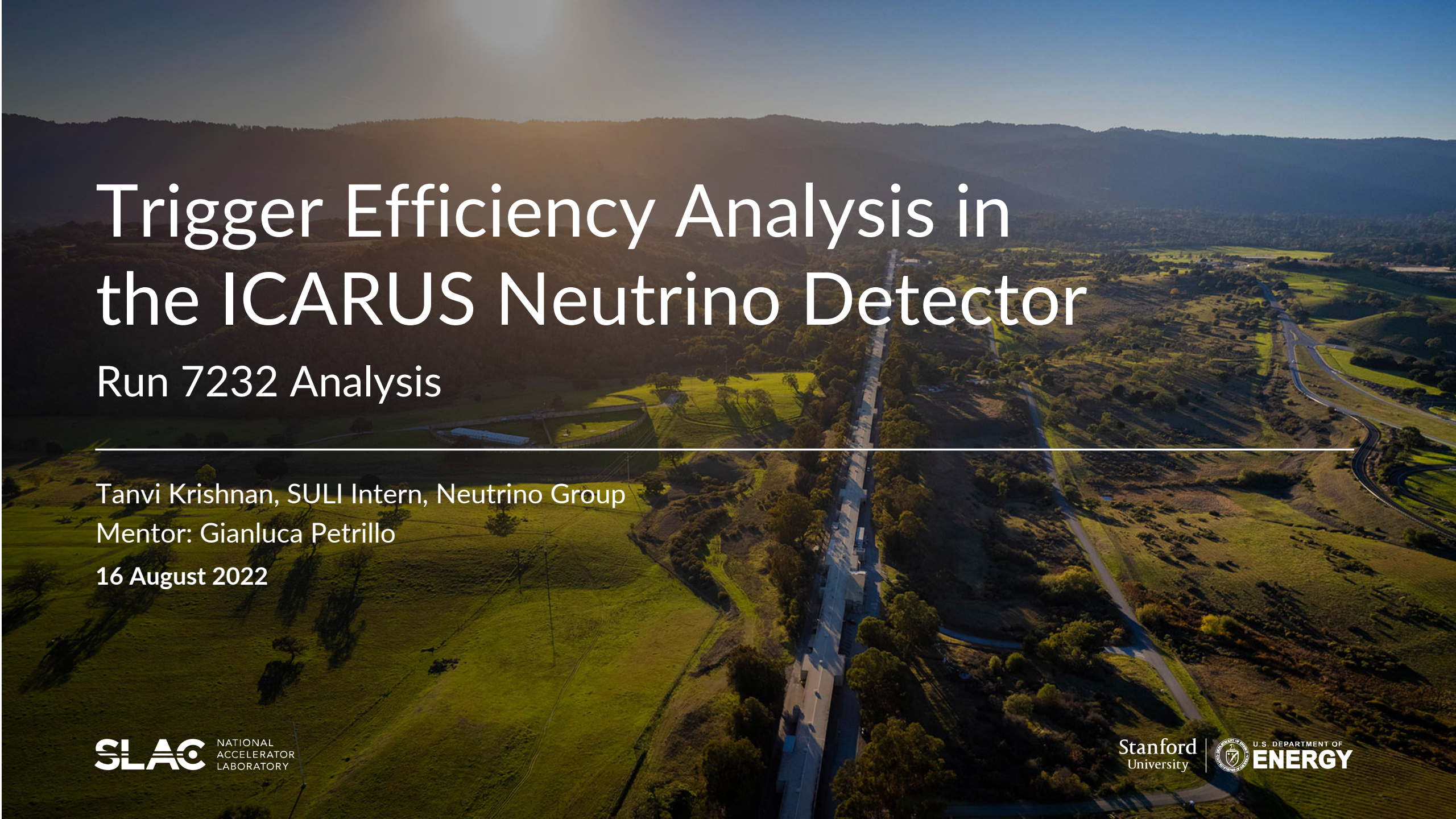

Trigger Efficiency Analysis in the ICARUS Neutrino Detector

Run 7232 Analysis

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16 August 2022

SLAC NATIONAL ACCELERATOR LABORATORY

Stanford University | U.S. DEPARTMENT OF ENERGY

Agenda

1 Efficiency Analysis

2 The 2m Track Anomaly

3 Other Possible Considerations

4 Conclusions and Next Steps

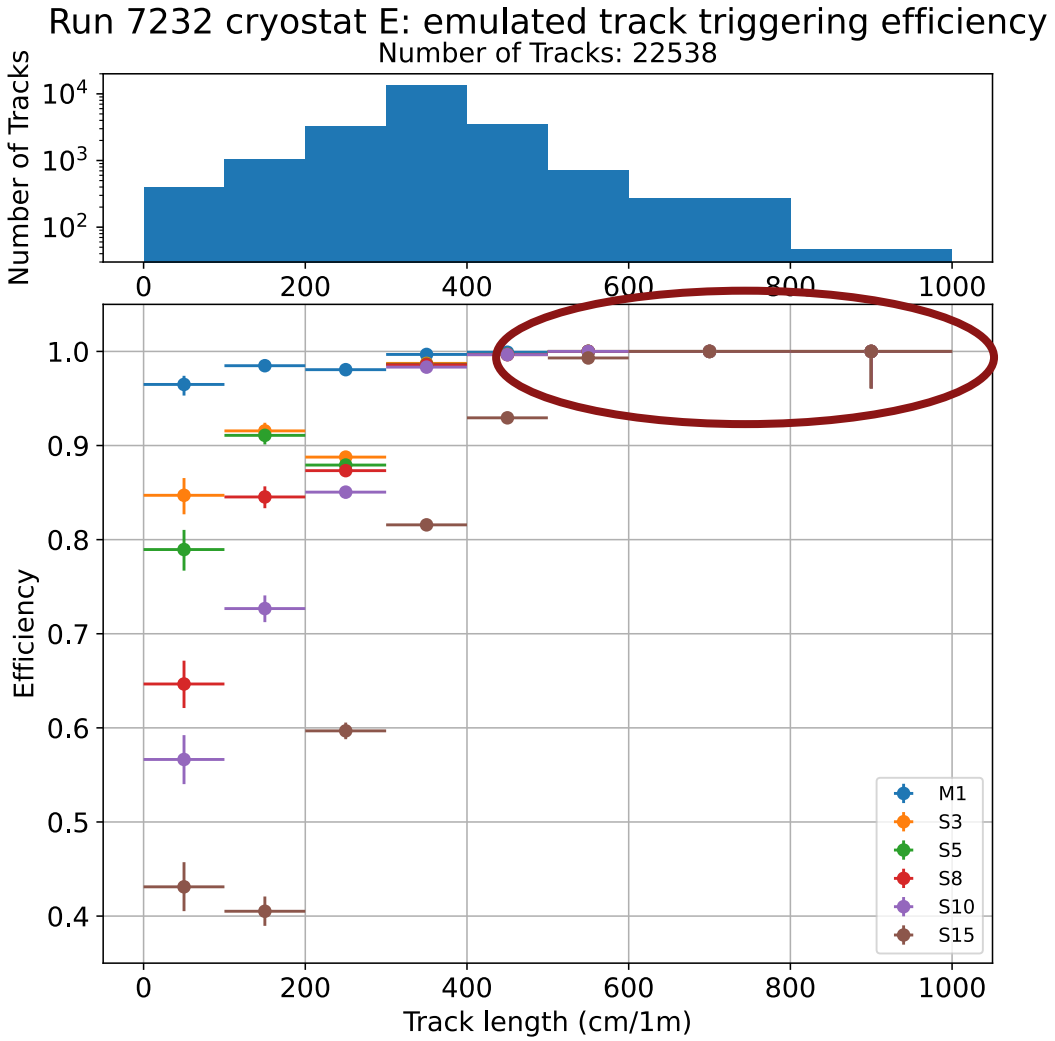
Efficiency Analysis

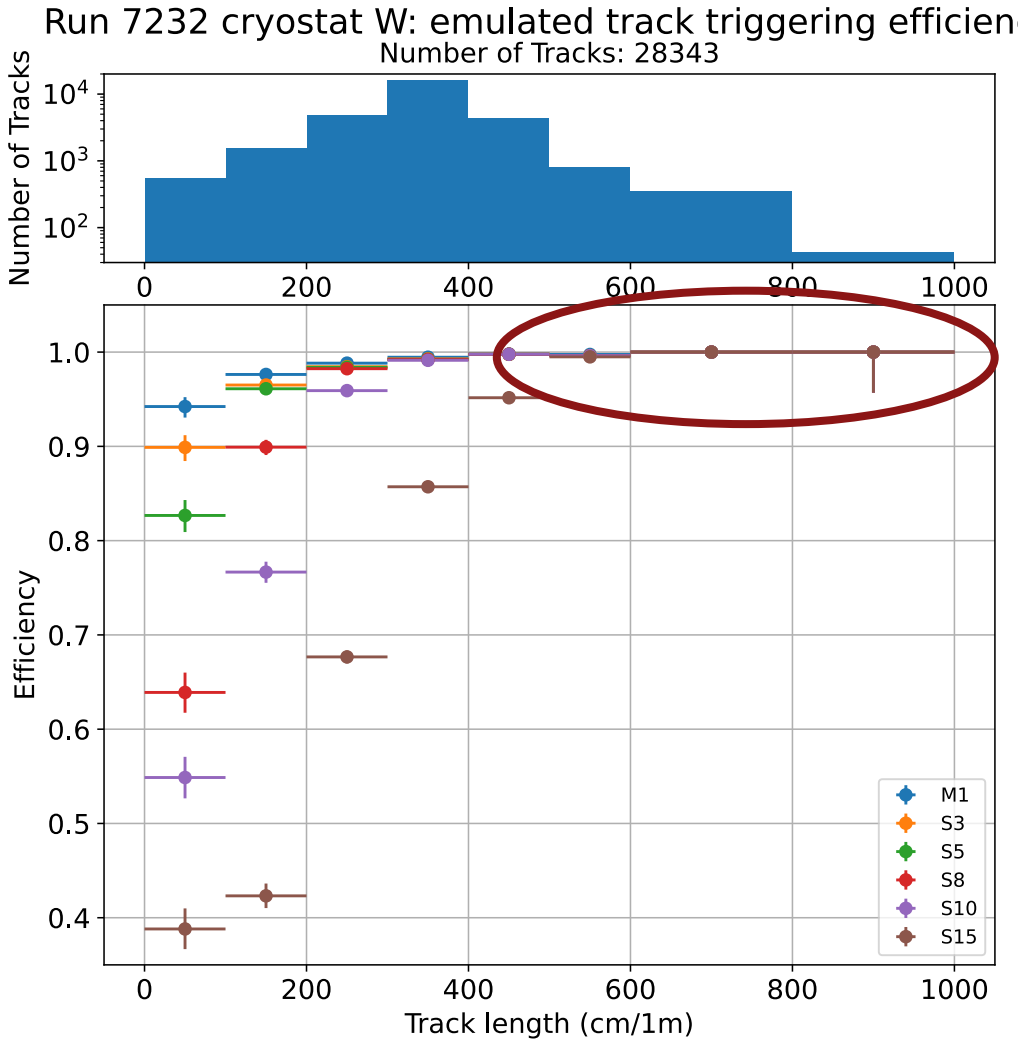
What does our data look like?

- "Minimum bias" run from November 30, 2021
  - Data collected without hardware trigger constraints
  - Software used to emulate trigger performance under different light requirement levels
- Cathode-crossing tracks only
  - Only tracks for which we can reconstruct the time without biasing trigger efficiency measurement
  - Hope to look at tracks that don't cross cathode in the future, reducing sample bias

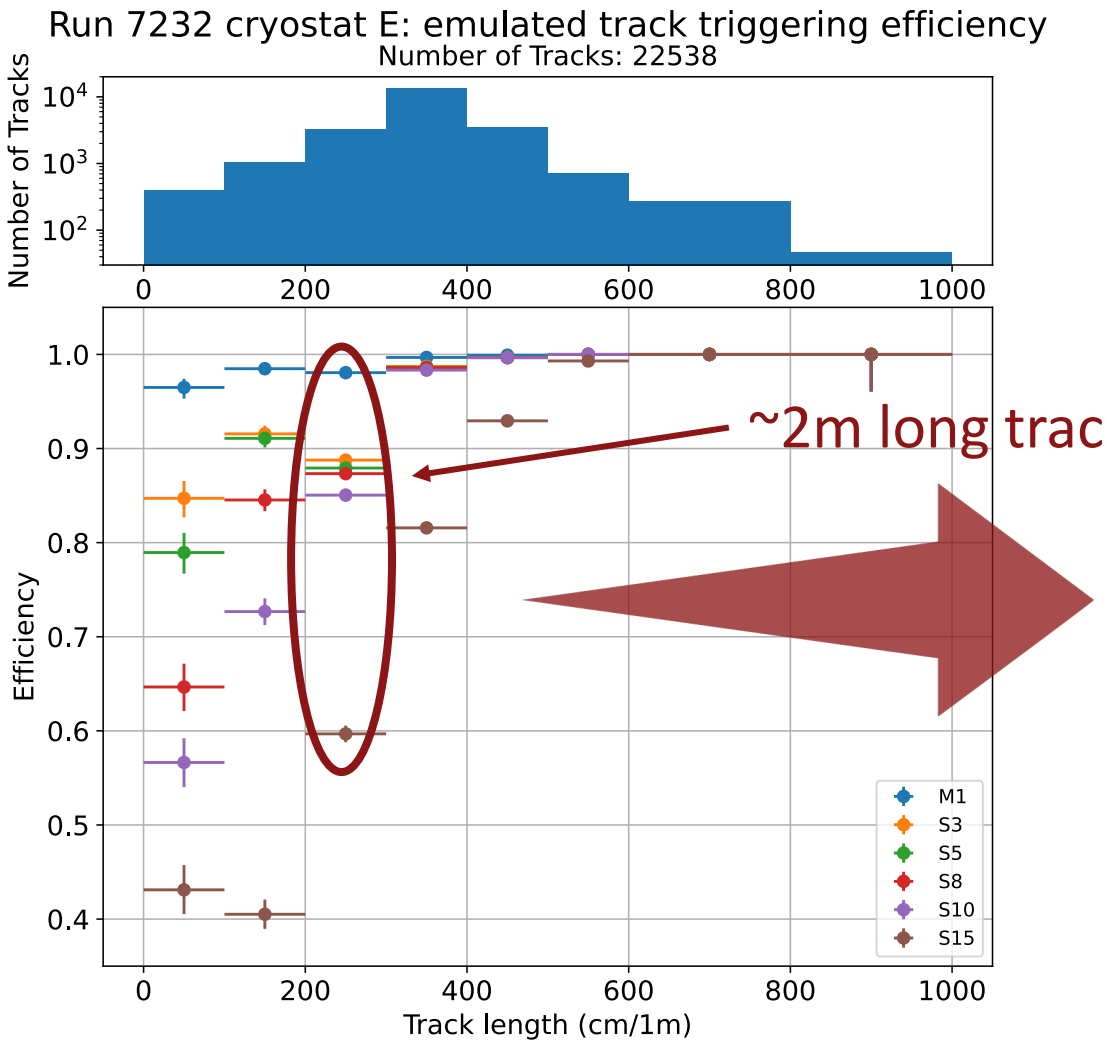
$$\text{Efficiency} = \frac{\text{selected tracks that would trigger}}{\text{selected tracks}}$$

Efficiency of Trigger as a function of Track Length

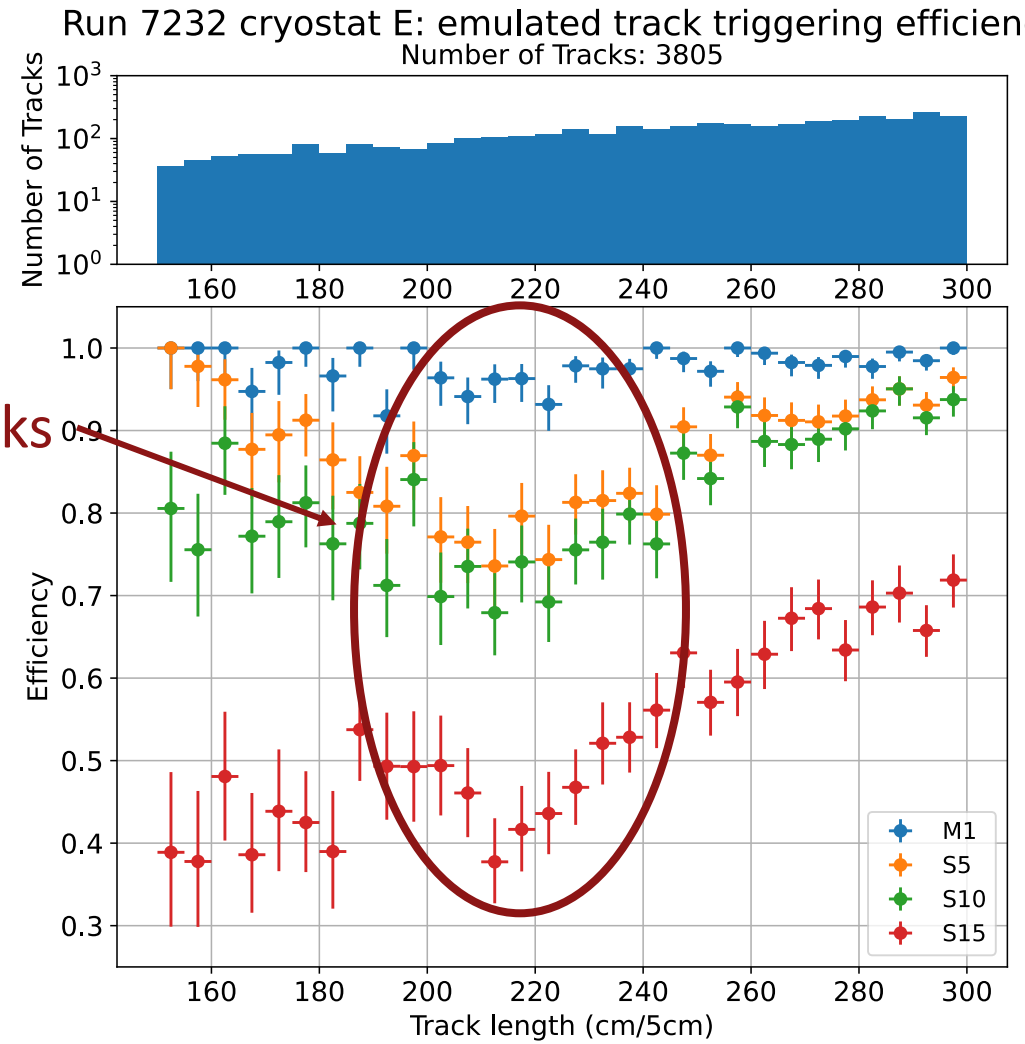




Efficiency of Trigger as a function of Track Length



~2m long tracks



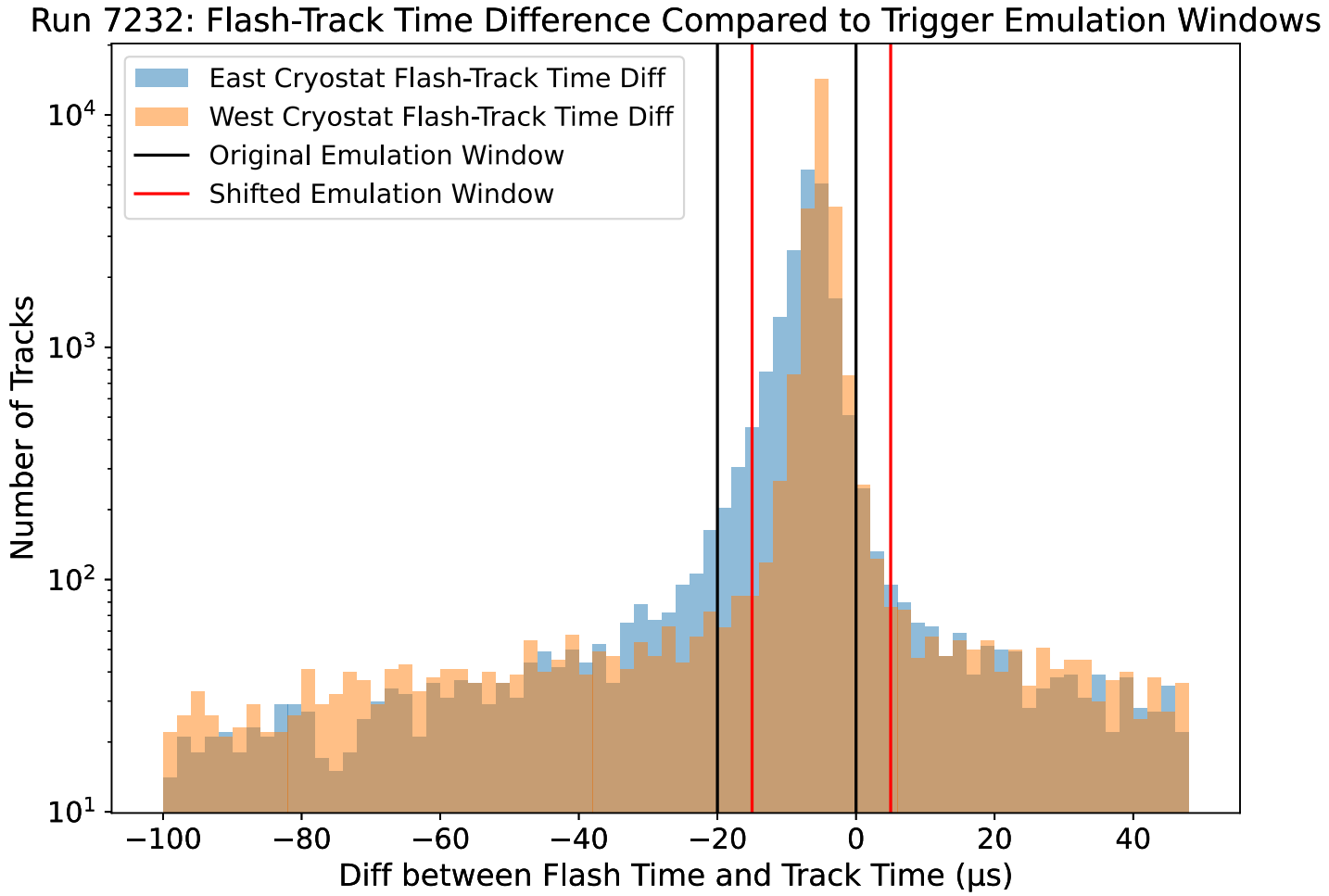
The 2m Track Anomaly

The 2m Track Anomaly

Tracks ~2m in length have a noticeably lower efficiency than slightly shorter or longer tracks

- Especially evident in East cryostat but also present in West cryostat (less severely)
- No noticeable spatial pattern for non-triggering tracks
- Statistics limited for current dataset, hoping a newer run will provide more insight

Shifting the Trigger Emulation Window

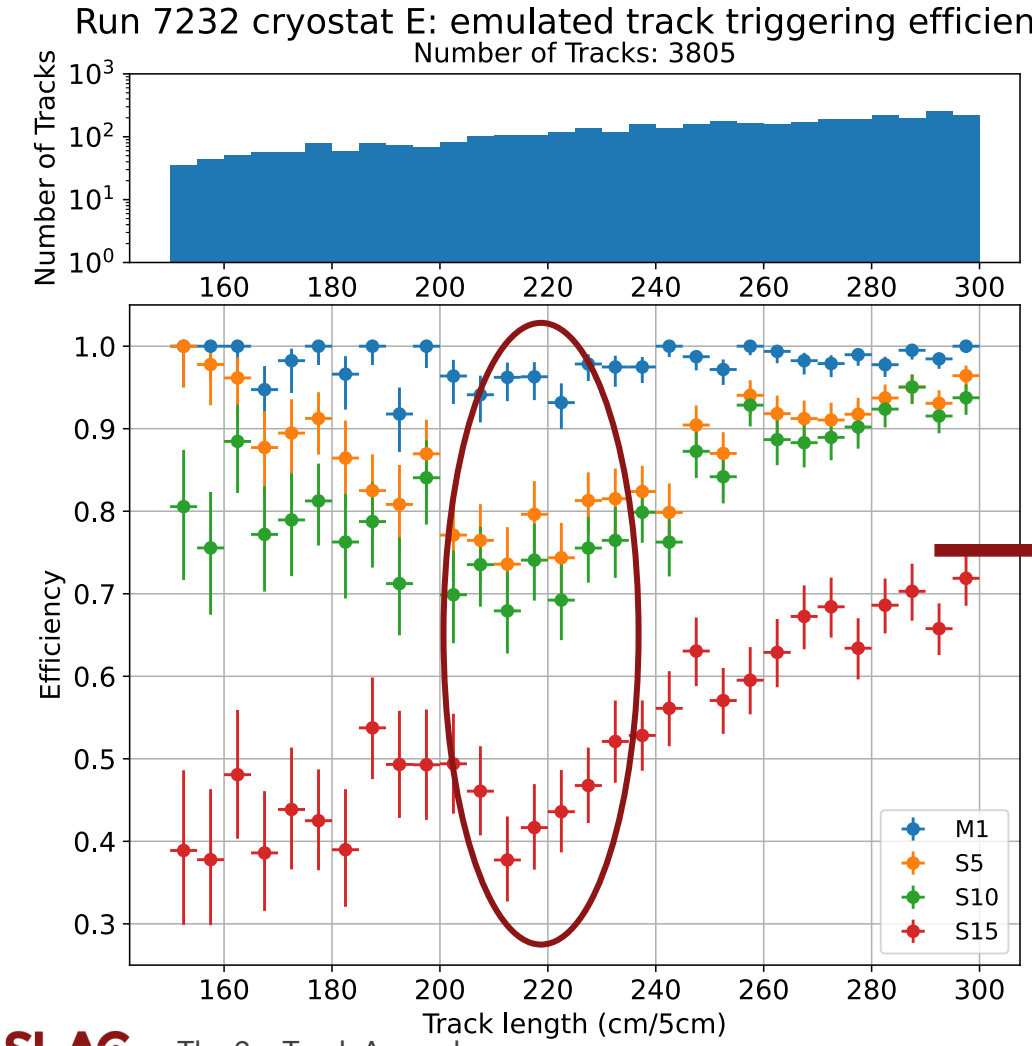


Possible Solution:

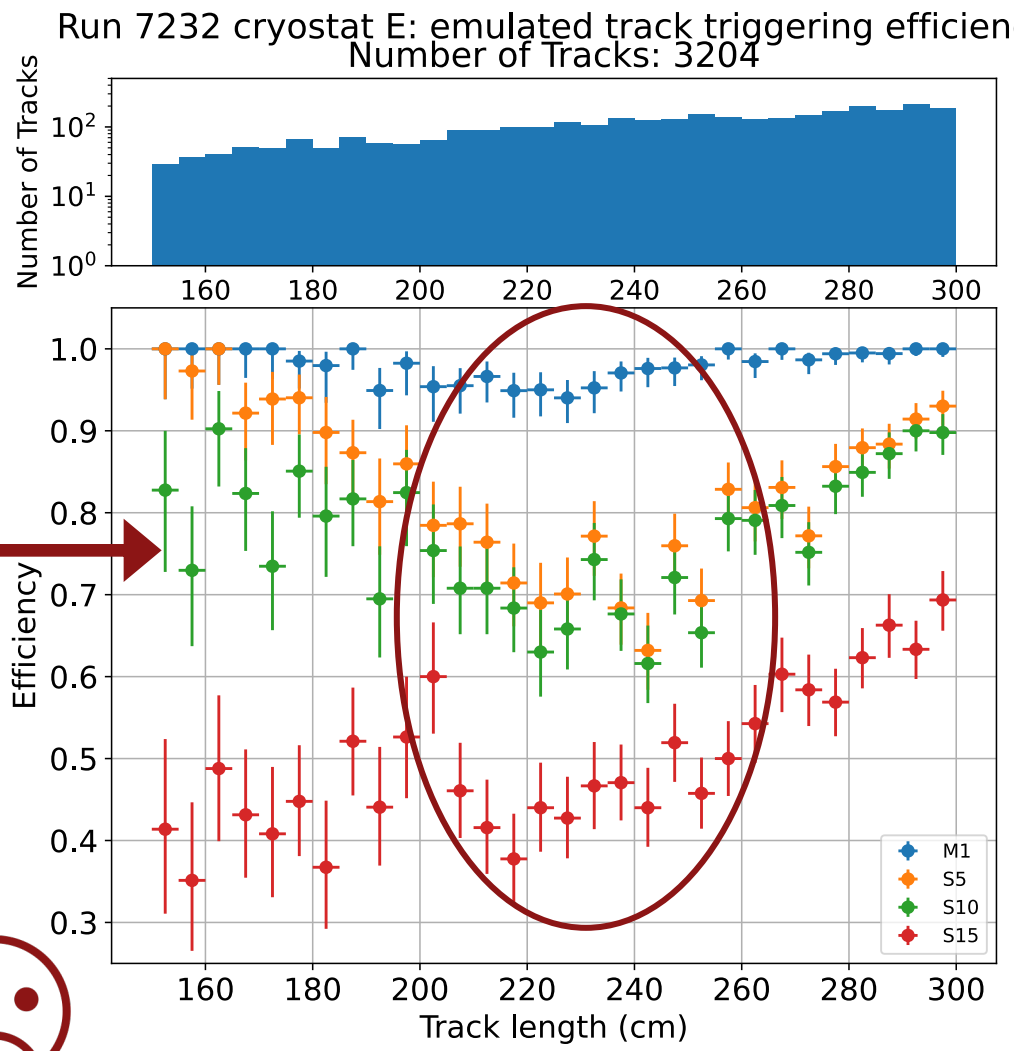
- In Trigger Emulation software, we look for light in a 20 µs window before the track time (t0), and check whether that light exceeds chosen light requirement level
- Most tracks of length ~2m that failed to trigger matched to light occurring <5µs after t0
- Shifted window later by 5 µs to see whether overall efficiency improved

Shifting the Trigger Emulation Window: East Cryostat

Original Emulation Window

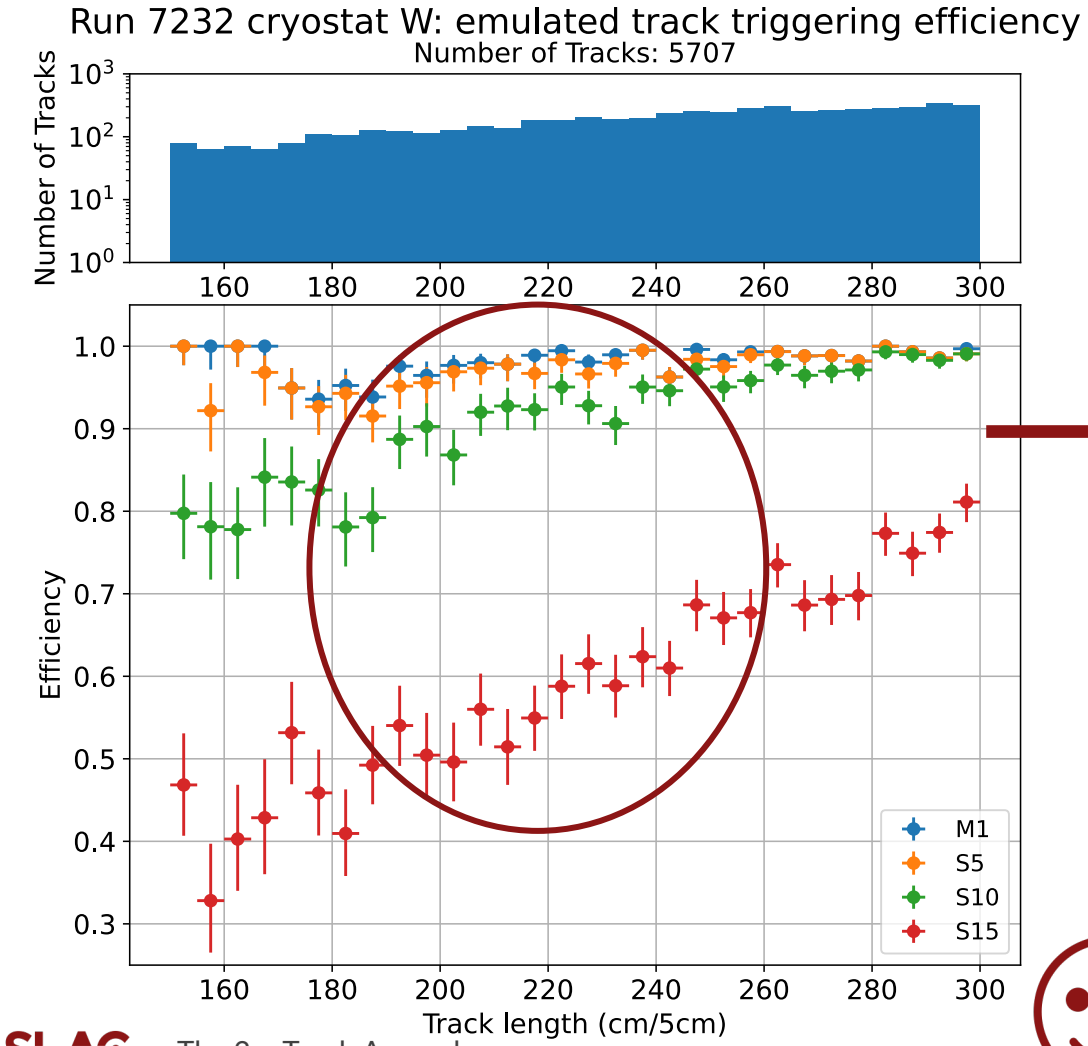


Shifted Emulation Window

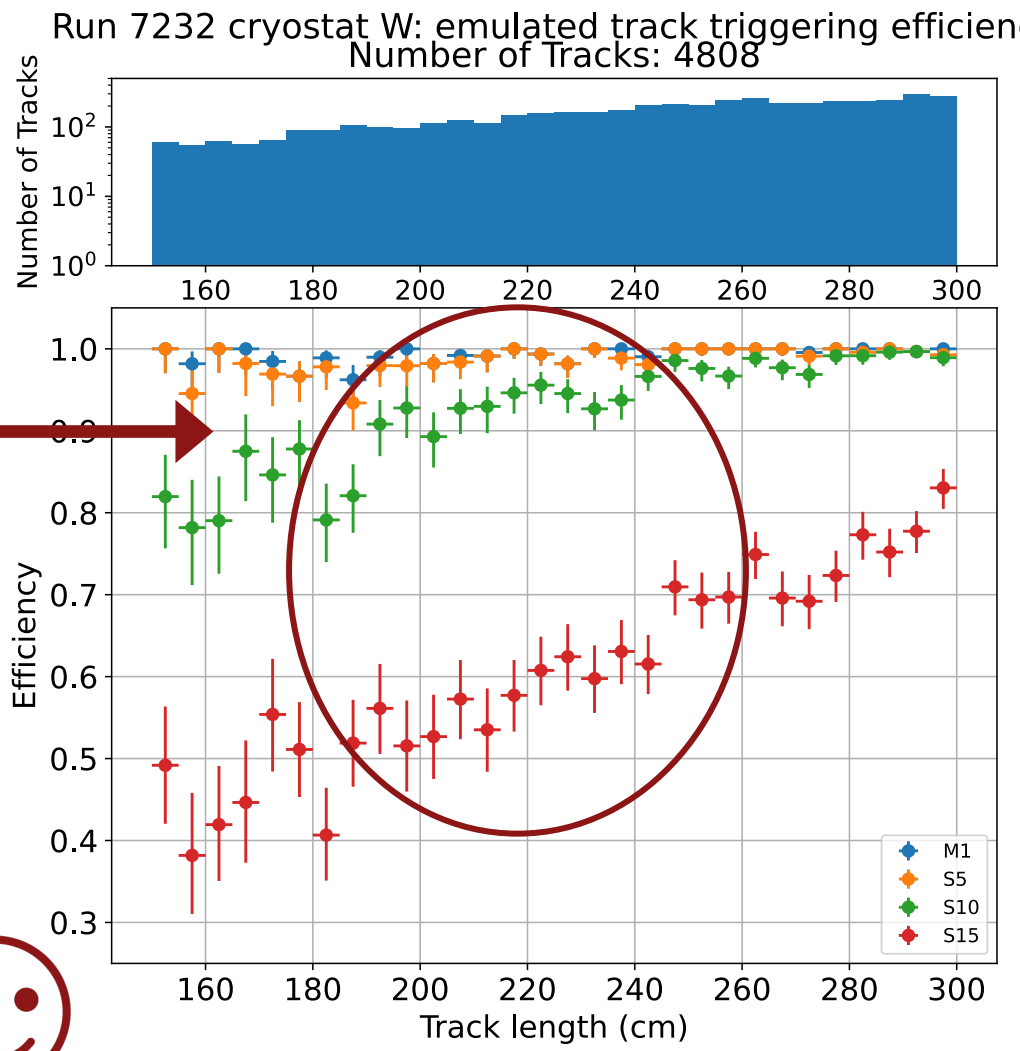


Shifting the Trigger Emulation Window: West Cryostat

Original Emulation Window



Shifted Emulation Window



Other Possible Considerations

Potential Causes of the 2m track anomaly

Possible connections

1. Shifting trigger emulation window, t0 reconstruction
   - Somewhat for 2m tracks
2. Length balance ratio of tracks on either side of cathode
3. Smaller track component along the z-axis, large track component along the x-axis
   - Not specific to 2m tracks (geometric bias)
4. Border distortions of electric field
5. Y-axis cathode-crossing position
   - Lower visibility of photons at high y-values
   - Photons lost if they hit the field cage, fewer PMTs at high y-values

Ruled out connections

1. Not time dependent
2. Not from cathode bending
   - Cathode bending shouldn't greatly affect t0 reconstruction
3. Not specific to y-direction of tracks
4. Likely not due to split tracks during track reconstruction
   - From what we saw of the event display (not a statistically significant sample)
   - Also, most tracks appear to go from one edge of cryostat to another (>60% have at least 1 endpoint at an edge of the cryostat)

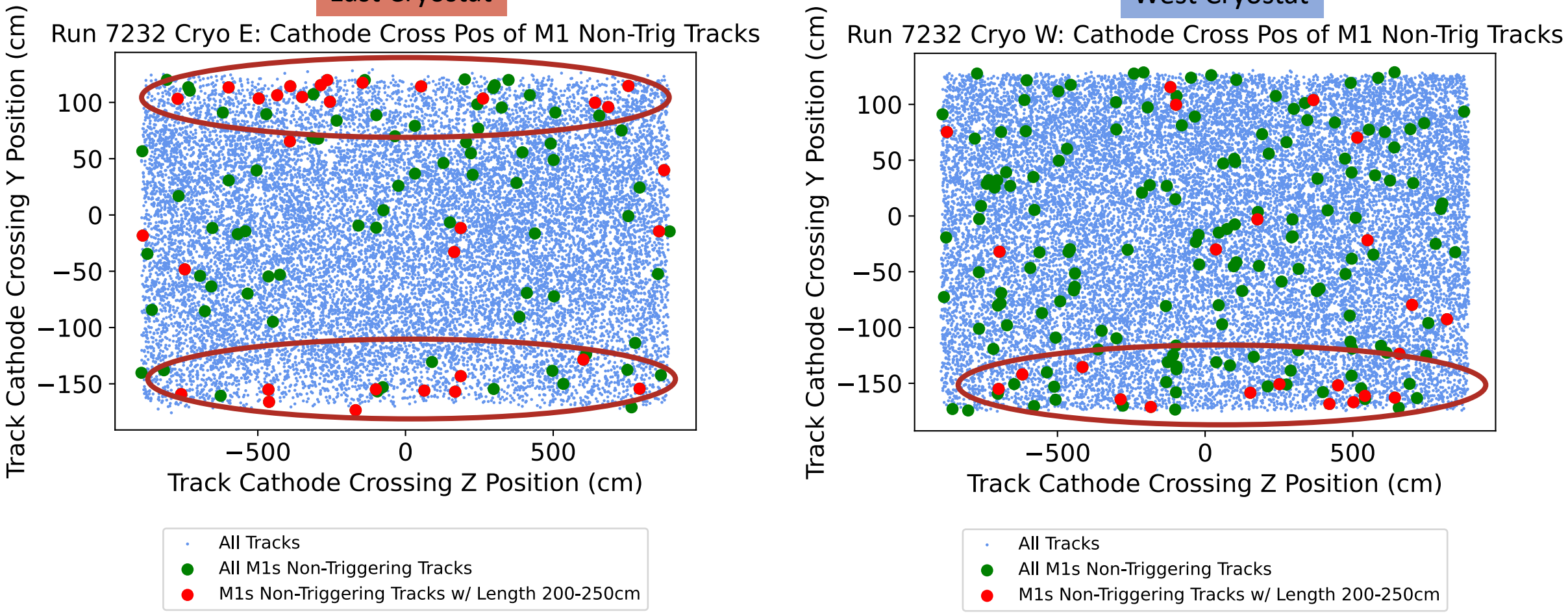
Possible connection:

Y-axis cathode-crossing position

East Cryostat

(-20 µs, 0 µs) Emulation Window

West Cryostat



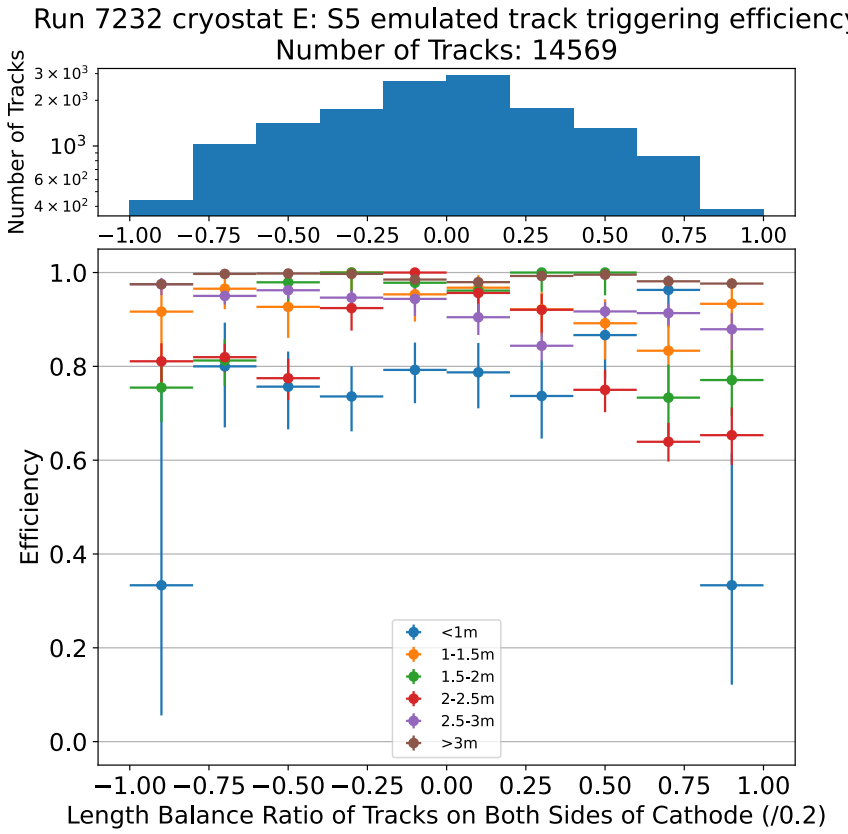
Possible connection:

Length balance ratio of tracks on either side of cathode

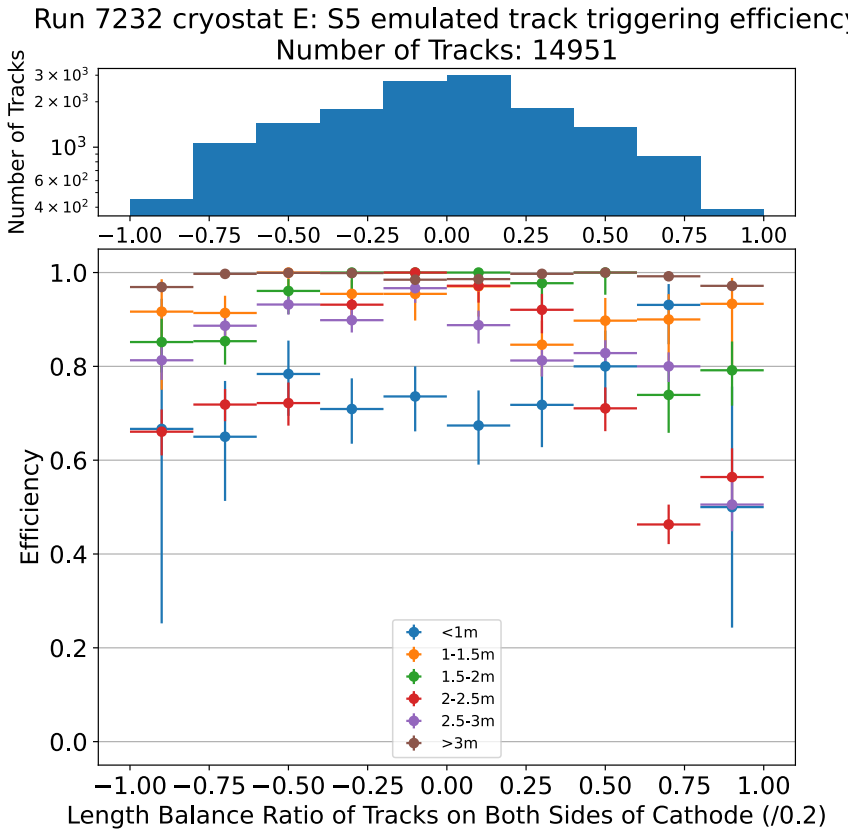
Balance Ratio	≈ -1	≈ 0	≈ 1
Primary TPC of Track	East	Both	West

East Cryostat

(-20 µs, 0 µs) Emulation Window



(-15 µs, 5 µs) Emulation Window



Possible connection:

Length balance ratio of tracks on either side of cathode

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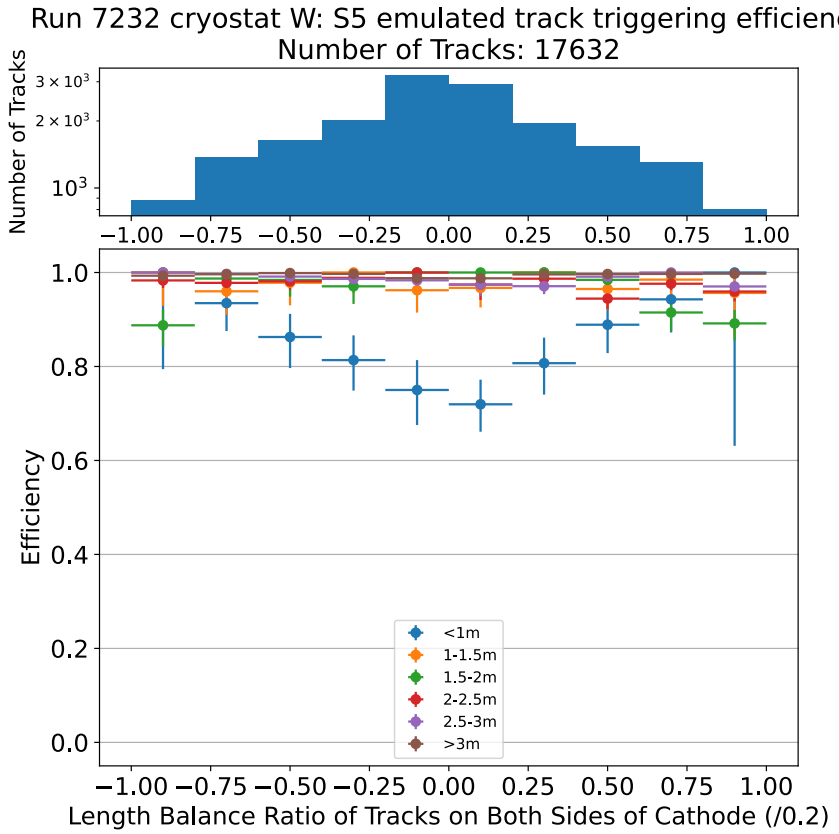
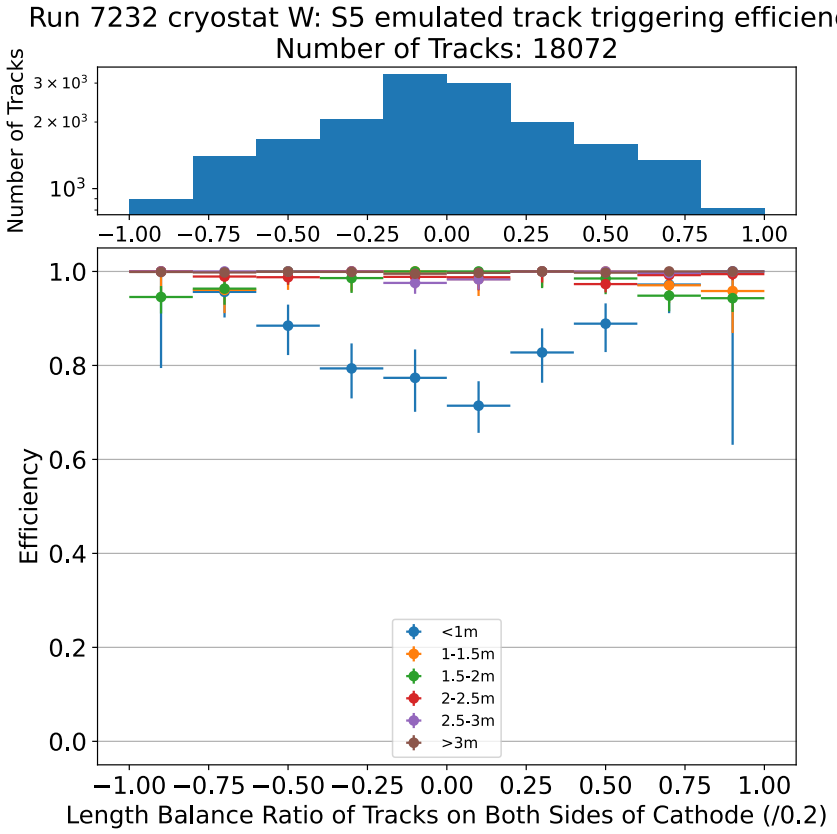
Primary TPC of Track	East	Both	West

West Cryostat

(-20 µs, 0 µs) Emulation Window



(-15 µs, 5 µs) Emulation Window

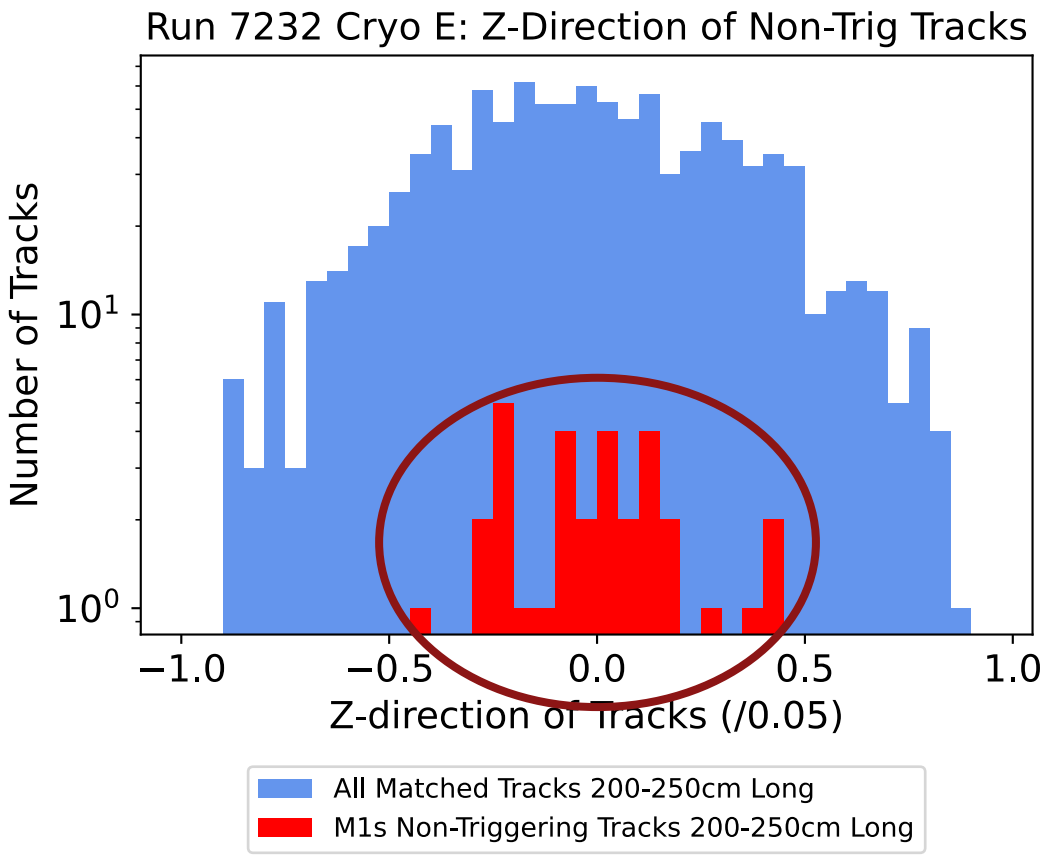


Possible Connection:

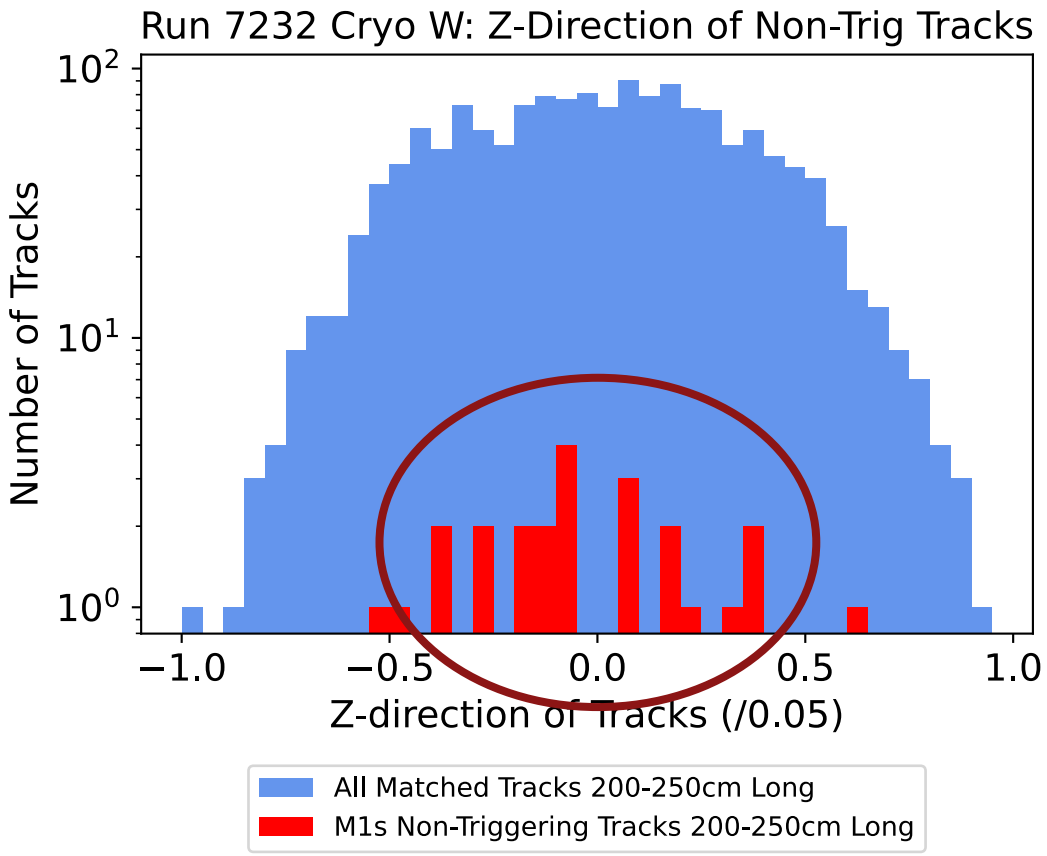
Smaller track angle along the z-axis

(-20 µs, 0 µs) Emulation Window

East Cryostat



West Cryostat

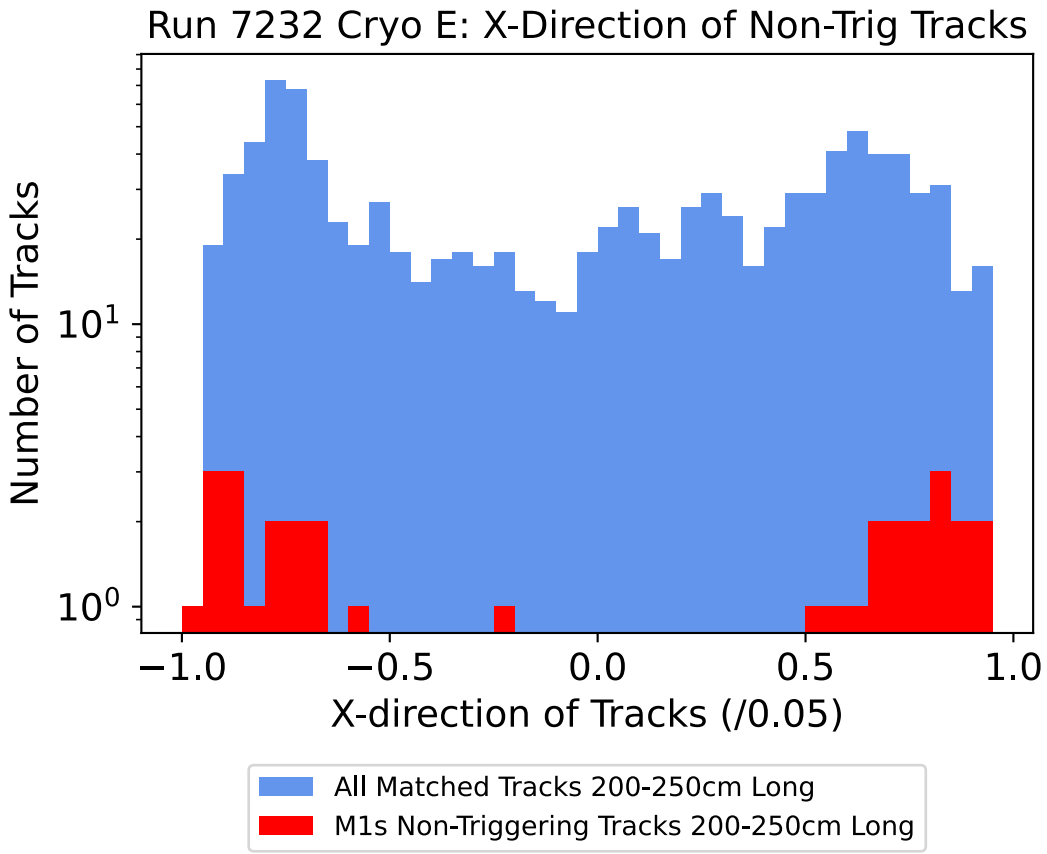


Possible Connection:

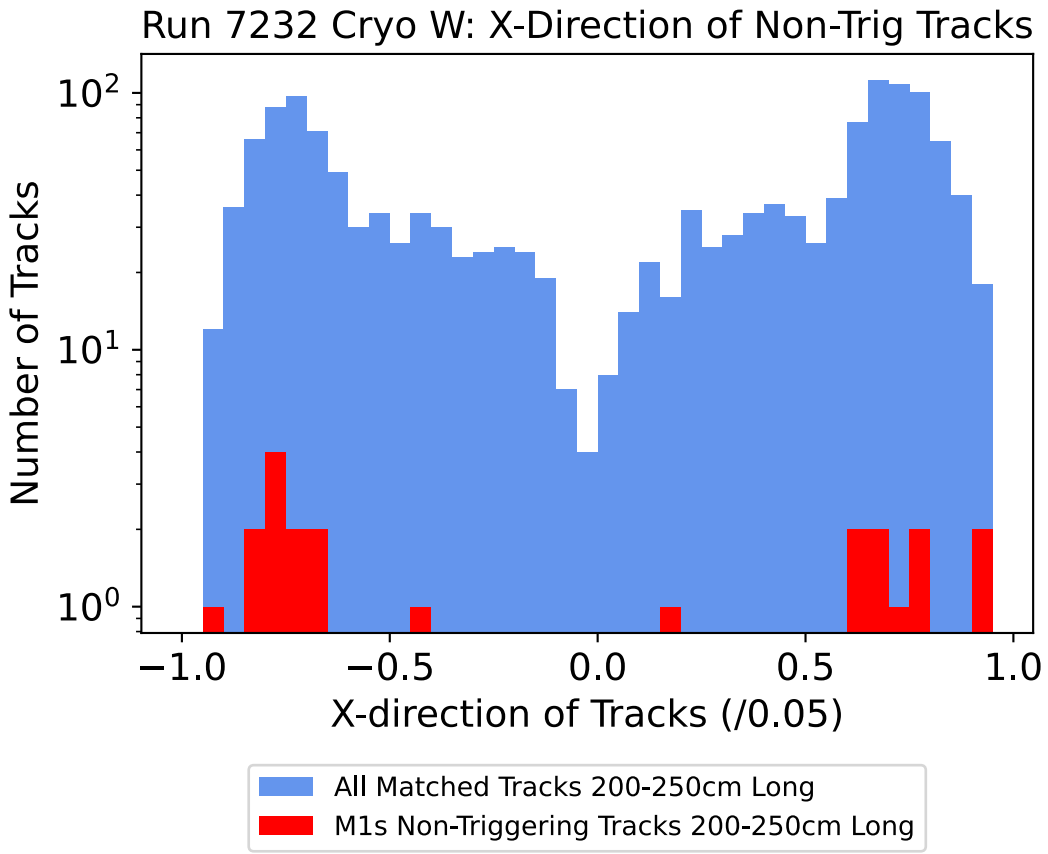
Large track angle along the x-axis

(-20 µs, 0 µs) Emulation Window

East Cryostat



West Cryostat



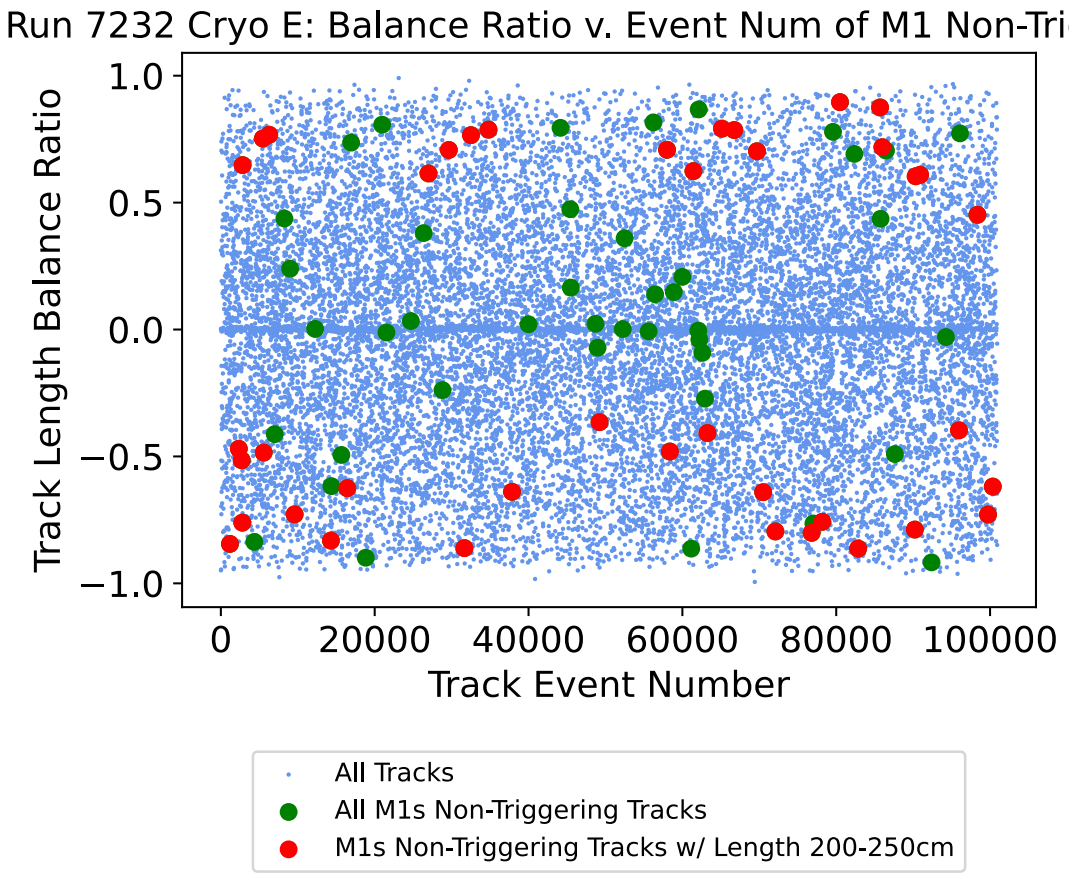
Ruled Out Connection:

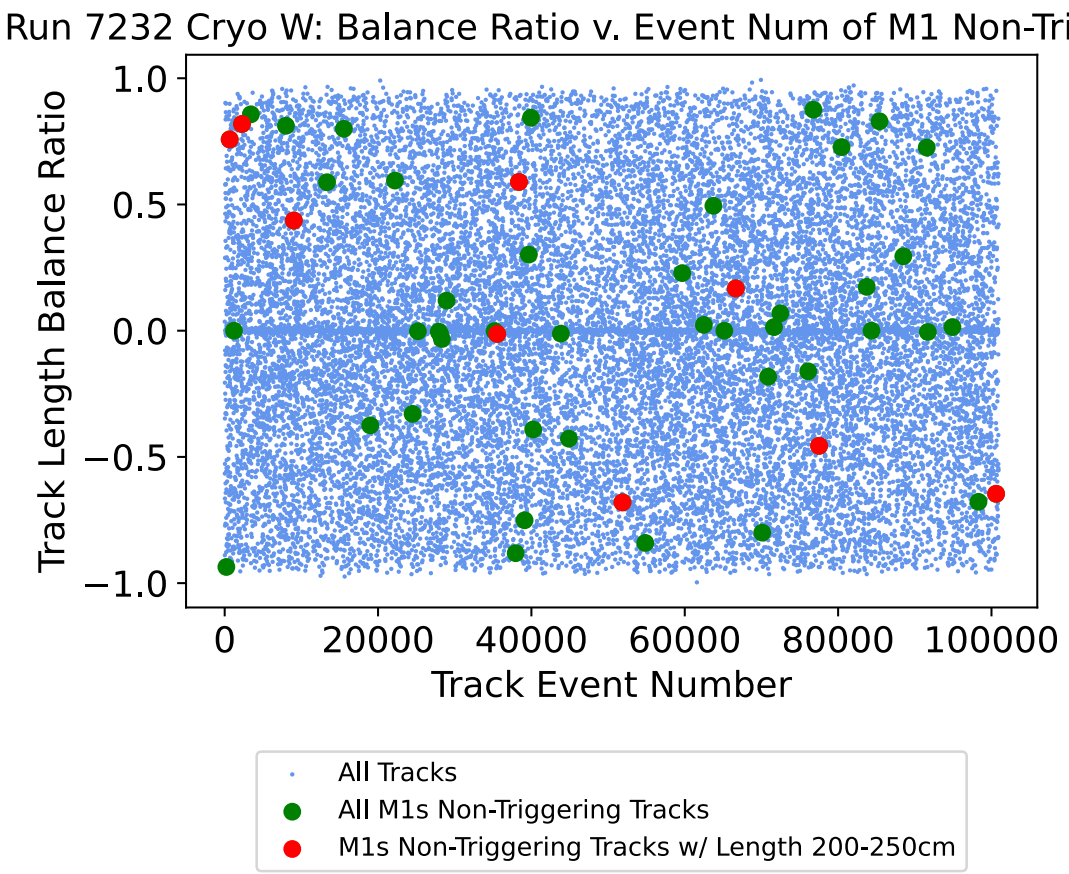
Not time dependent

East Cryostat

(-15 µs, 5 µs) Emulation Window

West Cryostat



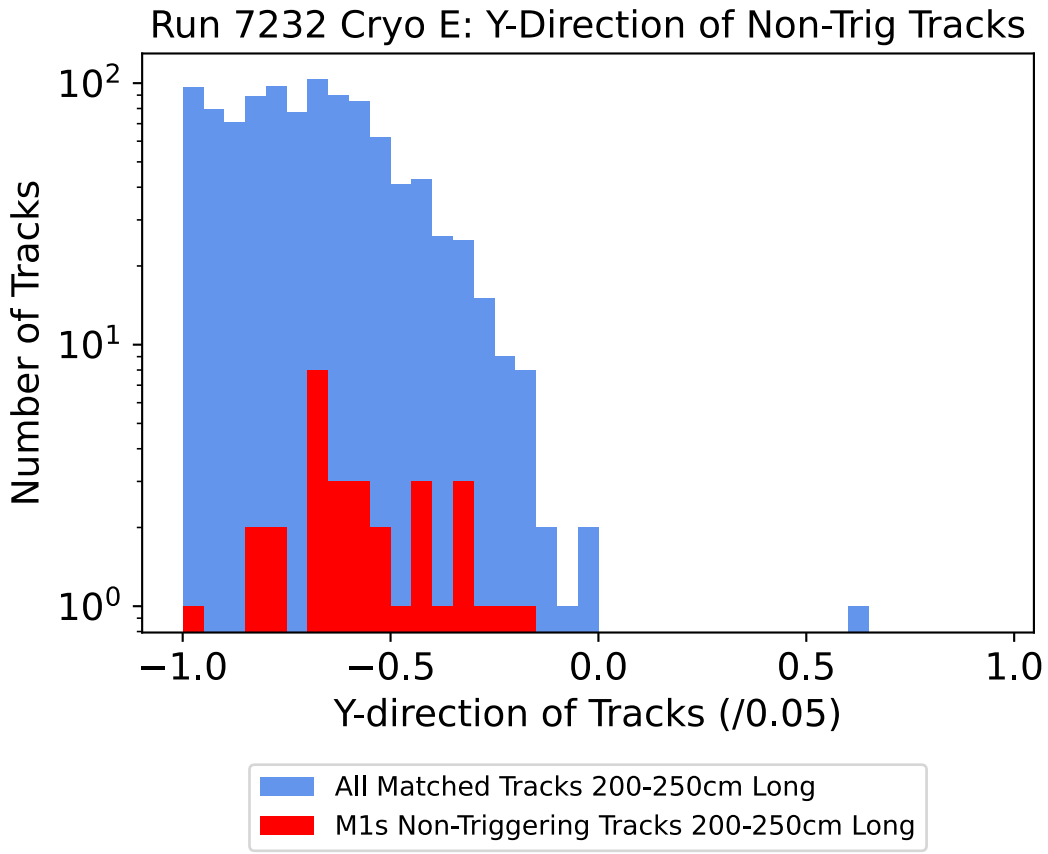


Ruled Out Connection:

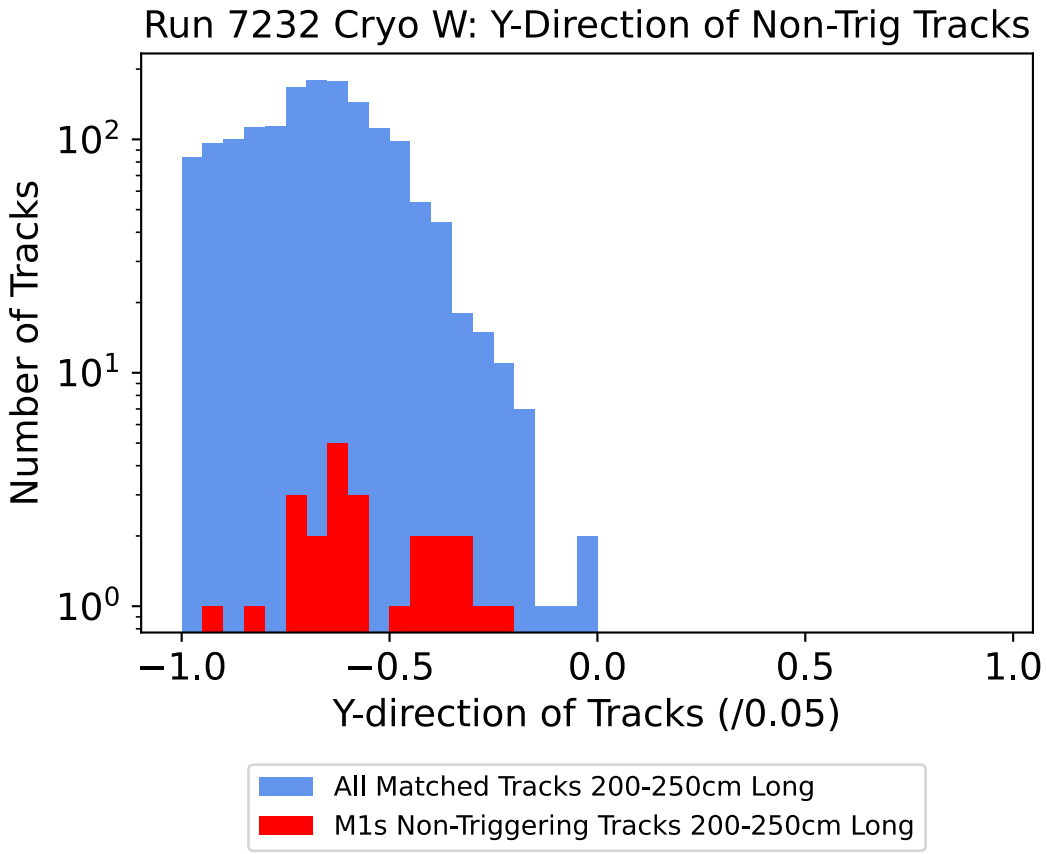
Track angle along the y-axis

(-20 µs, 0 µs) Emulation Window

East Cryostat



West Cryostat



Conclusions and Next Steps

Conclusions and Next Steps

- Still investigating the 2m track anomaly
- New minimum bias run (Run 8650)
  - Repeat these analyses to understand changes
  - Look for efficiency improvements or any new features to study
  - Bug in the processing code found which resulted in errors in emulated trigger performance, so there have been delays in this analysis due to reprocessing
- Later analyze CRT-matched tracks
  - CRT (Cosmic Ray Tagger) is a set of sensors covering outside of detector
  - Detect cosmic particles entering or leaving the cryostat
  - CRT hits can be matched to tracks within the TPCs and can provide us with time and position information for tracks that don't necessarily cross the cathode

Additional Slides

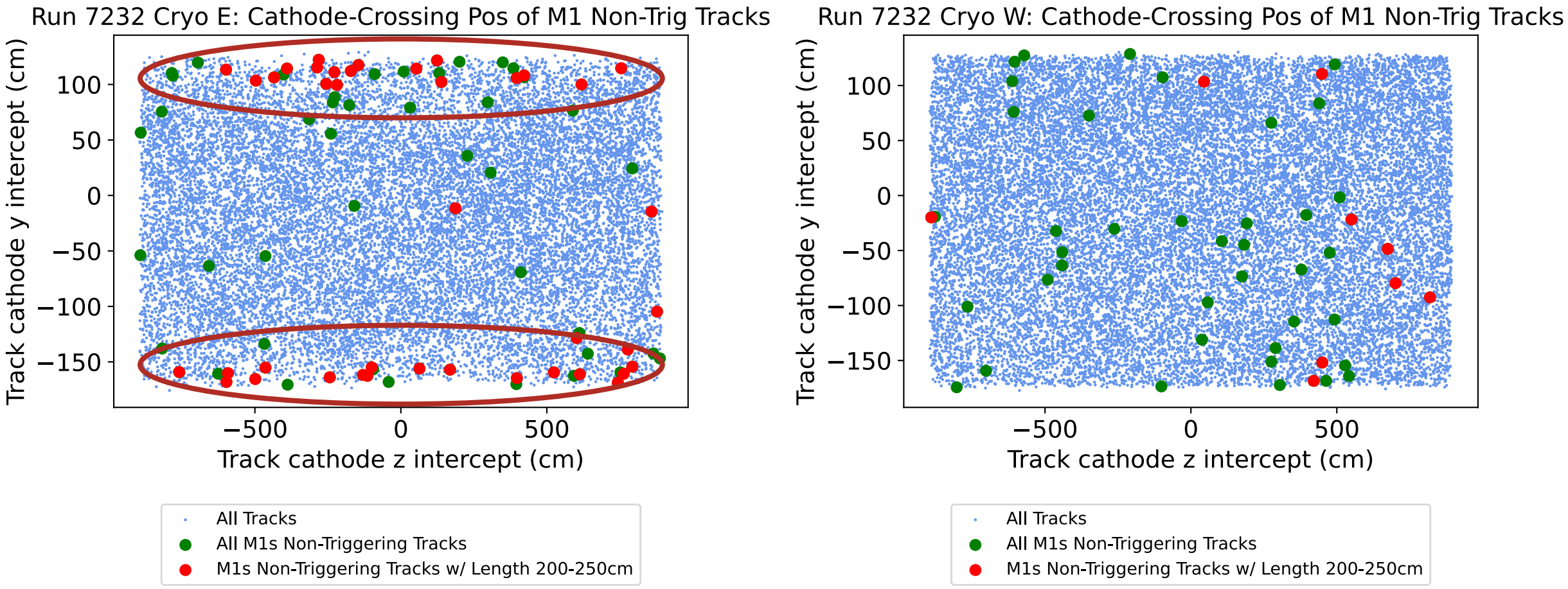
Possible connection:

Y-axis cathode-crossing position

East Cryostat

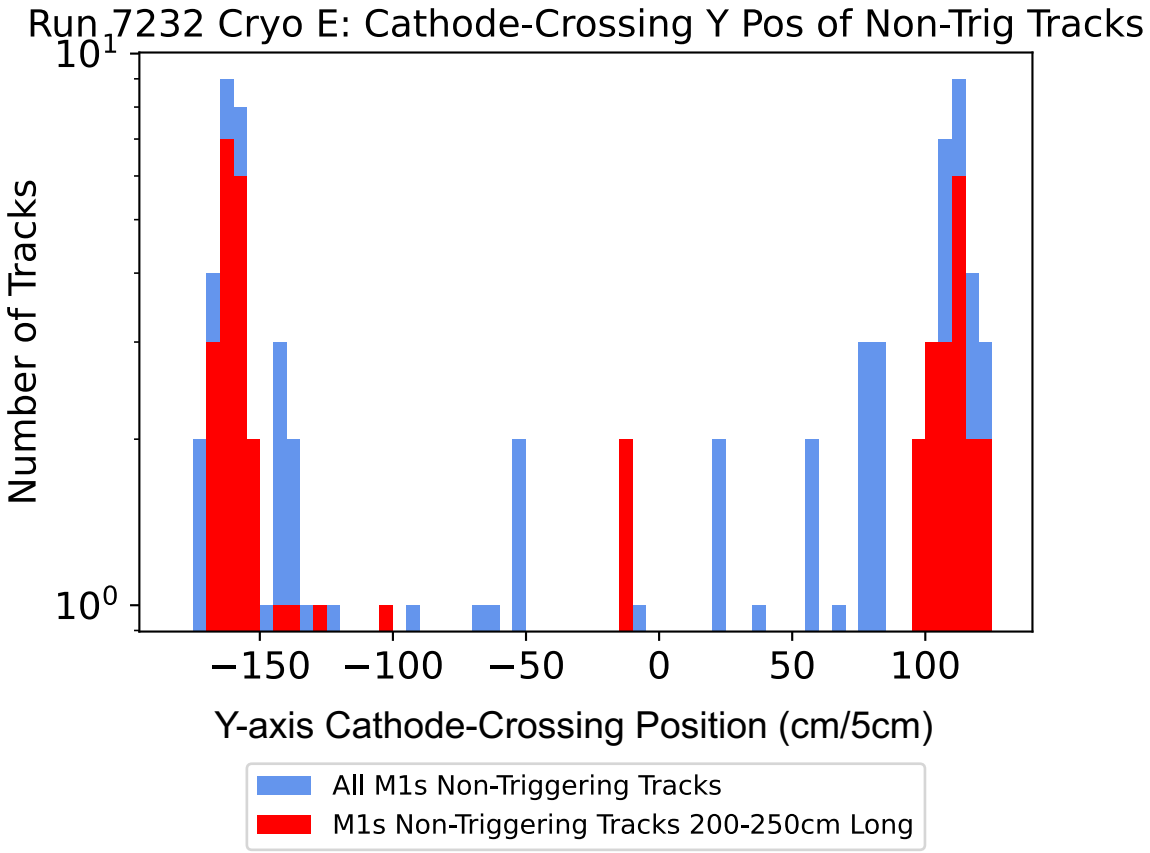
(-15 µs, 5 µs) Emulation Window

West Cryostat



Possible connection:

Y-axis cathode-crossing position



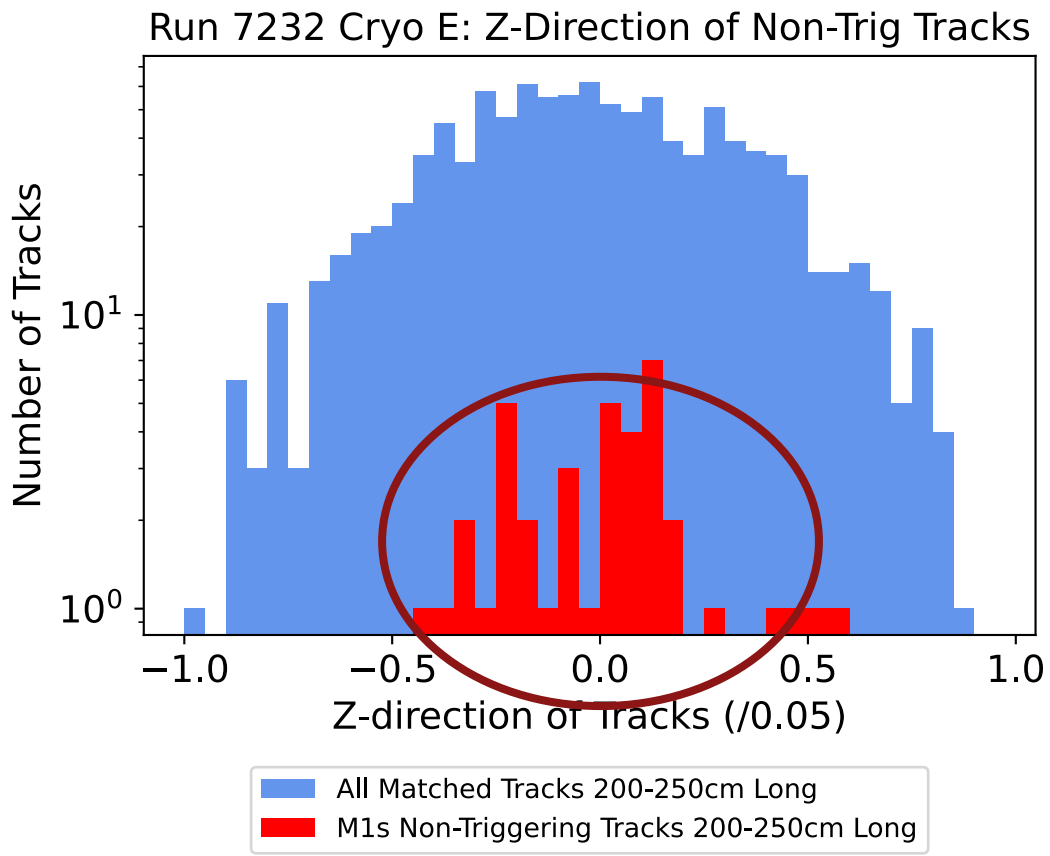
- Proportion of M1 non-triggering tracks with y-axis cathode-crossing position between -150 cm and 90 cm = **0.362**
- Number of M1s non-triggering tracks with lengths 200-250 cm = **42**
- Estimated Number of M1 non-triggering tracks with lengths 200-250 cm with y-axis cathode-crossing position between -150 cm and 90 cm = 0.36 x 42 = **15.2**
- Actual Number of M1 non-triggering tracks with lengths 200-250 cm with y-axis cathode-crossing position between -150 and 90 cm = **6**

Possible Connection:

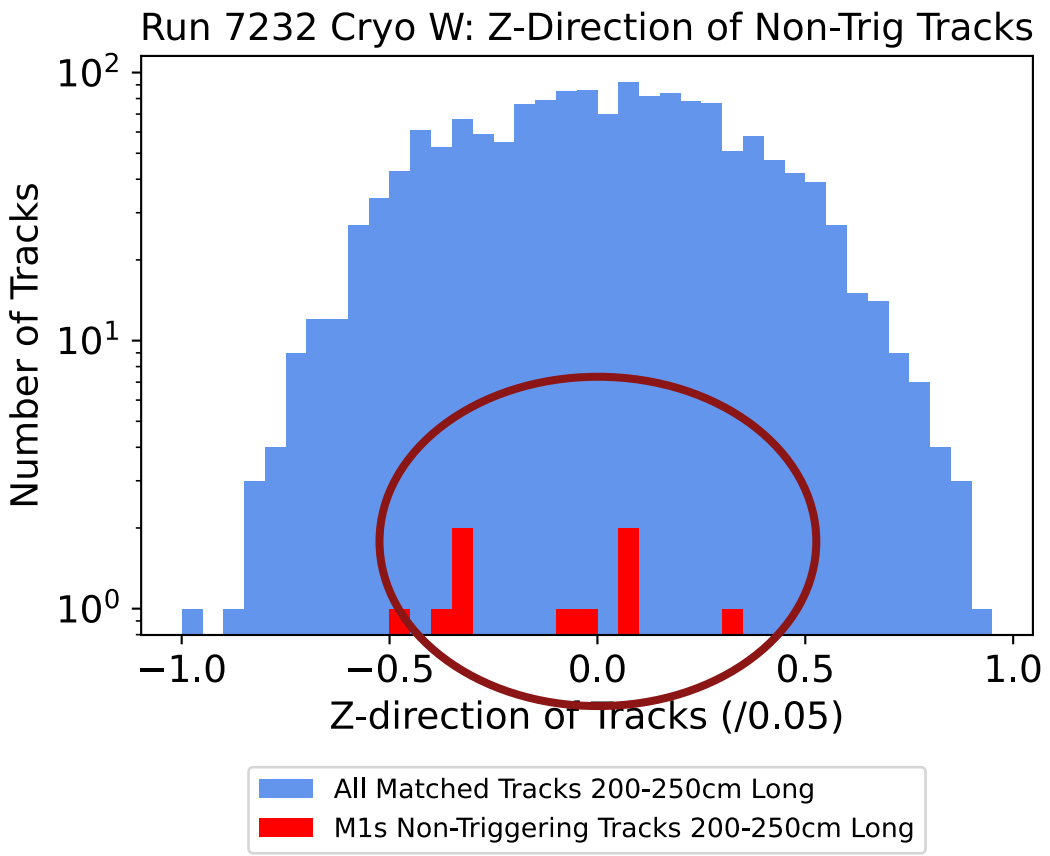
Smaller track angle along the z-axis

(-15 µs, 5 µs) Emulation Window

East Cryostat



West Cryostat

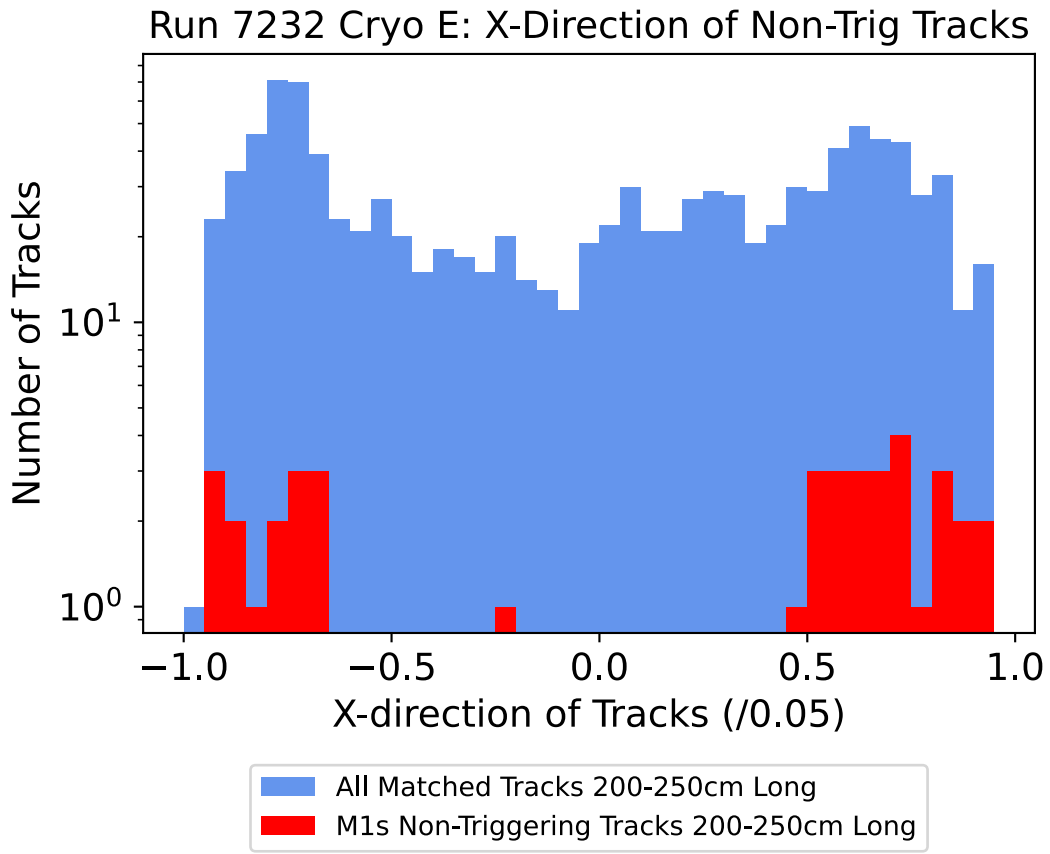


Possible Connection:

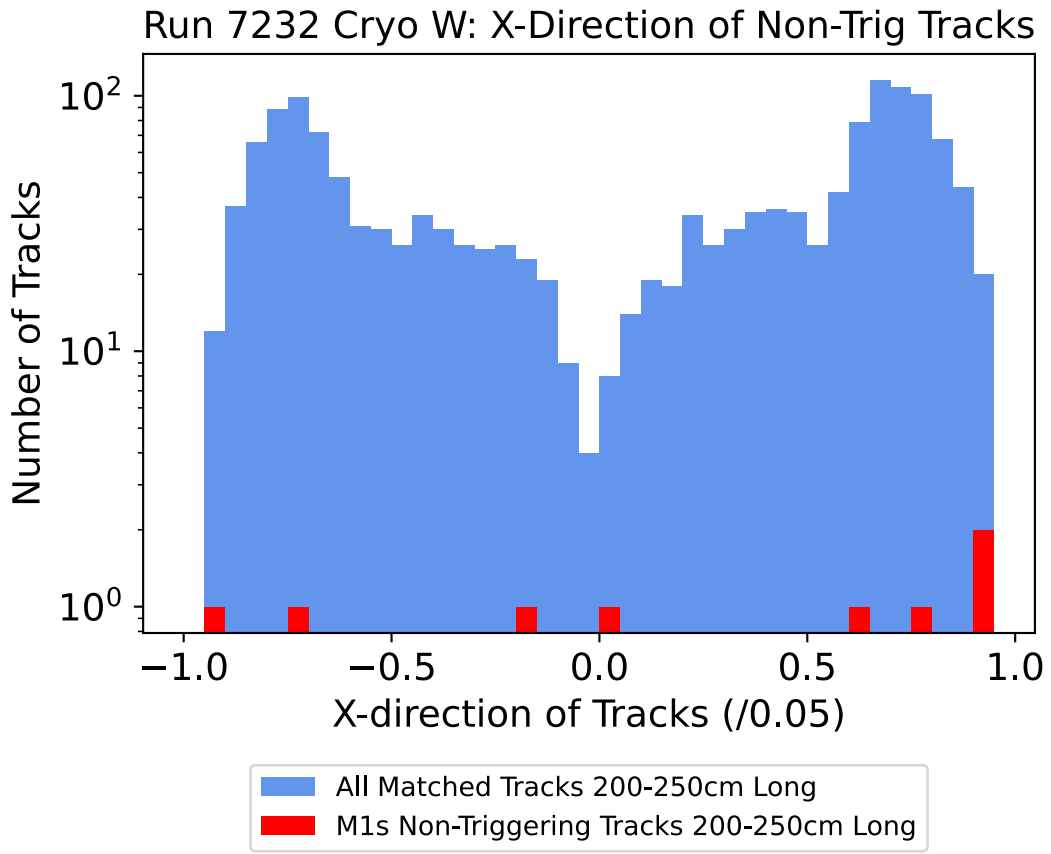
Large track angle along the x-axis

(-15 µs, 5 µs) Emulation Window

East Cryostat



West Cryostat



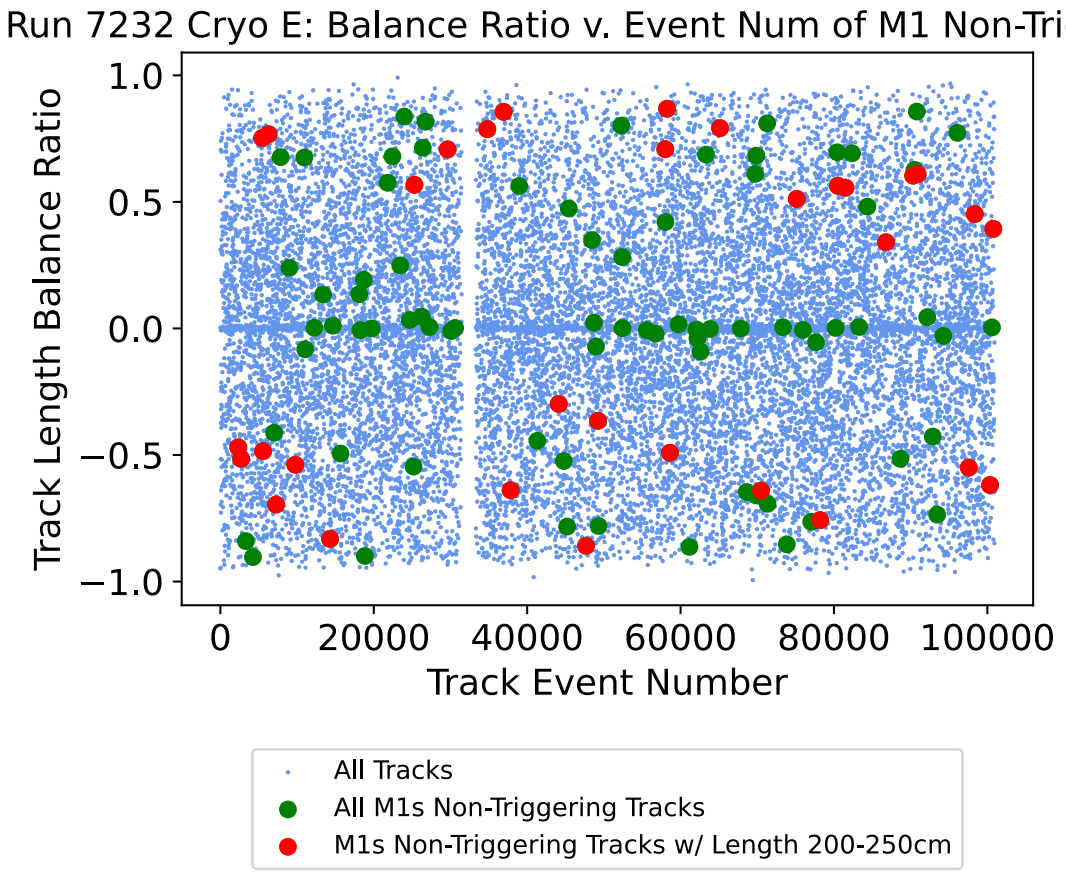
Ruled Out Connection:

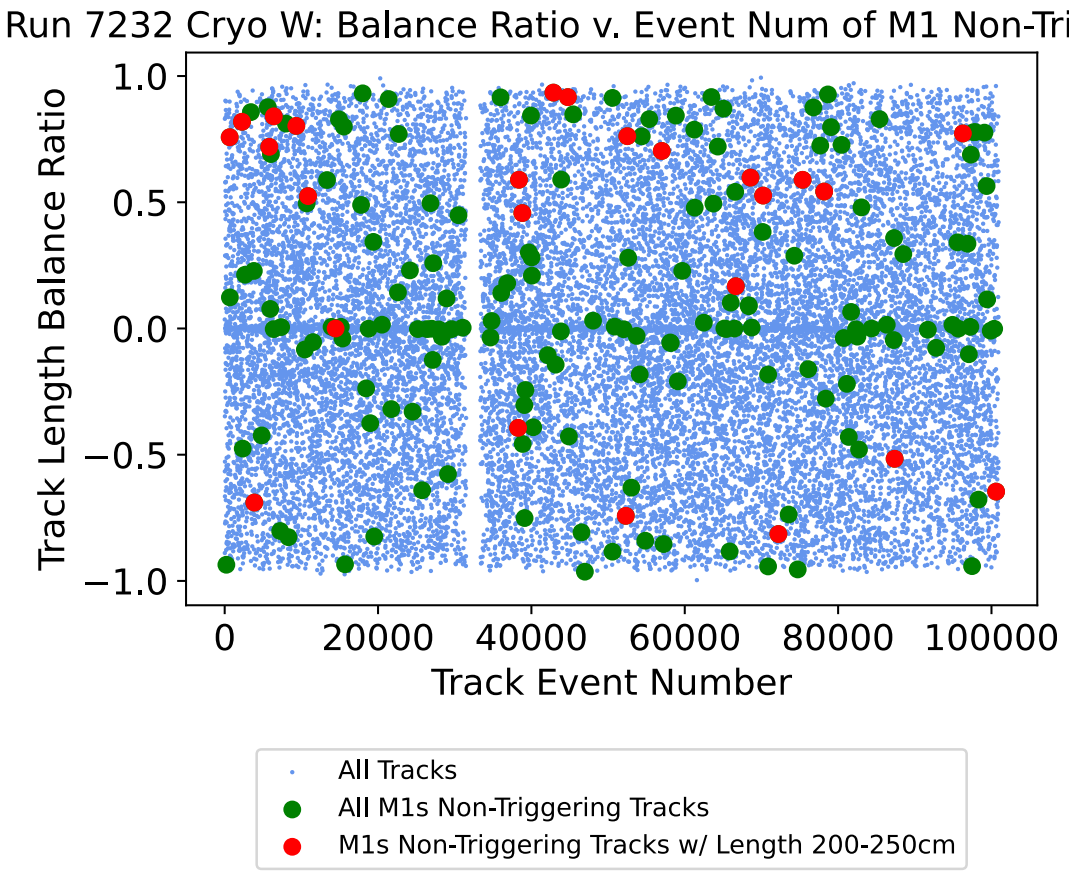
Not time dependent

East Cryostat

(-20 µs, 0 µs) Emulation Window

West Cryostat



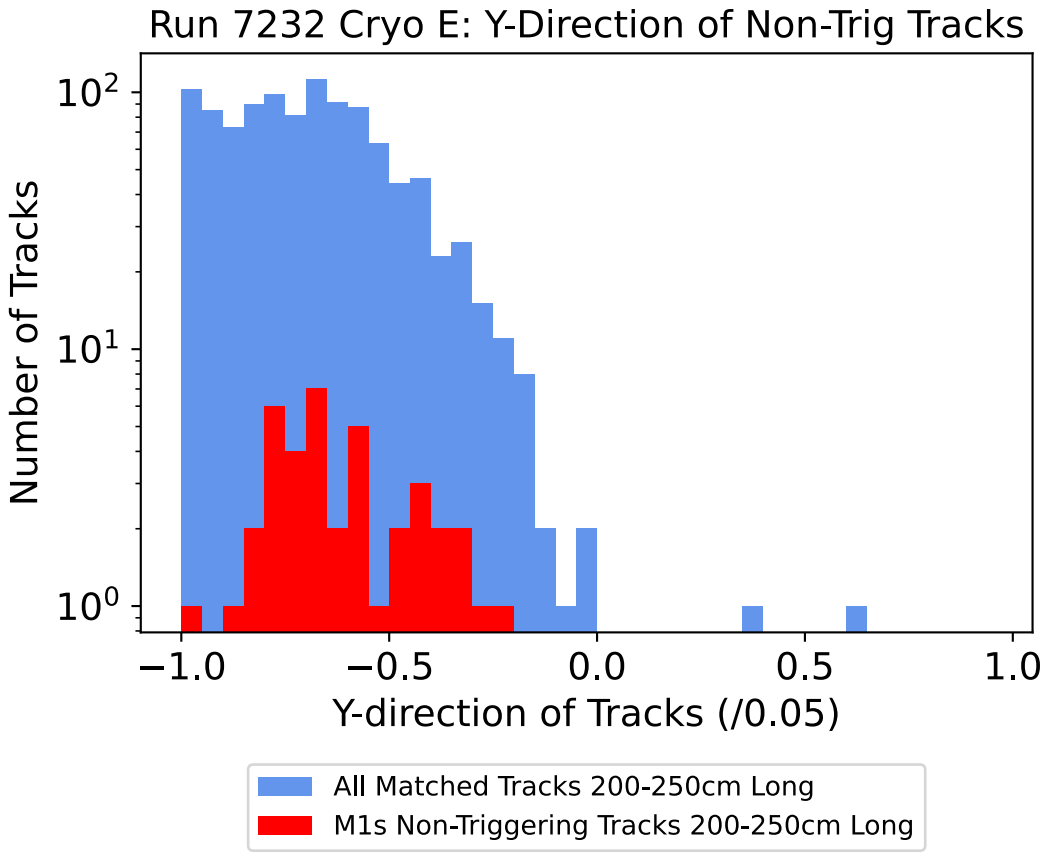


Ruled Out Connection:

Track angle along the y-axis

(-15 µs, 5 µs) Emulation Window

East Cryostat



West Cryostat