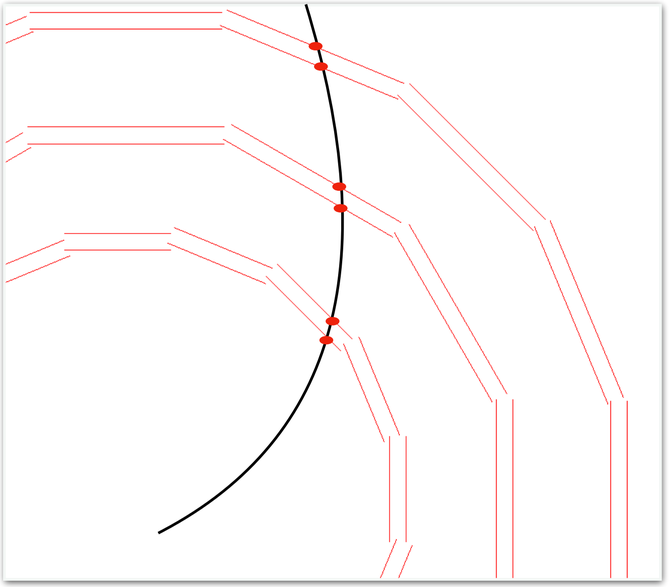
Tracking validation and detector performances



Emilia Leogrande, Daniel Hynds

CLICdp Collaboration Meeting

CERN – 30th Aug 2017

Introduction to this talk

- Software validation and detector optimization proceed closely intertwined

- The performances of the CLIC detector model CLIC_o3_v11 have been studied with the iLCSoft release 2017-07-27 comparing 3 different tracking algorithms:
  - Truth tracking
  - Conformal tracking + Extrapolator
  - Conformal tracking full

  - Single mu, Z=>uds and ttbar events are simulated and reconstructed to test:
    - pattern recognition in terms of number of hits per track
    - tracking efficiency
    - momentum resolution
    - first look at displaced tracks

Truth Tracking

1) PATTERN RECOGNITION

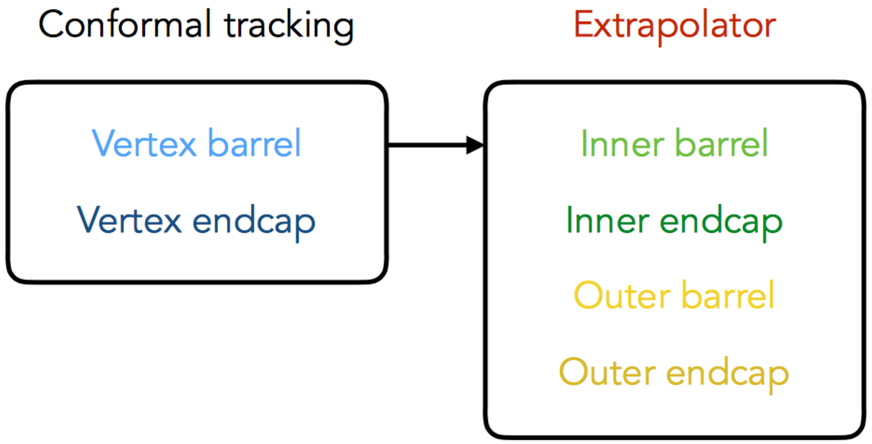
MC Particle → Simulated hits → Reconstructed hits → Track

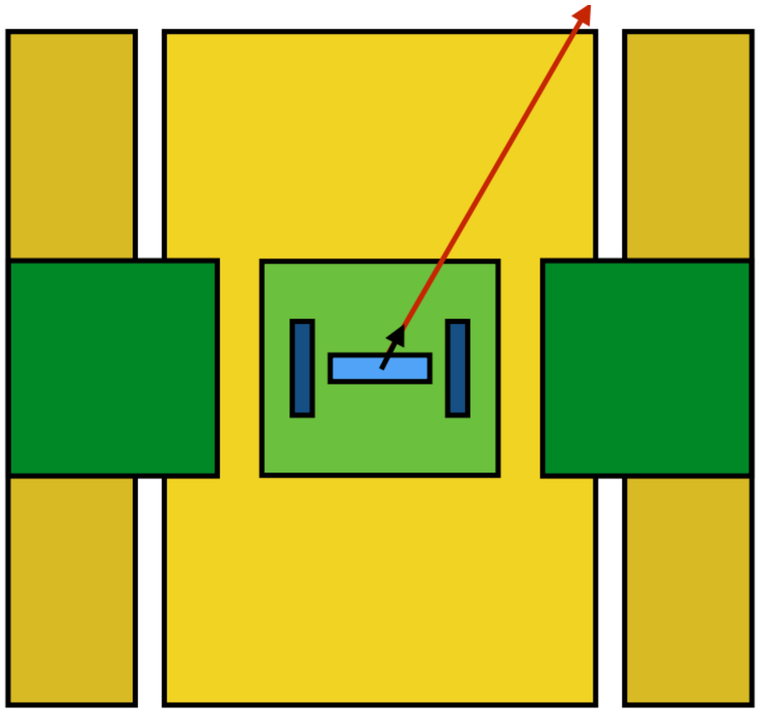
2) TRACK FITTING

- PREFIT:
  - helix made with 3 hits (1st, middle, last on track)
  - helix parameters used to initialize the fit
- FIT:
  - fit backward (last to first hit) with a Kalman step
  - hits are added to the fit one by one according to $\Delta\chi^2$ cut
  - track propagated to the IP

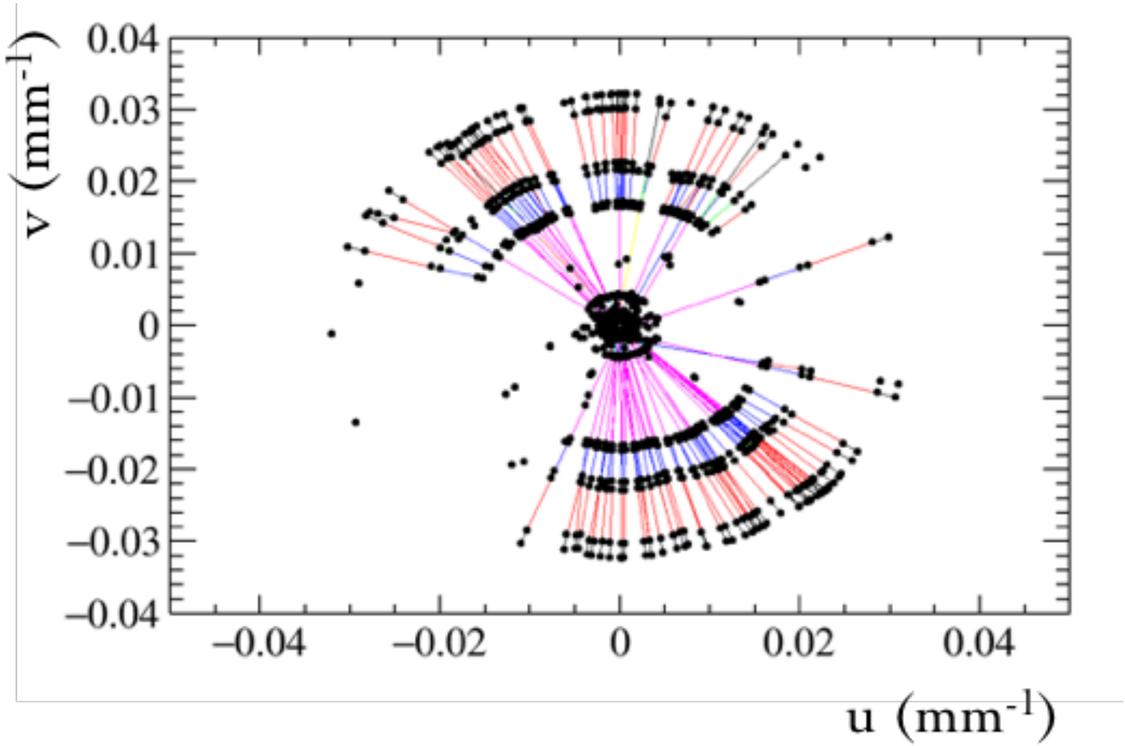
N.B.: REFIT not applied in the shown results

Conformal Tracking + Extrapolator





- Conformal mapping applies a geometry transform that maps circles in the xy plane to straight lines in the uv plane
- Cellular automaton used to perform straight line search
- Tracks reconstructed using hits only in the vertex detector, extrapolation through the tracker using Kalman filter



Conformal Tracking ‘full’

- Extrapolator needs to be run before search for displaced tracks => better to pick up tracker hits in conformal tracking
- Combinatorics can be large for CA, apply staged tracking strategies that pick up “easier” tracks first
- Same algorithm runs on all subdetectors treating them the same (no hard-coded layer lookup etc.)

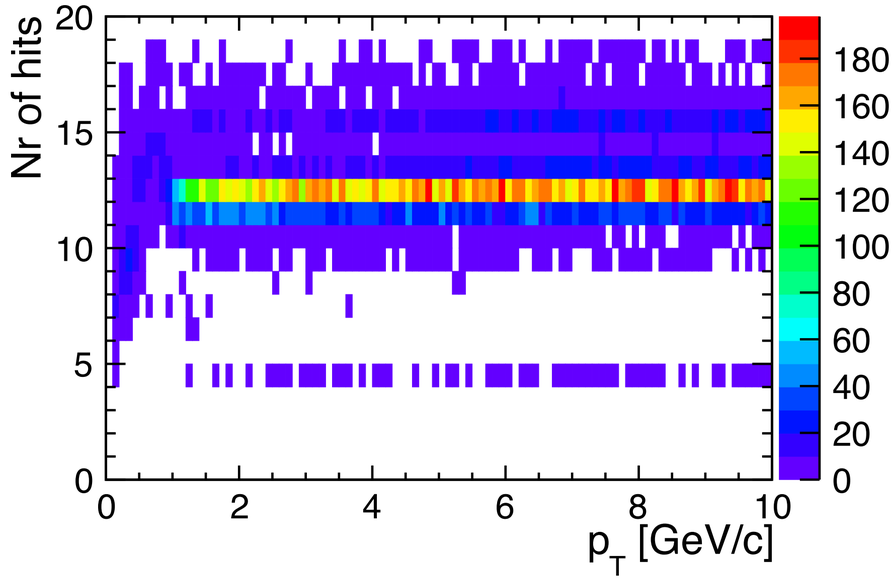
Conformal tracking

Build tracks	Vertex barrel	Standard cuts
Extend tracks	Vertex endcap	Standard cuts
Build tracks	Vertex B+E	Standard cuts
Build tracks	Vertex B+E	Looser cuts
Extend tracks	Tracker collections	Standard cuts
Extend tracks	Tracker collections	Looser cuts
Build tracks	All collections	Displaced cuts

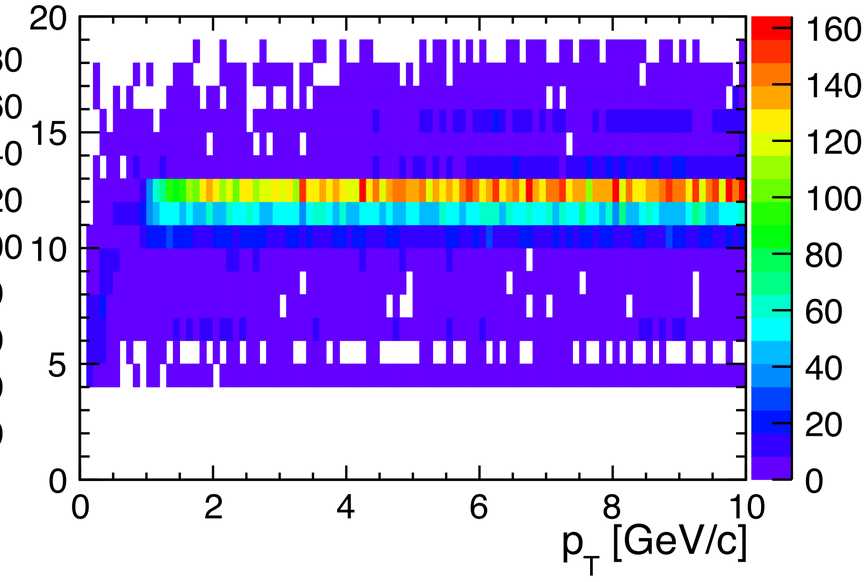
Testing pattern recognition algorithms

- 2M single muon events
  - isotropic angular distribution, linear energy distribution 0-500GeV
- Hits per track distribution as a function of p_T, θ and φ

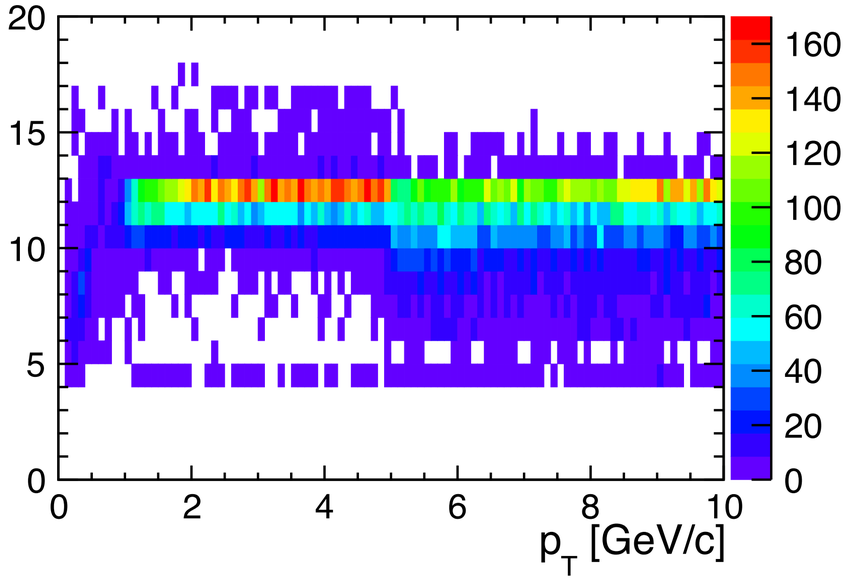
Truth Tracking



Conformal Tracking (VTX) + Extrapolator



Conformal Tracking (FULL)



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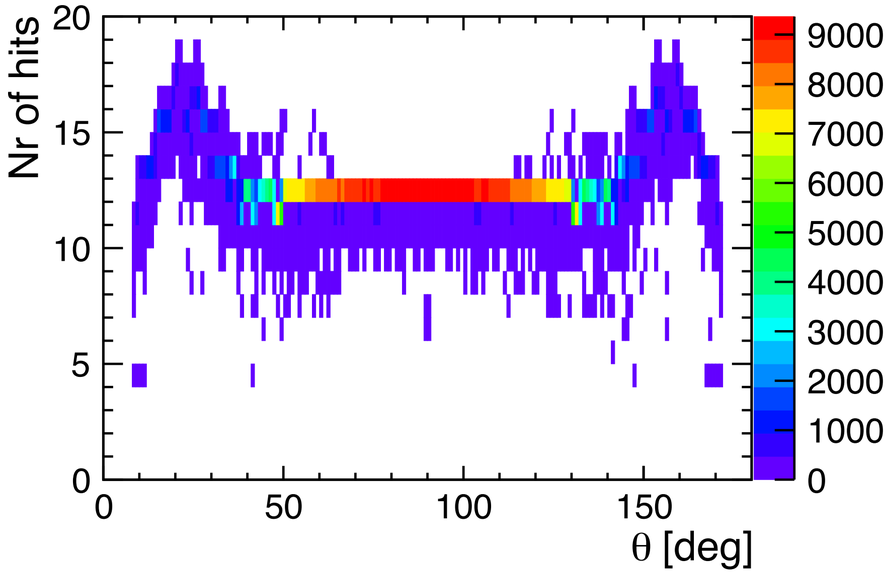

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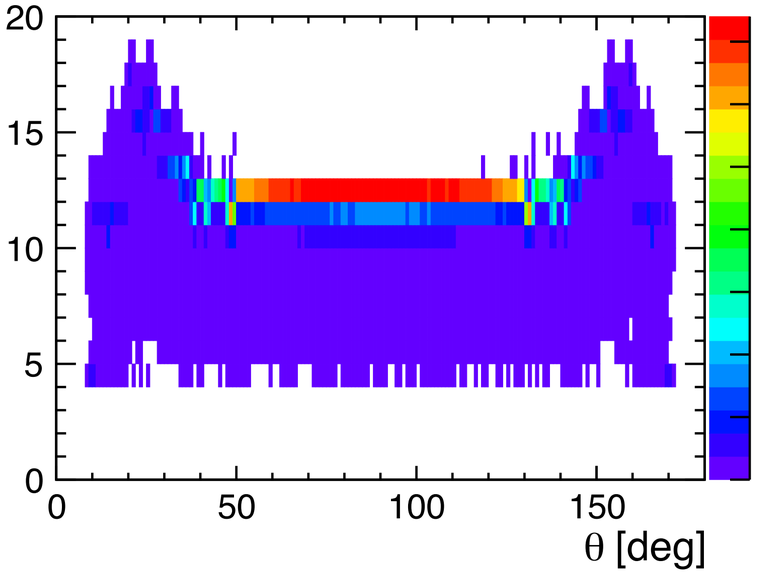
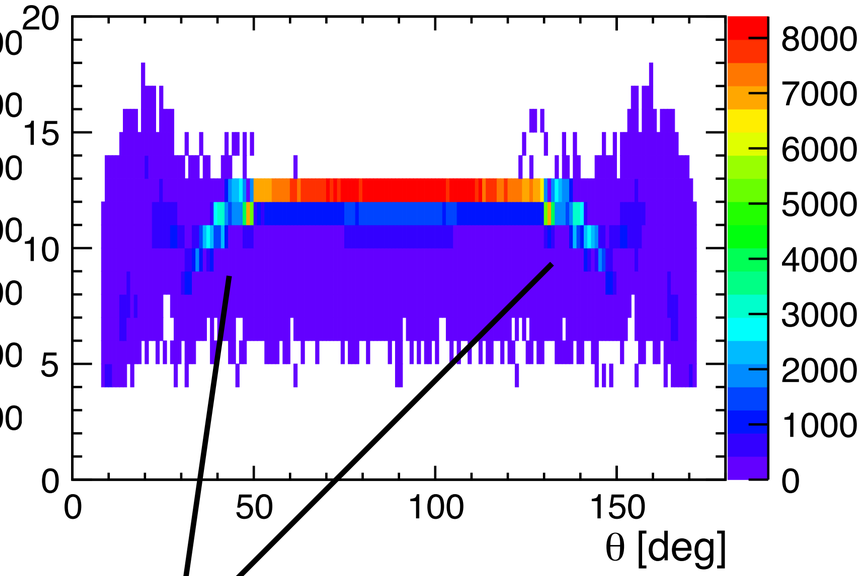


Conformal Tracking (FULL)



- What happens: hits are discarded due to high $\Delta\chi^2$ per hit during fit in the z-s plane. Fixed in the latest release ✓

Testing pattern recognition algorithms

- 2M single muon events
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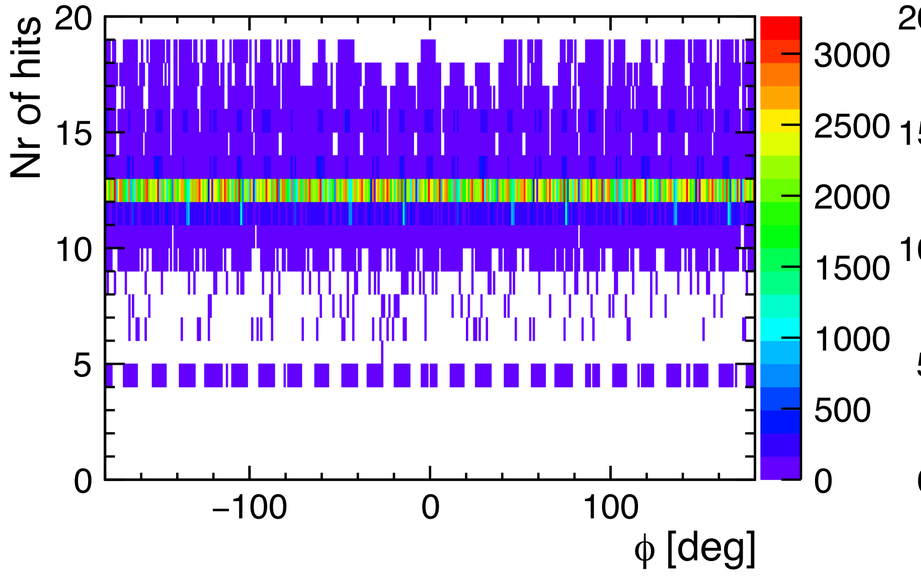
Truth Tracking



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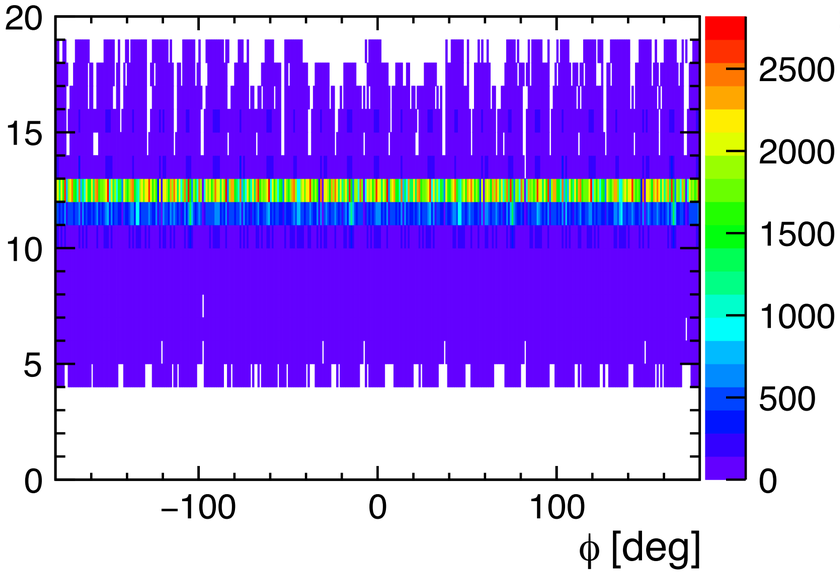

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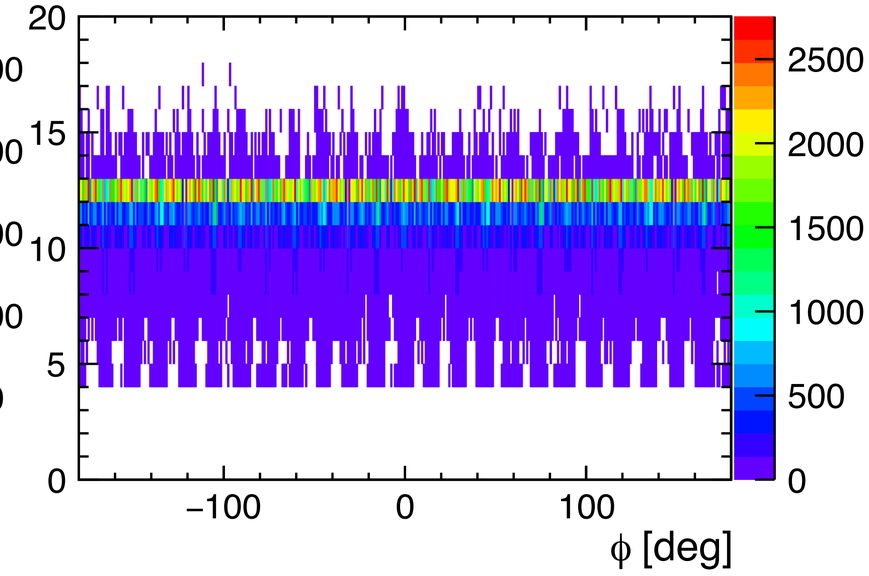


Tracking efficiency

$$\text{Tracking efficiency} = \frac{\text{Nr of reconstructed tracks}}{\text{Nr of reconstructable particles}}$$

Nr of reconstructable particles:

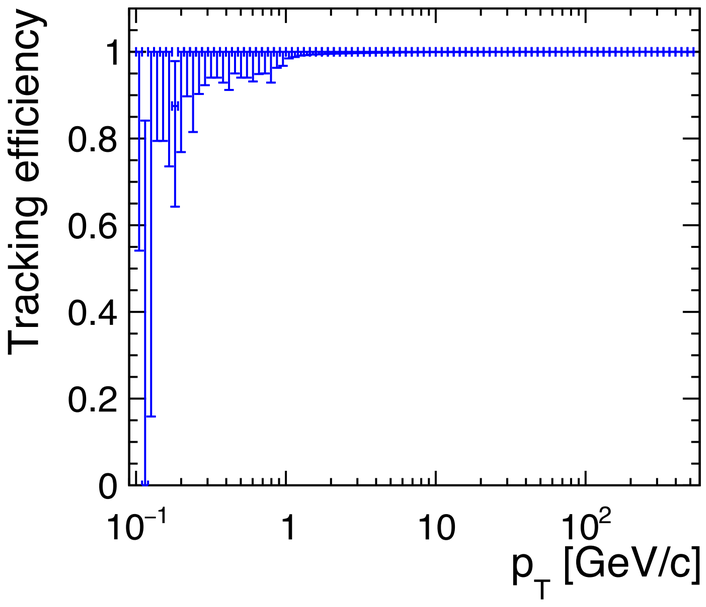
- ☆ PDG = 13 (muons) ***
- ☆ vertex = 0
- ☆ Nr hits >= 4
- ☆ $|\cos(\theta)| < 0.99$, i.e. $8^\circ < \theta < 172^\circ$
- ☆ $p_T > 100$ MeV/c
- ☆ is not a loop, i.e. no more than one hit on the same layer of the same sub detector

*** this requirement will not be used for complex events (Z=>uds, ttbar)

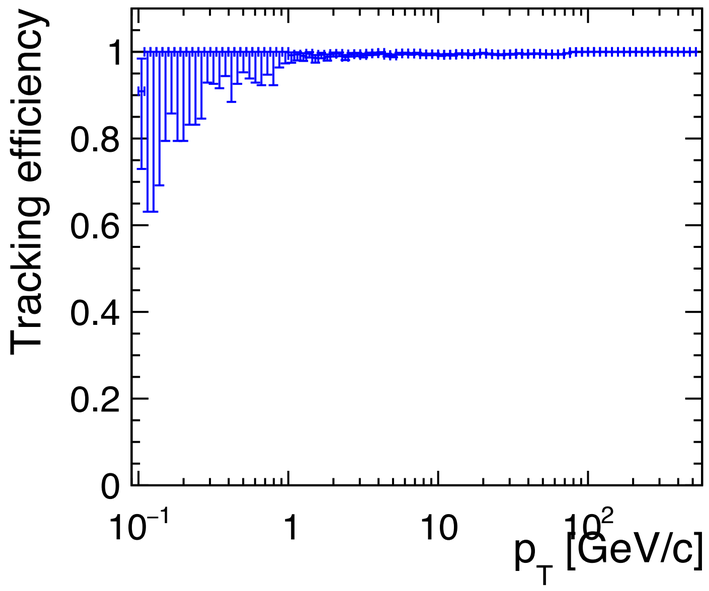
Tracking efficiency

- 2M single muon events
  - isotropic angular distribution, linear energy distribution 0-500GeV
- Tracking efficiency as a function of p_T, θ and φ

Truth Tracking



Conformal Tracking (VTX) + Extrapolator



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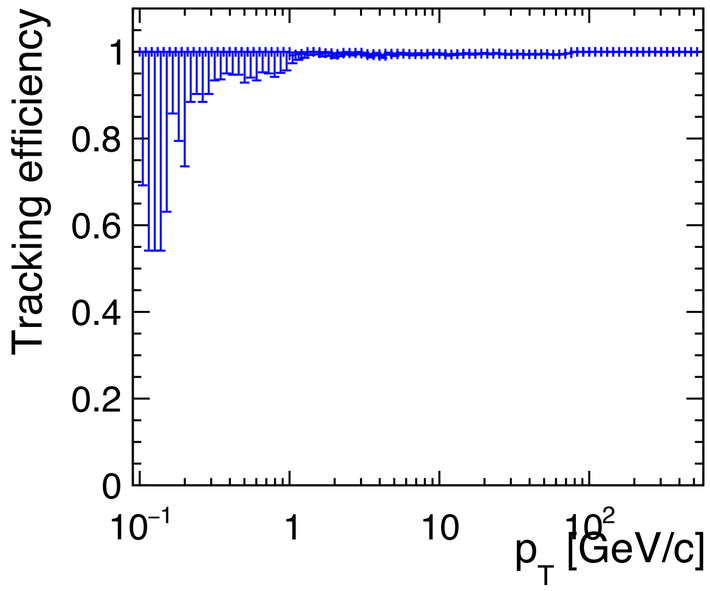

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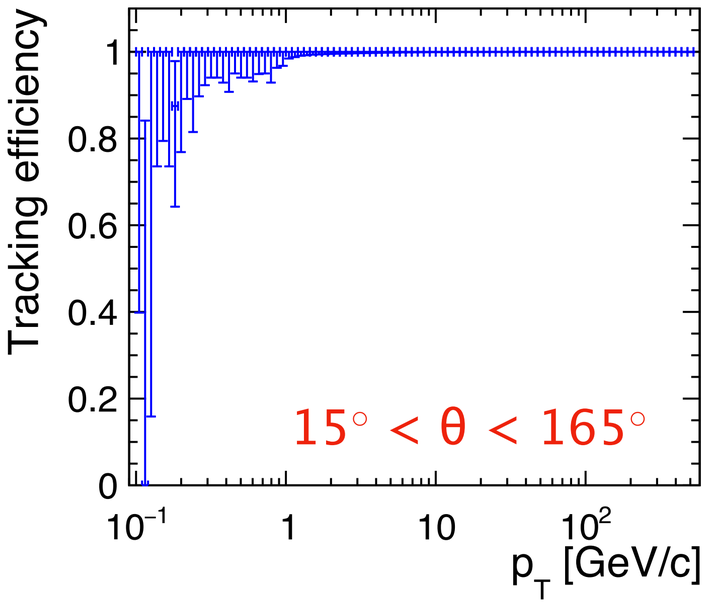

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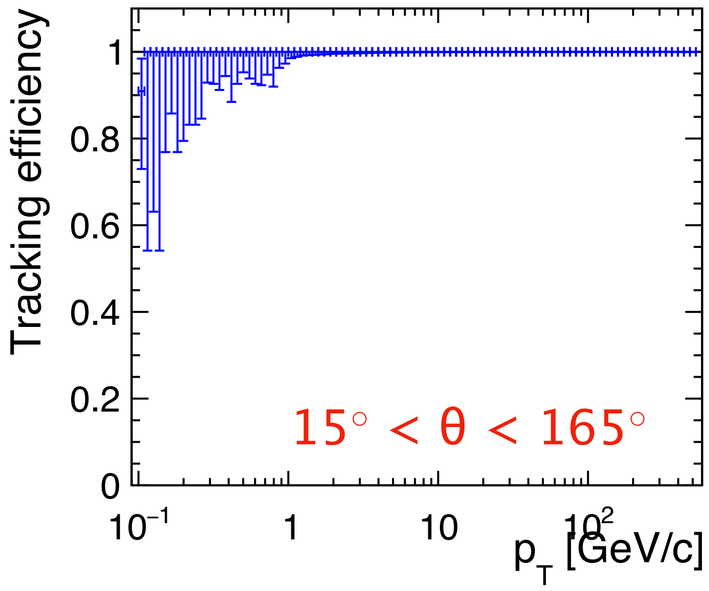

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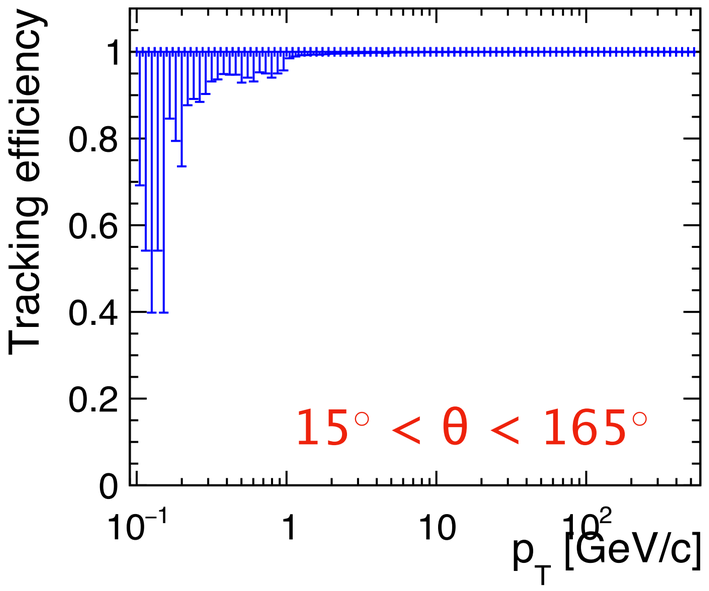

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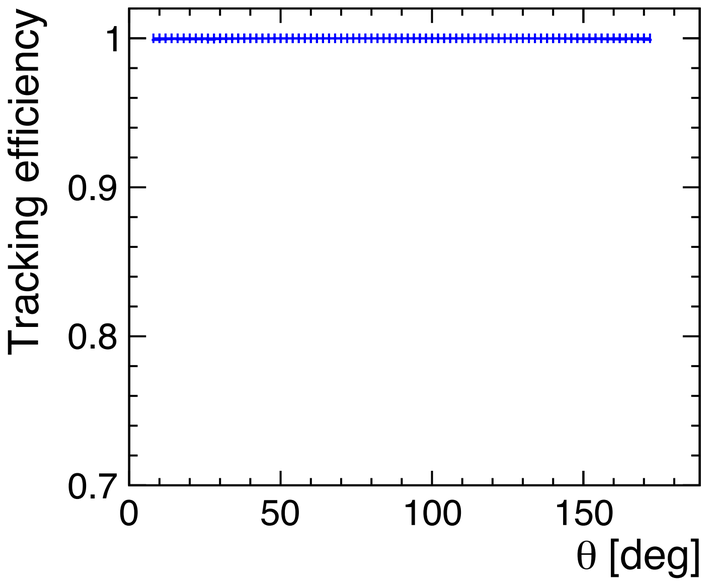

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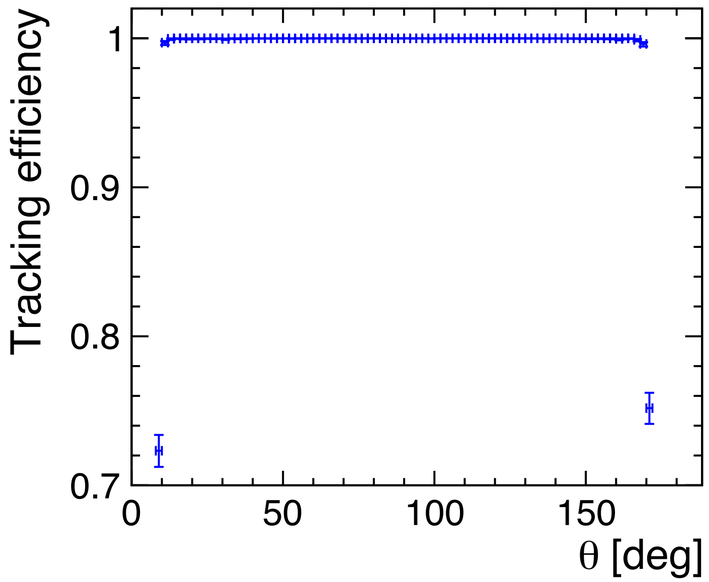

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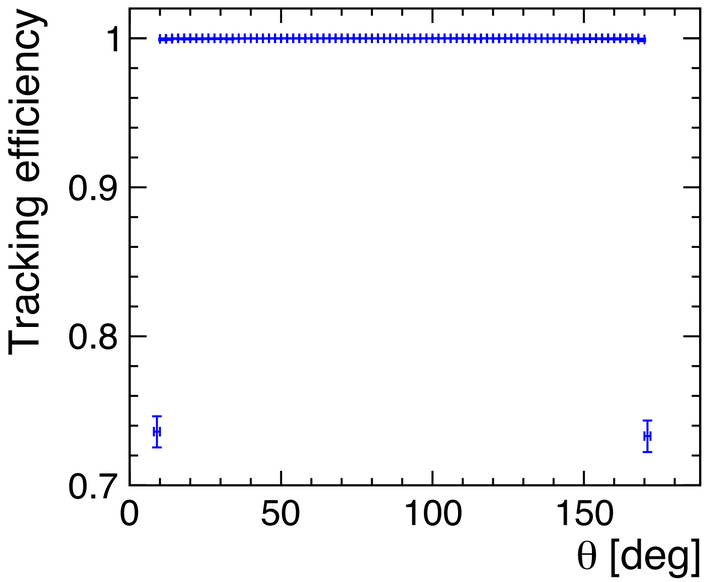

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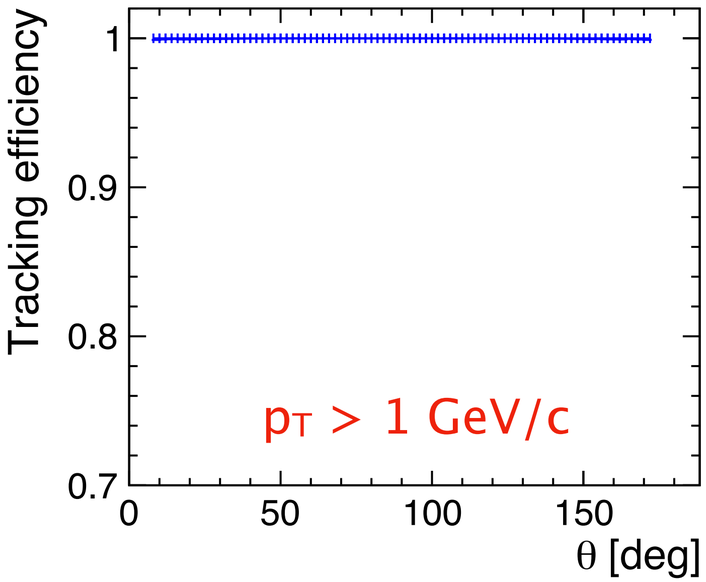

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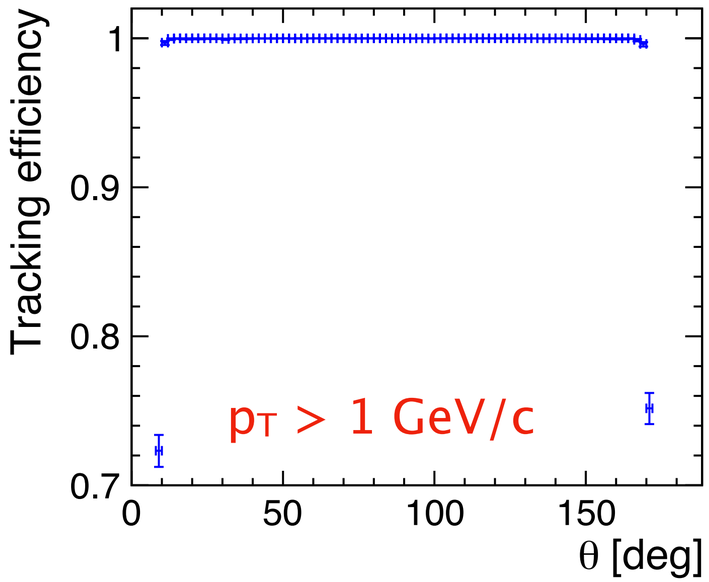

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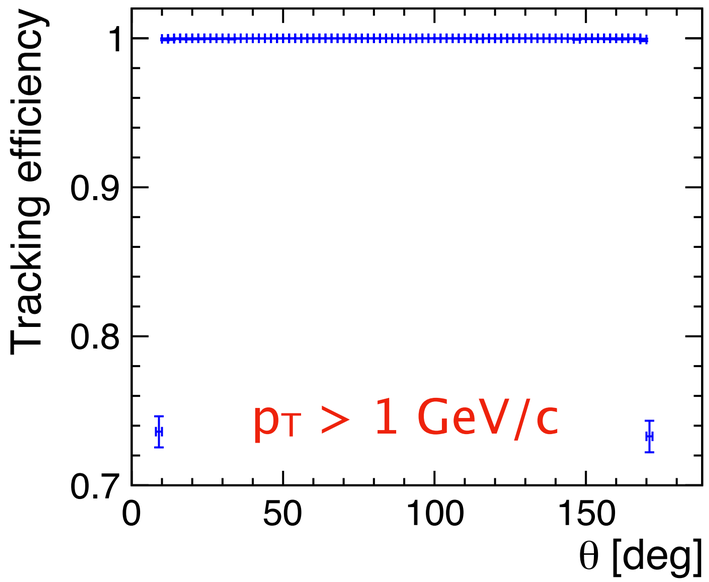

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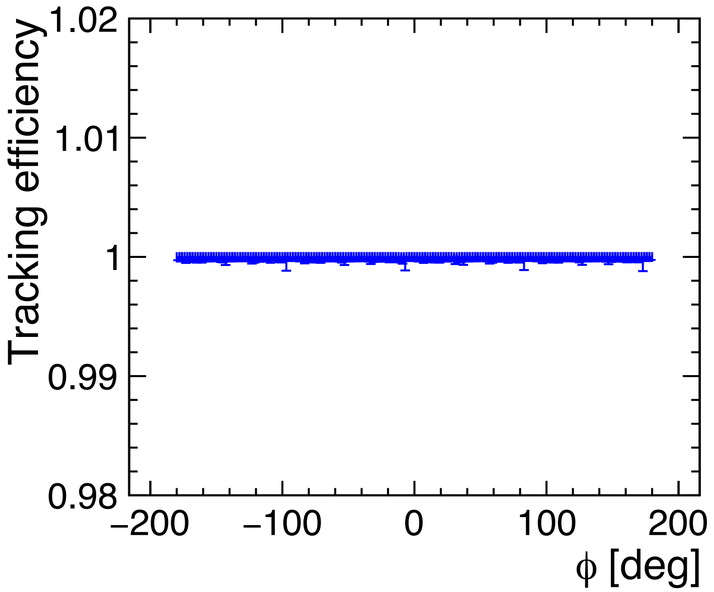

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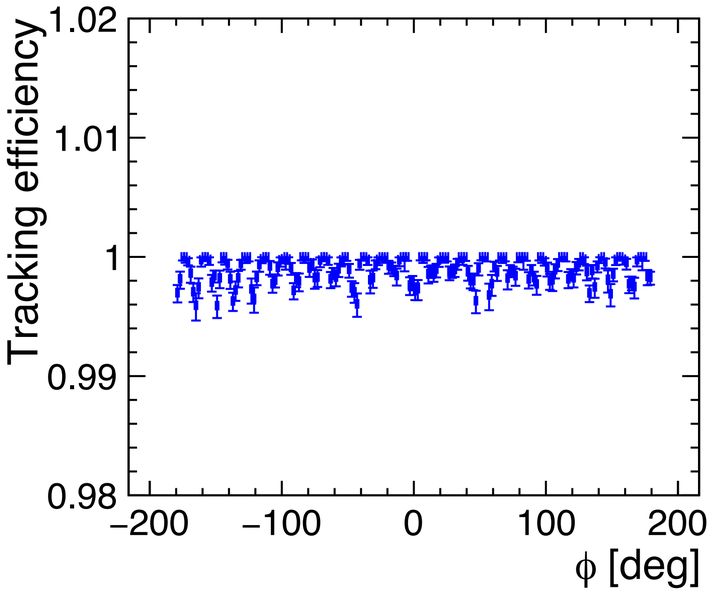

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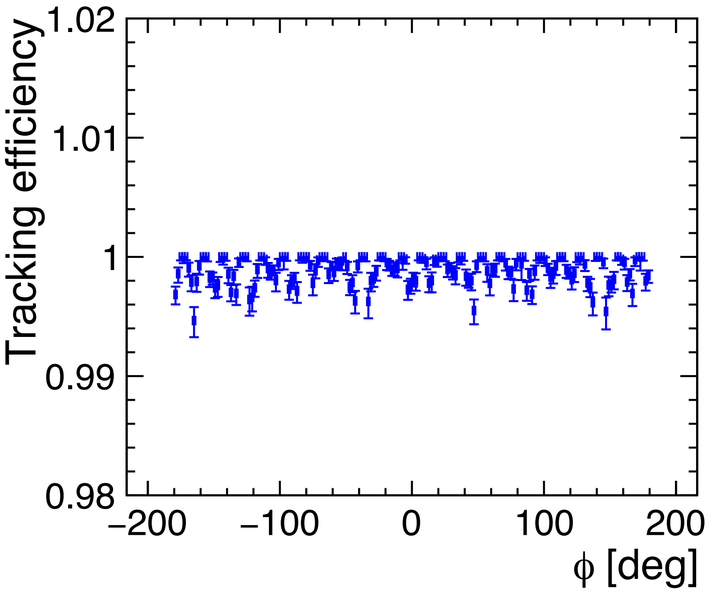

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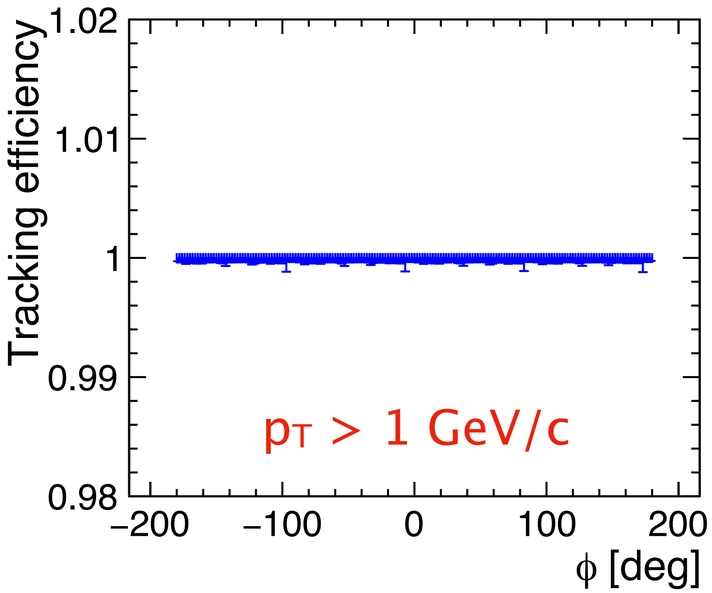

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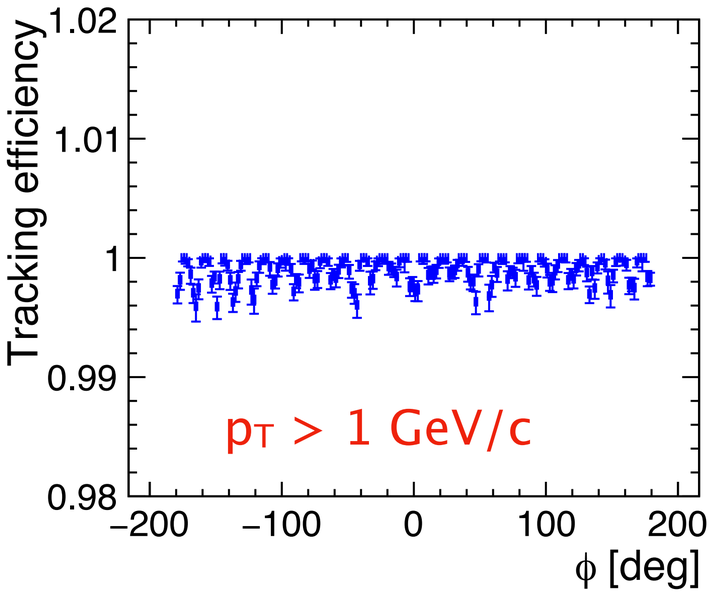

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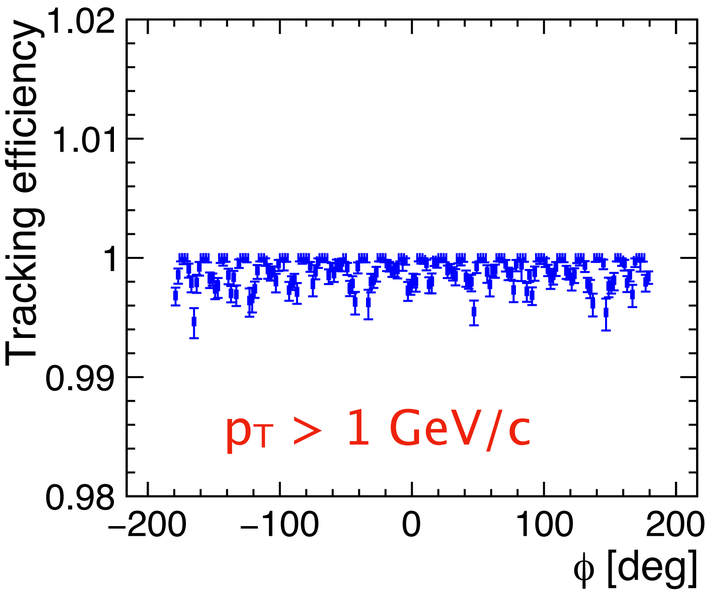
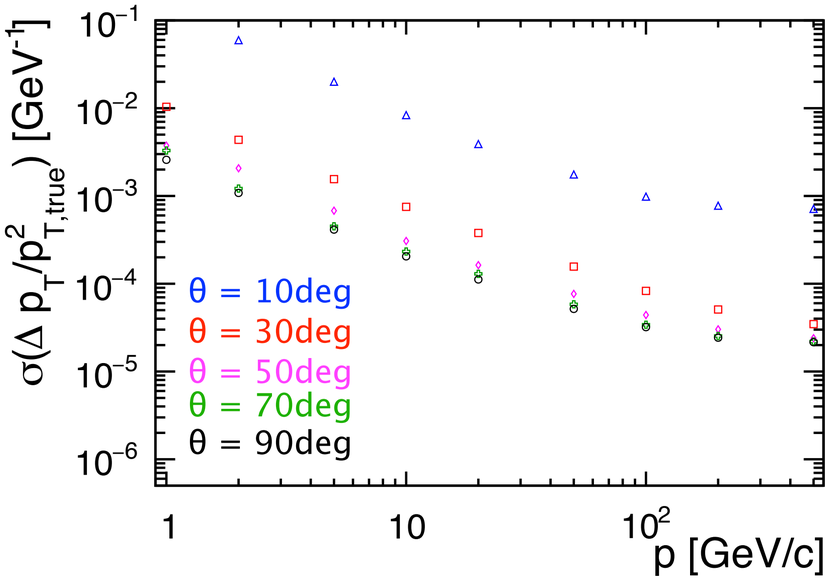


Momentum resolution

- 10k muons guns
  - fixed energy = GeV {1,2,5,10,20,50,100,200,500}
  - fixed theta = deg {10,30,50,70,89}
- Resolution = σ of the Gaussian fit of the distribution $(p_{T,reco} - p_{T,true}) / p_{T,true}^2$

Truth Tracking



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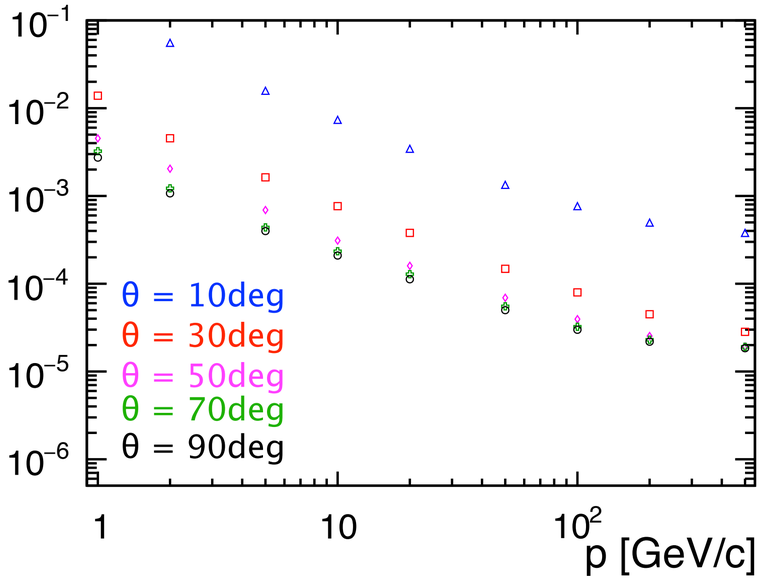

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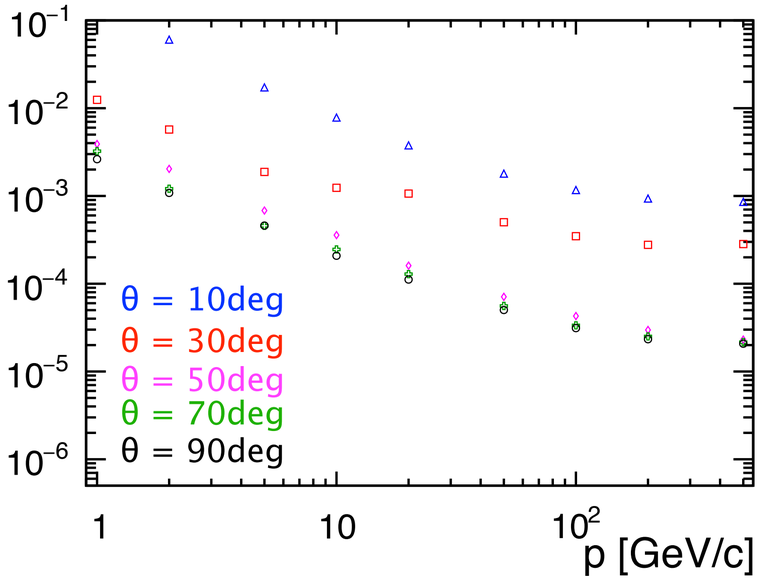


✓ Single muons are reconstructed with an efficiency of 100% down to 100MeV/c and in the full phase space down to 10 (170) deg

✓ Momentum resolution achieved: 2×10^{-5} for high energy (500GeV) muons in the central barrel

✓ Conformal Tracking shows almost no differences with Truth Tracking

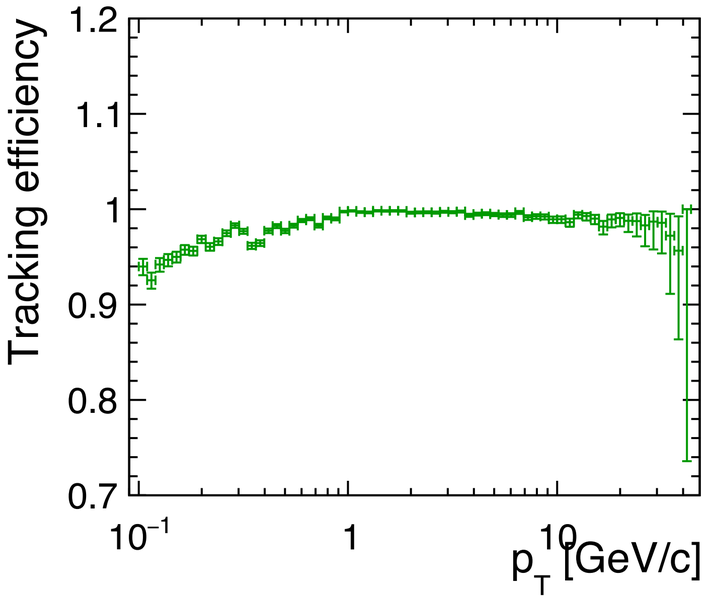
✎ Conformal Tracking Full rejects hits in the transition region barrel-endcap (30-50deg). Issue is understood and fixed in the latest release

NEXT: Z => uds @ 91 GeV

Tracking efficiency

- 10k Z=>uds events
- Tracking efficiency as a function of p_T, θ and φ

Truth Tracking



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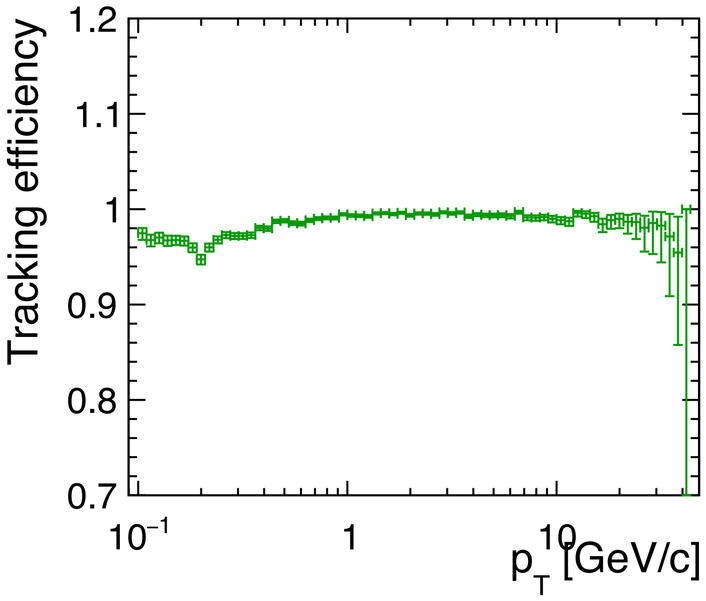

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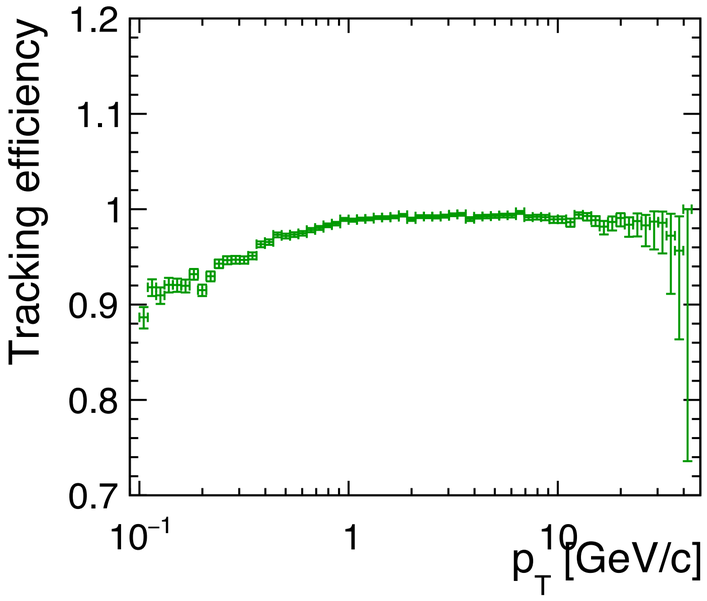

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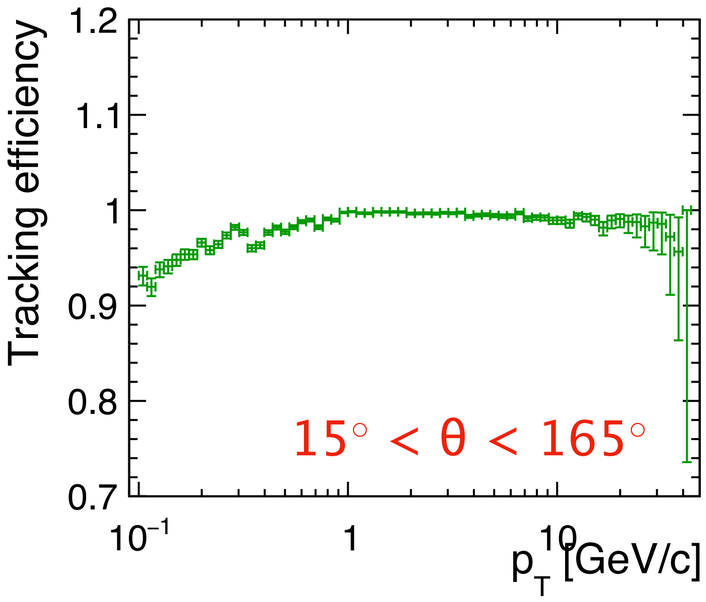

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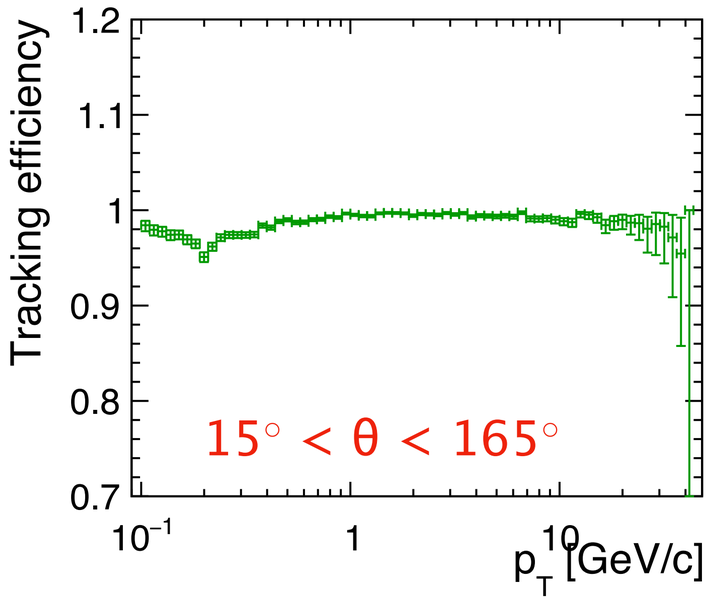

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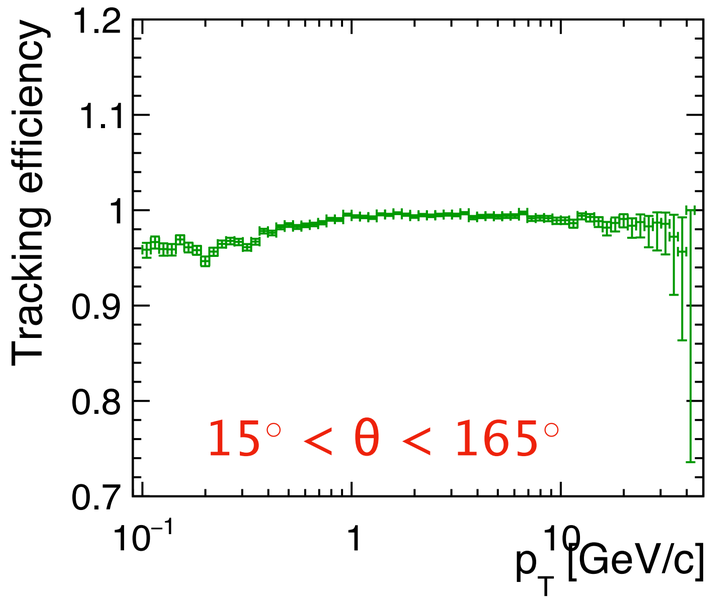
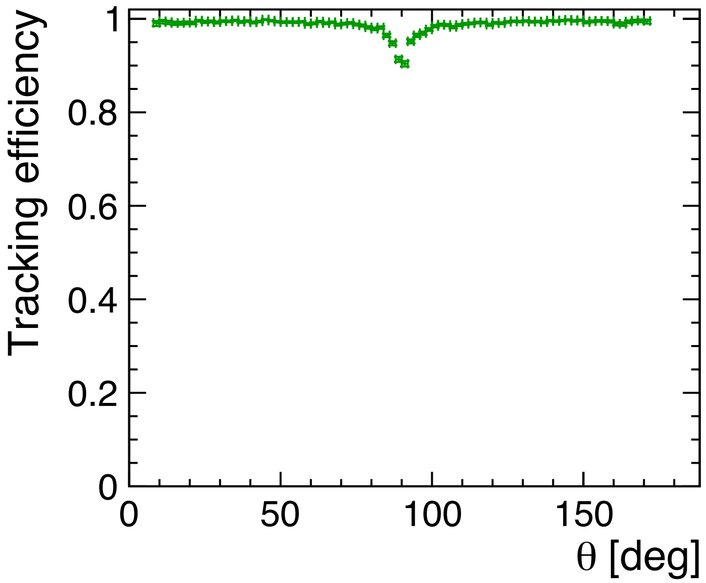


Tracking efficiency

- ☆ 10k Z=>uds events
- ☆ Tracking efficiency as a function of p_T, θ and φ

Truth Tracking



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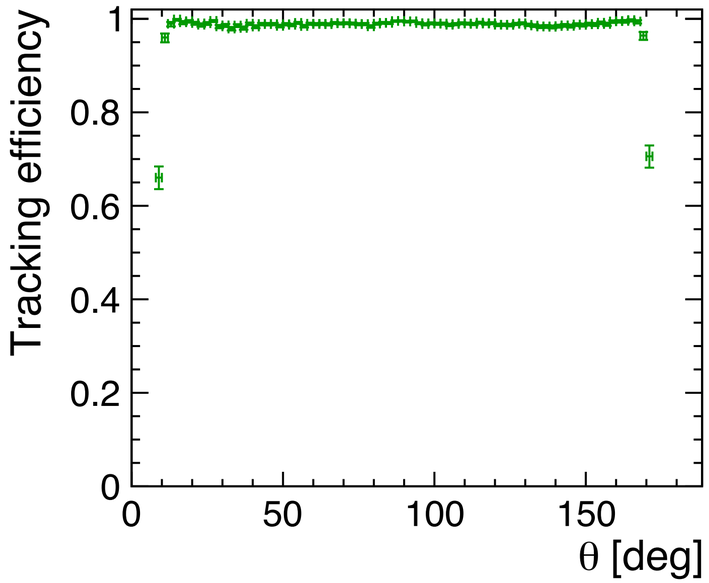

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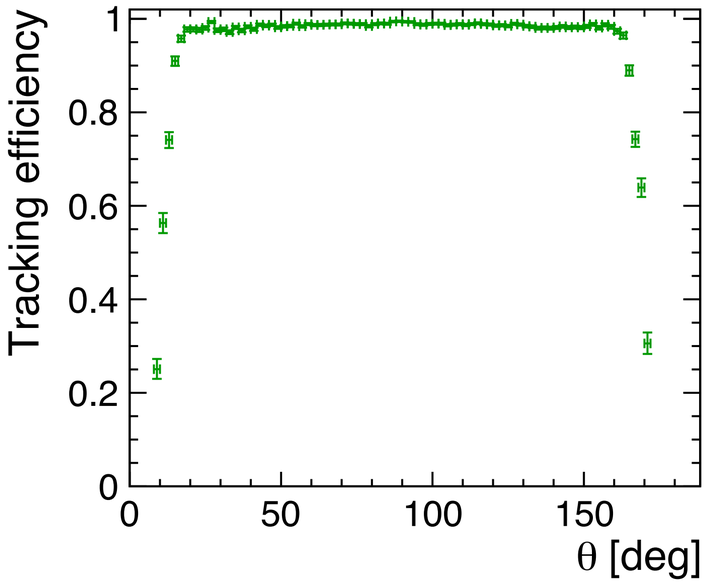

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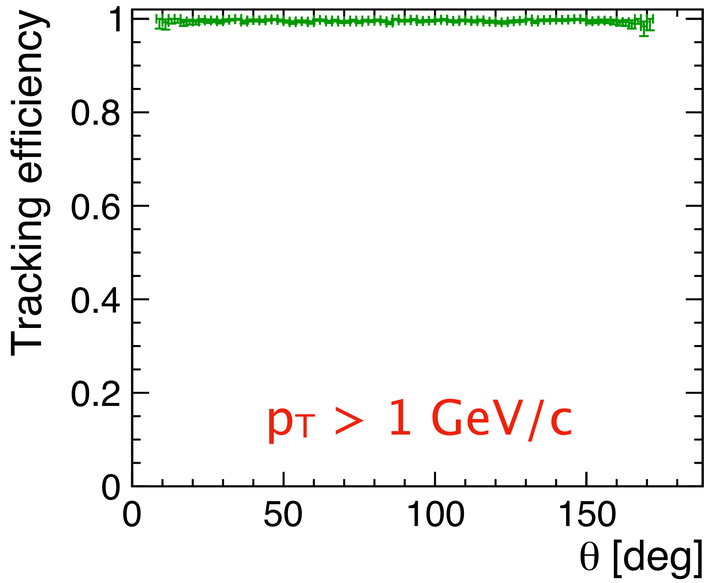
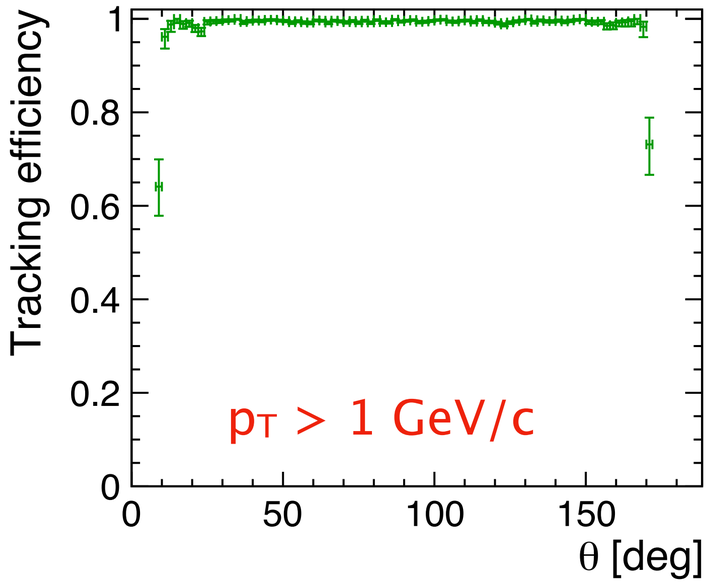
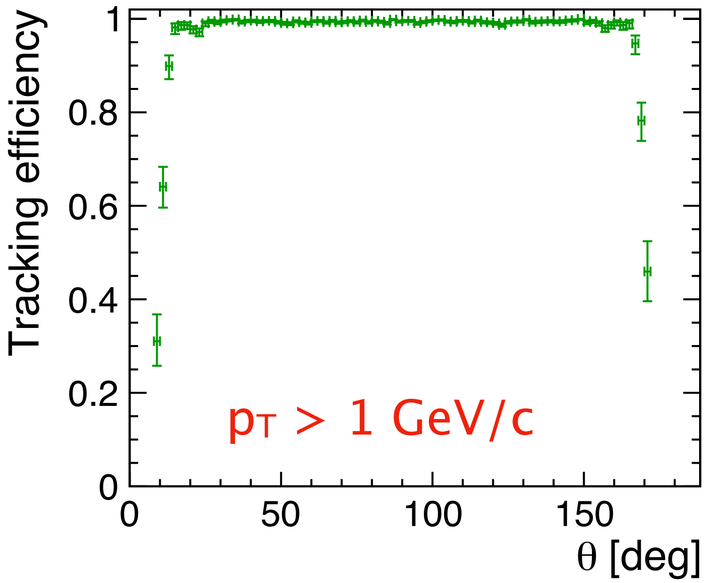


Conformal Tracking (VTX) + Extrapolator



Conformal Tracking (FULL)

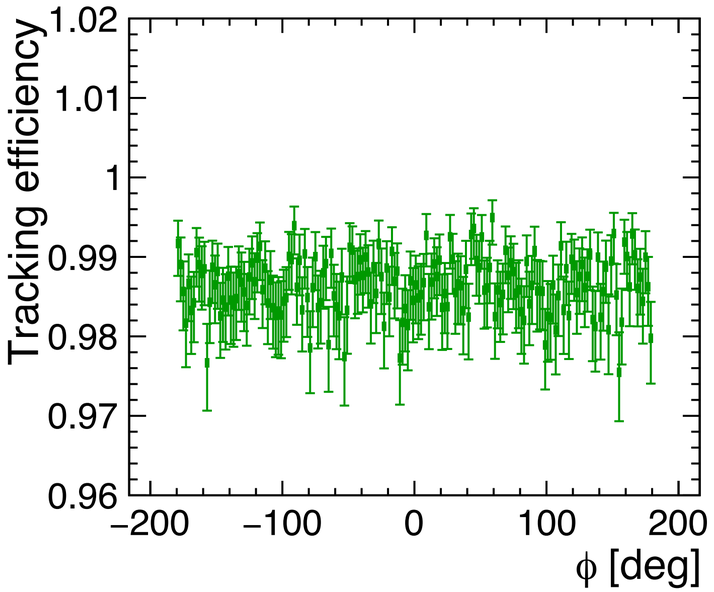


- Differences in the drop-off in very forward region

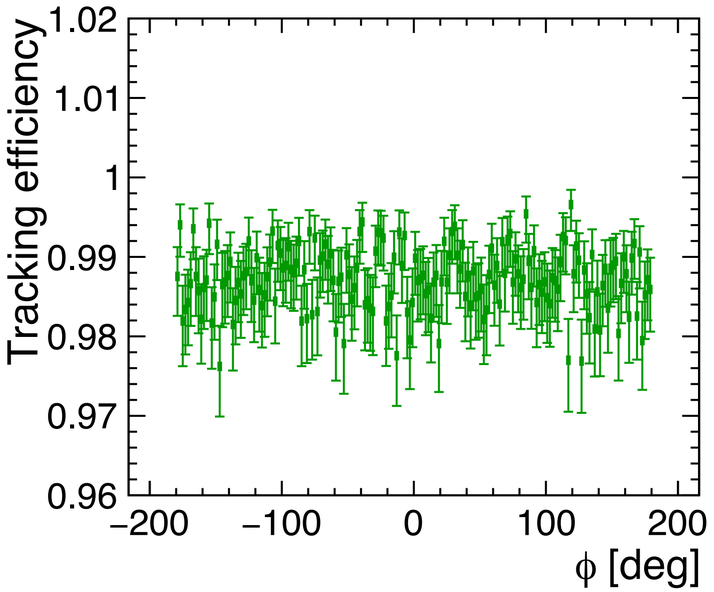
Tracking efficiency

- 10k Z=>uds events
- Tracking efficiency as a function of p_T, θ and φ

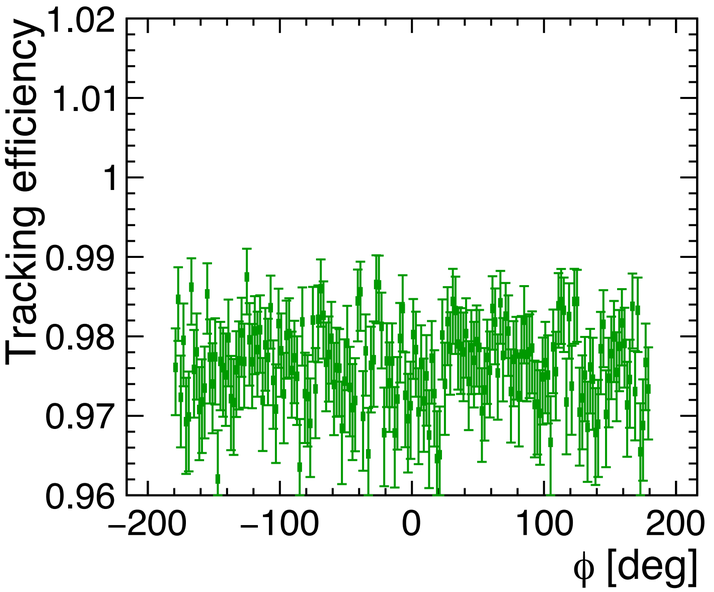
Truth Tracking



Conformal Tracking (VTX) + Extrapolator



Conformal Tracking (FULL)



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- 10k Z=>uds events
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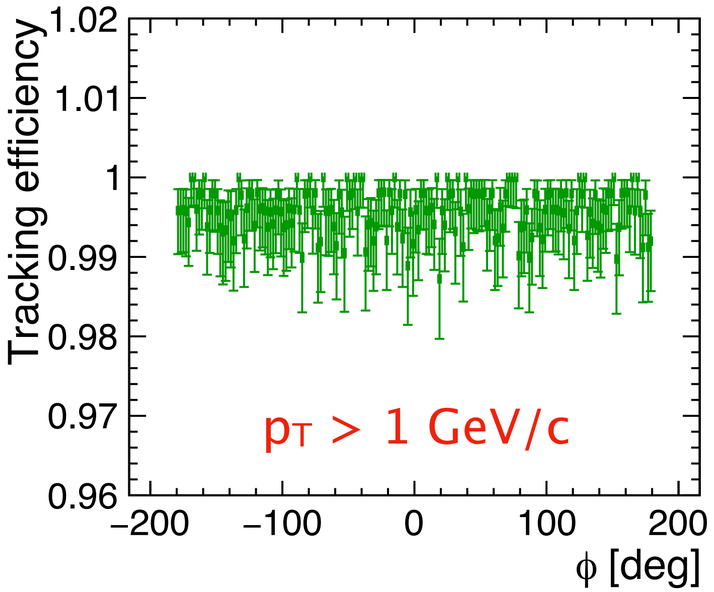
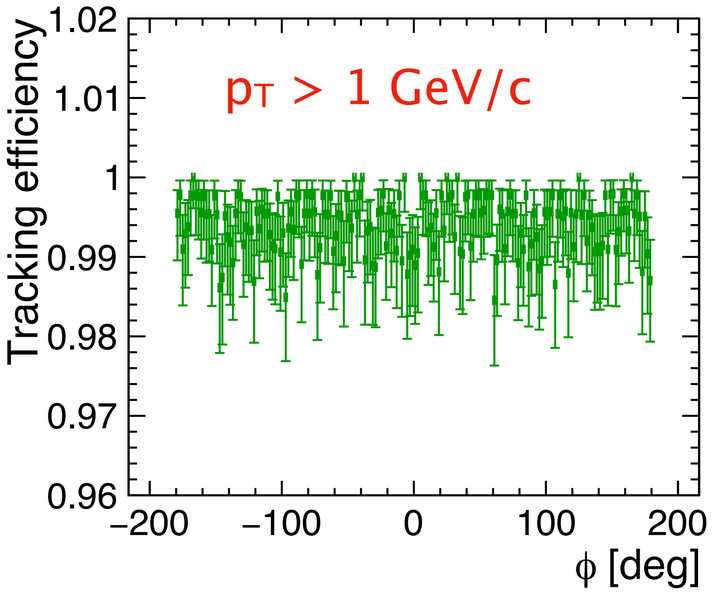
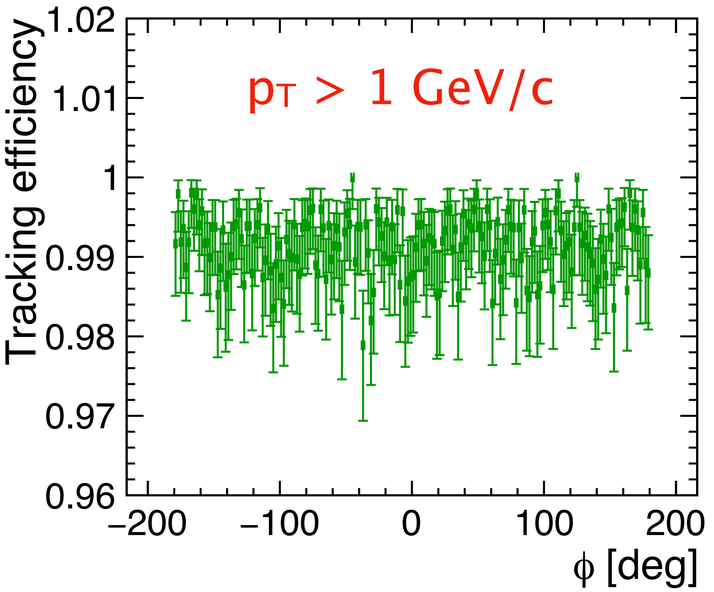
Truth Tracking



Conformal Tracking (VTX) + Extrapolator



Conformal Tracking (FULL)



✓Z=>uds events at 91GeV are reconstructed with a tracking efficiency larger than 90% (and around 99% above 1GeV/c)

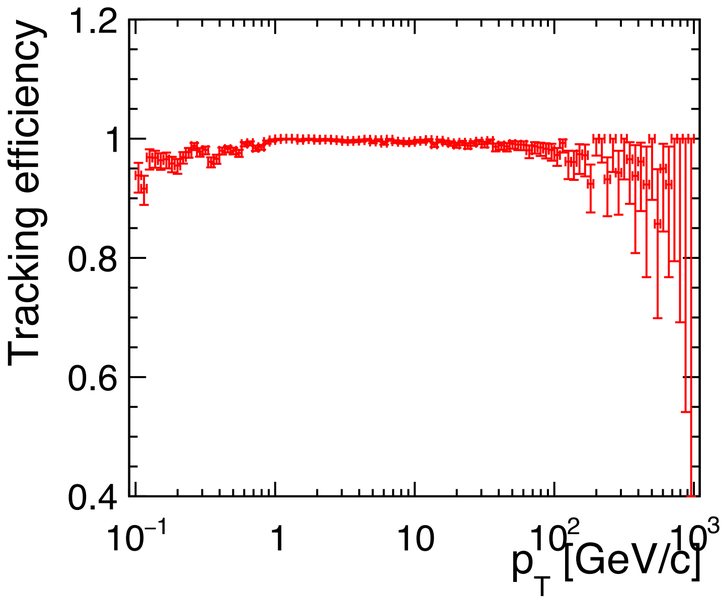
✎ Conformal Tracking Full shows a deeper drop-off at very forward region expected to be solved in the latest release (to be tested)

NEXT: ttbar @ 3 TeV

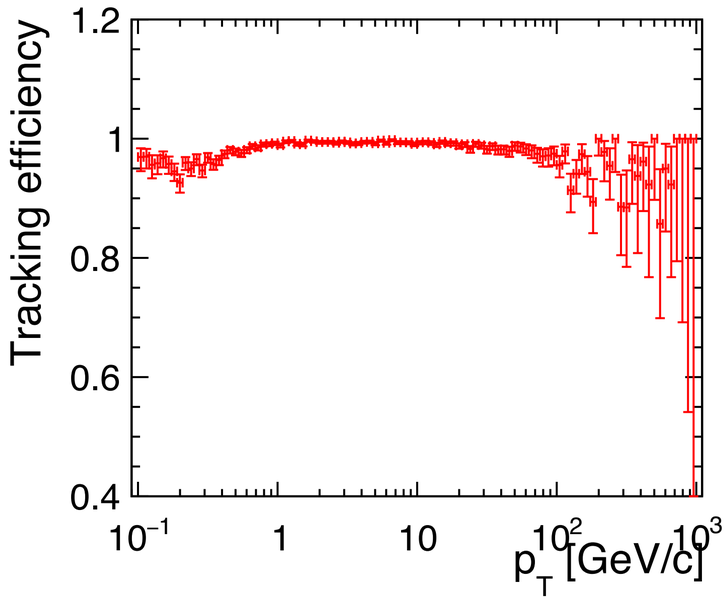
Tracking efficiency

- 1k ttbar events
- Tracking efficiency as a function of p_T, θ and φ

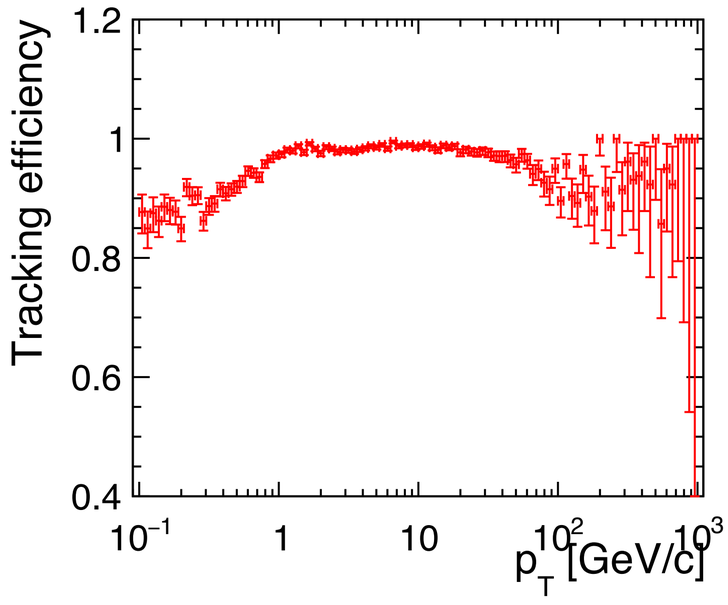
Truth Tracking



Conformal Tracking (VTX) + Extrapolator



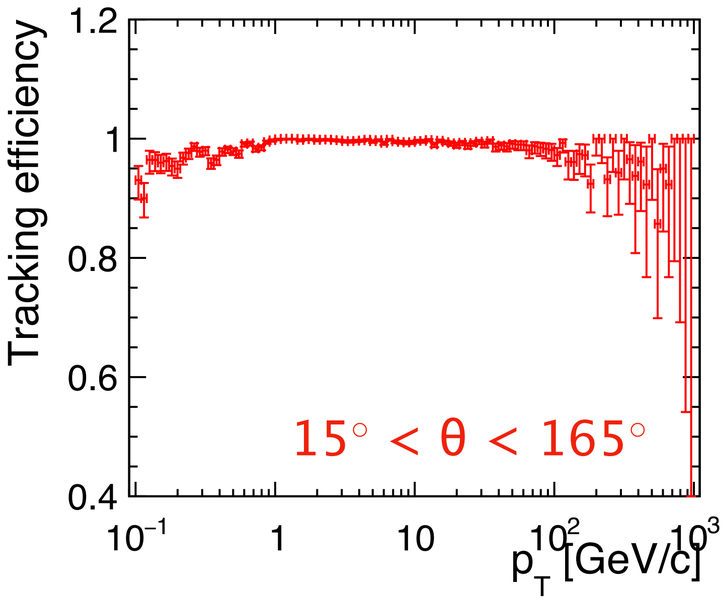
Conformal Tracking (FULL)



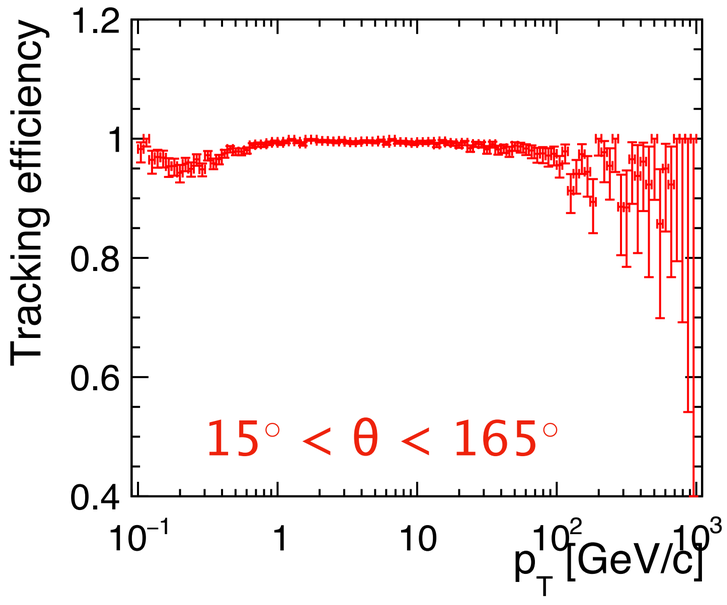
Tracking efficiency

- 1k ttbar events
- Tracking efficiency as a function of p_T, θ and φ

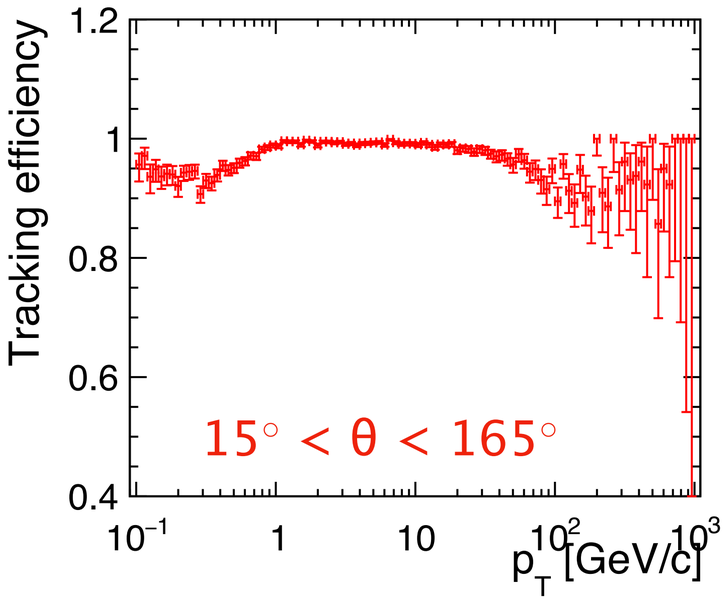
Truth Tracking



Conformal Tracking (VTX) + Extrapolator



Conformal Tracking (FULL)

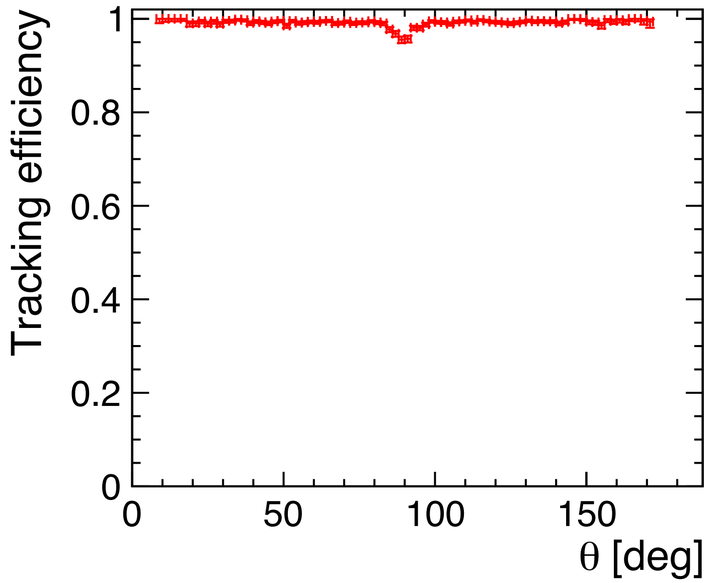


- Slight efficiency loss above 100GeV/c

Tracking efficiency

- 1k ttbar events
- Tracking efficiency as a function of p_T, θ and φ

Truth Tracking



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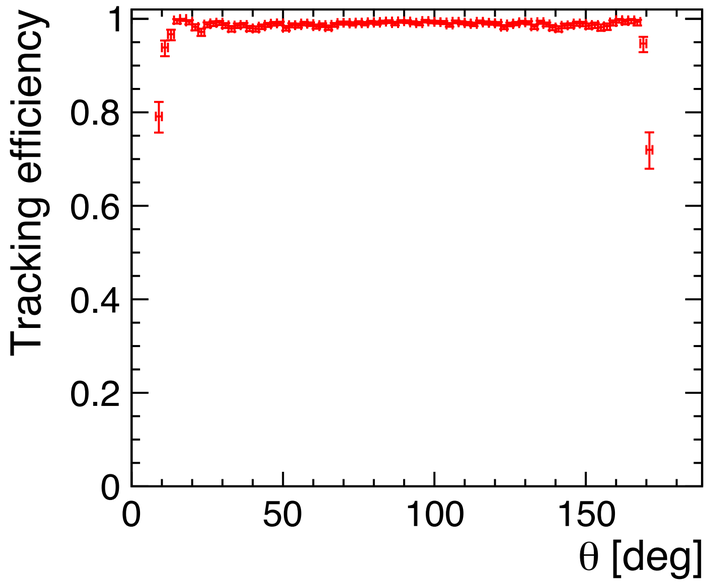
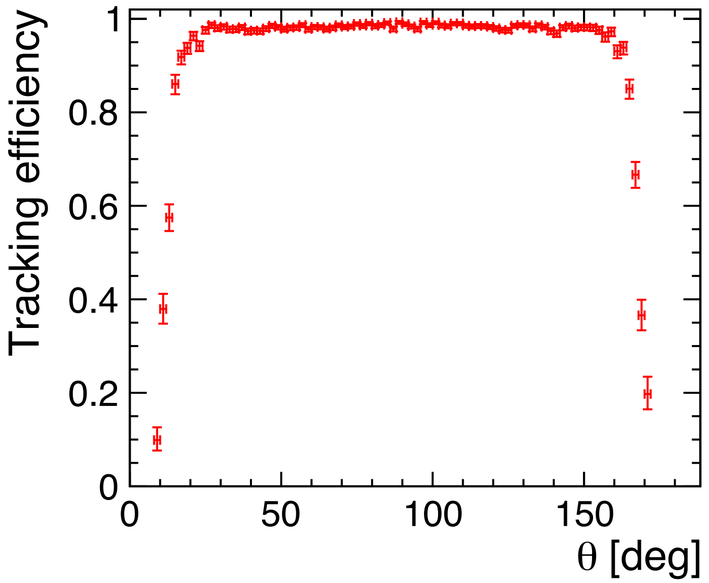


Conformal Tracking (FULL)



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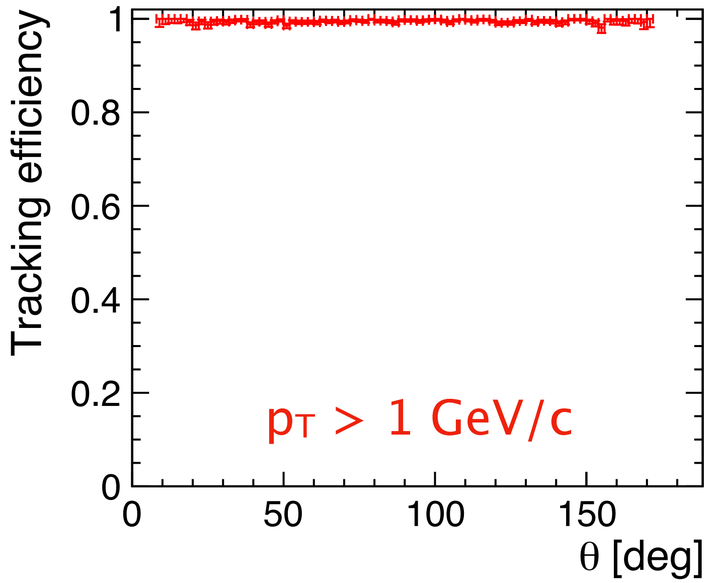
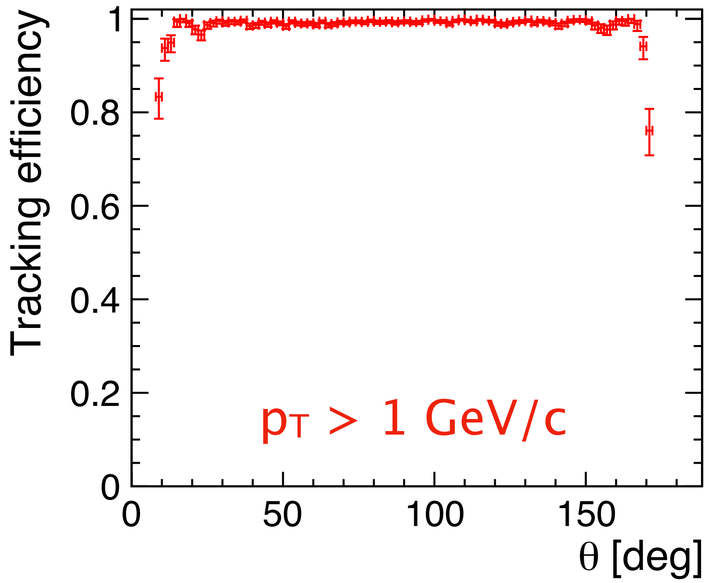
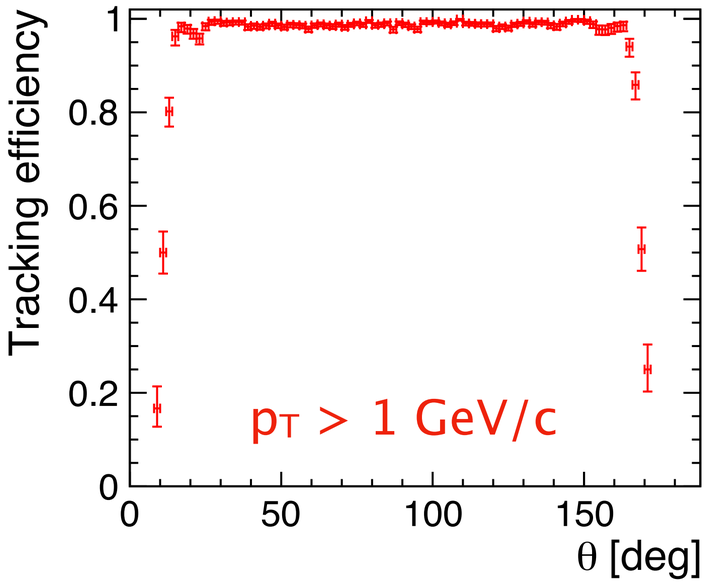
Truth Tracking



Conformal Tracking (VTX) + Extrapolator



Conformal Tracking (FULL)



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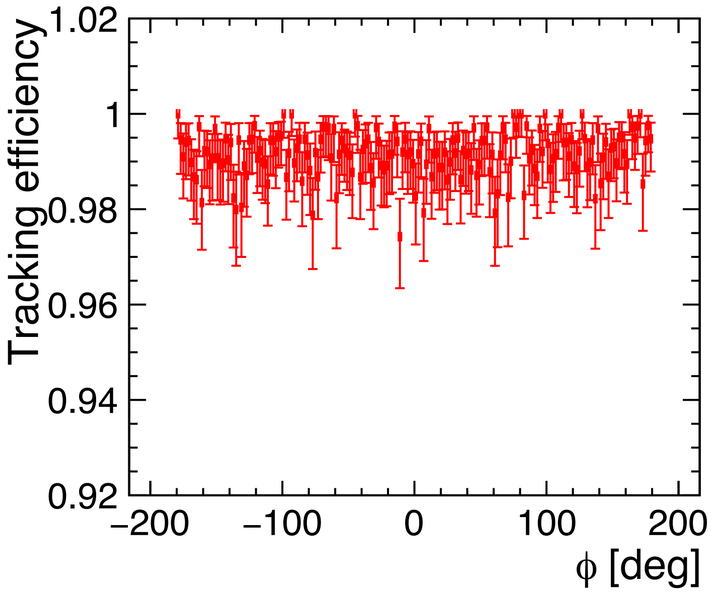
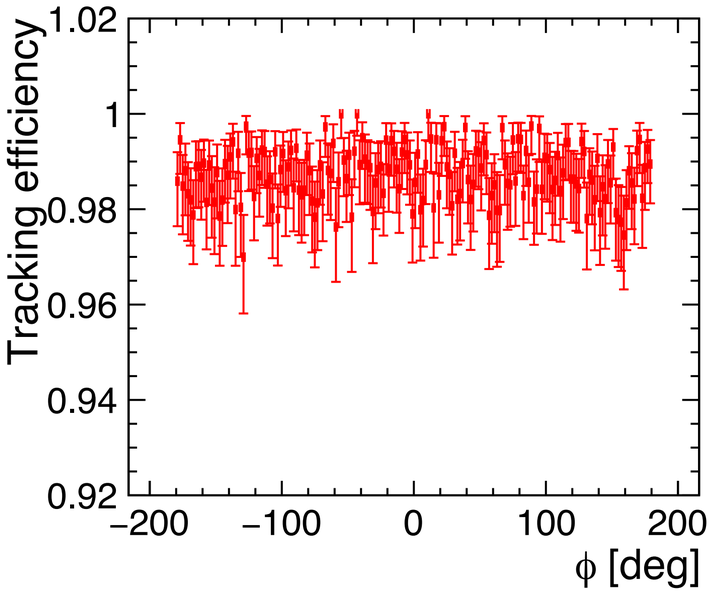
Truth Tracking



Conformal Tracking (VTX) + Extrapolator



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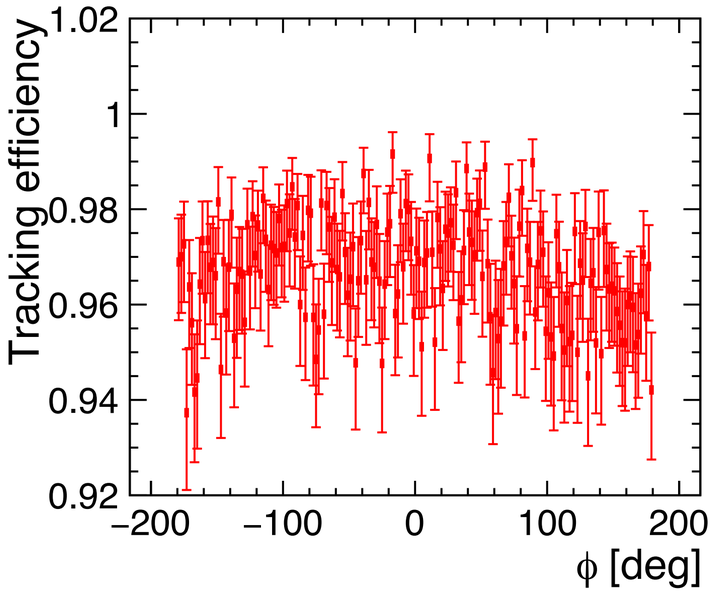

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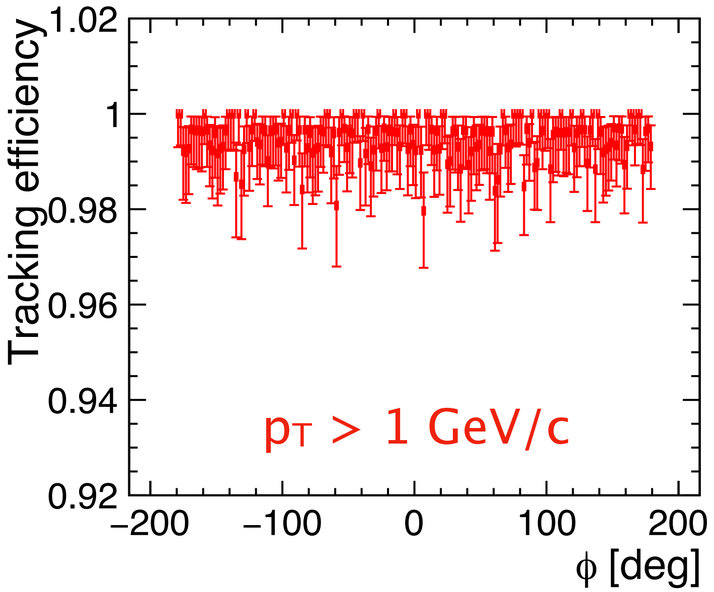
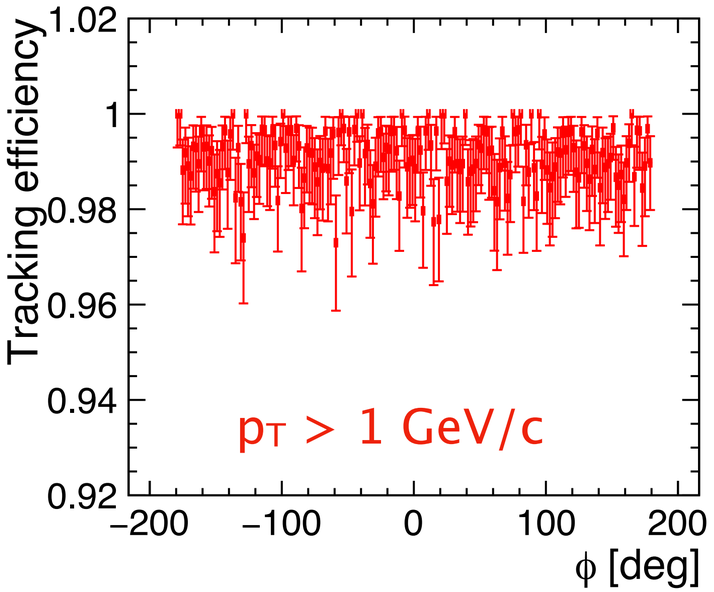
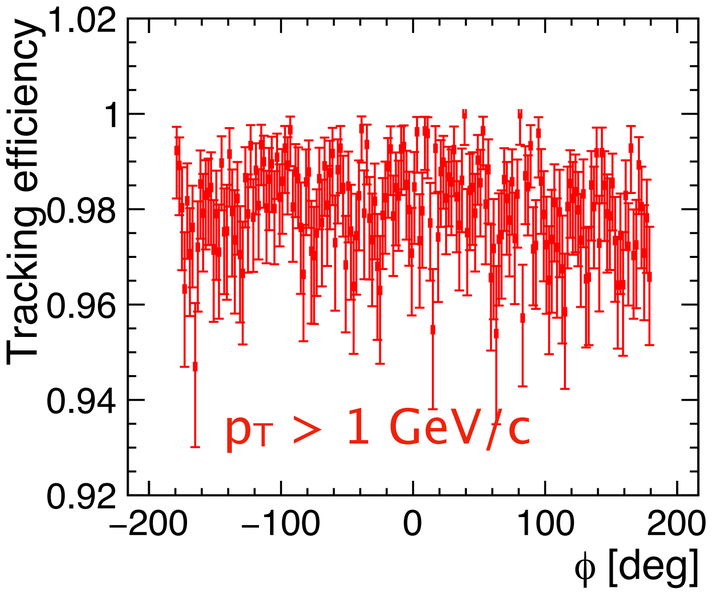
Truth Tracking



Conformal Tracking (VTX) + Extrapolator



Conformal Tracking (FULL)



✓ ttbar events @ 3TeV are reconstructed with a tracking efficiency larger than 90% (and around 99% between 1 and 100GeV/c)

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Summary and news

- ✓ Single muons are reconstructed with an efficiency of 100% down to 100MeV/c and in the full phase space down to 10 (170) deg
- ✓ Momentum resolution achieved: 2×10^{-5} for high energy (500GeV) muons in the central barrel
- ✓ Z=>uds events at 91GeV are reconstructed with a tracking efficiency larger than 90% (and around 99% above 1GeV/c)
- ✓ ttbar events @ 3TeV are reconstructed with a tracking efficiency larger than 90% (and around 99% between 1 and 100GeV/c)

Summary and news

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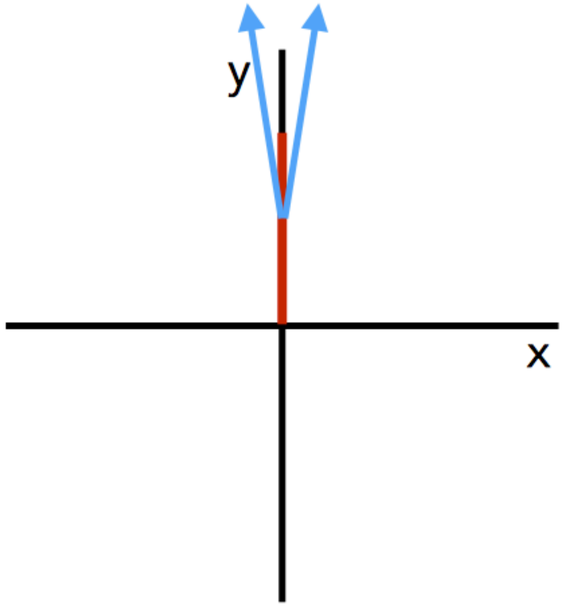
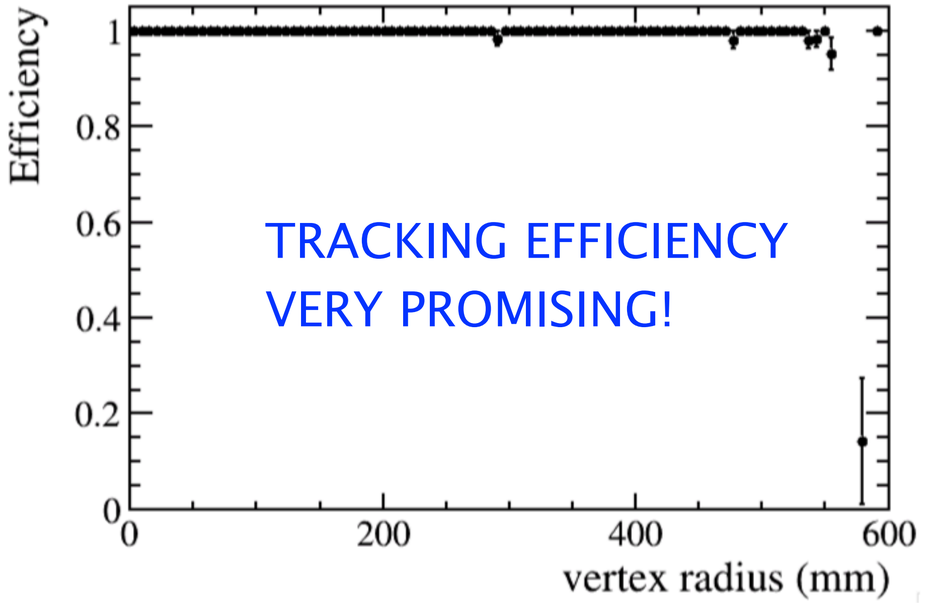
FIRST LOOK AT DISPLACED TRACKS

- ☆ 100GeV displaced muons generated in $0 < y < 1$m
- ☆ $80^\circ < \theta, \varphi < 100^\circ$ to point away from IP
- ☆ cuts tuning optimized to reduce execution timing





What's next

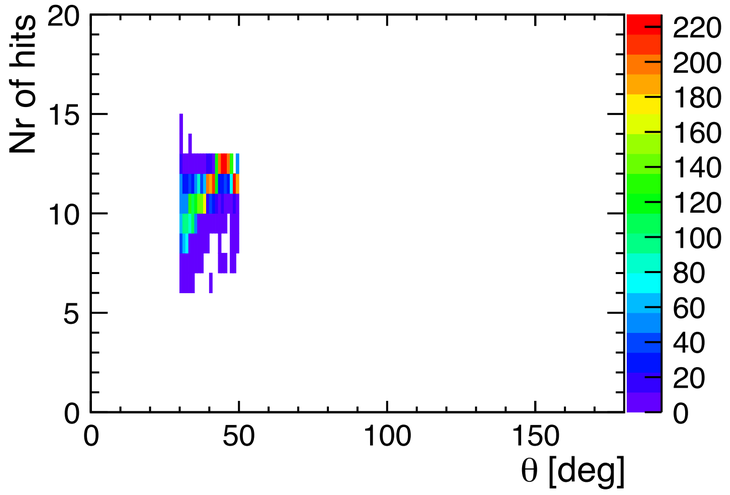
- Conformal Tracking 'full' is converging to be the designated tracking strategy for CLIC
  - fixes for the hits loss in the transition regions already committed in the latest release
  - effort is being put in to reduce the timing and memory consumption in high multiplicity events due to the large combinatorics
  - thorough validation of the reconstruction of displaced tracks is ongoing
  - next major step foreseen: background (γγ->hadrons, incoherent pairs) overlay

Thanks for your attention

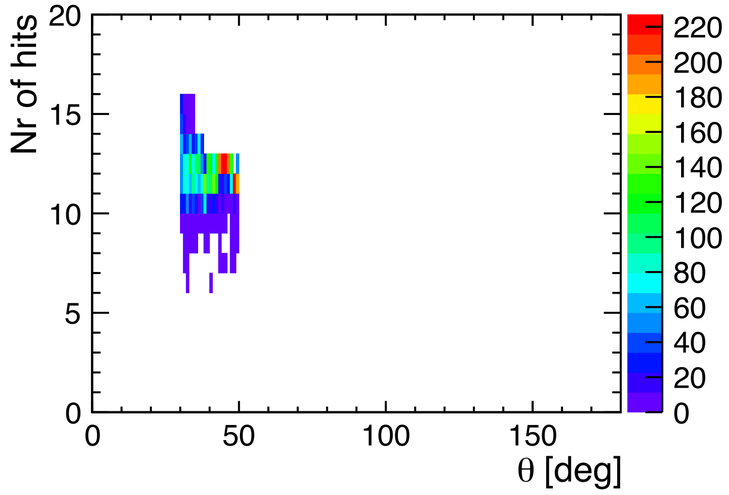
BACKUP

Conformal Tracking full — transition regions

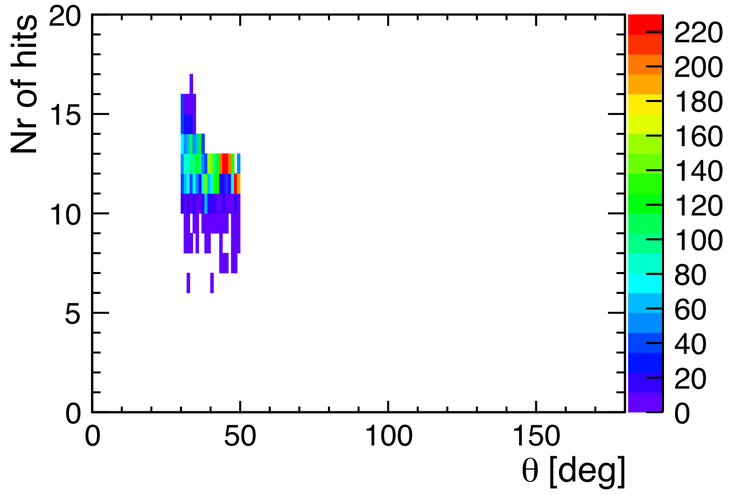
errZ = 10^-5 mm



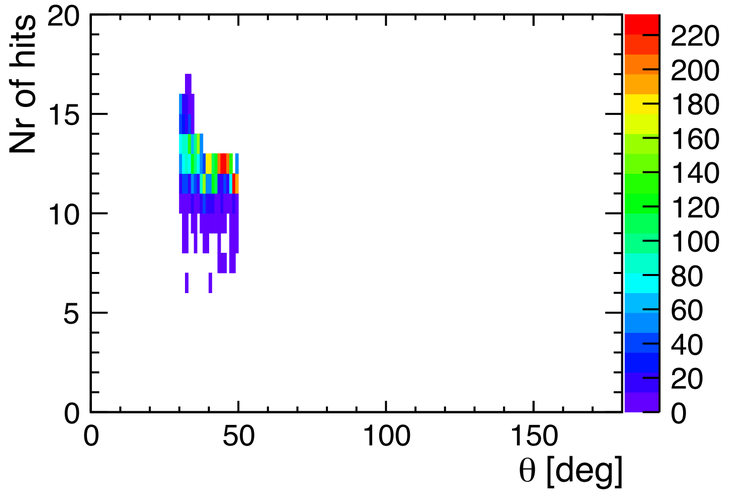
errZ = 100 µm



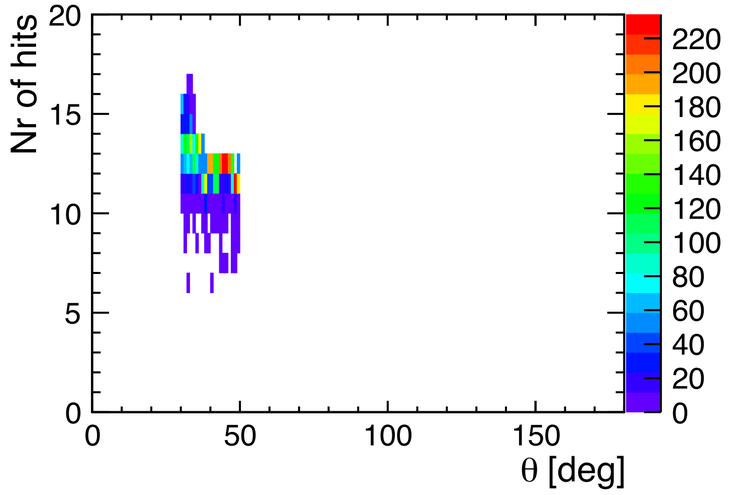
errZ = 150 µm



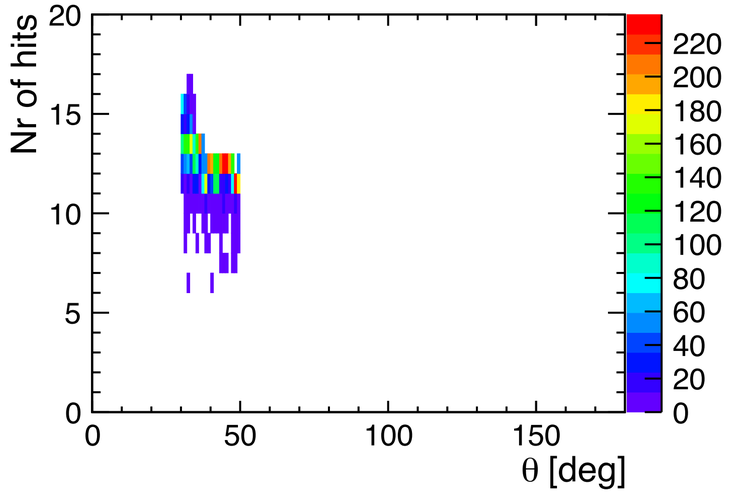
errZ = 200 µm



errZ = 250 µm

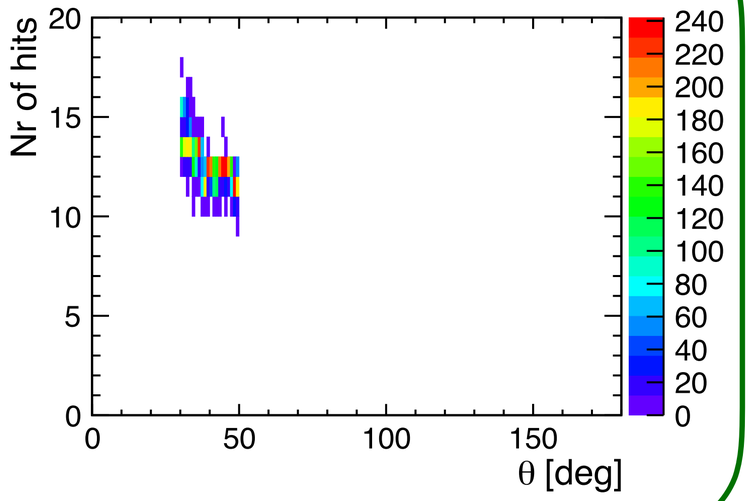


errZ = 300 µm

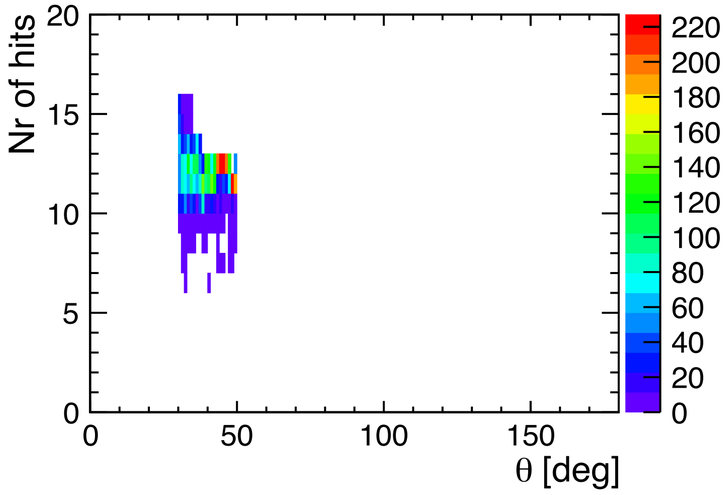


Conformal Tracking full — transition regions

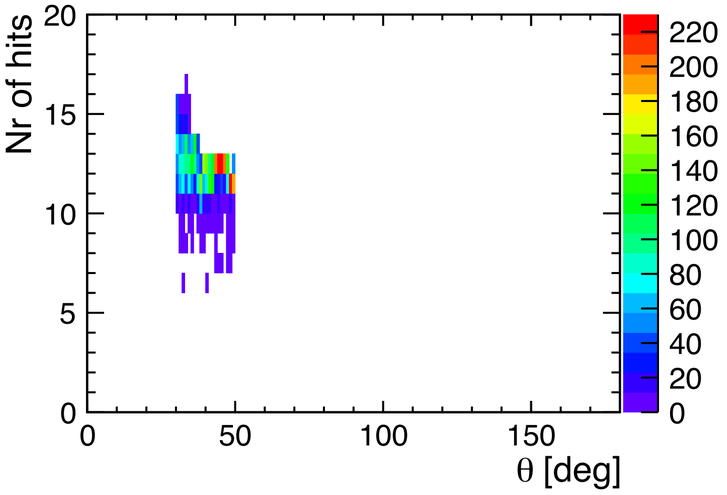
MC



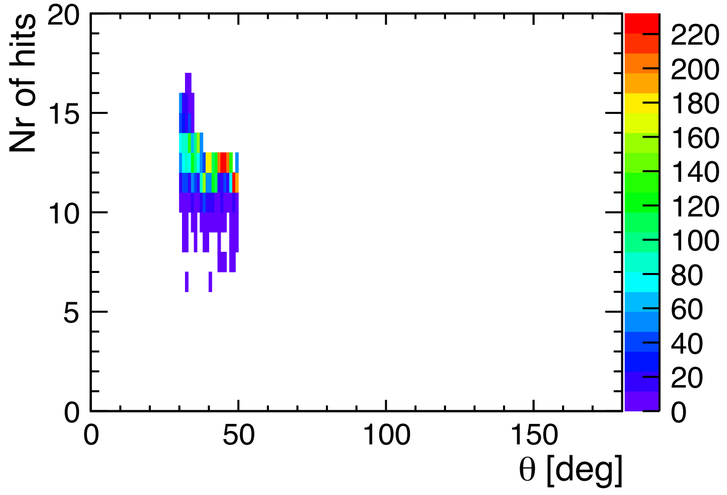
errZ = 100 μm



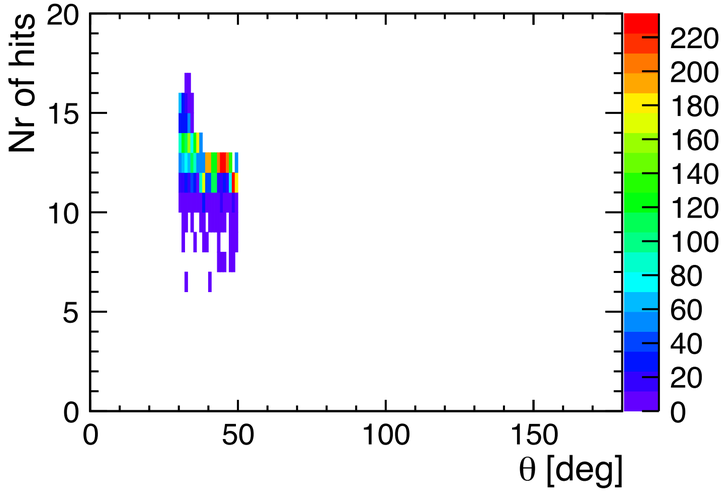
errZ = 150 μm



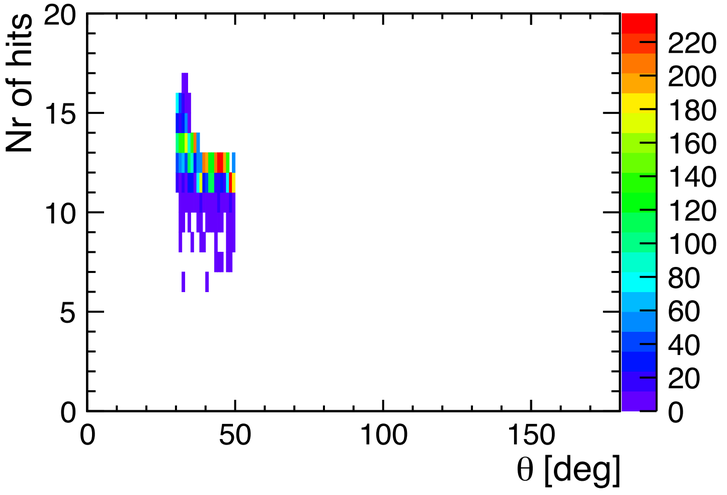
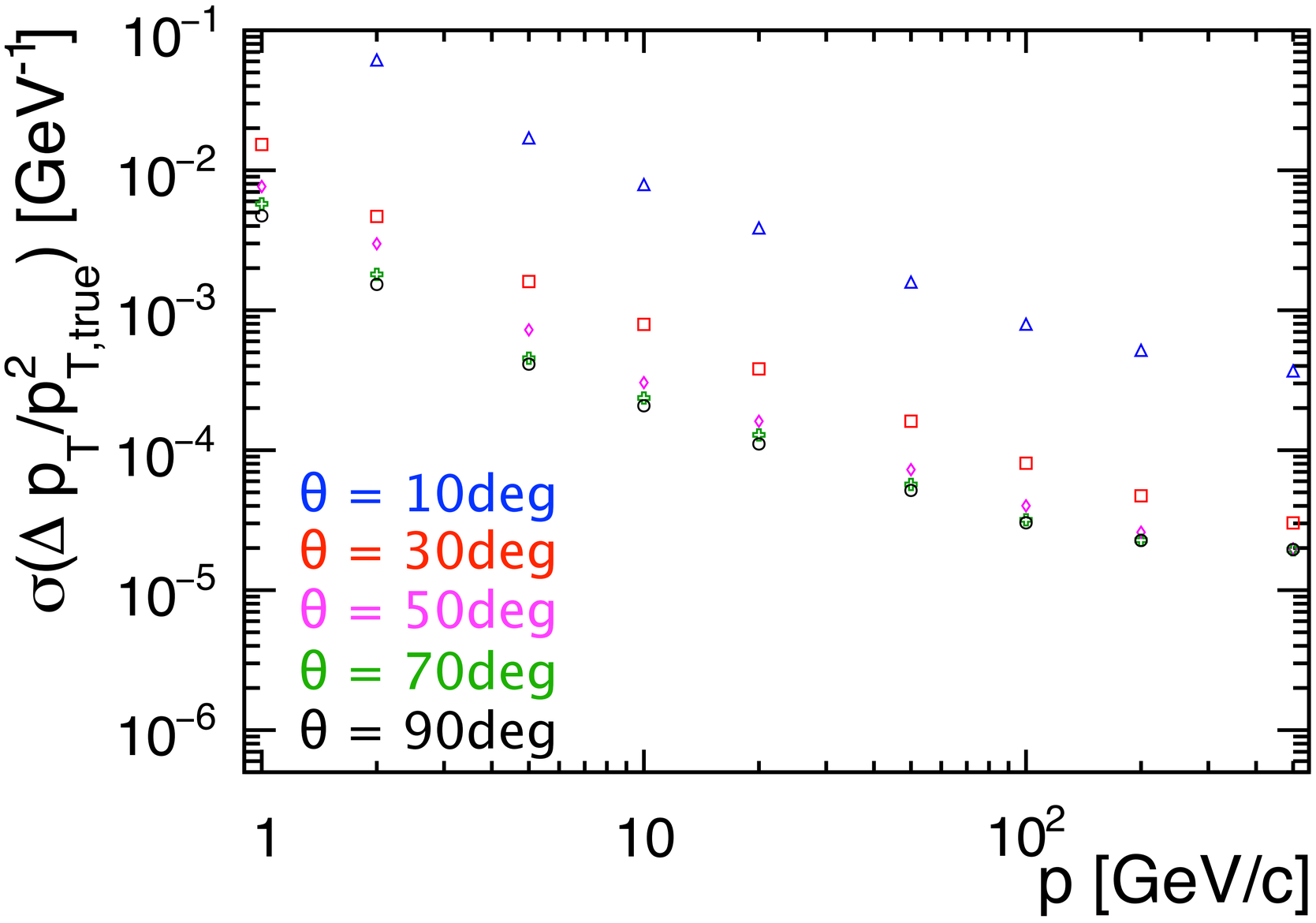
errZ = 200 μm



errZ = 250 μm



errZ = 300 μm



Conformal Tracking full — momentum resolution after Nhits fix