

Matching between CRT hits and reconstructed TPC tracks

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protoDUNE Reconstruction Meeting
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Outline

During the collaboration meeting, I reported ([here](#)) on the status of work to match CRT hits and reconstructed TPC tracks; part of a plan to produce a MC-based demonstration of the space charge calibration:

- ⇒ One-to-one matching was performed between CRT hits and reconstructed track projection in each CRT planes
- ⇒ **But, only $\sim 15\%$ of the matched tracks had the same TrackID as the primary muon (CRT hit)!**

The problem

In protoDUNE, as triggering will happen on the beam:

- ⇒ 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

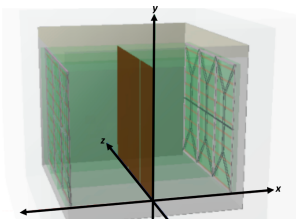
This presentation

Perform matching using CRT hit combinatorial tracks; working first on the y - z plane and then on the x - z plane.

Cosmic Ray Tagger (CRT)

CRT in this study covers the active TPC volume in:

- ⇒ **Front:** $z = -202$ cm, -404 cm $< x < 404$ cm, -19 cm $< y < 626$ cm
- ⇒ **Back:** $z = 944$ cm, -404 cm $< x < 404$ cm, -19 cm $< y < 626$ cm
- ⇒ **Top:** $y = 861$ cm, -404 cm $< x < 404$ 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 geometry is not included in the MC yet. **Hits** in CRT are defined as:

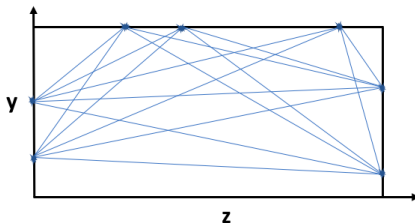
- ⇒ Intersection point between any of the CRT plane and primary muon
- ⇒ Each of two dimensions within the CRT plane is individually smeared by a Gaussian with $\sigma = 2.5$ cm (expected CRT position resolution)

In a sample of **2 GeV/c beam overlaid with cosmics** events:

Hits	No. per event
Front	27.4
Back	27.1
Top	57

Combinatorial tracks

Hits in the Front, Back, and Top CRT planes are combined to generate **combinatorial tracks**. For example, if there are 2, 3, and 2 hits on Front, Top, and Back planes, respectively, there would be total of $(2 \times 3) + (3 \times 2) + (2 \times 2) = 16$ 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.



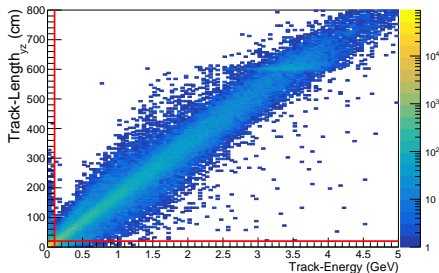
In a sample of 2 GeV/c beam overlaid with cosmic events:

Primary muon hits	No. per event
Front-Back	0.4
Front-Top	5.0
Back-Top	4.5

Combinatorial tracks	No. per event
Front-Back	752
Front-Top	1580
Back-Top	1556

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

- ⇒ Loose cuts as we don't know both true track energy or true track length for reconstructed cosmics
- ⇒ Track-Energy > 0.1 GeV
- ⇒ Track-Length_{yz} > 20 cm (as we will work first on the y-z plane, this is needed to ensure reasonable track selection)

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In a sample of **2 GeV/c beam overlaid with cosmics** events:

	No. of tracks with same TrackID as primary muon with 2 hits (per event)
Front-Back	0.44
Front-Top	1.5
Back-Top	1.2

Not all the primary muons get reconstructed! Integrated reconstruction efficiency for muons with 2 hits is 32%.

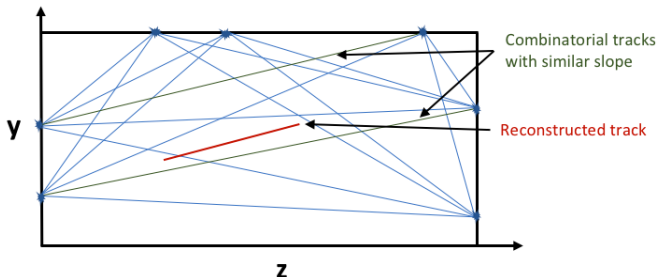
Matching I

Pair each reco tracks with combinatorial tracks if:

$$\Rightarrow |\text{trackSlopeYZ} - \text{combinatorialSlopeYZ}| < 0.006$$

→ ensures that the reco track and the combinatorial track have similar slope in y-z plane

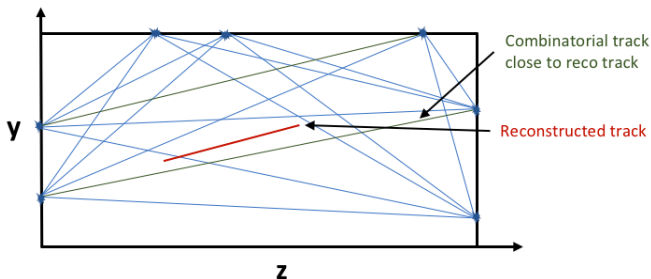
- $\text{trackSlopeYZ} = (\text{trackEndPositionY} - \text{trackStartPositionY}) / (\text{trackEndPositionZ} - \text{trackStartPositionZ})$
- Combinatorial track's start and end position is set according to reco track's start and end z-positions



Matching I

Pair each reco tracks with combinatorial tracks if:

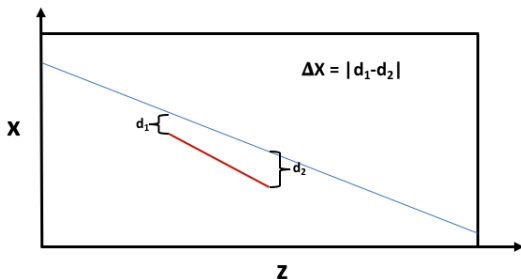
- ⇒ $|\text{predictedTrackStartPositionY} - \text{trackStartPositionY}| < 15 \text{ cm}$ and $|\text{predictedTrackEndPositionY} - \text{trackEndPositionY}| < 15 \text{ cm}$
- ensures that the reco track and the combinatorial track are close in y-direction
 - $\text{predictedTrackStartPositionY} = (\text{combinatorialSlopeYZ} \times \text{trackStartPositionZ}) + \text{yInterceptCombinatorial}$



Matching I

Pair each reco tracks with combinatorial tracks if:

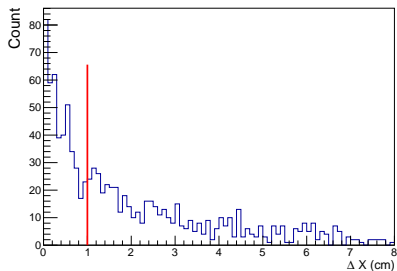
- ⇒ $|\text{trackSlopeXZ} - \text{combinatorialSlopeXZ}| < 0.1$
 - ensures that the reco track and the combinatorial track have similar slope in x-z plane
- ✓ Calculate $\Delta X = ||\text{predictedTrackEndPositionX} - \text{trackEndPositionX}| - |\text{predictedTrackStartPositionX} - \text{trackStartPositionX}||$
 - true matched pair should have small ΔX
 - considering other options



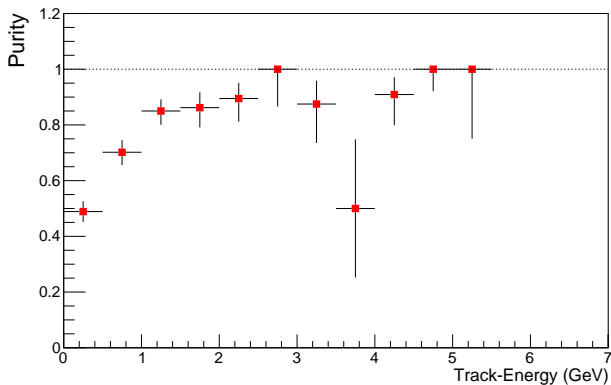
Matching II

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 $\Delta X < 1.0$ cm are considered to be matched



Matching III



⇒ Purity = (no. of matched track with same TrackID as combinatorial track)/(no. of all matched track)

⇒ Integrated purity = 68 %

Outlook

- ⇒ This study was performed with 990 events (2 GeV/c beam overlaid with cosmics)
- ⇒ Still some fine-tuning is necessary. Suggestions, comments are welcome.
- ⇒ Look at purity as a function of true track energy, add matching efficiency, total efficiency
- ⇒ Try other definitions of ΔX - understand tail of the distribution
- ⇒ The MC sample that we have requested (beam overlaid with cosmics, muon halo, and space charge effect) is still being produced
- ⇒ Once the new MC is available, will re-perform the study