# HCANA and lessons learned from analyzing TDC1190 and FADC250 data

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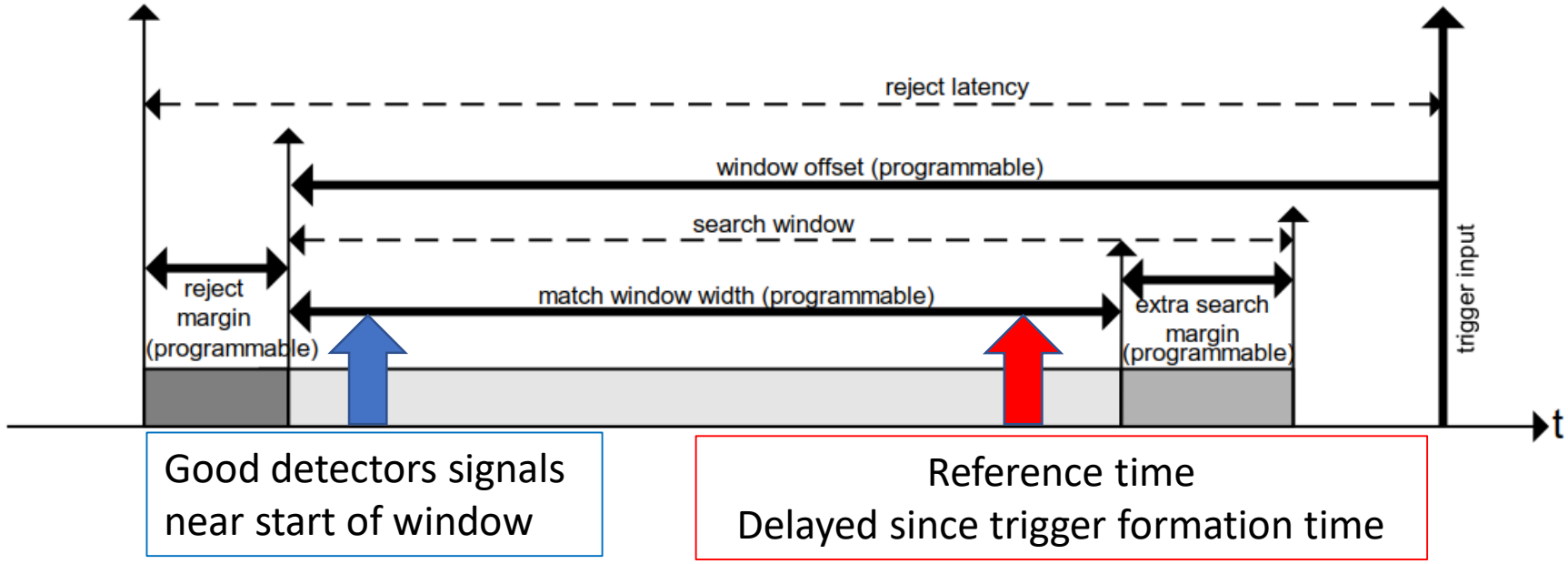
Hall C Winter 2020 Collaboration meeting

# TDC1190

- Used by Scintillators and Drift Chambers for time information
- Multi-Hit TDC, Hall C reads all the leading edge pulses within a match window width.
  - Width  is about 0.8 to 1.1us for Scintillators and 2us for DC.  (Has varied some over time)
  - Window offset relative to trigger input. (Has varied some over time)
- Time Resolution of trigger input is 25ns.
  - Trigger input can be Singles (3/4 HODO, EL_REAL, EL_CLEAN) or Coincidence.
- Need to take time difference between two channels to reach 0.0997ns/channel resolution.
- Use one channel of TDC to be the “reference time” signal.
  - Need signal that will be there for every trigger. Reference time is a copy of the trigger input.

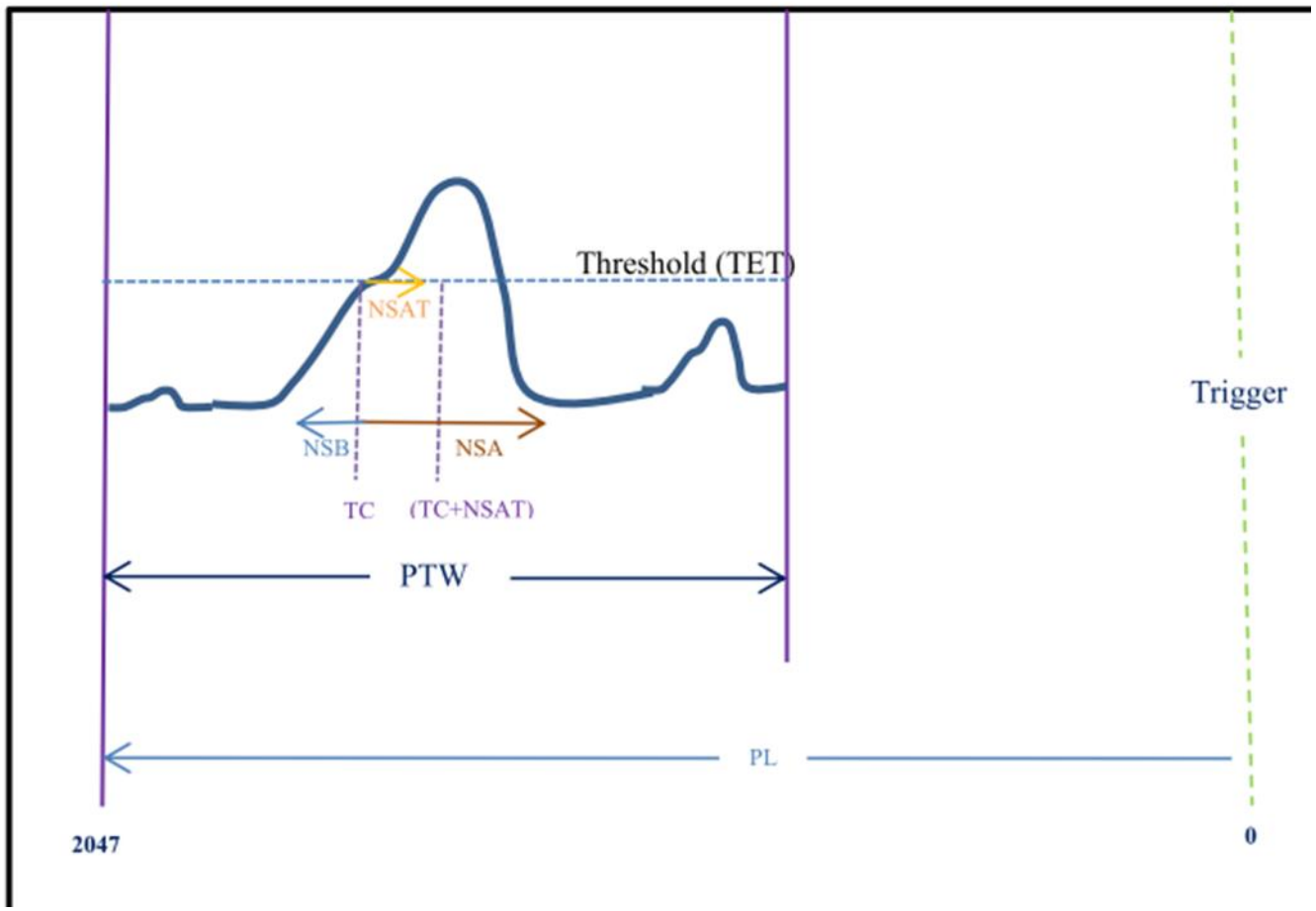



Good detectors signals near start of window

Reference time
Delayed since trigger formation time

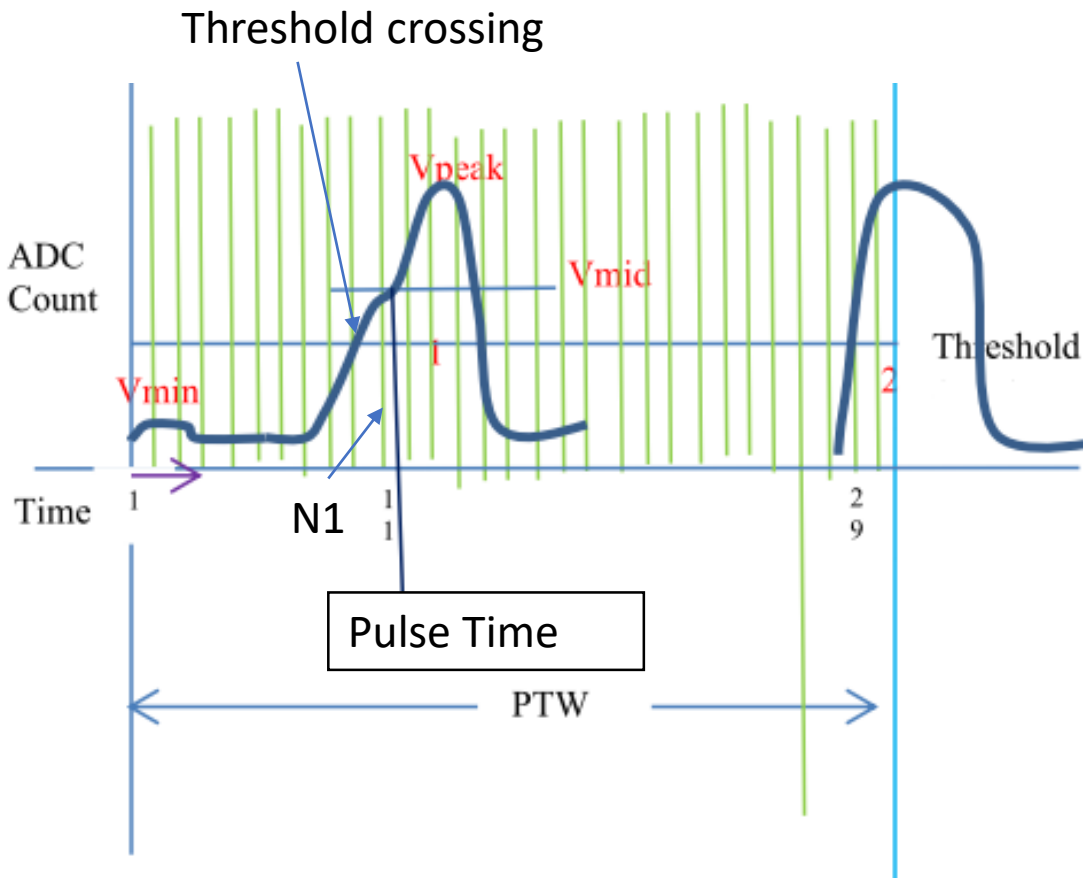
# FADC250 Pulse Integral and Pedestal

- When Trigger received FADC250 looks for up to four pulses in buffer.
- From trigger time, it has Programmable Lookback (PL) and the Programmable Trigger Window (PTW).
- Hall C run in “mode 9” which returns the pulse pedestal, integral, peak and time.




- Pulse found if NSAT=1 samples (4ns ADC) above Threshold.
- Threshold Crossing (TC) defined as first sample to cross threshold.
- Pulse Integral sum of samples from NSB=3 before TC to NSA=26 after. (116ns).
- Pulse Pedestal is the sum of the NPED=4 samples at the beginning of the PTW.
- After finding pulse, next pulse can be found when sample is below Threshold. Even if this within the NSA.

# FADC250 Timing & Peak



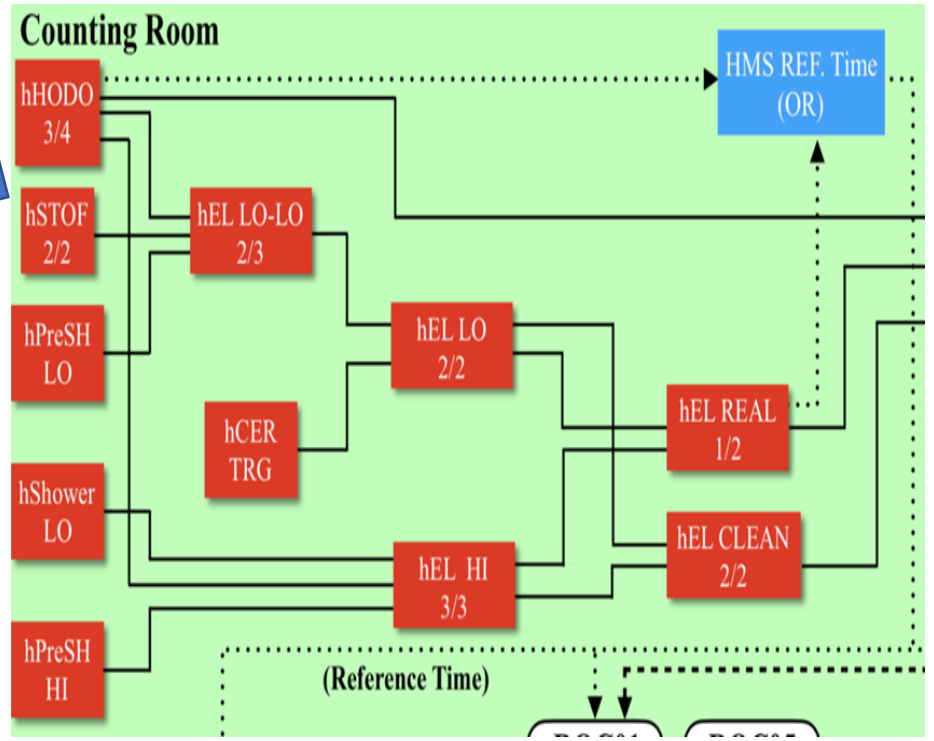

- VMIN = average of first 4 sample of PTW
- Pulse amp = VPEAK = the sample after threshold crossing when sample ADC decreases.
- VMID= (VPEAK-VMIN)/2. Determine sample N1 containing VMIN
- Pulse Time = 64*[VMID-V(N1)]/[V(N1+1)-V(N1)]
  - Time in 62.5ps bins
- If any of the first 4 samples of PTW above threshold then cannot determine the VMID
  - Pulse Time = time of threshold crossing
  - Time in 4ns bin
  - Pulse amp = 0
  - In HCANA, pulses with pulse amp =0 are not used!

# Brief History of Reference Time

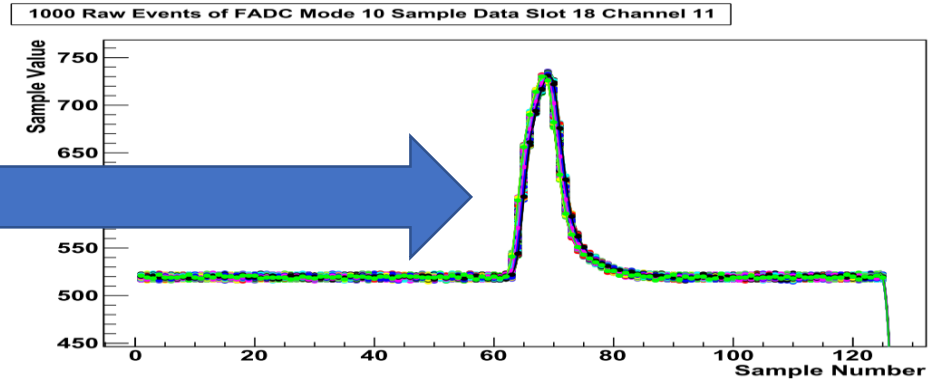
## Which triggers to use as reference time?

- In the beginning
  - OR of HODO, STOF, EL_REAL, EL_CLEAN
  - Each delayed.
- Jan 2018
  - OR of HODO, EL_REAL, EL_CLEAN
  - Remove STOF, since EL_REAL contains STOF
- Aug 2018 (logbook entry)
  - OR of HODO, EL_REAL
  - EL_REAL for every EL_CLEAN
- Dec 2019 (logbook entry)
  - HODO only
  - Removed STOF from EL_LO_LO

"Hall C Trigger Electronics" by C. Yero




- Reference time for FADC250 made by putting the logic reference time through an RC circuit to produce an analog signal.



# Need to select reference time for each detector

- Designate the reference time signal for each detector in the detector map.
- Generally, each TDC1190 needs its own reference time
- Access the reference time data with the TRIGDET class.

| Ref. Time Name | Physical Location | *hcana* Leaf Name |
|---|---|---|
| hFADC_TREF_ROC1 | ROC1::SLOT18::Ch11 | T.{spec}.hFADC_TREF_ROC1_adcPulseTimeRaw |
| hTref1 | ROC1::SLOT02::Ch06 | T.{spec}.hT1_tdcTimeRaw |
| hTref2 | ROC1::SLOT20::Ch127 | T.{spec}.hT2_tdcTimeRaw |
| hDCREF1 | ROC3::SLOT08::Ch15 | T.{spec}.hDCREF1_tdcTimeRaw |
| hDCREF2 | ROC3::SLOT16::Ch63 | T.{spec}.hDCREF2_tdcTimeRaw |
| hDCREF3 | ROC3::SLOT04::Ch111 | T.{spec}.hDCREF3_tdcTimeRaw |
| hDCREF4 | ROC3::SLOT13::Ch95 | T.{spec}.hDCREF4_tdcTimeRaw |
| hDCREF5[3] | ROC3::SLOT02::Ch127 | T.{spec}.hDCREF5_tdcTimeRaw |

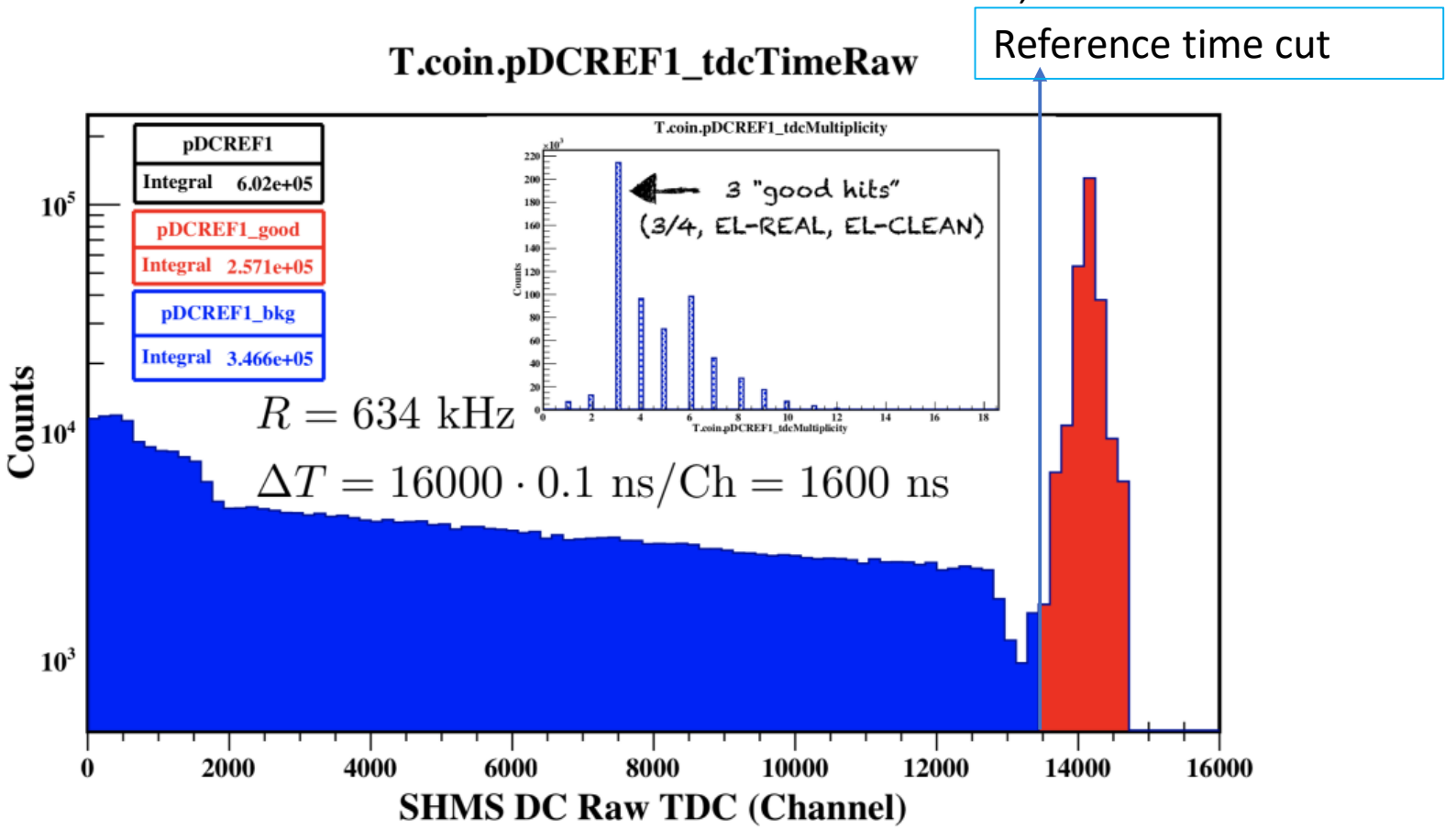
Exception is that in HMS ROC3 one reference time for all TDC

| Ref. Time Name | Physical Location | *hcana* Leaf Name |
|---|---|---|
| pFADC_TREF_ROC2 | ROC2::SLOT14::Ch11 | T.{spec}.pFADC_TREF_ROC2_adcPulseTimeRaw |
| pTref1 | ROC2::SLOT20::Ch15 | T.{spec}.pT1_tdcTimeRaw |
| pTref2 | ROC2::SLOT19::Ch31 | T.{spec}.pT2_tdcTimeRaw |
| pDCREF1 | ROC6::SLOT06::Ch79 | T.{spec}.pDCREF1_tdcTimeRaw |
| pDCREF2 | ROC6::SLOT07::Ch79 | T.{spec}.pDCREF2_tdcTimeRaw |
| pDCREF3 | ROC6::SLOT08::Ch79 | T.{spec}.pDCREF3_tdcTimeRaw |
| pDCREF4 | ROC6::SLOT09::Ch79 | T.{spec}.pDCREF4_tdcTimeRaw |
| pDCREF5 | ROC6::SLOT10::Ch79 | T.{spec}.pDCREF5_tdcTimeRaw |
| pDCREF6 | ROC6::SLOT11::Ch47 | T.{spec}.pDCREF6_tdcTimeRaw |
| pDCREF7 | ROC6::SLOT12::Ch47 | T.{spec}.pDCREF7_tdcTimeRaw |
| pDCREF8 | ROC6::SLOT13::Ch47 | T.{spec}.pDCREF8_tdcTimeRaw |
| pDCREF9 | ROC6::SLOT14::Ch15 | T.{spec}.pDCREF9_tdcTimeRaw |
| pDCREF10 | ROC6::SLOT15::Ch47 | T.{spec}.pDCREF10_tdcTimeRaw |

In Hall C DocDB, "General Hall C Analysis Procedure in 12 GeV Era" by Carlos Yero gives details and examples of setting these cuts.

# Select reference time that matches the trigger

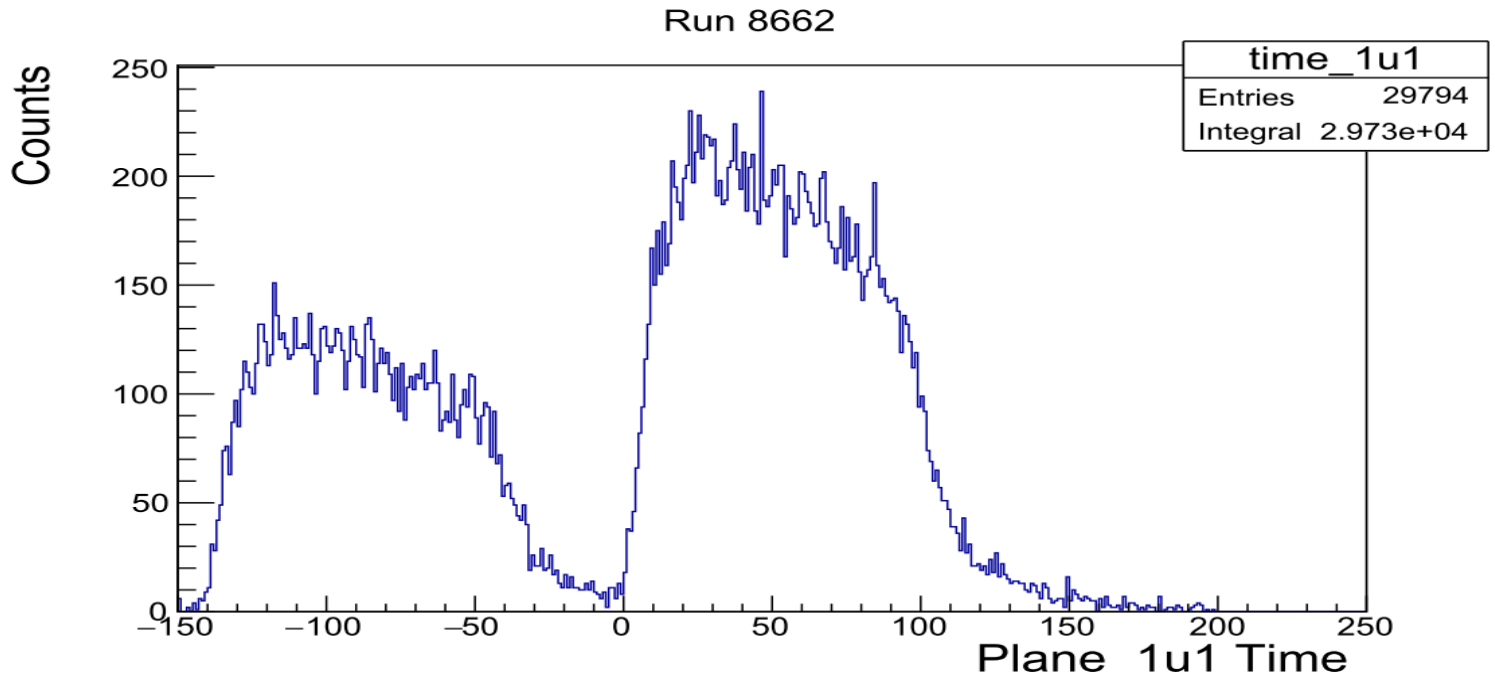
- Large match window width ( 0.8 – 2 μs) multiplied by trigger rate can give high multiplicity.
- Set reference time cut. Select first hit that is above time cut. If none, then select first in window.



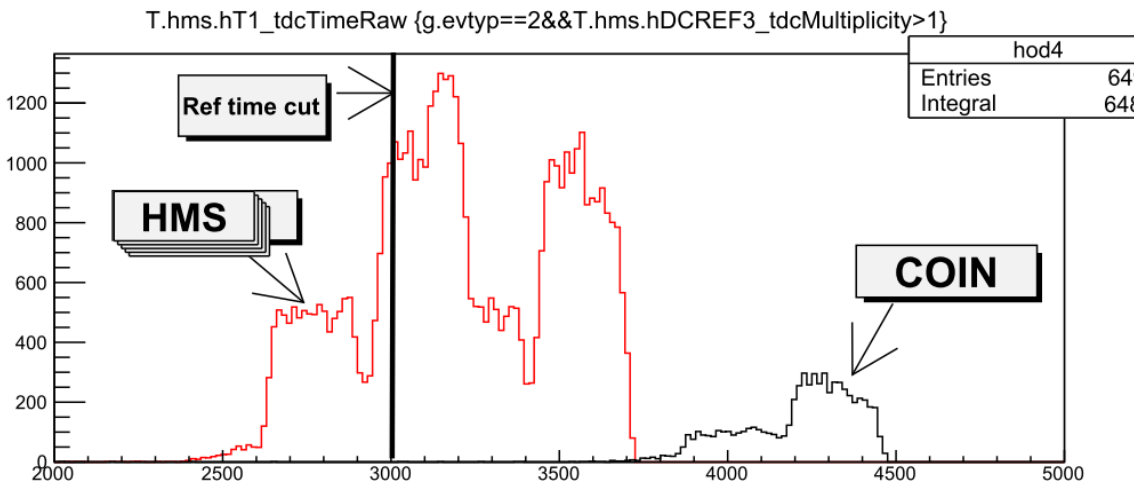

In Hall C DocDB, "General Hall C Analysis Procedure in 12 GeV Era" by Carlo Yero gives details and examples of setting these cuts.

# Lesson One: Problem

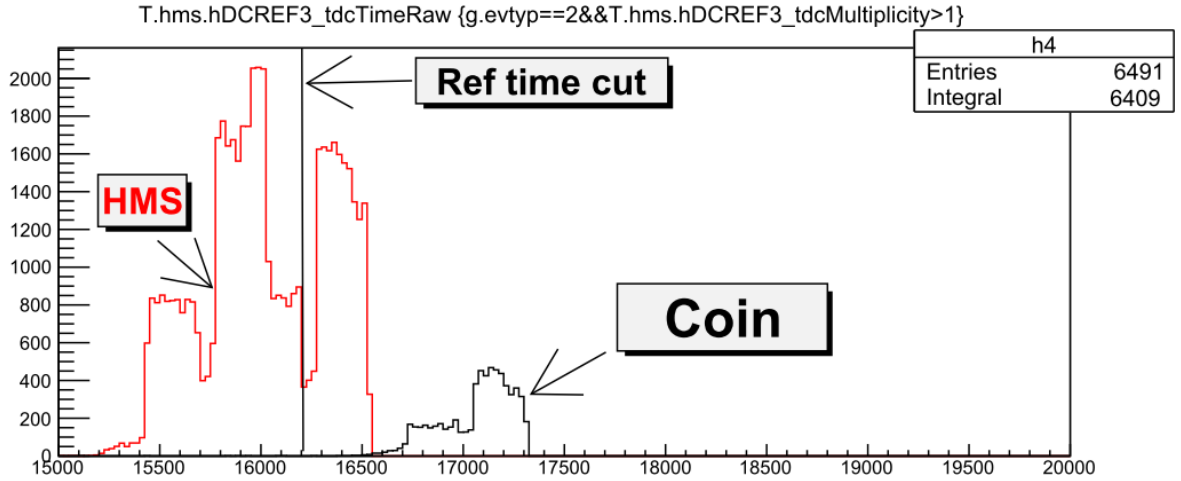
- Problem that two distinct drift time spectra seen online:



# Lesson One: Solution




Hodoscope reference time




Drift chamber reference time

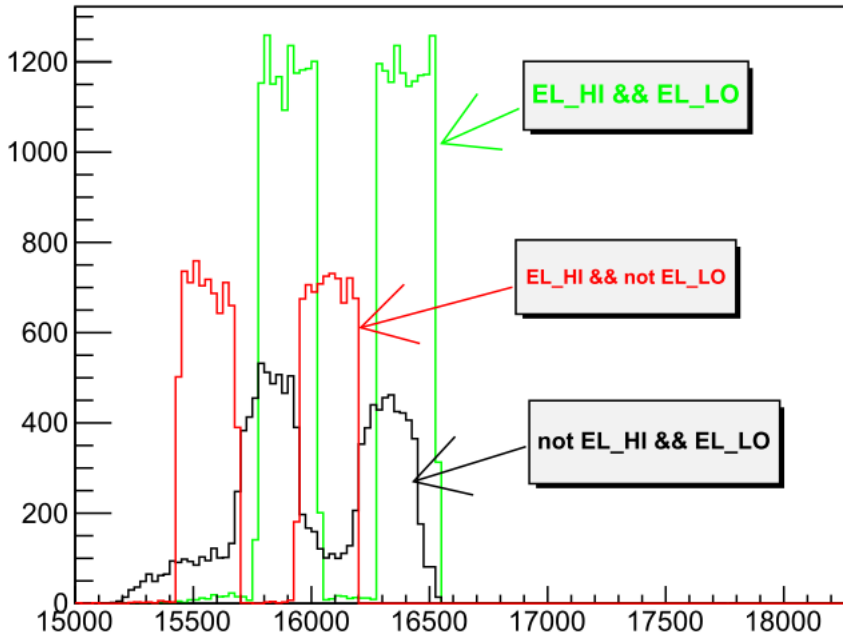
- Reference time cut set for COIN trigger and in middle of HMS Singles.
- The Hodo and DC detectors would pick different reference times.

## Lesson Learned:

1. Ideally, modify HCANA to have separate reference time cut for different triggers.
2. For now, need to have cut which proper treats all triggers or separate replay.
3. In general, want to have each detector pick the same reference time.
   - Need to have reference time cut for each detector at similar time distance from the good time.

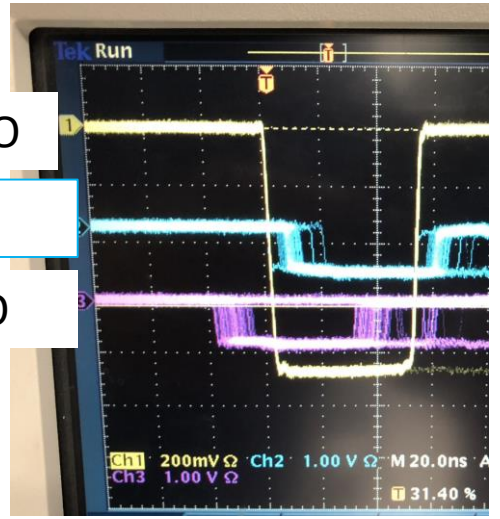
# Details of HODO Reference Time spectra

HMS trigger is EL-REAL
HMS reference is HODO (3-of-4 Scin)

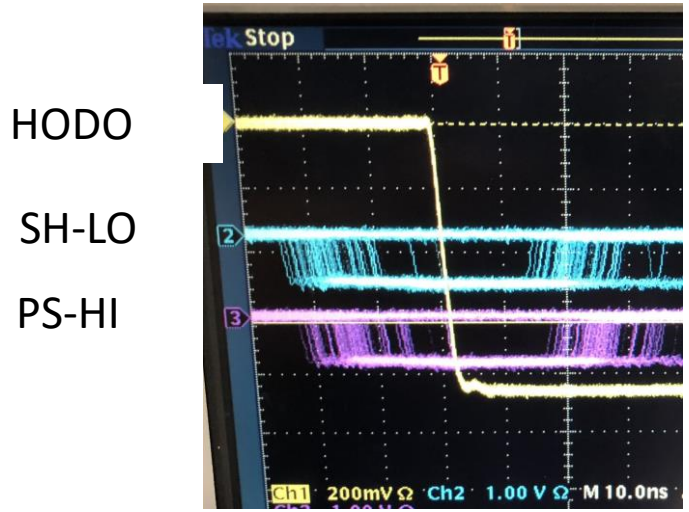



HMS HODO raw reference time (channel=0.1ns)

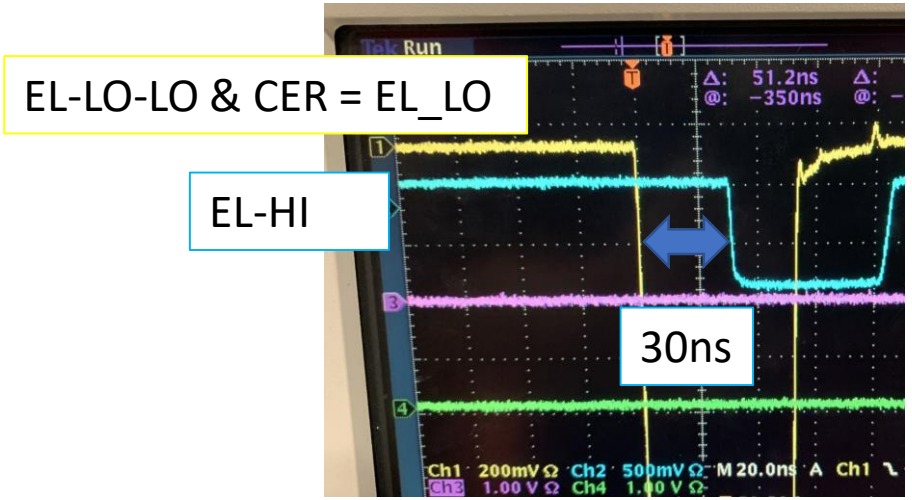
EL-LO-LO (2 of 3)




EL-HI (3 of 3)



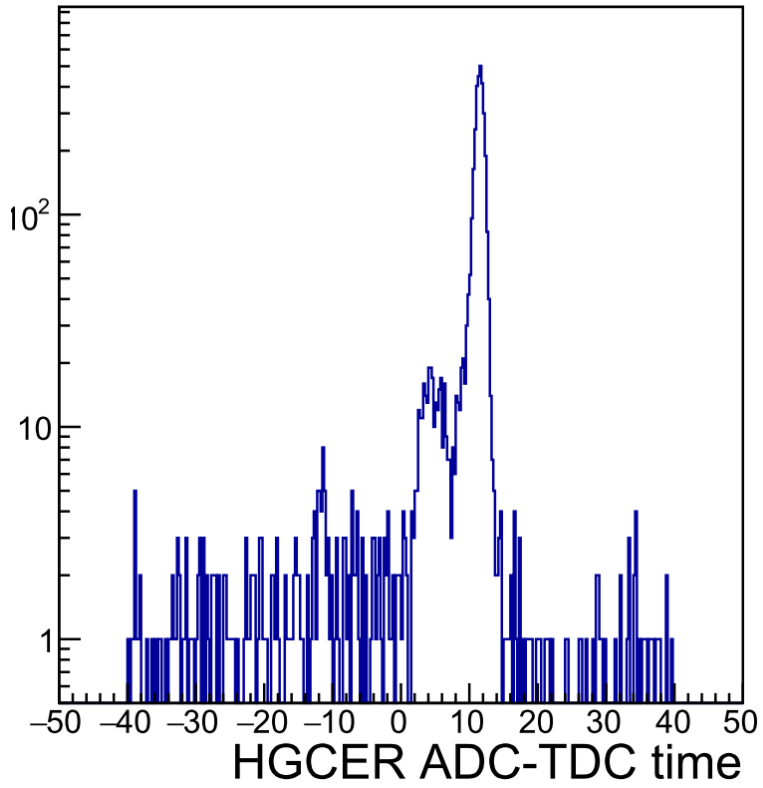

EL-REAL (1 of 2)

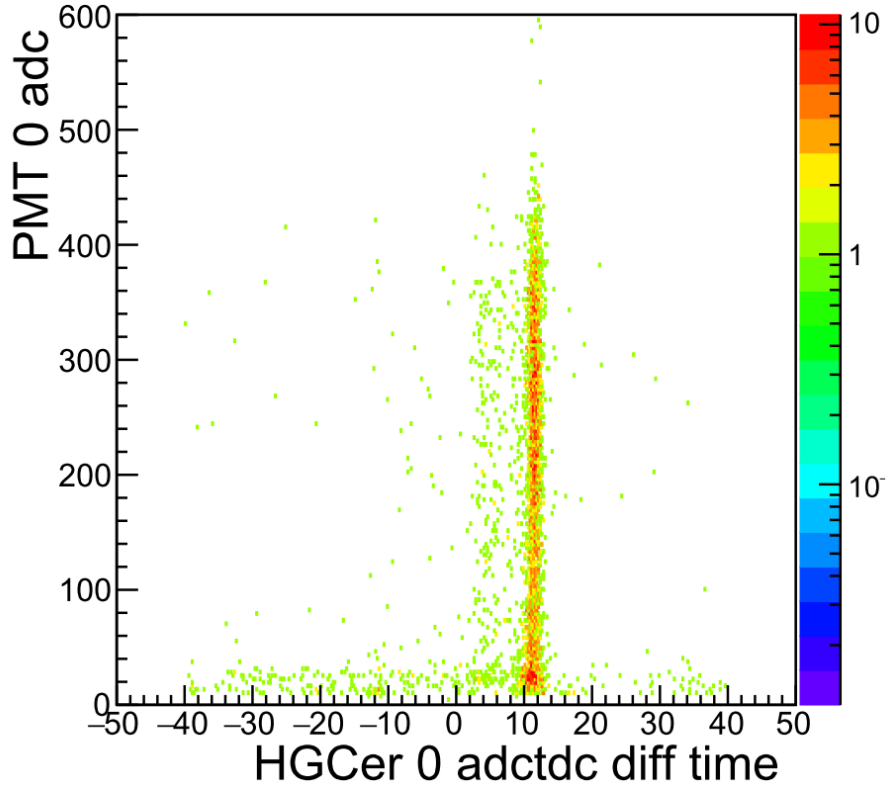



- EL_HI && EL_LO set by HODO in EL-LO-LO
- EL_HI && not EL_LO set by EL_HI
- Not EL_HI && EL_LO set by STOF in EL-LO-LO (no PS-LO)

# Lesson Two : Problem

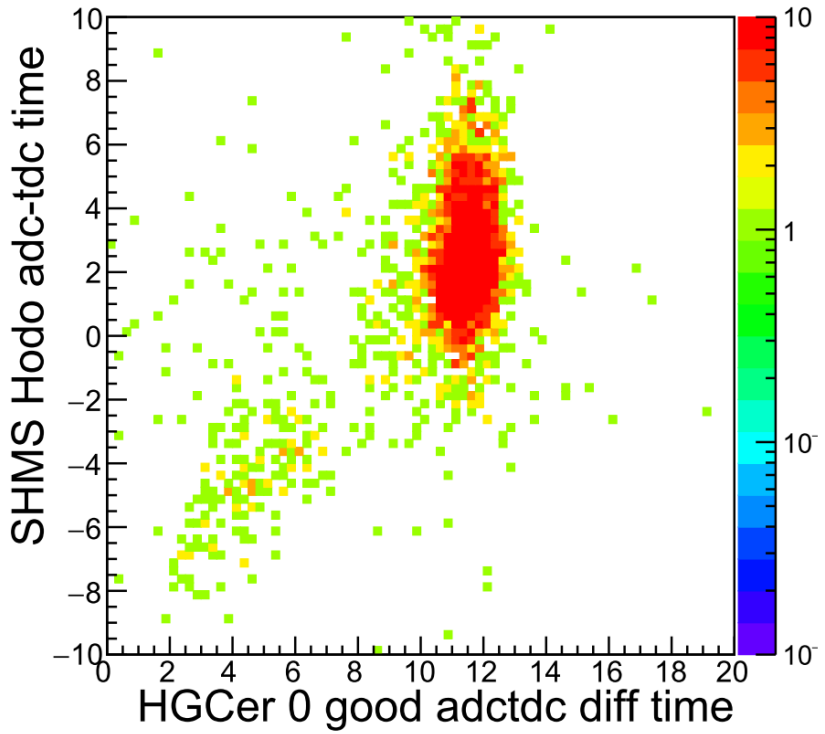
- For each detector calculate ADC time – HODO starttime (ADCTDC Diff time) to identify good pulse in FADC channel.
- SHMS Heavy Gas , events with only one hit on one PMT show two peaks. Each PMT has same behavior.
- Should both peaks  be included as good pulses?  ADC versus ADCTDC Diff time look similar



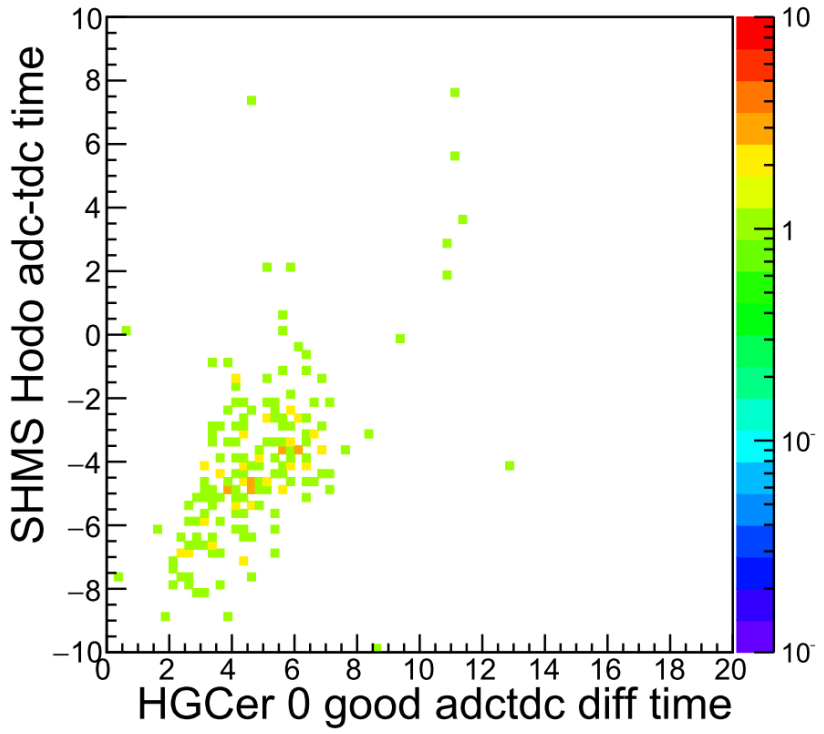



# Lesson Two : Solution

All events, one hit in CER0



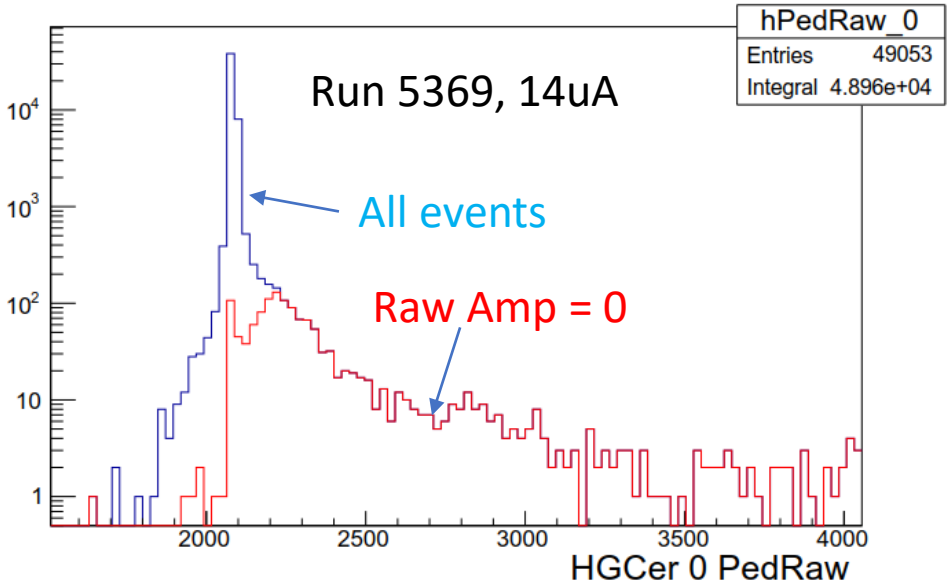

Events with Ref Time Amp = 0

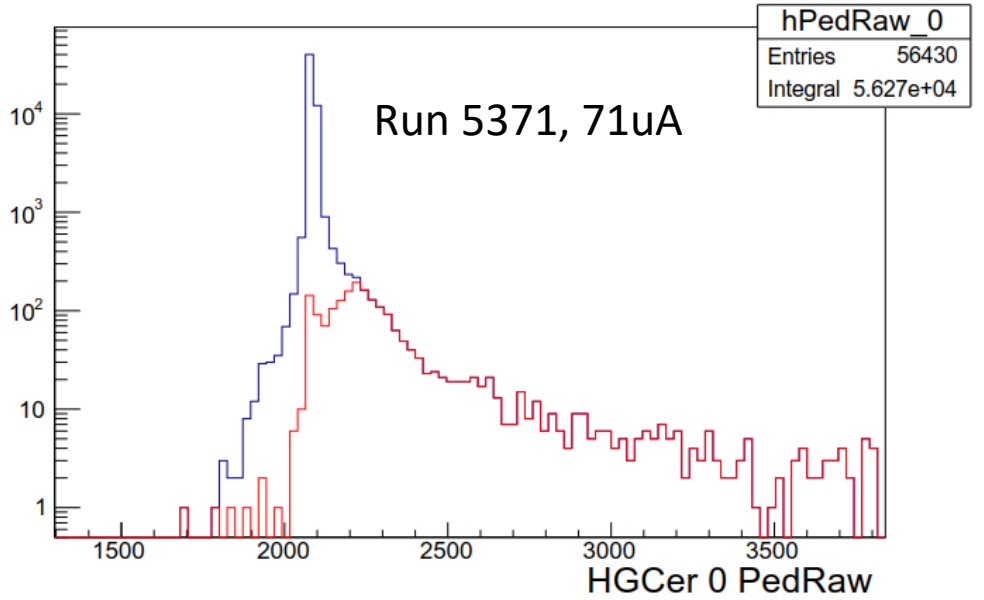



- Lesson Learned:
  1. The ADC reference time must have bad pedestal region, so using the coarse 4ns time.
  2. All events are good and should be included in analysis.

# Lesson Three : Problem

- What to do when accidental hit in first four samples of FADC250?
- Presently HCANA eliminates the hit. In effect, makes a rate dependent loss.




| Run | Current | PMT0 | | | |
|---|---|---|---|---|---|
| 5369 | 15uA | 1.2% | 1.7% | 1.3% | 1.4% |
| 5367 | 45 | 3.0% | 3.9% | 2.8% | 3.0% |
| 5371 | 71 | 3.8% | 5.3% | 4.0% | 4.1% |

# Lesson Three: Solution

- No easy solution.
- One solution:
  - Since pedestal for a channel is has small sigma, use the average pedestal to determine the pedestal subtracted pulse integral.
  - Problem is that the pulse integral is over 116ns so can get negative pulse integral if mismatch between the average pedestal and the “true” pedestal.
- Second solution:
  - If interested only in knowing if channel had an ADC signal ( for example, Cerenkov or Aerogel)
  - When pulse amp =0 then just set pulse integral to a nominal value.
  - Remember that the pulse time will be coarse.
- Long Term solution:
  - Change FADC250 firmware
  - When hit is in first four samples, then save the entire sample window and save the VPEAK.
  - Later in software can determine the pedestal from other parts of the sample window.

# Conclusion

- Lesson One:
  - Need to be careful when setting reference time gates when analyzing data taken with multiple triggers.
  - Need to be careful about matching the location of reference time in FADC and TDC.
- Lesson Two:
  - If accidental hit in the pedestal region of FADC, then FADC reference time will become a coarse threshold crossing time.
  - Need to widen ADCTDC diff time window to allow for the shift in time.
  - Rate dependent effect.
- Lesson Three:
  - If accidental hit in the pedestal region of FADC, presently HCANA ignores the hit.
  - This gives a rejection factor that is rate dependent.
  - Best solution to this problem may depend on detector and experiment.
  - Long term need modification to the FADC250 firmware.