Fermilab Test Beam and Prototype Test in STAR

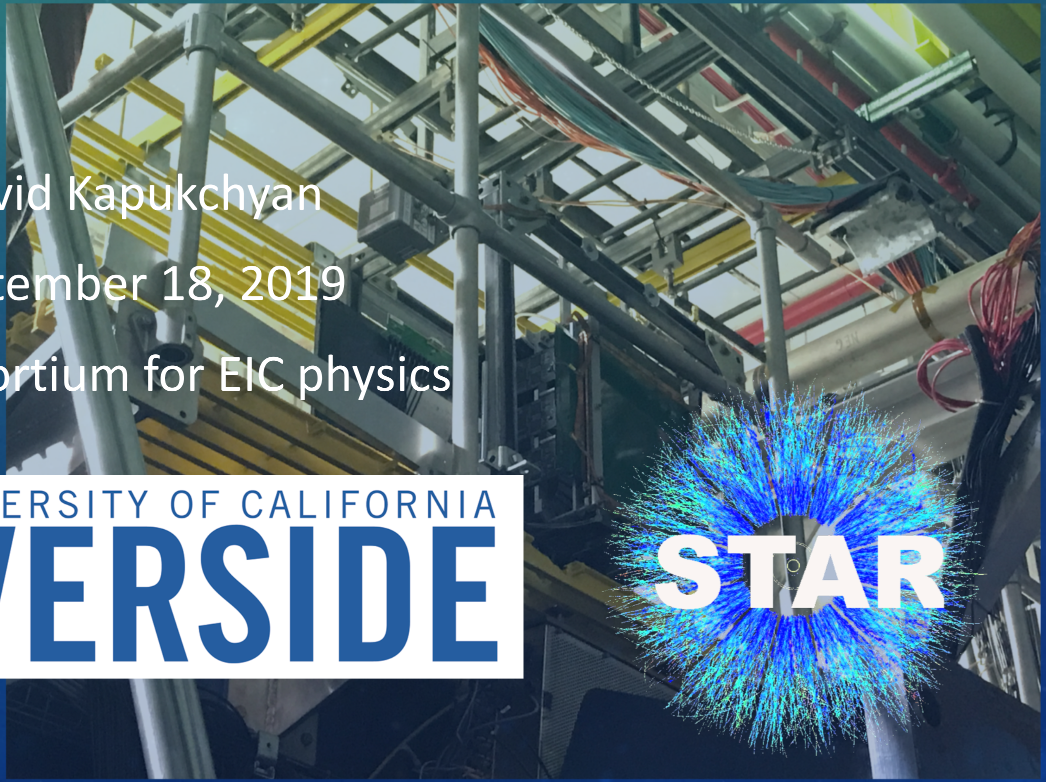
Outline

1. Overview
   a. STAR forward plans
   b. Forward Calorimeter System
2. Fermilab Test
   a. Setup
   b. Goals
   c. Results
3. FCS Prototype Test at STAR
   a. Run 19 Setup and Goals
   b. Tasks performed
   c. Results

David Kapukchyan

September 18, 2019

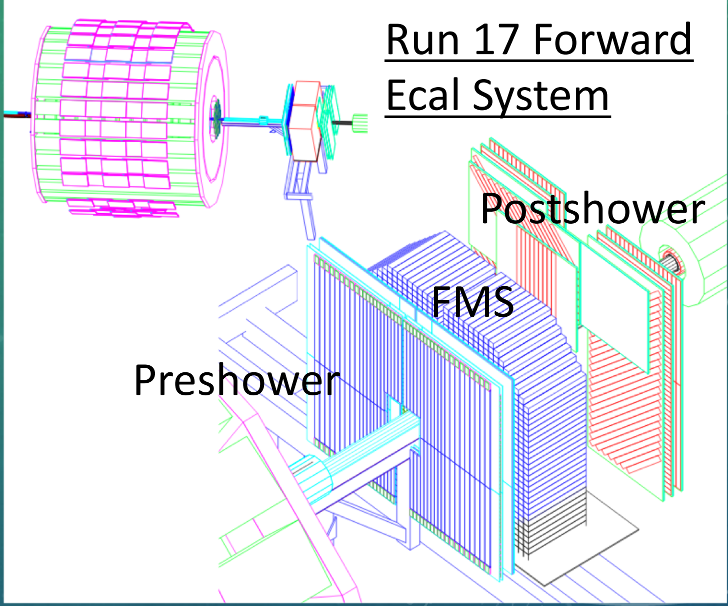
UC Consortium for EIC physics



UC RIVERSIDE UNIVERSITY OF CALIFORNIA

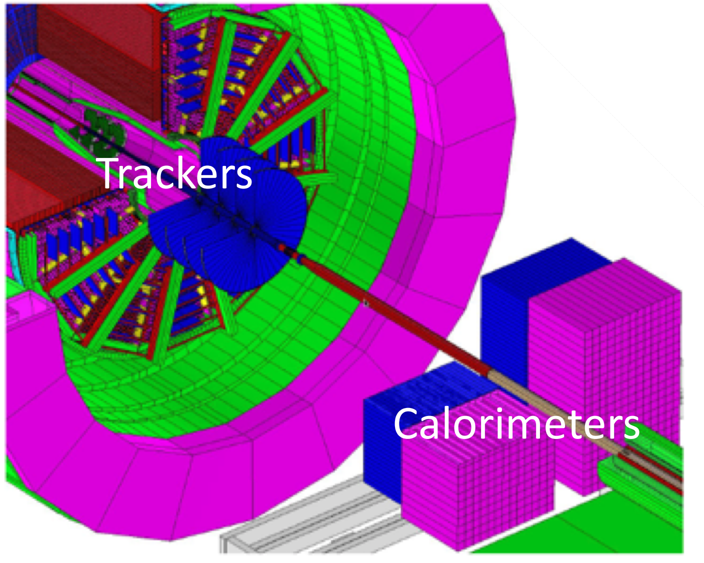
STAR

STAR Forward Upgrade Plans



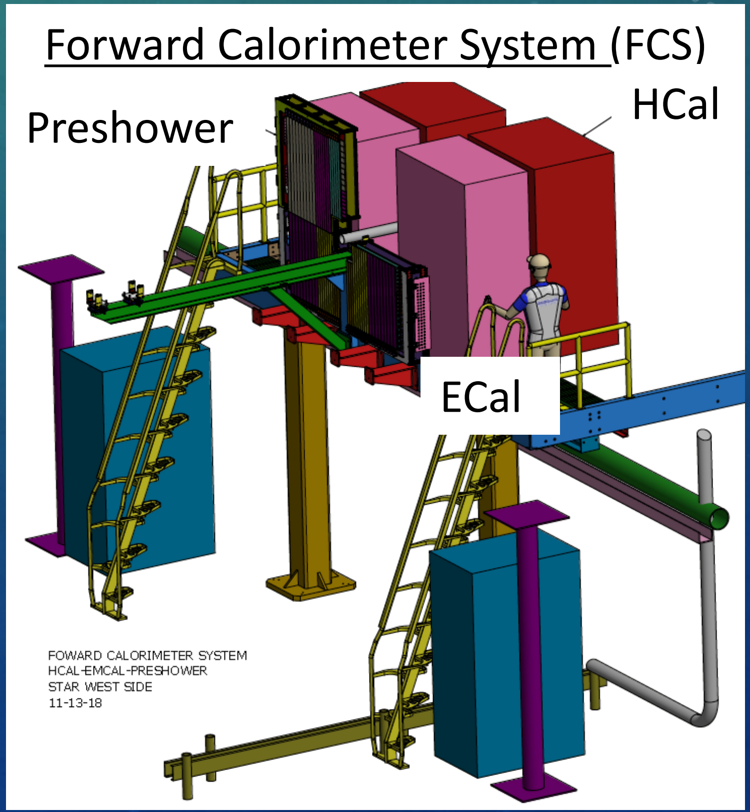
- Old STAR forward detectors were an electromagnetic calorimeter called the FMS and later a preshower (FPS) and postshower (FPOST)
- The forward upgrade is to extend the capability of this system by also installing trackers and a hadronic calorimeter.
- The improved capability is needed to understand TMDs - Transverse Momentum Dependent Parton Distribution Functions (PDFs)
- This new system will also utilize new electronics capable of taking higher quality data
- UC Riverside has been involved in the testing and running of this new calorimeter system and its electronics

STAR Proposed Forward Upgrade



Forward Calorimeter System (FCS)

- Consists of Preshower(fPRE), Electromagnetic Calorimeter (Ecal), and Hadronic Calorimeter(Hcal)
- Preshower (fPRE)
  - Scintillator Hodoscope with SiPM readout
  - Re-use existing FMS preshower
- ECal
  - Re-use Pb/Sc sandwich from Phenix
  - Change to SiPM readout
- Hcal
  - Fe/Sc sandwich using SiPM readout
  - Will be built from scratch

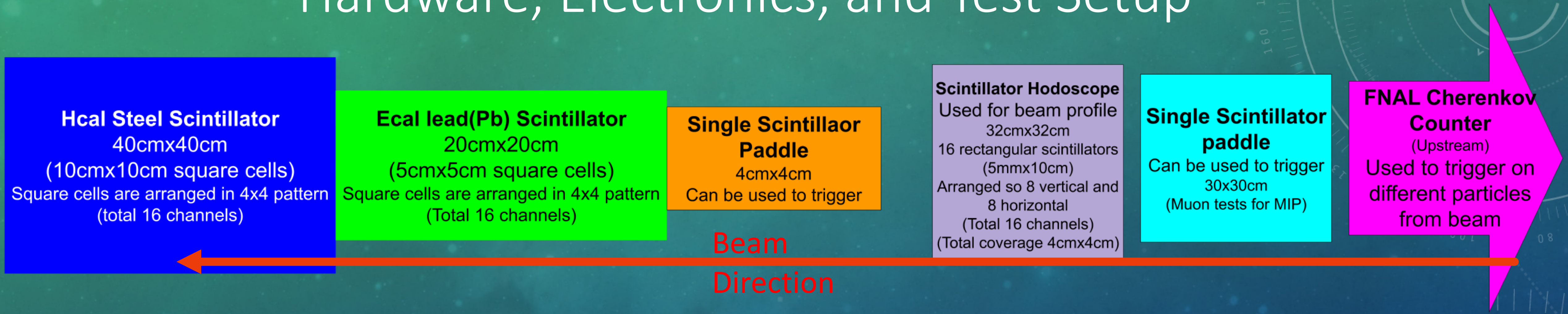


Fermilab Test

Hcal Prototype Test At Fermilab

- The proposed hadron calorimeter for the FCS underwent testing at Fermilab Test Beam Facility (FTBF) for calibration purposes
- It was also a chance to test a new electronics setup for reading data from calorimeters
  - The new electronics setup would allow us to take samples of the PMT/SiPM signal in real time
- This means we can analyze the individual signal itself to identify what kind of interaction happened
  - One such study was to test if slow neutrons coming from hadron showers could be detected
  - Another study was to compare hadronic and electromagnetic showers to determine if any difference could be seen at the signal level (Study done by UCR graduate student Ding Chen)

Hardware, Electronics, and Test Setup



- As can be seen from the diagram above the Test Setup contained multiple systems
- Main detector of this test was the Hadronic calorimeter (Blue)
- There were three detectors we could trigger on depending on the kind of analysis we were interested in
- Electronics used in calibration tests used traditional boards for signal integration
- New electronics installed to test the capability of digitizing signal in real time

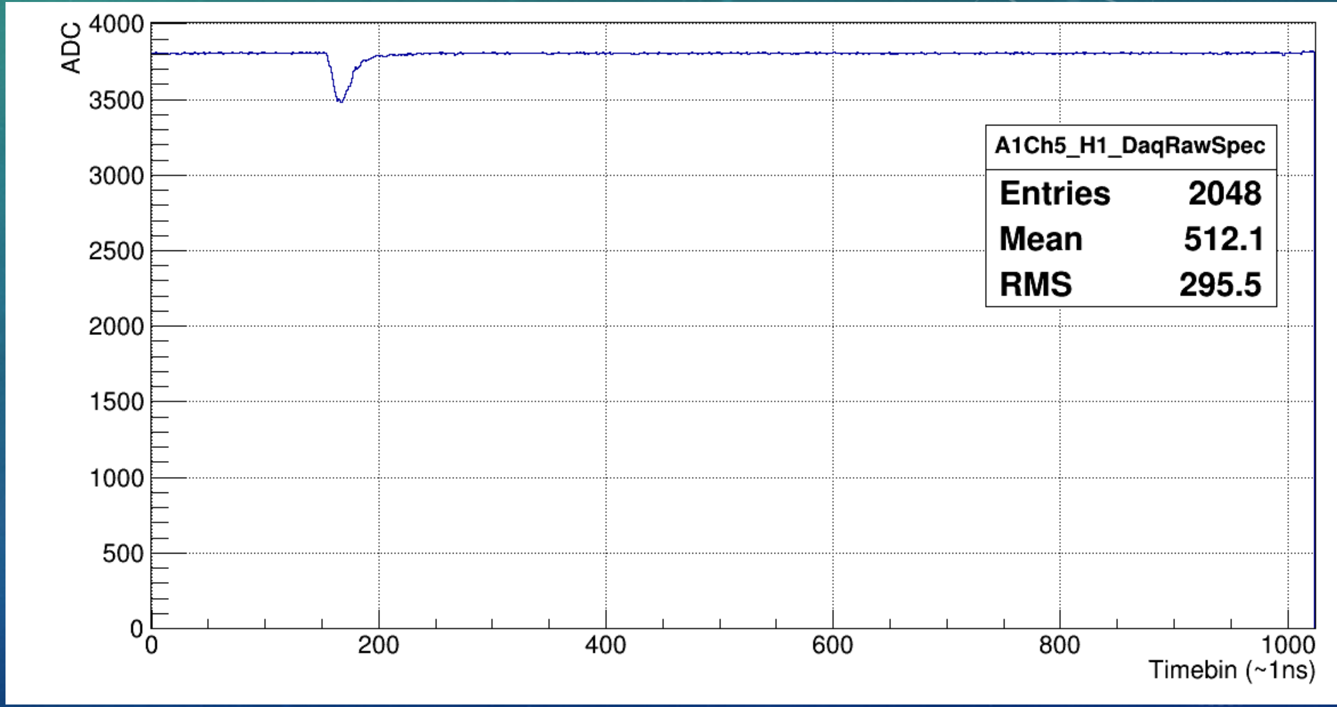
Hcal Channel Map
Inner 2x2 (Green)
Outer (Red)

0	1	2	3
4	5	6	7
8	9	10	11
12	13	14	15

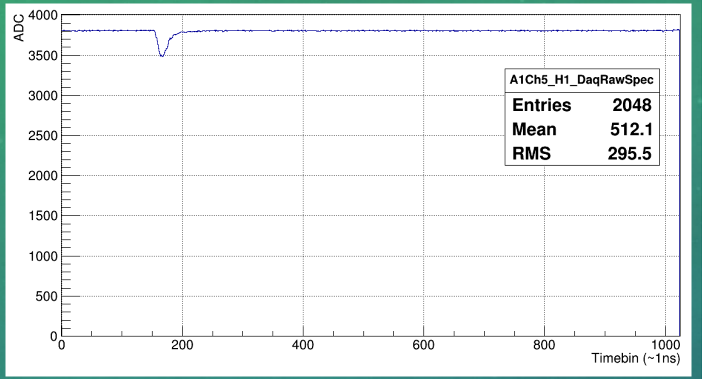
Description of New Electronics System

- Electronics board capable of digitizing signal from SiPM/PMT in real time
- These boards have a 1024 capacitor array for each channel capable of 1GigaSample/sec
  - This means every timebin (tb) corresponds to ~1ns
  - Each tb gives one 12 bit ADC value (0-4095)
- Traditionally such charge integration happens over entire pulse (QT boards at STAR)
- With the raw signal itself there are two things which are now needed to be done by hand
  1. Find the baseline
  2. Find the signal start time
  3. Sum the signal to get the more traditional ADC value

Sample Pulse from using new electronics readout

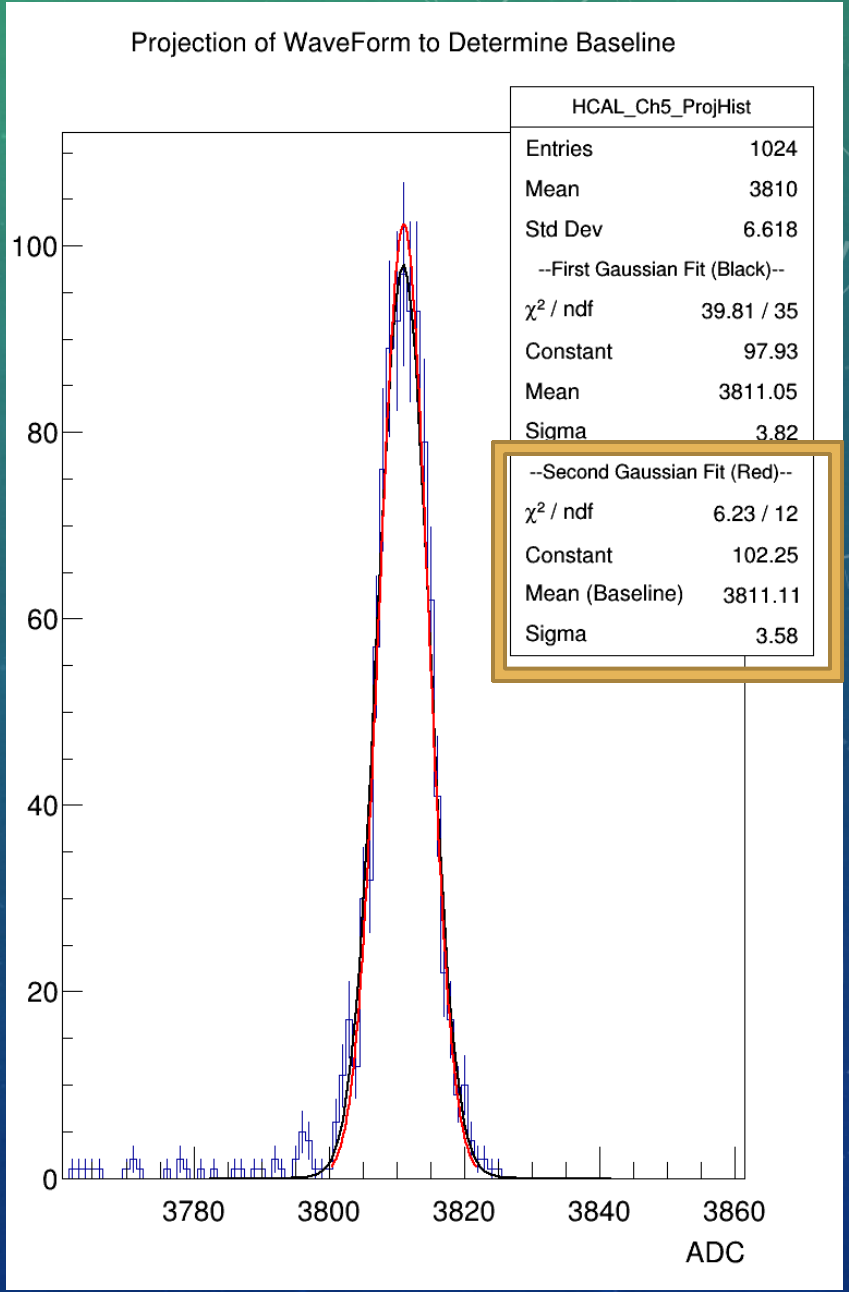


Finding the baseline



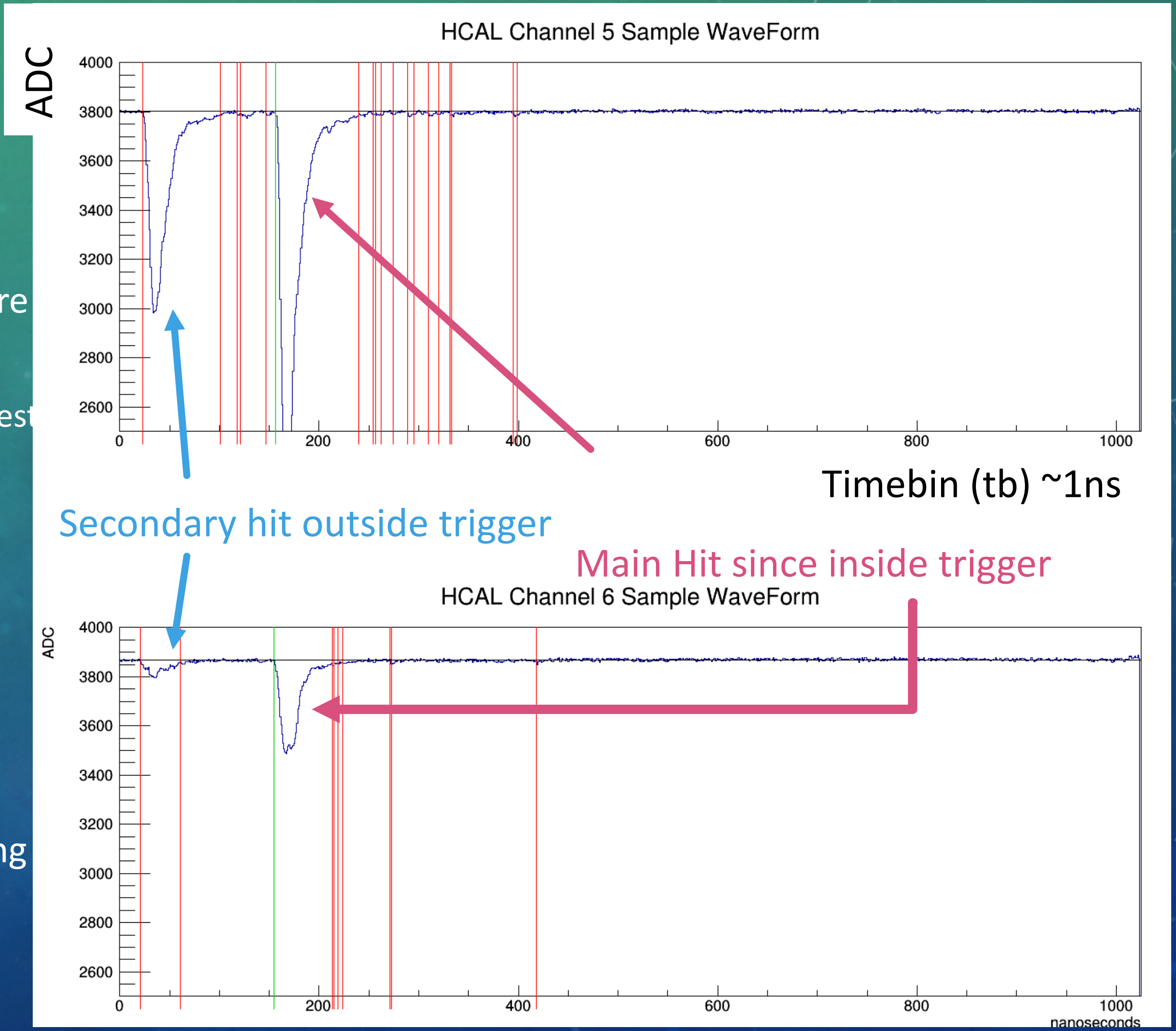
- This was done by projecting the pulse to the y-axis (ADC) and doing two gaussian fits
  - First fit was to max ± 30
  - Second fit was mean±2*sigma of first fit
- The mean of the second fit was the baseline
- This also gives a sigma to the baseline which will be important later in identifying the signal start time
- The plot on the top right shows one such example with its fit

Project along Y



Finding the Start Time (T0)

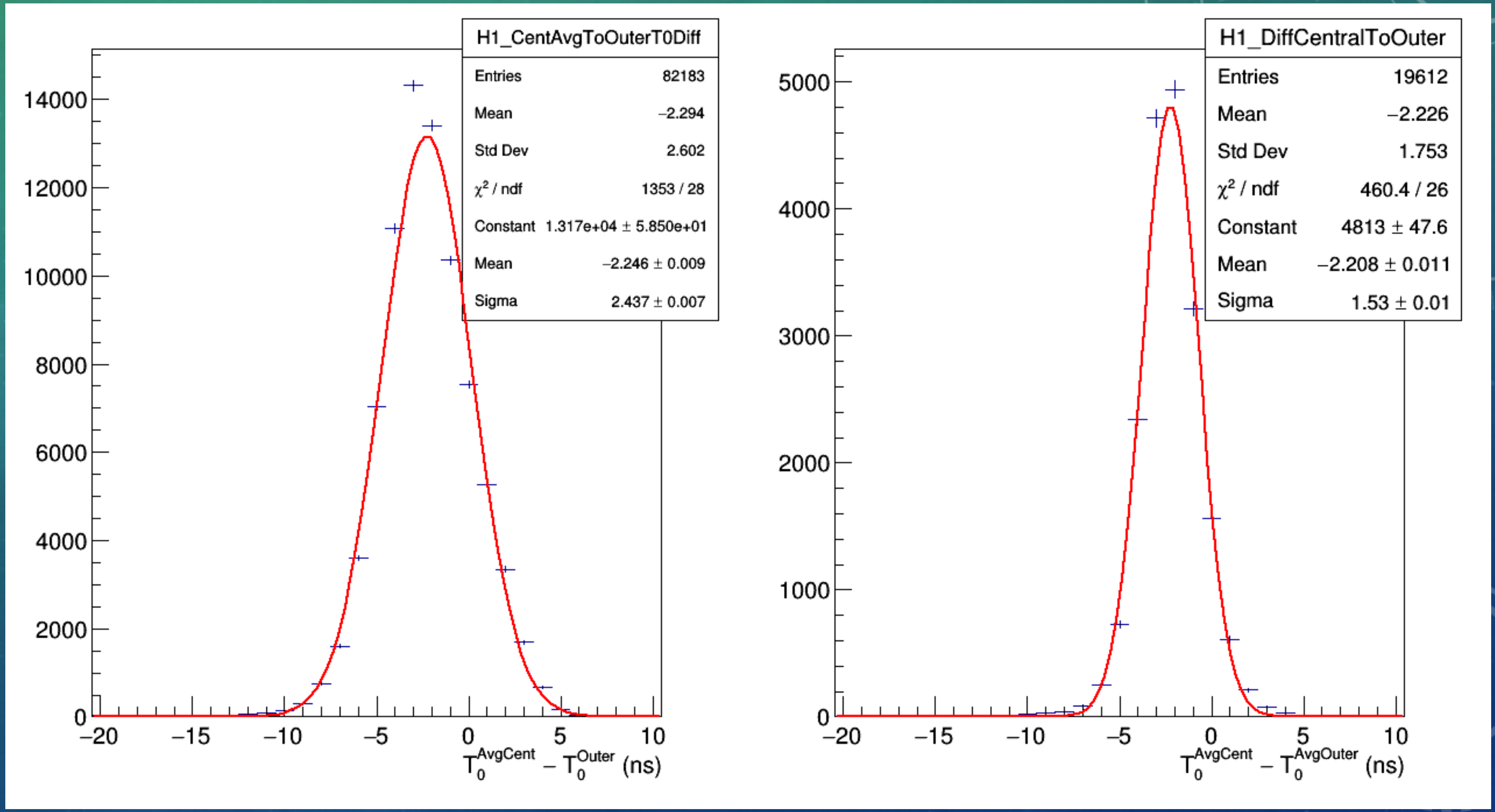
- This is done by scanning the pulse and checking where it goes 5*sigma above baseline
  - The 5 was chosen after testing to see which worked best
- This could lead to lots of false positives (Red Lines) which were ruled out by the following method
  1. If a potential T0 was found do a linear fit using ±4 tb
  2. If the slope fit was close to zero then rule it out.
- Now this left only the double peak cases where two signals would appear in the full 1024 tb pulse
- To eliminate these we checked which of the remaining T0s were inside of our trigger window of 120-220 tb
- Final T0 is green line in plots on right



0	1	2	3
4	5	6	7
8	9	10	11
12	13	14	15

Comparing T0s To Detect Slow Neutrons

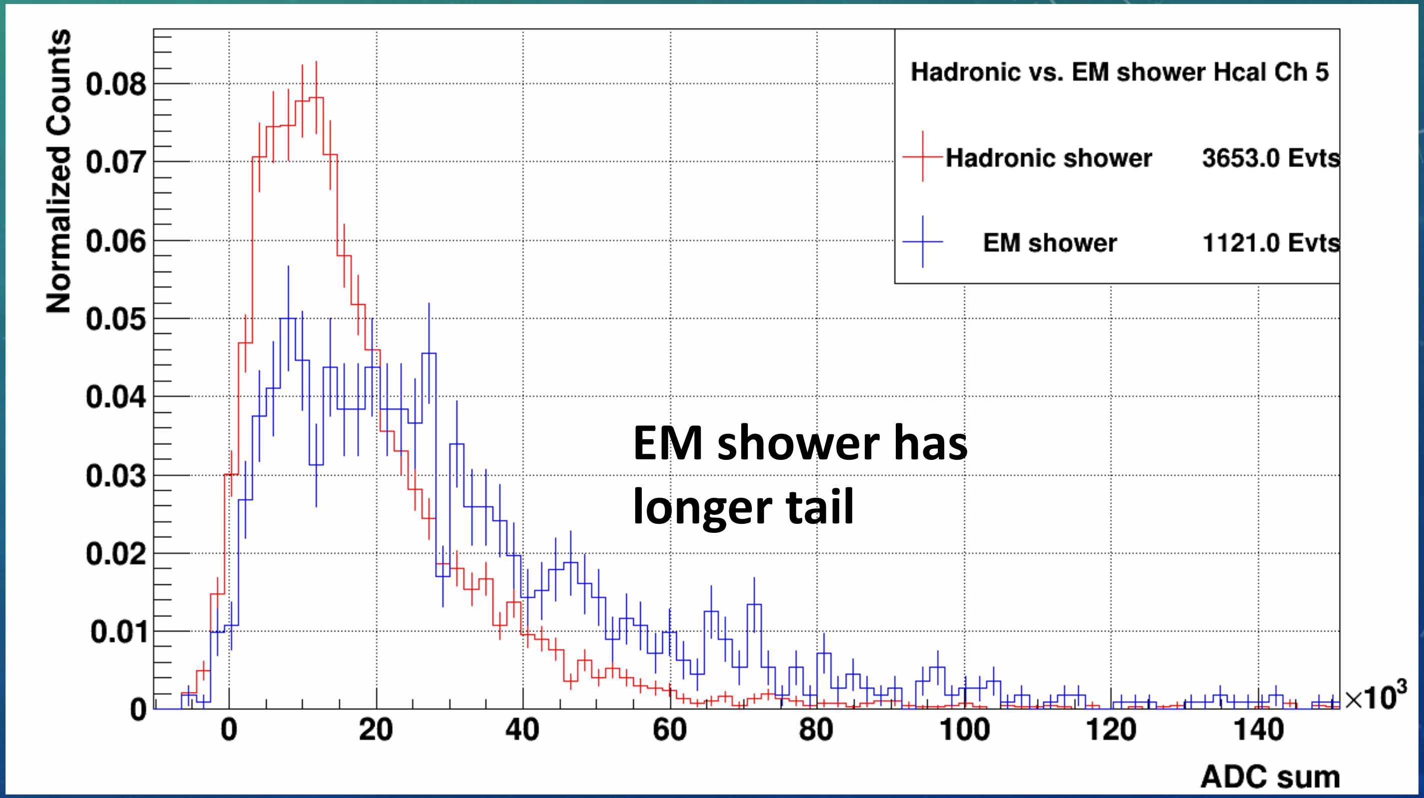
- Ecal was removed for this test and a 20cm lead block placed in front Hcal to induce showers
- Beam was 120 GeV mixed species of protons, pions, electrons
- The T0 for the inner 2x2 was averaged $T0^{AvgCent}$ was compared to the outer channels T0 ($T0^{Outer}$)
- Also the $T0^{AvgCent}$ was compared to the average T0 for the outer channels ($T0^{AvgOuter}$)



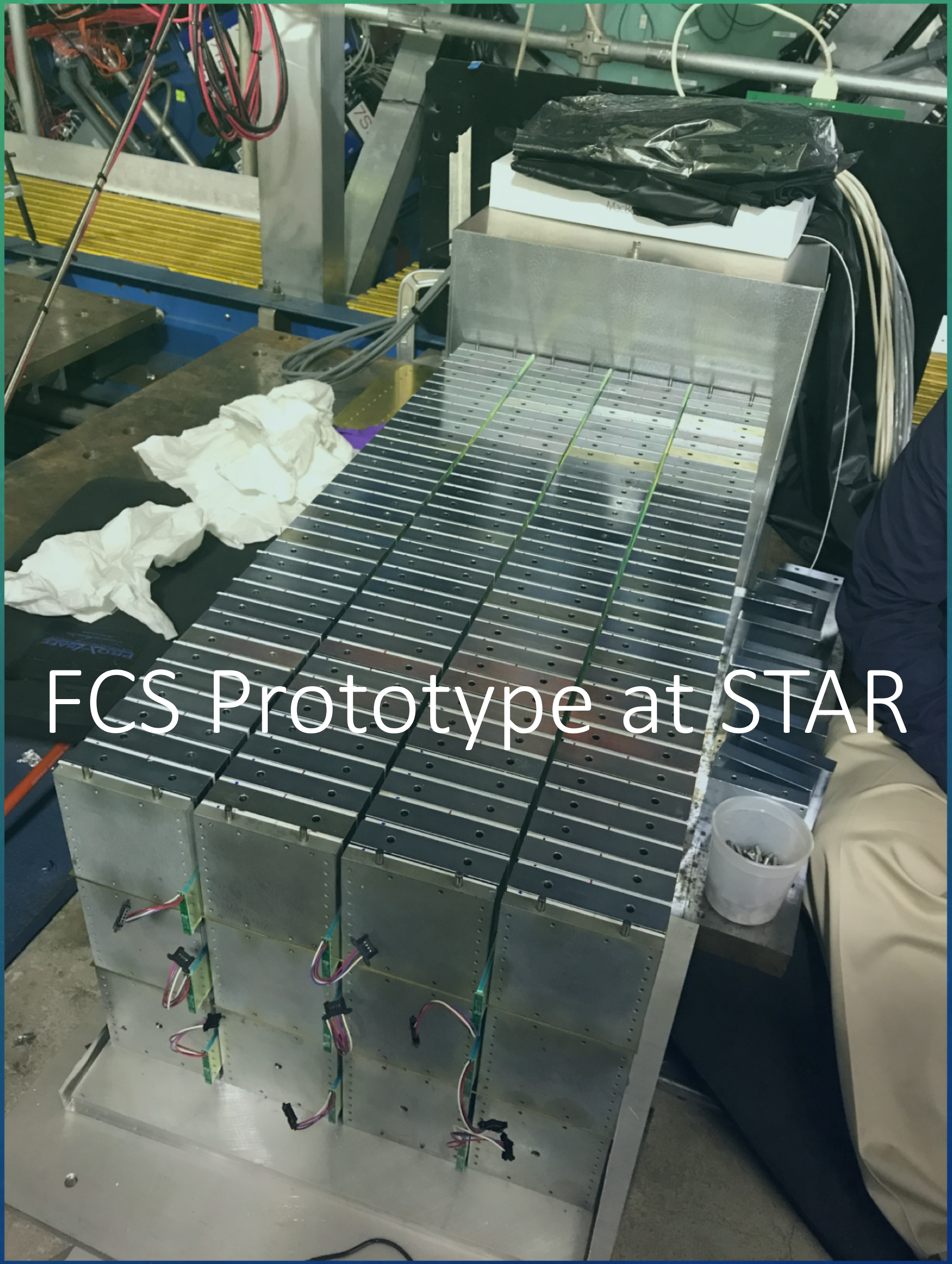
- As can be seen in both plots no there is no significant difference between signal times between outer and inner sectors
  - The 2ns shift is merely coming from travel time of shower from one cell to next

EM and Hadronic Showers

- The difference between electromagnetic showers and hadronic showers was also explored by UCR grad student Ding Chen
- The setup again included just the Hcal (no Pb) and the same mixed beam but at 20GeV
- Electron ID using FNAL Chernkov Counter tuned to electrons
- Compare the adc sum from EM shower to Hadronic showers
  - ADC sum was the found T0 plus 100 tb
- From plot it looks like Hadronic and EM showers do have different profiles

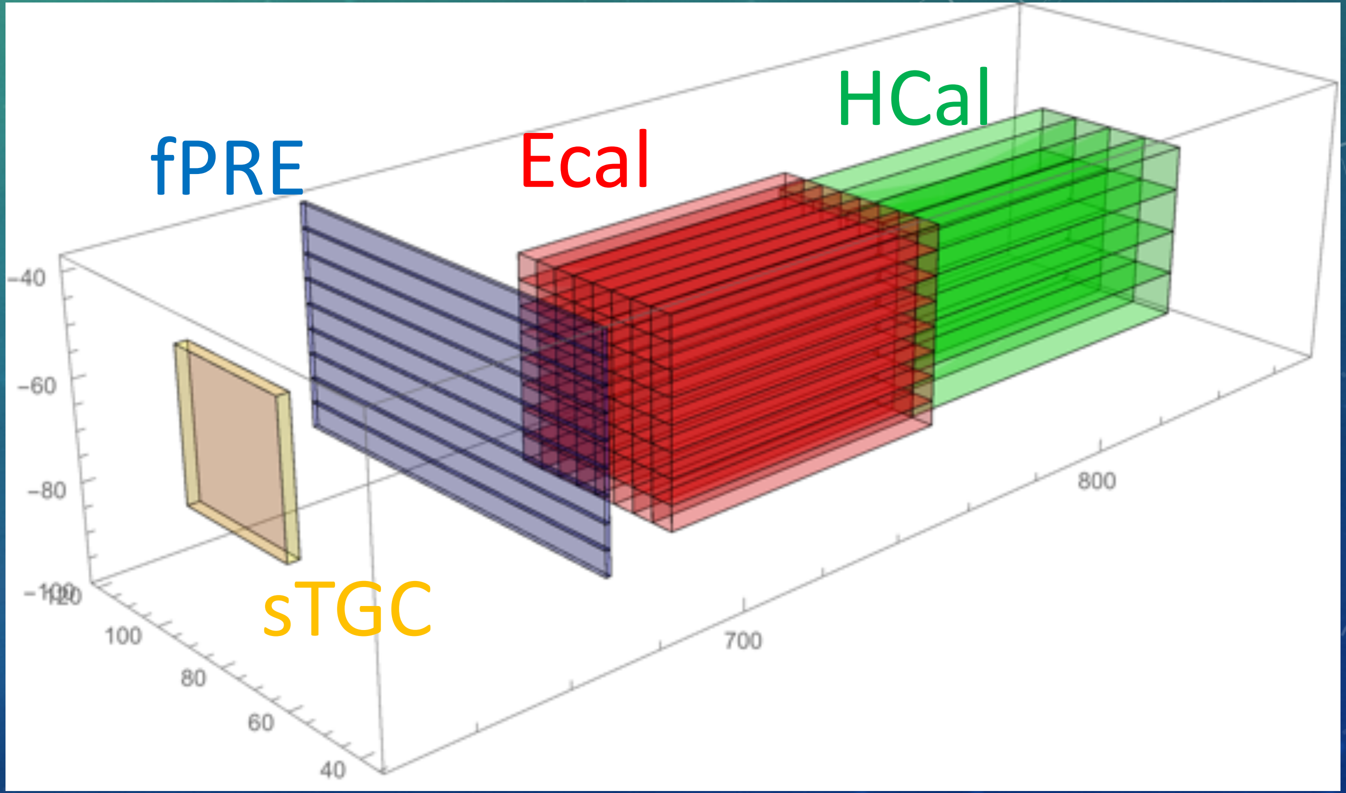


FCS Prototype at STAR

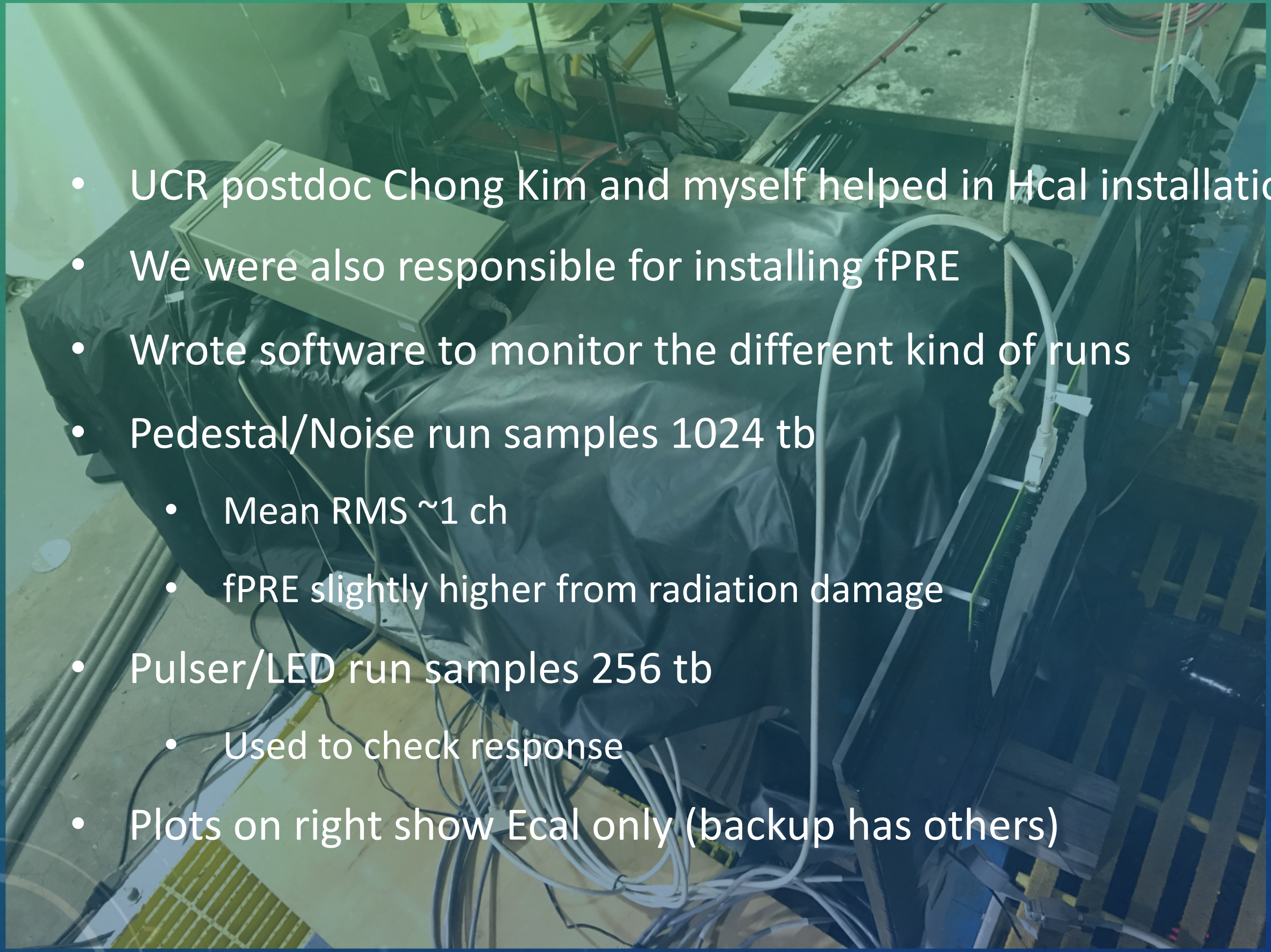


STAR FCS prototype in Run 19

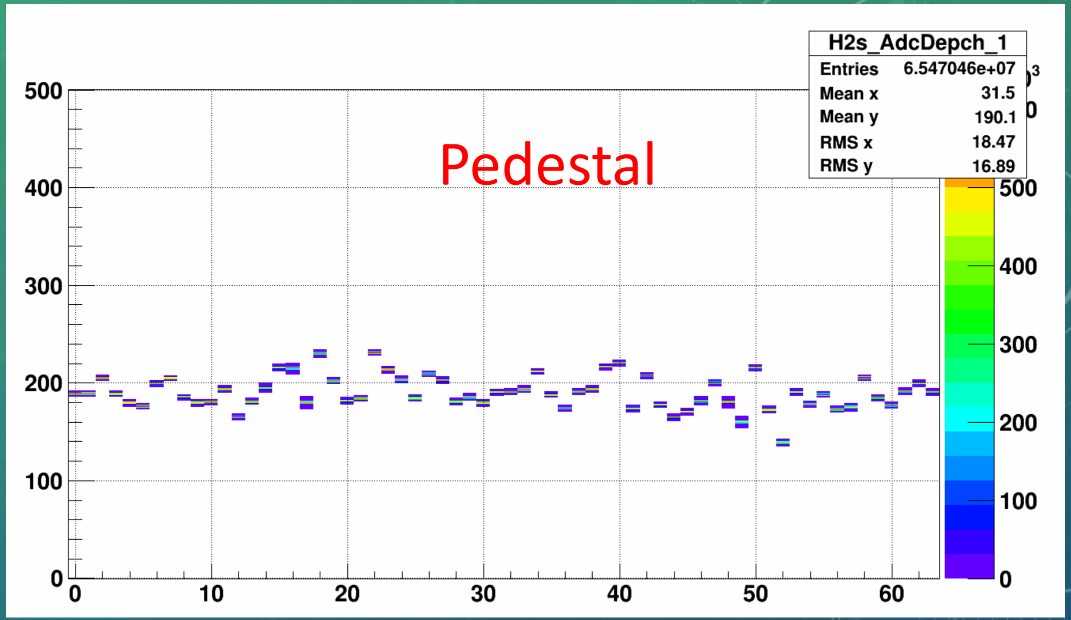
- FCS prototype consists of Ecal, Hcal, preshower (fPRE)
  - Ecal was 8x8 and similar material makeup to FNAL
  - Hcal was same as FNAL test
  - fPRE was layer 1 from FPOST (9 Scintillator slats)
- Also one sTGC module installed for testing, tracker
- New electronics board (DEP) for readout
  - This also captured SiPM signal in real time
  - DEP boards have 32 channels each (4 total)
  - Each channel samples 1/8 of RHIC tick (~12ns/tb)
  - 12 bit ADC (0-4095) per timebin (tb)

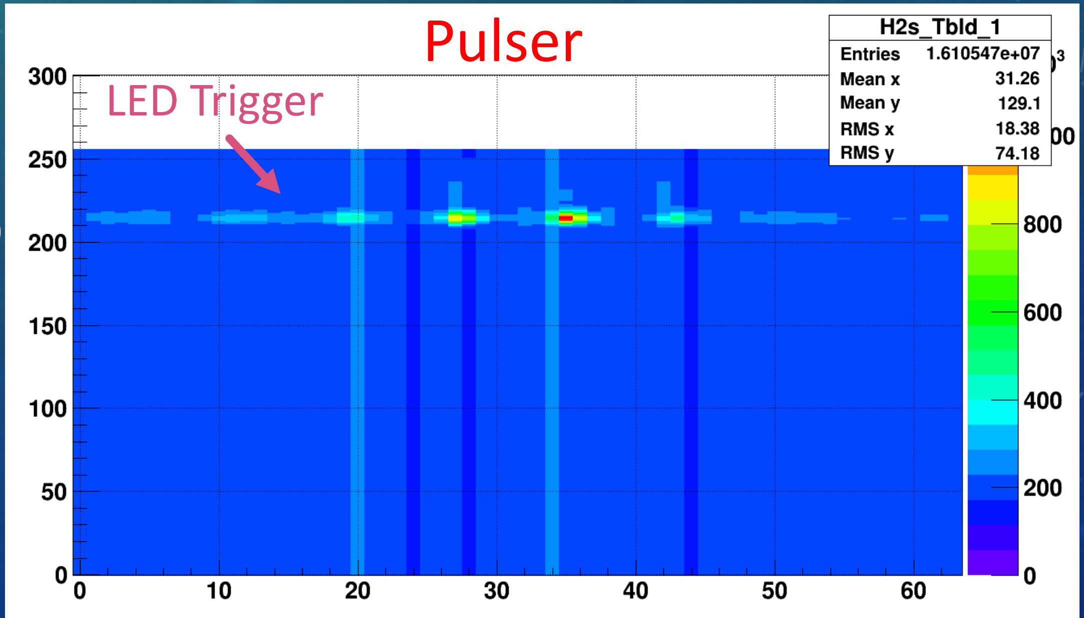


Commissioning and Testing



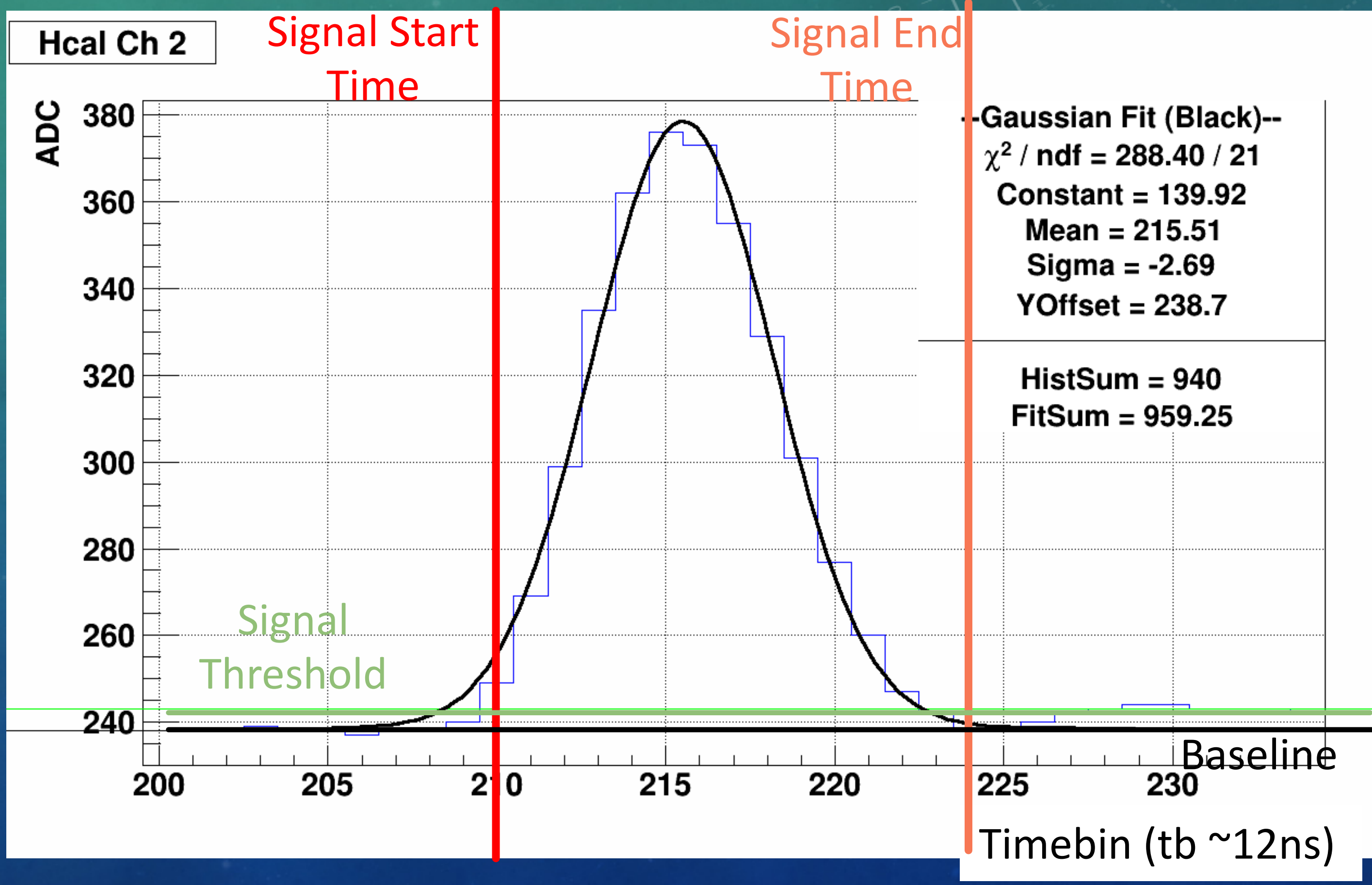
- UCR postdoc Chong Kim and myself helped in Hcal installation
- We were also responsible for installing fPRE
- Wrote software to monitor the different kind of runs
- Pedestal/Noise run samples 1024 tb
  - Mean RMS ~1 ch
  - fPRE slightly higher from radiation damage
- Pulser/LED run samples 256 tb
  - Used to check response
- Plots on right show Ecal only (backup has others)





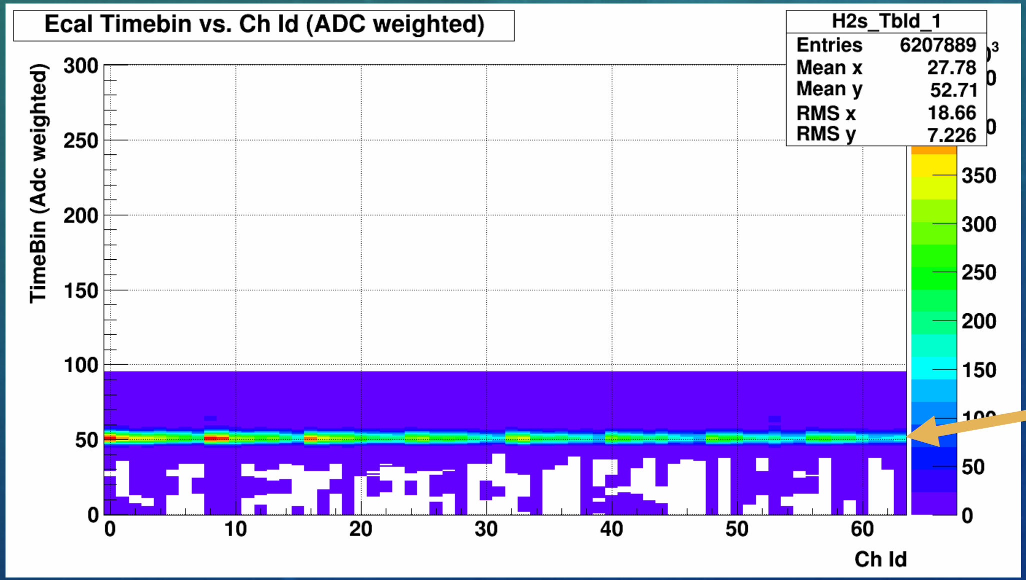
Pulser DEP signals and Signal Fitting

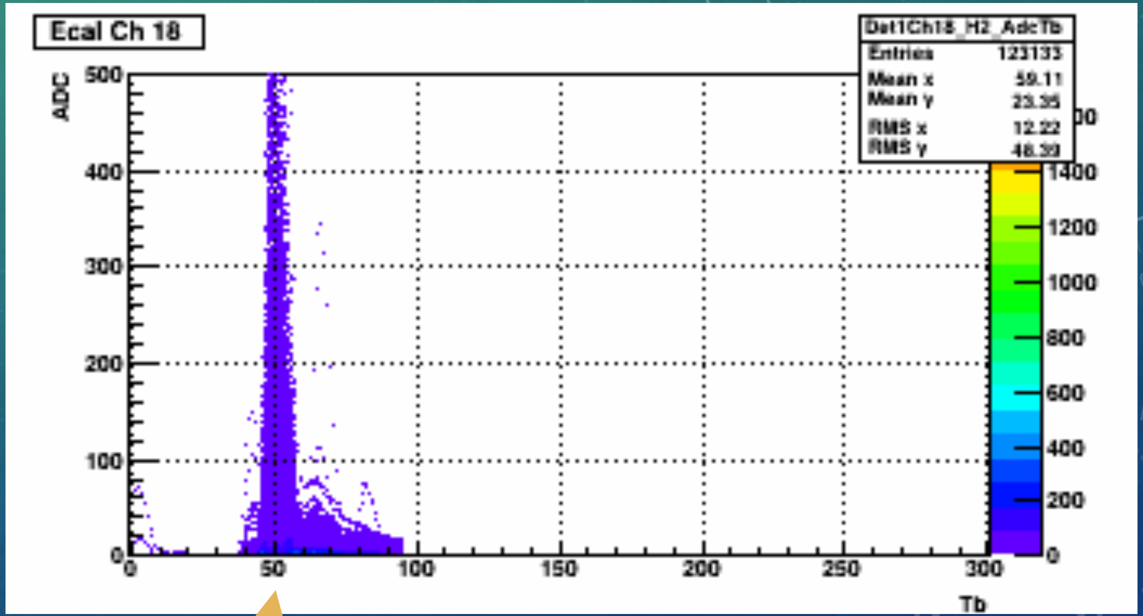
- Figure on right shows sample signal from Hcal
  - Blue histogram is signal
  - Black Gaussian line is Fit
  - Hcal and Ecal signal similar
- Algorithm first determines start and end time for signal based on signal threshold and ADC differences (derivative)
  - Modified FNAL algorithm
  - Ongoing development
- Start and End Tb are used for fit range
- Integration from summing ADC vs. Fit is also shown



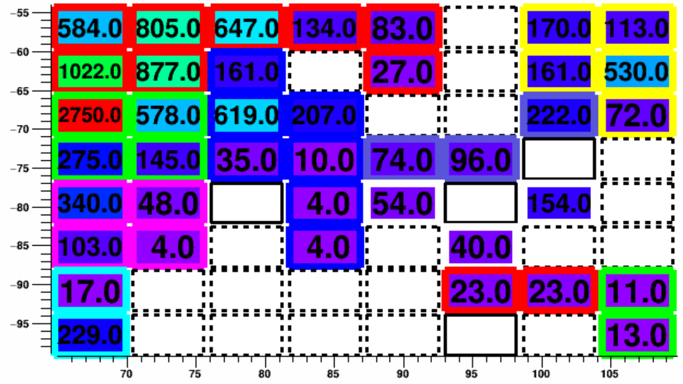
Physics Data

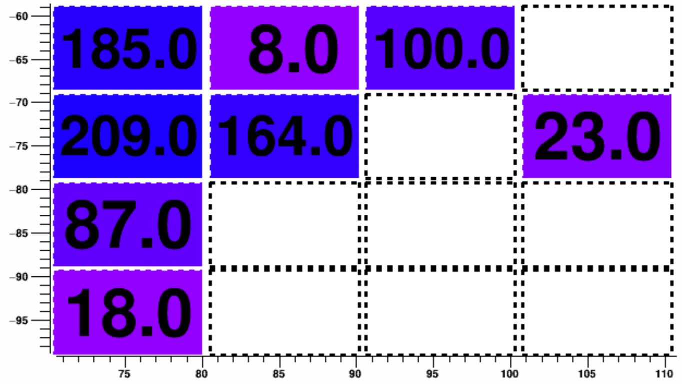
- Used last few days of Run 19 to take AuAu 200GeV data
- Physics mode data taking is pedestal subtracted and zero suppressed
  - Samples 160 tb (~ 20 RHIC crossings or ~ 2000ns)

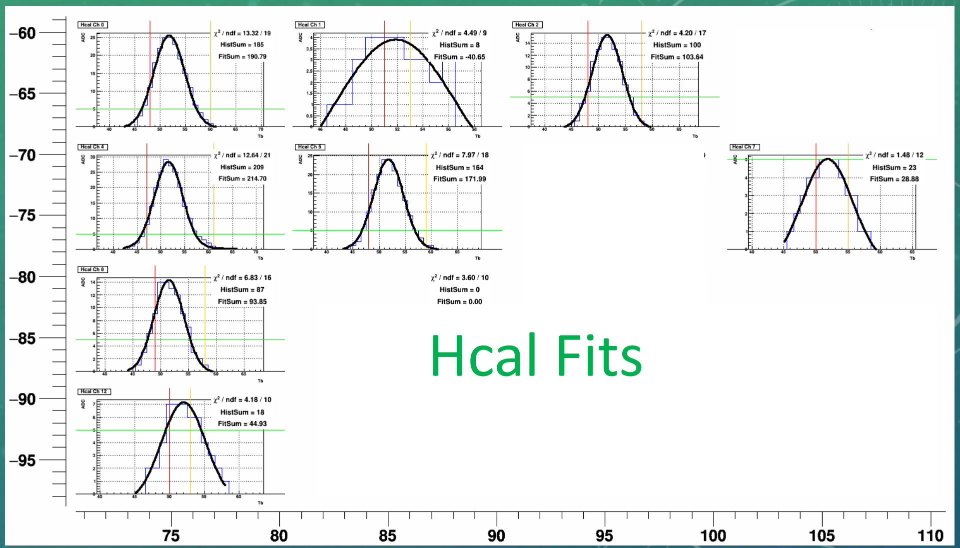




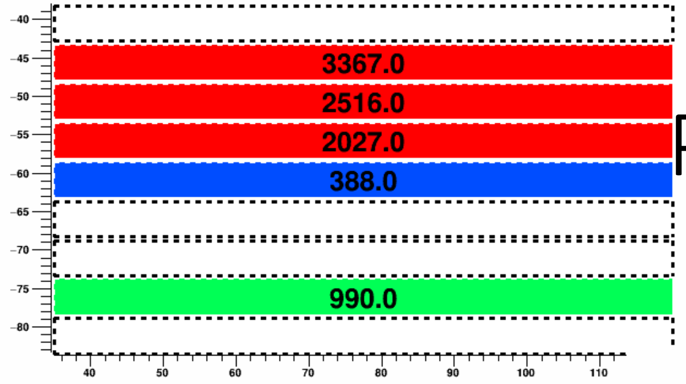
Triggered RHIC Crossing Roughly 50 tb (~600ns)

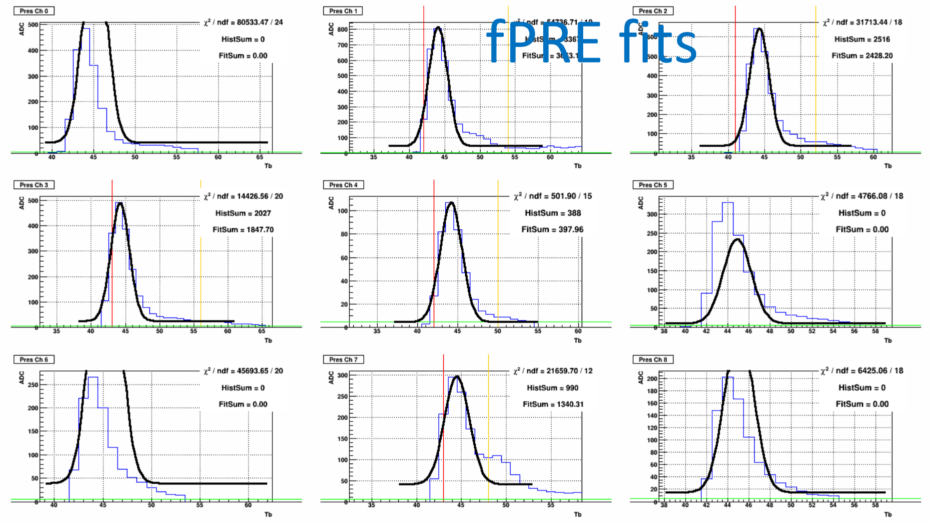




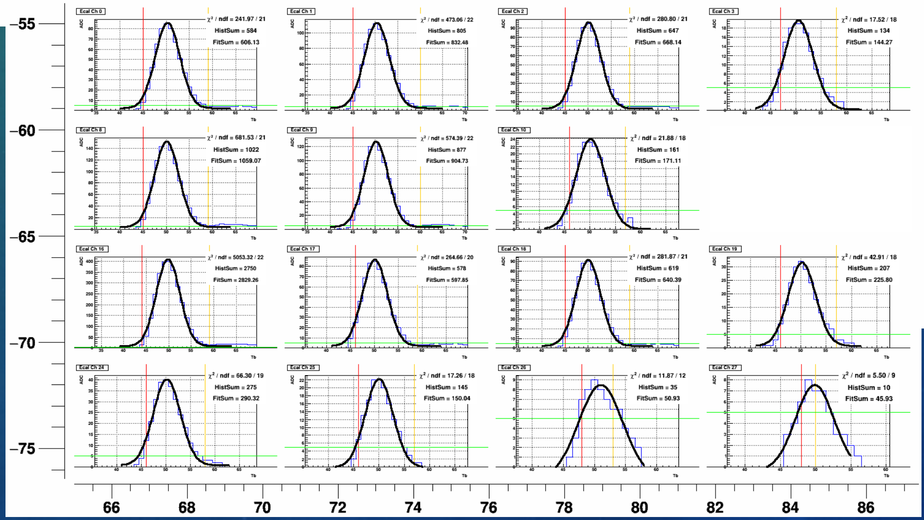


Physics Event Display





Ecal Fits

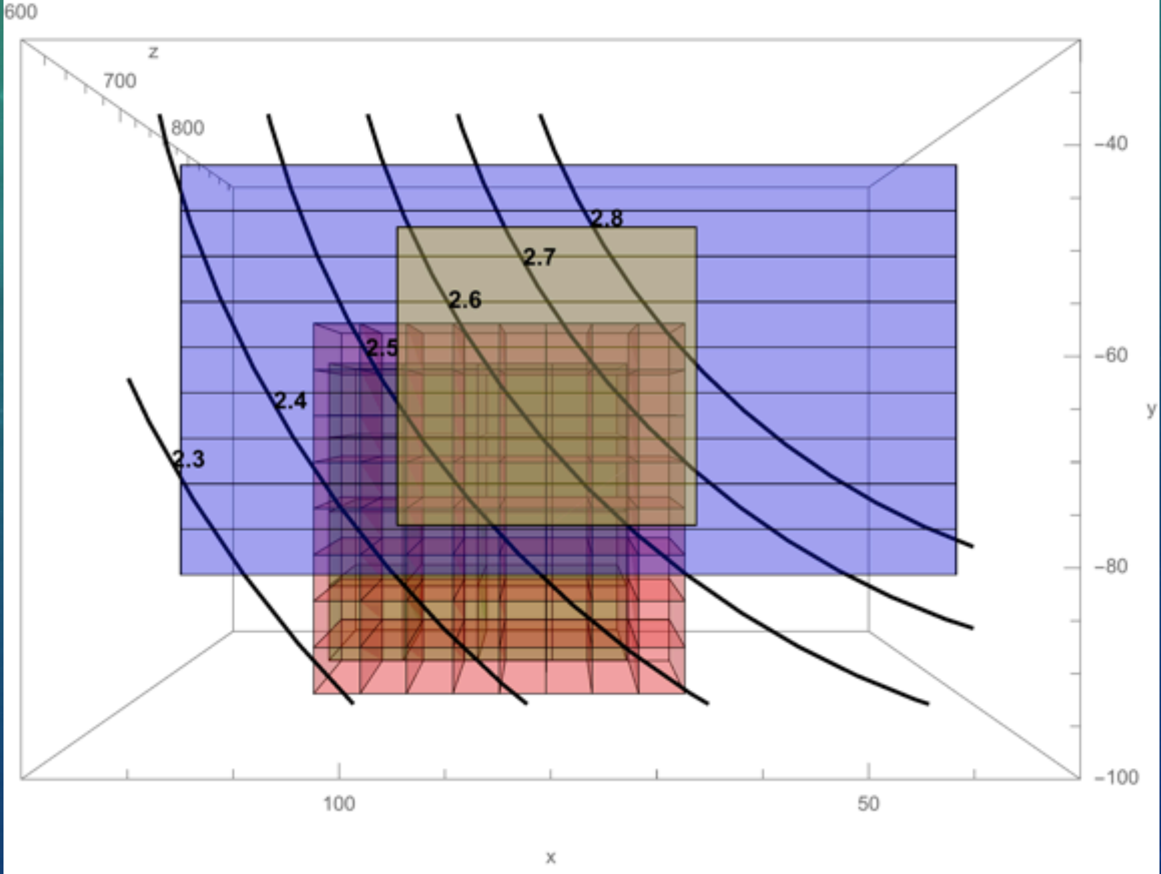


- One Physics event showing hits and clusters
- Select Signals also shown
- Some hits 0 due to fit failure
- Numbers in boxes are integrated sum

Conclusions

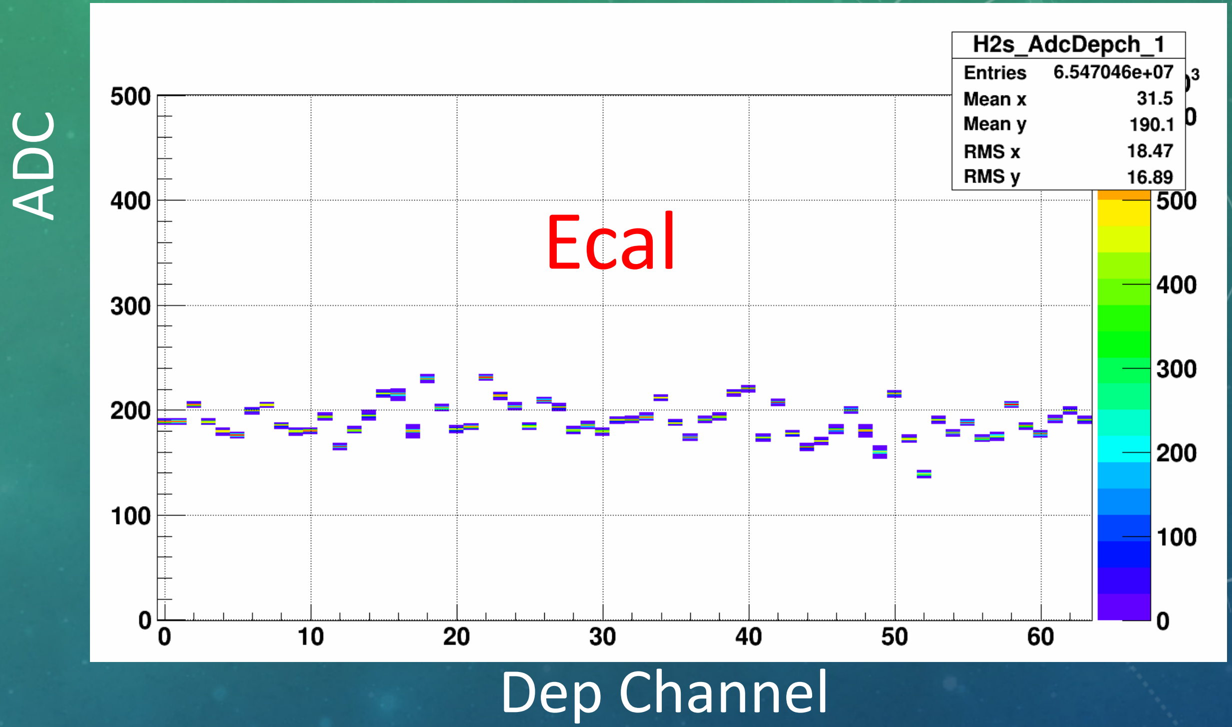
- Fermilab test results
  - Developed a signal start time algorithm
  - Unable to detect slow neutrons in hadron showers
  - Hadron and EM showers have different behavior
- Successful FCS prototype building, run, and data taking
- Software framework
  - Data Monitor done
  - Signal finding in progress
- Finding π^0 efforts ongoing by UCR grad student Xilin Liang (3:40pm talk)

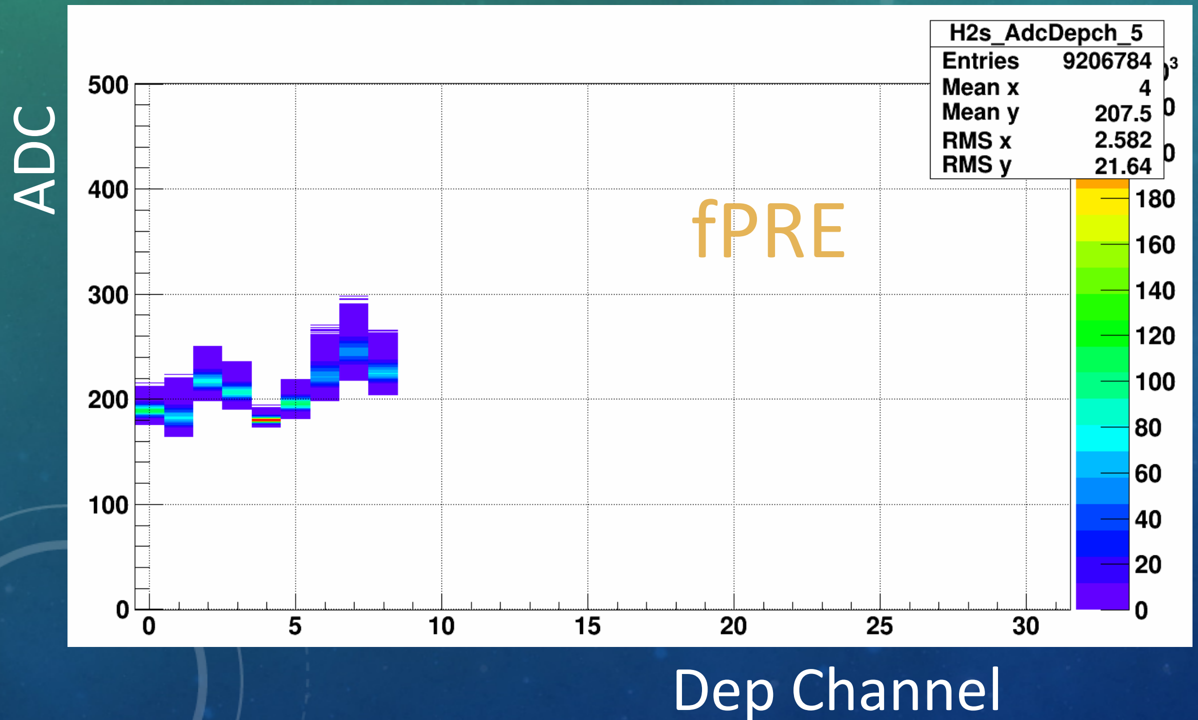
Geometry with Eta Rings

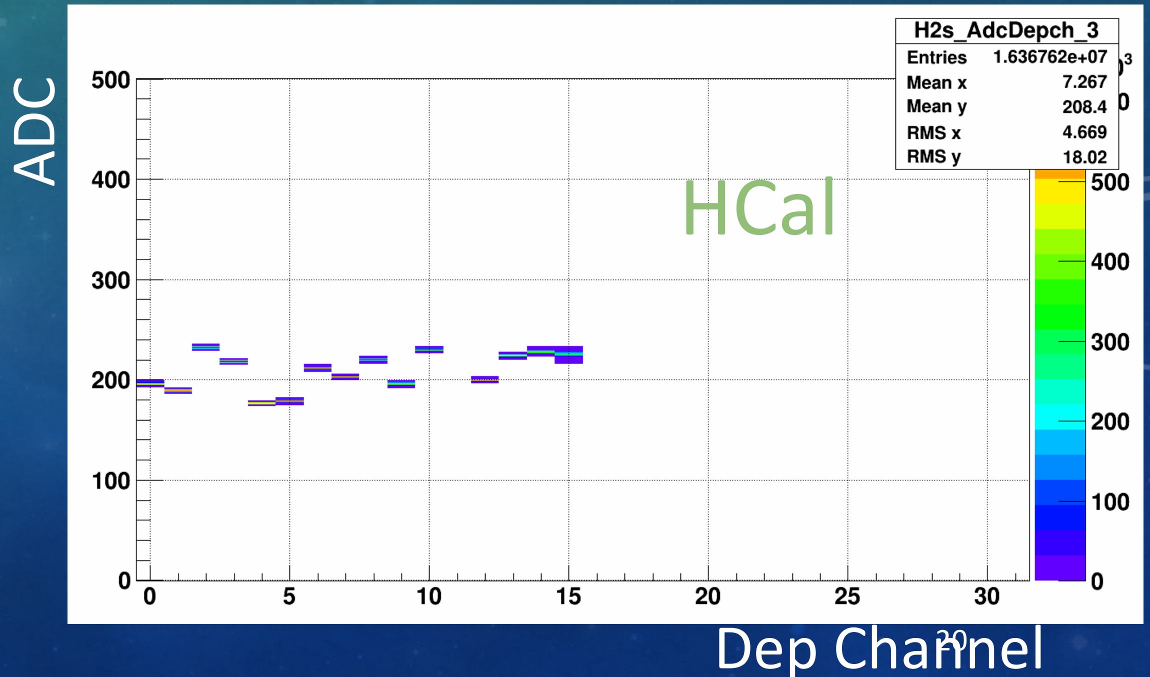


Pedestal Data

- Ecal RMS ~ 1ch
- Hcal RMS ~ 1ch
- Pres RMS ~ 5ch



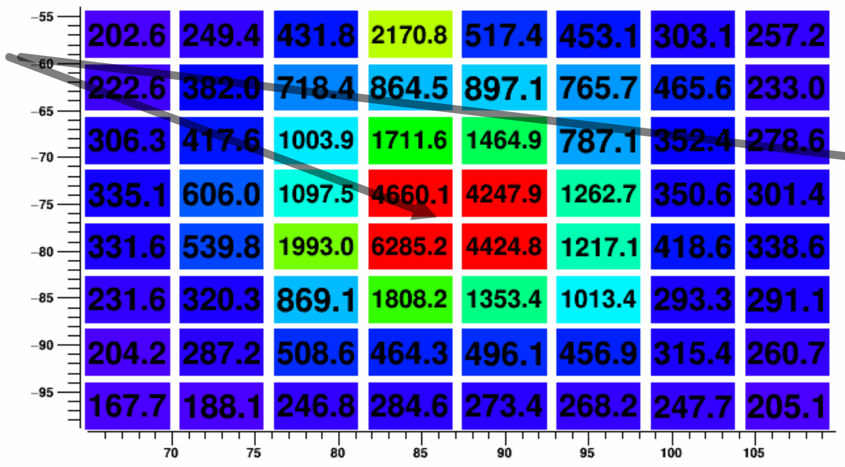


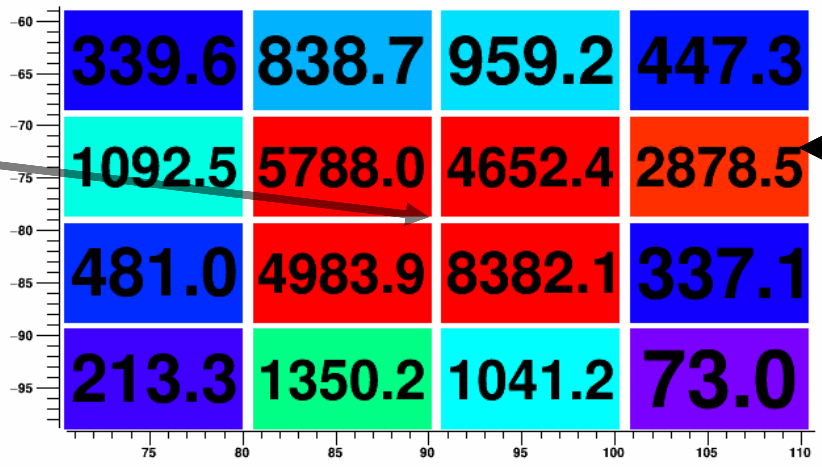


Pulser Event

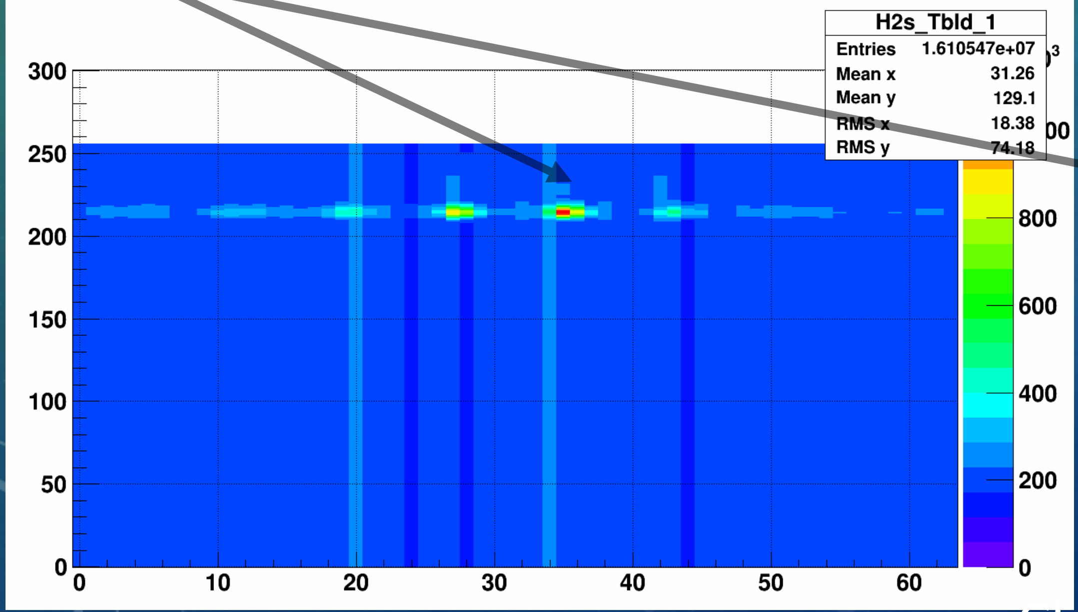
Clearly see that LED is in center

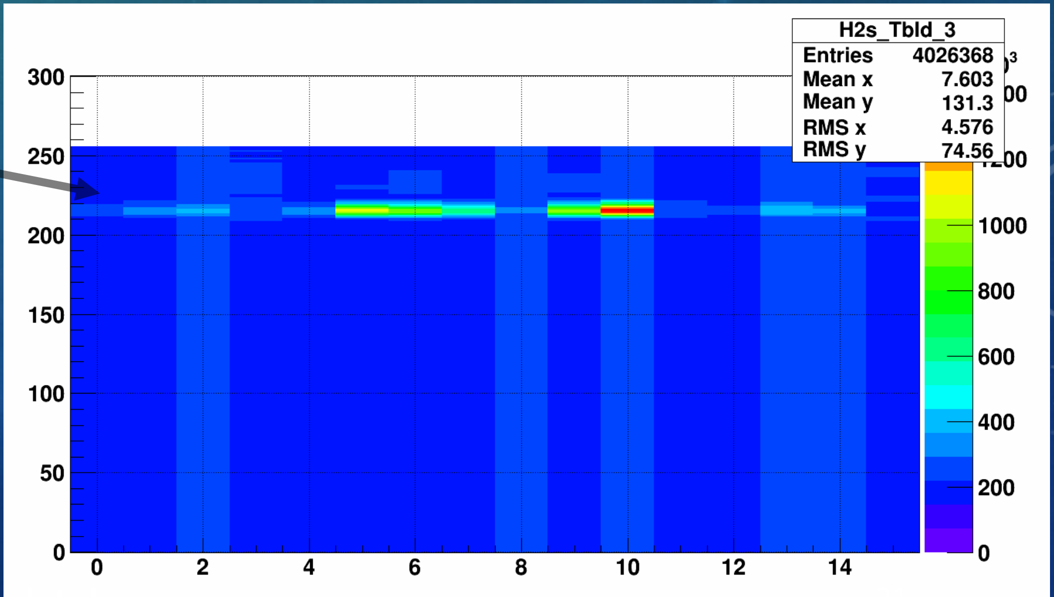
Pulser signal seen at Tb ~210





Numbers in boxes are the integrated signal value





Tb (Adc Weighted)

Channel Id