eRD16 and eRD16-related* simulations

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EICUG-YR Tracking Working Group Mtg.
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eRD16 and eRD16-related* simulations

Yue-Shi Lai, Ivan Velkovsky, Emily Bierman, Barbara Jacak, Winston DeGraw, Youqi Song, Dhruv Dixit, Fernando Torales Acosta, Rey Cruz Torres, Michael Lomnitz, Sam Heppelman, Spencer Klein, …

Thanks also EICUG software working group, BNL EIC task-force, sPHENIX, …

* The EIC generic detector R&D program has been and continues to be essential to this and many other efforts. Similarly, LBNL-LDRD, UC-MRPI, and other sources of funding have been and some continue to be essential to this effort.

eRD16+ simulation tools:

1. Event generator(s); pythia-eRHIC, eSTARlight, …
   here, pythia-eRHIC for event-overlap (pile-up) and open-charm

2. EIC-smear - event smearing,
   here, EIC-smear as an I/O library,

3. **LDT - fast simulation,**
   Originally developed by the Vienna group (Regler et al.),
   Use-cases include ILC and LHeC detector concept studies,
   MC with analytical track propagation through cylindrical barrels
   and disks including multiple-scattering in ideal solenoidal fields,
   parametrized digitization, Kalman track-reconstruction.
   Not GEANT-based.

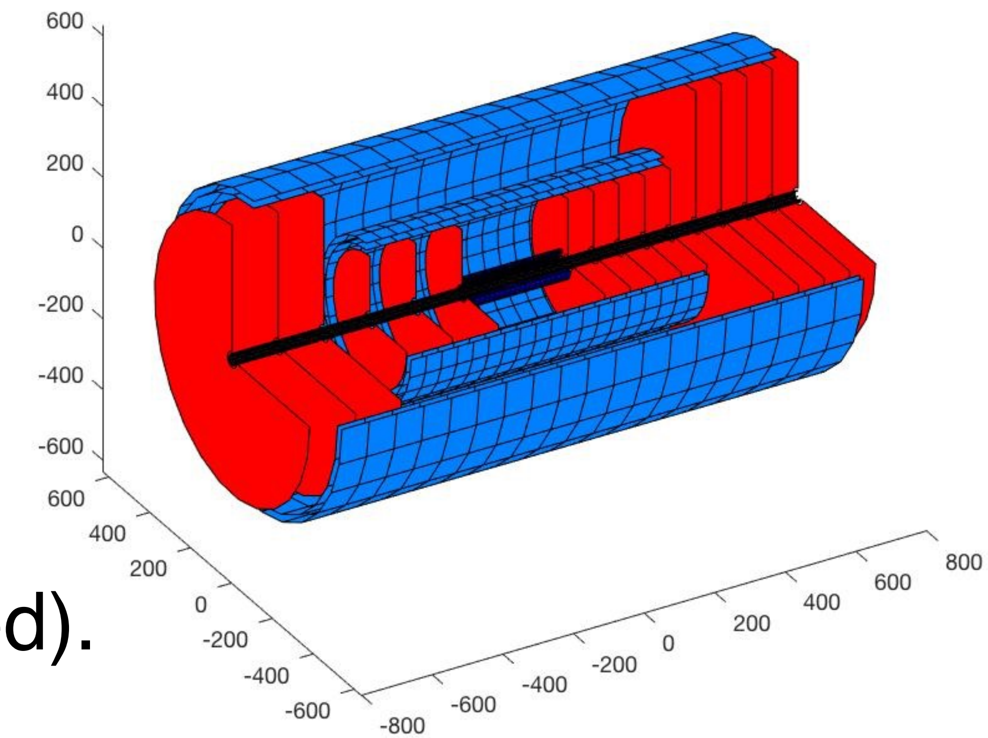
4. **EIC-root** - **full simulation** with parametrized sensor-response,
   GEANT-based - see, in particular, Alexander's talk last week.

5. Fun4All

6. (GenFit, RAVE, FastJet, …)

eRD16+ - LDT

- Charged-particle tracking toolset originally developed for ILC studies by the Vienna group, M. Regler, M. Valentan, and R. Frühwirth (2008):
  - Helix track model,
  - Multiple scattering,
  - Full track reconstruction from digitized hits using a Kalman filter,
  - Documented (and peer-reviewed).

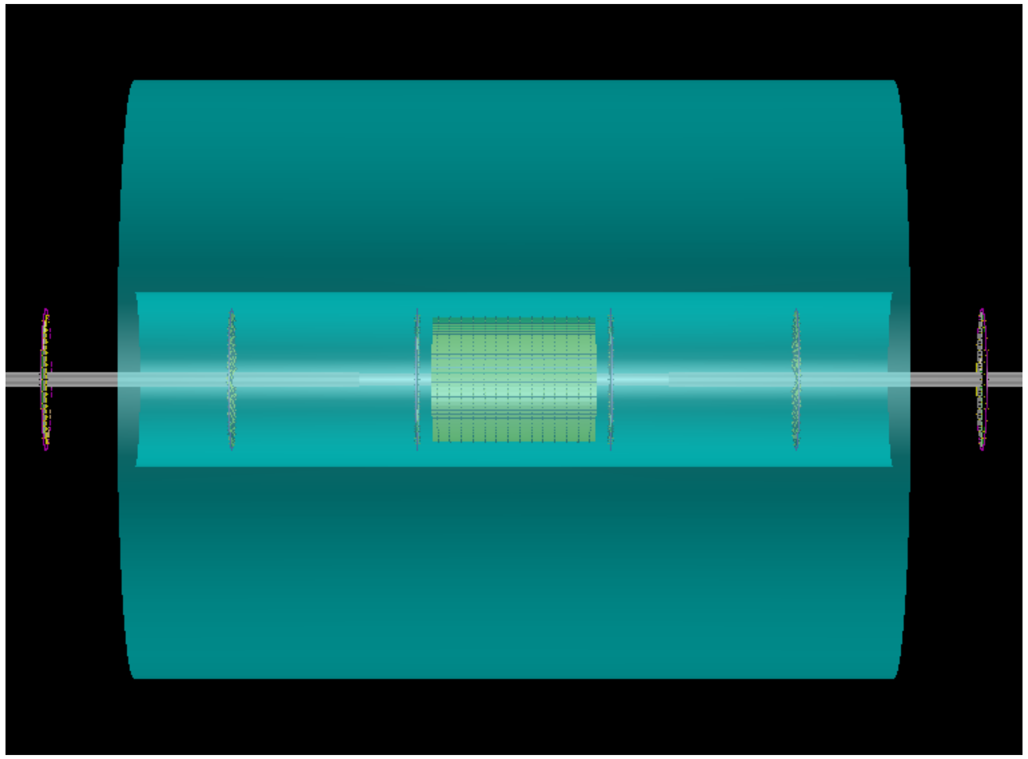


Hypothetical all-Si tracker in a 1.5T Solenoidal field.

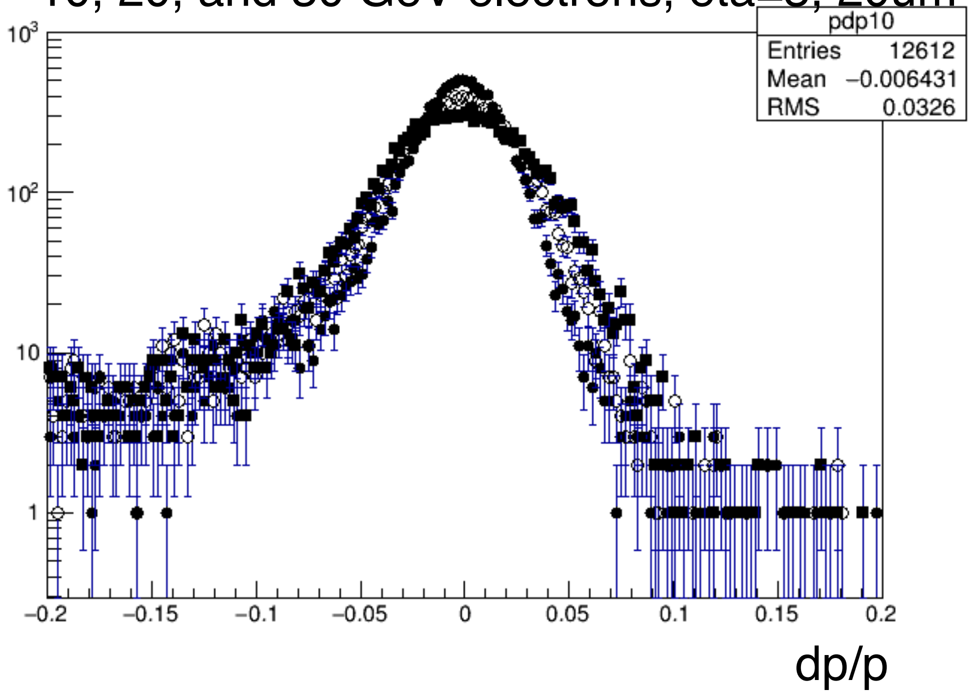
- Rapid studies of number of layers, disks, geometrical layout, etc.
- Use cases include ILC and LHeC detector concept studies, eRD16, shared with LANL for their forward-disk studies (March 2019),
- Two (now) known issues: low-$p_{(T)}$ threshold (out-of-the-box, straightforward to overcome), correlation between dip-angle and p_T lost through beam-pipe in p-mode (not straightforward).

eRD16+ - EIC-root

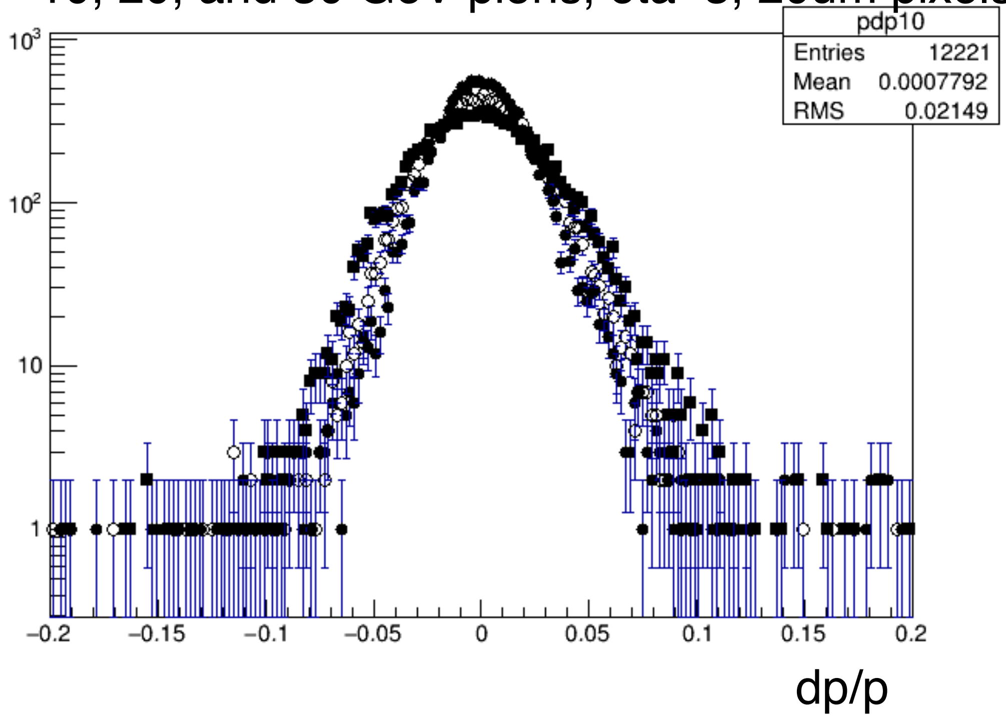
- Tails can and do matter, even in a simulation with three thin disks,



10, 20, and 30 GeV electrons, eta=3, 20um pixels



10, 20, and 30 GeV pions, eta=3, 20um pixels



- Handled (removed) in what follows by focusing on the central 2-3 sigma

- Detailed comparisons eRD16-eRD18

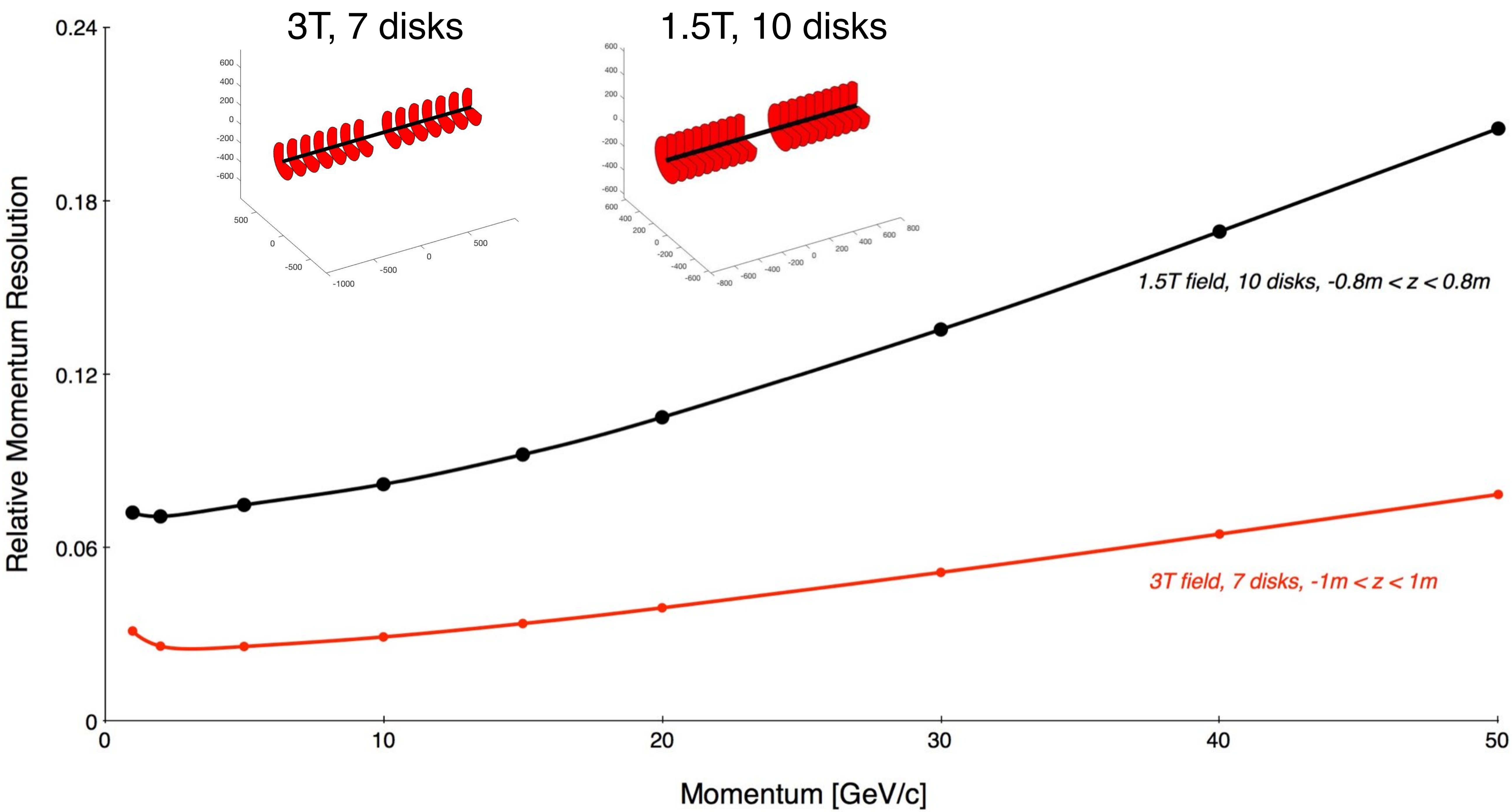
- eRD16 (and eRD18) geometries shared with LANL (March 2020)

eRD16^{+} - simulations

- Goal: forward/backward disk configuration, sensor specs, 1.5 and 3T
  Integration with barrel (vertex) layers, all-silicon concept(s)

eRD16+ - simulations

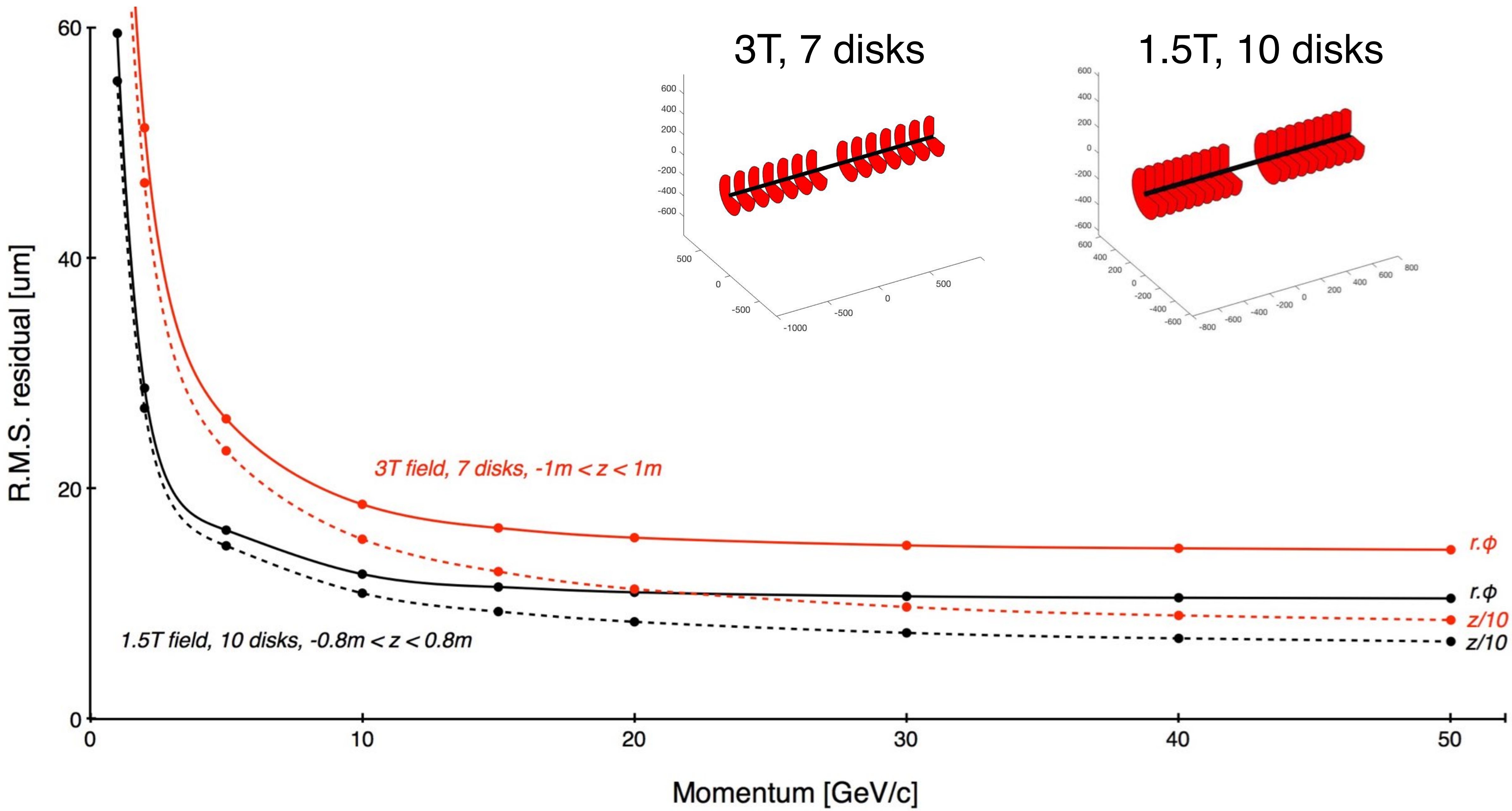
- Some initial (fast-)simulation results:



eta=3, 28um pixels, 3T initial contact with BNL-TF EICroot simulations

eRD16+ - simulations

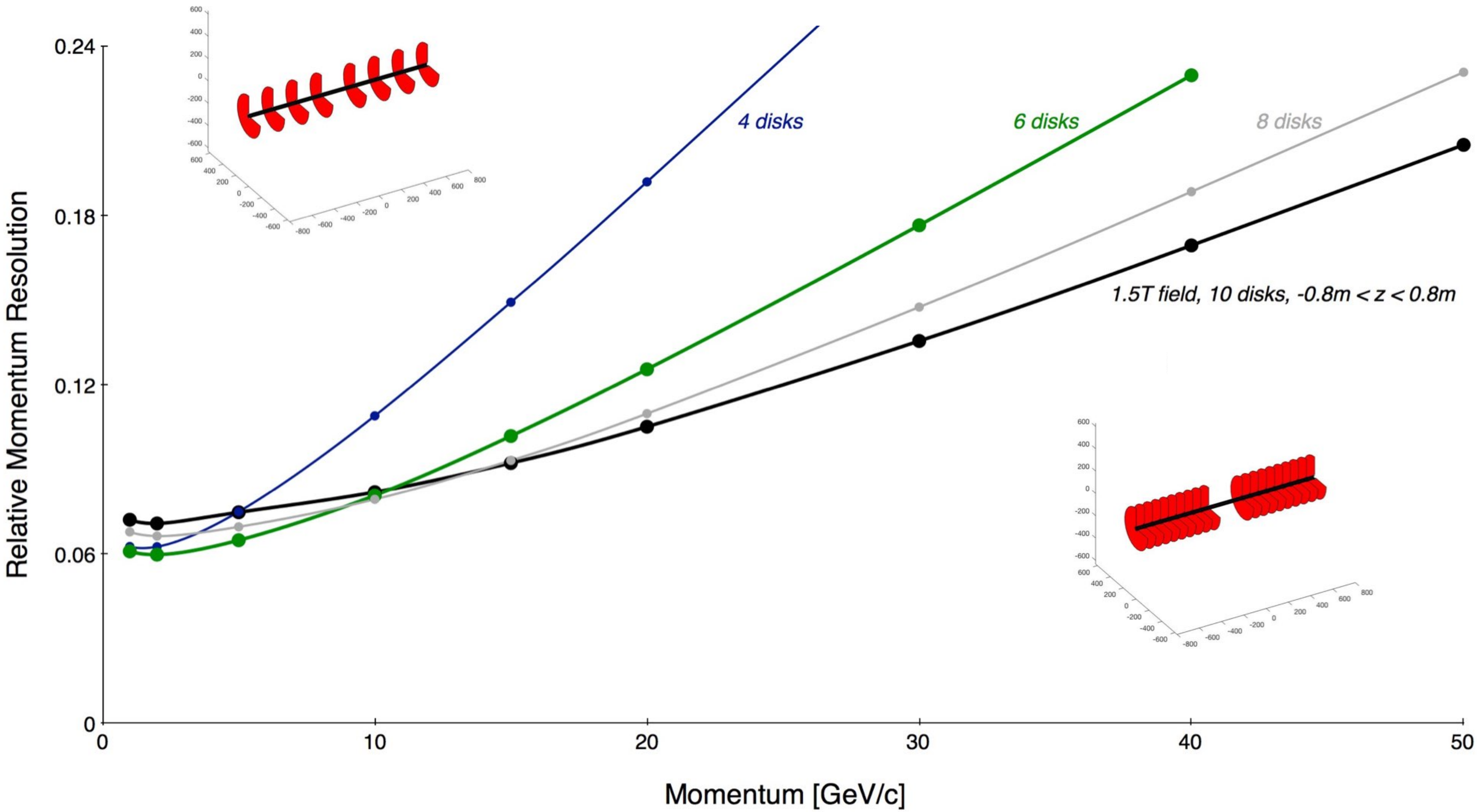
- Some initial (fast-)simulation results - single-track pointing resolution:



eta=3, 28um pixels

eRD16+ - simulations

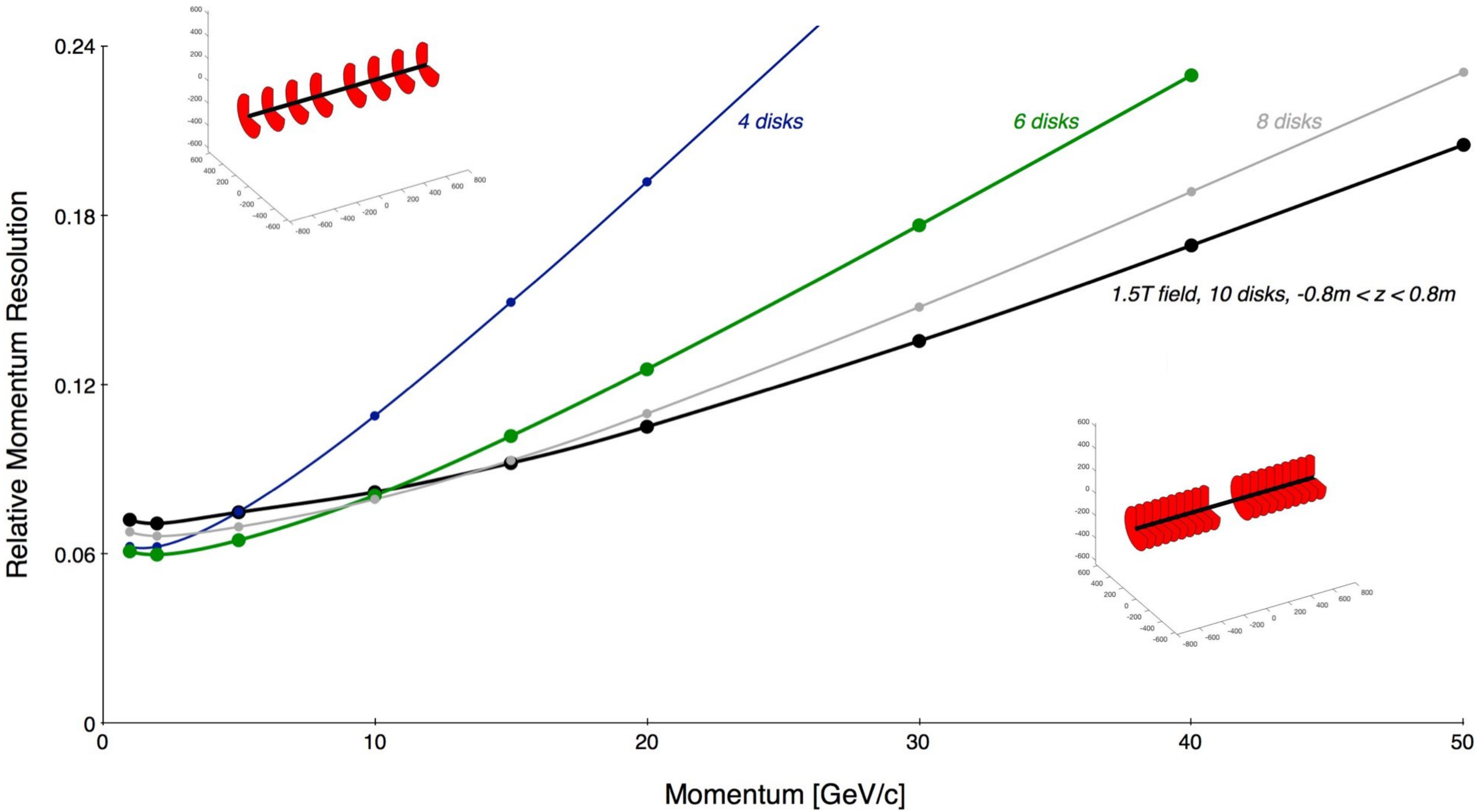
- Some initial (fast-)simulation results - disk-scans:



+ non-equidistant spacing, disks with different radii, z up to ~1.4m, …

eRD16+ - simulations

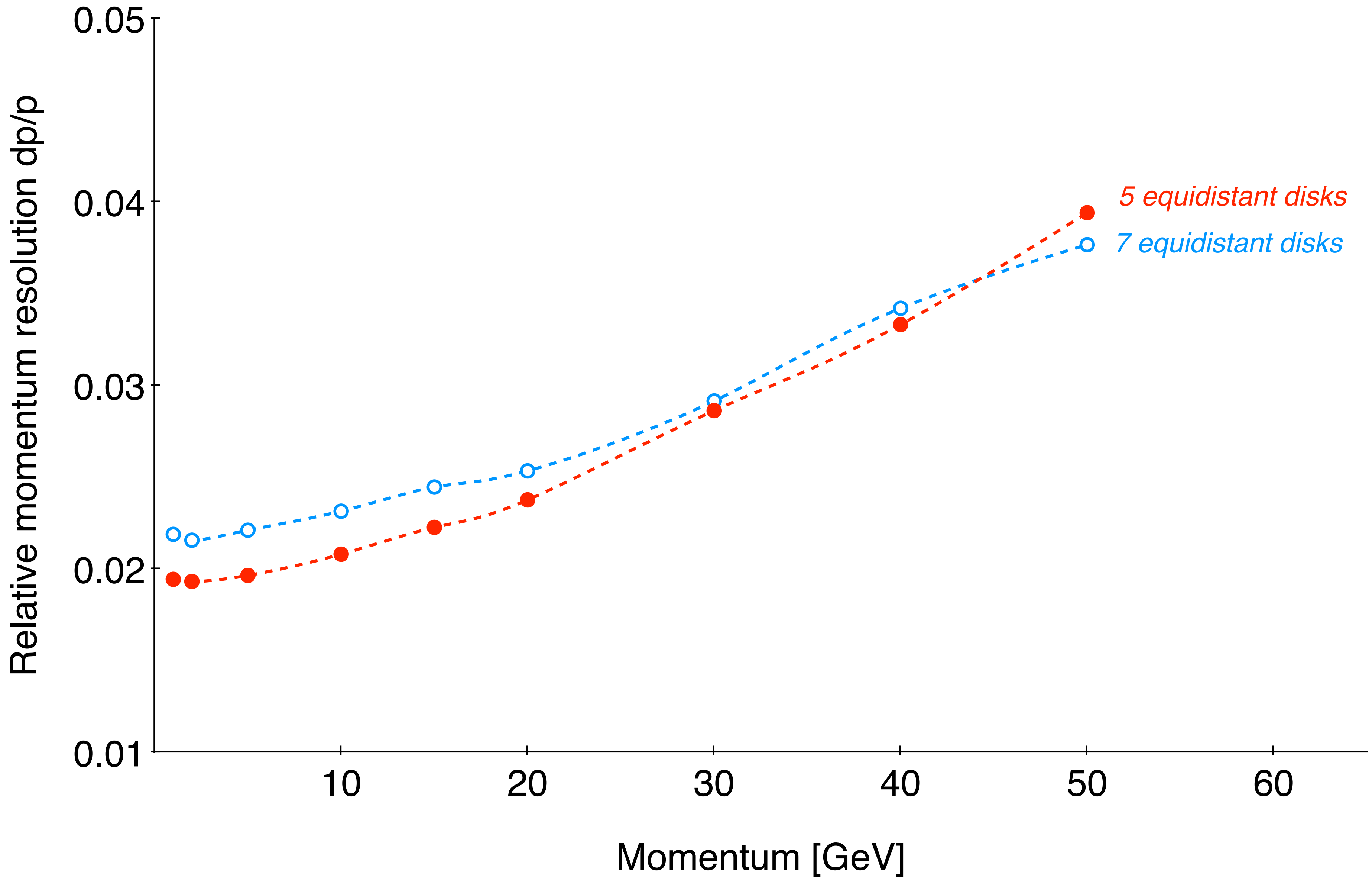
- Some initial (fast-)simulation results - disk-scans:



These days, multiple points of contact with EIC-root, 5-7 disk configs.

eRD16+ - simulations

- E.g. disk-scan from EICroot,

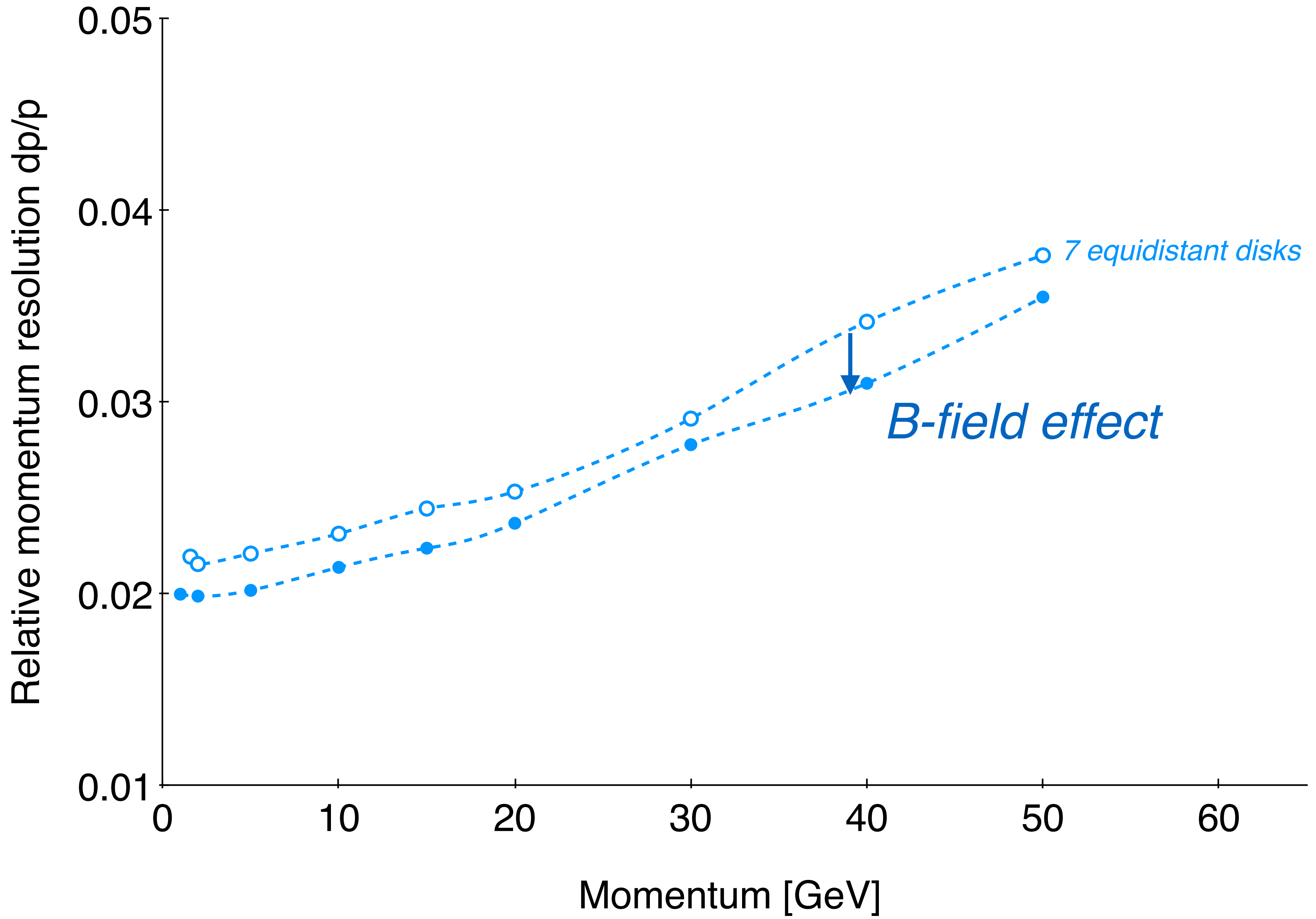


Equidistant disks with 20µm^2 pixels, 0.25 < z < 1.21m,

3T field (“open field”), eta =3

eRD16+ - simulations

- (default) “open field” versus 3T box:

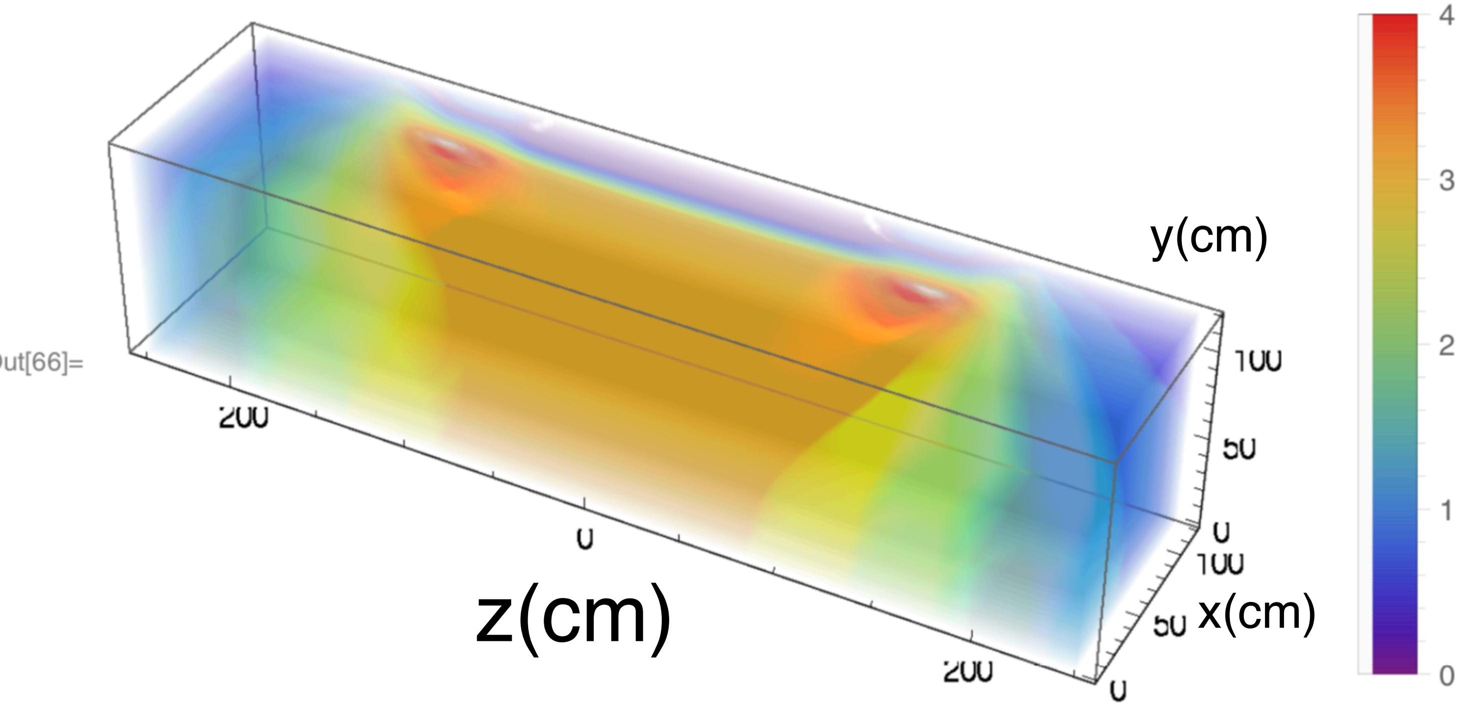


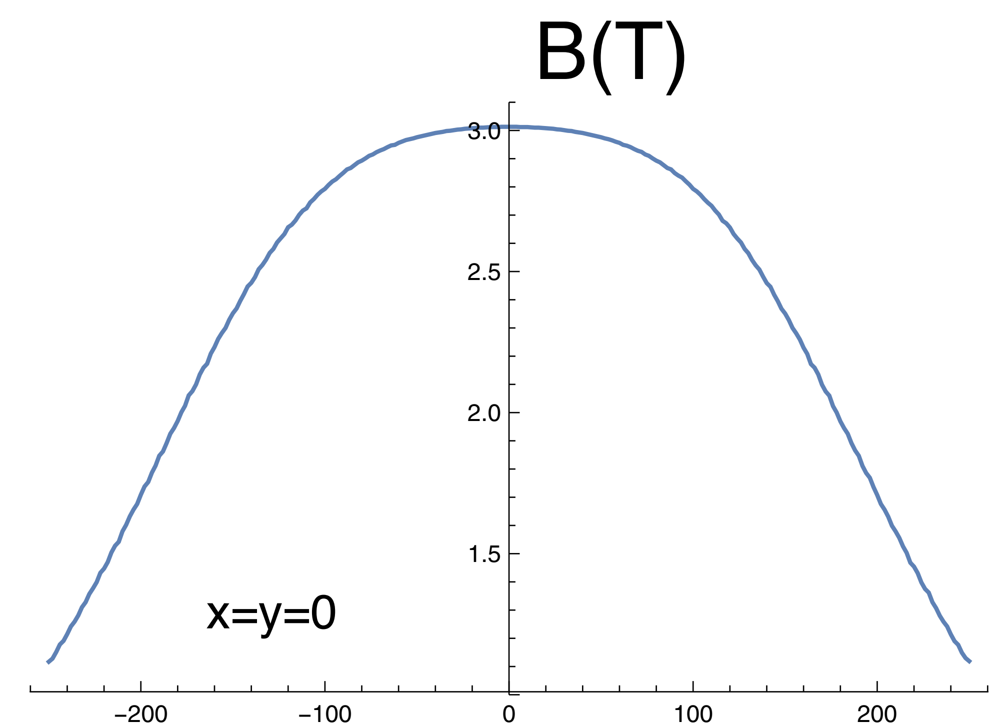
Equidistant disks with 20µm² pixels, 0.25 < z < 1.21m,

3T fields, eta =3

eRD16+ - simulations

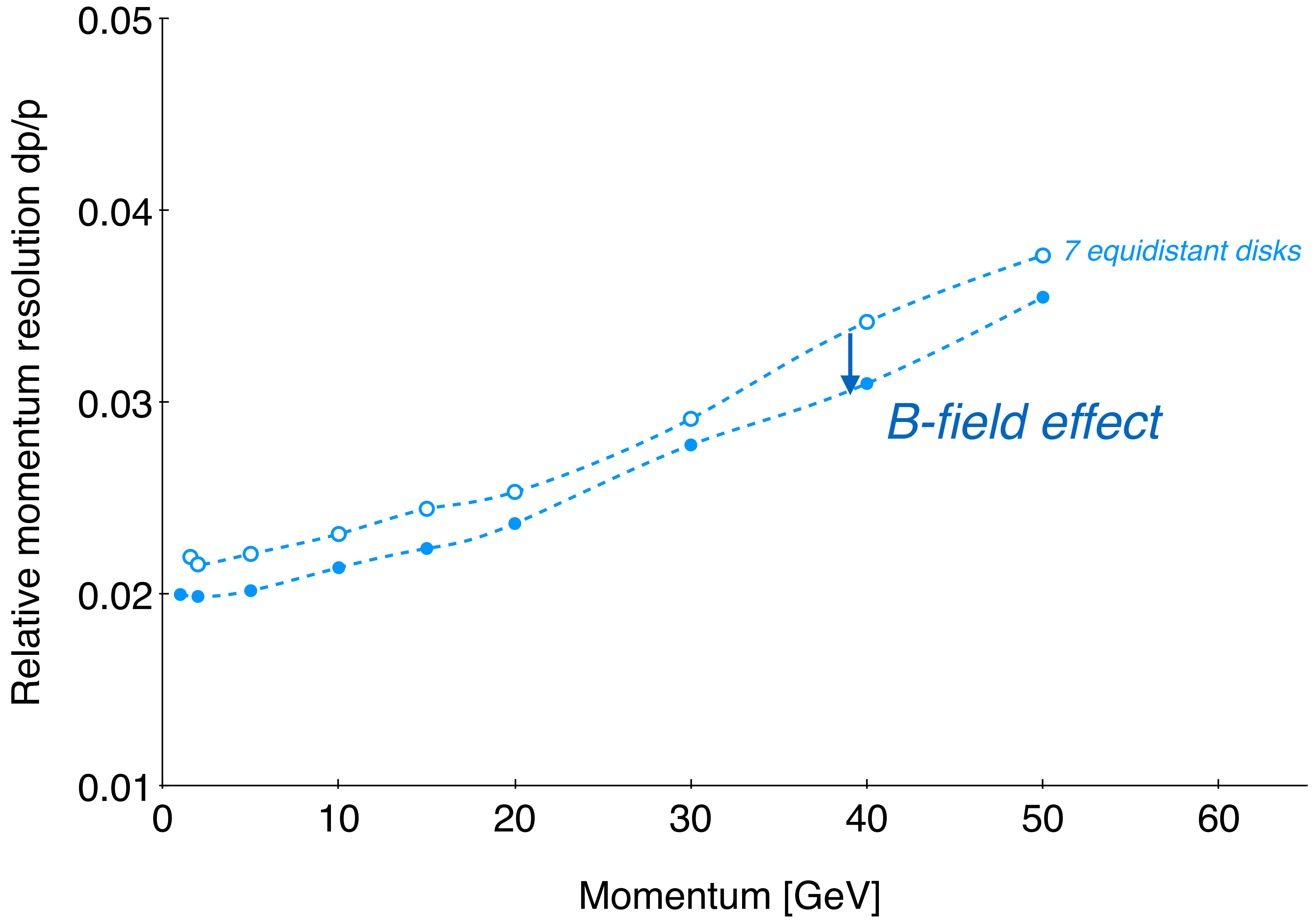
- (default) “open field” versus 3T box:





eRD16+ - simulations

- (default) “open field” versus 3T box field:

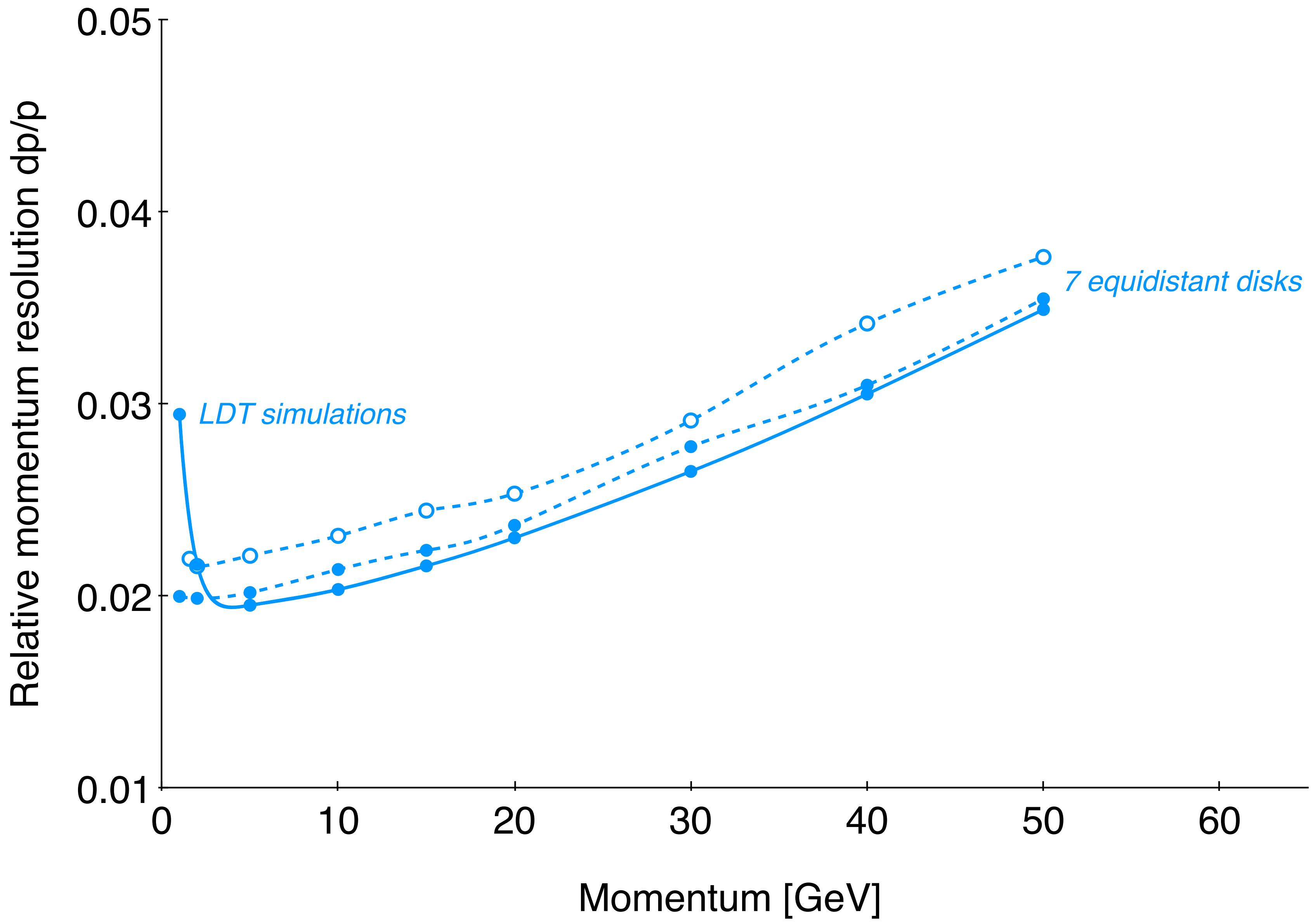


Equidistant disks with 20μm² pixels, 0.25 < z < 1.21m,

3T fields, eta =3

eRD16+ - simulations

- EIC-root and LDT comparison:

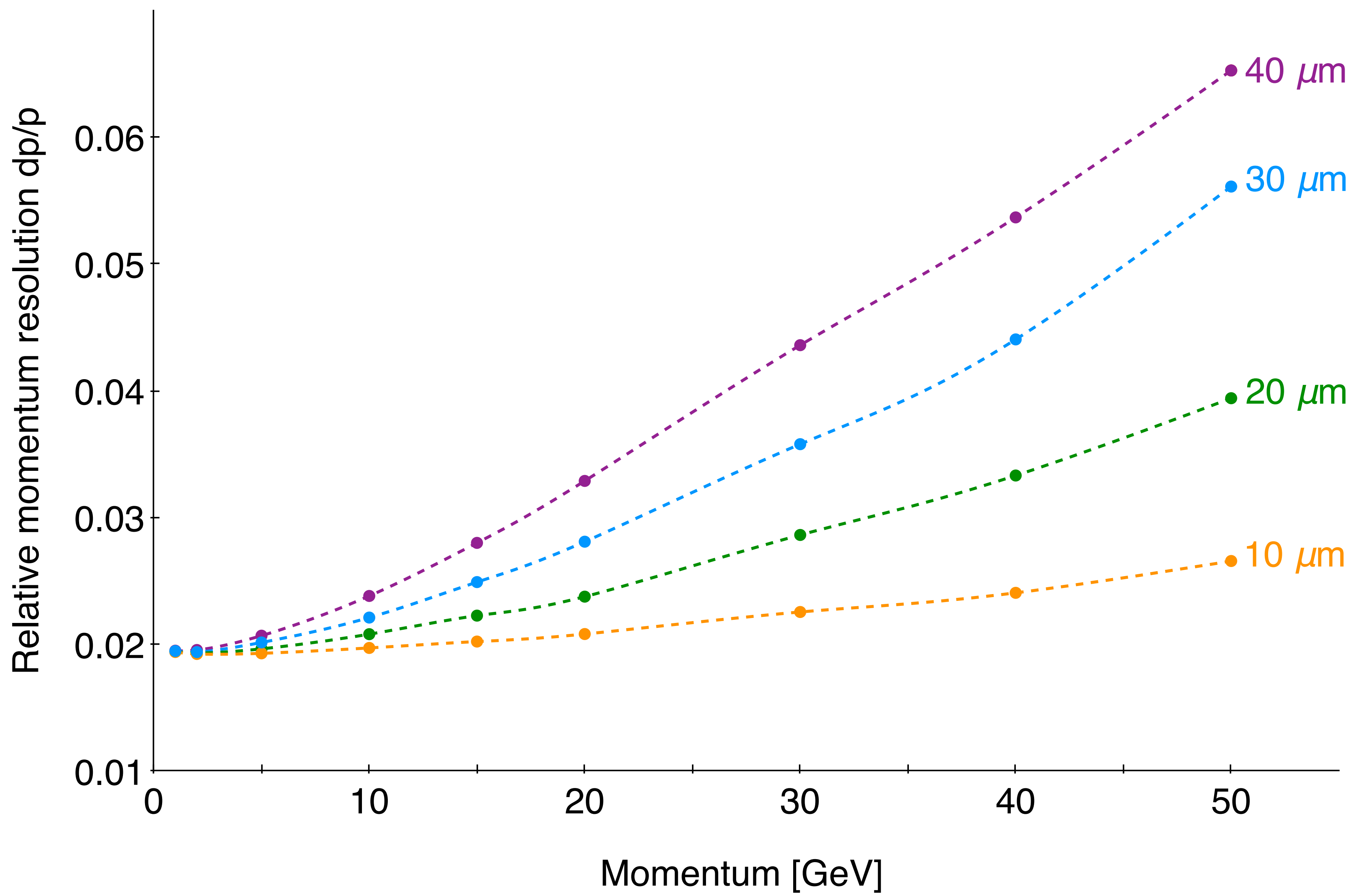


Up-turn at small-p is an LDT defect (c.f. slide 4),

Similar studies with 1.5T box field, # disks, etc.

eRD16+ - simulations

- EIC-root pixel-size scan

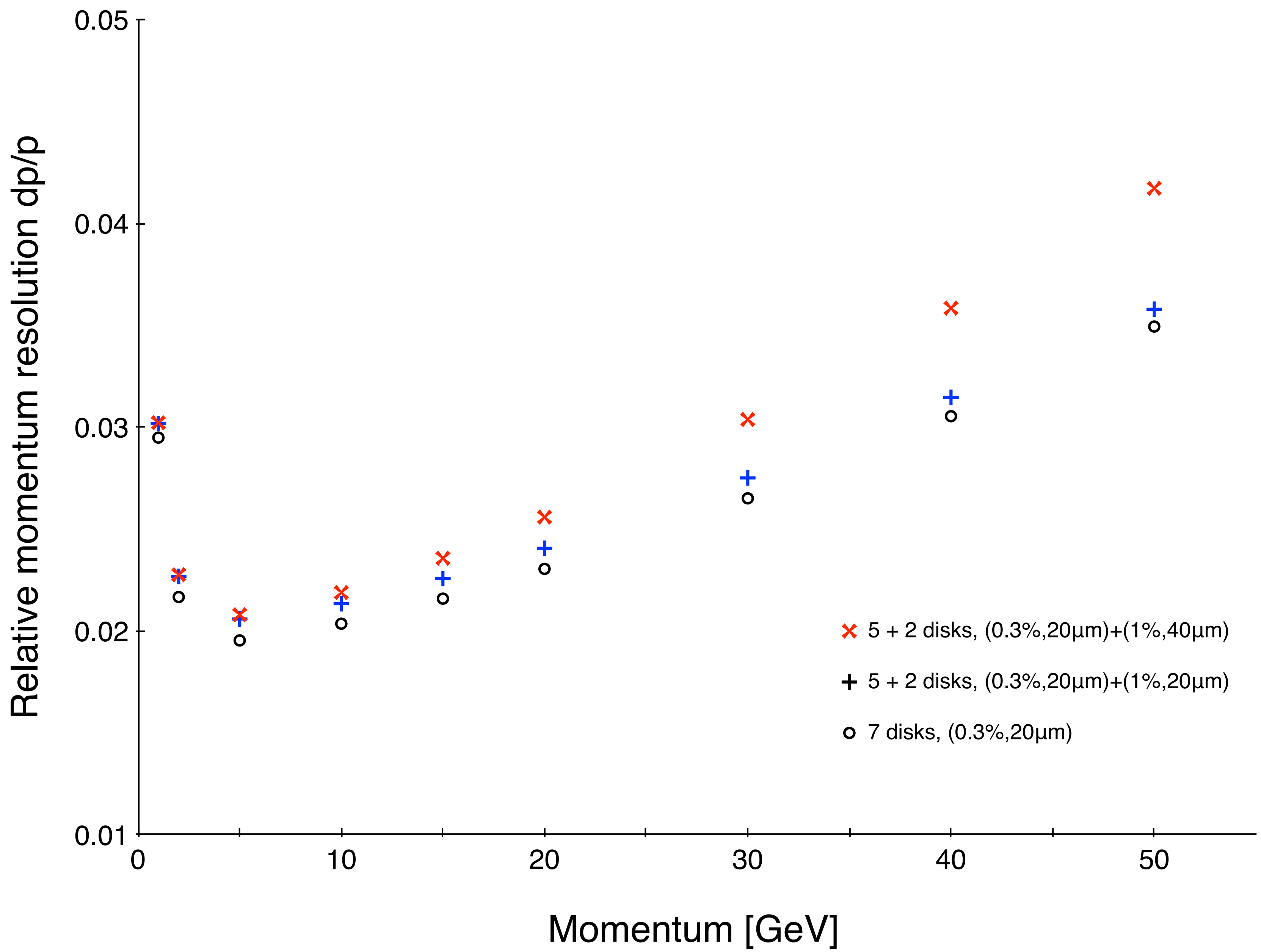


Equidistant disks, 0.25 < z < 1.21m, 3T field (open), eta =3

Point resolution is simply pixel-size/√12 here, no system effects.

eRD16+ - simulations

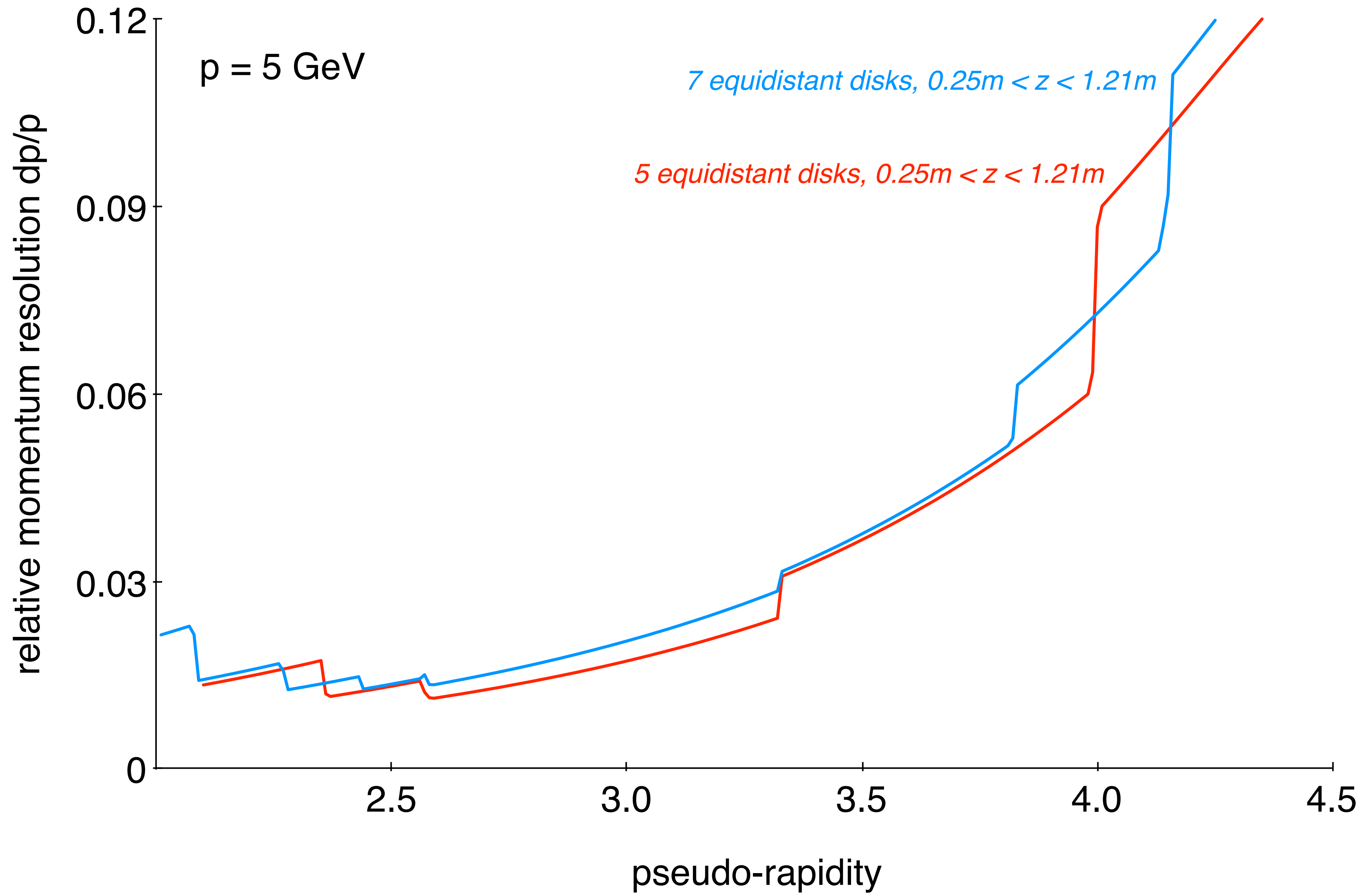
- A relevant “what-if” (from fast simulations):



- added material will cause ~negligible degradation of dp/p,
- larger pixels at high-z are undesirable, especially for large momenta in the forward hadron region.

eRD16+ - simulations

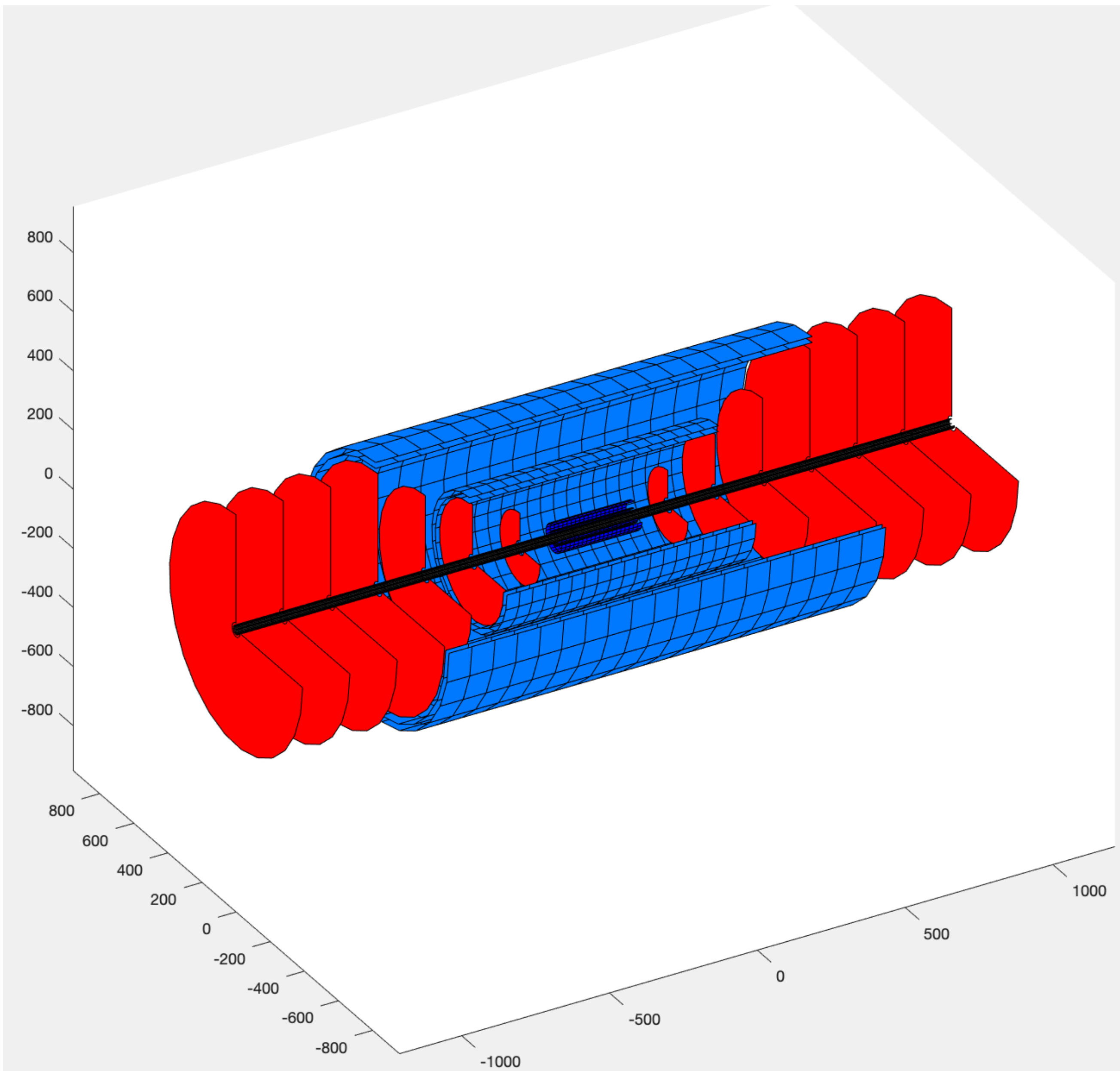
- Acceptance edges (- fine-binned LDT simulations):



Affected by dip-angle and curvature measurement (20μm pixels),
acceptance (18mm inner radii and 185mm out radii),
positions (disks are equidistant in *z*; nominal collision vertex),
traversed material (0.3% beam-pipe, 0.3% for each disk).

eRD16^{+} - simulations

- Integration with a central tracker:



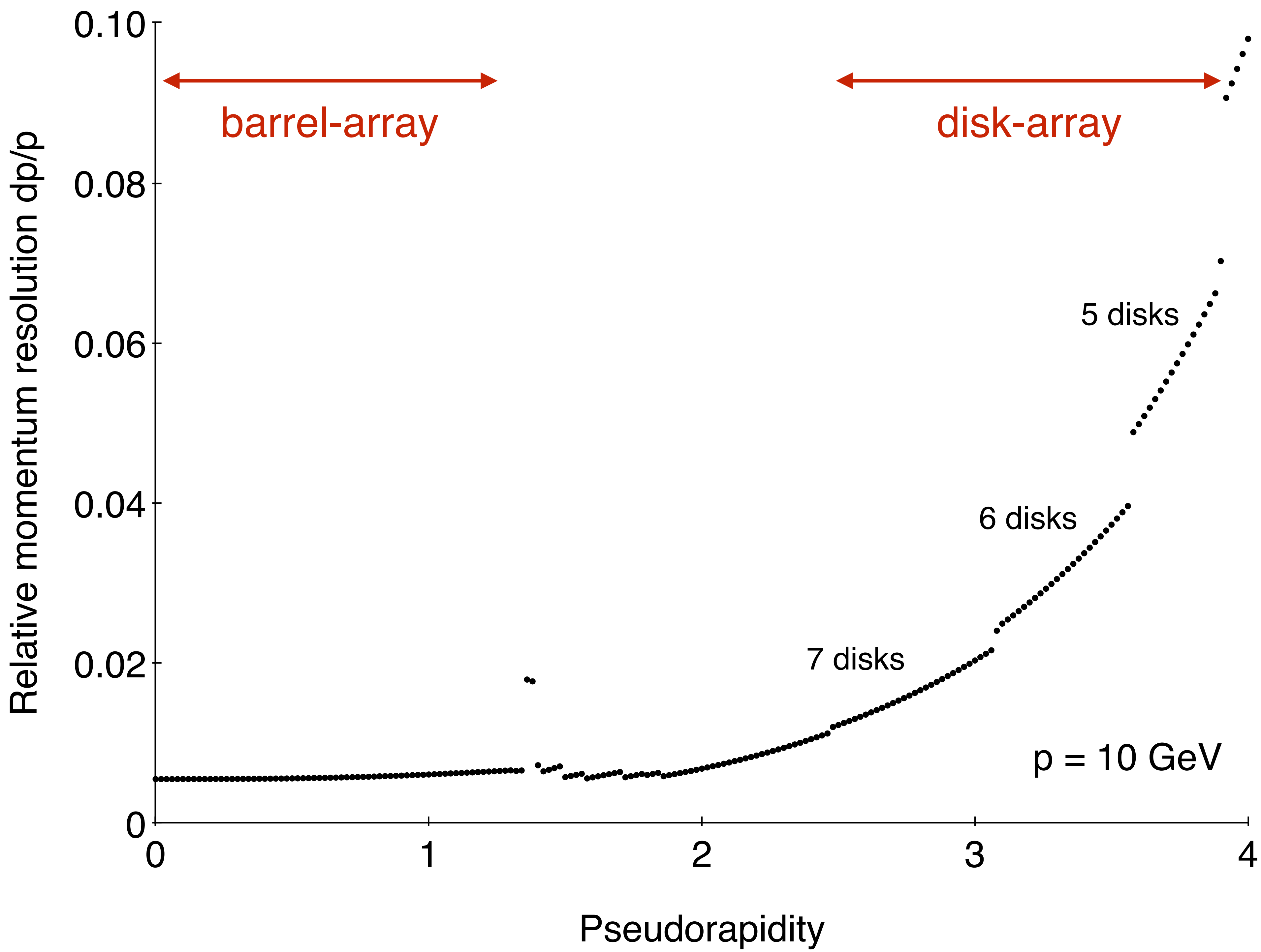
A few key values,

- 270mm long outer vertex layer, at 46mm radius, covers down to ~19.1^{o} or eta ~1.8
- 270mm long inner vertex layer, at 23mm radius, covers down to ~9.6^{o} or eta ~2.5
- disk closest to IP at z = 250mm with 23mm inner radius, corresponding to ~5.3^{o} or eta ~3.1
- outer barrel edges ~25-30^{o} or eta between 1.35 and 1.5.

- An all-silicon tracker, two eRD18 vertex layers, seven eRD16 "tapered" equidistant disks in a BeAST configuration, and an ALICE-like outer barrel, in a 3T solenoidal field.

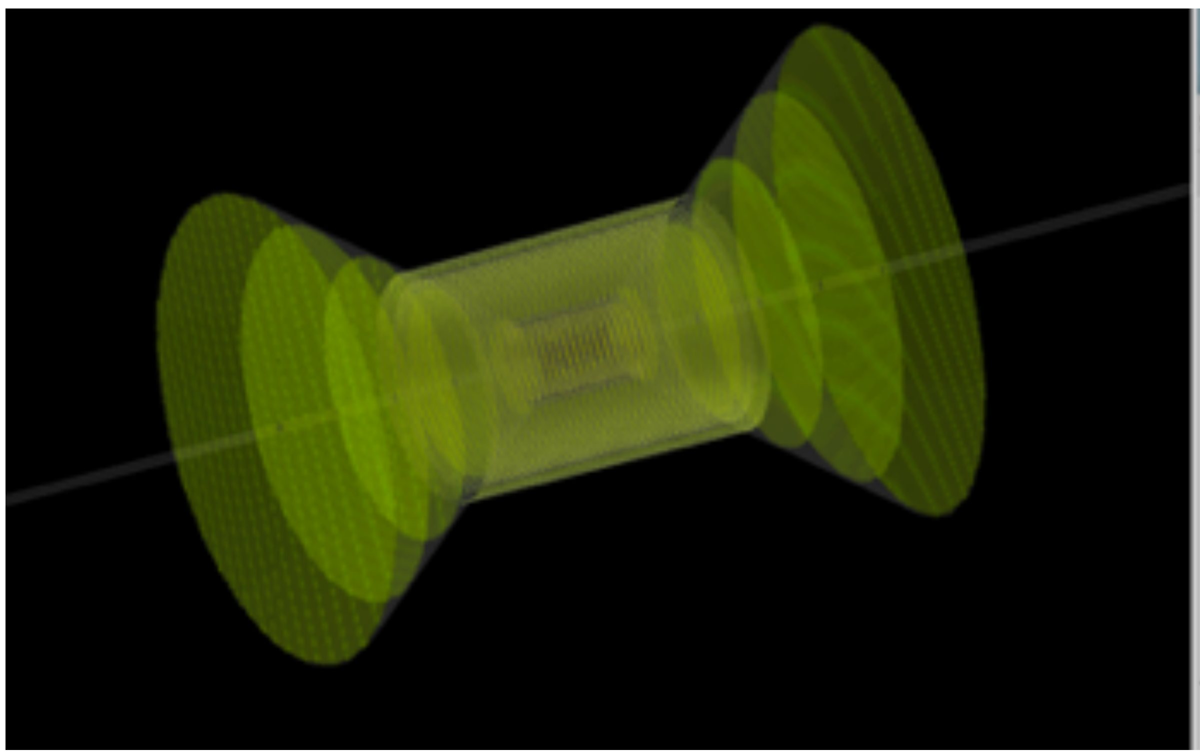
eRD16+ - simulations

- Integration with a central tracker:

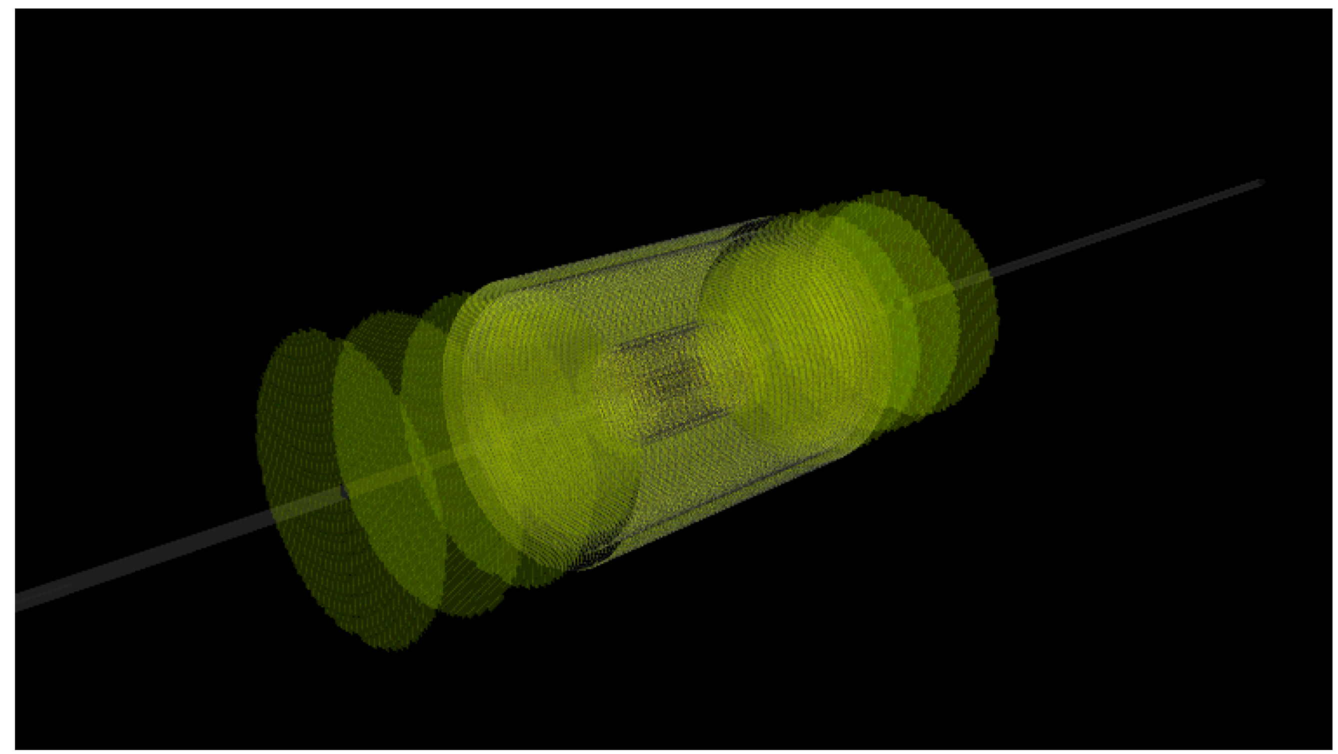


eRD16^{+} - simulations

- EIC-root:



all-Si configuration

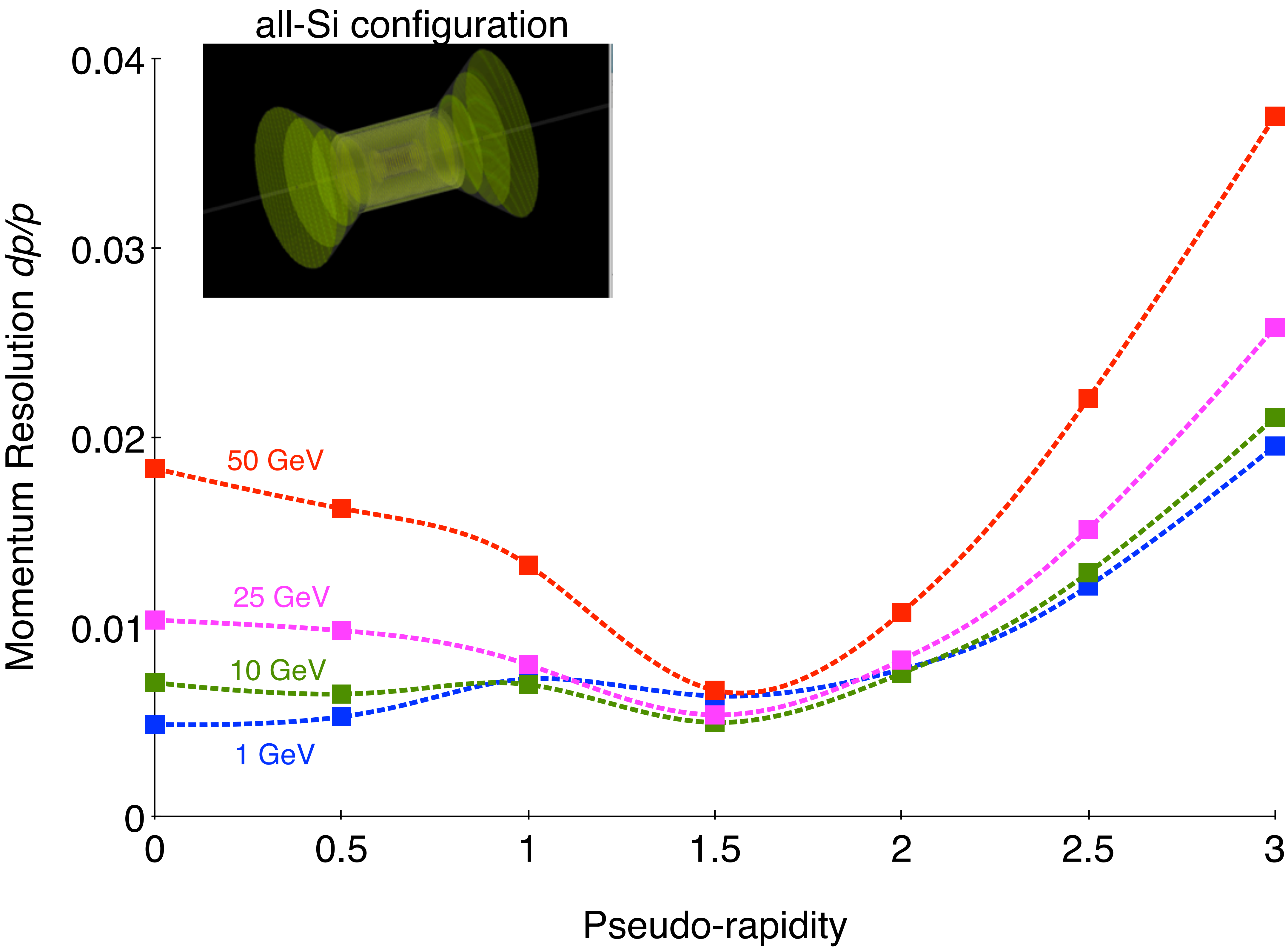


tapered all-Si configuration, r ~ 43cm

Identical barrel configurations, identical in length (*z*) to BeAST.

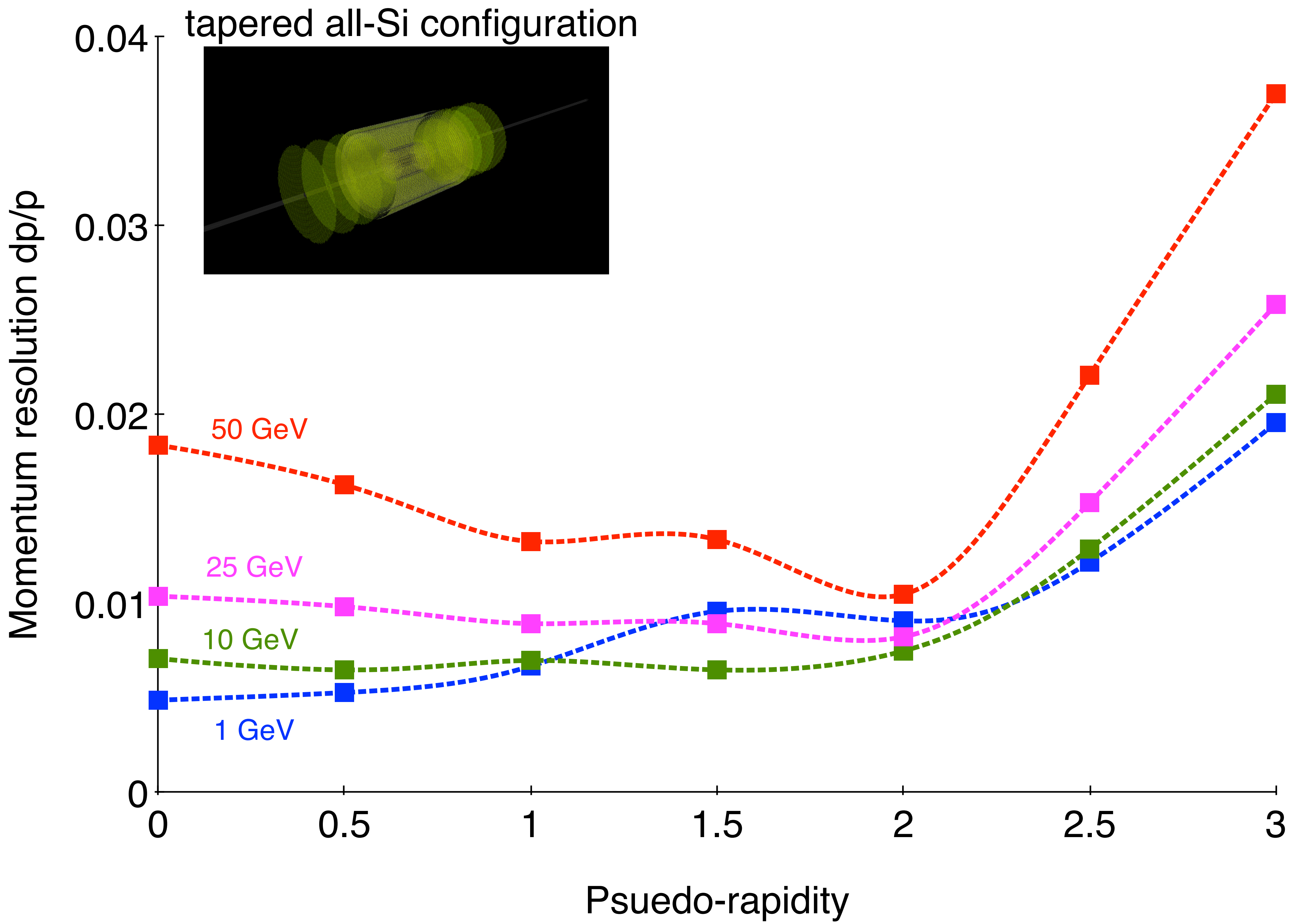
Material cones/cylinders surrounding the disks were implemented to make a start on the effects associated with support structures, read-out infrastructure, etc.; studies started/in progress.

eRD16+ - simulations



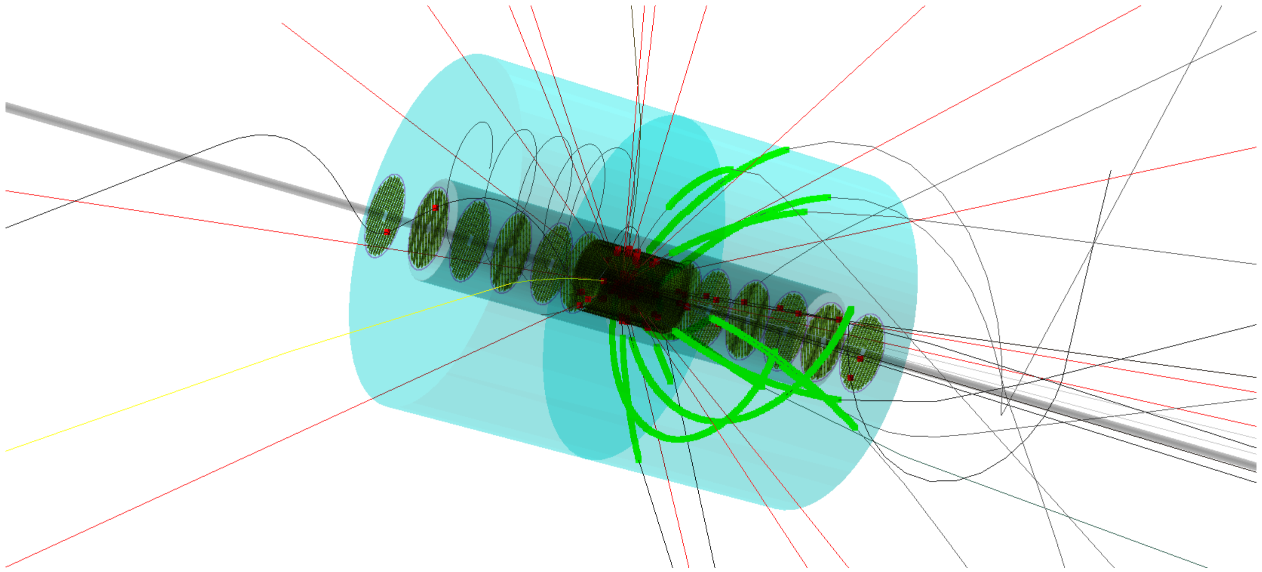
Resolution near ~1.5 results from large r disks; likely overkill.

eRD16+ - simulations

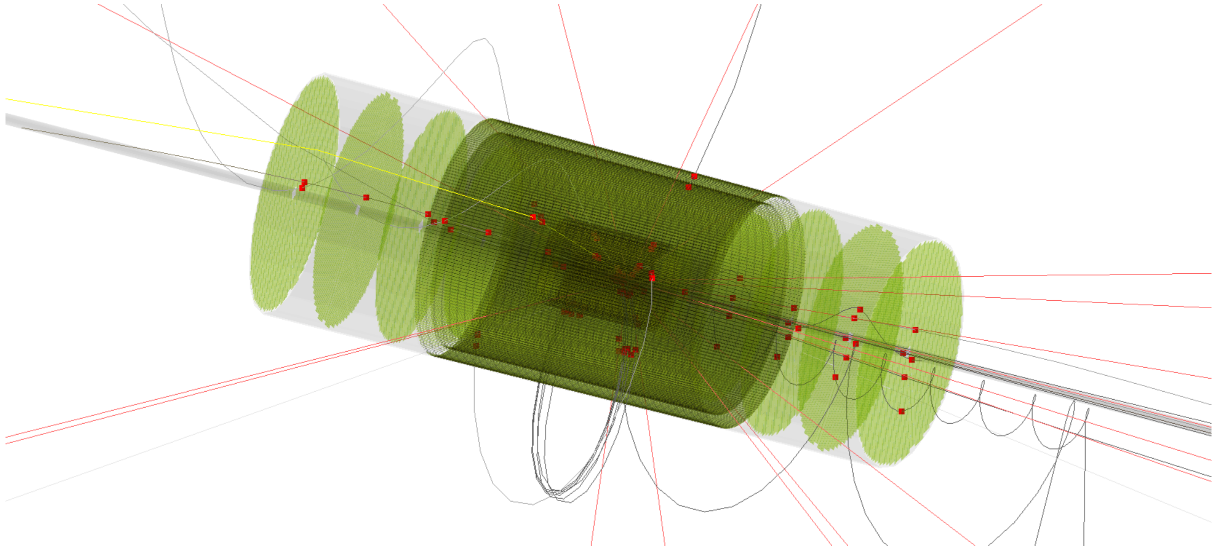


There is a lot in these plots.

eRD16+ - simulations



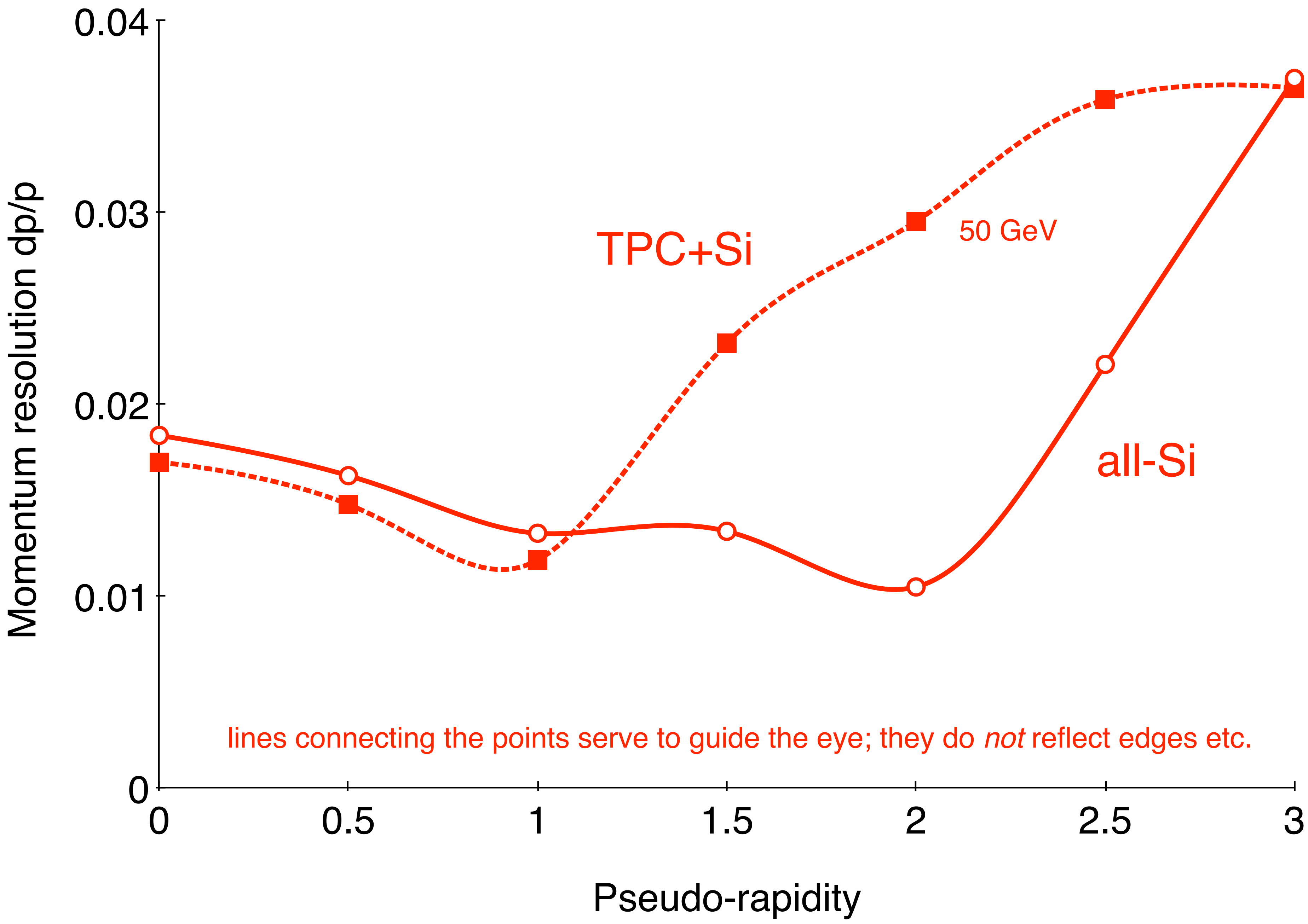
Beast TPC + Si barrels and disks (“hybrid”)



Si barrels and disks (“all silicon”)

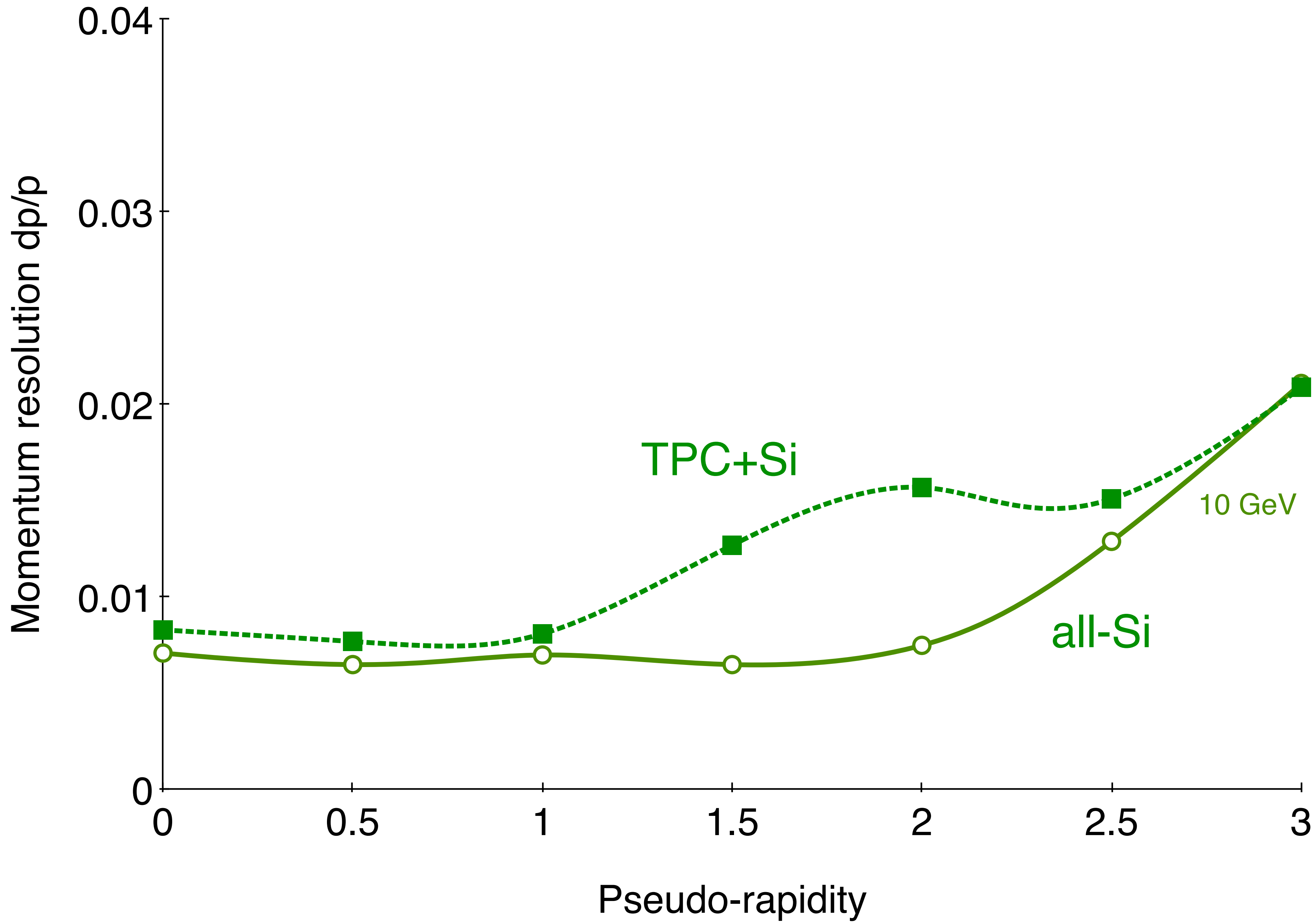
eRD16+ - simulations

- Comparison with (baseline) BeAST TPC+Si tracker:

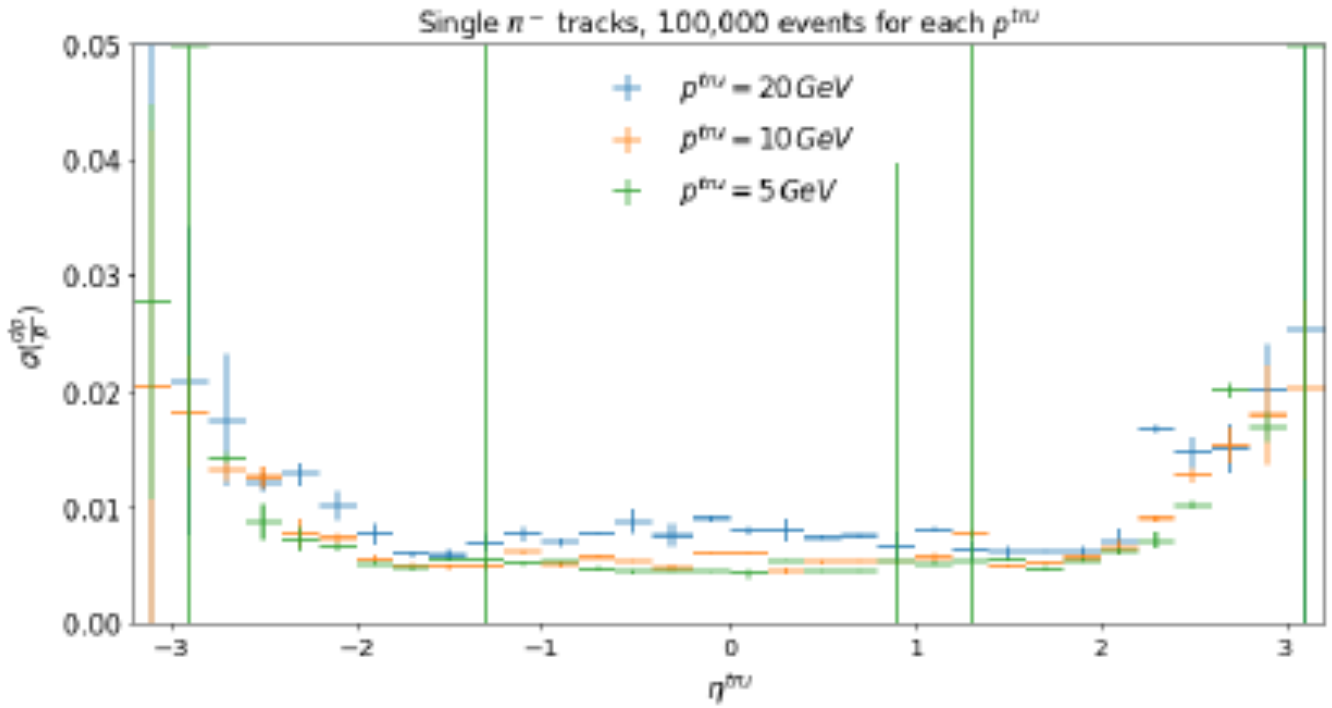


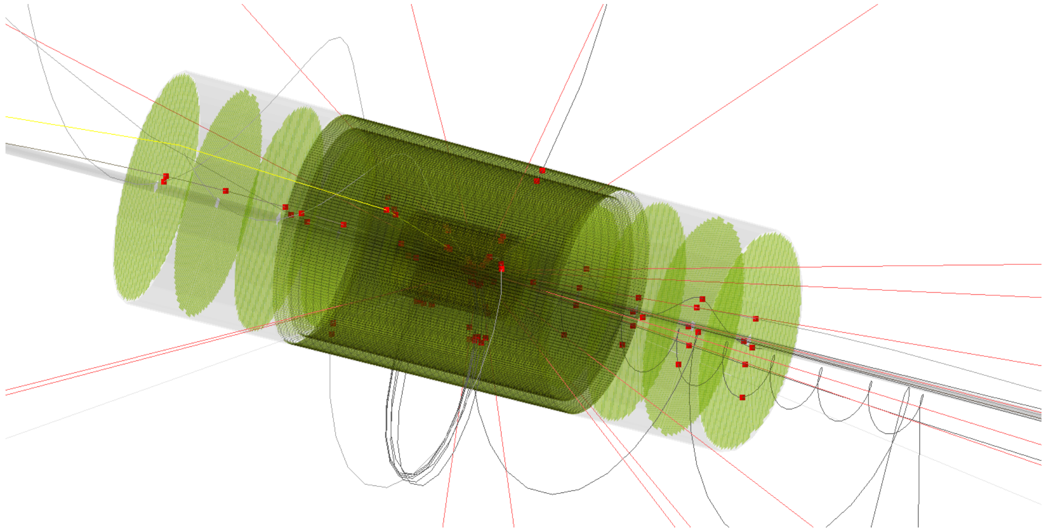
eRD16+ - simulations

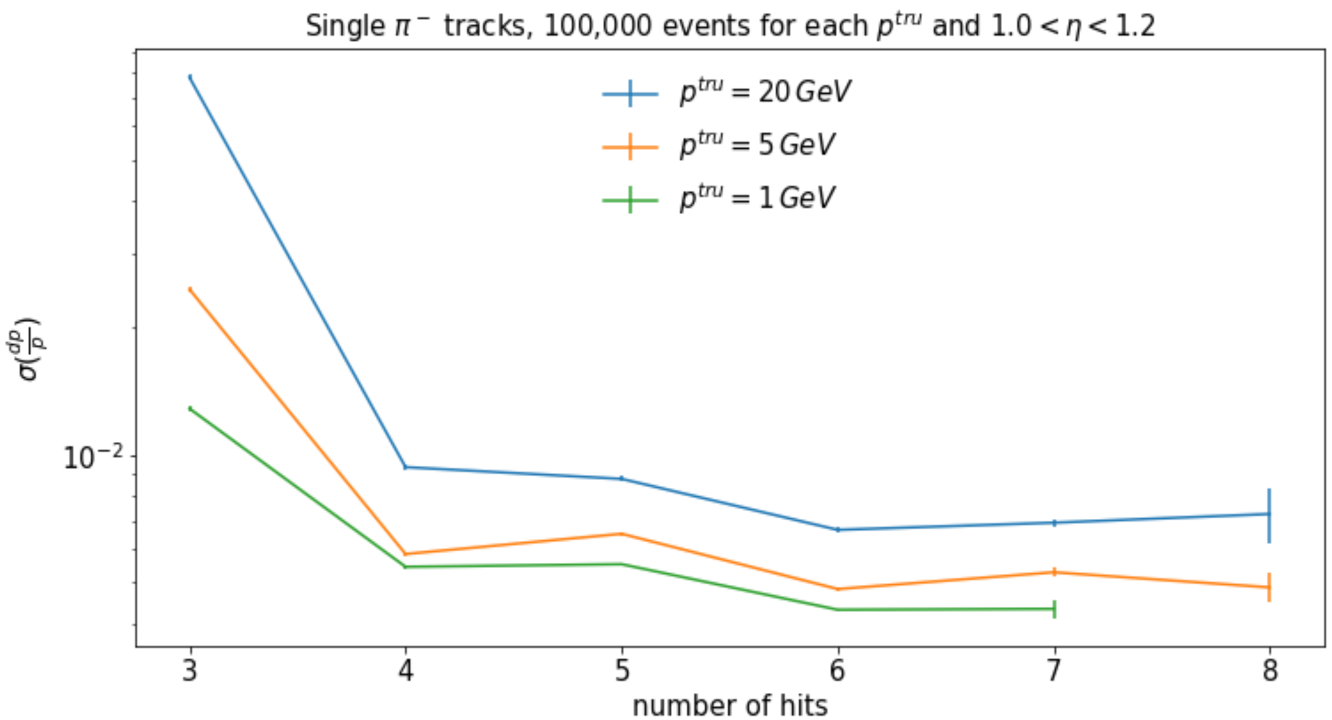
- Comparison with BeAST TPC+Si tracker:



eRD16+ - recent simulations







Support and services (grey):

- simplified model,
- “along the cones”,
- uniform in azimuth

Studies of transition region,

- acceptance edges and gaps
- Single tracks to jets,
- Tracking robustness with dropped hits,

Transition(-ing) to Fun4All, Cori,

See Rey’s talk today (or next week)

Iteration to refine the concept.

Towards a simulated physics-analysis

DESY 09-096
October 2009
ISSN 0418-9833

Measurement of the Charm and Beauty Structure Functions using the H1 Vertex Detector at HERA

H1 Collaboration

Abstract

Inclusive charm and beauty cross sections are measured in e^-p and e^+p neutral current collisions at HERA in the kinematic region of photon virtuality $5 \leq Q^2 \leq 2000\ \mathrm{GeV}^2$ and Bjorken scaling variable $0.0002 \leq x \leq 0.05$. The data were collected with the H1 detector in the years 2006 and 2007 corresponding to an integrated luminosity of 189 pb^{-1}. The numbers of charm and beauty events are determined using variables reconstructed by the H1 vertex detector including the impact parameter of tracks to the primary vertex and the position of the secondary vertex. The measurements are combined with previous data and compared to QCD predictions.

Accepted by Eur. Phys. J. C.

- Reduced charm cross-section and F_2 will be core measurements at the future EIC,
- Several prior studies for EIC, e.g.

  Y. Furletova et al, arXiv:1610.08536,

  E. Aschenauer et al, arXiv:1708.05654

  K-tag, D-meson invariant mass, (parametrized) vertex capability.
- Here, *initial* instrument-capability study with displaced tracks, similar to the original H1 measurement with their vertex detector.

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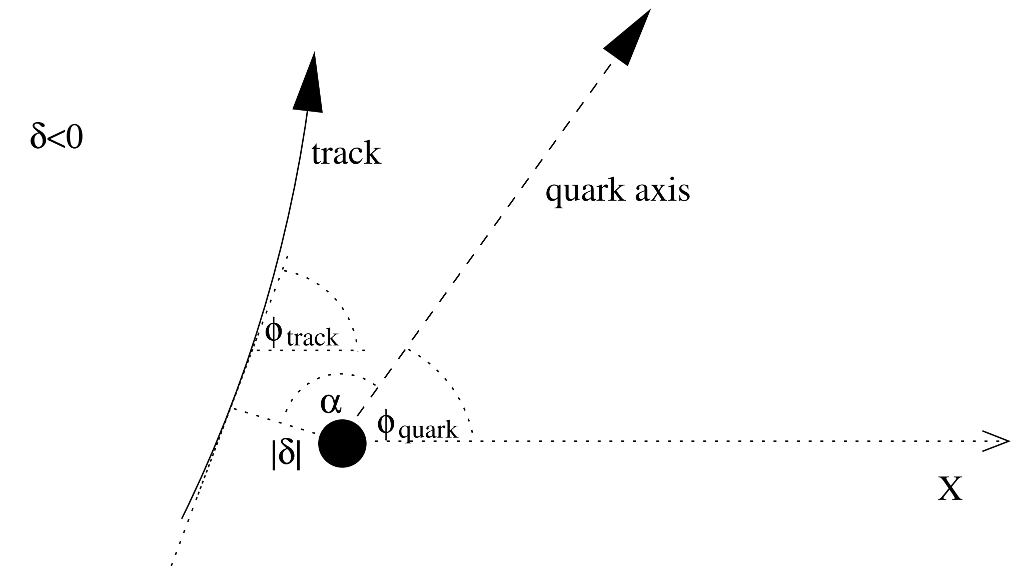
- Key concept, ordering of signed-significance of individual tracks w.r.t. beam-line constraint,



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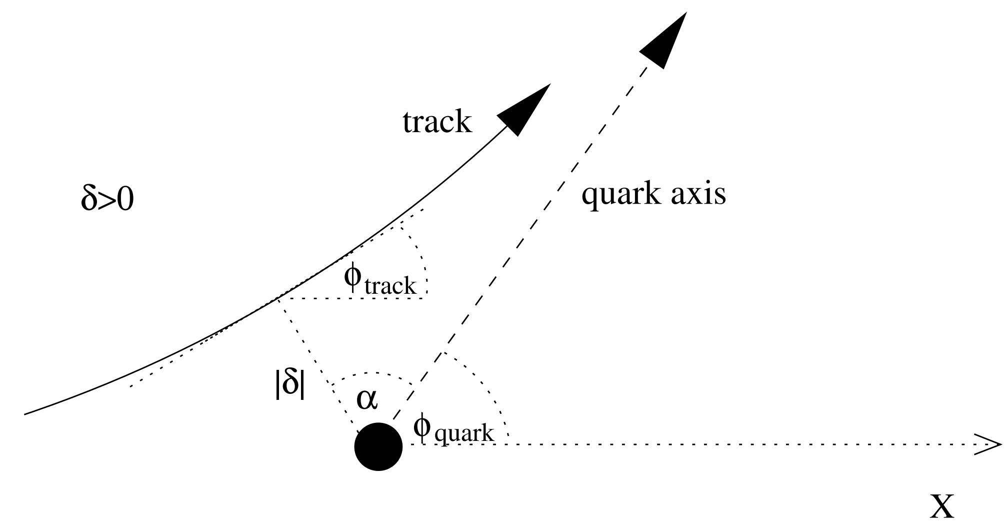

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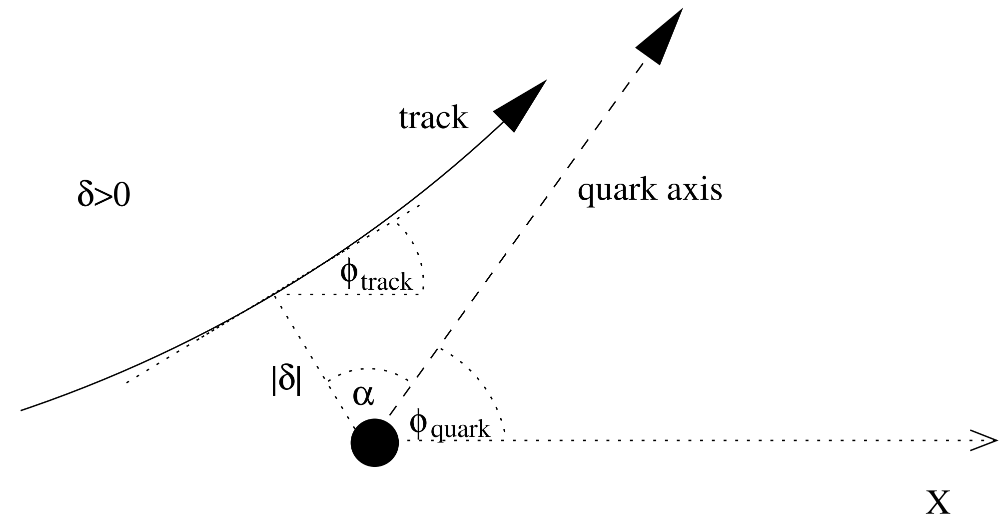

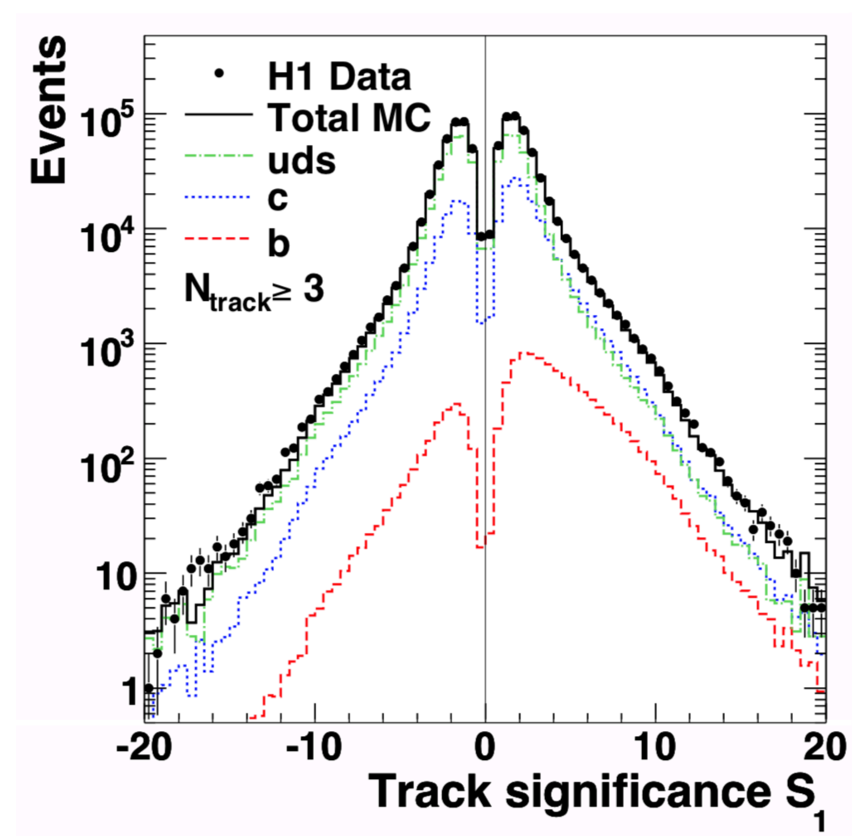

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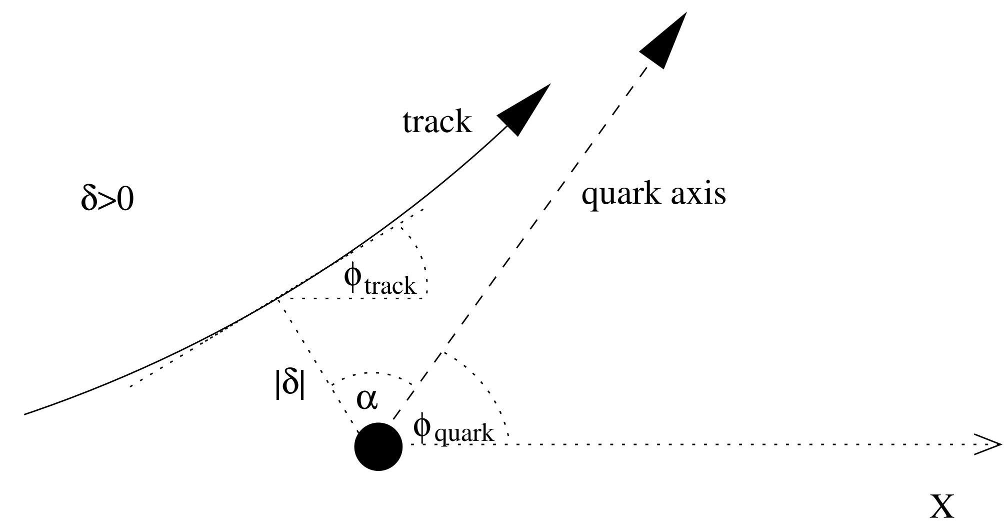

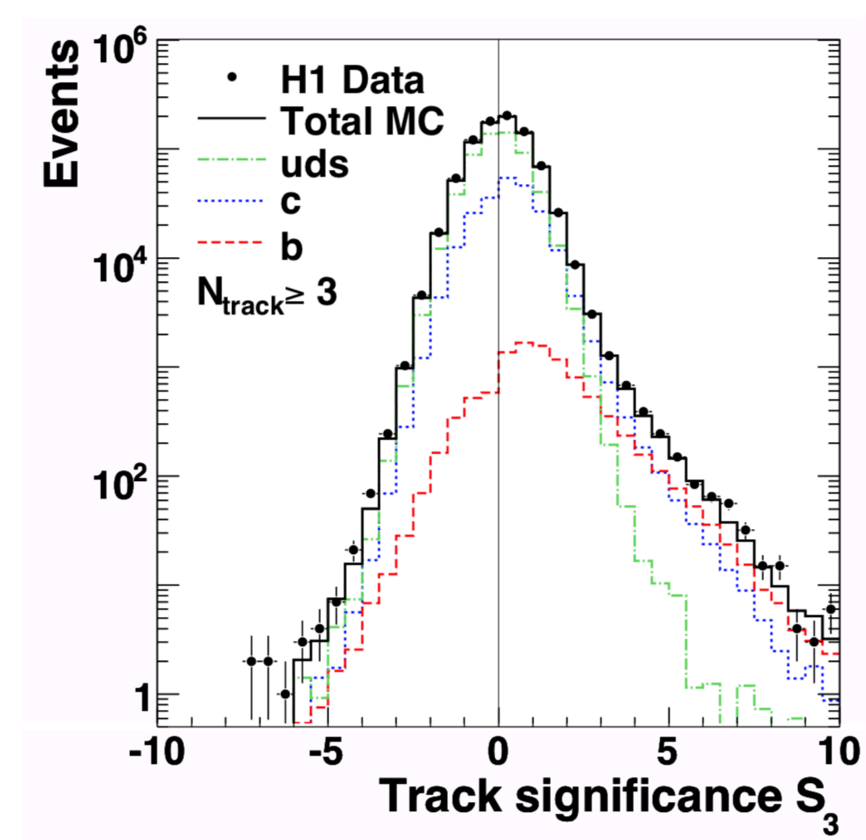

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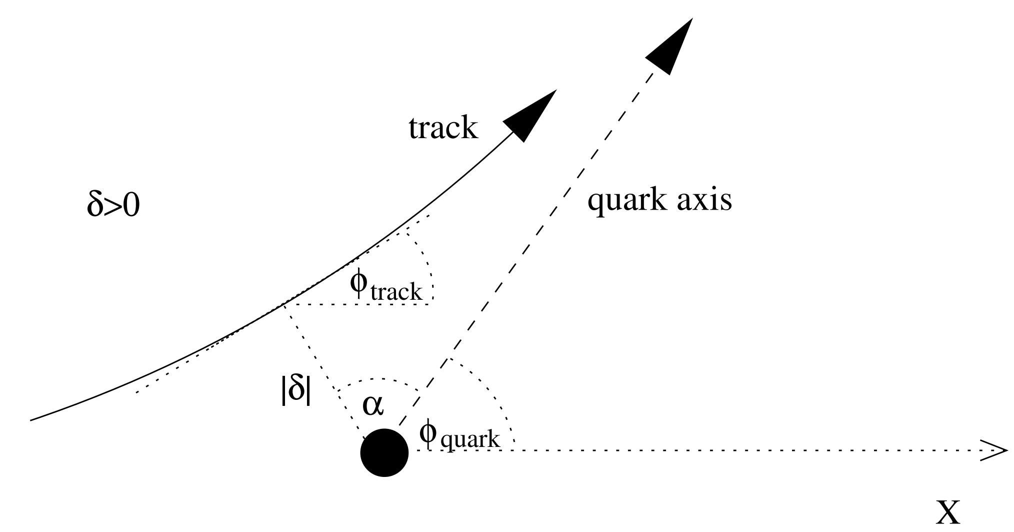

- S_1, S_2, S_3, …
- Photon-gluon fusion is an important production process at EIC; results in two “jet” events,
- Multi-particle study; combines aspects of jet-finding and vertexing.

eRD16^{+} - simulated analysis

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- *Initial* instrument-capability EIC study:
- 10 x 100 GeV e+p; Pythia-eRHIC,
- Instrument response from EICRoot,
- TPC+Si and all-Si concepts,
- Standalone GENFIT/RAVE event reconstruction and vertexing,
- Quark direction from scattered electron,

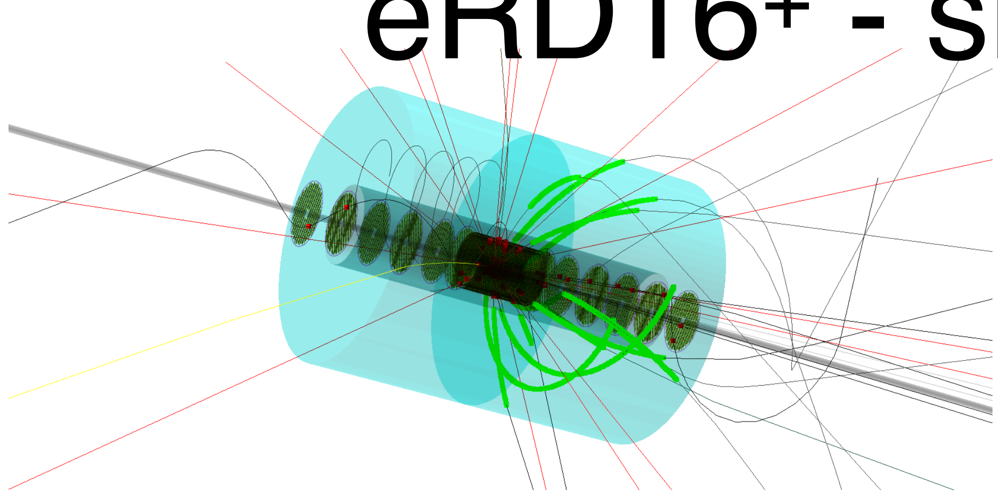
  - 1 particle/jet semi-inclusive DIS,

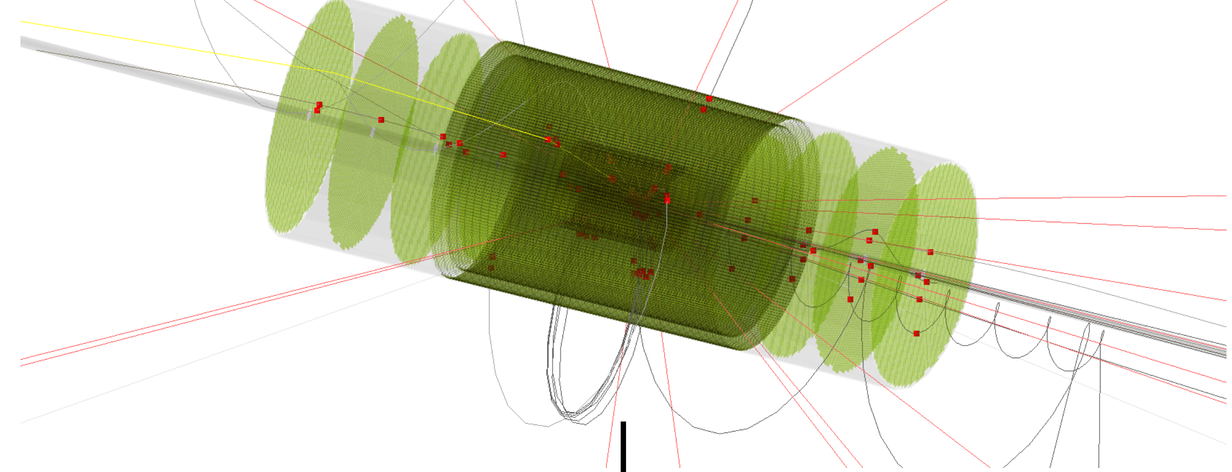
  and from FASTJET jet-reconstruction,

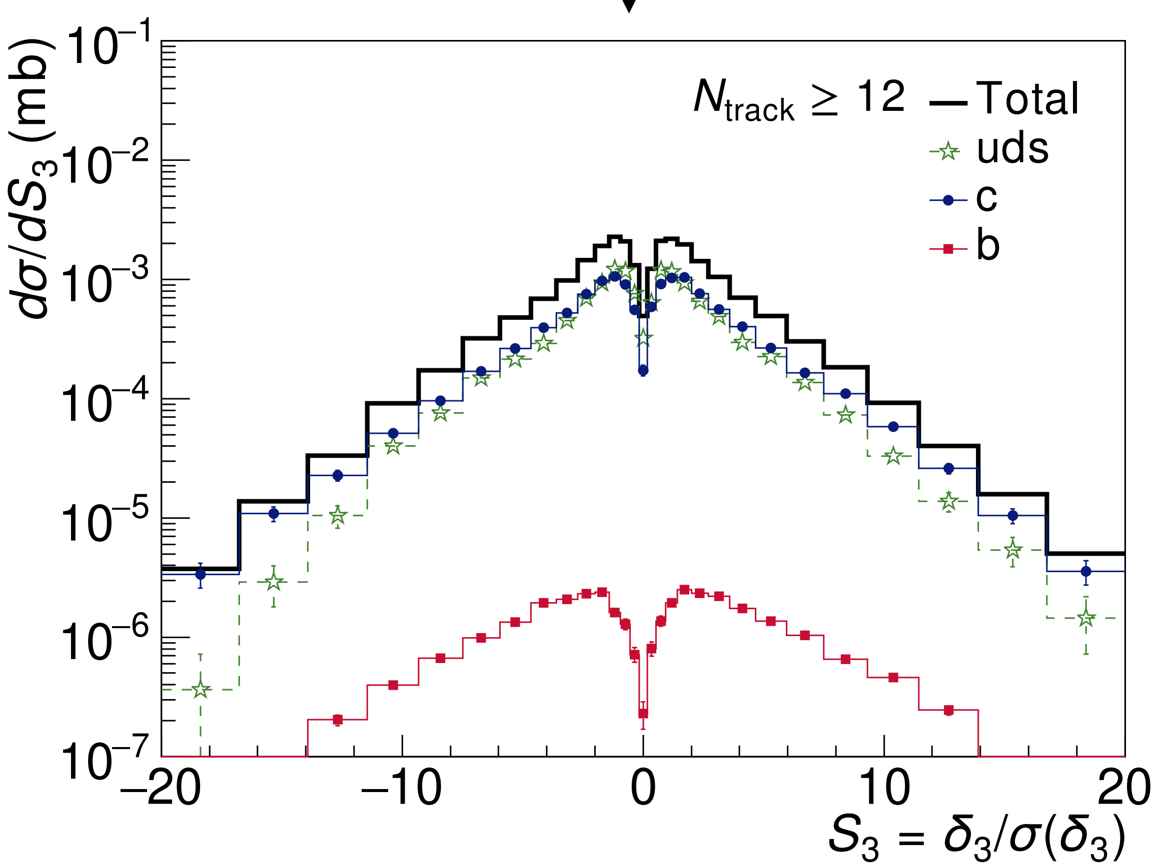
  - e.g. photon-gluon fusion

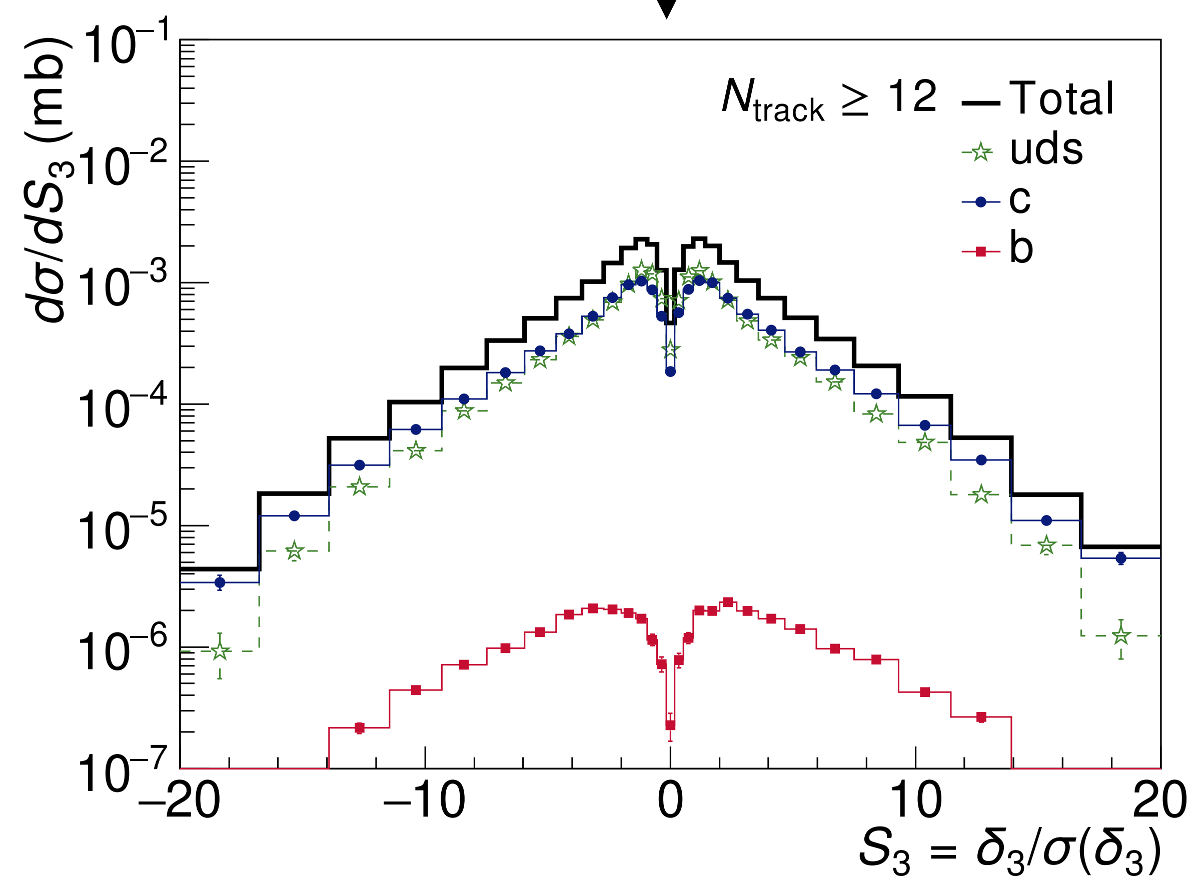
eRD16+ - simulated analysis

Note: scales differ



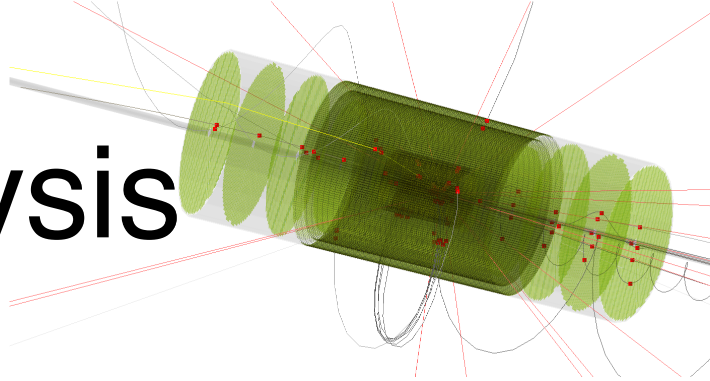




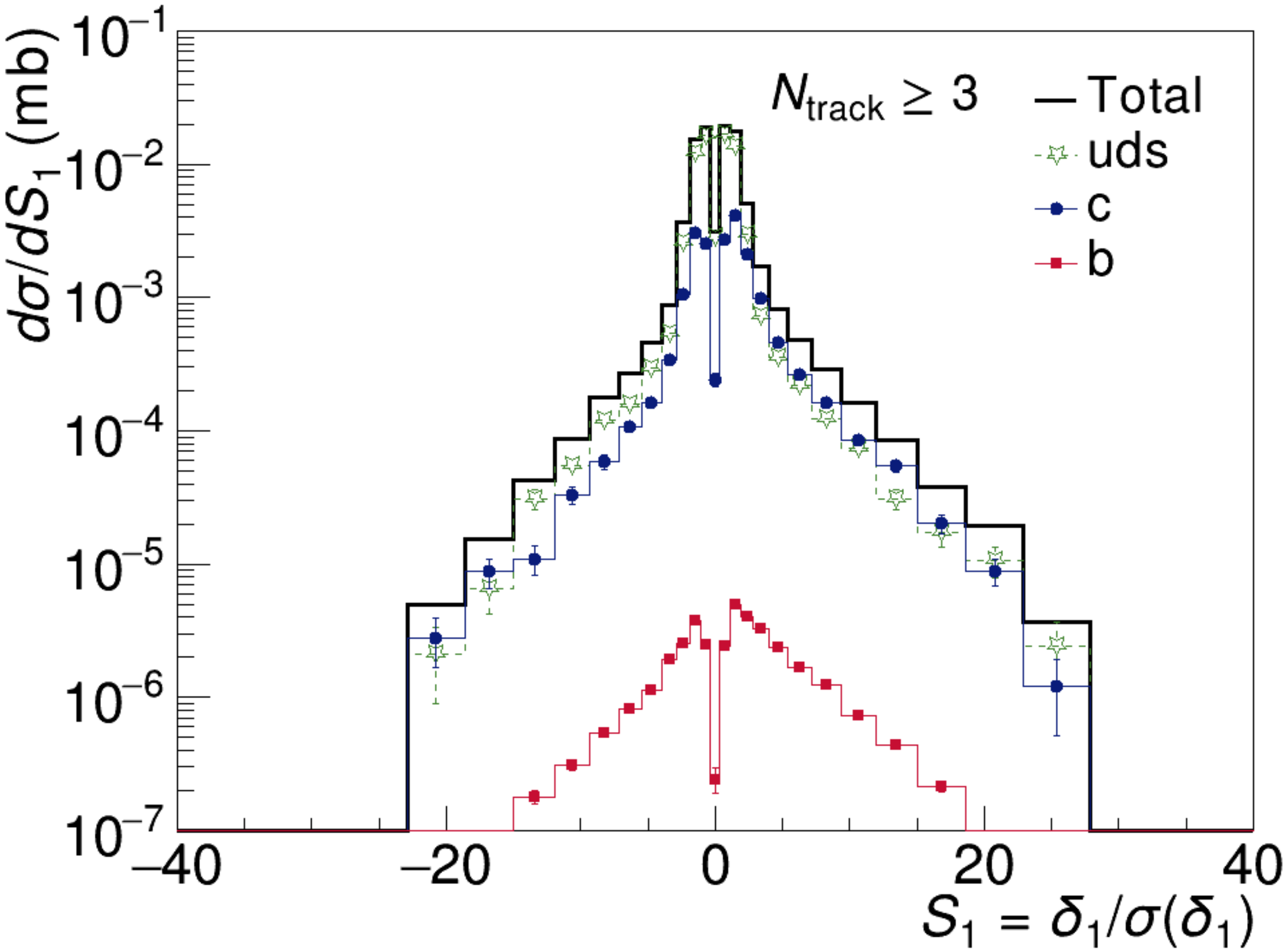


- Here, quark direction from scattered electron (i.e. limited sensitivity to photon-gluon fusion), and point-to-point distance and significance (i.e. full vertex reconstruction),
- Very similar distributions for TPC+Si and all-Si; consistent with vertex performance that is driven by the inner-most barrel layers, and overall acceptance expectations.

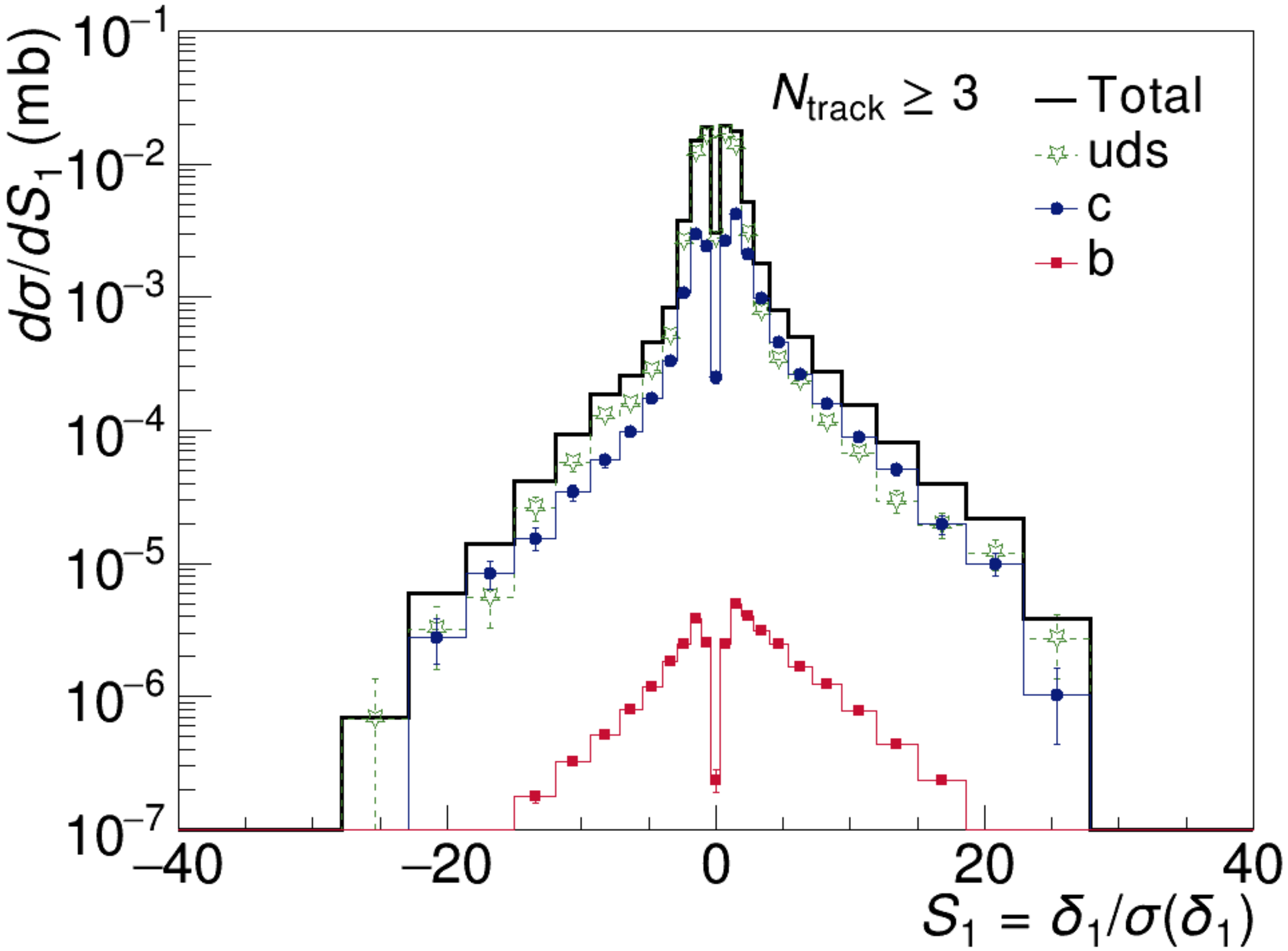
eRD16+ - simulated analysis



20 x 20 µm pixels

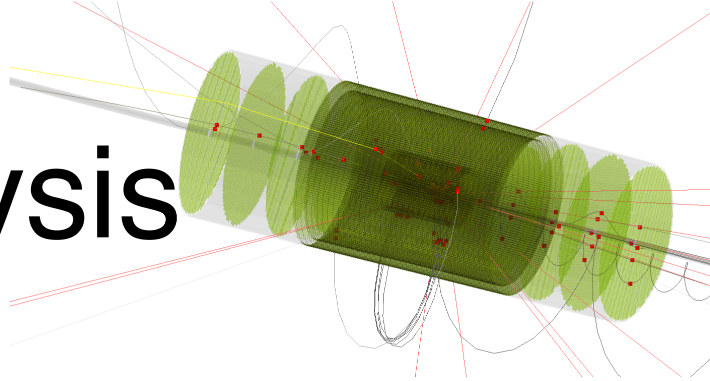


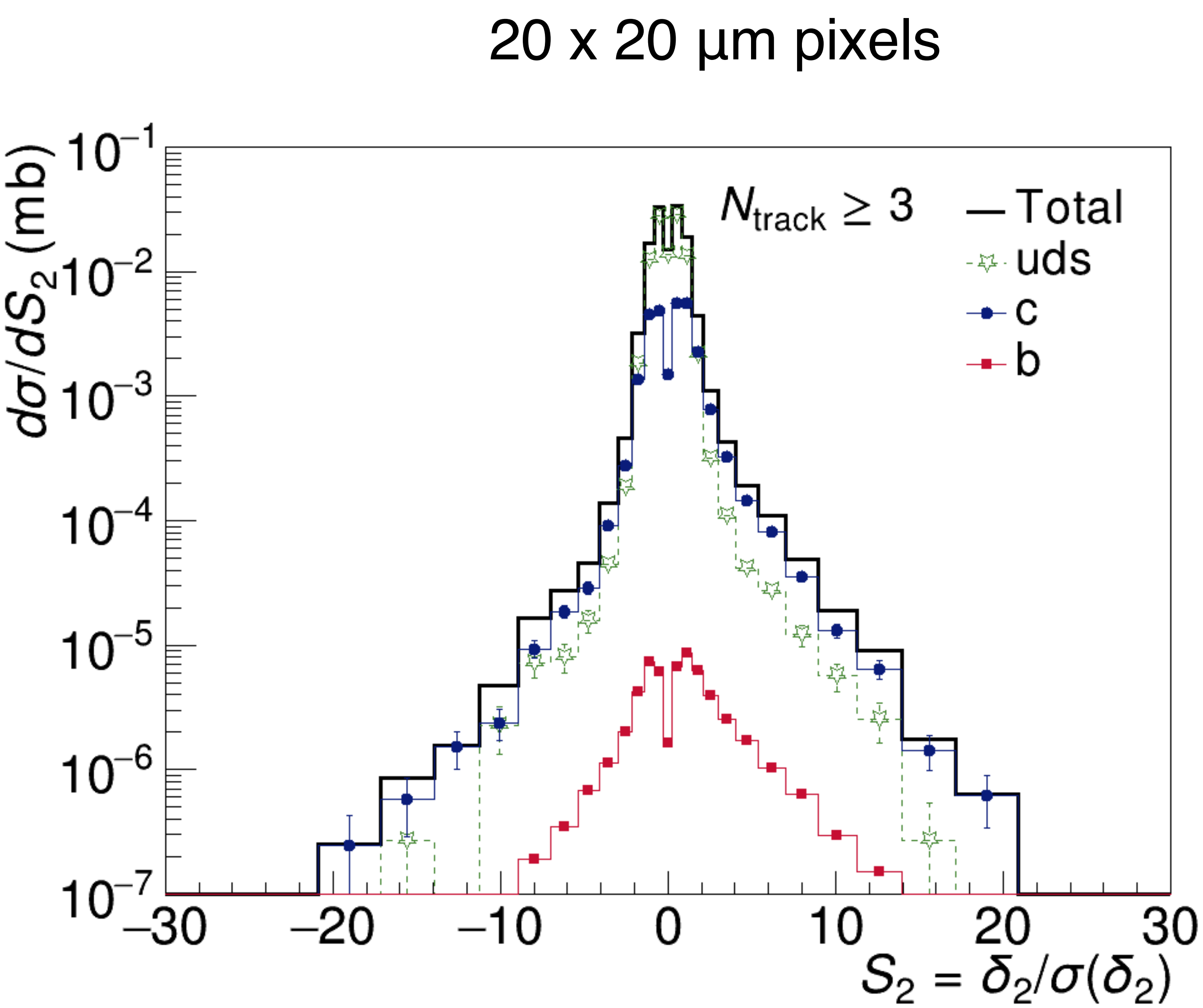
10 x 10 µm pixels

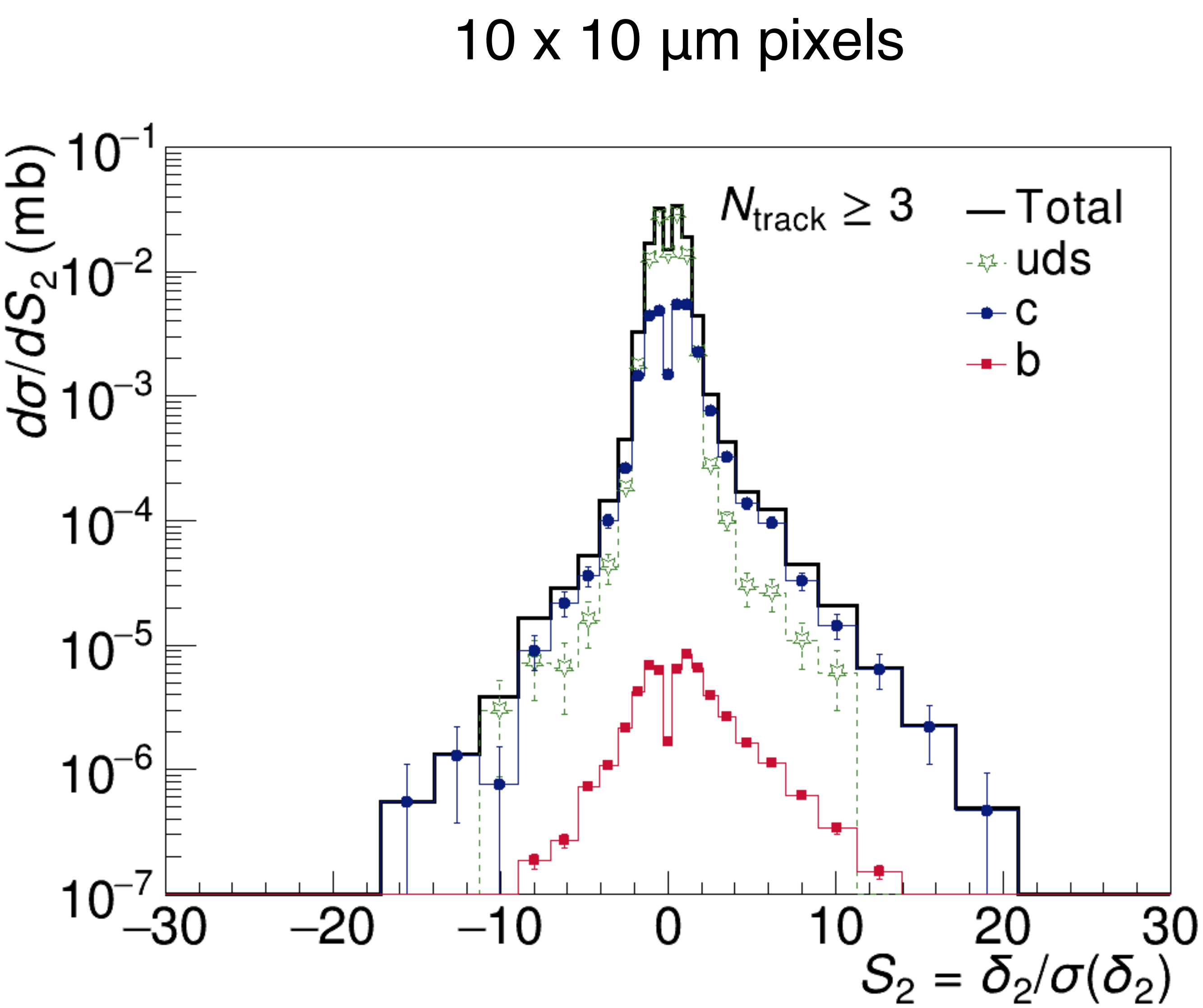


- Here, quark direction from FASTJET reconstruction; 20 µm beam-line constraint*
- Very similar, though *not* identical, distributions for all-Si concepts with 20 x 20 µm pixels and 10 x 10 µm pixels *with current material budgets.*

eRD16+ - simulated analysis

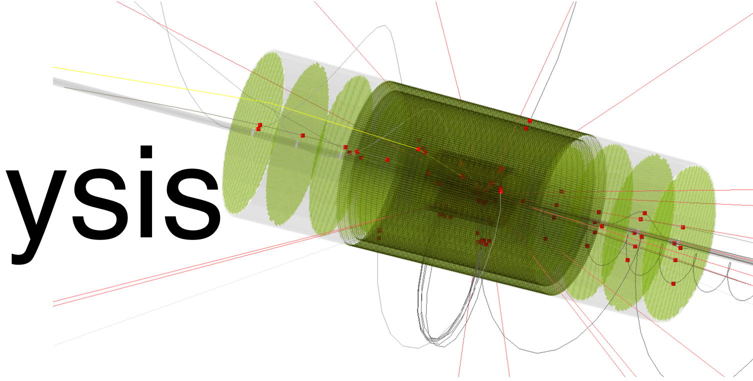




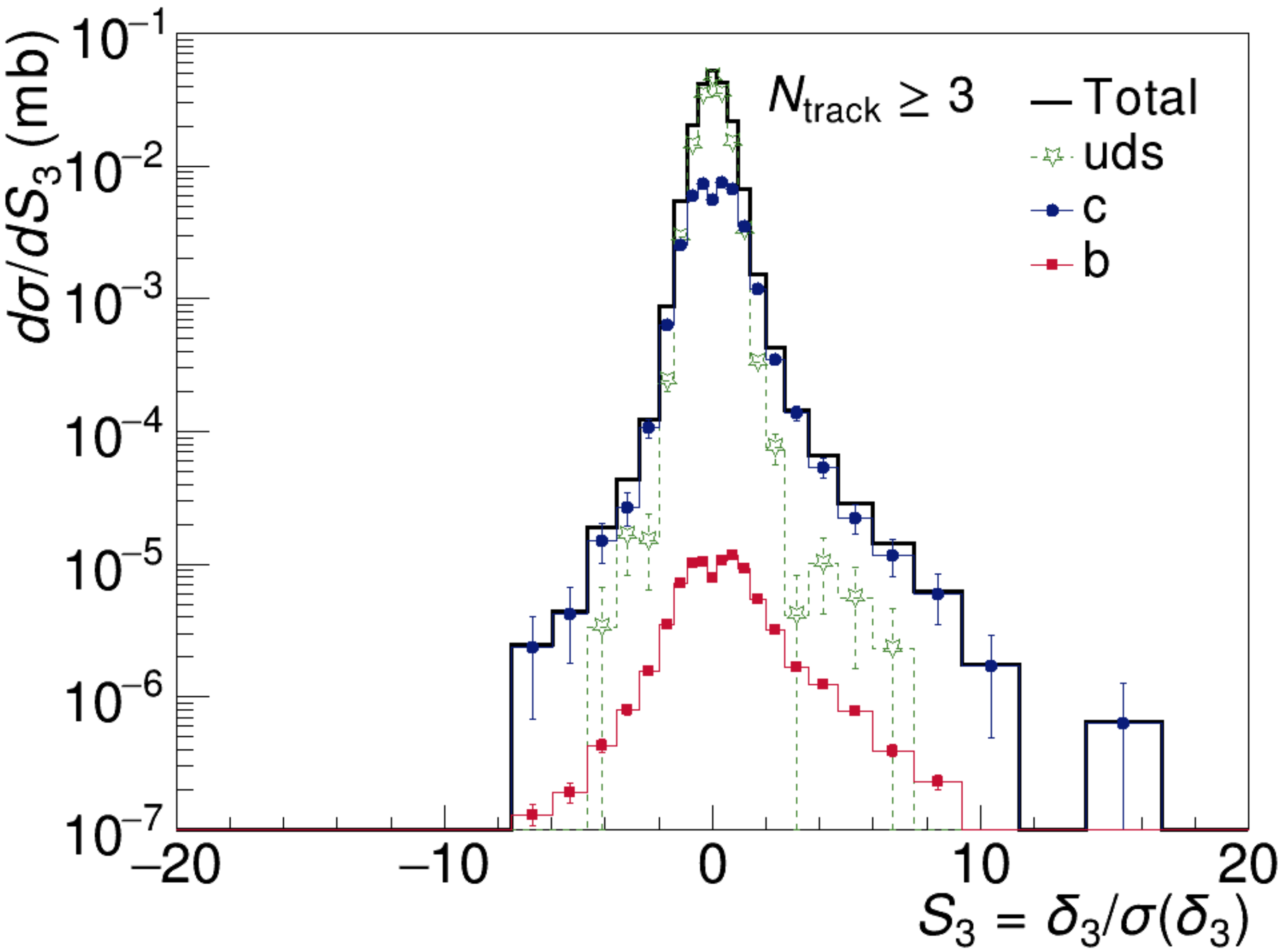


- Here, quark direction from FASTJET reconstruction; 20 µm beam-line constraint*
- Very similar, though *not* identical, distributions for all-Si concepts with 20 x 20 µm pixels and 10 x 10 µm pixels *with current material budgets.*

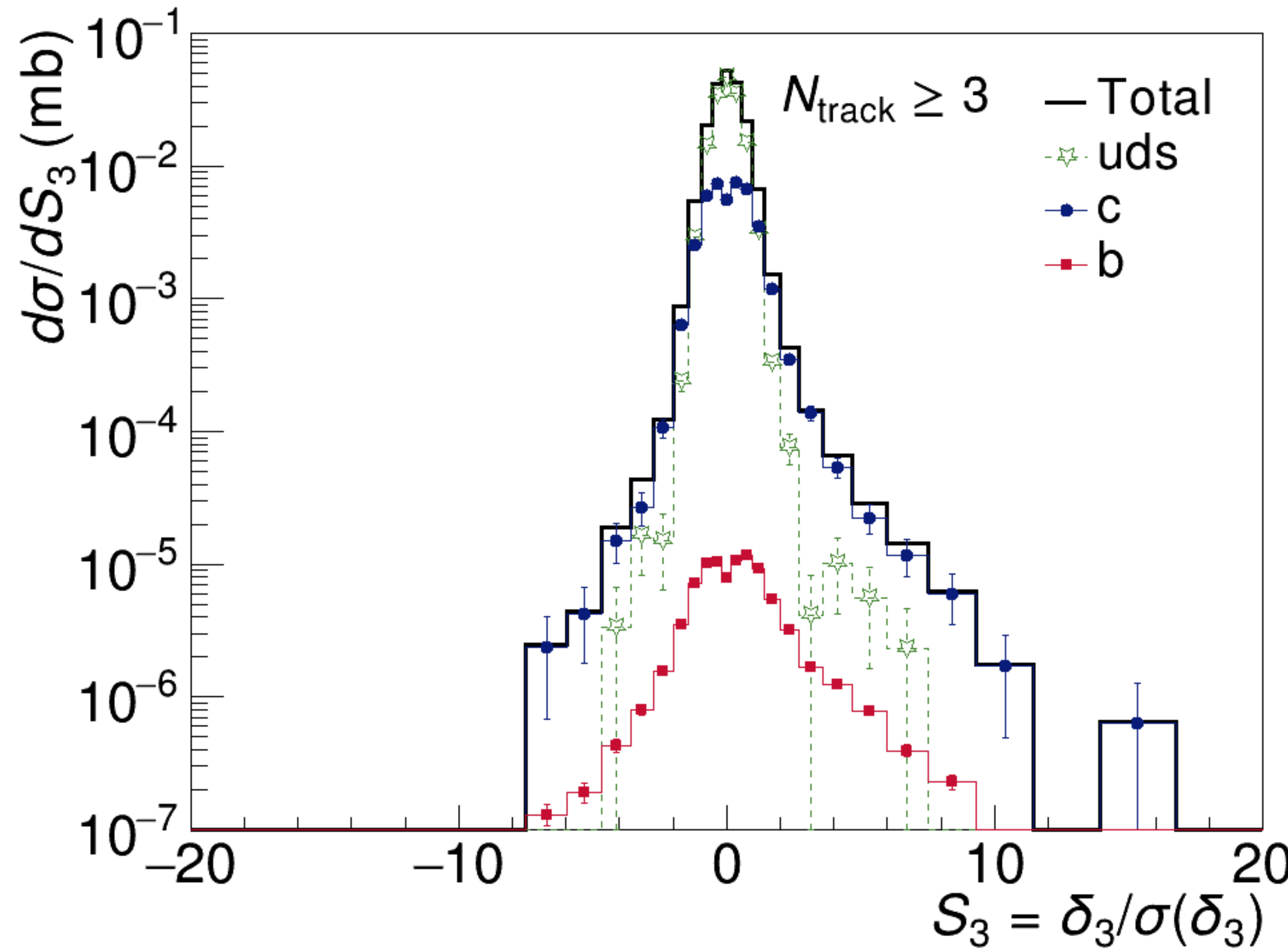
eRD16+ - simulated analysis



20 x 20 µm pixels



10 x 10 µm pixels



- Here, quark direction from FASTJET reconstruction; 20 µm beam-line constraint*
- Very similar, though *not* identical, distributions for all-Si concepts with 20 x 20 µm pixels and 10 x 10 µm pixels *with current material budgets.*
- Measurement capability fairly evident; bodes well (also) for full topological reconstruction.

eRD16^{+} - simulations

Forward/backward disk configuration, sensor specs, 1.5 and 3T, integration with barrel (vertex) layers, all-silicon concept(s) from a combination of fast and full simulations, X_0 scanned (though not to ITS3 levels),

There exists an all-silicon concept with similar performance to a BeAST(-like) TPC+Si concept; it is radially more compact.

All-Si may thus offer radial space for (alternate) PID,
might be more robust to field non-uniformity

Not covered here: pile-up (collision-event overlap vs. integration time studied),

Next: updated beam-pipe *and* crossing-angle,
improved implementation of services and support (c.f. Leo),
event-smearing parametrization,
(transition to supported framework(s), TPC parametrization(?)),
(updated/refined all-Si concept),