UNIVERSITY OF BIRMINGHAM | SCHOOL OF PHYSICS AND ASTRONOMY

Tracker Performance Simulations

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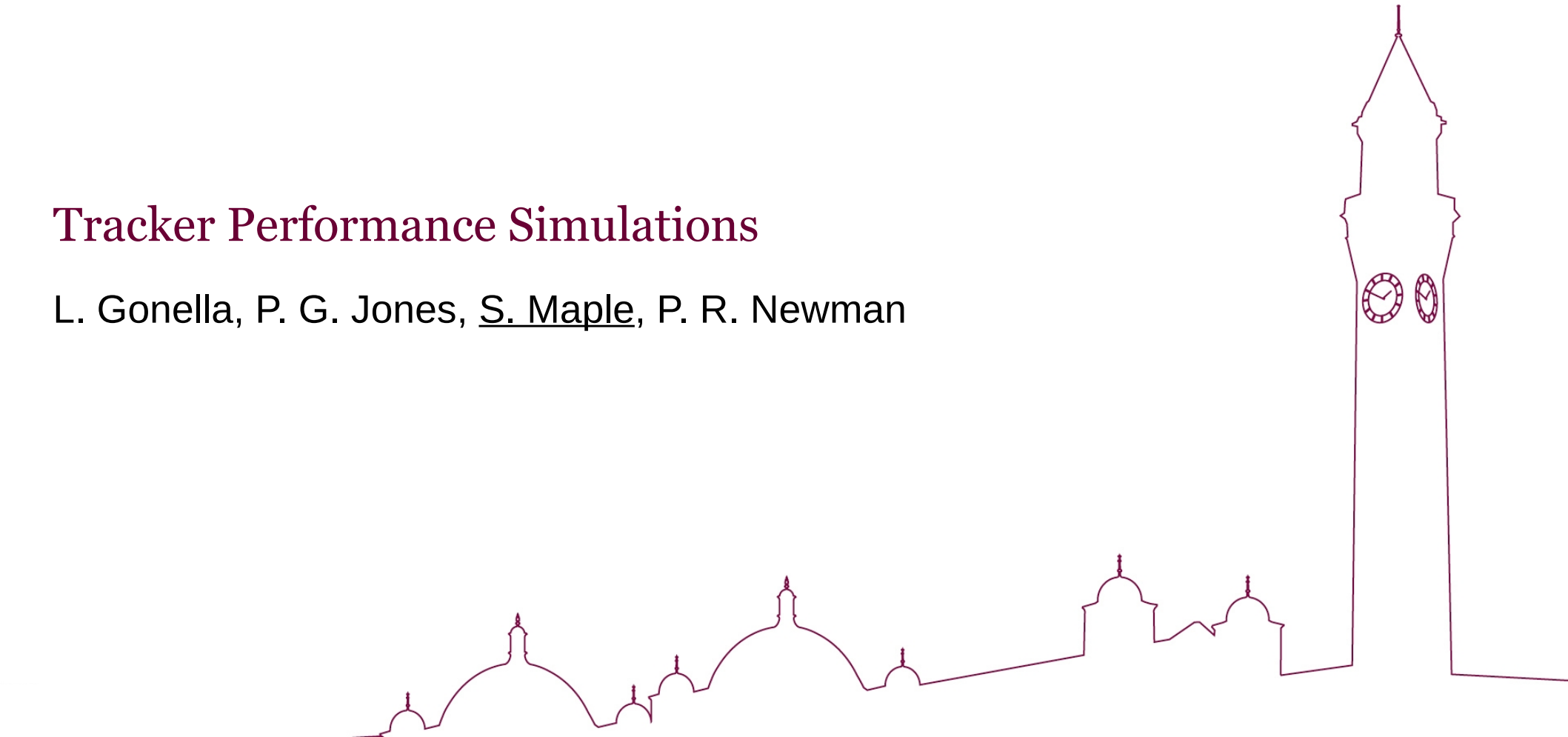


Tracking requirements

- High precision tracking measurements required for EIC physics program
  - Precise measurement of scattered electron (or hadrons) to reconstruct DIS kinematics
  - Momentum measurements for e.g. invariant mass resolution, E/p etc
  - Jet measurements (need tracks for particle-flow)
  - Determination of primary vertex, secondary vertex separation

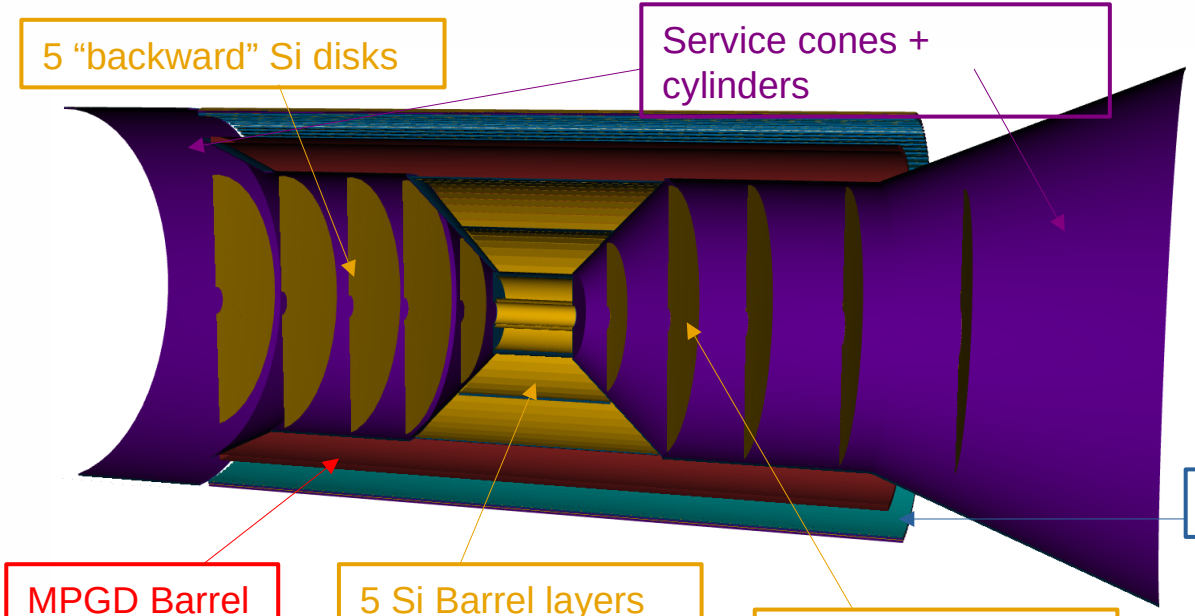
$$Q^2 = 2E_e E'_e(1+\cos\theta_e)$$
$$y = 1 - \frac{E'_e}{2E_e}(1-\cos\theta_e)$$

Tracking requirements from PWGs						
			Momentum res.	Material budget	Minimum pT	Transverse pointing res.
η						
-3.5 to -3.0	Central Detector	Backward Detector	σp/p ~ 0.1%×p ⊕ 0.5%	~5% X0 or less	100-150 MeV/c	
-3.0 to -2.5					100-150 MeV/c	dca(xy) ~ 30/pT μm ⊕ 40 μm
-2.5 to -2.0			σp/p ~ 0.05%×p ⊕ 0.5%		100-150 MeV/c	dca(xy) ~ 30/pT μm ⊕ 20 μm
-2.0 to -1.5					100-150 MeV/c	
-1.5 to -1.0					100-150 MeV/c	
-1.0 to -0.5		Barrel	σp/p ~ 0.05%×p ⊕ 0.5%		100-150 MeV/c	dca(xy) ~ 20/pT μm ⊕ 5 μm
-0.5 to 0						
0 to 0.5						
0.5 to 1.0						
1.0 to 1.5		Forward Detector	σp/p ~ 0.05%×p ⊕ 1%		100-150 MeV/c	dca(xy) ~ 30/pT μm ⊕ 20 μm
1.5 to 2.0					100-150 MeV/c	
2.0 to 2.5					100-150 MeV/c	
2.5 to 3.0			σp/p ~ 0.1%×p ⊕ 2%		100-150 MeV/c	dca(xy) ~ 30/pT μm ⊕ 40 μm
3.0 to 3.5					100-150 MeV/c	dca(xy) ~ 30/pT μm ⊕ 60 μm

EPIC tracker design informed by desire to meet momentum and DCA_T requirements set by physics working groups

Tracker Simulation Configuration

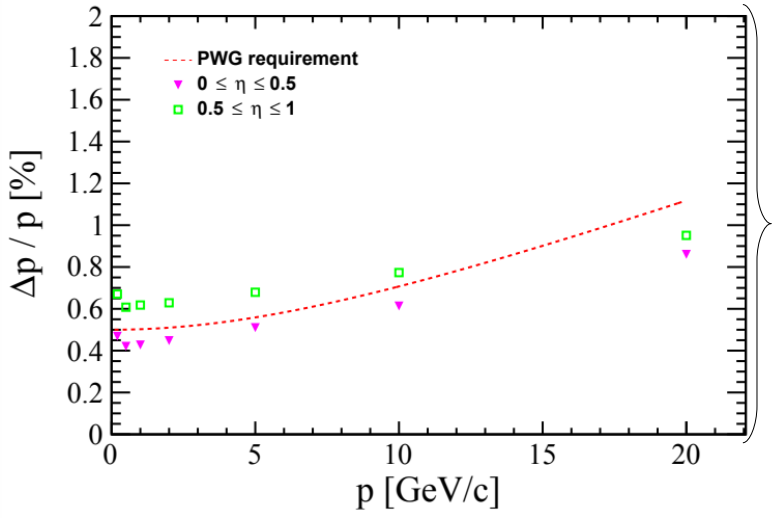
- Results shown in following slides use the single pion simulation files available on S3 (EPIC Brycecanyon 22.11.2)
  - Simulation geometry defined with layers positioned as detailed in summary talk
  - Pions of energies between 100MeV and 20GeV fired from particle gun at origin
  - Hits recorded and tracks reconstructed with EICrecon/Juggler* (ACTS)



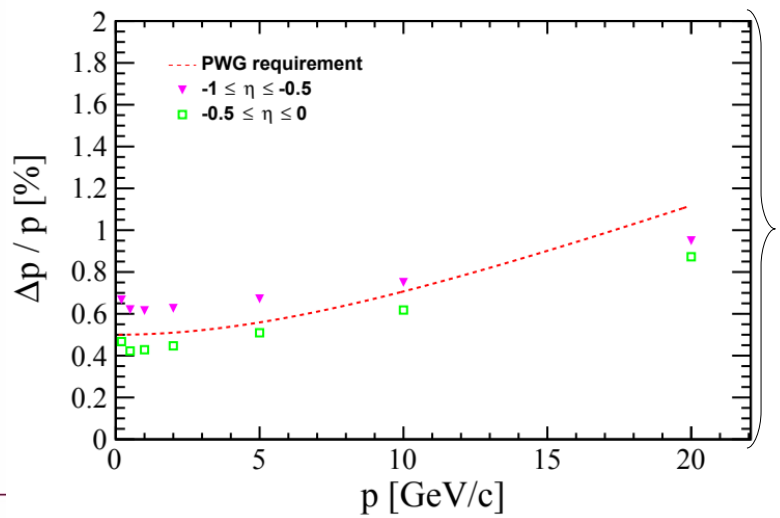
Note: Hits in the ToF are not used during track reconstruction in these simulations

Relative Momentum Resolution (Central)

- PWG requirement met for |η| < 0.5 for all momenta
- Requirement not met for 0.5 < |η| < 1
  - Note: Service cone begins at η = 0.88 therefore extra material seen in range 0.5 < |η| < 1
  - Requirement met for -0.88 < |η| < 0.88 (see backup)



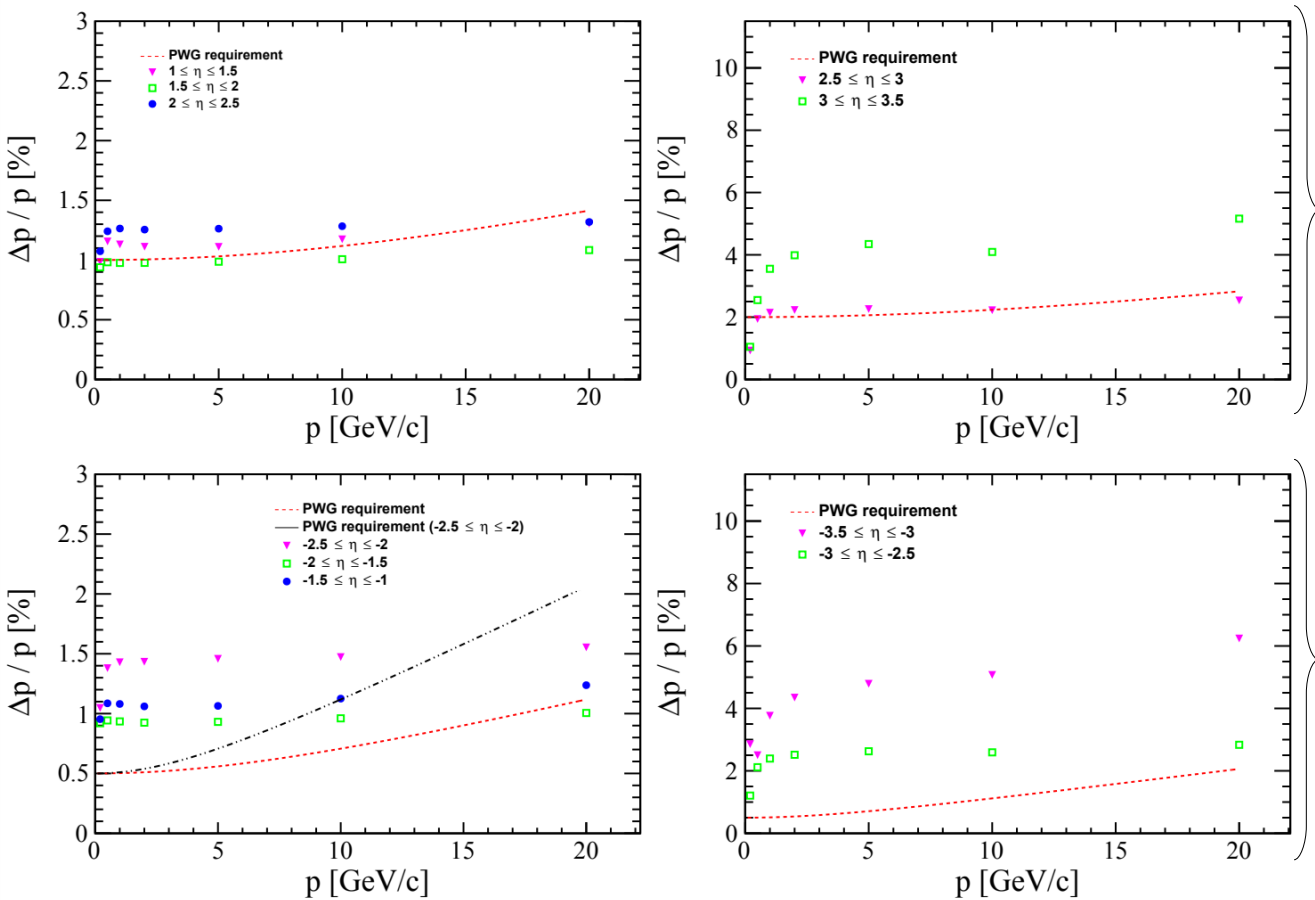
Hadron going



Electron going

Relative Momentum Resolution (Forward/Backward)

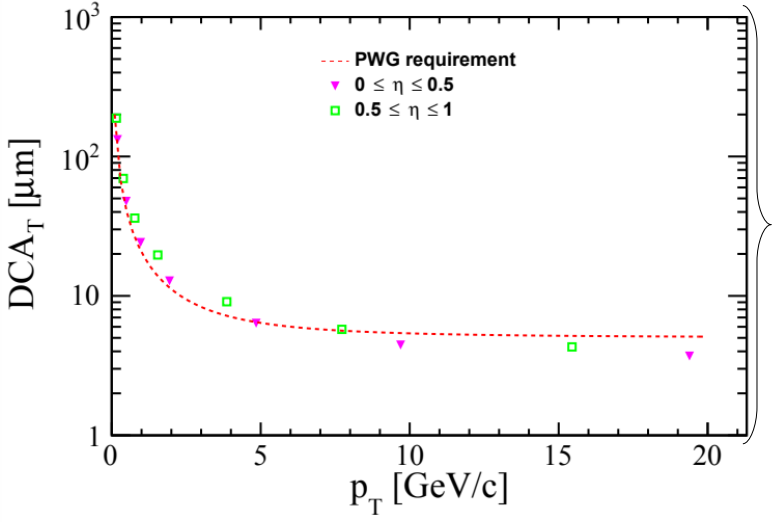
- Smaller lever arm for disks in the electron going direction → worse resolution compared to hadron going direction
- Different amount of support and service material crossed in different η ranges (See diagram in backup)
- Fwd/Bwd requirements only met over full momentum range for 1.5 < η < 3
  - Different reqs for Fwd/Bwd



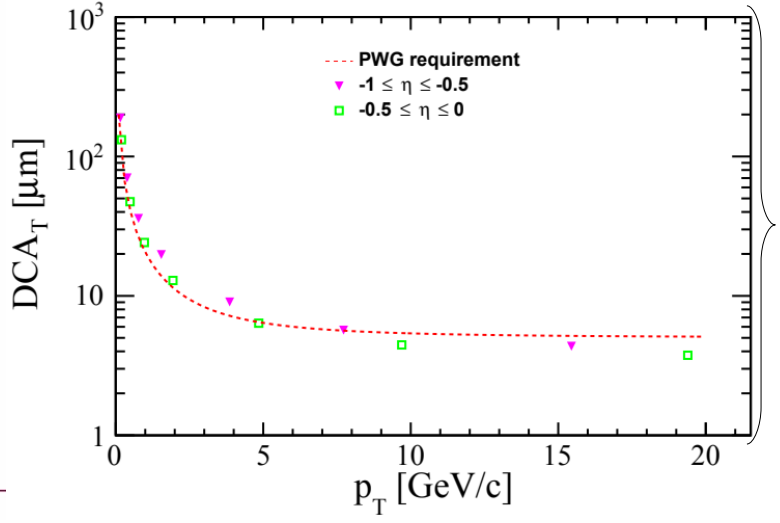
Transverse Pointing Resolution (Central)

- Performance consistent with requirement for |η| < 0.5 at all momenta
- Requirement not met for |η| > 0.5 in barrel region below ~8 GeV

Note: x-axes are p_T for DCA_T resolutions



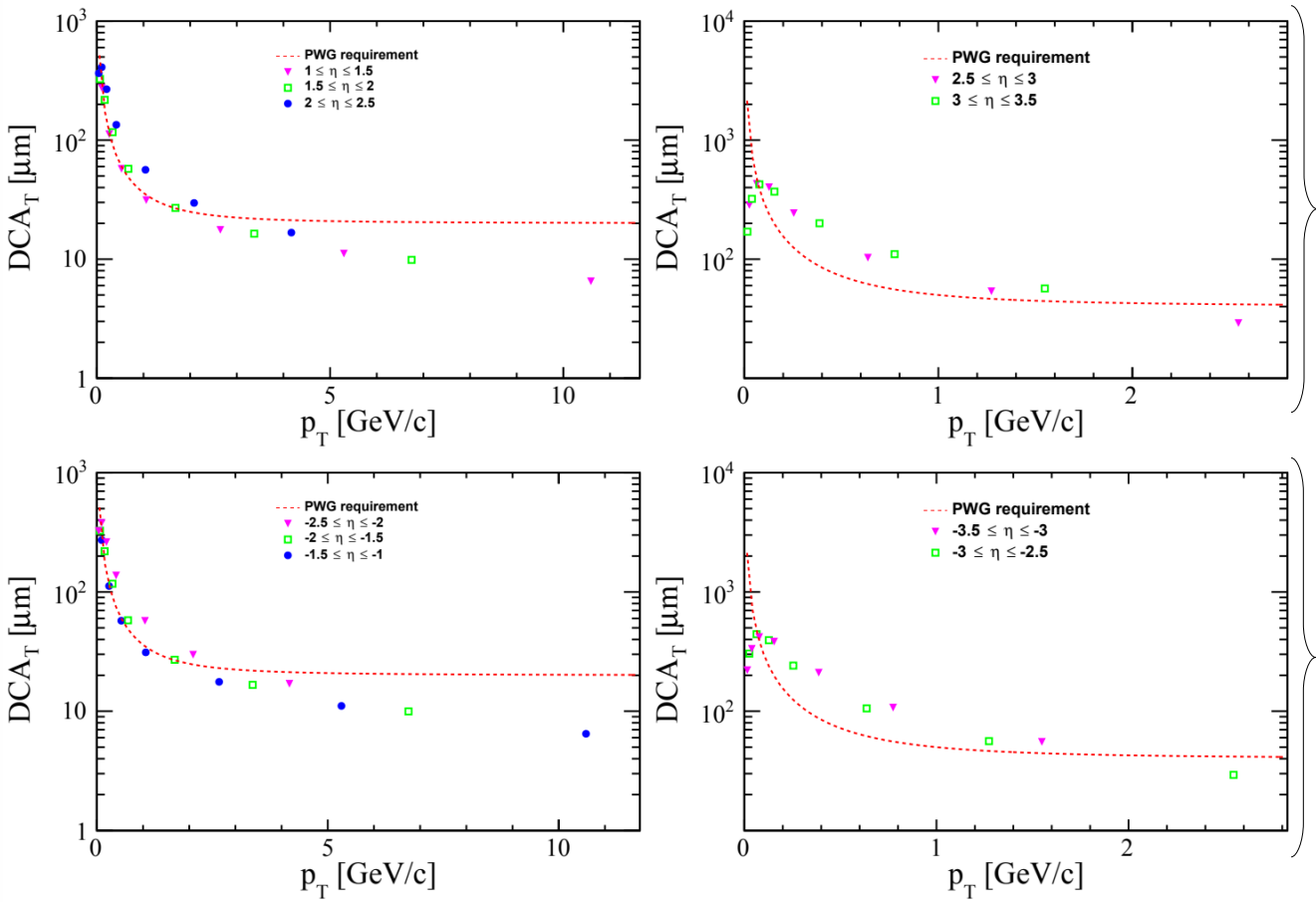
Hadron going



Electron going

Transverse Pointing Resolution (Forward/Backward)

- Fwd/Bwd pointing resolution consistent with requirements at all momenta for $1 < |\eta| < 2$
- Requirements met at $|\eta| > 2$ for $p_T > \sim 2$ GeV

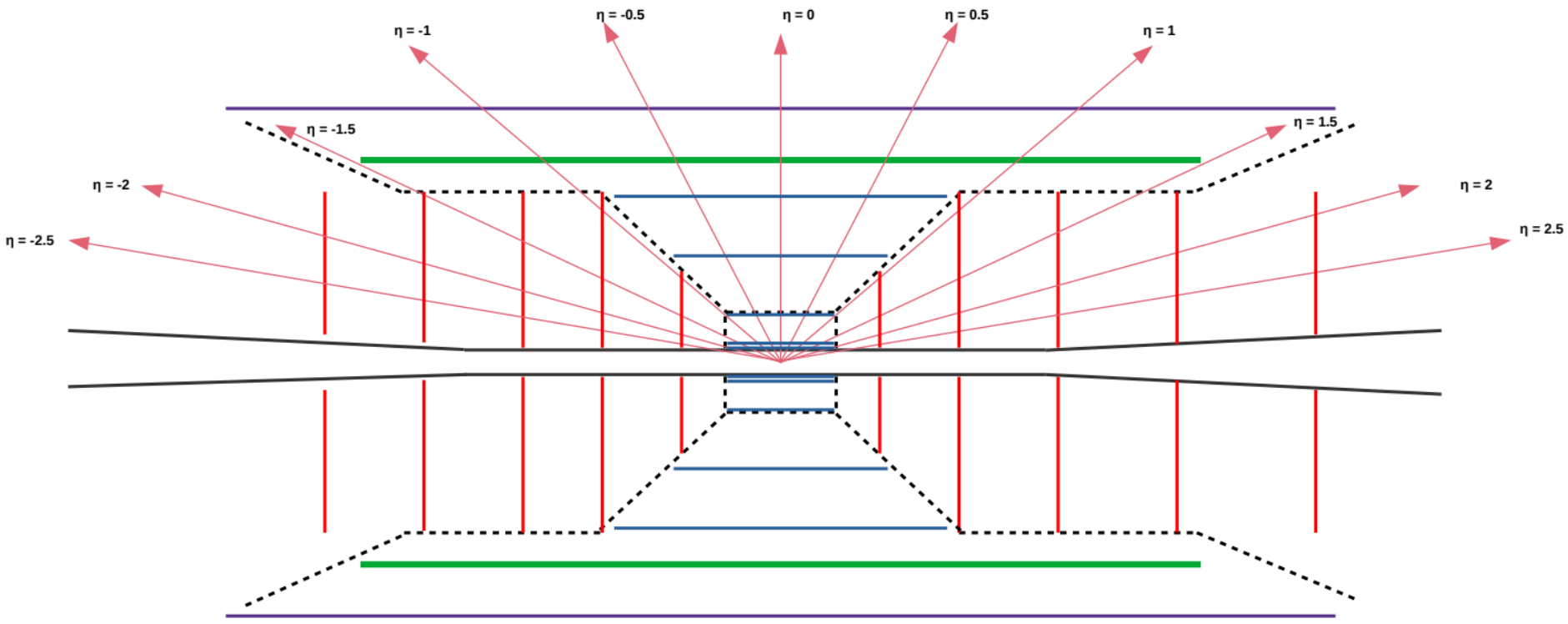


Summary

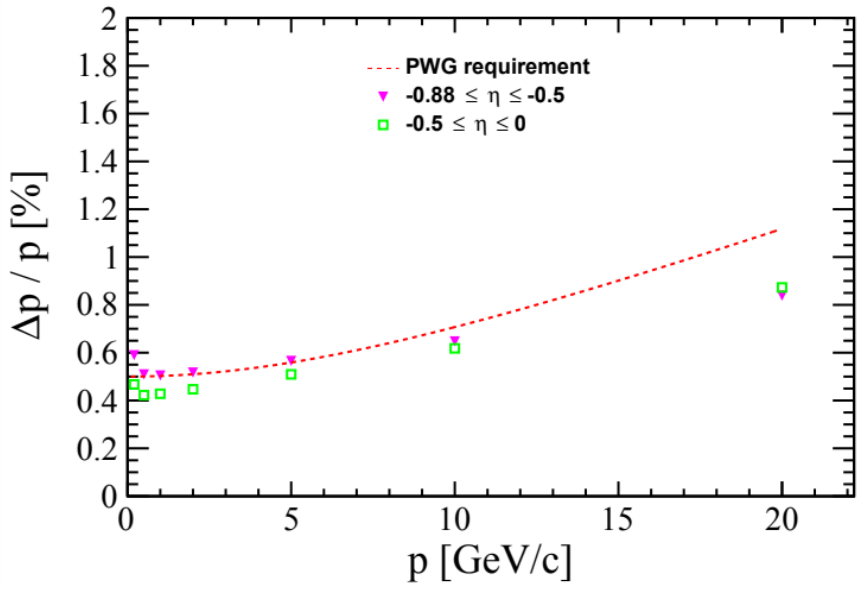
- The measurements necessary for the EIC physics program impose stringent requirements on the momentum and pointing resolution of the EPIC detector
  - For both momentum and DCA_T resolution there are challenges meeting requirements in the forward and backwards directions, this has been the case for previous configurations studied in the yellow report and detector proposals
- Effect from passive material on tracking and vertex performance is notable. Geometry description to be kept up to date with R&D progress on low material solutions

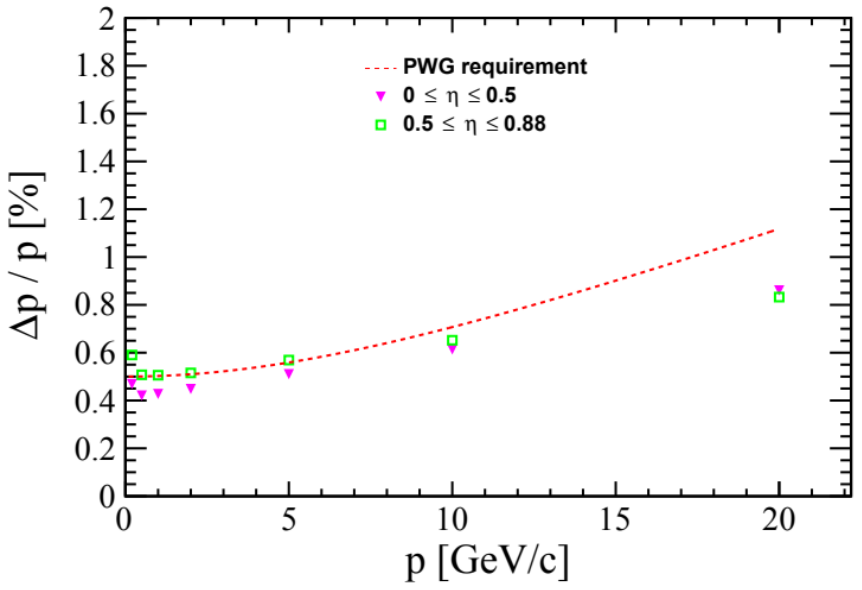
Backup

Detector layout



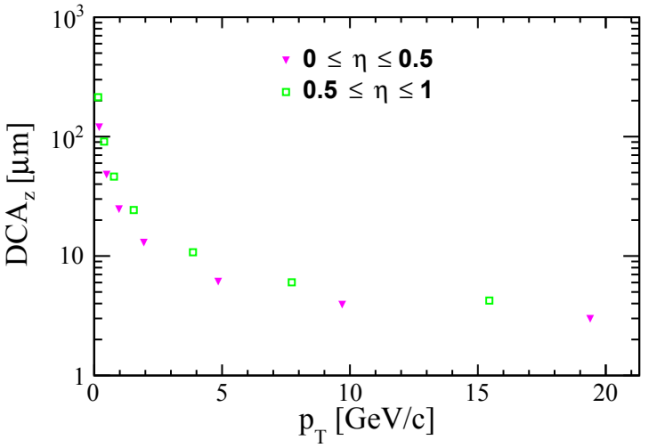
Before Support Cone Momentum Resolution

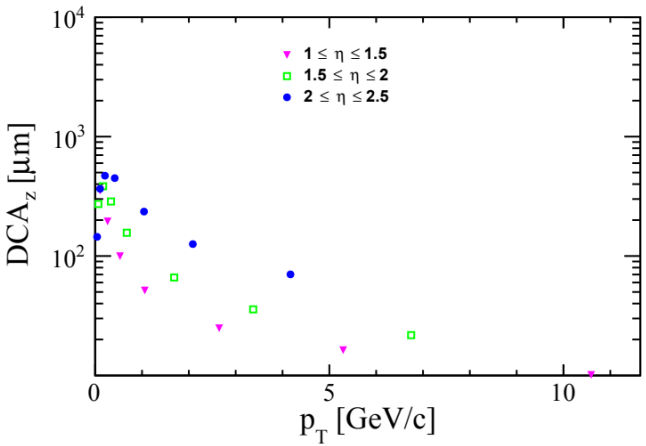


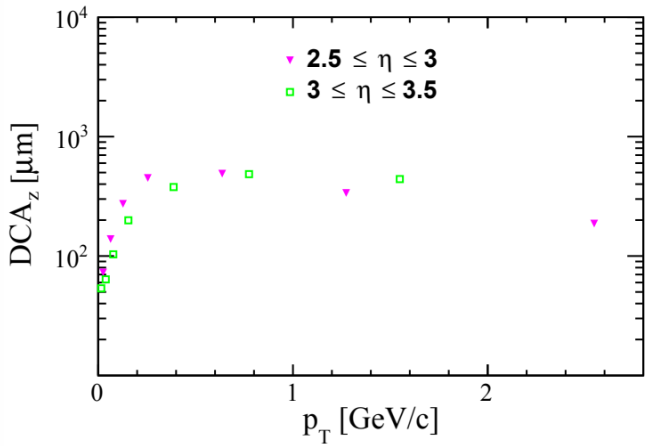


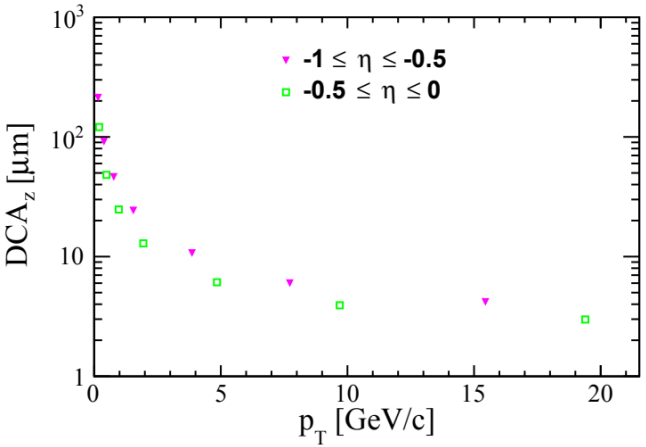
Momentum resolution consistent with requirements up to η=0.88 (support cone)

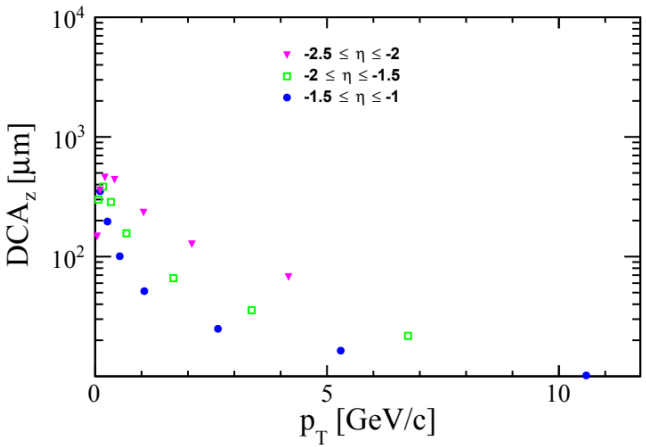
Longitudinal Pointing Resolution

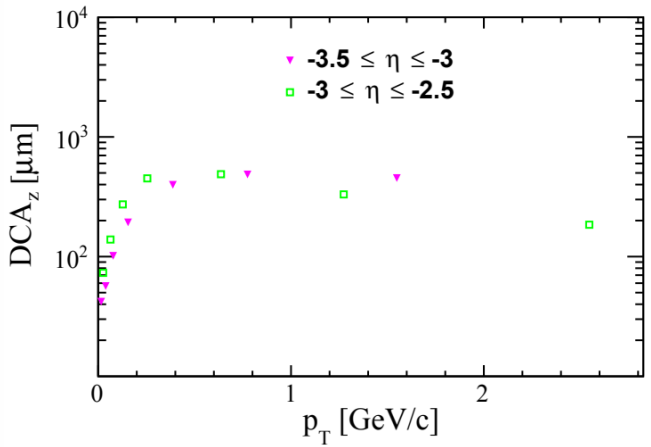








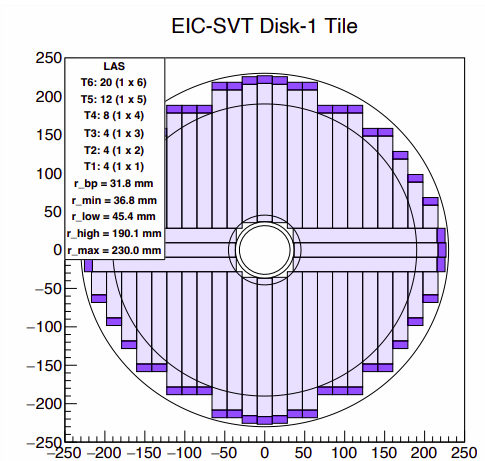




Acceptance around beampipe

- Disks consist of tiles of ITS3-like sensors, with length and width determined by the ITS3 reticle
  - The result is that the inner opening of the disks is not perfectly circular → instead they are squared off
  - This means that there isn't full azimuthal acceptance at the inner radii we've been using (beampipe radius +5mm)

Disks in simulations



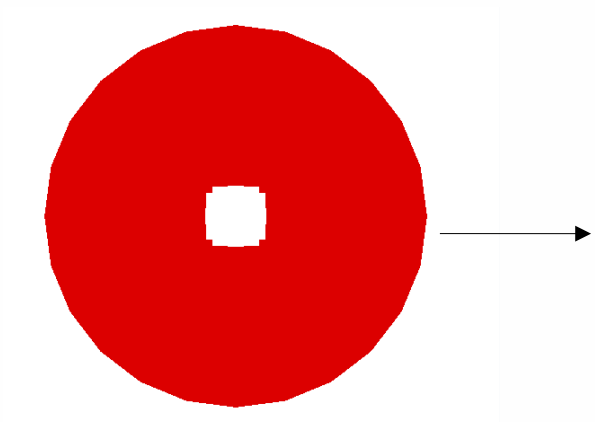
Realistic disks

* P. G. Jones
https://indico.bnl.gov/event/15486/contributions/62590/attachments/40656/67919/EIC-Sensors-Jones.pdf

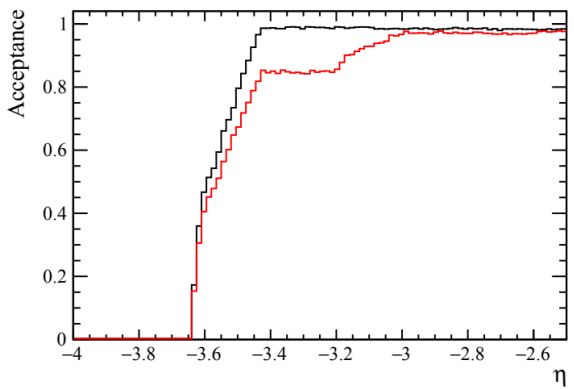
Disk acceptance vs η

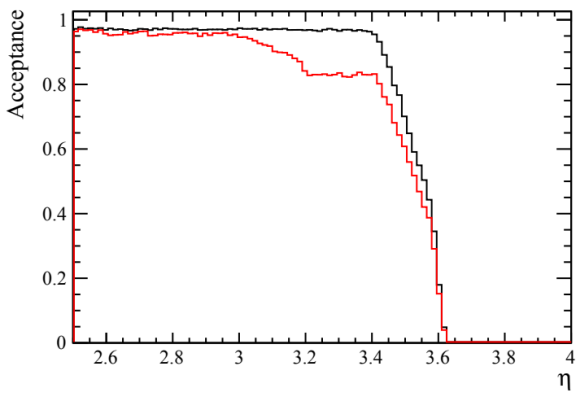
- Implemented disk modules in Fun4All with inner cutouts in the same shape as the “realistic” disks as produced by the tiling algorithm
  - Particles propagated by Geant4, tracks reconstructed by Genfit (instead of ACTS)
- Generated events in far forward/backward region and studied acceptance in η bins:

$$Acceptance = \frac{Number\ of\ events\ with\ at\ least\ 3\ hits}{Total\ number\ of\ events}$$



95% efficient disks
100% efficient disks

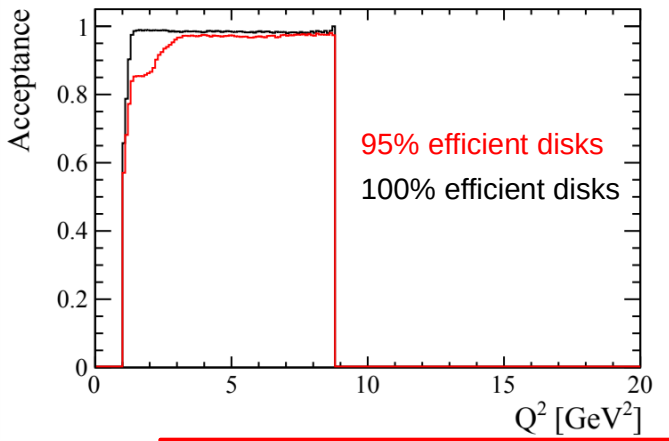


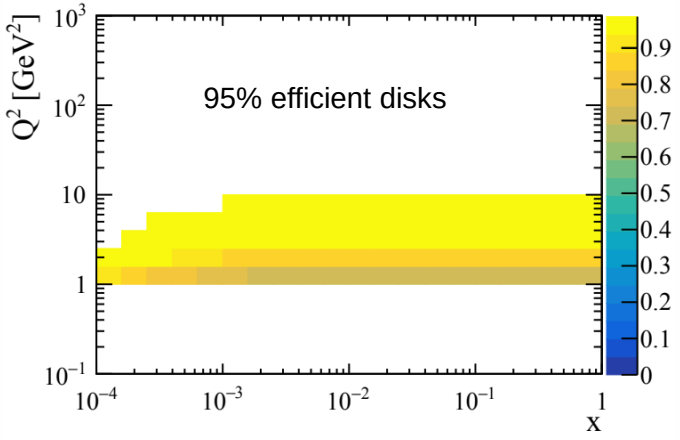


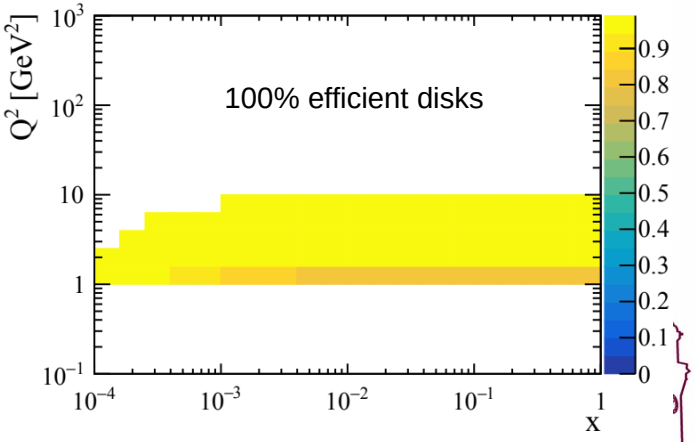
Disk acceptance vs (x-)Q^2

- Considered only 18x275 GeV^2 NC-DIS events (Pythia8, $Q^2 > 1\ GeV^2$)
  - Scattered electron mapped to relevant η bin and weighted number of reconstructed events by acceptance in this η bin and recorded x-Q^2 for the event
    → Acceptance here is fraction of events reconstructed in a given x-Q^2 range

Higher x lower Q^2 bins lose acceptance





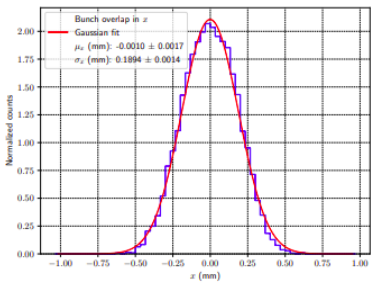


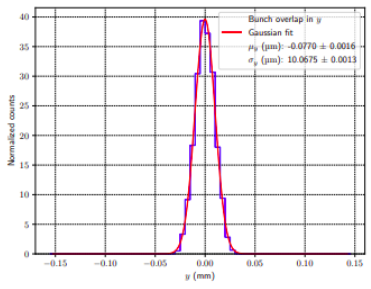
Acceptance > ~80% for all bins Q^2>1GeV^2 for 100% efficient disks

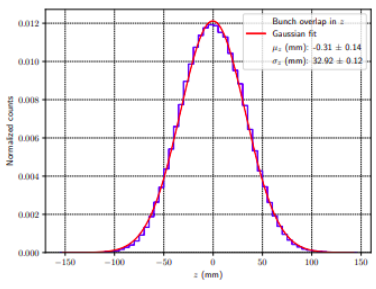
https://github.com/eic/documents/blob/master/reports/general/Note-Simulations-BeamEffects.pdf

Effect of beamspot on tracking performance

- A very helpful report on beam conditions at EIC was produced last year
  - This included a transport model which allows one to obtain the primary vertex distribution in terms of x, y, z







- → Generated single particle events in Fun4All with the origin vertex distributed according to these distributions

Accelerator and beam conditions critical for physics and detector simulations for the Electron-Ion Collider

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Abstract

We identify accelerator and beam conditions at the Electron-Ion Collider (EIC) that need to be included in physics and detector simulations. For our studies, we implement accelerator and beam effects in the Pythia 8 Monte Carlo event generator and examine their influence on the measurements in the central and far-forward regions of the detector. In our analysis, we demonstrate that the accelerator and beam effects can be also studied accurately by modifying the Monte Carlo input to detector simulations, without having to implement the effects directly in the event generators.

1 Interaction Regions at the Electron-Ion Collider

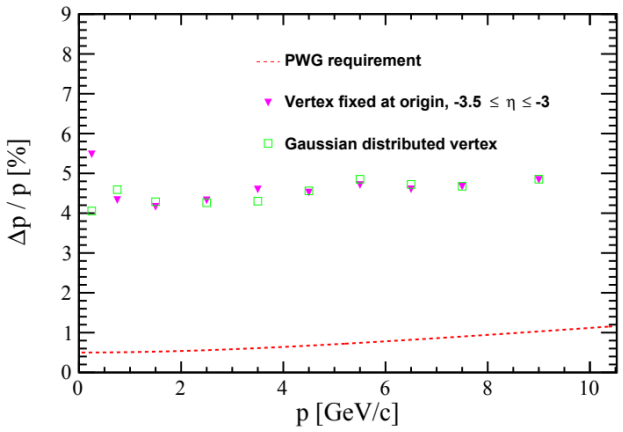
The present interaction region (IR) and detector designs for the Electron-Ion Collider (EIC) are the result of considerations which fulfill all of the below requirements:

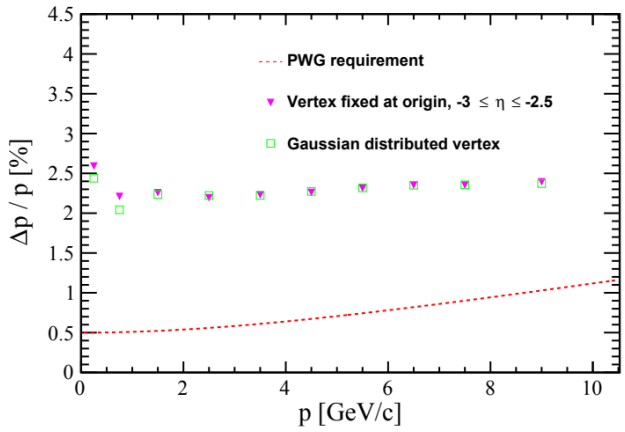
- Versatile center-of-mass energy, E_{CM}, within the range of 30 GeV to 140 GeV.
- A luminosity of up to $10^{34}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$.
- High polarization of electron and light ion beams with arbitrary spin patterns, with time-averaged polarization of up to 70%.
- Beam divergences at the interaction point (IP) and apertures of the interaction region magnets that are compatible with the acceptance requirements of the colliding beam detector.
- Collisions of electrons with a large range of light to heavy ions (protons to uranium ions).
- Up to two interaction regions.

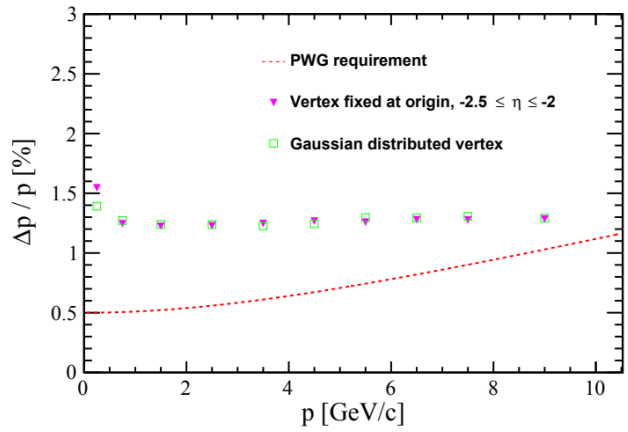
To realize these requirements a couple of design choices have been made, which need to be included in the physics and detector simulations to get the most accurate description. The purpose of the interaction region is to focus the beams to small spot sizes at the collision point and to separate them into their respective beam lines while providing the space and geometry required by the physics program for the detector. The separation is accomplished by a total crossing angle of 25 mrad (or 35 mrad) between the two beams, which has the advantage of avoiding the introduction of separator

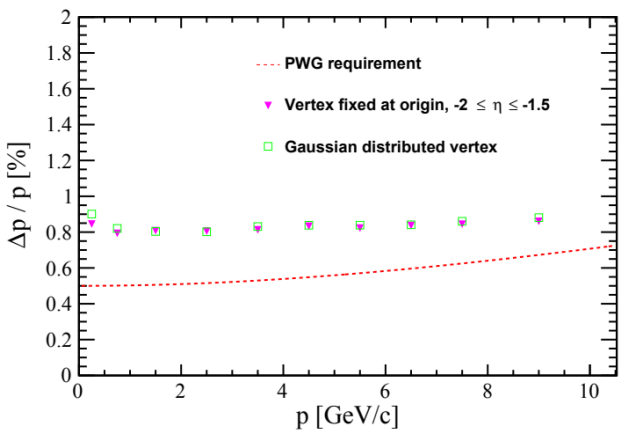
1

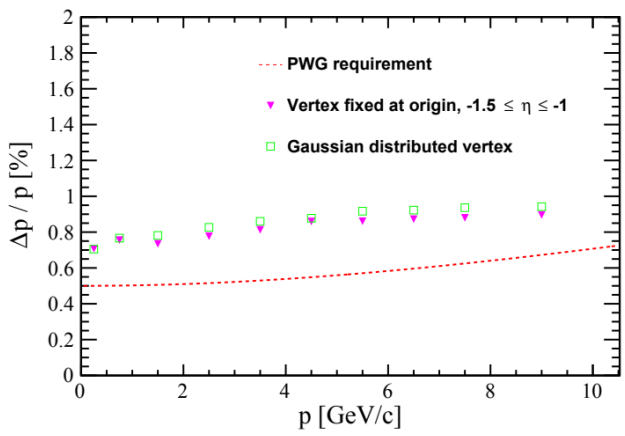
Momentum resolution - Backward





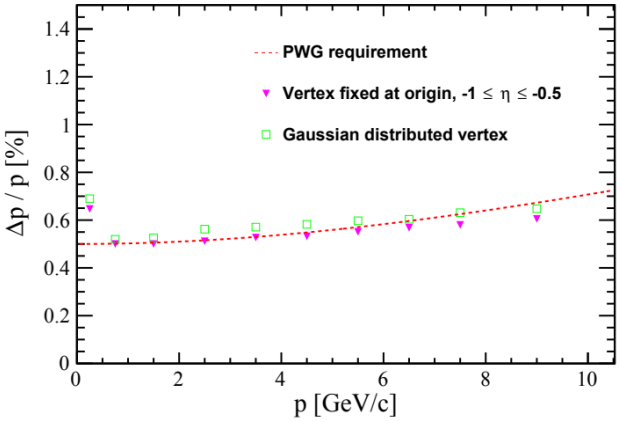


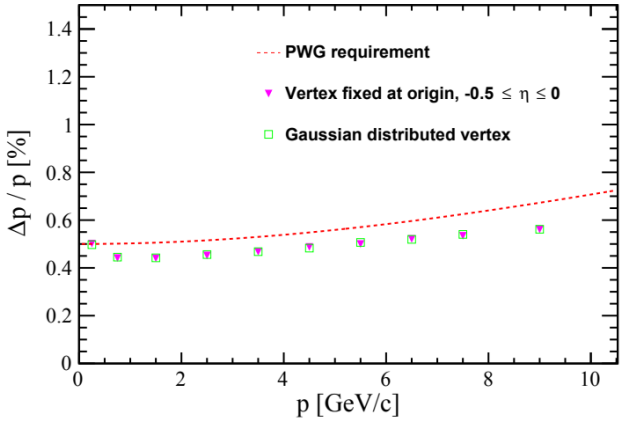


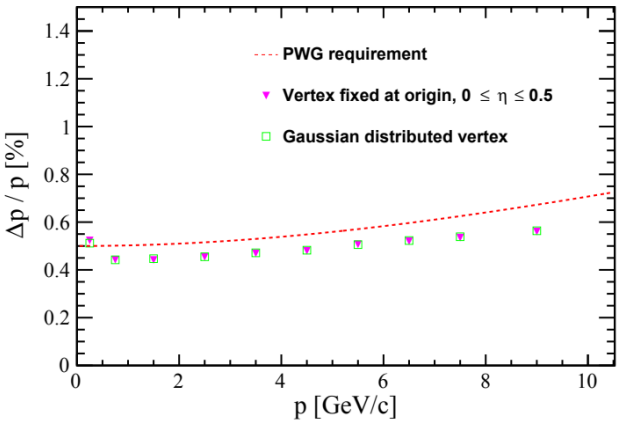


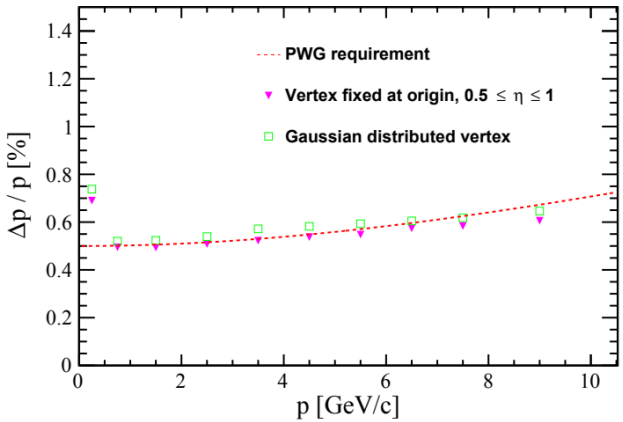
- A very small loss of performance for -1.5<η<-1, with other regions being mostly the same

Momentum resolution - Central



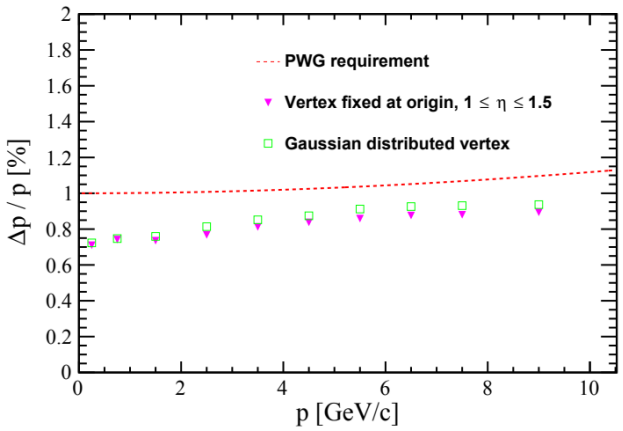


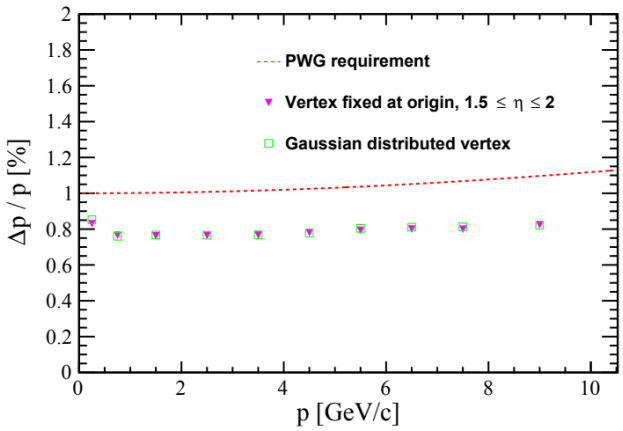


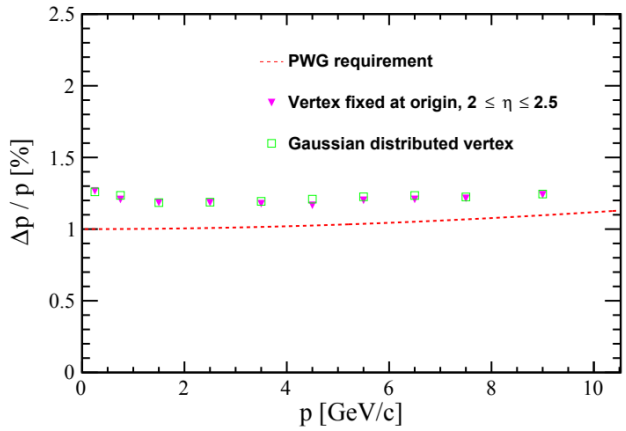


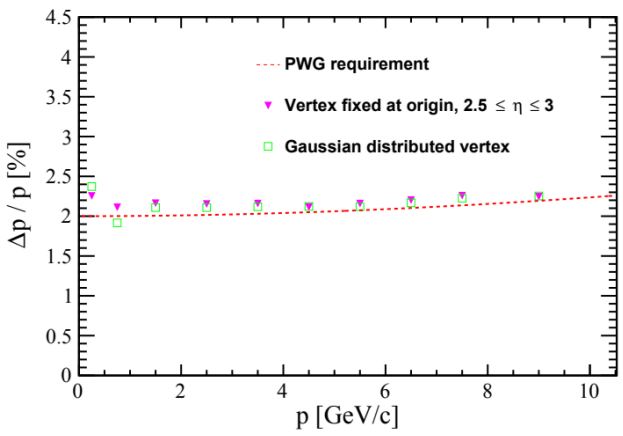
- Small difference in performance for 0.5<|η|<1

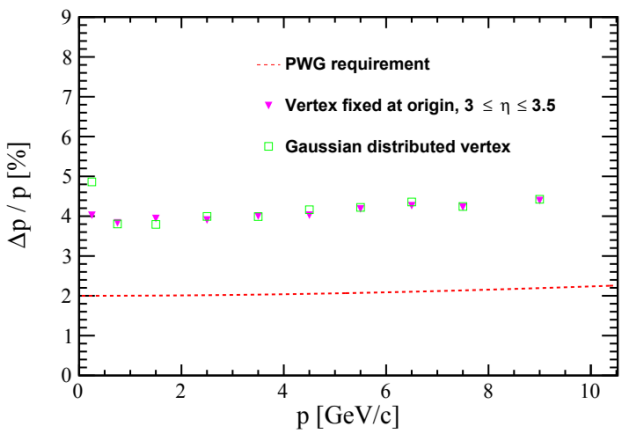
Momentum resolution - Forward





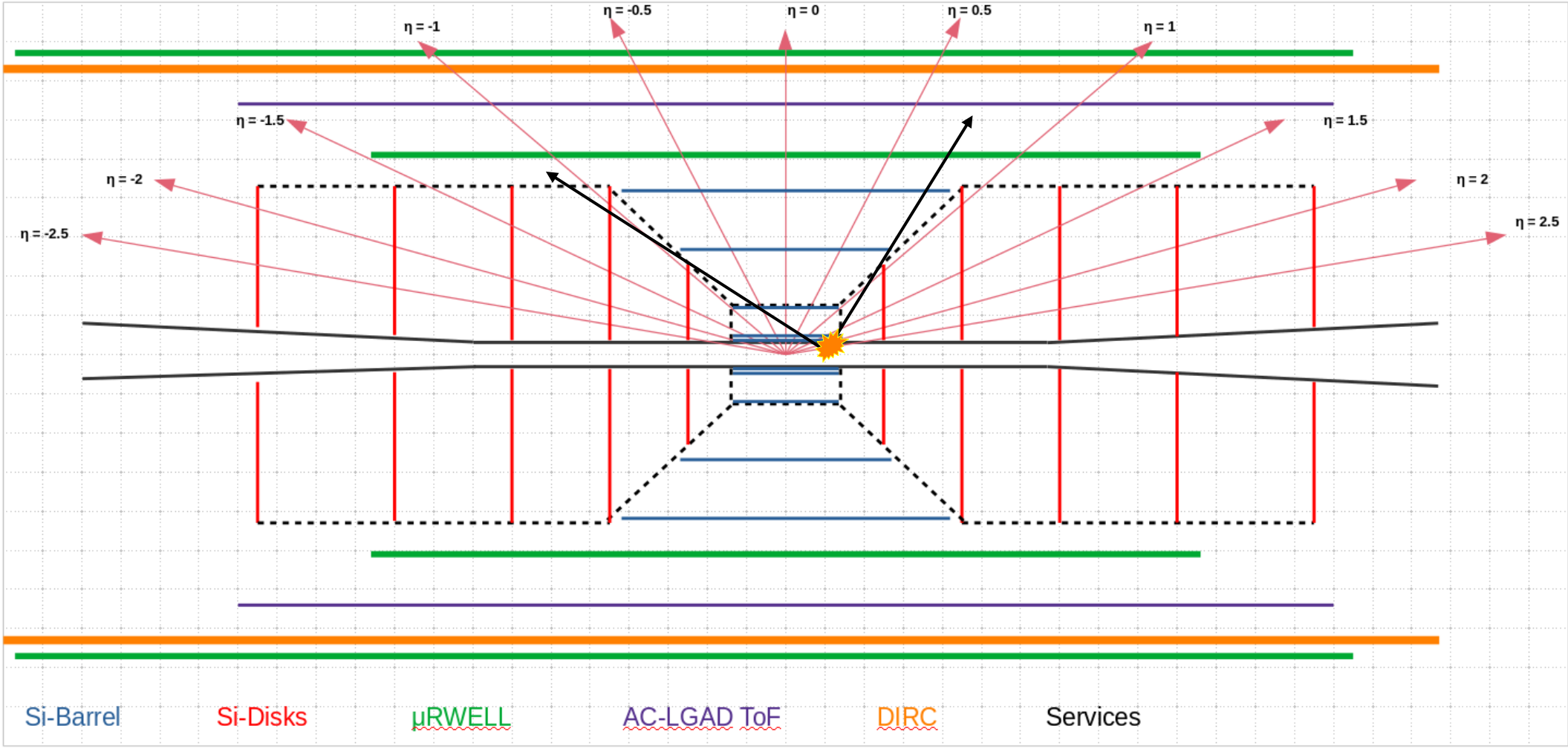




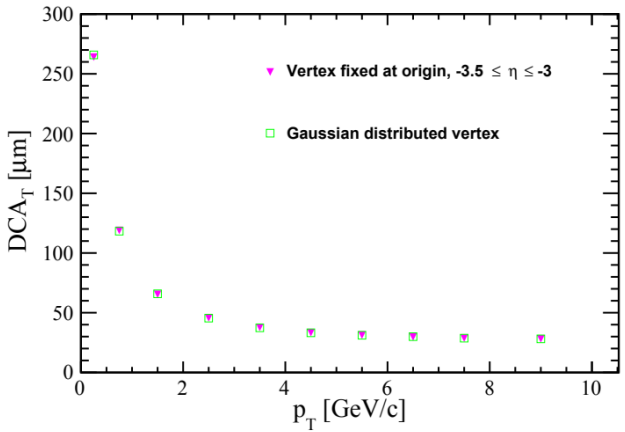


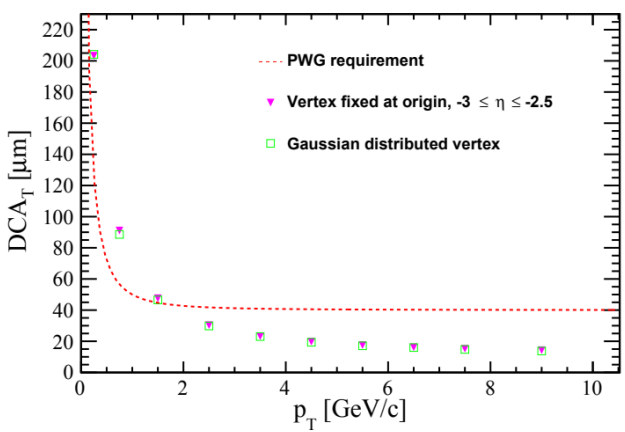
- Same trend as for Backward: only 1<η<1.5 shows a small loss of performance
- Can attribute this to extra material seen when crossing over service cone

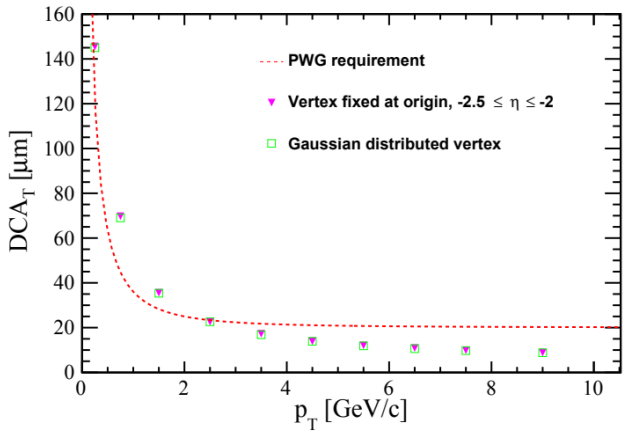
Extra material seen by particles from offset vertex if they traverse service cone

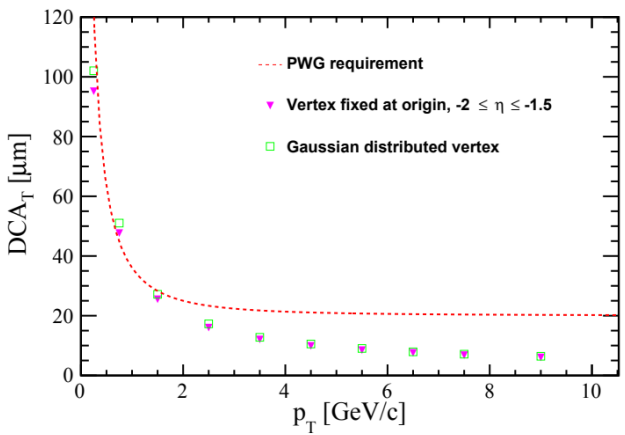


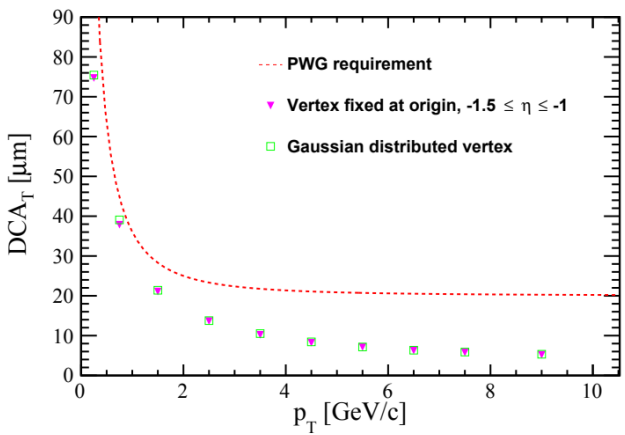
Transverse pointing resolution - Backward





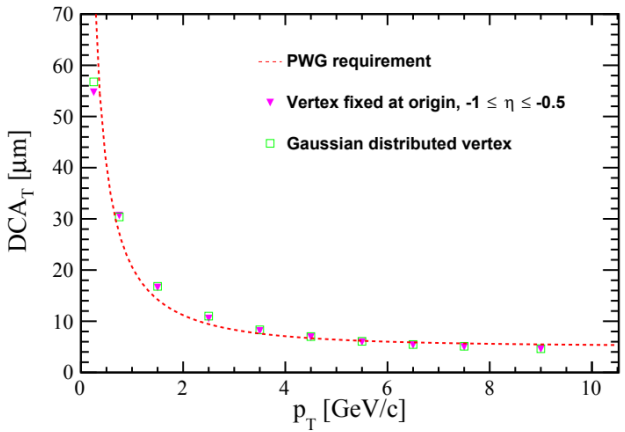


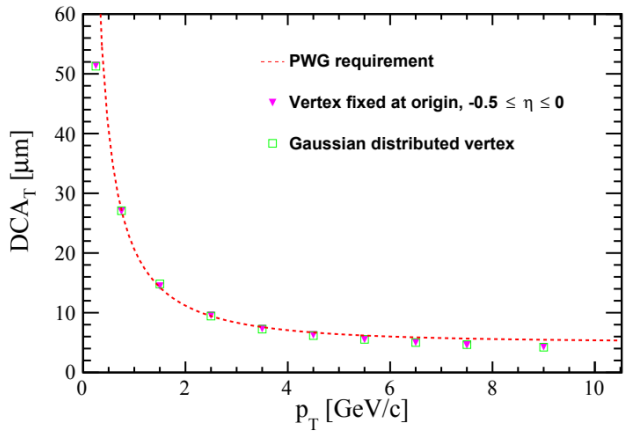


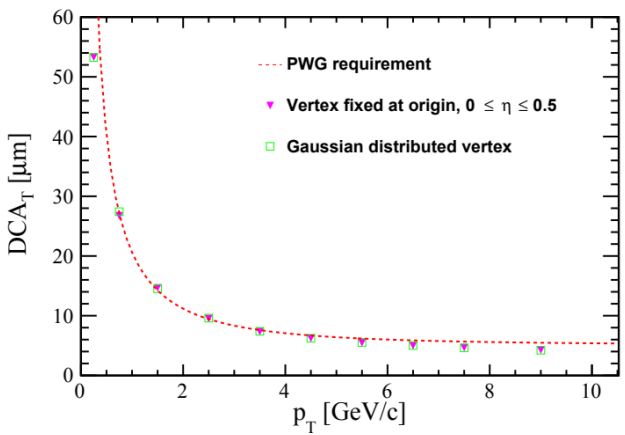


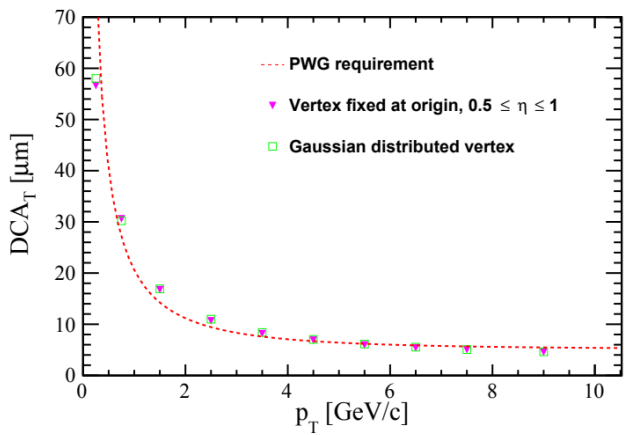
- No significant differences in transverse pointing resolution

Transverse pointing resolution - Central



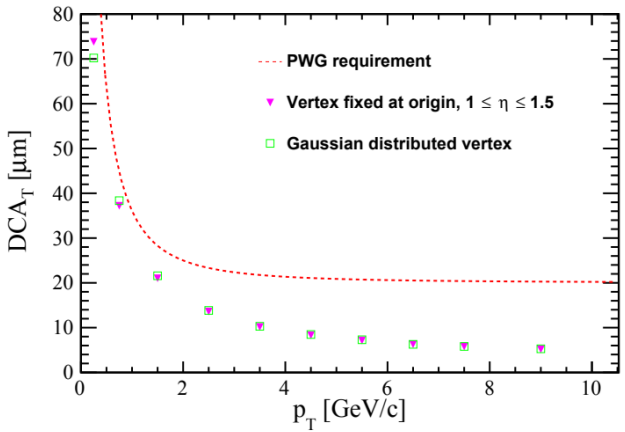


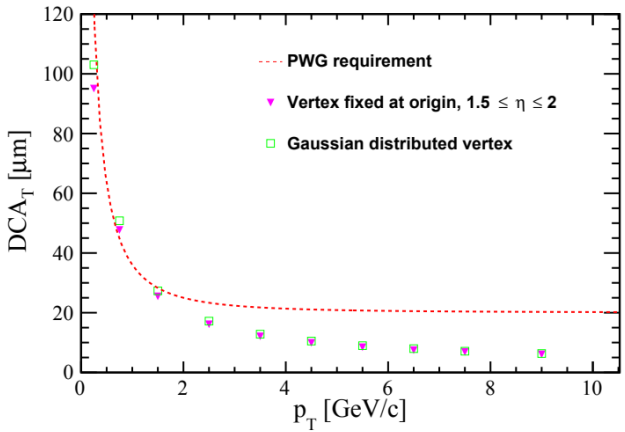


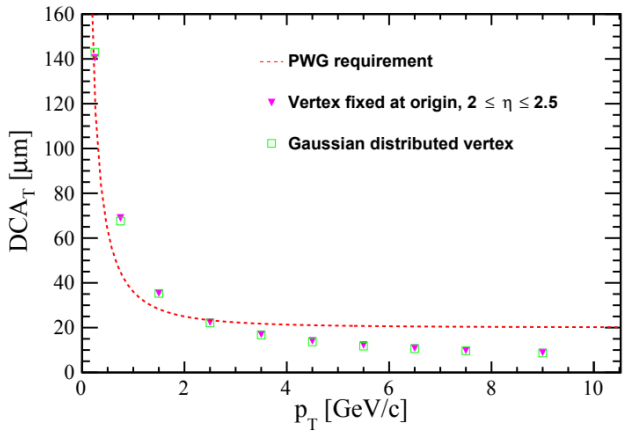


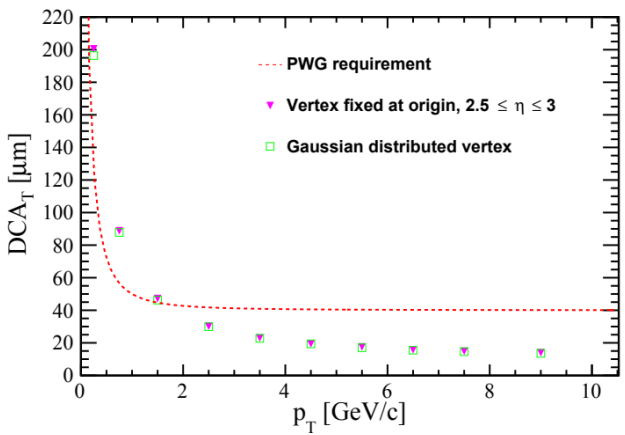
- No significant differences in transverse pointing resolution

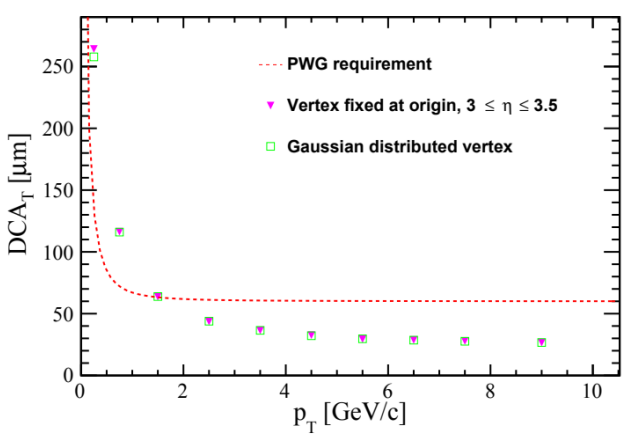
Transverse pointing resolution - Forward











- No significant differences in transverse pointing resolution