Silicon tracker configuration and simulations - part 4

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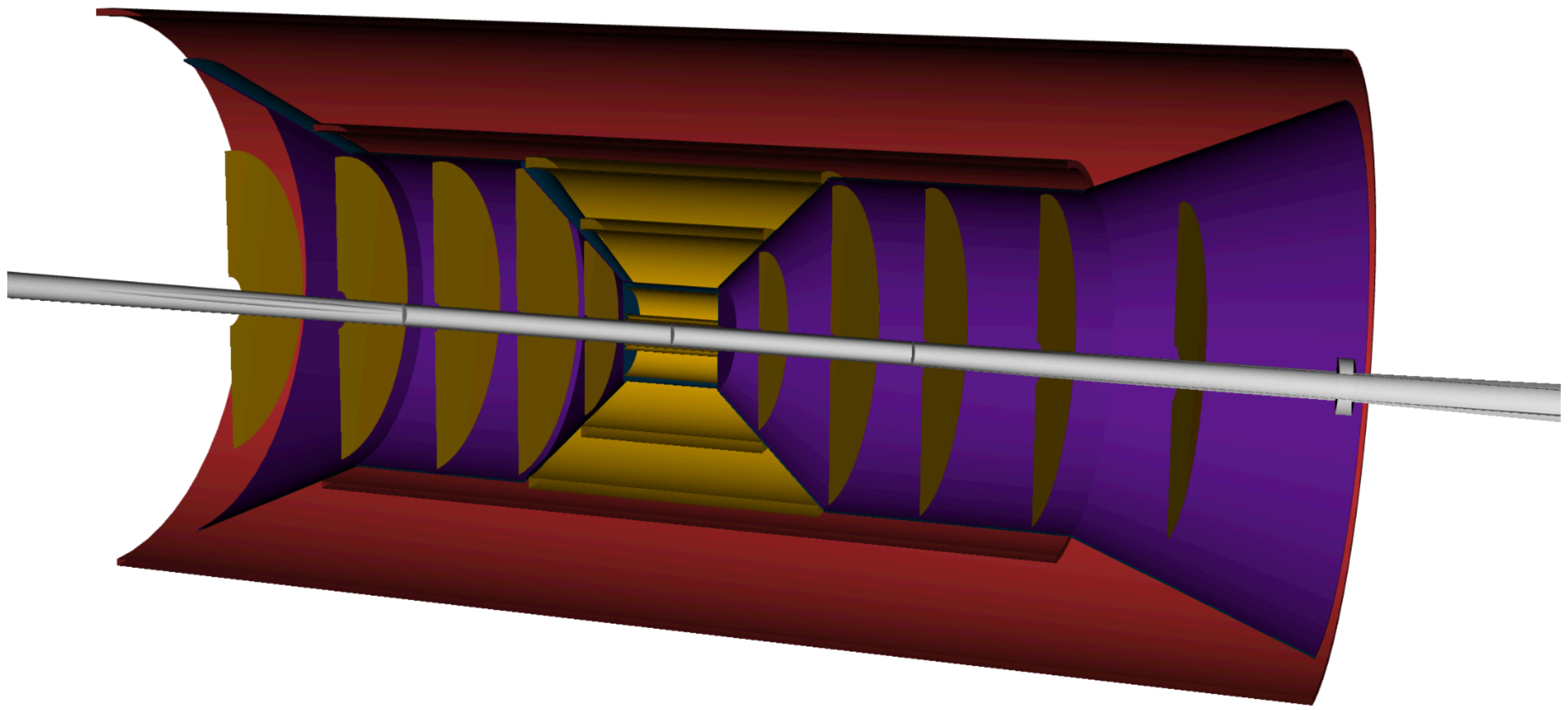
ePIC Tracking WG
February 9, 2023

Reminder - Update on Geometry (Oct. 2022)



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/

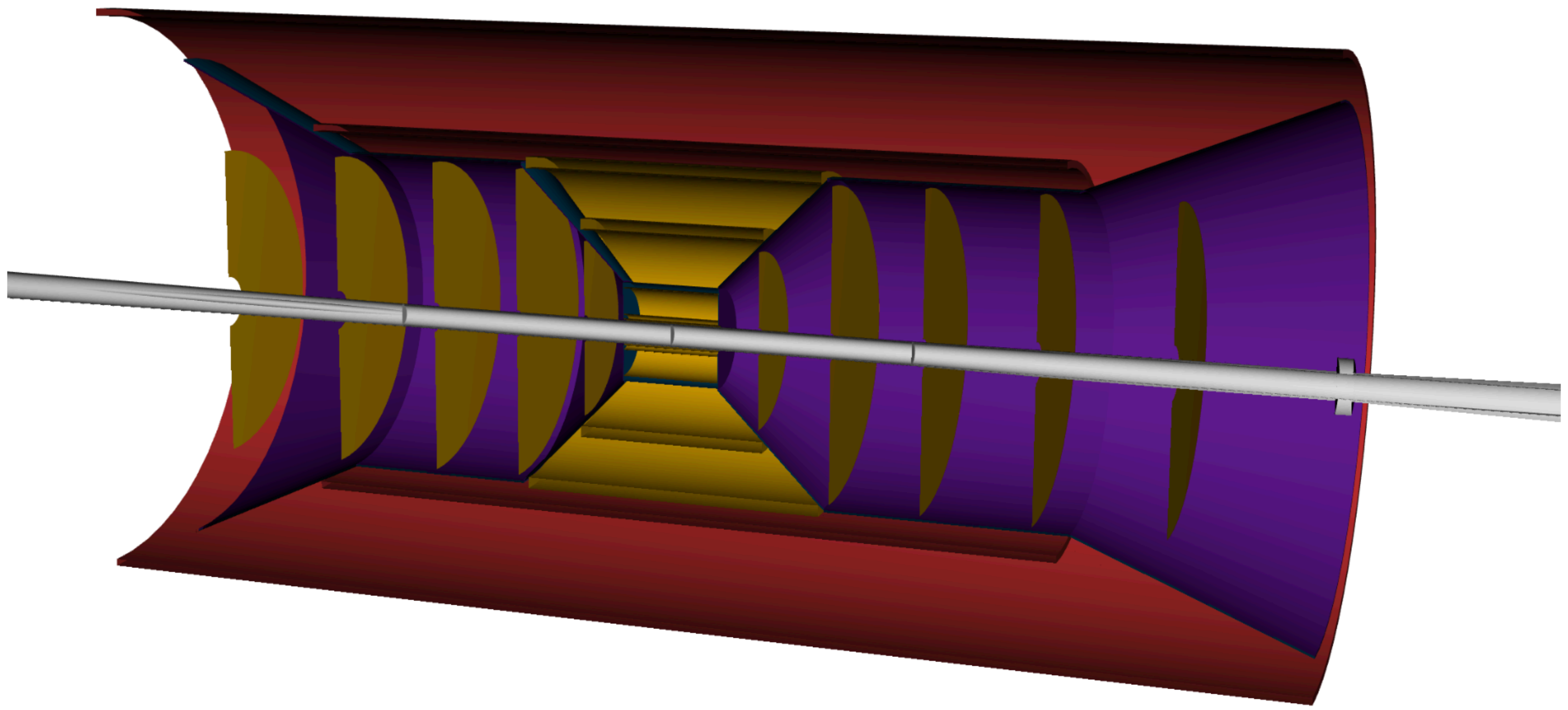
New envelopes as of September 29, c.f. https://eic.jlab.org/Geometry/Detector/Detector-20220929172703.html
- z_{min} = -1186 mm, z_{max} = 1800 mm, r_{out} = 600 mm

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.

October 2022 Geometry



Updated barrel reference geometry:

- 2 curved silicon vertex layers, r = 36, 48 mm, l = 270mm
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Updated disk reference geometry:

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The simulation implementation of the disks has a (near-) **circular** and **centered** beam openings that surround the beam pipes. They are **not** “minimal envelopes" around the beam-pipes. They are **not** based on the current understanding of sensor layout either. Addressing this before the March campaign would seem a decent goal, in my opinion. (Early insights can be gleaned e.g. from Stephen Maple’s work with alternative radii.)

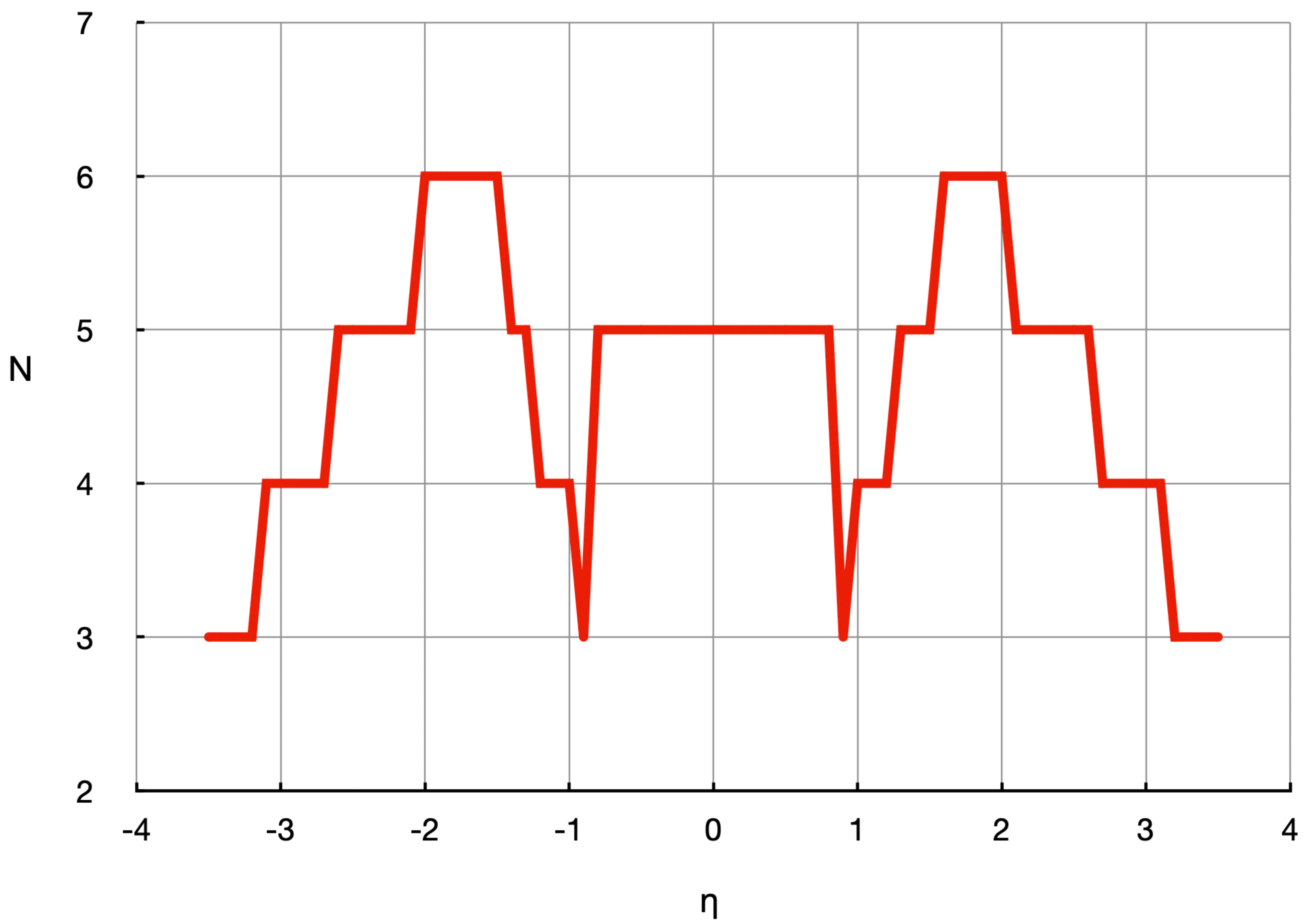
This limitation enters and affects studies, for example of low-Q^2 acceptance, that are now starting.

One can estimate the transverse momentum threshold for each of the detection layers “on the back of an envelope” form the (t)wiki geometry, p_T [GeV/c] > ~0.3 × 1.7 [T] × r [m] / 2. This implies a **total momentum threshold** of **p > ~0.35 GeV/c** to be within the acceptance of the outermost disks.

One can also to count the number of traversed layers, N, within the acceptance “on the back of that same envelope.” The acceptance of the innermost vertex layer is **$|\eta|$ < 2.0**. The inner radius of the innermost disks corresponds to **$|\eta|$ ~ 2.6**. With these arrays of five disks, one should not expect to traverse more than four detection layers for **$|\eta|$ > 2.6**. One should not expect to traverse more than three detection layers for **$|\eta|$ > 3.2**. One should not expect to track beyond **$|\eta|$ ~ 3.6** (in both directions) with this type of configuration.

There is not really a “free lunch” in disk placement; one way to think about this is that the inner and outer radii “couple” acceptance (outside of the cone region).

October 2022 Geometry



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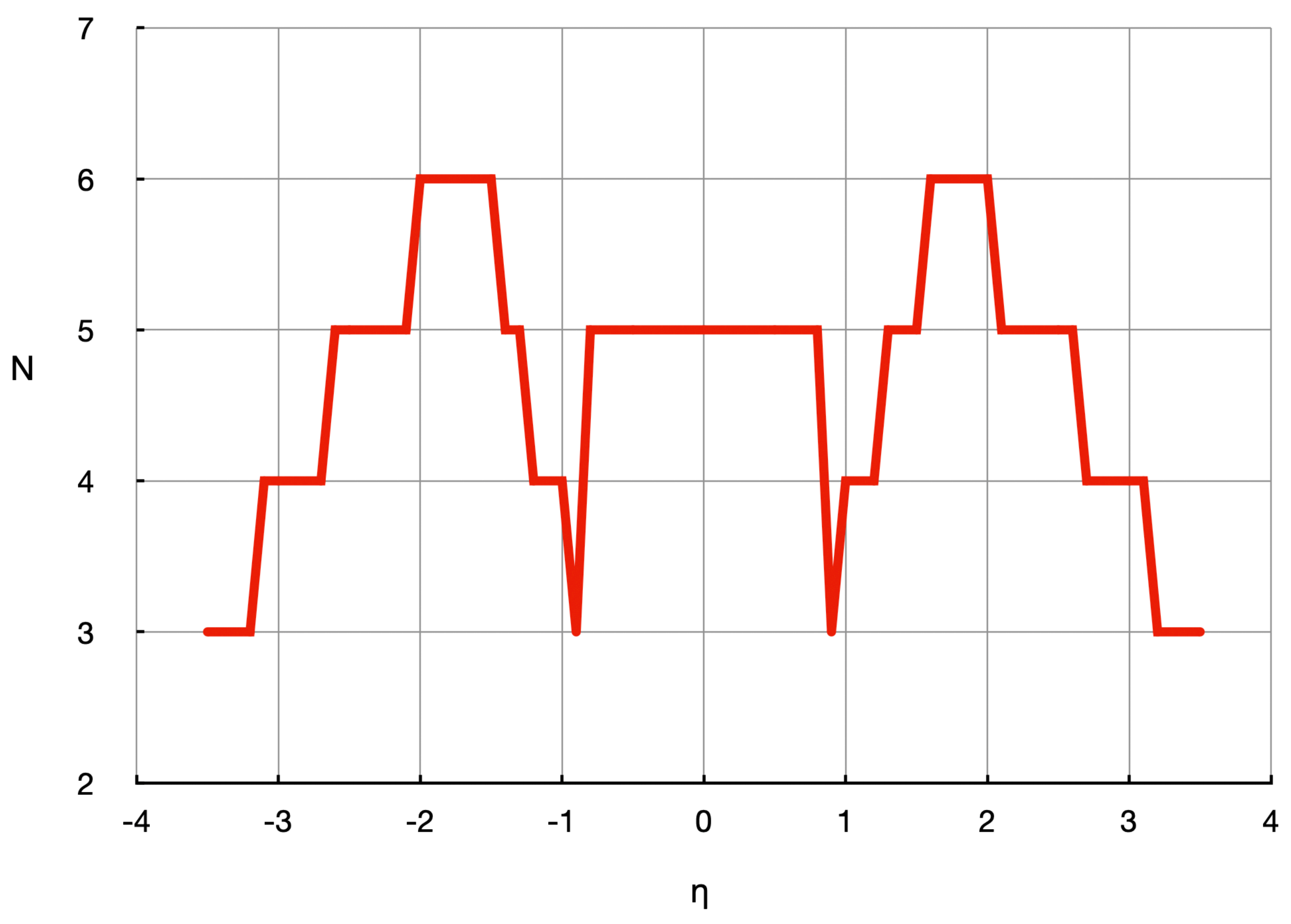
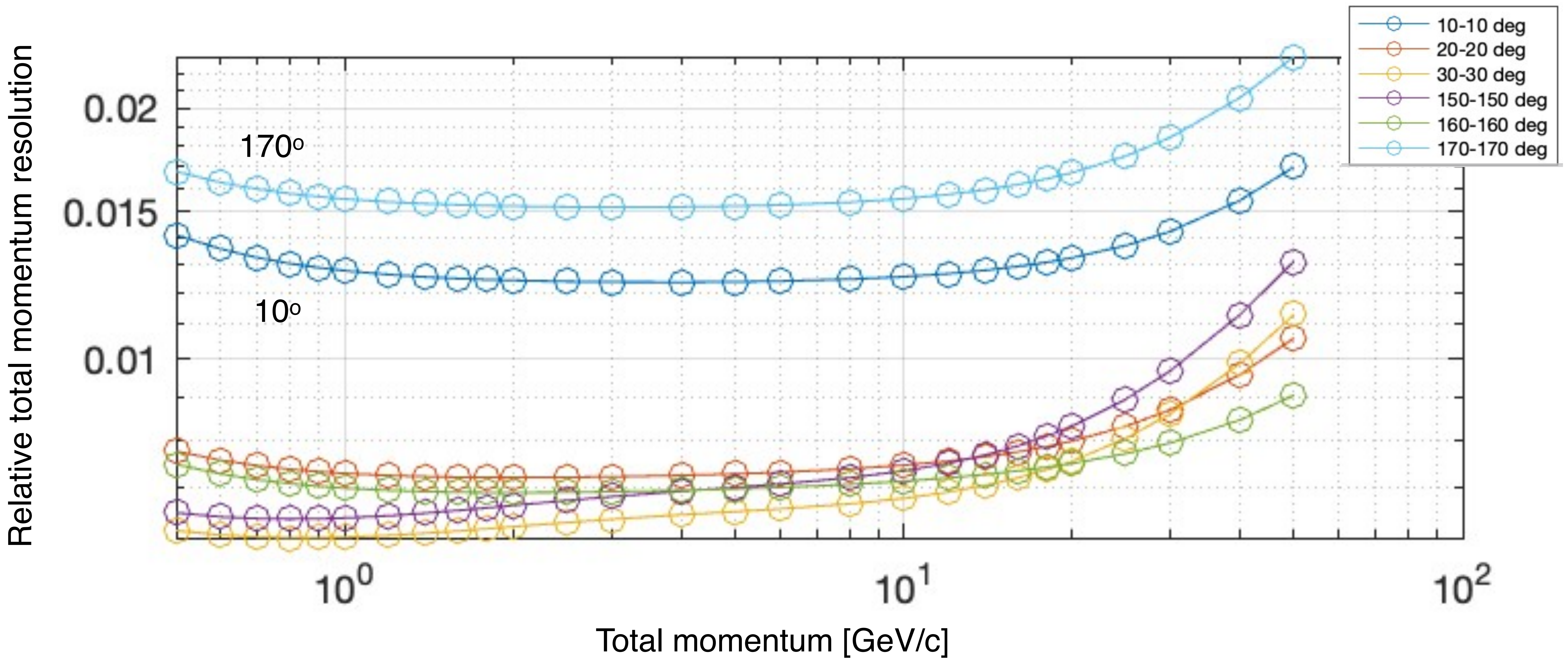
Hadron- and electron-arm Asymmetry

Since the -1150 < z < 1350 mm envelope is different, and the disk placements are not identical, the acceptance and resolution is not fully symmetric.

Momentum resolution does not scale as one might expect from the difference in L^2 - it is slower due multiple scattering and B field drop-off; in the fast simulation results below, multiple scattering is taken into account while the B field is constant at 1.7 T throughout the tracking volume.





The resolution curves here are simply for a fixed and equal momentum; it is both a bit wider and narrower than the phase space, depending on angle.

There are, indeed, some (perhaps) counter-intuitive effects with angle — angle and acceptance edges affect d*L* as well as N and traversed material.

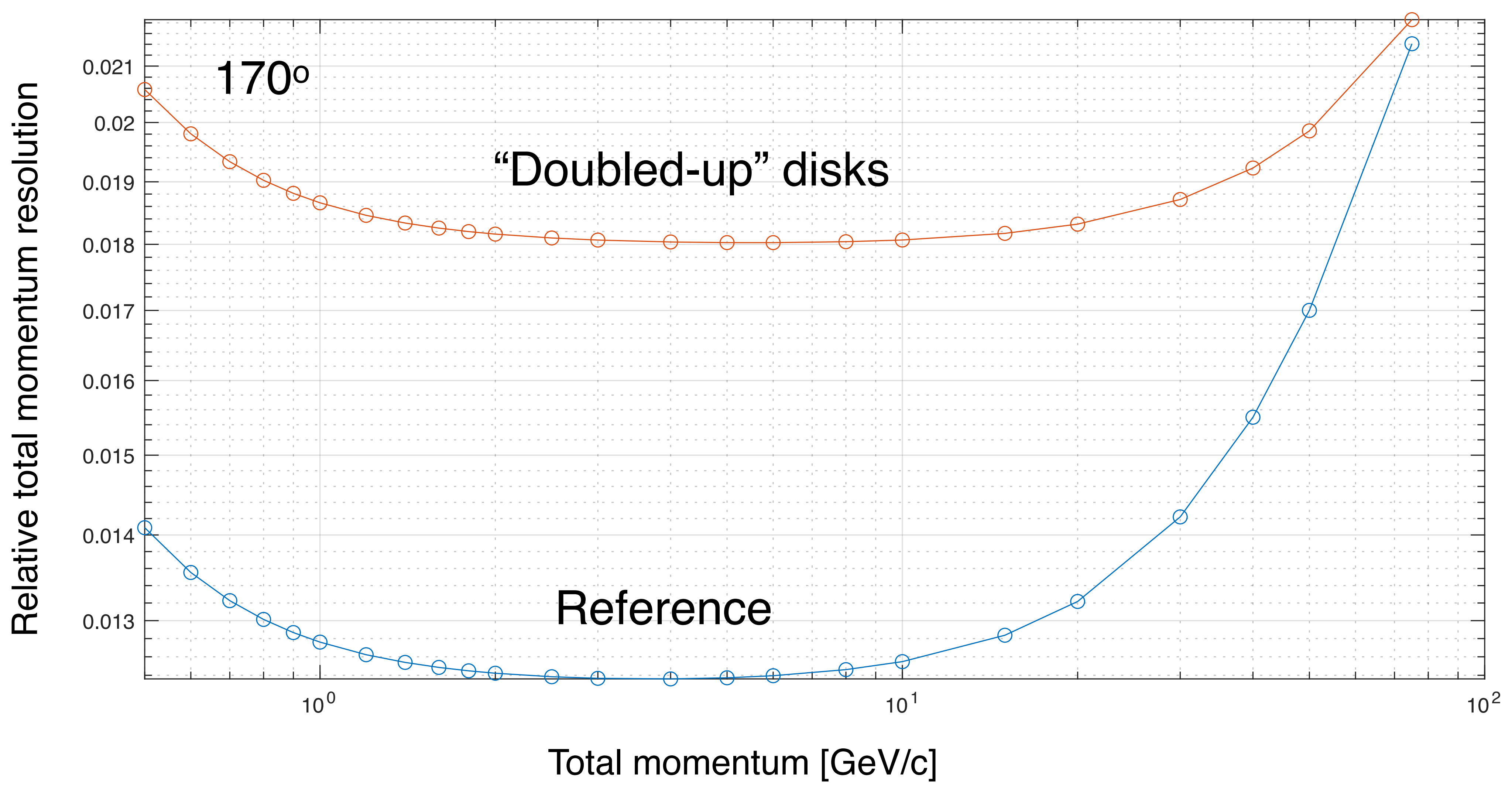
Who does not want more points?

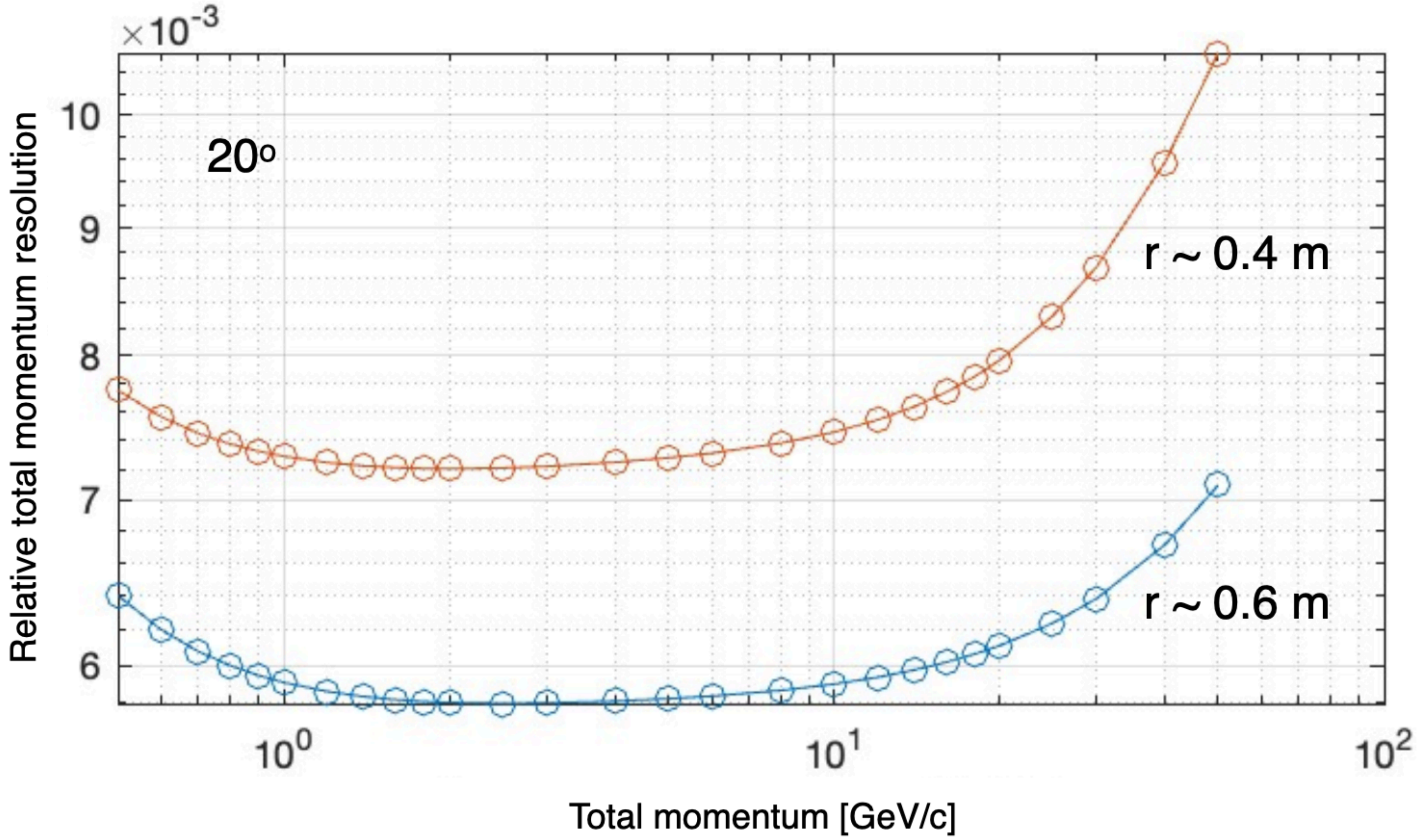
“Doubling-up” all disks would come with a track-resolution performance penalty, essentially over all of the available phase-space,

This is not a new insight; traversed material matters and often outweighs N for MAPS at EIC, Service load, cost, etc. are factors to consider as well, of course,

A more meaningful path *could* be to consider doubling the outermost disk and working inwards; track-finding cost-benefit analysis will need to come from full simulations (preferably after those are further along),

ATHENA considered a sixth disk in the hadron-going direction and found that beneficial,





I do not consider concerns of (low) N specific to the far-backward or far-forward region,

Since ePIC is not (yet?) using the radial space 0.4 < r < 0.6 all that productively, in my opinion, one *could* consider *if* increasing disk radii is beneficial,

All else being equal — a spherical cow in vacuum — this will improve resolutions and acceptance e.g. in the SIDIS region,

All-else-being equal — that is, hypothetical — performance is illustrated in the figure on the left for the two outer disk radii as indicated,

Of course, not all else will be equal. Service load will obviously increase, although some of it will be with better projectivity. Resolution penalty from probable increase in material will, at least in parts, be compensated by gain from acceptance.

Increase in area would be about 3m^2 or 30%, Costs do *not* scale in area, but if we decide to pursue this path further, then it will obviously (need to) be paired with a cost model.