2x2 Chicago Meeting

April 2, 2024

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2x2 Paper Update

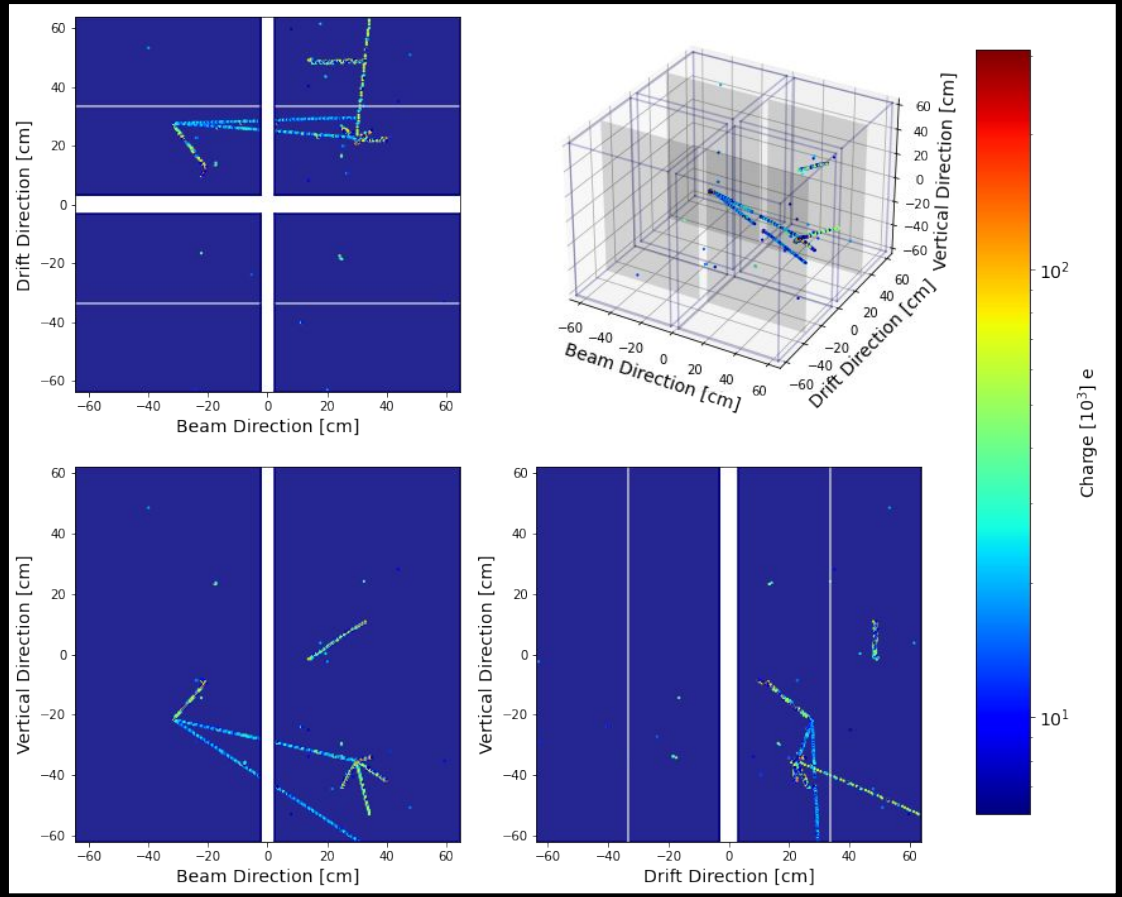
Link to Overleaf Draft:
https://www.overleaf.com/6419191385gzxrjygksbcb#1adc5e

- Introduction, Hardware, and Commissioning are drafted
- Currently communicating with cosmic + rock muon simulation folks for Backgrounds section
- Updated beam flux plots currently in production
- **Need better event displays**–Elise has begun pushing this in working groups

Any and all comments welcome in the draft above!

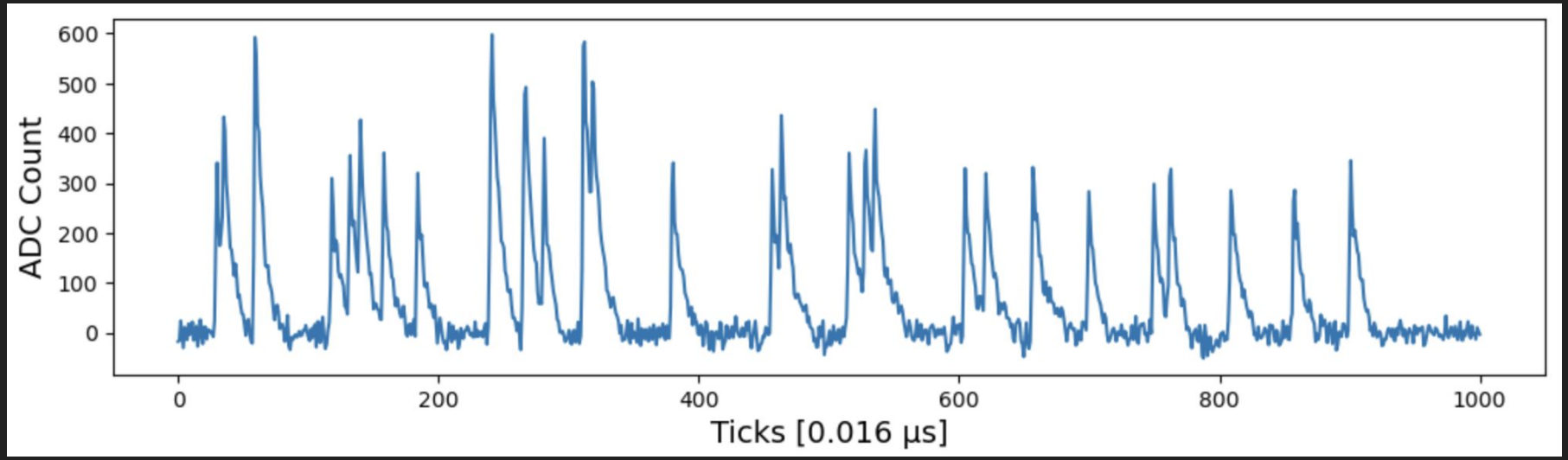
Other Event Display

- Made stop-gap event display for placeholder in paper draft
- Used it in presentation in analysis meeting to advocate for more event displays → hopefully, there will be more/better event displays coming



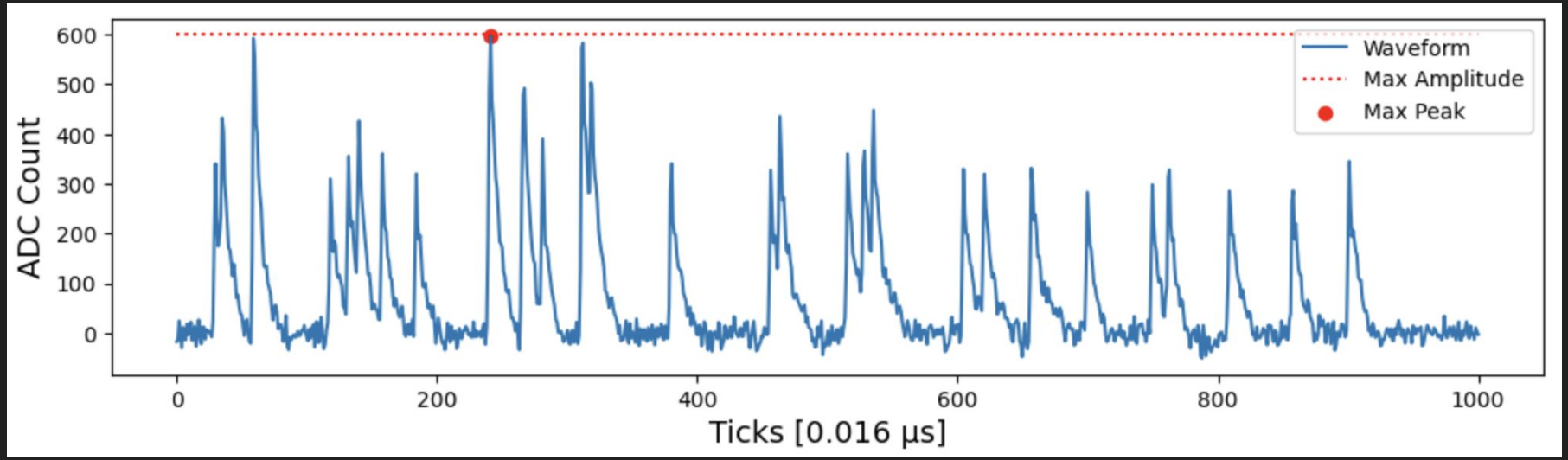
2x2 LRS Warm Commissioning

Does the Light Output Make Sense?



Observe: No light signal at tick 200–just dark counts throughout

Test 1: Over 1005 Events, Avg. Maximum by Channel

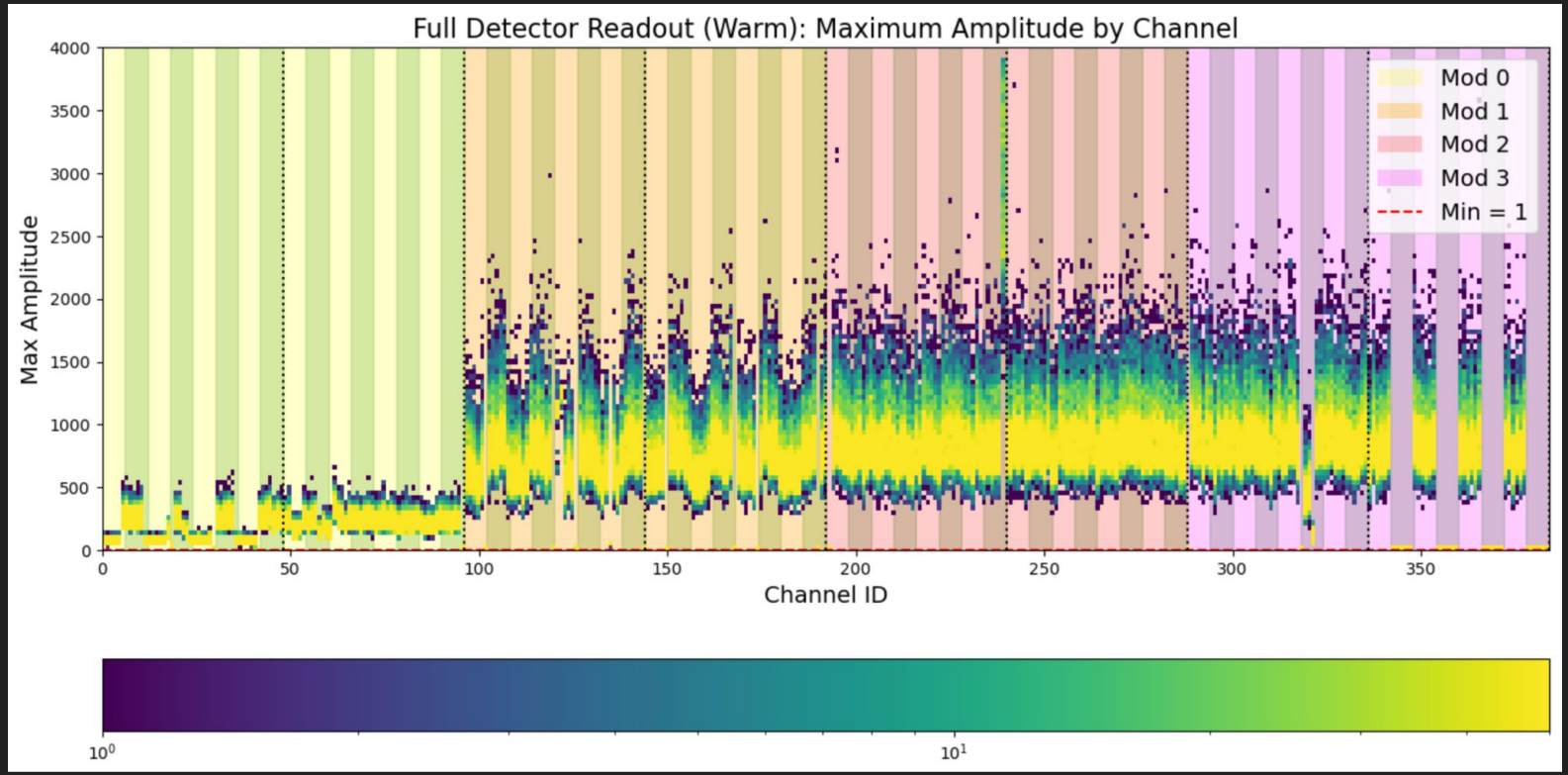


Observe:

Only concerned with **global maximum**

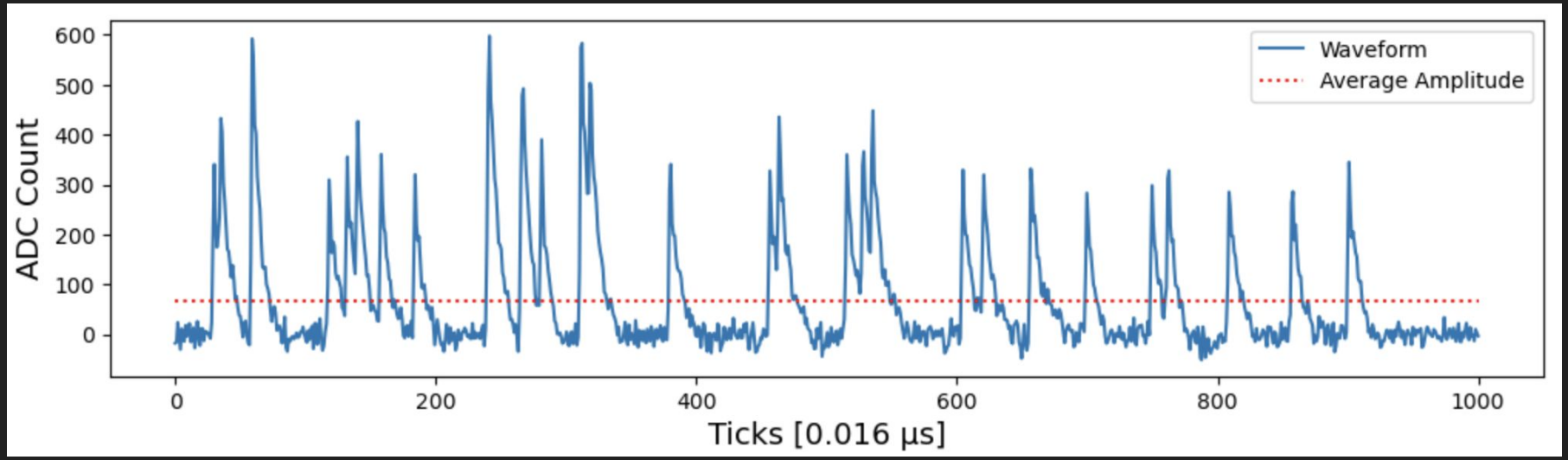
Single p.e. dark count: ~ 300 ADC counts

Test 1: Over 1005 Events, Avg. Maximum by Channel



Observe: Max. dark count is ~ 1 p.e. In Mod-0, and ~ 3 p.e. in Mods 1, 2, &3

Test 2: Over 1005 Events, Avg. Amplitude by Channel

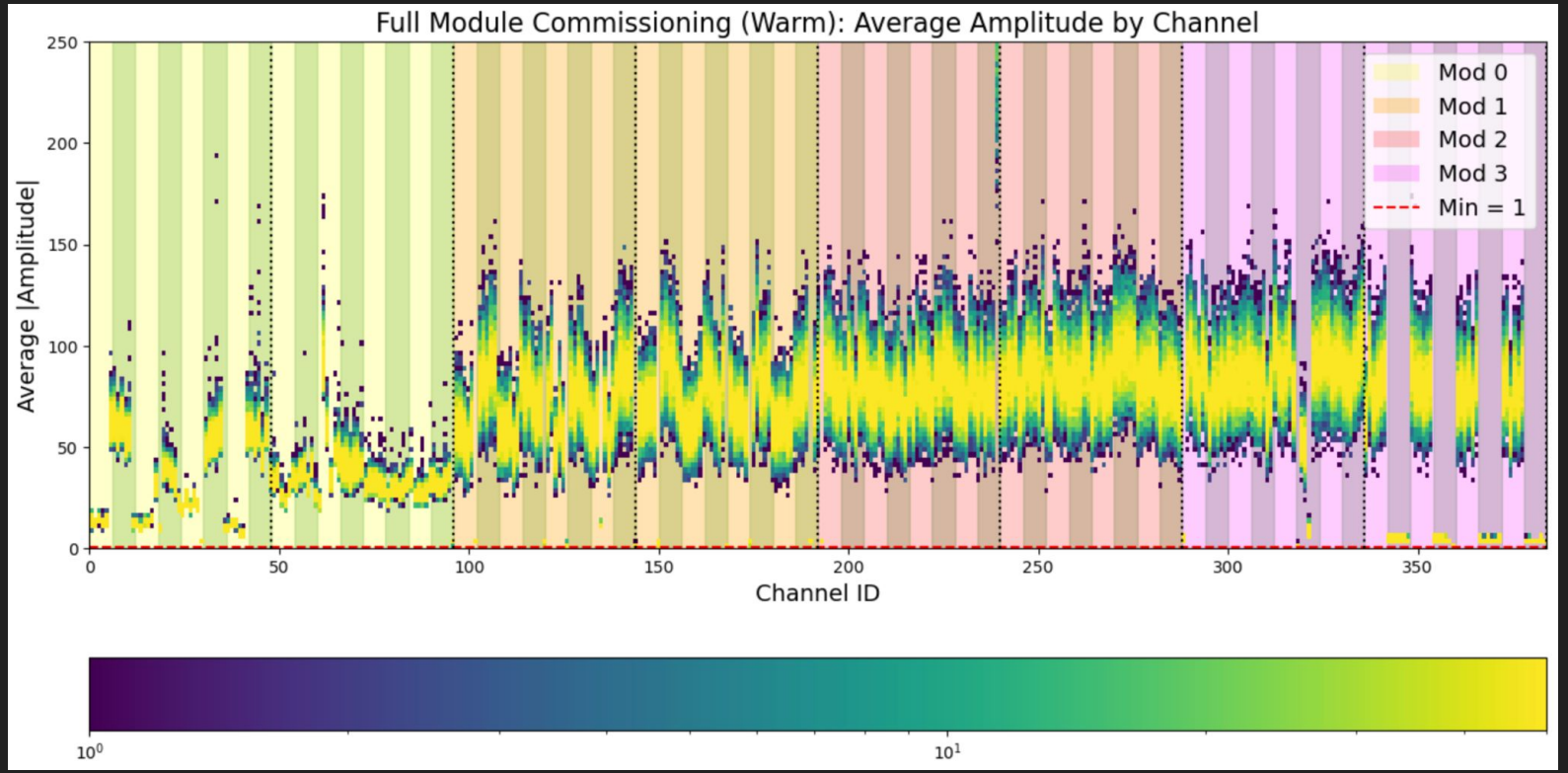


Observe:

Only concerned with **global average**

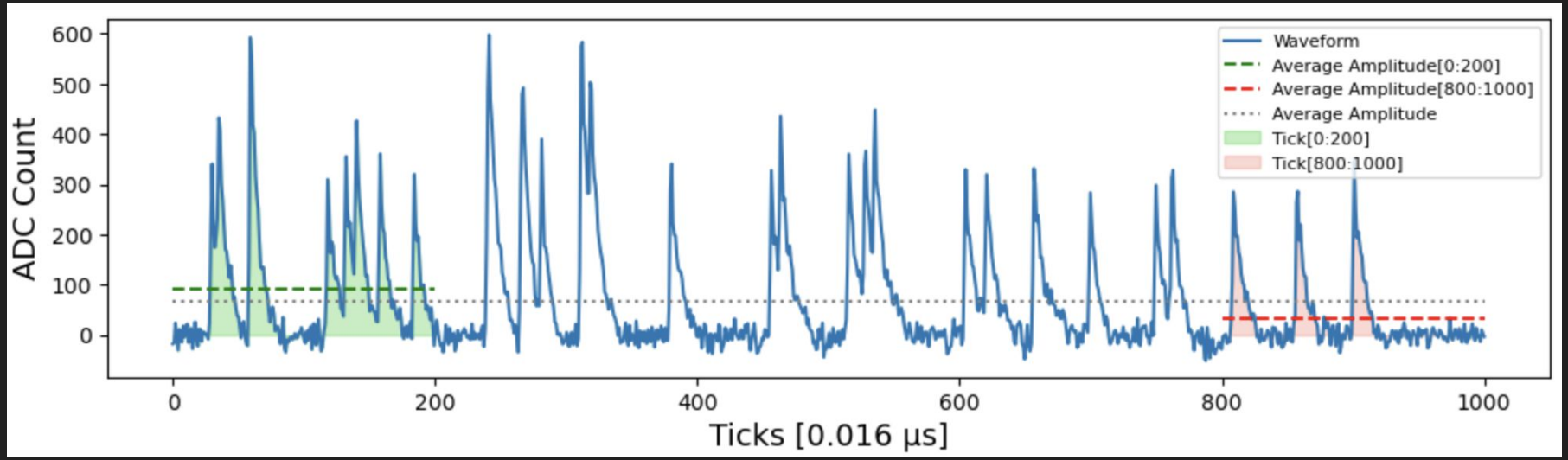
Average this value for each of 384 SiPM channels over 1005 events…

Test 2: Over 1005 Events, Avg. Amplitude by Channel



Observe: Not very different. ACLs, in general, are noisier. Mod 3 ACLs are non-responsive.

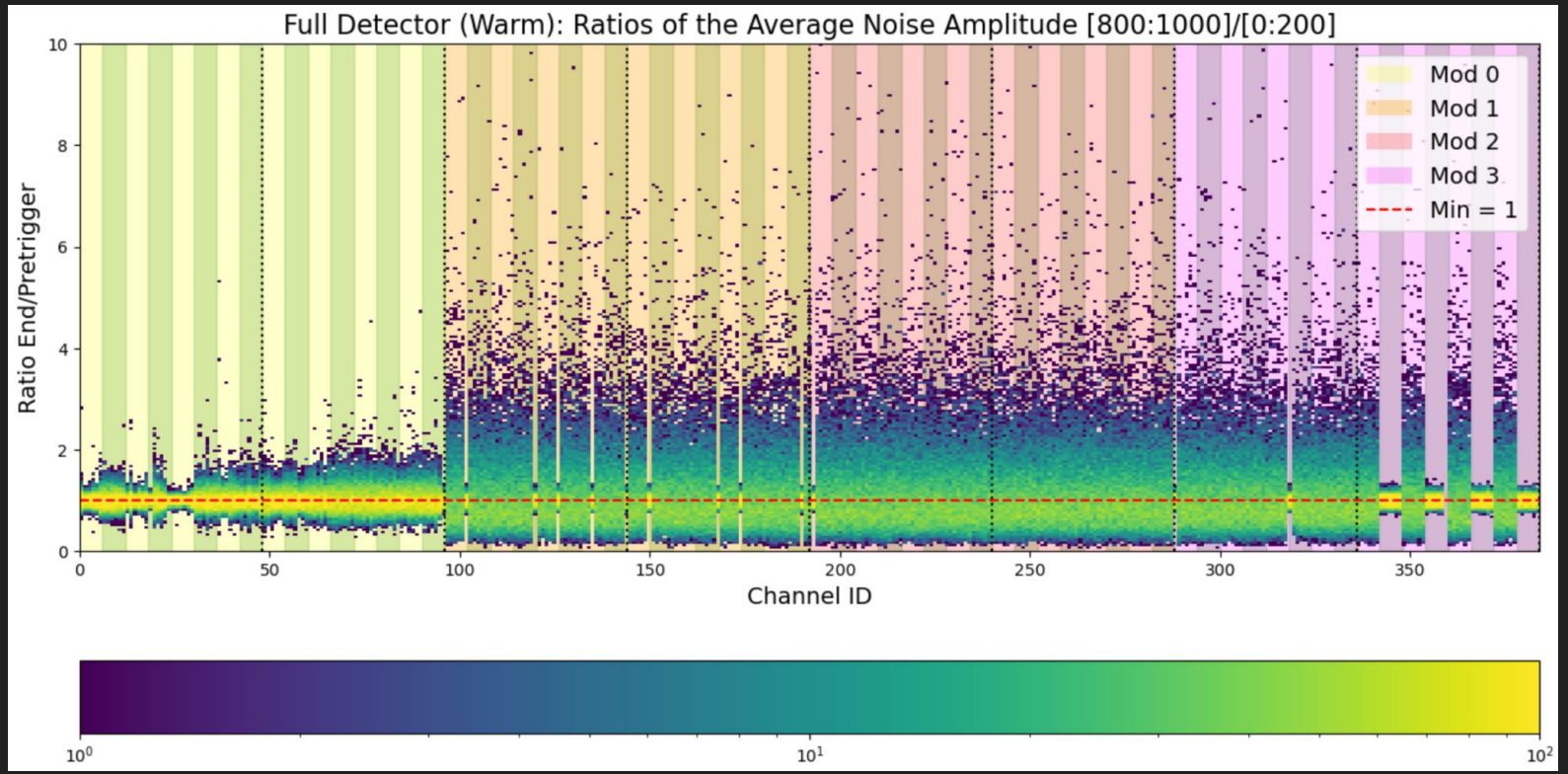
Test 3: Over 1005 Events, Avg. Ratio of Noise Amp Across Wvfm



Observe:

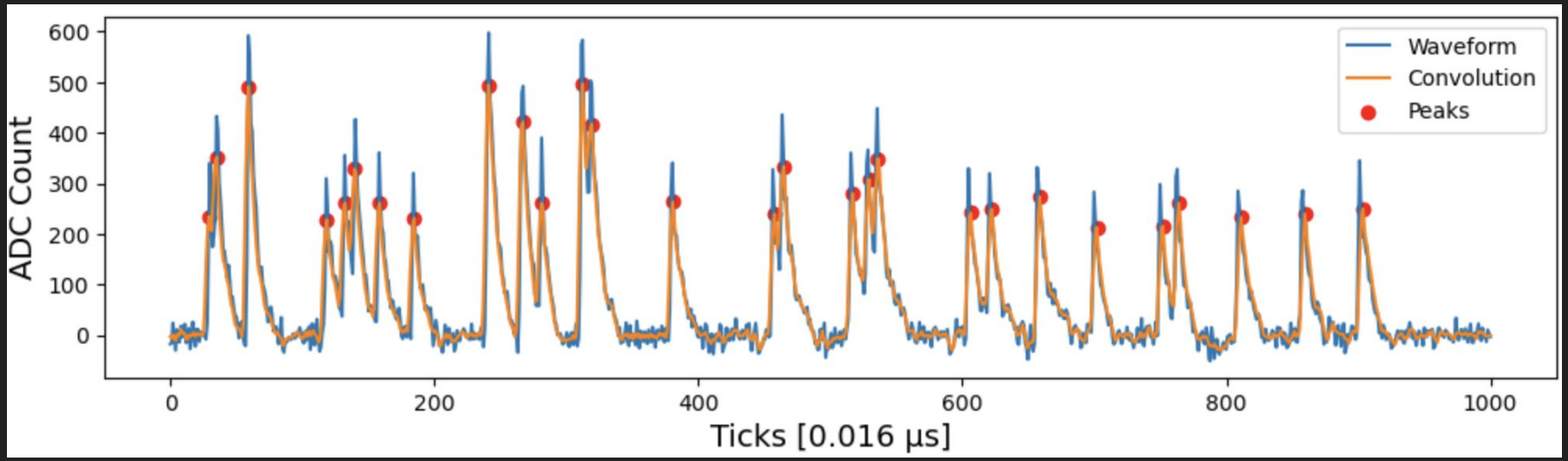
Take ratio: Avg [800:1000] / Avg [0:200]

Test 2: Over 1005 Events, Avg. Amplitude by Channel



Observe: On average, there are as many dark counts early in the waveform as there are late

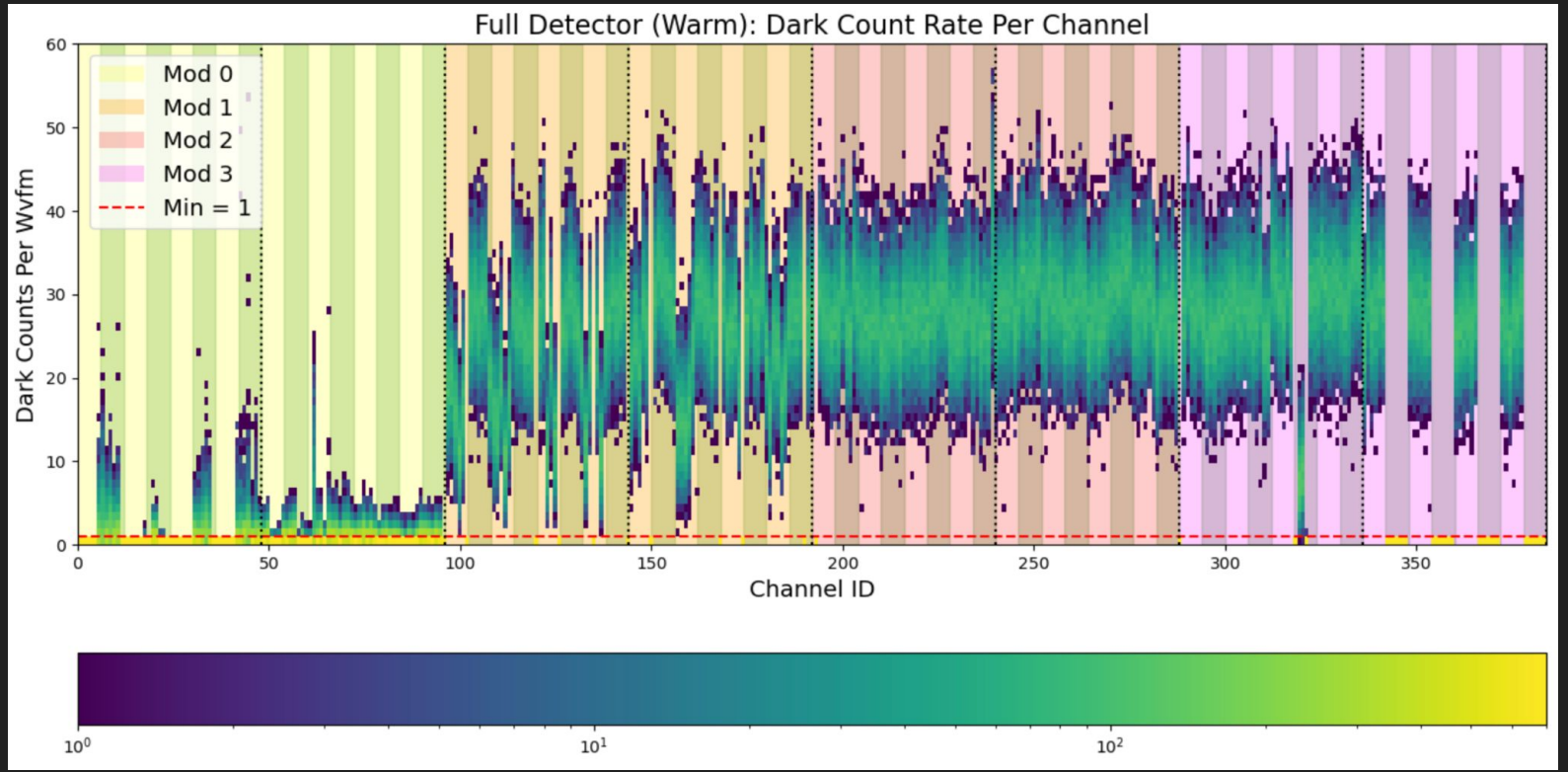
Test 4: Over 1005 Events, Avg. Dark Count Rate



Observe:

Most dark counts appear to be single p.e.

Test 2: Over 1005 Events, Avg. Amplitude by Channel

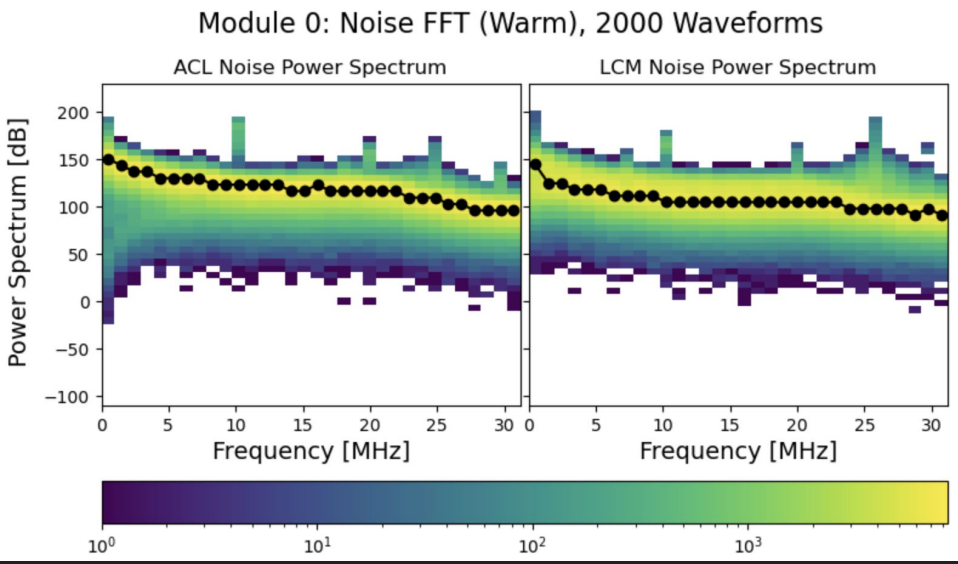


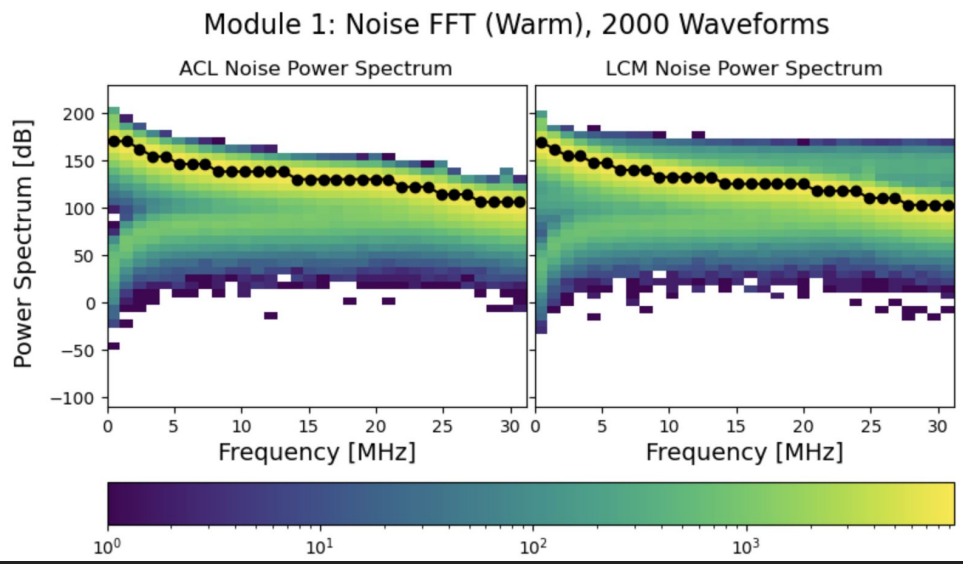
Observe: On average, 30 dark counts / 16 μs (1.9 MHz), **lower for Mod-0**

Light Noise FFTs:

Main Takeaway: Dark Counts in warm drown out electronics noise

- See: 10 MHz peak





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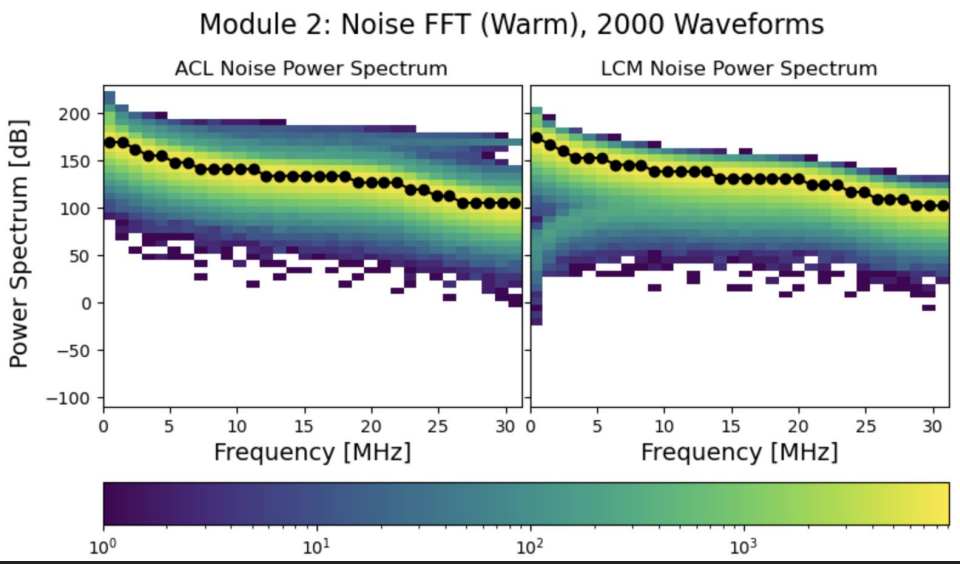
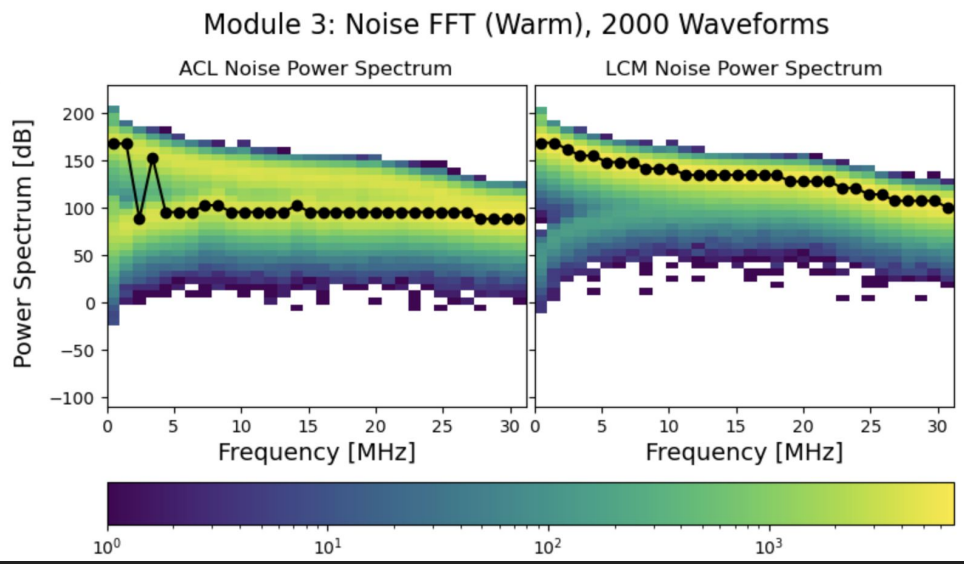




Updates on ML Reco Benchmarking

- Gave additional presentation at ND Prototypes Analysis Meeting March 21, 2024
- Some updates from previously shown studies + additional suggestions

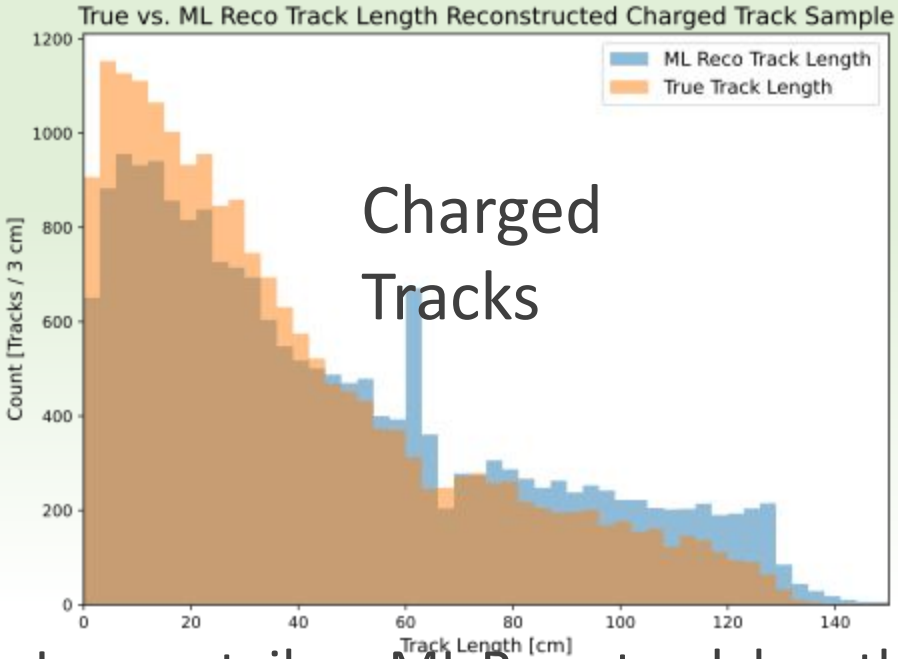
Current Work – Full Reco Benchmarking

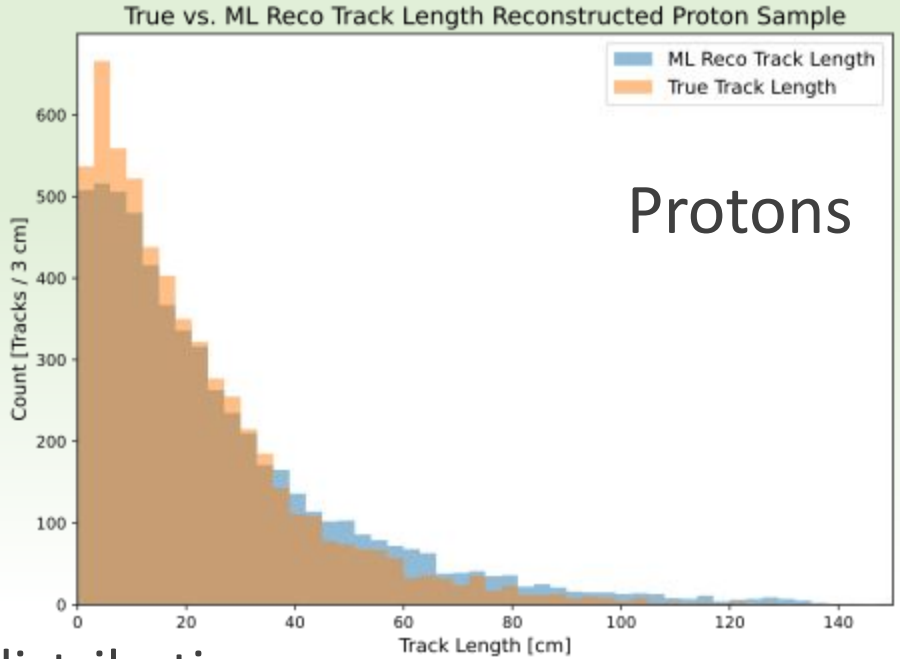
- Still want to look at calibration-file-level comparisons of data/MC using Bern Module data and simulation (see my presentation last week for update on Bern module cosmics simulation status)
- Also want to investigate **full proton reconstruction using CAFs** by comparing reco and true particle kinematics (see other presentation last week for first results)
- As CAFs currently only contain **ML Reco** information, this is the reconstruction I'm evaluating

Sample Details

- Used MiniRun4.5 Beta 3 CAFs (200 files)
- As ML Reco has some known PID issues, I look at all **reconstructed** charged track-like particles and also just **reconstructed** protons in comparison to **best match true particles**
- Cut on ML Reco “Overlap” variable such that **require reco/true match to have >=0.5 overlap**
- No **throughgoing tracks**
- No tracks with reco start or end points at the **upstream edge of detector (within 1.0 cm)**
- Overall, **19594 charged tracks** and **5726 protons**

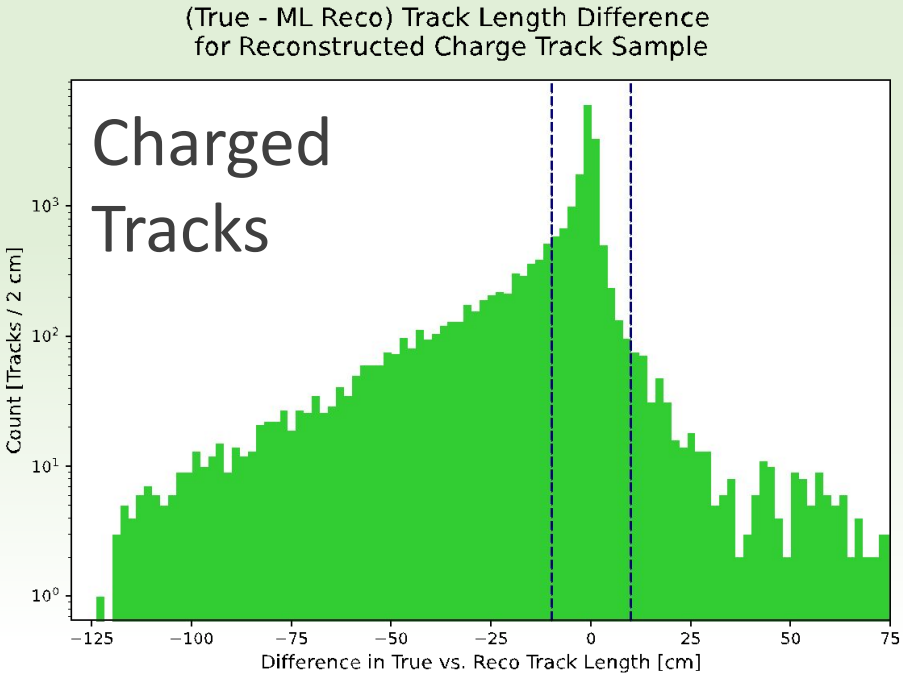
Charged Track and Proton Length

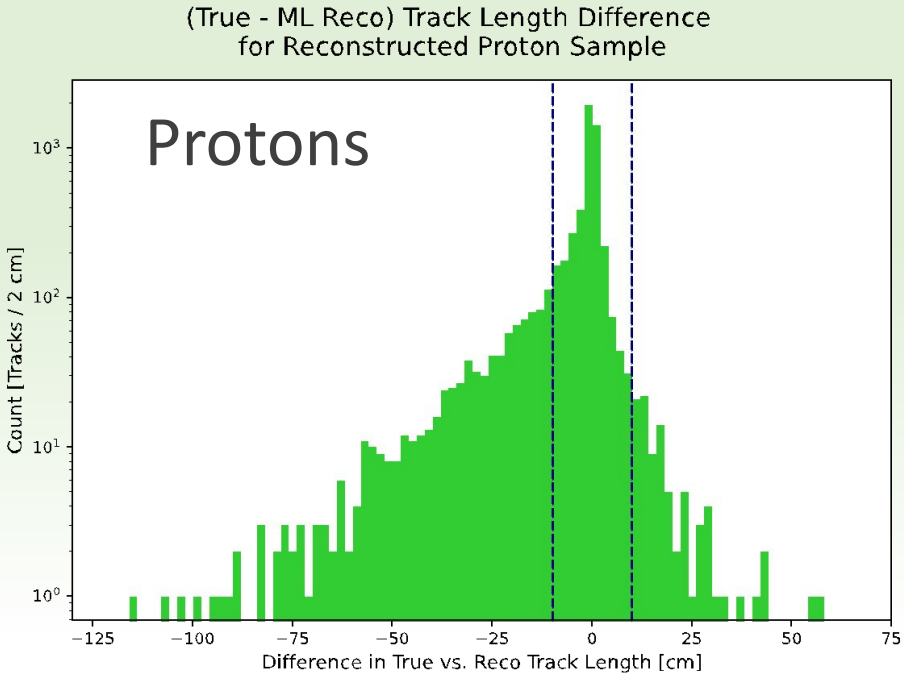




- Longer tail on ML Reco track length distributions
- More short true tracks

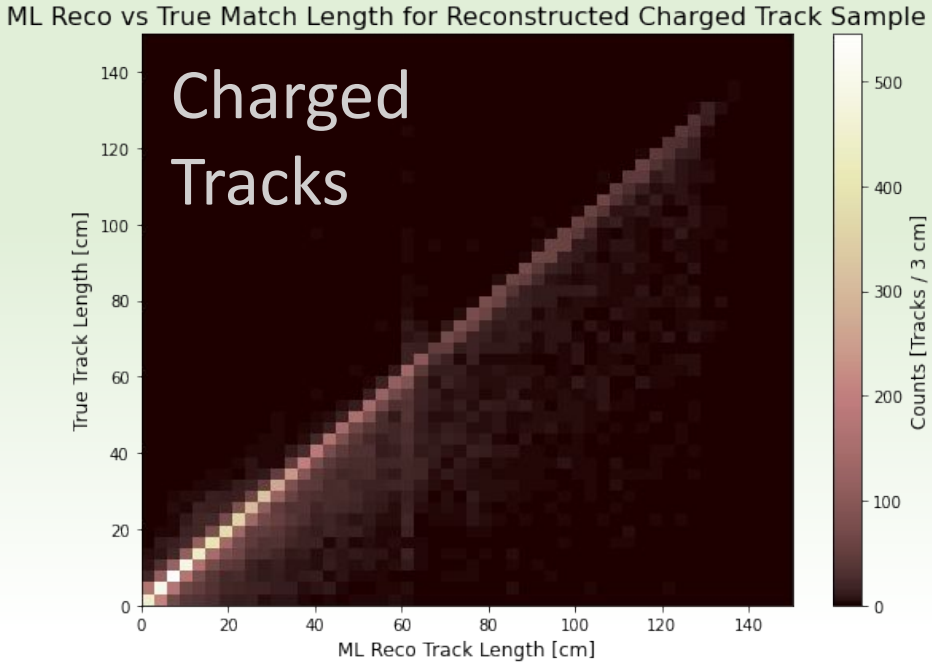
Charged Track and Proton Length Difference

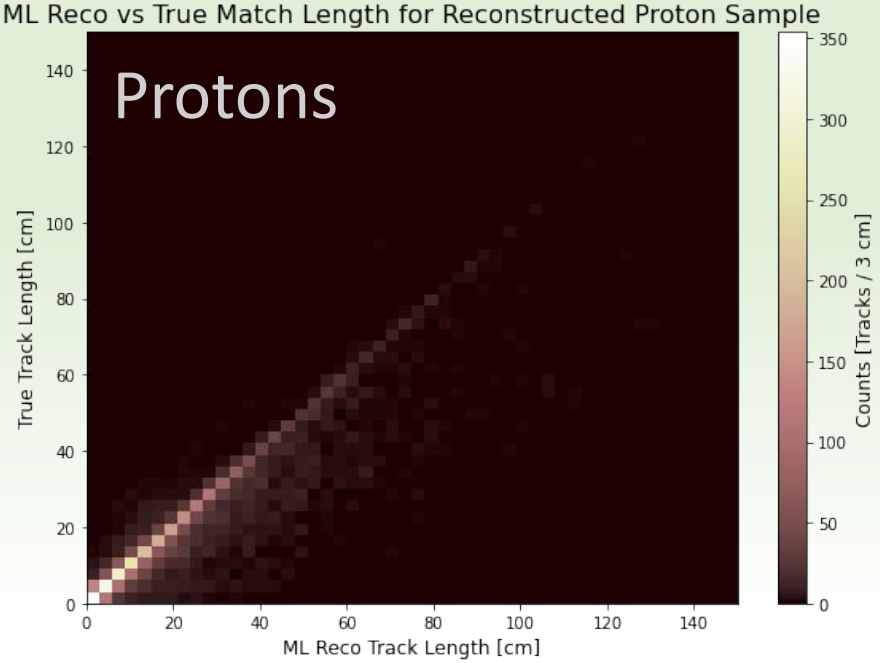




- Many more than expected reco/true matches with >10 cm track length differences

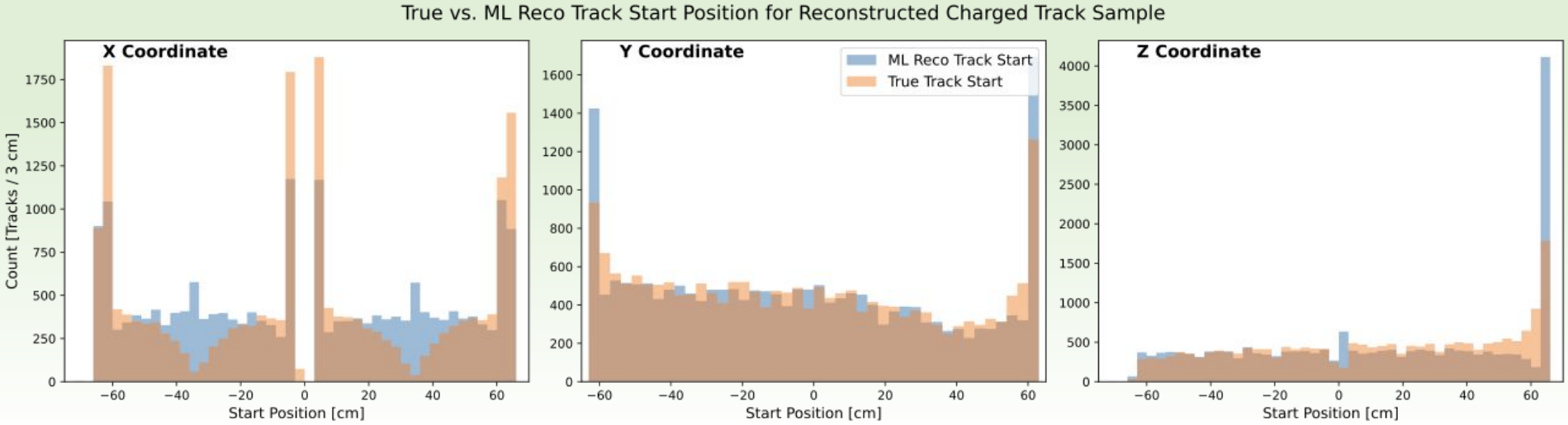
Charged Track and Proton Length Comparison





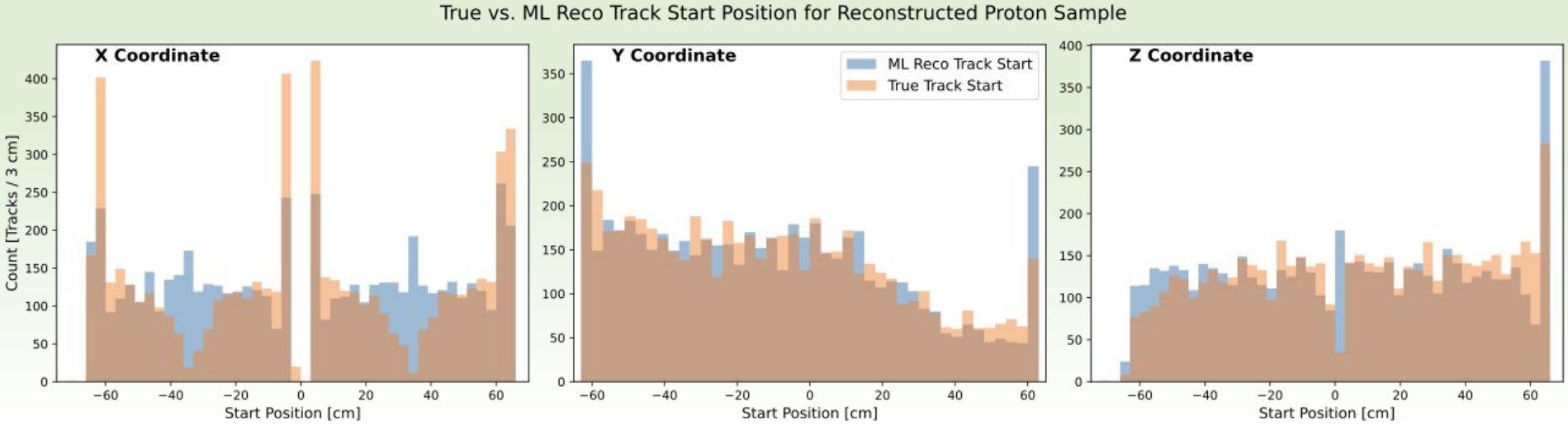
- True match tracks more likely to be shorter than reconstructed tracks vs. longer

Charged Track Start Position



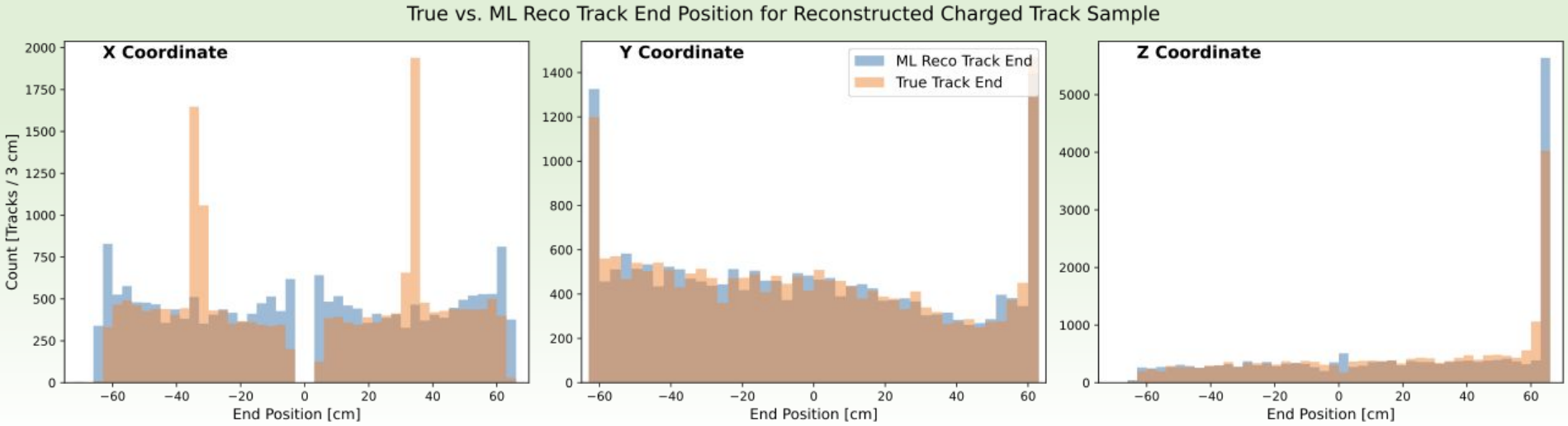
- Significant differences in x-coordinate distribution
- Large spikes at edges for ML Reco in y, z

Proton Start Position



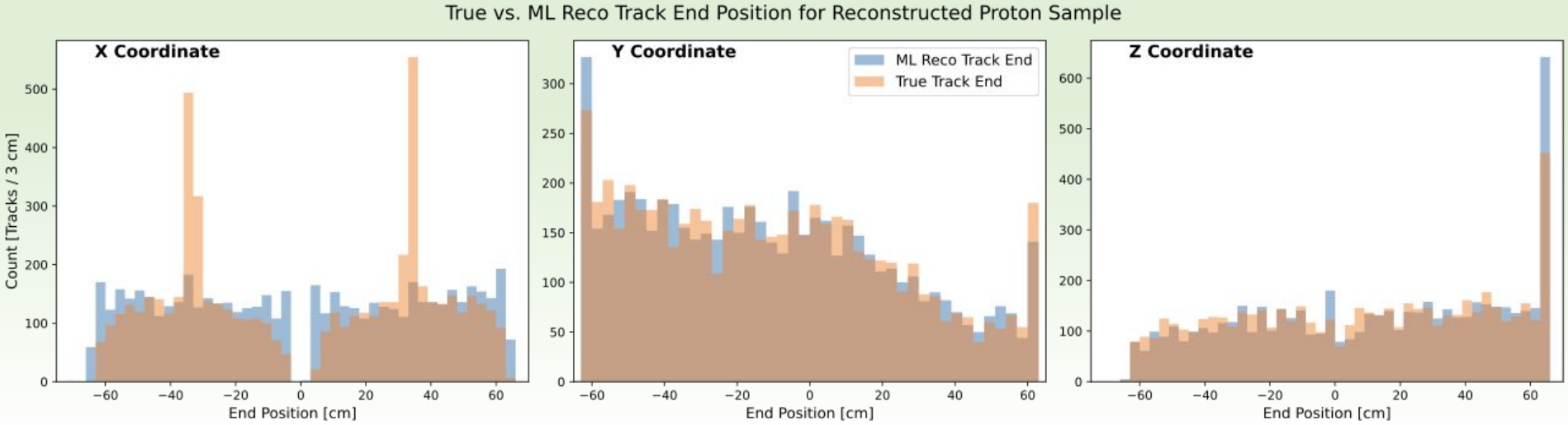
- Significant differences in x-coordinate distribution
- Large spikes at edges for ML Reco in y, z

Charged Track End Position



- Significant differences in x-coordinate distribution

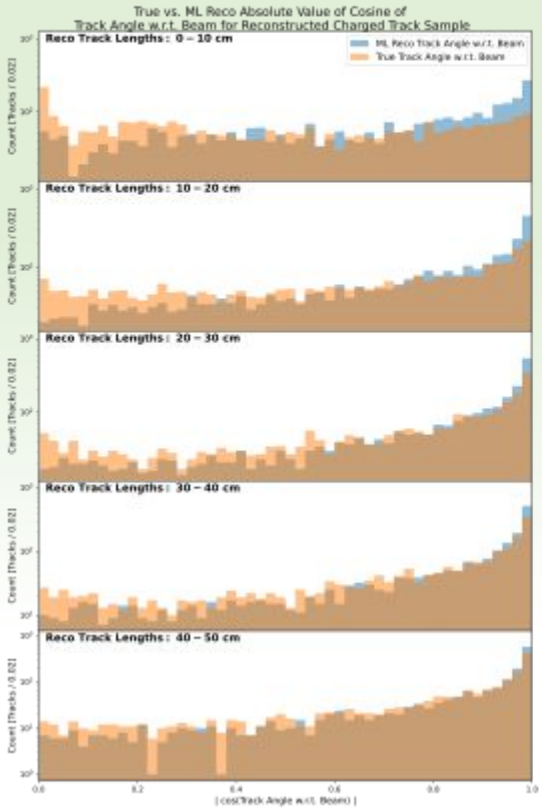
Proton End Position

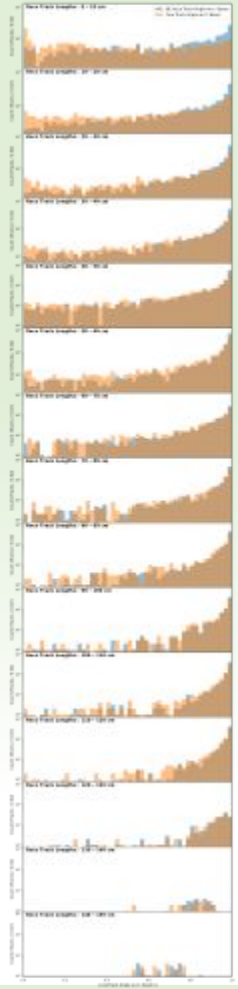


- Significant differences in x-coordinate distribution

(Absolute value of the cosine of the)

Charged Track Angle w.r.t Beam

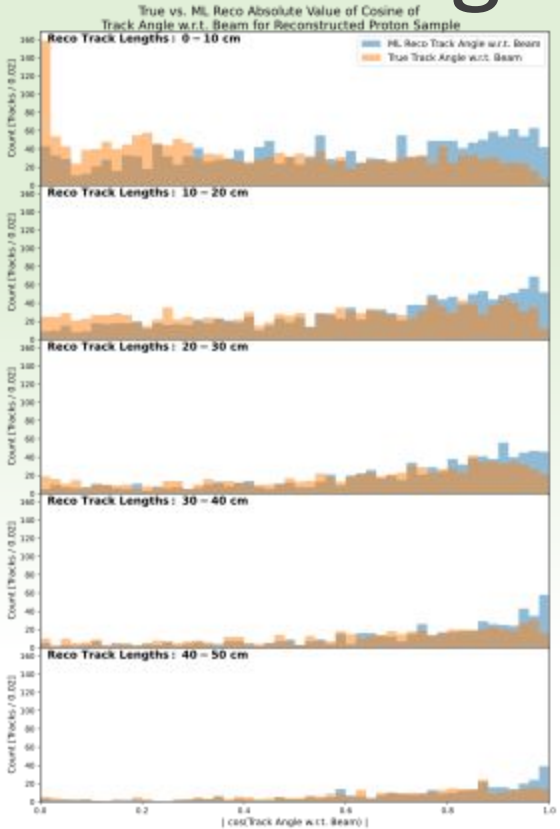


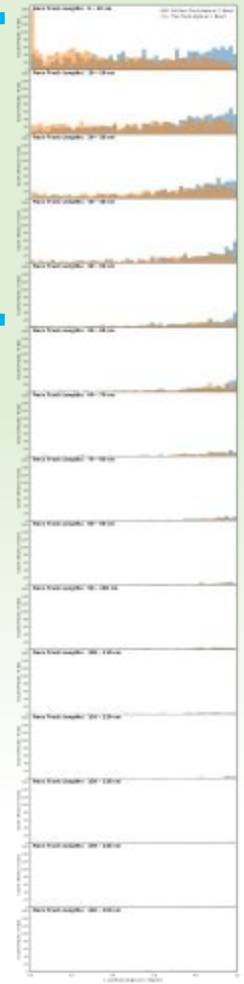


- Binned by reconstructed track length in 10 cm bins
- **Note:** log scale on y-axis
- For shorter tracks, clear difference in true vs. reco distributions

(Absolute value of the cosine of the)

Proton Angle w.r.t Beam

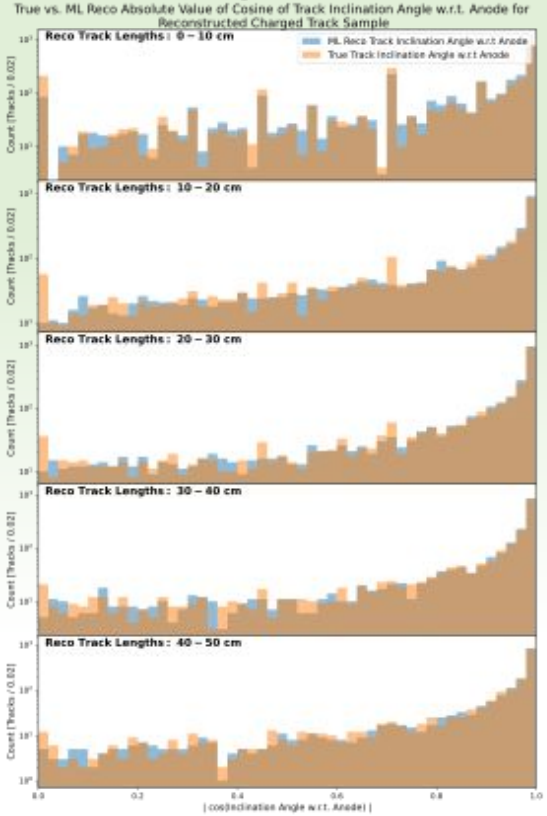


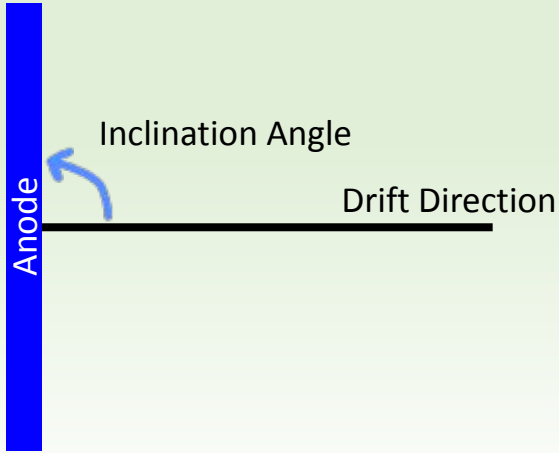


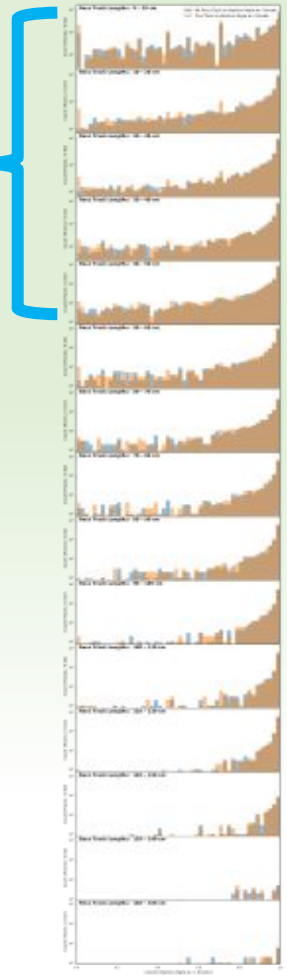
- Binned by reconstructed track length in 10 cm bins
- **Note:** normal scale on y-axis
- For shorter tracks, clear difference in true vs. reco distributions

(Absolute value of the cosine of the)

Charged Track Inclination Angle



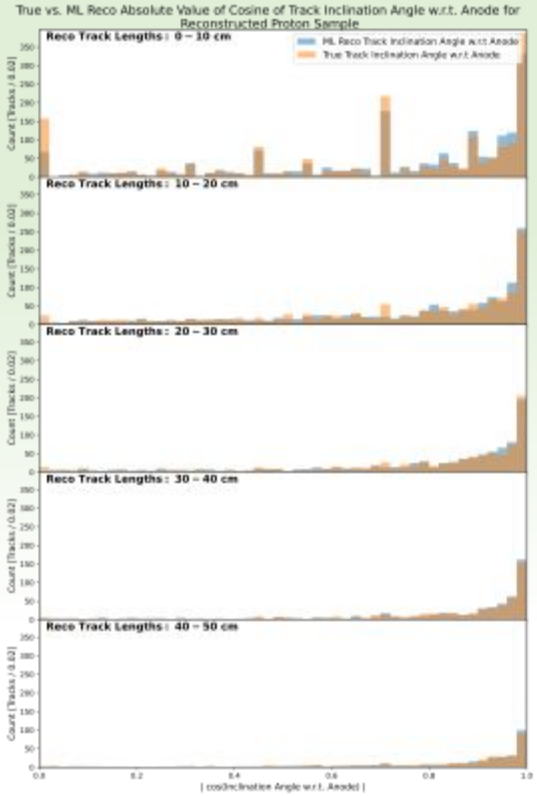


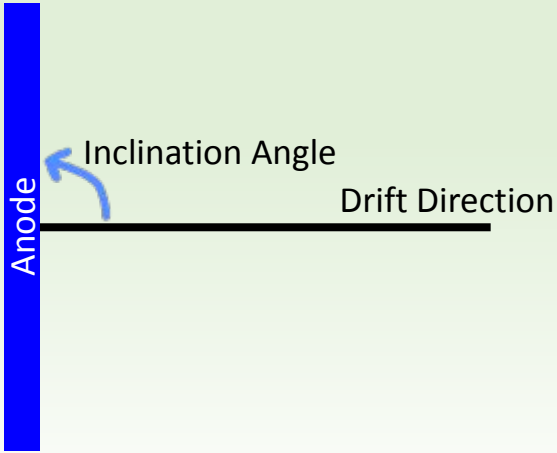


- Binned by reconstructed track length in 10 cm bins
- **Note:** log scale on y-axis

(Absolute value of the cosine of the)

Proton Inclination Angle

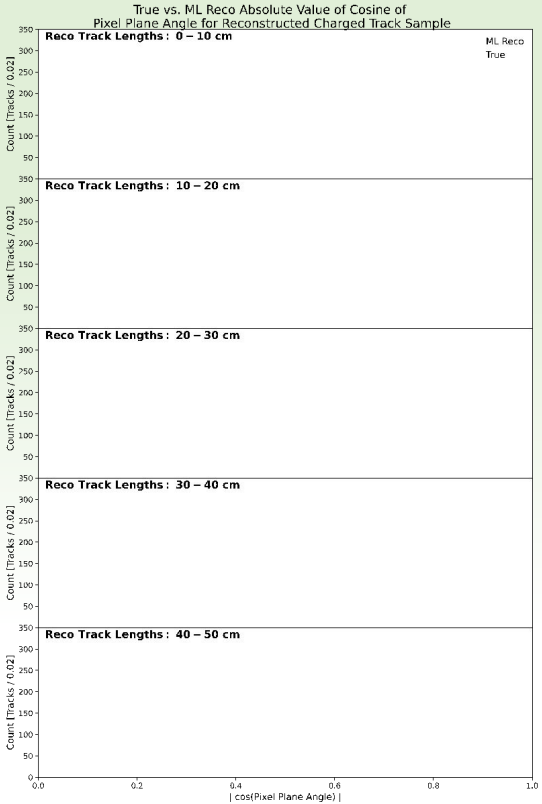


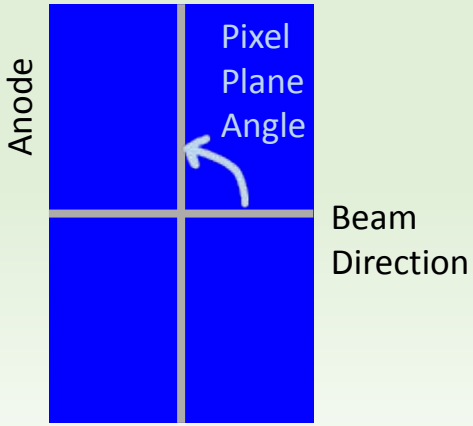


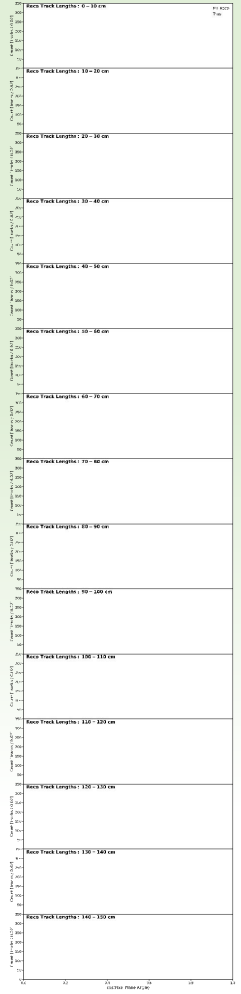
- Binned by reconstructed track length in 10 cm bins
- **Note:** normal scale on y-axis

(Absolute value of the cosine of the)

Charged Track Pixel Plane Angle*



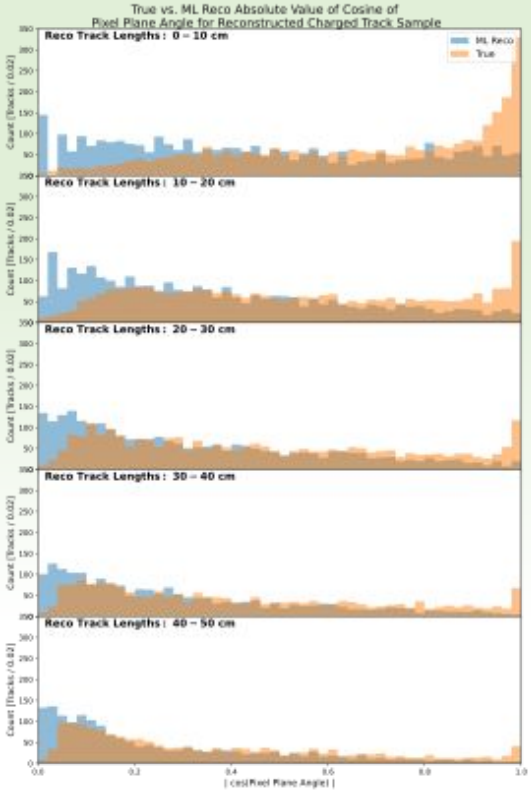


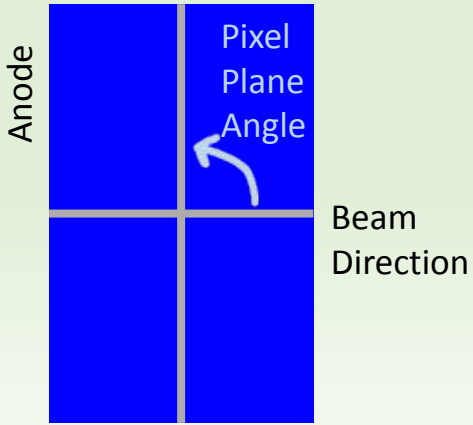


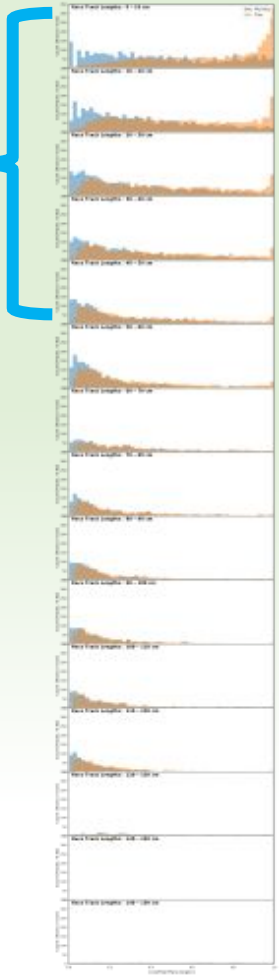
- Binned by reconstructed track length in 10 cm bins
- **Note:** log scale on y-axis
- For all tracks, clear difference in true vs. reco distributions

(Absolute value of the cosine of the)

Proton Pixel Plane Angle*

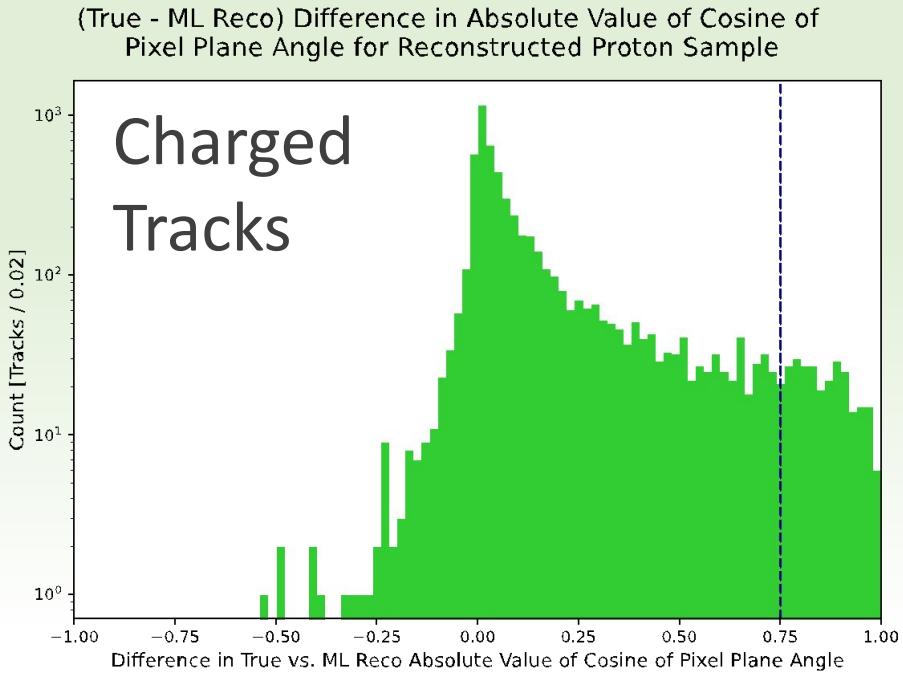


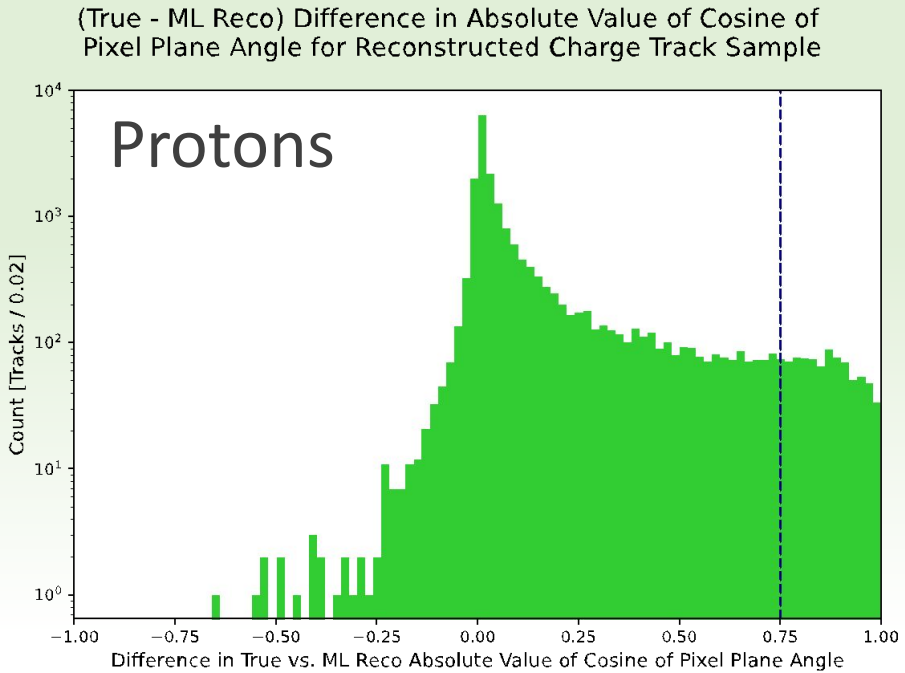




- Binned by reconstructed track length in 10 cm bins
- **Note:** normal scale on y-axis
- For all tracks, clear difference in true vs. reco distributions

Difference in Abs. Cos. of Pixel Plane Angle

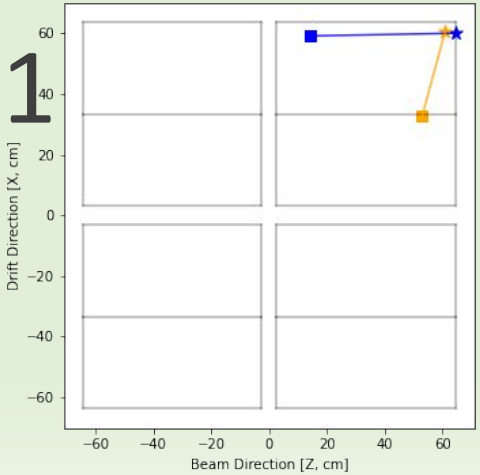




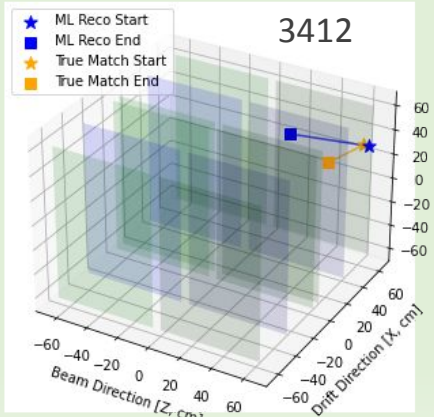
- Line at +0.75 difference □ filtered here and looked at true vs. reco tracks above this difference threshold

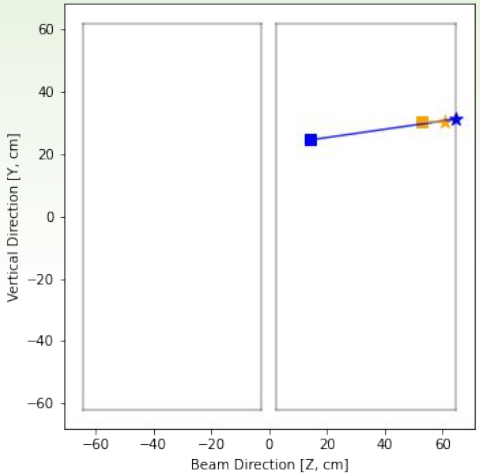
Ex: Charged Track #1

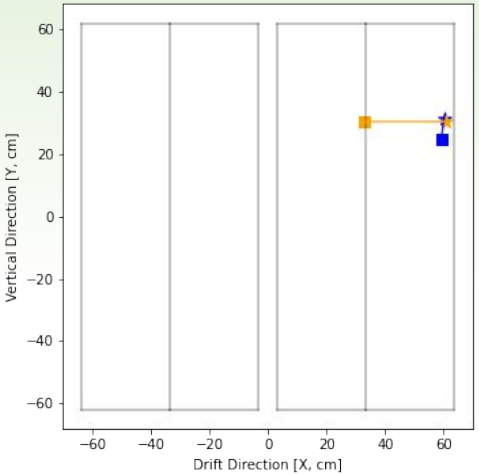
- Best alignment on “pixel plane” view (bottom left)



Track 3412

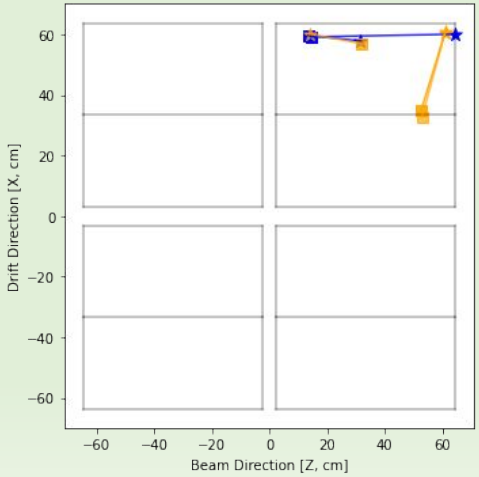




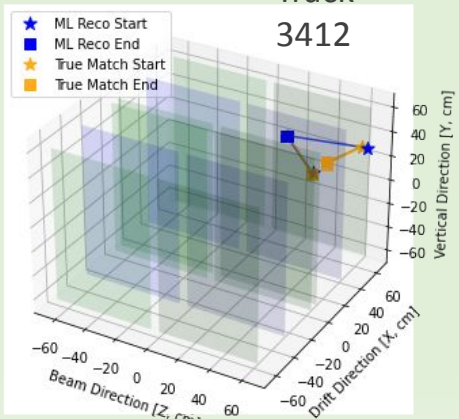


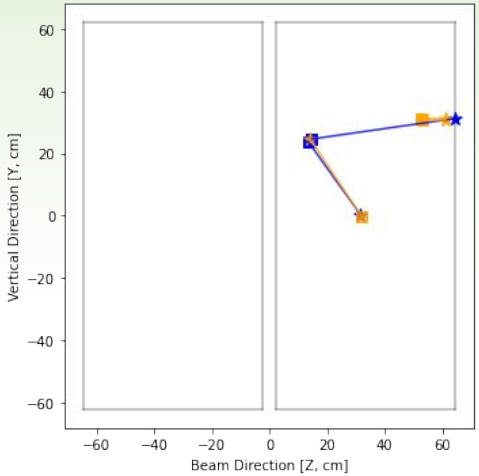
“Full Event” #1

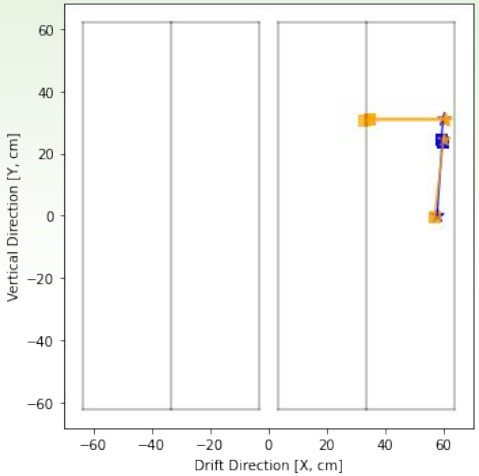
- **Reconstructed** tracks shown:
  - All reco tracks from same **file**, **spill**, and **reco interaction** as **reco** track in last slide
- **True** tracks shown:
  - All reco tracks from same **file**, **spill**, and **true interaction** as **true** track in last slide



Track 3412

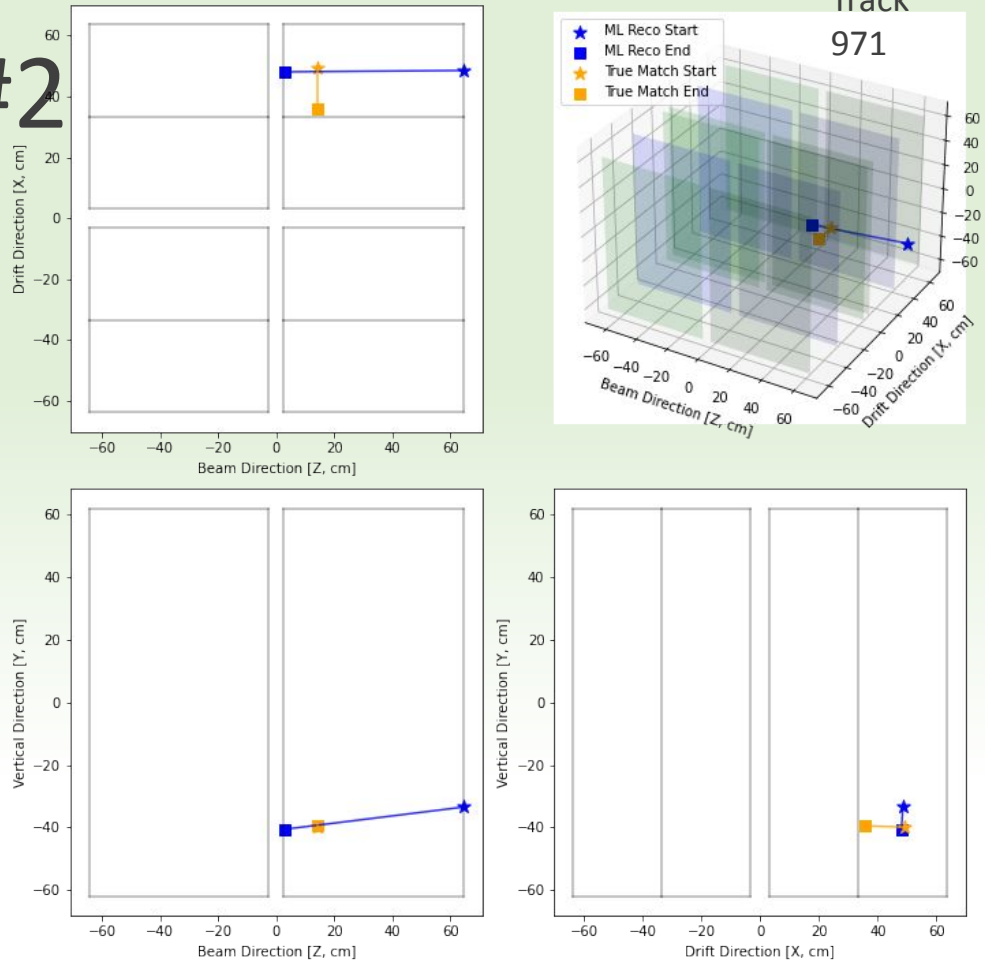






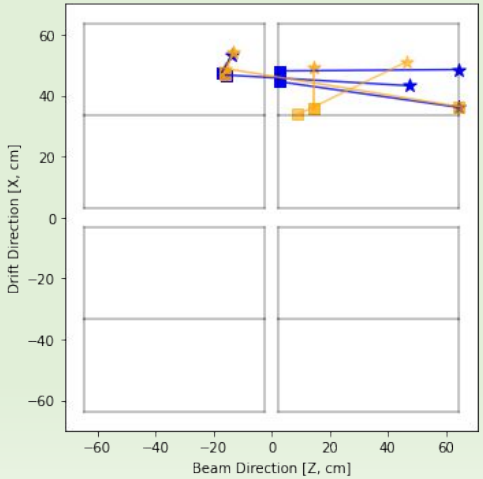
Ex: Charged Track #2

- Best alignment on “pixel plane” view (bottom left)

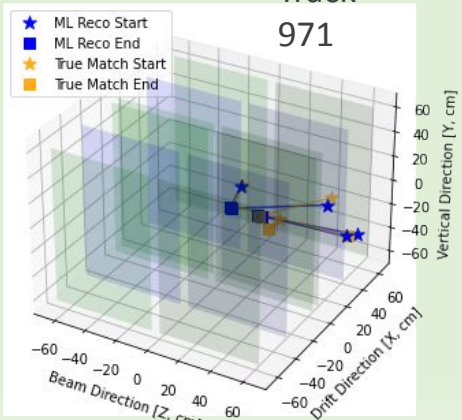


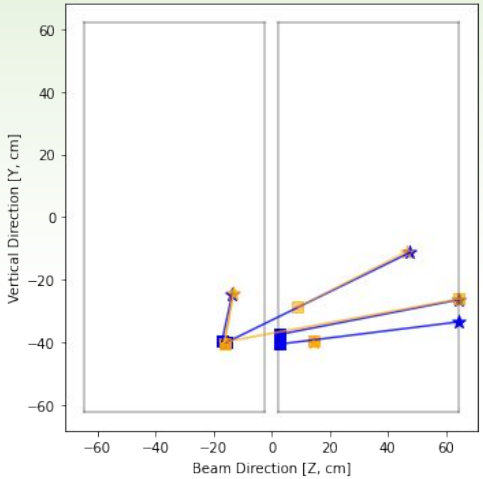
“Full Event” #2

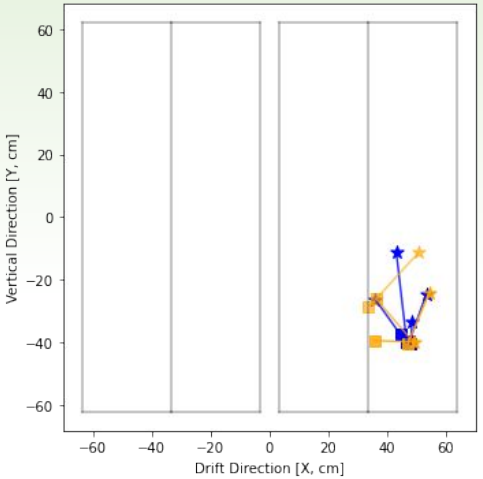
- **Reconstructed** tracks shown:
  - All reco tracks from same **file**, **spill**, and **reco interaction** as **reco** track in last slide
- **True** tracks shown:
  - All reco tracks from same **file**, **spill**, and **true interaction** as **true** track in last slide



Track 971

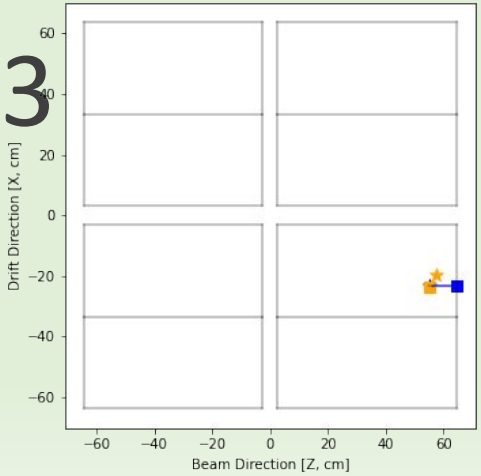




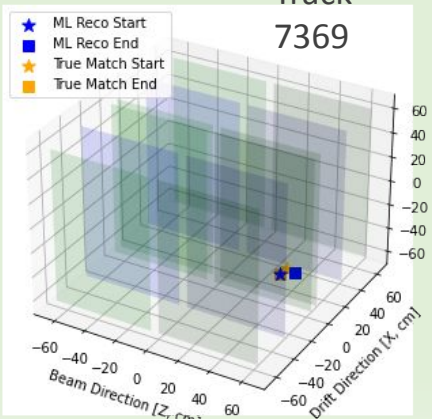


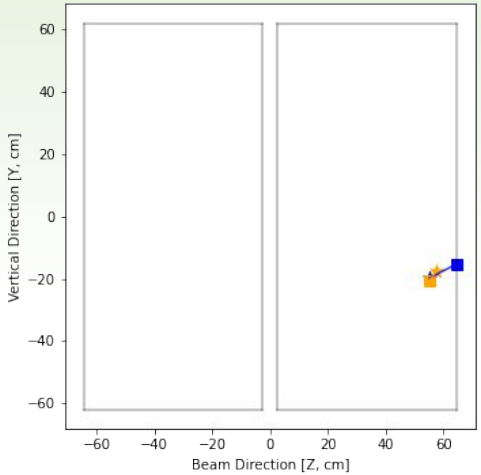
Ex: Charged Track #3

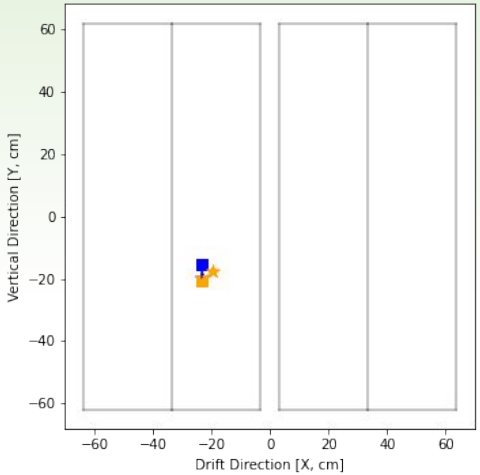
- Best alignment on “pixel plane” view (bottom left)
- Note that **true match end** and **ML Reco start** match better than true/reco start or true/reco end



Track 7369

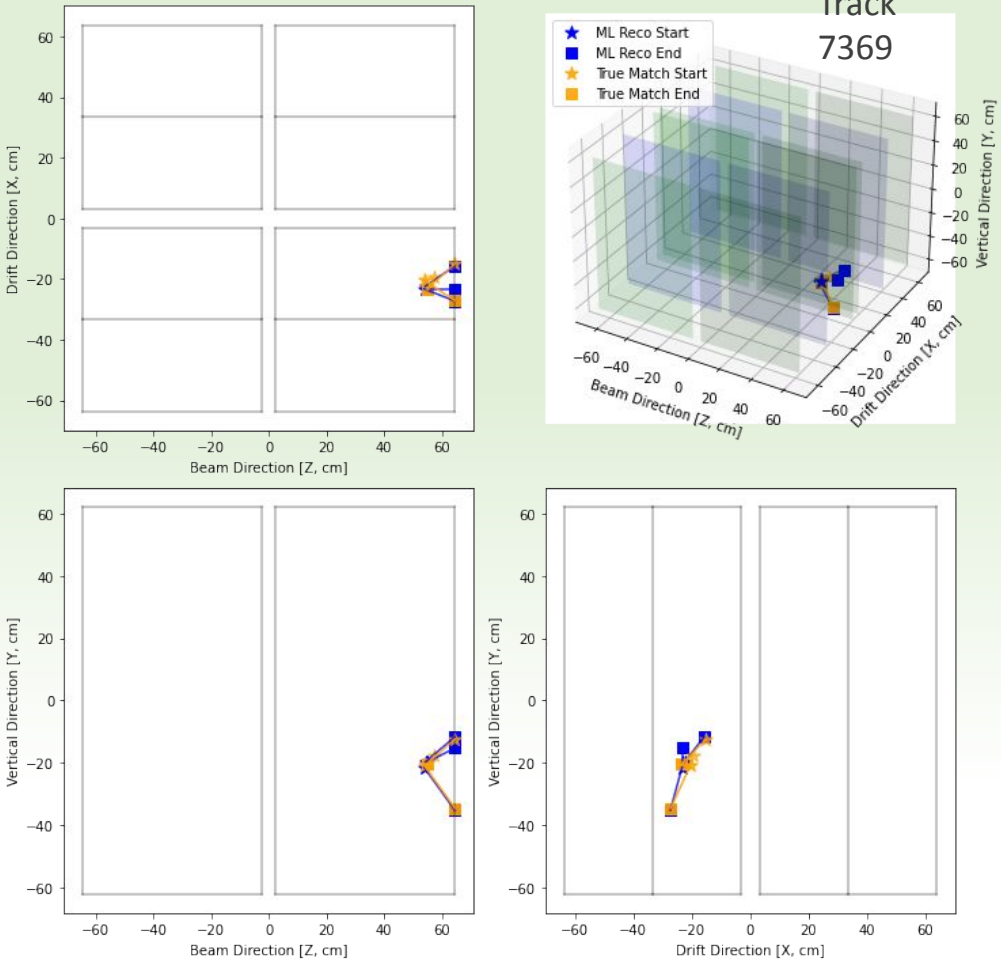






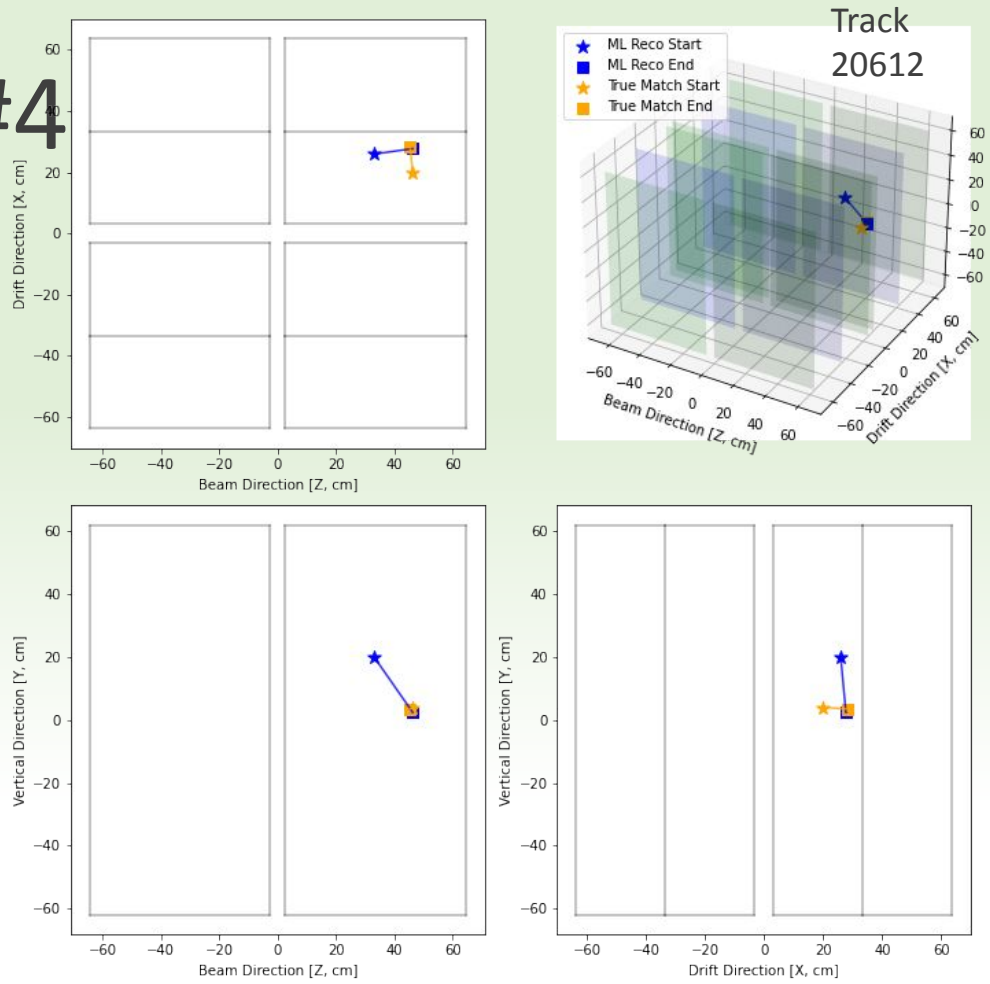
“Full Event” #3

- **Reconstructed** tracks shown:
  - All reco tracks from same **file**, **spill**, and **reco interaction** as **reco** track in last slide
- **True** tracks shown:
  - All reco tracks from same **file**, **spill**, and **true interaction** as **true** track in last slide



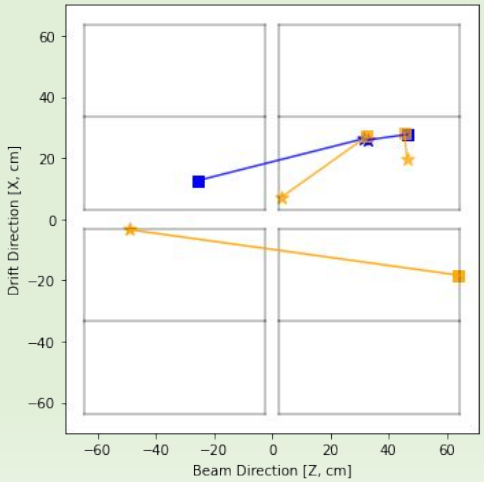
Ex: Charged Track #4

- Best alignment on “pixel plane” view (bottom left)

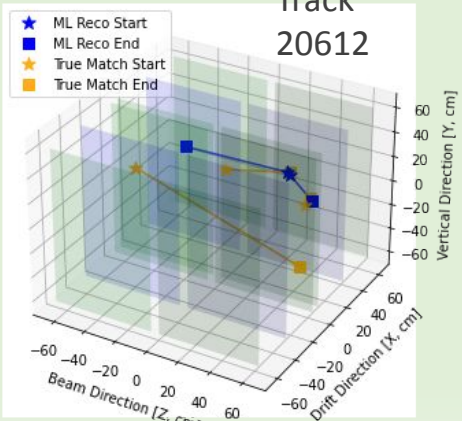


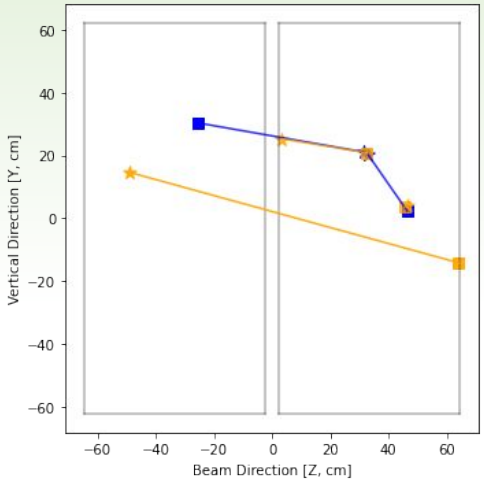
“Full Event” #4

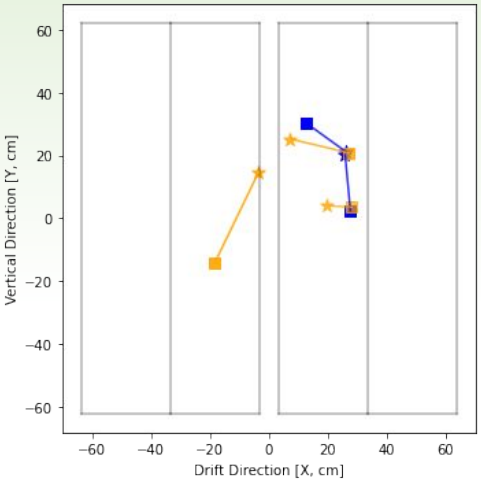
- **Reconstructed** tracks shown:
  - All reco tracks from same **file**, **spill**, and **reco interaction** as **reco** track in last slide
- **True** tracks shown:
  - All reco tracks from same **file**, **spill**, and **true interaction** as **true** track in last slide



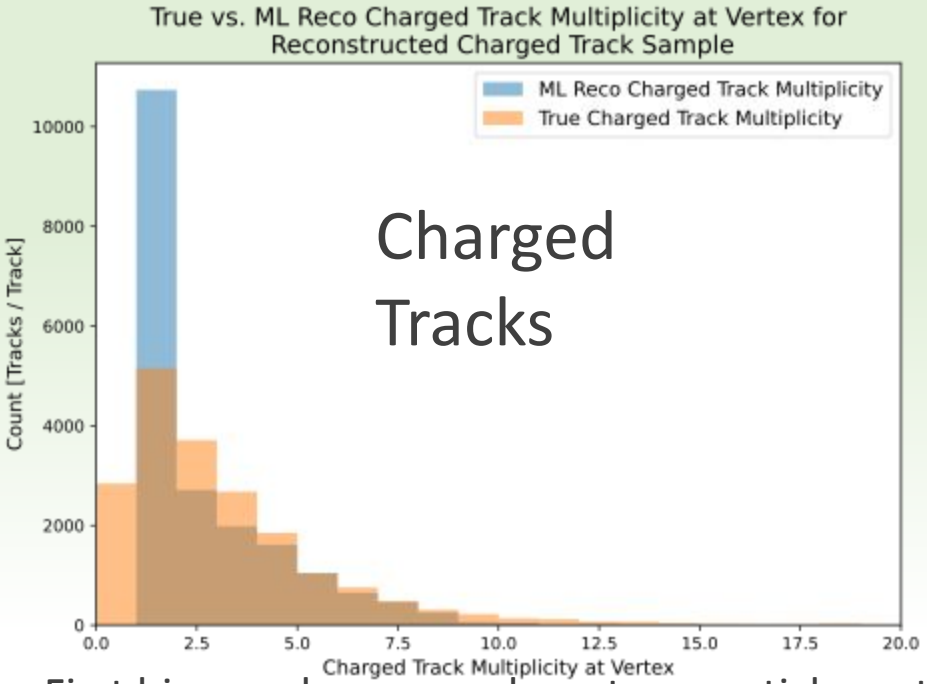
Track 20612

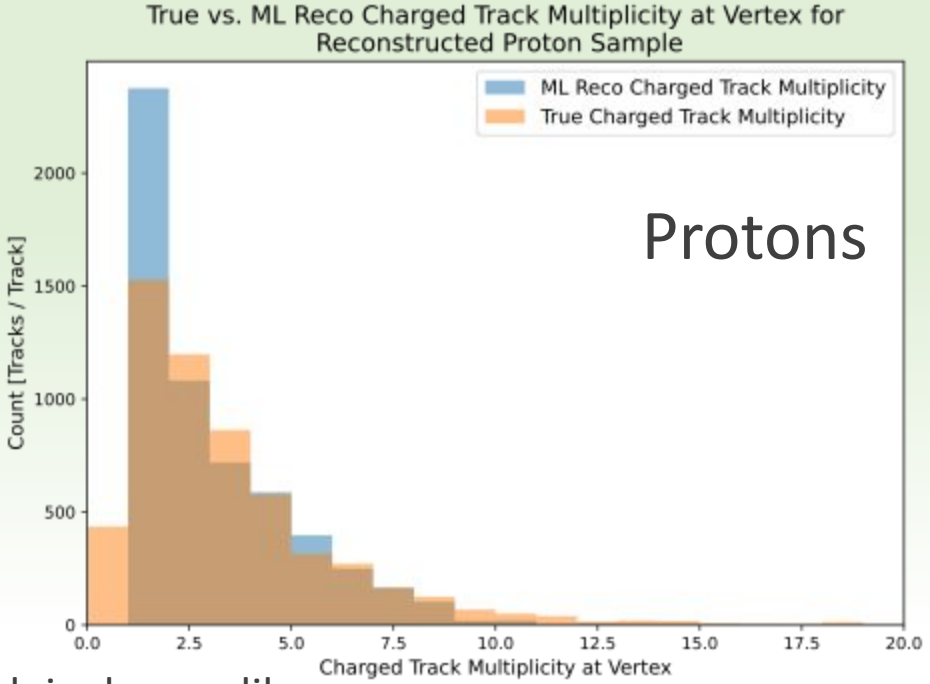






Track Multiplicity at Vertex





- First bin may be cases where true particle match is shower-like
- In the future, will look at kinematics by true track multiplicity at vertex to get a better understanding of reconstruction fidelity in high activity environments

Future Studies

- Break down plots I showed in terms of different variables (e.g. by charged track multiplicity at the vertex, by start/end position, etc.) to **identify specific failure modes**
- Similar studies w/ **reflowed Bern data/new cosmics samples** run through ML Reco
- Look at **proton thresholds** using a sample of true protons
- Create **samples of TRUE protons and charged tracks** and make plots similar to what I've shown here
- Make **efficiency vs. purity** plots with reco protons, charged tracks
- Make plots such that they can be **easily reproduced** for new iterations of ML Reco (i.e. when it is retrained)
- Make **more informative full event display** to see all activity vs. single set of matched tracks

Additional Comments from Others

- Look at angles based on Cartesian coordinates
- Look at differences true vs. reco angles and start/end positions
- Look at events for particular failure modes in official ML Reco event display
- Look at events with different “overlap” amounts true vs. reco