Offline Calibration and Performance Monitoring of the PXD

PXD Workshop and 24th International Workshop on DEPFET Detectors and Applications

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HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

Belle II

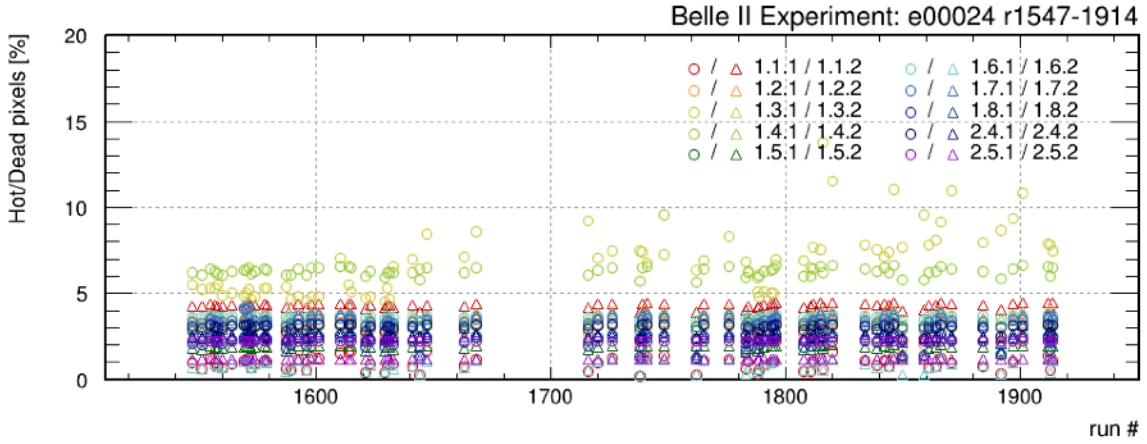
DEPFET Active Pixel Detector

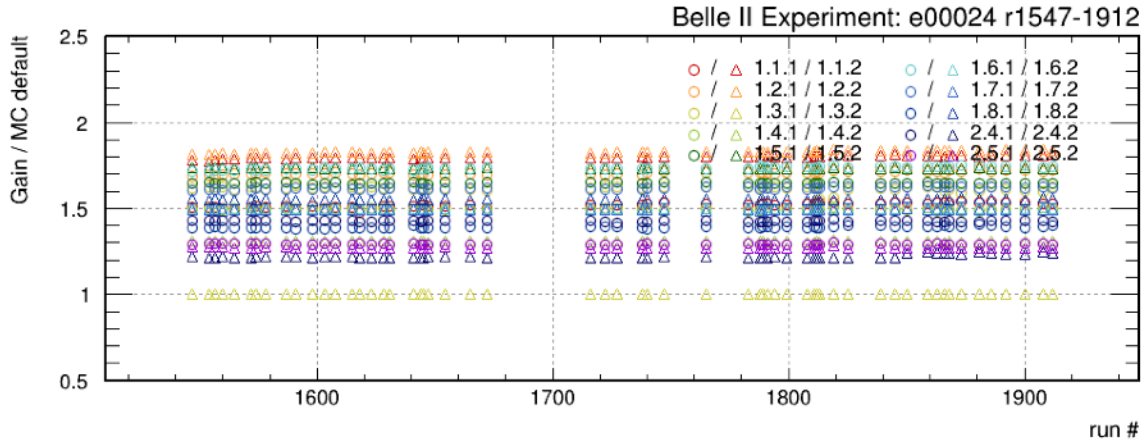
DESY.

PXD offline calibration

The current status

- Enabled calibrations:
  - Pixel masking to detect hot/dead pixels
  - Gain calibration to estimate relative Gq
    - 24 regions per module: pixels controlled by the same ASICs (switcher, DCD and DHP)
- The current status
  - Proc13 is still ongoing
    - Chunk 1 (exp. 7, 8, 10) : done
    - Chunk 2 (exp. 12) : done
    - Chunk 3 (exp. 14) : to be started
    - Chunk 4 (exp. 16) :
    - Chunk 5 (exp. 17) :
    - Chunk 6 (exp. 18) :
  - Prompt 32 (run 1547-1916 exp. 24): just finished



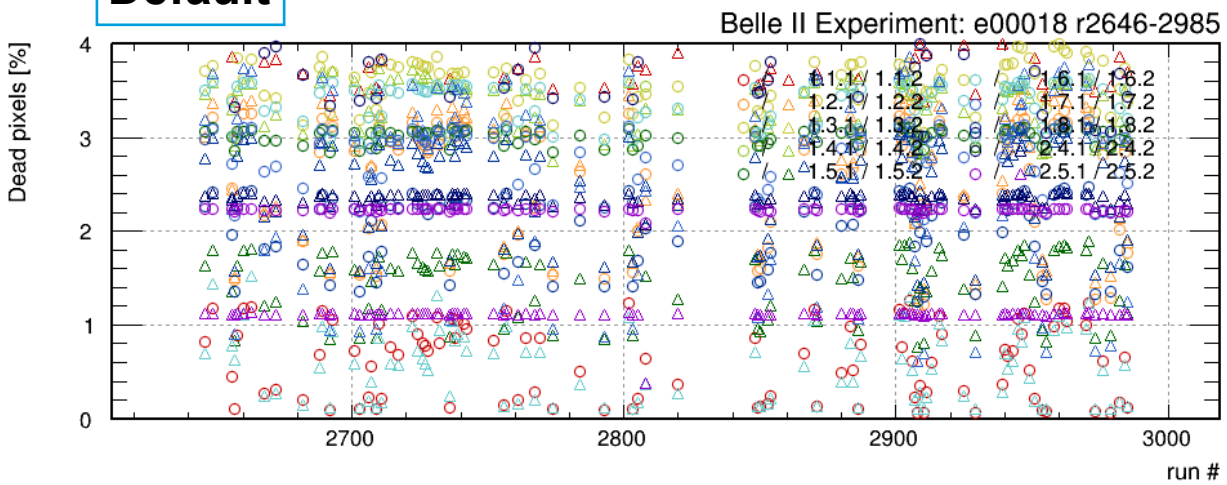


PXD offline calibration

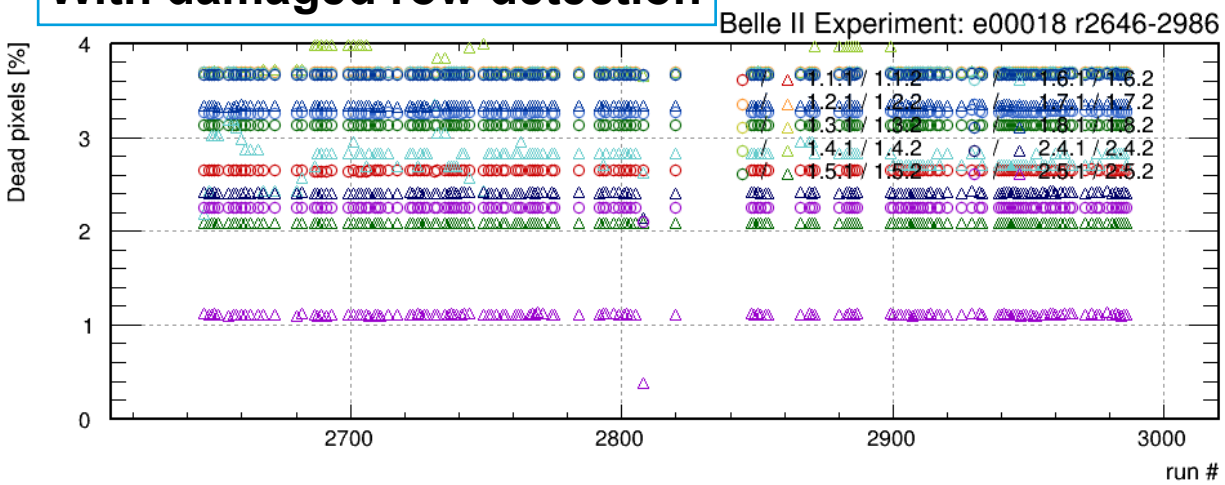
Issues

- Issues:
  - Almost no good runs in experiment 7 and 8
    - Calibrations stuck if using recoverable runs
      - No statistics for too many runs: empty events from unpacker
    - Robust dead pixel detection is still to be implemented
      - Basic ideas have been studied and validated with s-proc2

Default



With damaged row detection

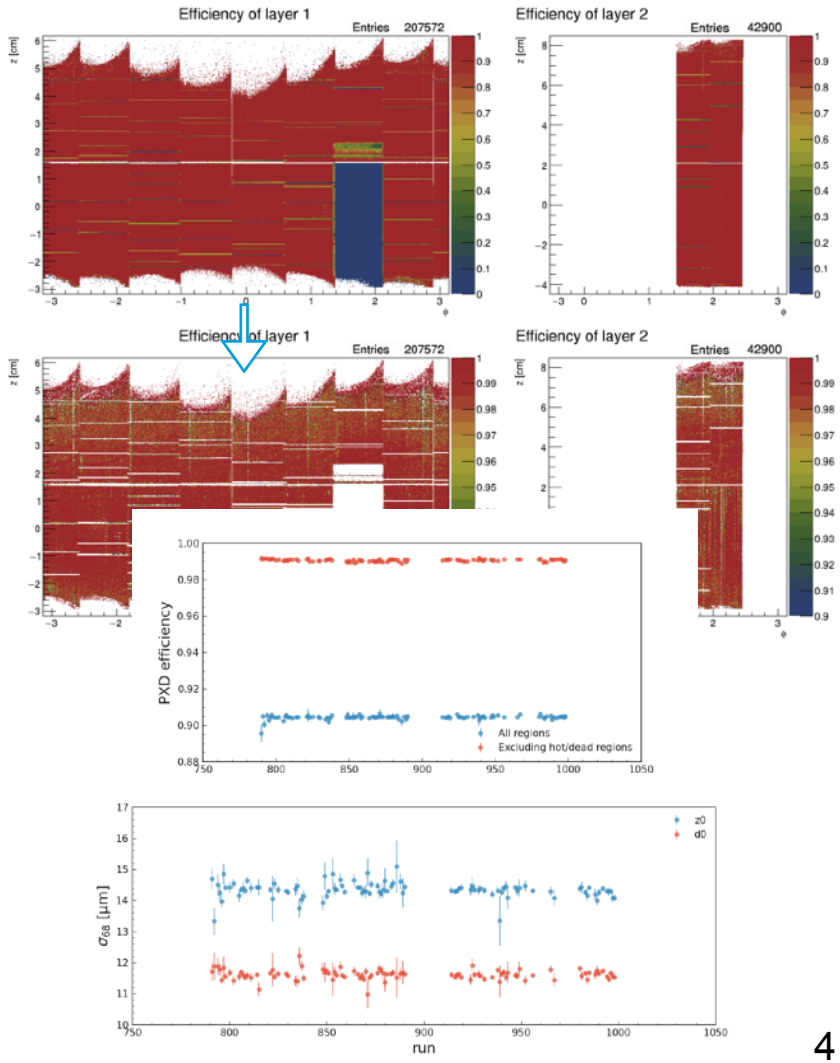


Performance monitoring

The current status

bucket30

- What's already implemented in basf2
  - Based on Airflow+CAF (calibration analysis framework)
    - Using cDSTs (calibration Data Summary Table)
  - Served as validation for the PXD and its related calibrations
  - Attached to PXD gain calibration with variables for performance studies collected
    - PXD detection ⊕ hit finding efficiency
      - # of track intersection and # of matched PXD hits in predefined regions (z-phi)
      - Powerful to find hit finding issues, e.g. inefficiency patterns of PXD overlap regions in the past, and new ones?
    - d0/z0 resolutions
      - : 1-D histograms of $\Delta d_0/\sqrt{2}$ and $\Delta Z_0/\sqrt{2}$ of HLT Bhabha skim.
        - Using selections from the 2019 Belle II note → only the forward part of backward module is covered
          - $|\lambda|$ < 0.5 and p_t > 1 GeV



Performance monitoring

The missing part

- Spatial resolution of the PXD in z-phi bins → long term plan
  - Hope to work with cDST and doesn't repeat tracking
  - Track states before using PXD hits are probably good enough
    - Also help to tune PXD CKF ?
- d0/z0 resolution vs pseudo-momentum: 2-D histograms → **preliminary studies** in this talk

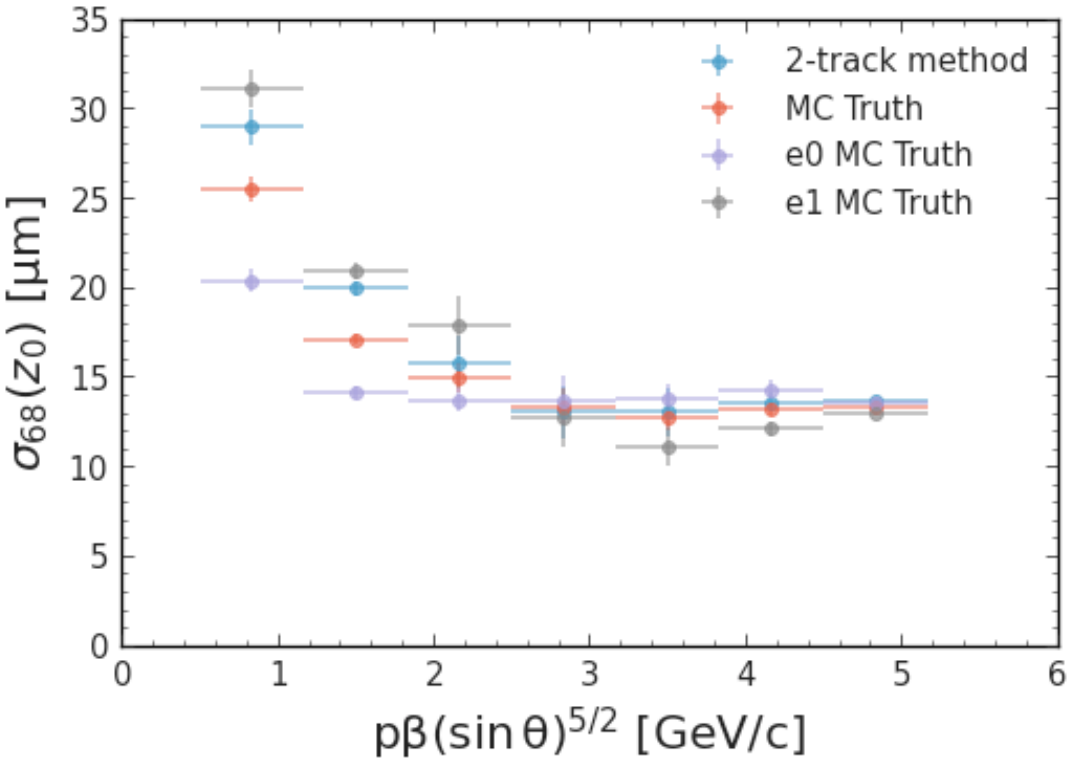
Performance monitoring

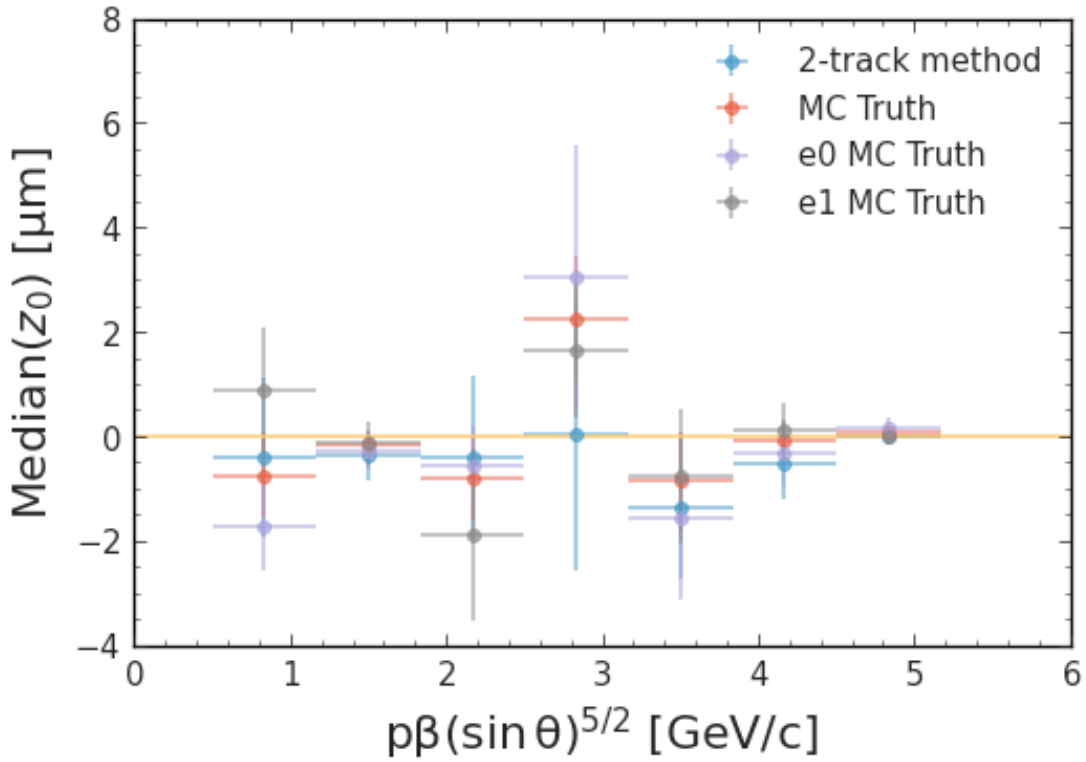
Validation of the 2-track method with MC (Bhabha skim and mumu_tight skim)

- Selections
  - nCDCHits>20, nSVDHits>=8, nPXDHits>=1, dr<0.3 cm, abs(dz) < 1.0 cm
  - Requiring PXD Layer1 hit (firstPXDLayer==1)
  - 9.5 < InvM < 11.5 GeV for better resolution at low pseudo-momentum
  - P > 2 GeV for Bhabha and > 3 GeV for di-muon
- Methods used to estimate d0/z0 resolutions vs pseudo-momentum
  - **2-track Method**: estimate with $\Delta d_0(z_0)/\sqrt{2}$, no MC true info used, d0/z0 corrected with IP
    - Requiring both tracks have pseudo-momentum in the same bin.
  - **MC Truth**: estimate resolutions with true d0/z0, not corrected with IP
    - e^+ (μ^+) and e^-(μ^-) are mixed in this case
  - **e0 (mu0) MC Truth**: similar to the second method, and only use e^+(μ^+)
  - **e1 (mu1) MC Truth**: similar to the second method, and only use e^-(μ^-)

Revisit the back-to-back 2-track method

Validation with Bhabha MC14ri_a

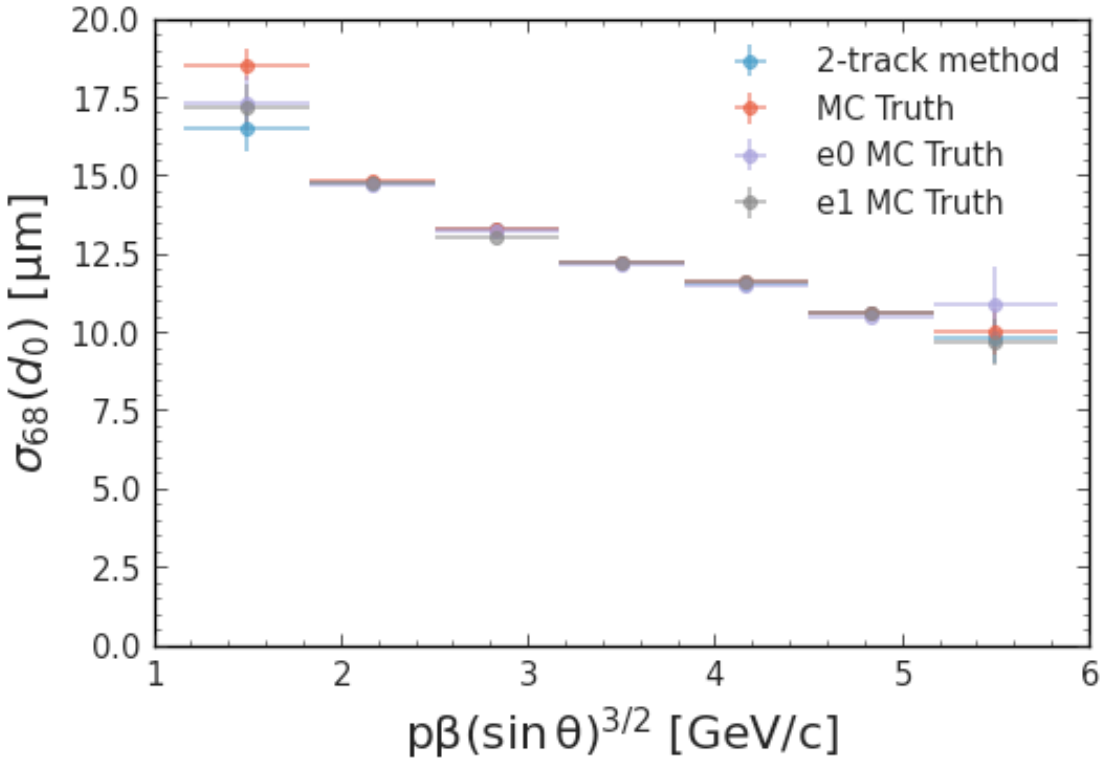




e^+ and e^- show different dependence
2-track method underestimates z0 resolution compared with **MC Truth** when $p\beta(\sin\theta)^{5/2} < 2$

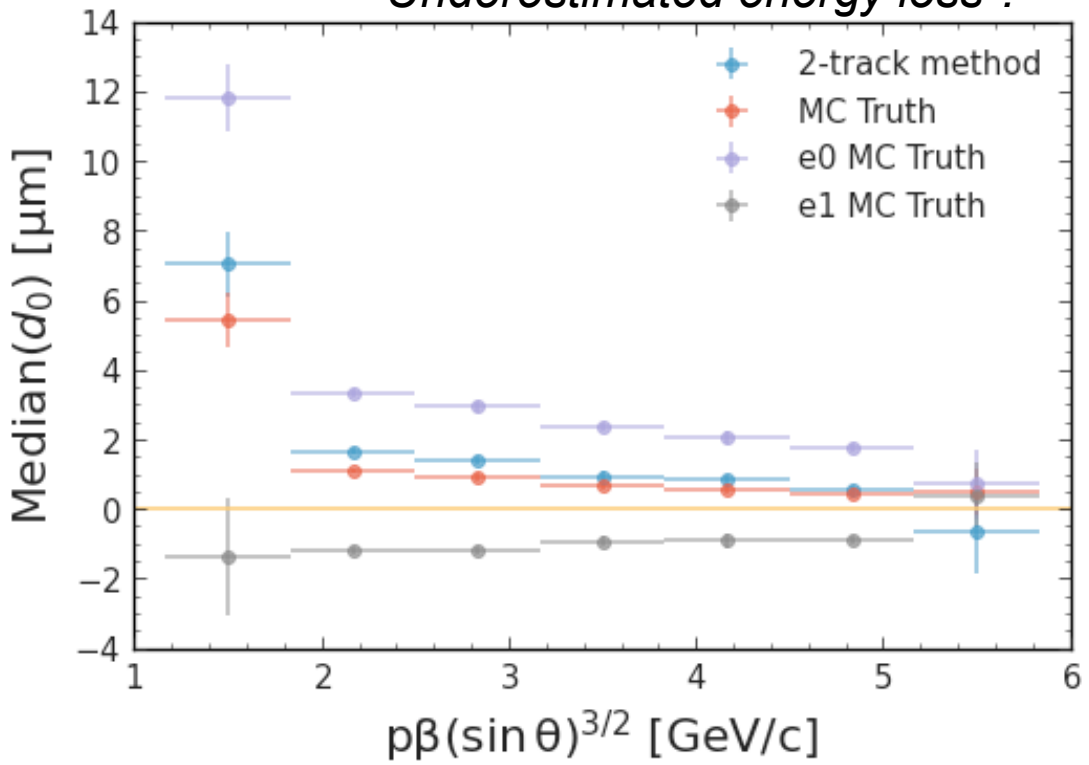
Revisit the back-to-back 2-track method

Validation with Bhabha MC14ri_a



All methods agree with each other for d0 resolution

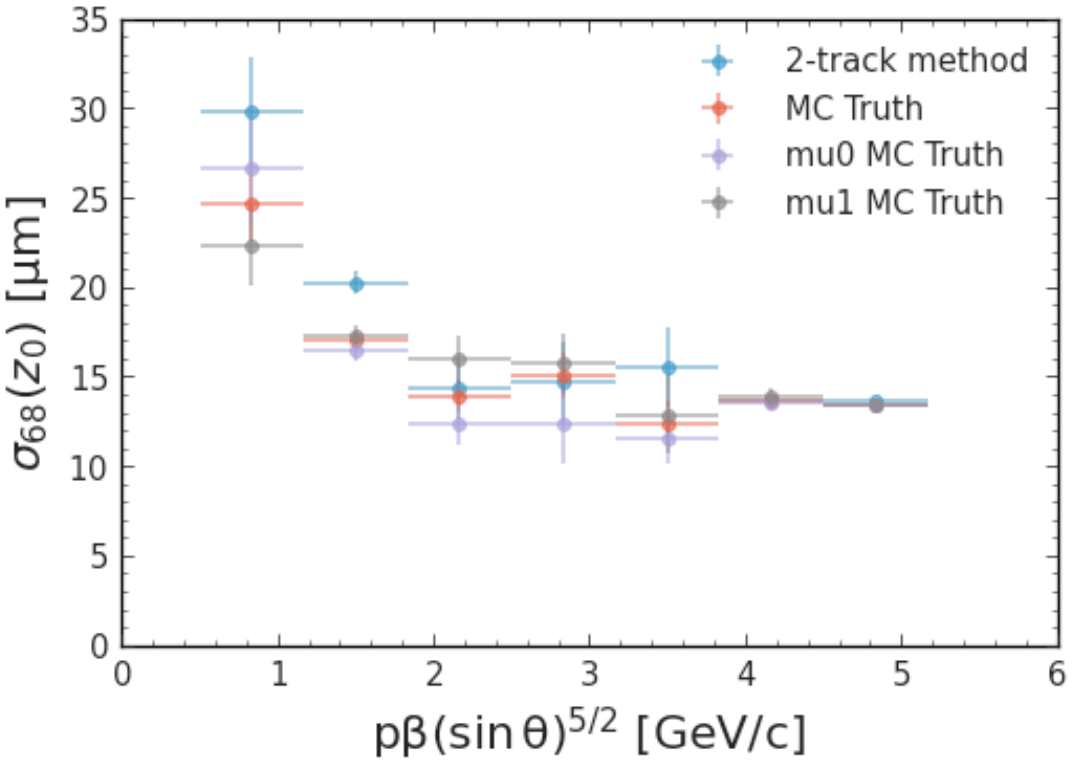
Underestimated energy loss ?

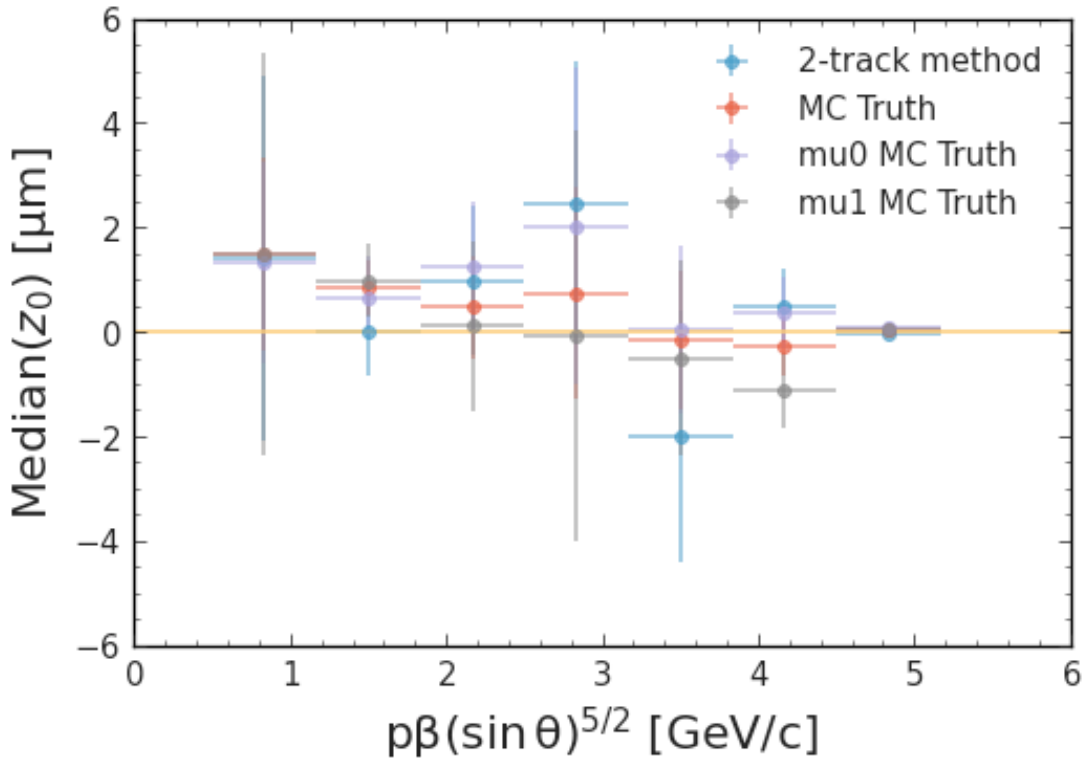


Bias observed for all regions, decreasing as $p\beta(\sin\theta)^{3/2}$ increases
e+ and e- are biased in the opposite direction

Revisit the back-to-back 2-track method

Validation with dimu of MC14ri_a



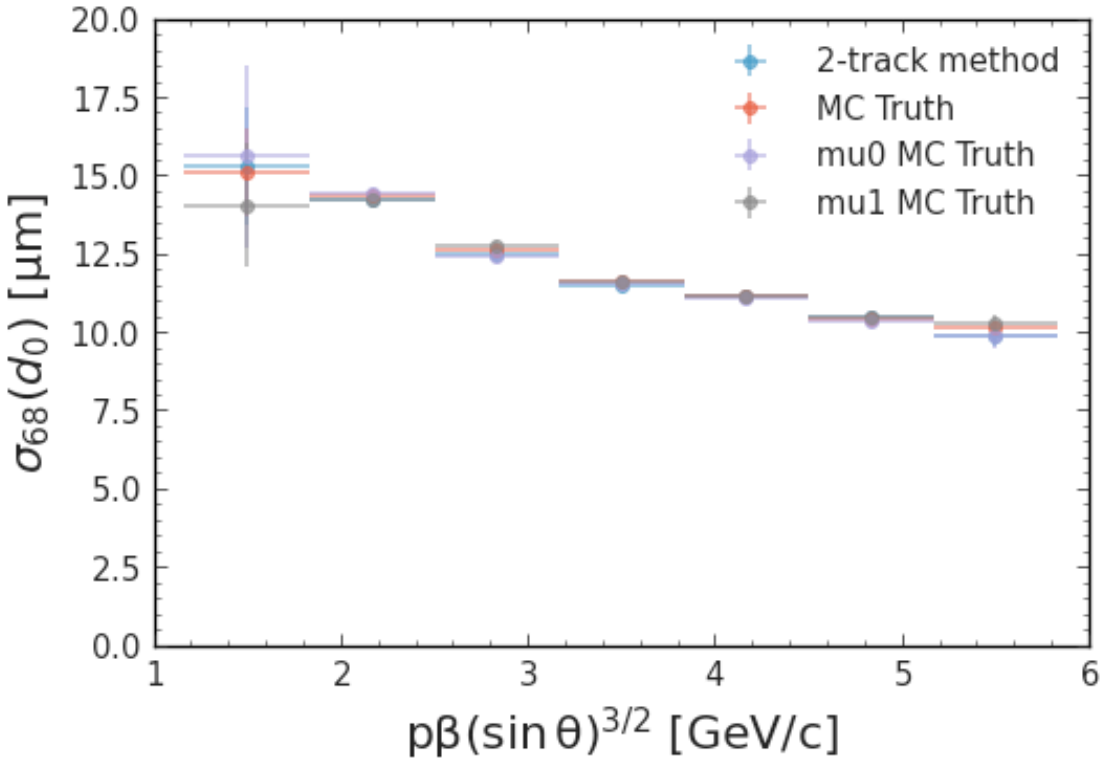


Better agreement between μ^+ and μ^-

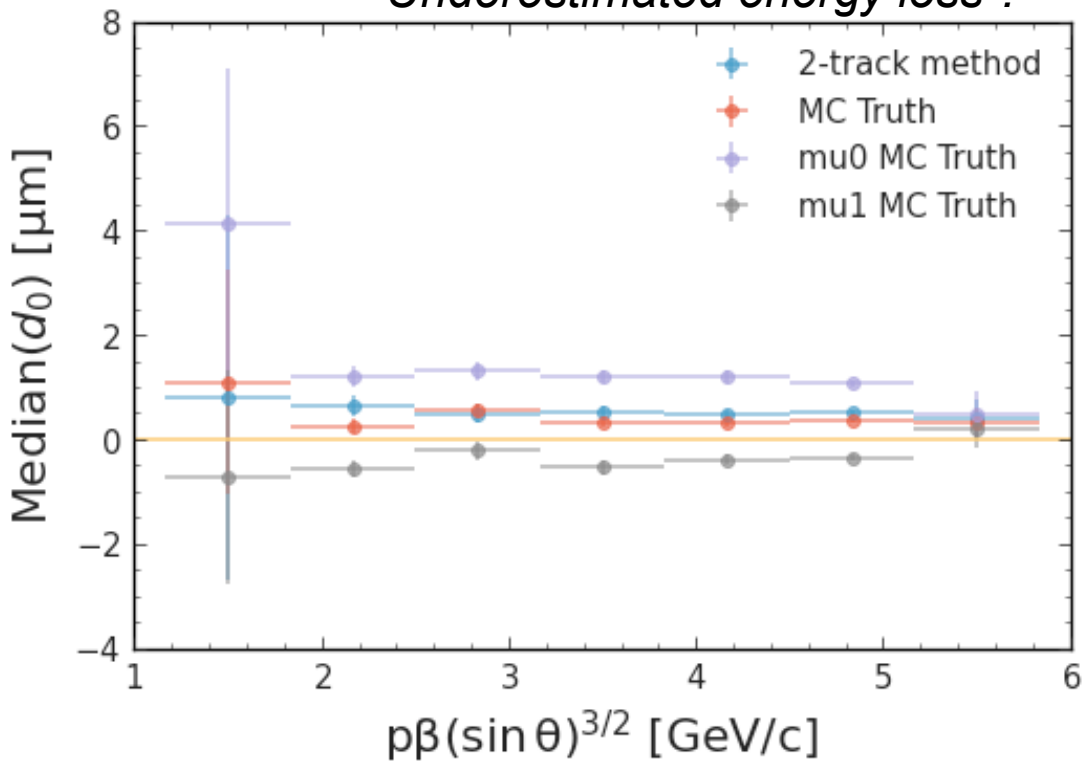
2-track method underestimates z0 resolution compared with **MC Truth** when $p\beta(\sin\theta)^{5/2} < 2$ as in Bhabha

Revisit the back-to-back 2-track method

Validation with dimu of MC14ri_a



Underestimated energy loss ?

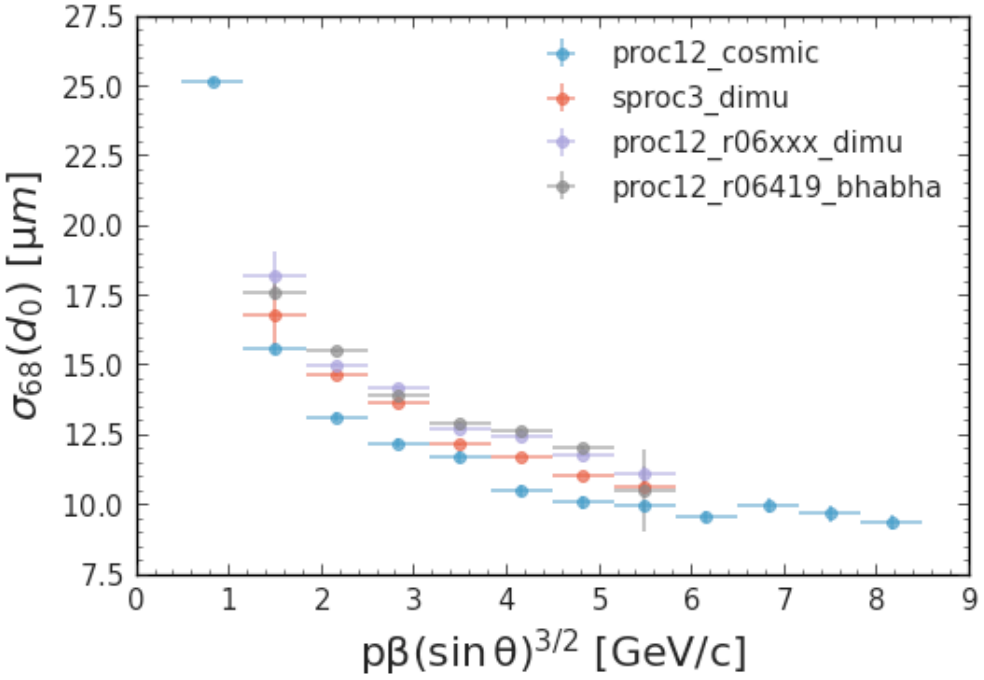


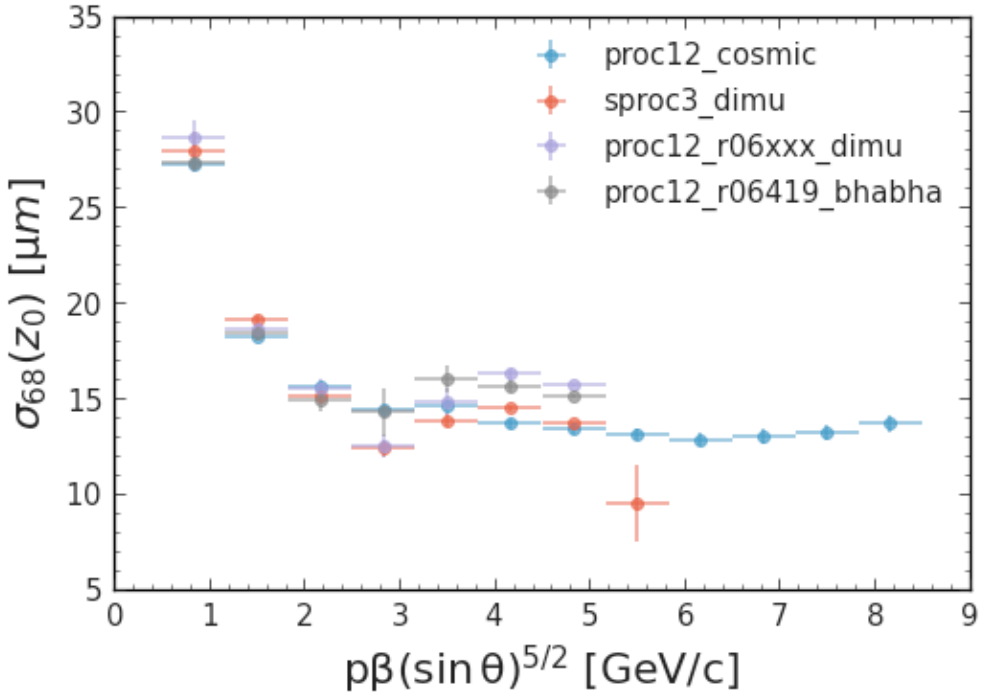
All methods agree with each other for d0 resolution

Similar bias as in Bhabha but the charge asymmetry is smaller than that in Bhabha

d0/z0 resolution vs pseudo-momentum

Statistical error only



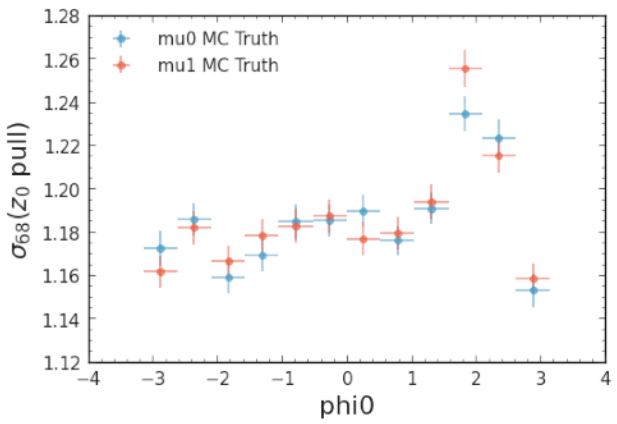


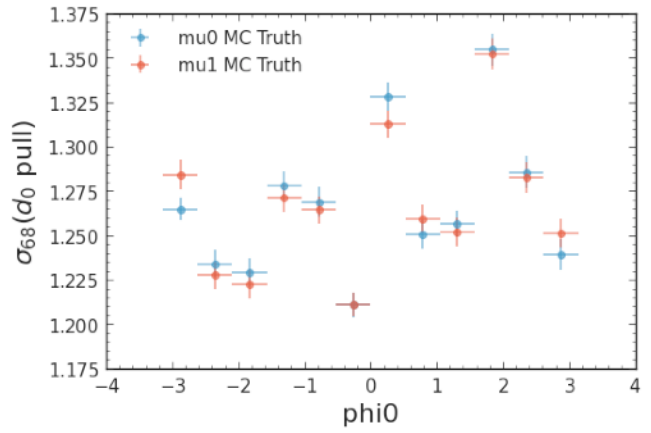
Cosmic selections: HLT cosmic, abs(d0) < 1.0 cm, -2.0 < z0 < 4.0 cm, no InvM and momentum cut

- The 2-track method works quite well for d0 and will underestimate z0 resolutions
- Results from Bhabha and di-muon are consistent and are slightly worse than from the cosmic

Summary

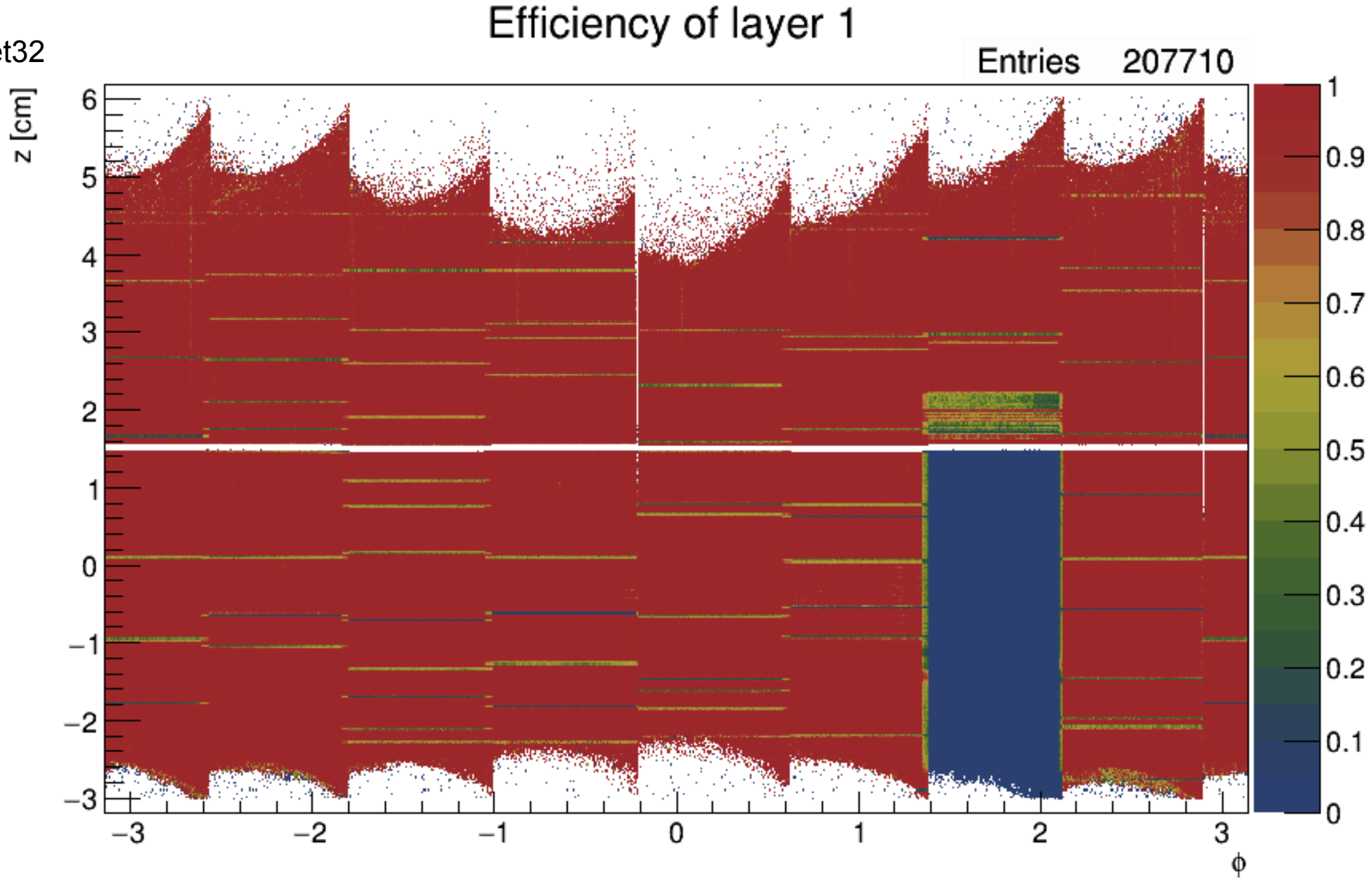
- Lack of person power as all the other tasks: < 0.5 person
- Current offline calibration algorithms work fine
  - Need reliable run quality flags in experiment 7 and 8 (not only PXD flags)
  - Feature to detect pixels from damaged switcher gates is to be finalised
- Performance monitoring has been automatised and has been used to find issues from tracking
  - d0/z0 resolution vs pseudo-momentum is ready to be implemented
  - A lot of issues in tracking has been found by the pull study of d0/z0 with the MC samples
    - Issues in PXD hit reconstruction
      - Bias of hit position
      - Underestimated hit errors?



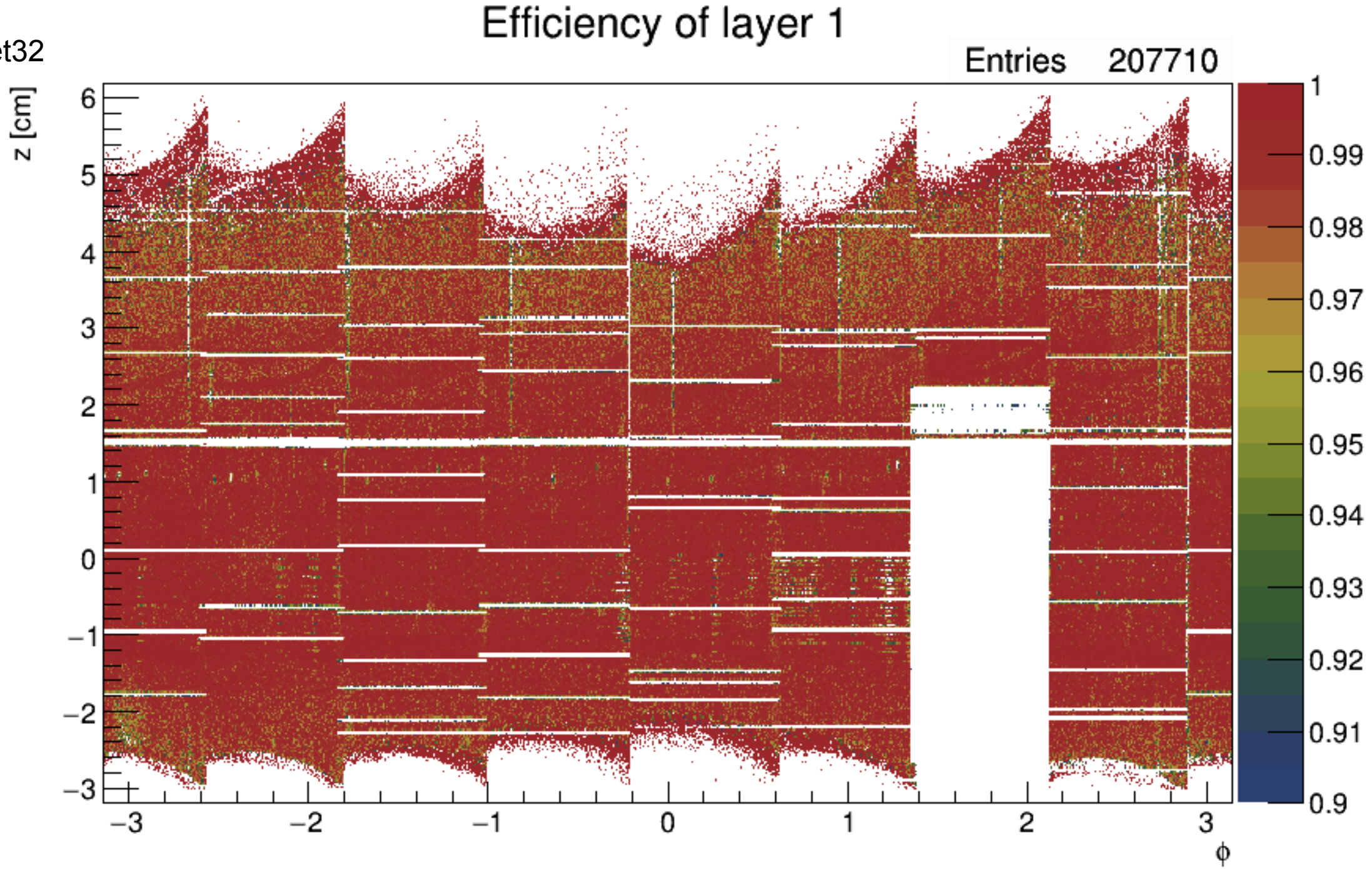


Thank you !

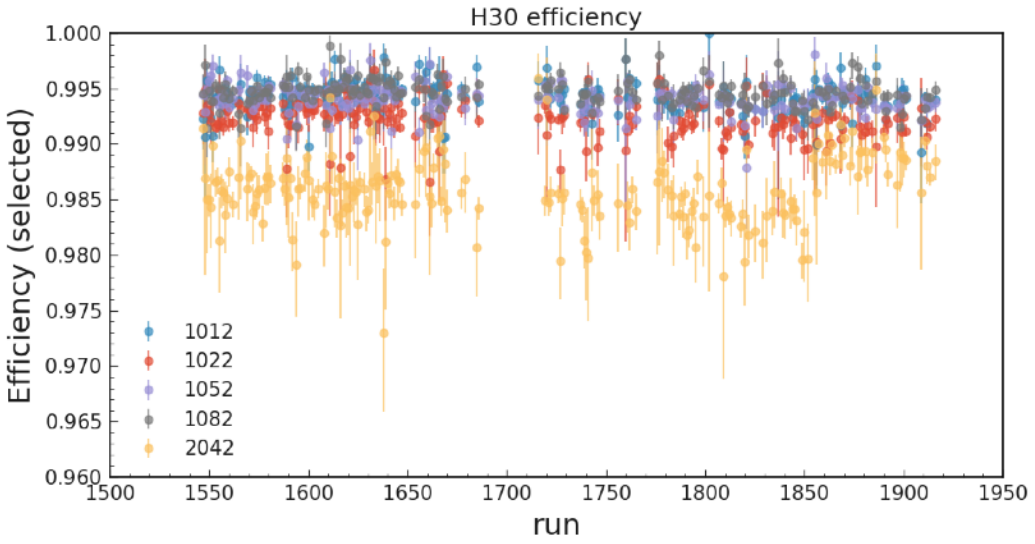
Bucket32

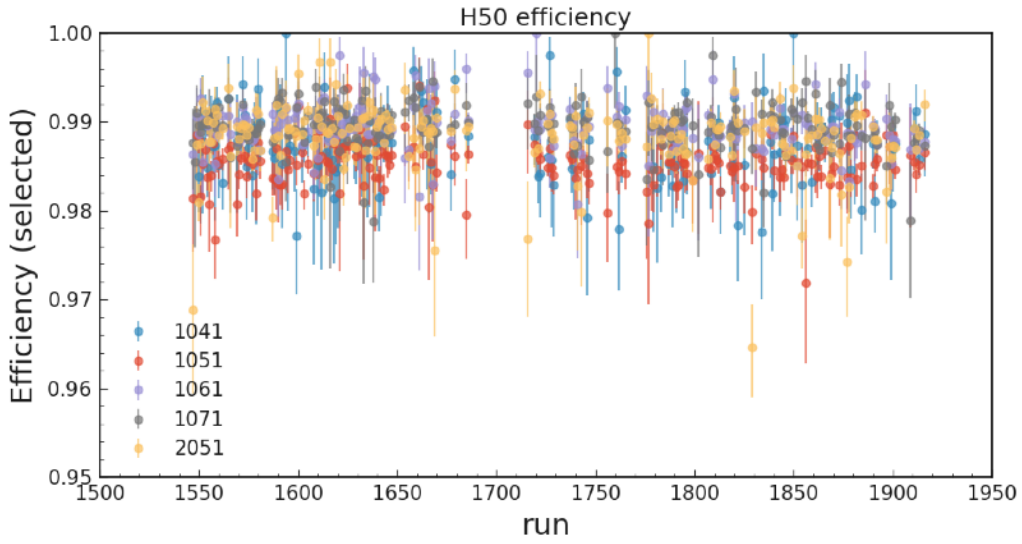

Efficiency of layer 1
Entries 207710
z [cm]
6
5
4
3
2
1
0
−1
−2
−3
−3
−2
−1
0
1
2
3
ϕ
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0

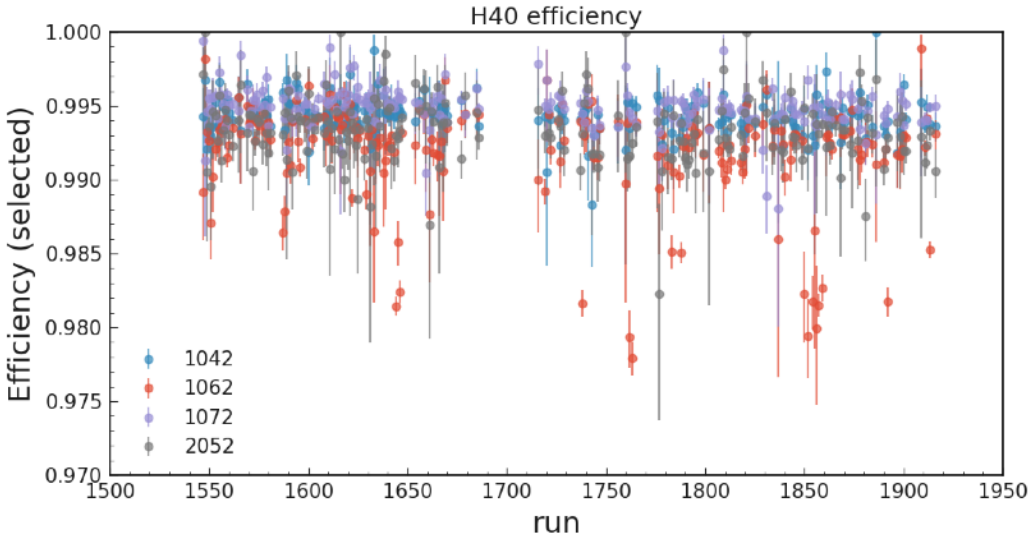
Bucket32

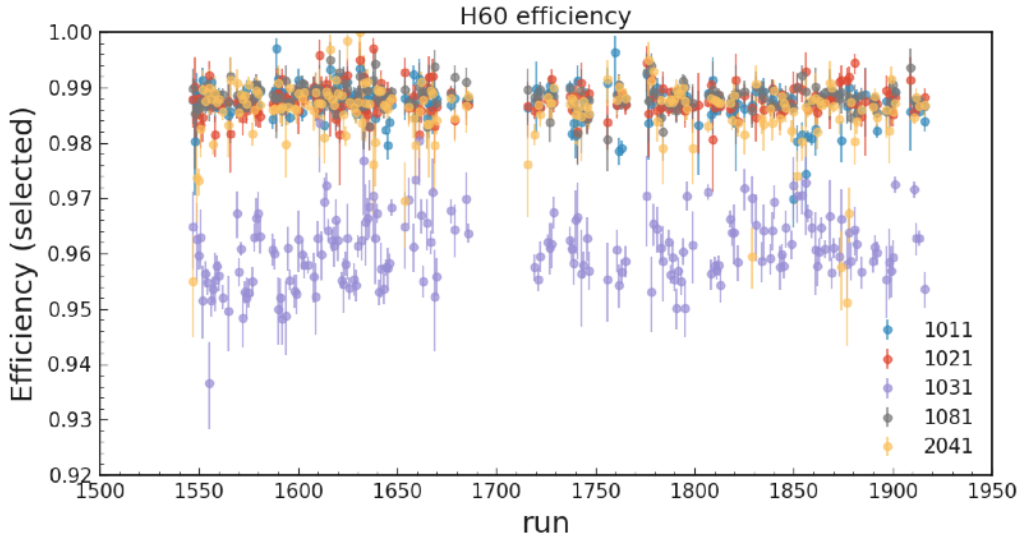

Efficiency of layer 1
Entries 207710
z [cm]
6
5
4
3
2
1
0
−1
−2
−3
−3
−2
−1
0
1
2
3
ϕ
1
0.99
0.98
0.97
0.96
0.95
0.94
0.93
0.92
0.91
0.9

Bucket32


H30 efficiency
Efficiency (selected)
run
1012
1022
1052
1082
2042

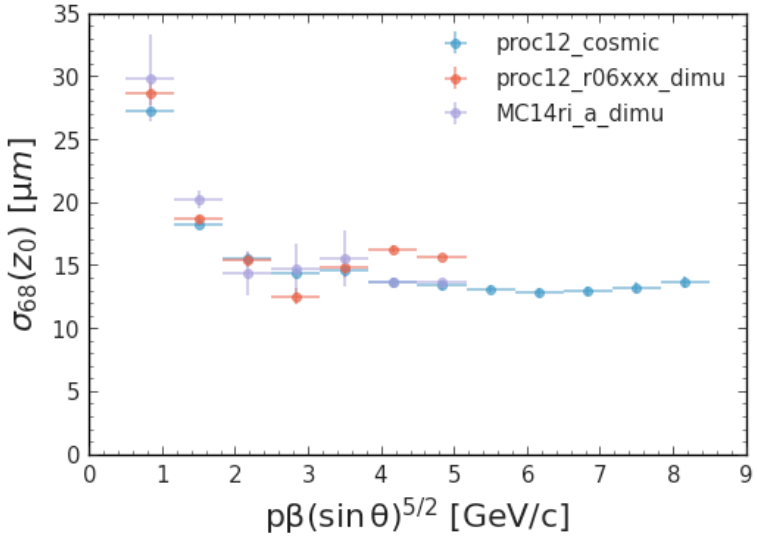

H50 efficiency
Efficiency (selected)
run
1041
1051
1061
1071
2051

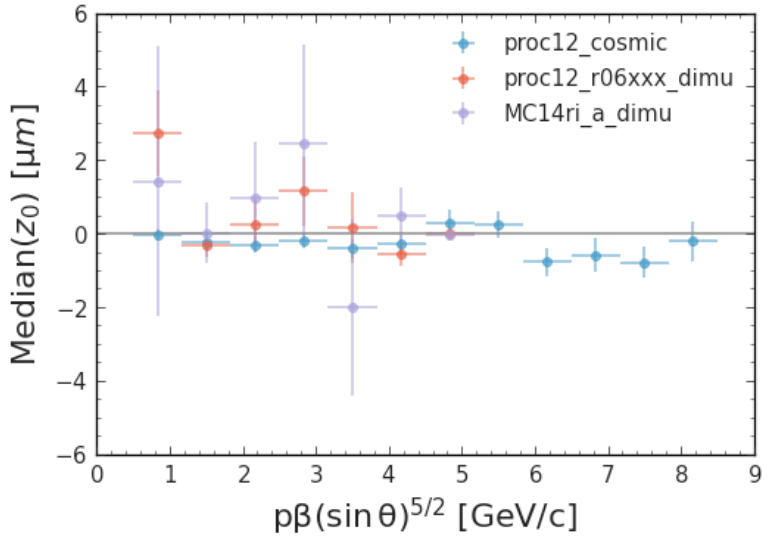

H40 efficiency
Efficiency (selected)
run
1042
1062
1072
2052

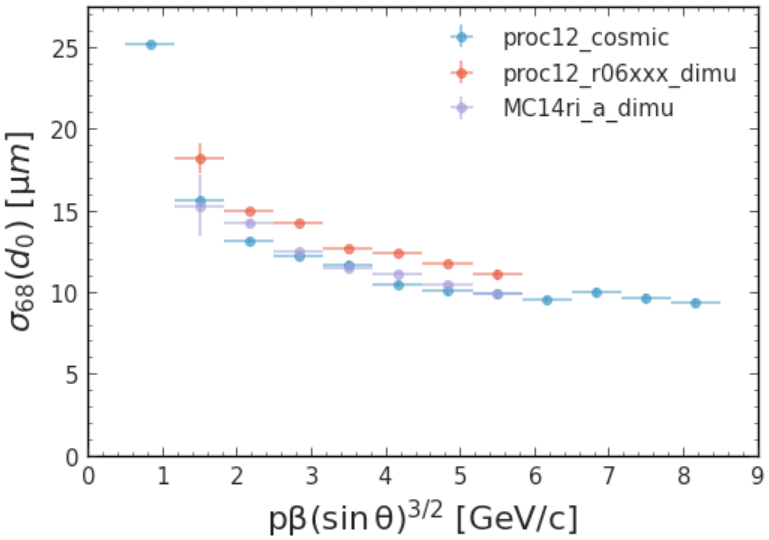

H60 efficiency
Efficiency (selected)
run
1011
1021
1031
1081
2041

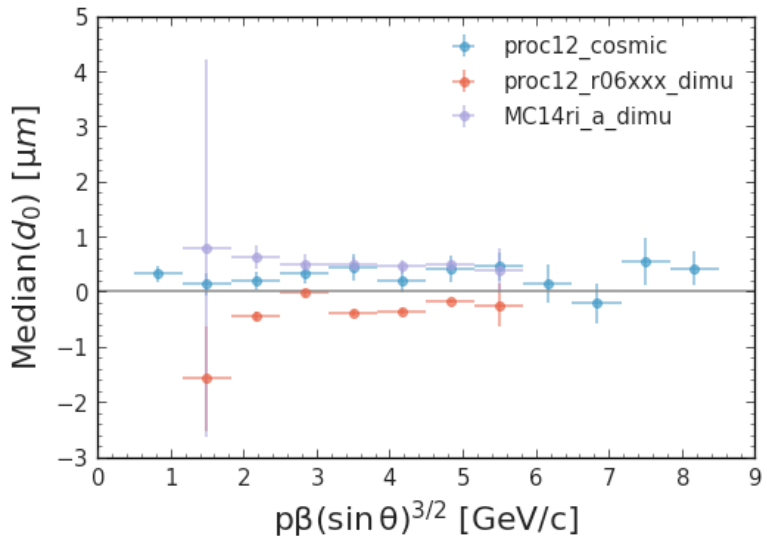
d0/z0 resolution vs pseudo-momentum

Di-muons including cosmic





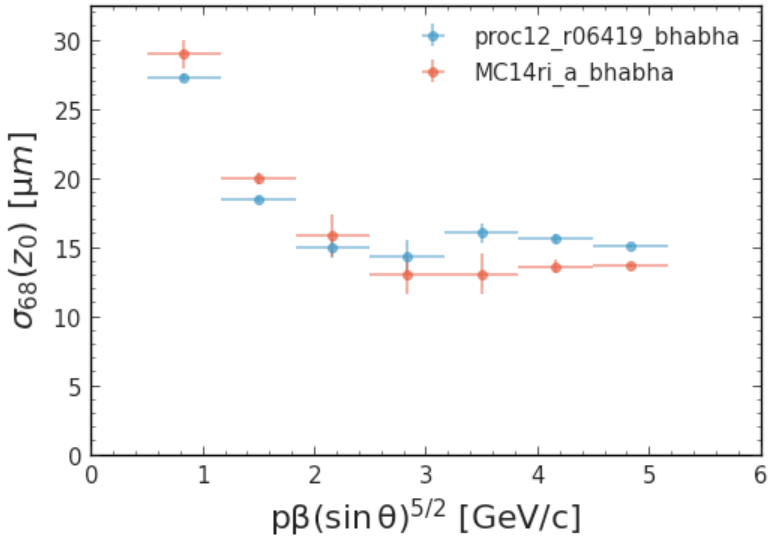


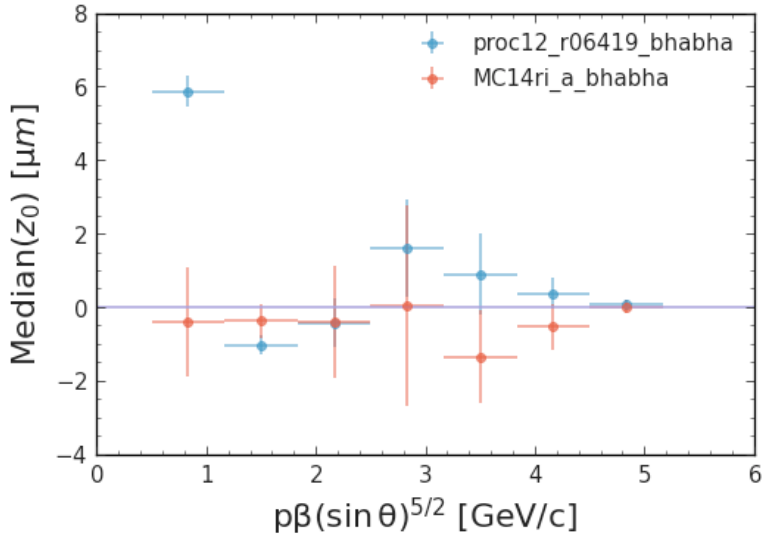


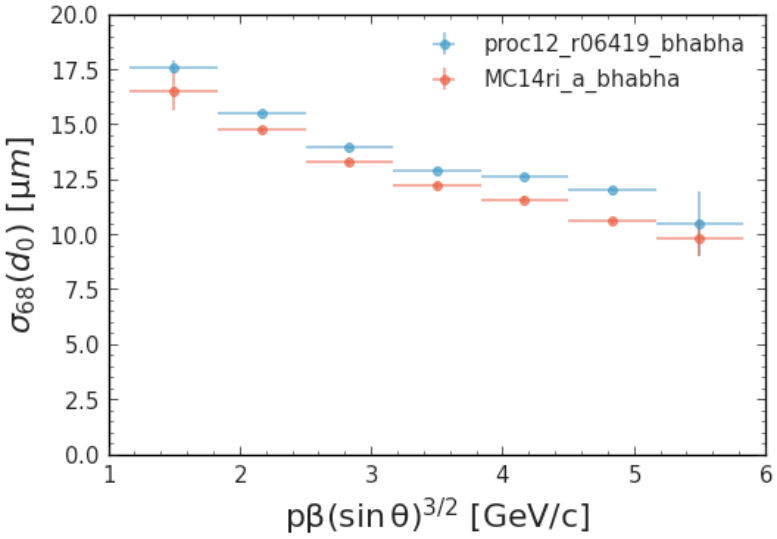
d0/z0 resolution vs pseudo-momentum

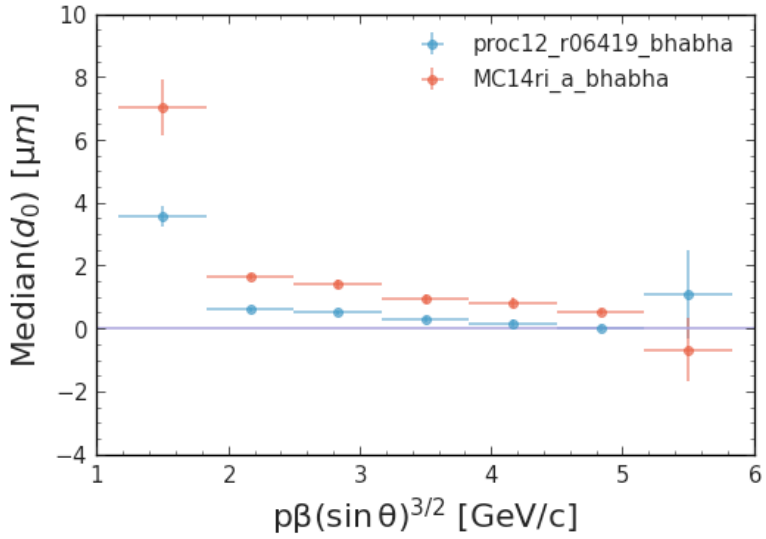
Bhabha

Statistical error only



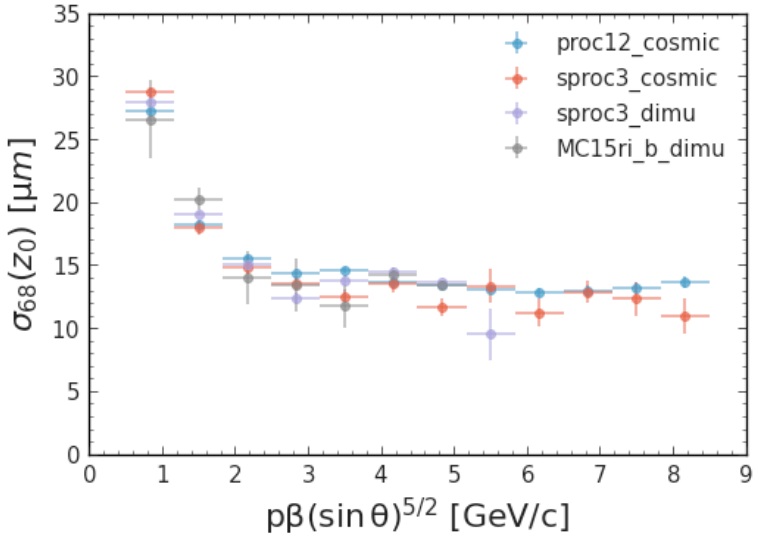


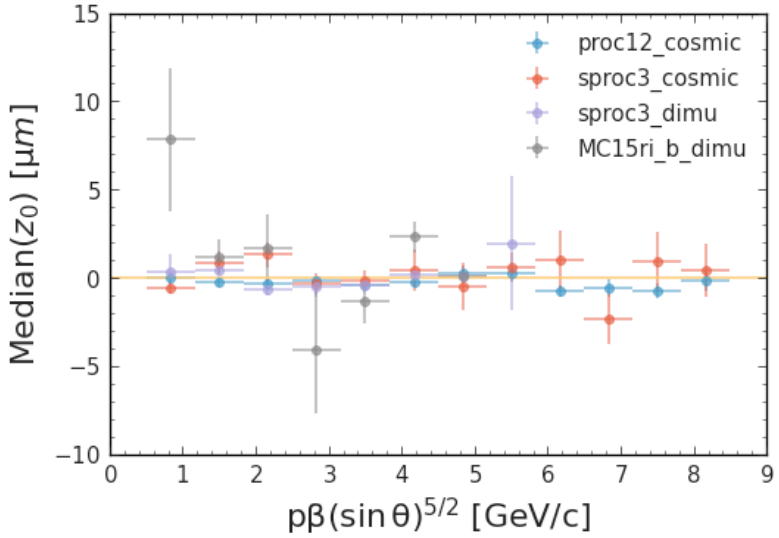


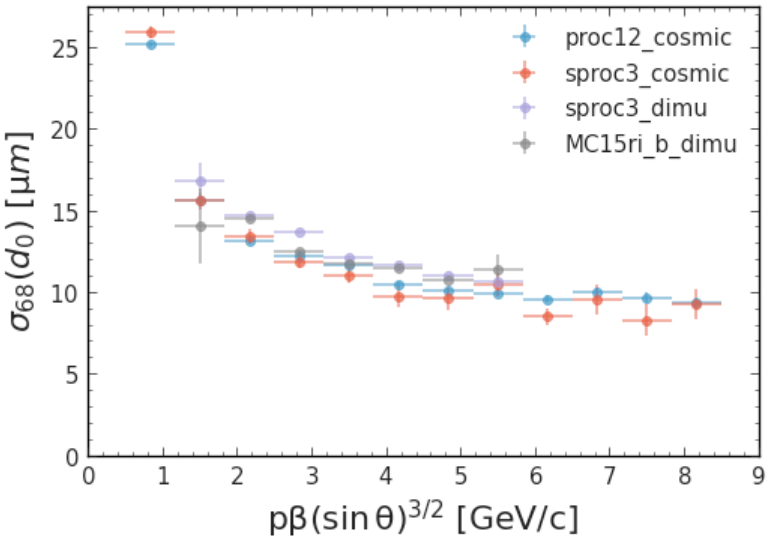


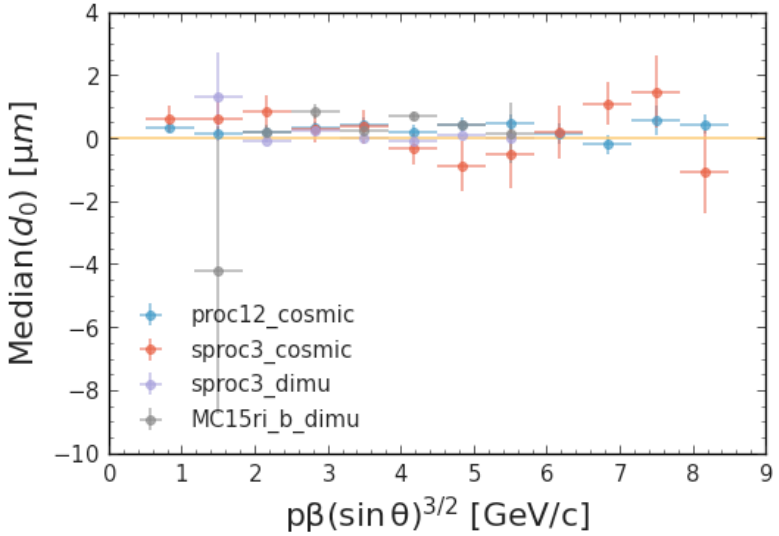
d0/z0 resolution vs pseudo-momentum

Di-muons including cosmic







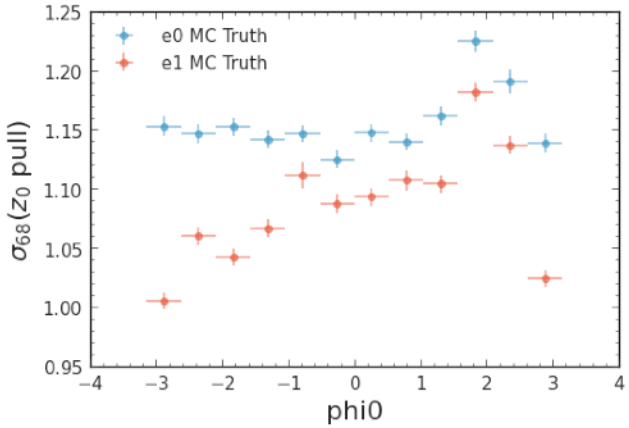


Better performance and data MC agreement with release-06 ?

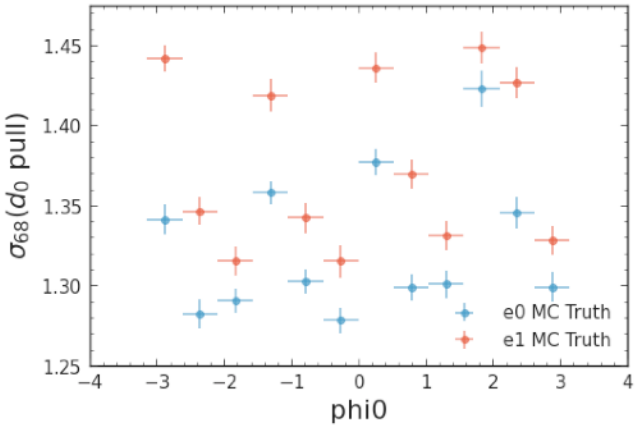
Check the pull vs variables w/o constraint of the same pseudo-p bin

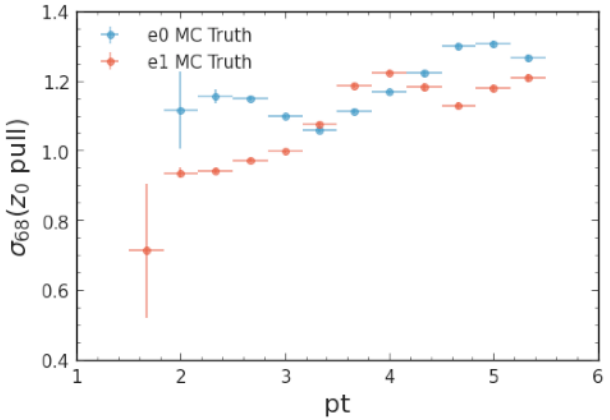
Validation with Bhabha MC14ri_a

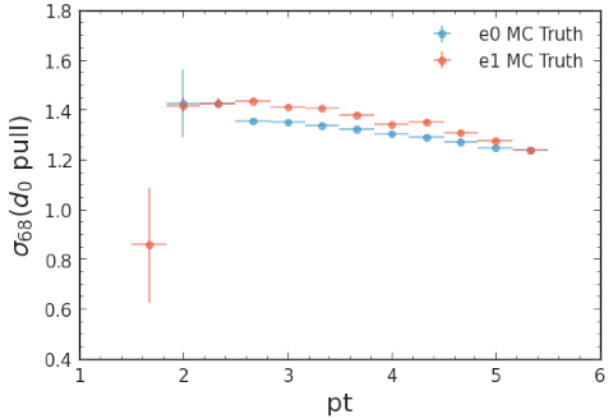
- What fit hypotheses used for e^+ and e^- by default? Still Pions? Repeat the study with IP corrected d0/z0?
  - Cannot explain all these results
  - More plots in backup slides
  - Interesting ones here:

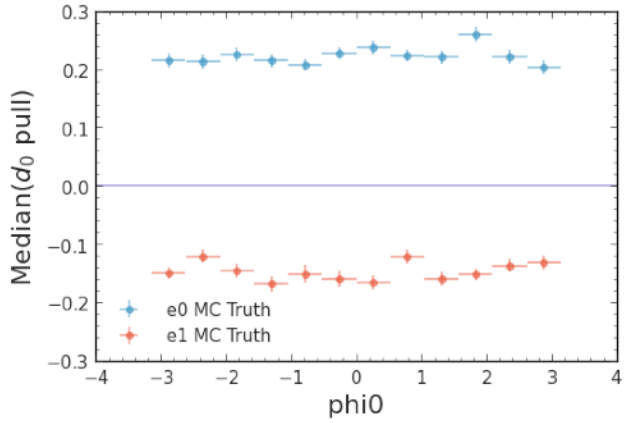


Effect of more materials in layer 2 ?
Hit error in PXD is too small?



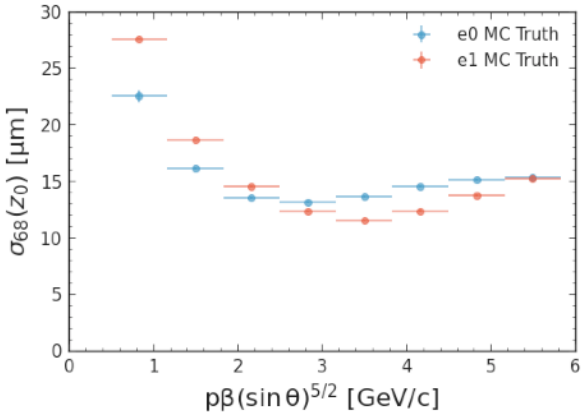


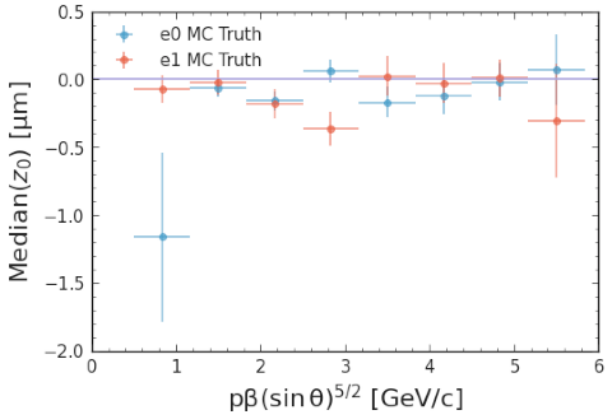


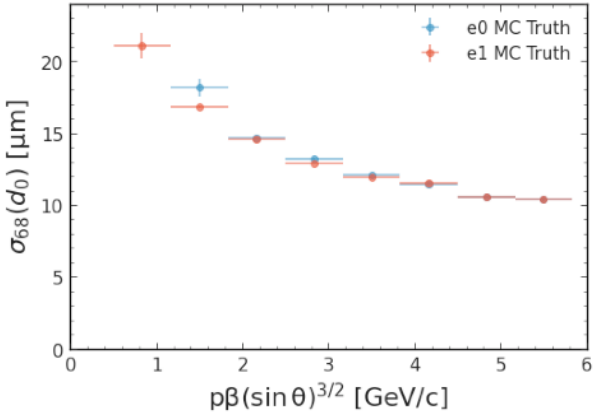


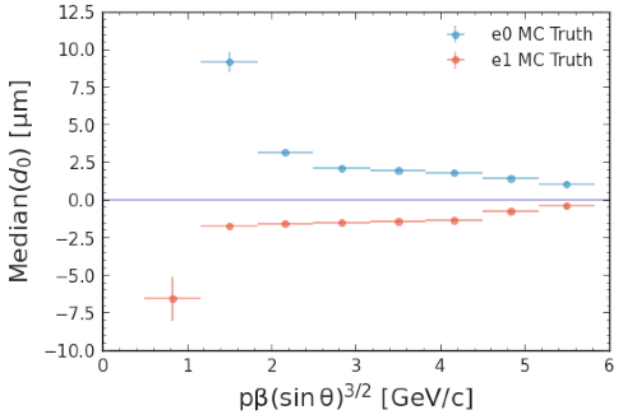
Check the pull vs variables w/o constraint of the same pseudo-p bin

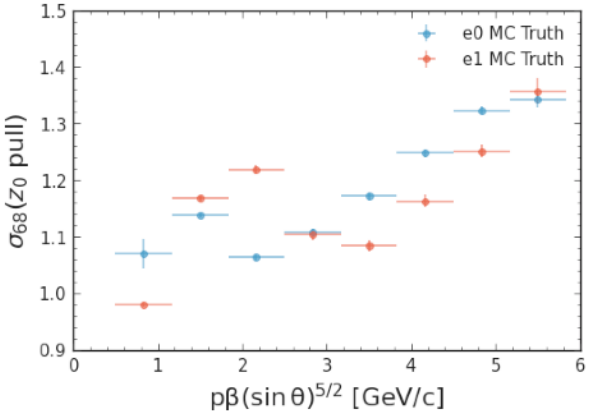
Validation with Bhabha MC

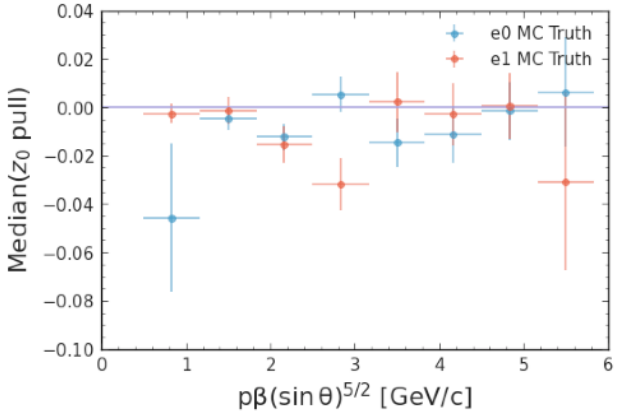


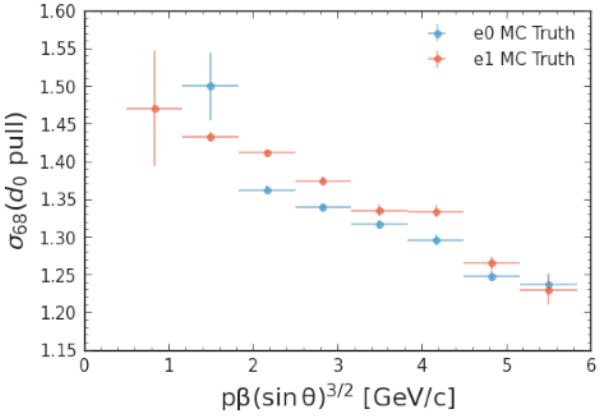


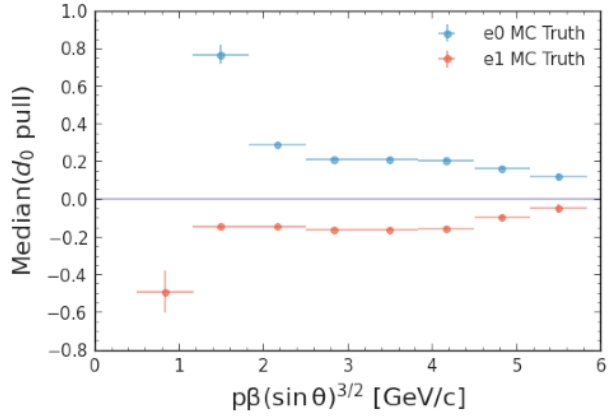






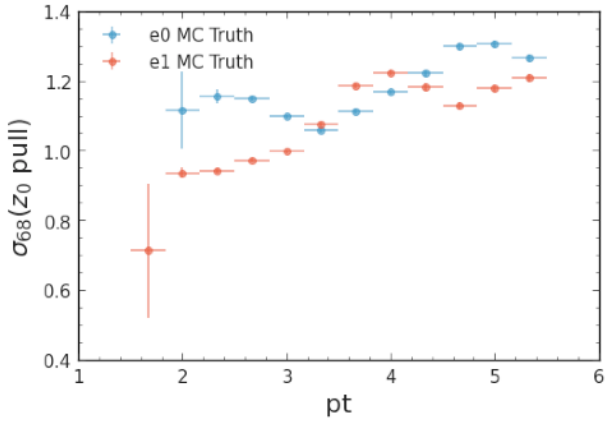


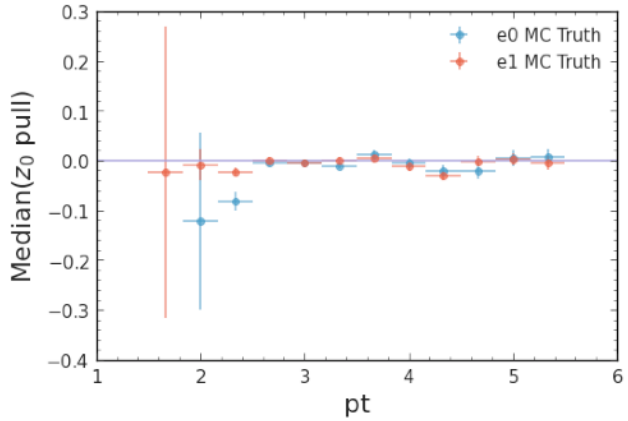


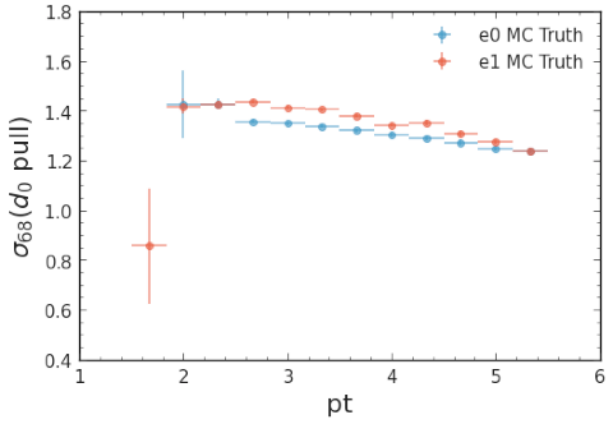


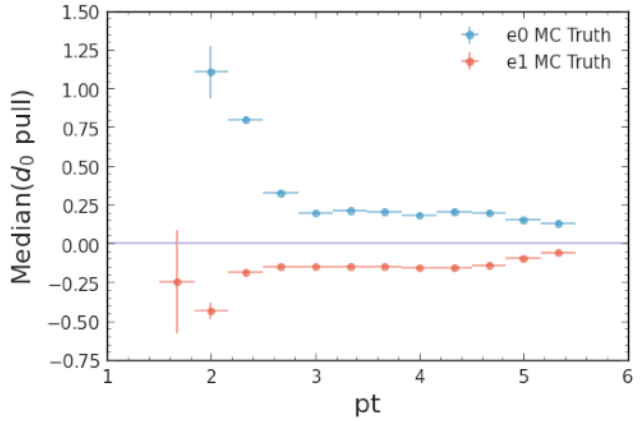
Check the pull vs variables w/o constraint of the same pseudo-p bin

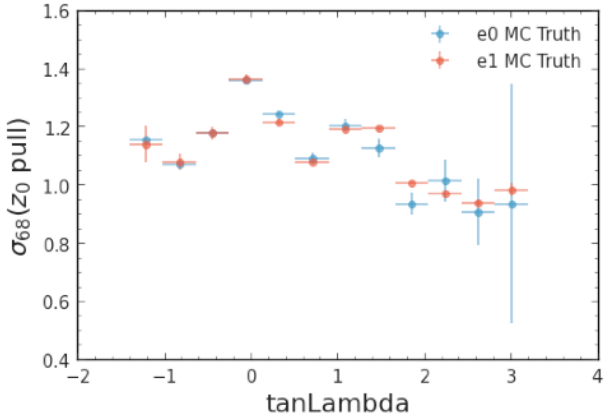
Validation with Bhabha MC

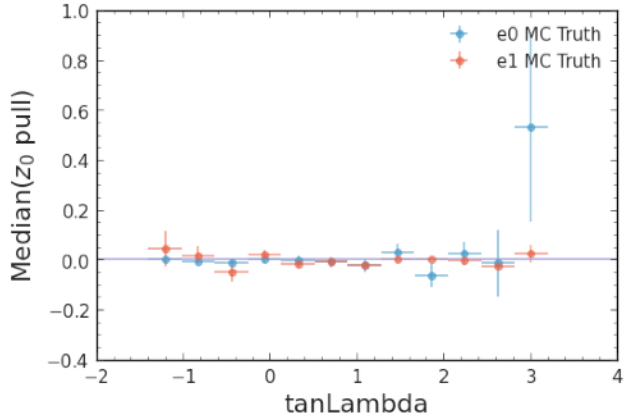


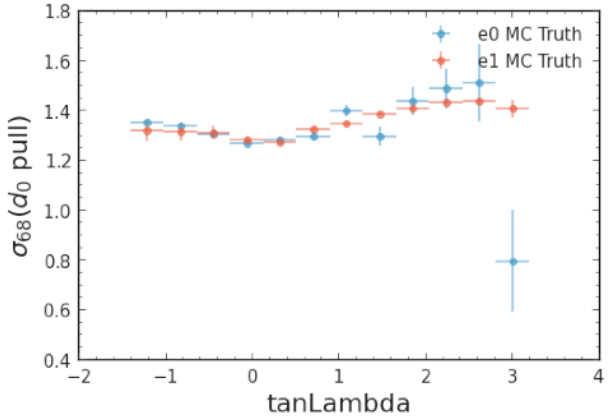


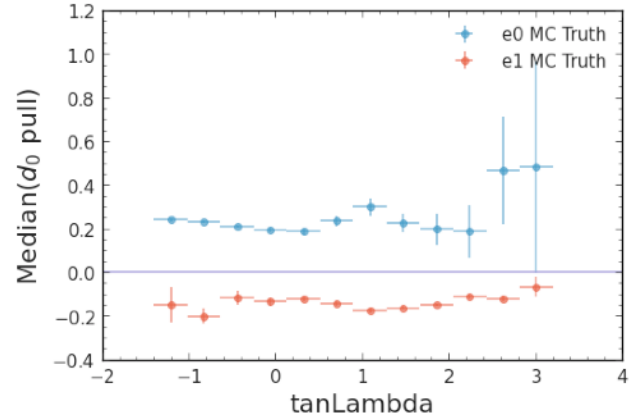






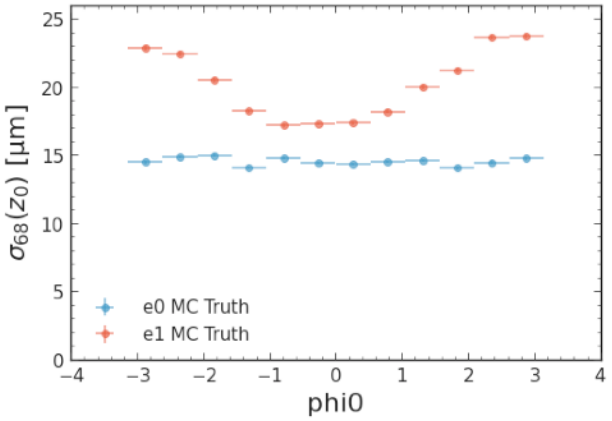


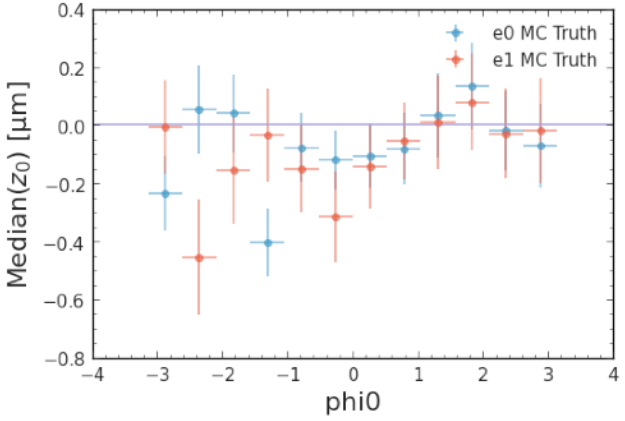


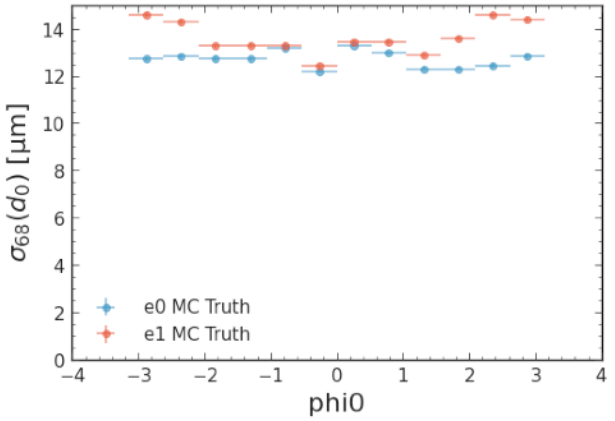


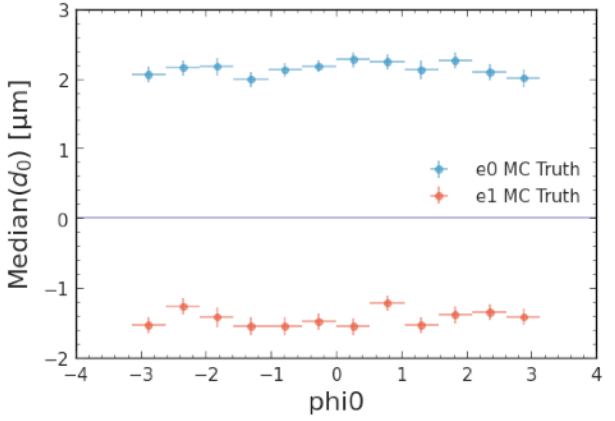
Check the pull vs variables w/o constraint of the same pseudo-p bin

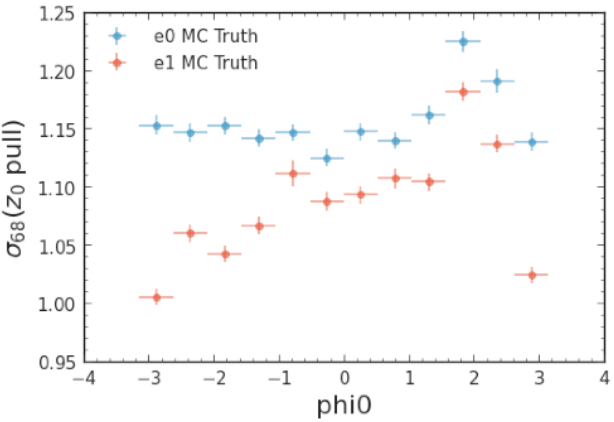
Validation with Bhabha MC

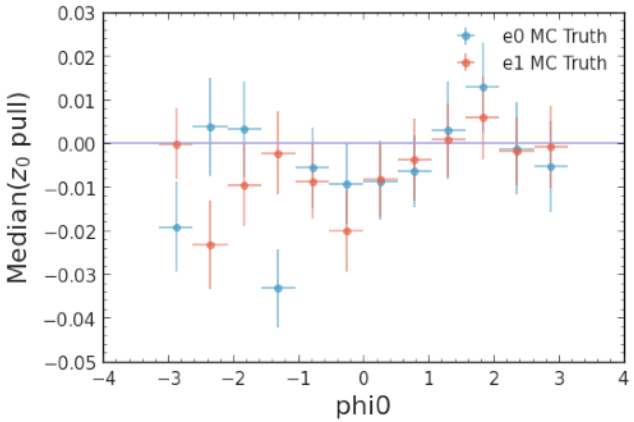


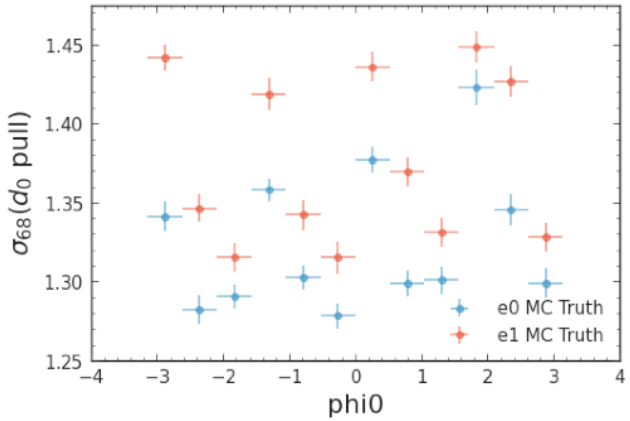


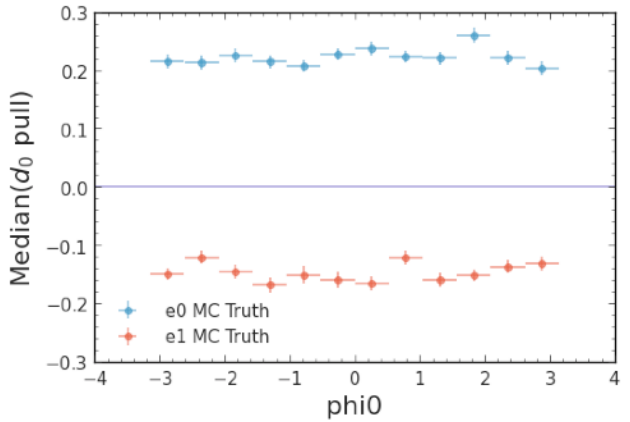












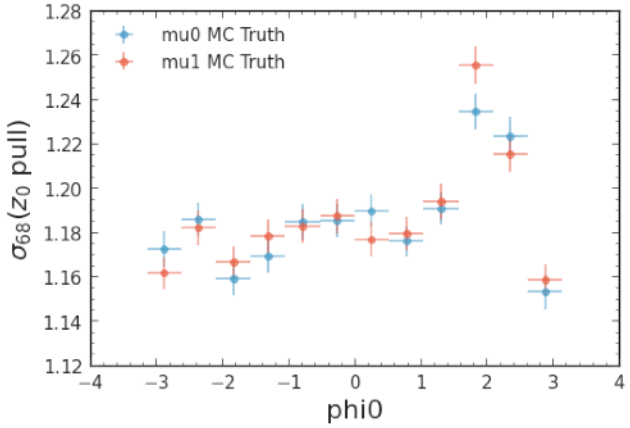
Check the pull vs variables w/o constraint of the same pseudo-p bin

Validation with di-muon of MC14ri

- μ^+ and μ^- behave more similarly than e^+ vs e^-

Similar in MC15ri

- Some items to check:
  - Kalman filter initialisation after smoothing
  - Underestimated processing errors (material effect)?
  - Underestimated hit errors?



Effect of more materials in layer 2 ?
Hit error in PXD is too small?