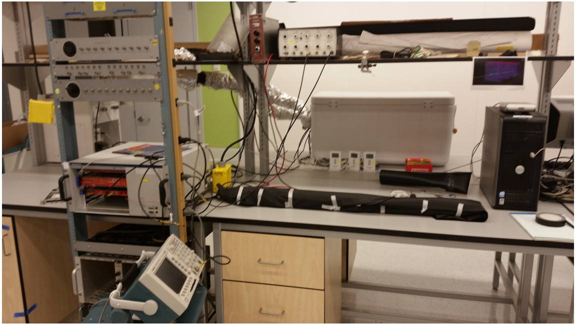
# Current Studies Using the CAEN V1743 @NYU

B. Kaplan (NYU), A. Haas (NYU)

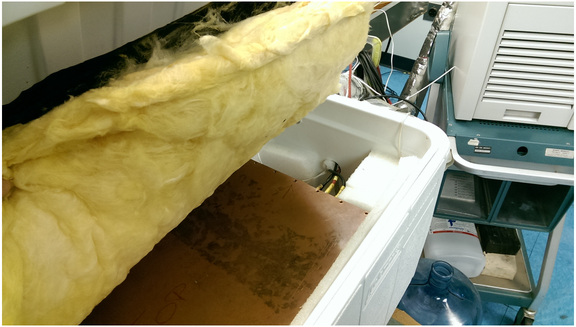
December 15, 2016

# The Setup in the NYU Lab



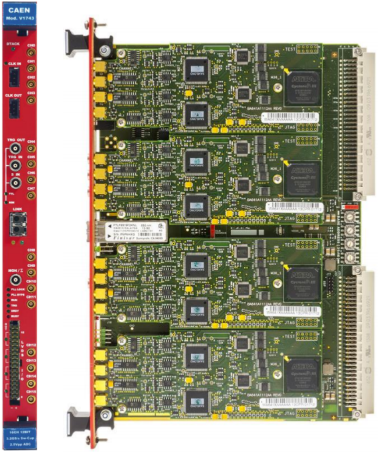
- Scintillator(s) + PMT (Hamamatsu R2083) readout by CAEN V1743
  - PMT glued to small scintillator
  - Can take data w/ or w/out large scintillator attached
  - Junction between small and large not very clean
    $\Rightarrow$ will lead to inefficiencies
  - Currently make this switch by hand
- LED attached next to small scintillator
  - Pin prick hole to reduce light entering scintillator
  - Controlled by a pulser, which also provides an external trigger

# Cooling the PMT



- We also have a setup to cool the PMT
- Though, it was not used for results presented today

# The Read-Out Hardware: CAEN V1743




Overview:

- 16 analog read-out channels, continuously sampled at 3.2 GS/s into a 1024 cell ring
- Programmable trigger logic, including an external trigger
- Both and internal clock and an external one (for sync-ing multiple boards to the same clock)
- Equipped with both VME and Optical Link interfaces
- Cost per channel is about $400

Complete information can be found on the CAEN website

# CAEN V1743: The Input Channel

Each board has 16 analog channels
Pairs of channels organized into 8 groups

- input signals are continuously sampled at 3.2 GS/s (default)
  $\Rightarrow$ 0.3 ns resolution in pulse shape
- signal stored in a 1024 cell buffer (event), digitized with 12 bit res.
- each channel has a programmable 16-bit discriminator, which generates a trigger request (hit)
- separate readout to monitor hit-rate for each channel
  $\Rightarrow$ watch for hot or dead channels
- during digitization of signal, the board cannot handle additional triggers
  $\Rightarrow$ maximum dead time of 125 $\mu$s
- when a trigger arrives 3 consecutive events are digitized and buffered, reducing impact of the dead time

# Interacting w/ the CAEN V1473

## CAEN Provided C++ Libraries

1. High level functions: initialization, configuration and readout
   - Rather new board ⇒ we have been finding bugs!
   1.1 Event layout in readout buffer different than in manual
   1.2 Configuration of channels/groups not working
   - CAEN is already developing a new version of the lib and manual
2. Low level direct access to registers on the board
   - Can be used to configure channels/groups

## 3 Trigger Modes

Software Trigger: Useful for measuring electronic noise
Channel Self-Trigger: Used for data taking, i.e. trigger on pulses
External Trigger: Timed with LED pulser

## Output: TTree

- Each event stored in 1024-bin histograms for each active channel
- Meta-data (e.g. event and trigger counts, TDC, etc.)

# Measuring Readout Rates

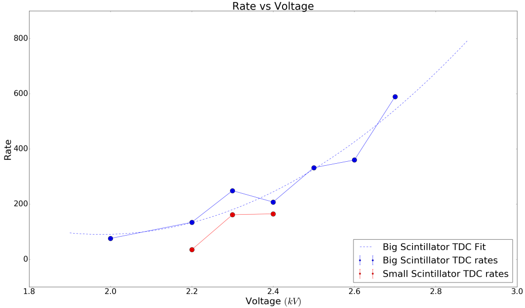
## TDC

- The ‘eventInfo’ header in each event contains a 40-bit TDC
- The CAEN software decodes this into a 64-bit long integer, w/ 1 bit = 5 ns
- We use this to get a measure of the readout rate
- Another variable in the header, ‘EventTimeTag’, contains nonsense

# Measuring Readout Rates

## TDC

- The 'eventInfo' header in each event contains a 40-bit TDC
- The CAEN software decodes this into a 64-bit long integer, w/ 1 bit = 5 ns
- We use this to get a measure of the readout rate
- Another variable in the header, 'EventTimeTag', contains nonsense




- Rate scan taken with -5mV trigger
- As expected, rates go up for large scintillator
- Will be interesting to see what the temperature dependence is, as well

Plot by S. Das

# A Closer Look

- For the next set of slides, data was collected @2.4kV w/ a -2mV trigger

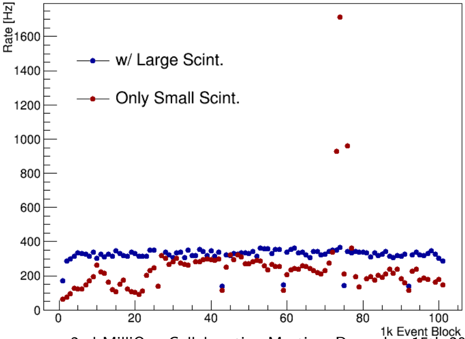
- We will be comparing data recorded with...
  1. both the small + large scintillator
  2. only the small scintillator
  3. the LED pulser on, and tuned to create single PE in the PMT
     - Pulsing at around 2.5 kHz, to drown out backgrounds
     - Note: TDC data in this run seems corrupted. Need to follow up with CAEN.

# Data Quality

1. O(0.5%) of events have TDC==0
   - We reject these events
   - Need to ask CAEN why this happens

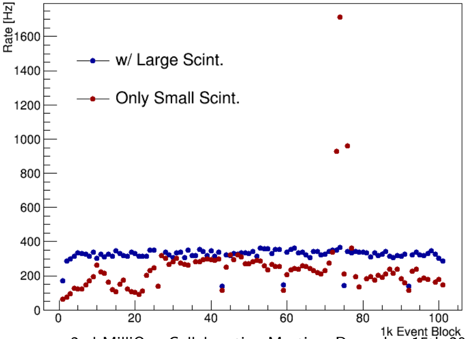
# Data Quality

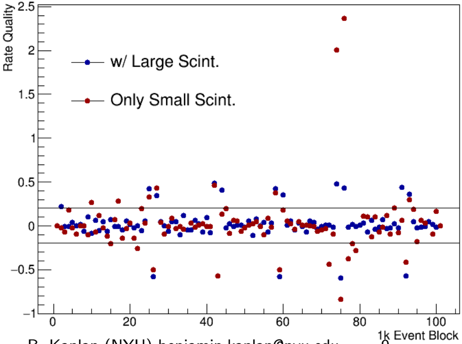
1. O(0.5%) of events have TDC==0
   - We reject these events
   - Need to ask CAEN why this happens
2. We looked at the rate in 'lumi' blocks of 1000 events
   - Large scint. run was clearly more stable
   - Several rate 'blips'



# Data Quality

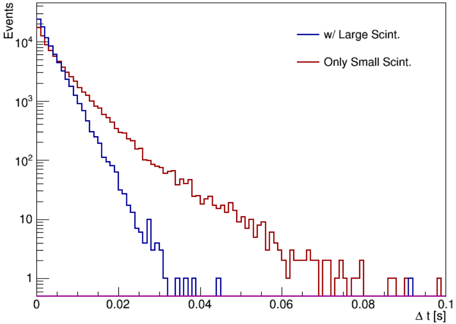
1. O(0.5%) of events have TDC==0
   - We reject these events
   - Need to ask CAEN why this happens
2. We looked at the rate in 'lumi' blocks of 1000 events
   - Large scint. run was clearly more stable
   - Several rate 'blips'
3. Define 'rate quality' by comparing block rate to average of neighboring bins
   - Only keep blocks with $-0.2 <$ quality $< 0.2$

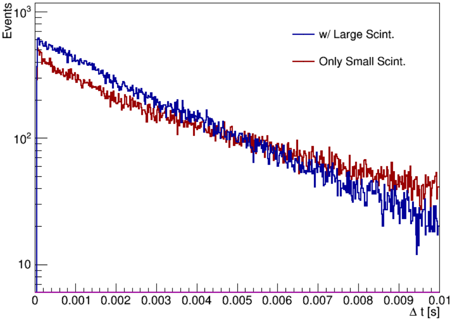


# Time Structure

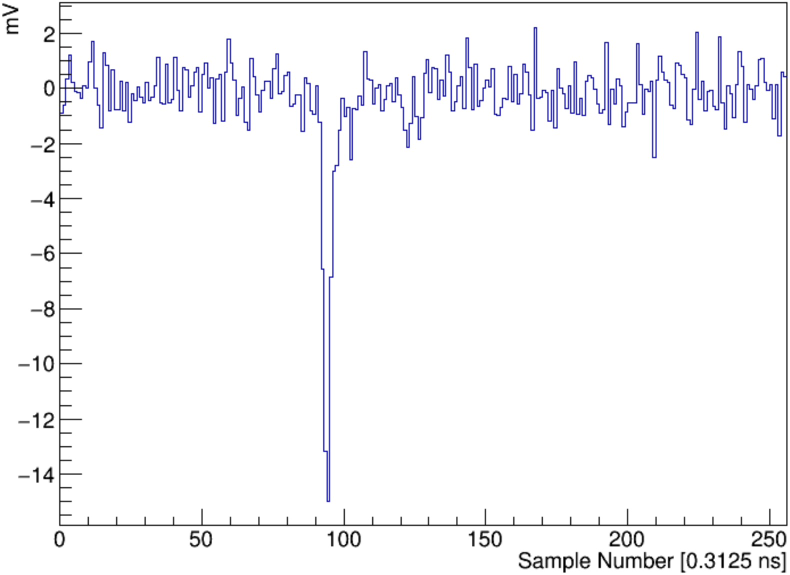
As a quick check, we can look at the $\Delta t$ between suqsequent events



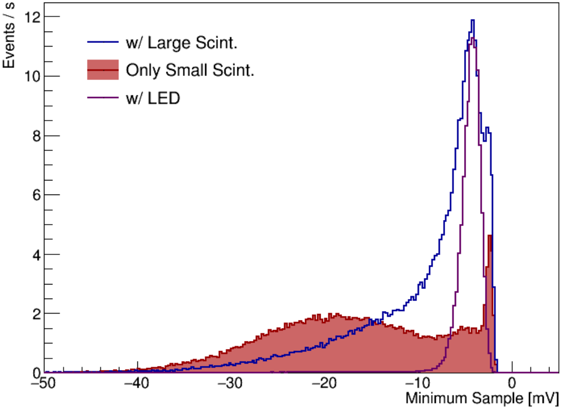

- Note the slightly non-exponential behavior at low $\Delta t$ in the small scint.
- Was much worse before the quality cuts, but needs further investigating

# Sample Event



# Minimum Sample

- Data w/out LED is normalized by dividing the total time of the run
- LED data has arbitrary normalization




Some initial observations...

- Right-most peak is likely electronic noise
- LED data is mostly 1 P.E. (more on this later)
- Sizable backgrounds in no-LED runs
- Significant difference in shape w/ large scint.

# Peak Finding Algorithm

- We can get some more information, if we study the shape of the pulse.
- To do that, we need a way to locate 'bumps' in the spectrum

# Peak Finding Algorithm

- We can get some more information, if we study the shape of the pulse.
- To do that, we need a way to locate 'bumps' in the spectrum

**The Algorithm (v1)**

1. Find the minimum sample
2. Step left (right) and look for 3 bins with average close to 0: either
   - greater than than 10% of the minimum
   - greater than -1 mV

# Peak Finding Algorithm

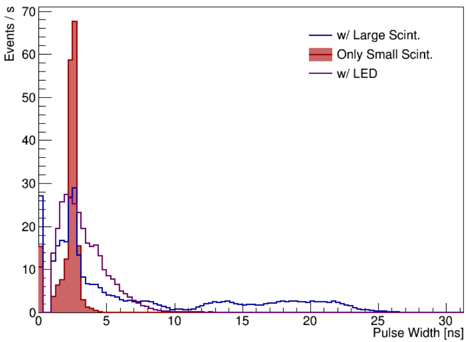
- We can get some more information, if we study the shape of the pulse.
- To do that, we need a way to locate 'bumps' in the spectrum

**The Algorithm (v1)**

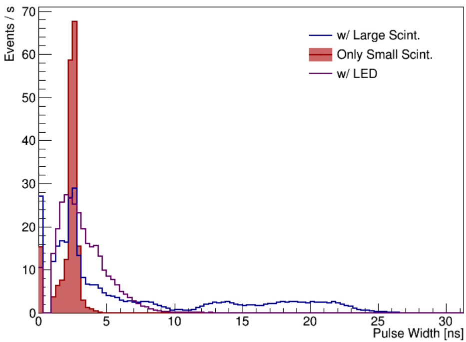
1. Find the minimum sample
2. Step left (right) and look for 3 bins with average close to 0: either
   - greater than than 10% of the minimum
   - greater than -1 mV

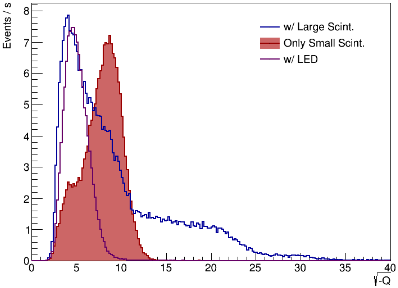
- We define the 'width' as
  (N steps left + N steps right - 1) * ( sample size $\sim$ 0.3 ns)
- Pulses w/ 'width' == 1, are rejected as electronic noise

1. Pulse width
   - There are many wide pulses from the large scint.
   - The LED pulses are wider than those from the small scint.

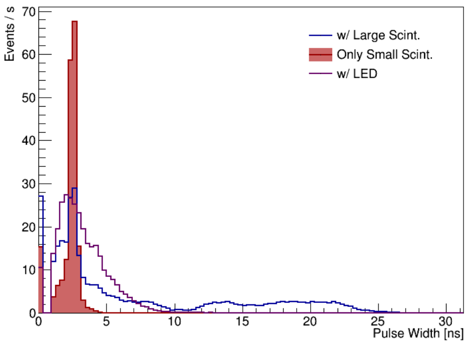


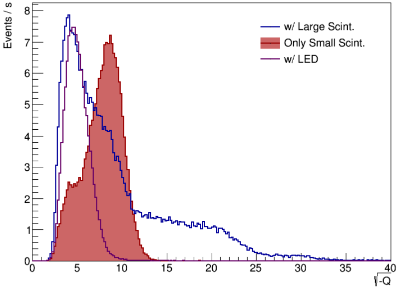
1. Pulse width
   - There are many wide pulses from the large scint.
   - The LED pulses are wider than those from the small scint.
2. Pulse integral ($\sqrt{\text{charge}}$)
   - Clear structure from 1 P.E., and other backgrounds

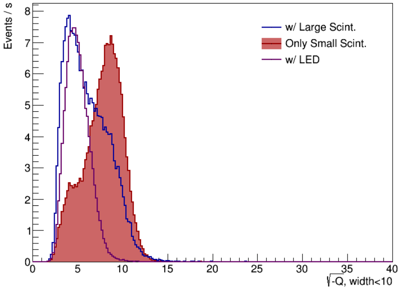


1. Pulse width
   - There are many wide pulses from the large scint.
   - The LED pulses are wider than those from the small scint.
2. Pulse integral ($\sqrt{\text{charge}}$)
   - Clear structure from 1 P.E., and other backgrounds
   - Requiring width $< 10$, removes high $-Q$ tail



# Can we do Better?

- Not all of the light from an interaction will be in the pulse
- It might be worth including additional ‘bumps’ in the same event

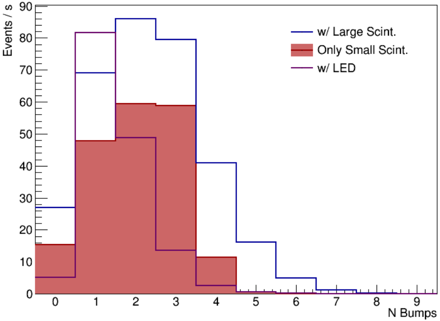
# Can we do Better?

- Not all of the light from an interaction will be in the pulse
- It might be worth including additional ‘bumps’ in the same event

**The Algorithm (v2)**

1. Perform algorithm v1 to find the primary pulse
2. Take the samples that remain to the right of the pulse
3. Repeat algorithm v1 on those samples to find another bump
   3.1 Find the new minimum sample (it must be below -2 mV)
   3.2 Step left (right) and look for 3 bins with average close to 0: either
      - greater than than 10% of the minimum
      - greater than -1 mV
   3.3 Reject any bumps w/ width = 1
4. If you find a bump, go back to step (2), but do so for the samples to the right *and the left*

# New Algorithm ⇒ New Variables

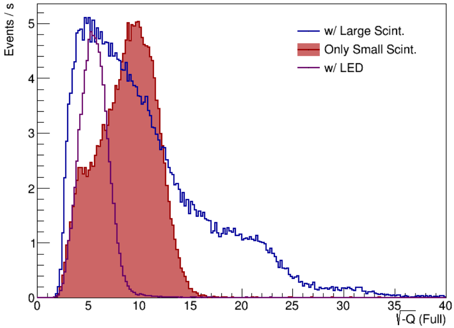


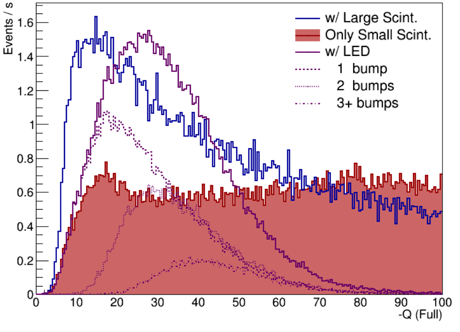

Some observations...

- The LED data often have more than 1 bump. Could this be related to the number of P.E.? (more on this in a bit)

# A Closure Look at -Q

Using the $2^{nd}$ algorithm...




- '1 bump' LED data looks to have the same shape as the low -Q small scint.
- Backgrounds produce more light in the large scint., giving the larger -Q tail
- More smearing in the large scint. $\Rightarrow$ less clean small -Q distribution

# Some Final Thoughts

## What Have We Learned?

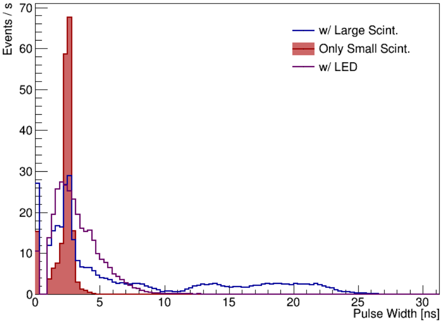
- We are able to see 1 P.E.'s in the data collected with the LED, the small scint. and the large scint.
- The 1 P.E. rate appears to double once we attach the large scint.
  - It is unclear how much of this is from smearing and efficiency loss from larger backgrounds

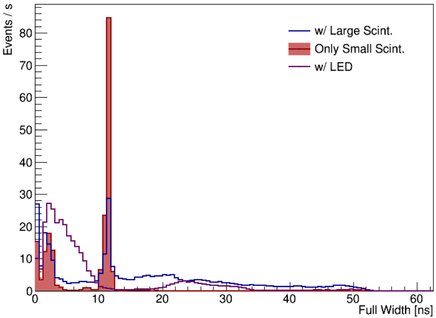
## The Next Steps

- It would be great to have simulated mQ data to compare against
- We will continue to improve our setup and explore these shape variables
- Once we get our radioactive sources into the new lab, we can start other measurements with the large scint.

# Backup

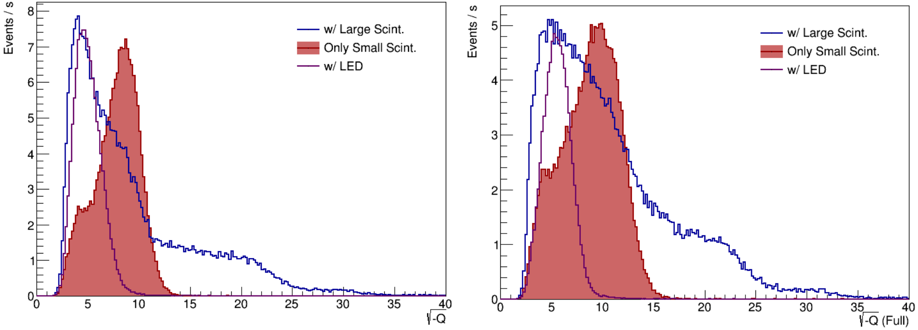
# Comparing Algorithms




- The LED data are mostly unchanged
- There is a striking peak around 11 ns, that we are still investigating. Our best guess is that it is an artifact of the electric circuit

# Comparing Algorithms




- The LED data are mostly unchanged, maybe a bit wider
- The 1 P.E. rate for the small scint. is comparable
- The 1 P.E. rate for the large scint. drops by O(30%)!