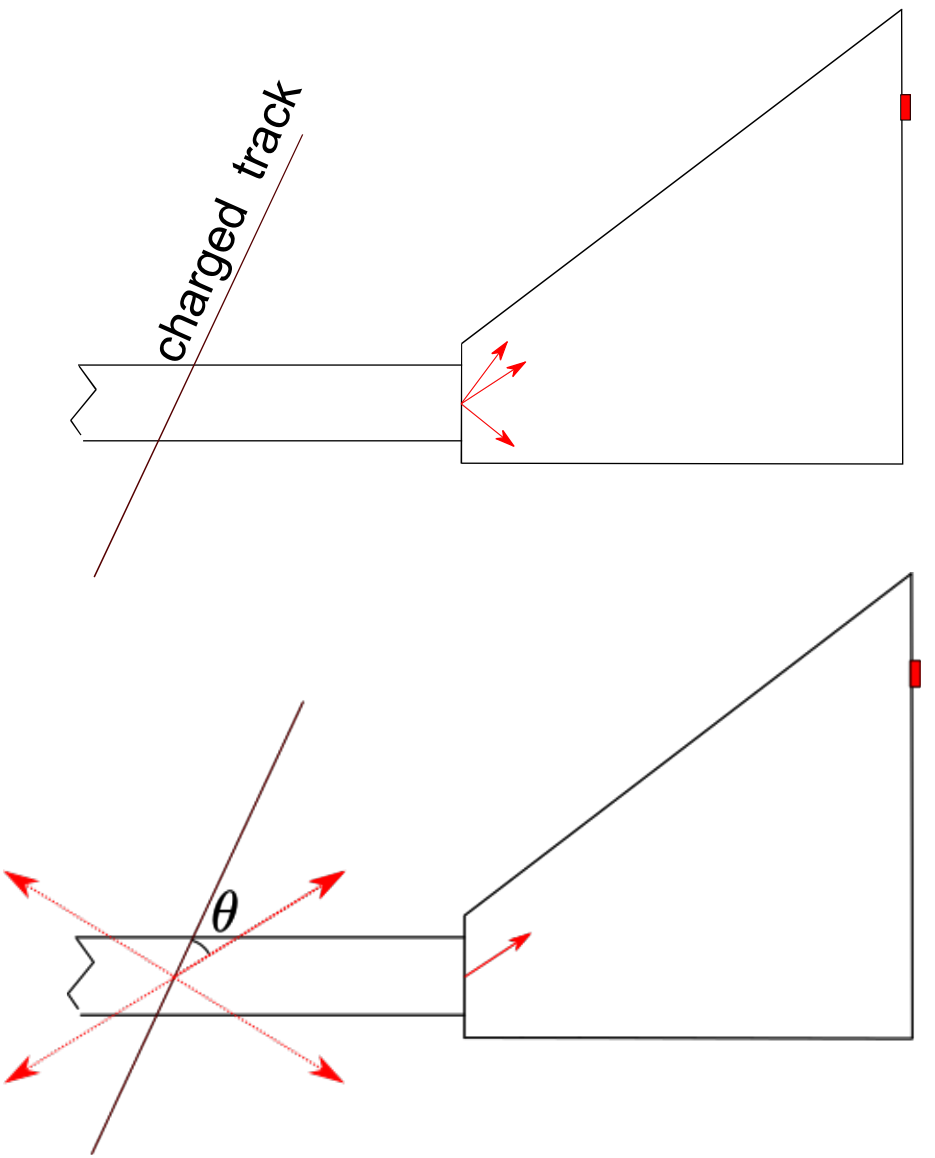




Geometrical Reconstruction

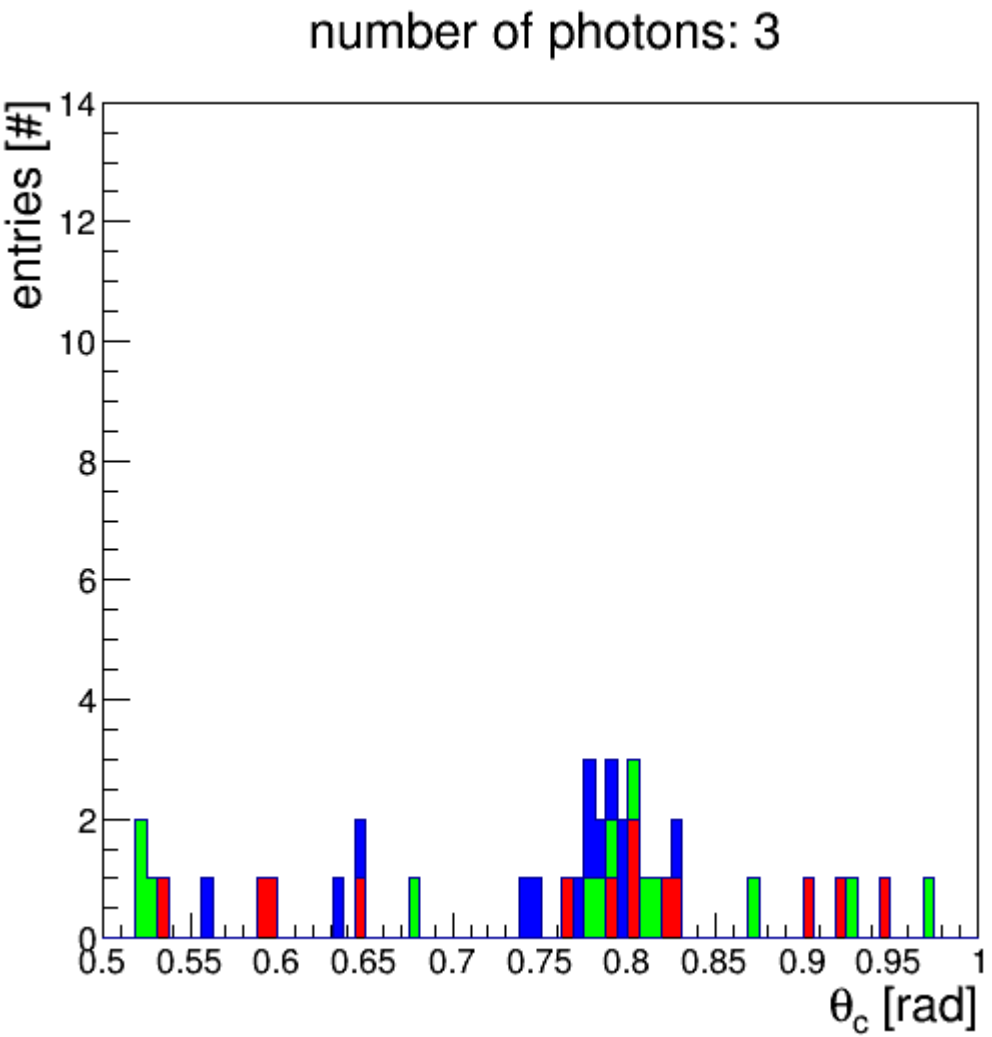
- Reconstruction: direction from LUT for hit pixels are combined with charge track direction

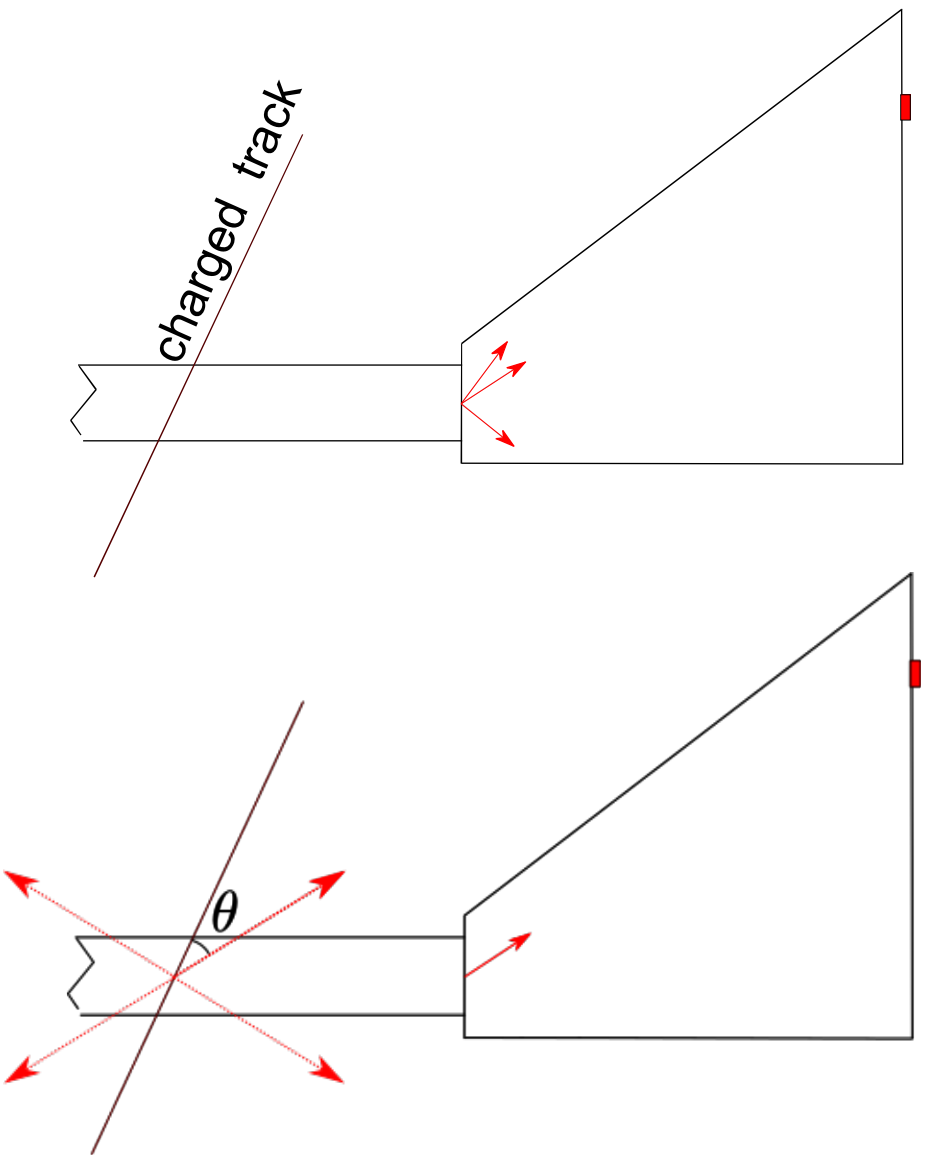




Geometrical Reconstruction

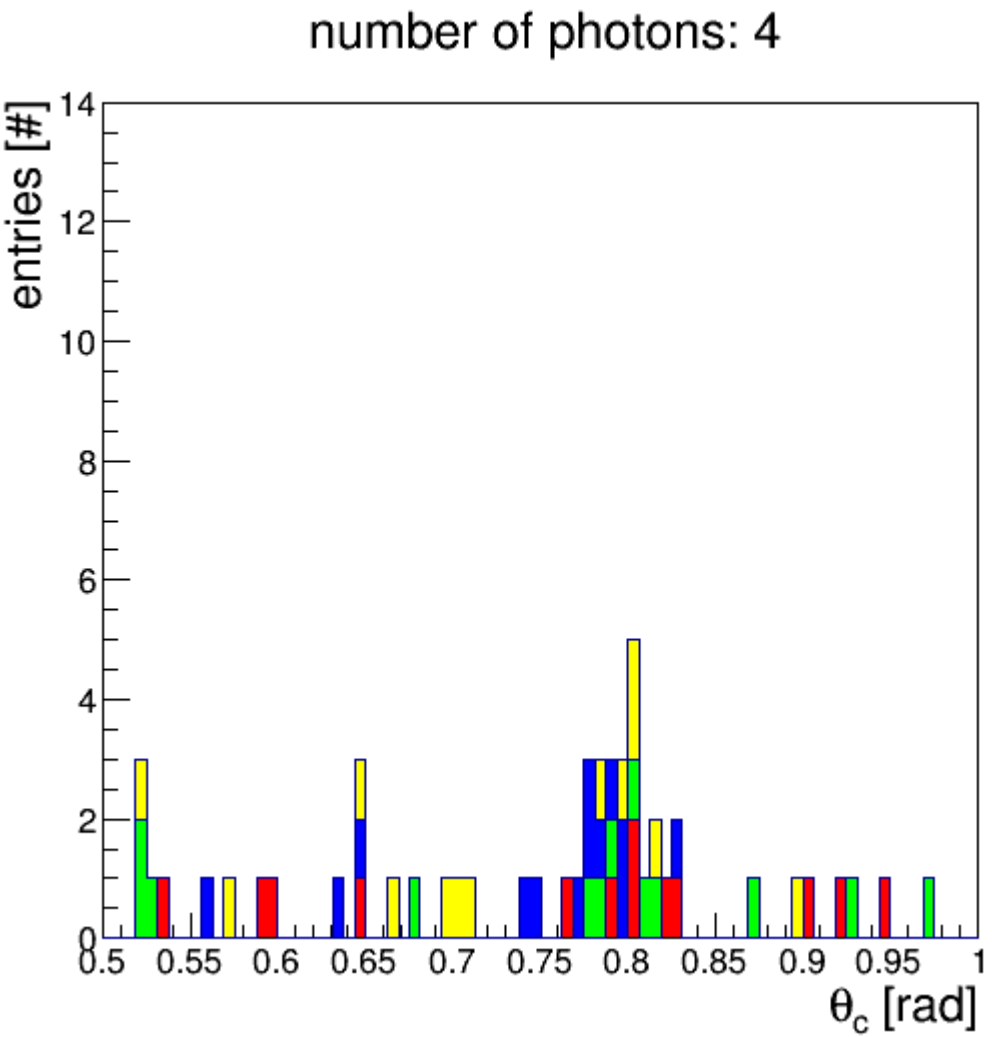
- Reconstruction: direction from LUT for hit pixels are combined with charge track direction

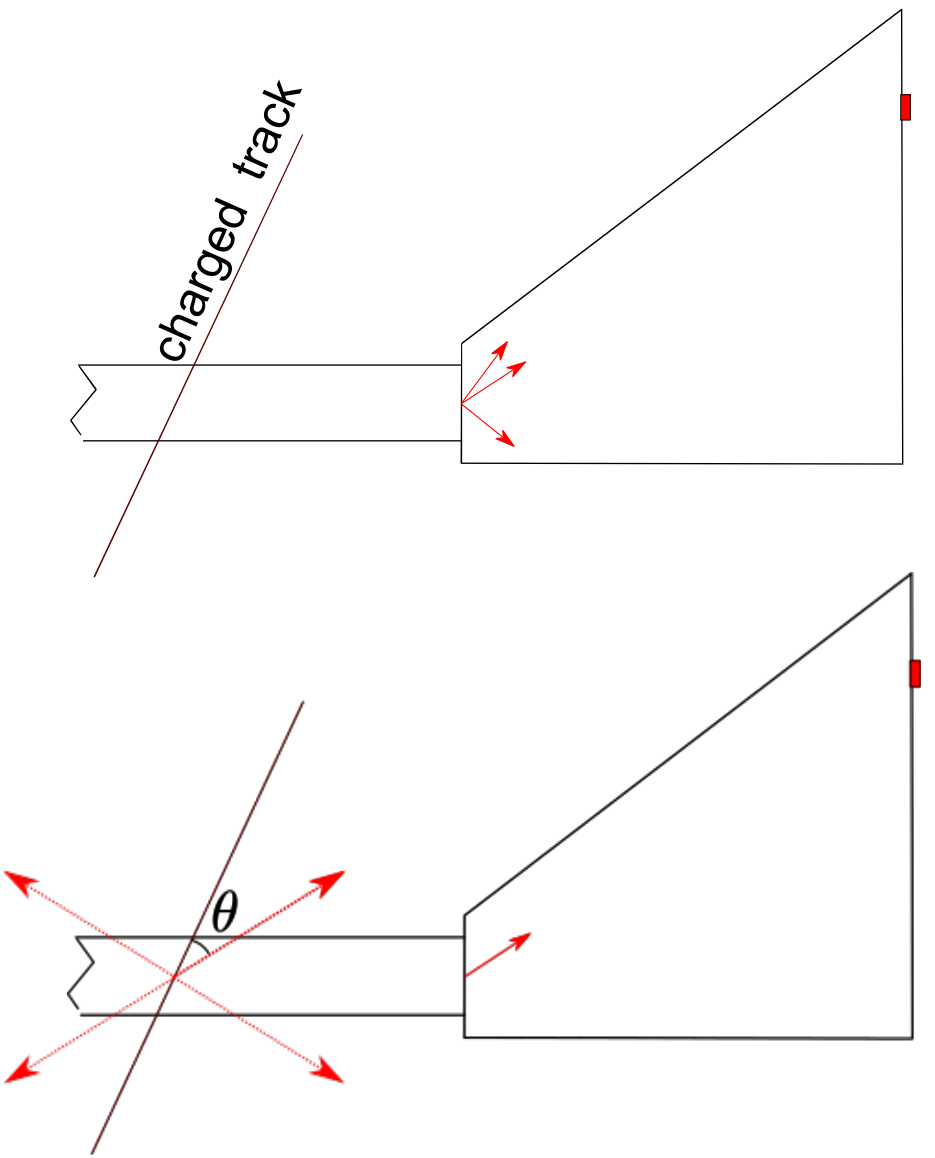




Geometrical Reconstruction

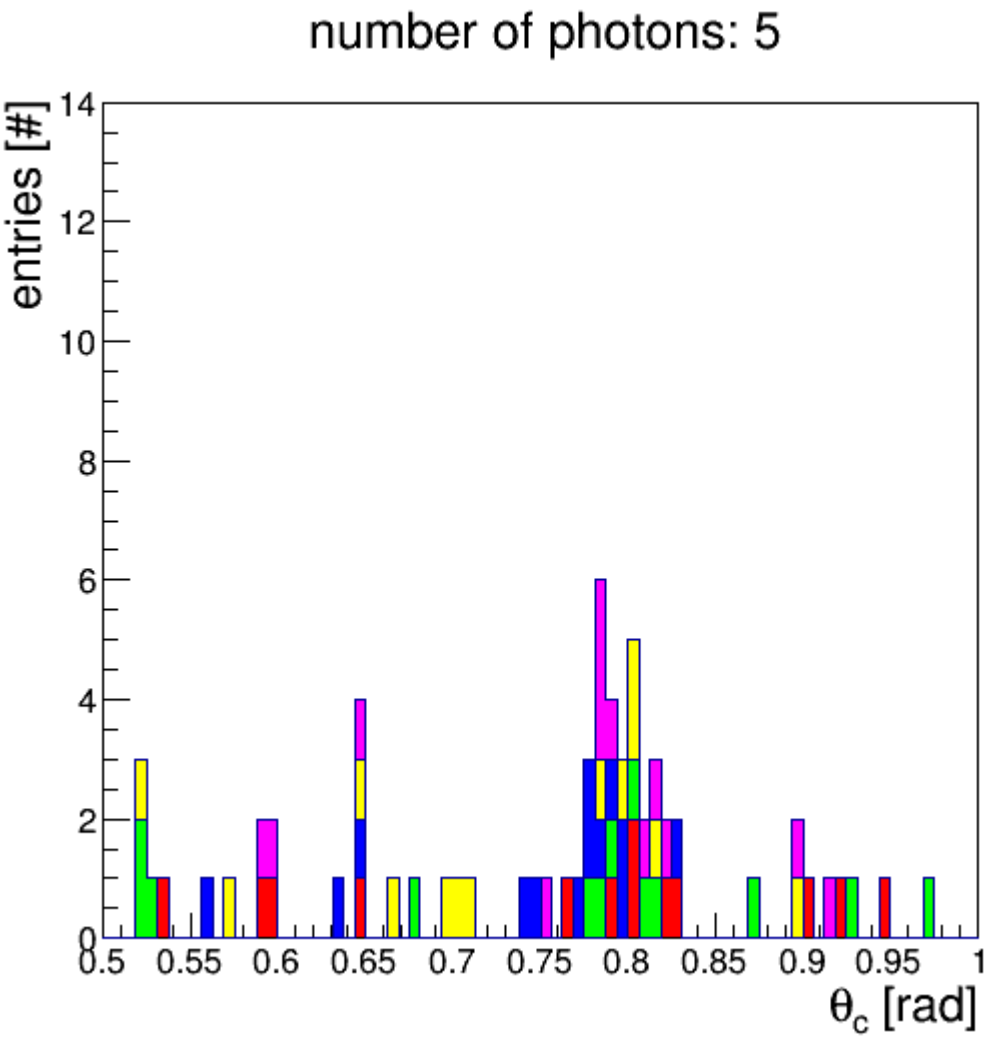
- Reconstruction: direction from LUT for hit pixels are combined with charge track direction

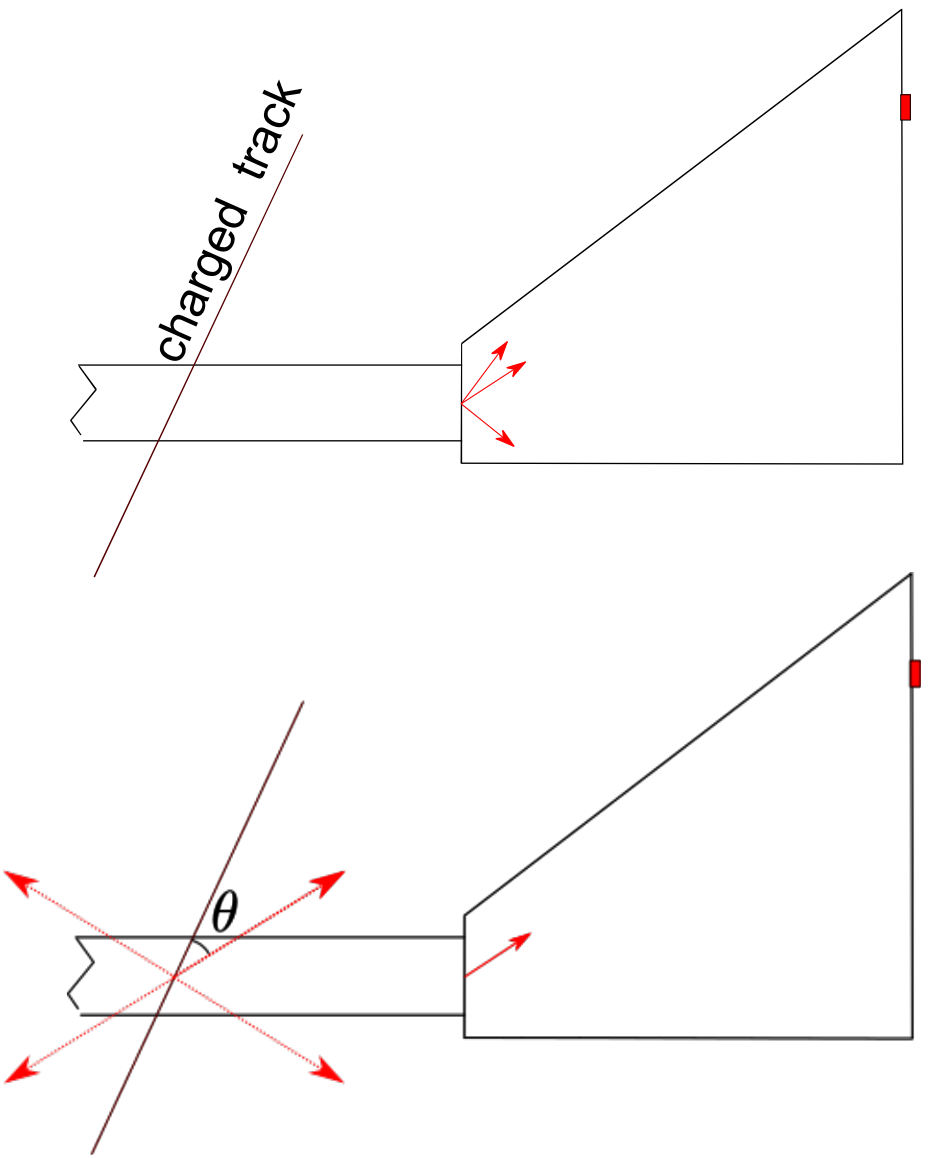




Geometrical Reconstruction

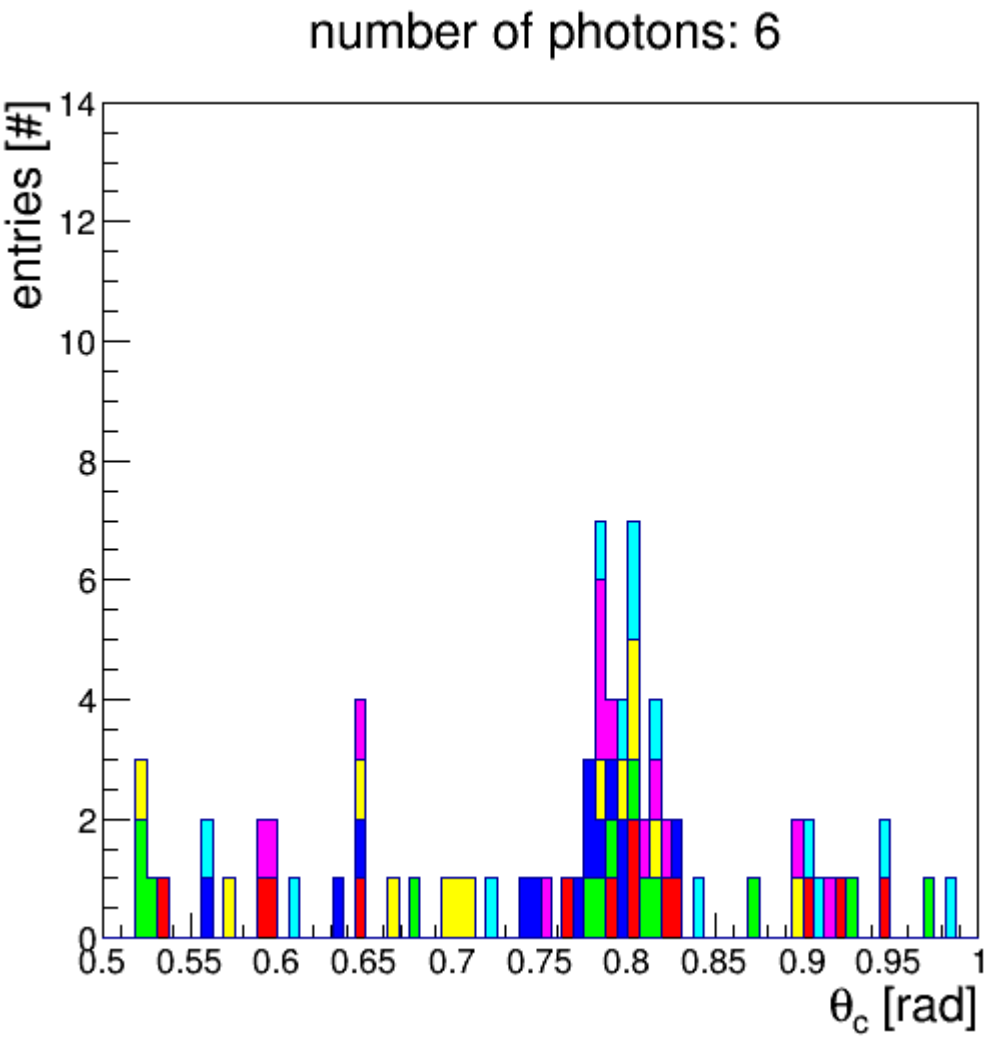
- Reconstruction: direction from LUT for hit pixels are combined with charge track direction

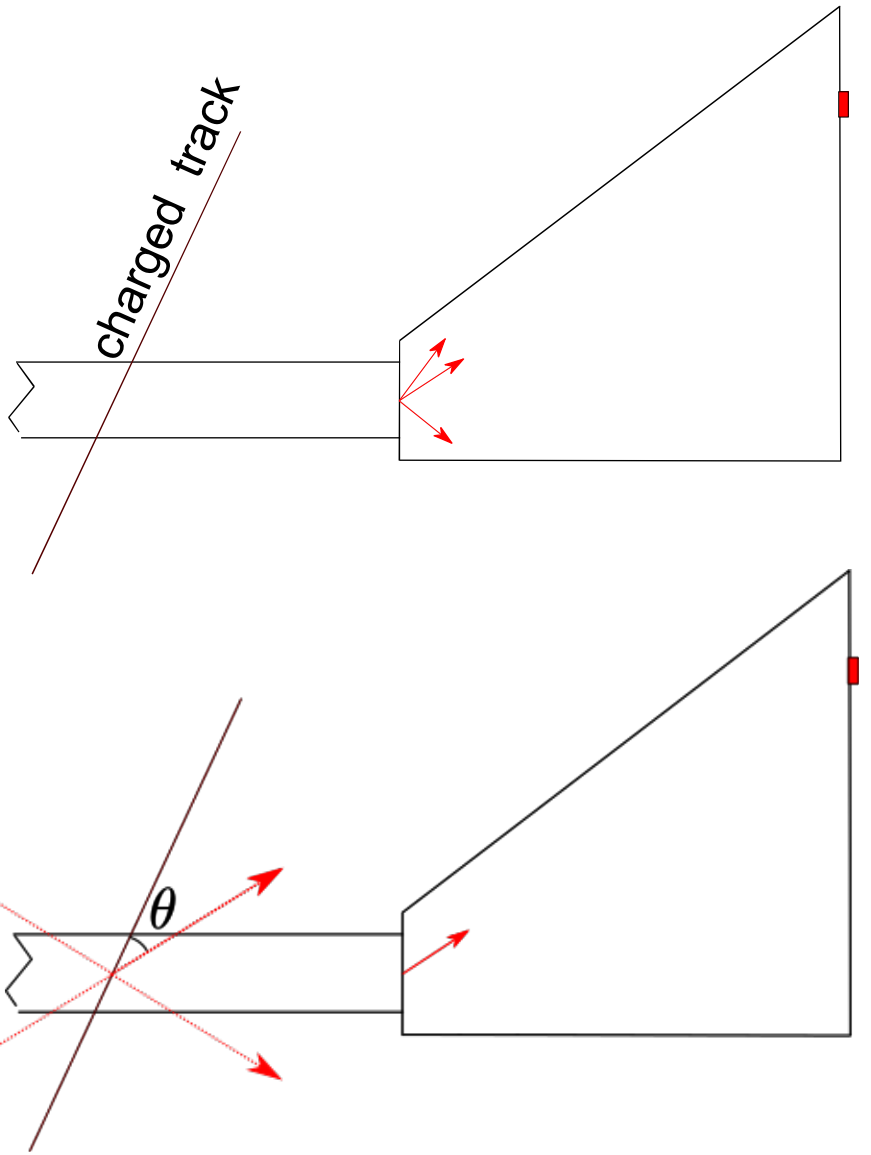




Geometrical Reconstruction

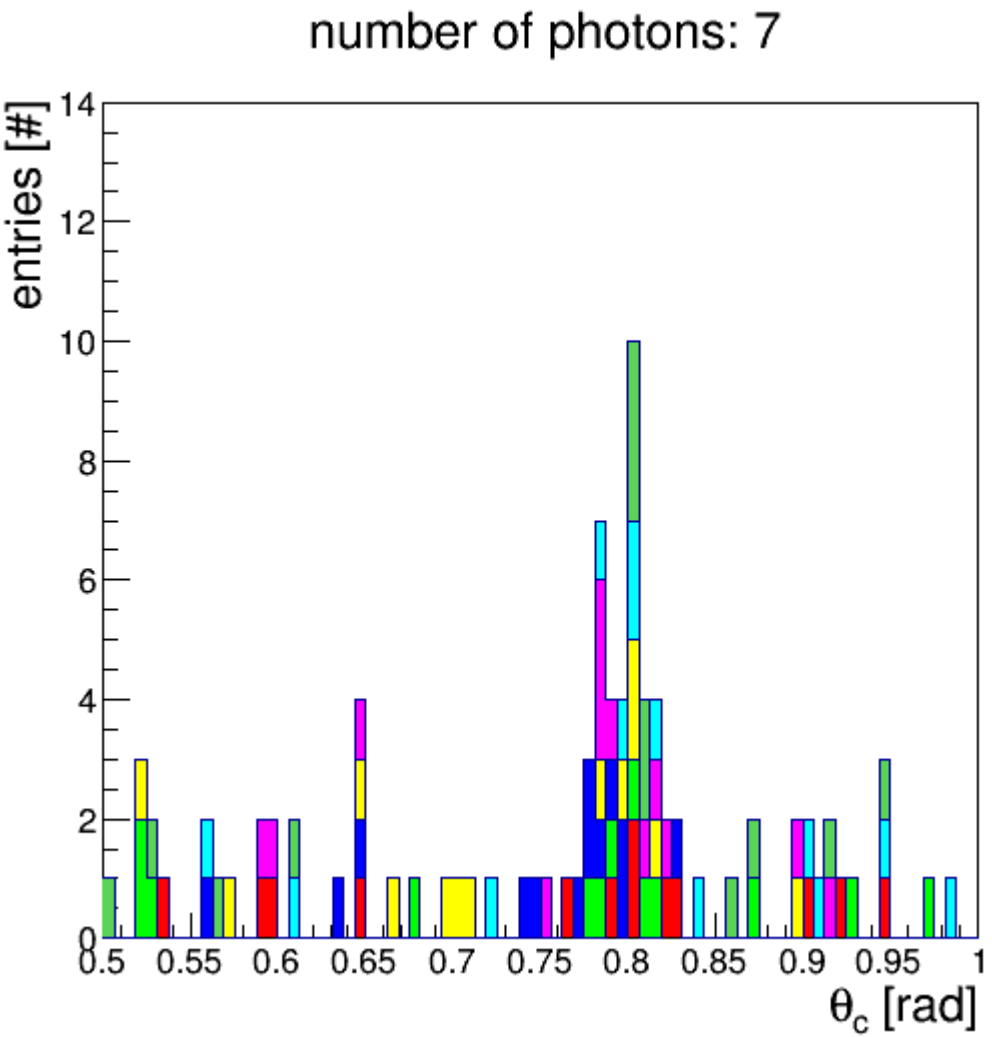
- Reconstruction: direction from LUT for hit pixels are combined with charge track direction

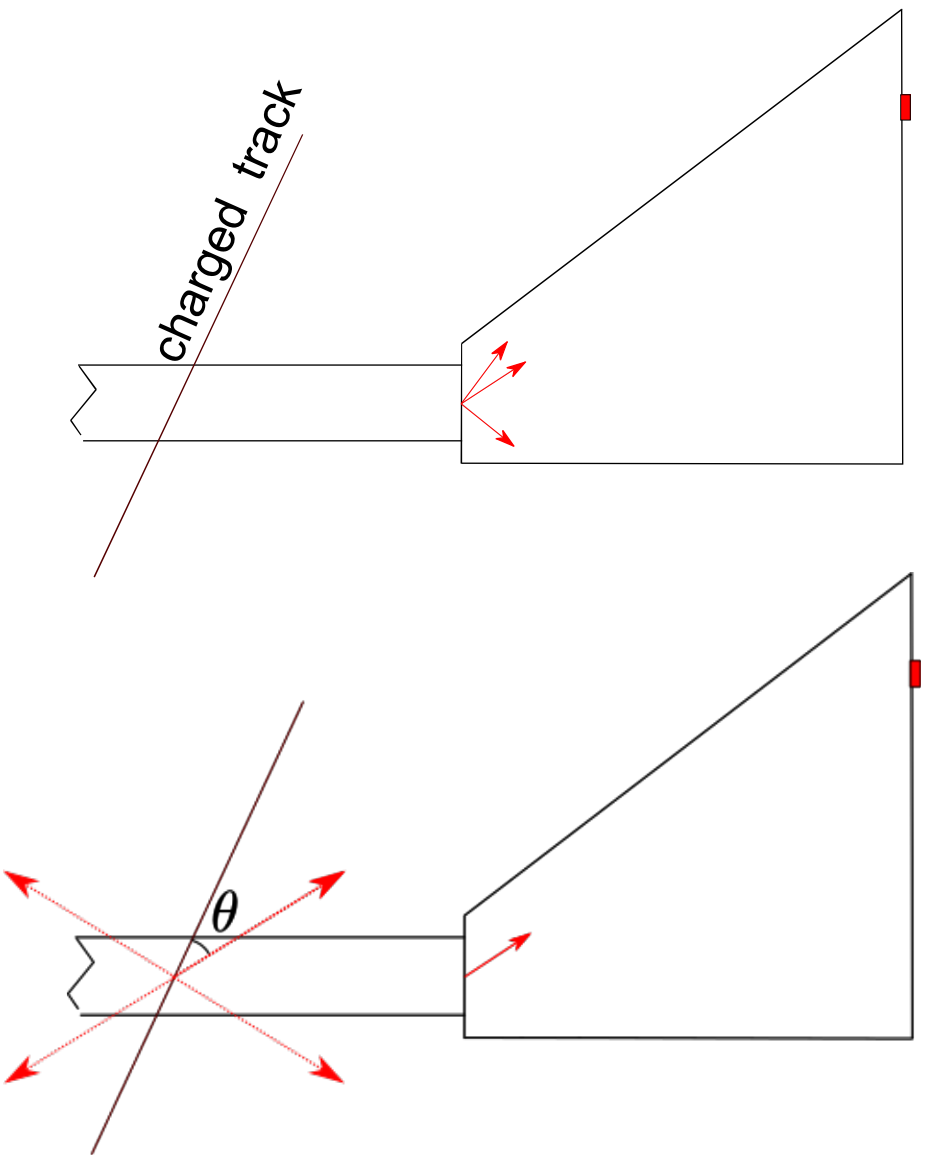




Geometrical Reconstruction

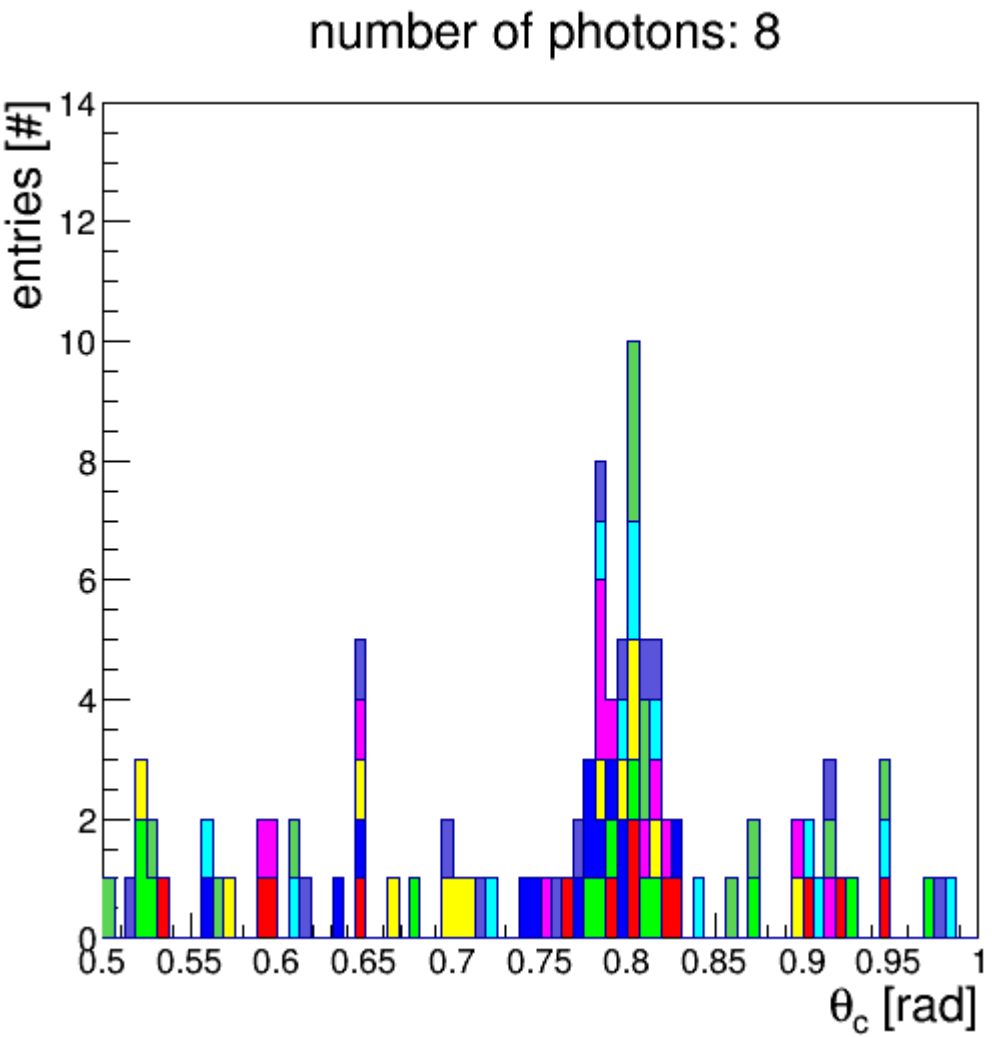
- Reconstruction: direction from LUT for hit pixels are combined with charge track direction

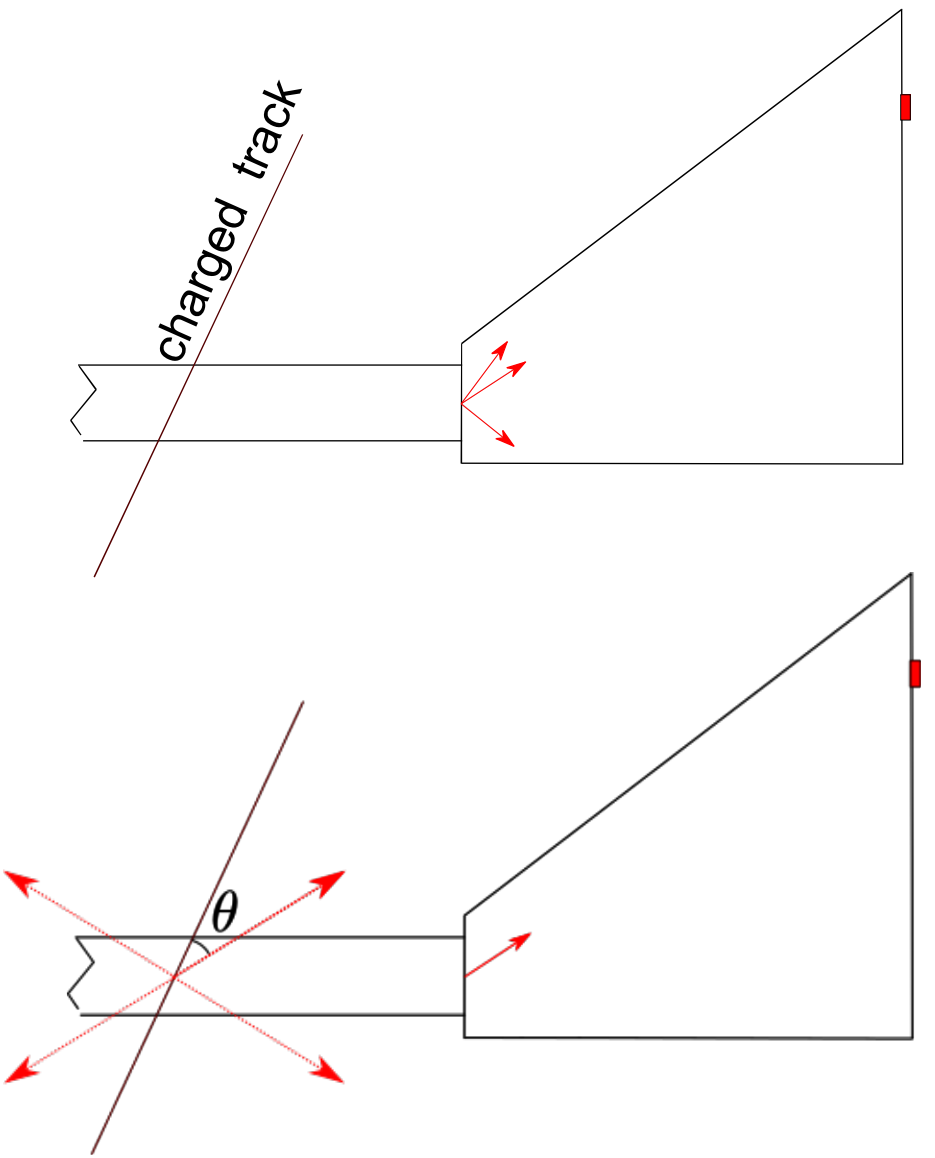




Geometrical Reconstruction

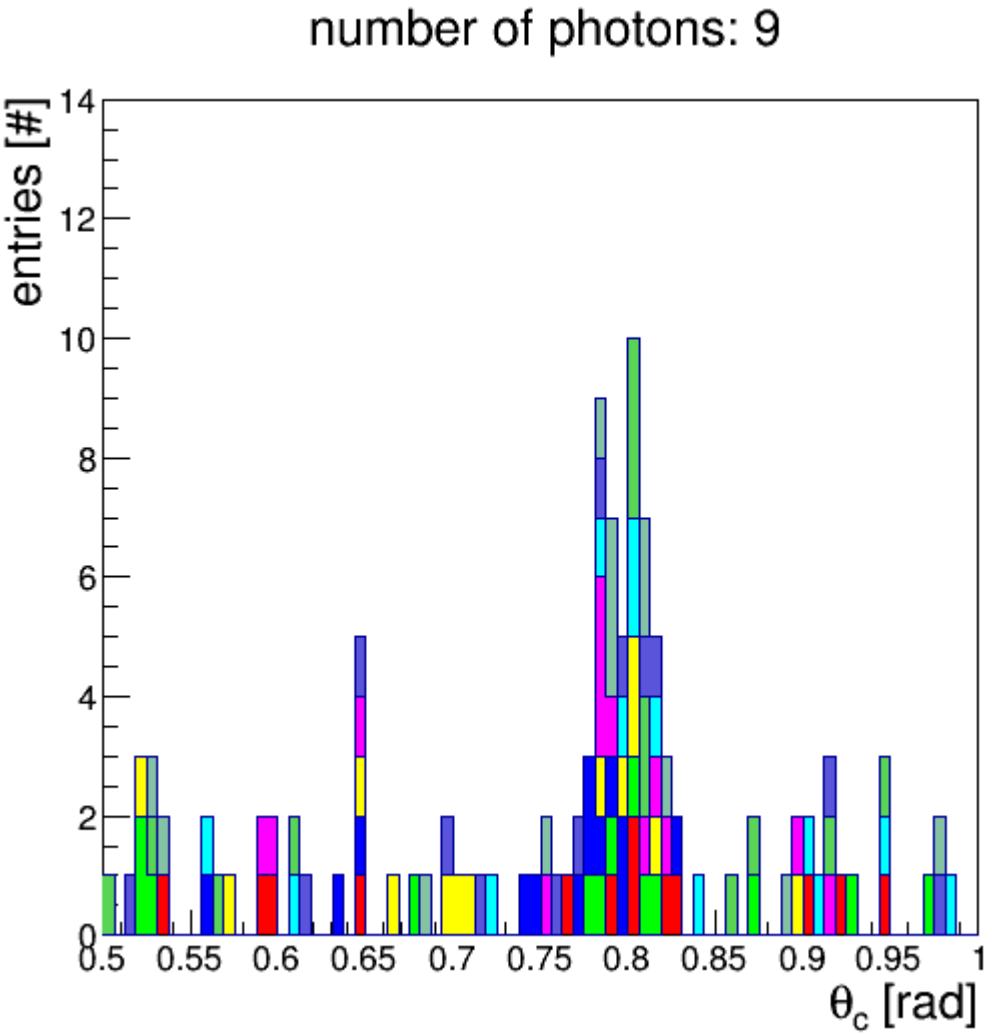
- Reconstruction: direction from LUT for hit pixels are combined with charge track direction

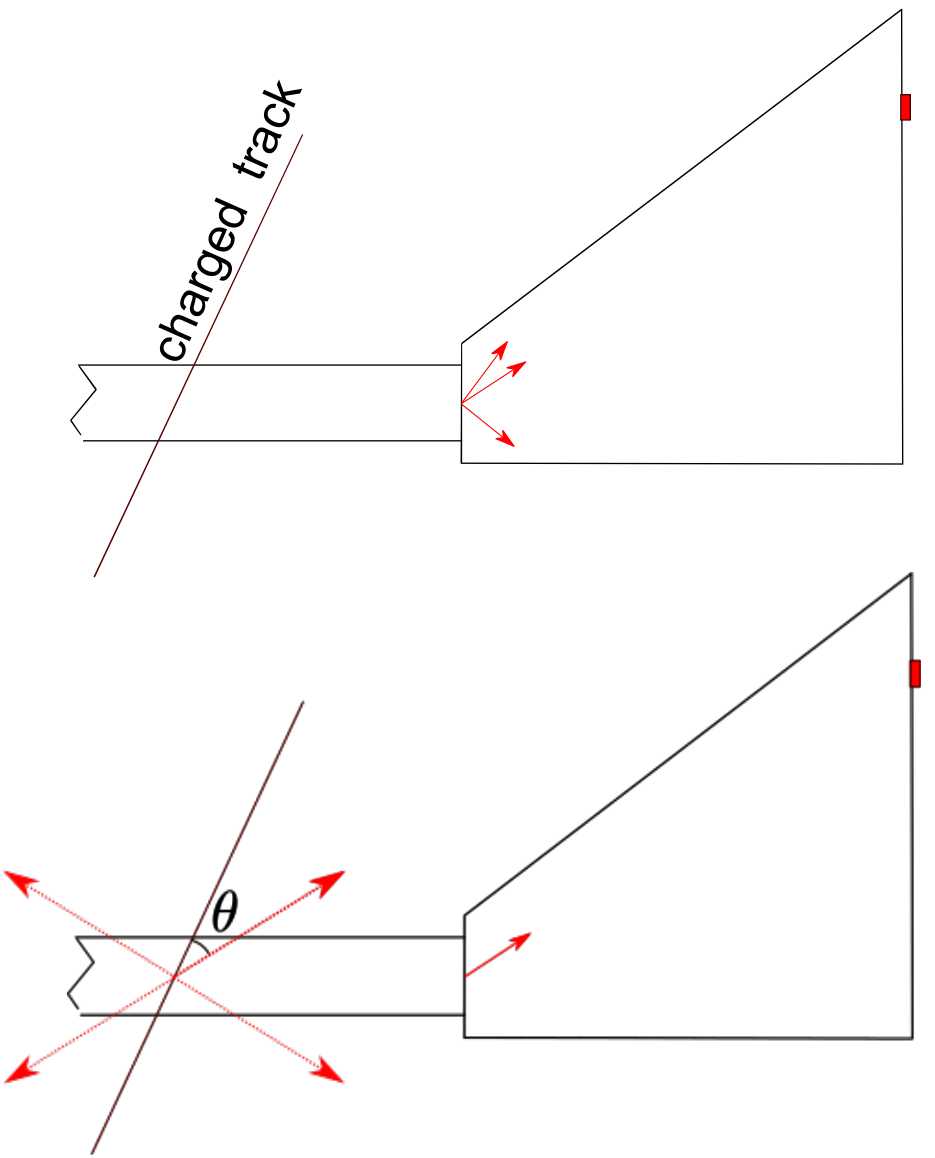




Geometrical Reconstruction

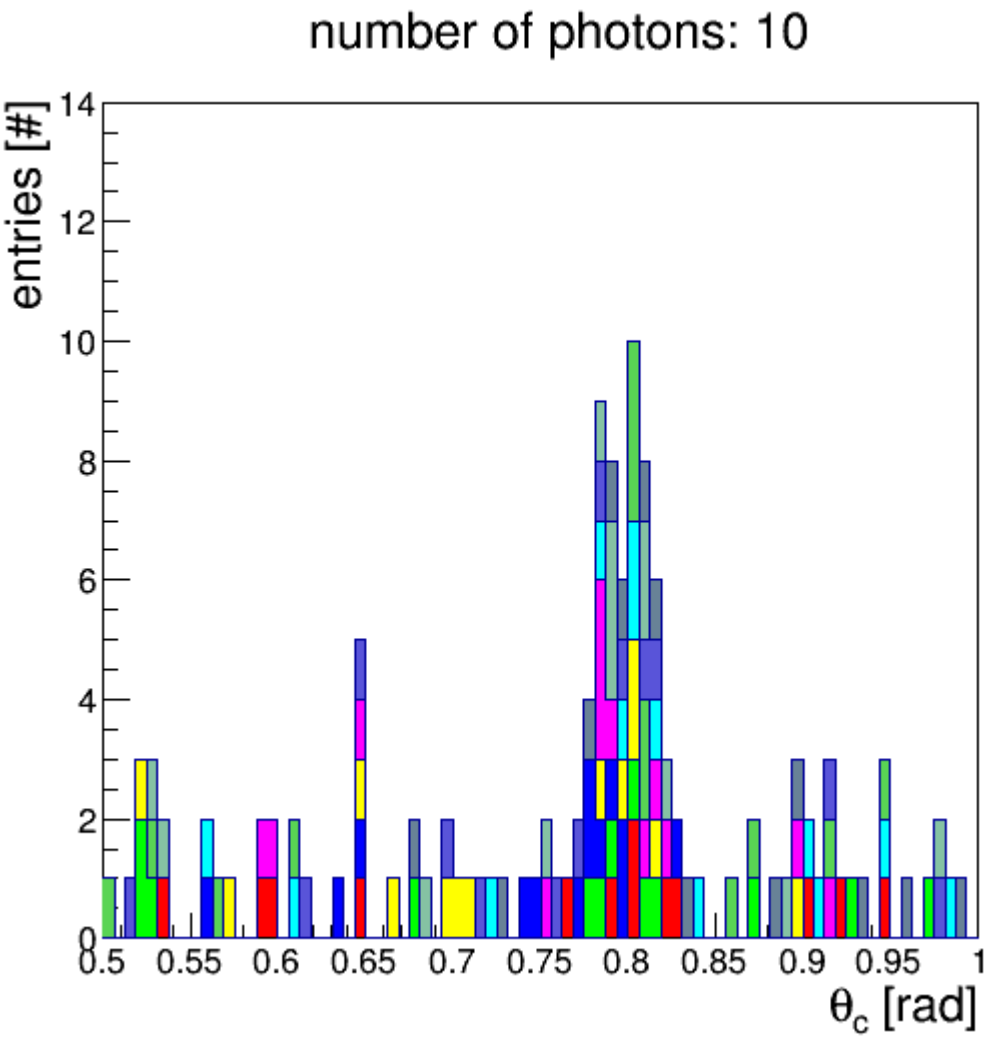
- Reconstruction: direction from LUT for hit pixels are combined with charge track direction

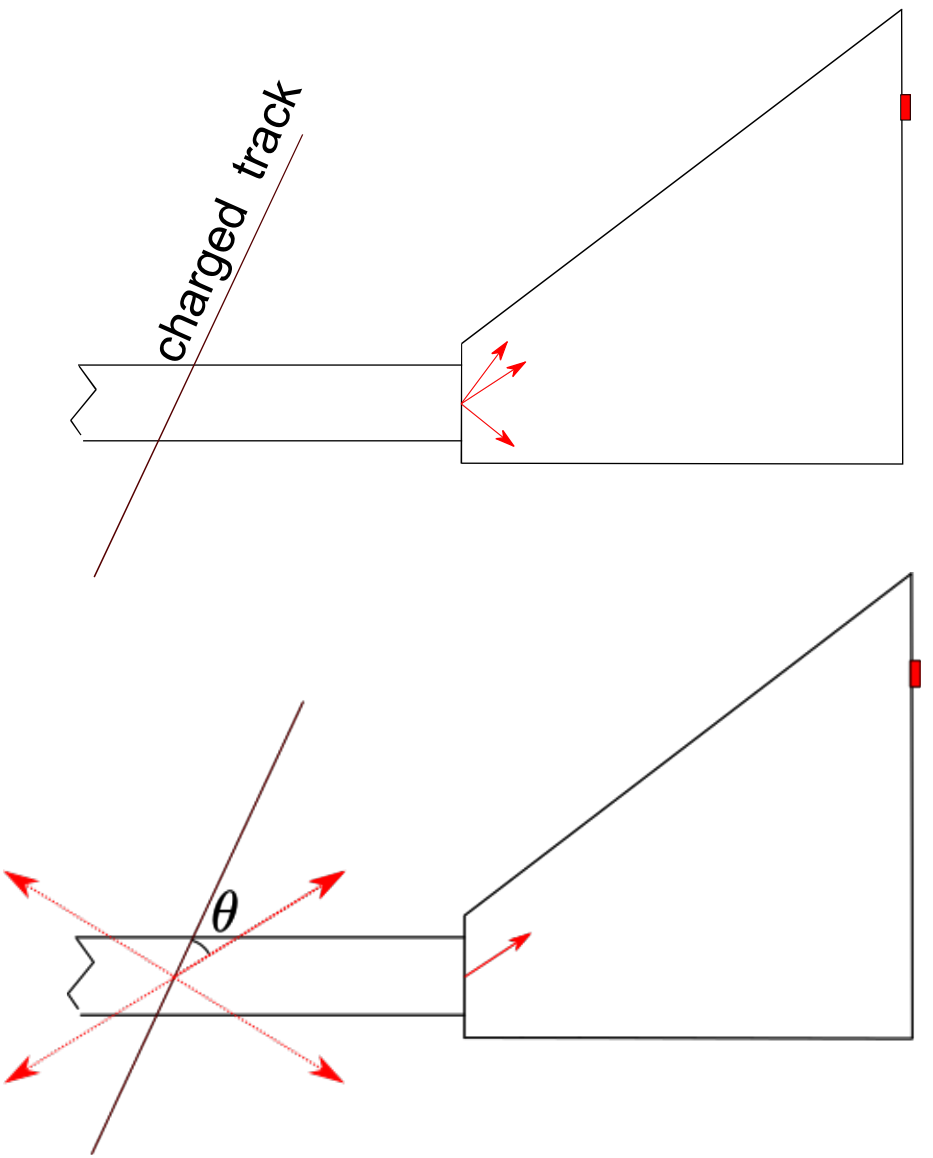




Geometrical Reconstruction

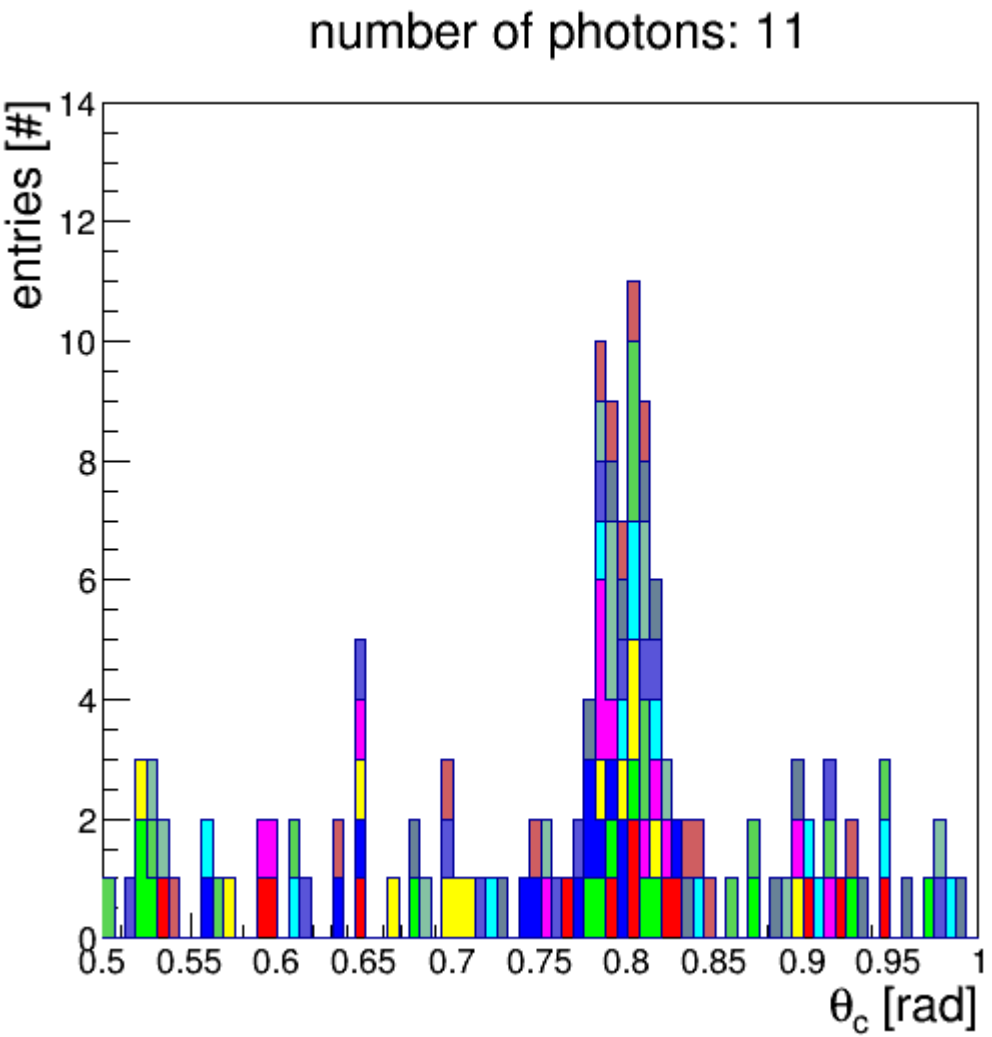
- Reconstruction: direction from LUT for hit pixels are combined with charge track direction

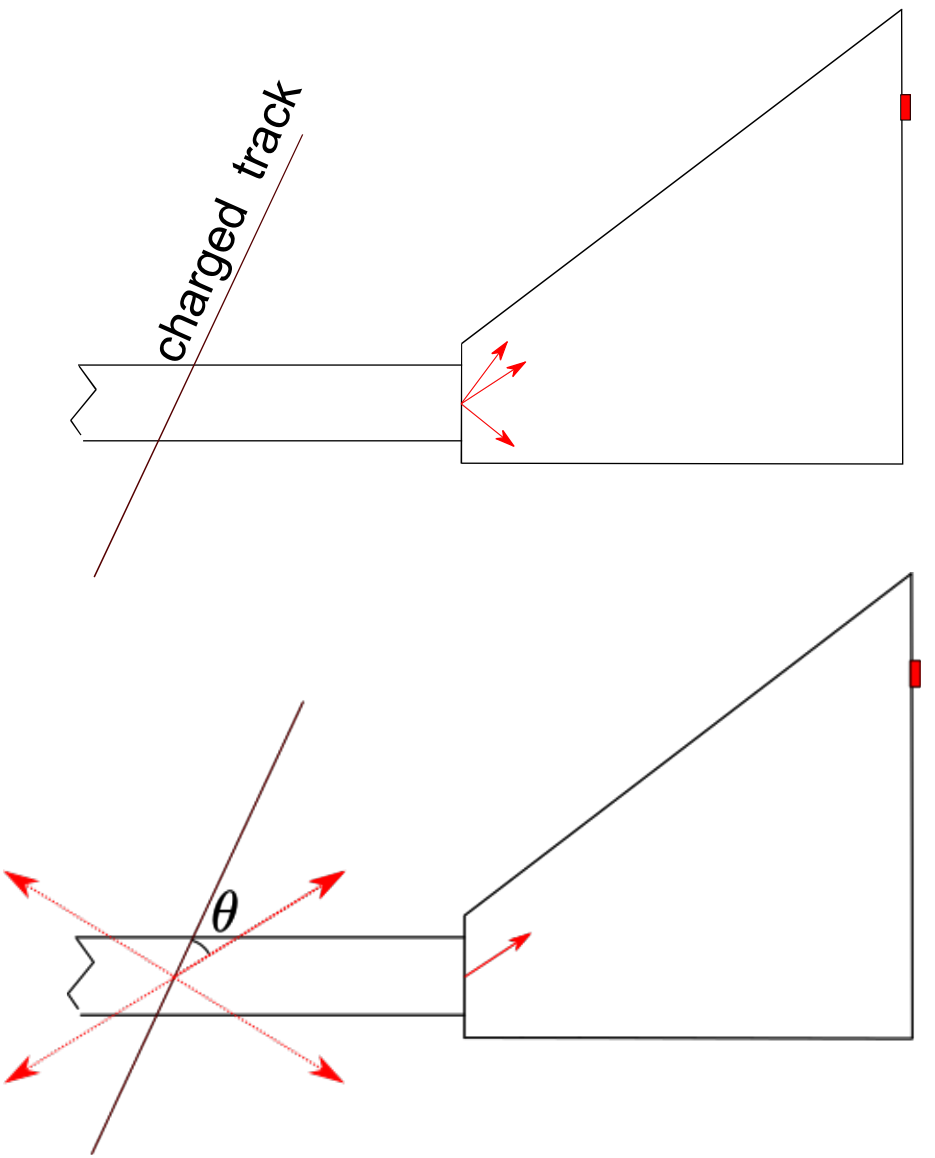




Geometrical Reconstruction

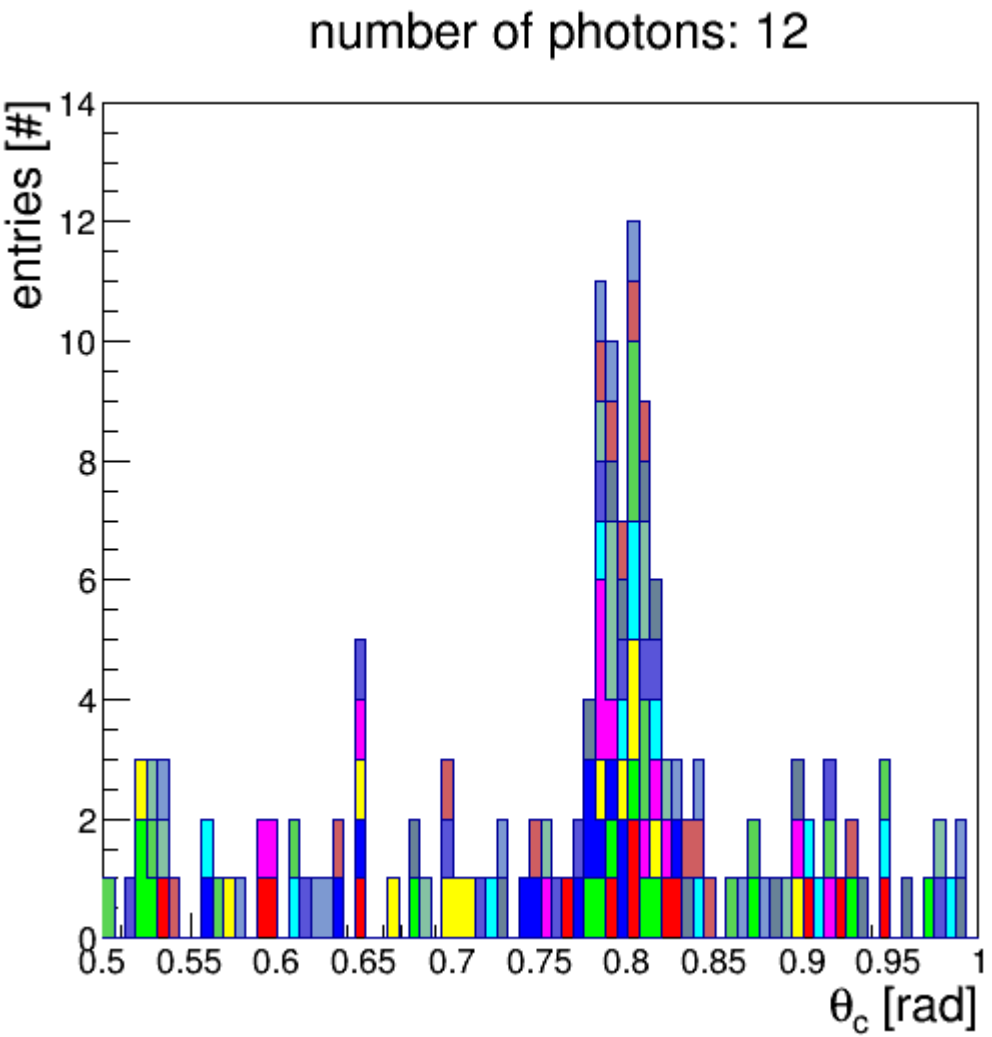
- Reconstruction: direction from LUT for hit pixels are combined with charge track direction

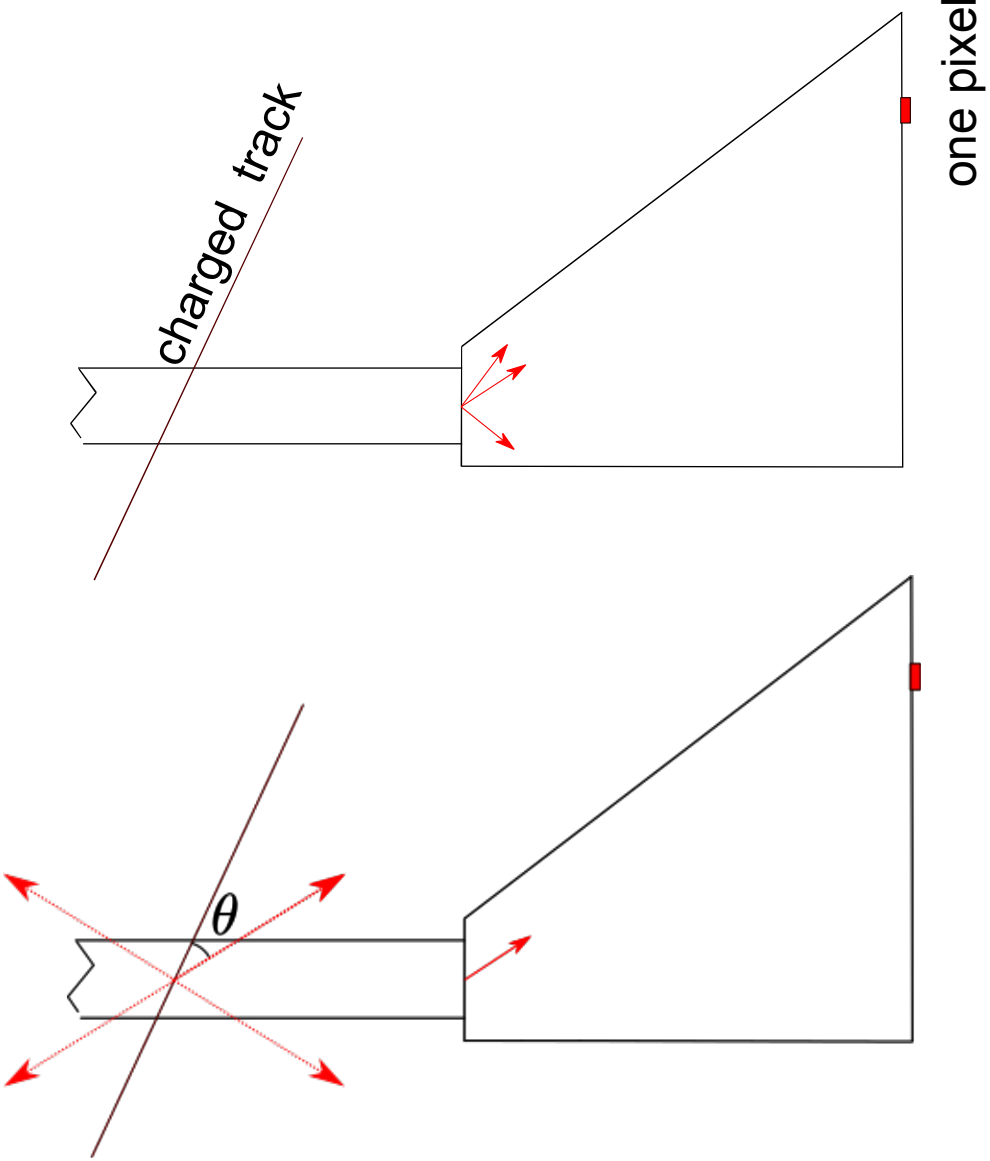




Geometrical Reconstruction

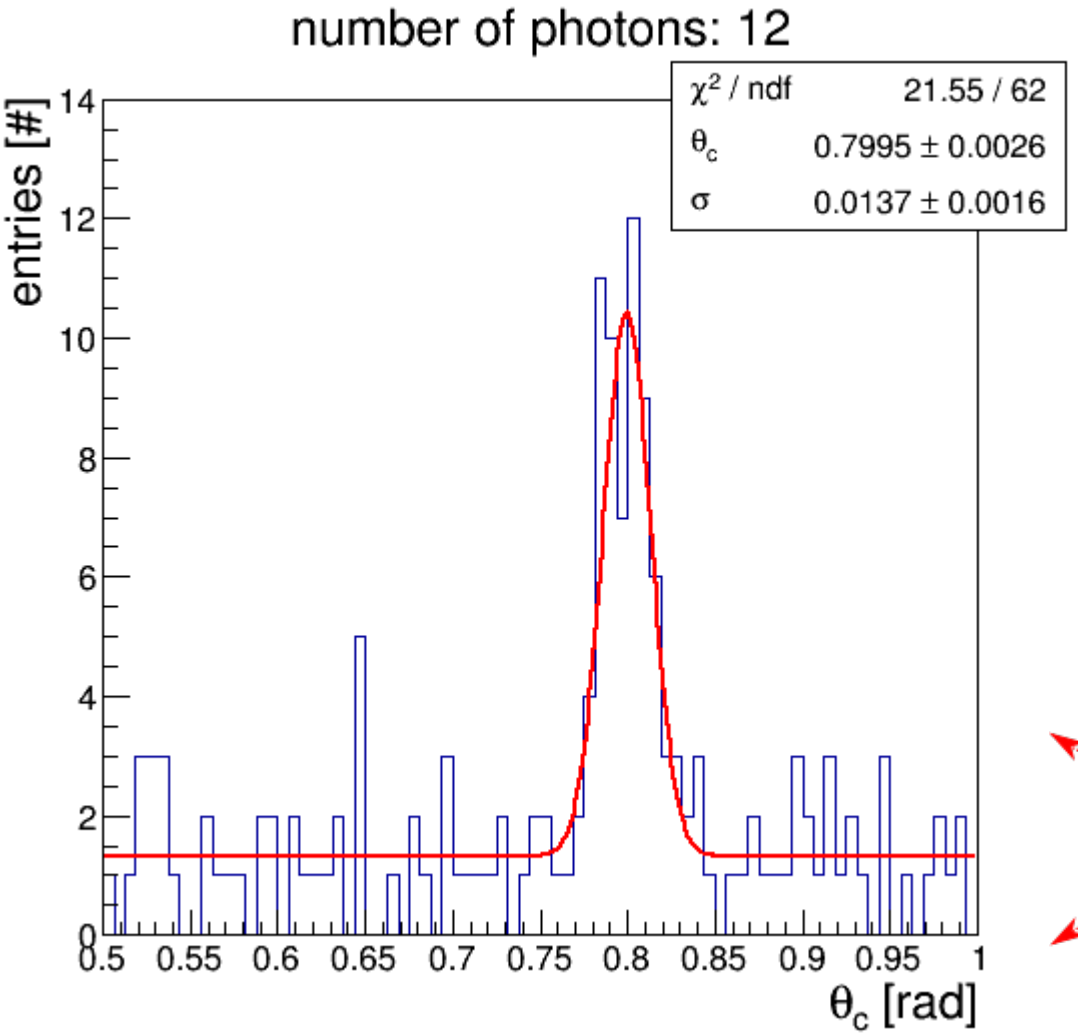
- Reconstruction: direction from LUT for hit pixels are combined with charge track direction

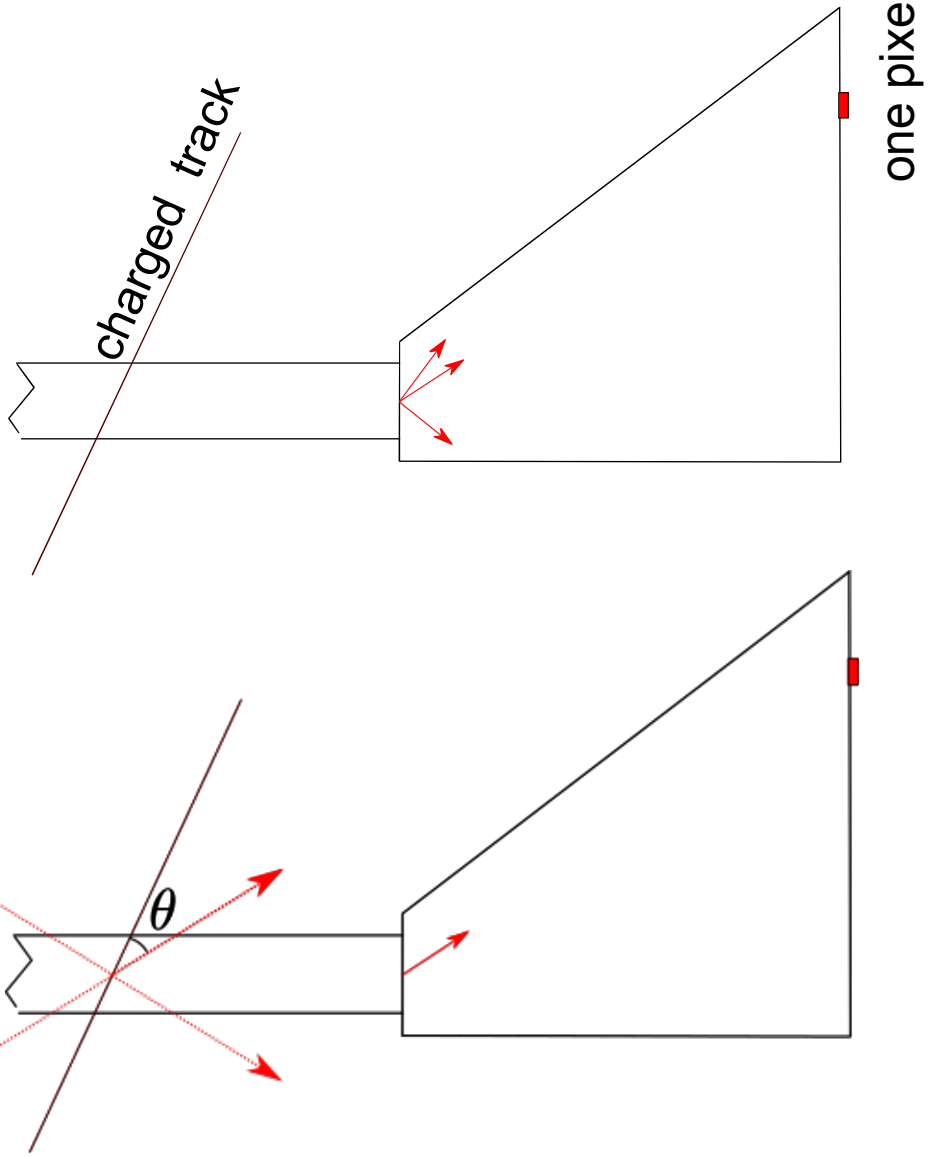




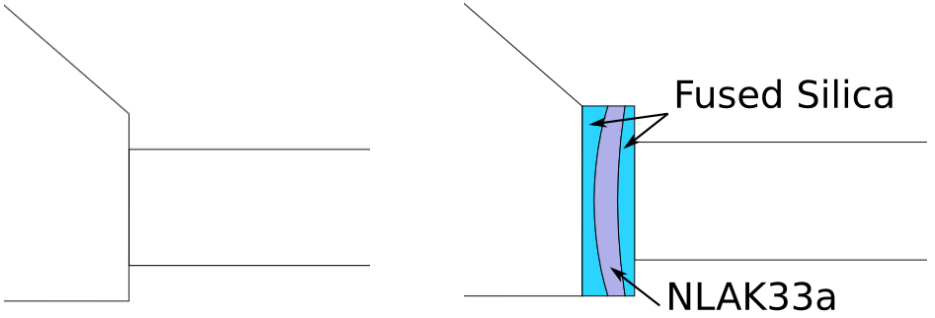
Geometrical Reconstruction

- Reconstruction: direction from LUT for hit pixels are combined with charge track direction

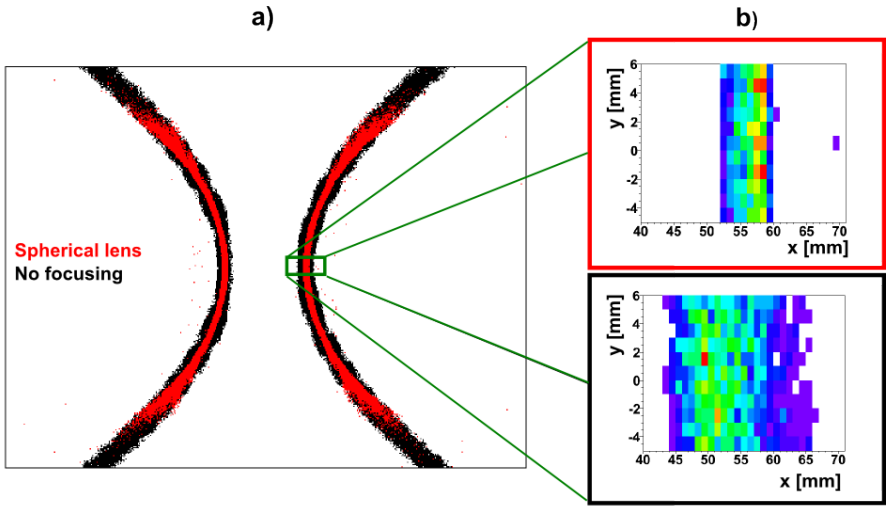




Example of reconstruction

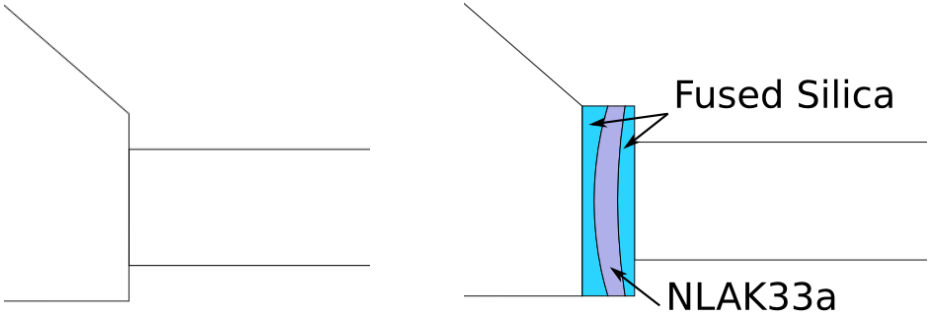


3-layer lens with high-refractive index materials (NLAK33)

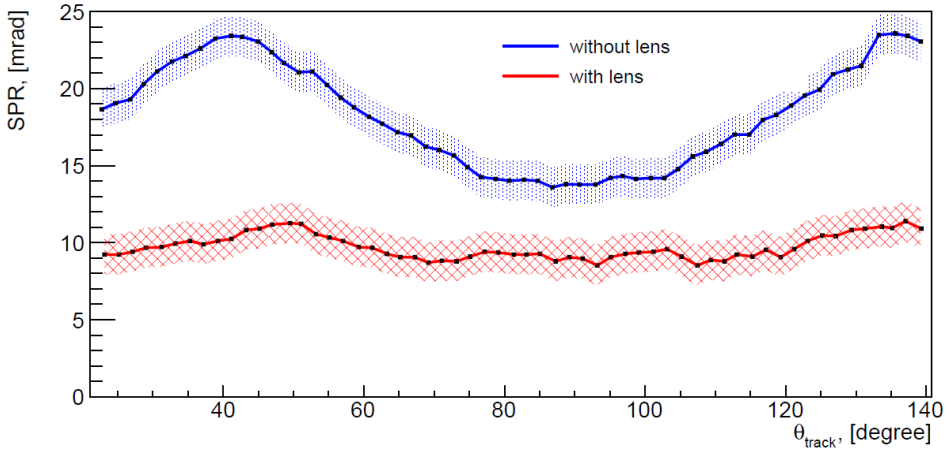


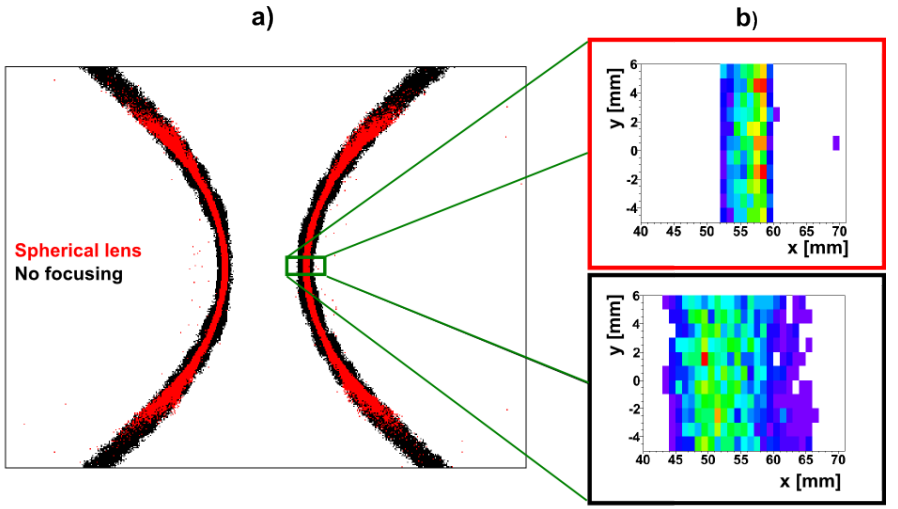
more in the next presentation
by Lee Allison

Example of reconstruction



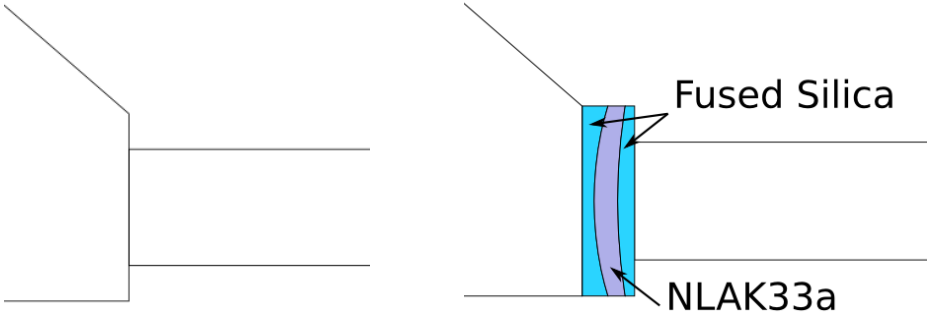
3-layer lens with high-refractive index materials (NLAK33)



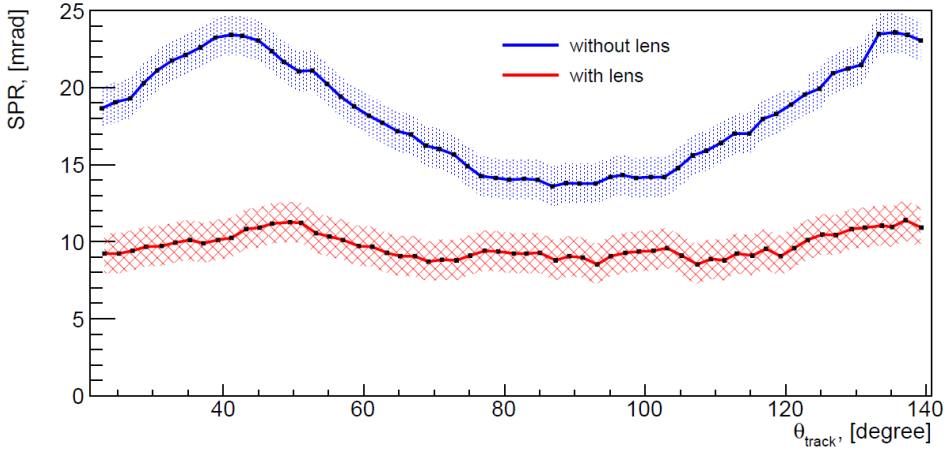


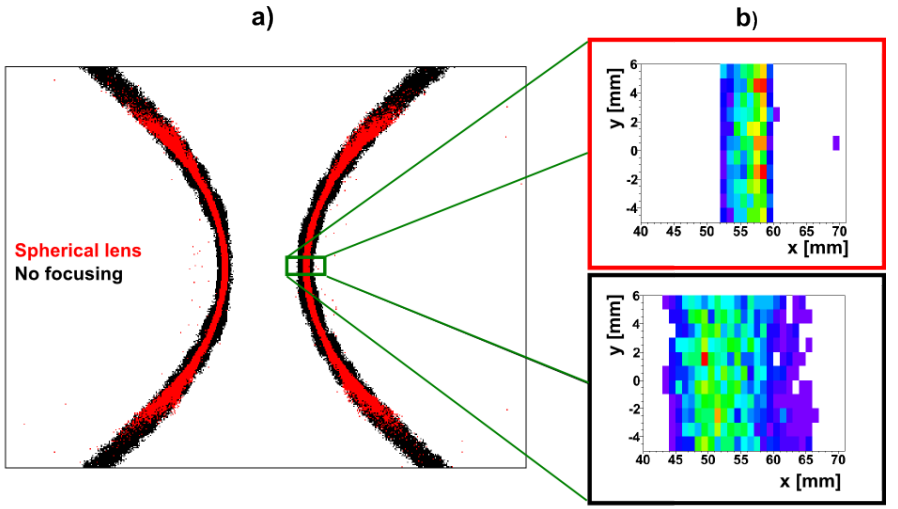
more in the next presentation
by Lee Allison

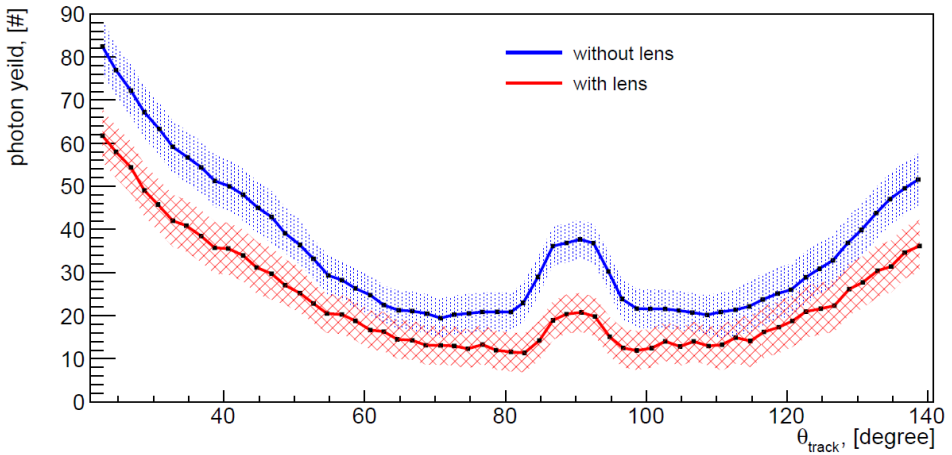
Example of reconstruction



3-layer lens with high-refractive index materials (NLAK33)

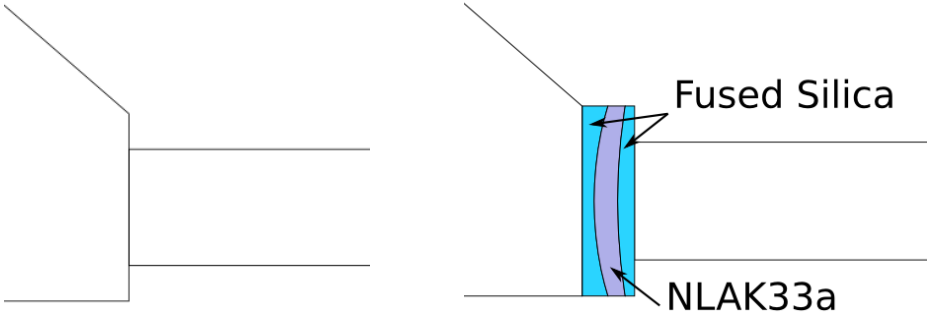




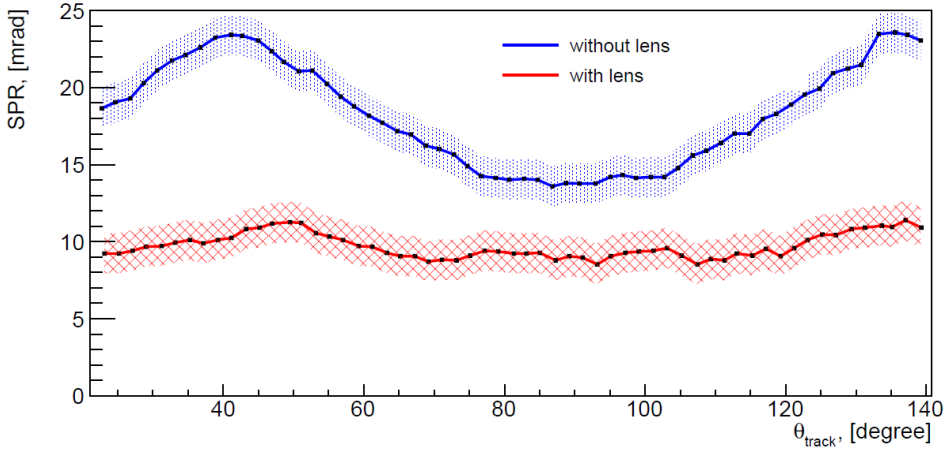


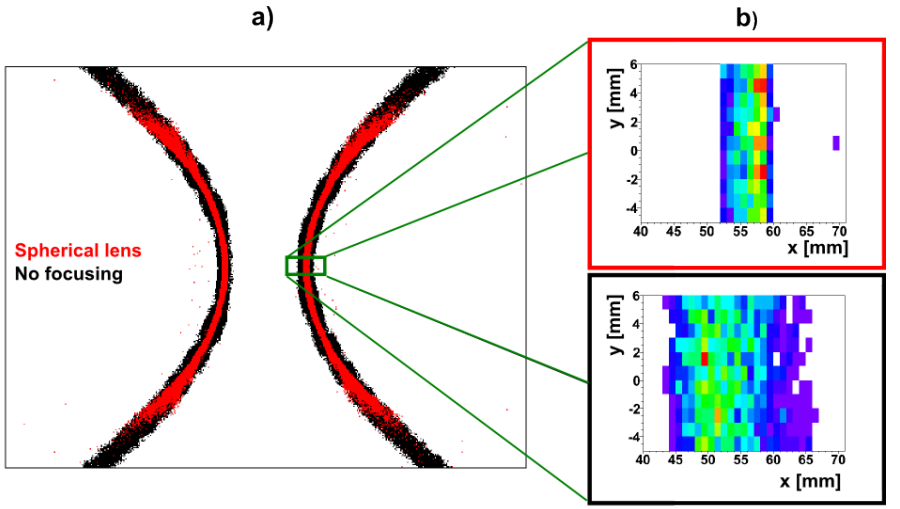
more in the next presentation
by Lee Allison

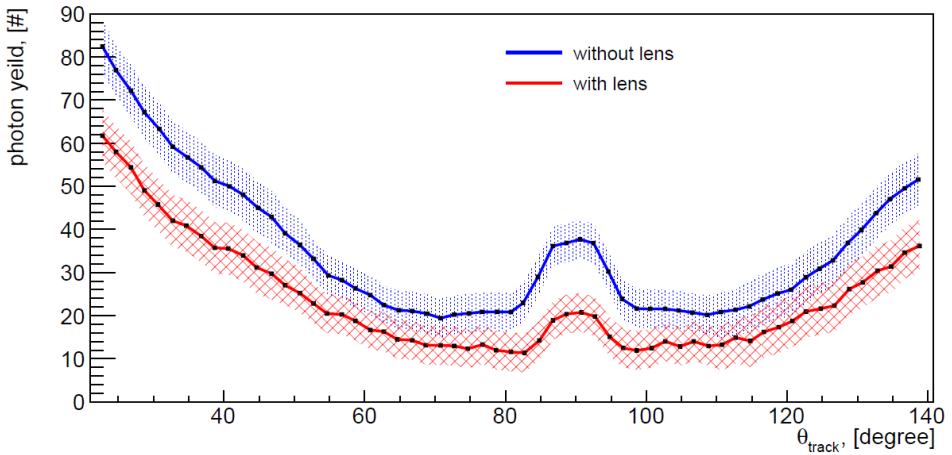
Example of reconstruction



3-layer lens with high-refractive index materials (NLAK33)





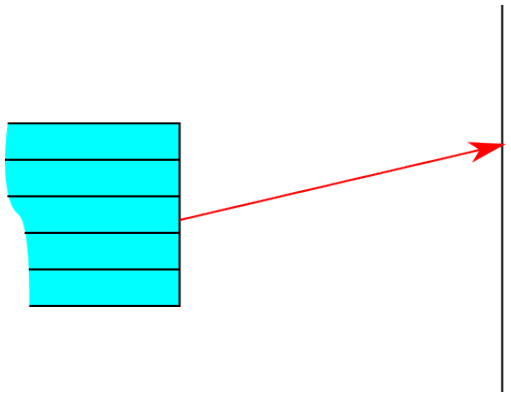


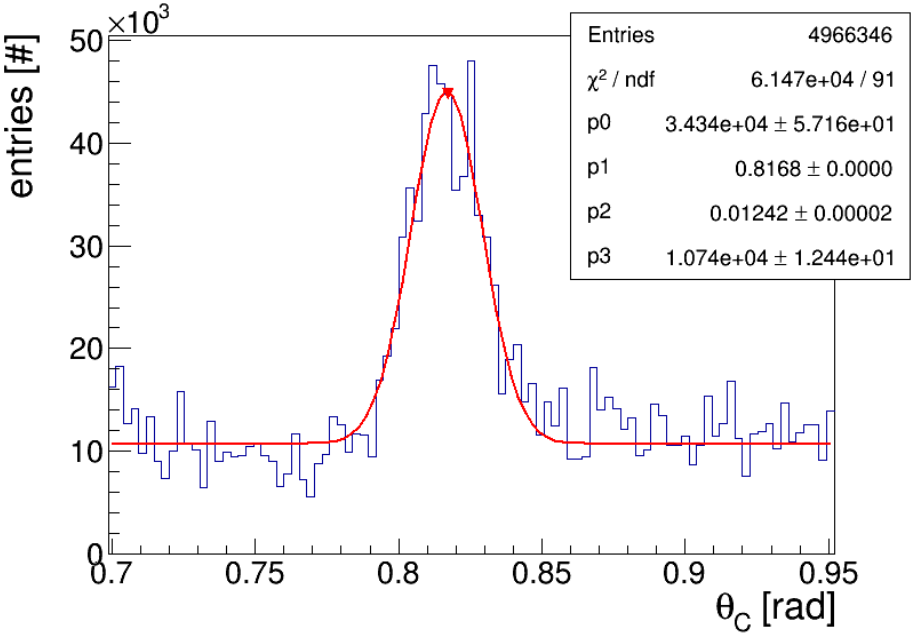
more in the next presentation
by Lee Allison

➔ Design with lens satisfies the PANDA PID requirements

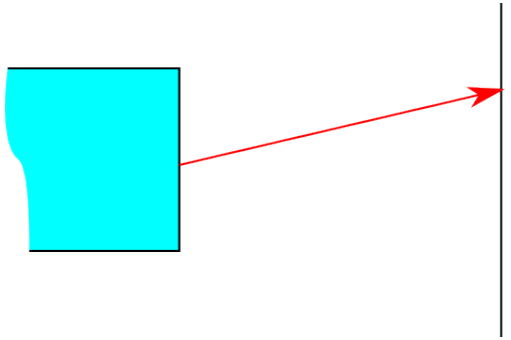
Geometrical Reconstruction

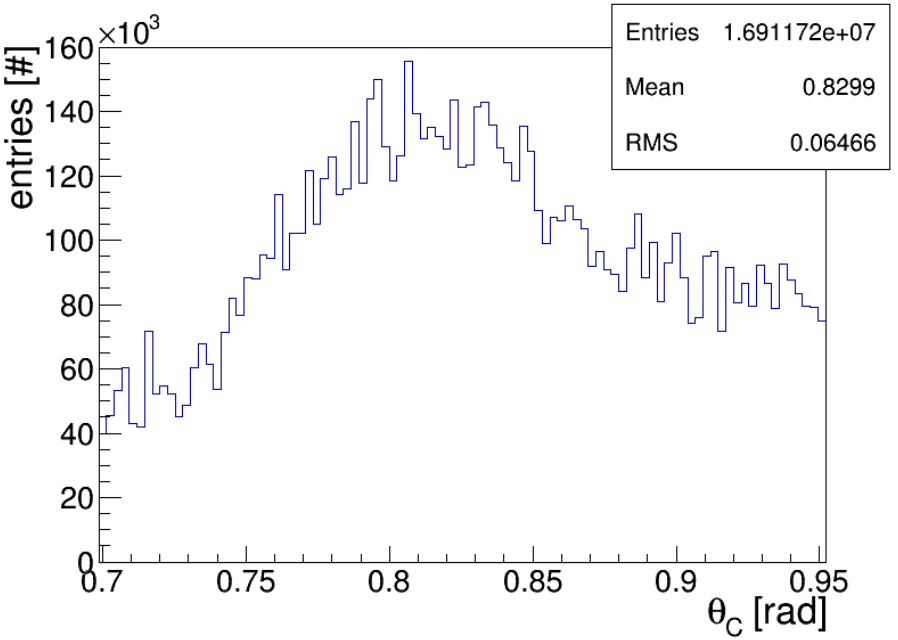
Works with narrow bars





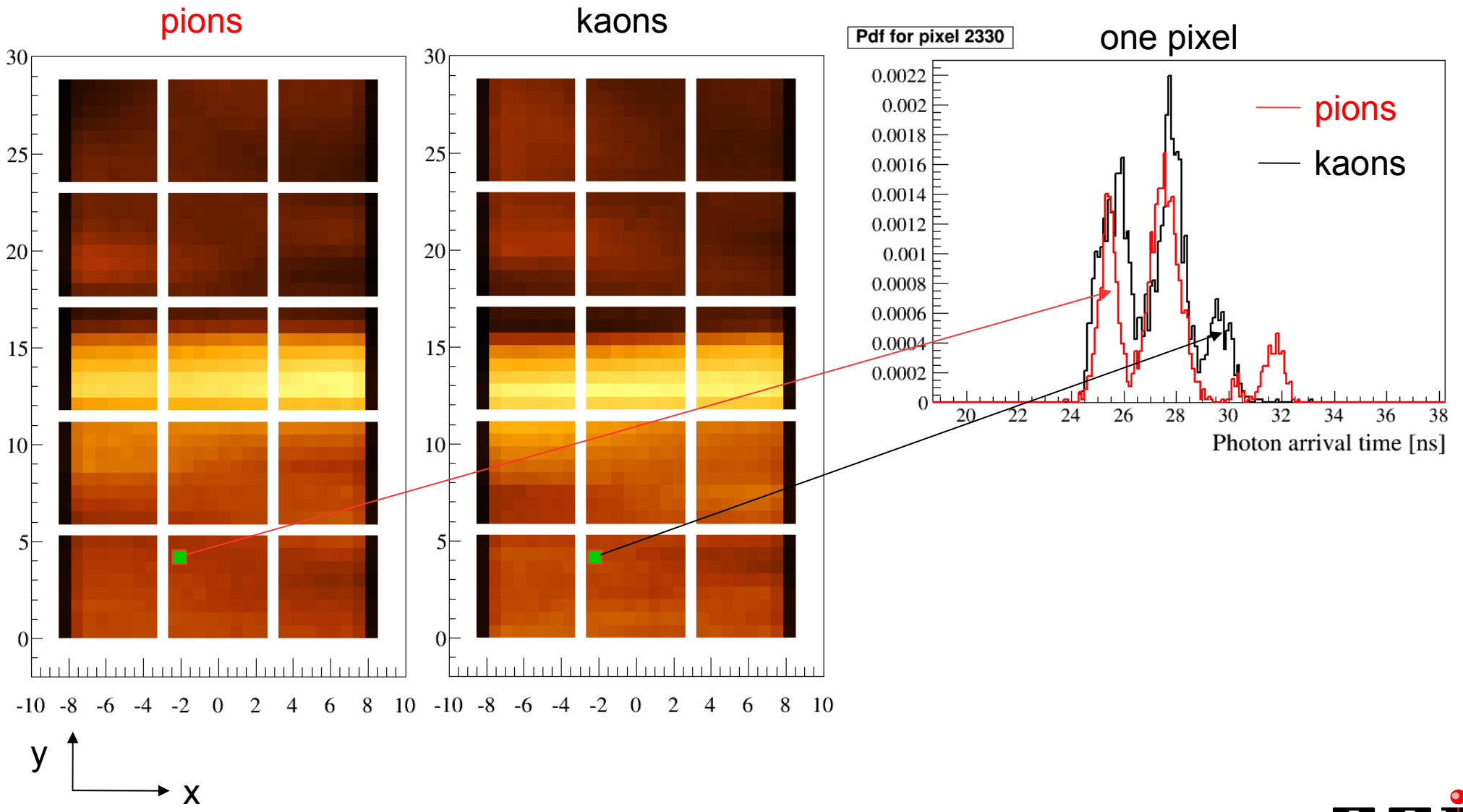
Width of radiator **not negligible** anymore





Time Likelihood Imaging

Belle II-like reconstruction.

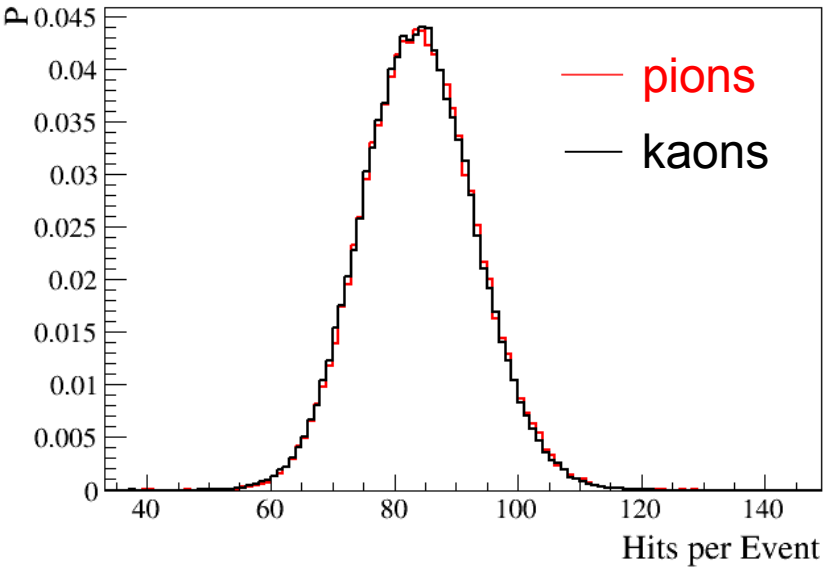


Time Likelihood Imaging

- Reconstruction: arrival time of each photon from given track is compared with PDF to calculate time-based likelihood for the photon to originate from a given particle

Time Likelihood Imaging

- Reconstruction: arrival time of each photon from given track is compared with PDF to calculate time-based likelihood for the photon to originate from a given particle

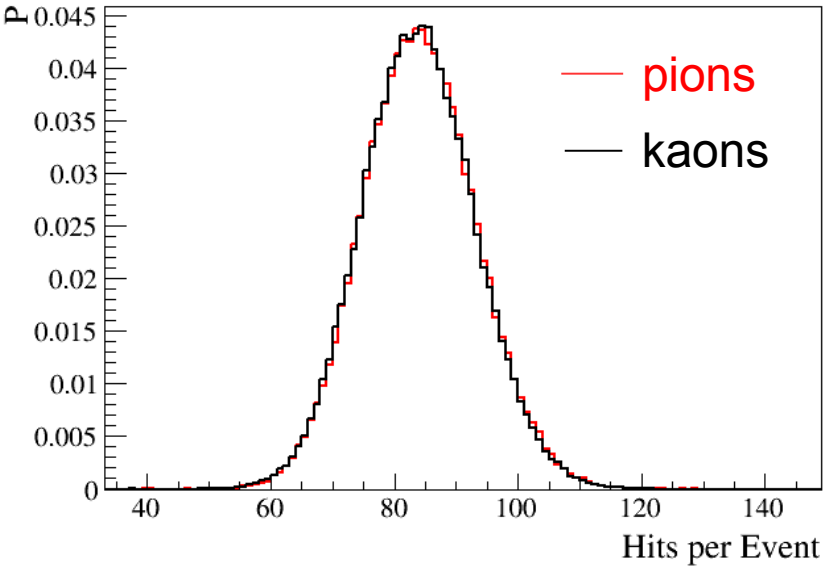


- Full likelihood:

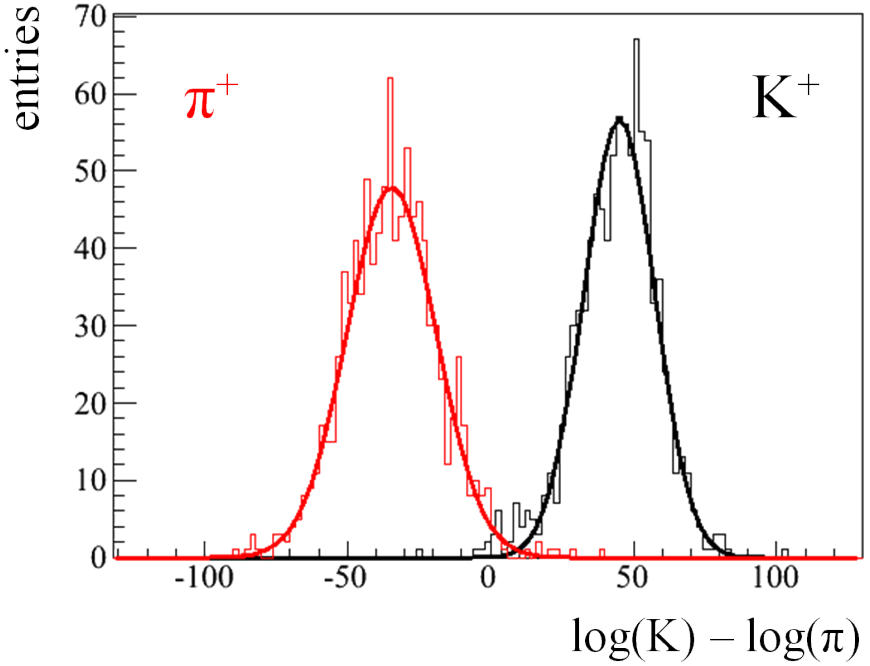
$$L_H = \prod_N \mathrm{pdf}(x_i, y_i, t_i; H) \times P_{N_0}(N)$$

Time Likelihood Imaging

- Reconstruction: arrival time of each photon from given track is compared with PDF to calculate time-based likelihood for the photon to originate from a given particle



Example: momentum = 3 GeV/c
angle = 22°

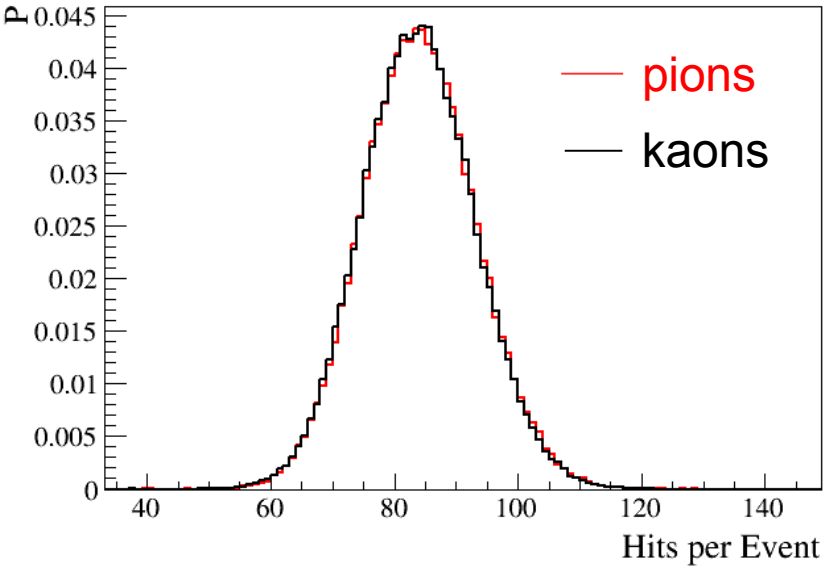


- Full likelihood:

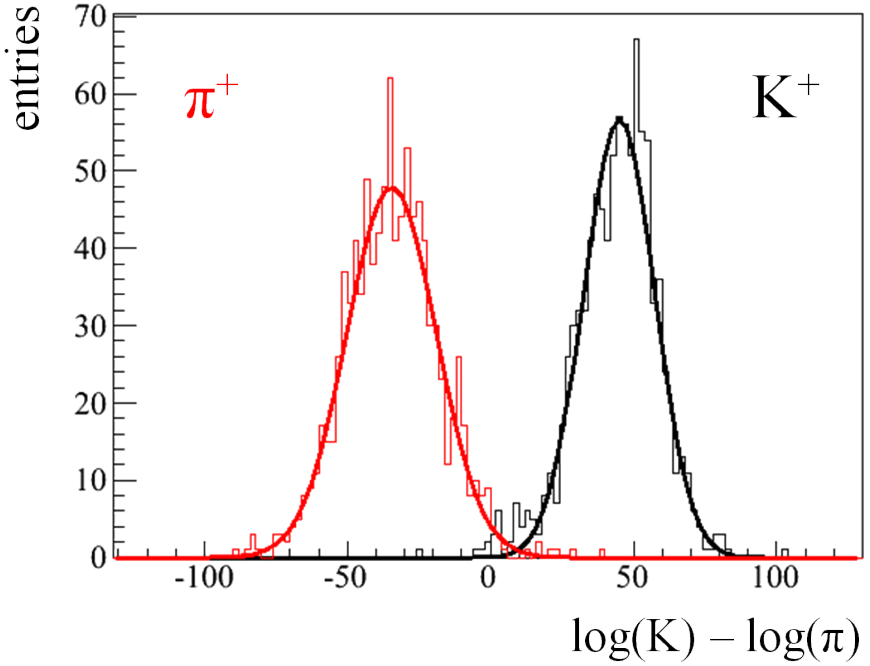
$$L_H = \prod_N \mathrm{pdf}(x_i, y_i, t_i; H) \times P_{N_0}(N)$$

Time Likelihood Imaging

- Reconstruction: arrival time of each photon from given track is compared with PDF to calculate time-based likelihood for the photon to originate from a given particle



Example: momentum = 3 GeV/c
angle = 22°

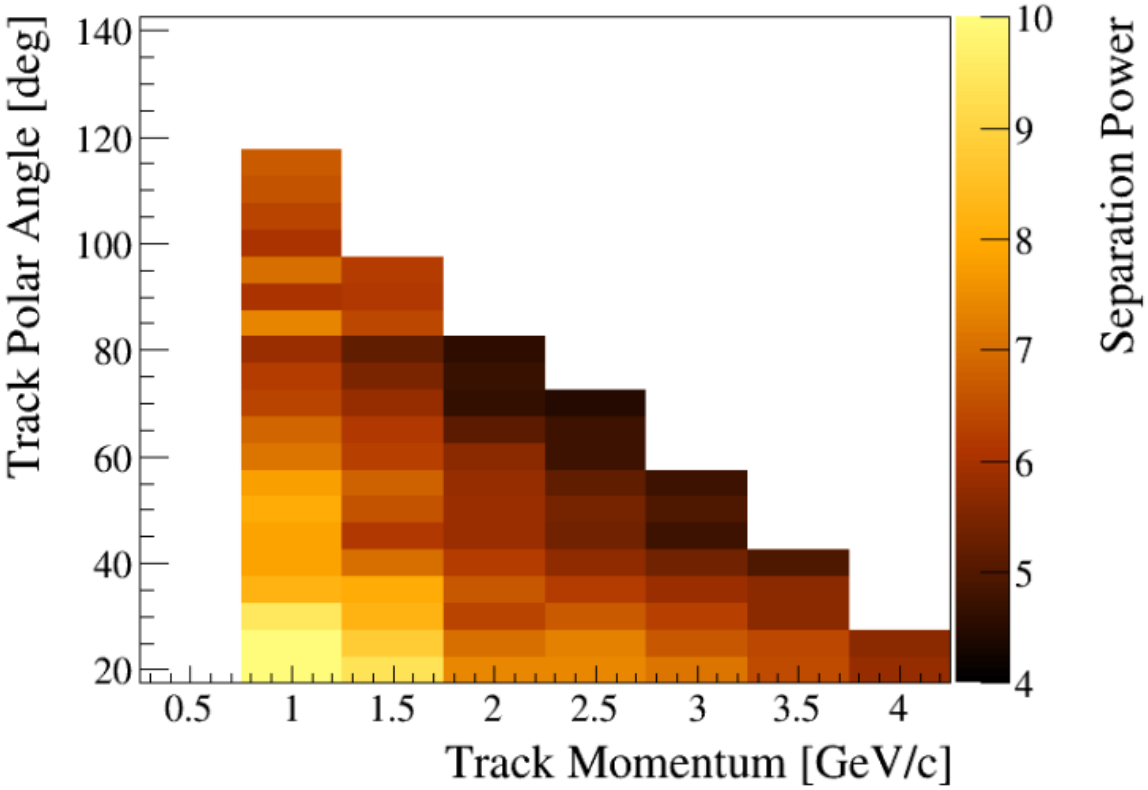


- Full likelihood:

$$L_H = \prod_N \mathrm{pdf}(x_i, y_i, t_i; H) \times P_{N_0}(N)$$

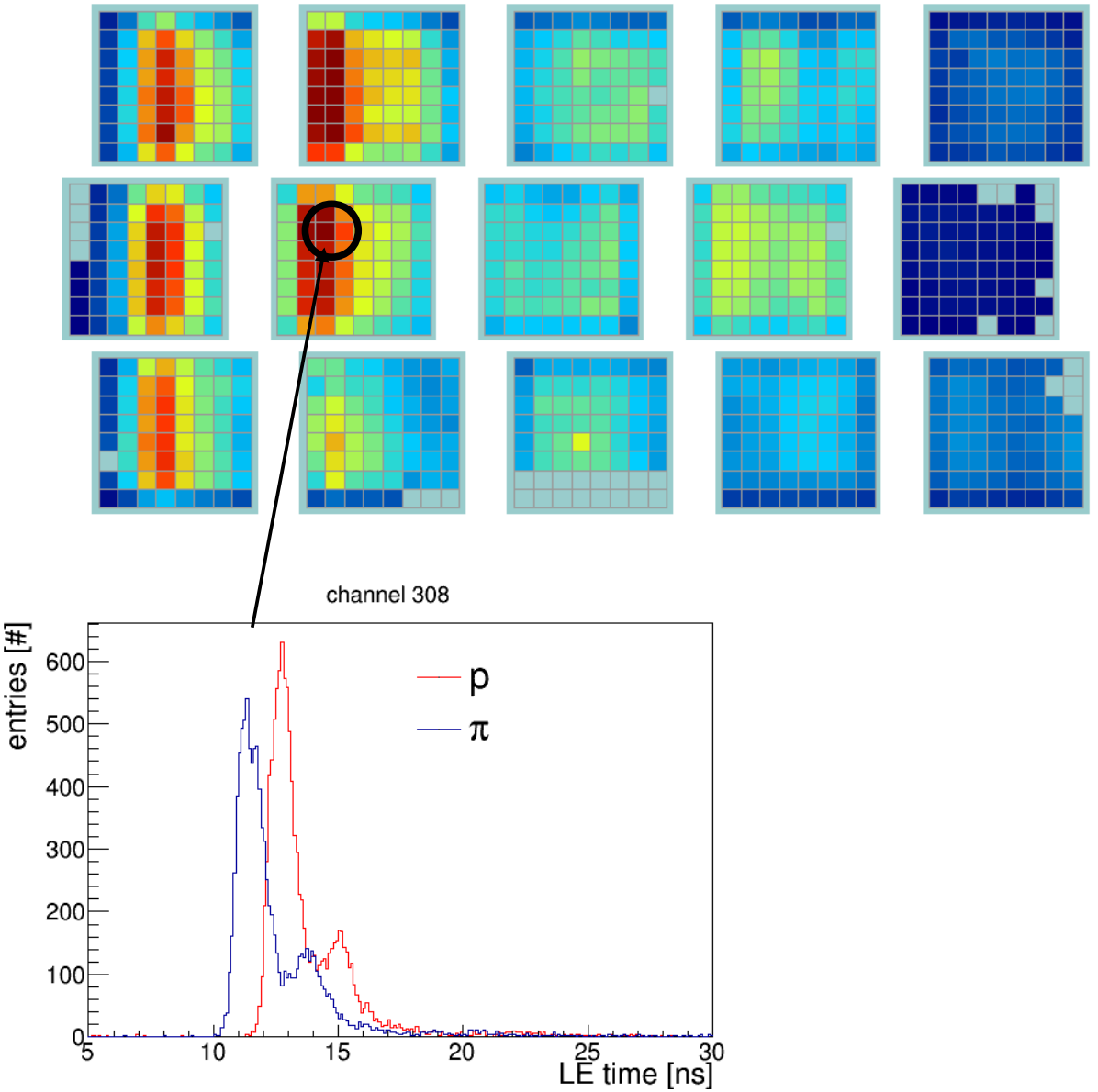
➔ Clean π/K separation at 3.5 GeV/c even without optics

Time Likelihood Imaging

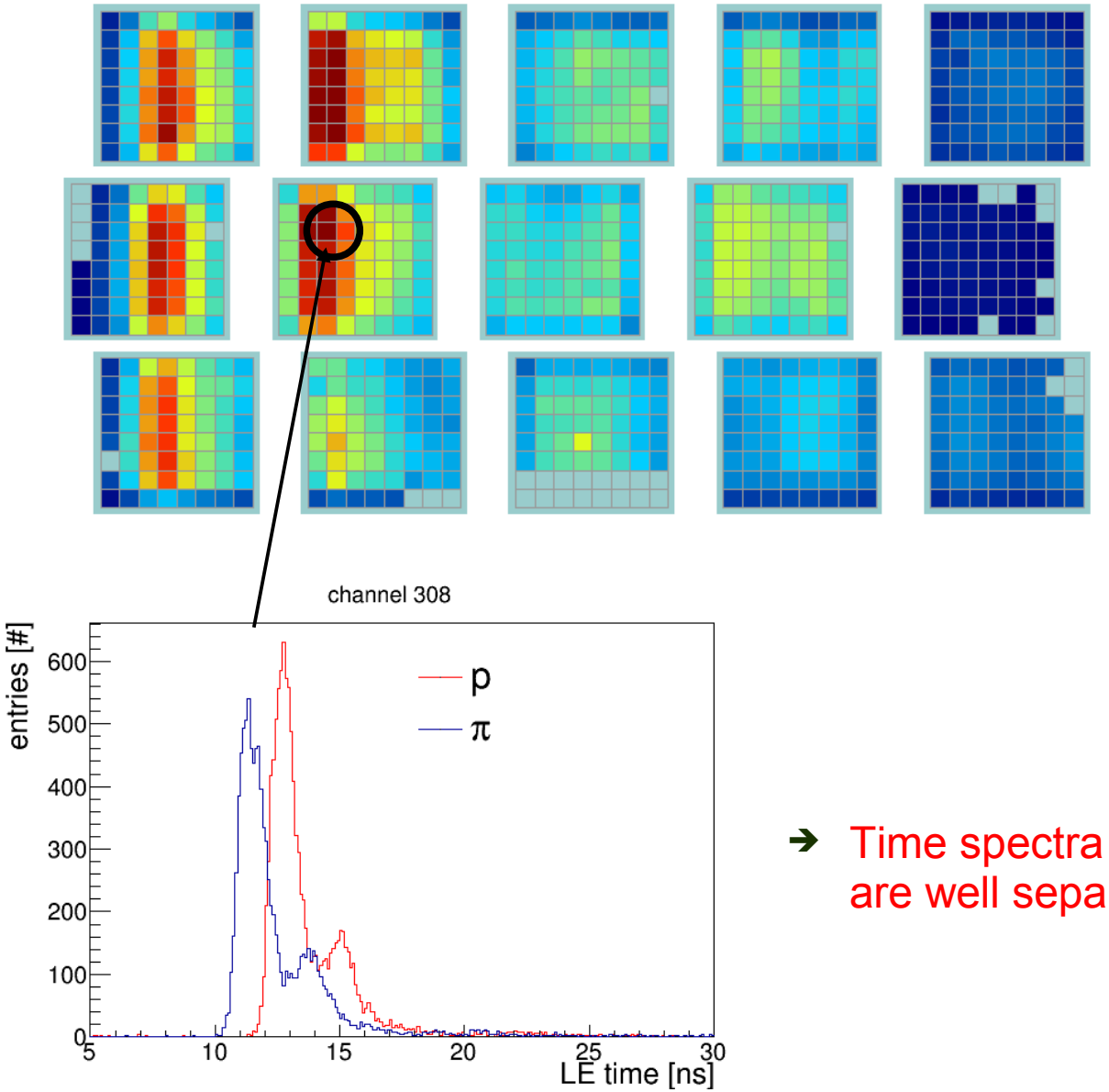


➔ Satisfies the PANDA PID requirements

CERN beam time example



CERN beam time example

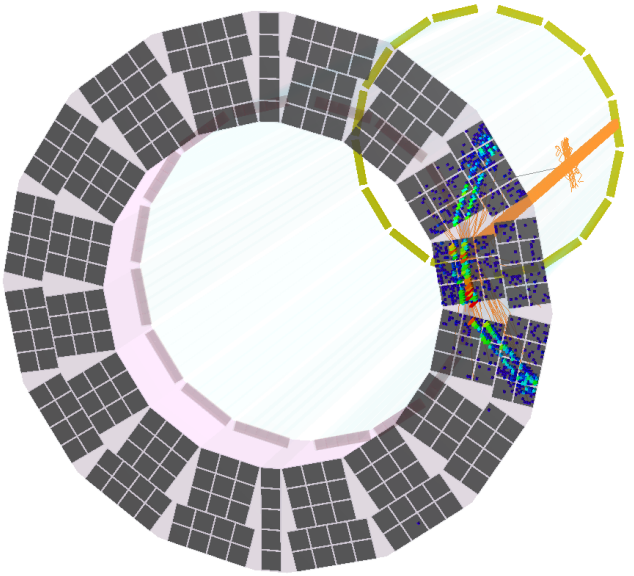


➔ Time spectra of pions and protons are well separated

Reconstruction Methods: Summary

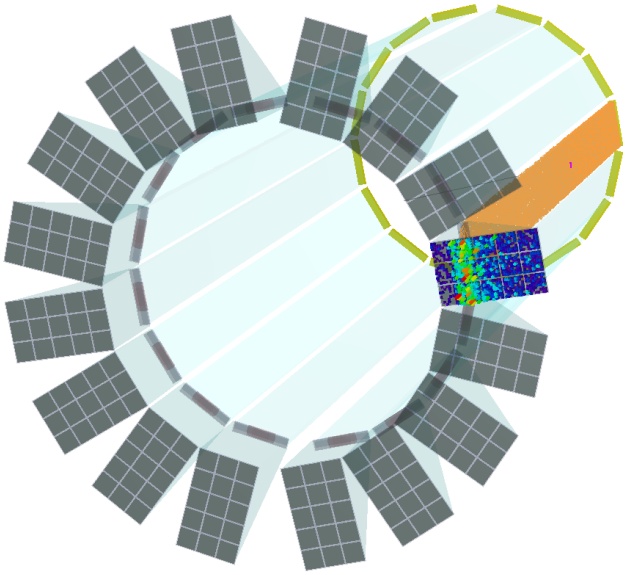
Geometrical reconstruction:

- works for narrow bars
- fails with wide plates
- SPR – is measured quantity



Time Likelihood Imaging:

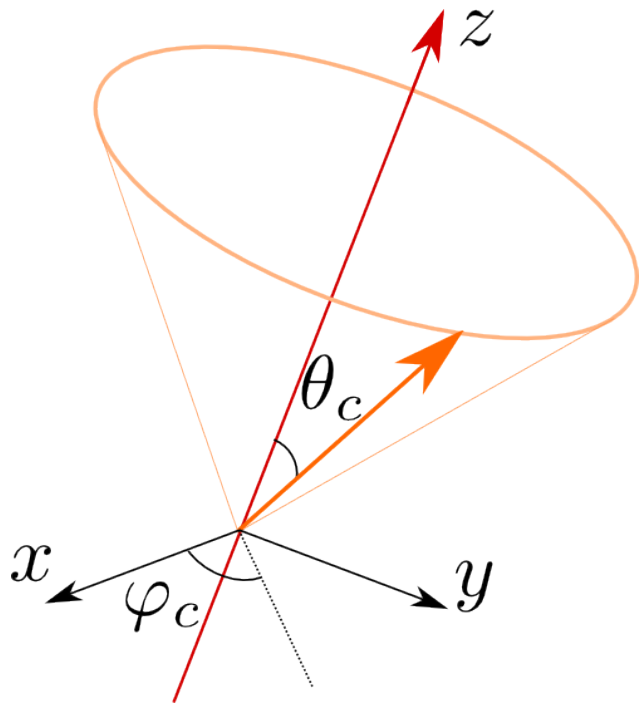
- works for narrow bars
- works for wide plates
- no SPR

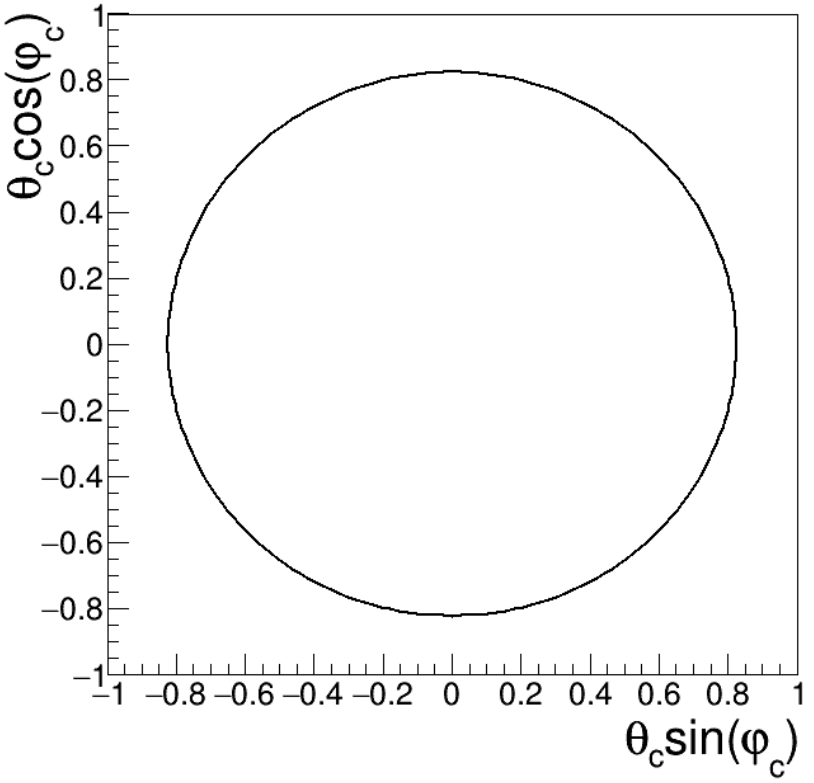


Correction of the track direction

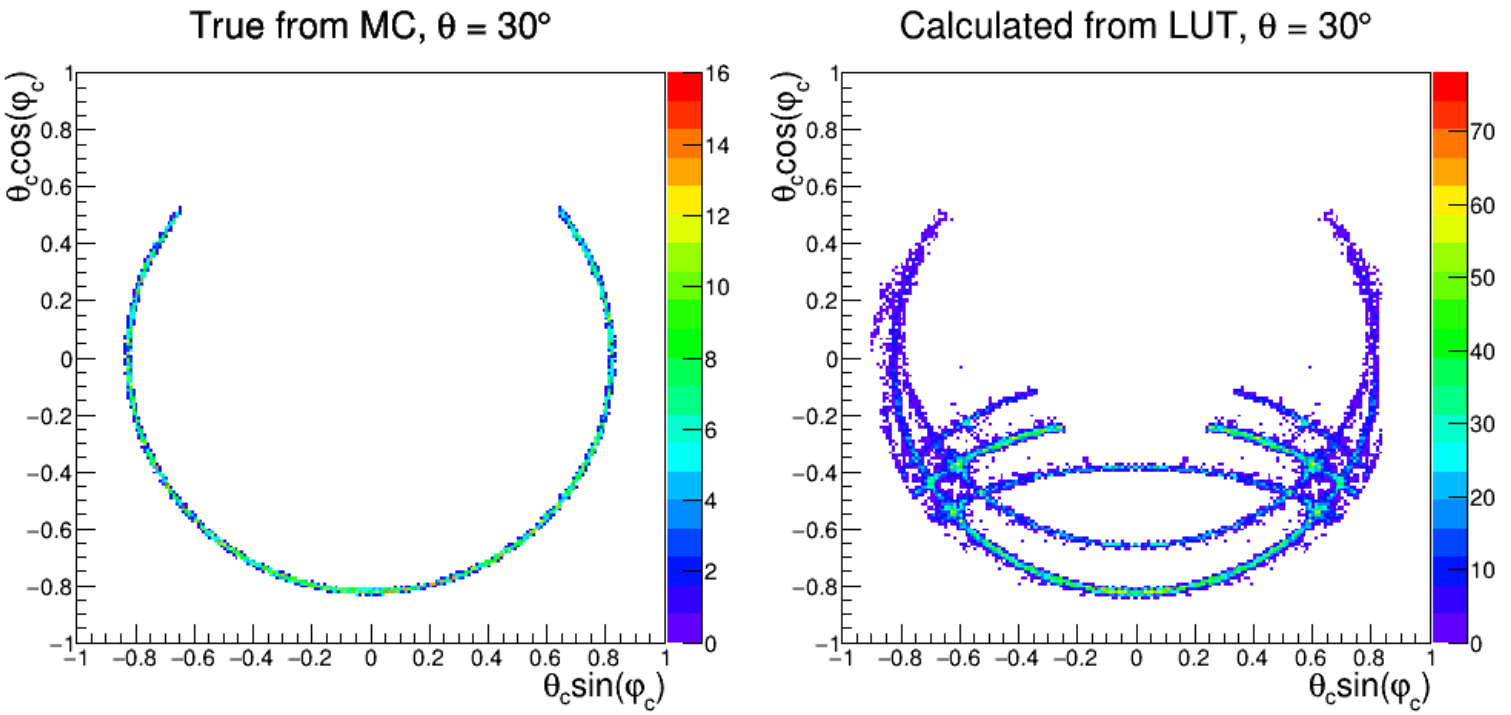
$$\sigma_{\theta_C}^{\text{track}} = \sqrt{\left(\frac{\sigma_{\theta_C}^{\text{photon}}}{\sqrt{N_{\text{photons}}}}\right)^2 + \left(\sigma^{\text{correlated}}\right)^2}$$

$\sigma^{\text{correlated}}$ track resolution, multiple scattering, etc.
Not affected by DIRC

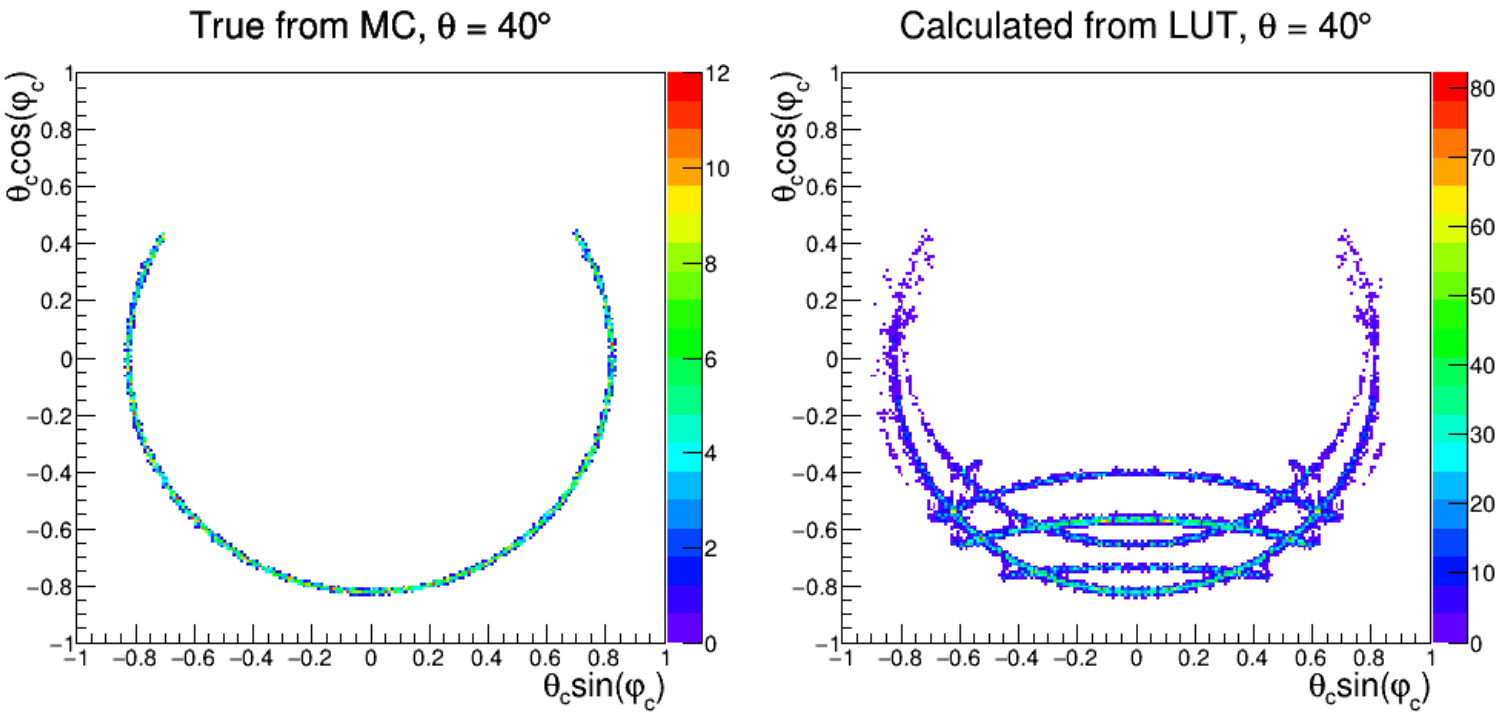




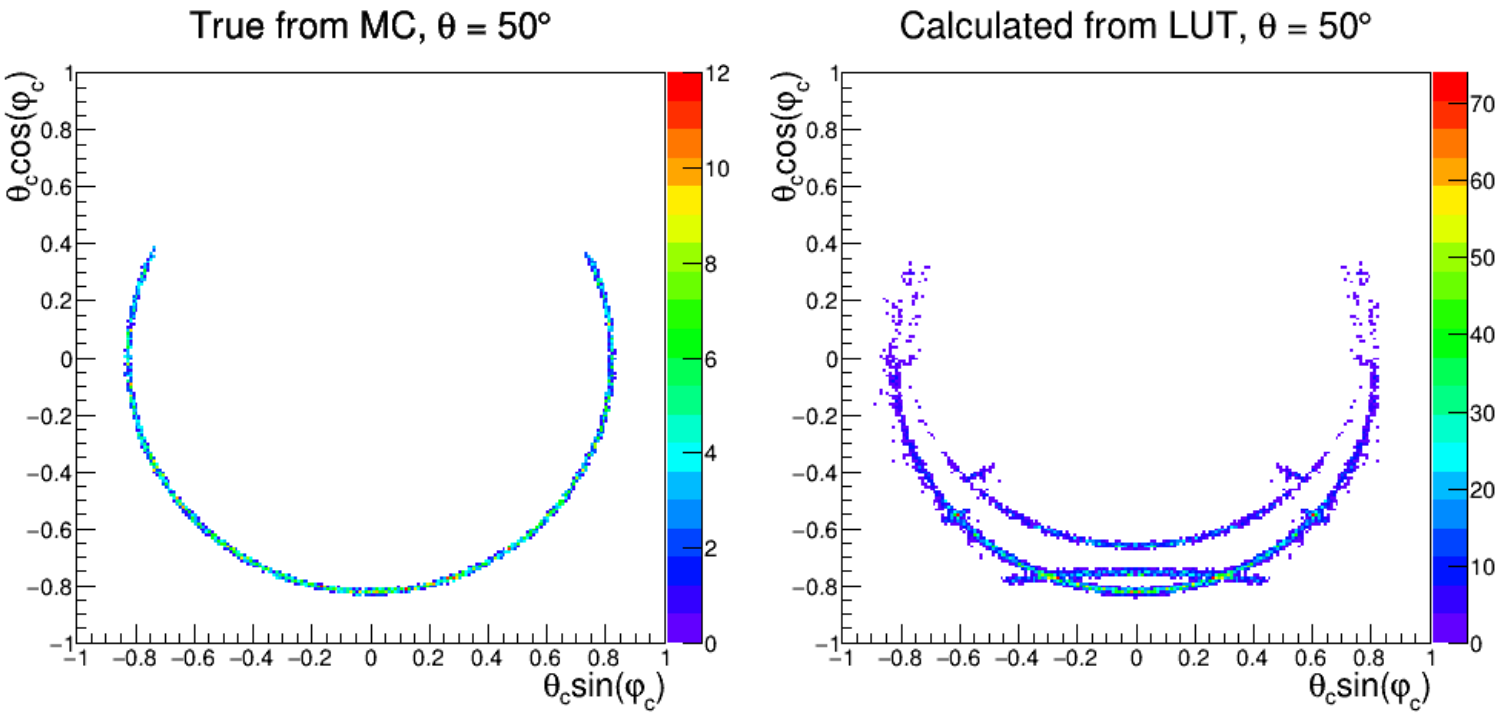
Correction of the track direction



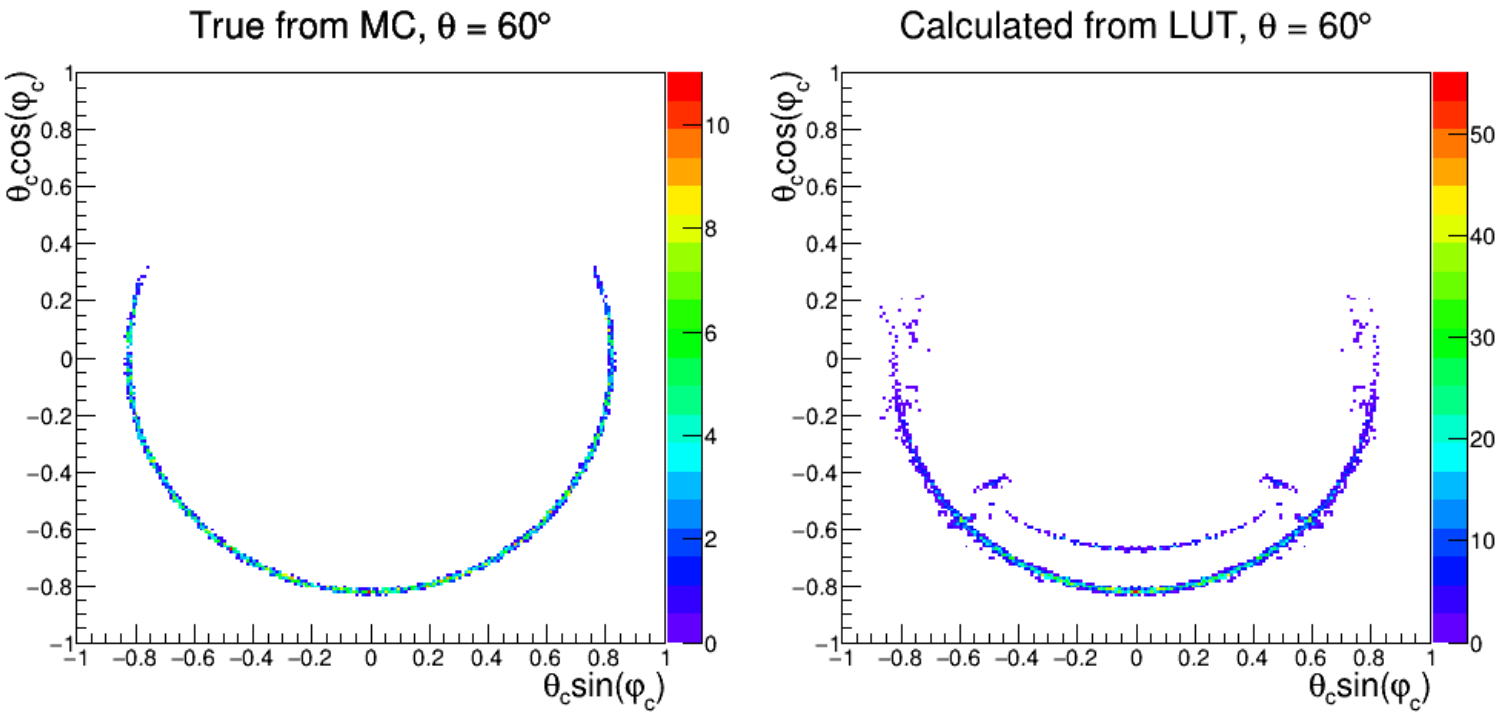
Correction of the track direction



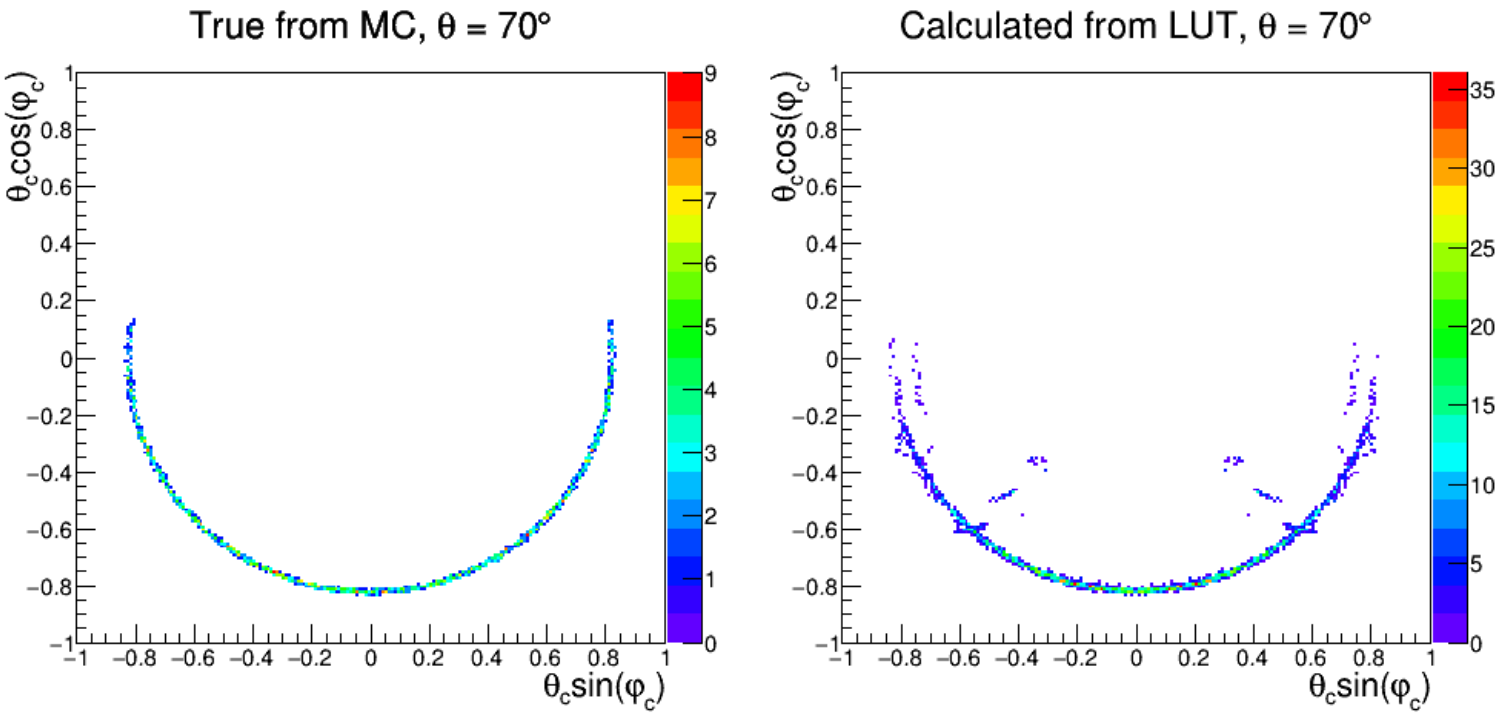
Correction of the track direction



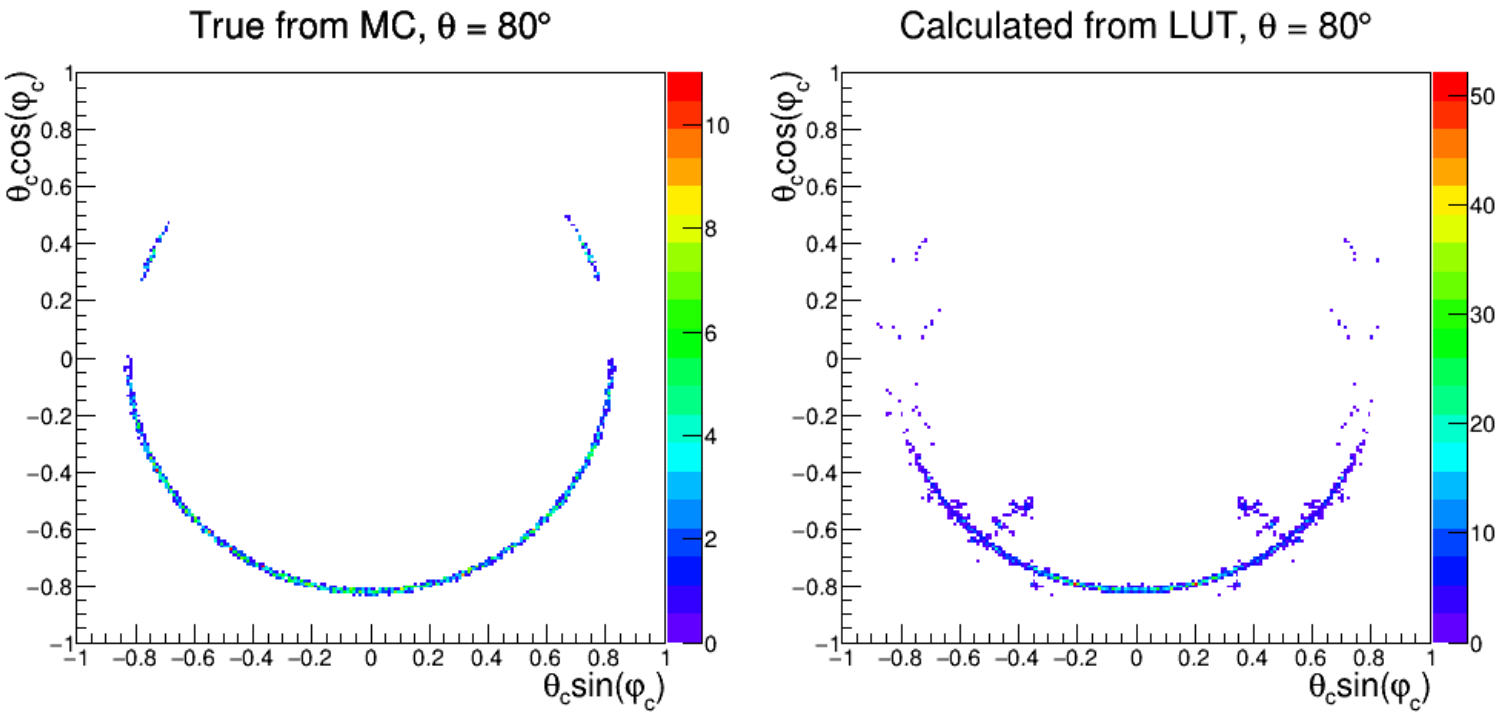
Correction of the track direction



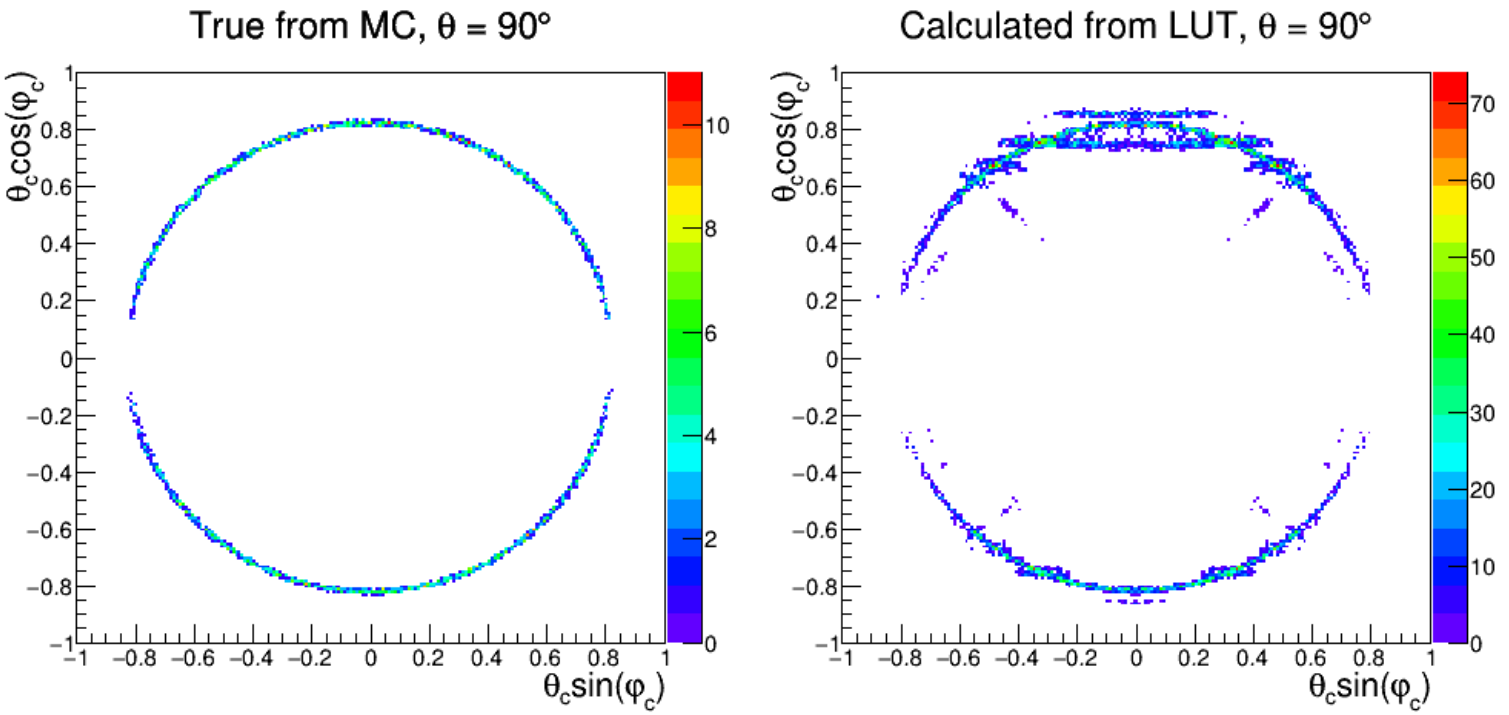
Correction of the track direction



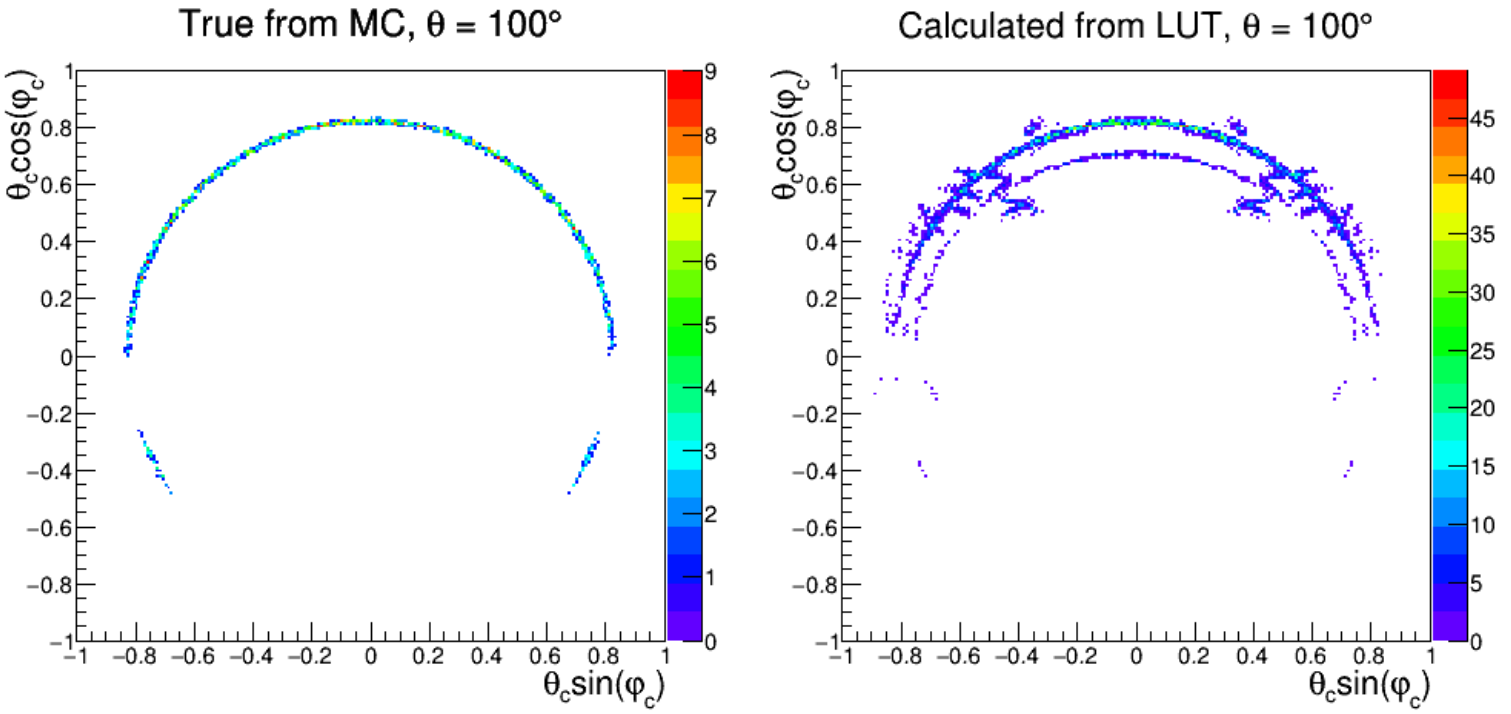
Correction of the track direction



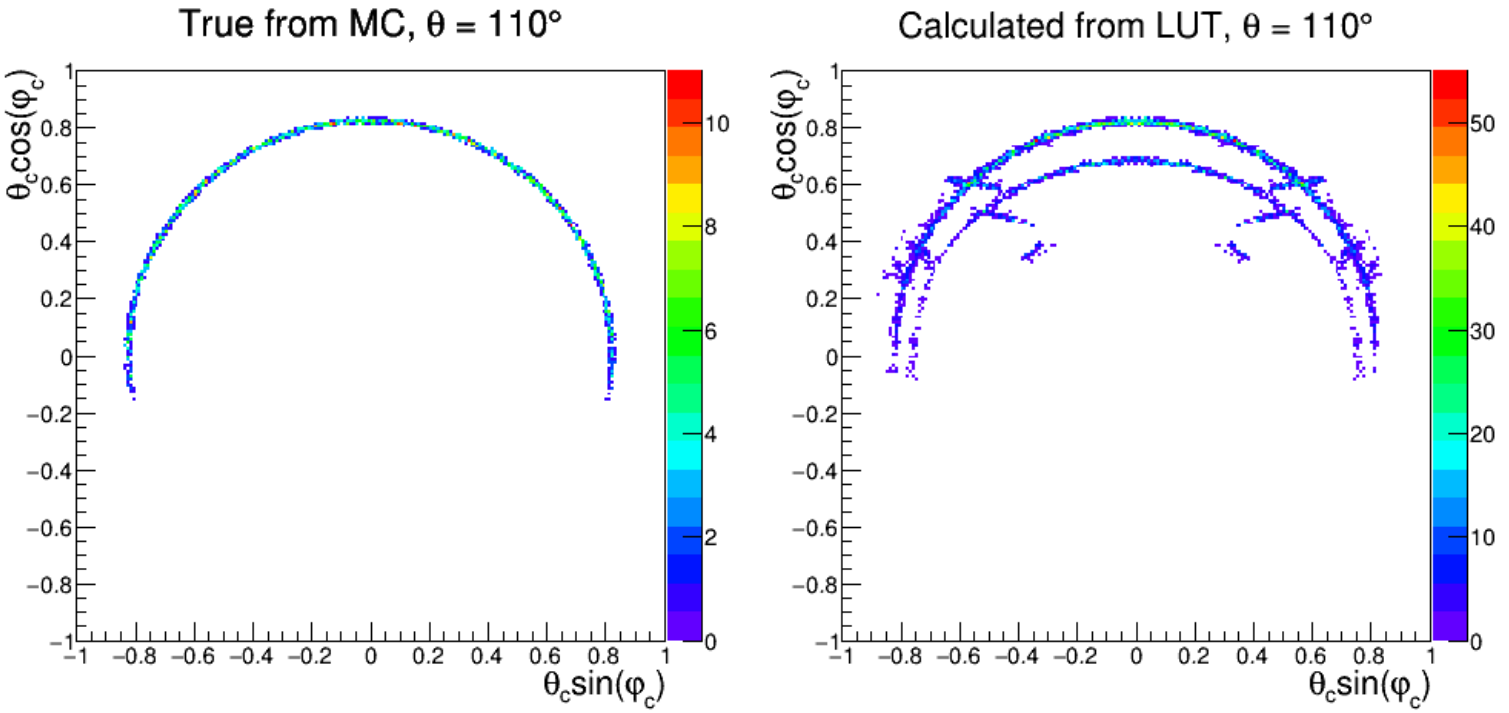
Correction of the track direction



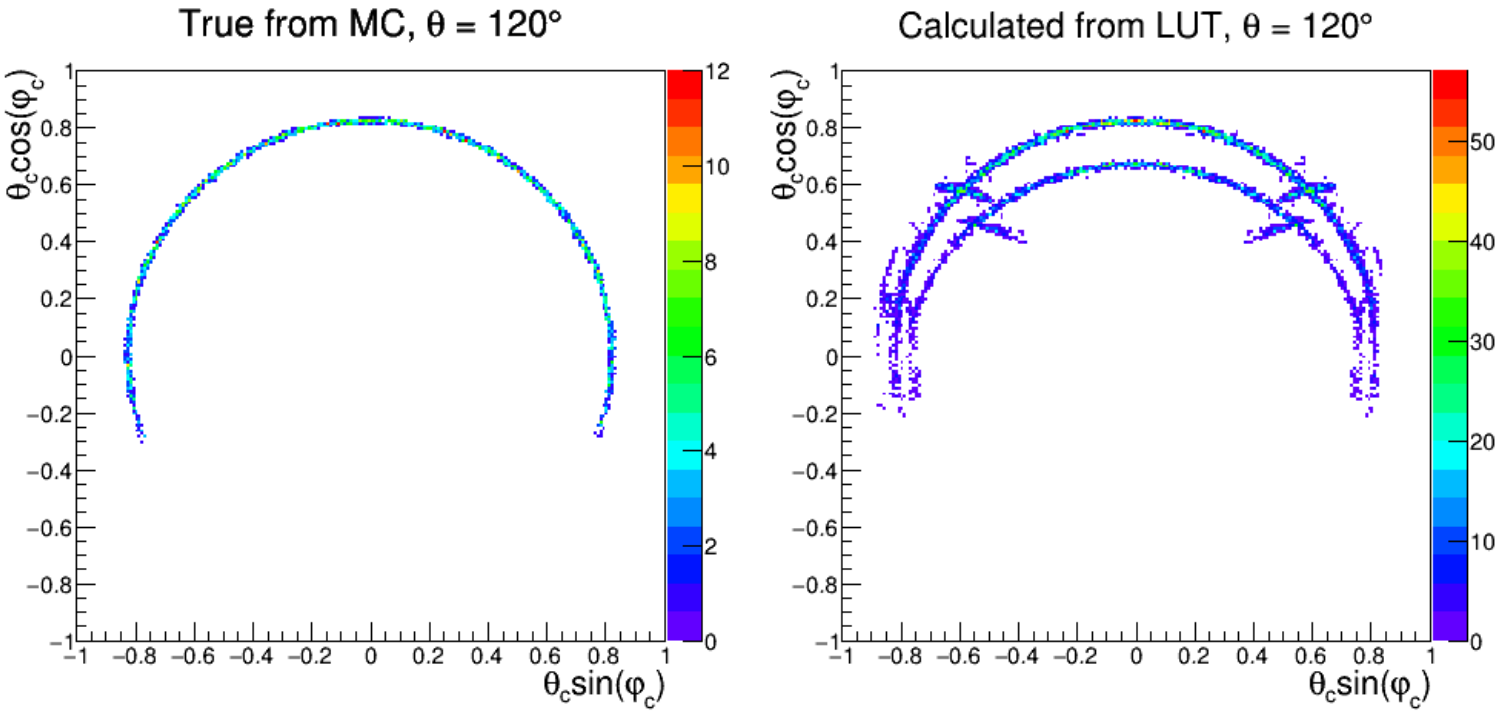
Correction of the track direction



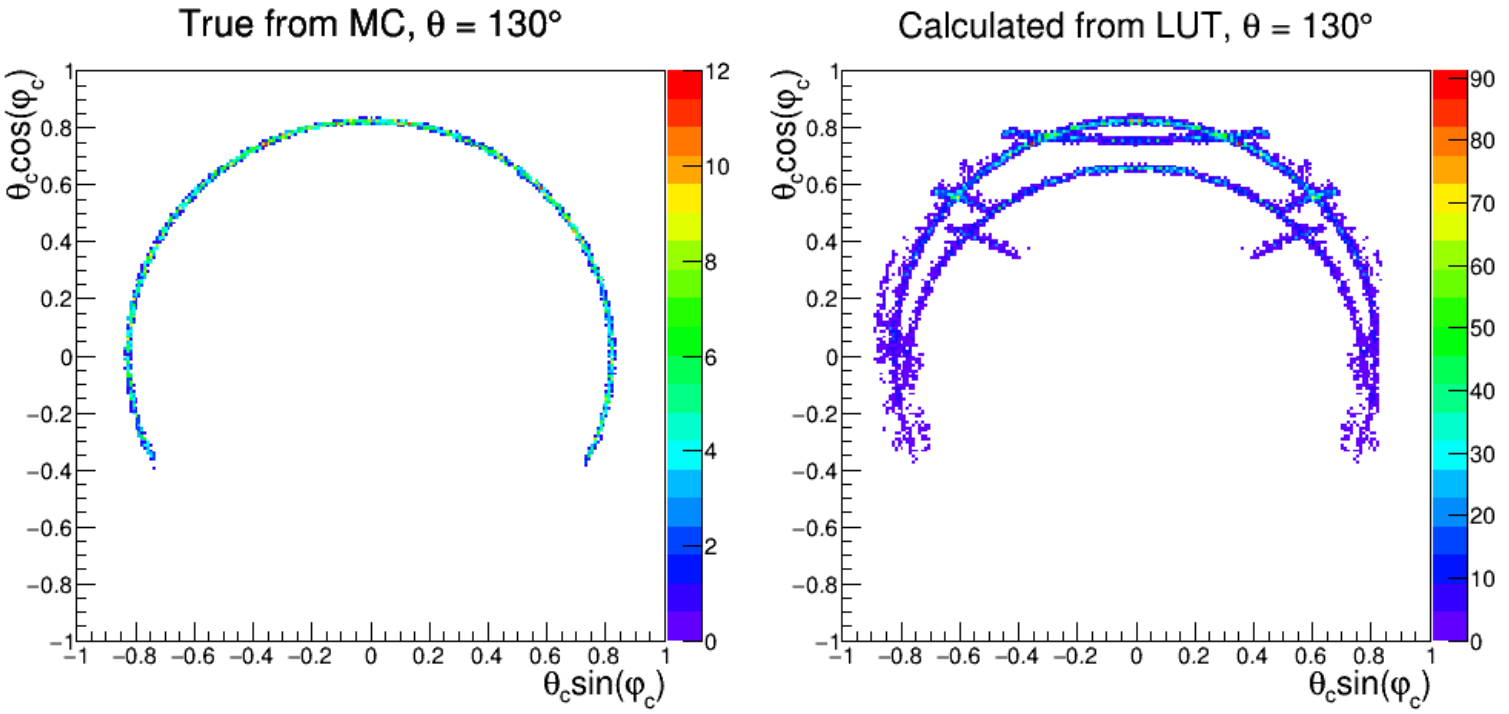
Correction of the track direction



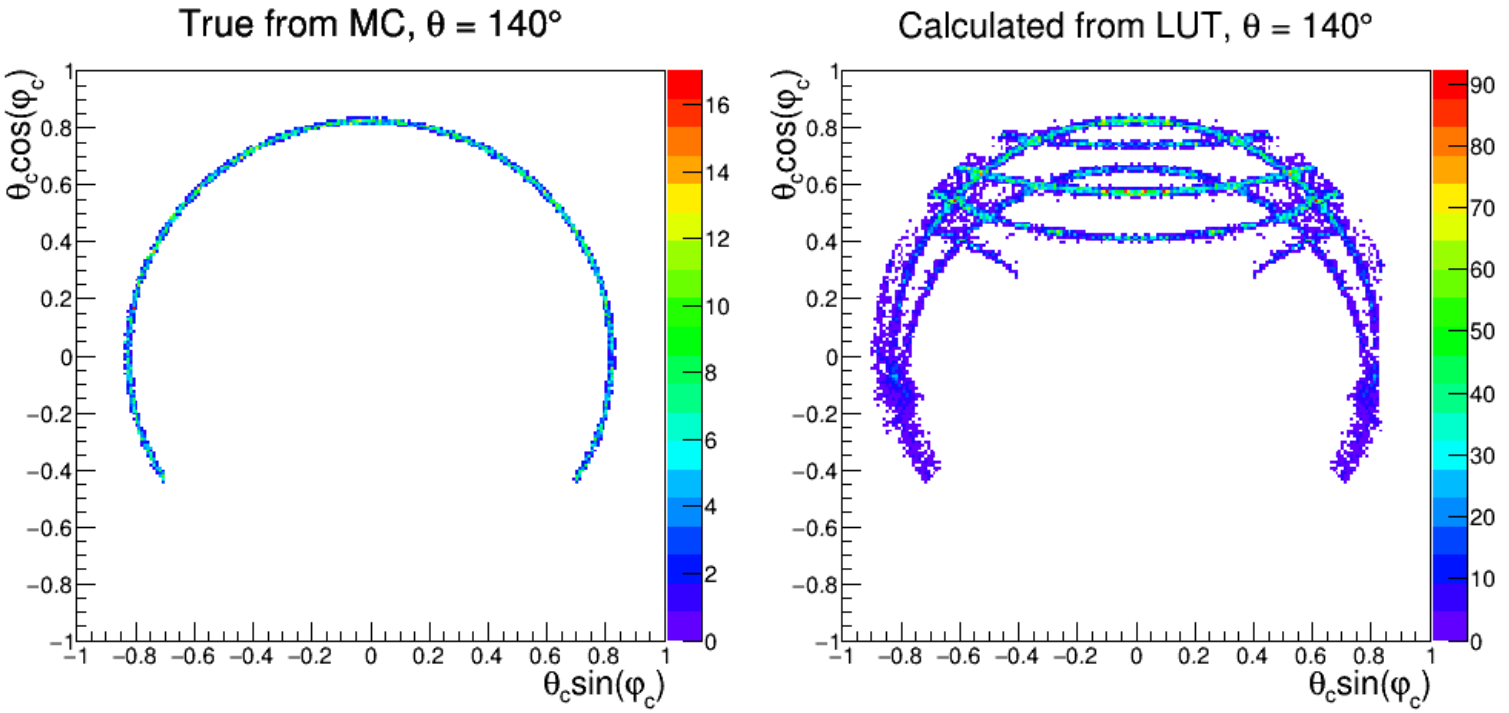
Correction of the track direction



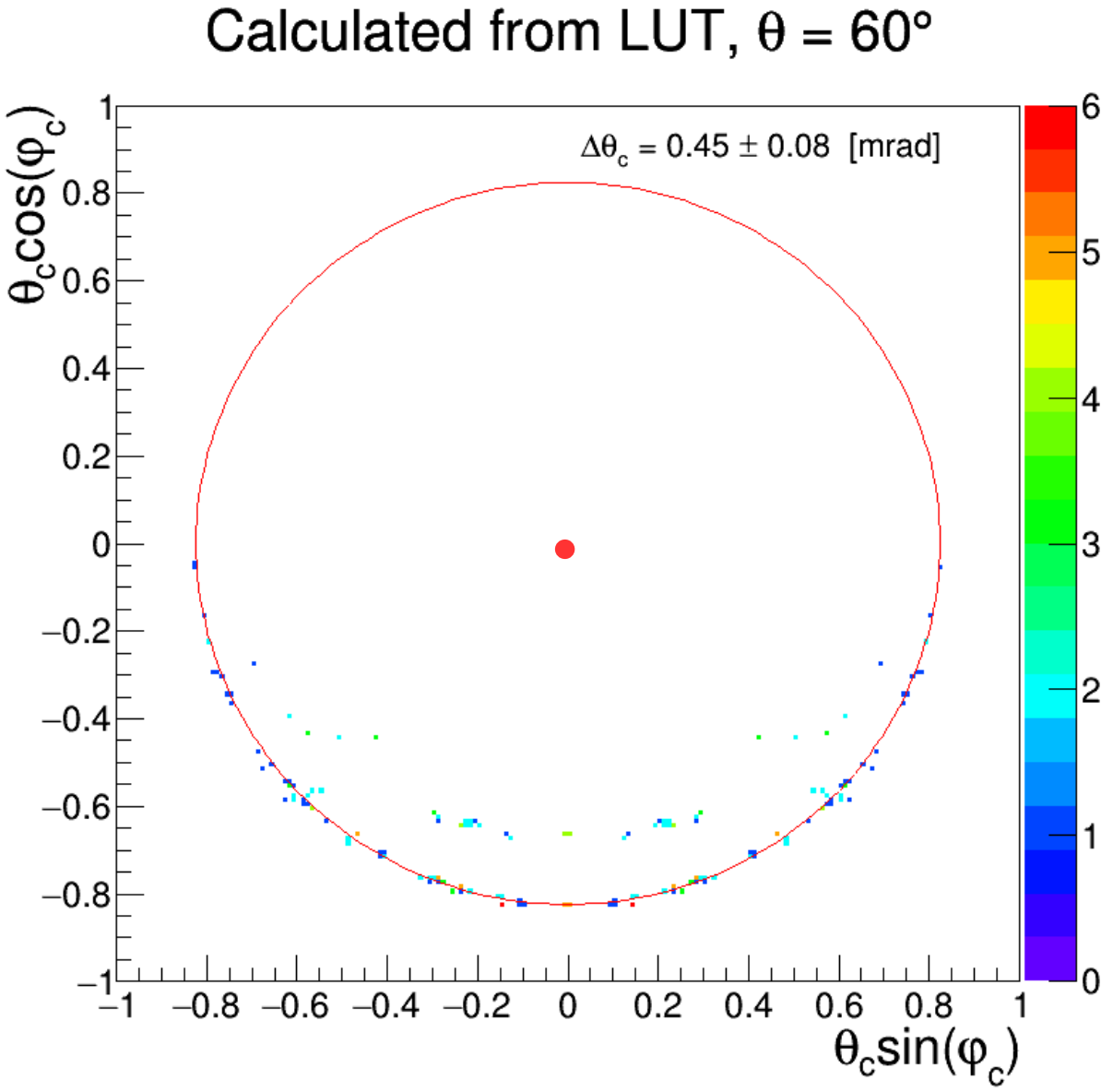
Correction of the track direction



Correction of the track direction

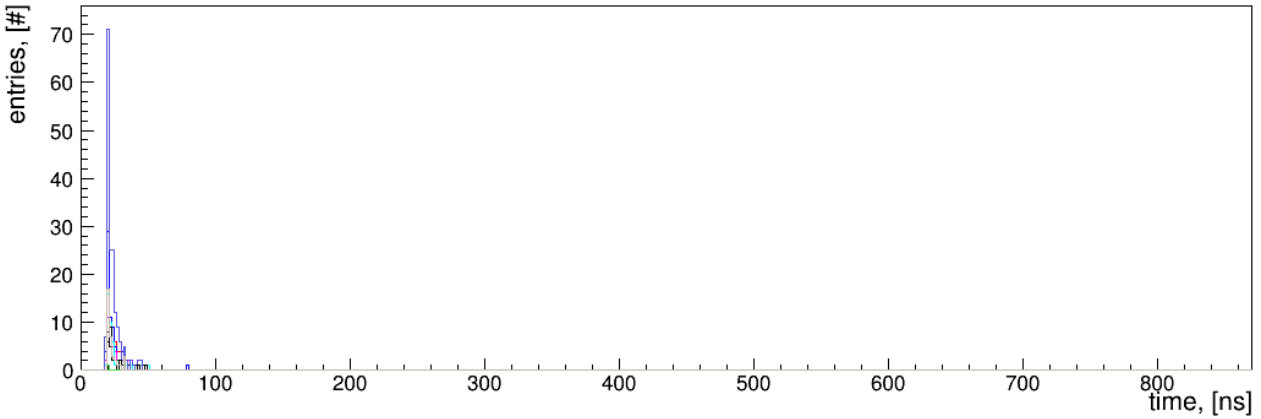


Correction of the track direction



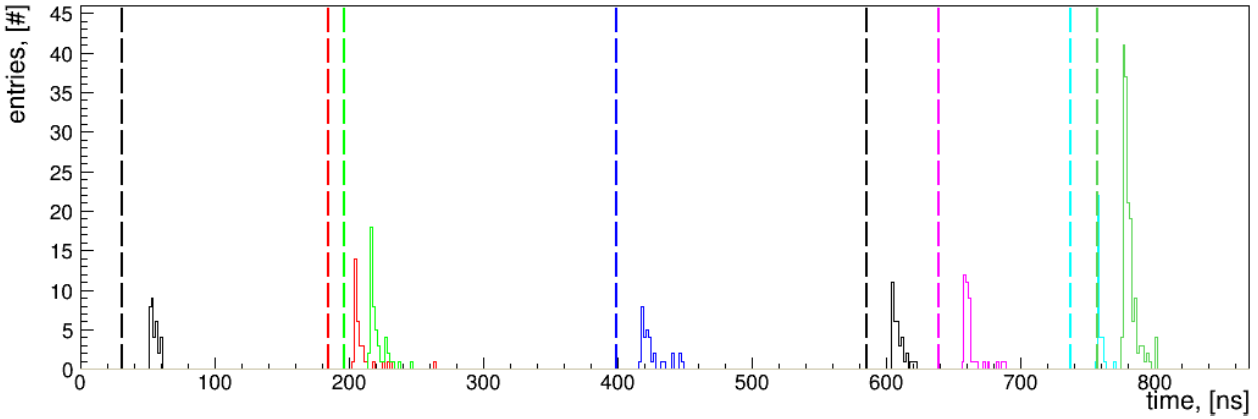
Time based simulations

- Start with event-based simulations.



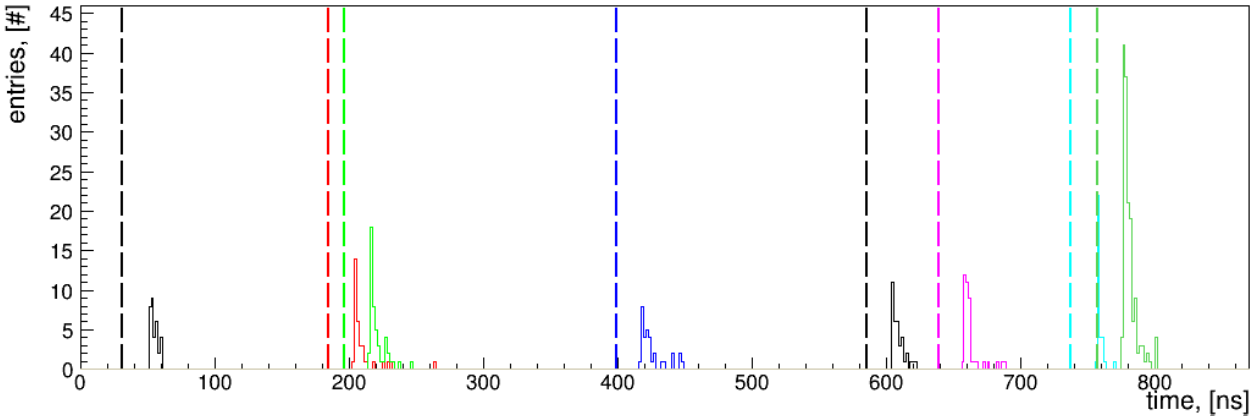
Time based simulations

- Start with event-based simulations.
- Assigning time stamp to Barrel DIRC hits (@20 MHz):

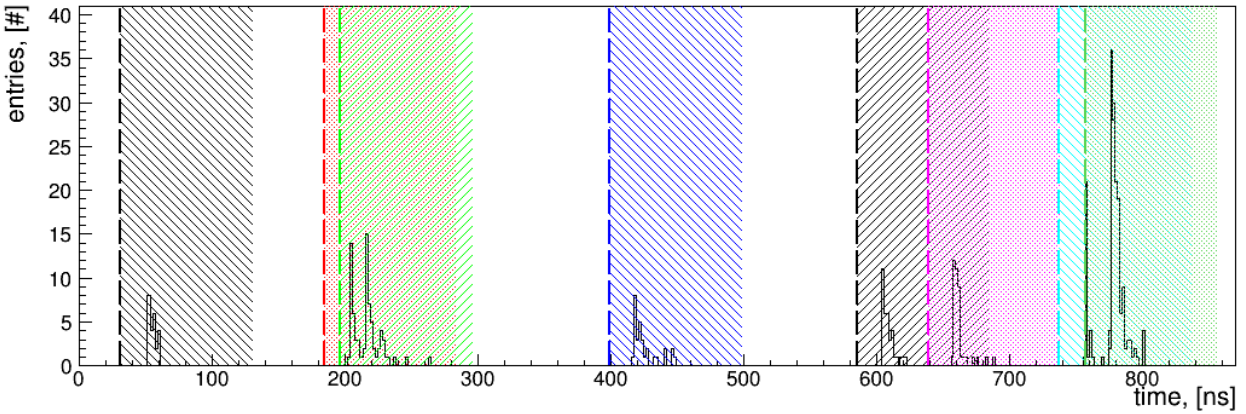


Time based simulations

- Start with event-based simulations.
- Assigning time stamp to Barrel DIRC hits (@20 MHz):

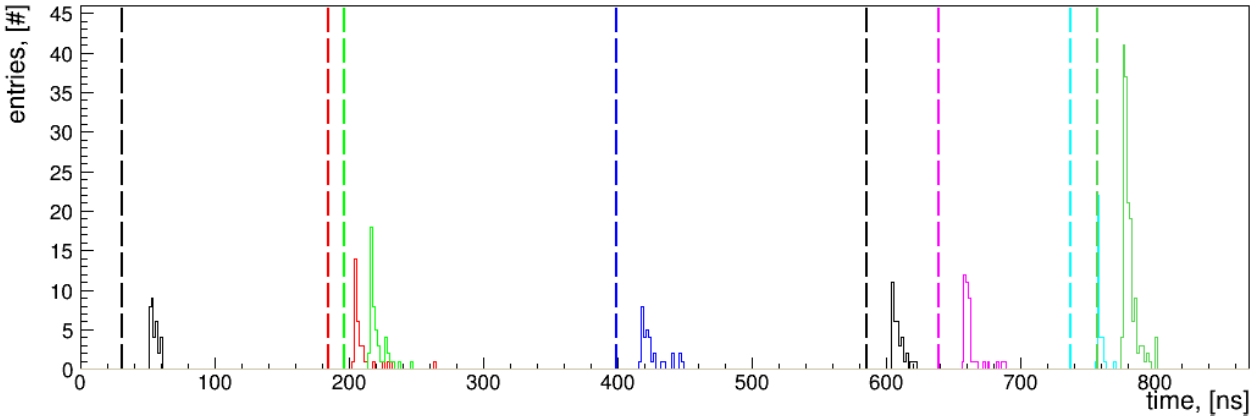


- Events-hits relationship after hit finder:

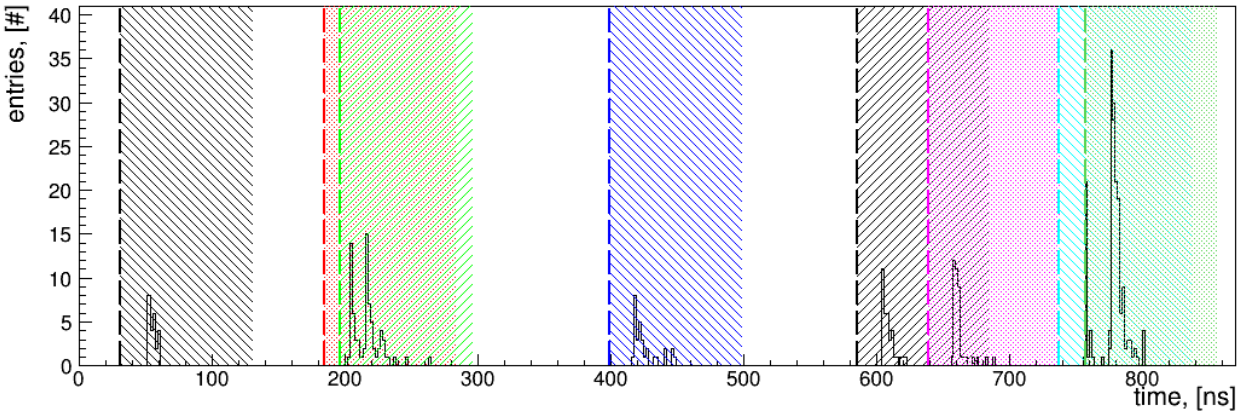


Time based simulations

- Start with event-based simulations.
- Assigning time stamp to Barrel DIRC hits (@20 MHz):

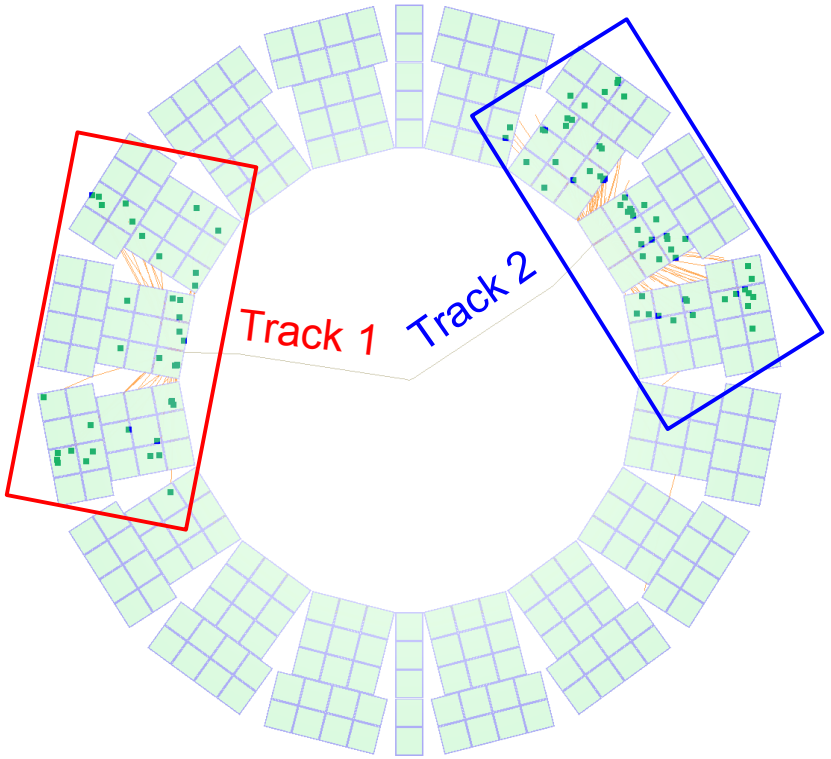


- Events-hits relationship after hit finder:



- Two things happens during time-based simulations:
  - Lost hits due to pile-up
  - Ambiguous assignment of hits to their tracks/events

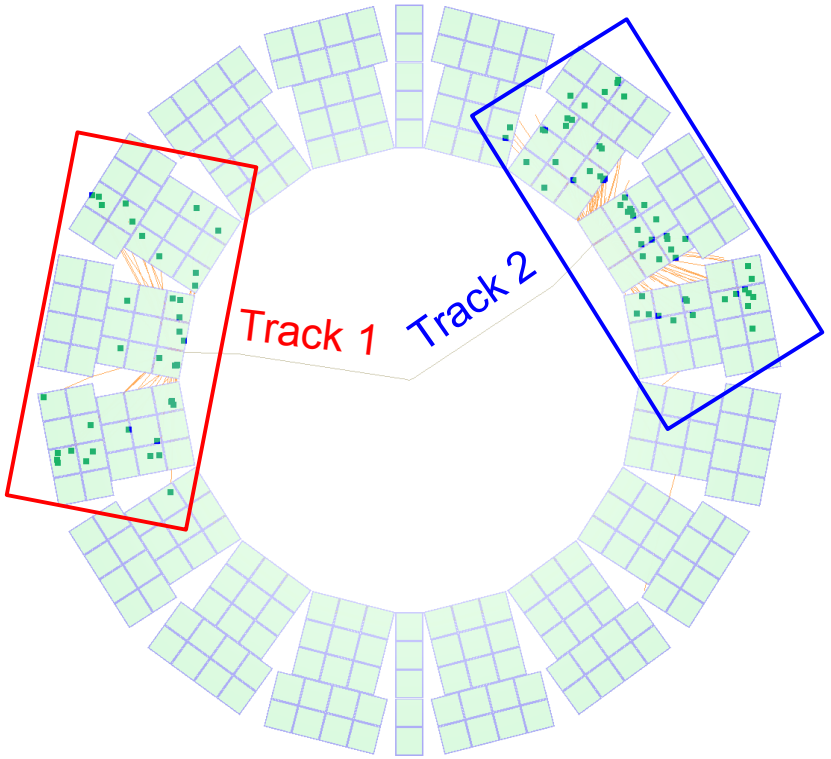
Hits separation

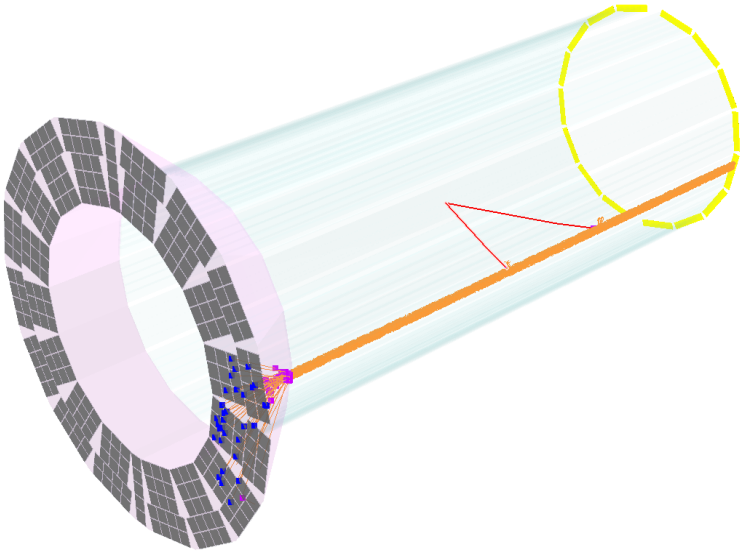


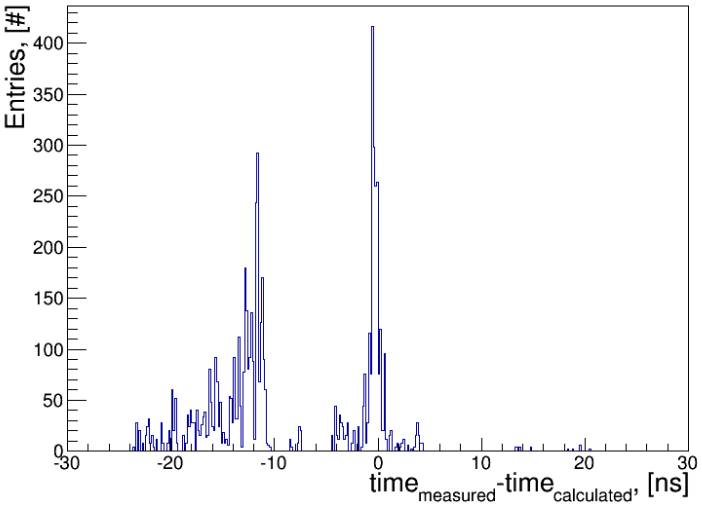
- good separation in space
- ~4 % of tracks are hit same bar box

(using DPM)

Hits separation





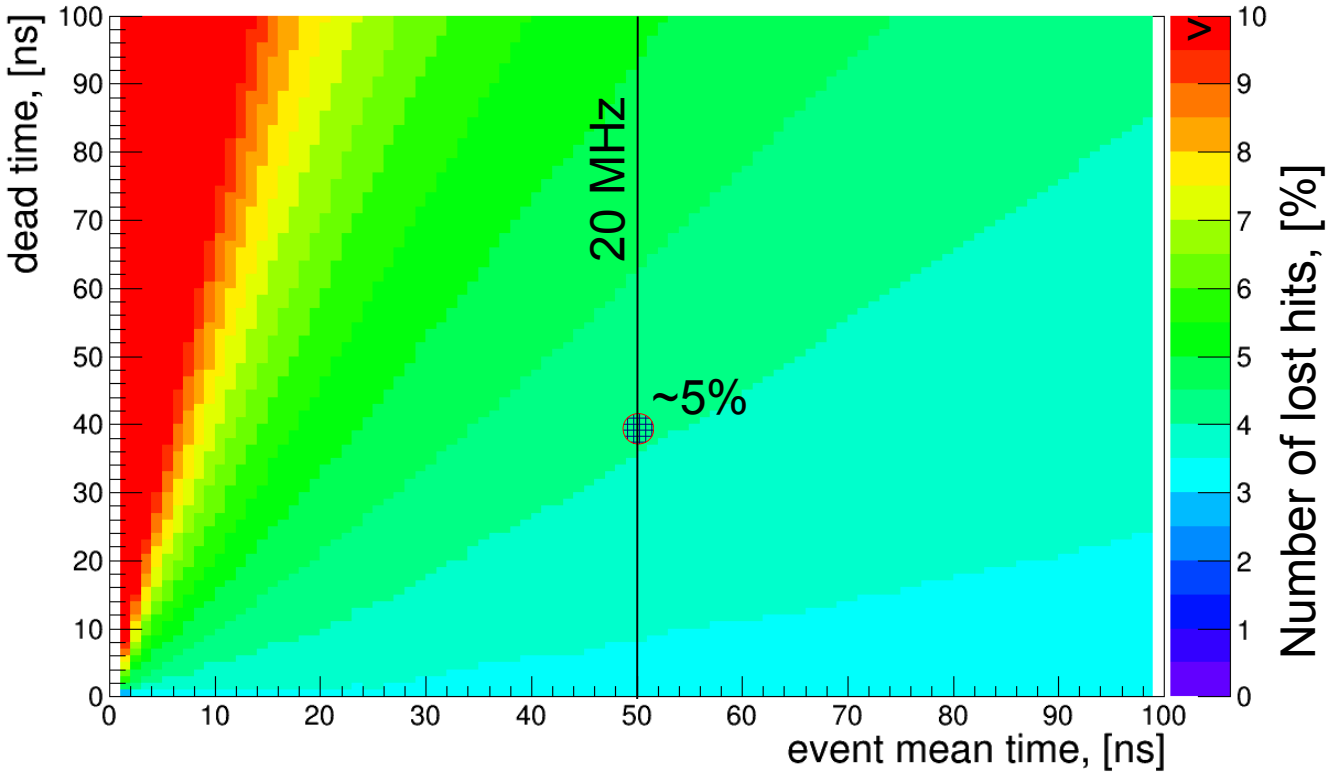


- good separation in space
- ~4 % of tracks are hit same bar box (using DPM)

- good separation in time
- 90% of 2 tracks in same barbox still could be separated using delta timing.

Pileup behavior

- 5 charged tracks in each event
- p = [1,3] GeV/c θ = [22, 140]° φ = [0, 180]°



- ~5 % of photons are lost due to pileup

(@ 20MHz and 40 ns dead time)

Summary and Outlook

- Barrel DIRC has full functional simulation software
- Two reconstruction methods are implemented
- Different geometry options of the PANDA DIRC detector were studied
- The base-line design satisfies PID requirements of PANDA
- Implemented time-based simulation
  - Hits from different track are good separated in space and time
  - Only 5 % of hits are lost due to pileup @ 20 MHz

- Ongoing R&D activities:
  - chromatic corrections
  - improving reconstruction algorithms

Summary and Outlook

- Barrel DIRC has full functional simulation software
- Two reconstruction methods are implemented
- Different geometry options of the PANDA DIRC detector were studied
- The base-line design satisfies PID requirements of PANDA
- Implemented time-based simulation
  - Hits from different track are good separated in space and time
  - Only 5 % of hits are lost due to pileup @ 20 MHz

- Ongoing R&D activities:
  - chromatic corrections
  - improving reconstruction algorithms

Thank you for the attention