PMTrack Performance Study

Avik Ghosh

Introduction

- CC and ES interactions were simulated using SN GVKM input neutrino spectrum.

- To extract the pointing information the interaction vertex and particle tracks need to be reconstructed.

- The reconstruction utilizes PMTrack algorithm to do so.

- We have electron truth and reconstructed information (direction, vertex position and energy).

Obtained simulation files from Janina

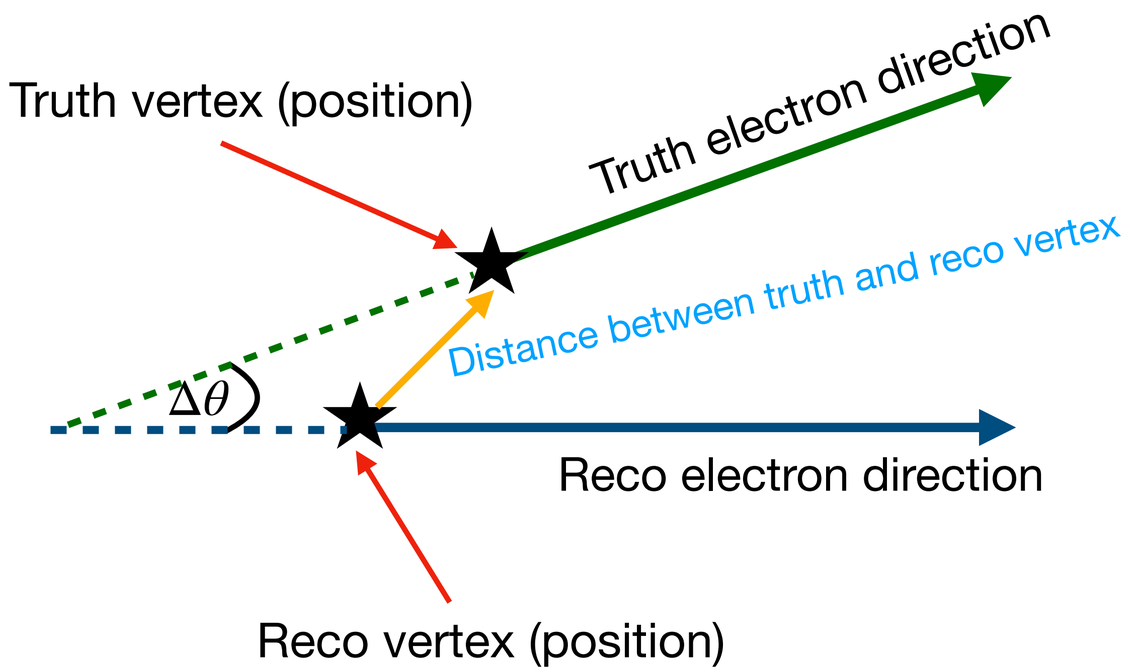
Goal

- Analyze and compare the truth and reco information to study resolution for electron energy, direction and interaction vertex position.

- Study how inefficient PMTrack is? i.e How often it fails to reconstruct tracks?

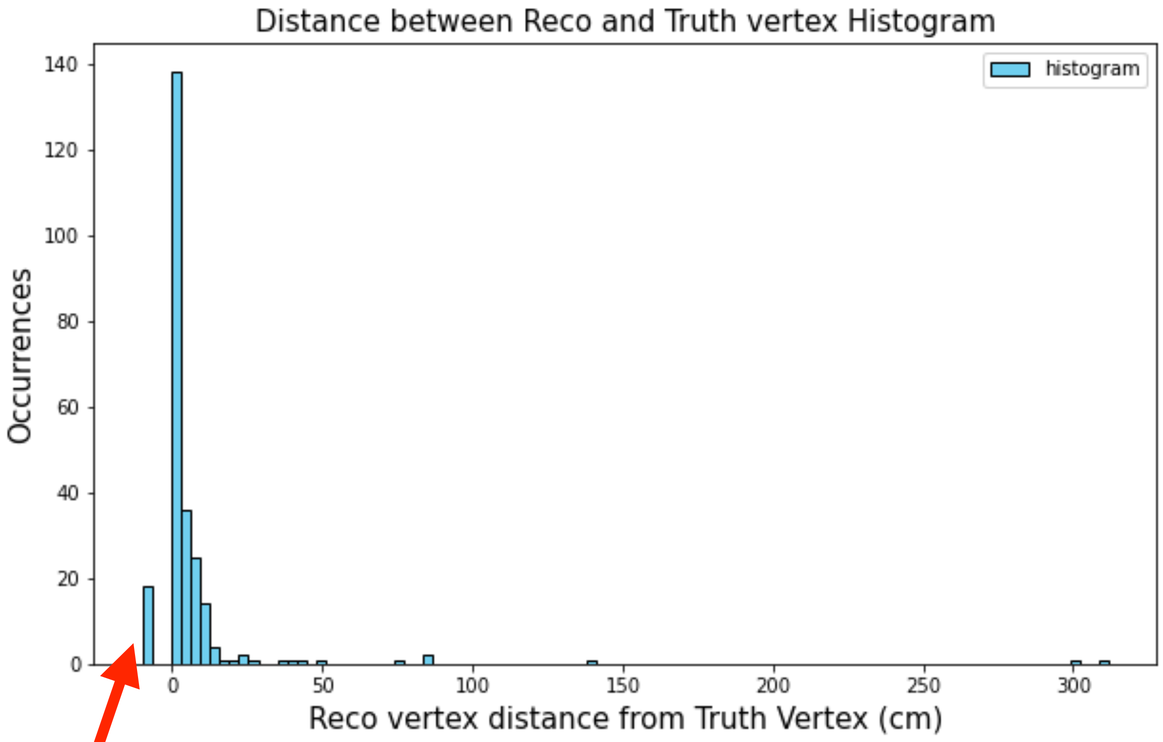
- To understand how PMTrack’s performance depends on Energy.

Understanding Truth and Reco direction and Position

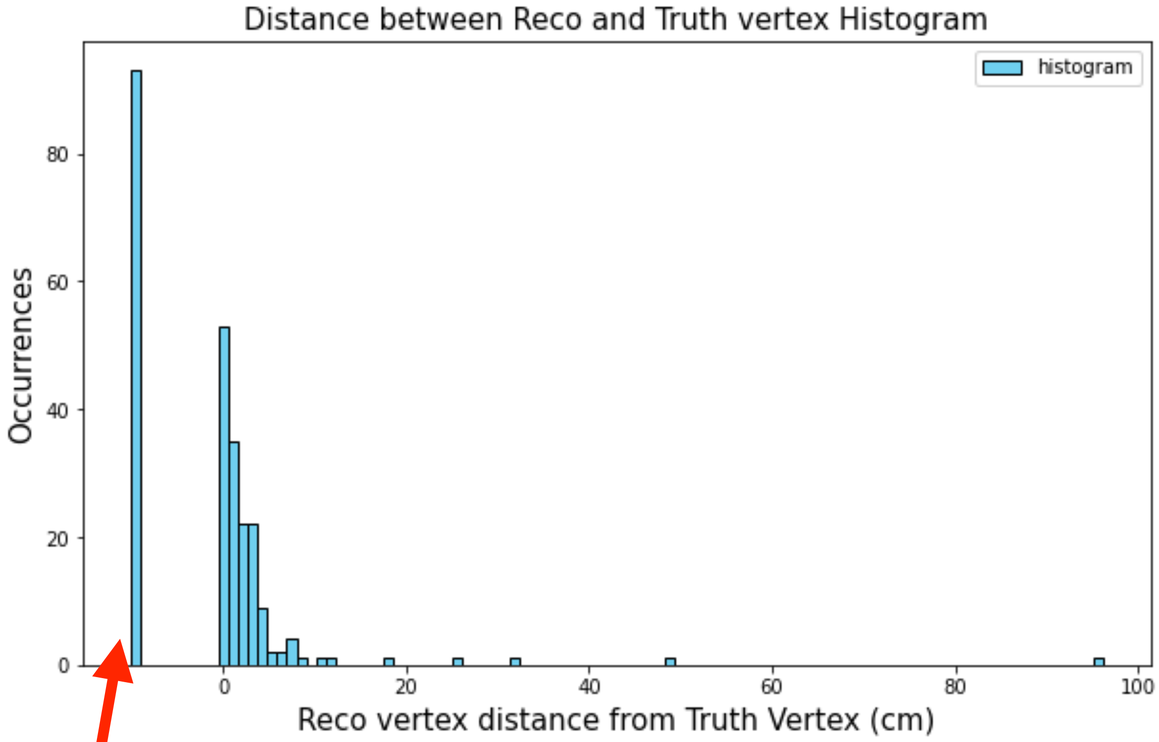


Distance between truth vertex and reco vertex

Distribution



CC Interaction



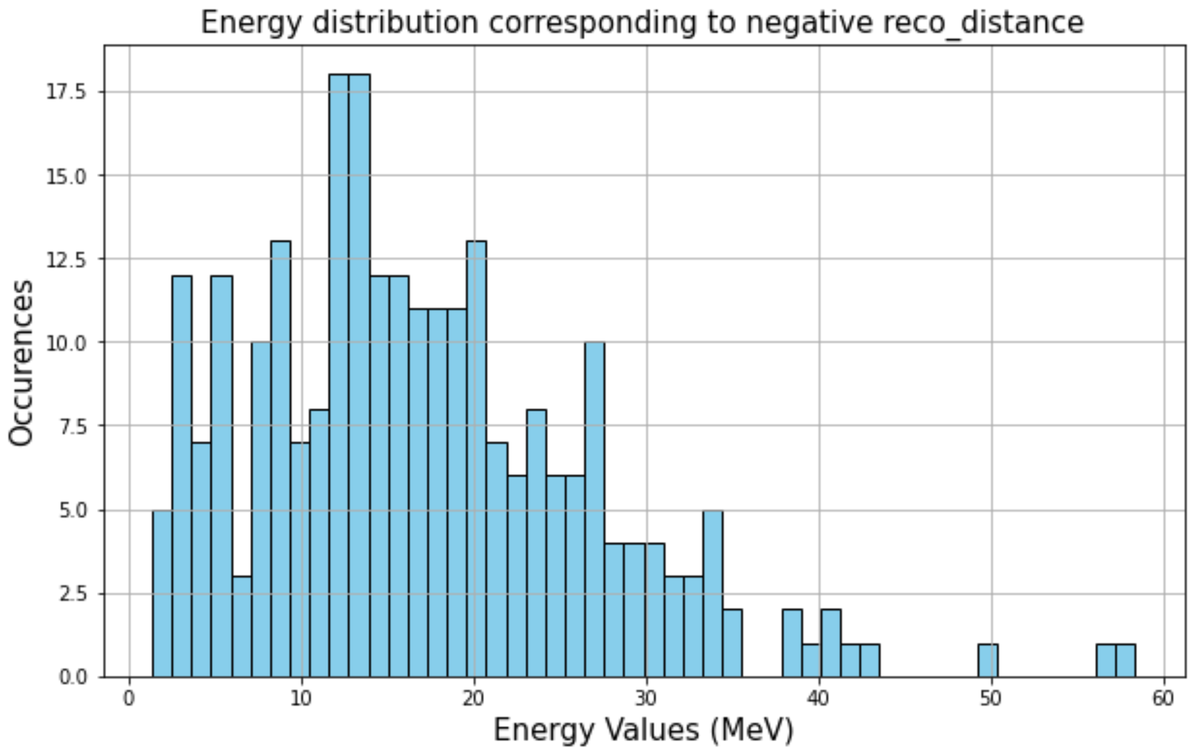
ES Interaction

Negative value (-10)
Assigned for distance b/w truth and reco vertex

Possible Reasons for Reconstruction Failures?

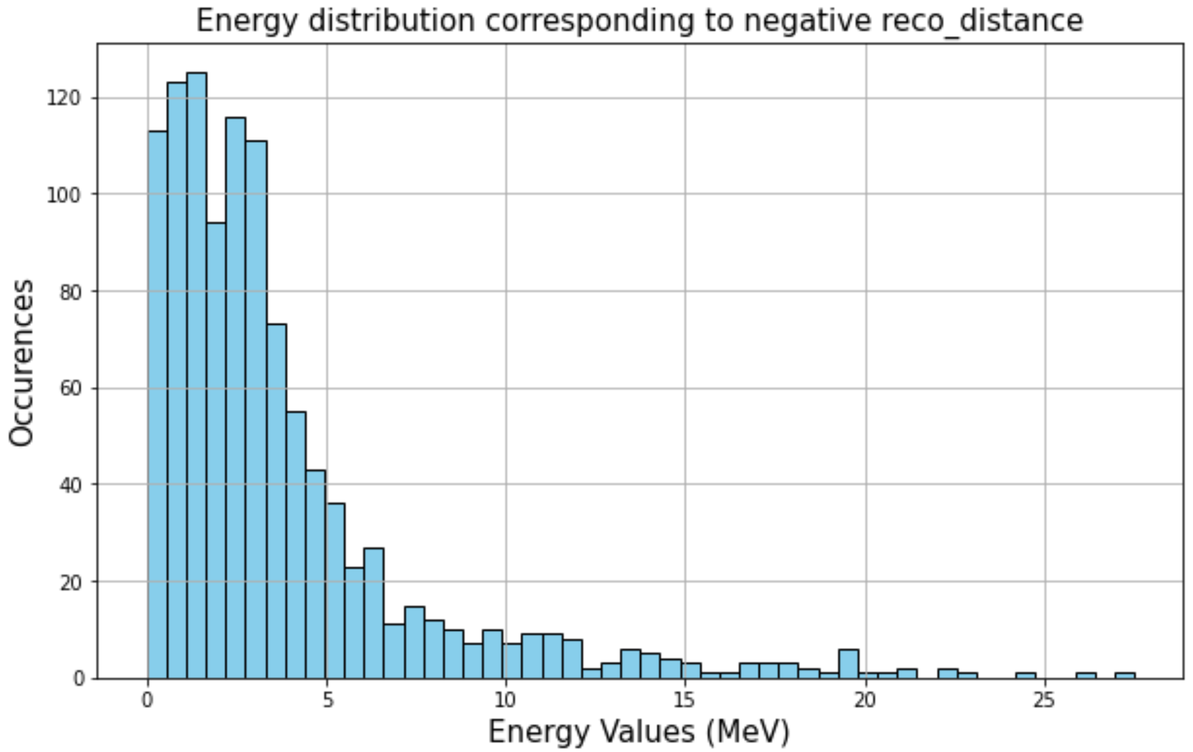
- Energy dependency
- Number of hits
- Inclination of the primary electron direction to the collection plane

Reconstruction Failures: Energy Dependency



CC Interaction

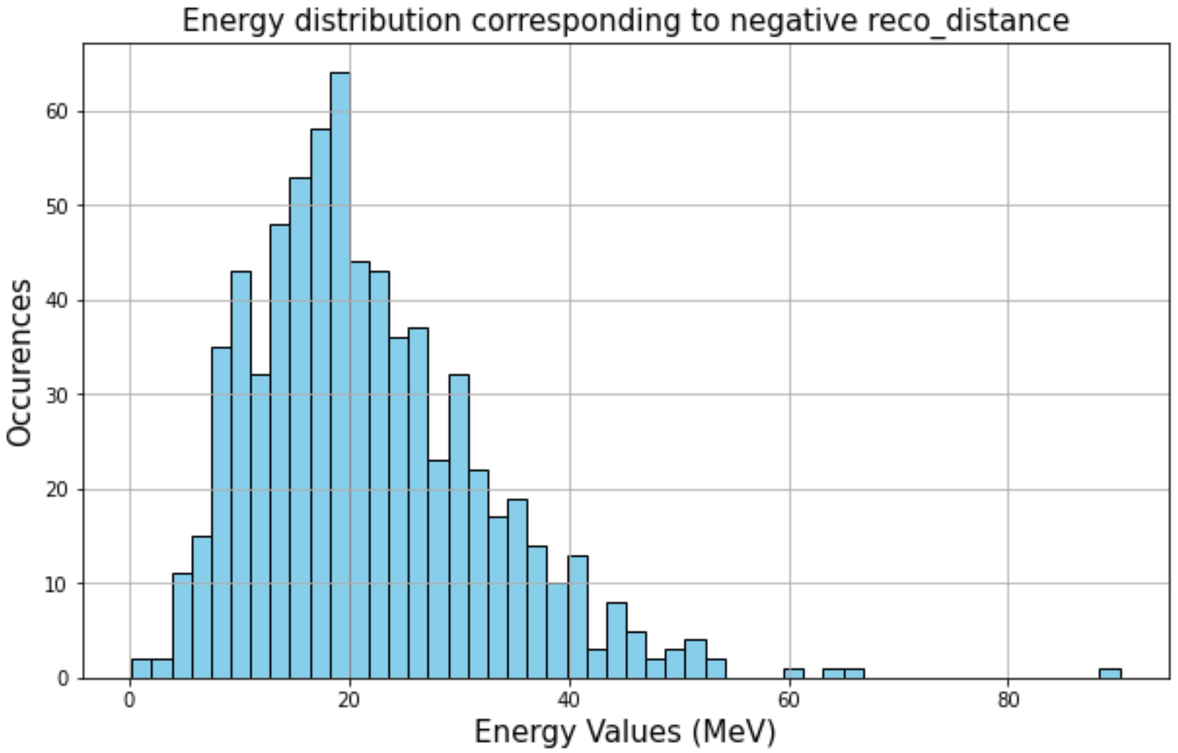
Reconstruction Failure percentage: 8.7



ES Interaction

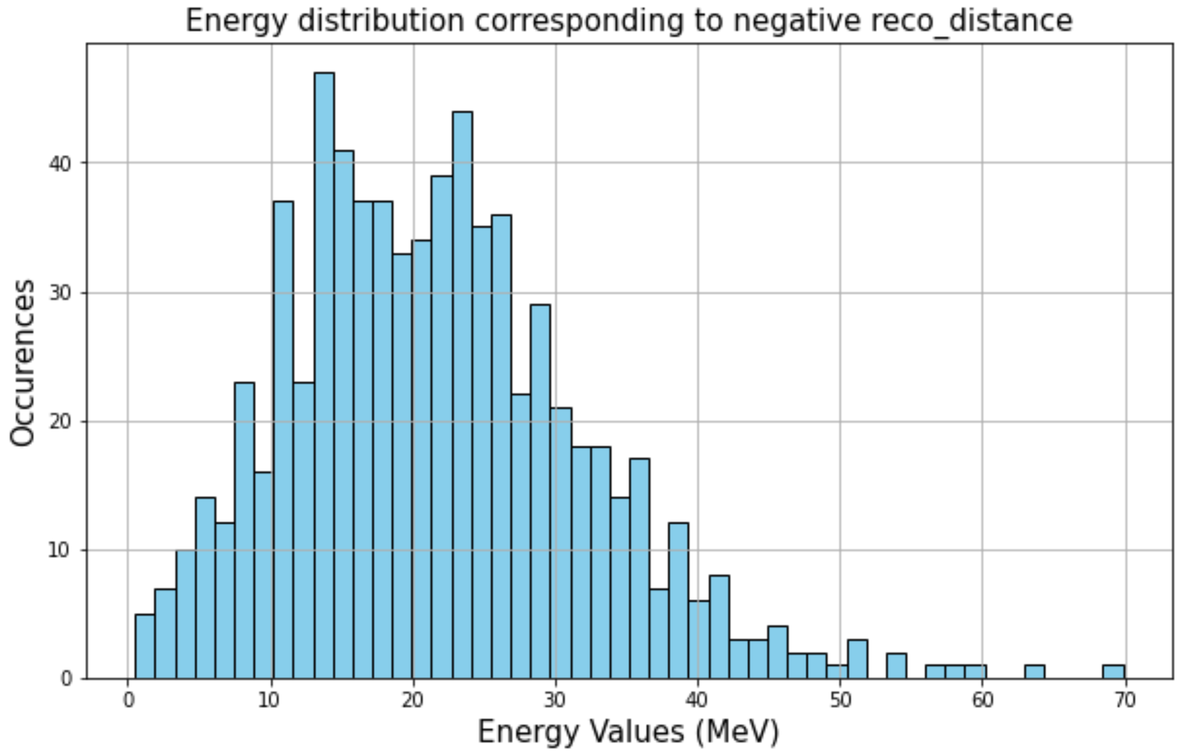
Reconstruction Failure percentage: 36.3

Reconstruction Failures: Energy Dependency (newbkg)



CC Interaction

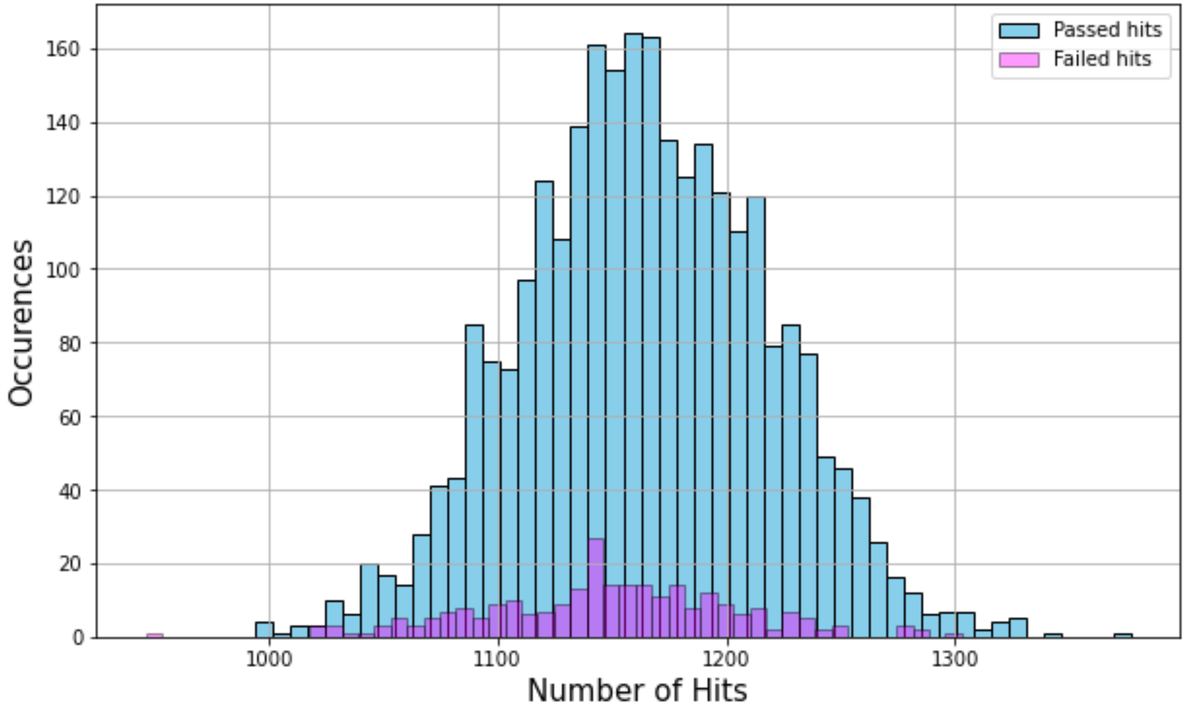
Reconstruction Failure percentage: 70.4



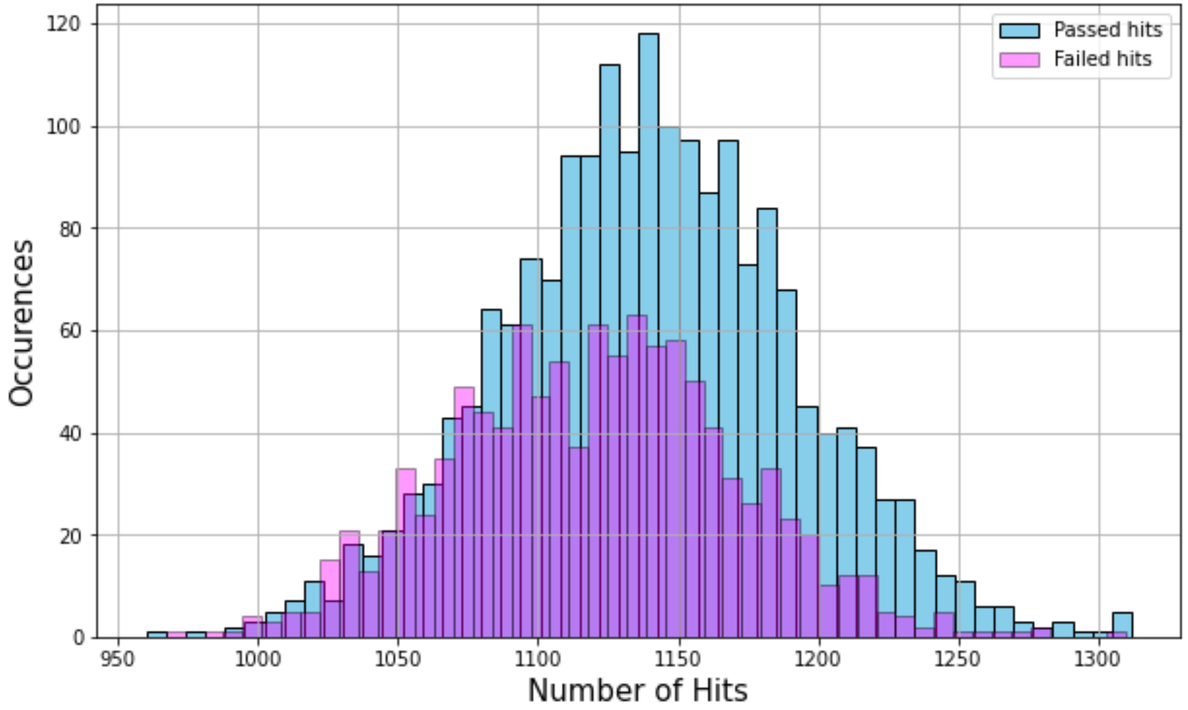
ES Interaction

Reconstruction Failure percentage: 72.7

Reconstruction Failures: Number of Hits Dependency

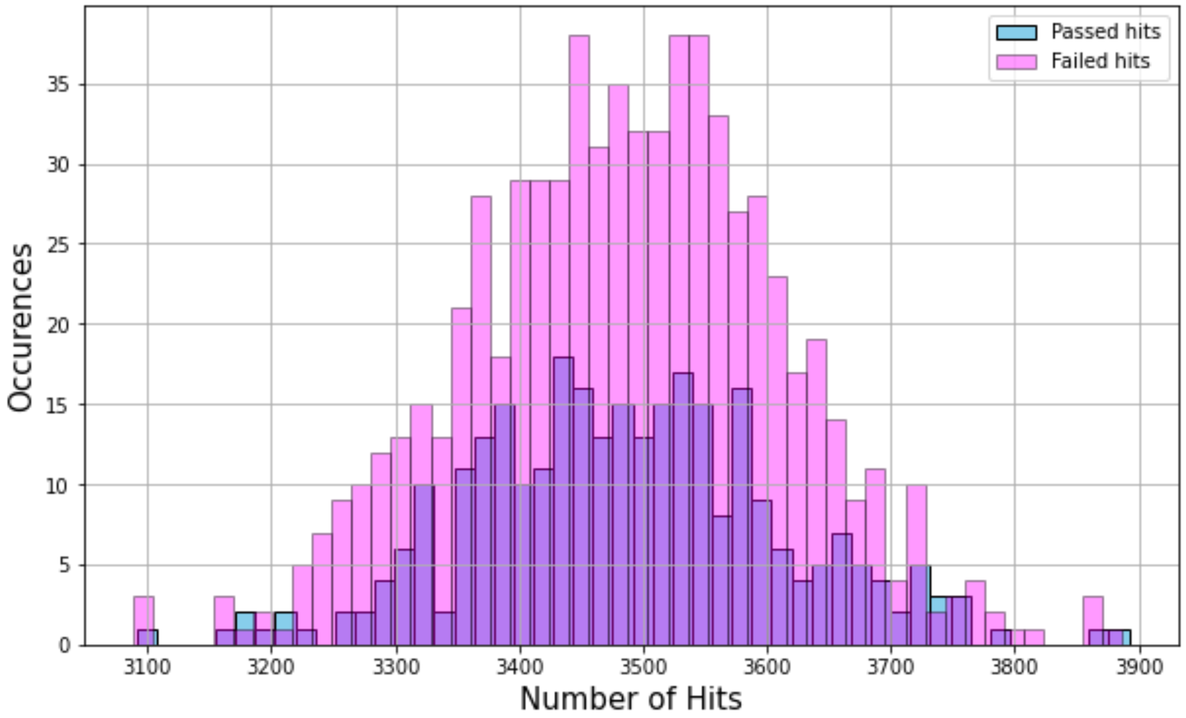


CC Interaction

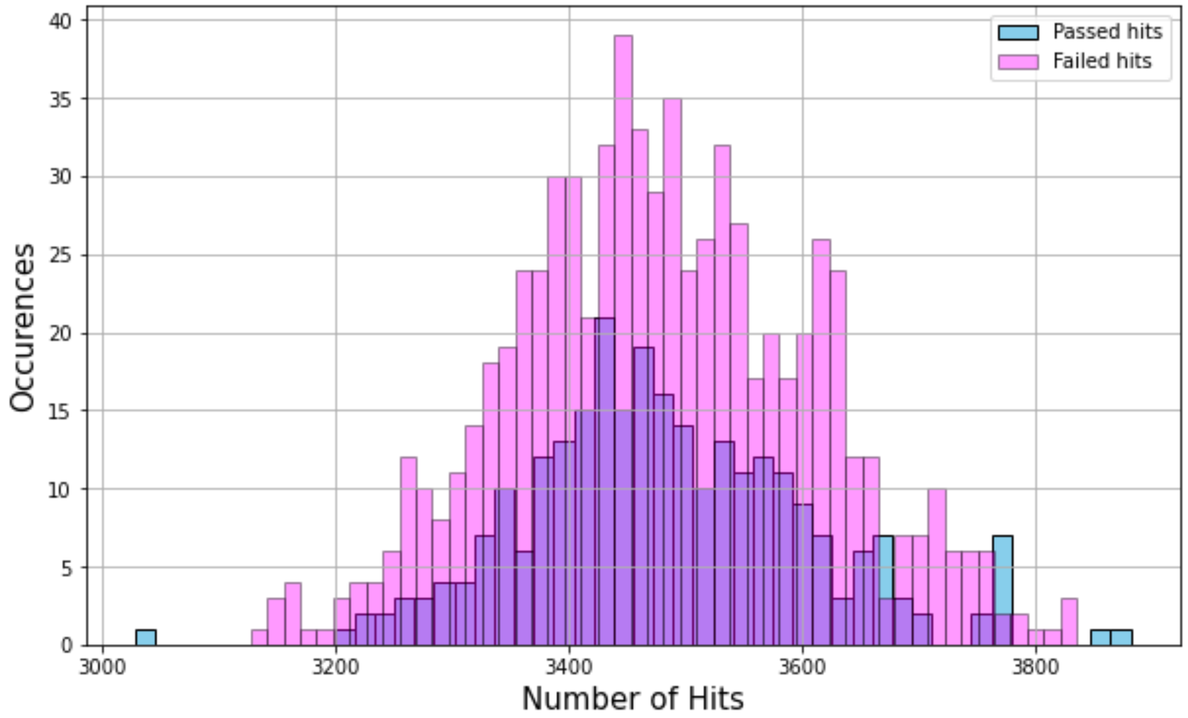


ES Interaction

Reconstruction Failures: Number of Hits Dependency (newbkg)

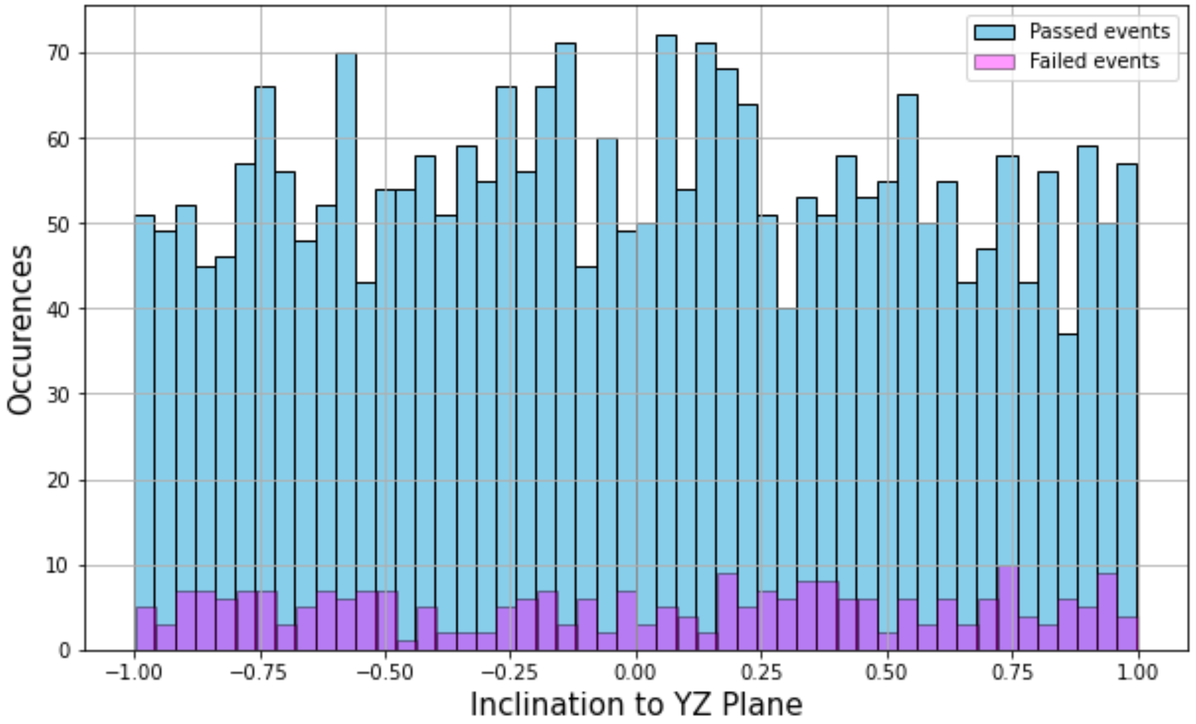


CC Interaction

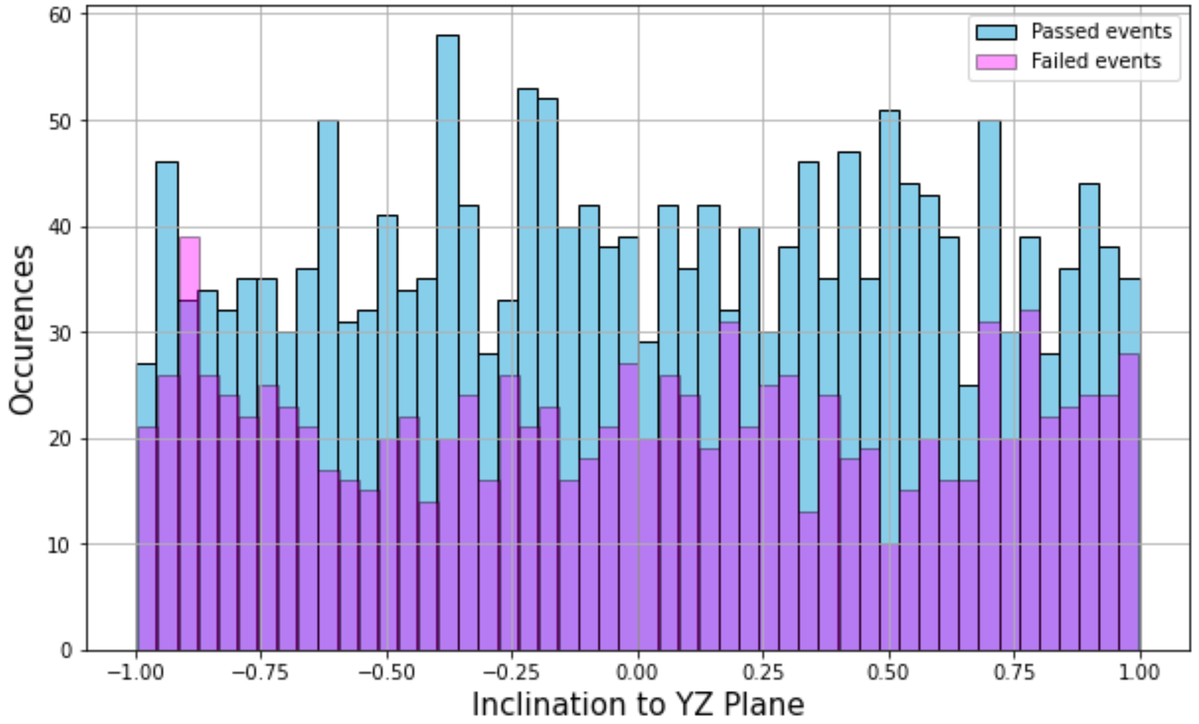


ES Interaction

Reconstruction Failures: Electron track inclination to Collection Plane

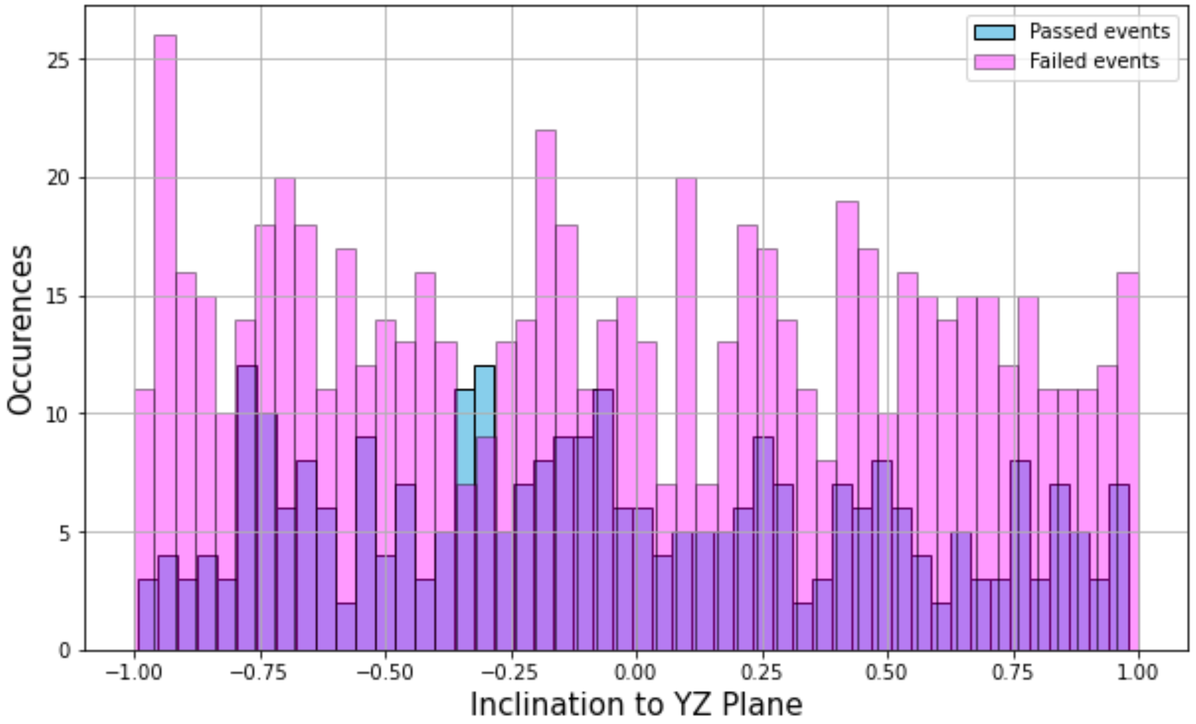


CC Interaction

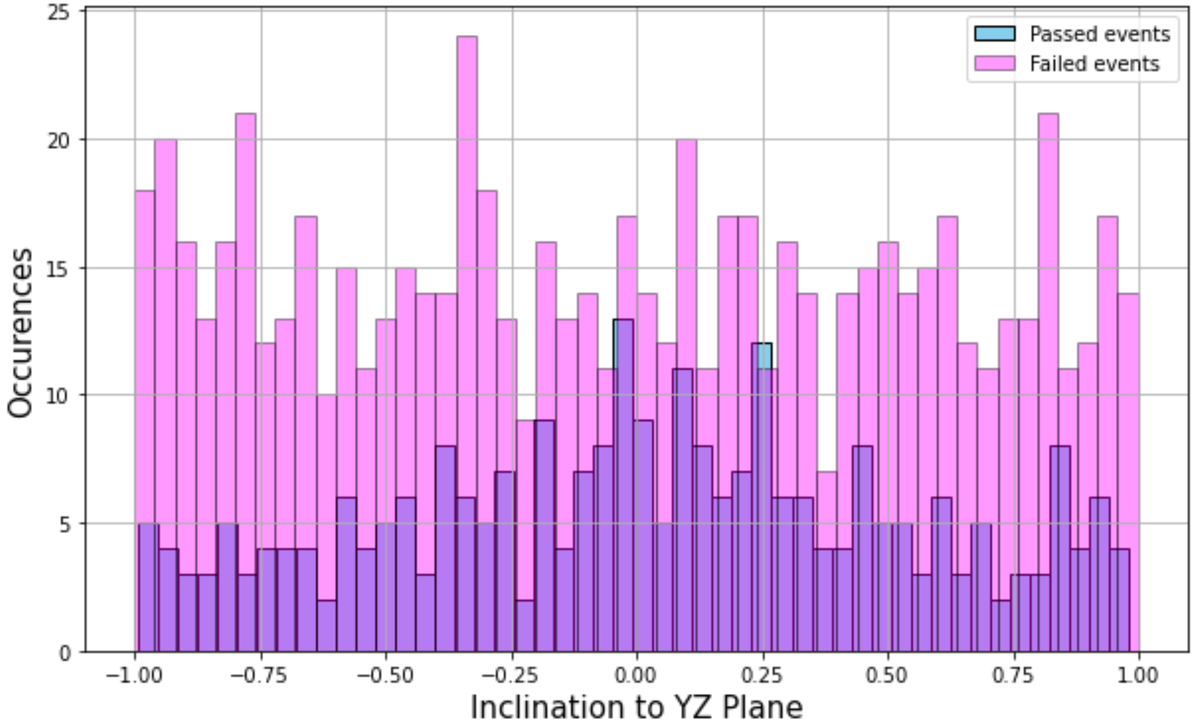


ES Interaction

Reconstruction Failures: Electron track inclination to Collection Plane (newbkg)

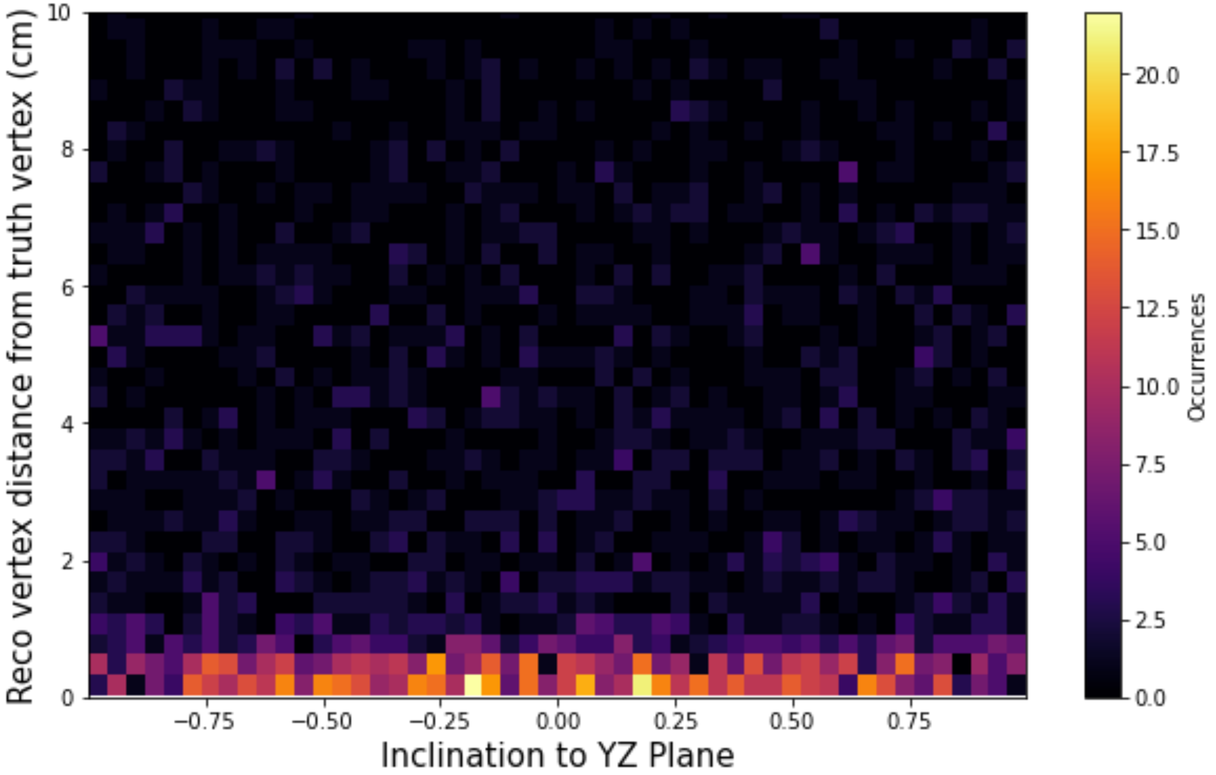


CC Interaction

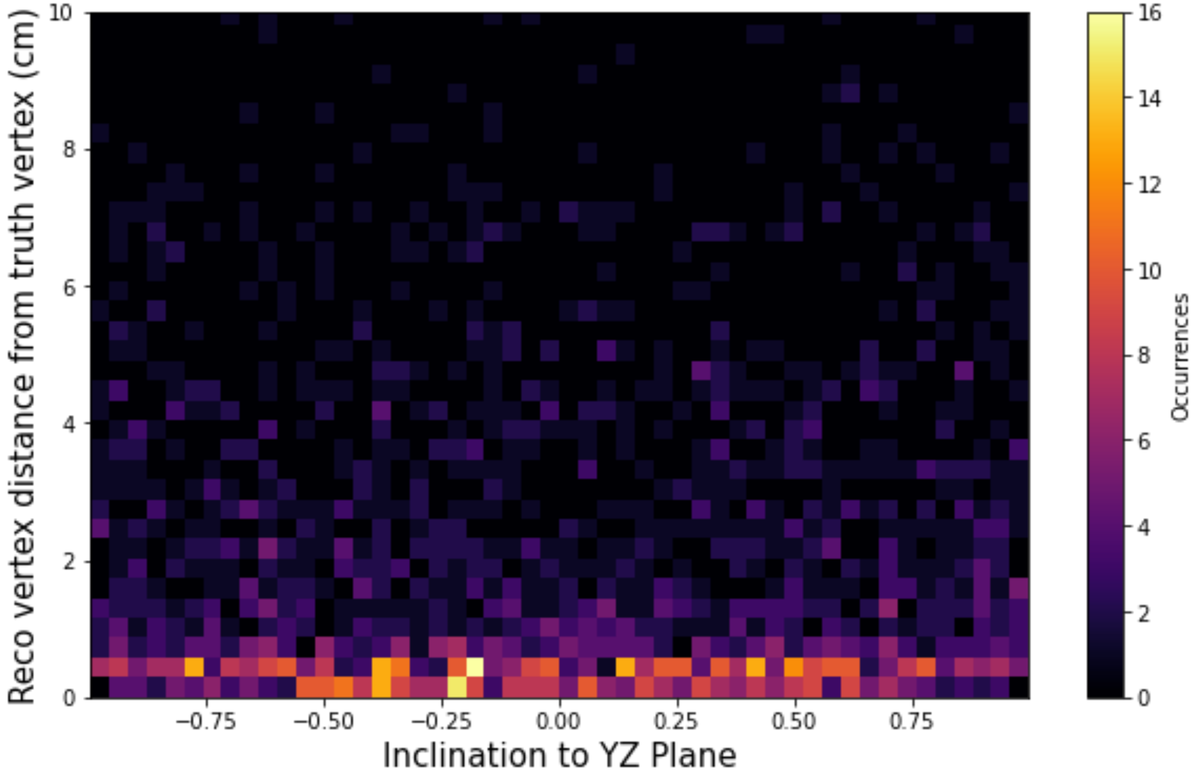


ES Interaction

Then does the inclination impact reconstruction resolution?



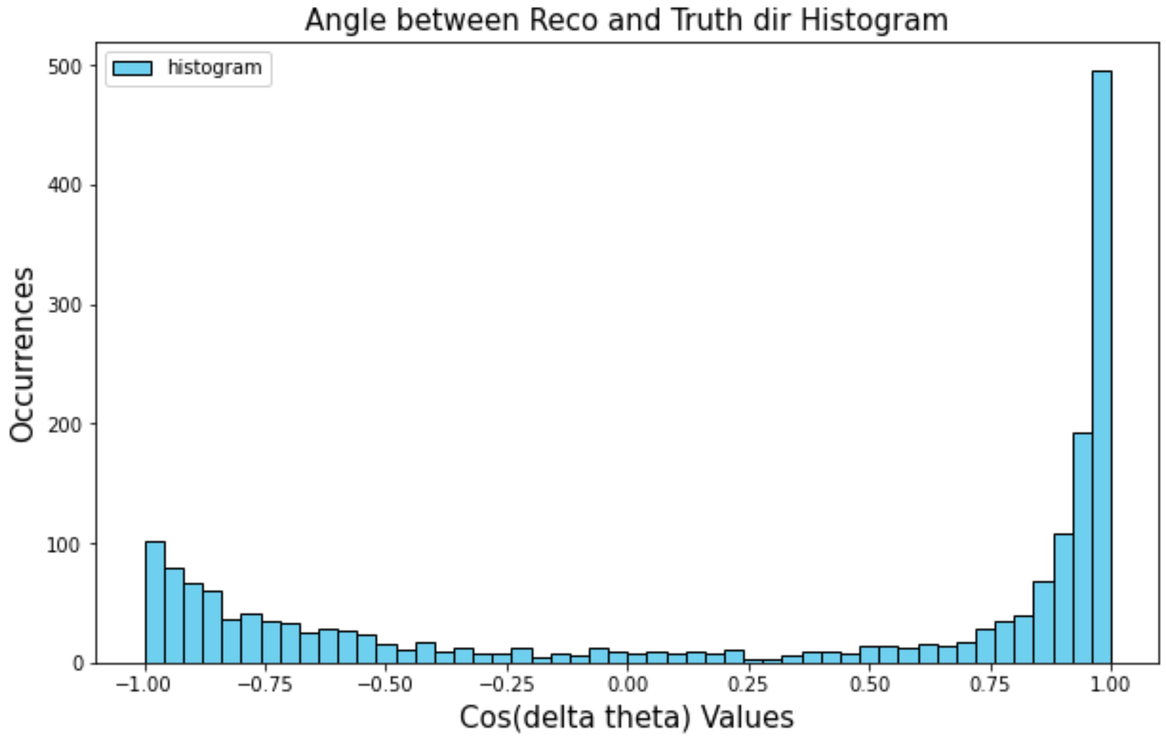
CC Interaction



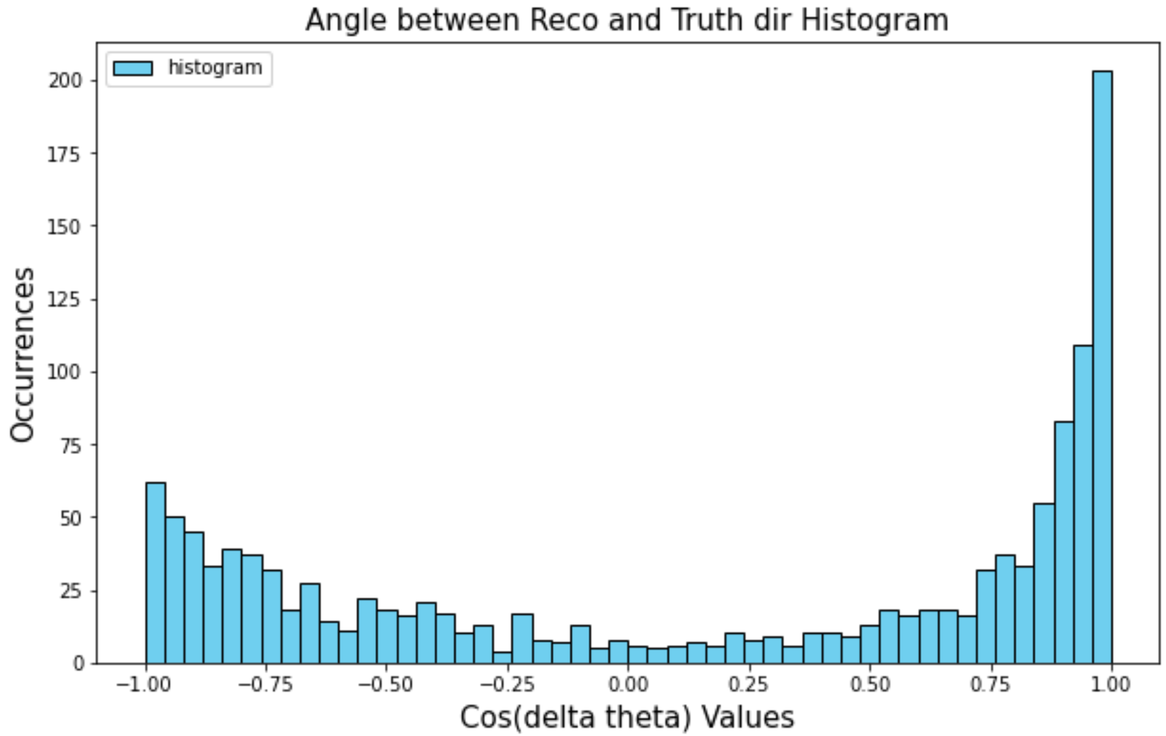
ES Interaction

Cosine of the Angle between truth dir vector and reco dir vector

Distribution



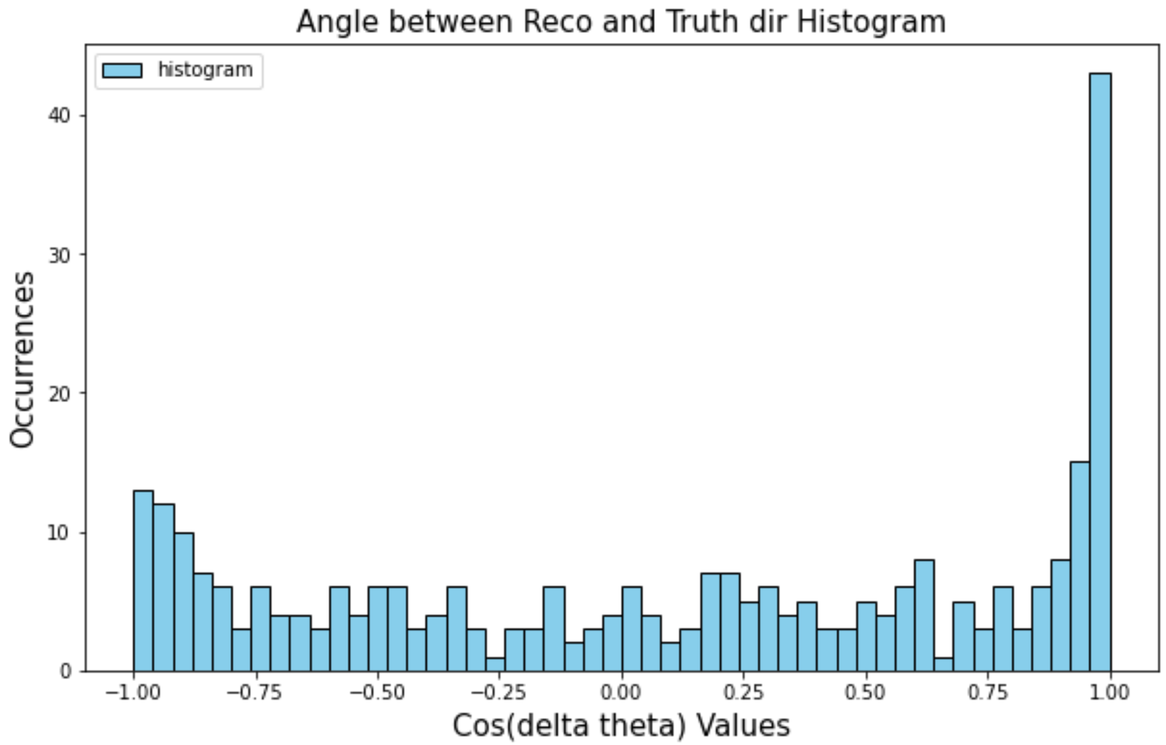
CC Interaction



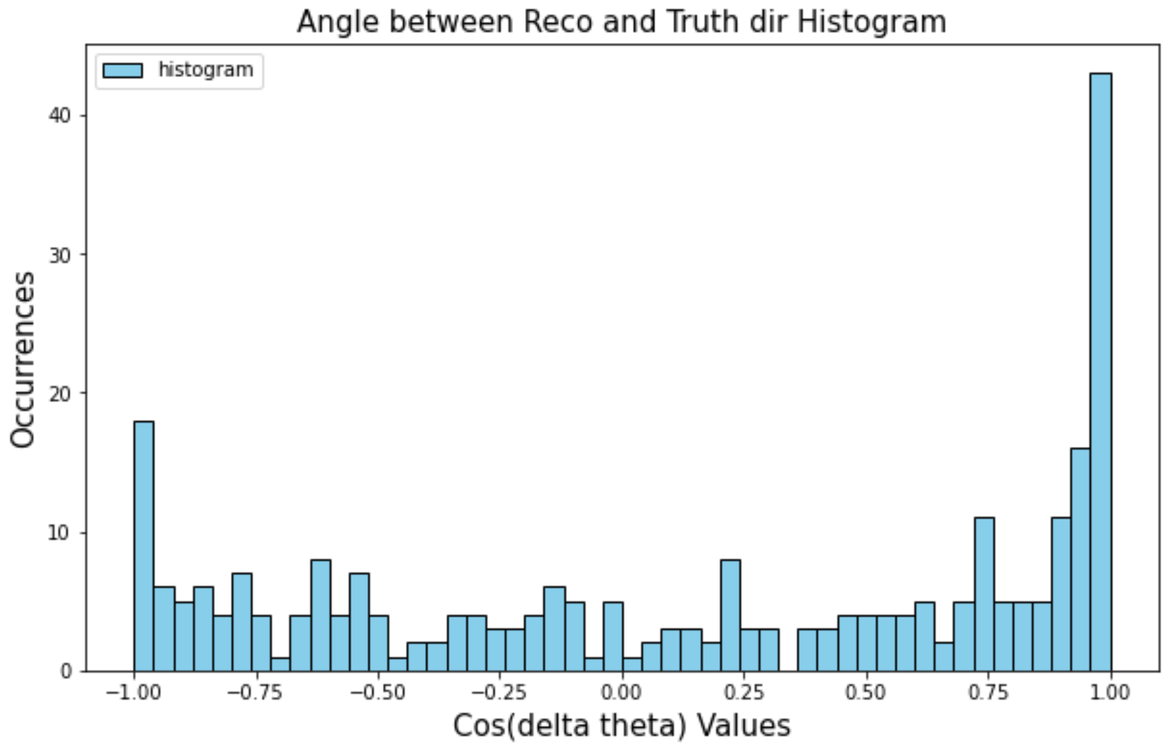
ES Interaction

Cosine of the Angle between truth dir vector and reco dir vector (newbkg)

Distribution



CC Interaction

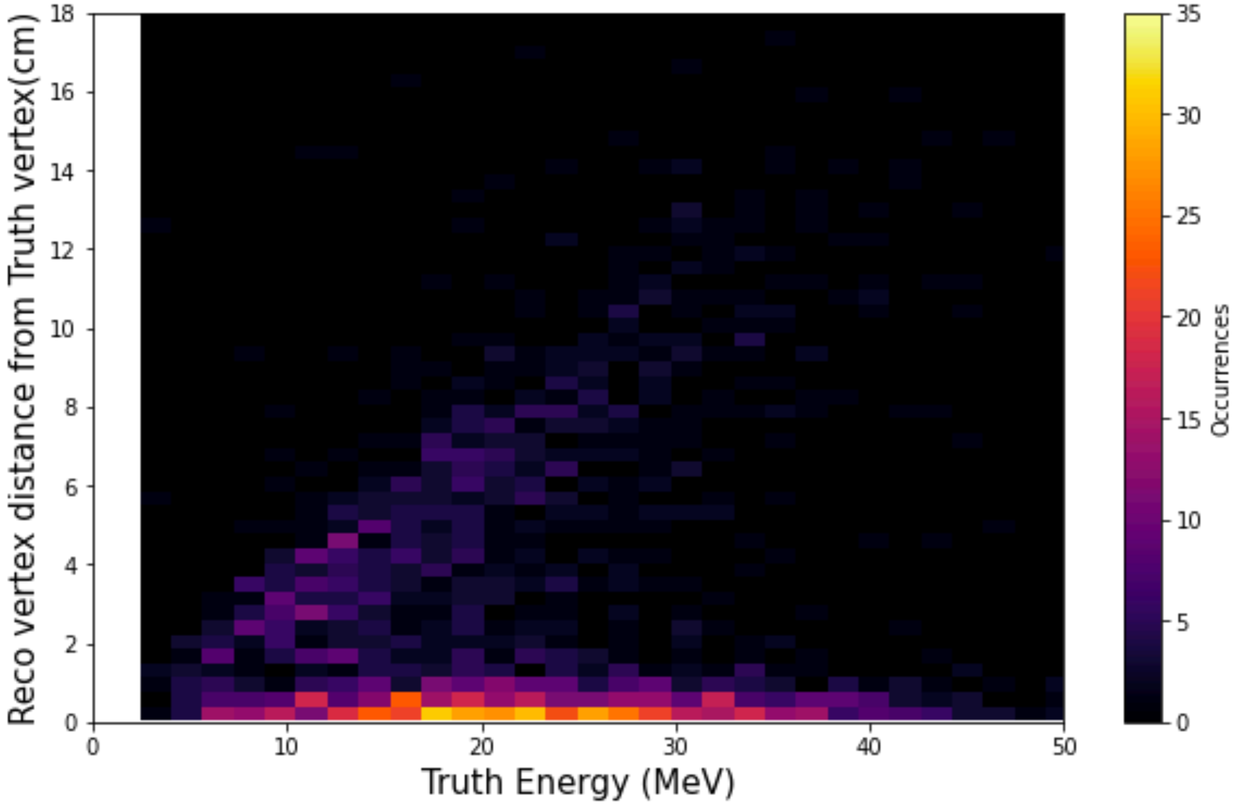


ES Interaction

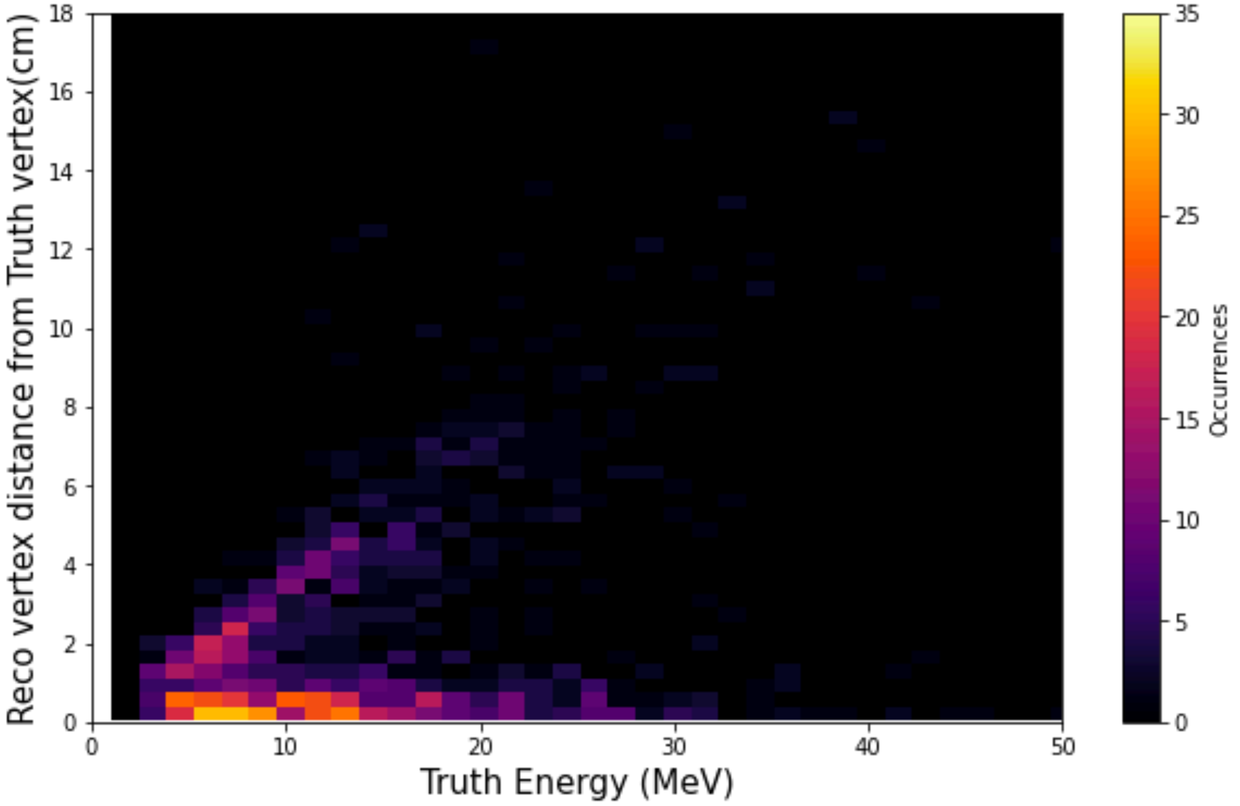
Distance between truth vertex and reco vertex

Distribution with Energy dependence (Zoomed in)

All Events

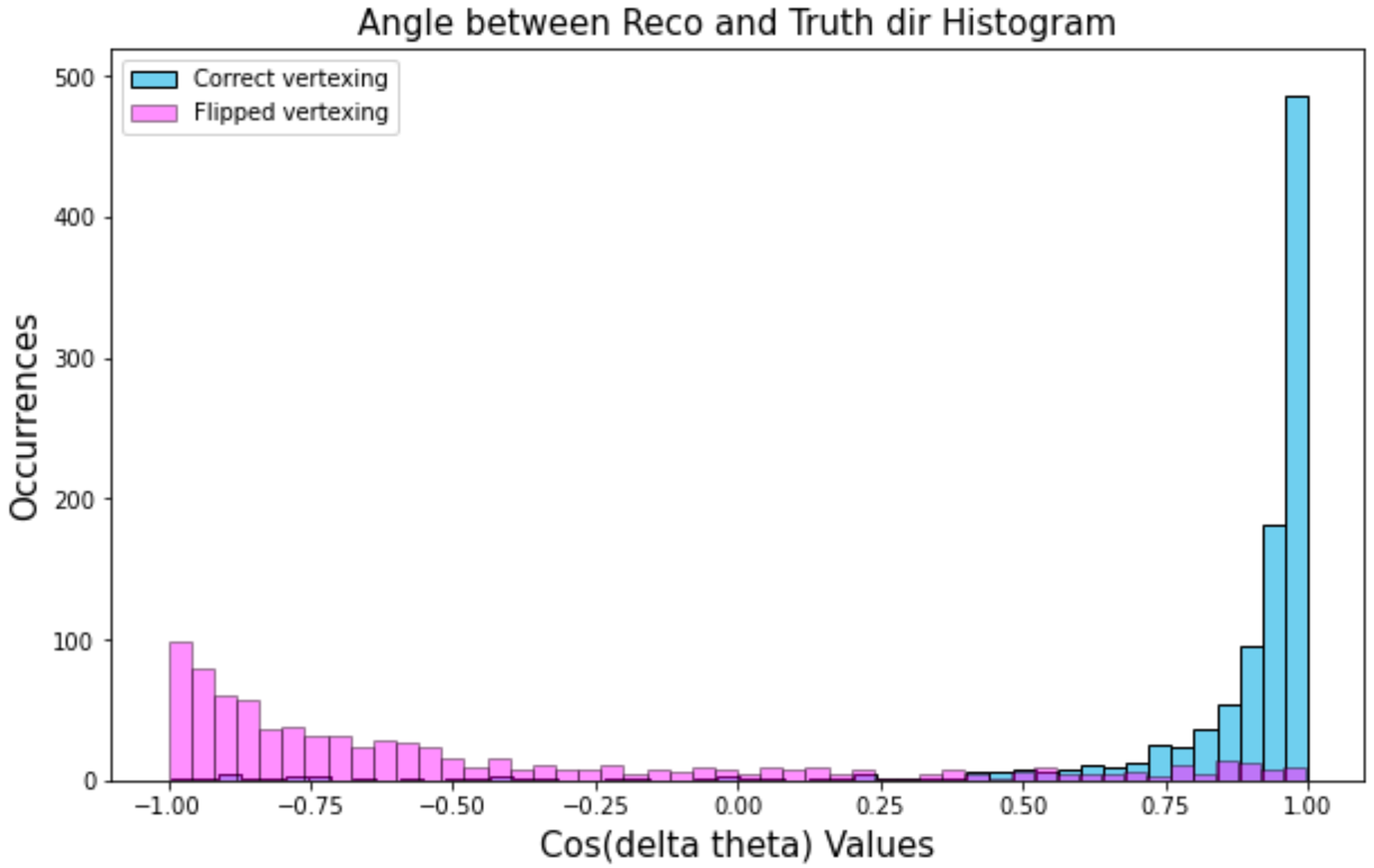


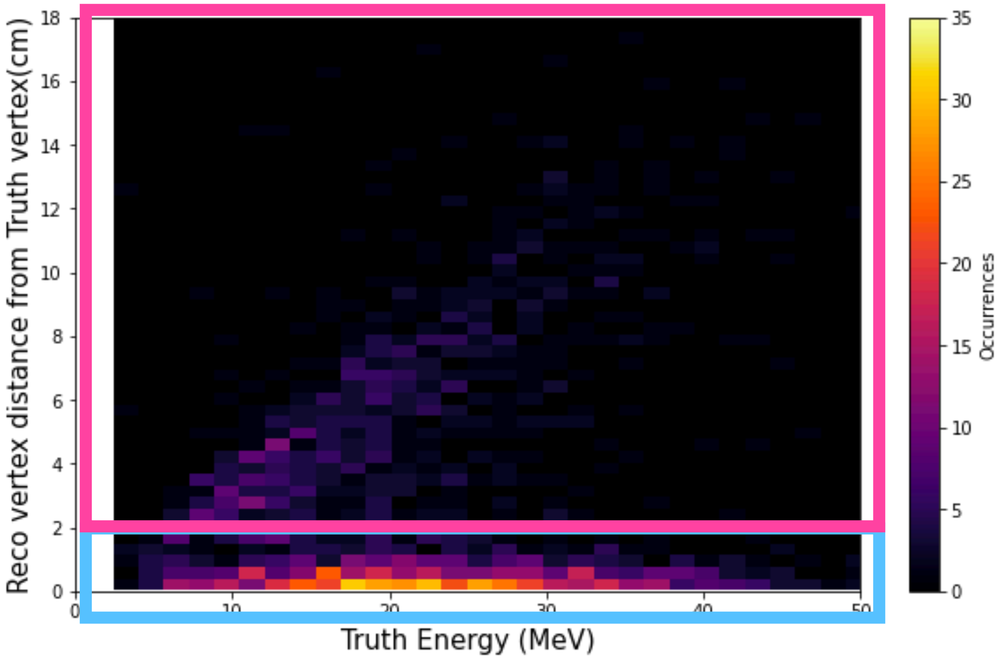
CC Interaction



ES Interaction

Cos (delta theta) distribution for correct vertexing and flipped vertexing





CC Interaction

Primary and Secondary tracks

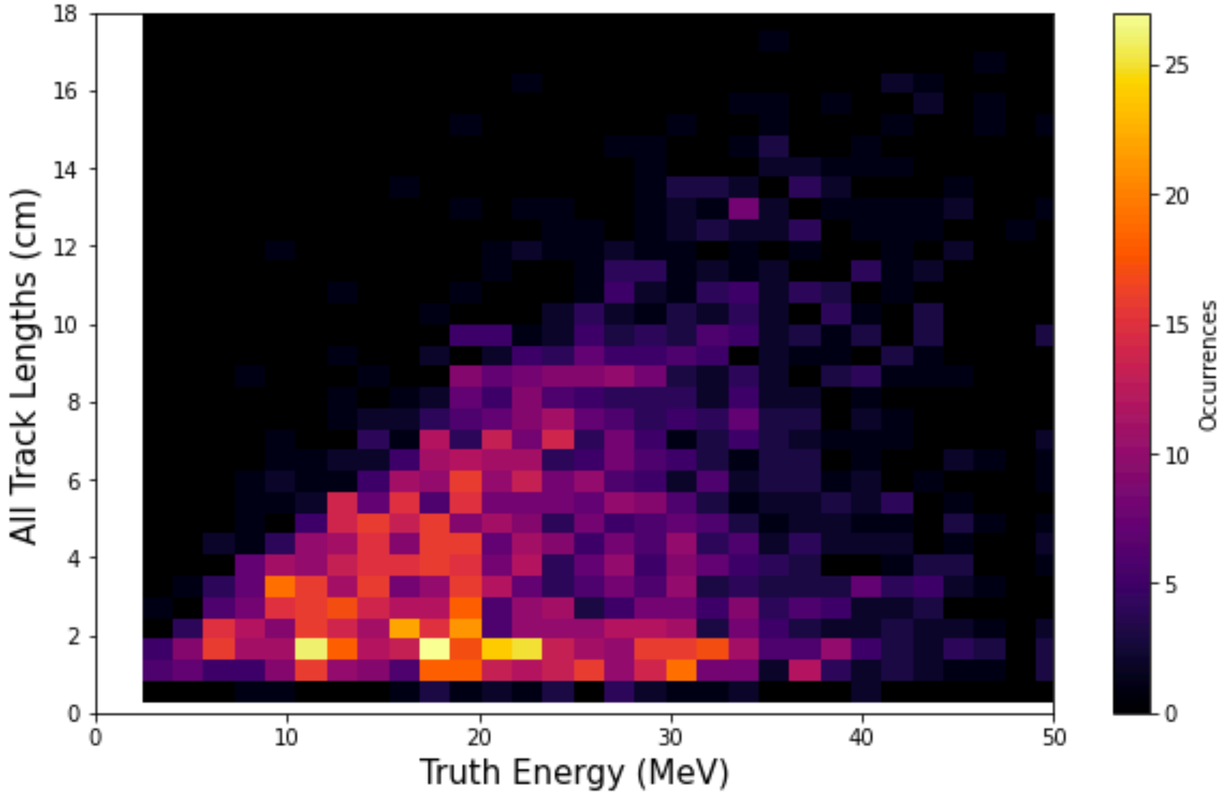
For a total of 2000 events

Fraction of tracks / Interaction	Primary	Secondary 1st	Secondary 2nd	Secondary 3rd	Total tracks
CC	63.75	27.56	7.23	1.46	2877
ES	81.54	15.93	2.34	0.19	1582

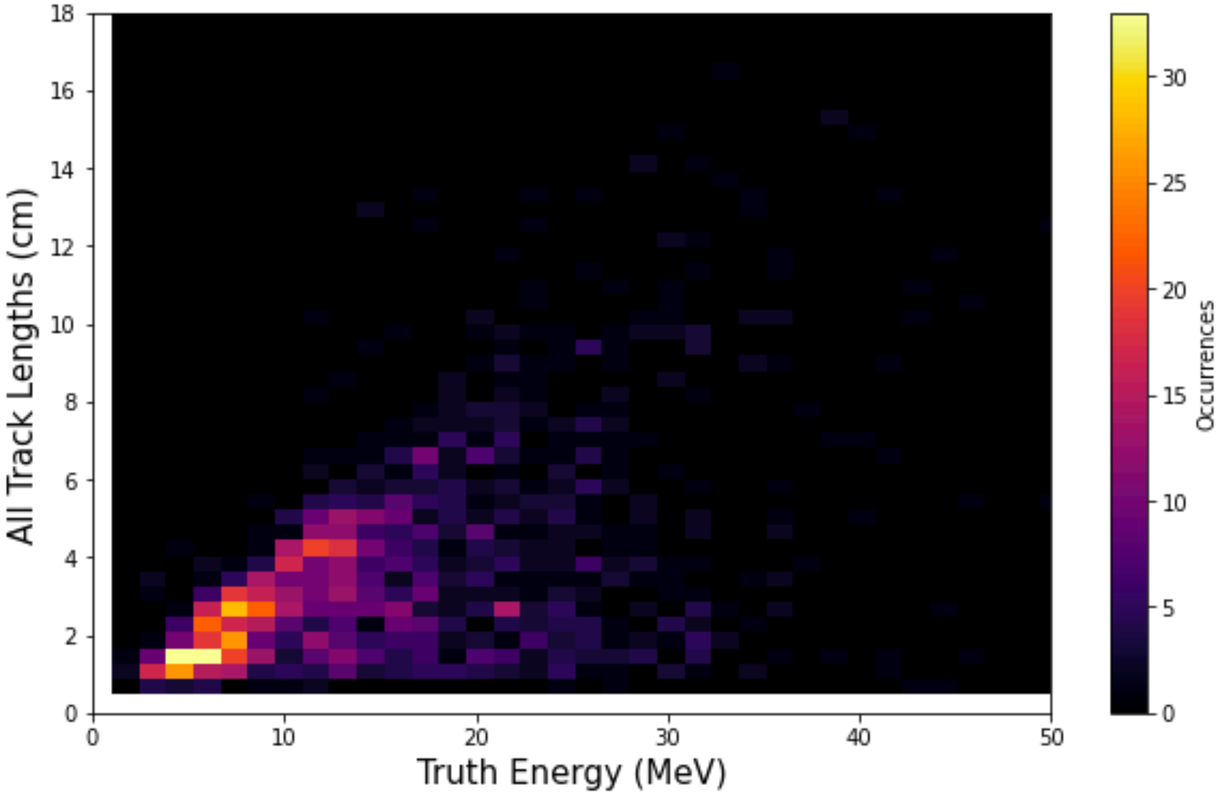
No tracks for events where reconstruction failed

Reconstructed Track length (All tracks)

Distribution with Energy dependence (Zoomed In)



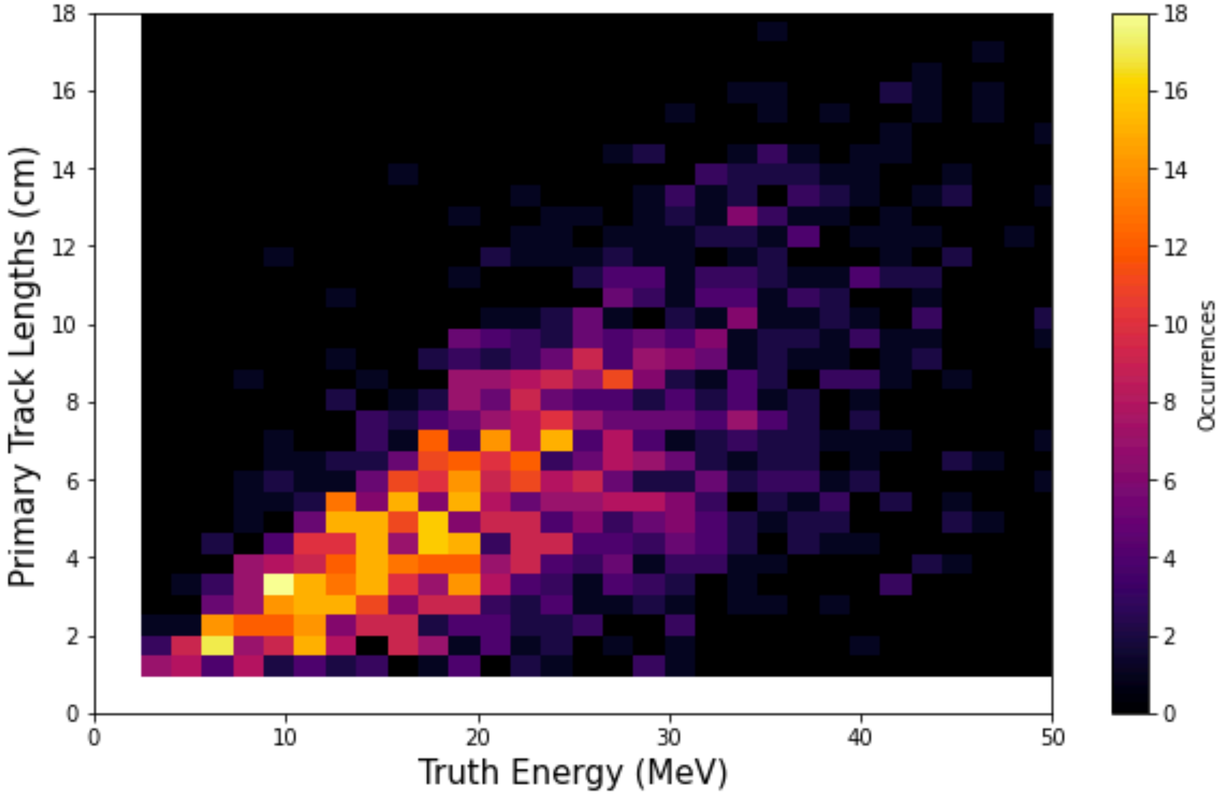
CC Interaction



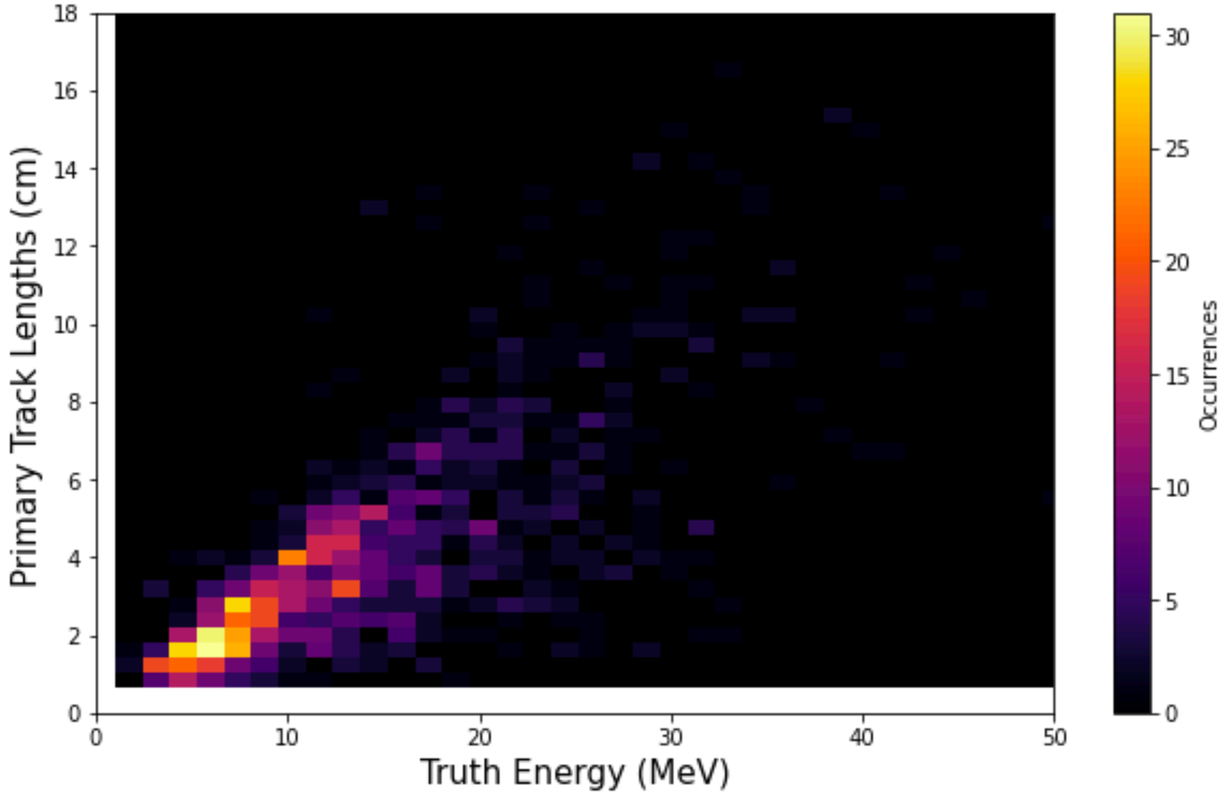
ES Interaction

Reconstructed Track length (Primary tracks only)

Distribution with Energy dependence (Zoomed In)



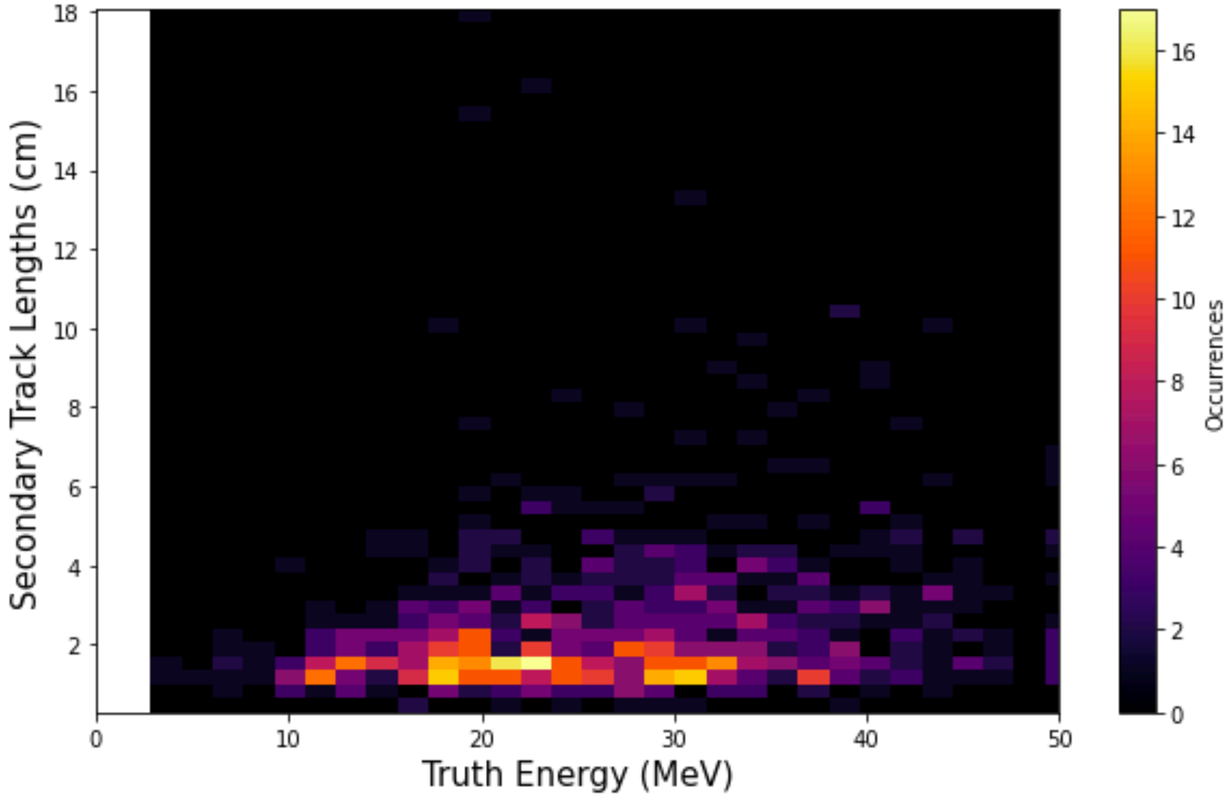
CC Interaction



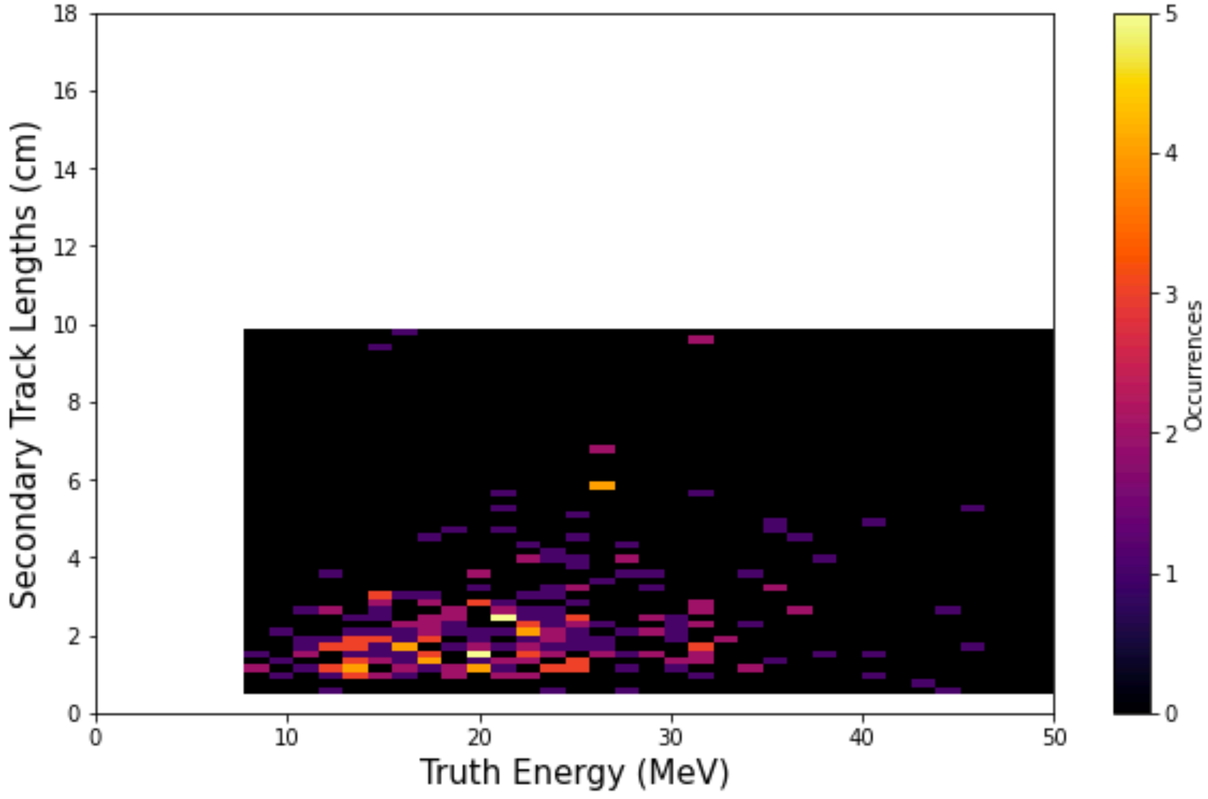
ES Interaction

Reconstructed Track length (Secondary tracks only)

Distribution with Energy dependence (Zoomed In)



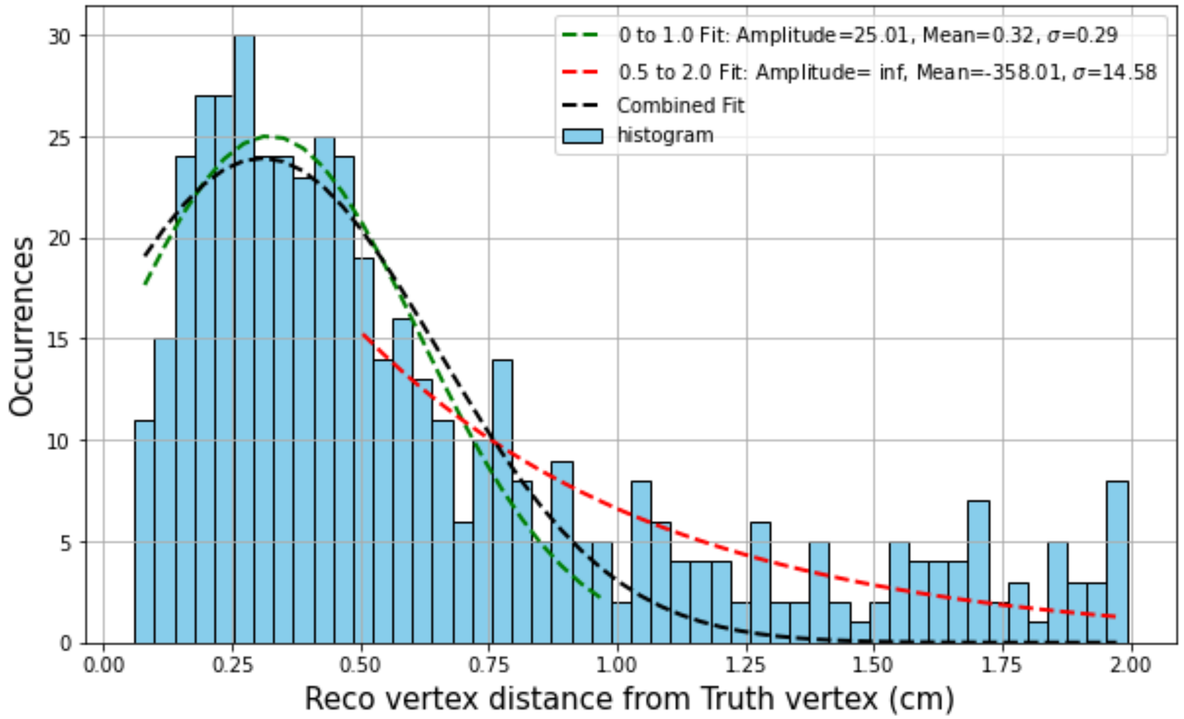
CC Interaction



ES Interaction

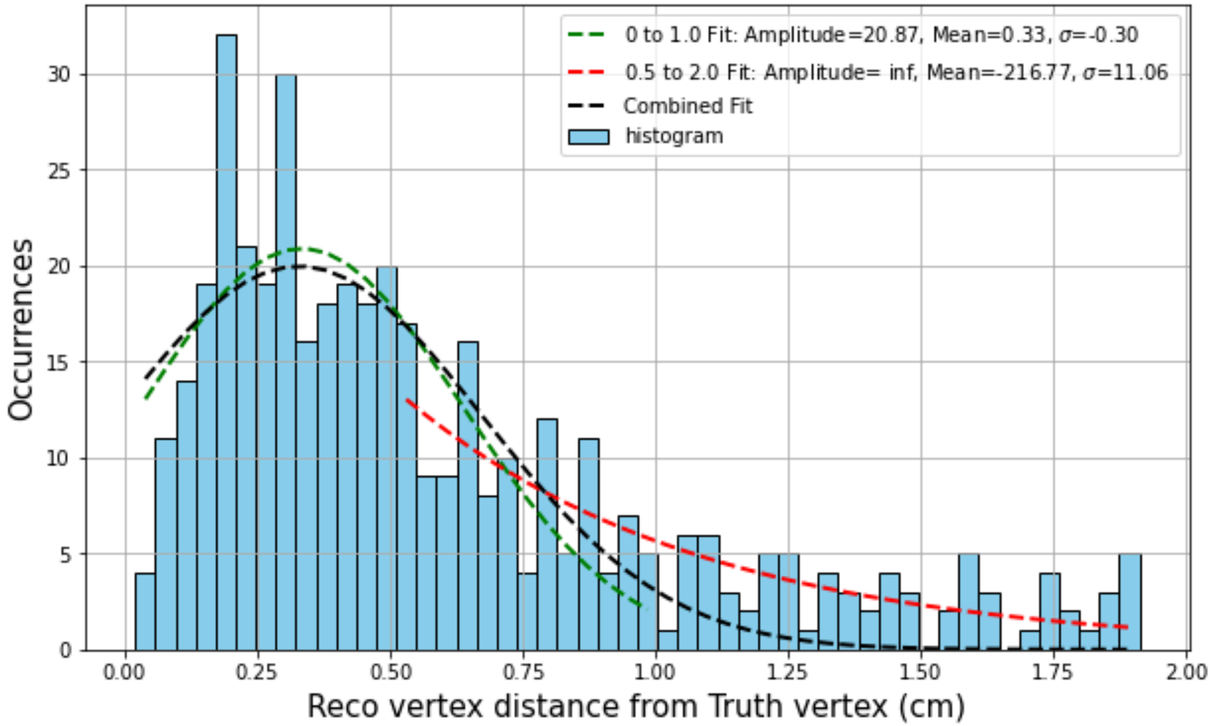
Reco vertex distance distribution over 10MeV energy bins

Energy: 10-20 MeV




```
Parameters of the combined Gaussian fit:
Amplitude1: 23.91892616936817
Mean1: 0.3088550715352538
Sigma1: 0.34069272272652296
Amplitude2: 8.897506006765735e+136
Mean2: -41717.86878008308
Sigma2: 864.7992830604734
```

CC Interaction

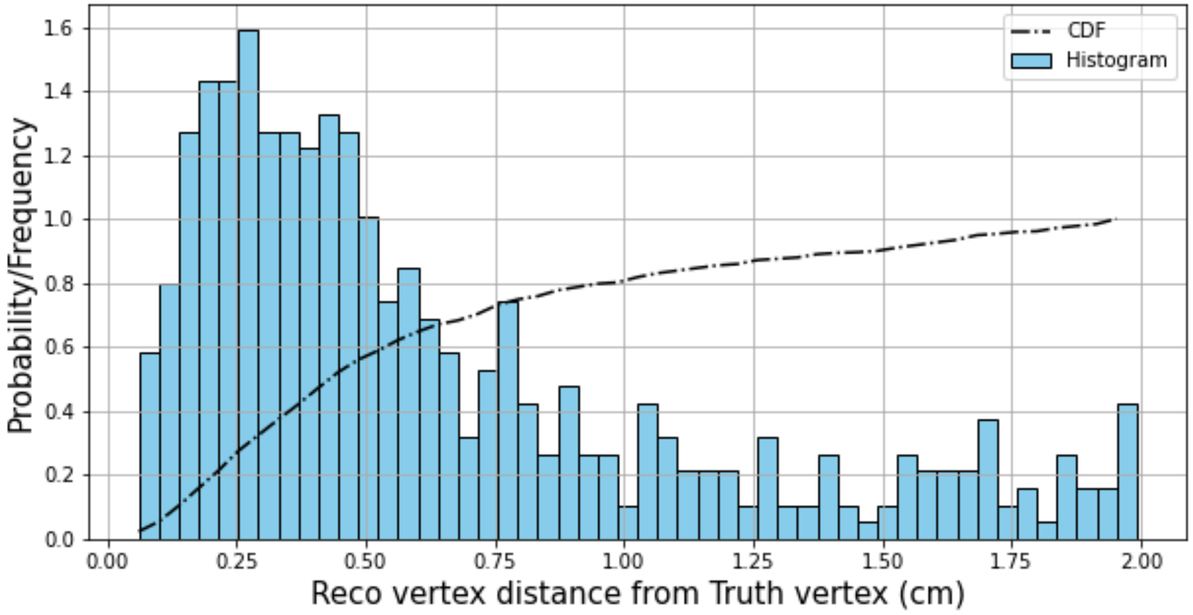



```
Parameters of the combined Gaussian fit:
Amplitude1: 19.943344545483775
Mean1: 0.3281221152873577
Sigma1: -0.34685732314762624
Amplitude2: 1.2104811148050677e+89
Mean2: -15273.985501143028
Sigma2: 399.8829170962865
```

ES Interaction

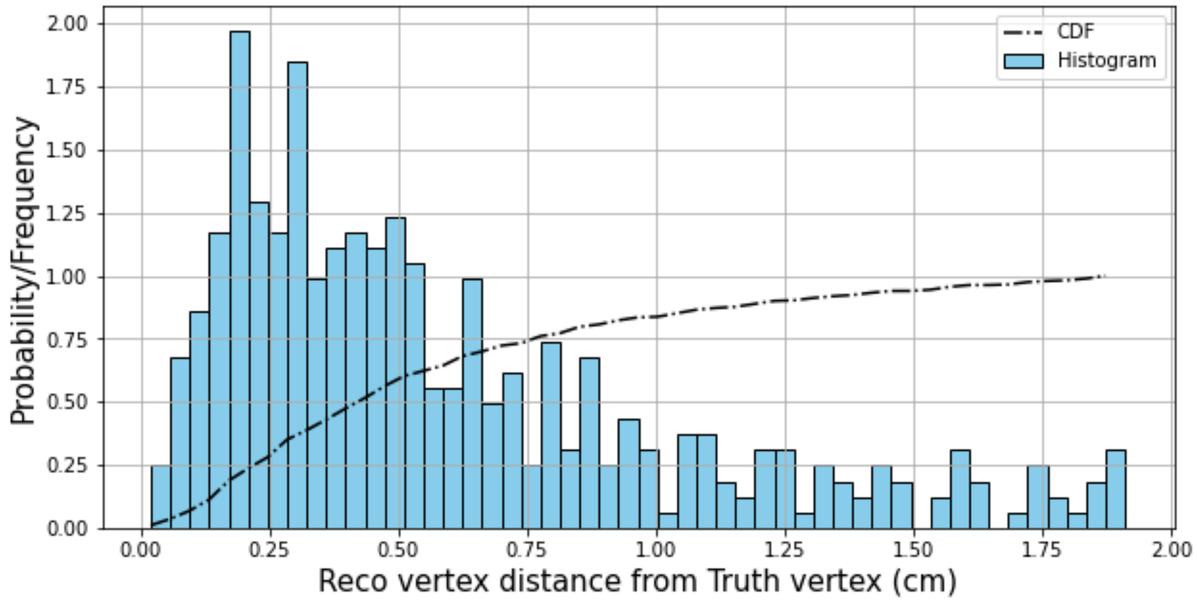
CDF for the Reco vertex distance distribution

Energy: 10-20 MeV




```
Probability of the distance being less than 0.5 cm: 55.94%
Probability of the distance being less than 0.25 cm: 21.31%
```

CC Interaction

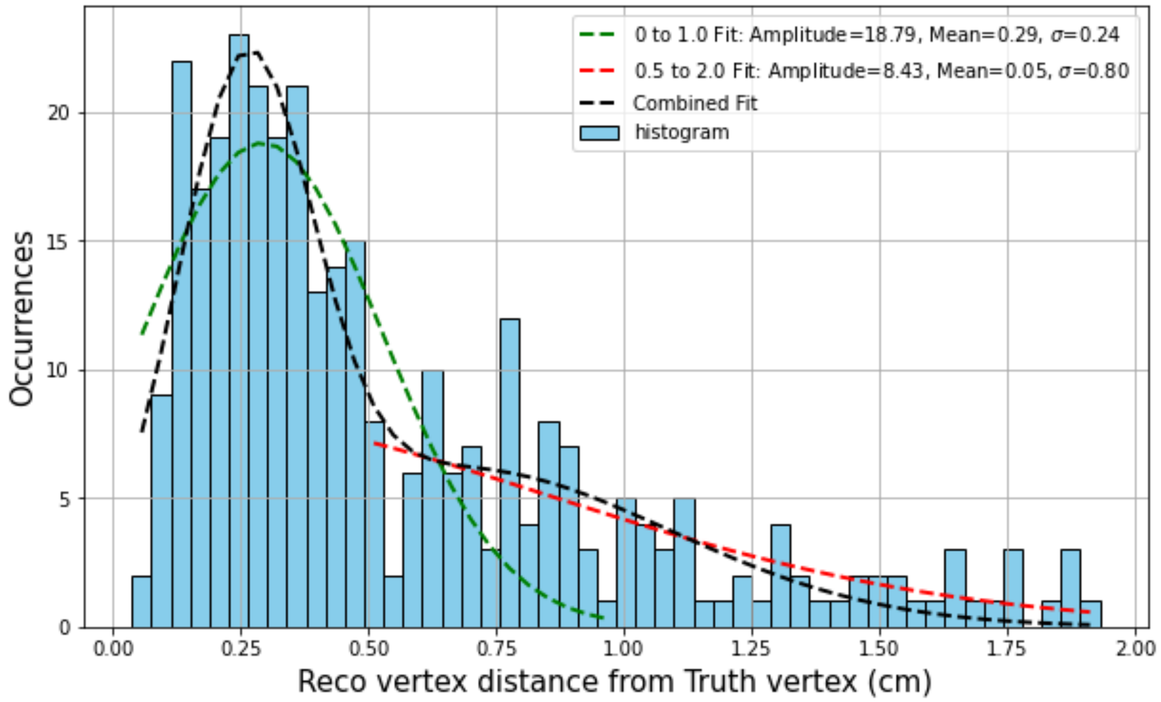



```
Probability of the distance being less than 0.5 cm: 56.18%
Probability of the distance being less than 0.25 cm: 27.97%
```

ES Interaction

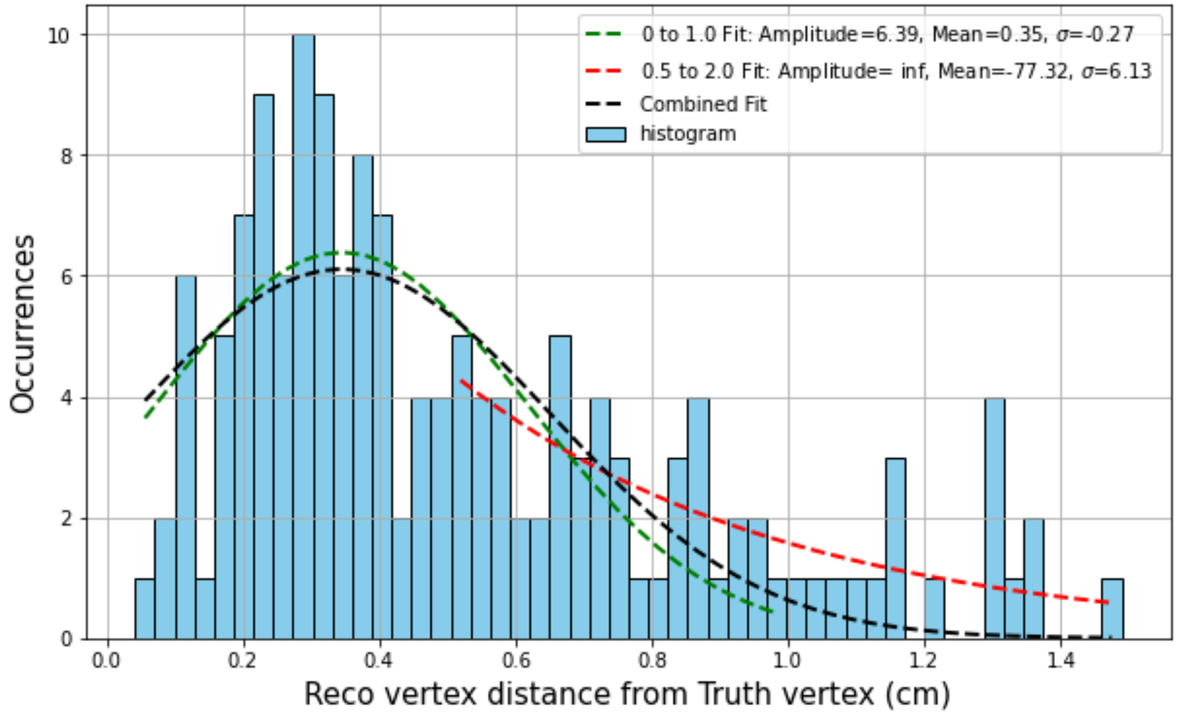
Reco vertex distance distribution over 10MeV energy bins

Energy: 20-30 MeV




```
Parameters of the combined Gaussian fit:
Amplitude1: 18.631680431520845
Mean1: 0.25976059015094716
Sigma1: 0.1298614354358703
Amplitude2: 6.155605292404322
Mean2: 0.6737173173175254
Sigma2: 0.41734682671051904
```

CC Interaction

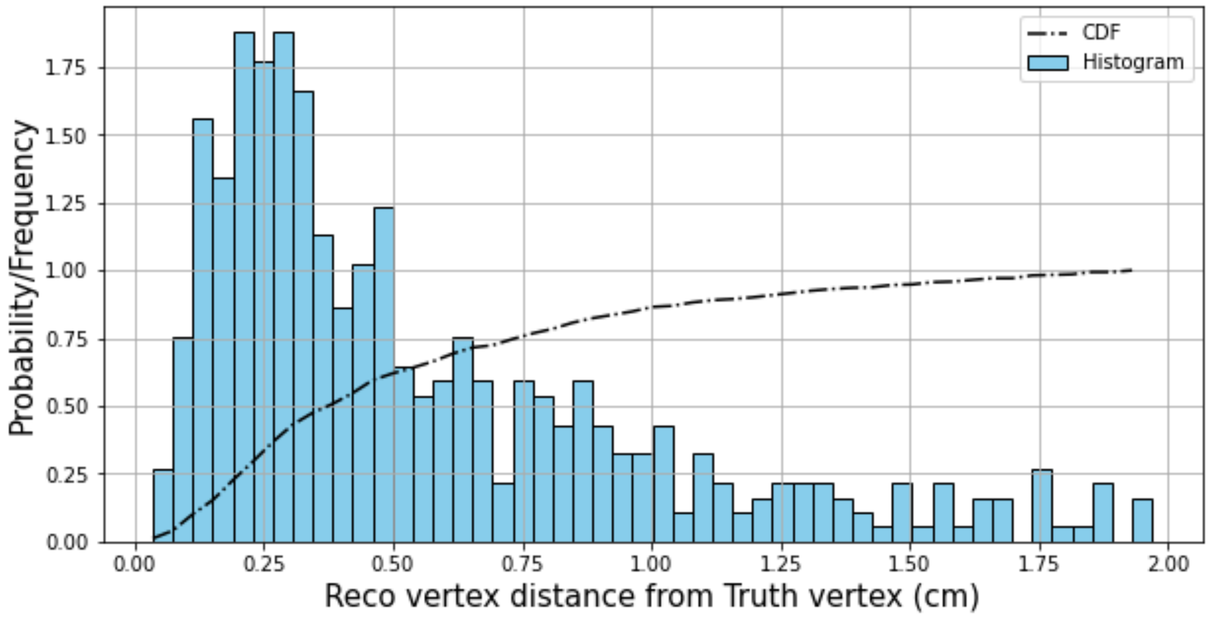



```
Parameters of the combined Gaussian fit:
Amplitude1: 6.110201232512845
Mean1: 0.3448483614162669
Sigma1: -0.3069021998054474
Amplitude2: 1.63293255184681e+39
Mean2: -3888.432315561174
Sigma2: 159.06255574021094
```

ES Interaction

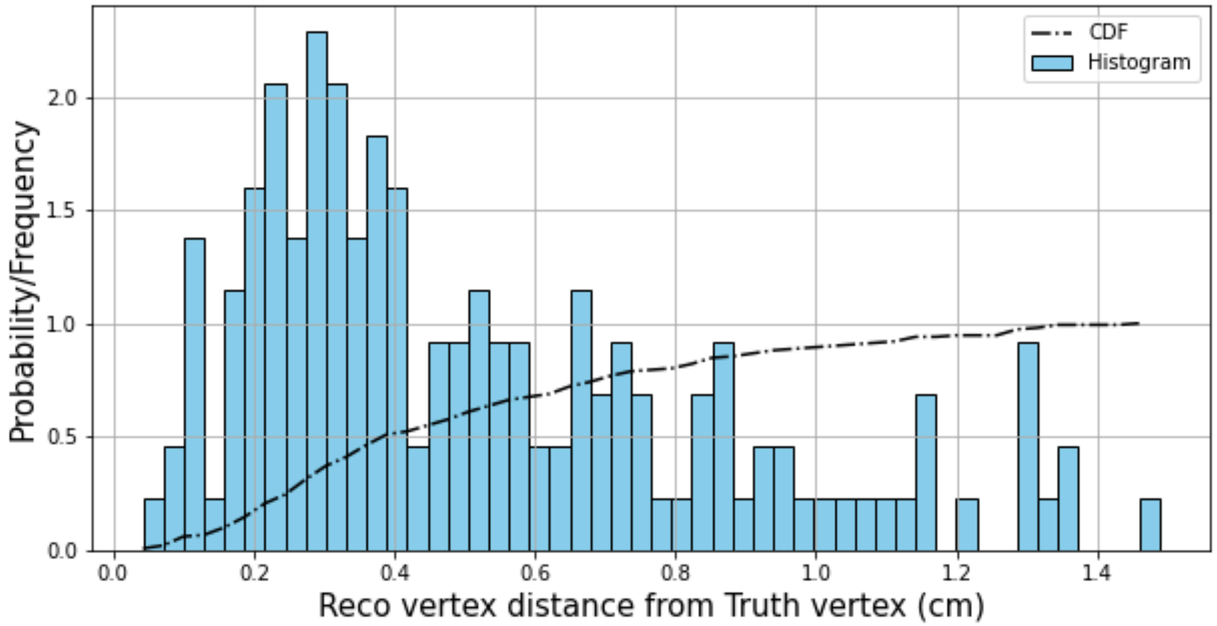
CDF for the Reco vertex distance distribution

Energy: 20-30 MeV




```
Probability of the distance being less than 0.5 cm: 61.95%
Probability of the distance being less than 0.25 cm: 29.31%
```

CC Interaction

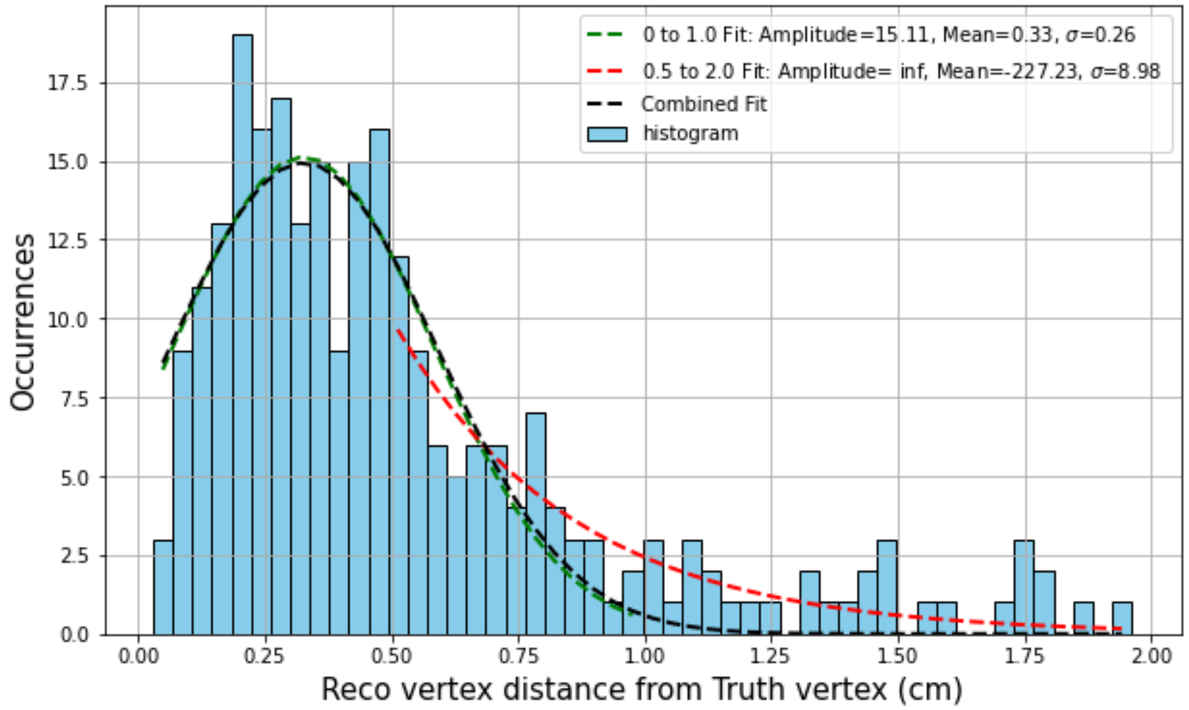



```
Probability of the distance being less than 0.5 cm: 57.62%
Probability of the distance being less than 0.25 cm: 24.50%
```

ES Interaction

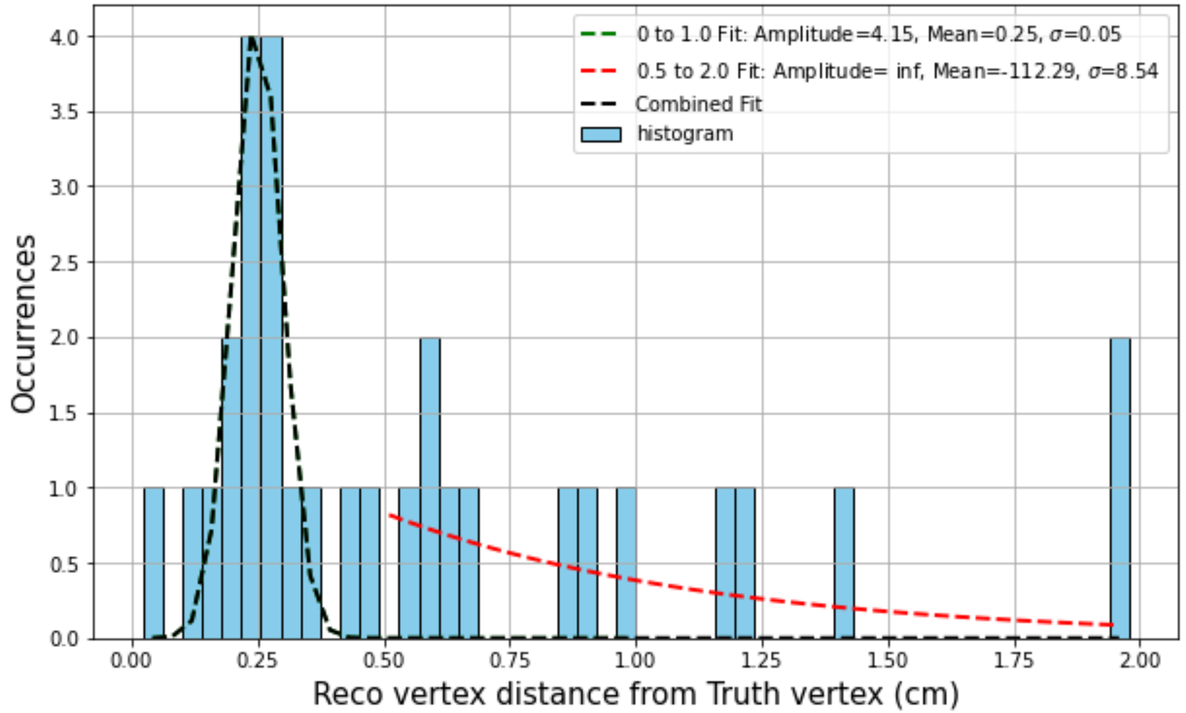
Reco vertex distance distribution over 10MeV energy bins

Energy: 30-40 MeV




```
Parameters of the combined Gaussian fit:
Amplitude1: 14.93112662063731
Mean1: 0.3261250608264537
Sigma1: 0.26423065032206344
Amplitude2: 2.1686628200776898e+145
Mean2: -26477.79135752009
Sigma2: 528.1146067780523
```

CC Interaction

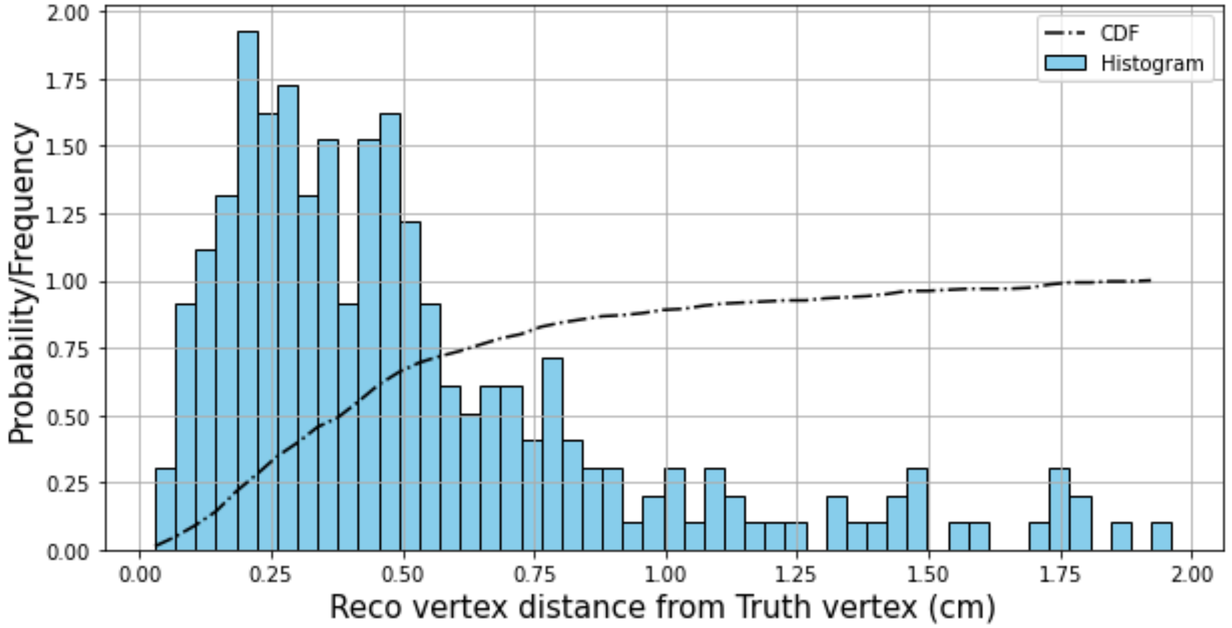



```
Parameters of the combined Gaussian fit:
Amplitude1: 4.15340303227108
Mean1: 0.24984349273093046
Sigma1: 0.04869864757181801
Amplitude2: -3.398733792775791e+41
Mean2: 11892.940787305732
Sigma2: -271.54803520508636
```

ES Interaction

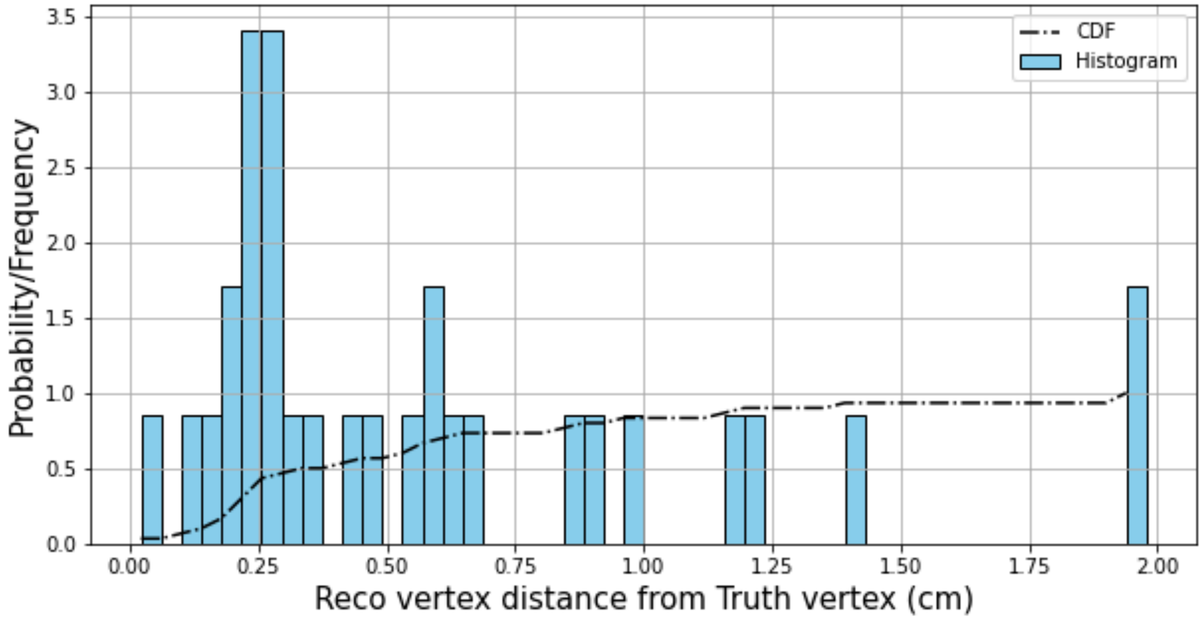
CDF for the Reco vertex distance distribution

Energy: 30-40 MeV




```
Probability of the distance being less than 0.5 cm: 65.88%
Probability of the distance being less than 0.25 cm: 27.84%
```

CC Interaction




```
Probability of the distance being less than 0.5 cm: 56.67%
Probability of the distance being less than 0.25 cm: 30.00%
```

ES Interaction

Reco vertex resolution in different energy ranges

Reco vertex distance / Energy range	**< 0.25 cm**	**< 0.5 cm**	**< 1 cm**
10 - 20 MeV	21.31% (CC) 27.97% (ES)	55.94% (CC) 56.18% (ES)	80.12% (CC) 83.45% (ES)
20 - 30 MeV	29.31% (CC) 24.50% (ES)	61.95% (CC) 57.62% (ES)	84.82% (CC) 89.40% (ES)
30 - 40 MeV	27.84% (CC) 30.00% (ES)	65.88% (CC) 56.67% (ES)	89.02% (CC) 83.33% (ES)

To do

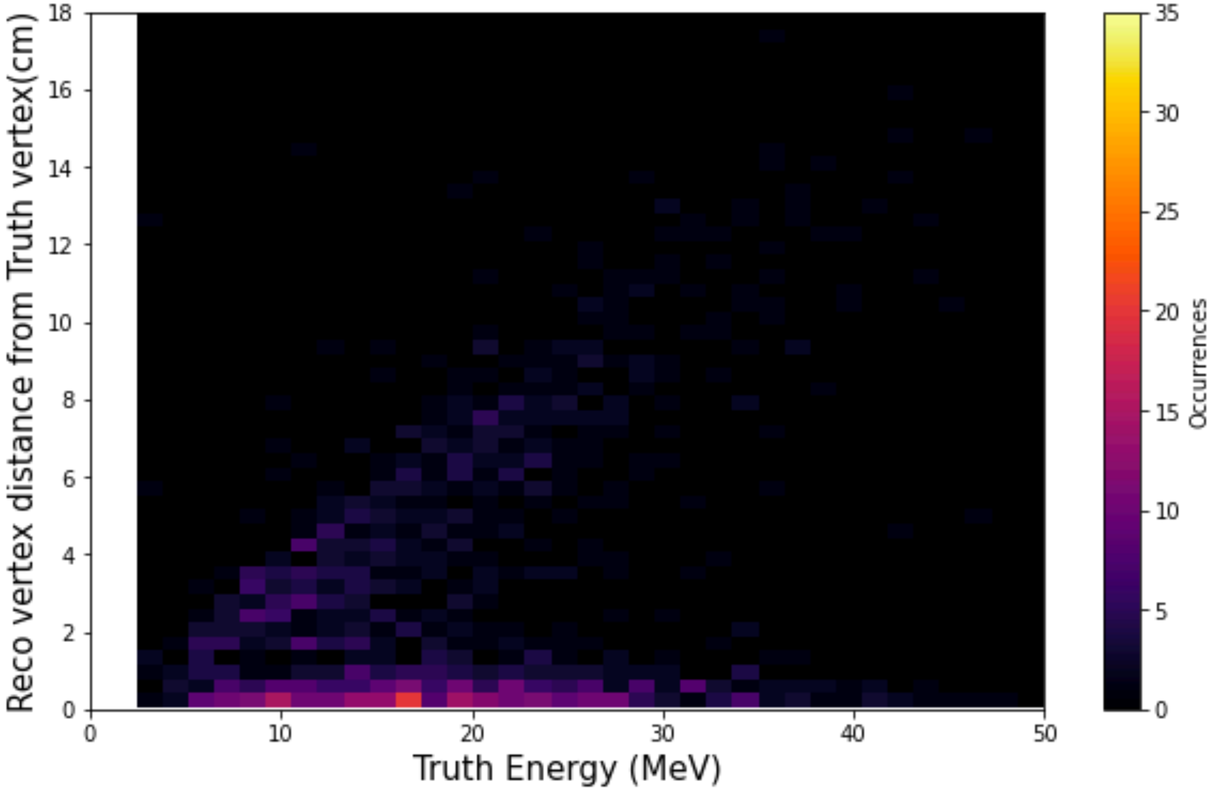
- Include Energy resolution study
- Study low energy events separately to identify if there is any energy dependence present
- Investigate the reason behind reconstruction failures in more detail
- Include relation between the electron direction and neutrino direction truth info and look at the energy dependence

Backups

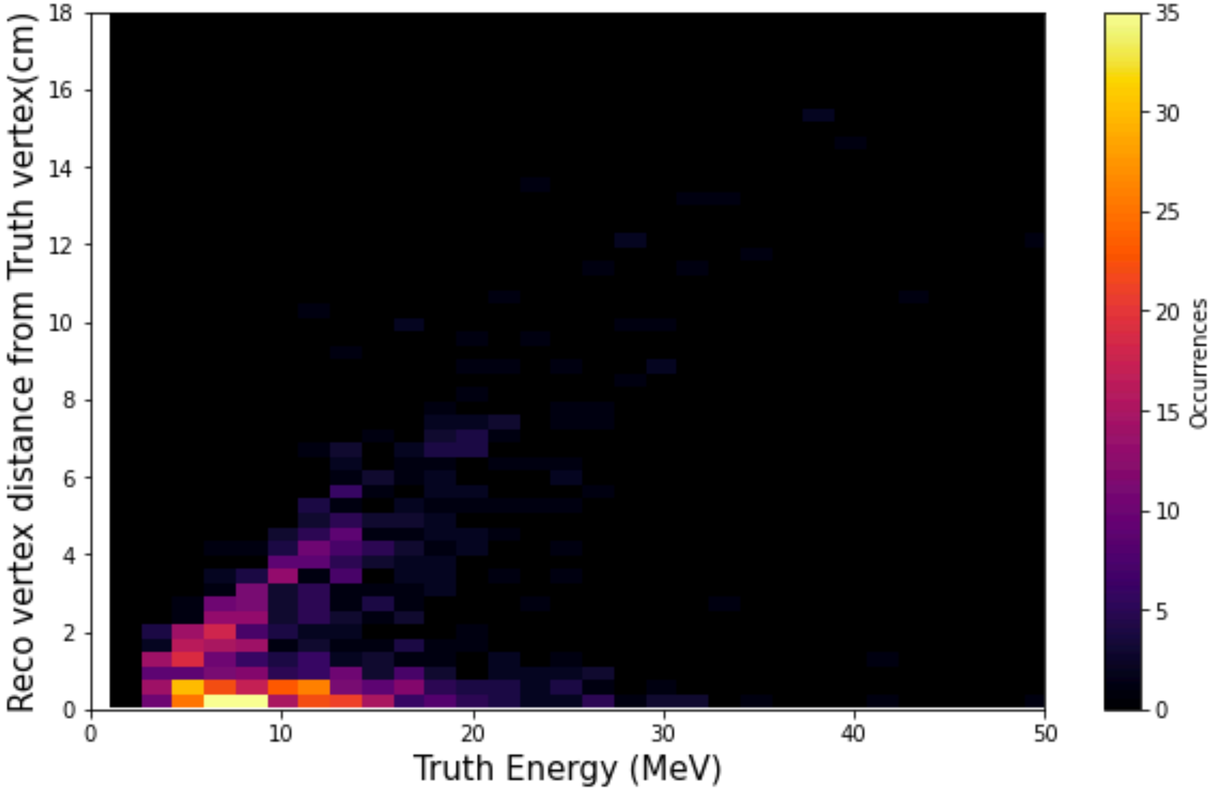
Distance between truth vertex and reco vertex

Distribution with Energy dependence (Zoomed in)

Events with Primary tracks only



CC Interaction

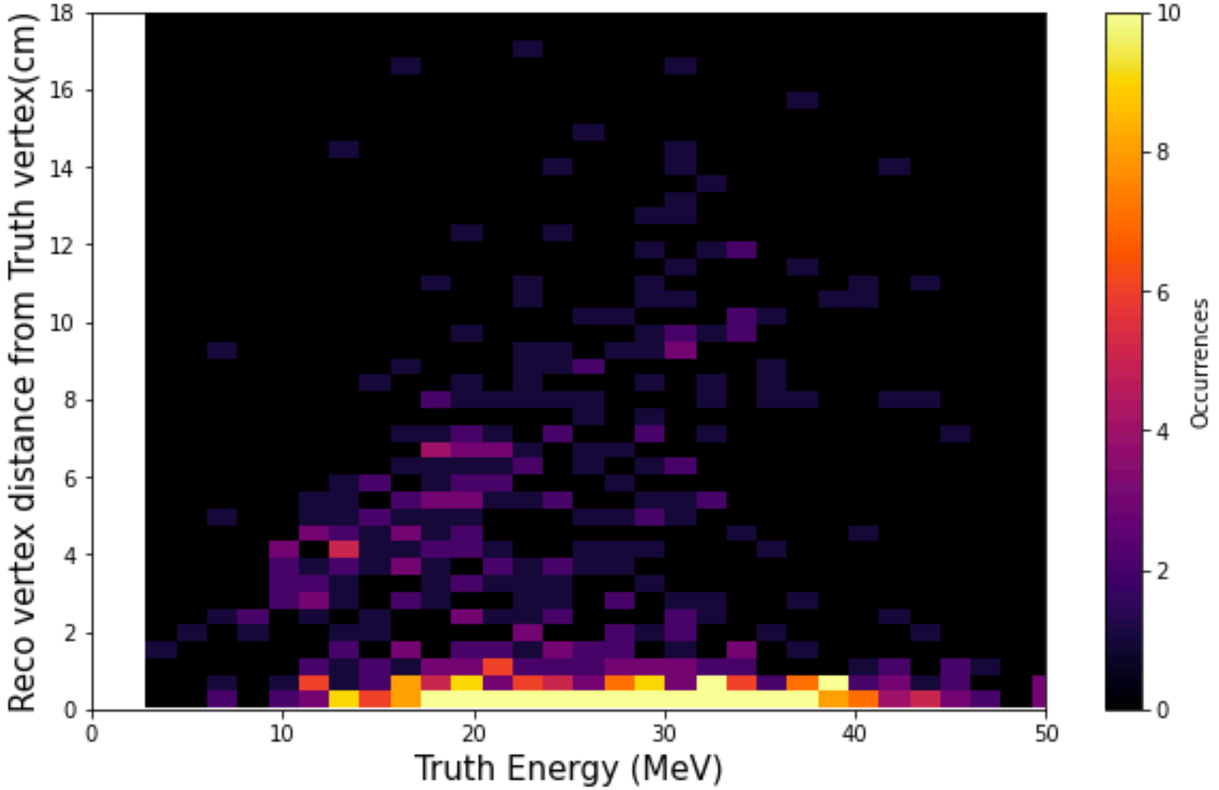


ES Interaction

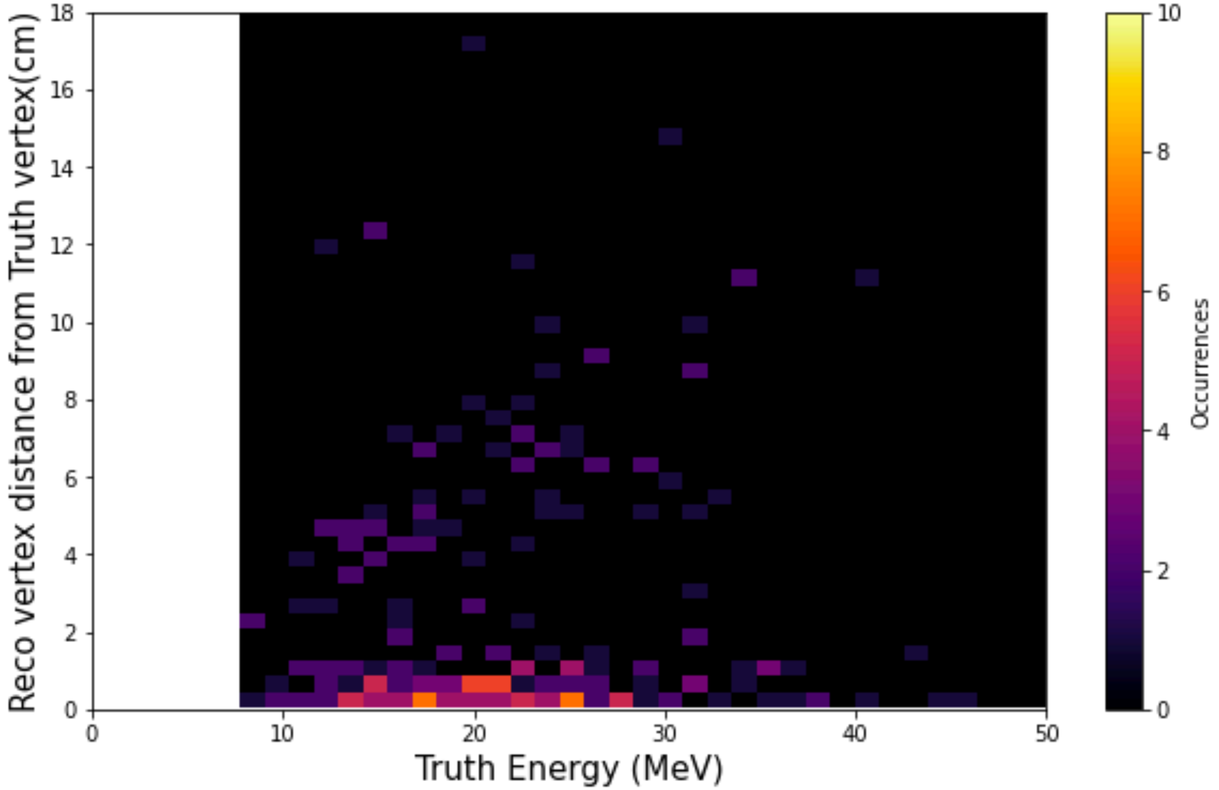
Distance between truth vertex and reco vertex

Distribution with Energy dependence (Zoomed in)

Events with Multiple tracks only



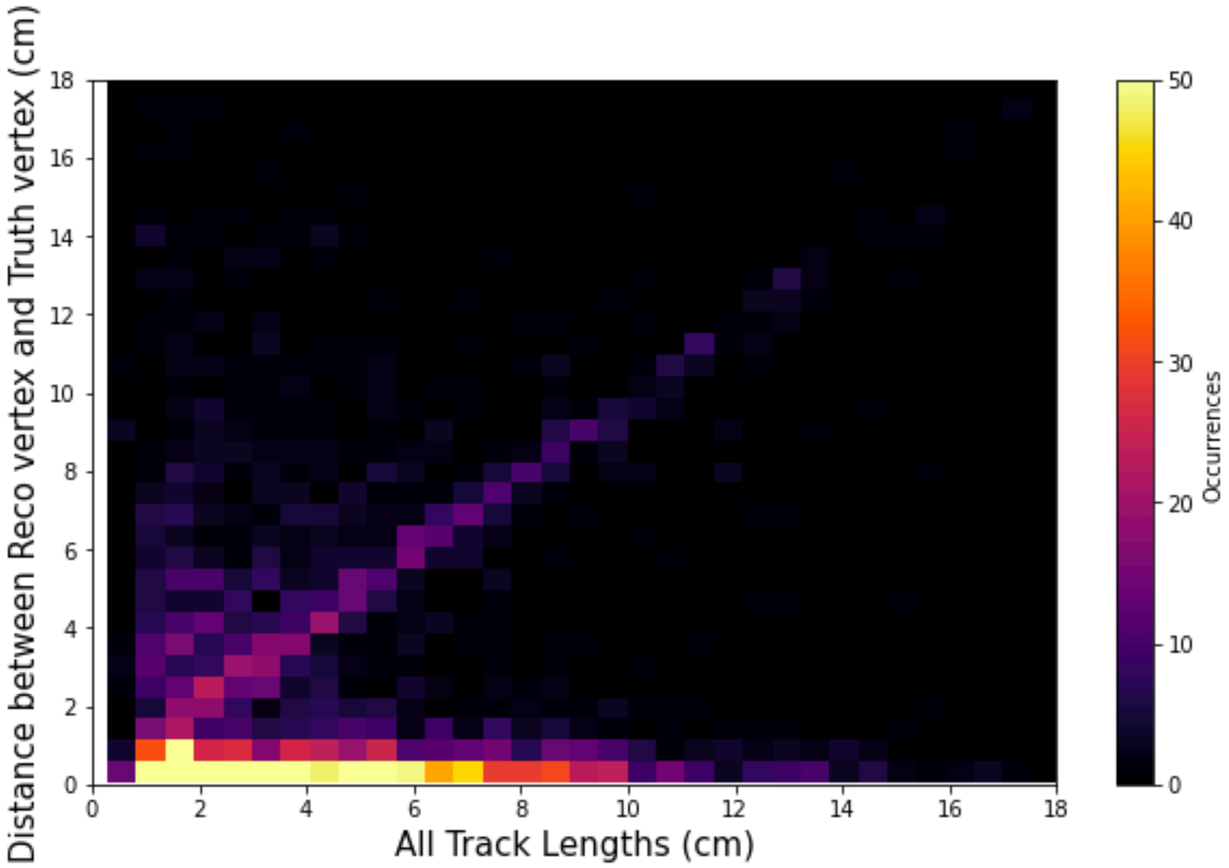
CC Interaction



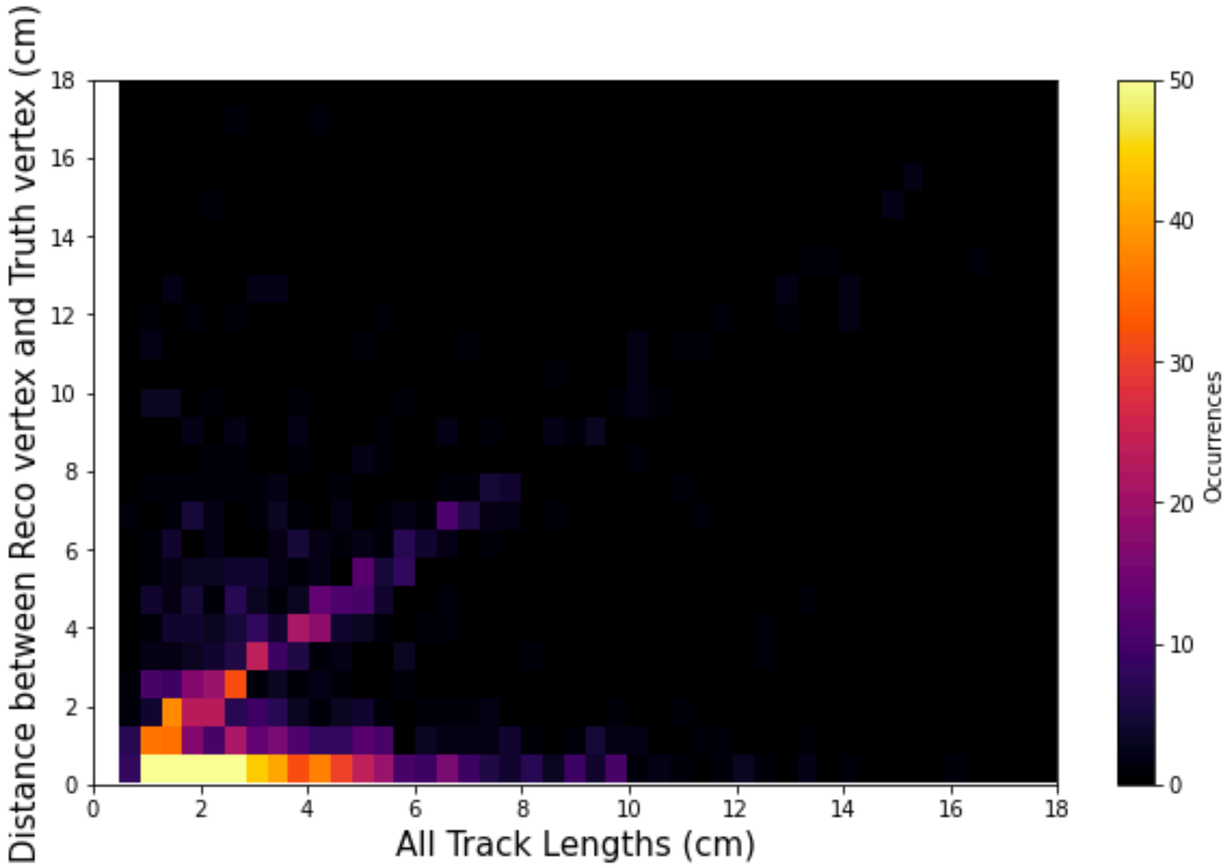
ES Interaction

Distance between Truth and Reco vertex Vs

Reconstructed Track length (All Tracks)



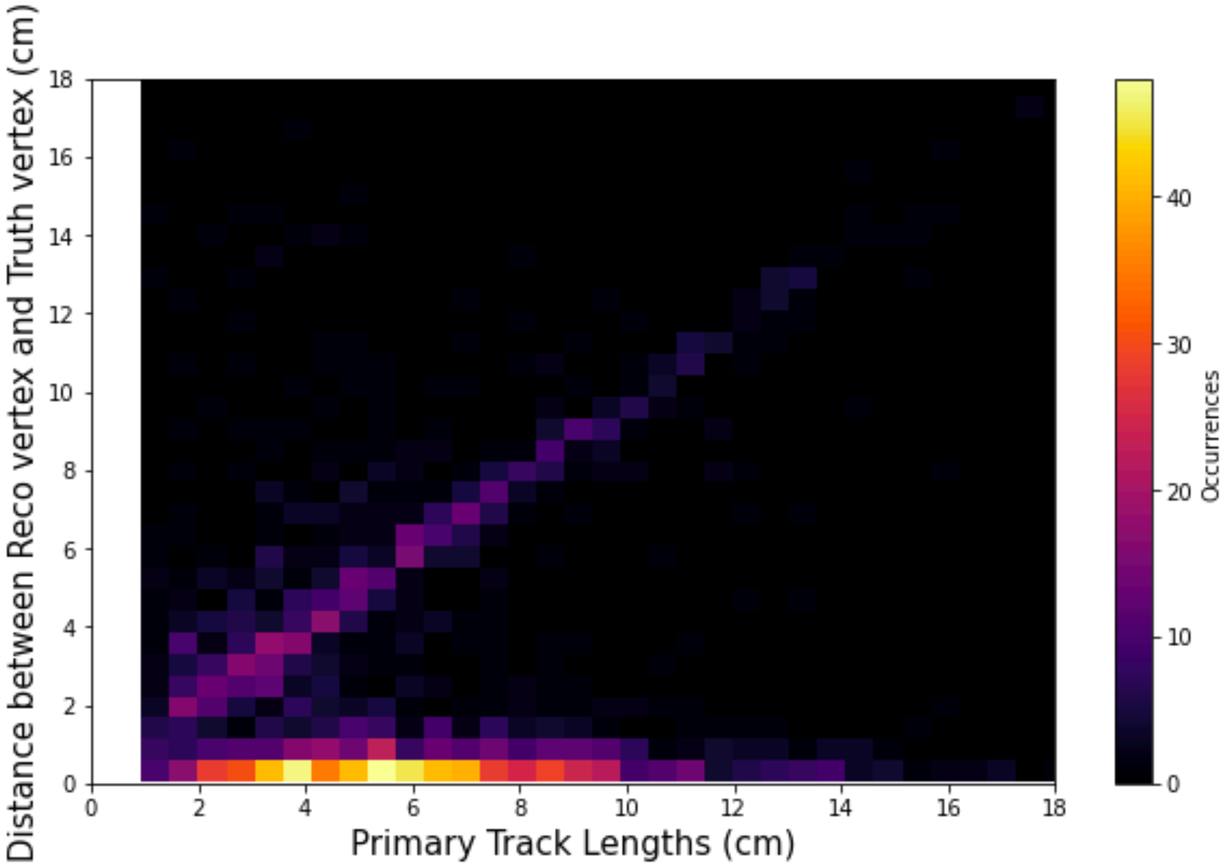
CC Interaction



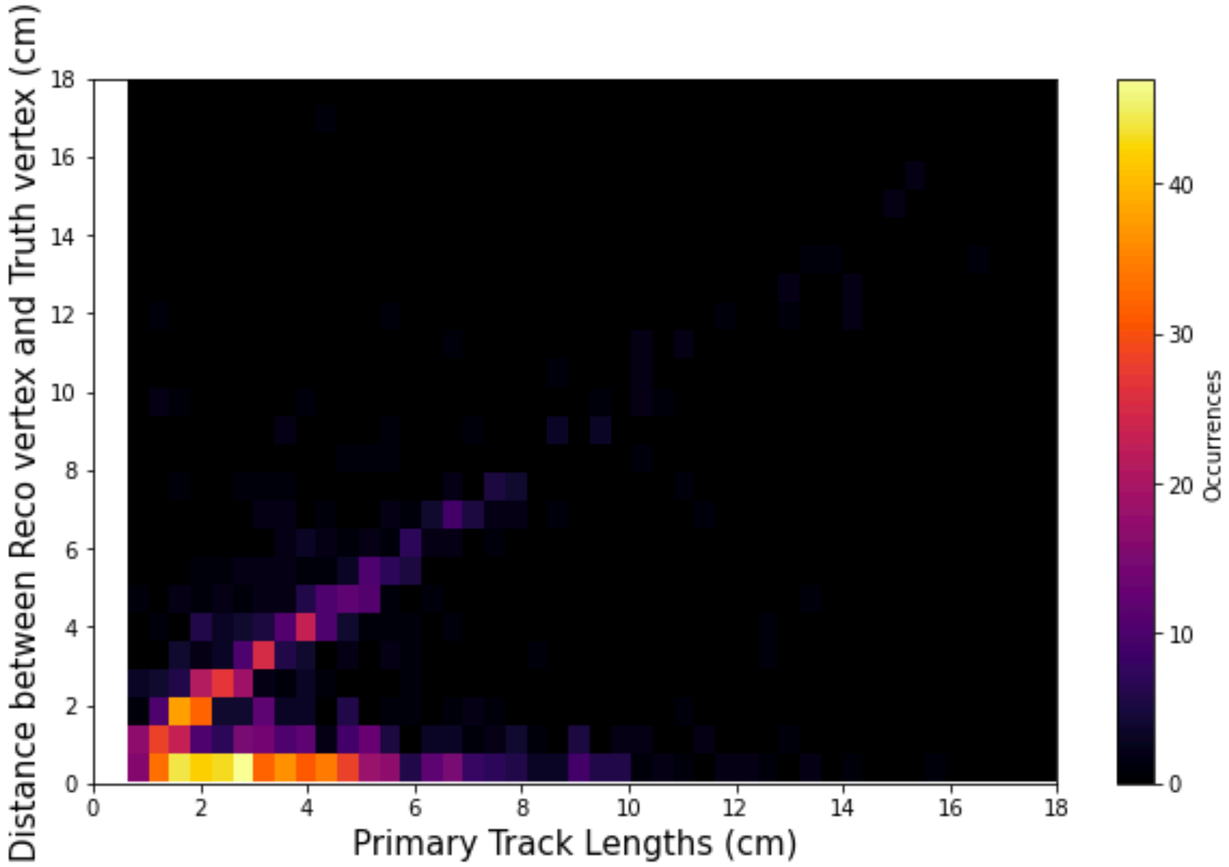
ES Interaction

Distance between Truth and Reco vertex Vs

Reconstructed Track length (Primary Tracks)



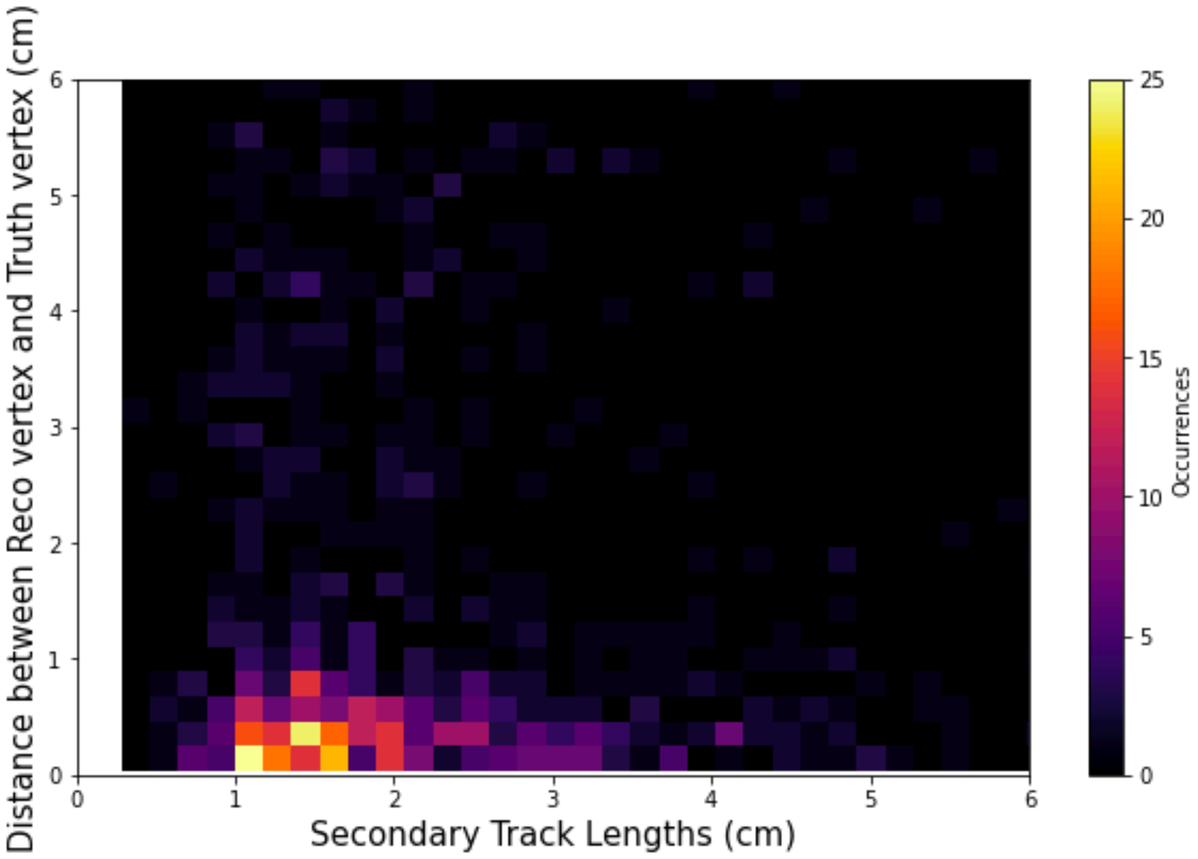
CC Interaction



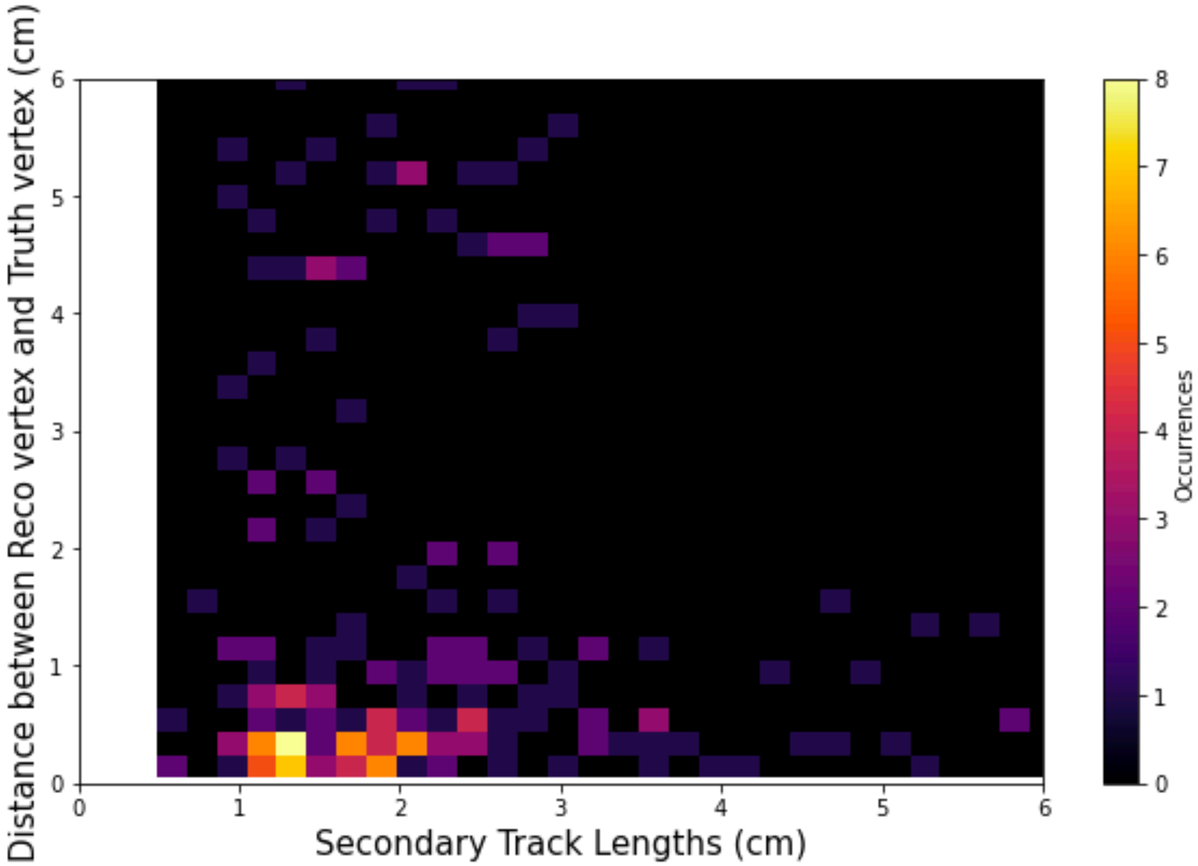
ES Interaction

Distance between Truth and Reco vertex Vs

Reconstructed Track length (Secondary Tracks)



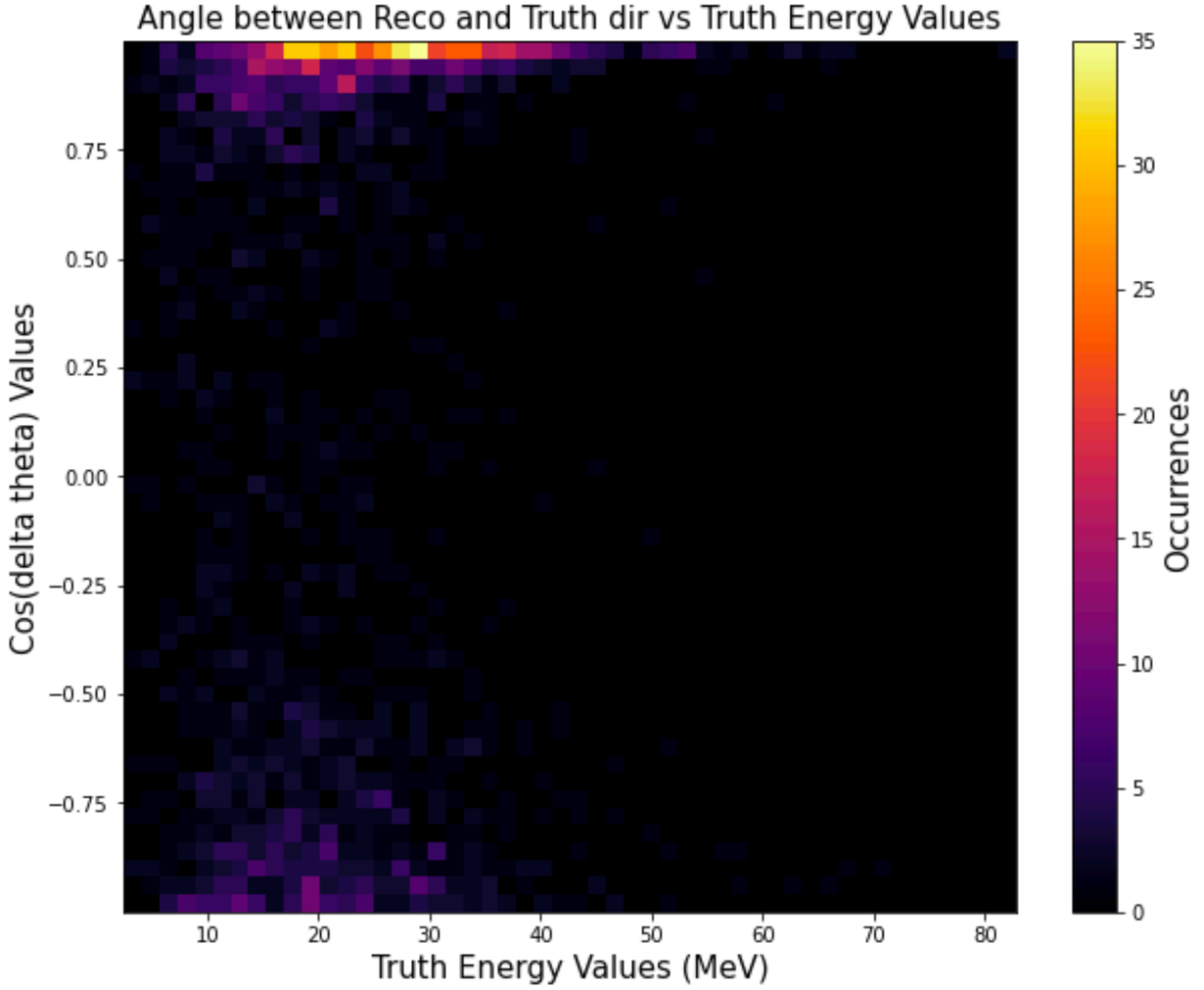
CC Interaction



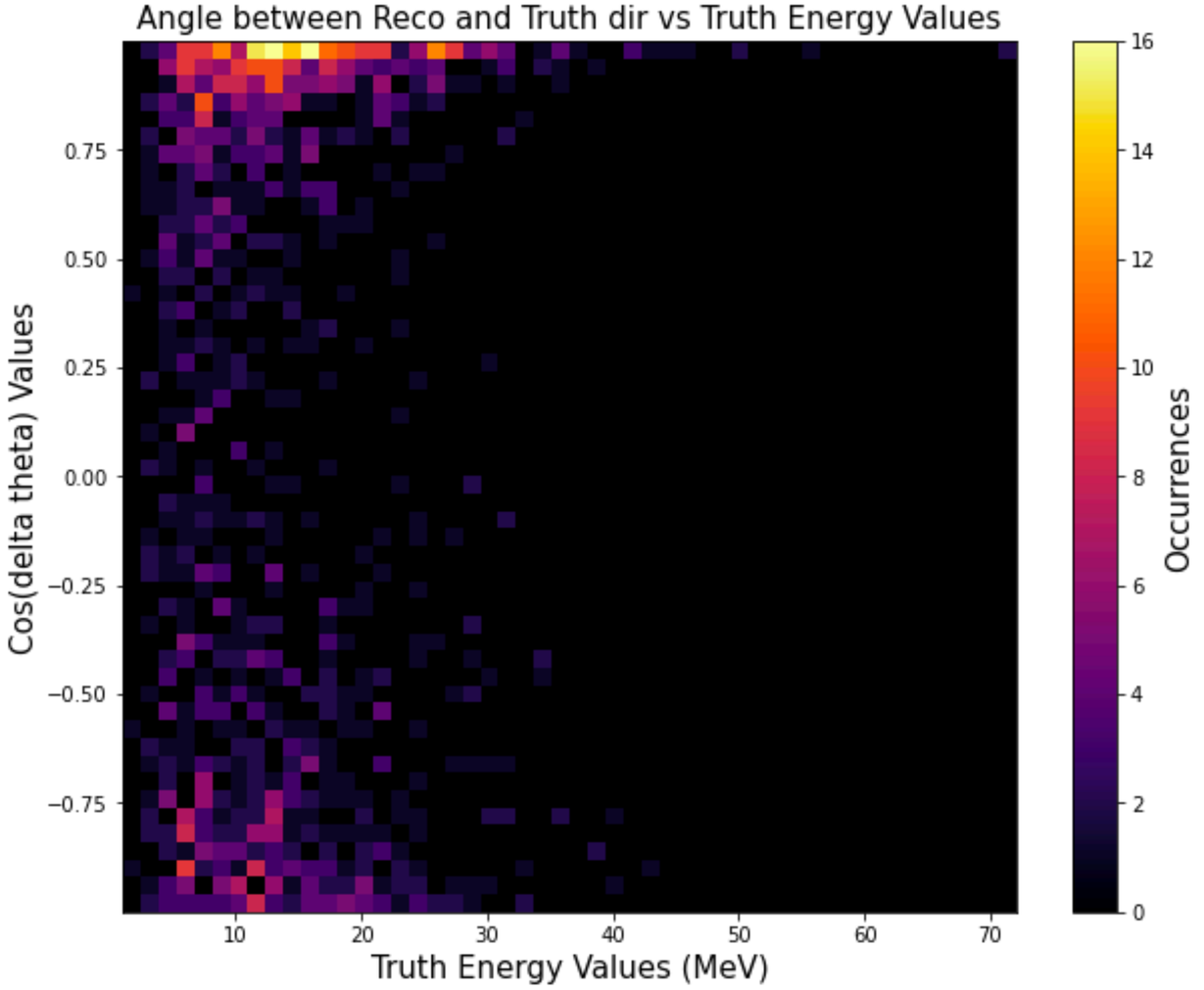
ES Interaction

Cosine of the Angle between truth dir vector and reco dir vector

Distribution with Energy dependence



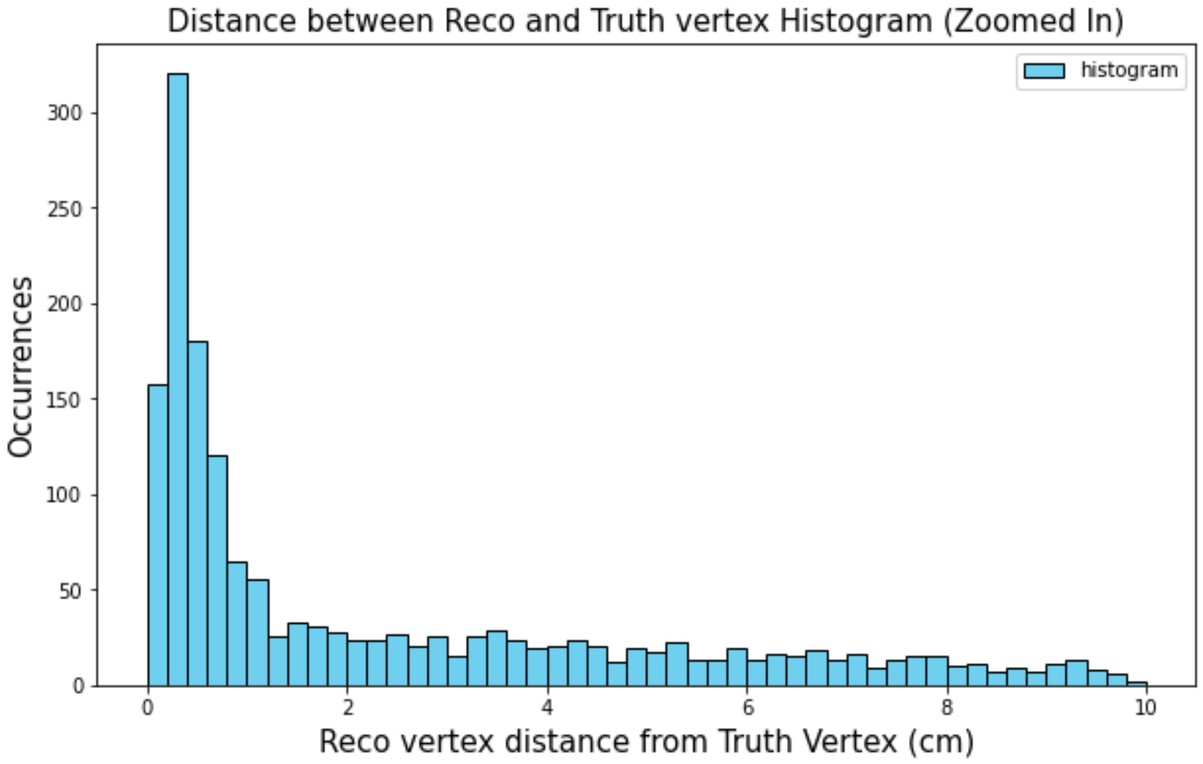
CC Interaction



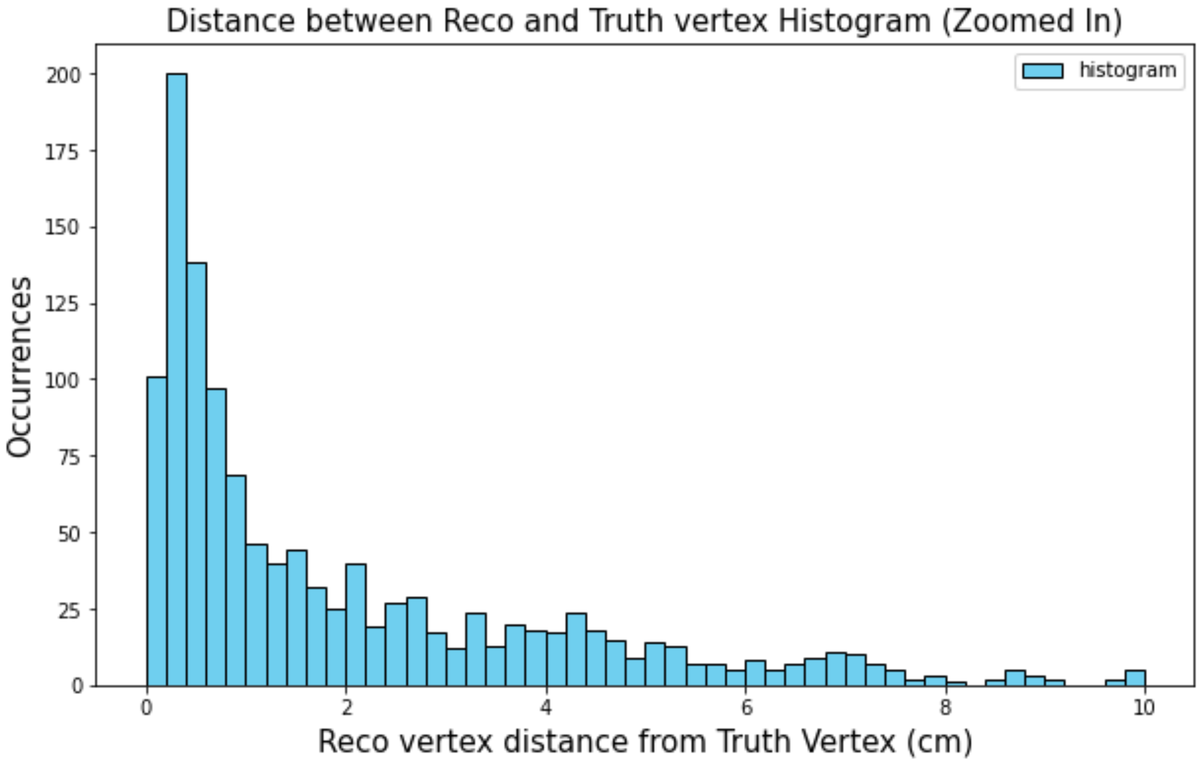
ES Interaction

Distance between truth vertex and reco vertex

Distribution (Zoomed in)



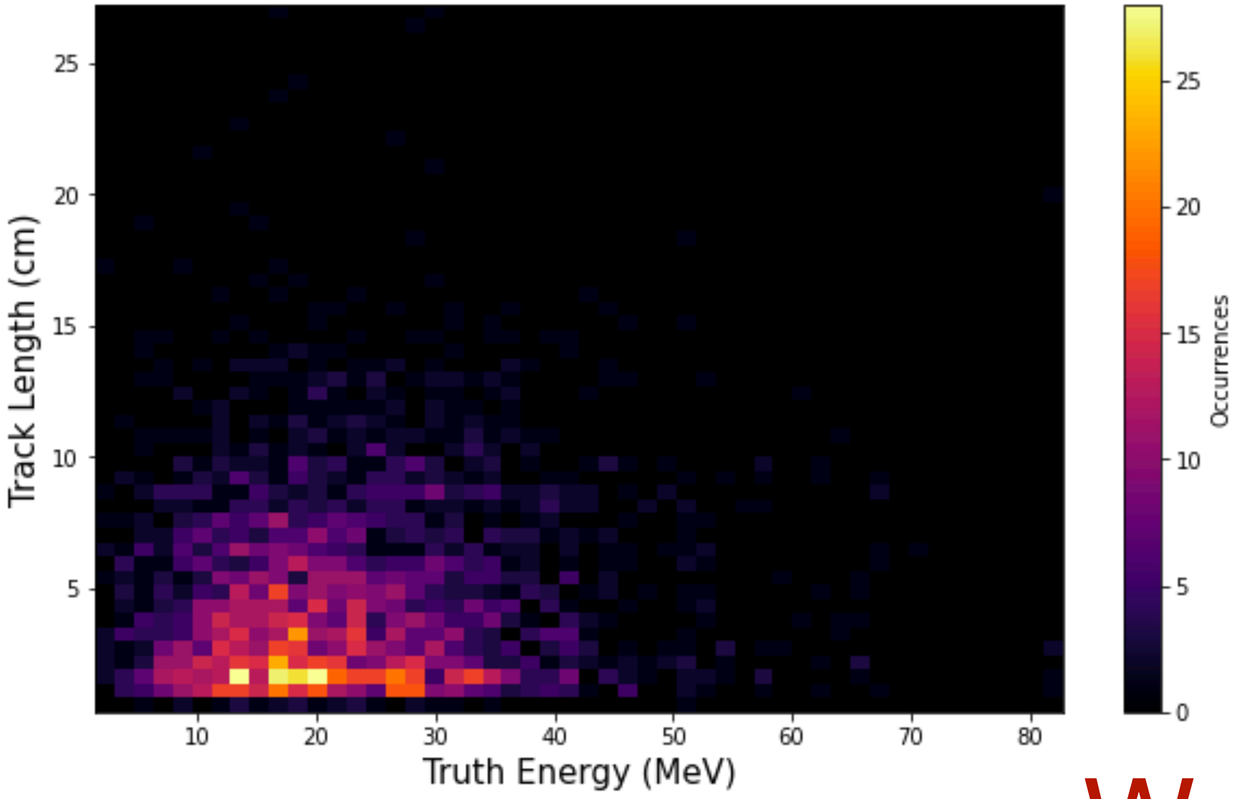
CC Interaction



ES Interaction

Reconstructed Track length (All tracks)

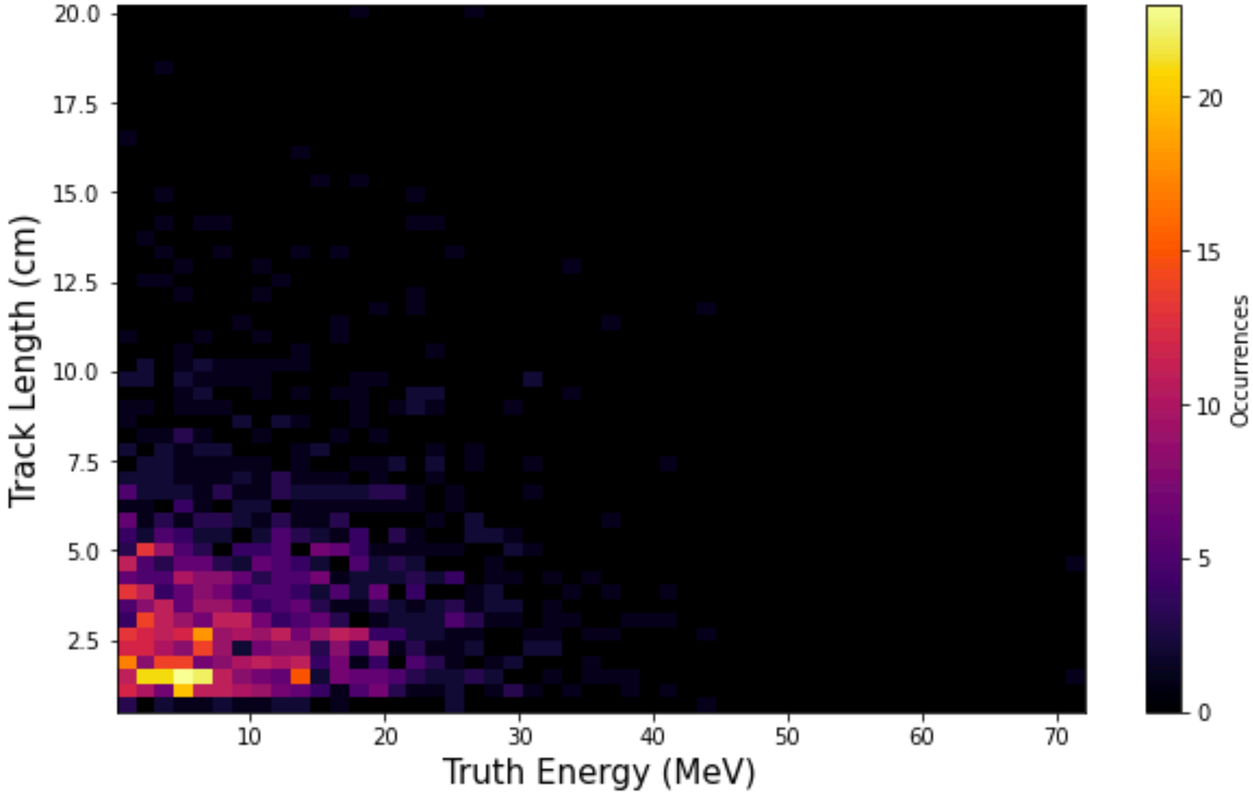
Distribution with Energy dependence



CC Interaction

Wrong

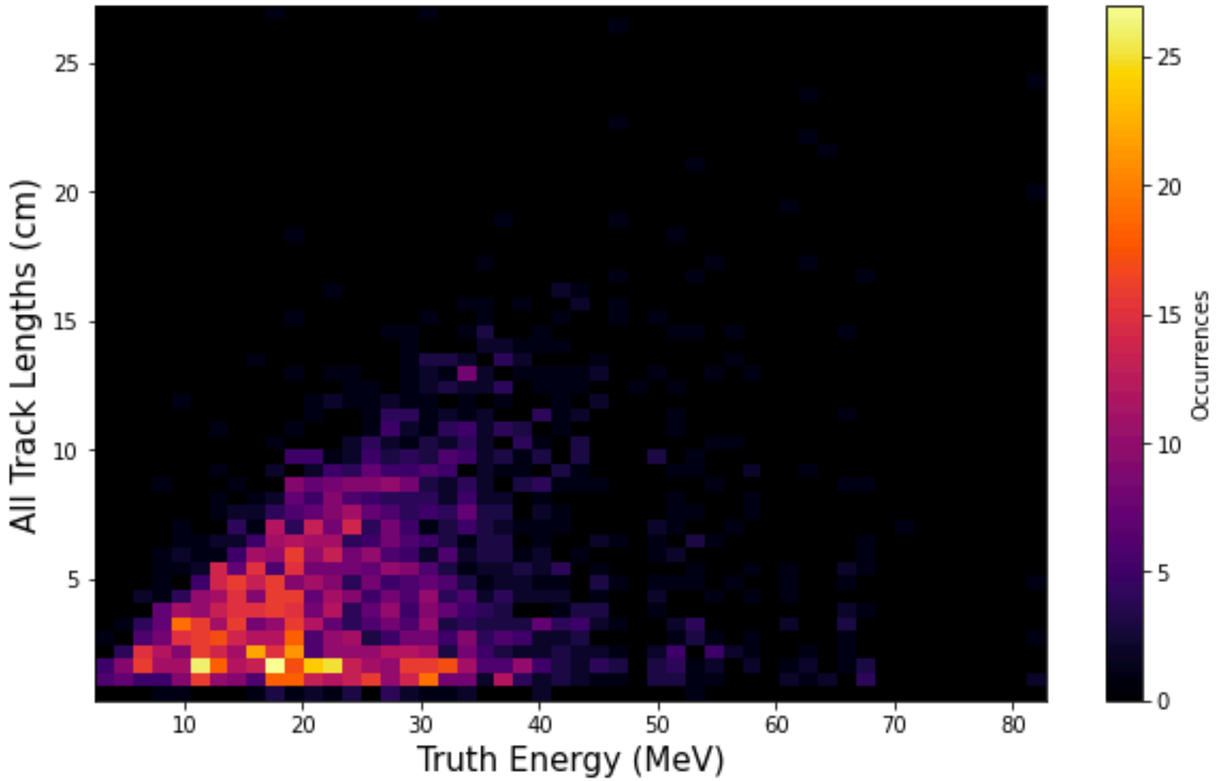
(what I showed earlier)

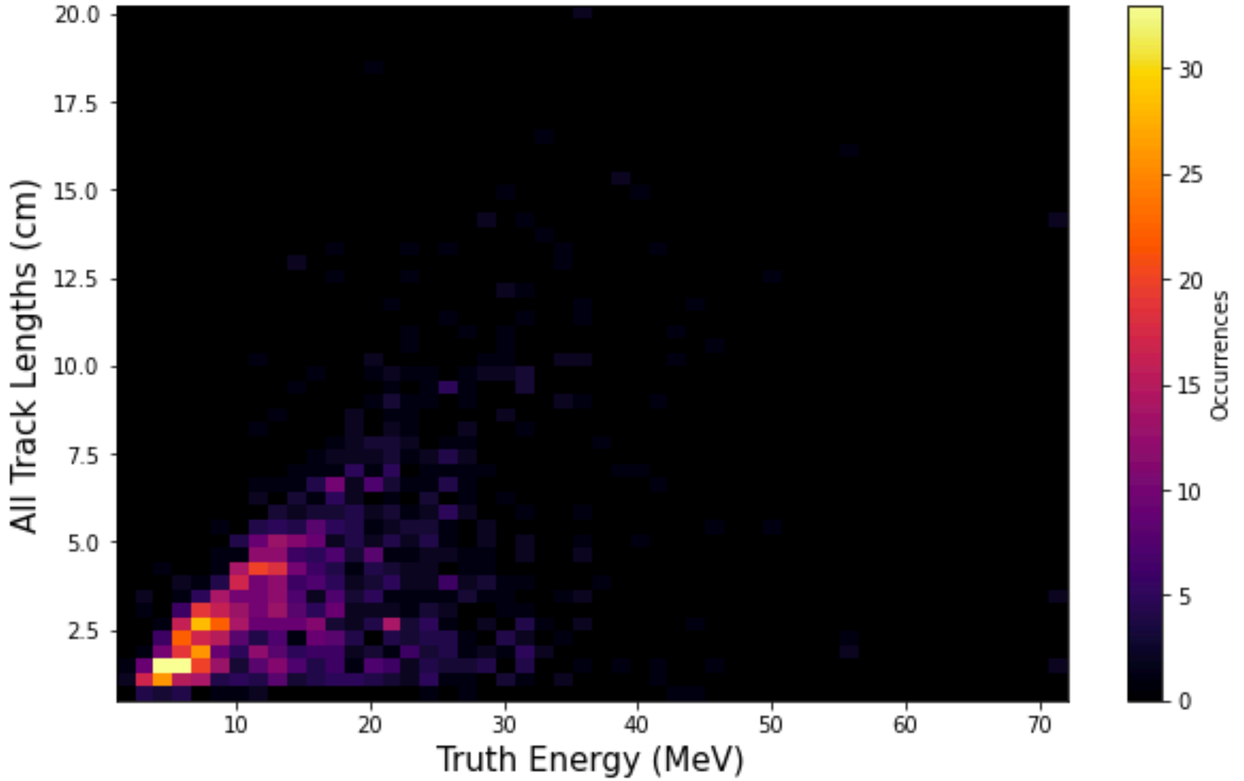


ES Interaction

Reconstructed Track length (All tracks)

Distribution with Energy dependence





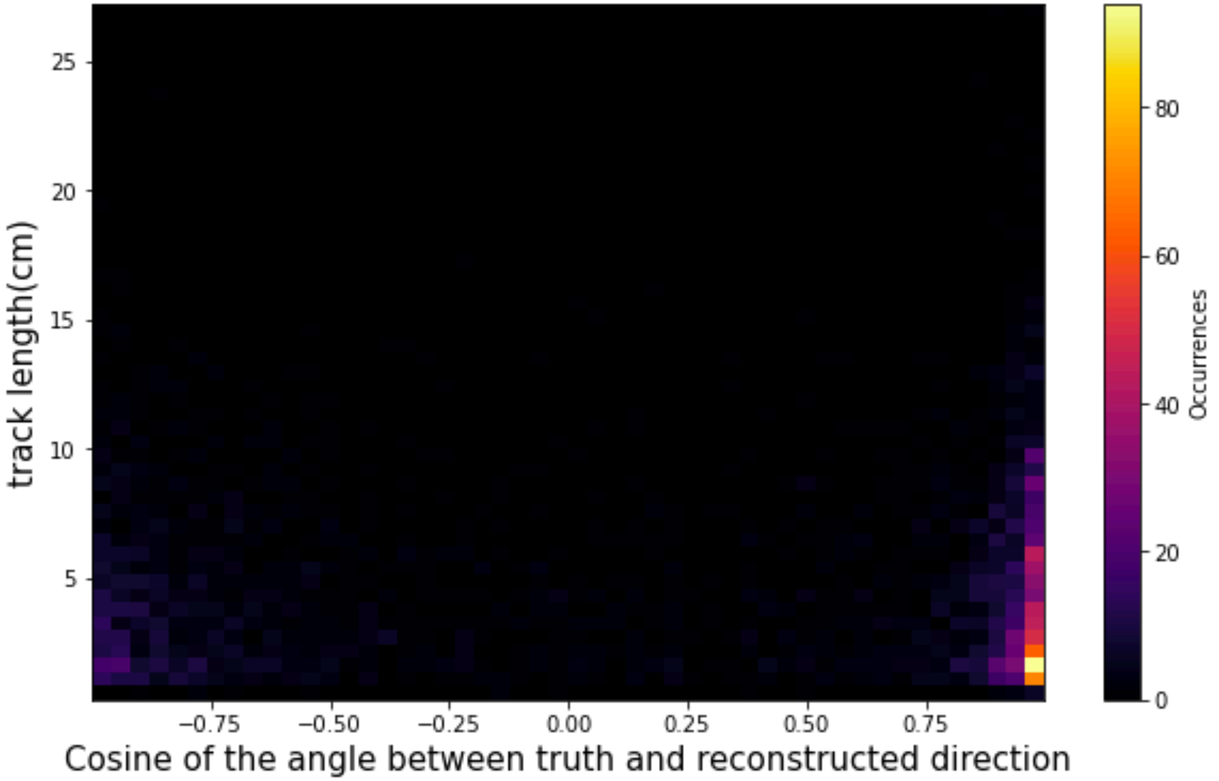
CC Interaction

Correct

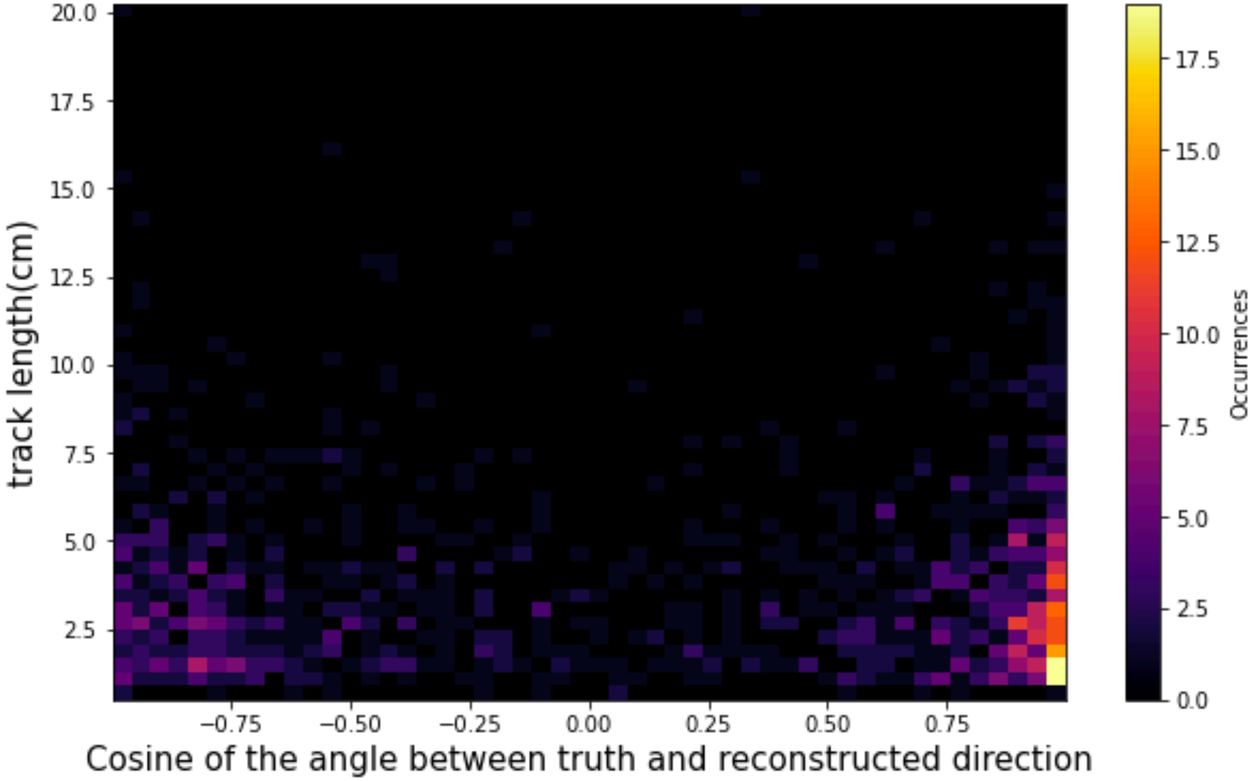
ES Interaction

Reconstructed Track length

Distribution with difference between truth and reconstructed direction



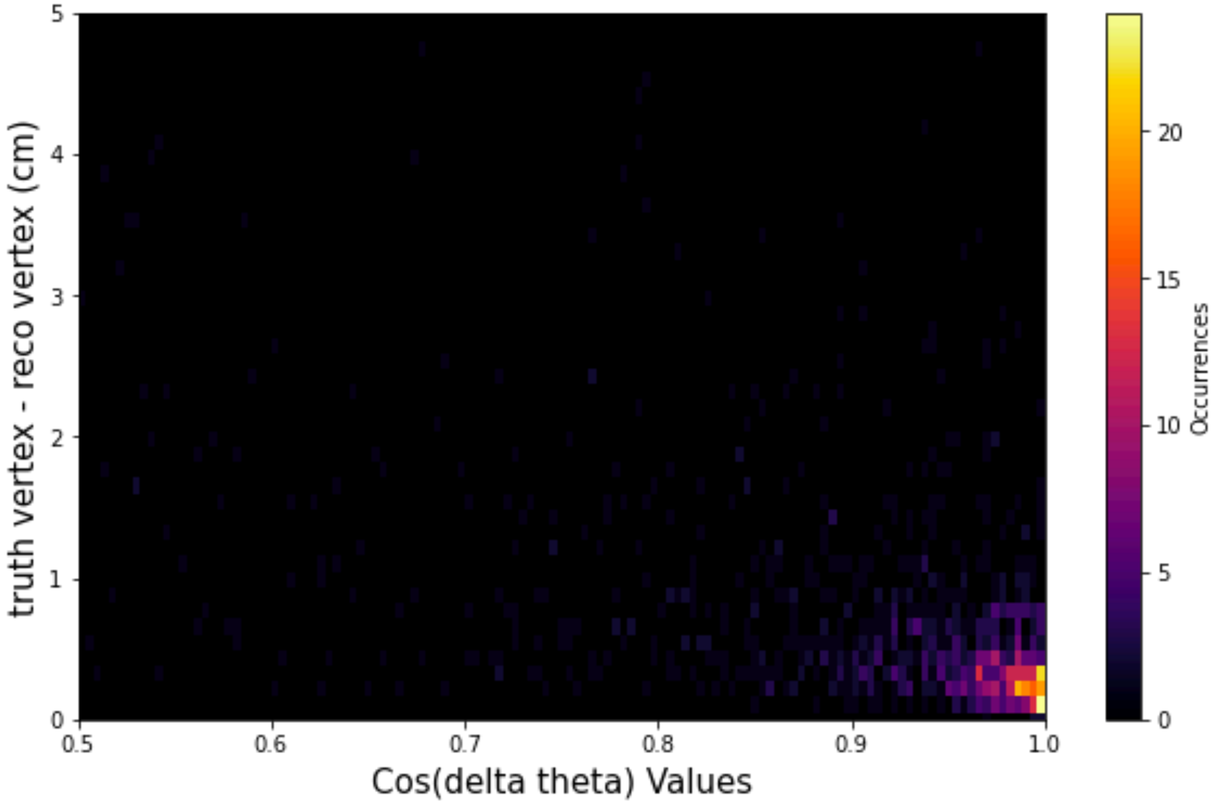
CC Interaction



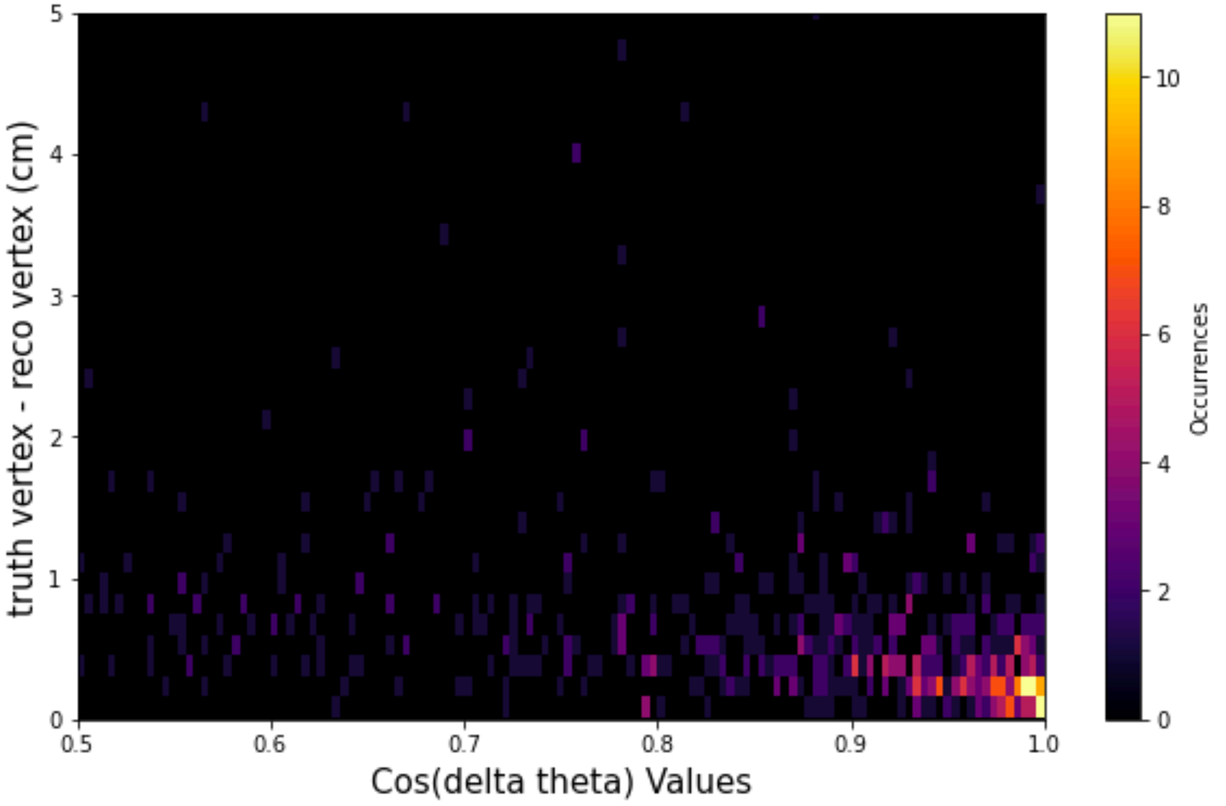
ES Interaction

Distance between truth and reco vertex vs cosine of the angle between truth and reco direction

Distribution (Zoomed in)



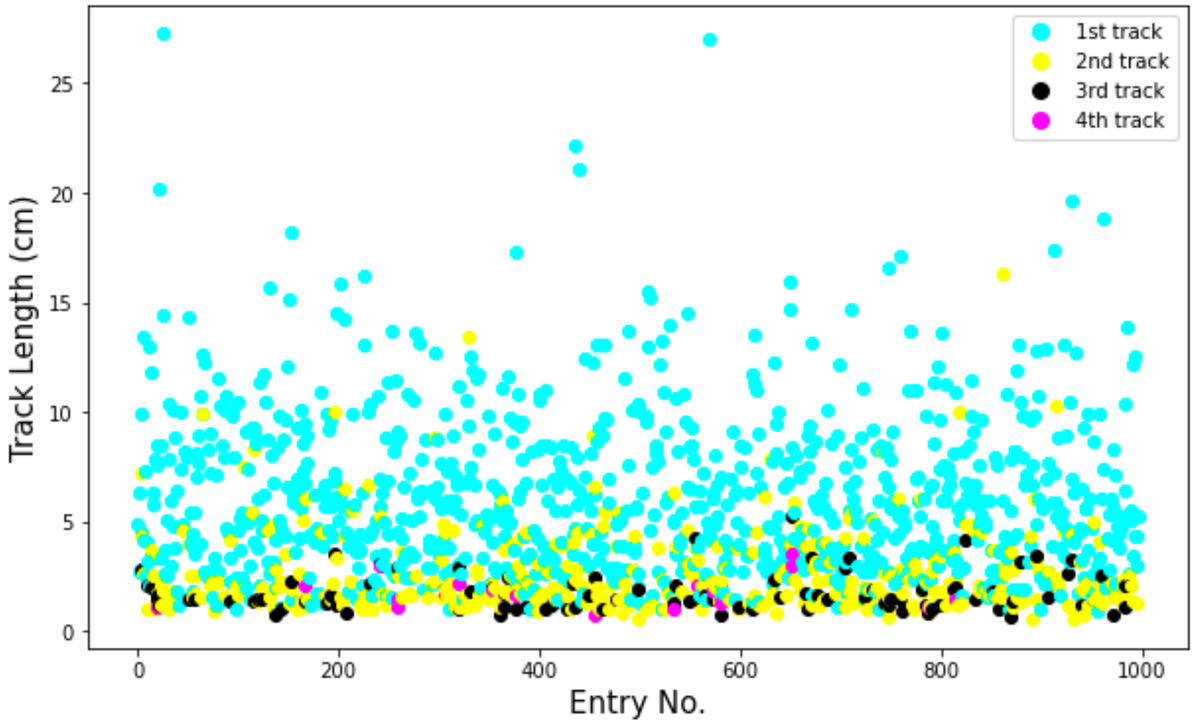
CC Interaction



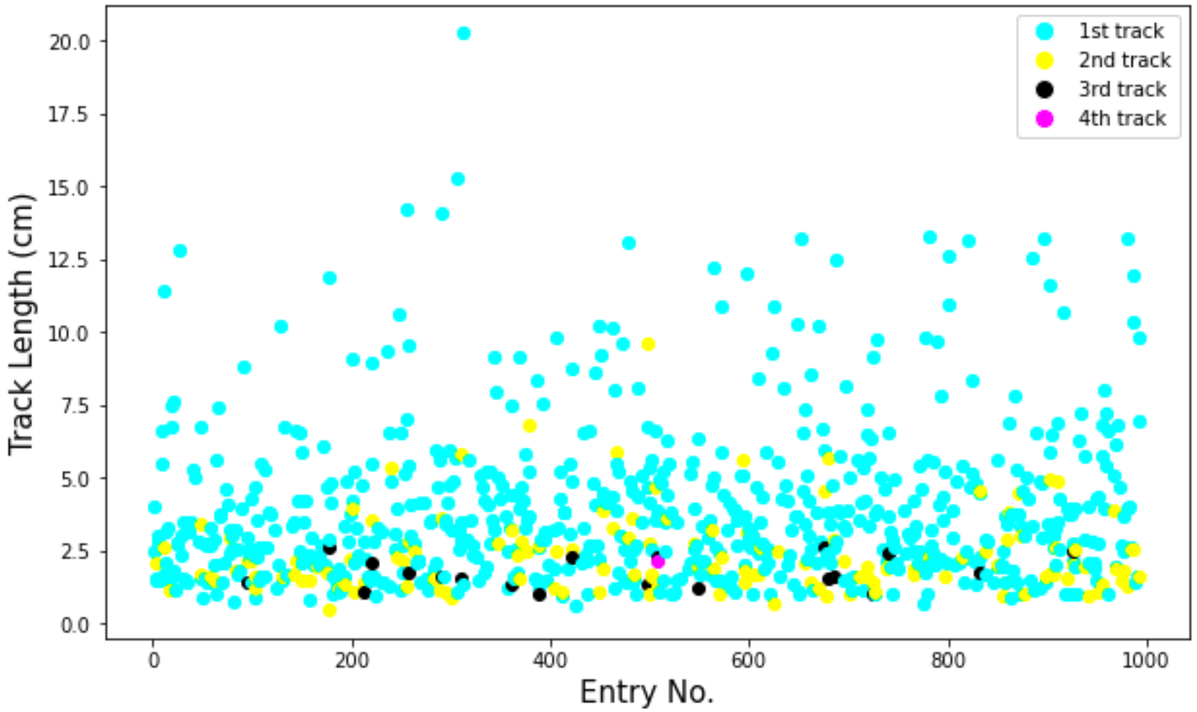
ES Interaction

Reconstructed Track length

Distribution

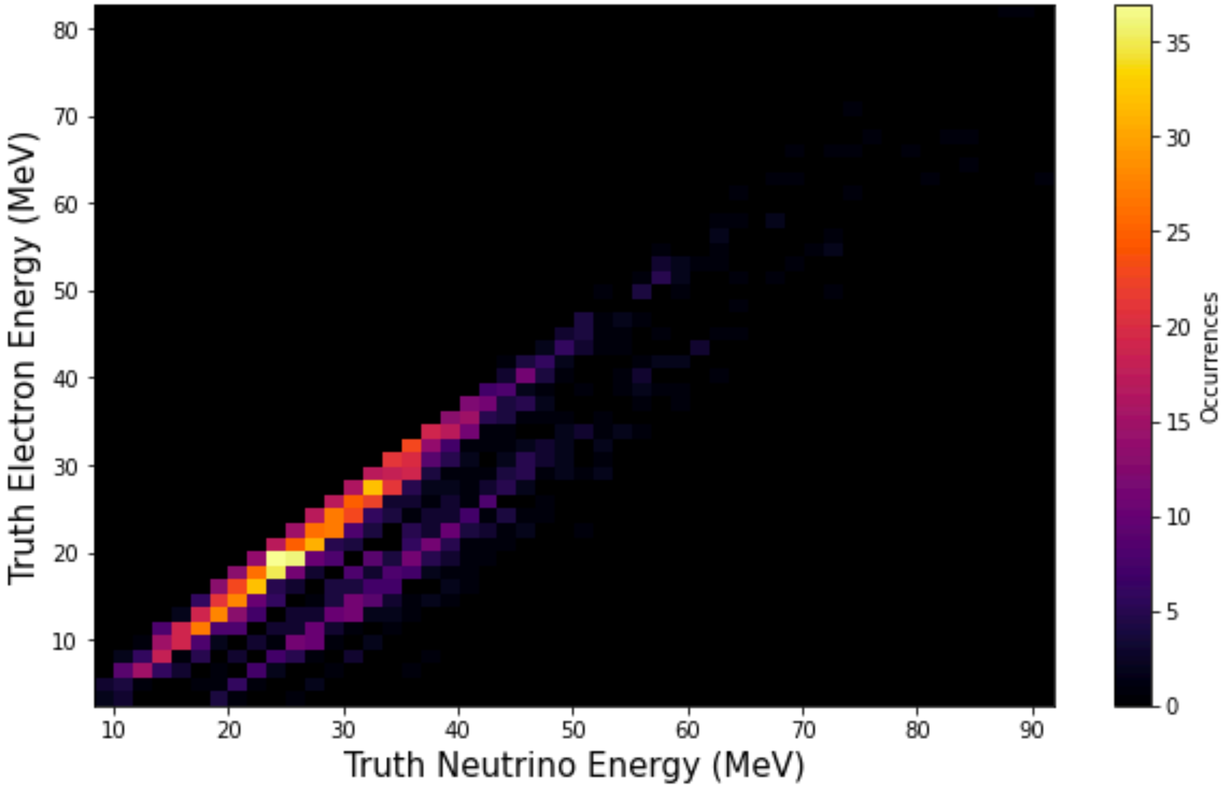


CC Interaction

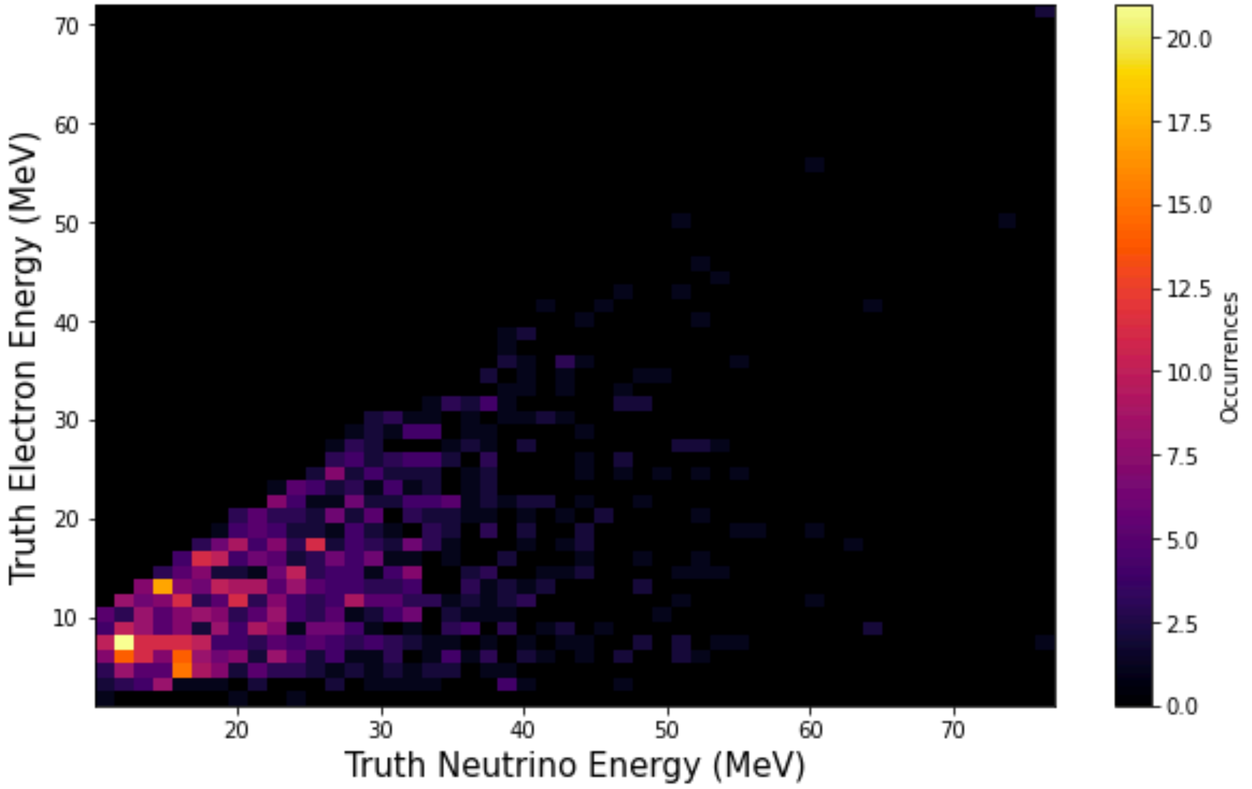


ES Interaction

Truth Neutrino Energy Vs Truth Electron Energy



CC Interaction



ES Interaction