



# Commissioning of the Cosmic Ray Tagger and measurement of its veto efficiency on the selection of contained neutrino interactions in SBND

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Final presentation

25th September 2024



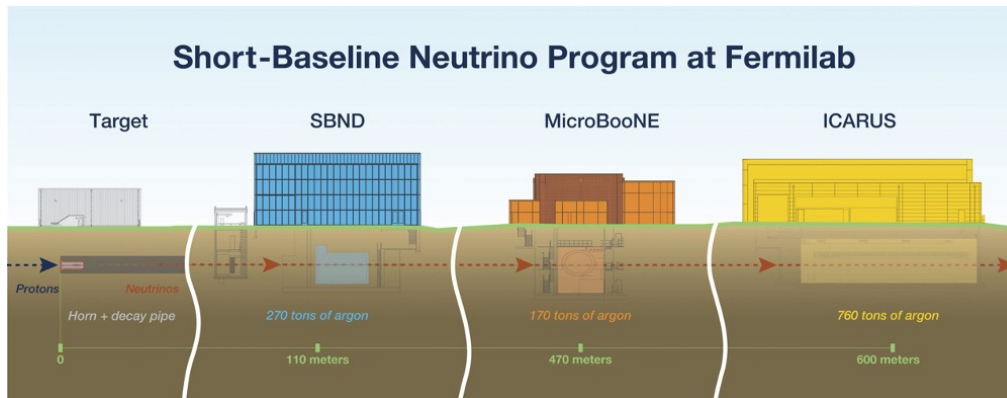
# *A LITTLE REFRESHER...*



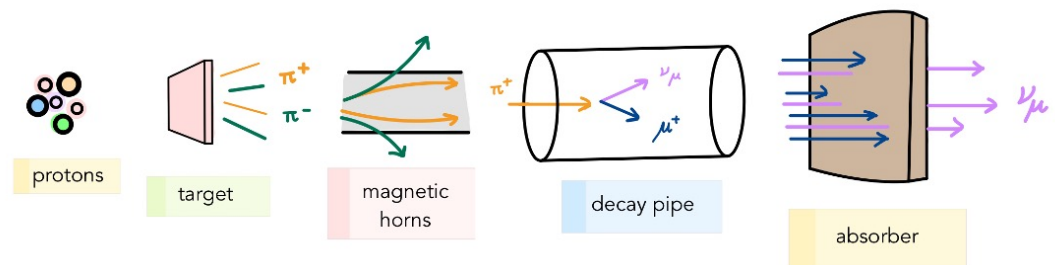
# Short Baseline Near Detector



- The Short-Baseline Near Detector (SBND) will be one of three liquid Argon neutrino detectors sitting in the Booster Neutrino Beam (BNB) at Fermilab, as part of the Short-Baseline Neutrino Program.
- MicroBooNE and ICARUS are the intermediate and far detectors in the program, respectively



Neutrino beam production

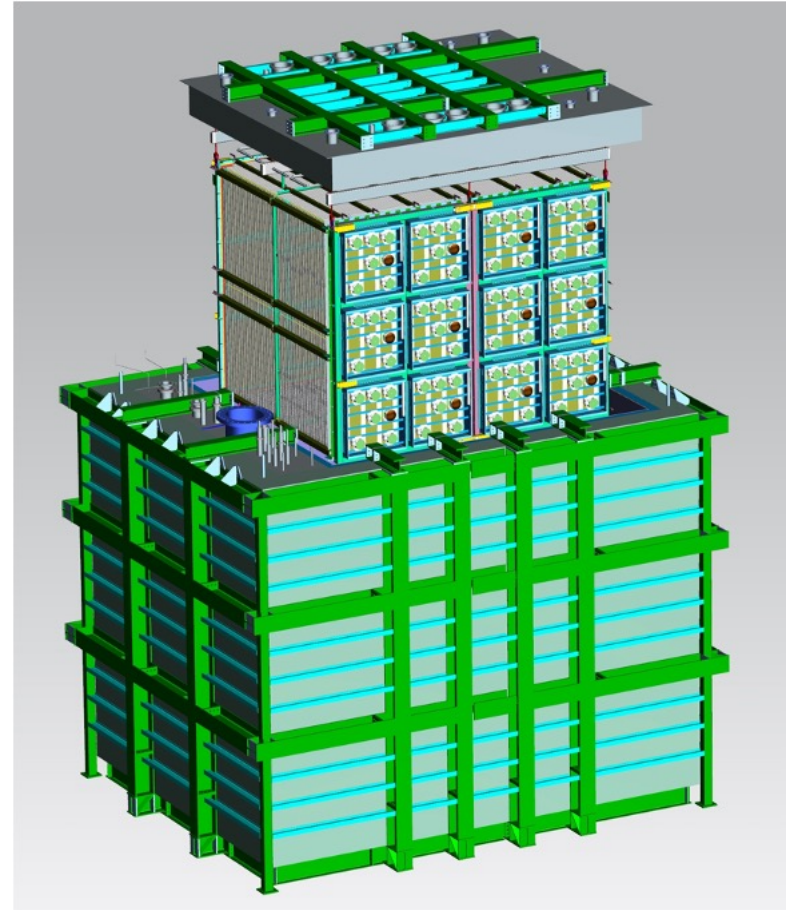
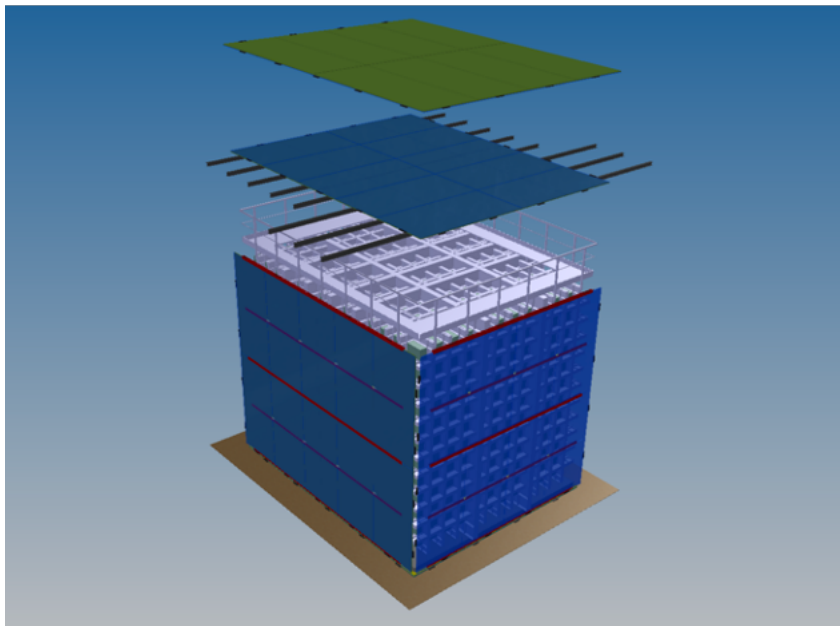


# SBND Cosmic Ray Tagger



SBND is a multi-component system with three different detectors:

- Time Projection Chamber (TPC)
- Photon detection system (PDS)
- Cosmic Ray Tagger (CRT)

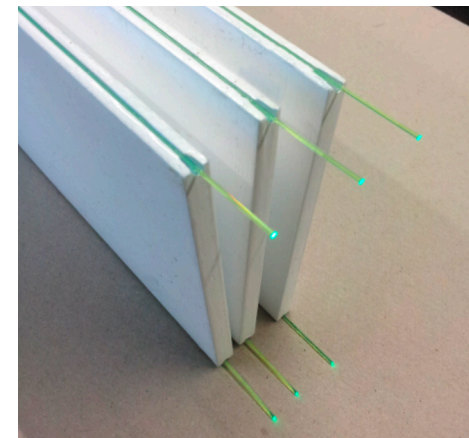
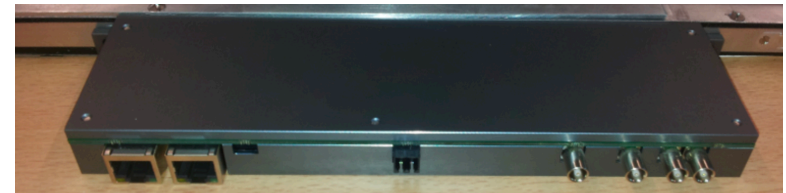
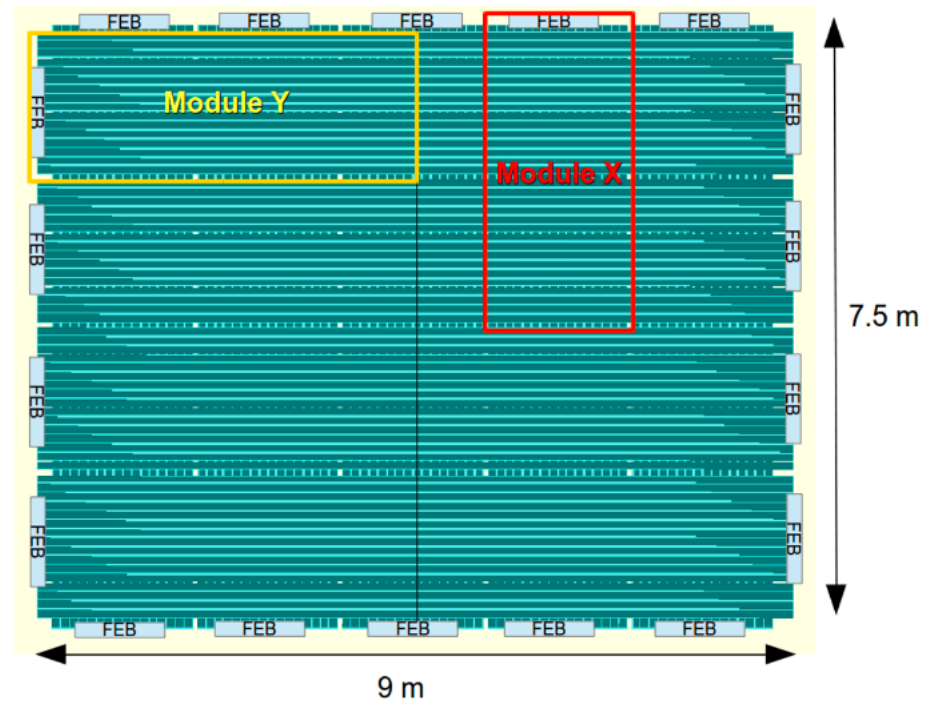


# CRT Scintillating Tracker Design



The SBND Cosmic Ray Tracker consists of **seven planes** made up of several scintillating modules.

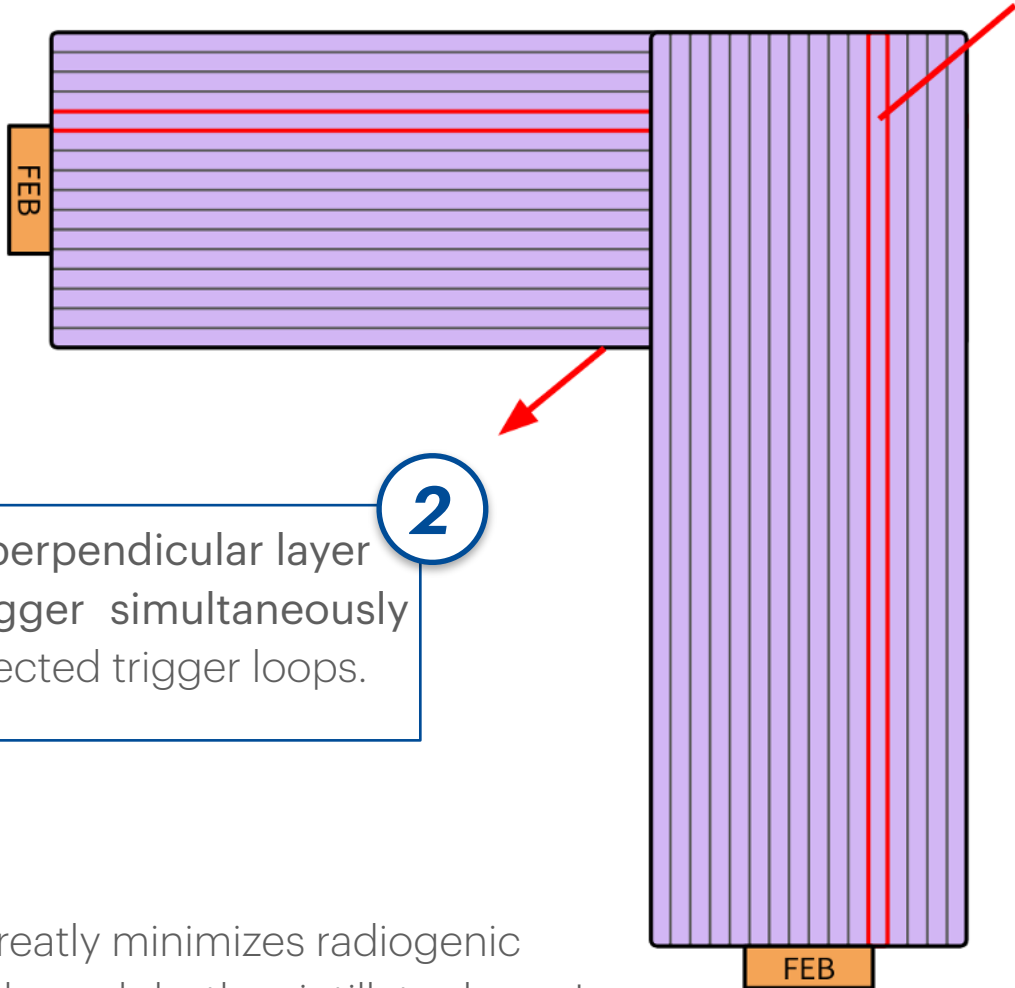
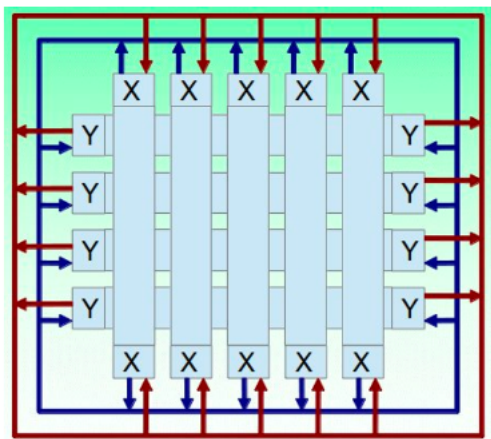
Each of these planes is composed of modules arranged in two **perpendicular layers**, with each module read out at its outer edge by a Front-End Electronics Board (FEB).



# CRT Electronic readout system

1

Each FEB needs a coincident signal above the threshold from the two channels of a scintillating strip to avoid dark noise fake hits.



2

A strip in the perpendicular layer must also trigger simultaneously through connected trigger loops.

This 4-fold coincidence greatly minimizes radiogenic backgrounds that don't pass through both scintillator layers!



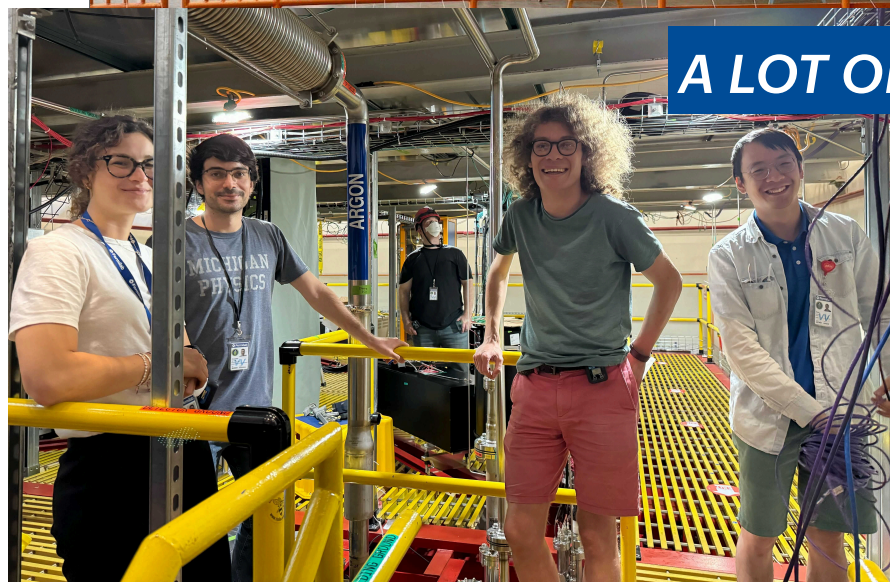


# *PREVIOUSLY ON...*

# CRT Top Low commissioning



**A LOT OF CABLES!**





# CRT Top Low commissioning



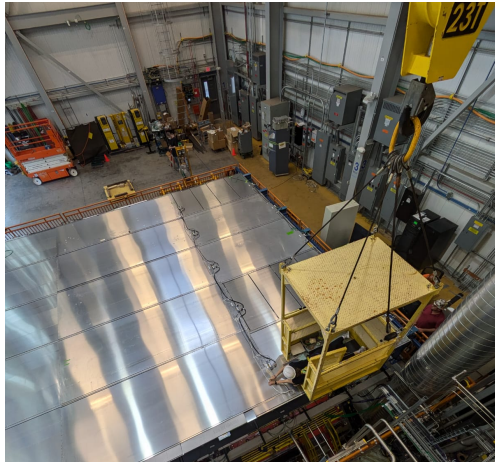
On August 13th, we finished installing the CRT Top Low!



# *IN THE NEW EPISODE ...*



# CRT Top High commissioning

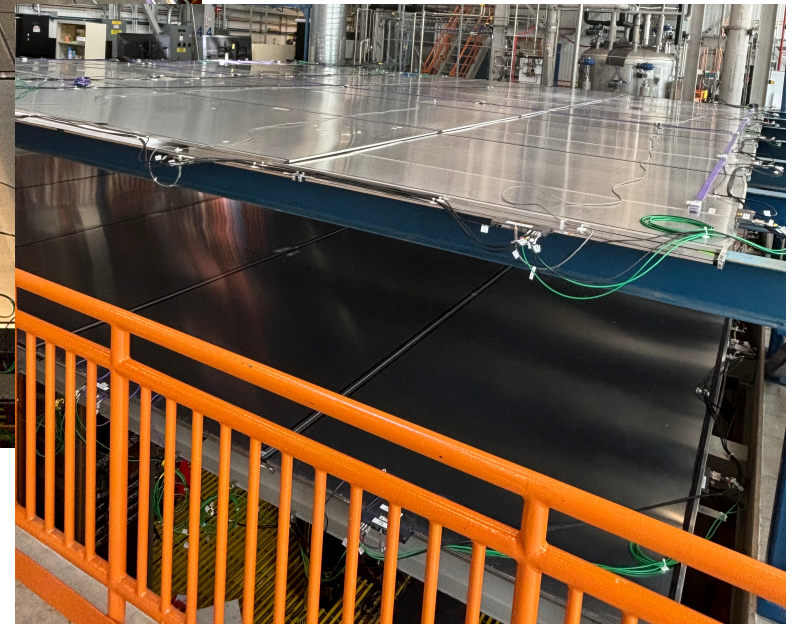
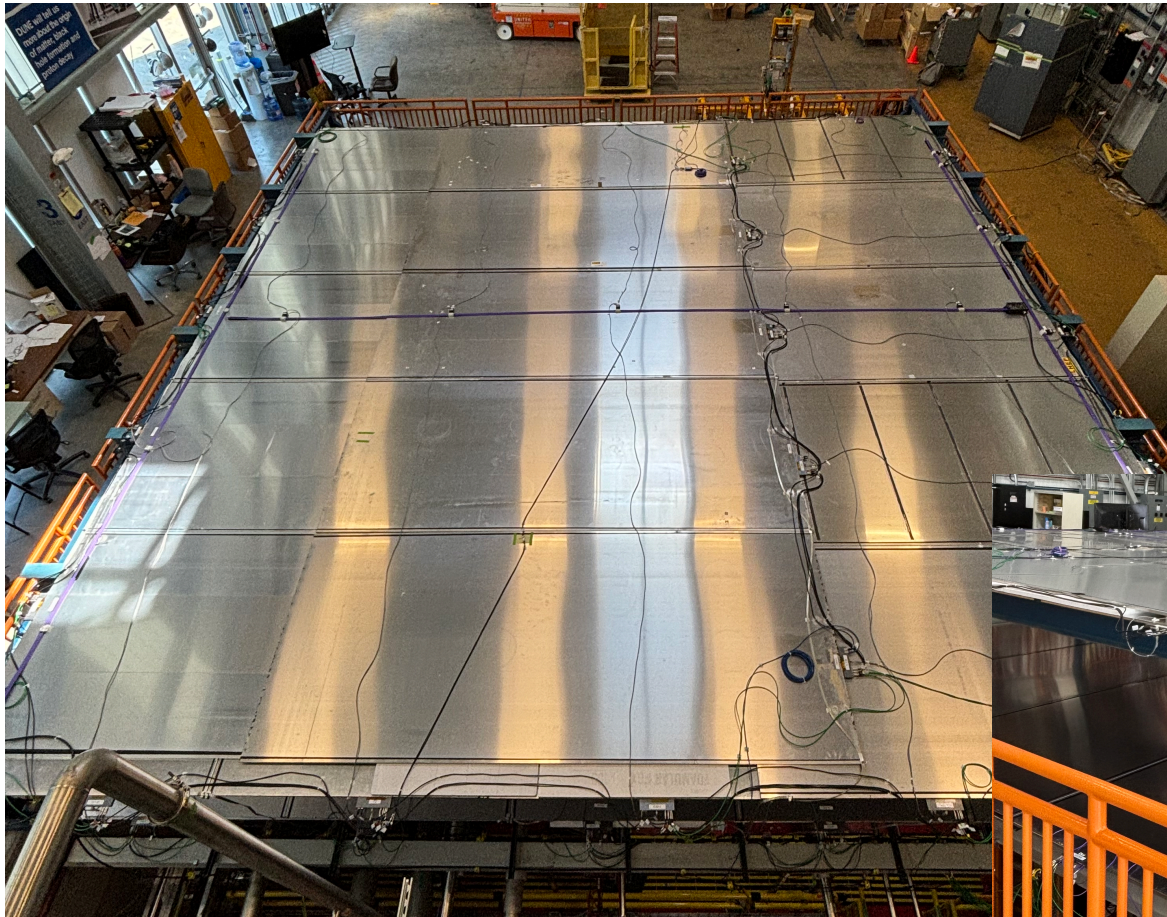


**EVEN MORE CABLES,  
AND THERE'S ALSO A CRANE !!**





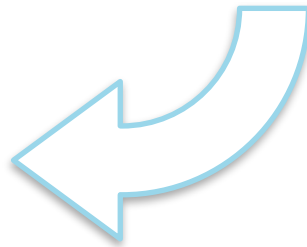
# CRT Top High commissioning



On September 13th, we finished installing the CRT Top High!

# *WHAT ABOUT DATA ANALYSIS?*

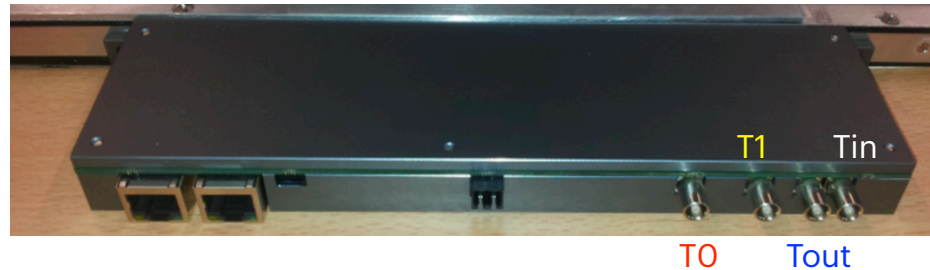
CRT Top High validation



# CRT Top High validation



During the validation of the new layer, it is essential to primarily analyze the proper functioning of the time signals.

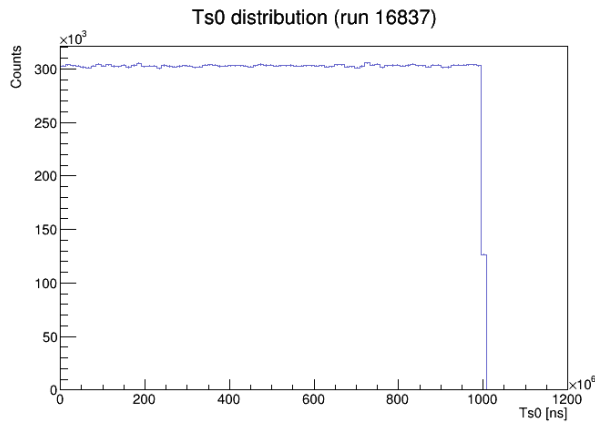


For the validation of the CRT Top High, three runs of approximately 20 minutes were acquired:

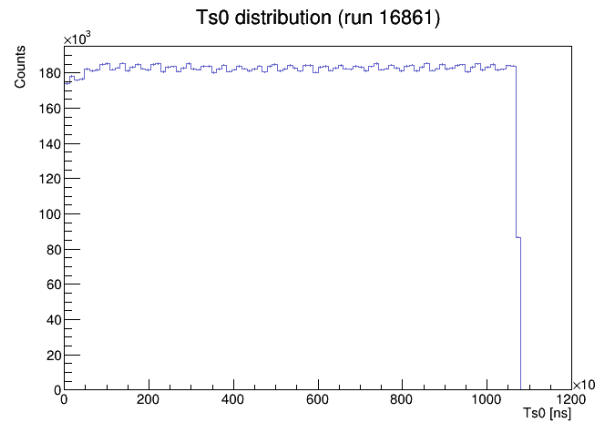
- 16837, normal run
- 16861 and 16903, with T0 & T1 fibres swapped for T1 clock validation



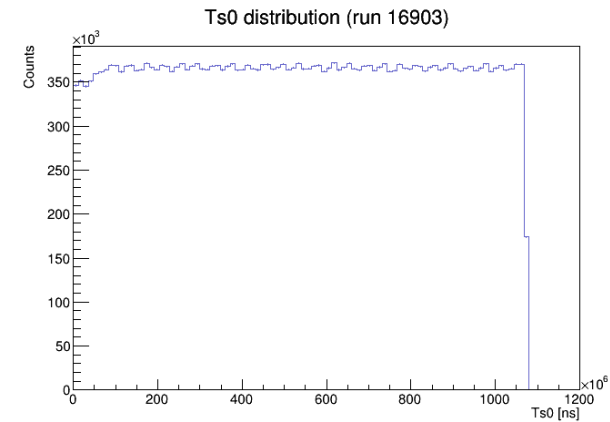
# CRT Top High validation Ts0 distribution



RUN 16837



RUN 16861

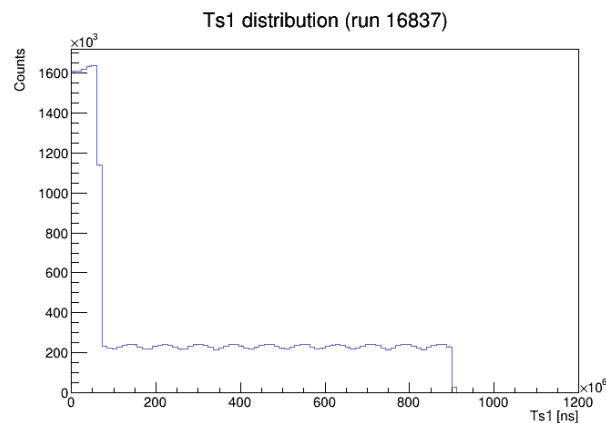


RUN 16903

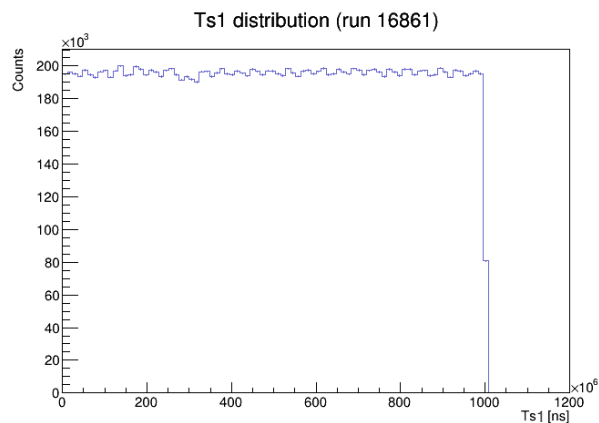


As expected they all show a uniform distribution (either 1 s if it is receiving PPS or  $\sim 1.07$  s)

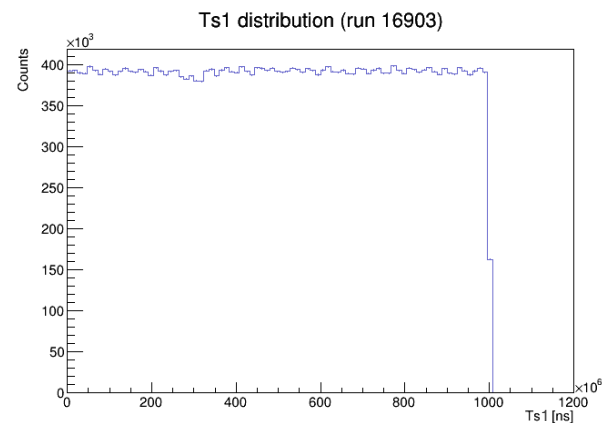
# CRT Top High validation Ts1 distribution



RUN 16837



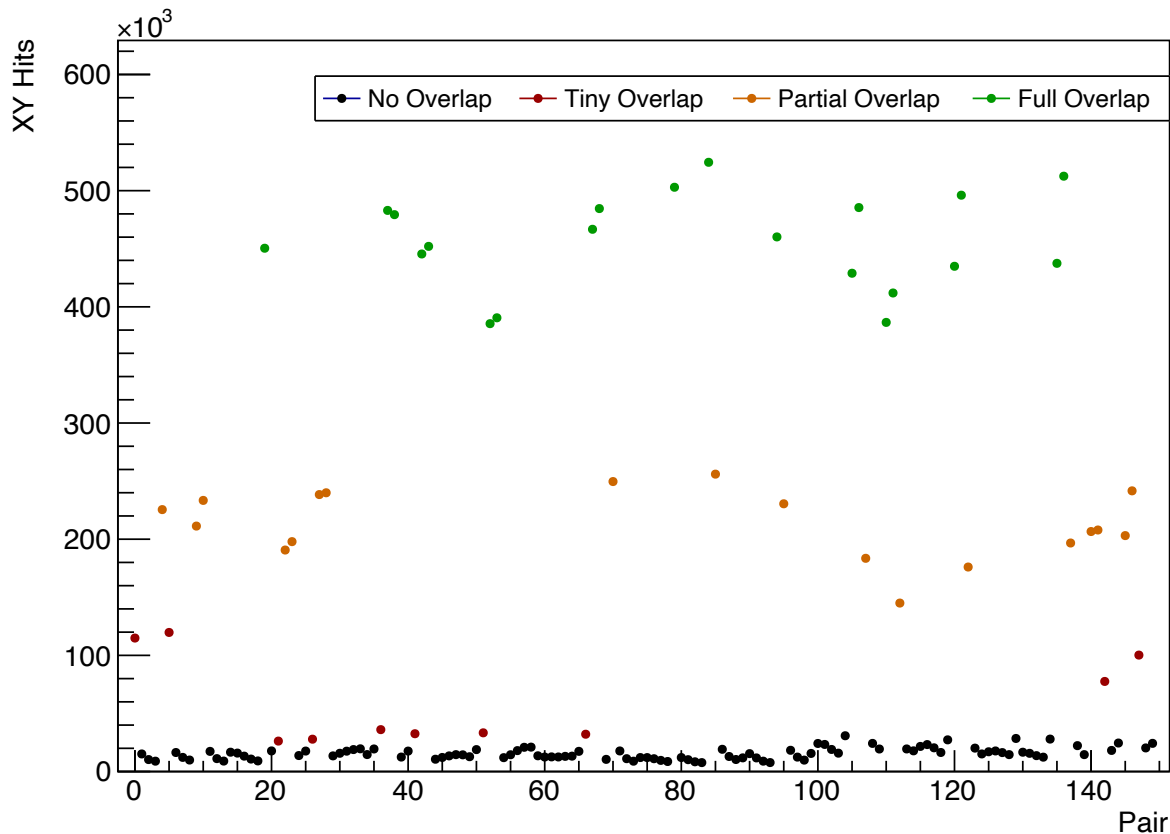
RUN 16861



RUN 16903

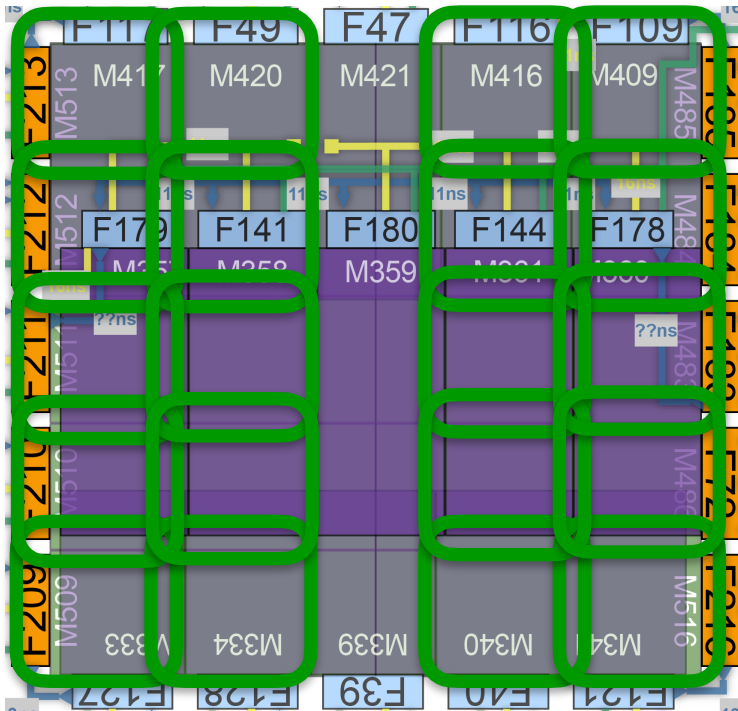
✓ Run **16837** shows the fake beam distribution, while the swapped runs (**16861** & **16903**) show the uniform distribution

# CRT Top High validation Tin/Tout

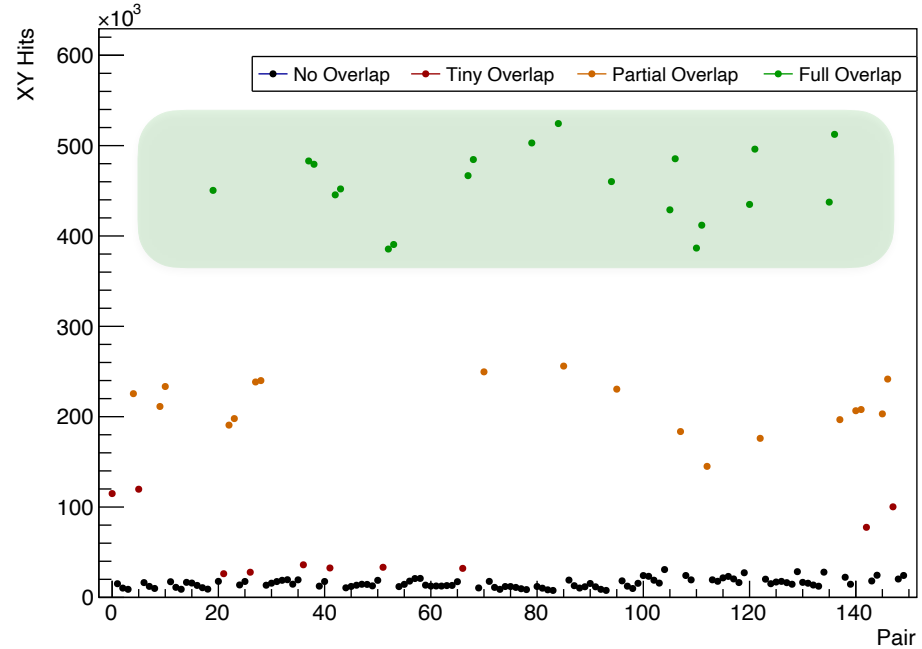


In this plot, each 3D point corresponds to any coincident readouts from both the X and Y modules. Depending on the geometric arrangement of the modules, we can identify three distinct groups.

# CRT Top High validation Tin/Tout

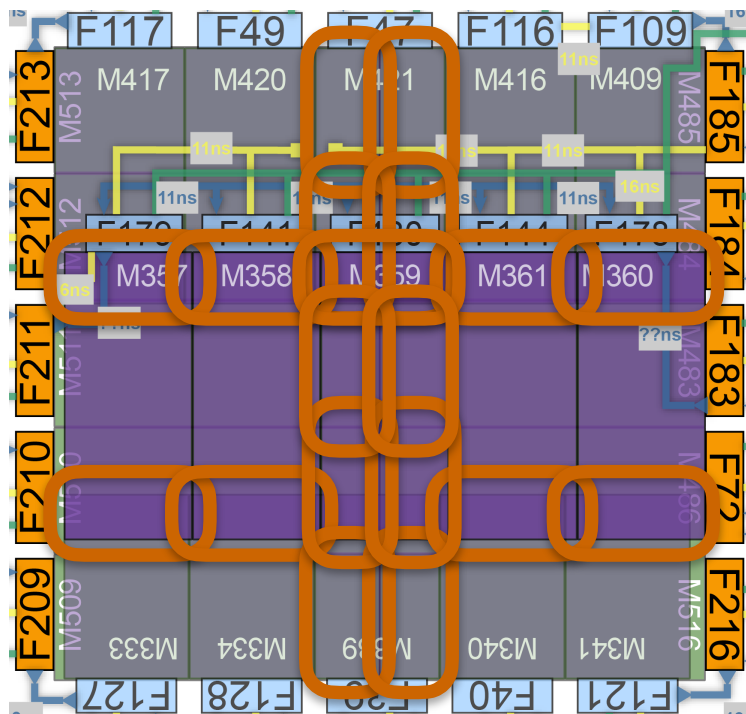


FULL OVERLAP

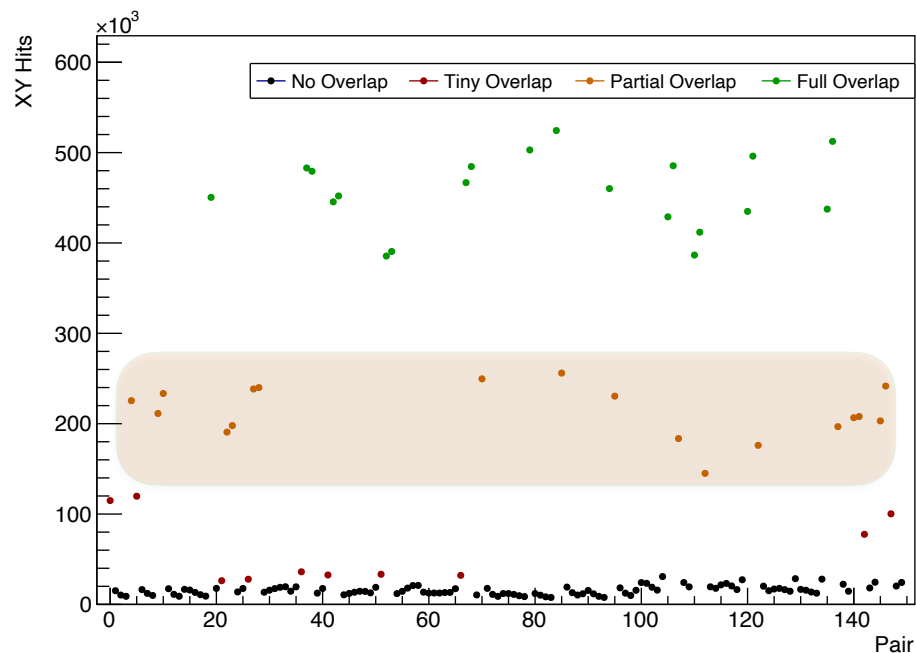




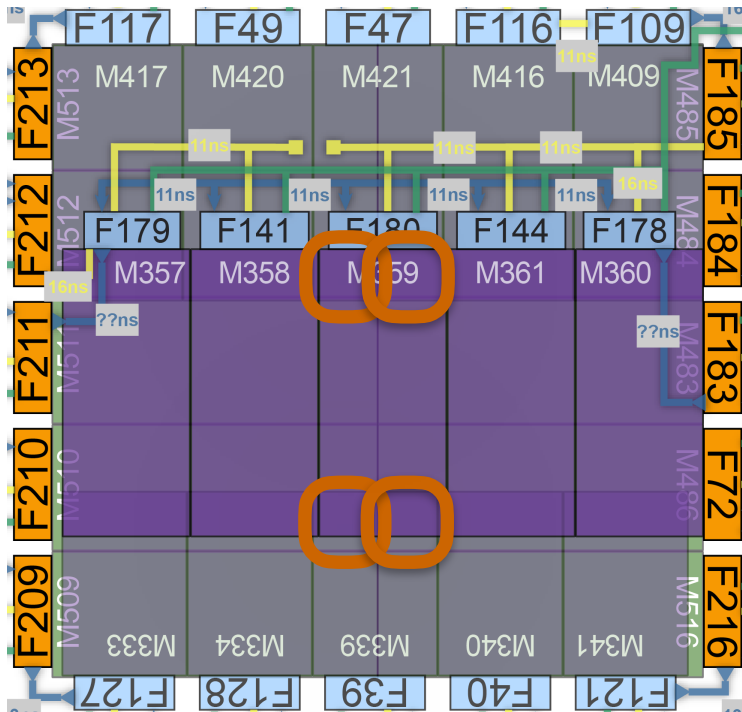
# CRT Top High validation Tin/Tout



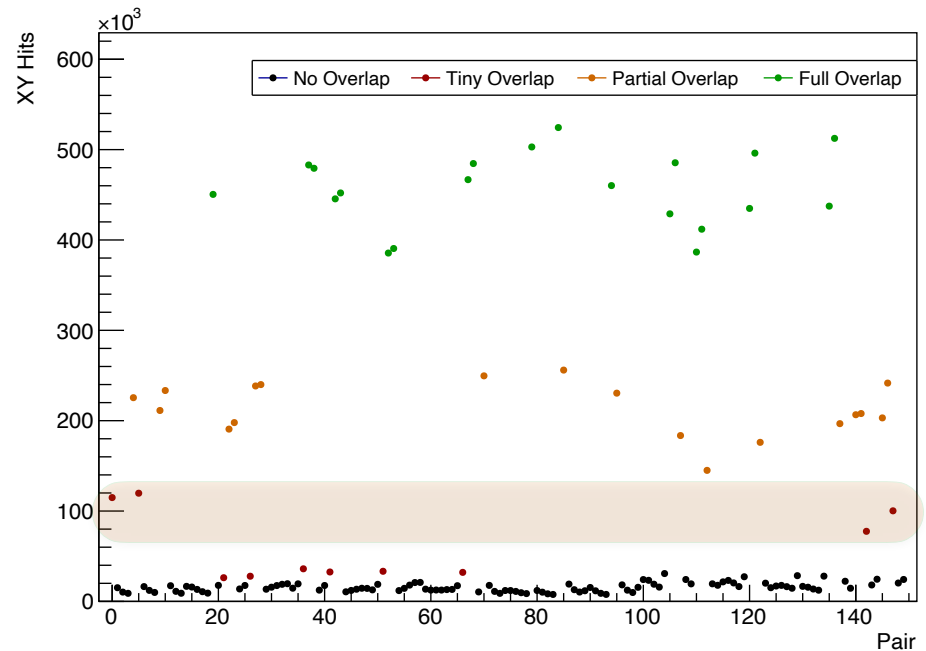
*PARTIAL OVERLAP*



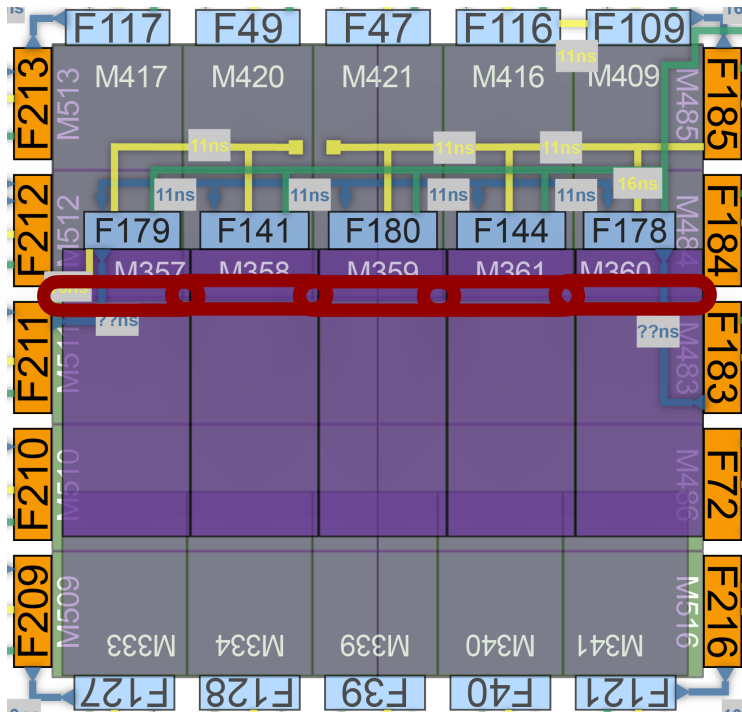
# CRT Top High validation Tin/Tout



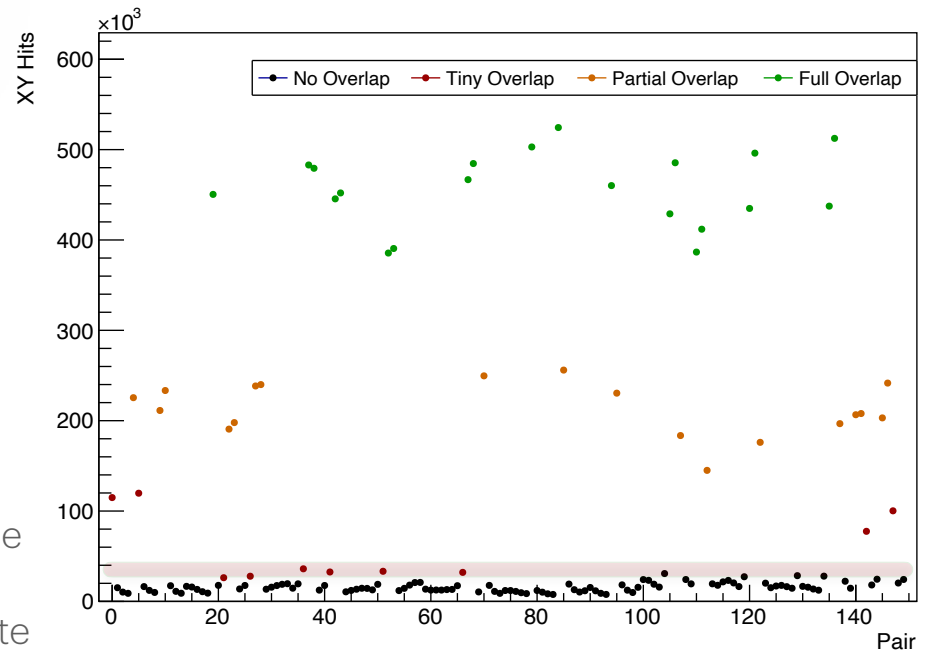
SMALLER PARTIAL OVERLAP



# CRT Top High validation Tin/Tout



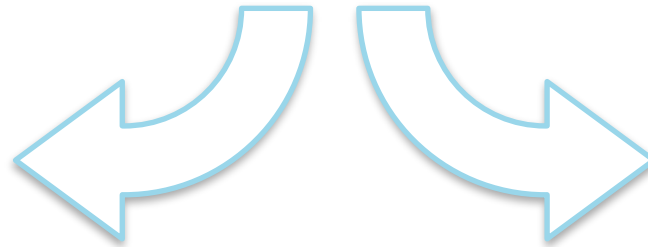
TINY OVERLAP



The XY reconstruction thus confirms the agreement between the geometric arrangement of the modules and the rate of recorded events!

## ***WHAT ABOUT DATA ANALYSIS?***

CRT Top High validation



The measure of the efficiency of using a CRT veto in a contained neutrino trigger

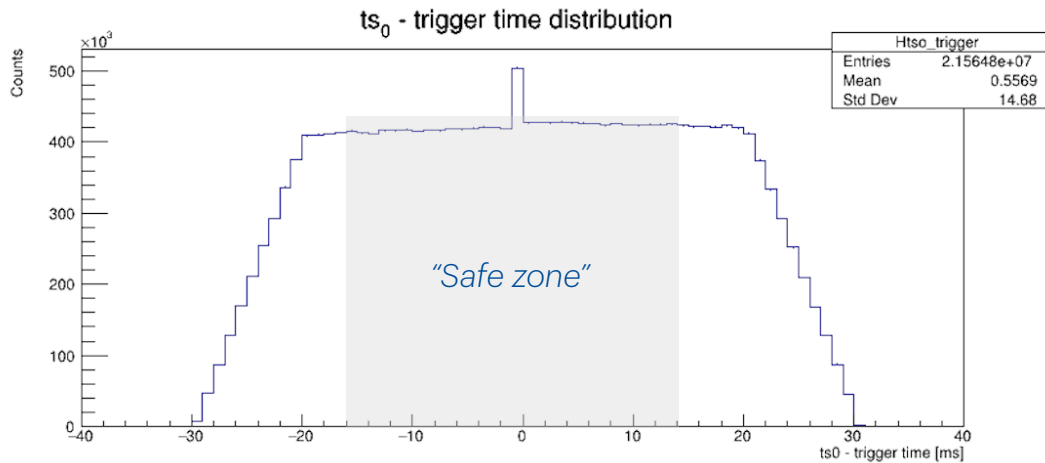
# CRT veto efficiency



The goal is to calculate how efficiently the CRT acts as a veto in a contained neutrino event, in other words it is the probability of not triggering the CRT veto during a fully contained neutrino interaction



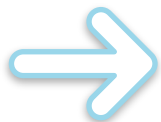
Selection of recorded events within a 30 ms time window from the trigger



# CRT veto efficiency



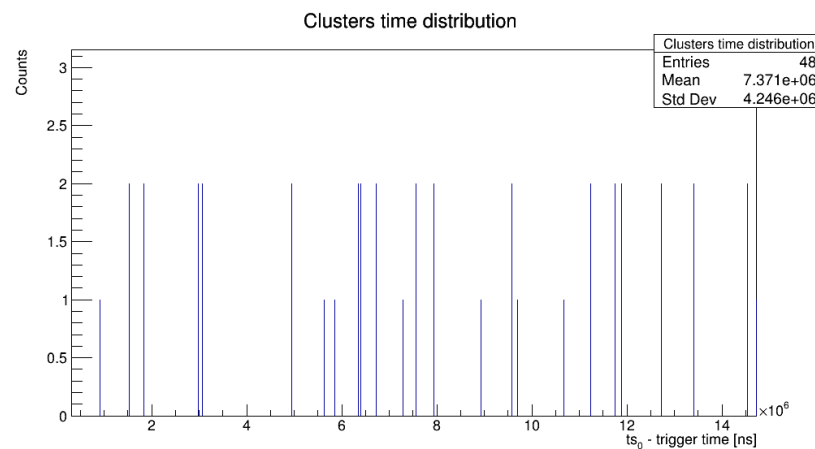
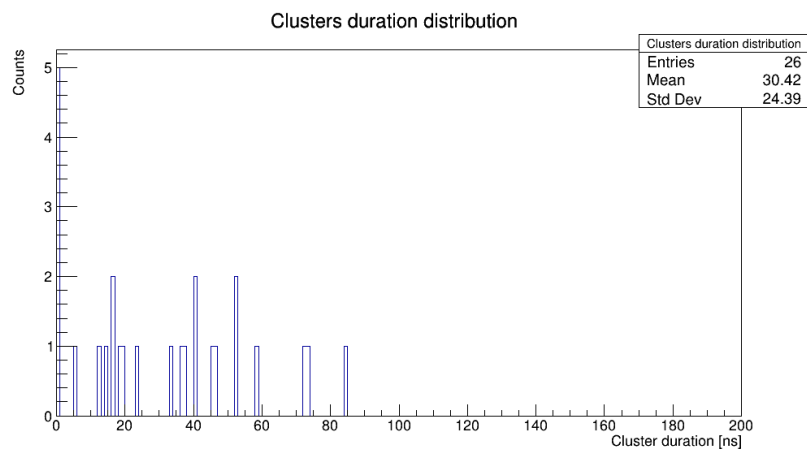
The goal is to calculate how efficiently the CRT acts as a veto in a contained neutrino event, in other words it is the probability of not triggering the CRT veto during a fully contained neutrino interaction



Selection of recorded events within a 30 ms time window from the trigger



Group the signals into subgroups of 200 ns



# CRT veto efficiency



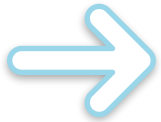
The goal is to calculate how efficiently the CRT acts as a veto in a contained neutrino event, in other words it is the probability of not triggering the CRT veto during a fully contained neutrino interaction



Selection of recorded events within a 30 ms time window from the trigger



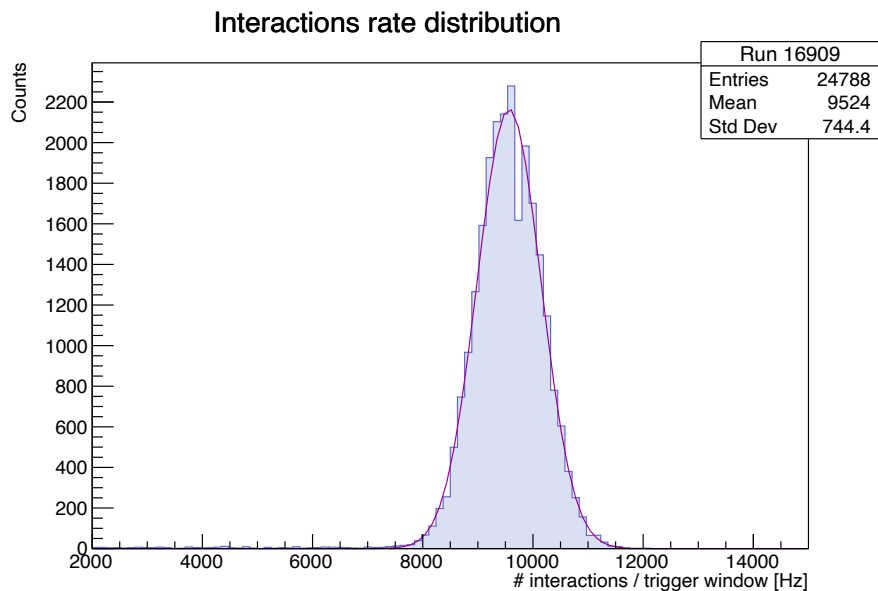
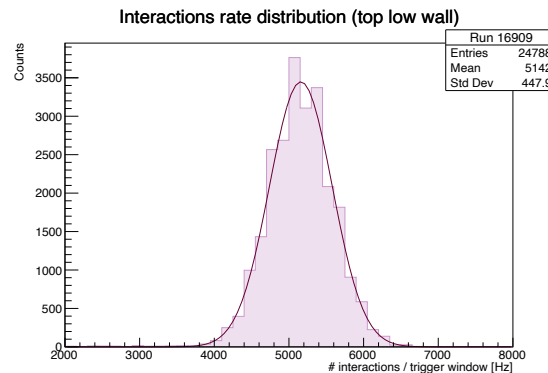
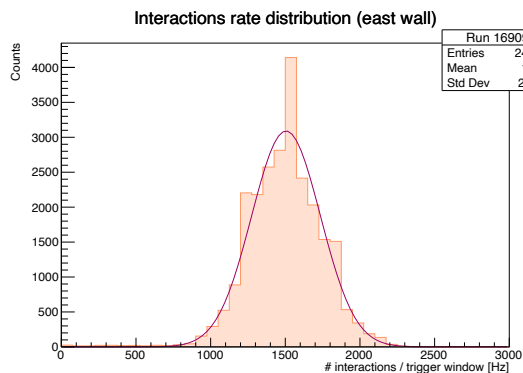
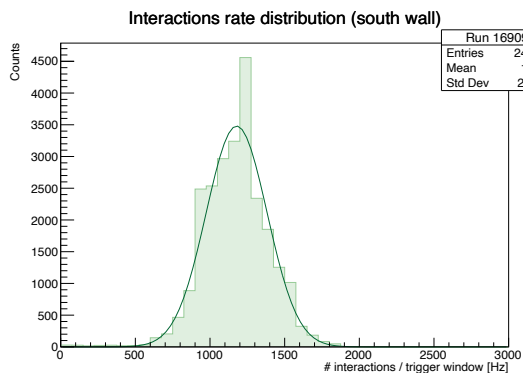
Group the signals into subgroups of 200 ns



Count the number of revealed subgroups to estimate the rate of cosmic rays on the walls of the CRT



# CRT veto efficiency

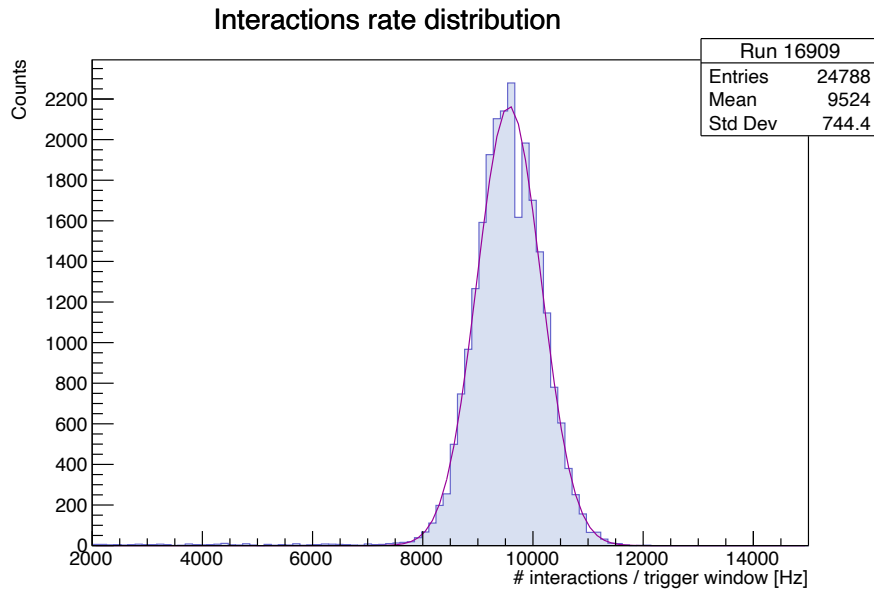
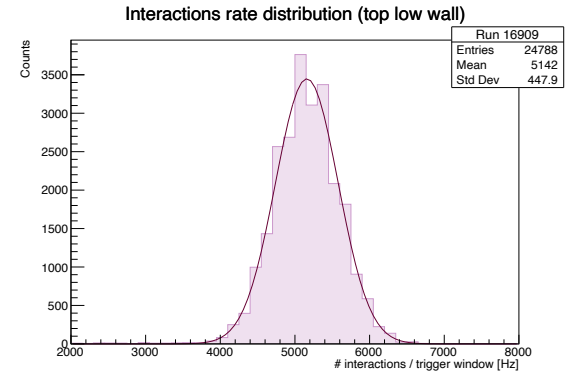
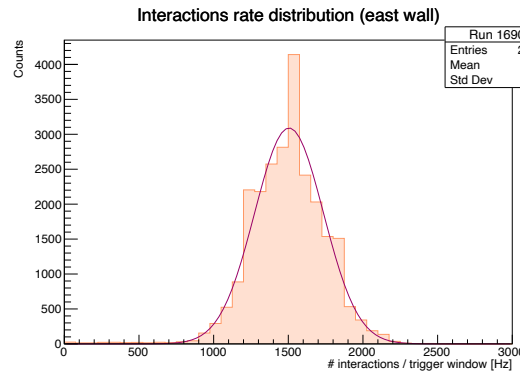
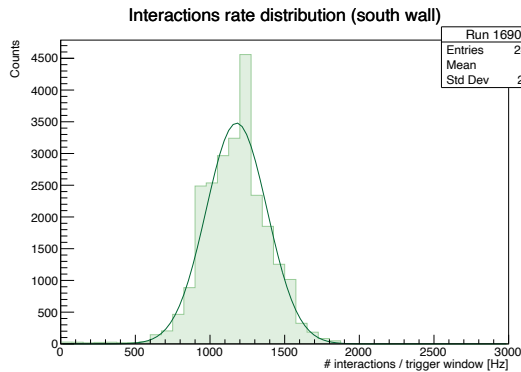


If we consider the contributions from all the walls:

- SOUTH wall ~ 1150 Hz
- NORTH wall ~ 1300 Hz
- EAST wall ~ 1500 Hz
- WEST wall ~ 1500 Hz
- BOTTOM wall ~ 2300 Hz
- TOP LOW wall ~ 5150 Hz
- TOP HIGH wall ~ 5150 Hz

**18000 Hz**

# CRT veto efficiency



In a neutrino beam spill of about  $2 \mu s$ , the efficiency of the CRT veto (considering all the walls, including the Top High) is about **98%**



**Thank you for the attention!**

A special thanks to Michelle, Henry and the SBND team!

# ***BACKUP SLIDES***

# XY rate feb pairs

```

mac5_pairs = { { 117, 213 },
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               { 49, 213 },
               { 49, 212 },
               { 116, 185 },
               { 116, 184 },
               { 109, 185 },
               { 109, 184 },
               { 127, 209 },
               { 128, 209 },
               { 40, 216 },
               { 121, 216 },
               { 179, 211 },
               { 179, 210 },
               { 141, 211 },
               { 141, 210 },
               { 144, 183 },
               { 178, 183 },
               { 178, 72 },
               { 144, 72 } },

mac5_small_pairs = { { 47, 213 },
                    { 47, 185 },
                    { 47, 212 },
                    { 47, 184 },
                    { 127, 210 },
                    { 128, 210 },
                    { 39, 209 },
                    { 39, 216 },
                    { 40, 72 },
                    { 121, 72 },
                    { 144, 184 },
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                    { 180, 211 },
                    { 180, 183 },
                    { 180, 210 },
                    { 180, 72 },
                    { 178, 184 },
                    { 179, 212 } },

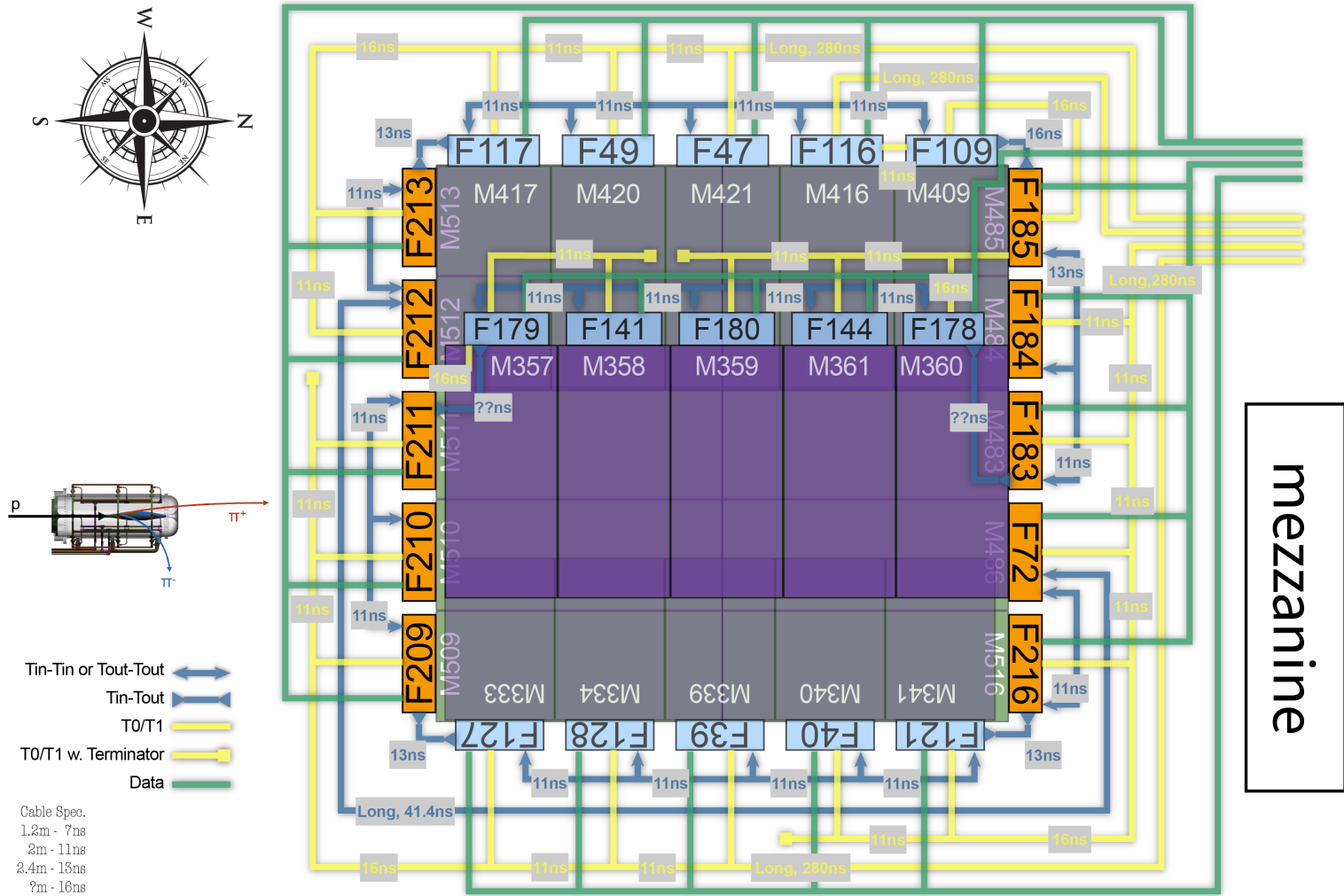
mac5_very_small_pairs = { { 117, 211 },
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                          { 39, 72 },
                          { 180, 212 },
                          { 180, 184 } },

```

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INDEX: 2	39	184	INDEX: 28	47	213	INDEX: 54	116	209	INDEX: 80	127	72	INDEX: 106	141	211	INDEX: 132	179	184
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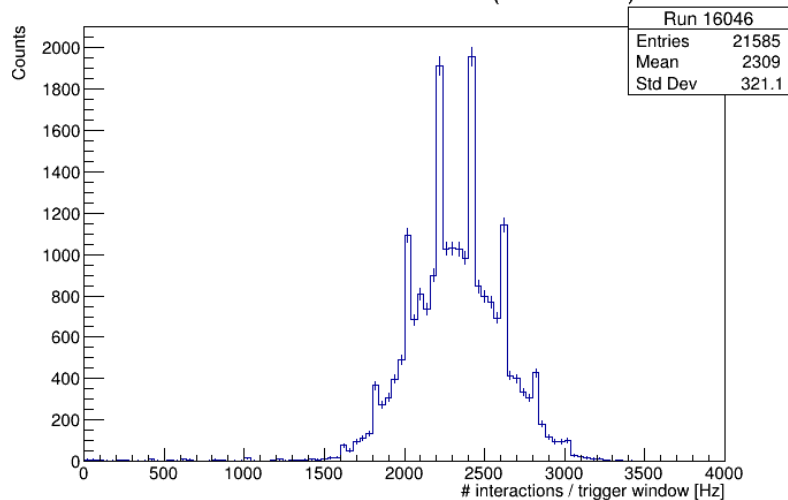
# CRT Top High map



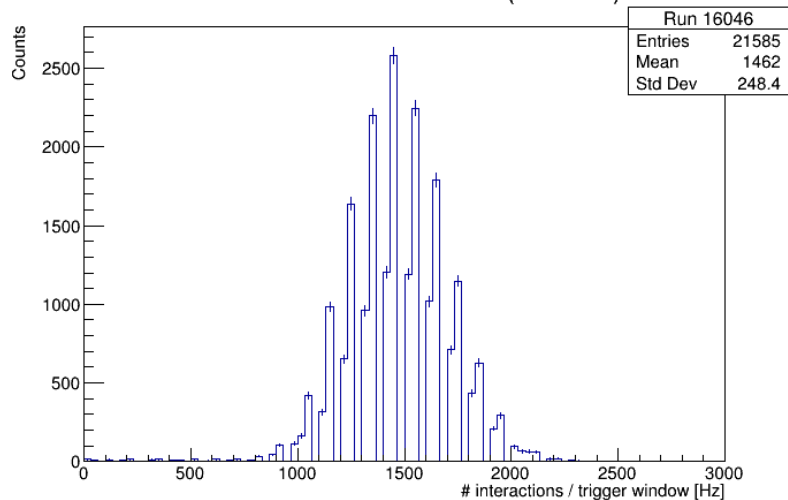
mezzanine

# CRT veto efficiency

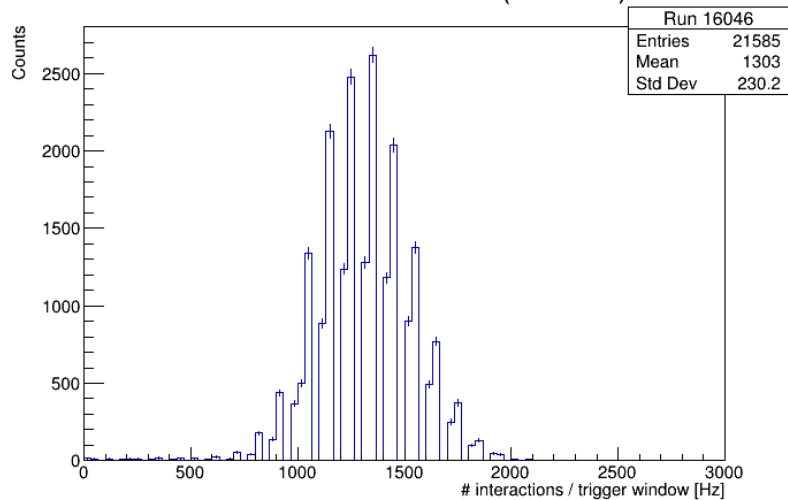
Interactions rate distribution (bottom wall)



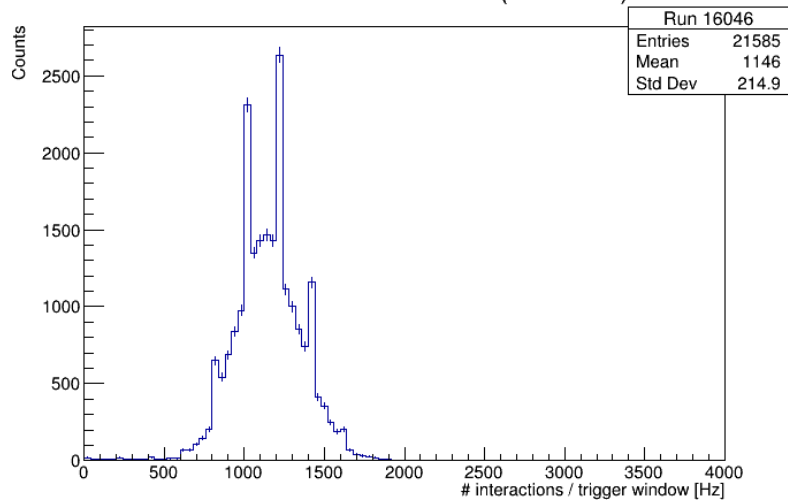
Interactions rate distribution (east wall)



Interactions rate distribution (north wall)

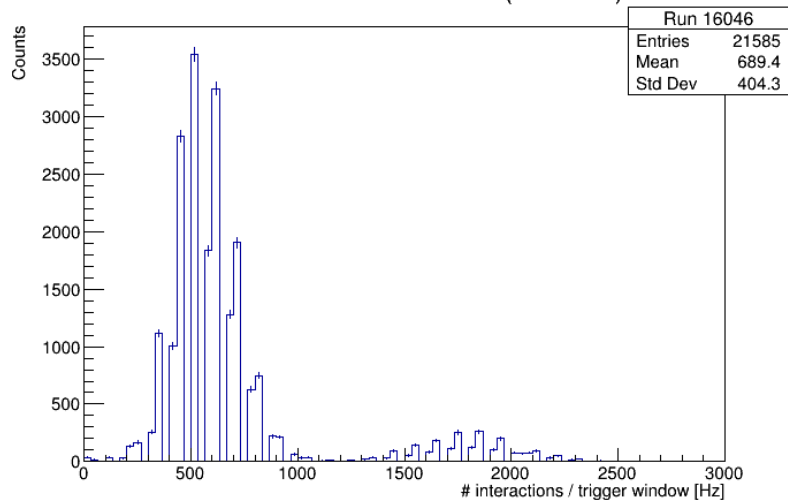


Interactions rate distribution (south wall)

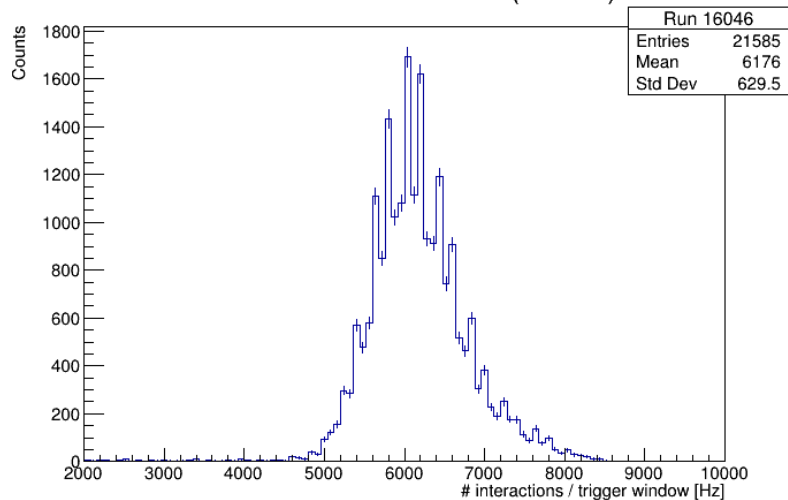


# CRT veto efficiency

Interactions rate distribution (west wall)



Interactions rate distribution (all walls)



Interactions rate distribution (all walls)

