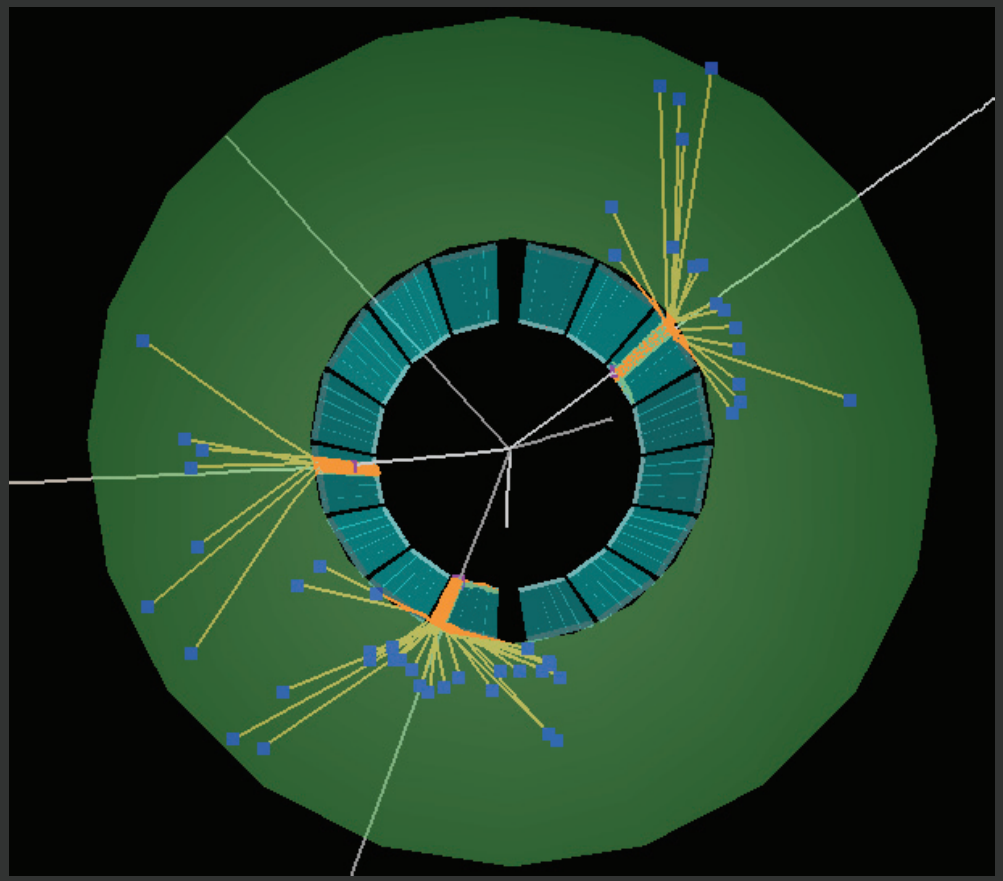
Simulation & Reconstruction for the PANDA Barrel DIRC Detector



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Overview

- PANDA Barrel DIRC - baseline design
- Simulation of Barrel DIRC - design options
- Reconstruction approach and results
- Open technical questions
- Summary

For details see talk C.Schwarz
“The PANDA Barrel DIRC”
05.04.2011, 14:00

Barrel DIRC Design

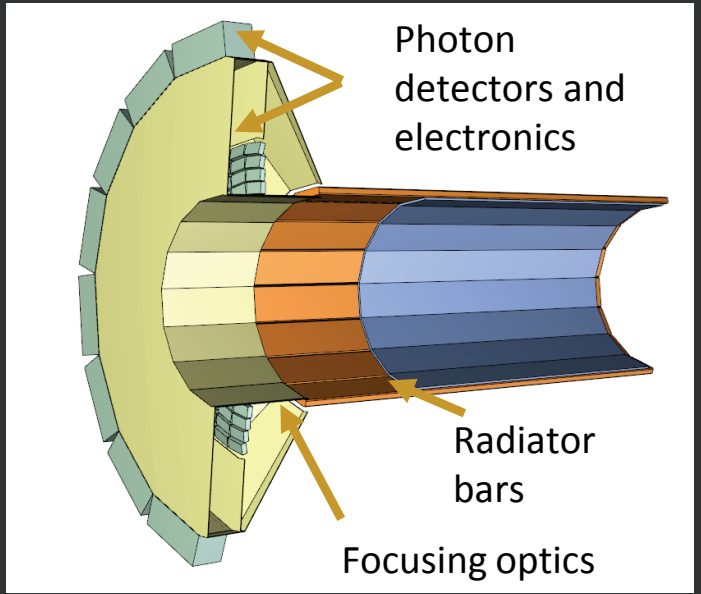
- PANDA Barrel DIRC design is based on BABAR DIRC design with several improvements (focusing optics, compact expansion volume and fast photon timing).

- Barrel radius ≈50 cm; expansion volume depth - 30 cm.

- 80 radiator bars, synthetic fused silica
  17mm (T) × 33mm (W) × 2500mm (L).

- Compact photon detector:
  30 cm oil-filled expansion volume,
  10K-15K channels of MCP-PMTs.

- Required performance:
  Single photon Cherenkov angle resolution: 8-9 mrad
  Number of photoelectrons per track: >20
  PID: at least 3 standard deviations π/K separation from 0.5 GeV/c up to 3.5 GeV/c

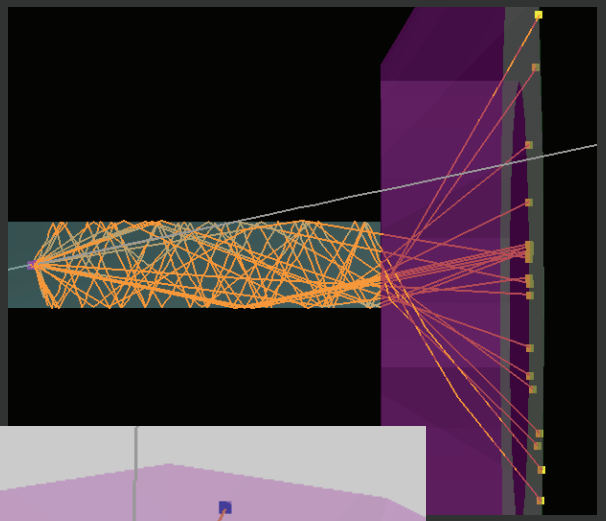


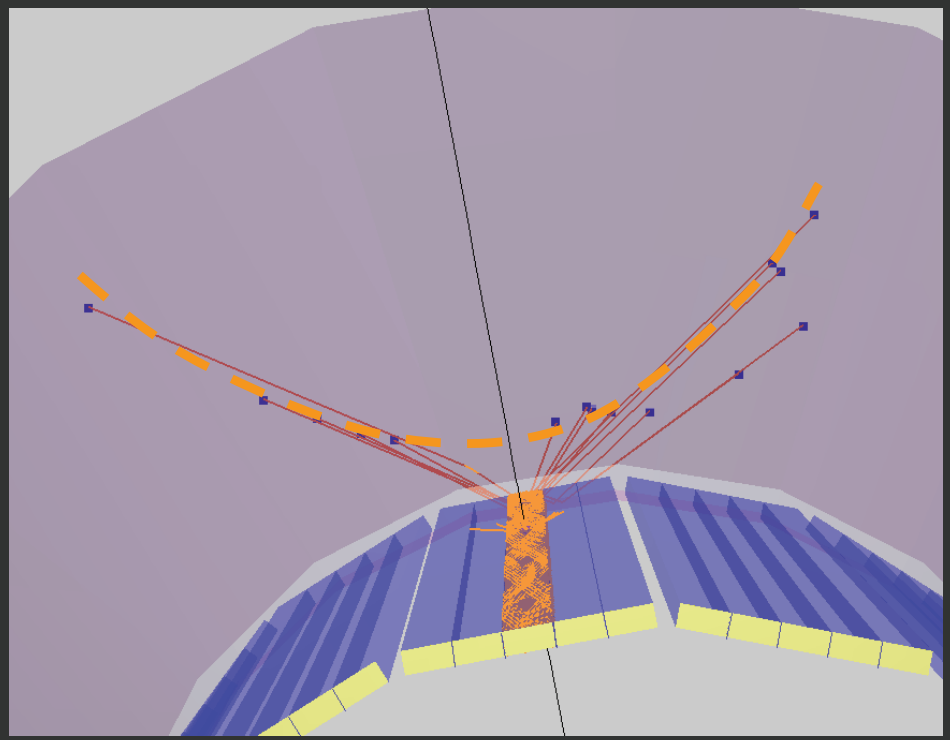
- Many parameters are not yet optimized.

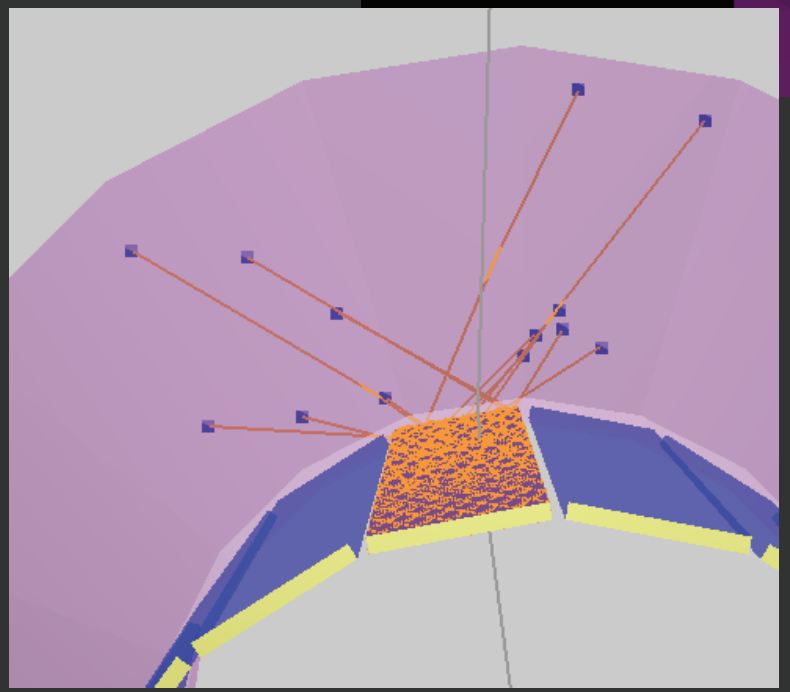
- Several design options need to be investigated.

Design Options

- Radiators: bar vs plate
  (potential lower cost of production)

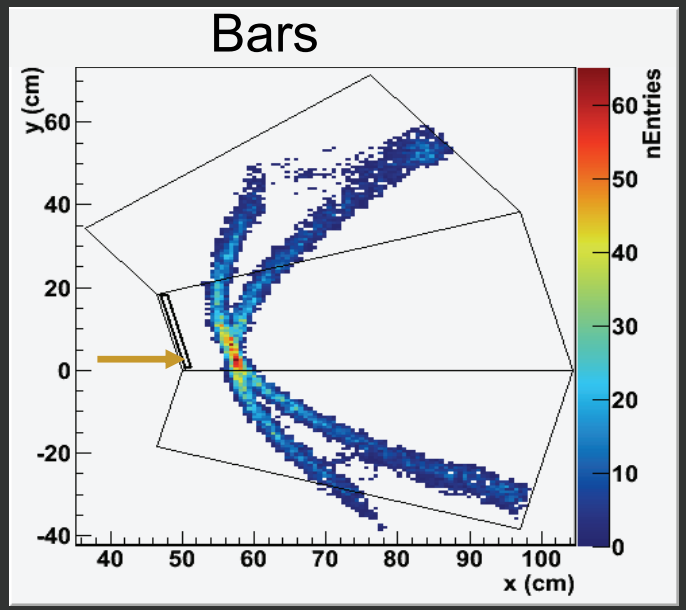


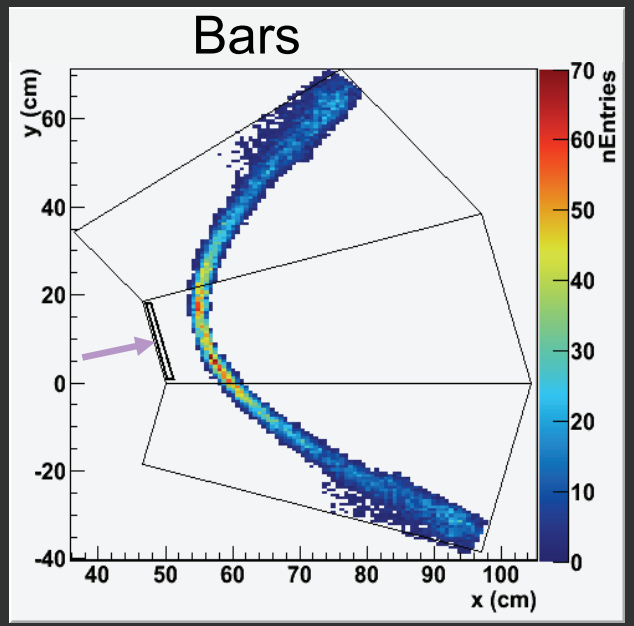


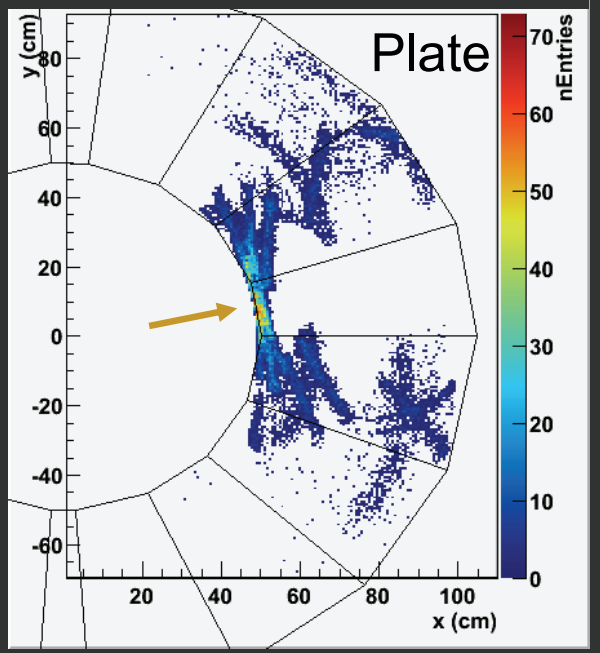


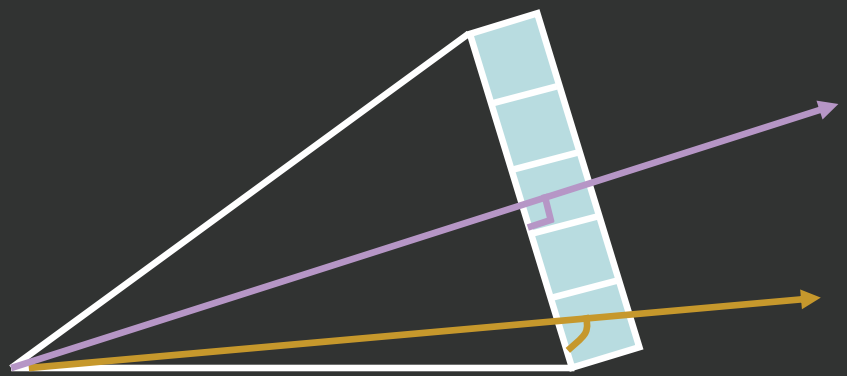
Design Options

- Radiators: bars. Hit pattern when different bars or a plate are hit



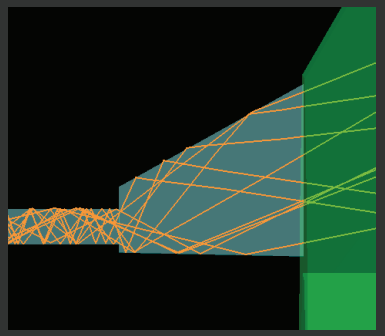




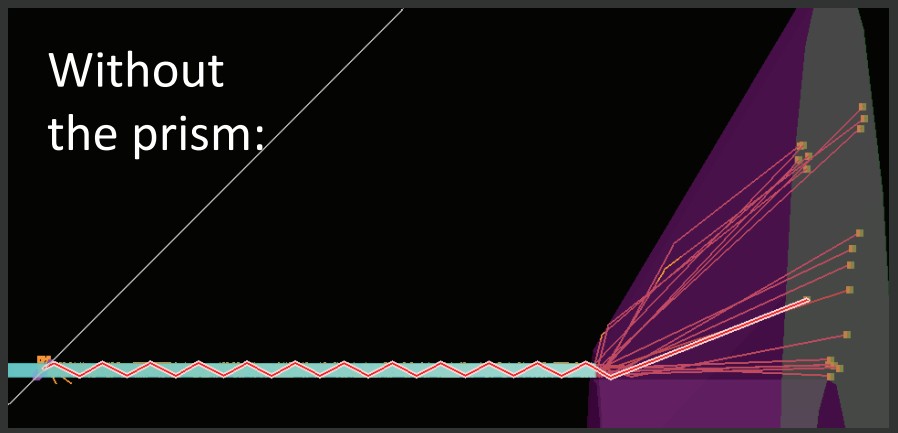


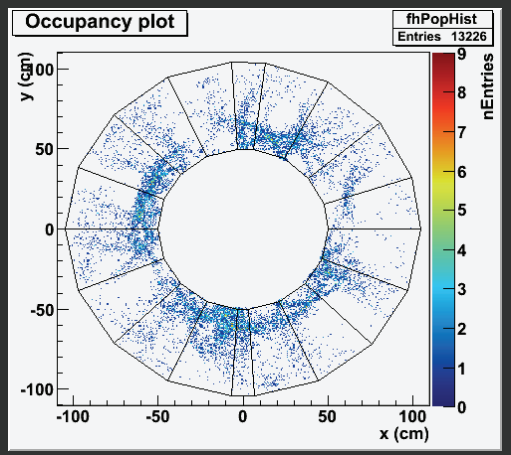
Local azimuth angle
defines the rings pattern
for bars

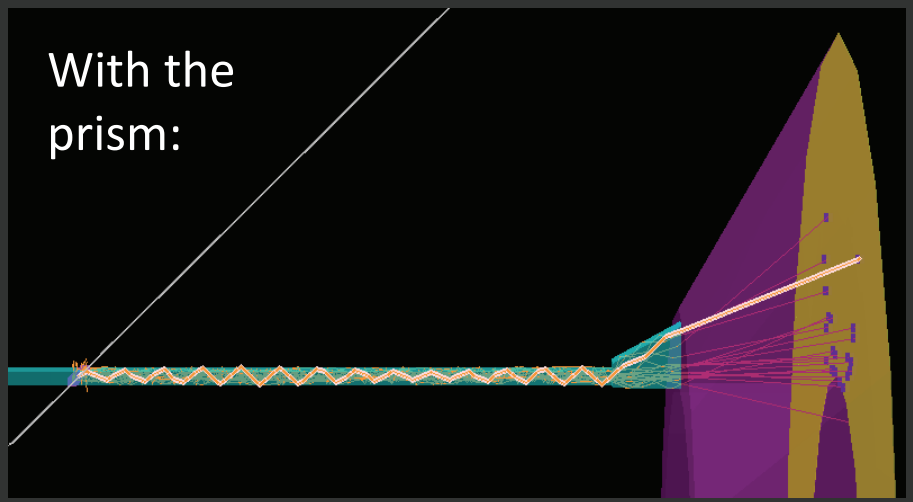
Design Options

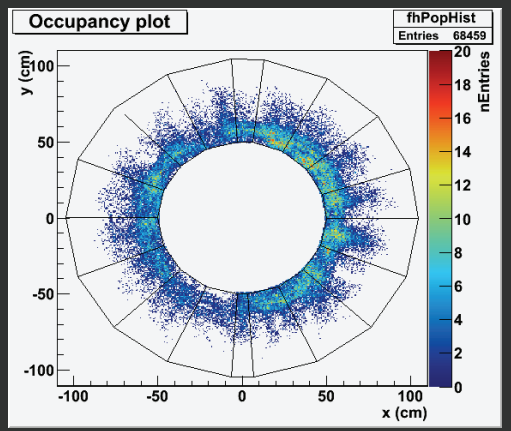


- Prism – to compress the phase space in radial direction and reduce the number of required detector pixels

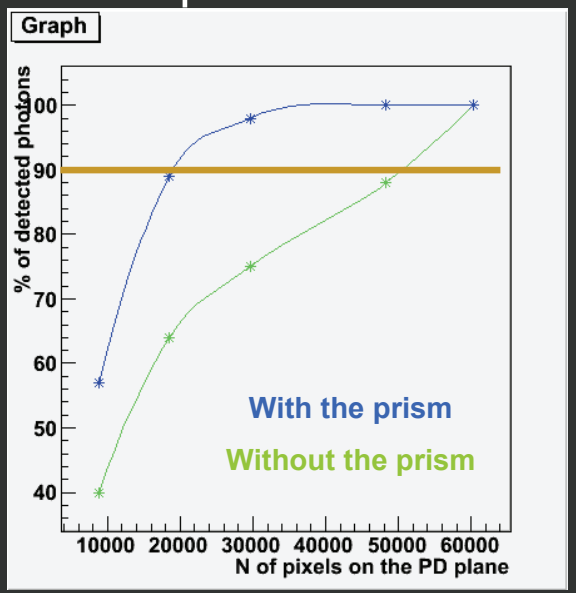






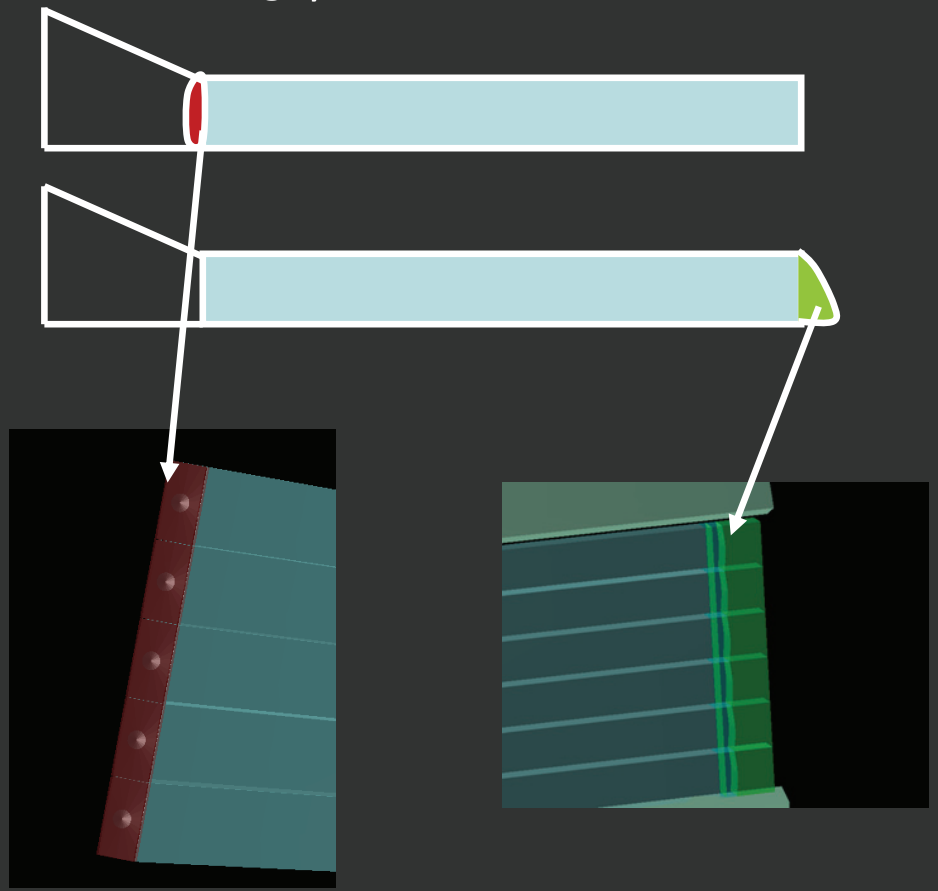


Without prism need 3 times more pixels to detect 90% of photons:



Design Options

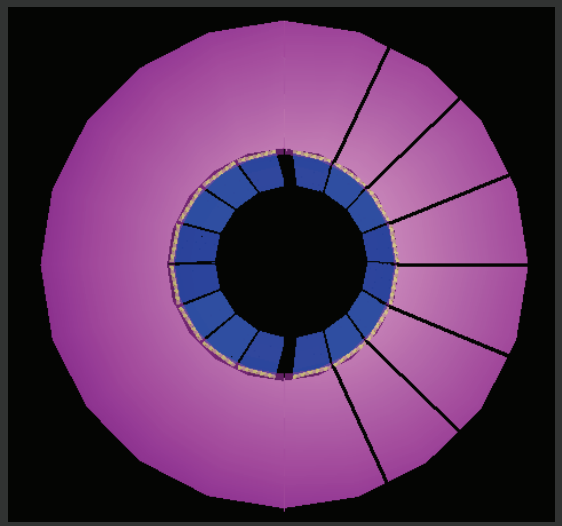
- Focusing:
  - Lens
  - Backward mirror
  - Forward mirror (inspired by Belle II design)

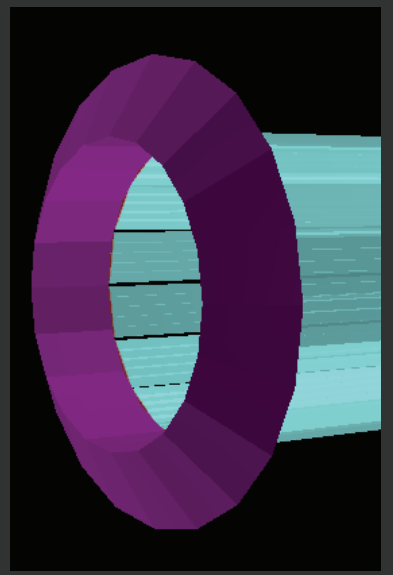


- Expansion volume:

  Single tank or 16 optically isolated ones?

Tilted PD plane





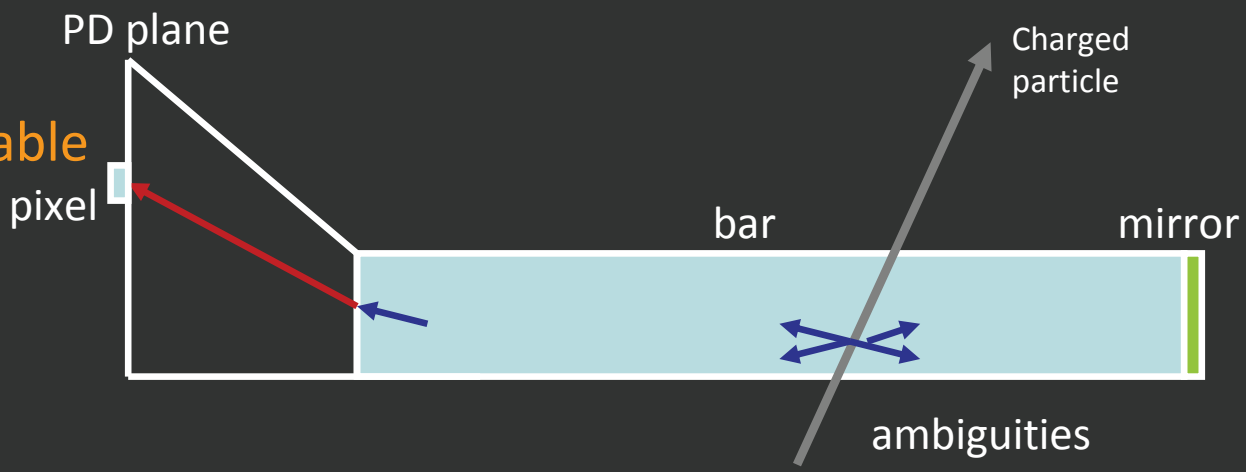
Reconstruction Approach

- Proven reconstruction method – BABAR-type reconstruction using lookup tables
  - For detector performance evaluation need to determine $\theta_c^{particle}$ defined as $\cos\theta_c^{particle}=1/\beta n$
  - θ_c^{photon} defined from photon and particle directions
  - In the reconstruction $\theta_c^{particle}$ is obtained from combining $N_{photons}$ measurements of θ_c^{photon} for one charged particle
  - Fast access to photon direction via lookup table makes use of pixel-bar association, possible use for online kaon identification at trigger stage

Reconstruction Approach

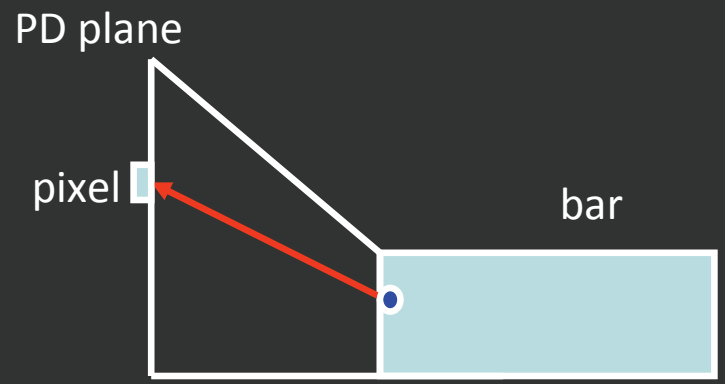
Lookup table

In **lookup table** the initial direction of a photon for each pixel is stored

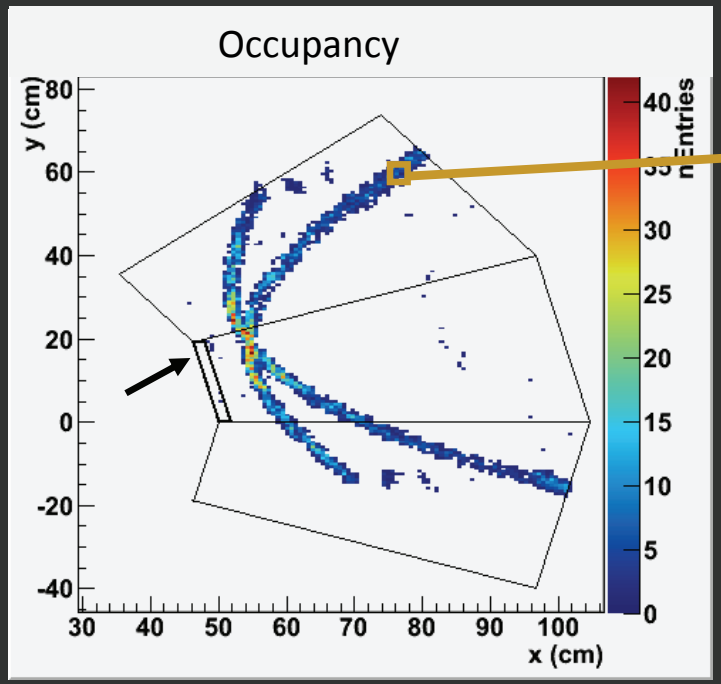


To create a lookup table we used "PhotonGun" in GEANT4:

- Optical photons (3.5 eV energy) produced at the end of the bar covering the whole detector plane
- Store photon direction for each pixel

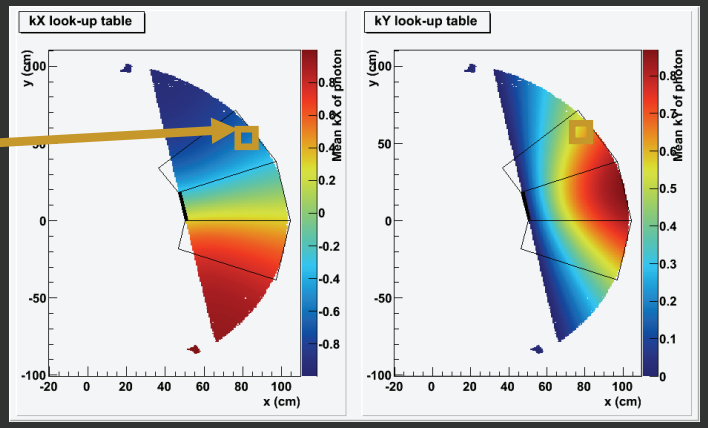


Reconstruction: step-by-step



Single track events (3 GeV/c pions, θ=120°, ϕ=16°)

Look up hit pixel

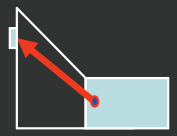


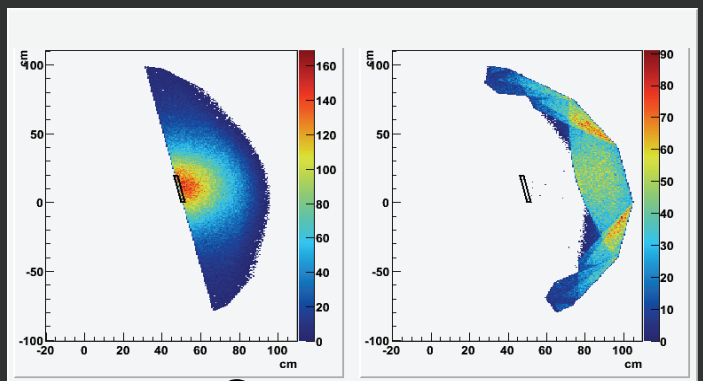
Photon initial direction

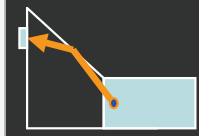
(kX, kY)

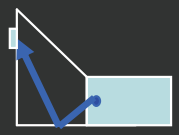
in bar coordinate system

Possible photon trajectories:

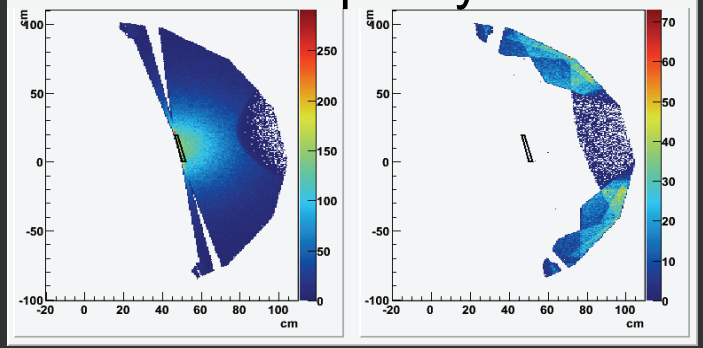


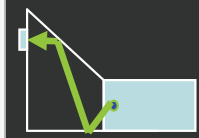




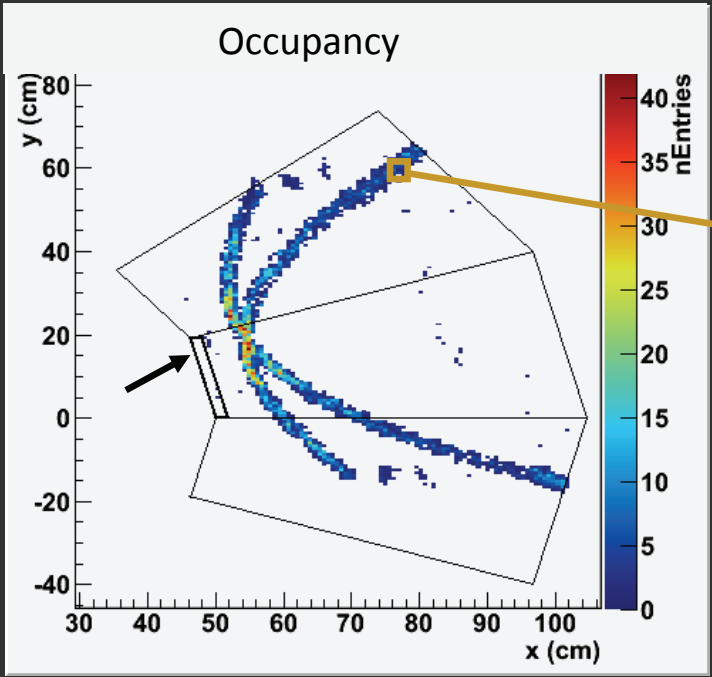


Occupancy





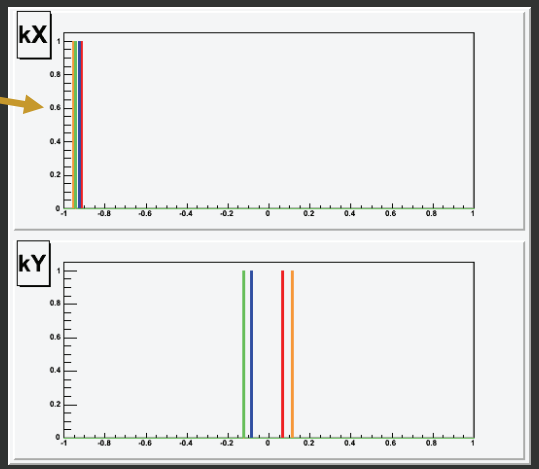
Reconstruction: step-by-step

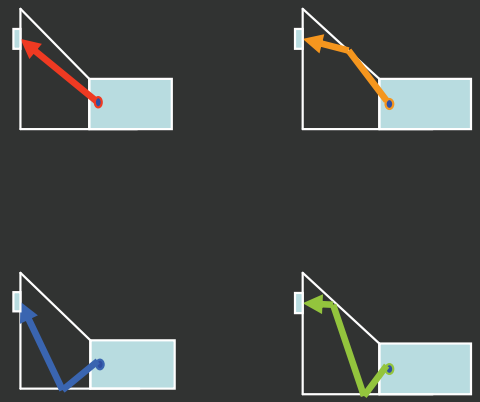


Single track events

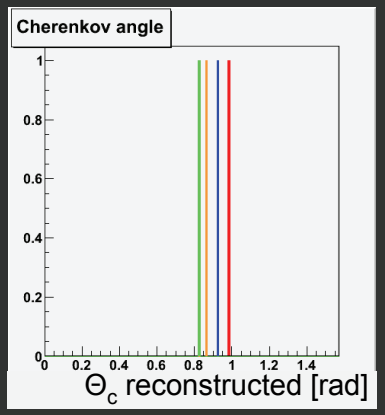
Photon direction for particular pixel,

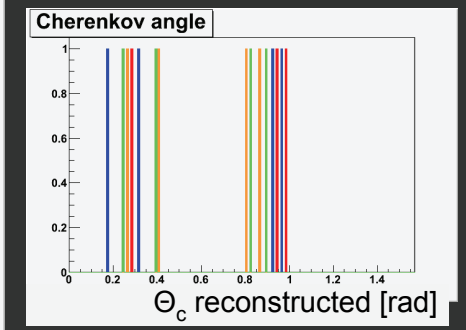
colors show different ambiguities -





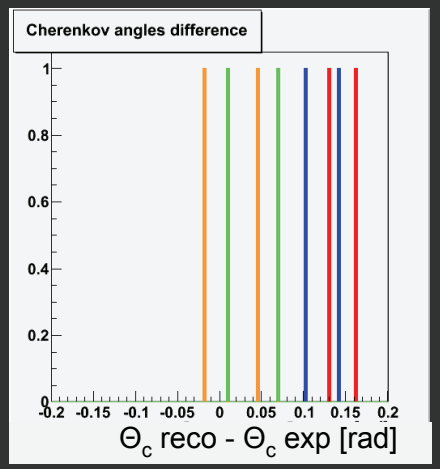
Combining photon direction and charged particle direction (from tracking system):





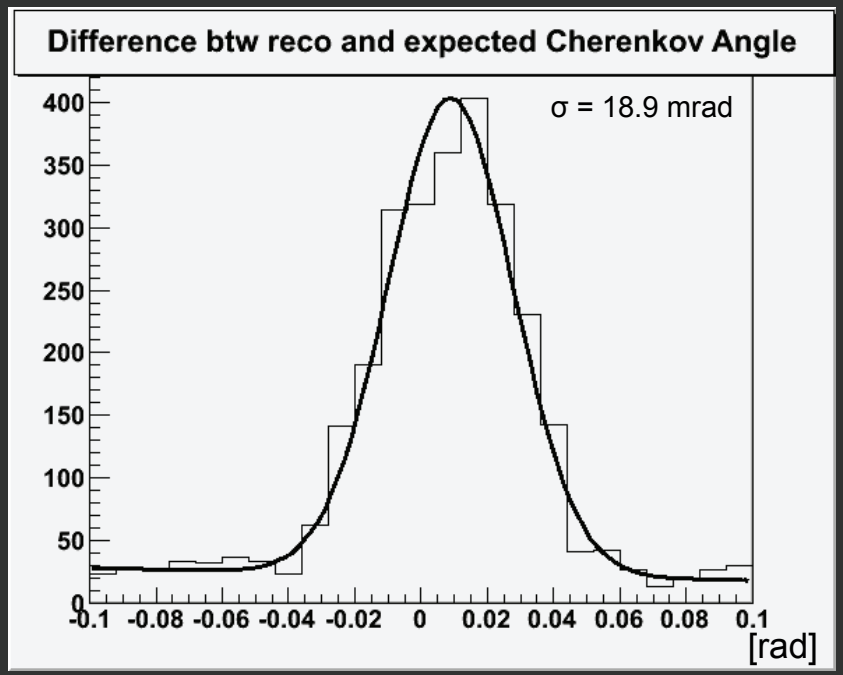
with bar ambiguities

Difference between reconstructed and expected Cherenkov angle:



Results

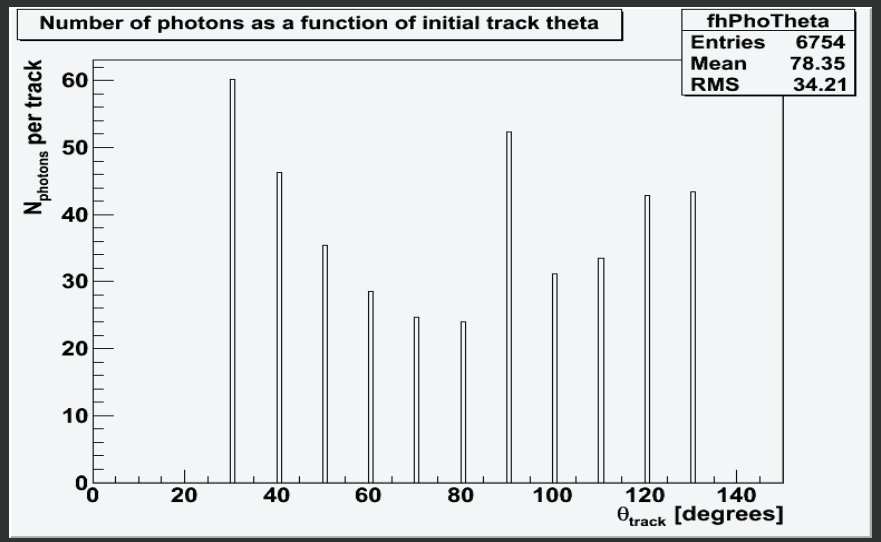
Apply described method to all hits:

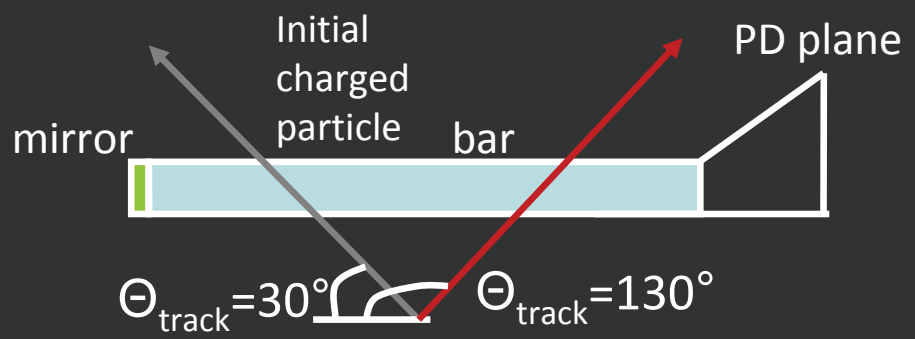


Single photon resolution is ***18.9 mrad***

Expected resolution is ***18 mrad*** *(based on pixel size, bar size, chromatic dispersion)*

Number of detected photons per track as a function of polar angle:

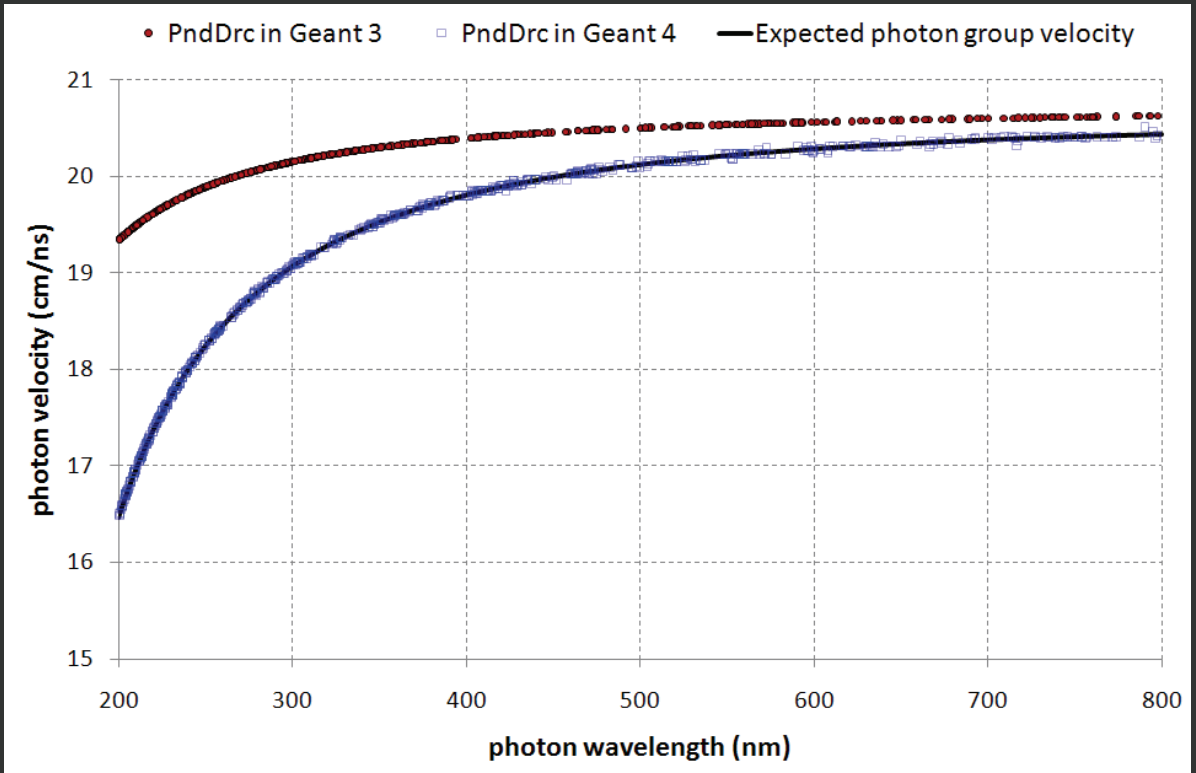




No focusing ⟶ at least 24 photons per track

Open technical questions

- Group velocity of optical photons in Geant 3 and Geant 4 using Virtual MonteCarlo (VMC) class:



Group velocity

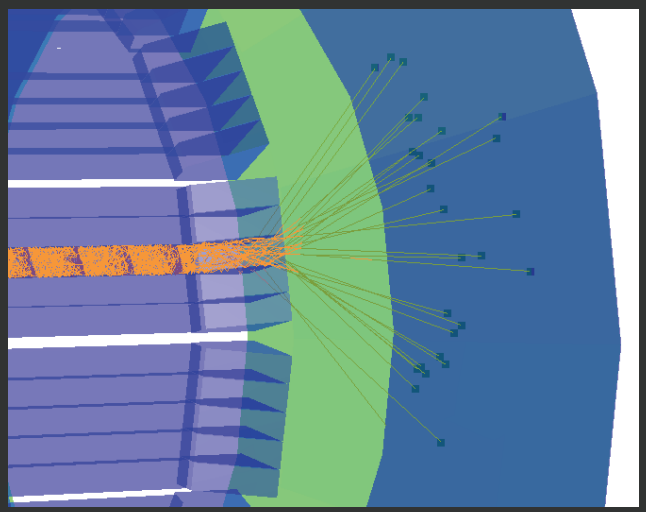
in Geant4 is right,

in Geant3 is not!

- currently not possible to include DIRC geometry as ROOT file, have to use geometry definition in DIRC source code

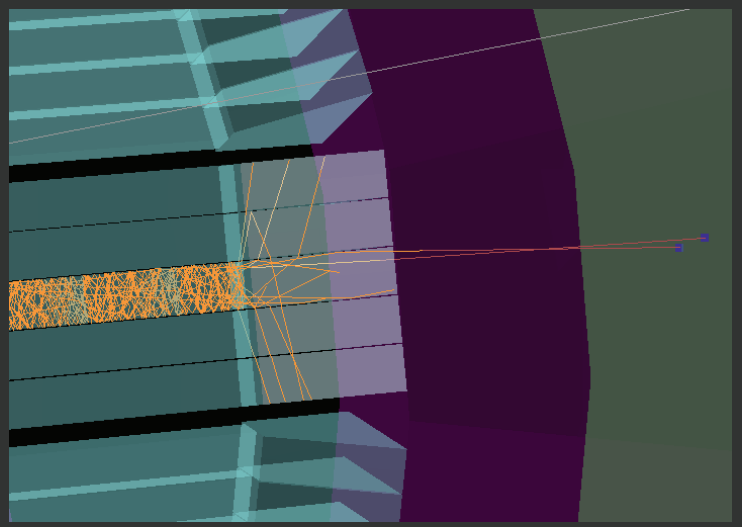
Open technical questions

- Wrong behavior of optical photons within some geometrical objects (TArb8, A+B, A-B…) in Geant 4 using Virtual MonteCarlo (VMC) class:



← Prism (as TArb8 object) in Geant 3

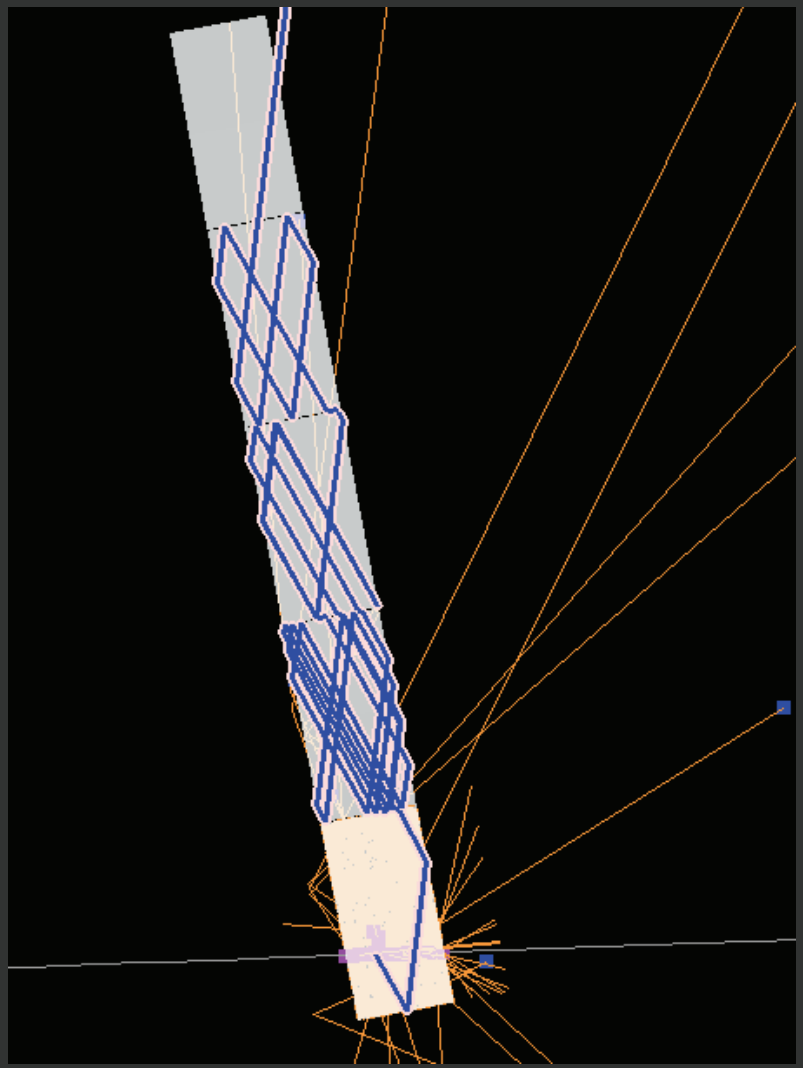
Prism (as TArb8 object) in Geant 4: non-physical photon path, photon loss →



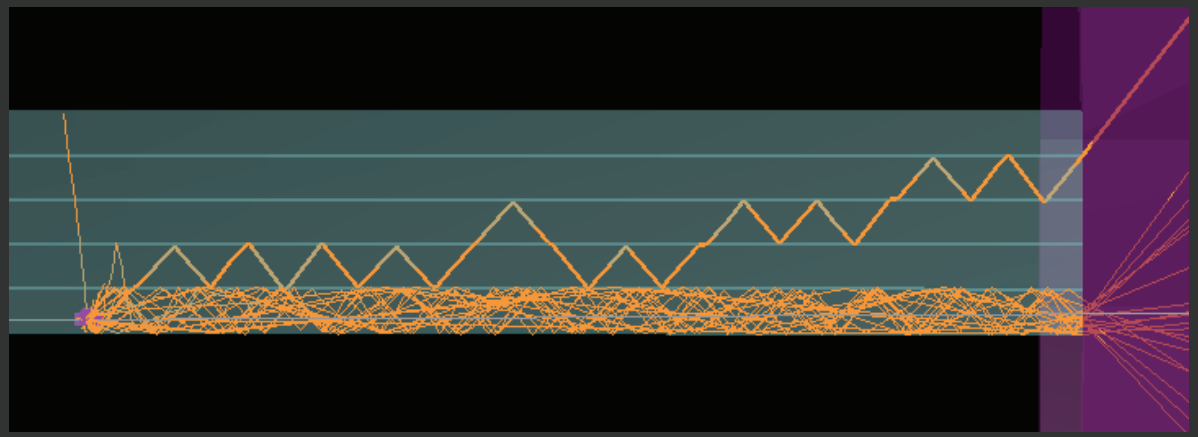
- Time of simulation in Geant 4 is 5-10 times larger than in Geant 3 !

Open technical questions

- Weird behavior of Cherenkov photons during total internal reflections (Geant 4):



bar end view



side view

This problem is solved by introducing optical surfaces around bars!

Summary & Outlook

- Goal - evaluate the performance of different DIRC designs (number of detected photons, single photon resolution)

- First reconstruction attempt using simplified design (no focusing) and lookup tables → obtained resolution is consistent with expectation

- Next: study the detector performance for several design options to choose the best performance and final Barrel DIRC design. Produce performance plots for the TDR.