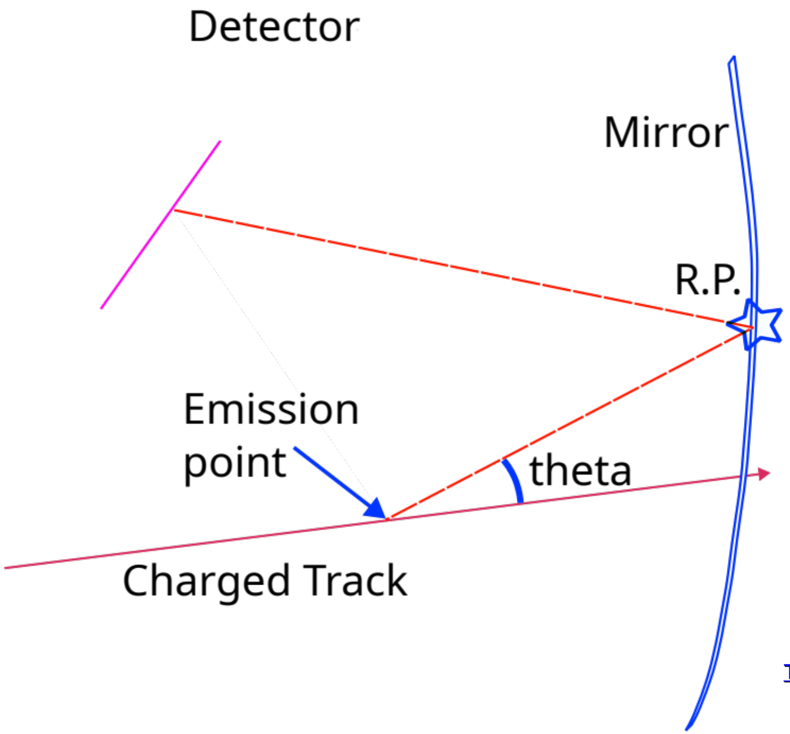
dRICH data-model in ePIC simulation framework

Chandradoy Chatterjee
INFN Trieste

Outline

- dRICH reconstruction algorithm in a nutshell.
- Existing data model
- Foreseen use of additional mc photon info.
- Alignment of dRICH
- Conclusions.

Reconstruction of Cherenkov angle



1. The reconstruction is based on Inverse Ray Tracing (IRT).
2. Unknown/s: Reflection point on the mirror surface, emission point (with some approximation an emission point can be assumed, hence it introduces an uncertainty).
3. Iterative way to estimate the Cherenkov angle (polar angle between Cherenkov photons and track) wrt a fixed origin (beam direction, mirror centre) and detected hit coordinates.

Theory of ring imaging Cherenkov counters; Ypsilantis and Segunoit; NIMA Volume 343, Issue 1, 1 April 1994, Pages 30-51

An example from COMPASS

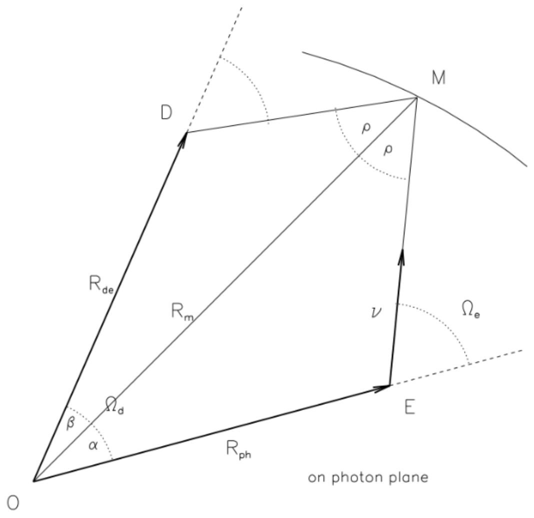


Figure 1: Geometry of the reconstruction.

$$\frac{\sin(\rho+\alpha)}{R_m} = \frac{\sin\rho}{R_{ph}} = \frac{\sin\Omega_e}{R_m}$$

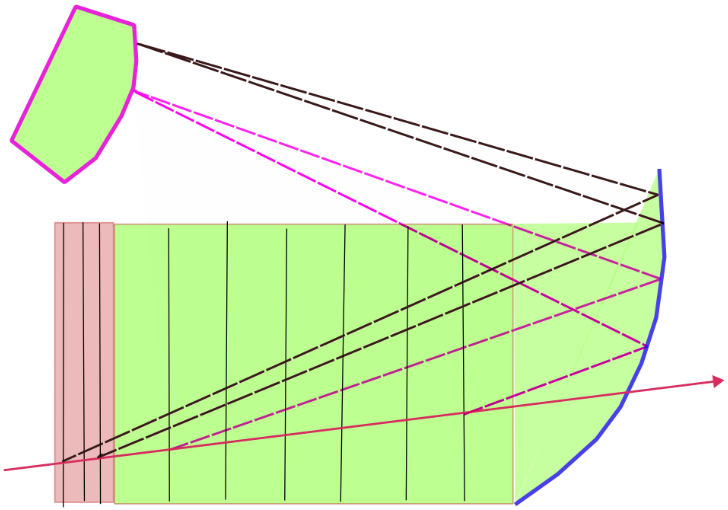
$$\bar{\nu} = \frac{\sin\Omega_e}{\sin\Omega_d}\bar{R}_{de} - \frac{\sin(\Omega_e - \Omega_d)}{\sin\Omega_d}\bar{R}_{ph}$$

Ω_e is computed iteratively.

$$\theta_C = \arccos\left(\frac{\bar{\nu}\cdot\bar{P}}{P}\right)$$

https://agenda.infn.it/event/30966/contributions/167136/attachments/89733/120728/COMPASS_Pattern_Recognition_V2.pdf

Reconstruction of Cherenkov angle dRICH



1. In ePIC dRICH the IRT uses a slightly different concept than COMPASS. Essentially, a generalized implementation what was actually first used by HERMES. Implemented by A.Kiselev during ATHENA proposal time for dRICH and pfRICH together.
2. The origin is considered as the unit-vector along the beam-line (0,0,1).
3. Instead of assuming a single emission point, different slices through the radiator is considered. The emission point can be each of the projected track points. Each emission point provides a Cherenkov angle, an average is passed as the final Cherenkov angle.

Note: IRT v2, completely removes these number of emission points.

What do we need from the data model

- Multiple requirements:
  - Requirement for Cherenkov angle reconstruction.
  - Requirement of Detector Characterization.
  - Requirement for Particle identification.

List of essential variables

Cherenkov angle Reconstruction

- The track information inside the radiator. Track projections come from tracking information.
- The detector and mirror geometry. (Geometry information)
- Digitized hit coordinates.
- Returns Reconstructed polar and azimuthal angle.

Detector Characterization

- Number of Cherenkov photons detected, refractive index, (sim level info) photon energies.
- Cherenkov angles (polar and azimuthal).
- Digitized hit location, sensor ID, sector ID. → Comes from cellID information.
- TDC and ADC information. (Currently not used in the algorithm. But, for noise suppression and hit selection will be used.)
- Radiator hypothesis.
- Not implemented in data model but needed: mc photon path length throughout the radiator and its reflection point in the mirror, and may be reflected track position on the sensor surface.

Particle Identification

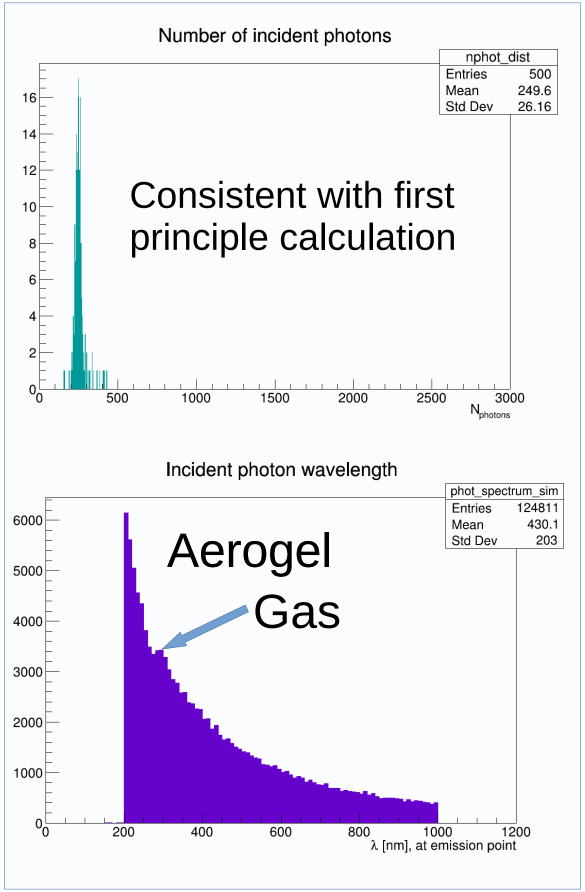
- Currently, our PID technique is not optimal.
- We assign certain weights based on photons matching one hypothesis over the other.
- A likelihood or chi-square based algorithm, may infer a new variable (preferably) of OneToMany kind where un-normalized probabilities for different mass hypothesis are passed for a track.

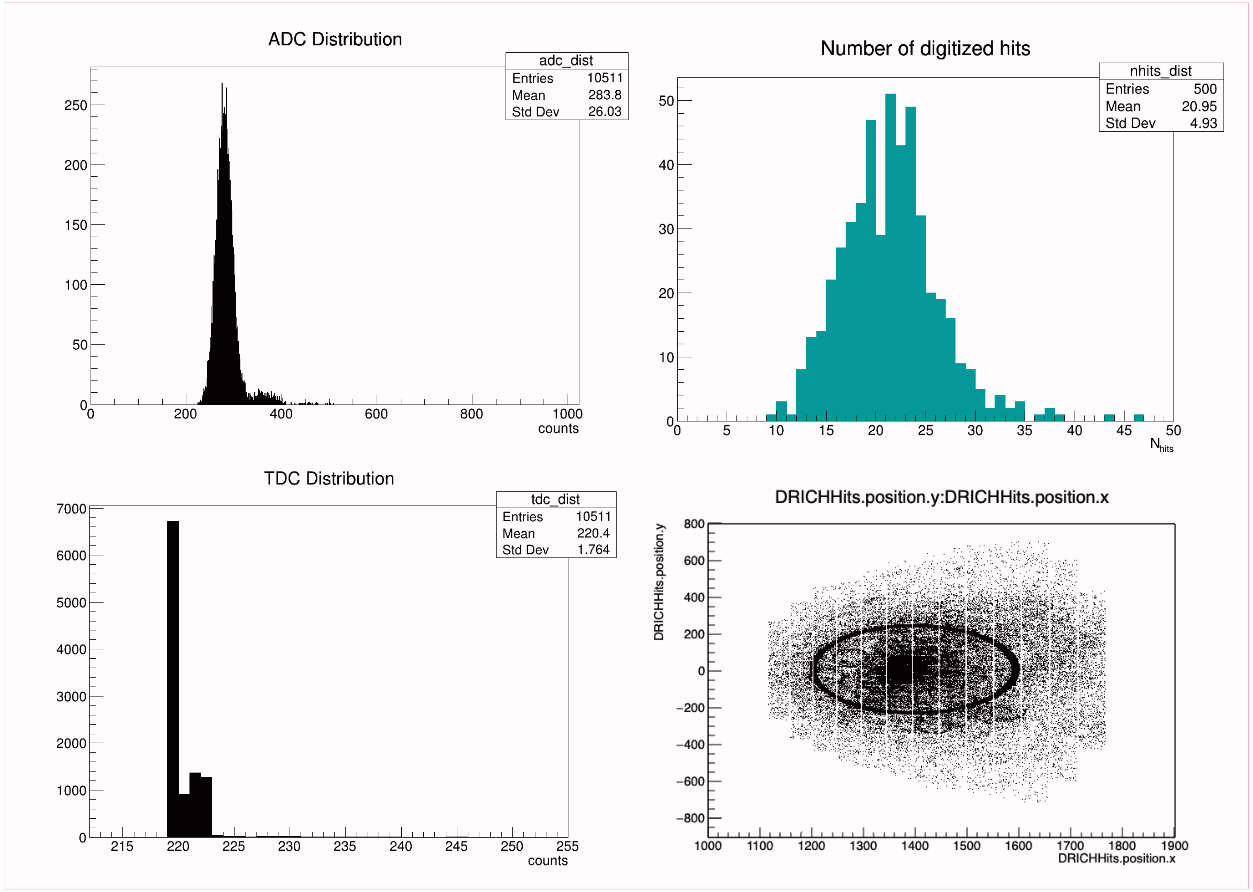
dRICH data model

```
Author: "A. Kiselev, C. Chatterjee, C. Dilks"
Members:
  - float              npe              // Overall photoelectron count
  - float              refractiveIndex   // Average refractive index at the Cherenkov photons' vertices
  - float              photonEnergy      // Average energy for these Cherenkov photons [GeV]
VectorMembers:
  - edm4eic::CherenkovParticleIDHypothesis hypotheses         // Evaluated PDG hypotheses
  - edm4hep::Vector2f                      thetaPhiPhotons    // estimated (theta,phi) for each Cherenkov photon
OneToOneRelations:
  - edm4eic::TrackSegment                  chargedParticle    // reconstructed charged particle
OneToManyRelations:
  - edm4eic::MCRecoTrackerHitAssociation   rawHitAssociations // raw sensor hits, associated with MC hits
```

```
edm4eic::RawTrackerHit:
  Description: "Raw (digitized) tracker hit"
  Author: "W. Armstrong, S. Joosten"
  Members:
    - uint64_t          cellID            // The detector specific (geometrical) cell id.
    - int32_t           charge            // ADC value
    ## @TODO: is charge appropriate here? Needs revisiting.
    - int32_t           timeStamp         // TDC value.
```

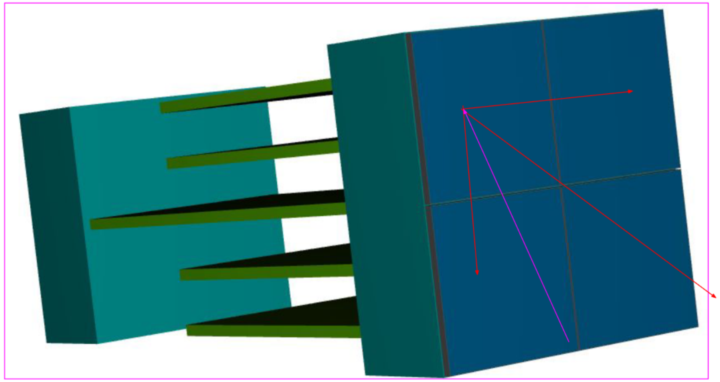
dRICH mc and reco hits

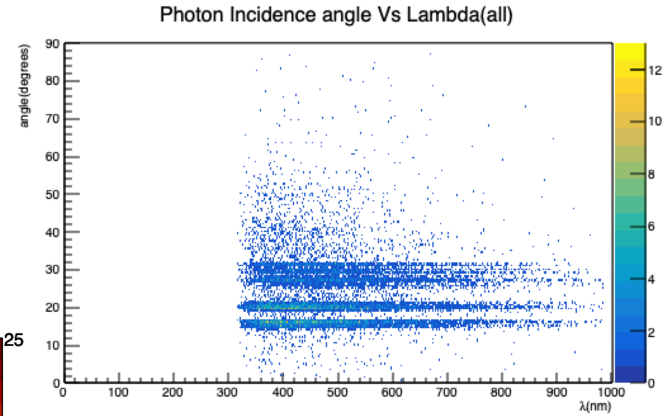


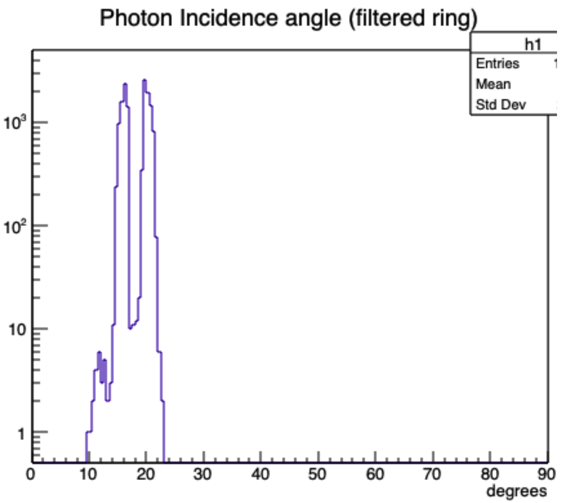


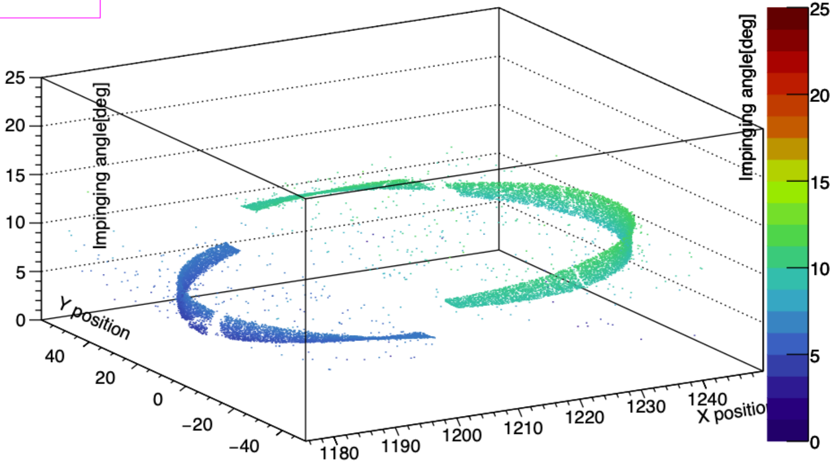
An example of mc and reco mixed analysis

Definition of the sensor surface normal

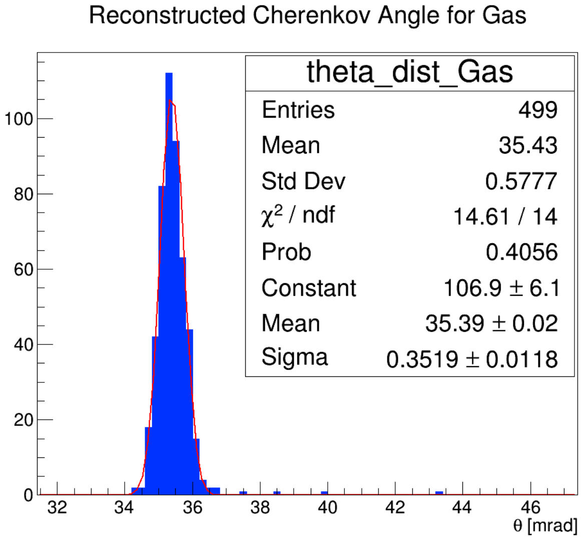


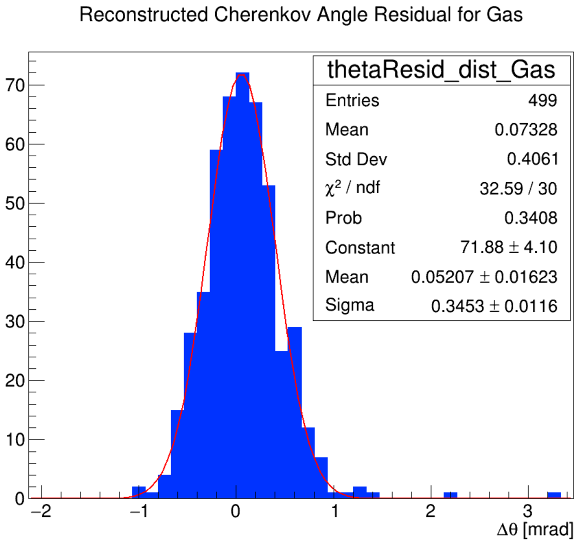


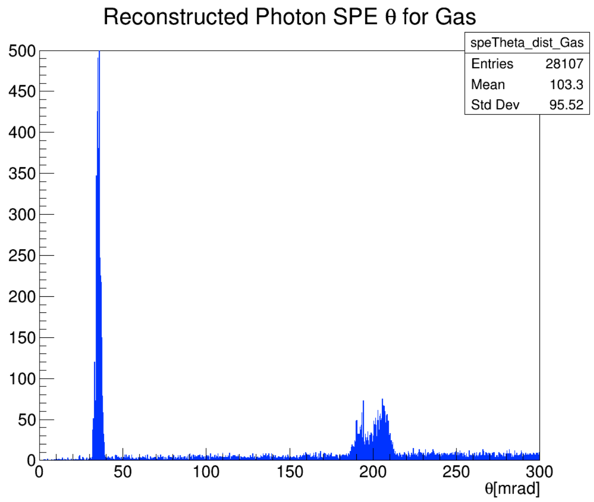


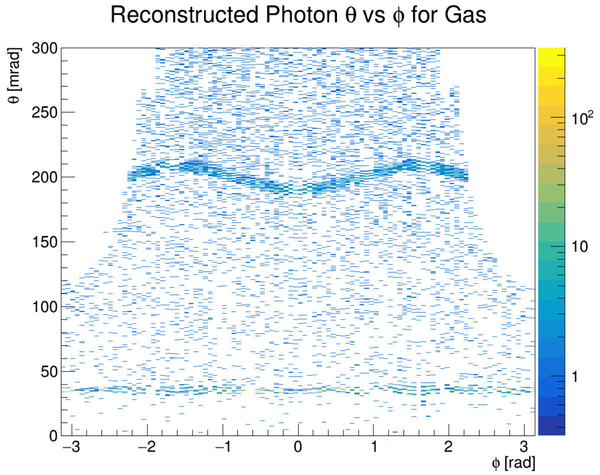


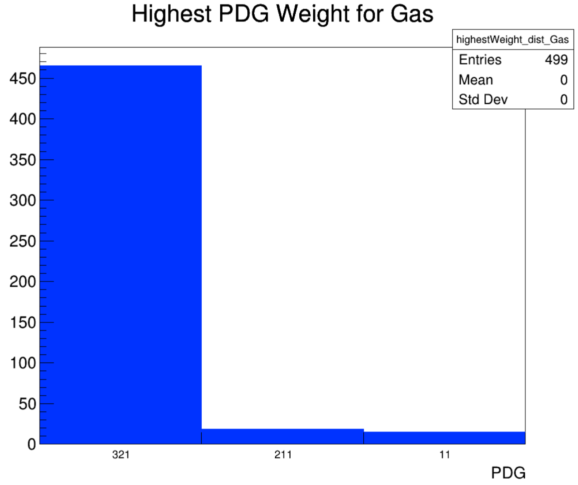
dRICH reconstructed angle and PID







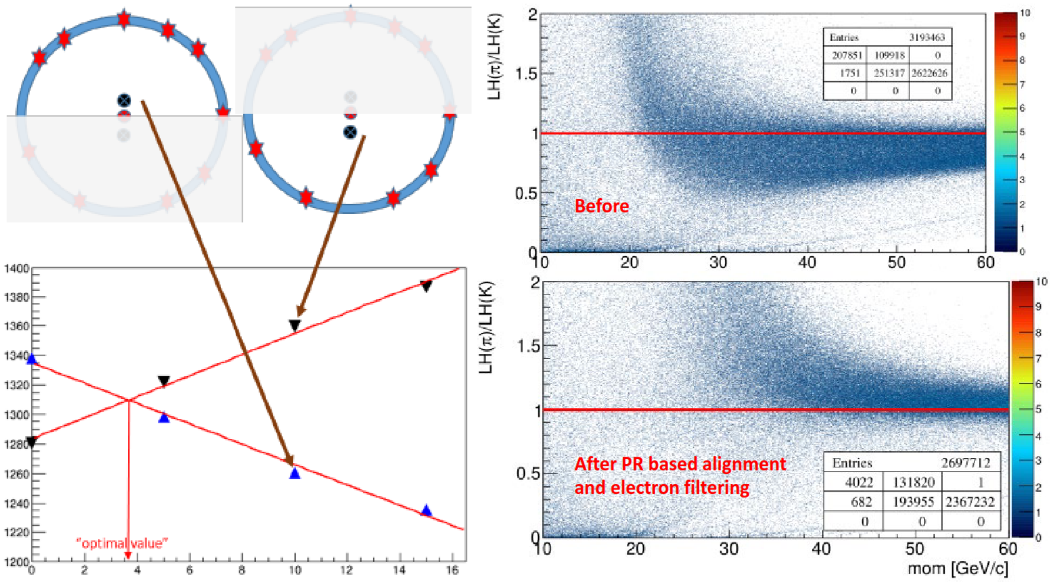




Single 30 GeV kaon at eta 2.5
We have injected some noise.

RICH Alignment (a COMPASS Example)

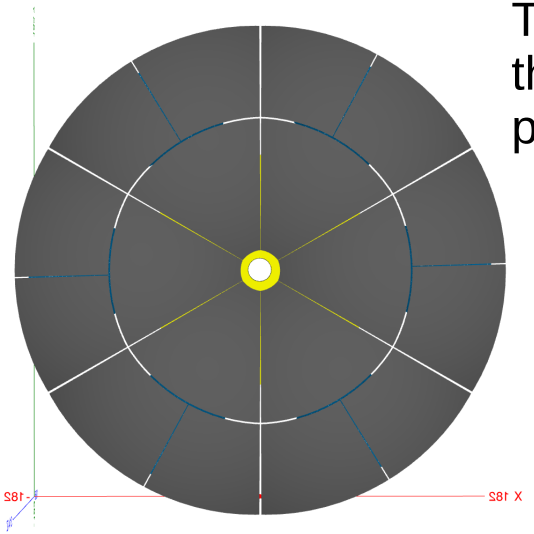
PR to tune the PID performance: example of 2016 COMPASS data II



Importance of track reflection point by mirror on sensor surface:

1. It gives back the centre of the ring.
2. Allows to open window to pick relevant photons in interesting region.
3. Debugging and alignment of RICH.

Information related to photon path



The reflection point of the photons in different segments of the mirror (possibly with slightly different radii) will allow to perform individual mirror piece alignment.

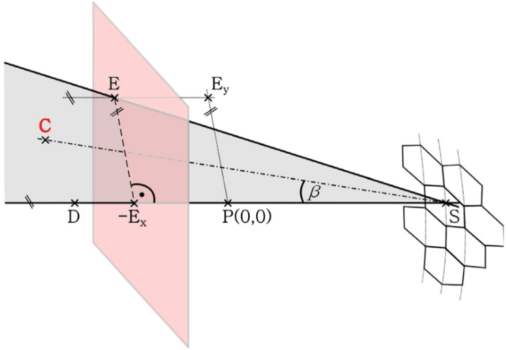
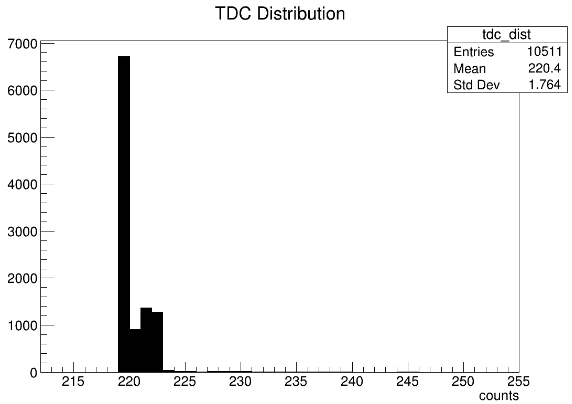


Fig. 1. Determination of mirror orientation – 3D scheme of the geometry used in the algorithm for the absolute measurements of mirrors misalignments. *P* is the principal point of CLAM camera, *E* is point of the retroreflective rectangular grid and *D* is the image of the point *E* on the camera sensor, *S* stands for the reflection point on the mirror surface and *C* for the centre of curvature of the mirror.

Real life example of COMPASS CLAM system



Time of flight of photon based on travelled path can be used to have an idea on the time cut to reduce noisy hits.

Conclusions

- We are using almost all the exiting candidates of our data model. The ADC and TDC information related to the hits are currently not used. But, will be used in future.
- Our current data model suffices most of the detector characterization, preparation of the look-up table.
- We can imagine to extract some more information (some of them are possibly not existing in the DM) to optimize, monitor the dRICH geometrical, optical and read-out aspects. This may need to add (if not already extractable) few more information related to the mc photons, its path length and its reflection planes. Can we imagine to have switches to turn on specific data model for detector related studies?
- We also imagine the current reconstruction algorithm will be upgraded (with possibility of more than one reconstruction algorithm) and would require to have redefinition of the existing data model. But, this is iterative and at this point not fully decided.
- There is an existing reconstruction synergy of dRICH and pfRICH, this overlap will somewhat affect us.