Mx2 in SPINE

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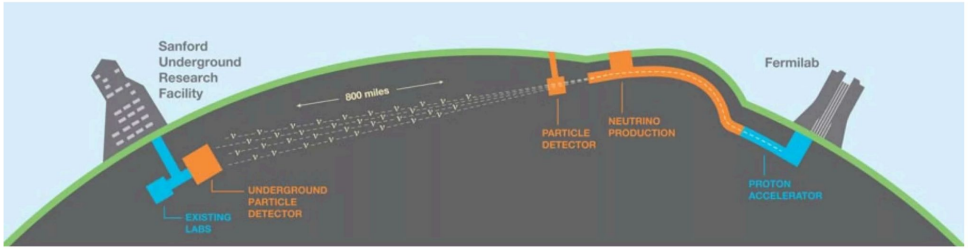
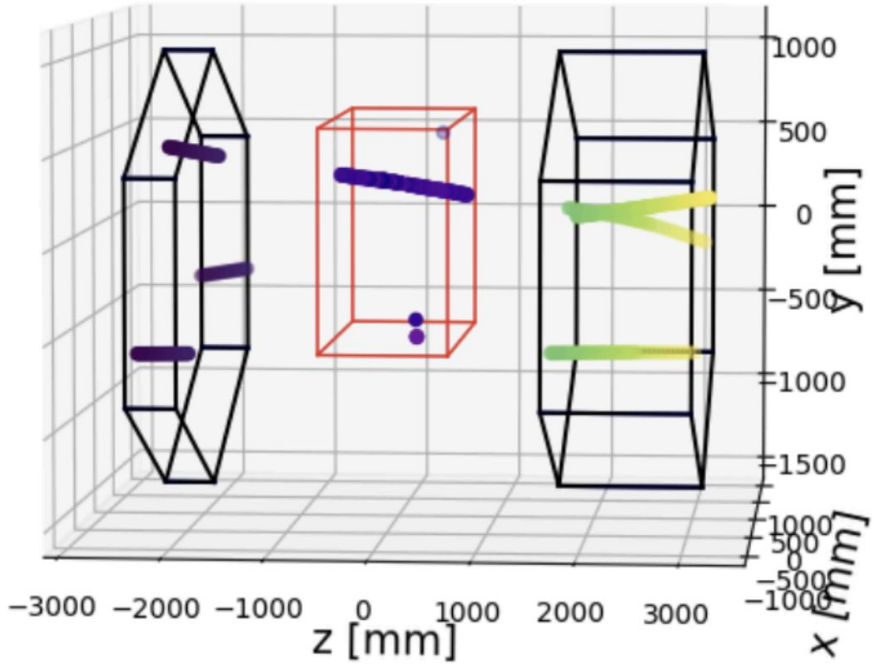
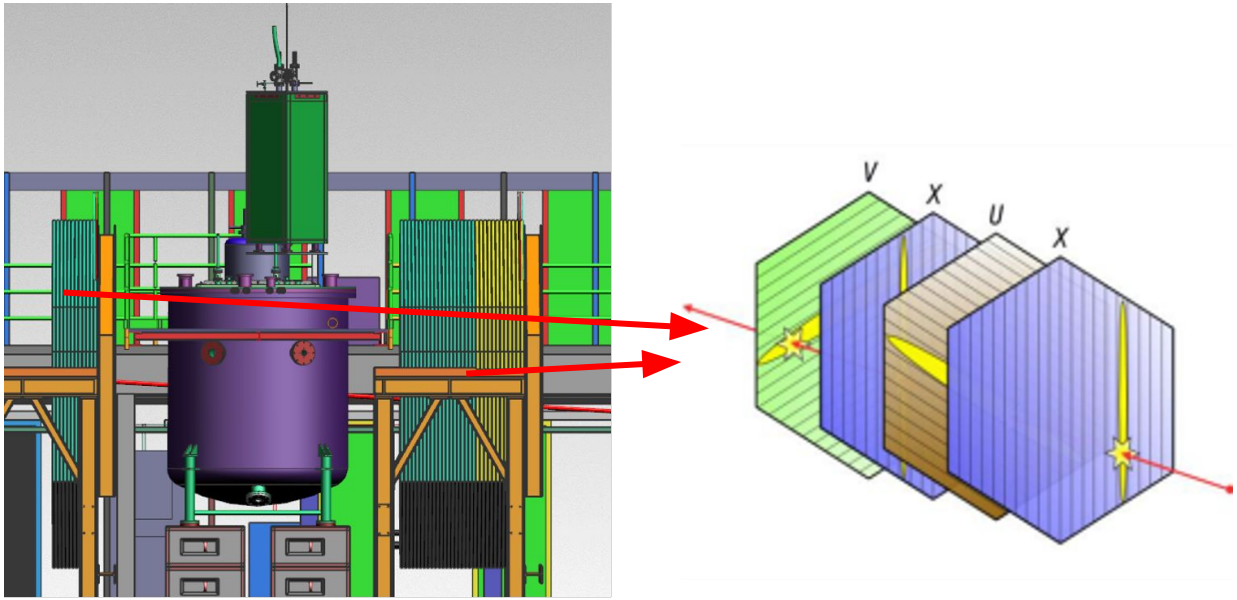




- DUNE is a planned neutrino accelerator experiment
- A machine learning framework has been developed to analyze data from DUNE's detectors
- Currently DUNE only has a small prototype detector
- It needs to be supplemented with old MINERvA detector pieces to help it capture long particle tracks (especially muons)
- New machine learning is needed to analyze data from both the prototype and MINERvA detector pieces

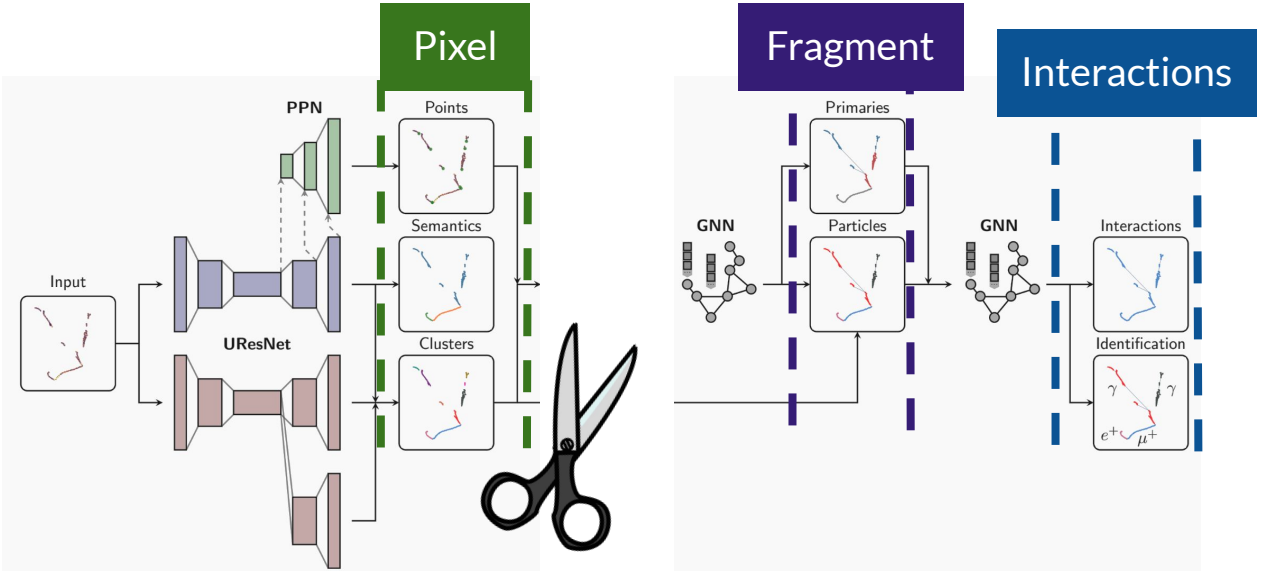
Challenges for putting Mx2 in SPINE

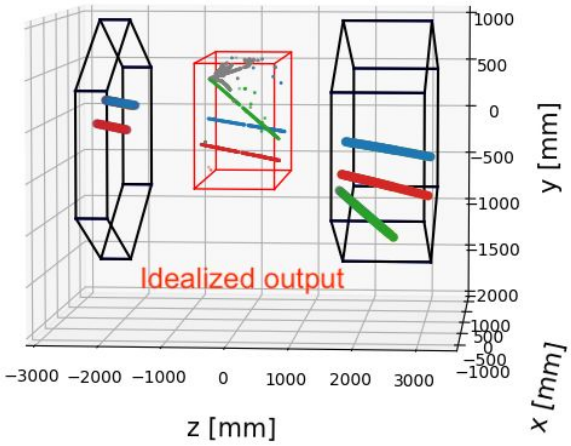
- Goal: Put Mx2 into spine
  - Challenging because Mx2 are sets of scintillator planes, not LArTPCs
  - MINERvA showers are 2d information only right now
  - Decided to focus on tracks only for proof of concept model



Mx2 Into GrapPA

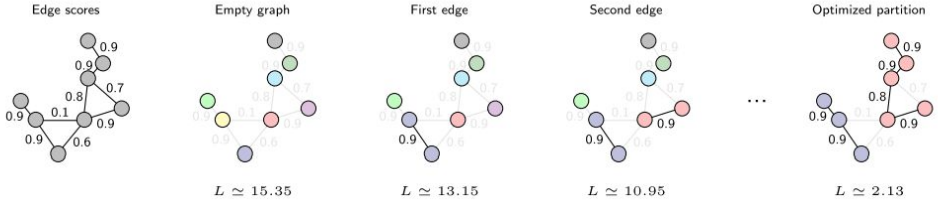
- MINERvA stores unique identification for reconstructed track PER entry
  - Upstream and downstream are separately reconstructed
  - Would like to call each reco-ed track as one “cluster”





Mx2 Into GrapPA

- Insert just MINERvA Up+Downstream into GrapPA



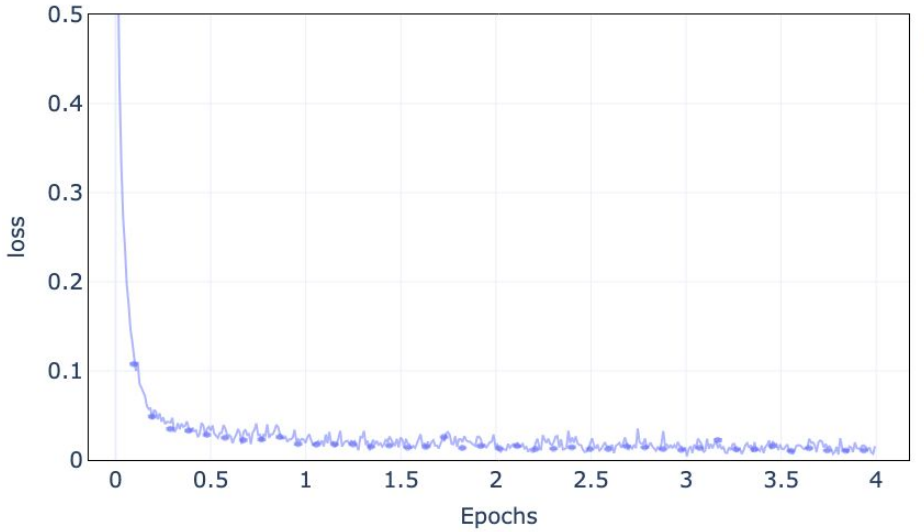
- Geometric features are calculated by grappa
  - Need to format our file such that it can be used to calculate these features
    - Input is barebones, essentially just position information for each voxel

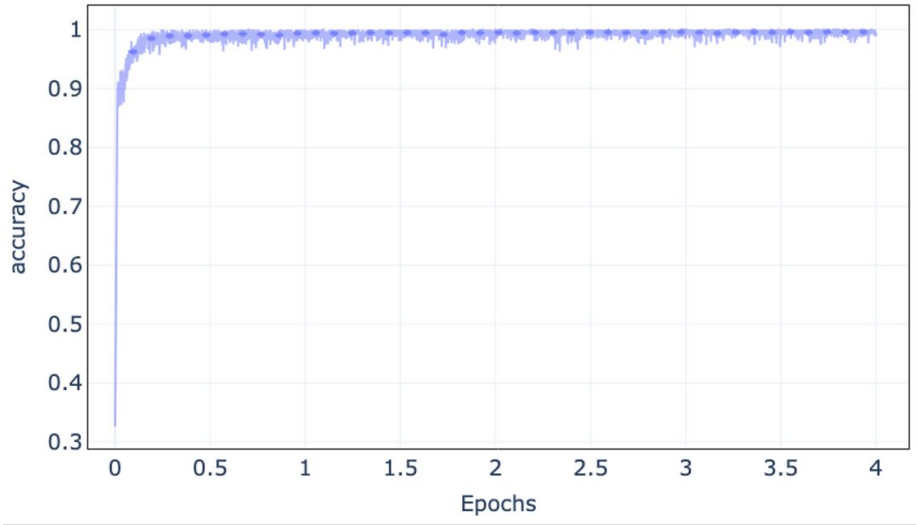
Geometric features are a list of summary statistics of the distribution of fragment voxels in Euclidean space. It includes the following 22 features:

(i) normalized covariance matrix (9 features);
(ii) normalized principal axis (3 features);
(iii) centroid (3 features);
(iv) number of voxels (1 feature);
(v) initial point (3 features);
(vi) normalized initial direction (3 features).

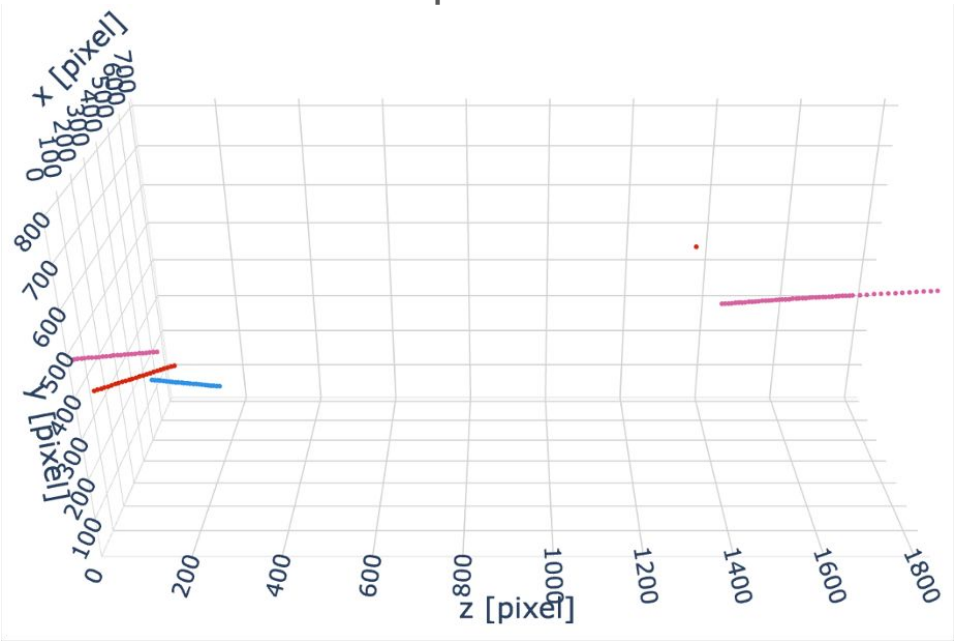
Training

- Training set of 33,361 events, test set of around 12k events
- Perhaps the speed is unsurprising considering the simplicity of the task?
- 99.5% accuracy on test set around the second epoch

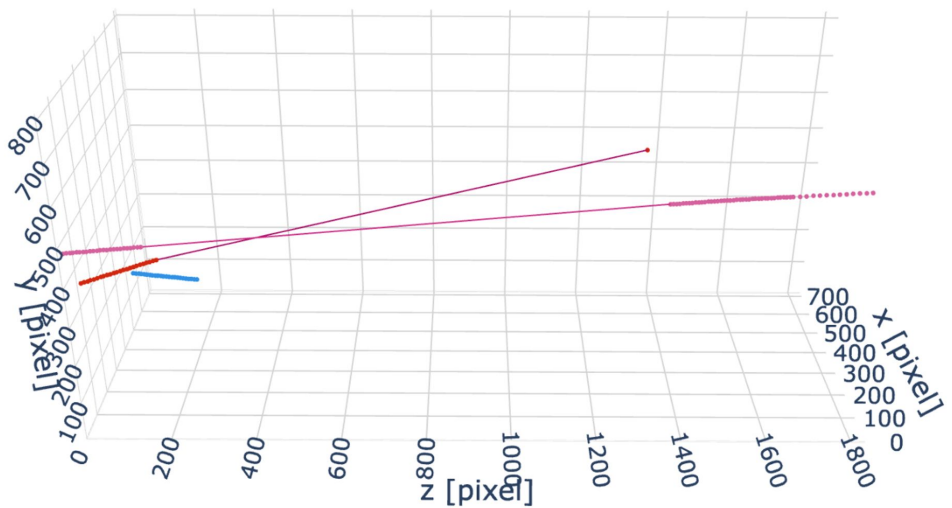




Input



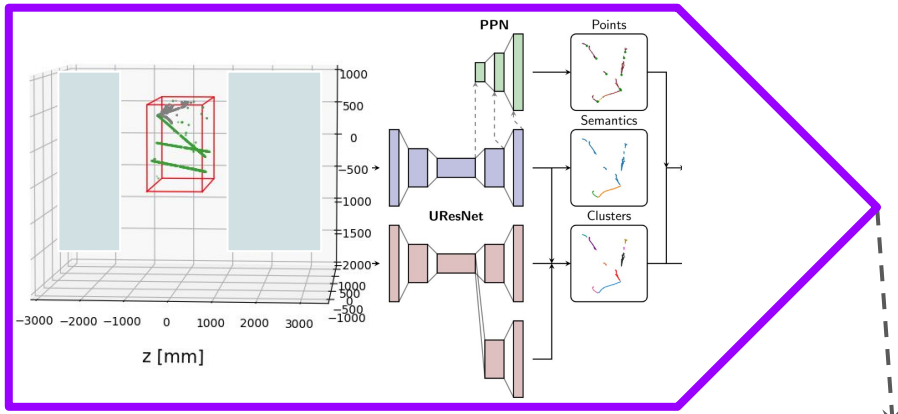
Prediction

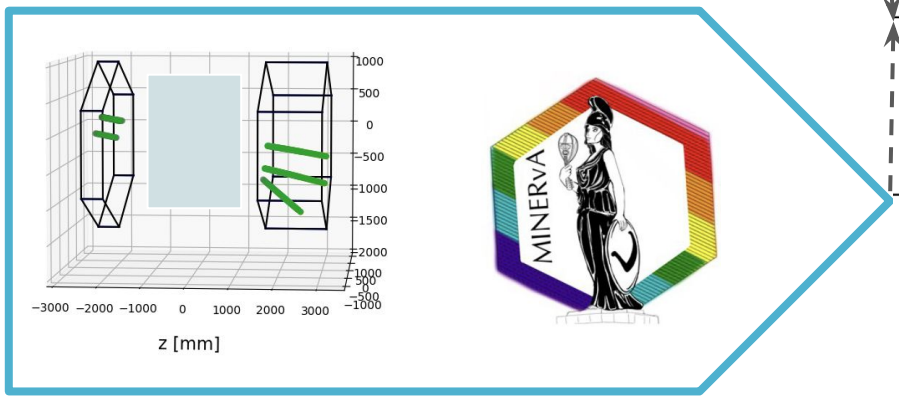


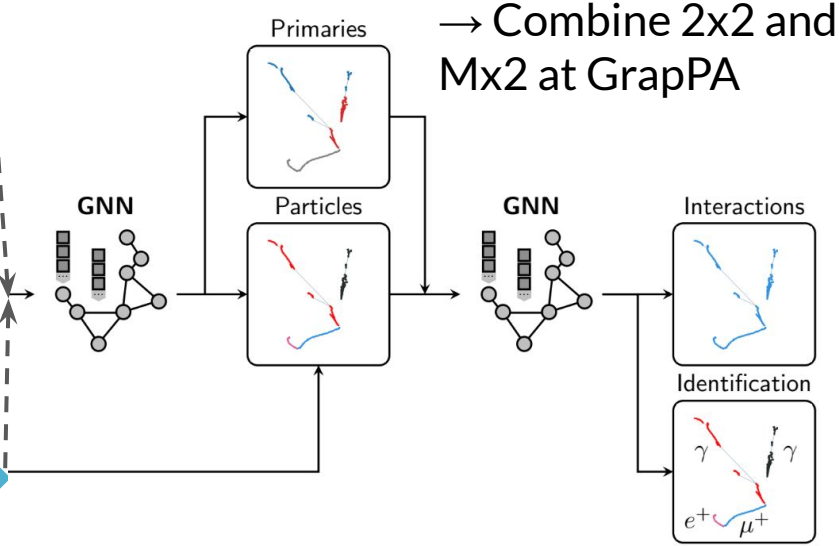
- Color of clusters shows true particle track
- Line between clusters shows model prediction
- Events look good

Next Steps

Idea for direction:
→ Keep SPINE structure the same
→ Convert 2d Shower to 3d
→ Combine 2x2 and Mx2 at GrapPA

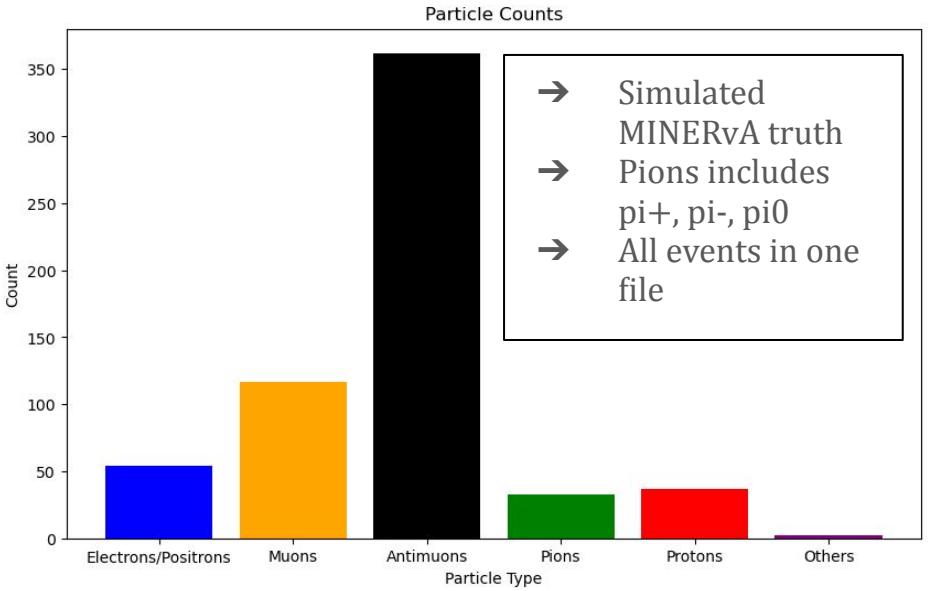


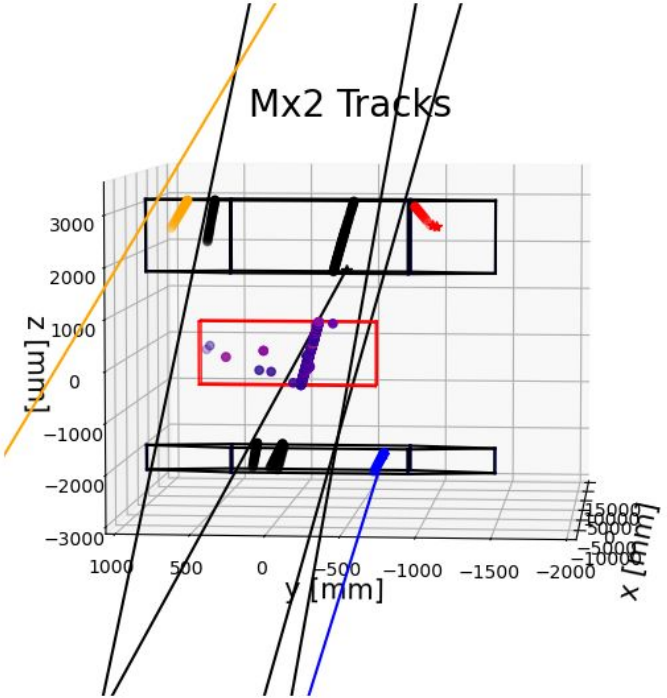




Backup

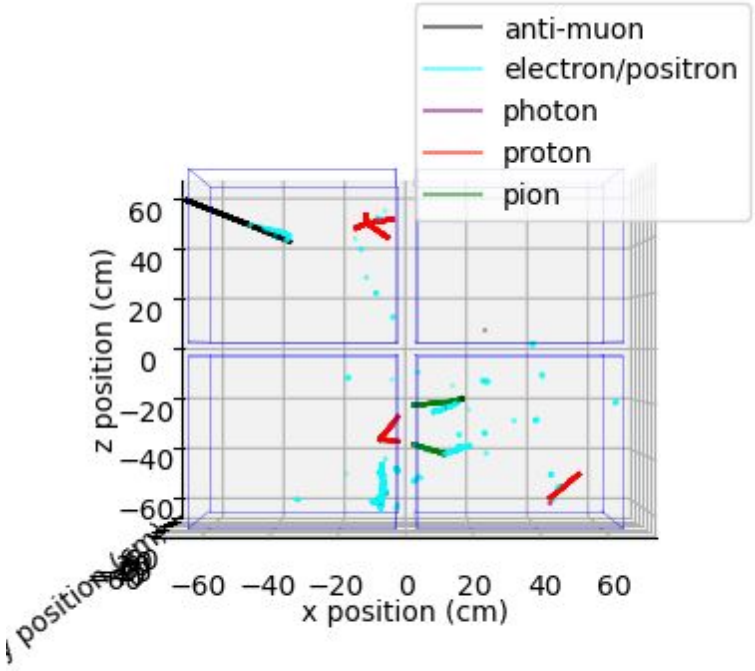
Diving into Mx2 Truth

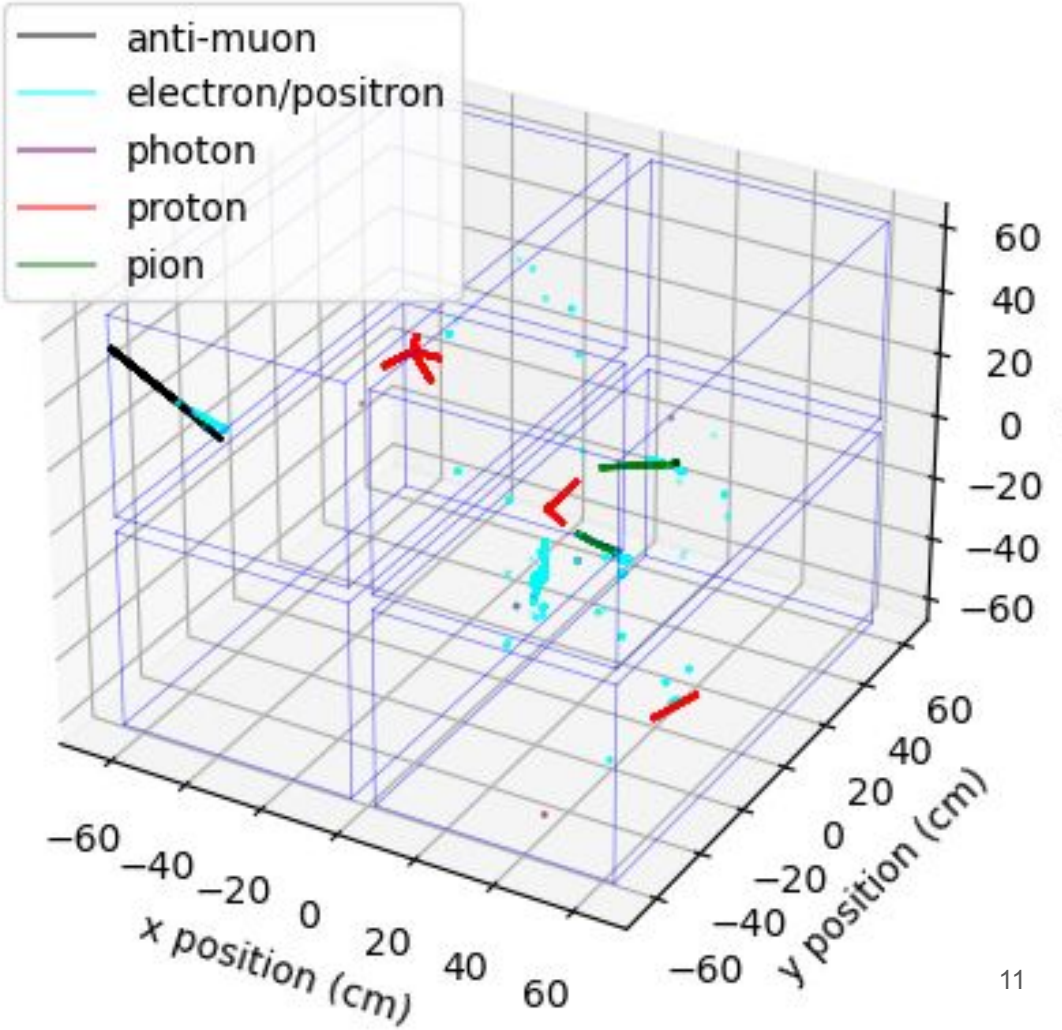




In ONE File: 192 Entries

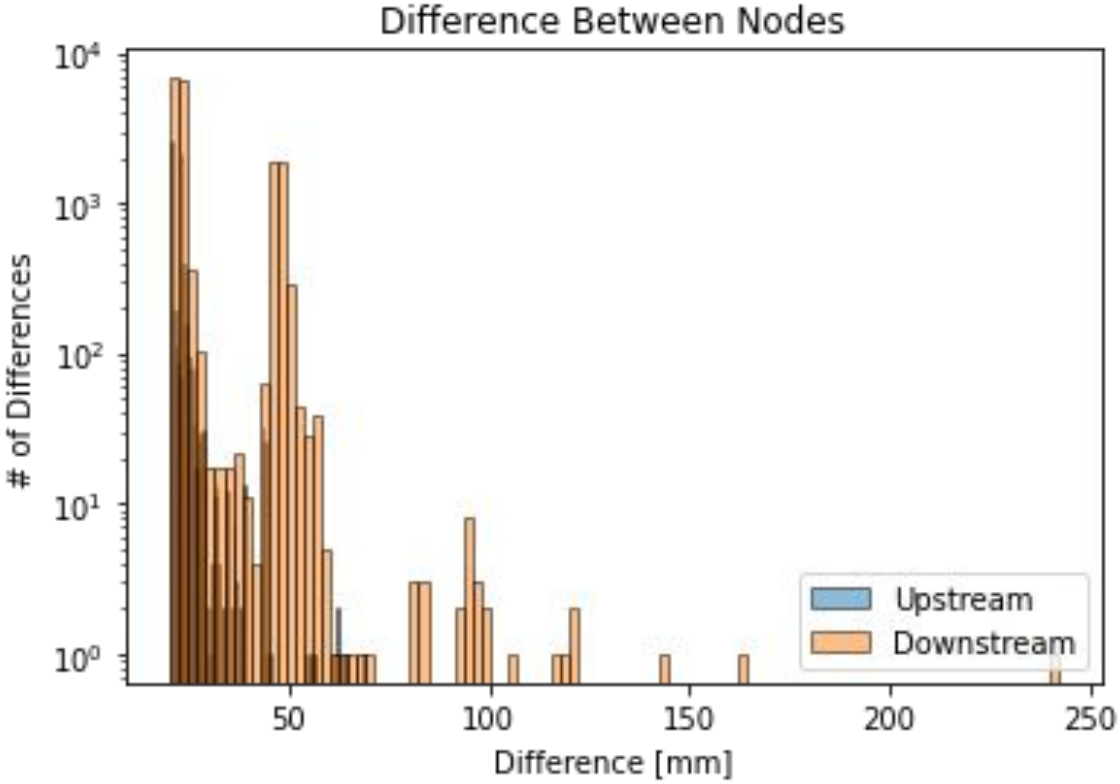
Diving into 2x2 Truth





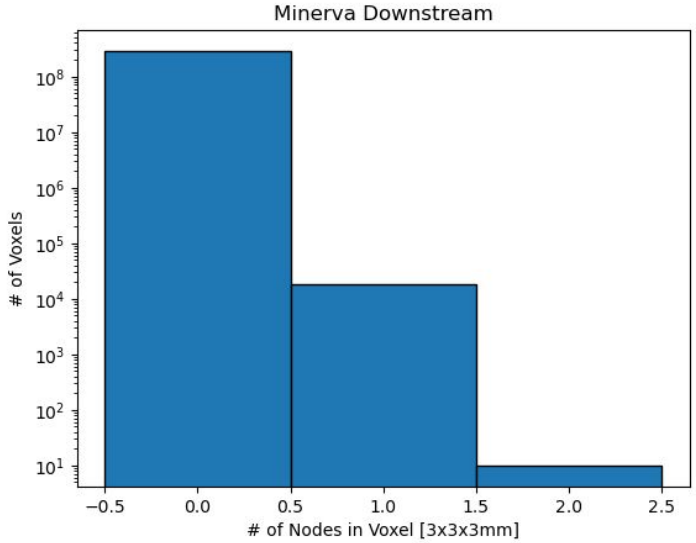
Event #34

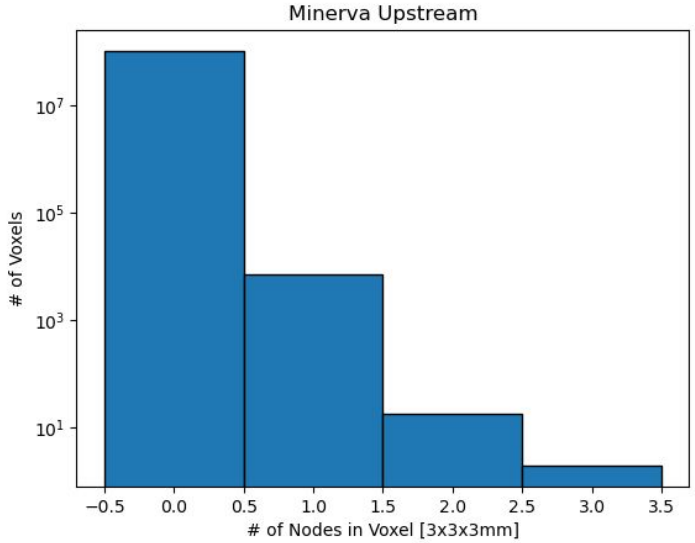
How detailed are the Mx2 Reconstructed Tracks?

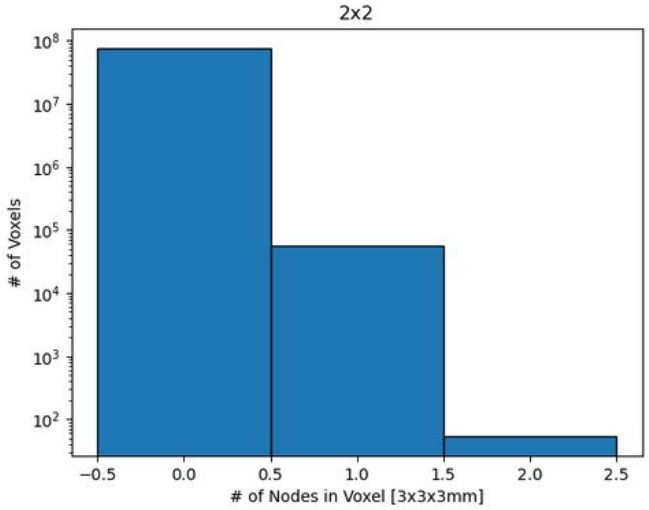


Upstream & downstream separated

2 peak structure caused by resolution of MINERvA

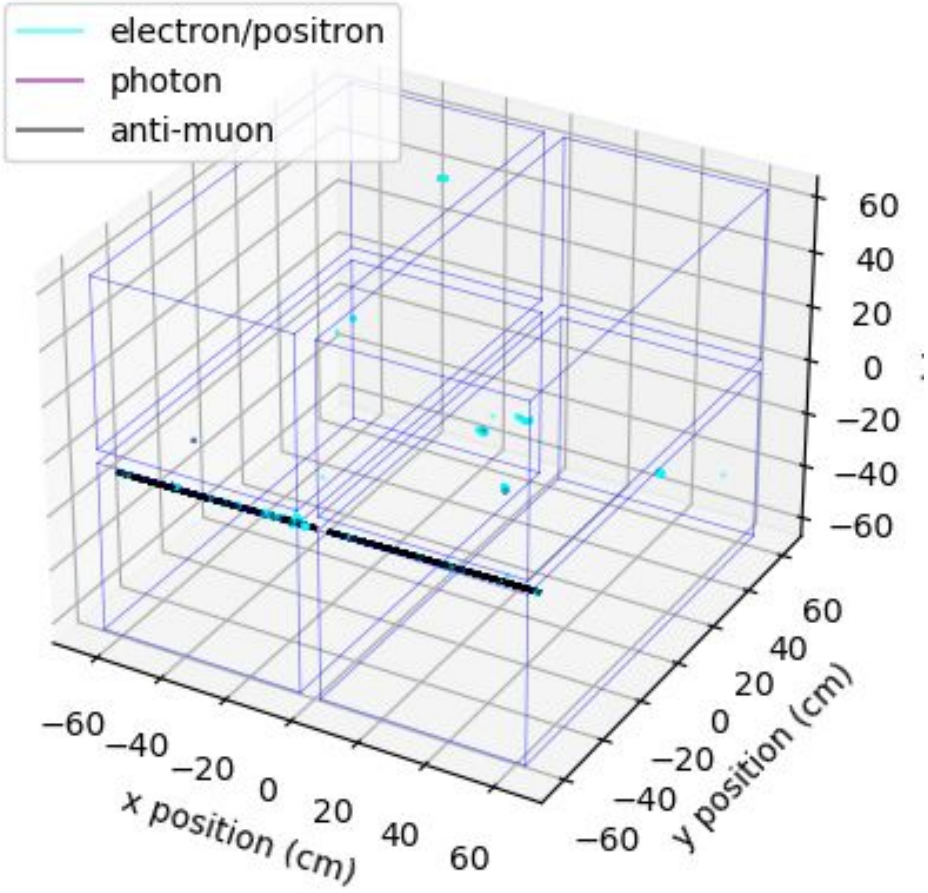




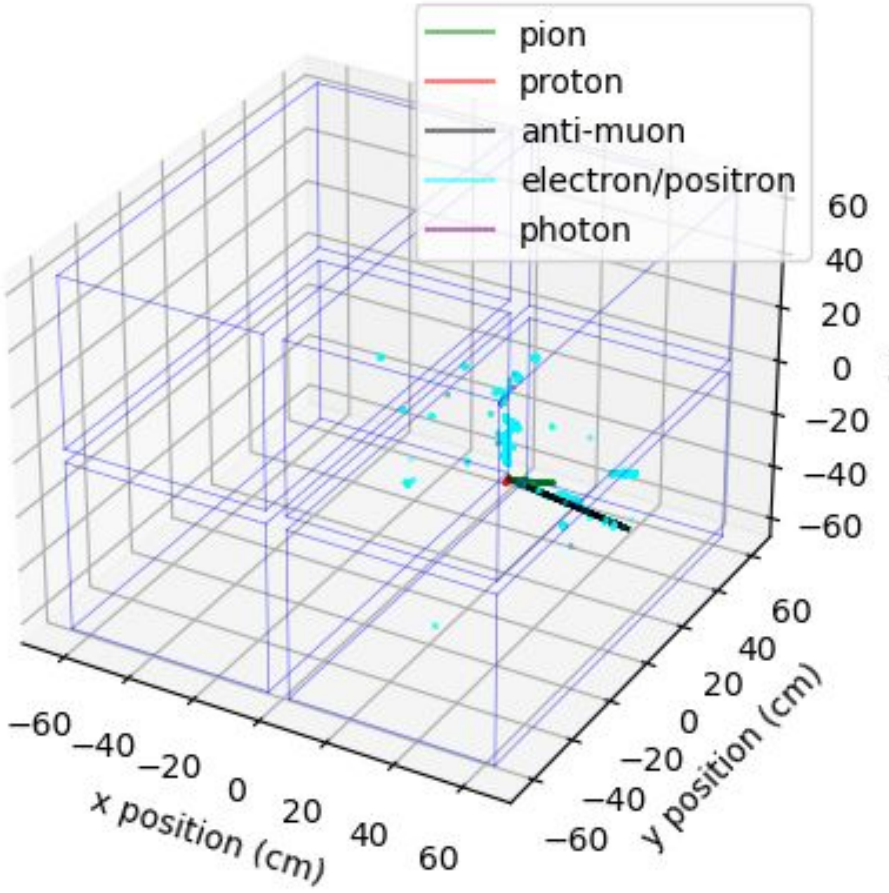


Average of 55 neutrino interactions per beam pulse for full detector

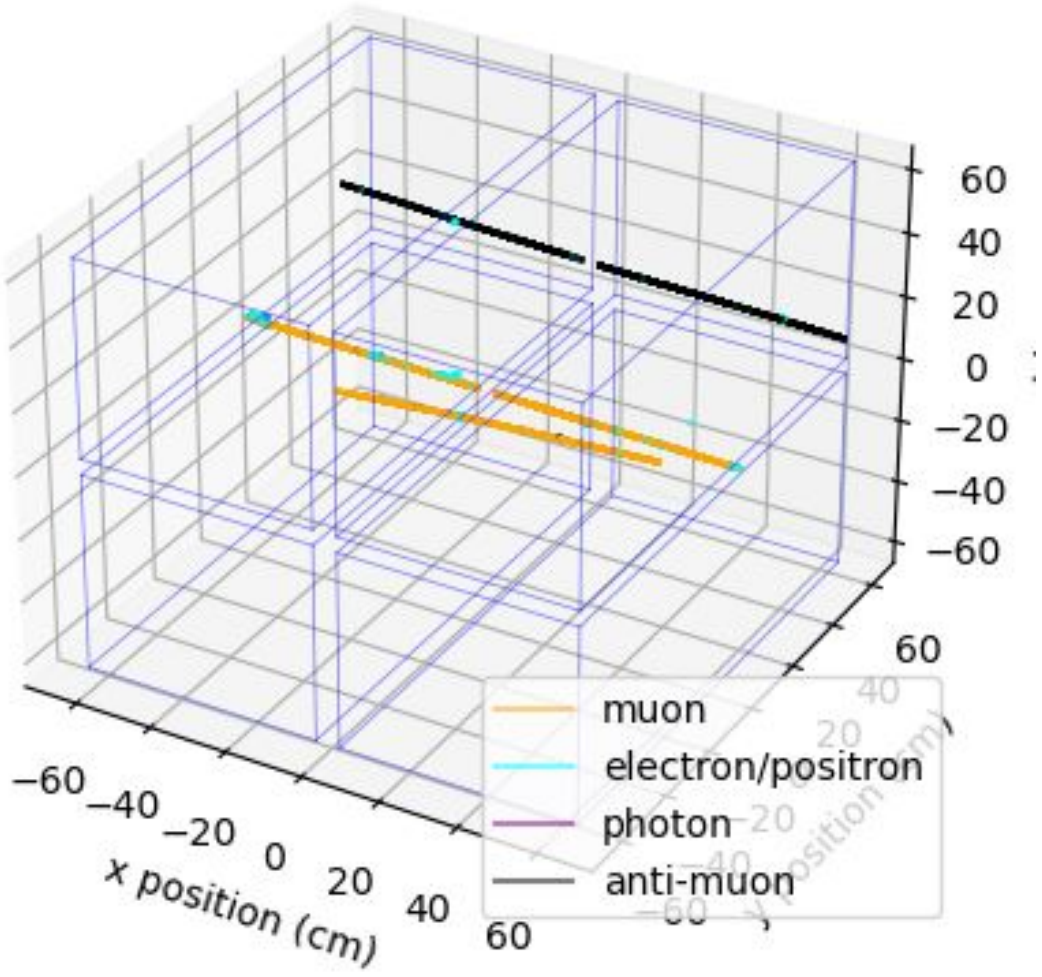
Is stacking events a good way of understanding multiple simultaneous events?

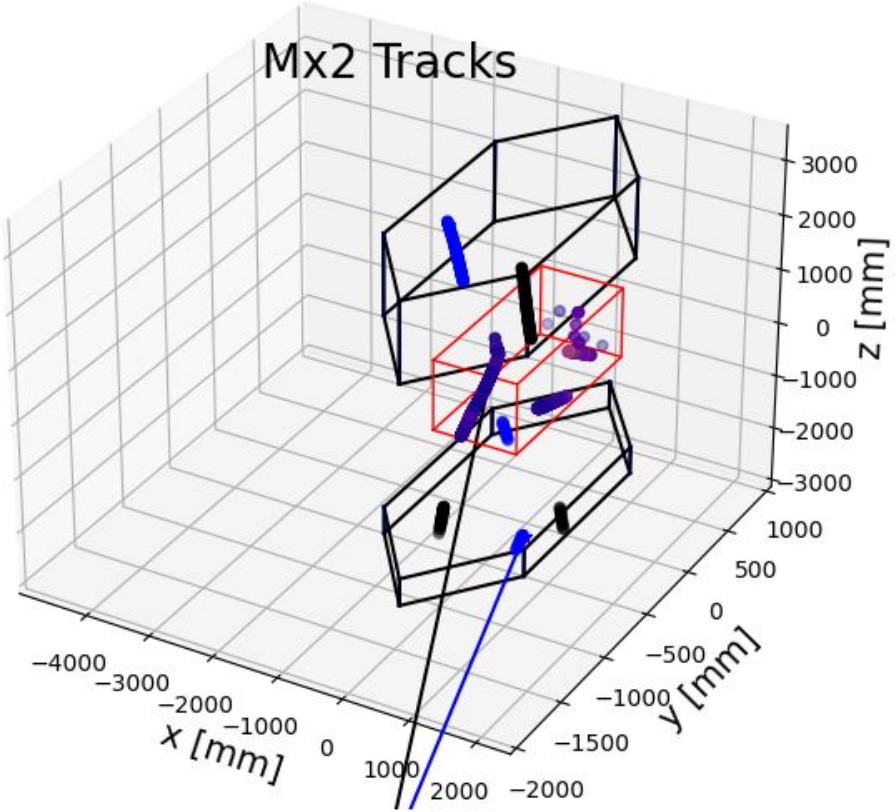

electron/positron
photon
anti-muon
x position (cm)
y position (cm)

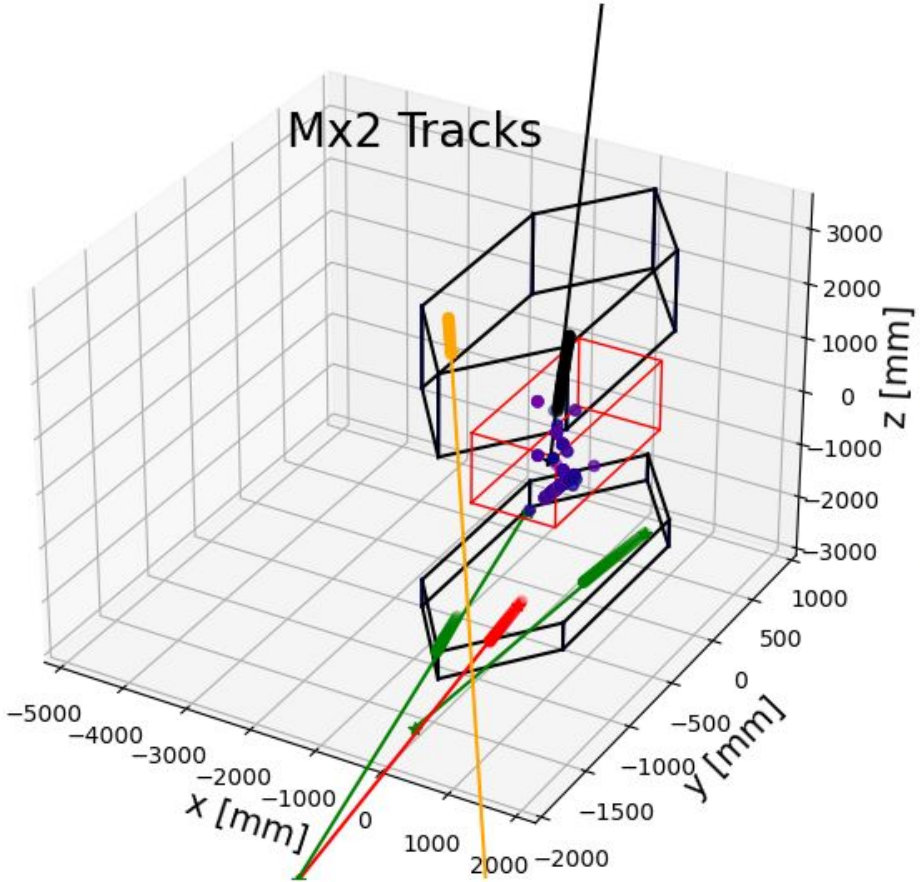
103


pion
proton
anti-muon
electron/positron
photon
x position (cm)
y position (cm)

107

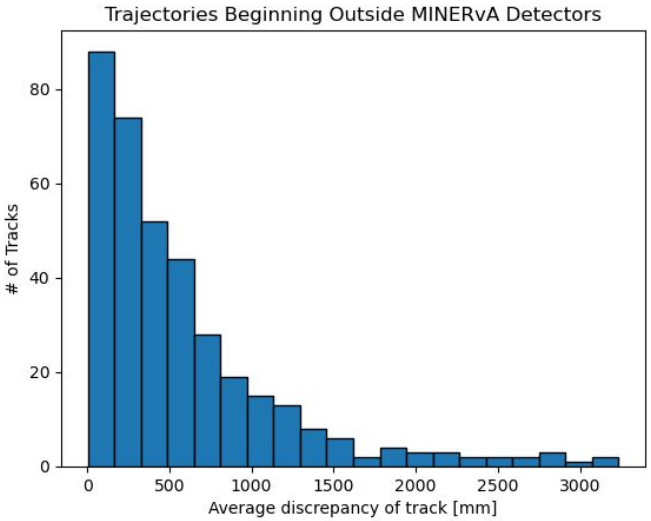

60
40
20
0
−20
−40
−60
60
−60
−40
−20
0
20
40
60
x position (cm)
muon
electron/positron
photon
anti-muon

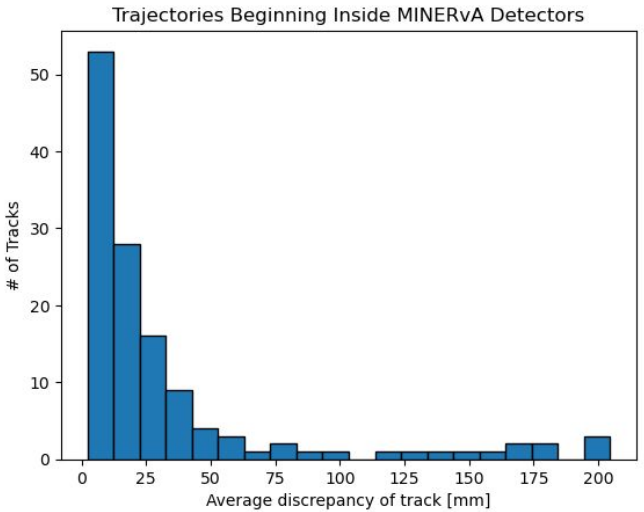

Mx2 Tracks
3000
2000
1000
0
−1000
−2000
−3000
z [mm]
1000
500
0
−500
−1000
−1500
−2000
y [mm]
−4000
−3000
−2000
−1000
0
1000
2000
x [mm]


Mx2 Tracks
3000
2000
1000
0
−1000
−2000
−3000
z [mm]
1000
500
0
−500
−1000
−1500
−2000
y [mm]
−5000
−4000
−3000
−2000
−1000
0
1000
2000
x [mm]

Outlier track distances [mm] not shown in the histogram (out):

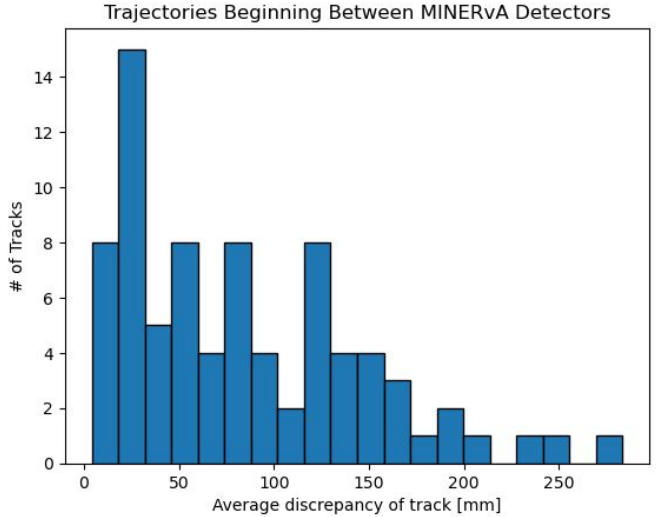
1. 4027.941 94238
2. 13053.00 520443
3. 4063.440 77296
4. 6536.354 77547
5. 4500.534 86683
6. 5197.468 74855
7. 4725.637 48528
8. 4906.706 67921
9. 4335.718 98159
10. 4192.697 55047





Outlier track distances [mm] not shown in the histogram (between):

1. 967.99903437
2. 339.18152325
3. 2463.7028581
4. 277.28518761
5. 906.02641152
6. 1154.3405612
7. 262.7109147
8. 266.50595075
9. 285.9578416
10. 1082.20153785
11. 614.49998759

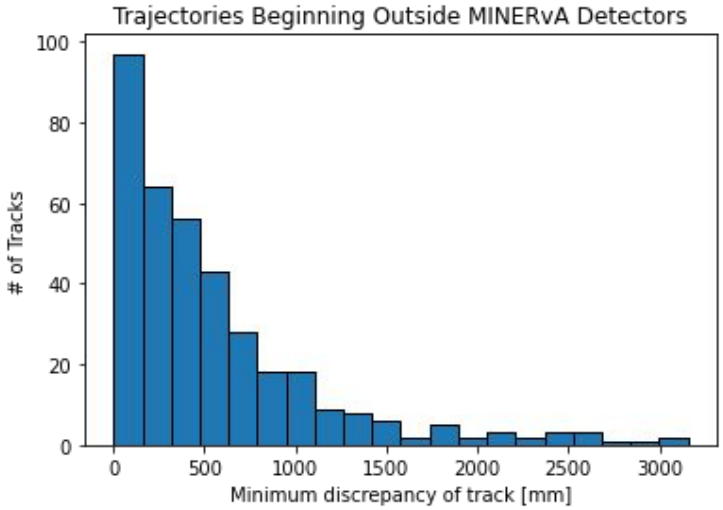


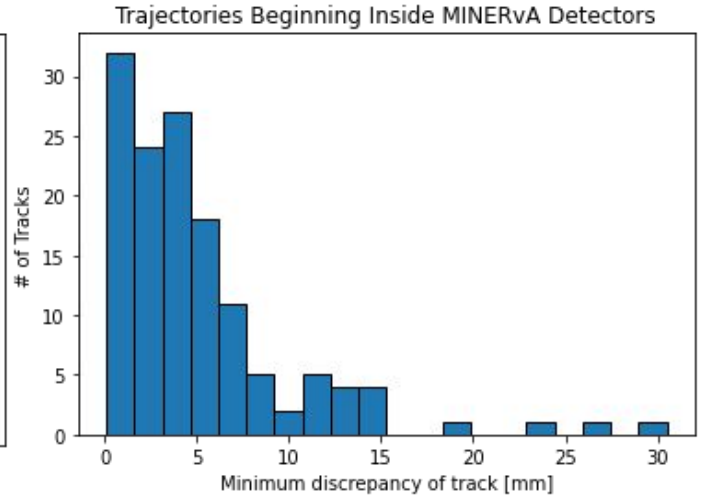
Outlier track distances [mm] not shown in the histogram (between):

1. 471.5258871
2. 594.4696957
3. 713.83769277

Outlier track distances [mm] not shown in the histogram (out):

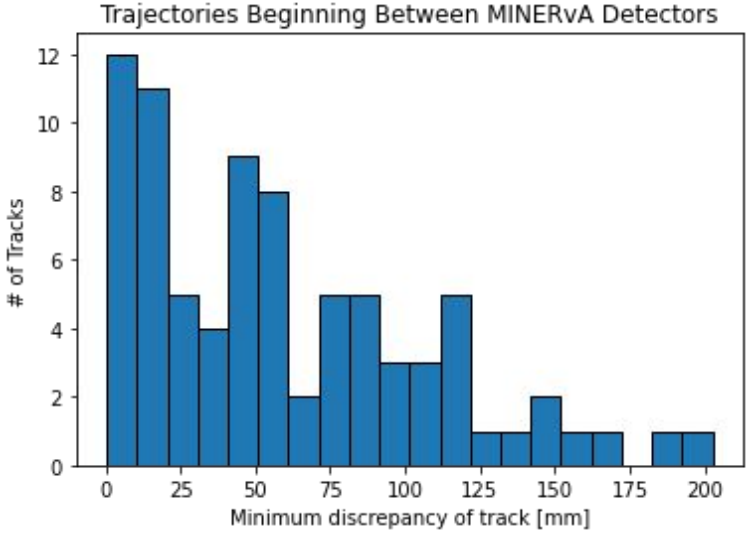
1. 4000.444 6819
2. 12996.53 684748
3. 4061.688 1255
4. 6240.834 16229
5. 4483.841 91624
6. 4974.562 18886
7. 4621.536 28791
8. 4905.332 4456
9. 4273.779 45061
10. 3862.628 517





Outlier track distances [mm] not shown in the histogram (in):

1. 119.1060 0575
2. 53.03724 349
3. 56.06059 828
4. 46.04747 848
5. 41.53936 816

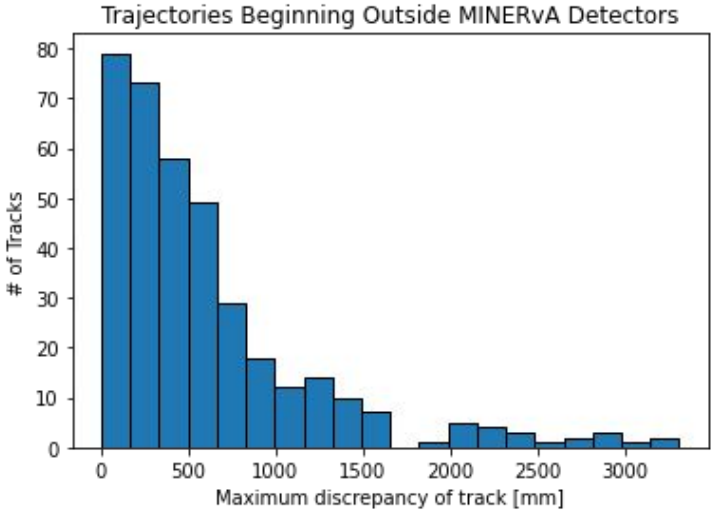


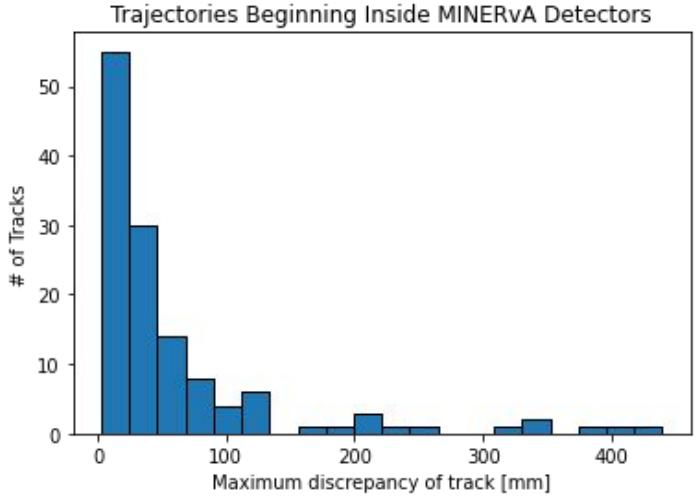
Outlier track distances [mm] not shown in the histogram (in):

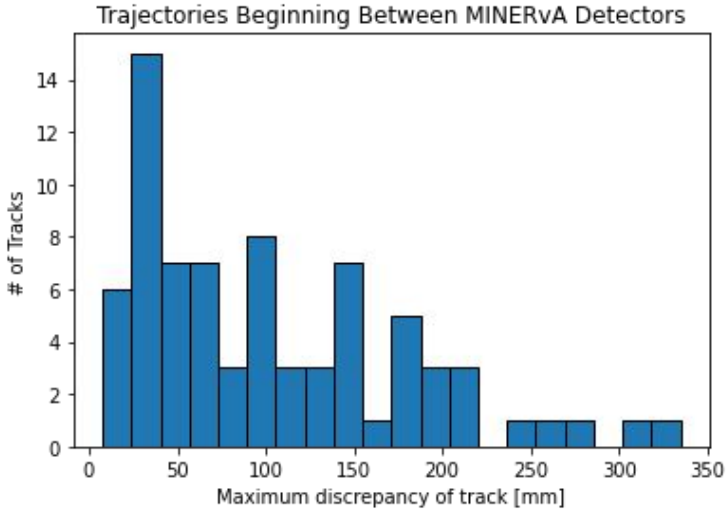
1. 345.0270 7264
2. 467.9203 6432
3. 569.8452 2099

Outlier track distances [mm] not shown in the histogram (out):

1. 4054.94349821
2. 13111.18250128
3. 4066.19953907
4. 6738.77041954
5. 4516.99888031
6. 5337.77109498
7. 4835.31830675
8. 4908.04998466
9. 4425.18105338
10. 4332.38783857







Outlier track distances [mm] not shown in the histogram (in):

1. 644.14634367
2. 774.26967903
3. 453.08657559
4. 473.03673724
5. 908.24857615
6. 477.38120921650.06884511

Outlier track distances [mm] not shown in the histogram (in):

1. 3905.49484552
2. 4190.58741558
3. 817.47113494
4. 1666.17013213
5. 2275.39516008
6. 3314.32935965
7. 712.35945205
8. 532.14787352
9. 752.75162336
10. 3065.02480392
11. 1180.37275475