Development of an Integrated Tracking Layout (for ePIC)

Matt Posik (Temple U.) — posik@temple.edu
Ernst Sichtermann (LBNL) - epsichtermann@lbl.gov

ePIC Collaboration Meetting
Faculty of Physics, University of Warsaw
Warsaw, Poland — July 26, 2023

Based on work by many, over extended periods

ePIC tracking working group conveners prior to May 2023: Francesco Bossi (CEA-Saclay), Kondo Gnanvo (JLab), Laura Gonella (University of Birmingham), Xuan Li (LANL)

MPGD, ToF, and SVT Detector Subsystem Collaborations; TIC

EIC Project: Elke Aschenauer, Roland Wimmer, …

Software working groups; track reconstruction working group, background task force

ACTS external colleagues: Andreas Salzburger, Xiaocong Ai, Corentin Allaire, Paul Gessinger, …

Many (early-career) colleagues; Kolja Kauder (BNL), Shyam Kumar (INFN), Shujie Li (LBNL), Beatrice Liang-Gilman (UCB), Stephen Maple (University of Birmingham), Joe Osborn (BNL), Dmitry Romanov (JLab), Nicolas Schmidt (ORNL), Barak Schmookler (UCR), Rey Cruz-Torres (LBNL), Emma Yeats (UCB), …

Ample opportunities to get involved — https://indico.bnl.gov/category/404/

Context

- EIC Yellow Report (YR), Nucl. Phys. A 1026 (2022) 122447 sets the initial goals and requirements,

- Detector Proposals, in particular the ECCE proposal that was selected as the project reference,

- My take on the overall approach,
    - Silicon Vertex Tracker (SVT) forms the core of the tracker
    - SVT drives most of the resolutions at the collision vertex; charged particle momentum resolutions, angular resolutions, (displaced) vertex resolutions
    - Outer tracker provides fast points for pattern recognition, time in time-of-flight, and aids tracking into the PID subsystems

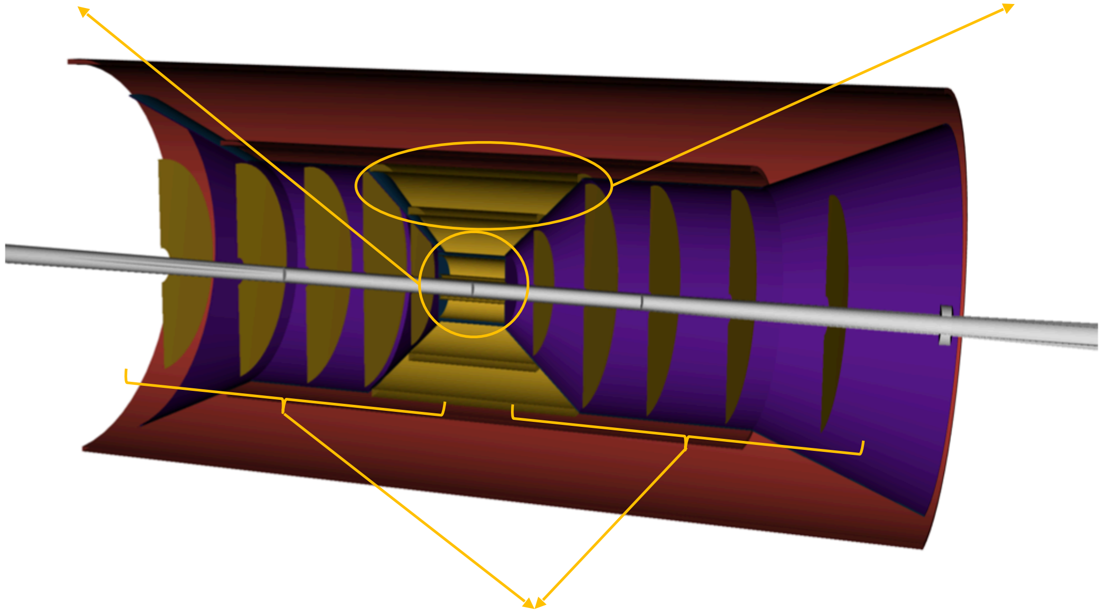
- By the January 2023 ePIC Collaboration Meeting, the reference tracker had been revised:
    - New solenoid magnet provides a 1.7 T baseline field,
    - SVT barrel redone to achieve YR resolutions,
    - SVT forward disk array reconfigured to achieve YR resolutions,
    - SVT backward disk array extended to increase acceptance and optimize resolutions,

- A few important changes external to the tracking subsystem since January 2023:
    - Innermost imaging layer of the BEMC adds a track point behind the DIRC,
    - Backward PID now known; minor effect on backward envelope for tracking,

SVT

Inner Barrel (IB)
- 2 curved silicon vertex layers
- 1 curved dual-purpose layer

Outer Barrel (OB)
- 1 stave-based sagitta layer
- 1 stave-based outer layer



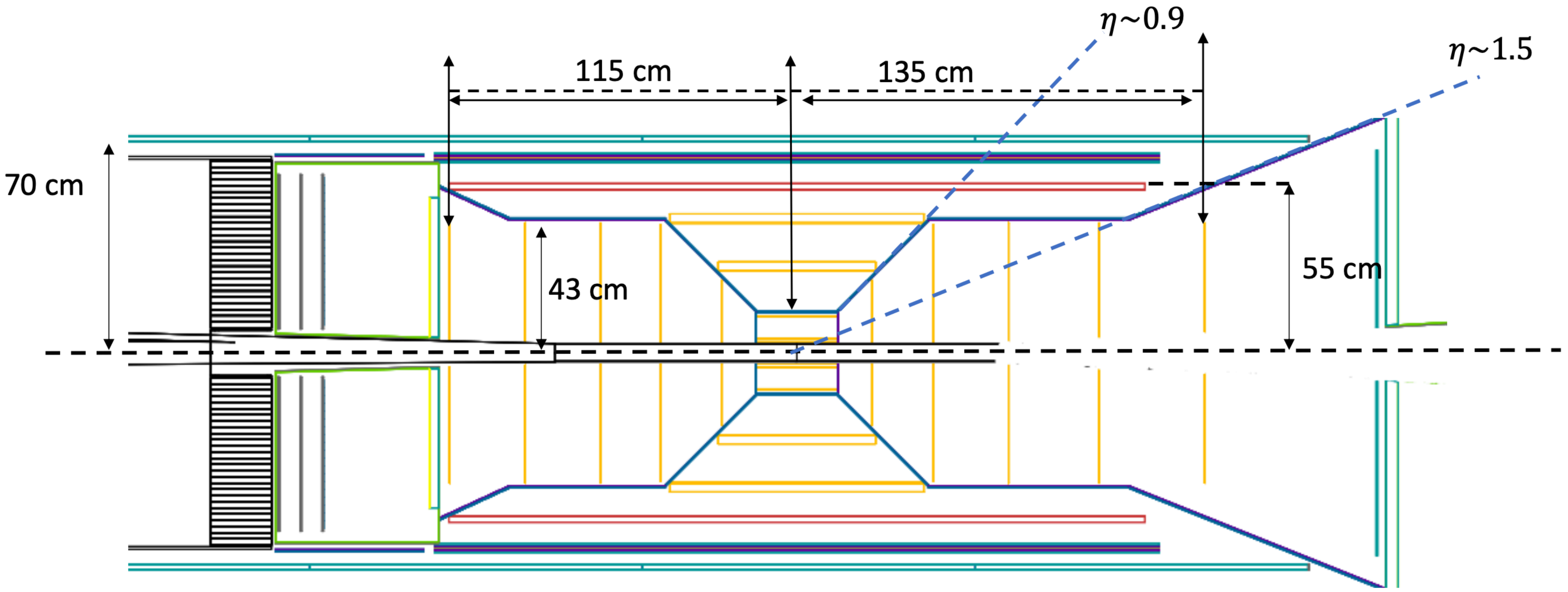
Electron/Hadron Endcaps (EE, HE)
- 5 disks on either side of the IP

Total (active) area ~ 8.5 m²

Extensively studied, for example as part of the so-called “Brycecanyon” simulation configuration — note, Brycecanyon predates the reconfiguration of the *outer* tracker

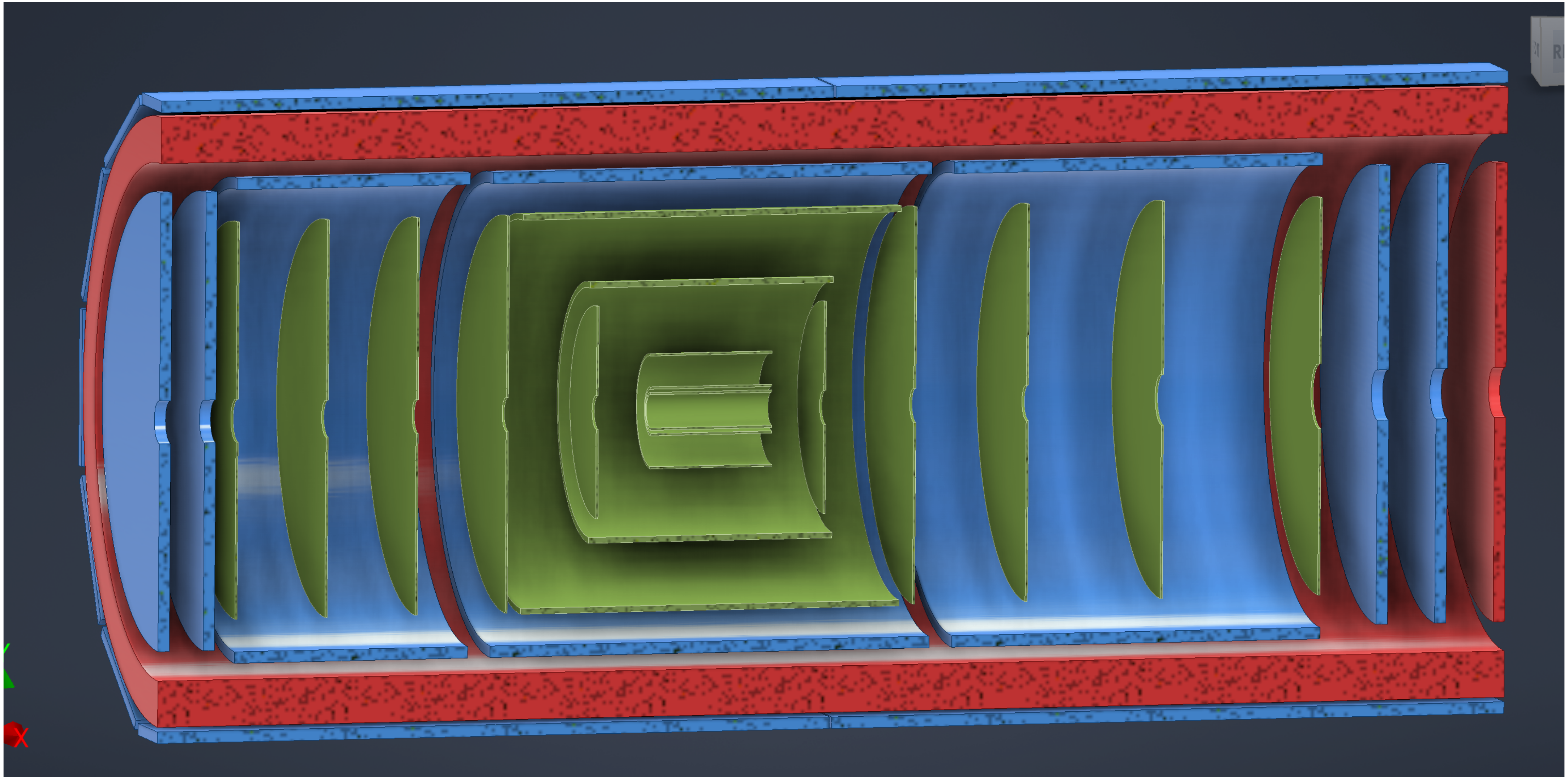
Laura Gonella’s talk tomorrow (Thursday) morning has a wealth on the SVT technical aspects and development.

SVT - “Brycecanyon” geometrical configuration



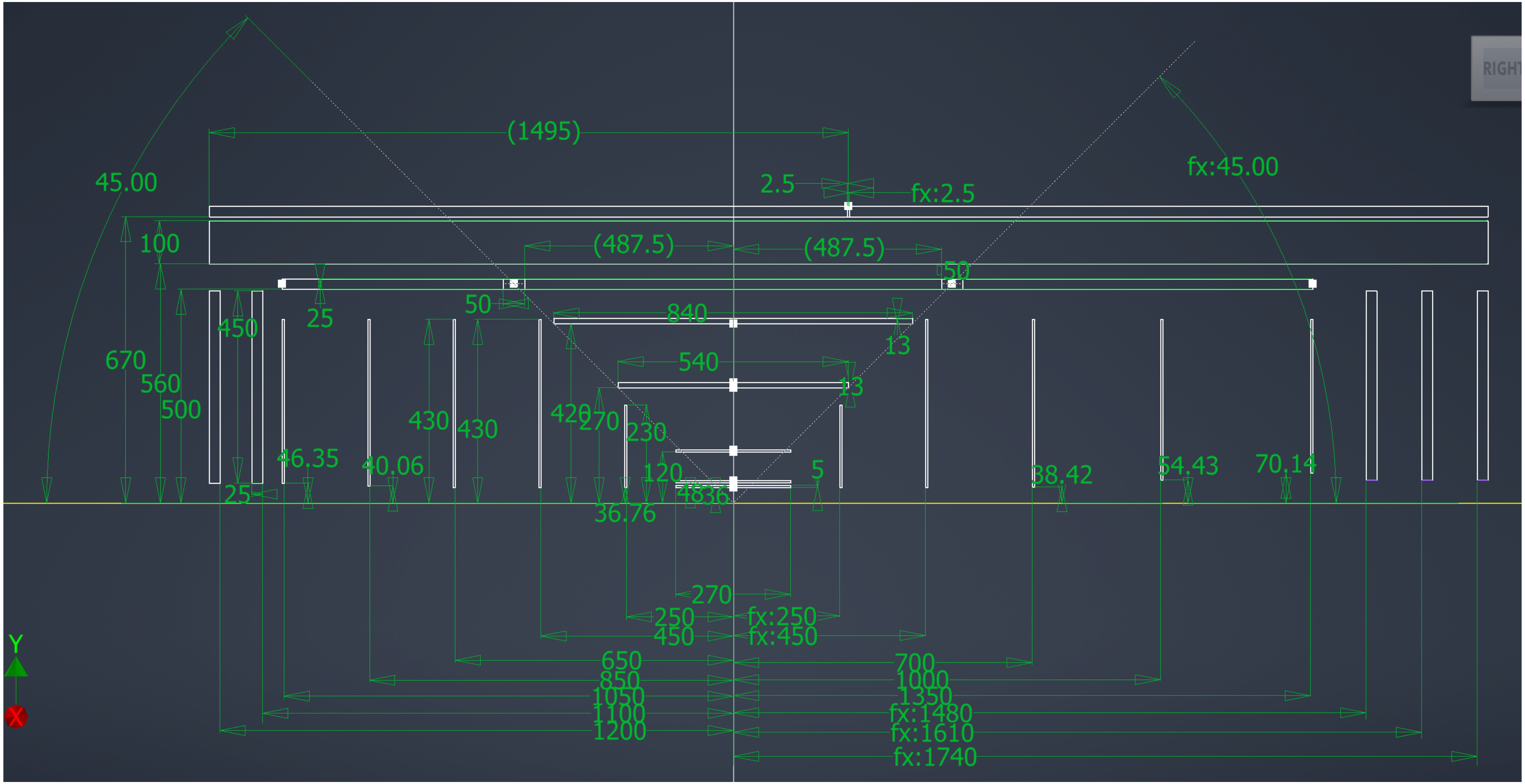
Key remaining question was about outer (MPGD) tracker configuration; several variants considered.
Time-of-flight barrel and forward endcap carried forward from reference.

MPGD configuration going forward — "Craterlake" in simulations

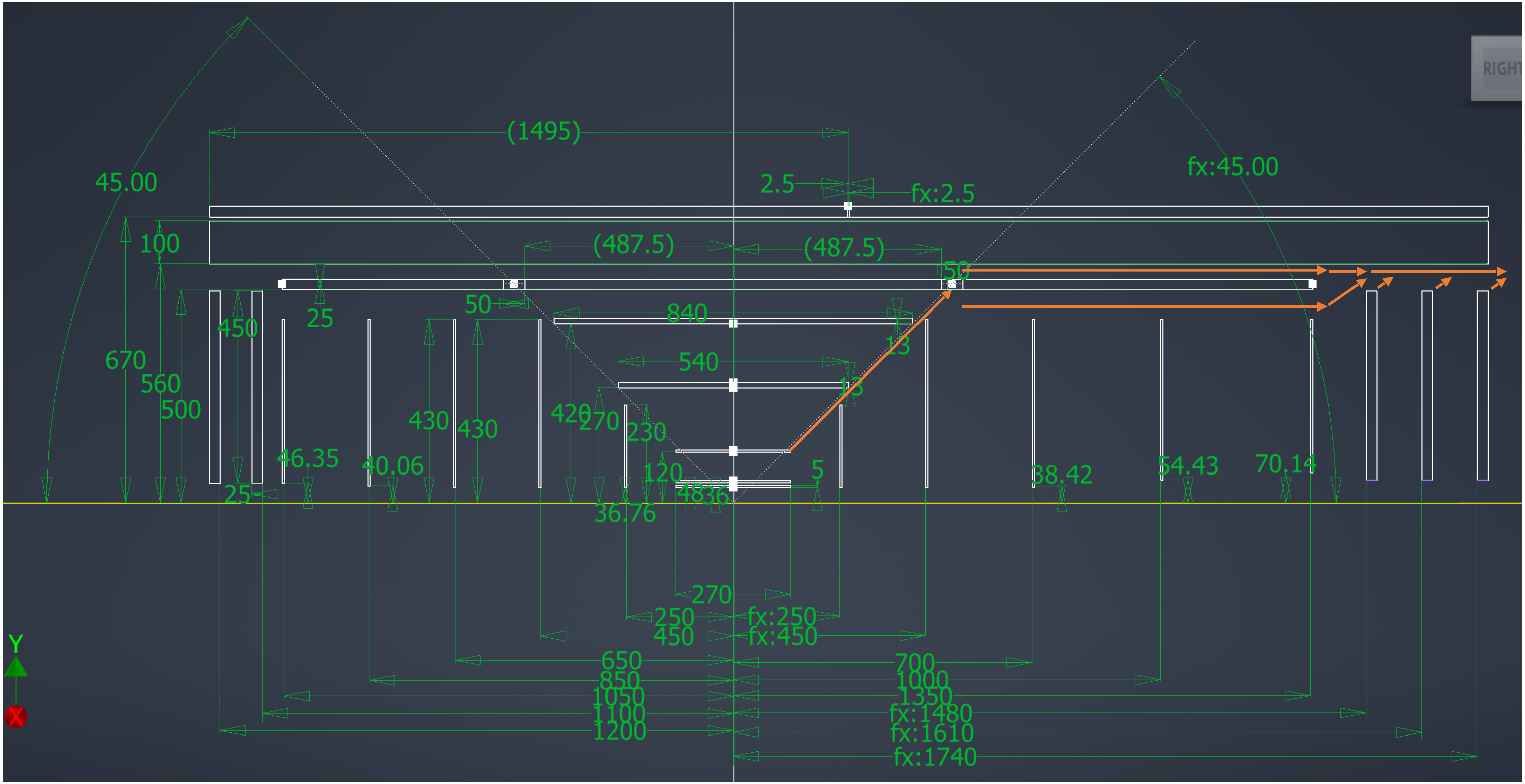


SVT MPGDs ToF (fiducial volume)

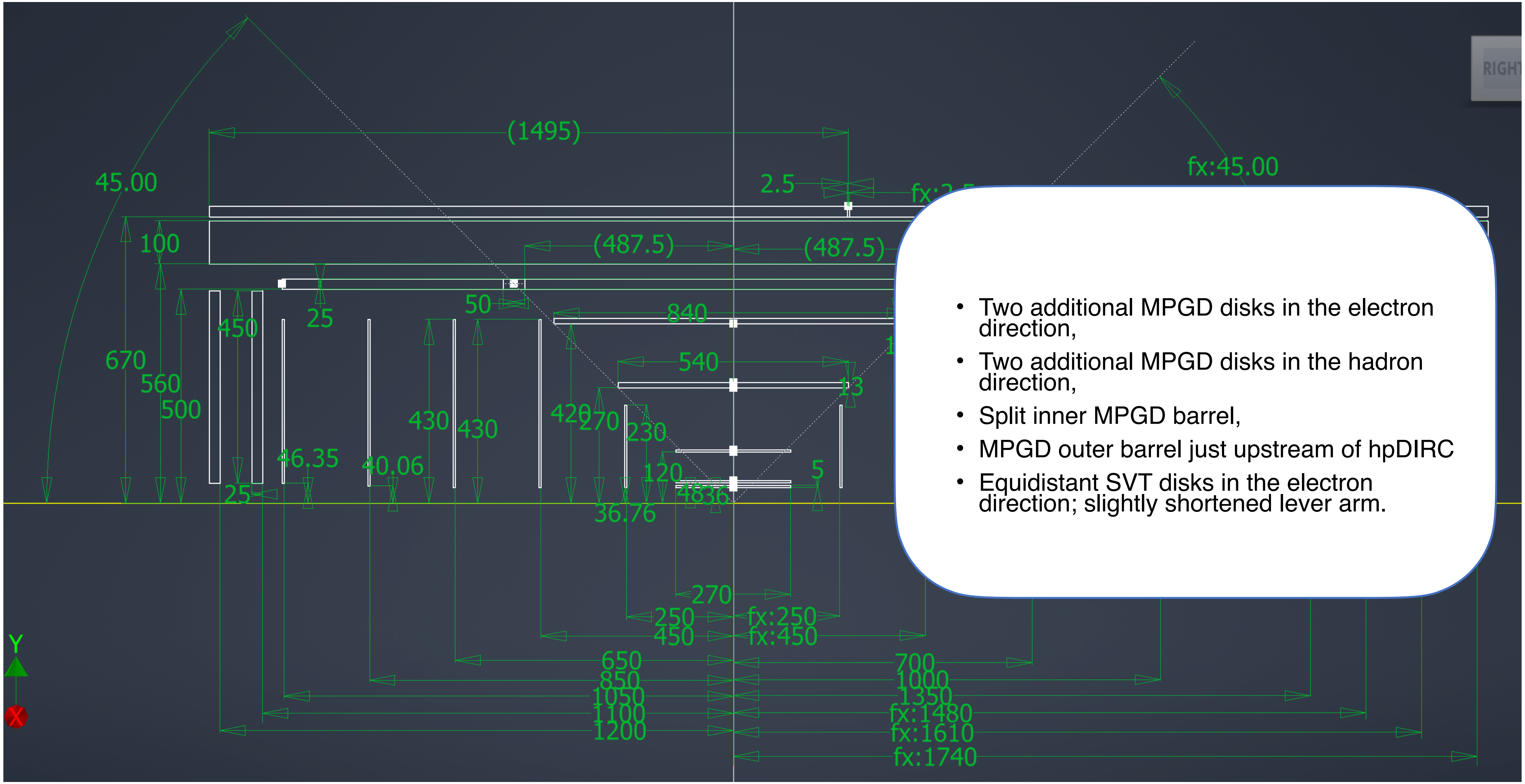
Tracking Layout



ePIC Tracking Layout — Service Routing

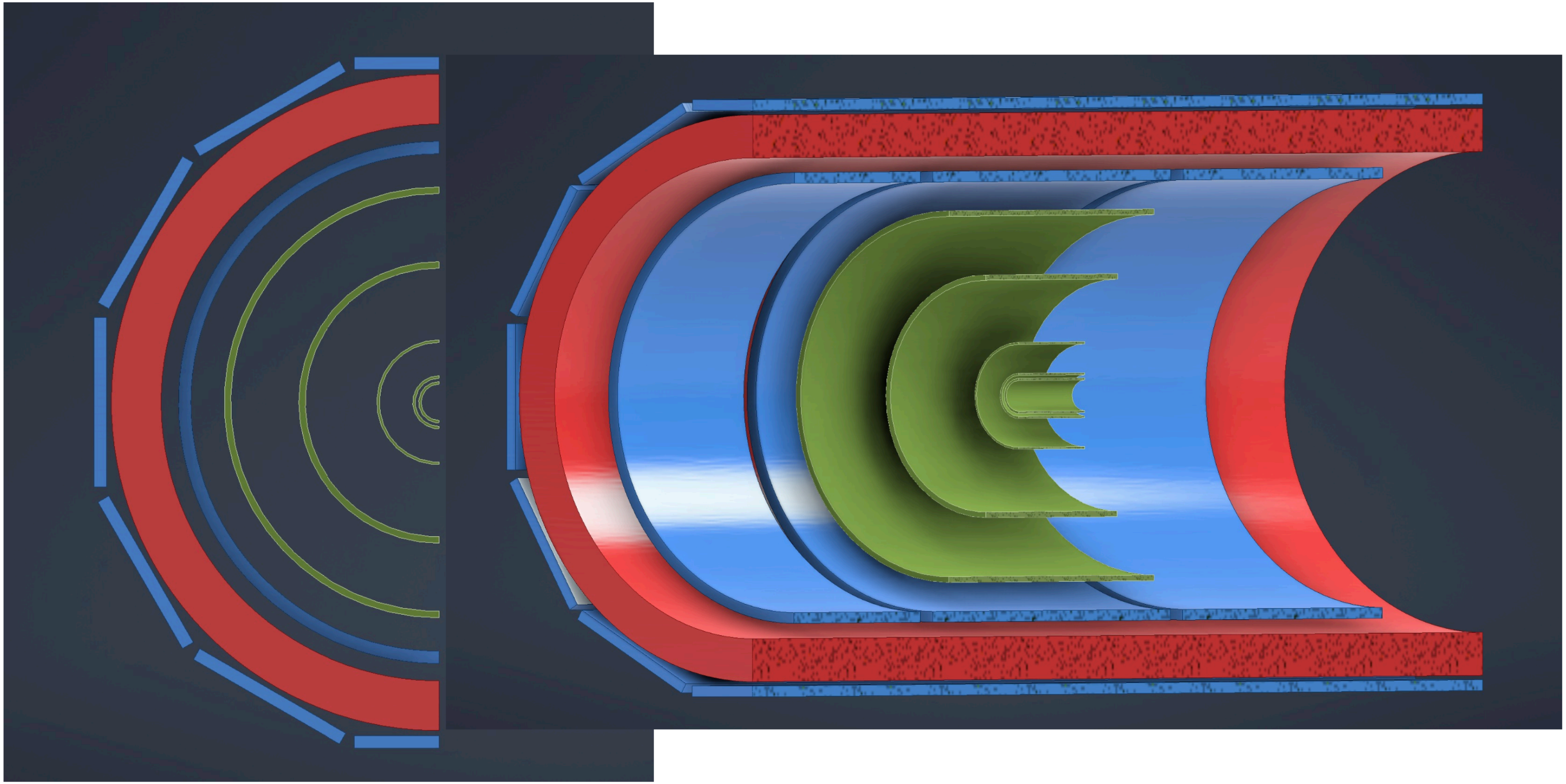


Tracking Layout



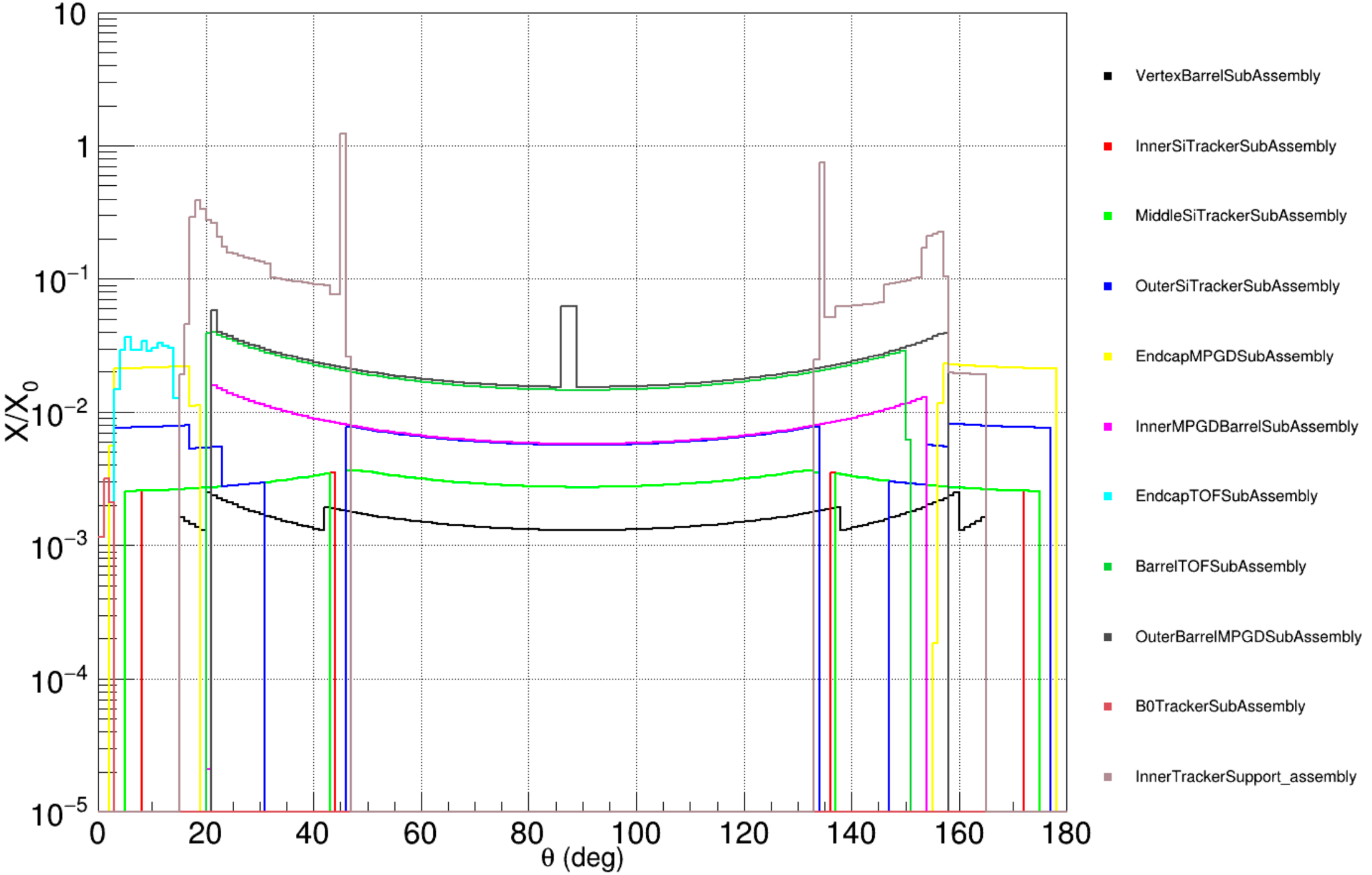
- Two additional MPGD disks in the electron direction,
- Two additional MPGD disks in the hadron direction,
- Split inner MPGD barrel,
- MPGD outer barrel just upstream of hpDIRC
- Equidistant SVT disks in the electron direction; slightly shortened lever arm.

ePIC Tracking Layout



Intense effort to achieve readiness for the July simulation campaign,
Cannot stress enough that this is/was the work of many — thanks to this work, we have initial results!

Tracker Material



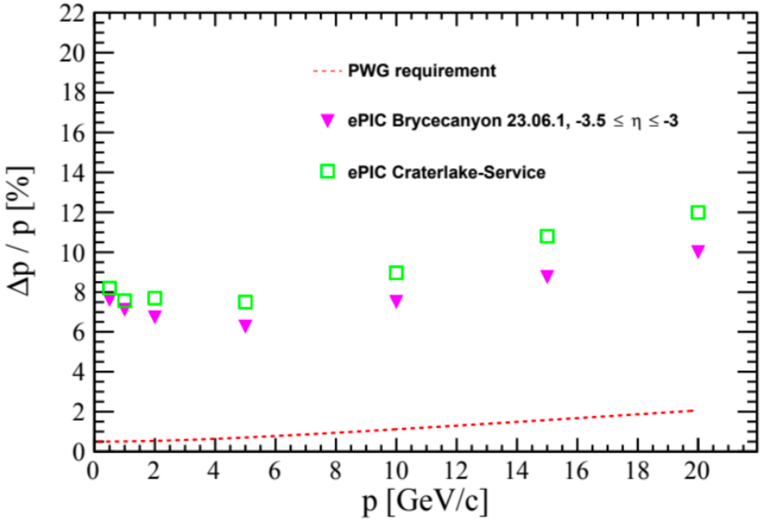
- A very busy figure, indeed!

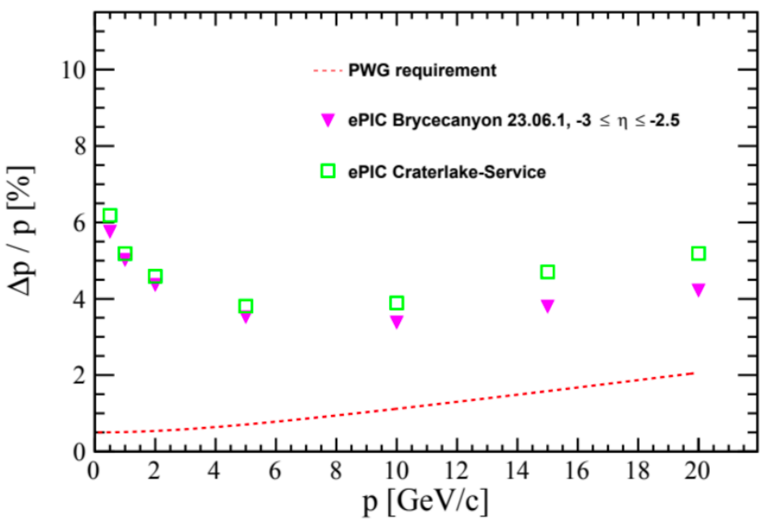
Two main/gross features:

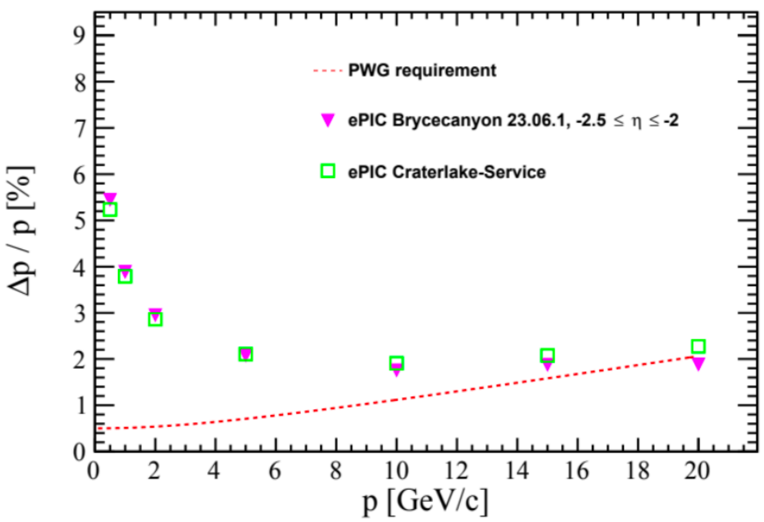
- Minimal material in the active areas of the SVT,
- ~10% service material.

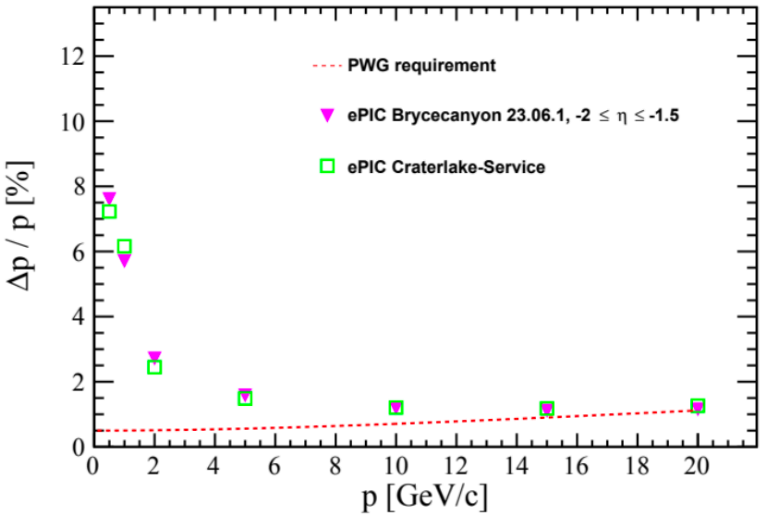
Courtesy Shyam Kumar (INFN Bari)

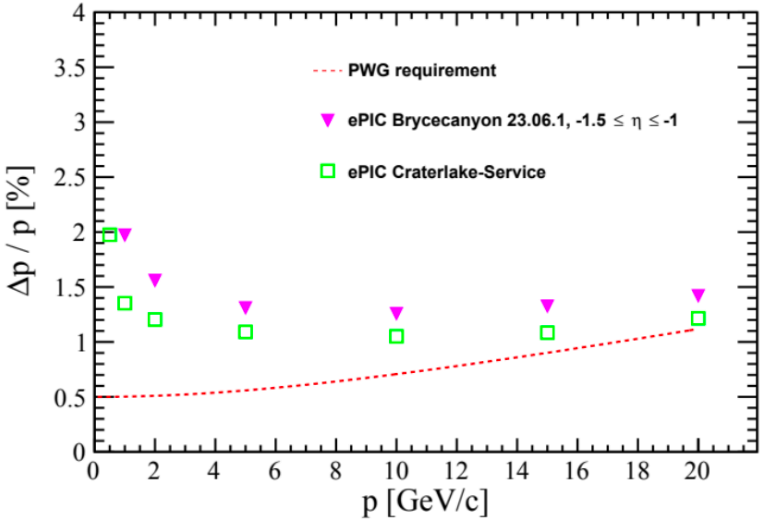
ePIC momentum resolution — backward region







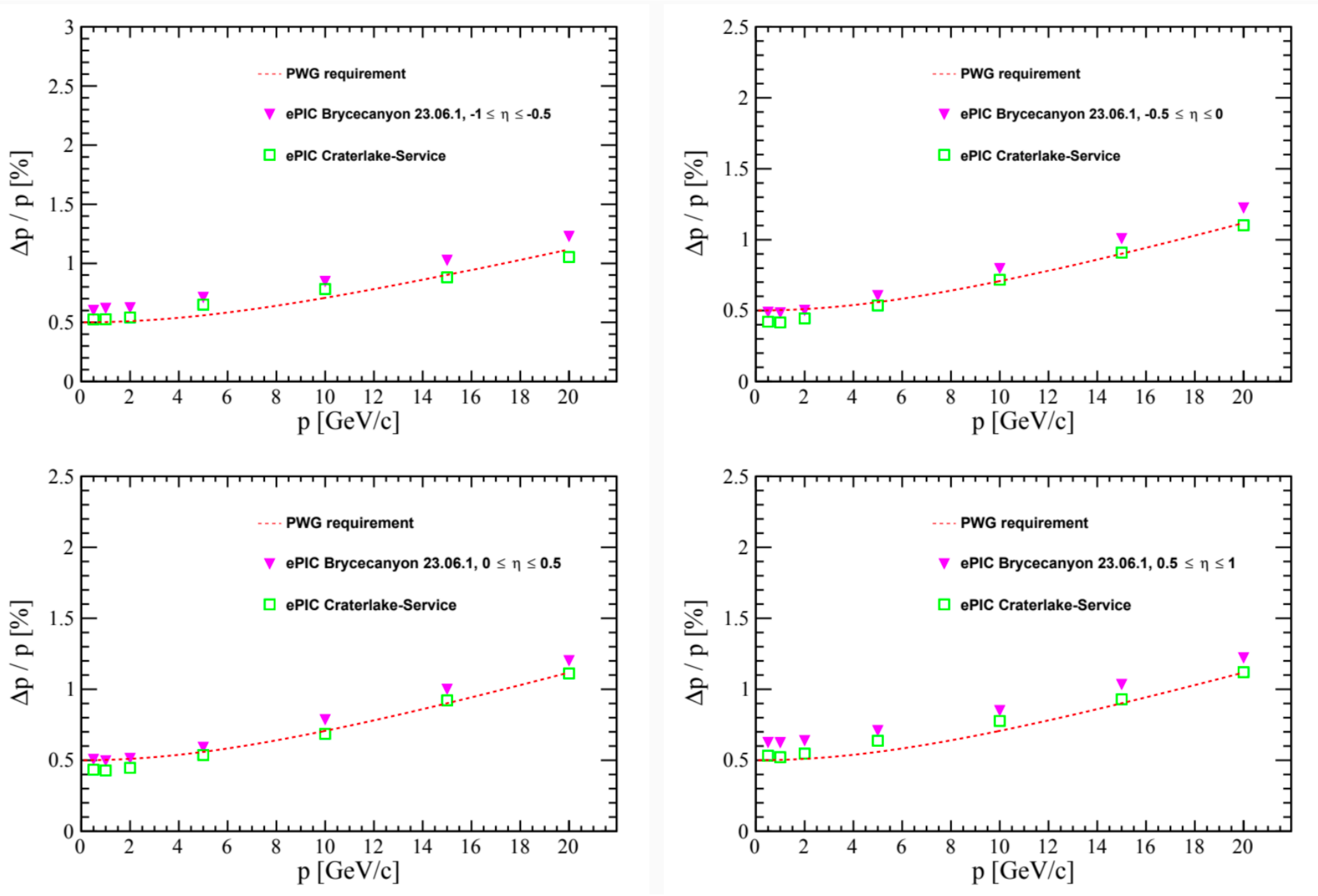




- Overall correspondence between “Brycecanyon” and “Craterlake”
- Slightly worse “Craterlake” performance originates in slightly reduced SVT lever arm (no, it does *not* scale like L^2)
- YR performance is a challenge in this region.

Courtesy Stephen Maple (University of Birmingham)

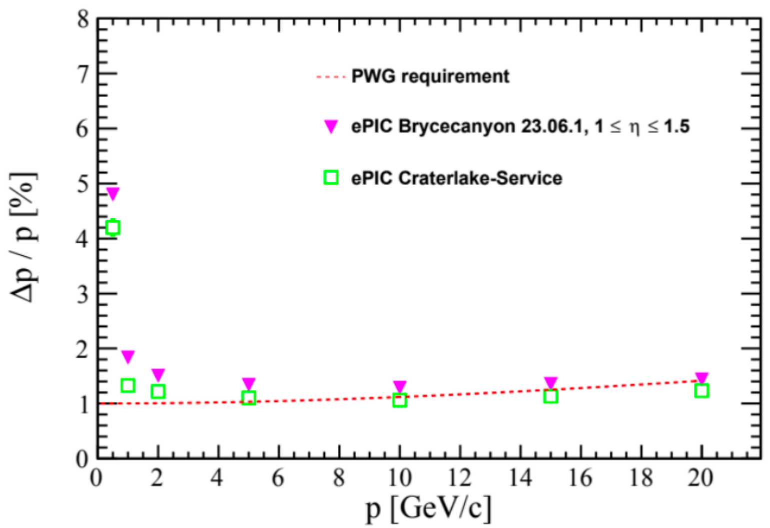
momentum resolution — central region

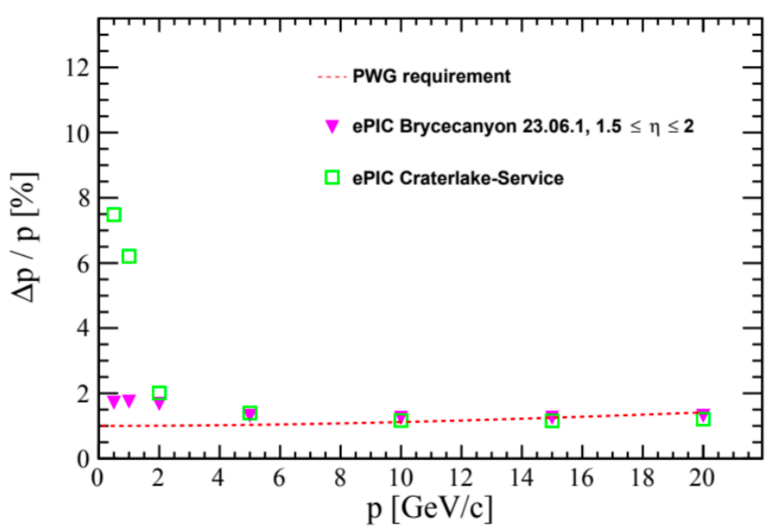


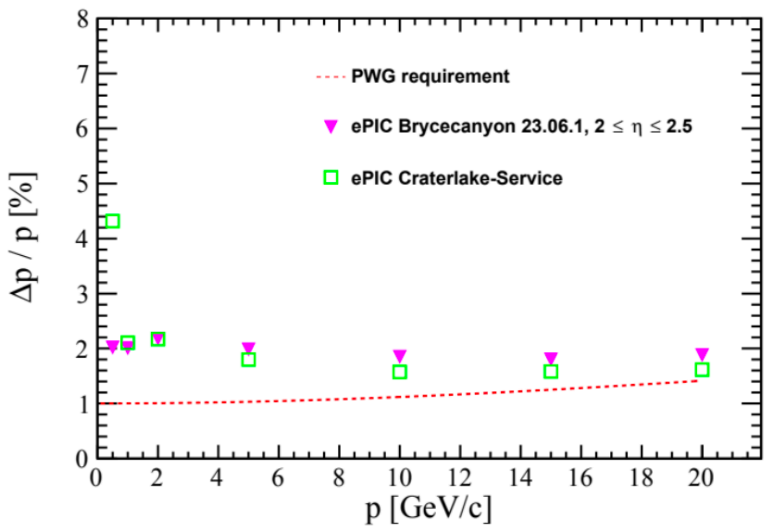
- Overall correspondence between "Brycecanyon" and "Craterlake"
- Slightly better "Craterlake" performance has its origins in differences in the material description (budget),
- YR performance is achievable.

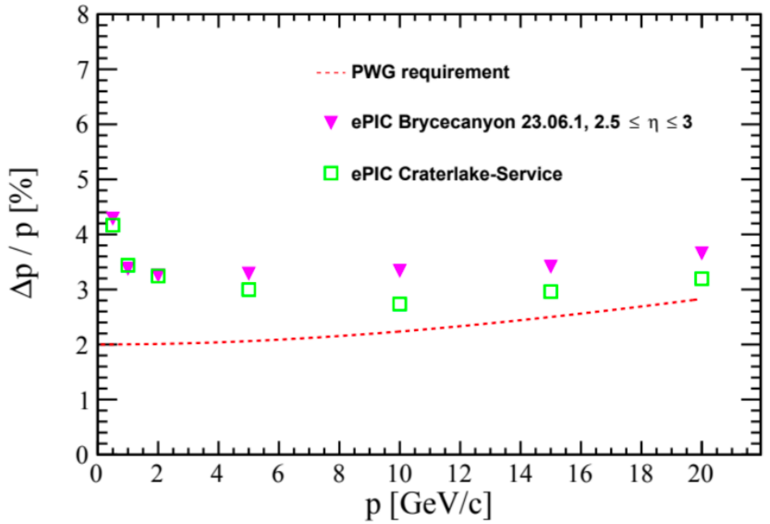
Courtesy Stephen Maple (University of Birmingham)

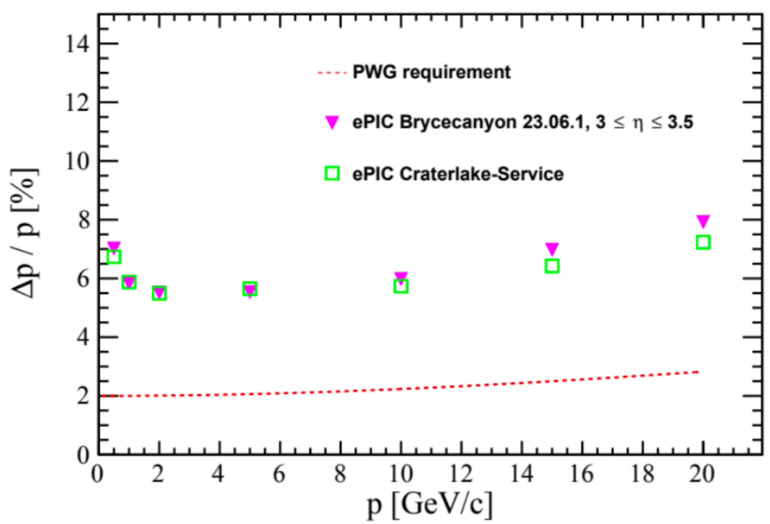
ePIC momentum resolution — forward region







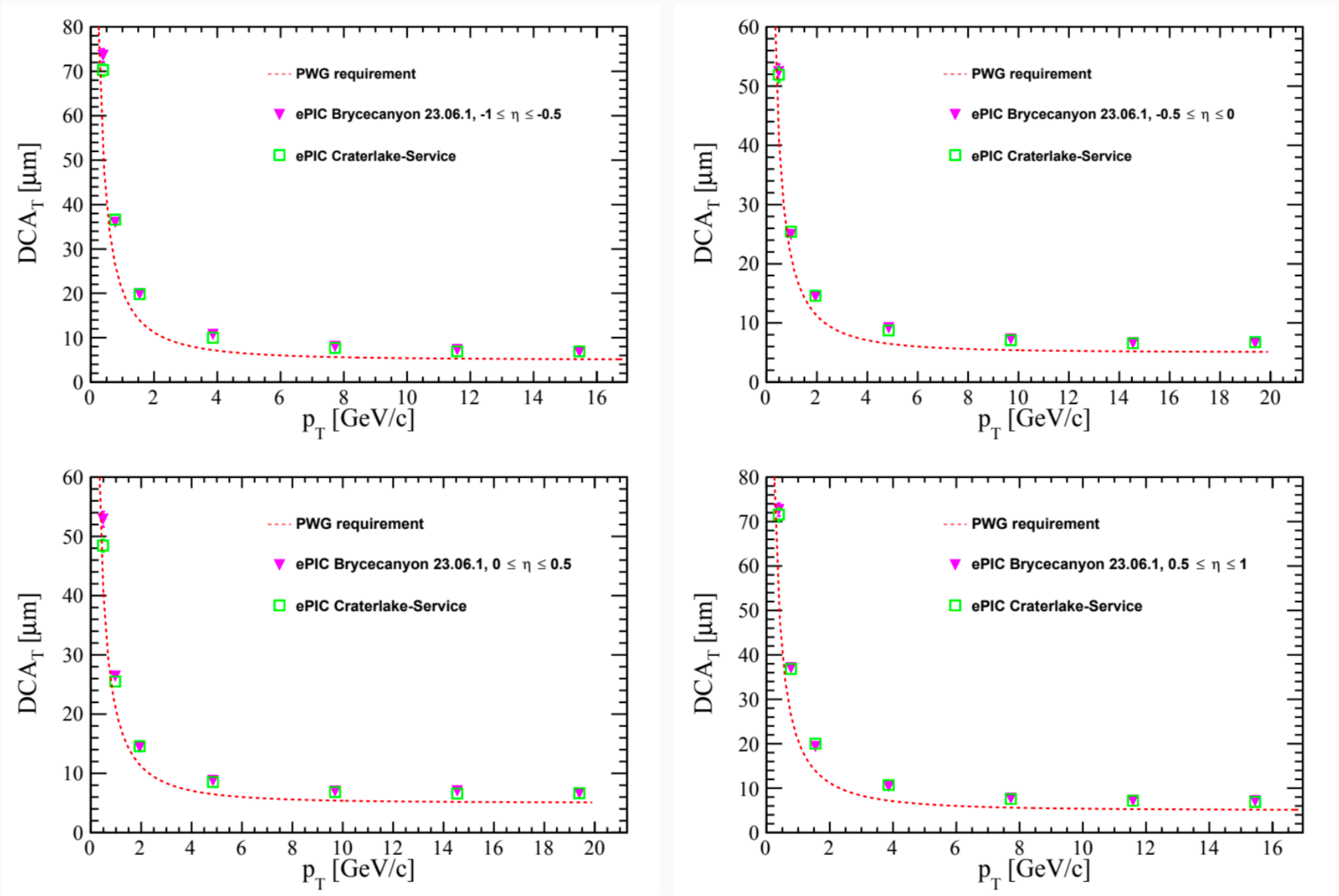




- Overall correspondence between “Brycecanyon” and “Craterlake”
- Additional lever-arm with MPGD in the hadron direction has a modest, beneficial effect,
- YR performance within reach over a fair range.

Courtesy Stephen Maple (University of Birmingham)

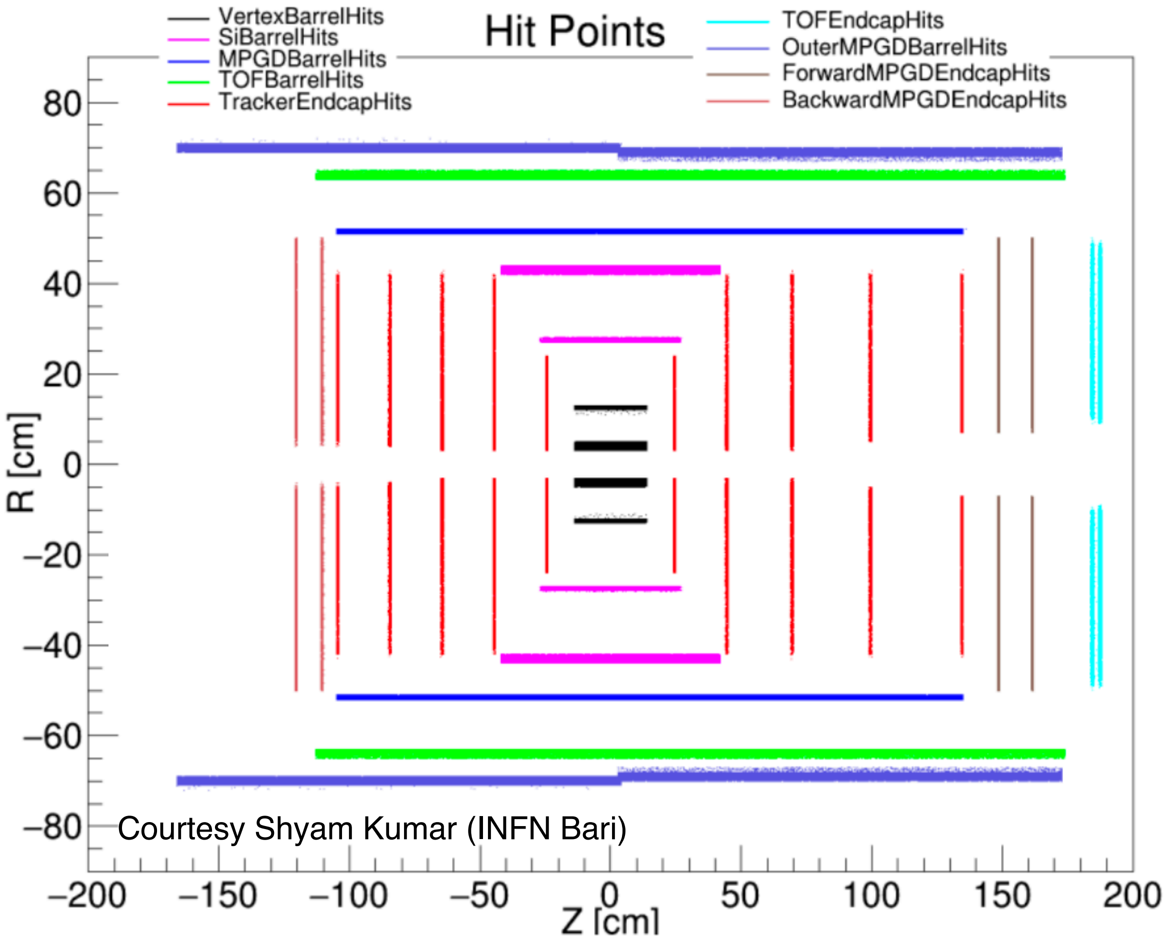
DCA resolution — central region



- Overall correspondence between “Brycecanyon” and “Craterlake”
- Performance driven by innermost barrel vertex layers,
- YR performance within reach; currently dominated/ limited by extrapolation through the beam-pipe,

Courtesy Stephen Maple (University of Birmingham)

Hit Points and Track Finding



Courtesy Shyam Kumar (INFN Bari)

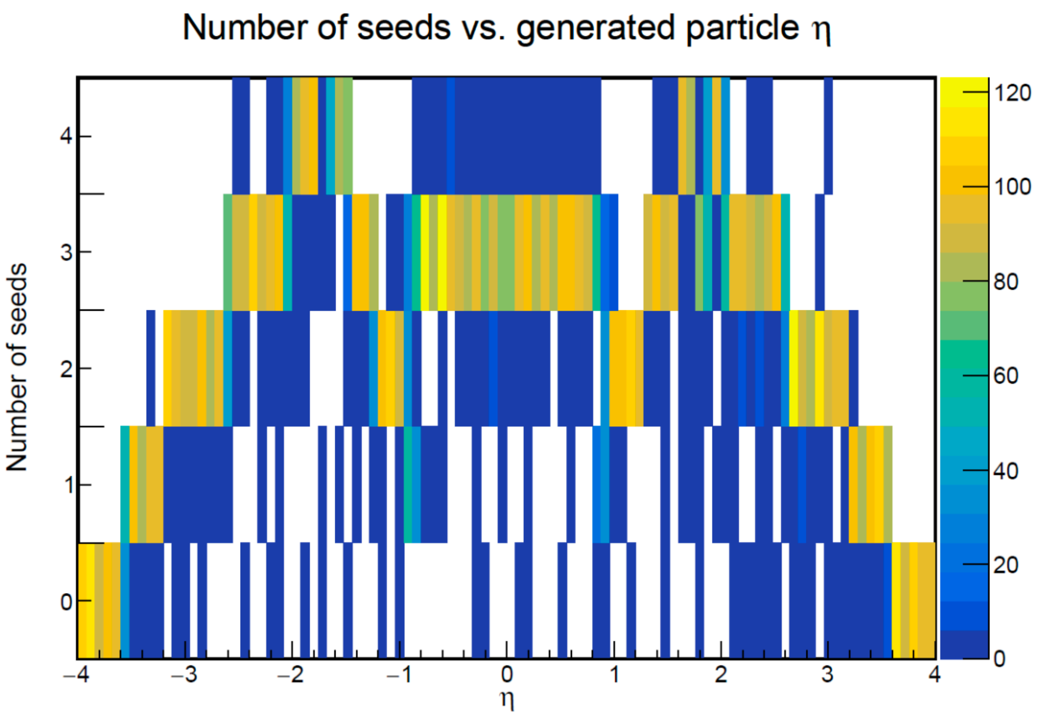
ACTS seed finder and filter parameters

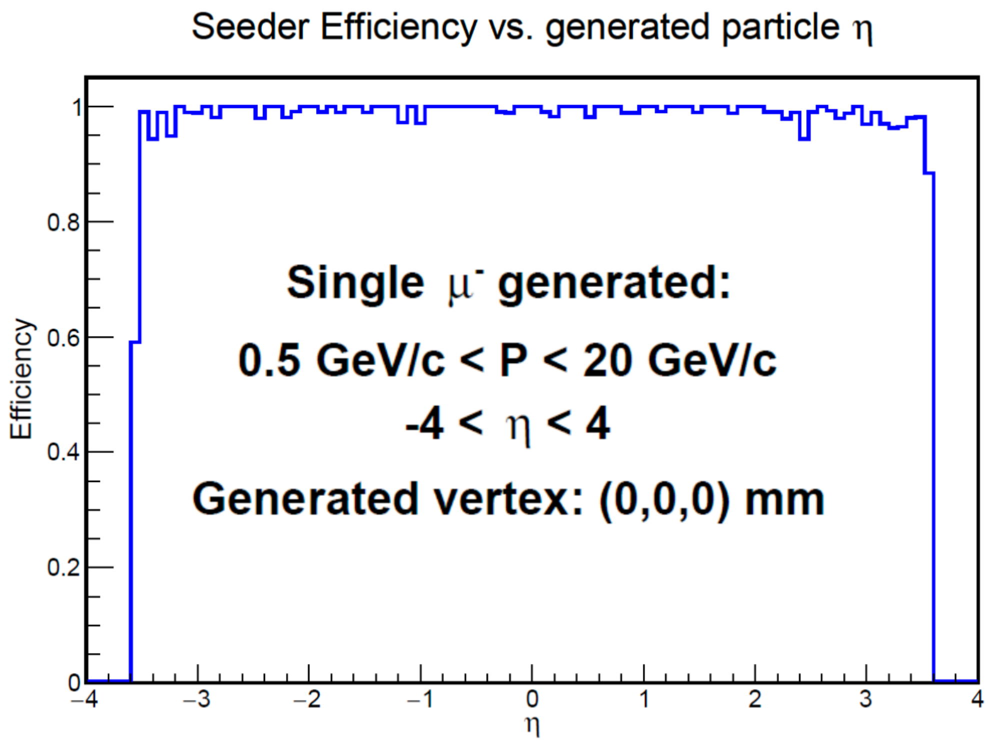
Parameter	Description	Value
bFieldInZ	z component of magnetic field	1.7 T
rMax	Maximum r value to look for seeds	440 mm
rMin	Minimum r value to look for seeds	33 mm
zMin	Minimum z value to look for seeds	-1500 mm
zMax	Maximum z value to look for seeds	1700 mm
beamPosX	Beam offset in x	0
beamPosY	Beam offset in y	0
deltaRMinTopSP	Min distance in r between middle and top SP in one seed	**10 mm**
deltaRMinBottomSP	Min distance in r between middle and bottom SP in one seed	**10 mm**
deltaRMaxTopSP	Max distance in r between middle and top SP in one seed	**200 mm**
deltaRMaxBottomSP	Max distance in r between middle and top SP in one seed	**200 mm**
collisionRegionMin	Min z for primary vertex	-250 mm
collisionRegionMax	Max z for primary vertex	250 mm
cotThetaMax	Cotangent of max theta angle	**27.29**
minPt	Min transverse momentum	100 MeV/cotThetaMax
maxSeedsPerSpM	Max number of seeds a single middle space point can belong to - 1	0
sigmaScattering	How many standard devs of scattering angles to consider	5
radLengthPerSeed	Average radiation lengths of material on the length of a seed	0.1
impactMax	Max transverse PCA allowed	3 mm
rMinMiddle	Min R for middle space point	20 mm
rMaxMiddle	Max R for middle space point	400 mm
bFieldMin	min B field	0.1

Joe Osborn (BNL), Rey Cruz-Torres (LBL), Barak Schmookler (UCR), Emma Yeats (UCB)

Not all outer hits are used yet, for example, hits in the BEMC innermost imaging layer are not yet in tracking

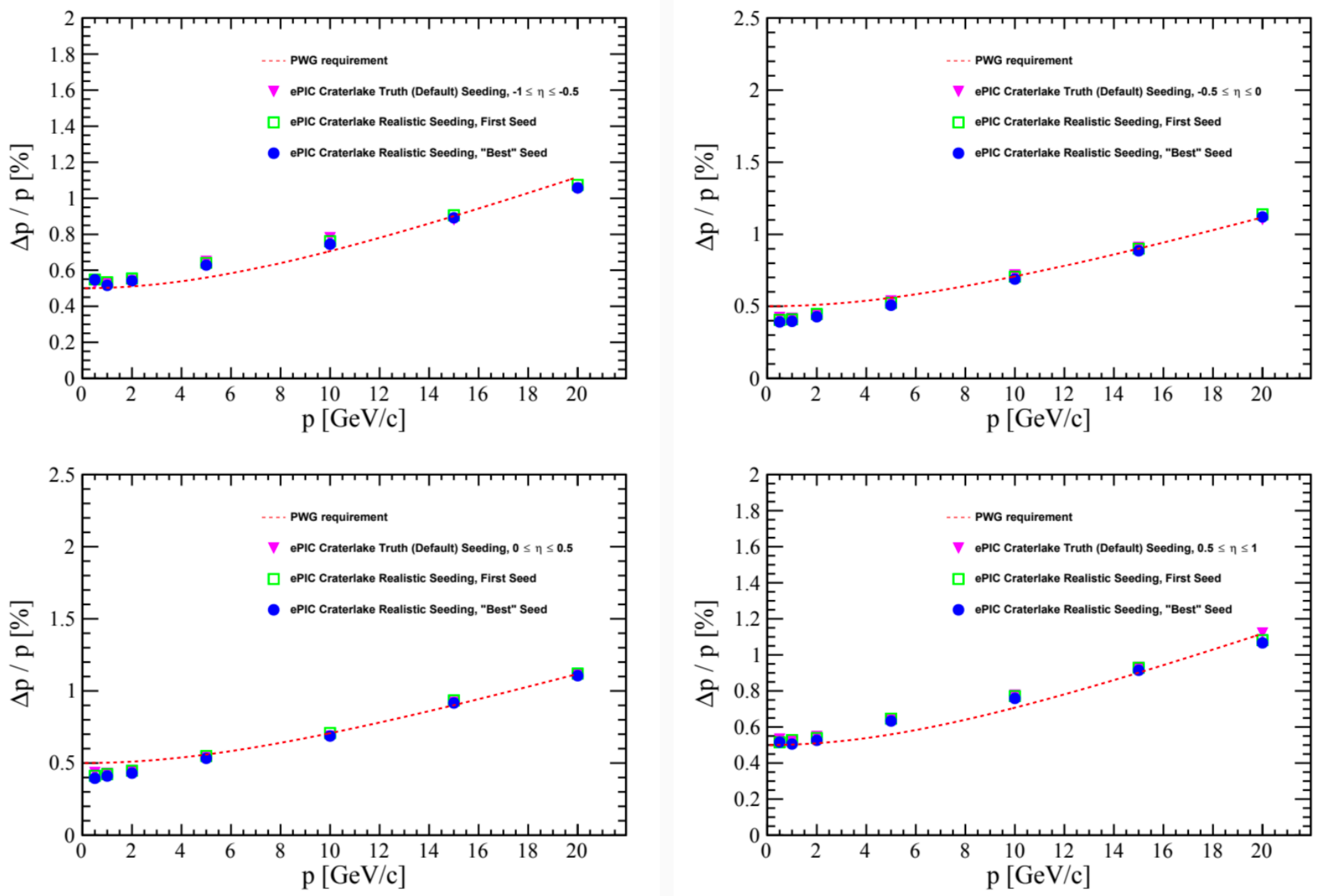
Hit Points and Track Finding





Courtesy Barak Schmookler (UCR)

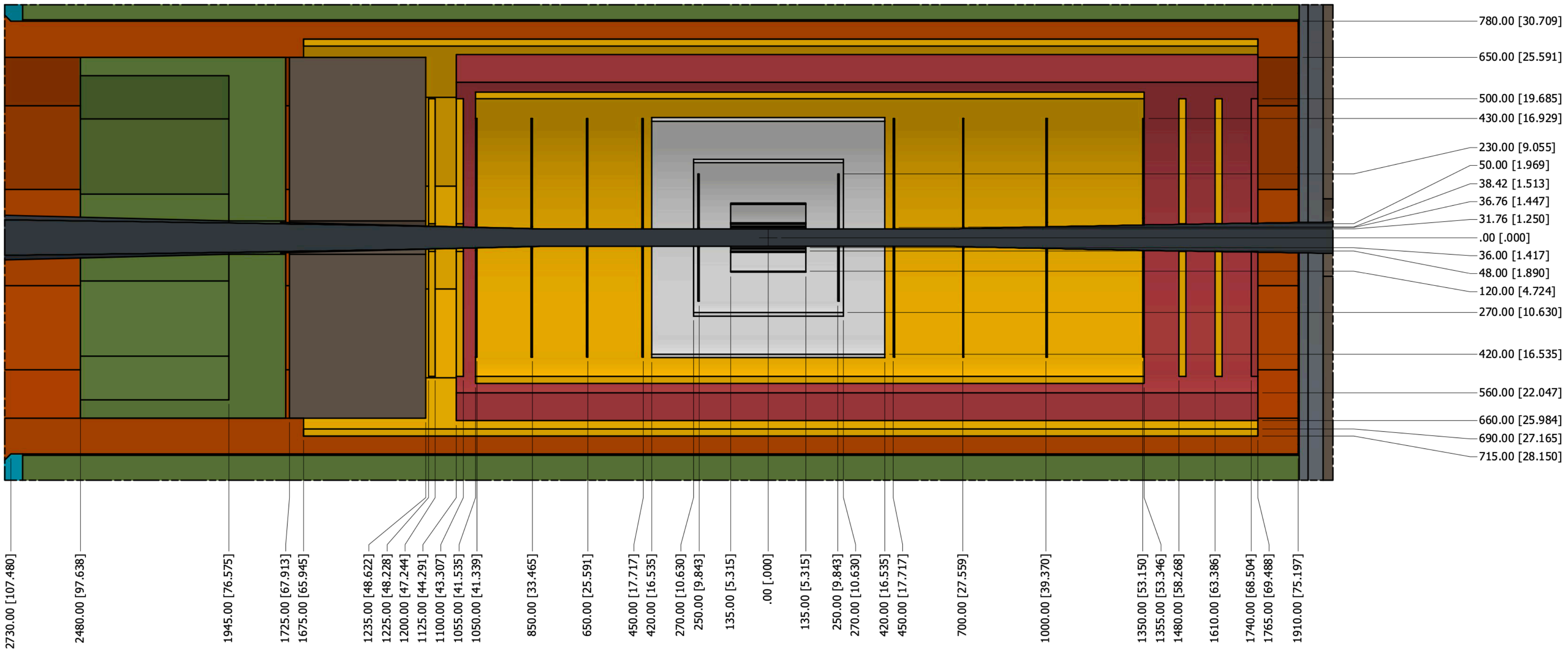
Track Finding and Reconstruction



- Overall, excellent agreement between truth-seeded and found tracking performance (!)
- (Track finding actually performs slightly better in the forward and backward regions),
- Initial insights in seeding of single tracks embedded in backgrounds — see Barak Schmookler's contribution at https://indico.bnl.gov/event/20126/
- Ongoing work to extend from single tracks to DIS events, without and subsequently with backgrounds.

Courtesy Stephen Maple (University of Birmingham)

Closing comments



Thanks to the work by many, ePIC now has a complete(d) inner and outer tracker layout,

Layout is consistent between mechanical engineering and simulation space; simulations include initial description of services,

Initial results exhibit expected behaviors,

Increasing realism in track finding and reconstruction; tracks embedded in backgrounds,

Not covered here — angular resolutions into the PID subsystems, see e.g. Nico Schmidt's contribution https://indico.bnl.gov/event/19882/ (still based on Brycecanyon),

Ample opportunities to get involved and set the next steps; increased realism in detector descriptions and response, design integration(s), (displaced) vertex finding, …