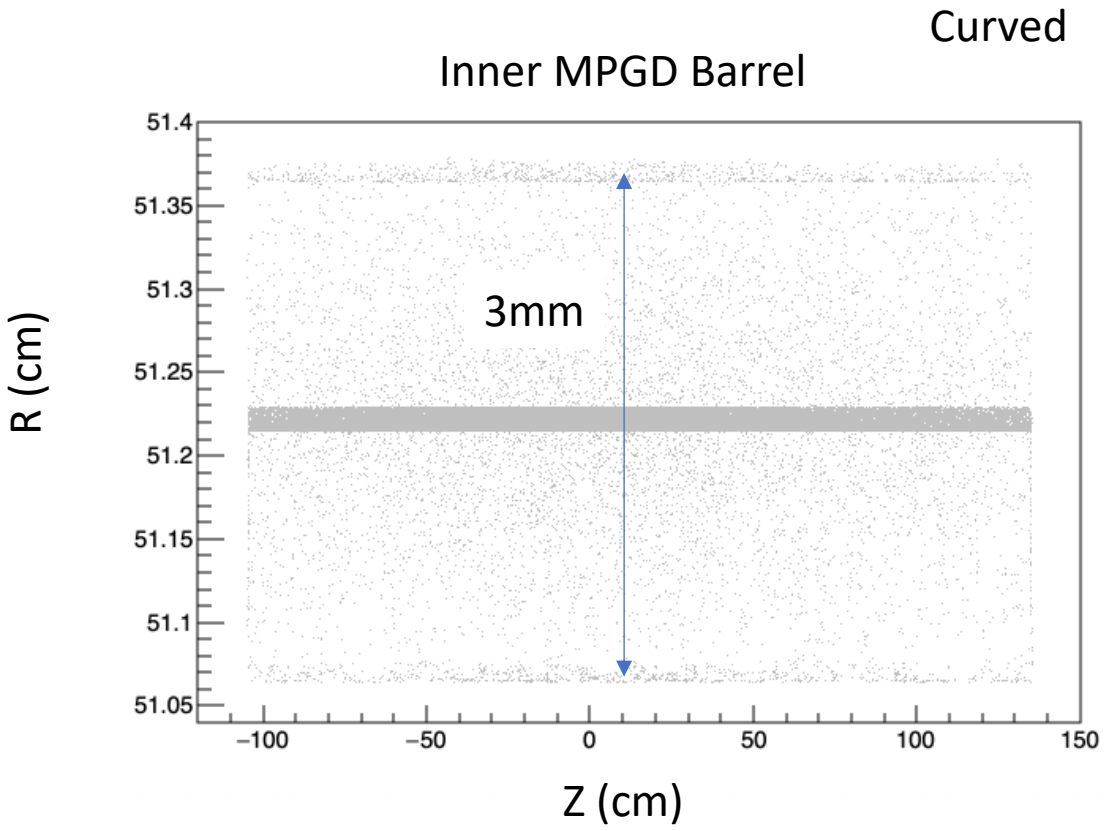
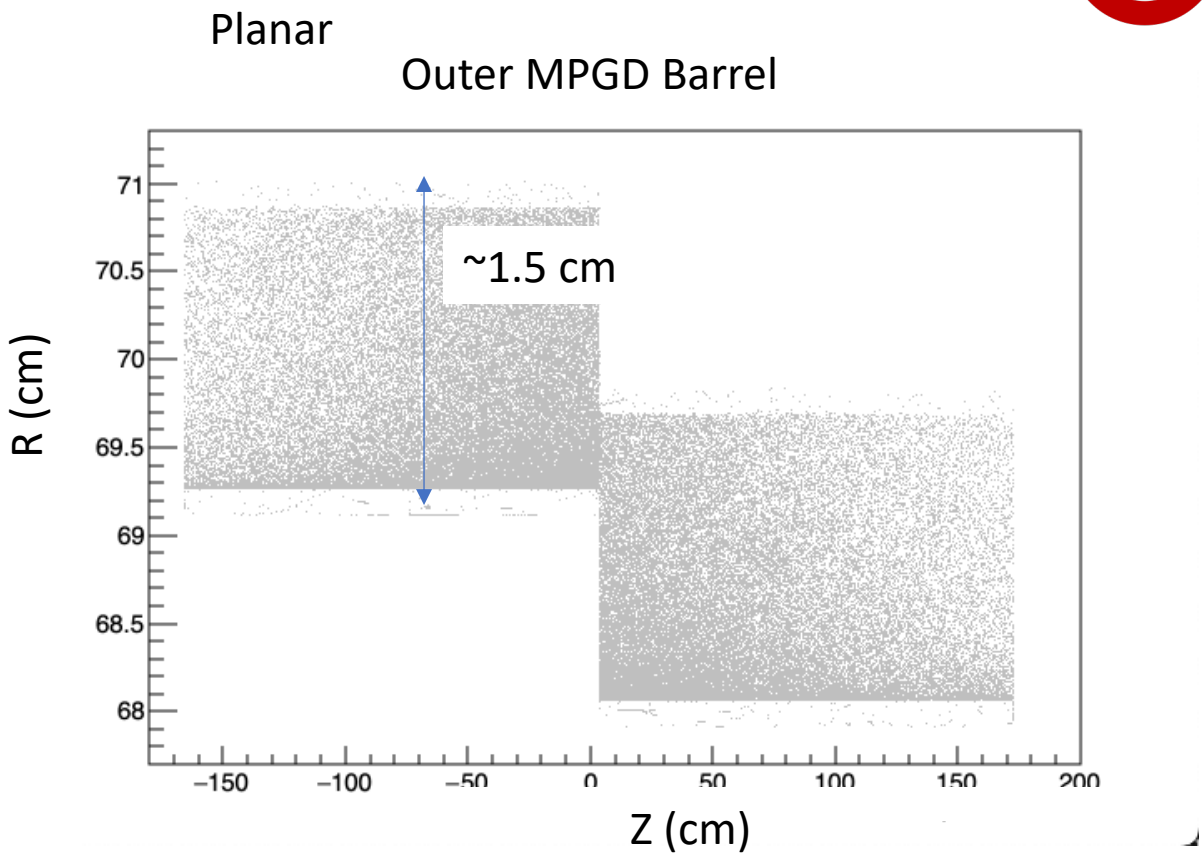
No Found Bug

- MPGDs have a 3mm drift gap that is set to be the sensitive volume
  - ~~Outer MPGD Barrel seems to have a sensitive thickness of ~1.5cm.~~ → Outer MPGD is planar and here I show R



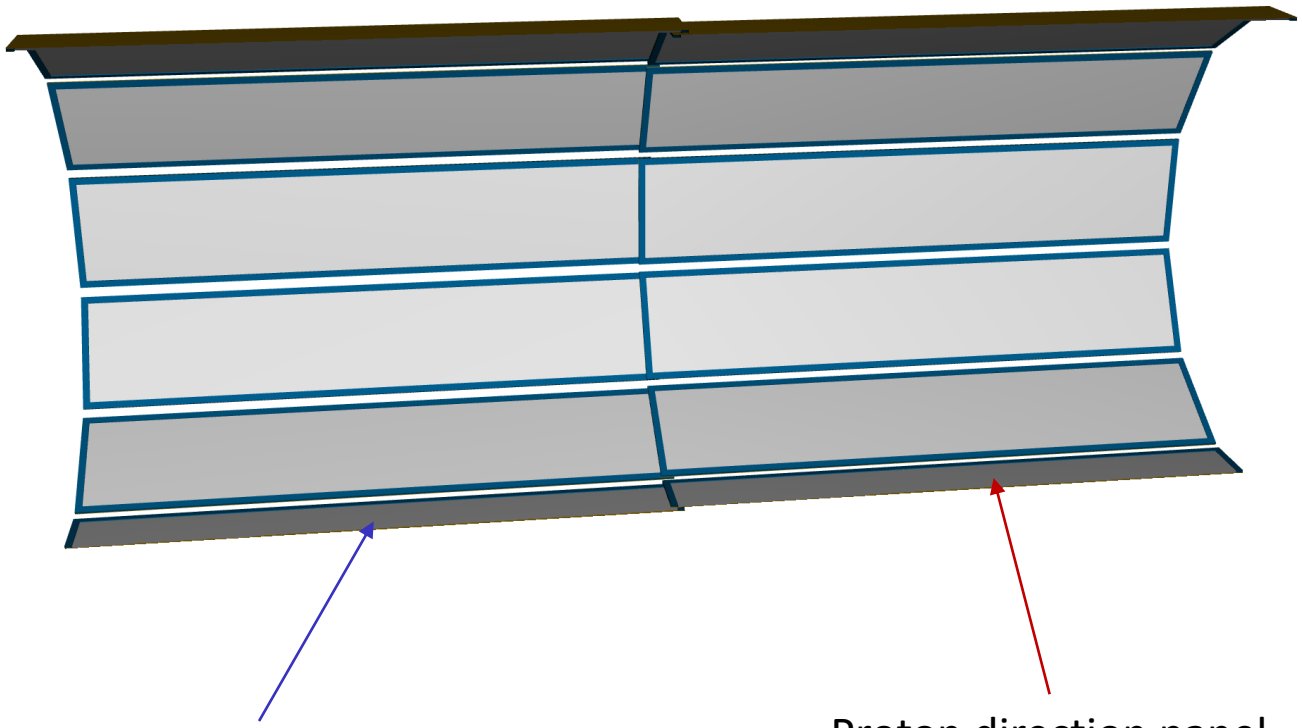


No Found Bug

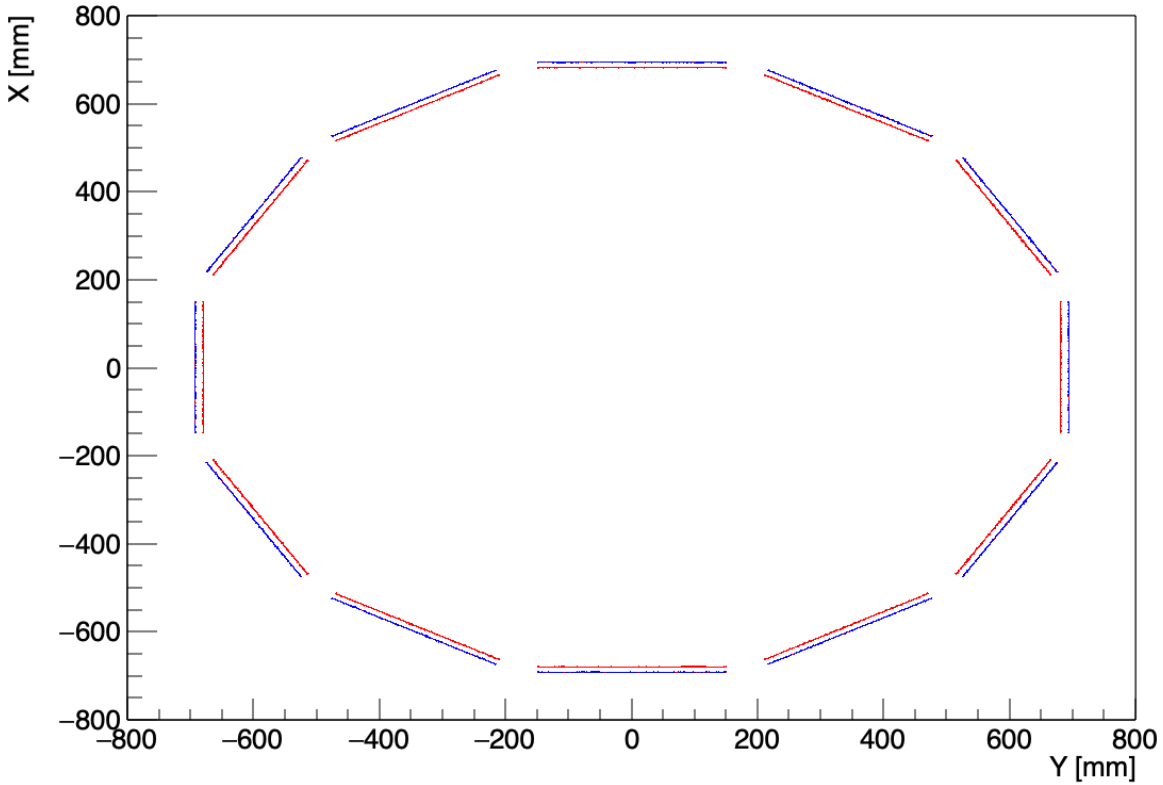
- MPGDs have a 3mm drift gap that is set to be the sensitive volume

Electron direction panel

proton direction panel



Outer MPGD Barrel

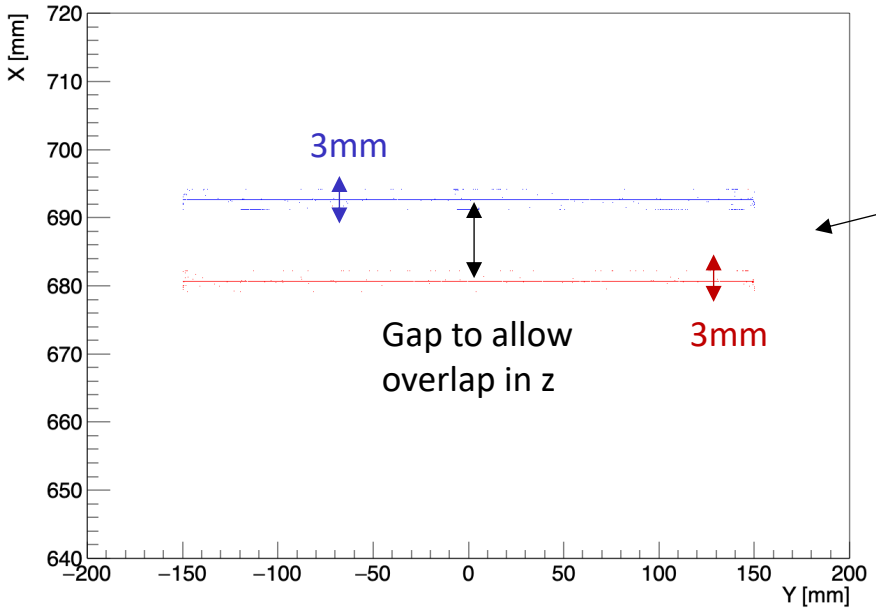


No Found Bug

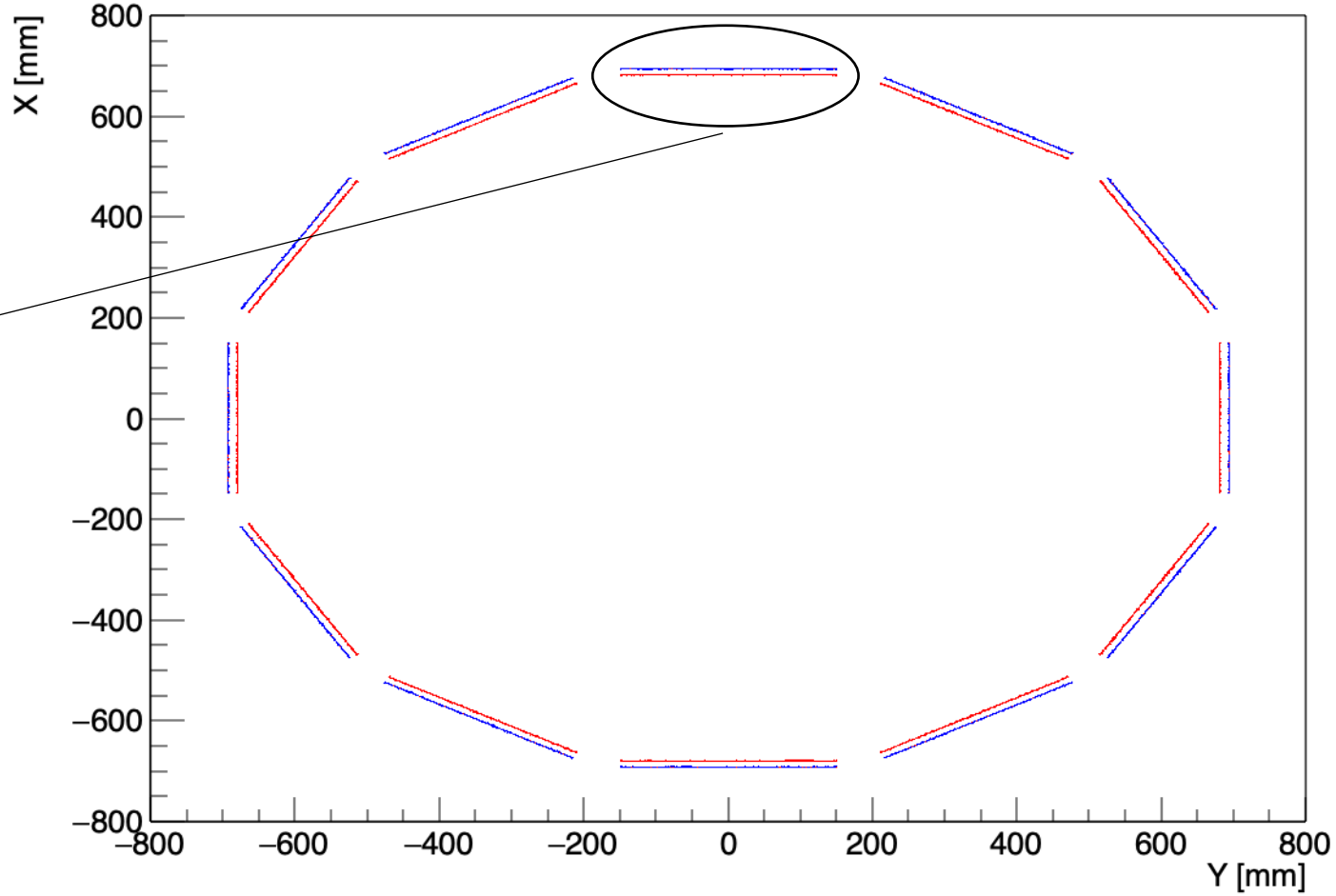
- MPGDs have a 3mm drift gap that is set to be the sensitive volume

Electron direction panel

proton direction panel



Outer MPGD Barrel



No Found Bug

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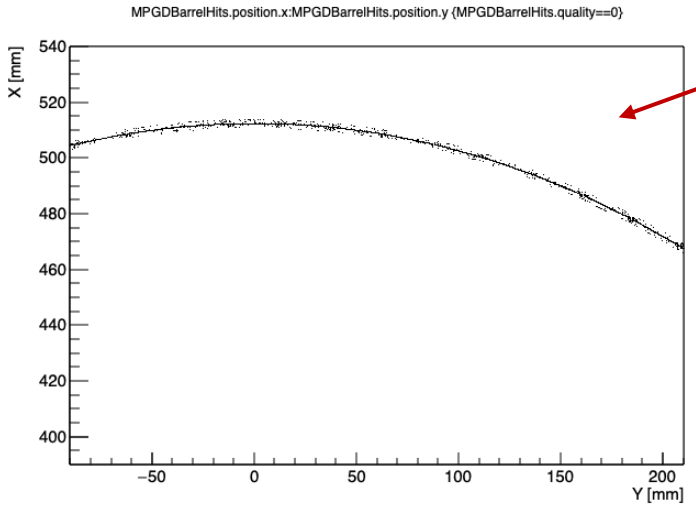
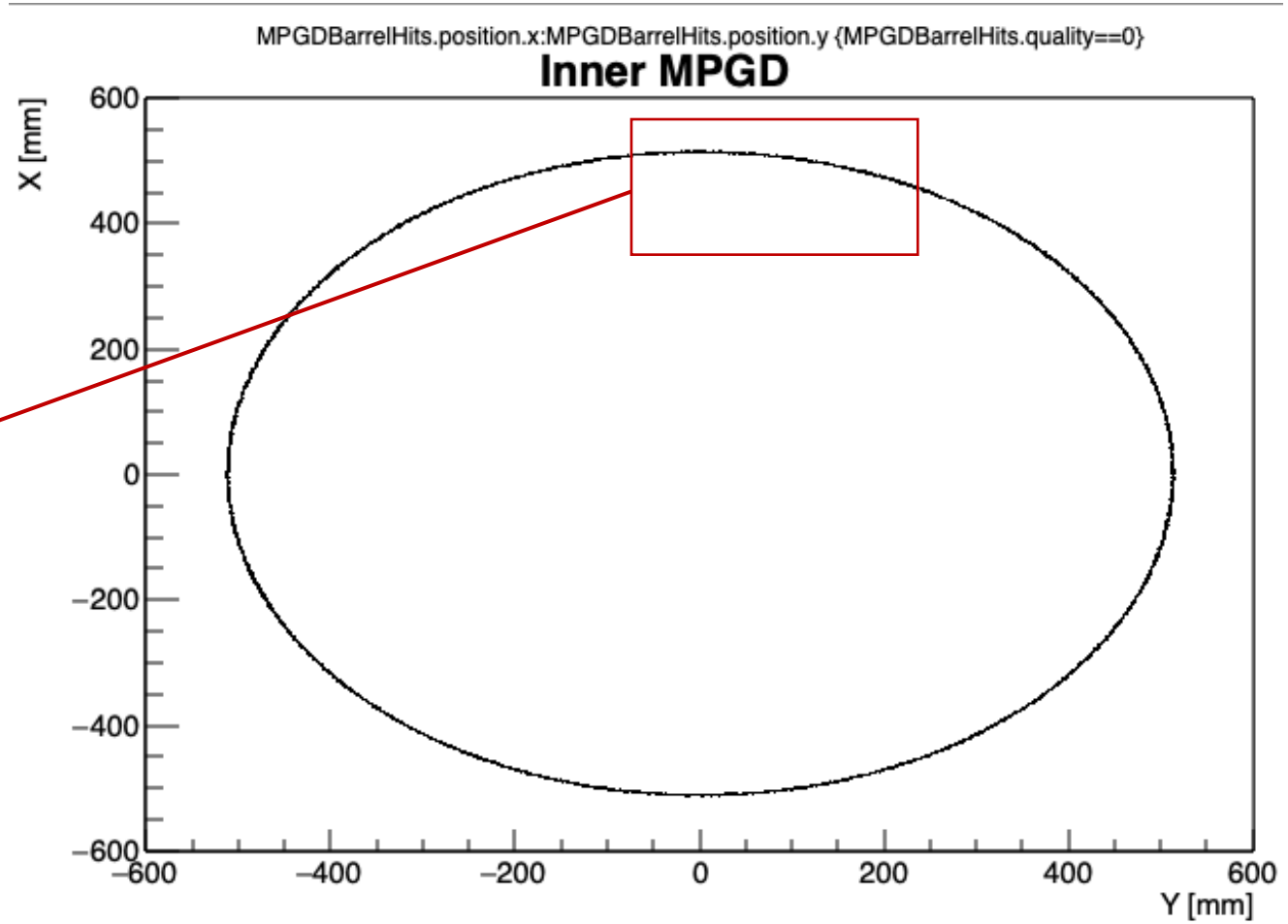


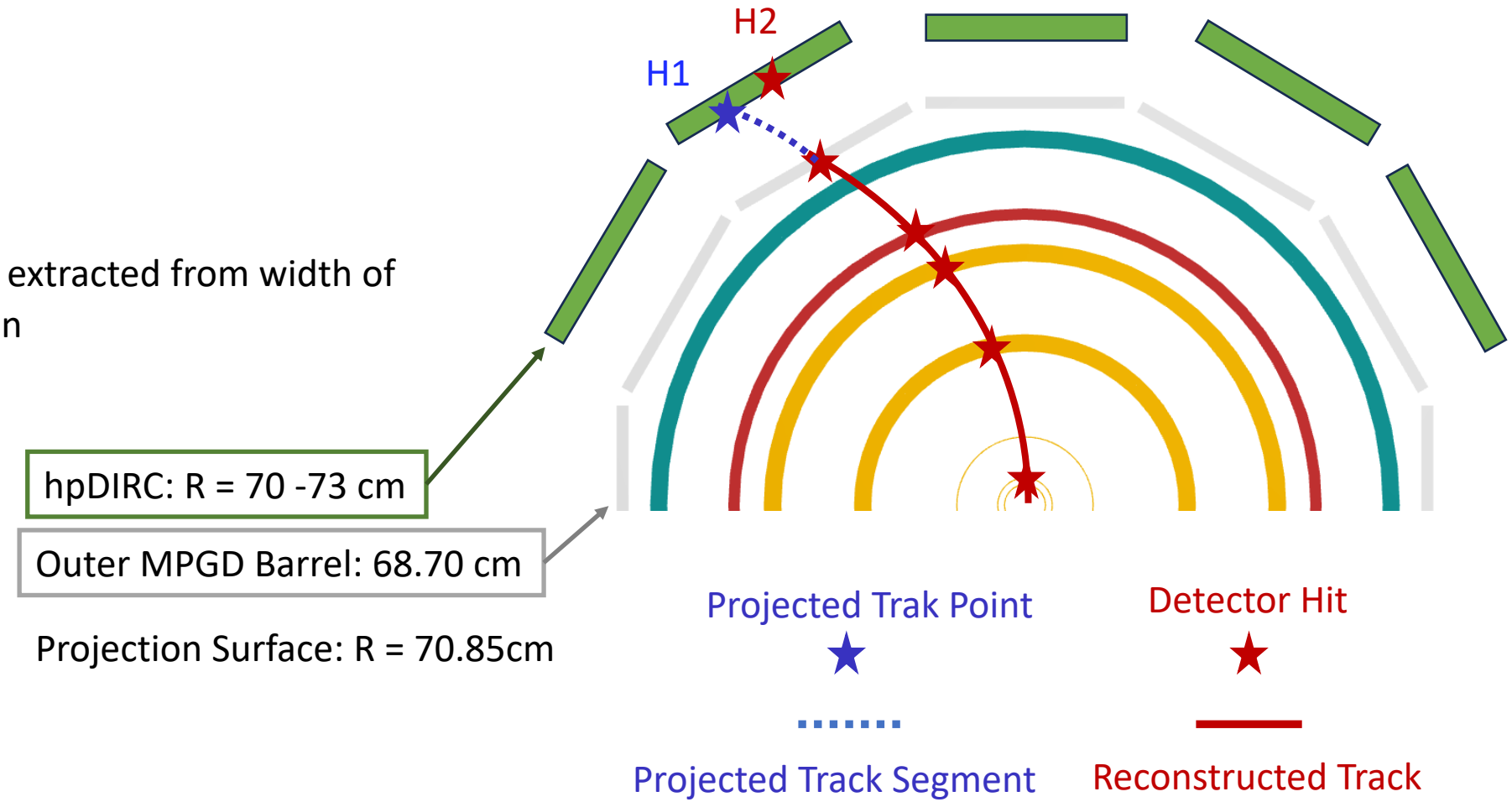


Angular Resolution Definition

- Use position projected point vectors of projected track point (H1) and **nearest** DIRC hit (H2) to obtain angles:
  - Projected Point (x,y,z) hits → θ_{proj} , ϕ_{proj}
  - DIRC Point (x,y,z) hits → θ_{dirc} , ϕ_{dirc}

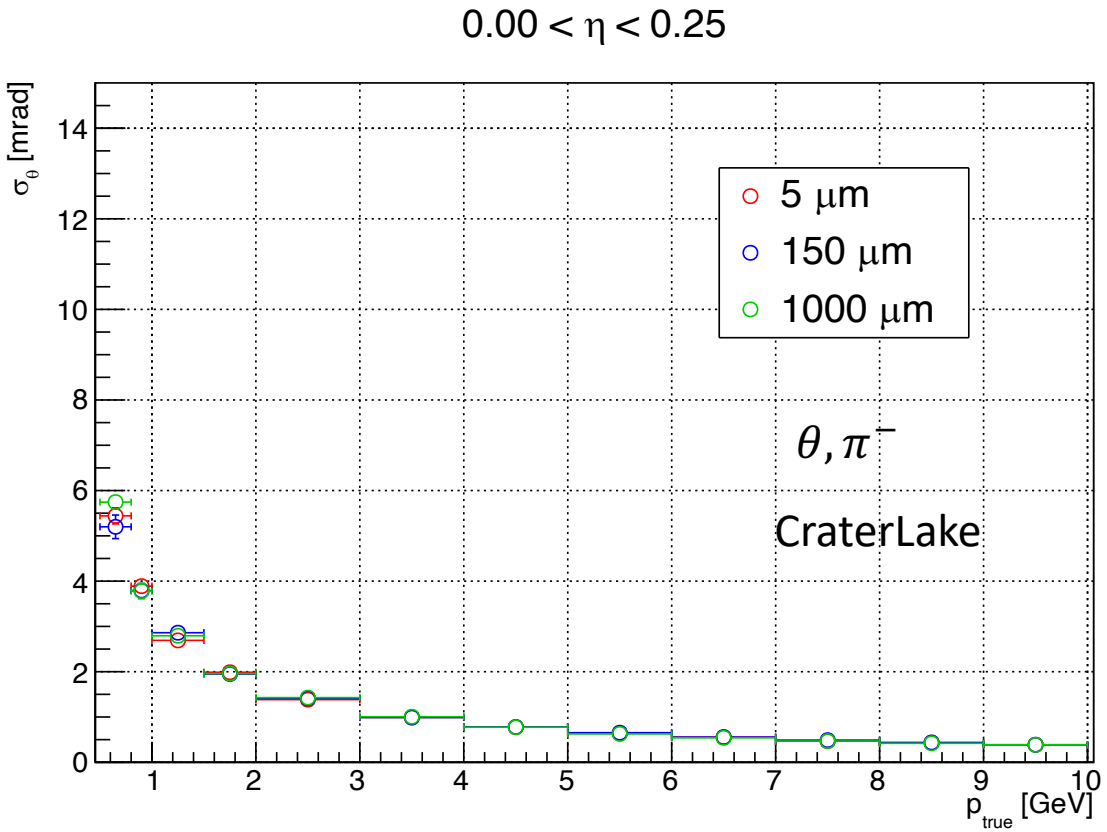
- Angular differences are:
  - $\theta_{proj} - \theta_{dirc}$
  - $\phi_{proj} - \phi_{dirc}$

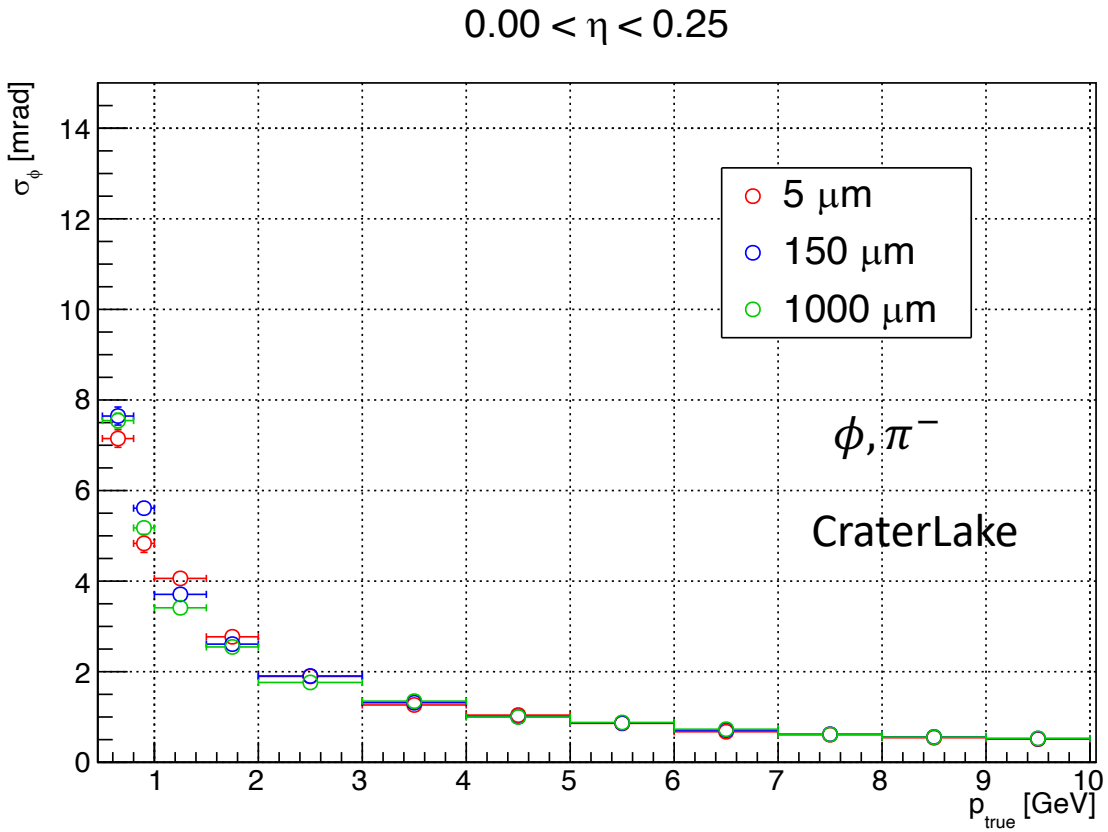
- Angular resolution $\sigma_\theta, \sigma_\phi$ are extracted from width of assumed Gaussian distribution



Angular Resolution

- Vary outer MPGD barrel resolution
  - **No significant dependance seen on outer barrel MPGD resolution**





Angular Resolution

- Vary outer MPGD barrel resolution
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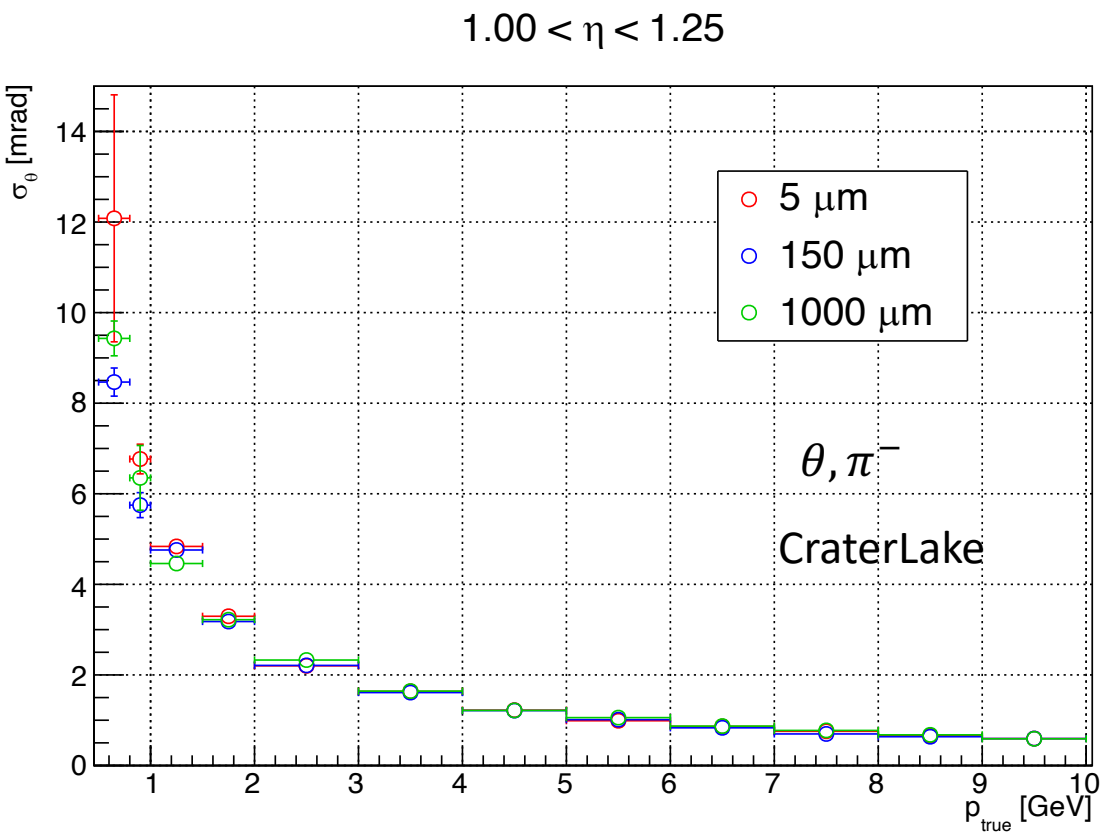
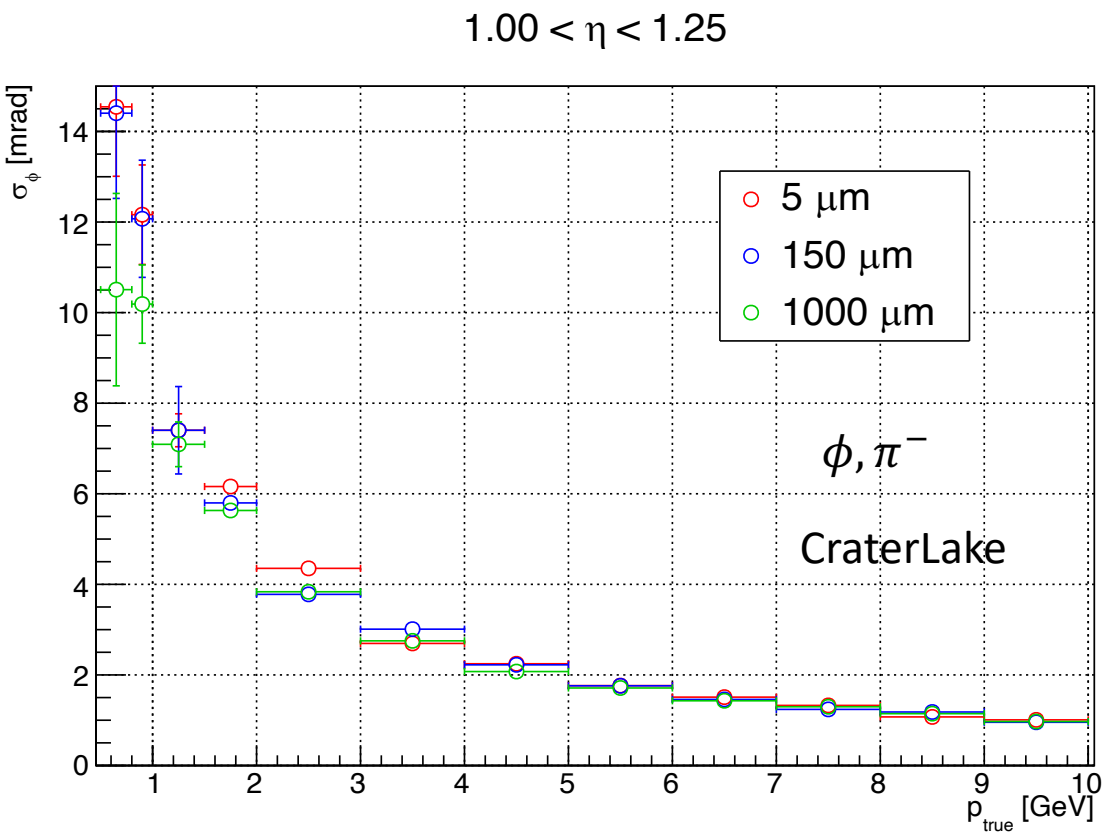
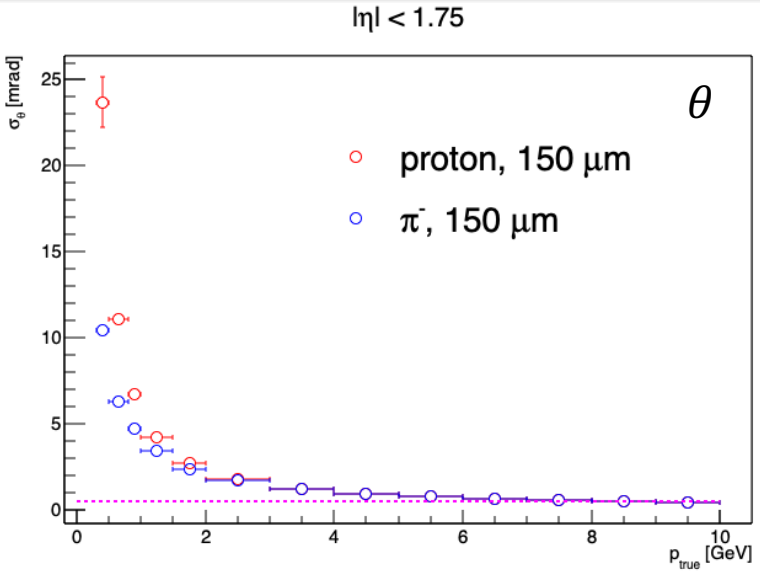
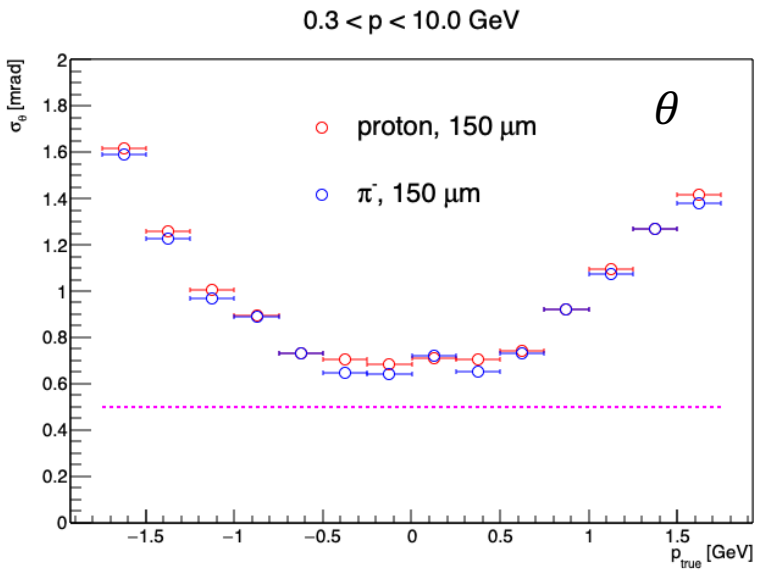


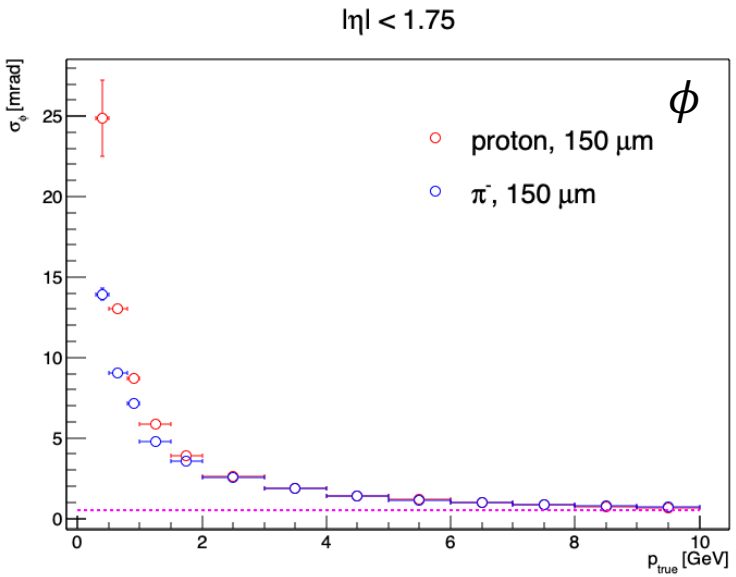


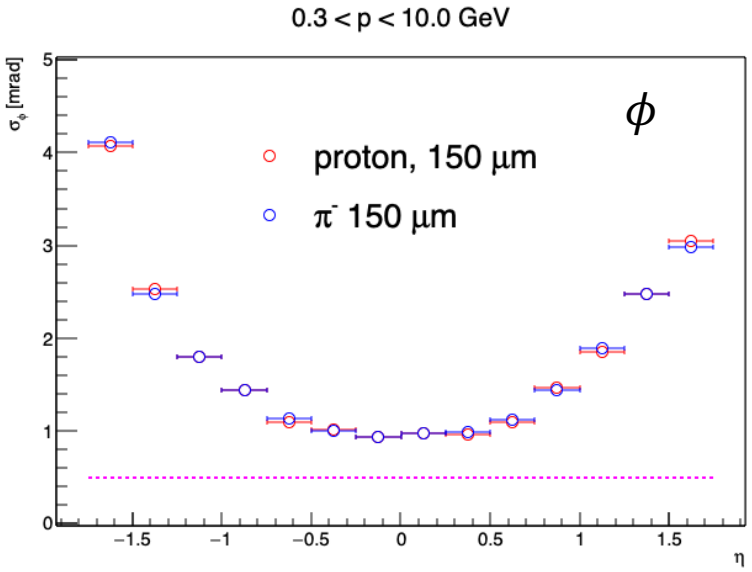
Angular Resolution: Proton vs. Pion

- **Resolutions with protons worse than with pions (π^-)**
  - mainly at low momentum (< 2 GeV)



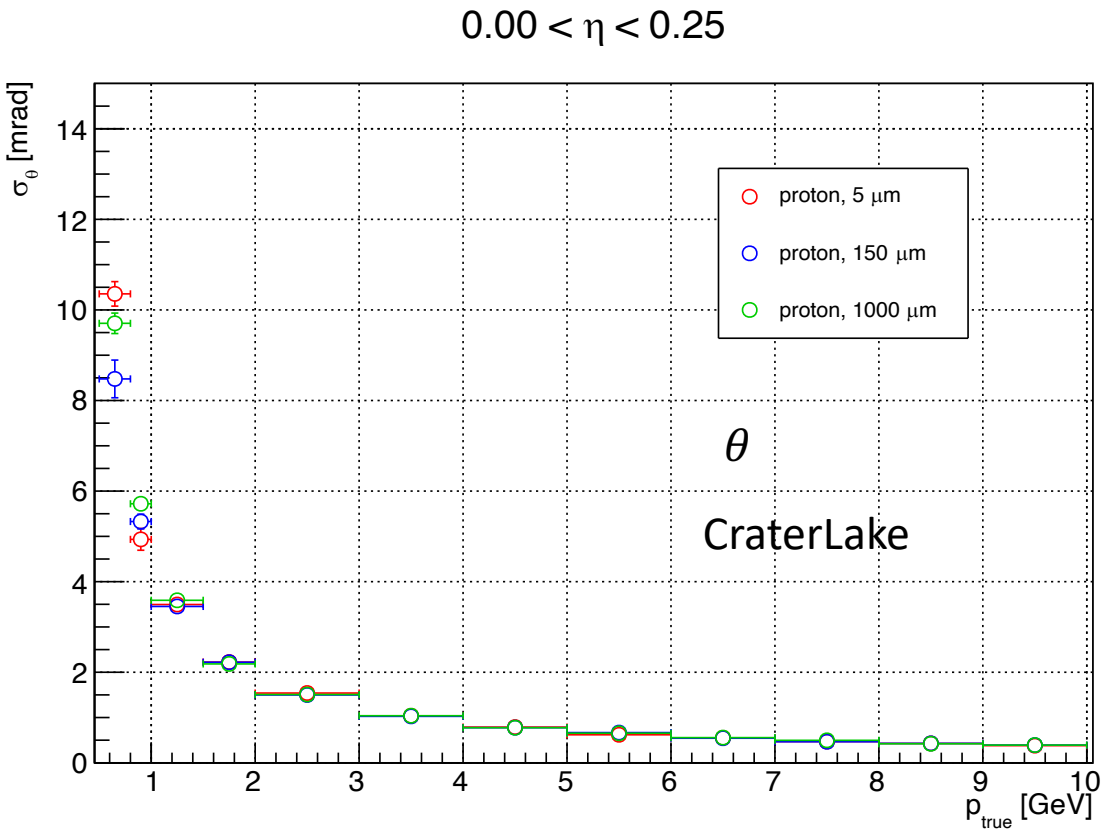


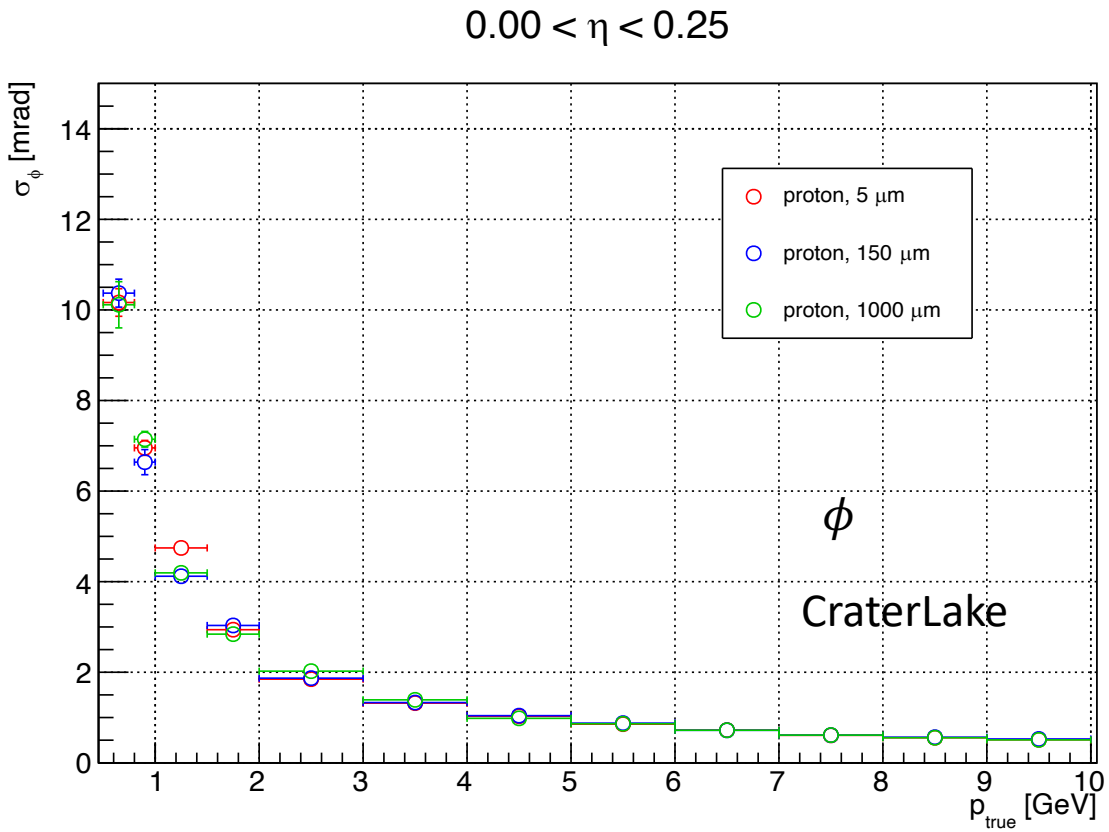




Angular Resolution: Proton

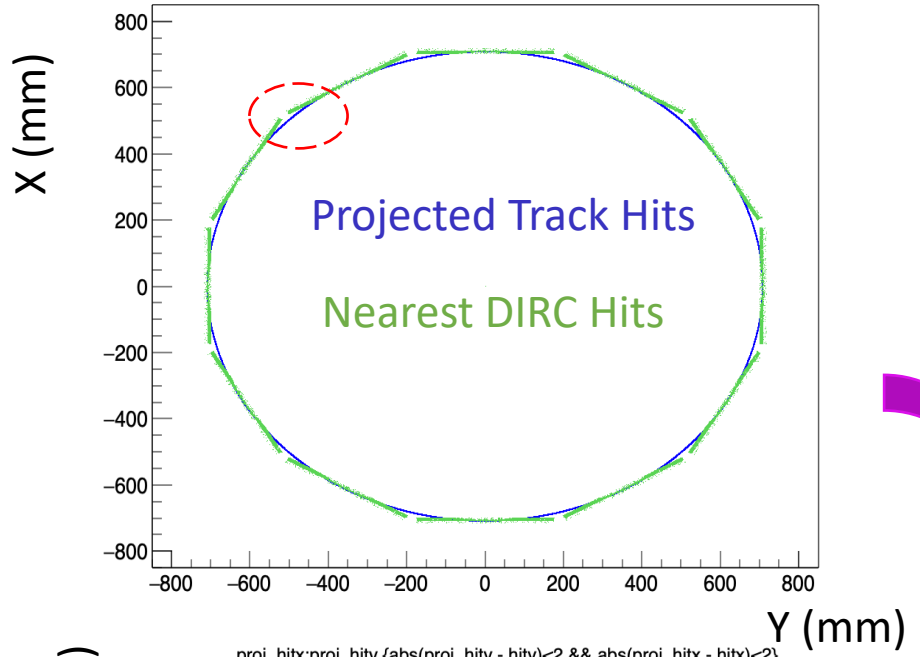
- Vary outer MPGD barrel resolution
  - **Protons show same level of sensitivity to angular resolutions as found with pions (π^-)**

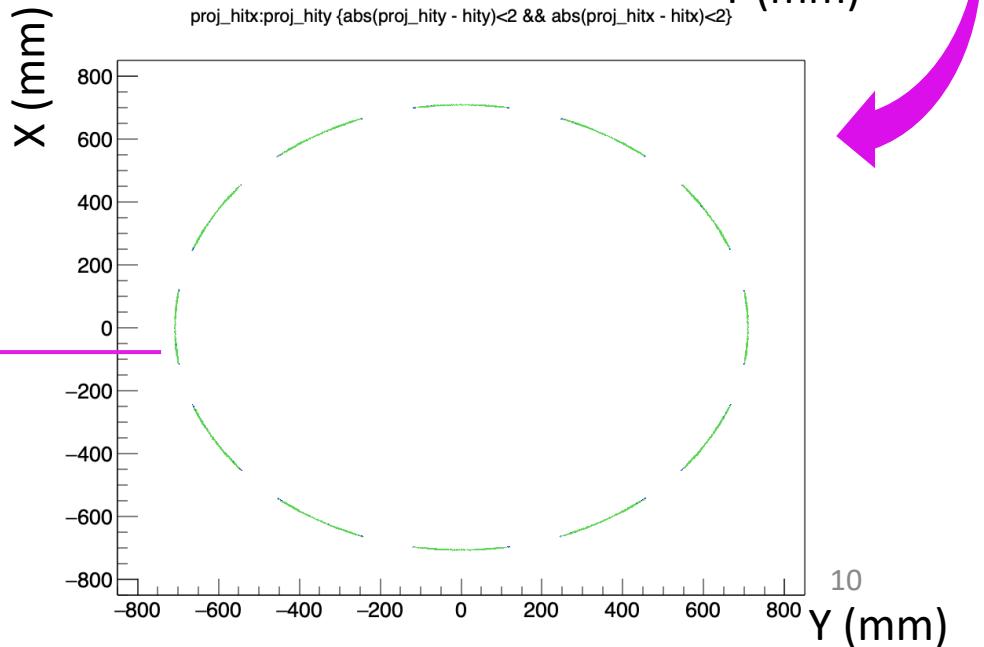


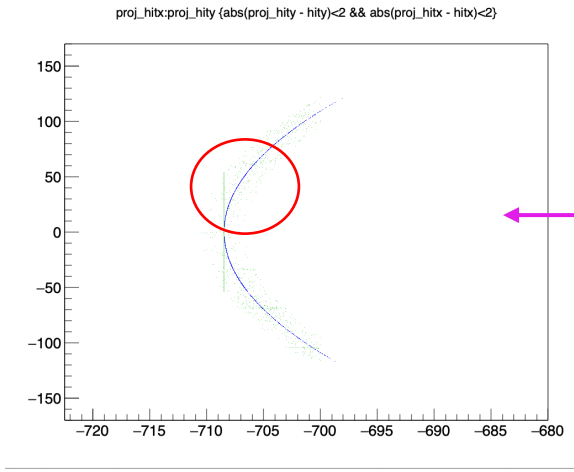


Acceptance Cut

- Implement a cut to include DIRC hits that are near the projected surface
  - $\left|(x_{proj} - x_{DIRC})\right| < 2\ mm$
  - $\left|(y_{proj} - y_{hit})\right| < 2\ mm$
- Cuts lead to improvement, but most DIRC hits still far from projected curved surface



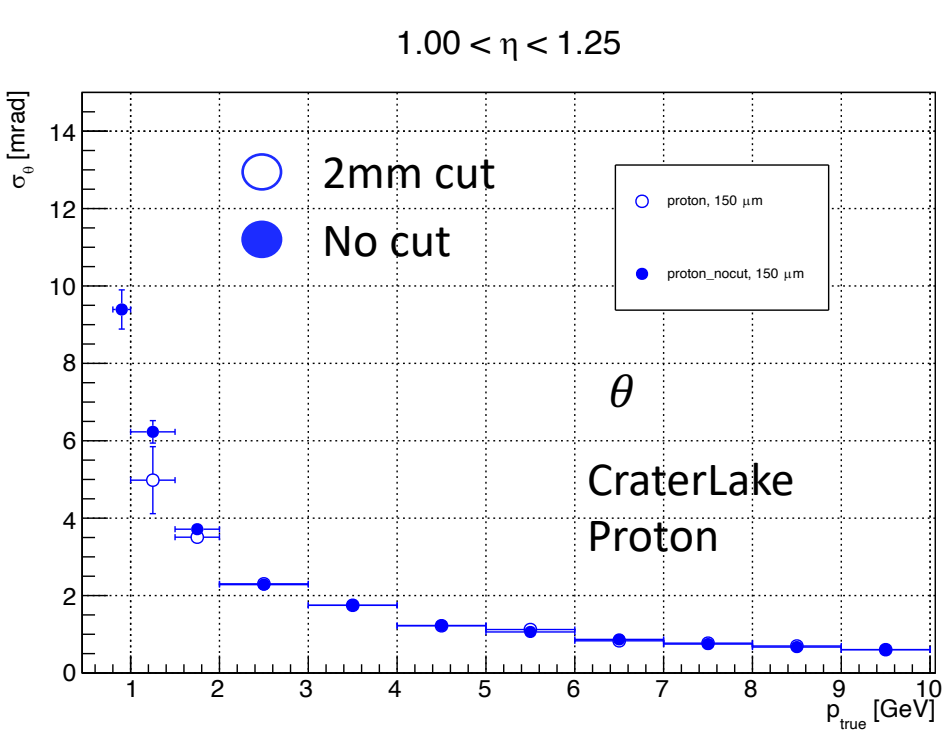


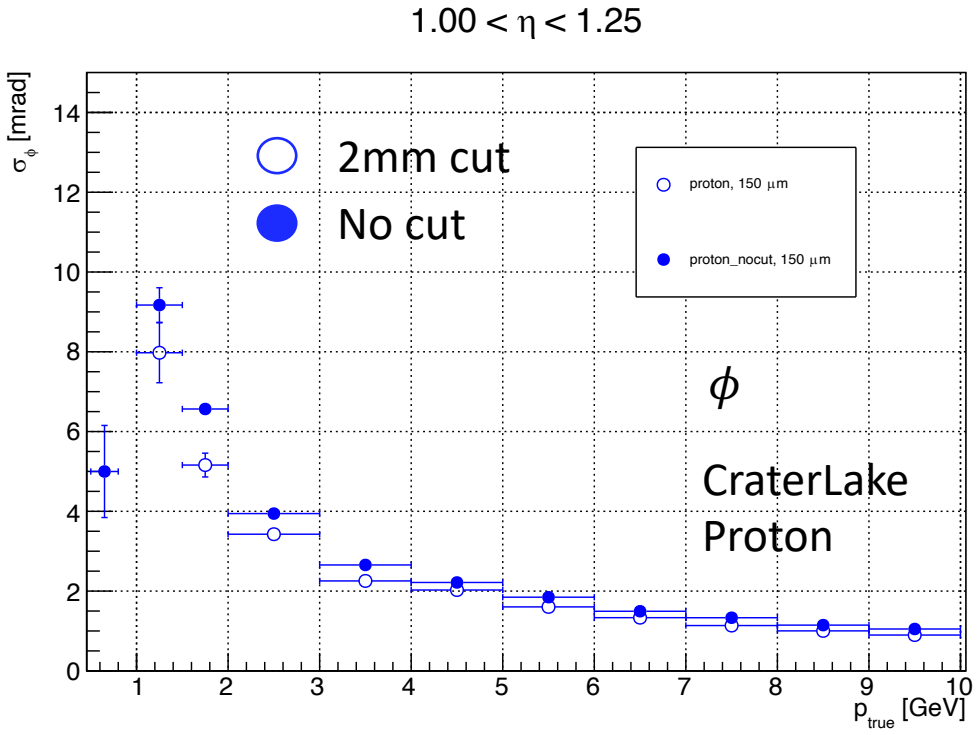


Cut Study

- Implement a cut to include DIRC hits that are near the projected surface
  - $\left|(x_{proj} - x_{DIRC})\right| < 2\ mm$
  - $\left|(y_{proj} - y_{DIRC})\right| < 2\ mm$

➢ **Generally, cut provides better resolution, mainly at lower momentum**

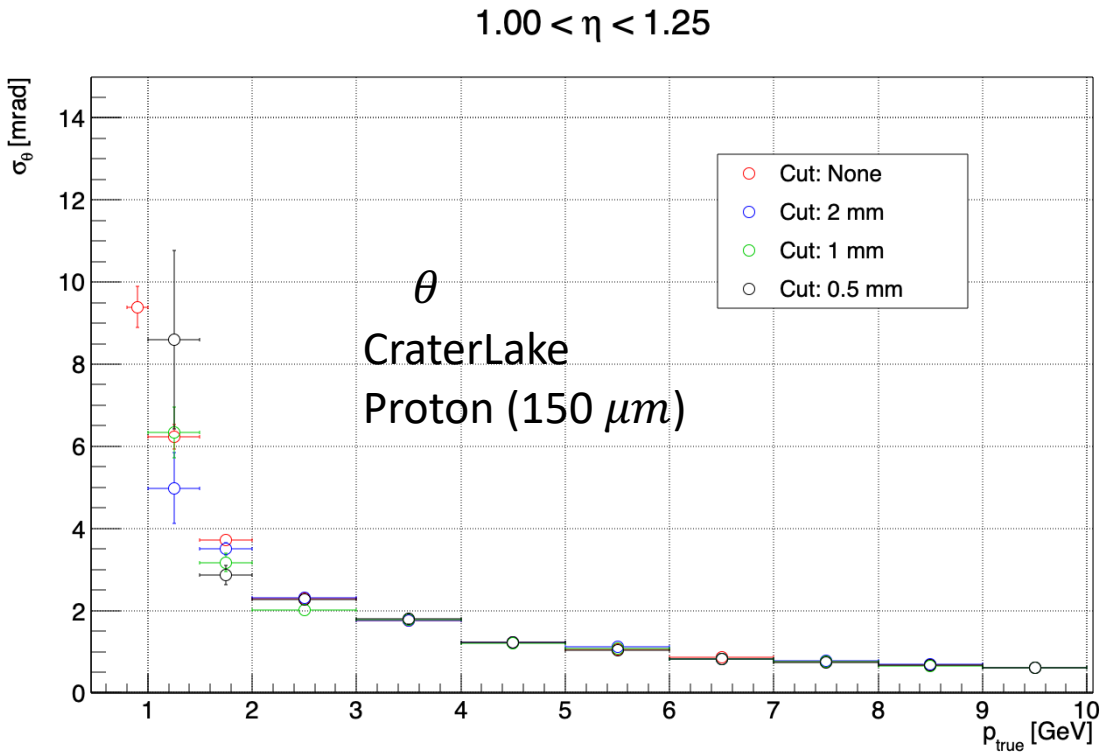


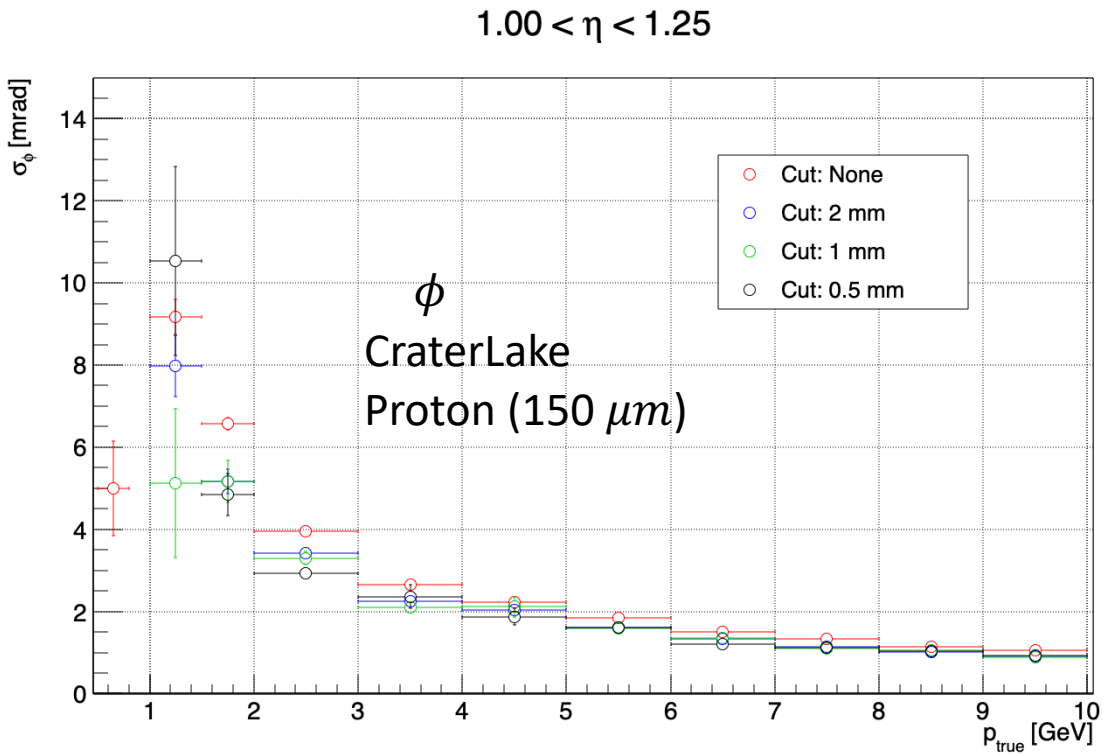


Cut Study

- Cut Sensitivity

➢ **No significant sensitivity to outer barrel MPGD resolution**





Cut Study

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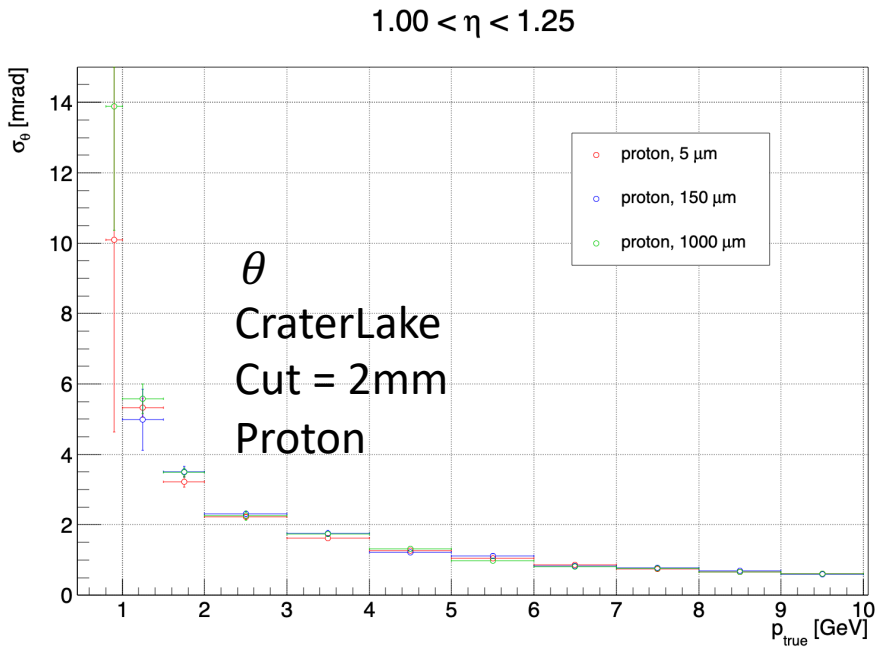
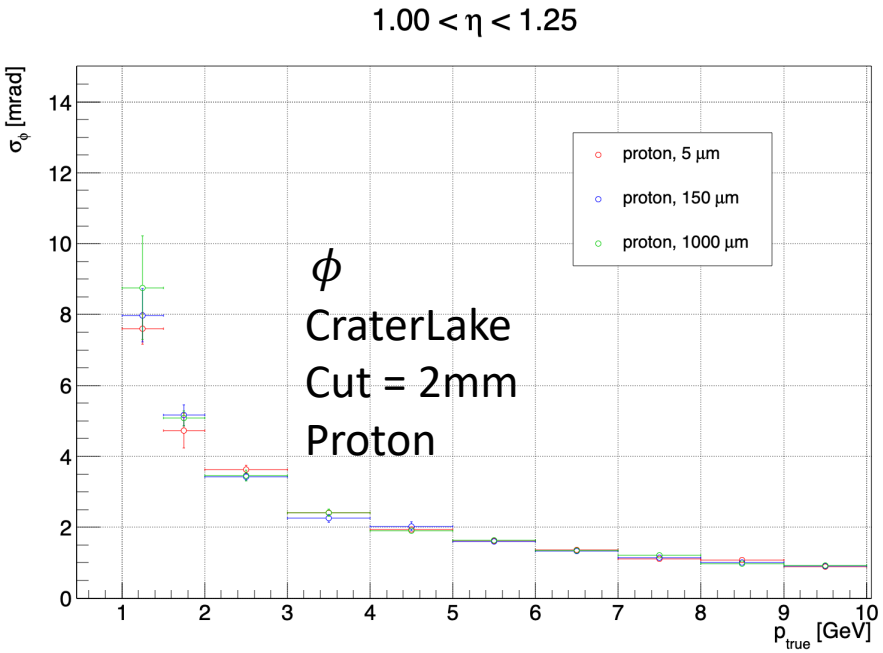
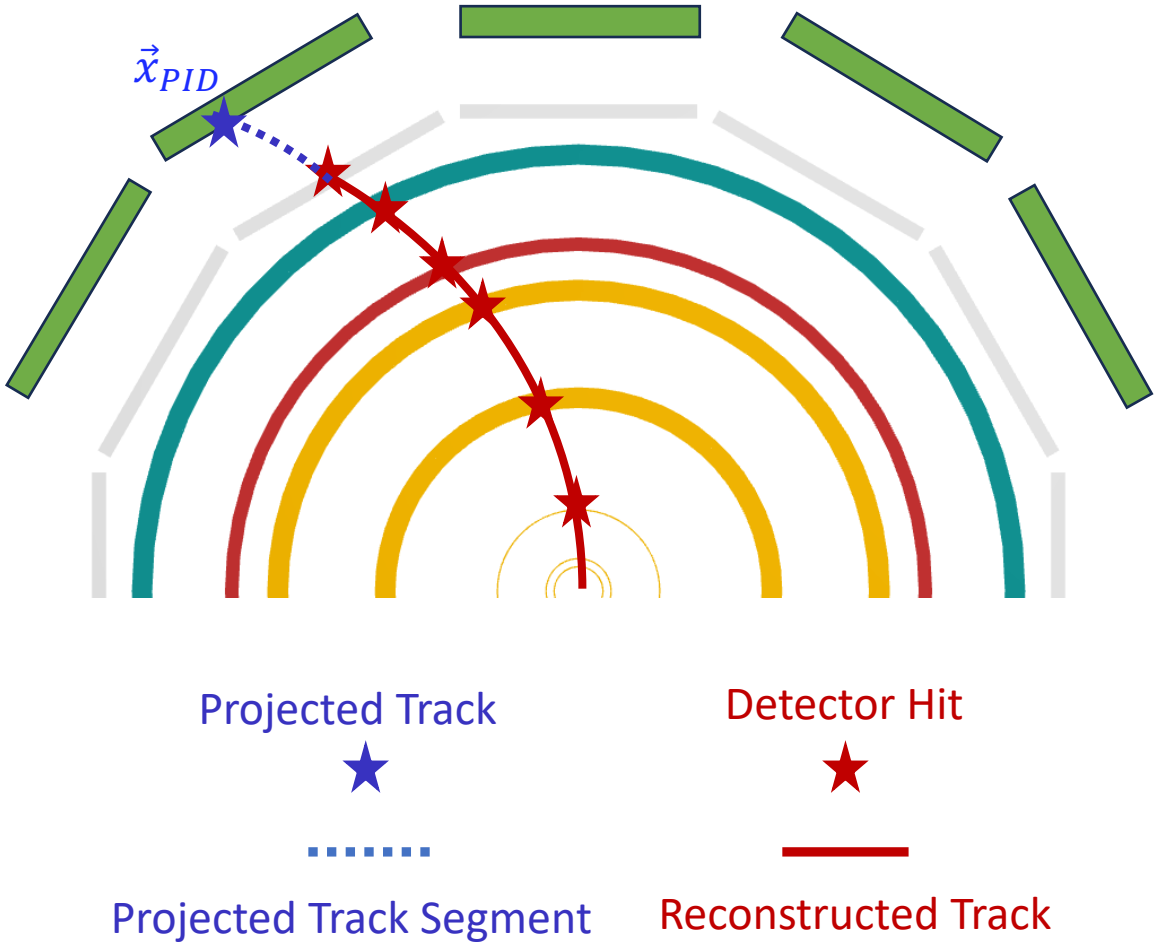




Next Studies (1)

❑ Track Errors

- Use projected track state vector a to get track direction impacting PID surface
  - $\vec{x}_{PID} = \left(l_0, l_1, \theta, \phi, \frac{q}{p}\right)$
- Obtain track direction uncertainty from covariance matrix
  - $var(\theta), var(\phi), cov(\theta, \phi)$
- Use number of measurements in track fit and its χ^2 to select good quality tracks to study



Projected Track Point Information

```
// Get trajectories from tracking
auto trajectories = event->Get<eicrecon::TrackingResultTrajectory>("CentralCKFTrajectories");
auto trajectoriesSeed = event->Get<eicrecon::TrackingResultTrajectory>("CentralCKFSeededTrajectories");
```

```
    // Iterate over trajectories
    m_log->debug("Propagating through {} trajectories", trajectories.size());
    for (size_t traj_index = 0; traj_index < trajectories.size(); traj_index++) {
        auto &trajectory = trajectories[traj_index];
        m_log->trace(" -- trajectory {} --", traj_index);
```

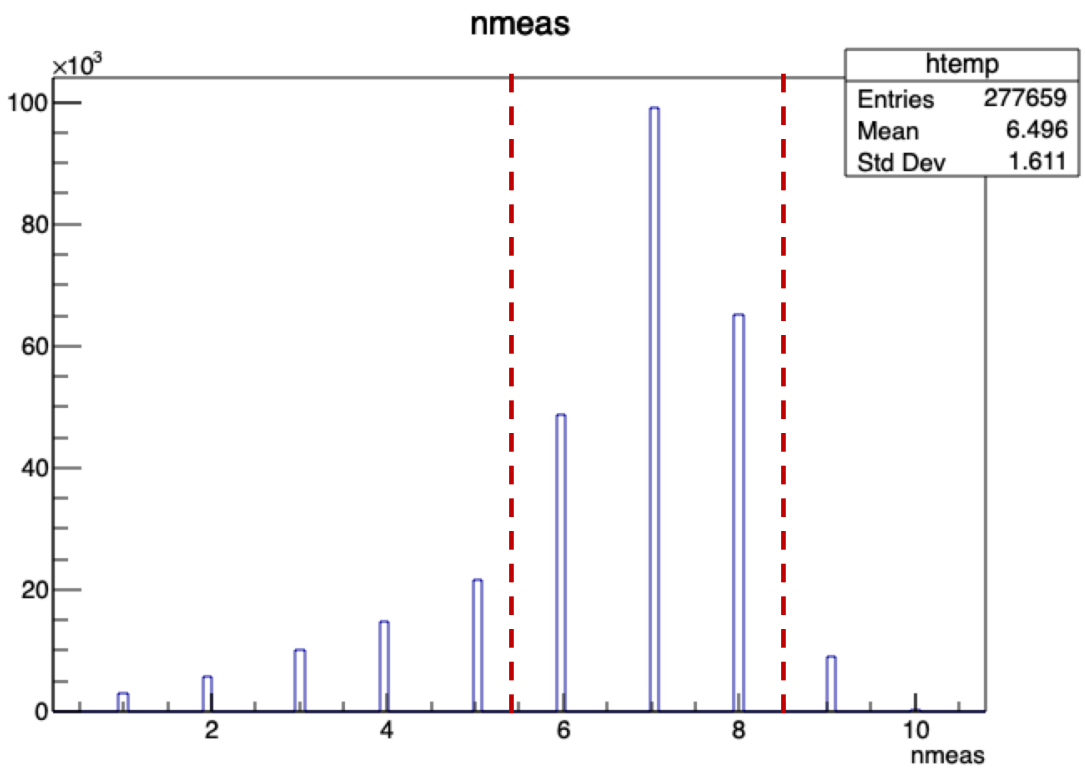
```
    // Collect the trajectory summary info
    auto trajState = Acts::MultiTrajectoryHelpers::trajectoryState(mj, trackTip);
    int m_nMeasurements = trajState.nMeasurements;
    int m_nStates = trajState.nStates;
    double m_chi2Sum = trajState.chi2Sum;
    int m_NDF = trajState.NDF;
```

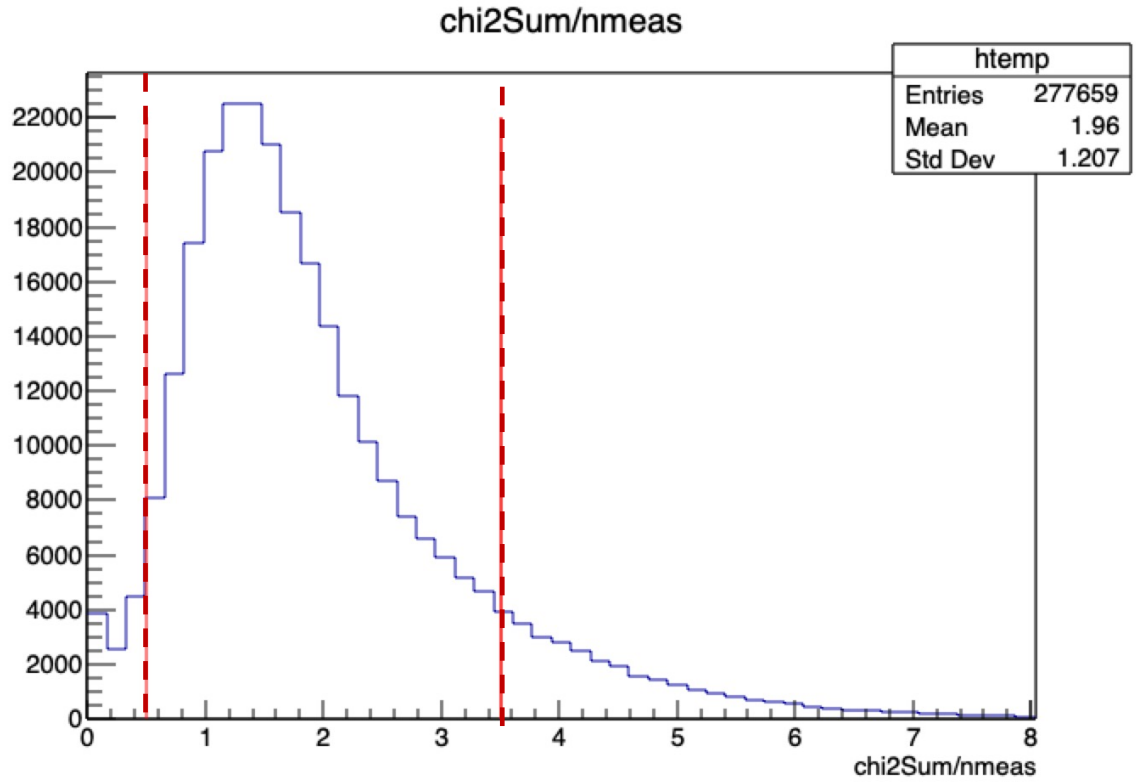
```
  std::unique_ptr<edm4eic::TrackPoint> projection_point;
  try {
      // >>> try to propagate to surface <<<
      //projection_point = m_propagation_algo.propagate(trajectory, m_hcal_surface);
      projection_point = m_propagation_algo.propagate(trajectory, m_DIRC_center_surface);
  }
```

```
// Now go through reconstructed tracks points
auto pos = projection_point->position;
auto length =  projection_point->pathlength;
m_log->trace("   {:>10} {:>10.2f} {:>10.2f} {:>10.2f} {:>10.2f}", traj_index, pos.x, pos.y, pos.z, length);
auto theta_center = projection_point->theta;
auto phi_center   = projection_point->phi;
auto theta_center_error = projection_point->directionError.xx;
auto phi_center_error = projection_point->directionError.yy;
auto theta_phi_center_error = projection_point->directionError.xy;
```

Also done for seeded trajectories

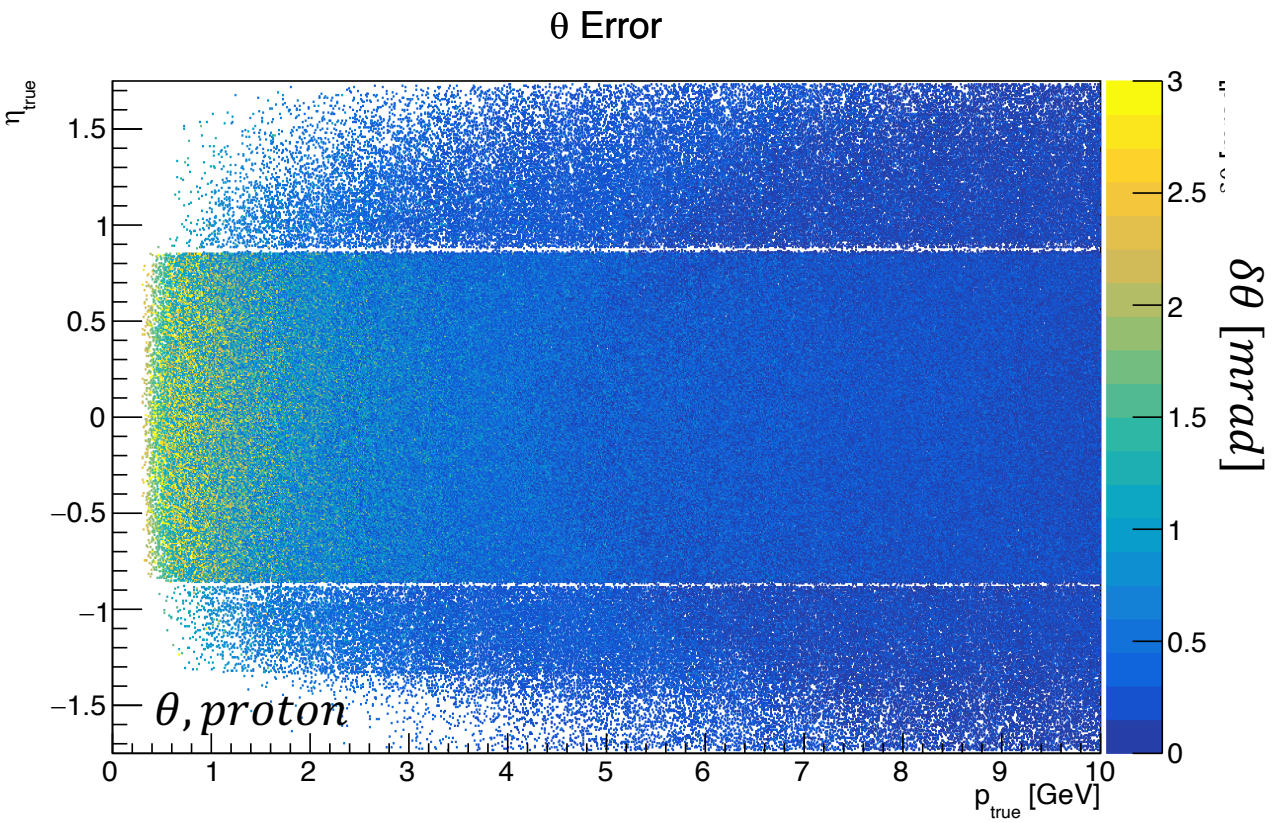
Track Quality Cuts

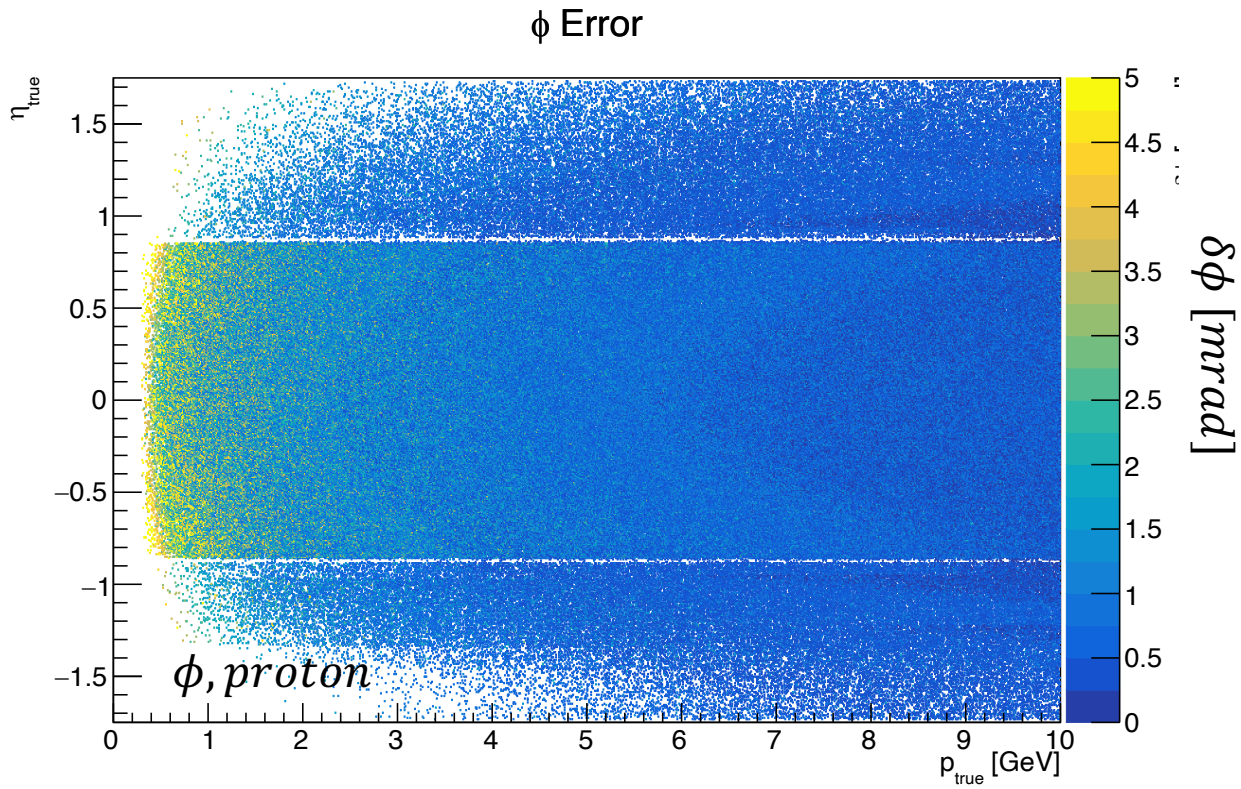




Truth Seeded Angular Uncertainty: Proton

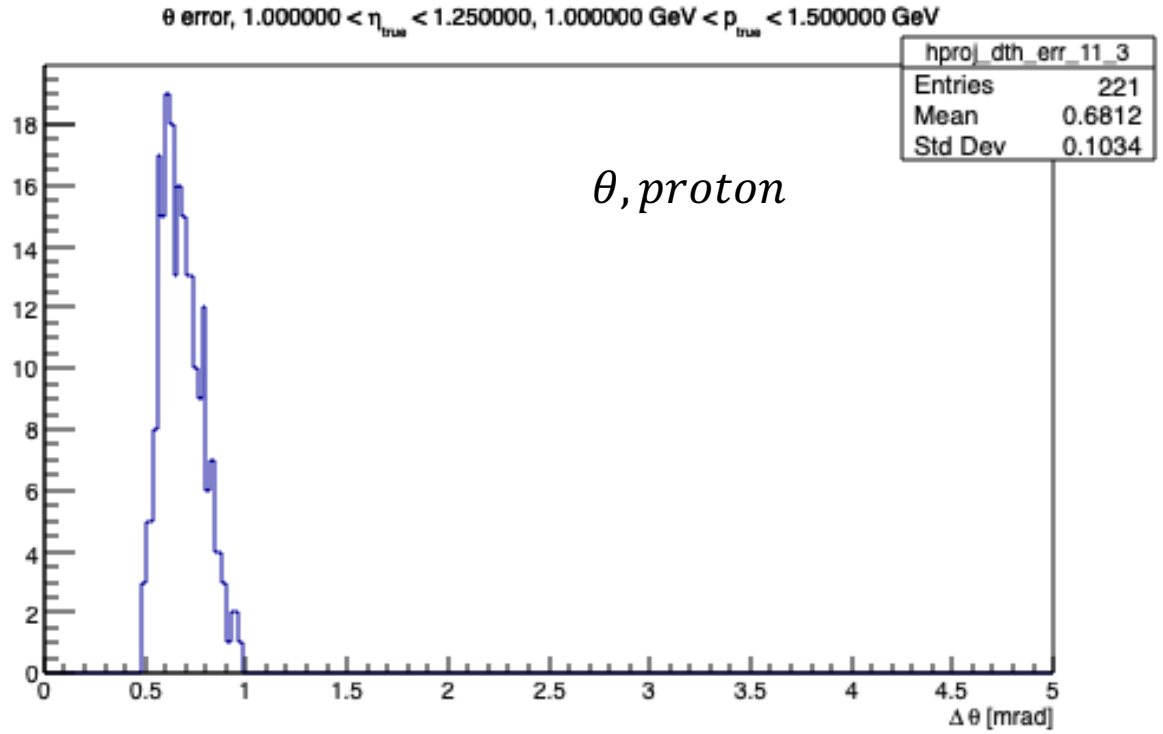
- **Angular uncertainties much smaller than angular resolution computed using previous method (e.g. match to DIRC hit)**
  - Related to readout segmentation used in DIRC for study (3mm pitch X-Y-Z grid)?
  - $\delta\theta, \delta\phi$ are $\sqrt{(Variance)}$, from covariance matrix projected to DIRC

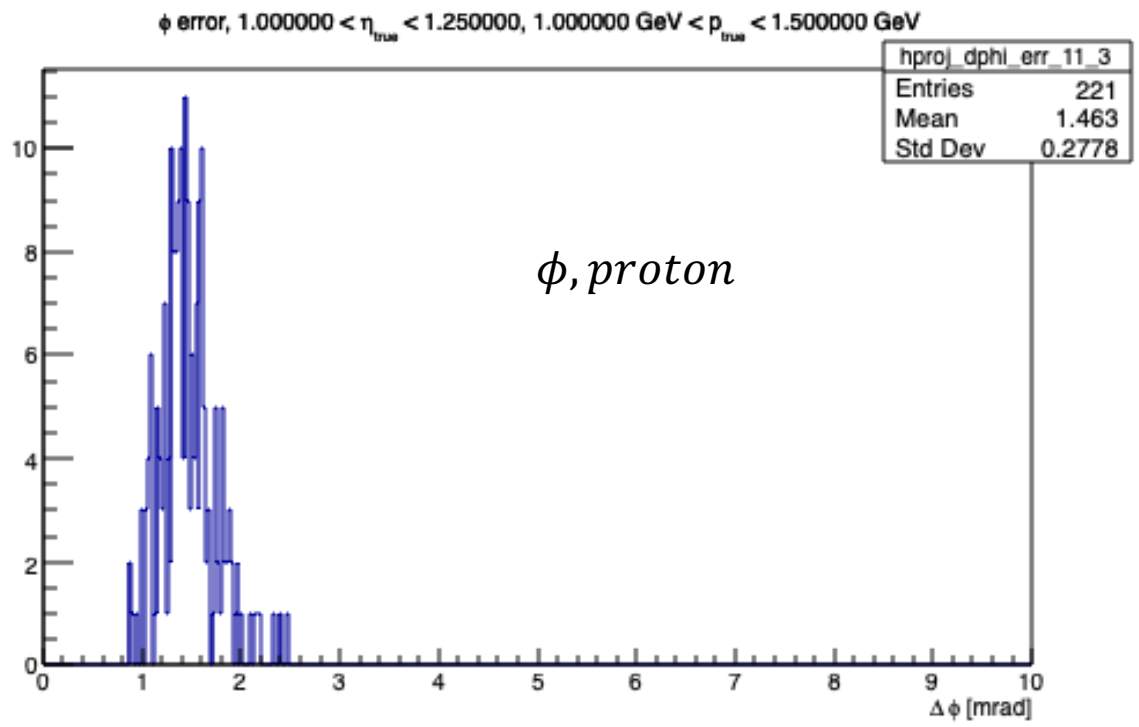




Uncertainty Distributions

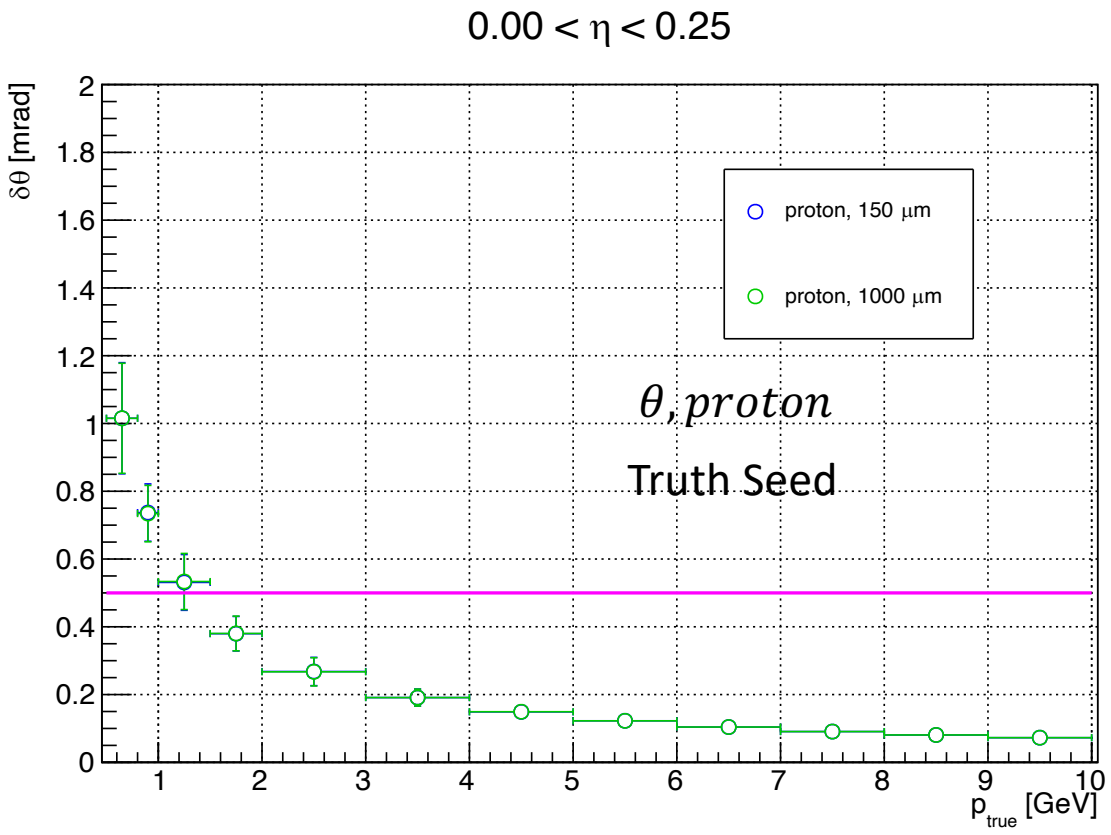
- Plot sqrt(variance), variance obtained from covariance matrix
  - Histogram mean = angular uncertainty
  - Histogram RMS = error bar

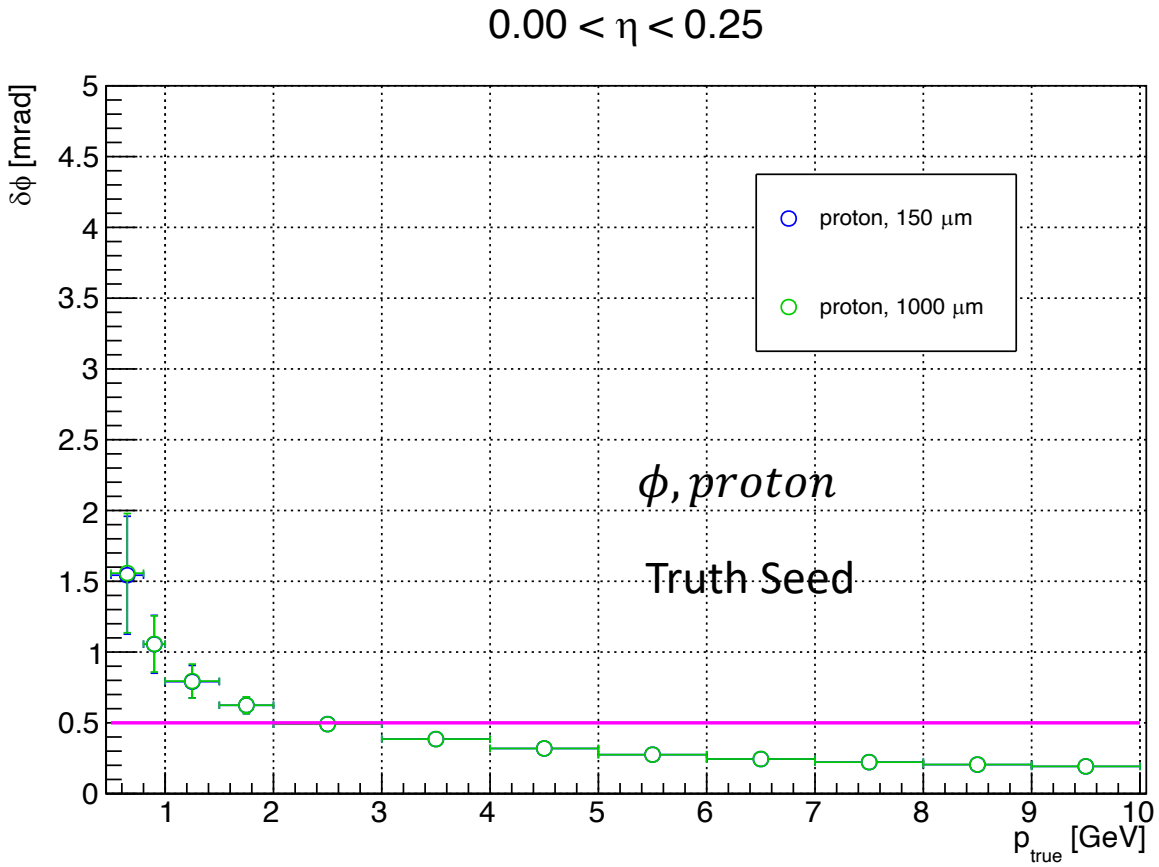




Truth Seeded Angular Uncertainty: Proton

- Track Direction Uncertainty Sensitivity
- **No significant sensitivity to outer barrel MPGD resolution**





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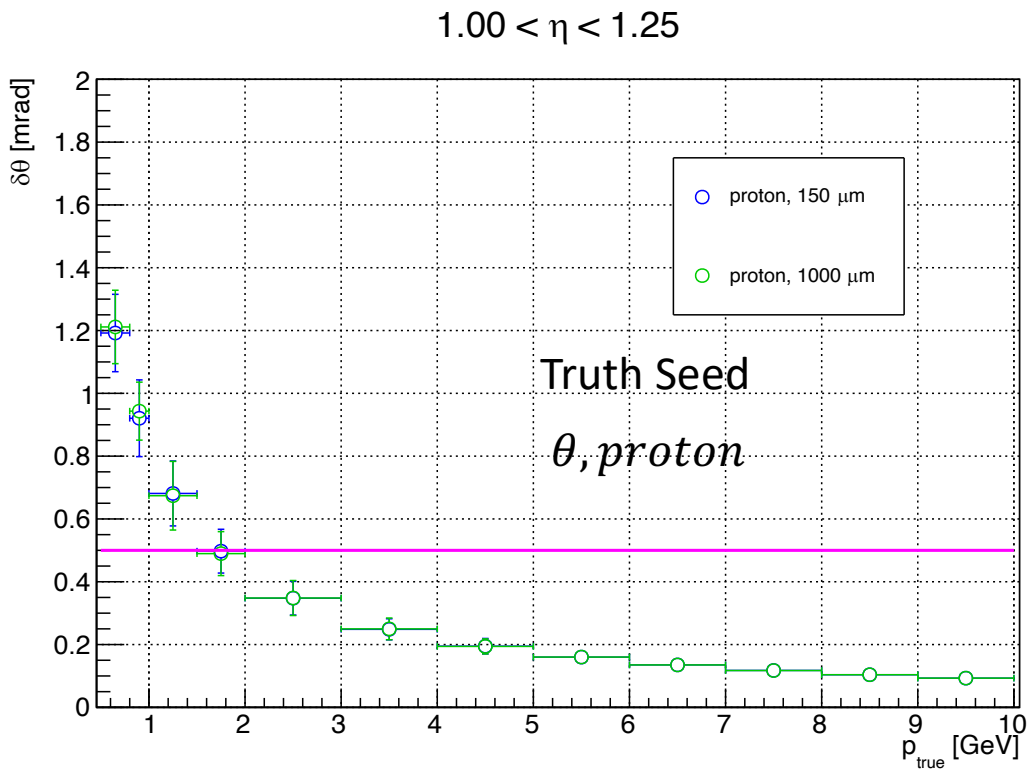
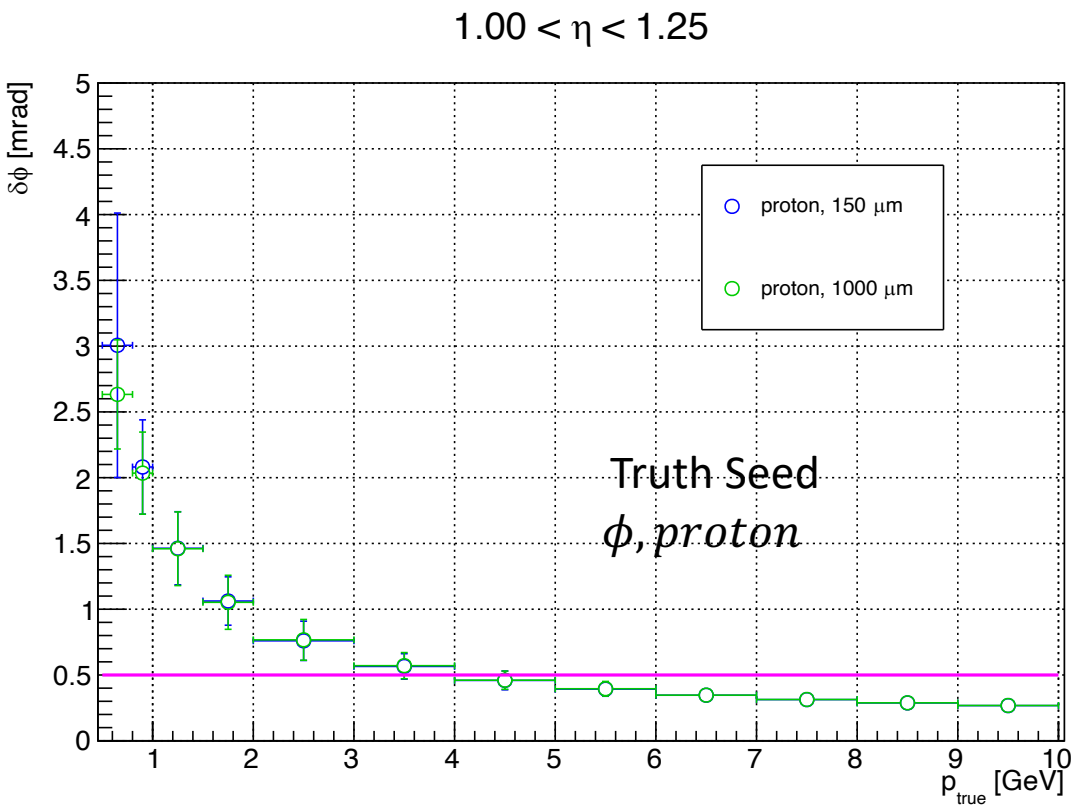
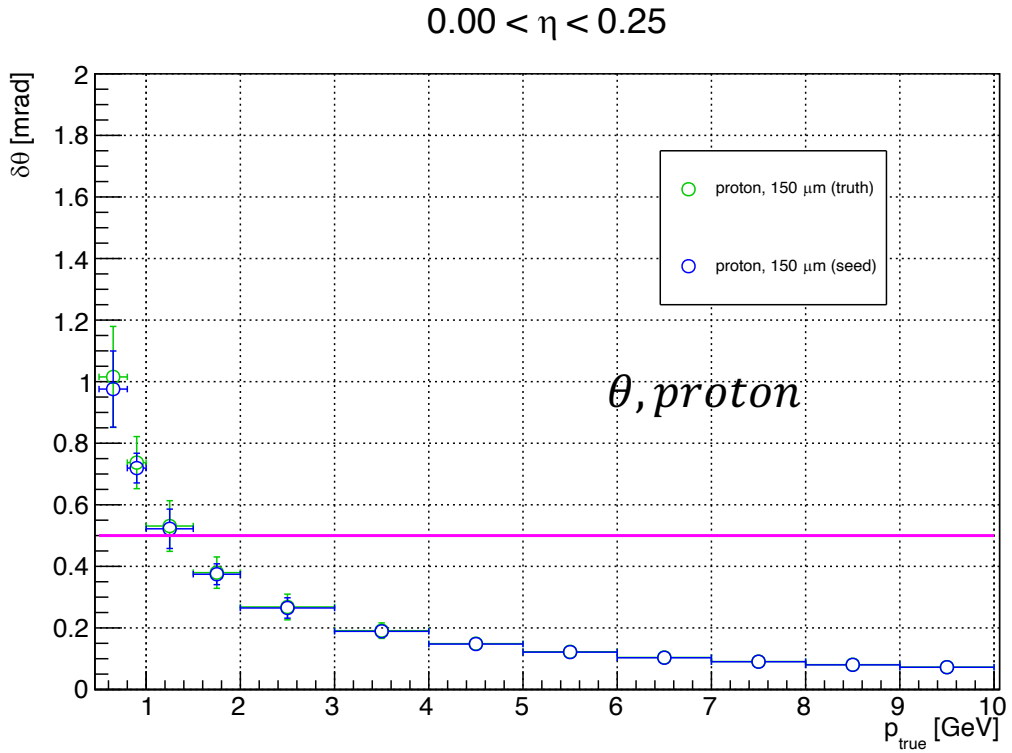
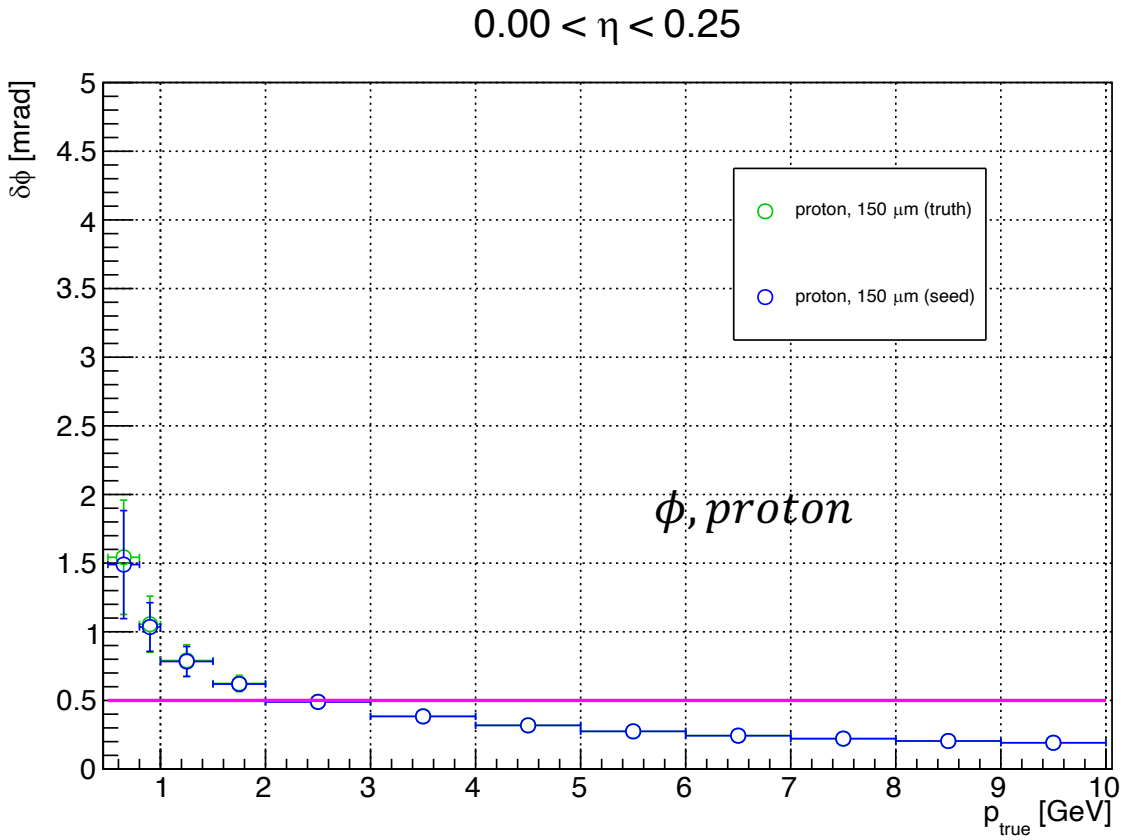




Truth Seeded vs. Realistic Seeded: Proton

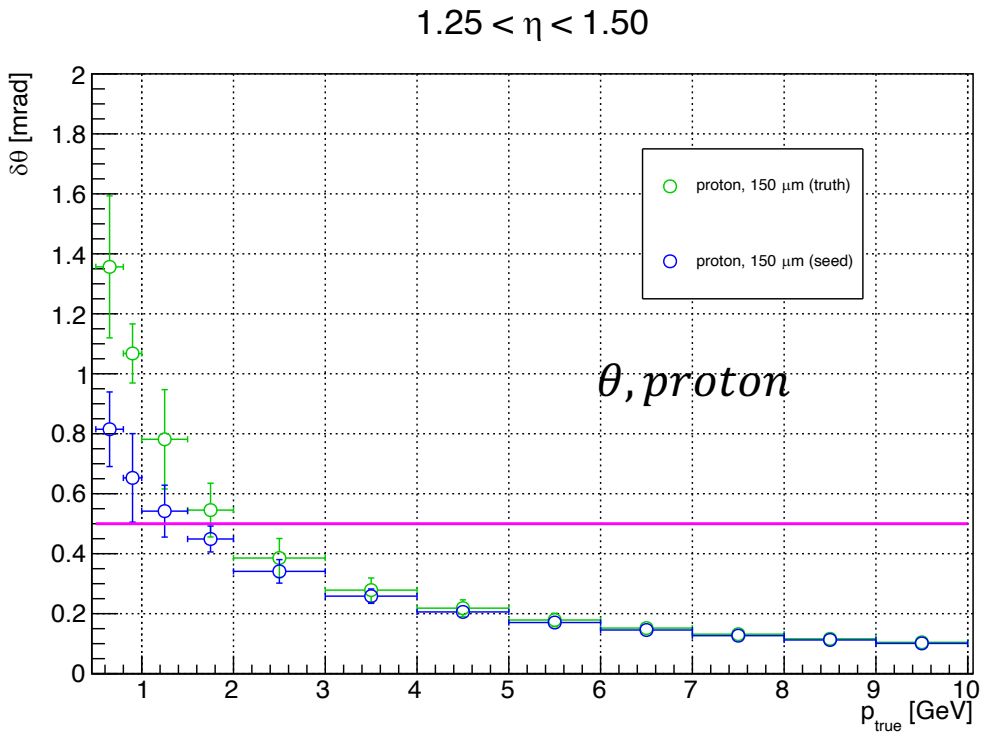
- **Similar results between truth and realistic seeding**

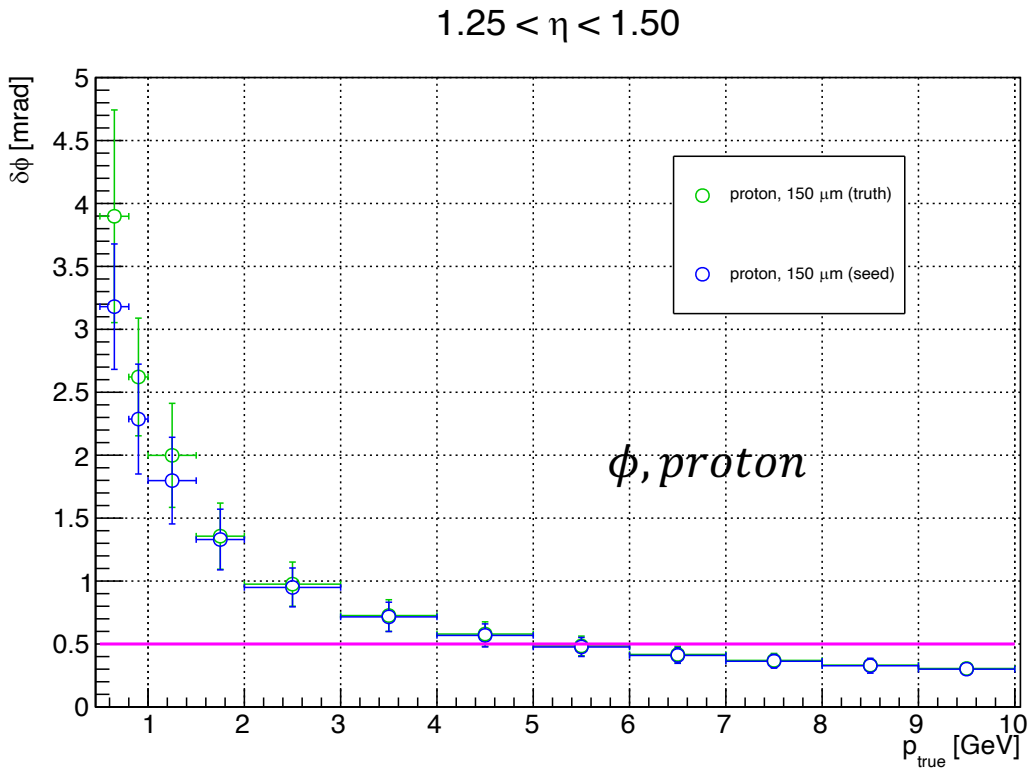




Truth vs. Realistic Seed Angular Uncertainty: Proton

- **Similar results between truth and realistic seeding**
  - Slightly better performance form realistic seeding at low momentum
  - Behavior consistent with studies of momentum resolution done by S. Maple



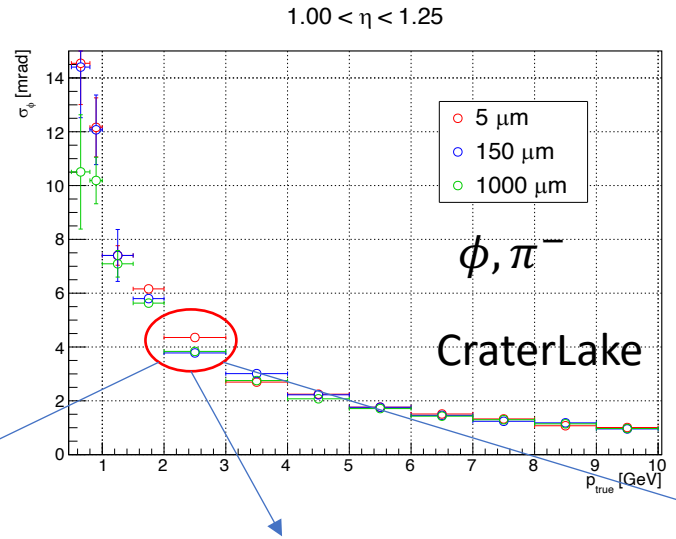


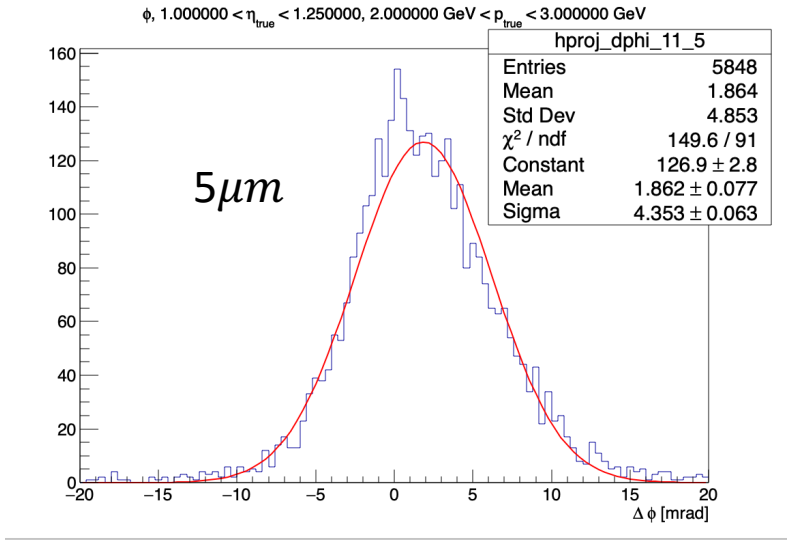
Conclusions

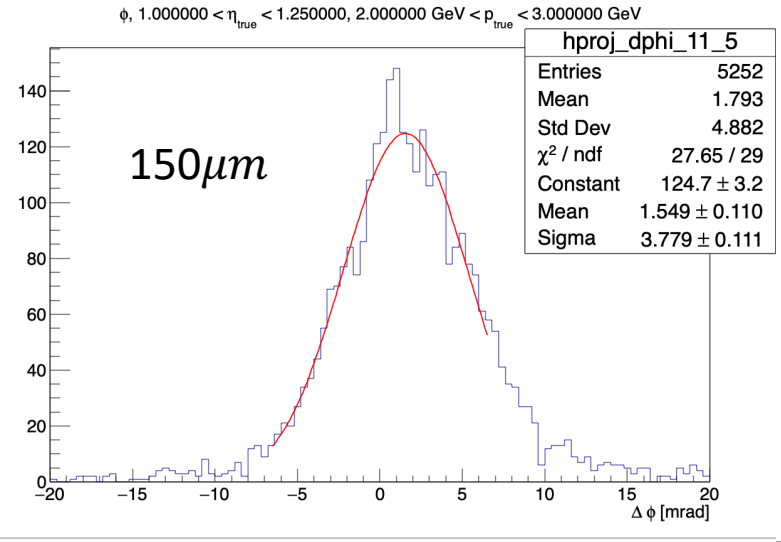
1. Two methods were used to assess the impact of the outer MPGD barrel resolution on the angular precision of the track as it enters the DIRC.
    - Method 1: Extract angular resolutions using projected track information and nearest DIRC hit
    - Method 2: Use covariance matrix of track projected to DIRC to obtain track direction uncertainties
2. Both methods show outer MPGD barrel resolutions have no significant effect on the angular information.
3. Angular resolutions calculated form Method 1 are much larger than track direction uncertainties calculated from Method 2.
    - Possibly due to 3mm space point resolution used for DIRC hit in Method 1?

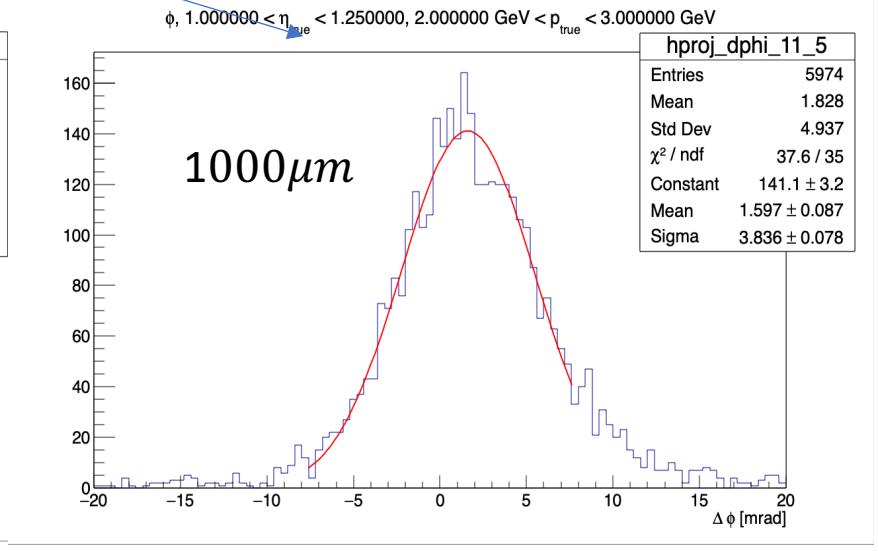
Backup

Angular Resolution



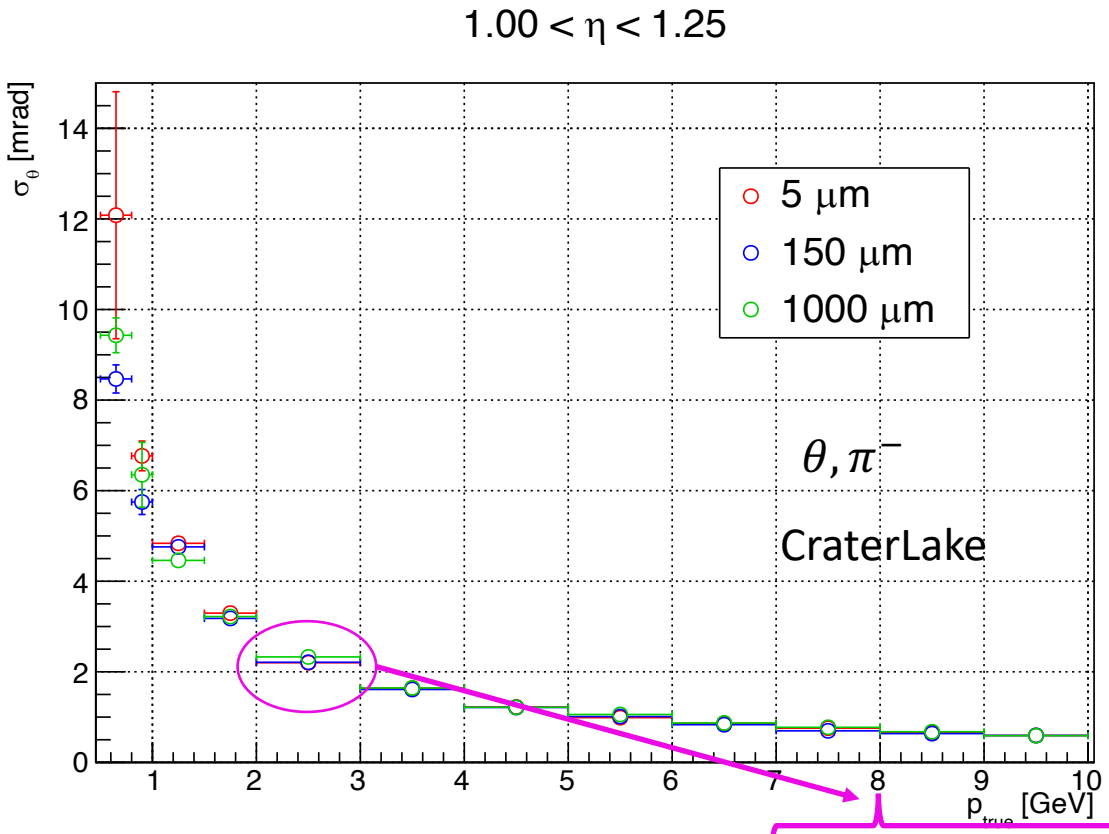


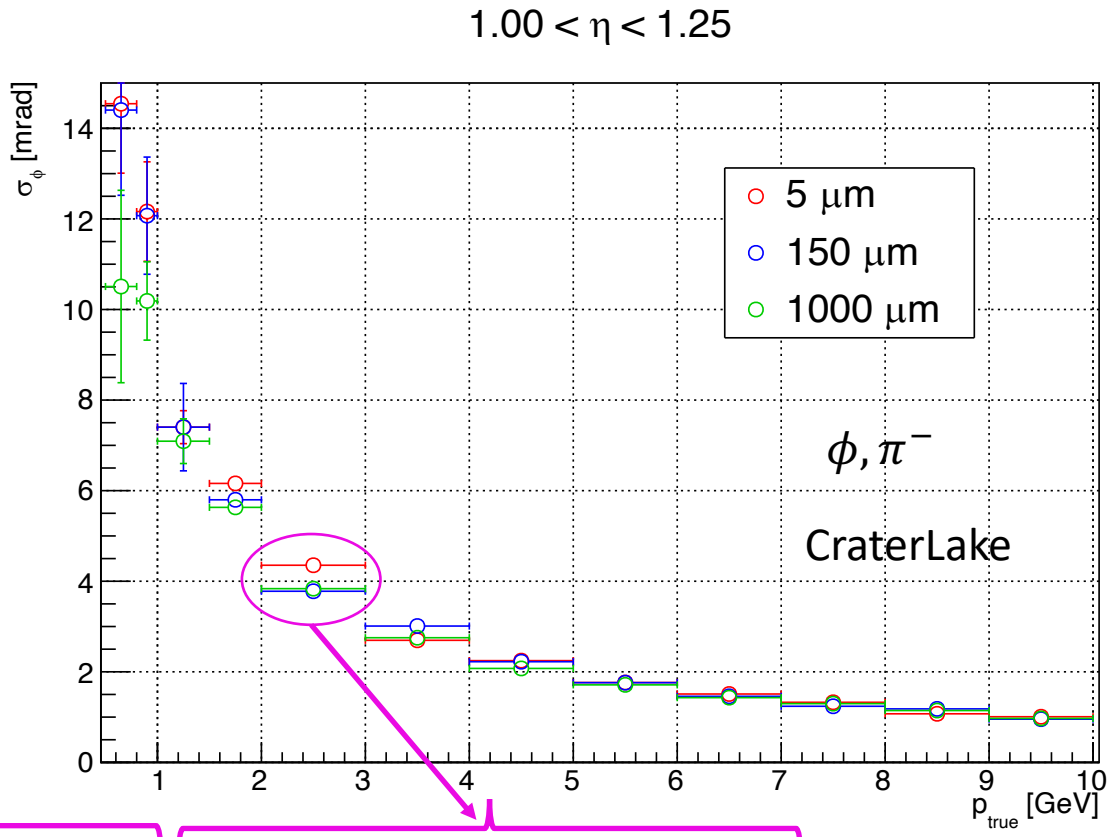




Angular Resolution

- Vary outer MPGD barrel resolution

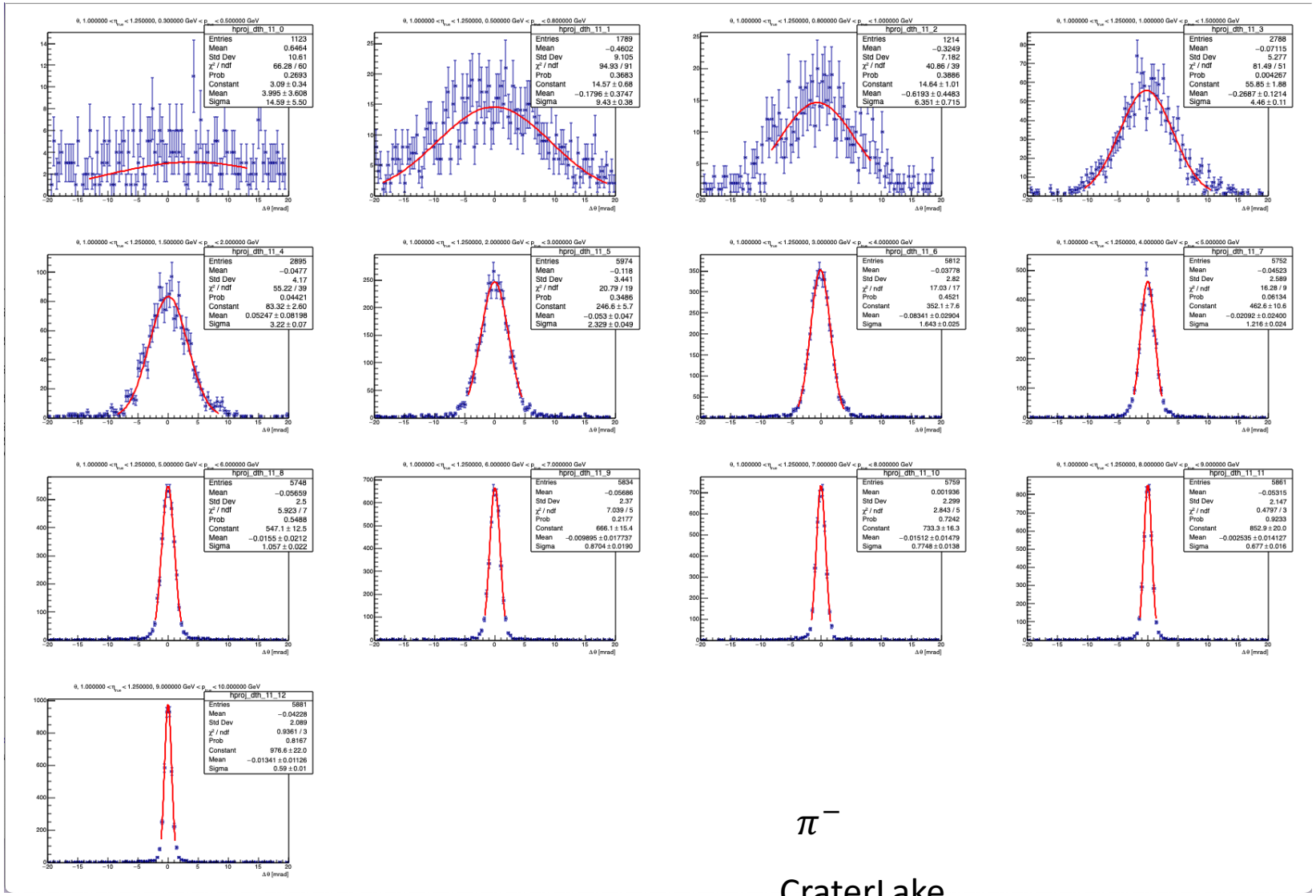




MPGD Res. (um)	Th Res. (mrad)	Th Ch2/dof	Phi Res. (mrad)	phi Ch2/dof
5	2.20	1.10	4.35	1.64
150	2.21	1.39	3.78	0.95
1000	2.33	1.09	3.84	1.07

Angular Resolution Fits

- Fits:
  - $1.00 < \eta < 1.25$
  - $p - bins$
  - θ



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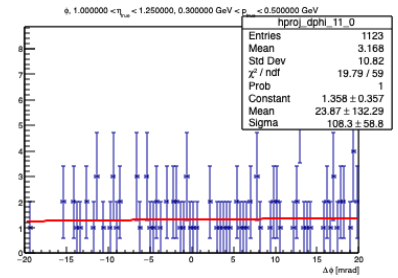
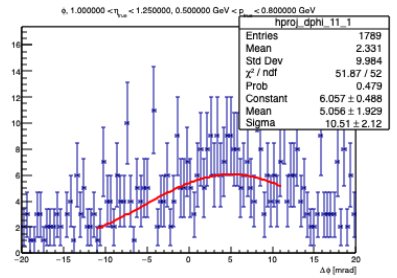
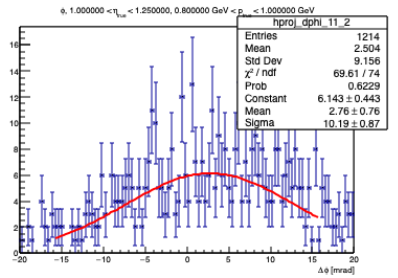
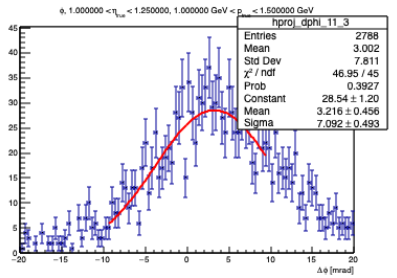
Angular Resolution Fits

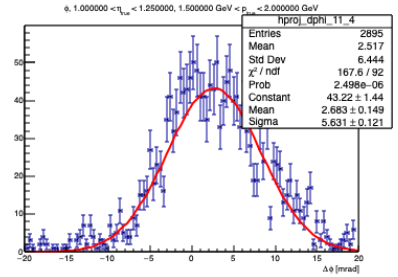
- Fits:
  - $1.00 < \eta < 1.25$
  - $p - bins$
  - ϕ

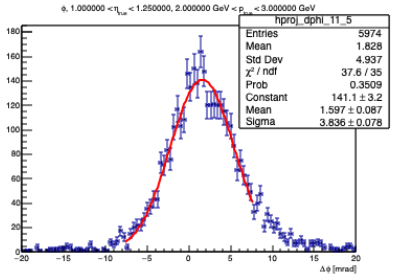


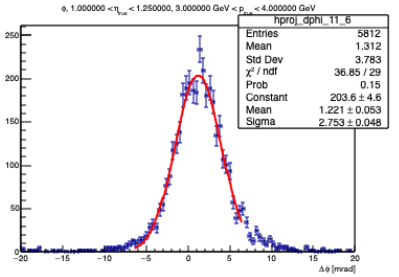


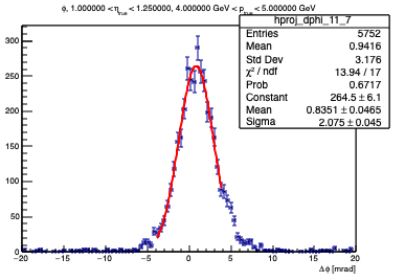


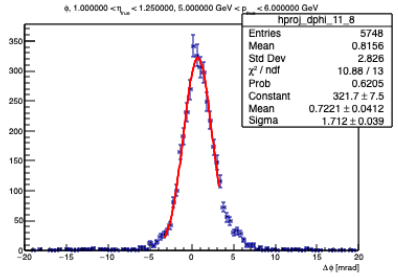


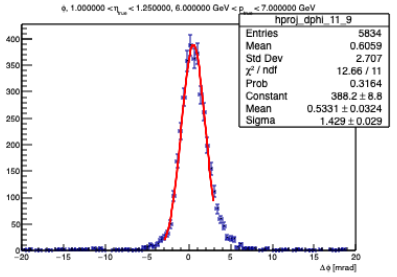


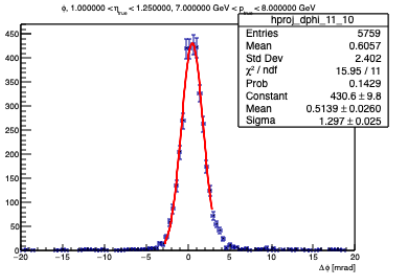


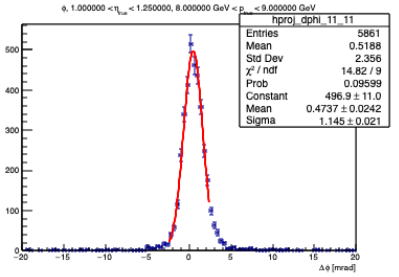


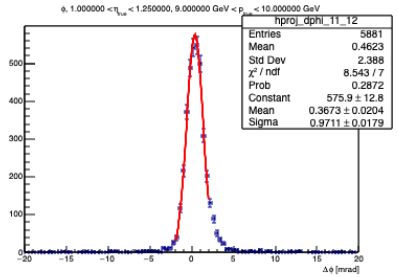












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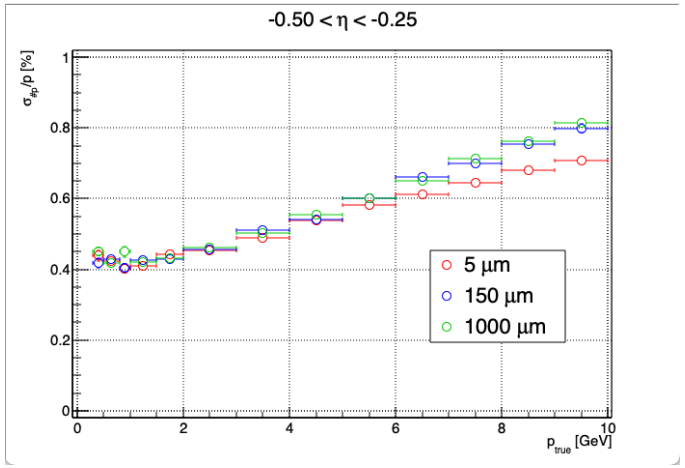
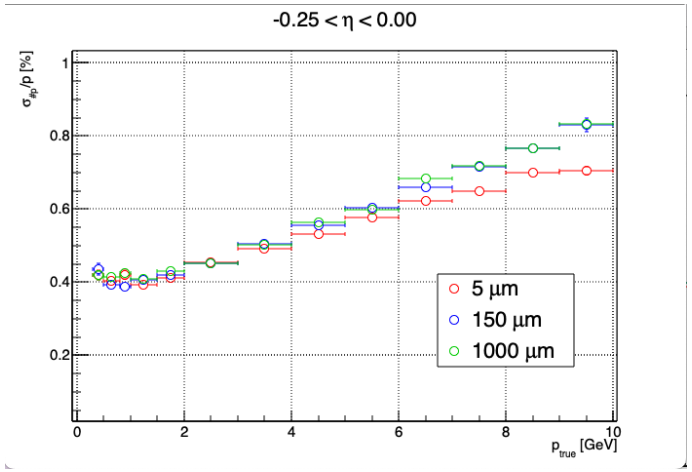
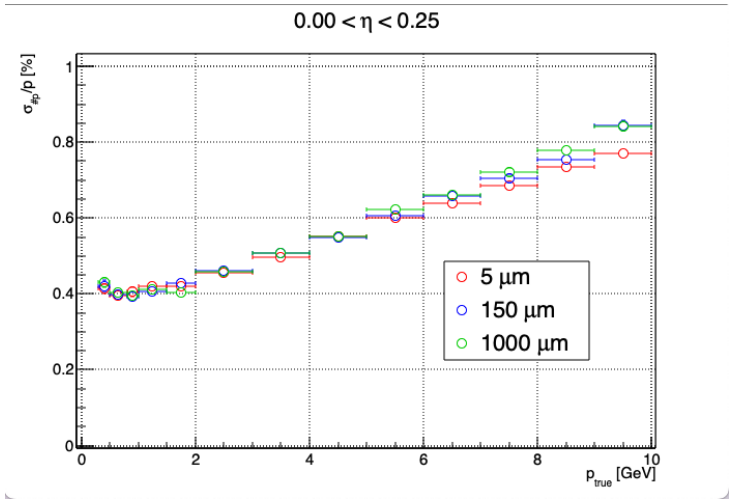
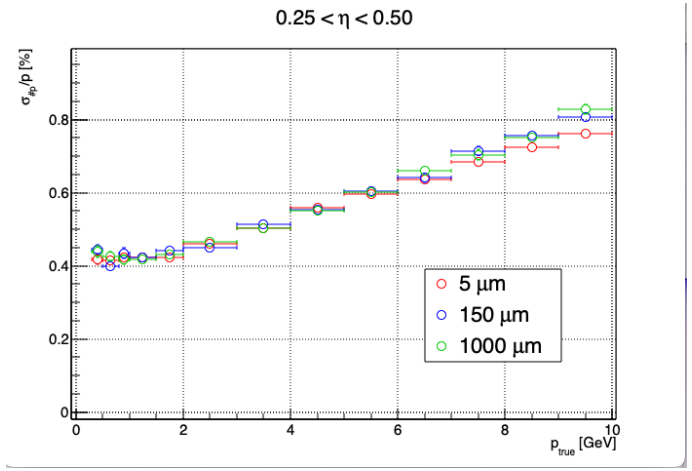
Relative Momentum Resolution









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Cut Study

- Cut Sensitivity
  - No significant sensitivity to outer barrel MPGD resolution