Matching between CRT hits and reconstructed TPC tracks

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Local DUNE Weekly Meeting
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Outline

- ⇒ The Space Charge Effect (SCE) is the build-up of slow-moving positive ions in a detector leading, to a distortion of the electric field within the detector
- ⇒ It is anticipated that the space charge distortions in ProtoDUNE maybe as large as 20 cm
- ⇒ As a part of a plan to produce a MC-based demonstration of the space charge calibration, reconstructed TPC tracks need to be matched to Cosmic Ray Tagger (CRT) hits
- ⇒ However, matching is not trivial as triggering will happen on the beam in protoDUNE:
  - Only cosmics that fall within the readout window will be reconstructed
  - We will not know their true time; and hence the true position in the drift direction x

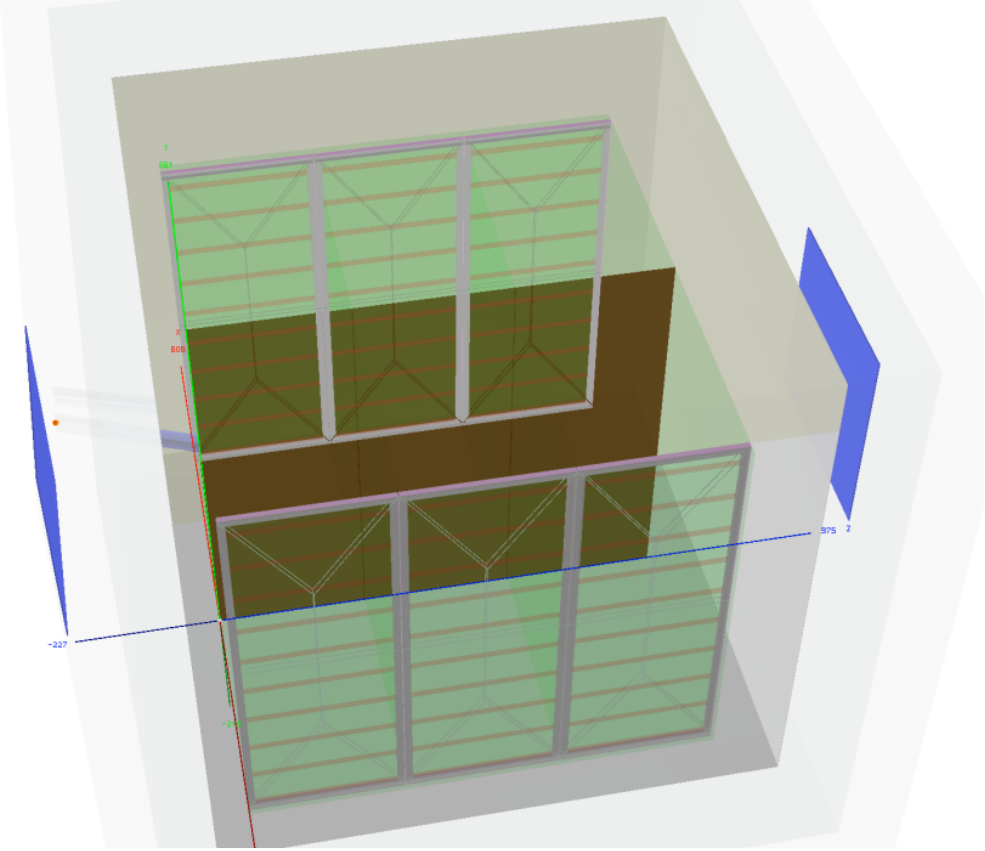
Methods

Two different methods of matching have been developed:

- ⇒ Method 1: Utilizes two CRT planes and performs matching using CRT hit position (x, y, z)
- ⇒ Method 2: Utilizes only one CRT plane and performs matching using CRT hit position and time (x, y, z, t); this work can be extended in the future to tag cosmics

Cosmic Ray Tagger (CRT)

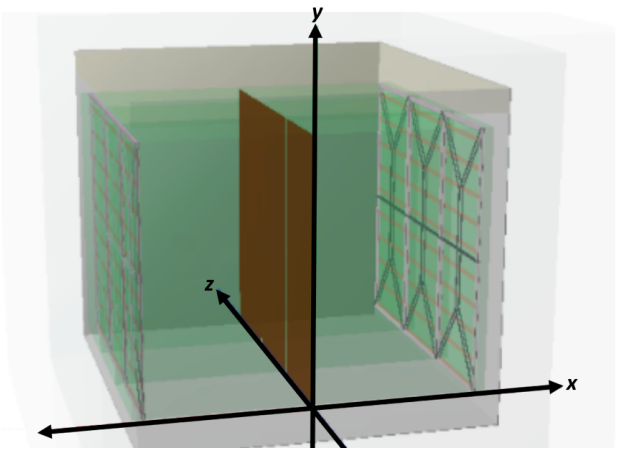
Although possible locations for CRT modules are currently under investigation, in MCC9, simple CRT volumes are included. However, these volumes are included without segmentation.



Cosmic Ray Tagger (CRT)

Toy model CRT in this study covers the active TPC volume in:

- ⇒ **Front:** z= **-202 cm**, -404 cm $< x <$ 408 cm, -19 cm $< y <$ 626 cm
- ⇒ **Back:** z = **944 cm**, -404 cm $< x <$ 408 cm, -19 cm $< y <$626 cm
- ⇒ **Top:** y = **861 cm**, -404 cm $< x <$ 408 cm, 24 cm $< z <$ 670 cm



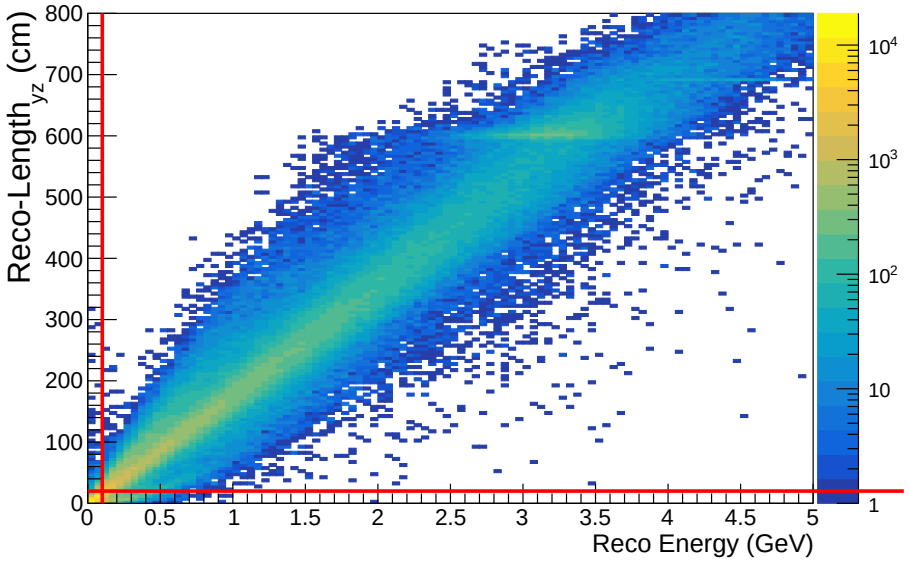
TPC Active Boundaries:
x: -380.434 to 380.434 cm
y: 0 to 607.499
z: -0.494 to 695.286

CRT hits are dummied up from truth information and are defined as:

- ⇒ Intersection point between any of the CRT plane and primary muon in the readout window; CRT hit time is primary muon T_0
- ⇒ Each of two dimensions within the CRT plane is individually smeared by a Gaussian with sigma = 2.5 cm (expected CRT position resolution)
- ⇒ CRT hit time is smeared by a Gaussian with sigma = 16 ns (expected CRT timing resolution as each module is expected to require a 62.5 MHz clock)

Reconstructed tracks

- ⇒ Using **pmtrack Track Module** to access reconstructed tracks
- ⇒ **Energy** deposited by the track is calculated by summing energy from hits associated with the track
- ⇒ **TrackID** of the track is assigned same as the Geant4 supplied TrackID of the particle contributing the maximum energy



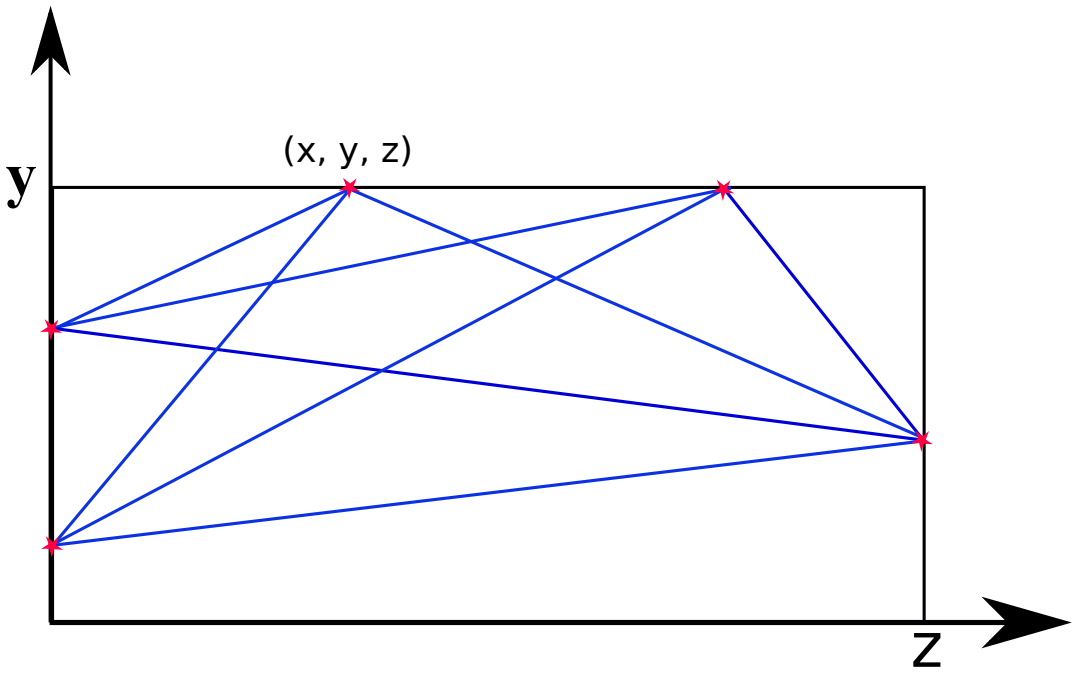
Track selection

- ⇒ Track-Energy > 0.1 GeV (loose cuts as we don't know true track energy)
- ⇒ Track-Length$_{yz}$ > 40 cm (as we will work first on the y-z plane, this is needed to ensure reasonable track selection)

Method 1

Combinatorial tracks

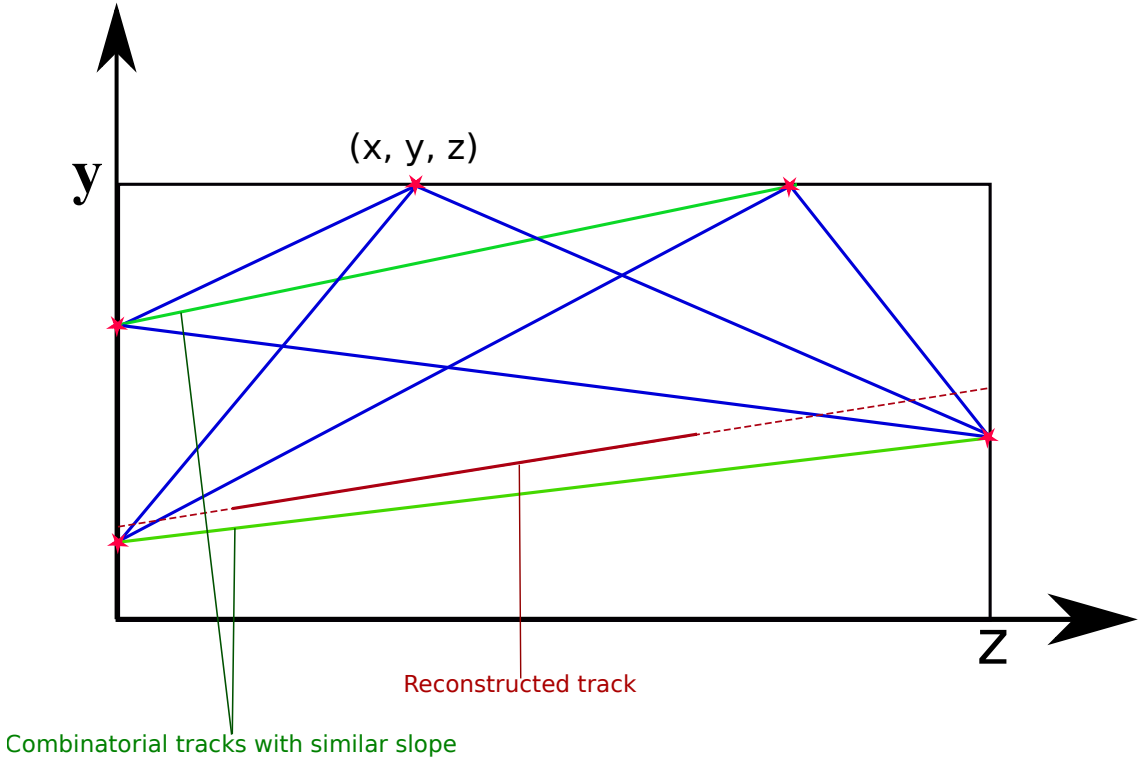
Hits in the Front, Back, and Top CRT planes are combined to generate **combinatorial tracks**. For example, if there are 2, 2, and 1 hits on Front, Top, and Back planes, respectively, there would be total of $(2 \times 2) + (2 \times 1) + (2 \times 1) = 8$ combinatorial tracks. The idea is to select true tracks from these combinatorial: working first on the y-z plane and then on the x-z plane.



Matching

Pair each reco tracks with combinatorial tracks if:

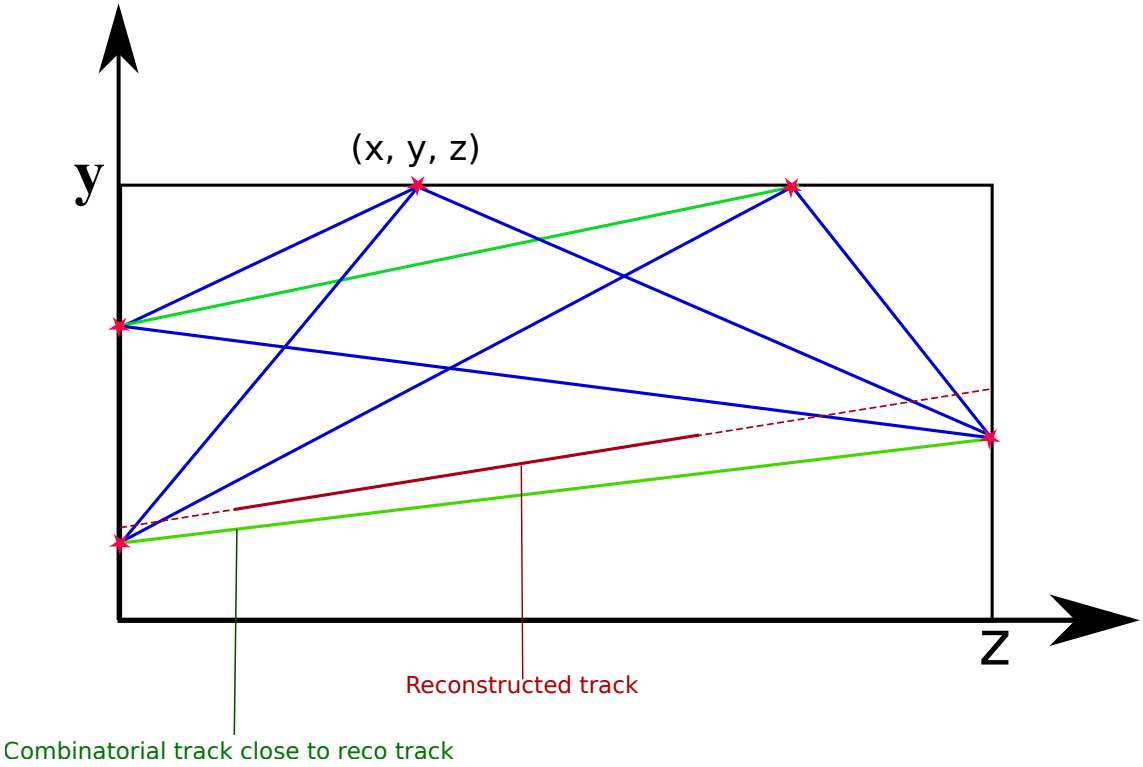
- ⇒ |**trackSlopeYZ - combinatorialSlopeYZ**| $<$ **0.1**
  → ensures that the reco track and the combinatorial track have similar slope in y-z plane
  → Combinatorial track's start and end position is set according to reco track's start and end z-positions



Matching

Pair each reco tracks with combinatorial tracks if:

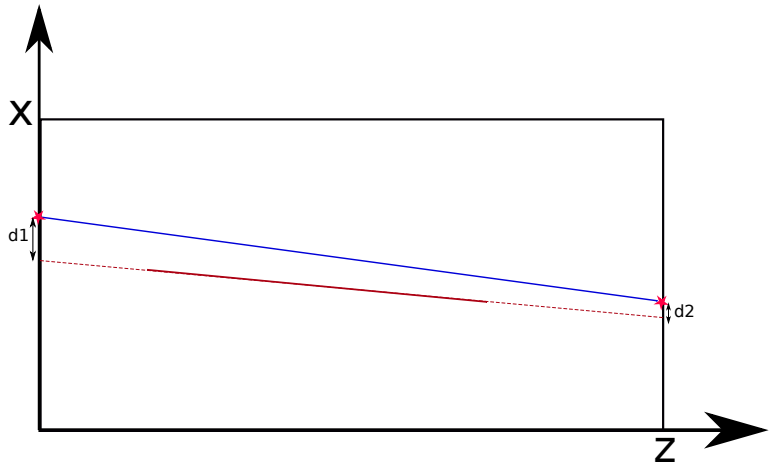
⇒ |**predictedHitPositionY** - **HitPositionY**| $<$ **25 cm**; in both direction
→ ensures that the reco track and the combinatorial track are close in y-direction



Matching

Pair each reco tracks with combinatorial tracks if:

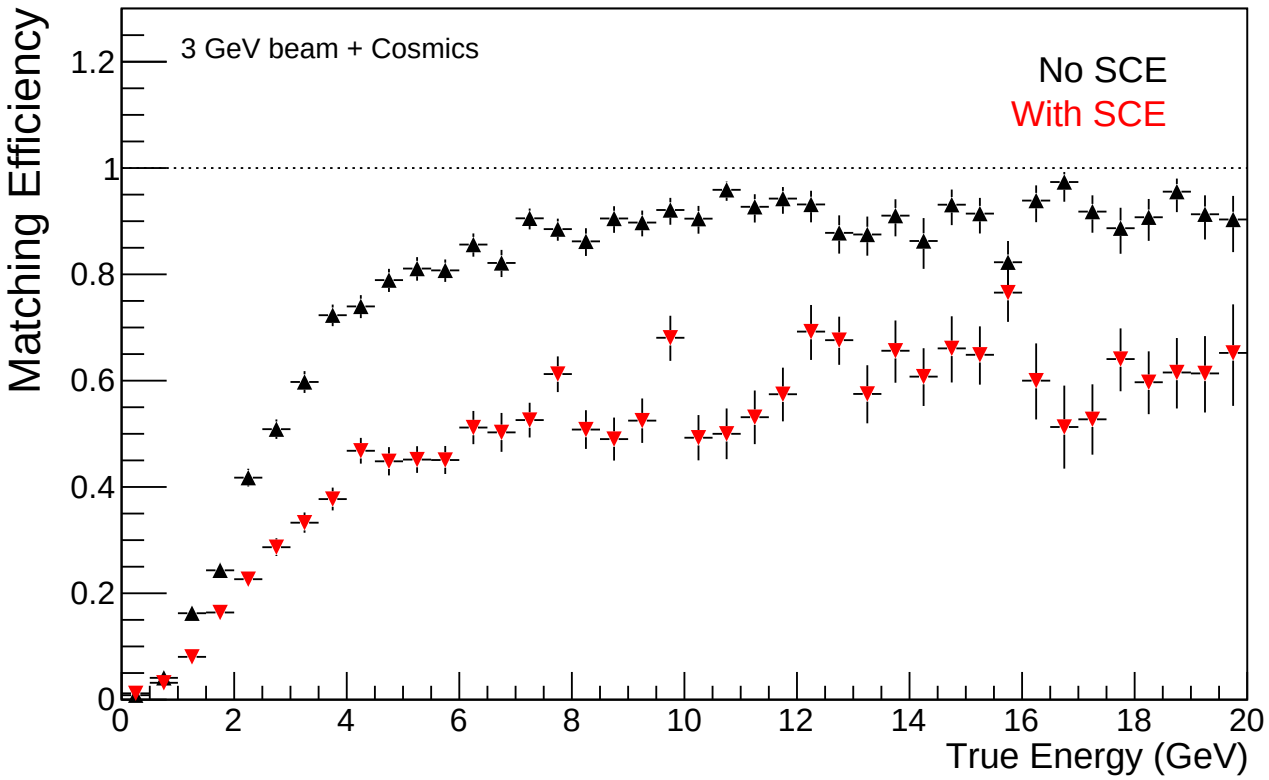
- ⇒ |**trackSlopeXZ - combinatorialSlopeXZ**| $<$ **0.1**
  → ensures that the reco track and the combinatorial track have similar slope in x-z plane
- ✓ Calculate $\Delta\mathbf{X} = ||d_1| - |d_2||$
  → true matched pair should have small ΔX



Ensure one-to-one matching:

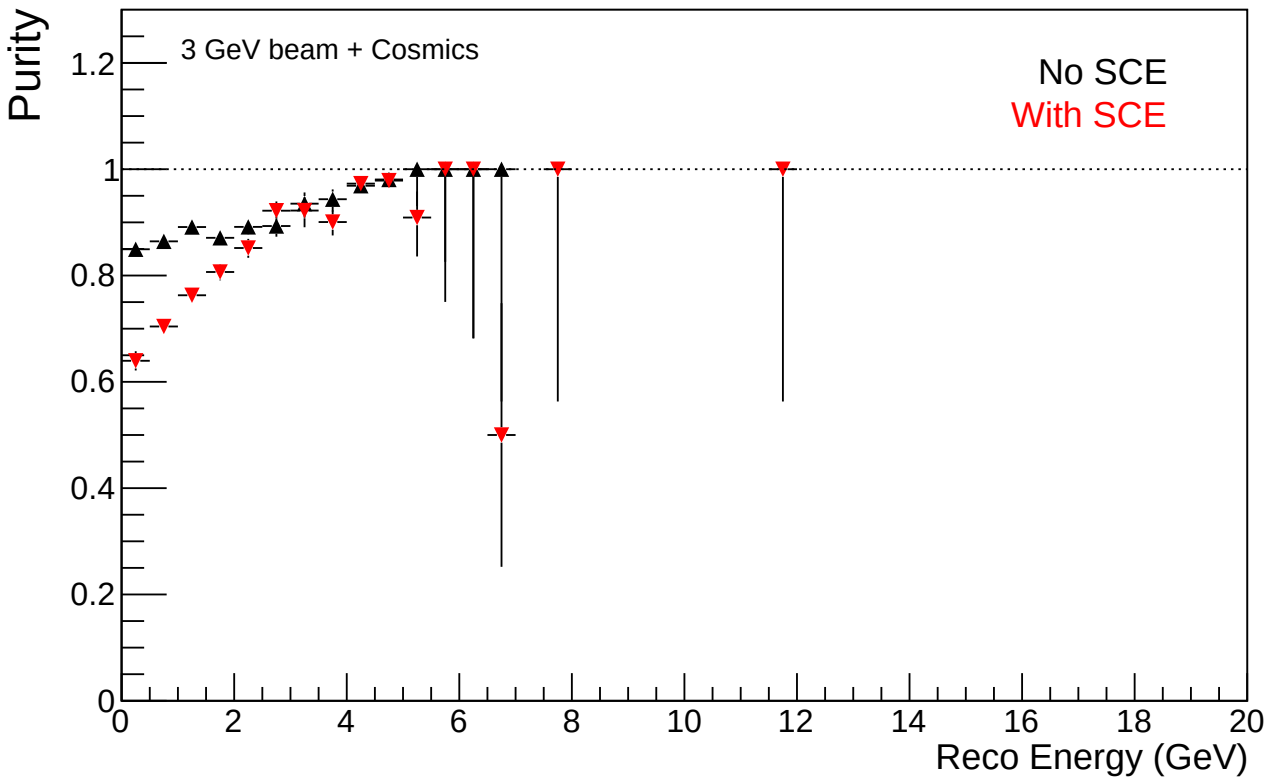
- ⇒ Give priority to pair with smallest ΔX
- ⇒ Reco track can't be used twice, CRT hit can't be used twice
- ⇒ Only pairs with ΔX $<$ 35 cm are considered to be matched (ensures physically reasonable matching)

Matching Efficiency



- ⇒ Matching Efficiency = (no. of reco tracks with good match)/(no. of reco tracks matched to primary muon with two CRT hits)
- ⇒ Good match means reco track have the same TrackId as combinatorial track (with both hits from same primary muon)

Purity



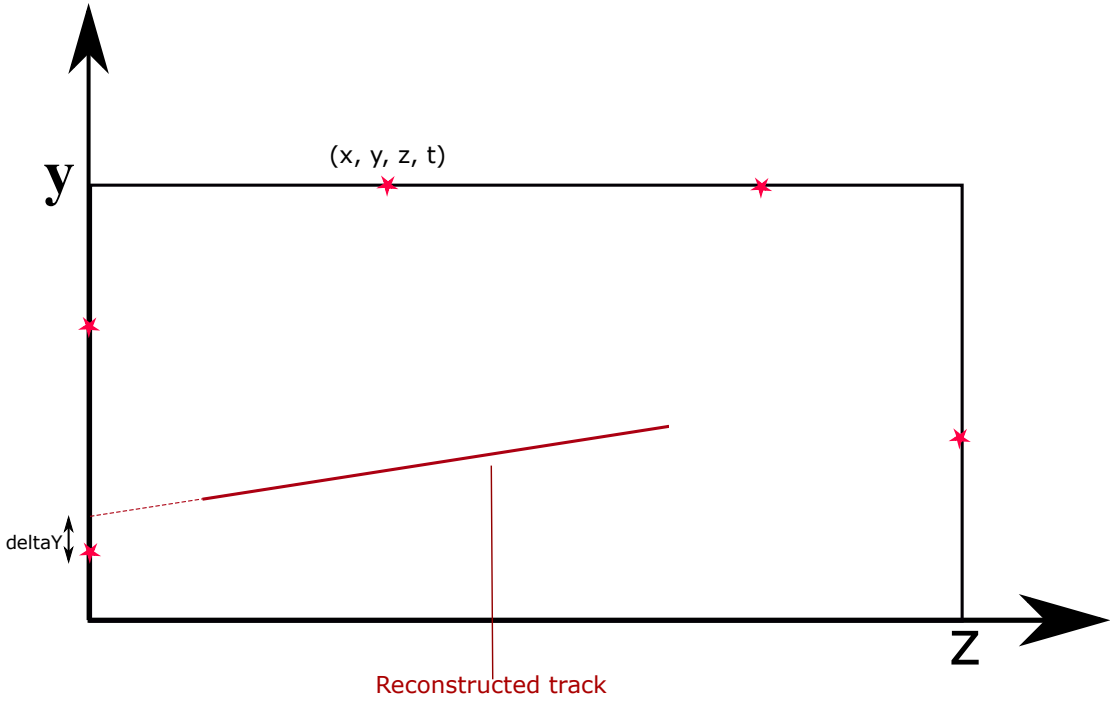
- ⇒ Purity = (no. of reco tracks with good match)/(no. of reco tracks with all match)
- ⇒ Good match means reco track have the same TrackId as combinatorial track (with both hits from same primary muon)
- ⇒ Note: As combinatorial track can originate from hits by two different primary muons, can't plot as a function of true energy

Method 2

Matching

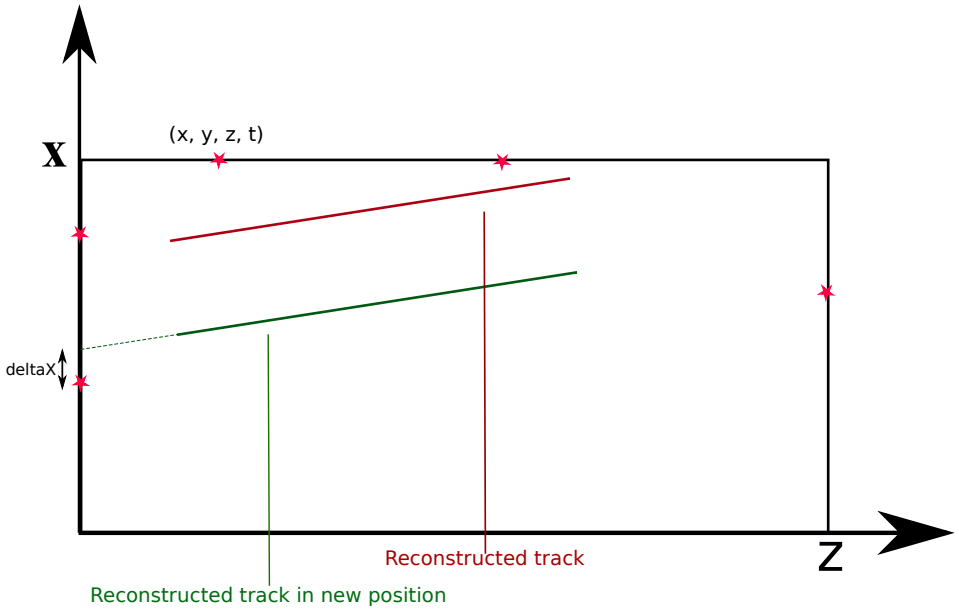
Pair each reco tracks with CRT hit if:

⇒ |**predictedHitPositionY - HitPositionY**| $<$ **55 cm**
→ ensures that the reco track and the CRT hit are close in y-direction



Matching

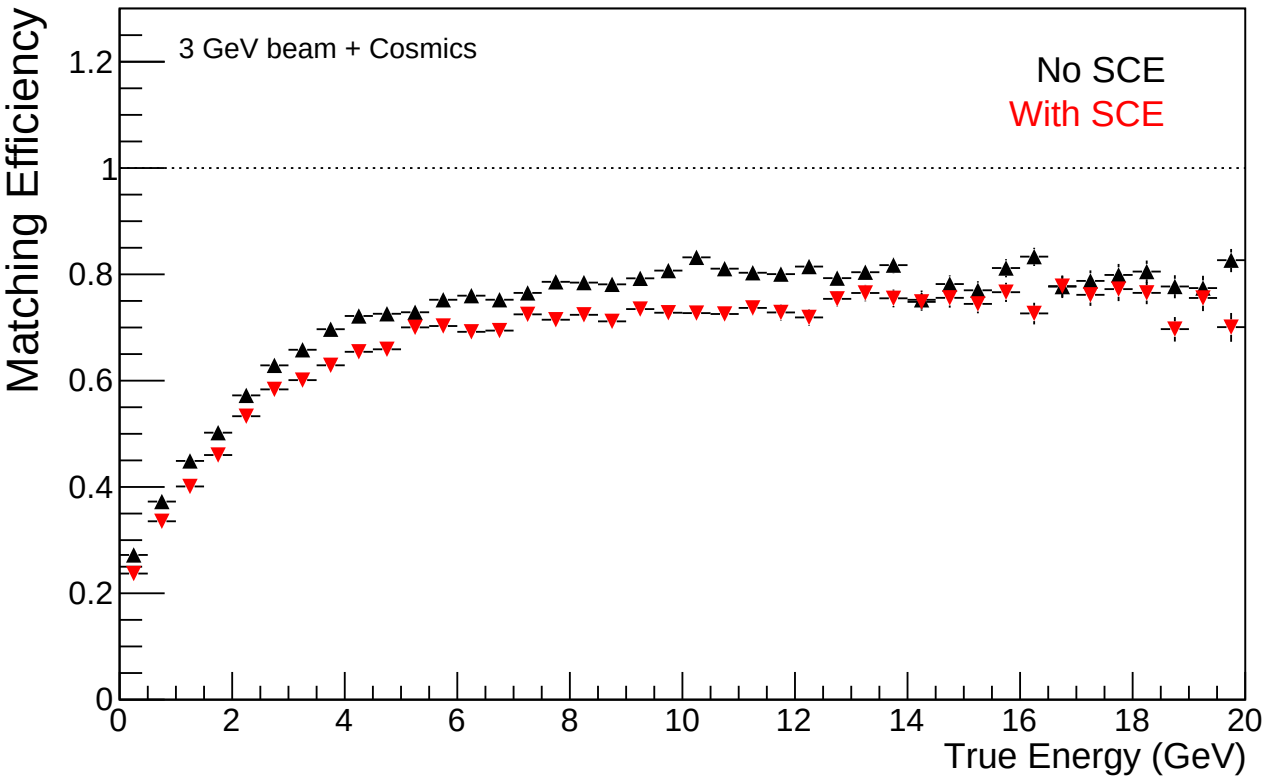
- ⇒ Use T_0 from CRT hit to calculate new start and end track position in x
- ⇒ Calculate Δ**X** = |**predictedHitPositionX - HitPositionX**|



Ensure one-to-one matching:

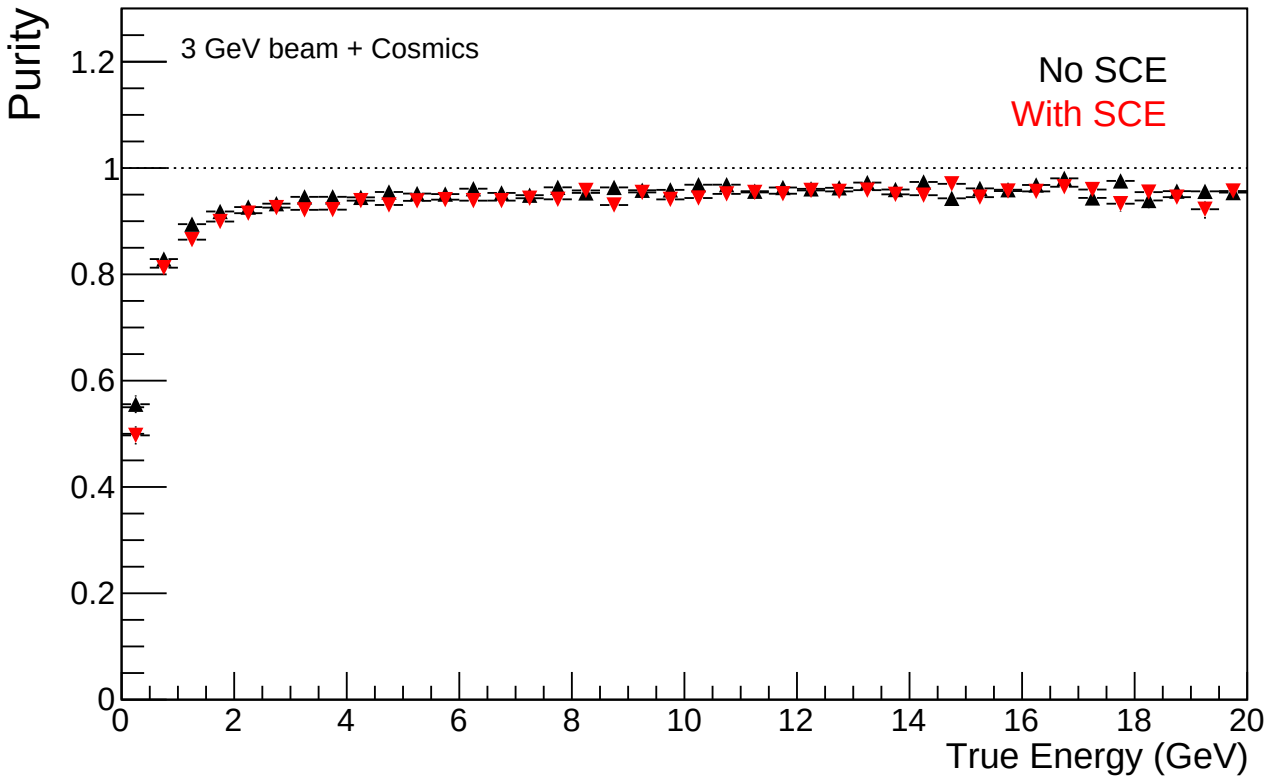
- ⇒ Give priority to pair with smallest ΔX
- ⇒ Reco track can't be used twice, CRT hit can't be used twice
- ⇒ Only pairs with $\Delta X < 55$ cm are considered to be matched (ensures physically reasonable matching)

Matching Efficiency



- ⇒ Matching Efficiency = (no. of reco tracks with good match)/(no. of reco tracks matched to primary muon with at-least one CRT hits)
- ⇒ Good match means reco track have the same TrackId as CRT hit

Purity



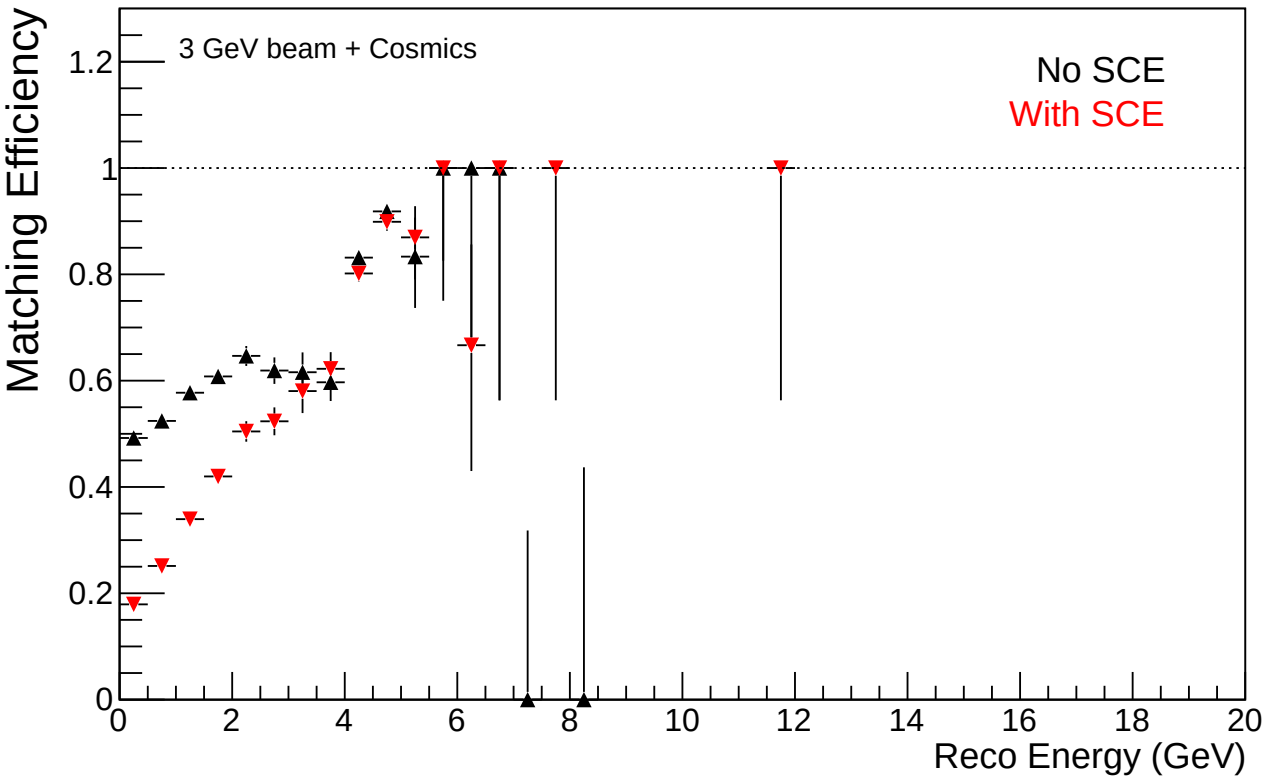
- ⇒ Purity = (no. of reco tracks with good match)/(no. of reco tracks with all match)
- ⇒ Good match means reco track have the same TrackId as CRT hit

Outlook

- ⇒ Overall, Method 2 seems to perform better than Method 1
- ⇒ Will proceed to use Method 2 to tag reco tracks with CRT hit- will use these samples for the demonstration of the space charge calibration
- ⇒ Also, will extend Method 2 to tag cosmics

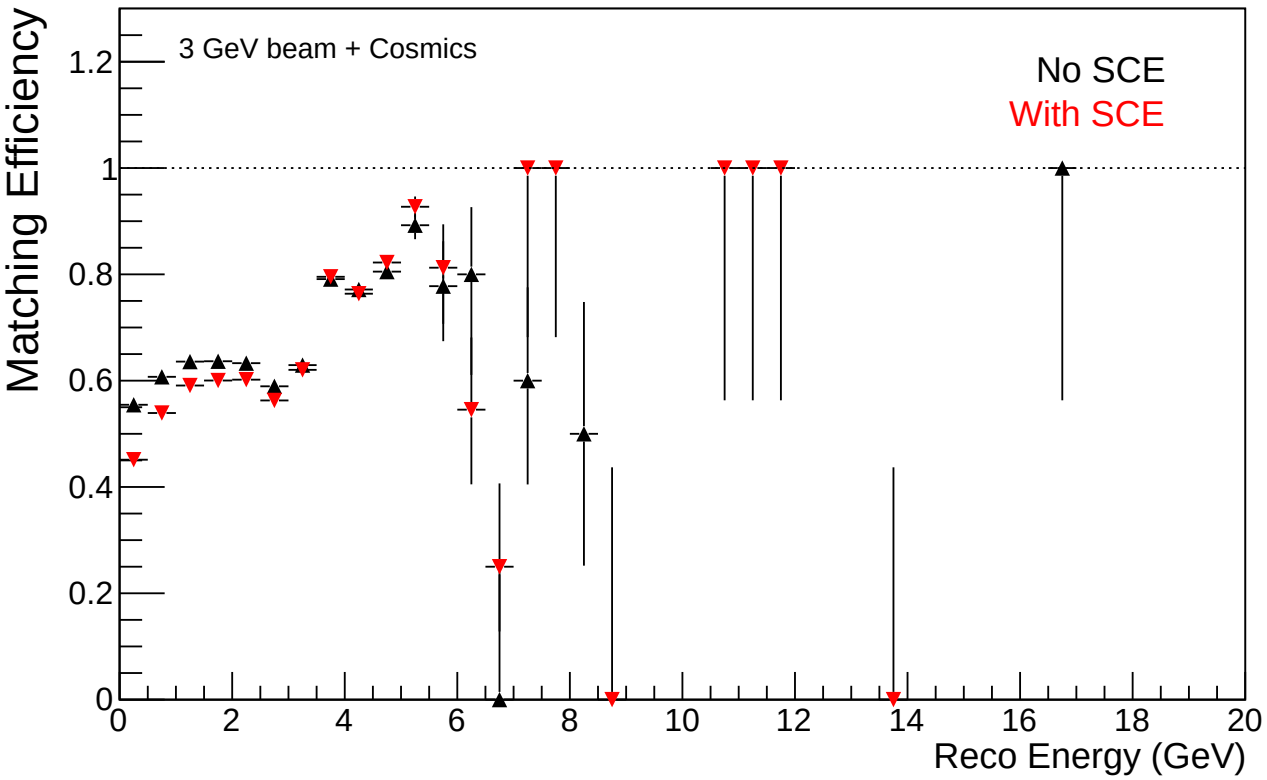
Backup

Method 1: Matching Efficiency



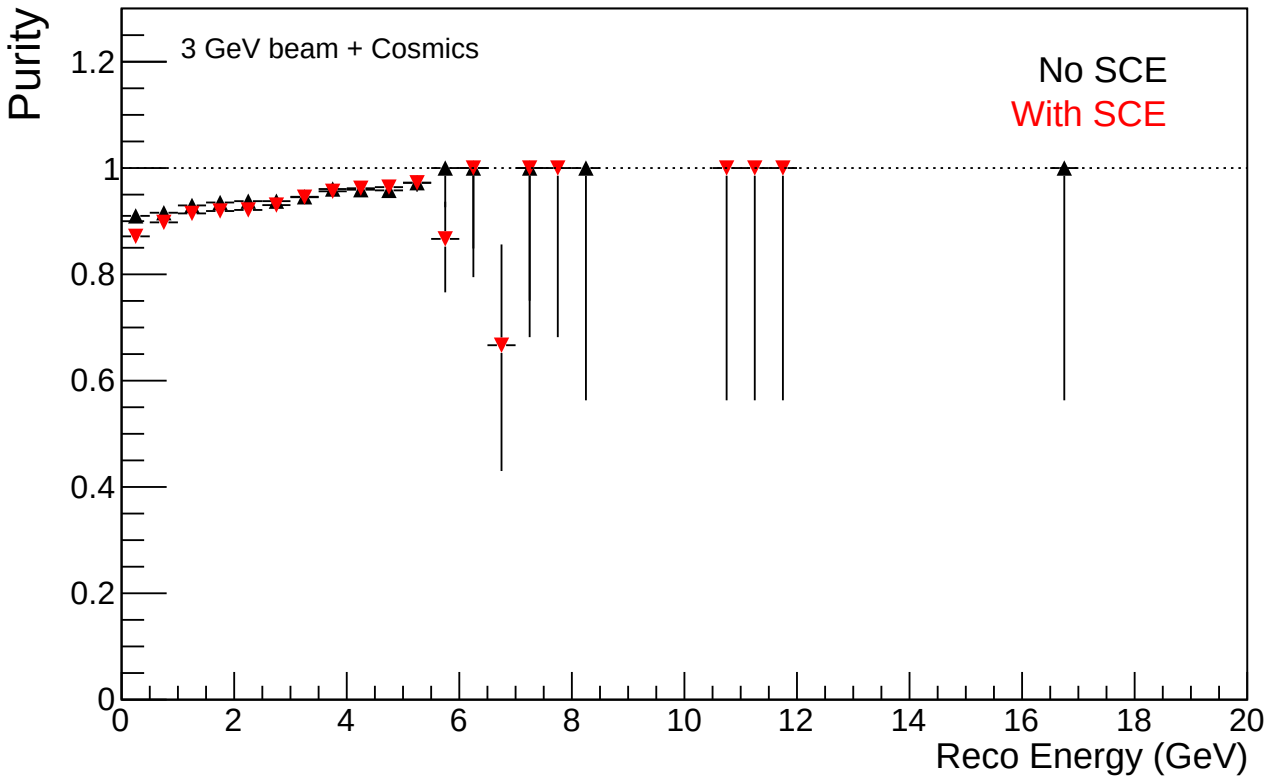
- ⇒ Matching Efficiency = (no. of reco tracks with good match)/(no. of reco tracks matched to primary muon with two CRT hits)
- ⇒ Good match means reco track have the same TrackId as combinatorial track

Method 2: Matching Efficiency



- ⇒ Matching Efficiency = (no. of reco tracks with good match)/(no. of reco tracks matched to primary muon with at-least one CRT hits)
- ⇒ Good match means reco track have the same TrackId as CRT hit

Method 2: Purity



- ⇒ Purity = (no. of reco tracks with good match)/(no. of reco tracks with all match)
- ⇒ Good match means reco track have the same TrackId as CRT hit