Ongoing studies of tracking configuration scenarios

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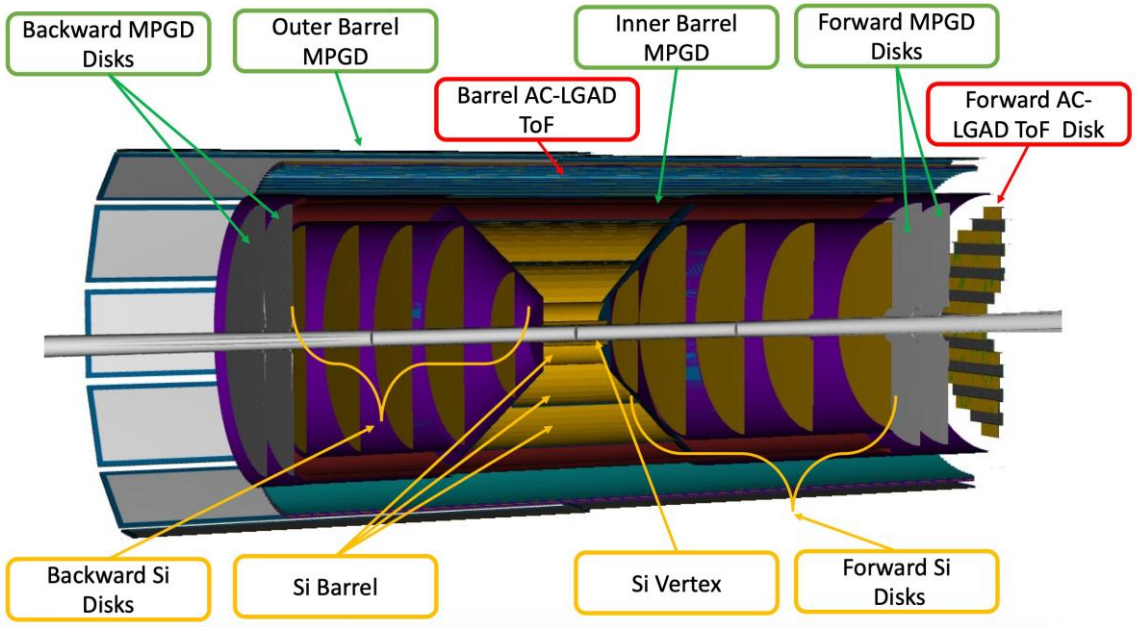
(on behalf of the tracking CC WG)

Central Tracker baseline

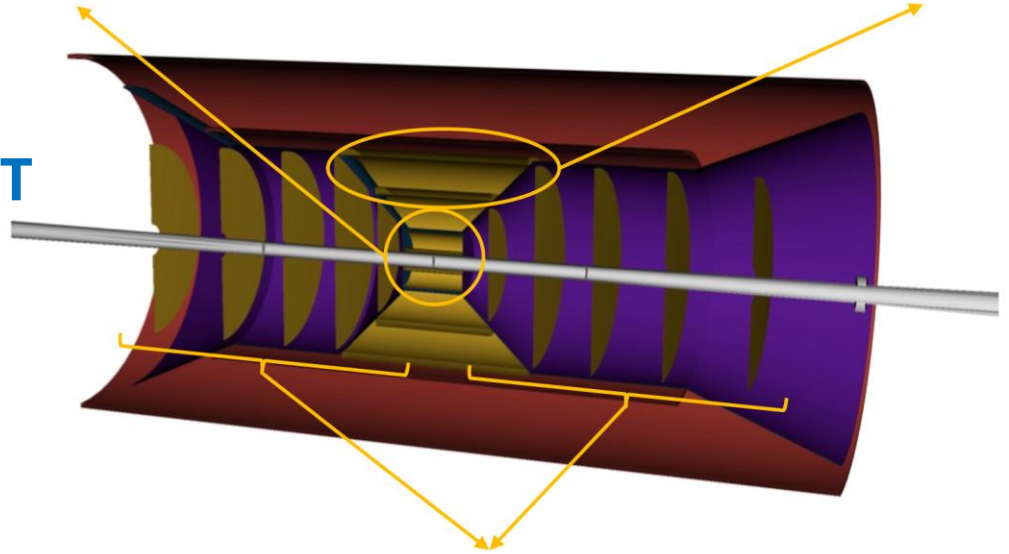
Full tracking system: Silicon Vertex Tracker (SVT) + MPGDs + AC-LGAD TOF detectors



Inner Barrel (IB)
- Two curved silicon vertex layers
- One curved dual-purpose layer
- 0.05% X/X0 per layer

Outer Barrel (OB)
- One stave-based sagitta layer
- One stave-based outer layer
- 0.25/0.55% X/X0 per layer

SVT



Electron/Hadron Endcaps (EE, HE)
- Five disks on either side of the Interaction Region
- 0.25% X/X0 per layer

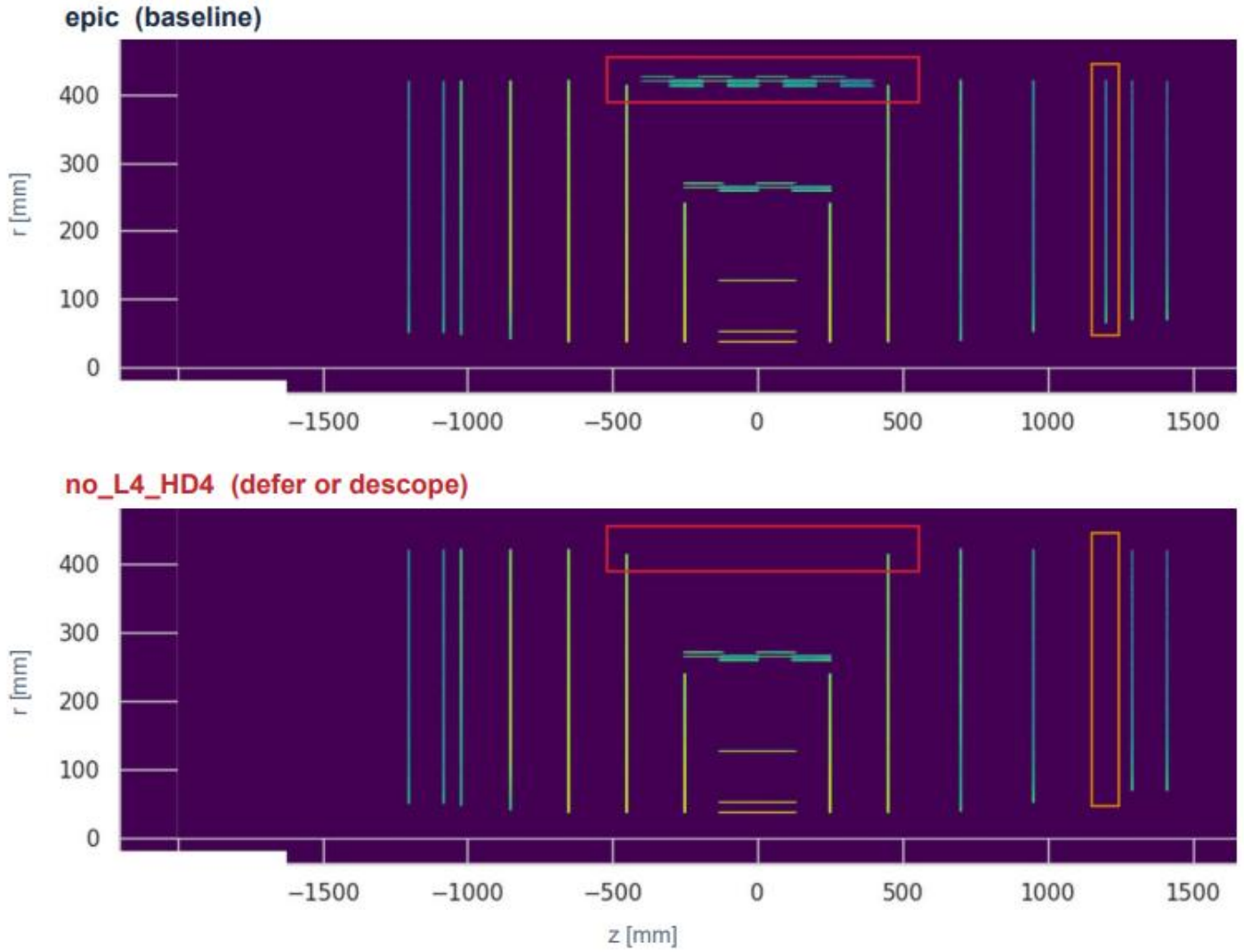
MPGDs and **AC-LGADs** provide
- additional hit points for track reconstruction (**<150 μm**, **30 μm**)
- fast timing hits for background rejection (**10-20 ns**, **30 ps**)

65 nm MAPS technology (ALICE ITS3)
O(20x20 μm^2) pixel size
Total active area of 8.5 m^2

Motivation

- As discussed at the ePIC general meeting last month, due to funding constraints, a scenario under consideration is to descope or defer SVT layer L4. In addition, descoping or deferring one of more SVT disks in the hadron direction is also being considered.
- The tracking CC WG has been tasked to lead the effort to understand the impact of any configuration changes to the tracking system.
- This effort involves close coordination with the SVT, MPGD, and ToF DSCs, as well as with all the physics WGs.

What has been done so far



L4 outermost SVT barrel
$r \approx 42$ cm, $|z| \lesssim 45$ cm
→ $|\eta| \lesssim 0.9$

HD4 hadron-side disk 4
$z \approx +120$ cm, $r \approx 6$–42 cm
→ $1.8 \lesssim \eta \lesssim 3.7$

The acceptances do not overlap,

$|\eta| < 1$ → impact from L4 only

outside $|\eta| < 1$ → impact from HD4 only

single simulation, separate decisions.

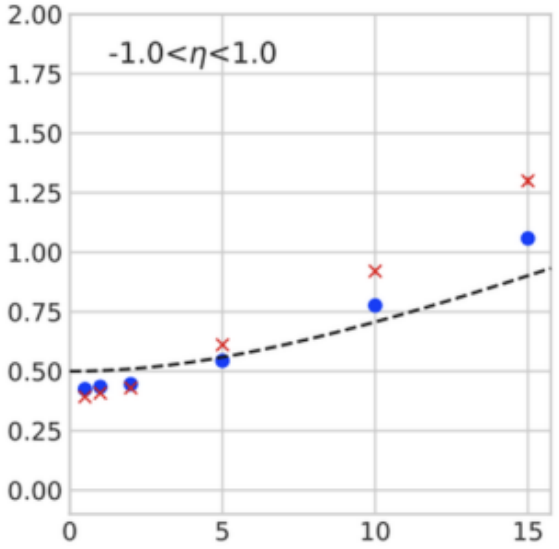
Staves and disks were removed, whereas services were kept in these simulations. Tracking was not re-tuned for the reduced geometry. The reconstruction is the one optimised for the full detector.

SVT region of the central-tracker hit map, 10×275 forced DIS + background. Simulations by Shujie Li, using NERSC.

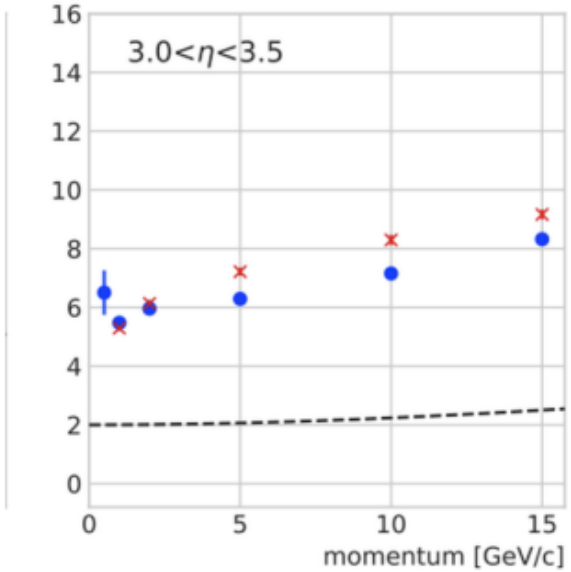
Shown by Ernst at general meeting last month

What has been done so far

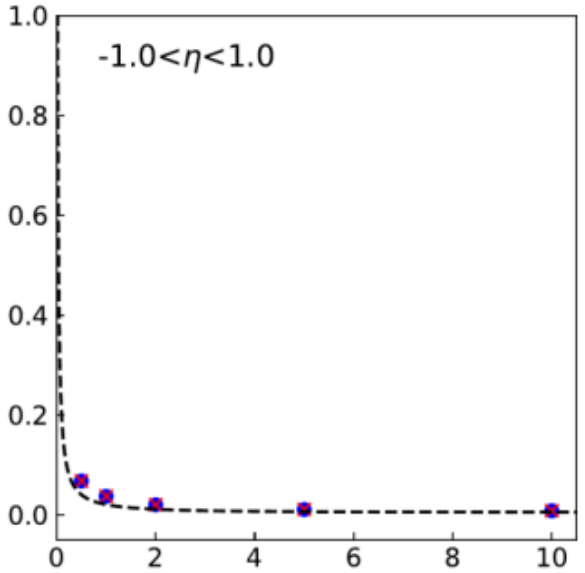
Single particle momentum and (transverse) impact-parameter resolution



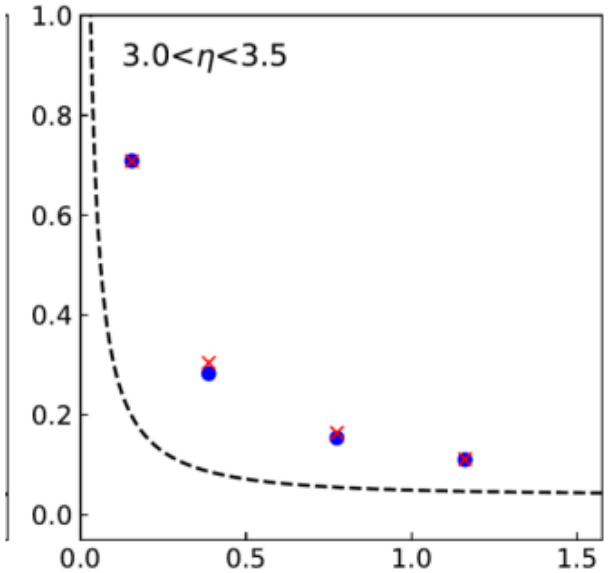
δp/p [%], |η| < 1



δp/p [%], 3.0 < η < 3.5



DCA_r [mm], |η| < 1



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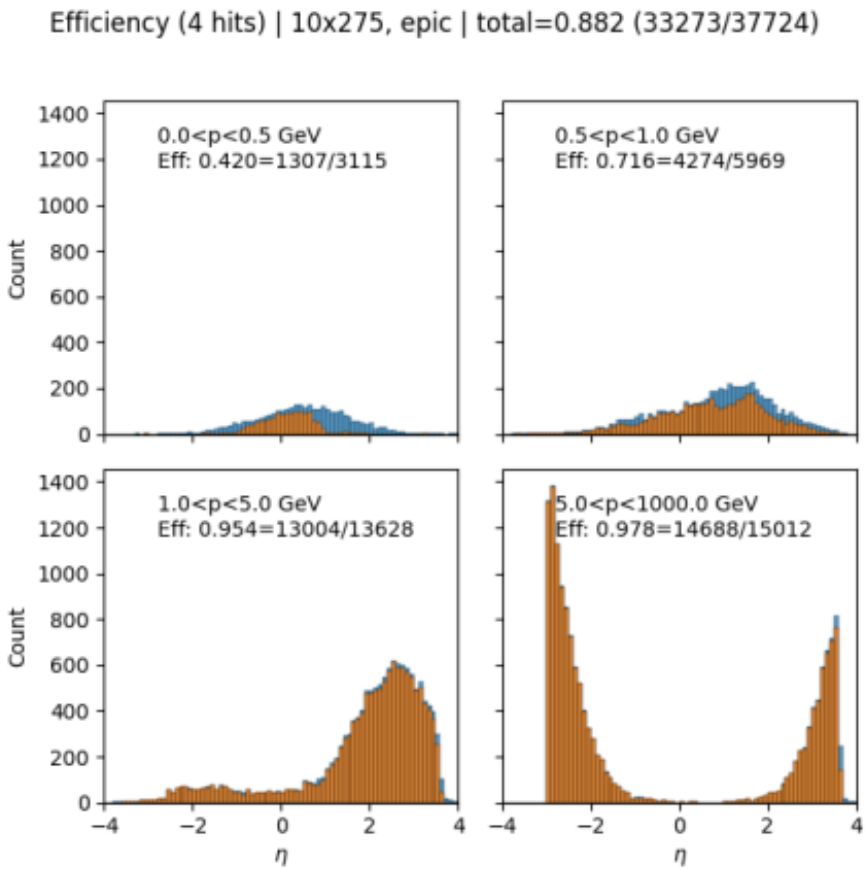
Shown by Ernst at general meeting last month

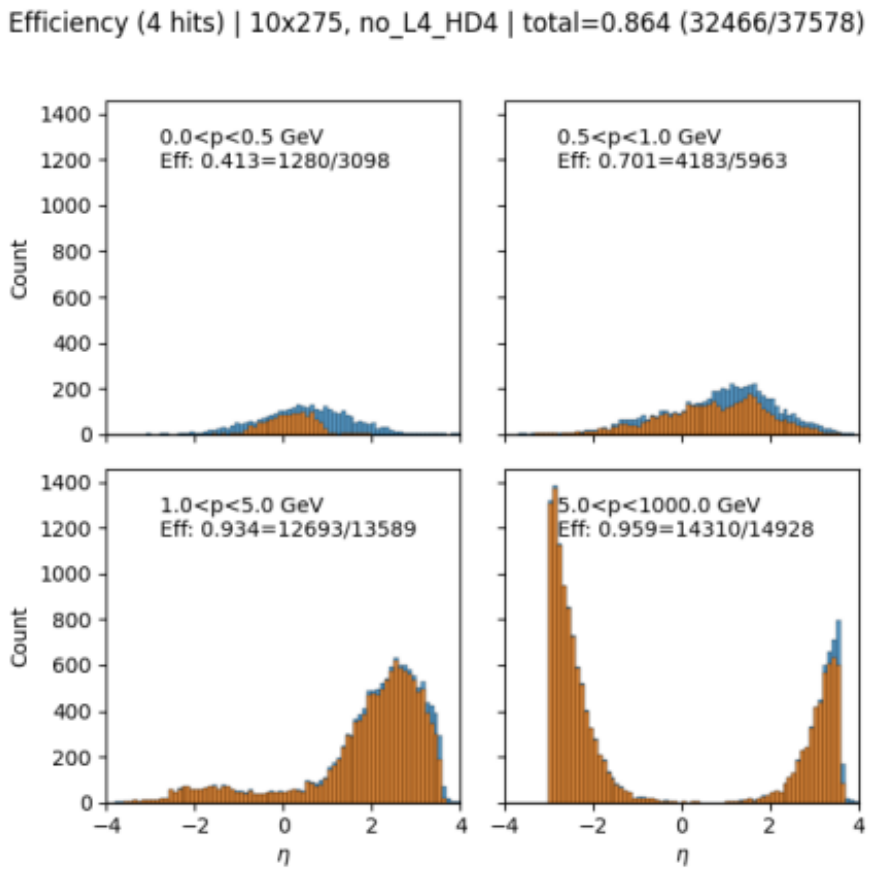
What has been done so far

Pattern-recognition studies including machine backgrounds – efficiency

epic



no_L4_HD4



Full simulation, 10×275 forced DIS + background, no noise. Blue = good signal particles; orange = those with a good signal track.

Shown by Ernst at general meeting last month

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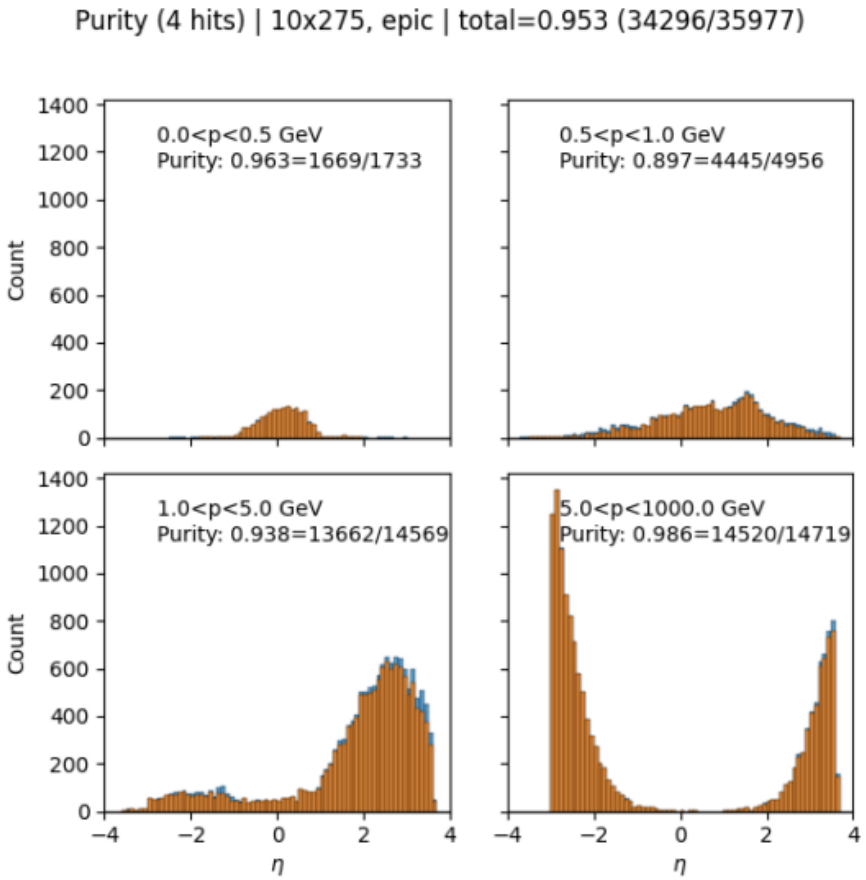
Pattern-recognition studies including machine backgrounds – purity

epic



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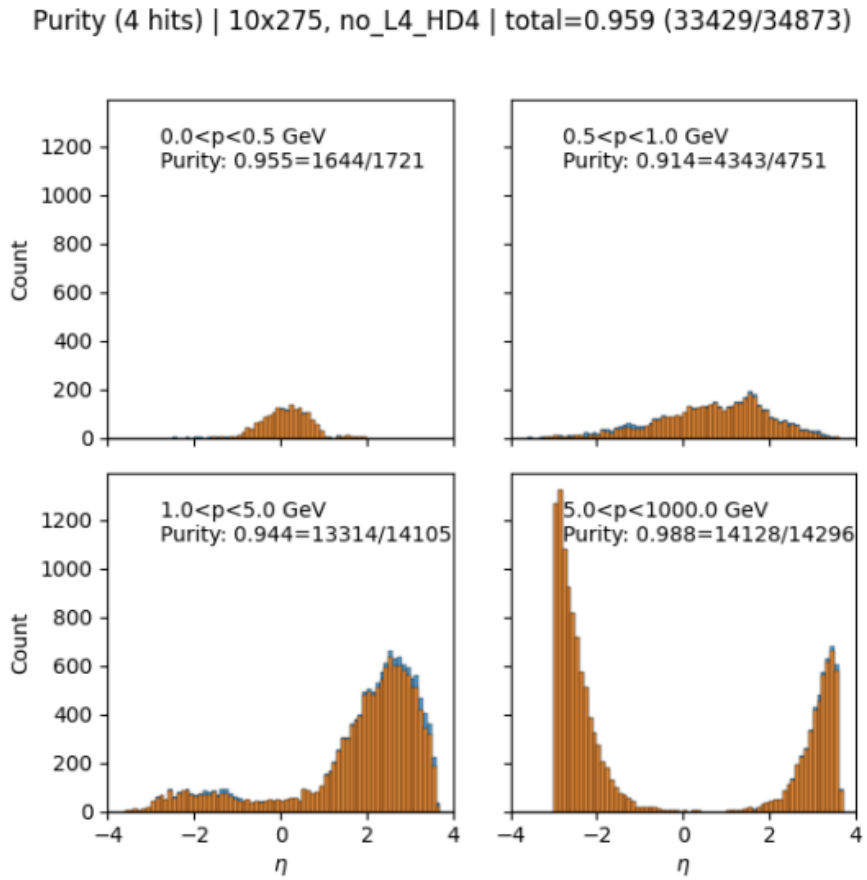

Same samples. Blue = all valid tracks; orange = good signal tracks. Purity = good signal tracks / valid tracks.

Shown by Ernst at general meeting last month

What additional work is needed

- The results shown above find no ‘show-stopper’, but they are only the first step.
- We hope to answer the following questions related to removing SVT layers:
  - If detector noise is included in the simulations in addition to machine background, do the above conclusions about tracking efficiency and purity remain the same?
  - Can any degradations we observe to the tracking performance be recovered by tuning our track-finding algorithm?
  - What are the impacts of the ToF position resolution and the inclusion of the BIC imaging layers on the performance changes? Are these impacts relevant for the overall track reconstruction performance or for the track projections into the outer PID system?
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SVT detector noise rates

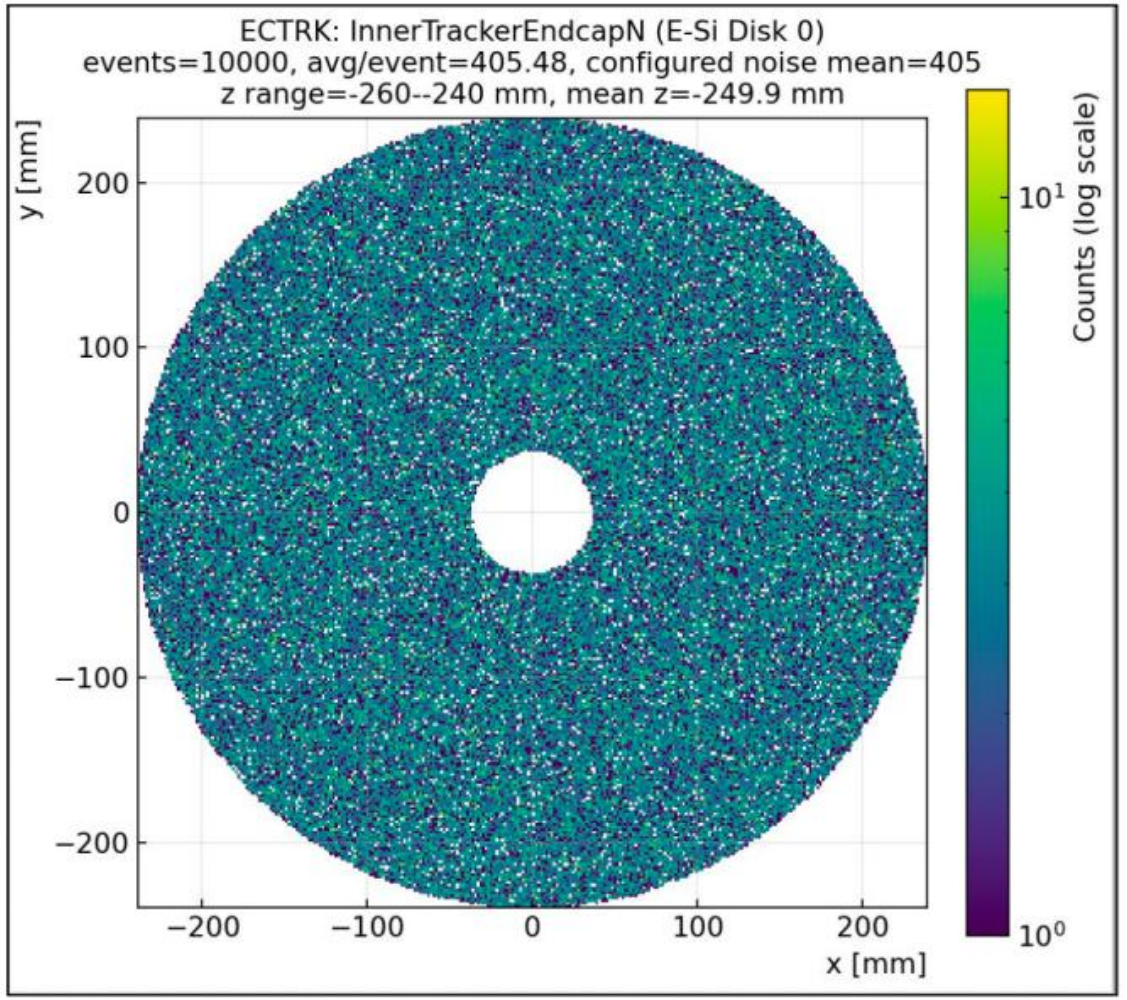
Detector name	Barrel layers	R [mm]	L [mm]	Area [mm]	# of pixels	# of noise hits per event*	# of background hits (10x275, 10um Au) per 2us
VertexBarrel	L0	36	270	6.11E+04	1.53E+08	76	722
	L1	48	270	8.14E+04	2.04E+08	102	503
	L2	120	270	2.04E+05	5.09E+08	254	309
SagittaSiBarrel	L3	270	540	9.16E+05	2.29E+09	1,145	987
OuterSiBarrel	L4	420	800	2.11E+06	5.28E+09	2,639	630
Detector name	**Disks**	**R1 [mm]**	**R2 [mm]**	**Area [mm]**	**# of pixels**	**# of noise hits per event***	**# of background hits (10x275, 10um Au) per 2us**
InnerTrackerEndcapN	E-Disk1	36.76	230	3.24E+05	8.10E+08	405	258
MiddleTrackerEndcapN	E-Disk2	36.76	430	1.15E+06	2.88E+09	1,442	463
OuterTrackerEndcapN	E-Disk3	36.76	430	1.15E+06	2.88E+09	1,442	445
	E-Disk4	40.06	430	1.15E+06	2.88E+09	1,440	290
	E-Disk5	46.35	430	1.15E+06	2.87E+09	1,435	62
InnerTrackerEndcapP	H-Disk1	36.76	230	3.24E+05	8.10E+08	405	223
MiddleTrackerEndcapP	H-Disk2	36.76	430	1.15E+06	2.88E+09	1,442	311
OuterTrackerEndcapP	H-Disk3	38.42	430	1.15E+06	2.88E+09	1,441	73
	H-Disk4	54.43	430	1.14E+06	2.86E+09	1,429	13
	H-Disk5	70.14	430	1.13E+06	2.83E+09	1,414	10

*1 event = 2μs

Sampled fake-hit rate: FHR < 5 x 10^{-7} per event per pixel

Implementation in ePIC simulation

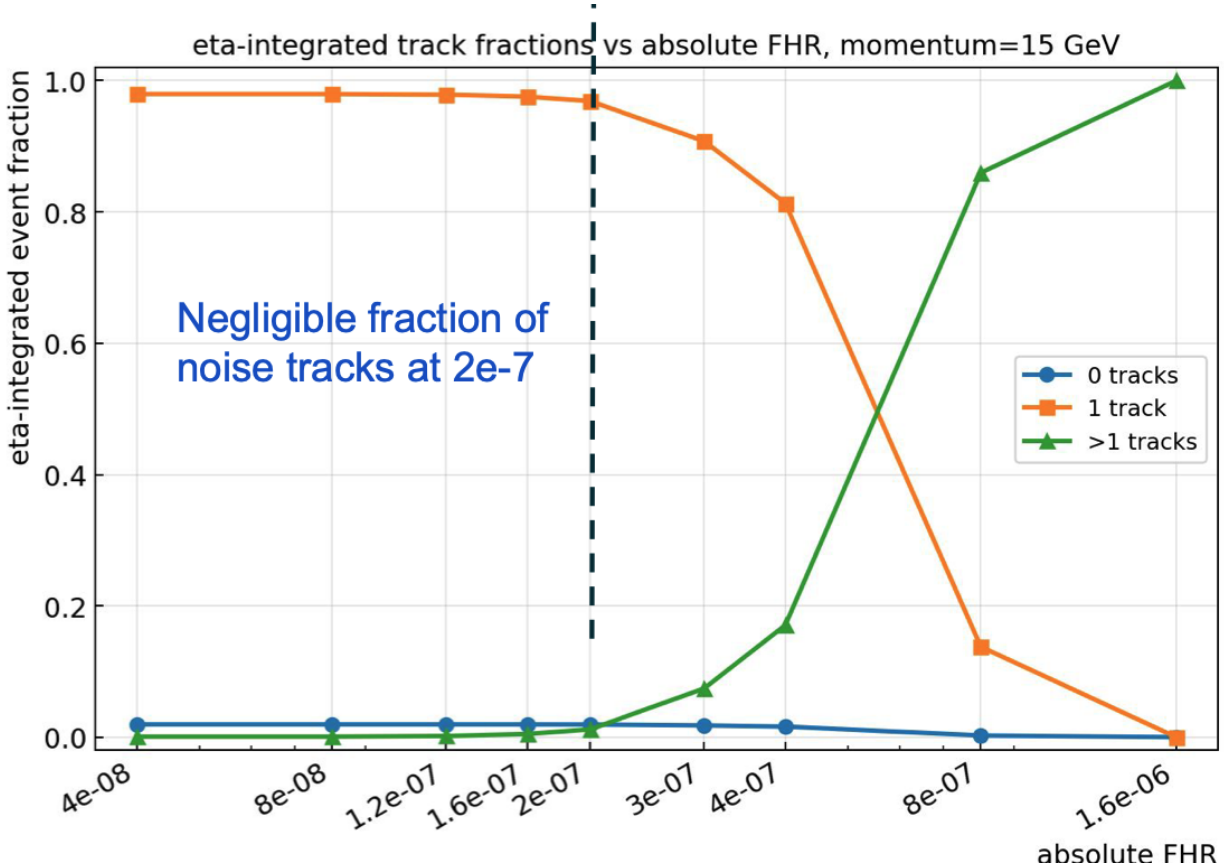
- Noise injection in SVT layers has now been fully implemented.
- Ongoing effort to use the same infrastructure to inject noise in (B)ToF at a baseline frequency of 30 Hz/channel: EICRecon#2979.
- Noise rate in MPGDs in assumed to be small compared to machine-background rate. The plan is to consider noise implementation following the completion of more-realistic MPGD digitization.



Work by Beatrice Liang-Gilman, Joshua Sobajic, and Shujie Li

Impact of SVT noise in single-particle simulations

- With the baseline ePIC configuration, we have studied the impact of SVT noise in single-particle simulations.
- We will repeat these studies with the modified configuration(s) and the inclusion of (B)ToF noise.



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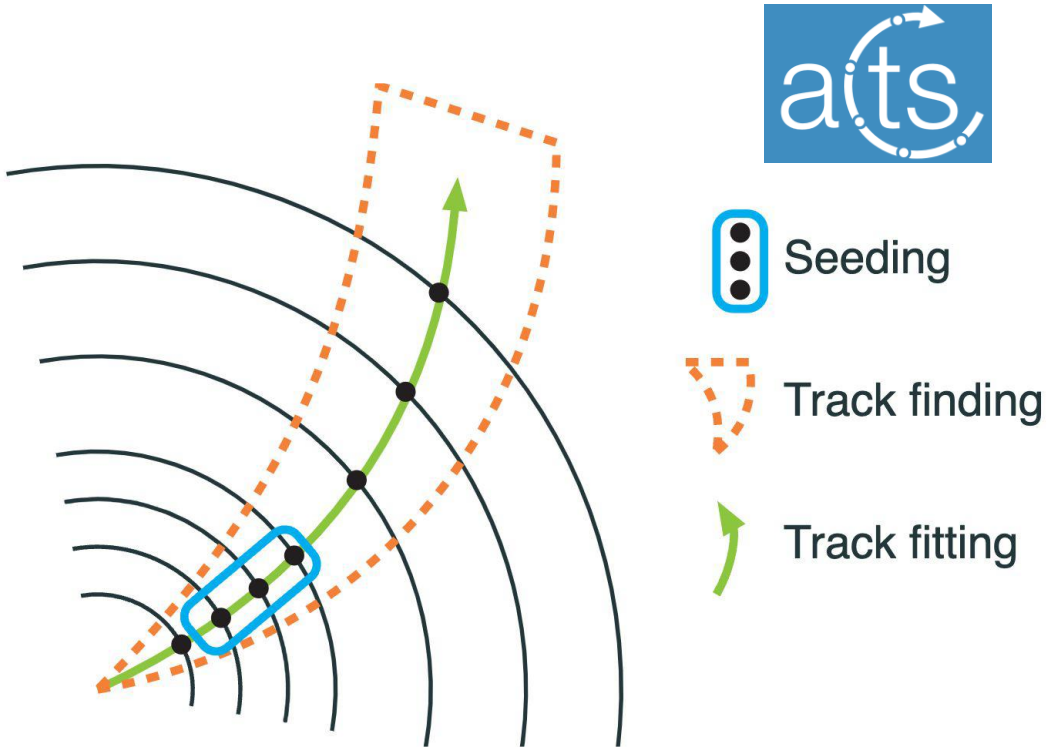
Track reconstruction workflow

- The current track reconstruction scheme first builds seeds (tracklets) in the SVT using a loose set of cuts.
- The track seeds are then projected to the other tracking layers and additional SVT, MPGD, TOF hits are attached.
- The final track parameters are saved at the reconstructed track's point-of-closest approach to the beamline (z-axis) following track smoothing.



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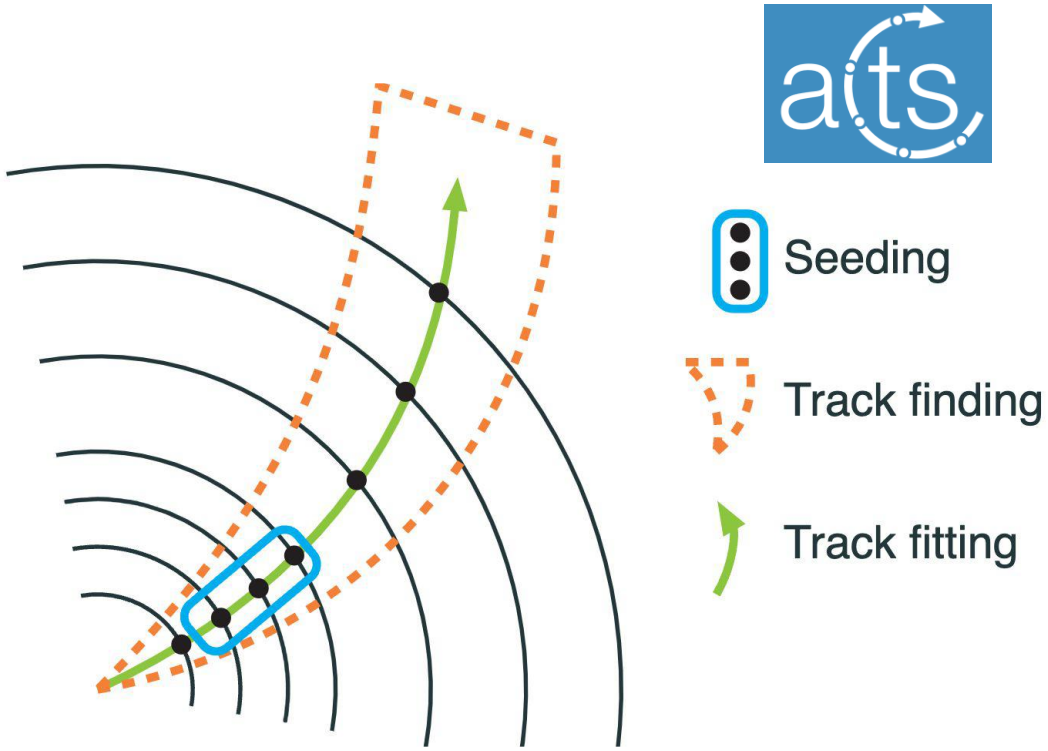
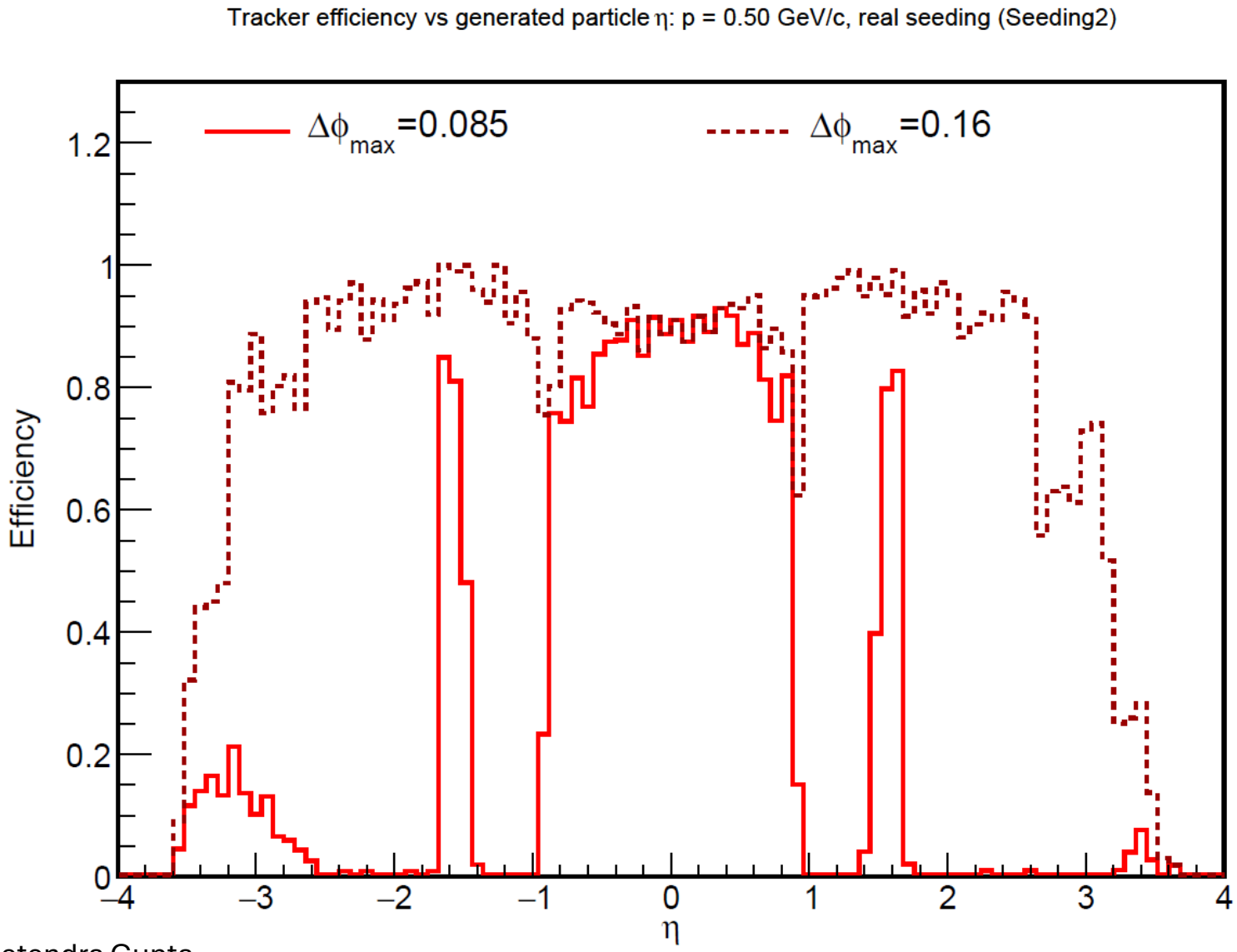


Much of our current effort related to parameter tuning focuses on the seed-finding stage.

Example: Seed-finding parameter tuning can improve low-momentum tracking efficiency

Results shown for baseline ePIC tracking configuration



Work by Jeetendra Gupta

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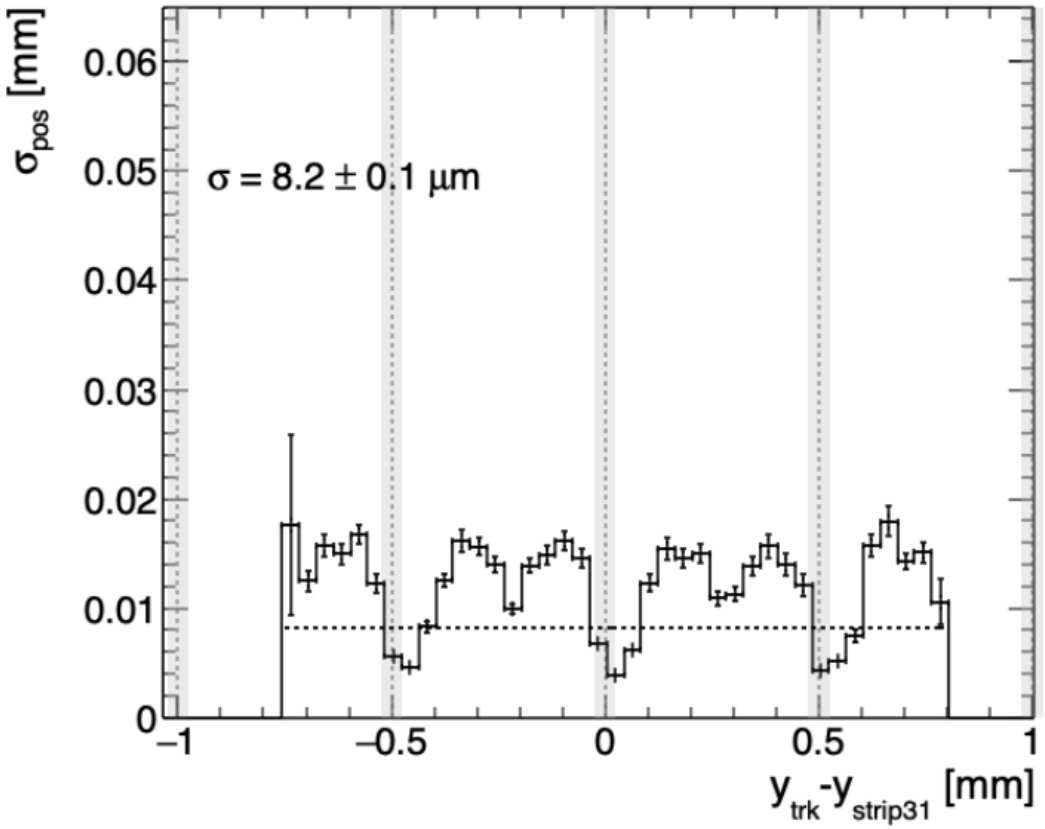
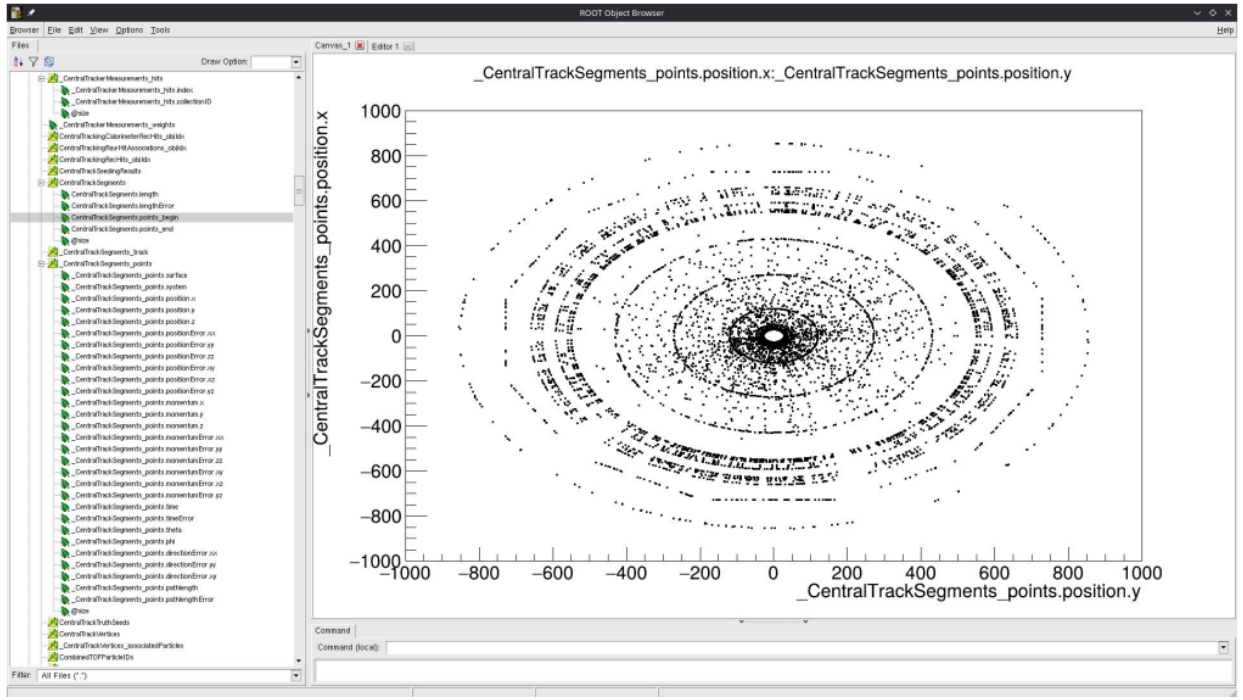
ToF position resolution and BIC layers

- Position resolution of BTOF strip sensor in December 2025 DESY test beam showed better position resolution than currently used in ePIC simulation.



- Most of the infrastructure to integrate the 1st BIC layer into the track reconstruction has been developed.
- Some work is needed to inject the hits into the track reconstruction: EICRecon#1570.



Work by Wouter Deconinck

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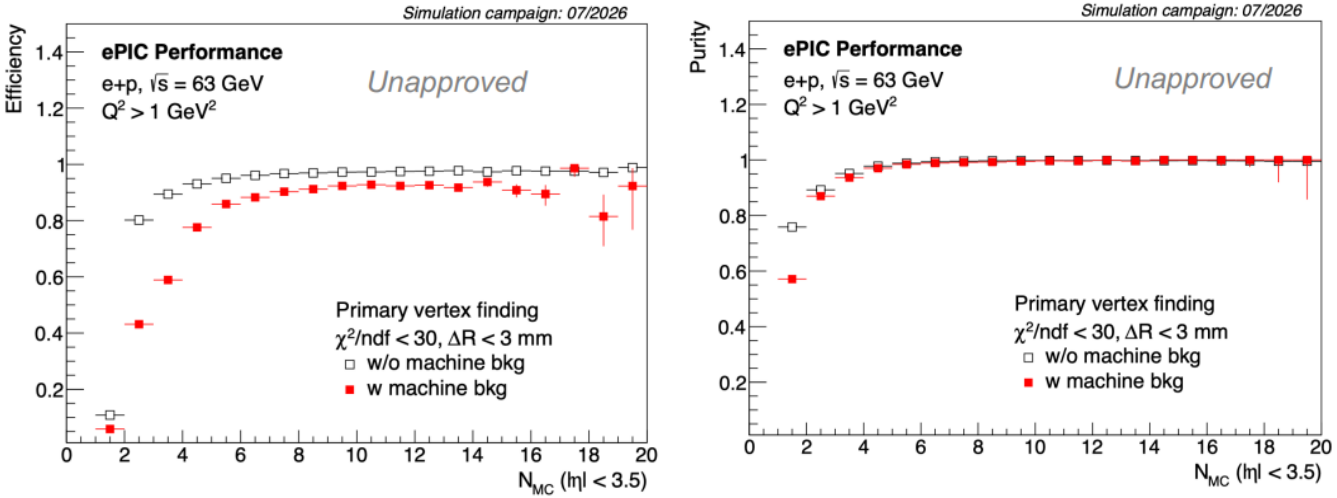
Coordination with the PWGs

- The modified-configuration results shown last month were based on simulation that included $Q^2 > 1 GeV^2$ inclusive DIS collisions and machine backgrounds. We need help from the physics WGs to check the results for other reactions.
- In addition, we need to study the impact on holistic reconstruction (e.g. electron finding); and primary vertexing (not just single-track pointing resolution)

Primary vertexing efficiency and purity



Work by Rongrong Ma

Results shown for baseline ePIC tracking configuration

Point of discussion: Distribution of modified-configuration simulations

- As mentioned above, the simulations shown last month that included the removed SVT L4 and HD4 layers were performed ‘locally’ by Shujie Li.
- Shujie made the modifications to the simulation geometry, updated the tracking software’s view of geometry, ran the simulation that included machine backgrounds, and ran our tracking analysis scripts.
- If we wish the PWGs to study the items mentioned on the previous slide, we need to centrally produce simulations that include the modified tracking configuration(s). How do we want to do this?

Conclusions

- First studies of impact of possible SVT configuration changes on the tracking performance were shown last month.
- We are building on these initial studies to get a firmer understanding of the impact of SVT layer removals.
- In order for the physics WGs to contribute to these studies, we need to consider how best to centrally create simulations with modified tracking configurations.