Status of PID/Tracking Requirements

Thomas Ullrich

ePIC Collaboration Meeting, ANL

January 11, 2024

BROOKHAVEN NATIONAL LABORATORY

Reminder: CD-3A Review

Charge Question to be Addressed:

1. Is the project team effectively executing the work? Are technical issues appropriately and proactively being addressed?
2. Are R&D and design efforts yielding sufficiently advanced designs and mitigating technical risks, particularly in strong hadron cooling? Are the proposed CD-3A long-lead procurements appropriate and do they support project risk mitigation? Have the proposed CD-3A long-lead procurements attained final design?
3. Is the project making adequate progress developing the performance baseline? Is the project scope defined well and logically? Are the schedule and cost estimates credible? Do plans include adequate scope, schedule, and cost contingency? Are estimates for the proposed CD-3A long-lead procurements appropriate? Can these procurements be tracked properly?
4. Are ES&H and QA properly addressed given the project's current stage of development?
5. Is the project being properly managed? Are risks being effectively managed? Is a management team in place to successfully execute the project including the CD-3A scope? Are roles and responsibilities documented and understood?
6. **Has the project satisfactorily addressed recommendations from previous reviews?**
7. Is the project ready for CD-3A approval?

Recent PID Review

Electron-Ion Collider

Incremental Design and Safety Review of the Particle Identification Detectors

July 20, 2023

Performed Remotely at Jefferson Lab

Newport News, Virginia

July 5-6, 2023

Committee Report (close-out):

"*Recent progress has been made in ePIC's cross-cutting PID WG to understand tracking requirements for PID detectors. Requirements documents should capture the bi-directional interface between tracking and PID detectors: e.g., translation between extrapolated track impact point and angle resolution requirements for PID detectors. It could be evaluated where the PID subdetectors can contribute to improving the tracking performance and how in the reconstruction algorithms this could be integrated.*"

So in short, provide a document that provides:

(1) Requirement on tracking precision from PID detectors

(2) Outline what the PID detectors can do for tracking

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Follow up

- Meeting to agree on definition of angular resolution May 2023
- First meeting of PID during the Warsaw meeting in July 2023
  - Devise plan towards a requirement document
  - TU agreed to be editor
  - DCSs agreed to provide necessary input
  - Finish document in 2023

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this was then …

Status of Requirement Document

Requirements on the bi-directional interface between tracking and particle identification detectors

October 30, 2023

Draft 1.0

PID and Tracking Working Group

Draft exists but key sections are missing

- sections marked by green boxes exist (doesn't mean they are perfect)
- rest missing

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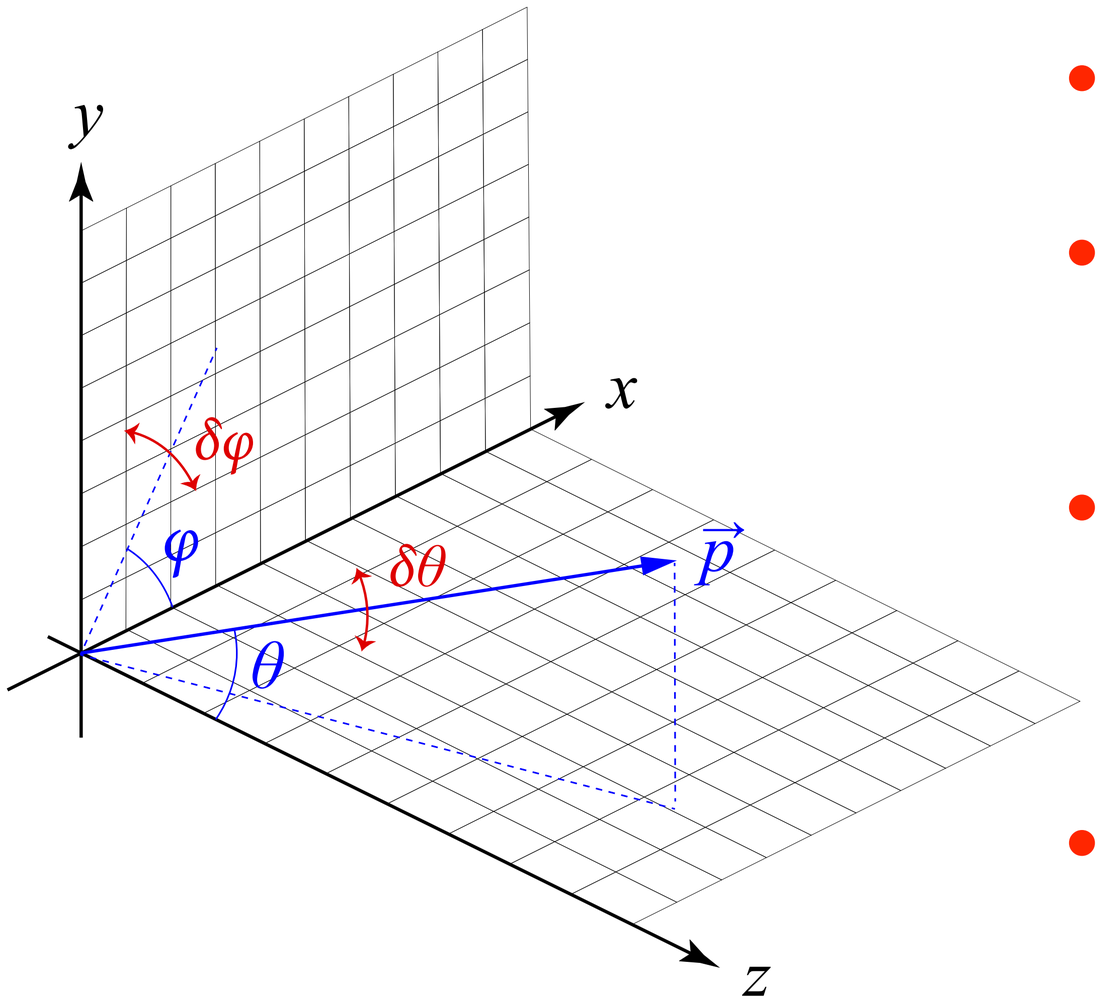
Hope is that this session helps to motivate the effort (incl. editor)

Reminder: Angular Resolution Definitions (I)

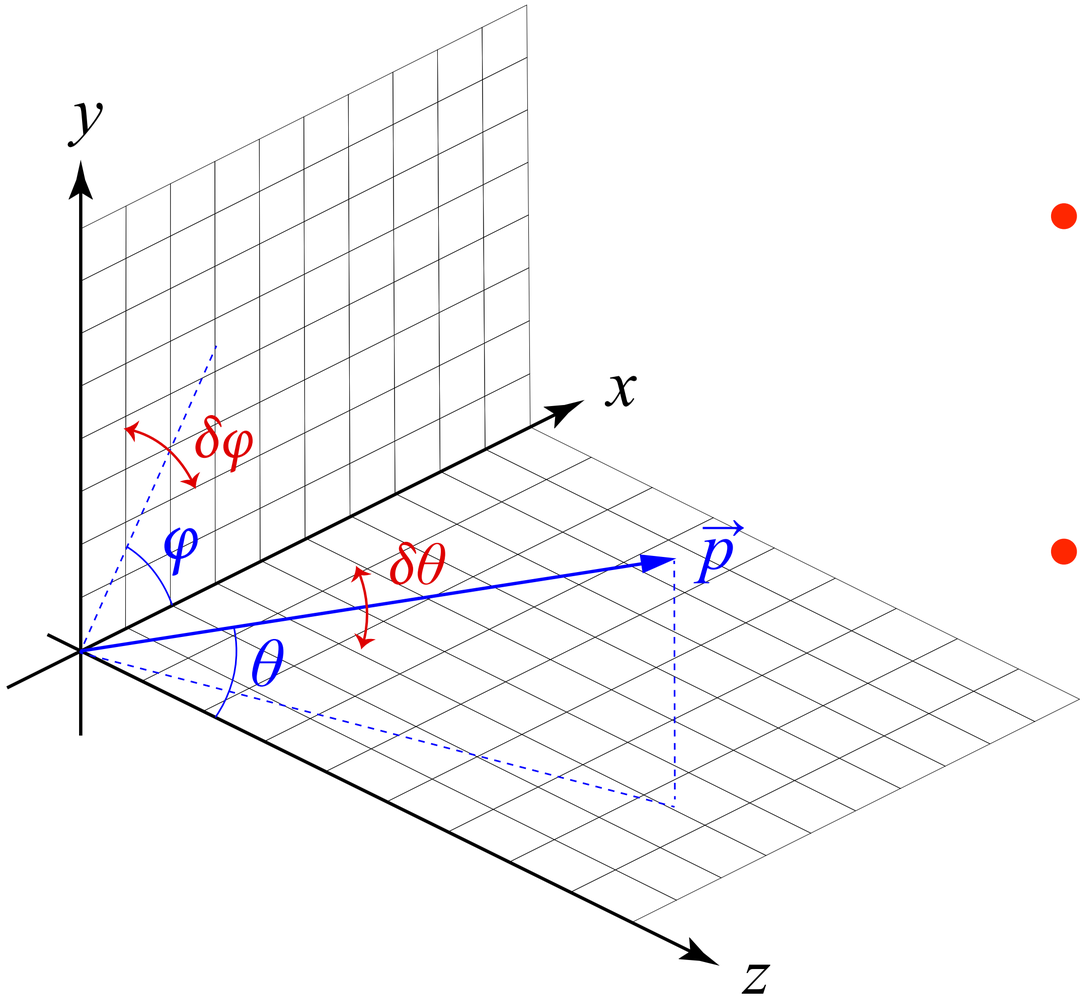
Tracking:



- Based on cylindrical coordinate system
- Angular resolution reported is with respect to this system.
- System is the most natural for tracking purposes but usefulness for PID detectors varies.
- It was decided that ePIC will not impose a single definition on all systems but will allow definitions of angular resolution specific to the different PID systems.
- Converting from one system to the other is in all cases rather trivial.

Reminder: Angular Resolution Definitions (II)

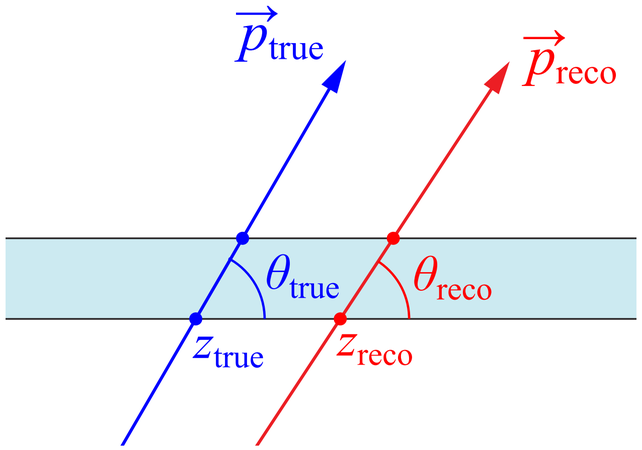
ToF:



- Based on AC-LGAD sensors arranged in a cylinder in the barrel and on a disk in the forward region.
- While their main purpose is to provide time-of-flight information for low-p PID, due to its high granularity it also serves as tracking detector.
- Consequently, the ToF system uses the same definition of angular resolution as the tracking system described above.

Reminder: Angular Resolution Definitions (III)

hpDIRC:



- Key variables to access matching between tracking and hpDIRC in the lab coordinate system are:
  - $\Delta\theta = \theta_{\text{reco}} - \theta_{\text{true}}$
  - $\Delta\varphi = \varphi_{\text{reco}} - \varphi_{\text{true}}$
  - $\Delta z = z_{\text{reco}} - z_{\text{true}}$
- hpDIRC hit pattern is **not** a ring, making it much more difficult to reliably fit a ring center.
- Makes the hpDIRC more sensitivity to angular tracking resolution of the tracking system that enters the Cherenkov angle resolution per particle as a correlated term:

$$\sigma^2_{\theta_{\text{C,particle}}} = \sigma^2_{\theta_{\text{C,photon}}} / N_\gamma + \sigma^2_{\text{correlated}}$$

Cherenkov angle resolution per particle

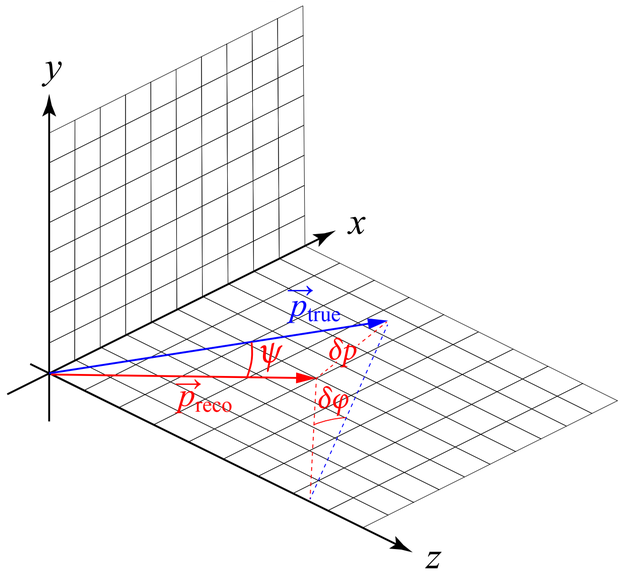
Cherenkov angle resolution per photon

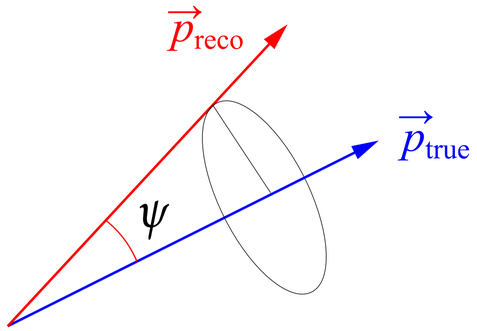
# of detected photons per particle

Contributions from tracking and multiple scattering

Reminder: Angular Resolution Definitions (IV)

dRICH/pfRICH:





$$\cos\psi = \frac{\vec{p}_{\text{true}} \cdot \vec{p}_{\text{reco}}}{|\vec{p}_{\text{true}}||\vec{p}_{\text{reco}}|}$$

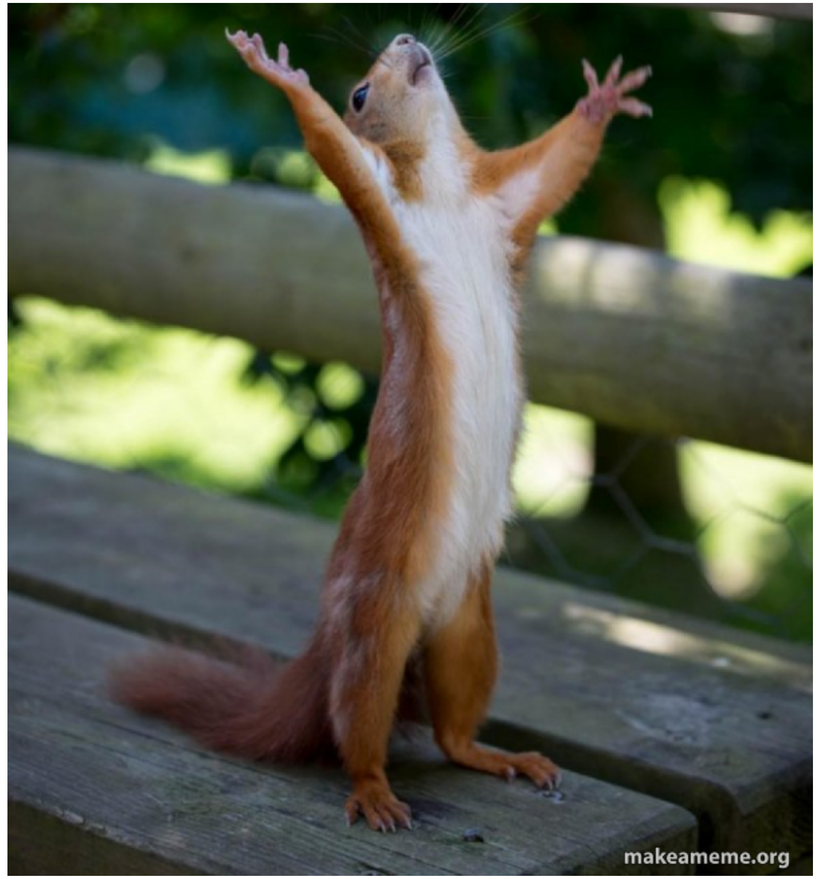
- For RICH detectors we measure the angle between the Cherenkov photon and the reconstructed track.
- The angular tracking divergence, which is now defined as the angular difference, ψ, between the reconstructed and the actual track momentum, contributes to the Cherenkov angle uncertainty.
- Tracking angular divergence, $\delta\psi \approx \delta\vec{p}/|\vec{p}|$, is different from the azimuthal angular error in the lab cylindrical coordinate system, $\delta\phi \approx \delta\vec{p}/|\vec{p_T}|$.
- Difference is $\delta\psi \approx \delta\phi \sin\theta$, which is a factor of 10 difference at a pseudorapidity of $\eta \approx 3$
- Such an effect is minimal for the polar angular component.

What can the PID detectors do for tracking?

Arguments will be a bit more general and likely w/o much support from our main simulation stream. This needs discussion and brainstorming.

- Knowing the ID of a particle allows an improved refit of the track (Kalman filter) with better MS knowledge and possible improved p resolution.
- Integration time of tracker (Si) is around 2-3 microsec. That means that there is the possibility of fake/distorted tracks that can be eliminated with solid timing information from ToF.
  - Putting a hard number (say N% improvements in purity) is tough given our current reconstruction. Need only basic ideas. These could be back on the envelope calculation on what timing is need to avoid pile-up tracks. ToF resolution probably far better than anything needed. Likely the MPGDs will already do.
- Questions
  - What if PID detectors detect a potential track that was not found in the tracker?
    - Use this info to improve pattern recognition in tracker?
  - Lots of idea that imply iterative procedures. Is it worth it?

Thank you for your attention



Next:
Input & thoughts from DCS on angular resolution requirements