ColdBox data analysis for Membrane electronics

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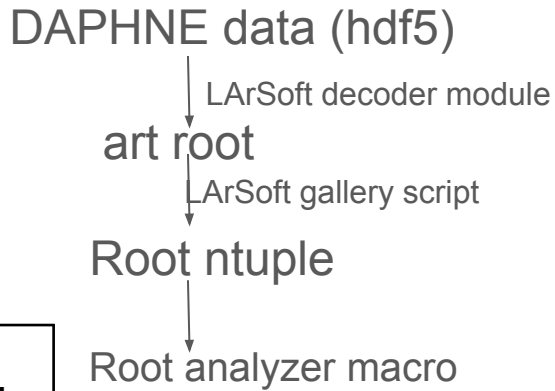
Operation conditions and Data samples for this Analysis

VD ColdBox at NP – January 2024 (~20 to 31 - to check)

- SiPM: FBK TT operated at 32.5 V (5.5 over-voltage)
- VD-style: DVDM-C
- HD-style: DMEM
- DAPHNE V2 (62.5 MHz - 16 ns/tick)
- LED: 275 nm (low intensity -> 4.8 V))



Date	Run	N.wfm /N.LEDPulses	DAPHNE AFE setting (attenuation)
	24037	5633/ 84495	600
	24062	2906/ 43590	1925
	24089	4964/ 74460	1330
	24097	6016/ 90240	1860

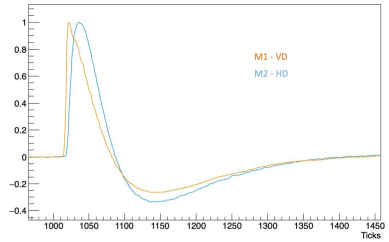
Analysis goals

- SPE Signal Amplitude [ADC] and Baseline Noise rms [ADC] at different DAPHNE Attenuation setting ==> *Amplitude SNR*

- SPE Signal Integral [ADCxtTick] and Baseline Noise Integral [ADCxtTick] at different DAPHNE Attenuation setting ==> *Integral SNR*

Methods

- Use all data: wfm(800 mus) with <16> LED pulses => split into 16wfm(50mus)
- Avg baseline (pre-samples), Baseline subtraction
  - Option: Apply filters (denoising) [Taking moving average of 4 points before and 4 points after a given point, and applying Total variation 1D denoising filter (TV1D)]
  - Option: apply evt. Selection
- Find signal => Signal Max = Amplitude [ADC]
  - If No signal in wfm => baseline avg=Noise [ADC]
- *Amplitude Finger Plot => Amplitude SNR (at different DAPHNE Attenuations)*
- Align to max amplitude time
  - Define Integration window (tot n.of Ticks, n.Ticks before/after max amplitude time) [Note: HD and VD signal shape is different, ~same zero-crossing time]
    - => Signal Integral [ADC x tTick]
    - If no signal in window => baseline integral [ADC x tTick]
  - *Integral Finger Plot => Integral SNR at different Integration windows and at different Attenuations*

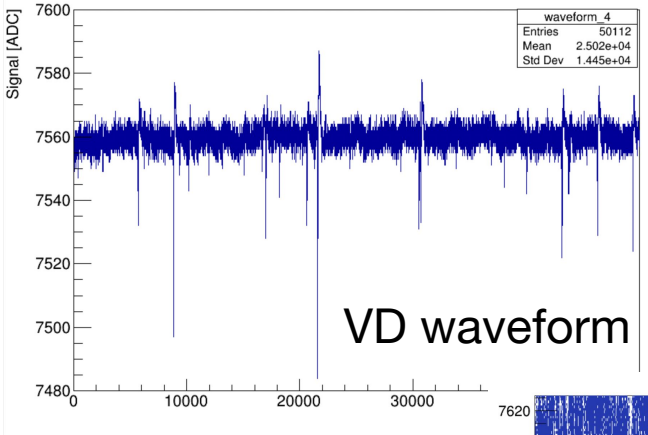


Amplitude Study - Results

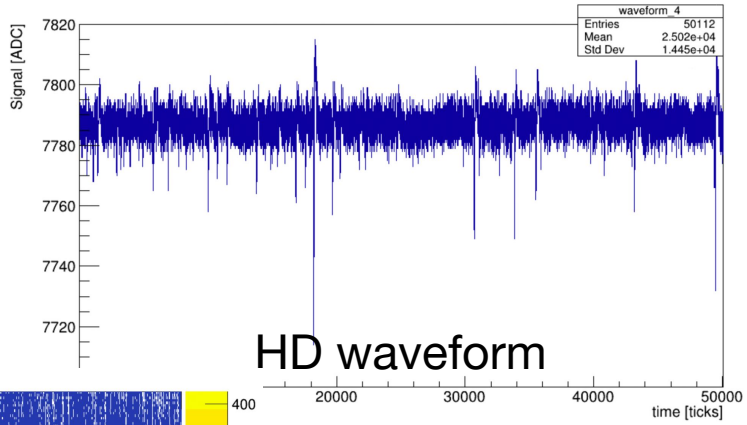
- Examples of small wfm's w/ w/out signals (0, 1, 2/few PEs) for VD and HD
- Amplitude analysis: examples of Noise distribution and finger plot (VD vs HD) for given attenuation, different denoising (and raw).
- Big table for Amplitude
- Some graphs from table
  - SPE-Amplitude vs AFE for VD and HD
  - Noise-RMS vs AFE for VD and HD
  - SNR vs AFE for VD and HD
  - SNR vs SPE-Amplitude for VD and HD

Amplitude Study:

Run 24062 [each waveform spans ~50,000 ticks = 800 micro-sec
LED pulses appears at an interval of 3125 ticks, however there is a jitter

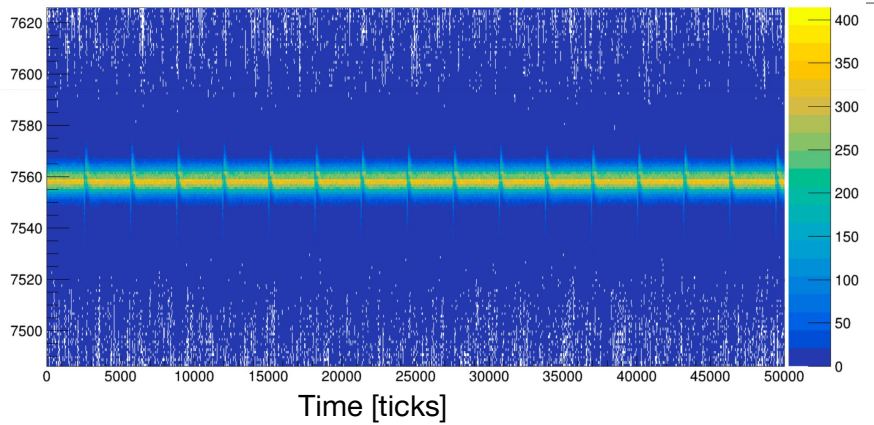


VD waveform



HD waveform

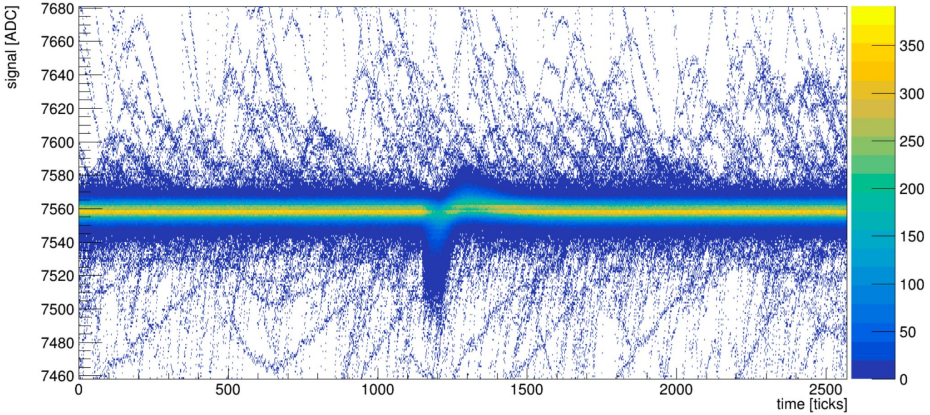
ADC



Left fig: Overlaying all waveforms in a run 24062 [VD]

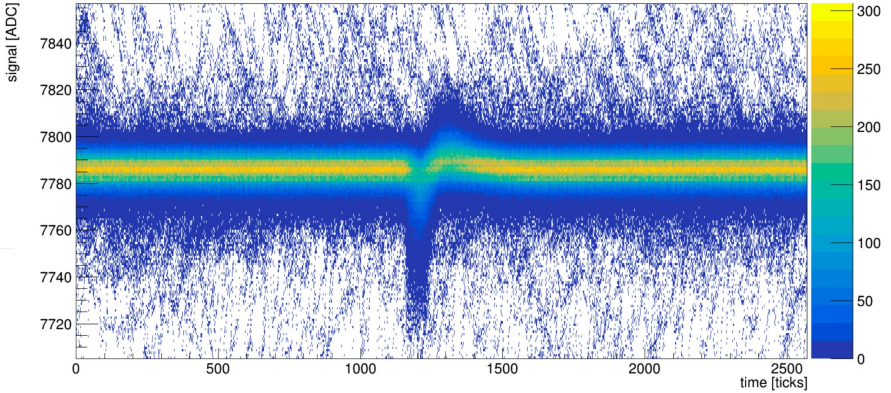
16 LED pulses; however, last pulse has a short window; so not considered for analysis

Each waveform is divided into 15 segments equal segment considering 1200 ticks before the pulse and 1500 after the pulse.



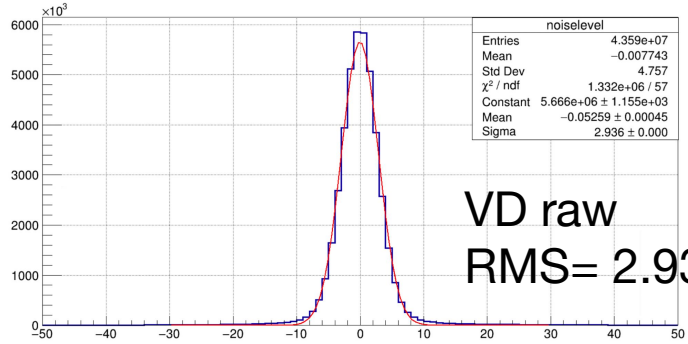
VD style

One segment around an LED pulse

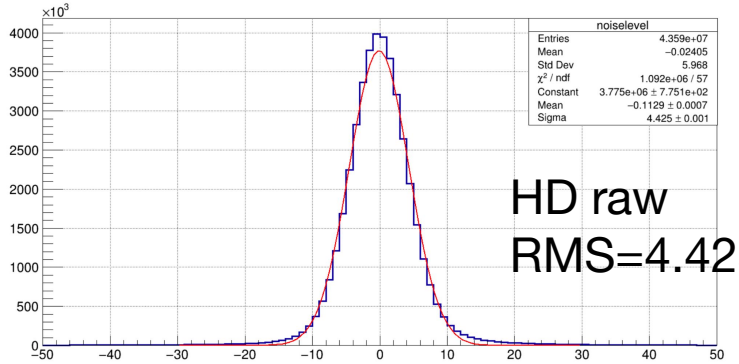


HD style

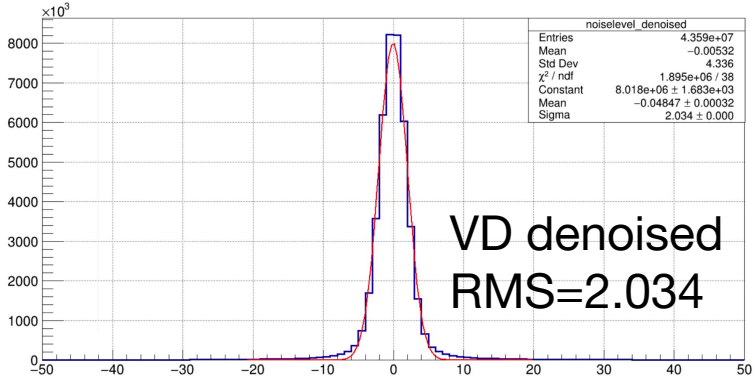
RMS noise on baseline:



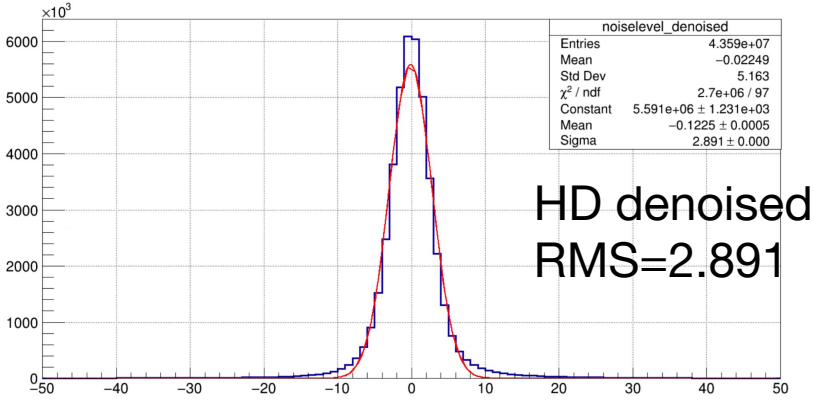
VD raw
RMS= 2.936



HD raw
RMS=4.425

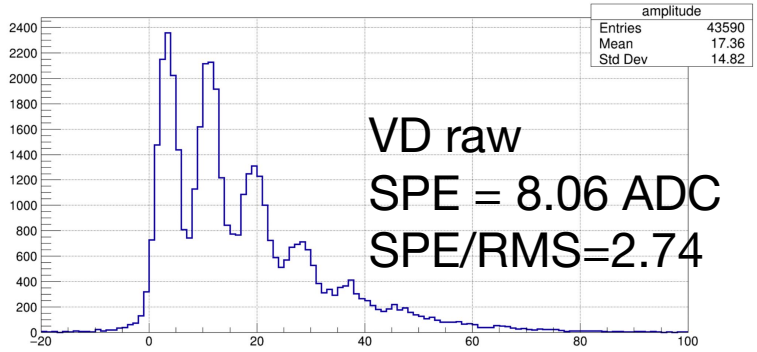


VD denoised
RMS=2.034

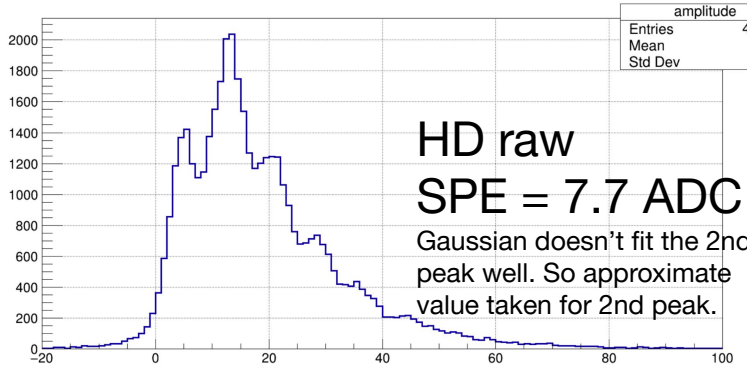


HD denoised
RMS=2.891

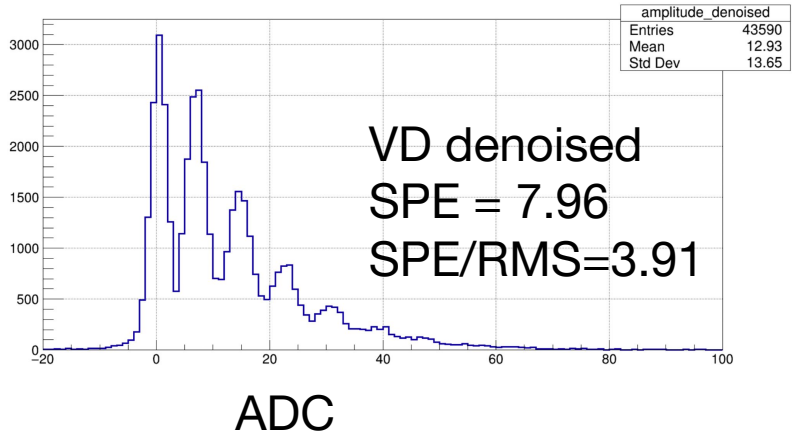
Signal amplitude: SPE amplitude is measured by fitting Gaussian to the 2nd and 3rd peak and taking the difference between fitted mean values.



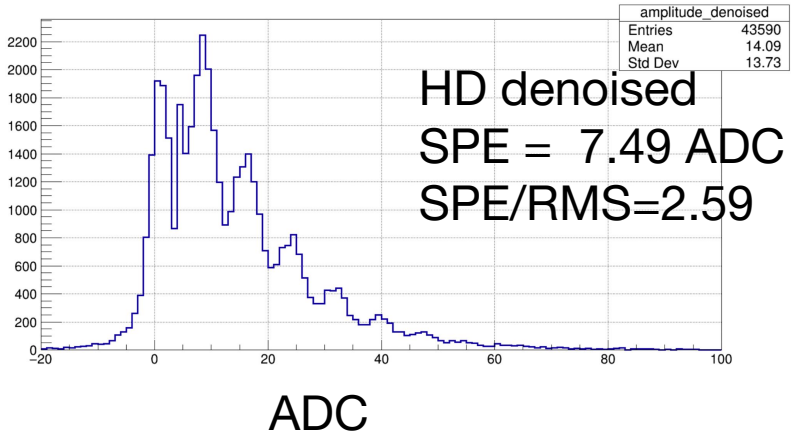
VD raw
SPE = 8.06 ADC
SPE/RMS=2.74



HD raw
SPE = 7.7 ADC
SPE/RMS =1.74
Gaussian doesn't fit the 2nd peak well. So approximate value taken for 2nd peak.



VD denoised
SPE = 7.96
SPE/RMS=3.91

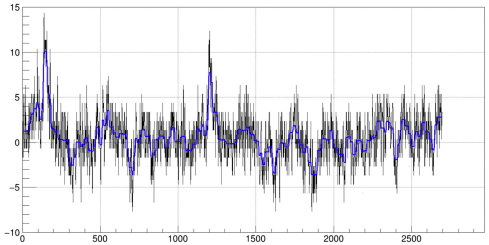


HD denoised
SPE = 7.49 ADC
SPE/RMS=2.59

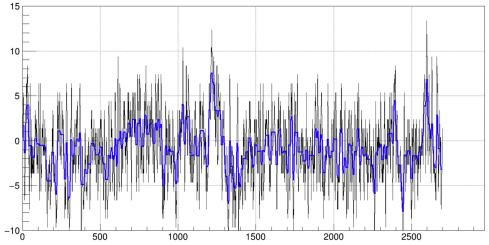
Some LED pulses after baseline subtraction and inverting DAPHNE output [24062]

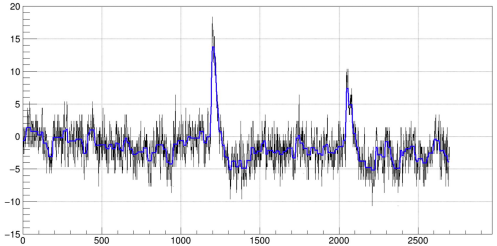
VD

HD

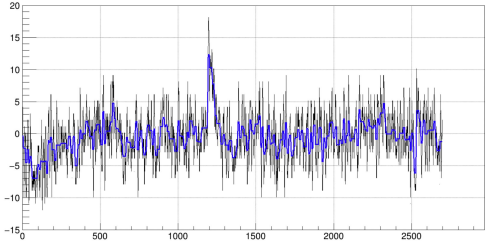


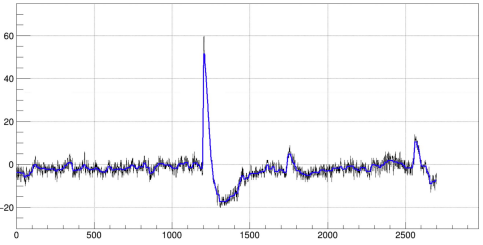
Candidate 1PE



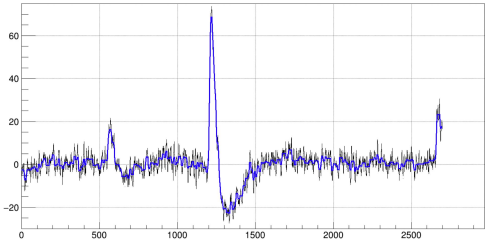


Candidate 2PE

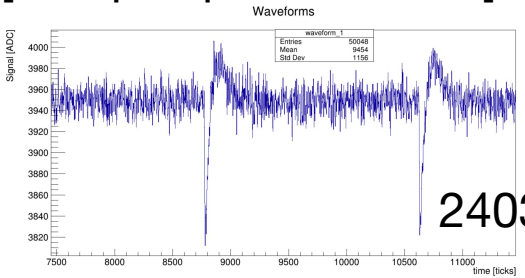




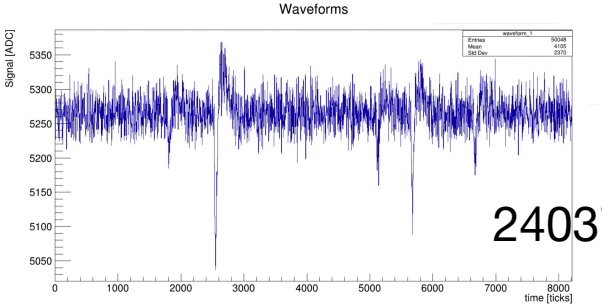
Larger pulses



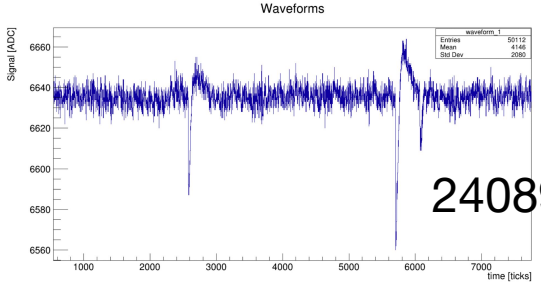
Similar analysis were performed for run (24037, 24089, 24097) [Sample pulses below]



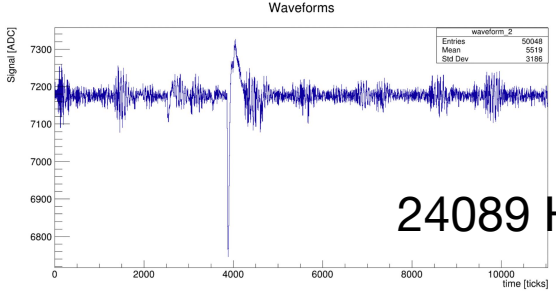
24037 VD



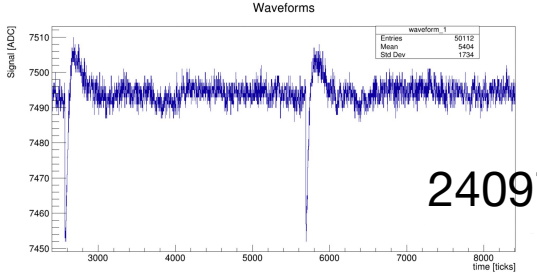
24037 HD



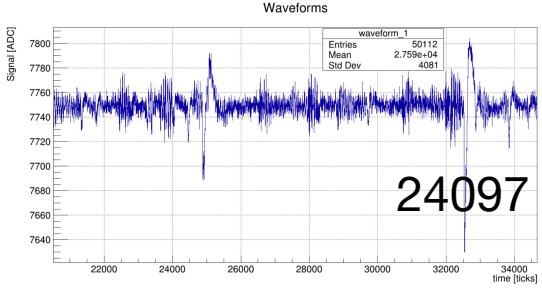
24089 VD



24089 HD



24097 VD



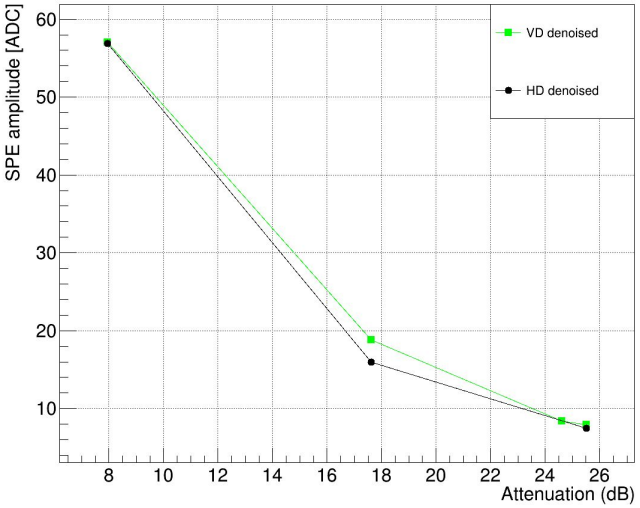
24097 HD

Amplitude study summary table:

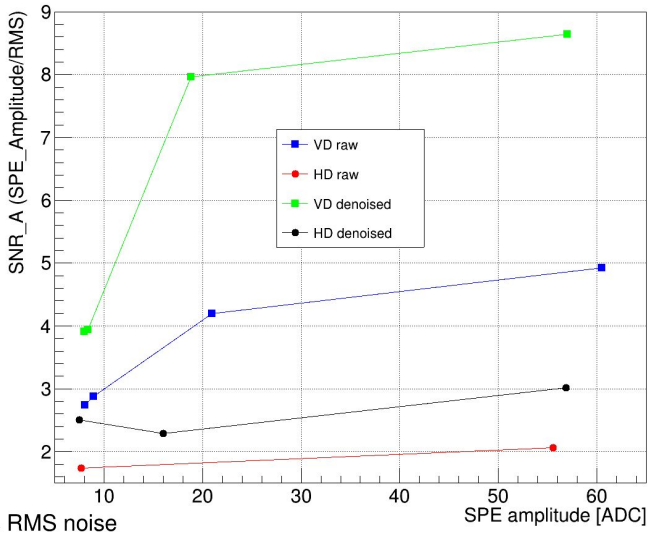
Run	DAPHNE AFE Setting attenuation	Electronics type	Amplitude (raw) ADC	Amplitude denoised ADC	Baseline noise rms (raw) ADC	Baseline noise rms (denoised) ADC	SNR_A (Amplitude/rms) raw	SNR_A (Amplitude/rms) denoised
24037	600	VD	60.49	57.01	12.26	6.6	4.93	8.64
		HD	55.56	56.9	26.9	18.8	2.06	3.02
24089	1330	VD	20.97	18.8	4.99	2.36	4.2	7.97
		HD	NA*	16.0	15.65	>7.0 (big non-gaussian tail)	NA	2.29
24097	1860	VD	8.94	8.36	3.1	2.12	2.88	3.94
		HD	NA*	NA*	6.94	>4.9		
24062	1925	VD	8.06	7.96	2.936	2.034	2.74	3.91
		HD	7.7	7.49	4.425	2.891	1.74	2.51

*Unable to resolve based on amplitude distribution (plot in back up)

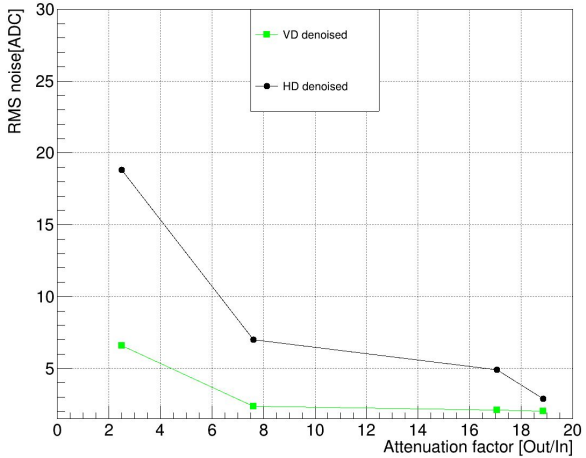
SPE amplitude (denoised) vs attenuation (dB)



SNR (Amplitude/baseline rms) vs SPE amplitude



Attenuation factor vs RMS noise



Integral Study - Results

- Aligned wfm's superimposed in "persistence" plot - examples for VD and HD
  - Integration Windows
- Integral analysis: examples of Noise distribution and finger plot (VD vs HD) for given attenuation,
- Different integration window: SNR variation for one run (highest attenuation)
- Big table for Integral
- Some graphs from table
  - SPE-Integral vs AFE for VD and HD
  - Noise vs AFE for VD and HD
  - SNR vs AFE for VD and HD
  - SNR vs SPE-Amplitude for VD and HD

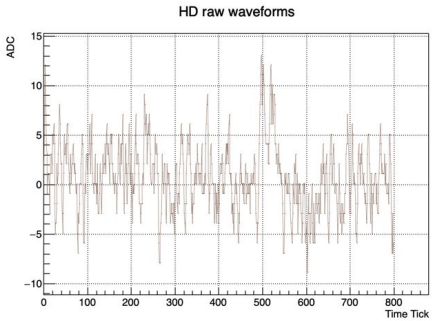
Integral study

Waveforms are baseline subtracted and peaks are aligned.

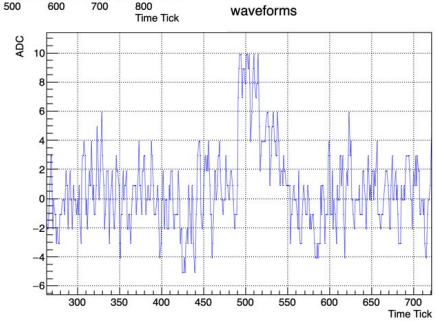
An integration window is made around the position of the pulses.

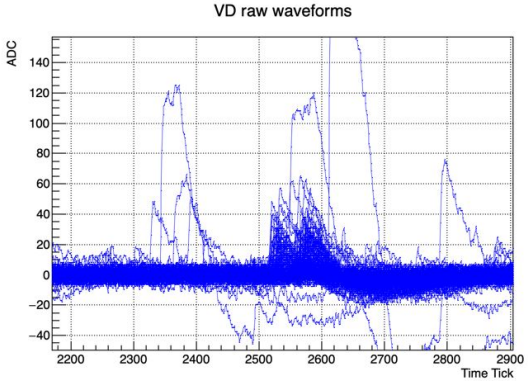
Run 24062 (AFE=1925)

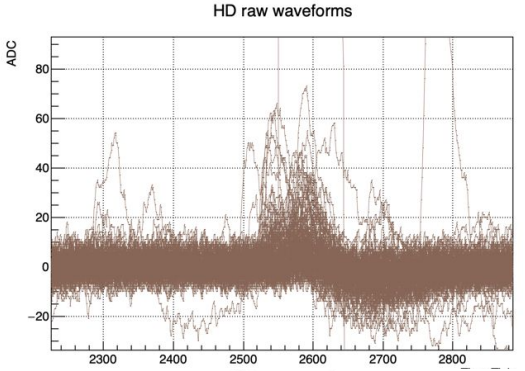
100% of the event are used (no cut) 46500 events.

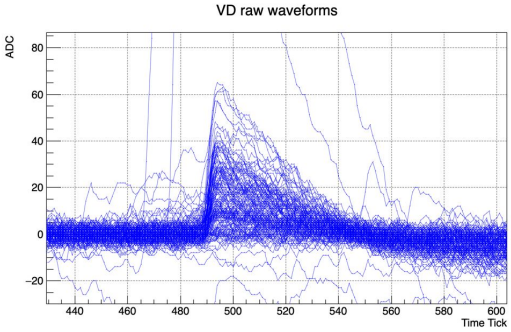


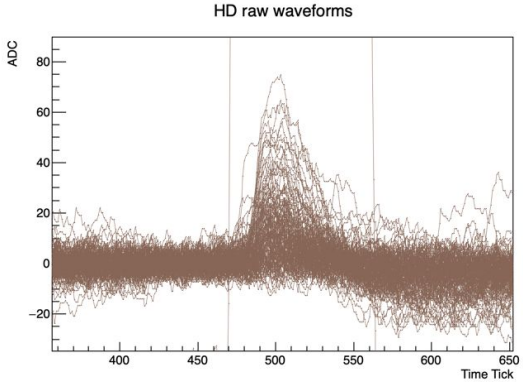
SPE examples











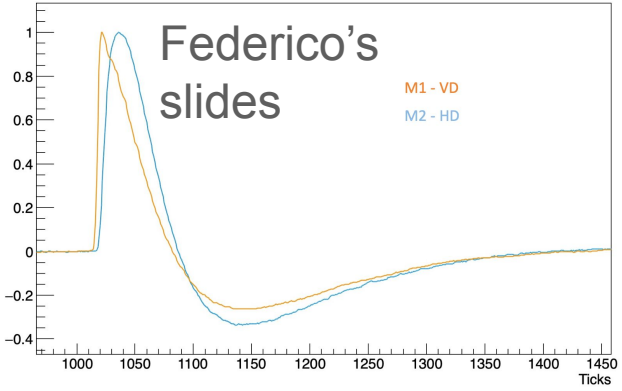
SNR vs integration window

Integration window starts immediately before the pulse rising edge. Since the VD rising edge is faster than the HD rising edge, the starting point is not the same:

Pulse rising edge(from Federico's slides):

HD: 150 ns

VD: 65 ns



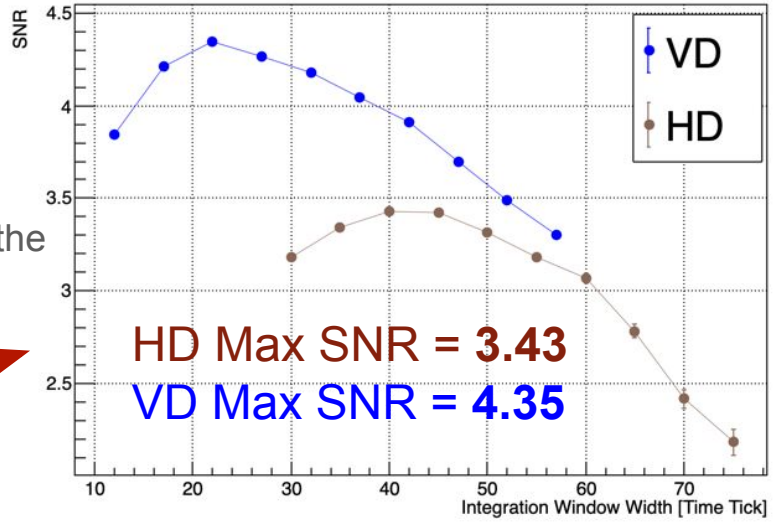
Integration window starting point:

HD: 20 ticks before the max

VD: 12 ticks before the max

SNR is defined as the separation between the mean of the PE peaks integral divided by the standard deviation of the 0 PE peak.

A study of the SNR vs integration window width is made.



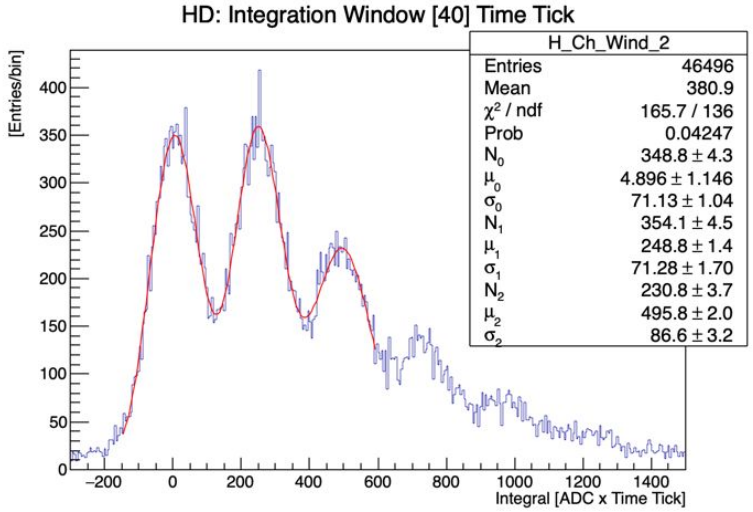
Run 24062 (AFE=1925)- highest attenuation

Integral histograms

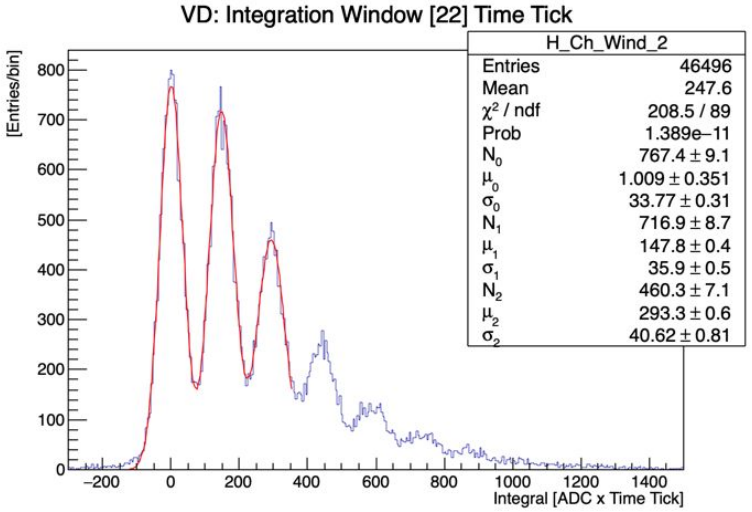
$$SNR = \frac{\mu_1 - \mu_0}{\sigma_0}$$

Using the integration window giving the max SNR for both.
More histograms in backup slides.

HD Max SNR = **3.43**



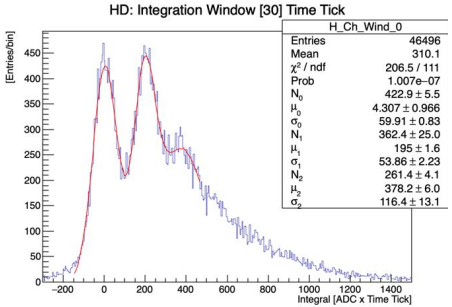
VD Max SNR = **4.35**

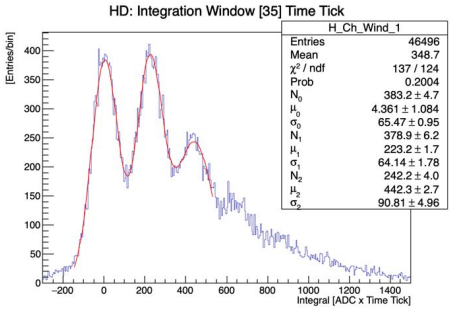


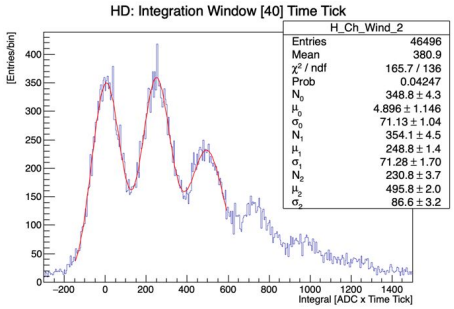
BackUP

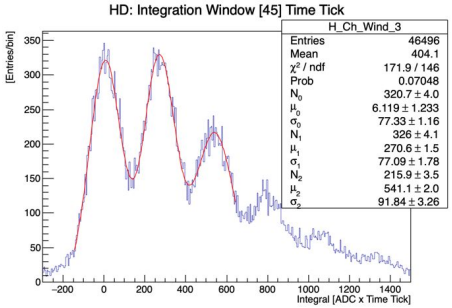
Backup Slides

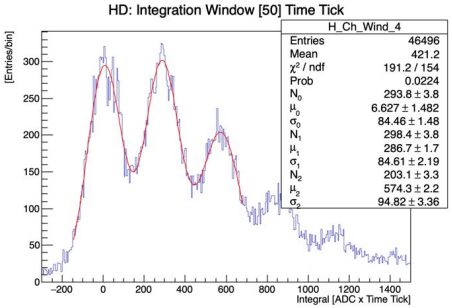
HD integral histograms

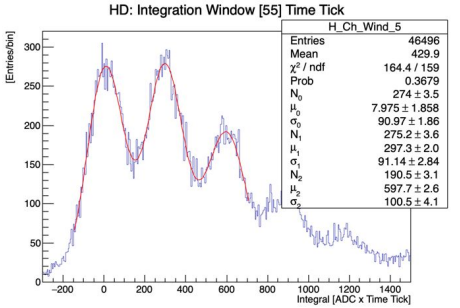


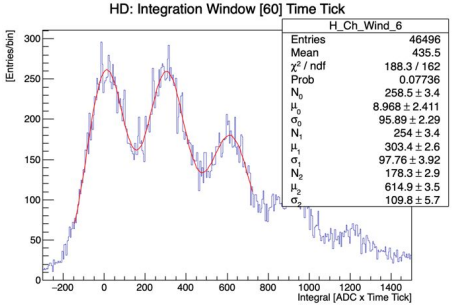


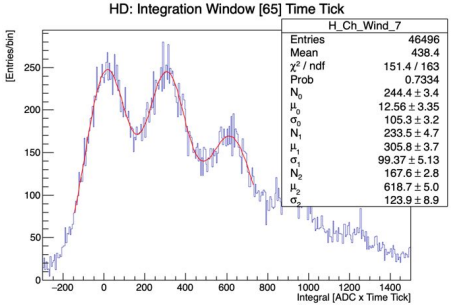


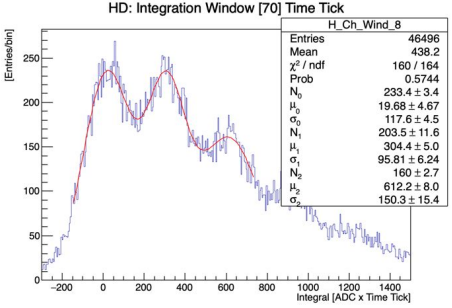


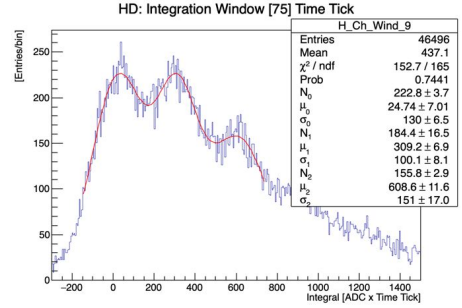




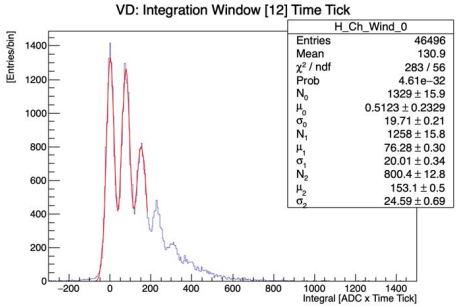


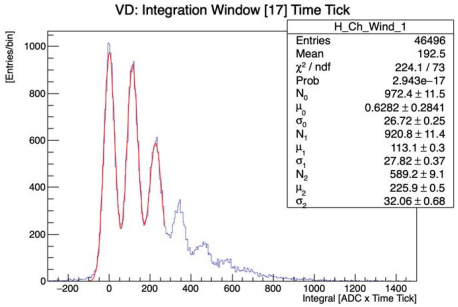


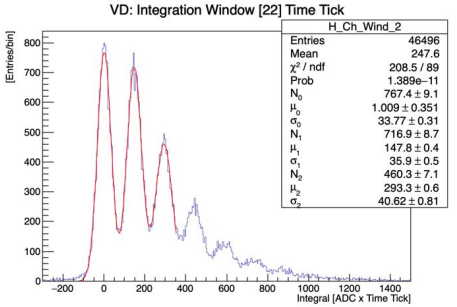


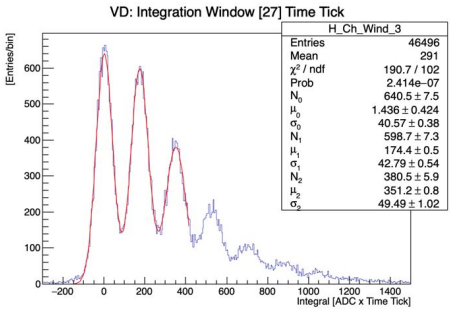


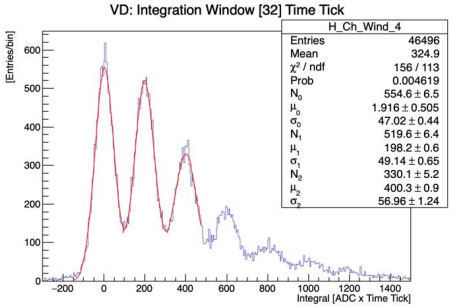
VD integral histograms

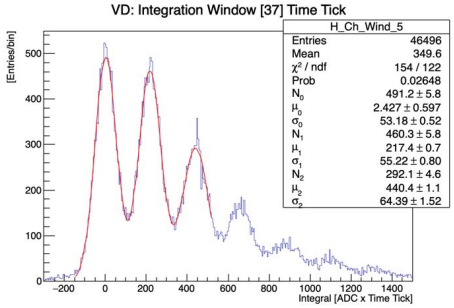


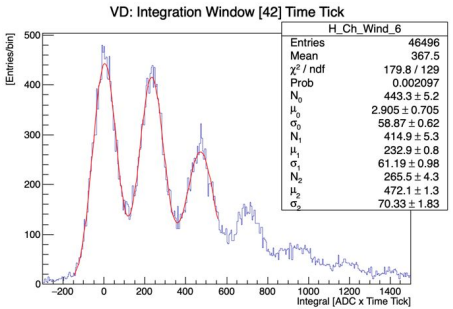


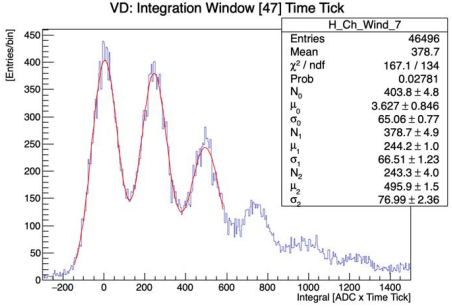


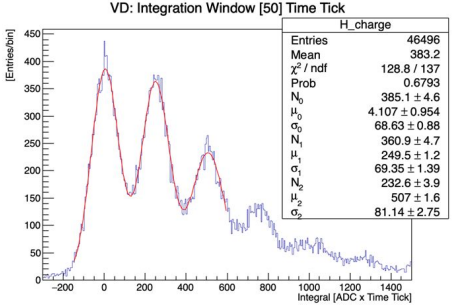


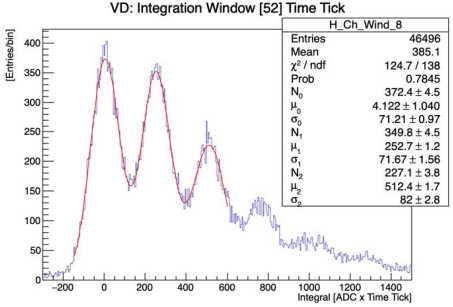


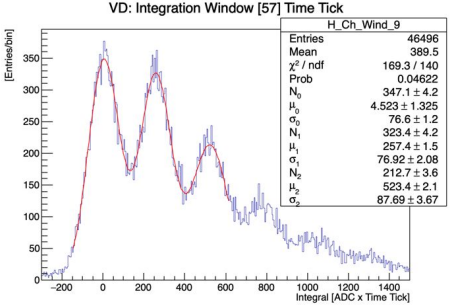








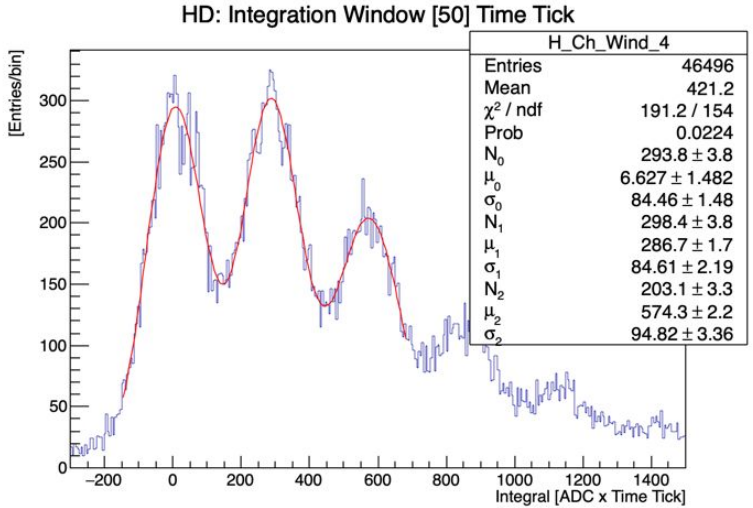




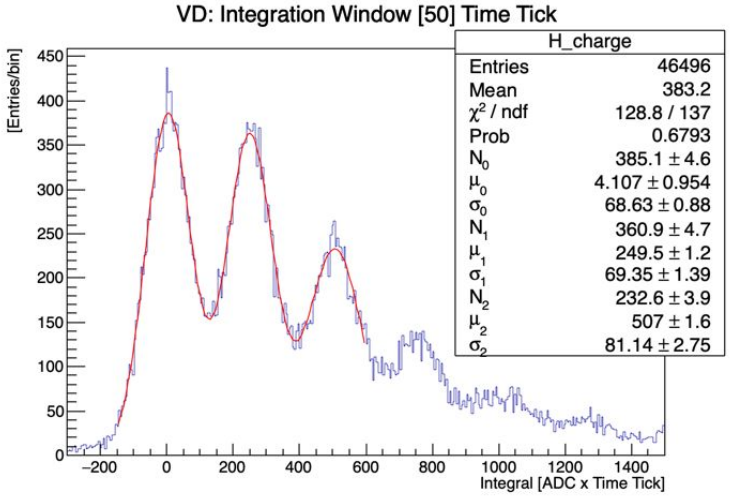
Integral histogram for the same integration window in both 50 ticks

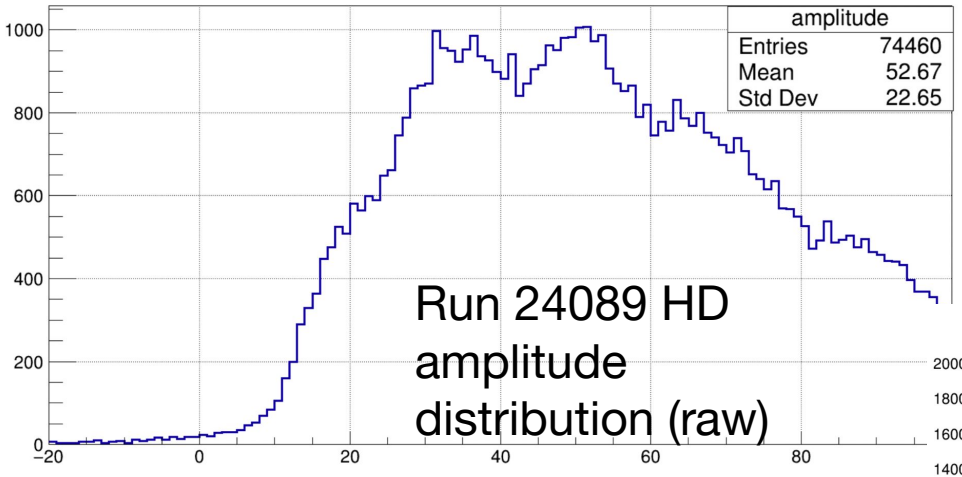
Note: 50 tick is the same window used by Federico

HD Max SNR = **3.3**



VD Max SNR = **3.6**

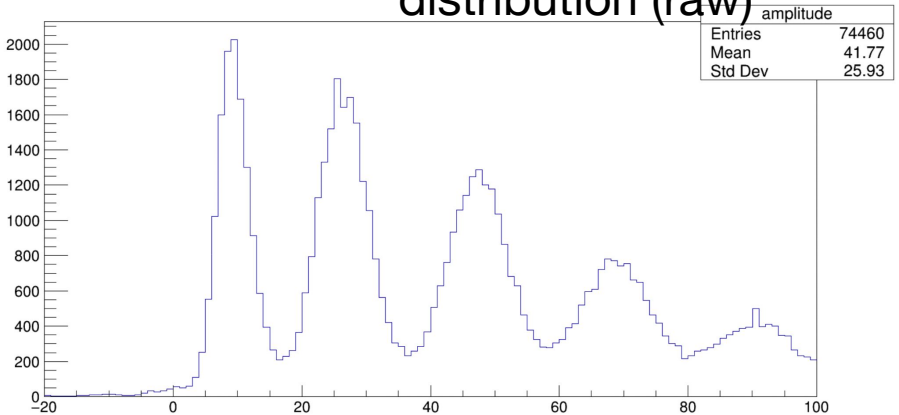




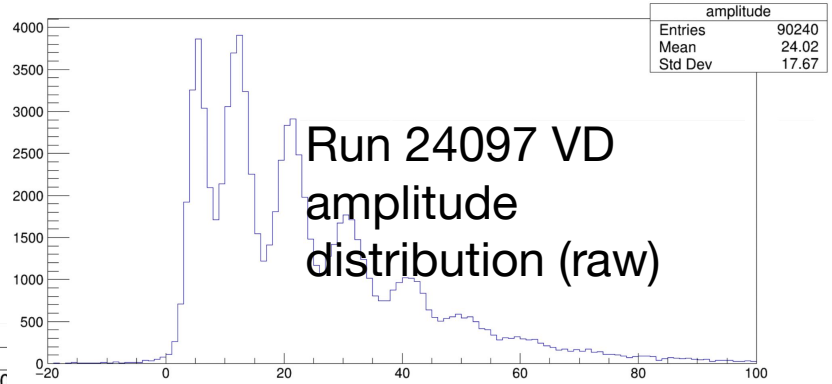
Run 24089 HD amplitude distribution (raw)

ADC

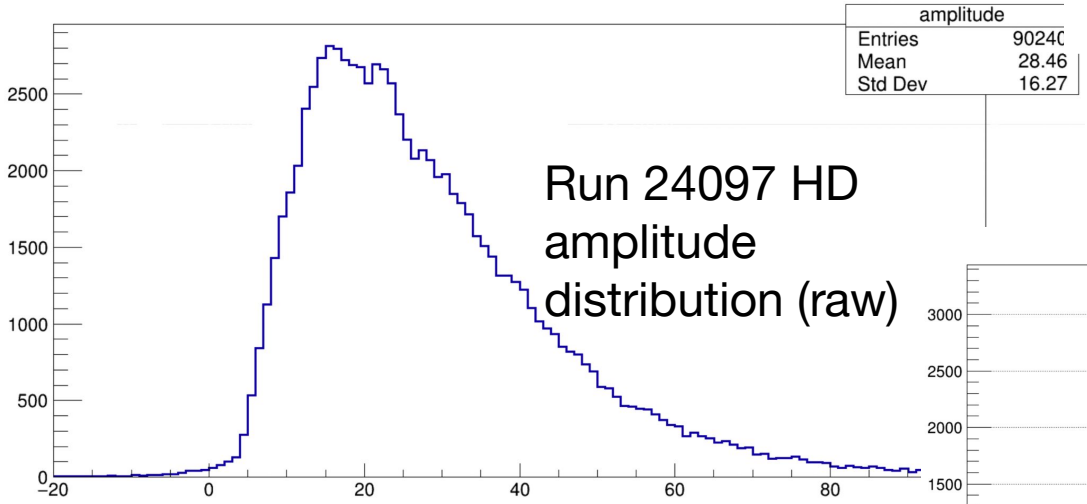
Run 24089 VD amplitude distribution (raw)



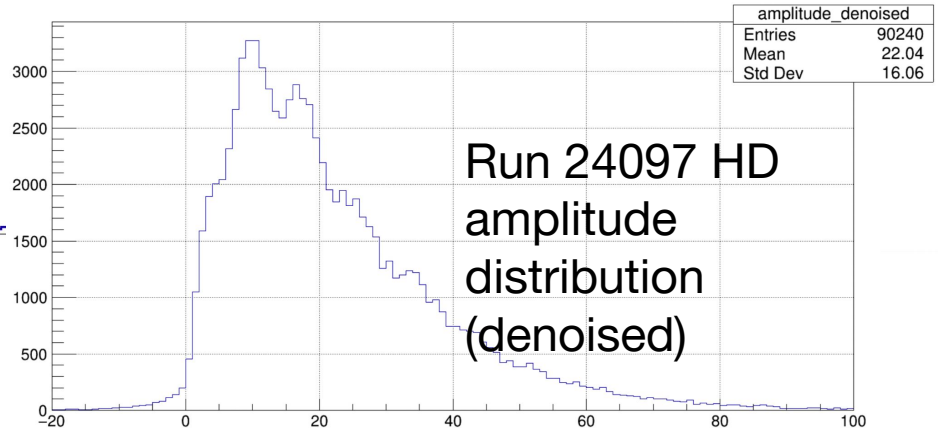
ADC



Run 24097 VD amplitude distribution (raw)

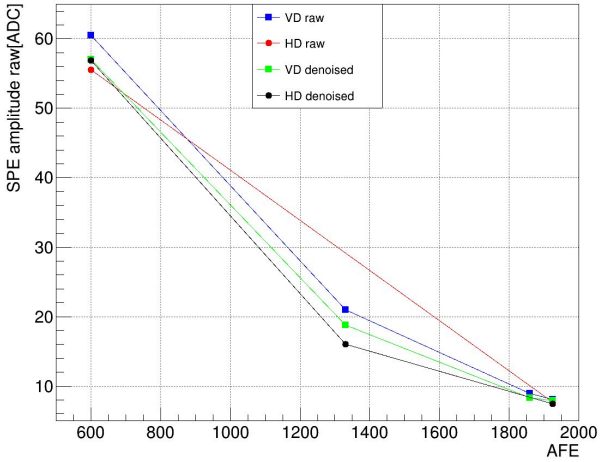


Run 24097 HD amplitude distribution (raw)

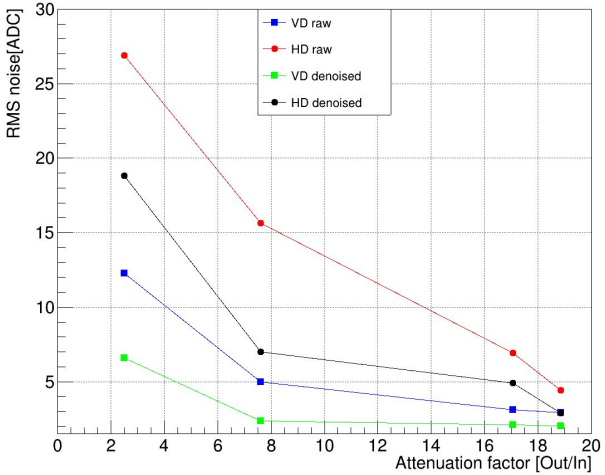


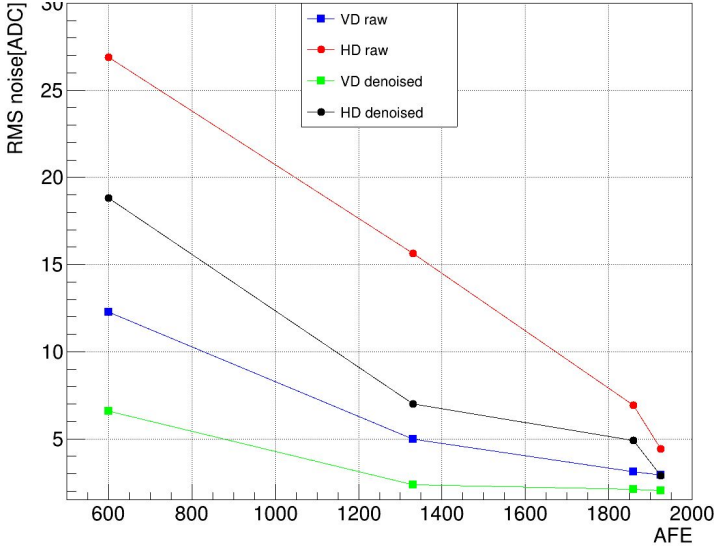
Run 24097 HD amplitude distribution (denoised)

AFE vs SPE amplitude



AFE vs RMS noise





Attenuation factor vs RMS noise