eRD16: Forward/Backward Tracking at EIC using MAPS Detectors

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Abstract:

We propose continued conceptual development of tracking stations with silicon-sensors near the collision vertex to detect the scattered electron and produced secondary hadrons at forward and backward angles. The main focus is on disks with thinned-silicon sensors (MAPS) with the goal to arrive at physics-driven sensor specifications, the overall geometrical arrangement of the forward/backward disks, disk layout, conceptual arrangement of services, and integration with central barrel tracking subsystems. Part of this work will be pursued in collaboration with eRD18, which focuses on mid-rapidity tracking and sensor development.

EIC Generic Detector R&D
Advisory Committee Mtg.
Jefferson Lab, July 13, 2017

Outline

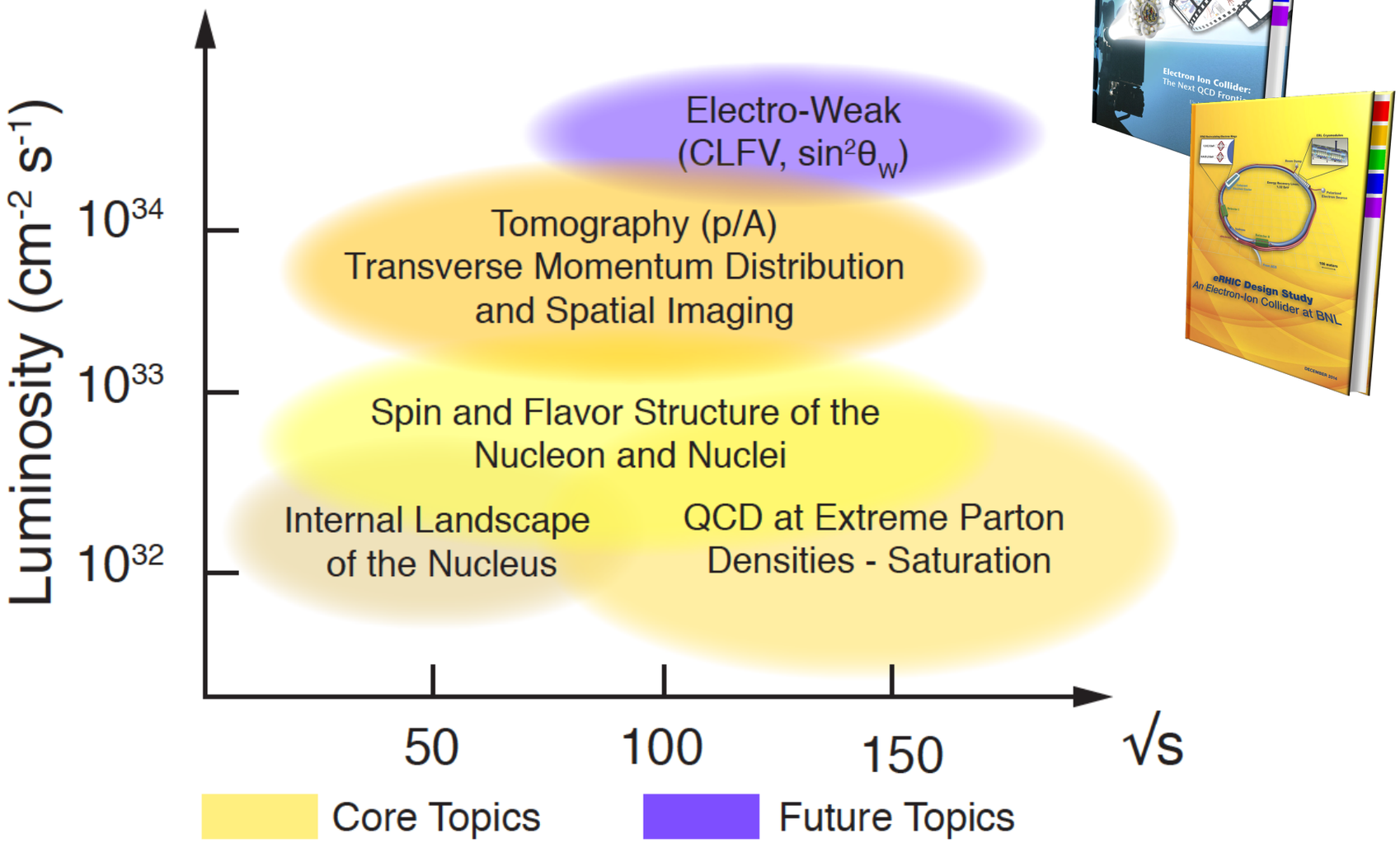
- Introduction
  - RNC physics interests in EIC
  - Instrumentation efforts in relation to EIC

- Simulation progress,
  - Tools used,
  - Selected topics and results

- Proposed effort
  - Simulation development and studies
  - Collaboration with eRD18, Peter Jones et al,
  - Start on investigating services,
  - Request

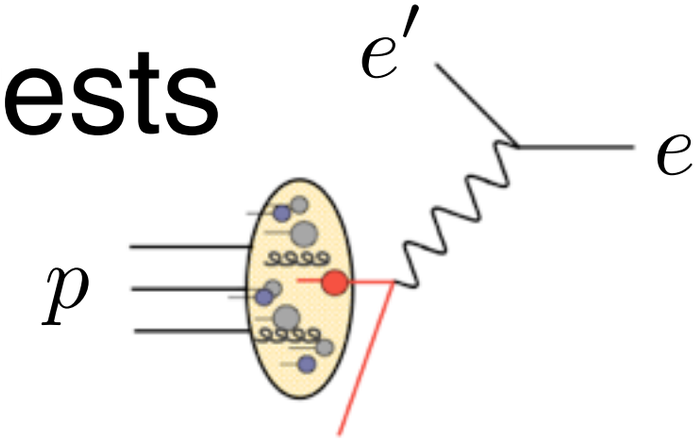
RNC - EIC Physics Interests

Interest in *gluon-dense matter:*

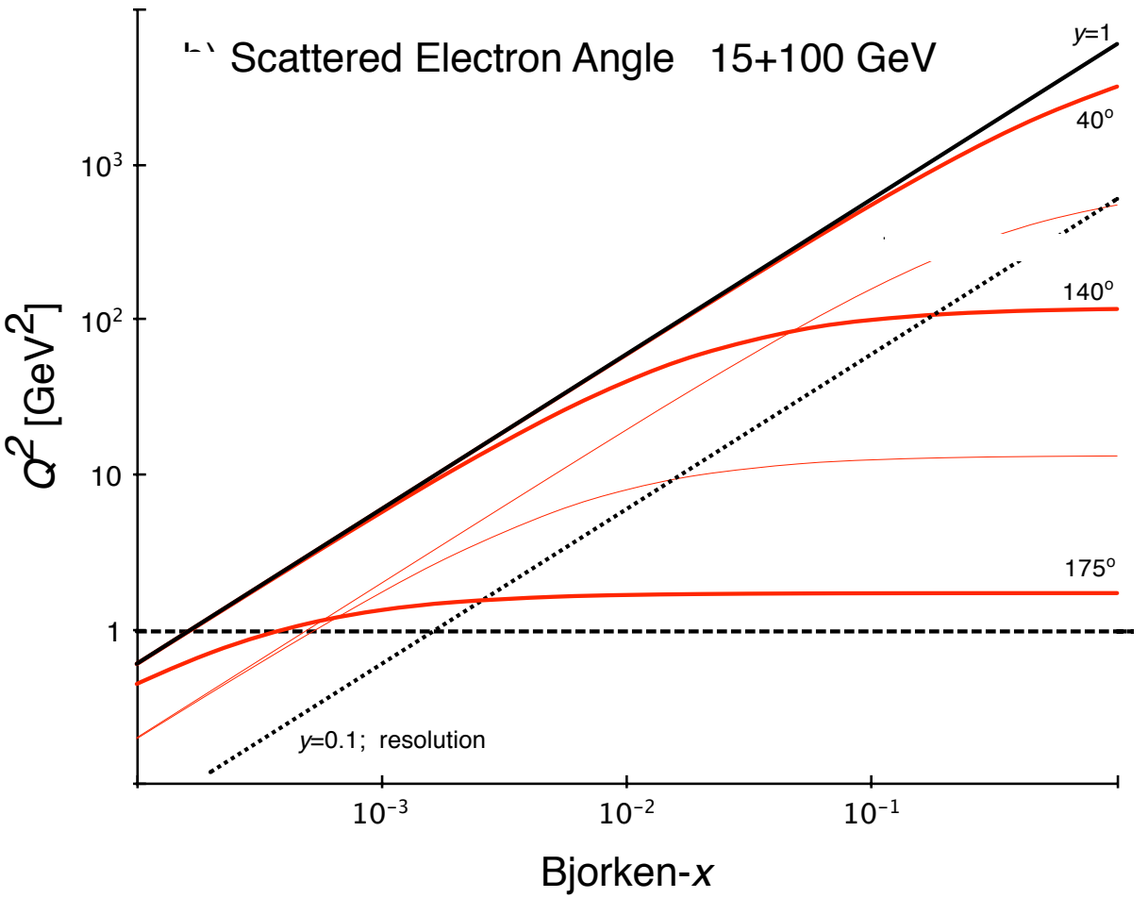


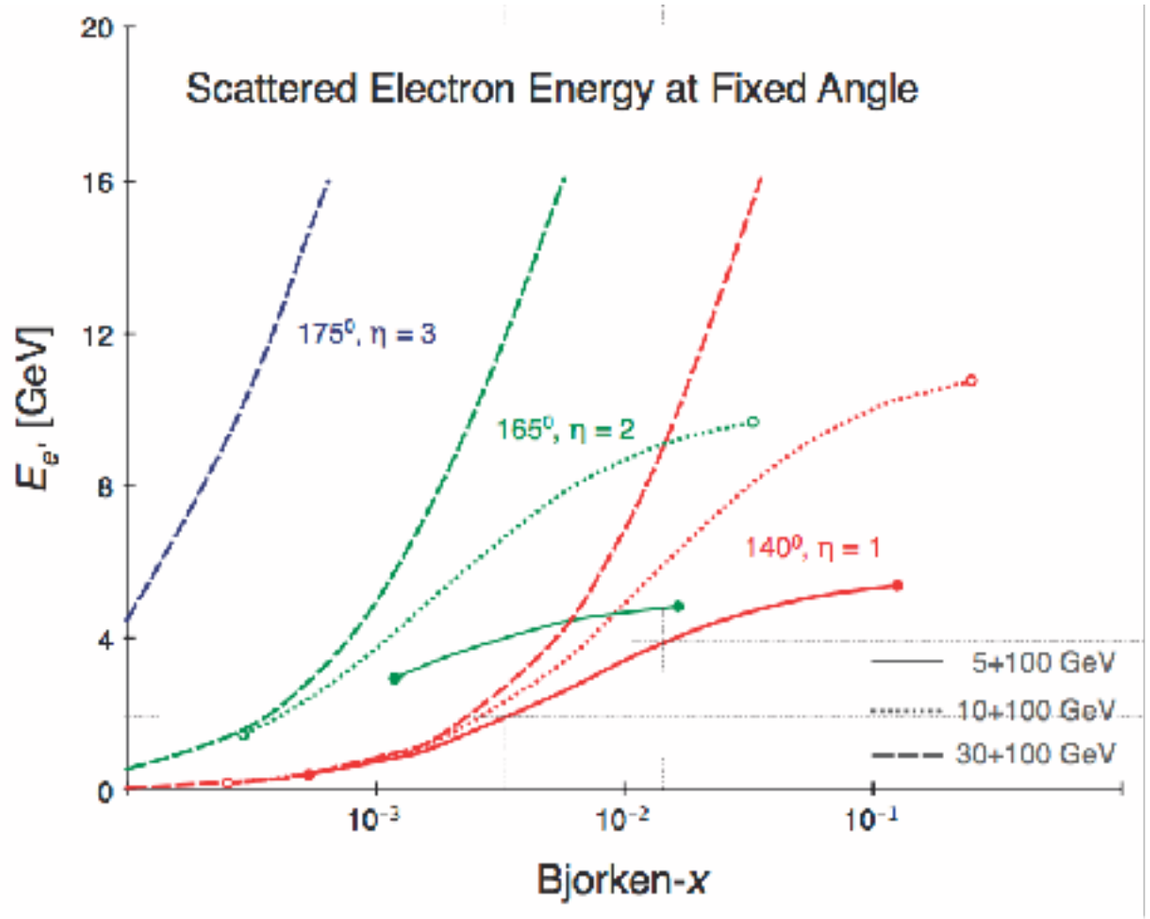
implies a need for *high*-√s,
observables $F_2(x,Q^2)$, $F_L(x,Q^2)$, $g_1(x,Q^2)$ at *low*-x
+ diffraction, dijets, heavy flavor, …

RNC - EIC Physics Interests



Interest in gluon-dense matter:





necessitates instrumentation at *backward* angles w.r.t. the hadron beam (HERA convention),

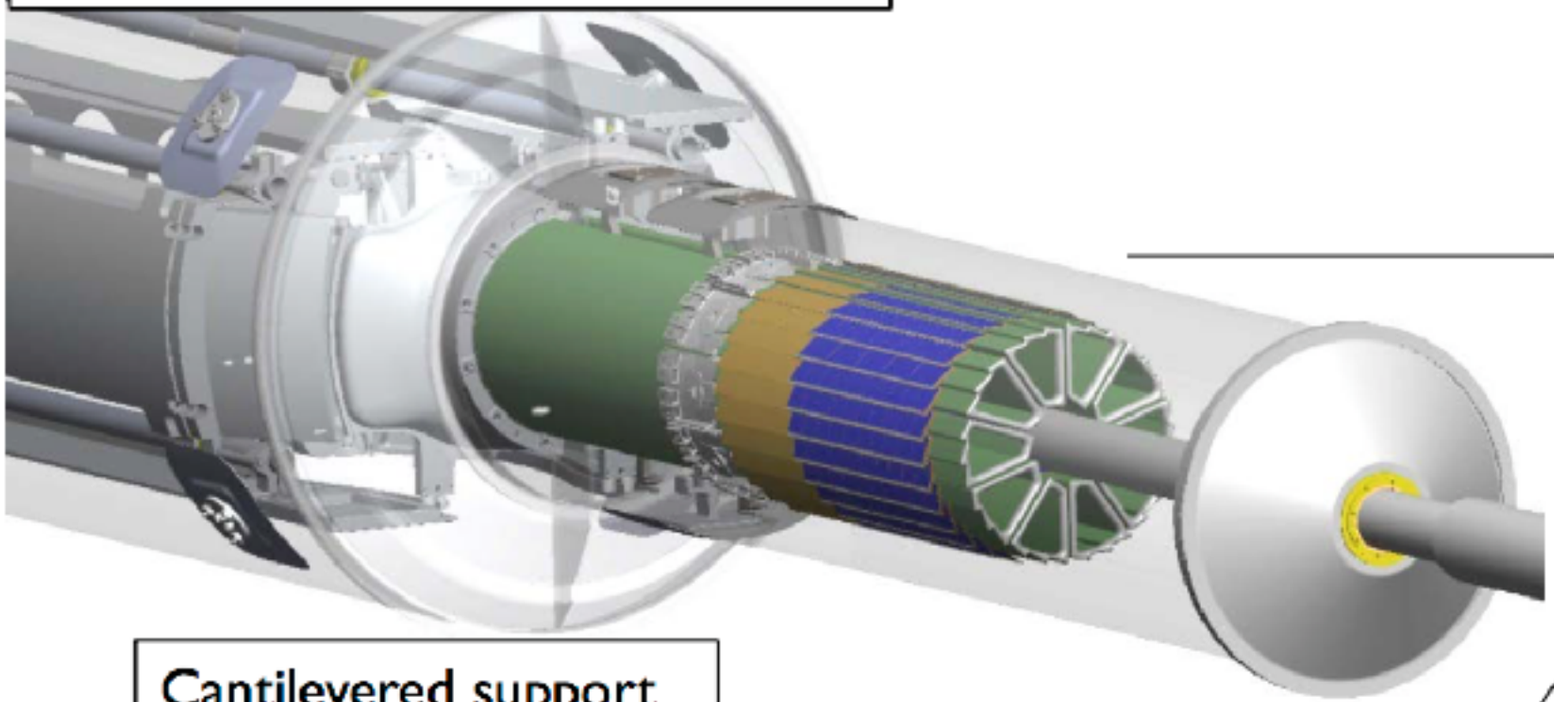
semi-inclusive observables do so at *forward* angles.

RNC - STAR HFT-PXL

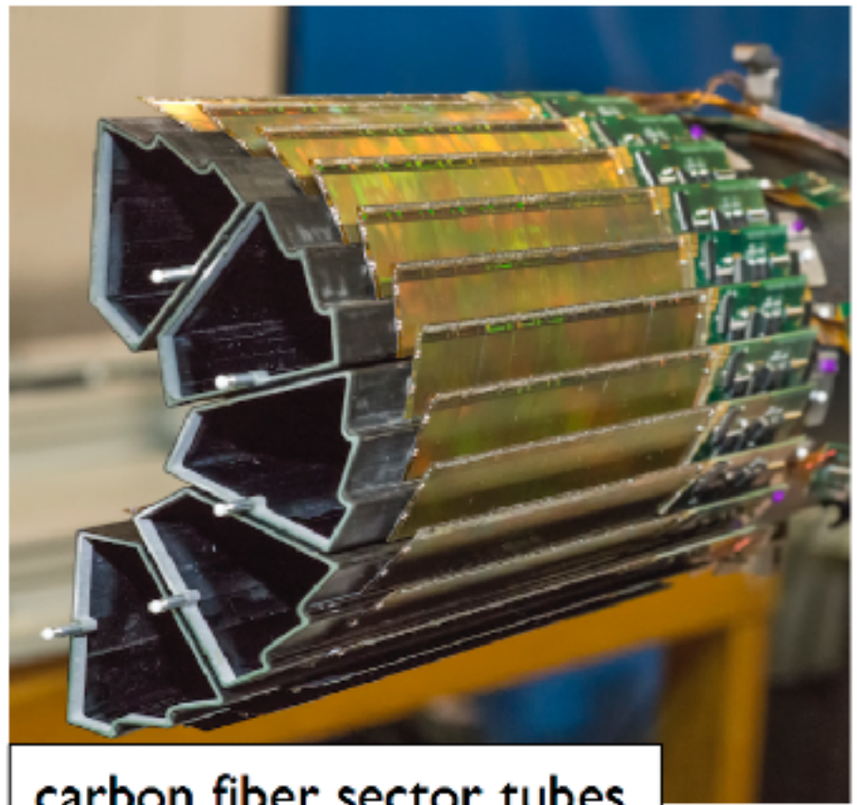
10 sectors total
5 sectors / half
4 ladders / sector
10 sensors / ladder

Highly parallel system

Mechanical support with kinematic mounts (insertion side)



Cantilevered support

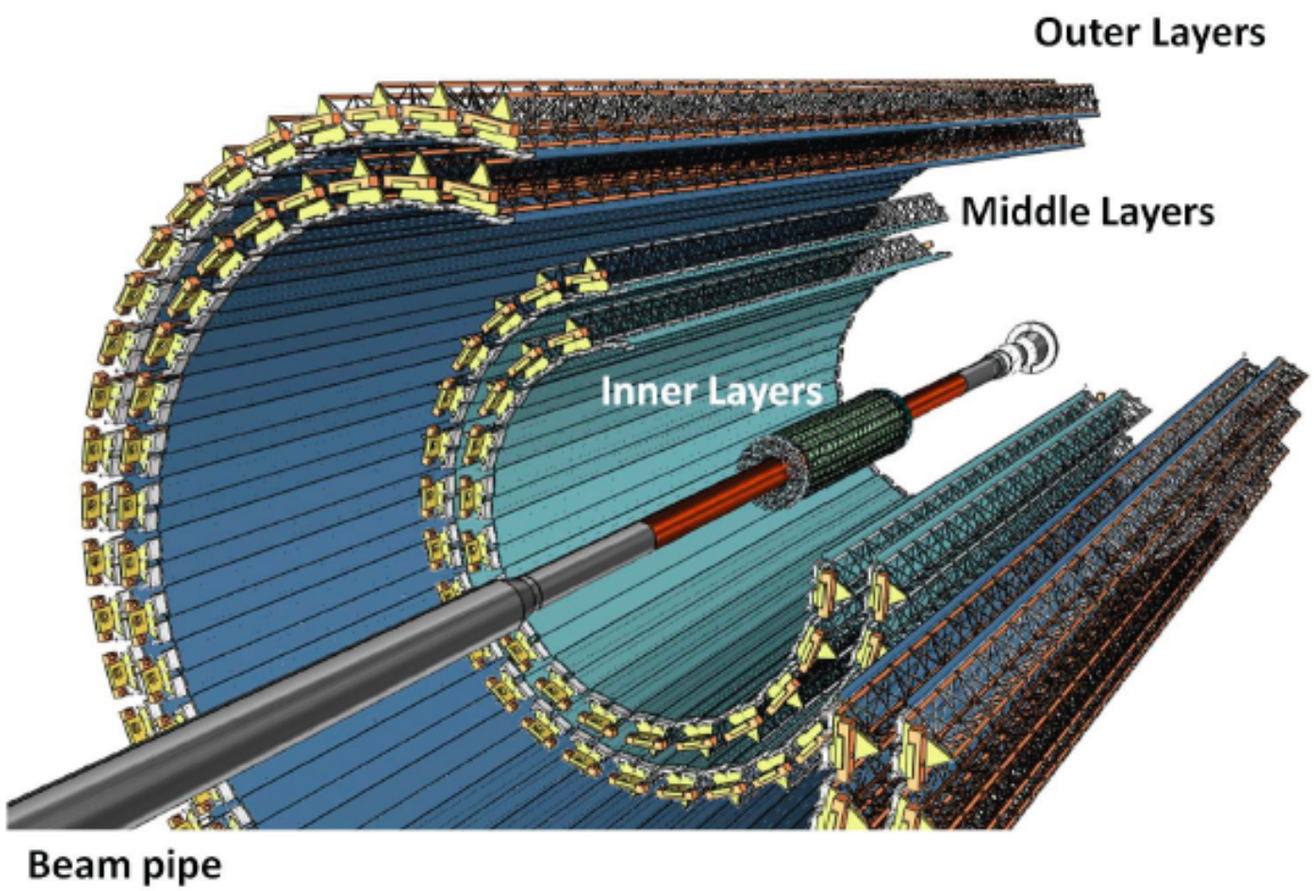


carbon fiber sector tubes
(~ 200 μm thick)

Ladder with 10 MAPS sensors (~ 2×2 cm each)

Courtesy G. Contin (LBL-RNC), for the STAR collaboration, QM2015

RNC - ALICE ITS Upgrade



- 7 layers
- 10 m^2 of silicon
- Installation in early 2019
- X/X_0 ~ 0.3% (inner layers)
- X/X_0 ~ 0.8% (outer layers)

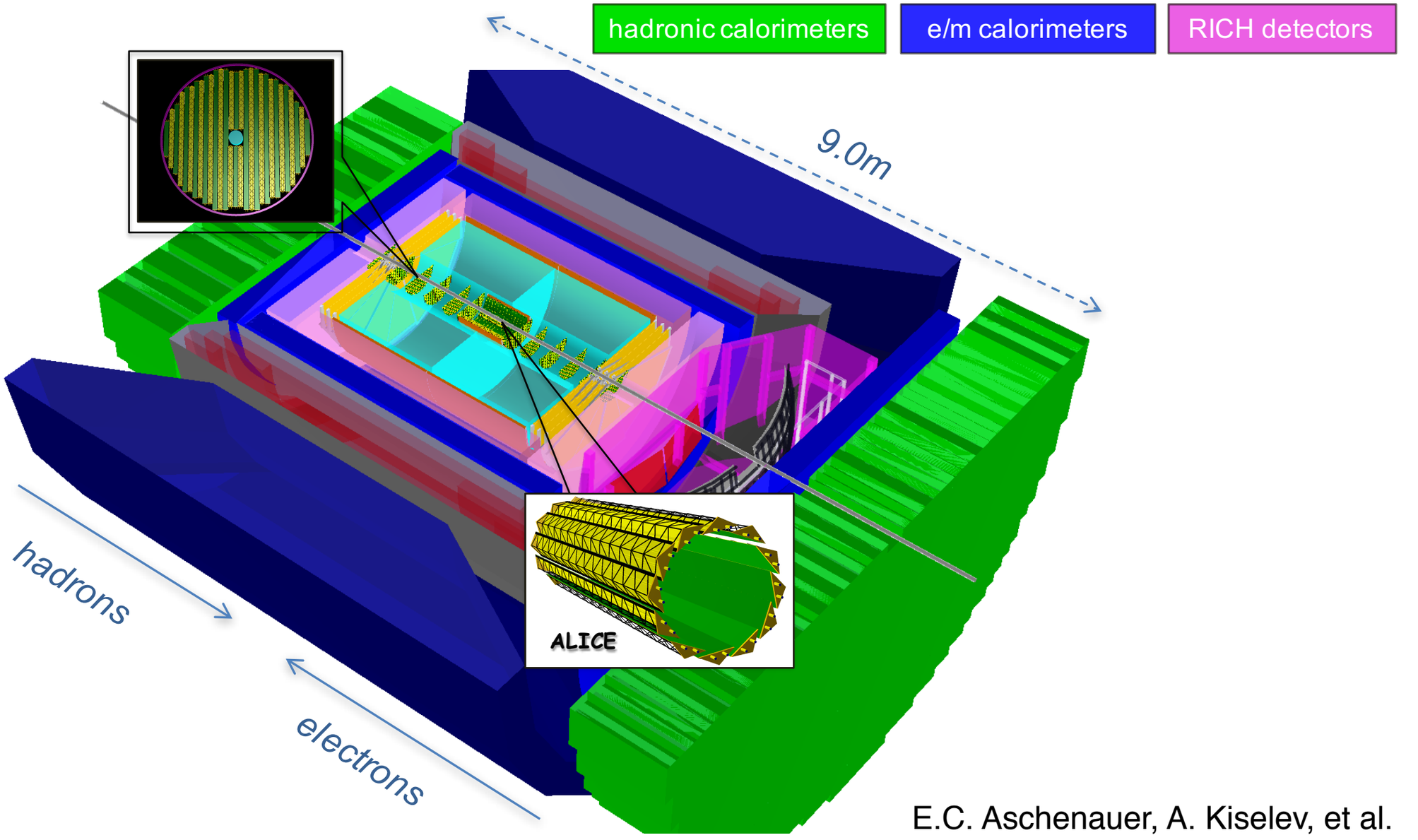
Anticipated use of CERN-developed MAPS sensors, ALPIDE:

Dimensions:	15mm x 30mm
Pixel pitch:	28µm x 28µm
Integration time:	approx. 4 µs
Power consumption:	39mW/cm^2

TDR: http://iopscience.iop.org/0954-3899/41/8/087002/

Vertex tracker for sPHENIX being proposed.

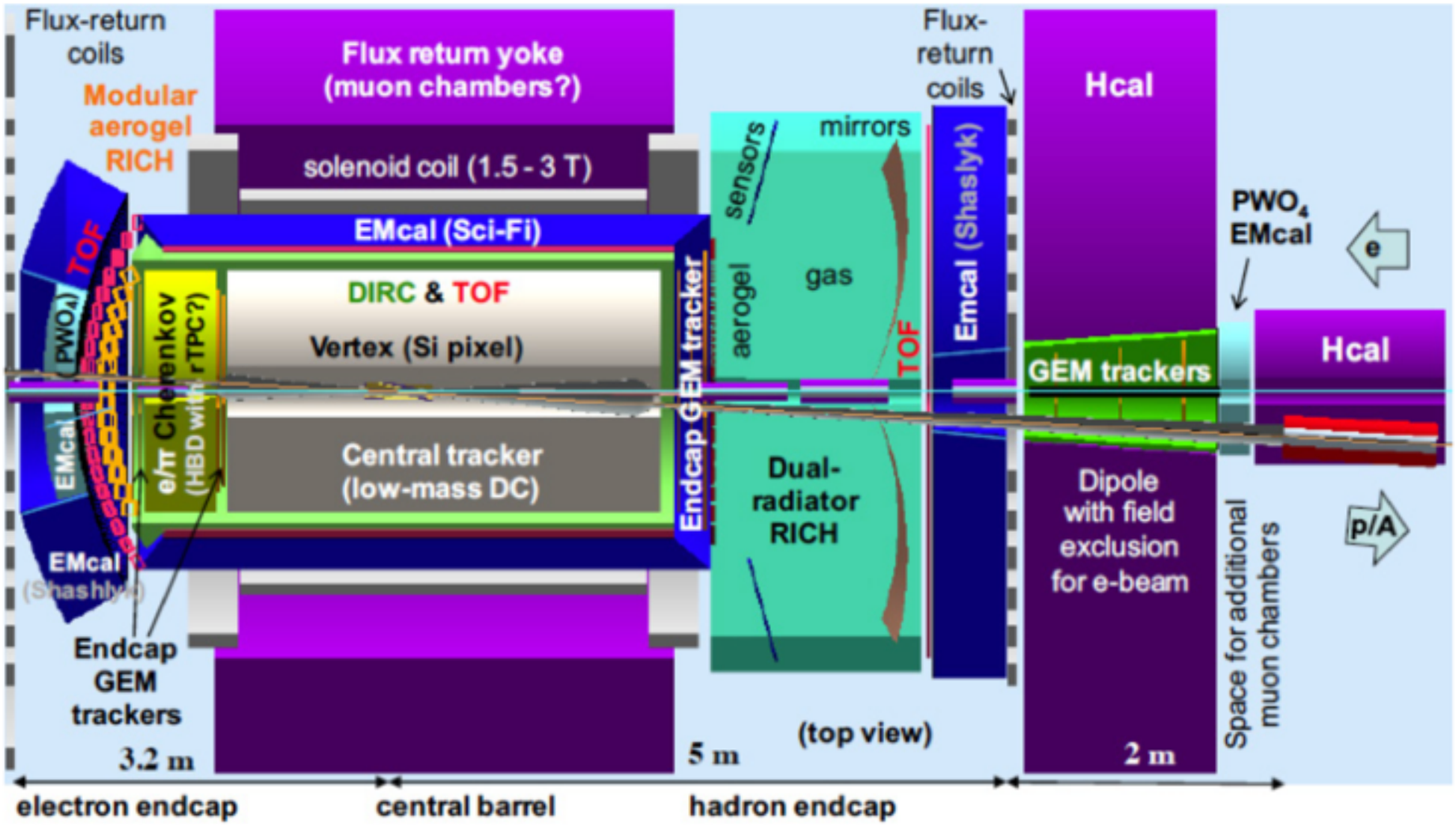
EIC - eRHIC Model Detector (BeAST)



E.C. Aschenauer, A. Kiselev, et al.

MAPS-based Si; optimize resolutions, provide vertexing, minimize Bremsstrahlung.

EIC - JLEIC Model Detector



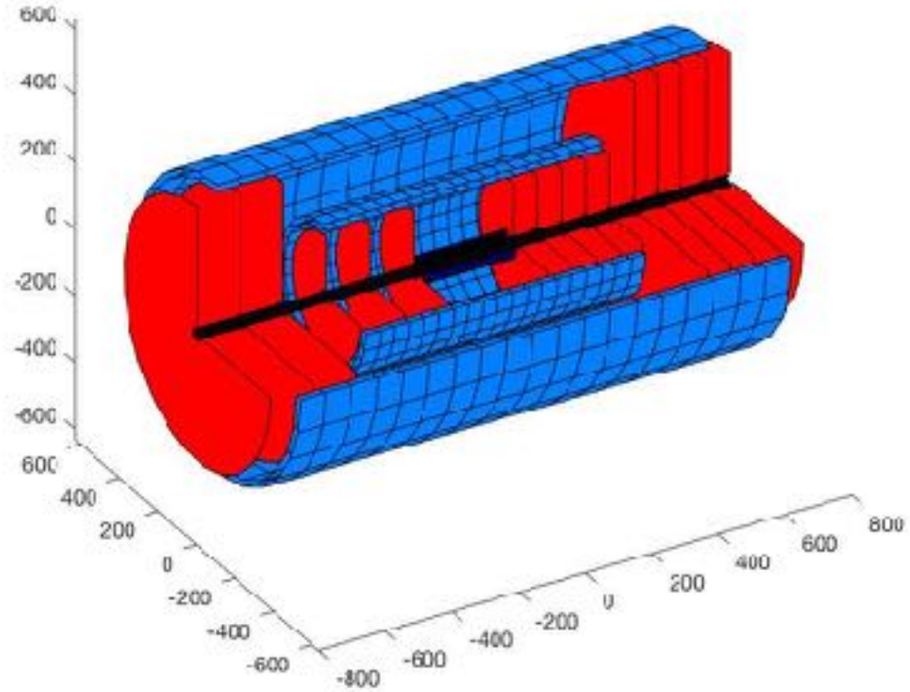
JLEIC Detector and Interaction Region Study Group

Si pixel detectors covering central and forward rapidities.

Aim for *high resolution* and *low mass* solutions.

RNC - EIC R&D Simulations

- 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.



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

- Rapid studies of number of layers, disks, geometrical layout, etc.
- Work done with UCB undergraduate students Ivan Velkovsky, Winston DeGraw (see also earlier reports).

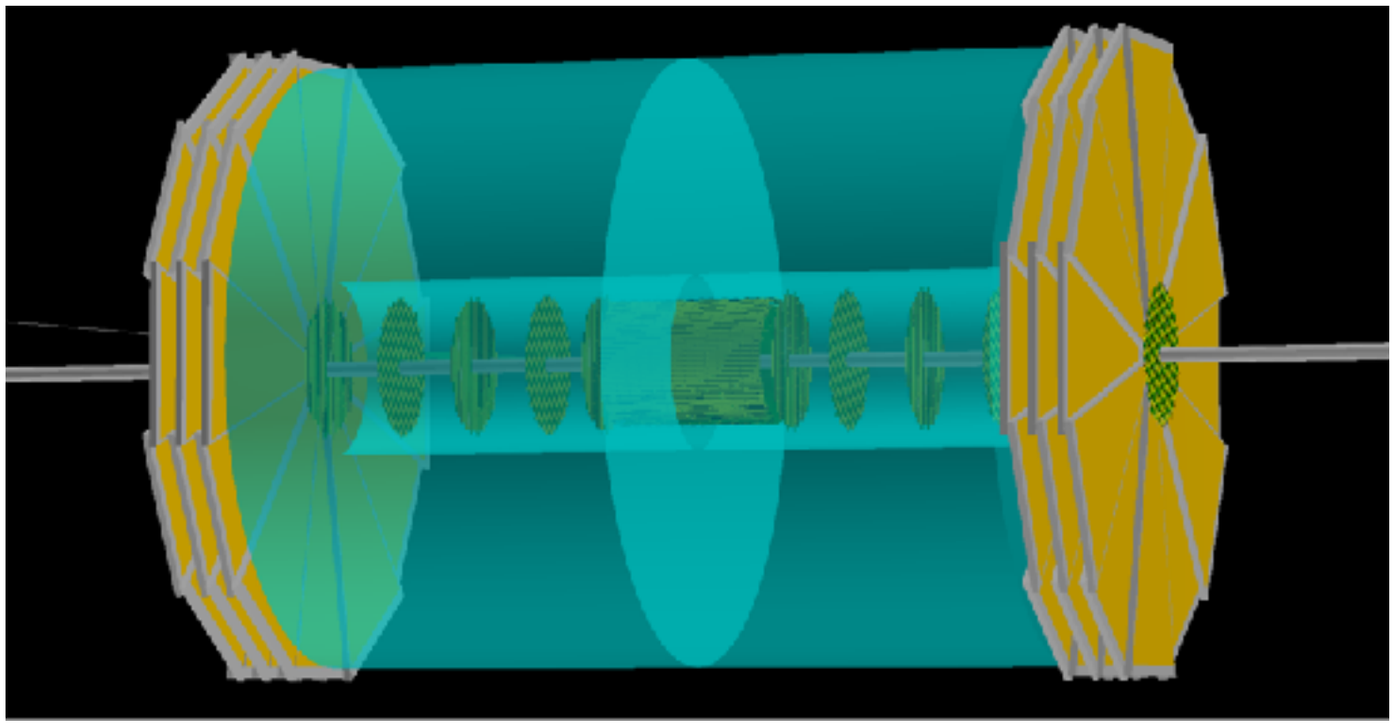
RNC - EIC R&D Simulations

- Toolset(s) developed by EIC task-force at BNL;

  EICRoot; GEANT-based simulations

  Pythia-eRHIC,

  (EIC-smear)



BeAST; seen are the TPC, Si-barrel and disks, and large-area GEMs

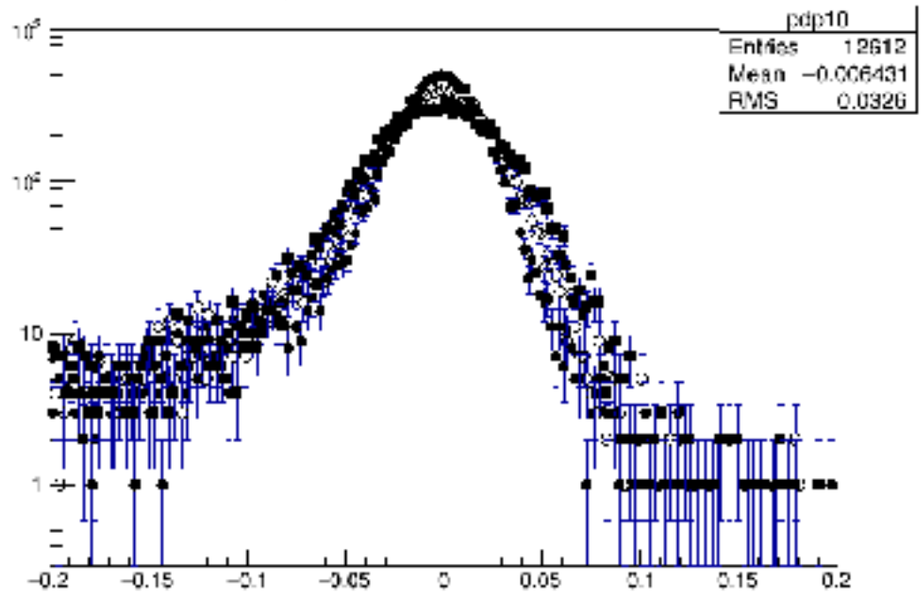
- Work done by Yue Shi Lai, and ongoing to
  confirm/refute key findings from fast simulations,
  changes to improve geometry and infrastructure.

- Preferred toolset going forward, as the issues need more realistic answers, and for collaboration with eRD18.

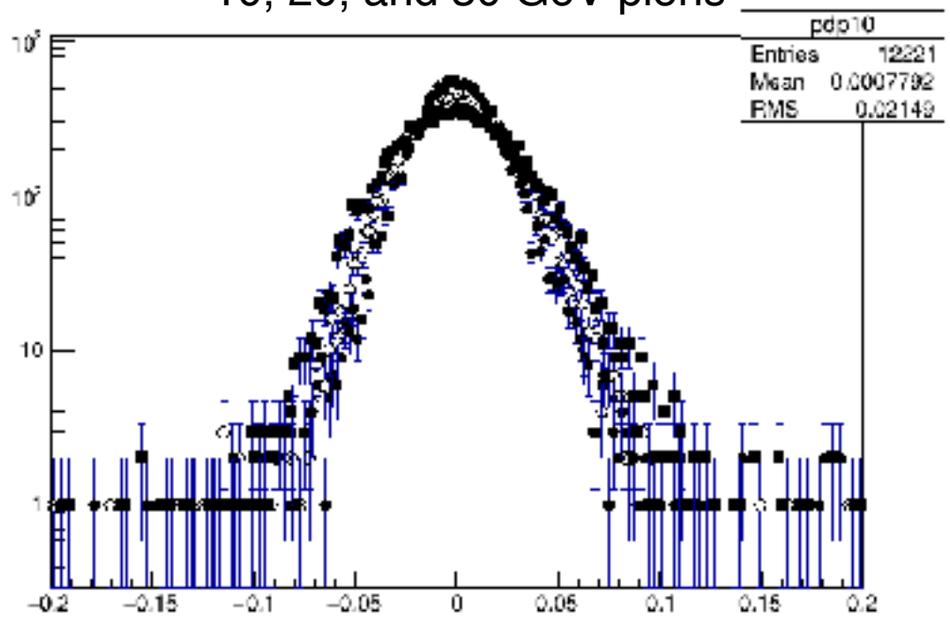
RNC - EIC R&D Simulations

- For example,

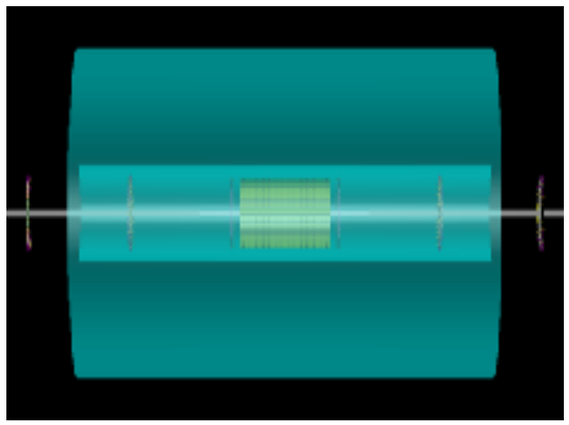
10, 20, and 30 GeV electrons



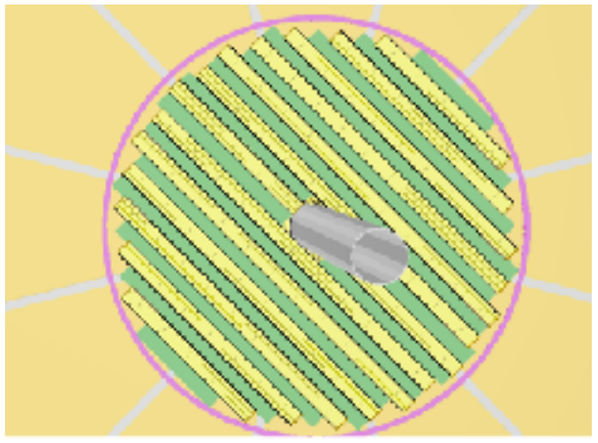
10, 20, and 30 GeV pions



Tails (can/do) matter, even in a 3-disk simulation.

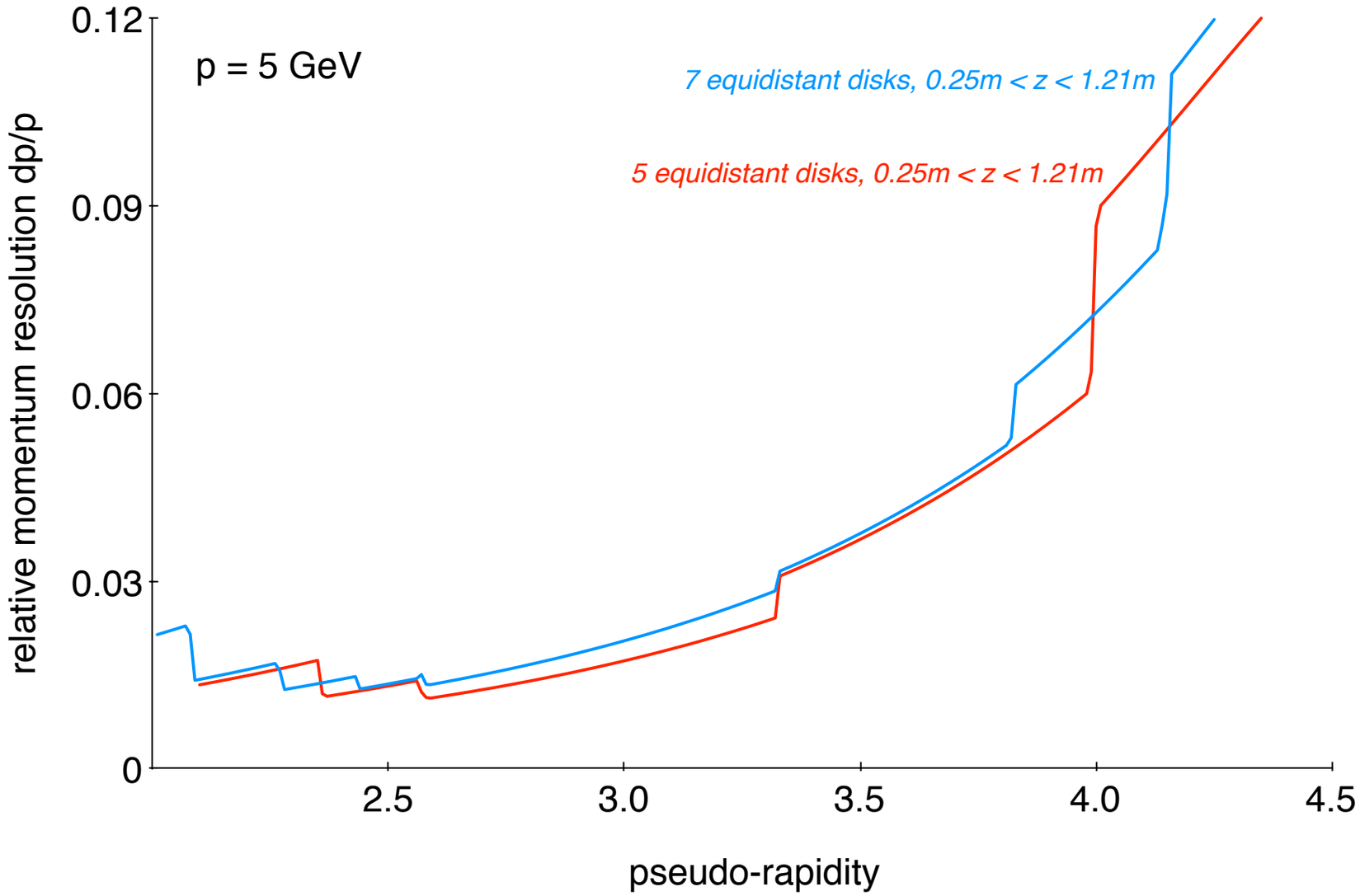


- Supports and infrastructure.



RNC - EIC R&D Simulations

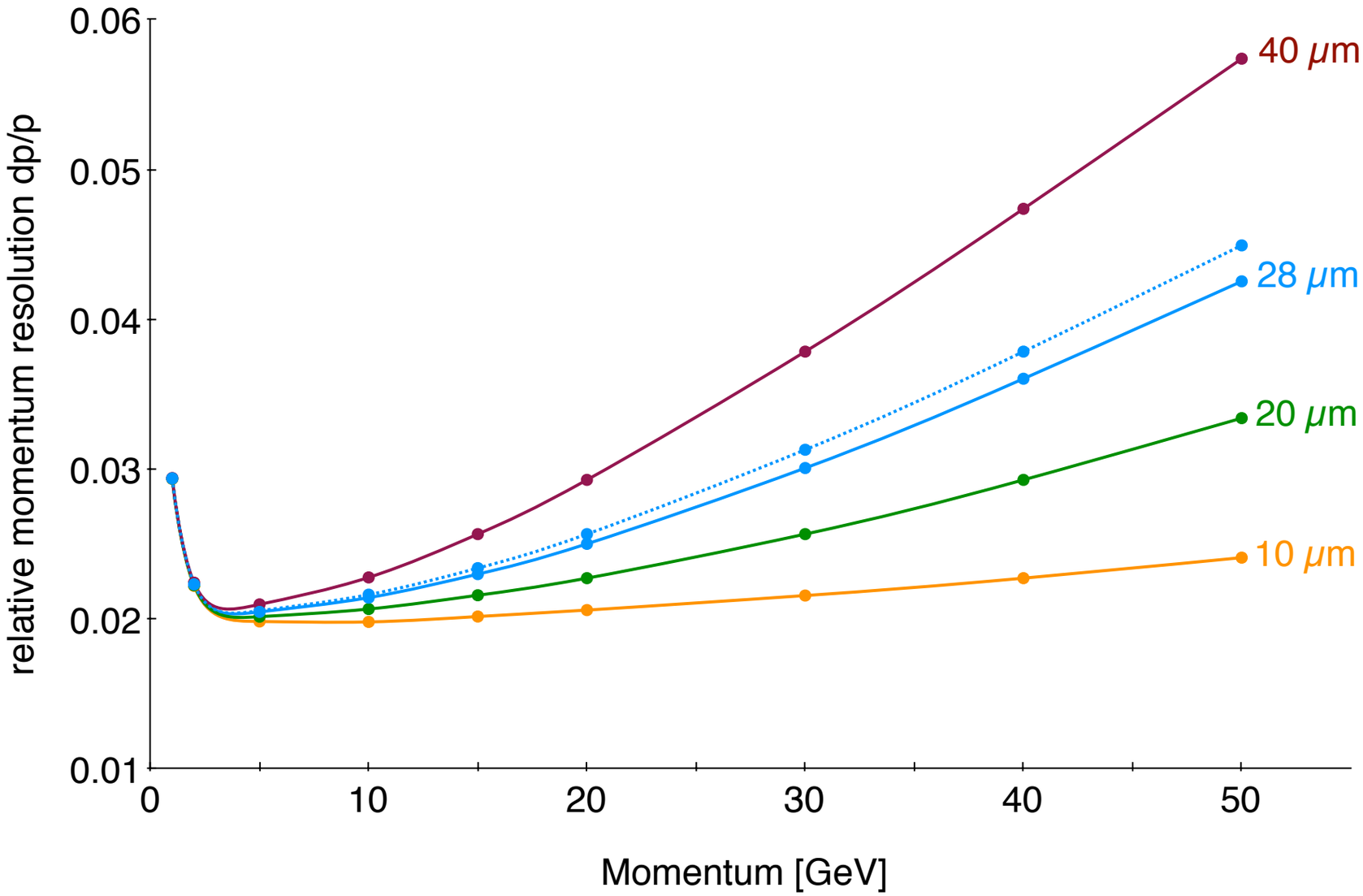
Fine-binned LDT results for disks in a 3T field (BeAST):



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).

RNC - EIC R&D Simulations

LDT scan of pixel-size; 7 equidistant disks in a 3T field (BeAST):



Pseudo-rapidity is 3 here; measurements from all disks.

Momentum is *inside* the beam-pipe here; upturn at low (absolute) momentum originates mostly with uncertainty in the dip-angle.

RNC - EIC R&D Simulations

Initial considerations of timing and rates,

- eRHIC: 10 MHz beam bunch repetition rate, or higher (100ns separation, or less),
  JLEIC: 476 MHz (2.1ns),

- Not every bunch crossing produces a collision,

- The track density in a typical collision is modest; few tracks are produced,

- The Si-sensors considered *so far* (effectively) integrate over multiple beam-crossings,
  ~4μs for ALPIDE, c.f. Peter Jones's talk - eRD18

- Tracks and events need to be associated with each other and
  with the beam-crossing (spin config.)

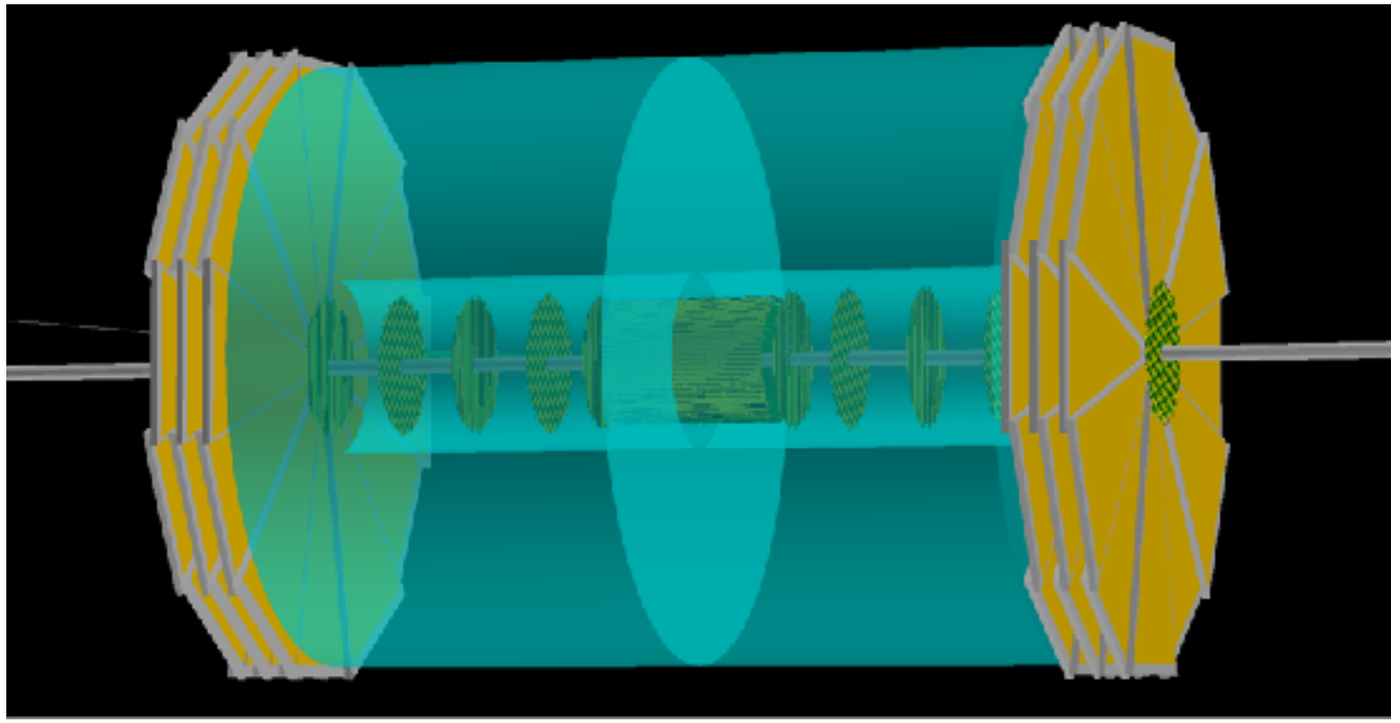
- Implications for optimal EIC Si sensors?

RNC - EIC R&D Simulations

Initial considerations of timing and rates,

- Several possible approaches to handle the issues. We start here with `anchoring' tracks to one or more faster detection layers.

- The large area GEMs in the BeAST design, for example, might serve this purpose.



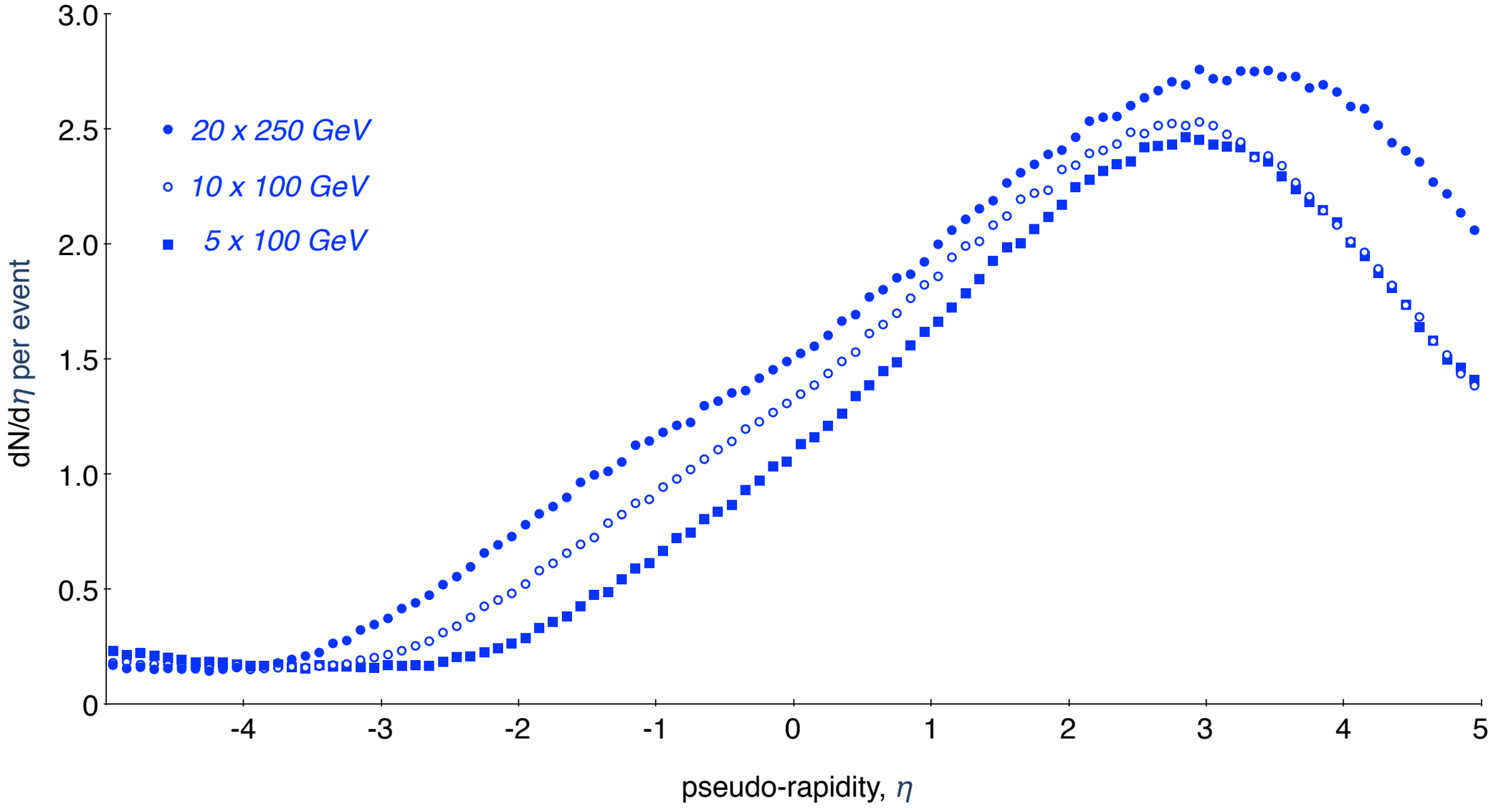
BeAST; seen are the TPC, Si-barrel and disks, and large-area GEMs

- Alternatives could include one or more fast Silicon disks or barrel layers, or …

RNC - EIC R&D Simulations

Initial considerations of timing and rates,

PythiaeRHIC simulations of track-densities for different beam-energy configurations

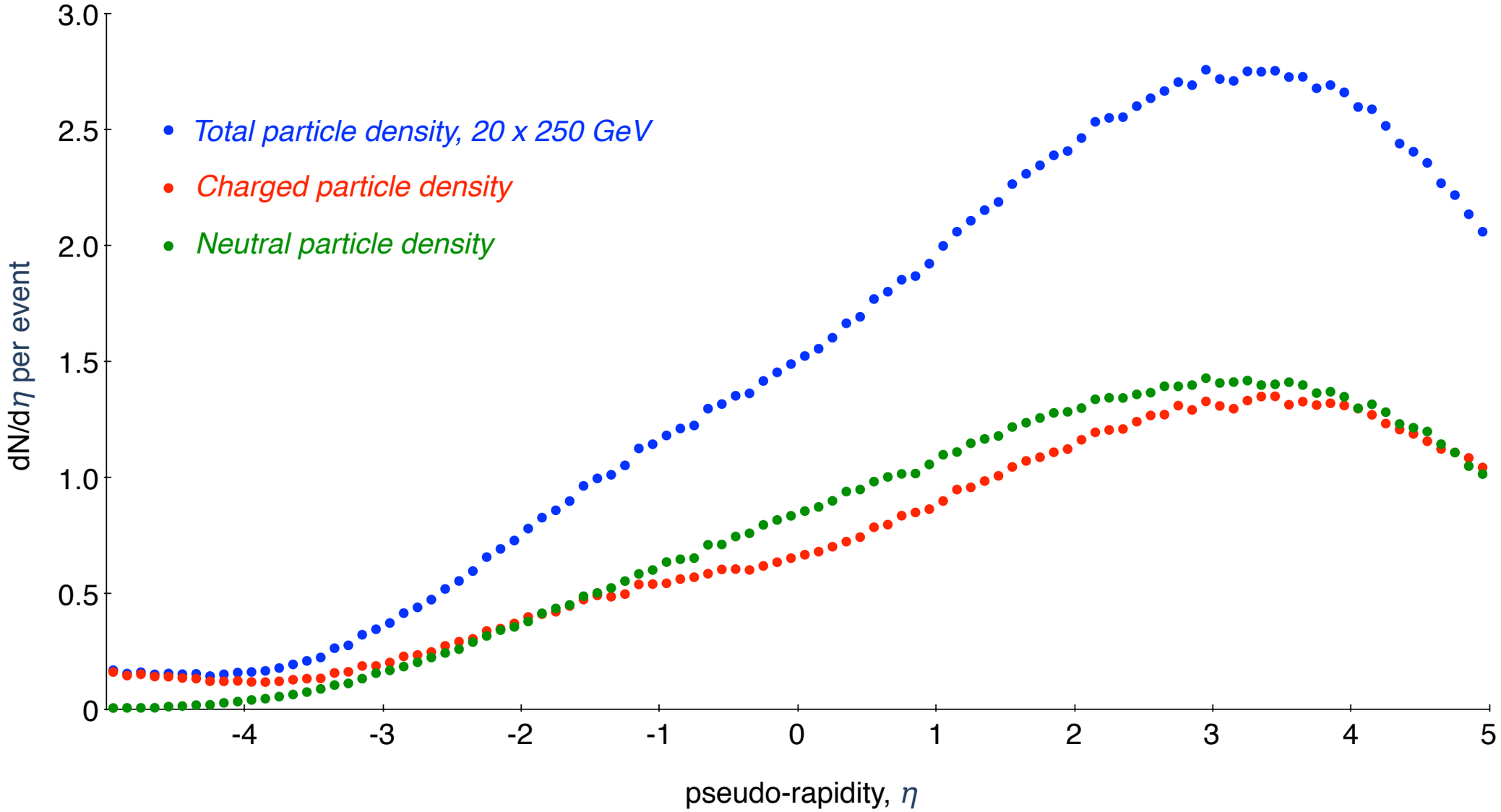


Here, consider the forward hadron direction and 20x250 GeV as a driving case.

RNC - EIC R&D Simulations

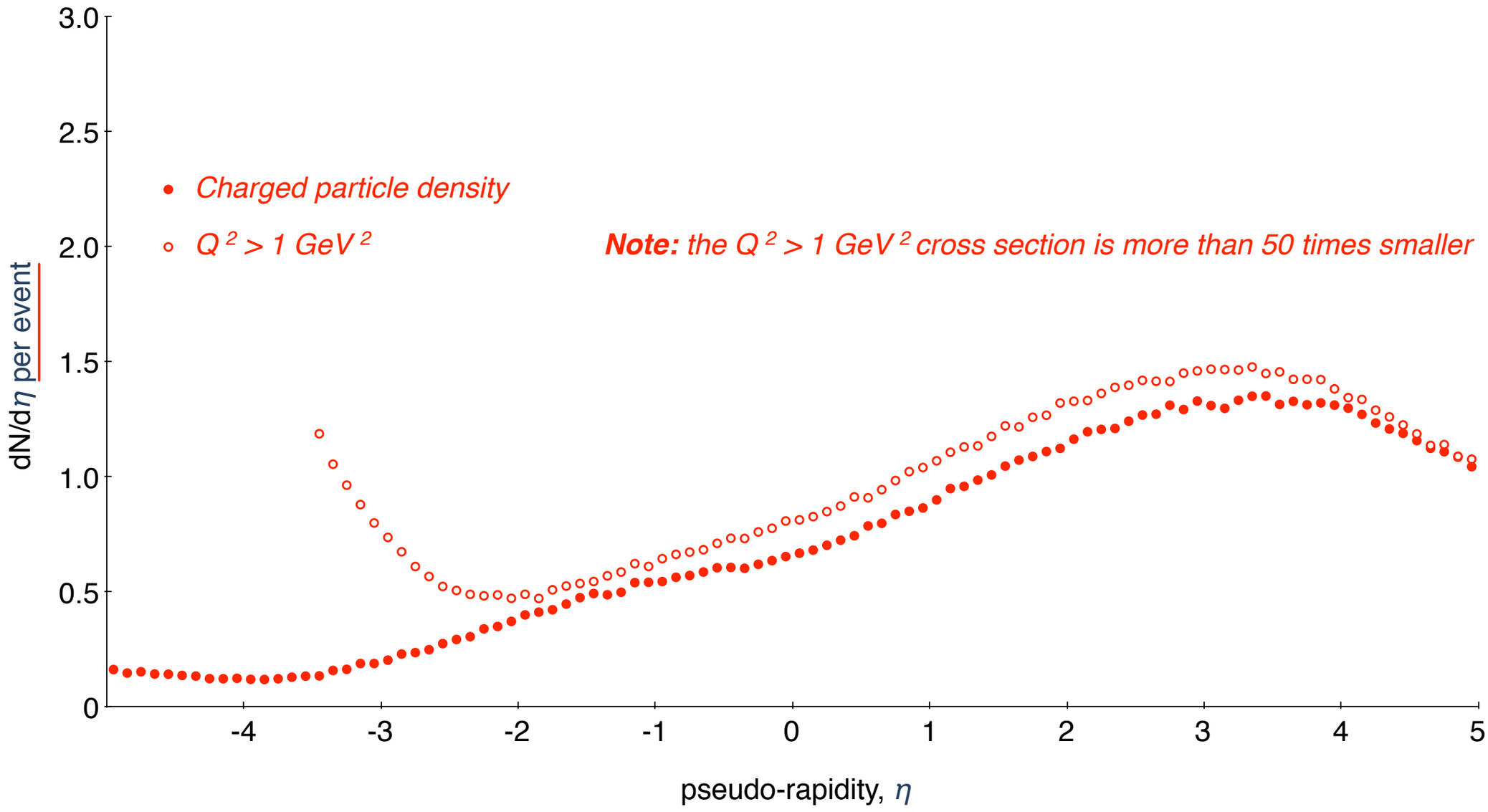
Initial considerations of timing and rates,

PythiaeRHIC simulations of track-densities for *charged* particles



RNC - EIC R&D Simulations

Intermezzo, particle densities for DIS events are not vastly different.



RNC - EIC R&D Simulations

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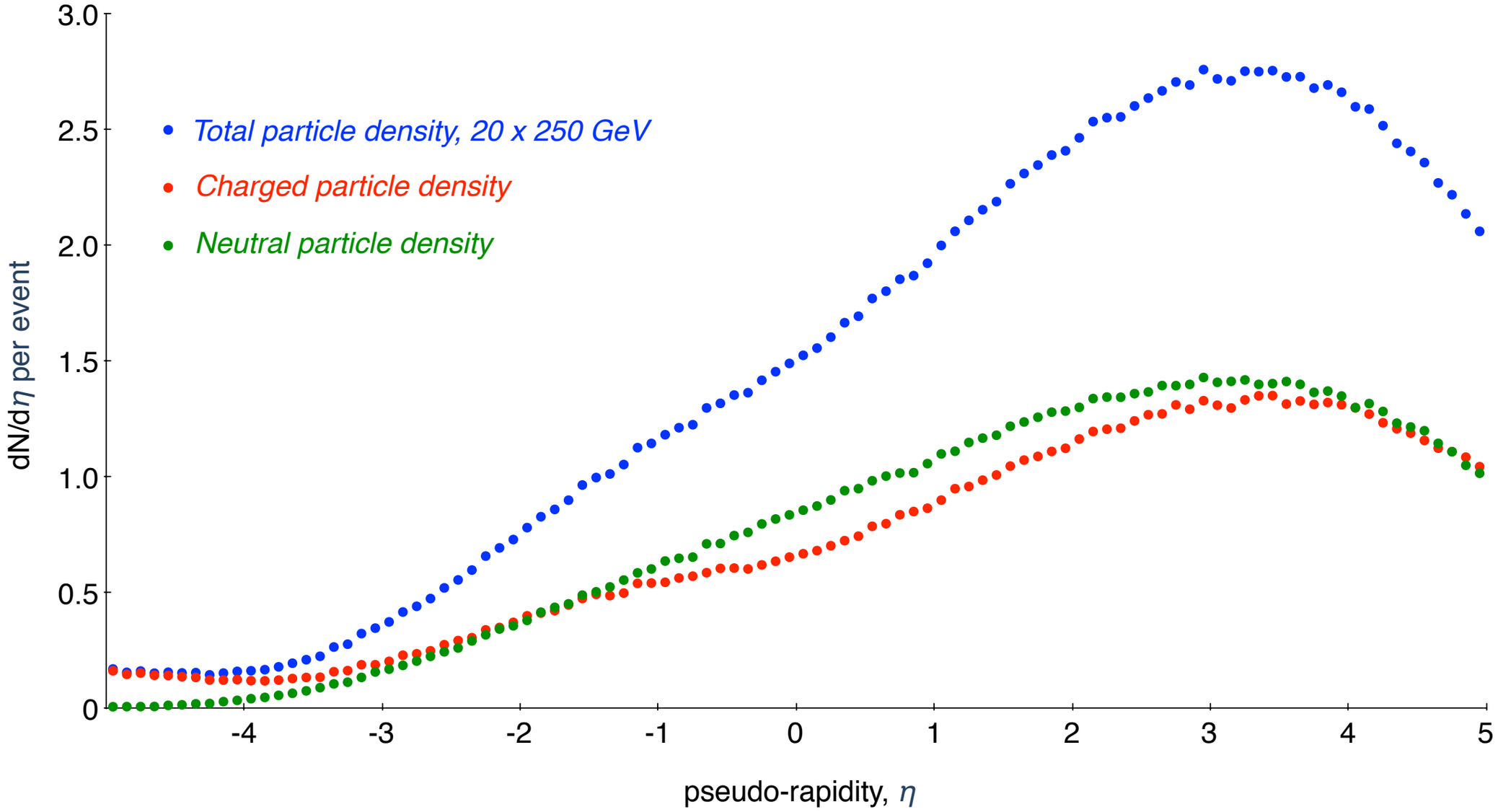

RNC - EIC R&D Simulations

Initial considerations of timing and rates,

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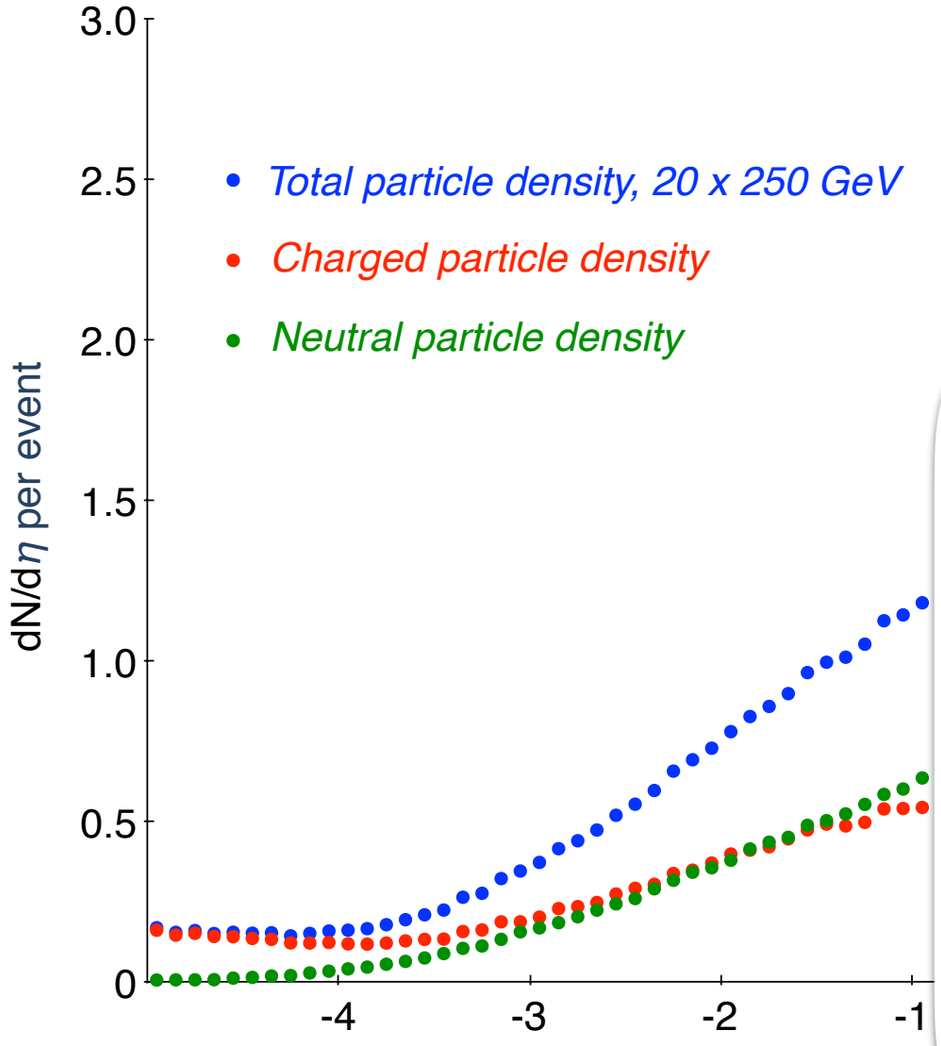


L ~ $10^{33(34)}$cm^{-2}s^{-1} implies:

~50 (500) kHz event rate

<< bunch repetition rate

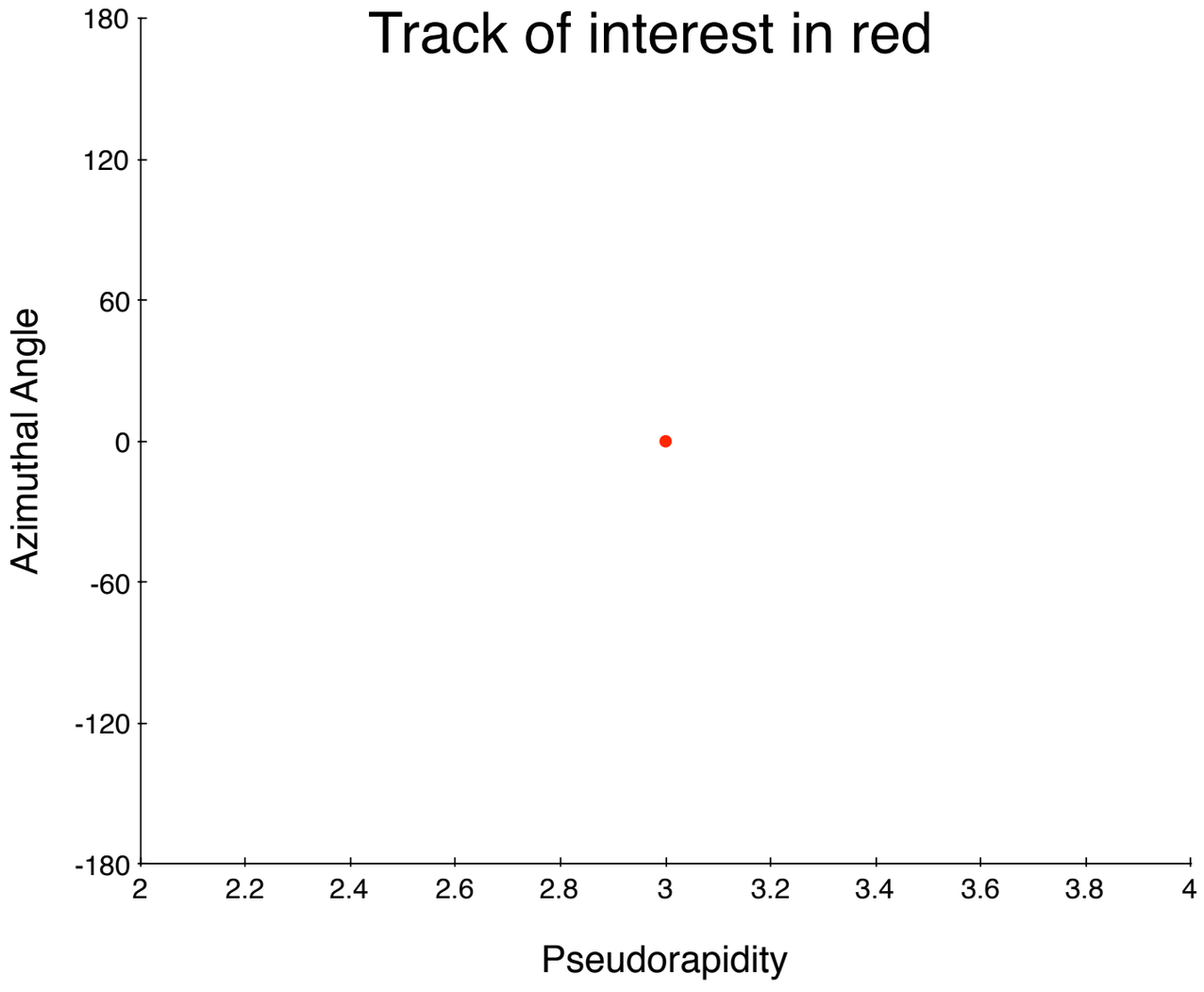
~ similar to ~μs integration times

Simulated *standalone* and in LDT as overlap of full and potentially multiple events.

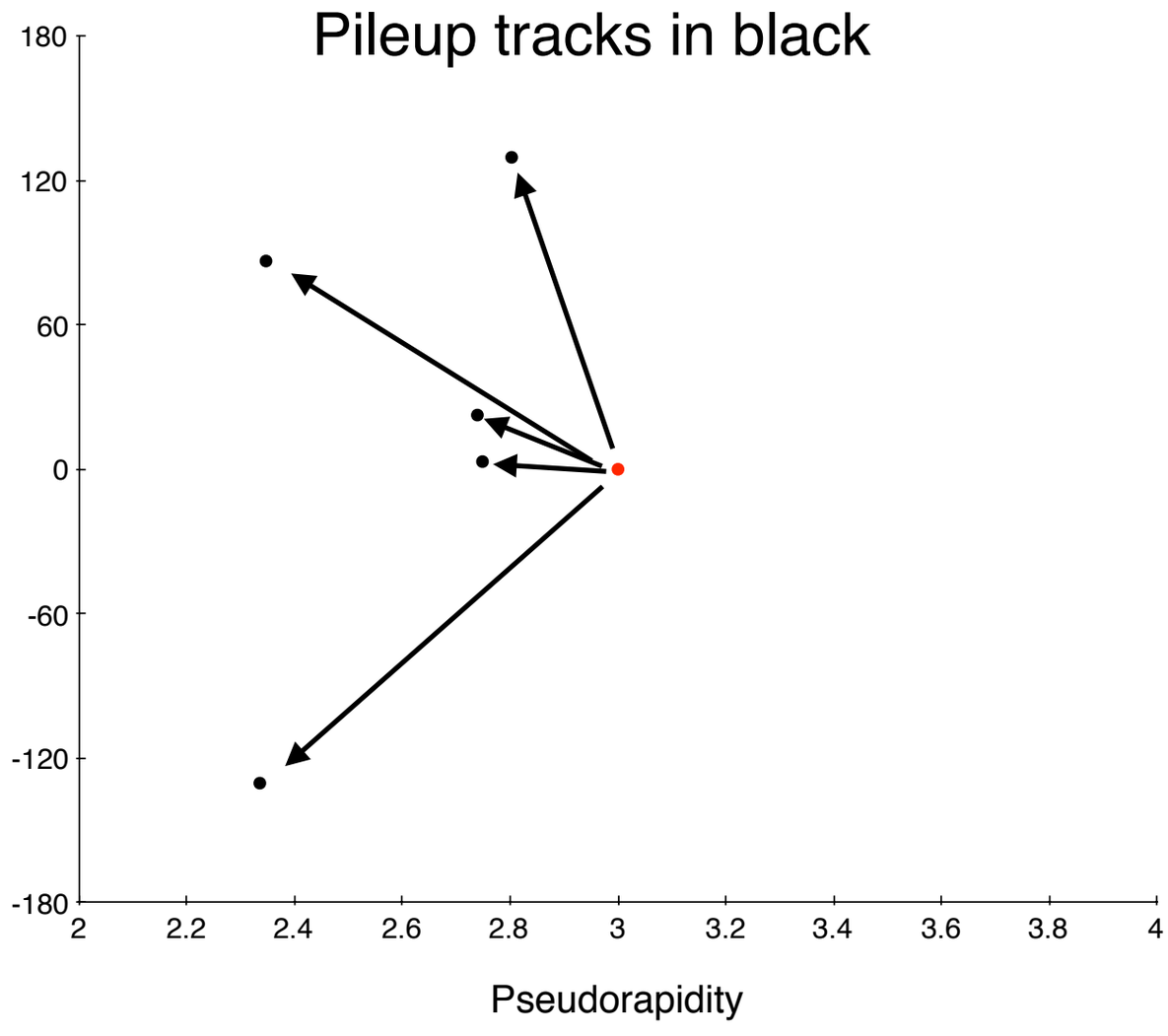
RNC - EIC R&D Simulations

Initial considerations of track/event pileup in Si-sensors

Track of interest in red



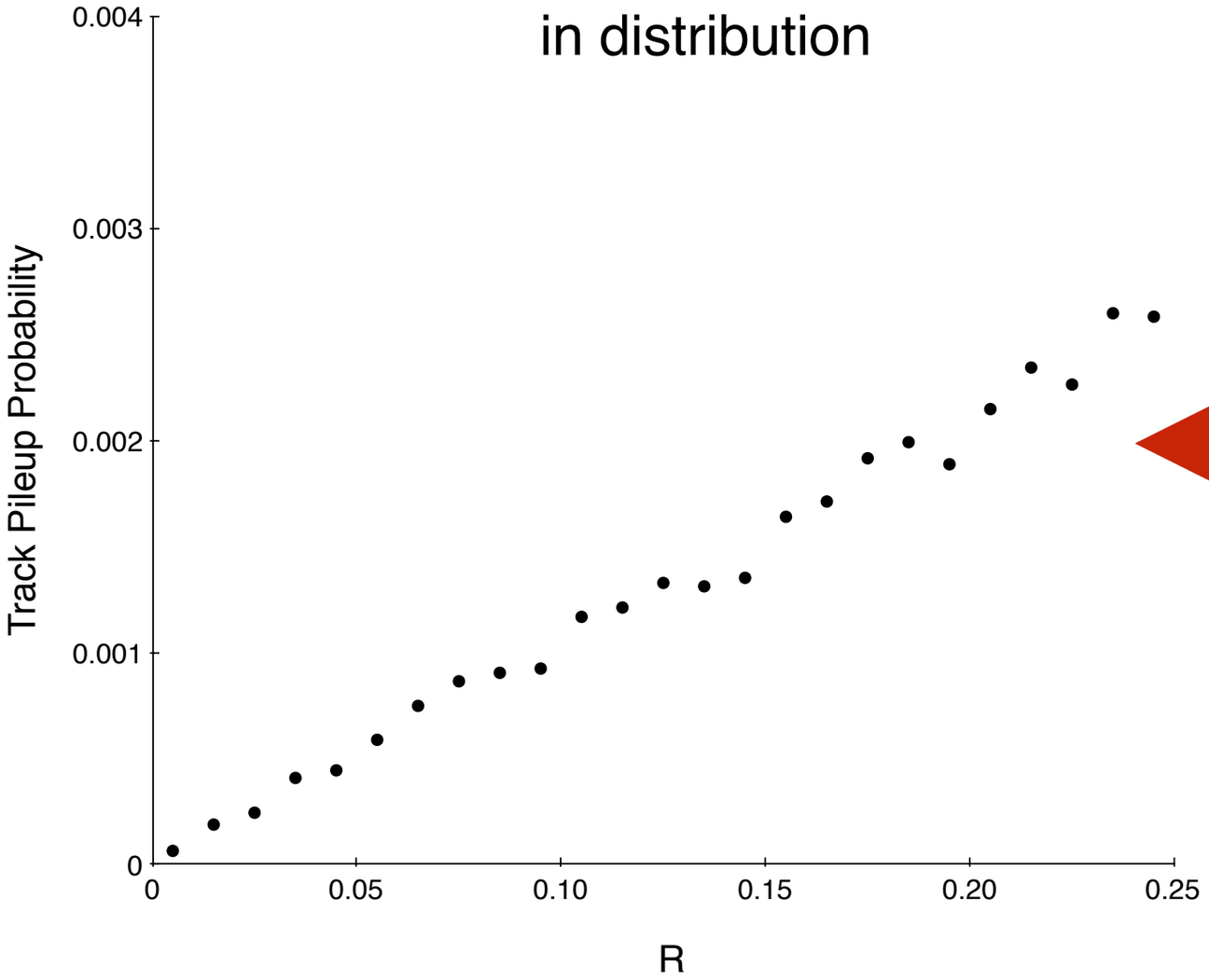
Pileup tracks in black

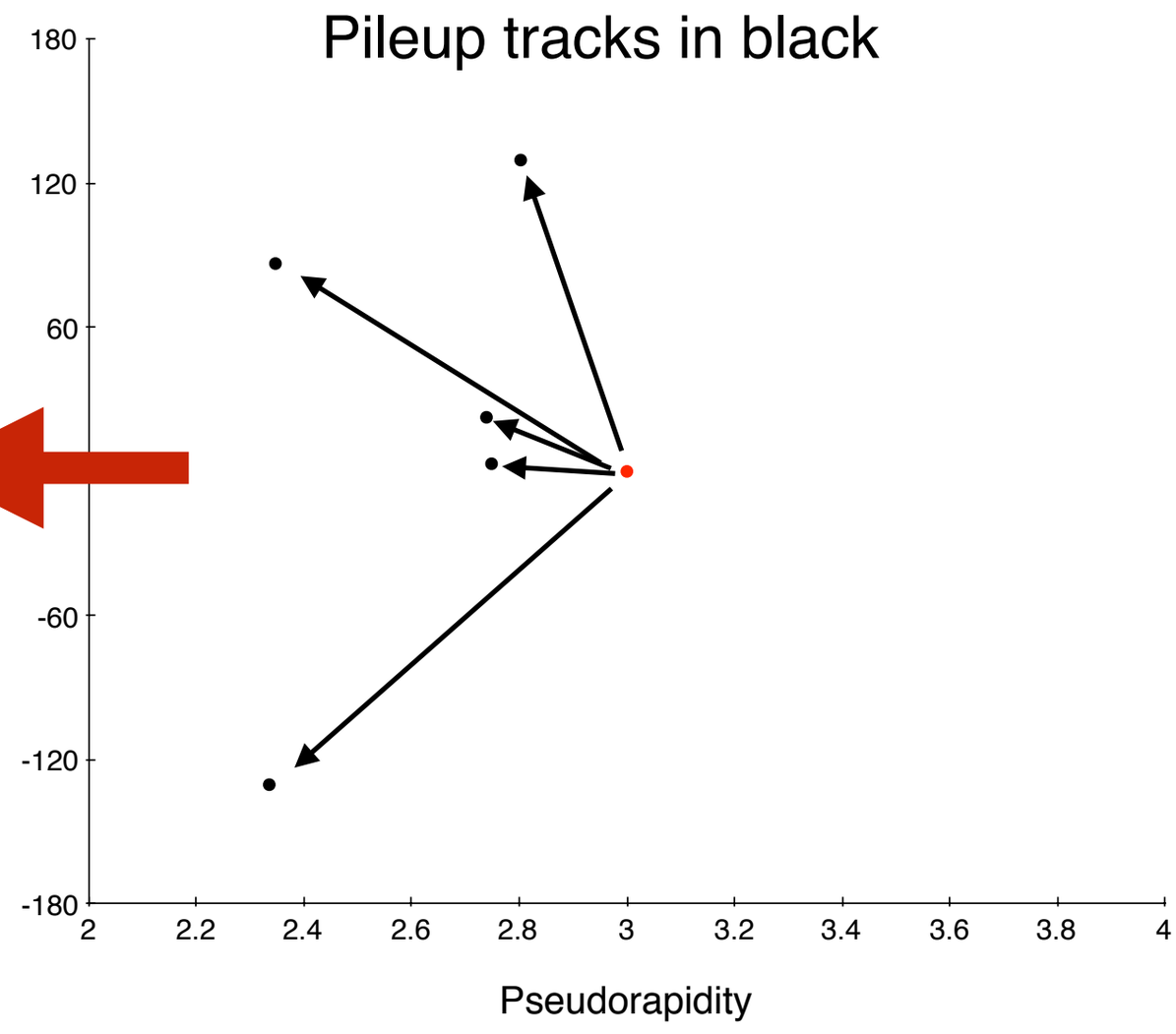


L ~ 10^{33}cm^{-2}s^{-1}, event pileup probability 0.04/μs, 10μs integration.

RNC - EIC R&D Simulations

Initial considerations of track/event pileup in Si-sensors





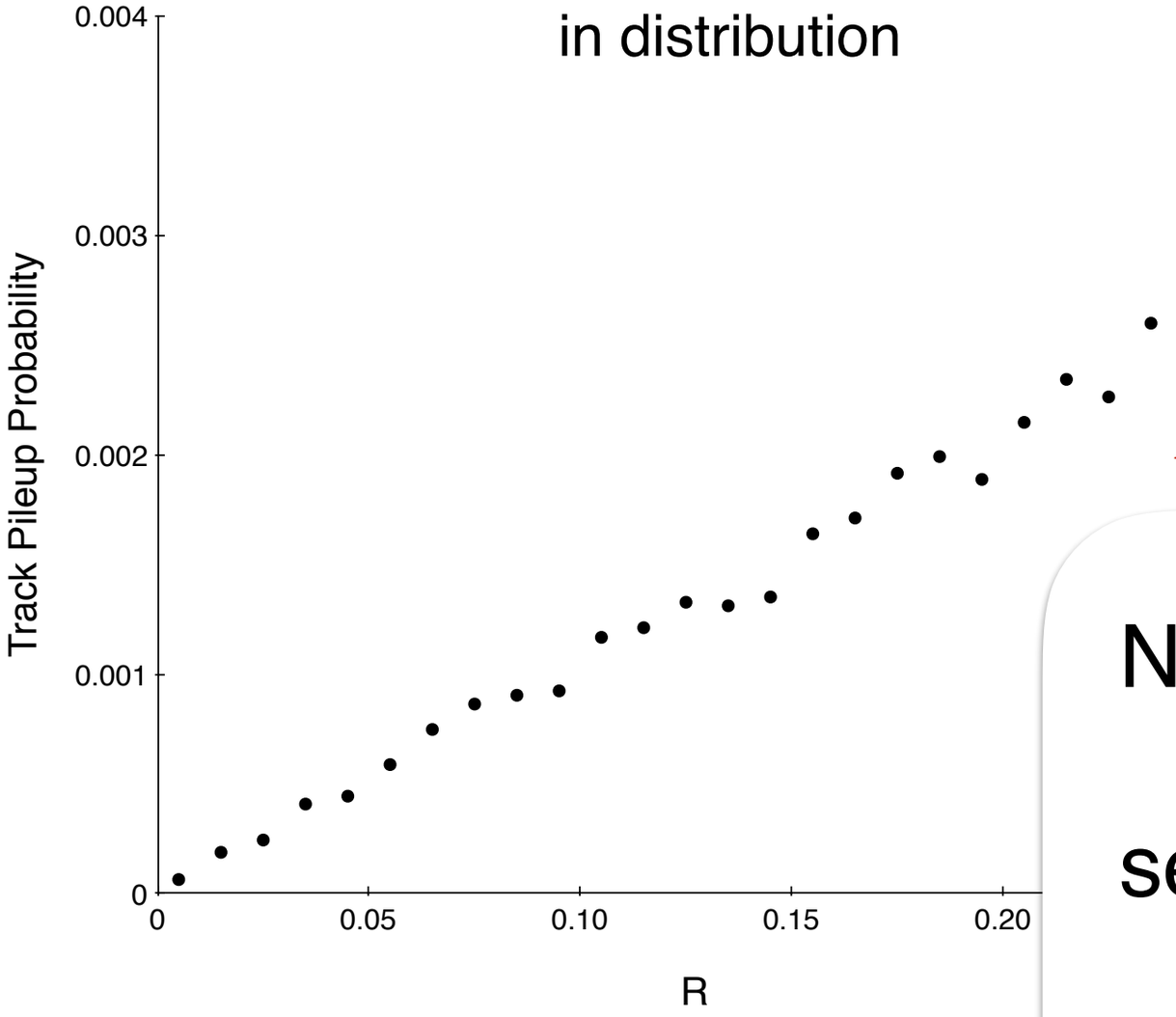
L ~ 10^{33}cm^{-2}s^{-1}, event pileup probability 0.04 per μs, 10μs integration,

1mm resolution at 1m corresponds to ~0.01 in R for eta~3,

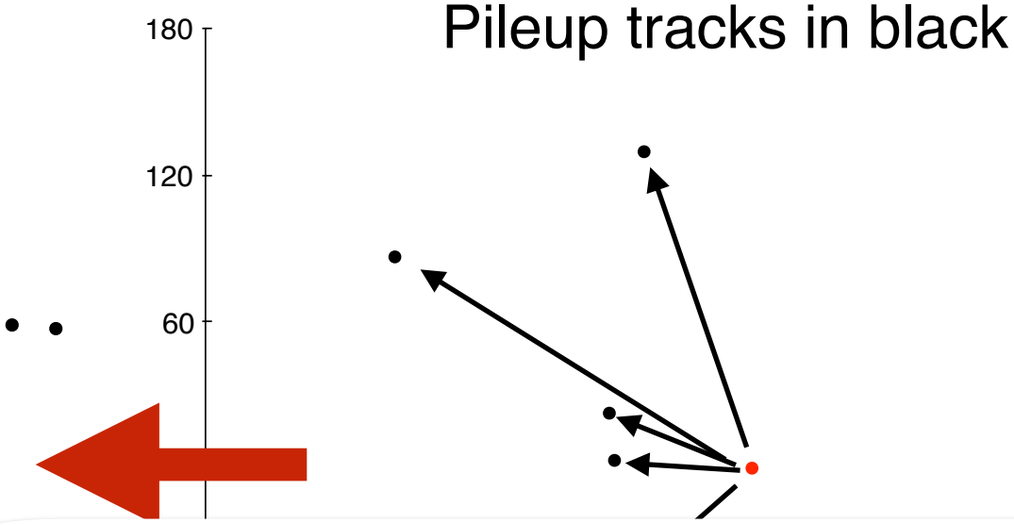
→ Within capability of BeAST large area forward GEMs; JLab to be studied

RNC - EIC R&D Simulations

Initial considerations of track/event pileup in Si-sensors



in distribution



Pileup tracks in black

Not the last word, obviously:

seek to incorporate in EICRoot,

study background(s), noise, …

L ~ 10^{33}cm^{-2}s^{-1}, event pileup p

1mm resolution at 1m corresp

→Within capability of BeAST large area forward GEMs; JLab to be studied

eRD16 and eRD18

- Started video conferences, roughly monthly, to discuss ongoing work and plans,
- Made a start towards joint layout simulations, with a common toolset and detector descriptions; EICRoot,
- Initial division of effort along (main) physics interests,
- Aim for a set of optimized requirements for barrel and disks in FY18,
- Beyond FY18, aim for design, submission (and tests) of one or more EIC-specific sensor prototypes,
- Potential to form a consortium on that timeline.

RNC - Next Steps and Request

- Complete set of simulations proposed for the last cycle with the BNL-EIC task force framework (w. postdoc Yue Shi Lai),

- Complete and document set of independent simulations (w. students Ivan Velkovsky, Winston DeGraw),

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- Incorporate event pileup studies in EICRoot framework, physics studies.

- Started collaboration with eRD18 opens exciting opportunity of a new sensor that is better suited to EIC science demands; requires *new* simulation effort.

- Services: limited near-term possibilities for low-mass aluminum conductor development (ALICE-ITS is basically in production); return to this topic the end of period,
  make an initial assessment of air-cooling internal to the support structure; investigate if/how prior R&D within LBNL Physics and Engineering Divisions, and industry, for staves can be adapted to disks

- Request:

50% postdoc support	$83,616
student support	$ 8,276
M&S	$ 2,584
Total	$94,476 (including LBNL overheads)