eRD6 EicRoot Tracking Simulation Work

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(For the eRD6 Consortium)

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College of
Science and Technology
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Outline

- EicRoot Simulations within eRD6
  1. Central Region -- Temple University (TU)
     - TPC
     - MPGD
  2. Endcap Region -- Florida Institute of Technology (FIT)
     - GEM trackers
  3. Integrated Detector -- (TU)

TPC Support Material

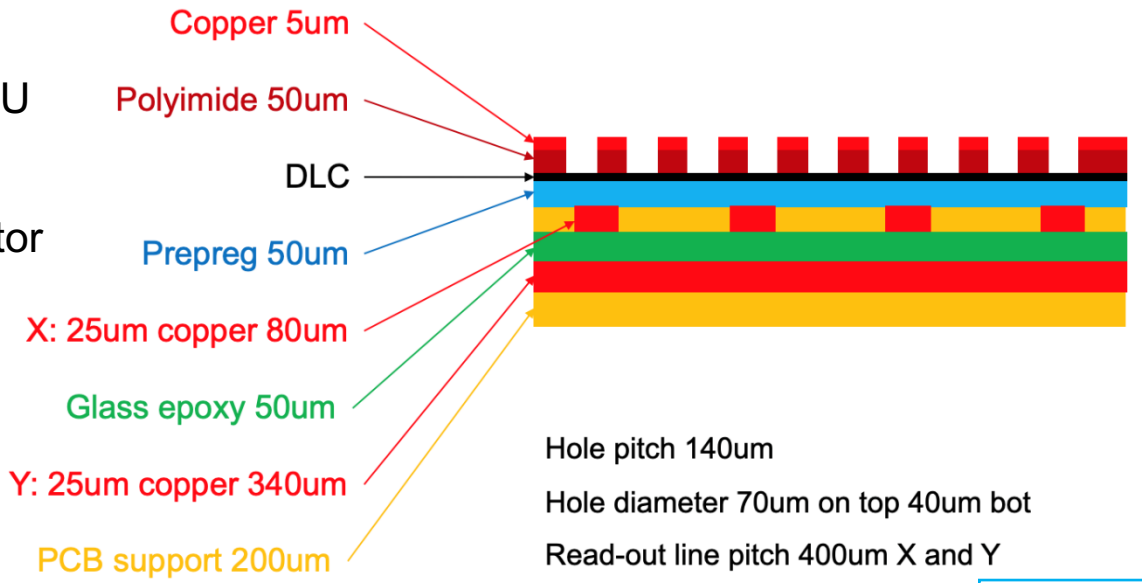
- The inner and outer field cages are made of 9 layers each
- Using the information found here (lines 170-200):
  - https://github.com/sPHENIX-Collaboration/coresoftware/blob/master/simulation/g4simulation/g4tpc/PHG4TpcSubsystem.cc#L152

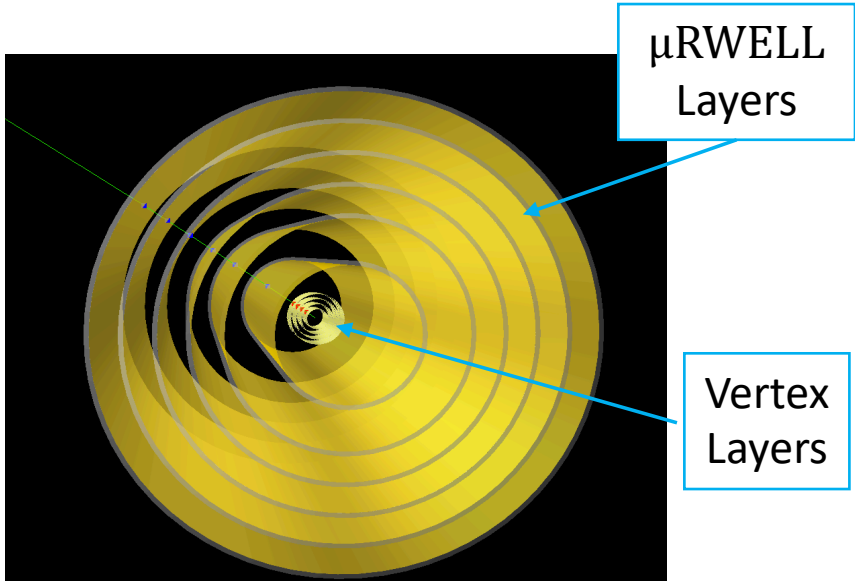
Layer	Material	Thickness	X/X_0 (%)
Layer 1	Copper	0.001735	0.1205
Layer 2	FR4	0.025	0.145
Layer 3	NOMEX	1.27	0.1207
Layer 4	Copper	0.001735	0.1205
Layer 5	FR4	0.025	0.145
Layer 6	Kapton	0.2286	0.80
Layer 7	Copper	0.001735	0.1205
Layer 8	Kapton	0.05	0.175
Layer 9	Copper	0.001735	0.1205
		Total	**1.87**

- The material for the EIC simulation TPC has been updated to have the same material budget found in sPHENIX

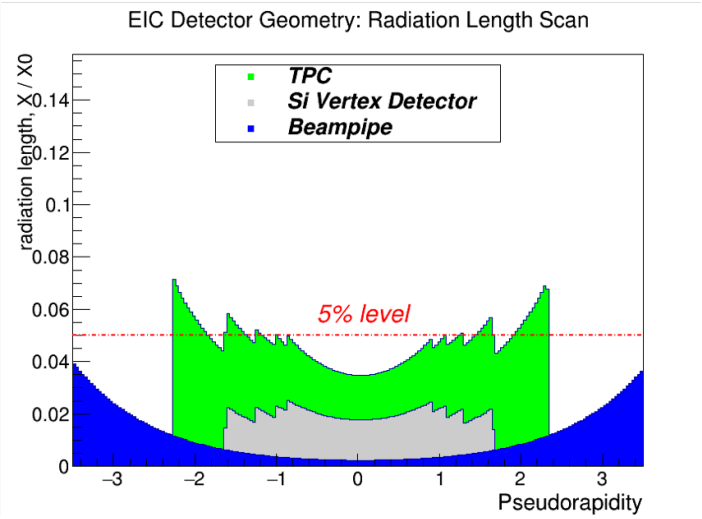
MPGD Material Budget

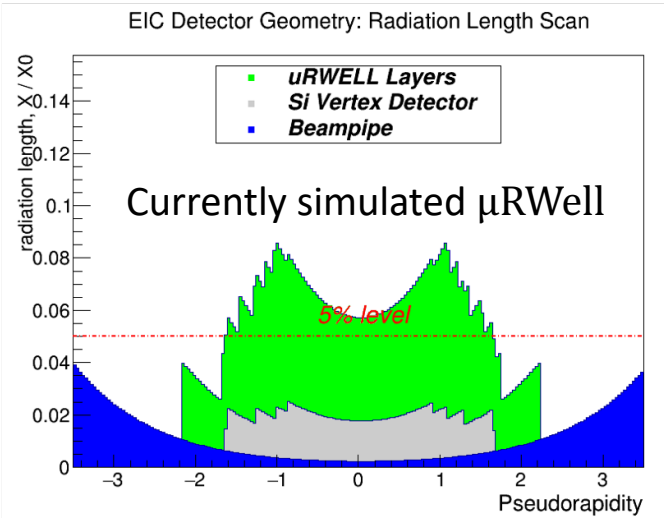
- Cylindrical μRWell simulation overview
  - TU graduate student Nick Lukow has taken over the bulk of the TU simulation work.
  - Investigate central tracking performance with silicon vertex detector and cylindrical μRWell layers.
- Detectors
  - **Silicon vertex detector**
    - 4 layers each with X-Y pixel resolution of 20 μm - 20 μm
  - **Nominal Cylindrical μRWell Barrel Tracker**
    - Consists of six 2m long cylindrical layers covering radii from 22.5 cm - 77.5 cm
    - For each layer
      - $\phi - Z$ resolution of ~100 μm x ~100 μm (https://doi.org/10.1016/j.nima.2019.04.004)
      - Detector material , $\chi \ /\chi_0 = 0.64\%$
      - Additional 15 mm of $ArCO_2$ implemented as drift gap
    - No support structures are included

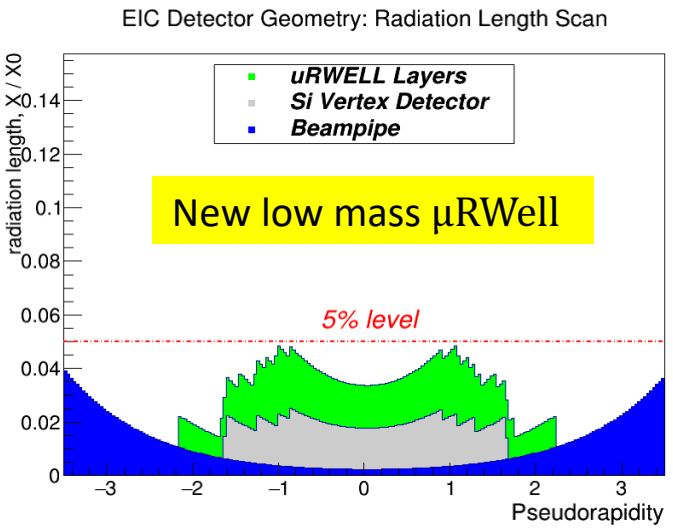




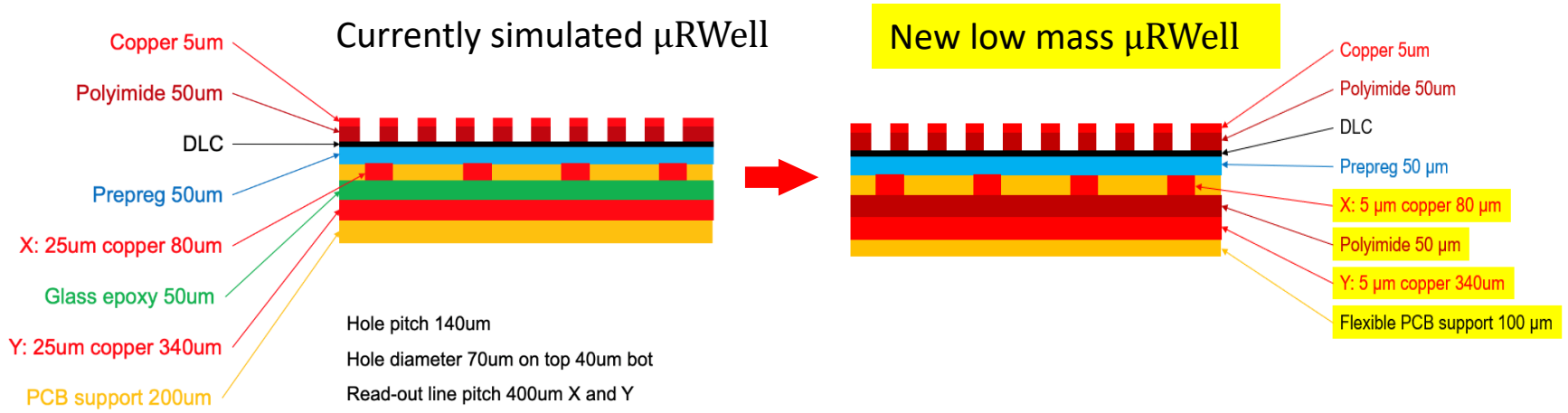
Material Scan







- Low mass detector **not** simulated in EicRoot and will be implemented into Fun4All simulations.



Addition of DIRC Material

- Added DIRC material to simulation
  - Total material: 17.5%
- Reconstructed track parameters can also be extracted from behind the DIRC now

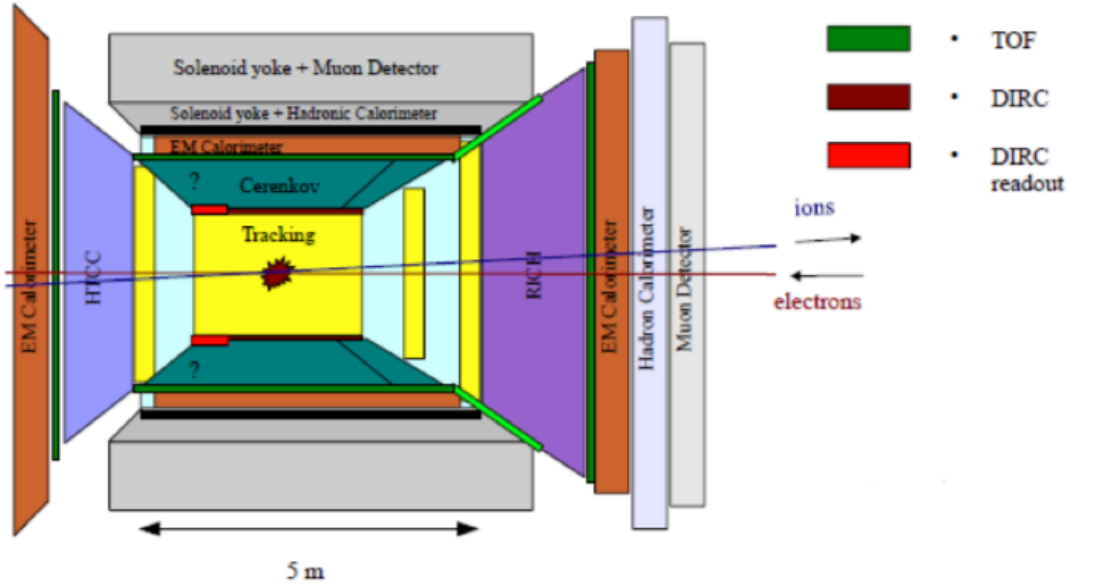


Figure 11: Detector cartoon showing the DIRC inside of the supplementary gas Cherenkov (Option 2).

Compared with Option 1, Option 2 has three main advantages:

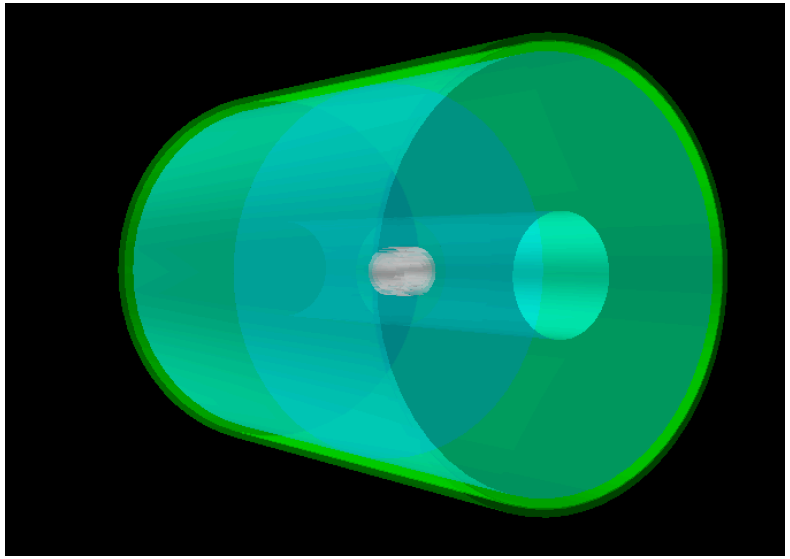
1. Reducing the radius (and length) of the DIRC makes it significantly less expensive.
2. The proximity to the central tracker gives a better angular resolution for the incident track.
3. The shorter DIRC bar will suffer less from chromatic dispersion and will offer better timing.

There are, however, also some disadvantages:

1. Adding 0.15 - 0.20 r.l. of material in front of the gas Cherenkov will expose it to δ-electrons.
2. The proximity to the collision point will increase the solid angle covered by the expansion volume.
3. The increased distance to the TOF will reduce the timing benefits of the TOF detector.
4. It would not allow extending the DIRC bars outside of the endcap as they would interfere with the electron tracking at intermediate angles.

TPC Parameter Study

- Simulation samples with every combination of the following detector options was created:
  - For the TPC:
    - Transverse Resolution: {70, 90, 110} μm
    - Transverse Dispersion: {20, 40, 60} $\mu m/\sqrt{D}$
    - Longitudinal Resolution: {250, 500} μm
    - Longitudinal Dispersion: {0.5, 1.0, 1.5} $\mu m/\sqrt{D}$
    - Pad Size: {0.5, 1.0}. cm
- Each detector configuration was tested with simulations for every combination of:
  - Electron momentum: {1, 2, 3, 4, 5, 6, 7, 8}
  - Electron polar angle: {43, 66, 89}
  - Parameterization done at:
    - Interaction Point
    - DIRC
    - Post-DIRC
- Simulations includes 4 layers of silicon vertex detector ($20\mu m \times 20\mu m$)



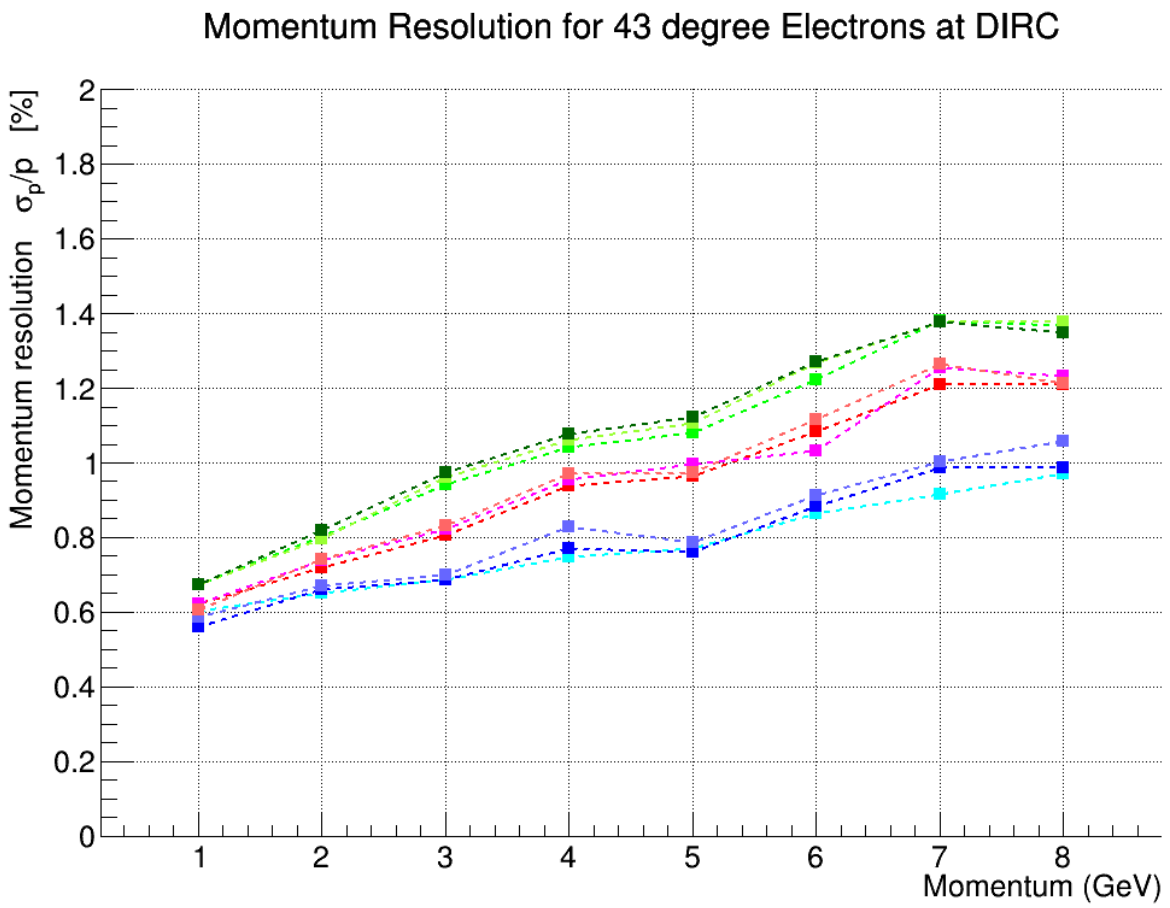
NOTE: Following slides only show DIRC parameterizations for 43 Degree electrons, 1000 events per point

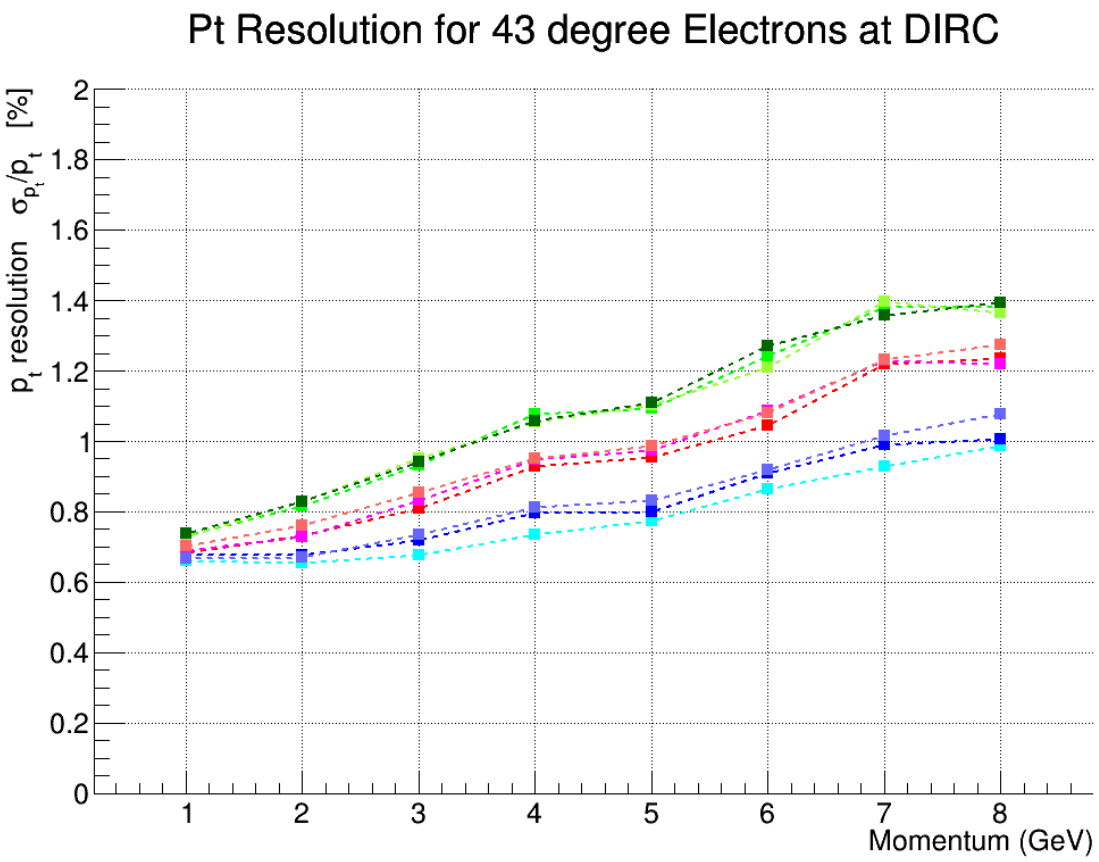
TPC: Transverse Resolution/Dispersion

- Residuals are mostly sensitive to the dispersion (20/40/60 $\mu m/\sqrt{D}$)
- Most sensitivity is in momentum/ p_t
- Experimental results give estimates for these transverse values (Resolution: **90**, Dispersion: **40**)

Transverse Intrinsic Resolution x Dispersion (μm)

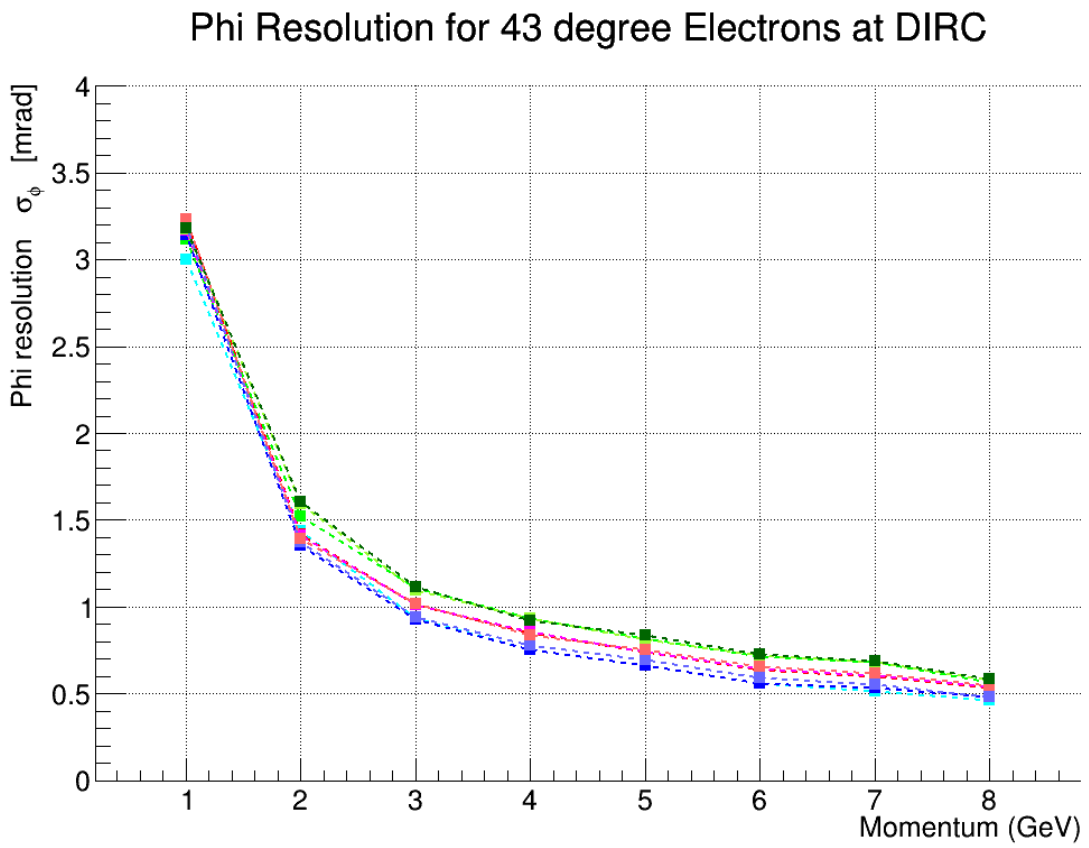
70x20	90x20	110x20
70x40	90x40	110x40
70x60	90x60	110x60

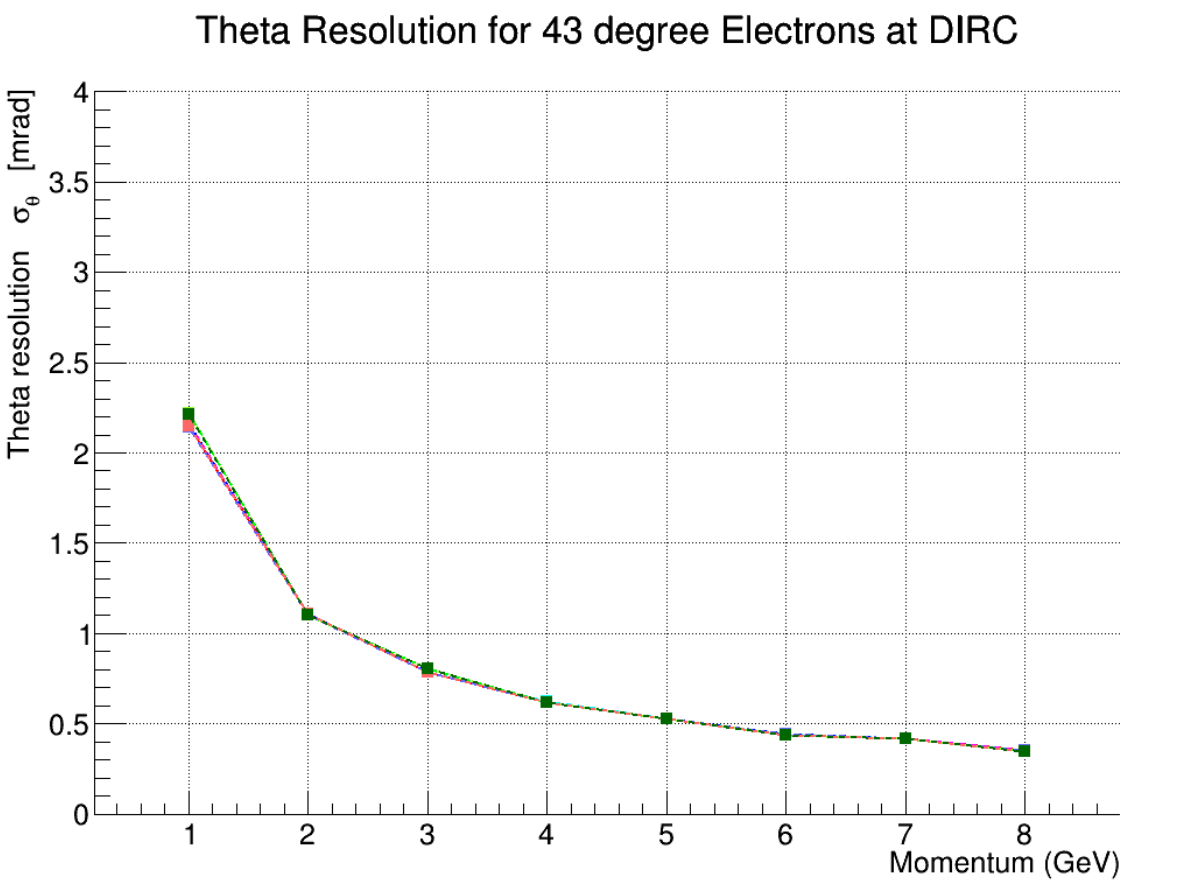




TPC: Transverse Resolution/Dispersion

- Residuals are mostly sensitive to the dispersion (20/40/60 $\mu m/\sqrt{D}$)
- Little sensitivity in phi
- Effectively no sensitivity in theta
- Experimental results give estimates for these transverse values (Resolution: **90**, Dispersion: **40**)



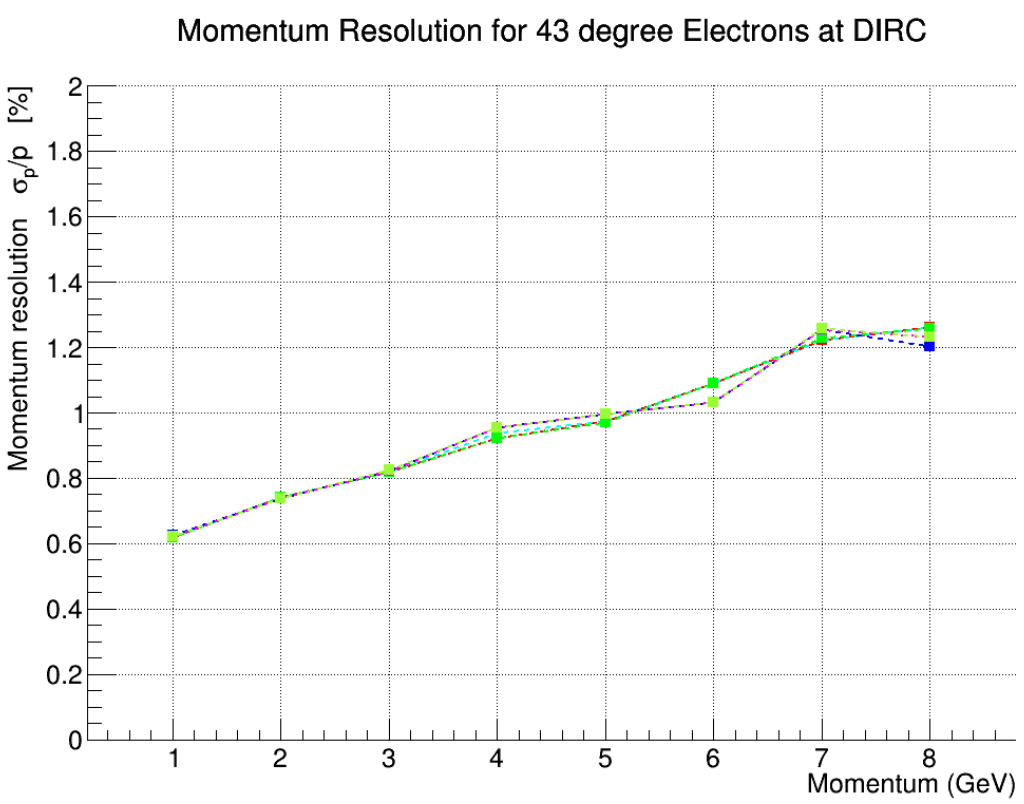


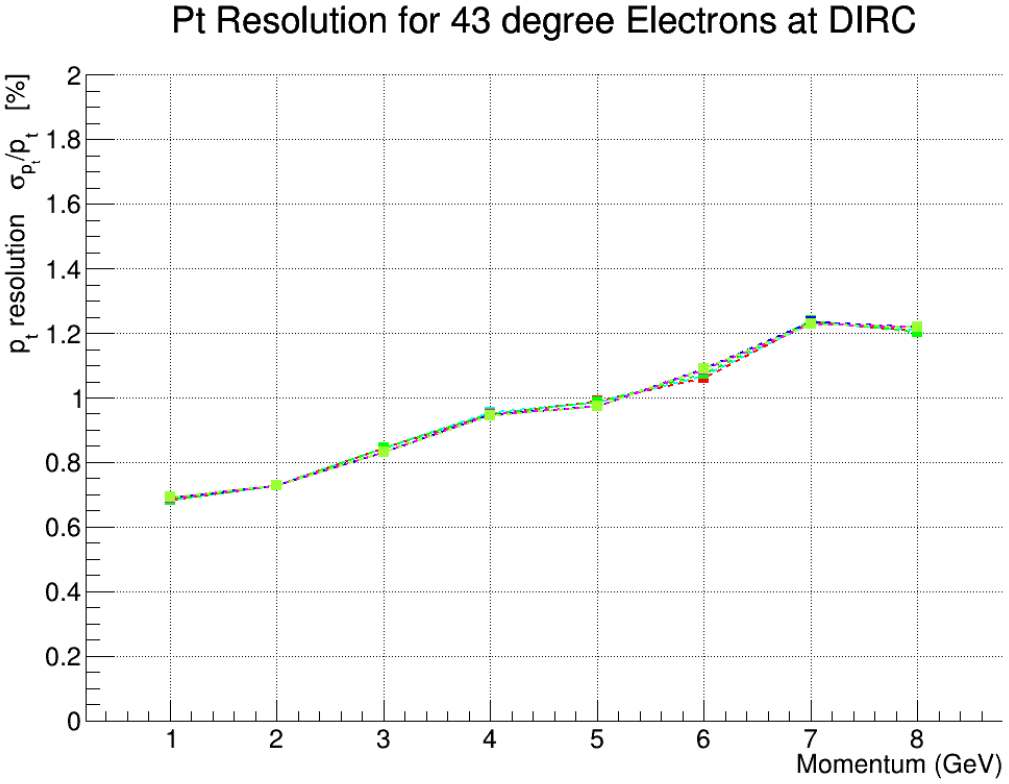
TPC: Longitudinal Resolution/Dispersion

- Residuals largely insensitive to the parameter changes investigated (nominal values in **bold**)
  - Long. resolution: 250 and **500** μm
  - Dispersion: 0.5, **1.0**, and 1.5 $\mu m/\sqrt{D}$
- These are the values for which there is no experimental results for
  - But there is **little sensitivity** to these values when varying by %50 of the default values

Longitudinal Intrinsic Resolution x Dispersion (μm)

- 250x0.5
- 250x1.0
- 250x1.5
- 500x0.5
- 500x1.0
- 500x1.5





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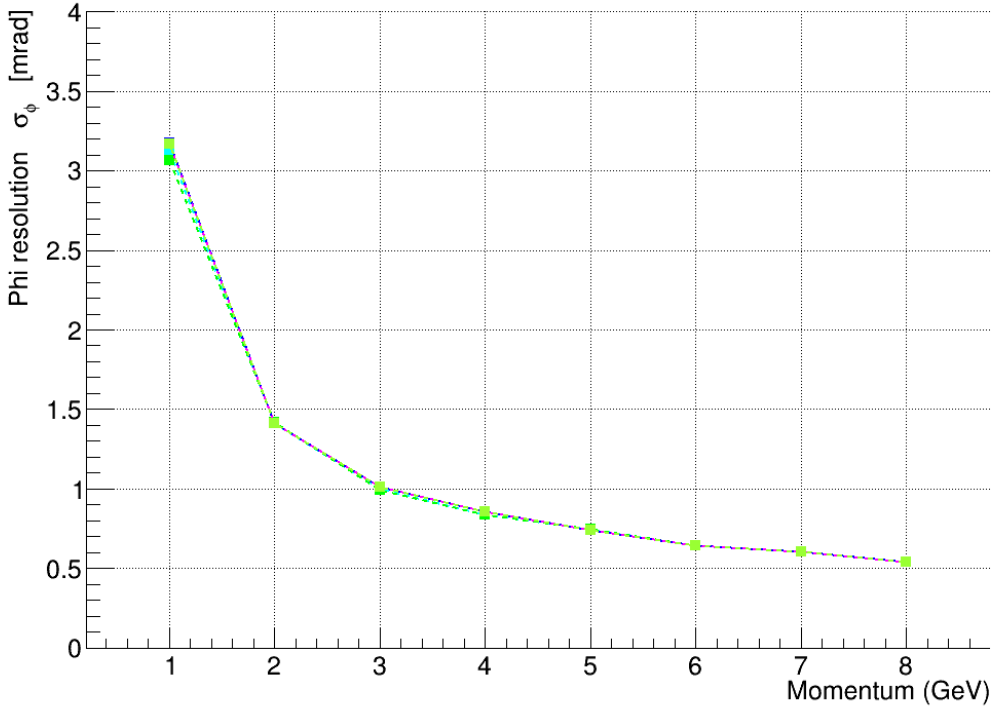
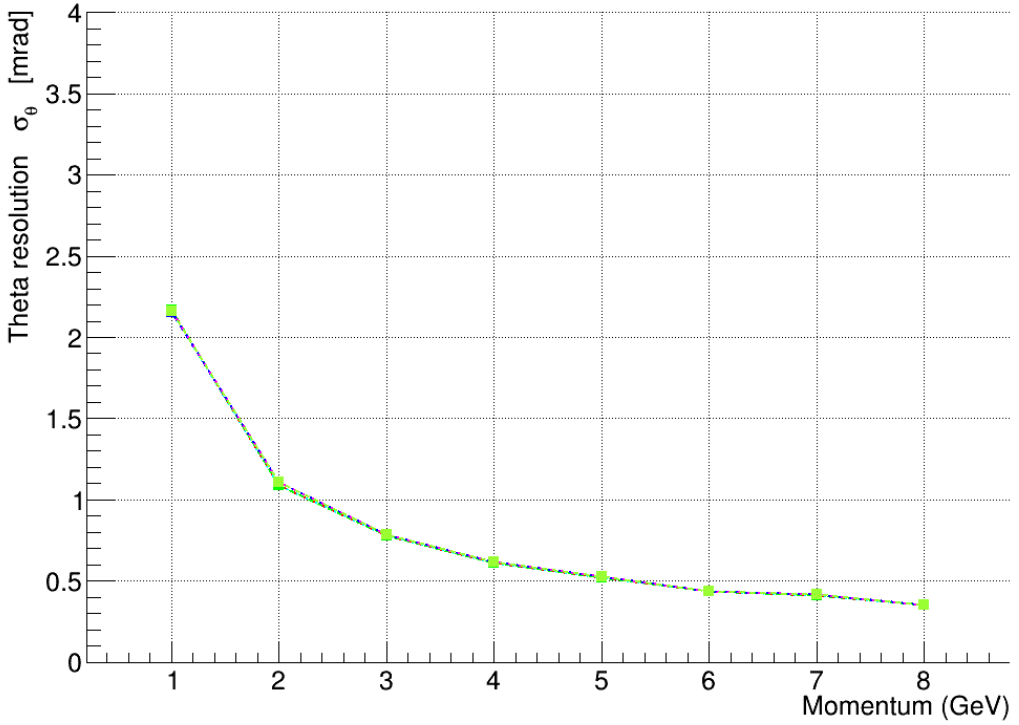
Longitudinal Intrinsic Resolution x Dispersion (μm)

- 250x0.5
- 250x1.0
- 250x1.5
- 500x0.5
- 500x1.0
- 500x1.5

Phi Resolution for 43 degree Electrons at DIRC

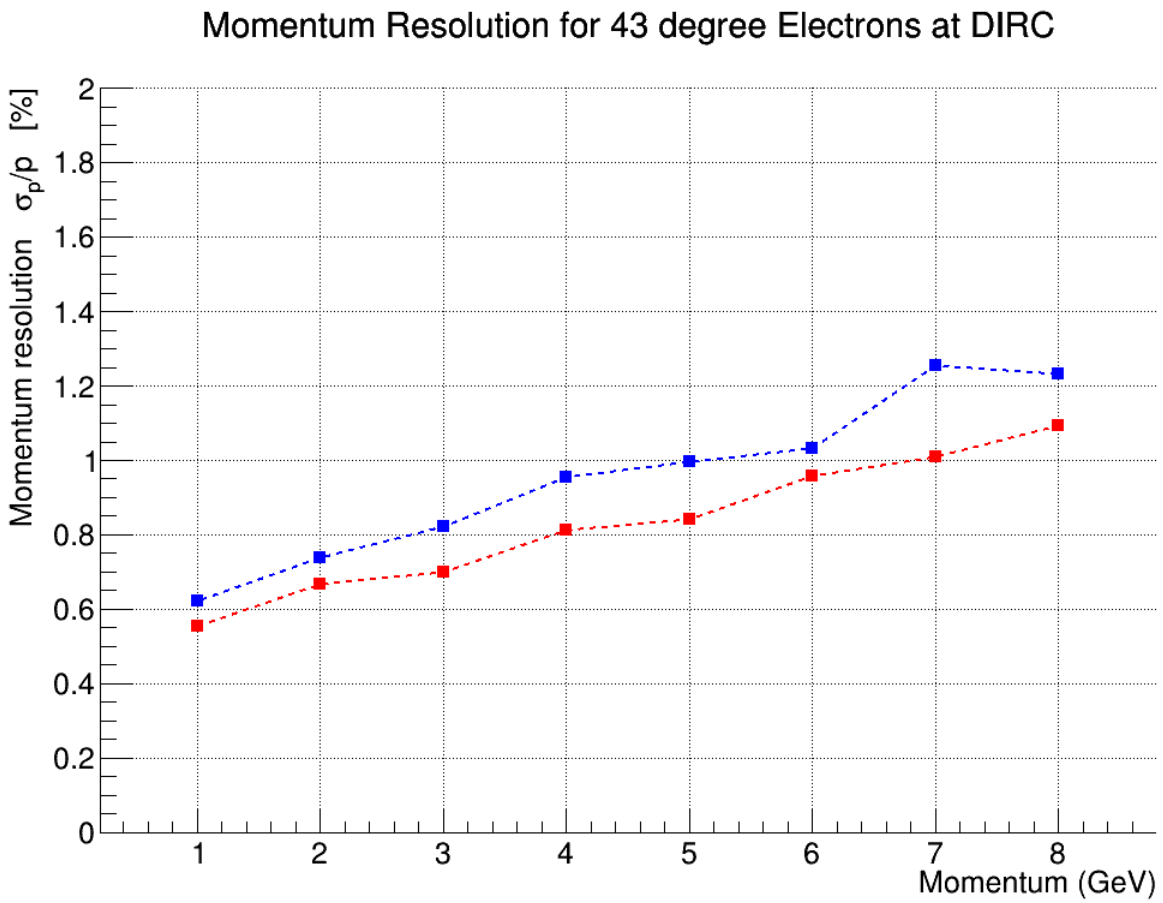


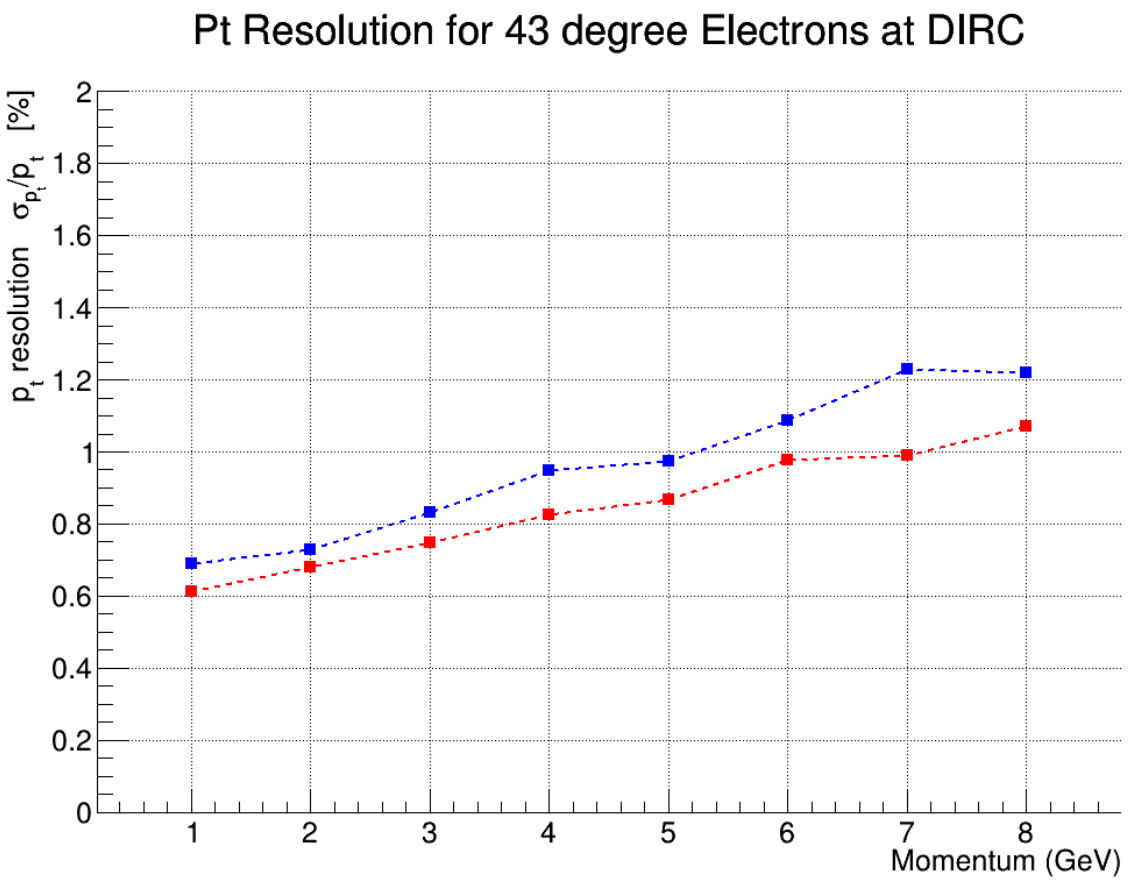
Theta Resolution for 43 degree Electrons at DIRC



TPC: Pad Size

- Each parameter shows a dependence on the pad size. With smaller pad sizes performing better.
  - 0.5 cm
  - 1.0 cm (more realistic)





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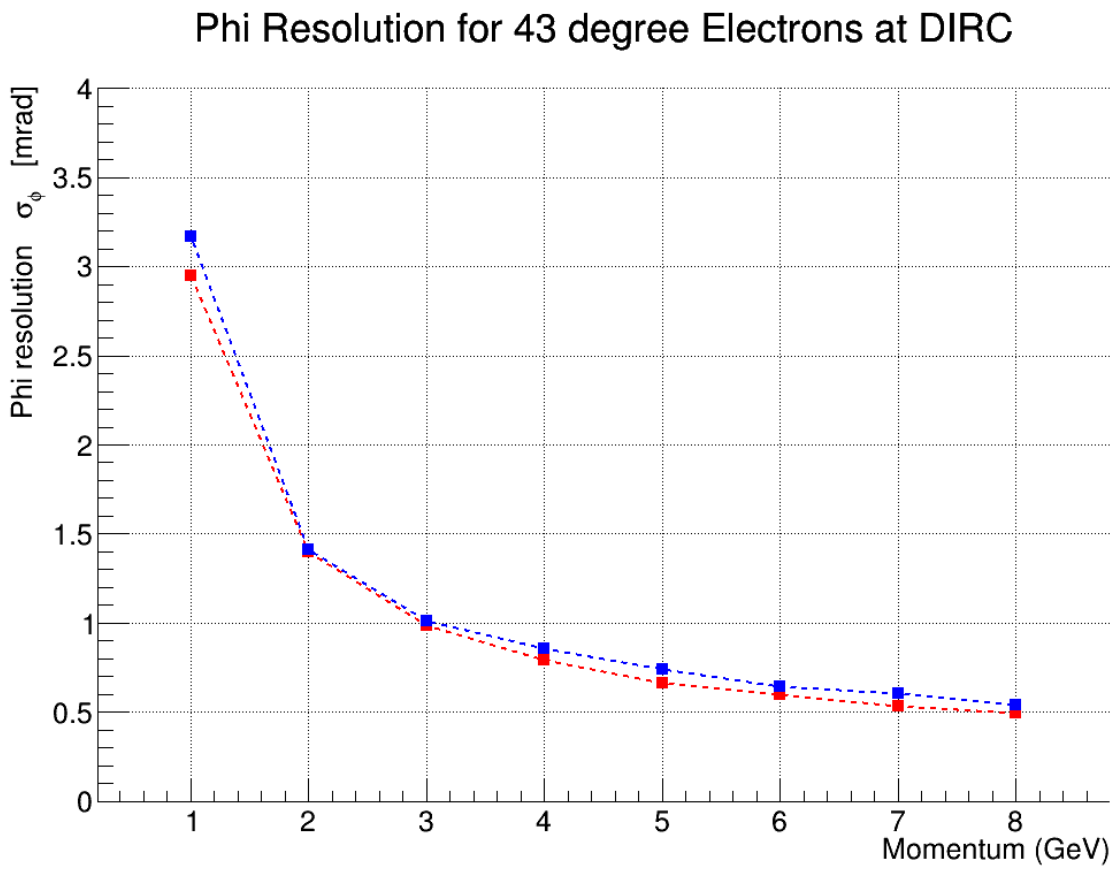
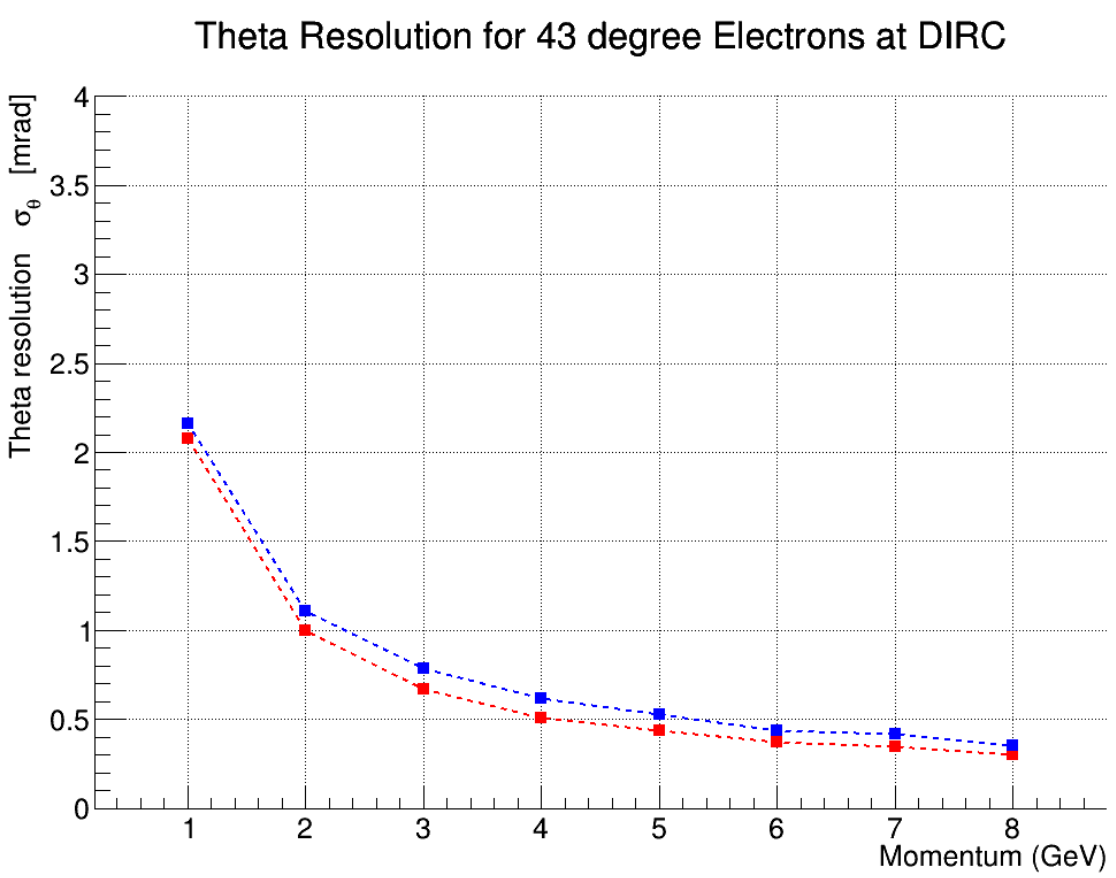
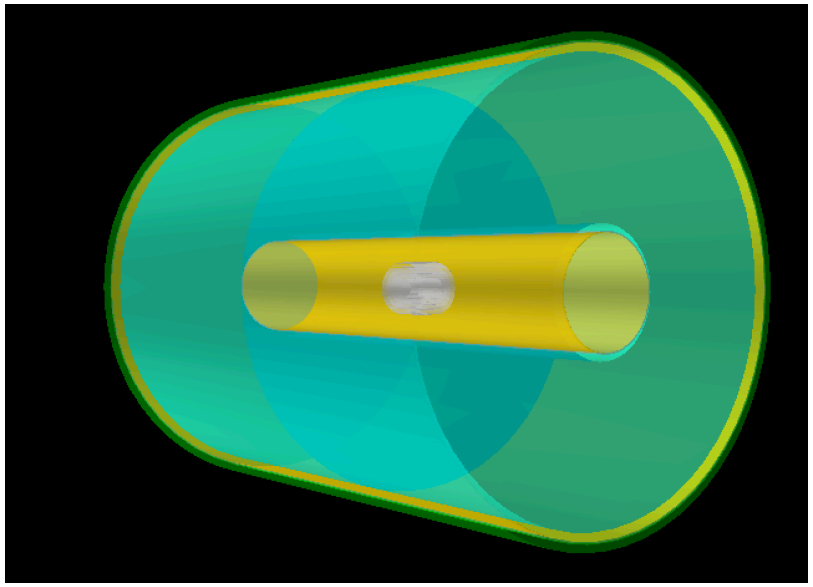


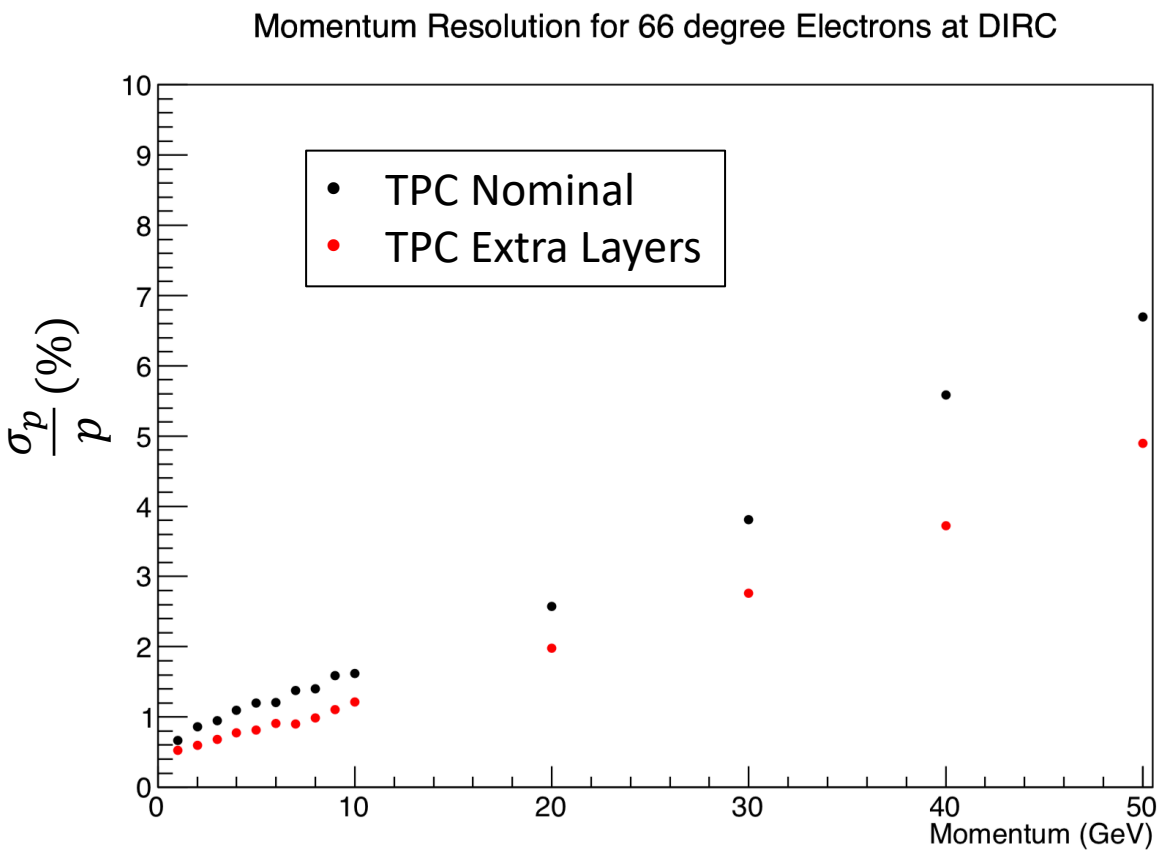


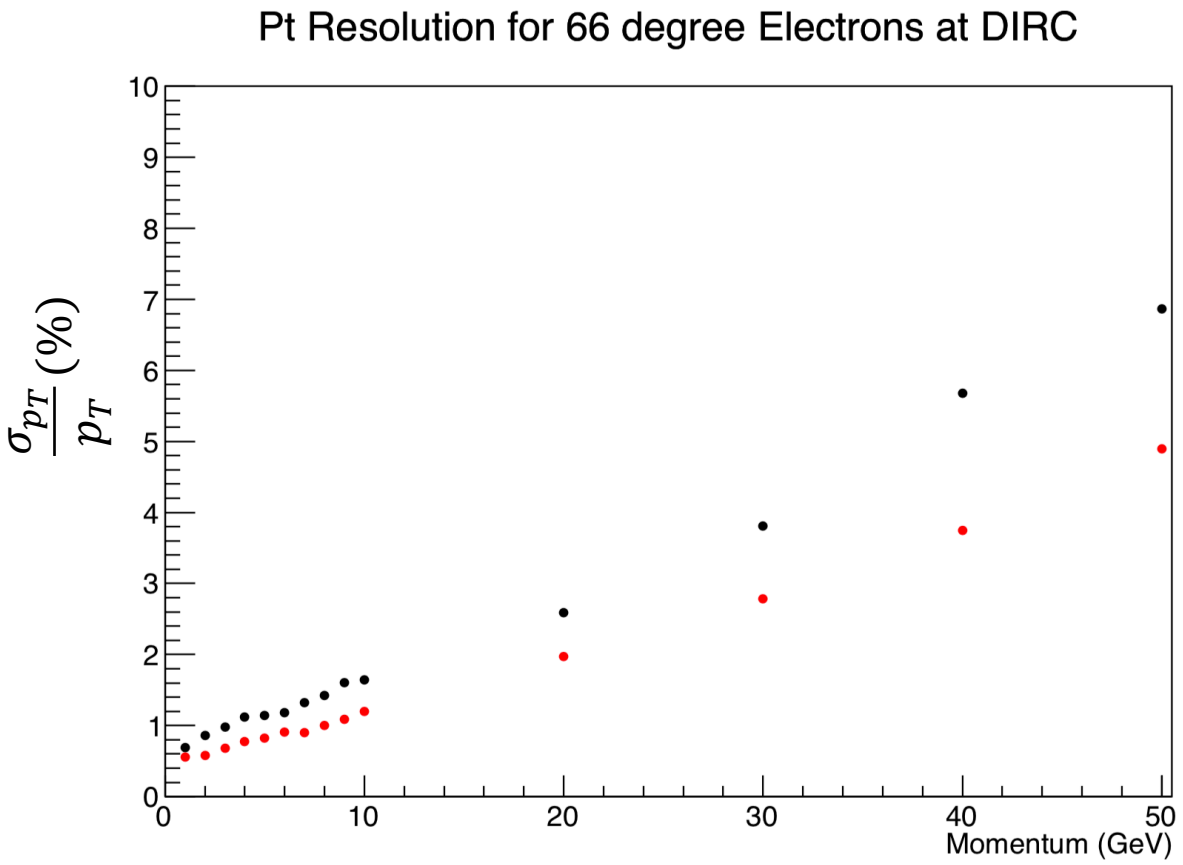
MPGD Cylindrical Support Layers



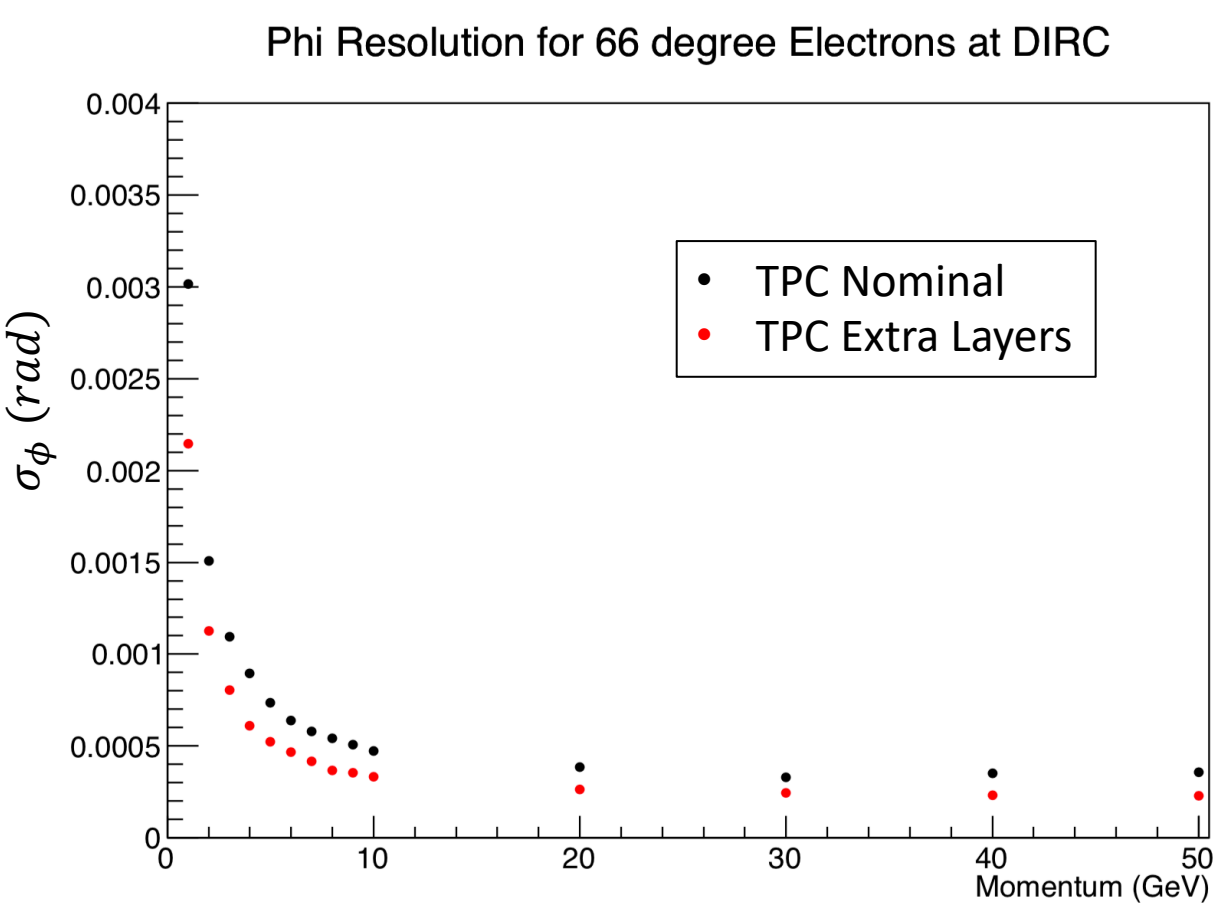
TPC configuration with 2 fast μRWELL ($100\mu m \times 100\ \mu m$) inner and outer layers

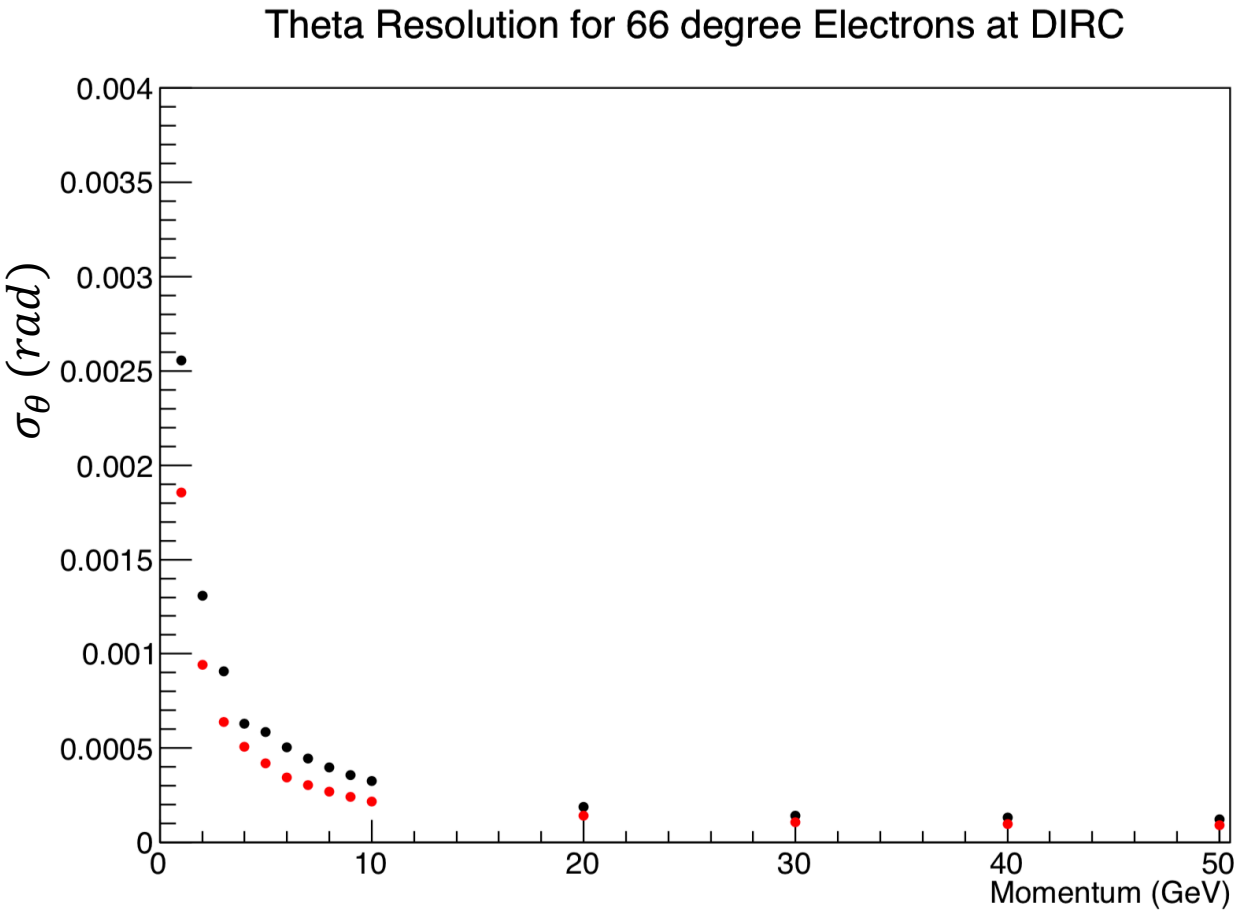
TPC + Cylindrical MPDG Tracker Performance





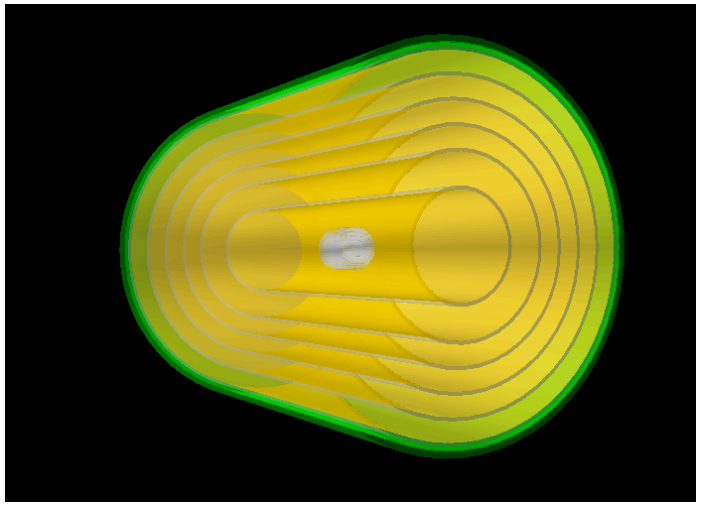
TPC + Cylindrical MPDG Tracker Performance





Cylindrical MPGD Barrel

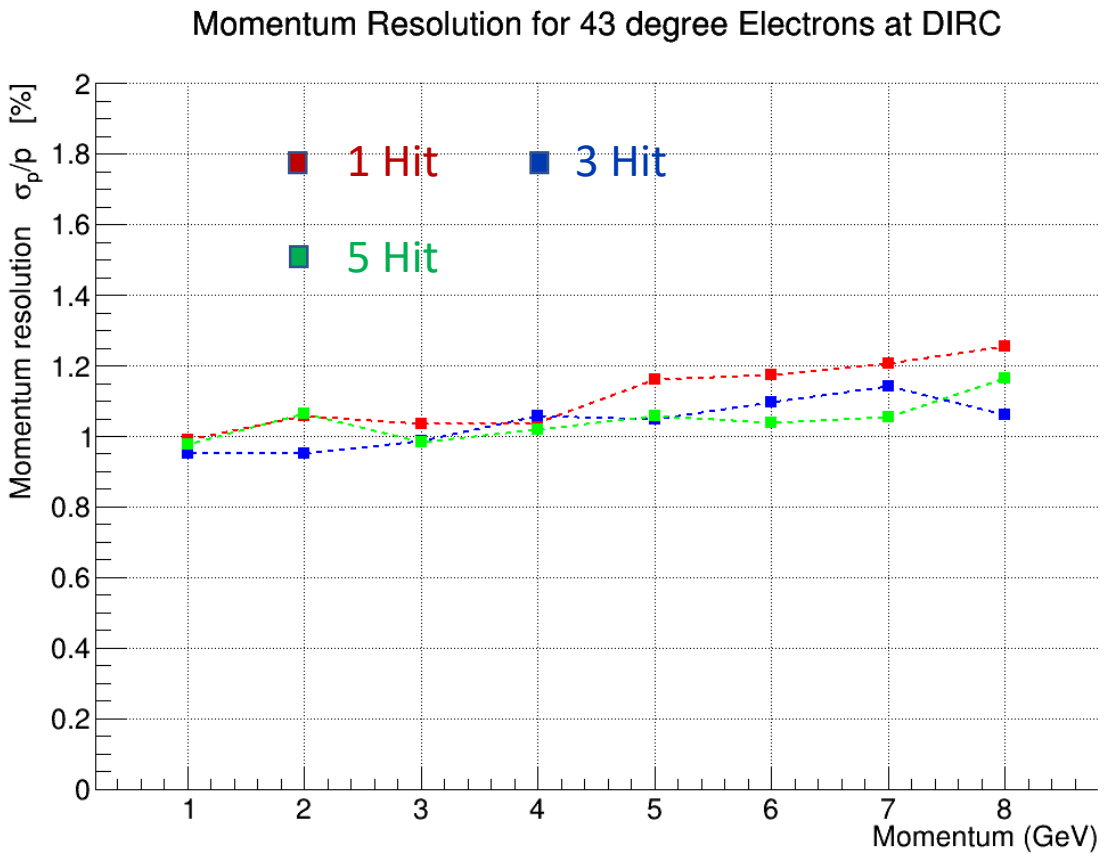
- Simulation samples with every combination of the following detector options was created:
  - For the uRWELL:
    - Intrinsic Resolution: {100, 150} μm
    - Hits per Layer: {1, 3, 5}
- Each detector configuration was tested with simulations for every combination of:
  - Electron momentum: {1, 2, 3, 4, 5, 6, 7, 8}
  - Electron polar angle: {43, 66, 89}
  - Parameterization done at:
    - Interaction Point
    - DIRC
    - Post-DIRC
- Simulations includes 4 layers of silicon vertex detector ($20\mu m \times 20\mu m$)

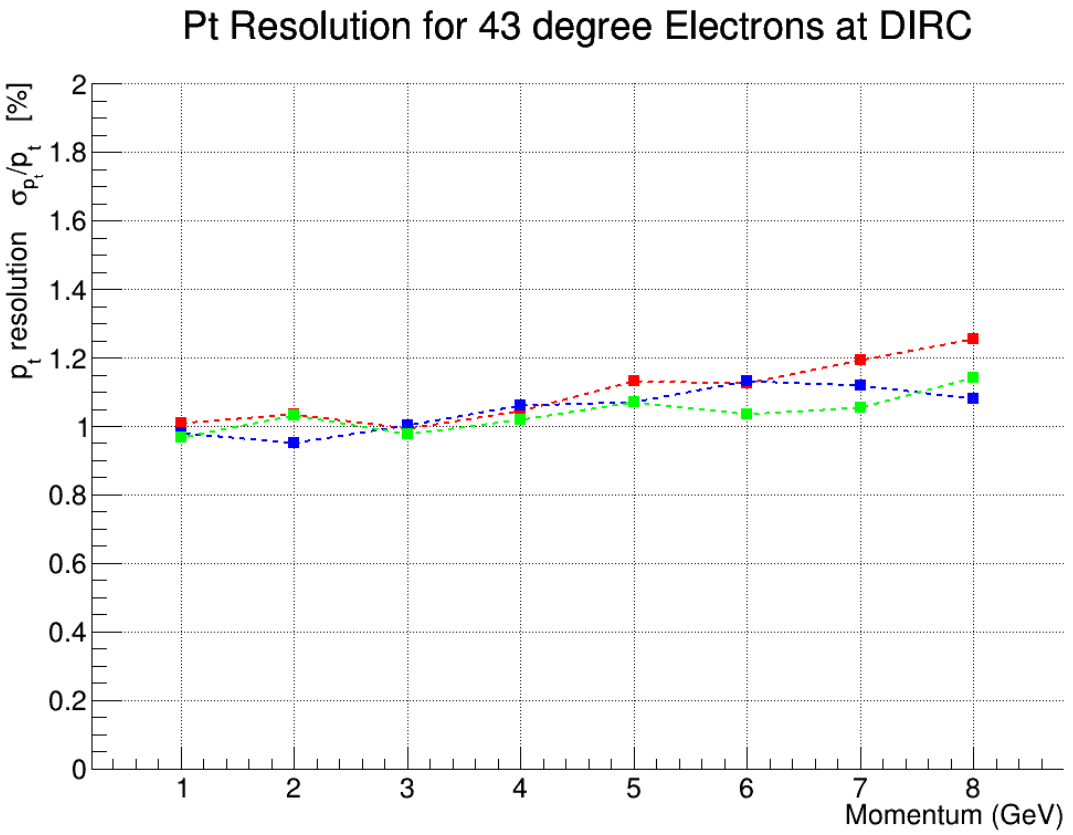


NOTE: Following slides only show DIRC parameterizations for 43 Degree electrons, 1000 events per point

Performance with Number of Hits

- When operating in μTPC mode, the MPGD will see several hits.
- Each parameter shows a dependence on the number of hits. With more hits performing better.





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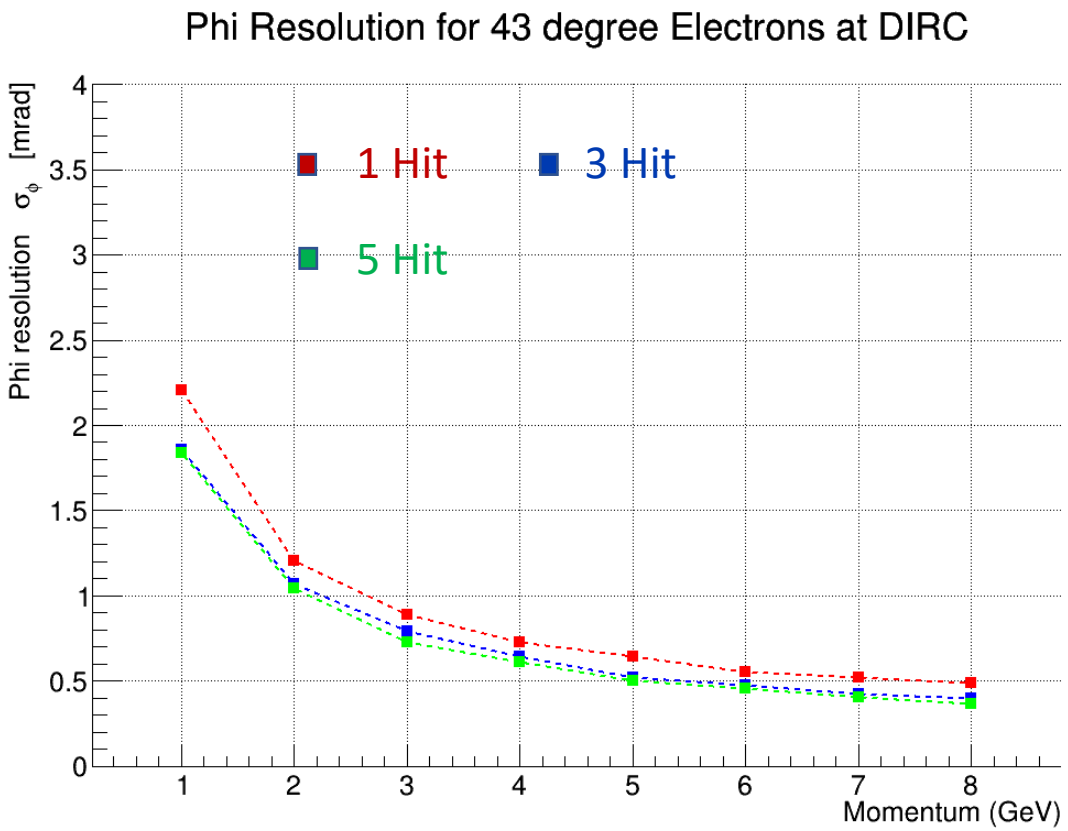
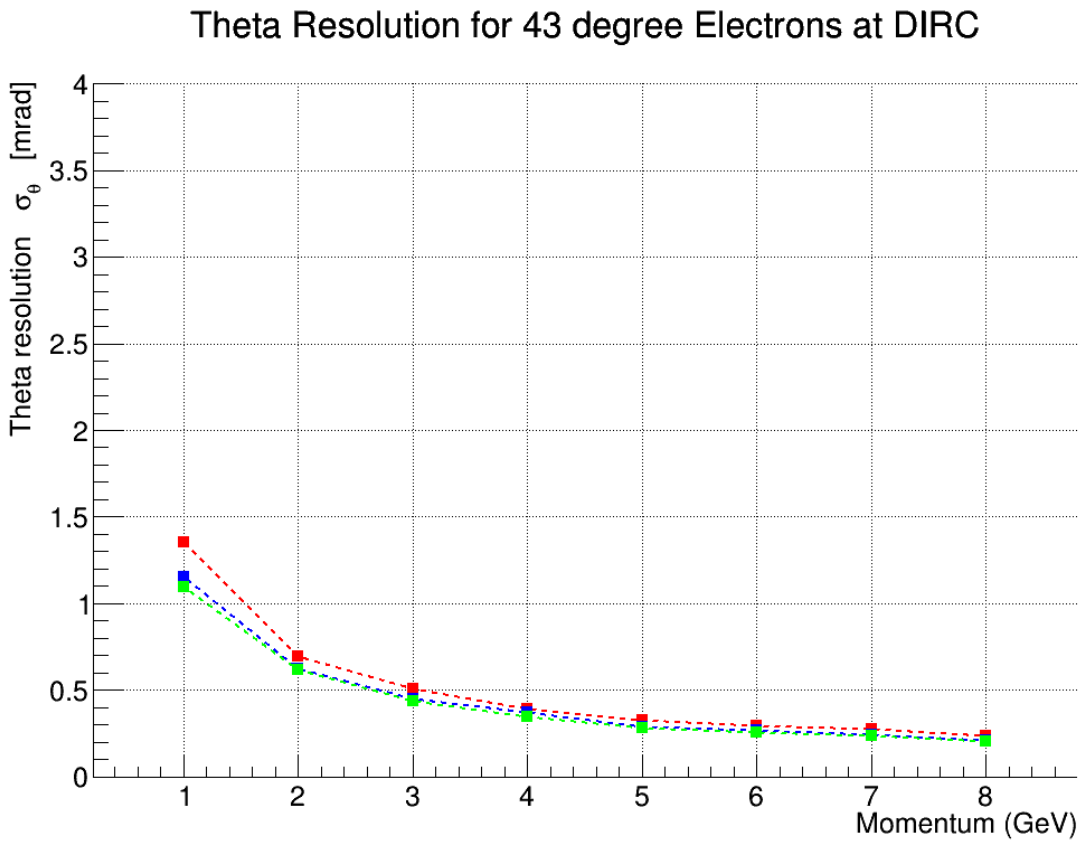
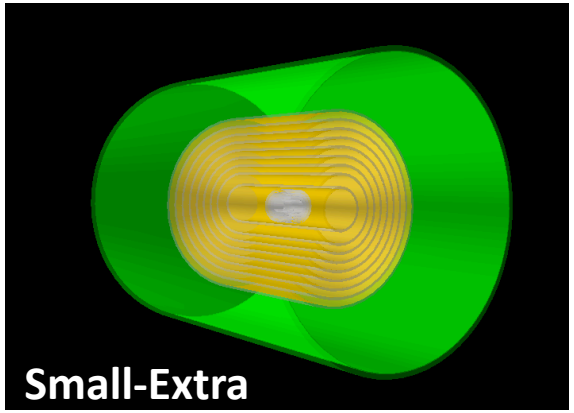
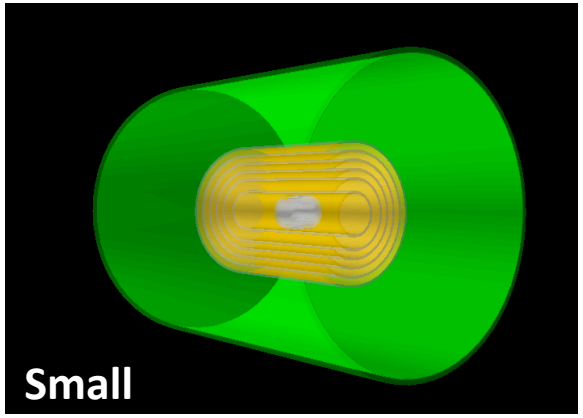




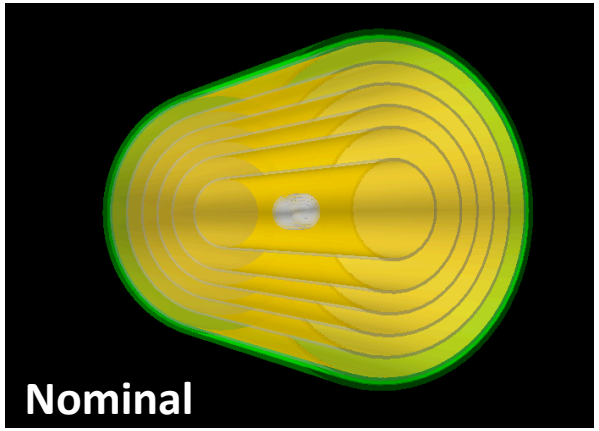
Compact Cylindrical MPGD Barrel Study



Radii of Layers (cm):
11.25, 18.75, 23.75, 28.75, 33.75, 38.75, 43.75, 48.75, 53.75

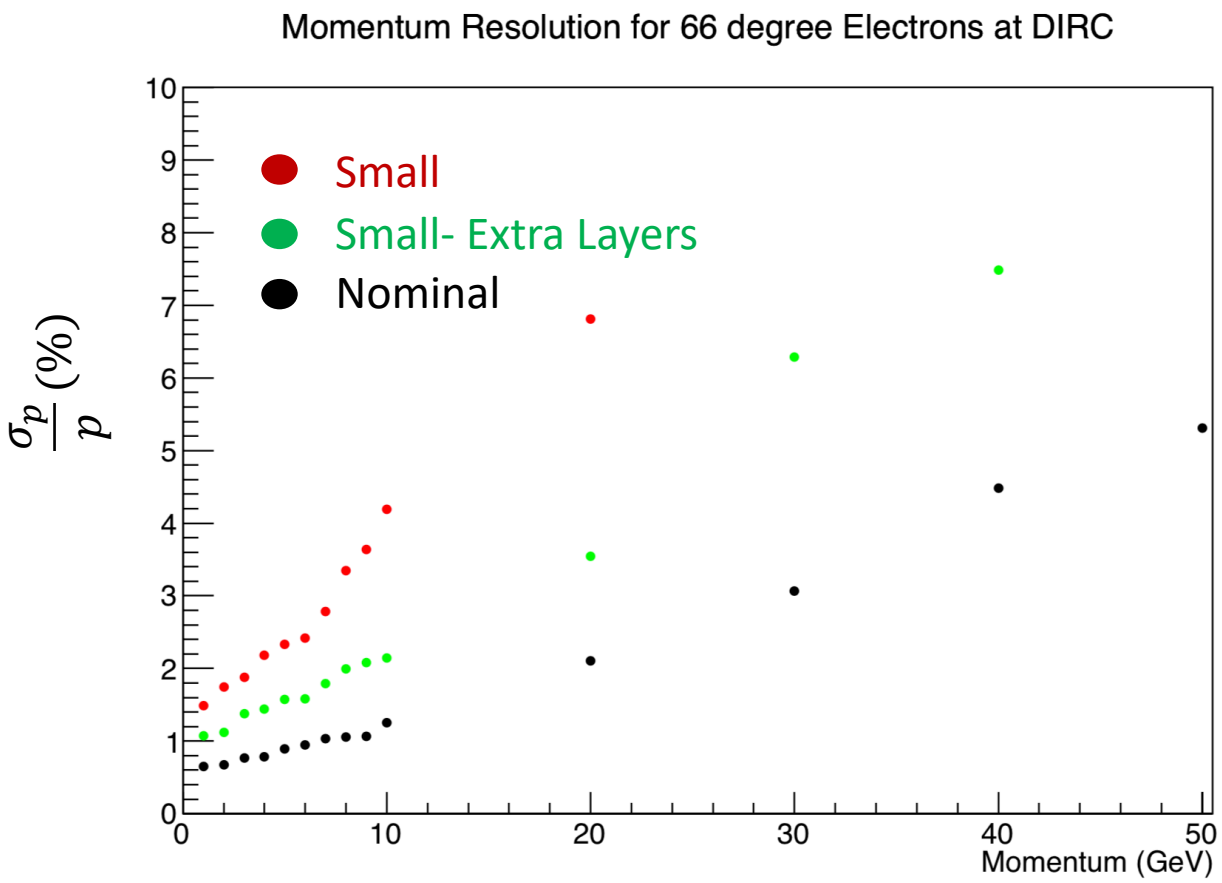


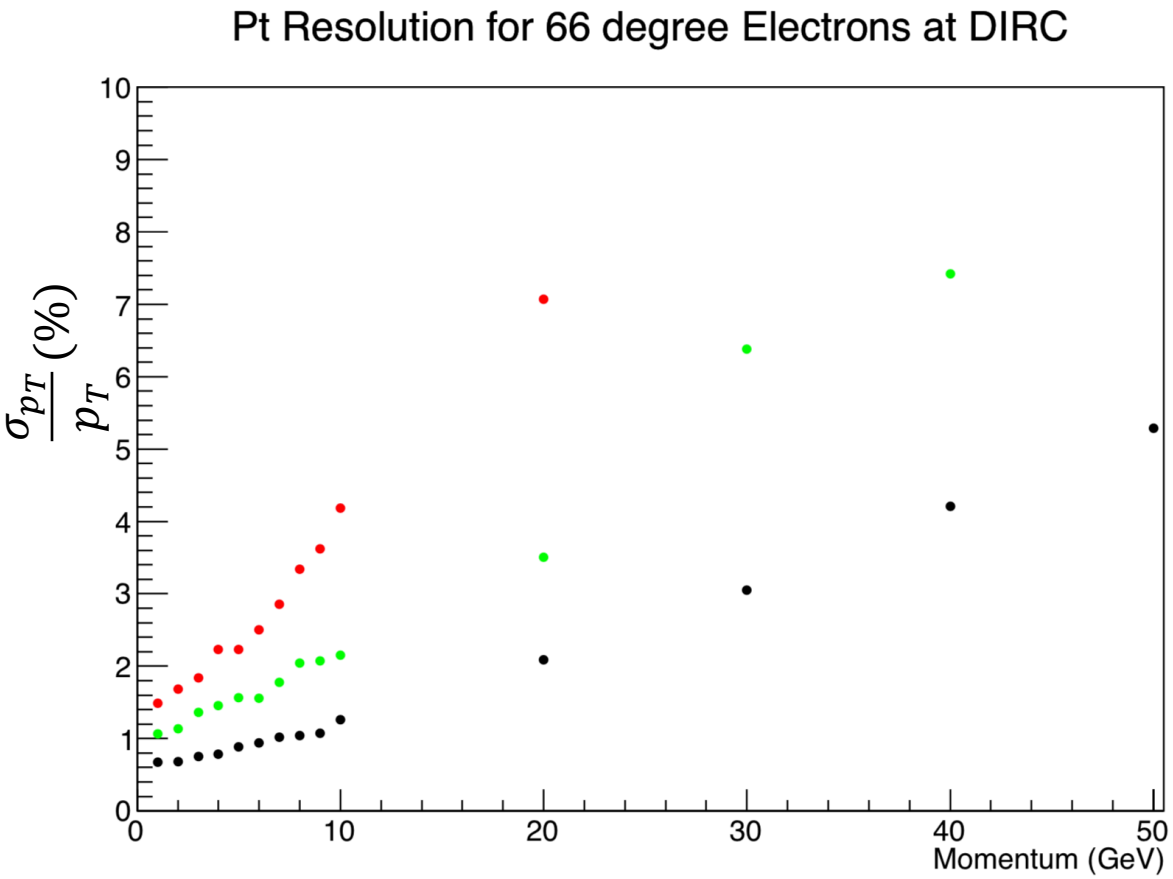
Radii of Layers (cm):
11.25, 18.75, 23.75, 28.75, 33.75, 38.75



Radii of Layers (cm):
22.5, 37.5, 47.5, 57.5, 67.5, 77.5

Compact Cylindrical MPGD Barrel Performance





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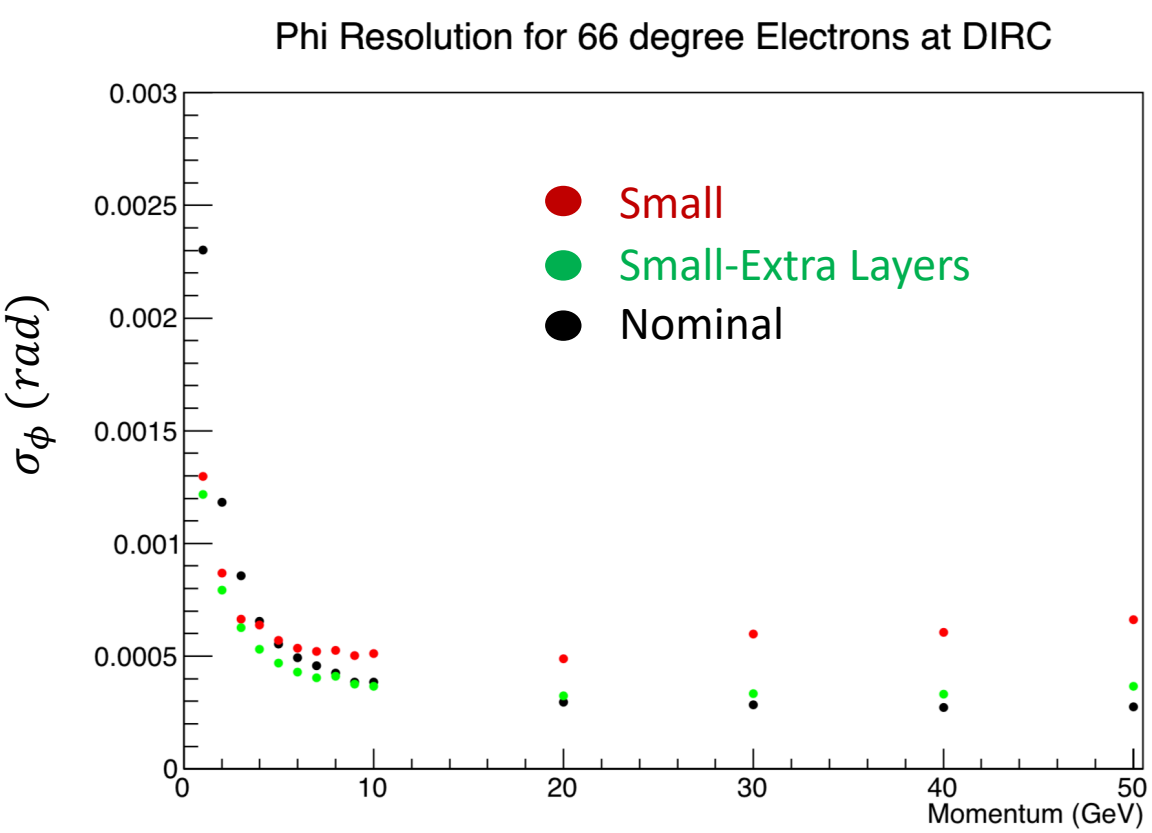
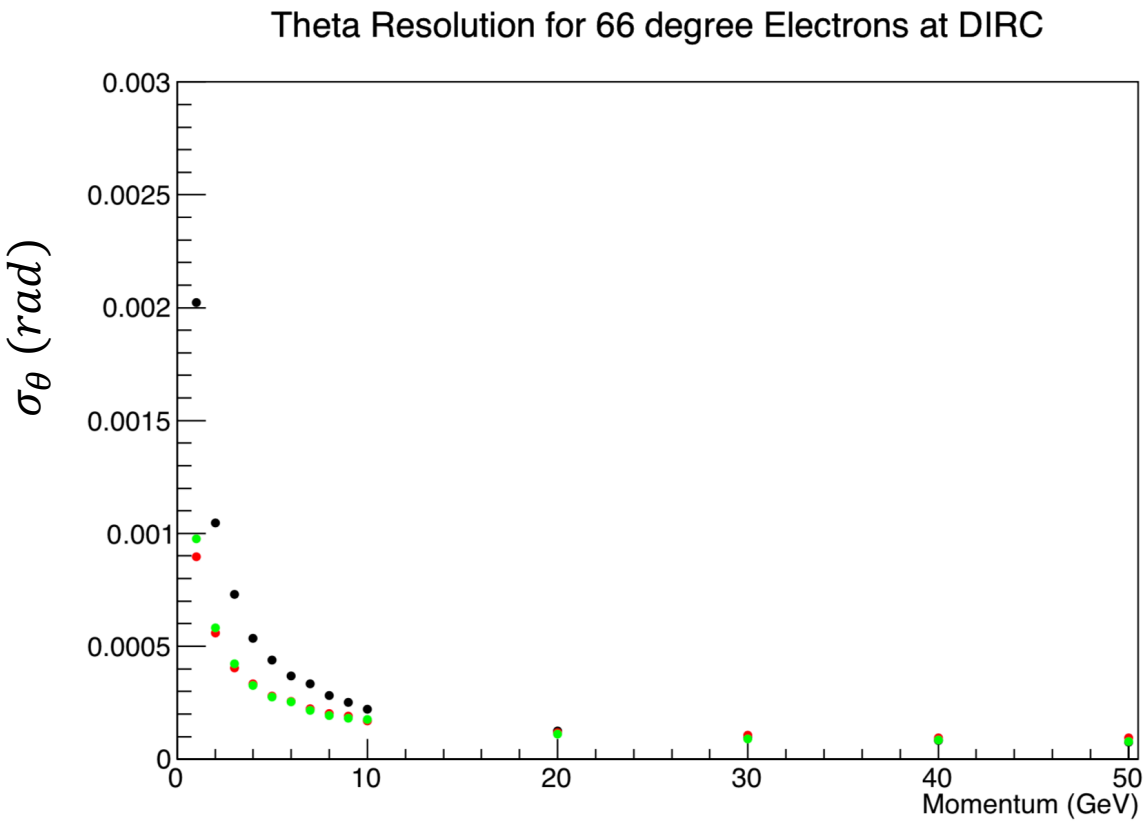


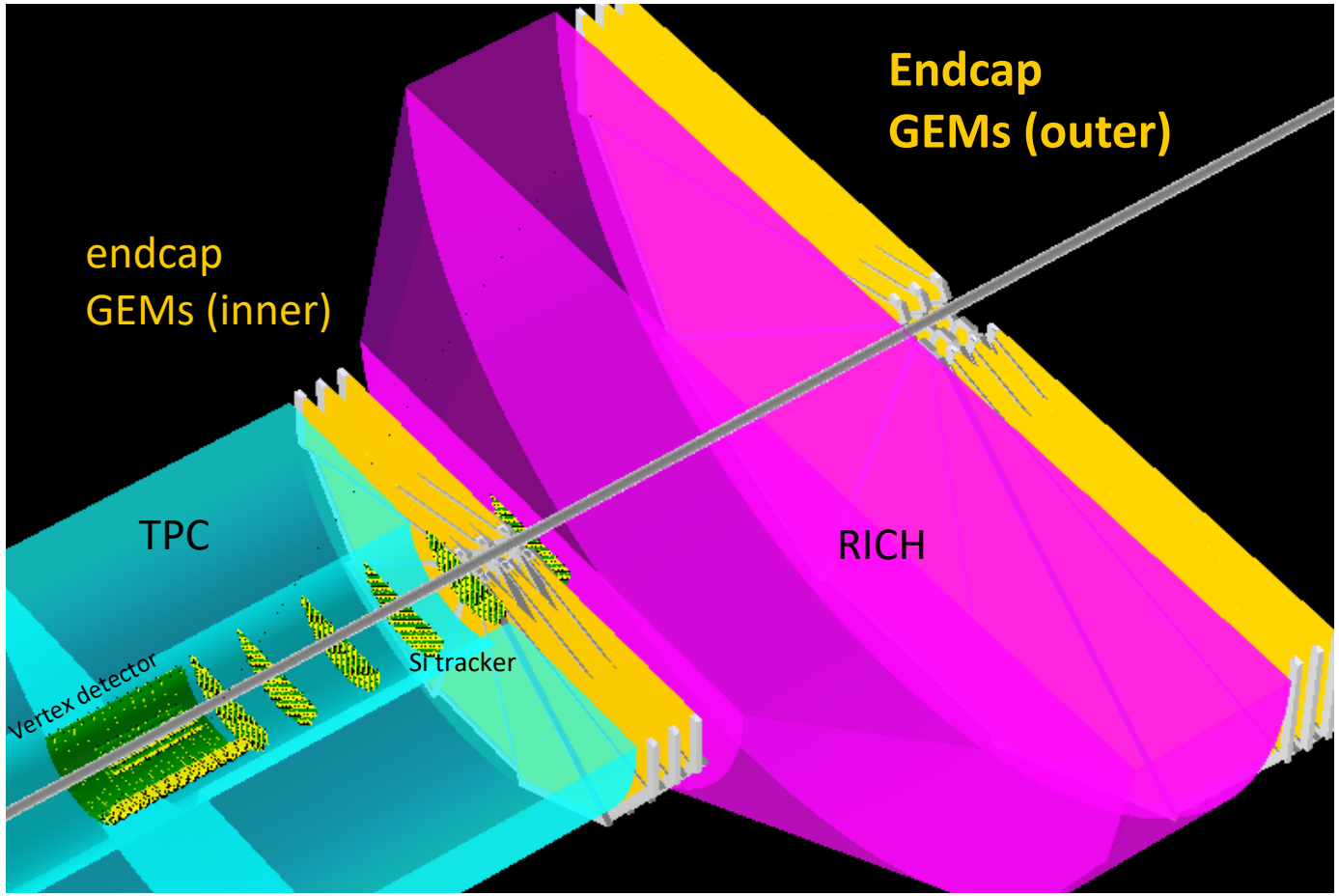


Endcap Tracking Simulations

- Adding outer forward GEM detectors to the BeAST design to improve the precision in measuring track impact points on the RICH, would help with seeding the RICH ring reconstruction
- Begin investigating the impact of endcap GEM (outer) detectors on the track momentum resolution
- Detectors
  - Vertex tracker
  - Silicon tracker
  - Endcap GEMs (inner)
  - Endcap GEMS (outer)
  - TPC
  - RICH volume
  - B = 1.5 T

EIC BeAST Detector simulated using the EicRoot framework (B = 1.5 T)

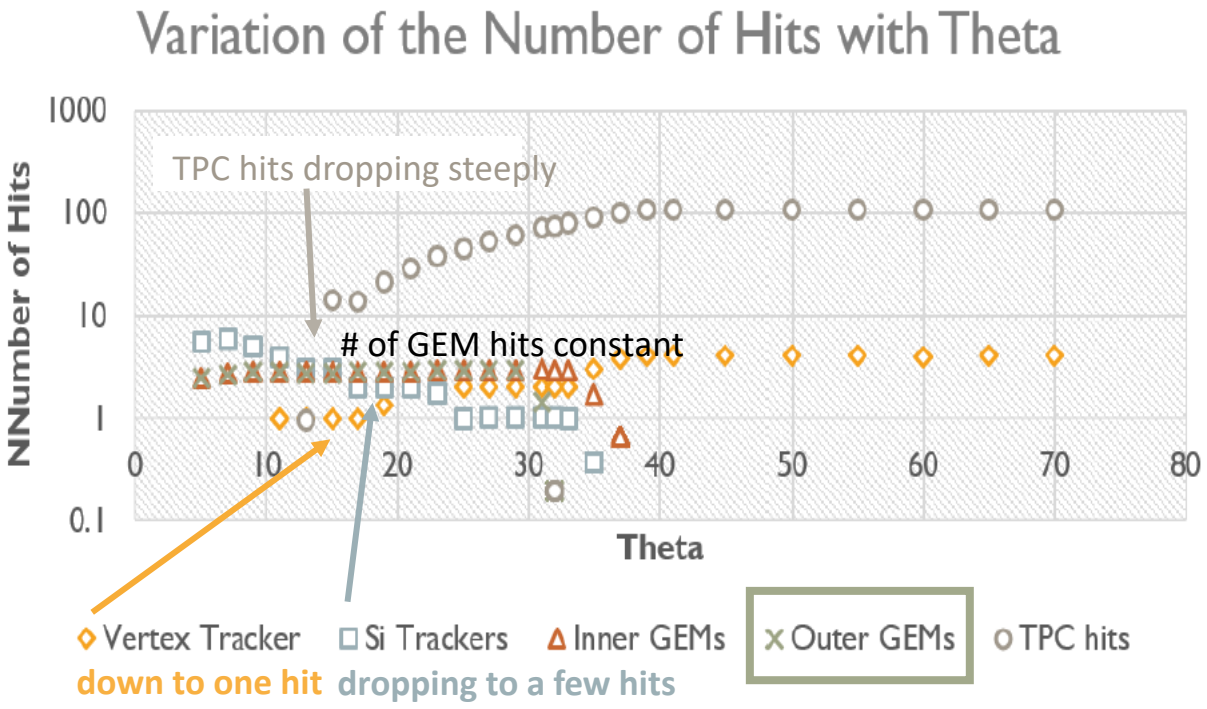
Detectors simulated: Vertex tracker, Silicon trackers, GEMs, TPC, and RICH volume

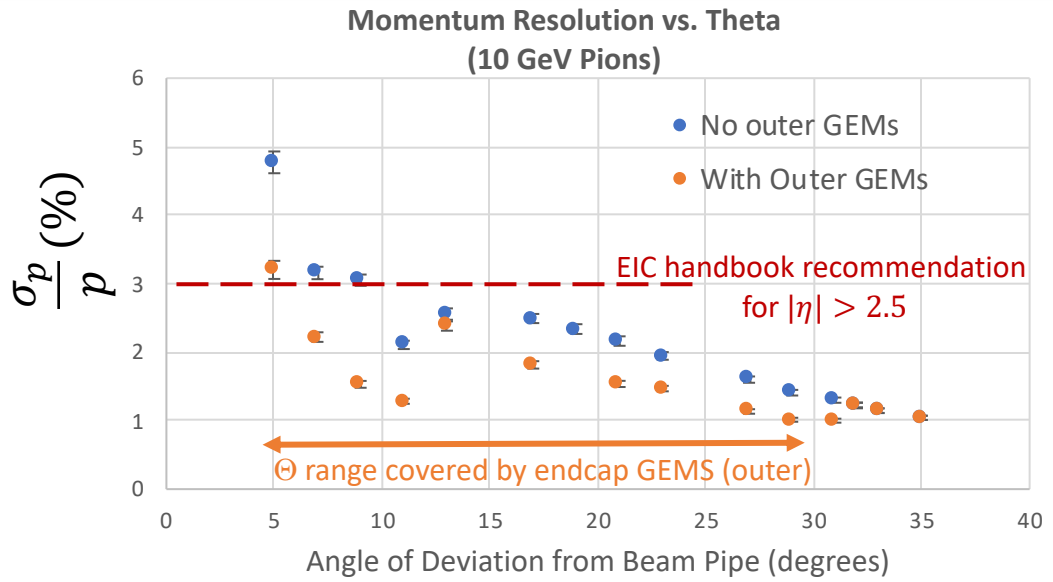


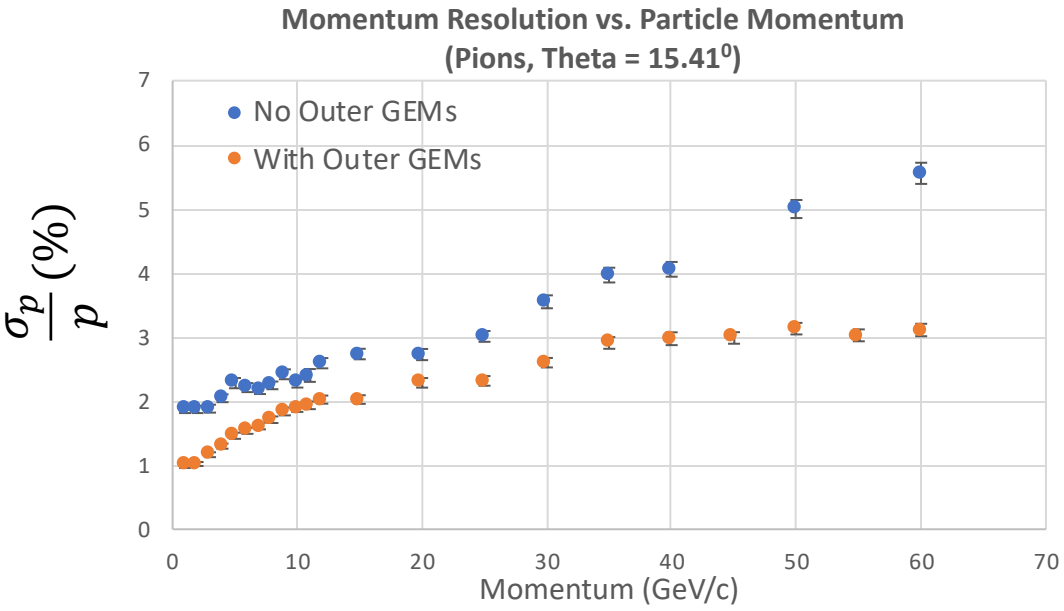
Endcap Tracking Performance

- Significant improvement to momentum resolution for tracks that hit the endcap GEMs (outer)

- Largest improvements at small angles (< 11 degrees) and for high-momentum particles







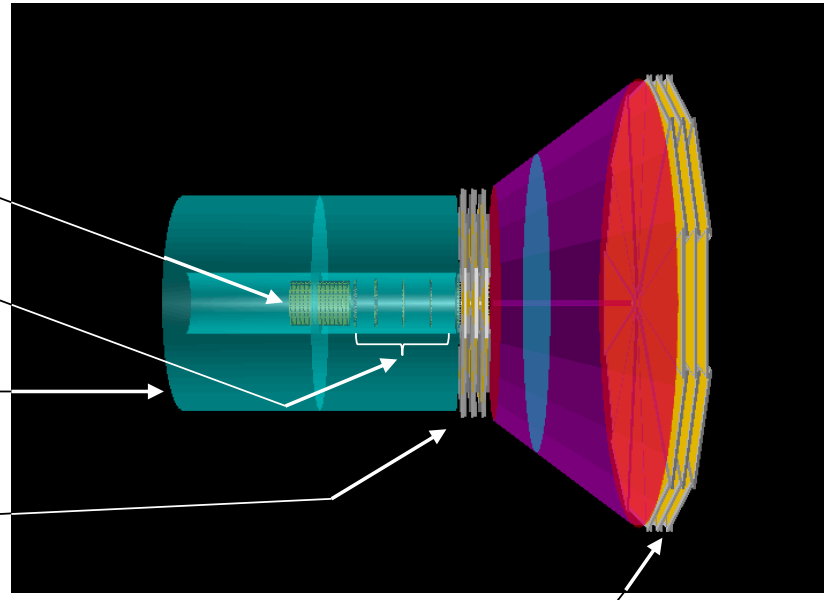
BeAST Detector

- Use a BeAST configuration to study magnetic field strength and tracking resolutions

All “naïve” default resolution parameters*

Detectors:

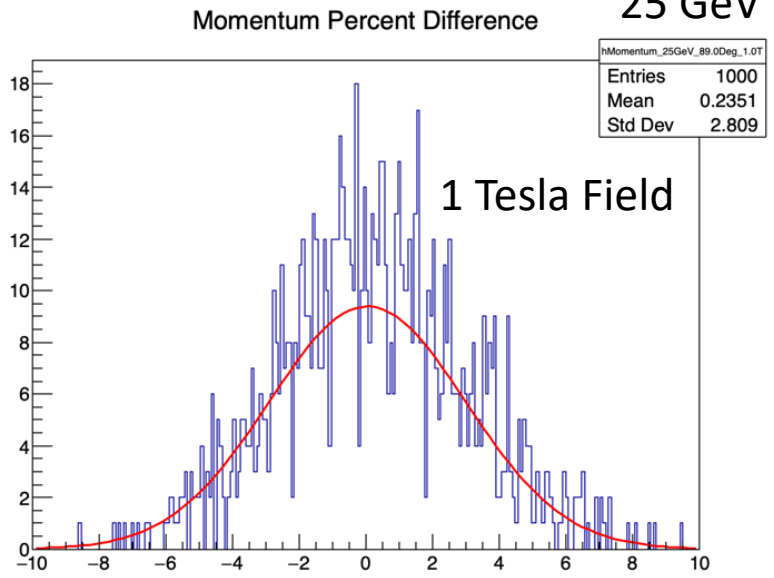
- **Silicon Vertex Tracker**
  - $5.8\ \mu m \times 5.8\ \mu m$ resolution
- **Forward Silicon Trackers**
  - $5.8\ \mu m \times 5.8\ \mu m$ resolution
- **TPC**
  - Intrinsic longitudinal resolution: $500\ \mu m$
  - Intrinsic transverse resolution: $200\ \mu m$
  - Longitudinal dispersion: $1\ \mu m/\sqrt{D[cm]}$
  - Transverse dispersion: $15\ \mu m/\sqrt{D[cm]}$
  - Vertical pad size: 0.5 cm
- **Endcap GEM (inner) Trackers**
  - $50\ \mu m \times 50\ \mu m$ resolution
- **Endcap GEM (outer) Trackers**
  - $100\ \mu m \times 100\ \mu m$ resolution

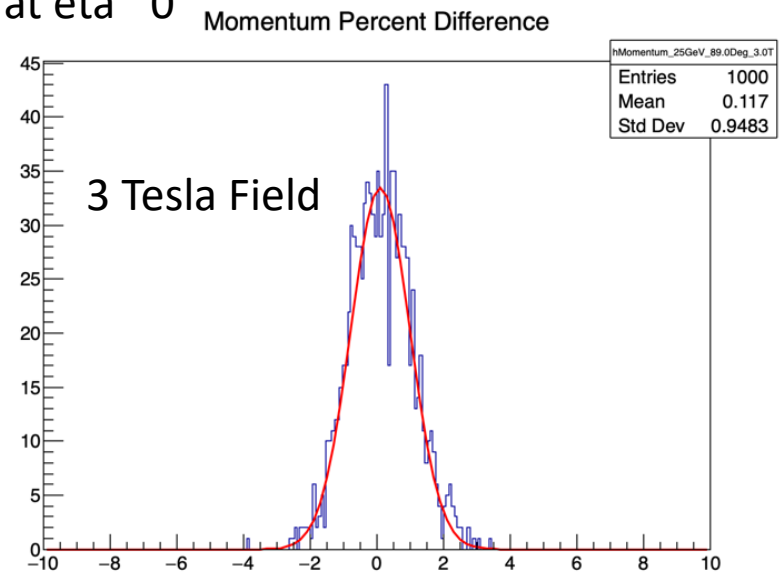


Central Tracking Work

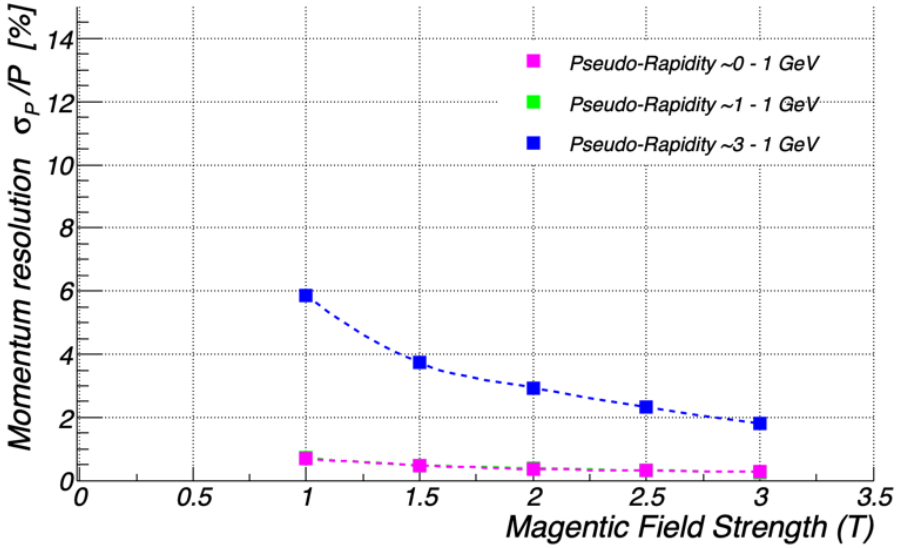
- Simulations were performed in EICRoot.
  - 1000 pions were thrown at $\eta = \{0, 1, 3\}$ and $p = \{1, 10, 25, 50\}\ GeV$
  - This was done for magnetic fields of {1.0, 1.5, 2.0, 2.5, 3.0} Tesla
  - The tracks were reconstructed, and the reconstructed momentum was compared to the actual momentum of the generated track.
  - Distributions of $\frac{(p_{Reconstructed} - p_{Monte\ Carlo})}{p_{Monte\ Carlo}}$ are made, and the standard deviation is taken as the momentum resolution.

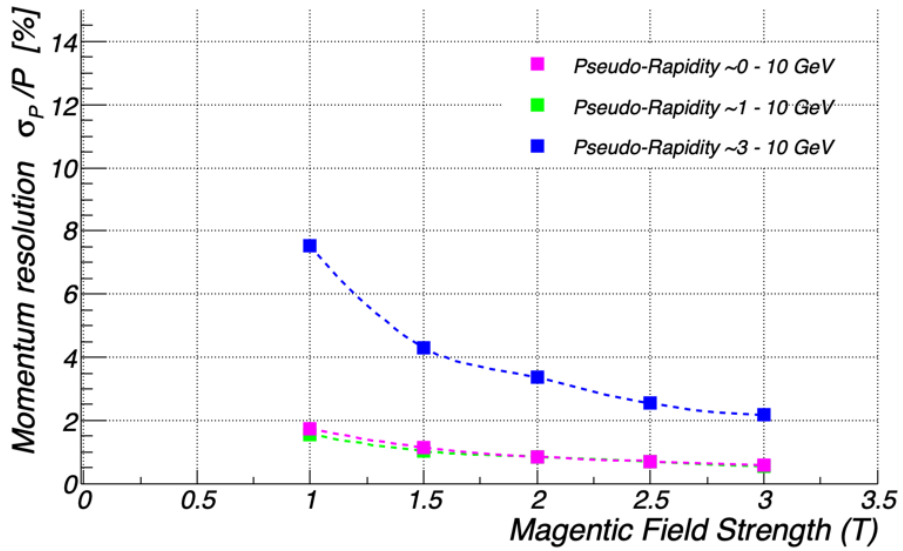
25 GeV Pions at eta ~0

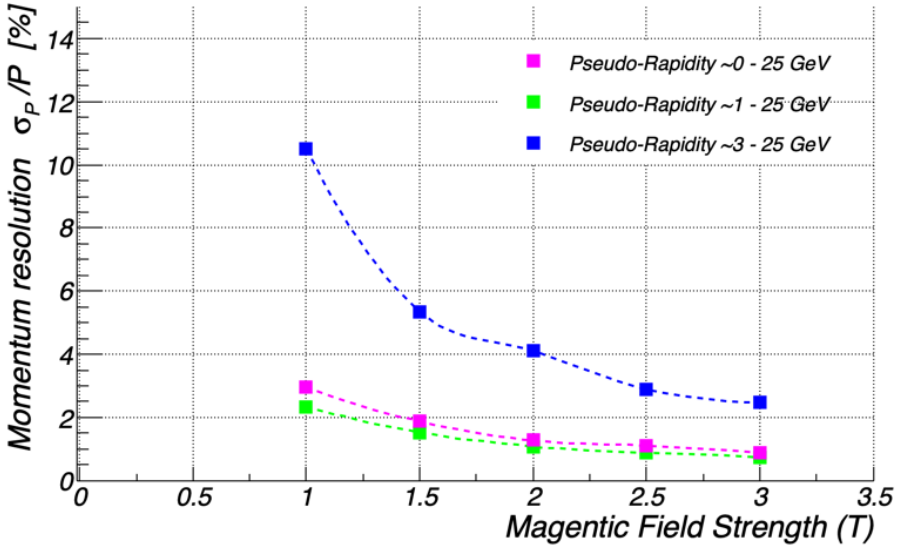


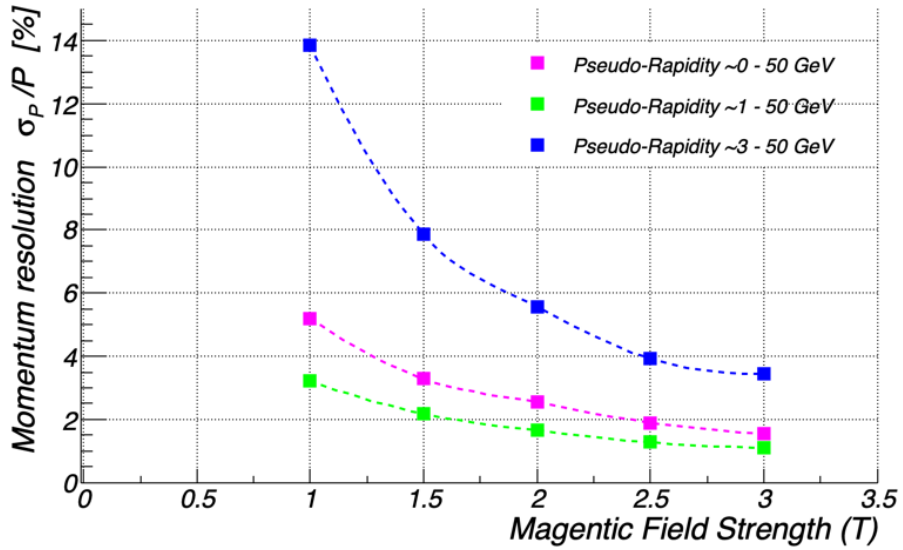


σ_p/p vs. B for Constant p









$\sigma_\theta \; vs. p$ for Different B Values