Impact of beampipe gold coating thickness

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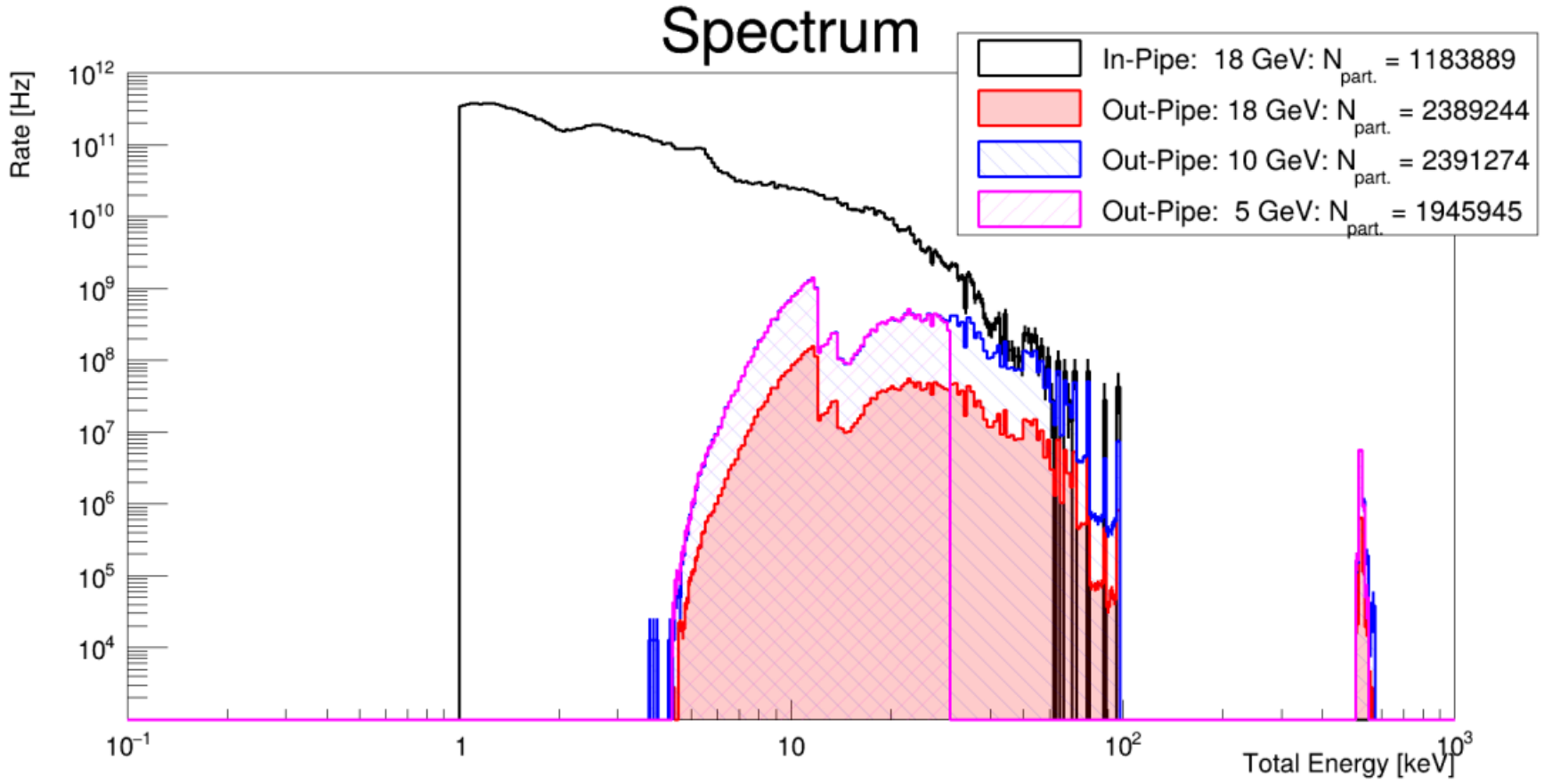
Work by: Andrii Natochii , Ernst Sichtermann , Francesco Bossù, Shujie Li

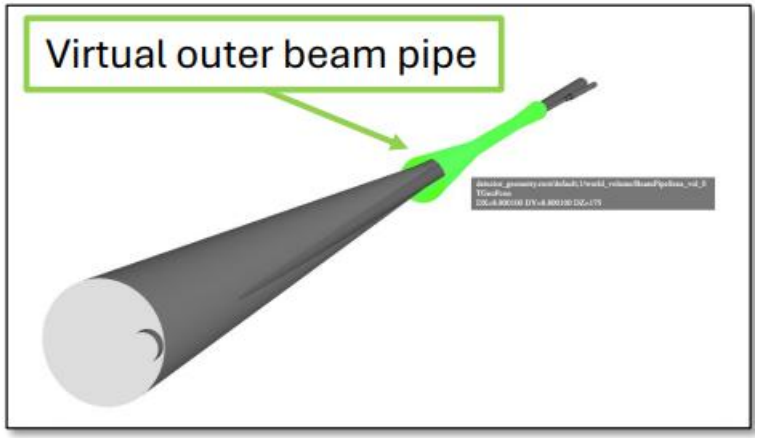
Synchrotron Radiation (SR) with 5 um Au coating



18 GeV: /gpfs02/eic/anatochii/SynradG4_HepMC_Files_SR_on_IP6/data/synrad/dataprod_rel_1.0.0/18x275/dataprod_rel_1.0.0_synrad_18x275_run001.preproc_10000repeats.hepmc3.tree.root

10 GeV: /gpfs02/eic/anatochii/SynradG4_HepMC_Files_SR_on_IP6/data/synrad/dataprod_rel_1.0.0/10x275/dataprod_rel_1.0.0_synrad_10x275_run001.preproc_10000repeats.hepmc3.tree.root

5 GeV: /gpfs02/eic/anatochii/SynradG4_HepMC_Files_SR_on_IP6/data/synrad/dataprod_rel_1.0.0/5x100/dataprod_rel_1.0.0_synrad_5x100_run001.preproc_10000repeats.hepmc3.tree.root



- For 18 GeV electron beam, we have SR photons escaping the beampipe at a rate of 3.3 GHZ (6600 photons / 2 us).
- The rate is 10 times higher for the high-current electron beam.

Motivation

- Andrii produced new SR simulations with the thickness of the gold coating on the beampipe increased from 5 um to 10 um.
- For the 10 GeV electron beam at full current, this decreased to overall SR rate for photons exiting the beampipe in the detector region from 36608 MHz to 13277 MHz.
- In the tracking/vertexing group, we studied the impact of doubling the gold coating thickness on
  1. Hit rates and data rates for the SVT and MPGD detector
  2. Single-particle tracking performance
  3. Track reconstruction and primary vertexing in the presence of all beam-induced backgrounds
- This allowed us to decide on which coating thickness should be used

SVT hit and data rates: 10 GeV electron beam + all backgrounds; 5 um Au coating

10x275 GeV setting **All counts are per millisecond (ms)**

1ms of mixed data = 1000 events x (one DIS collision at Q2 >1 GeV2 per 2us + beam background

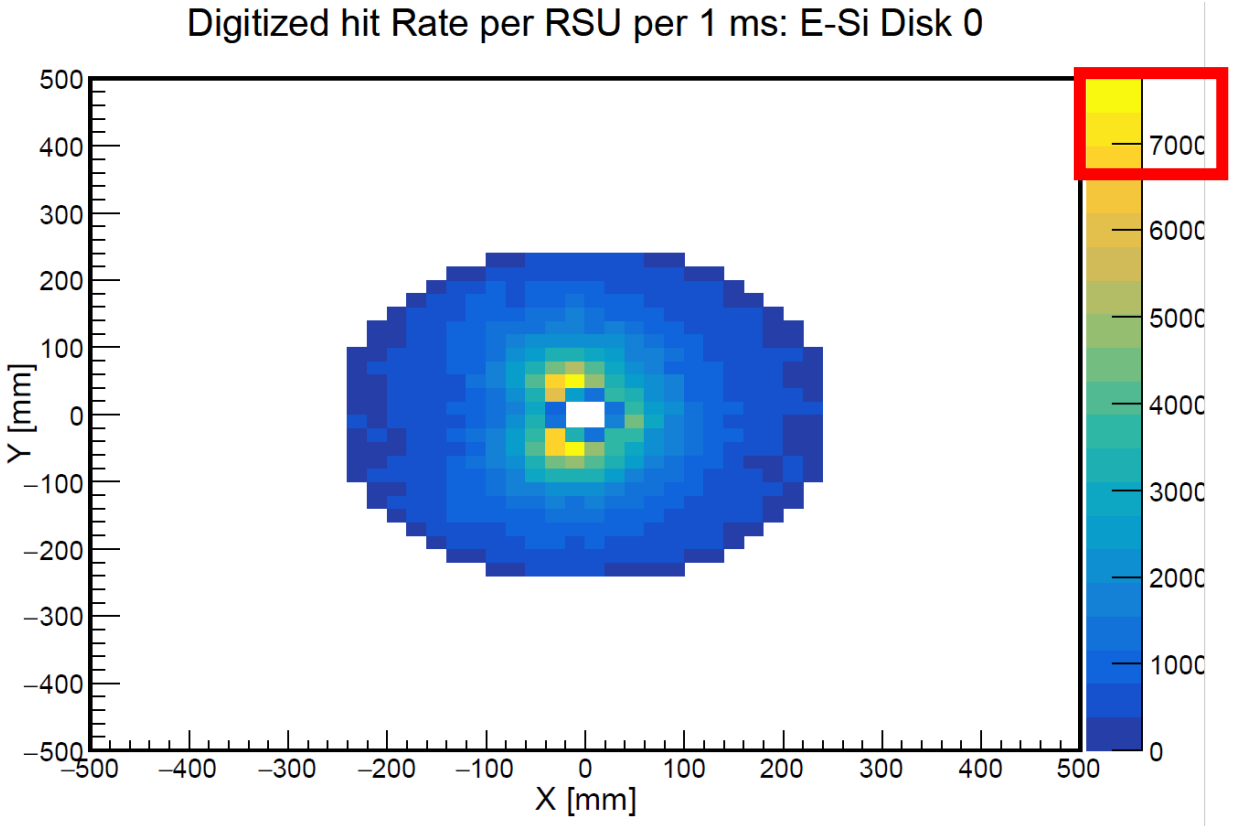
source file: **Shujie**: /25.10.4/epic_craterlake/Bkg_1SignalPer2usFrame/DIS/NC/10x100/minQ2=1/

Layer name	Total hits	single RSU	(9.8x3.5mm)	Total data rate (Gbps)	Max avg. RSU rate (Gbps)	Max avg. tile rate (MHz)
E-Si Disk 4	97019	158	29	12.4	0.02	3.7
E-Si Disk 3	618422	1830	259	79.2	0.23	33.2
E-Si Disk 2	940608	6518	790	120.4	0.83	101.1
E-Si Disk 1	976195	7358	1010	125.0	0.94	129.3
E-Si Disk 0	538309	7651	1072	68.9	0.98	137.2
H-Si Disk 0	438216	6471	825	56.1	0.83	105.6
H-Si Disk 1	624534	5788	907	79.9	0.74	116.1
H-Si Disk 2	165565	306	78	21.2	0.04	10.0
H-Si Disk 3	14334	162	42	1.8	0.02	5.4
H-Si Disk 4	7064	118	20	0.9	0.02	2.6
L0	1791732	21185	2301	229.3	2.71	294.5
L1	1095604	8731	959	140.2	1.12	122.8
L2	600729	1967	227	76.9	0.25	29.1
L3	1645551	2102	297	210.6	0.27	38.0
L4	888591	551	96	113.7	0.07	12.3
				1336.6		

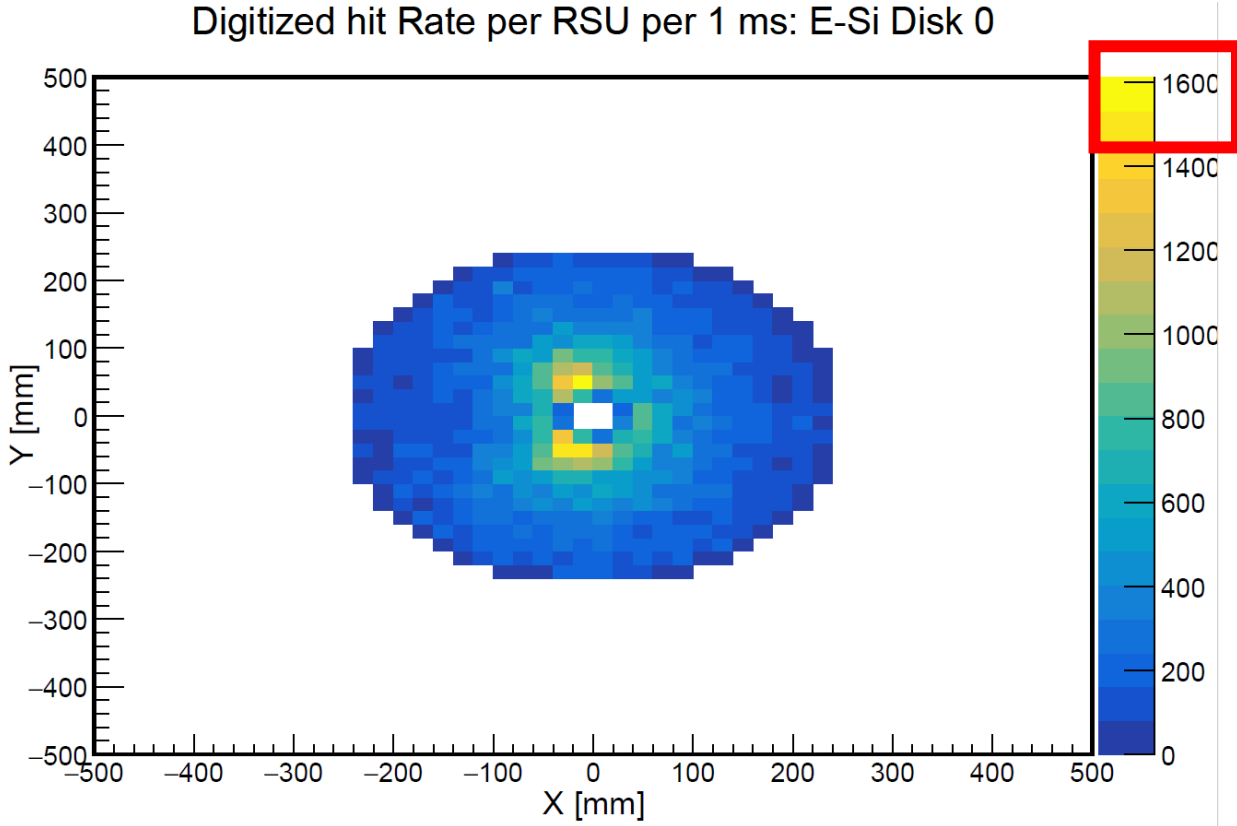
Note: conversion from hit to data rates uses the ~naïve 128 bits per hit for simplicity

SVT disks digitized hit rates: E-Si Disk 0

Results with 5um gold coating



Results with 10um gold coating



Maximum average RSU rate decreases by about a factor of 4.5

SVT rate comparison: 5 um vs. 10 um coating

10x275 GeV setting with 10um gold beampipe coating

All counts are per millisecond (ms)

1ms of mixed data = 1000 events x (one DIS collision at Q2 >1 GeV2 per 2us + beam background per event) / 2

source file: Barak: bgmerged_forced_10x275_scaled_SR_10um_n1000.hepmc3.tree.root

Layer name	Total hits	MAX hit on a single RSU (20x20mm)	Tile (9.8x3.5mm) added by Shujie	RSU rate ratio (5/10um)	Tile rate ratio (5/10um)
E-Si Disk 4	30795.5	46	12	3.43	2.42
E-Si Disk 3	144893.5	394	71	4.64	3.65
E-Si Disk 2	222633.5	1326	212	4.92	3.73
E-Si Disk 1	231321	1718.5	230	4.28	4.39
E-Si Disk 0	129167.5	1611.5	258	4.75	4.16
H-Si Disk 0	111486	1405.5	201	4.60	4.10
H-Si Disk 1	155315	1301	250	4.45	3.63
H-Si Disk 2	36344.5	144.5	35	2.12	2.23
H-Si Disk 3	6601.5	137	28	1.18	1.50
H-Si Disk 4	5000.5	86	18	1.37	1.11
L0	360928.5	4330	594	4.89	3.87
L1	251520	2188.5	250	3.99	3.84
L2	154420	538	73	3.66	3.11
L3	493530	711.5	110	2.95	2.70
L4	314902	217.5	39	2.53	2.46

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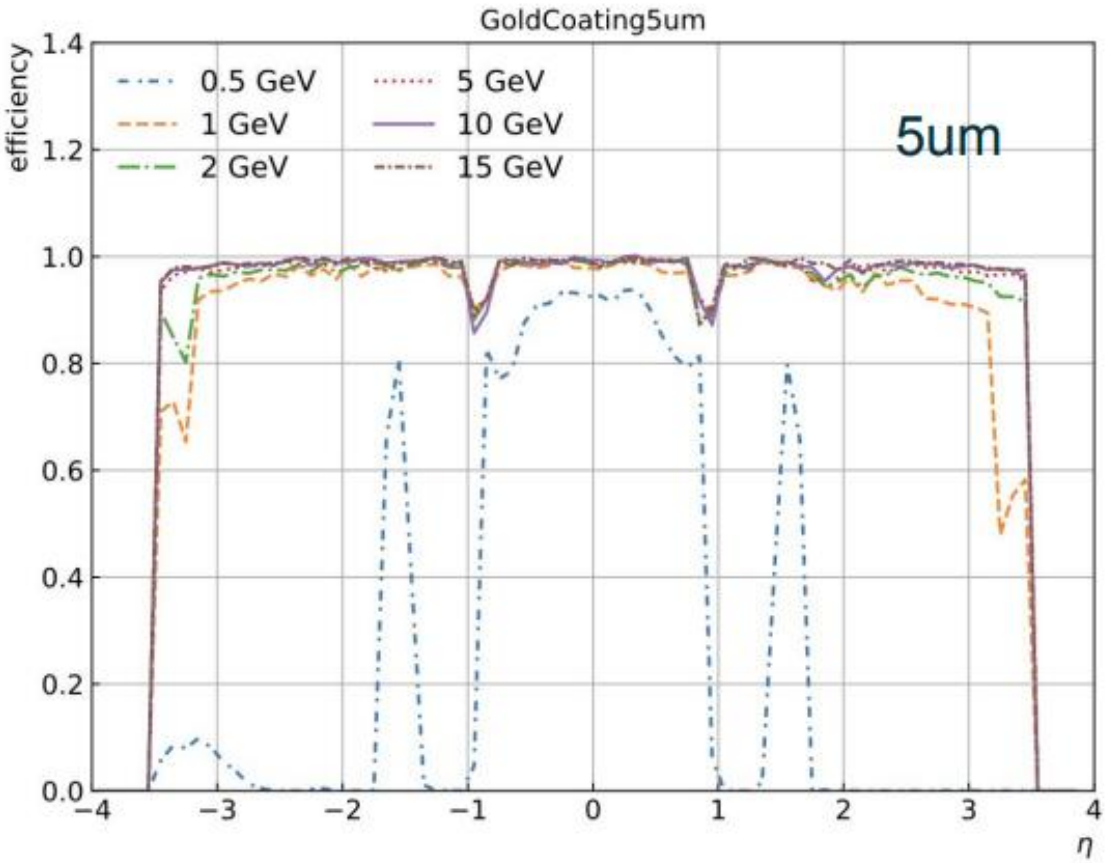
L4	314902	217.5			

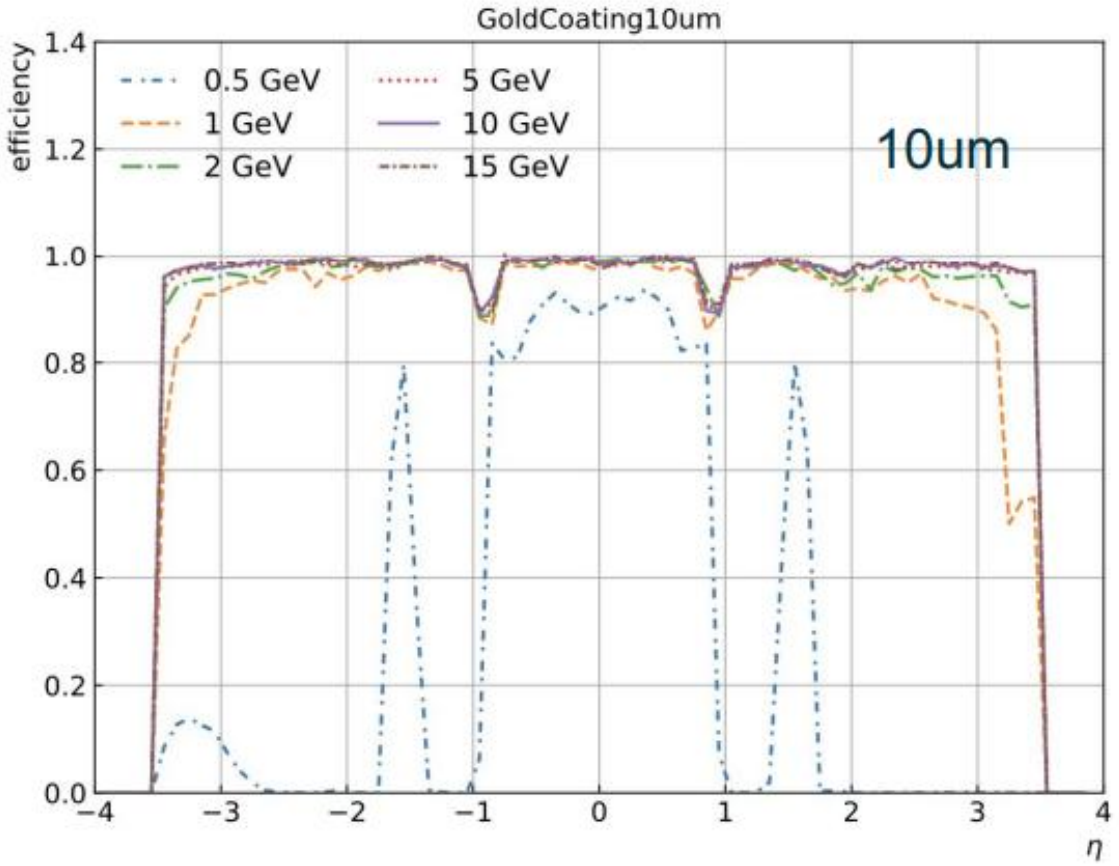
For MPGDs with 10 um Au coating:

- rates in CyMBaL (and BOT) decrease by a factor ~2
- for ECTs, decrease of 5%

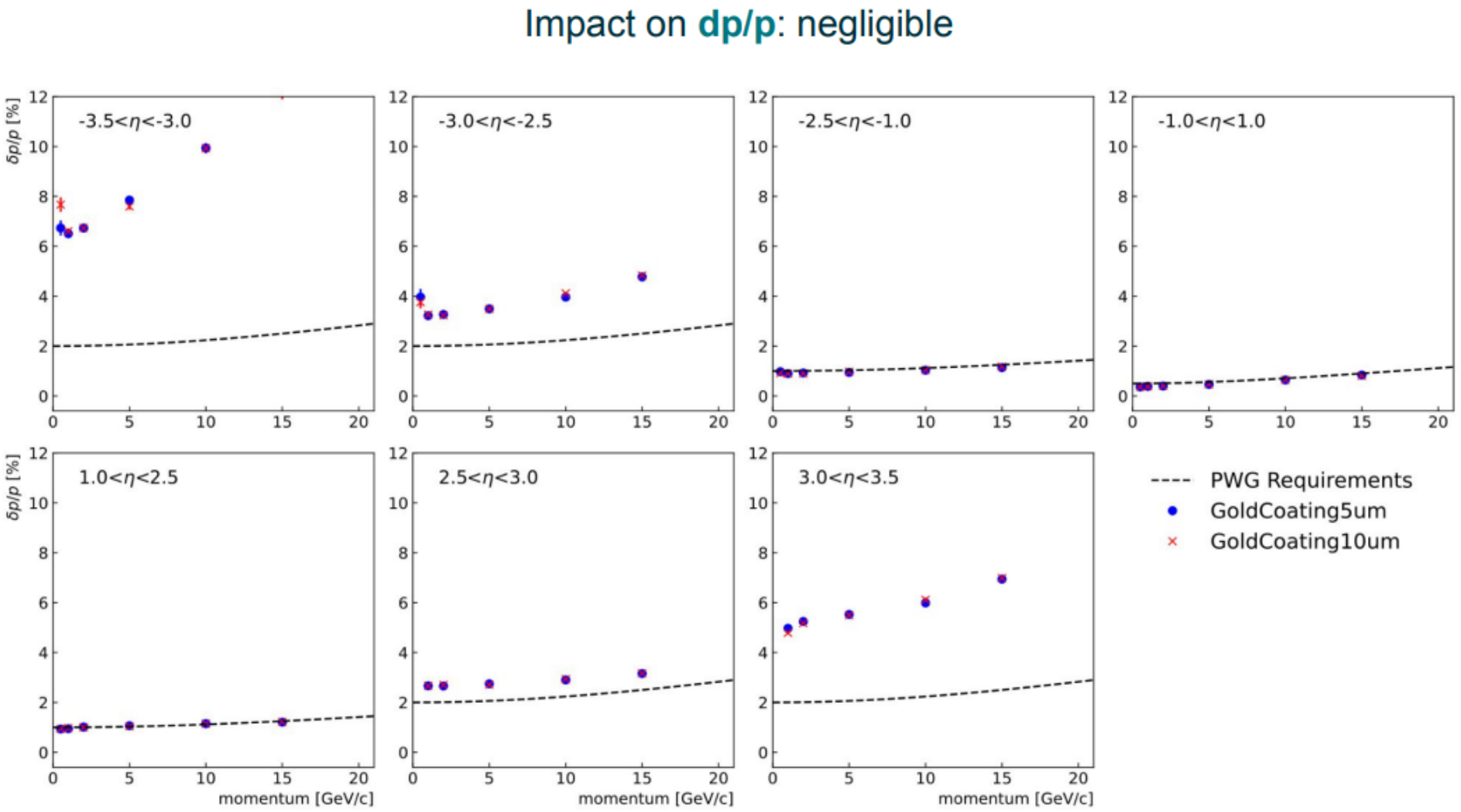
Single-particle tracking performance: Efficiency

Impact on **Efficiency**: negligible



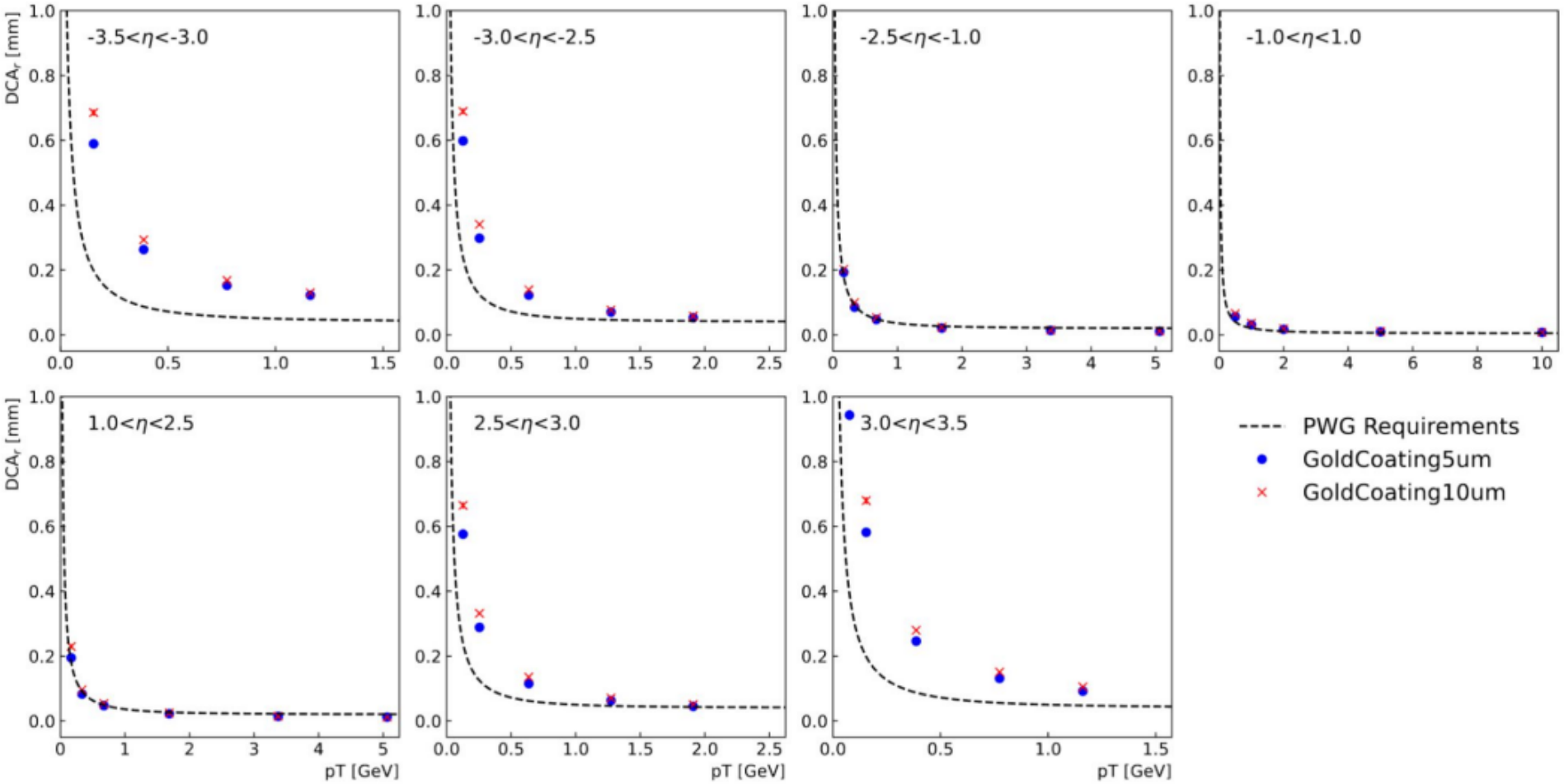


Single-particle tracking performance: Momentum Resolution



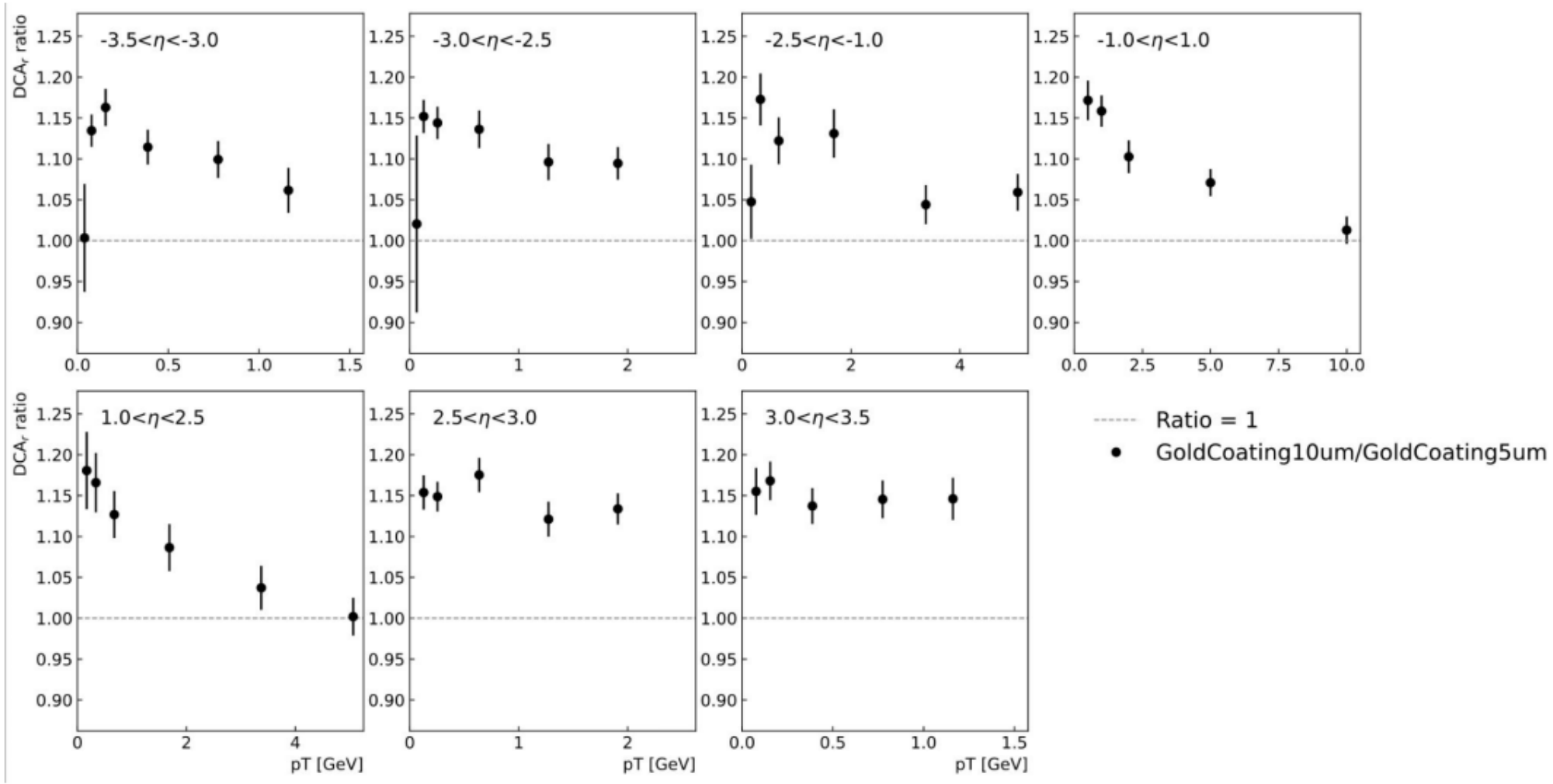
Single-particle tracking performance: Pointing Resolution

Impact on **DCAr**: didn't make a qualitative difference wrt requirements



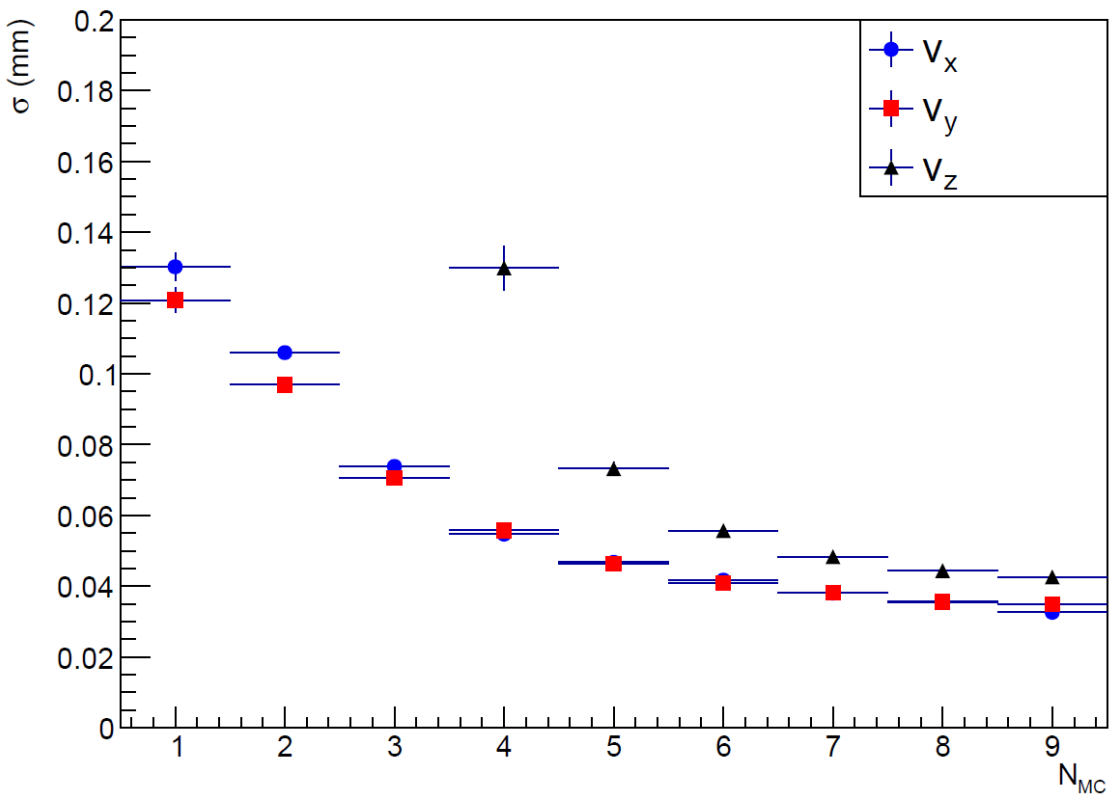
Single-particle tracking performance: Pointing Resolution

Impact on **DCAr** (shown in ratio): 0-20%

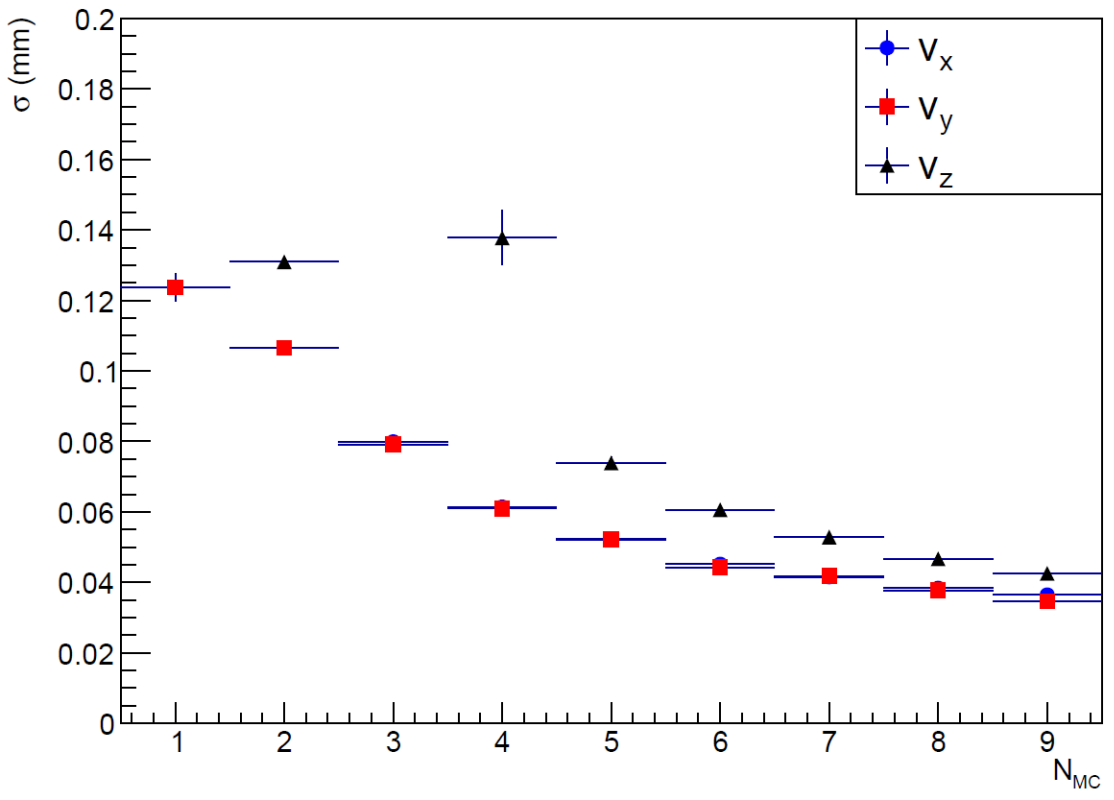


Primary vertexing performance: DIS signal events ($Q^2 > 1\ GeV^2$)

Results with 5um gold coating



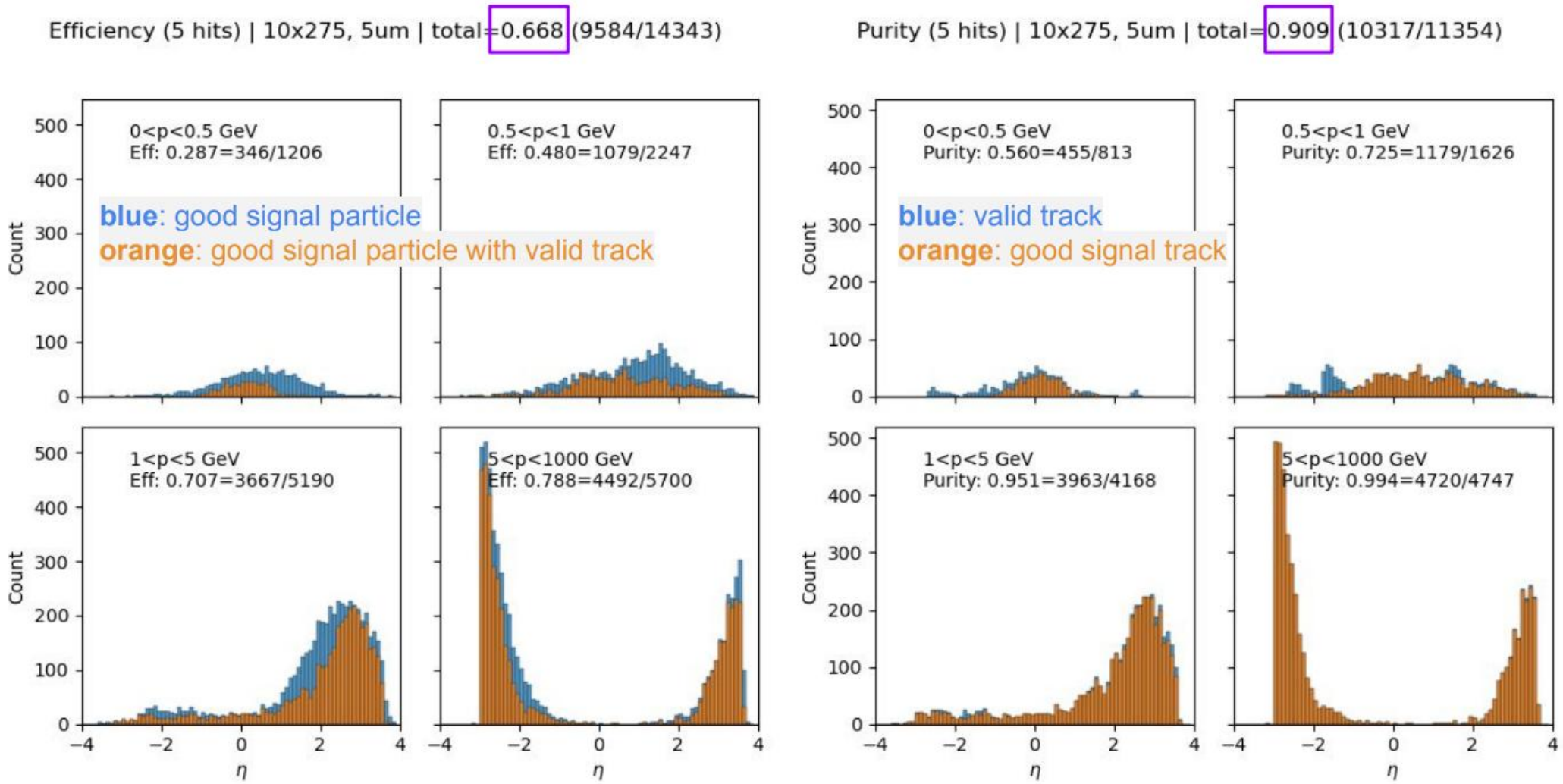
Results with 10um gold coating



N_{MC}: the number of generated charged particles with |eta| < 3.5 that originate from the true primary vertex

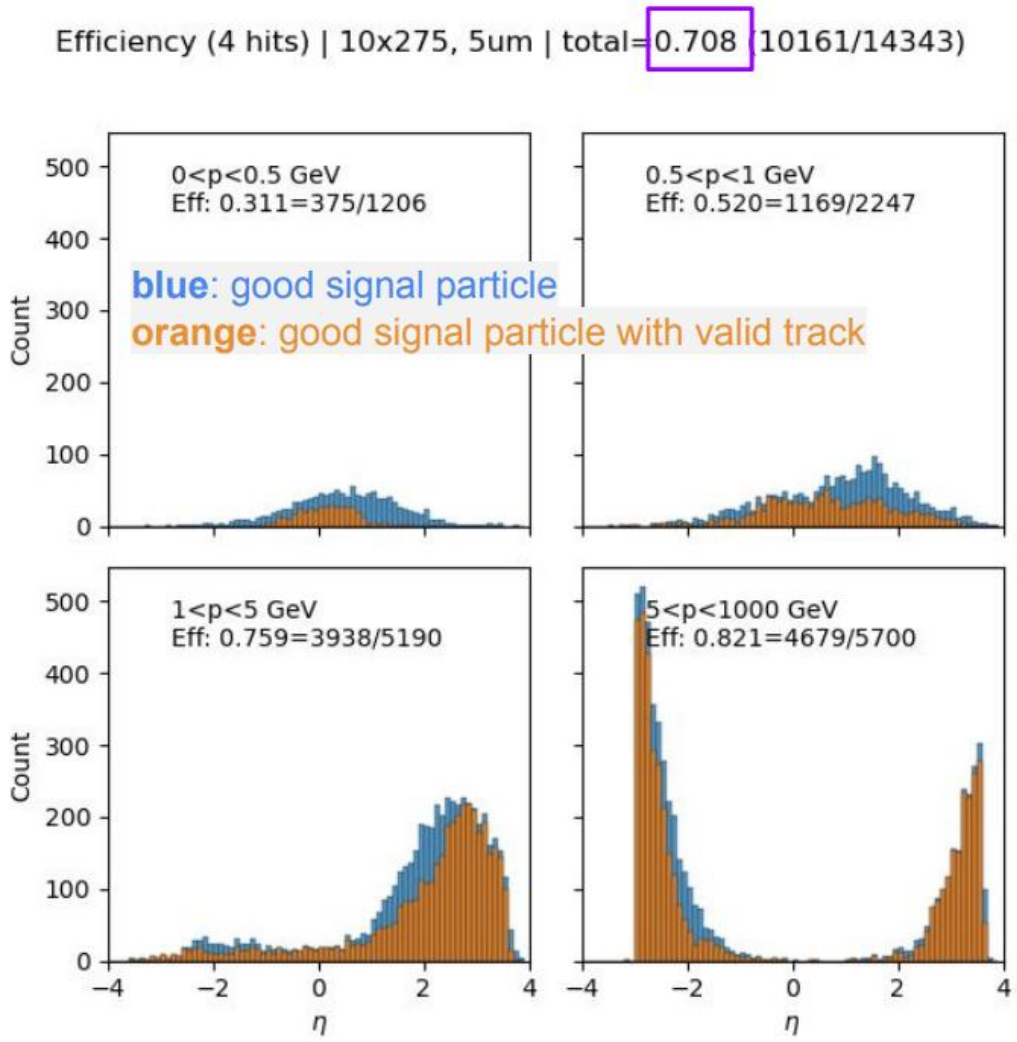
Tracking performance with all backgrounds: 5 um Au thickness

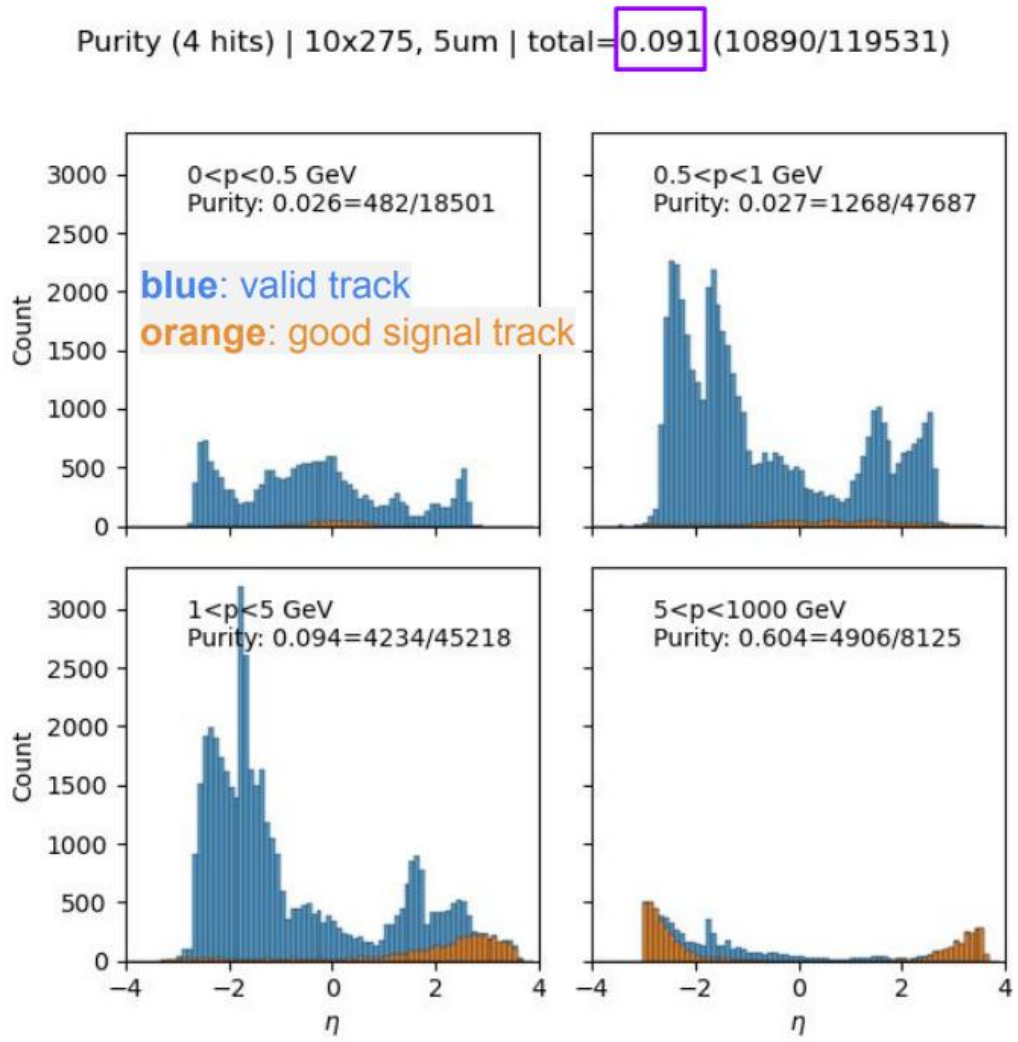
10x275, 5um gold coating, at least 5 hits per track: low efficiency, high purity



Tracking performance with all backgrounds: 5 um Au thickness

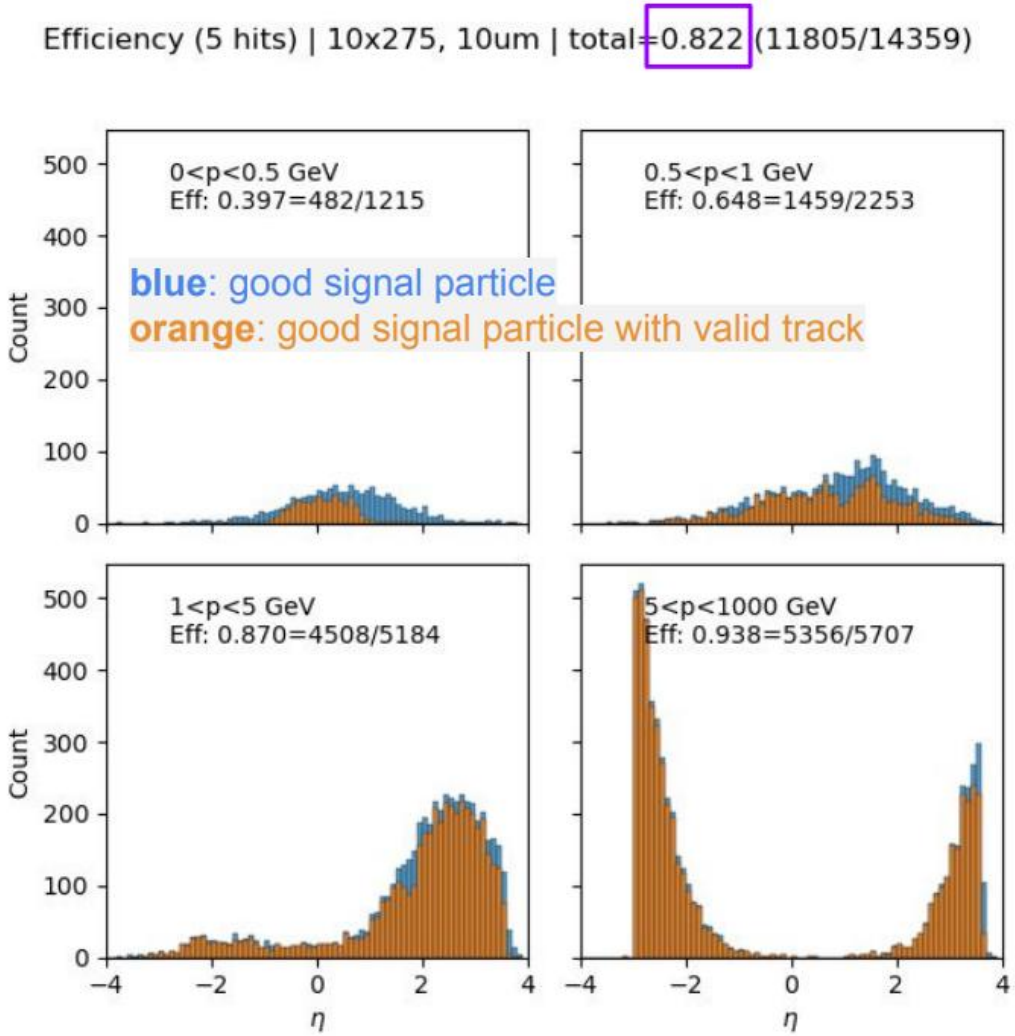
10x275, 5um gold coating, at least 4 hits per track: low efficiency, very low purity

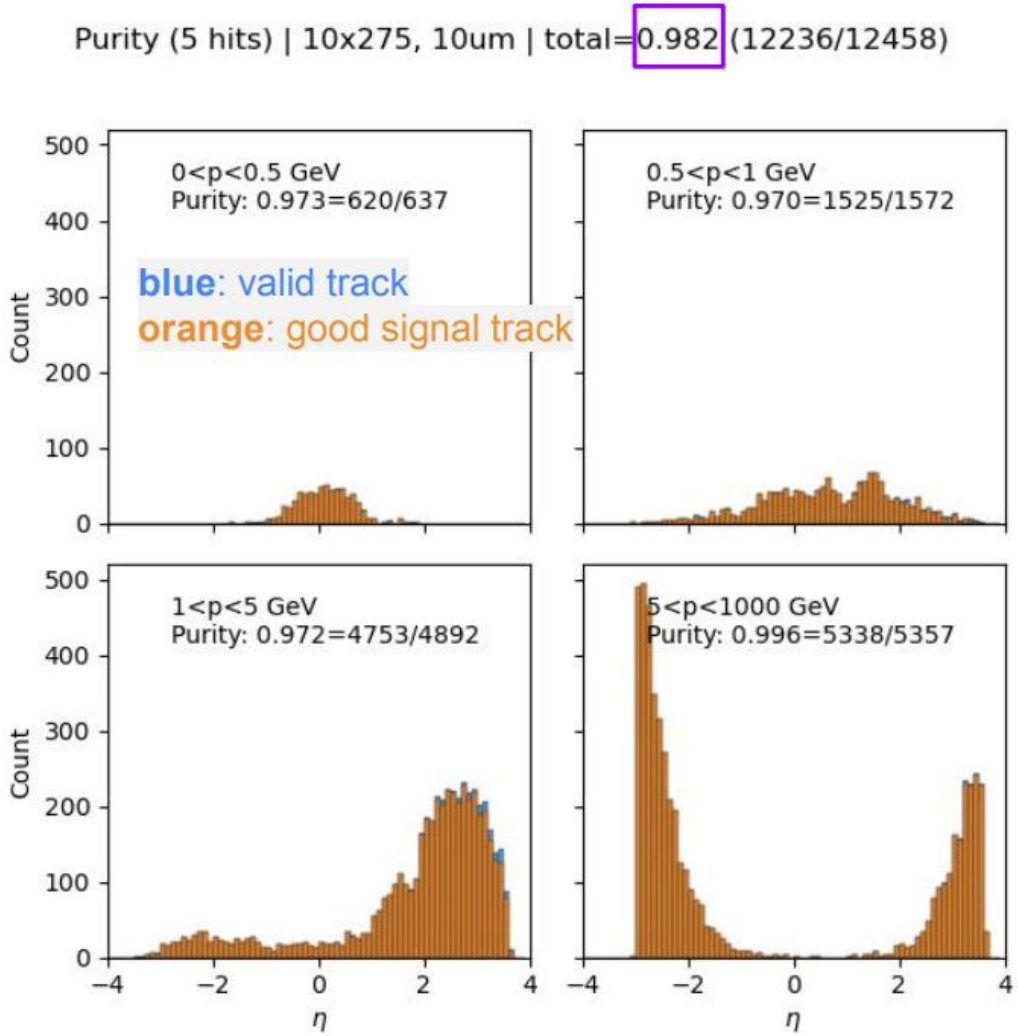




Tracking performance with all backgrounds: 10 um Au thickness

10x275, 10um gold coating, at least 5 hits per track: OK efficiency, high purity





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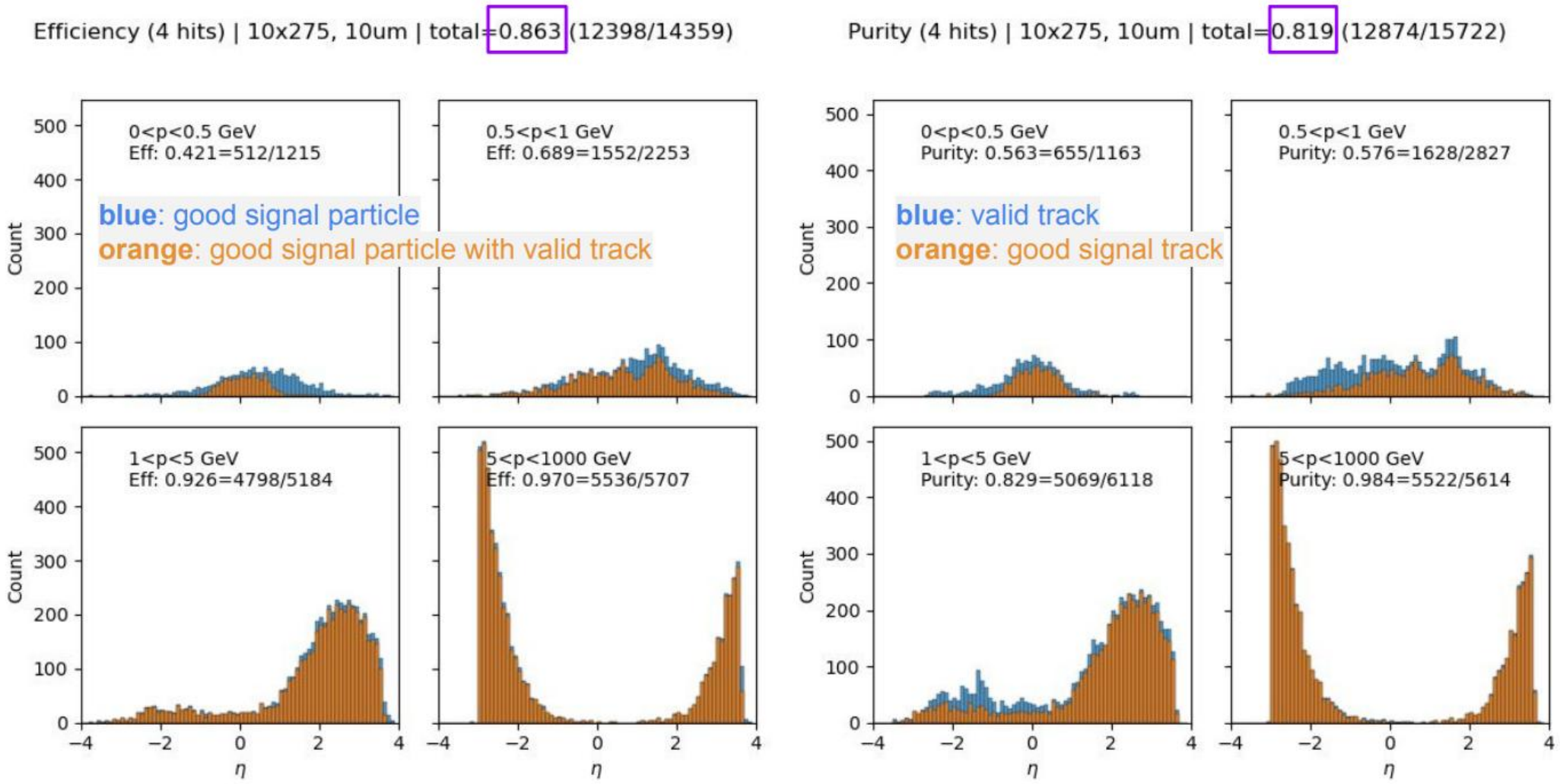

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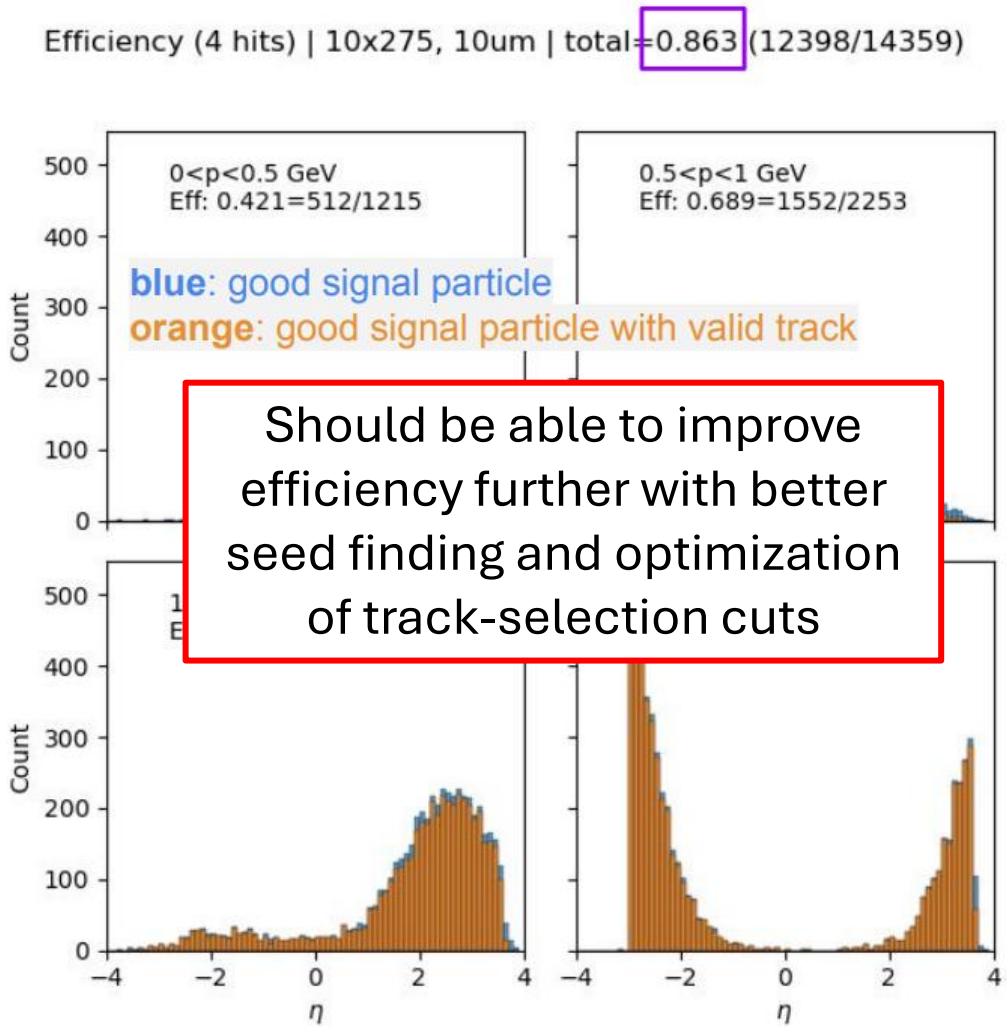
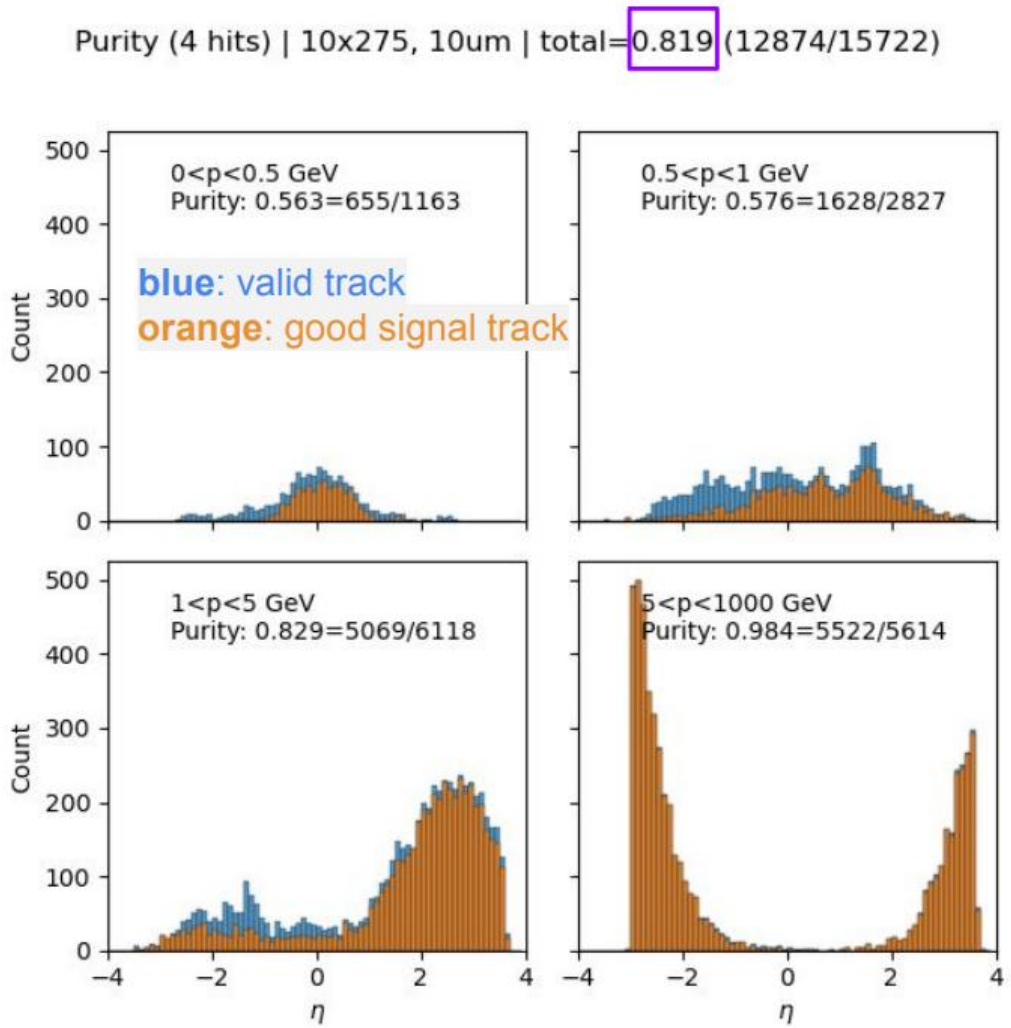


Should be able to improve efficiency further with better seed finding and optimization of track-selection cuts



Conclusions

- SR rate for photons escaping the beampipe decrease by a factor of about 3 when the Au coating is increased from 5 um to 10 um.
- SVT hit rates and data rates show a significant decrease with the 10-um coating.
- Impacts on single-particle pointing resolution and primary vertex resolution are modest.
- Track reconstruction performance for the 10 GeV electron beam setting in the presence of background is improved.
- Due to these studies, we will update the Au coating thickness from 5 um to 10 um.
- These changes have been made for the ongoing March simulation campaign:
  - Coating thickness in geometry: https://github.com/eic/epic/pull/1059
  - Update to Acts material map: https://github.com/eic/epic/pull/1060