# Timing Hodoscope Performance for GMn & Thesis Progress

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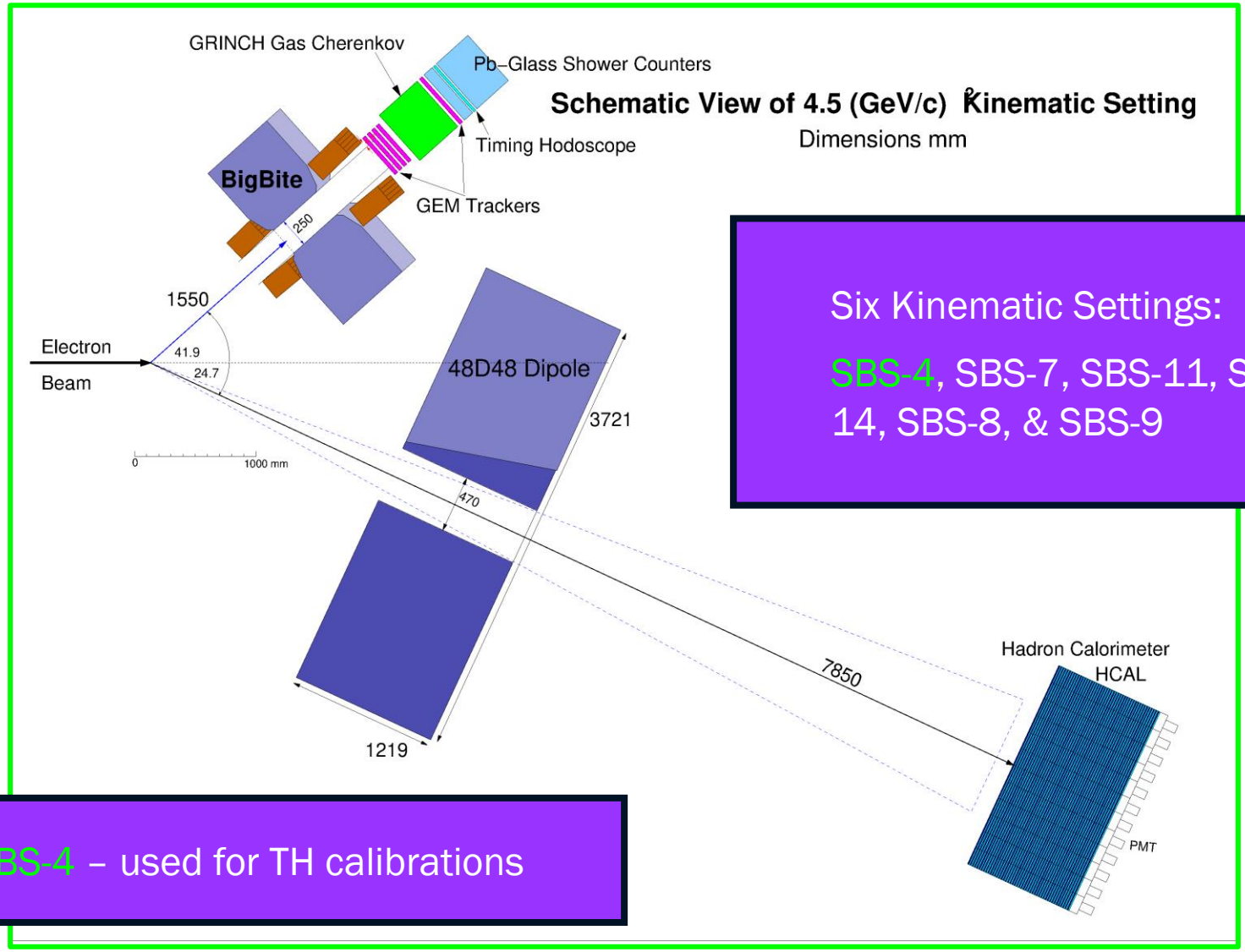
# Thesis Scope & Outline

- Title – "Performance and Commissioning of the BigBite Timing Hodoscope for Nucleon Form Factor Measurements at Jefferson Lab"
  - Chapter 1 – Introduction: Overview of Jefferson Lab, Nucleon Structure, the Coulomb Interaction, & Electron Scattering Formalism
  - Chapter 2 – Super BigBite Spectrometer (SBS): SBS Overview Design & Hall A Program, Formalism for EMFFs, Born Approximation, & Ratio Method
  - Chapter 3 – Timing Hodoscope (TH): Detector Design, Major Components, Data Acquisition (DAQ) System, & Analysis Structure
  - Chapter 4 – Non-Performance Info & Analysis: TH Detector Repairs, Construction, Installation, Commissioning Studies, and Calibrations
  - Chapter 5 – Performance Analysis for GMn: Physics Cuts, Energy Deposit, Clusters, Rates, Tracking Efficiency, Position Resolution, & Time Resolution
  - Chapter 6 – Conclusion: Final Results, Outlook, and Improvements

<Focus for this presentation>

# Super BigBite for GMn



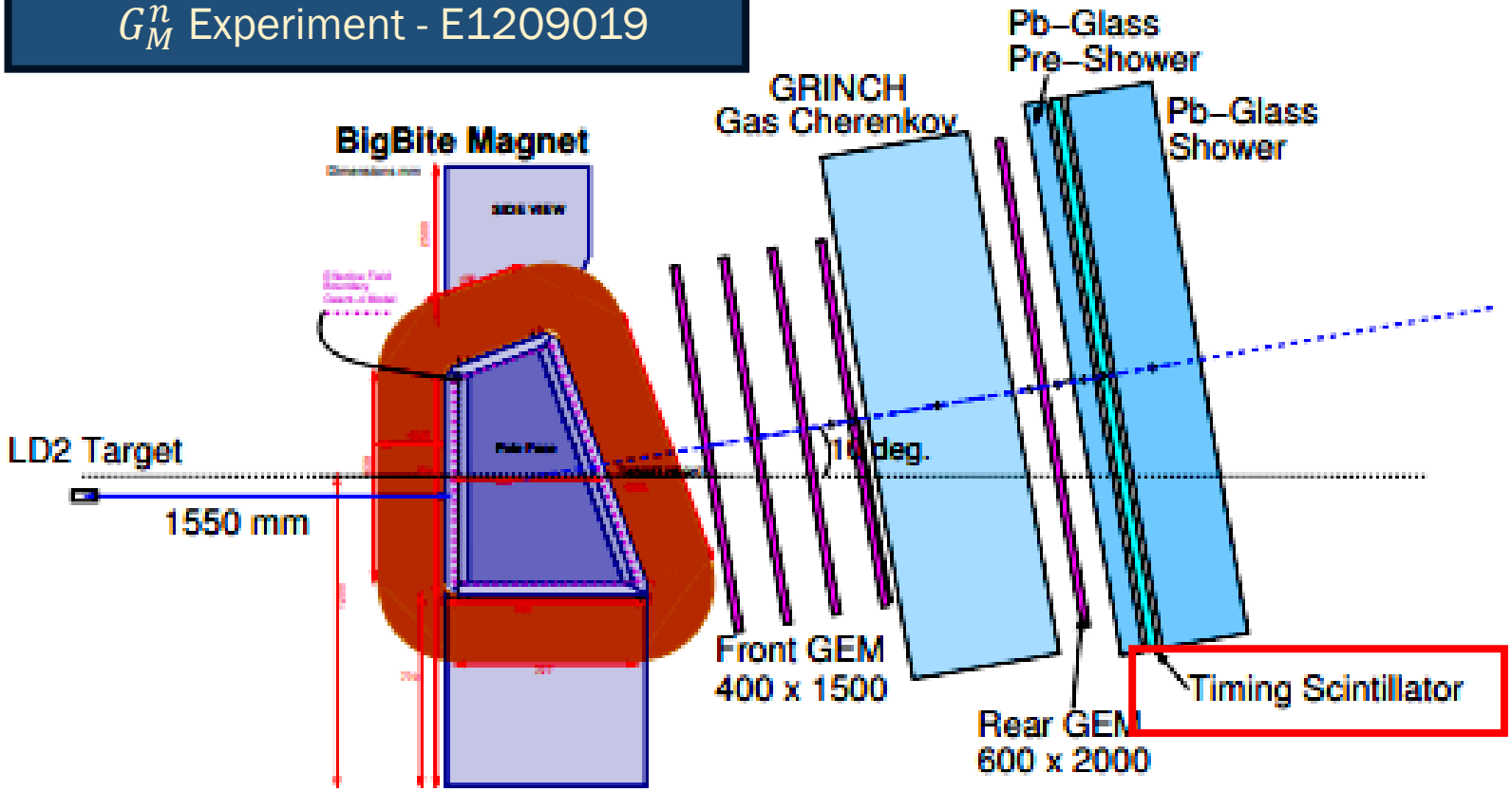

Six Kinematic Settings:

SBS-4, SBS-7, SBS-11, SBS-14, SBS-8, & SBS-9

SBS-4 – used for TH calibrations

# BigBite Electron Arm Design

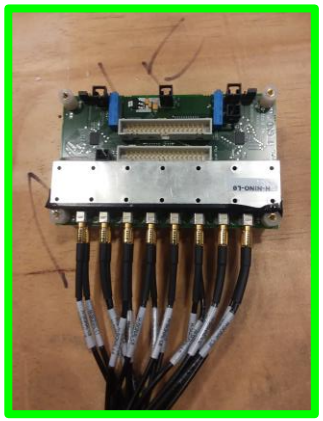
Fall 2021 installation, used for $G_M^n$ Experiment - E1209019

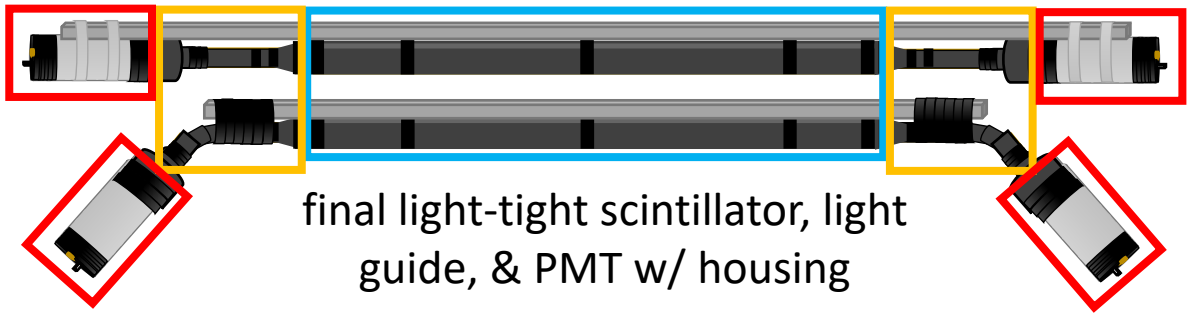



<Focus for the thesis>

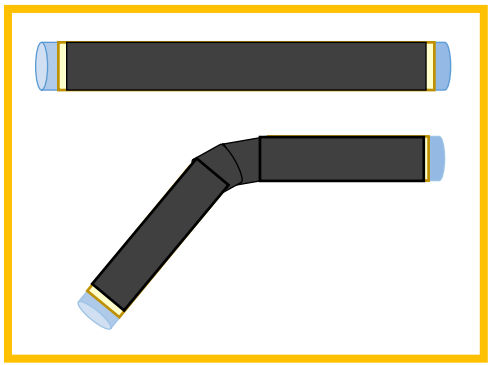
# Timing Hodoscope Design & Construction

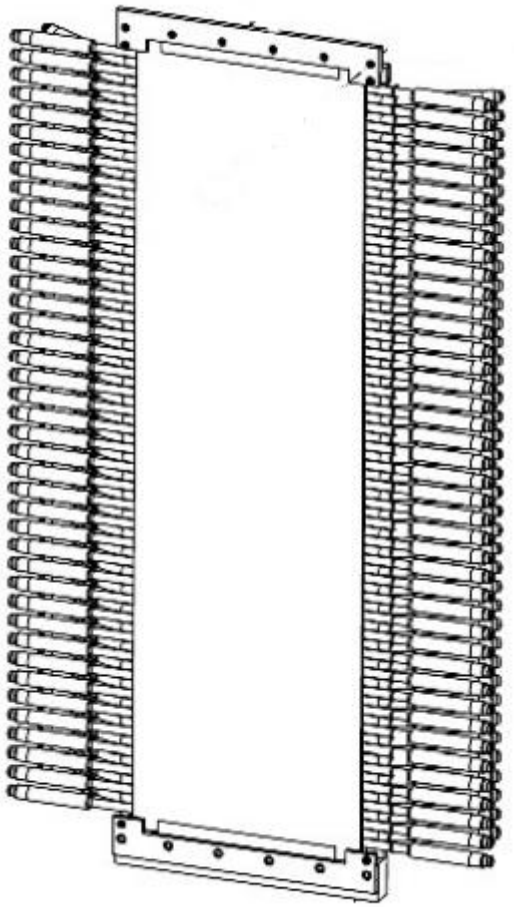
- Eljen EJ200 Plastic Scintillators, 600x25x25 mm (90)
- 180 Light Guides, Curved or Straight
- ET9124 PMTs, and housing (180)
- 12 NINO Cards, front-end amplifier discriminator cards
- DAQ & Installation – see back-ups





final light-tight scintillator, light guide, & PMT w/ housing





Timing Hodoscope Detector Diagram

# Timing Hodoscope Commissioning & Calibration

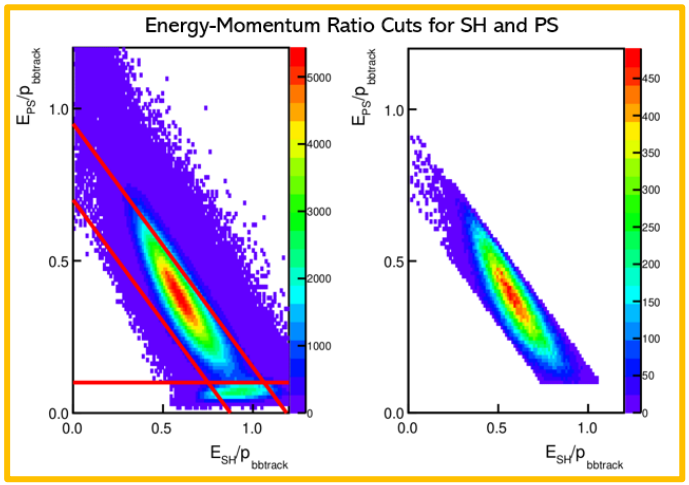
- Commissioning list:
  - ADC
    - Pedestals (for CAEN v792s)
    - PMT Charge Normalization
    - PMT Relative Gain
    - Multiplicity
  - TDC
    - Mean Time
    - Time Difference
    - Time Over Threshold
    - Multiplicity

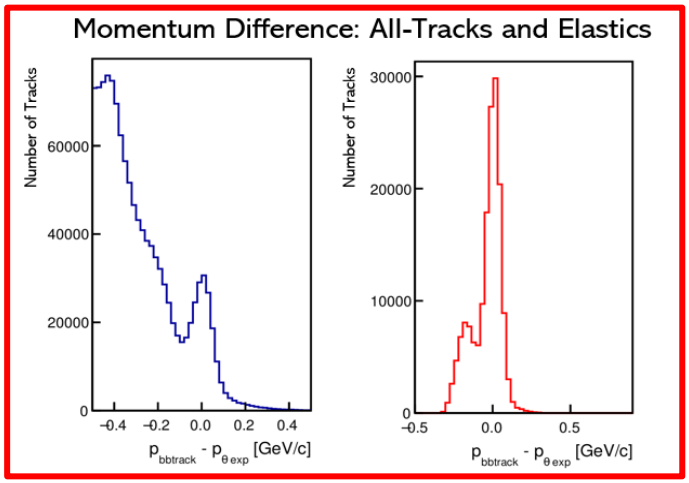
- Calibration list:
  - Timing Cuts (for TDC & Reference)
    - TDC Multiplicity
    - TDC Window
    - Time Over Threshold
  - TDC Alignment Offset
  - Time Walk Correction
  - Time Difference Offset
  - Scintillating Velocity Correction
  - Beam RF Alignment
  - Time of Flight Correction

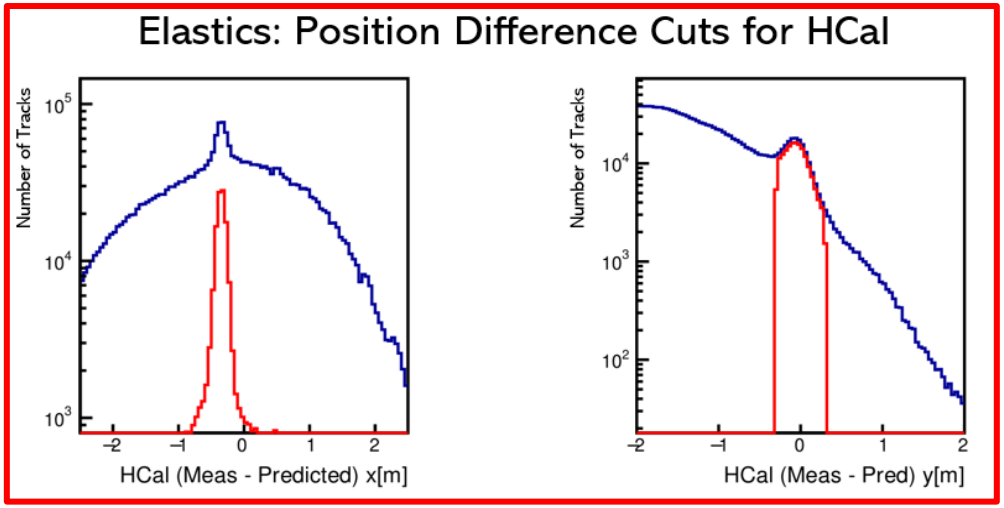
<see back-up slides>

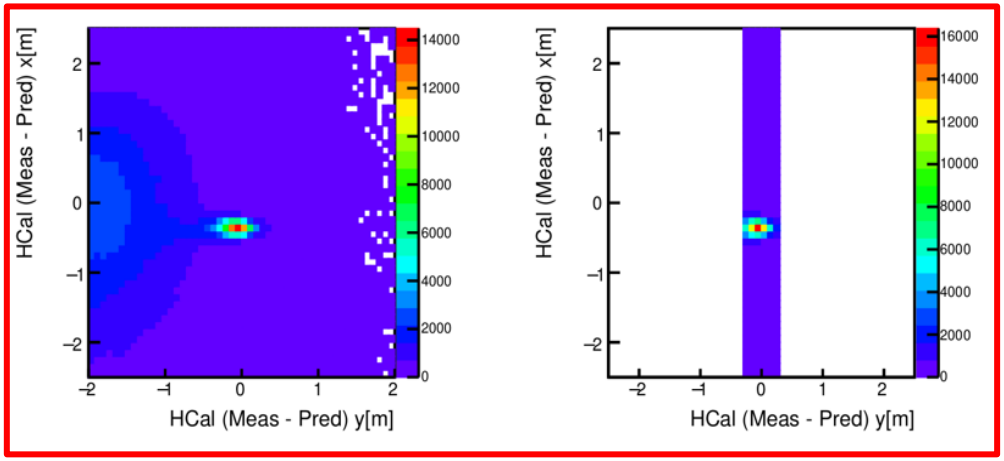
# Timing Hodoscope Performance: Physics Cuts

- 3 Layers of Physics Cuts for All-Tracks, All-Electrons, & Elastics
- All-Tracks Cuts – fiducial cuts, including time cuts in database used for calibrations



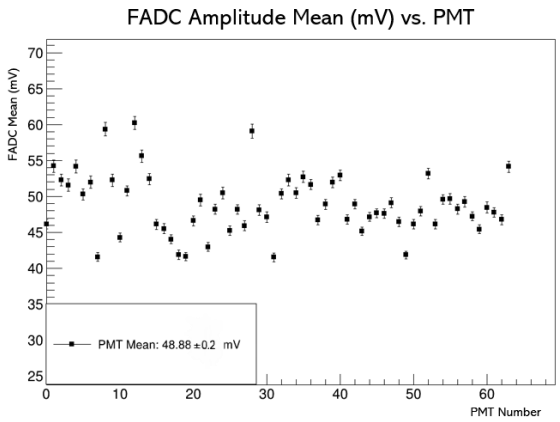



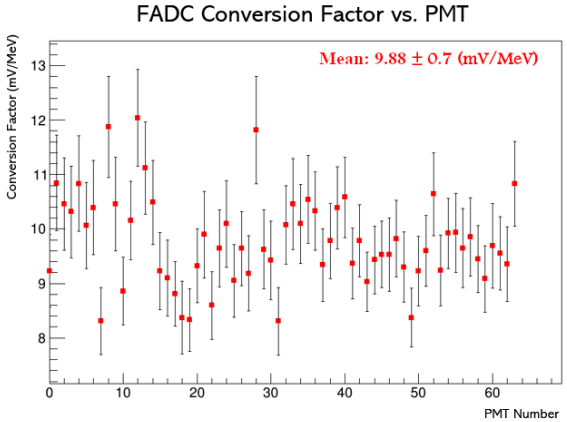



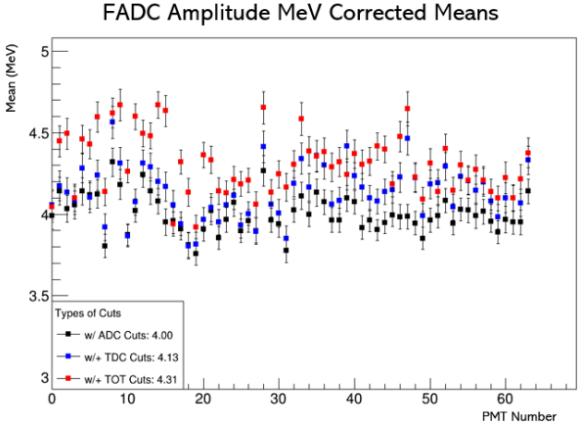



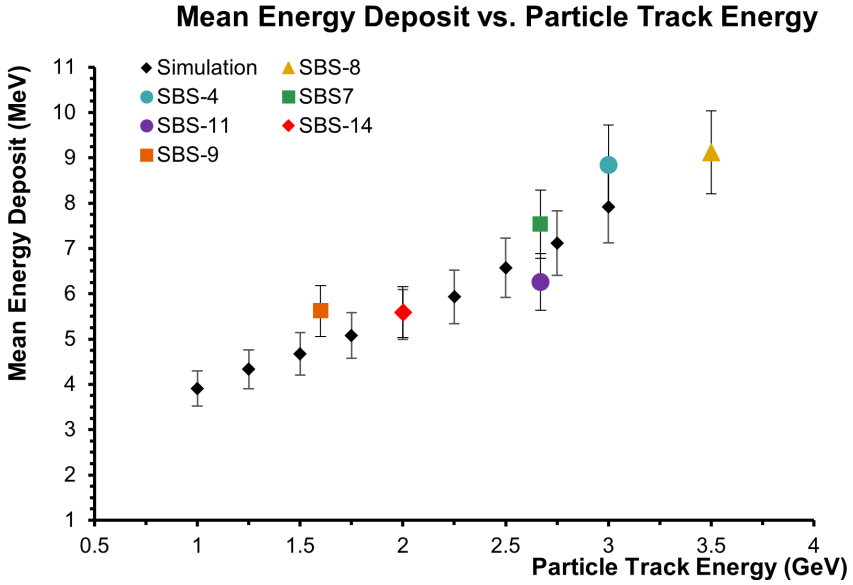
# Timing Hodoscope Performance: Energy Deposit

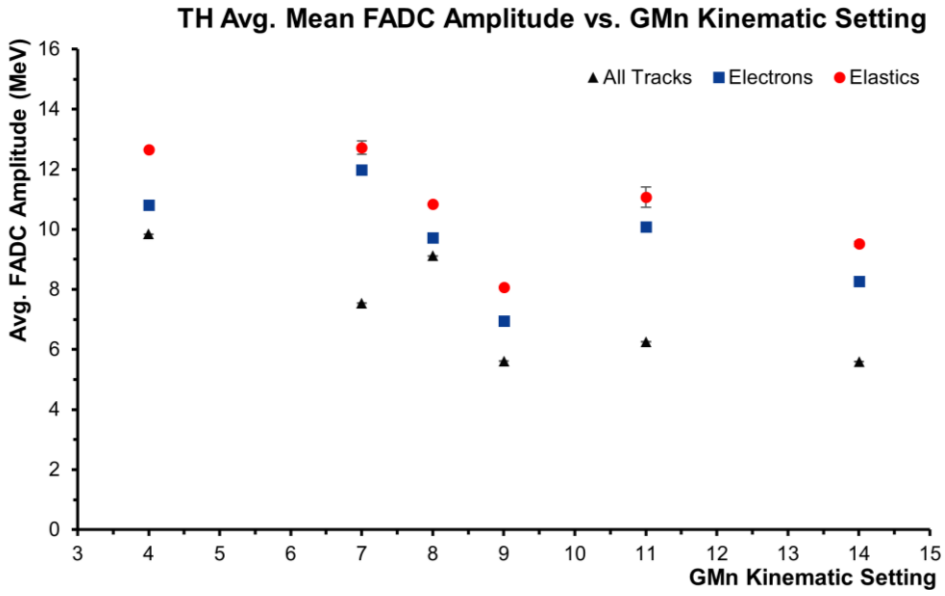
- 5 MeV deposited for cosmics (ideal), use to convert ~10 mV/MeV



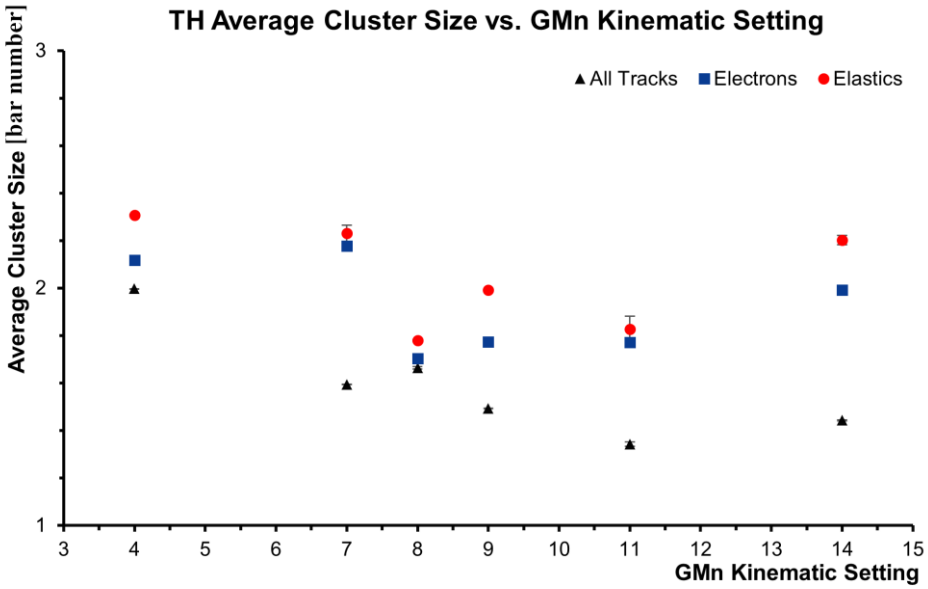



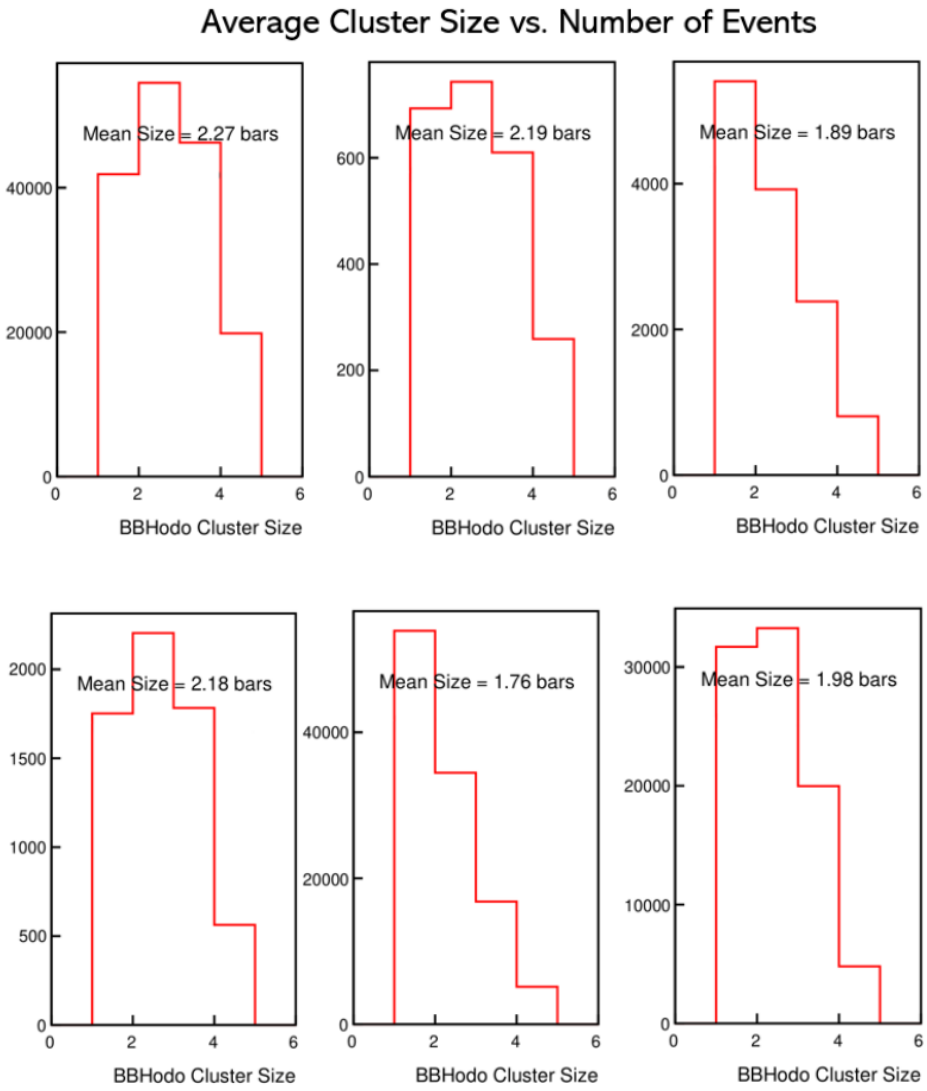



# Timing Hodoscope Performance: Clusters

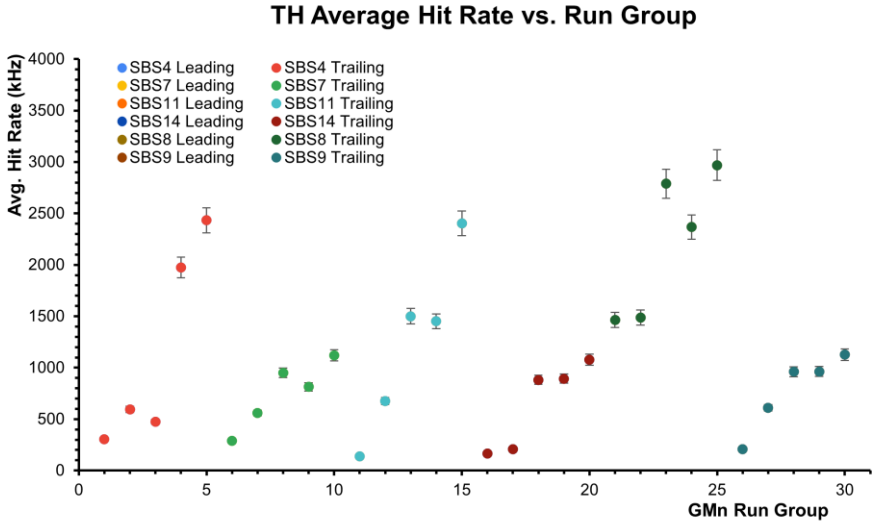
- clusters not exceeding 4 bars and mostly at 2 bars in size
- cluster-based analysis proved helpful during calibrations
- also allows for more precise position and time resolutions

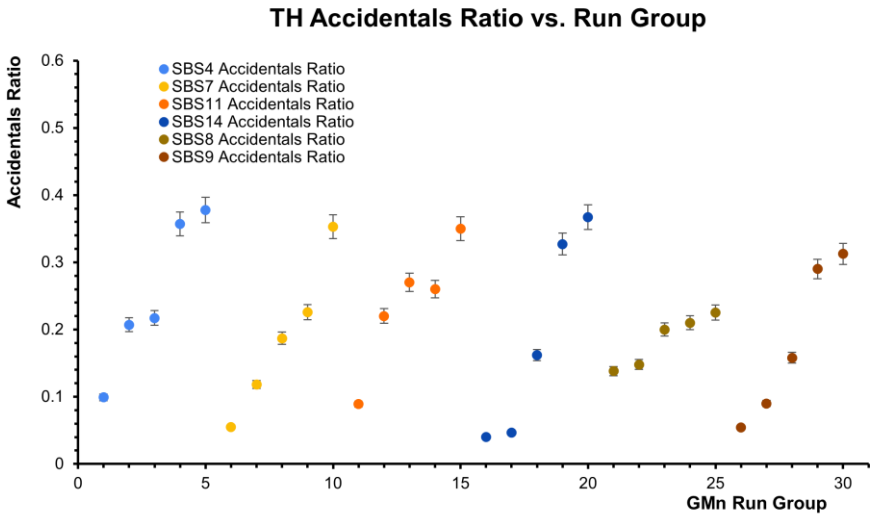


# Timing Hodoscope Performance: Rates

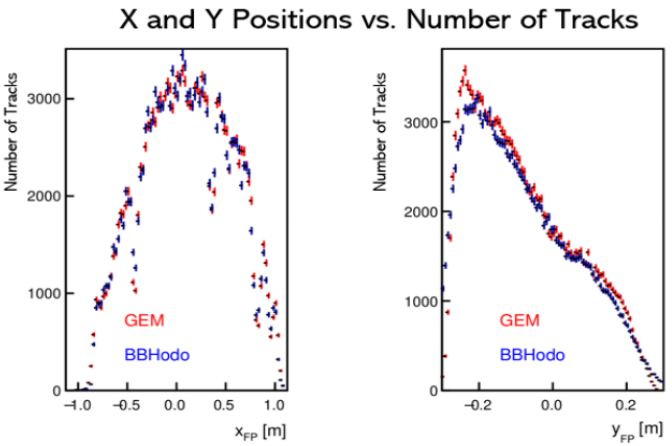
- rates increase with luminosity, varying kinematic settings, beam currents, and targets
  - changes in TDC window size, addition of shielding, and adjustments to PMT HV settings during GMn affect the rates
- accidentals from ratio of total hits in TDC peak to contribution from background
- more on occupancies and (no) evidence of pile-up in back-up slides

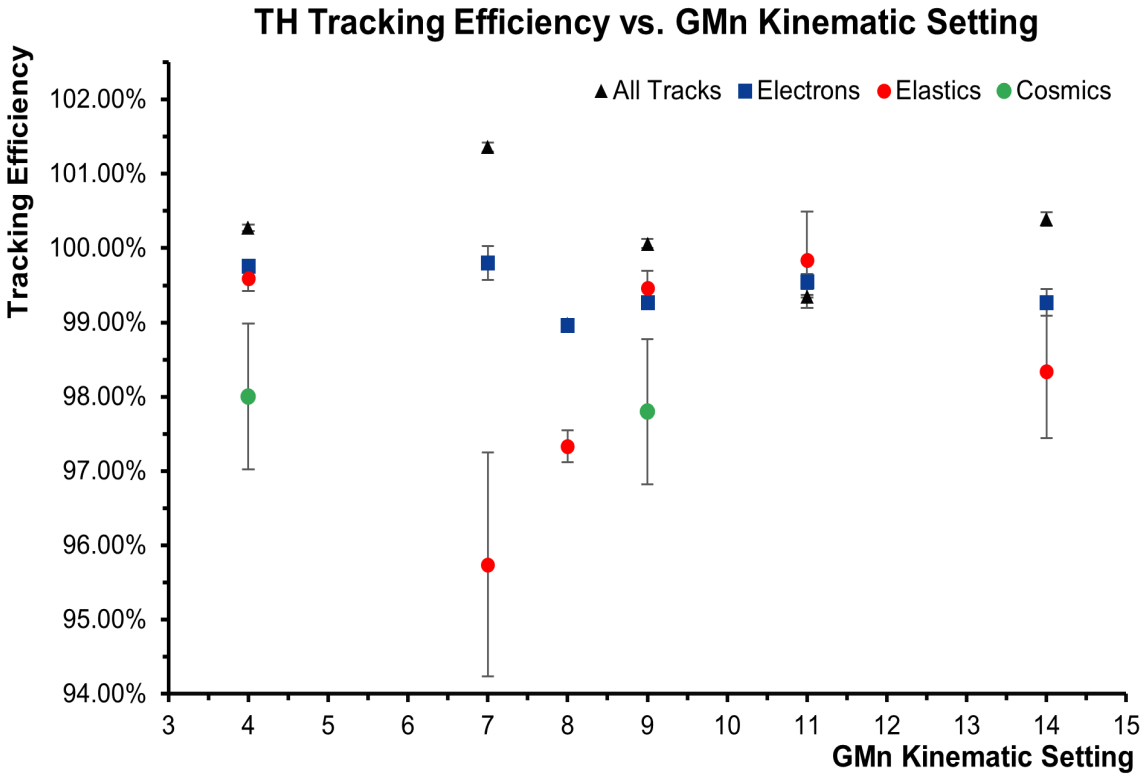


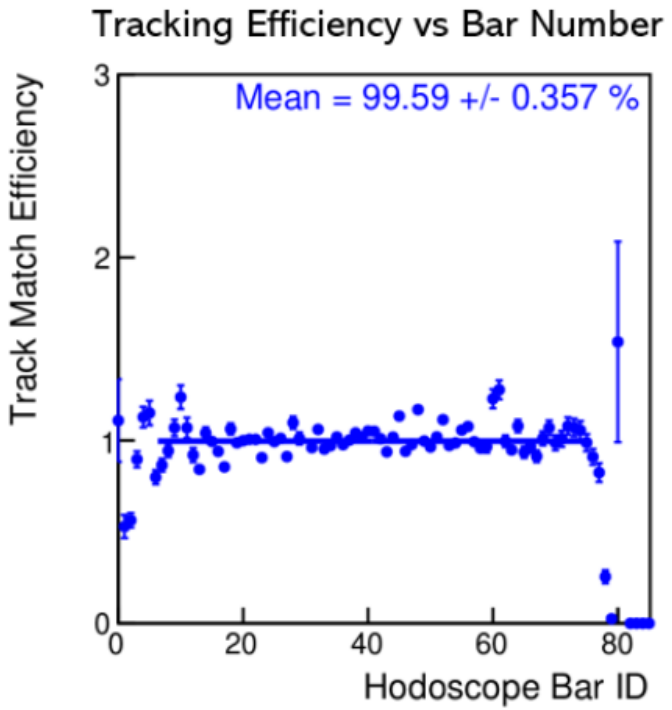



# Timing Hodoscope Performance: Tracking Efficiency

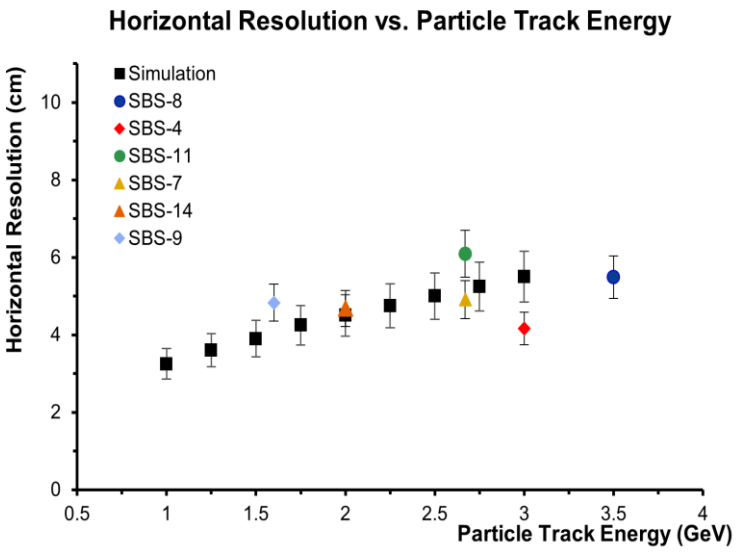
- comparison for tracking efficiency made between GEM layers and TH
- projected GEM track position onto TH using known distances (transport coordinates)

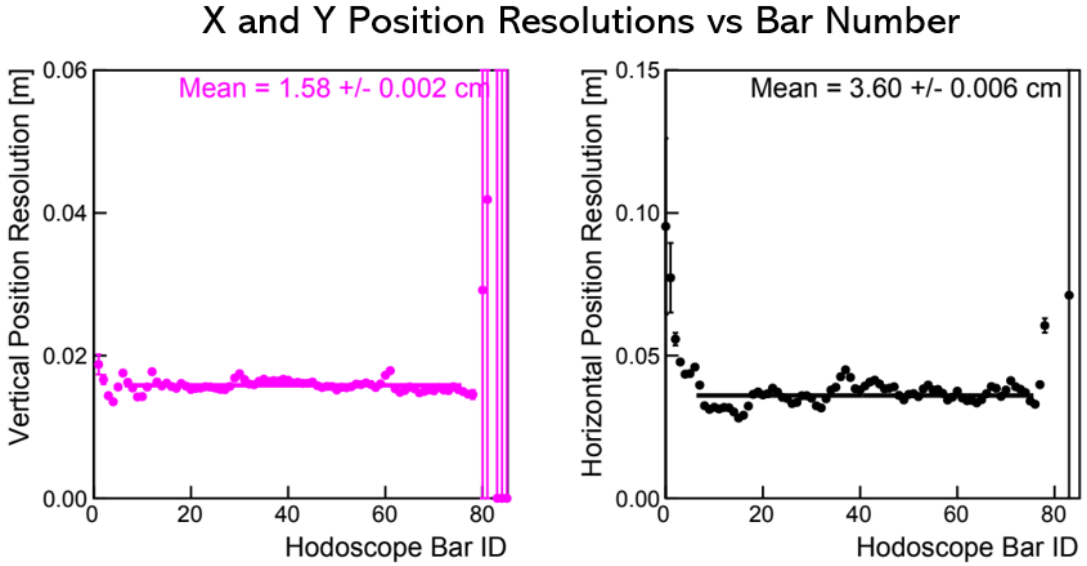


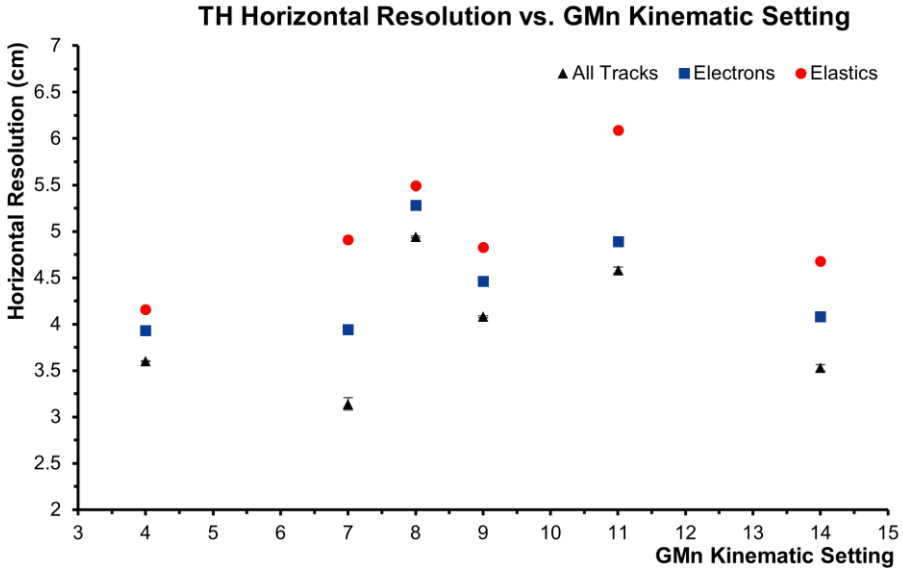



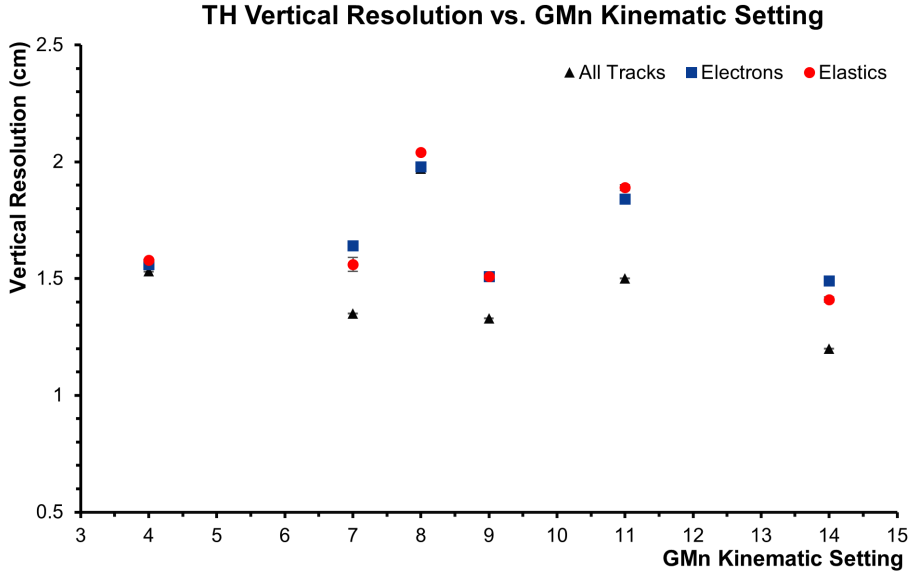



# Timing Hodoscope Performance: Position Resolution



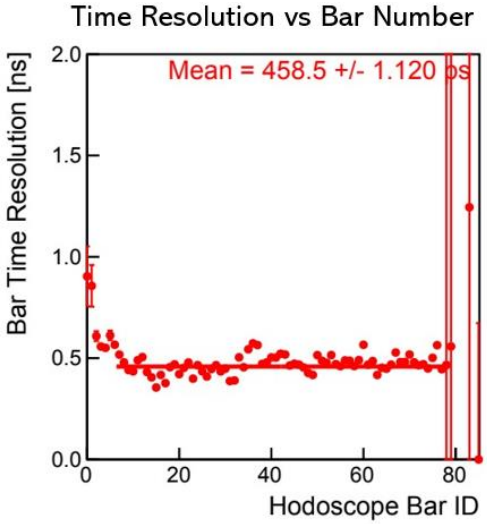



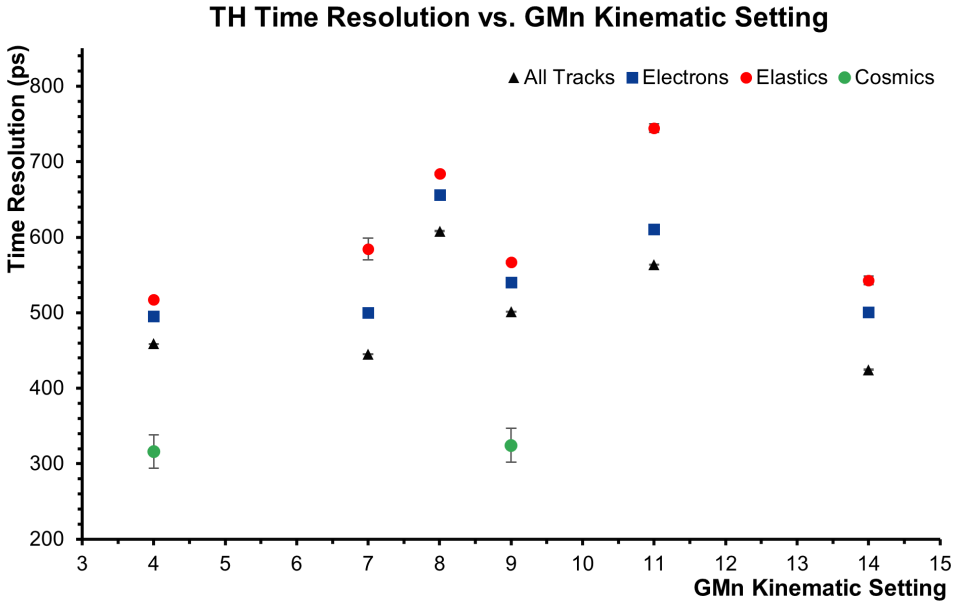



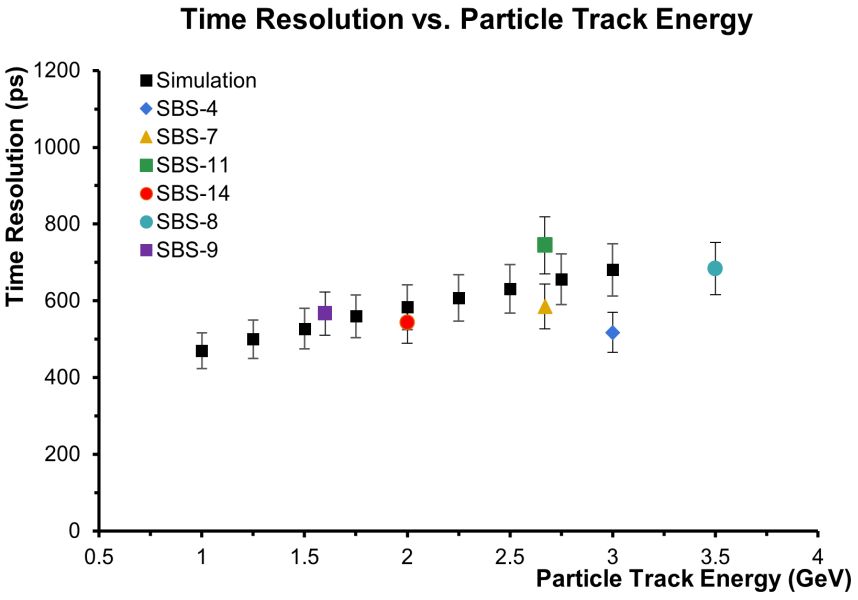



# Timing Hodoscope Performance: Time Resolution

- for elastics time resolution between 500-750 ps, almost twice intrinsic 300 ps
- doubling of time resolution largely caused by TH location behind the pre-shower detector
- confirmed with GEANT4 simulation, higher GeV equals larger showers and poorer resolution



# Thesis Outlook & Timeline

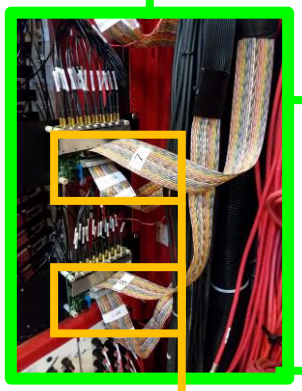
- Thesis Analysis – finished May 2023
  - includes commissioning studies, calibrations, and performance analysis of TH before and during GMn experiment
- Thesis Writing – finished three days ago
  - includes all five chapters, conclusions, and appendices
- Thesis Submission – this week, supervisors gave final approval, waiting on further guidance from the school

QUESTIONS?

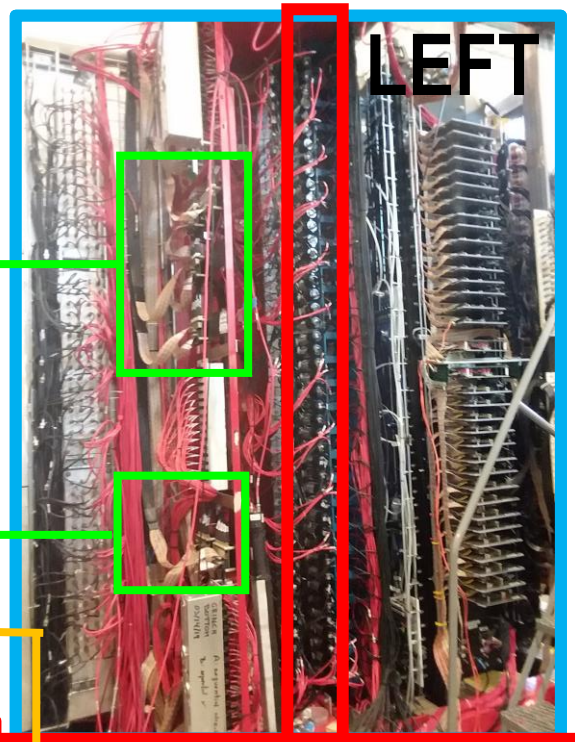
# Back-up Slides

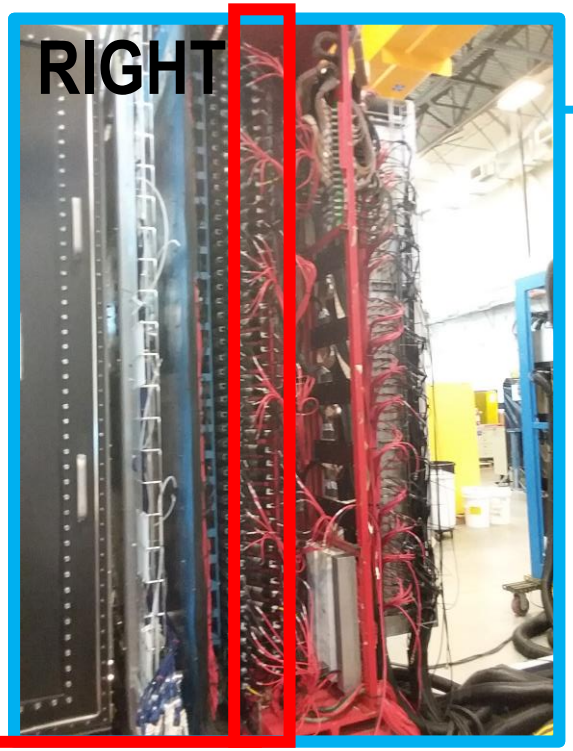
# Timing Hodoscope Design & DAQ

NINO Cards



ADC/TDC Cables



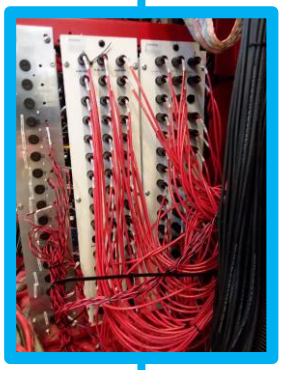




Stack and LEFT/RIGHT PMTs

CAEN TDC v1190 & FADC



HV/LV Cables



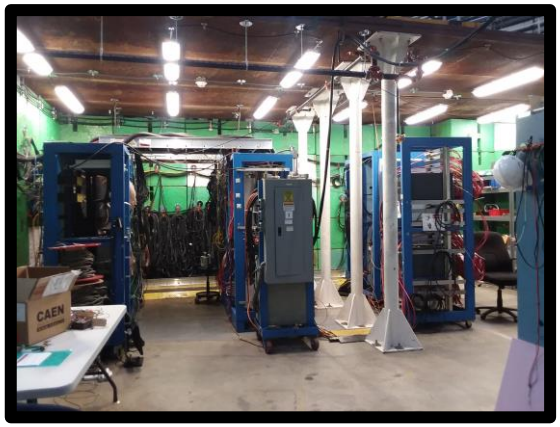
HV/LV DIS.

CAEN HV Crate 700-1000V

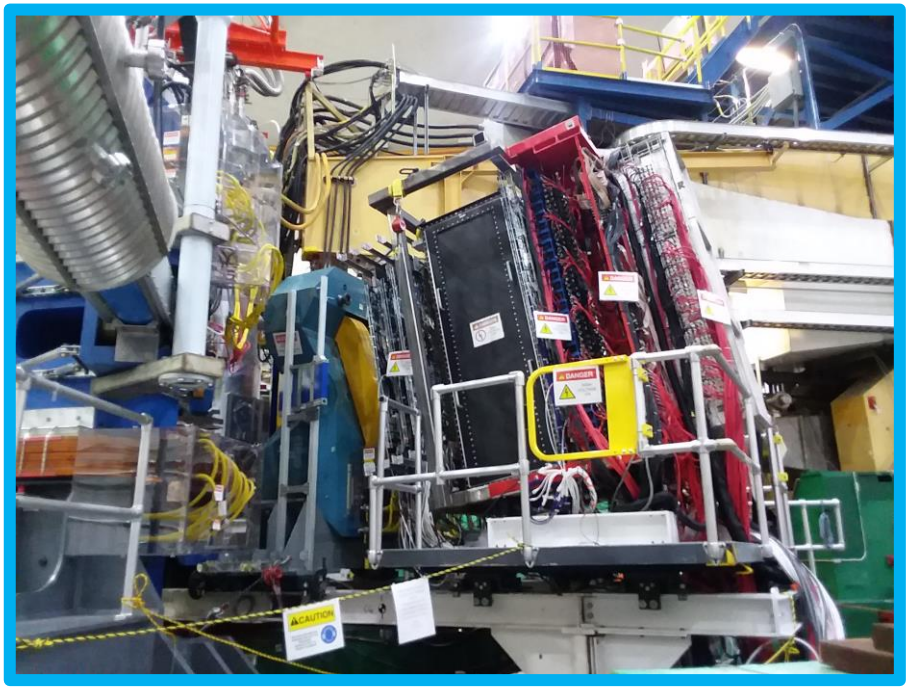
LV Power Source ~7V, 15A

# Super BigBite Installation

B U N K E R

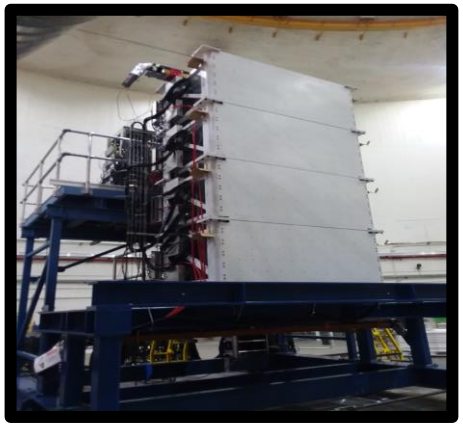



BigBite Right View





BigBite Left View

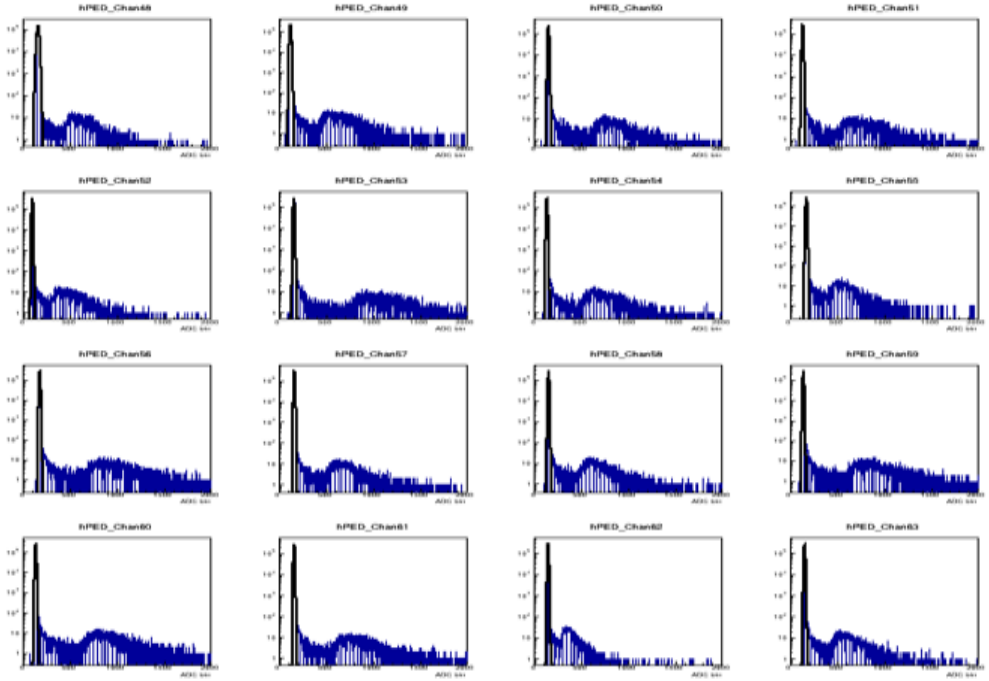


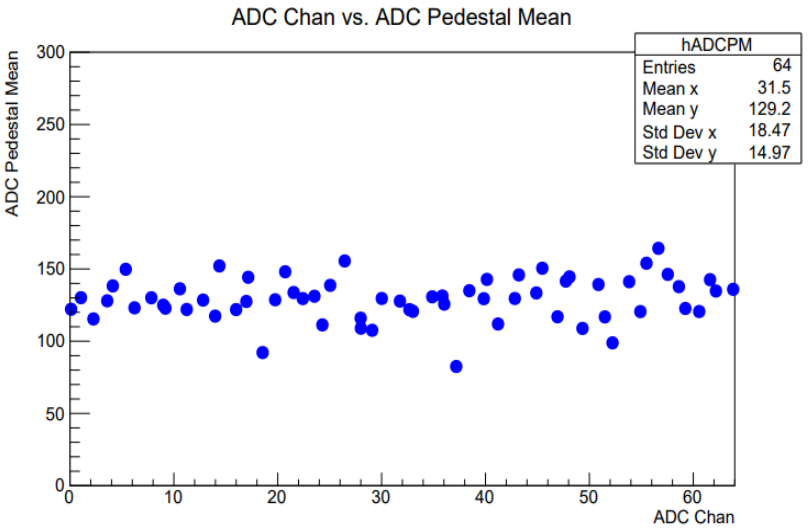
H C A L

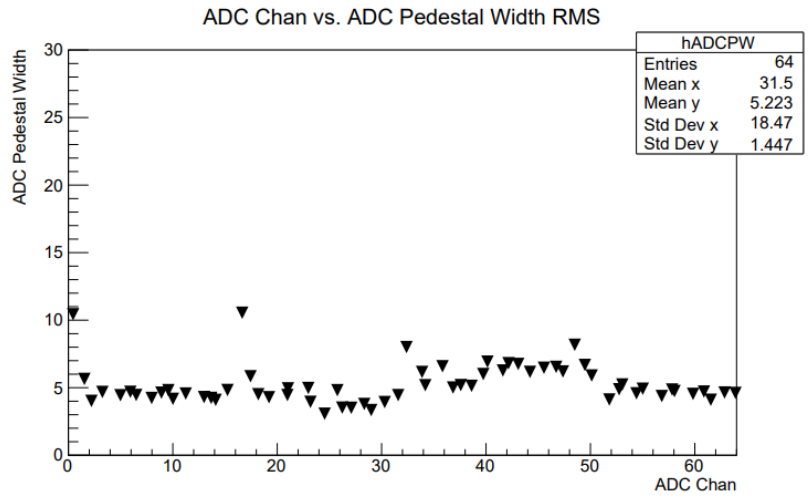
# Timing Hodoscope Commissioning: ADC Pedestals

- first step is to fit and subtract the ADC pedestal mean
- only for CAEN v792s, FADC do this automatically

ADC Pedestal Fit, 16 channels per NINO



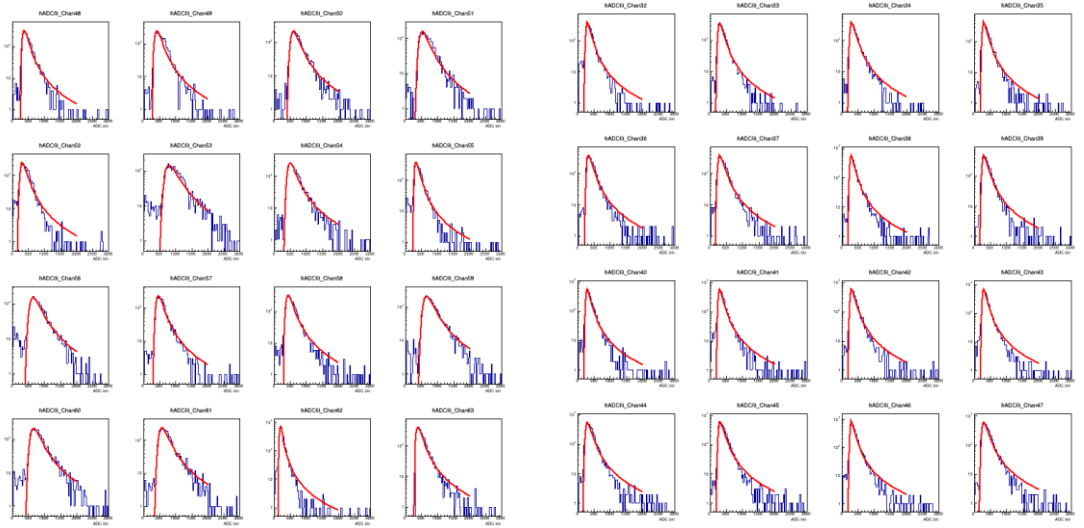


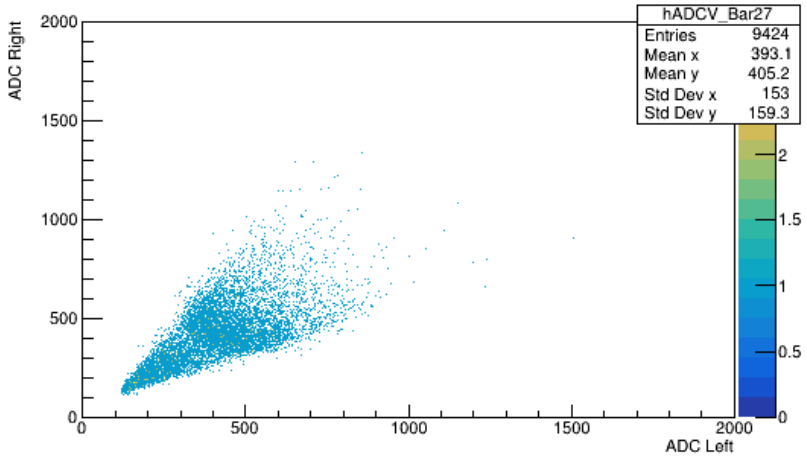
# Timing Hodoscope Commissioning: Charge Normalization

- next normalize ADC channels, cutout pedestal, optimize ADC MPV value for NINO operating range
- iterate through HV values (see next slide)
- using CAEN v792s, switched to FADC after move to Hall A

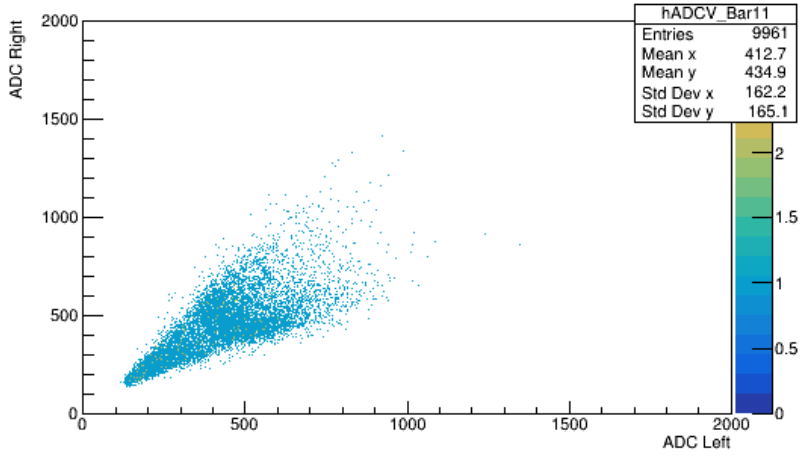
## ADC fit Before/After Normalization



ADC Bar 27 Left vs Right

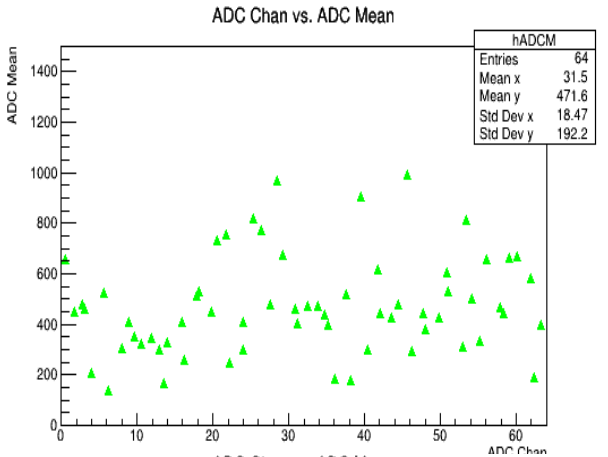


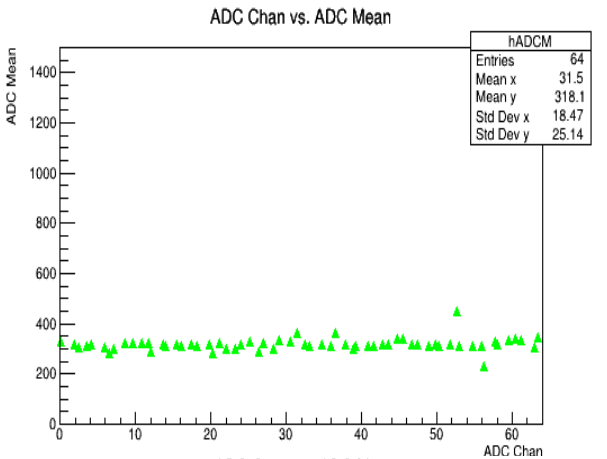

ADC Bar 11 Left vs Right

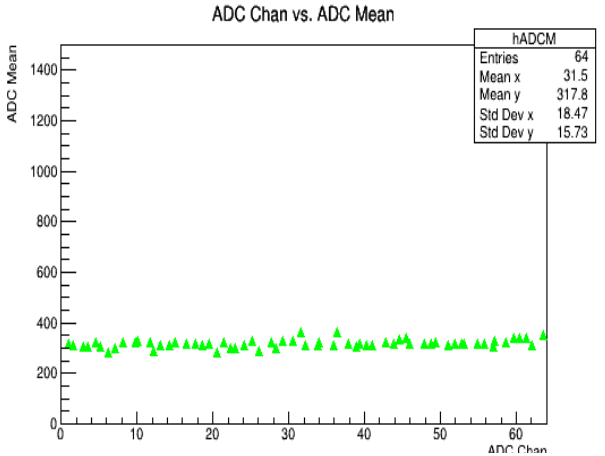


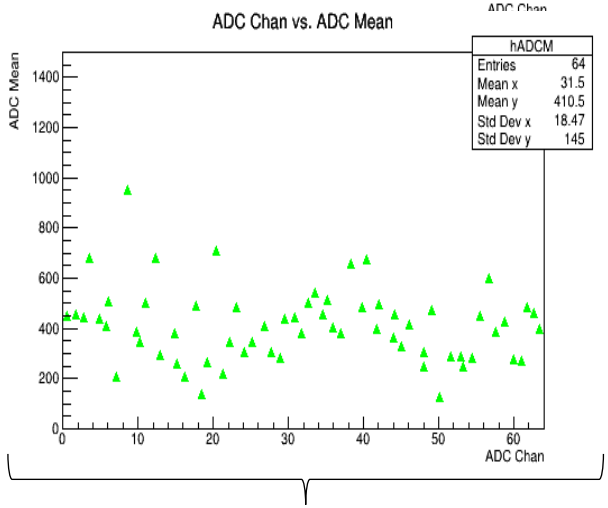
# Timing Hodoscope Commissioning: Charge Normalization

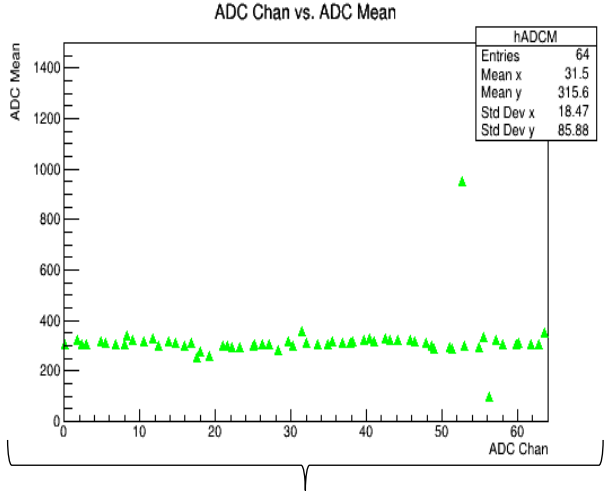
- DAQ allows for 64 ADC channels per data run, split detector into thirds

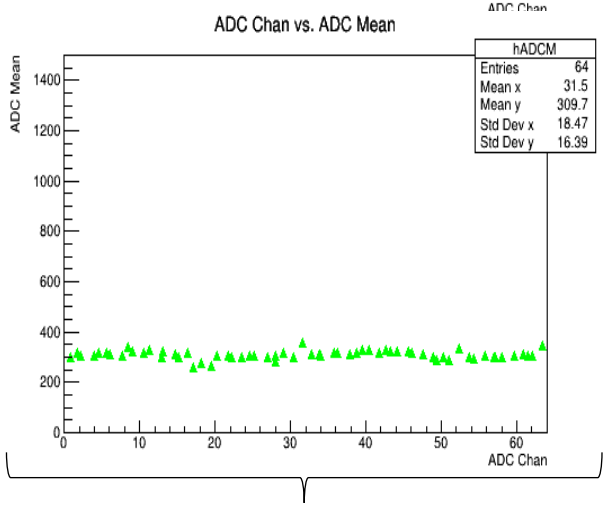


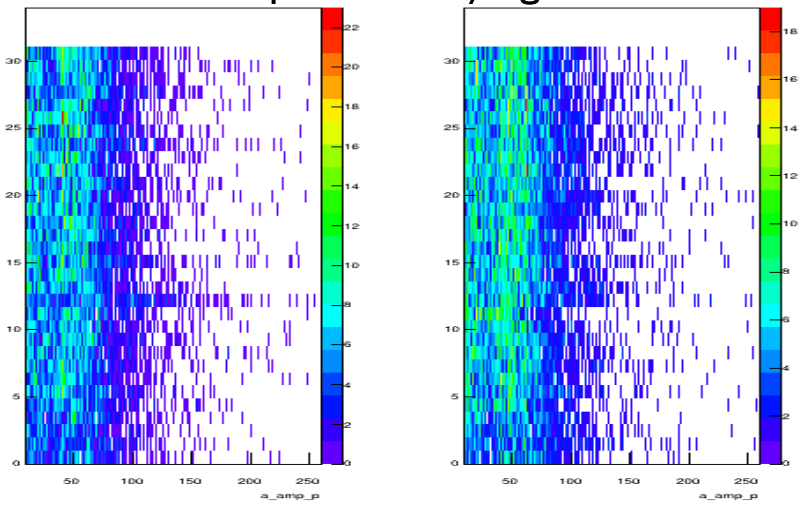




first round | second round | third round

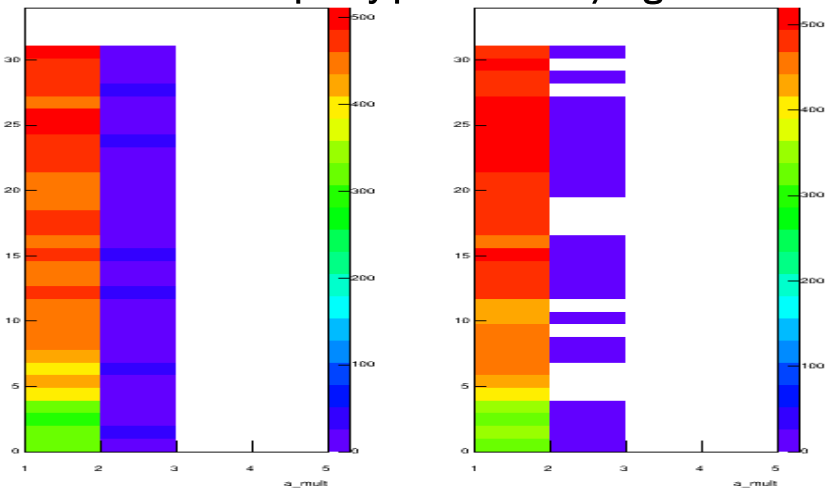
# Timing Hodoscope Commissioning: ADC & TDC

## Cosmics w/ BBCal in Hall A

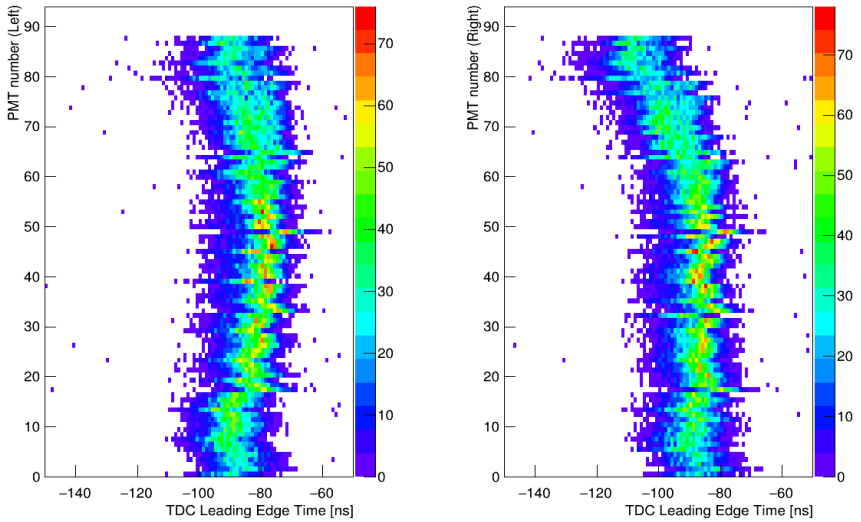
### FADC per PMT Left/Right



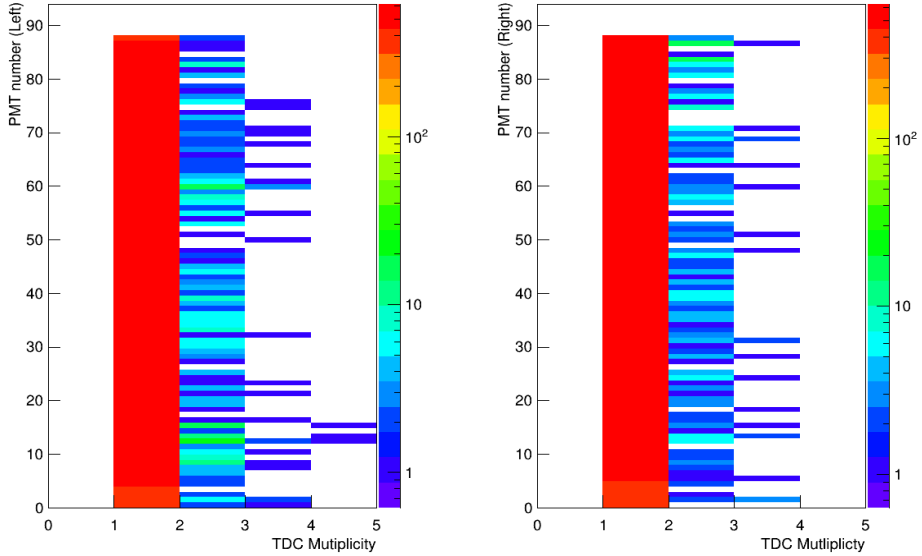

### FADC Multiplicity per PMT Left/Right



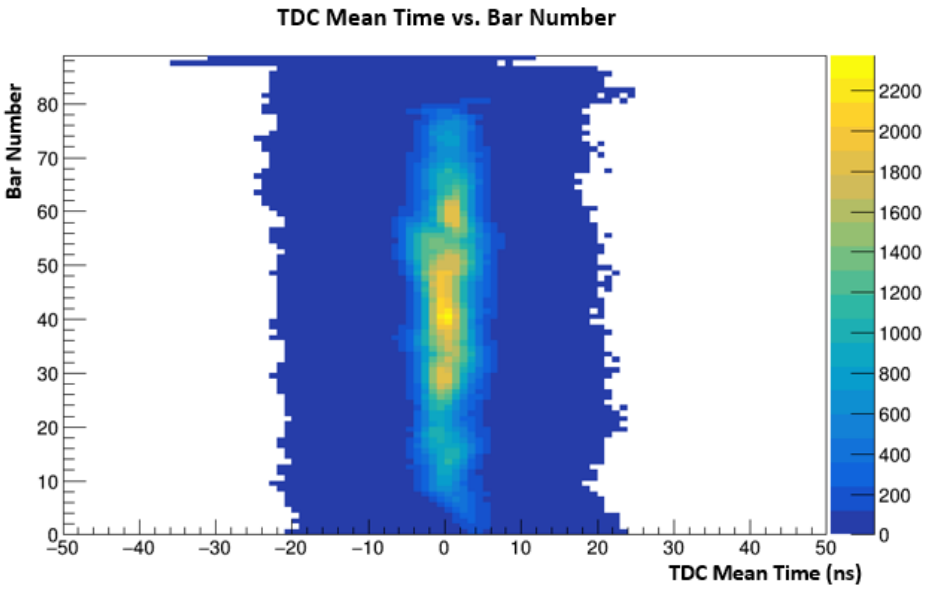

### TDC Leading Edge per PMT Left/Right

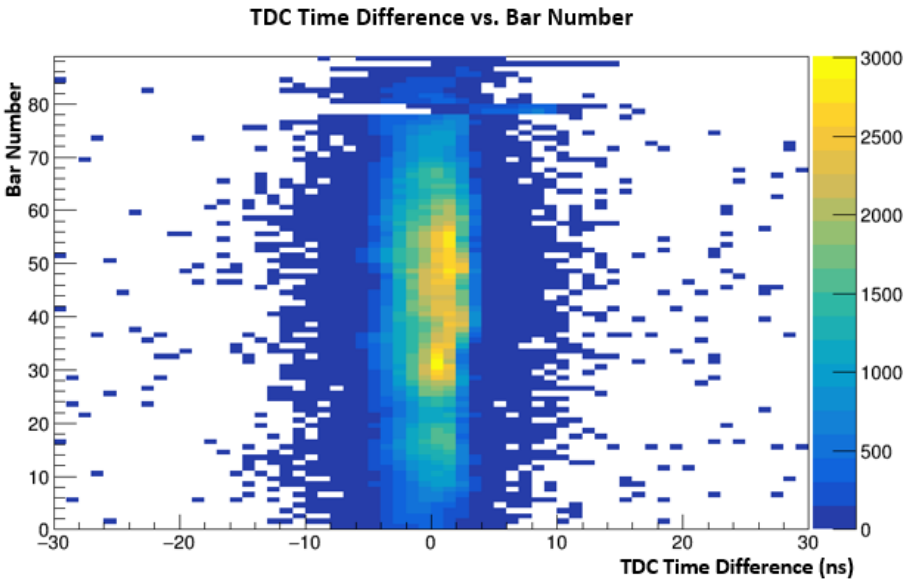


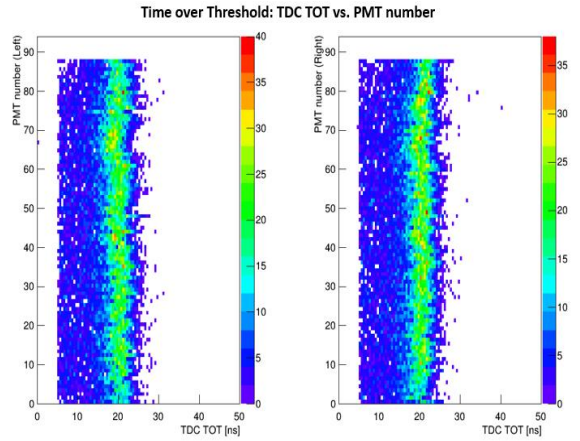

### TDC Multiplicity per PMT Left/Right

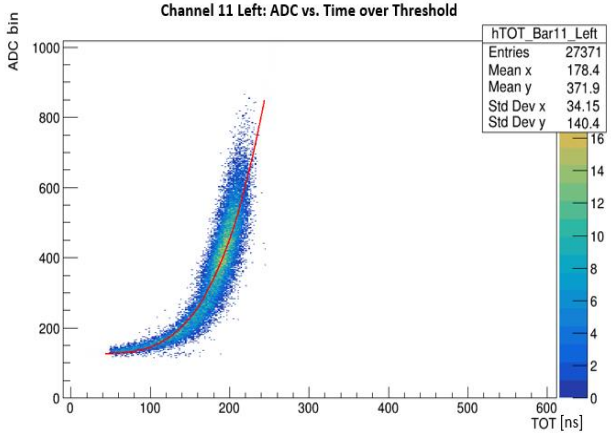


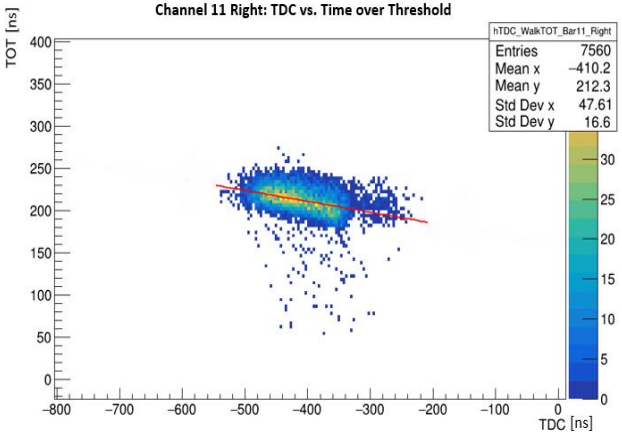
# Timing Hodoscope Commissioning: TDC



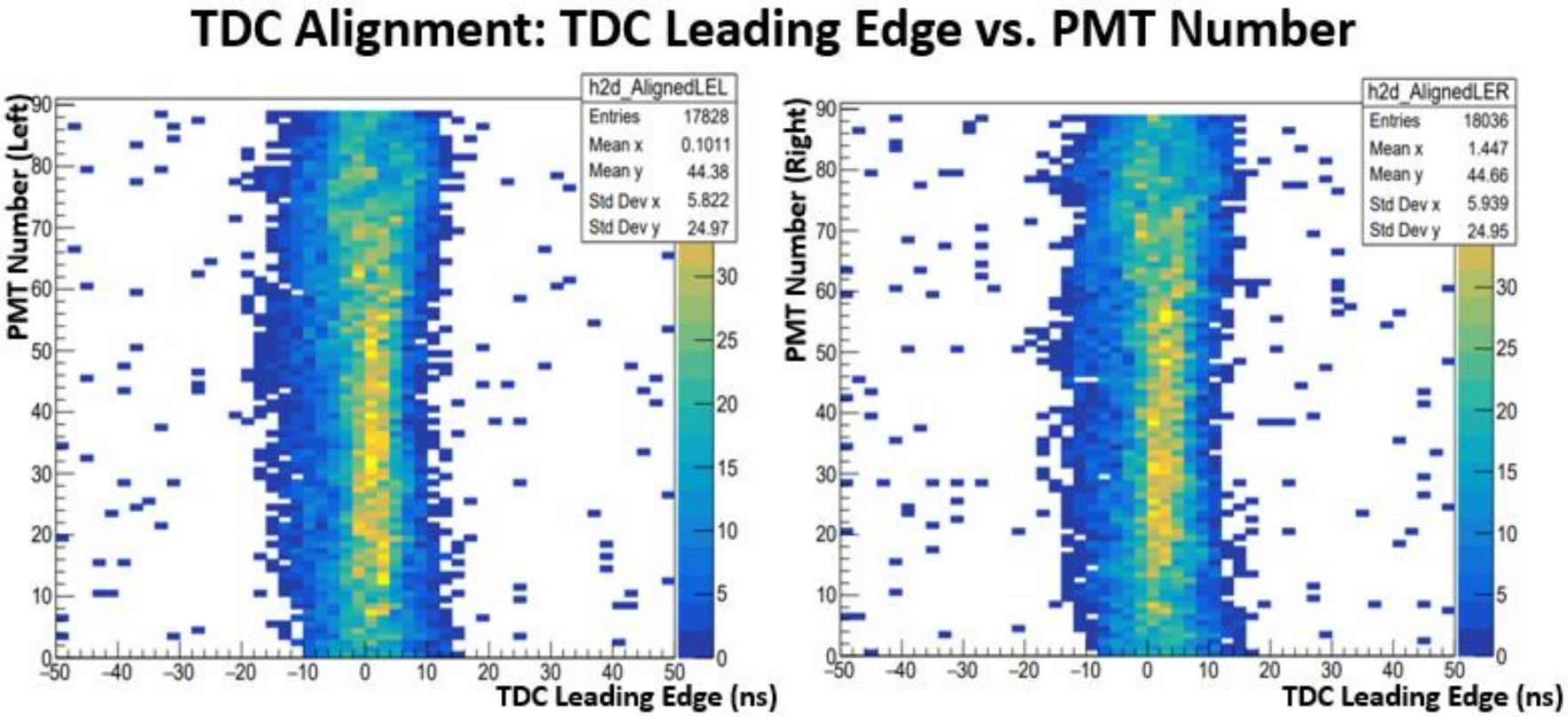



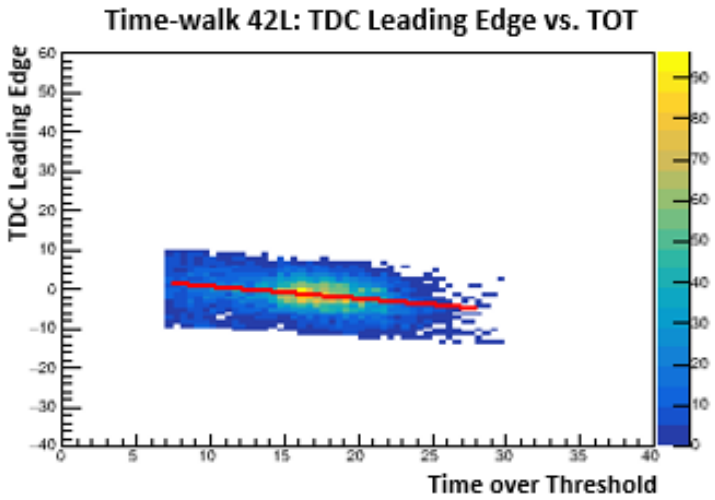
# Timing Hodoscope Calibration: TDC Alignment

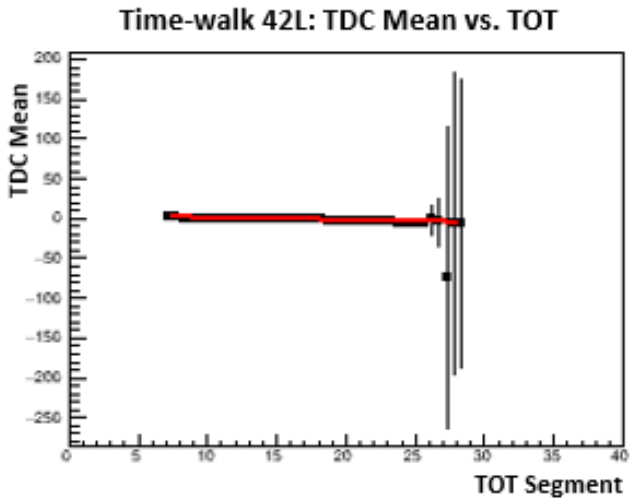
- align all TDC distributions to zero which represents center of TH detector bars

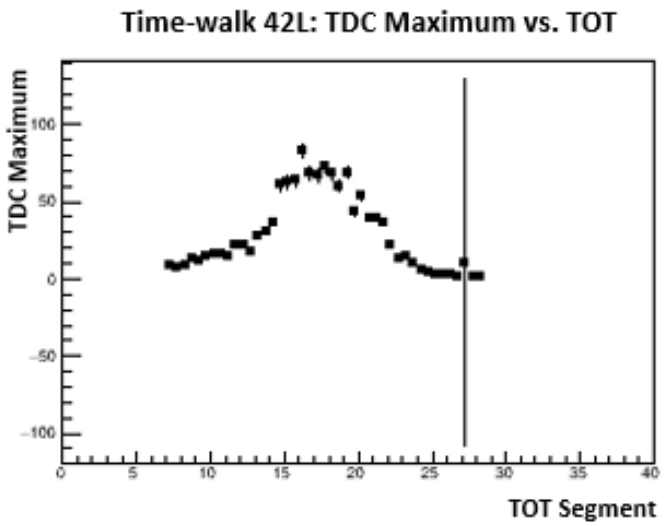


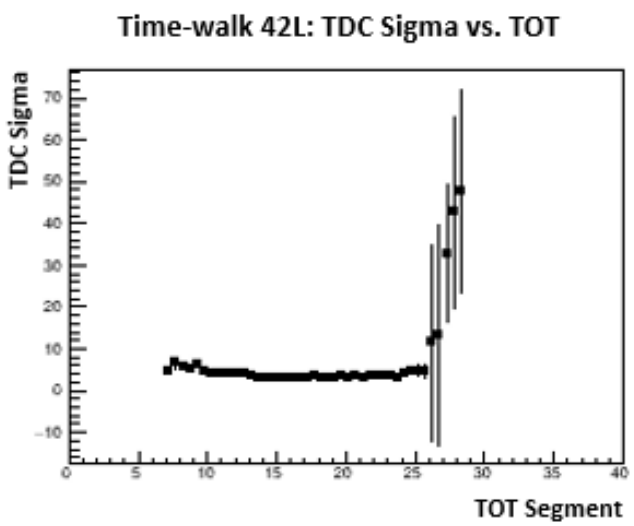
# Timing Hodoscope Calibration: Time-walk Correction

- use slope and intercept to adjust distribution slant caused by time-walk effect



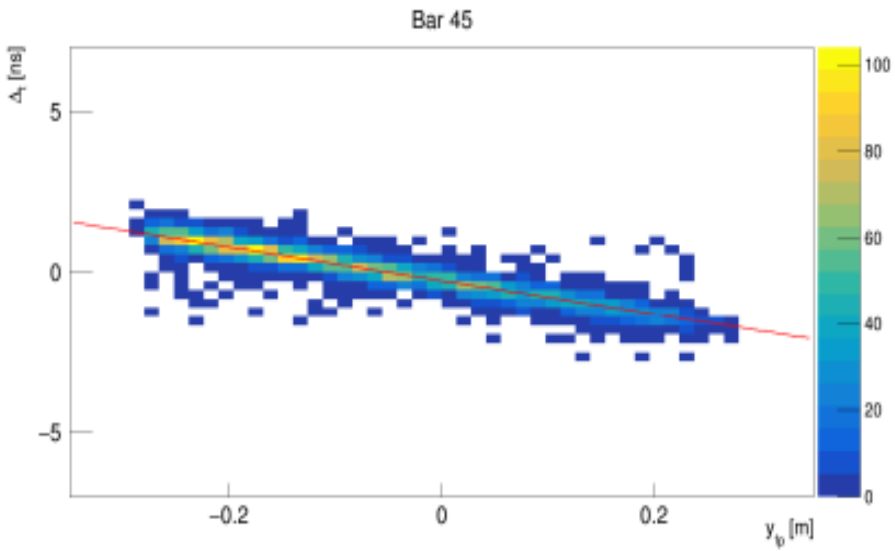



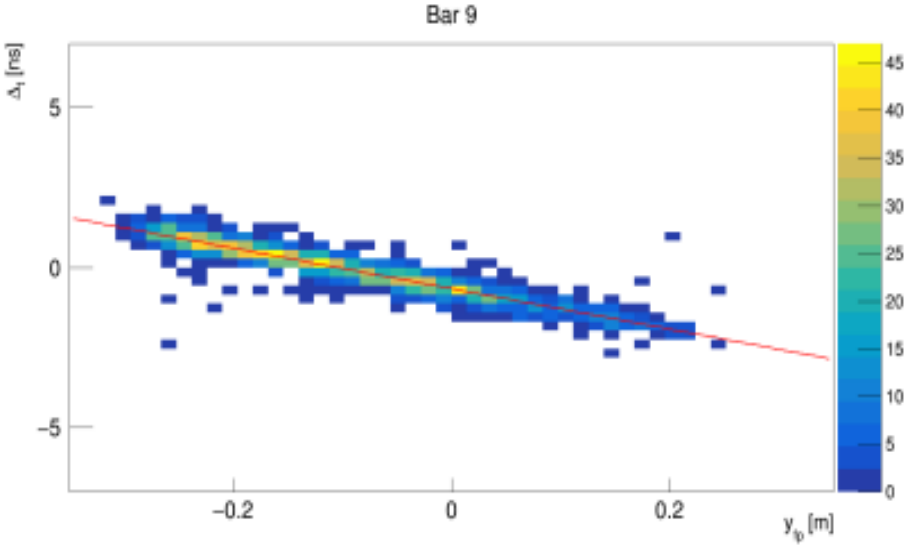



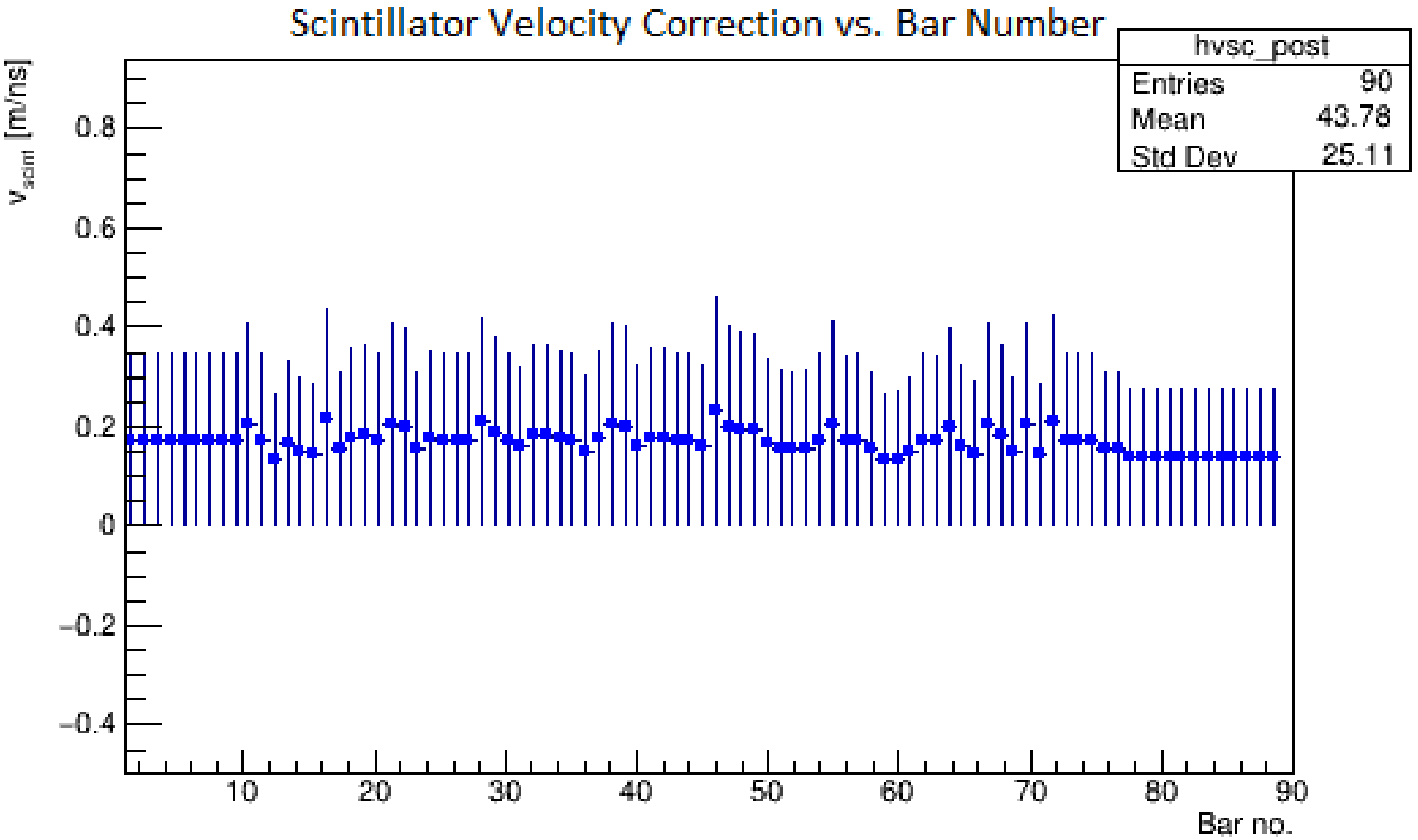
# Timing Hodoscope Calibration: Time Difference Offset

- use intercept as time difference offset, and slope as scintillator velocity correction (see next slide)



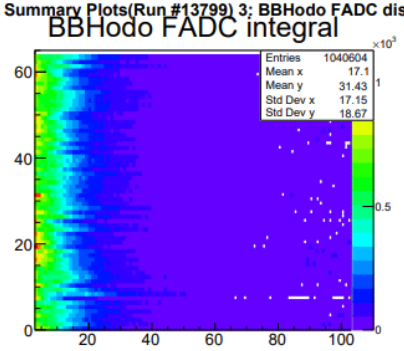



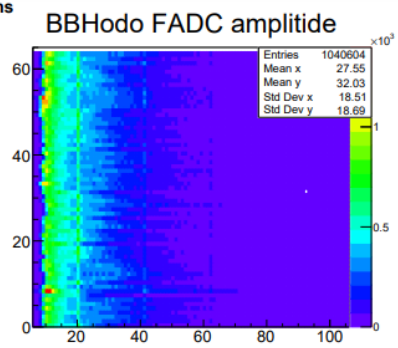
# Timing Hodoscope Calibration: Scintillation Velocity Correction

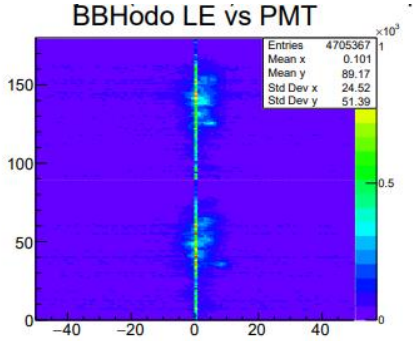


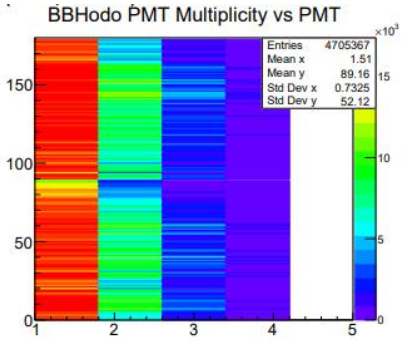
# Timing Hodoscope Performance: Monitoring Plots

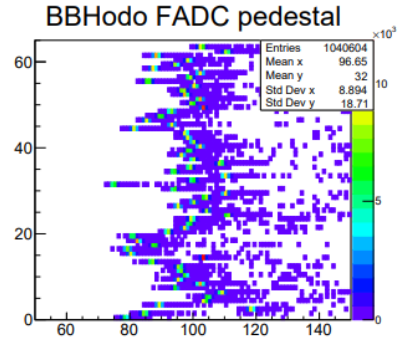
Summary Plots(Run #13799) 3: BBHodo FADC distributions

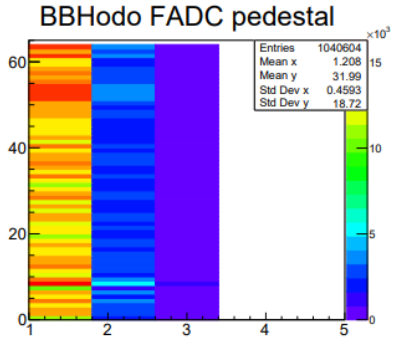


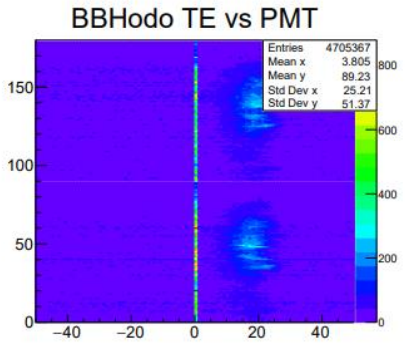



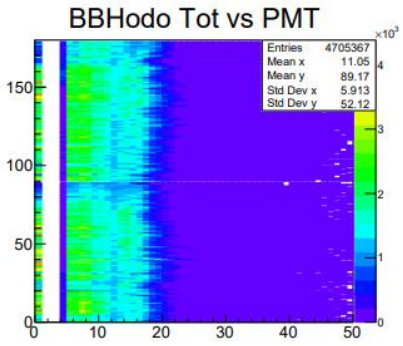



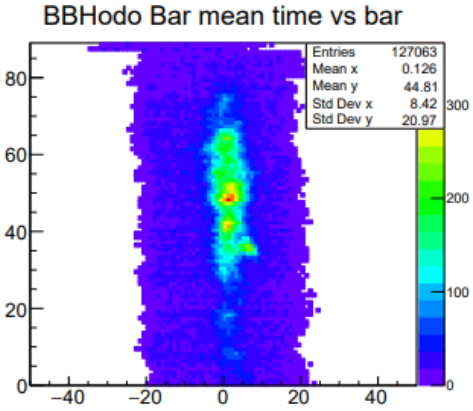



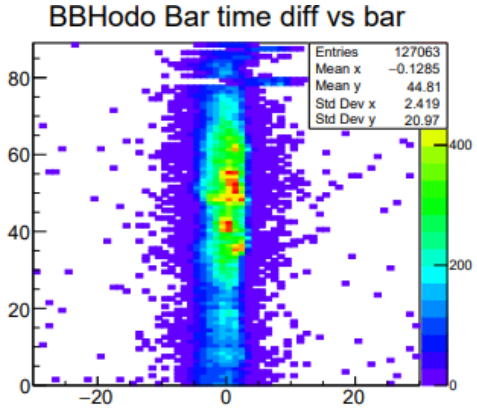



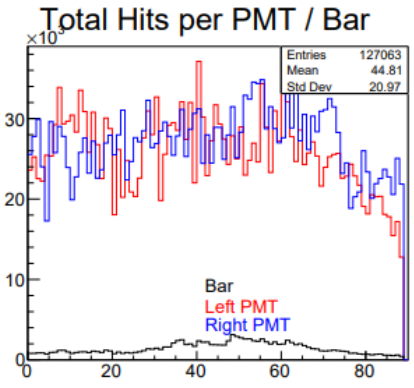



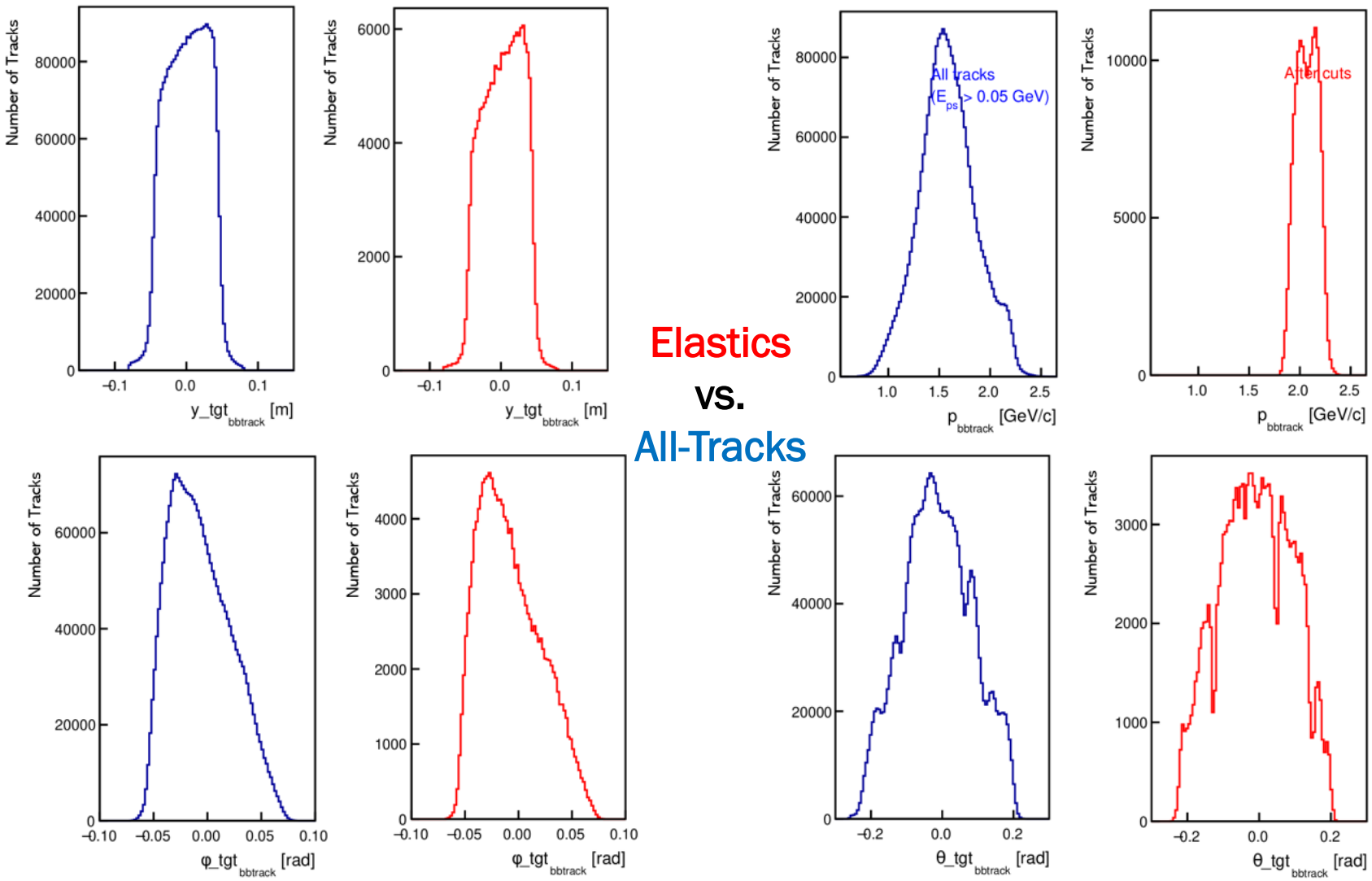



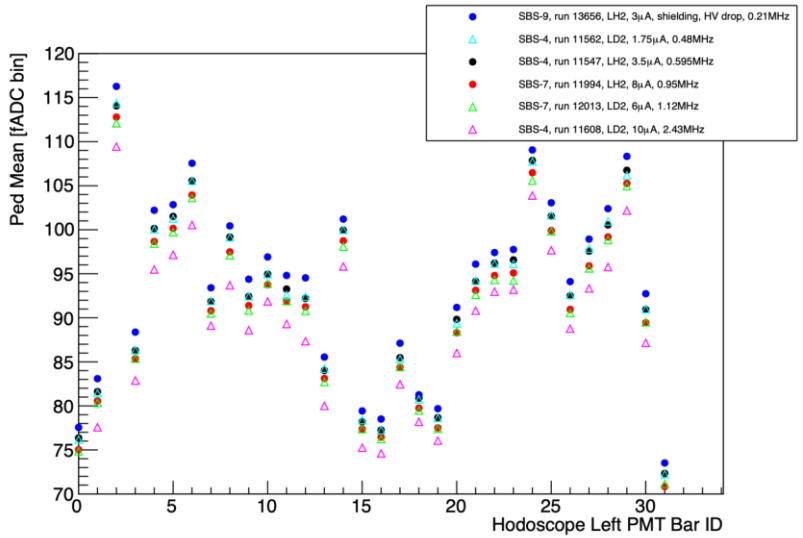



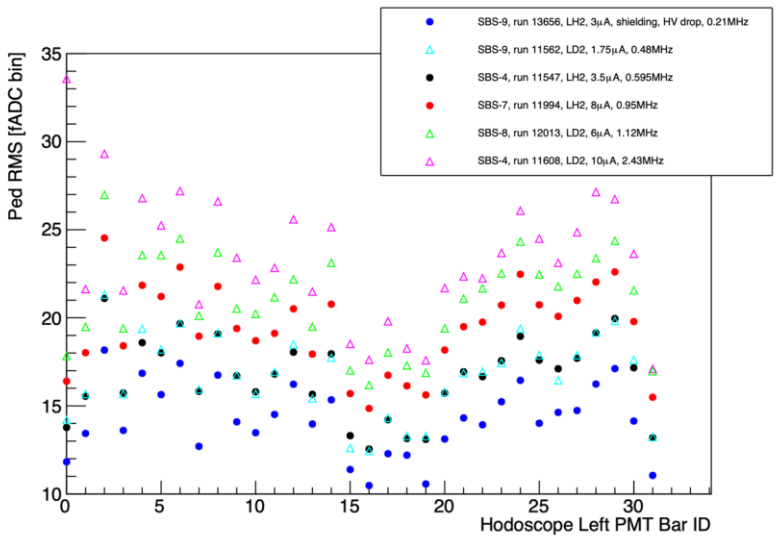



# Timing Hodoscope Performance: Physics Cuts



# Timing Hodoscope Performance: Pile-up




## No Evidence of Pile-up