

Run 7232 Trigger Efficiency Results

ICARUS Data-Driven Trigger Efficiency Measurement

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Motivation

- It is important to study the efficiency of the trigger in order to select the optimal level of filtering for the trigger
- We plotted the efficiency as a function of different track characteristics (length, starting and ending x coordinate, starting z coordinate)
- We plotted the efficiency under different simulated trigger settings:

M1: 1 PMT pair trigger

S3: 3 PMT pairs trigger

S5: 5 PMT pairs trigger

S8: 8 PMT pairs trigger

S10: 10 PMT pairs trigger

S15: 15 PMT pairs trigger

Methods

- Data from minimum bias run 7232
 - Full TPC readout (1.6 ms), Single PMT buffer readout (150 μ s)
 - Data provided by J. Zettlemoyer, the same dataset he used
- Plotted the efficiency of the emulated triggers given by the following formula (SBN DocDB 24191):
$$\epsilon = \frac{(TPC \text{ tracks with light info}) \cdot (\text{which would fire the trigger})}{TPC \text{ tracks with light info}}$$
- Only counted TPC tracks with t0 within -55 and 75 μ s to fully contain a 20 μ s interval for trigger evaluation
- Estimated error in efficiency using an “exact” Clopper-Pearson interval with a confidence level of 68.3%
- Goals:
 - Recreate efficiency plot v. track length by J. Zettlemoyer
 - Explore trigger efficiency using this dataset as a function of other variables

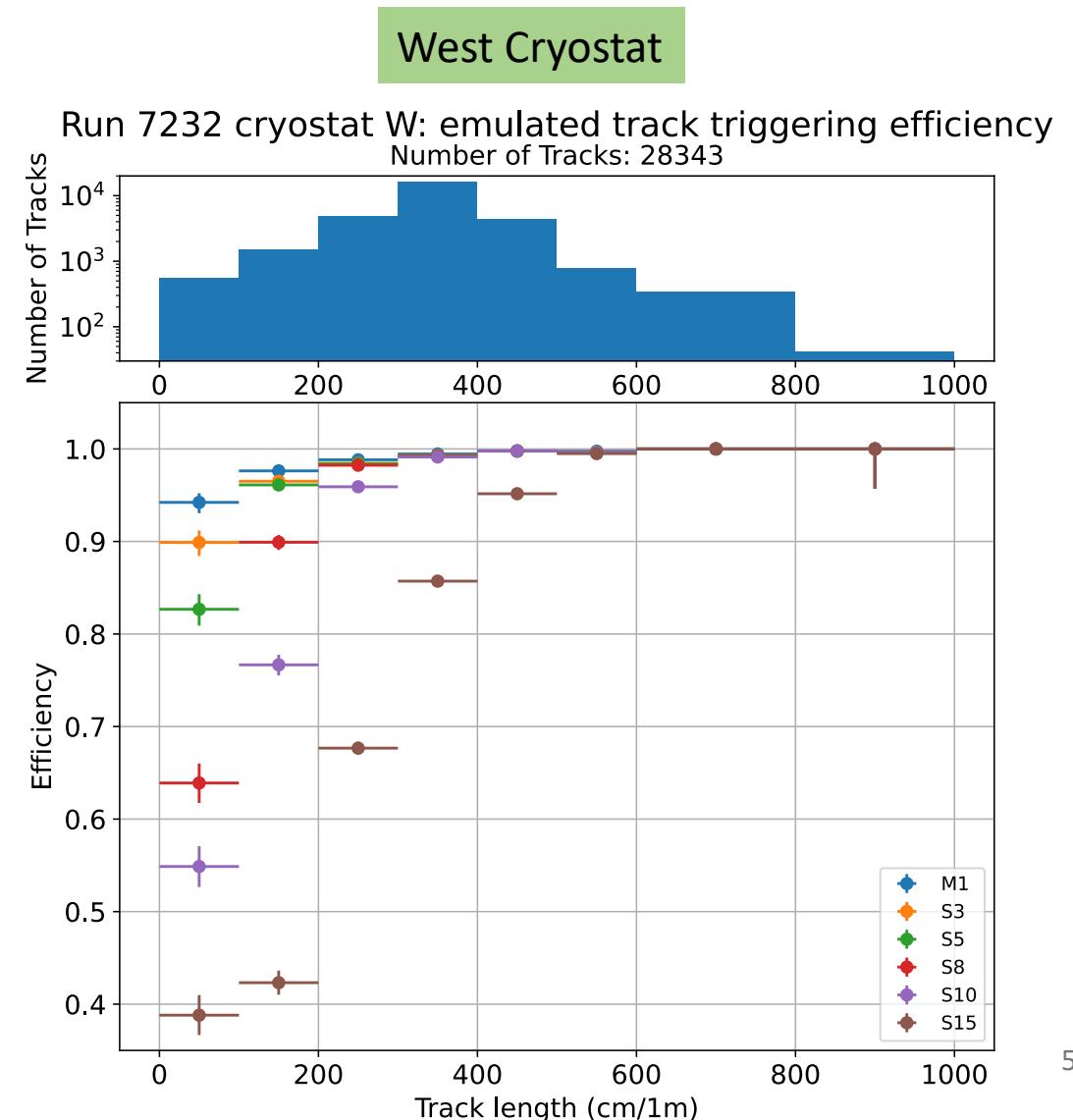
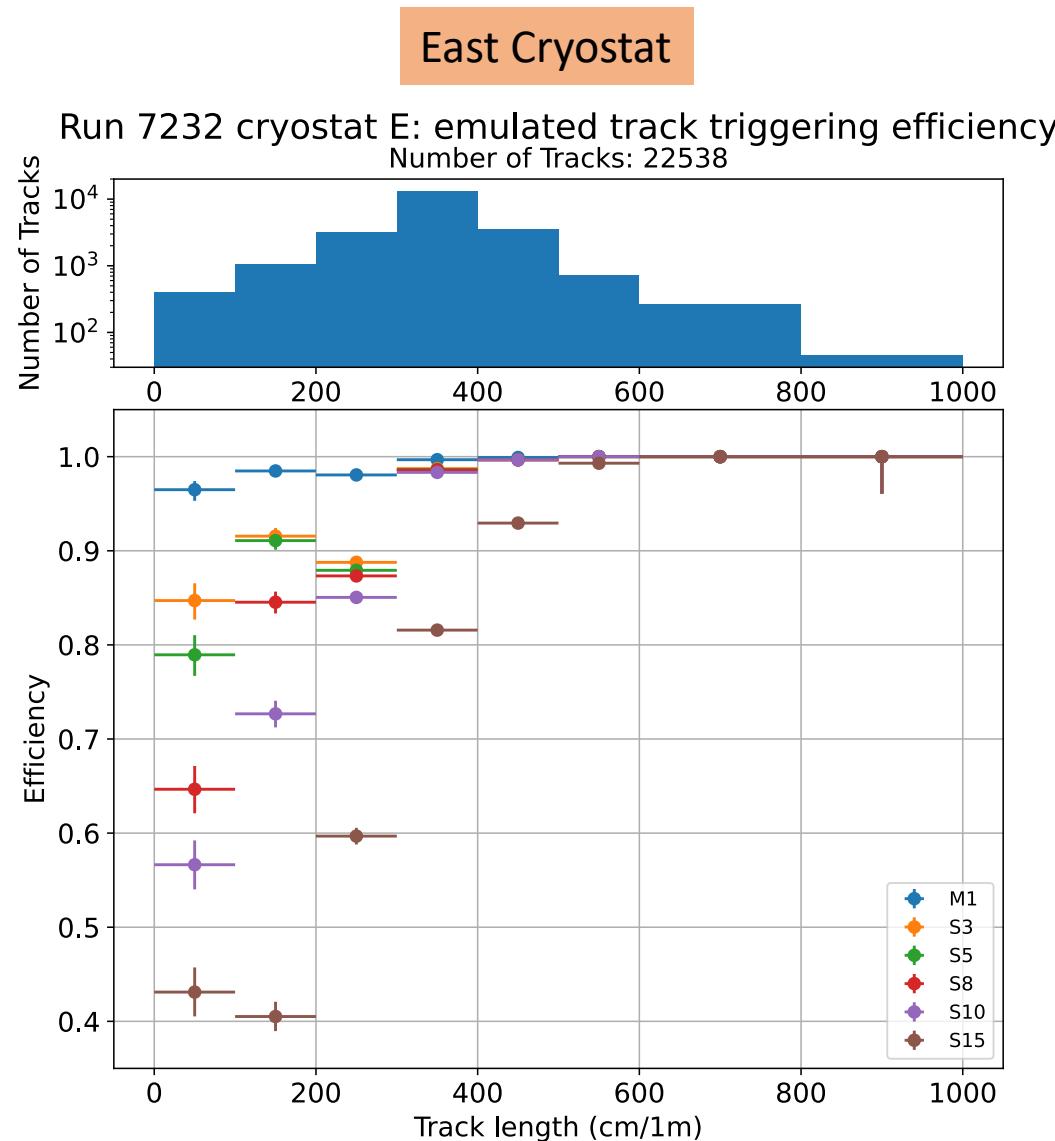
Efficiency Plots

Using reconstructed cathode-crossing tracks from a minimum-bias data run with different trigger emulations, comparing East and West cryostats

Trigger Emulation Window: (-20 μ s, 0 μ s)

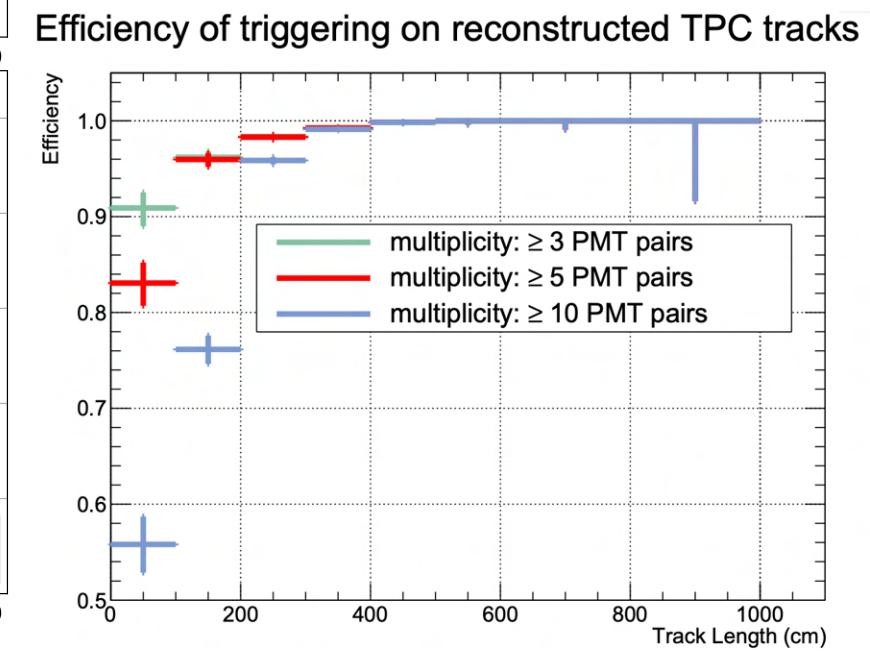
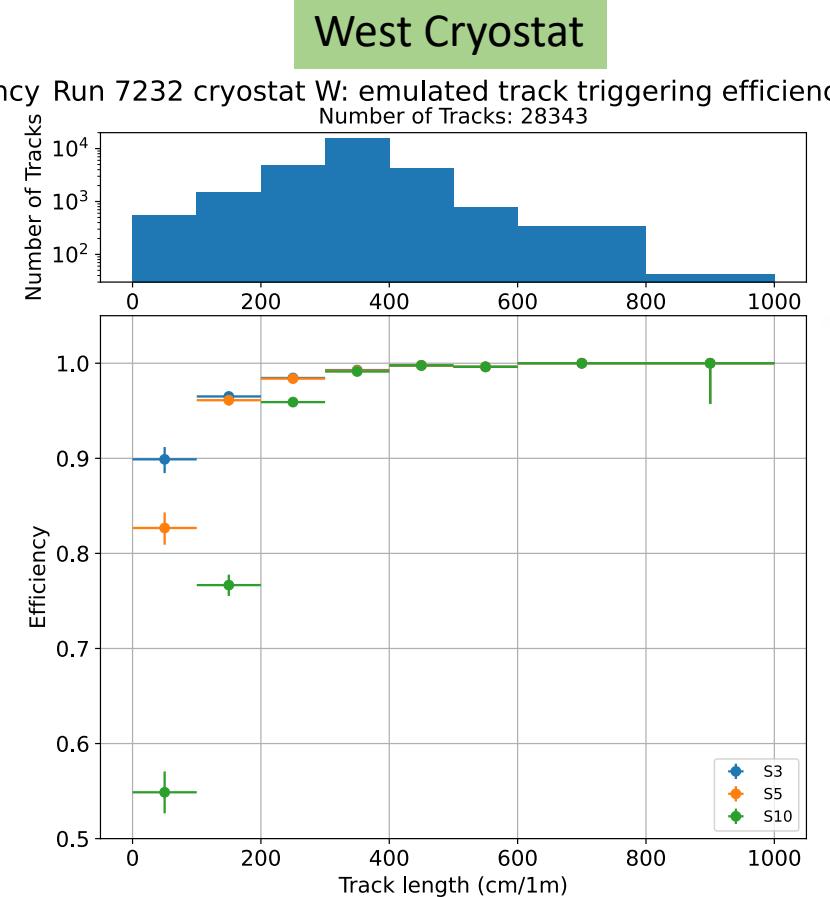
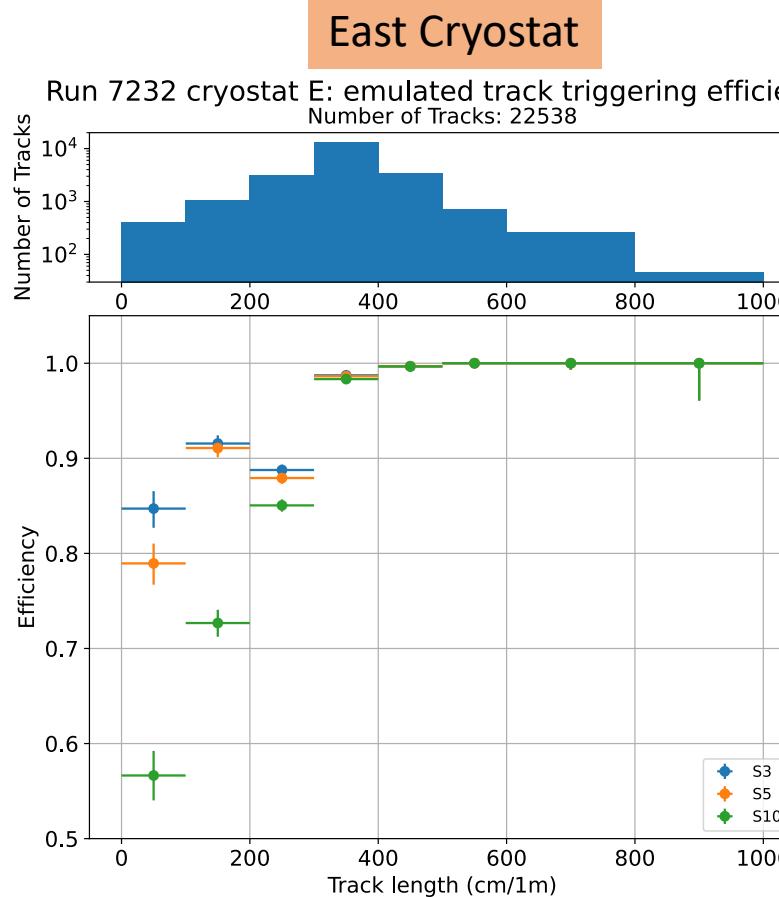
Track length

- There were very few (<0.05%) tracks longer than 1000 cm, so I focused on tracks shorter than 1000 cm



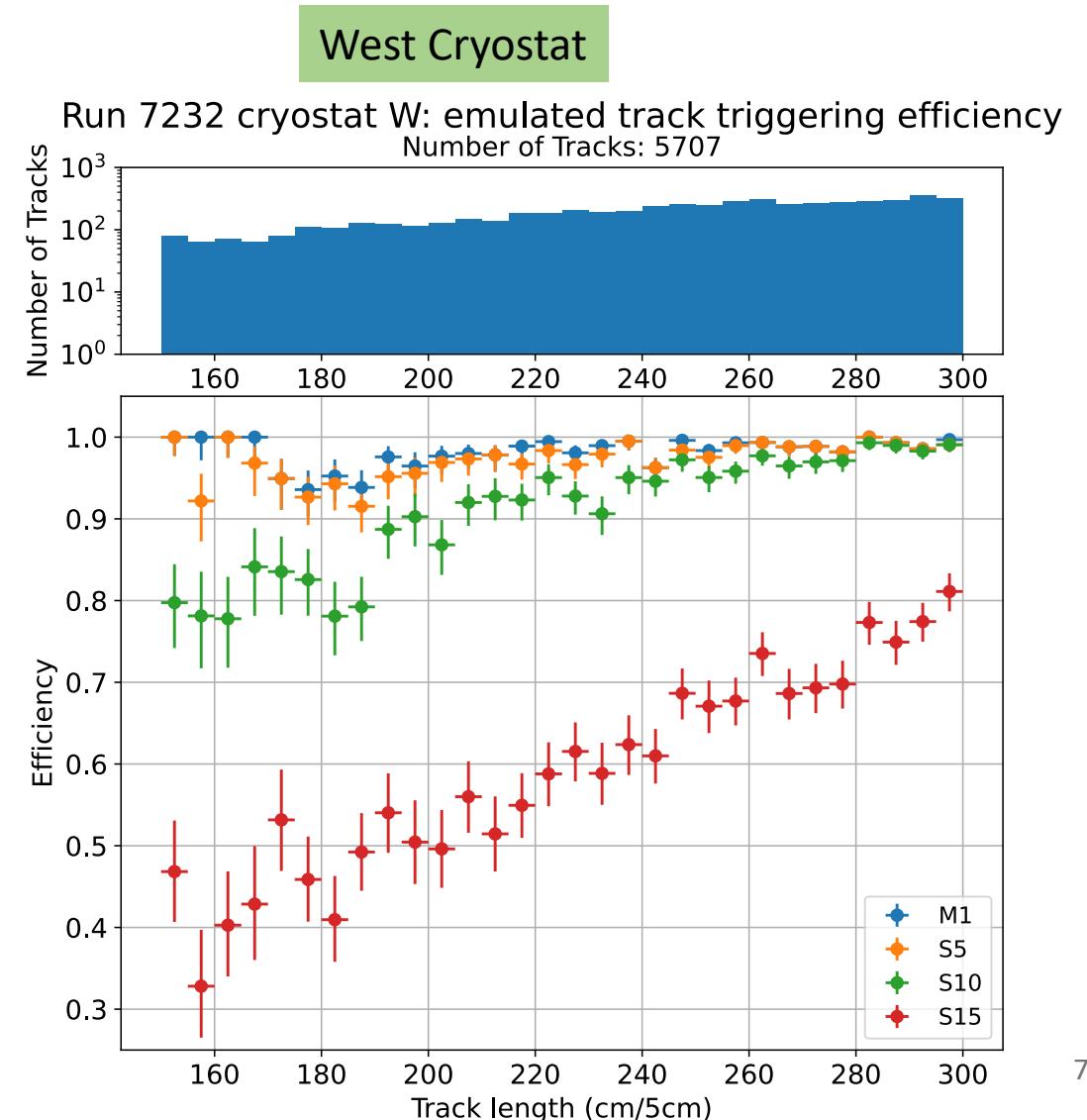
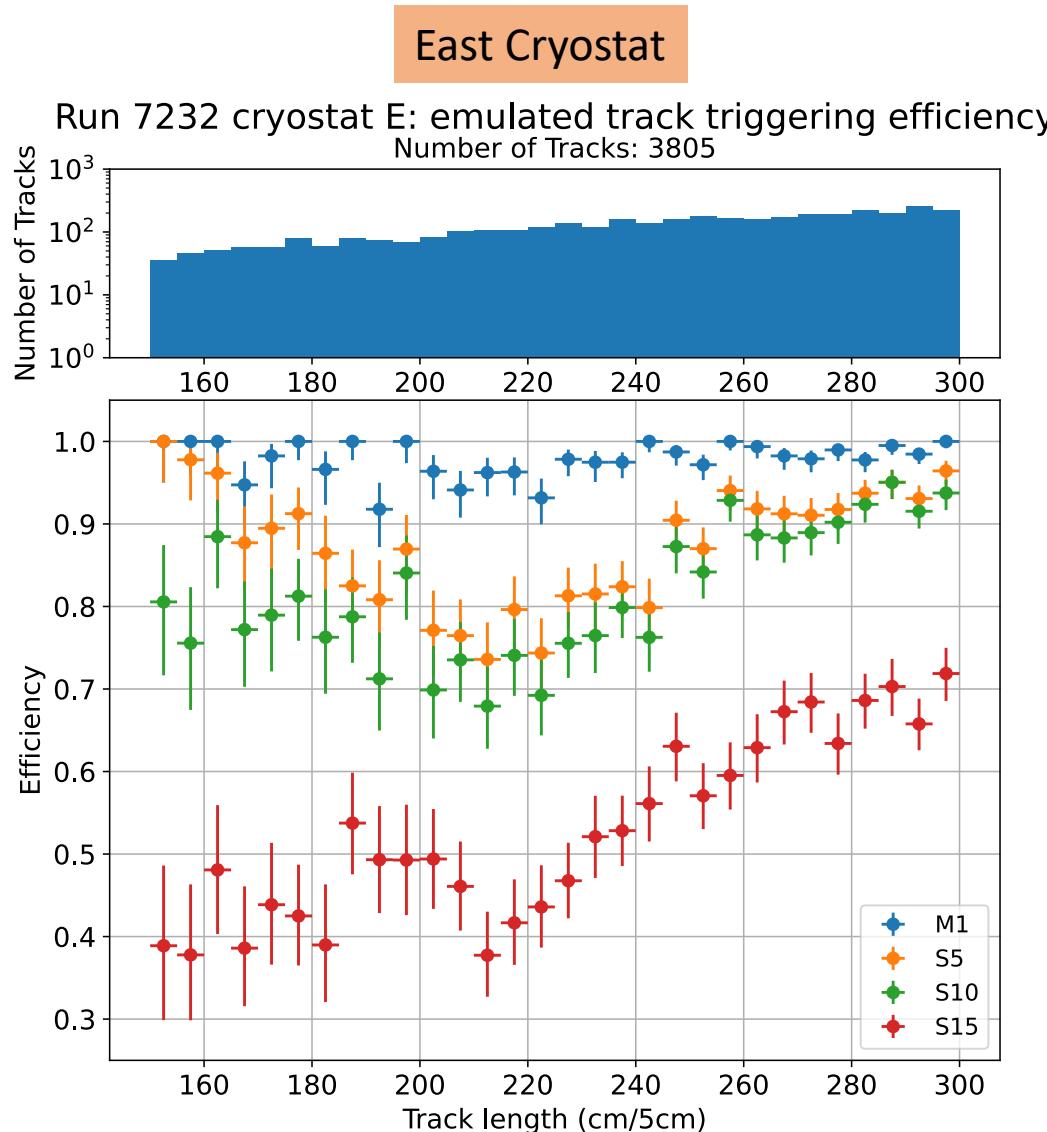
Track length

- I used this work to recreate a plot of trigger efficiencies by J. Zettlemoyer (SBN DocDB 26671)
- It appears that he used the data from the West cryostat, which matches well albeit slight variations in the magnitude of the error bars, as he probably used a different method for these calculations



Track length

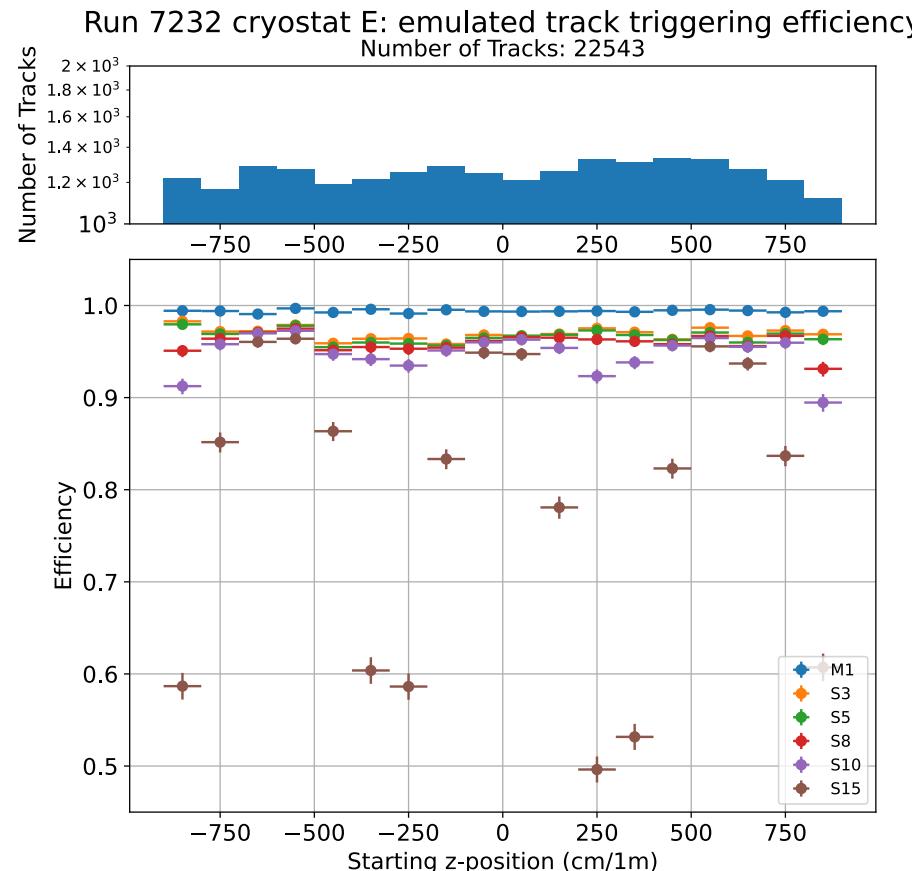
- In both cryostats there's a drop in efficiency of the emulated triggers for track lengths around 200-240 cm



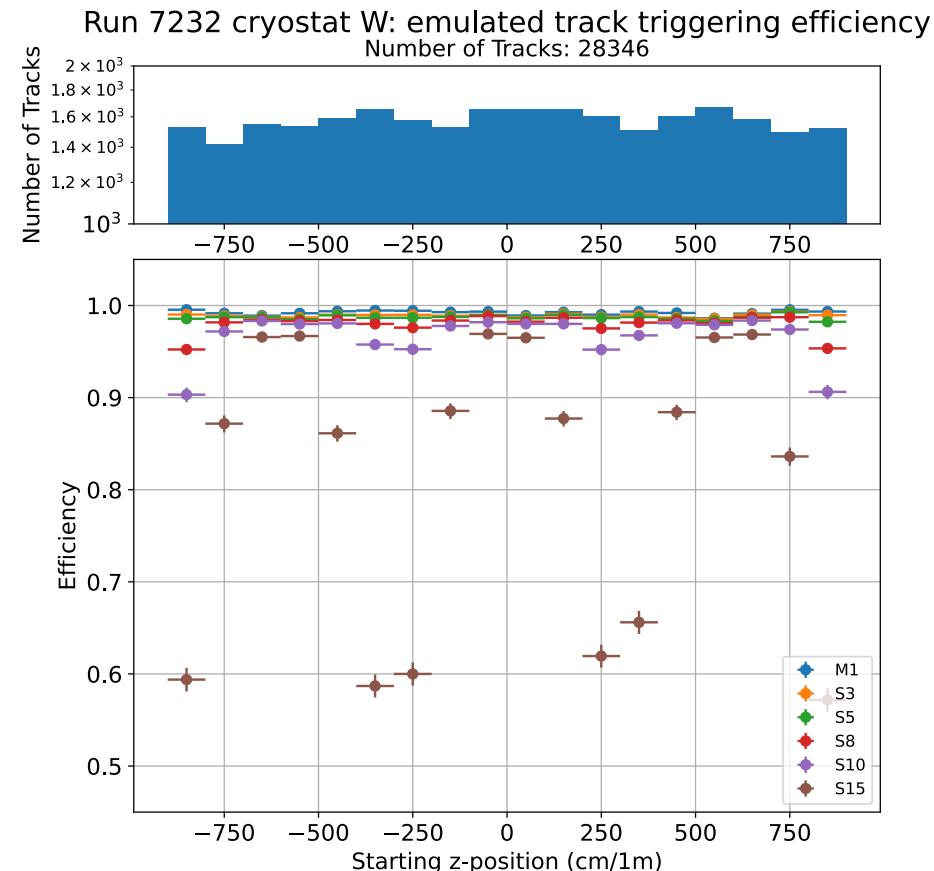
Starting z-position of tracks

- Starting z-position varied from about -900 cm to 900 cm and appears to be roughly evenly distributed
- The efficiency appears to have 3 peaks, most clear for S15 data, which makes sense as the trigger emulation used for this dataset has 3 sections of the cryostat along the z-axis, so efficiency is highest in the centers of those sections
- The sliding window setup should eliminate this issue.

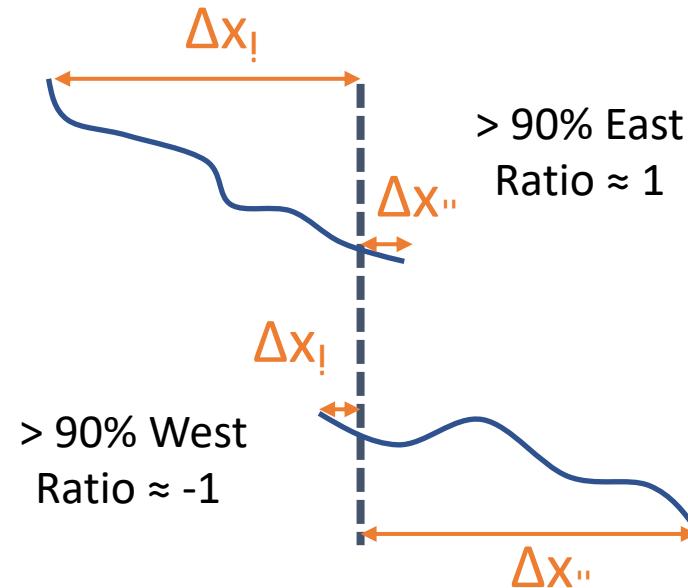
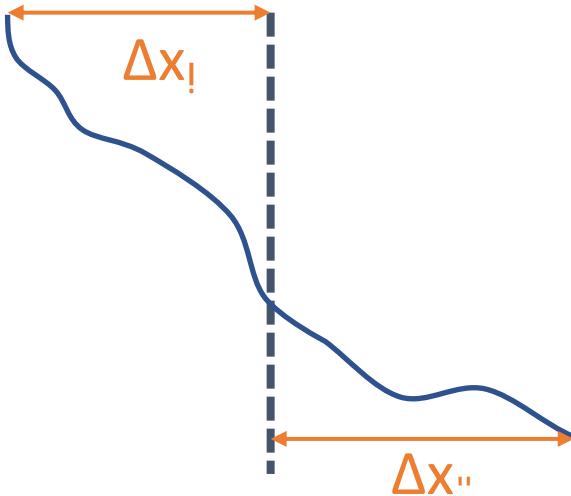
East Cryostat



West Cryostat



X-directional balance of tracks on either side of the cathode



$$\text{Balance ratio formula: } \frac{\Delta x_E}{\Delta x_W}$$

Δx_E and Δx_W are the x-distances to the cathode from the East and West track endpoints, respectively.

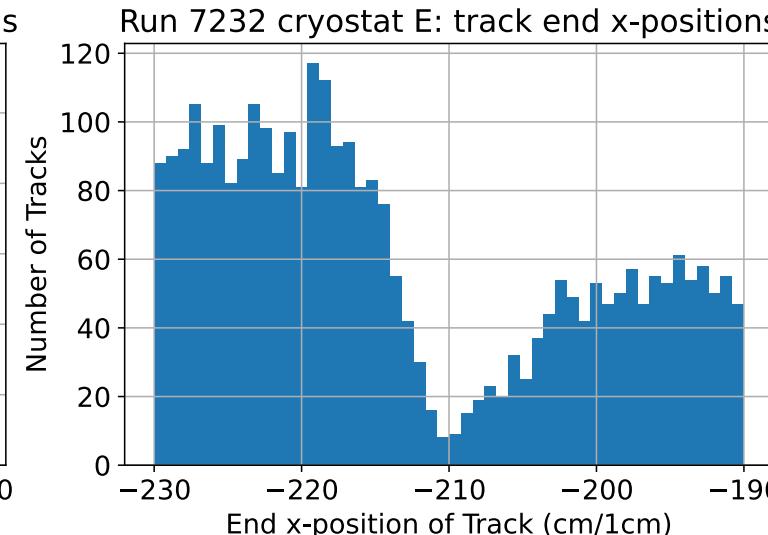
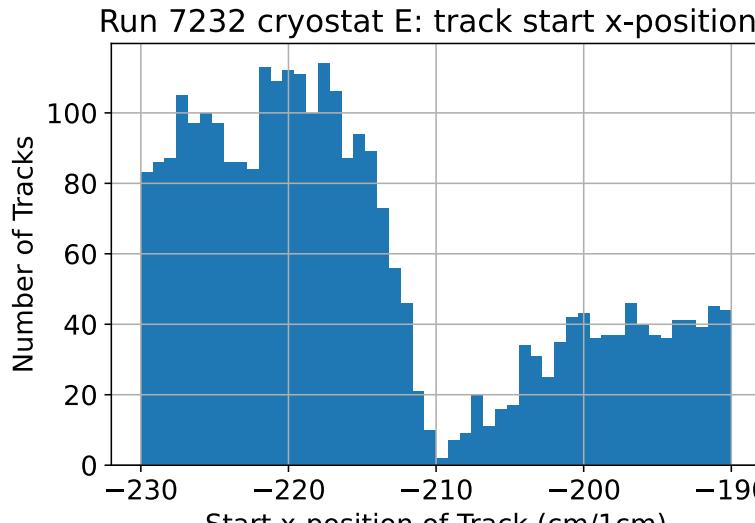
A balance ratio of

- ≈ 1 ! track mostly lies in the East section of the cryostat (with x-coordinate $> x_{\text{cathode}}$)
- ≈ -1 ! track mostly lies in the West section of the cryostat (with x-coordinate $< x_{\text{cathode}}$)
- ≈ 0 ! track is balanced evenly between the West and East sections of the cryostat

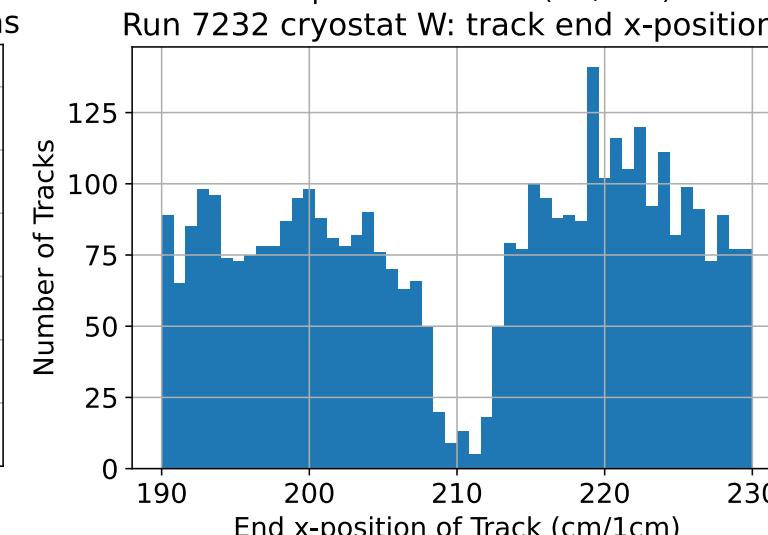
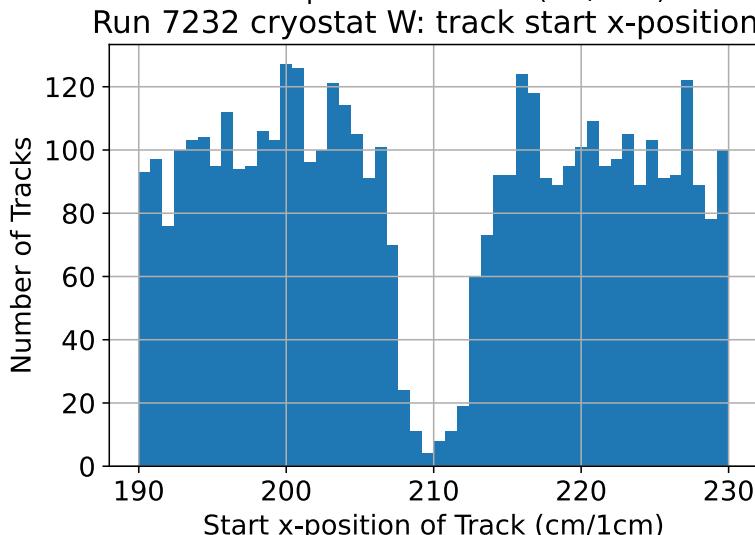
X-position of the cathode

- The start and end x-positions of tracks range from 0 to 400 cm, approximately
 - "start" and "end" label assigned by TPC pattern recognition (Pandora)
- There was a sharp drop in the number of tracks that start and end at $x=210$ cm for the West cryostat and $x=-210$ cm for the East cryostat which indicates that this is the x-position of the cathode

East Cryostat

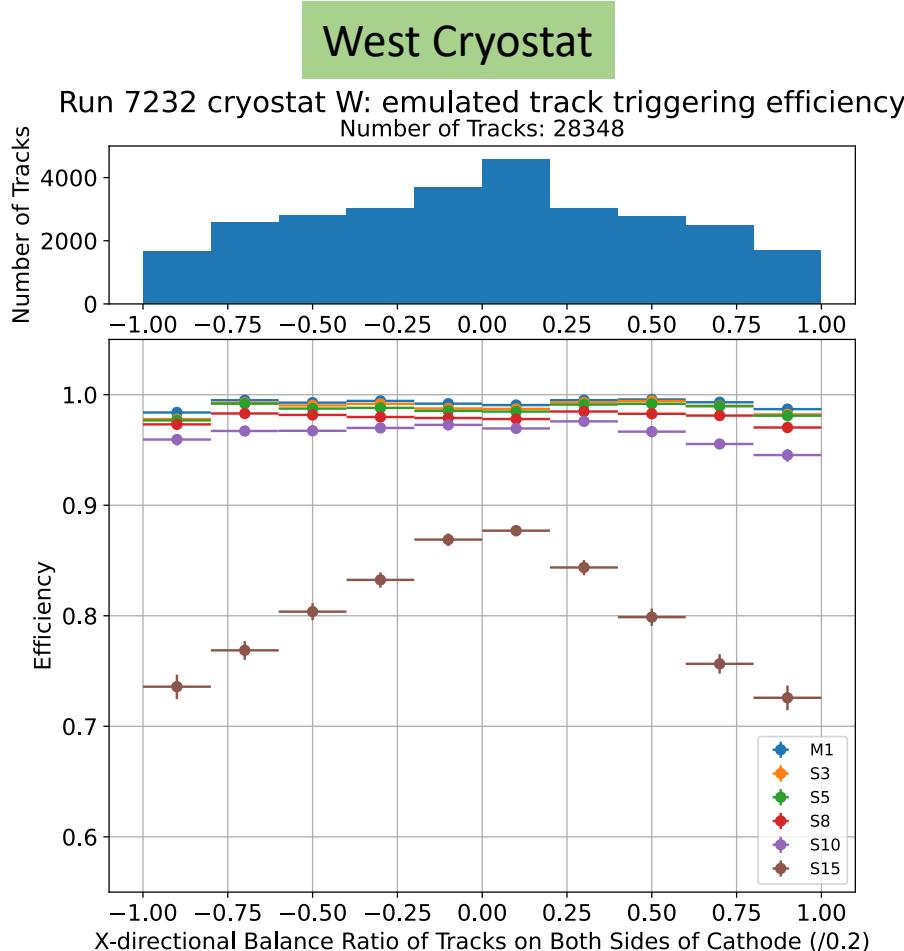
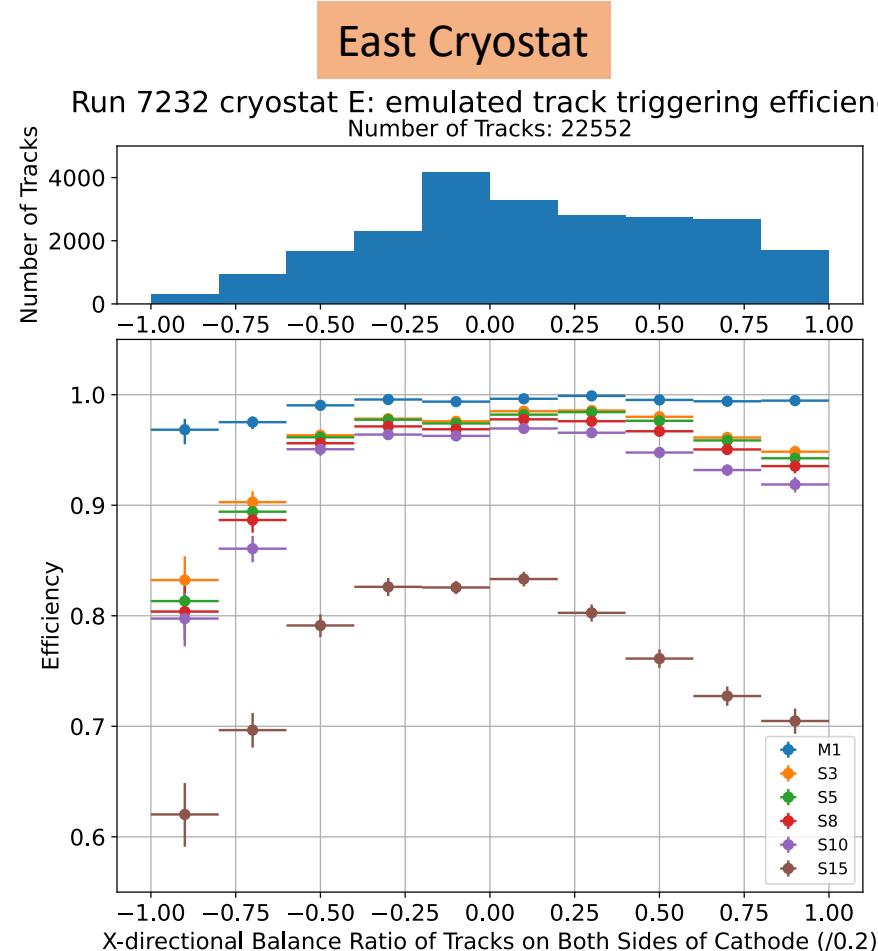


West Cryostat



X-directional balance of tracks on either side of the cathode

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



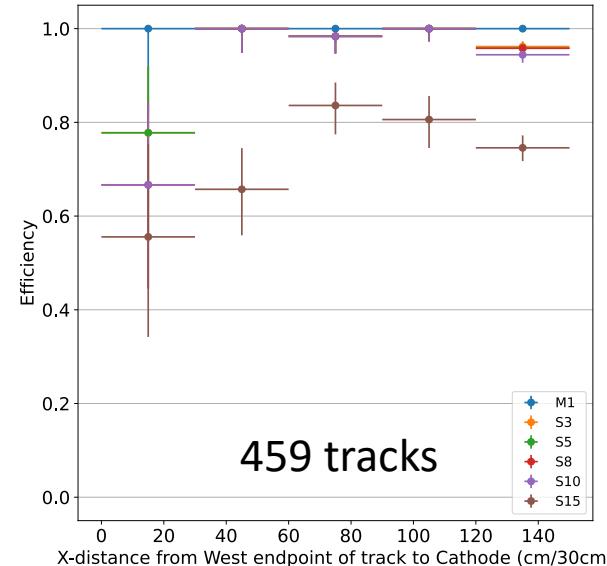
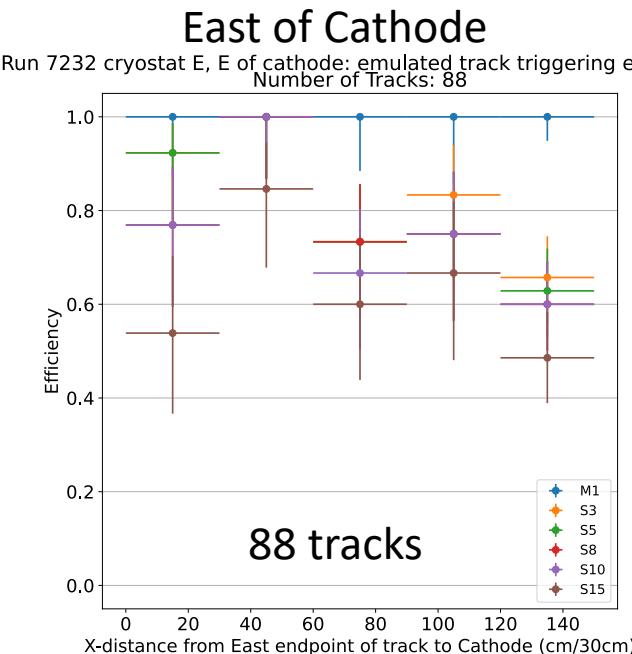
X-directional balance of tracks on either side of the cathode

- Why do balanced tracks have higher efficiency?
 - Some amount of light seen on both sides of cathode, rather than tracks on one side which let a few PMTs see a lot of light (amount of light doesn't matter, just the # of PMTs that detected more than the threshold)
 - Also perhaps that centered tracks are longer on average

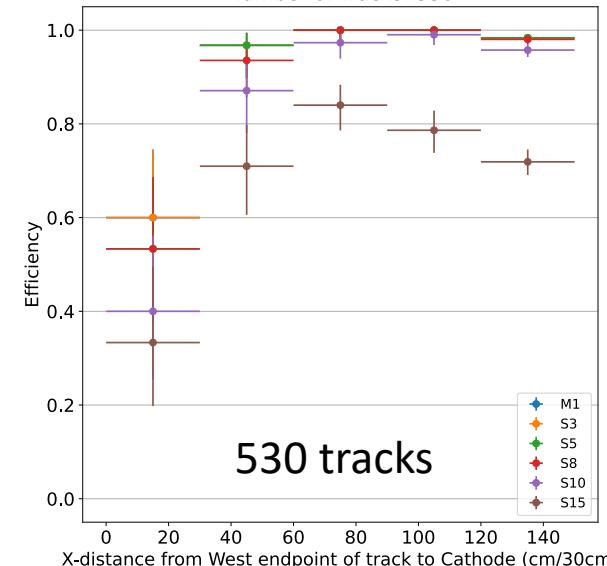
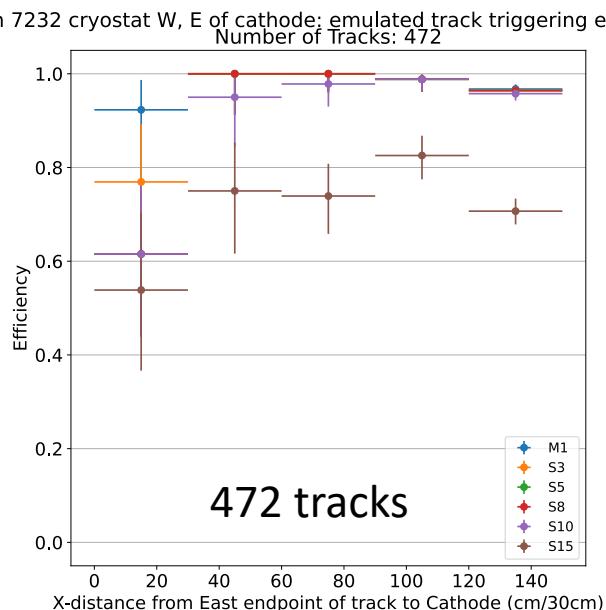
X-distance to Cathode from farther endpoint for tracks primarily on one side of the cathode

These plots describe tracks with a balance ratio more extreme than 0.9.

East Cryostat



West Cryostat

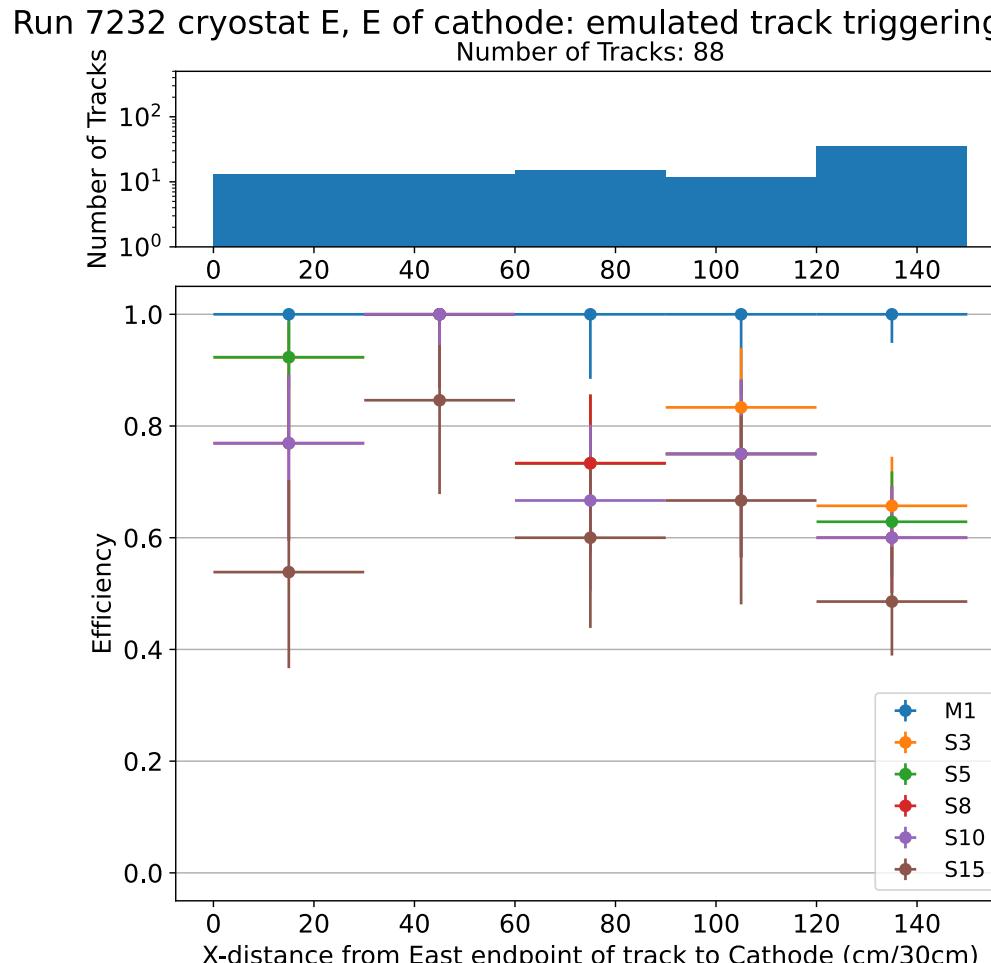


Distance to Cathode from farther endpoint for tracks primarily on one side of the cathode

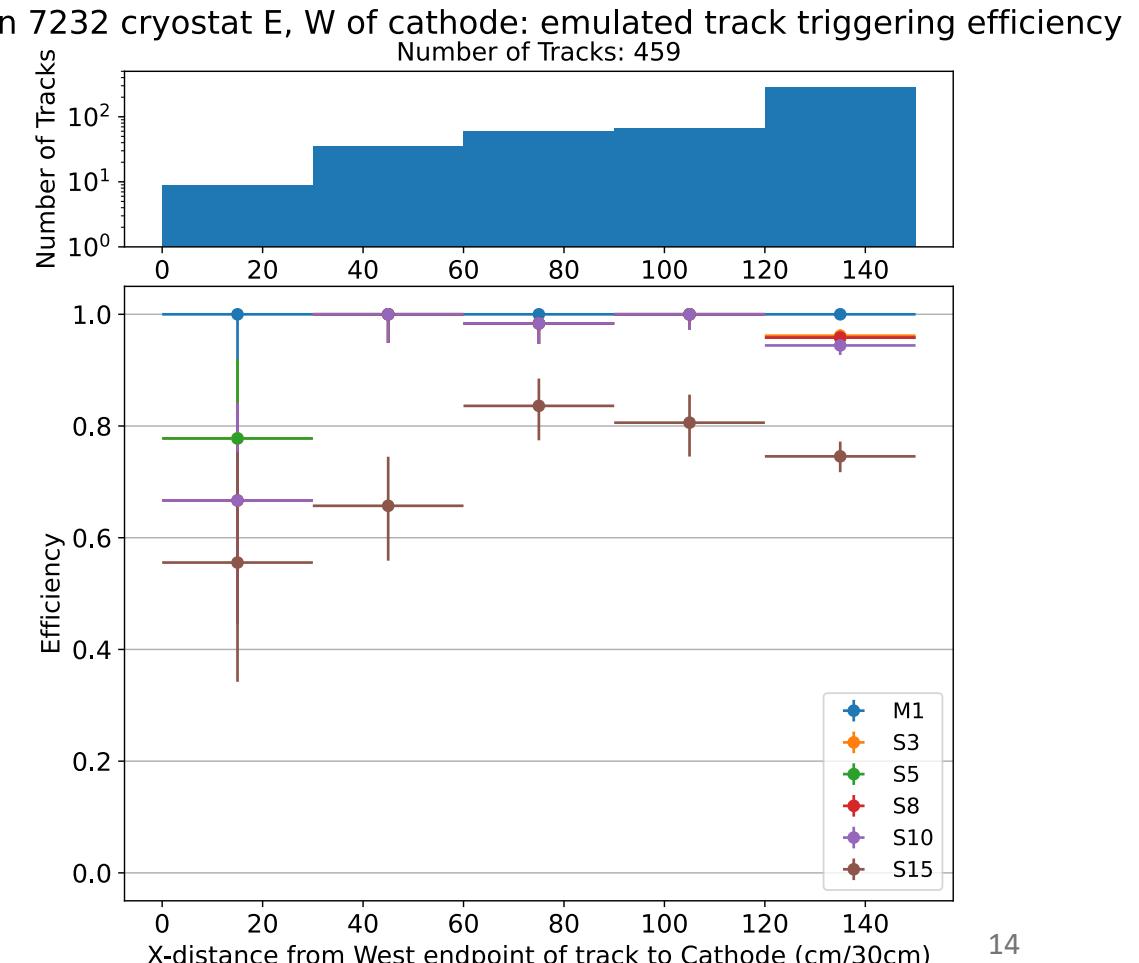
These plots describe tracks with a balance ratio more extreme than 0.9.

East Cryostat

East of Cathode



West of Cathode

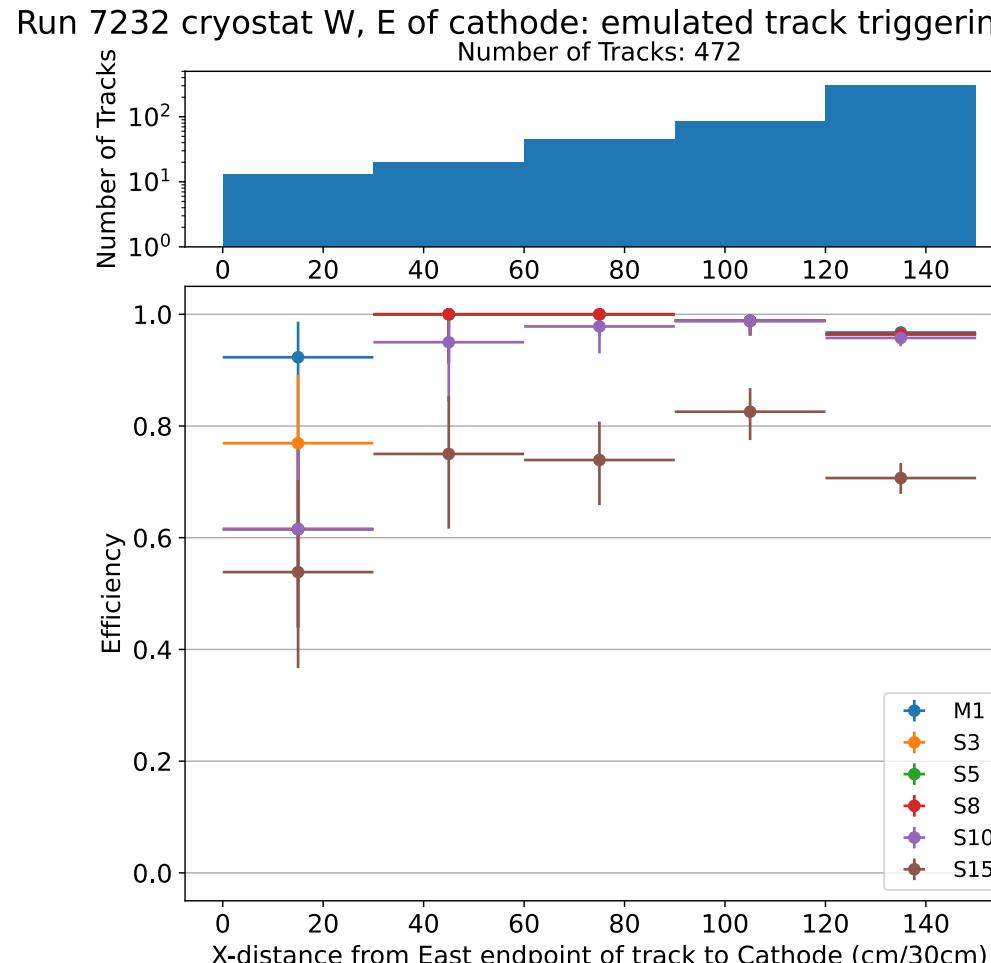


Distance to Cathode from farther endpoint for tracks primarily on one side of the cathode

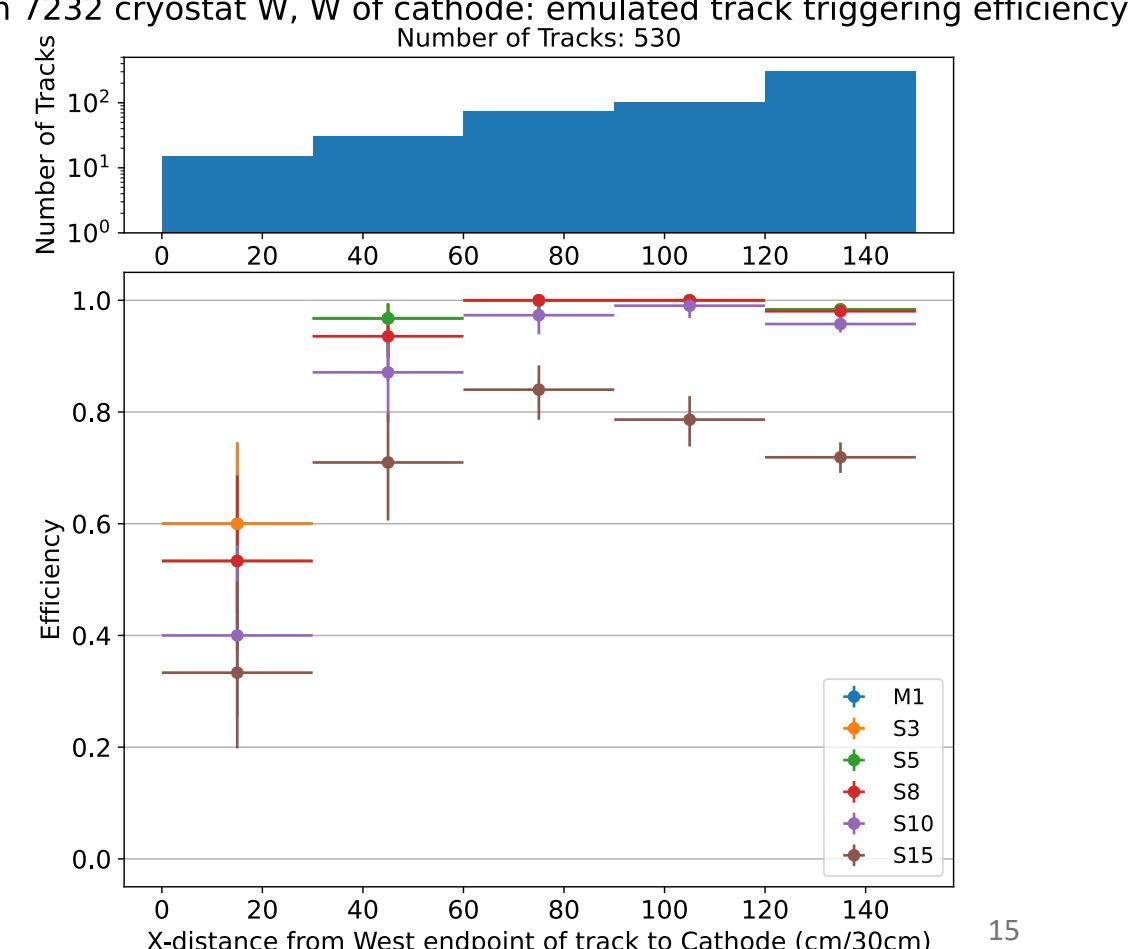
These plots describe tracks with a balance ratio more extreme than 0.9.

West Cryostat

East of Cathode

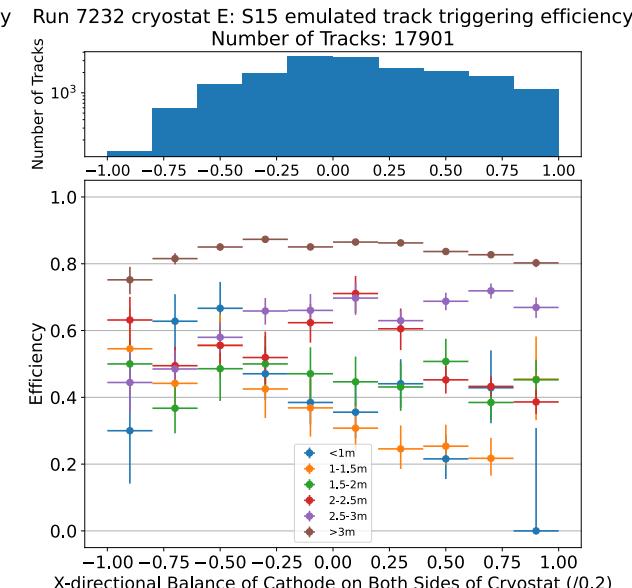
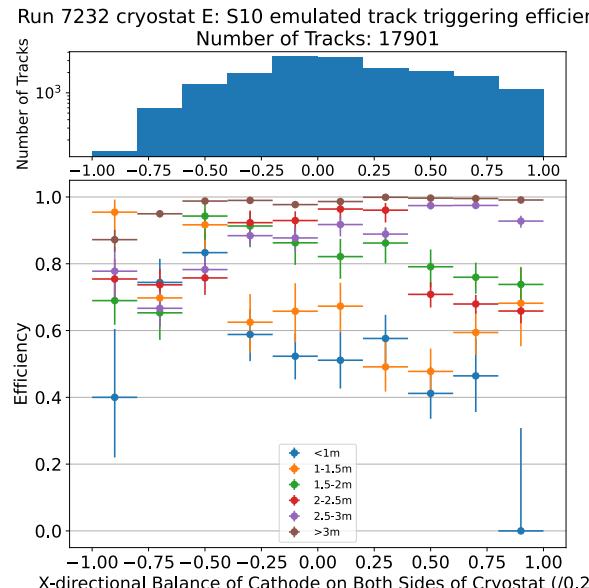
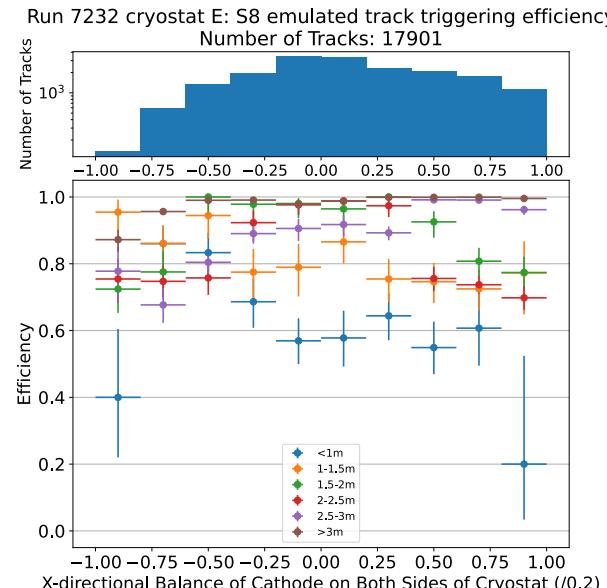
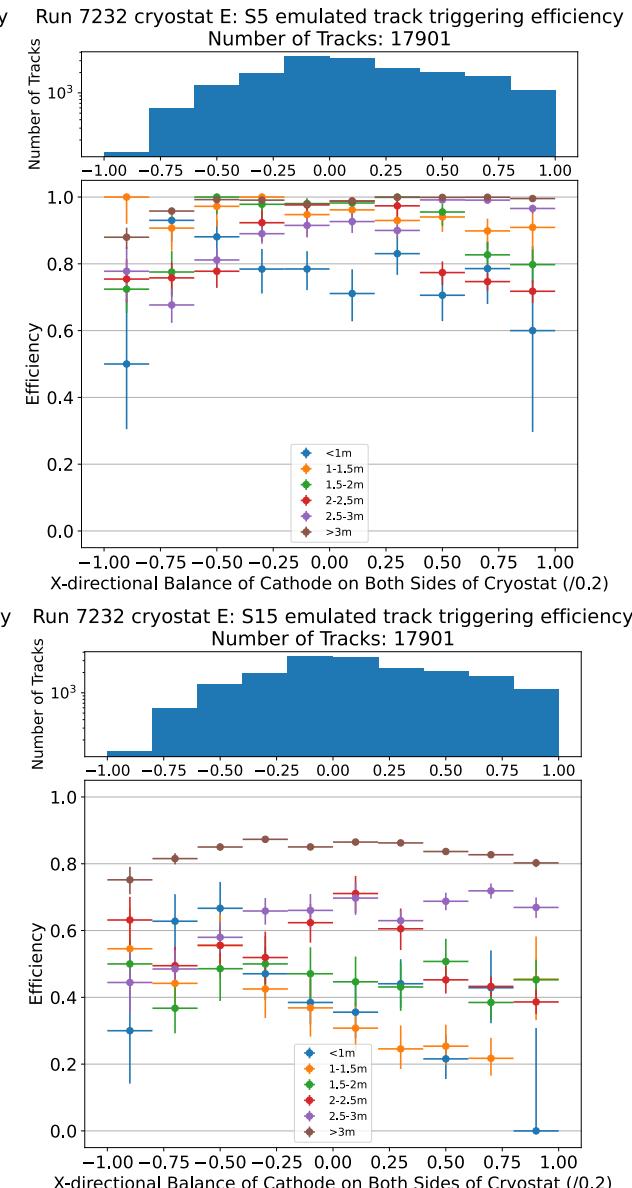
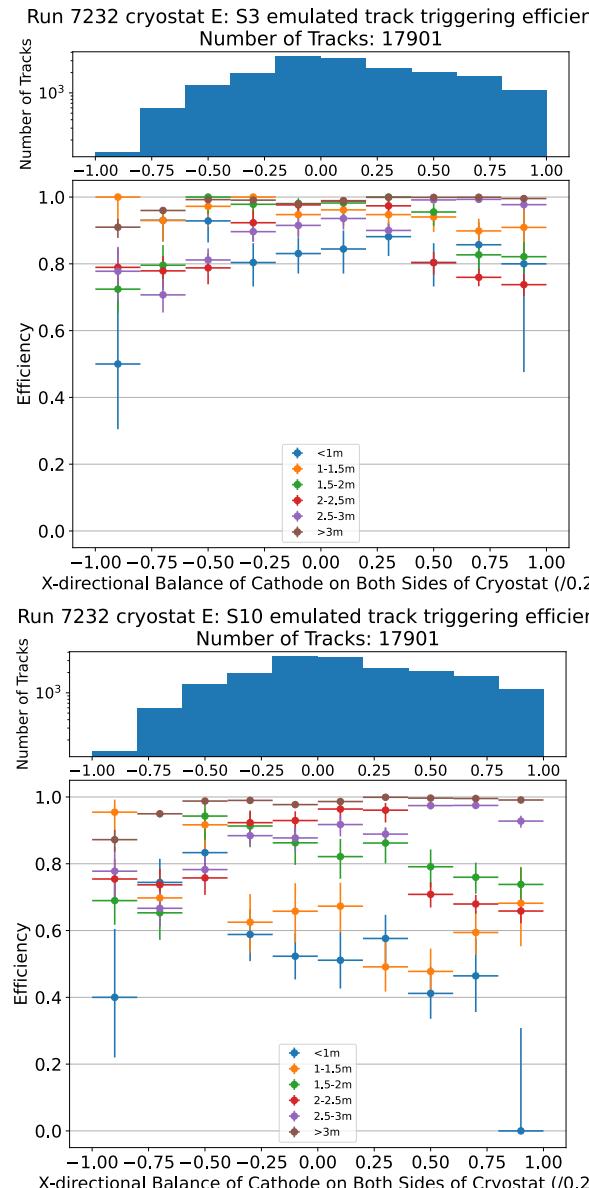
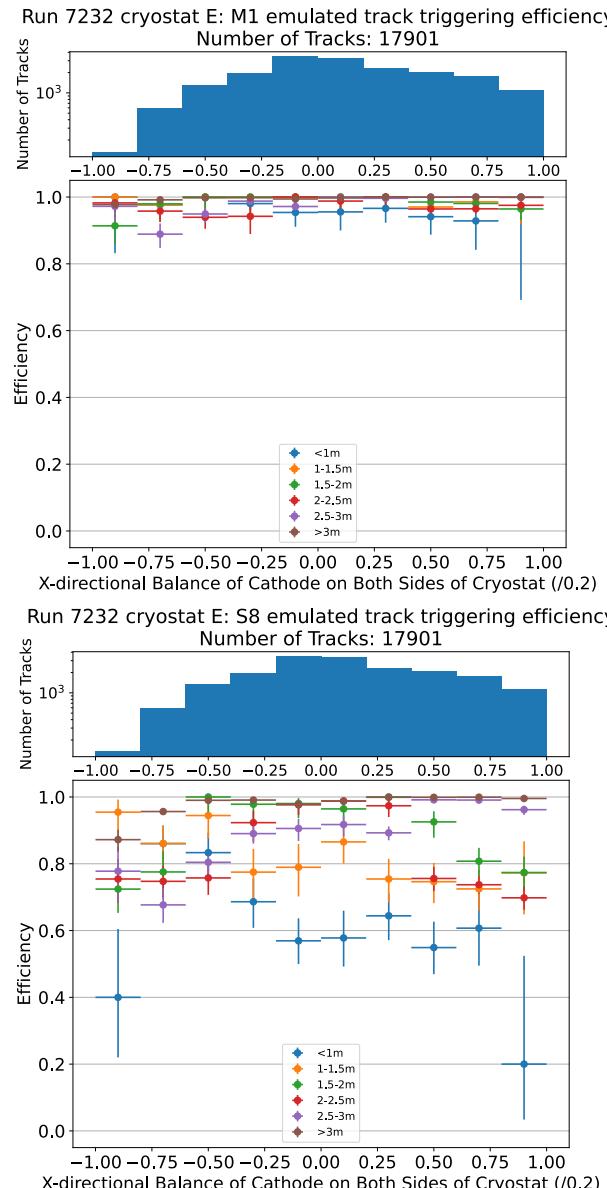


West of Cathode



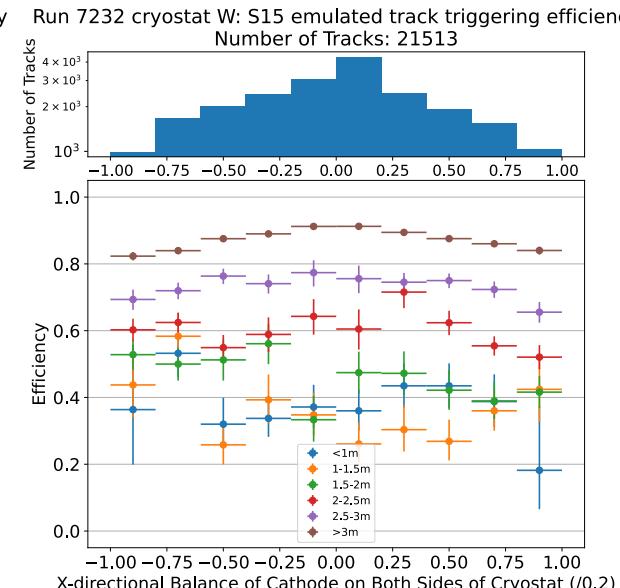
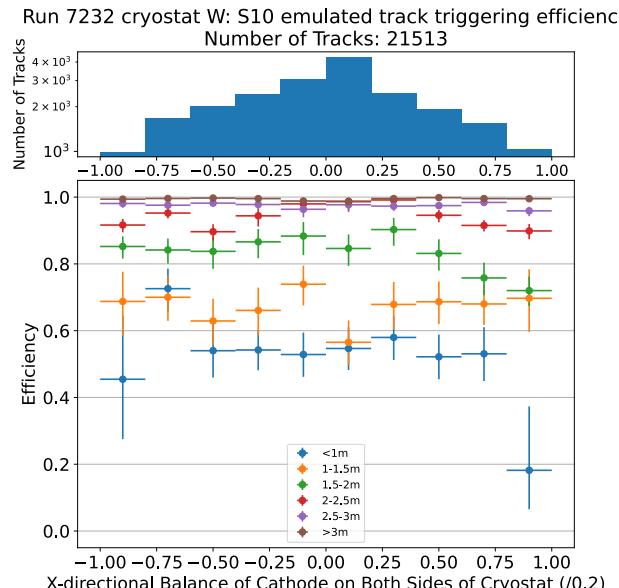
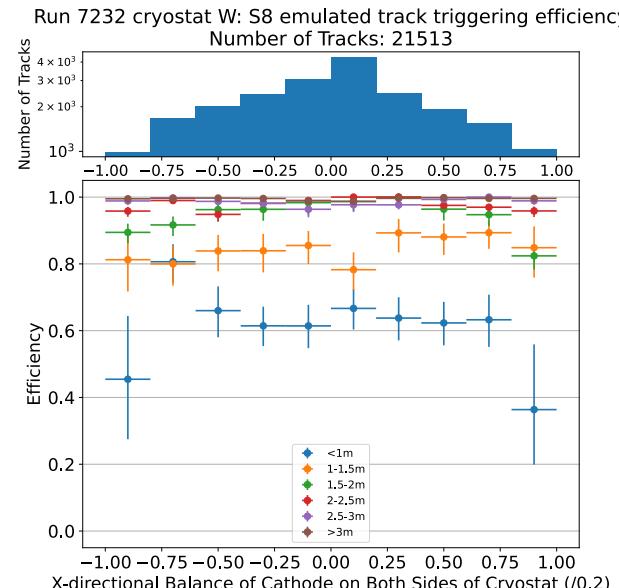
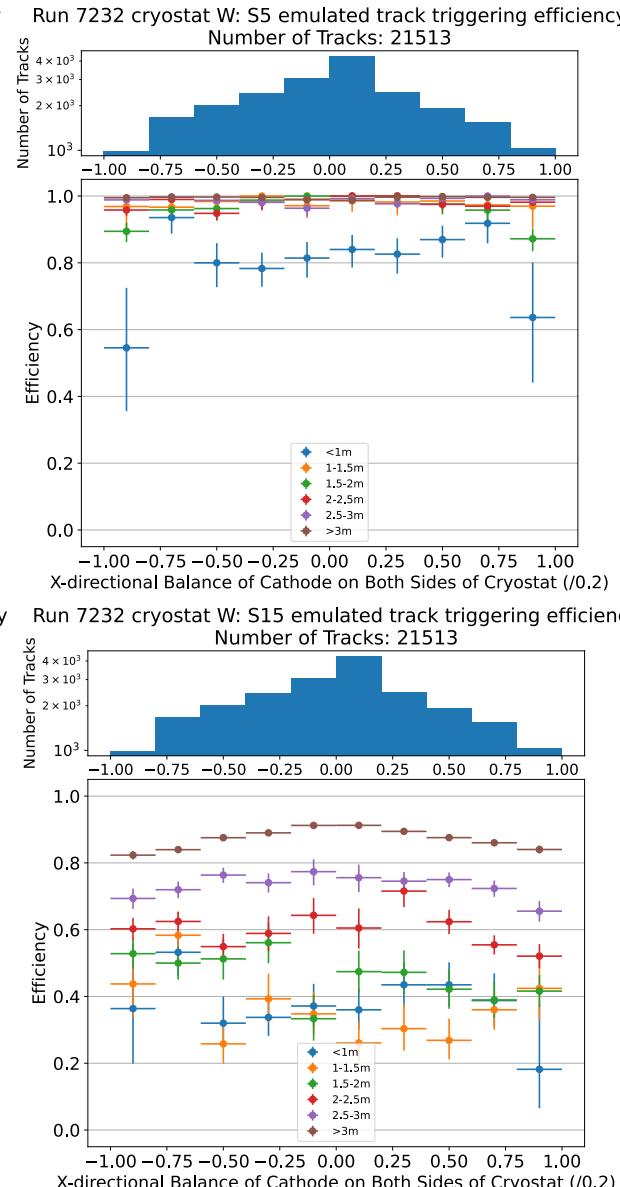
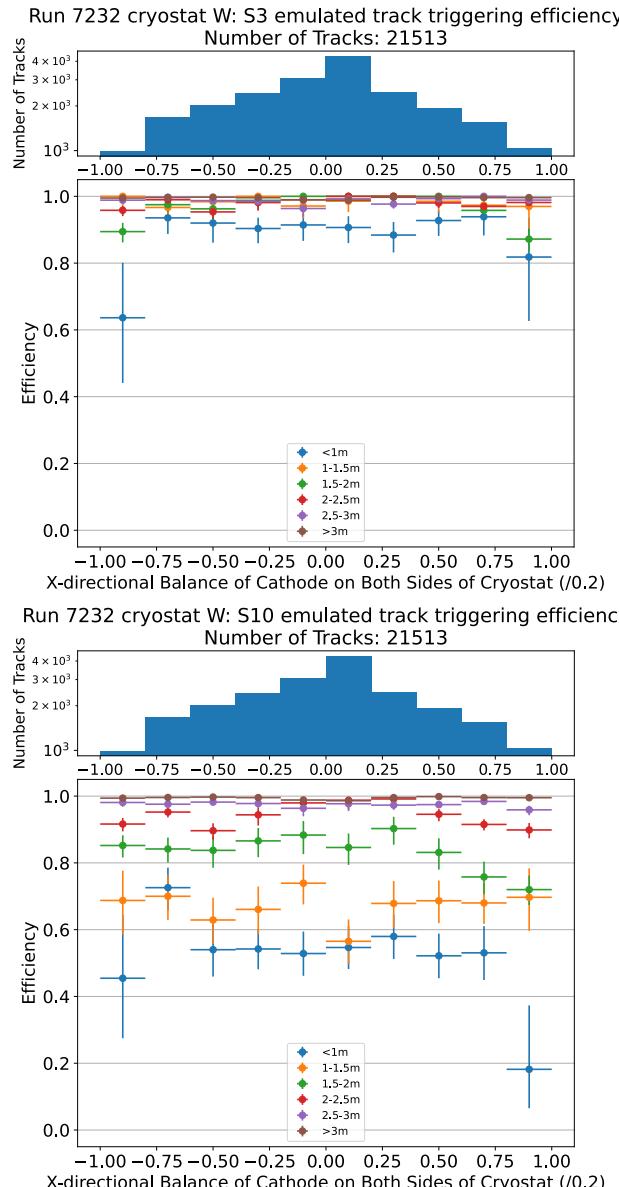
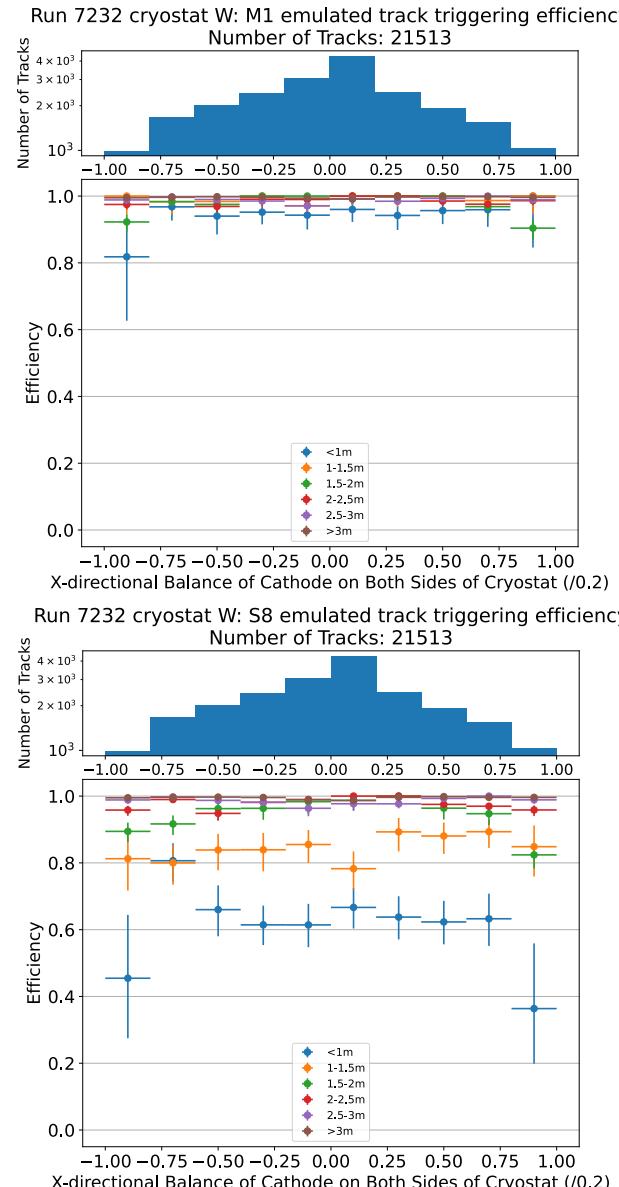
X-directional balance of tracks on either side of the cathode

East Cryostat



X-directional balance of tracks on either side of the cathode

West Cryostat



What does this tell us?

- There is indeed a drop in efficiency for unbalanced tracks around 2m in length
- Most significant in East cryo but also present in West cryo

Track-Flash Matching Algorithms

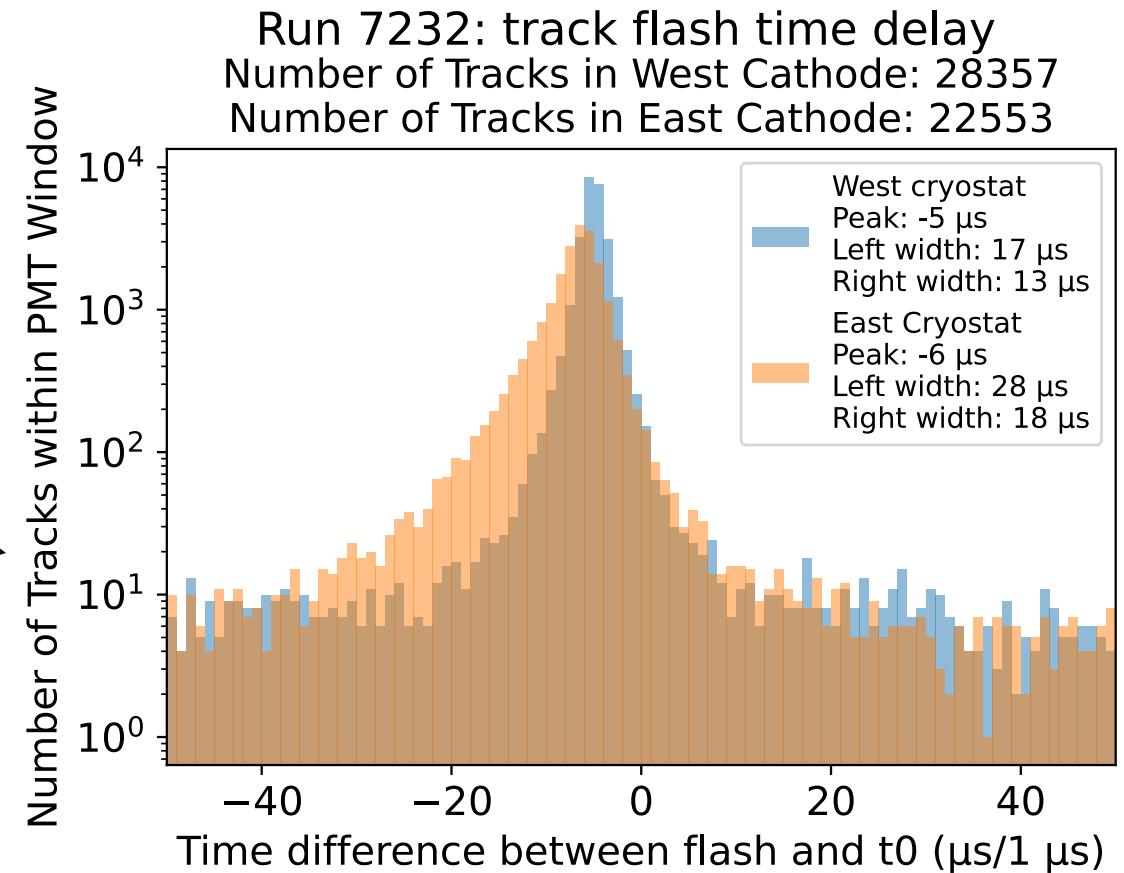
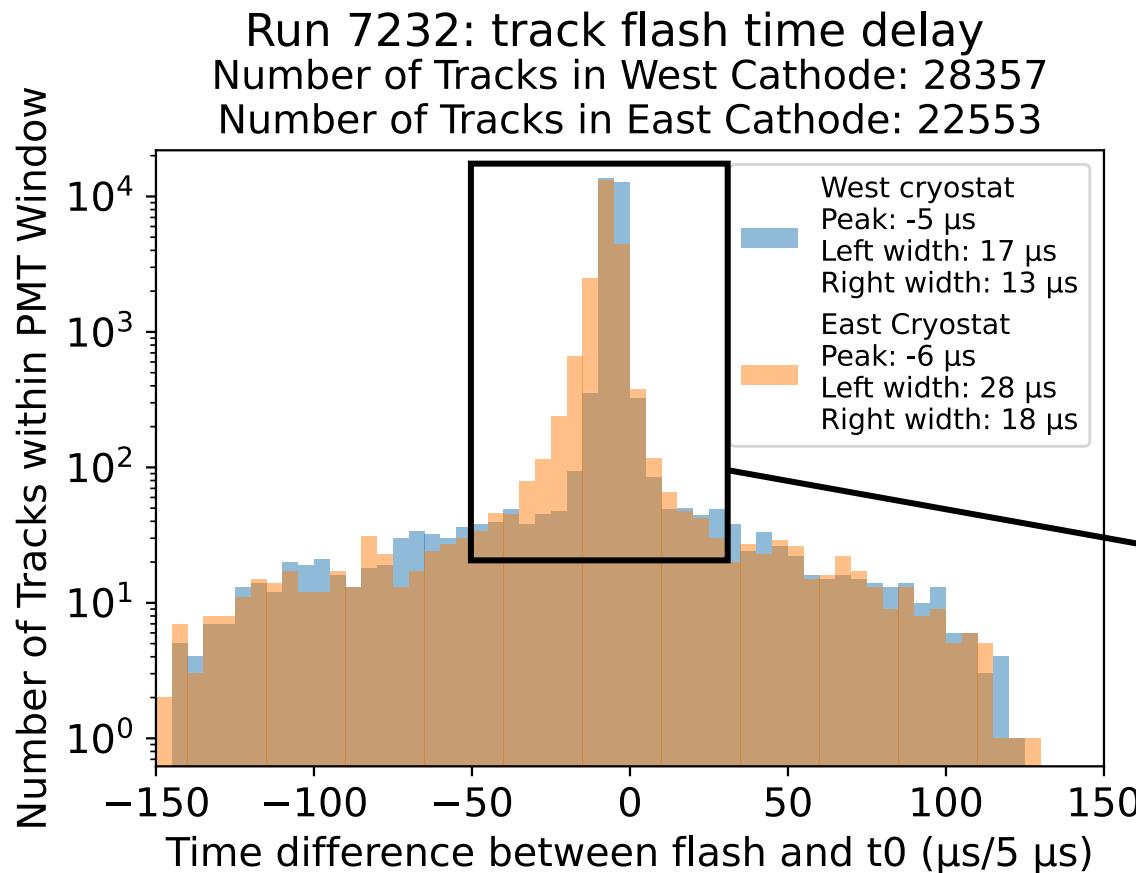
Matching tracks and flashes within a single PMT readout window using location-based and time-based algorithms and comparing the results

Two matching algorithms: location and time based

- Location Based Algorithm
 - Pick the flash that's closest in y-z position to the track's barycenter/midpoint
- Time Based Algorithm
 - This method
 - Pick the flash that's closest in time to the track time (t_0)
 - Keep only tracks with flashes within $(t_0 - 40 \mu\text{s}, t_0 + 20 \mu\text{s})$
 - From location-based matching, we found most matched tracks were within this range
- Both Algorithms
 - Allow multiple tracks to match to the same flash
 - Only consider tracks within the PMT readout window, t_0 within $(-55 \mu\text{s}, 75 \mu\text{s})$
 - This is in order to ensure that we should have the corresponding flash recorded

Matching by Barycenter of Flashes and Tracks

- Pick the flash whose location is closest to the midpoint of the corresponding track
- Below is plotted the time difference between the flash and its matched track



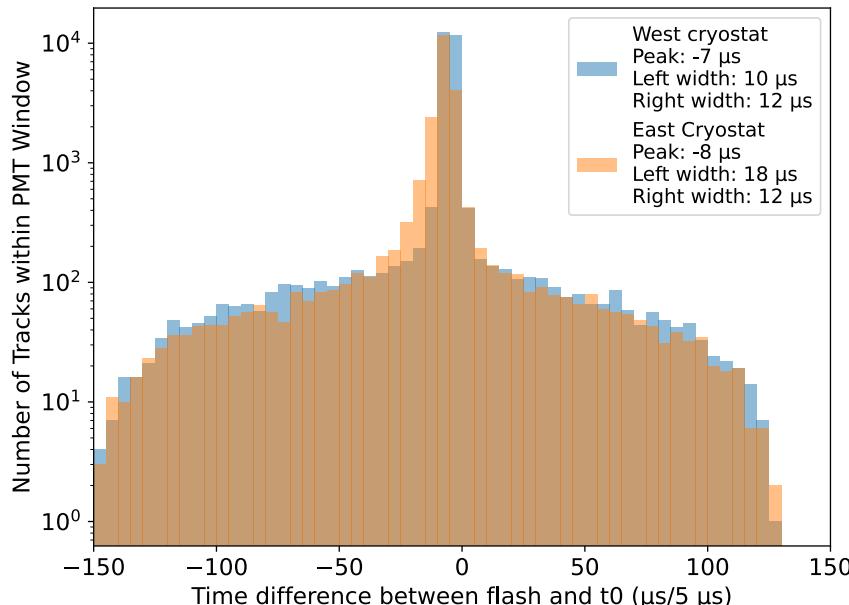
Exploration: Location of Tracks

- We checked whether it makes a significant difference to use the start, end, or midpoint of the track as the track's location
 - “start” and “end” label assigned by TPC pattern recognition (Pandora)
 - Midpoint/barycenter of track calculated using these start and end positions
- While there were slight variations, it didn’t significantly affect the plot

Start

Run 7232: track flash time delay

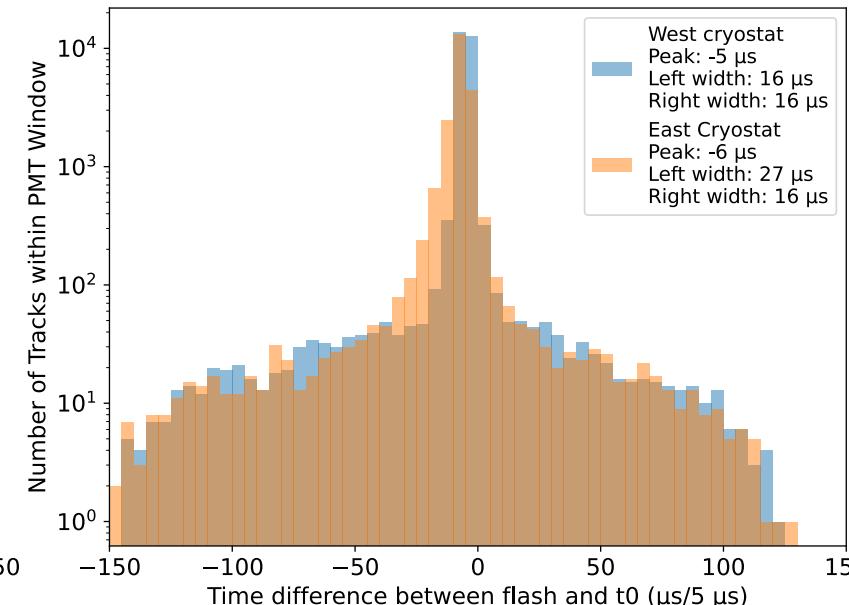
Number of Tracks in West Cathode: 28357
Number of Tracks in East Cathode: 22553



Barycenter

Run 7232: track flash time delay

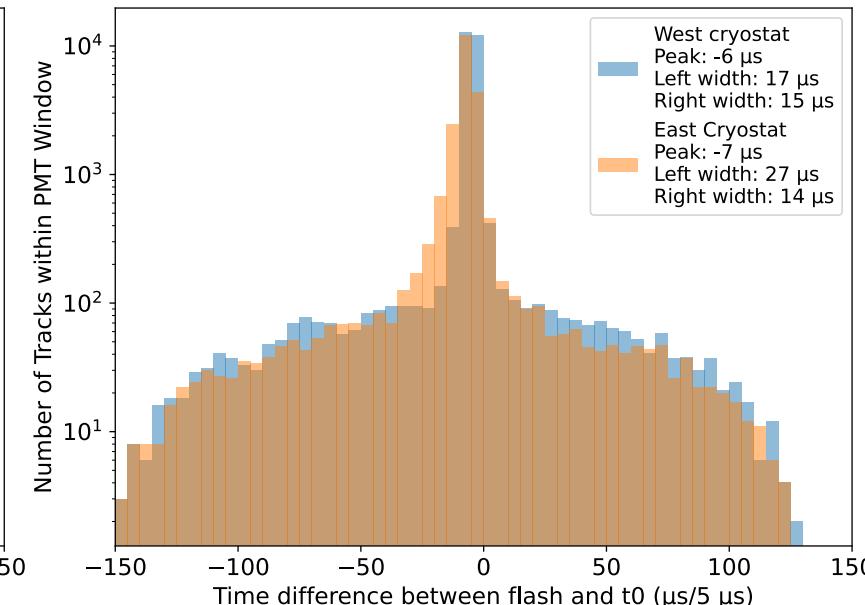
Number of Tracks in West Cathode: 28357
Number of Tracks in East Cathode: 22553



End

Run 7232: track flash time delay

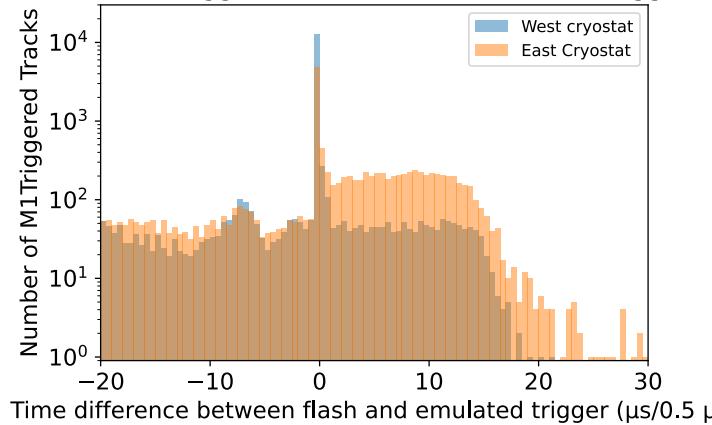
Number of Tracks in West Cathode: 28357
Number of Tracks in East Cathode: 22553



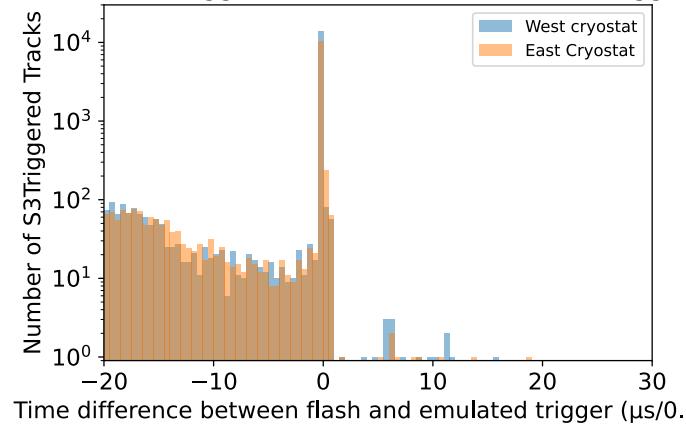
Time Difference between flash and emulated trigger

- We used **time-based** flash-track matching for this
- We expect this to mostly be 0, and we do see a large spike at 0
- There are more tracks slightly below 0 than slightly above, so there are more tracks where the flash is slightly before than the emulated trigger than tracks where the flash is slightly after
- In this plot, the time of the flash is already biased by our matching algorithm

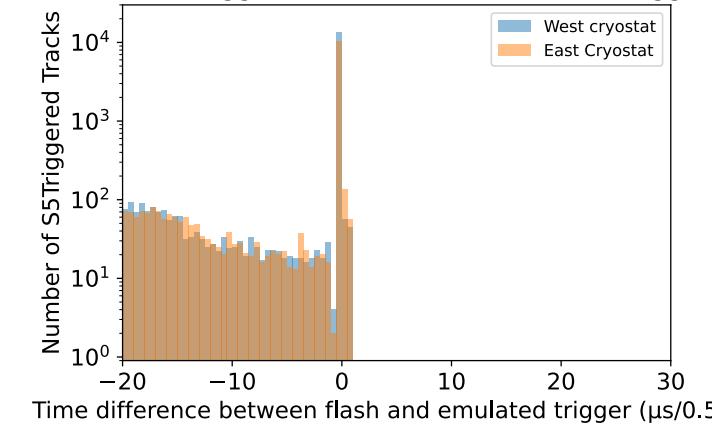
Run 7232 M1 Trigger: emulated track flash vs. trigger time



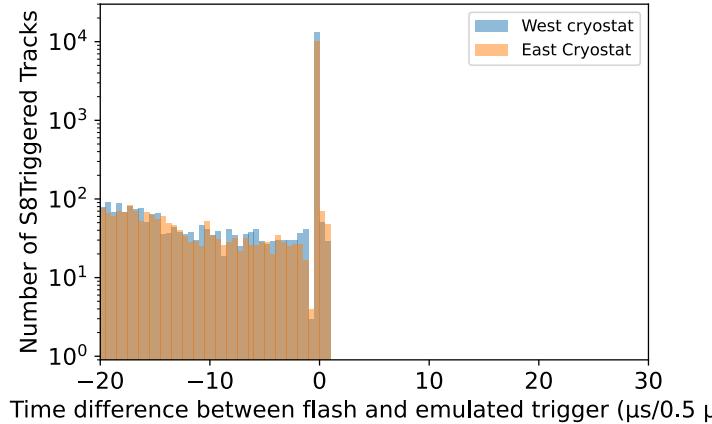
Run 7232 S3 Trigger: emulated track flash vs. trigger time



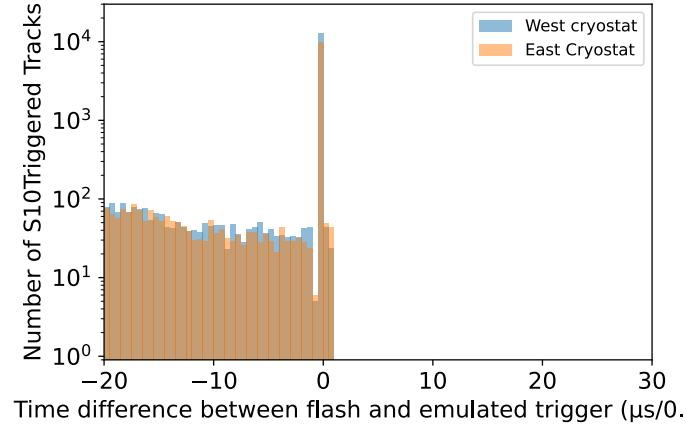
Run 7232 S5 Trigger: emulated track flash vs. trigger time



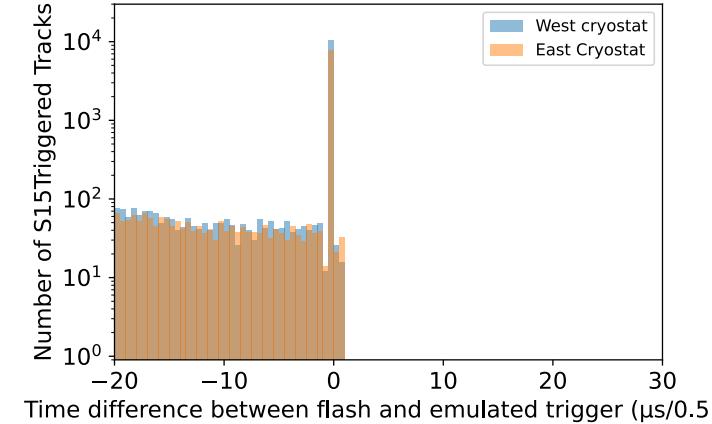
Run 7232 S8 Trigger: emulated track flash vs. trigger time



Run 7232 S10 Trigger: emulated track flash vs. trigger time



Run 7232 S15 Trigger: emulated track flash vs. trigger time



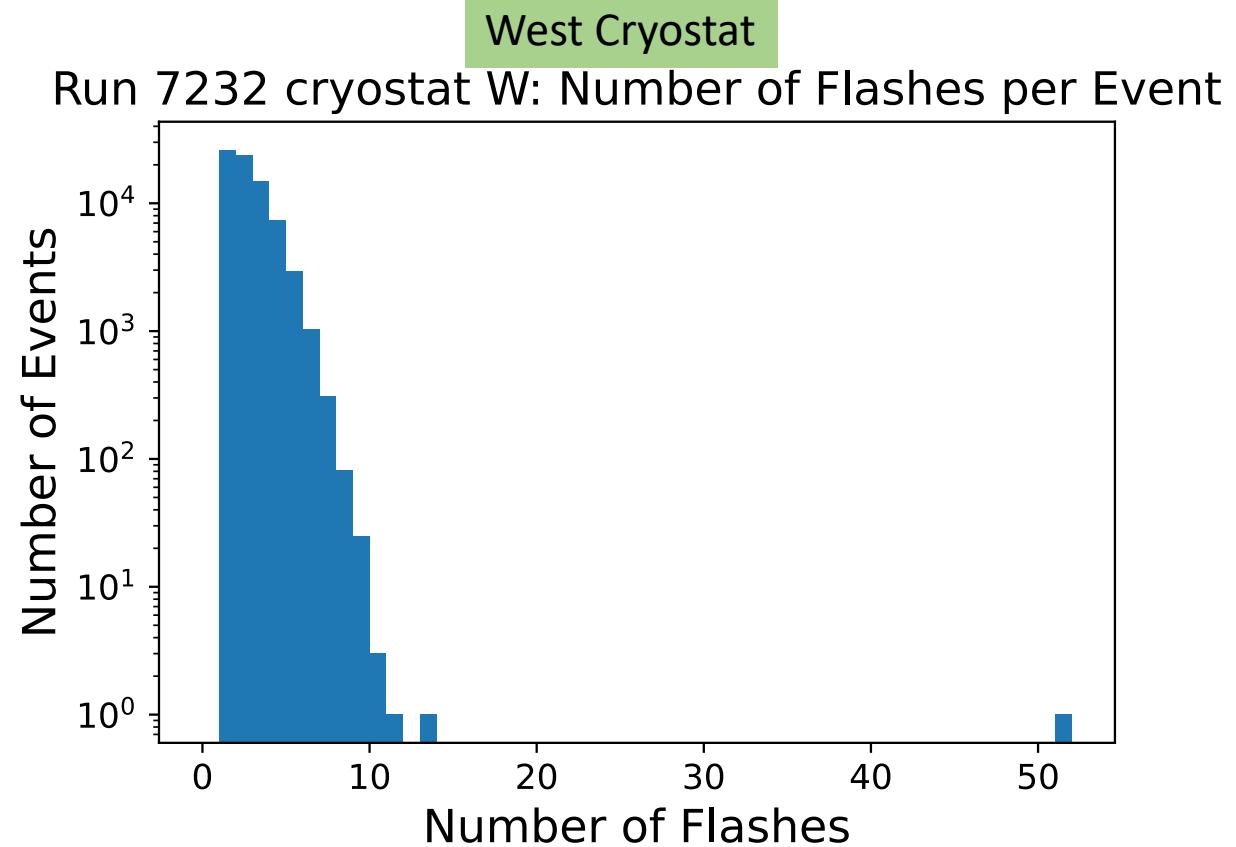
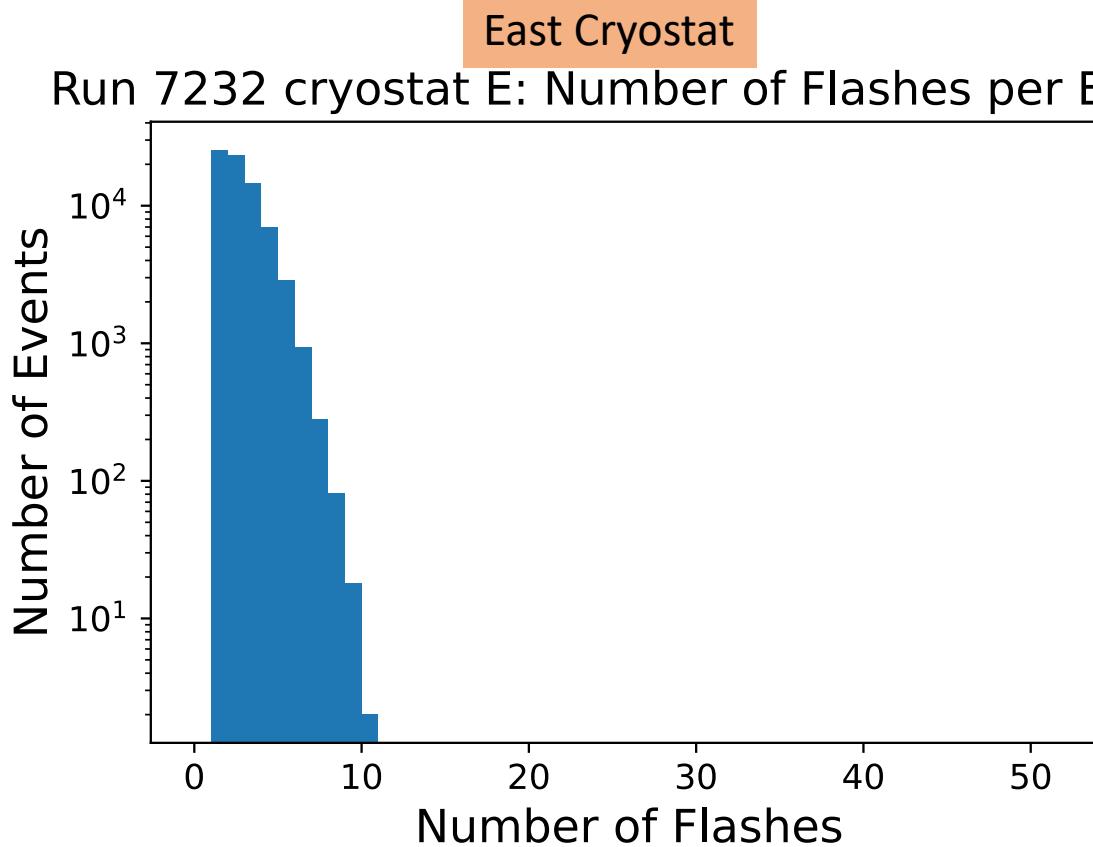
Understanding efficiency drop for
anode to cathode tracks

Thoughts so far...

- Look more closely at which PMT data for these anode-cathode tracks that don't trigger M1
 - Roughly 200 cm long, could fall into that dip seen in efficiency v. length plot
 - Look at waveform data (but first find that data)
- Which events are like this?
 - West cryostat:
 - West TPC (5 events): 46974, 78670, 2283, 219, 44755
 - East TPC (10 events): 21383, 50579, 70866, 63470, 42873, 35981, 74730, 97469, 14465, 76779
 - East cryostat:
 - None

Number of flashes per event

- Number of flashes per event looks similar between the two cryostats, but W cryostat has a couple outliers (events with a lot of flashes)

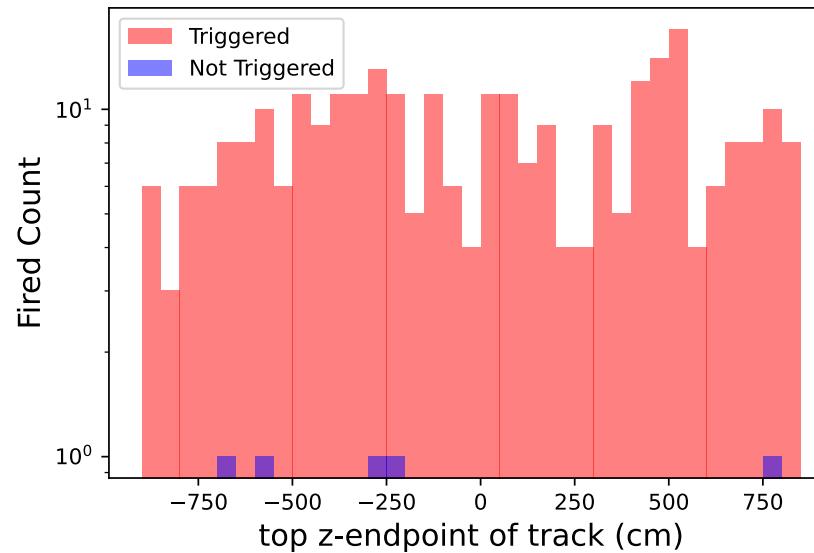


Looking at anode-cathode tracks in West Cryostat that don't trigger

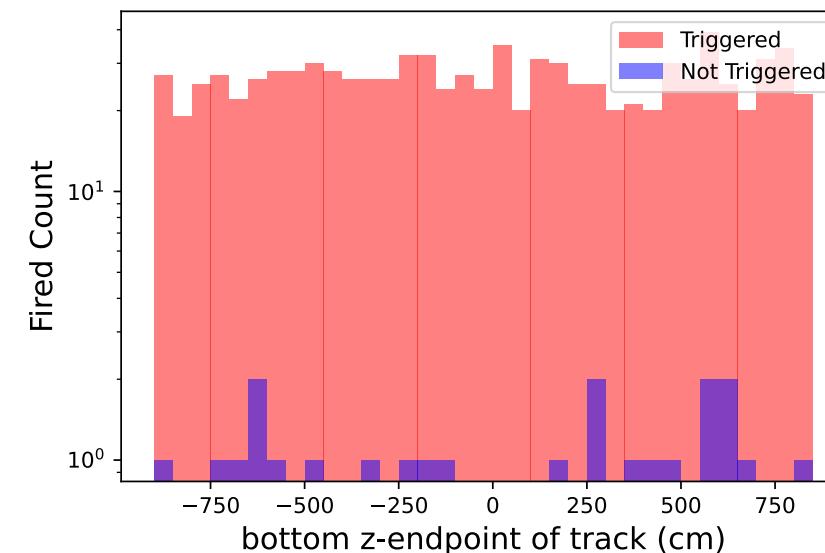
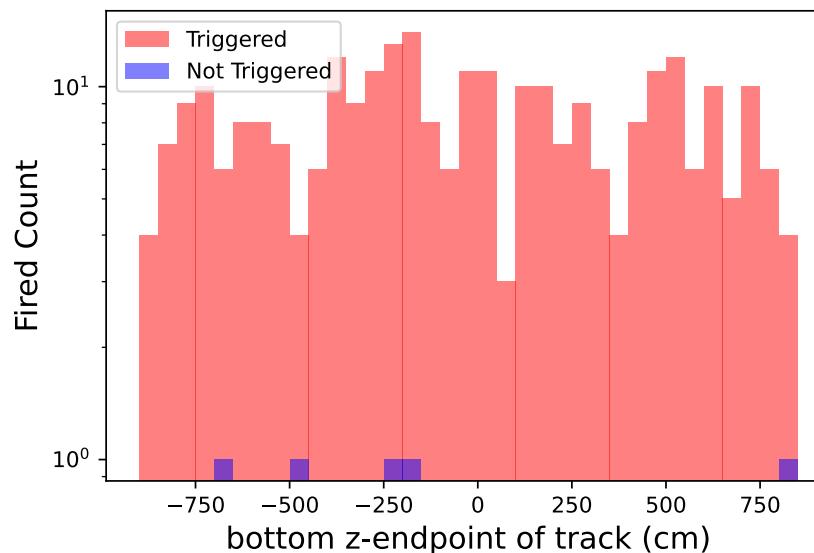
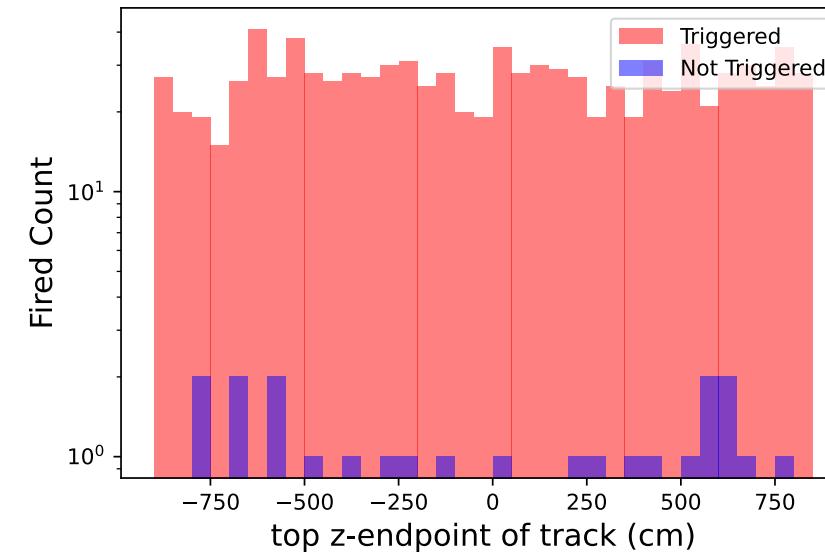
- Many of them appear to have light 1-2 μ s AFTER the track, whereas we're only looking for light 0-20 μ s BEFORE the track for the trigger emulation
 - Should we shift this window to t0-15 μ s to t0+5 μ s?
 - Would we gain more tracks than we'd lose?
- Perhaps the t0 reconstruction is worse for a certain type of track?
 - What do all of these tracks have in common?
 - Check starting and ending y-z positions and also length of track.

Fired and Not fired tracks (M1 trigger) vs. track z-position

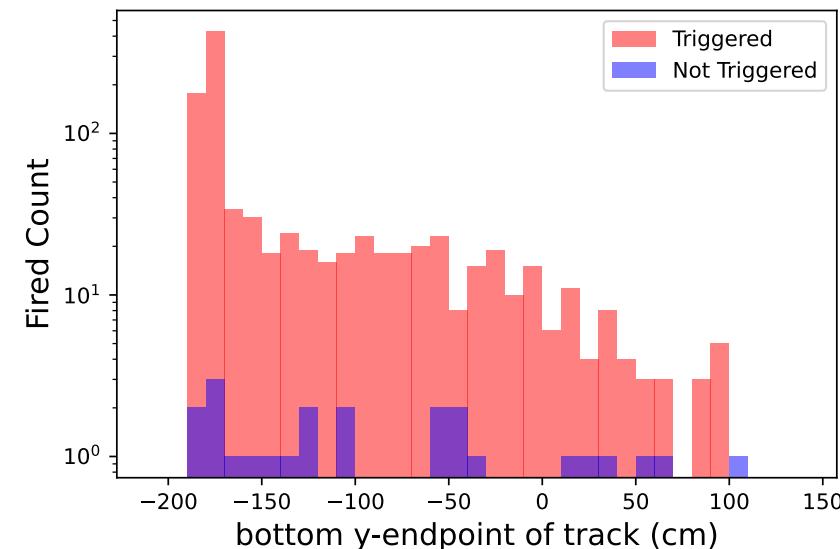
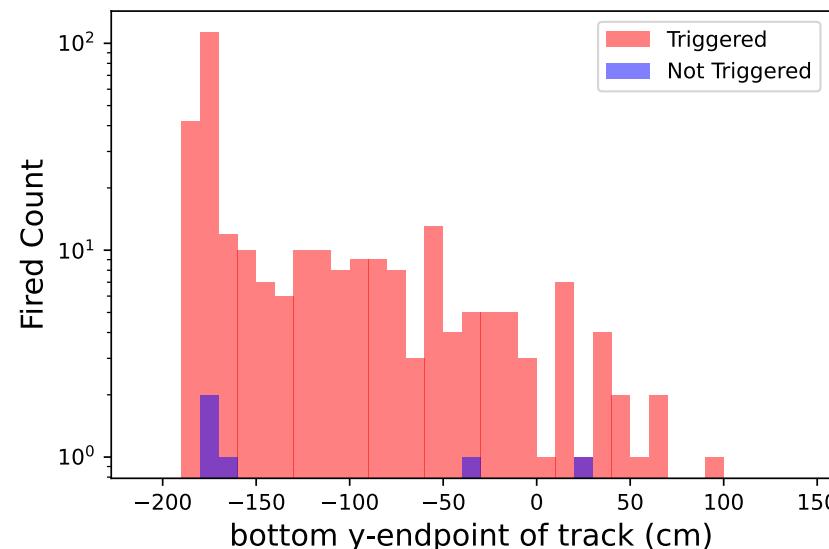
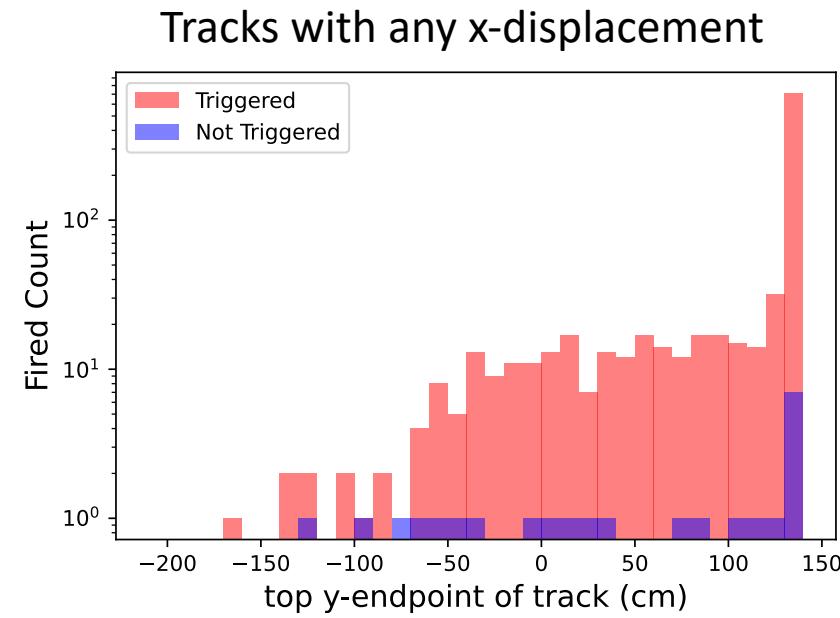
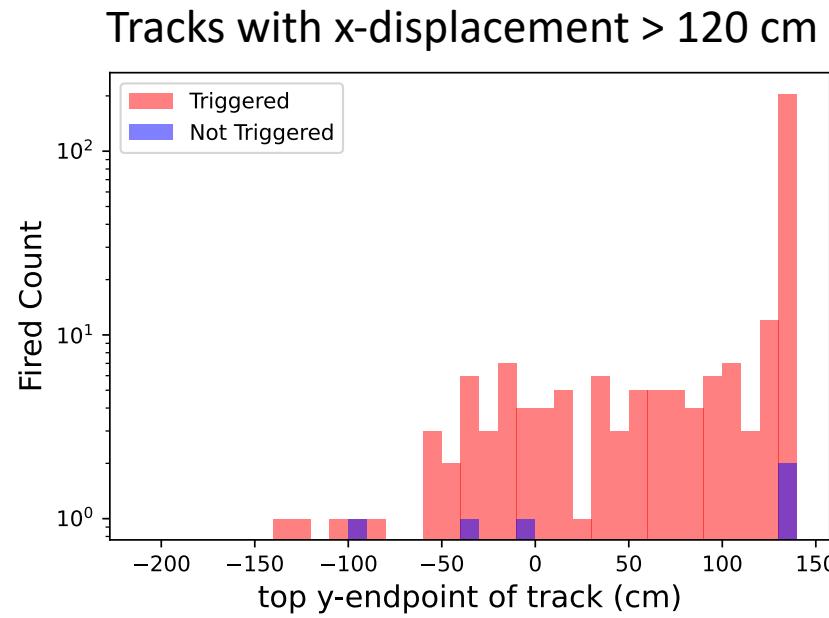
Tracks with x-displacement > 120 cm



Tracks with any x-displacement



Fired and Not fired tracks (M1 trigger) vs. track y-position

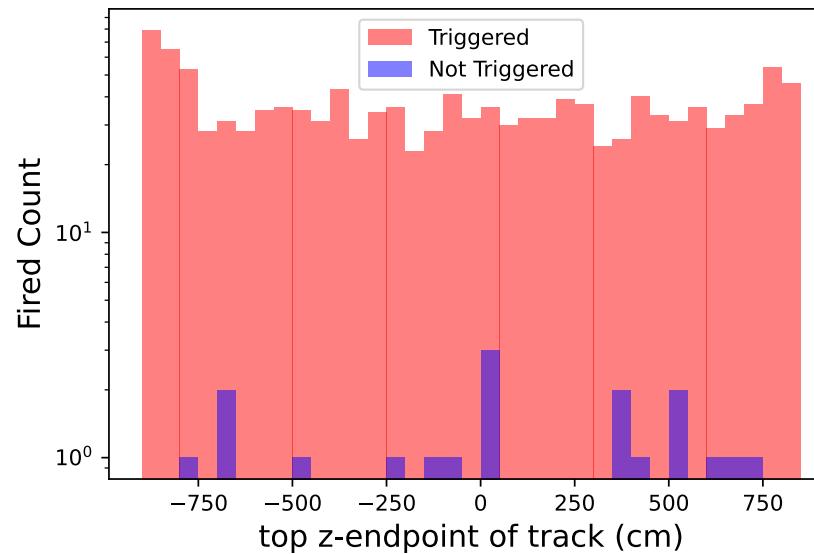


Looking at 200 cm long tracks in East cryostat

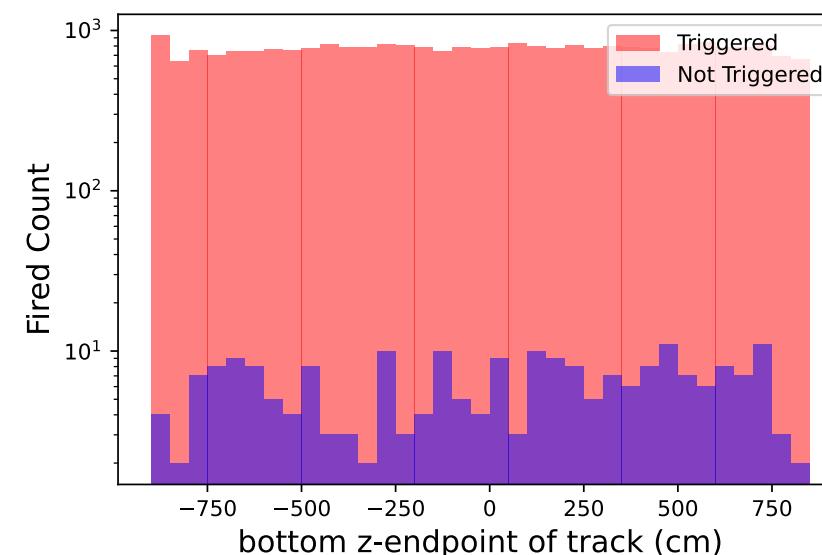
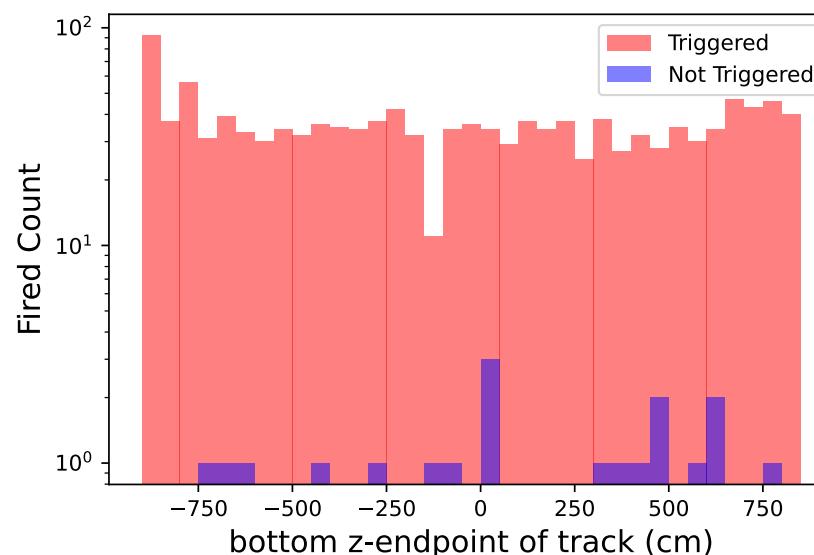
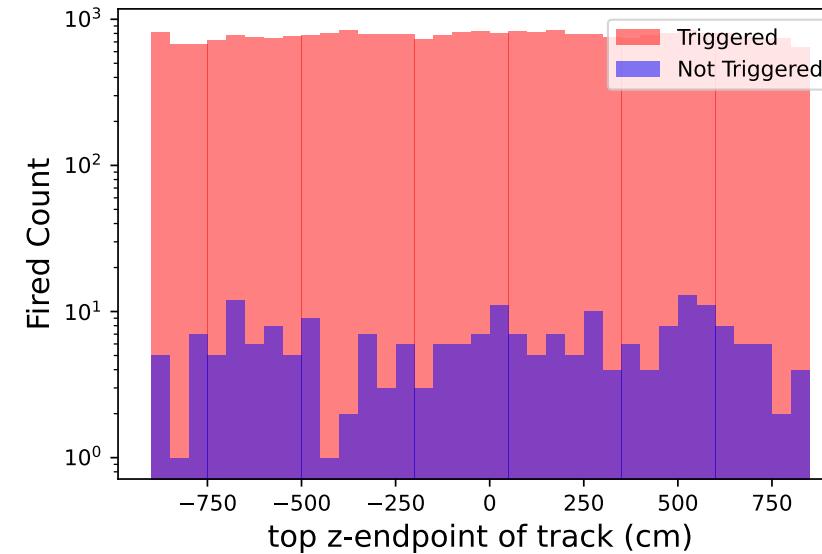
- Many of these also have light 1-2 μ s after the track...
 - Perhaps it would be beneficial to shift the window
- Perhaps one feature of these tracks with a worse t0 reconstruction is the length being around 200 cm?
 - Does this have anything to do with the y-z position? Perhaps it's because the cathode is not completely flat? Does the trend in misfired tracks align to certain z-positions or y-positions?
 - More concentrated around $-600 \text{ cm} < z < 0 \text{ cm}$ and $300 \text{ cm} < z < 600 \text{ cm}$ (see slide 26)
 - No y-correlation really

Fired and Not fired tracks (M1 trigger) vs. track z-position

Tracks with lengths between 200-240 cm

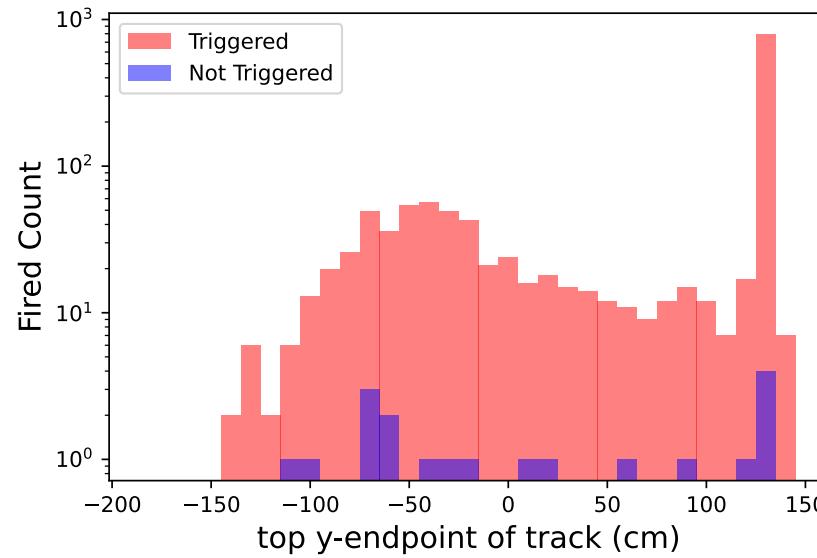


Tracks with any length

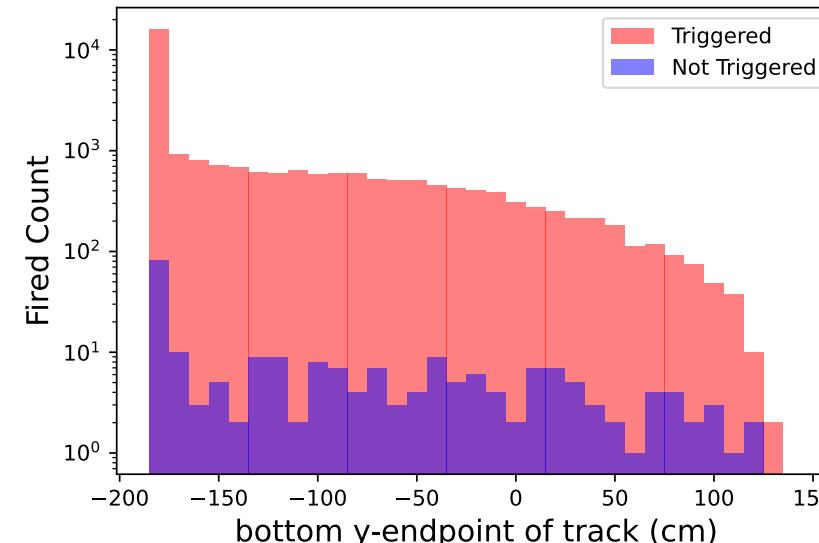
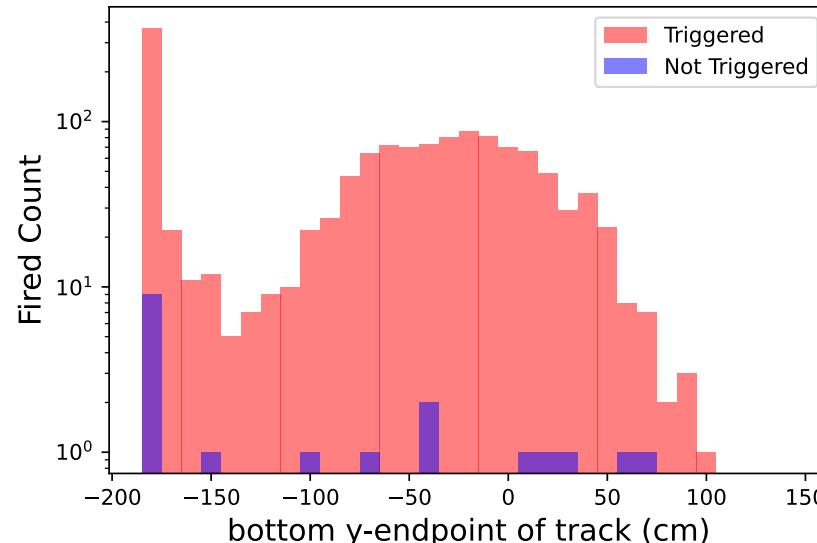
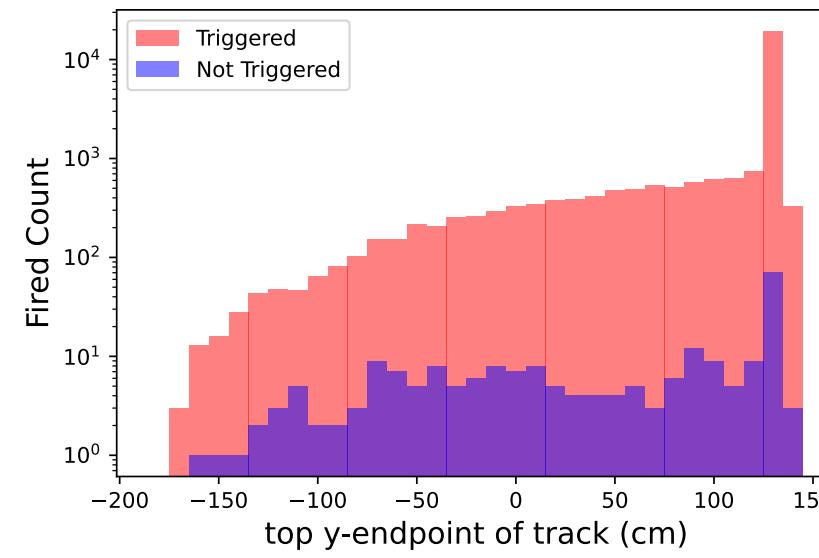


Fired and Not fired tracks (M1 trigger) vs. track y-position

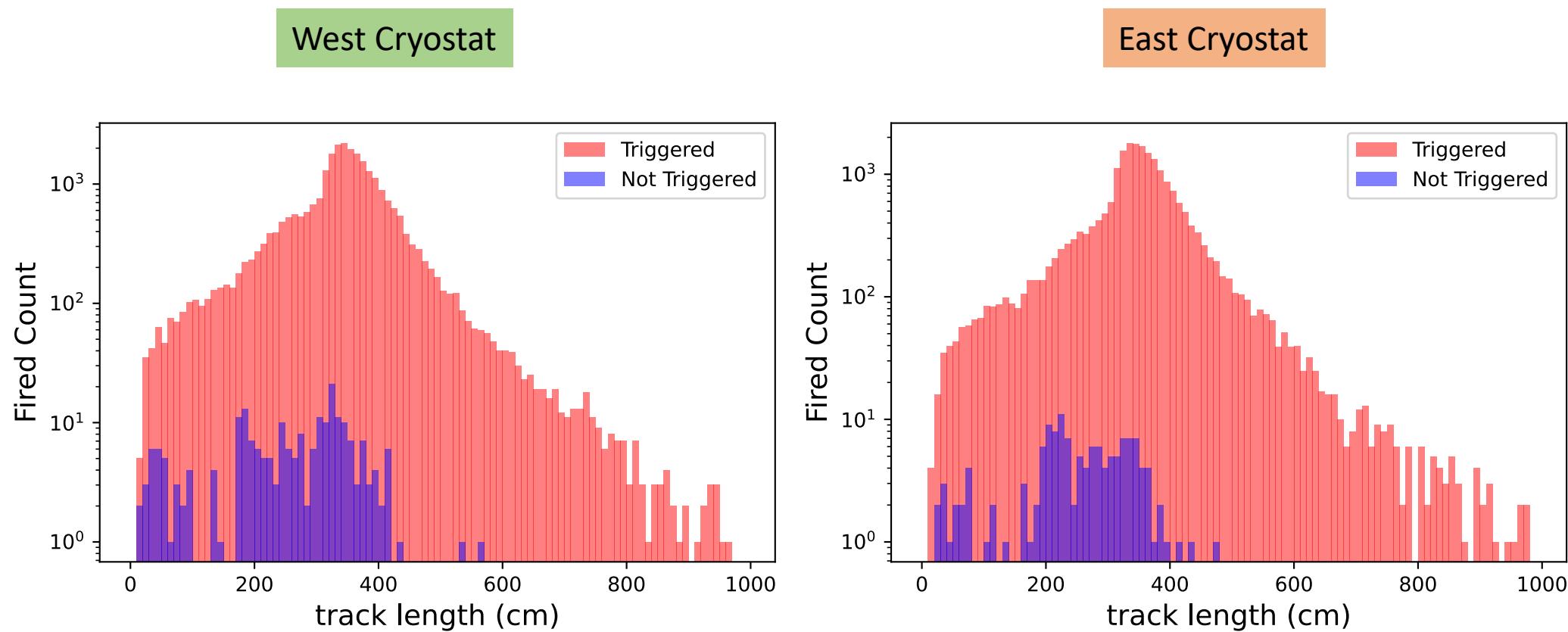
Tracks with lengths between 200-240 cm



Tracks with any length



Fired v. Not Fired Tracks (M1 trigger) by length

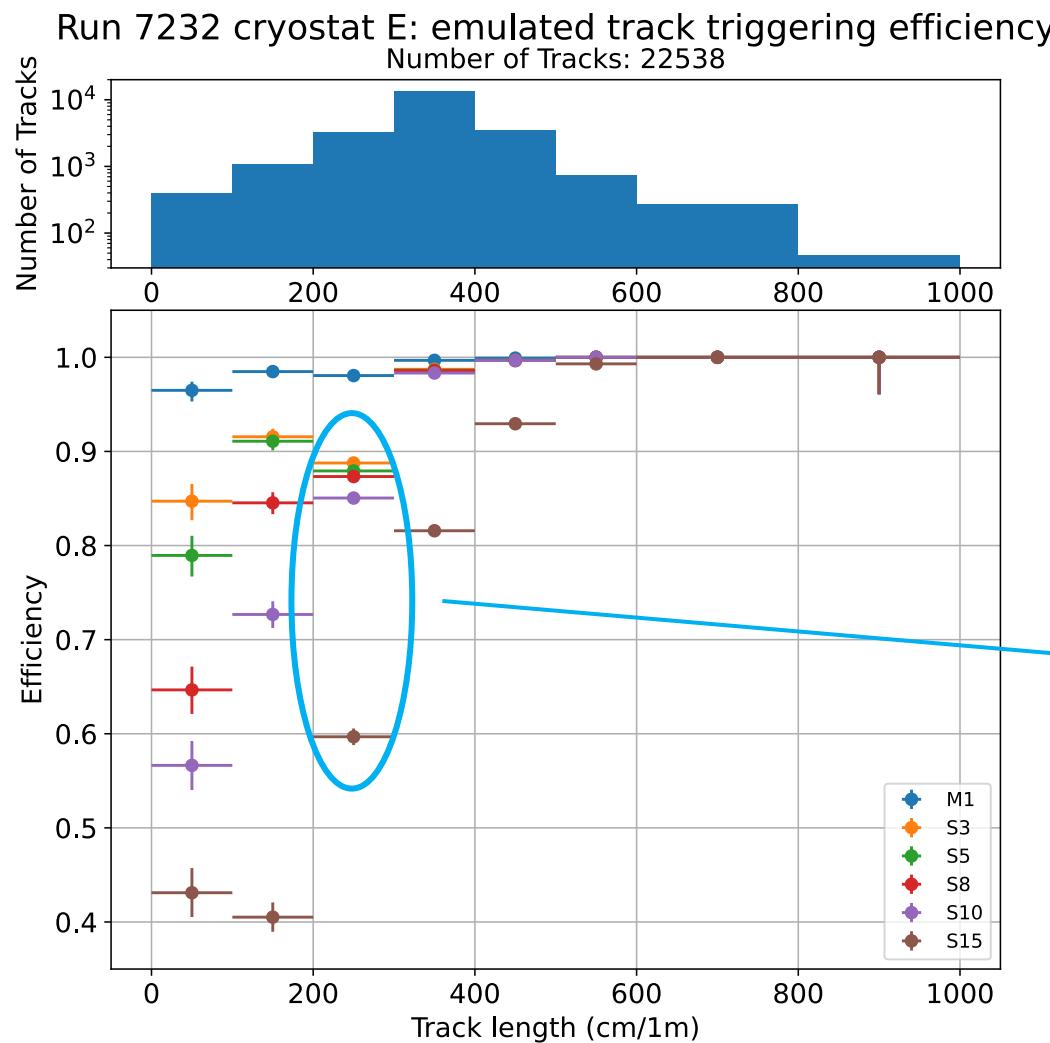


Shifted Emulation Window

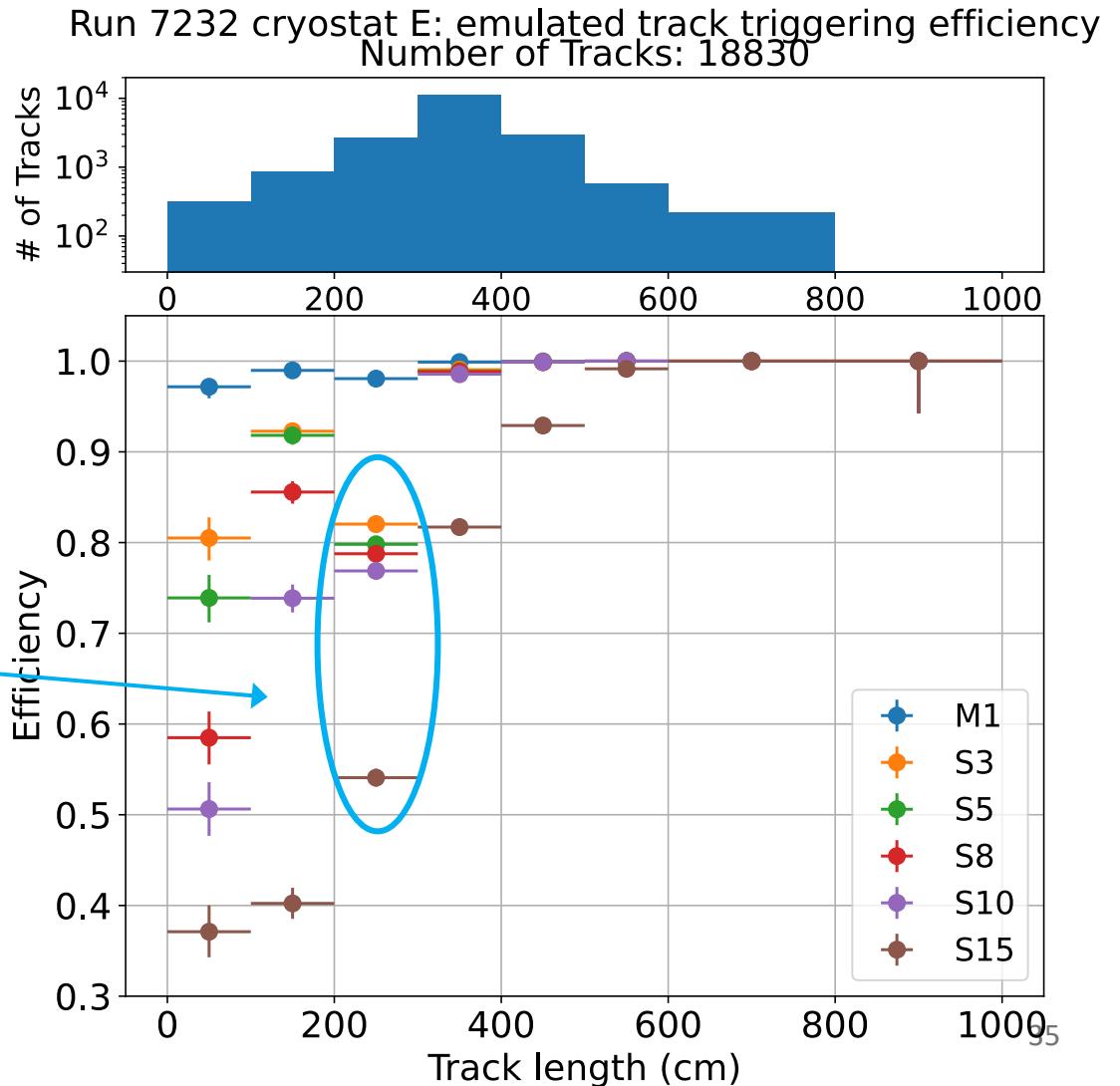
Shifted from (-20 μ s, 0 μ s) to (-15 μ s, 5 μ s)

Track length: East cryostat

(-20 μ s, 0 μ s) Emulation Window

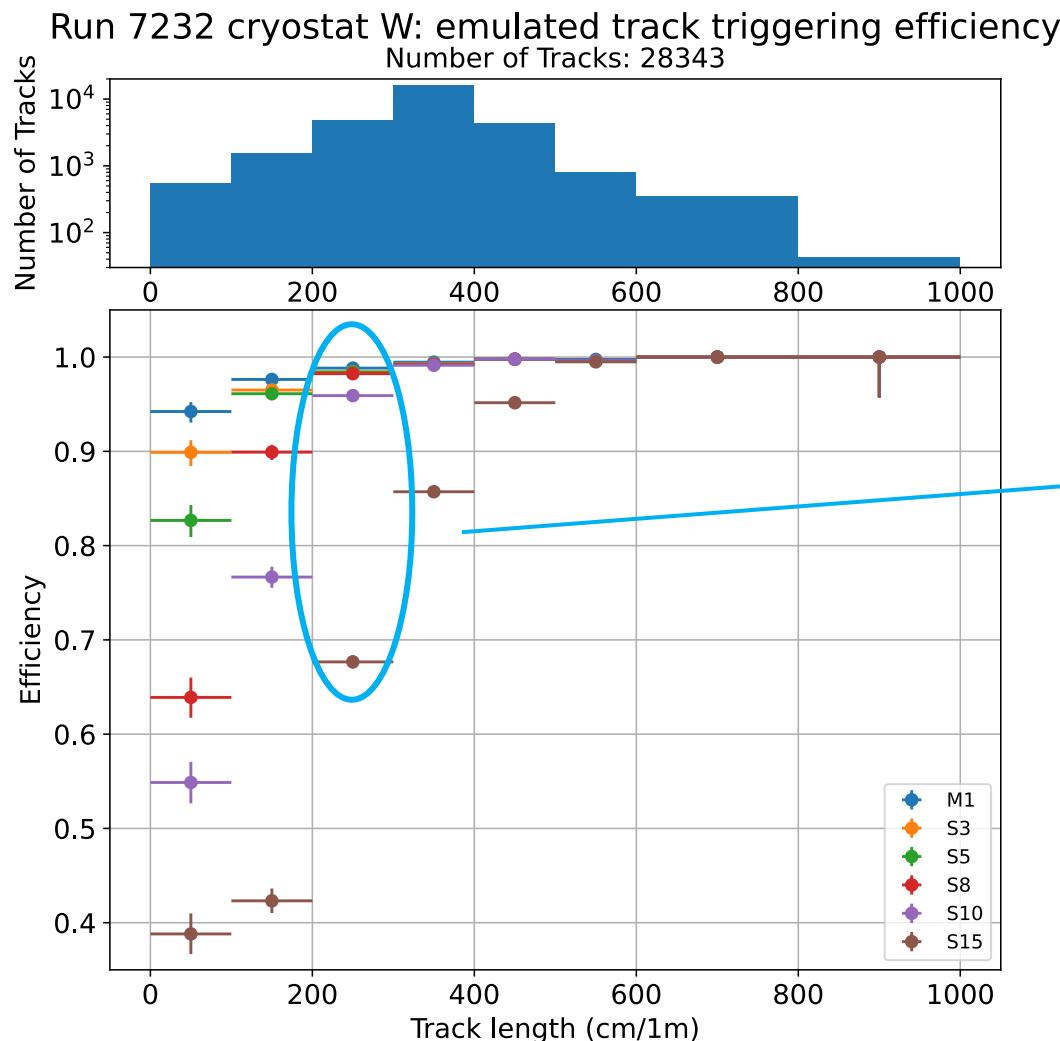


(-15 μ s, 5 μ s) Emulation Window

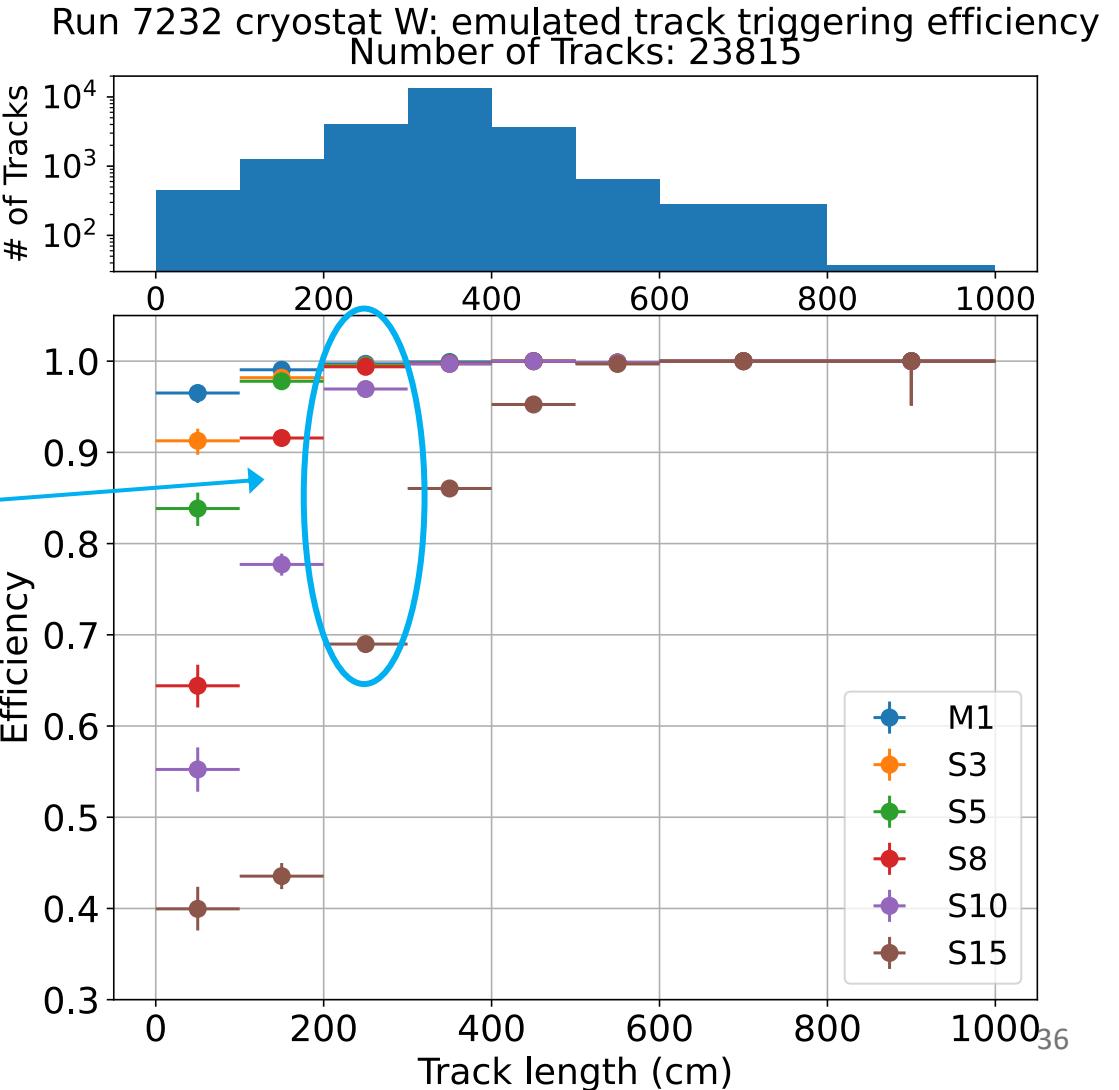


Track length: West Cryostat

(-20 μ s, 0 μ s) Emulation Window



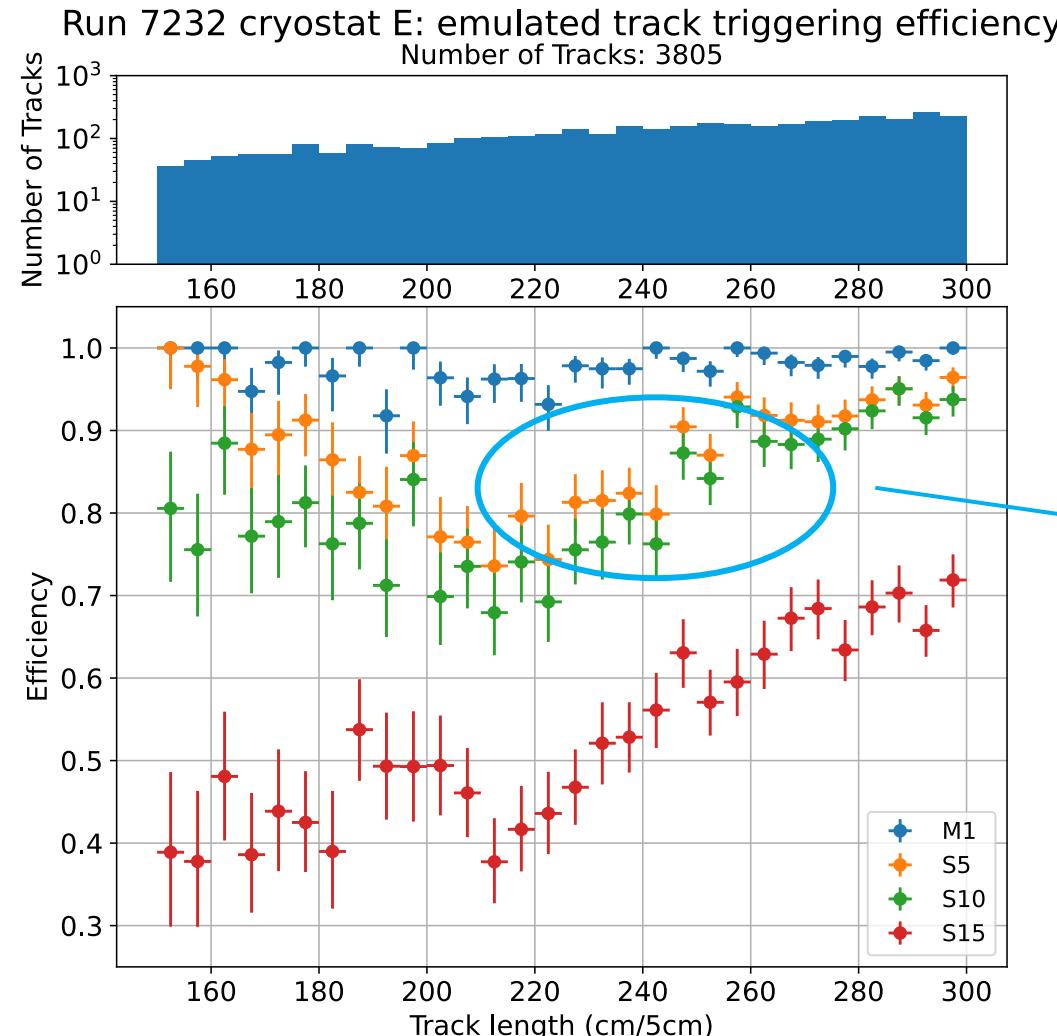
(-15 μ s, 5 μ s) Emulation Window



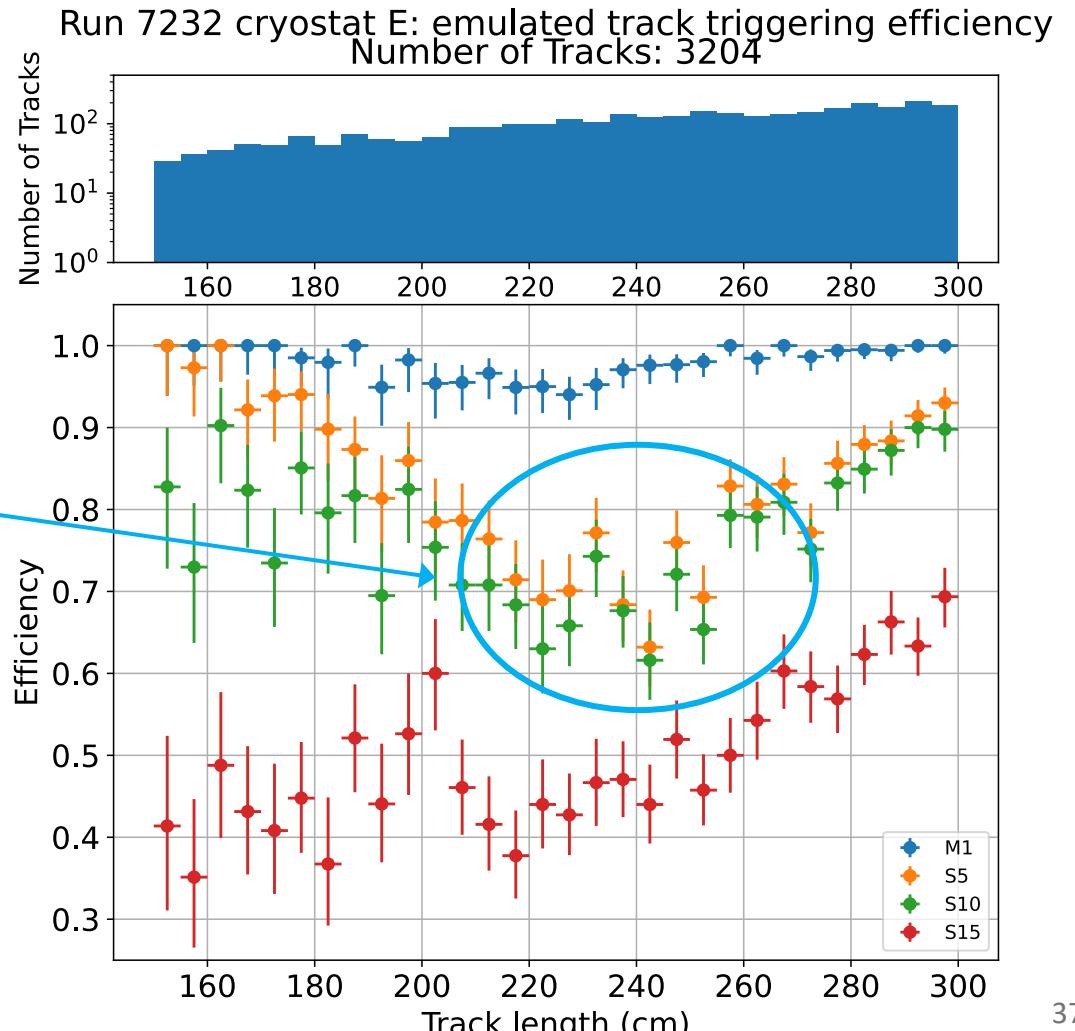
Track length: East Cryostat

- This seems to worsen the issue, especially between 220 - 260 cm

(-20 μ s, 0 μ s) Emulation Window



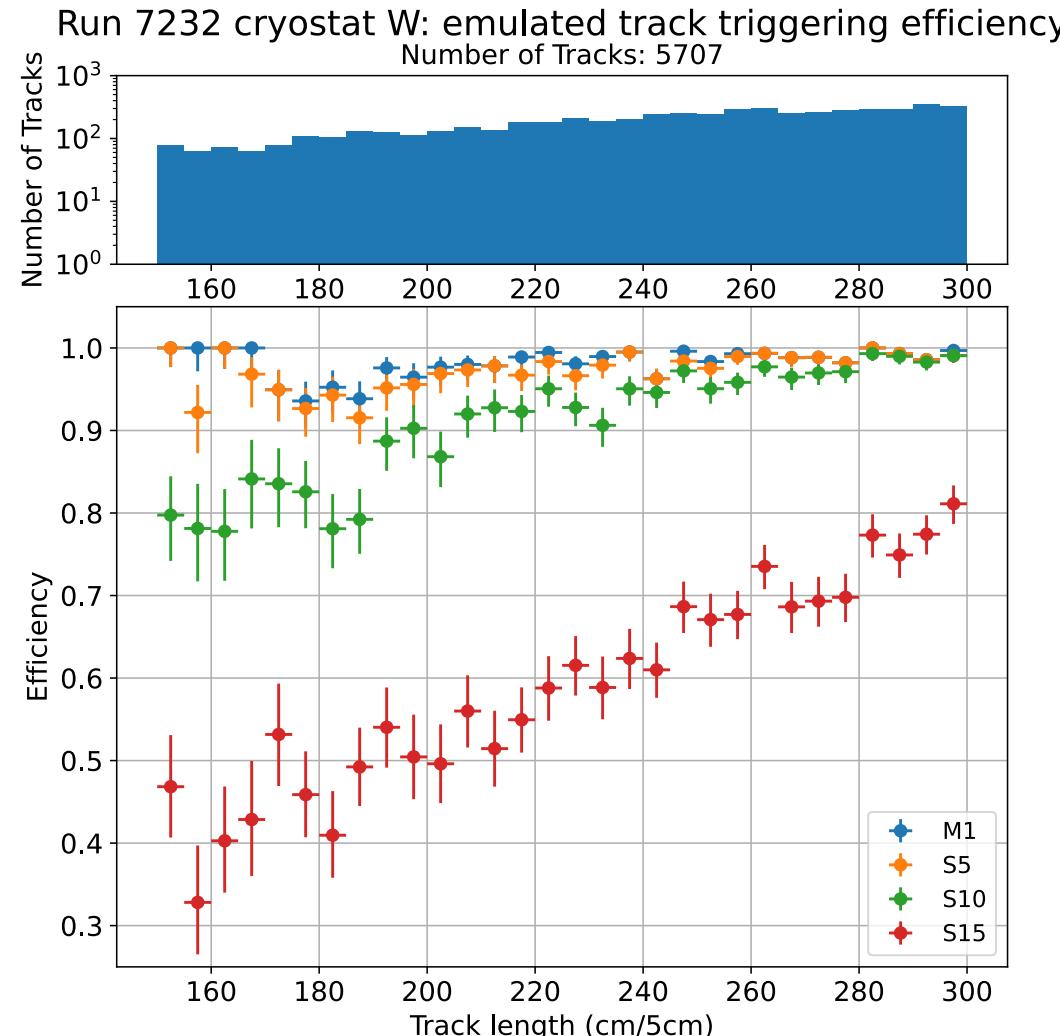
(-15 μ s, 5 μ s) Emulation Window



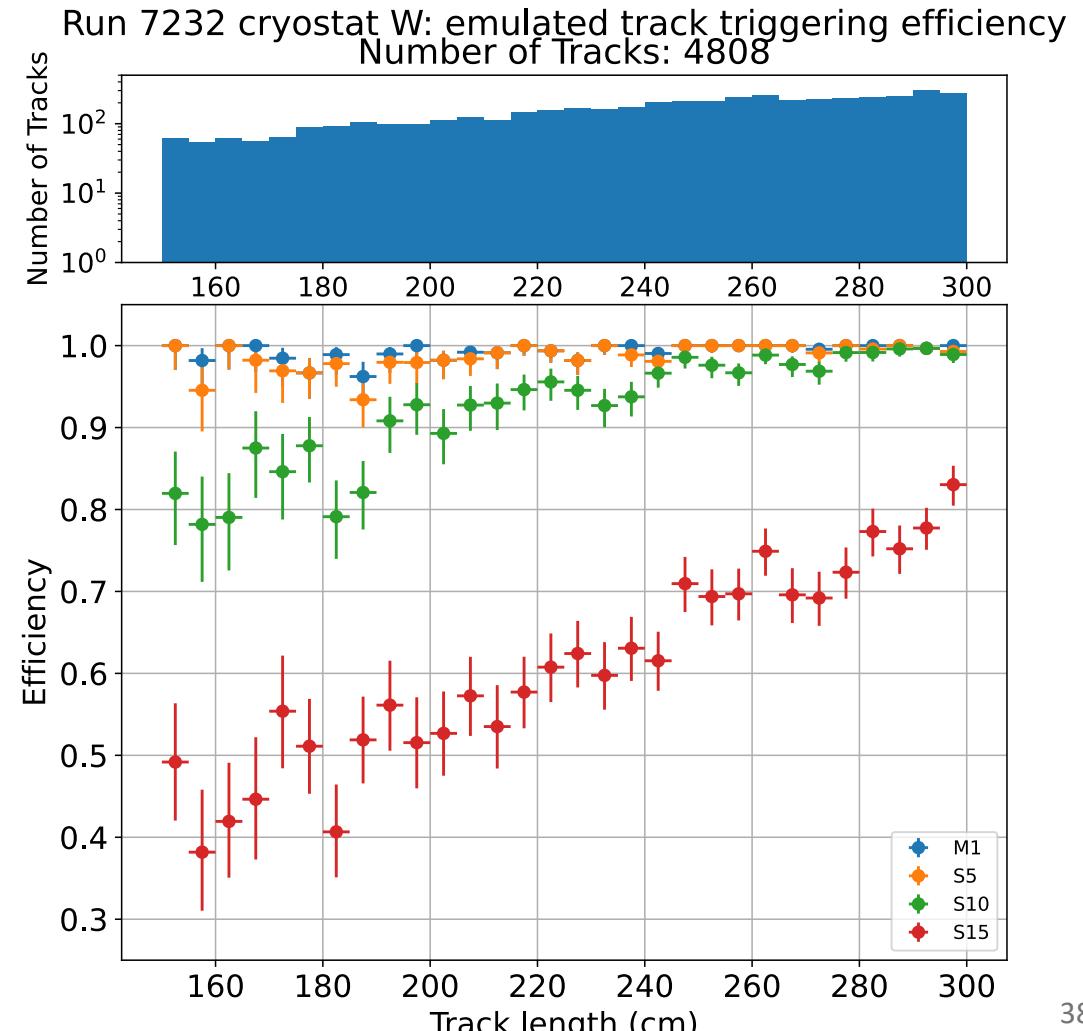
Track length: West Cryostat

- It really doesn't change much in this cryostat...

(-20 μ s, 0 μ s) Emulation Window



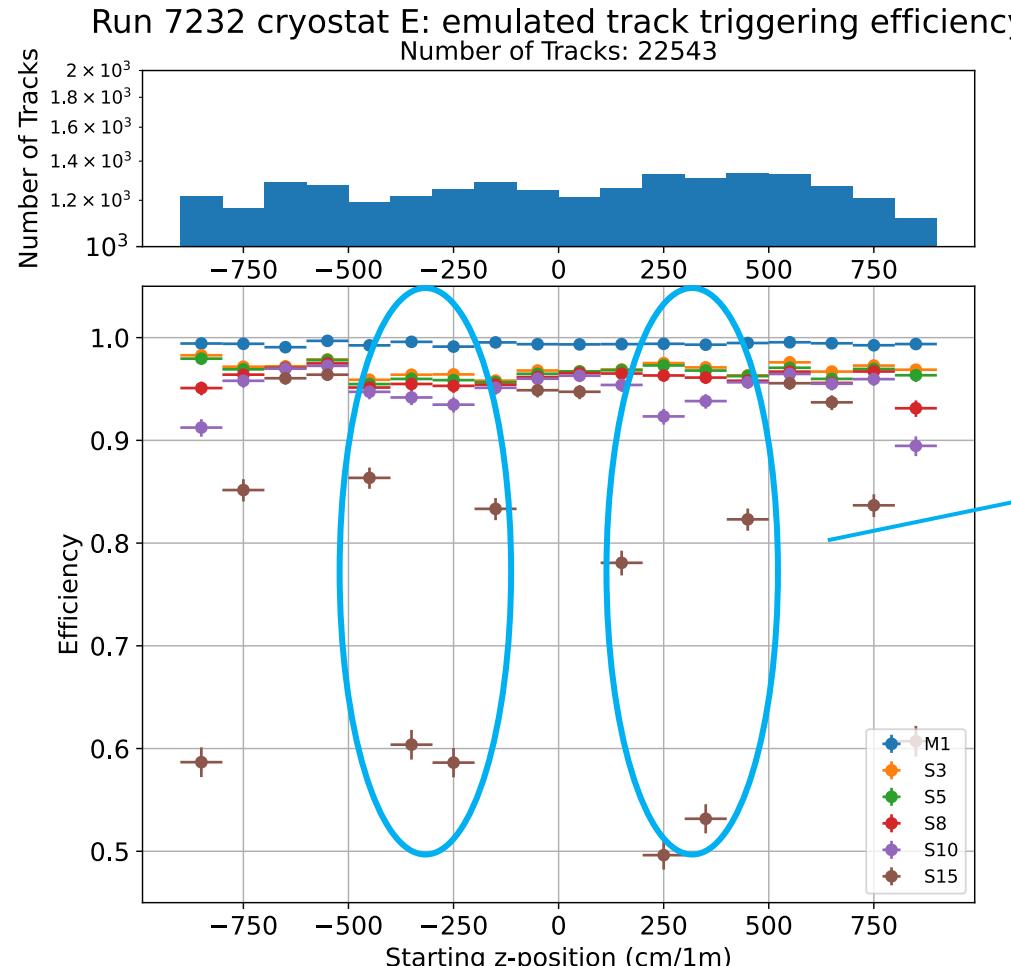
(-15 μ s, 5 μ s) Emulation Window



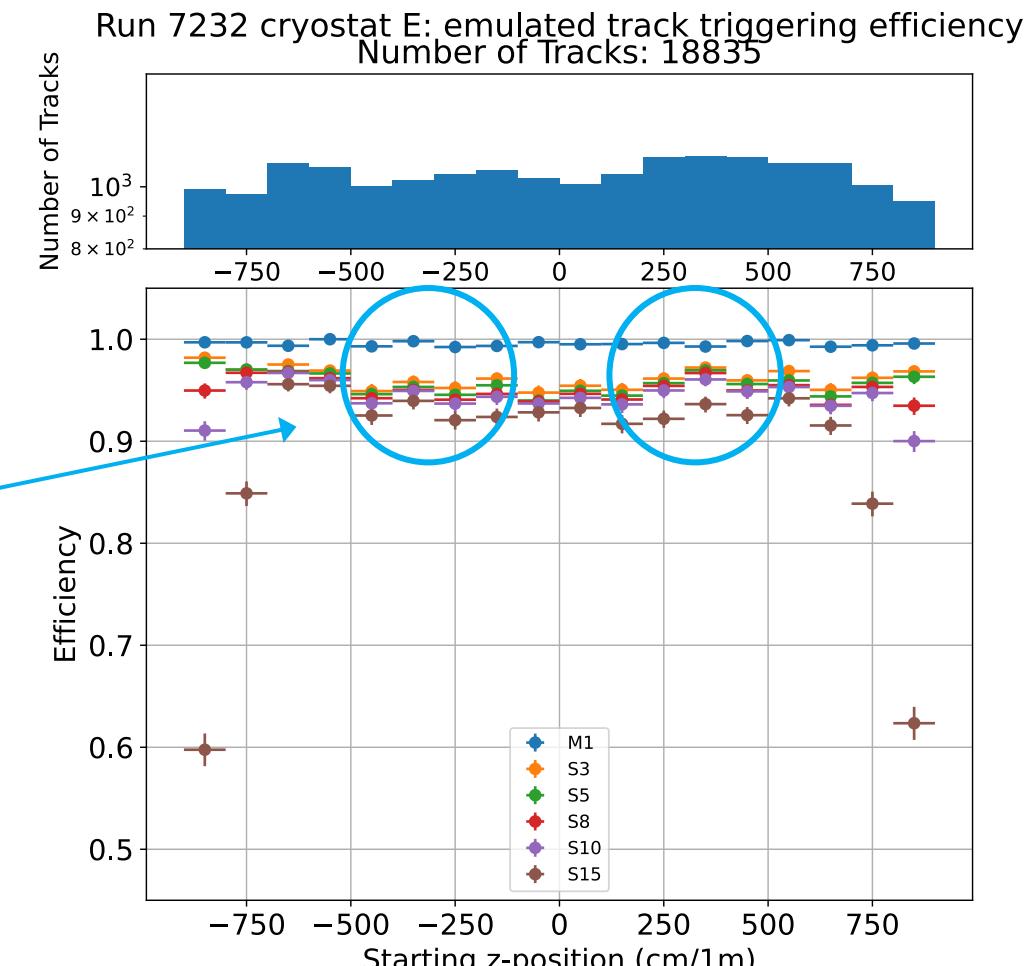
Starting z-position of tracks: East Cryostat

- Much better, as expected!

(-20 μ s, 0 μ s) Emulation Window
No Sliding Window



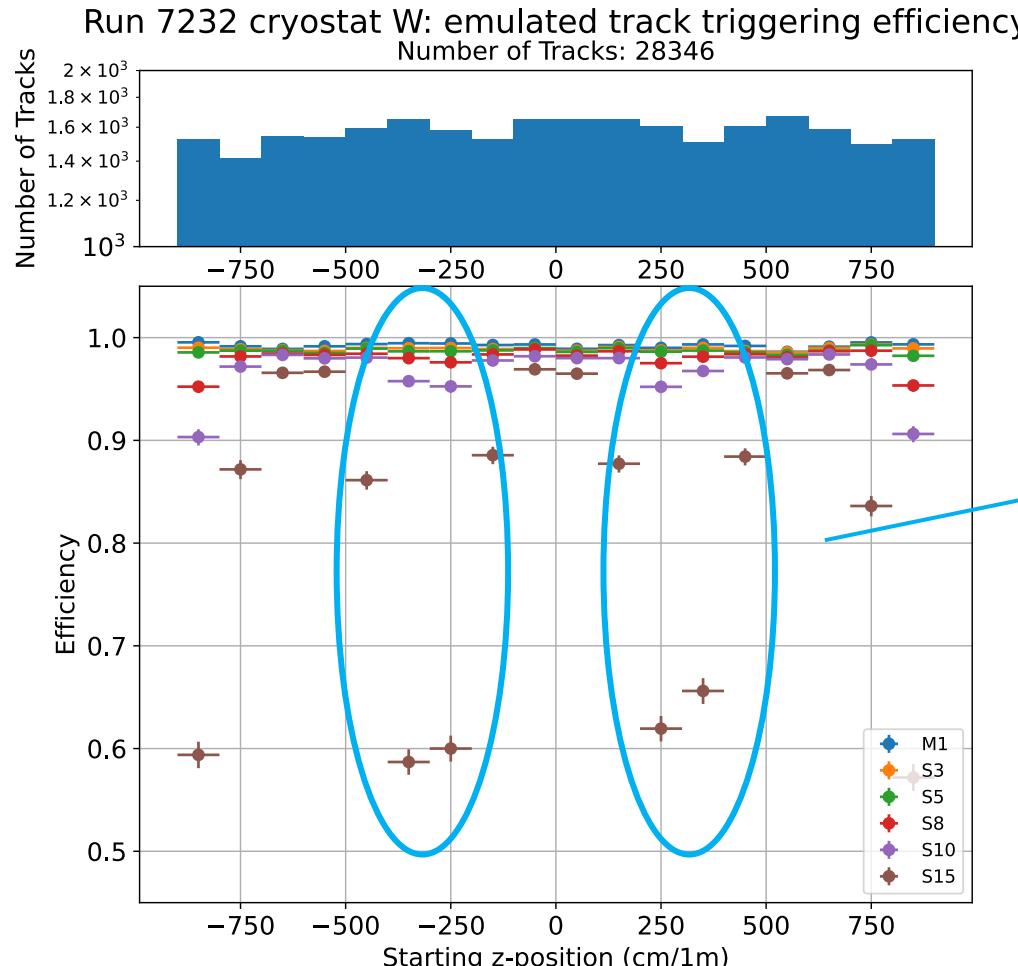
(-15 μ s, 5 μ s) Emulation Window
Sliding Window



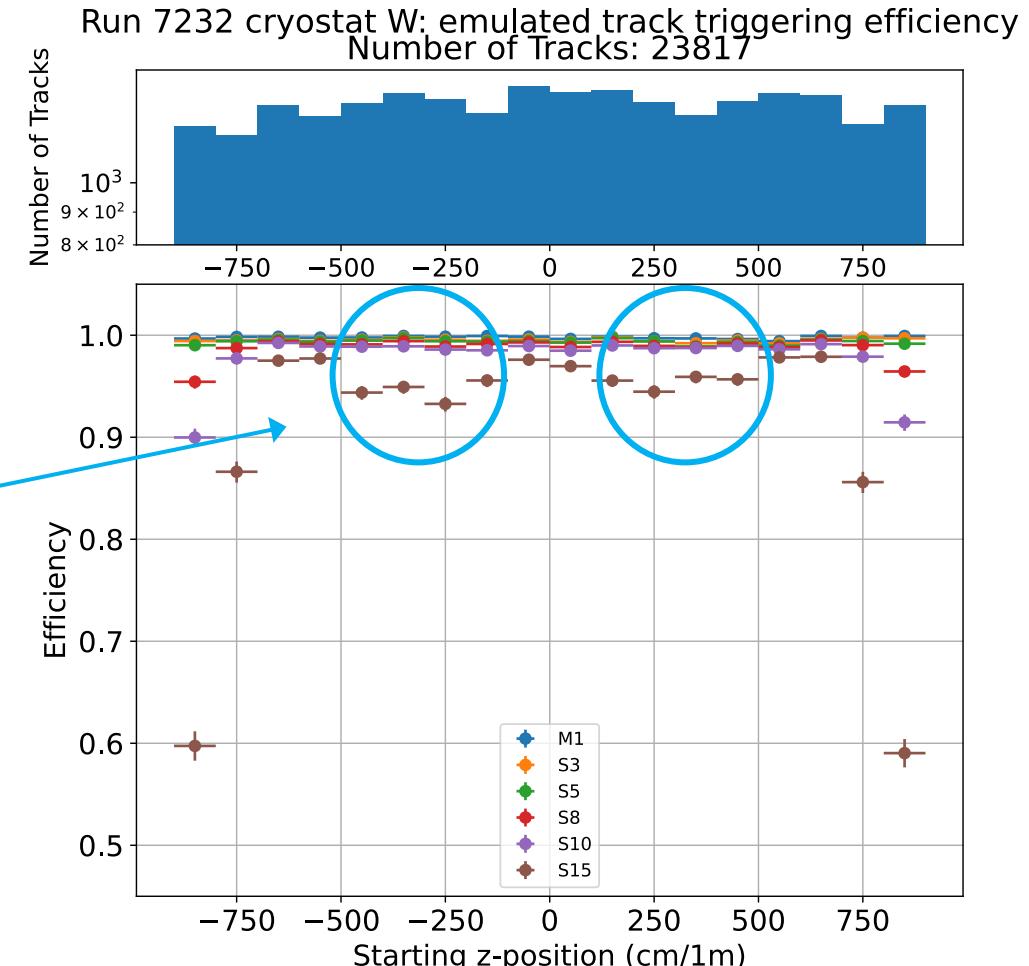
Starting z-position of tracks: West Cryostat

- Much better, as expected!

(-20 μ s, 0 μ s) Emulation Window
No Sliding Window



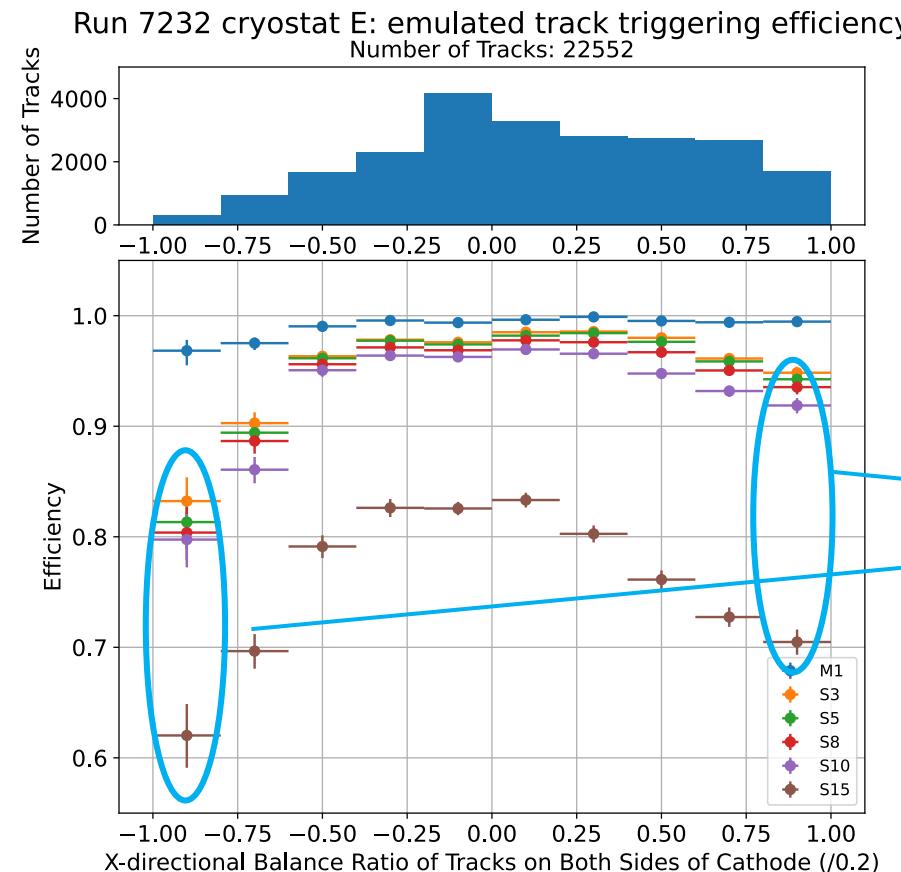
(-15 μ s, 5 μ s) Emulation Window
Sliding Window



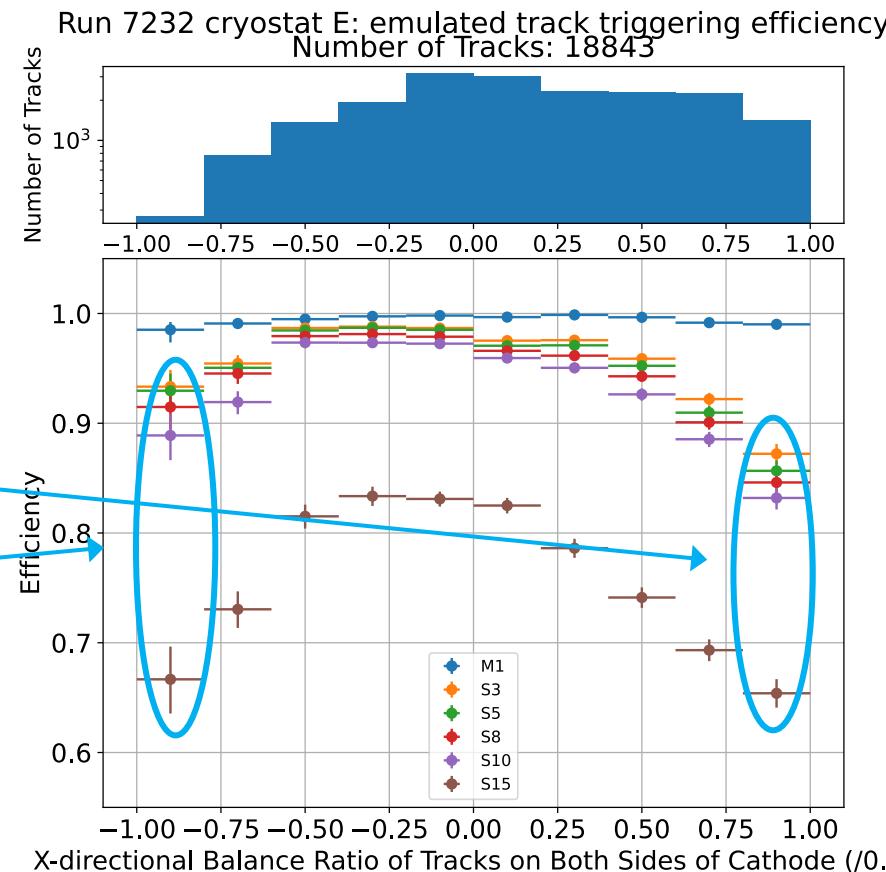
X-directional balance of tracks on either side of the cathode

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

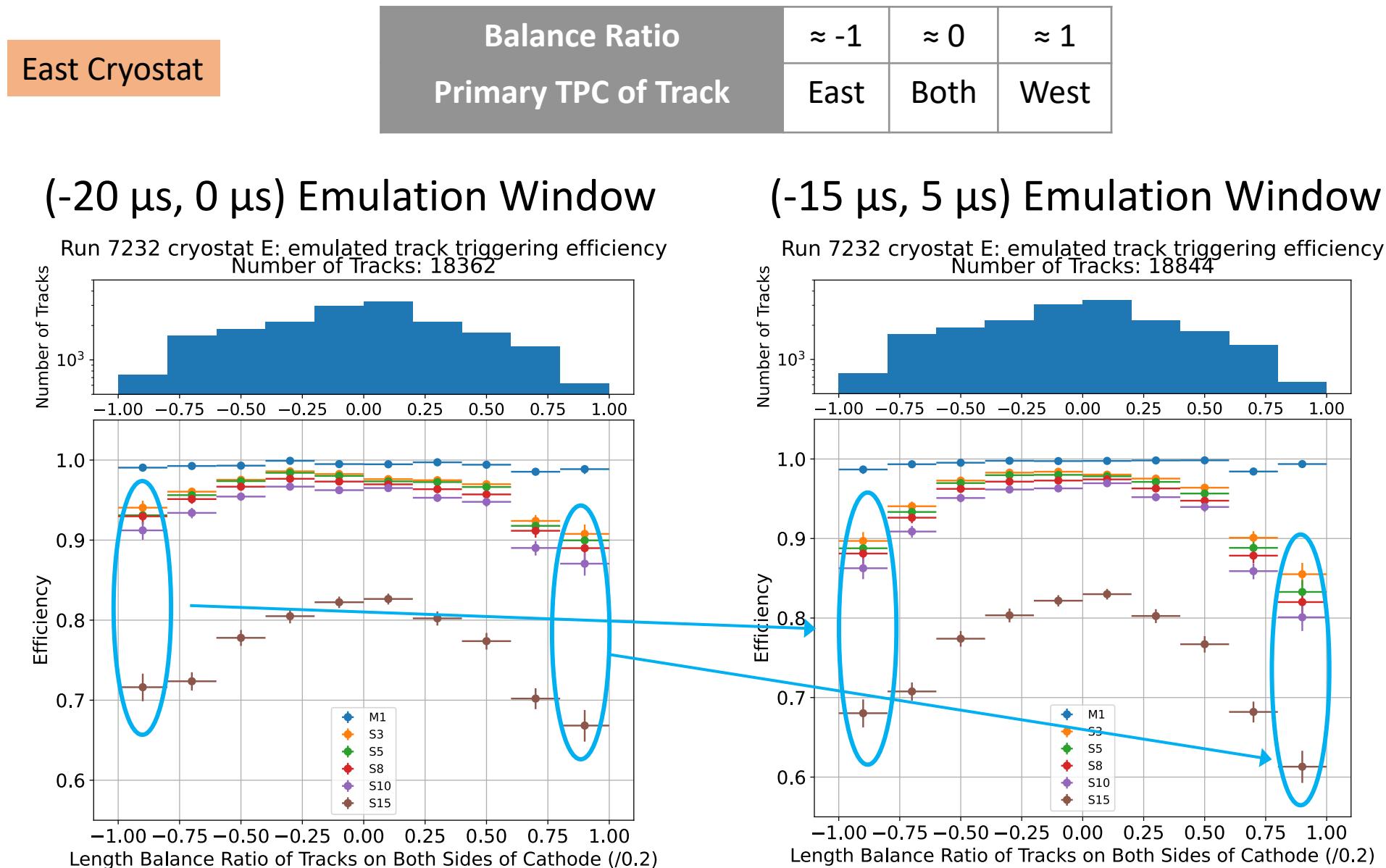
(-20 μ s, 0 μ s) Emulation Window



(-15 μ s, 5 μ s) Emulation Window



Length balance of tracks on either side of the cathode



Balance of tracks on either side of the cathode

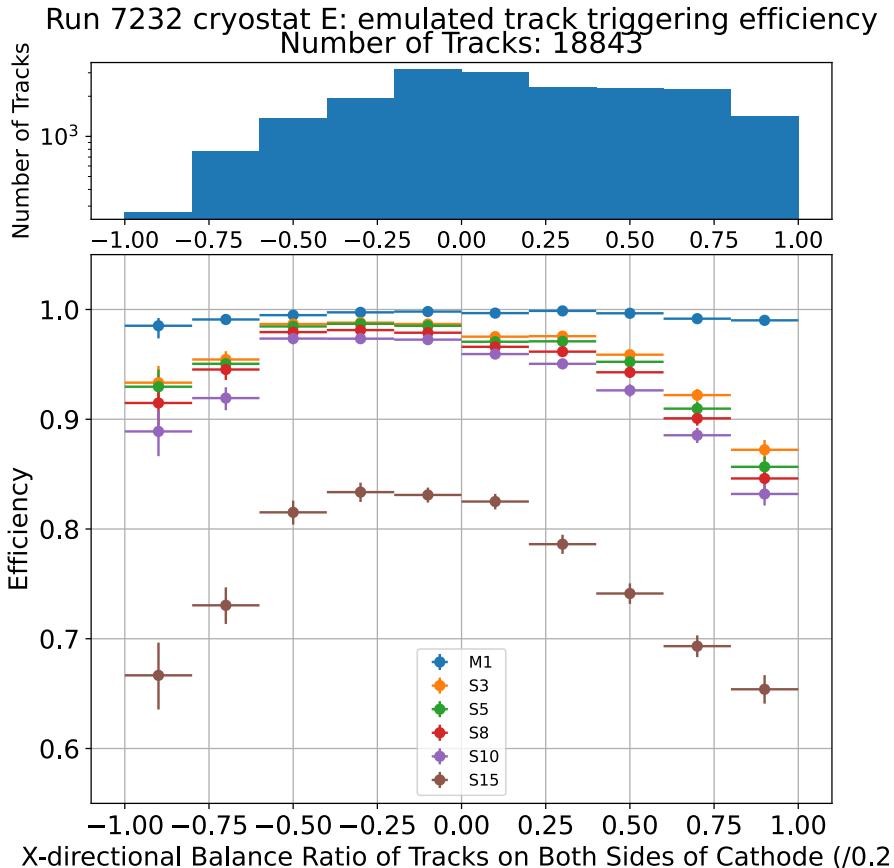
New emulation window

East Cryostat

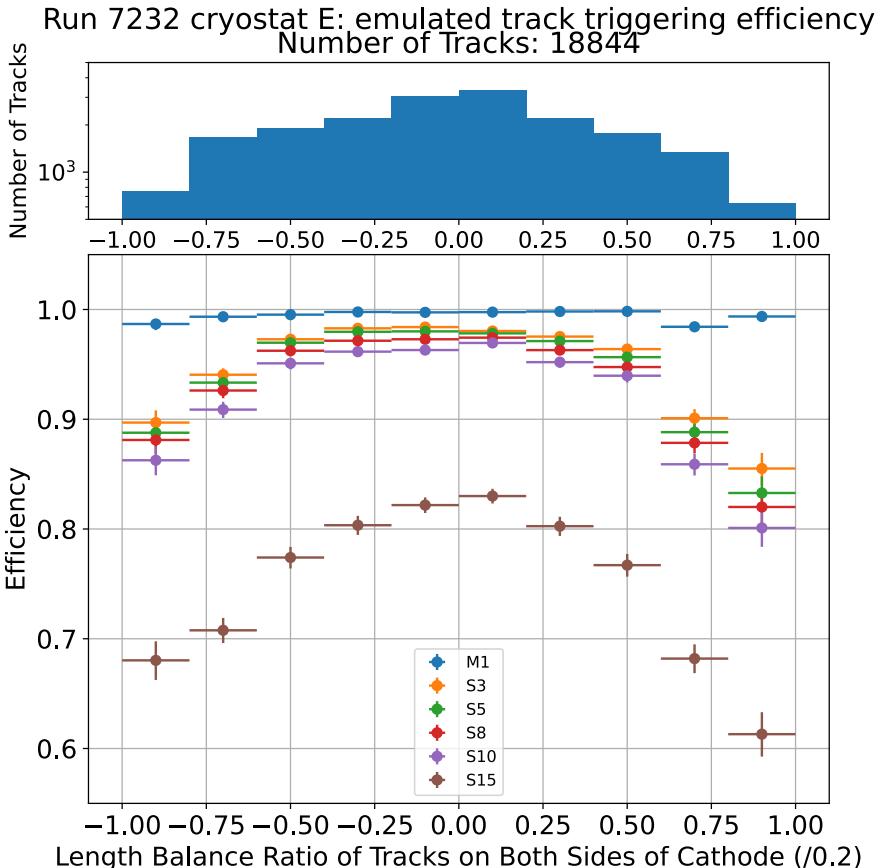
Balance Ratio
Primary TPC of Track

	≈ -1	≈ 0	≈ 1
East	East	Both	West

X-directional Balance Ratio



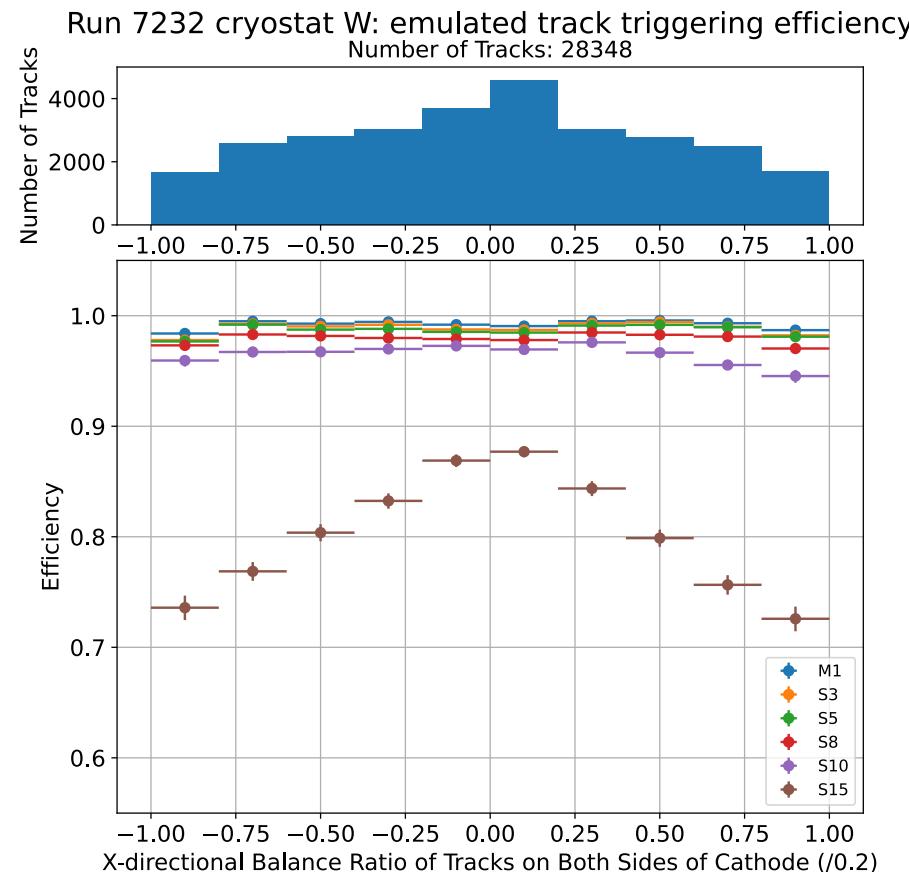
Length Balance Ratio



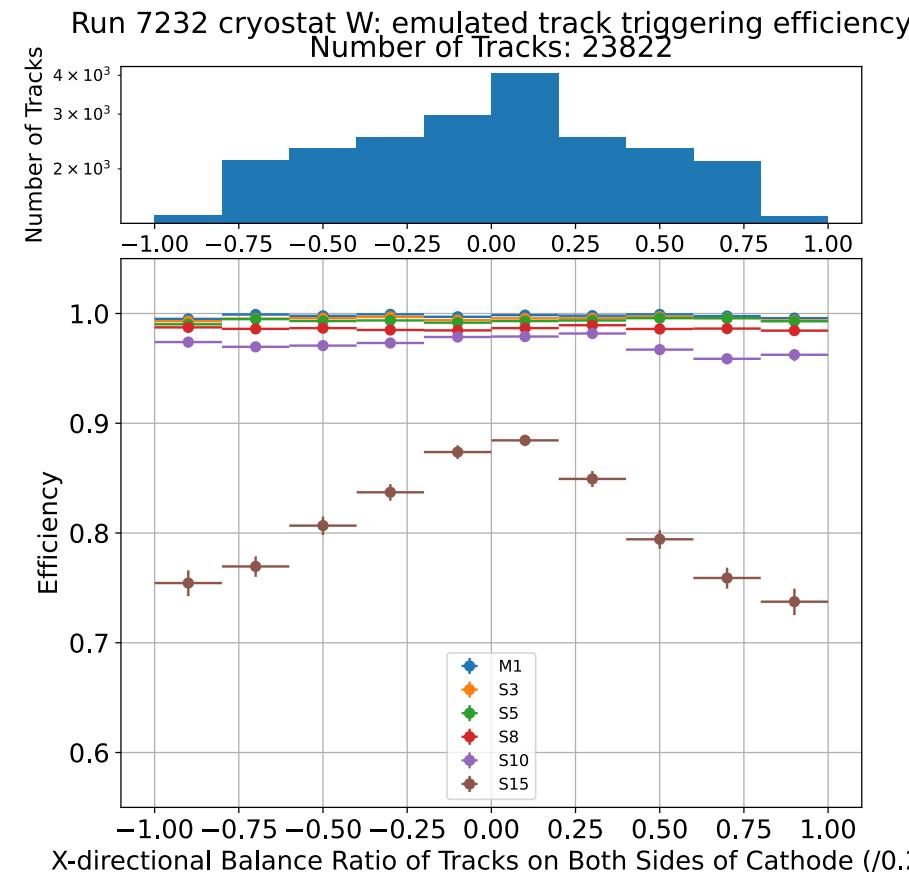
X-directional balance of tracks on either side of the cathode

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

(-20 μ s, 0 μ s) Emulation Window



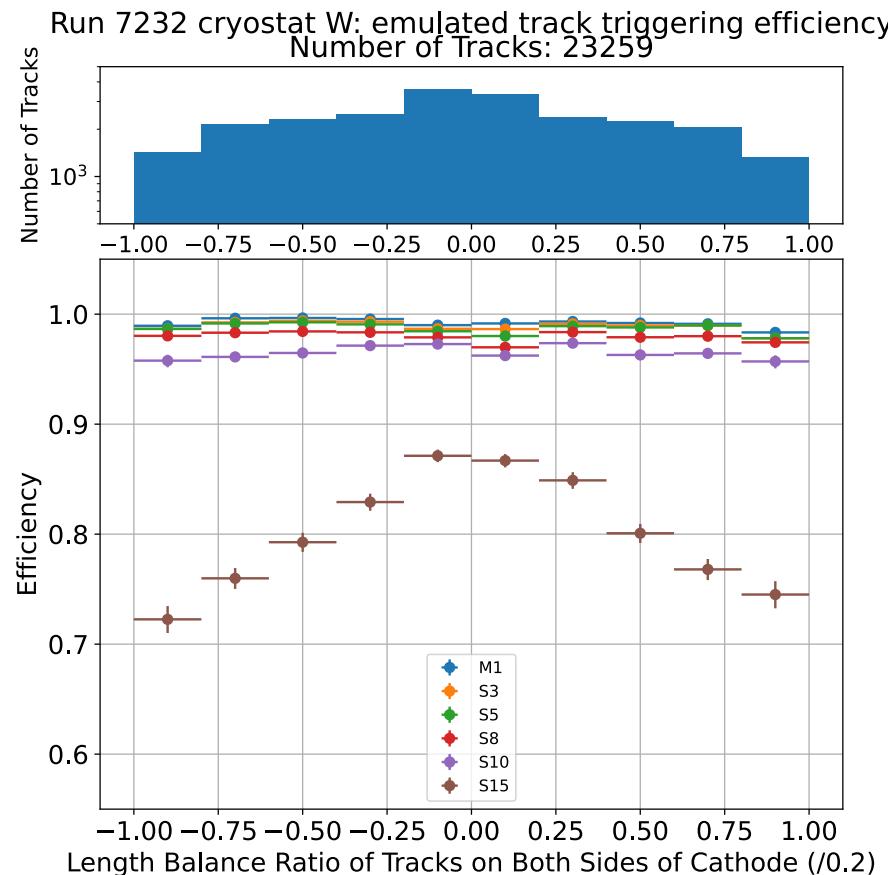
(-15 μ s, 5 μ s) Emulation Window



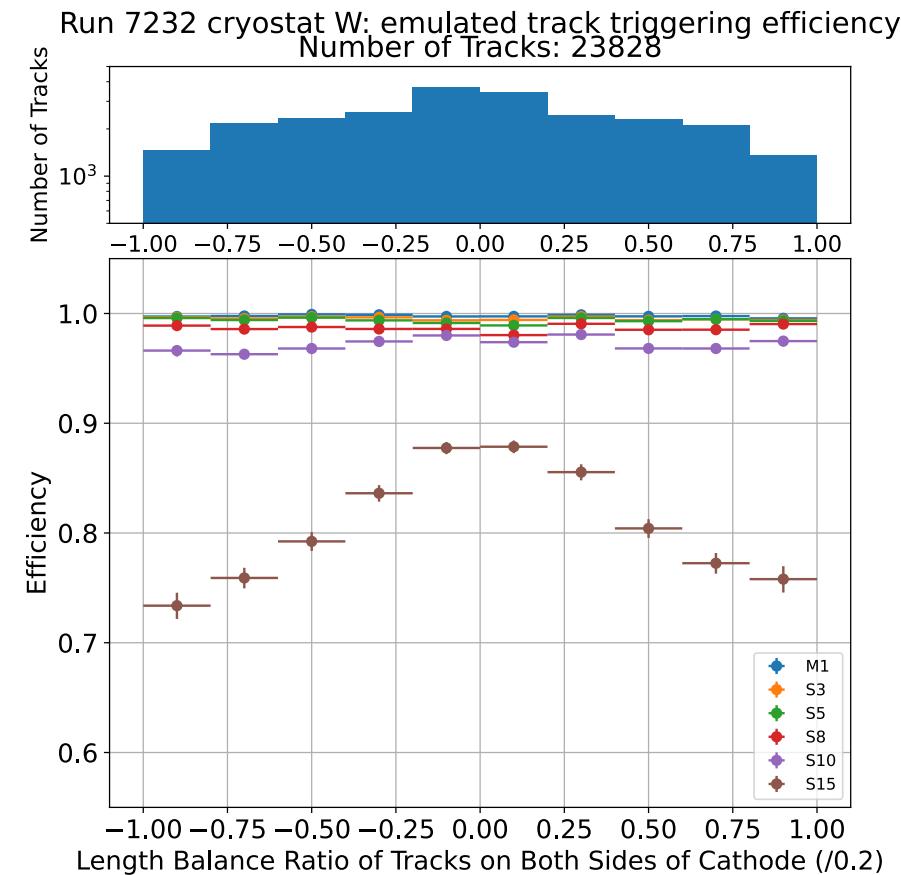
Length balance of tracks on either side of the cathode

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

(-20 μ s, 0 μ s) Emulation Window



(-15 μ s, 5 μ s) Emulation Window



Balance of tracks on either side of the cathode

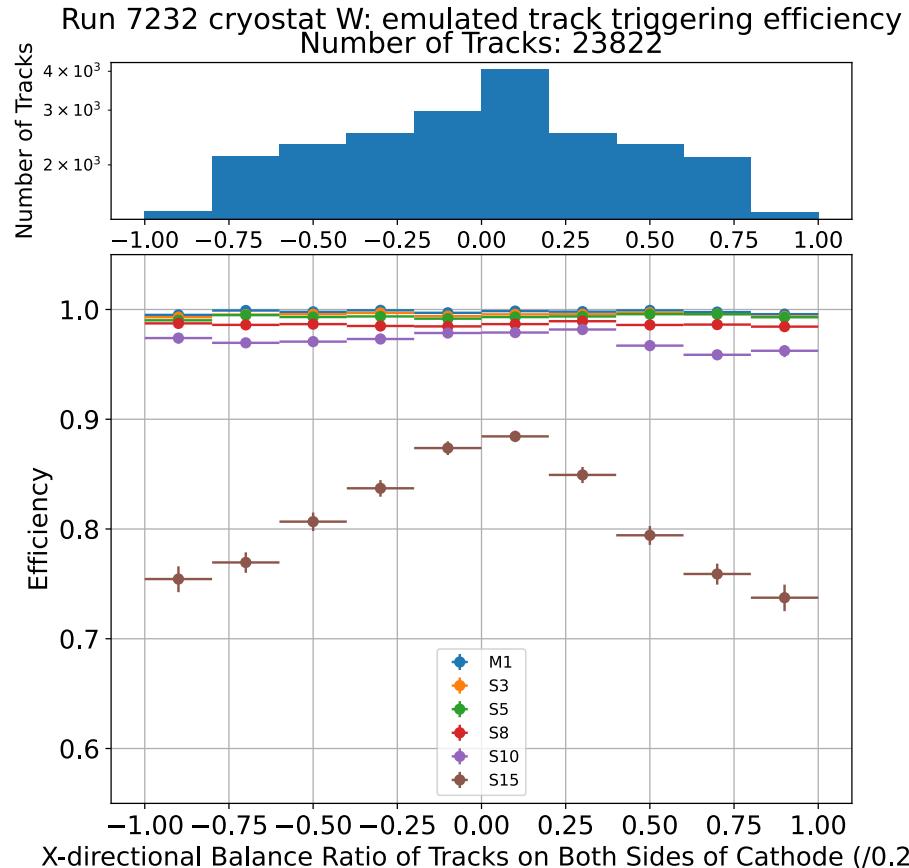
New emulation window

West Cryostat

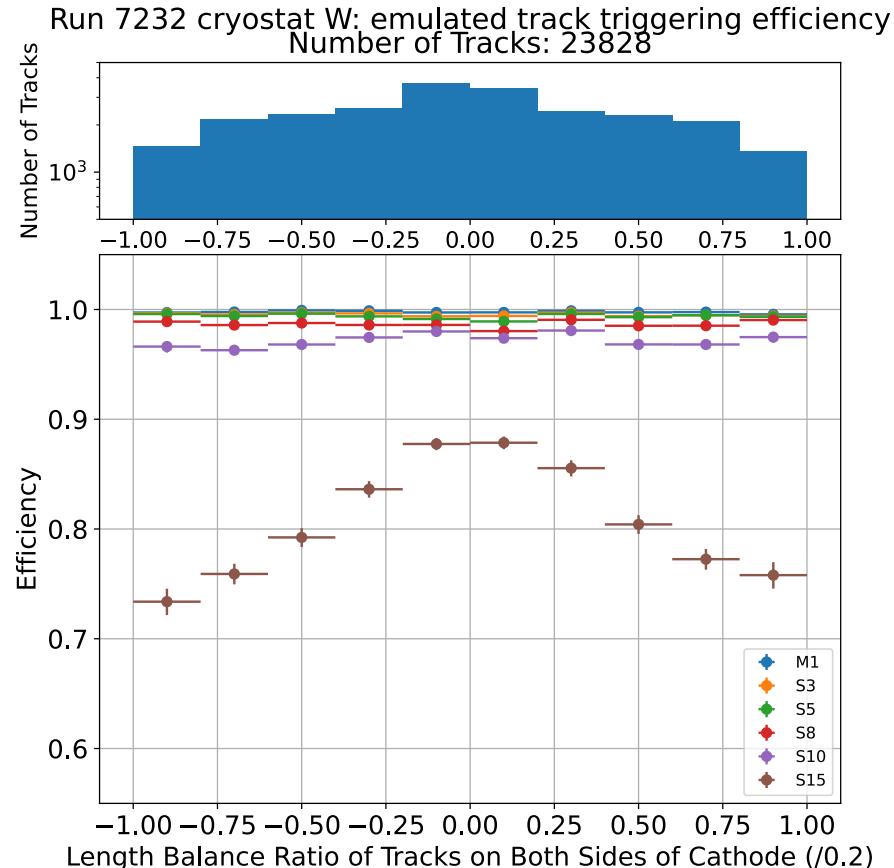
Balance Ratio
Primary TPC of Track

≈ -1	≈ 0	≈ 1
East	Both	West

X-directional Balance Ratio



Length Balance Ratio



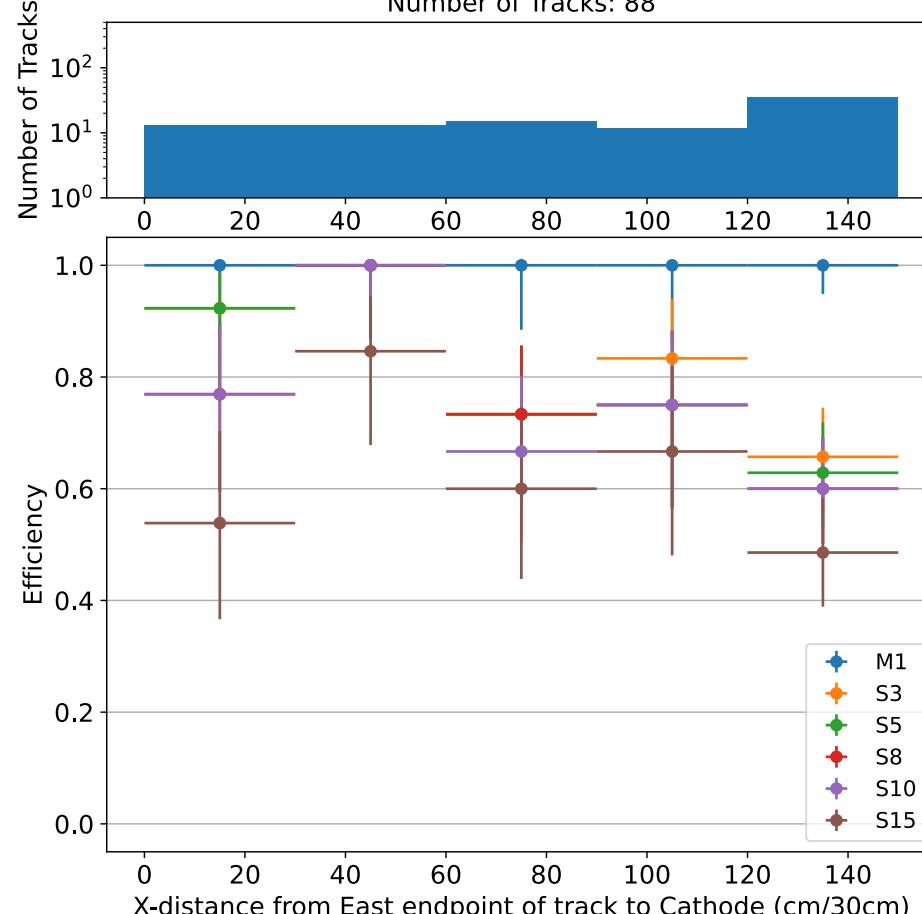
Distance to Cathode from farther endpoint for tracks primarily on one side of the cathode

These plots describe tracks with a balance ratio more extreme than 0.9.

East Cryostat, East of Cathode

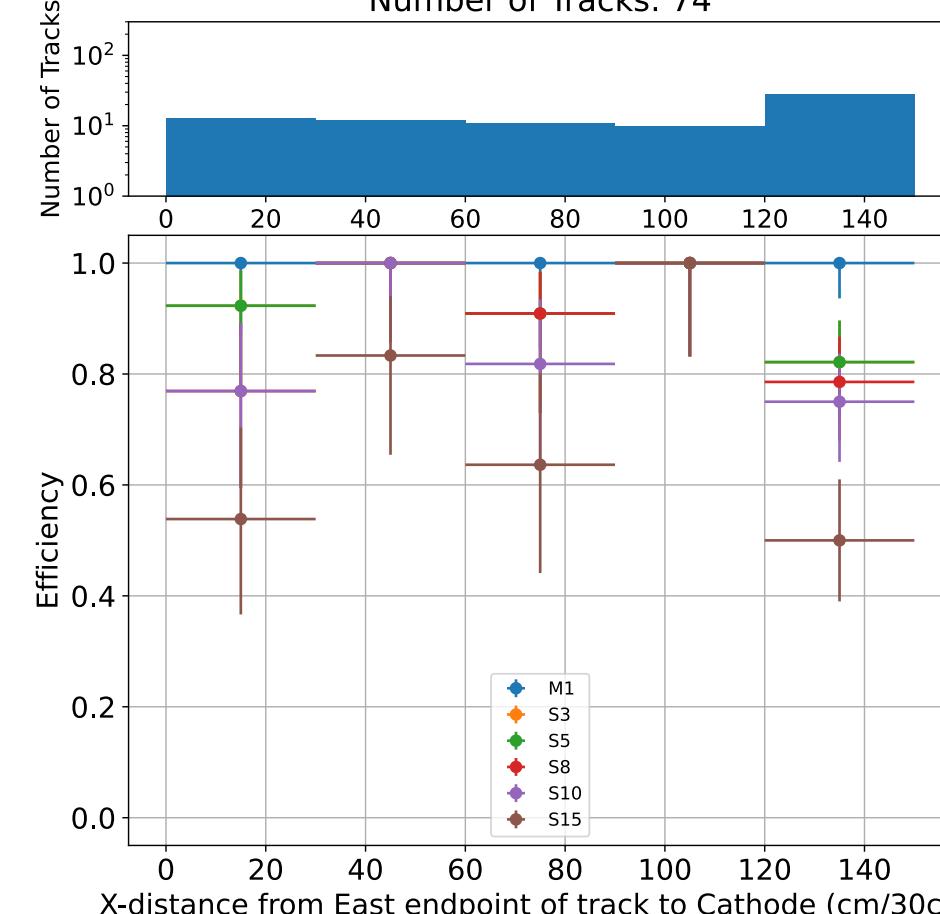
(-20 μ s, 0 μ s) Emulation Window

Run 7232 cryostat E, E of cathode: emulated track triggering efficiency
Number of Tracks: 88



(-15 μ s, 5 μ s) Emulation Window

Run 7232 cryostat E, E of cathode: emulated track triggering efficiency
Number of Tracks: 74



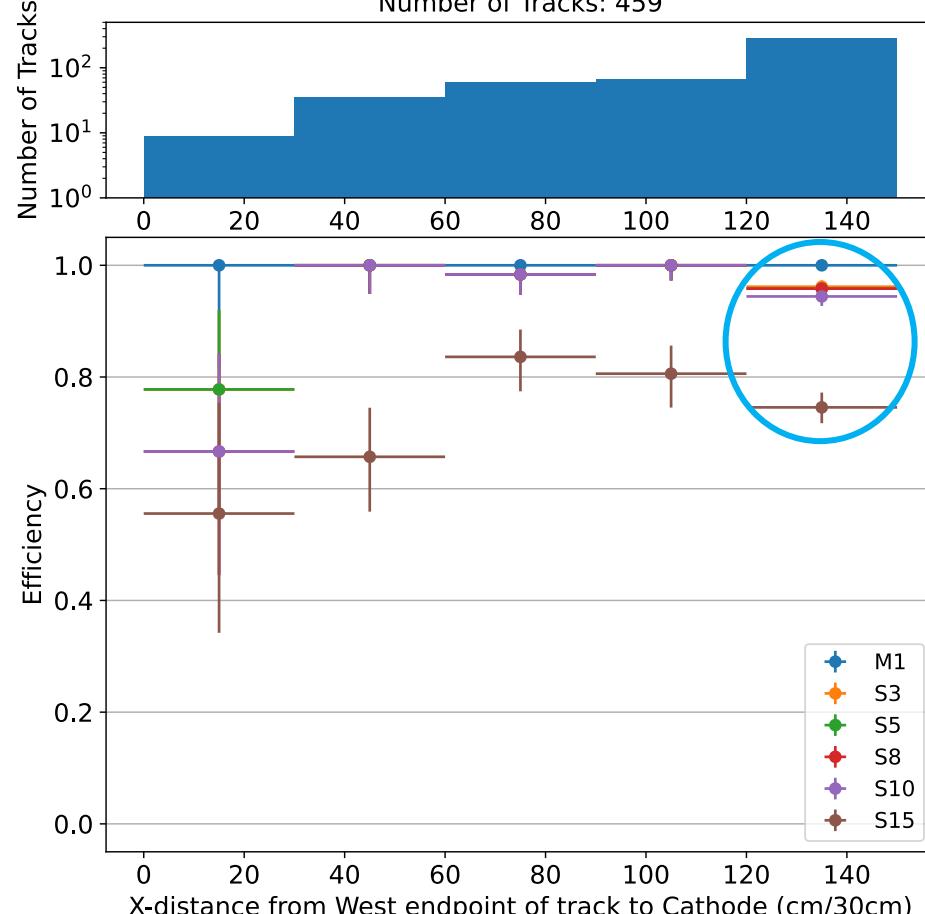
Distance to Cathode from farther endpoint for tracks primarily on one side of the cathode

These plots describe tracks with a balance ratio more extreme than 0.9.

East Cryostat, West of Cathode

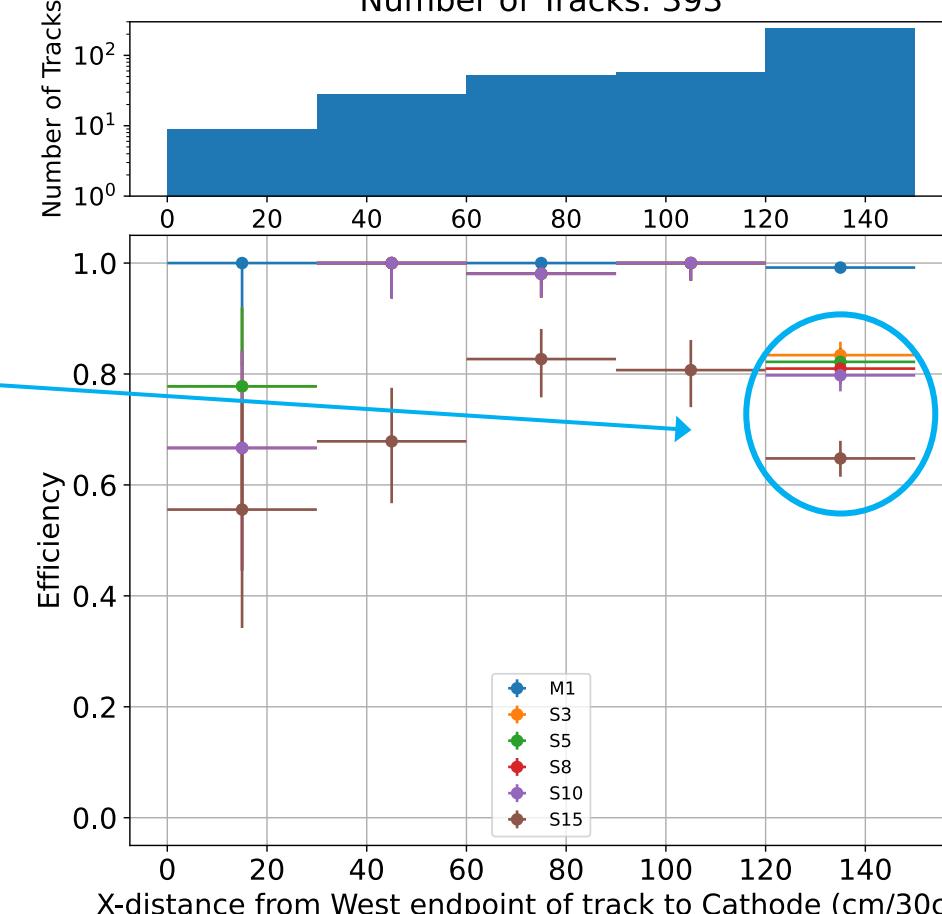
(-20 μ s, 0 μ s) Emulation Window

Run 7232 cryostat E, W of cathode: emulated track triggering efficiency
Number of Tracks: 459



(-15 μ s, 5 μ s) Emulation Window

Run 7232 cryostat E, W of cathode: emulated track triggering efficiency
Number of Tracks: 393



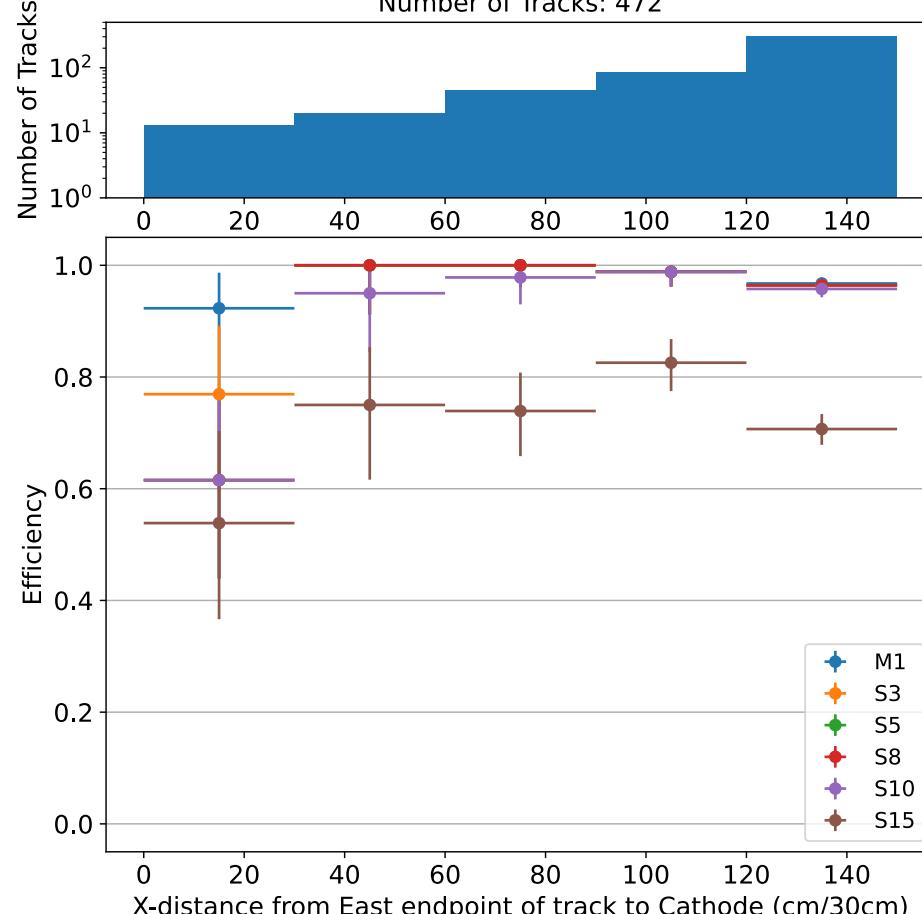
Distance to Cathode from farther endpoint for tracks primarily on one side of the cathode

These plots describe tracks with a balance ratio more extreme than 0.9.

West Cryostat, East of Cathode

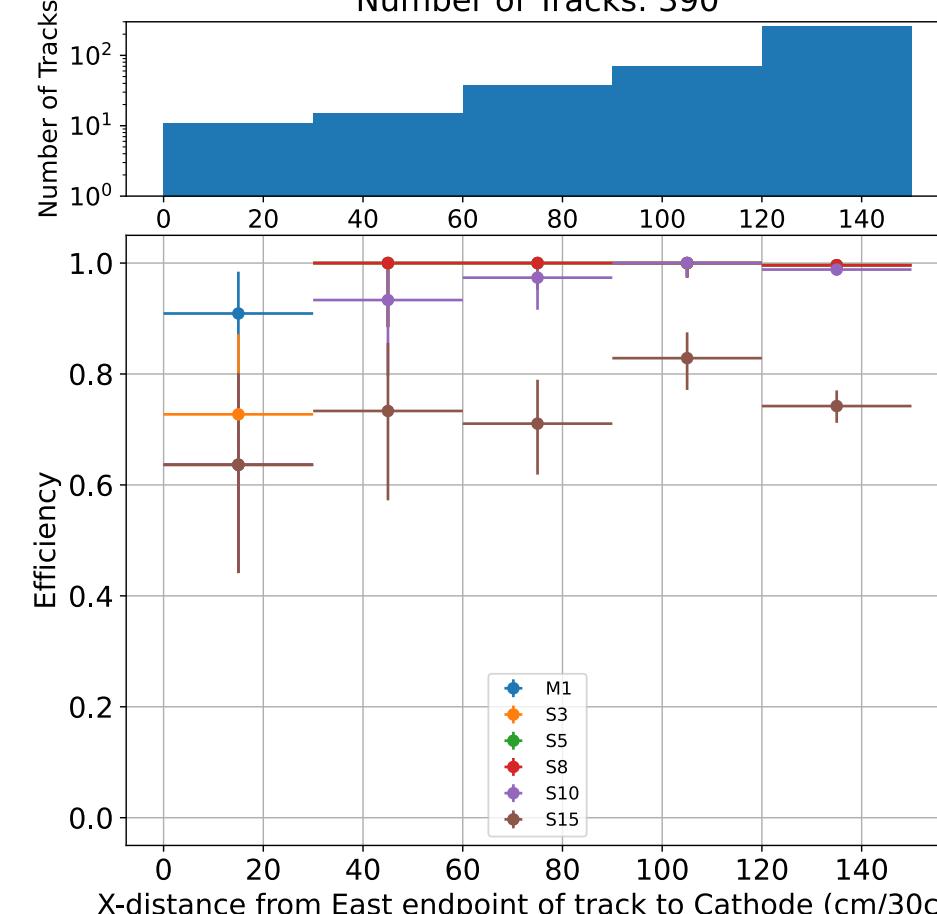
(-20 μ s, 0 μ s) Emulation Window

Run 7232 cryostat W, E of cathode; emulated track triggering efficiency
Number of Tracks: 472



(-15 μ s, 5 μ s) Emulation Window

Run 7232 cryostat W, E of cathode; emulated track triggering efficiency
Number of Tracks: 390

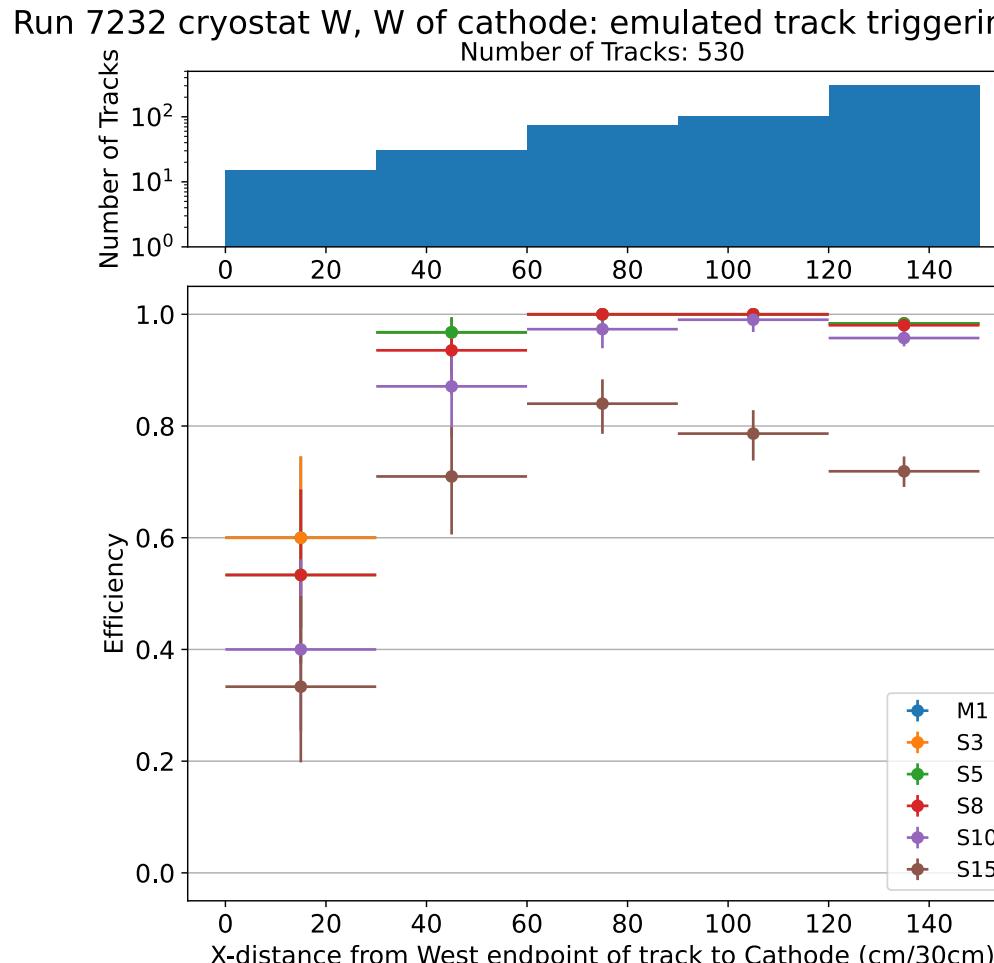


Distance to Cathode from farther endpoint for tracks primarily on one side of the cathode

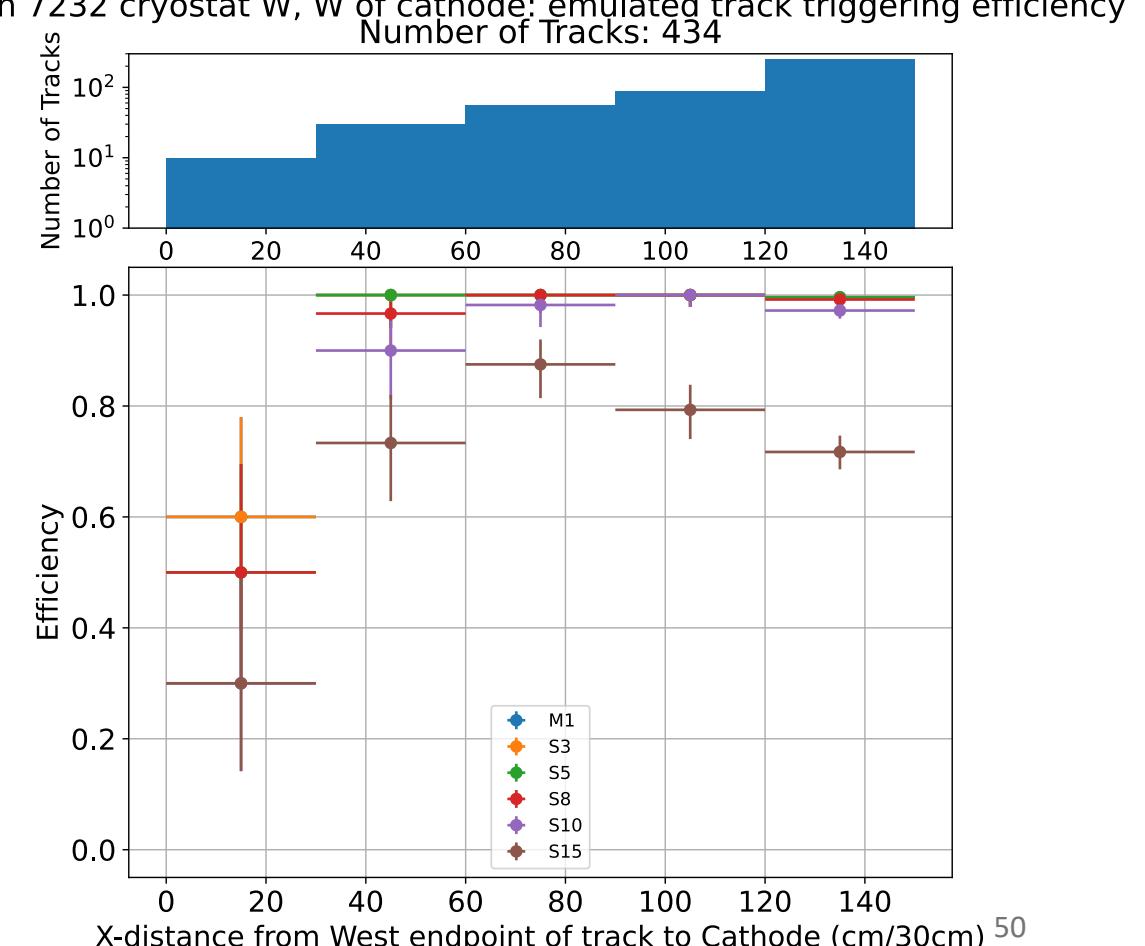
These plots describe tracks with a balance ratio more extreme than 0.9.

West Cryostat, West of Cathode

(-20 μ s, 0 μ s) Emulation Window



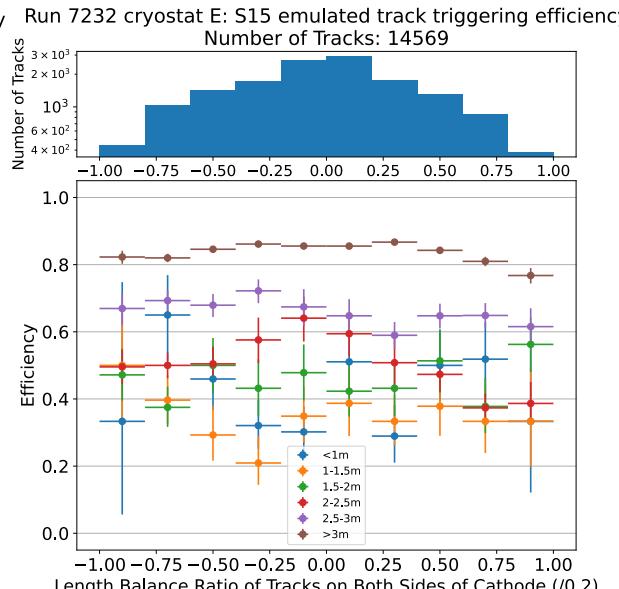
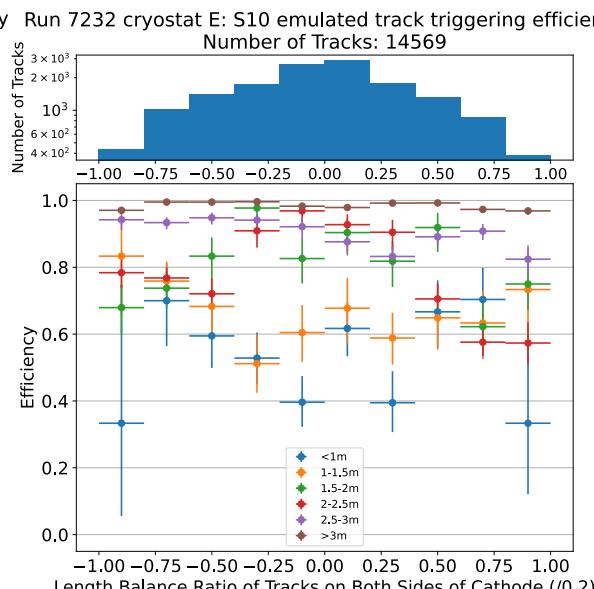
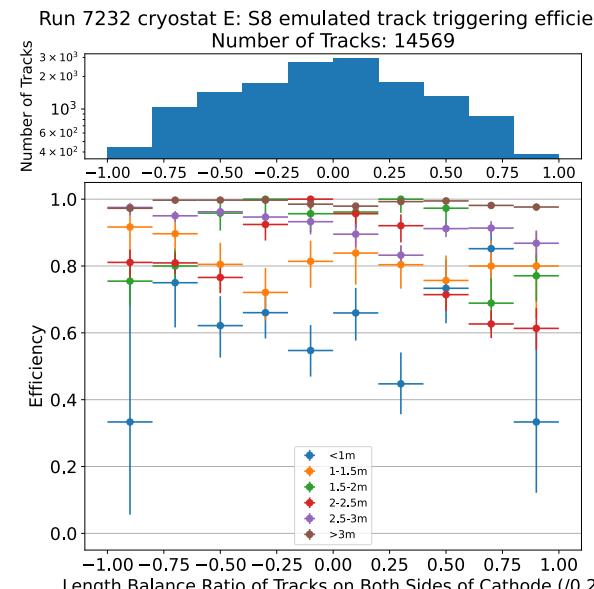
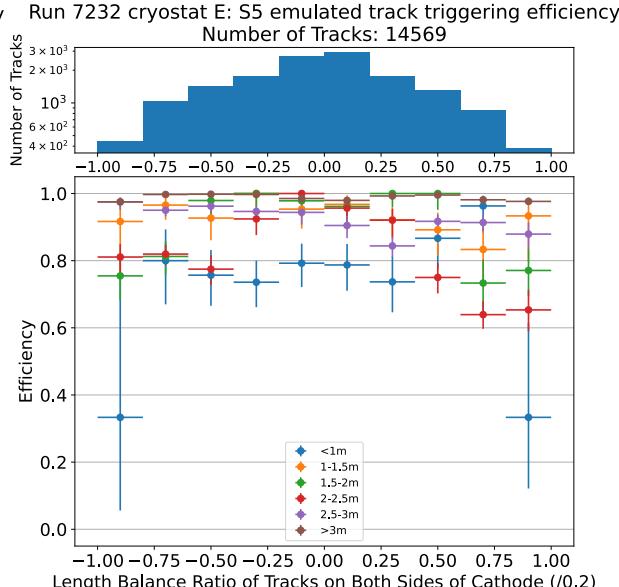
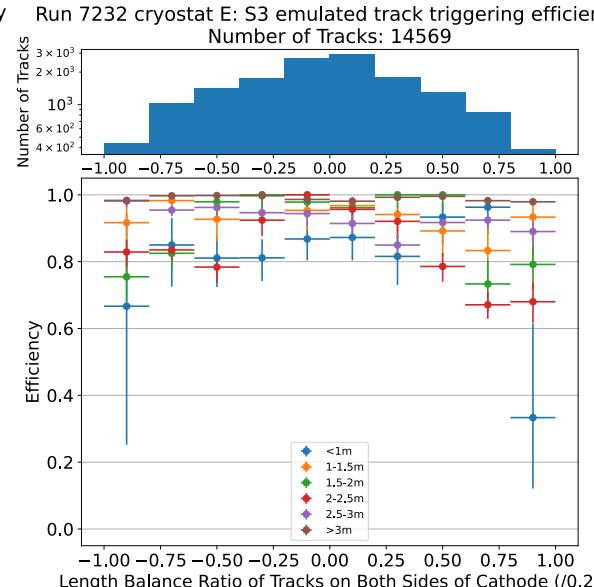
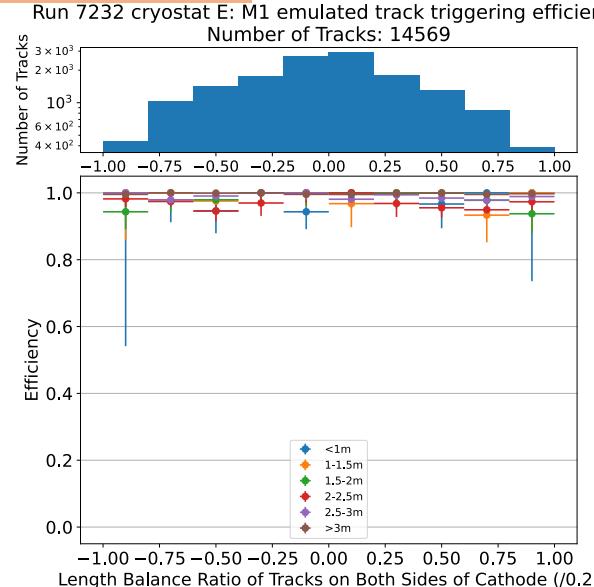
(-15 μ s, 5 μ s) Emulation Window



Balance of track lengths on either side of the cathode

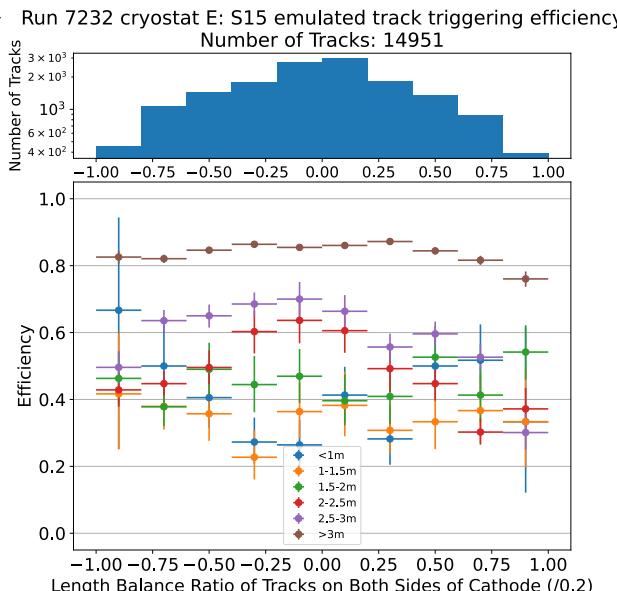
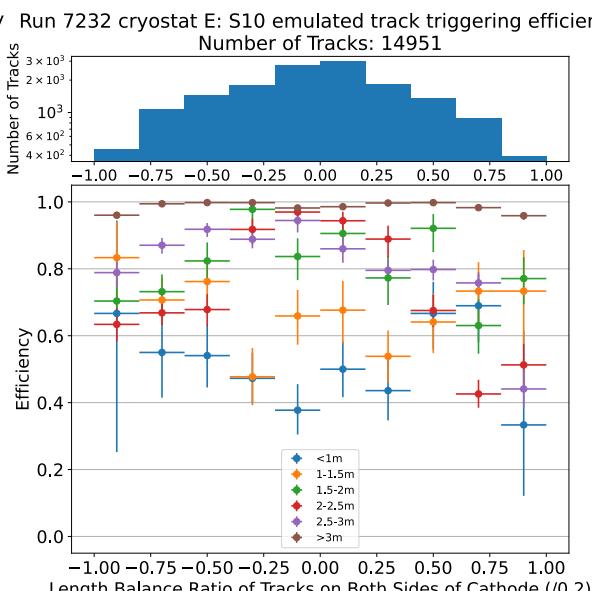
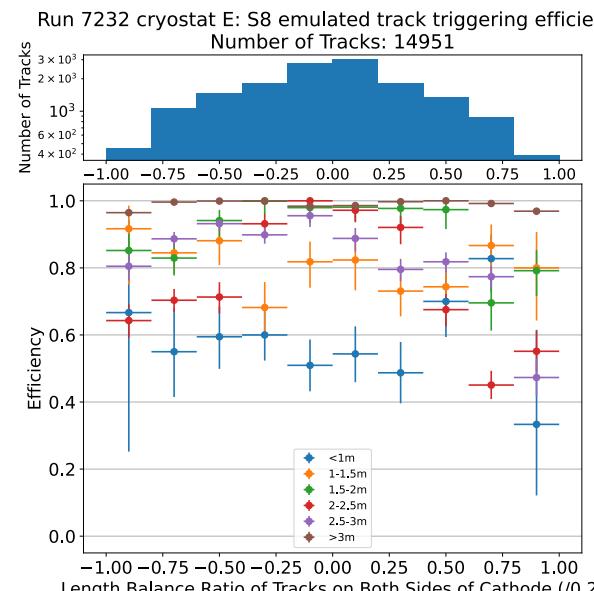
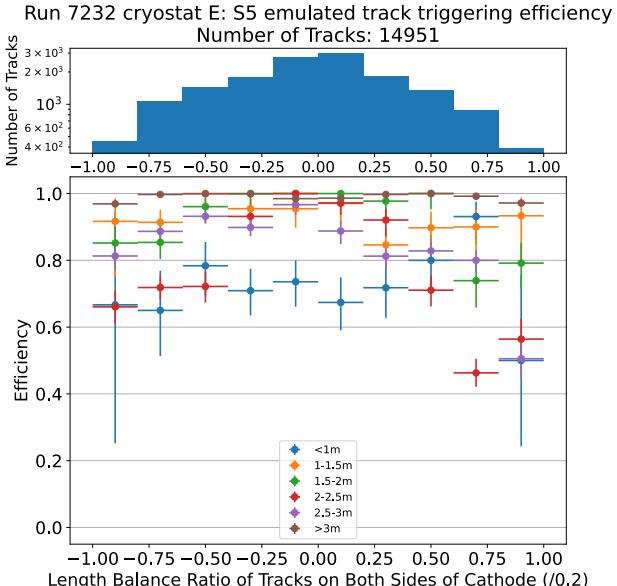
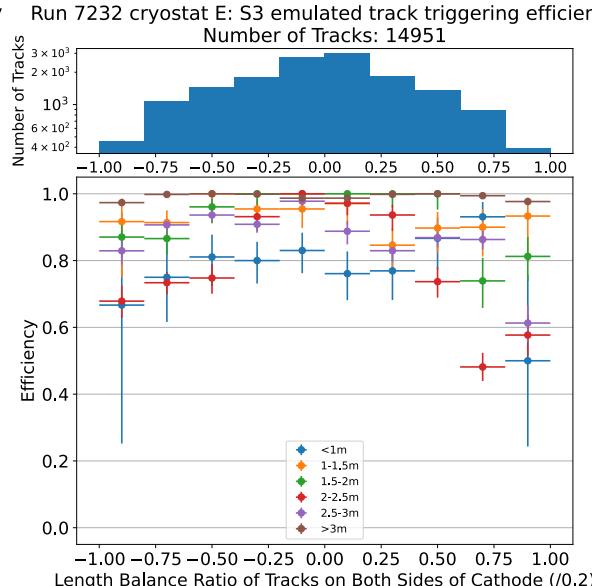
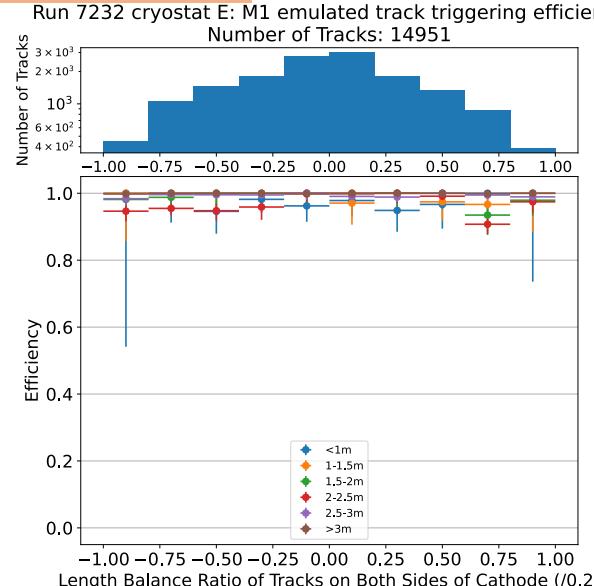
(-20 μ s, 0 μ s) Emulation Window

East Cryostat



Balance of track lengths on either side of the cathode

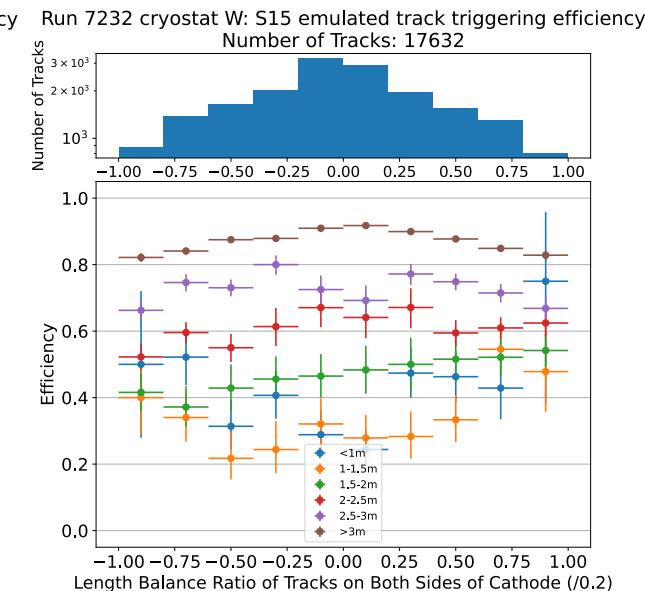
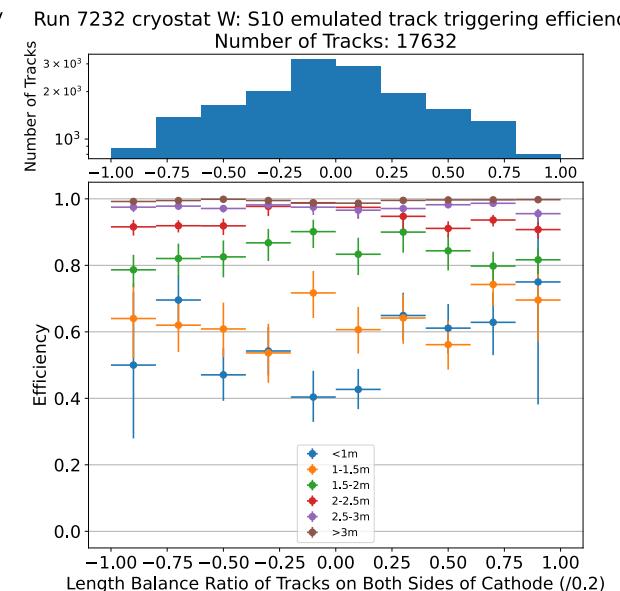
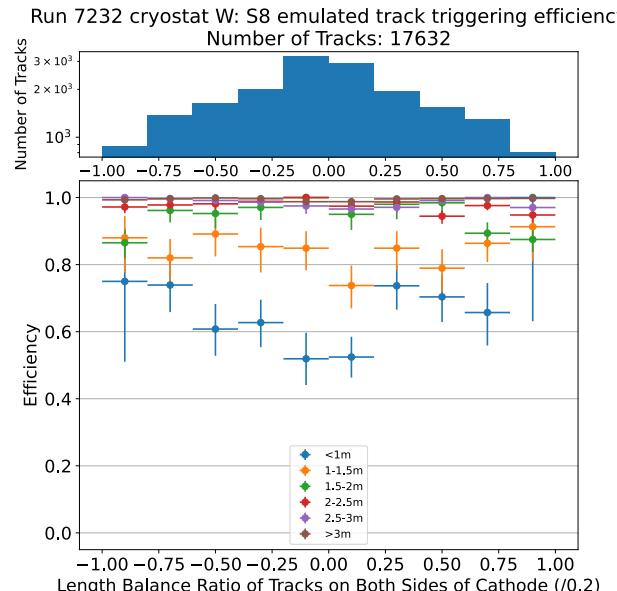
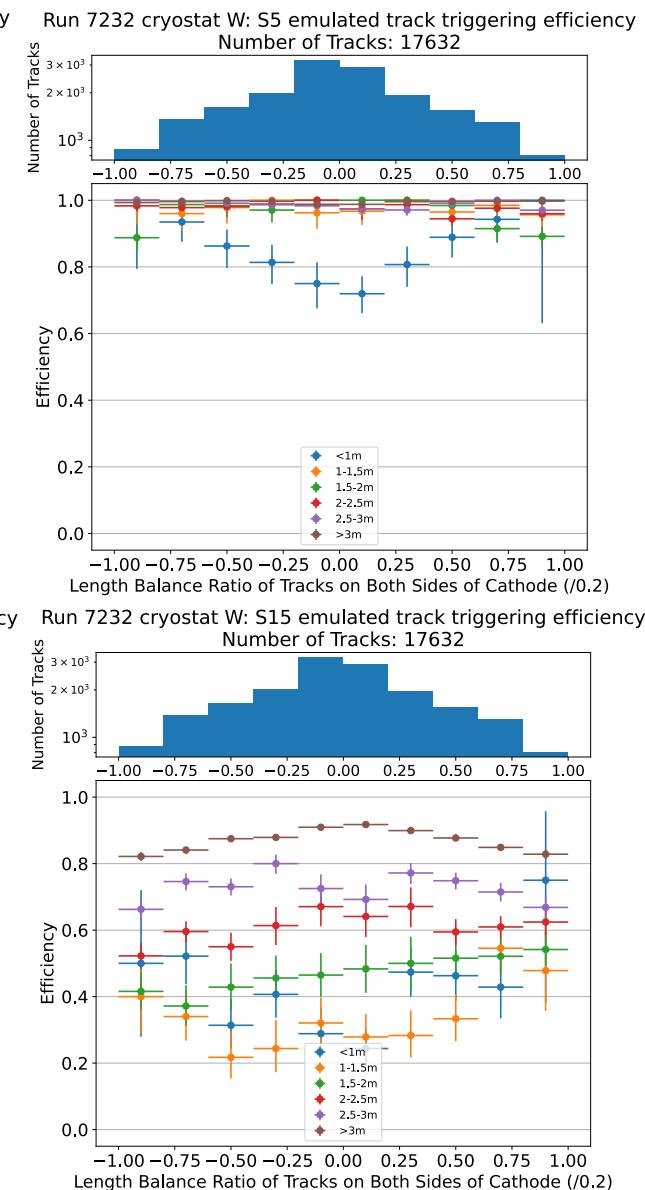
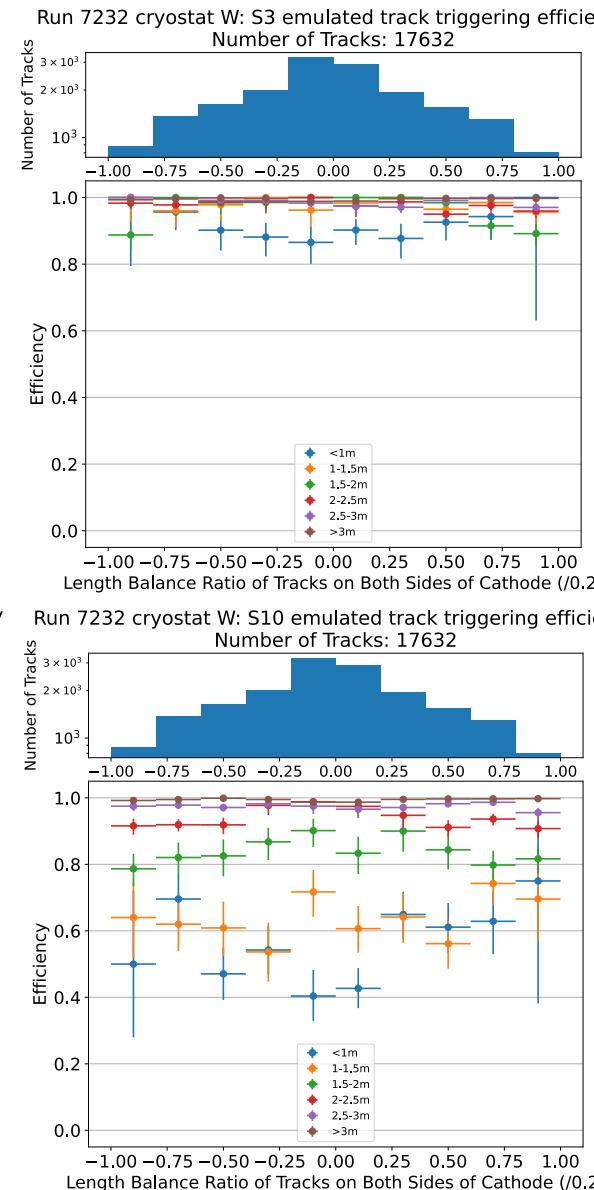
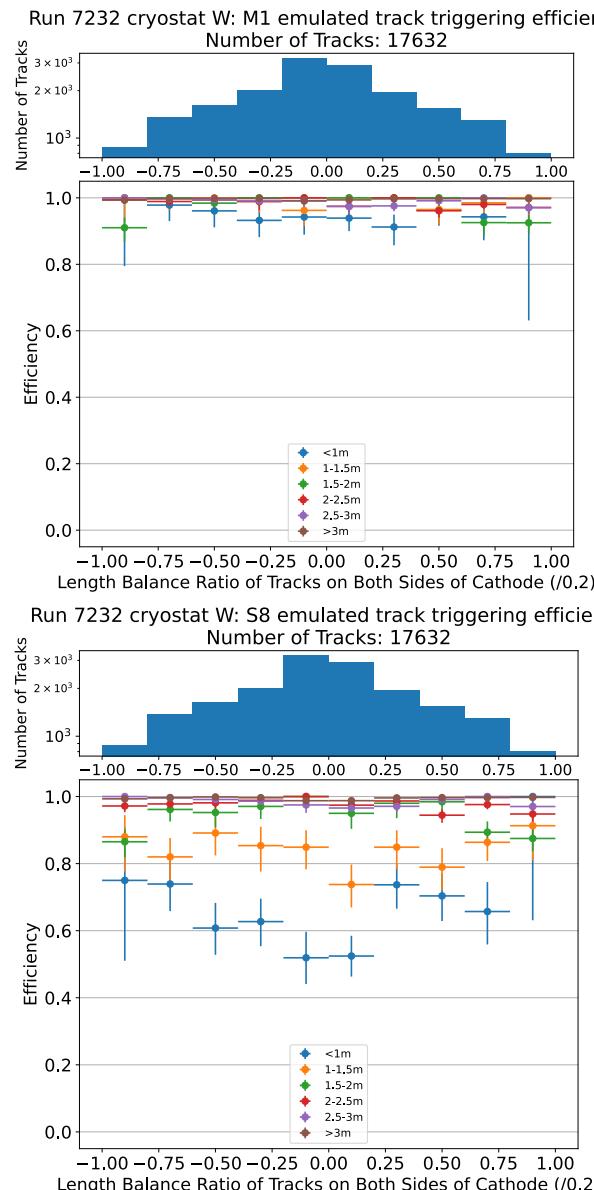
East Cryostat



Balance of track lengths on either side of the cathode

West Cryostat

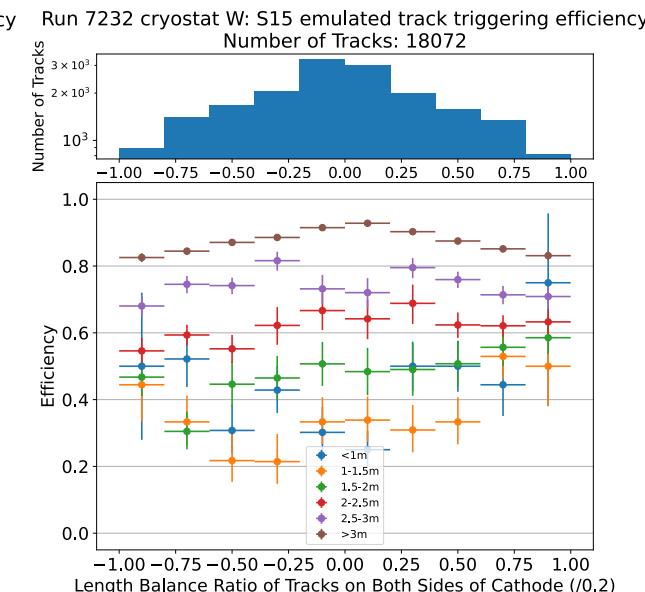
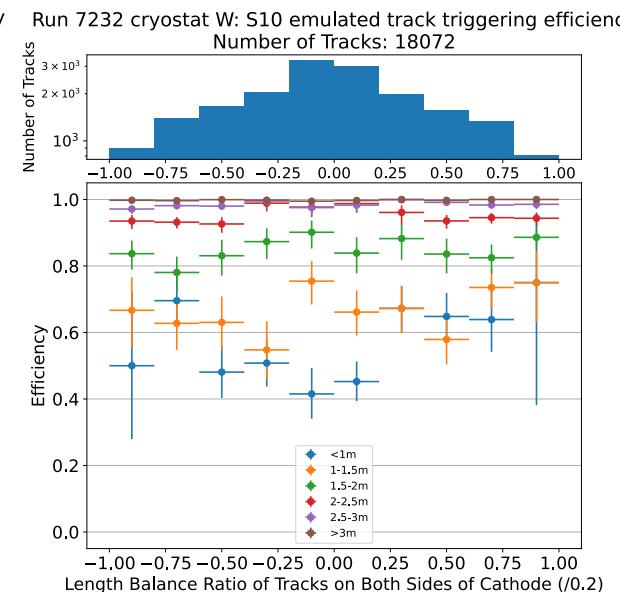
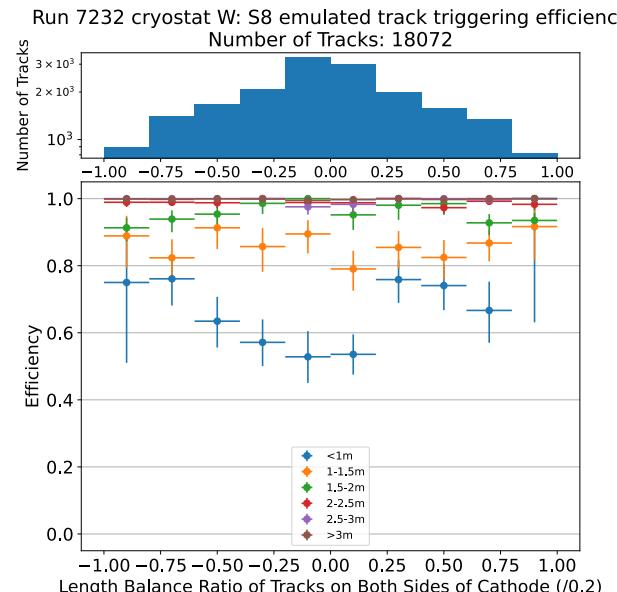
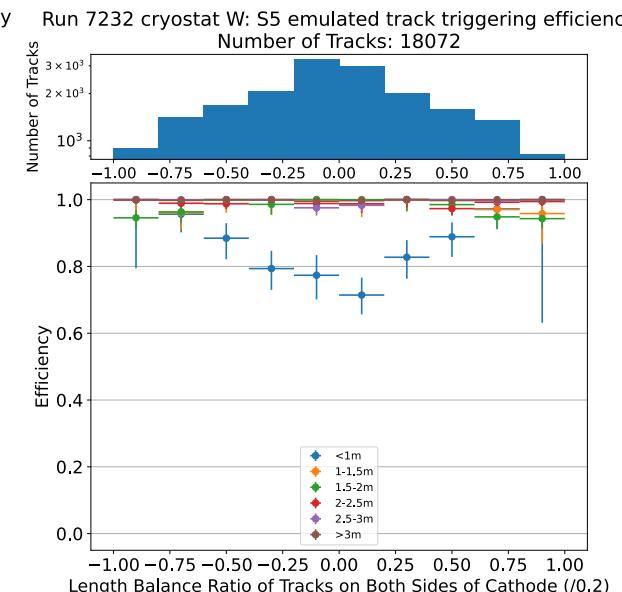
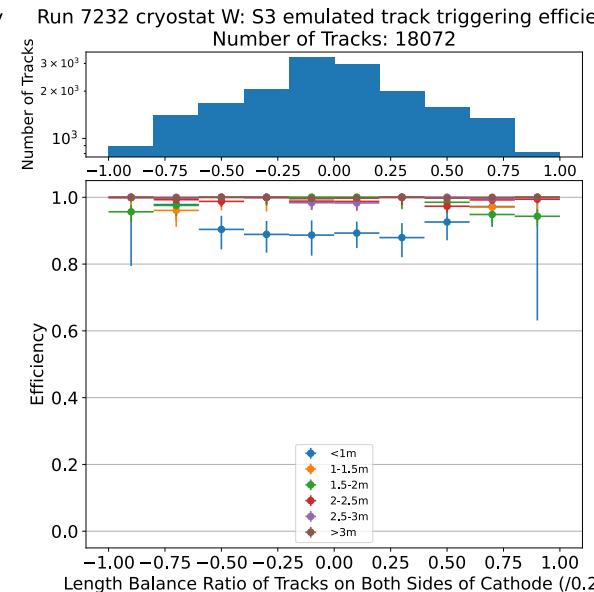
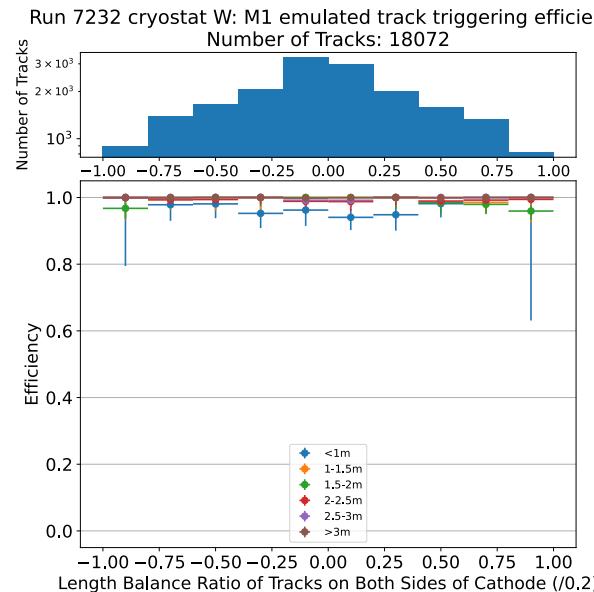
(-20 μ s, 0 μ s) Emulation Window



Balance of track lengths on either side of the cathode

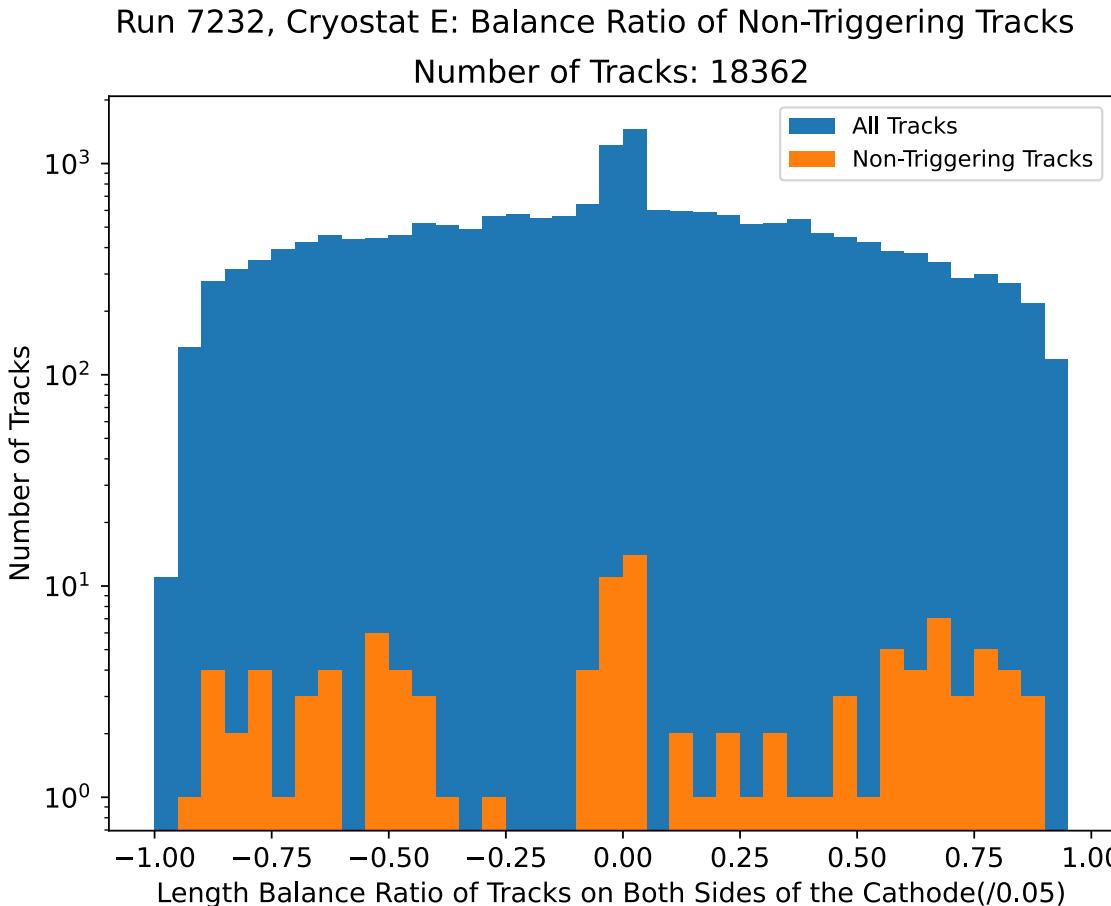
West Cryostat

(-15 μ s, 5 μ s) Emulation Window

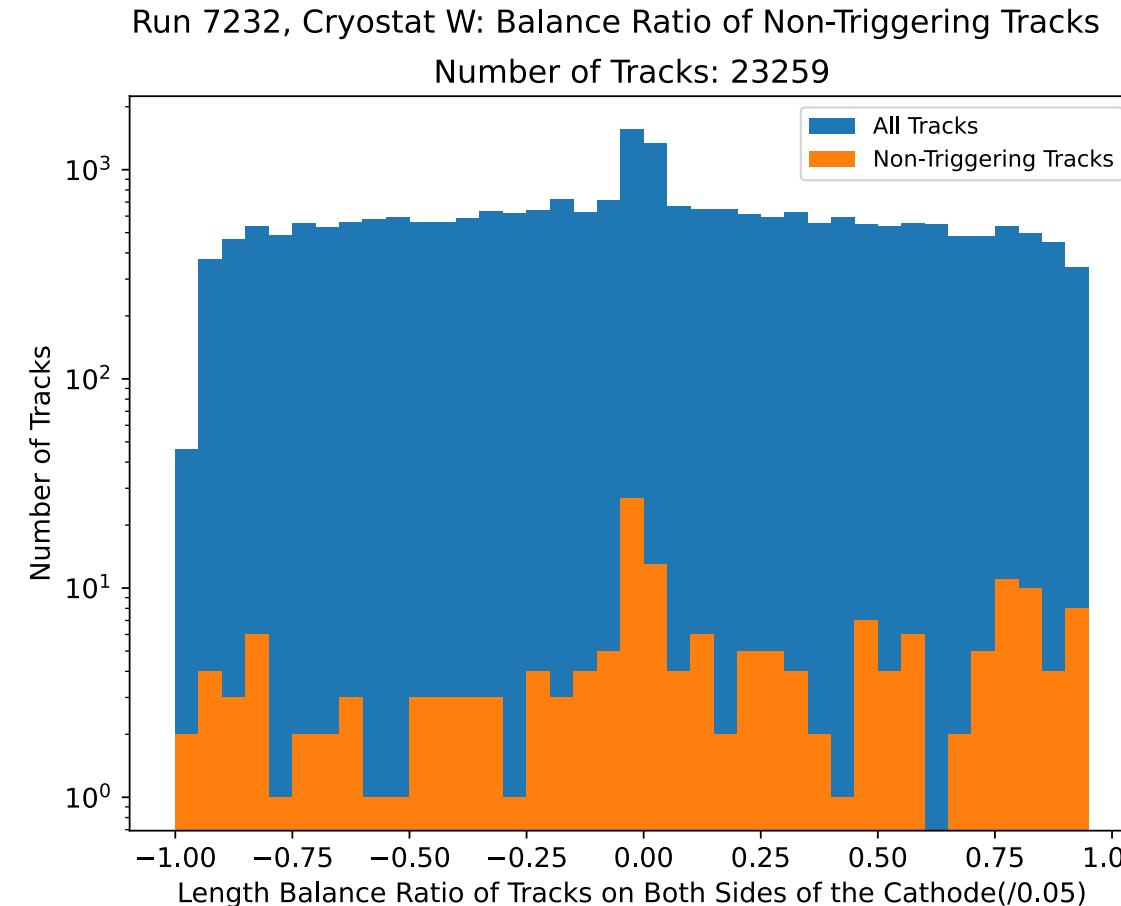


What balance ratios correspond to the non-triggering tracks? (-20 μ s, 0 μ s) Emulation Window

East Cryostat

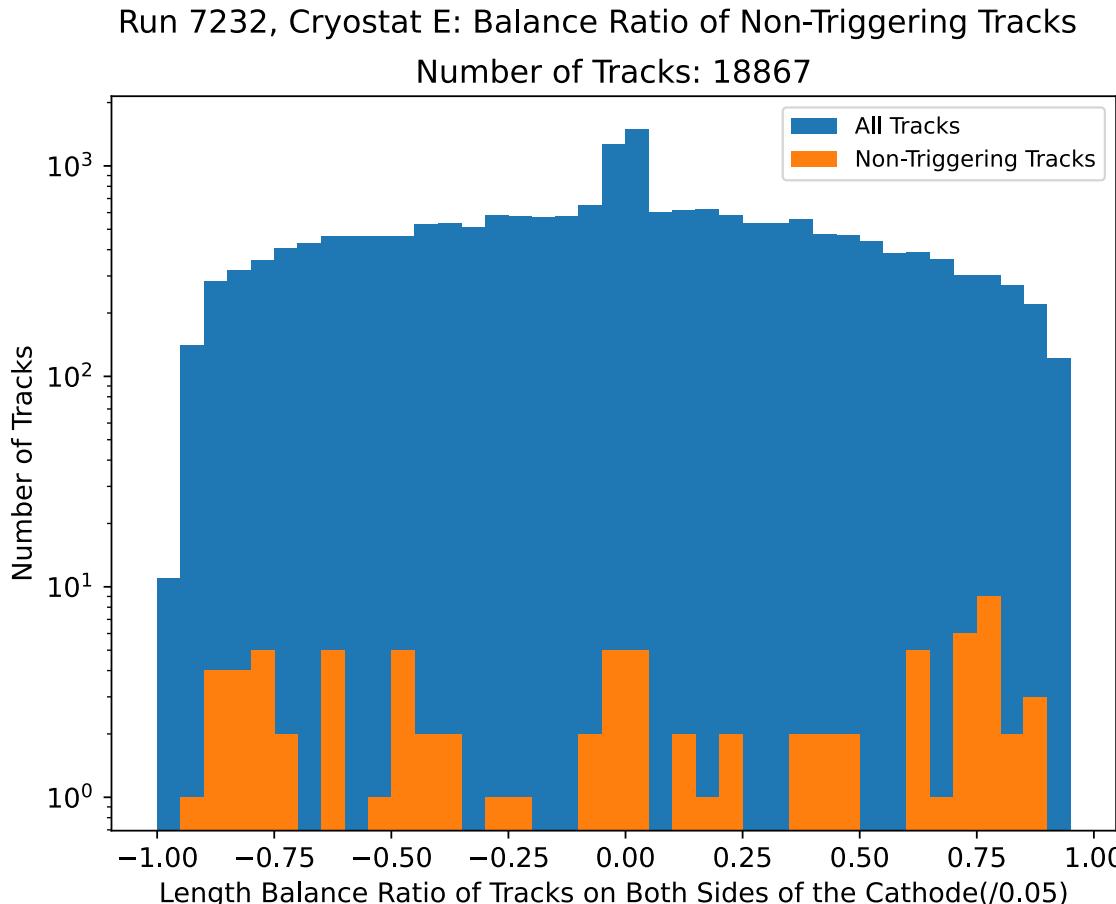


West Cryostat

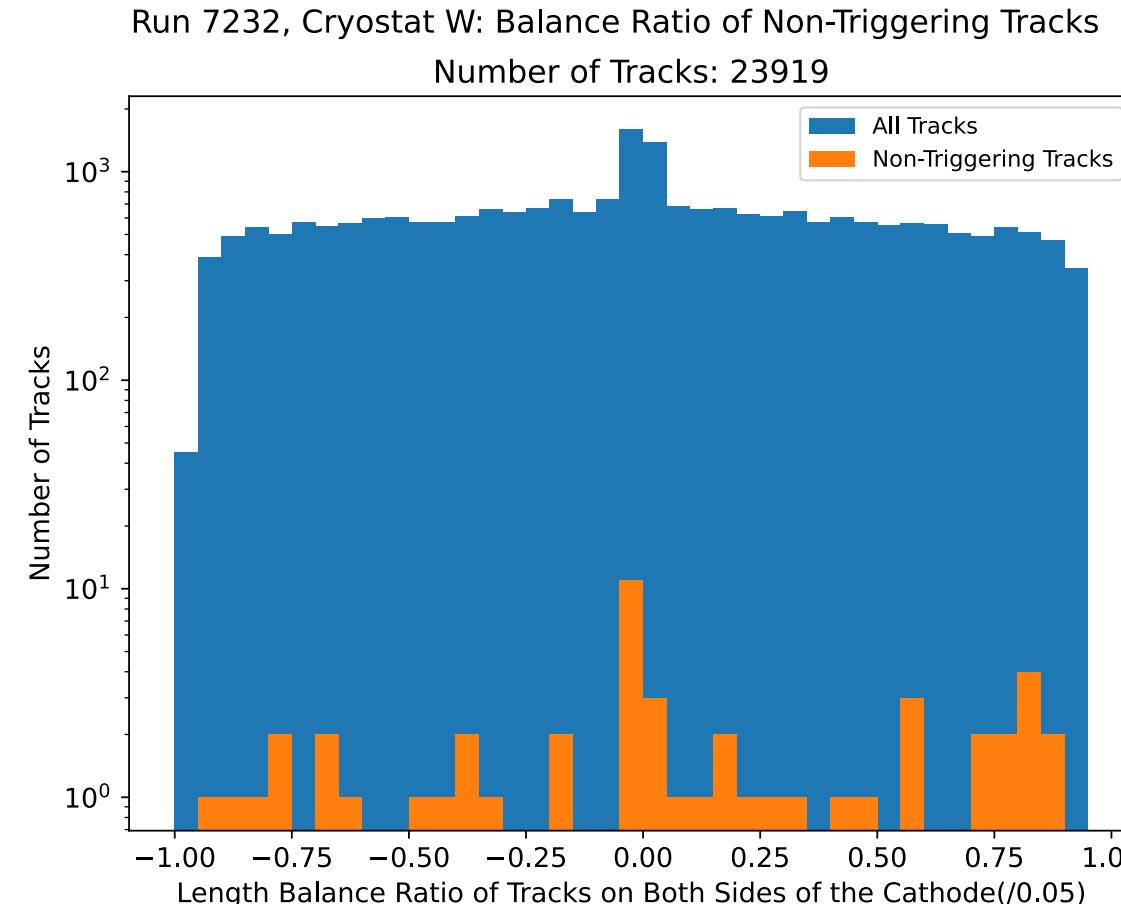


What balance ratios correspond to the non-triggering tracks? (-15 μ s, 5 μ s) Emulation Window

East Cryostat

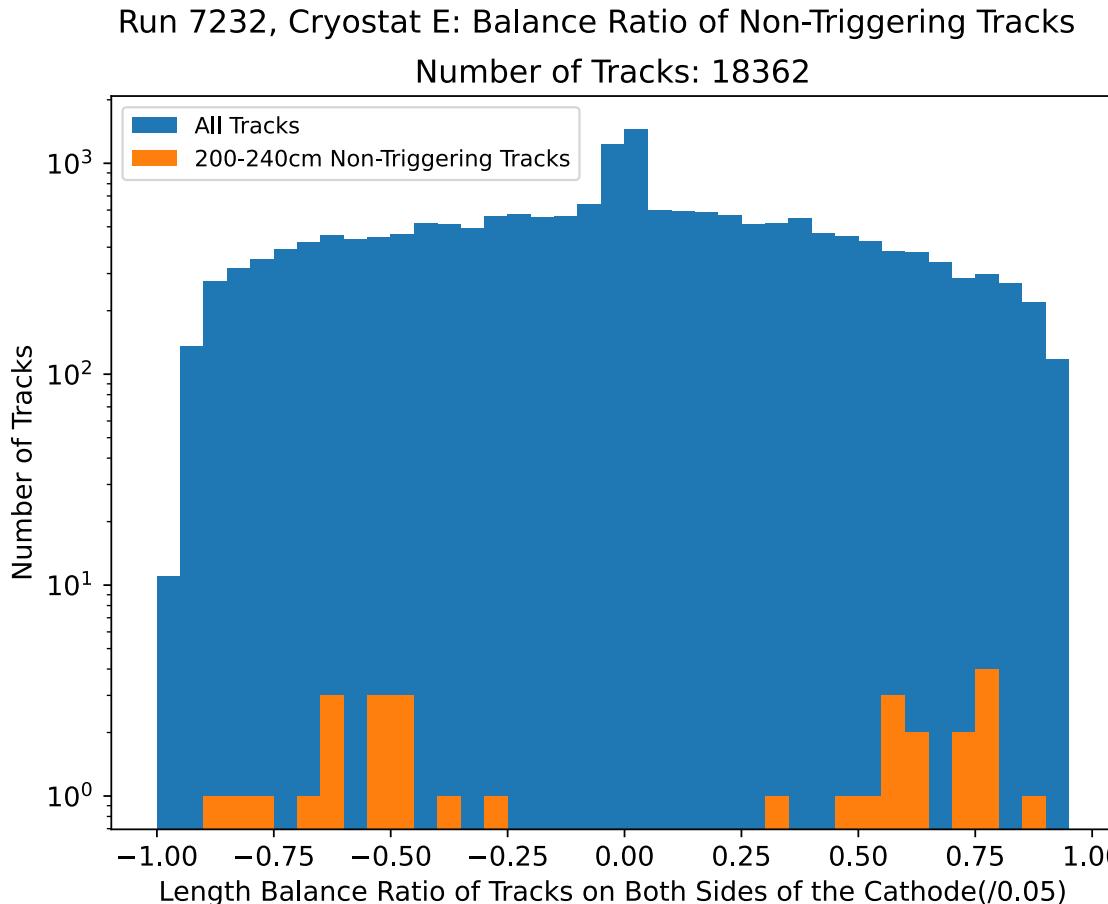


West Cryostat

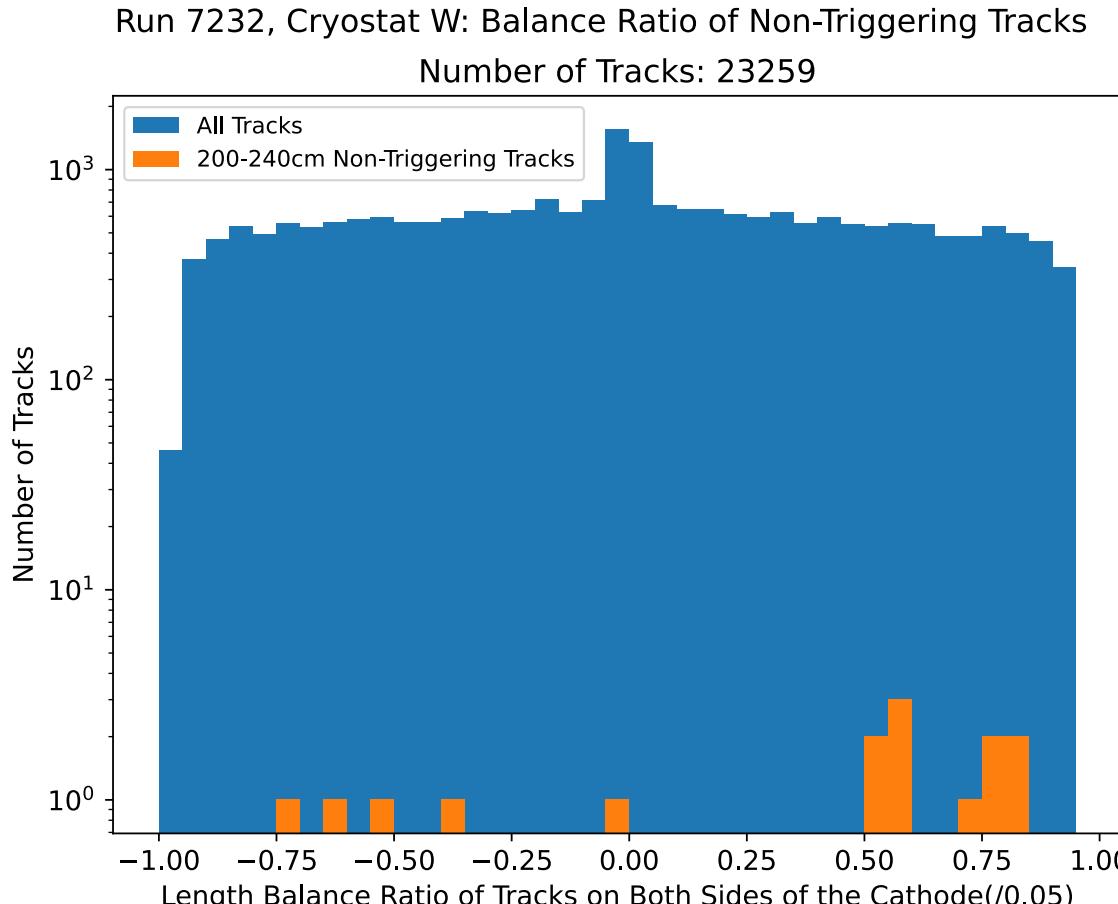


What balance ratios correspond to the non-triggering 200-240cm tracks? (-20 μ s, 0 μ s) Emulation Window

East Cryostat

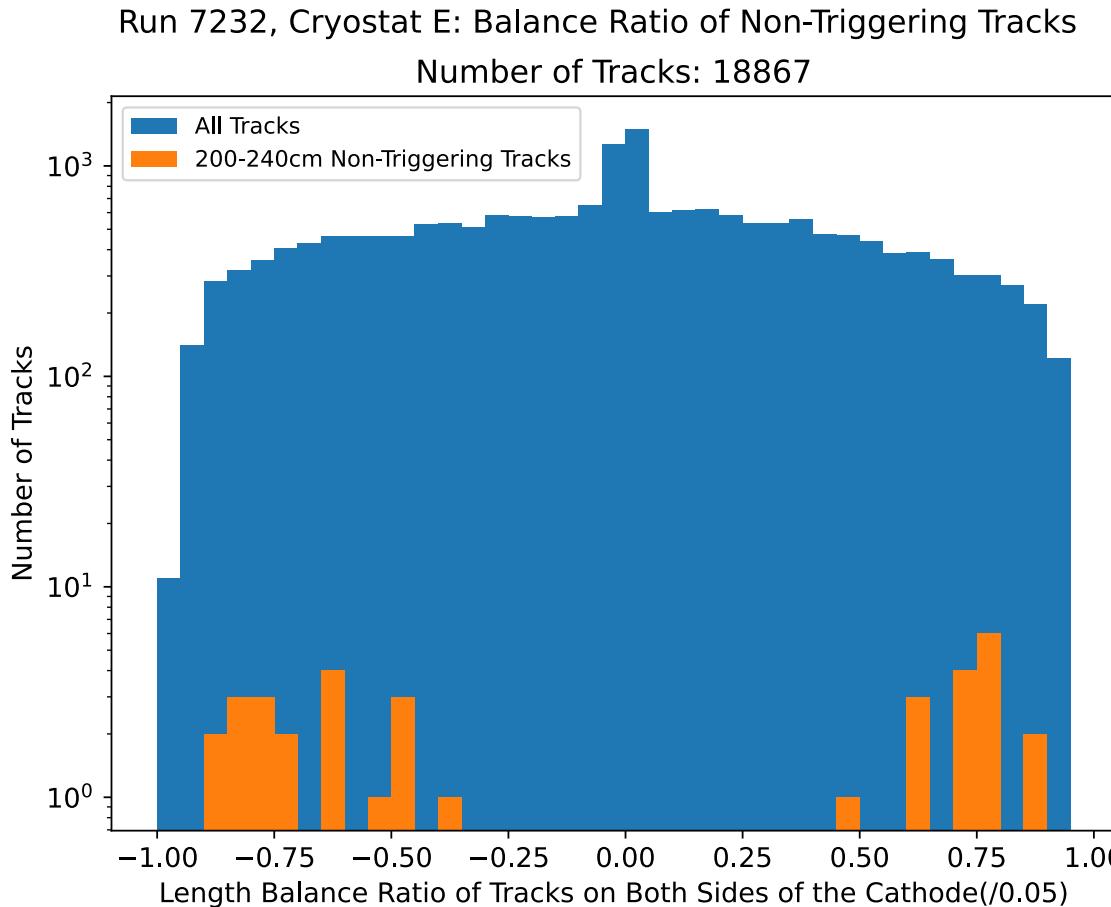


West Cryostat

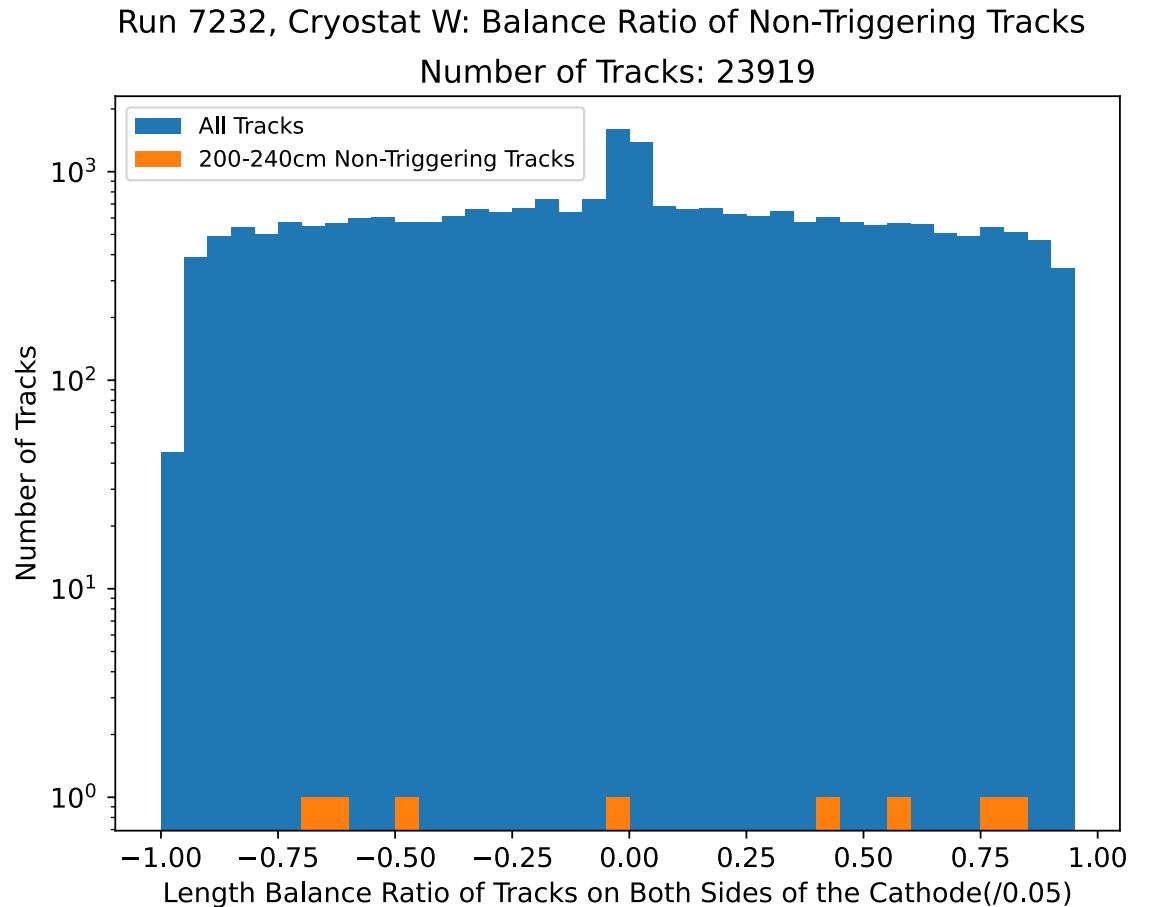


What balance ratios correspond to the non-triggering 200-240cm tracks? (-15 μ s, 5 μ s) Emulation Window

East Cryostat



West Cryostat

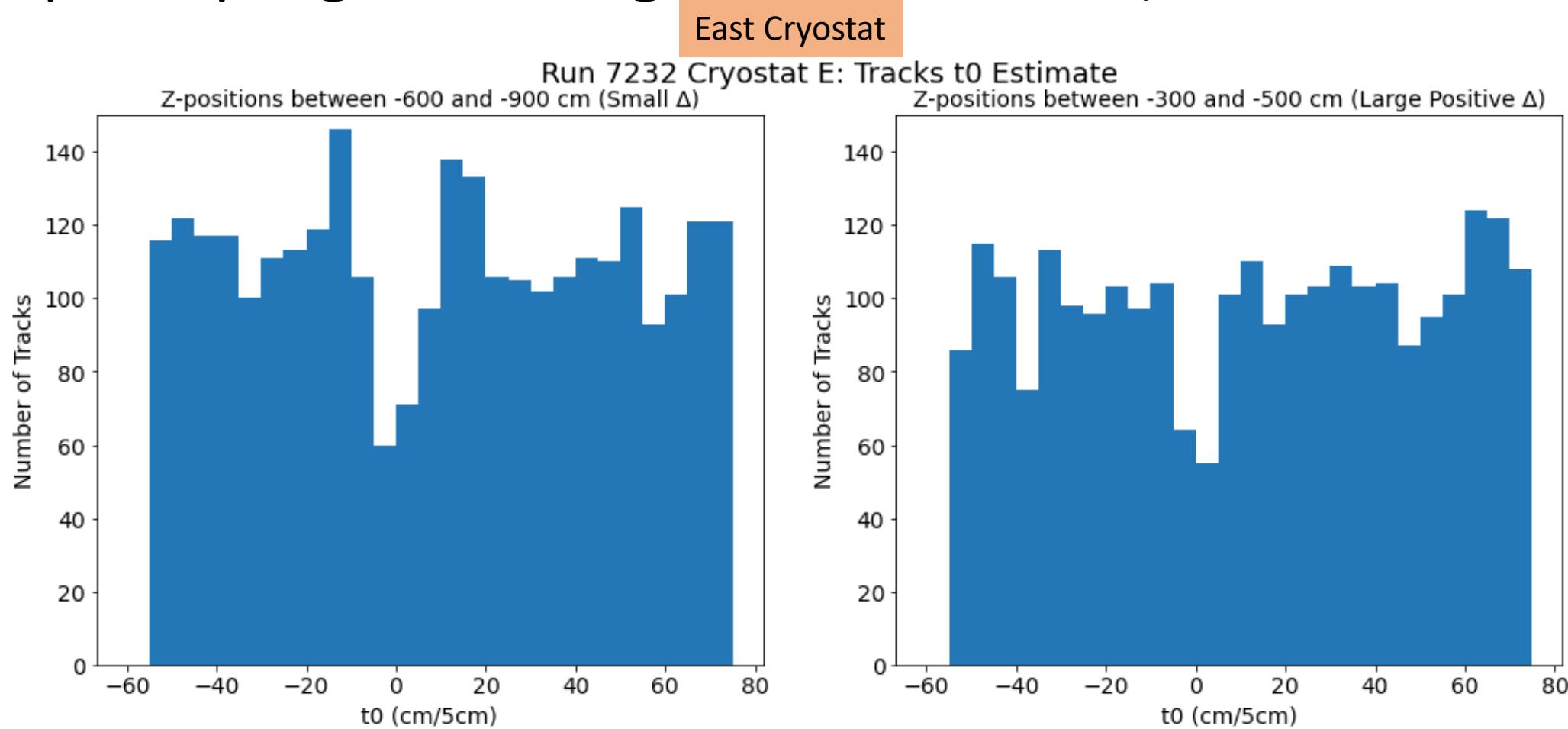


What do we think of the shifted window?

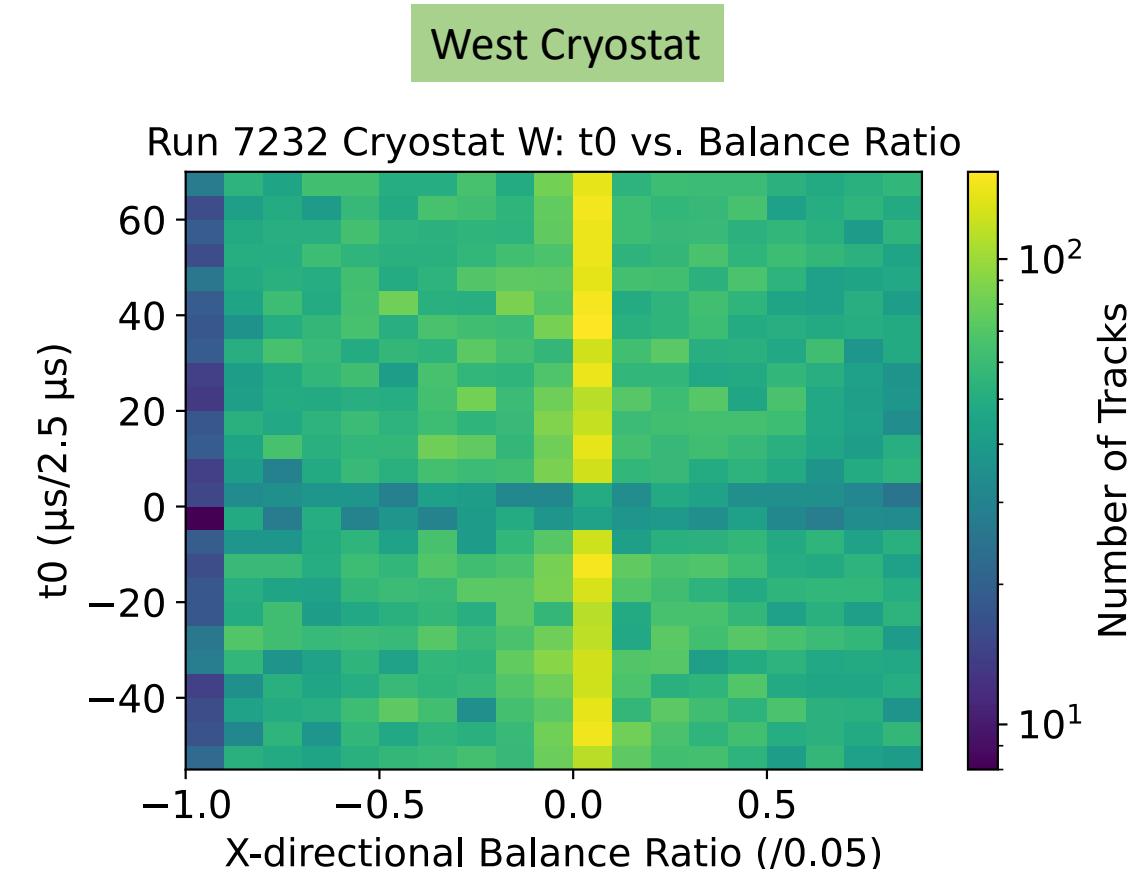
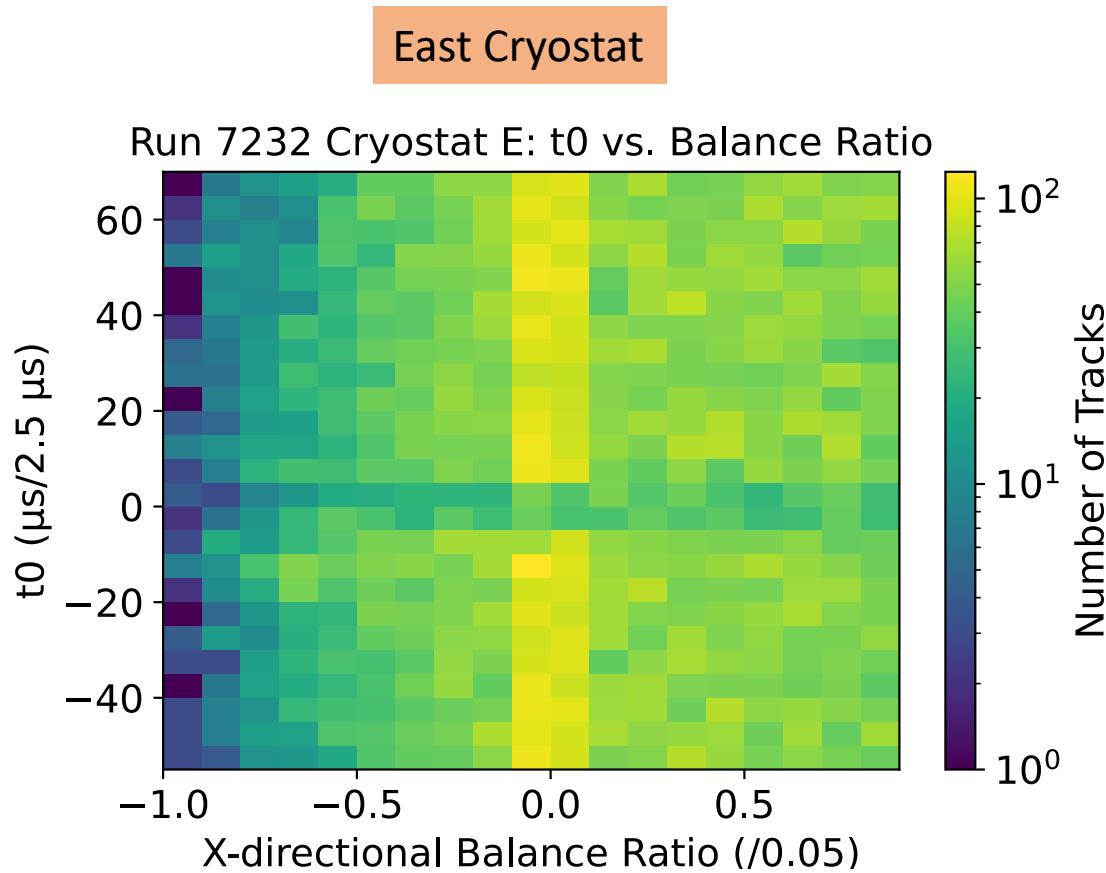
- It actually seems to make things worse in the East cryostat!
- Somewhat better in the West cryostat, but not significantly
- What other things could we try for the East cryostat?
 - Perhaps a different t_0 ?
- Sliding window, as expected, works great!

Other Shifted Window Tests

t0 distribution for low and high cathode Δ (by varying crossing z-coordinate)



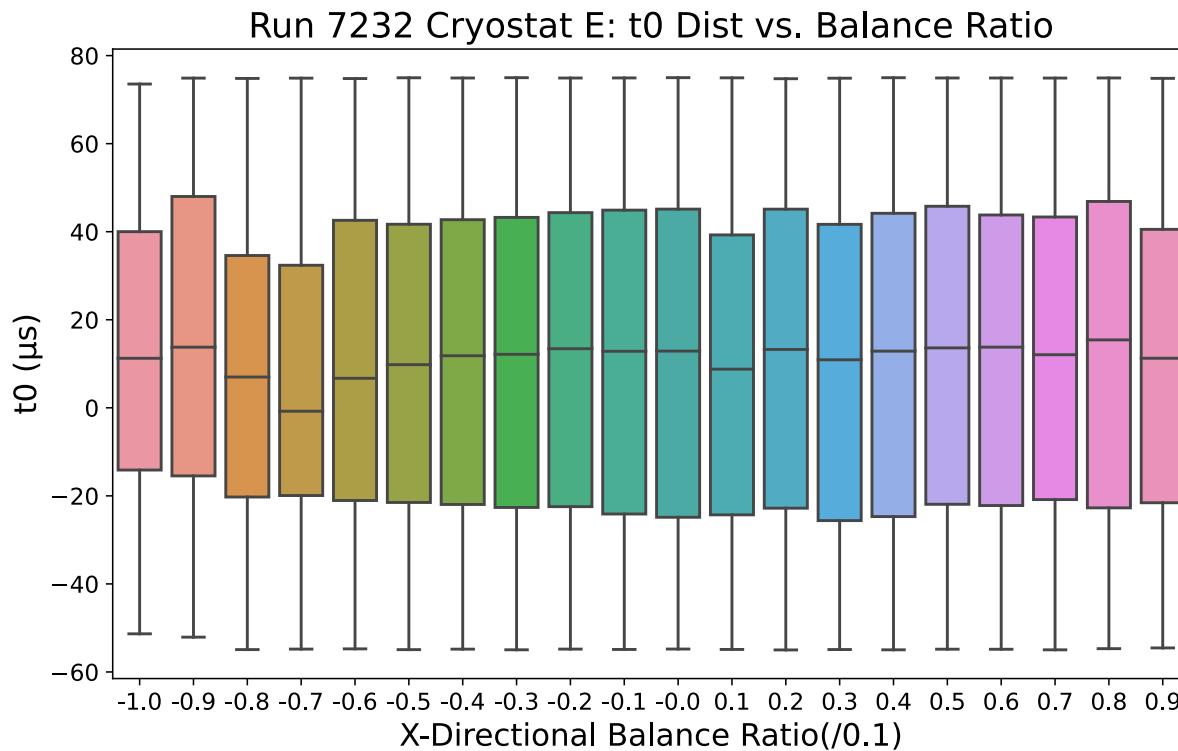
t_0 vs. Balance ratio for both cryostats



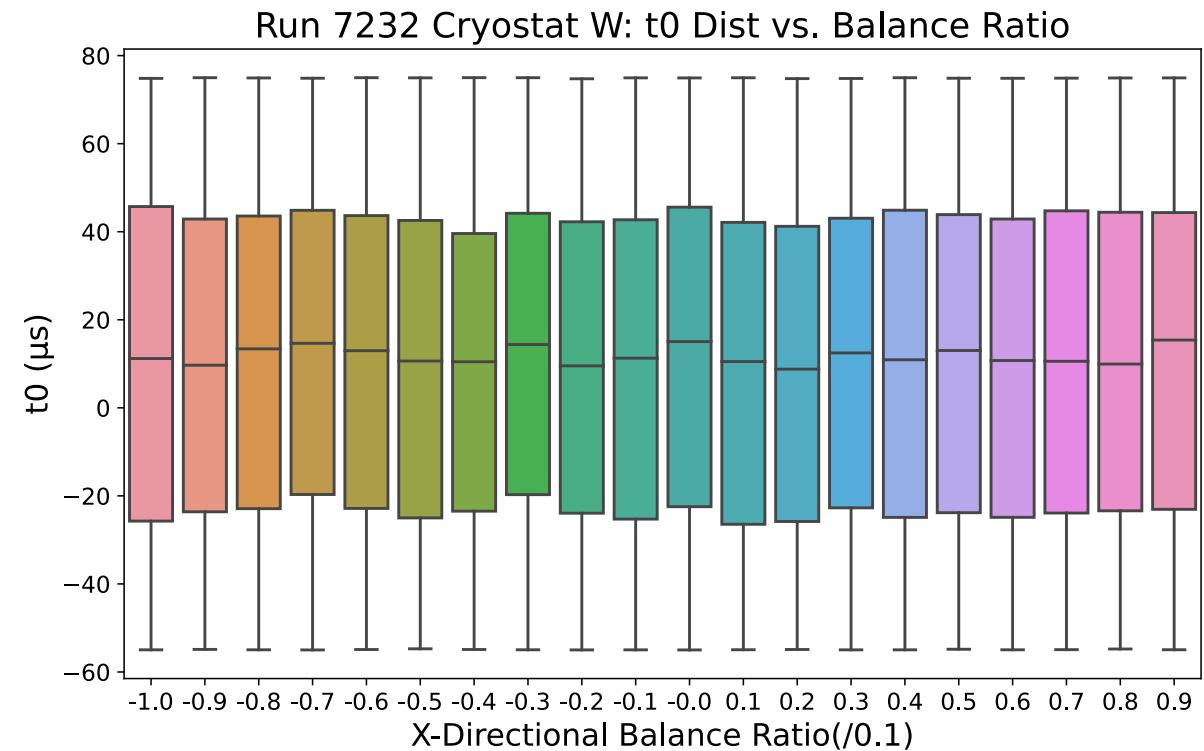
t0 distribution vs. balance ratio

(-20 μ s, 0 μ s) Emulation Window

East Cryostat



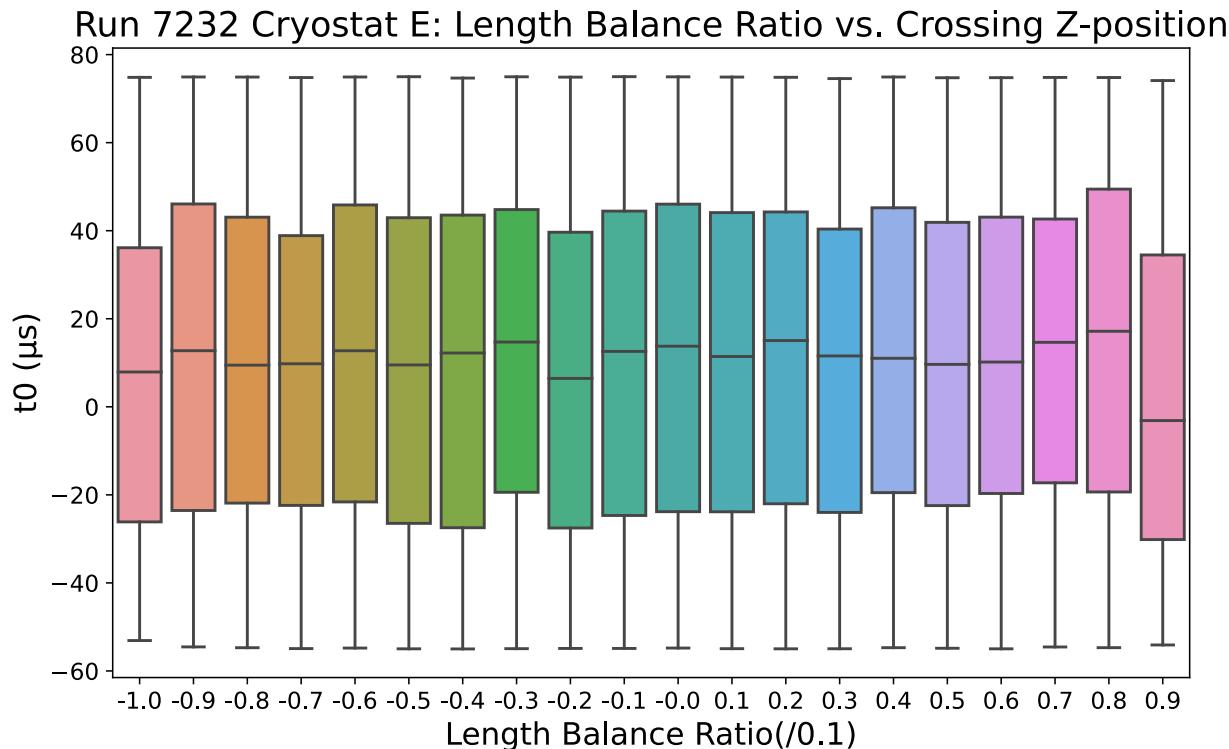
West Cryostat



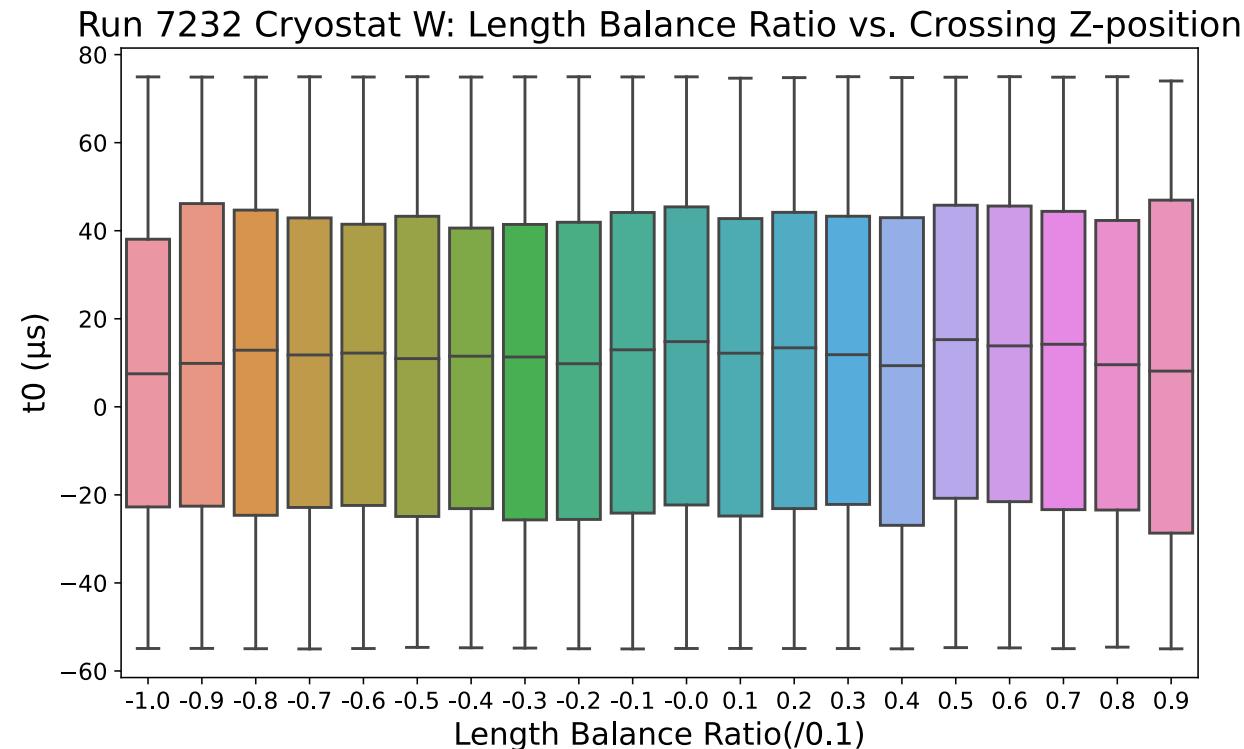
t0 distribution vs. balance ratio

(-15 μ s, 5 μ s) Emulation Window

East Cryostat



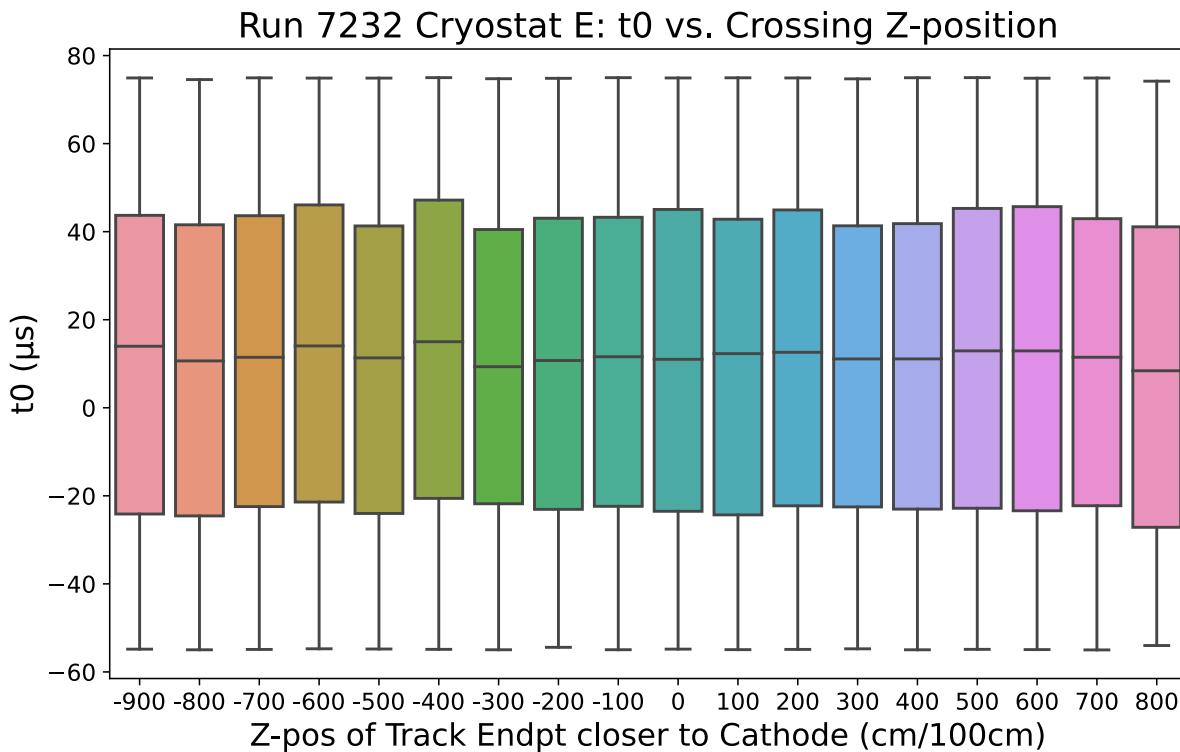
West Cryostat



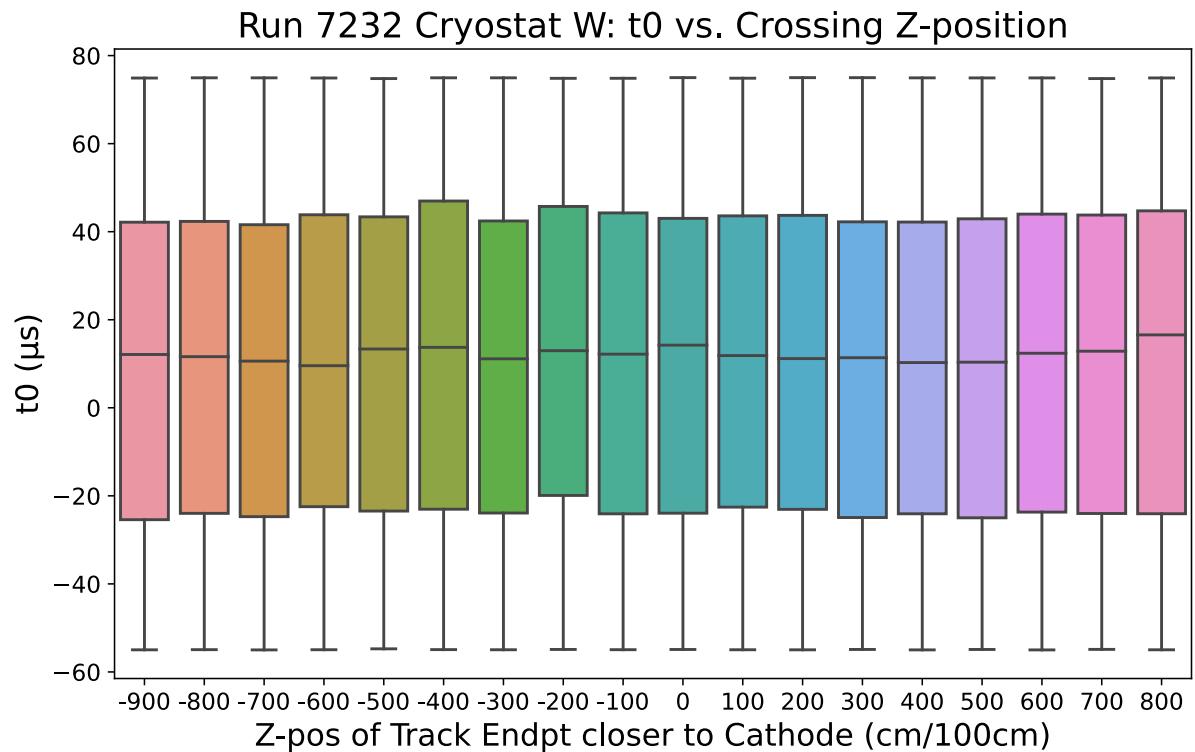
t0 distribution vs. crossing z-coordinate

(-20 μ s, 0 μ s) Emulation Window

East Cryostat



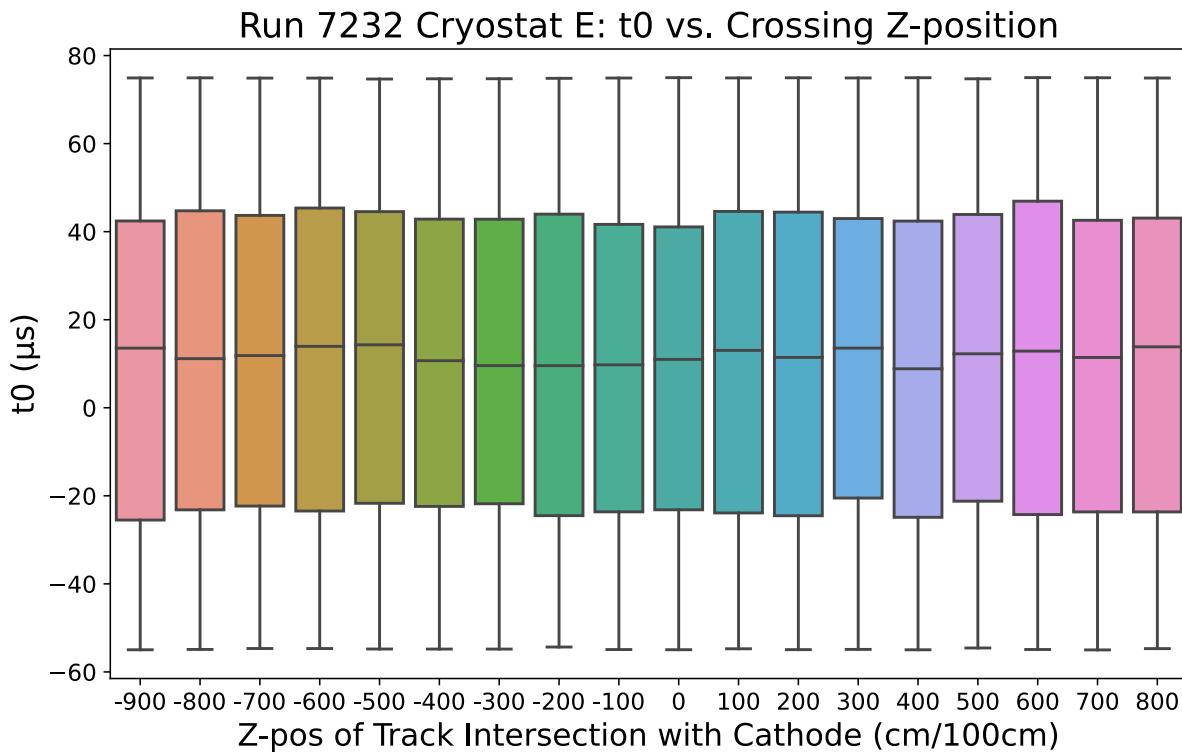
West Cryostat



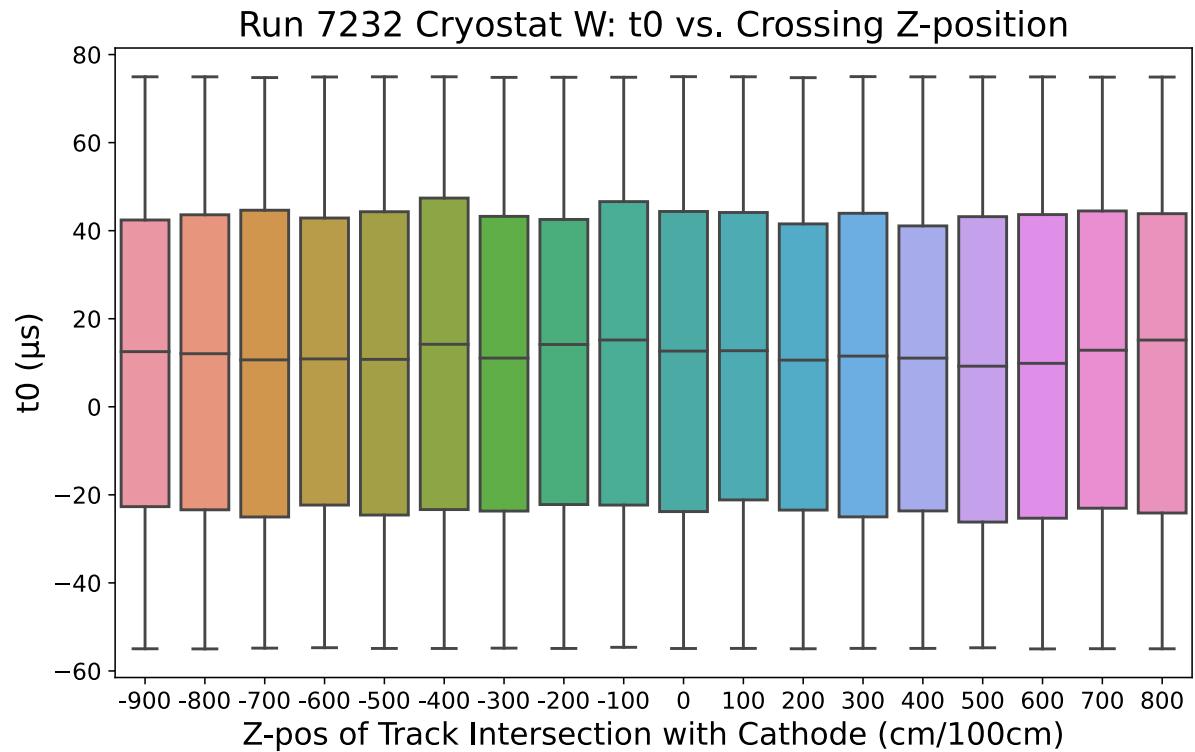
t0 distribution vs. crossing z-coordinate

(-15 μ s, 5 μ s) Emulation Window

East Cryostat



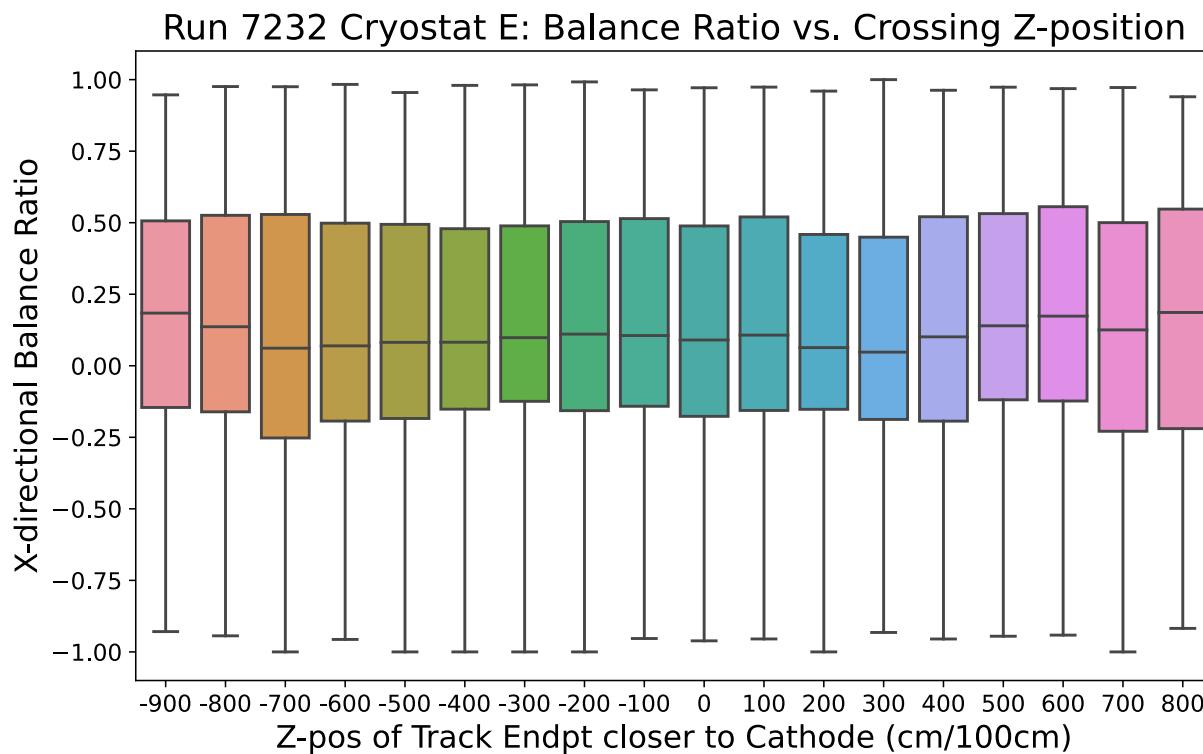
West Cryostat



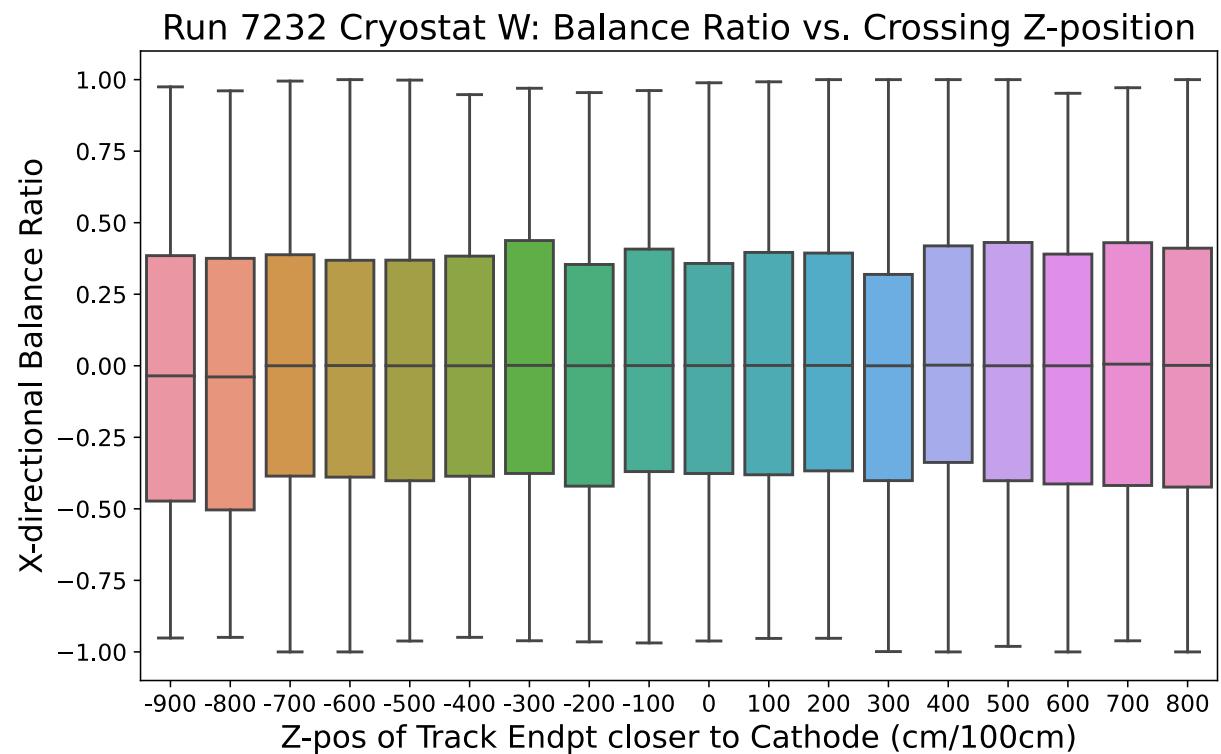
Balance ratio distribution vs. crossing z-coordinate

(-20 μ s, 0 μ s) Emulation Window

East Cryostat



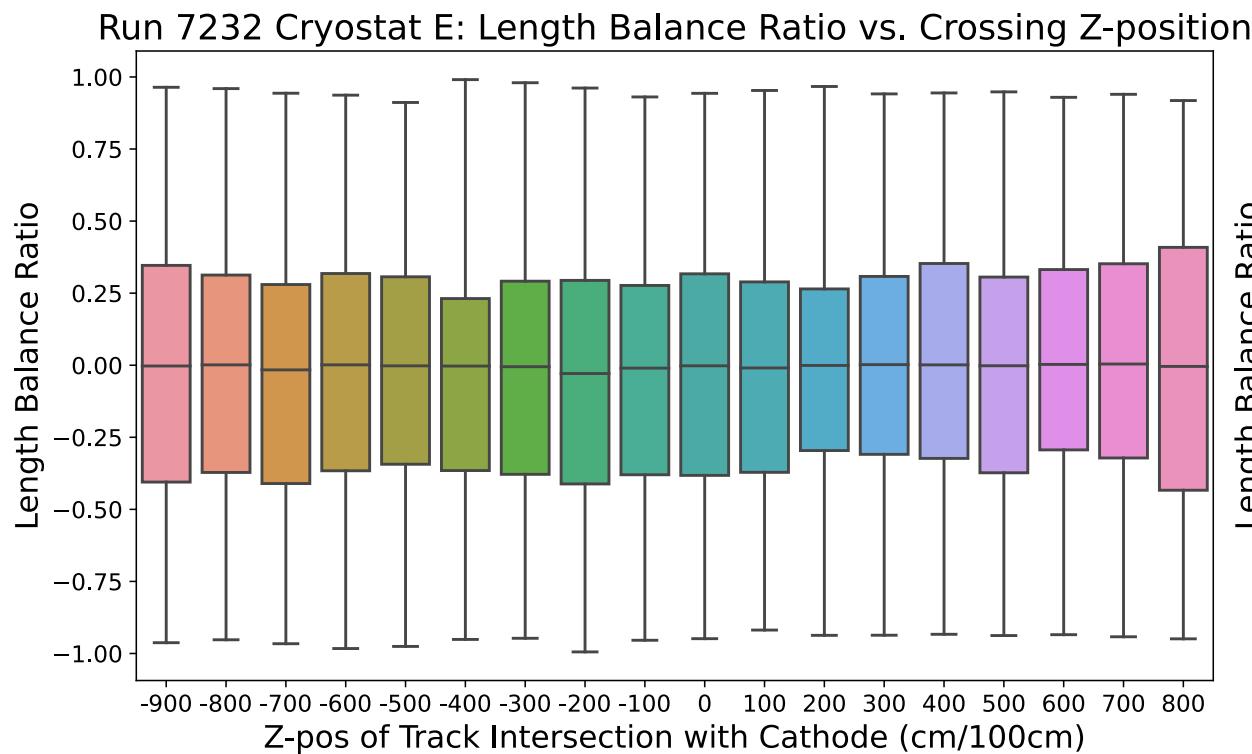
West Cryostat



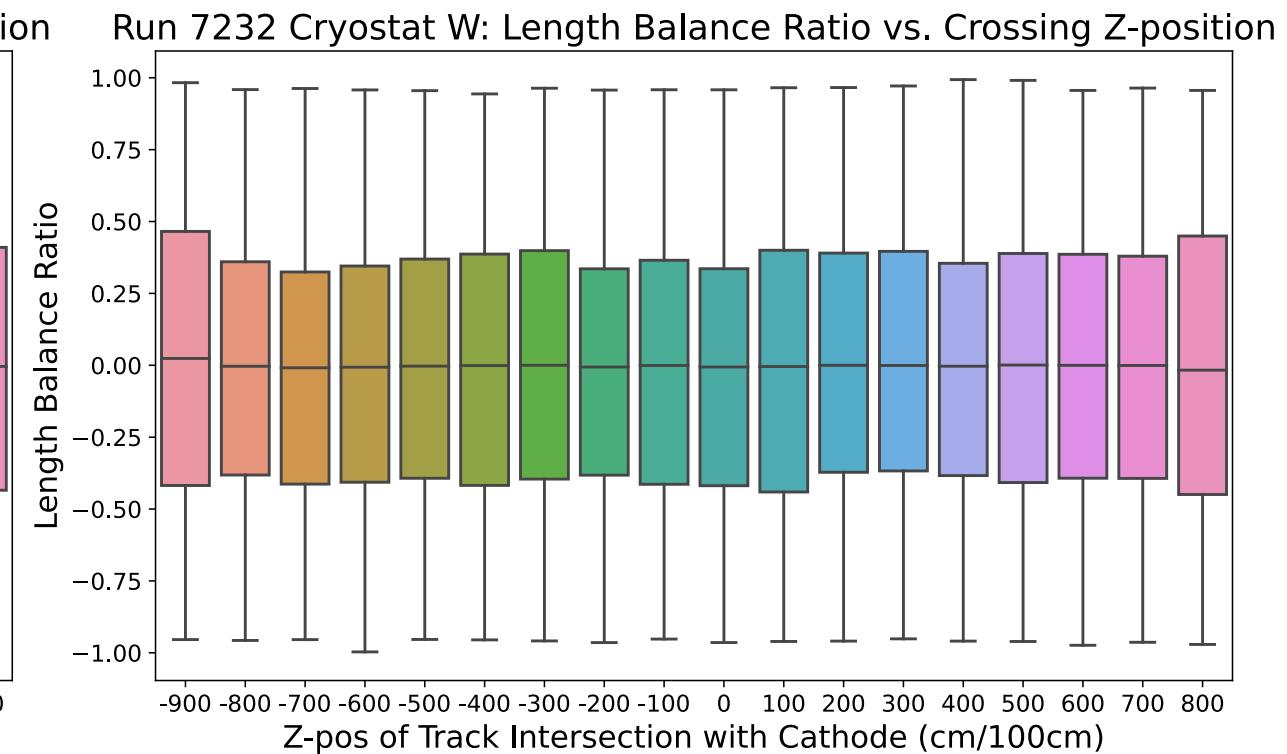
Balance ratio distribution vs. crossing z-coordinate

(-15 μ s, 5 μ s) Emulation Window

East Cryostat



West Cryostat



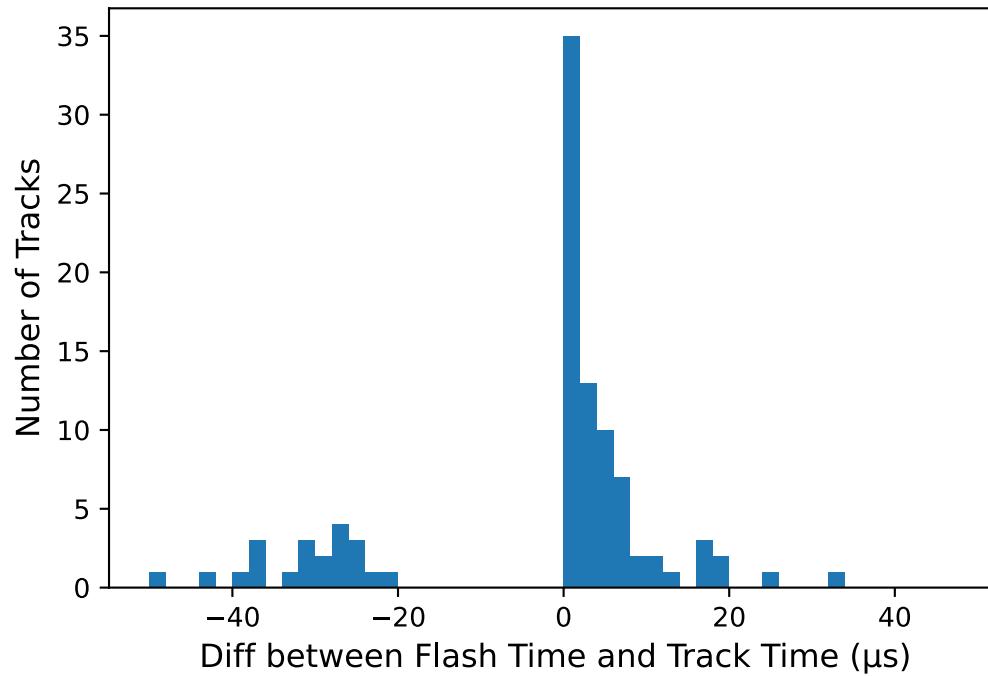
Flash-Track time difference for non-fired tracks in both cryostats

It appears the bias in t0 reconstruction isn't the same between cryostats – it's more variable in the East cryostat.

East Cryostat

105 tracks

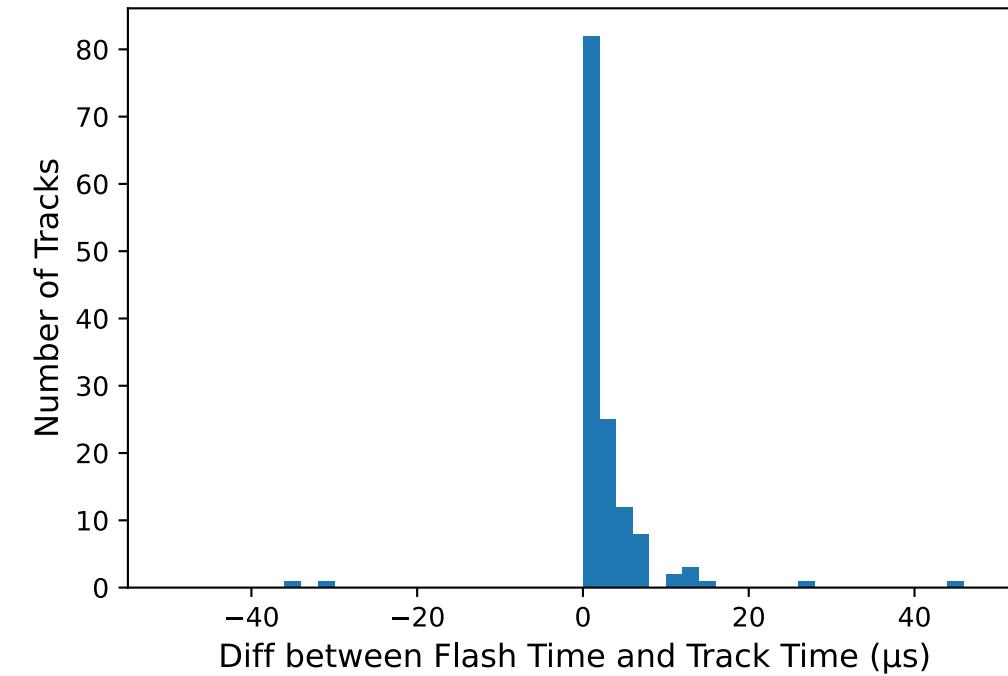
Run 7232 East Cryo: Flash-Track Time Diff For Non-Triggering Tracks



West Cryostat

143 tracks

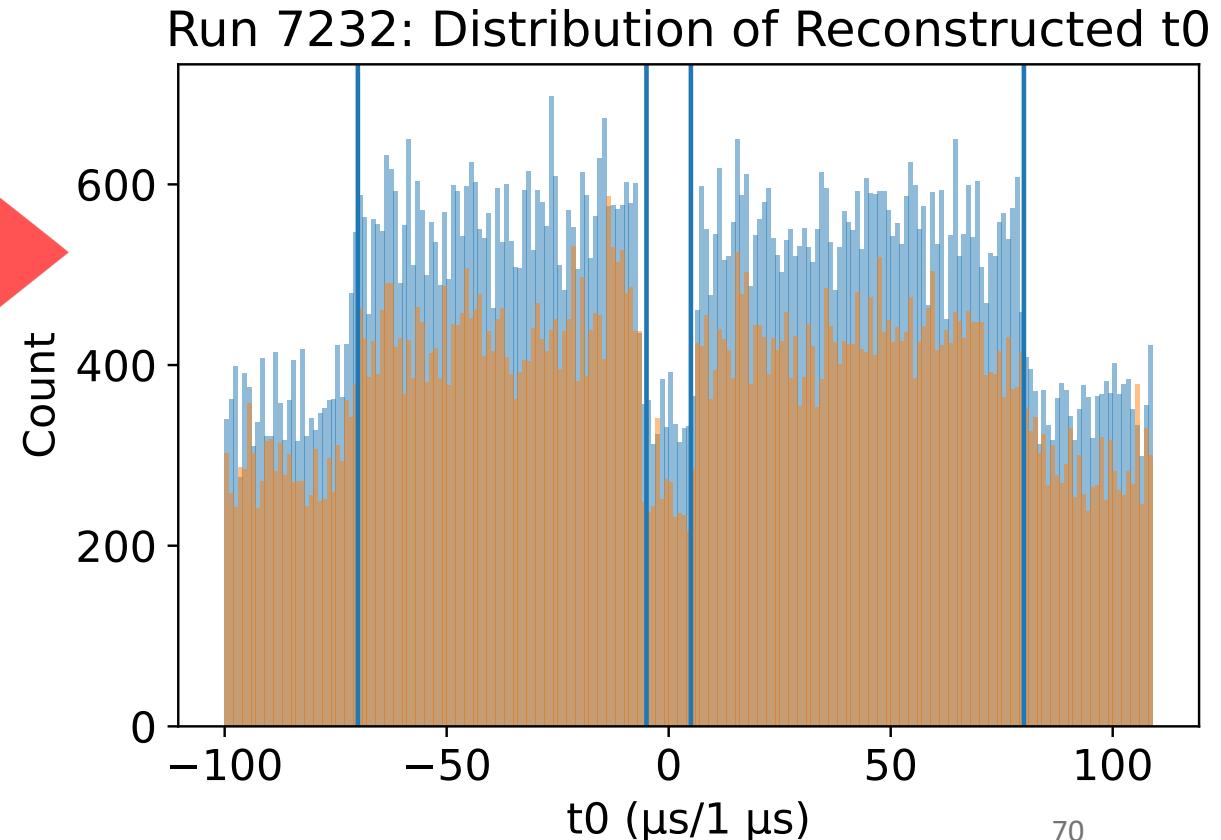
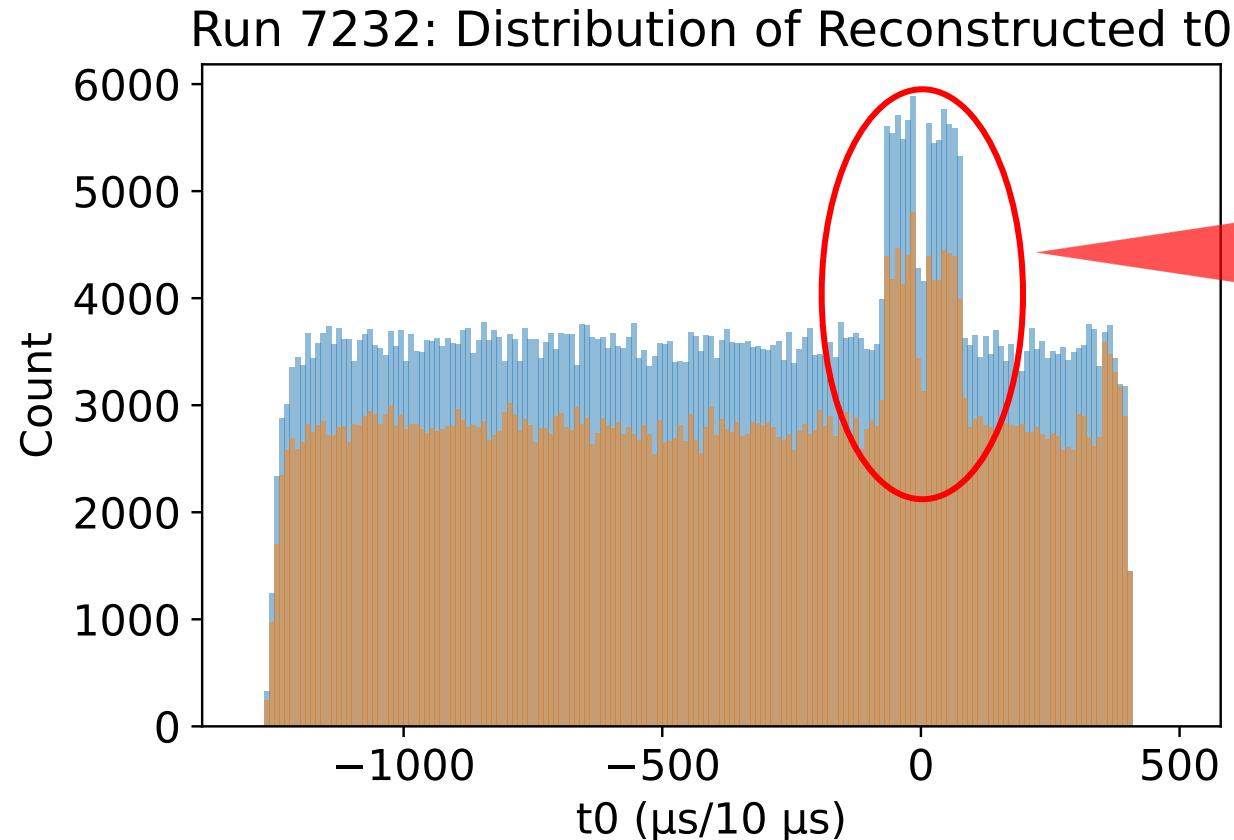
Run 7232 West Cryo: Flash-Track Time Diff For Non-Triggering Tracks



“Two towers” plot of reconstructed t0

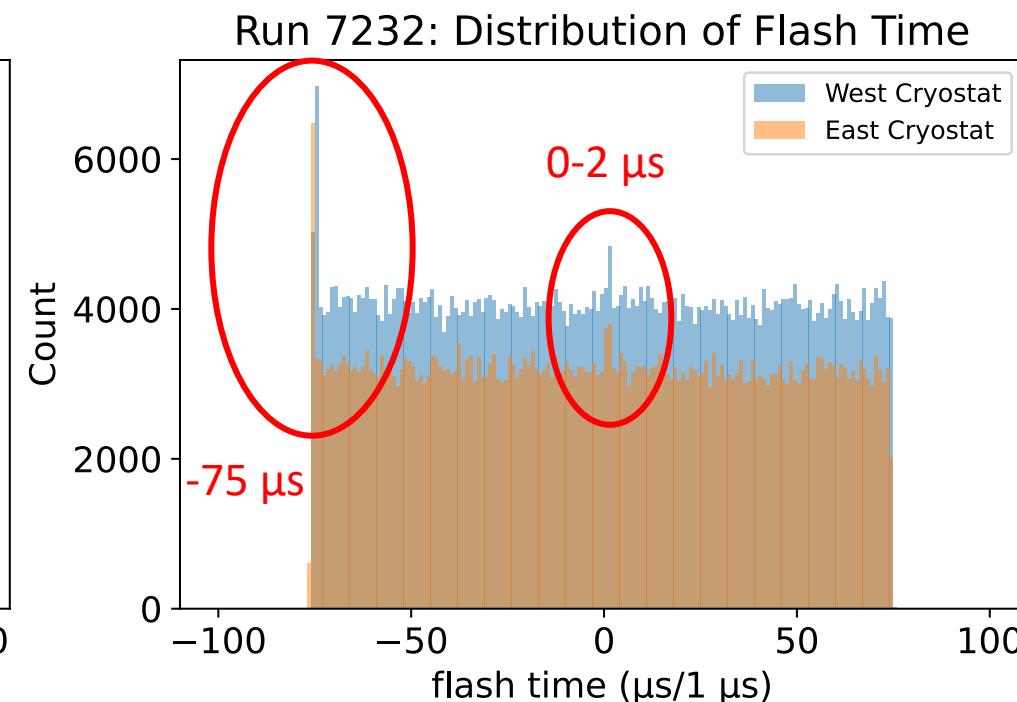
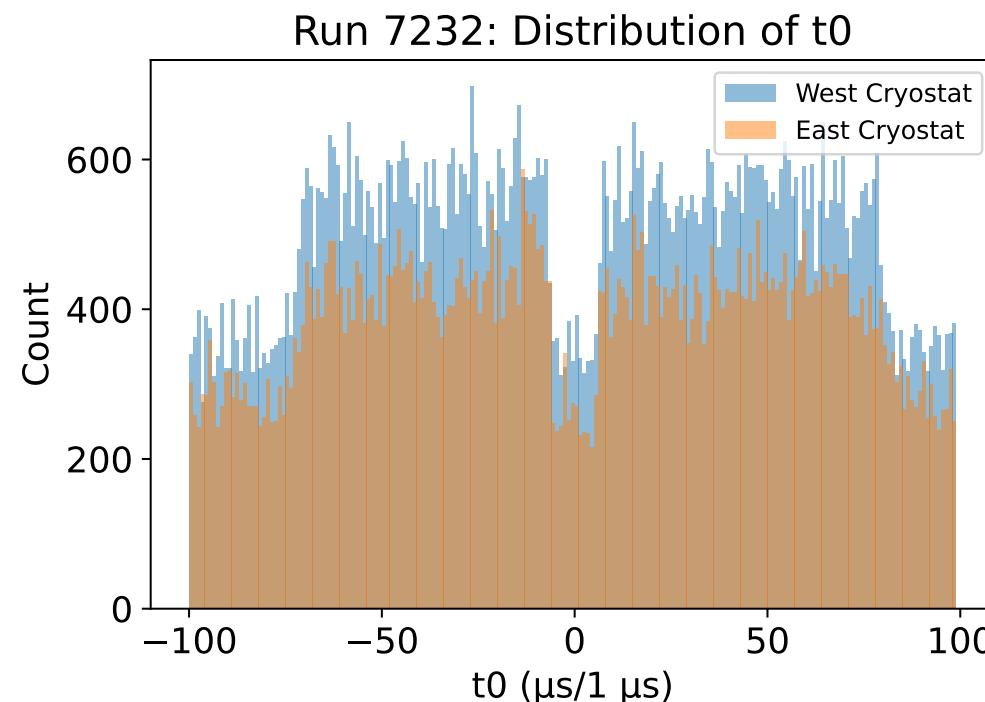
(-15 μ s, 5 μ s) Emulation Window

- This plot uses (-15 μ s, 5 μ s) interval, but the same pattern seen with different intervals
- Higher counts of t0 between (-70, -5) and (5, 80) μ s
- -75 μ s to 75 μ s is beam gate time – why is there a dip between -5 and 5 μ s?



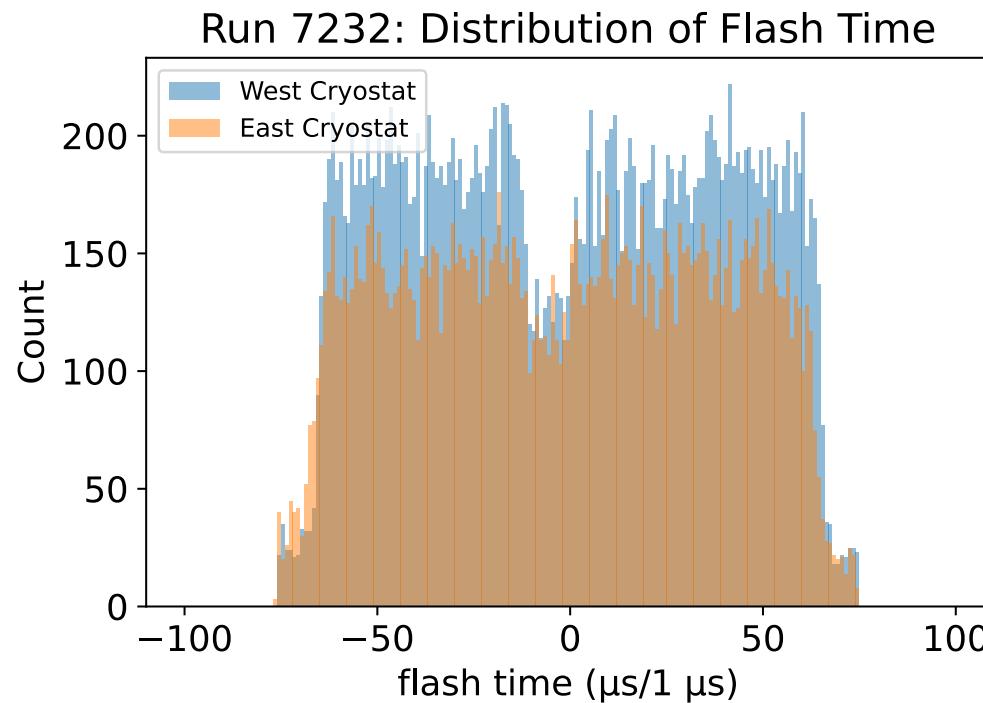
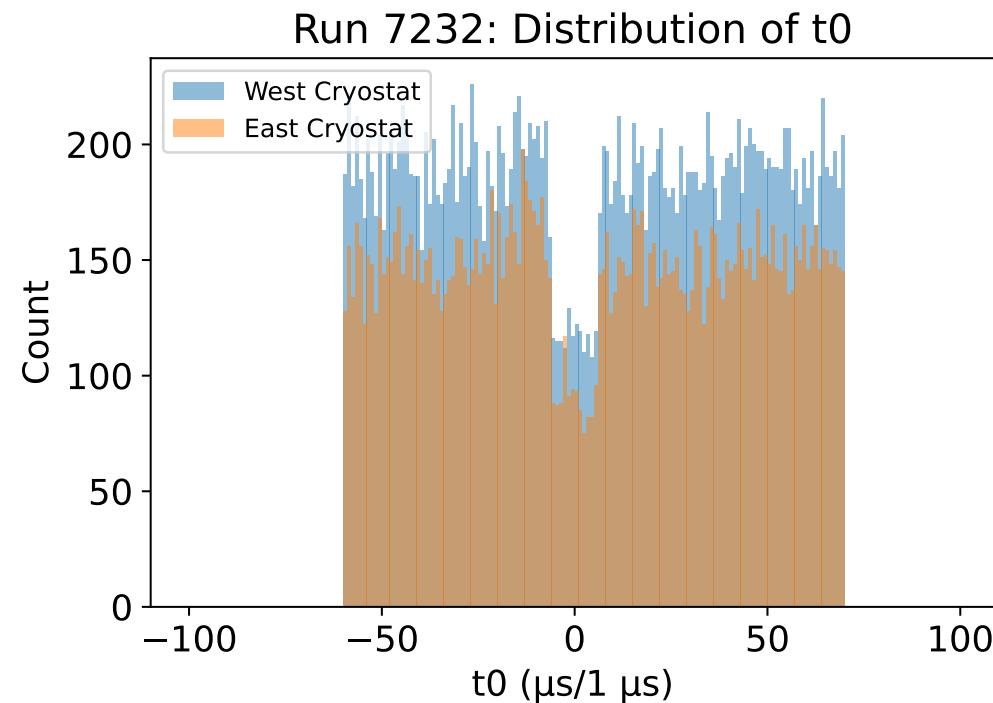
t_0 vs. flash time

- This plot uses $(-15 \mu\text{s}, 5 \mu\text{s})$ interval, but the same pattern seen with different intervals
- Right before the t_0 increase, there's a peak in flash time
- The first peak makes sense – more flashes “noticed” at the start of the emulation because that's when we start recording, and flashes that happened before might be recorded then too.
- Why is there a peak at 0?
- These are all (not matched) flashes – so they occur in varying multiplicities too I guess... perhaps this isn't a great measure.



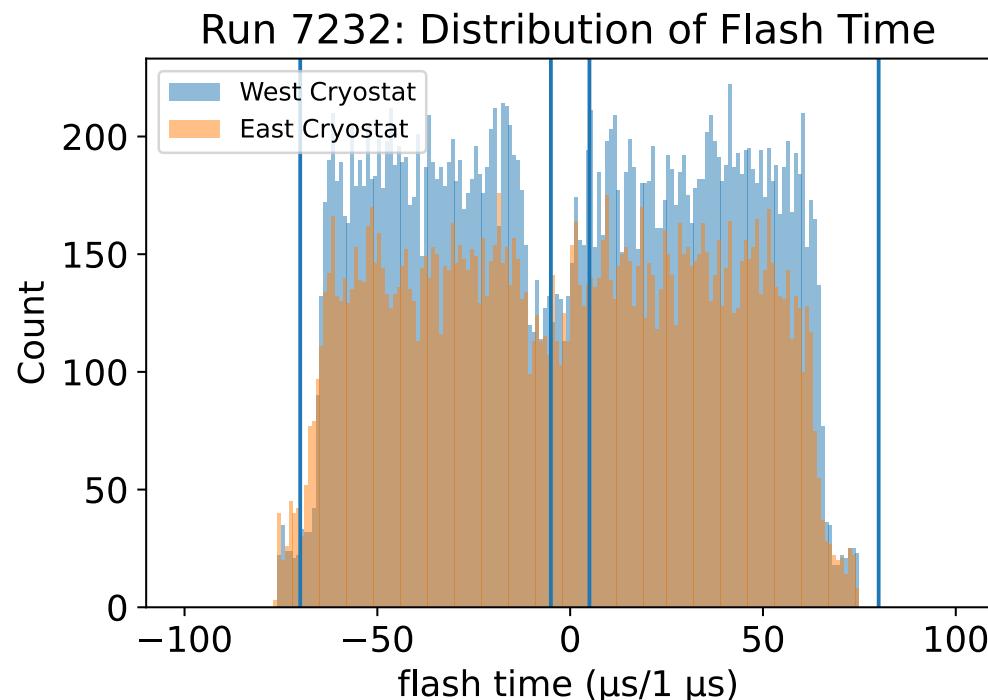
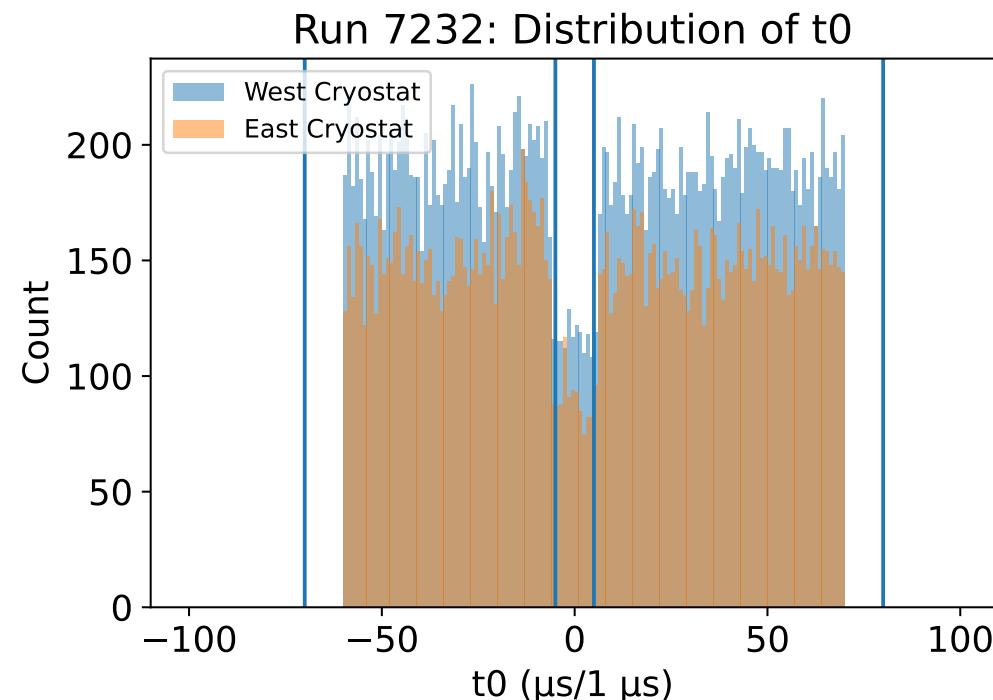
t_0 vs. flash time

- This plot uses $(-15 \mu\text{s}, 5 \mu\text{s})$ interval, but the same pattern seen with different intervals
- The distributions look similar, but the flash time distribution trails behind the t_0 distribution by a few μs



t_0 vs. flash time

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- The distributions look similar, but the flash time distribution trails behind the t_0 distribution by a few μs



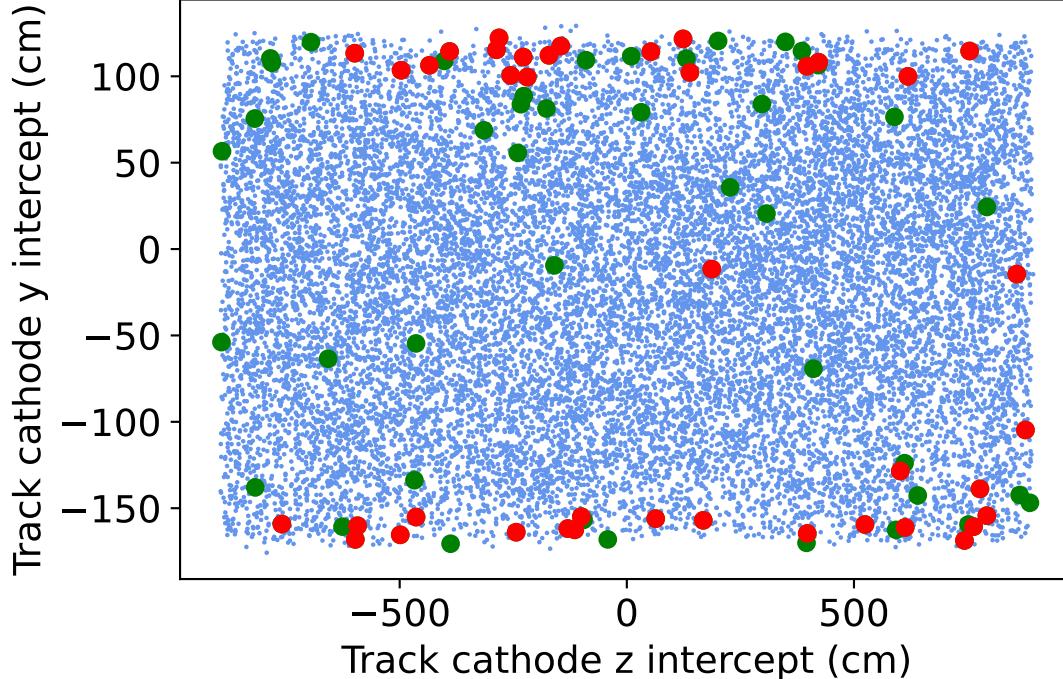
Location of 2m track anomaly – No sliding window

East Cryostat

(-15 μ s, 5 μ s) Emulation Window

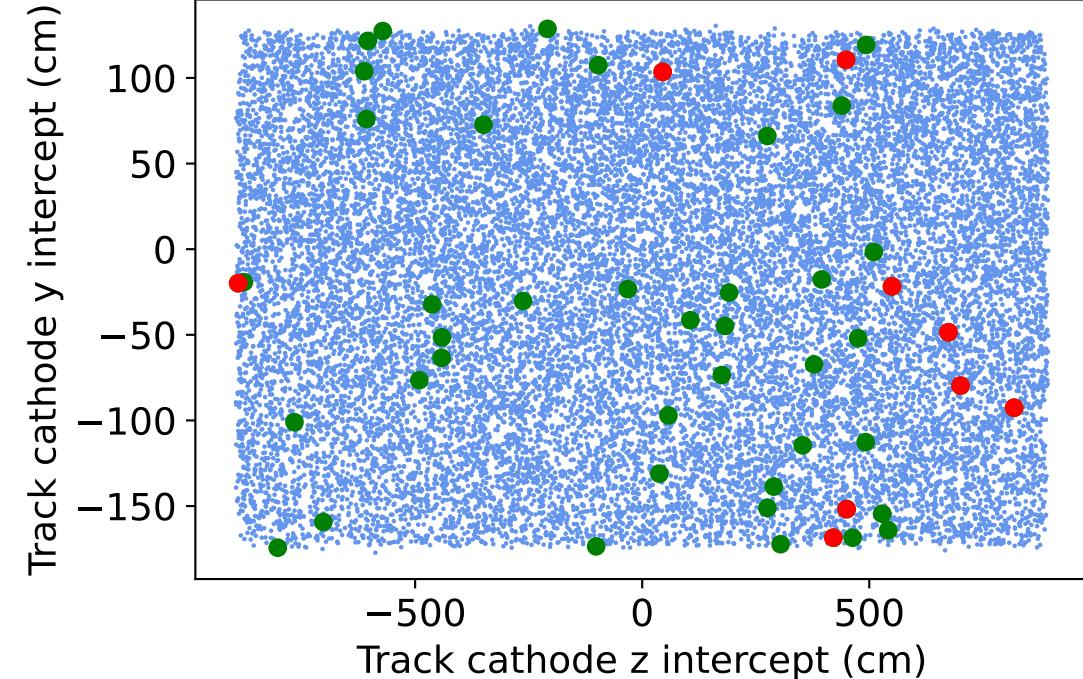
West Cryostat

Run 7232 Cryo E: Cathode-Crossing Pos of M1 Non-Trig Tracks



- All Tracks
- All M1 Non-Triggering Tracks
- M1 Non-Triggering Tracks w/ Length 200-250cm

Run 7232 Cryo W: Cathode-Crossing Pos of M1 Non-Trig Tracks



- All Tracks
- All M1 Non-Triggering Tracks
- M1 Non-Triggering Tracks w/ Length 200-250cm

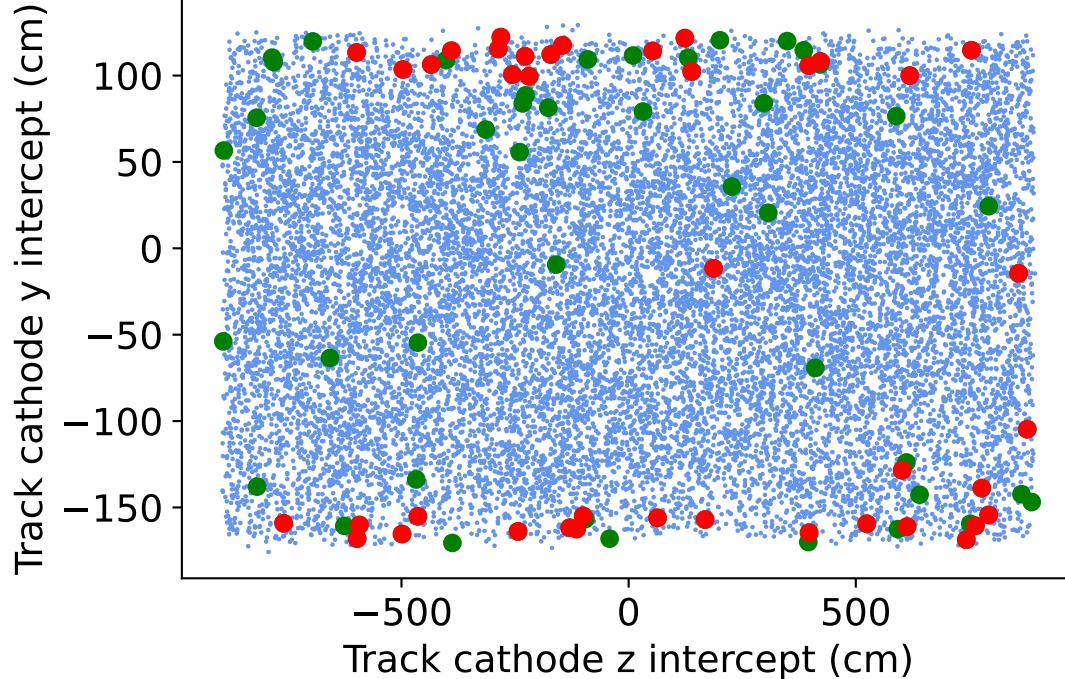
Location of 2m track anomaly

East Cryostat

(-15 μ s, 5 μ s) Emulation Window

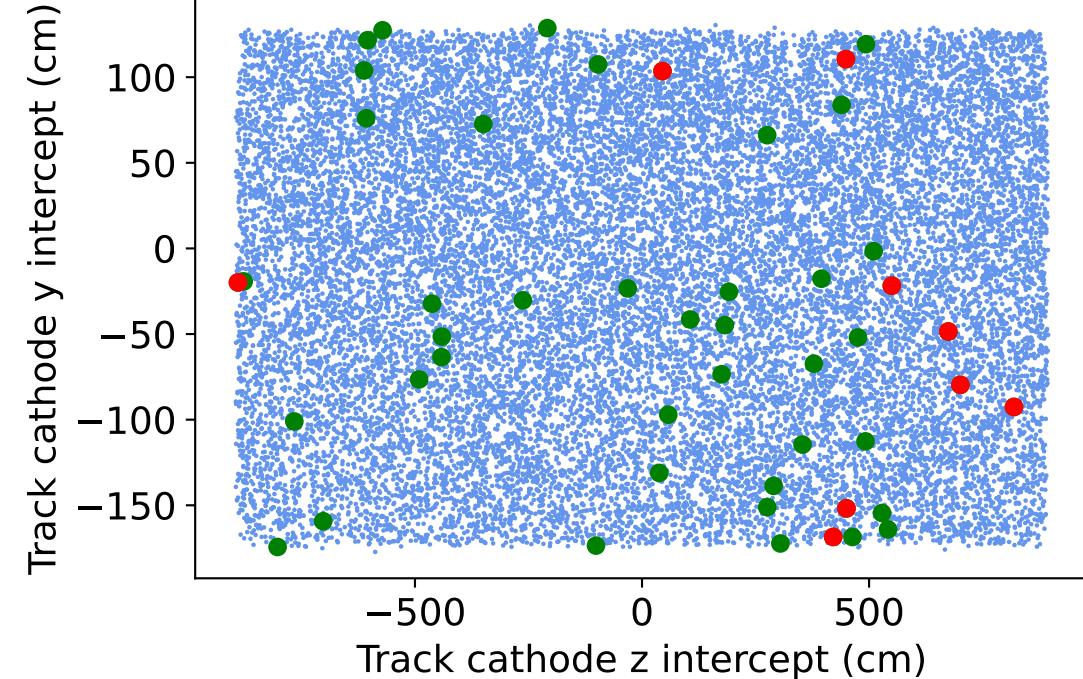
West Cryostat

Run 7232 Cryo E: Cathode-Crossing Pos of M1 Non-Trig Tracks



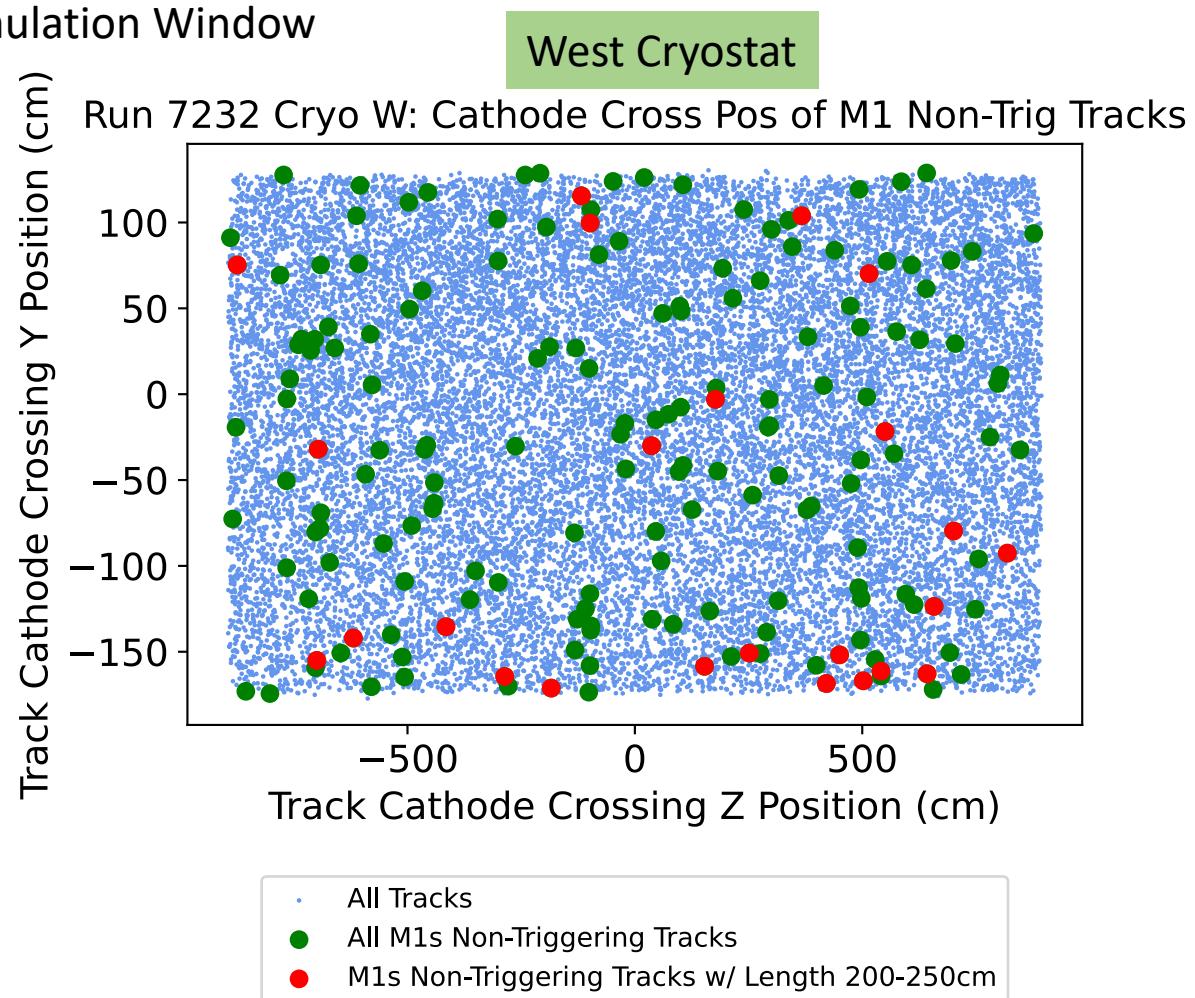
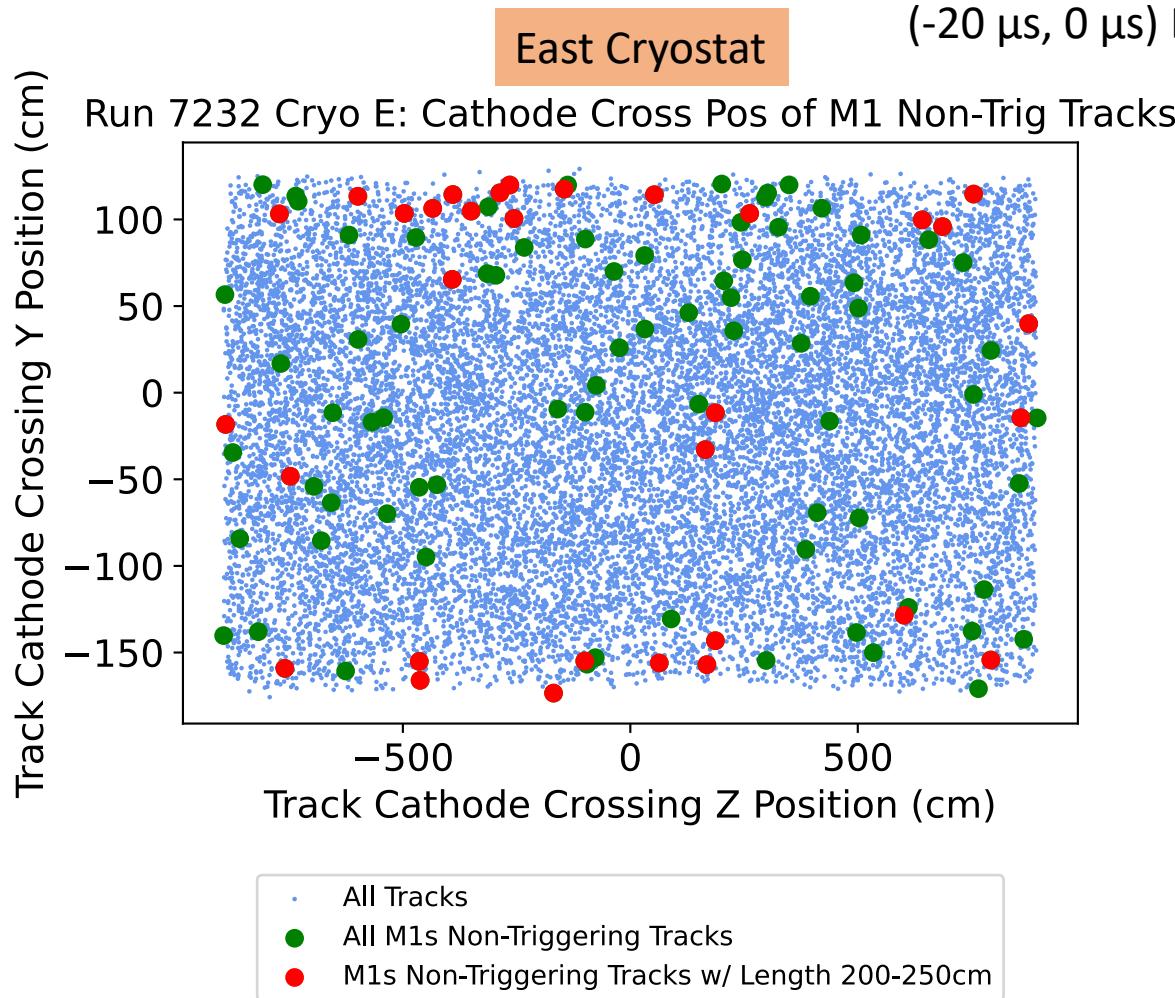
- All Tracks
- All M1s Non-Triggering Tracks
- M1s Non-Triggering Tracks w/ Length 200-250cm

Run 7232 Cryo W: Cathode-Crossing Pos of M1 Non-Trig Tracks



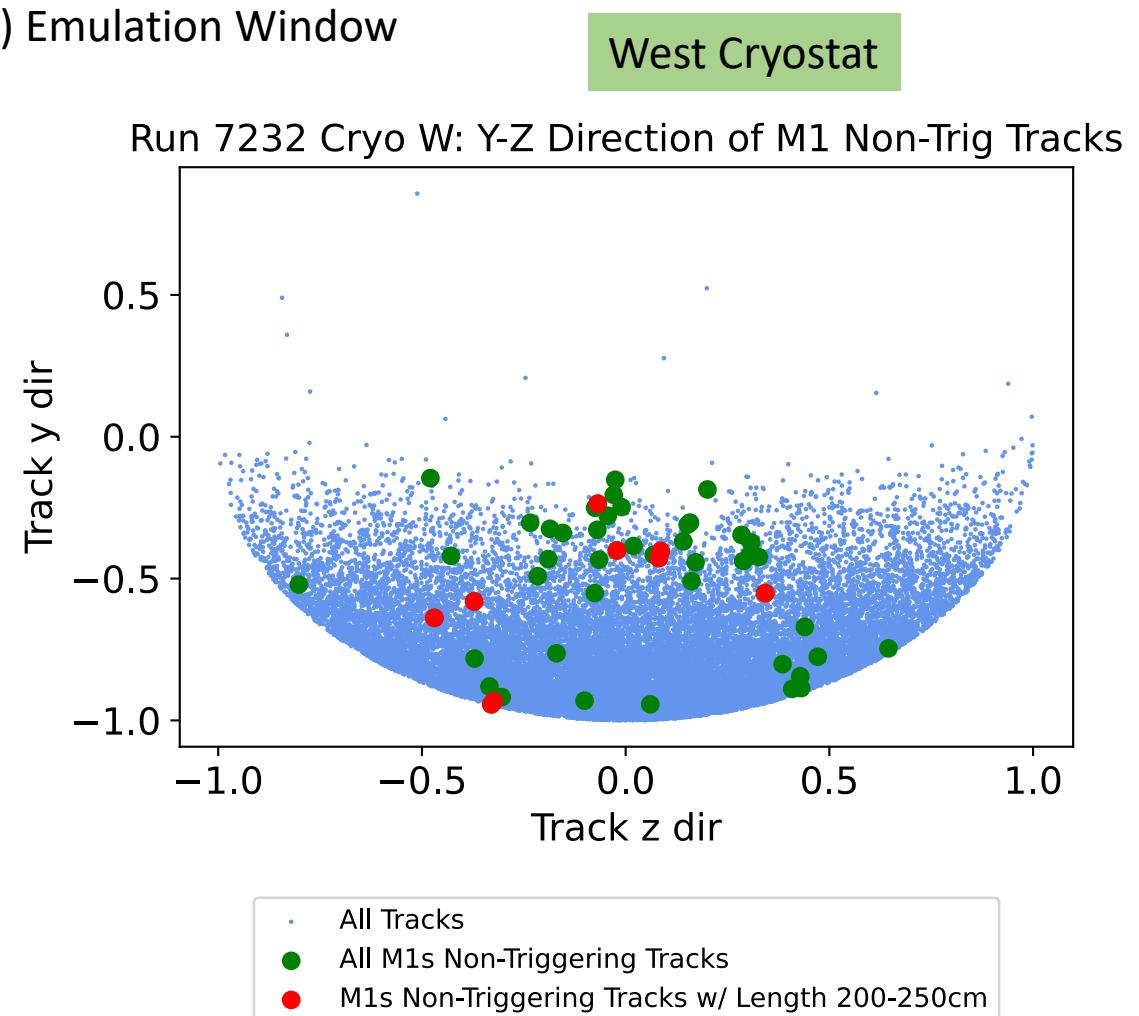
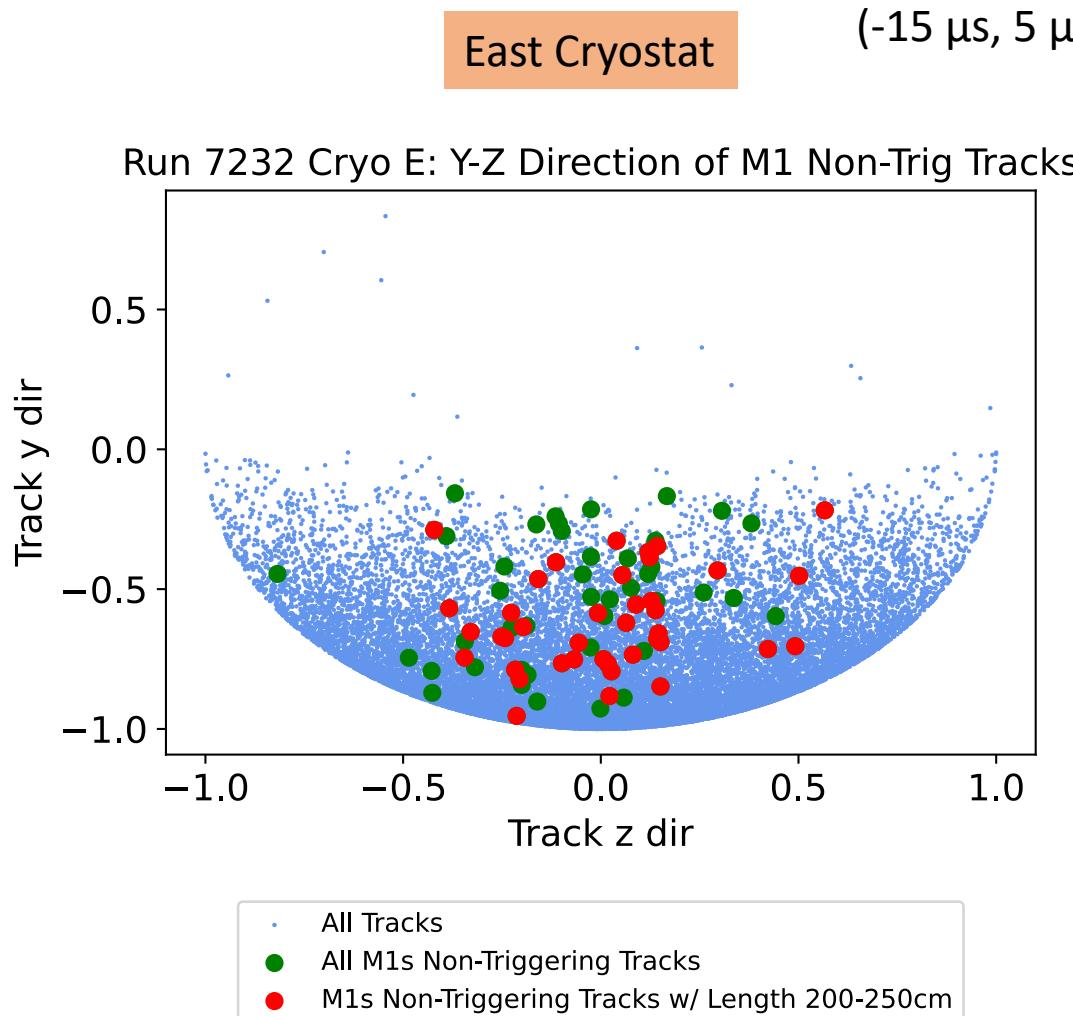
- All Tracks
- All M1s Non-Triggering Tracks
- M1s Non-Triggering Tracks w/ Length 200-250cm

Location of 2m track anomaly



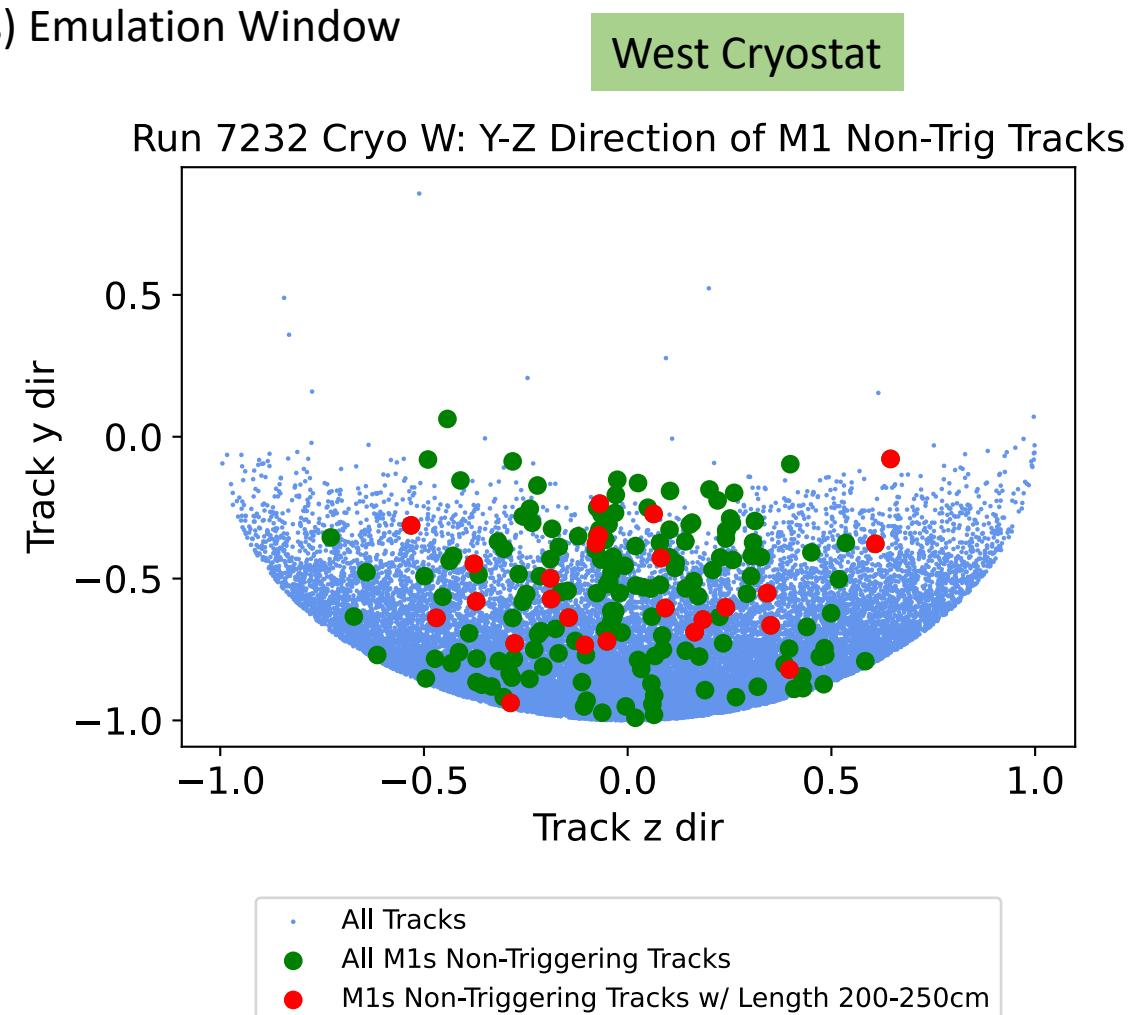
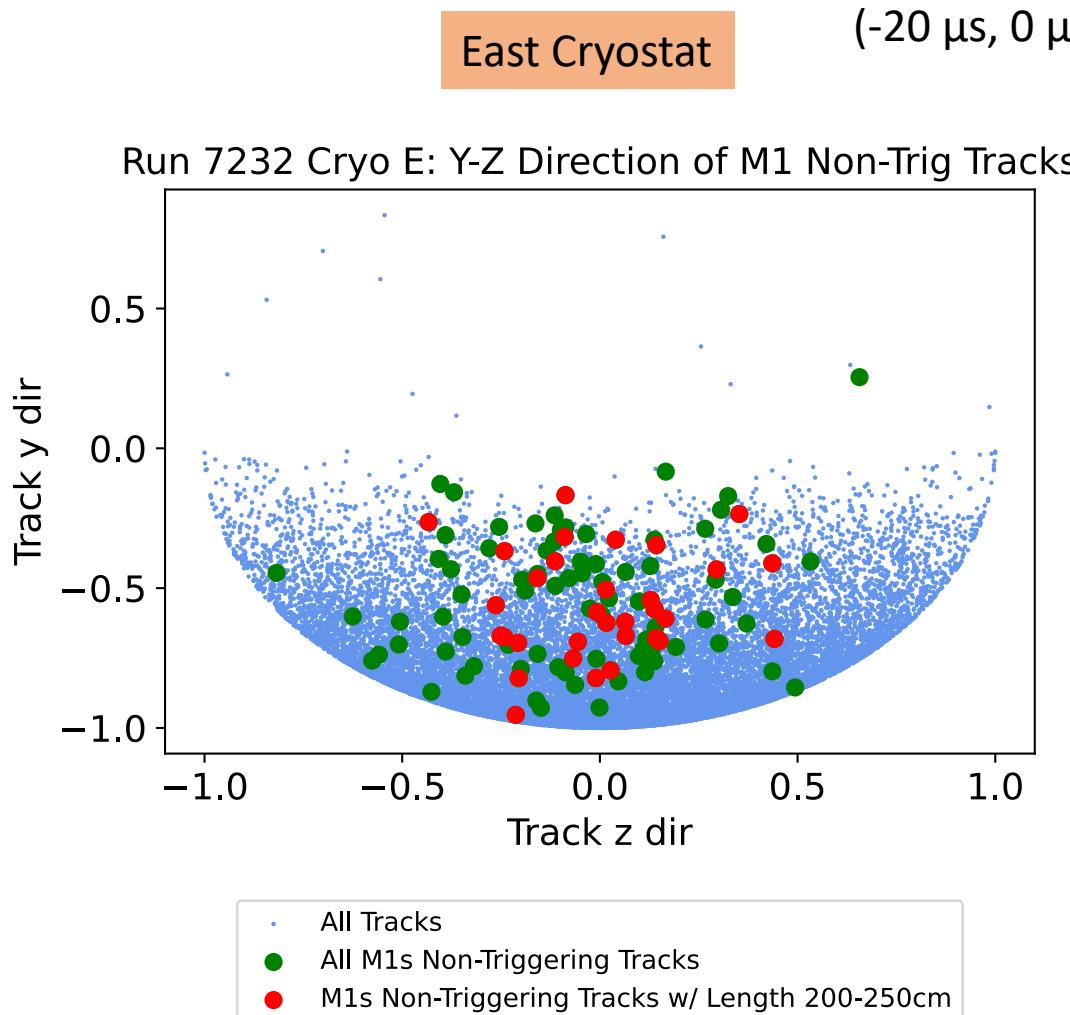
Y-Z Angle of Tracks – 2m track anomaly

- Non-triggering tracks seem to have restricted z-dir? Perhaps because of track density overall though



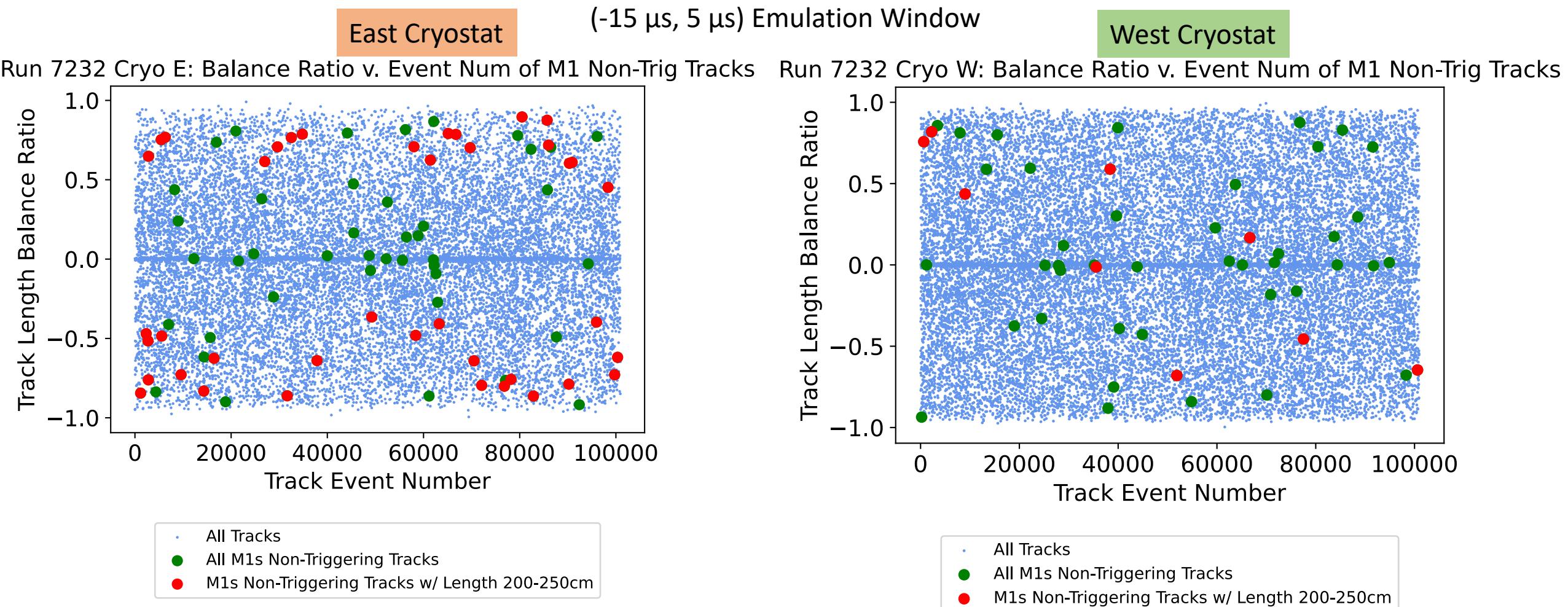
Y-Z Angle of Tracks – 2m track anomaly

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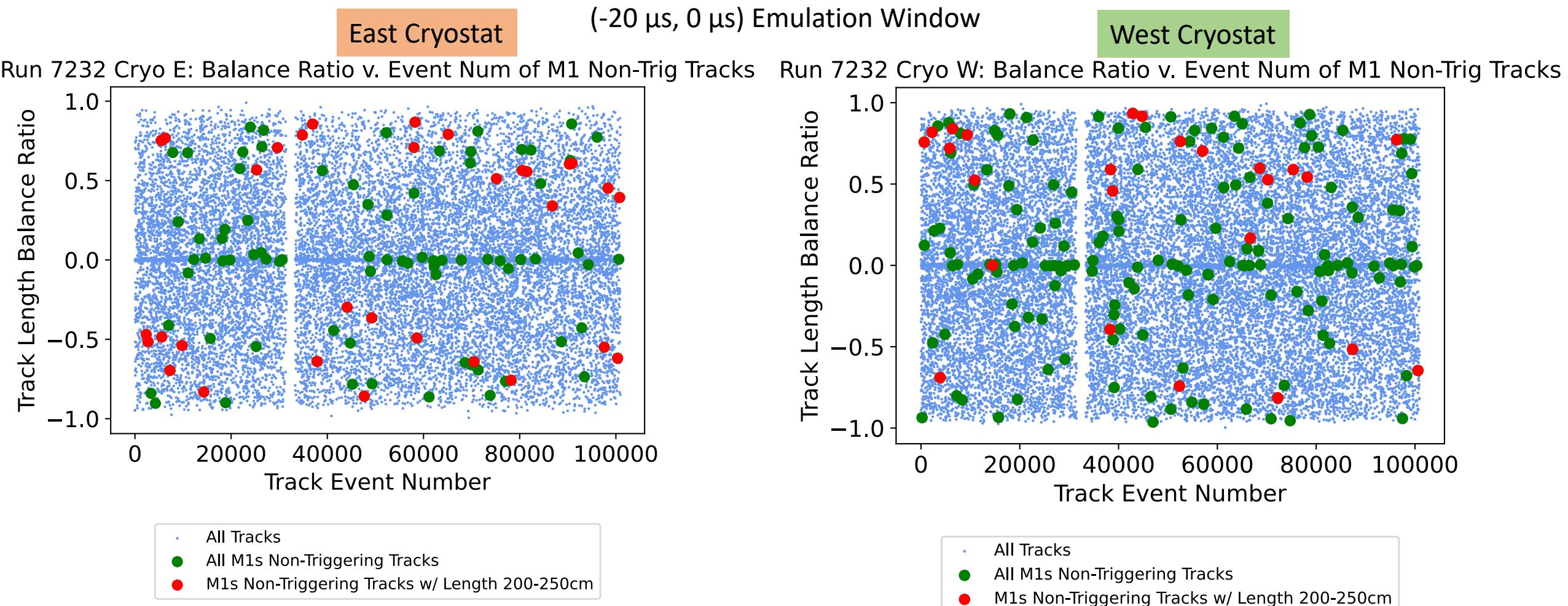
X-ratio vs. Event Number

- Is there a pattern w/ balance ratio of 2m tracks over time in cryo W? That's weird...
 - East cryo definitely has a trend – 2m tracks have higher balance ratios



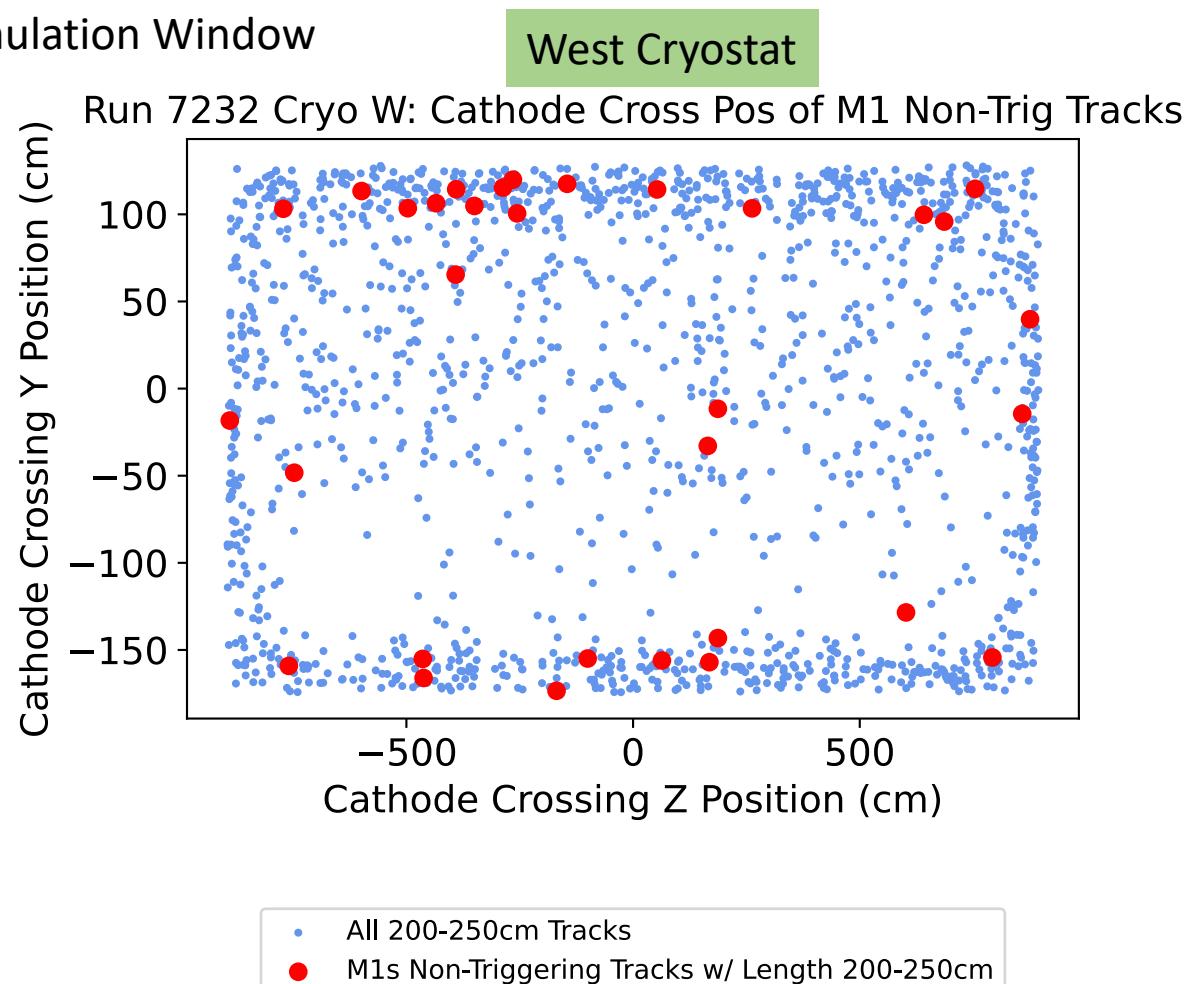
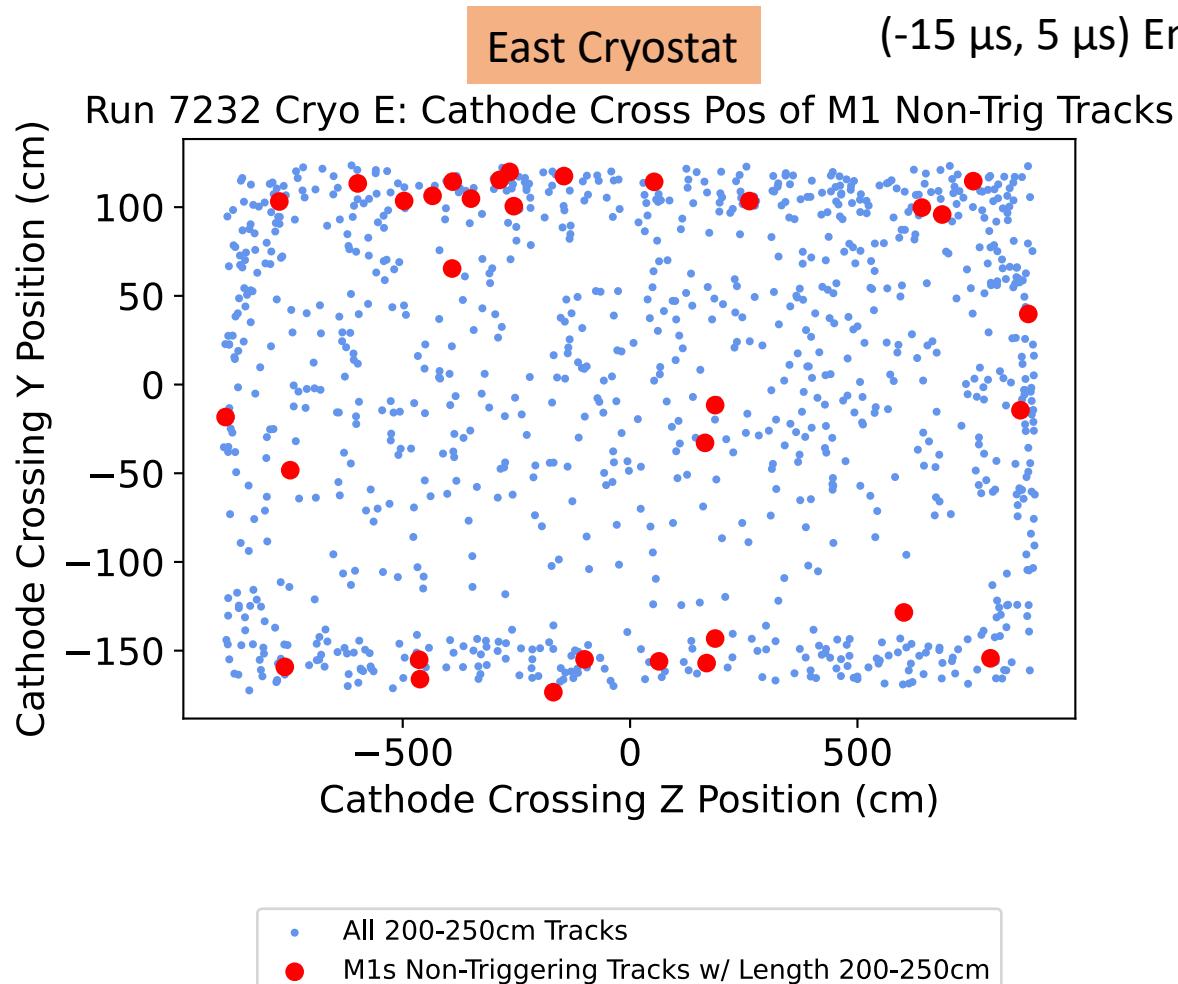
X-ratio vs. Event Number

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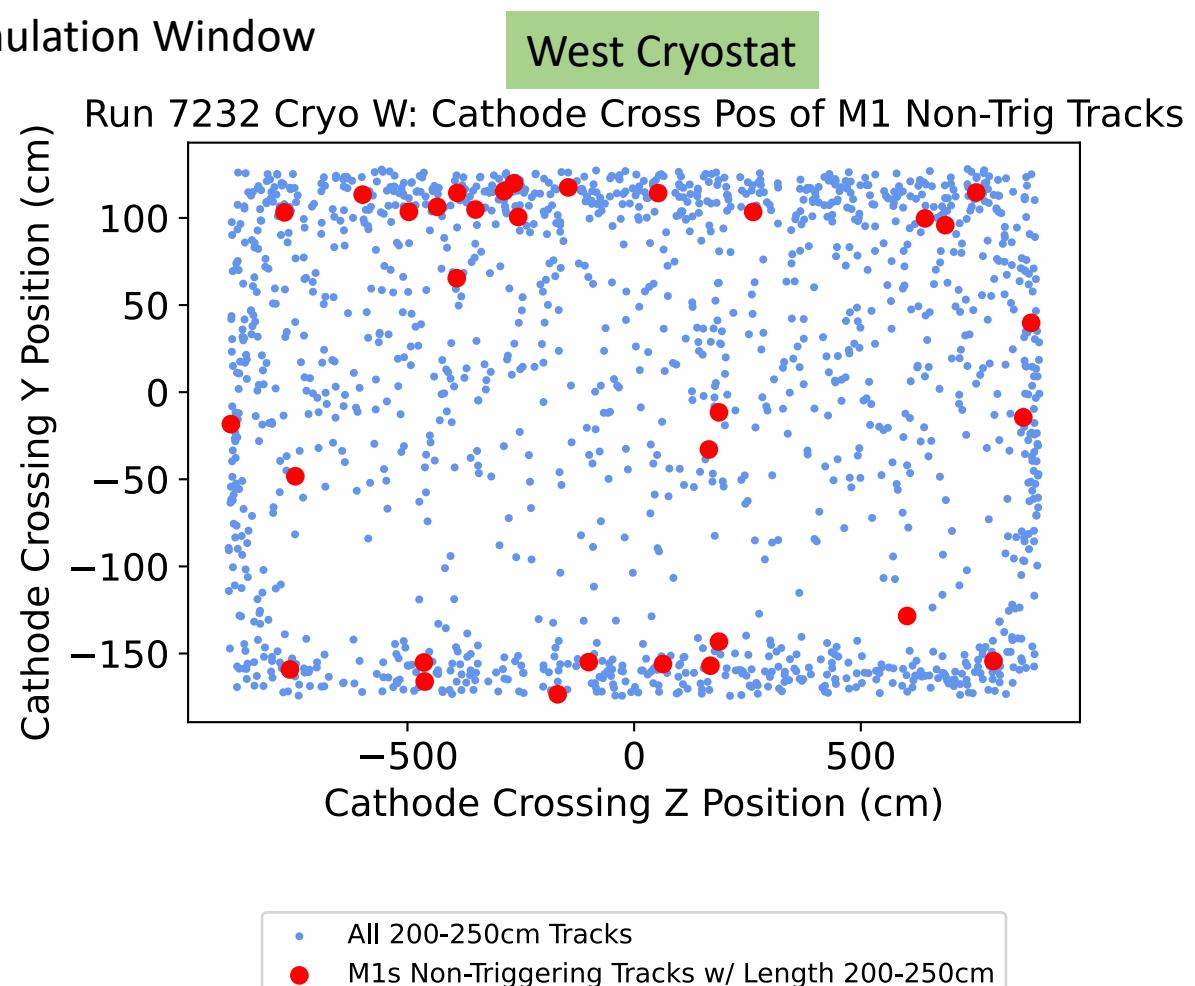
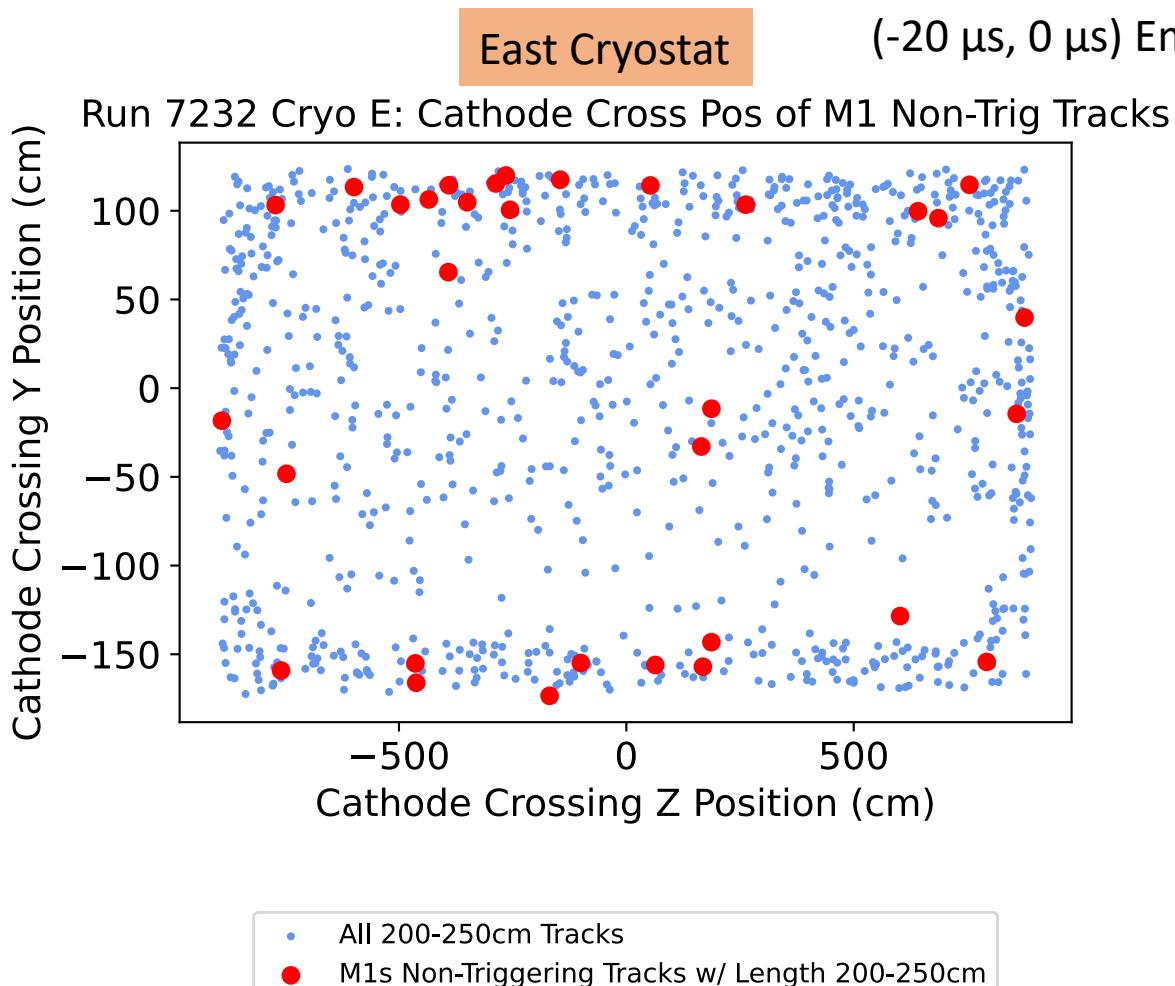
Location of Cathode Crossing

- 200-250cm tracks



Location of Cathode Crossing

- 200-250cm tracks



Cathode Crossing y-position

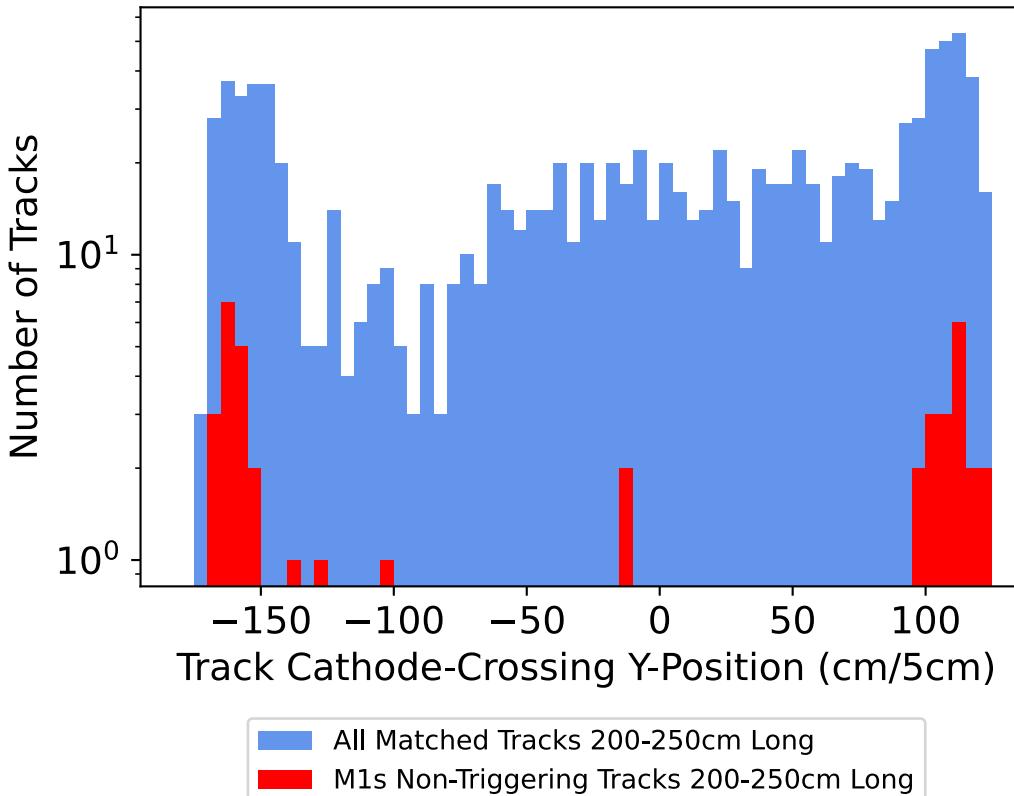
- 200-250cm tracks

East Cryostat

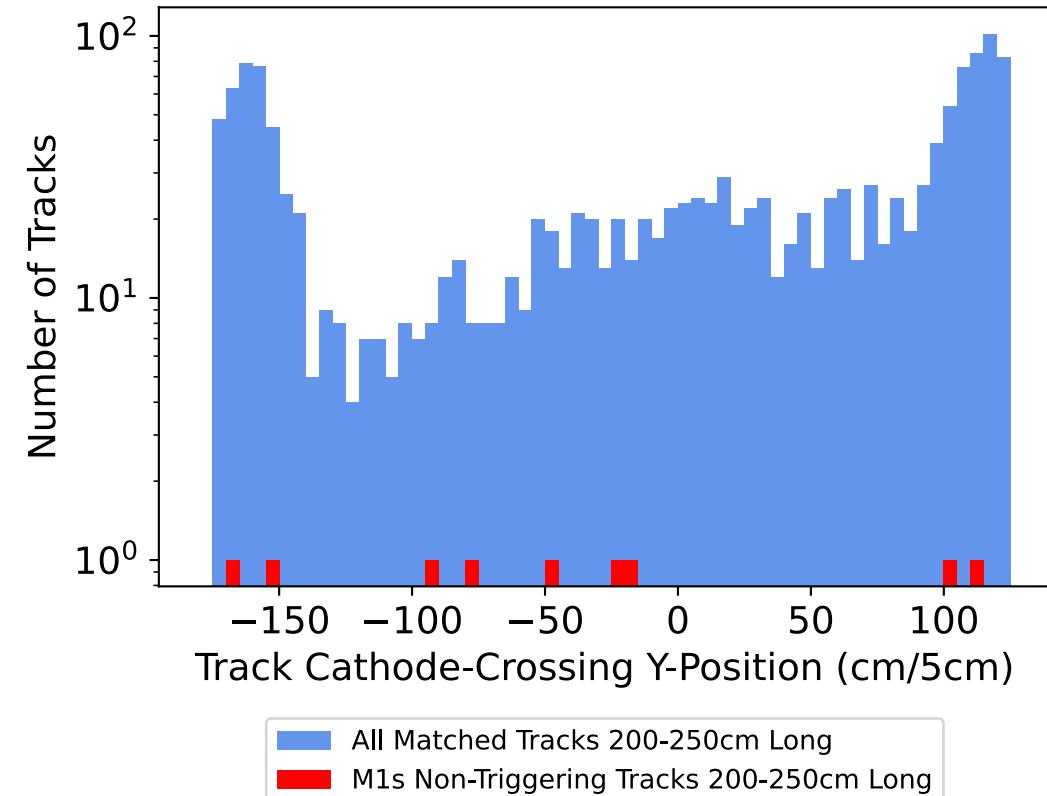
(-15 μ s, 5 μ s) Emulation Window

West Cryostat

Run 7232 Cryo E: Cathode-Crossing Y-Pos of Non-Trig Tracks



Run 7232 Cryo W: Cathode-Crossing Y-Pos of Non-Trig Tracks



Cathode Crossing y-position

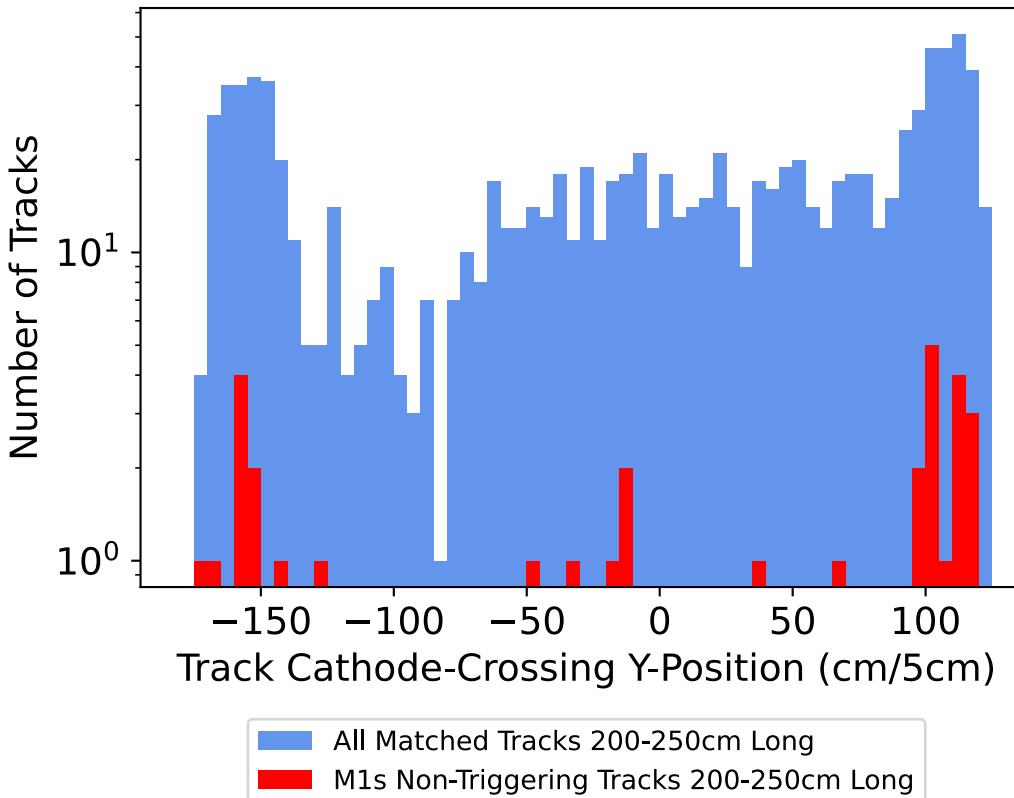
- 200-250cm tracks

East Cryostat

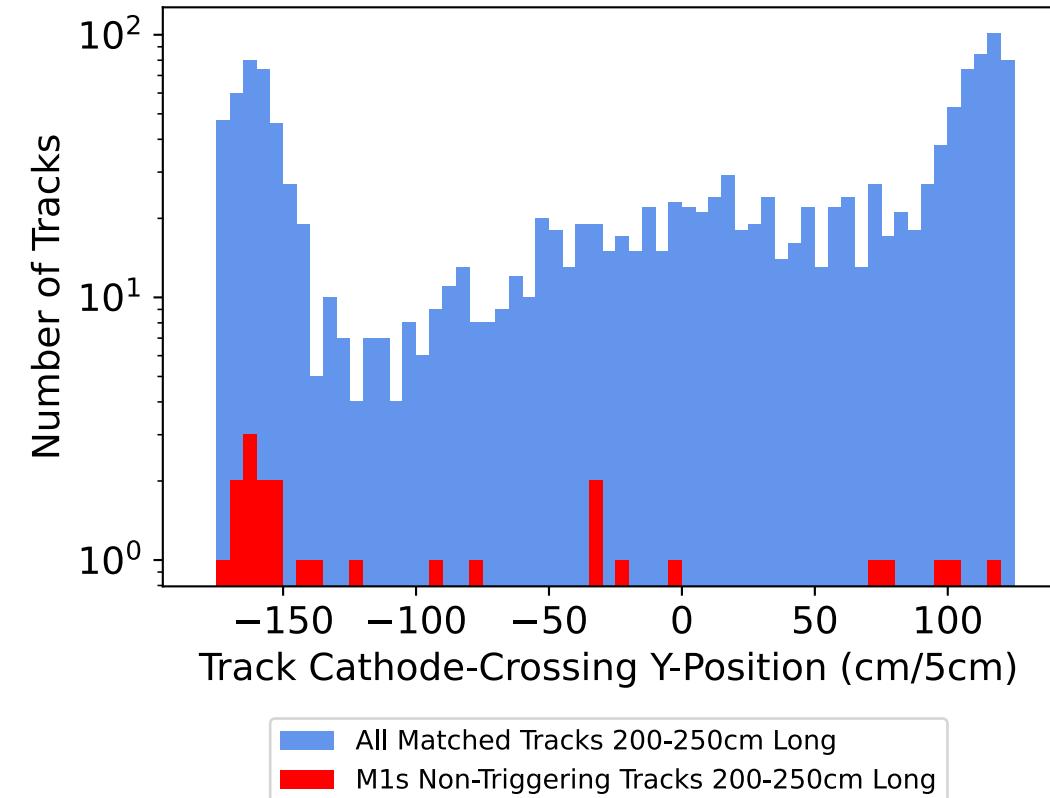
(-20 μ s, 0 μ s) Emulation Window

West Cryostat

Run 7232 Cryo E: Cathode-Crossing Y-Pos of Non-Trig Tracks



Run 7232 Cryo W: Cathode-Crossing Y-Pos of Non-Trig Tracks



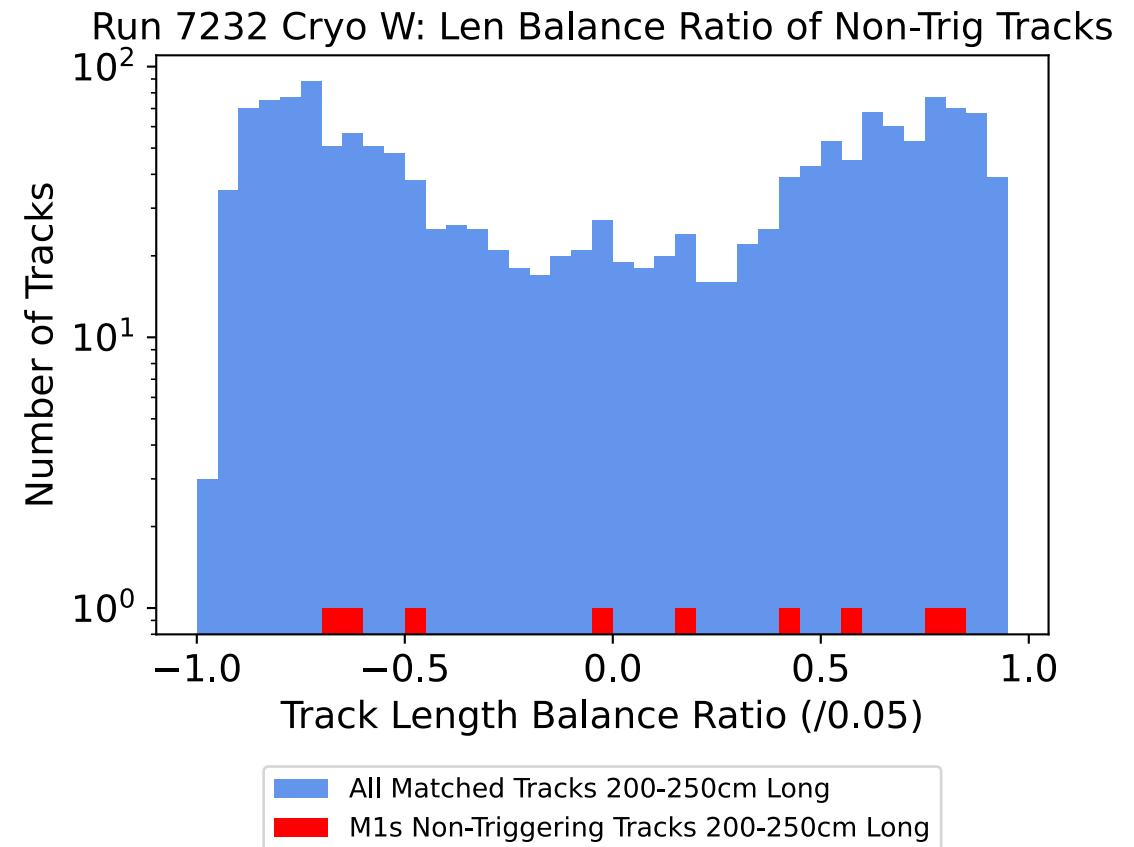
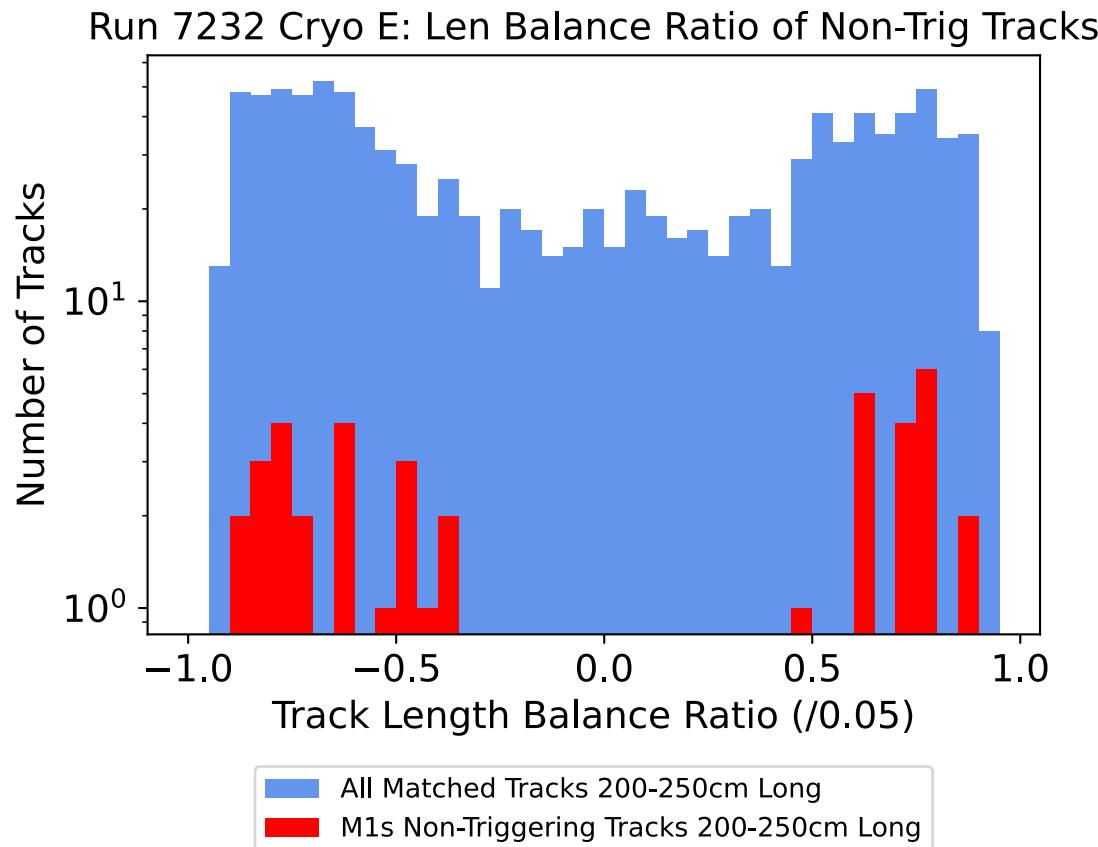
Balance Ratio

- 200-250cm tracks

East Cryostat

(-15 μ s, 5 μ s) Emulation Window

West Cryostat



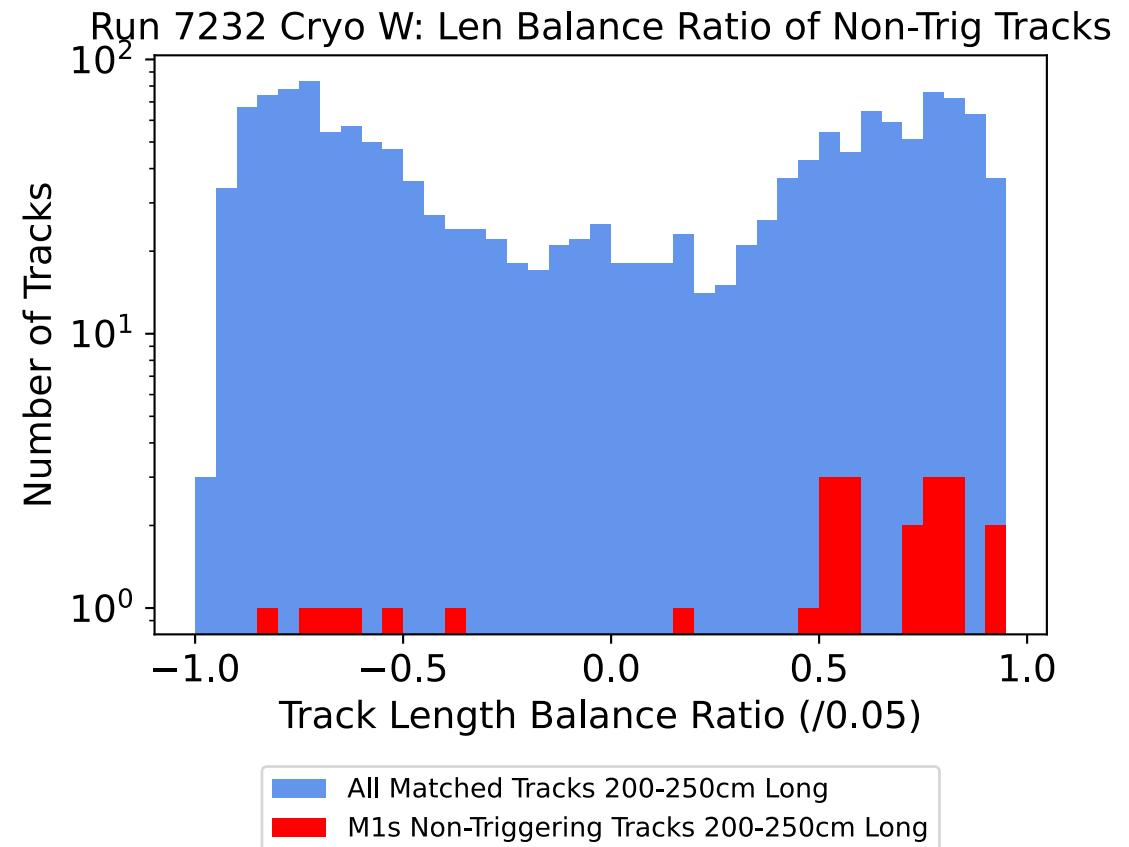
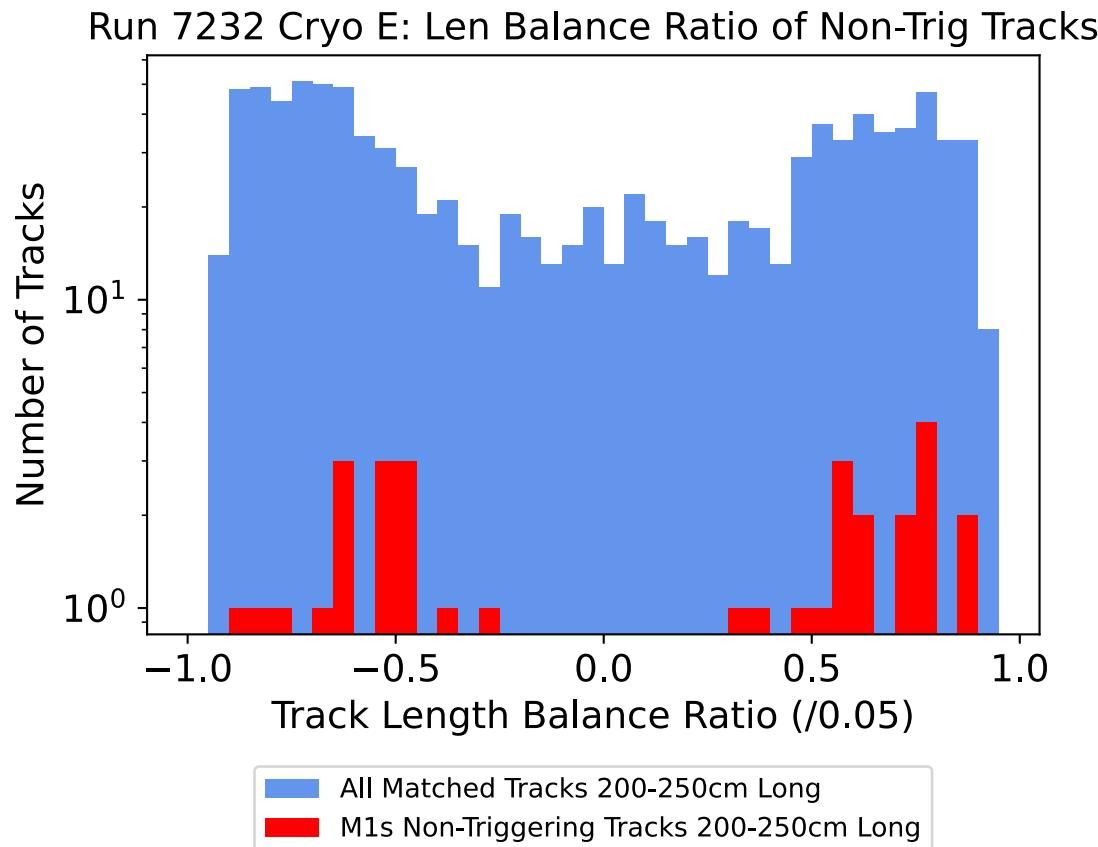
Balance Ratio

- 200-250cm tracks

East Cryostat

(-20 μ s, 0 μ s) Emulation Window

West Cryostat



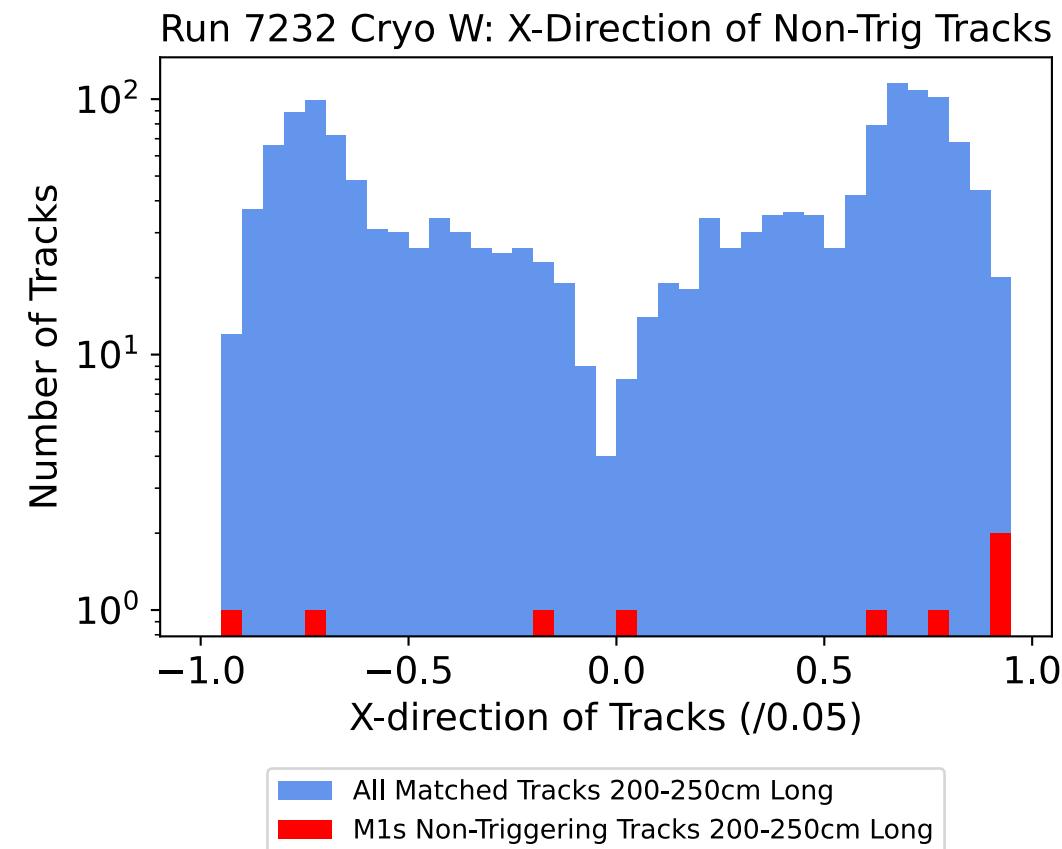
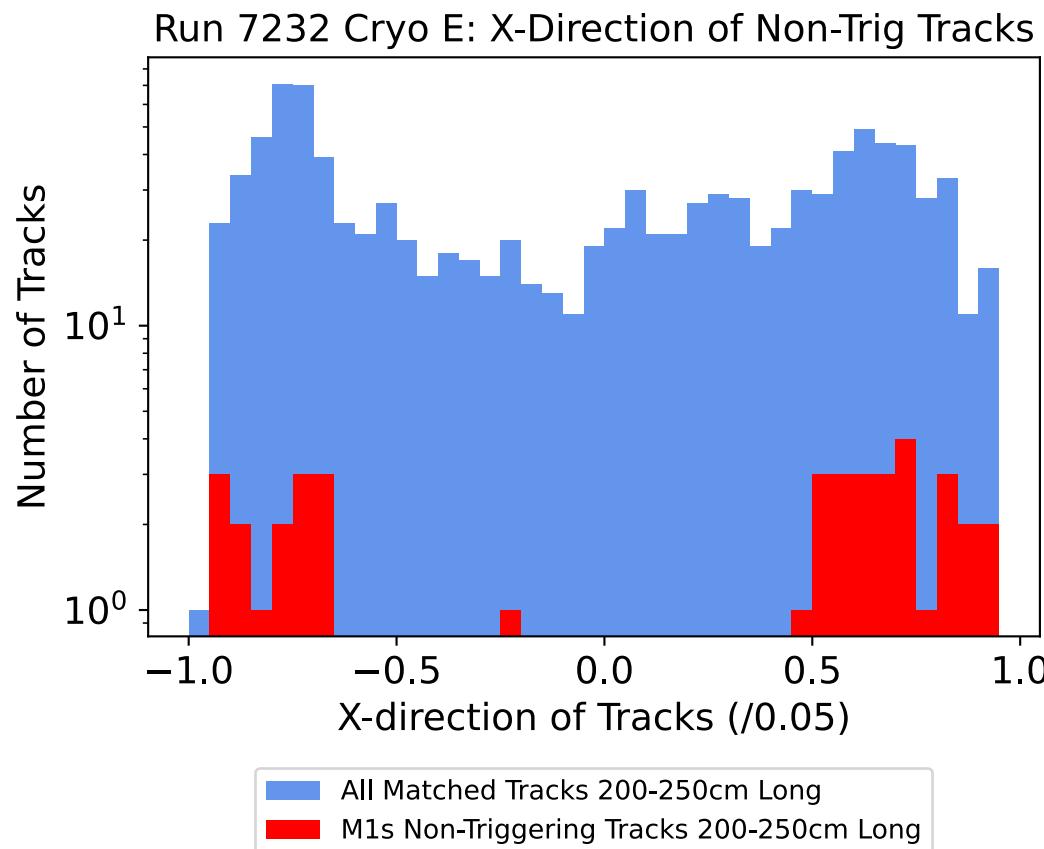
X-direction

- 200-250cm tracks

East Cryostat

(-15 μ s, 5 μ s) Emulation Window

West Cryostat



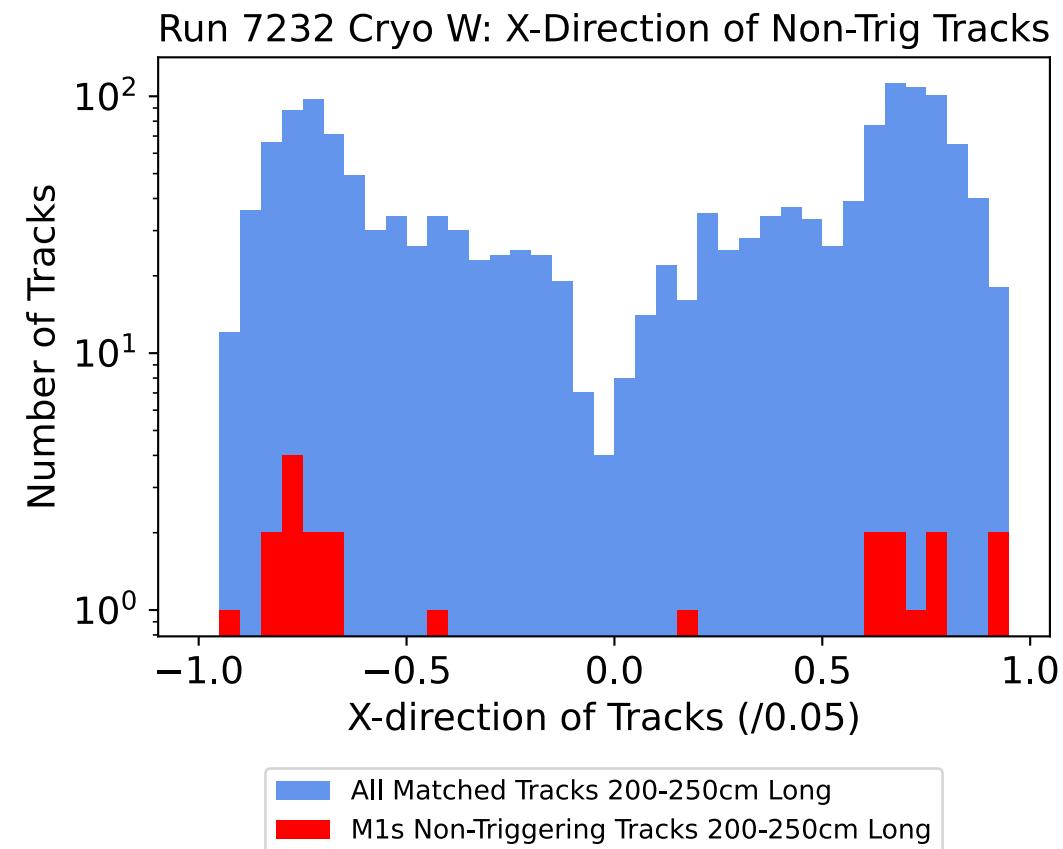
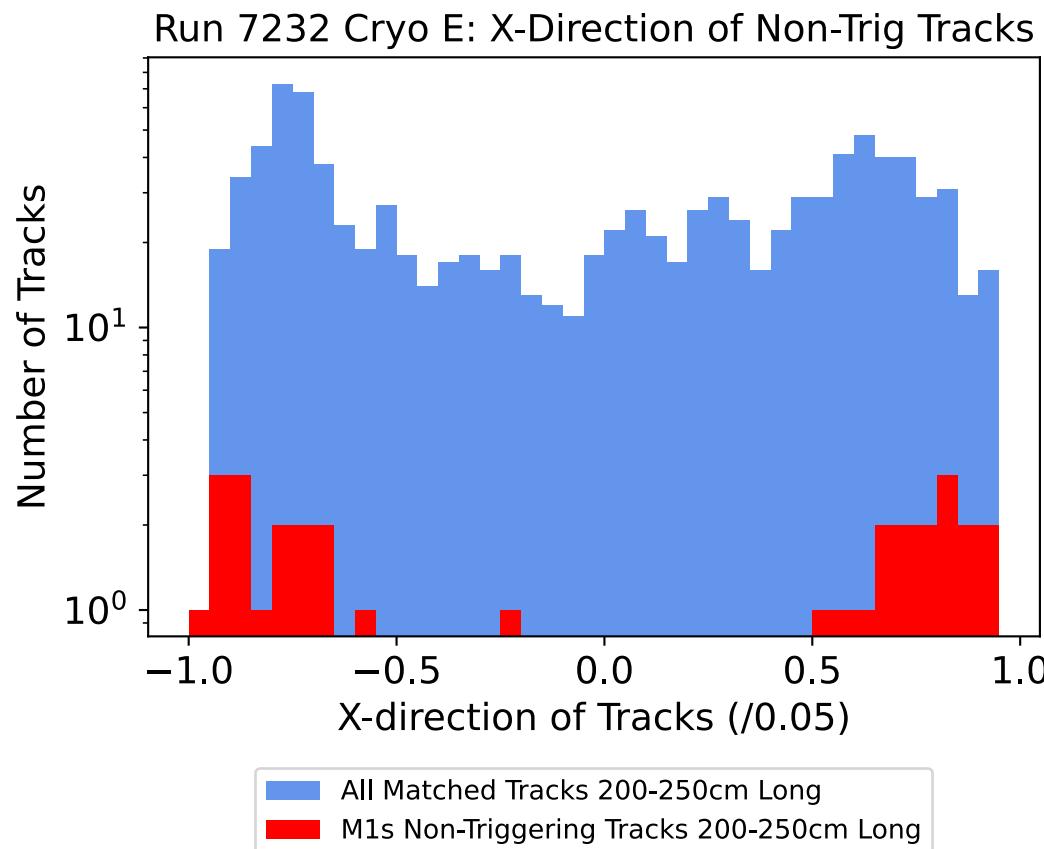
X-direction

- 200-250cm tracks

East Cryostat

(-20 μ s, 0 μ s) Emulation Window

West Cryostat



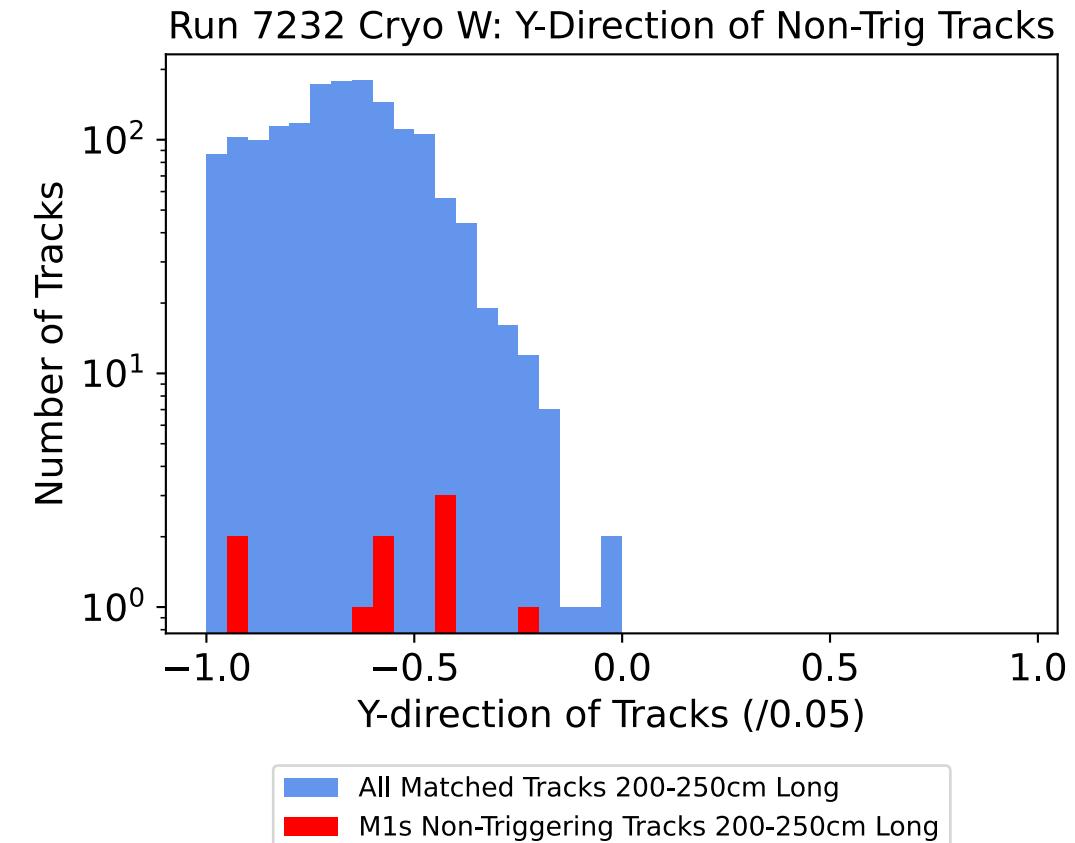
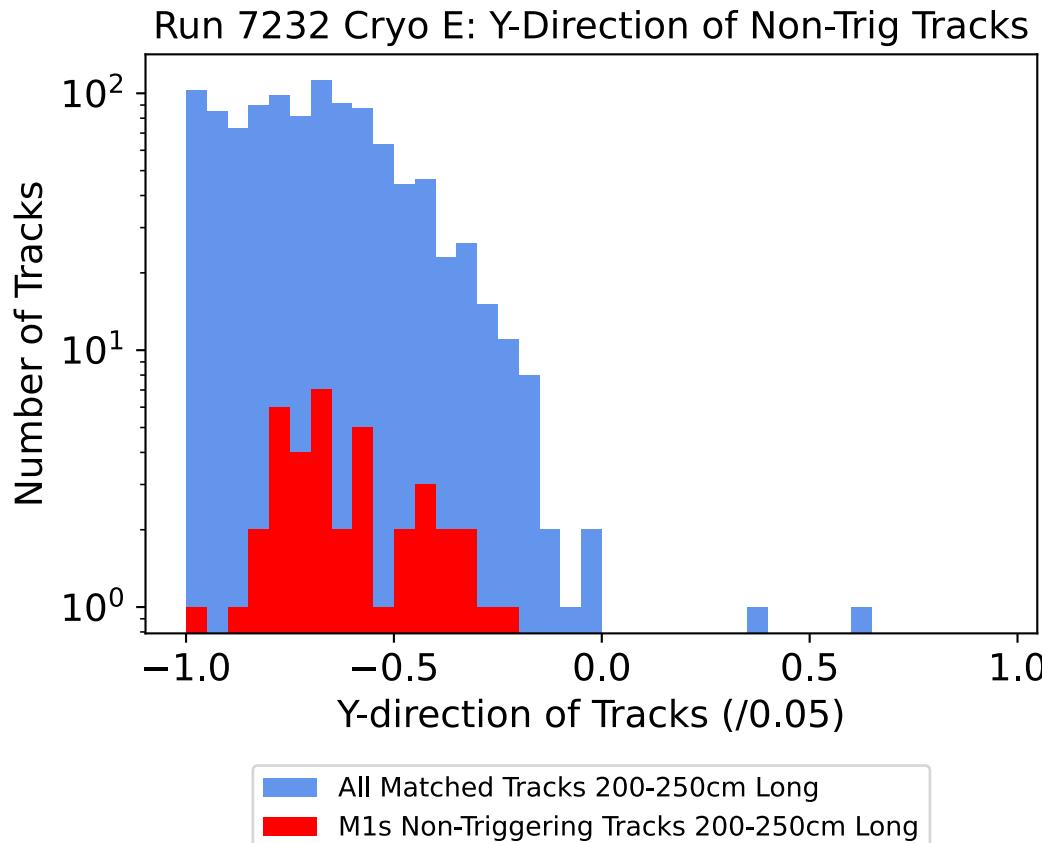
Y-direction

- 200-250cm tracks

East Cryostat

(-15 μ s, 5 μ s) Emulation Window

West Cryostat



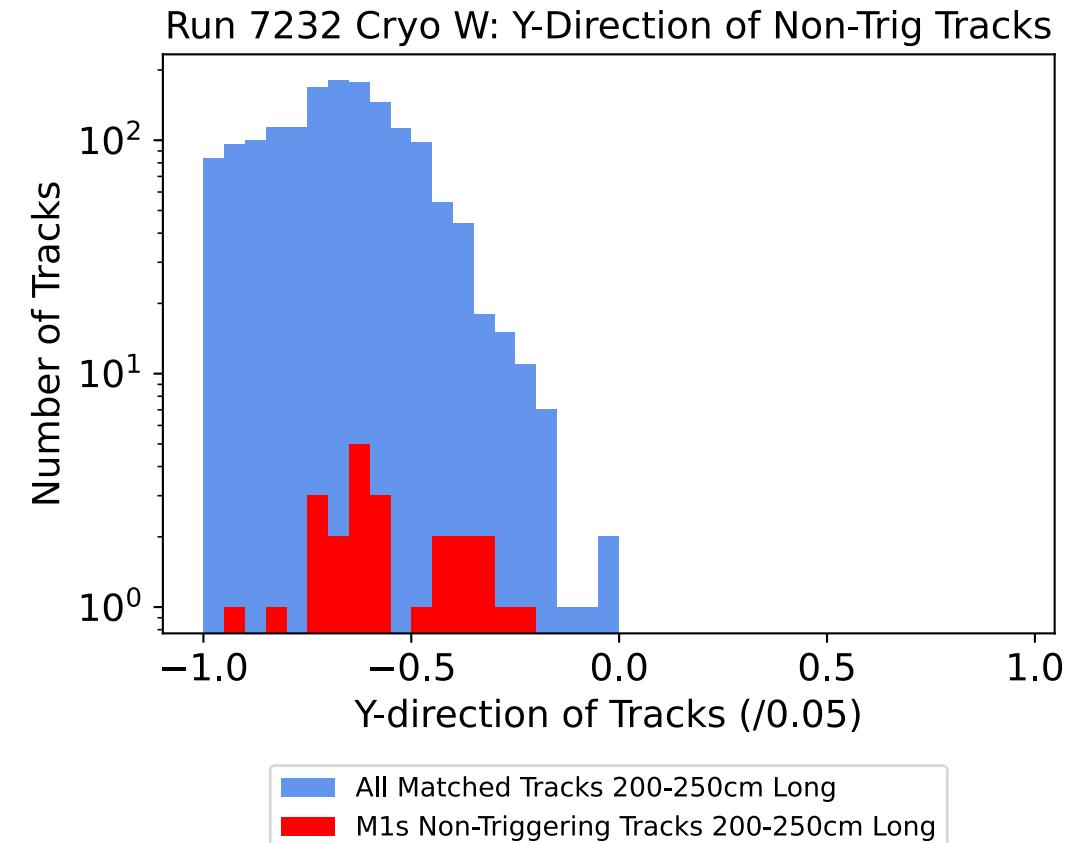
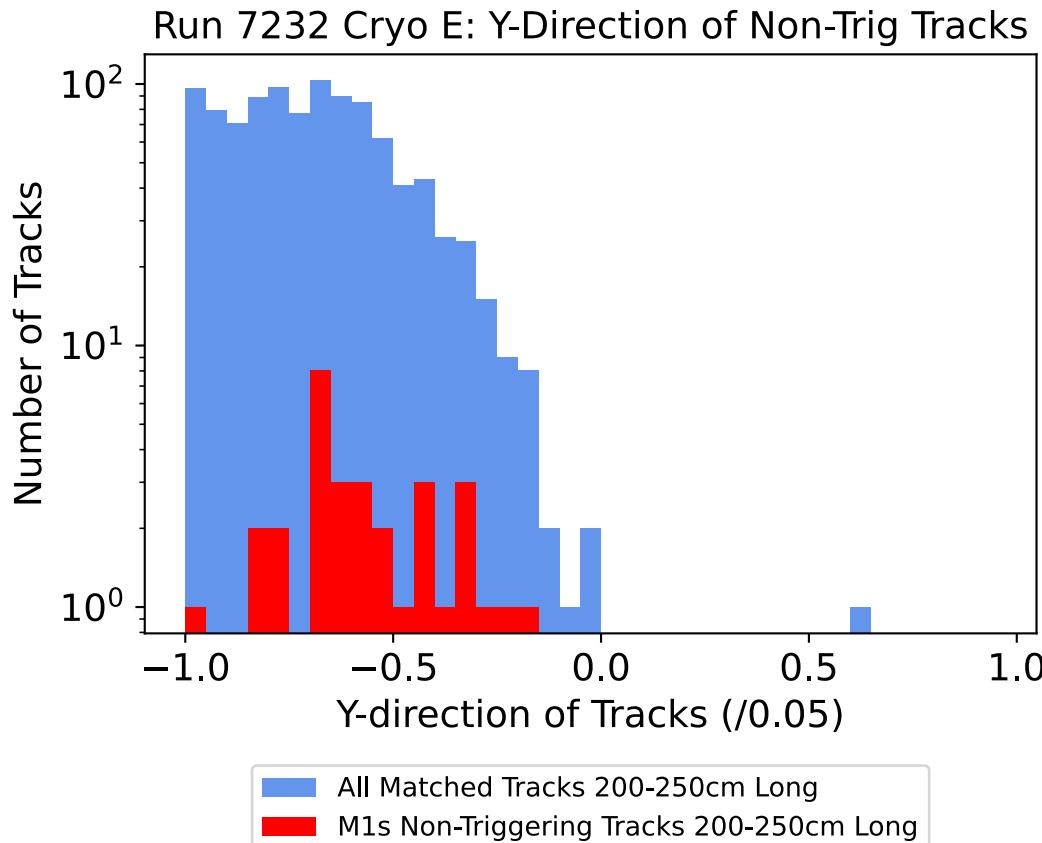
Y-direction

- 200-250cm tracks

East Cryostat

(-20 μ s, 0 μ s) Emulation Window

West Cryostat



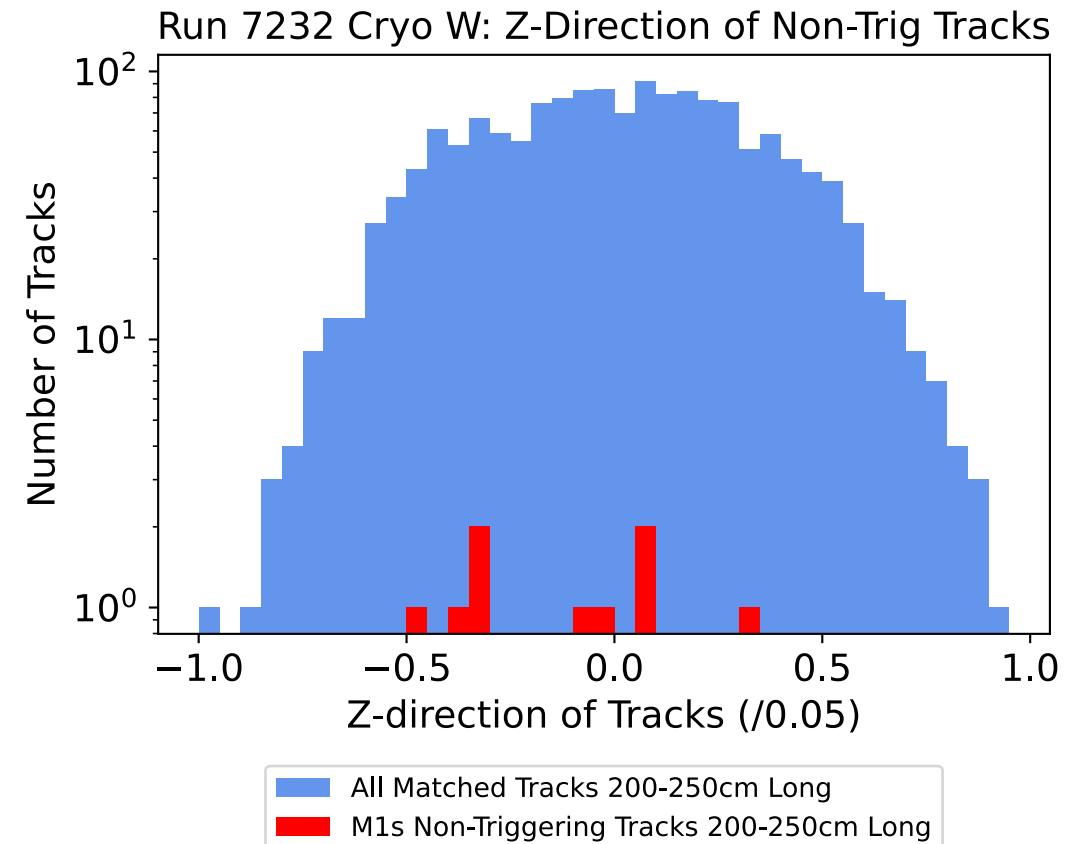
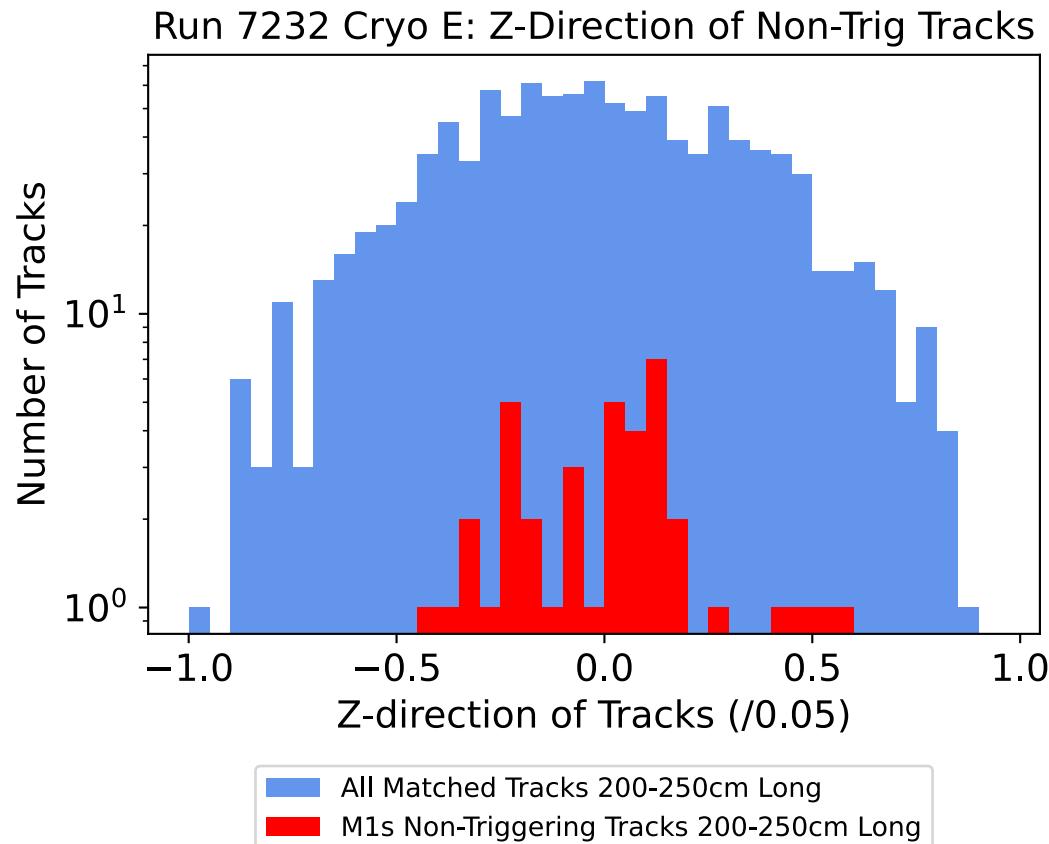
Z-direction

- 200-250cm tracks

East Cryostat

(-15 μ s, 5 μ s) Emulation Window

West Cryostat



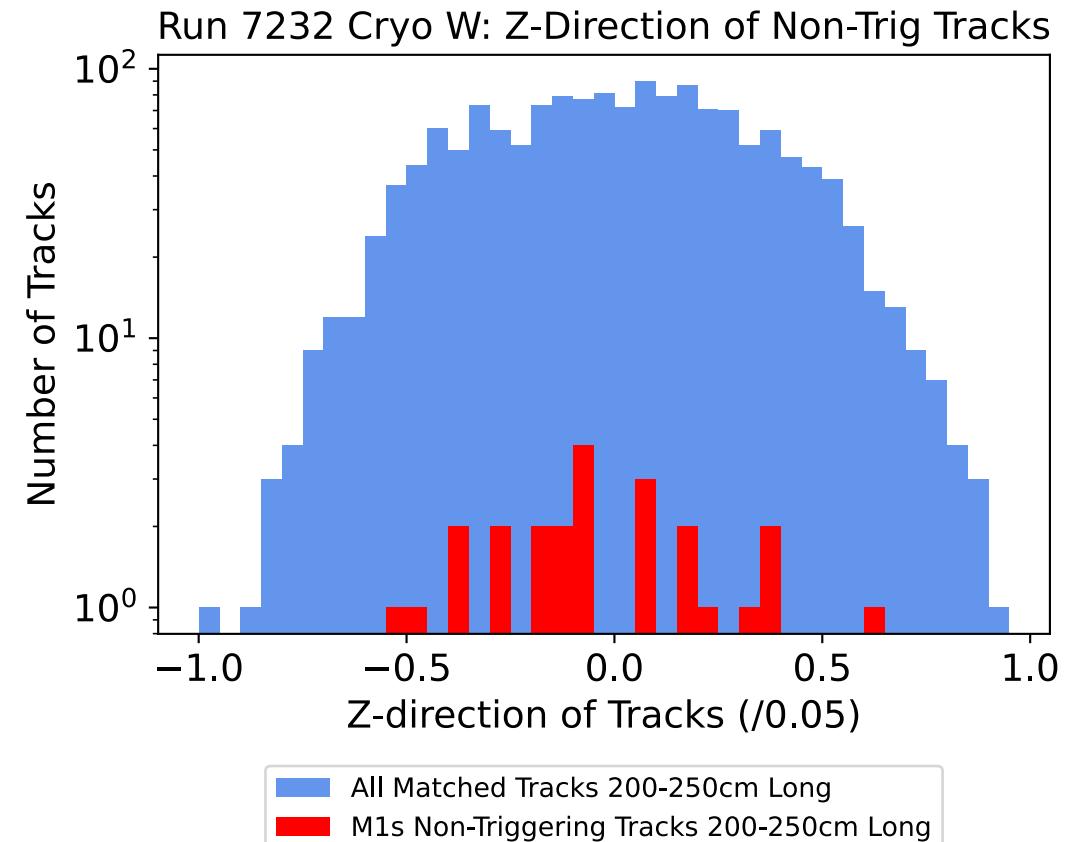
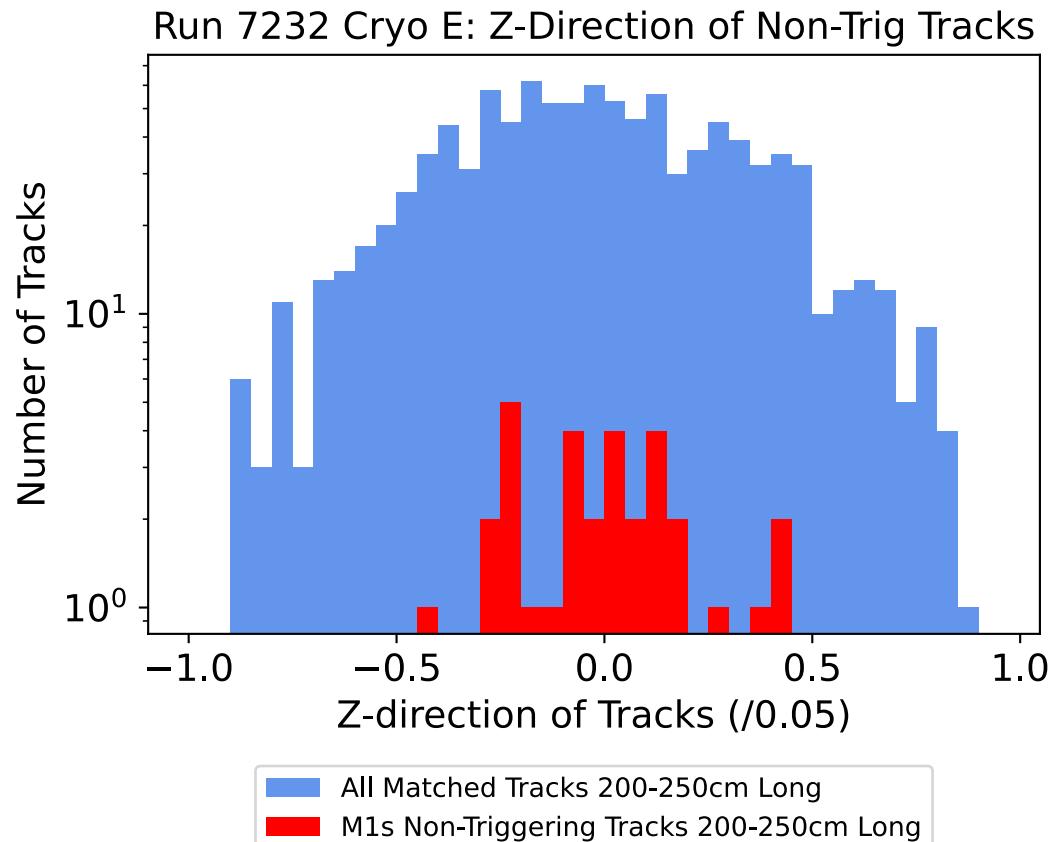
Z-direction

- 200-250cm tracks

East Cryostat

(-20 μ s, 0 μ s) Emulation Window

West Cryostat



Causes of 2m track issues

- Not time dependent (X-ratio vs. event number)
- Not from cathode bending (whiteboard that is now erased)
- Y cathode-crossing position
- Length balance ratio
- Not specific to downgoing particles at diff dir_y's (y-z angle)
- Dir_z closer to 0? Not just for 2m tracks.. - geometric bias too
- Shifting trigger emulation window, t0 reconstruction? – somewhat for 2m tracks
- Not split tracks during track reconstruction (event display, not statistically significant)
- Border distortions of electric field?
- Visibility of photons at high y-values - lost if they hit the field cage, fewer pmts
- Higher nonzero X-direction

Complete Tracks

Tracks crossing entirely through the cryostat – within 10 cm of y and z edges and within 15 cm of x edges

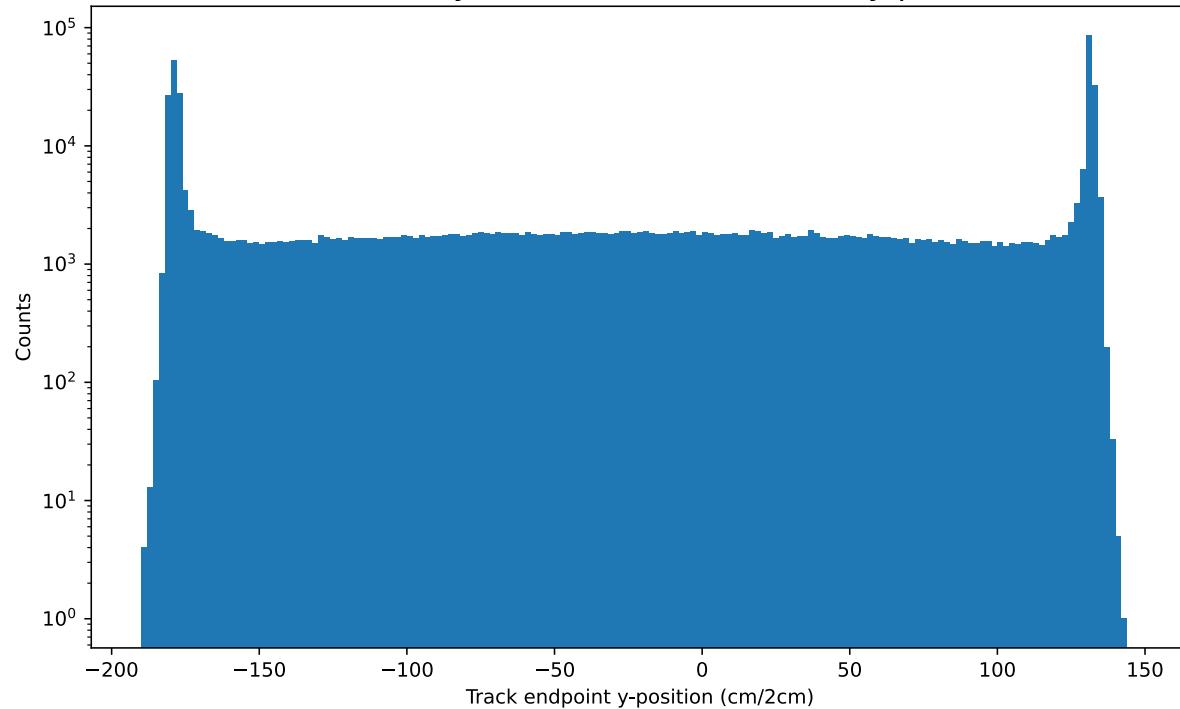
Y-axis Track Endpoint Distribution

East Cryostat

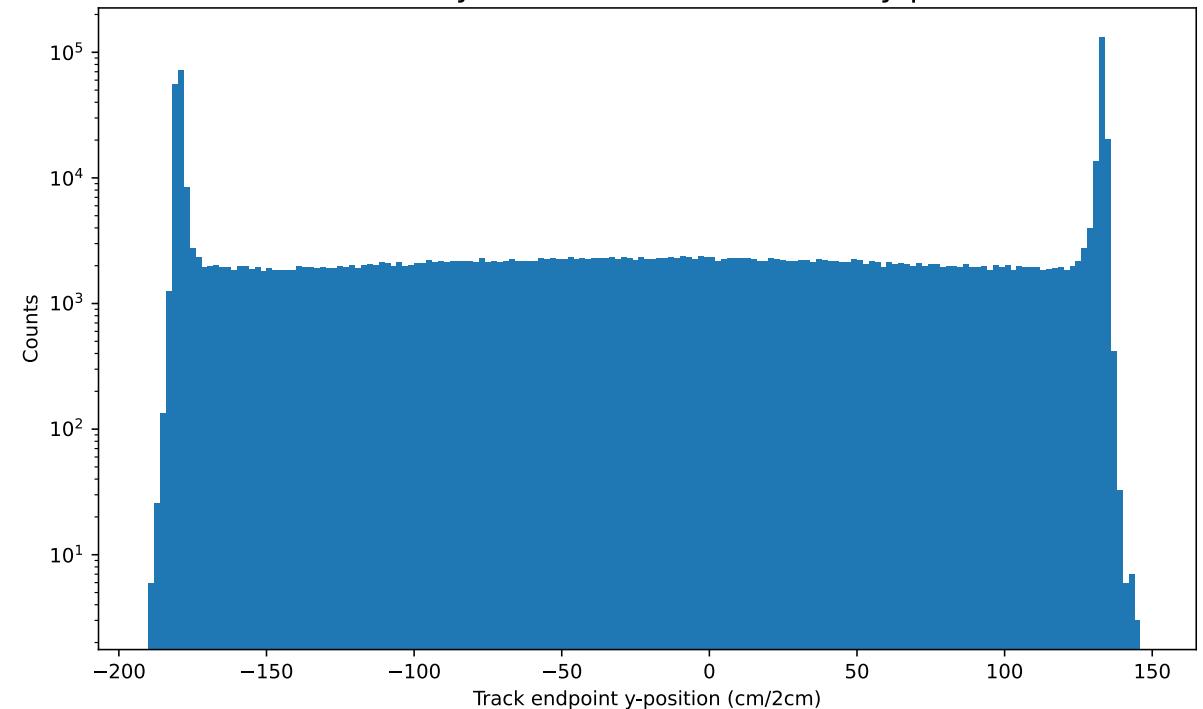
(-15 μ s, 5 μ s) Emulation Window

West Cryostat

Run 7232 Cryo E: Distribution of Track y-position



Run 7232 Cryo W: Distribution of Track y-position



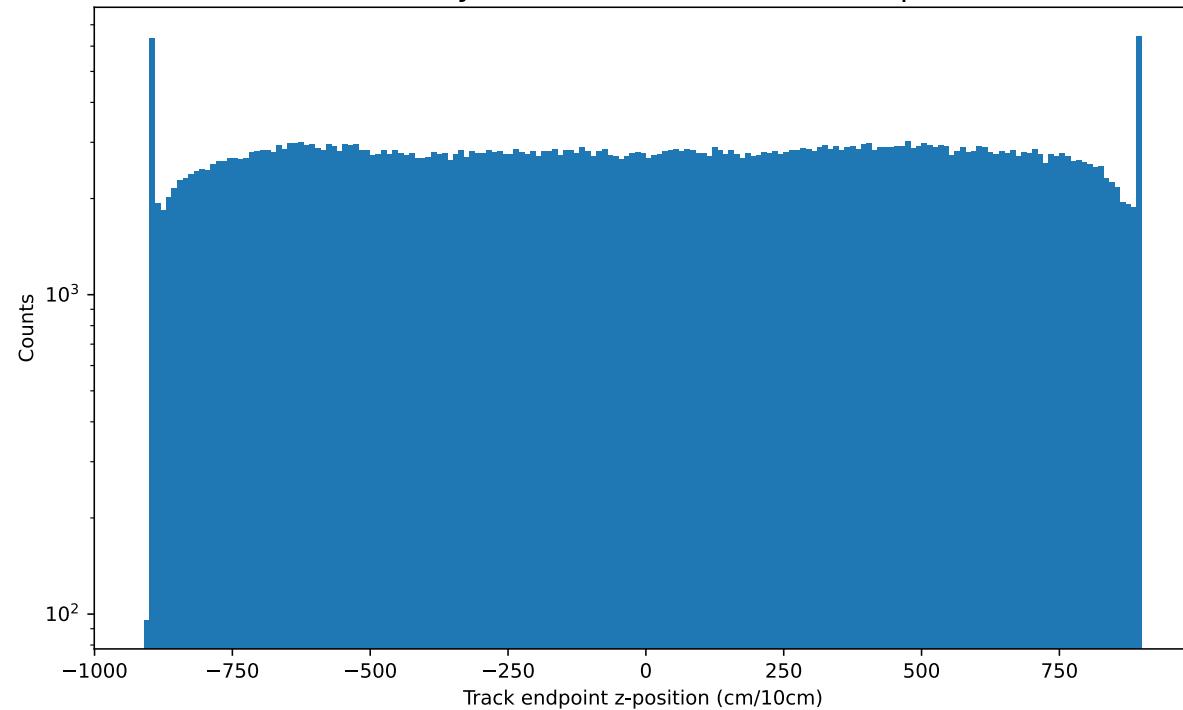
Z-axis Track Endpoint Distribution

East Cryostat

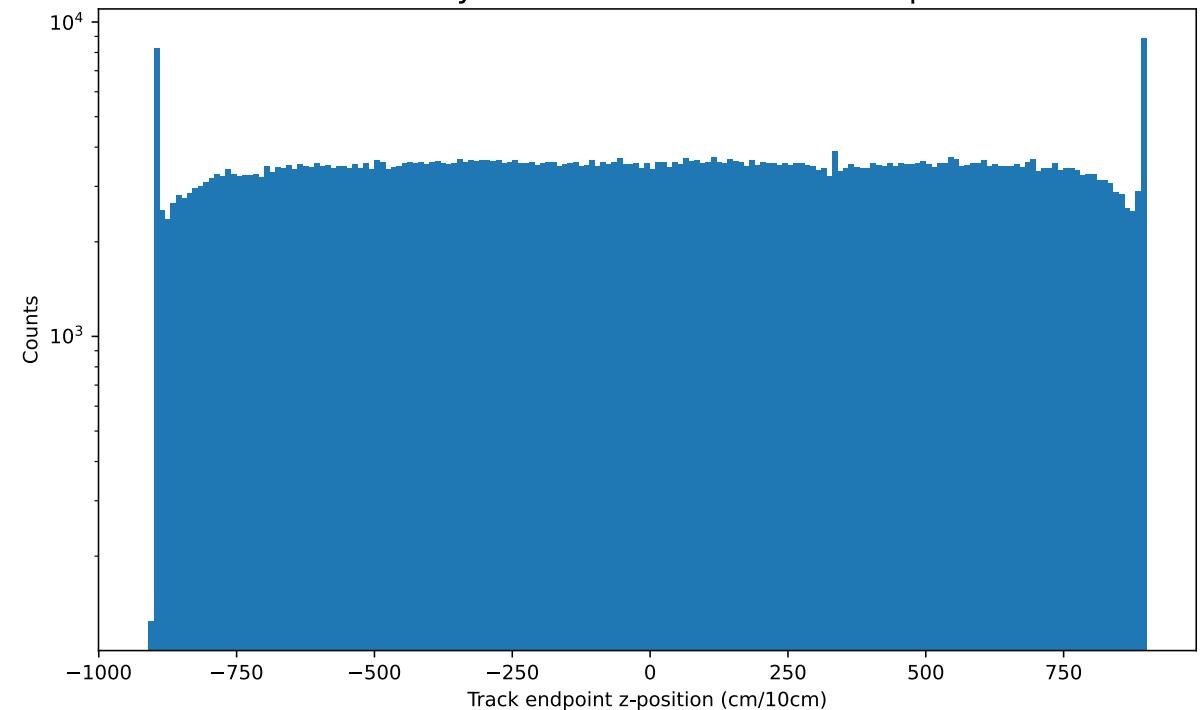
(-15 μ s, 5 μ s) Emulation Window

West Cryostat

Run 7232 Cryo E: Distribution of Track z-position



Run 7232 Cryo W: Distribution of Track z-position



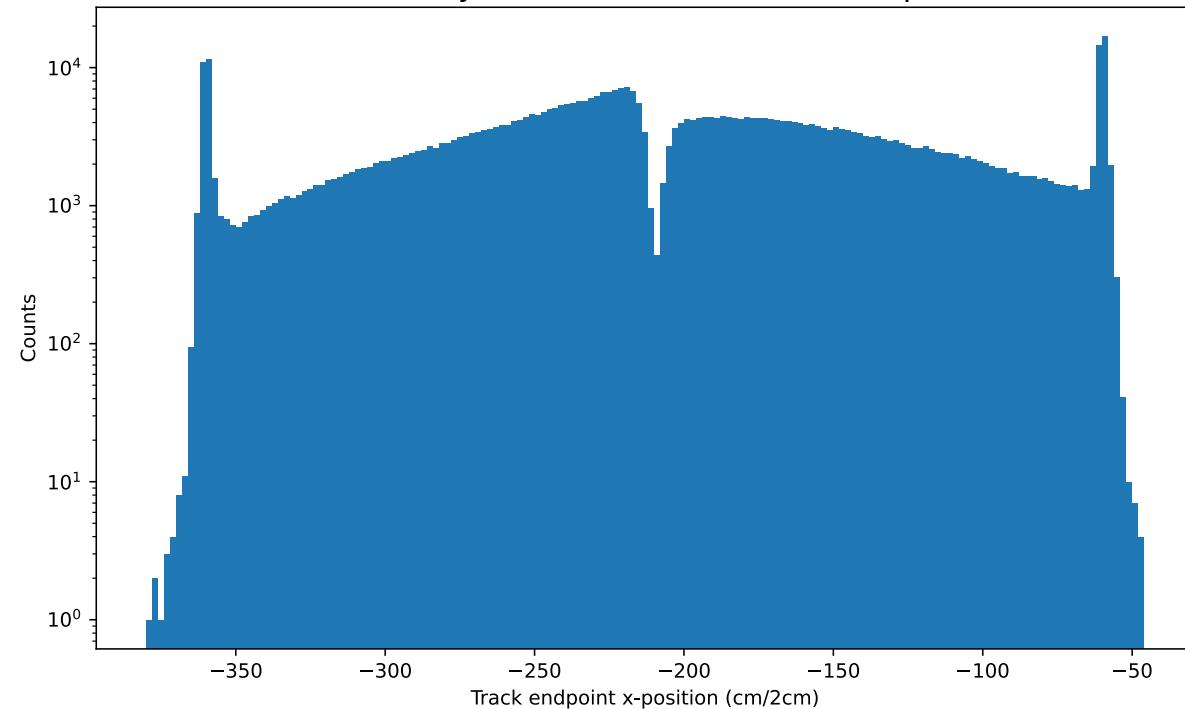
X-axis Track Endpoint Distribution

East Cryostat

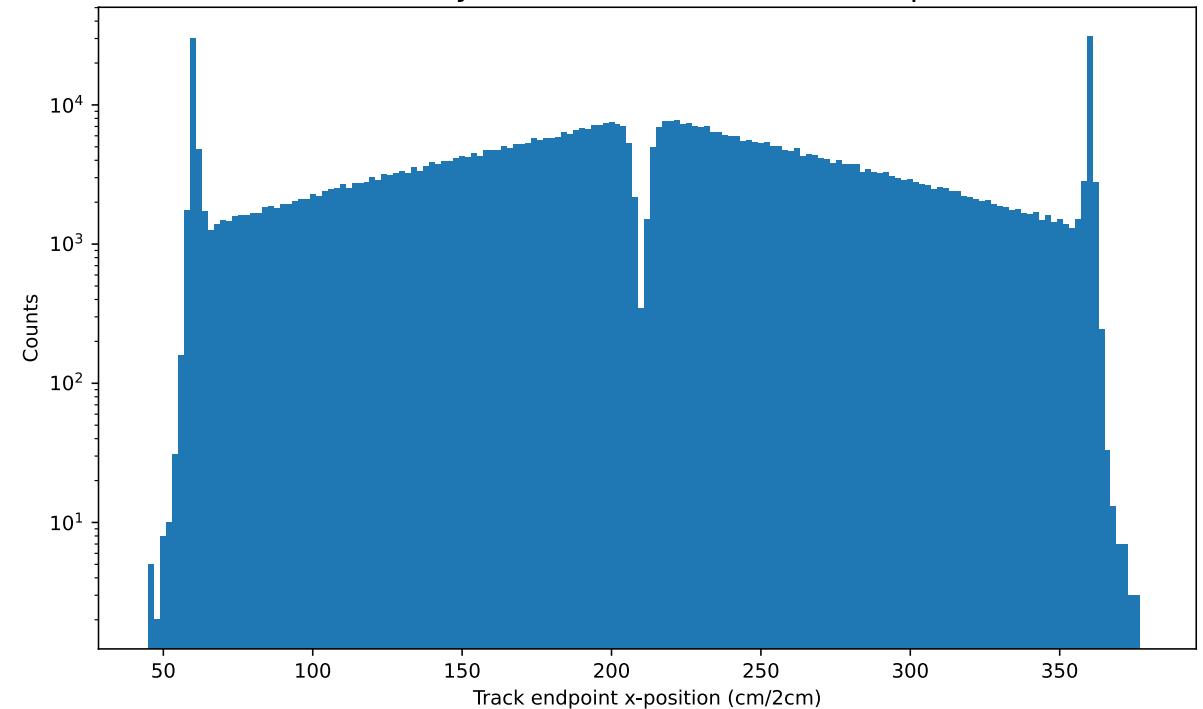
(-15 μ s, 5 μ s) Emulation Window

West Cryostat

Run 7232 Cryo E: Distribution of Track x-position

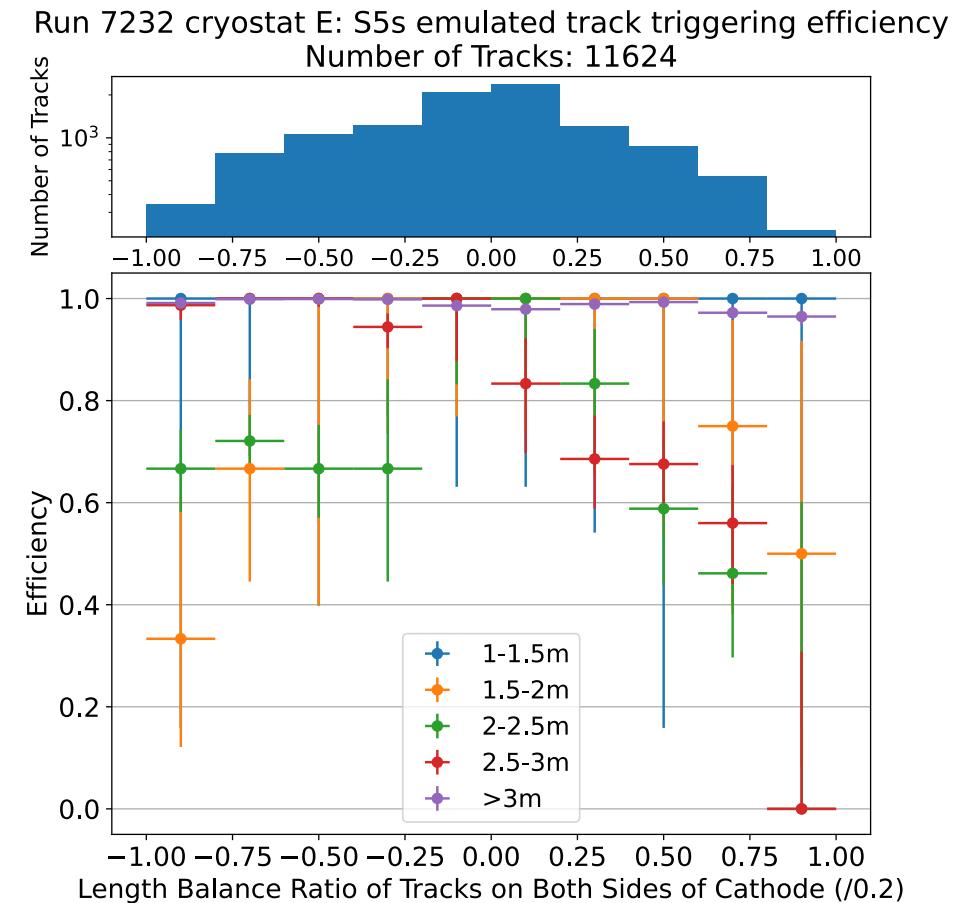
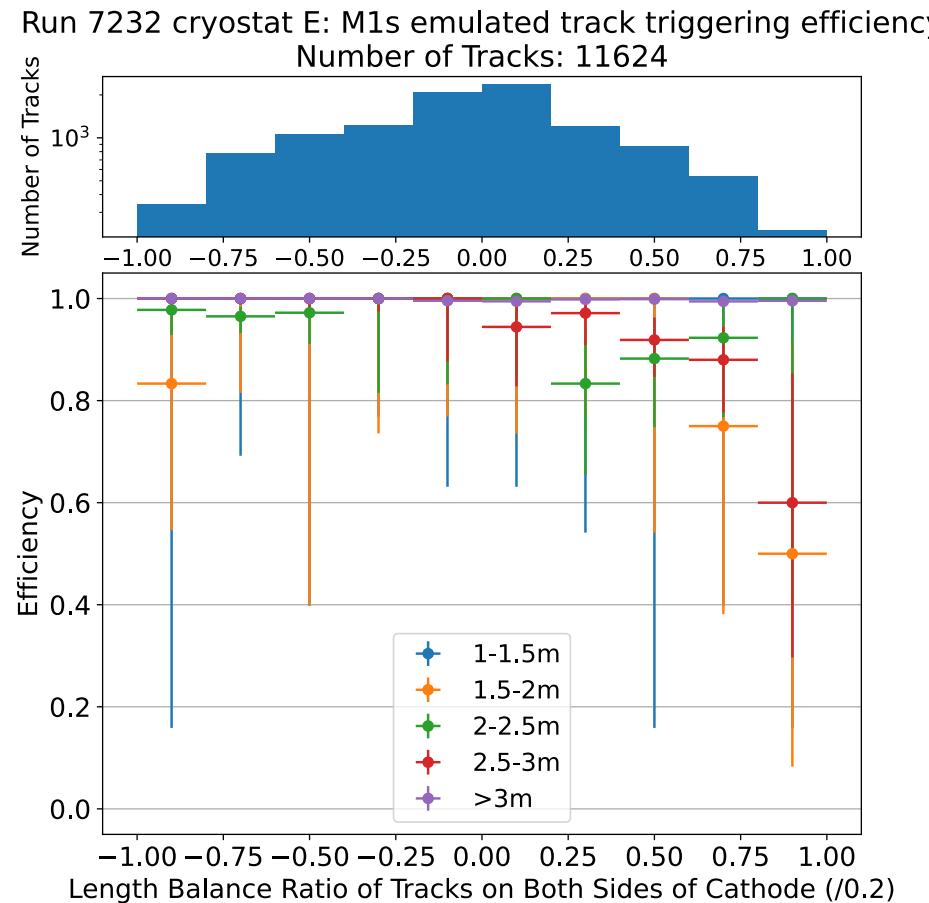


Run 7232 Cryo W: Distribution of Track x-position



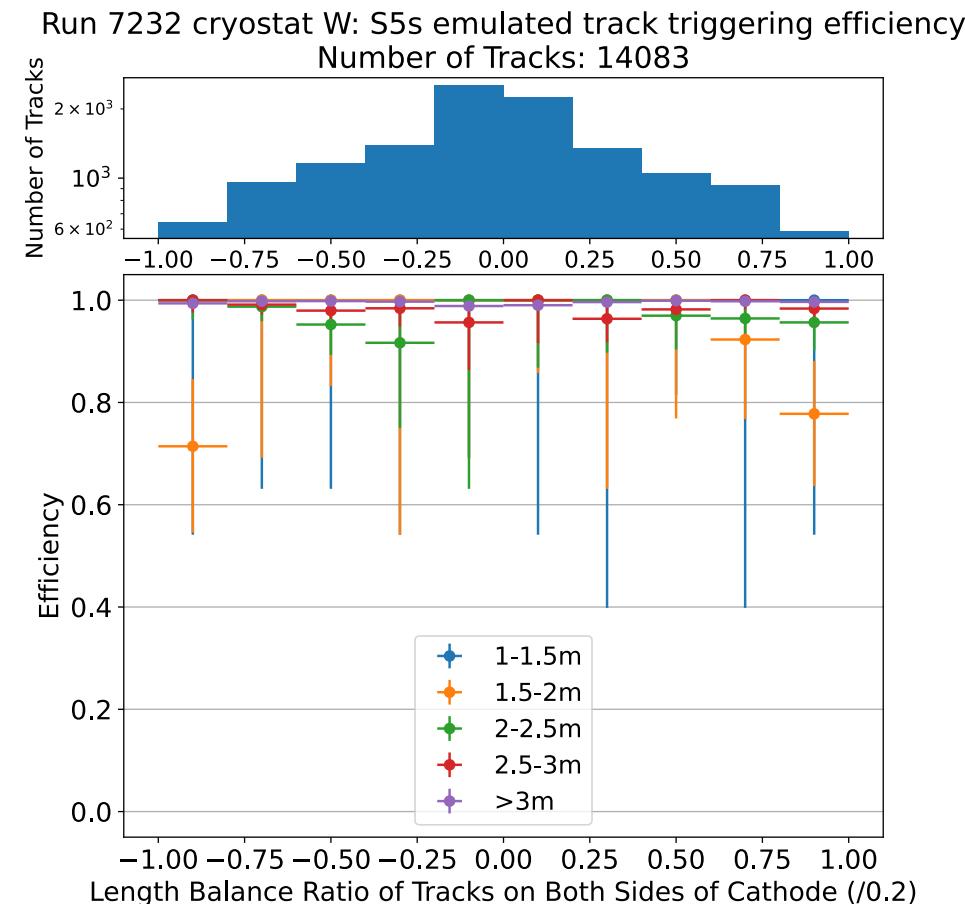
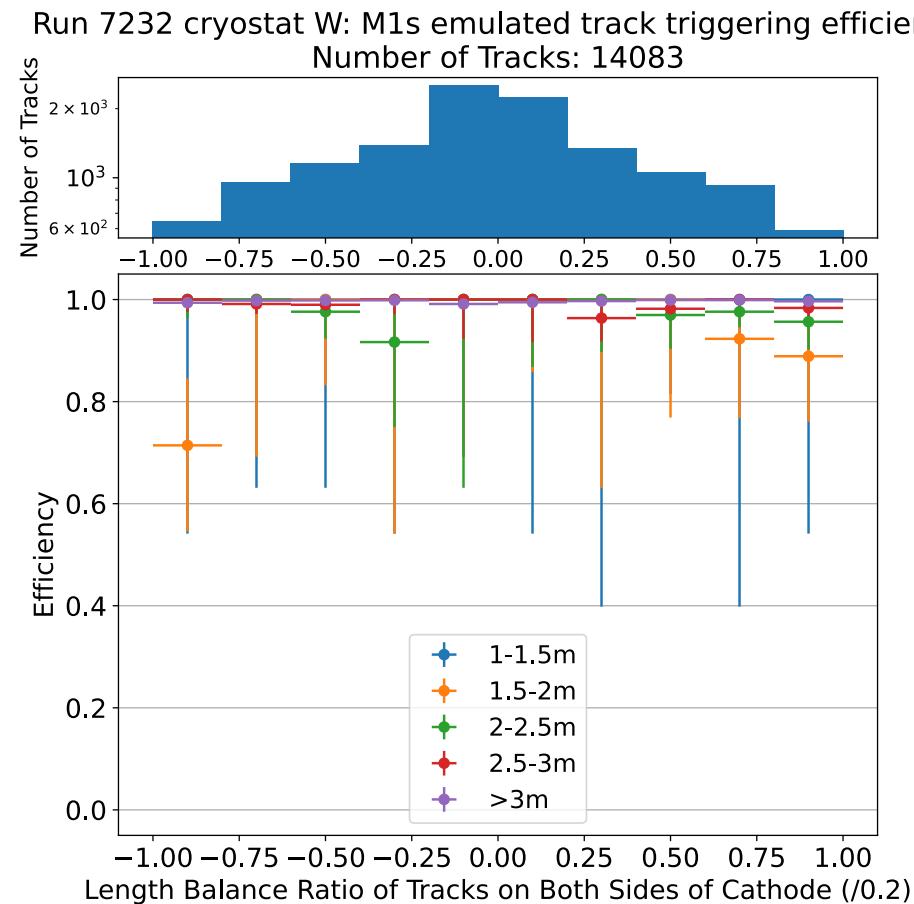
Length Balance Ratio of Complete Tracks – Cryostat E

(-20 μ s, 0 μ s) Emulation Window



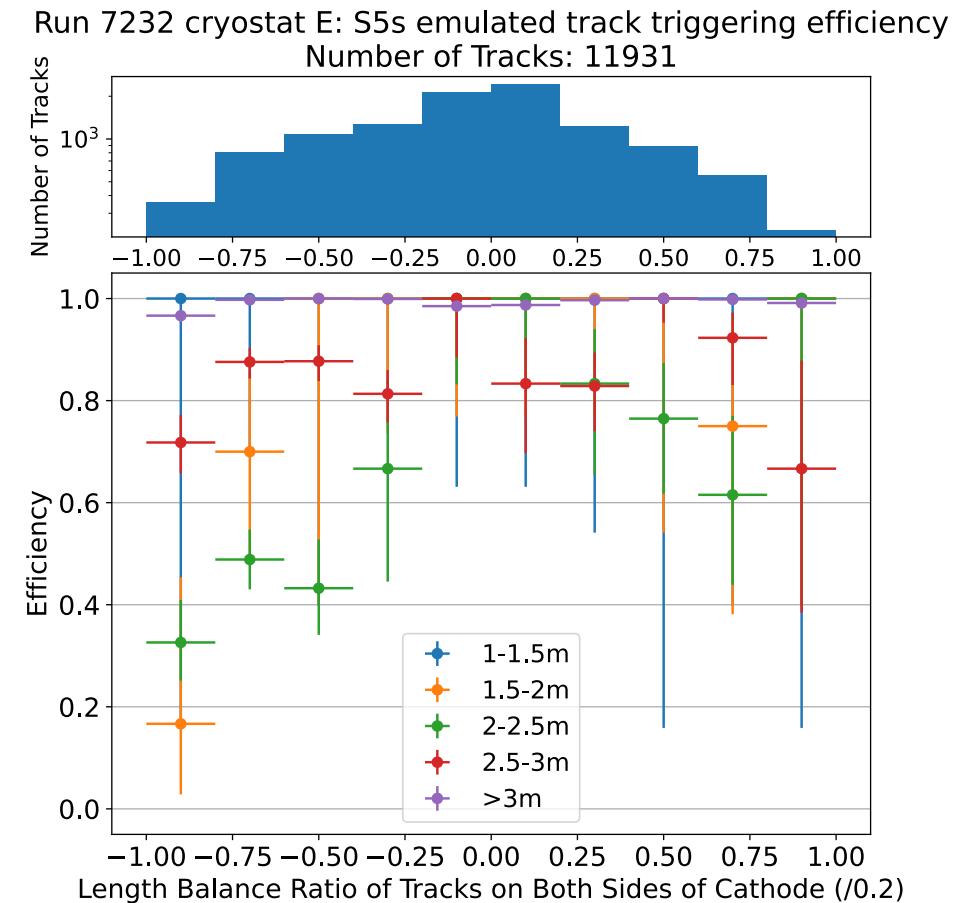
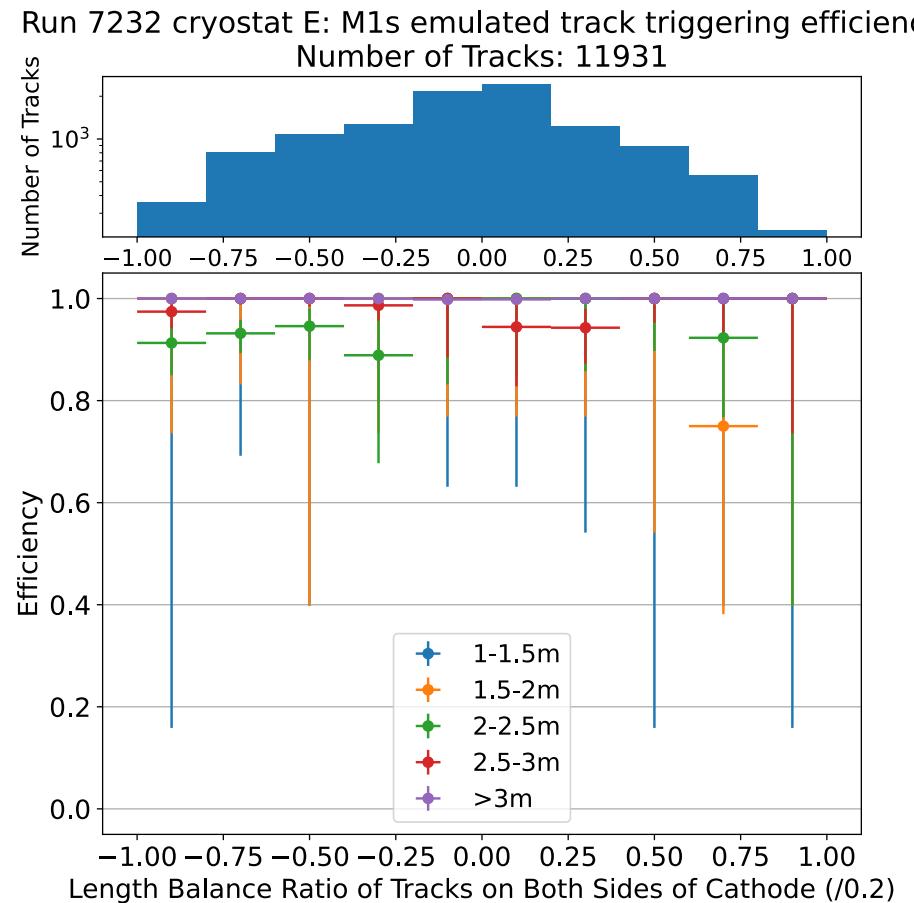
Length Balance Ratio of Complete Tracks – Cryostat W

(-20 μ s, 0 μ s) Emulation Window



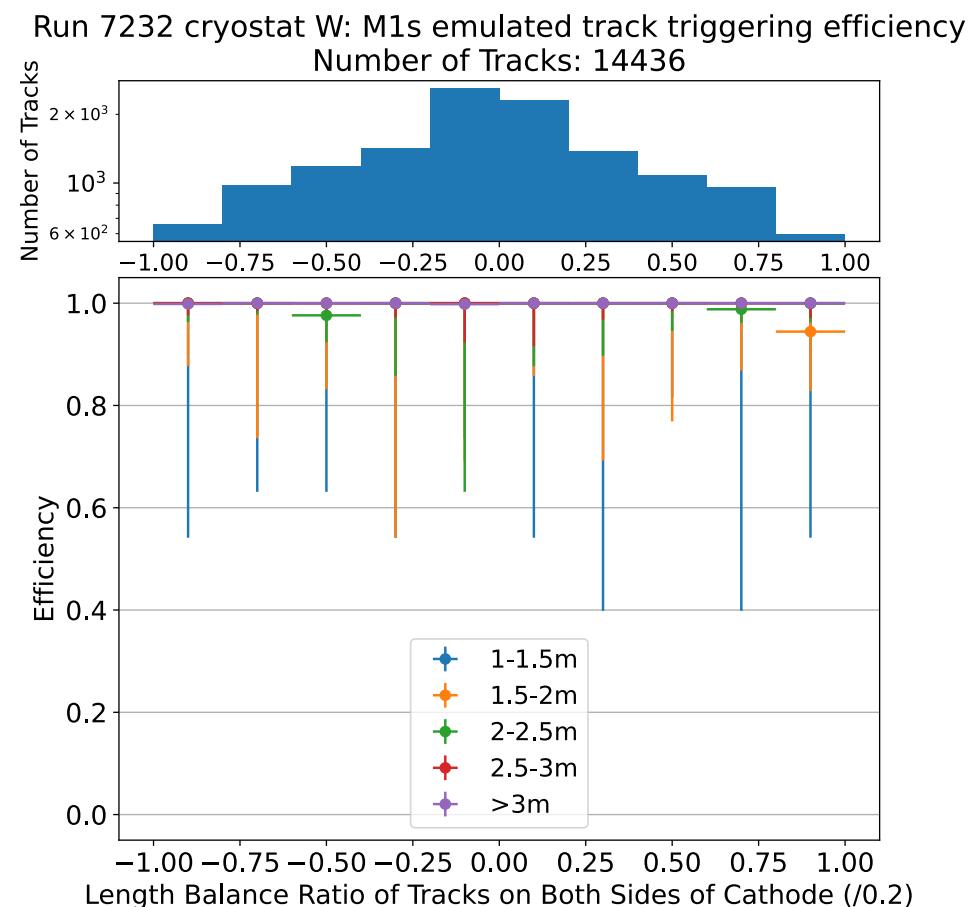
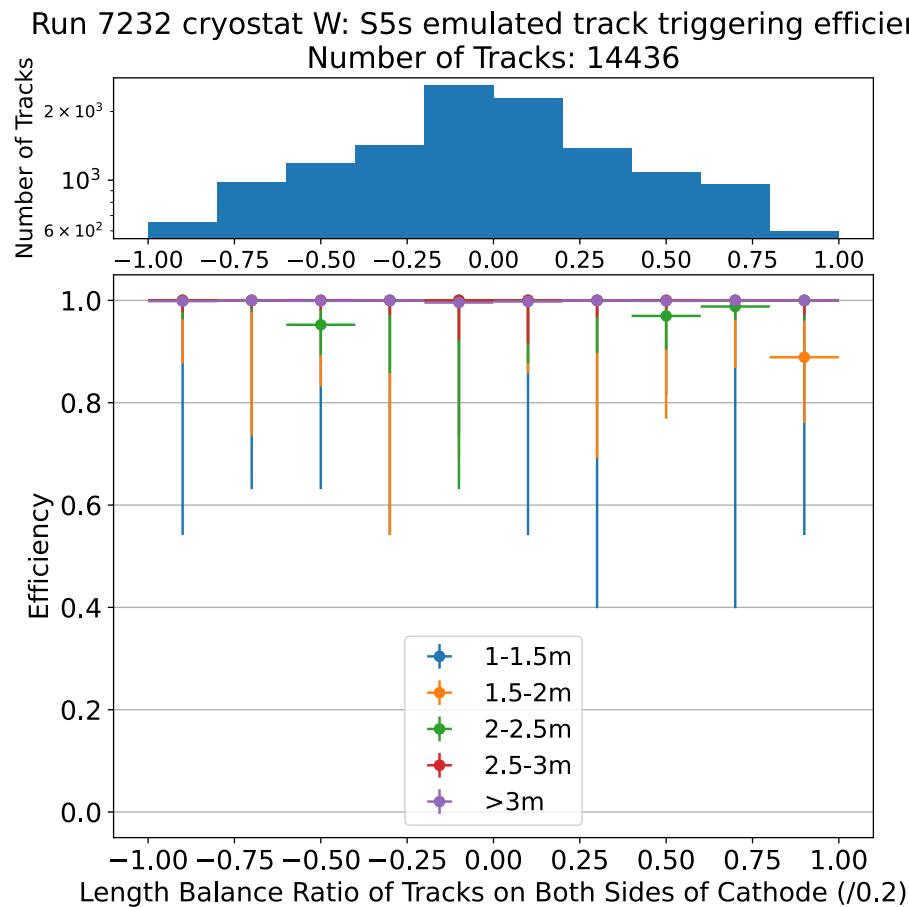
Length Balance Ratio of Complete Tracks – Cryostat E

(-15 μ s, 5 μ s) Emulation Window



Length Balance Ratio of Complete Tracks – Cryostat W

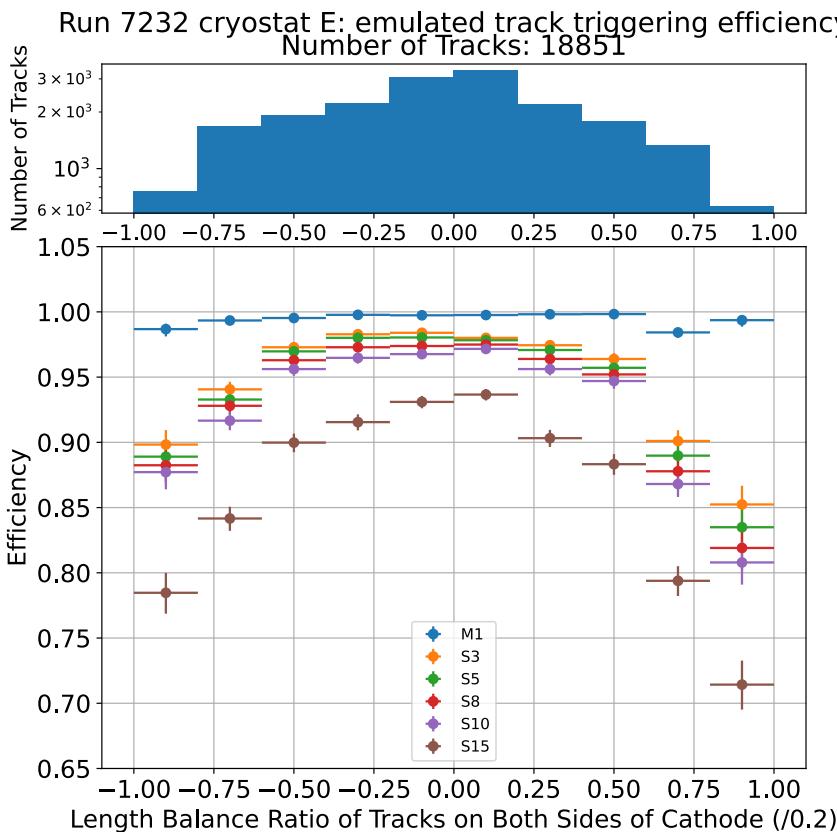
(-15 μ s, 5 μ s) Emulation Window



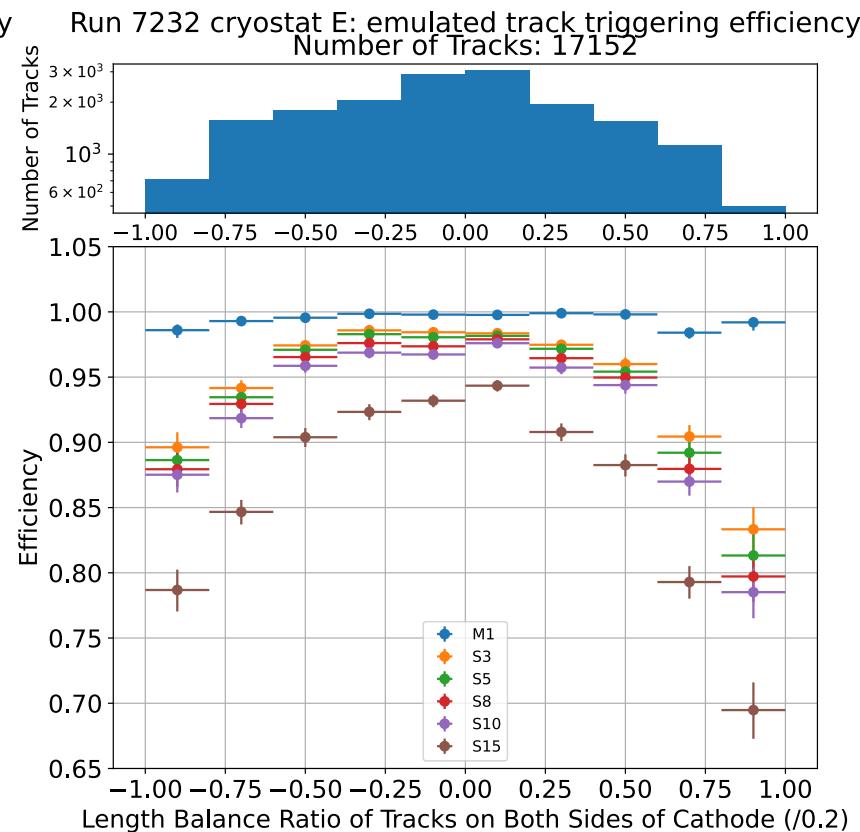
Balance Ratio of Tracks – Cryostat E

(-15 μ s, 5 μ s) Emulation Window

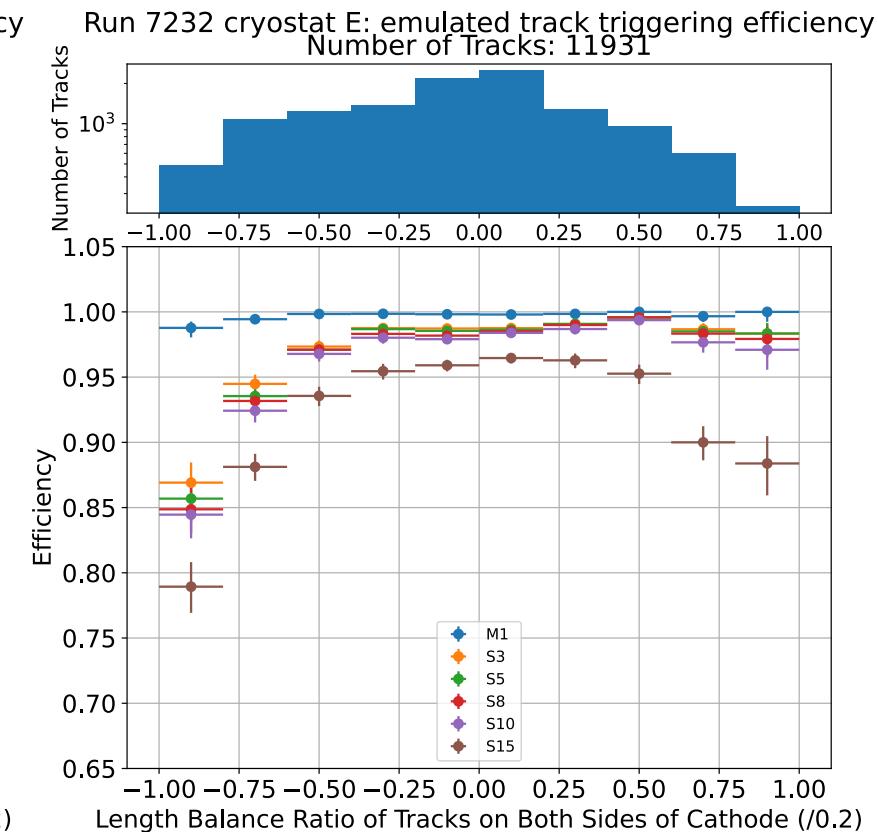
All Tracks



Entering Tracks



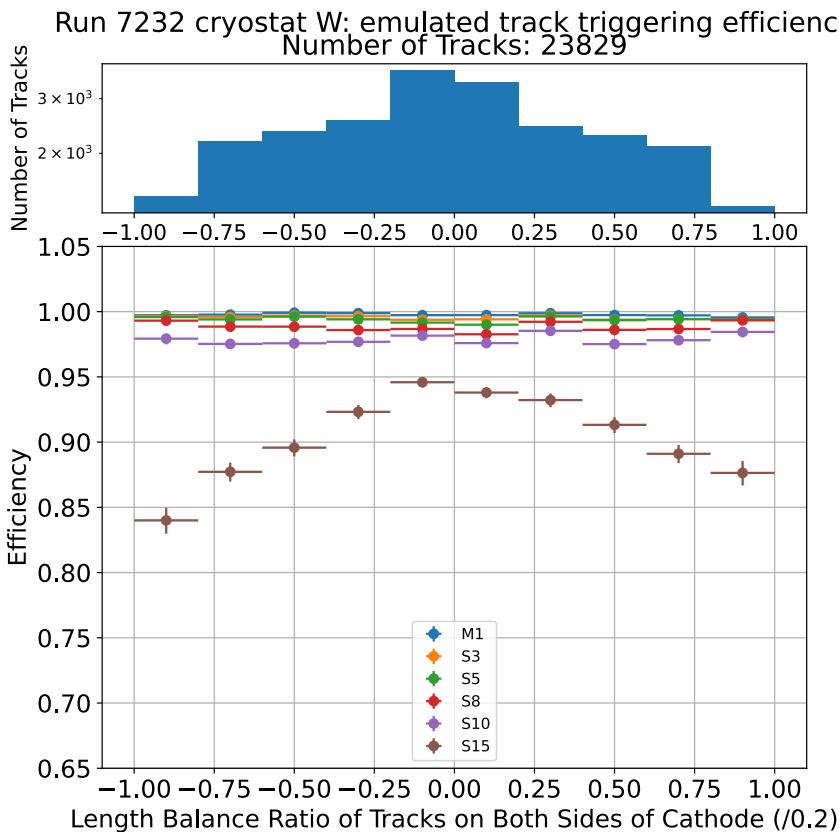
Complete Tracks



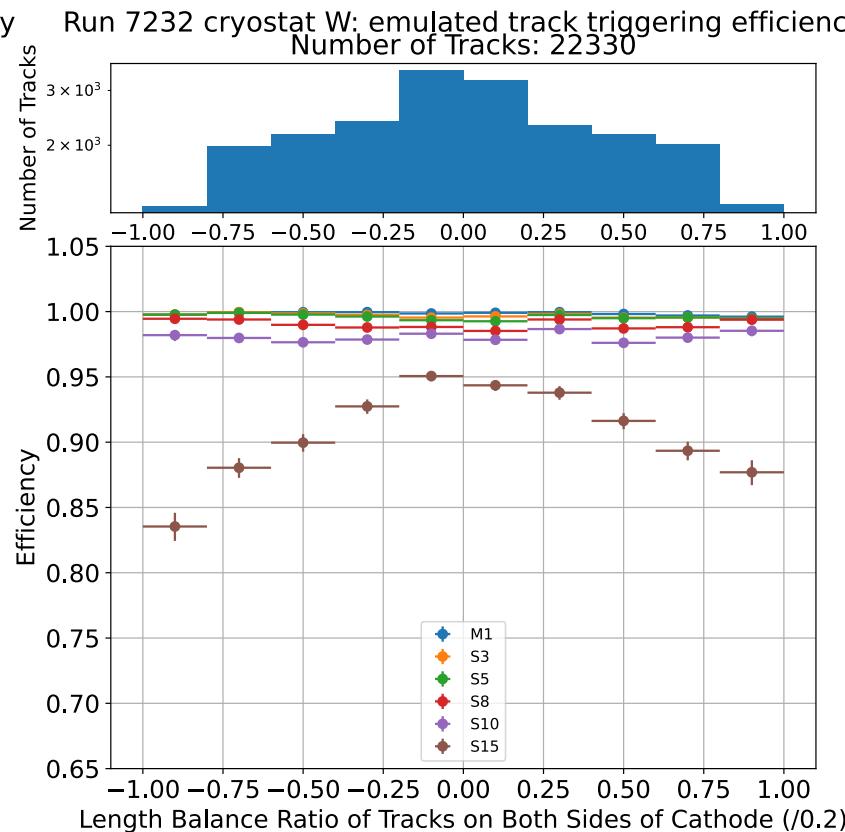
Balance Ratio of Tracks – Cryostat W

(-15 μ s, 5 μ s) Emulation Window

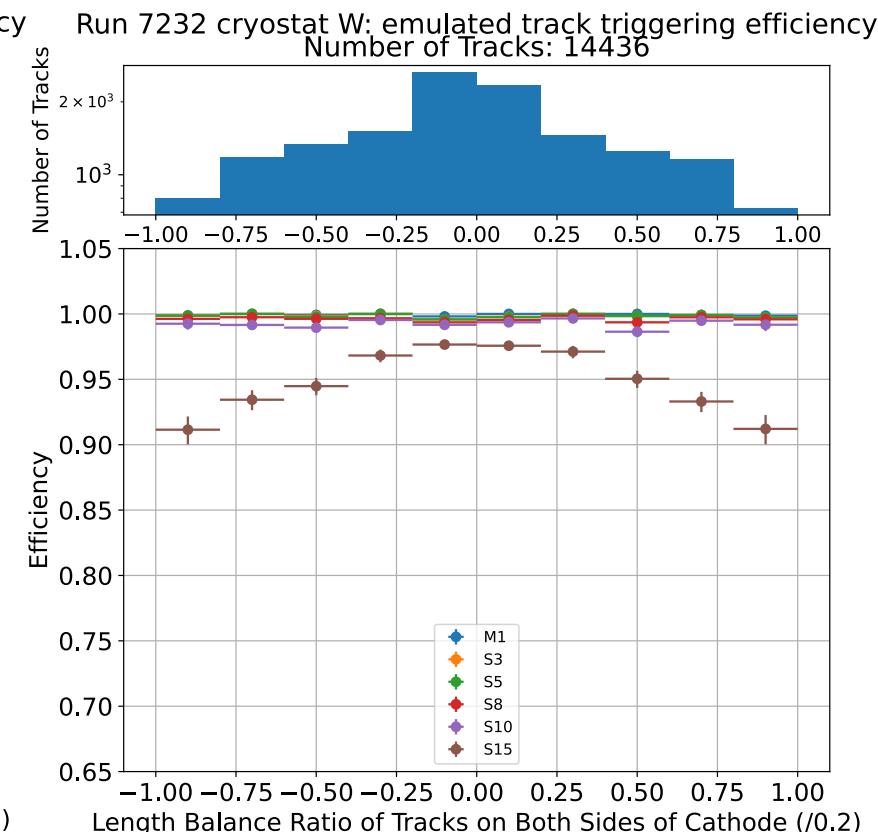
All Tracks



Entering Tracks



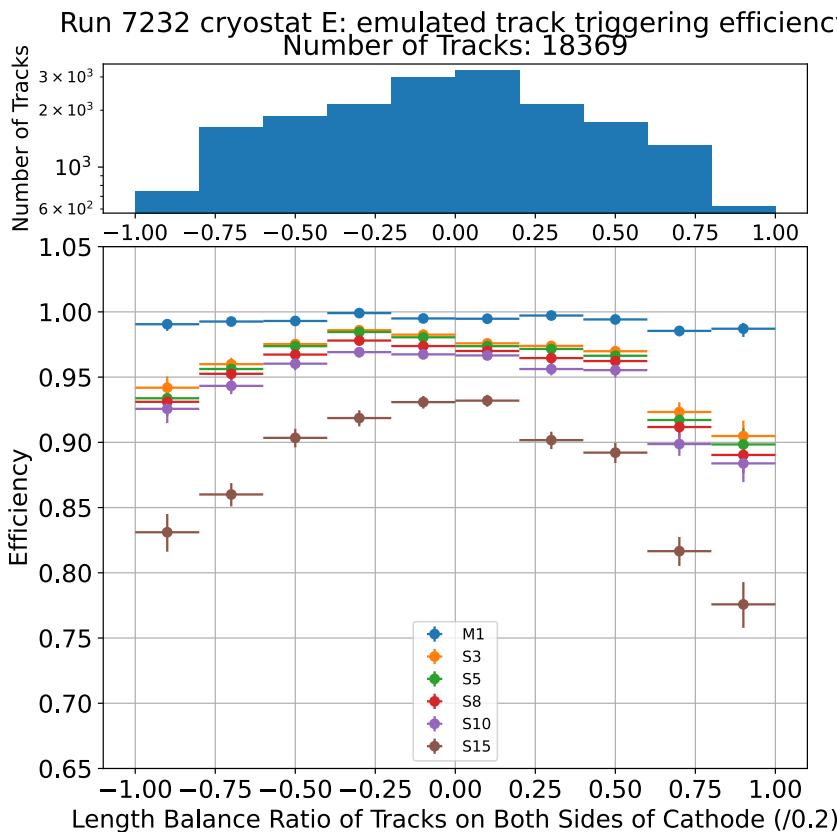
Complete Tracks



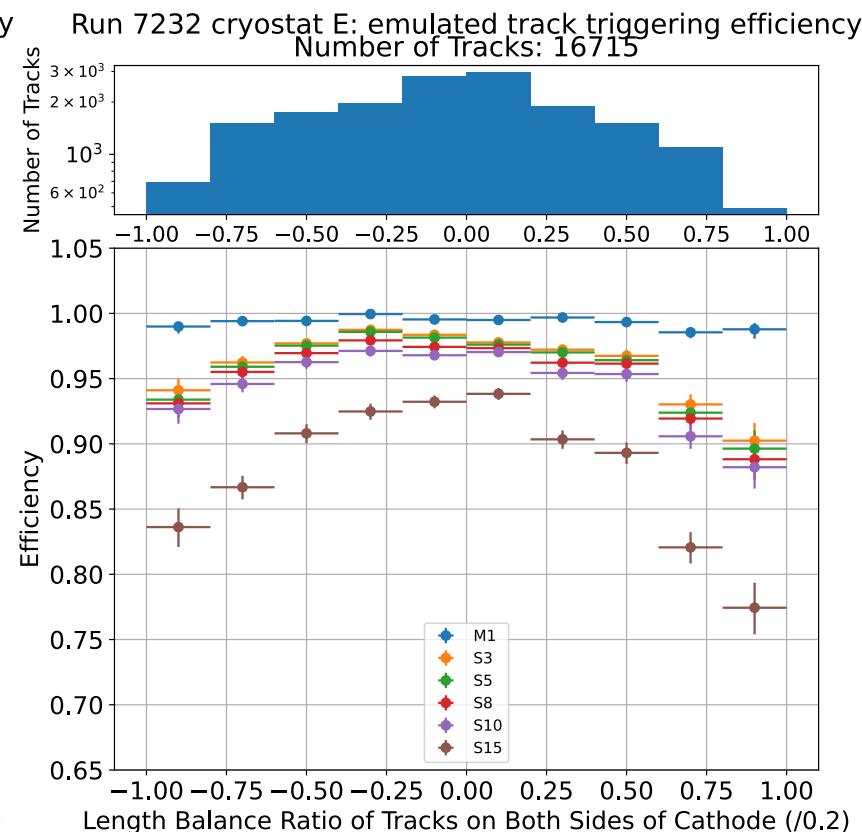
Balance Ratio of Tracks – Cryostat E

(-20 μ s, 0 μ s) Emulation Window

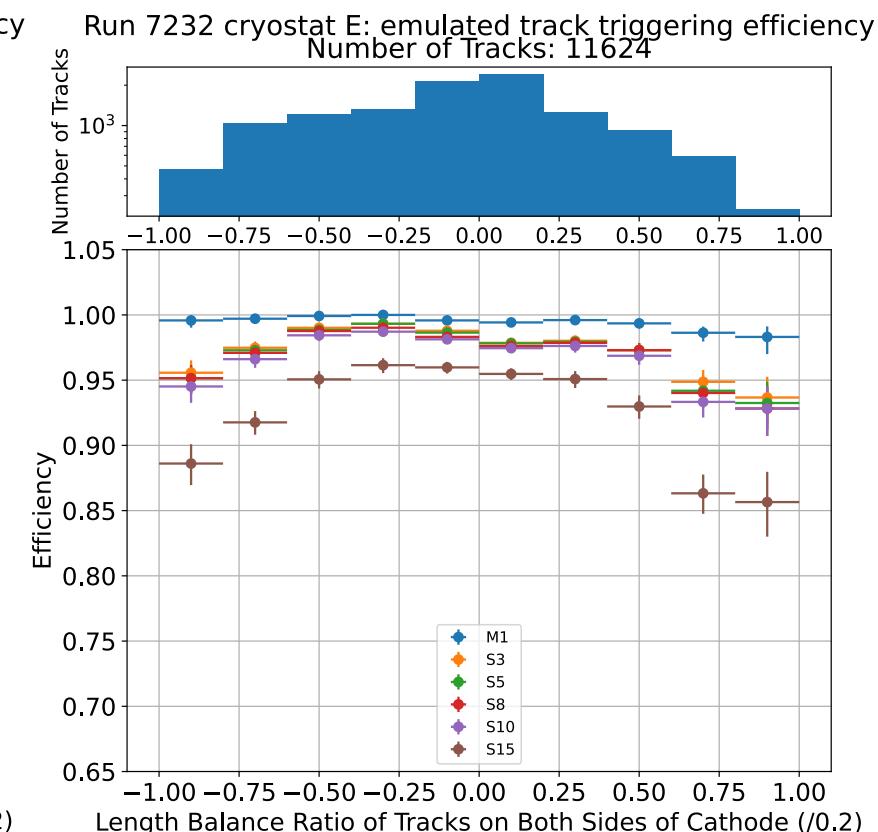
All Tracks



Entering Tracks



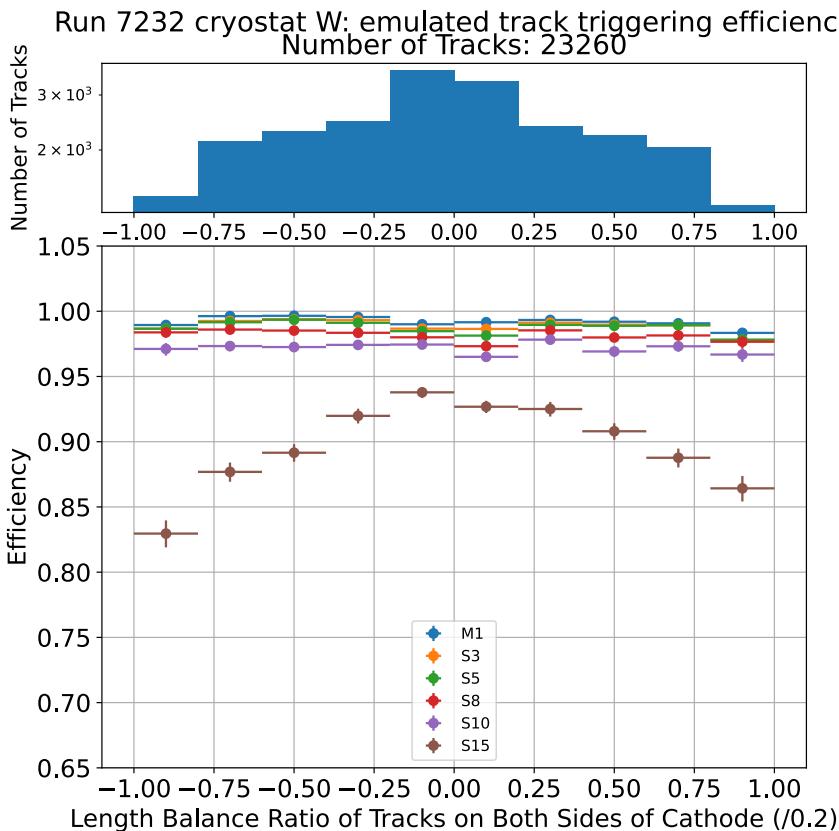
Complete Tracks



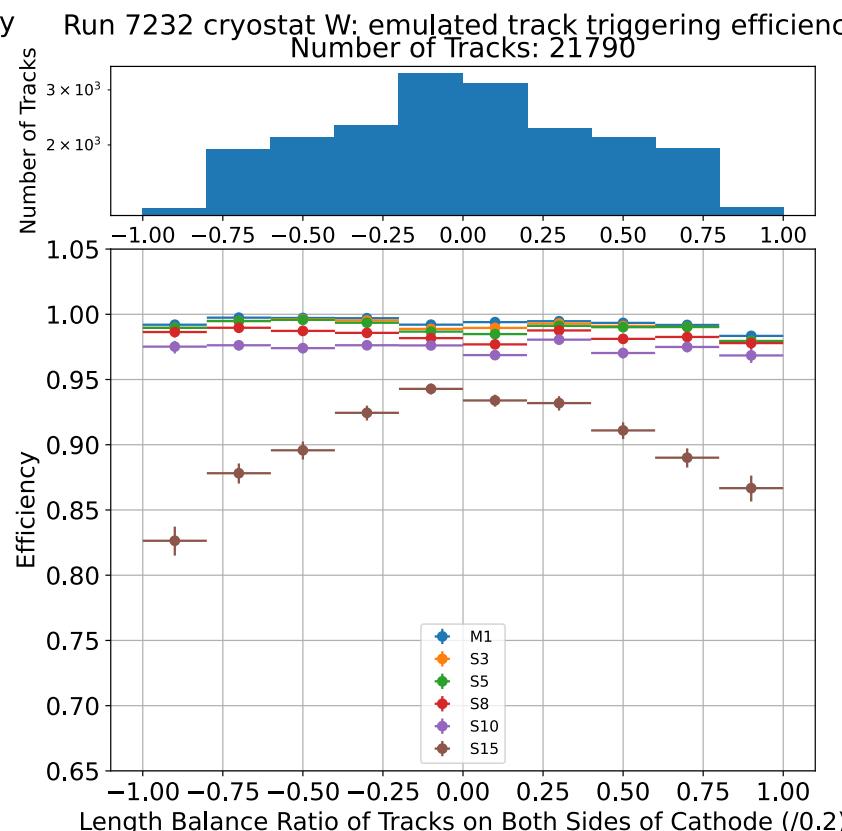
Balance Ratio of Tracks – Cryostat W

(-20 μ s, 0 μ s) Emulation Window

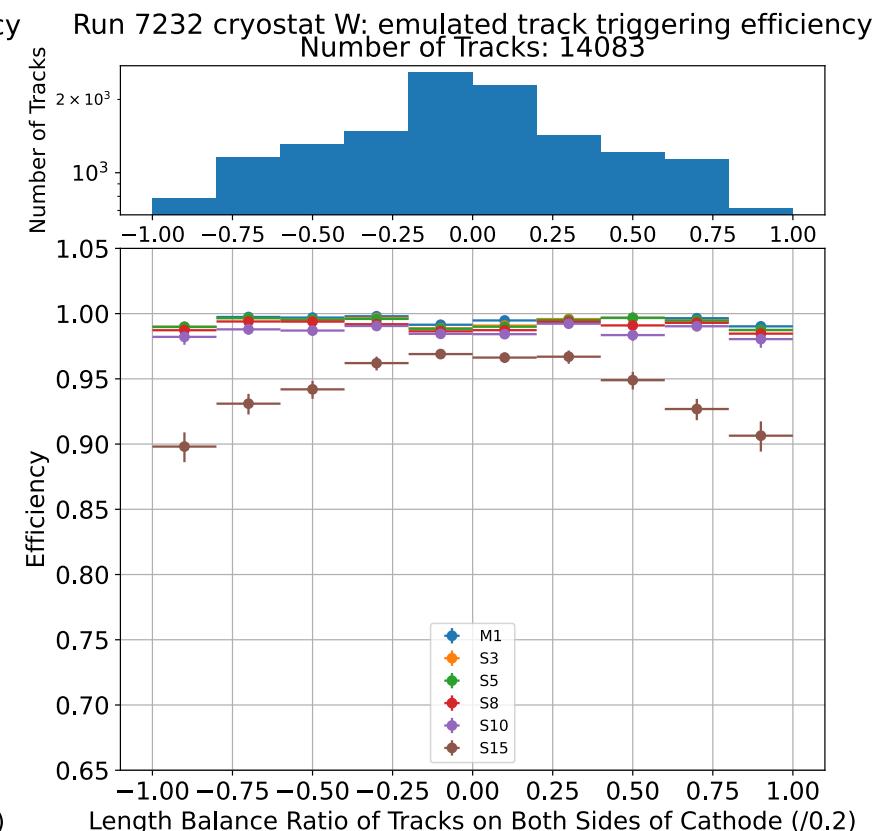
All Tracks



Entering Tracks



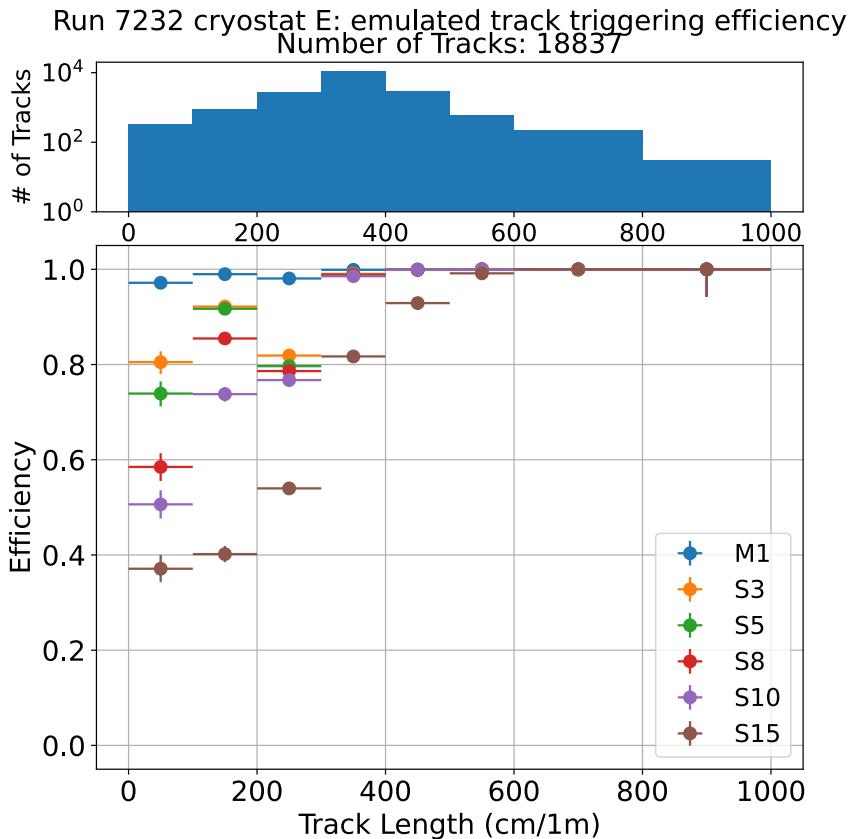
Complete Tracks



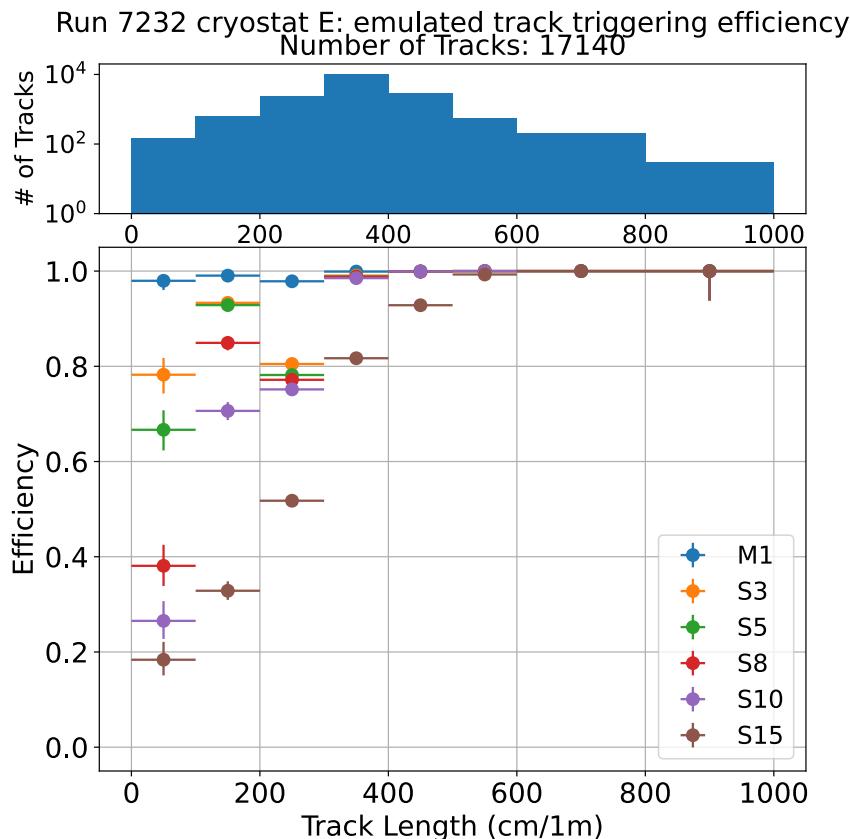
Track Length – Cryostat E

(-15 μ s, 5 μ s) Emulation Window

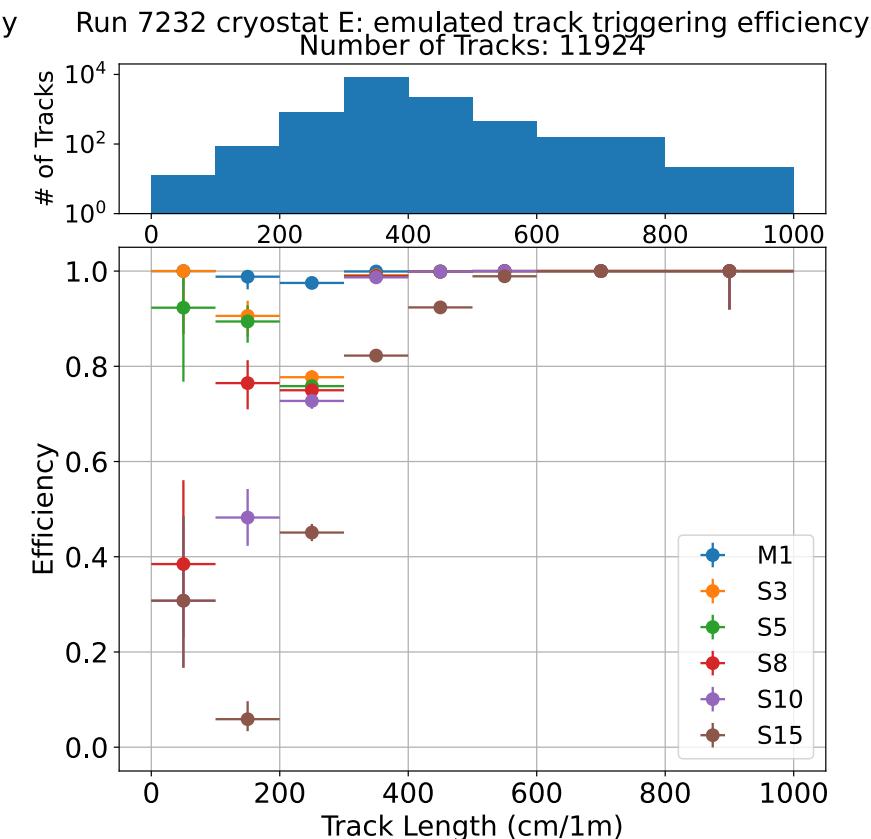
All Tracks



Entering Tracks



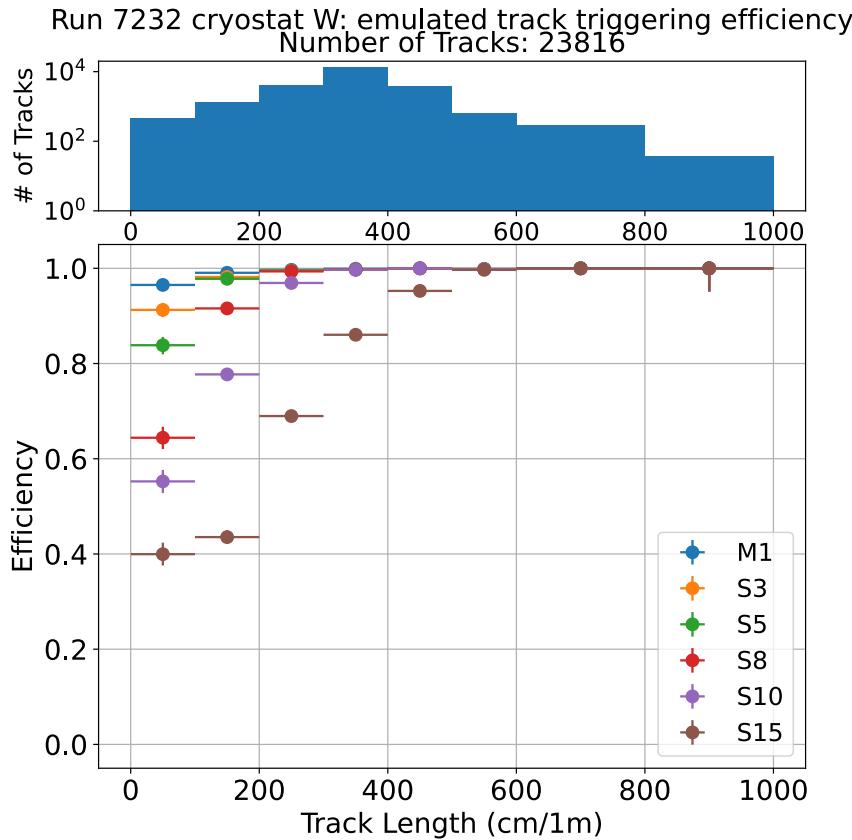
Complete Tracks



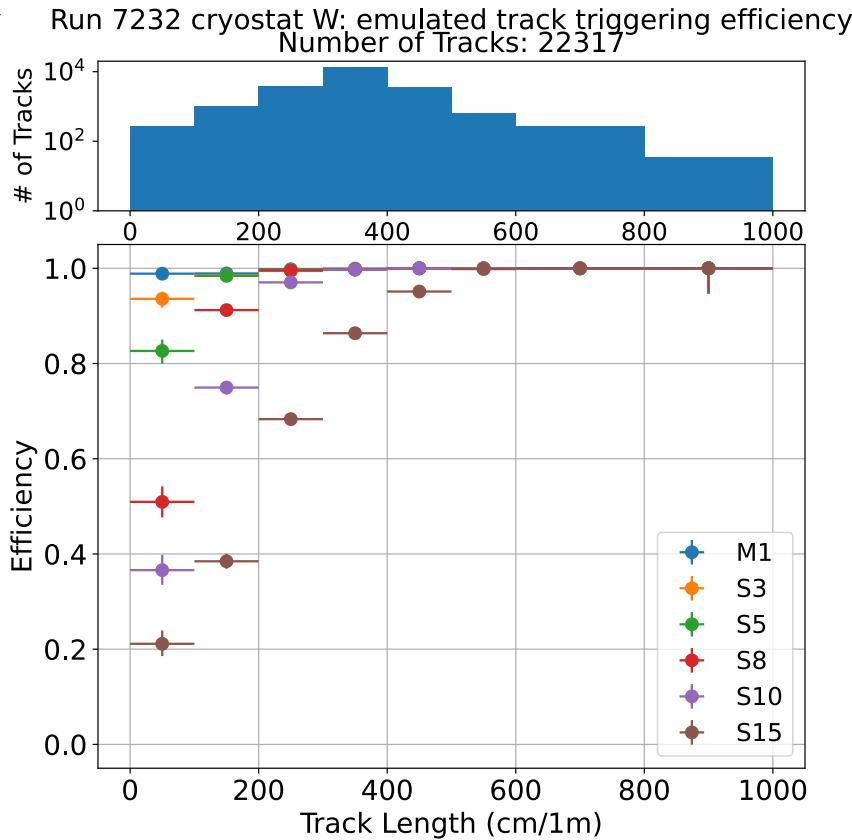
Track Length – Cryostat W

(-15 μ s, 5 μ s) Emulation Window

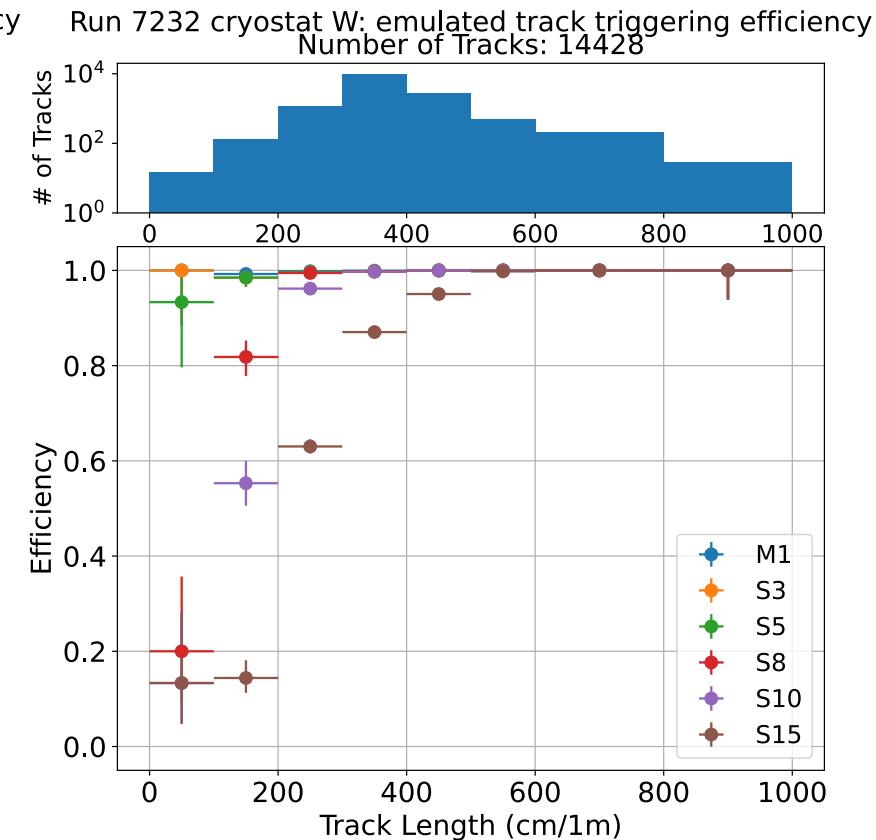
All Tracks



Entering Tracks



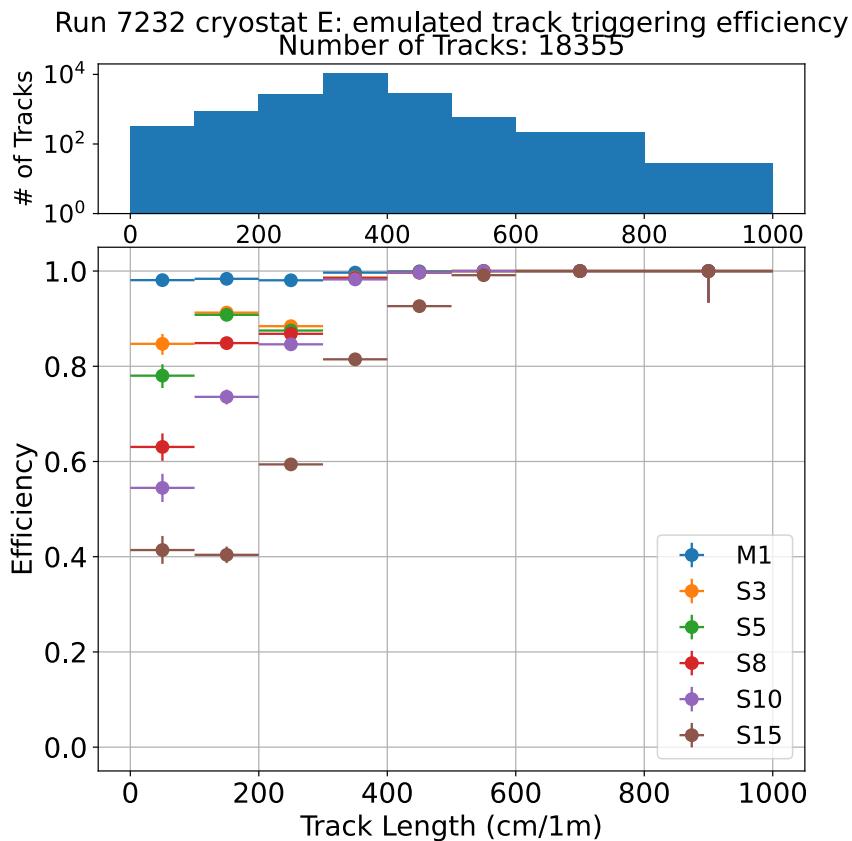
Complete Tracks



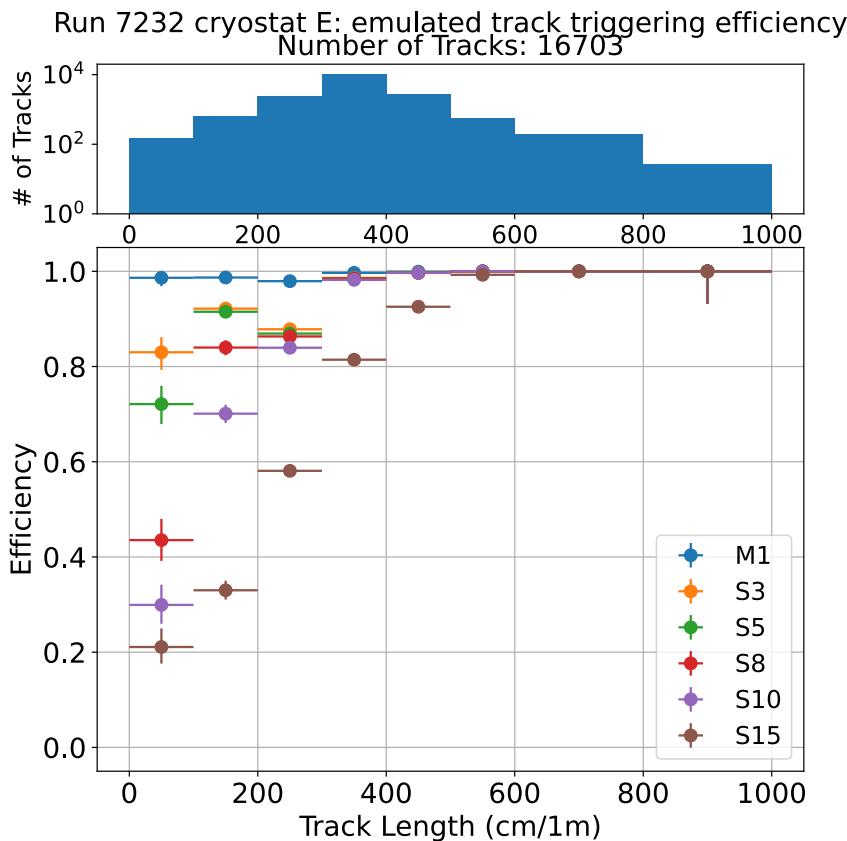
Track Length – Cryostat E

(-20 μ s, 0 μ s) Emulation Window

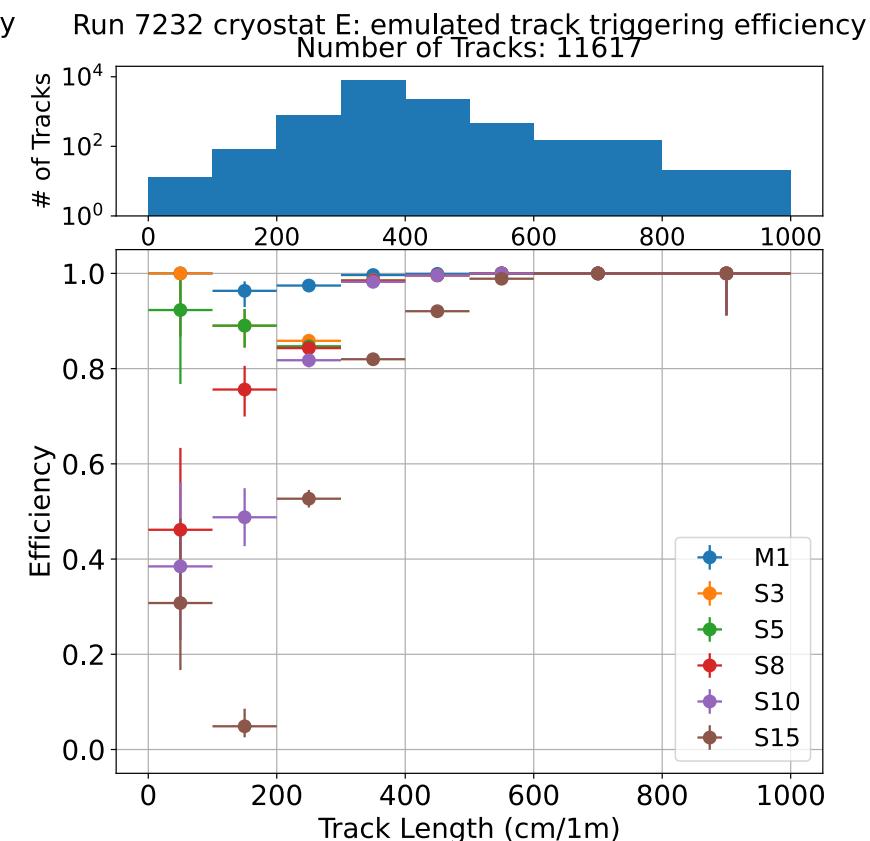
All Tracks



Entering Tracks



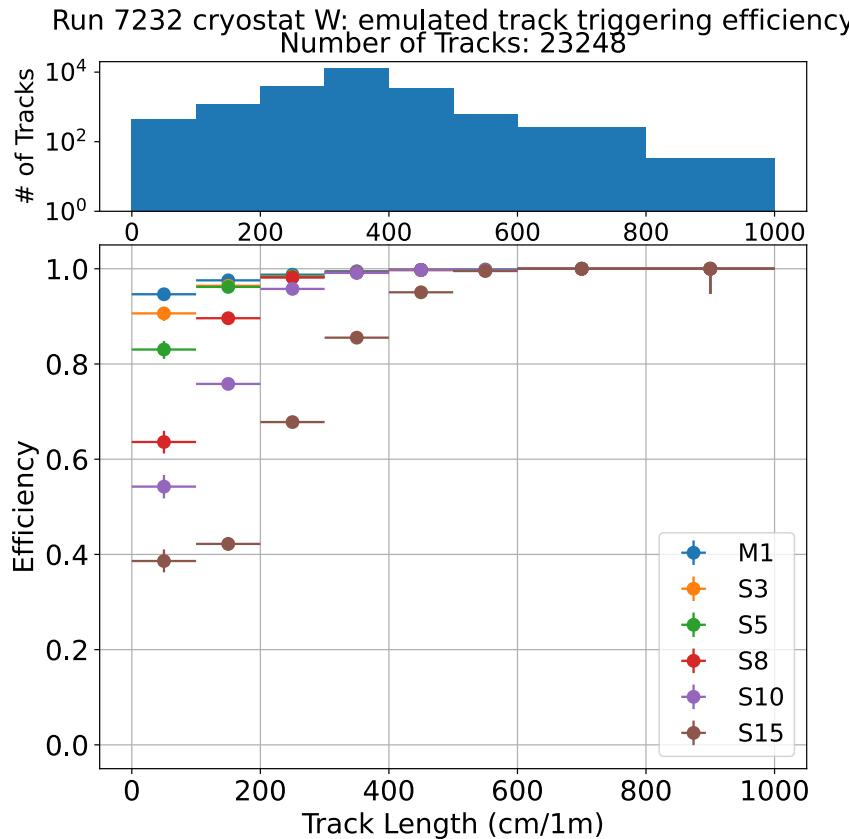
Complete Tracks



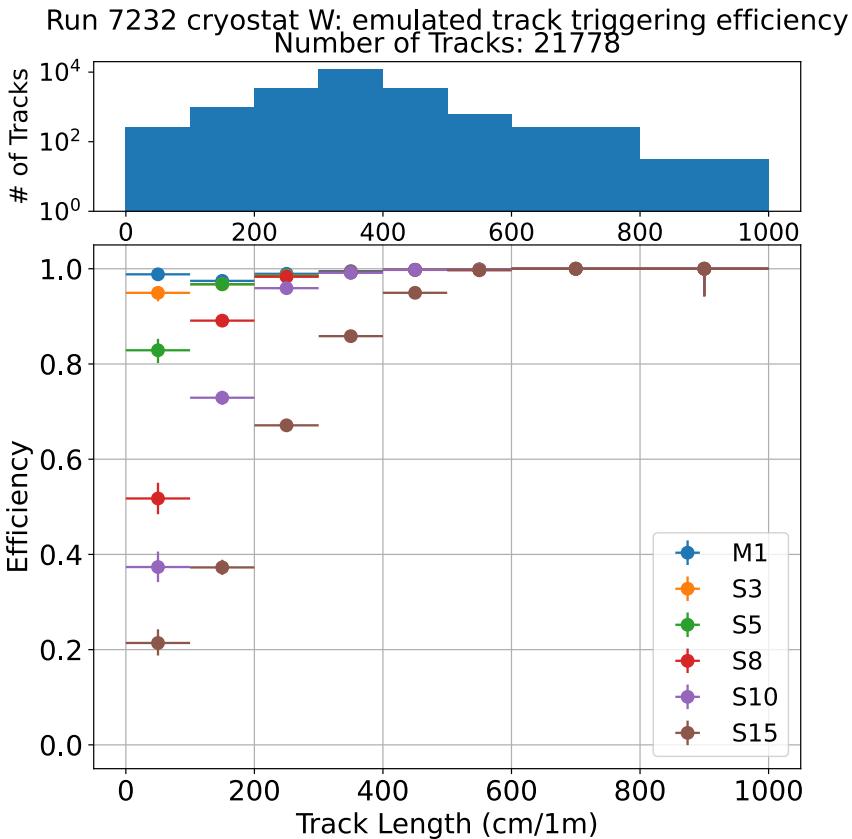
Track Length – Cryostat W

(-20 μ s, 0 μ s) Emulation Window

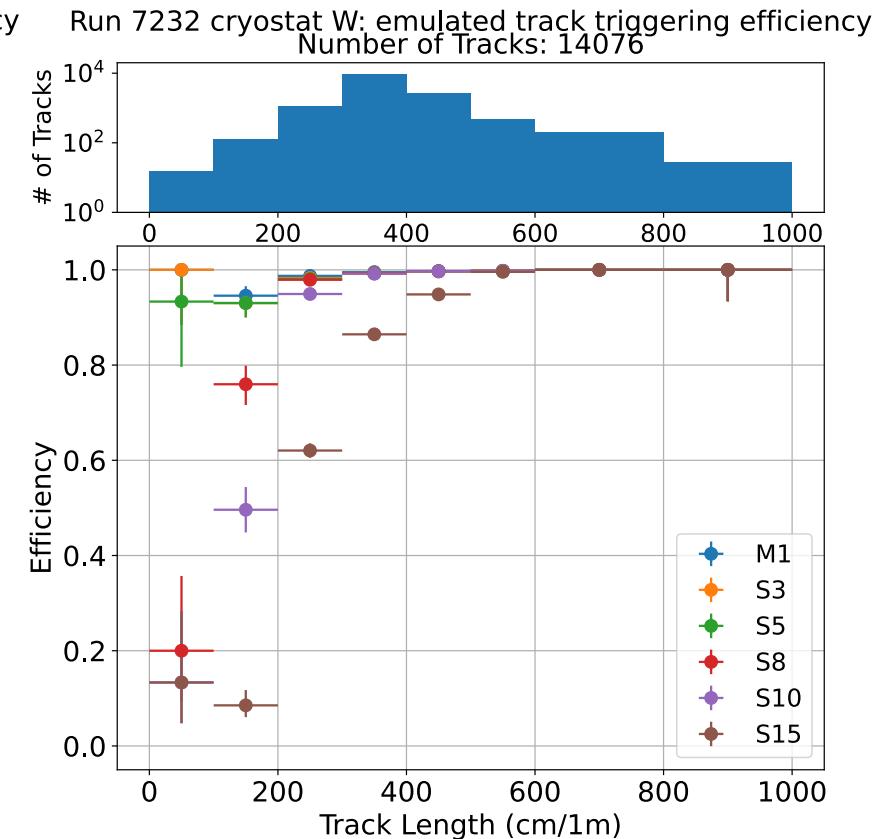
All Tracks



Entering Tracks



Complete Tracks



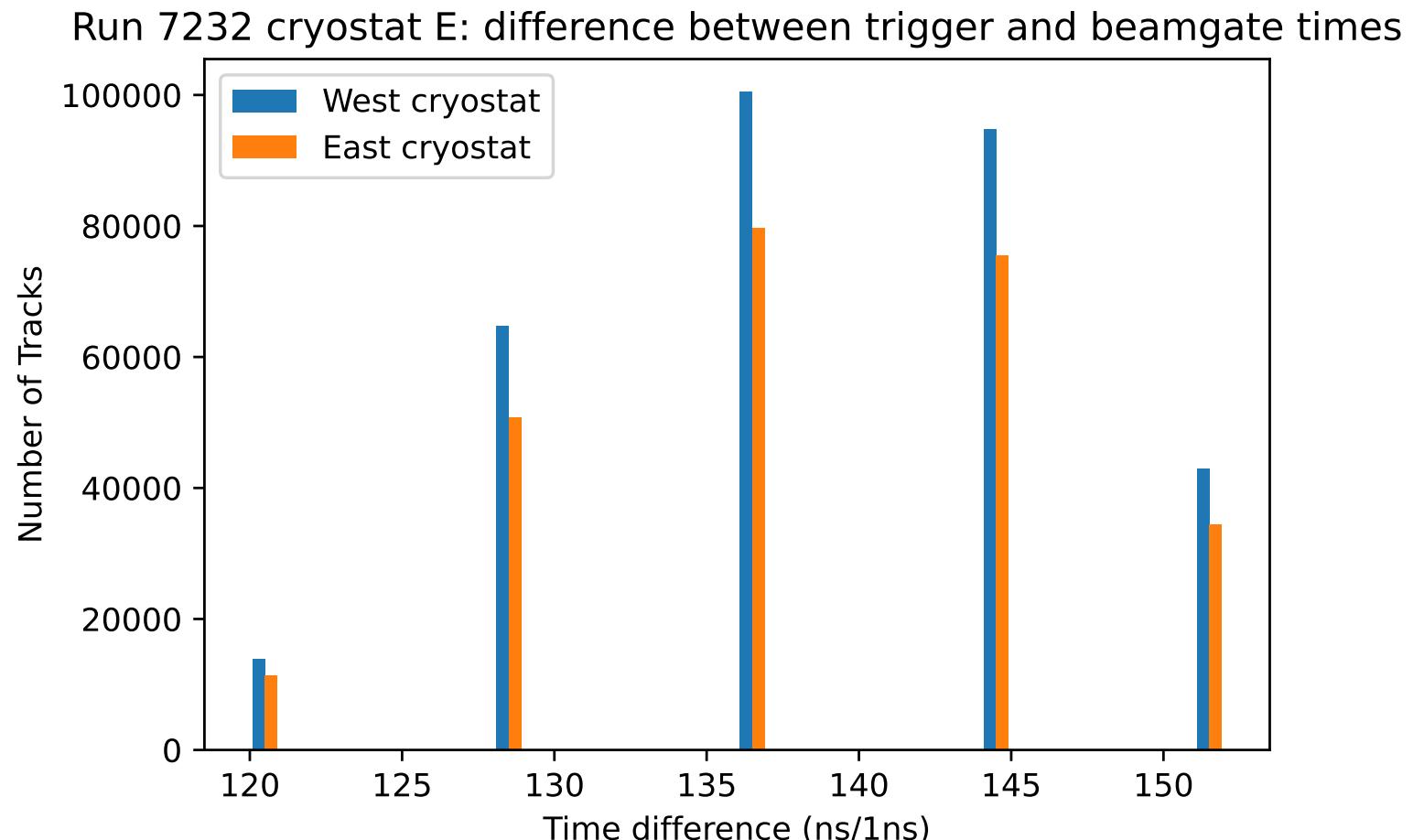
Conclusion/next steps

- CRT sample not ready yet
 - We have time to get comments/suggestions on these plots
- Balance ratio is meant to be a measure of the difference in energy deposition of a track on both sides of the cathode, since we are missing the necessary information in the tree to get a better estimate
 - It would be better to have the intersection point with cathode for each track
 - Or even better, the length or energy of the track on each side of the cathode
- It would be helpful to add trigger emulation with sliding windows
 - This would eliminate the drop in efficiency seen with the starting z-position plots
- The East cryostat and East TPC looked/behaved differently
 - Much fewer tracks primarily in the East TPC of the East cryostat, and a ~10% drop in efficiency
 - Larger drop in efficiency in the East cryostat for track lengths between 200 – 240 cm

Additional Slides

Time Difference between nominal trigger and beam gate

Time difference has 5 possible values, spaced 8 ns apart, from 120 ns to 152 ns. The mean time difference between nominal trigger and beam gate is 138.2 ns. This time difference is due to hardware delays.



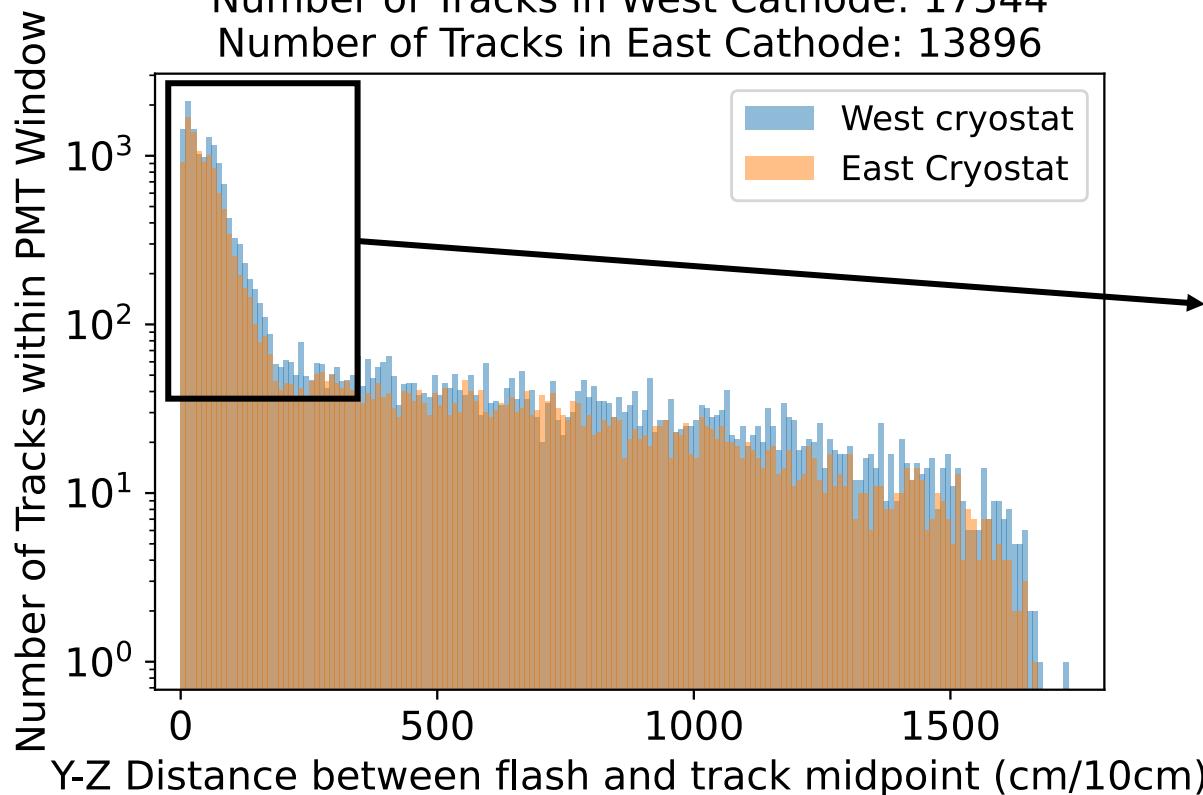
Matching by Time of Flashes and Tracks

- Pick the flash whose time is closest to the corresponding track and within ($t_0 - 40 \mu\text{s}$, $t_0 + 20 \mu\text{s}$)
 - We chose this based on the width of the time difference peak when tracks and flashes were matched by time
- Below is plotted distance between flashes and midpoints of tracks

Run 7232: Distance between Tracks and Flashes

Number of Tracks in West Cathode: 17544

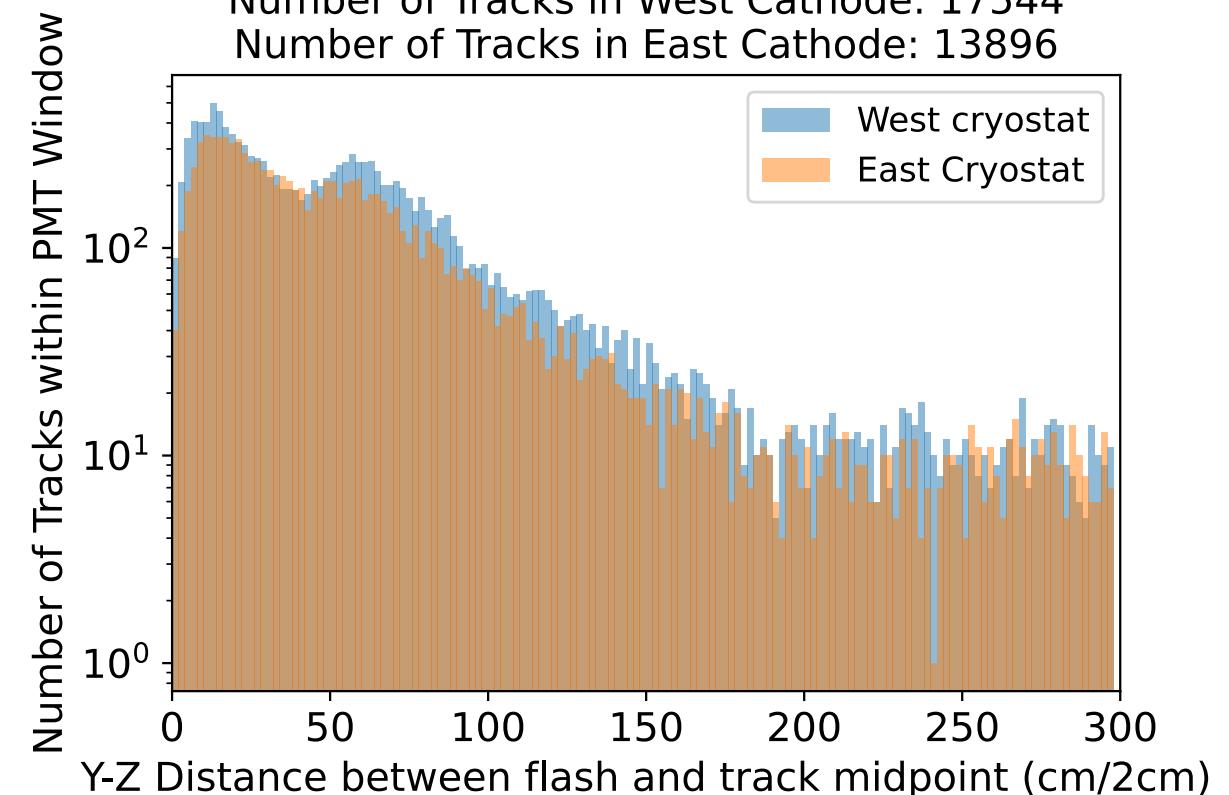
Number of Tracks in East Cathode: 13896



Run 7232: Distance between Tracks and Flashes

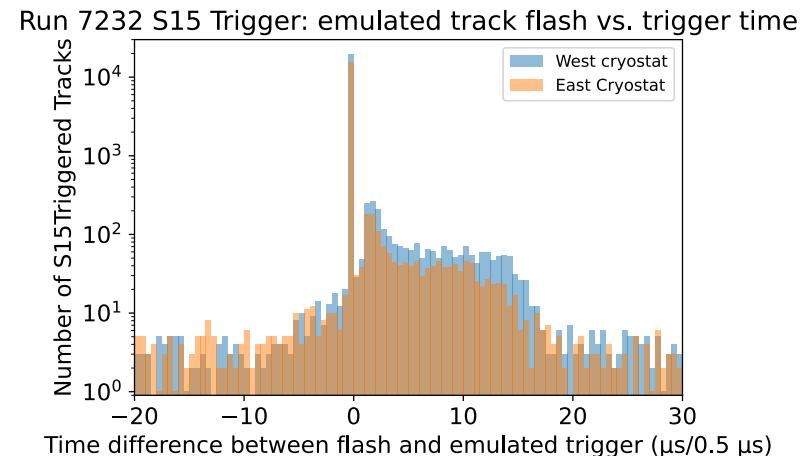
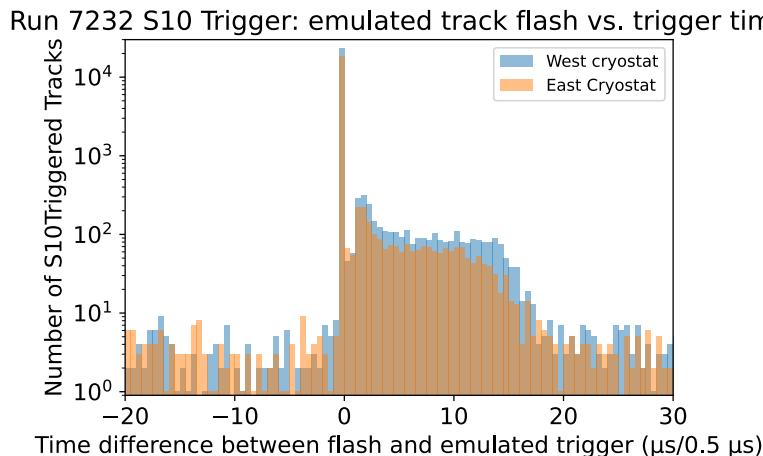
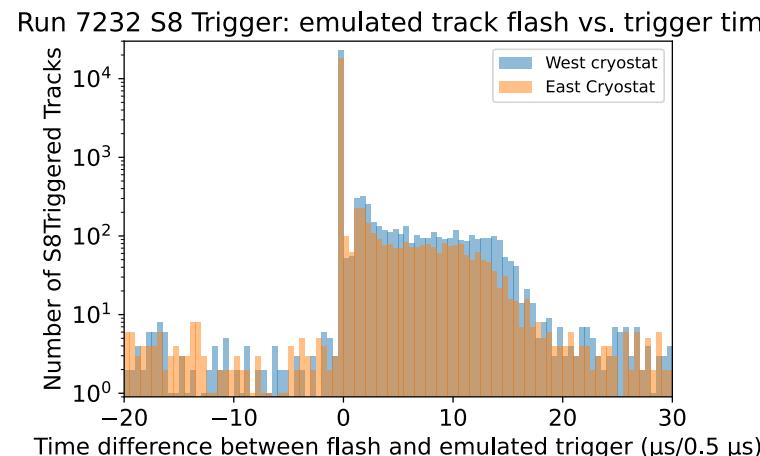
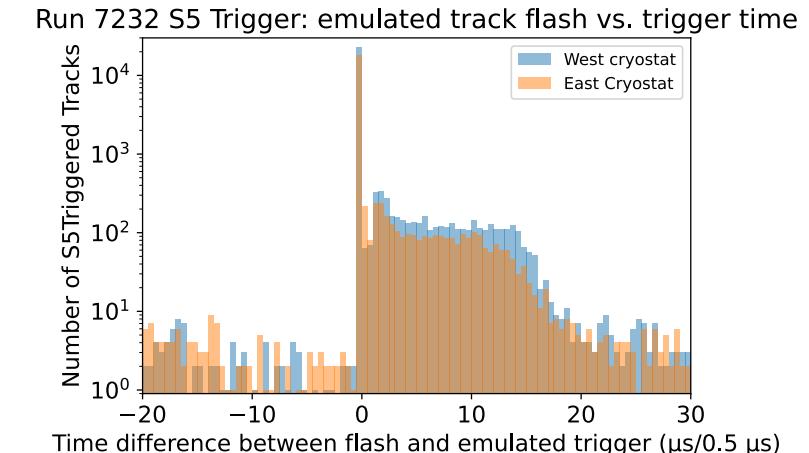
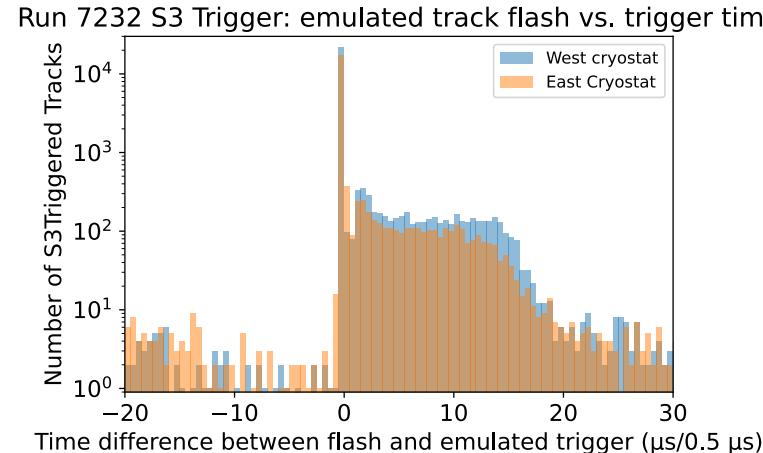
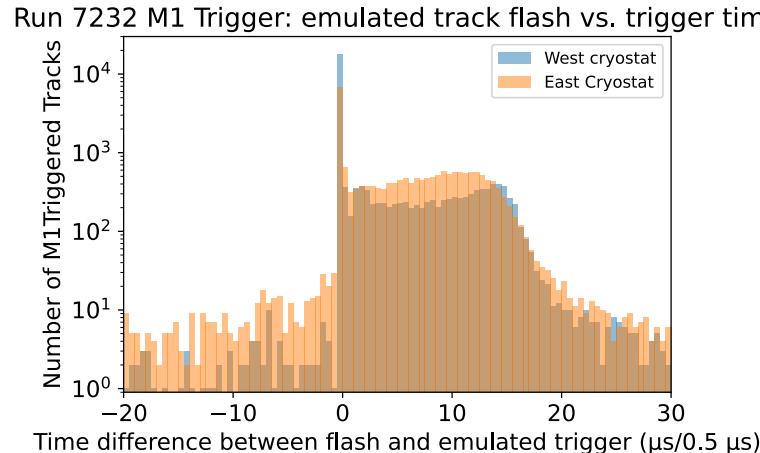
Number of Tracks in West Cathode: 17544

Number of Tracks in East Cathode: 13896



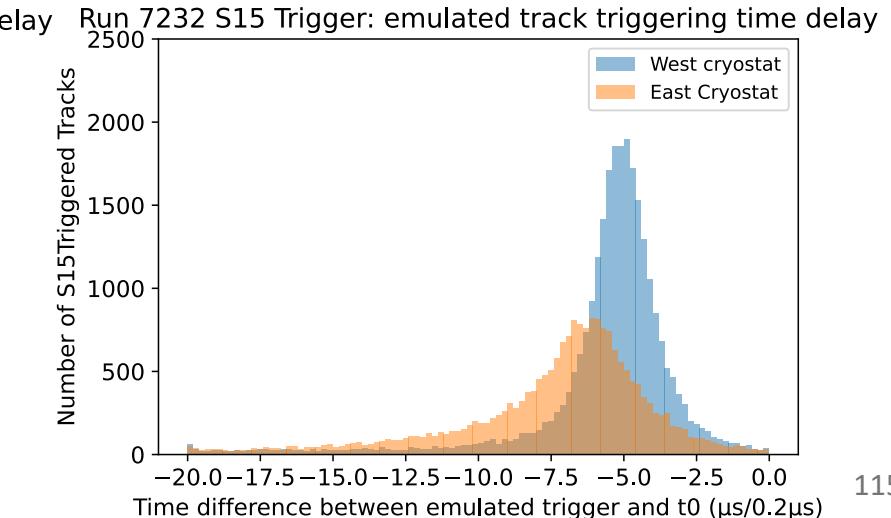
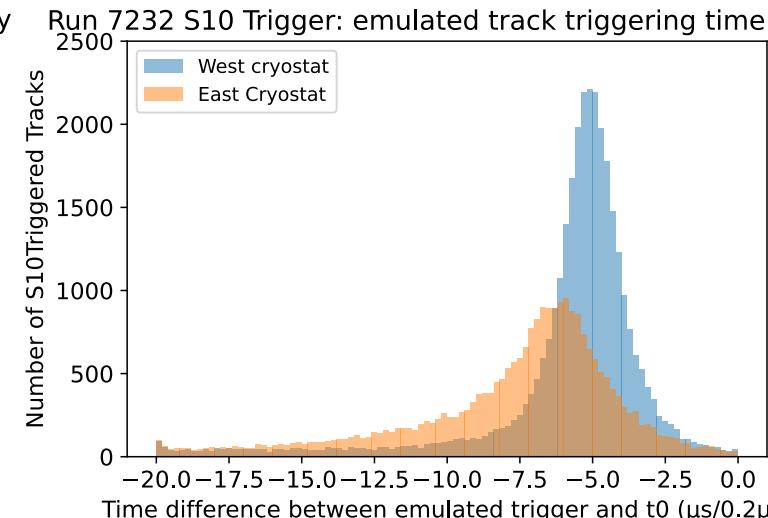
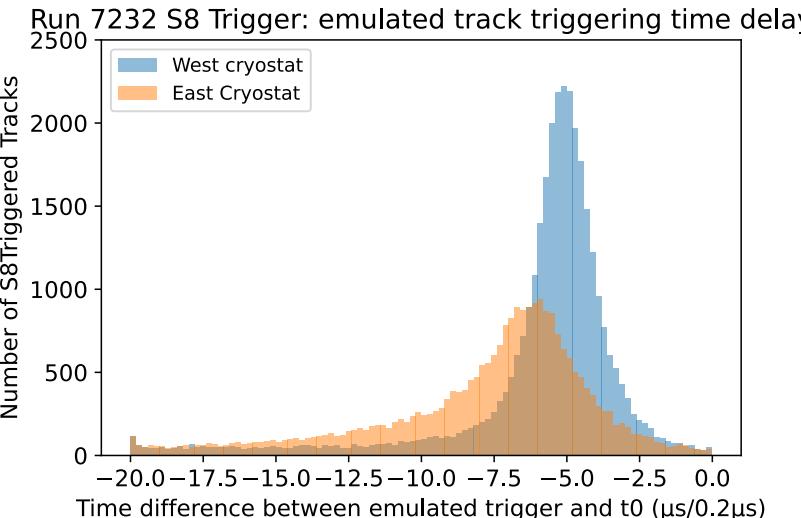
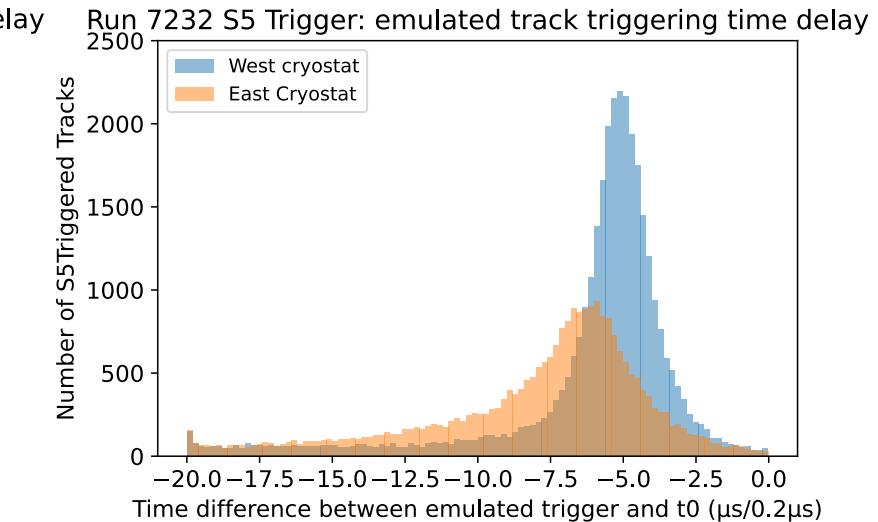
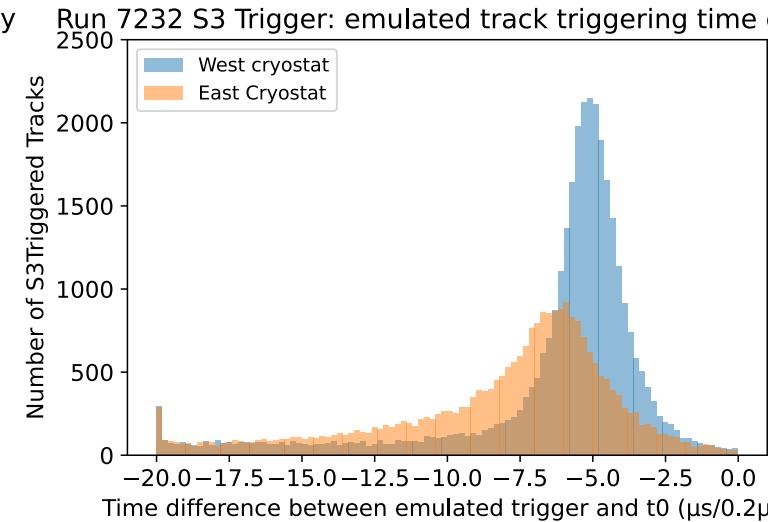
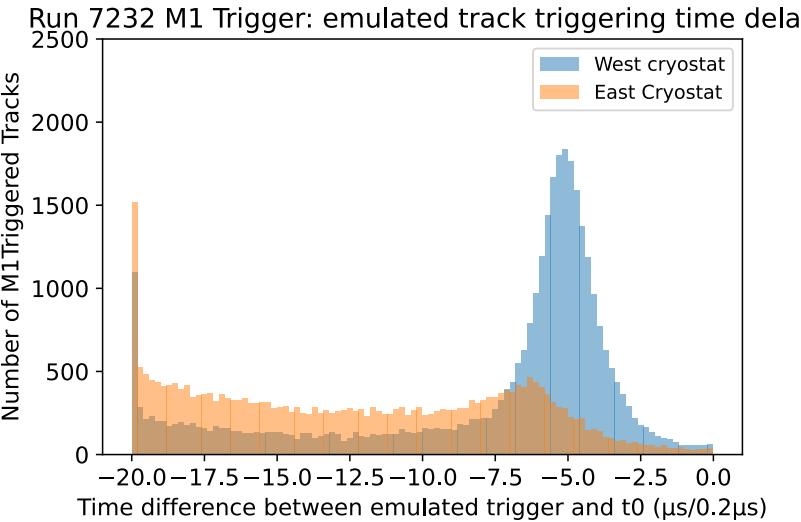
Time Difference between flash and emulated trigger

- We used **location-based** flash-track matching for this
- We expect this to mostly be 0, and we do see a large spike at 0
- There are more tracks slightly above 0 than slightly below, so there are more tracks where the flash is slightly later than the emulated trigger than tracks where the flash is slightly before



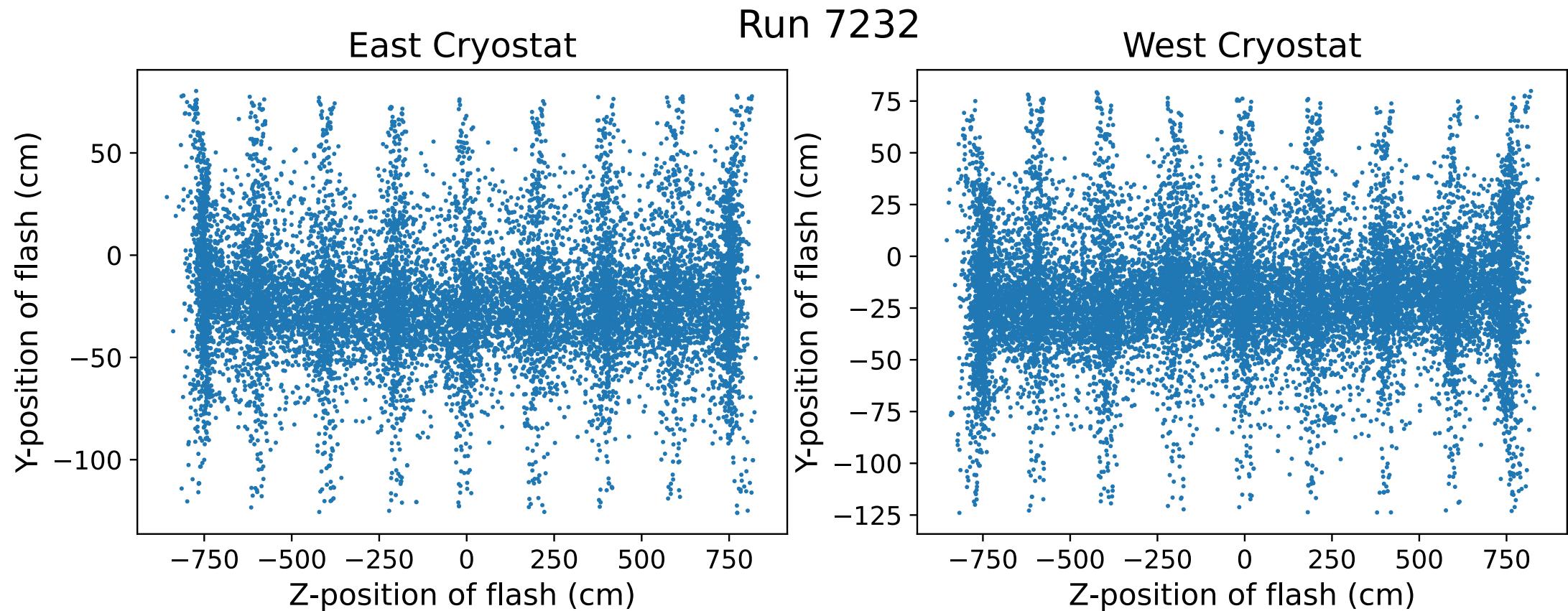
Time Difference between emulated trigger and t0 (track time)

- The time difference should not be negative – this shift is an artifact of the reconstruction
- The wide peak is the average time delay between the track and the trigger
- There is also a peak at -20 μ s. We used an interval from $t_0 - 20 \mu$ s to t_0 to evaluate the trigger response, so any residual light from events before the start of the interval could activate the trigger response immediately upon the start of that interval, as the trigger can only be activated once per spill. This causes the initial spike that can be seen at -20 μ s.



Y-Z positions of flashes in both cryostats

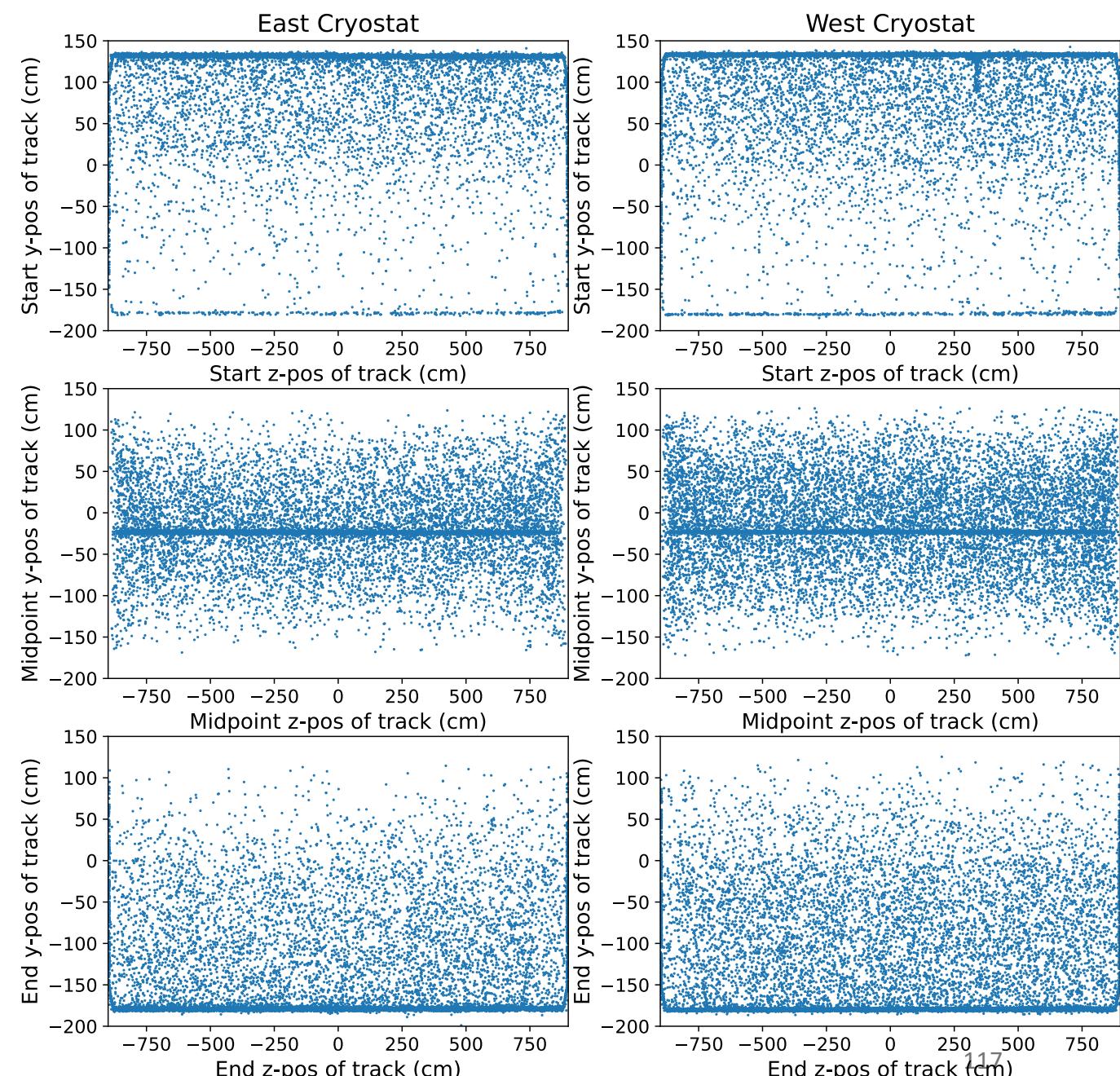
Distribution of flashes is not uniform - it is concentrated close to where the PMTs are located



Y-Z Positions of Tracks

It appears that using the midpoint of position of the track as a measure of the track's location is the most unbiased way to compare it to the flash position, which has a similar distribution

Run 7232



Distance Between track and Flash as a function of z-position of flash

Distance between track and flash peaks at 0-20 cm with a smaller peak at 50-80 cm. We don't fully understand what is causing this second peak, but it is independent of the z-position of the flash.

