# GRINCH Gas Cherenkov Detector for Super BigBite

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# **G**as **R**ing **I**magi**N**g **CH**erenkov (GRINCH) Detector

The purpose of the GRINCH is to discriminate between pions and electrons in electron scattering experiments in Super BigBite (SBS) program at Jefferson Lab, Hall A.

Installed in Hall A at Jefferson Lab as part of the BigBite electron arm for the Super BigBite Spectrometer summer 2021.

Filled with heavy gas and began commissioning with electron beam data during the GMn experiment in January 2022.

**Today we will talk about:**

- Cherenkov Radiation
- GRINCH Background
- Preliminary performance results from GMn
  - Cluster Finding Methods
  - Electron efficiency
- Next steps and future work

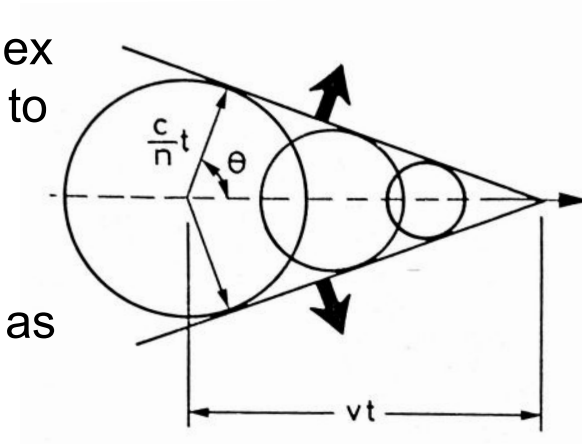
# Cherenkov Radiation

Cherenkov Radiation happens when an electromagnetic shock wave is formed when a particle travels faster than the speed of light in the medium.

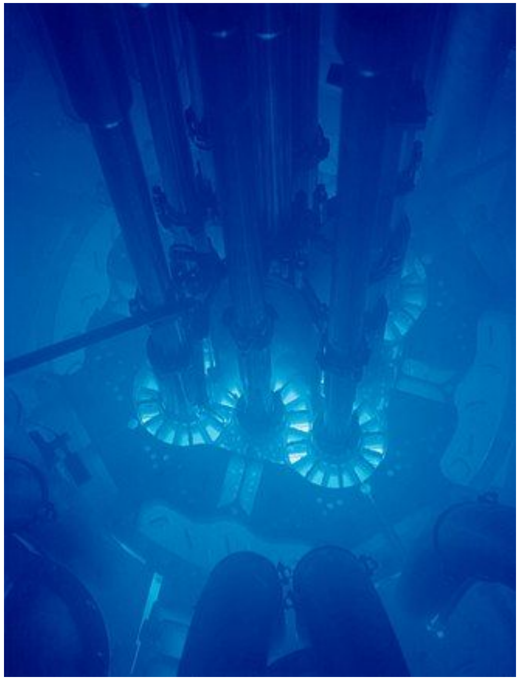
A medium with a certain index of refraction can be chosen to discriminate between velocities.

Light cone can be detected as a ring using photomulitpler tubes (PMTs).

Allows for discrimination between pions and electrons at the same momentum.




[1] Propagation of a Cherenkov light cone through a medium.



Cherenkov light in the Advanced Test Reactor, Idaho National Laboratory.

# GRINCH

**G**as **R**ing **I**magi**N**g **CH**erenkov detector

510 1-inch photomultiplier tubes (PMTs) in a honeycomb array.

4 highly reflective cylindrical mirrors.

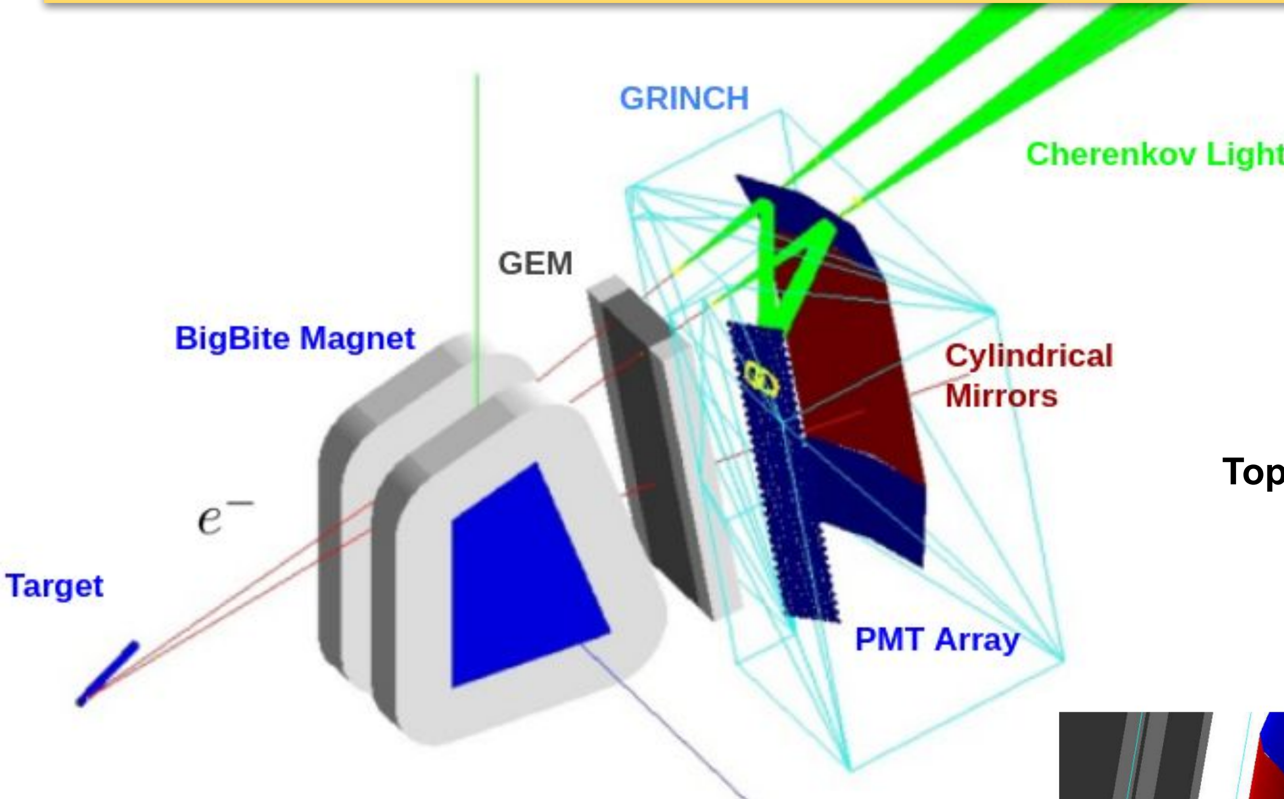
Filled with heavy gas $C_4F_8O$

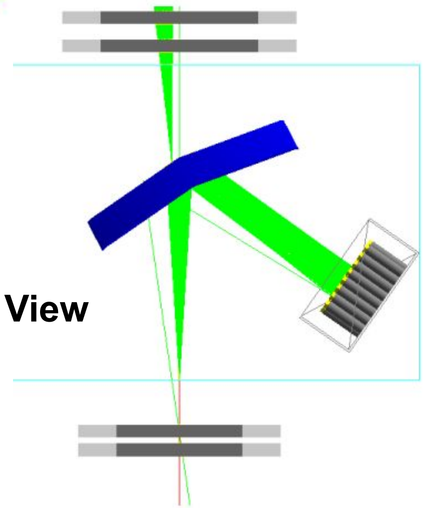
Pion Threshold of 2.7 GeV.

Small PMTs and specialized read-out hardware allow data to be collected in a high-background environment.

Todd Averett and the GRINCH in the TEDF high bay, Jefferson Lab.

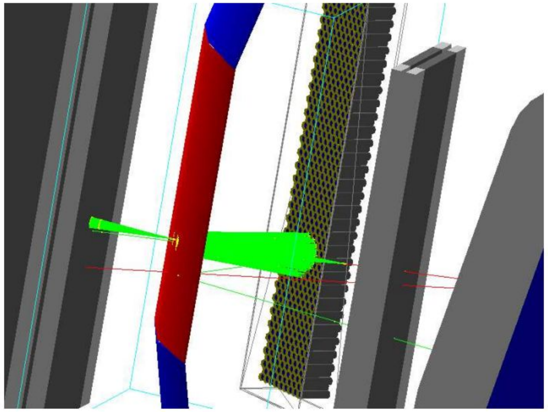
# GRINCH Design



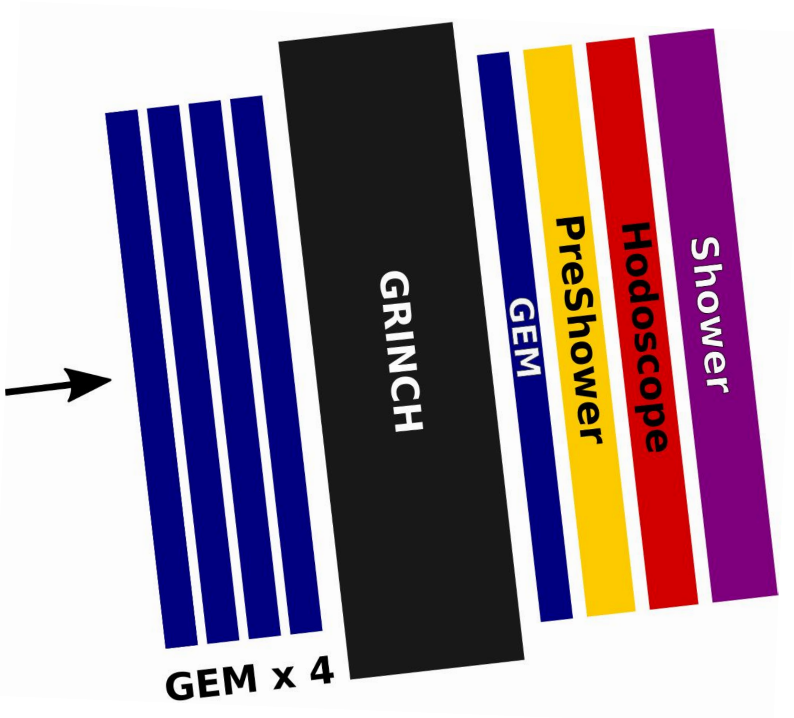
**Top View**

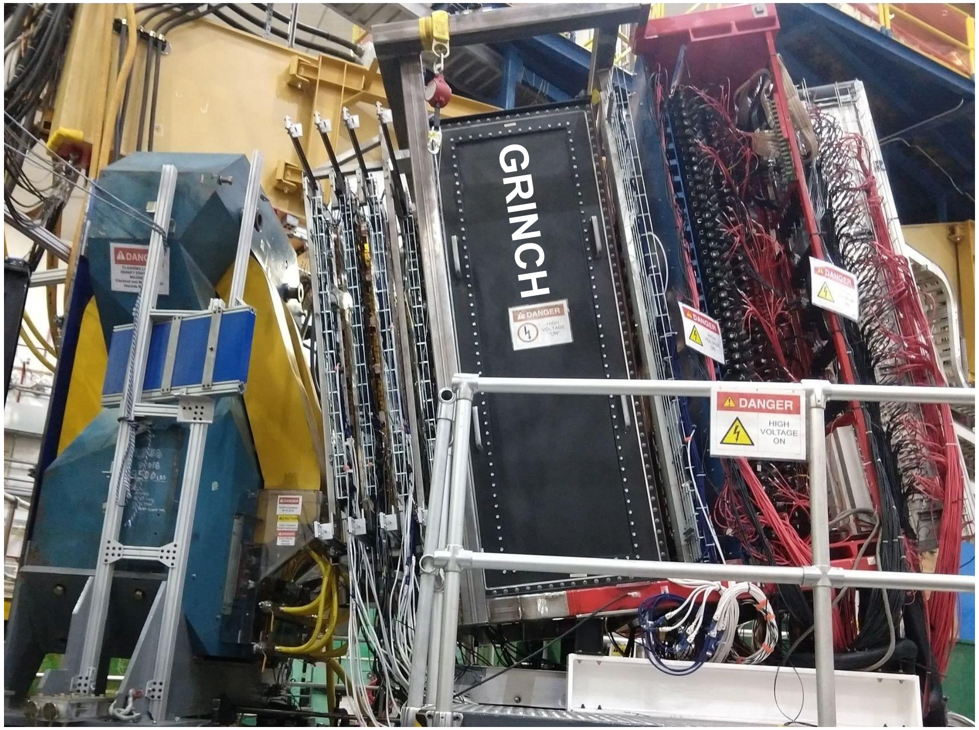
**Side View**



[3] GEANT4 Simulations

# GRINCH in BigBite




BigBite Magnet BigBite Spectrometer

# GRINCH PMT Behavior Analysis

Leading Edge (LE): when the signal crosses the threshold of the time-to-digital converter (TDC).

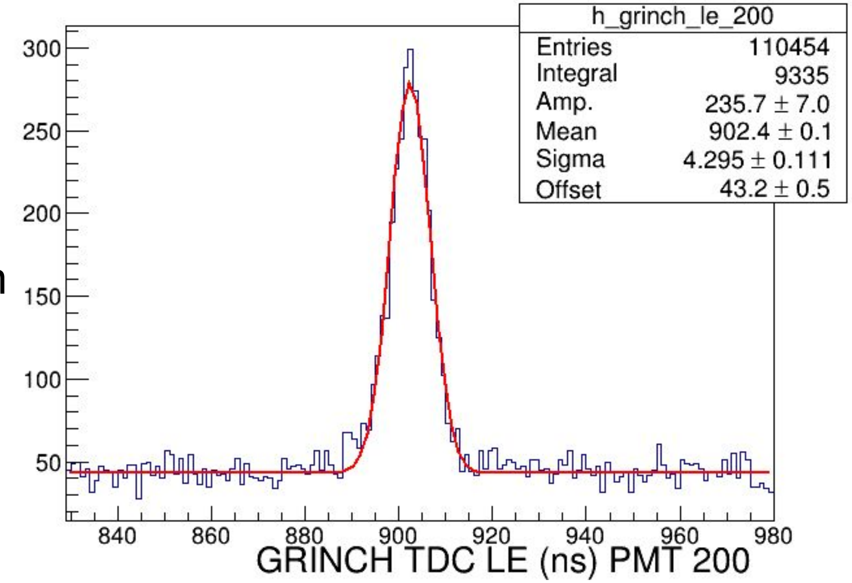
Fit each PMT to a gaussian with an offset.

**Timing Resolution <4.5 ns** for each PMT (sigma on gaussian fit)

**Background rate 250-450 kHz**, depending on the PMT and kinematic setting. Calculated from the offset.

**0.25% - 0.45% occupancy** on a 10 ns window

(chance that noise will occur during a given time window)



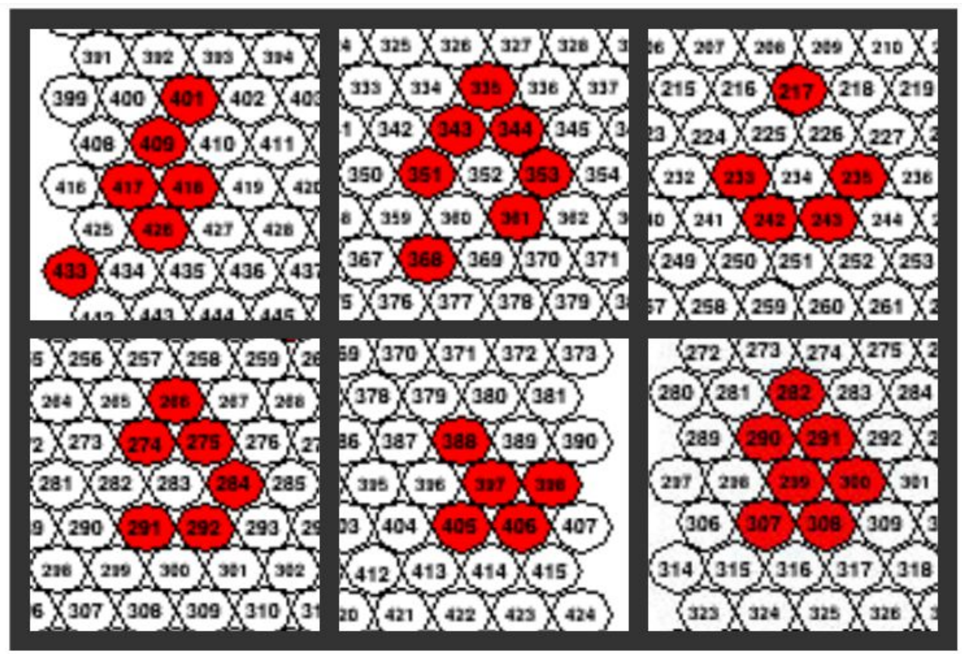

LE spectrum histogram for one PMT. GMn run 13719.

# Cluster Analysis

The Cherenkov light cones from electrons appear as clusters on the PMT array due to the path length of the light cone in the GRINCH.

Algorithm requires 3 or more neighboring PMTs to form a cluster.


[3] PMTs as seen from inside the GRINCH.



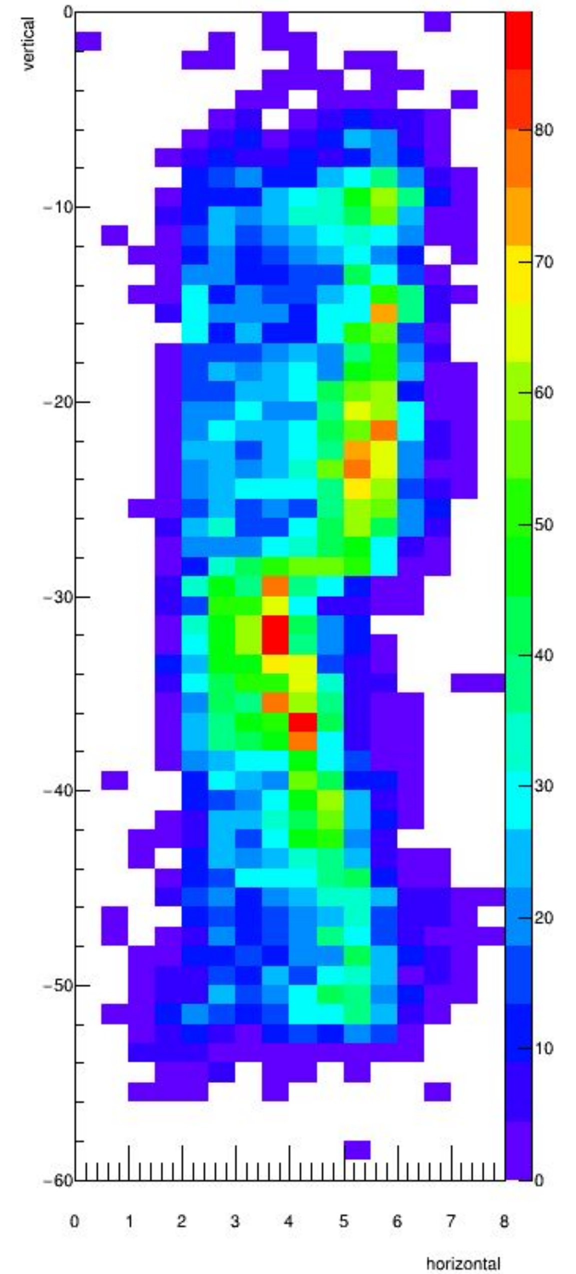
Examples of clusters from electron events, GMn run 13460

# Electron Detection Efficiency

Heat Map of cluster centers shows where the Cherenkov light cones hit the PMTs after being focused from the mirrors.

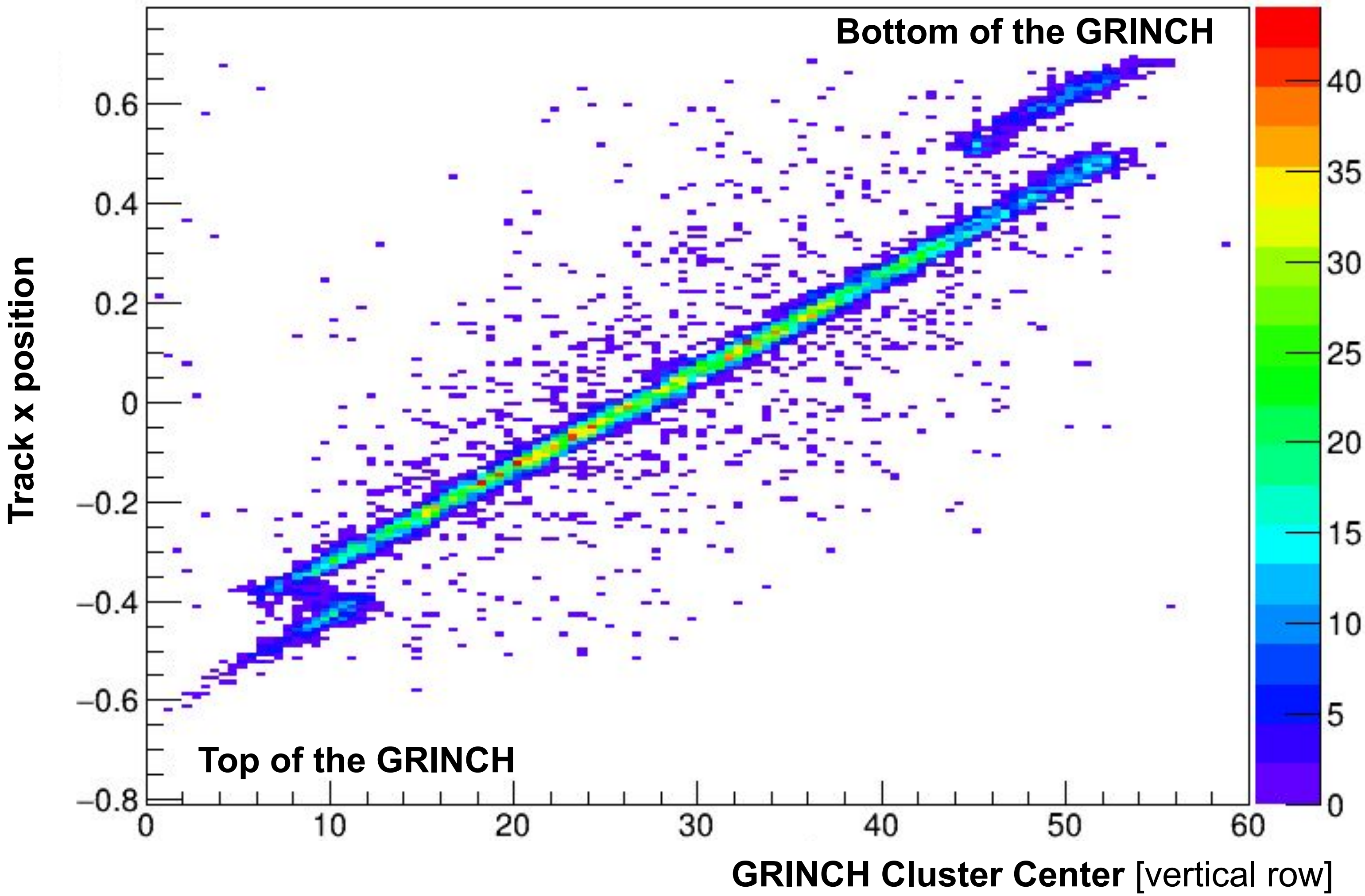
Electron Detection efficiency

- **85% - 97%** depending on the kinematic settings using clusters of 3 tubes. Increases over time as the concentration of heavy gas increased with time.
- Tight electron cuts are made on the other detectors and the particle track to find electron events. Then see if the GRINCH saw a cluster.




Histogram of cluster centers on the GRINCH PMT array, run 13719.

# Electron Track Correlation




Negative x is “up” in this transport coordinate system.

# Next Steps and Future Work

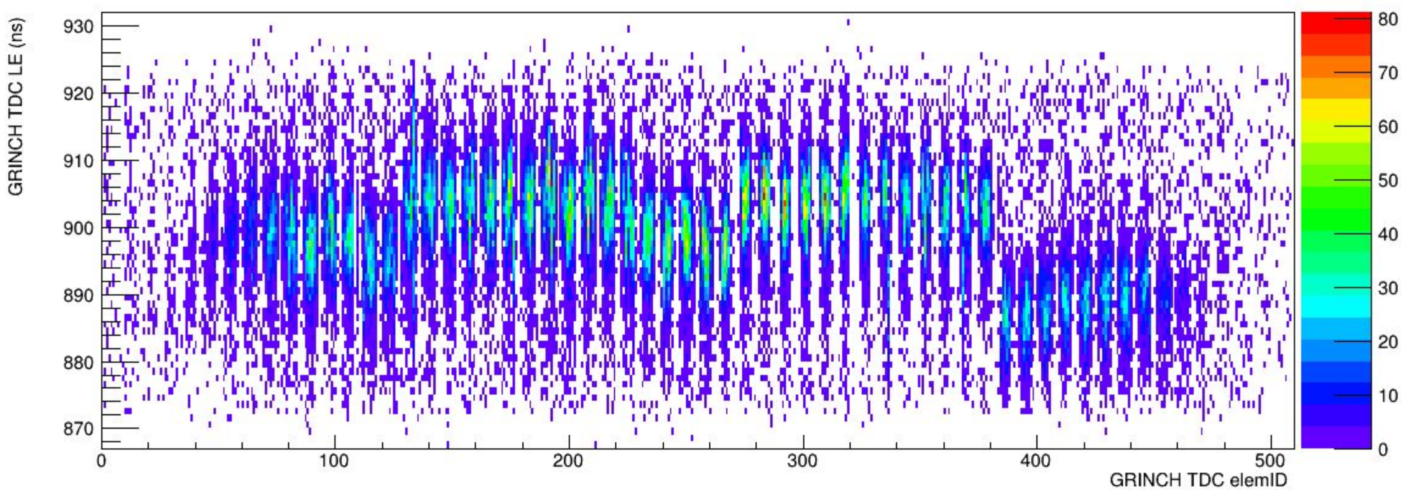
Leading Edge (LE) timing needs to be calibrated for each channel in order to make a tighter cut.

Investigate the effect of the SBS magnet fringe fields on the PMT gains.

Further investigate the behavior of the mirrors using particle tracks.

Calculate the electron detection efficiency and the pion rejection efficiency across the different kinematics for GMn.

Prepare GRINCH to run during GEn in late September.




2D histogram of the TDC leading edge for all the GRINCH PMTs in clusters. Run 13719

# Thank You!

Questions?


[1] *Techniques for Nuclear and Particle Physics Experiments*, W.R. Leo

[2] *GRINCH Detector Technical Document v.11*, Averett, Yao, Wojtskhowski, 2012

[3] Carlos Ayerbe Gayoso, 2018