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Track reconstruction with ACTS in ePIC detector

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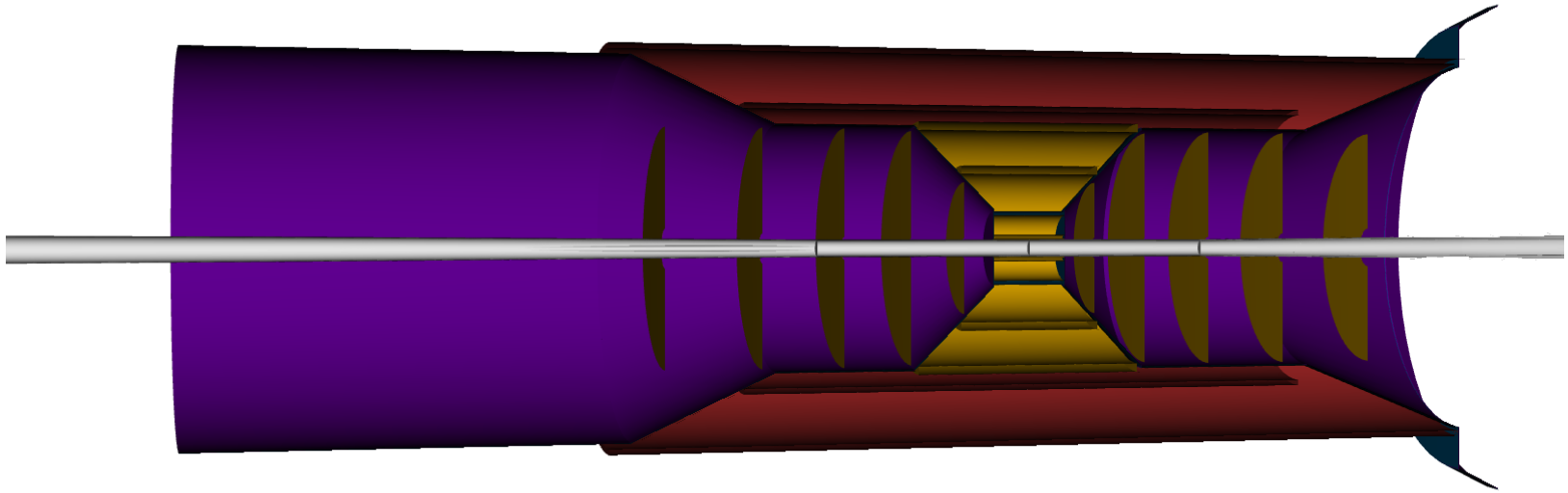
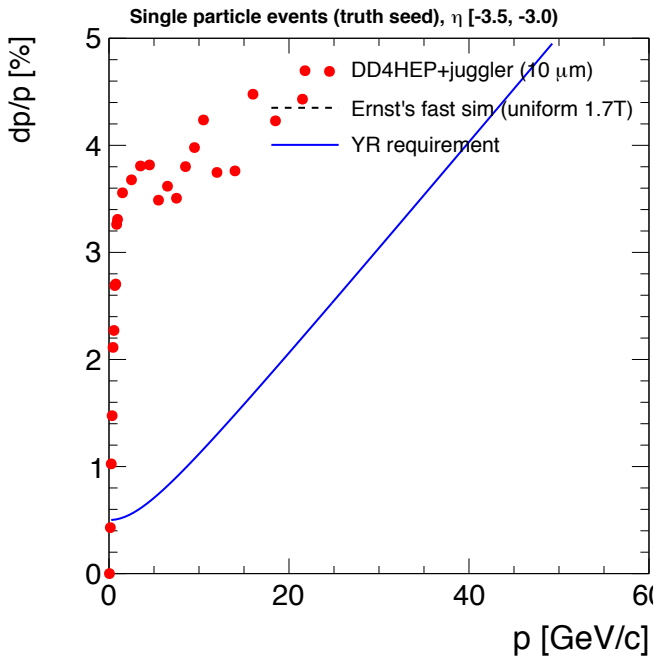
ePIC GD/I meeting, 10/31/2022

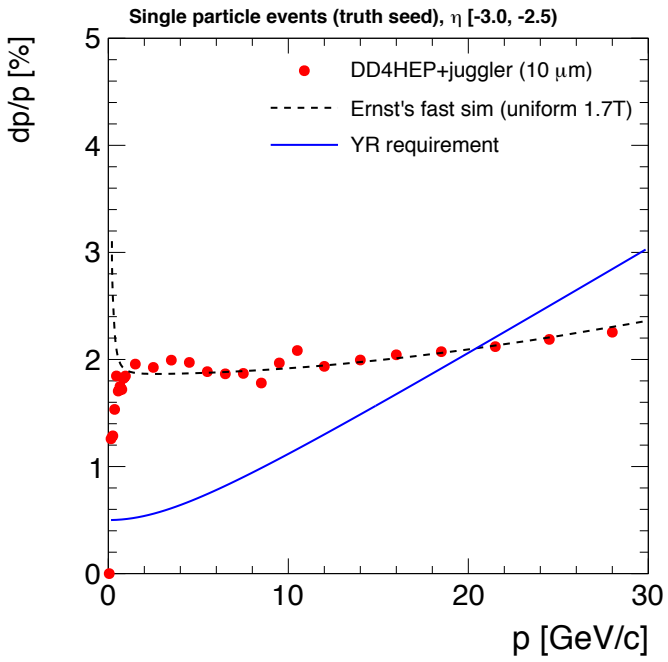
Track reconstruction performance

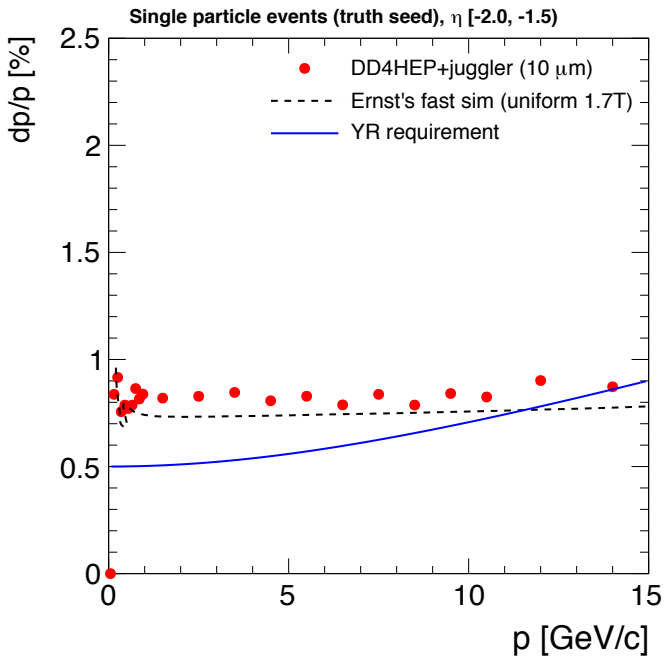
- Symmetric tracking geometry + 1.7T field
  - B field is scaled up from BarBar field map (1.5T to 1.7T)
  - ePIC geometry material map added by Shujie Li
- Performance test: check if the current geometry + track reconstruction algorithm gives resonable performance
  - Single pion events: uniform p, ϕ, η distribution (p range: 0 to 30GeV, η range: -3.5 to 3.5)
  - Track reconstruction with **truth seeding**

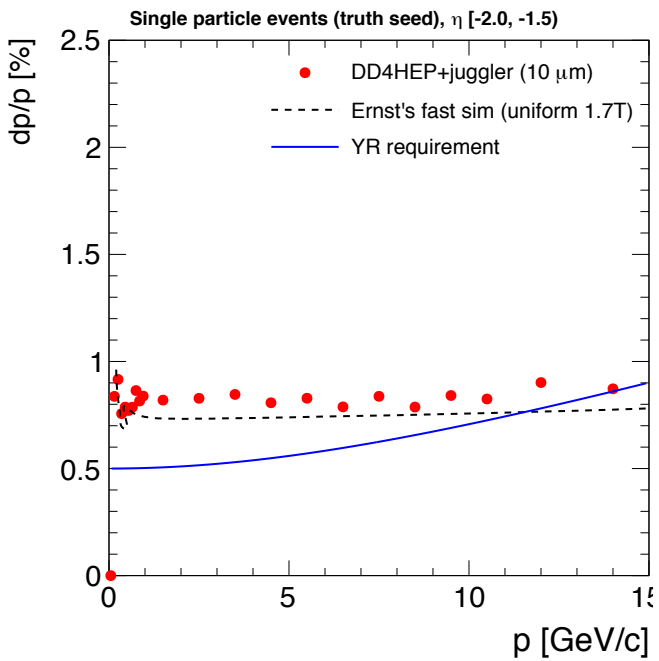


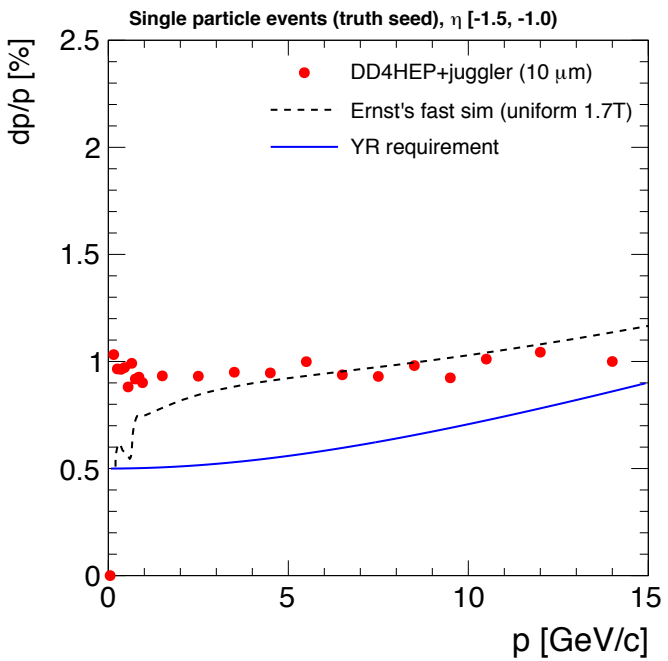
Momentum resolution (DD4HEP vs fast simulation)

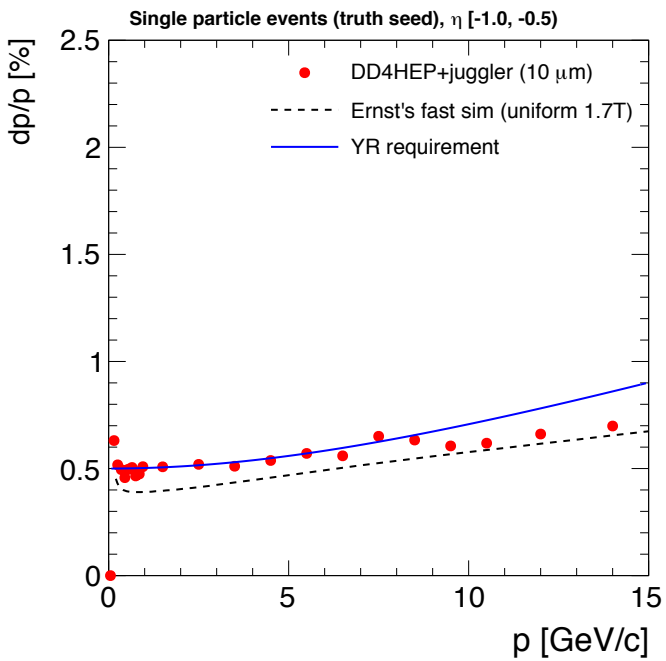












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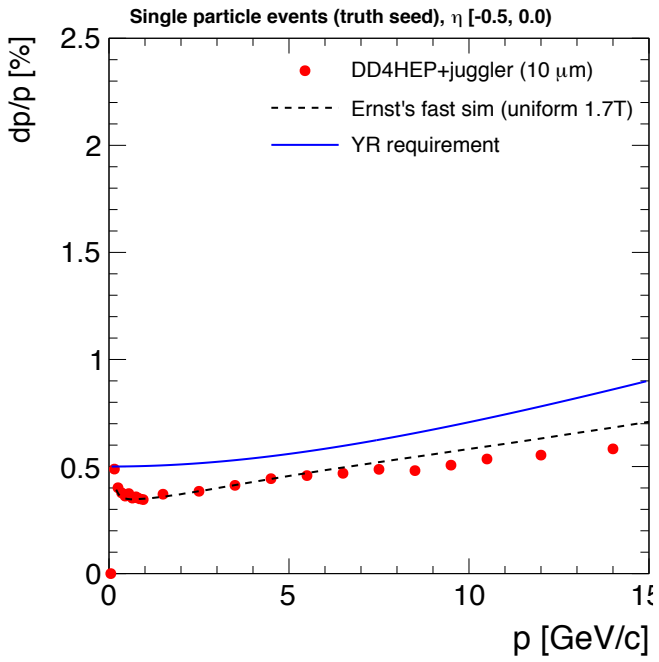
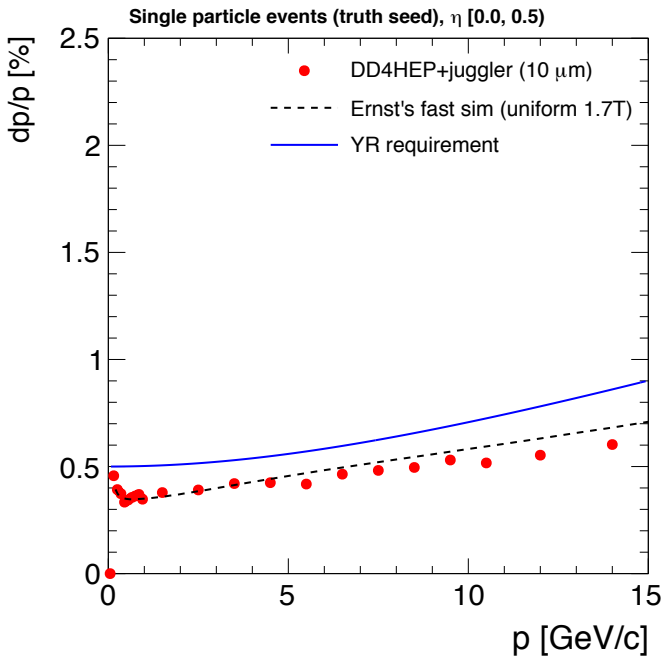
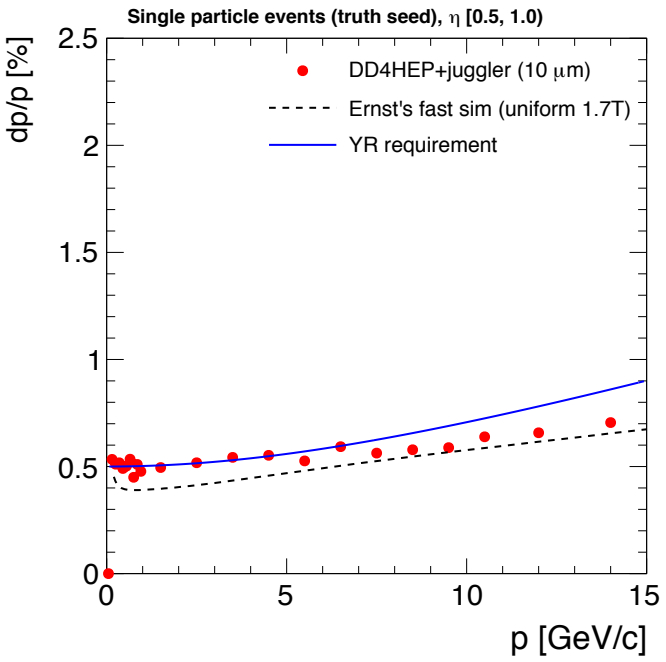
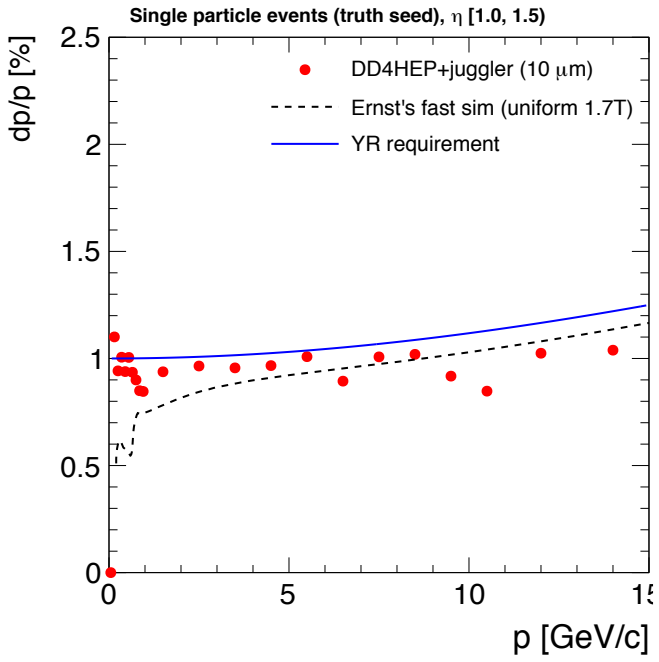
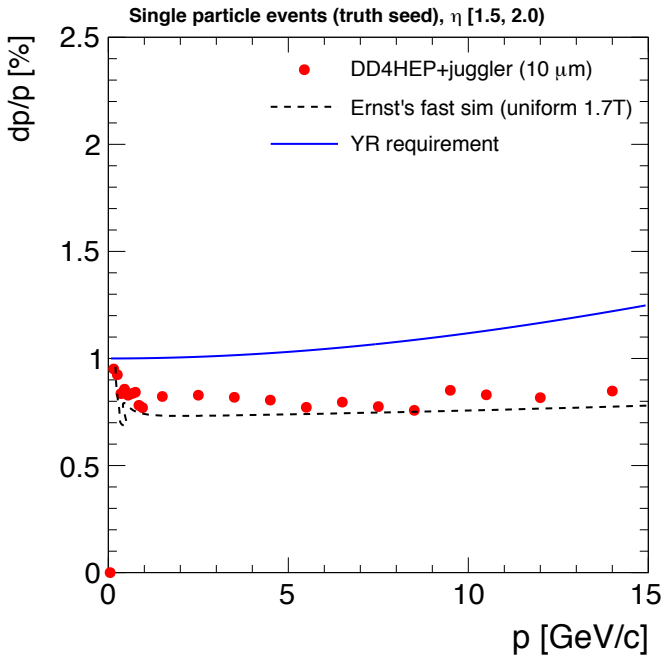
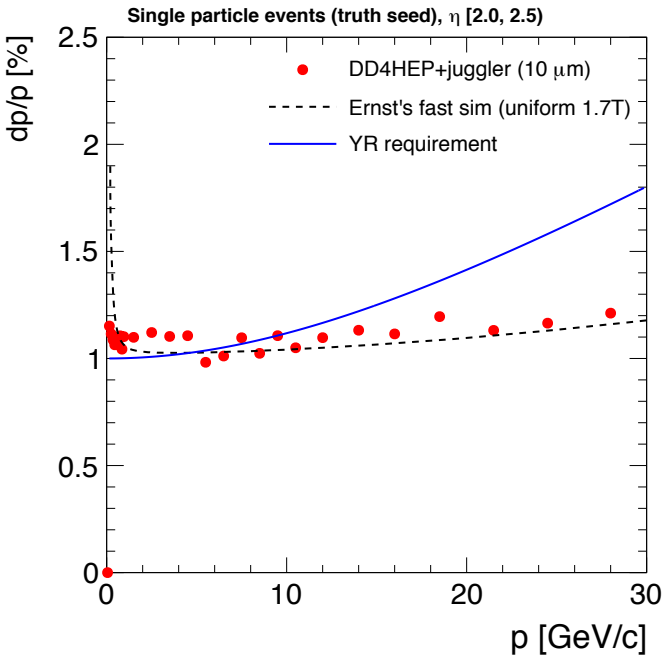




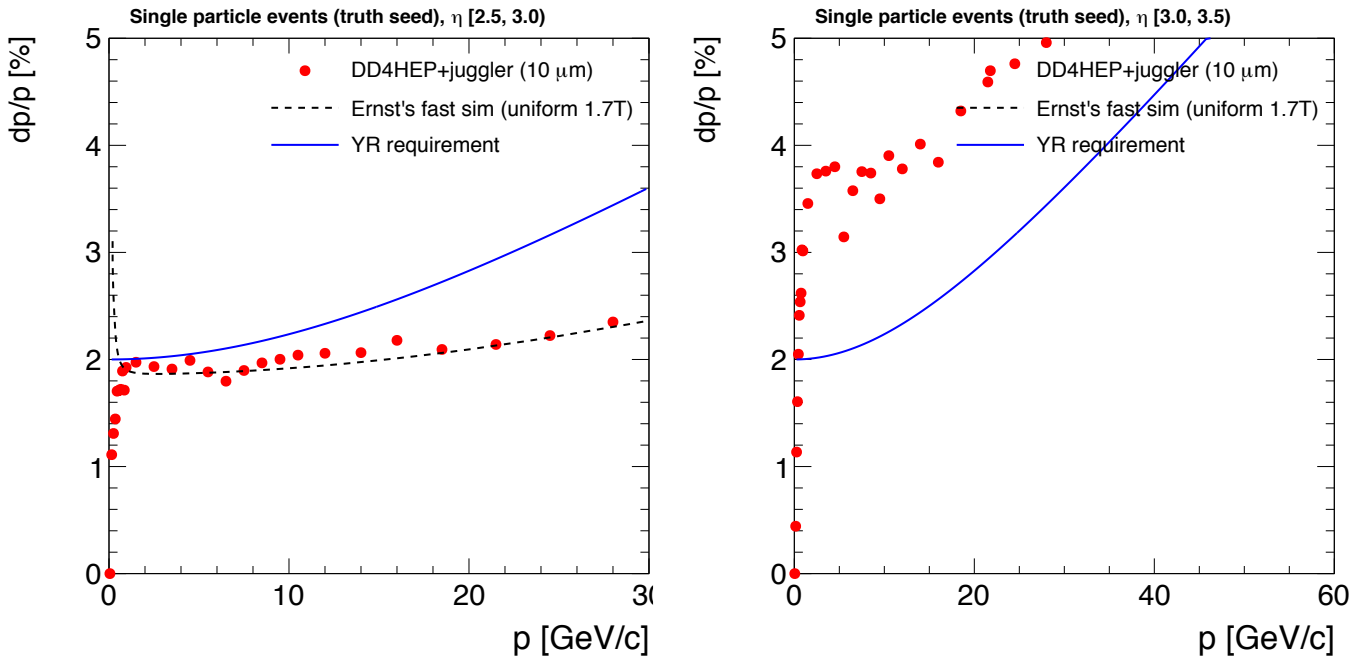








Momentum resolution (DD4HEP vs fast simulation)

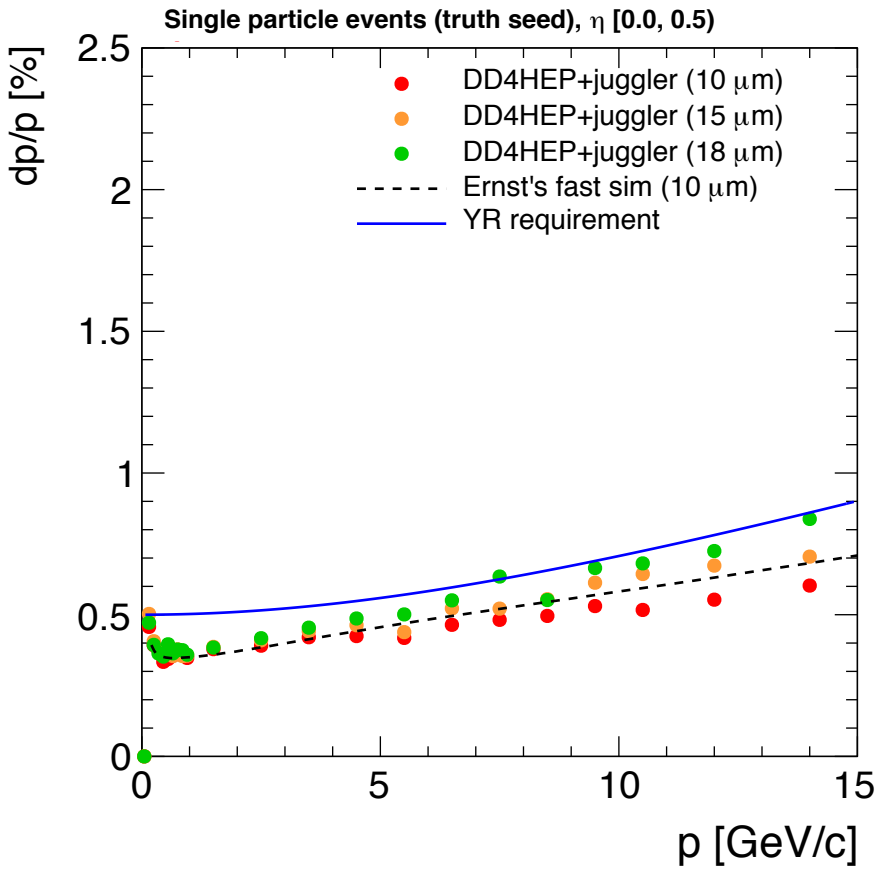


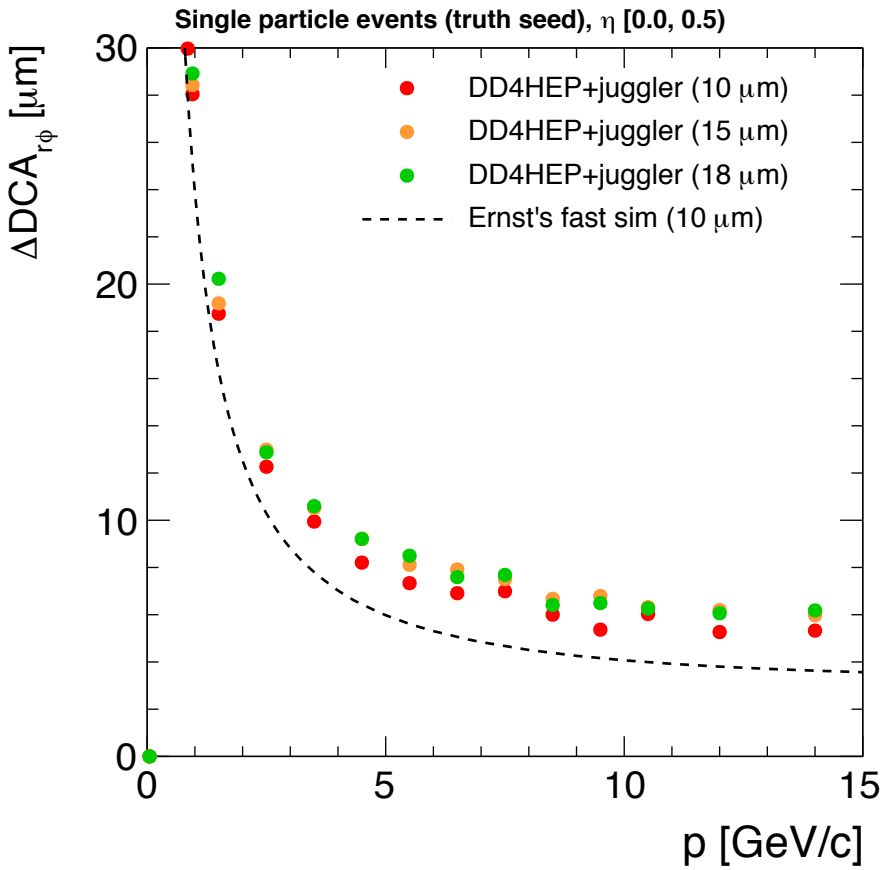
Results from DD4HEP in agreement with the fast simulation results

YR requirement achieved for most of the η range

Momentum and pointing resolution

- Comparison of different pixel sizes (10μm, 15μm, 18μm)
  - Intial study by Stephen Maple: https://indico.bnl.gov/event/17347
  - Sizable effect on the momentum resolustion (especially at higher p range)
  - Small effect on the pointing resolution: multiple scattering effect dominant (large and thick beam pipe)

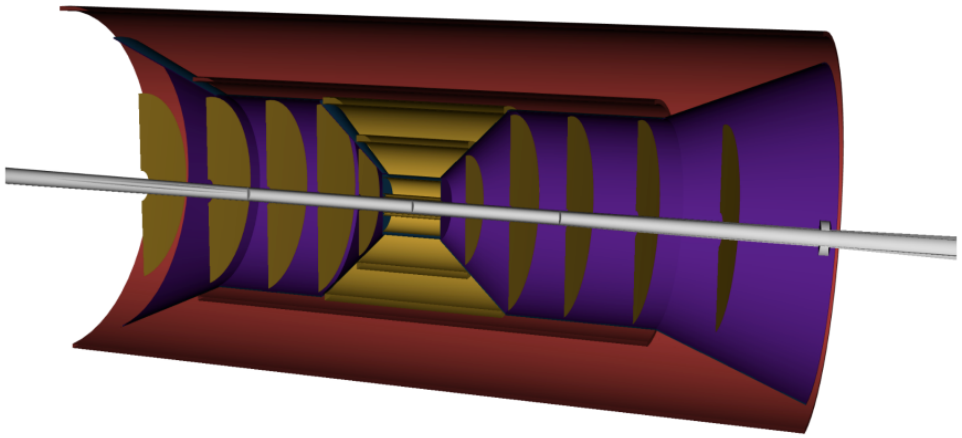




Disk position from the symmetric to new geometry

From Ernst's talk: https://indico.bnl.gov/event/17348/

Update on Geometry



Re-optimized baseline geometry discussed several times;
- 2 curved silicon vertex layers, r = 36, 48 mm, l = 270mm
- 1 curved silicon dual purpose layer r = 120mm, l = 270mm
- 1 stave-based sagita layer r = 270 mm, l = 540 mm
- 1 stave-based outer layer r = 420 mm, l = 840 mm

- 5 disks on either side of the nominal IP,
  - |z| = 250, 450, 700, 1000, 1350 mm
  - Inner radii >= 36 mm, outer radii <= 430 mm

Change necessary in the electron (negative) arm to accommodate new constraints mostly from PID, c.f.
- GD/I 2022-09-25, https://indico.bnl.gov/event/17295/
- EPIC 2022-10-06, https://indico.bnl.gov/event/17289/

New envelopes as of September 29, c.f. https://eic.jlab.org/Geometry/Detector/Detector-20220929172703.html
- z_{min} = -1186 mm, z_{max} = 1800 mm, r_{out} = 600 mm

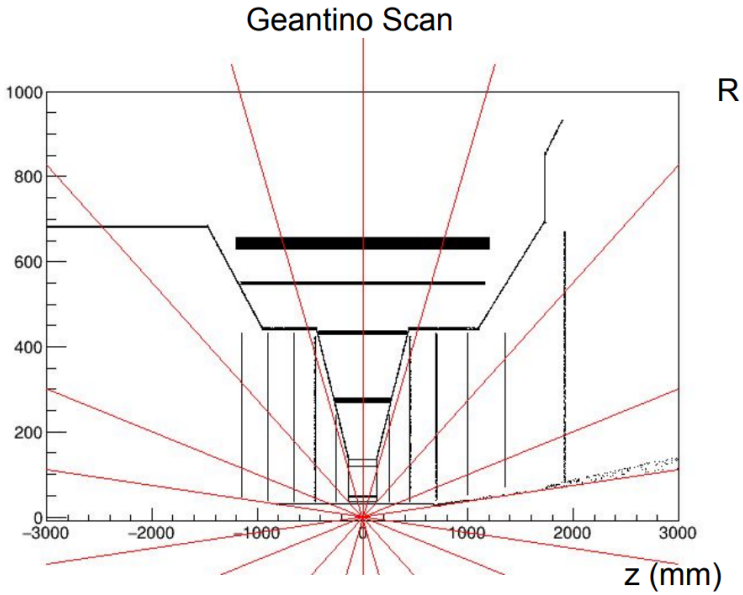
Propose a pragmatic approach of only "moving" the outermost disks in the electron direction inwards,
- z = -250, -450, -650, -900, -1150 mm
- minimal (or no) changes to inner and outer radii,
- inevitable loss of lever-arm in tracking, e.g. ~22% for $-2.5 < \eta < -2.0$

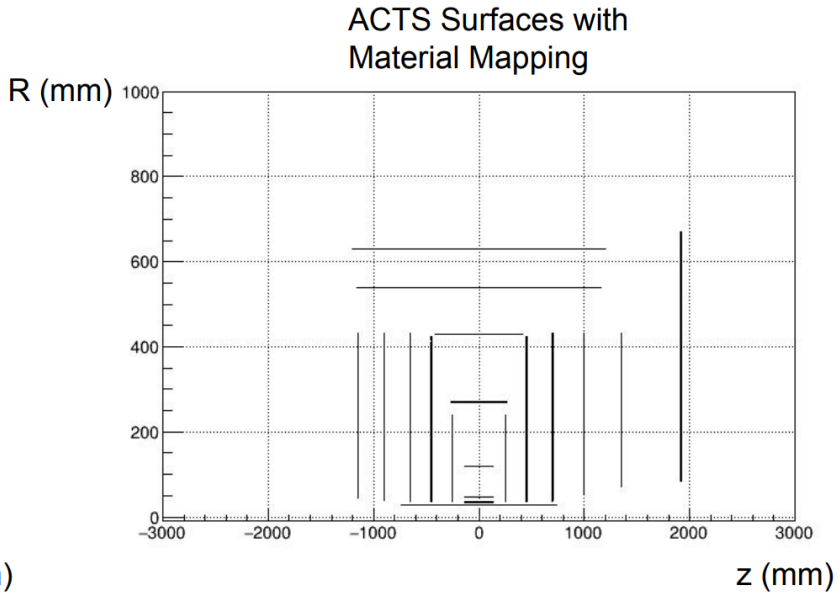
Alternatives considered:
- dropping outermost electron disk; results in inability to track for $\eta < -3.2$, suboptimal use of available space,
- moving innermost disk inwards to partially recover lever arm for $-2.5 < \eta < -2.0$; loss of commonality with hadron arm, acceptance near $\eta \sim -2.6$ - defer for now,
- changing the angle of the inner projective cone; seemingly inevitable to introduce additional material in the electron direction for $\eta > -1$
  no good arrangement to make the hadron-arm single-projective,

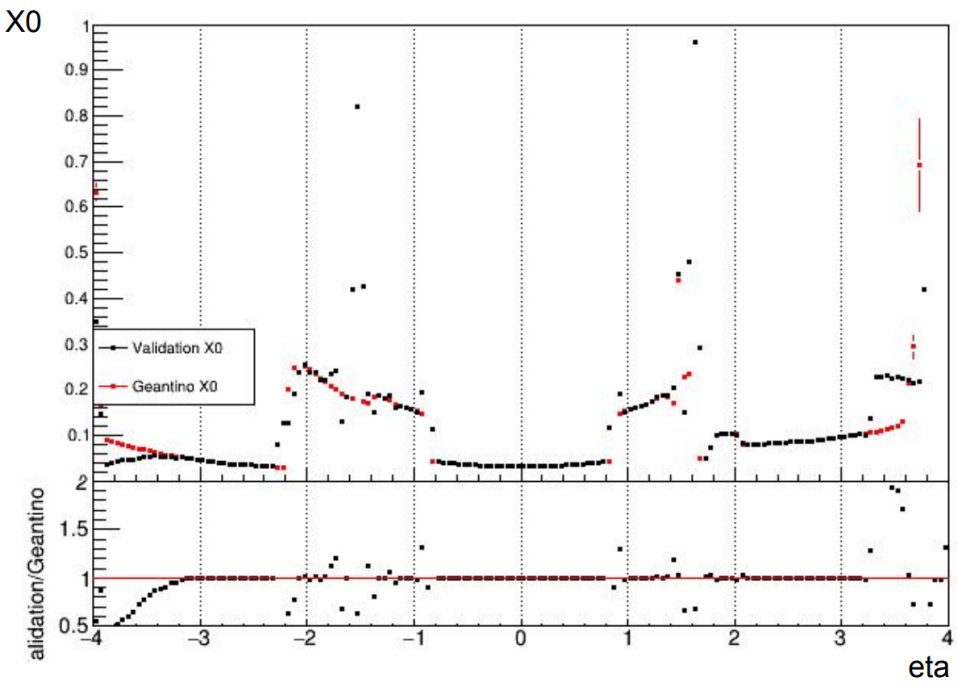
Not considered here / so far:
- r_{out} = 600 mm is now a combined envelope for MAPS and MPGD; could consider expanding the MAPS radius,
- small insert-like disks at large -z for far backward (electron) tracking to recover (and possibly extend) the tracking lever-arm in this region.

Details of the new tracking geometry implementation

From Shujie's talk: https://indico.bnl.gov/event/17394/



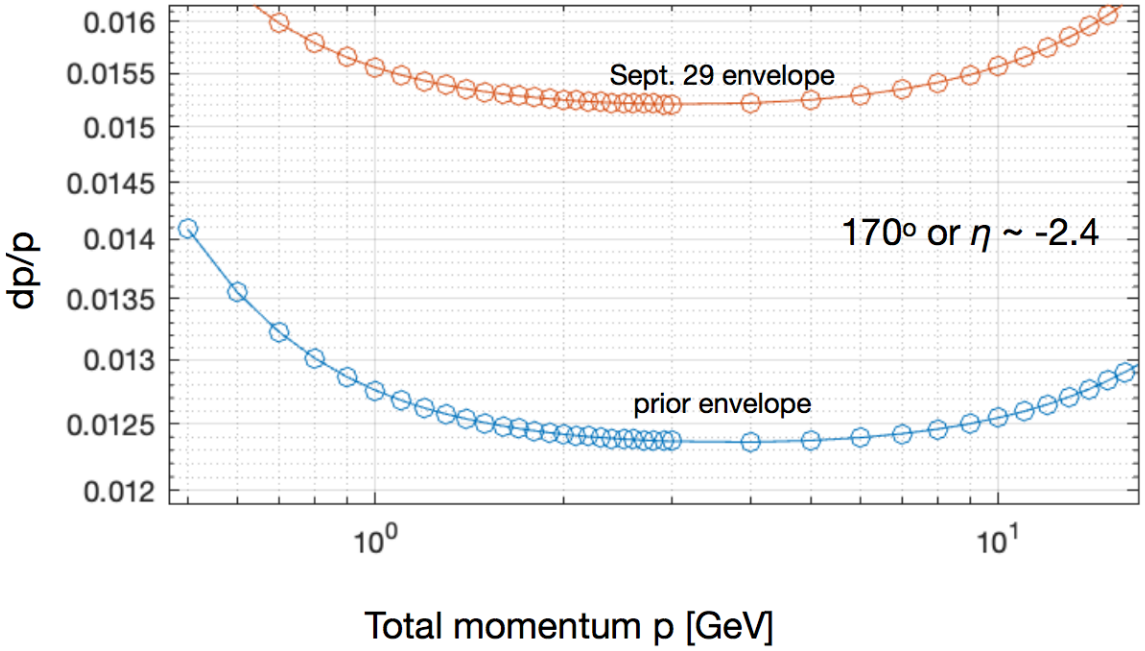


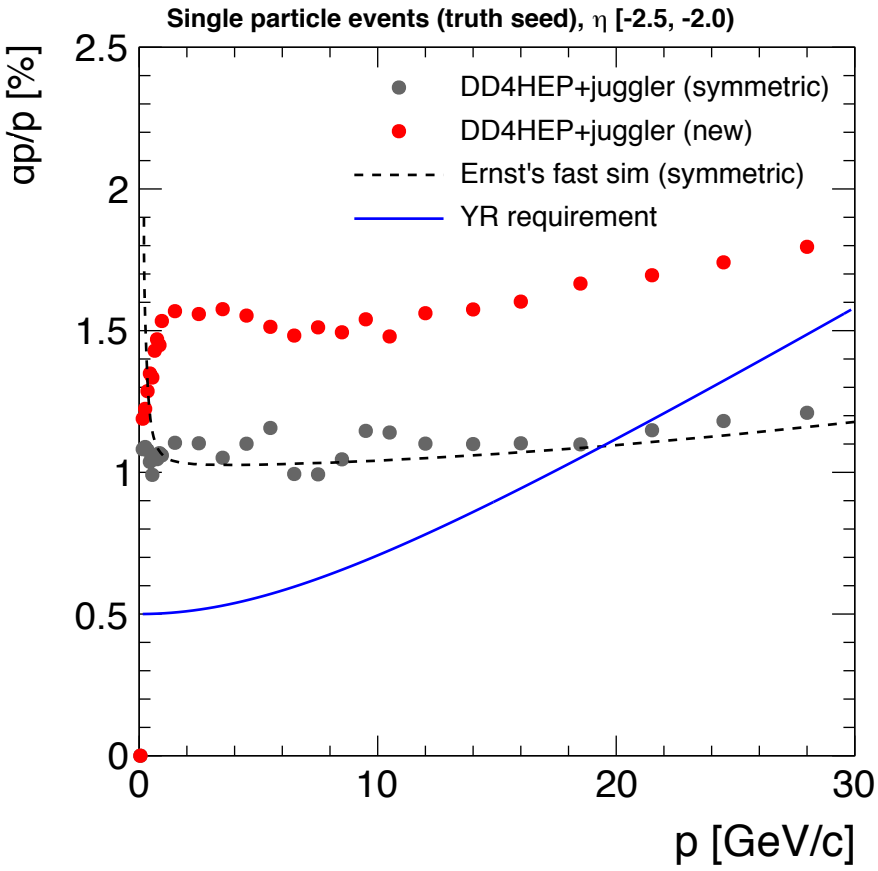


New geometry (+new magnetic field map)

- Geomtry update because of the new tracking envolope
  - Only change the electron-going side disk array: outter most 3 disks moved inwards (more details in Ernst' talk: https://indico.bnl.gov/event/17348/)
  - ~22% worse momentum resolution expected from the fast simulation study by Ernst
  - Consistent results from full simulation

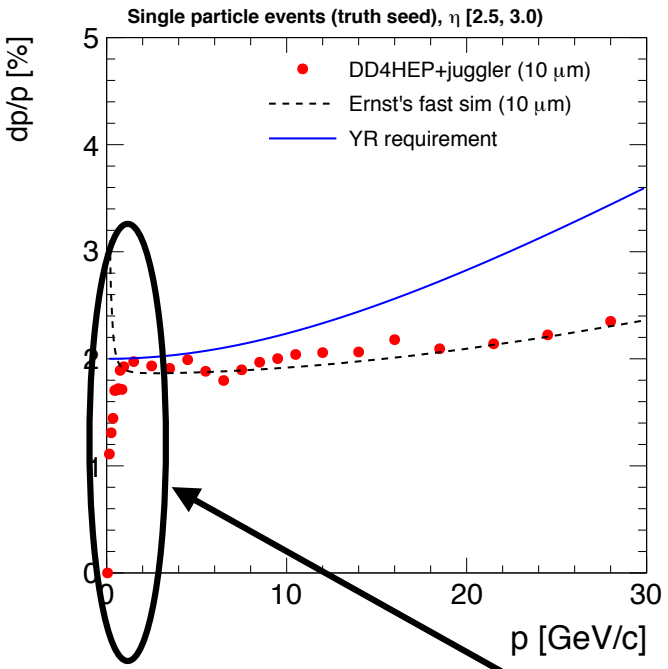
Figure credit: Ernst Sichterman

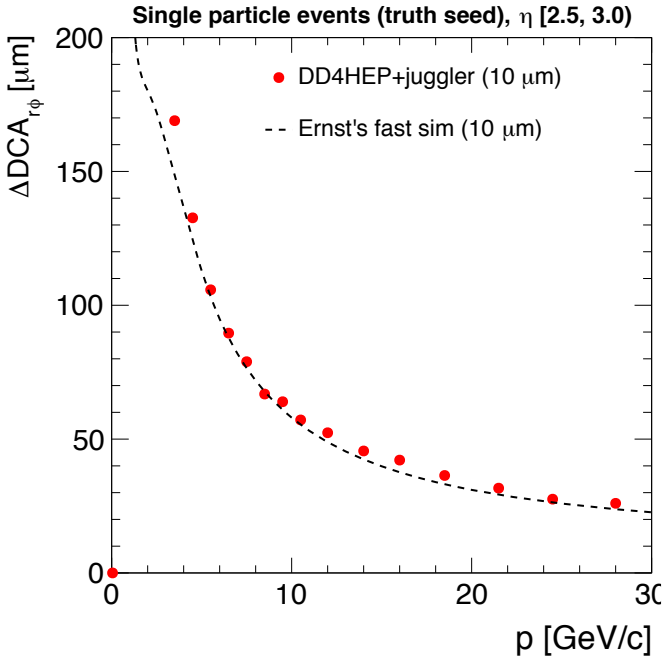


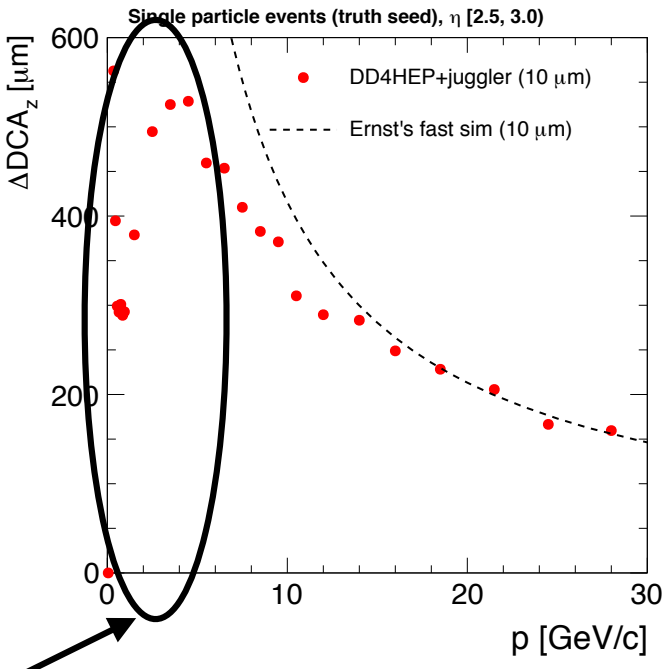


Outstanding issues with truth seeding

- p and DCA_z resolution show unexpected behavior towards low p at forward and backward rapidities
  - Expectation: increase of DCA_z towards low p which is observed in fast simulation and Fun4All (GenFit used for track fitting)





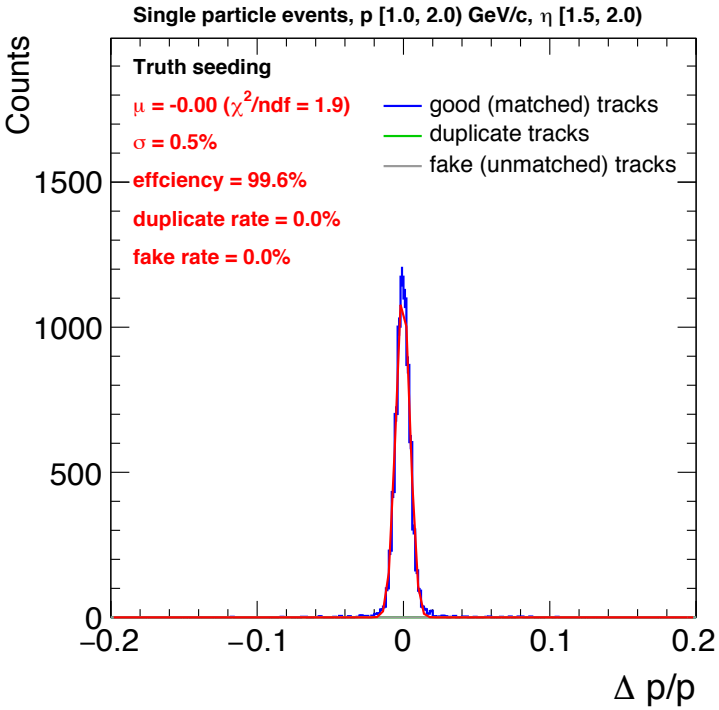


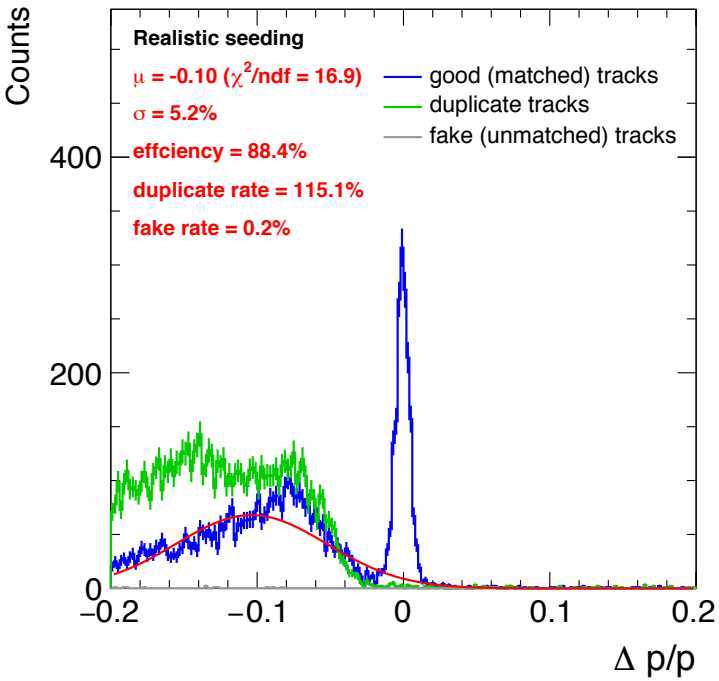
Unexpected behavior at very low p

Previously on realistic seeding

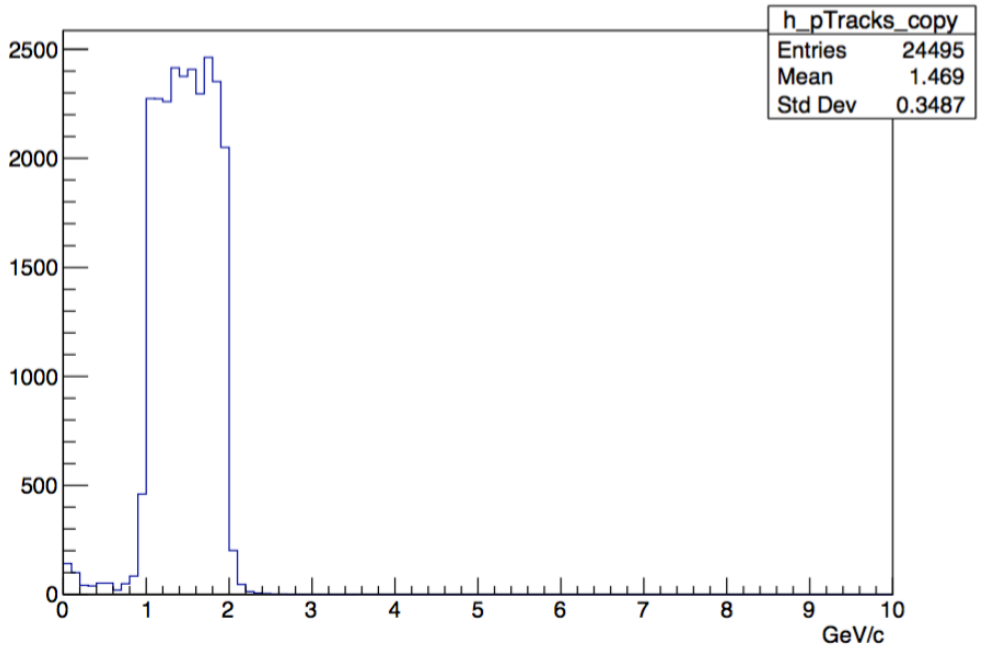
- Realistic seeding code developed by Yue Shi available in DD4HEP/juggler (https://indico.bnl.gov/event/16068/)
- Checked realistic seeding with ATHENA geometry (https://indico.bnl.gov/event/16583/)
  - Realistic seeding works well in midrapidity w/ "maxSeedsPerSpM = 1"
  - Low efficiency and problematic momentum reconstruction at low momentum (<10GeV) at forward rapidity

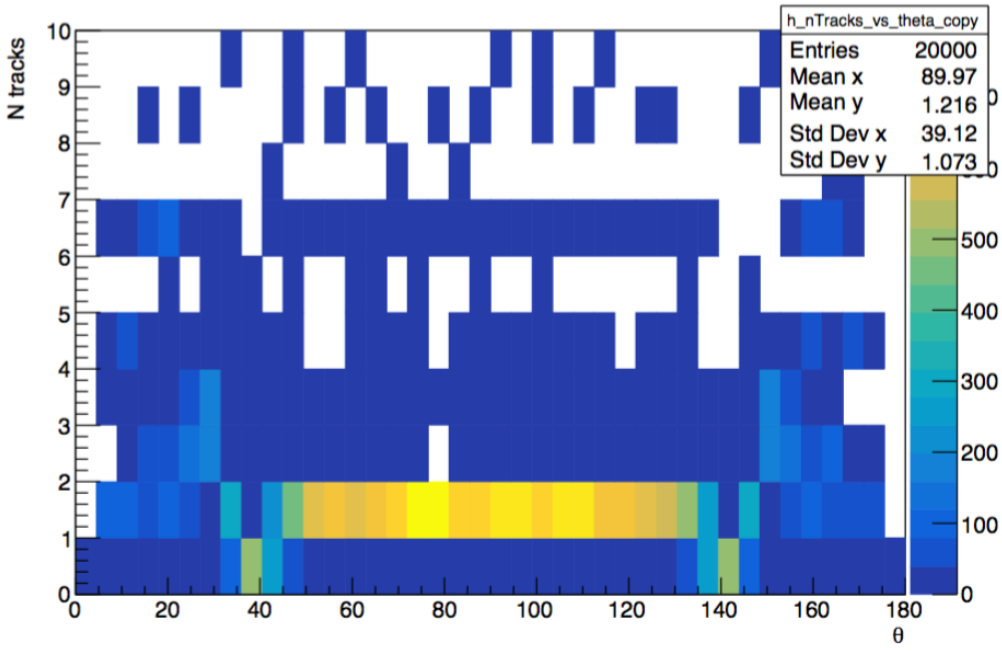
Code now improved by YueShi and tested with ePIC geometry





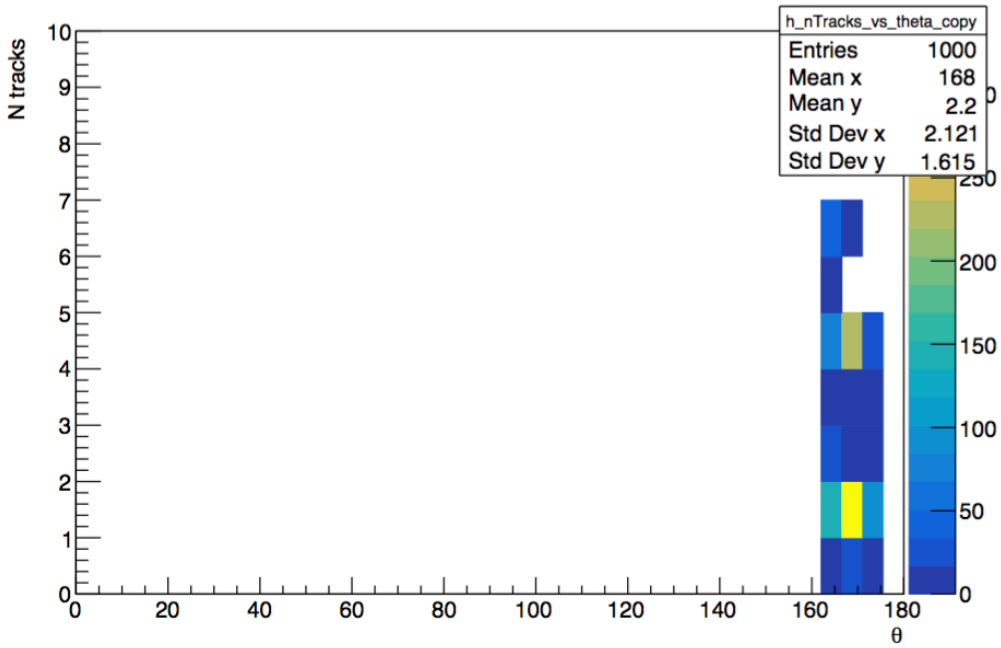
Realistic seeding status (by YueShi Lai)

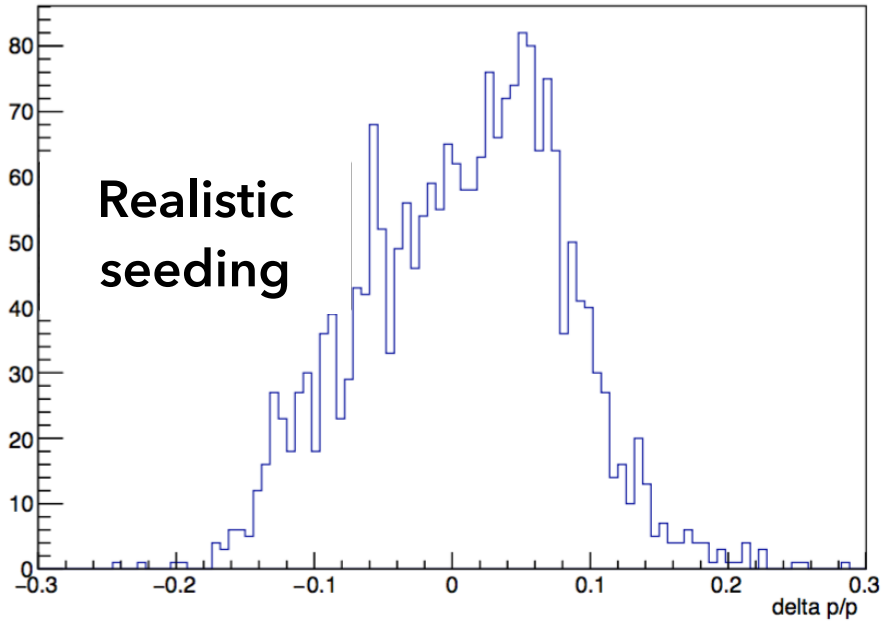




- Focus on the 1–2 GeV as the more challenging tracks
- "Ntrack = 0" is inefficiency, "Ntrack = 1" single reconstruction, "Ntrack ≥ 2" multiple reconstruction
- Good efficiency except for the 40° region
- Some multiple reconstruction in the forwards

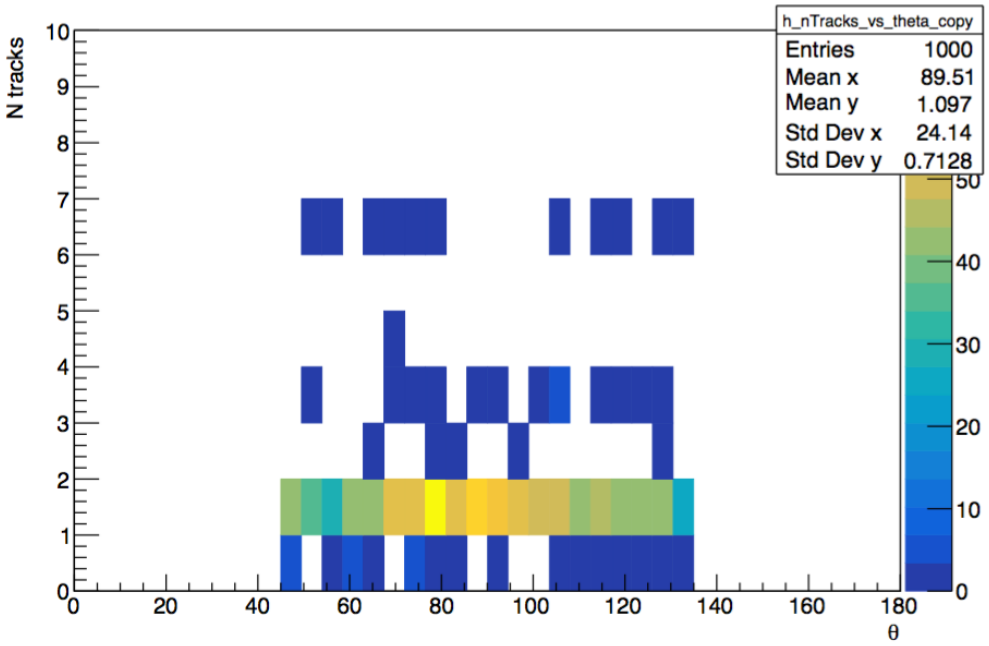
Forward (by YueShi Lai)

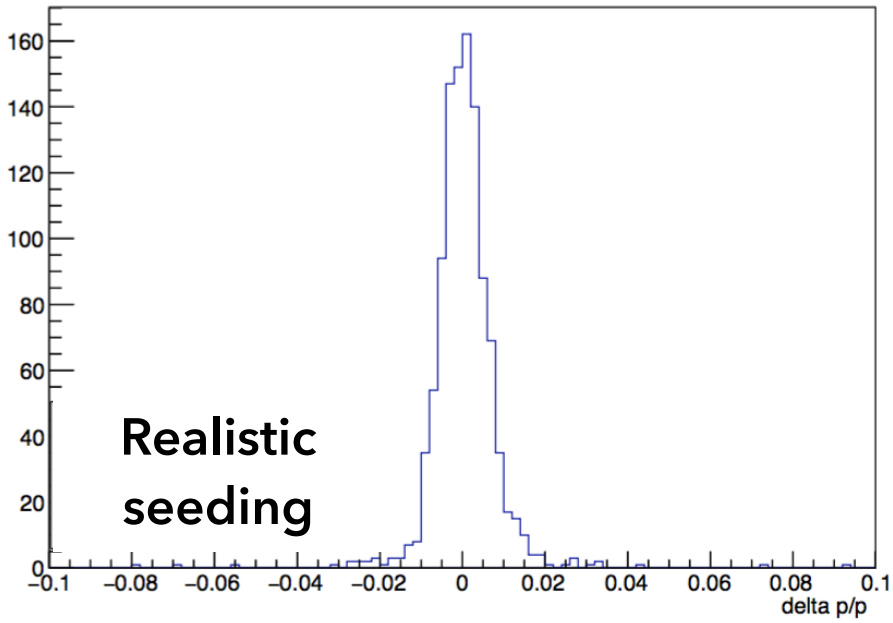




- Same 1-2 GeV tracks, $2 < \eta < 2.5$
- Reasonable performance, multiple reconstruction, some non-Gaussianess in the $\Delta p/p$

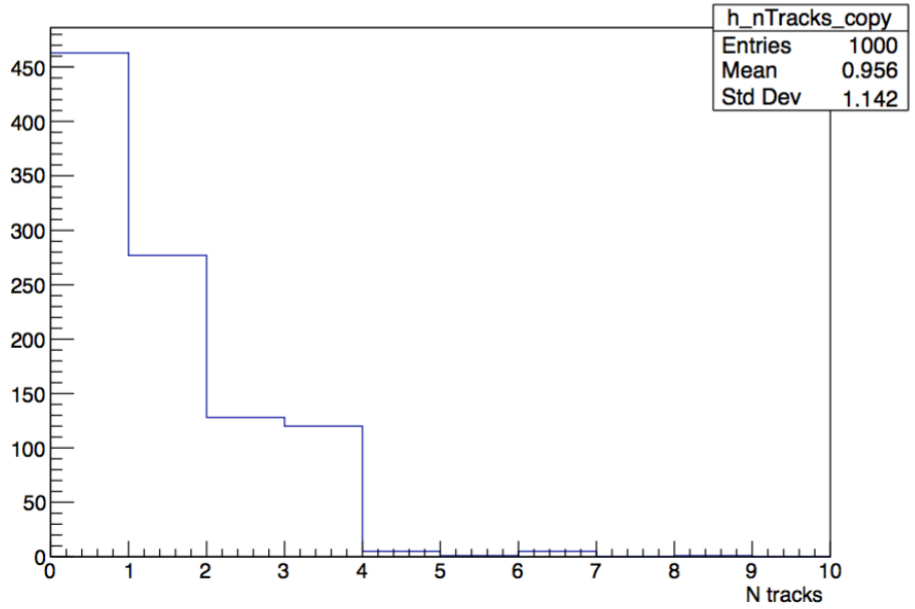
Forward (by YueShi Lai)





- Same 1-2 GeV tracks, $|\eta| < 0.88$
- Excellent performance in the midrapidity

Remaining issues (by YueShi Lai)



- 25–45°, the raw inefficiency is ≈ 45% (shown as 1D histogram for clarity)
- Tracing through ACTS shows that only 16% is genuine, no seeds found type of inefficiency
- About 30% failed to generate initial track parameter due to coordinate transform (i.e. geometry) failure
- Only recently traced to this granularity inside ACTS, currently under investigation

Summary

- Status of track finding and performance
  - Track reconstruction with truth seeding perform mostly as expected in DD4HEP with the material map (for both symmetic and updated geometry)
  - YR achieved in mid and forward rapidities
  - Missing information: more tracking information (χ^2, # of associated hits), primary/secondary vertex reconstruction

- Status of realistic seeding
  - Significant improvement since last version for low momentum tracks at forward rapidity
  - Current issue: the low efficiency around 25-45 degree, under investigation now
  - Plan to test with DIS events and events with background after stable and reasonable performance achieved with single track events