

# Trigger Efficiency Analysis in the ICARUS Neutrino Detector

Run 7232 Analysis

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# Agenda

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The 2m Track Anomaly

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# Efficiency Analysis

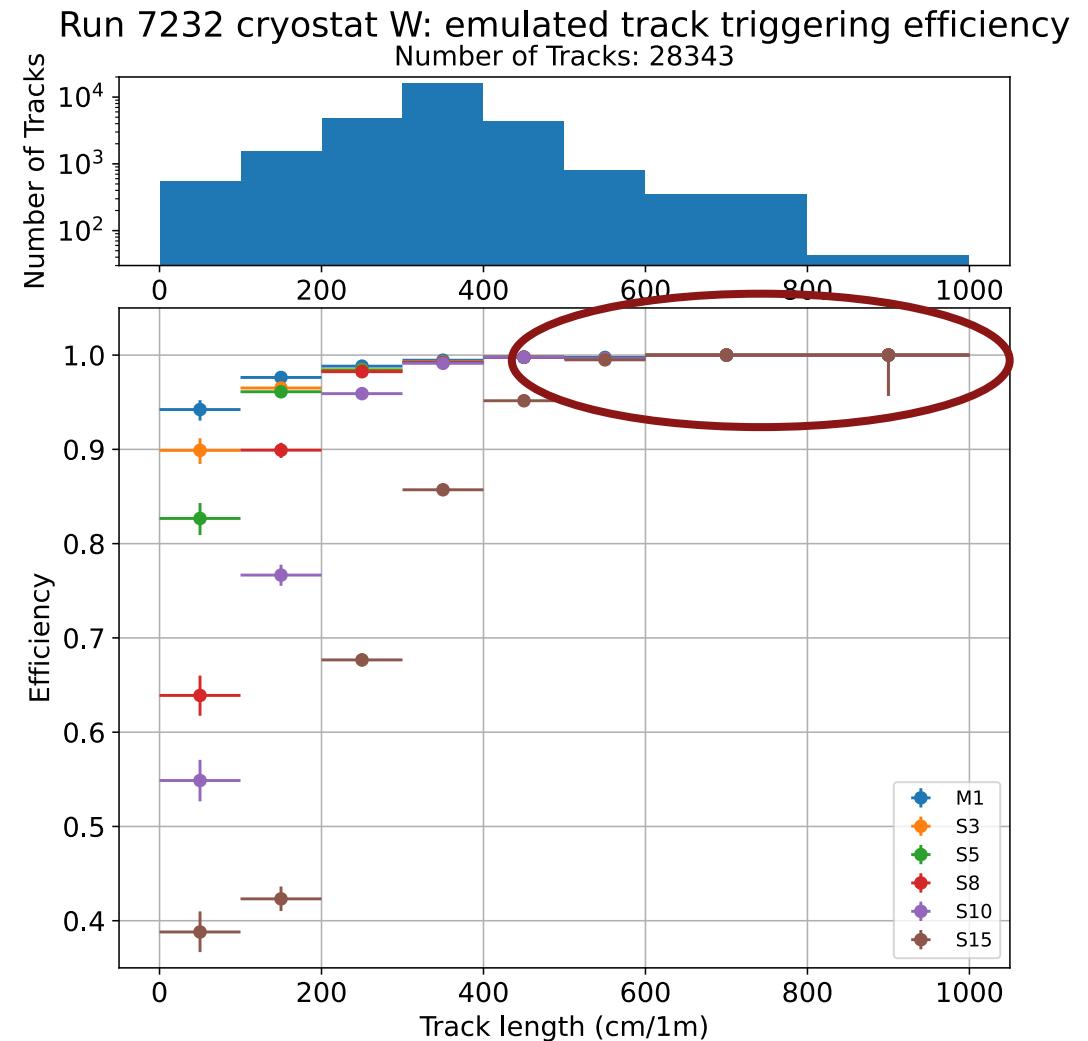
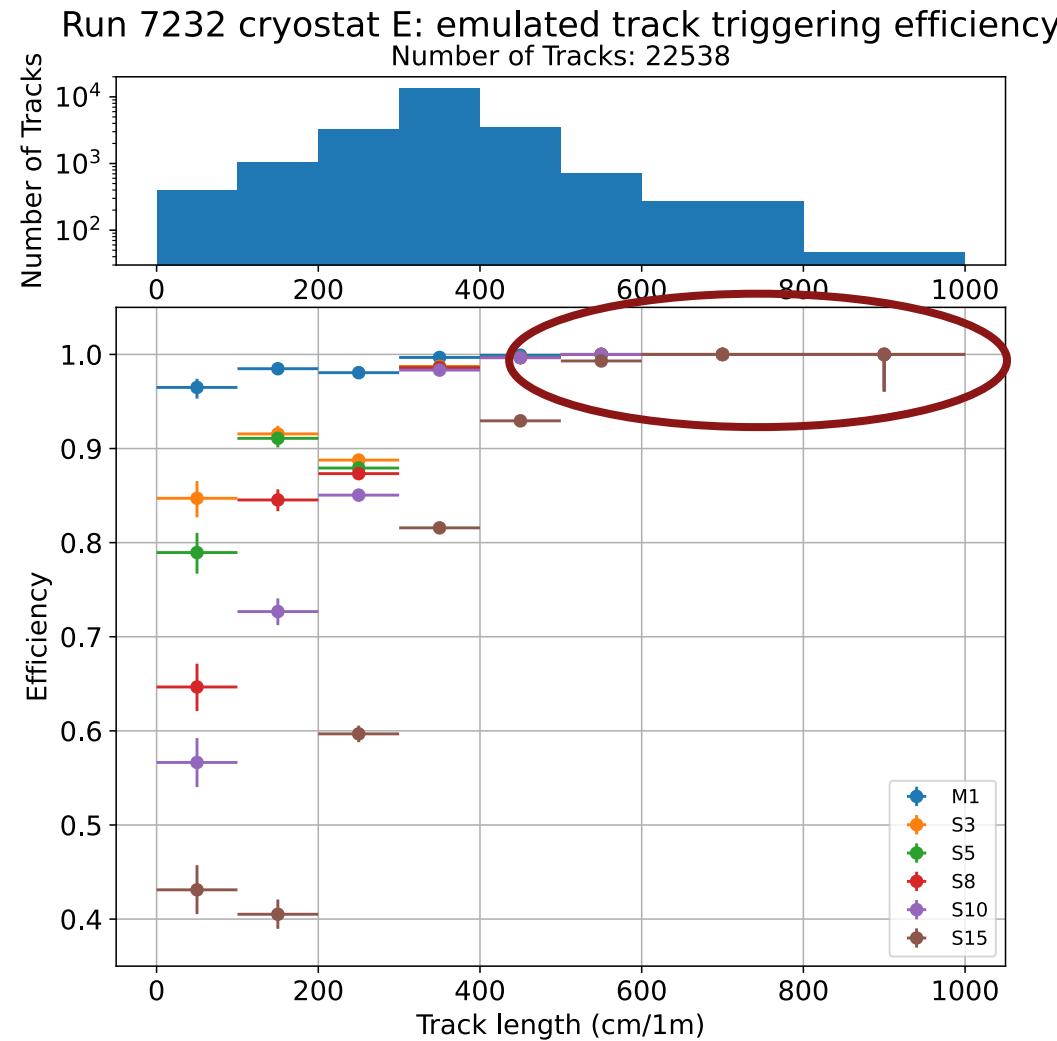
# What does our data look like?

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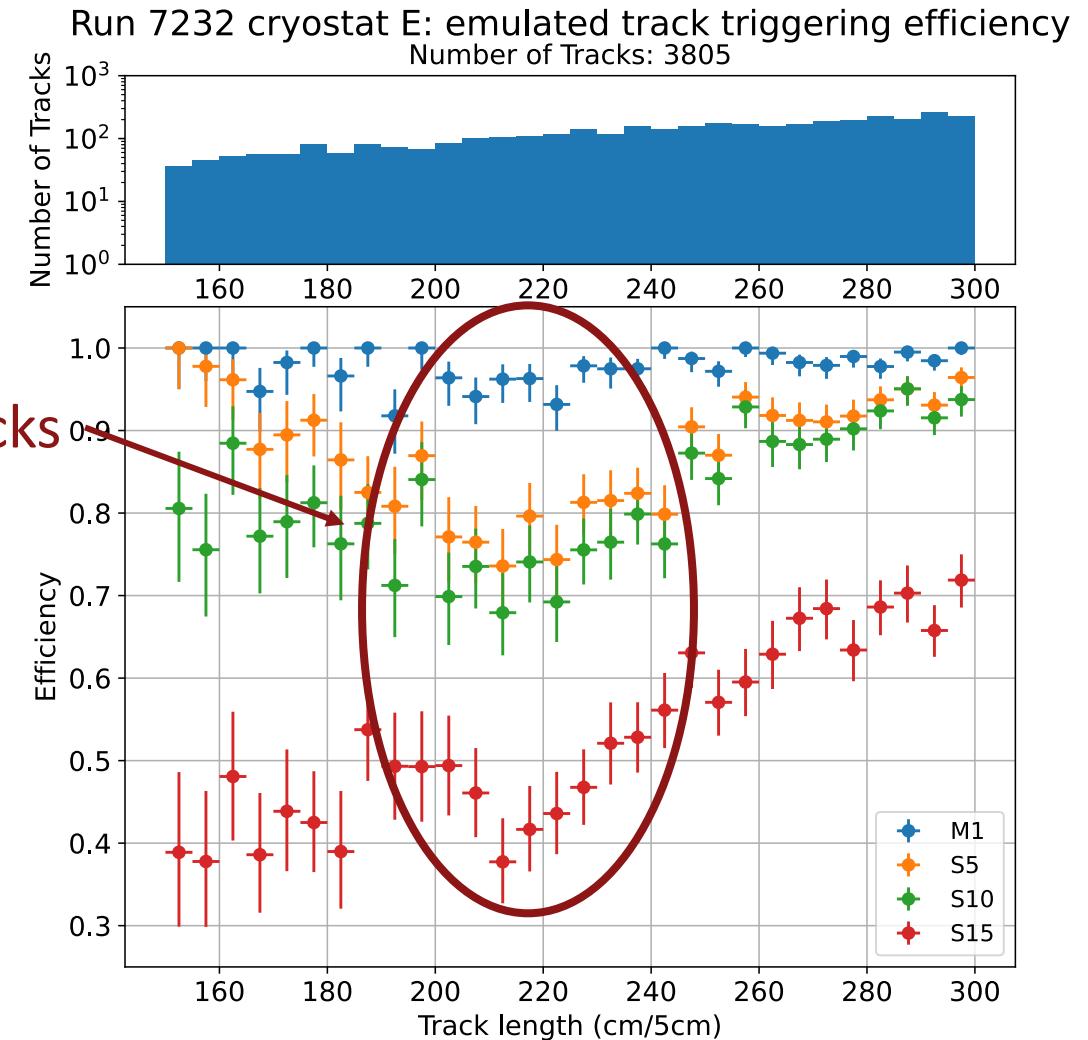
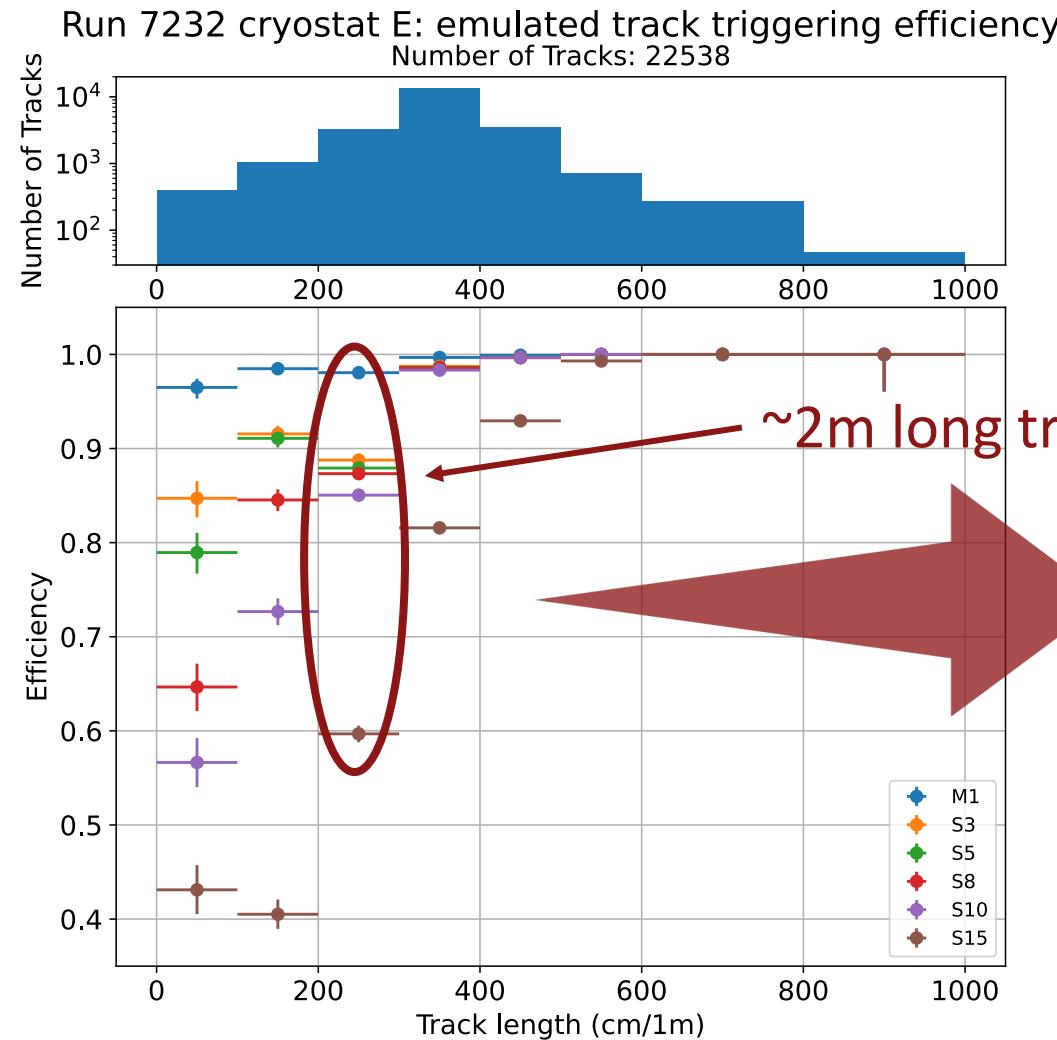
- “Minimum bias” run from November 30, 2021
  - Data collected without hardware trigger constraints
  - Software used to emulate trigger performance under different light requirement levels
- Cathode-crossing tracks only
  - Only tracks for which we can reconstruct the time without biasing trigger efficiency 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



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# The 2m Track Anomaly

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# The 2m Track Anomaly

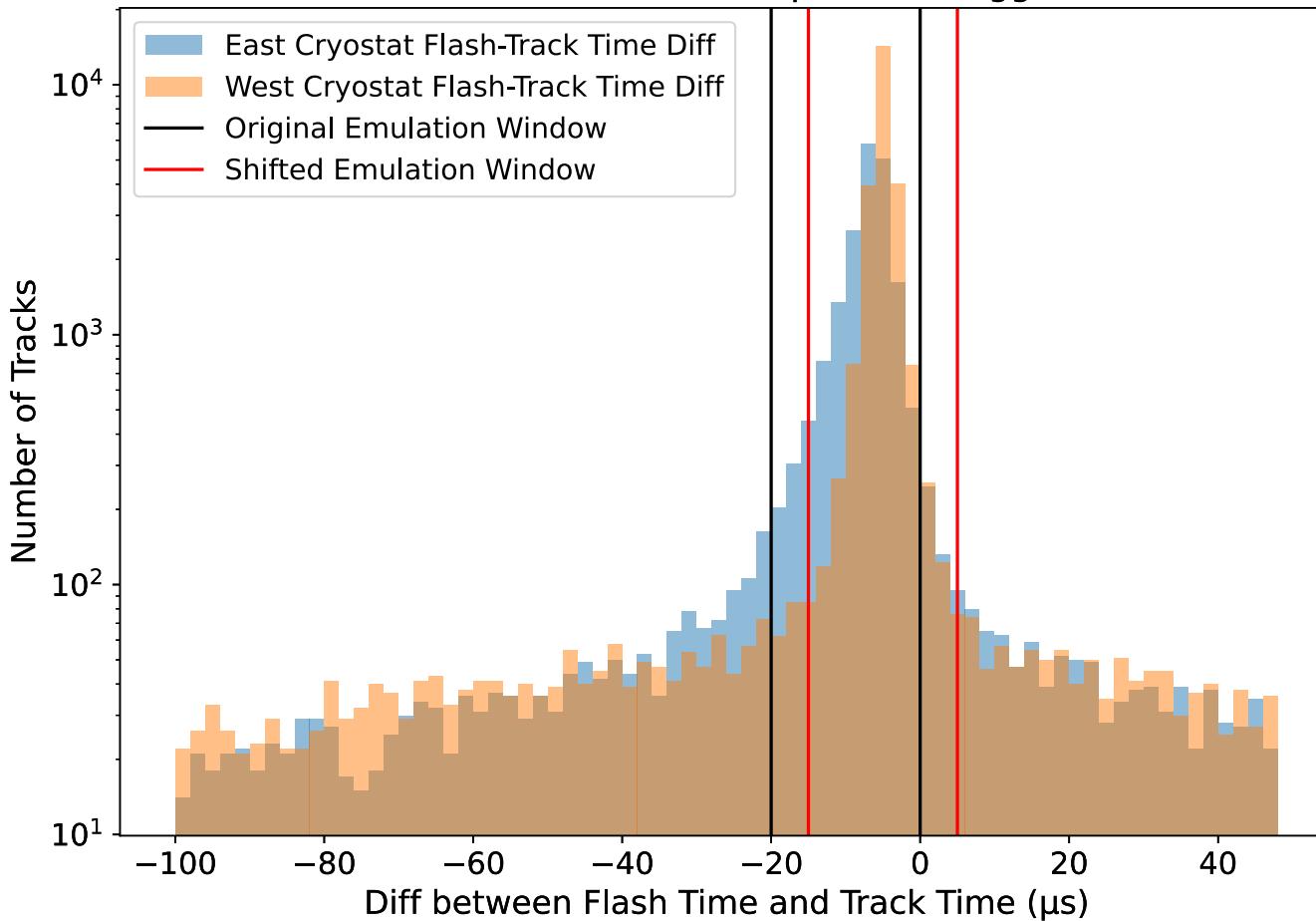
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Tracks ~2m in length have a noticeably lower efficiency than slightly shorter or longer tracks

- 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

Run 7232: Flash-Track Time Difference Compared to Trigger Emulation Windows



## Possible Solution:

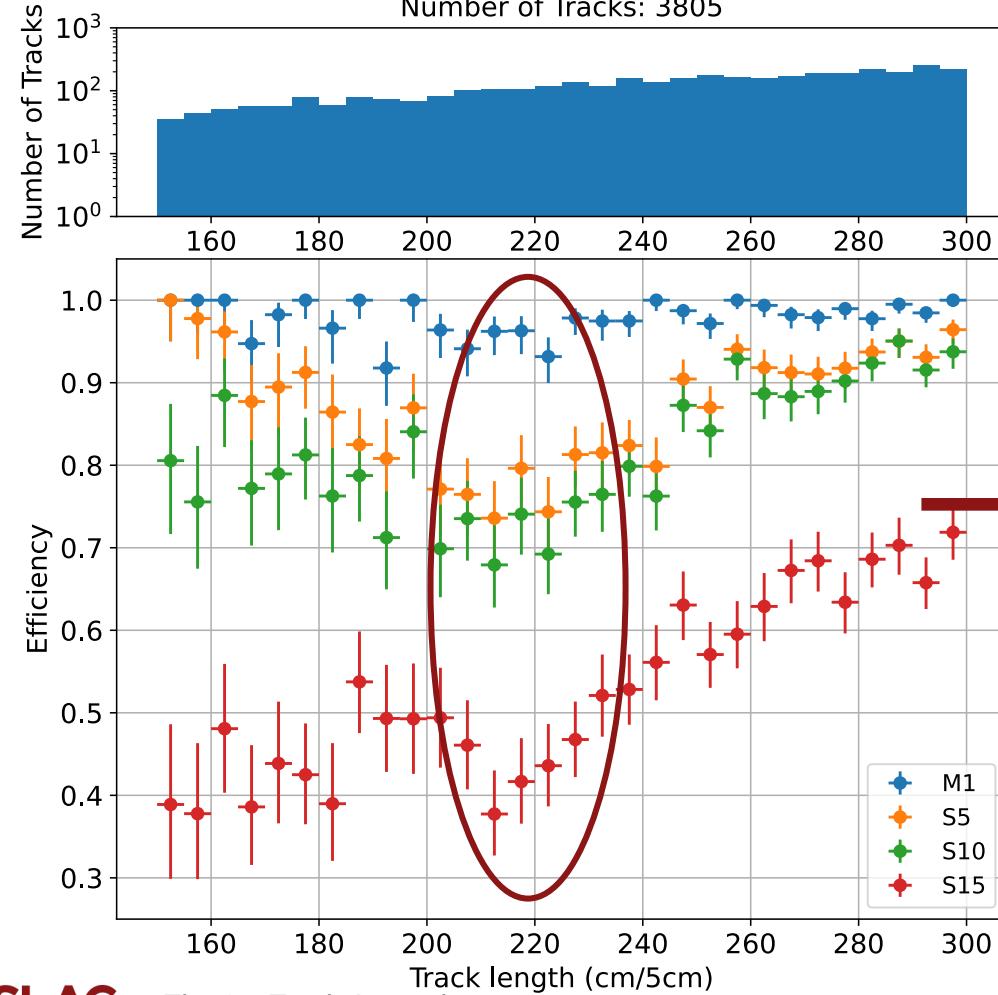
- In Trigger Emulation software, we look for light in a  $20 \mu\text{s}$  window before the track time ( $t_0$ ), and check whether that light exceeds chosen light requirement level
- Most tracks of length  $\sim 2\text{m}$  that failed to trigger matched to light occurring  $< 5 \mu\text{s}$  after  $t_0$
- Shifted window later by  $5 \mu\text{s}$  to see whether overall efficiency improved

# Shifting the Trigger Emulation Window: East Cryostat

## Original Emulation Window

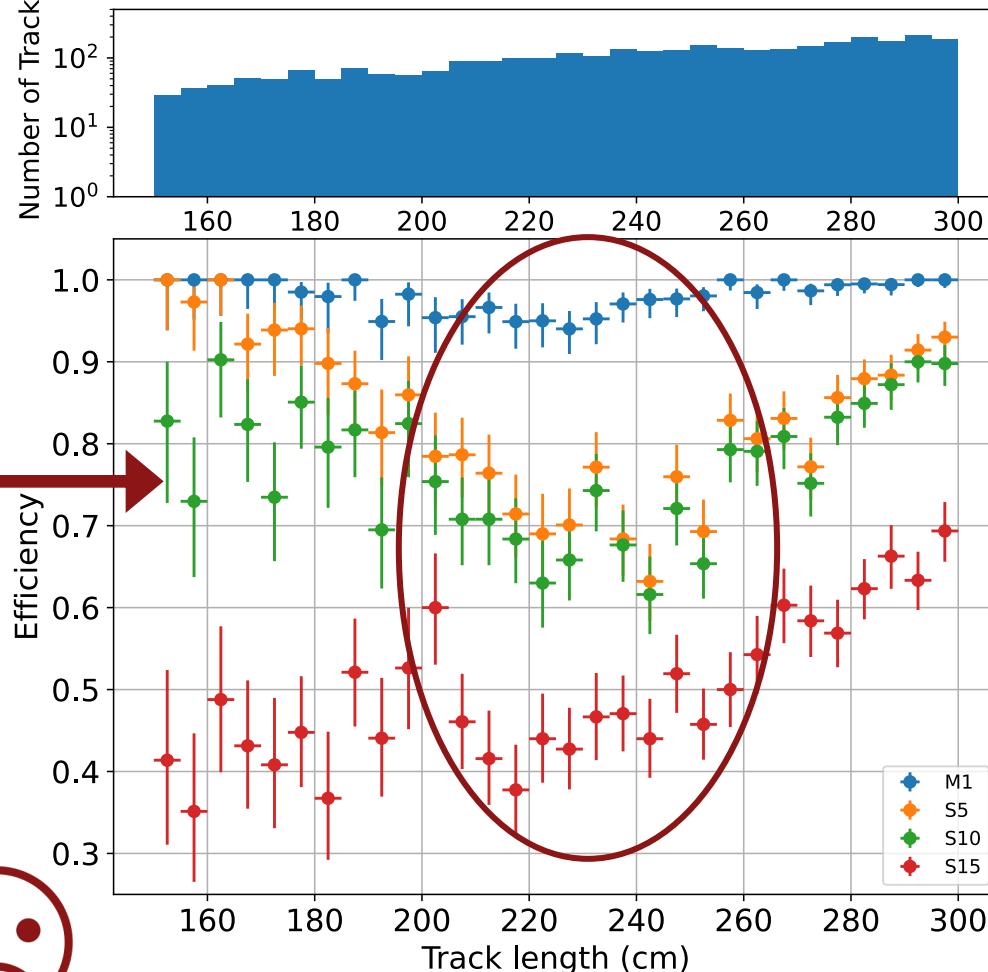
# Run 7232 cryostat E: emulated track triggering efficiency

Number of Tracks: 3805



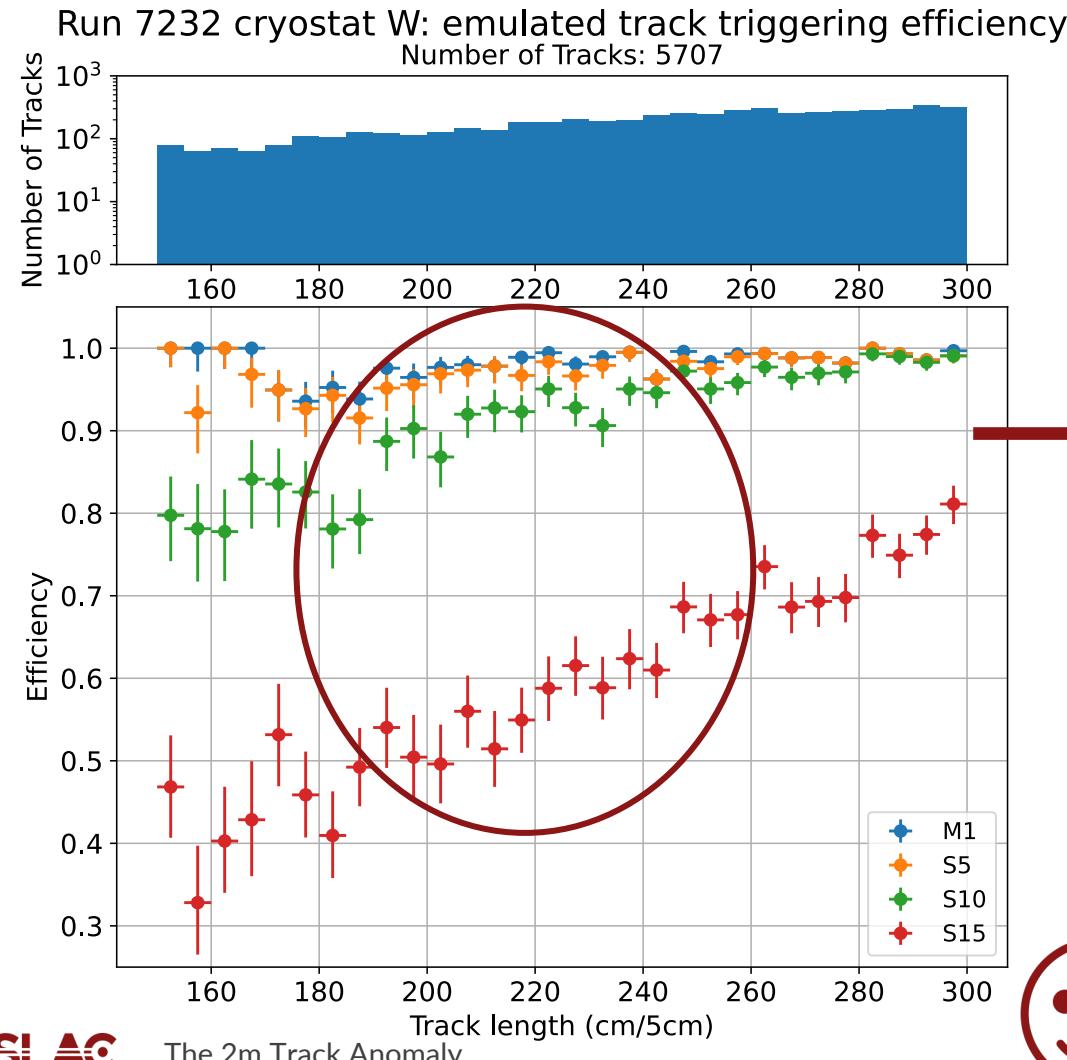
## Shifted Emulation Window

## Run 7232 cryostat E: emulated track triggering efficiency Number of Tracks: 3204

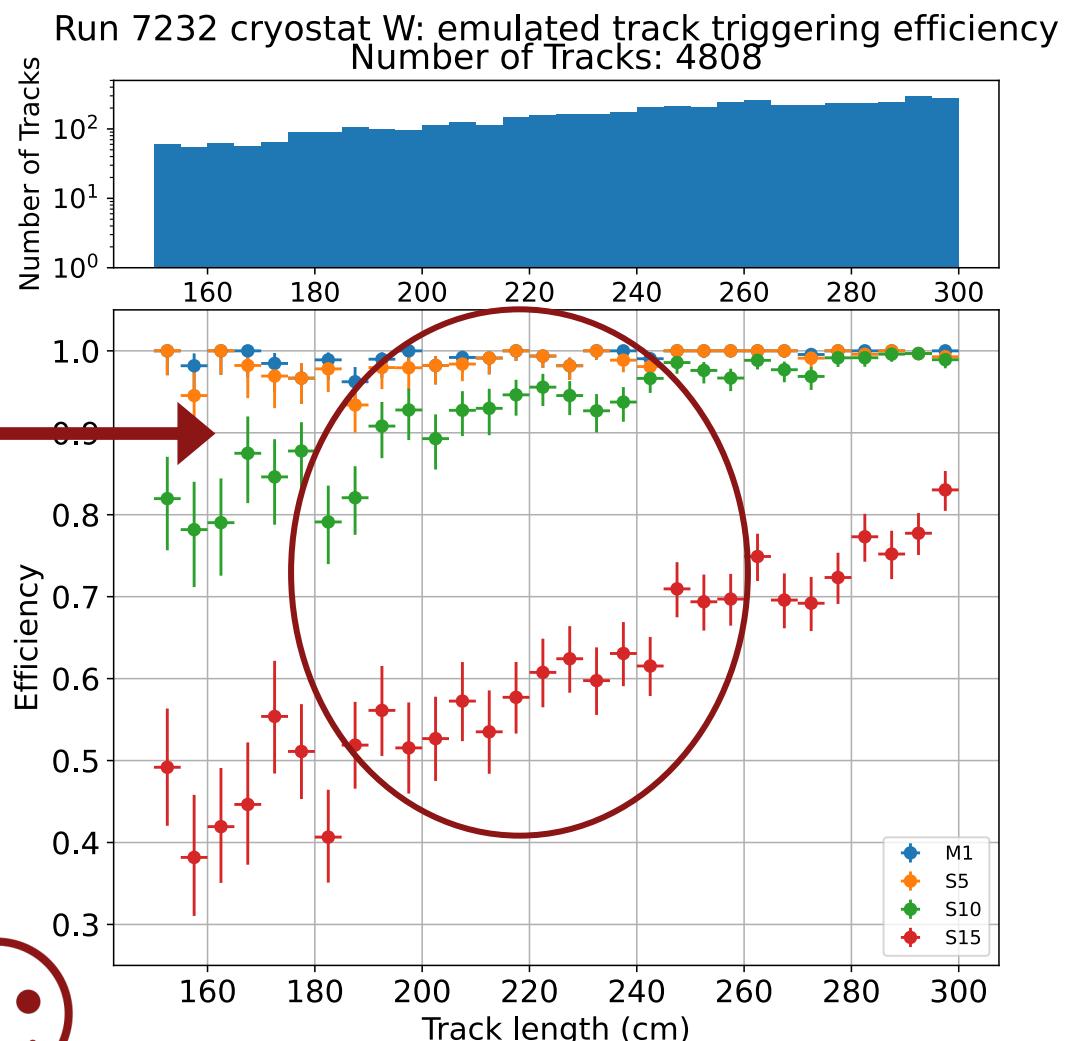


# Shifting the Trigger Emulation Window: West Cryostat

## Original Emulation Window



## Shifted Emulation Window



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## Other Possible Considerations

# Potential Causes of the 2m track anomaly

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## Possible connections

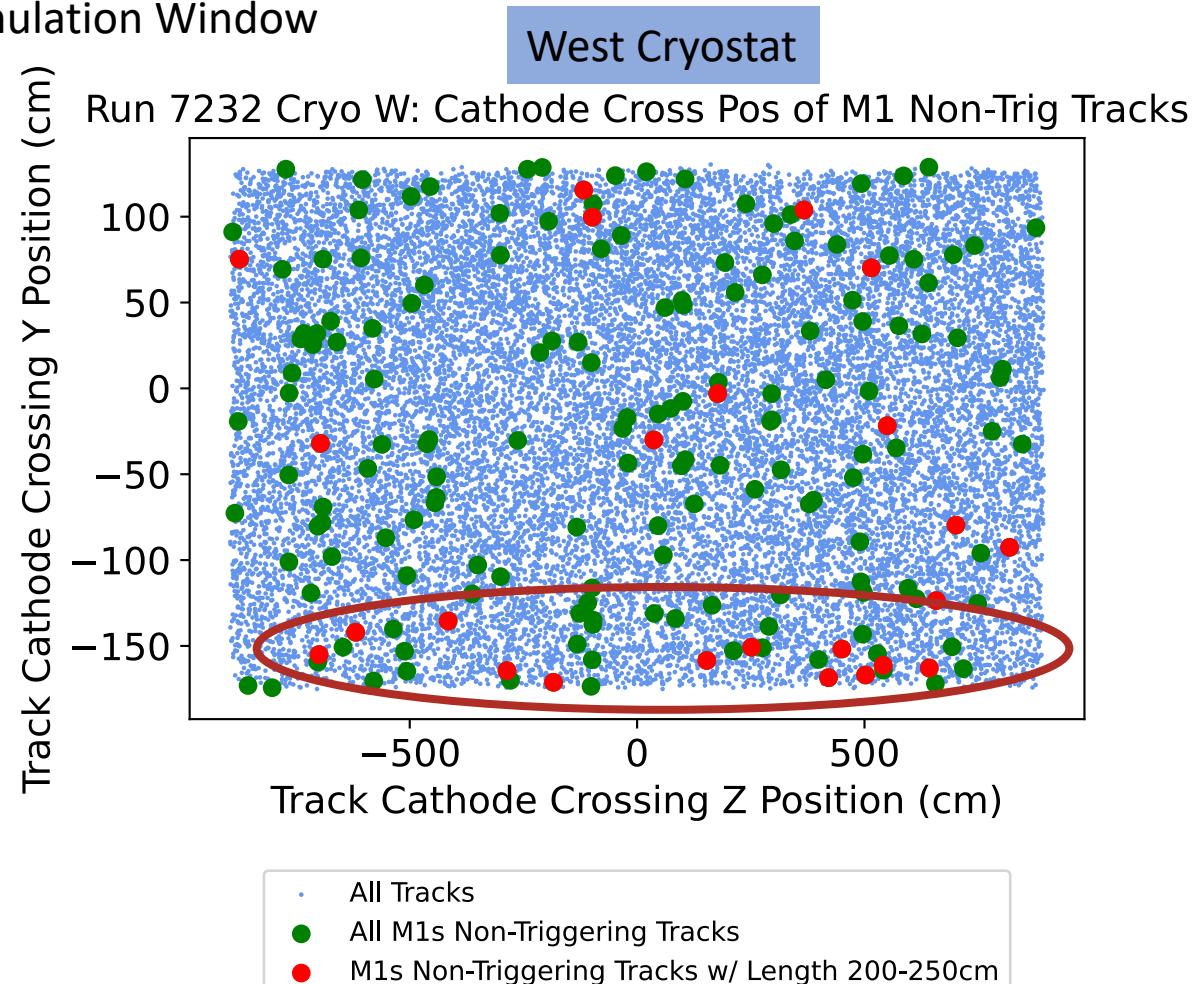
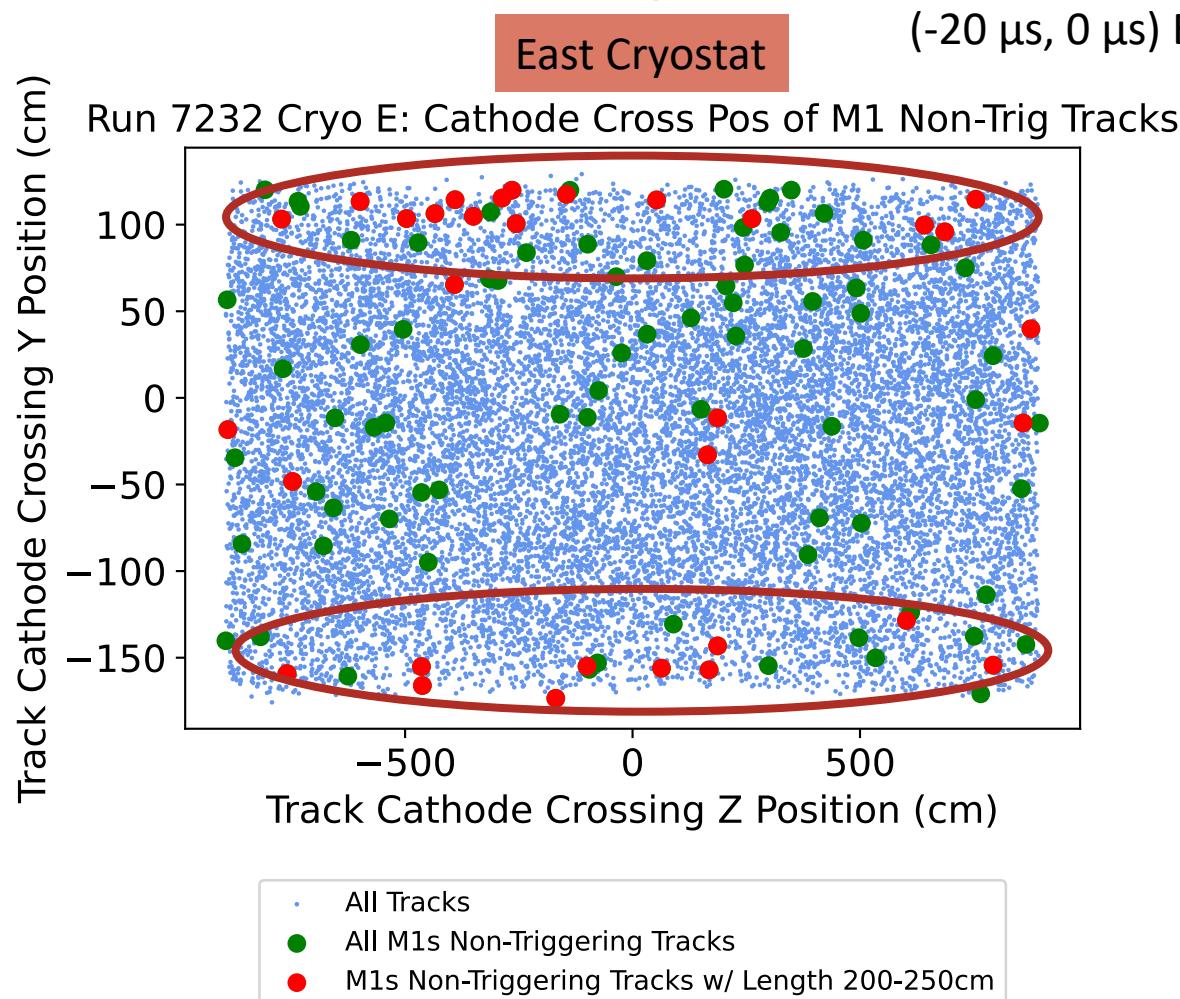
1. Shifting trigger emulation window, t0 reconstruction
  - Somewhat for 2m tracks
2. Length balance ratio of tracks on either side of cathode
3. Smaller track component along the z-axis, large track component along the x-axis
  - Not specific to 2m tracks (geometric bias)
4. Border distortions of electric 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

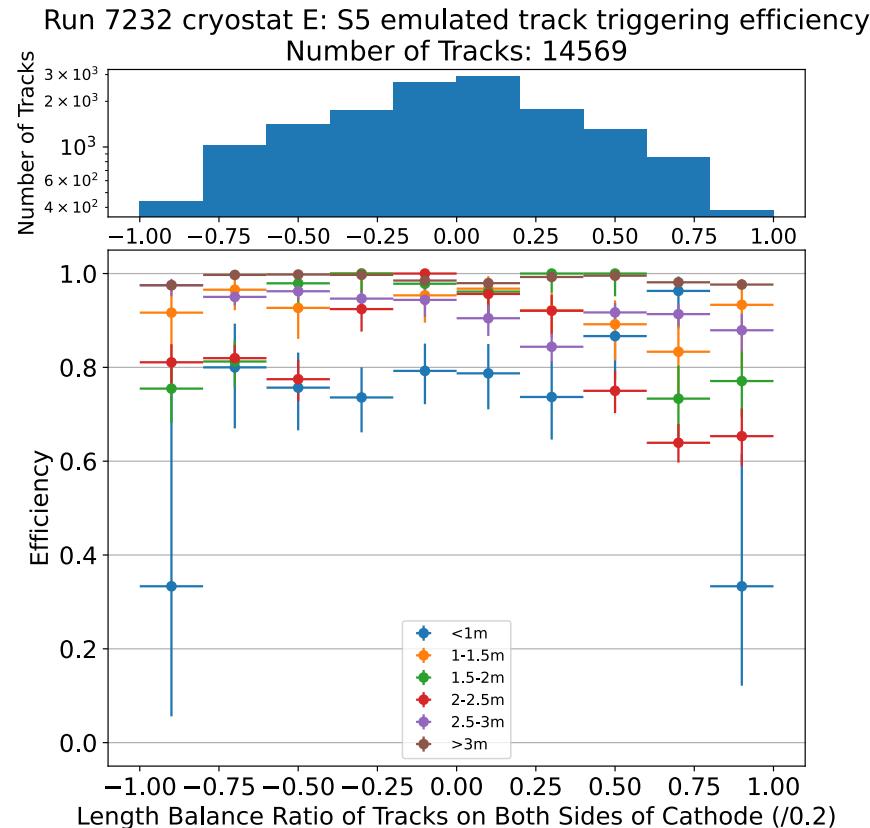


# Possible connection:

Length balance ratio of tracks on either side of cathode

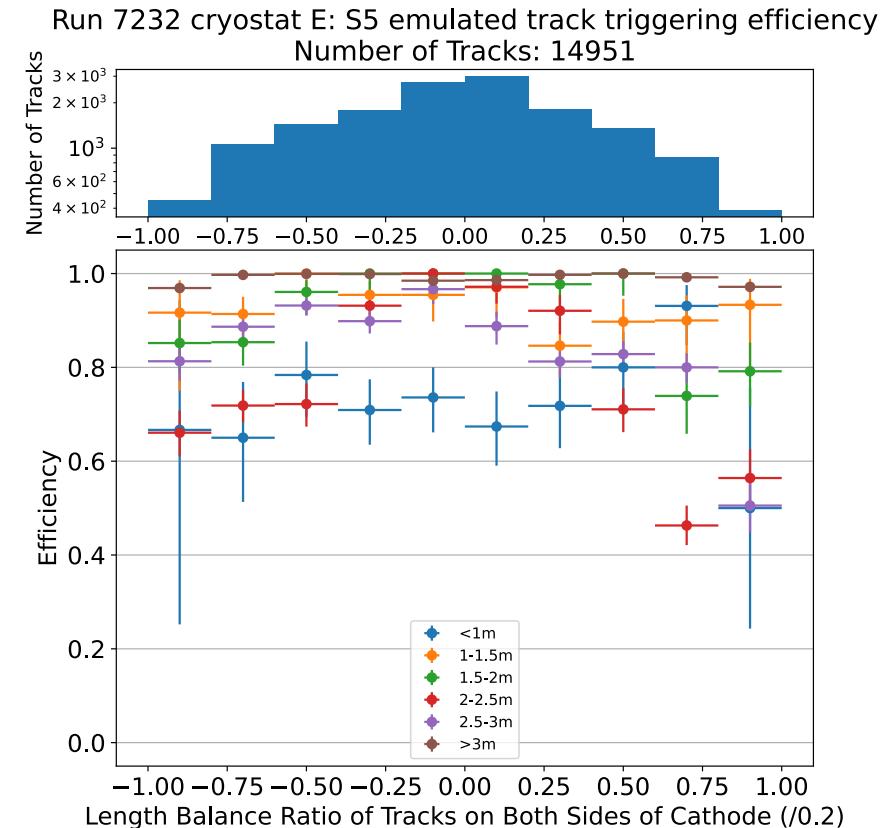
East Cryostat

(-20  $\mu$ s, 0  $\mu$ s) Emulation Window



Balance Ratio	$\approx -1$	$\approx 0$	$\approx 1$
Primary TPC of Track	East	Both	West

(-15  $\mu$ s, 5  $\mu$ s) Emulation Window



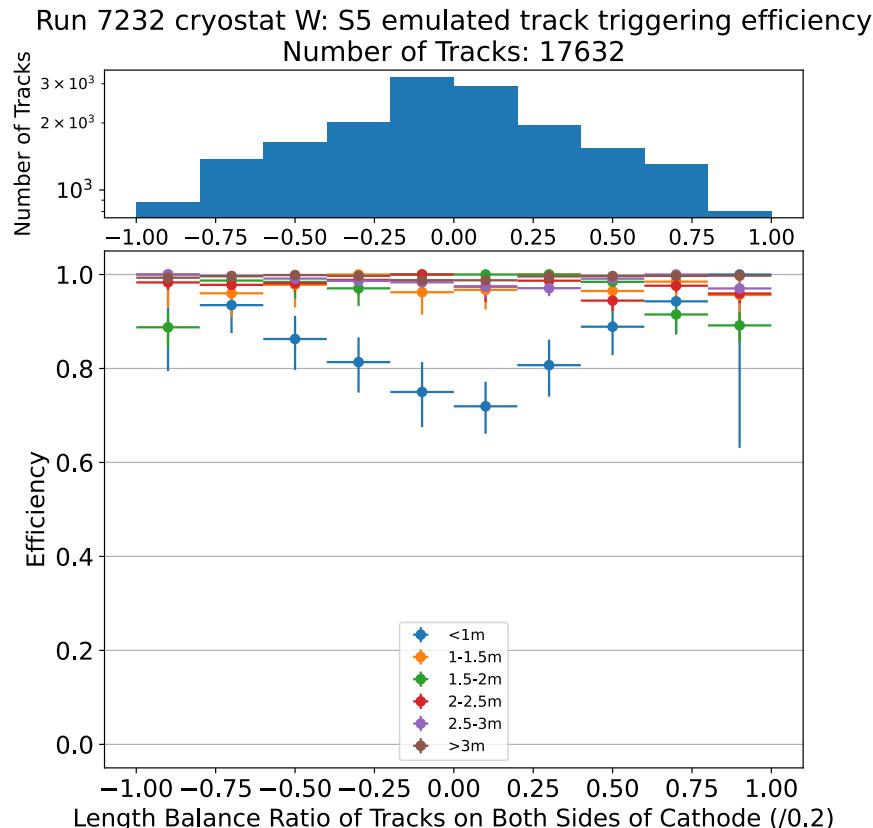
# Possible connection:

Length balance ratio of tracks on either side of cathode

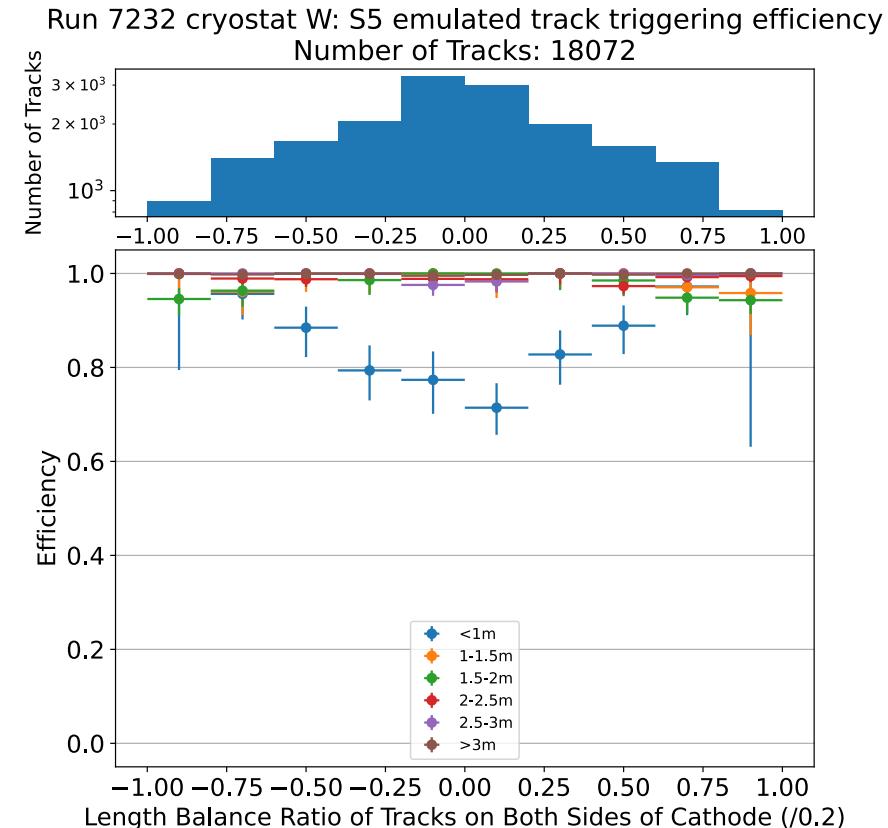
Balance Ratio	$\approx -1$	$\approx 0$	$\approx 1$
Primary TPC of Track	East	Both	West

West Cryostat

(-20  $\mu$ s, 0  $\mu$ s) Emulation Window

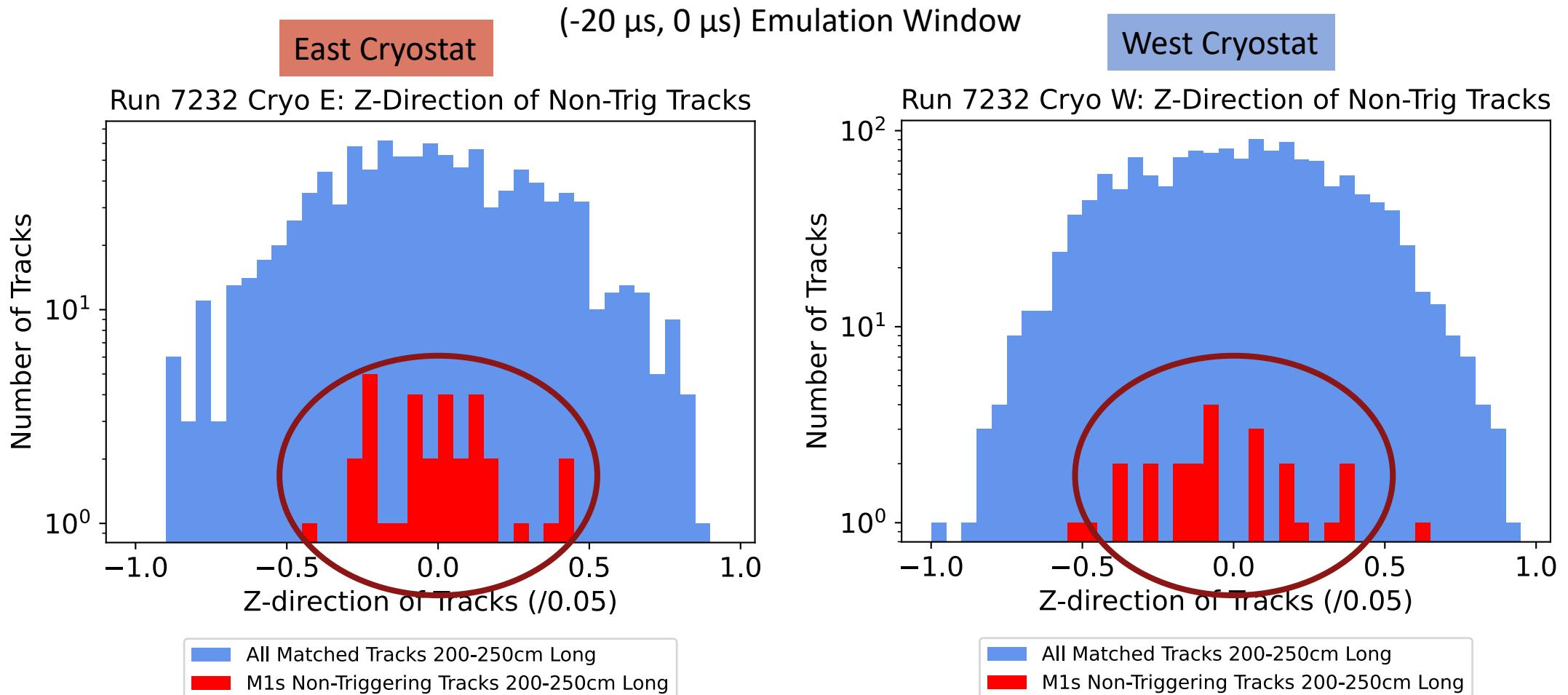


(-15  $\mu$ s, 5  $\mu$ s) Emulation Window



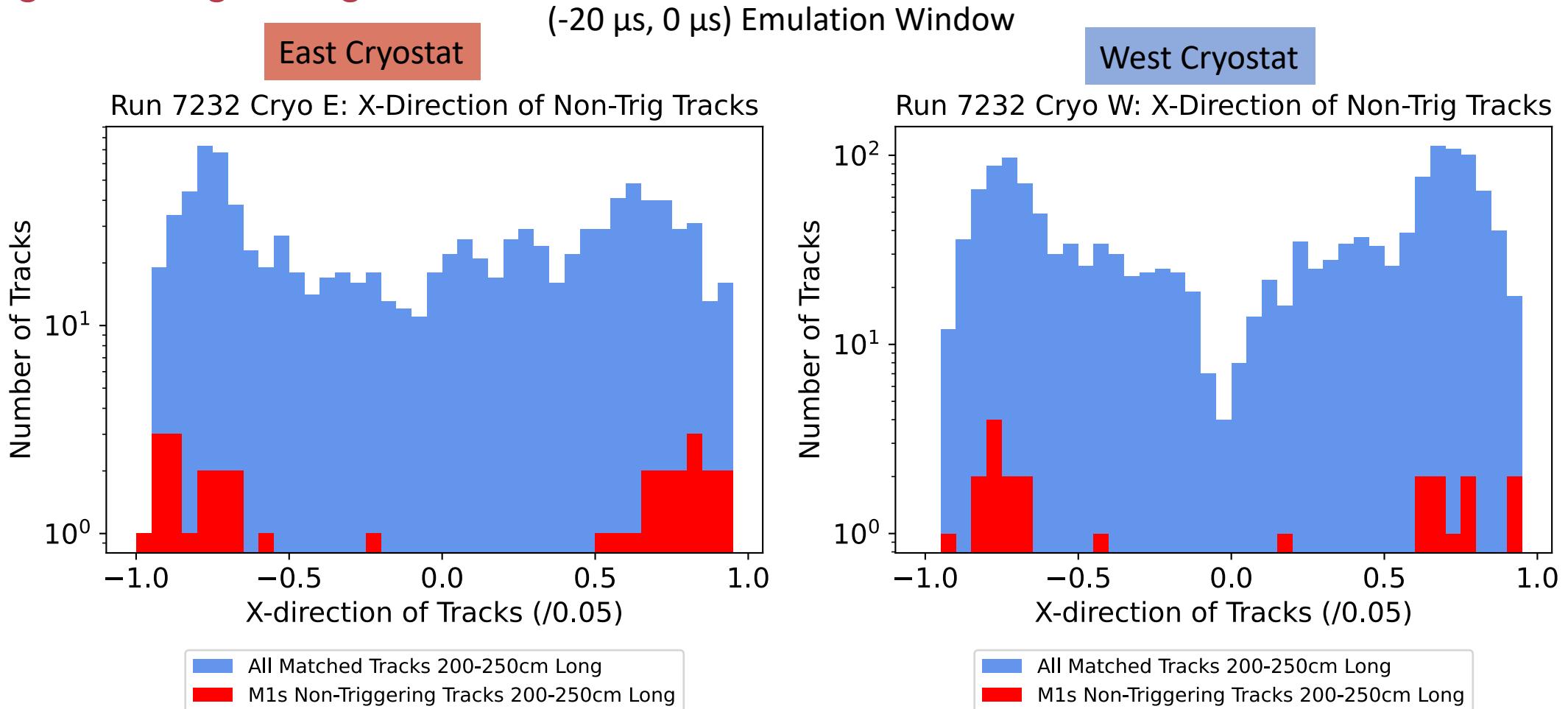
# Possible Connection:

Smaller track angle along the z-axis



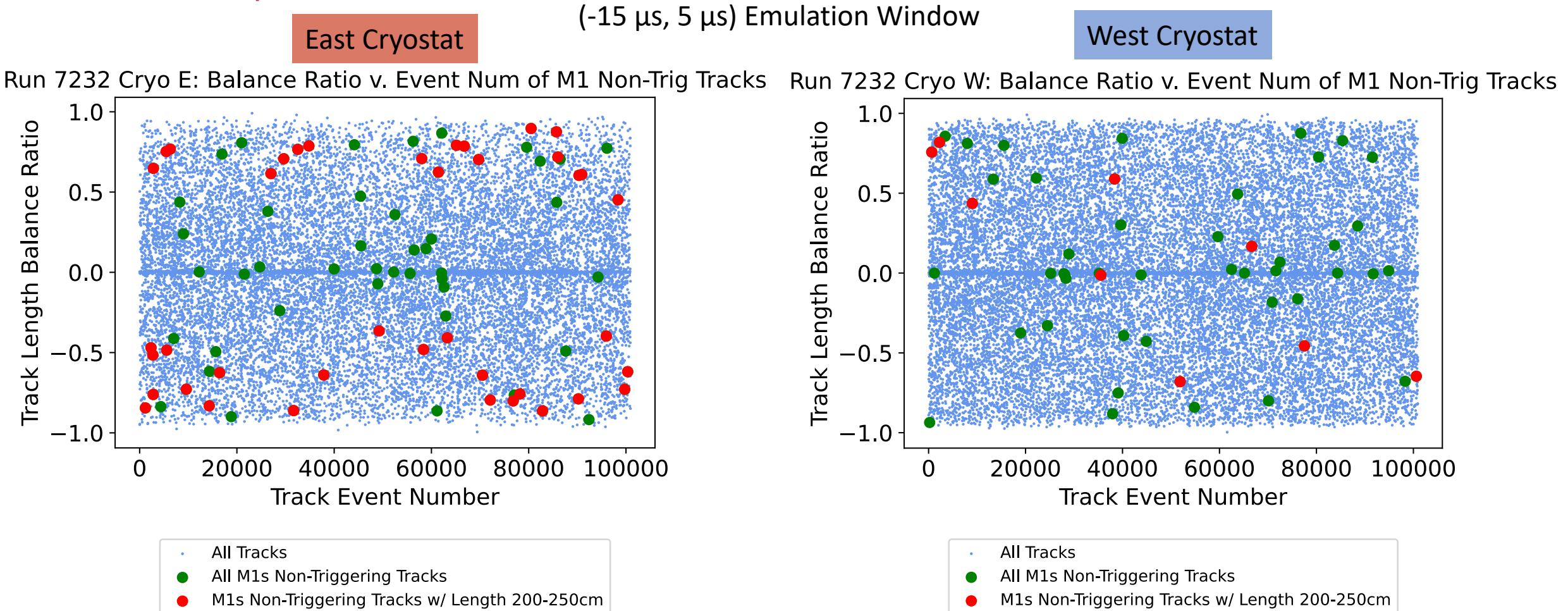
# Possible Connection:

Large track angle along the x-axis



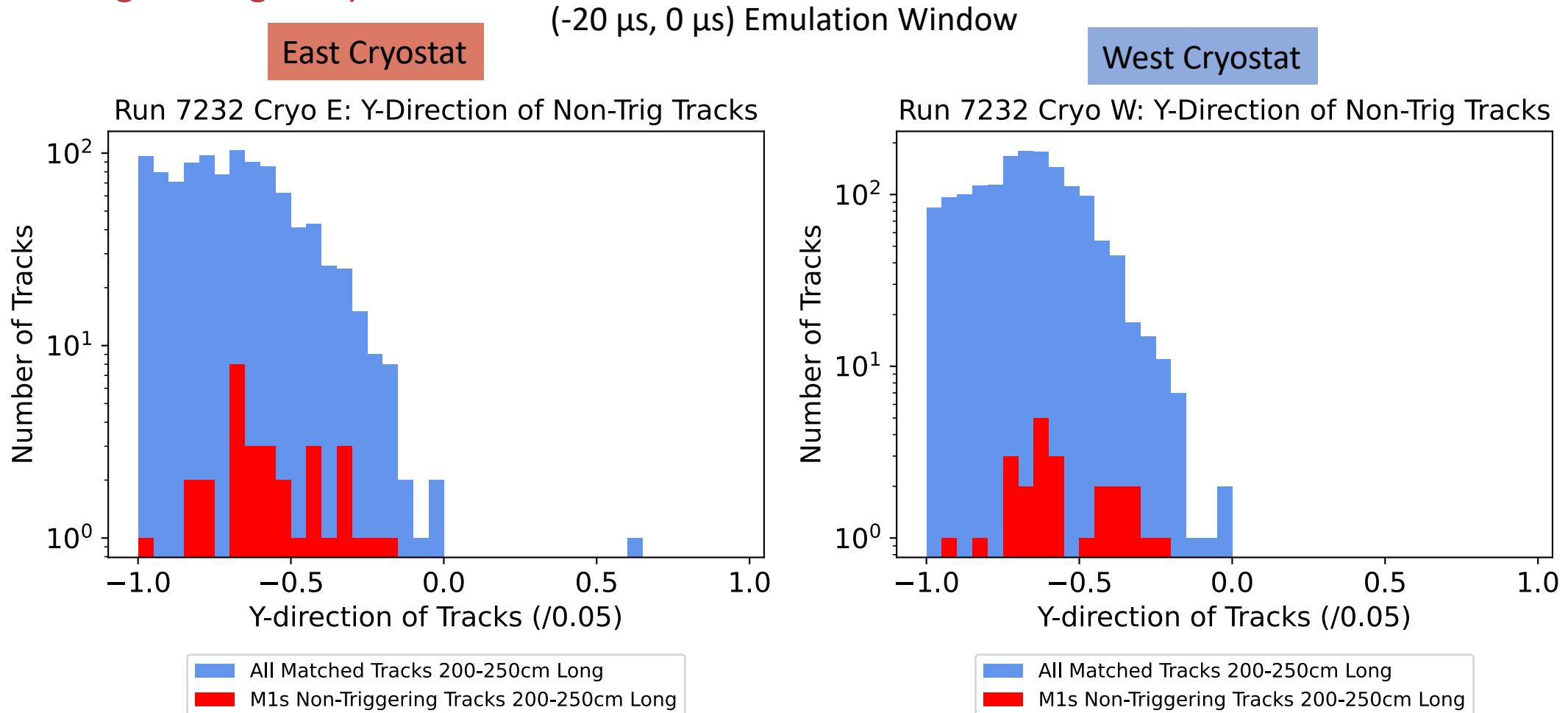
# Ruled Out Connection:

Not time dependent



# Ruled Out Connection:

Track angle along the y-axis



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# Conclusions and Next Steps

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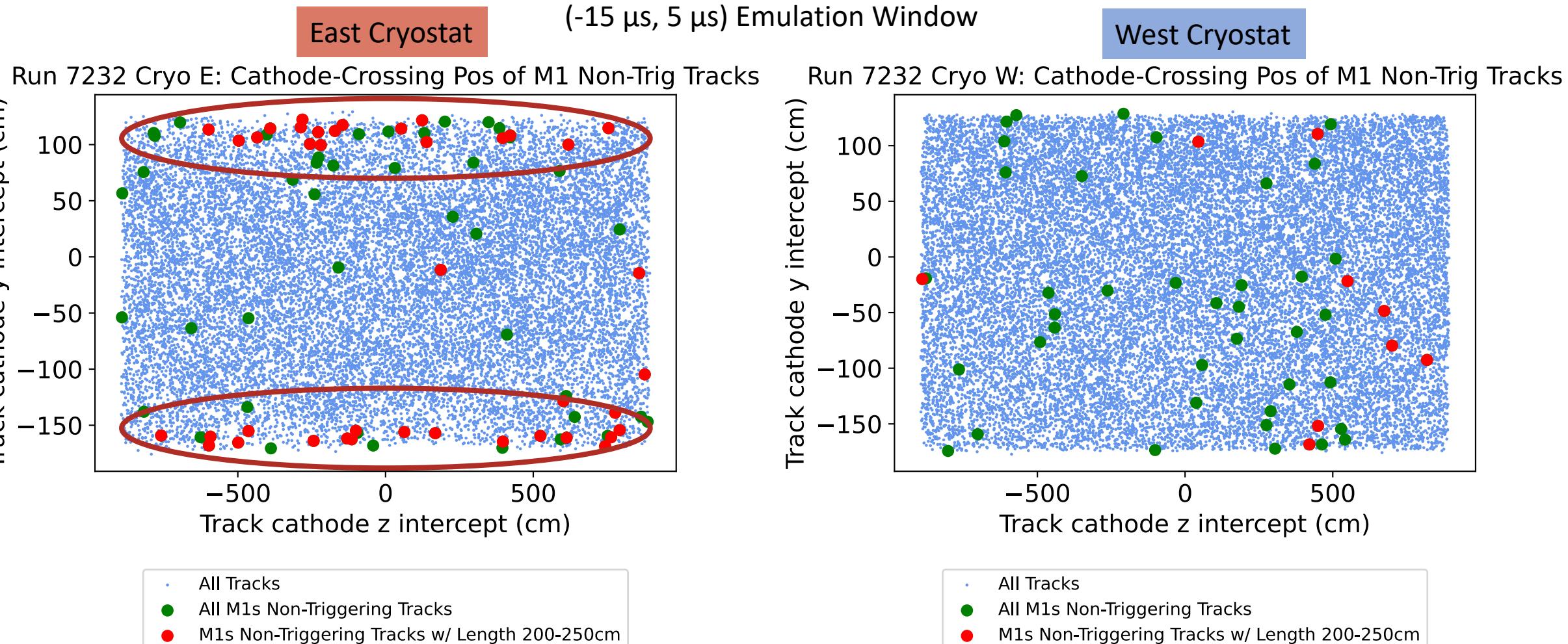
- Still investigating the 2m track anomaly
- New minimum bias run (Run 8650)
  - Repeat these analyses to understand changes
  - Look for efficiency improvements or any new features to study
  - Bug in the processing code found which resulted in errors in emulated trigger performance, so there have been delays in this analysis due to reprocessing
- Later analyze trigger efficiency for CRT-matched tracks

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# Additional Slides

# Possible connection:

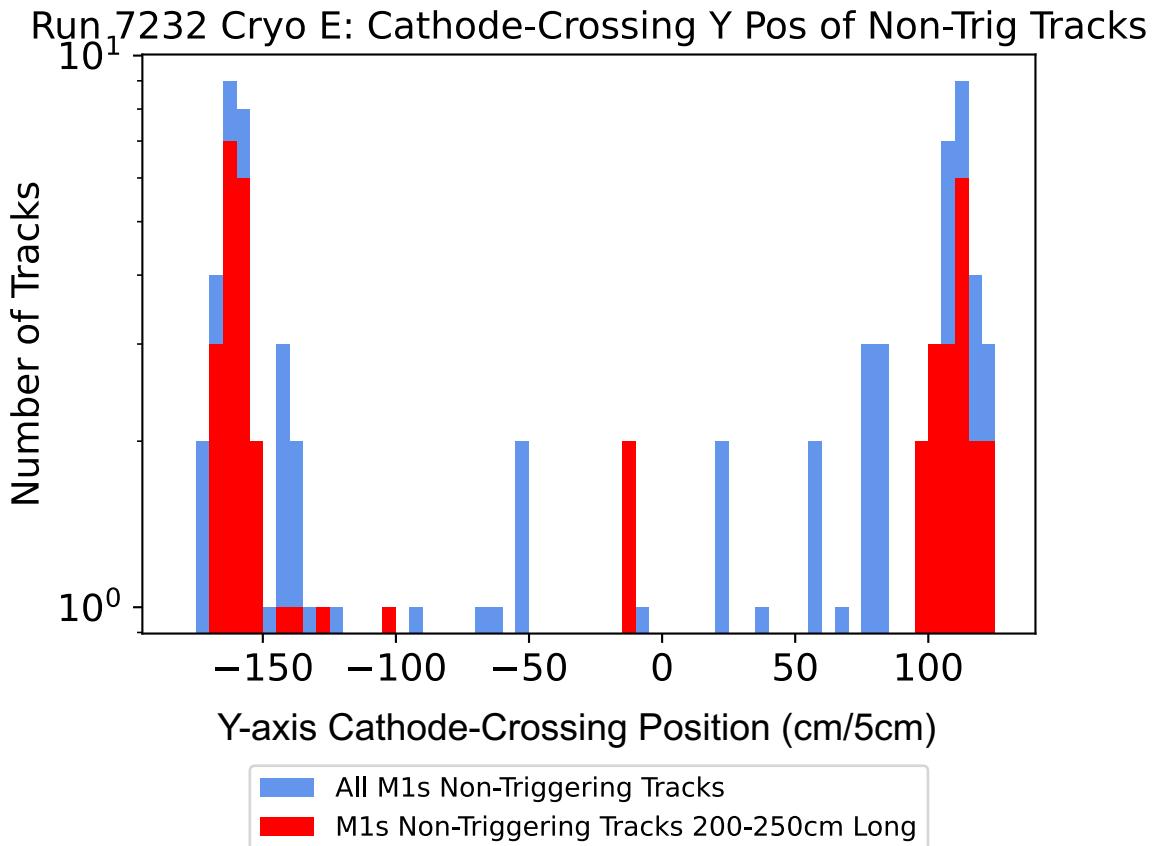
## Y-axis cathode-crossing position



# Possible connection:

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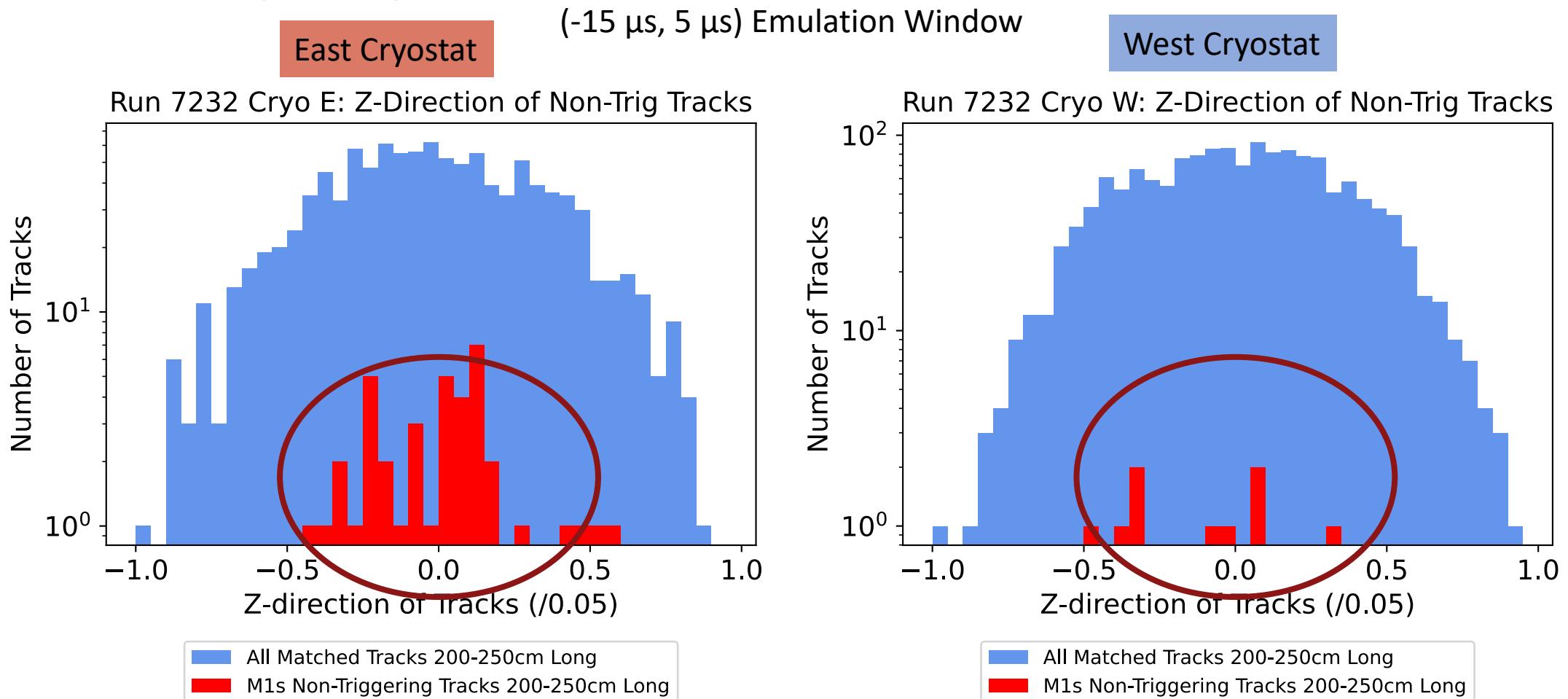
## Y-axis cathode-crossing position



- 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 =  $0.36 \times 42 = 15.2$
- Actual Number of M1 non-triggering tracks with lengths 200-250 cm with y-axis cathode-crossing position between -150 and 90 cm = **6**

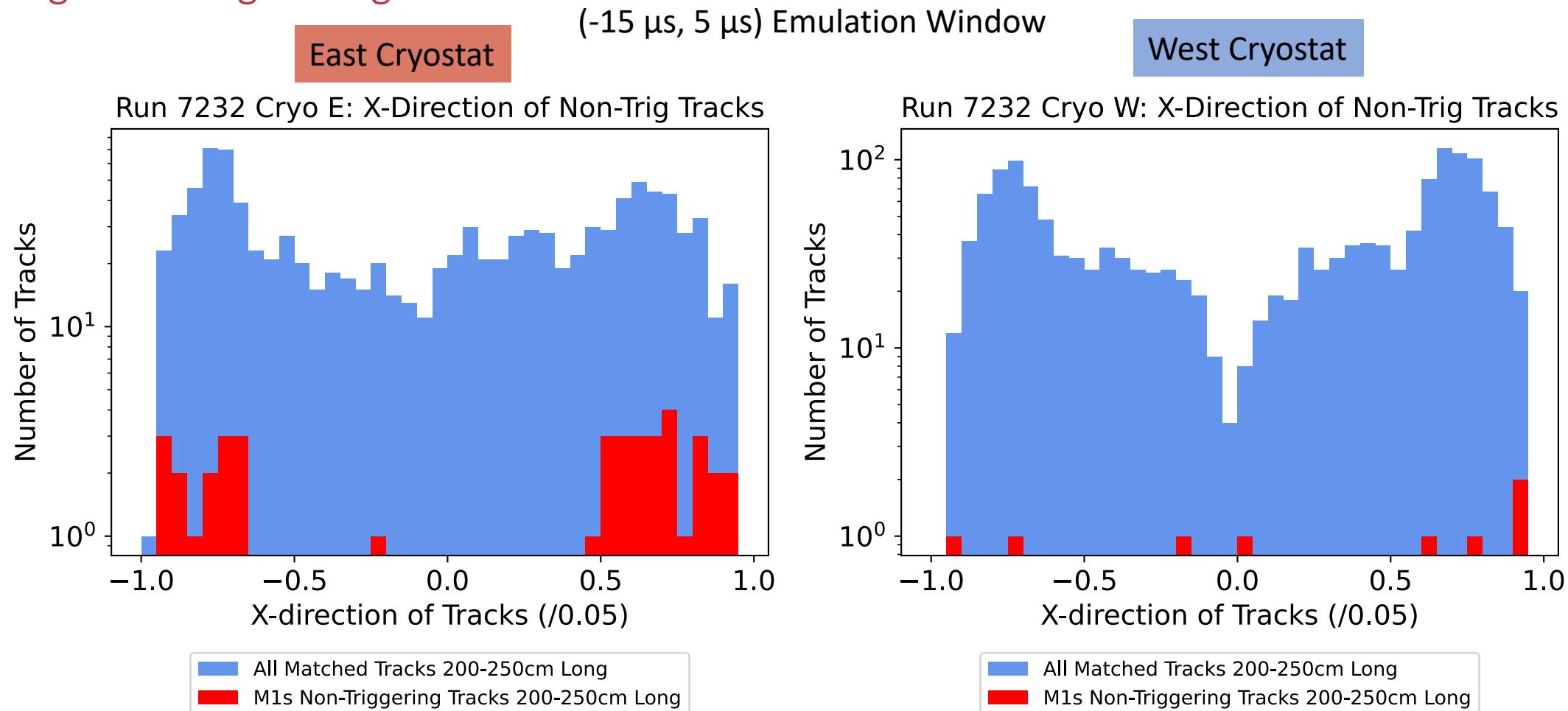
# Possible Connection:

Smaller track angle along the z-axis



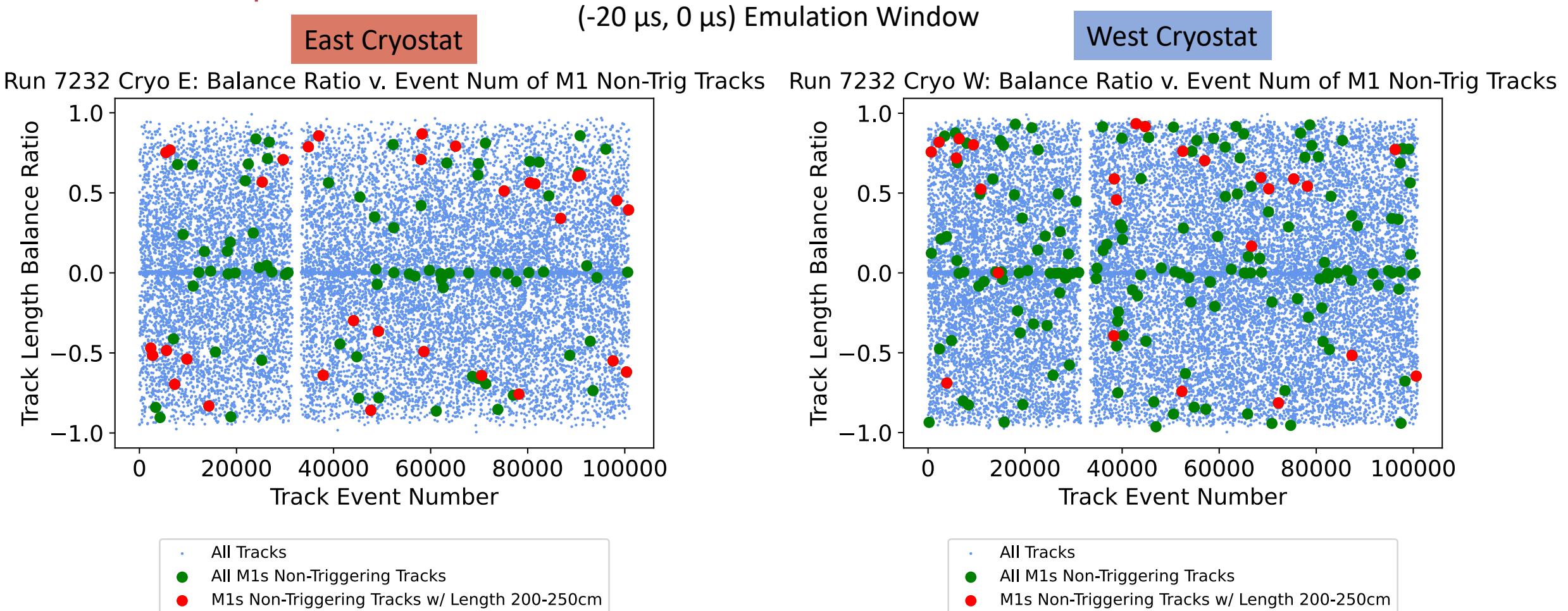
# Possible Connection:

Large track angle along the x-axis



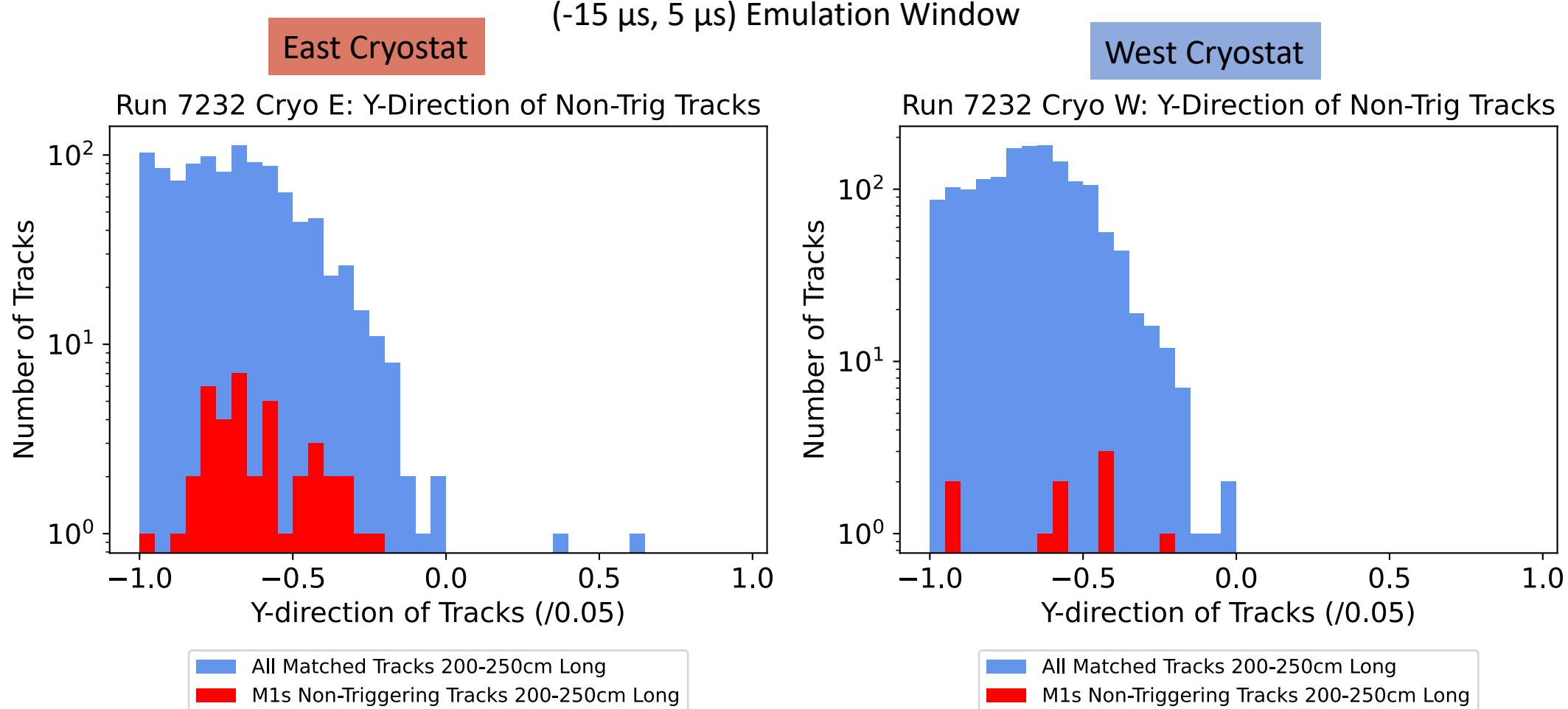
# Ruled Out Connection:

Not time dependent



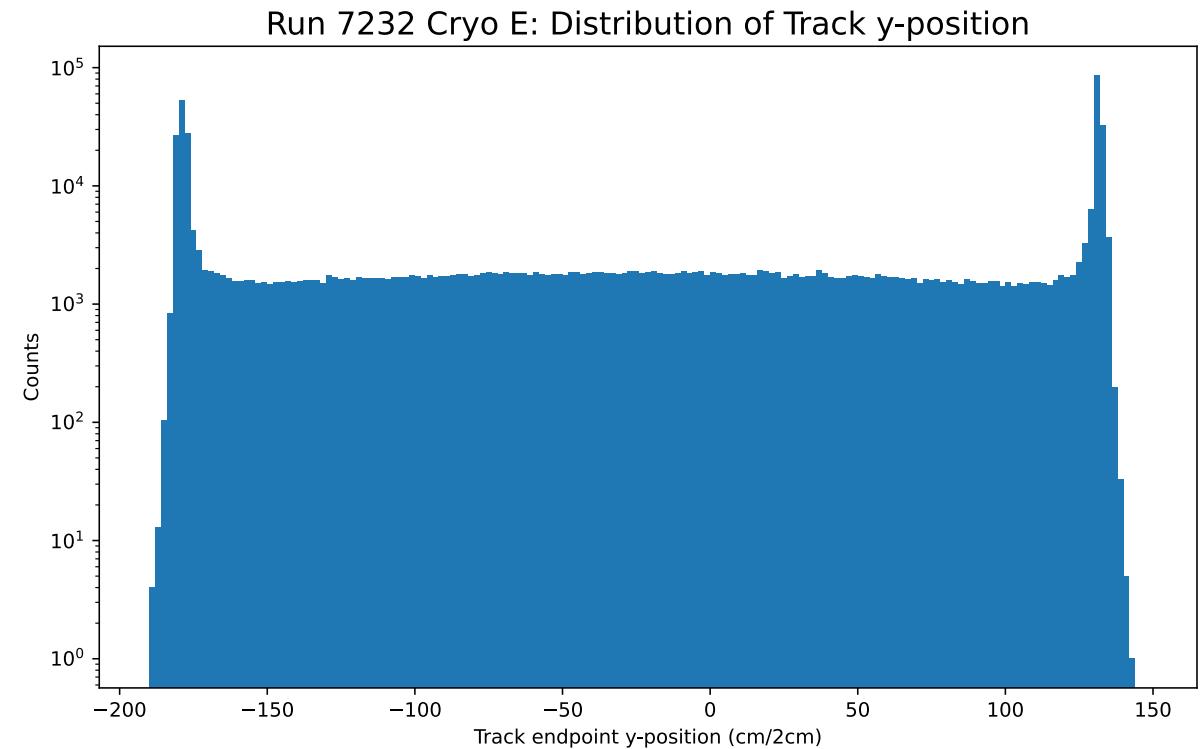
# Ruled Out Connection:

Track angle along the y-axis

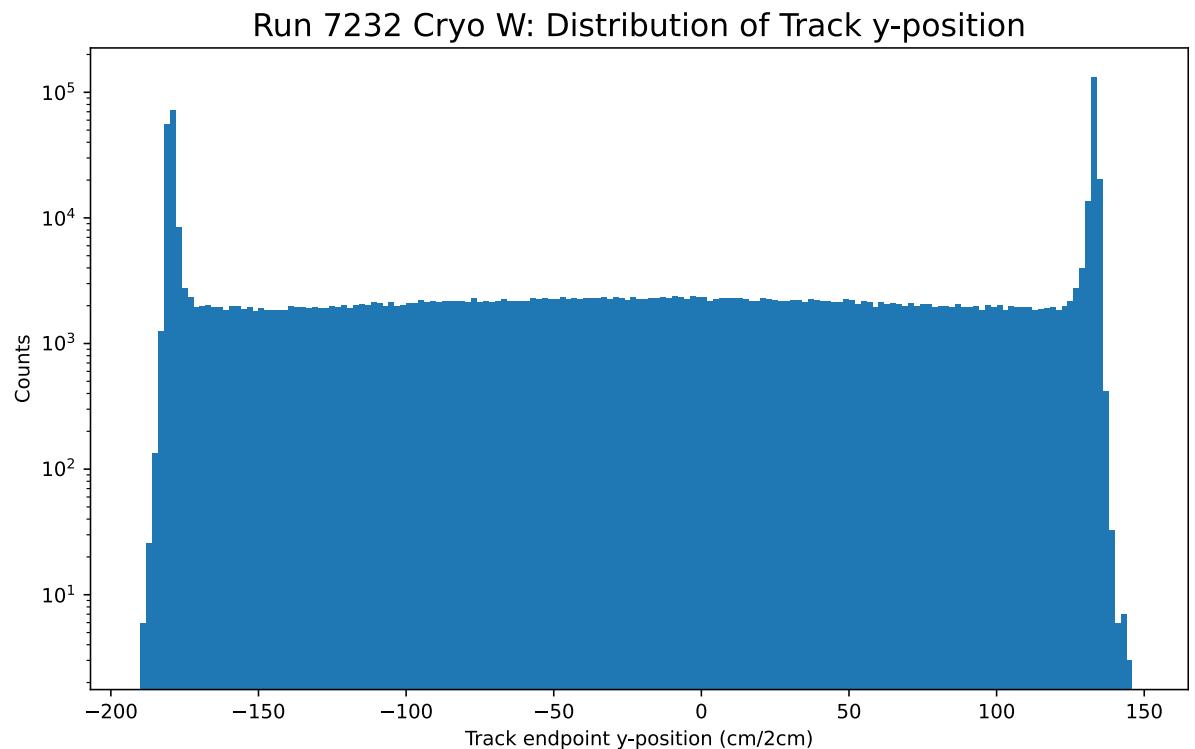


# Y-axis Track Endpoint Distribution

East Cryostat



West Cryostat



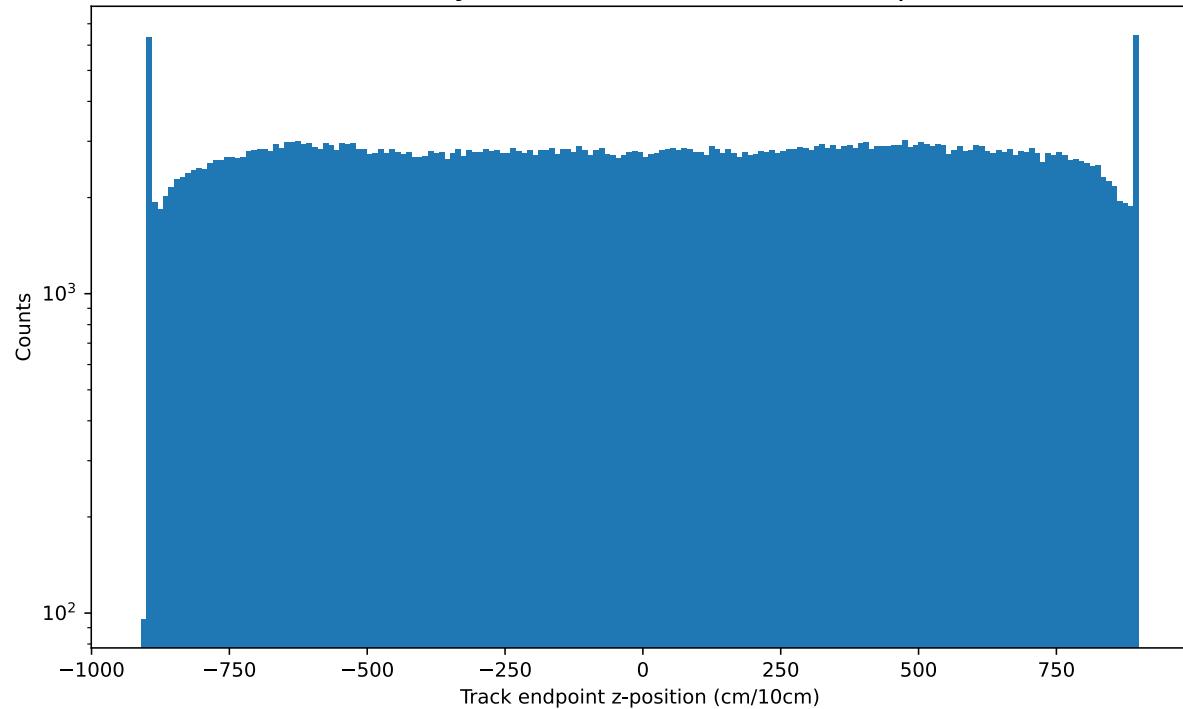
# Z-axis Track Endpoint Distribution

East Cryostat

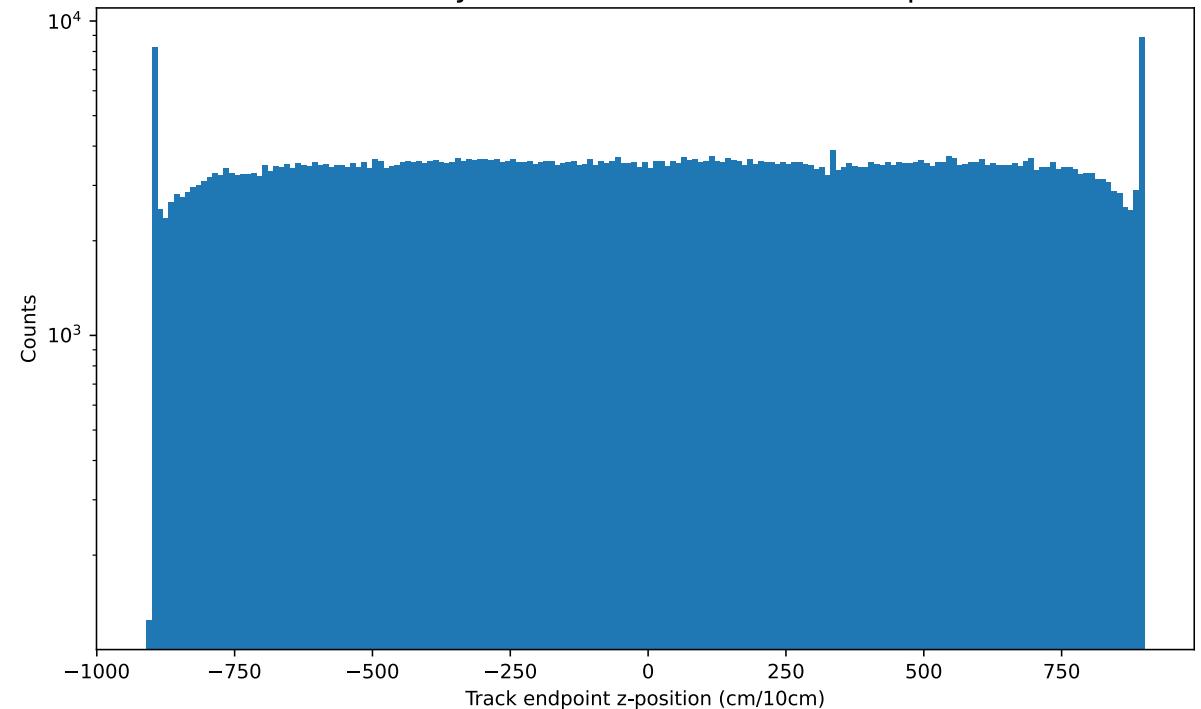
(-15  $\mu$ s, 5  $\mu$ s) Emulation Window

West Cryostat

Run 7232 Cryo E: Distribution of Track z-position



Run 7232 Cryo W: Distribution of Track z-position



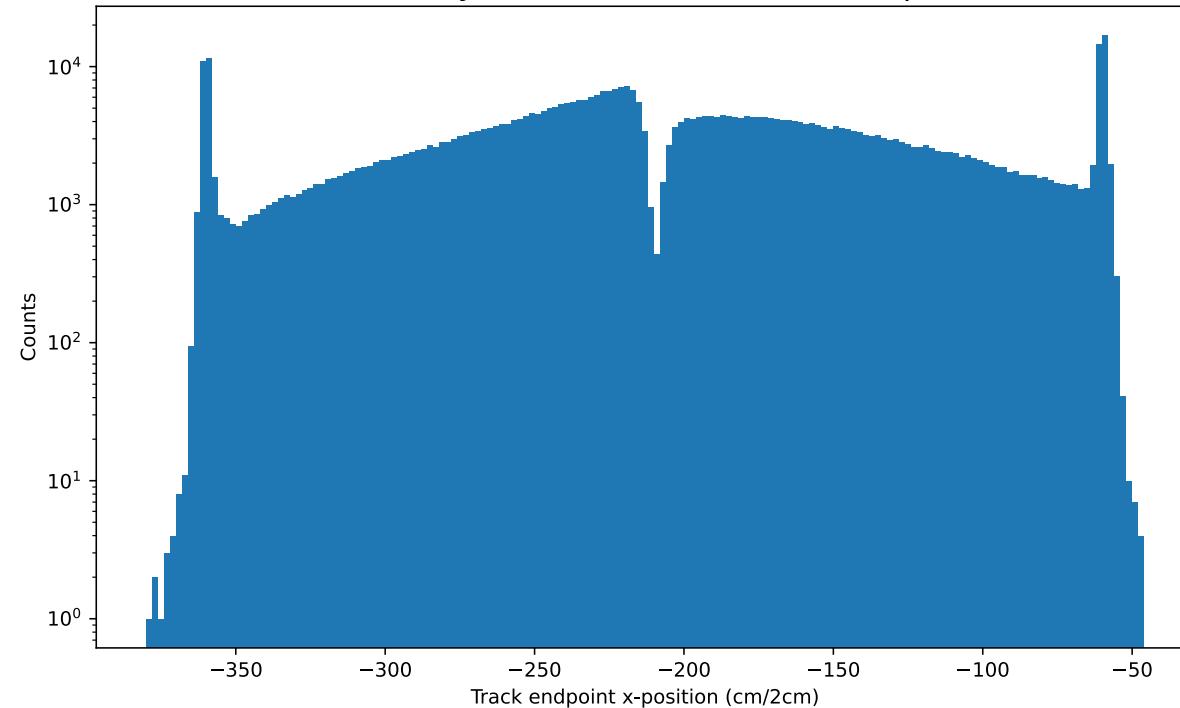
# X-axis Track Endpoint Distribution

East Cryostat

(-15  $\mu$ s, 5  $\mu$ s) Emulation Window

West Cryostat

Run 7232 Cryo E: Distribution of Track x-position



Run 7232 Cryo W: Distribution of Track x-position

