HD Electronic at MiB laboratories and at the Coldbox

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In this presentation

- Performance studies with 2 Daphnes and different AFEs
- Try to demostrate the reproducibility of the tests performed in different institutions and at the coldbox
- Assess possible limitation of the CB (if any)

In this presentation I show you a comparison between the outcomes of the second run of M1 and tests we conducted in Milan (MiB)

- Noise studies: FFTs with SiPMs biased below the breakdown voltage

  (many FFT plot -> headaches are guaranteed)
- SNR* and Dynamic Range evaluation
  - *Both integrals and RMS
  - Calibration with pulsed LED light

Setup and preliminary results: https://indico.fnal.gov/event/64355/contributions/289699/attachments/177182/241080/20240419_HD_AFEs.pdf

Noise studies @ coldbox

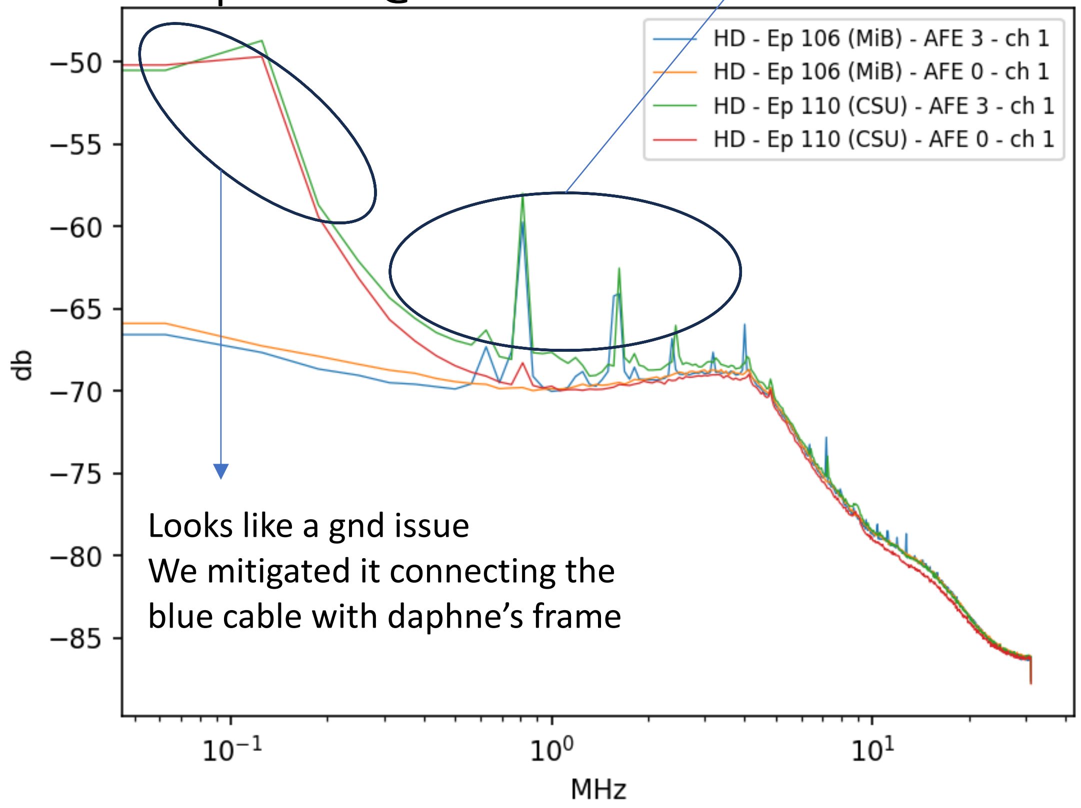
Two DAPHNEs – Two AFEs

PGA filter cutoff = 15MHz

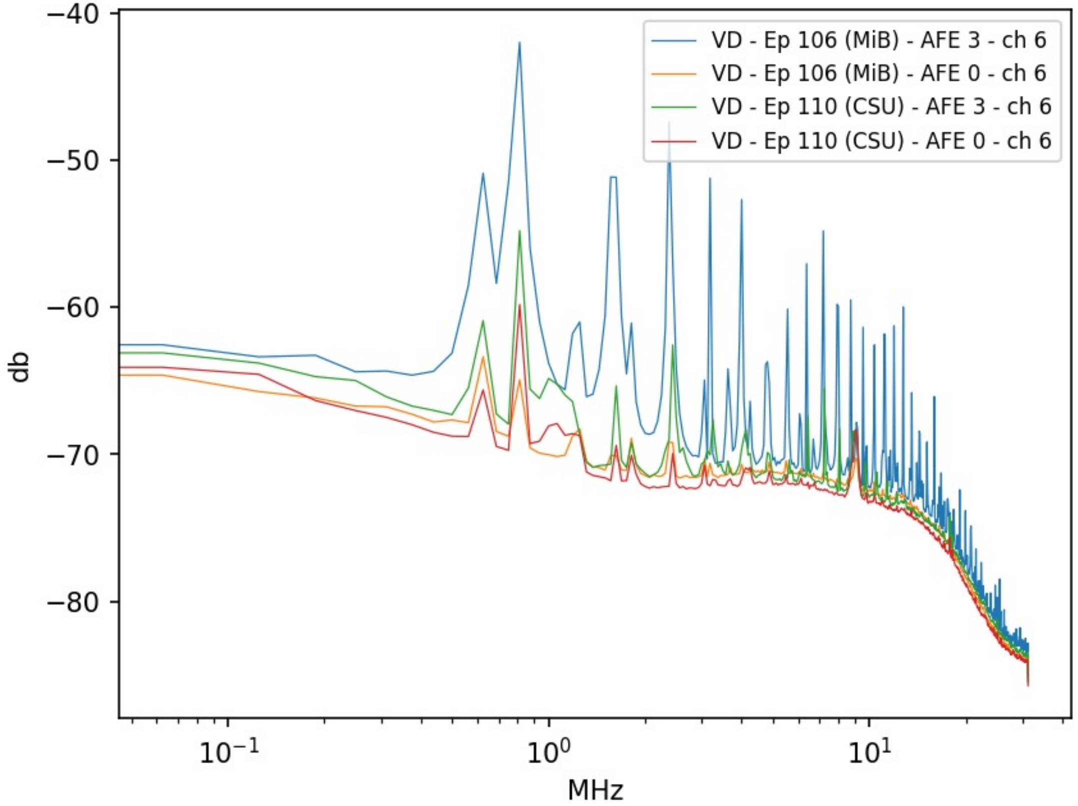
See next slides for one-to-one comparisons

Same spikes, same AFEs, different DAPHNEs

HD operated @ VGAIN = 0.7 V



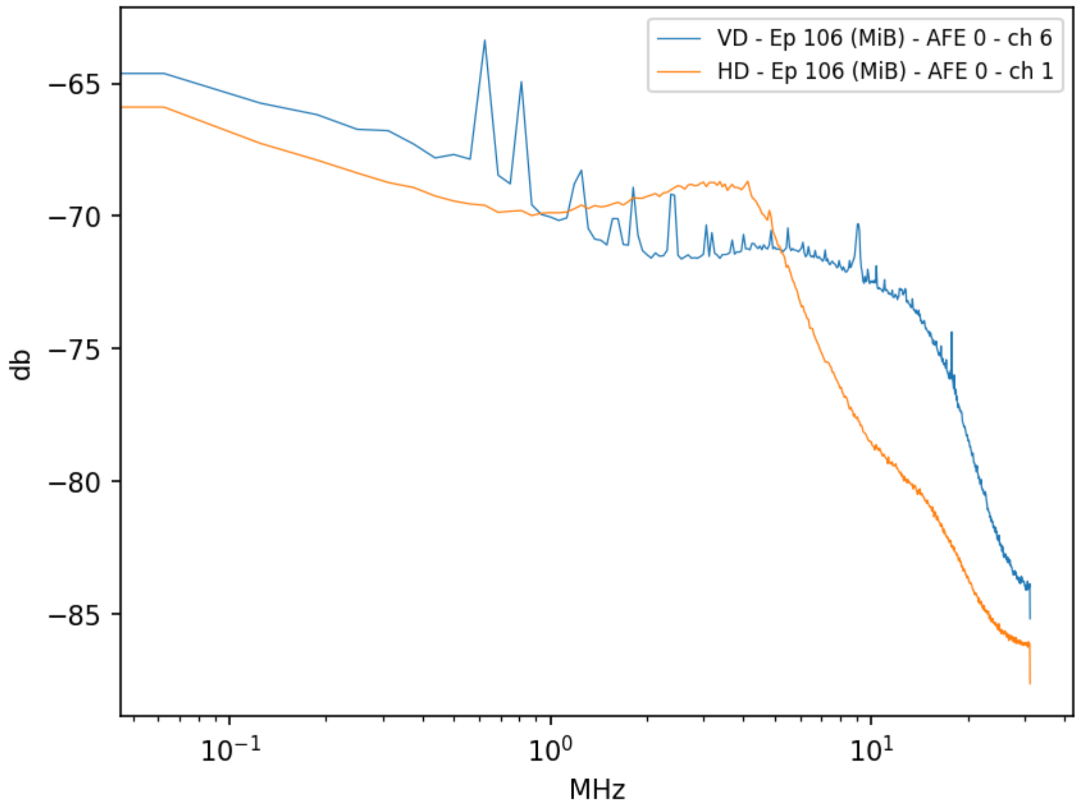
VD operated @ VGAIN = 0 V

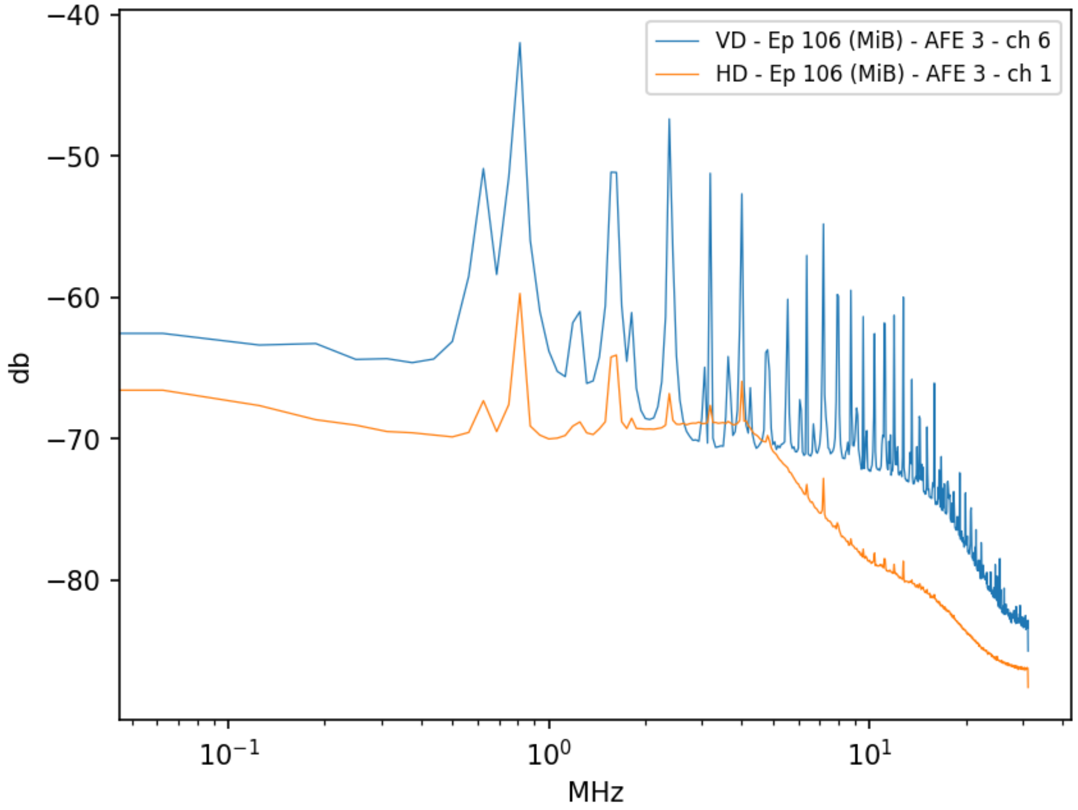


Endpoint 106

Aka Milano Daphne

Remember HD was read with VGAIN 0.7V and VD with 0V



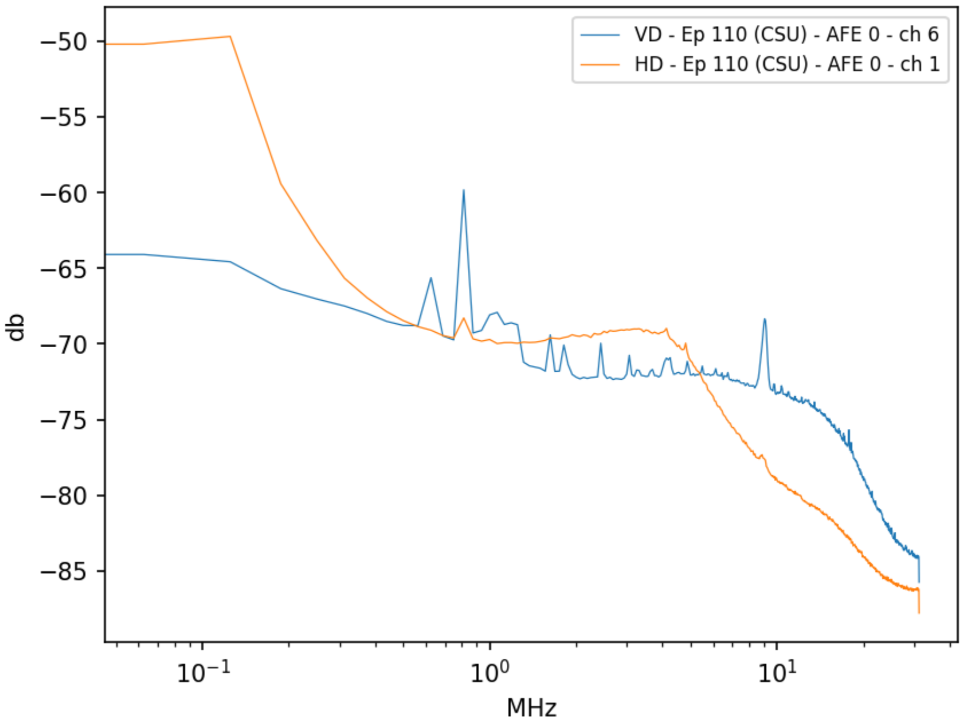


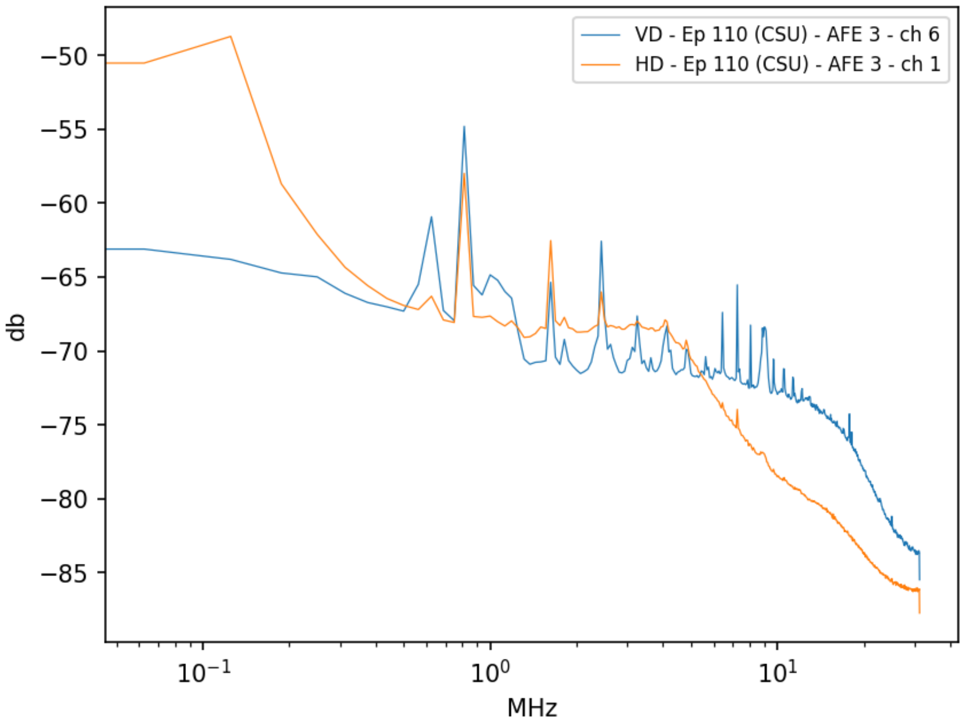
Endpoint 110

Aka CSU Daphne

Remember HD was read with VGAIN 0.7V and VD with 0V

My guess to explain why the grounding issue was affecting only HD is that VD had only a single differential pair in the DB15 connector, so the source of noise could come from the bias? This used to happen in Daphne V1 but should be solved in Daphne V2. So, I'm not very confident on this hypothesis. Any idea?



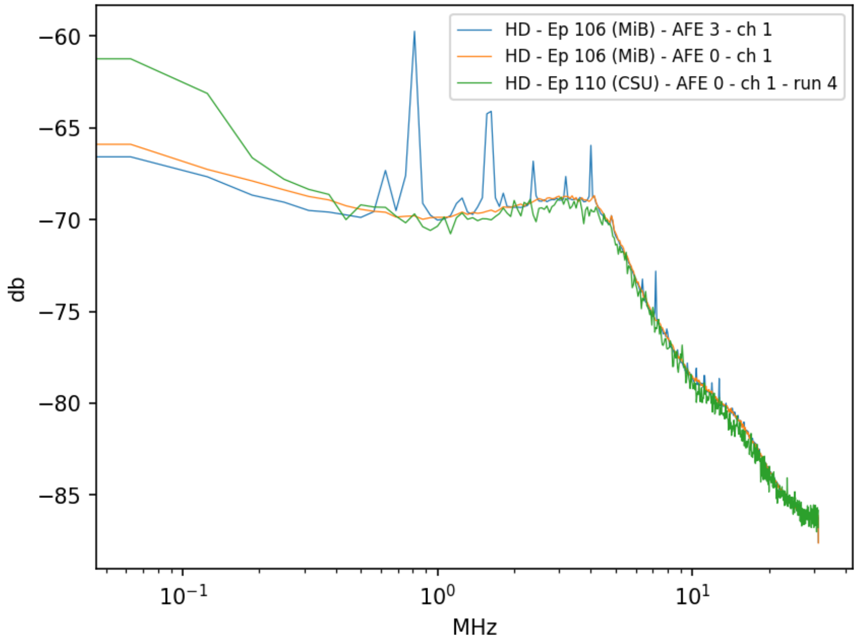


Endpoint 110

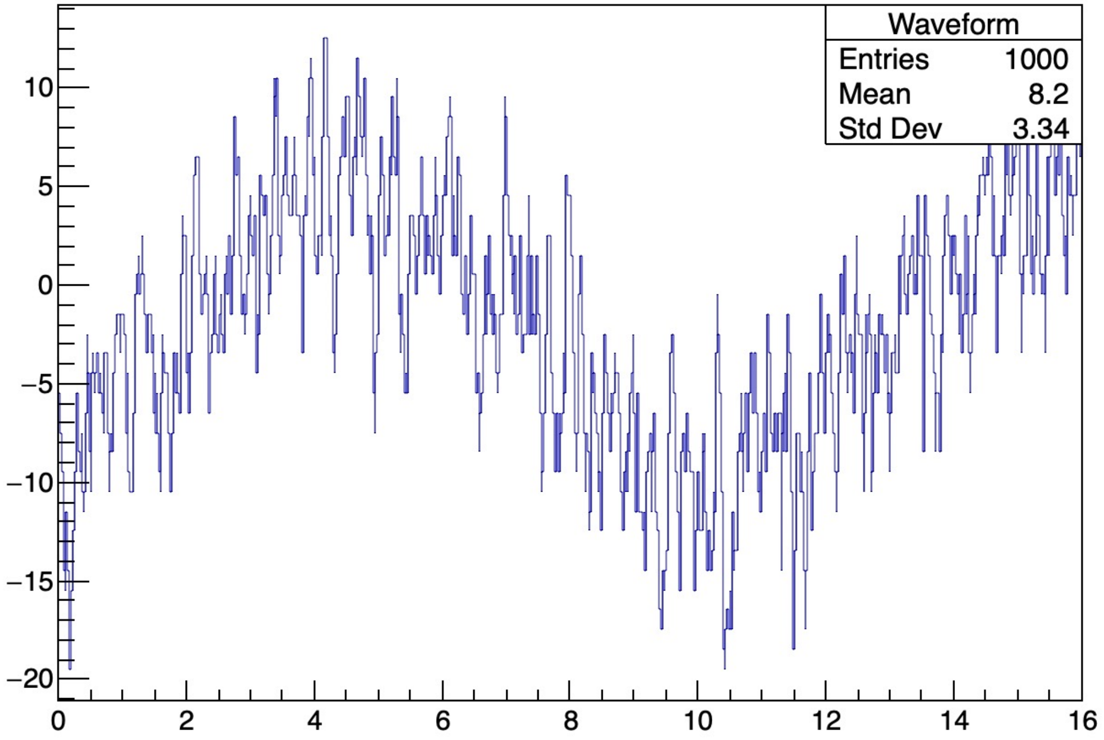
Aka CSU Daphne

The low frequency noise in CSU Daphne

To be fair, we have run 4 and run 5 where this noise is not so evident, but we obtain poor results in any case.



CSU DaphneAFE0 - noise run (previous slide)



MiB and CB

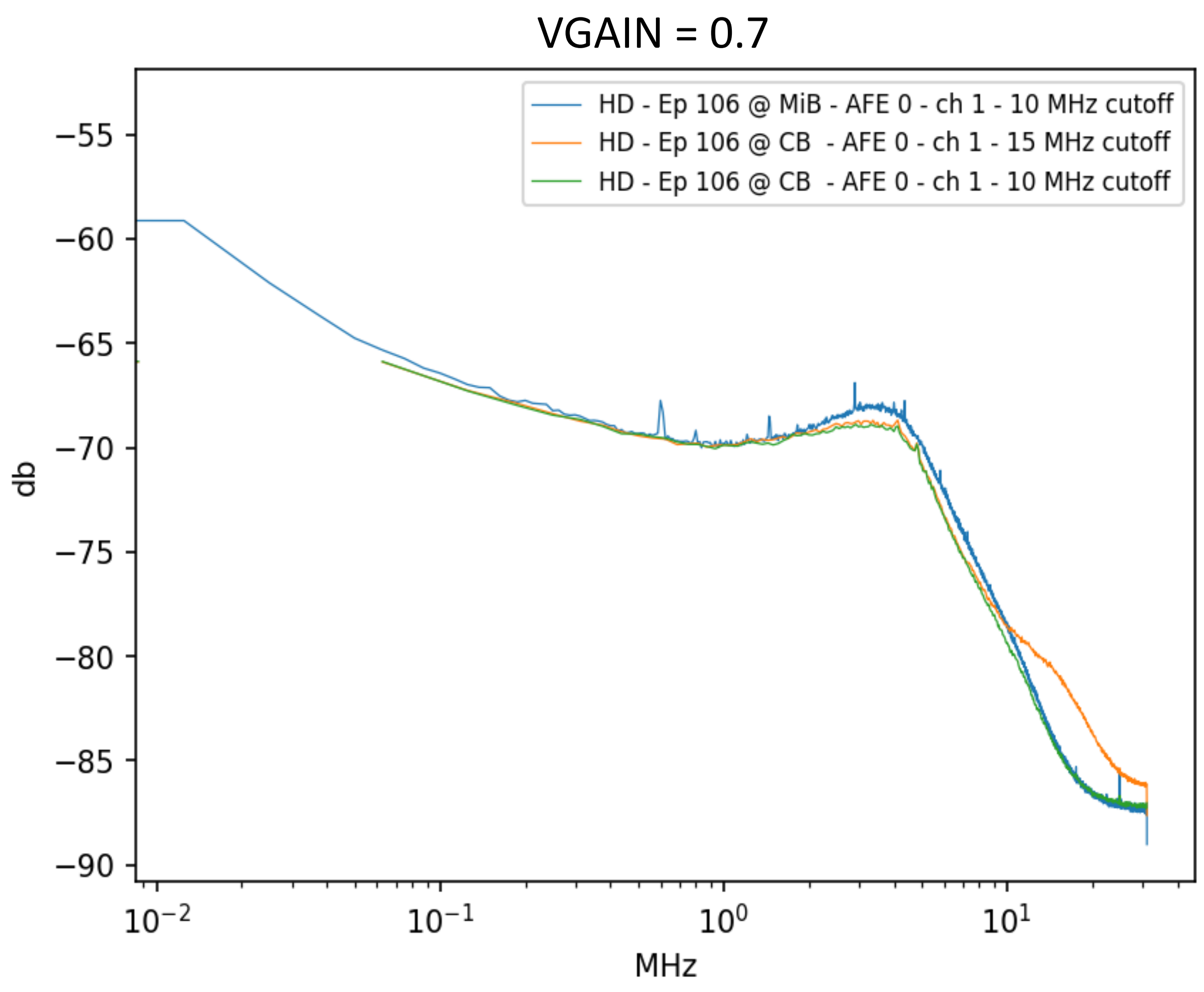
Comparison between the test-stands

How reproducible are our tests?

- Is the CB intrinsically noisier?
- … or the biggest difference comes from testing in LAr instead of liquid nitrogen?

We took data with two different cut-off frequencies in DAPHNE PGA filters

From the FFTs, it looks like that the level of the noise is almost the same in the two facilities



SNR and Dynamic range

Our beloved requirements

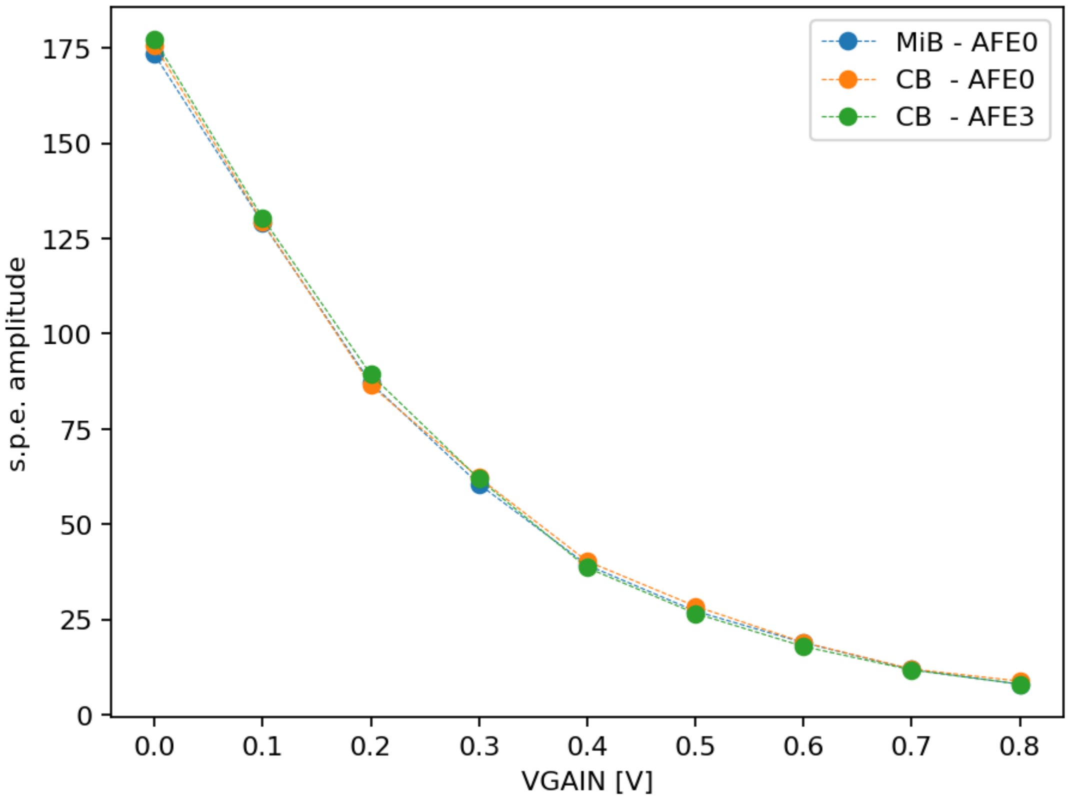
- A parameter to play with: VGAIN
  - The larger the VGAIN, the more is the attenuation: how this afffects the SNR
- Three possible SNR definition
  - Single p.e. integral / baseline fluctuations (integration window 52 ticks = 832 ns, **not fine-tuned**)
  - Single p.e. amplitude / baseline RMS
  - Single p.e. amplitude / baseline RMS - after a moving average of 20 tick length **(not fine-tuned**)
    - Note that this slightly decreases the s.p.e. amplitude
- Nominal Dynamic range: $\frac{Daphne\ resolution\ (2^{14}{=}16'384\ ADC)}{SPE\ peak{-}to{-}peak\ (Amplitude{+}undershoot)}$
  - Since we can move the offset, this is kind of realistic
- Having demonstrated that AFE3 is noisier, let's see the effect on SNR

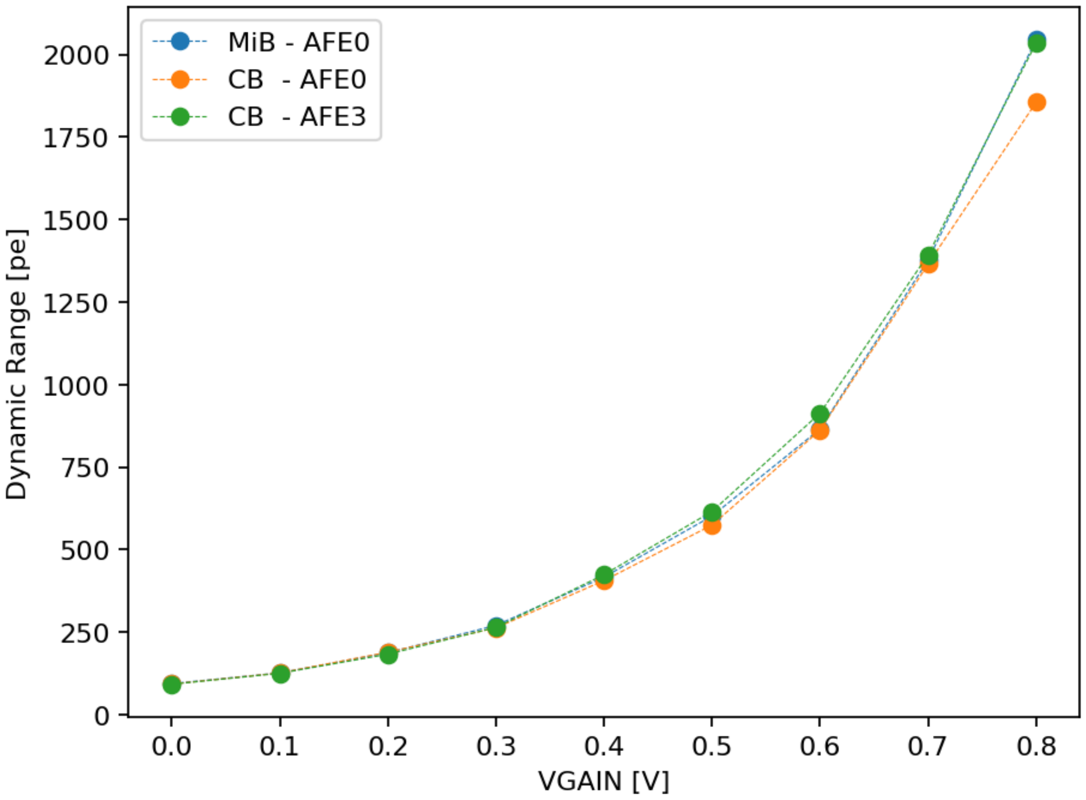
Let's go through the analyses and give them an interpetation

Signal and attenuation

The VGAIN effects

The VGAIN let us span in a large renge of s.p.e. amplitude and so dynamic range





SNR on the integrals

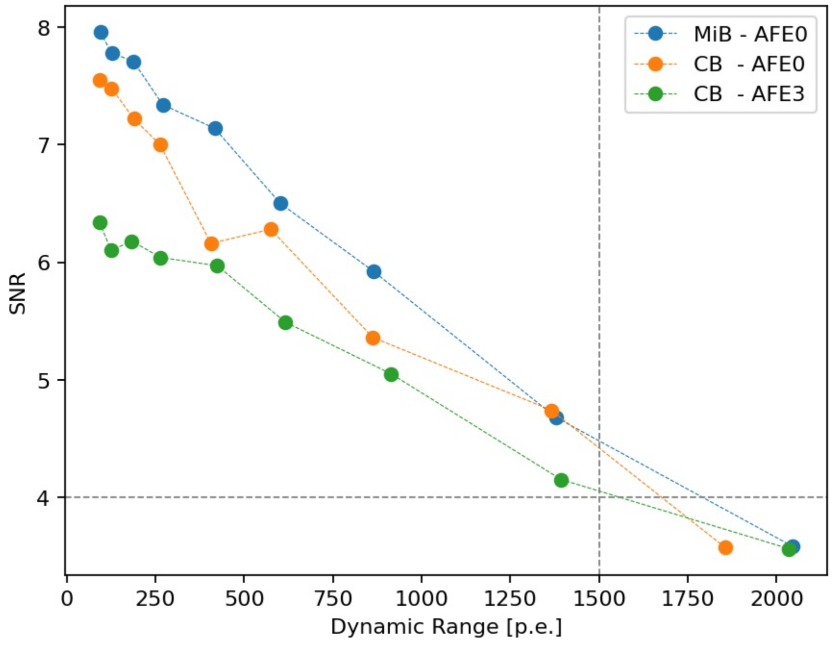
SNR vs DR or VGAIN

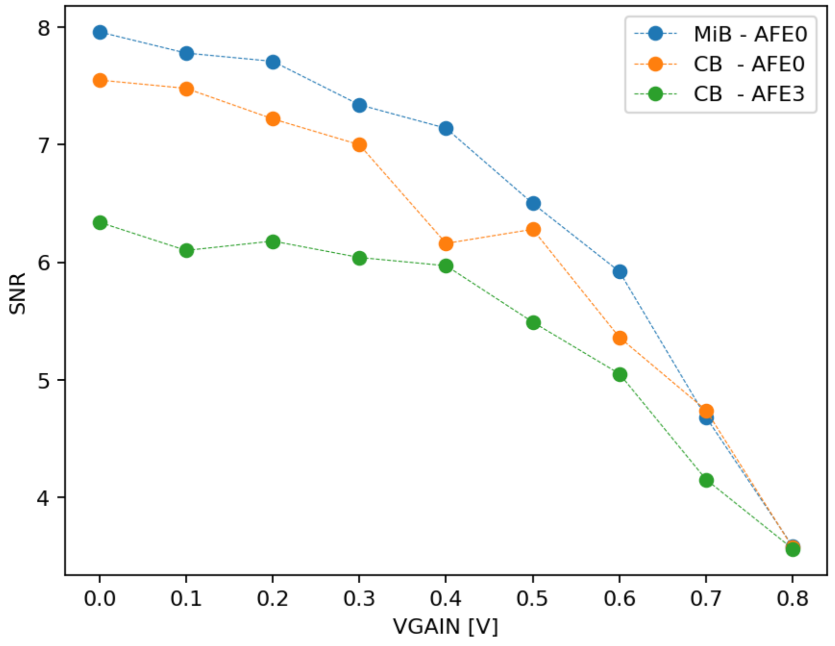
Even though we would expect a monotonic behaviour, the trend is clear

The AFE3 extra noise affects the SNR

About MiB > CB : since the s.p.e. amplitude observed in the two facilities and the FFTs of the noise are compatible, this might be due to a sub-optimal baseline computation due to scintillation light in the pre-trigger

With naïve calculus, I find this can the SNR of few percent and here we are observing a ~5% difference

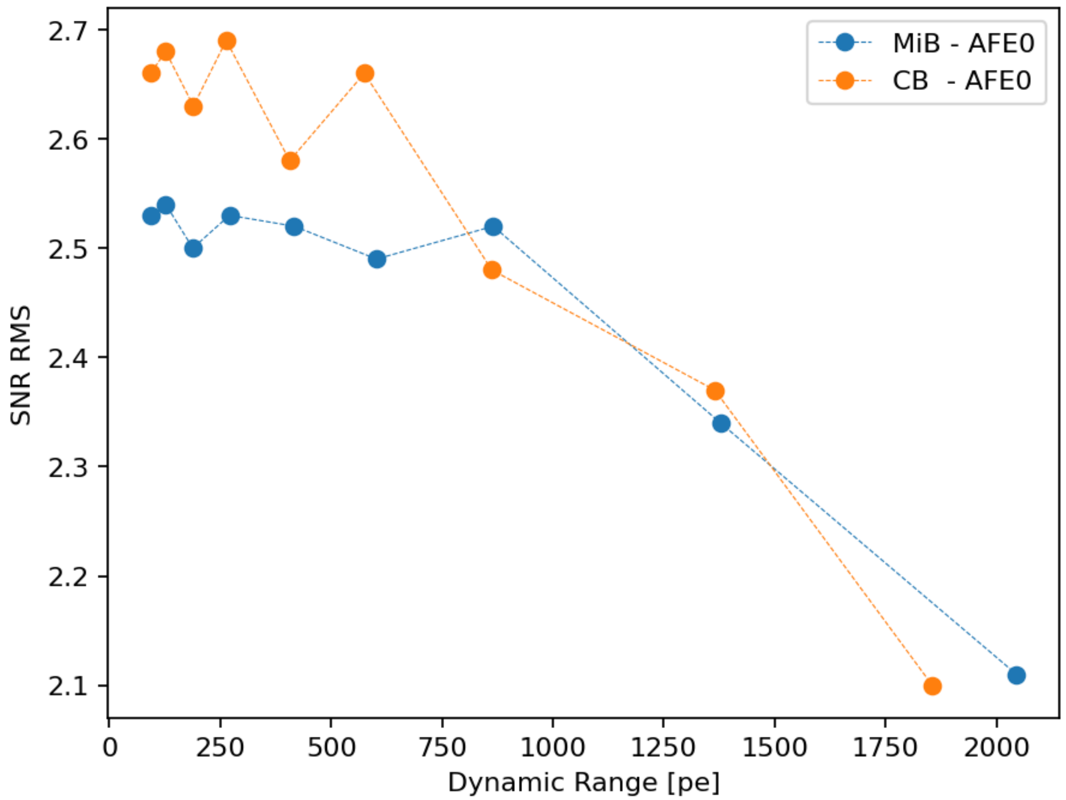


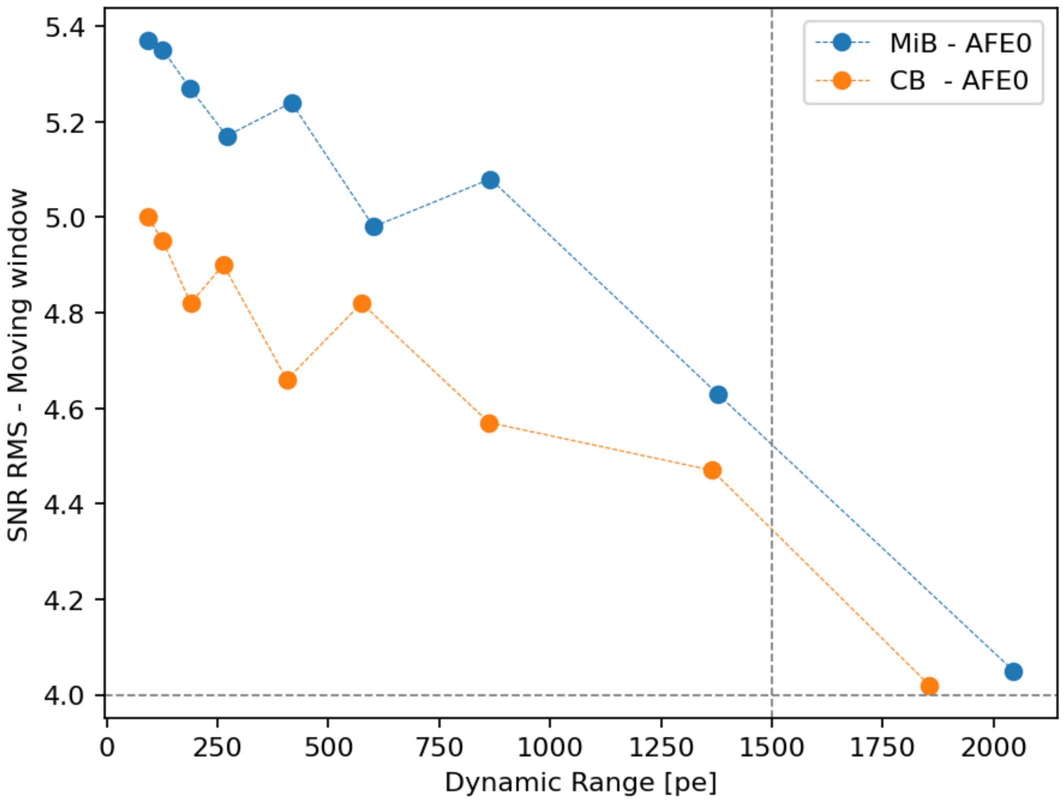


SNR with RMS

Raw and filtered waveforms

Quite interesting, the SNR with the RMS definition on filtered waveforms decreases slower than the one based on integral, for VGAIN=0.8 is even larger than it!





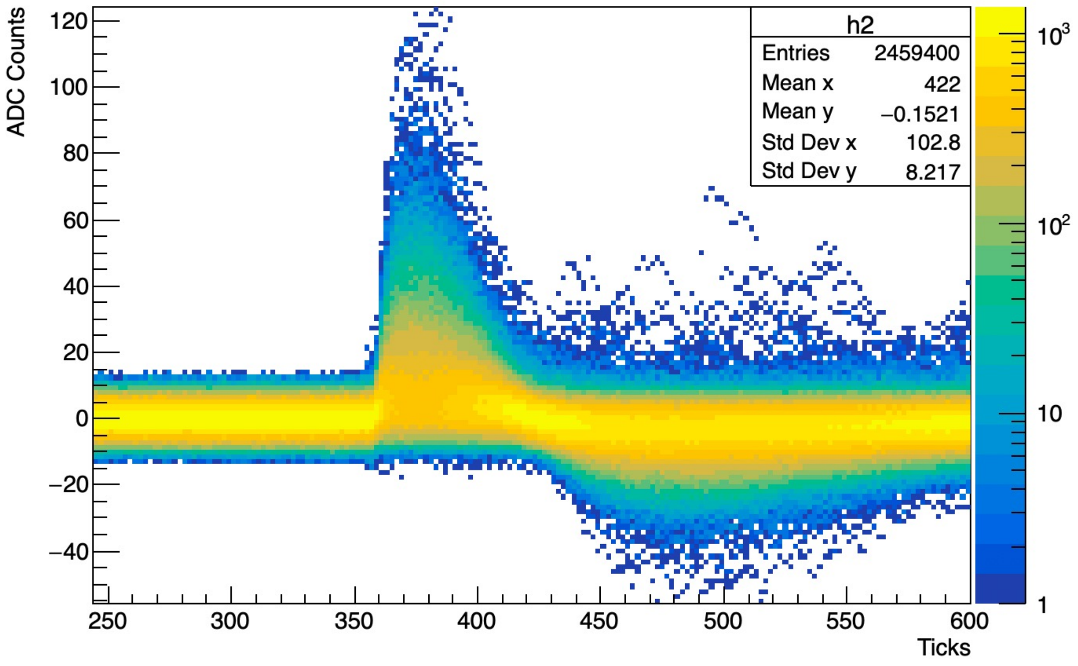
Persistence plots

Raw and filtered waveforms

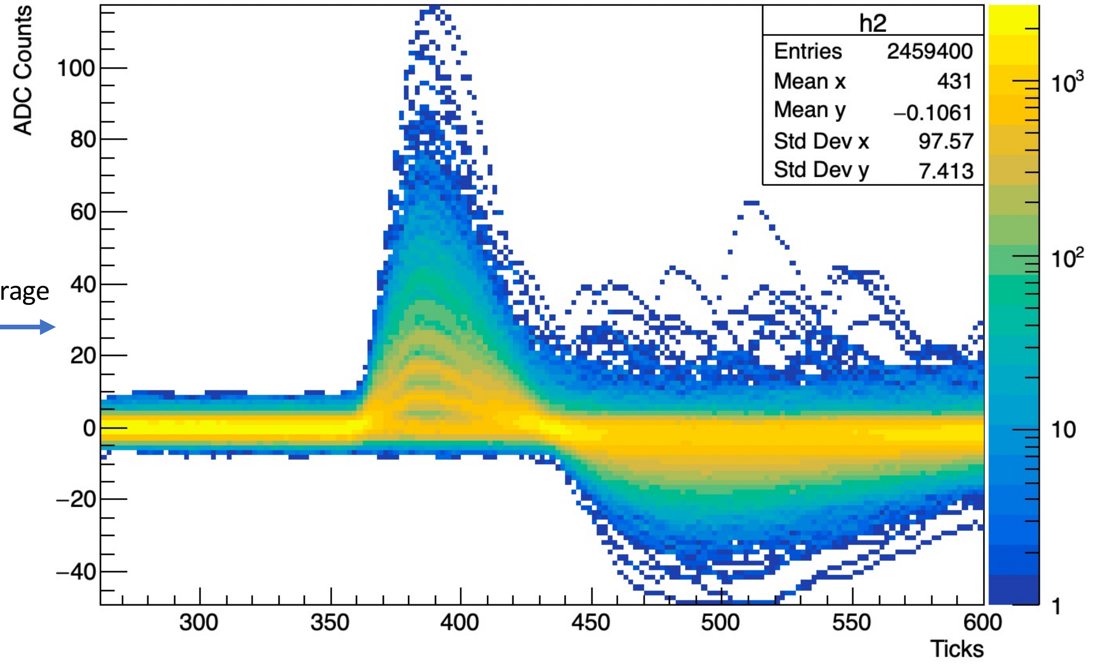
For all the analyses I requred that all the ticks in the pretrigger fall in the [-1.5 spe ampl;+ 1.5 spe ampl] range

An example from MiB data with VGAIN 0.7:

- DR 1’400 p.e. - SPE ampl 8.9 ADC – SPE undershoot 3 ADC
- SNR: integral = 4.7 – RMS = 2.3 – RMS moving average = 4.6



20 tick moving average



Table

Gain = integral over 52 ticks
S0 = Sigma 0 pe peak
Under = undershoot [ADC]
#WF = selected waveforms
SNR RMS = Spe ampl/RMS
Win 20 = using a 20 tick mov avg

Milano - HD - DAPHNE 106 - AFE 0 - CH 1 - SiPM FBK - Bias 32.5 V - Liquid Nitrogen												
Vgain	GAIN	S0	SNR	SPE AMPL	UNDER	BSL	#WF / 30k	RMS	SNR RMS	SPE ampl win 20	RMS win 20	SNR RMS win 20
0.0	4765.10	598.95	7.96	127.68	45.27	191.52	26300	50.55	2.53	122.17	22.76	5.37
0.1	3515.14	451.61	7.78	94.60	34.40	141.89	26500	37.28	2.54	91.14	17.03	5.35
0.2	2428.45	315.11	7.71	64.35	22.70	96.53	26200	25.78	2.50	62.58	11.88	5.27
0.3	1677.70	228.66	7.34	45.34	15.20	68.01	27100	17.92	2.53	43.34	8.38	5.17
0.4	1083.55	151.83	7.14	29.34	10.04	44.01	26500	11.63	2.52	28.05	5.35	5.24
0.5	747.77	114.96	6.50	20.27	6.91	30.41	26300	8.15	2.49	19.43	3.90	4.98
0.6	506.32	85.54	5.92	14.31	4.63	21.46	26100	5.68	2.52	13.66	2.69	5.08
0.7	326.33	69.76	4.68	8.86	3.03	13.29	23700	3.78	2.34	8.43	1.82	4.63
0.8	222.62	62.14	3.58	5.95	2.06	8.92	16750	2.82	2.11	5.72	1.41	4.05

Coldbox - HD - DAPHNE 106 - AFE 0 - CH 1 - SiPM FBK - Bias 32.5 V - Liquid Argon												
Vgain	GAIN	S0	SNR	SPE AMPL	UNDER	BSL	#WF / 10k	RMS	SNR RMS	SPE ampl win 20	RMS win 20	SNR RMS win 20
0	4760.00	630.00	7.55	131.00	44.70	196.00	6900	49.20	2.66	125.00	25.00	5.00
0.1	3550.00	475.00	7.48	98.00	31.30	147.00	7160	36.50	2.68	92.52	18.69	4.95
0.2	2450.00	340.00	7.22	67.05	19.40	101.00	7100	25.50	2.63	64.11	13.29	4.82
0.3	1700.00	242.00	7.00	47.40	14.80	71.10	7100	17.60	2.69	44.61	9.10	4.90
0.4	1100.00	178.00	6.16	30.31	10.00	45.50	7150	11.76	2.58	28.80	6.18	4.66
0.5	753.00	120.00	6.28	21.50	7.00	32.30	7025	8.07	2.66	20.00	4.15	4.82
0.6	512.00	95.60	5.36	14.20	4.80	21.40	6900	5.74	2.48	13.50	2.95	4.57
0.7	328.00	69.30	4.74	9.00	3.00	13.50	5800	3.80	2.37	8.48	1.90	4.47
0.8	233.00	65.30	3.57	6.38	2.45	9.57	4300	3.04	2.10	5.96	1.48	4.02

Coldbox - HD - DAPHNE 106 - AFE 3 - CH 1 - SiPM FBK - Bias 32.5 V - Liquid Argon												
Vgain	GAIN	S0	SNR	SPE AMPL	UNDER	BSL	#WF / 10k	RMS	SNR RMS	SPE ampl win 20	RMS win 20	SNR RMS win 20
0	4770.00	752.84	6.34	131.00	46.20	196.50	6500	53.40				
0.1	3518.13	576.72	6.10	98.70	31.70	148.05	6600	39.70				
0.2	2416.37	390.75	6.18	67.90	21.40	101.85		27.30				
0.3	1652.32	273.69	6.04	46.30	15.60	69.45	6700	18.50				
0.4	1056.85	177.13	5.97	29.00	9.60	43.50		11.90				
0.5	724.85	132.12	5.49	20.00	6.60	30.00		8.25				
0.6	484.62	95.90	5.05	13.40	4.53	20.10	6800	5.71				
0.7	317.38	76.40	4.15	8.68	3.08	13.02	5700	3.89				
0.8	214.89	60.31	3.56	5.89	2.16	8.84	4620	2.86				

Conclusion

… and plans

- The waveform selection applied was an attempt to make the comparison as fair as possible, reducing the impact of having light in the pre-trigger
    - I loose about 15% of the statistics when analyzing liquid nitrogen data (MiB) and about 30% in LAr (CB)
    - The remaining statistic is enough to consider the SNR estimates reliable (demonstrated here)
- The baseline RMS was computed looking at the pre-trigger of calibration run. Then, I cross-checked the results using noise data (SiPM bias < breakdown) and they were ok
- To be further invesigated:
    - AFE 3 noise – Is it something in common among the Daphnes?
    - CSU Daphne – noise with the bias? Or grounding at the coldbox?

THANKS SAM AND HENRIQUE!