Tracking detector studies in the new framework and next steps

Workshop on Detector and Physics simulation at a Muon Collider
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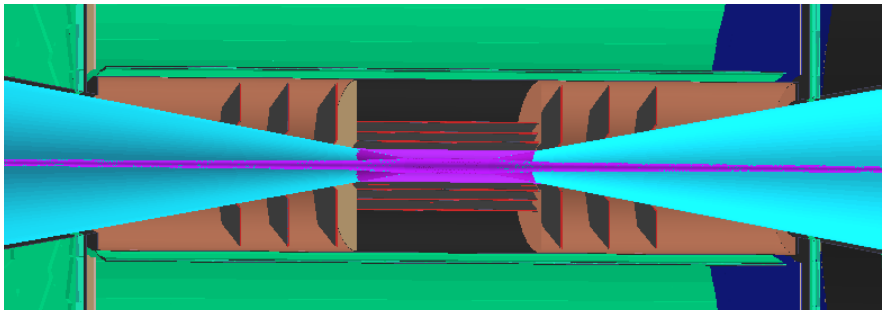
CLIC tracker

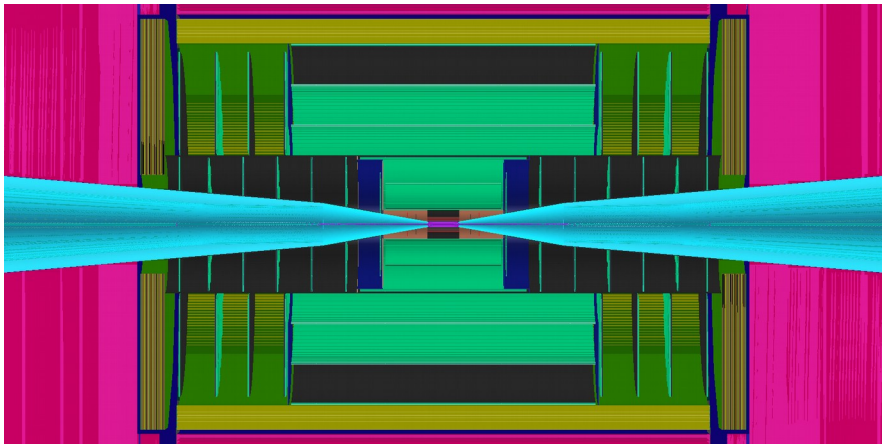


Vertex Detector: double-layers 25x25 μm^2 pixels (50 μm thick)
-Three cylindrical **barrels**
(R= 31-60 mm; L= 130mm)
-Three **endcap** disks
(|z|=160-298 mm R=33mm-102mm)

Subdetector	Pixel/strip sizes
Vertex (Barrel and Disks)	25 μm × 25 μm
Inner Tracker Disk 1	25 μm × 25 μm
Inner Tracker Disks 2–7	50 μm × 1 mm
Outer Tracker Disks	50 μm × 10 mm
Inner Tracker Barrel 1–2	50 μm × 1 mm
Inner Tracker Barrel 3	50 μm × 5 mm
Outer Tracker Barrel 1–3	50 μm × 10 mm

Inner Tracker: Micro-strips (200 μm thick)
-Three cyclindrical **barrels**
(R=127-554 mm; L=964,964,1384 mm)
-Seven **endcap** disks
(|z|=524-2190 mm,
R_{in}=72-250 mm R_{out}=404-555 mm)

Outer Tracker: Micro-strips (200 μm thick)
-Three cylindrical **barrels**
(R=819-1486 mm, L=2528 mm)
-Four **endcap** disks
(|z|=1310-2190 mm, R=618-1430 mm)



Track reconstruction steps

Main steps:

1) The inputs to the sequence of algorithms for the track reconstruction are the **reconstructed hits**

2) Then hits are grouped into track candidates (conformal tracking)

3)Refit of the tracks allows to associate trajectories to track candidates

FIRST STEP: smearing process

- Simulated hits (SimTrackerHit type) are transformed into reconstructed hits (TrackerHitPlane type) in the DDDigiProcessor
- The local positions of all simulated hits are smeared with Gaussian distribution (width equal to the single point resolution)

Tracks reconstruction steps II

SECOND STEP: Conformal Tracking

- Conformal tracking is used as pattern recognition algorithm for track reconstruction

  1) Conformal mapping (transformation of hit positions to the conformal space)

  2) Cellular tracks are built and extended by two **cellular automaton** algorithms. First cellular track candidates are found in the vertex barrel, than they are extended using hits in the tracker barrel and endcap detectors

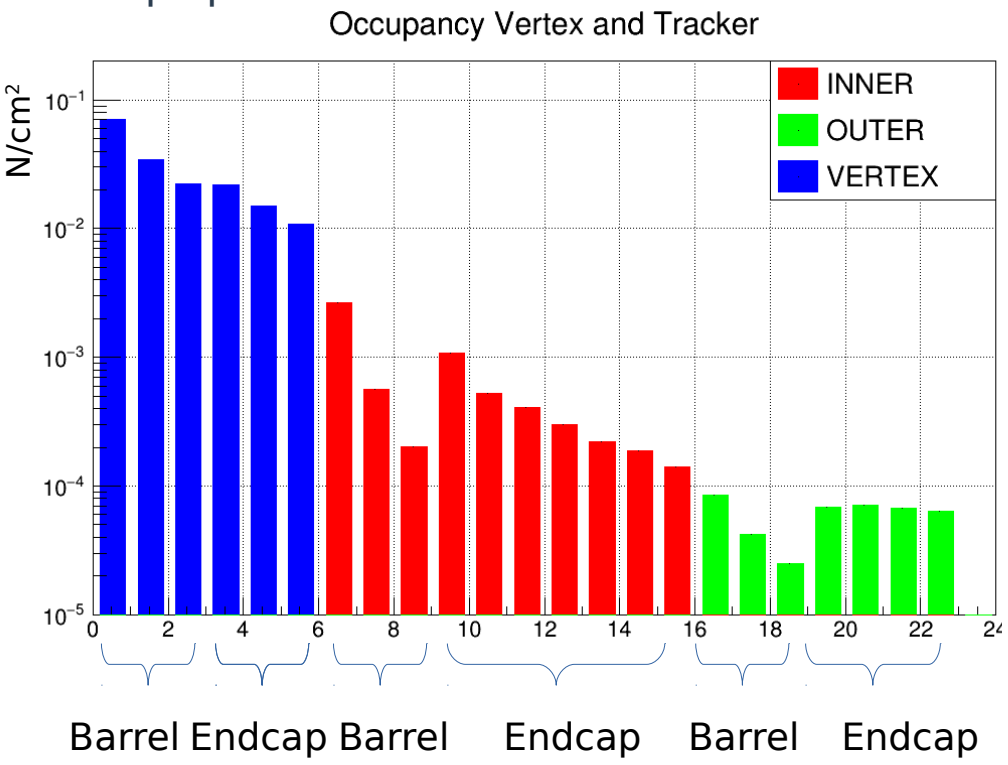
THIRD STEP: Track fitting

- For each cellular track candidate reconstructed, the track fit is run in order to obtain a precise estimation of the track parameters. It consists of a Kalman filter and smoother

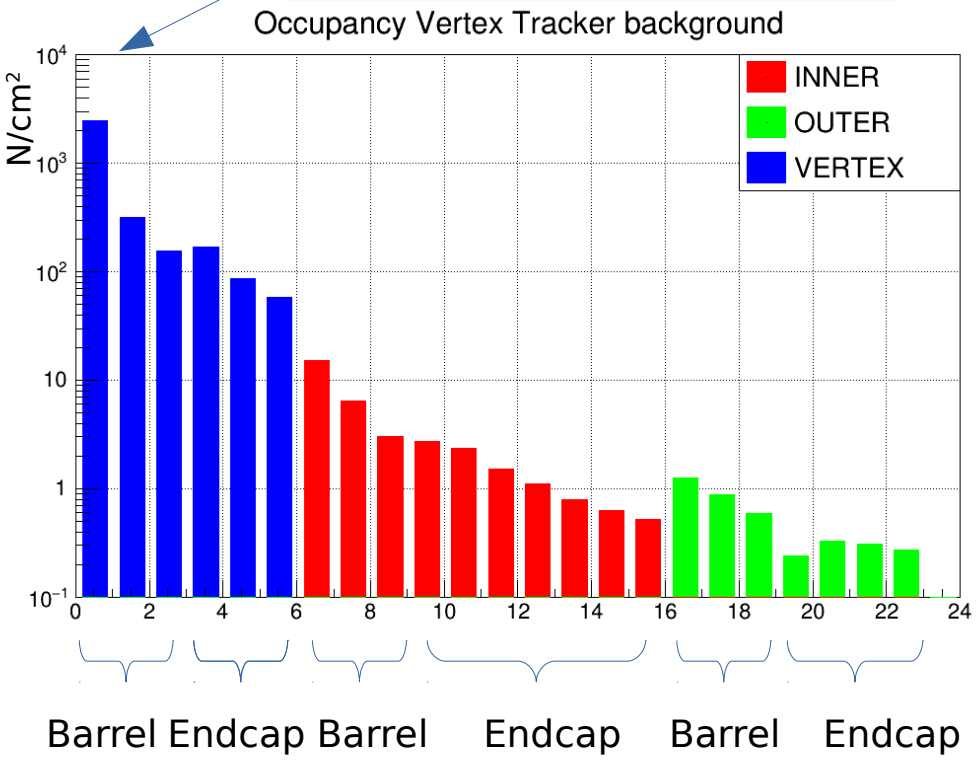
Occupancy of tracker

- Time window (collection integration time) [-0.25, 1] ns
- Cut on time has not been optimized yet

Process:
$\mu^+ \mu^- \rightarrow H\bar{\nu}\nu \rightarrow \bar{b}b\bar{\nu}\nu$ at 1.5 TeV

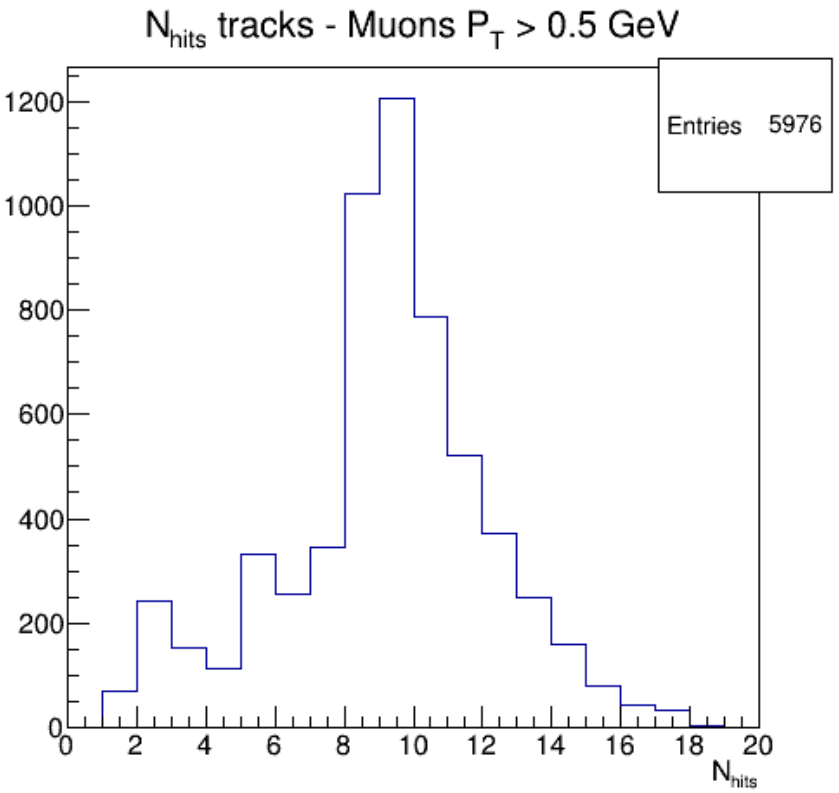


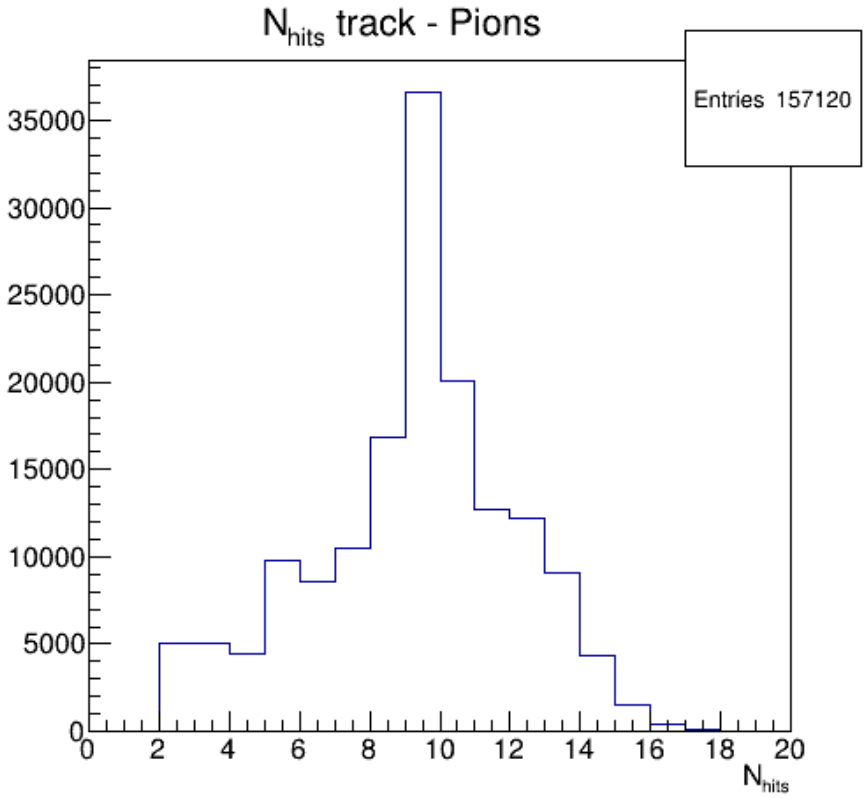
Maybe due to tracker digitazion



Hits number on tracker (signal)

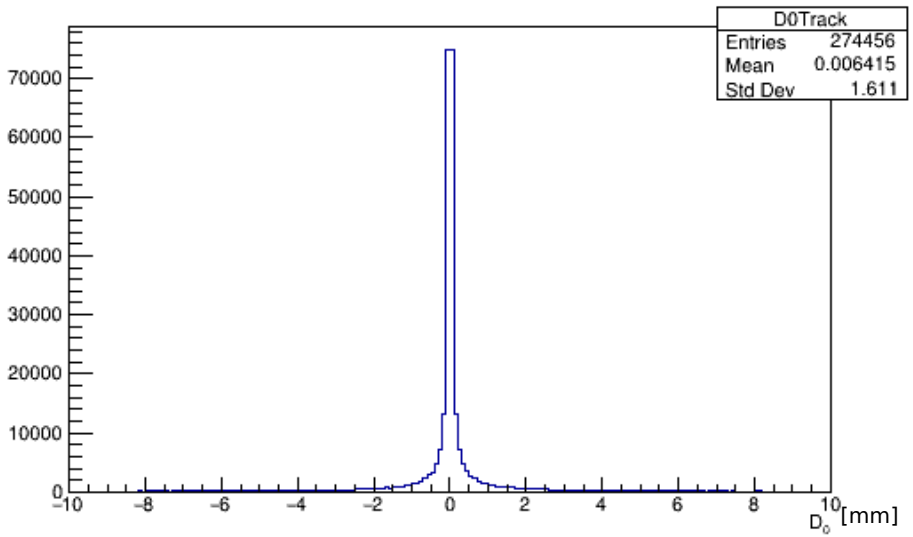
- Collections: TrackerHitPlane, LCRelation
- Number of hits from process $\mu^+ \mu^- \rightarrow H\bar{\nu}\nu \rightarrow \bar{b}b\bar{\nu}\nu$ at 1.5 TeV (10000 events)



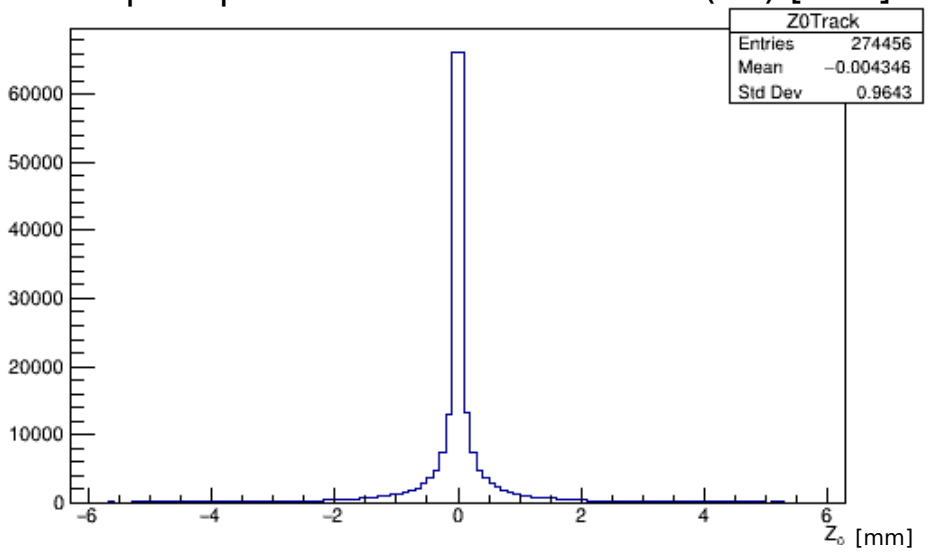


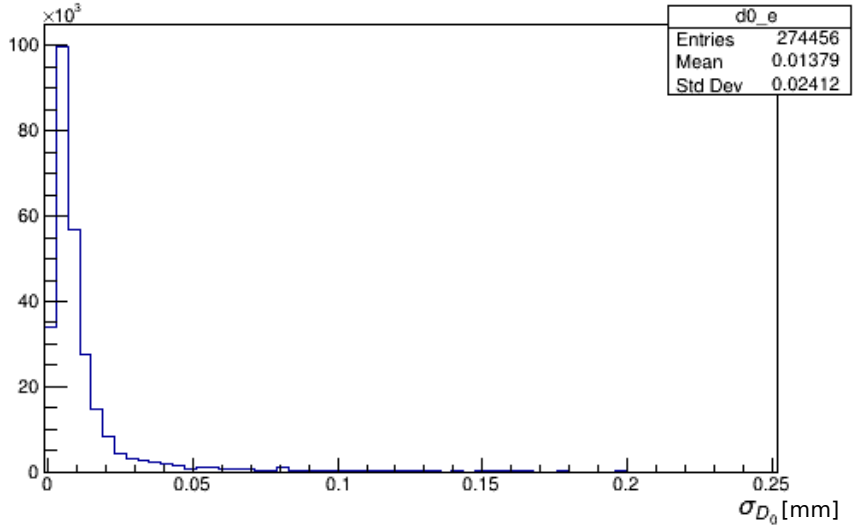
Track parameters

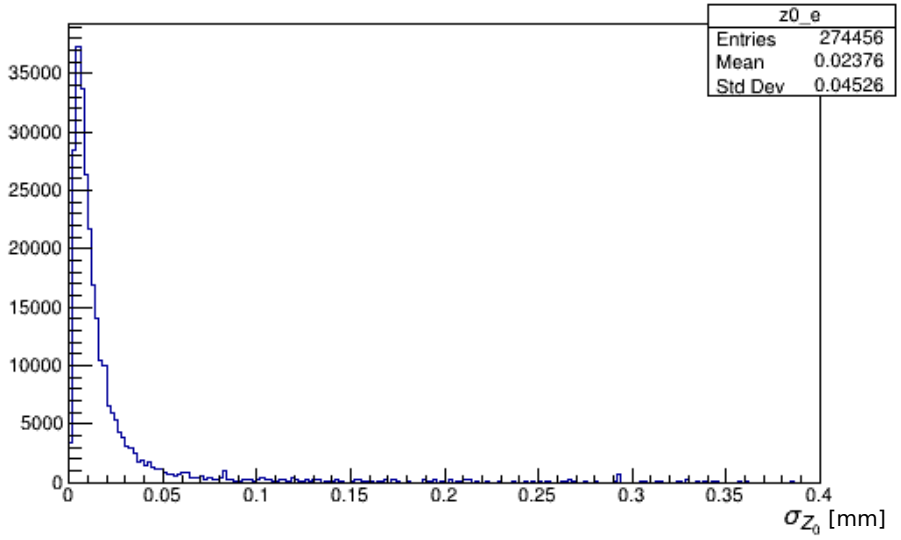
Impact parameter of the track in (r-phi) [mm]



Impact parameter of the track in (r-z) [mm]

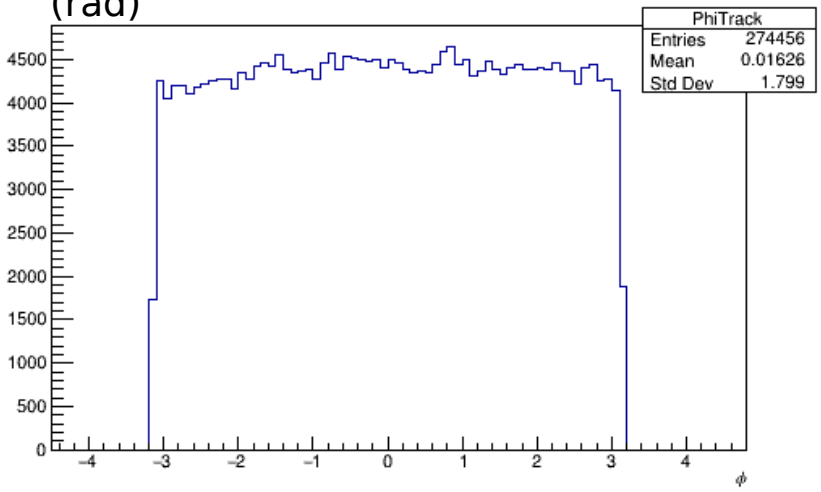


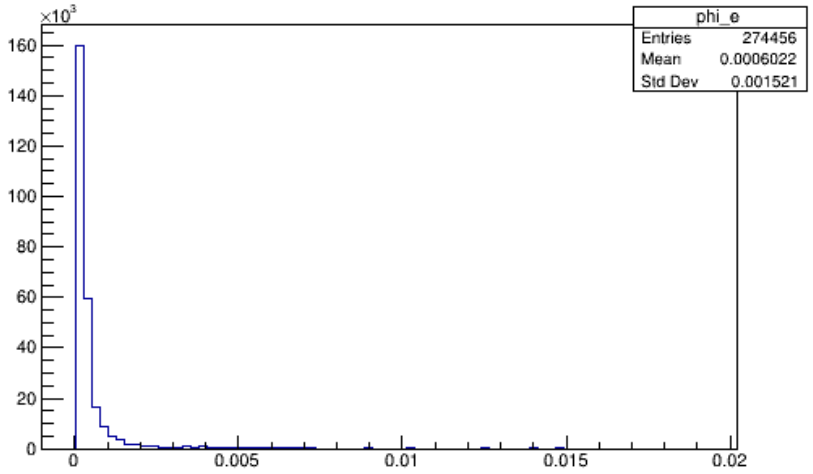




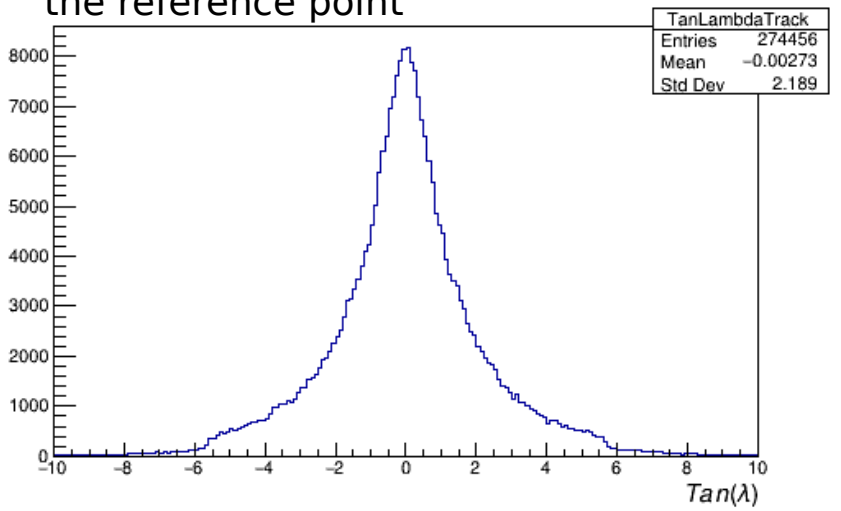
Track parameters

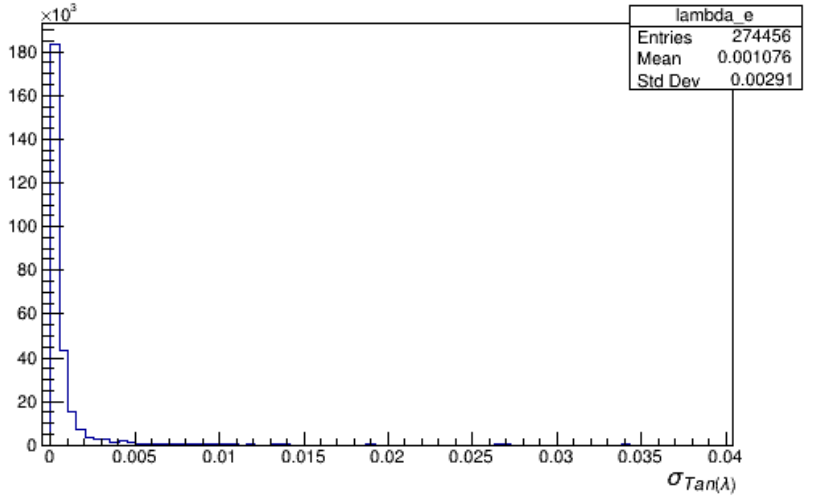
Phi of the track at the reference point (rad)



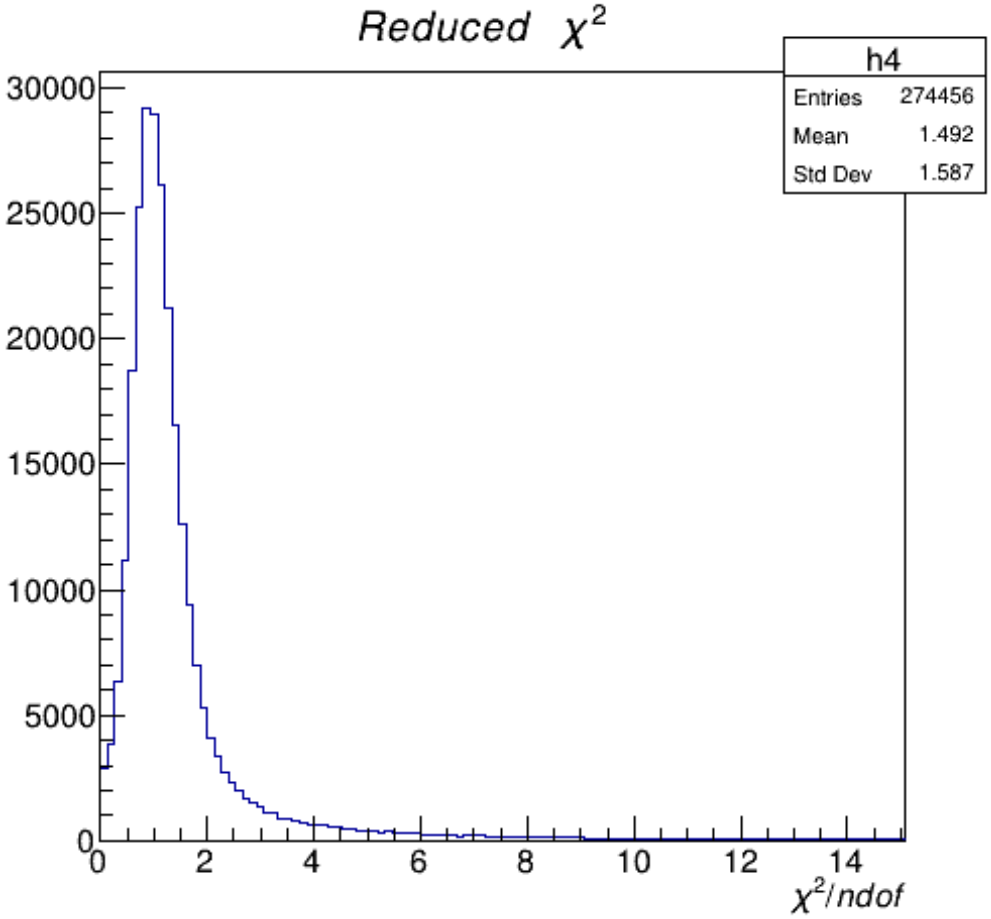


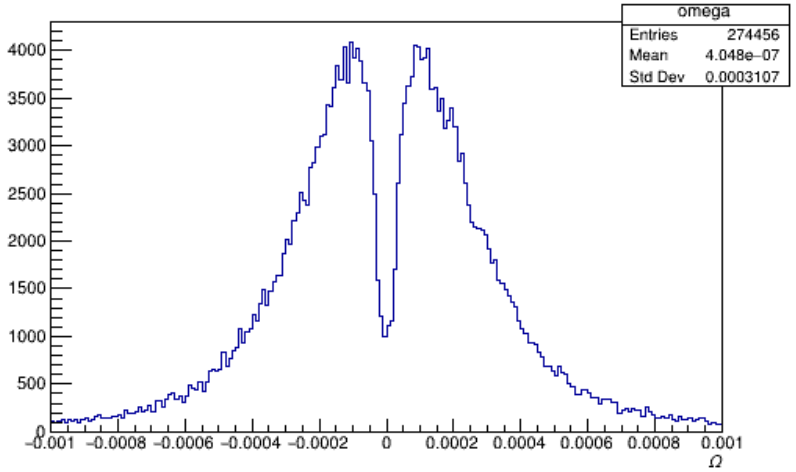
Lambda is the dip angle of the track in r-z at the reference point

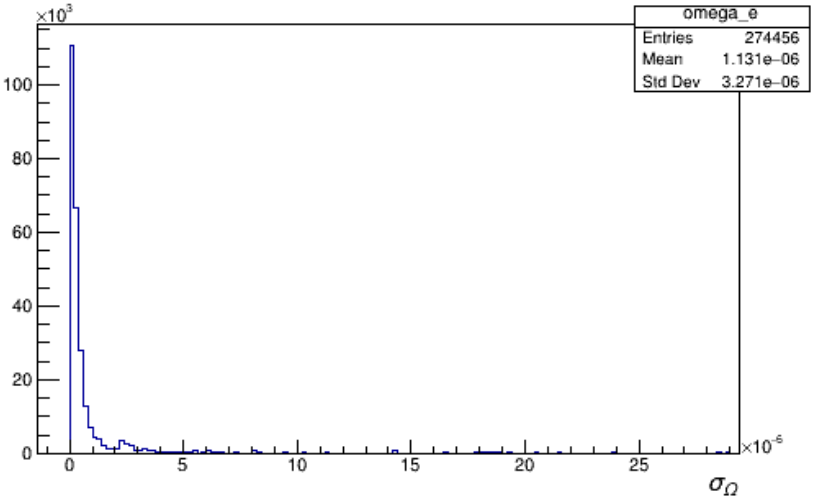




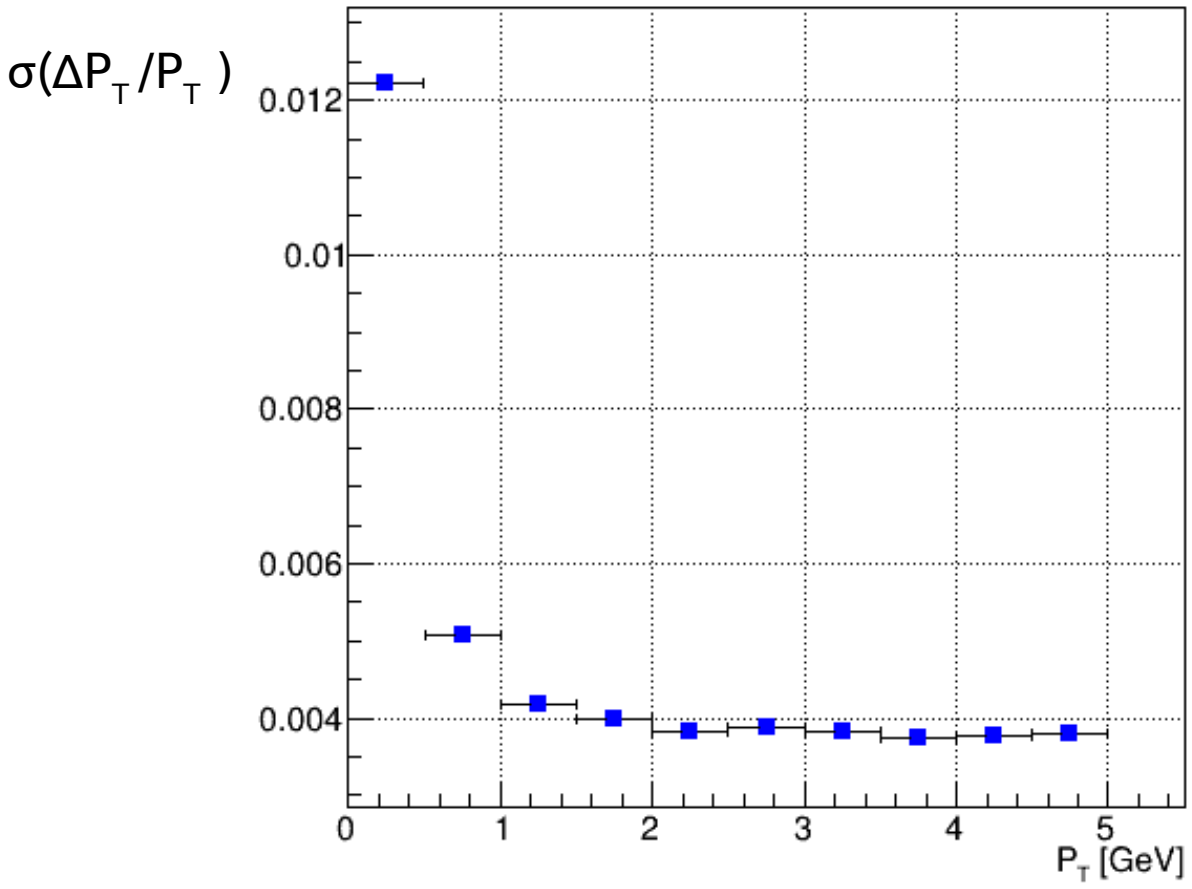
Omega is the signed curvature of the track in [1/mm]







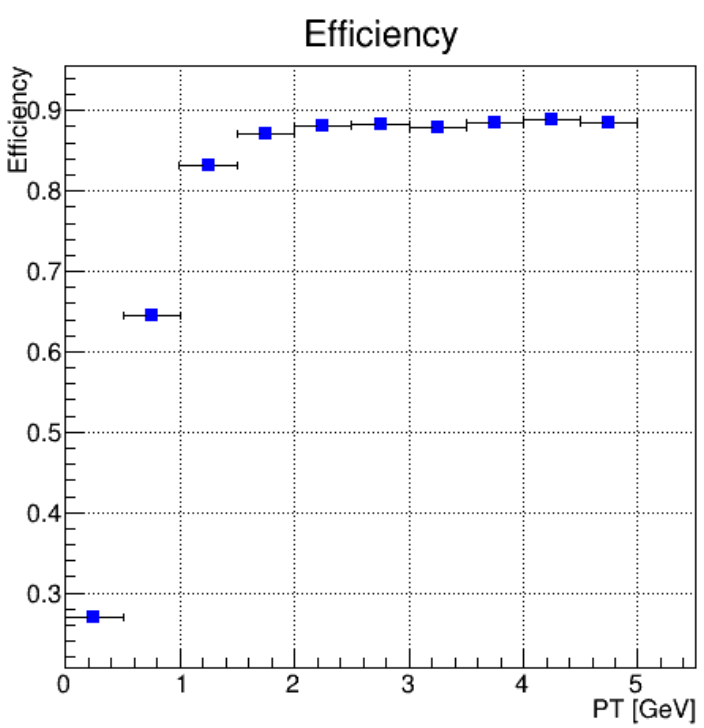
Sigma of $\Delta P_T/P_T$

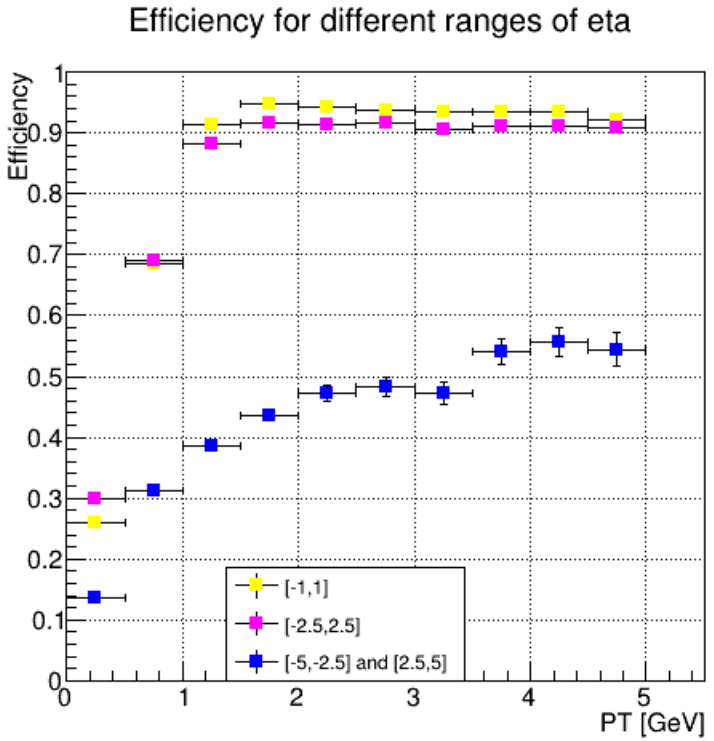


Reconstructed tracks for pions from process $\mu^+\mu^- \rightarrow H\nu\nu \rightarrow b\bar{b}\nu\nu$ at 1.5 TeV (10000 events)

Plot of tracking efficiency

- Tracks of charged **pions** from process $\mu^+ \mu^- \rightarrow H\bar{\nu}\nu \rightarrow \bar{b}b\bar{\nu}\nu$ at 1.5 TeV (10000 events)
- Efficiency= $N_{MC\text{-}match} / (N_{MC\text{-}unmatch} + N_{MC\text{-}match})$
- Collections: MCParticle, ReconstructedParticle, LCRelation





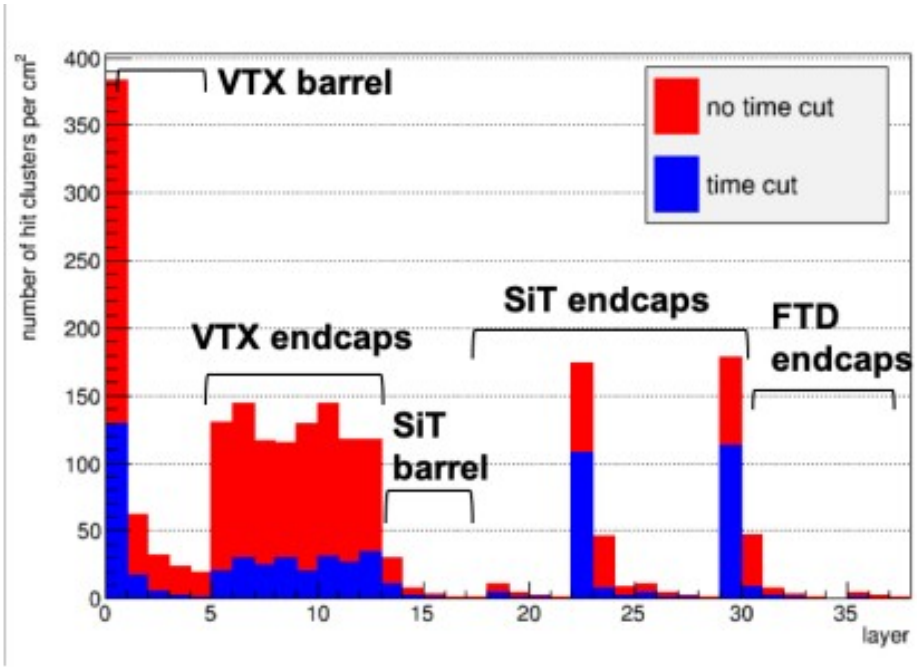
Work for future

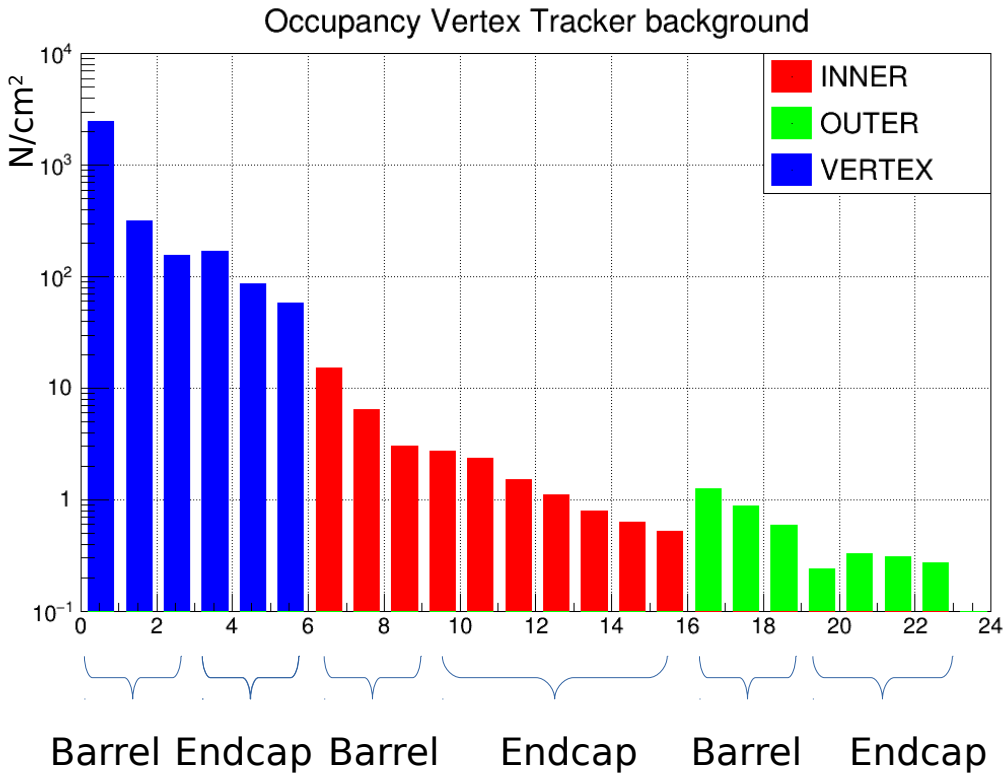
- All the studies about the optimization of the time window
- All the studies of the tracking have to be done with the mixed signal+background simulation

  The full single event reconstruction (signal+background) has not been performed yet:
- To simulate the background for one bunch crossing, 15000 subevents are used
- When the background is given “as signal” each subevent is analyzed as distinct events
- When the background files are given to the Overlay processor, the number of cellular tracks is too high...

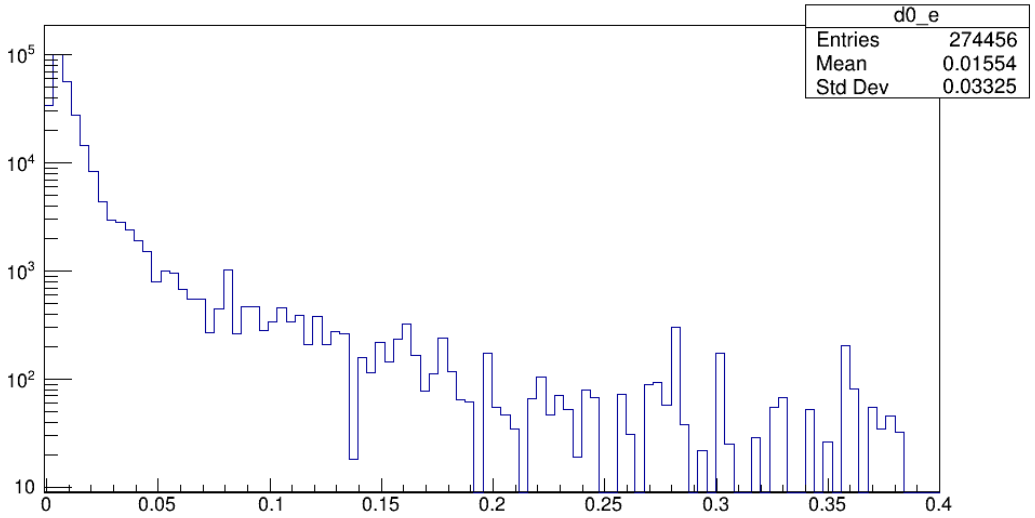
Backup

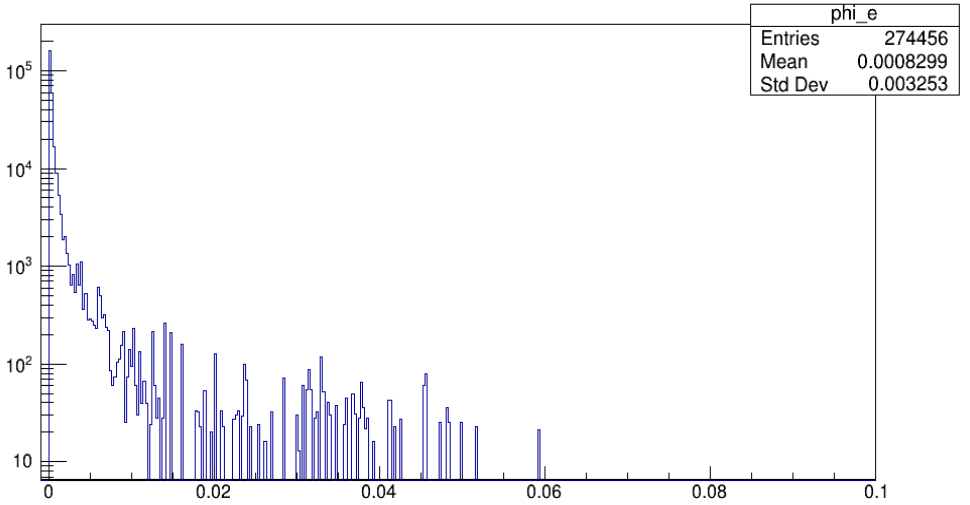
Comparison with previous occupancy

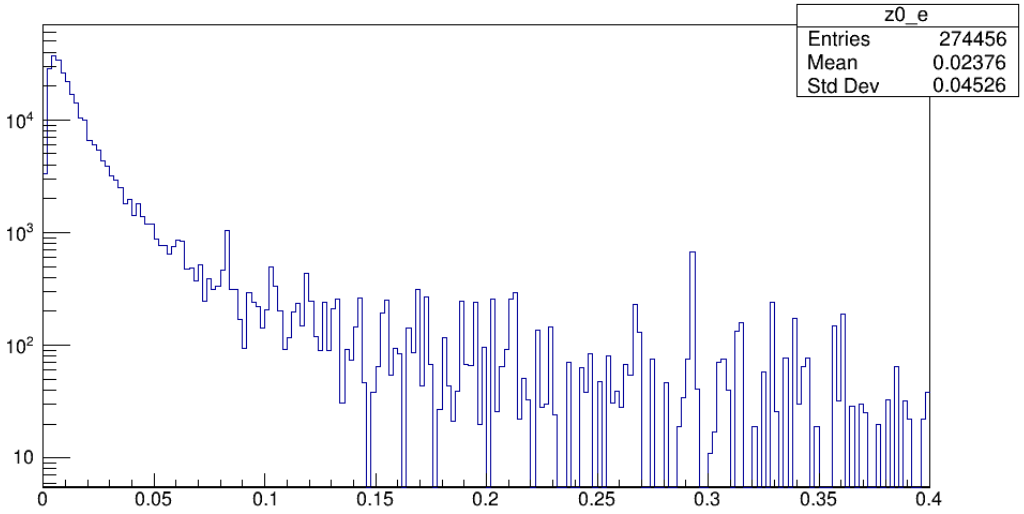




Log scale plots







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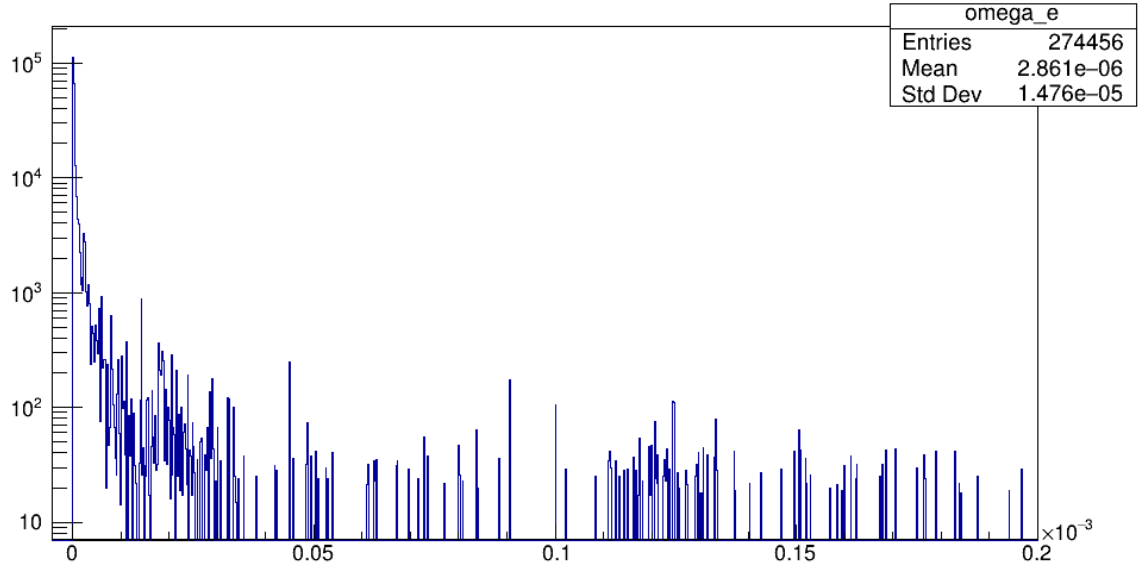

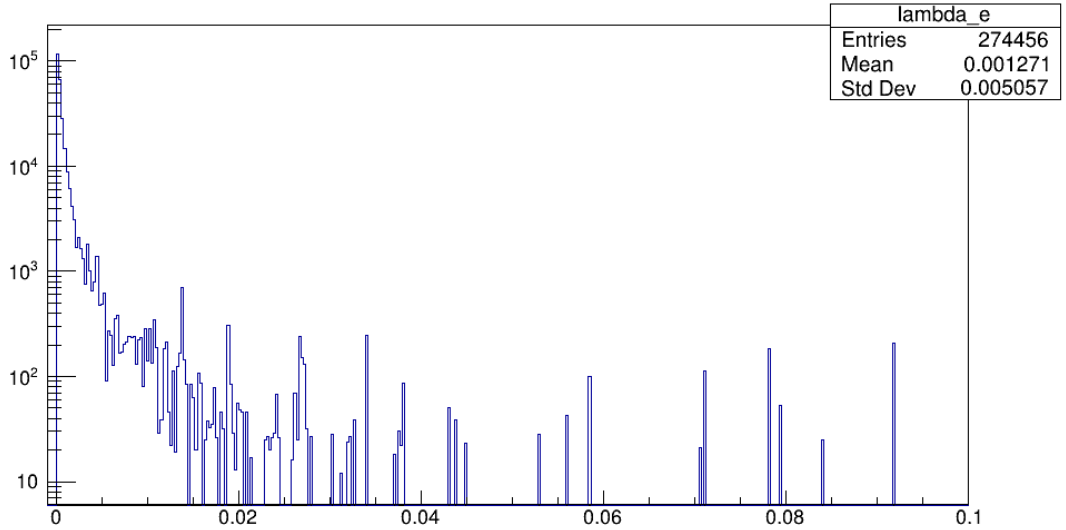

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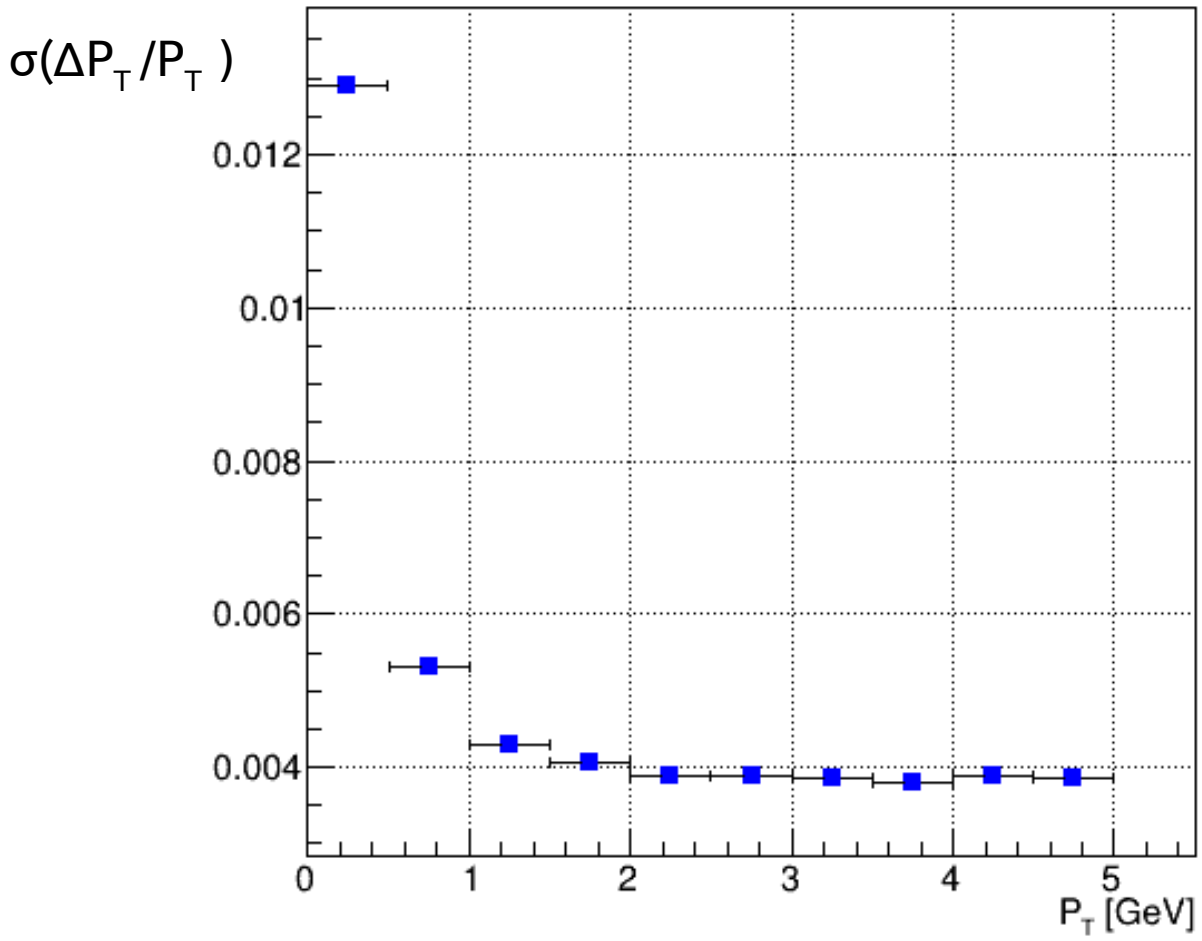
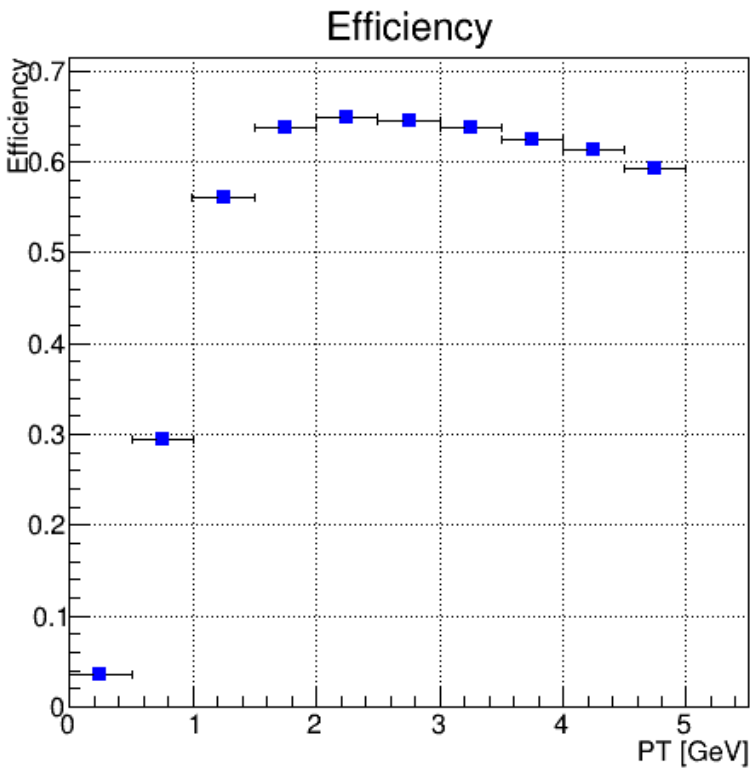
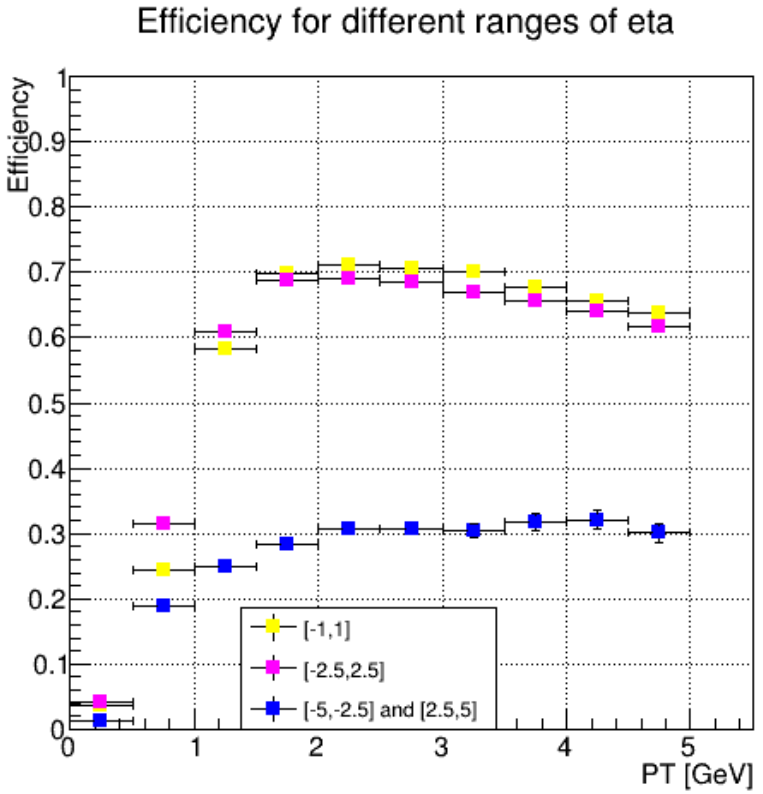


Reconstructed tracks from process $\mu^+ \mu^- \rightarrow H\bar{\nu}\nu \rightarrow \bar{b}b\bar{\nu}\nu$ at 1.5 TeV (10000 events)

Efficiency

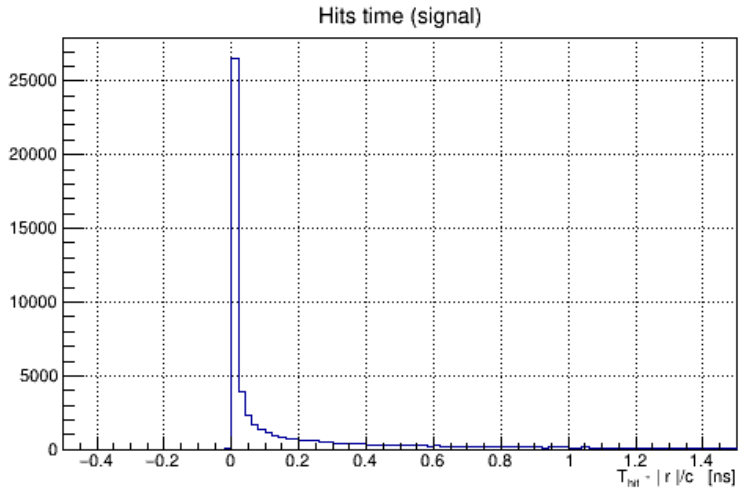
- Reconstructed tracks from process $\mu^+ \mu^- \rightarrow H\bar{\nu}\nu \rightarrow \bar{b}b\bar{\nu}\nu$ at 1.5 TeV (10000 events)
- Efficiency= $N_{MC\text{-}match} / (N_{MC\text{-}unmatch} + N_{MC\text{-}match})$



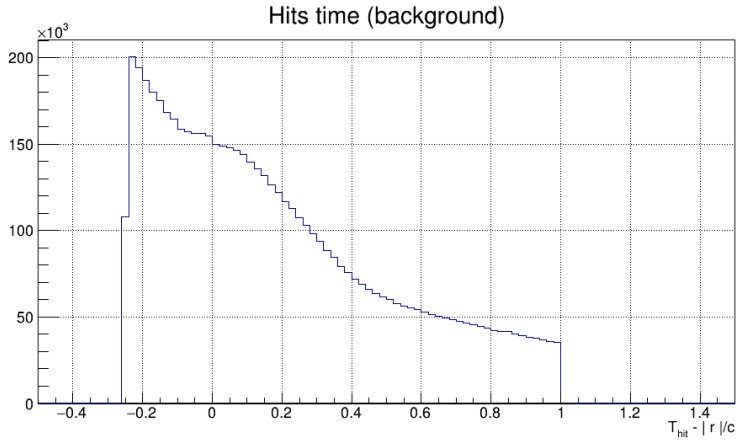


Timing

- The time information of the hits is contained in TrackerHitPlane type
- In the Overlay processor is possible to select a time windows (separately for each detector).



- Top: time of the hits with respect to the time of a photon from the interaction point, for 100 events of signal.



- Bottom: same, for 1 background event.
- Time window: from -0.25 ns to 1 ns

Conformal Tracking: Conformal Mapping

- Is a pattern recognition technique for track reconstruction
- Conformal tracking algorithm can be divided into two blocks:

  1) Conformal mapping

  2) Cellular automaton-based track finding

  The **conformal mapping** consists in a change of coordinates from Euclidean space (x,y) to **conformal space (u,v):**
- The radial order of the hit positions is **inverted** in the conformal space with respect to the global space: hits on the innermost part of the detector are mapped to outer regions in the (u, v) plane and vice versa
- The simple pattern recognition technique in original applications of conformal mapping: **grouping hits aligned** in the same direction **in the (u, v) plane**, by searching for peaks in the angular hit distribution in conformal space

Conformal Tracking: Cellular automata

- This simple technique does not take into account deviations from the straight line path (i. e. multiple scattering)
- To take these deviations systematically into account, pattern recognition in conformal space performed via **cellular automaton (CA)**
- The CA-based algorithm for track finding in conformal tracking consists of the creation and extension of **cells** (cell = segment connecting two hits). It consists of two main algorithms:

  1)the **building** of cellular track candidates

  2)the **extension** of cellular track candidates.

Building of cellular tracks candidate

- A subset (called **seeding collection**) of hits (**seed hits**) is selected
- Search for neighbouring hits:

$$\Theta \qquad [\Theta_{\text{seed hit}} - \Delta\Theta_{\text{neighbours}}, \Theta_{\text{seed hit}} + \Delta\Theta_{\text{neighbours}}]$$

- A small number of **seed cells** is created by connecting . This provides the basic set of track candidates to be further extended

- BREVE DESCRIZIONE DELL'ESTENSIONE