

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

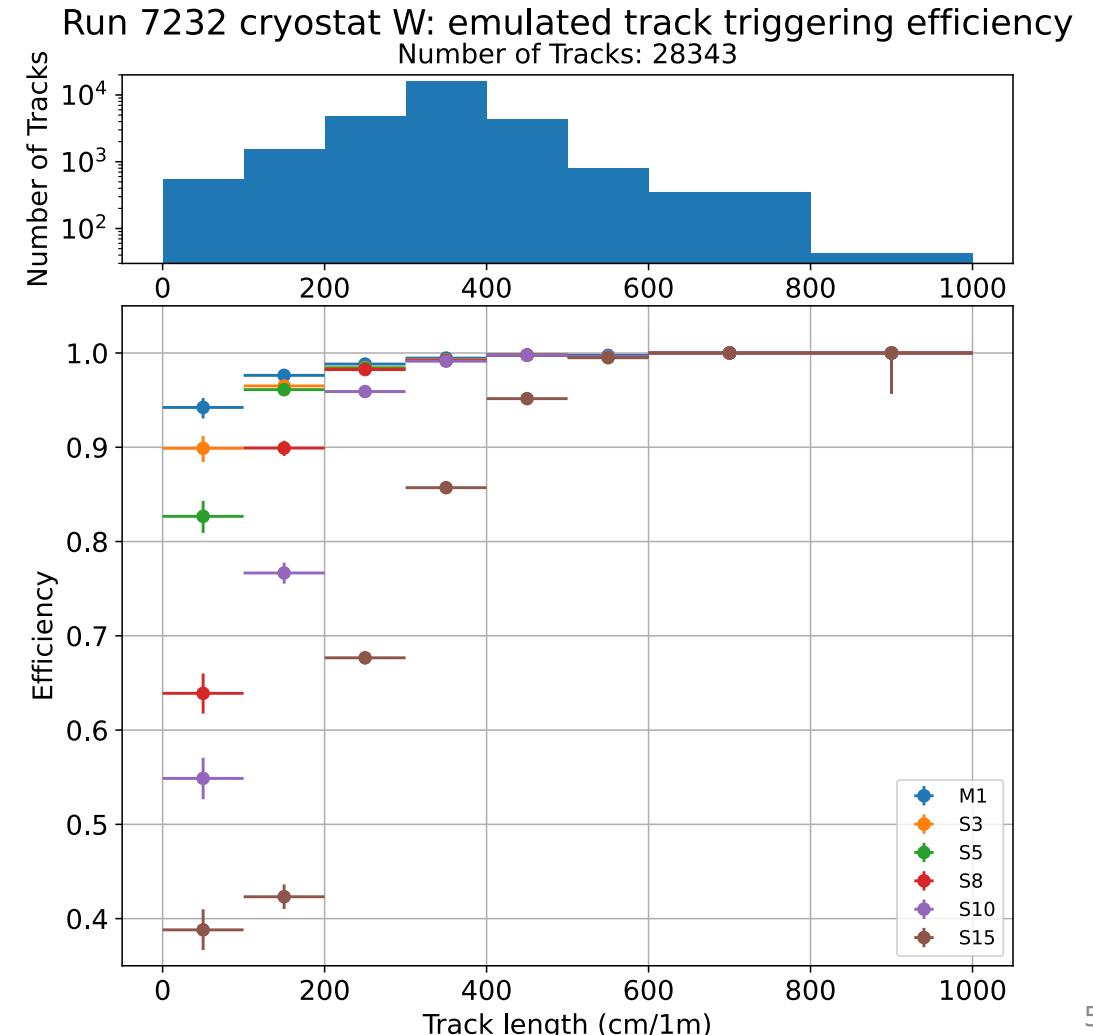
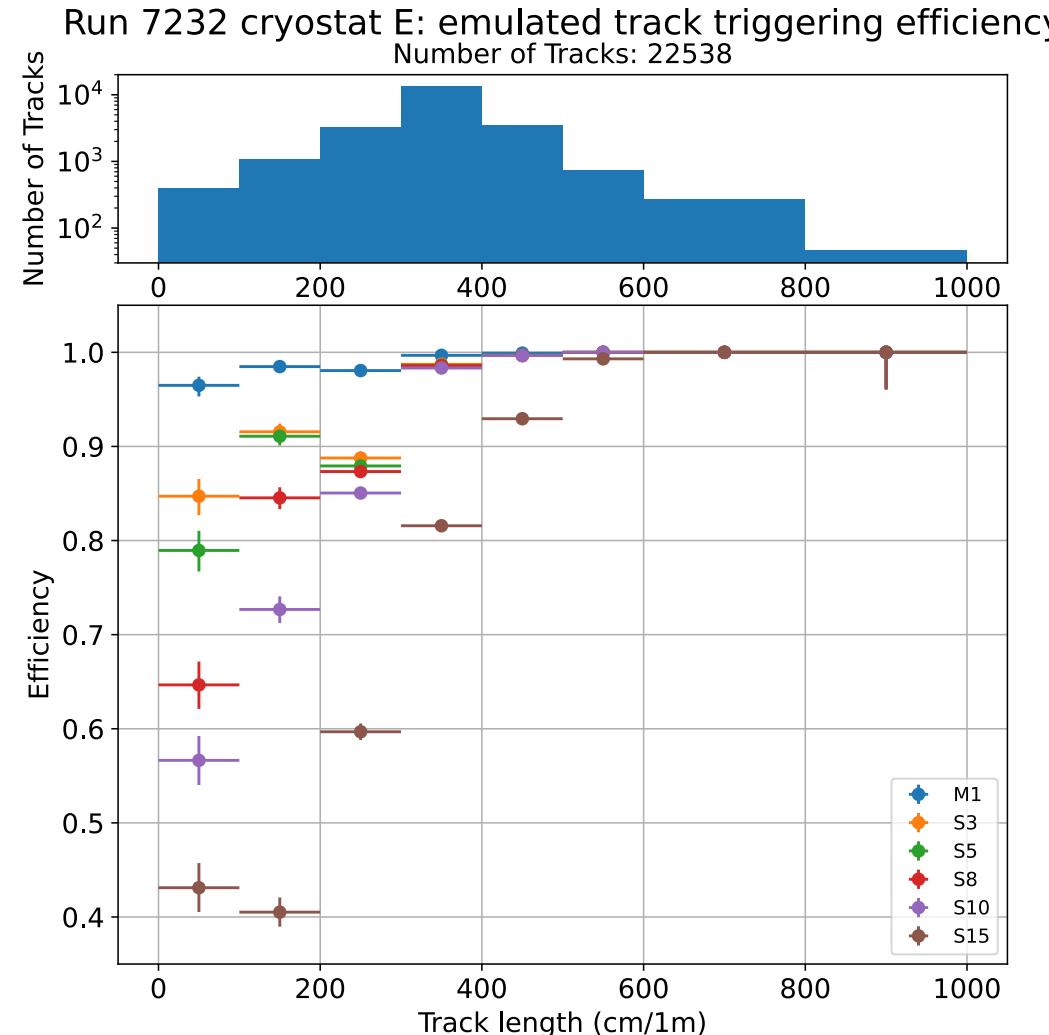
- Data from minimum bias run 7232
 - Full TPC readout (1.6 ms), Single PMT buffer readout (150 μ s)
 - Data provided by J. Zettlemoyer, the same dataset he used
- Plotted the efficiency of the emulated triggers given by the following formula (SBN DocDB 24191):
$$\epsilon = \frac{(TPC \text{ tracks with light info}) \cdot (\text{which would fire the trigger})}{TPC \text{ tracks with light info}}$$
- 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

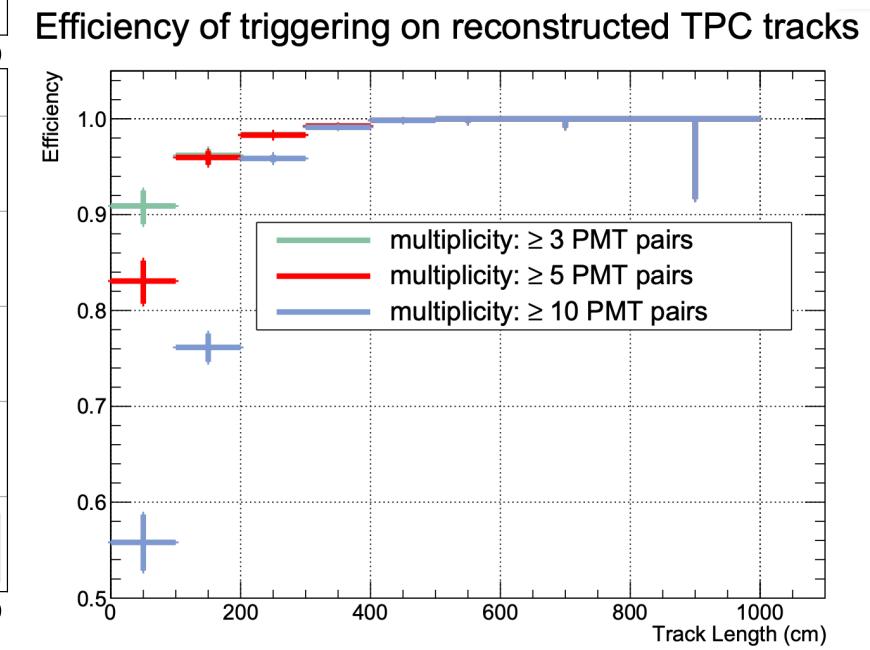
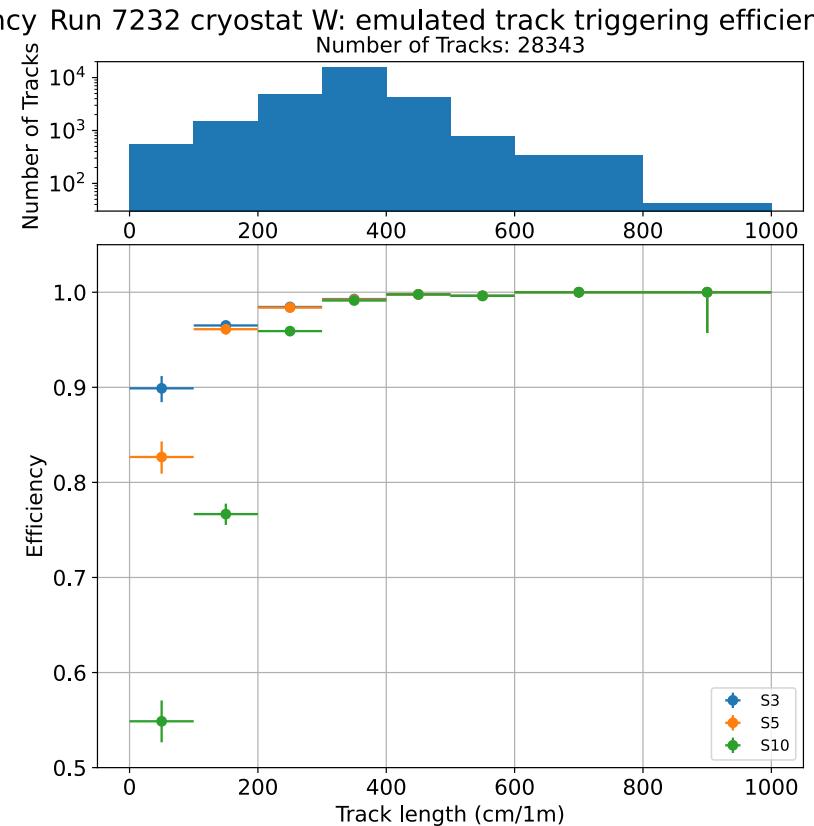
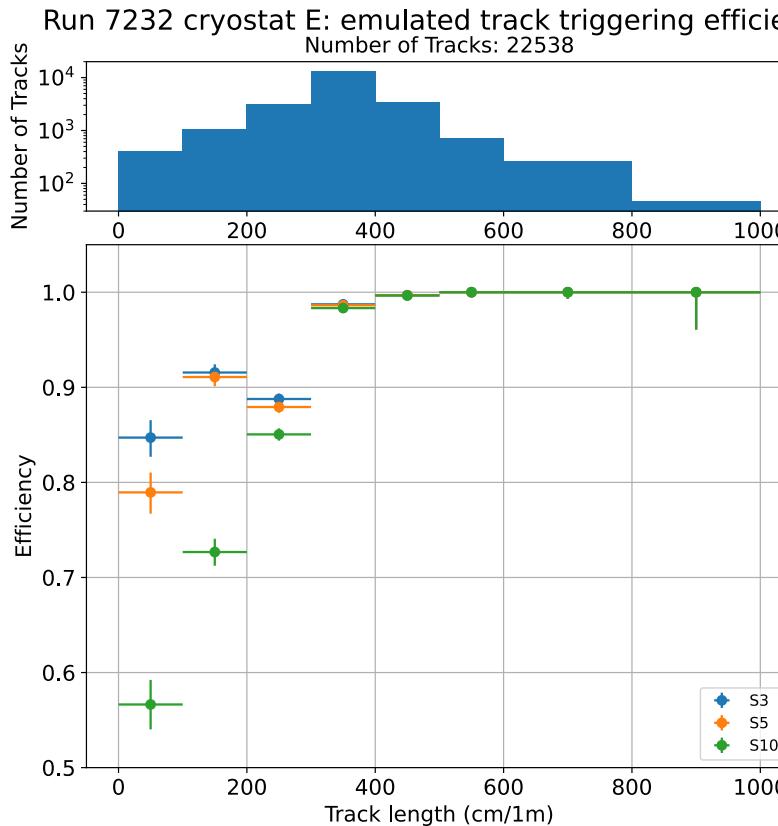
Track length

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



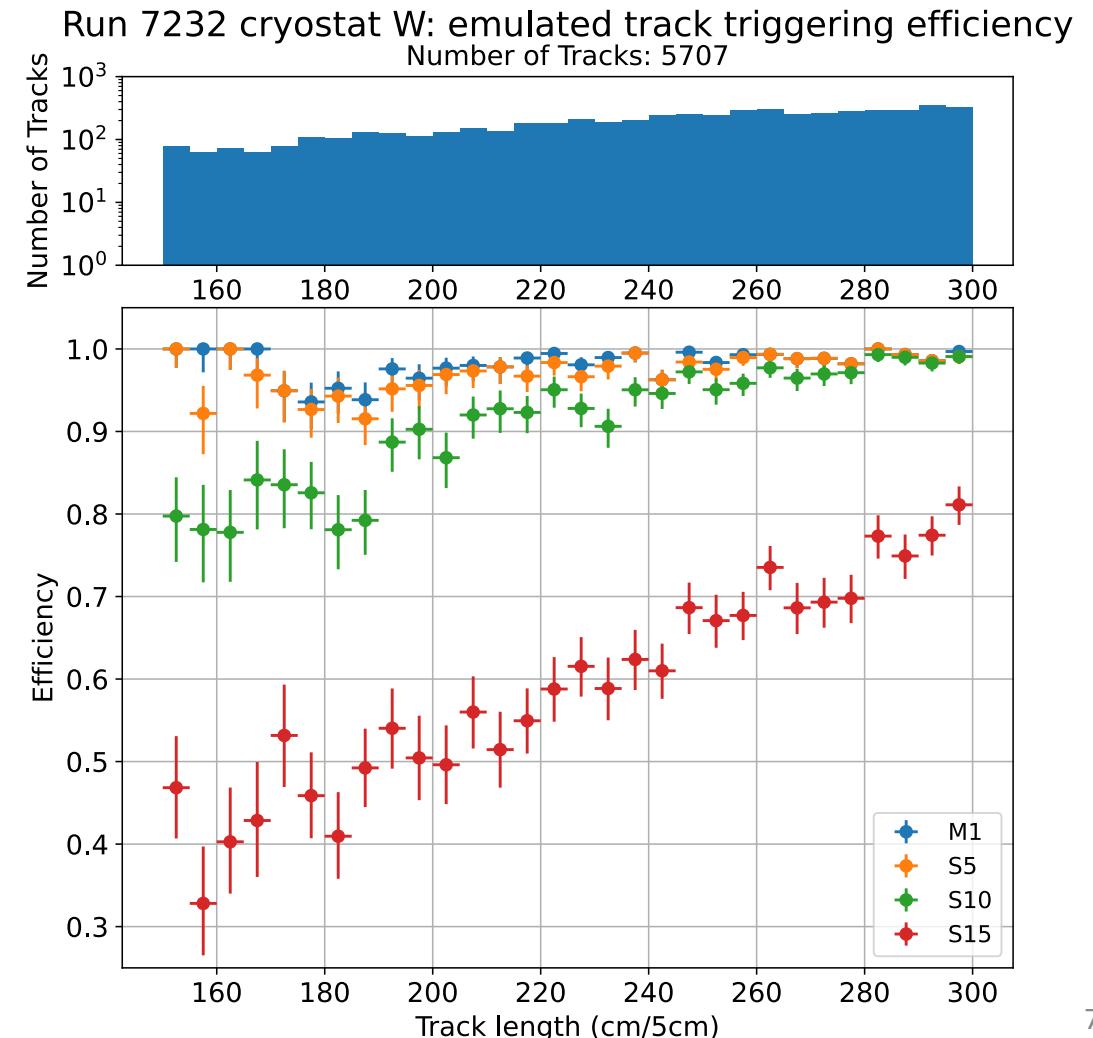
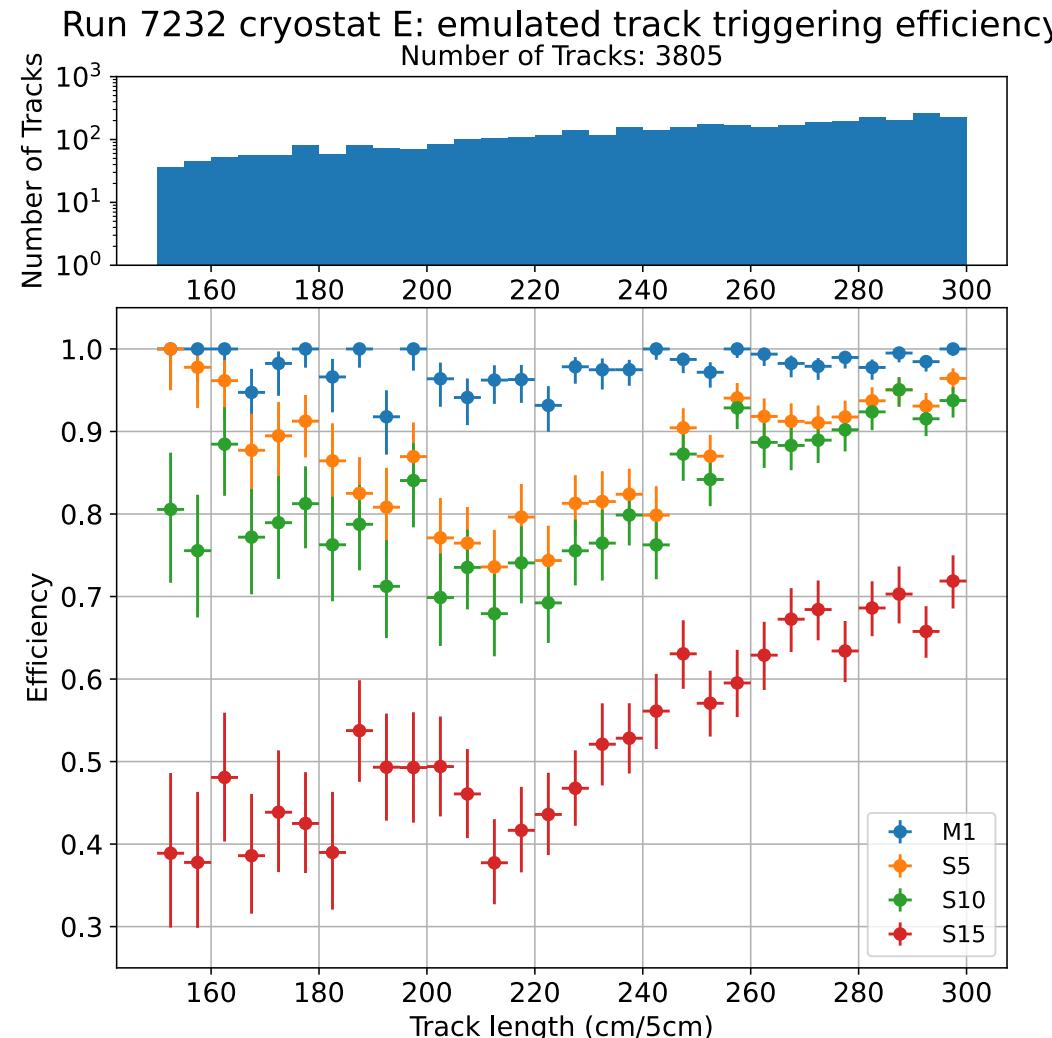
Track length

- 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



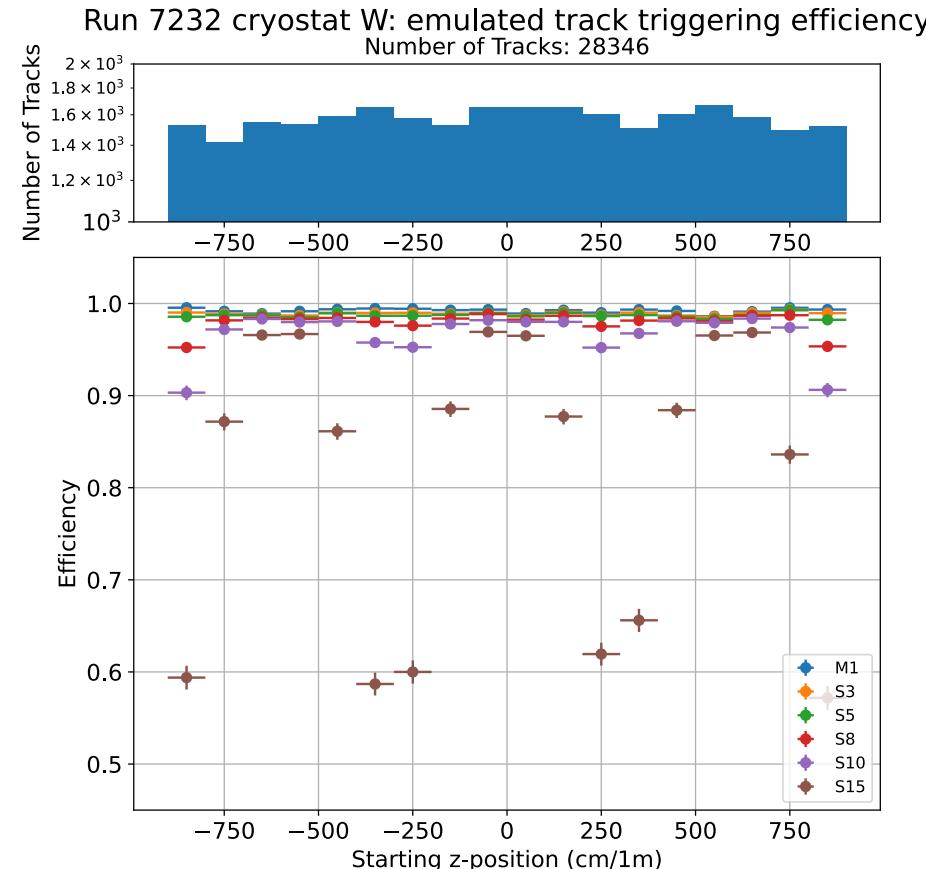
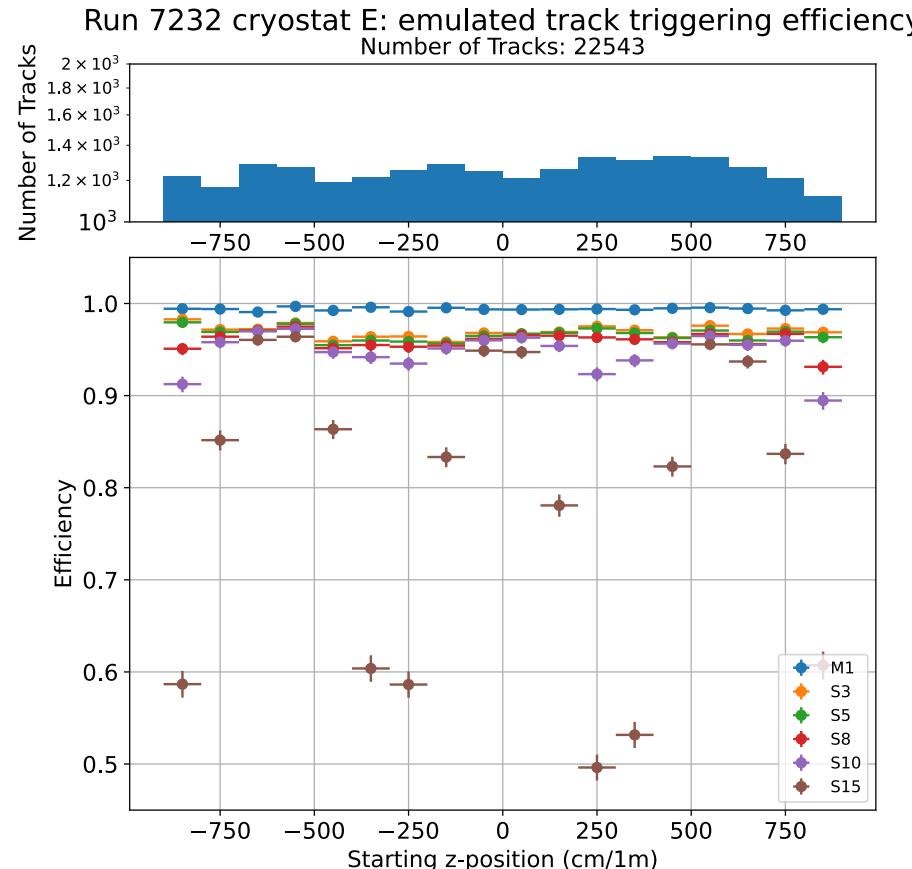
Track length

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

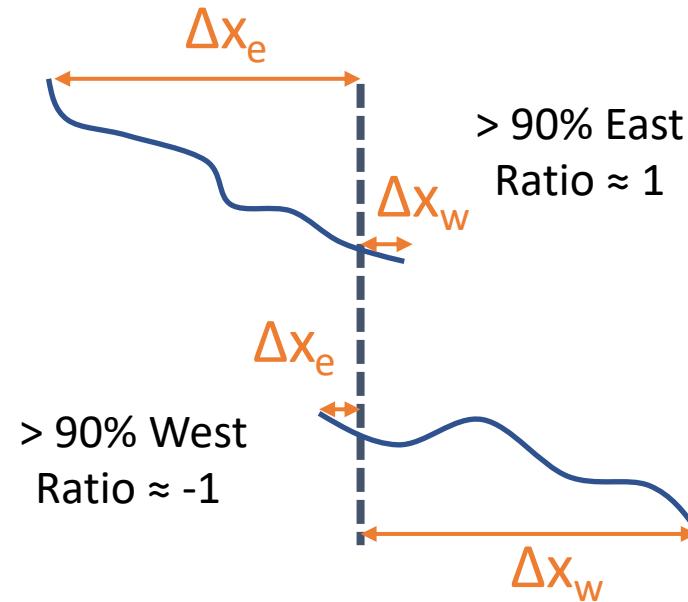
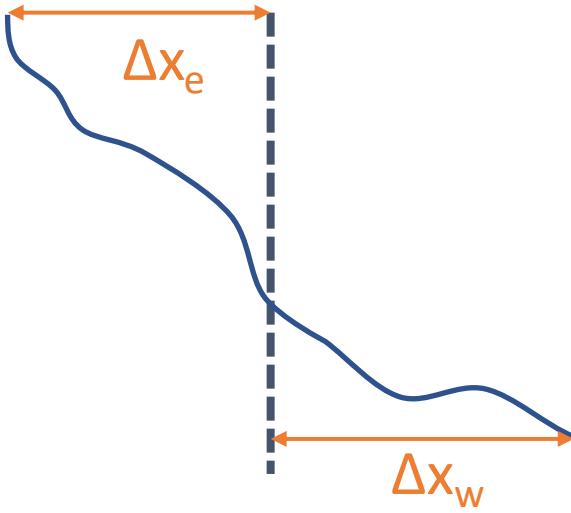


Starting z-position of tracks

- 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.



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



$$\text{Balance ratio formula: } \frac{\Delta x_w - \Delta x_e}{\Delta x_e + \Delta x_w}$$

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

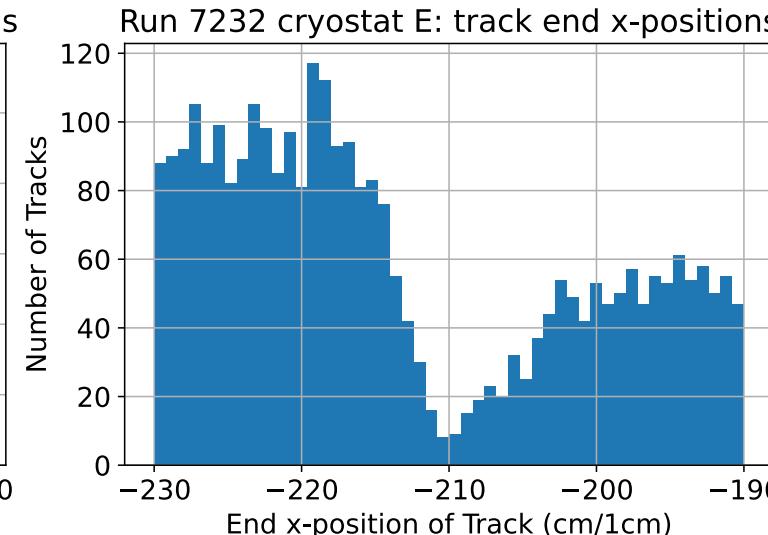
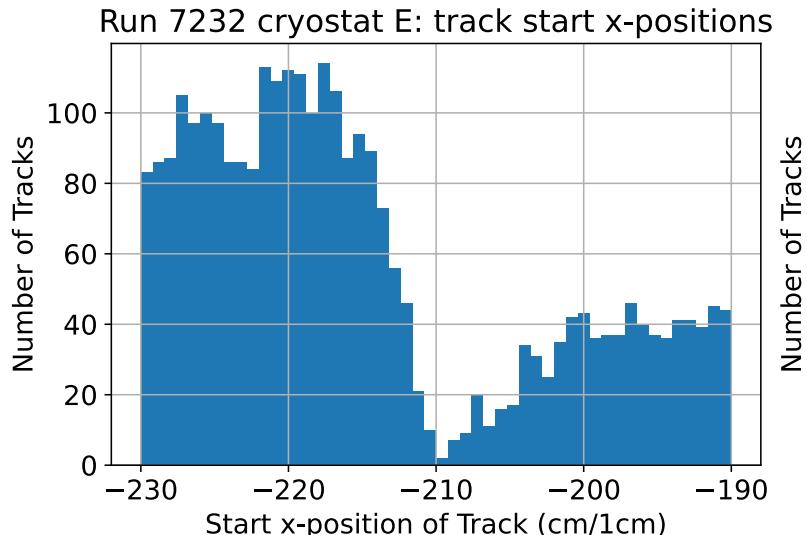
A balance ratio of

- ≈ 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

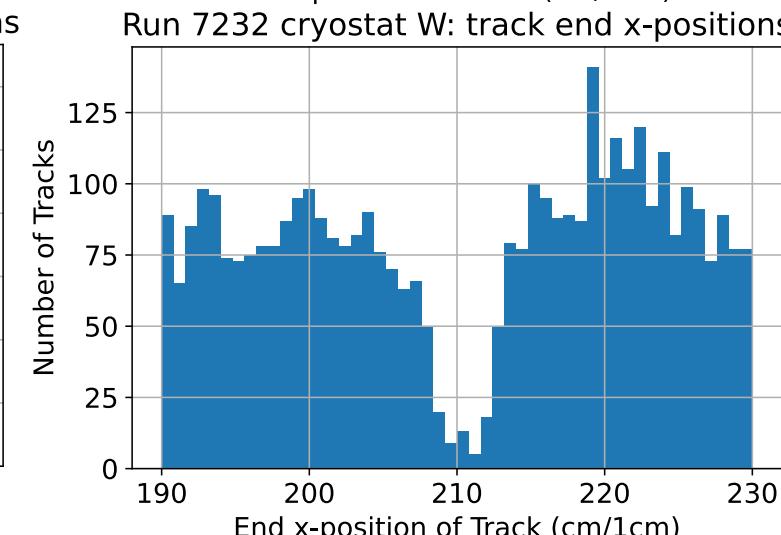
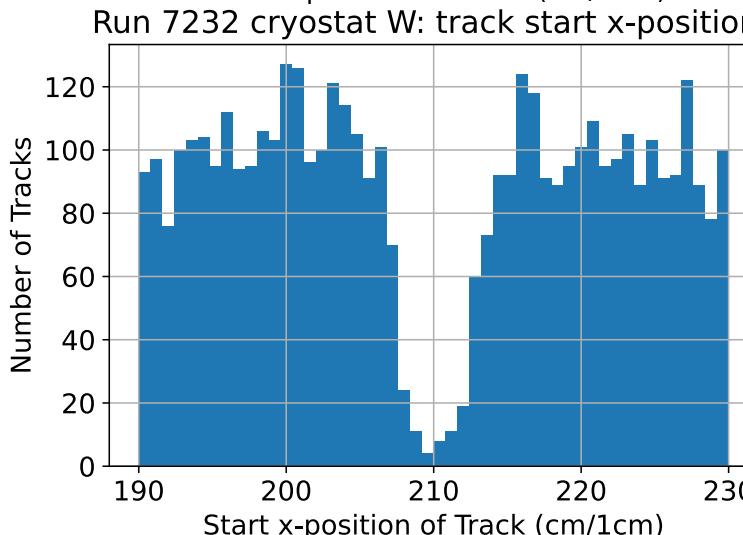
X-position of the cathode

- 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

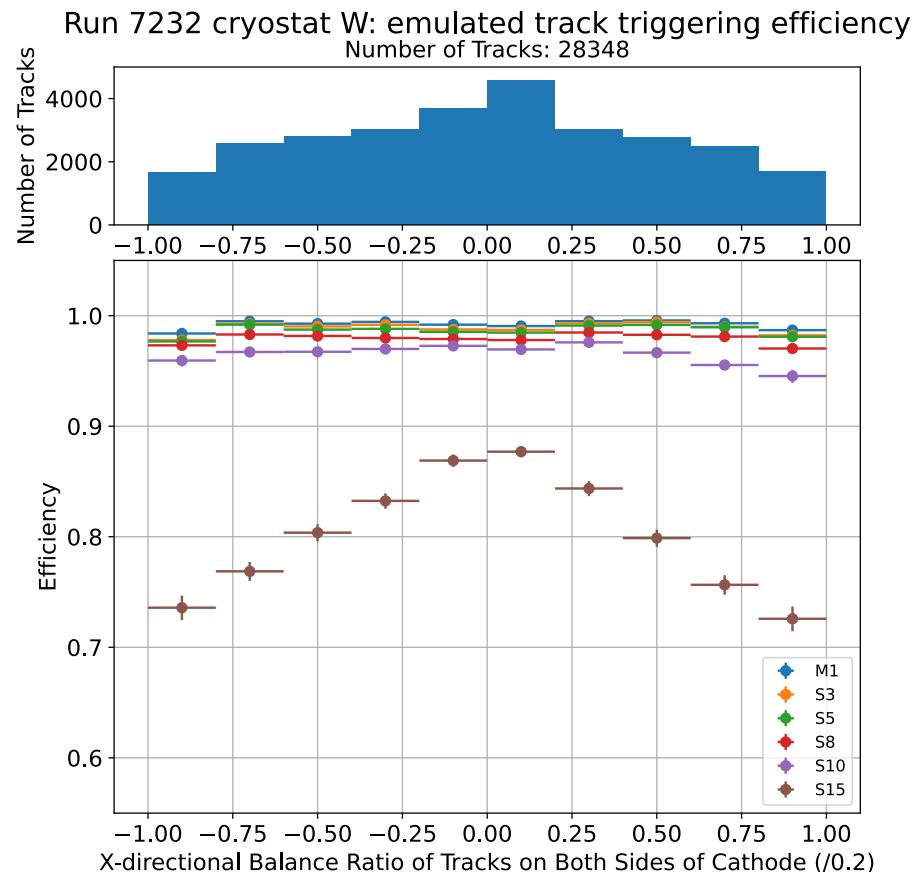
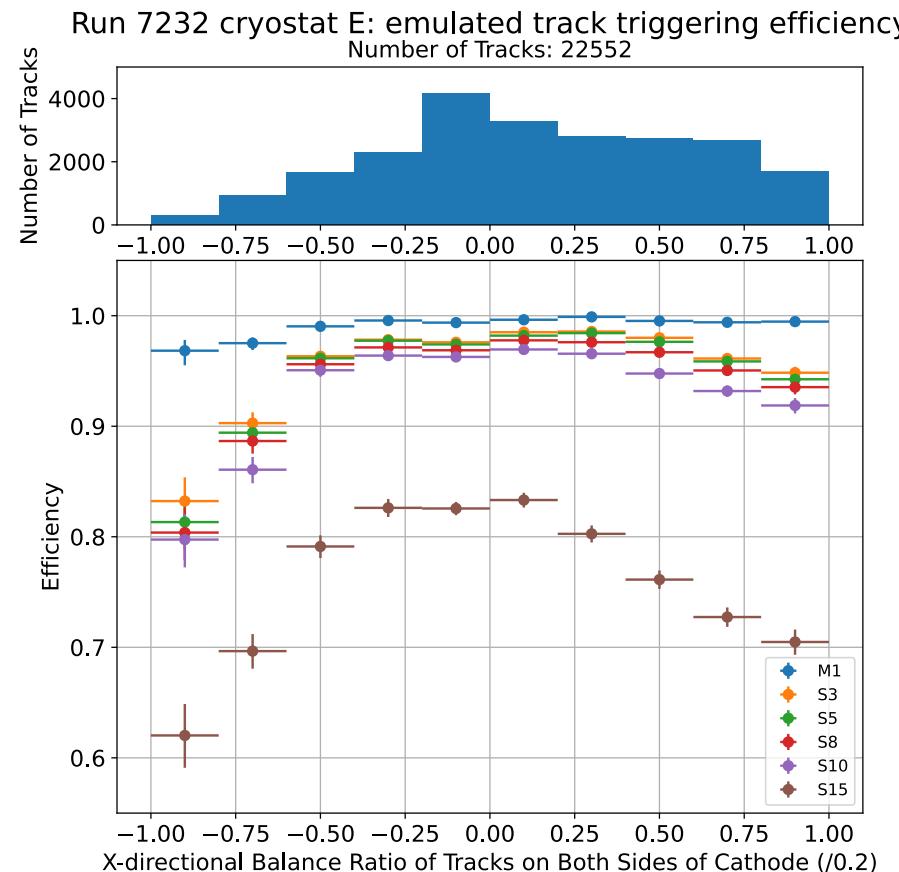


West Cryostat



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

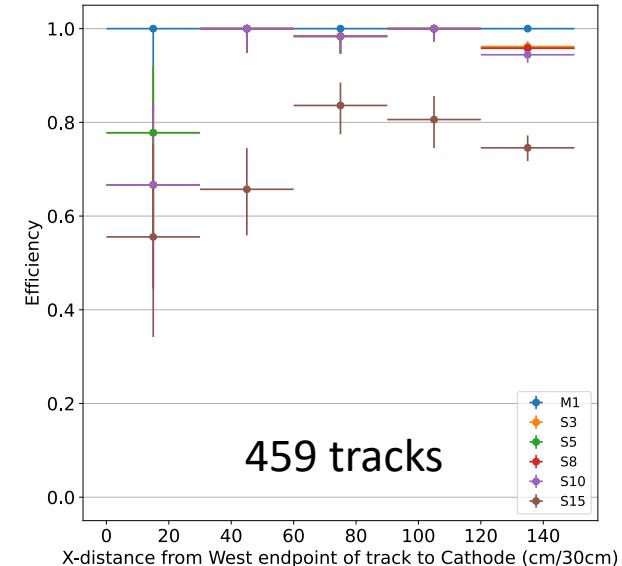
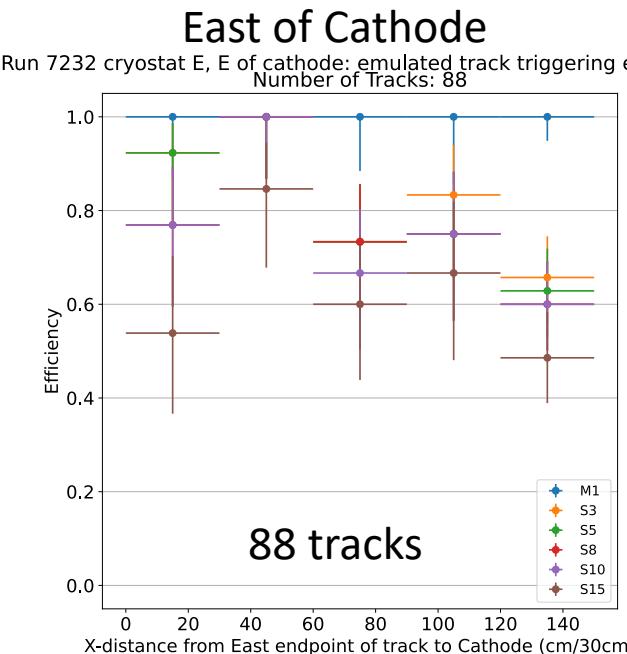
Balance Ratio	≈ -1	≈ 0	≈ 1
Primary TPC of Track	East	Both	West



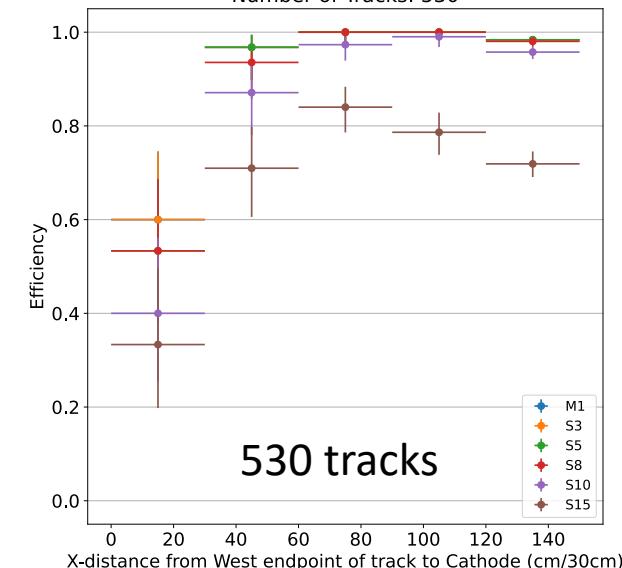
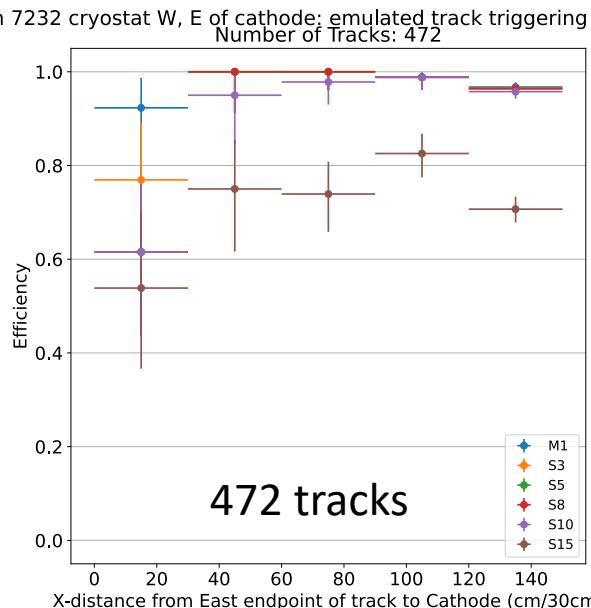
X-distance to Cathode from farther endpoint for tracks primarily on one side of the cathode

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

East Cryostat



West Cryostat

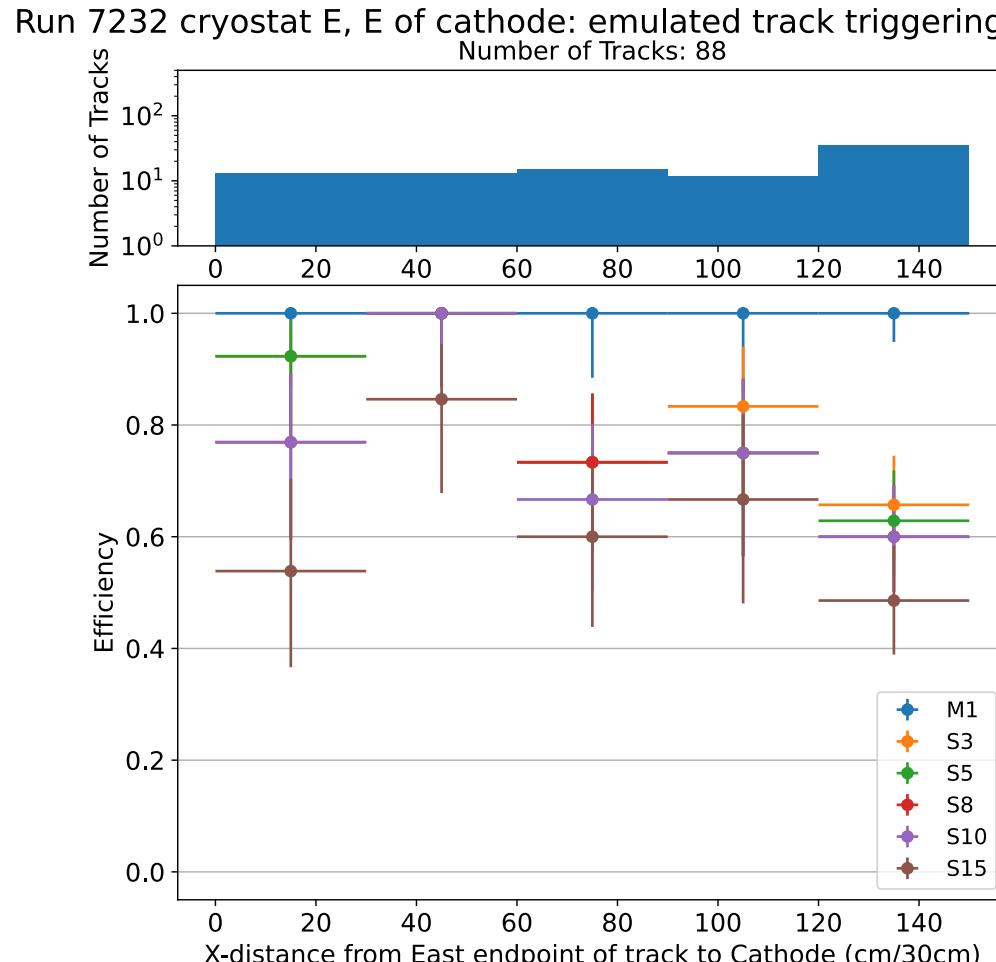


Distance to Cathode from farther endpoint for tracks primarily on one side of the cathode

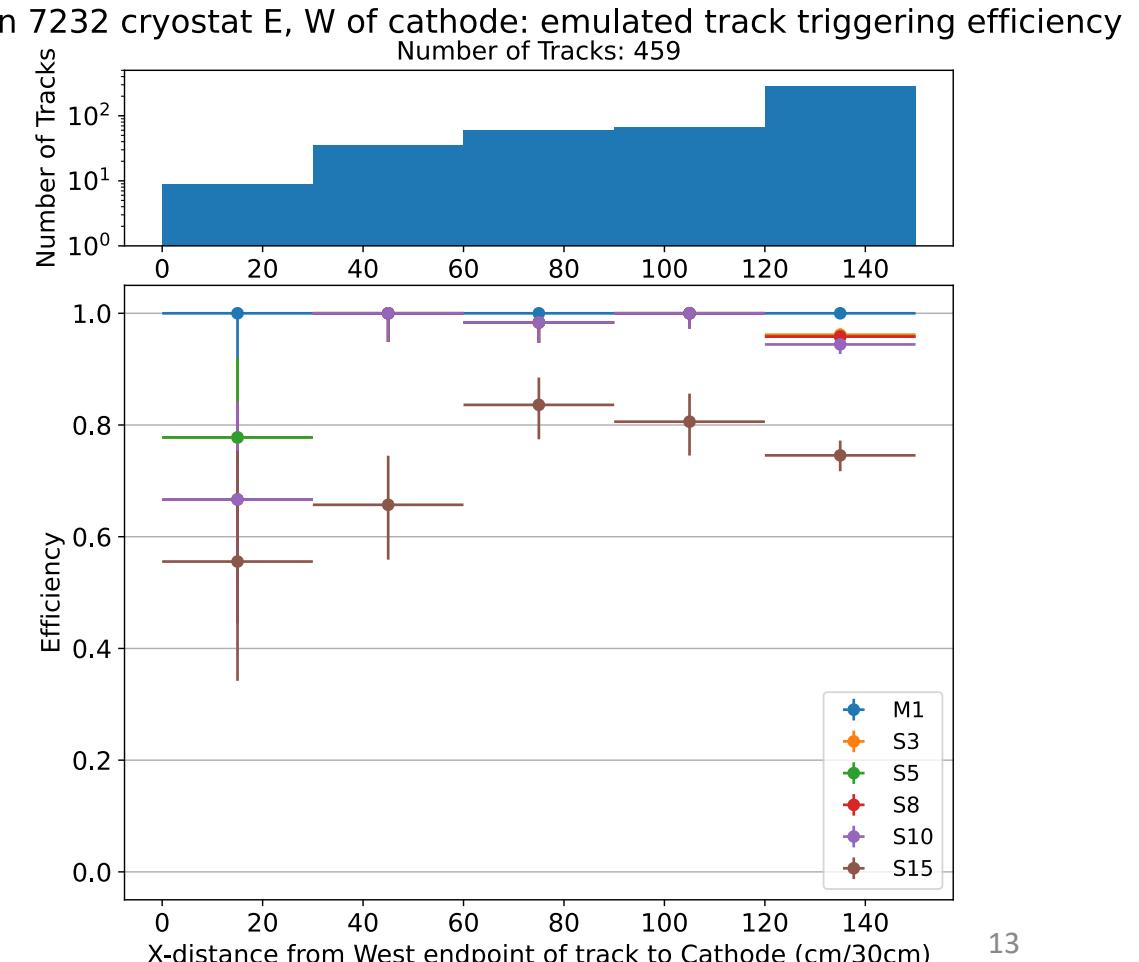
These plots describe tracks with a balance ratio more extreme than 0.9.

East Cryostat

East of Cathode



West of Cathode

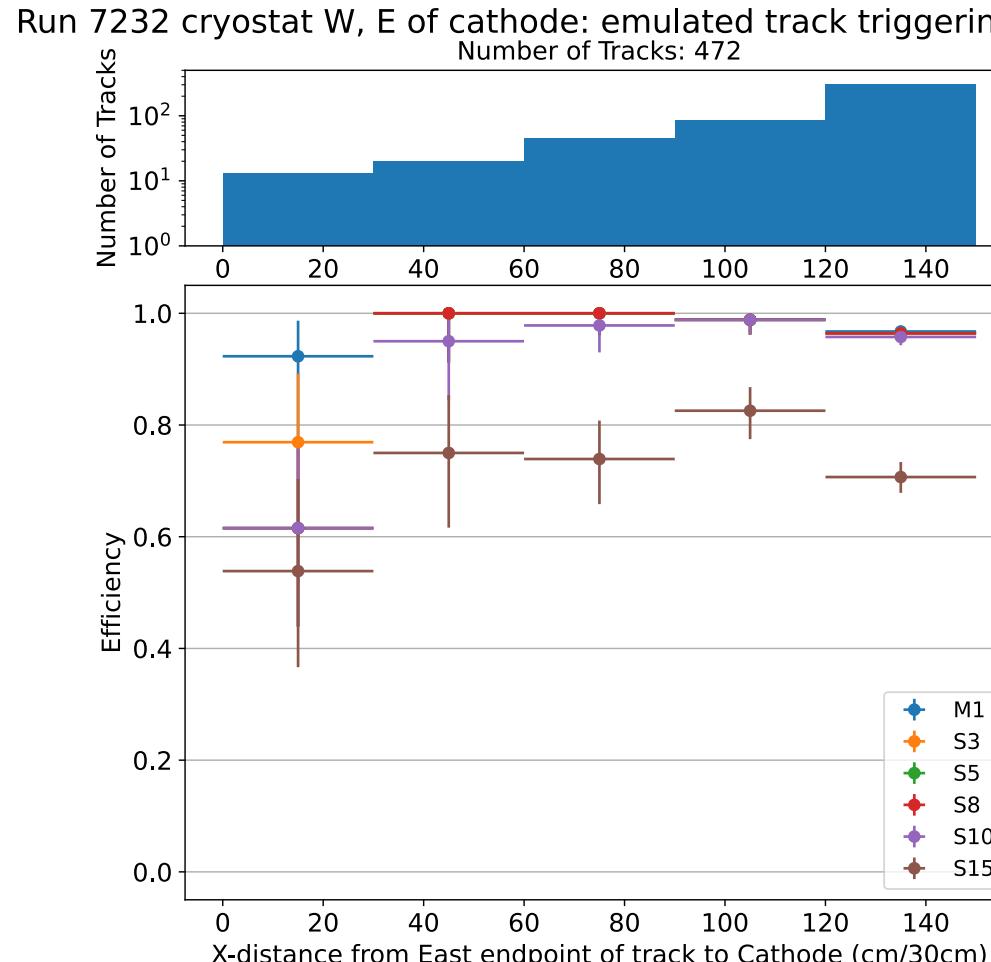


Distance to Cathode from farther endpoint for tracks primarily on one side of the cathode

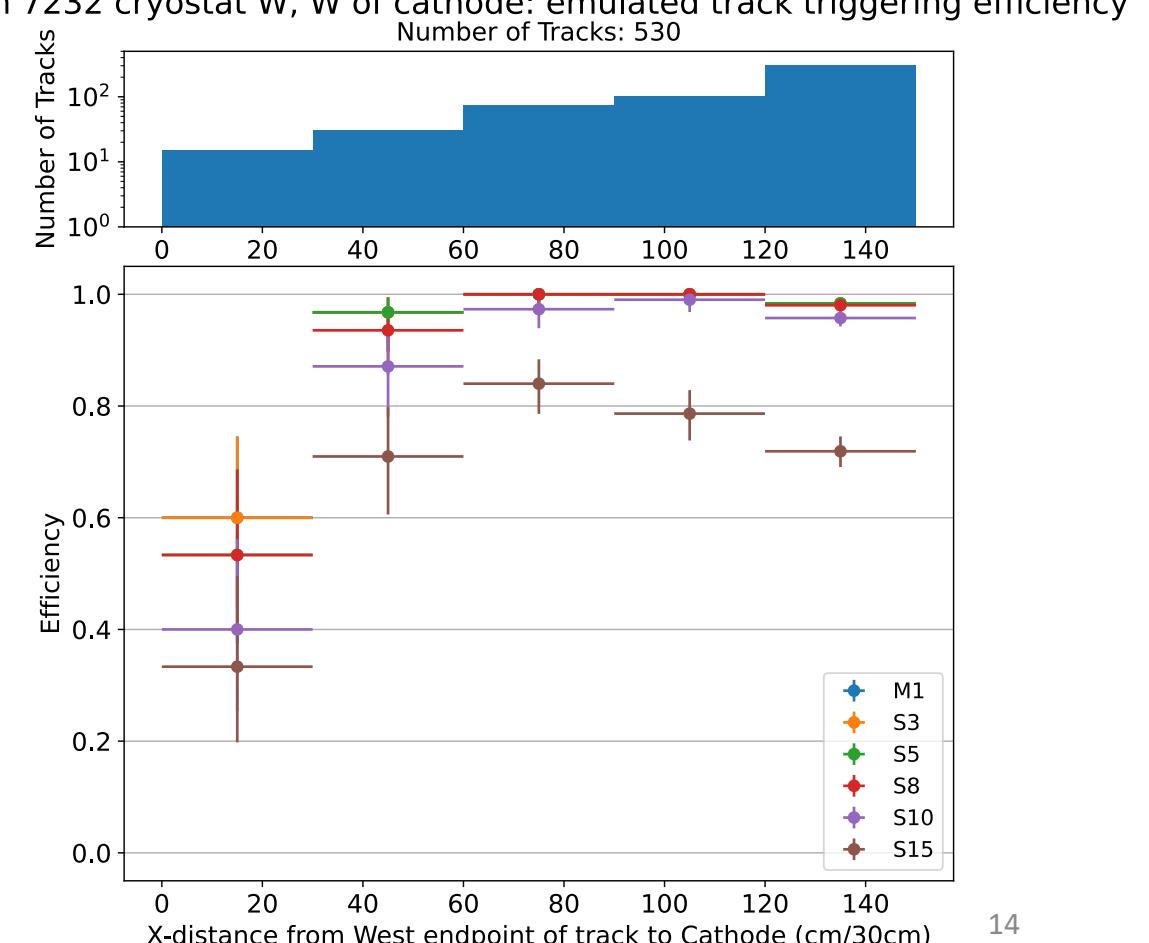
These plots describe tracks with a balance ratio more extreme than 0.9.

West Cryostat

East of Cathode



West of Cathode



Track-Flash Matching Algorithms

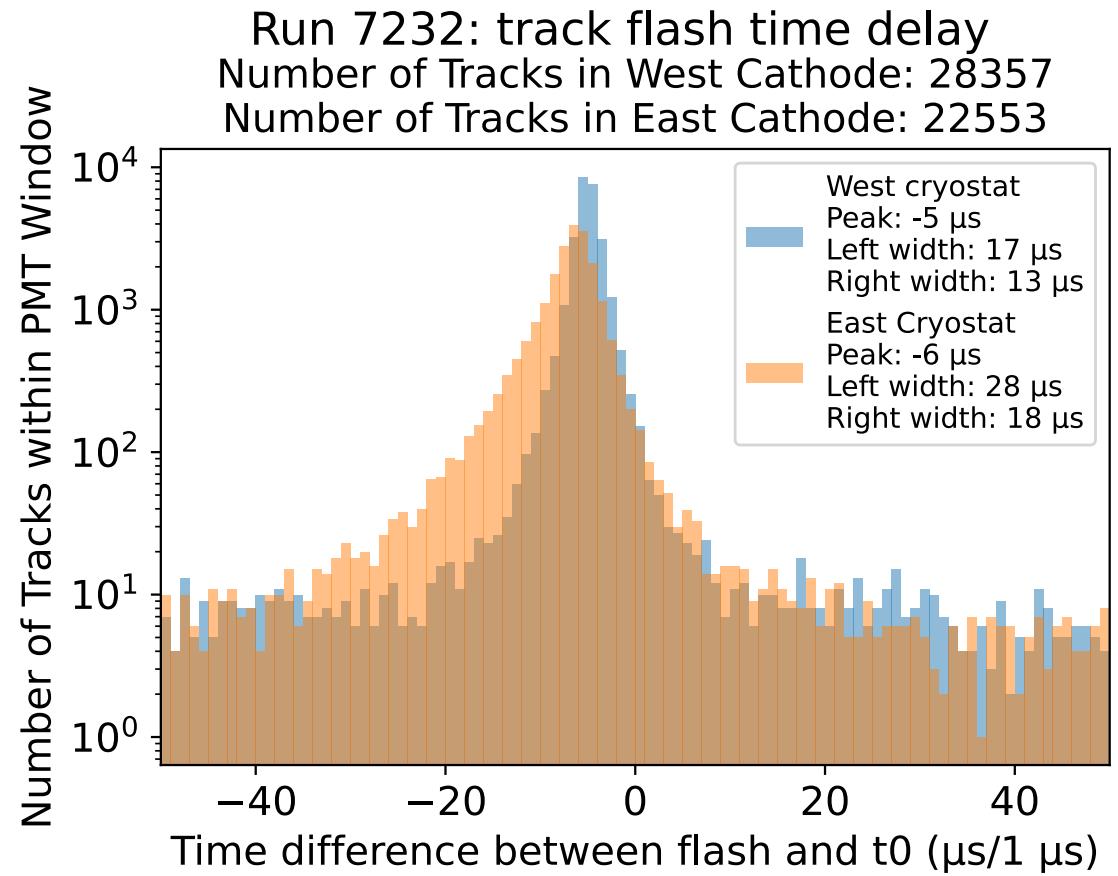
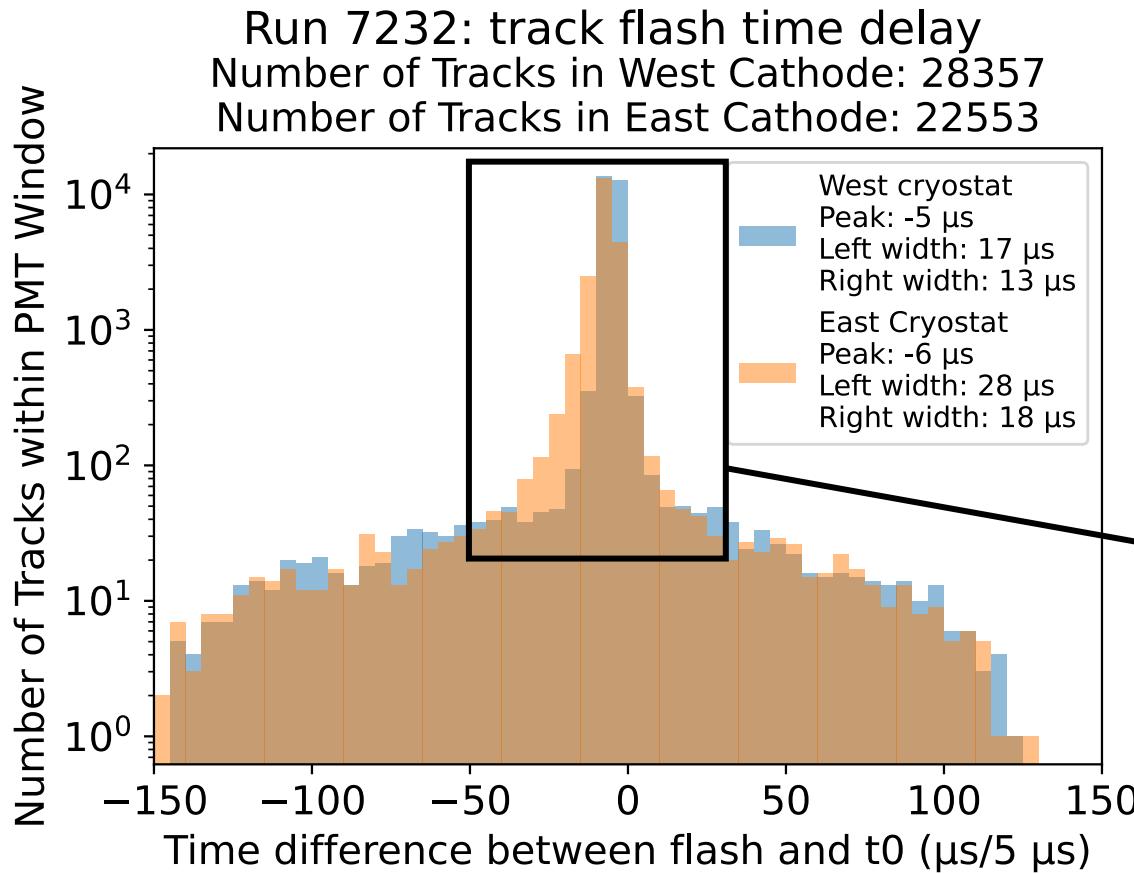
Matching tracks and flashes within a single PMT readout window using location-based and time-based algorithms and comparing the results

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



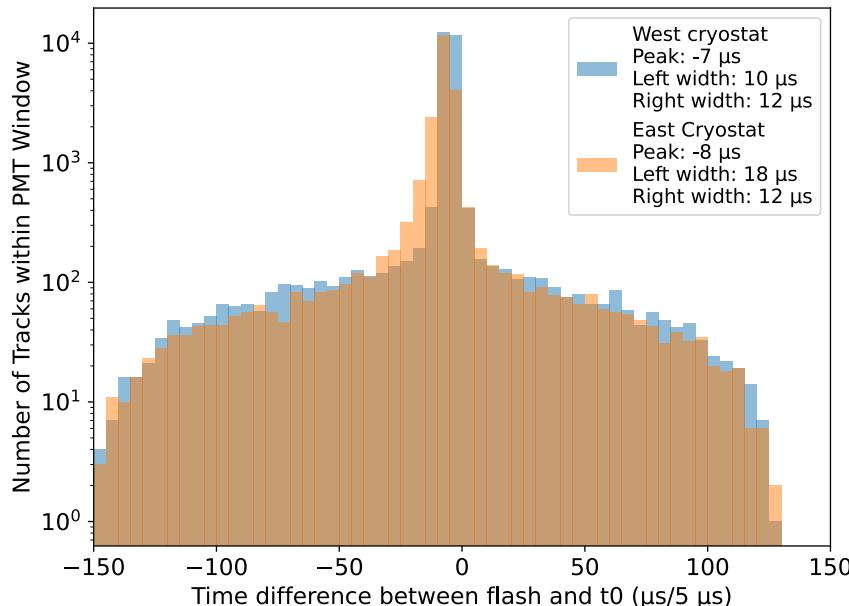
Exploration: Location of Tracks

- 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

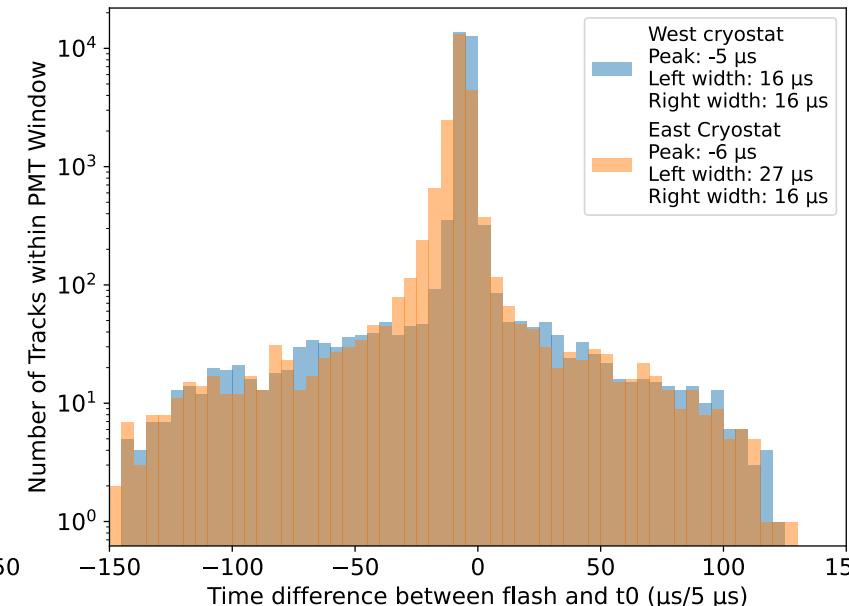
Number of Tracks in West Cathode: 28357
Number of Tracks in East Cathode: 22553



Barycenter

Run 7232: track flash time delay

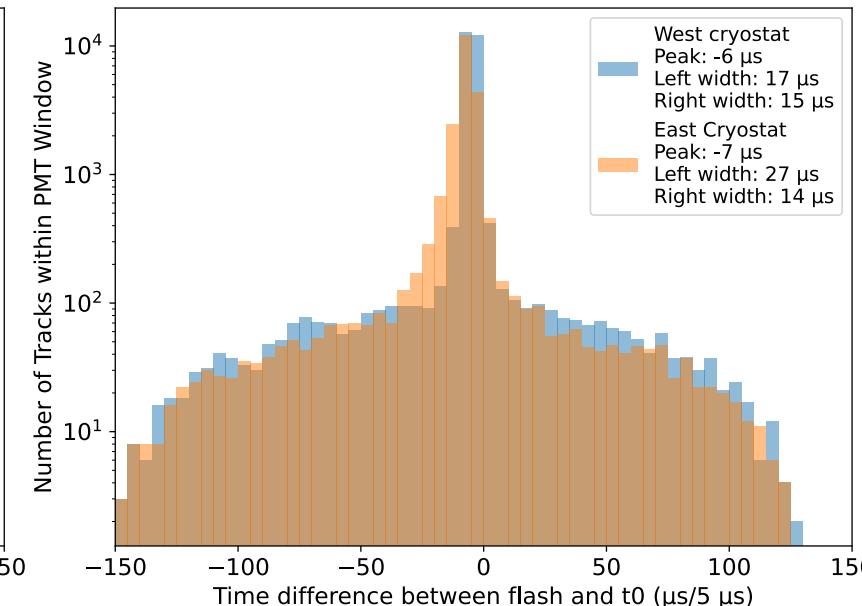
Number of Tracks in West Cathode: 28357
Number of Tracks in East Cathode: 22553



End

Run 7232: track flash time delay

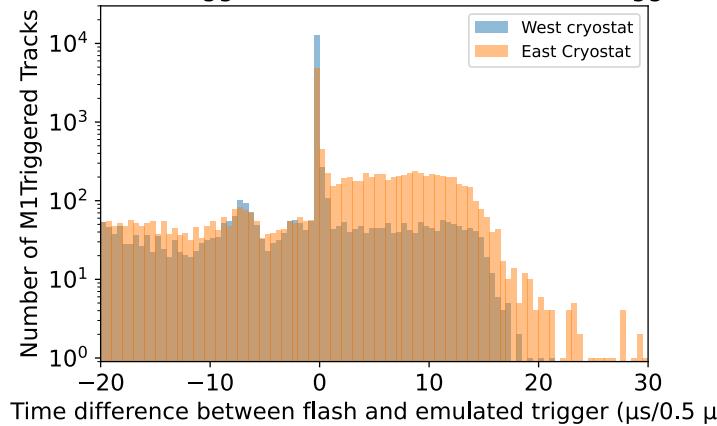
Number of Tracks in West Cathode: 28357
Number of Tracks in East Cathode: 22553



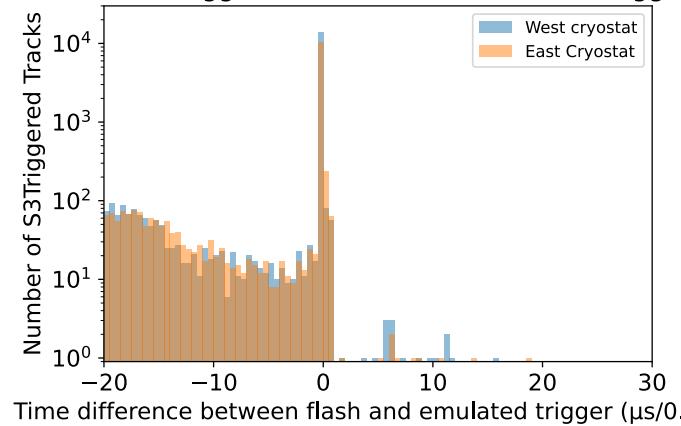
Time Difference between flash and emulated trigger

- 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

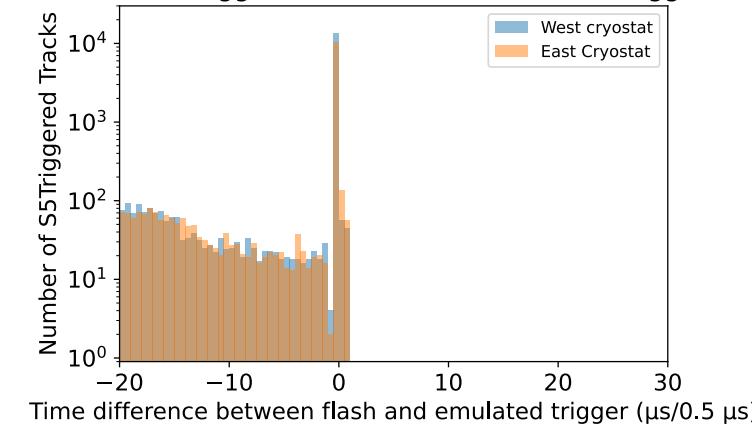
Run 7232 M1 Trigger: emulated track flash vs. trigger time



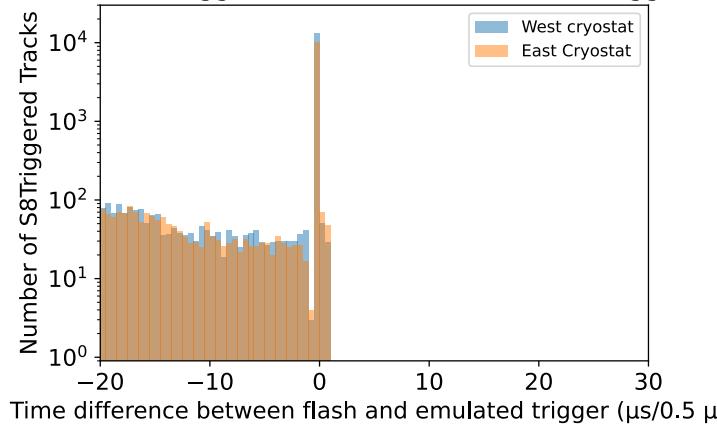
Run 7232 S3 Trigger: emulated track flash vs. trigger time



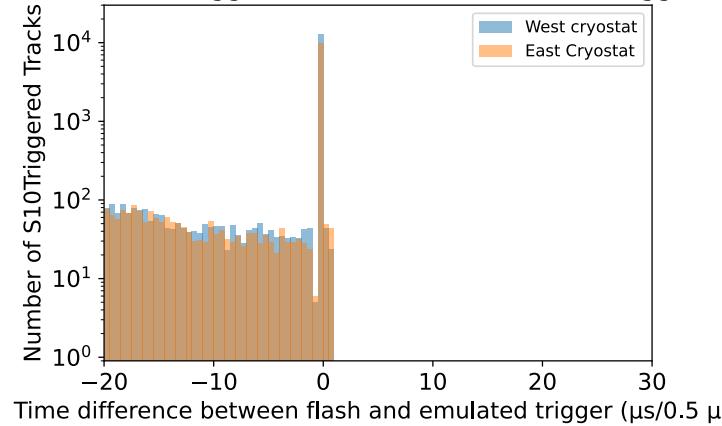
Run 7232 S5 Trigger: emulated track flash vs. trigger time



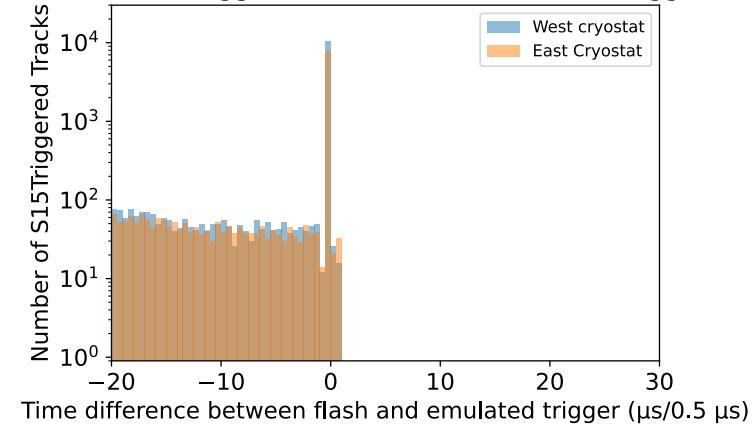
Run 7232 S8 Trigger: emulated track flash vs. trigger time



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



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



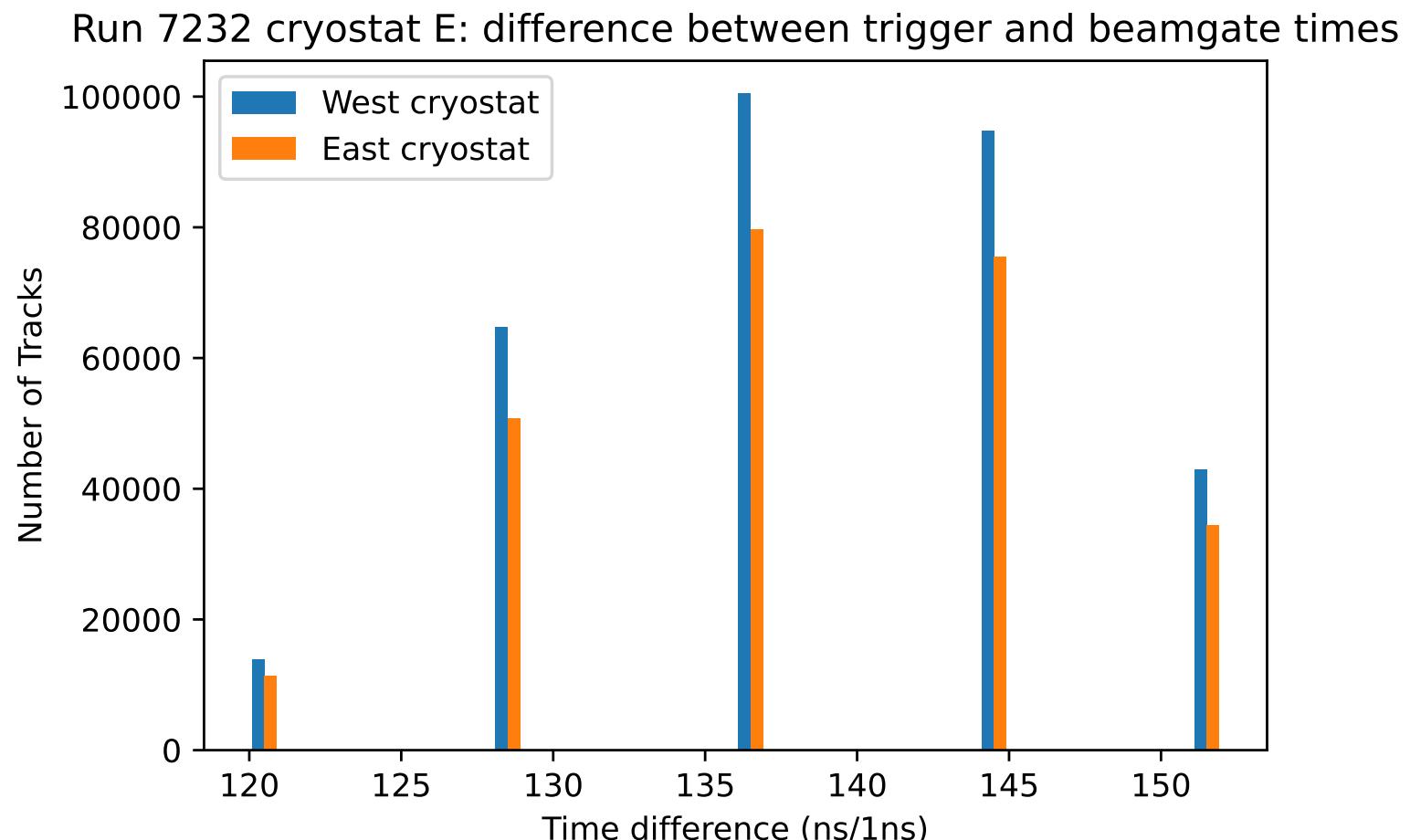
Conclusion/next steps

- 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.



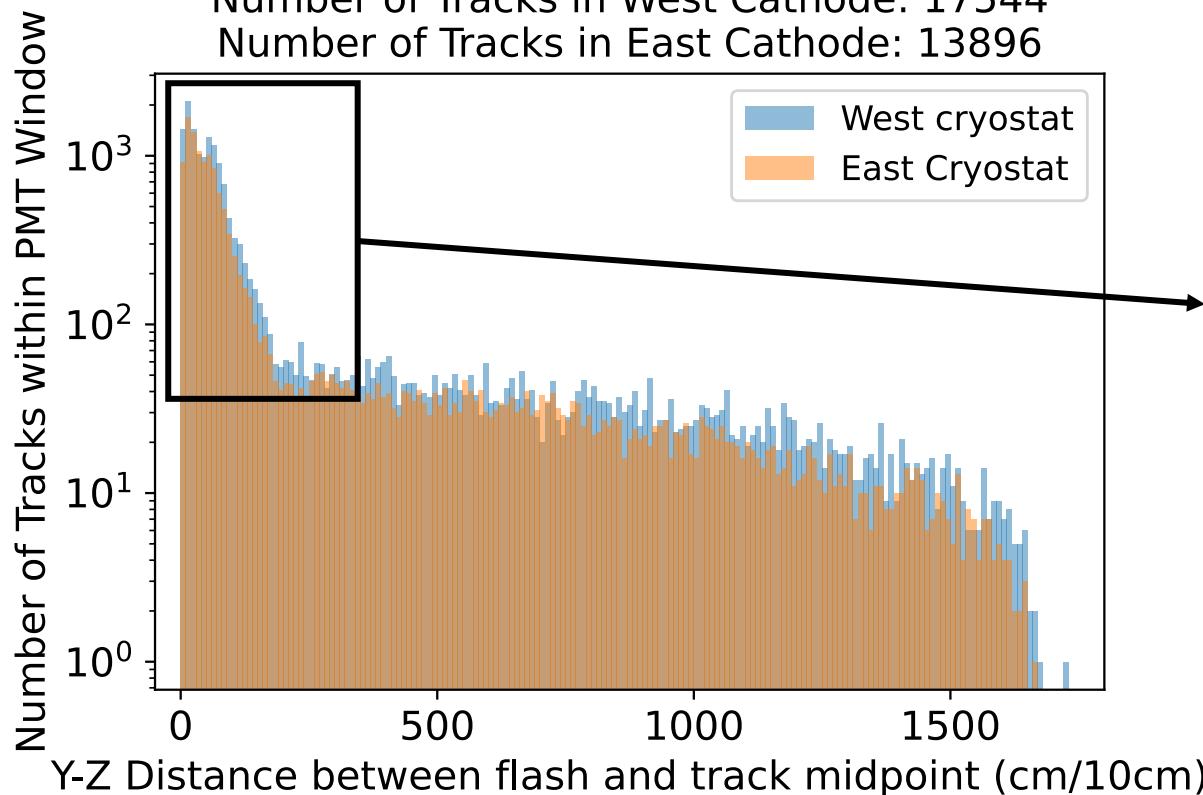
Matching by Time of Flashes and Tracks

- 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

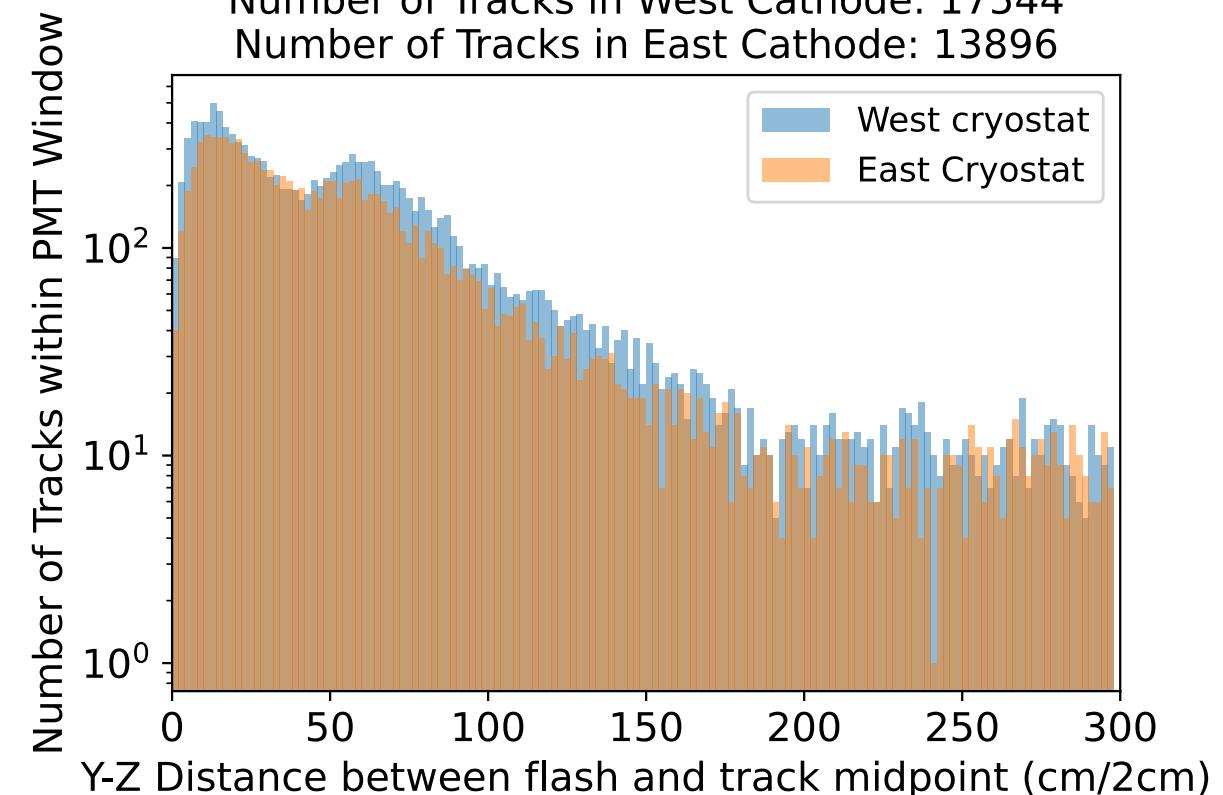
Number of Tracks in East Cathode: 13896



Run 7232: Distance between Tracks and Flashes

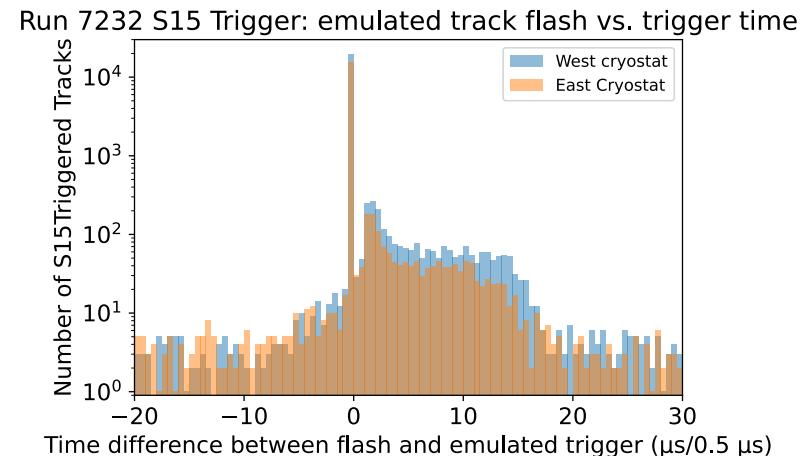
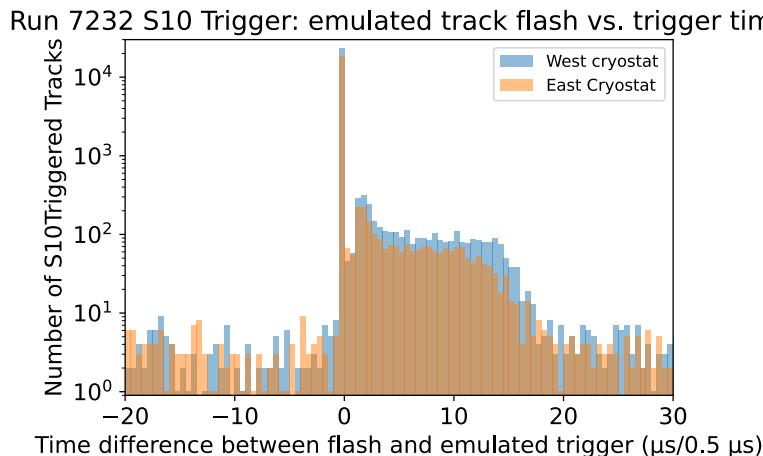
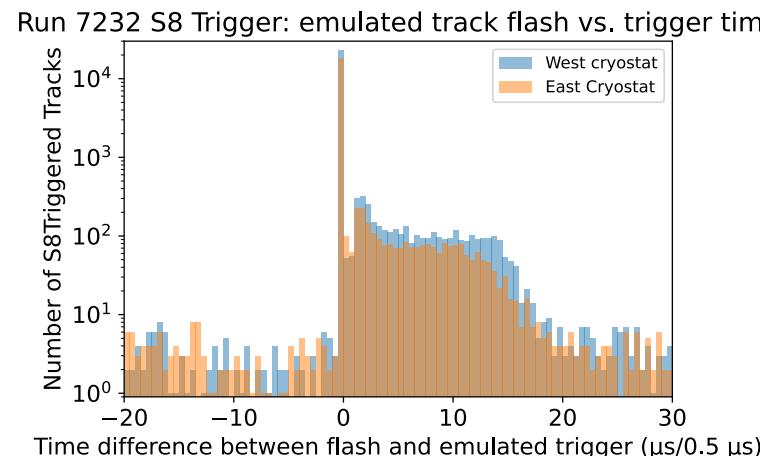
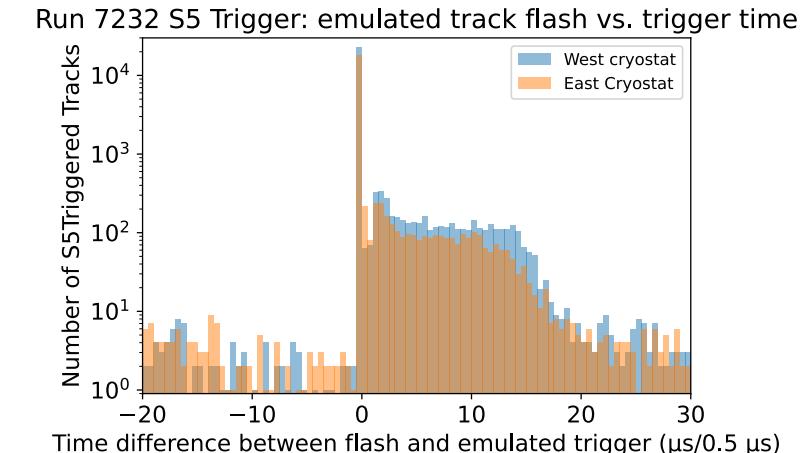
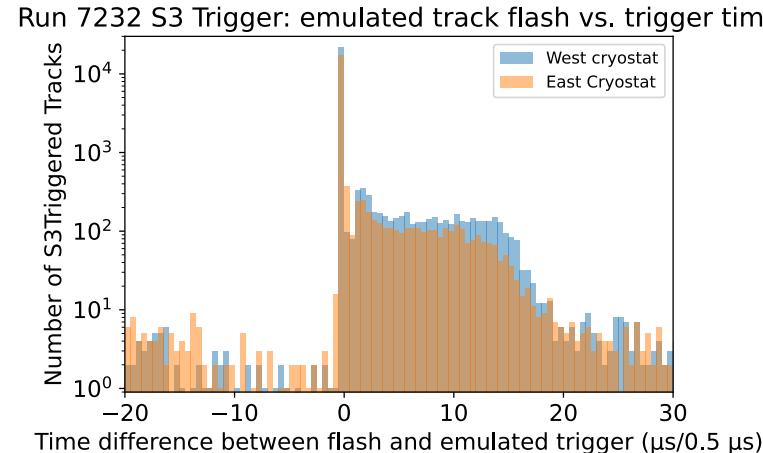
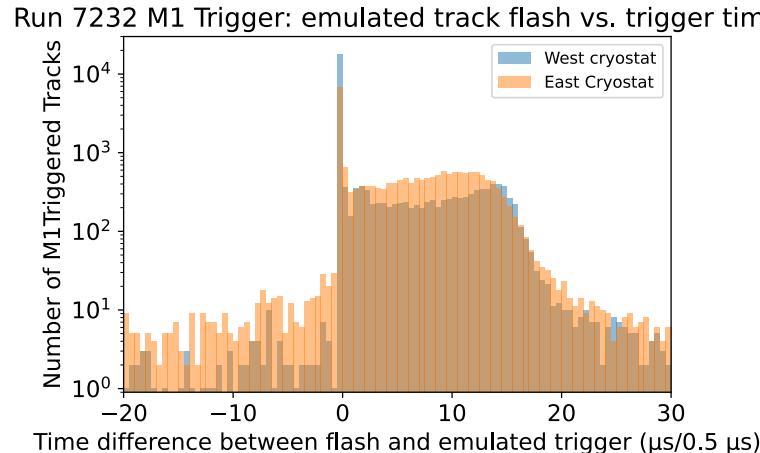
Number of Tracks in West Cathode: 17544

Number of Tracks in East Cathode: 13896



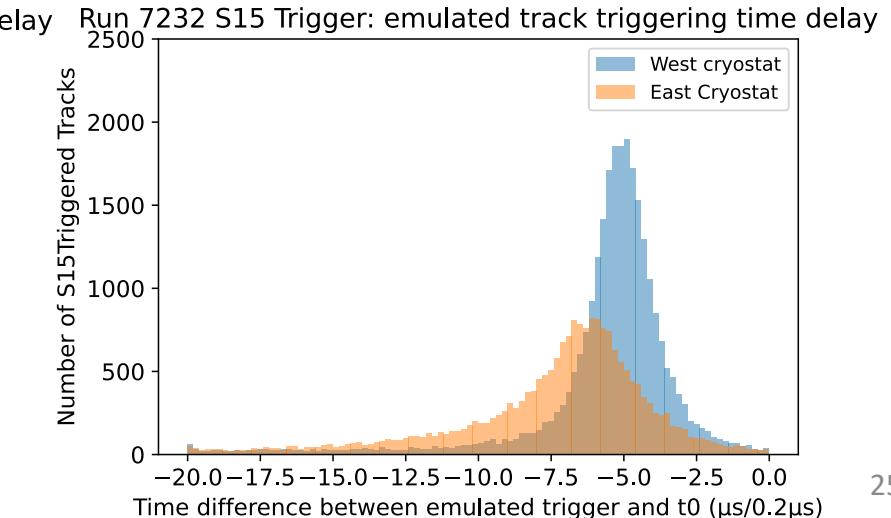
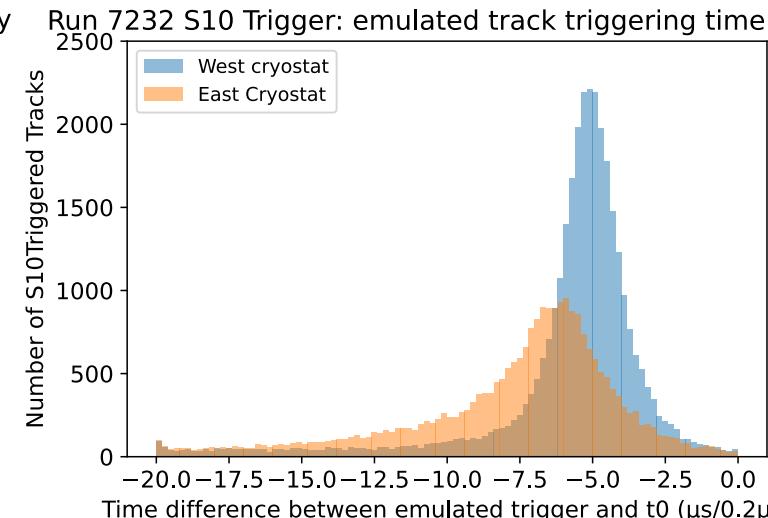
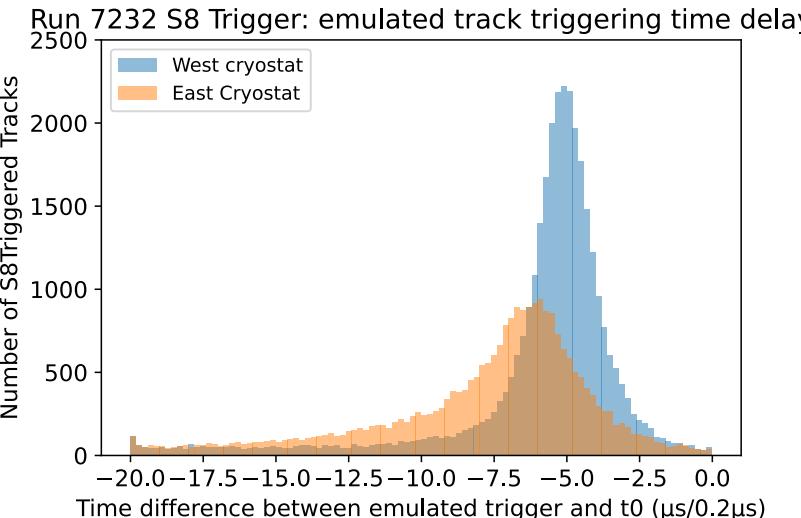
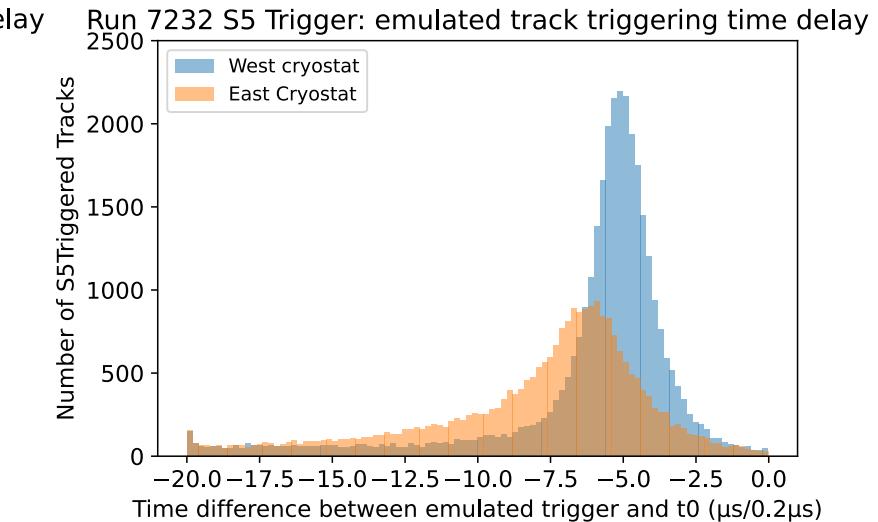
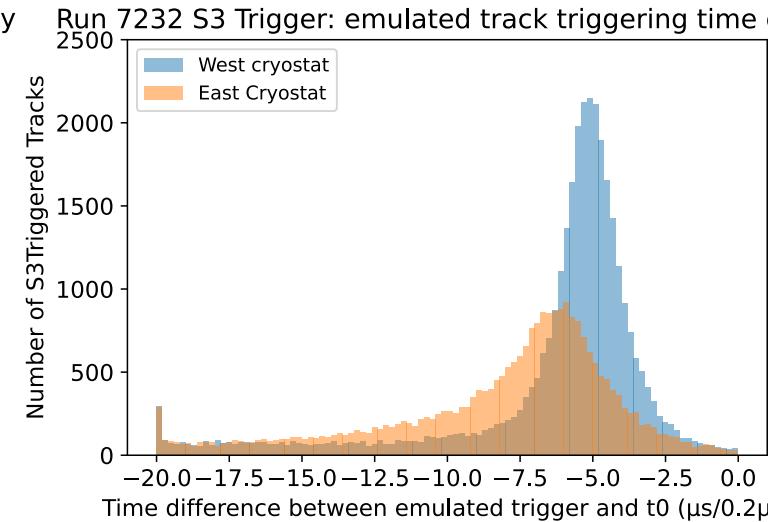
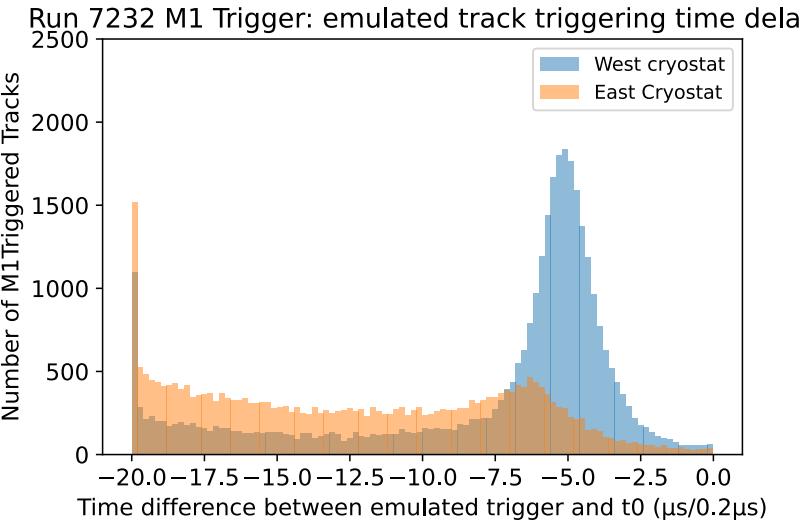
Time Difference between flash and emulated trigger

- 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



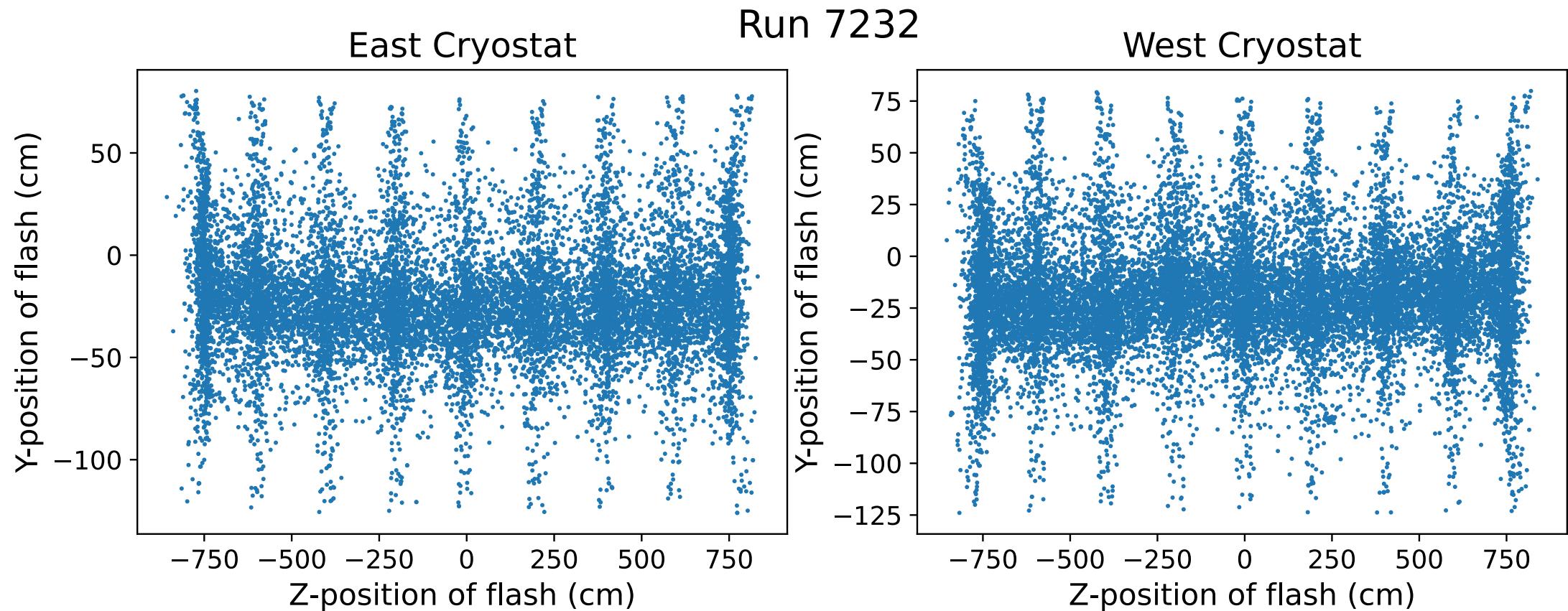
Time Difference between emulated trigger and t0 (track time)

- 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

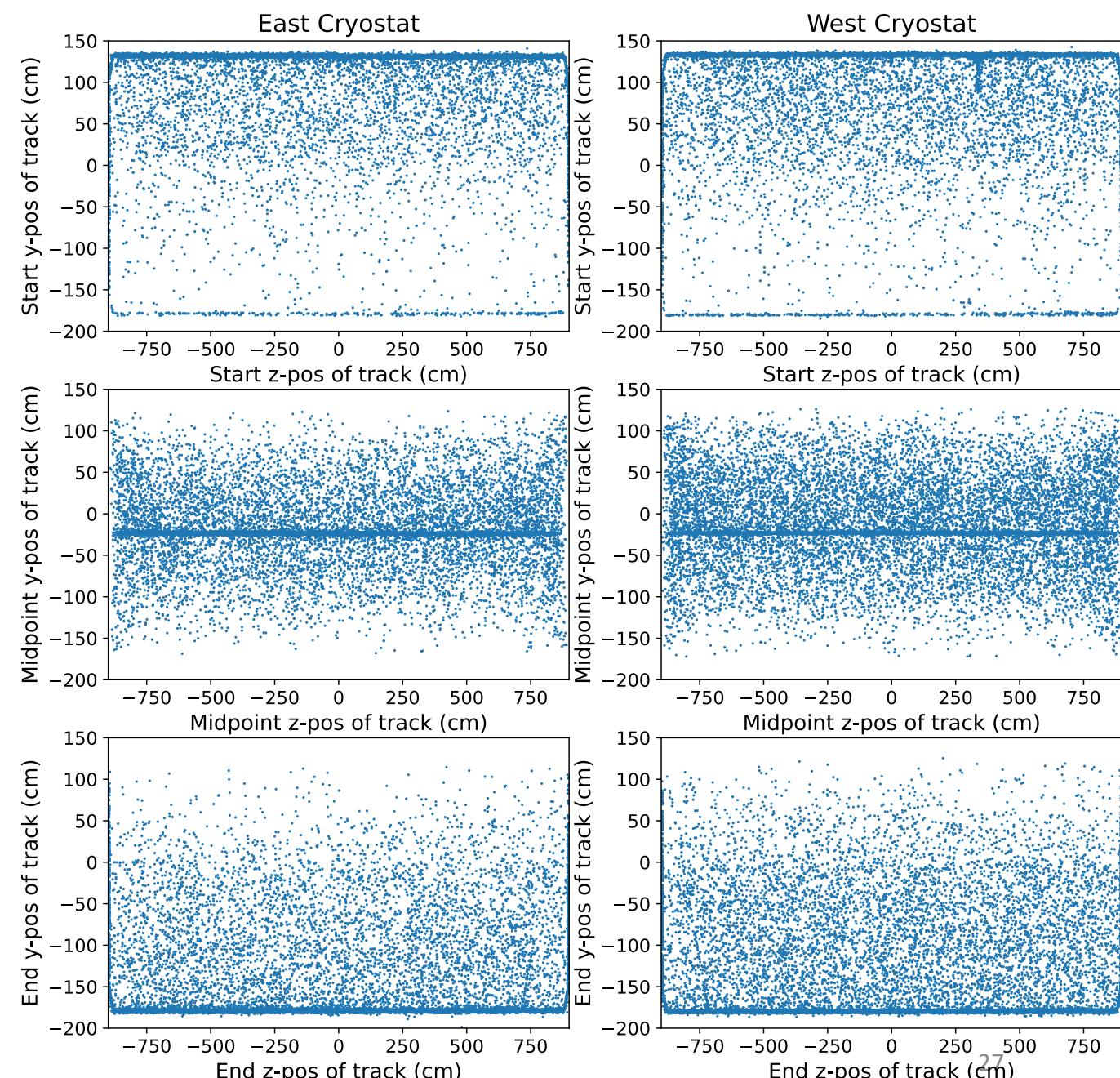
Distribution of flashes is not uniform - it is concentrated close to where the PMTs are located



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.

