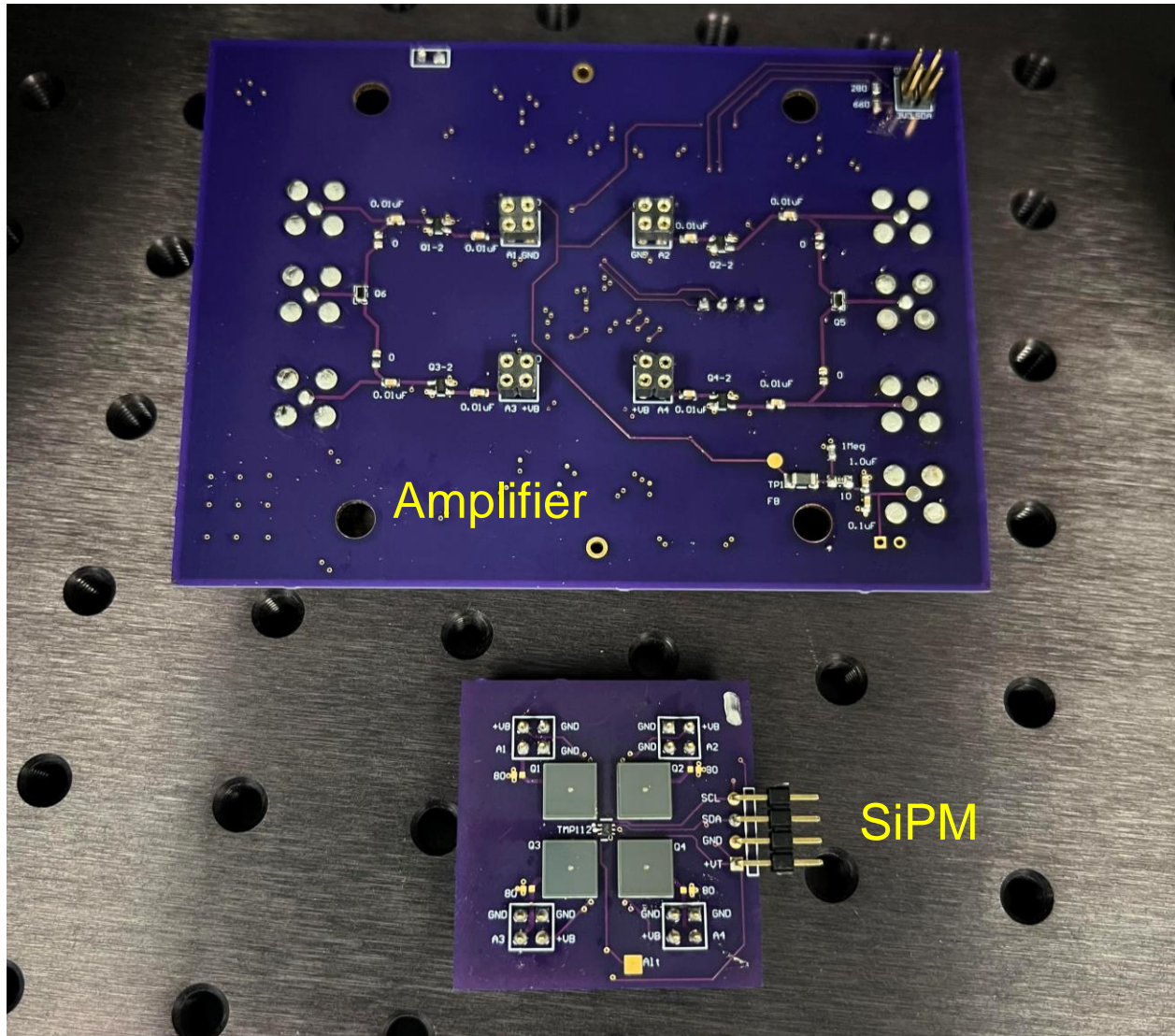


# Single crystal update

**Feb 9, 2023**

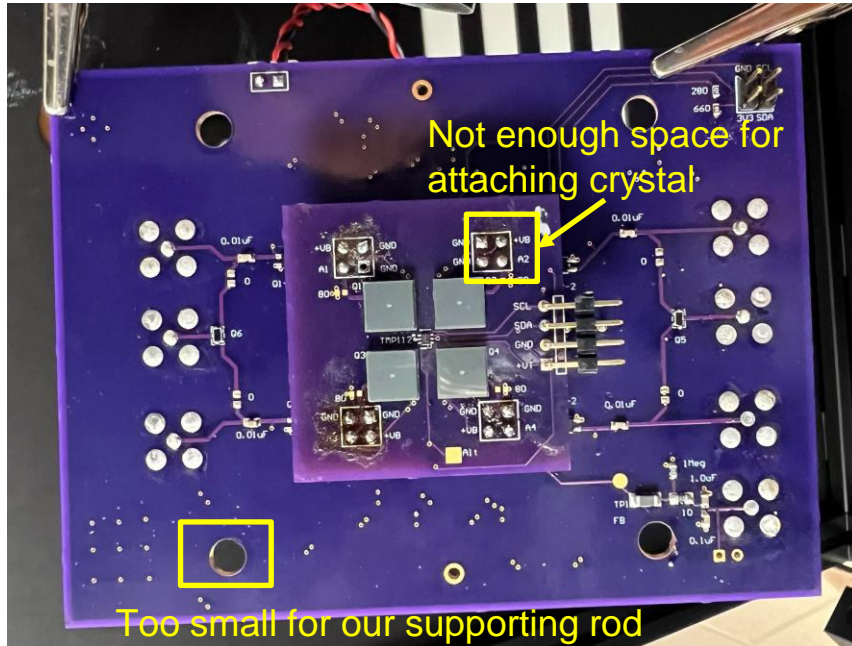
Yuxiang Guo

# New amplifier board from Virginia

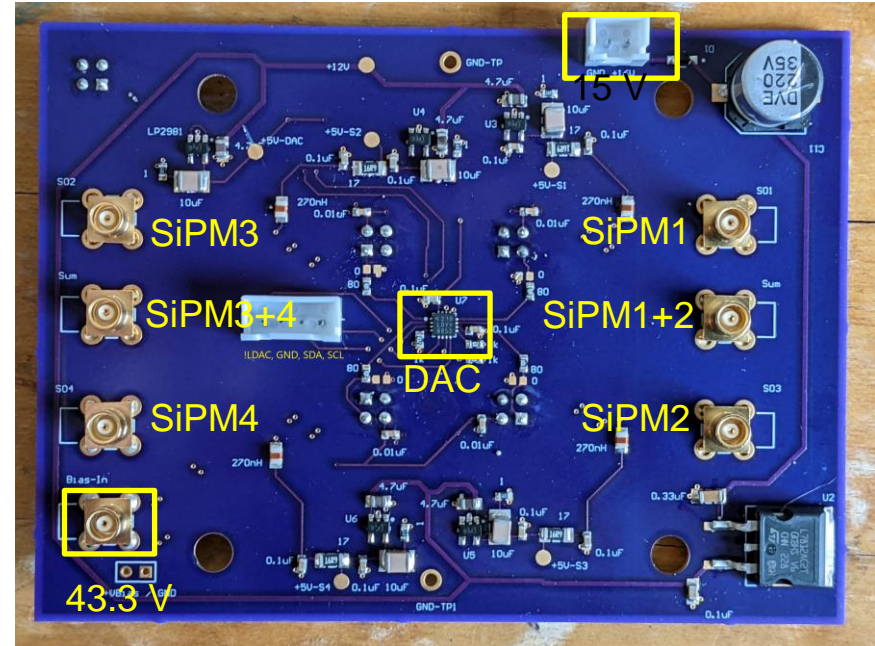


# New amplifier board from Virginia

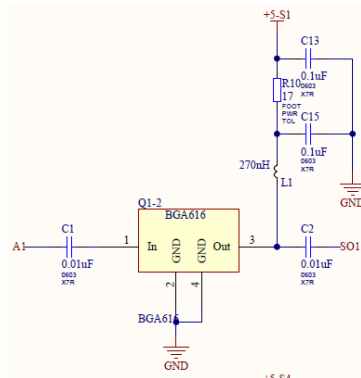
- 4 6mm\*6mm SiPMs (S14160-6050HS) on the daughter board
- One RF Amplifier (BGA616) for each SiPM, direct output
- Sum output for SiPM1+2, and SiPM3+4
- 4-channel DAC for individual SiPM HV adjustment



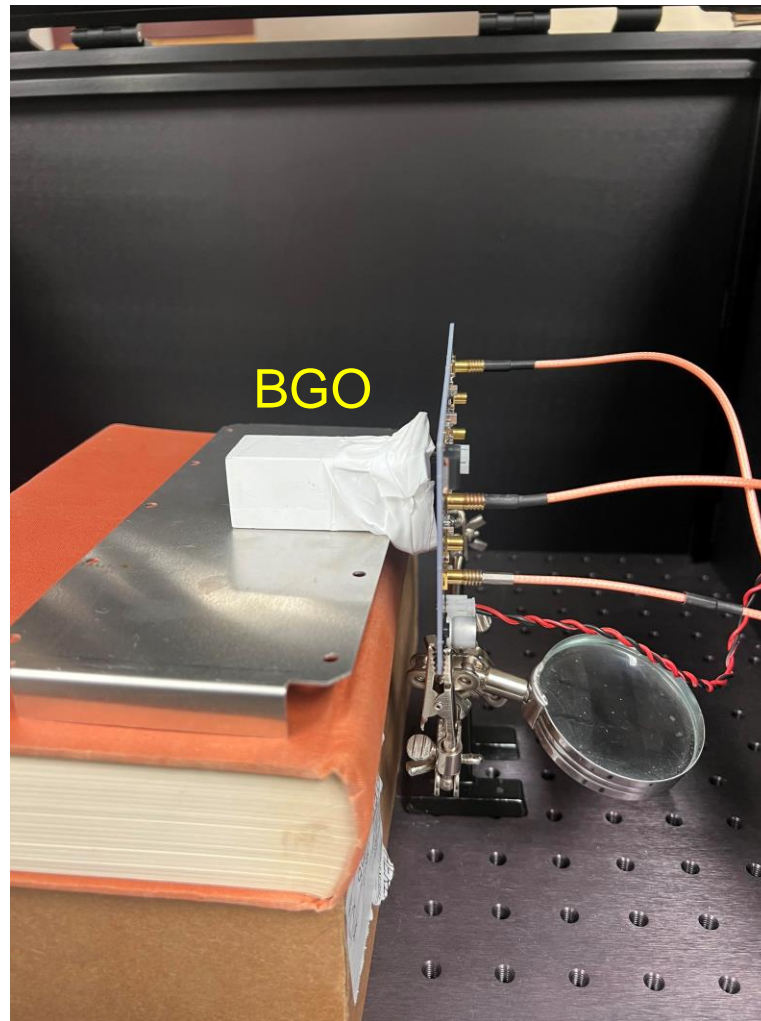
SiPM side



output side



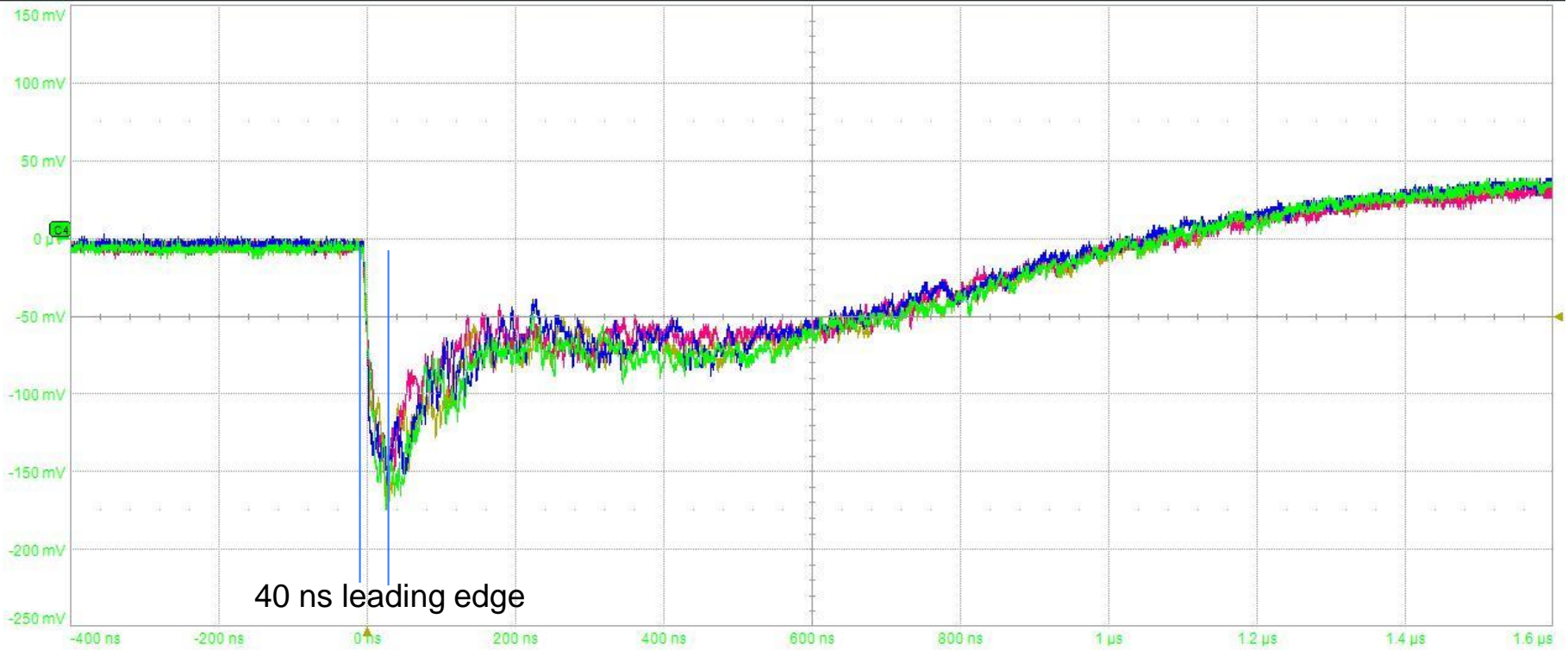
AC coupled amplifier circuit



Used a soldering support clamp  
BGO wrapped with SiPMs

# Waveform with BGO

File Vertical Timebase Trigger Display Cursors Measure Math Analysis Utilities Support Normal Gesture Undo



40 ns leading edge

| Measure | P1:ddelay(C1.C2) | P2:ddelay(C1.C3) | P3:ddelay(C1.C4) | P4:ddelay(C3.C4) | P5:period(C3) | P6:freq(C3)   | P7:E2E(C4.C3) | P8:freq(C1) |
|---------|------------------|------------------|------------------|------------------|---------------|---------------|---------------|-------------|
| value   | 280 ps           | 19 ps            | 858 ps           | 839 ps           | ---           | ---           | ---           | ---         |
| mean    | -210 ps          | -836 ps          | -467 ps          | 369 ps           | 375.6 ns      | 3.805 MHz     | ---           | ---         |
| min     | -3.791 ns        | -3.804 ns        | -3.349 ns        | -3.120 ns        | 99.916 ns     | 2.123042 MHz  | ---           | ---         |
| max     | 6.954 ns         | 1.251 ns         | 1.586 ns         | 3.348 ns         | 471.022 ns    | 10.008363 MHz | ---           | ---         |
| sdev    | 2.658 ns         | 1.552 ns         | 1.477 ns         | 1.792 ns         | 139.0 ns      | 3.103 MHz     | ---           | ---         |
| num     | 13               | 13               | 13               | 13               | 5             | 5             | ---           | ---         |
| status  | ✓                | ✓                | ✓                | ✓                | ⚠             | ⚠             | ---           | ---         |
| histo   | [Histogram bars] |                  |                  |                  |               |               |               |             |

|         |         |         |         |         |         |         |         |
|---------|---------|---------|---------|---------|---------|---------|---------|
| C1      | DC50    | C2      | DC50    | C3      | DC50    | C4      | DC50    |
| 50.0 mV | 50.0 mV | 50.0 mV | 50.0 mV | 50.0 mV | 50.0 mV | 50.0 mV | 50.0 mV |
| 50.0 mV | 50.0 mV | 50.0 mV | 50.0 mV | 50.0 mV | 50.0 mV | 50.0 mV | 50.0 mV |

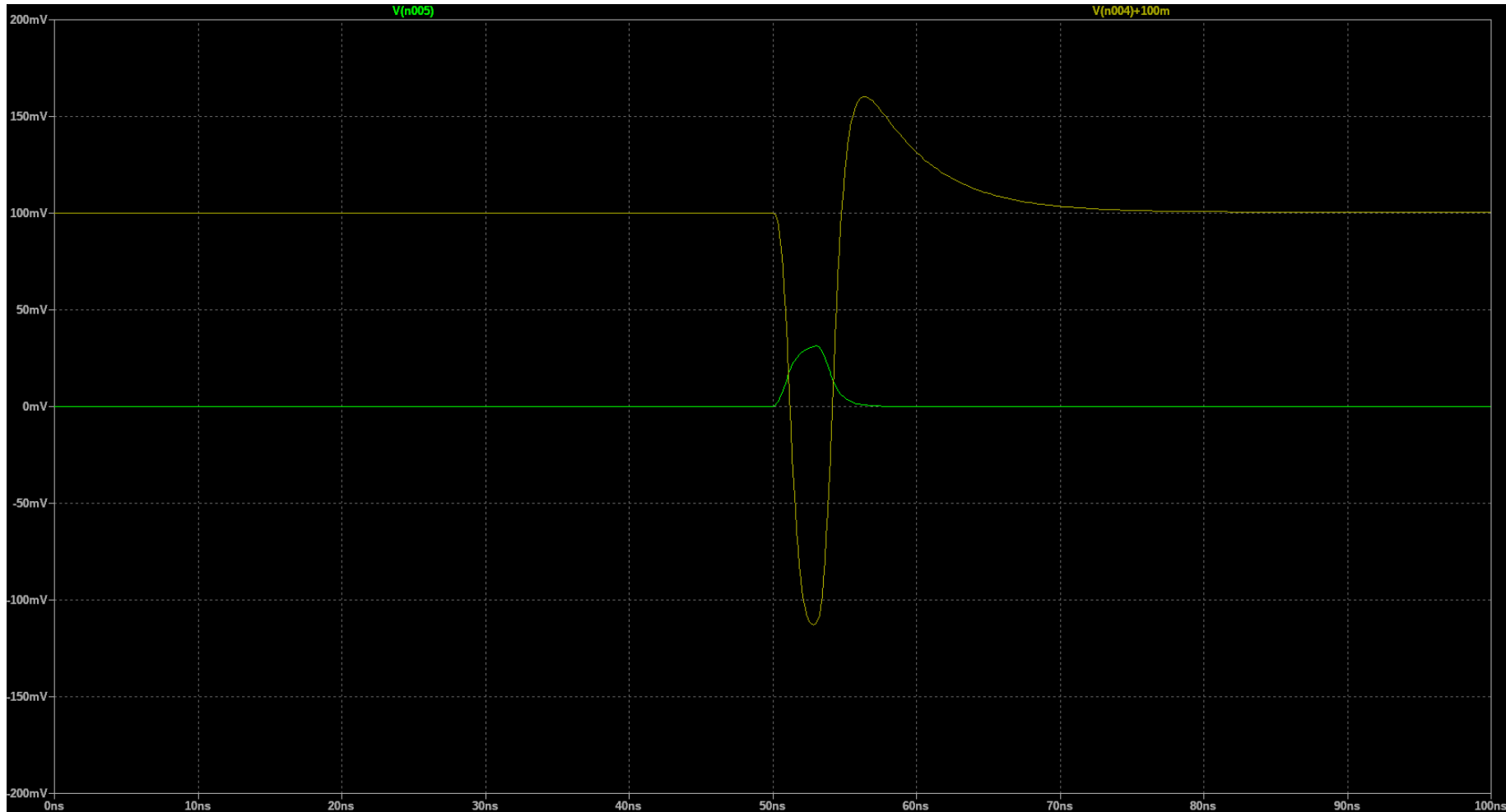
  

|       |            |         |          |
|-------|------------|---------|----------|
| Tbase | -600 ns    | Trigger | C1 DC    |
|       | 200 ns/div | Sing    | -50.0 mV |
|       | 10 kS      | Edge    | Neg      |

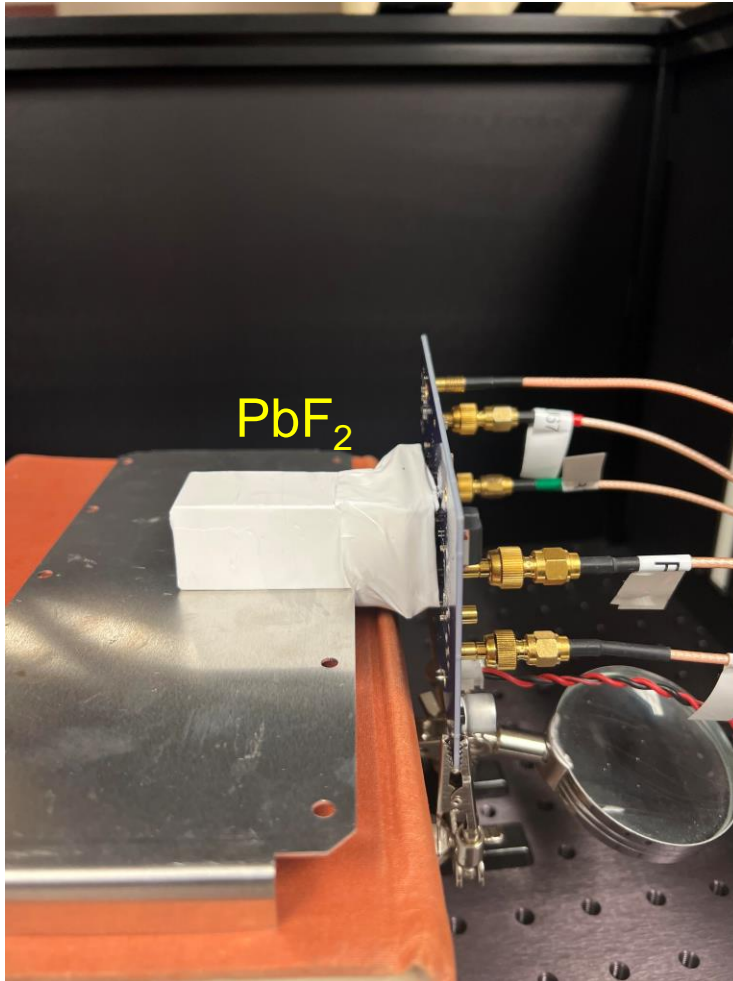
TELEDYNE LECROY

Waiting for Trigger 1/31/2023 10:32:11 PM

# Waveform from spice model of one SiPM channel



Simulated pulse (credit to Thomas Anderson)



|                   |                 |
|-------------------|-----------------|
| Time              | 12.1 h          |
| Trigger from SiPM | 6917            |
| Rate              | 6.3 s / trigger |

# Waveform with PbF<sub>2</sub>

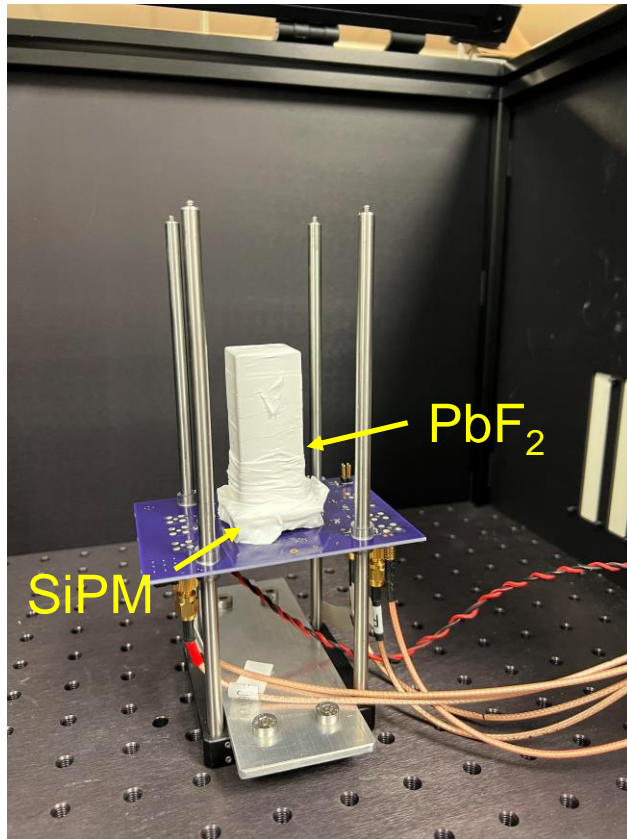


TELEDYNE LECROY

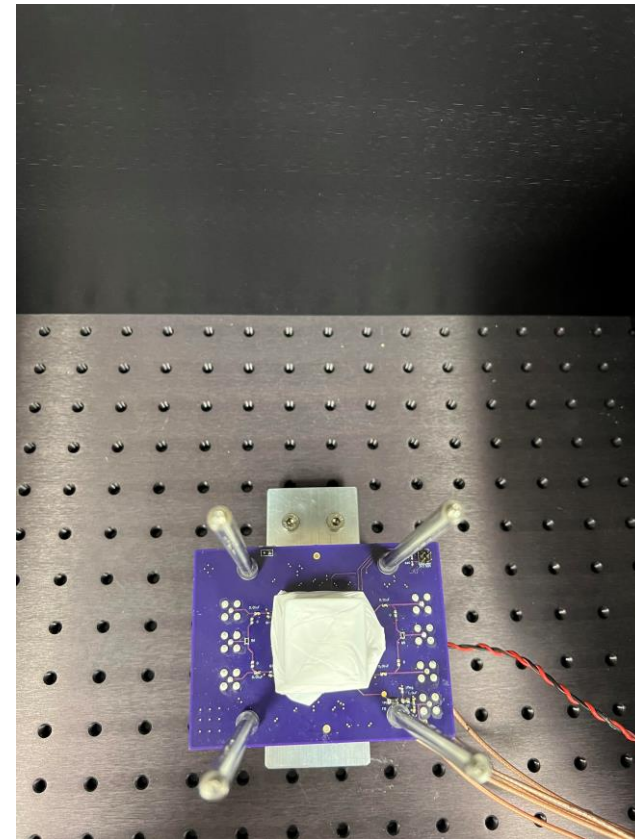
1/31/2023 11:30:28 PM



# Vertical setup with supporting rods



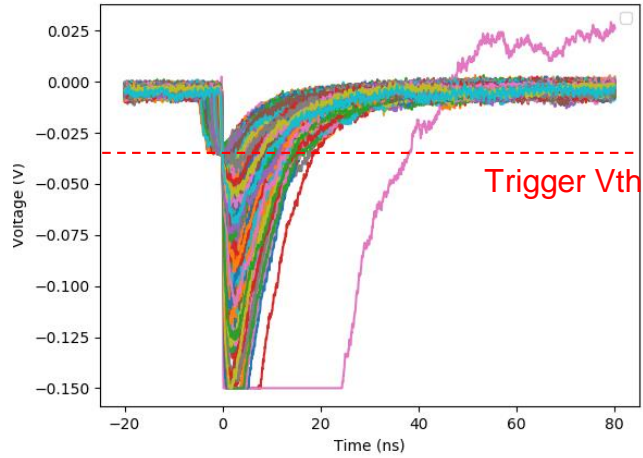
Vertical setup front view



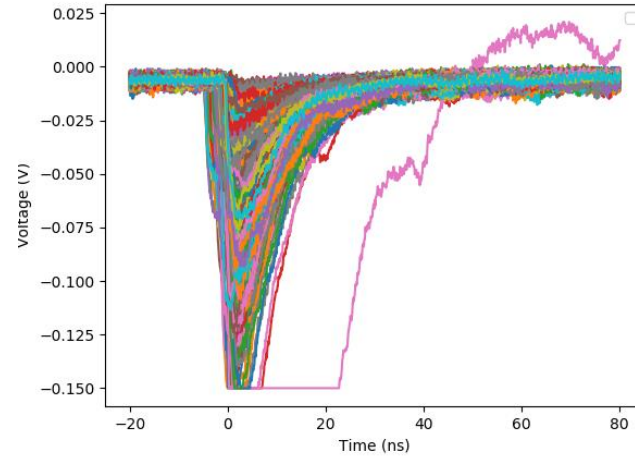
Vertical setup top view

# SiPM signals with trigger from SiPM1 ( $V_{th} = 30 \text{ mV}$ )

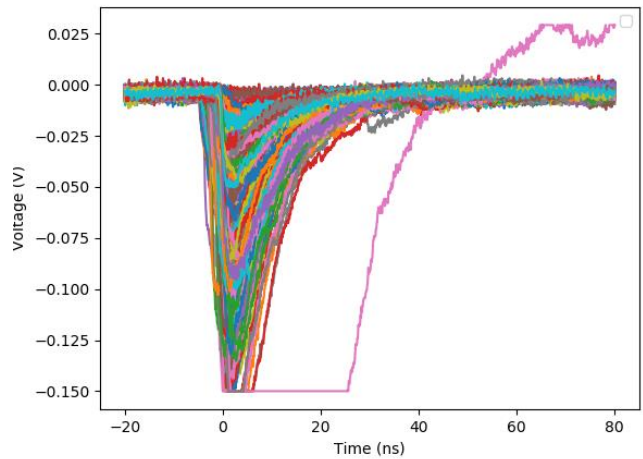
Waveform of first 1k events shown



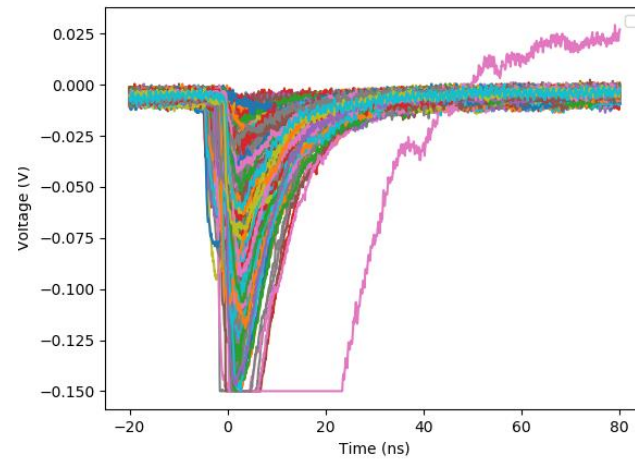
SiPM1



SiPM3



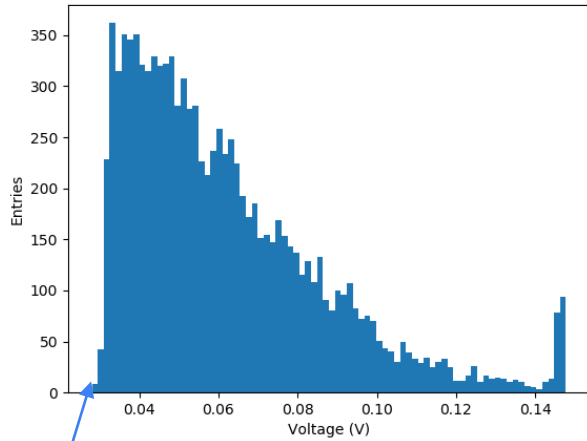
SiPM2



SiPM4

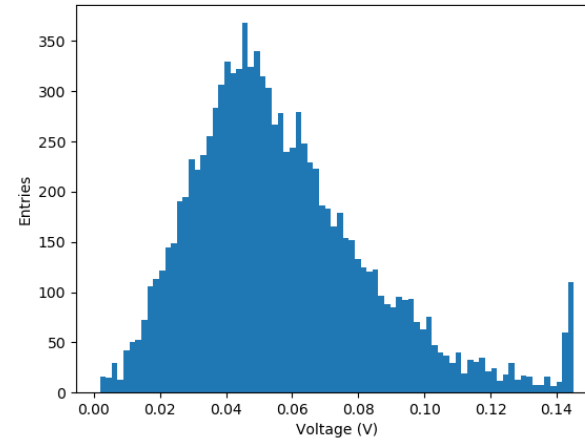
|                   |                 |
|-------------------|-----------------|
| Time              | 19.7 h          |
| Trigger from SiPM | 10434           |
| Rate              | 6.8 s / trigger |

# SiPM signals with trigger from SiPM1 ( $V_{th} = 30 \text{ mV}$ )

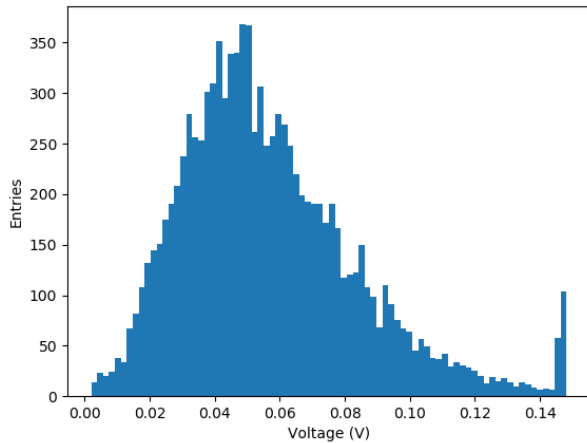


SiPM1

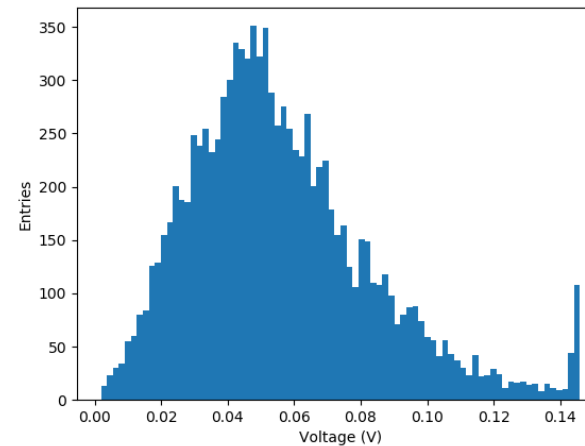
$V_{th}$  cut at 30 mV



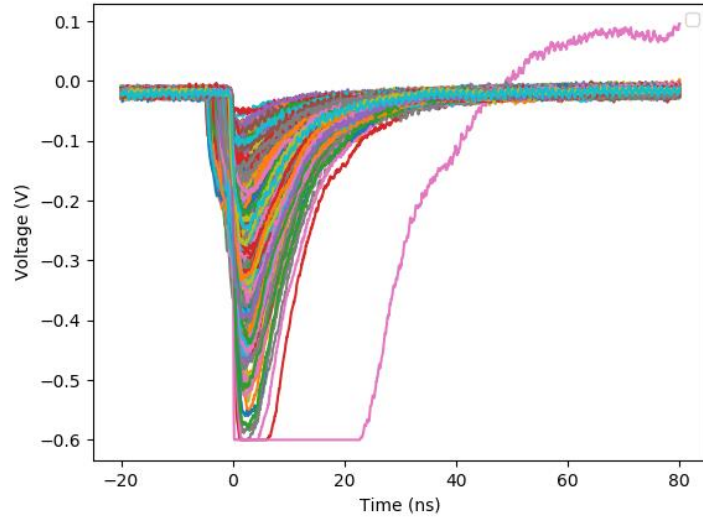
SiPM3



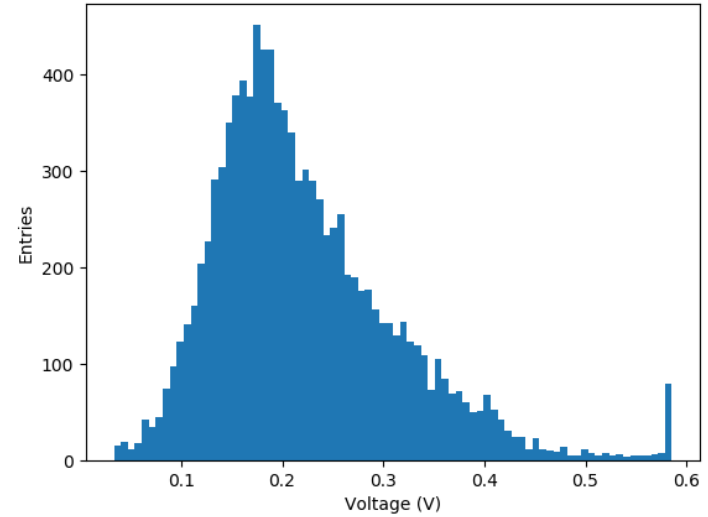
SiPM2



SiPM4

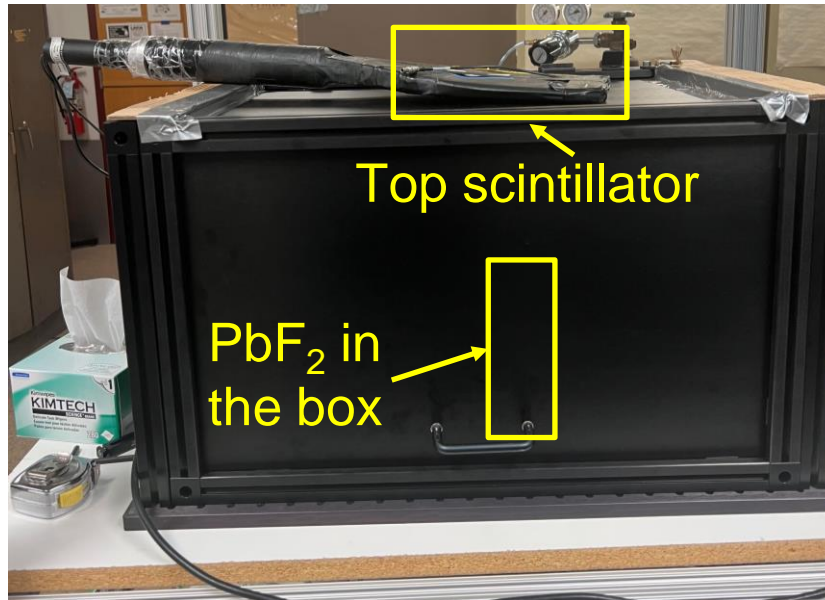


Sum of 4 SiPM signals



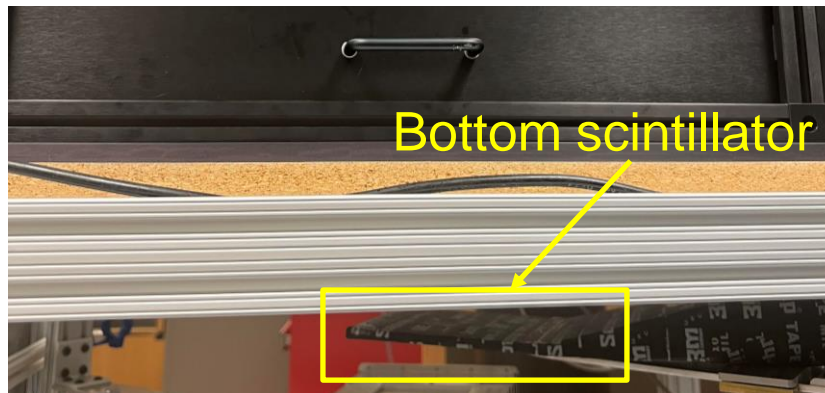
Sum signal amplitude histogram

# Scintillator coincidence signal as trigger

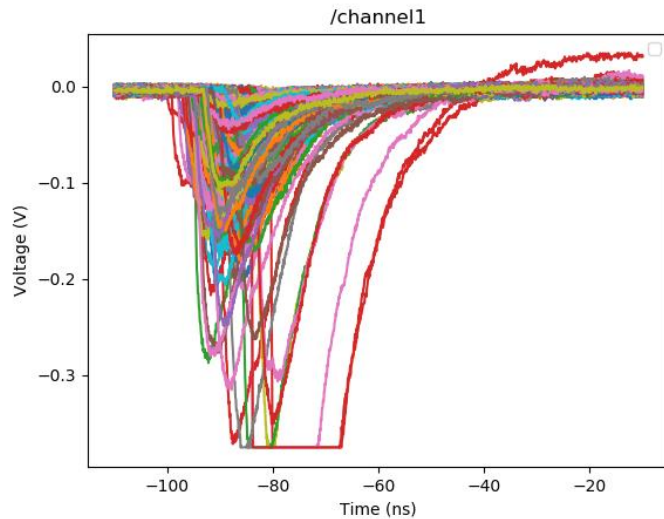


Using coincidence signal from the 2 scintillators as the oscilloscope trigger

|            |                   |
|------------|-------------------|
| Time       | 54.5 h            |
| Trigger    | 17151             |
| Rate       | 11.43 s / trigger |
| SiPM Event | 1189              |
| SiPM Rate  | 165s / event      |

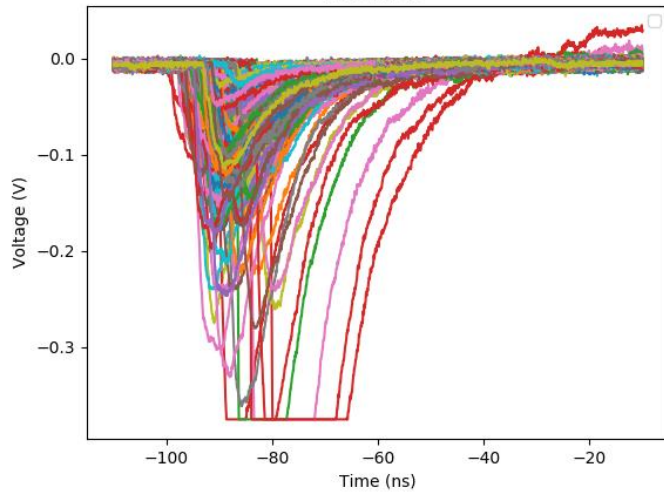


# All 1189 SiPM events with PbF<sub>2</sub>

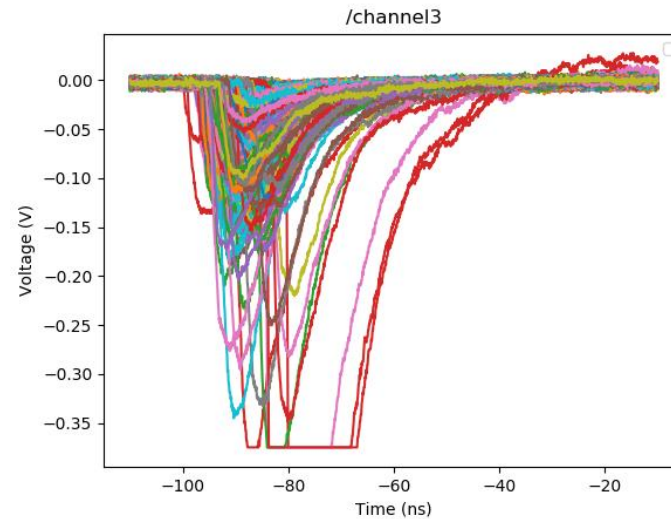


SiPM1

/channel2

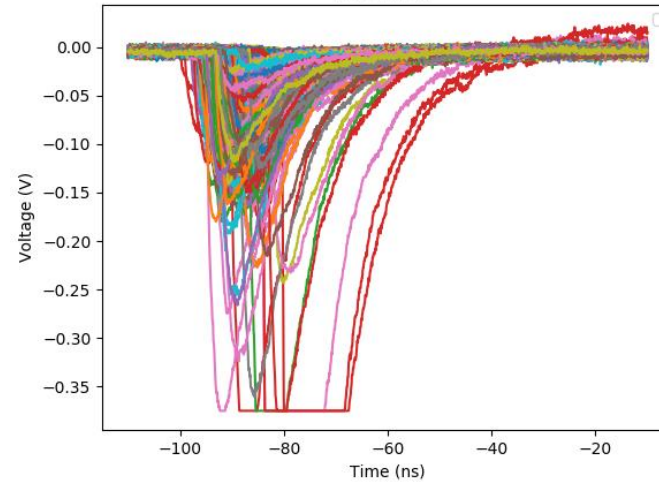


SiPM2



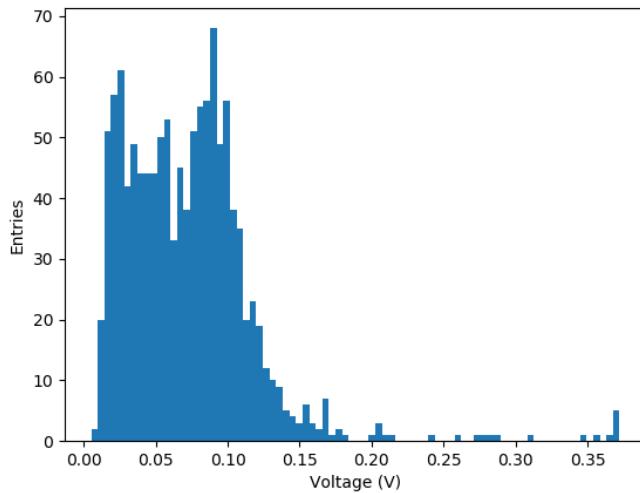
SiPM3

/channel4

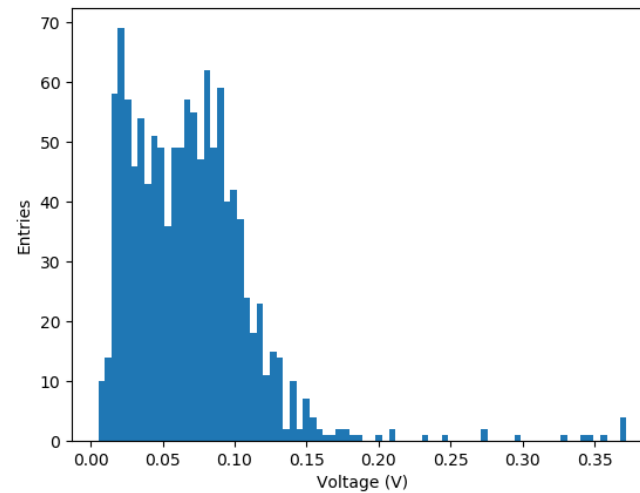


SiPM4

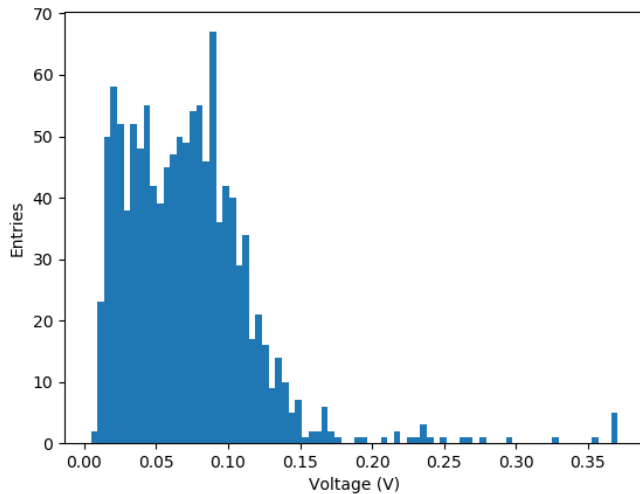
# Waveform peak amplitude distribution



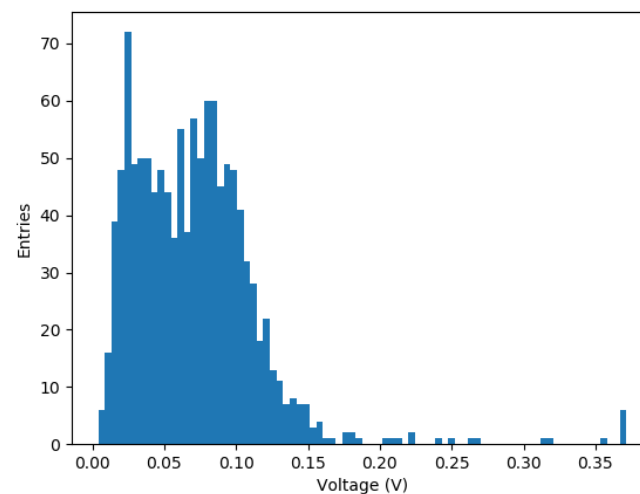
SiPM1



SiPM3



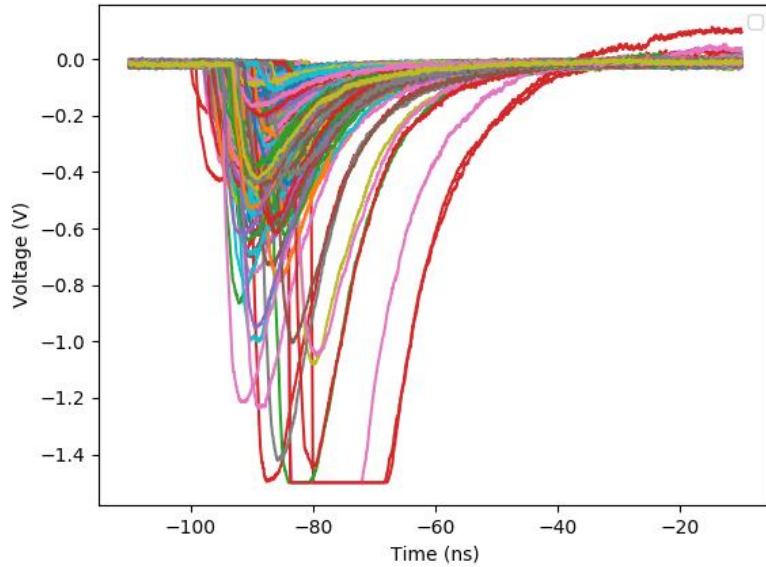
SiPM2



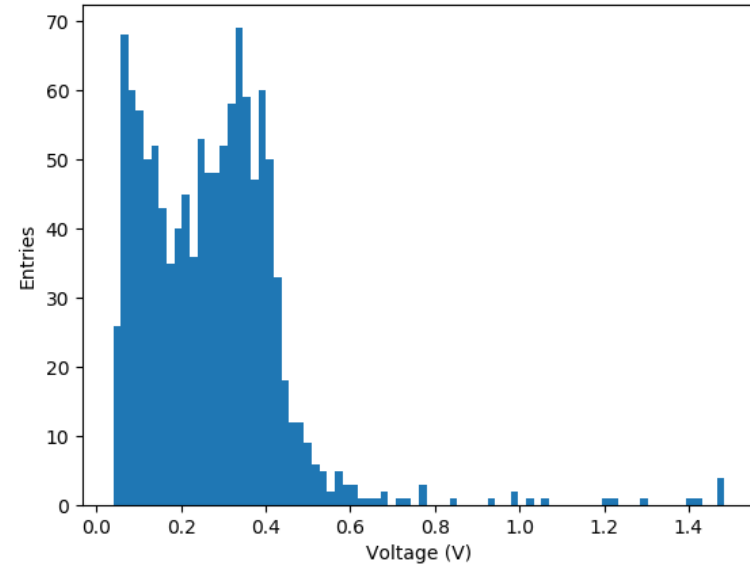
SiPM4

Are there 2 peaks for the amplitude distribution?

# Sum of 4 SiPM signals with $\text{PbF}_2$



Sum of 4 SiPM signals



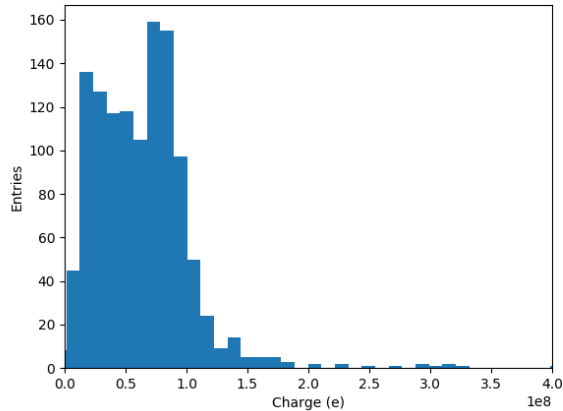
Sum signal peak amplitude histogram

Are there 2 peaks for the amplitude distribution?  
 Are the lower peak events caused by random noise?

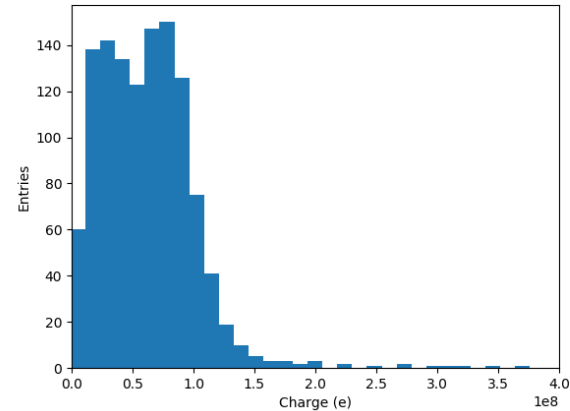


# Signal charge (waveform area) distribution

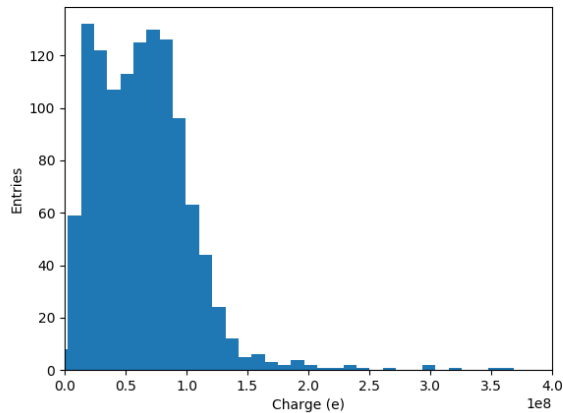
Charge is calculated by SiPM current (amplified) integrated over time ( $q=i*t$ ).  
 X-axis unit: e ( $1.6E-19$  c).



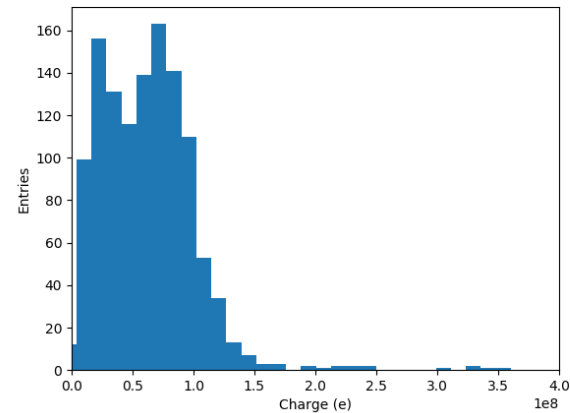
SiPM1



SiPM3



SiPM2

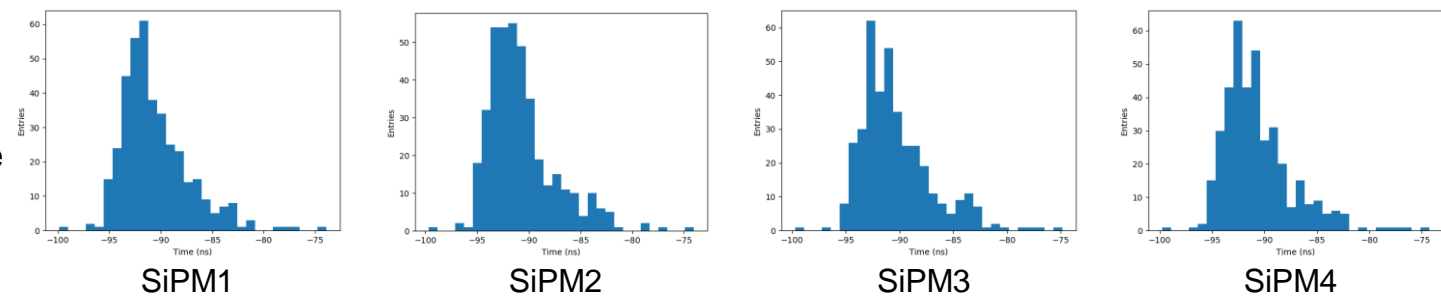


SiPM4

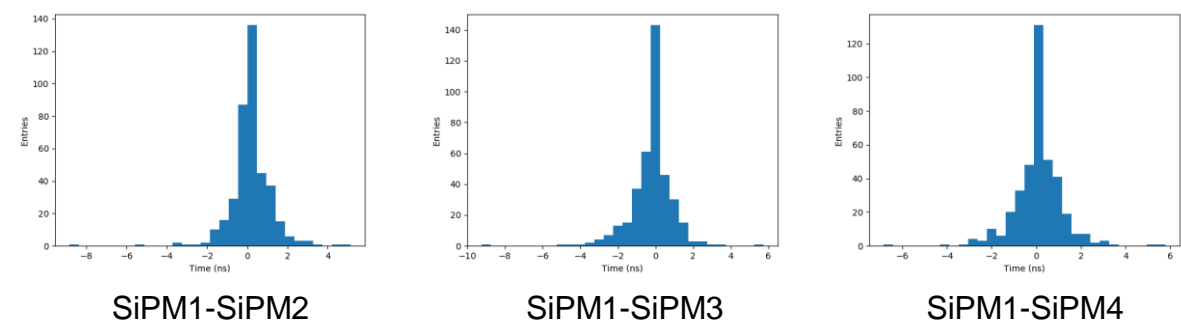
There are still 2 peaks in charge histogram for each SiPM.

# Leading edge threshold crossing time distribution ( $V_{th} = -15$ mV)

Peak <50 mV  
Leading edge time

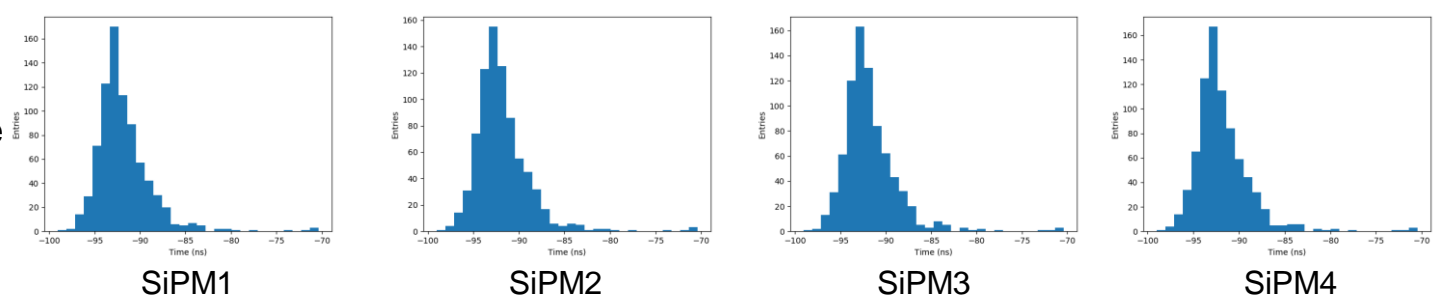


Peak <50 mV  
Leading edge time diff

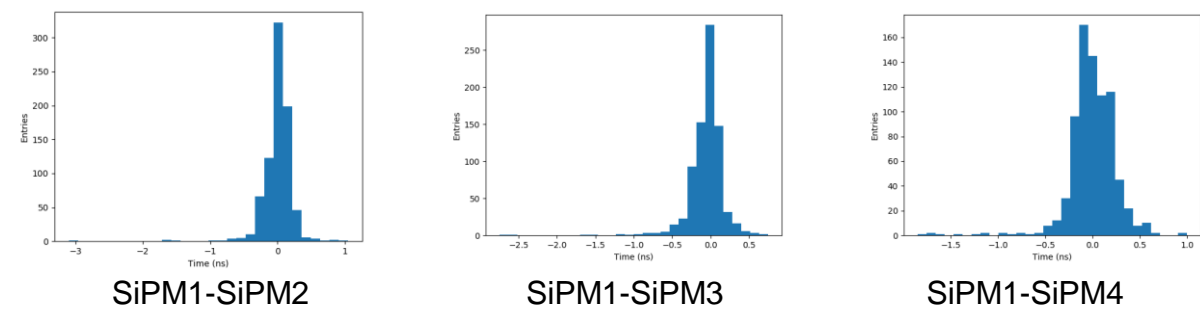


Correlated!

Peak >50 mV  
Leading edge time



Peak >50 mV  
Leading edge time diff



Correlated!

- New amplifier board works with the setup, will try DAC to control individual SiPM operating voltage.
- $\text{PbF}_2$  signal shows great difference from BGO signal.
- Two peaks found in scintillator trigger setup with  $\text{PbF}_2$ . Not at the same position as SiPM trigger setup with  $\text{PbF}_2$ .
- Signals are correlated for each event between 4 SiPMs, regardless of amplitude.
- We will apply black-out curtains to the outside of the dark box to isolate the lights from the outside, to reduce SiPM noise signals.