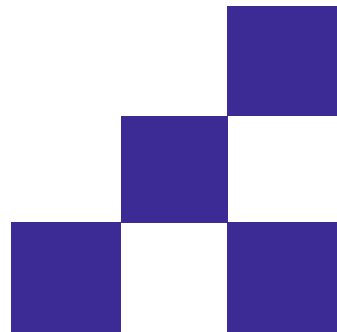
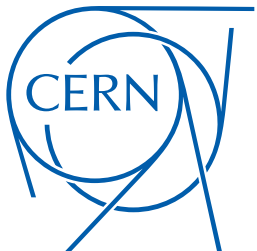




# ProtoDUNE SP PMA Track Stitching

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ProtoDUNE SP Reconstruction  
Meeting  
08/02/17

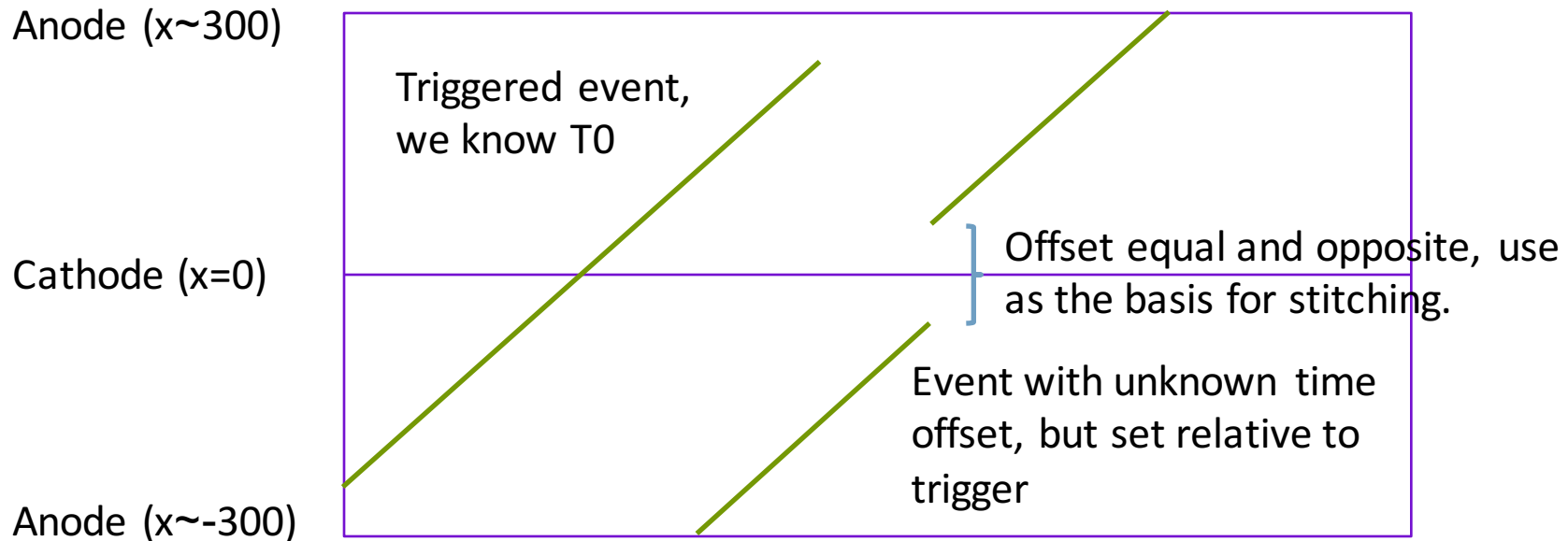


# Introduction

- The protoDUNE T0 will be defined by the beam trigger.
  - The T0 applies by default to all particles that deposit energy within the readout window.
  - This means that cosmics can be reconstructed with wrong positions in the drift direction.
- If a particle crosses the cathode, however, we can use this to define the T0 for that particular particle.
- I am working on an algorithm to stitch PMA tracks together across the CPAs and APAs.
  - Currently lives in larreco feature/lhw\_TrackStitcher

# Why is Stitching Needed?

- In protoDUNE, we will trigger on the beam.
  - This means we know the time of the beam event.
  - The large number of cosmics that happen to fall within the readout window will be reconstructed.
    - However, we don't know their true times, and hence the true position in the drift direction,  $x$ .



# Why is Stitching Needed?

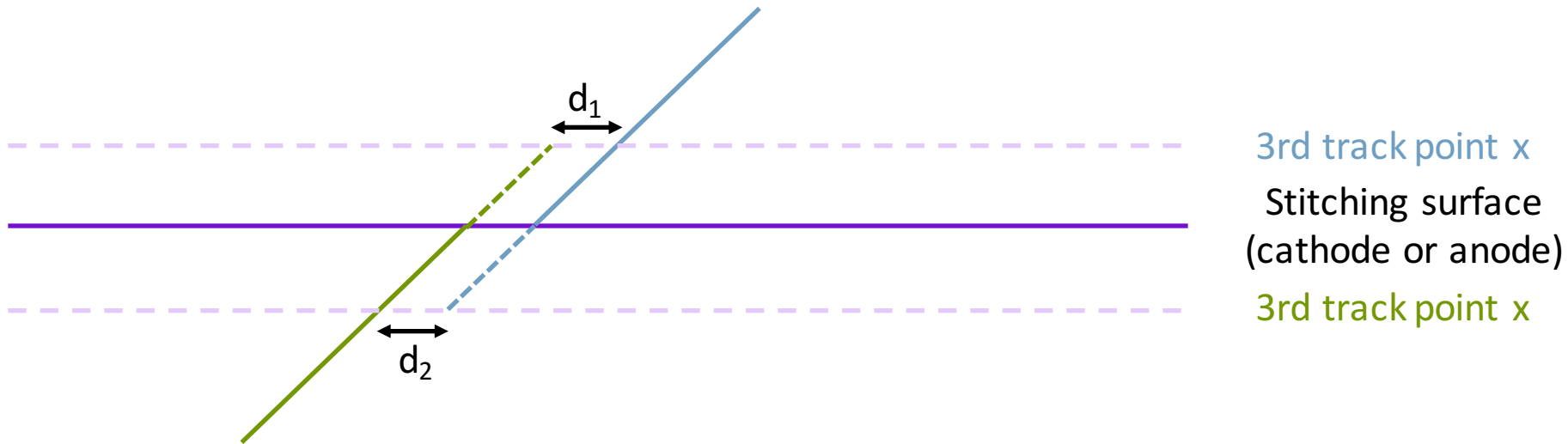
- In protoDUNE, we will trigger on the beam.
  - This means we know the time of the beam event.
  - The large number of cosmics that happen to fall within the readout window will be reconstructed.
- If we can stitch these tracks correctly, then we *know* their T0.
- The CPA / APA provides an absolute measurement of the track to pin it down fully.
- Provides us with further handles to correctly reconstruct tracks in the busy environment.

# Methodology

- Take a somewhat brute-force approach, but make attempts to reduce the dimensionality of the problem.
- Take a track, and shift it in  $x$  (again, this is perfectly valid since we don't know what the  $x$ -coordinate really is) to either the cathode or the anode.
- Iterate over all other tracks, shifting them to the same cathode or anode (if geometrically possible), and try to match the tracks together.
  - Matching attempted between all 4 combinations of track ends.

# Matching Approach

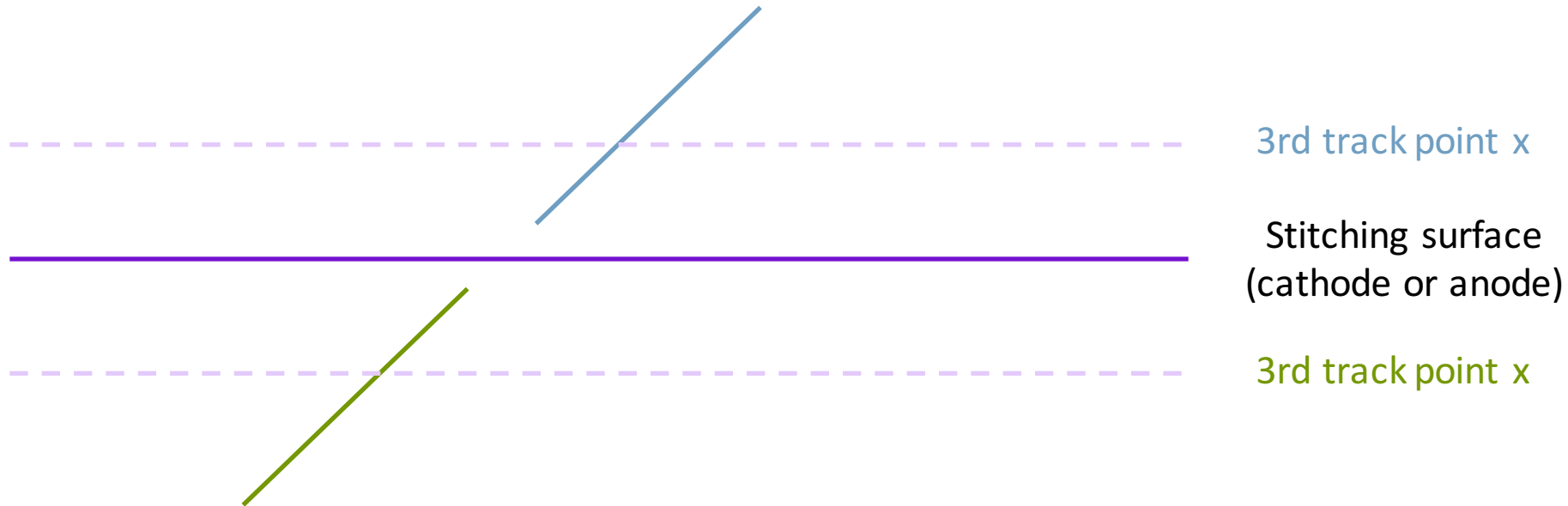
- Extrapolate from the 3<sup>rd</sup> final point on each track to the x-coordinate of the 3<sup>rd</sup> final point on the other.
  - Try to mitigate any odd end effects.



Whilst  $d_1$  and  $d_2$  are shown here in 2D, it is done in 3D in the code.

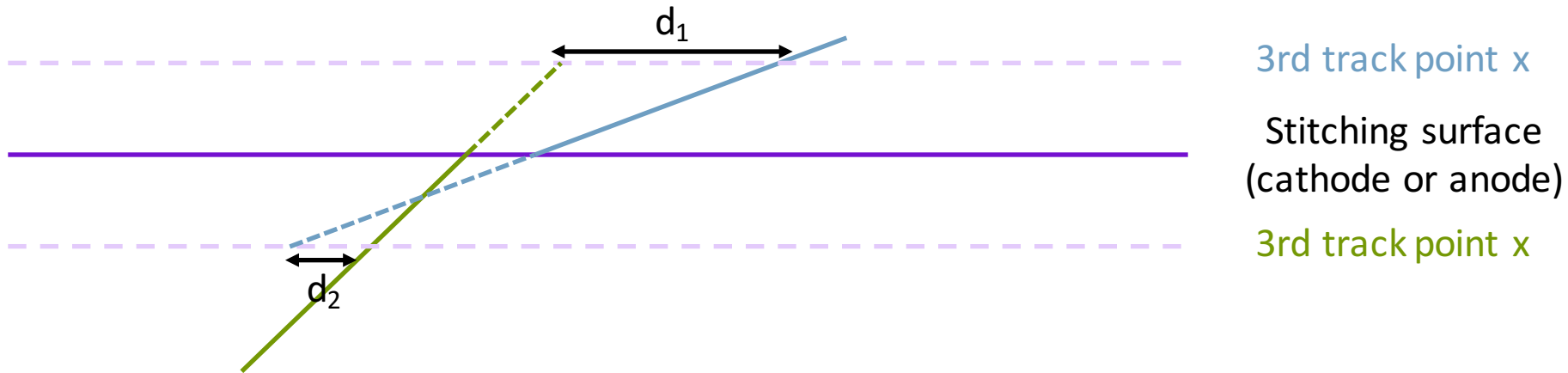
# Matching Approach

- Extrapolate from the 3<sup>rd</sup> final point on each track to the x-coordinate of the 3<sup>rd</sup> final point on the other.
  - Vary the shift to minimise  $d_1 + d_2$  and optimise the stitching.
  - A good match has small  $d_1 + d_2$



# Matching Approach

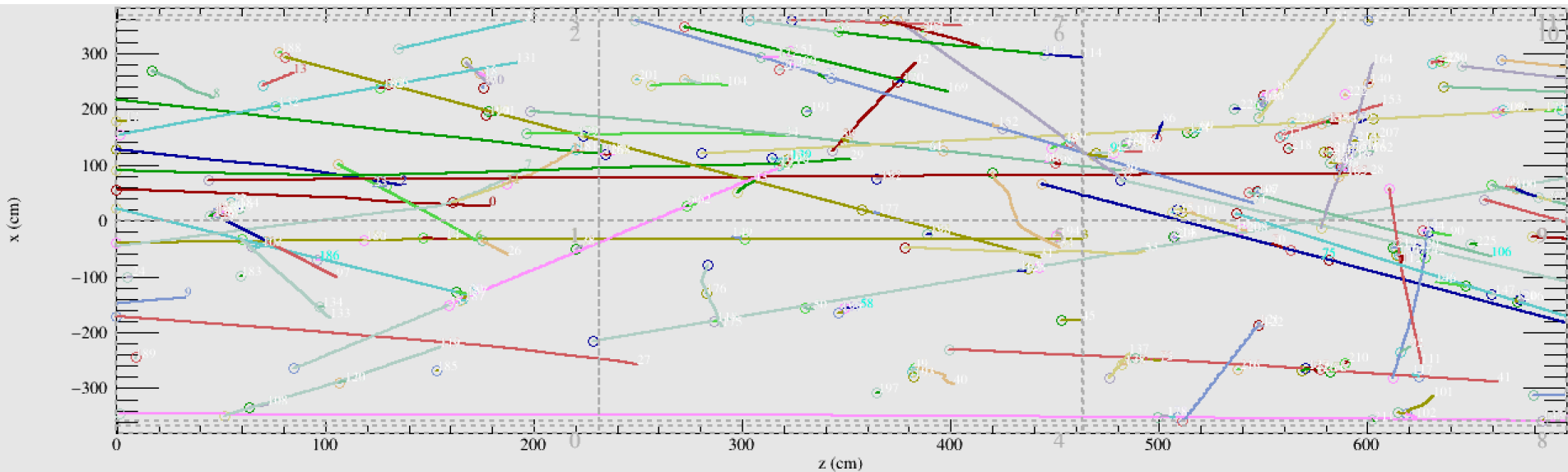
- Extrapolate from the 3<sup>rd</sup> final point on each track to the x-coordinate of the 3<sup>rd</sup> final point on the other.
  - Vary the x-shift within a few centimetres to minimise  $d_1 + d_2$
  - A poor match has large  $d_1 + d_2$





# Stitching Example - ProtoDUNE

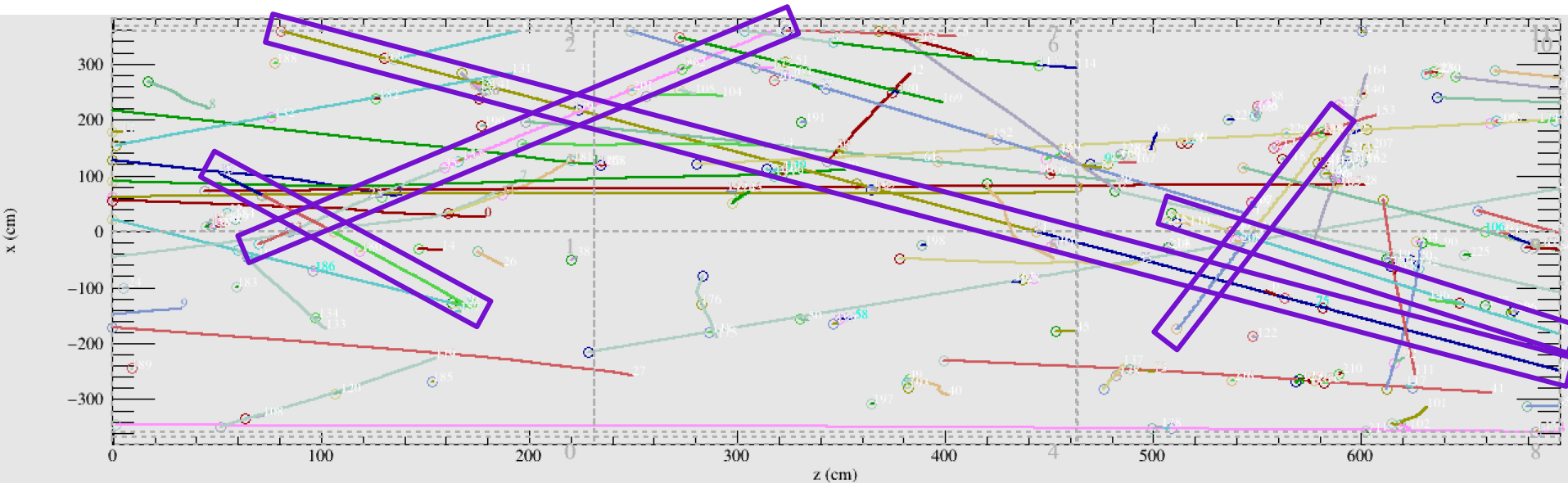
- Example of some matched cosmic muons.
  - A few bug fixes compared to the collaboration meeting.
  - Thanks to Robert for some updates for flipping tracks and vertexing.



# Stitching Example - ProtoDUNE

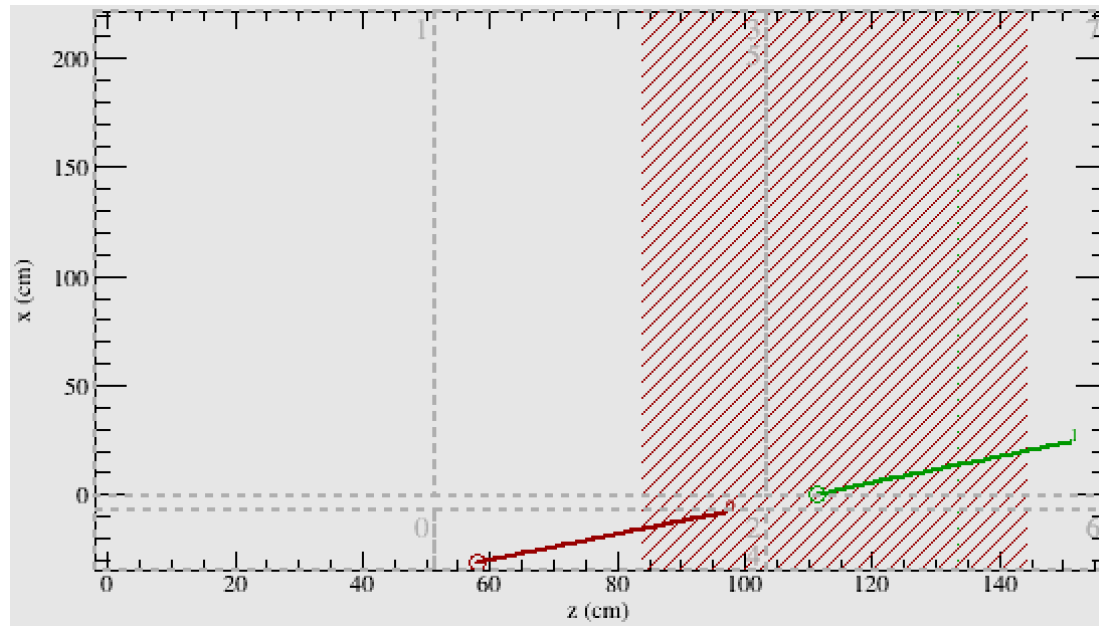
- Example of some matched cosmic muons.
  - A few bug fixes compared to the collaboration meeting.
  - Thanks to Robert for some updates for flipping tracks and vertexing.
- Those highlighted tracks are now correctly stitched at the cathode.

Now stitches all 5 tracks,  
not just the 3 I showed  
previously.



# Stitching Example – 35t

- ProtoDUNE doesn't have any APAs to cross, so look to the 35t to test that things work for APAs too.



Tracks 0 and 1 matching score = 0.685177

- -13.4016, 107.847, 88.0807 :: 0.49627, -0.20083, 0.84462

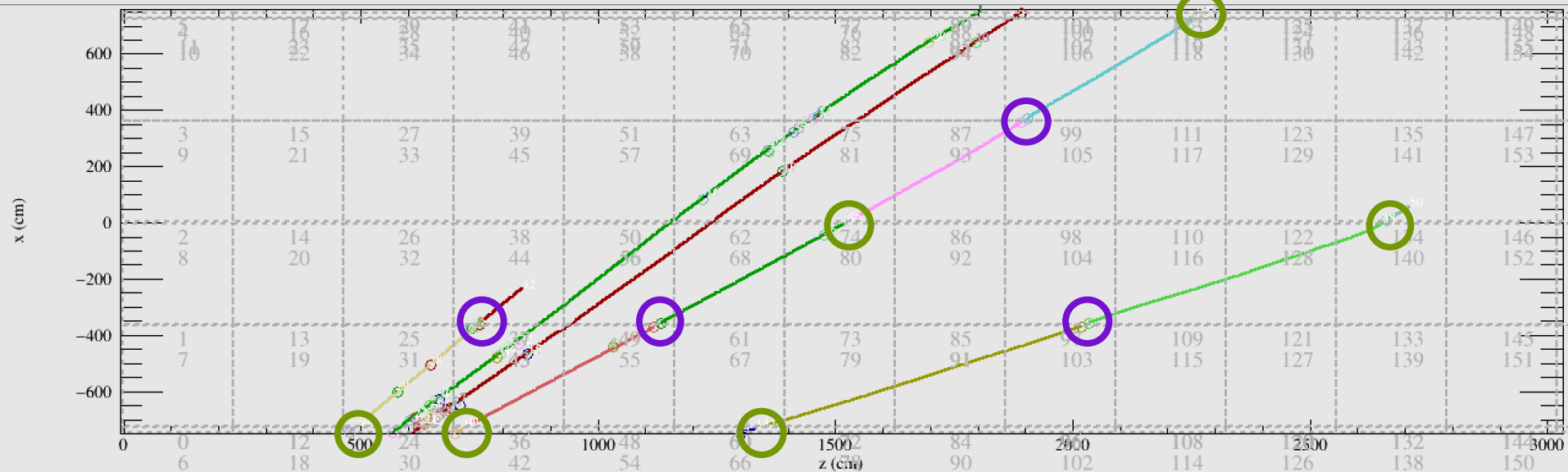
- 6.50702, 99.7532, 121.799 :: -0.50184, 0.211144, -0.838794

- 0, 4 :: 0, 4

- 0, 7 :: 0, 7 “Track in TPC4 matched to track in TPC7 with a good score”

# Stitching Example – DUNE FD

- Lots of potential for APA and CPA crossing in the FD.



- Circled points indicate where stitching is needed for CPA / APA.
  - Expect 4 CPA stitches and 6 APA stitches.
- NB: The long green and red tracks don't need stitching as their T0 is close enough to the trigger time of the particle gun.

# Stitching Example – DUNE FD

- Stitching output:

Passed 51 tracks for CPA stitching.

Tracks 3 and 28 matching score = 0.475028

- 374.096, -550.185, 736.832 :: 0.783344, -0.281468, 0.554209
- 346.096, -562.228, 761.311 :: -0.782737, 0.272266, -0.559638
- Match between TPC 37 and 38.

Tracks 20 and 30 matching score = 8.6971

- 376.067, -266.542, 1103.47 :: 0.668257, -0.0517871, 0.742125
- 355.89, -269.04, 1140.18 :: -0.677178, 0.0361086, -0.734933
- Match between TPC 49 and 50.

Tracks 37 and 47 matching score = 1.15409

- 370.292, 413.314, 2004.74 :: 0.480765, 0.228443, 0.846569
- 358.158, 424.25, 2043.46 :: -0.474885, -0.249255, -0.844012
- Match between TPC 103 and 104.

Tracks 39 and 46 matching score = 6.89703

- 355.877, -334.736, 1884.49 :: 0.714411, -0.0815799, 0.694954
- 384.007, -337.978, 1925.01 :: -0.70928, 0.0473396, -0.703336
- Match between TPC 99 and 100.

Passed 51 tracks for APA stitching.

Tracks 0 and 3 matching score = 1.36279

- 738.611, -426.125, 483.317 :: 0.784004, -0.293043, 0.547232
- 675.501, -447.362, 525.559 :: -0.784291, 0.277258, -0.554992
- Match between TPC 24 and 25.

Tracks 19 and 20 matching score = 0.822252

- 741.603, -235.121, 710.402 :: 0.676794, -0.0485403, 0.73457
- 689.147, -238.369, 759.238 :: -0.67059, 0.048994, -0.740208
- Match between TPC 36 and 37.

Tracks 30 and 39 matching score = 0.466064

- 21.134, -294.782, 1501.76 :: 0.67863, -0.0558751, 0.732352
- 15.8565, -297.616, 1538.22 :: -0.674995, 0.0526169, -0.735944
- Match between TPC 74 and 75.

Tracks 35 and 37 matching score = 0.548538

- 739.266, 250.147, 1322.72 :: 0.426106, 0.198685, 0.882586
- 718.245, 257.751, 1356.57 :: -0.421261, -0.204115, -0.883672
- Match between TPC 66 and 67.

Tracks 46 and 49 matching score = 1.3604

- 707.819, -371.388, 2242.64 :: 0.724269, -0.110232, 0.680649
- 742.114, -374.915, 2267.04 :: -0.737088, 0.0810212, -0.670923
- Match between TPC 112 and 113.

Tracks 47 and 50 matching score = 1.80648

- 14.7081, 554.884, 2642.36 :: 0.705562, 0.103619, 0.701031
- 19.6366, 557.903, 2671.36 :: -0.717242, -0.066312, -0.693662
- Match between TPC 140 and 141.

- Found all of the circled joins.
  - Checked the TPC numbers and positions and they all line up well.

# Summary

- I have a stitching algorithm up and running and it works for protoDUNE, 35t and the Far Detector.
  - Looks to be robust so far from hand-scanning events.
- Robert is finalising the code in PMA to make stitched tracks produce a single `recob::track` object.
- I will then move on to trying to quantify the performance for well defined samples of tracks.
- Finally, Robert, Dorota and I will define the reconstruction order:
  - Separate cosmic pass, etc.