SoLID HGC update

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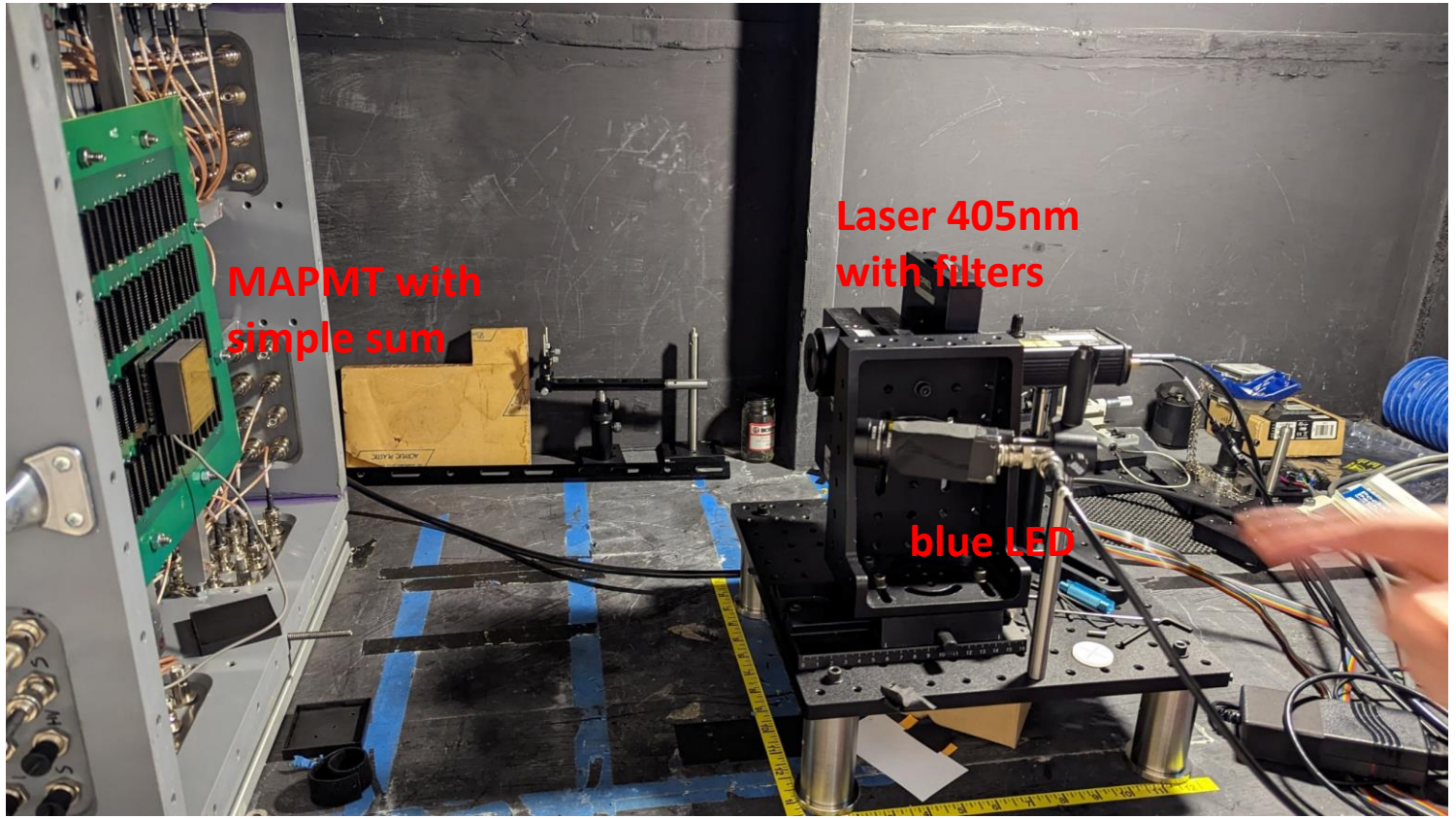
2023/12

Carl's test stand

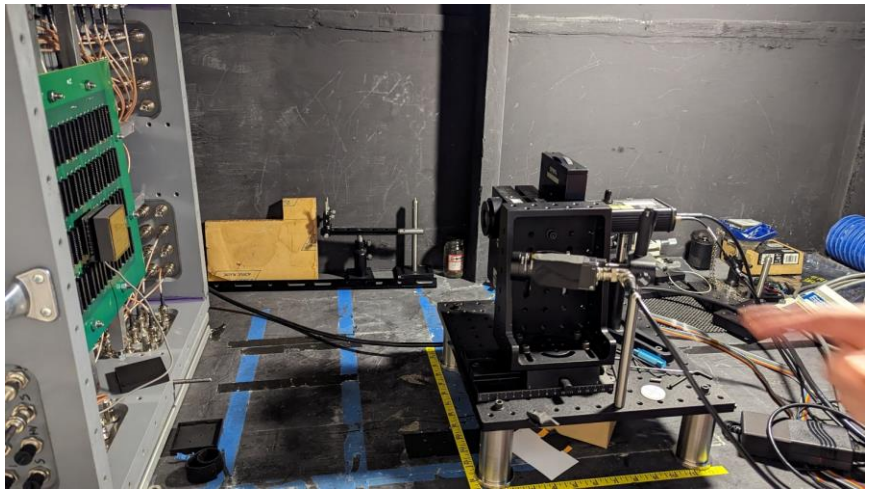
https://solid.jlab.org/wiki/index.php/Cherenkov_readout#Carl_test

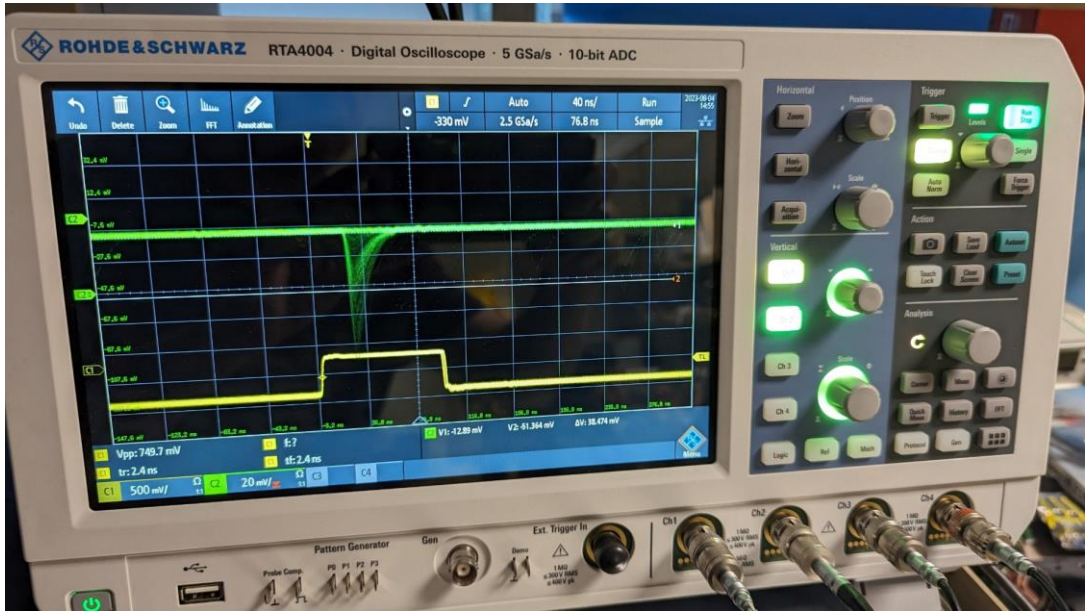
- In a large black box at ARC L215
- Laser with adjustable filters as signal with small number of photons
- LED as background with single photon at high rate
- Both have light diffused

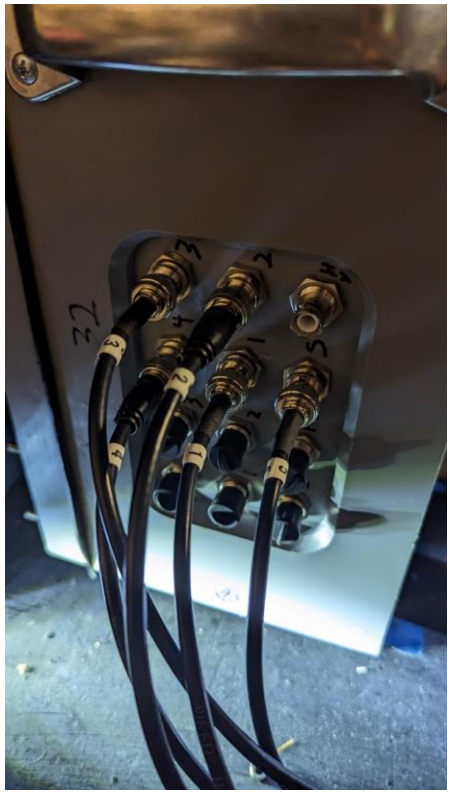


Test object 1

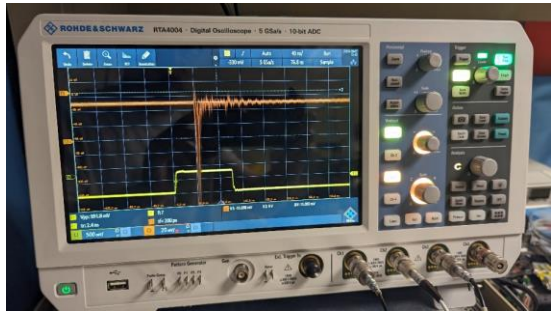
- MAPMT with 16-pmt simple sum readout board (2020 beamtest)
  - H12700-03 (SN HA0011) at position 32 (not the original PMT at this position)
    - HA0011 got WLS coating removed by accident before this test
  - 4 quad simple sum signal are positive and 1 sum signal is negative
    - signal wide ~50ns without oscillating tails
    - Simple sum board has ~10x amplifier, so no NIM amplifier used at this test







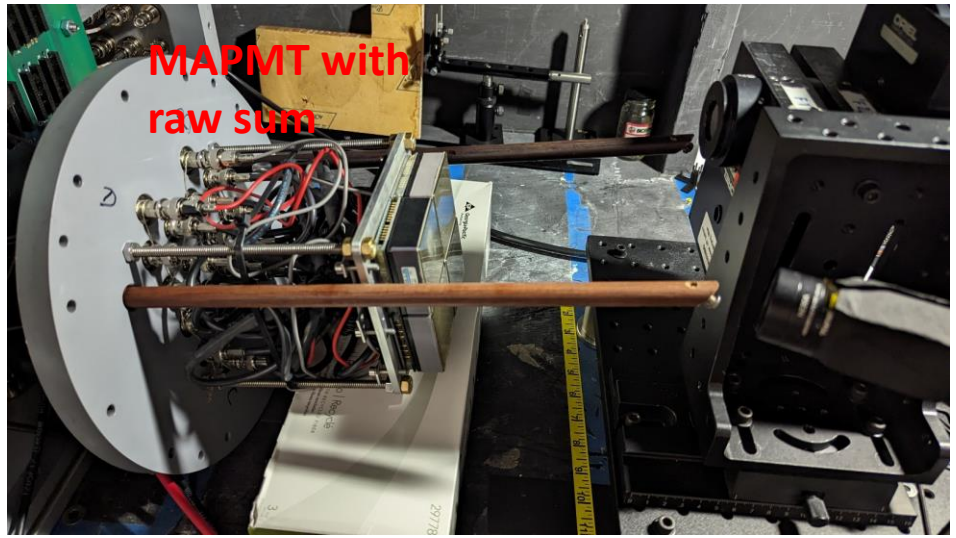
Test object 2

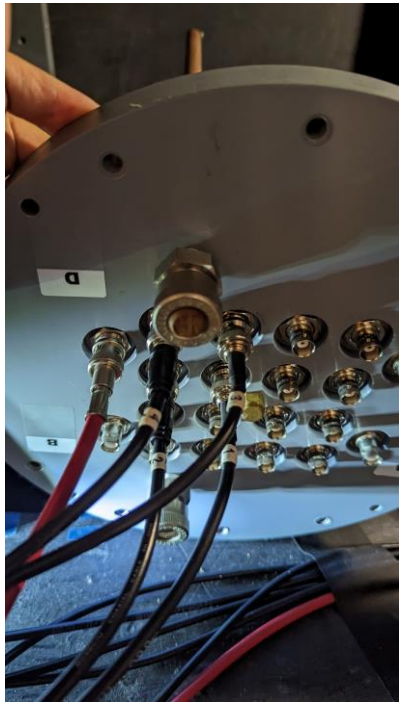


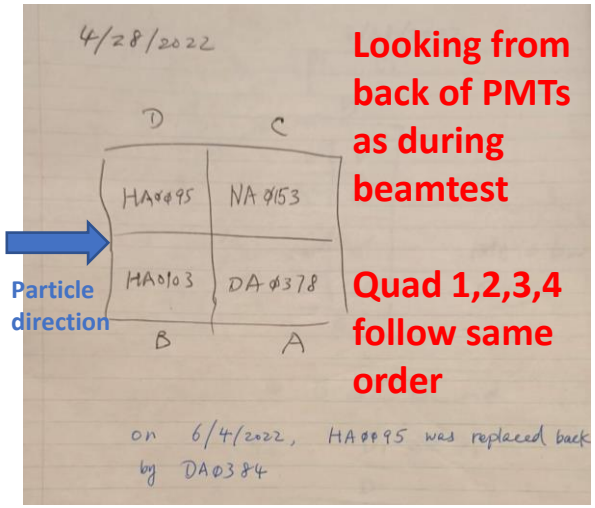
- MAPMT with raw sum readout (2022 beamtest)
  - PMT-D, H8500-03 with SN DA0384
  - PMT-B, H12700-03(?) with SN HA0103
  - PMT-A, H8500-03 with SN DA0378
  - PMT-C, H12700-03(?) with SN NA0153
  - (D and A can see labels, but B and C labels are hidden when installed. 2020 test paper mentioned 2 H8500-03 and 2 H12700-03 were used)

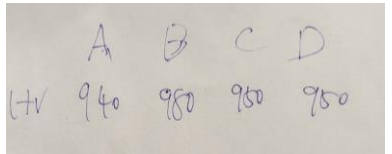
  - 4 quads of raw sum signals are negative
    - signal wide ~20ns with oscillating tails
    - 10x NIM amplifier used for this test

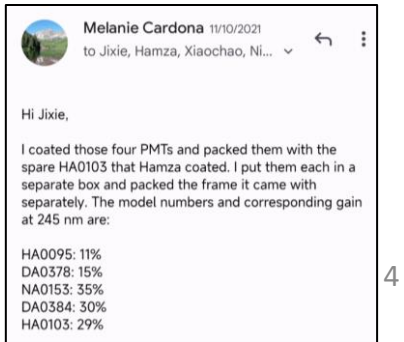
  - During beamtest, the readout is on the right side of tank looking from front. pmt B and D with two poles holding mirror are at front. pmt A and C are at back
  - Quad1,2,3,4 are shown on the photo, following PMT A,B,C,D order
  - During beamtest, 10x NIM amplifier used for 18deg, but no amplification for 82deg or 7deg









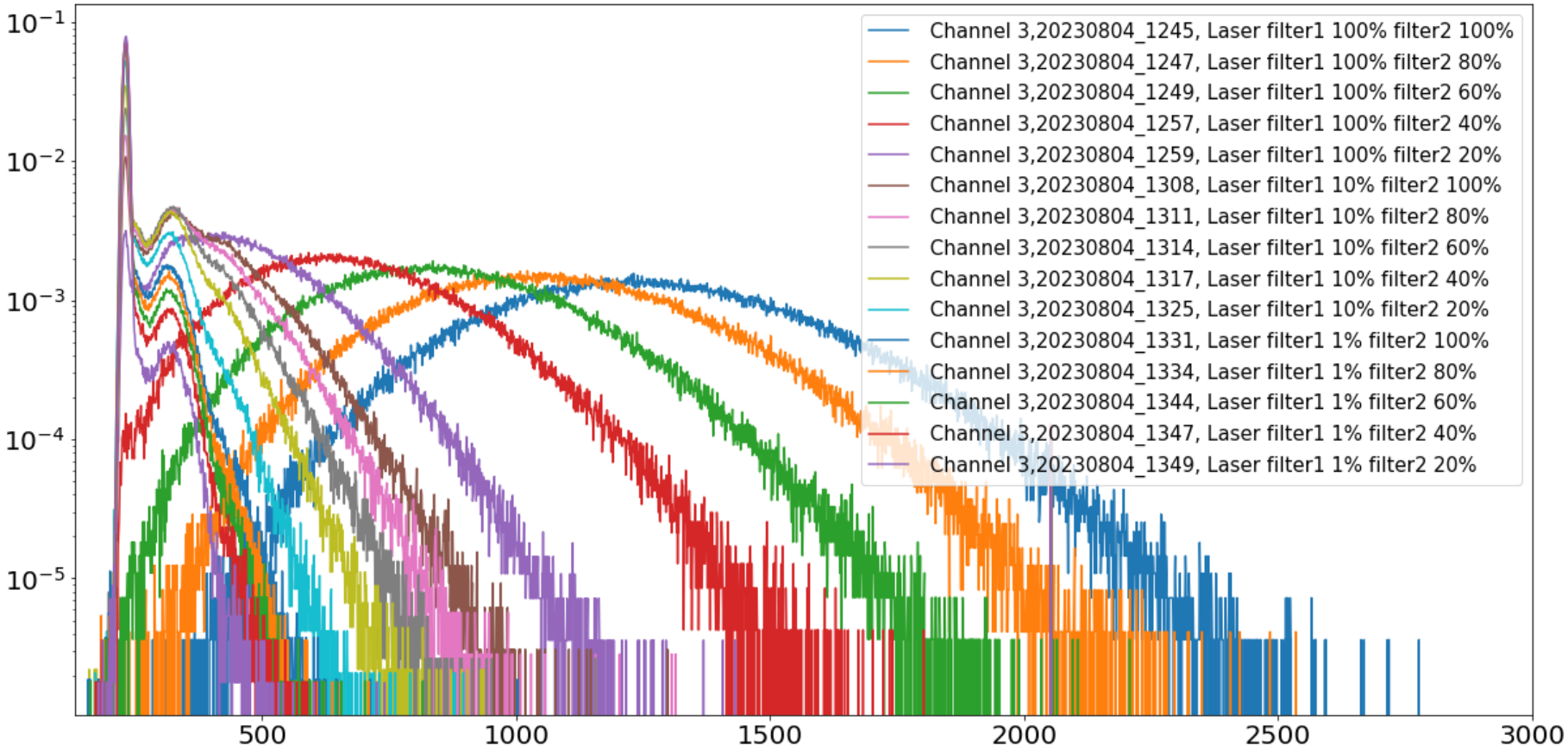


Result Summary

- Simple sum
  - Signal shape good with its built-in ~10x amplifier
  - pedestal shift to higher adc with light
  - Pedestal shift to lower adc and widen with high rate background
  - No obvious linearity problem at high rate background
  - No problem for gain and HV relation
- Raw sum
  - Signal shape has tails and some weird shape and it needs external amplifier
  - pedestal shift to higher adc with light slightly also
  - Pedestal not affected much by high rate background
  - No obvious linearity problem at high rate background
  - No problem for gain and HV relation

simple sum PMT (only light changes)

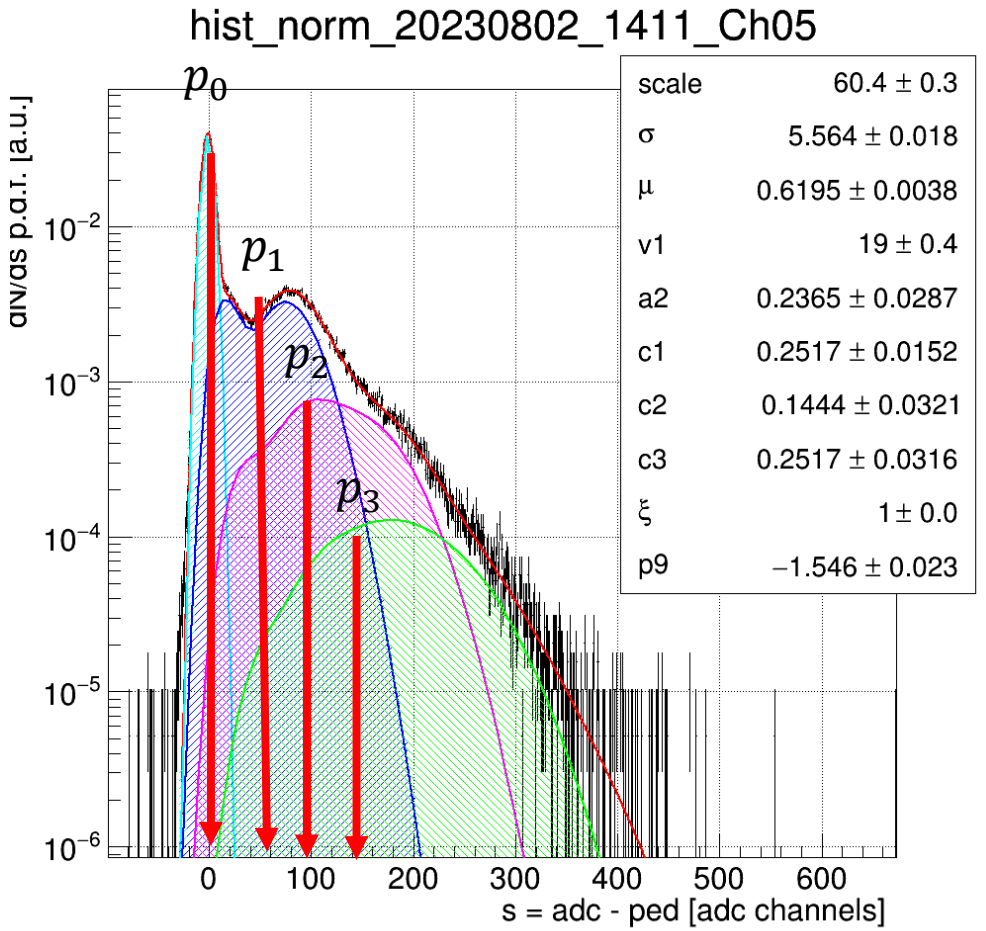
- Raw adc readings



Characterization of PMT response at low light

- External parameters (Poisson function convoluted with PMT response function)
- NPE follows Poisson distribution (mean μ)
- $\int p_m(s)ds = m * scale$ (scale/SPE)
- Pedestal position s_{ped} controlled by baseline currents
- resolution σ

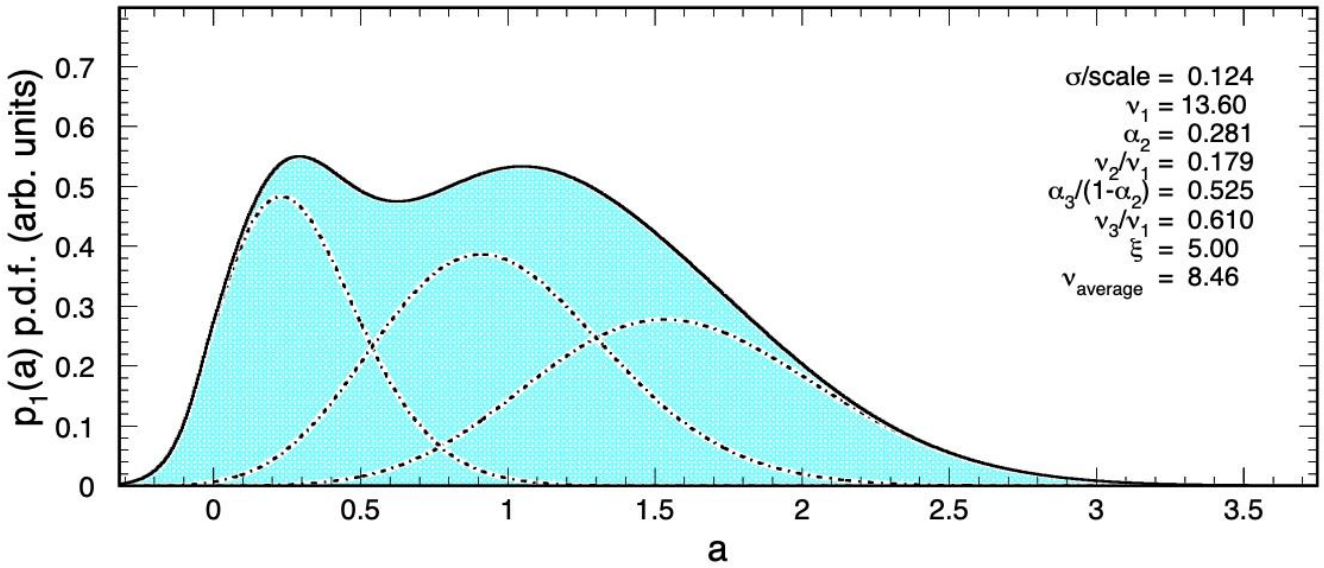
scale/SPE is lower than the first bump (could help understand why beamtest data has less NPE than sim?)



Follow papers on MAPMT pixel adc fitting (arxiv:1608.07525 and arxiv: 2202.07776), and apply the fit to quad and total sum

Characterization of PMT response at low light

- Internal parameters (PMT response function)
- 3 distinct regions with multiplication factor υ_i and portion α_i $(\alpha_1 = 1 - \alpha_2 - \alpha_3)$
- The statistical spread on the following dynodes described by ξ

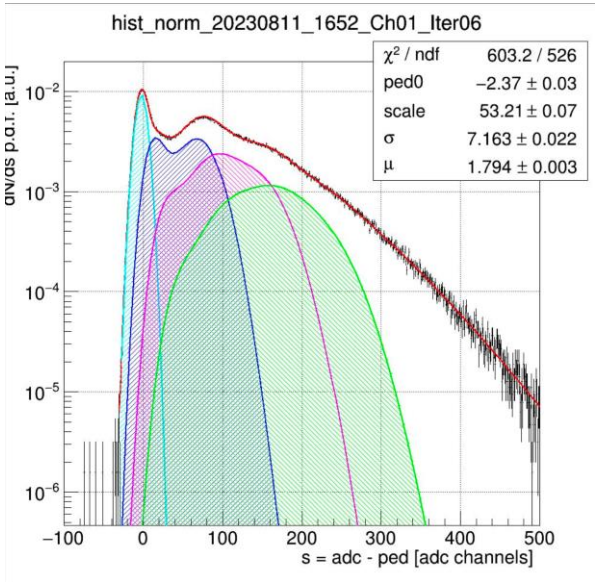


Characterization of PMT response at low light

- For datasets that only vary on light
- Global fit procedure to reach convergence across different runs
- Cycle of fitting: all parameter fit

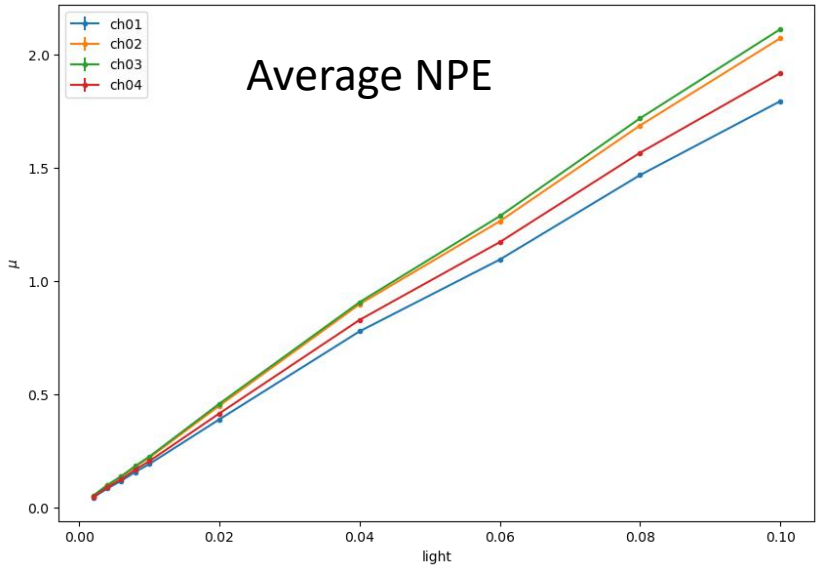
  average and fix internal parameters

  re-fit the external parameters
- Internal parameters characterize the PMT response
- Can be used in more general conditions



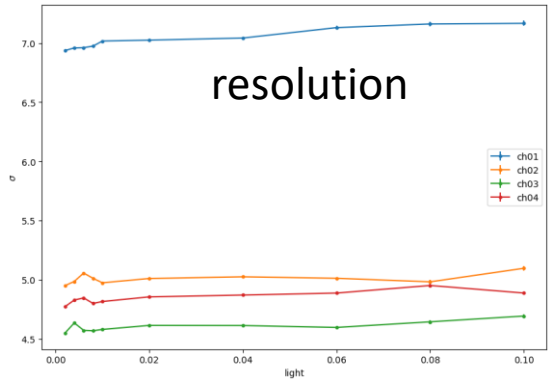
Fitting results of **simple sum PMT (only light changes)**

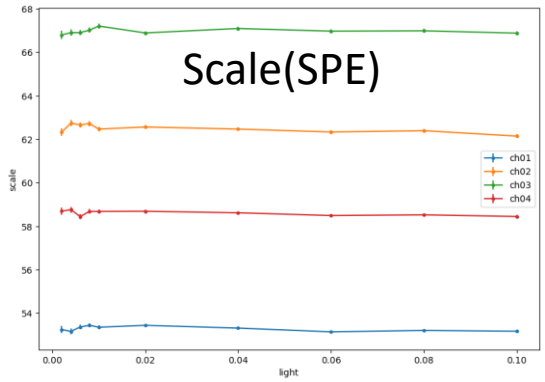
Bo Yu

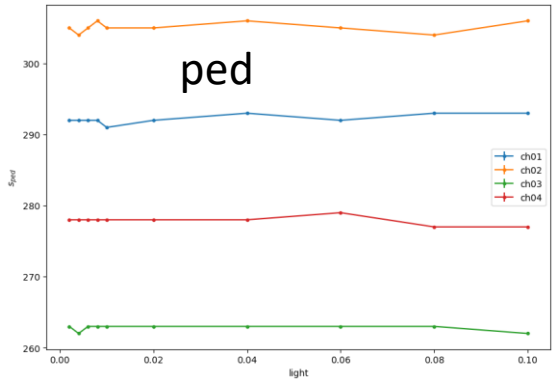


Results
NPE is proportional to amount of light, others are stable

Next steps:
Cross check the internal parameters with other groups of data (e.g. only HV changes)
Fit raw sum PMT readout
Start to use these parameters for the analysis of beam test data



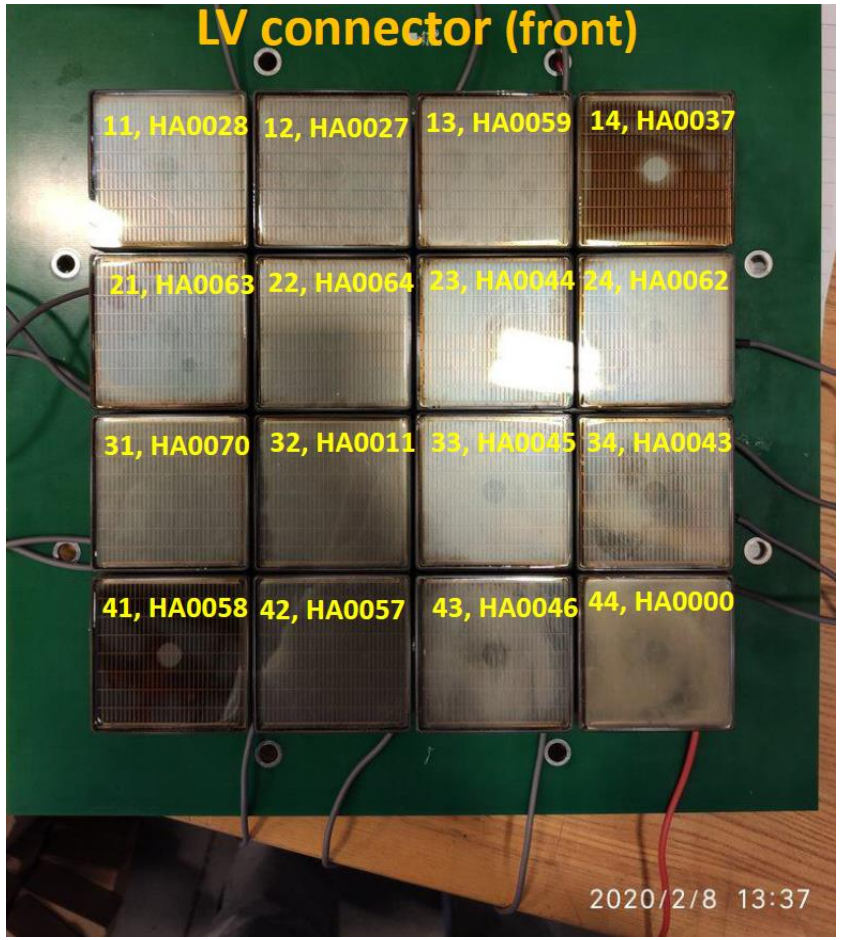




Checking MAPMT coating overtime:

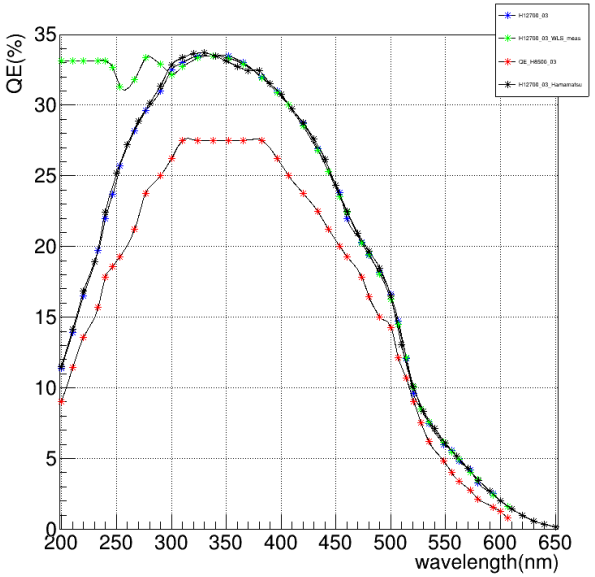
16 MaPMT H12700-03 WLS coated in Fall 2019 at Temple

2020/02/08
After coating, before beamtest



- Visually not much change after beamtest 2020 and 3 years of time
- PMT surface can be influenced by handling and preservation practices
- Testing relative QE change at 245nm in Dec 2023 at Temple (Hamza Atac and Nikos Sparveris)

PMT#	Relative QE change (%)	Comments
HA0045	19.17	Minor scratches on the coating
HA0037	x	No coating on the surface
HA0044	5.78	Some coating scratched off the surface
HA0064	18.18	Minor scratches on the coating
HA0070	14.07	Minor scratches on the coating



- No record when they were coated.
- Assuming 24% QE at 245nm from the manufacturer spec sheet, 24*1.2=29% QE. This is 12% lower than average 33% QE in Sylvester's plot.
- what's average gain change we can expect when coating MAPMT in large quantity? What's gain change near 200nm?

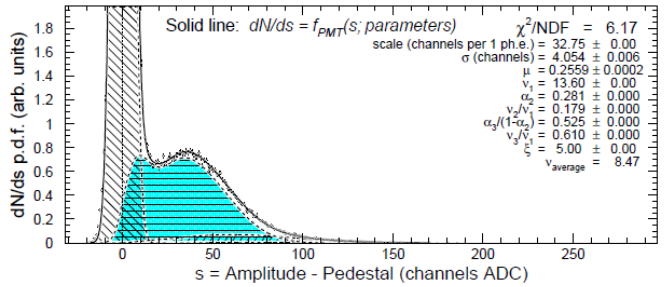
Understand Cher data and sim

- Cher Npe Beamtest data/sim=0.5-0.6
- Possible reasons
  - Npe in data underestimated from adc/(SPE adc)
    - SPE overestimated from simple Gauss fitting
  - MAPMT QE in sim overestimated
  - Mirror reflection in sim overestimated
  - CO2 refraction index in sim overestimated

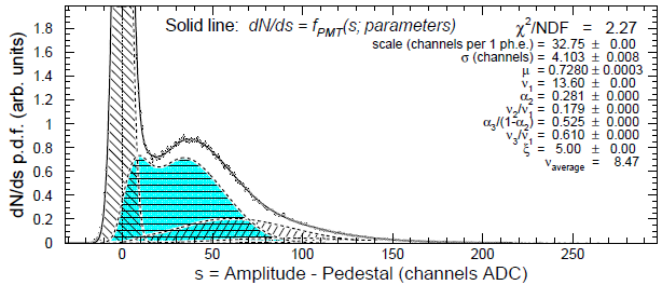
- backup

MAPMT signal fitting and single PE adc position determination

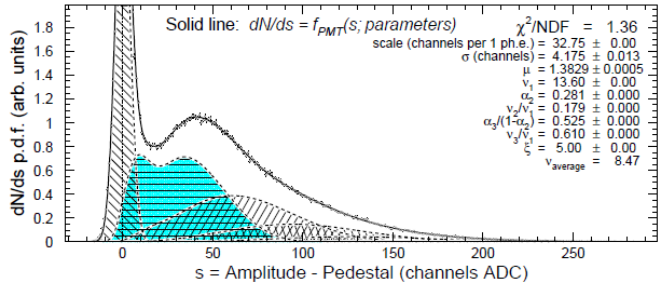
- Follow papers on MAPMT pixel adc fitting (arxiv:1608.07525 and arxiv: 2202.07776), and apply the fit to quad and total sum
- The fitting is a NPE poisson convoluted with a SPE function. The SPE function is not a simple gaussian but PMT type related and for MAPMT it can have two peaks
- "mu" is average NPE
- "scale" is SPE adc value, which can be near the dip of the 1st SPE function and lower than the 1st bump



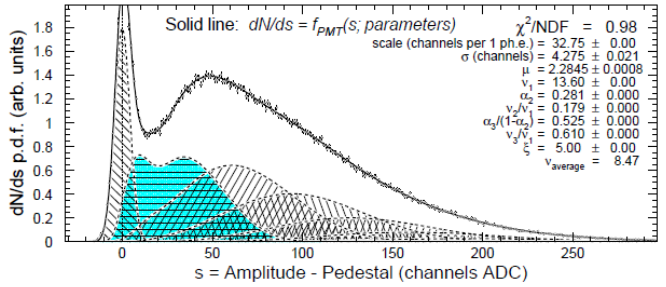
(a) H8500 MAPMT, anode #45, test setup at low light conditions corresponding to μ = 0.256



(b) H8500 MAPMT, anode #45, test setup at lower-medium light conditions corresponding to μ = 0.728



(c) H8500 MAPMT, anode #45, test setup at upper-medium light conditions corresponding to μ = 1.383

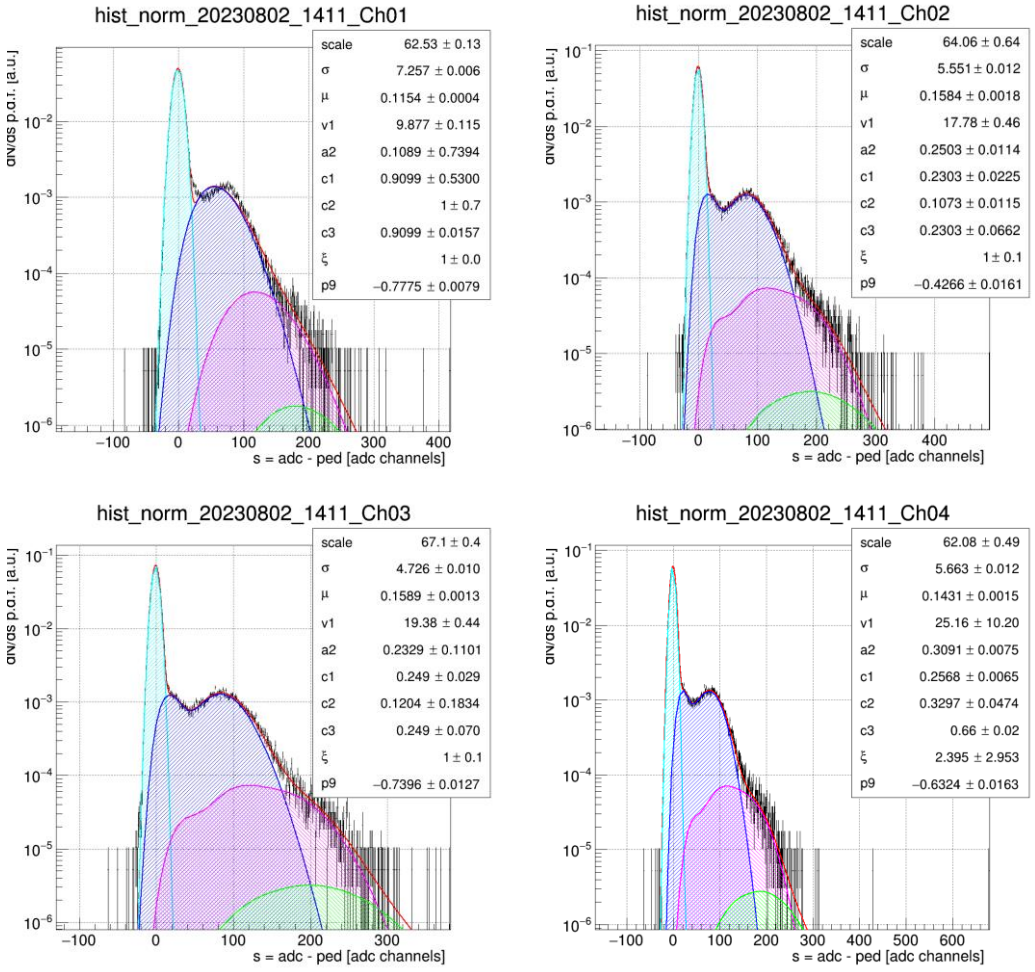


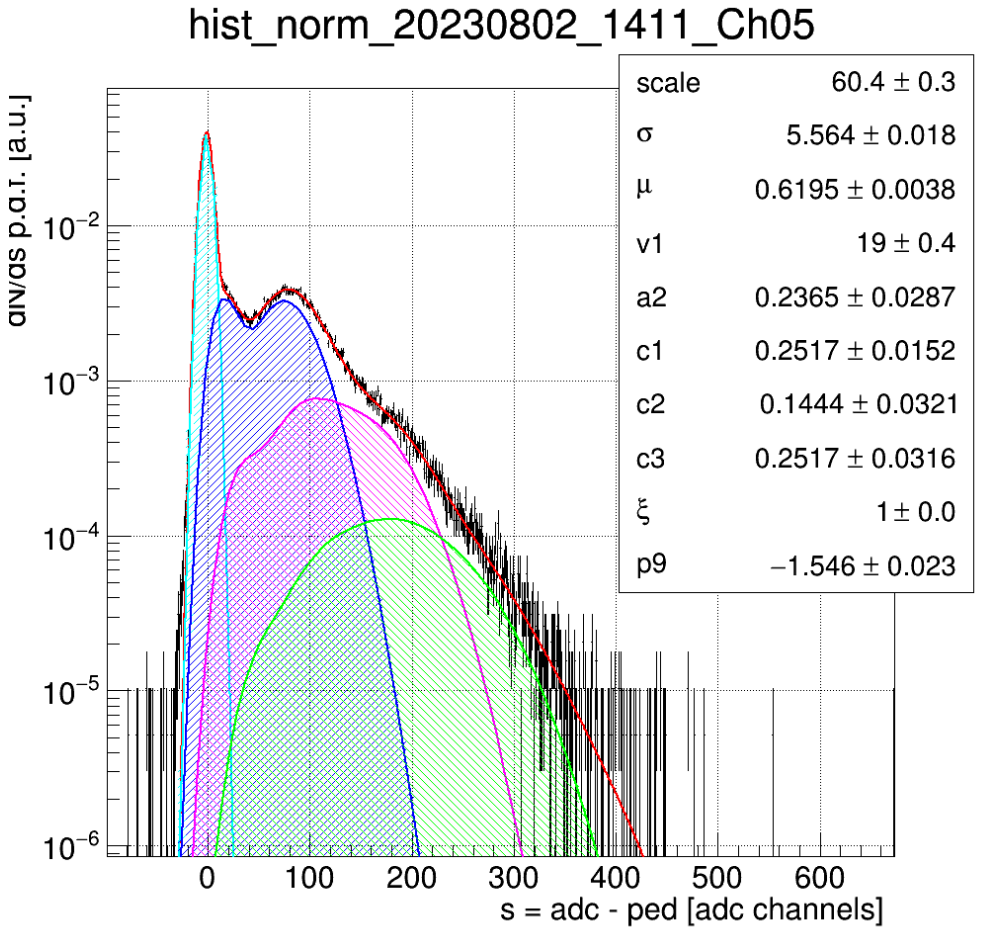
(d) H8500 MAPMT, anode #45, test setup at higher light conditions corresponding to μ = 2.285

Figure 2: A set of amplitude distributions measured with a Hamamatsu H8500 photomultiplier, similar to the set shown in Fig. 1, but on different anode #45. Ten measured distributions participated in the "global fit" procedure; four of them are shown.

- General way to get Npe for each event is to find SPE adc value by eye or fitting and divide adc of each value by it
- For beamtest data, if using 1st bump as SPE adc value instead of "scale", we can overestimate SPE adc value and thus underestimate NPE for each event, when using adc divide SPE value.
- Could this be the reason our 2020 and 2022 beamtest data Npe is underestimated comparing to sim by 40-50%?

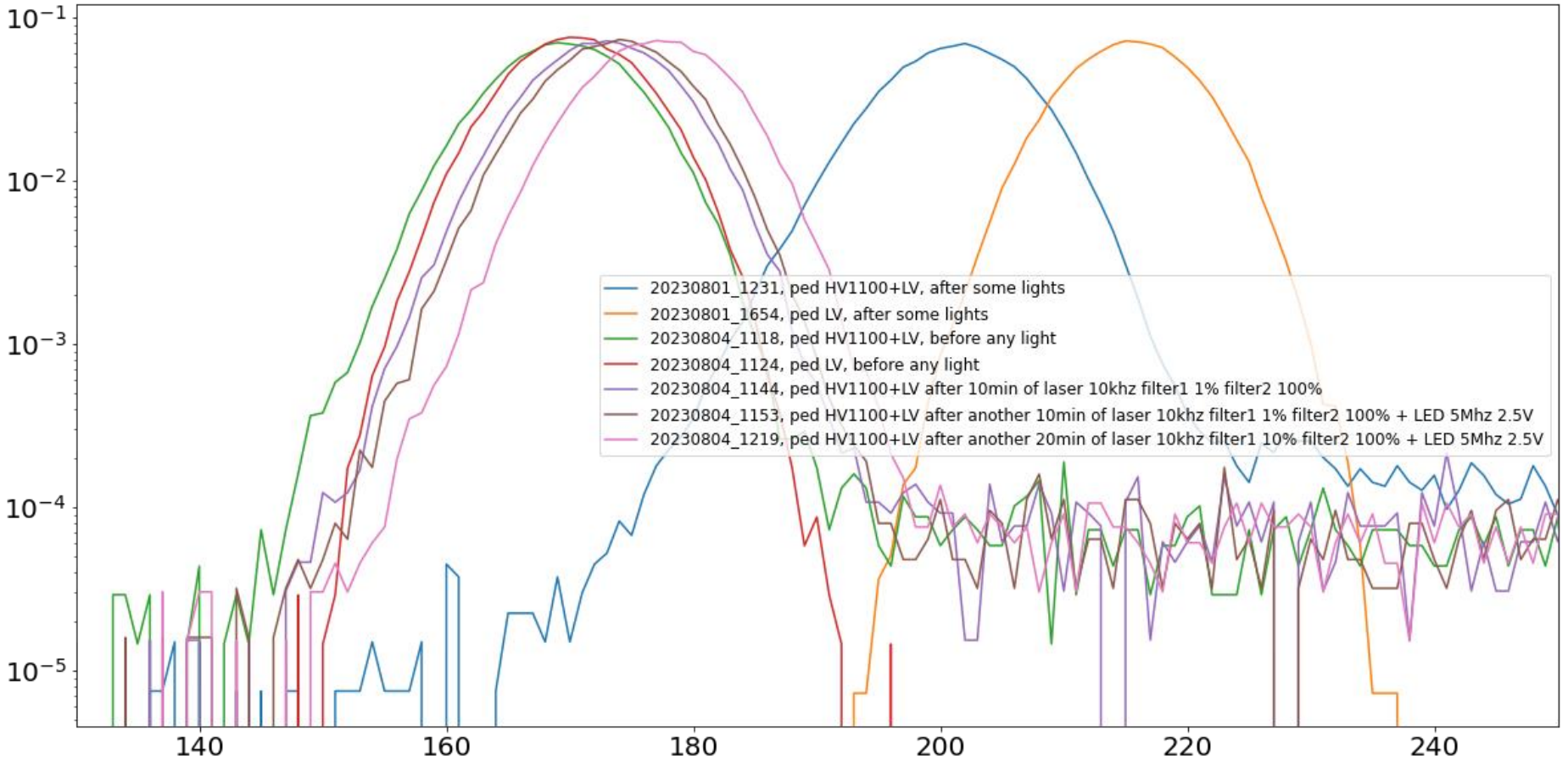
MAPMT simple sum: LED only (LED trigger)





At 2.5V, average PE (mu) is 0.6 at PMT sum, which means 55% no PE, 33% 1 PE, 10% 2 PE according to poisson distribution. Each quad has about ¼ of lights

MAPMT simple sum: ped



Pedestal is mainly from simple sum board, not pmt.
It will increase when expose to lights

MAPMT simple sum: ped

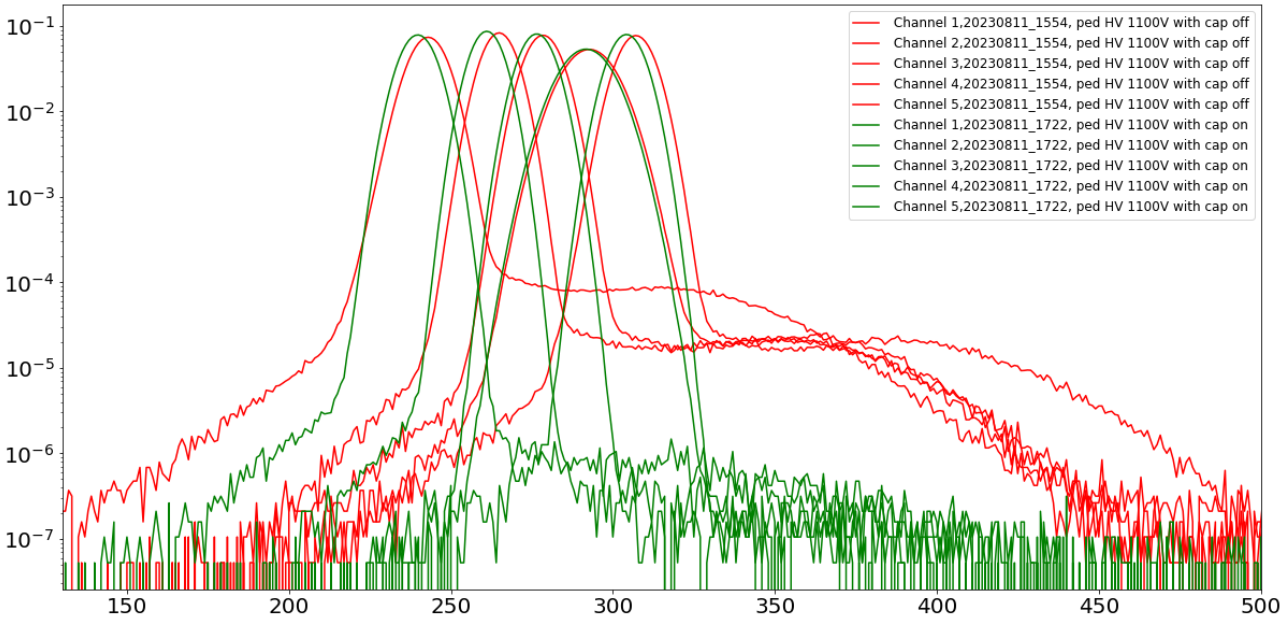
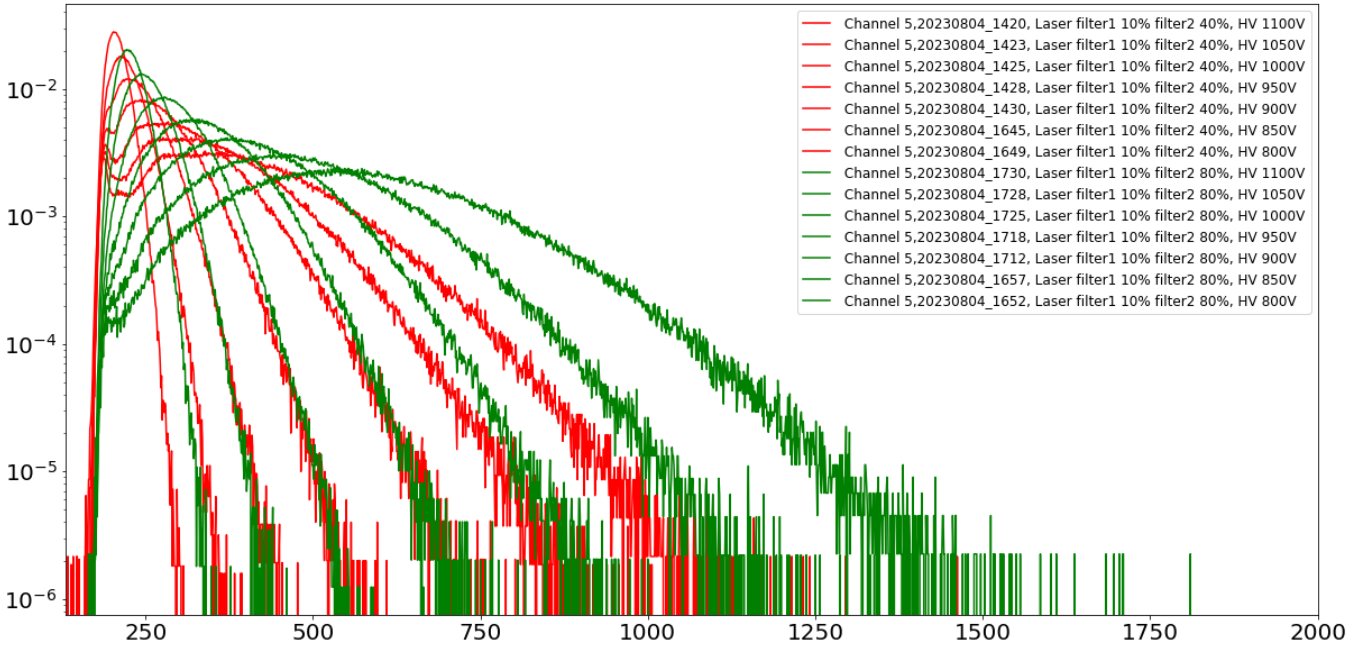


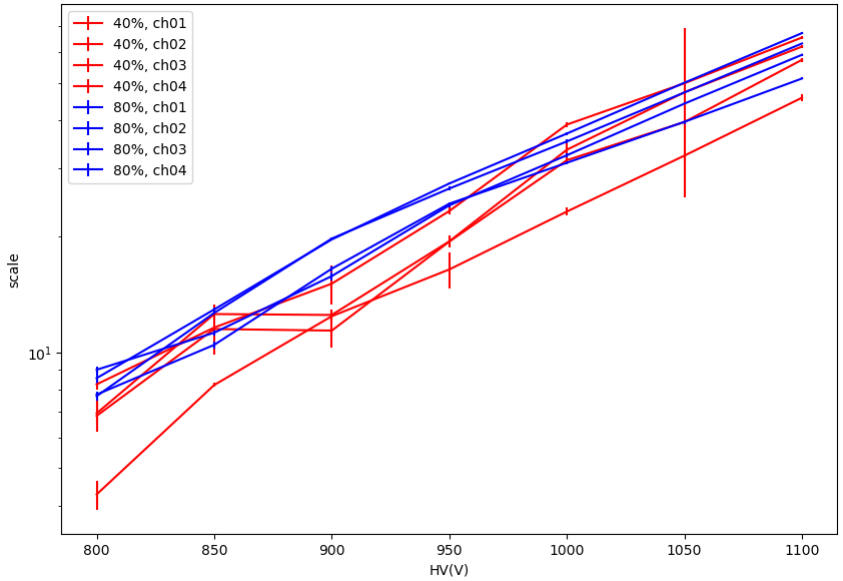
Table or plot with scale needed

There are small light leaks at a couple Hz level

MAPMT simple sum: laser only, HV change

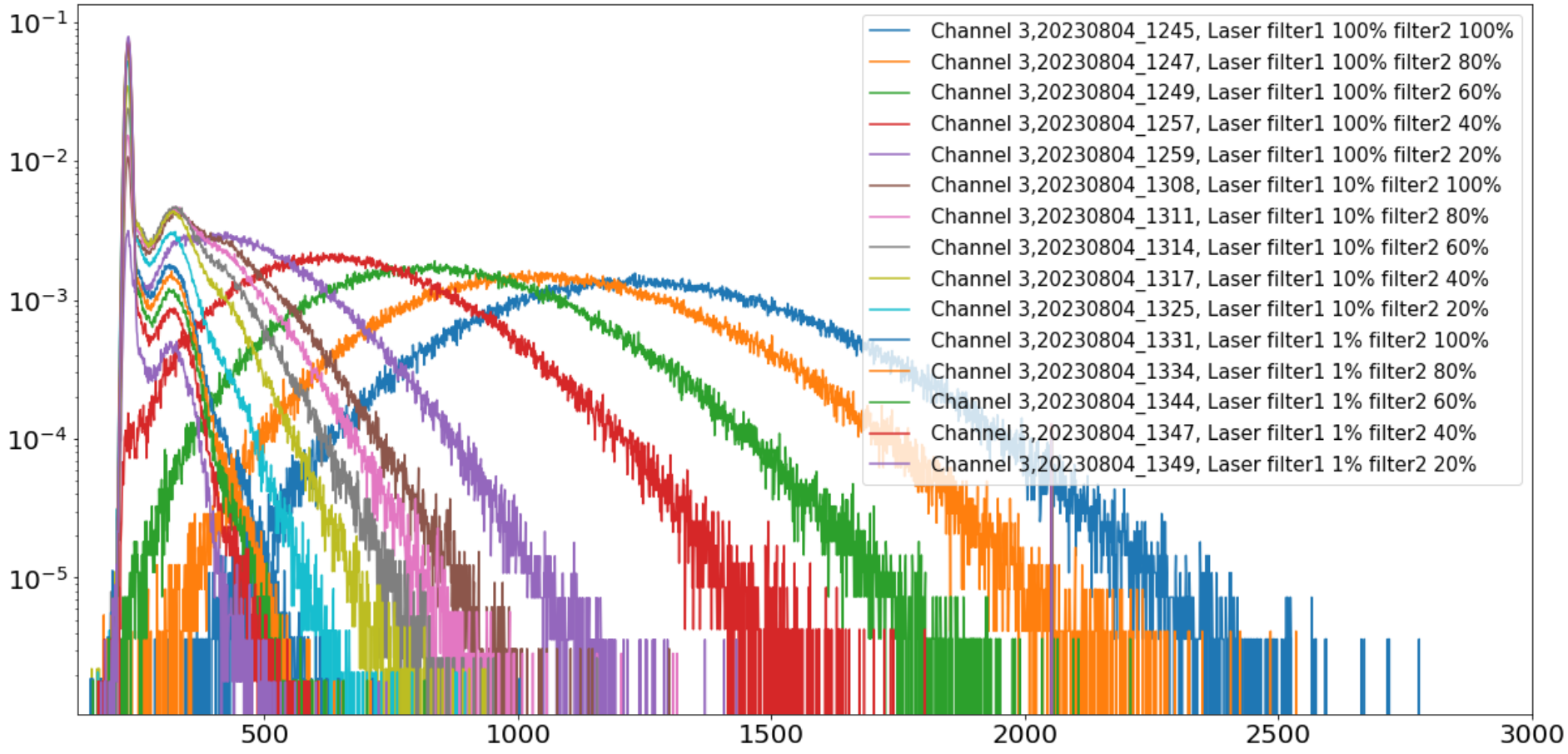


SPE (scale from fitting)



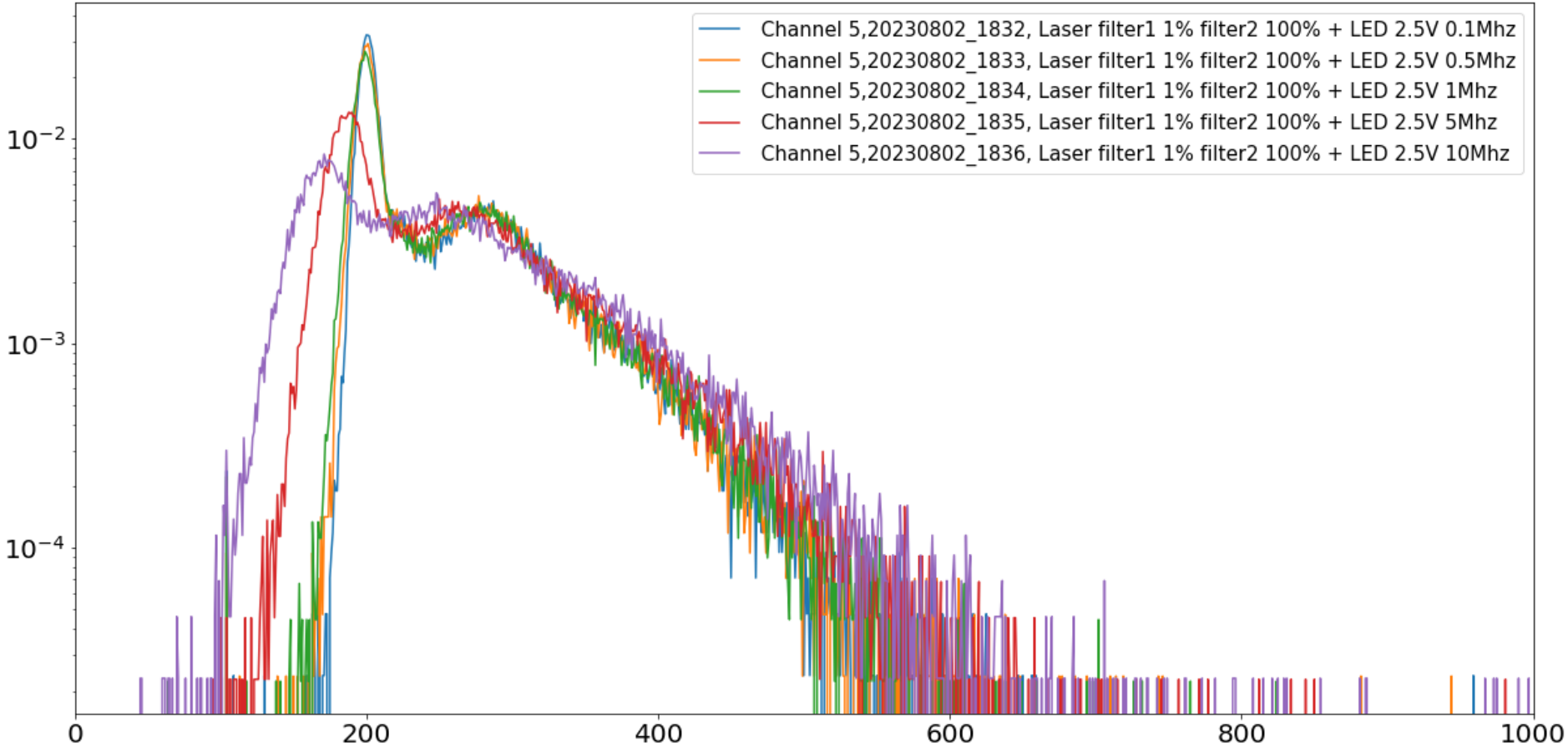
Gain increase with HV in log

MAPMT simple sum: laser only, light change



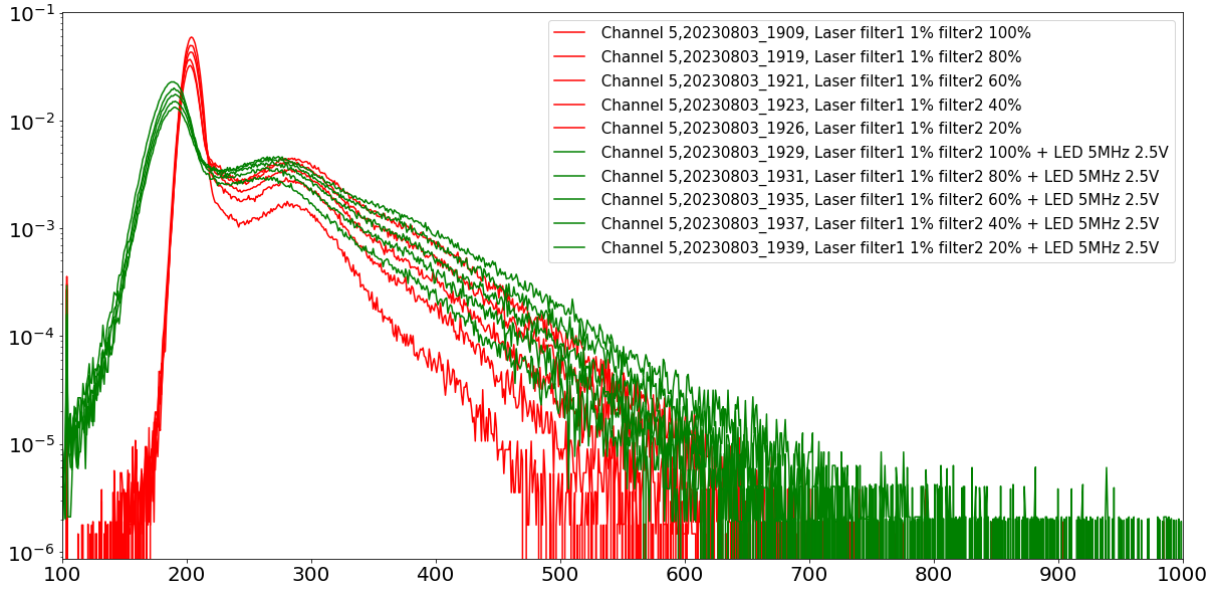
output increase with light input to high Npe

MAPMT simple sum: laser+LED, different LED light rate

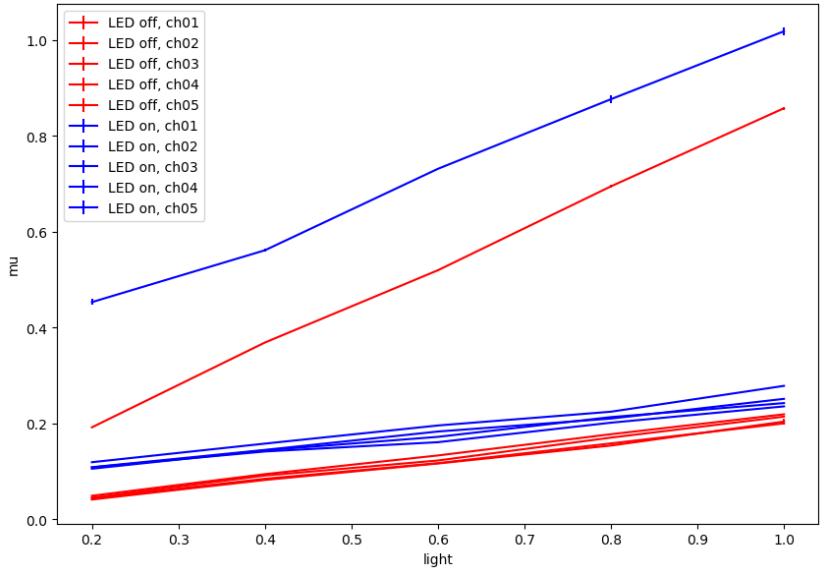


At 0.1,0.5,1MHz, pedestal doesn't change much, at 5 and 10MHz, pedestal is moved to lower values by LED
Possible reason is due to a lot of LED lights depleting photocathode, need more time to study and there is no easy fix

MAPMT simple sum: laser+LED, less laser light

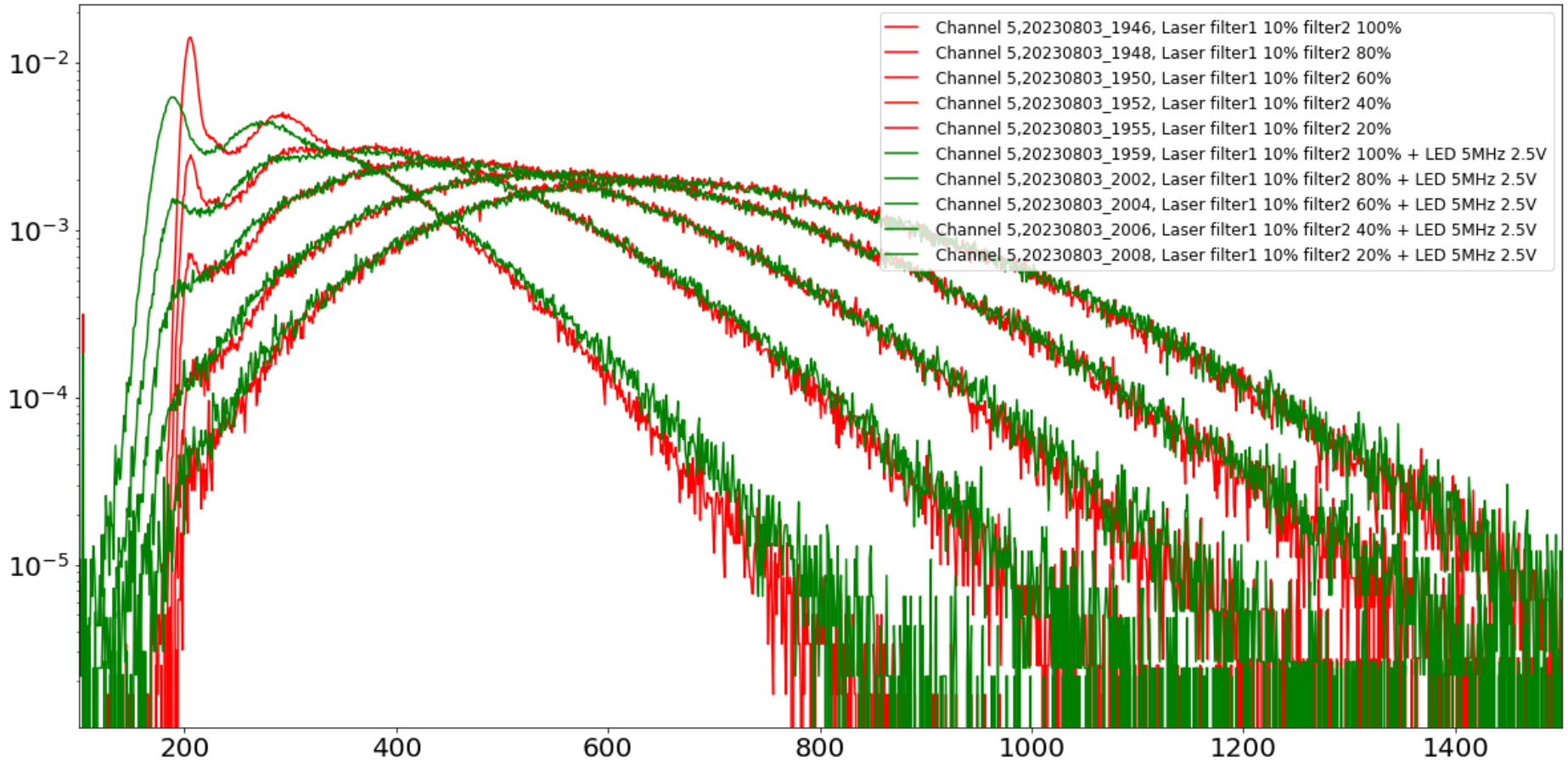


Average Npe (mu from fitting)



With LED 5MHz 2.5V, when laser and LED have comparable amounts of lights, adc are pushed to higher values by LED besides pedestal

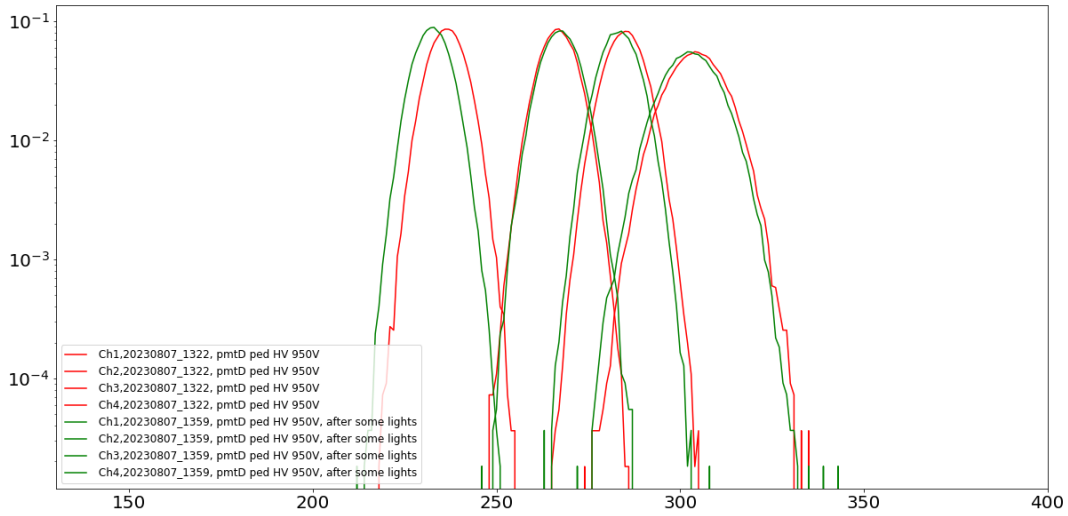
MAPMT simple sum: laser+LED, more laser light

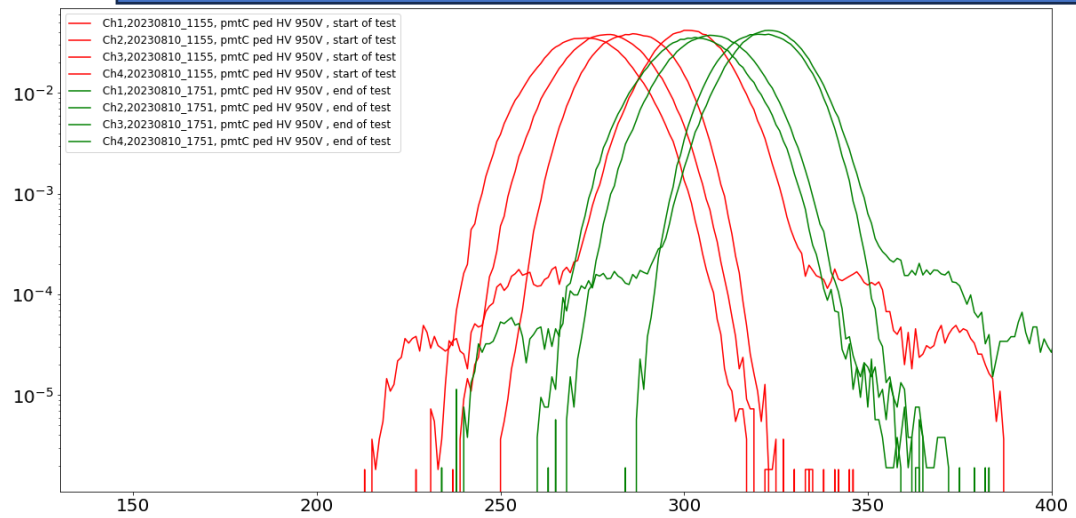


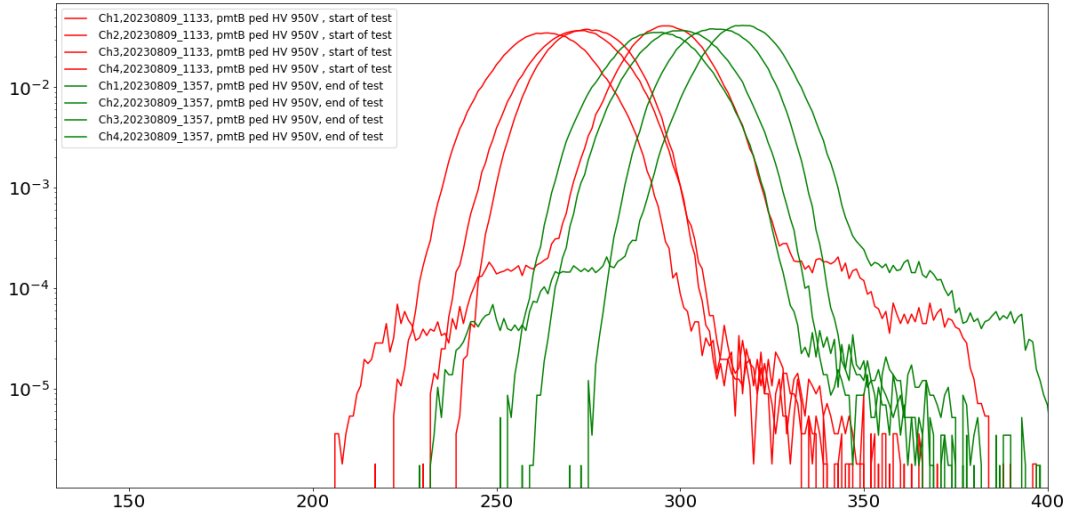
With LED 5MHz 2.5V, when laser lights are much stronger than LED lights, adc values are not affected much except pedestal

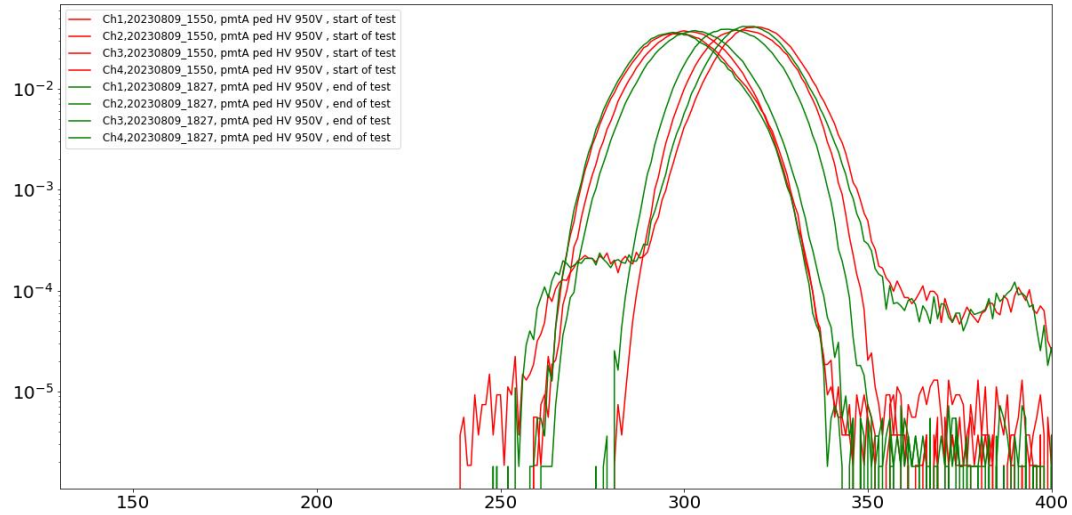
MAPMT raw sum: ped

- ped affected by light also and it's pmt dependent
- ped widen slightly with NIM 10x amplification (pmtB,A,C) comparing to without (pmtD)









MAPMT raw sum: ped

- Ch4 for all 4 pmts has some weird shape
- Similar light leak

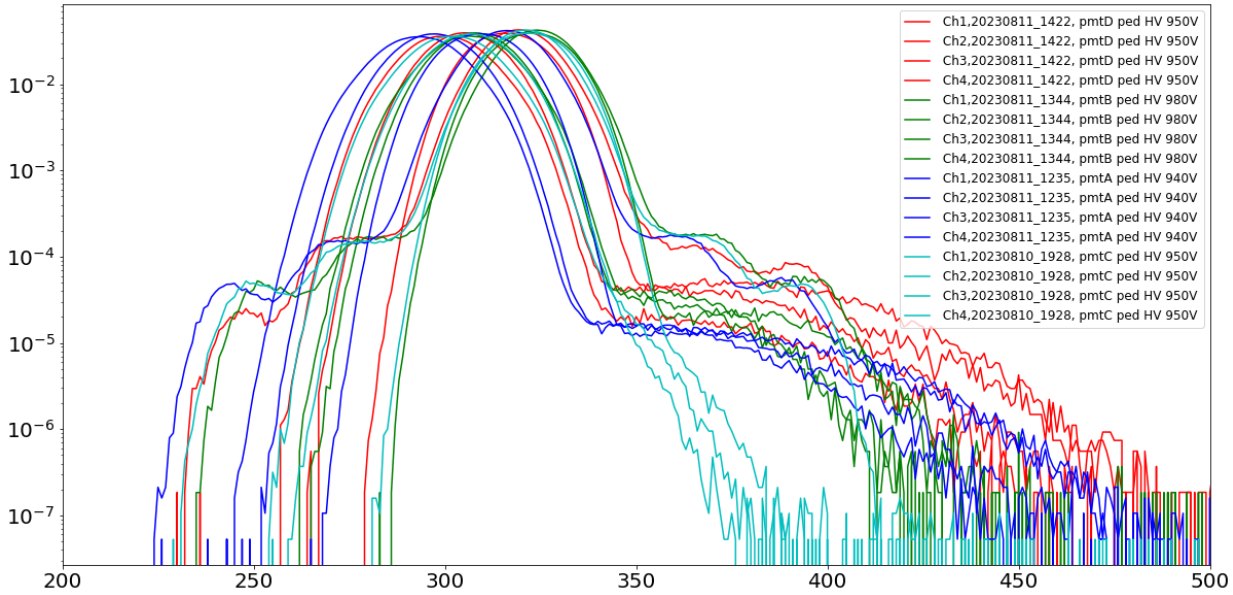
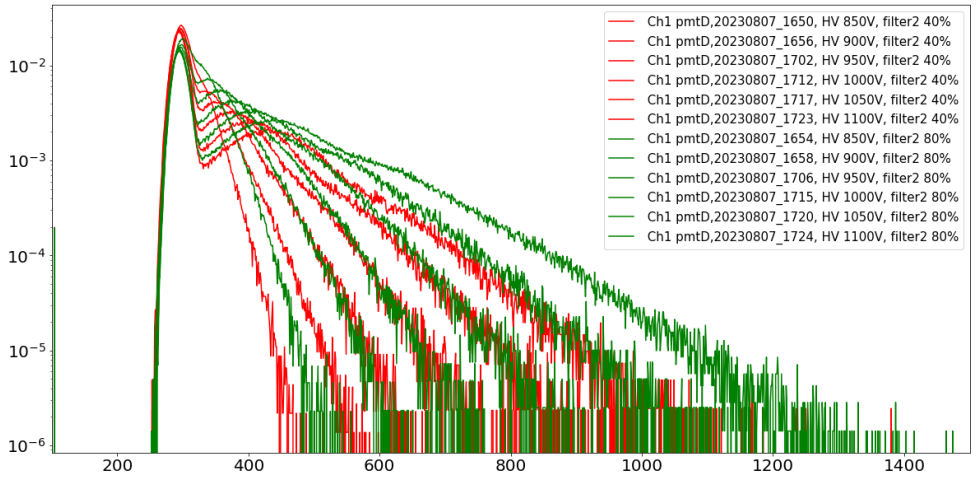
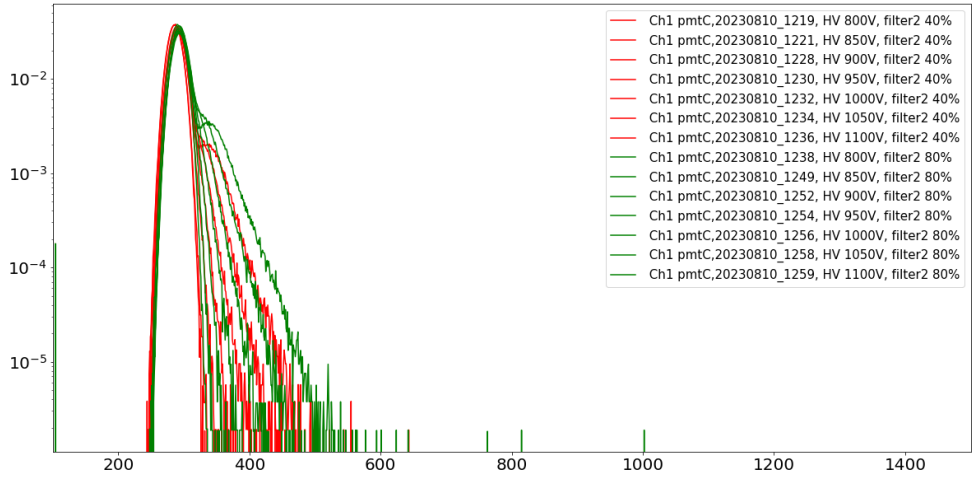
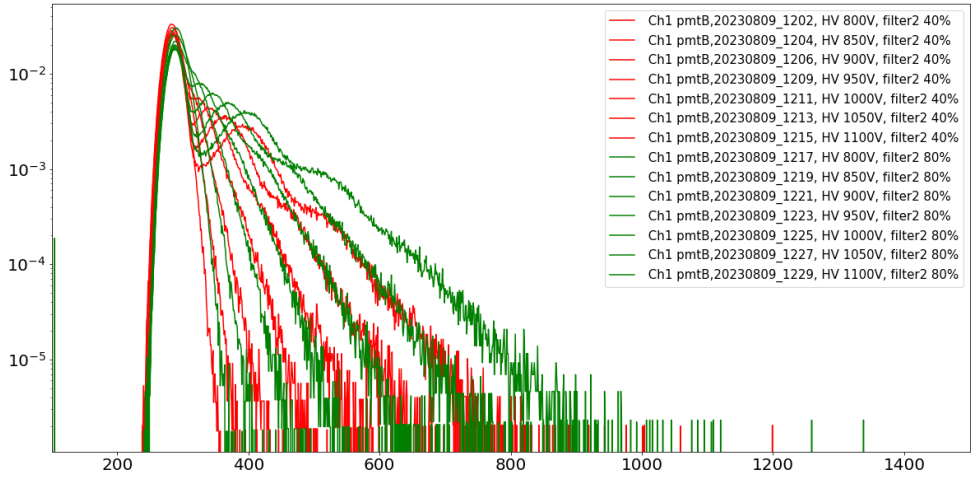


Table or plot with scale needed

MAPMT raw sum: laser only, HV change







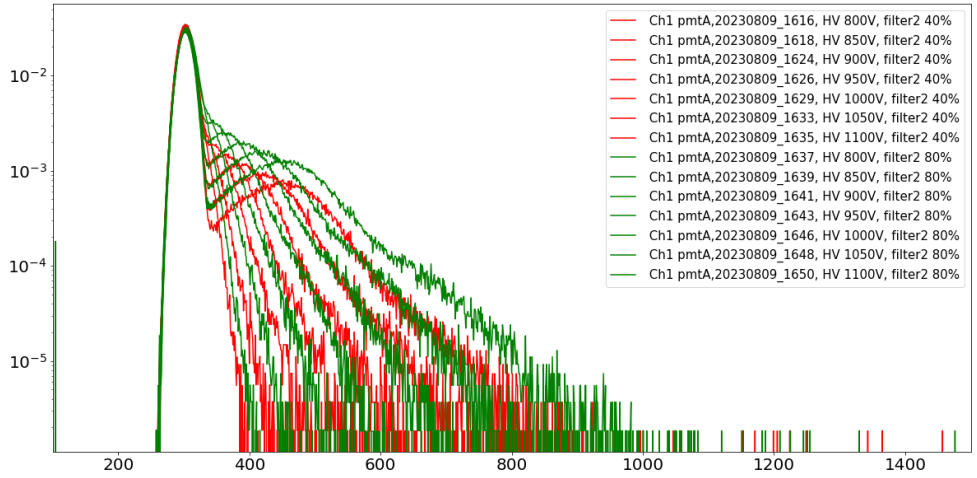
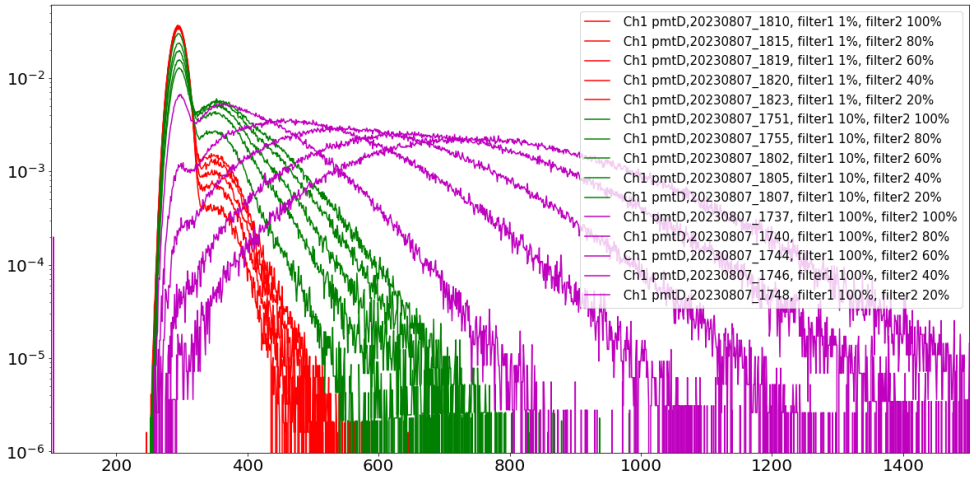
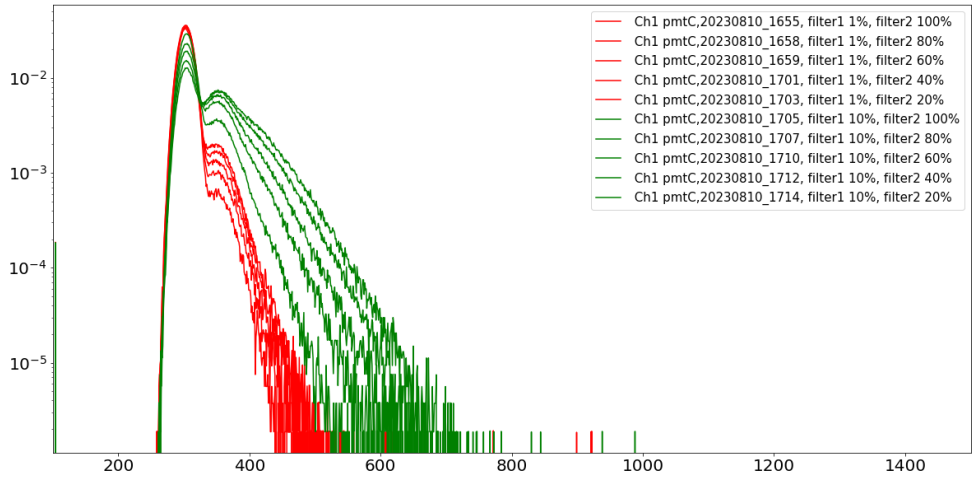
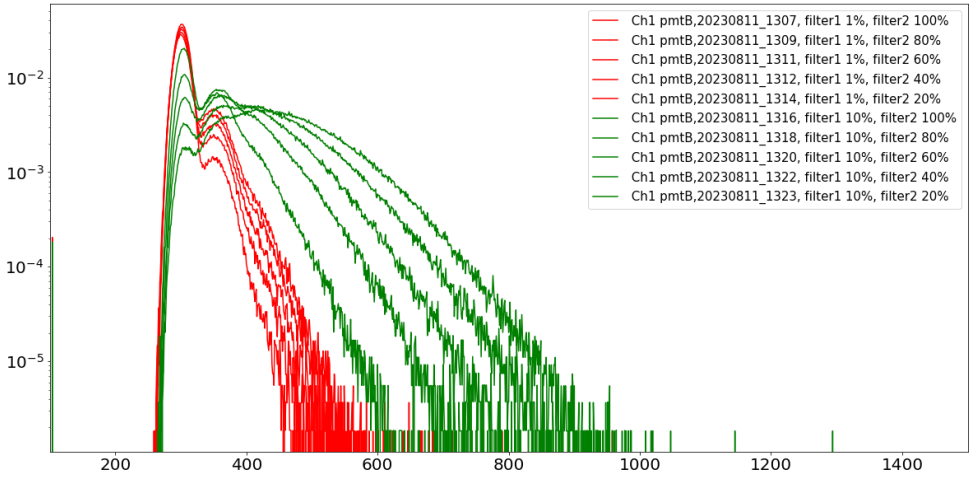


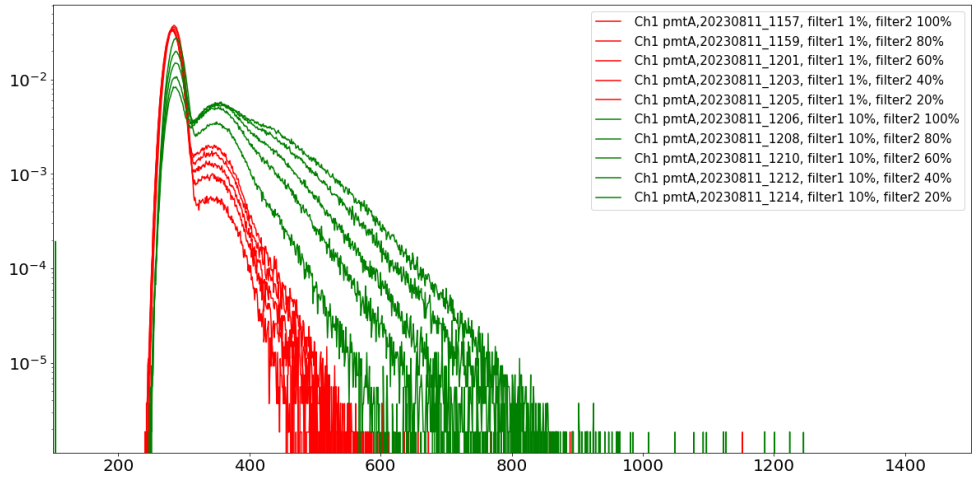
Table or plot with scale needed

MAPMT raw sum: laser only, light change

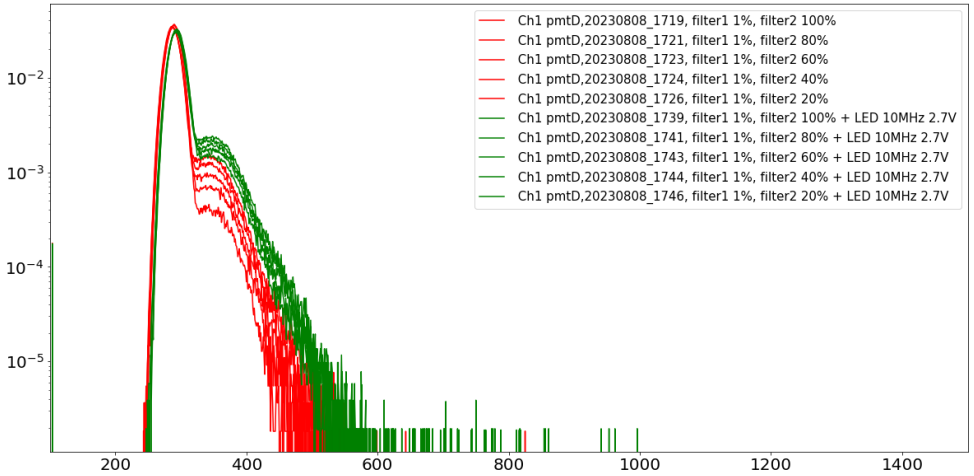








MAPMT raw sum: laser+LED, less laser light



MAPMT raw sum: laser+LED, more laser light