Characterization of Hamamatsu R5912 PMTs

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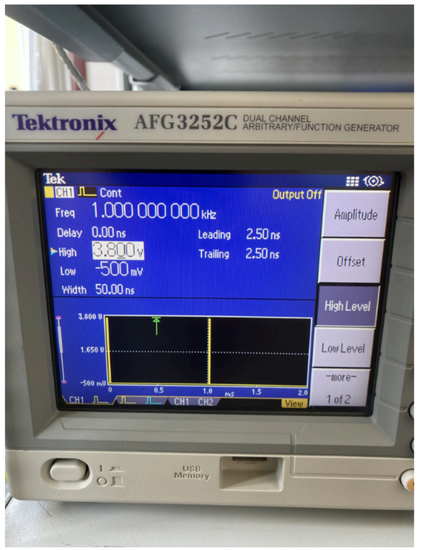
Calibration tests performed at FZU

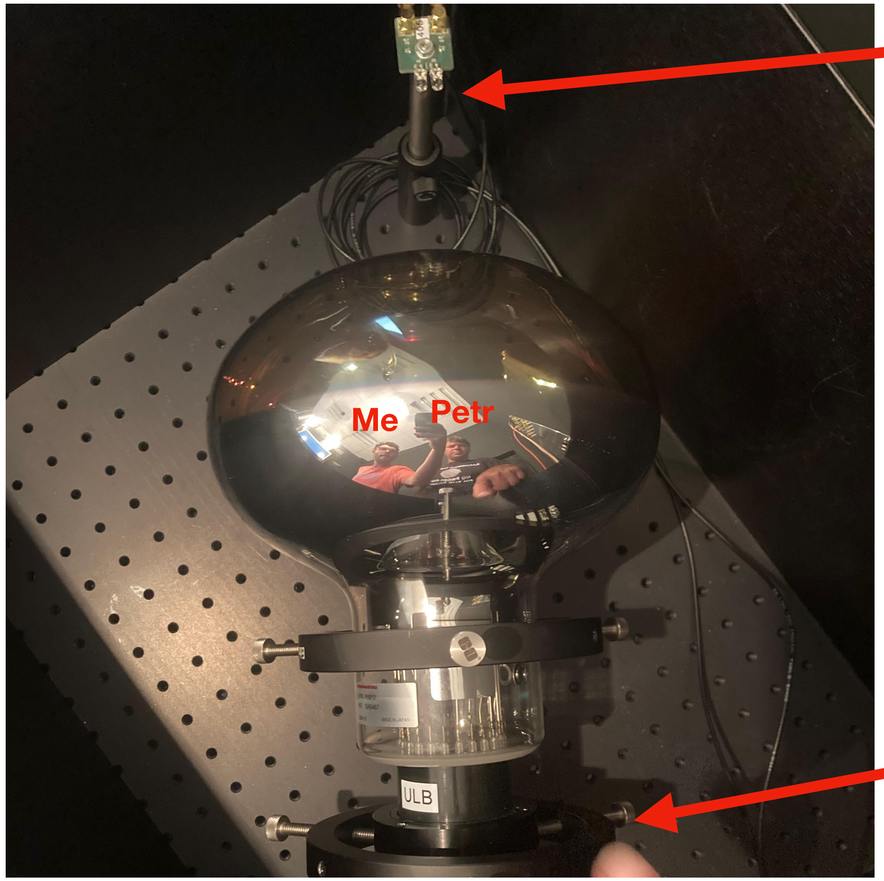
- Characterize Hamamatsu R5912 PMTs: are they suitable for PEPS?
- Six photomultiplier tubes were tested at FZU.
- - Single Photo Electron spectrum
  - Gain VS high voltage
  - Non-linearity
  - Afterpulse
- Followed the procedures in: Barnhill D. et. al. (2008). *Testing of photomultiplier tubes for use in the surface detector of the Pierre Auger observatory. Nuclear Instruments and Methods in Physics Research A,591, 453–466.*

Experimental setup

Signal generator: 1kHz, 50 ns steps



2 LED (λ = 405 nm)



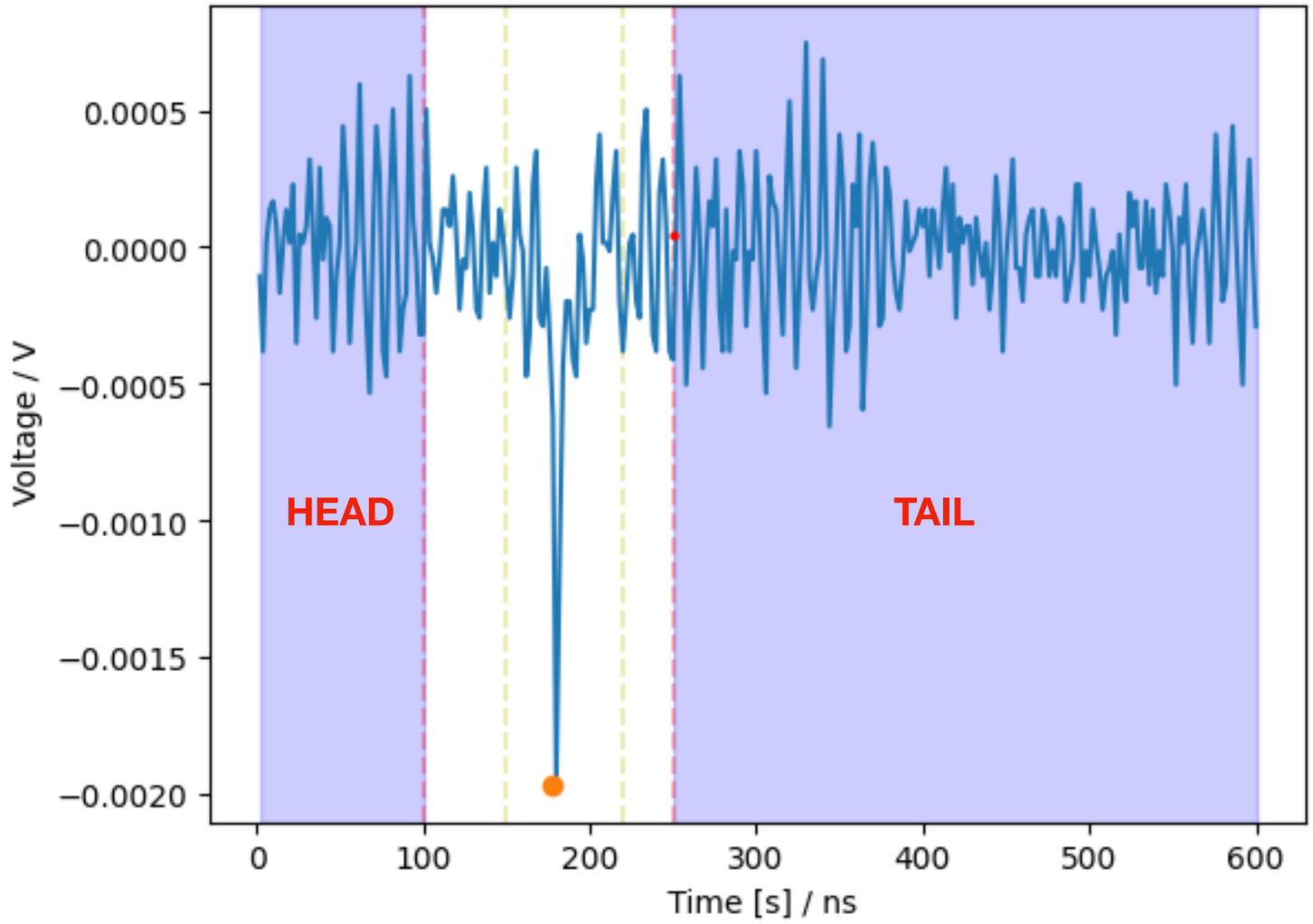
Hamamatsu base: HV input / signal readout

PMT placing inside the black box

Power supply and signal digitizer (500 MHz — 2 ns)

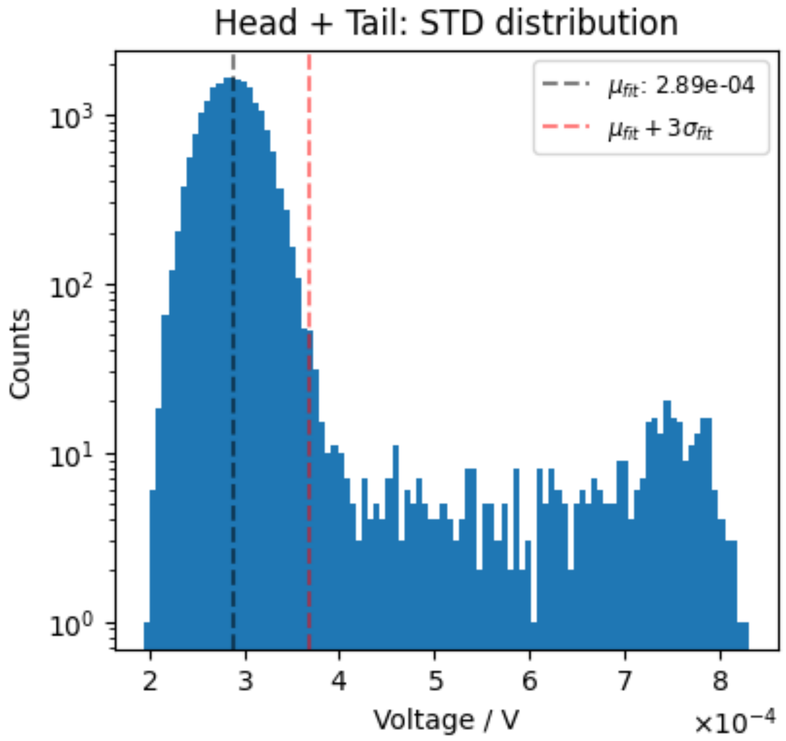
Trace quality cuts

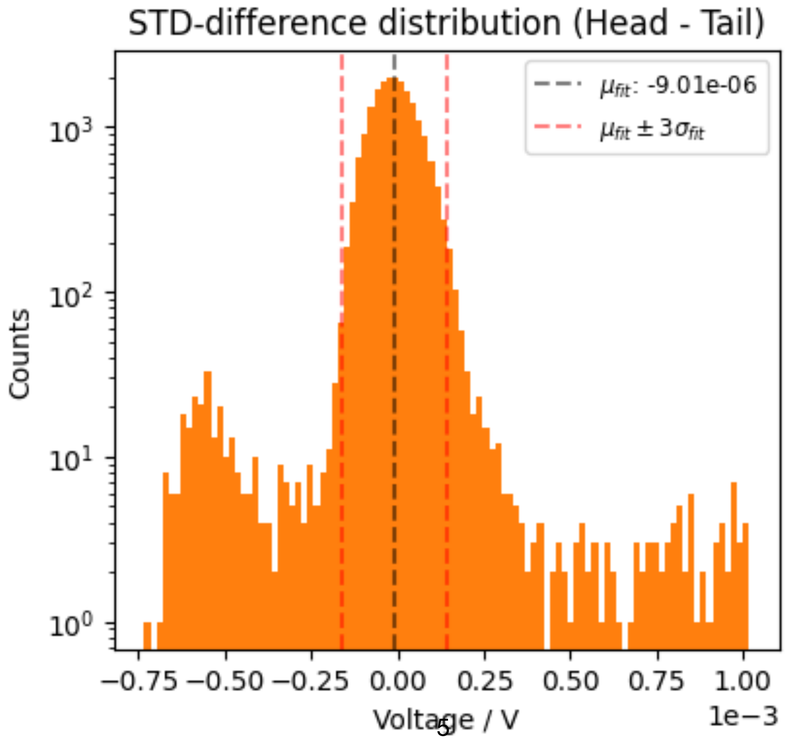
- **STD distribution**: the standard deviation distribution of the **HEAD + TAIL**
- **Mean-difference (HEAD - TAIL) distribution**
- **STD-difference (HEAD - TAIL) distribution**

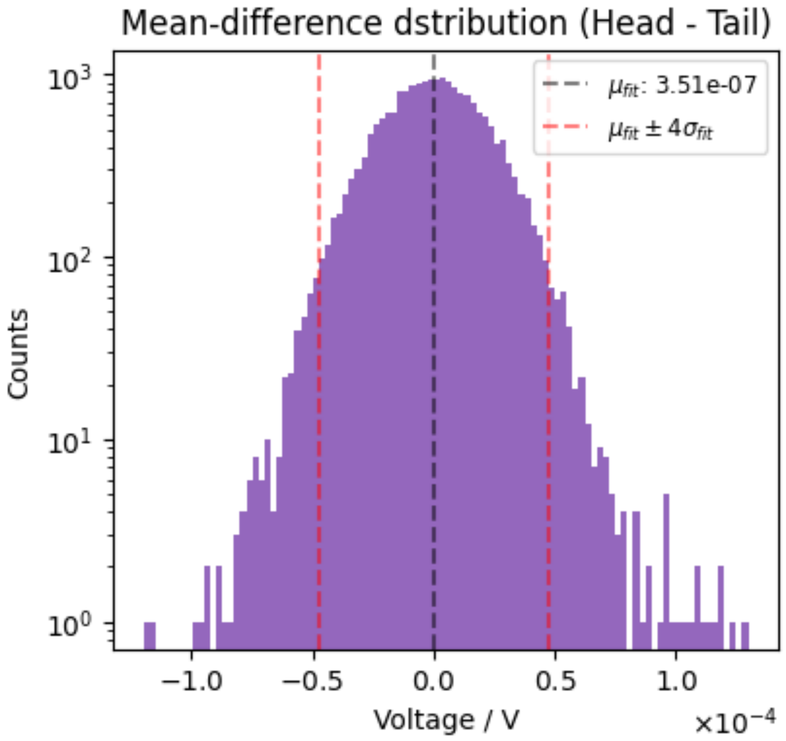


Distributions and cuts

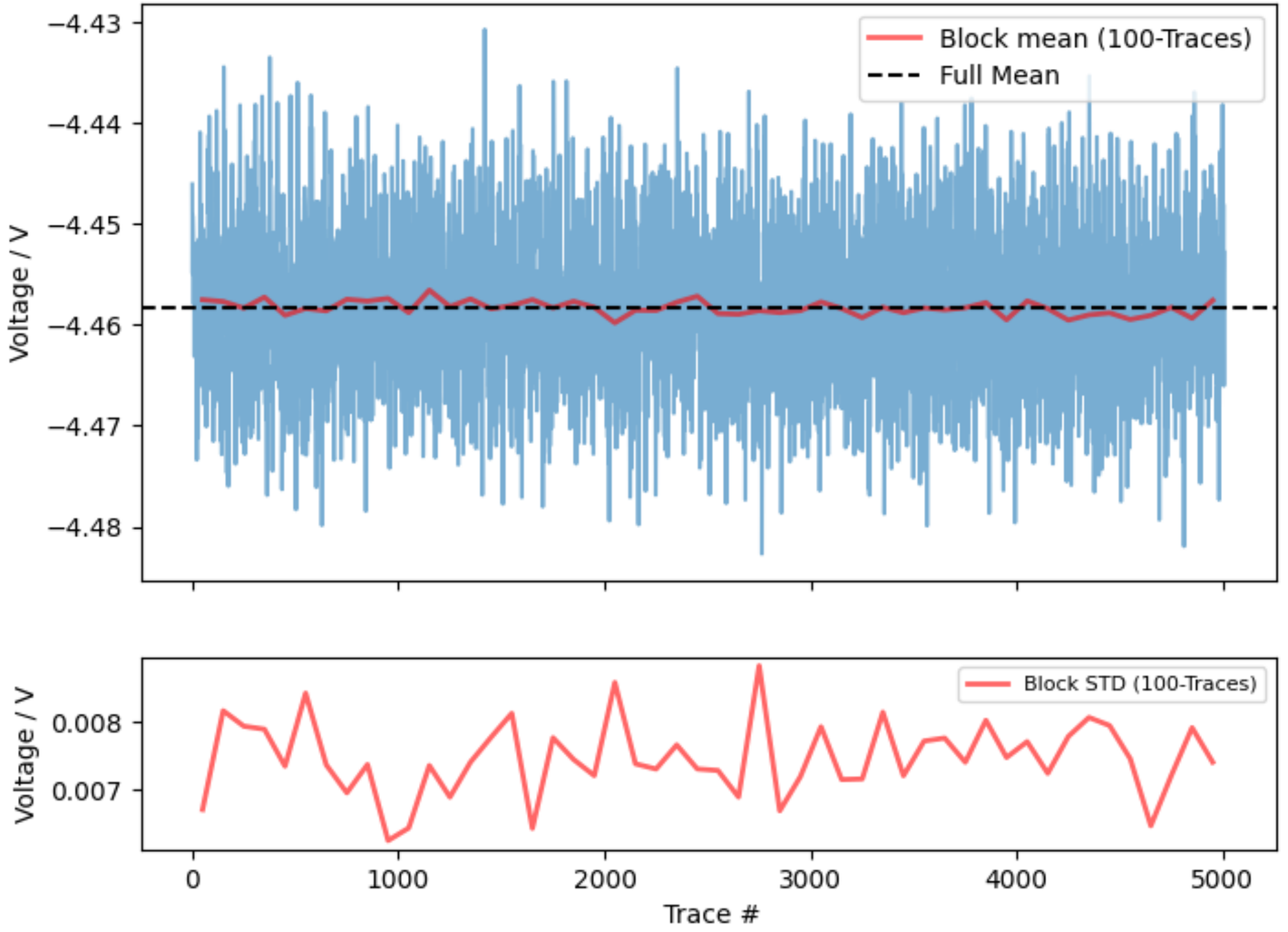
- The distributions are produced for each PMT dataset and the cuts are set at the chosen σ level.





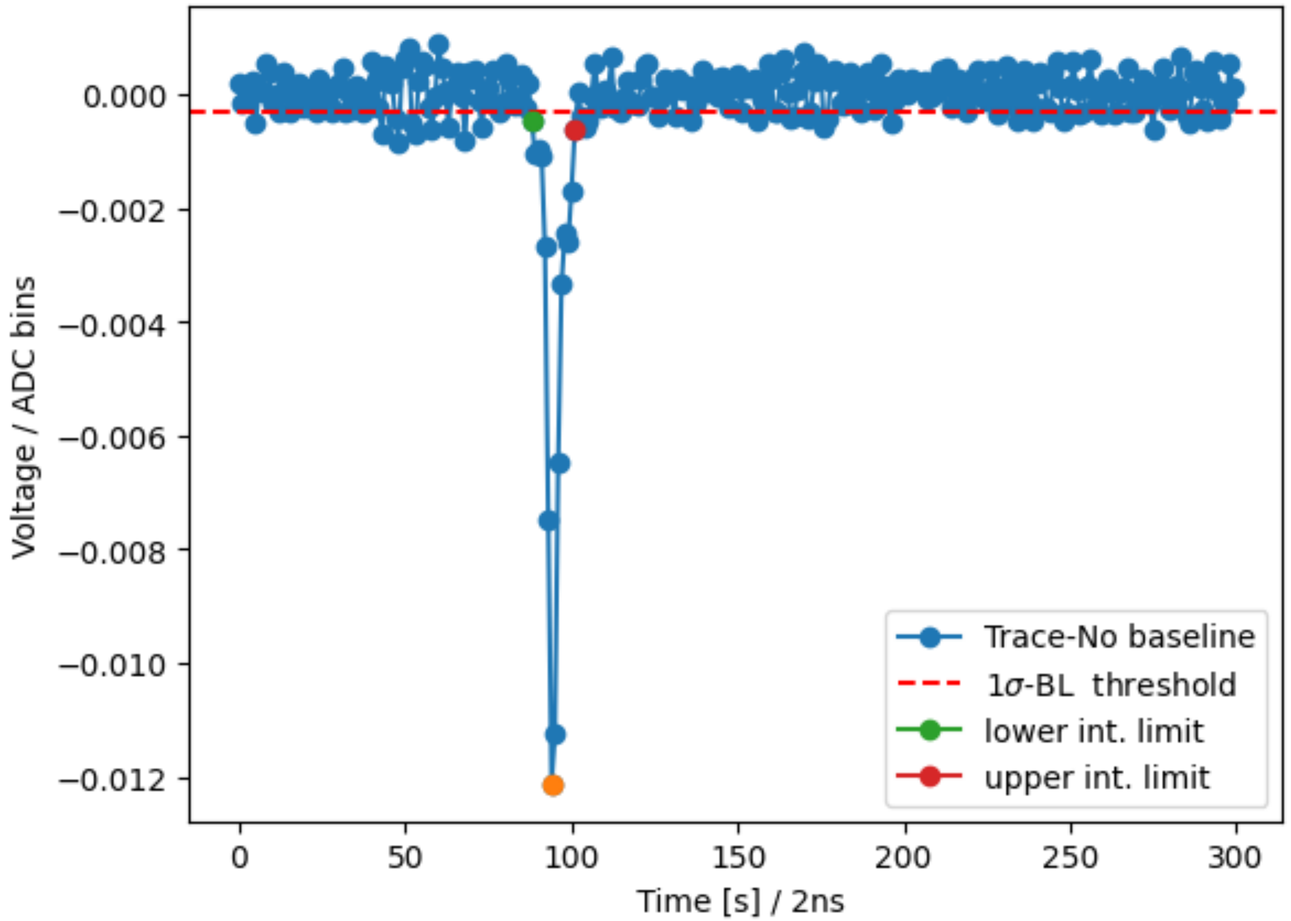


Signal peak vs time



Integration window

- IW is calculated for each trace using the SD of the noise from the first 50 bins at a chosen σ level.
- The algorithm moves left and right of the minimum and returns closest bins to the threshold
- If no significant peak is found (threshold chosen in 4σ), IW is set at a fixed range between bins 75-110



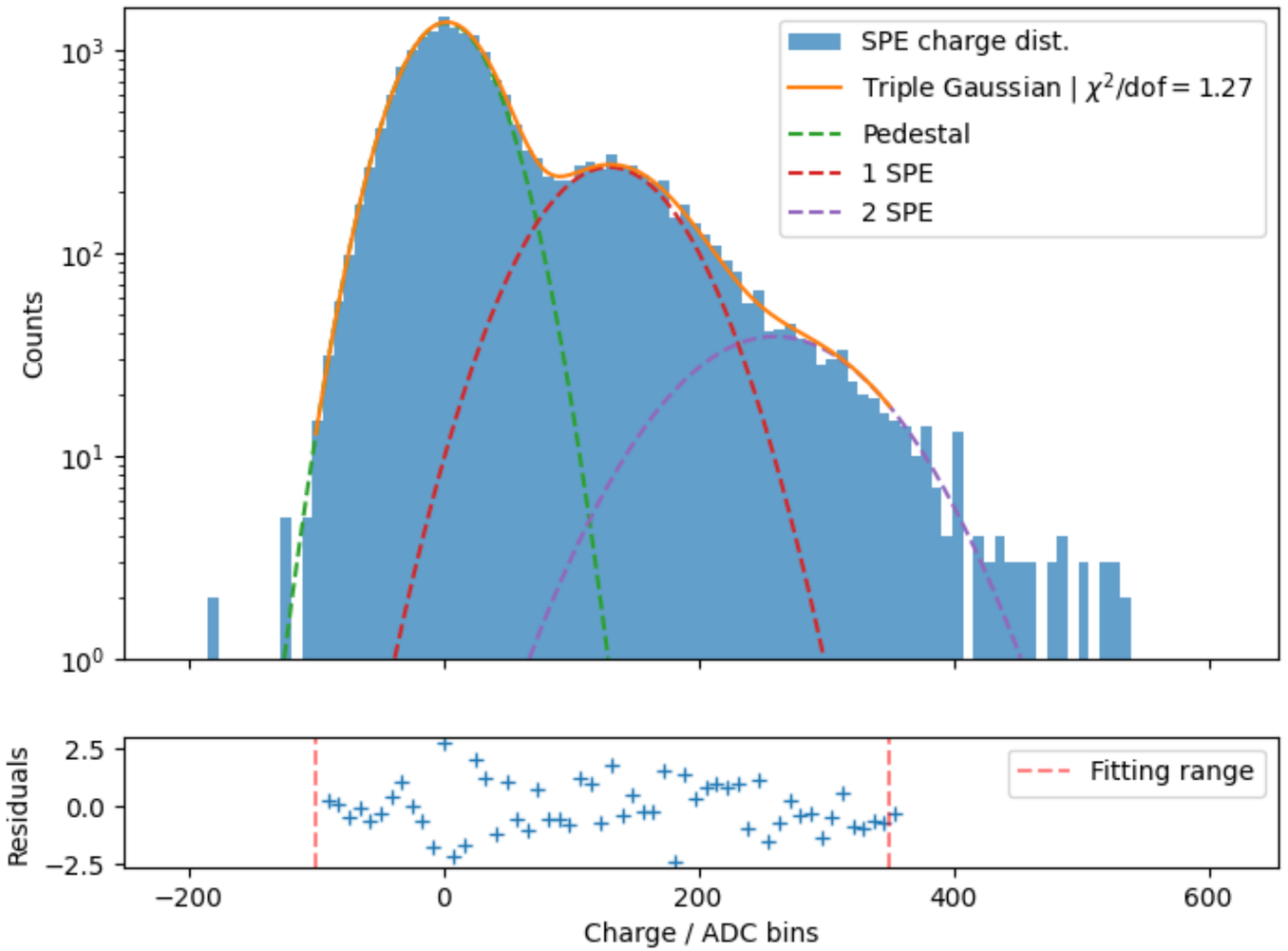
Single photo-electron (SPE) spectrum

- Used a low light intensity for the LEDs
- The SPE, mean (μ_{SPE}) and variance (σ^2_{SPE}) are extracted from a fit of the full distribution
- The SPE gain and resolution are calculated for each PMT
- $$G = \frac{1}{e}\left[\frac{\Delta V}{D}\cdot\frac{\Delta t}{R}\right]\mu_{SPE}$$

  ΔV : full V range of signal digitizer (0.5 or 2 V)
  D : discrete digital levels 2^{14} (14 bit ADC)
  Δt: time bin (2 ns)
  R: resistance (50 Ω)
- $$\sigma_G = \frac{\sigma_{SPE}}{Q_{SPE}}$$

$G \sim 1.94 \times 10^6$

$\sigma_G \sim 35\,\%$

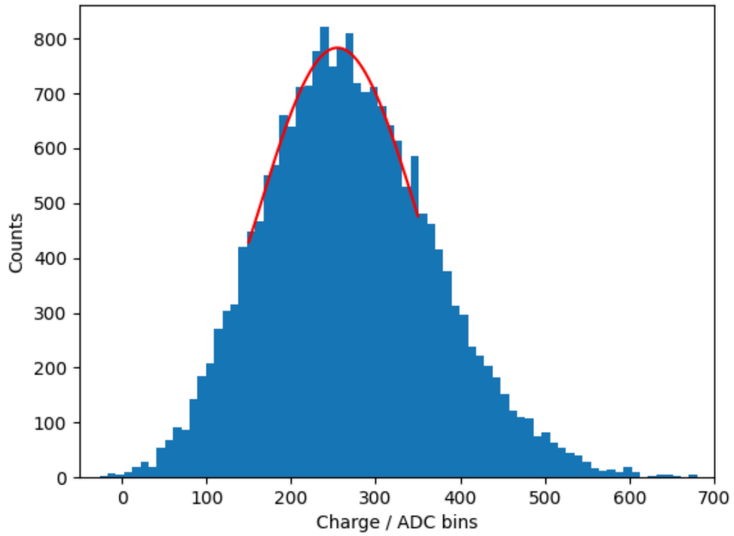


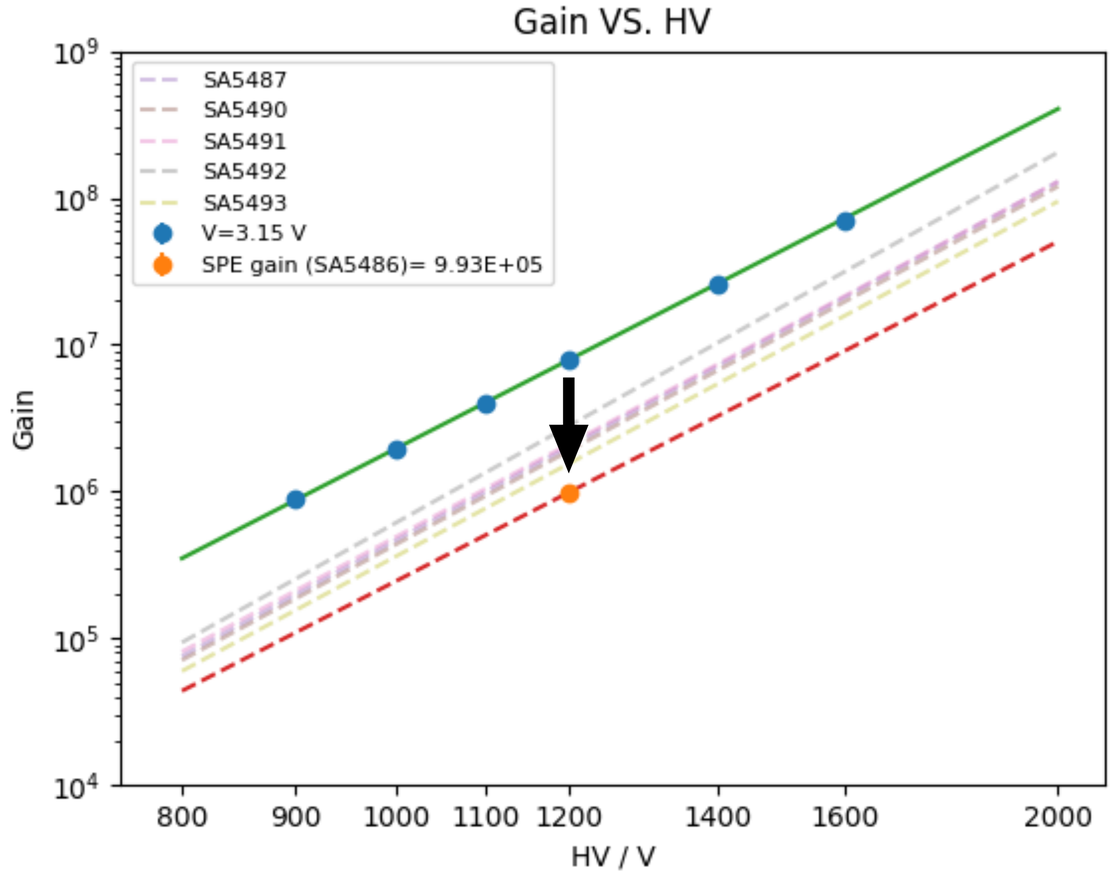
Gain vs. HV

- Increase intensity of light to have a better range
- Scan over the HV from 900 V to 1600 V
- Obtain the mean charge from a normal distribution fit around the charge-peak for each HV
- Fit linear functions a re-scale to go through SPE gain

$$\log_{10}(G) = \log_{10}(k) + a\ \log_{10}\left(\frac{HV}{V}\right)$$

PMT	$\log_{10}(\mathbf{k})$	a
SA5486	-16.79 ± 0.12	7.69 ± 0.04
SA5487	-17.74 ± 0.66	8.12 ± 0.22
SA5490	-17.79 ± 0.18	8.11 ± 0.06
SA5491	-17.56 ± 0.25	8.05 ± 0.08
SA5492	-18.48 ± 0.29	8.39 ± 0.09
SA5493	-16.33 ± 0.44	7.59 ± 0.14

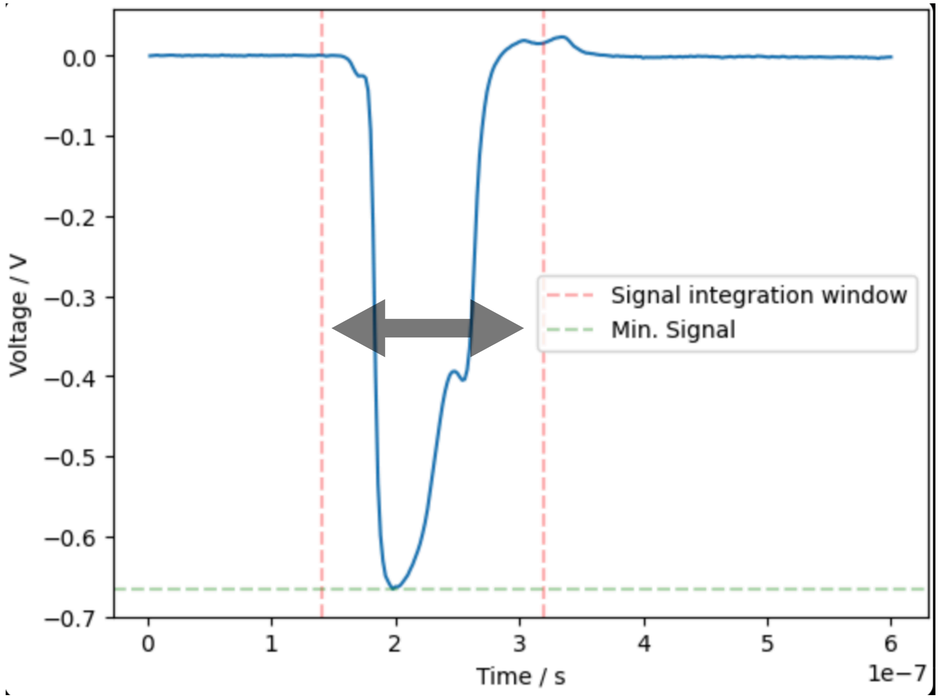


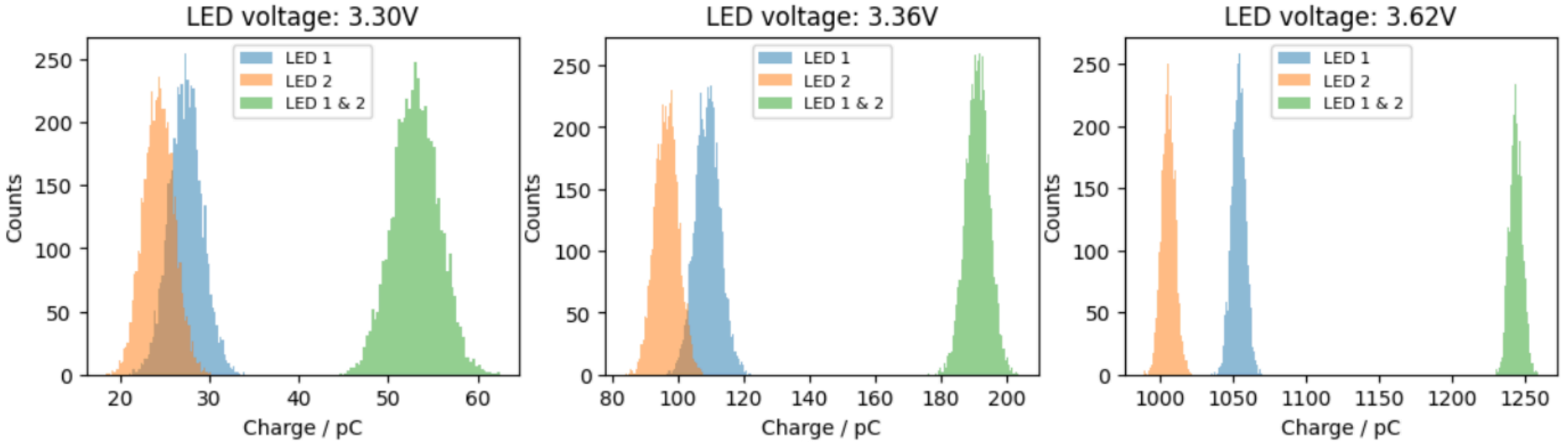


Non-linearity

- Measurement procedure
  - LED A is fired.
  - LED B is fired.
  - LED A & B are fired.

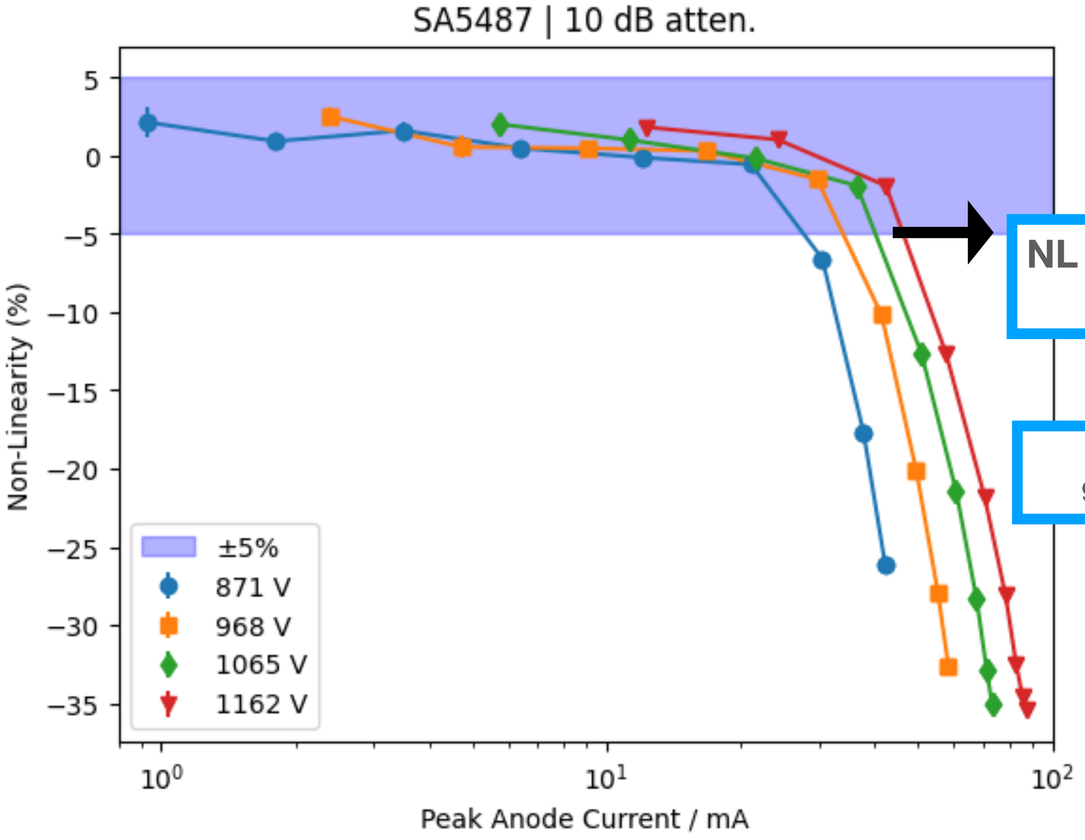
- Charge is estimated in each case by fitting a normal distribution.





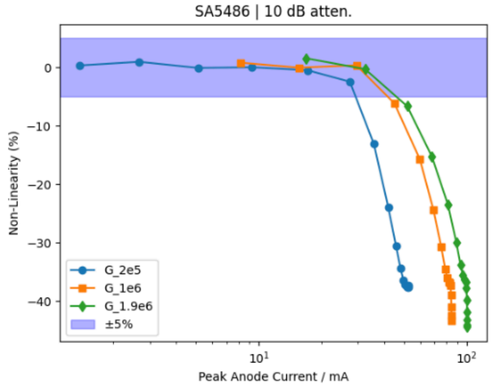
Non-Linearity

$$\mathrm{NL}(\%) = 100 \times \frac{\mathrm{Q}_{AB} - (\mathrm{Q}_A + \mathrm{Q}_B)}{\mathrm{Q}_A + \mathrm{Q}_B}$$

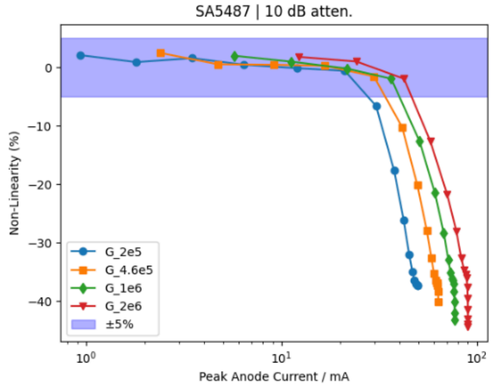


NL <5% @ ~50 mA/ 2.5 V

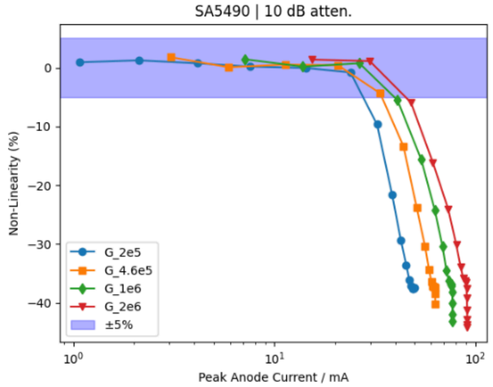
~5 V for Photonis 9” (GAP 2008-030)



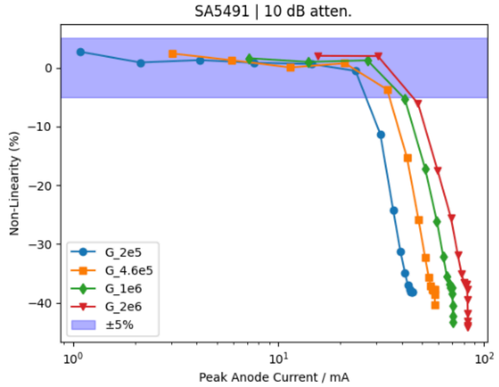
(a)



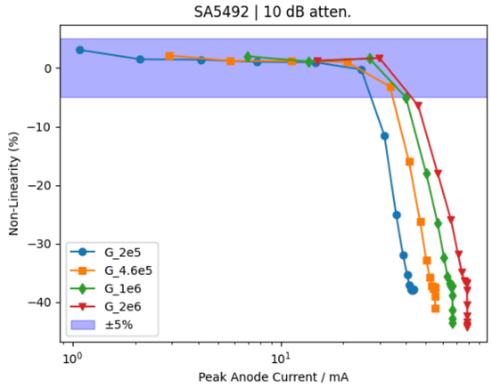
(b)



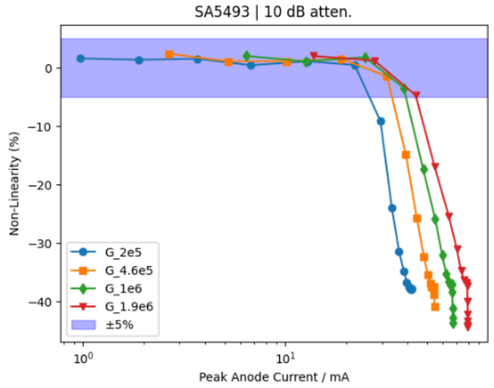
(c)



(d)



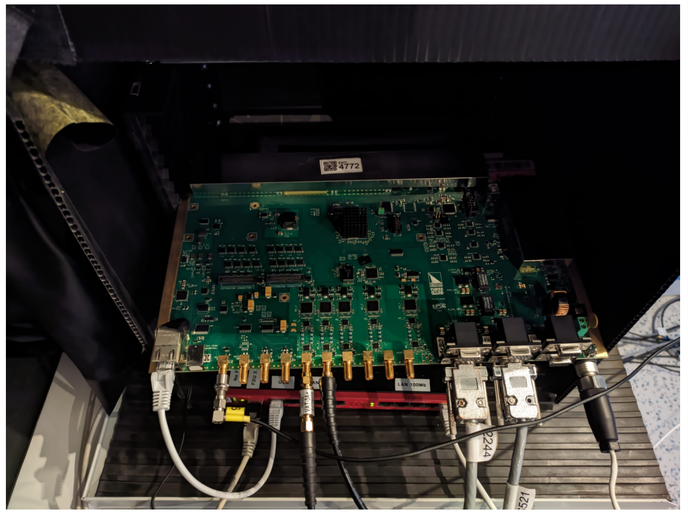
(e)



(f)

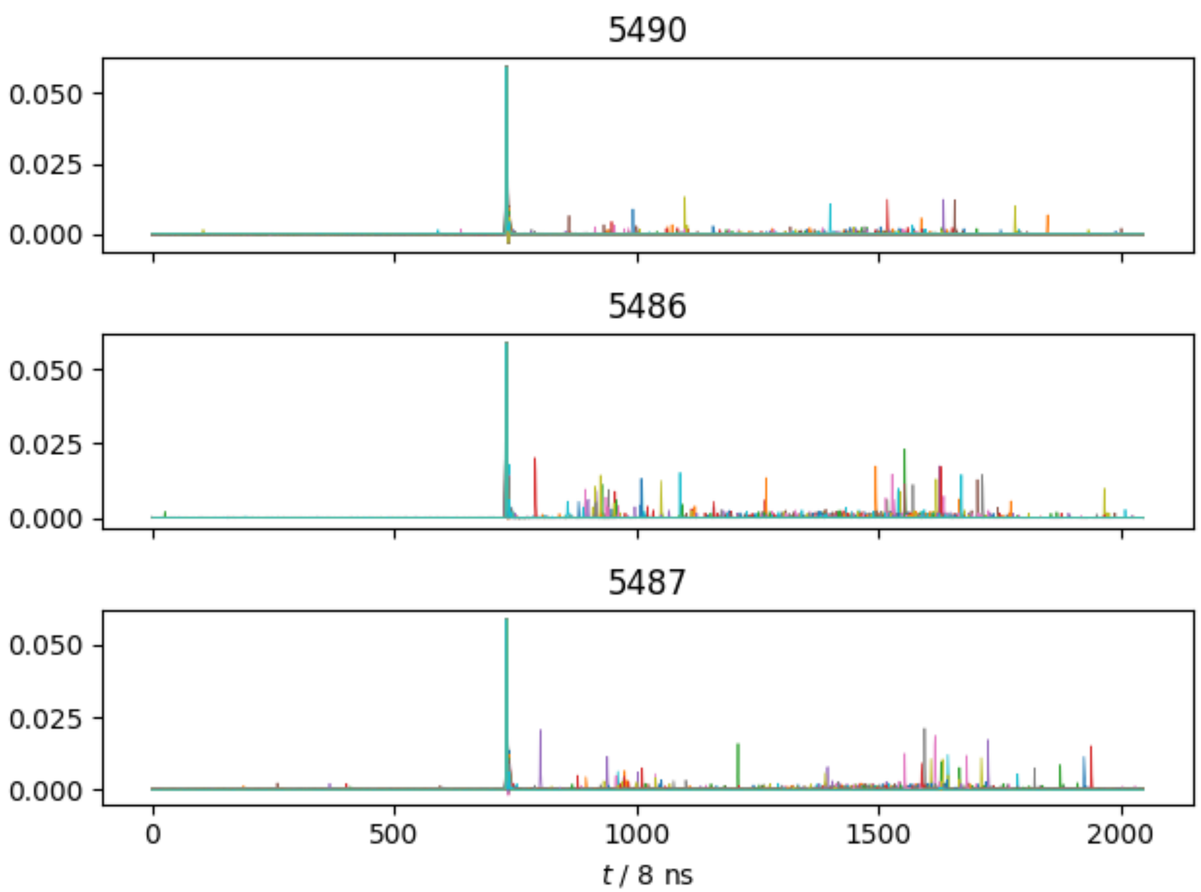
Afterpulses

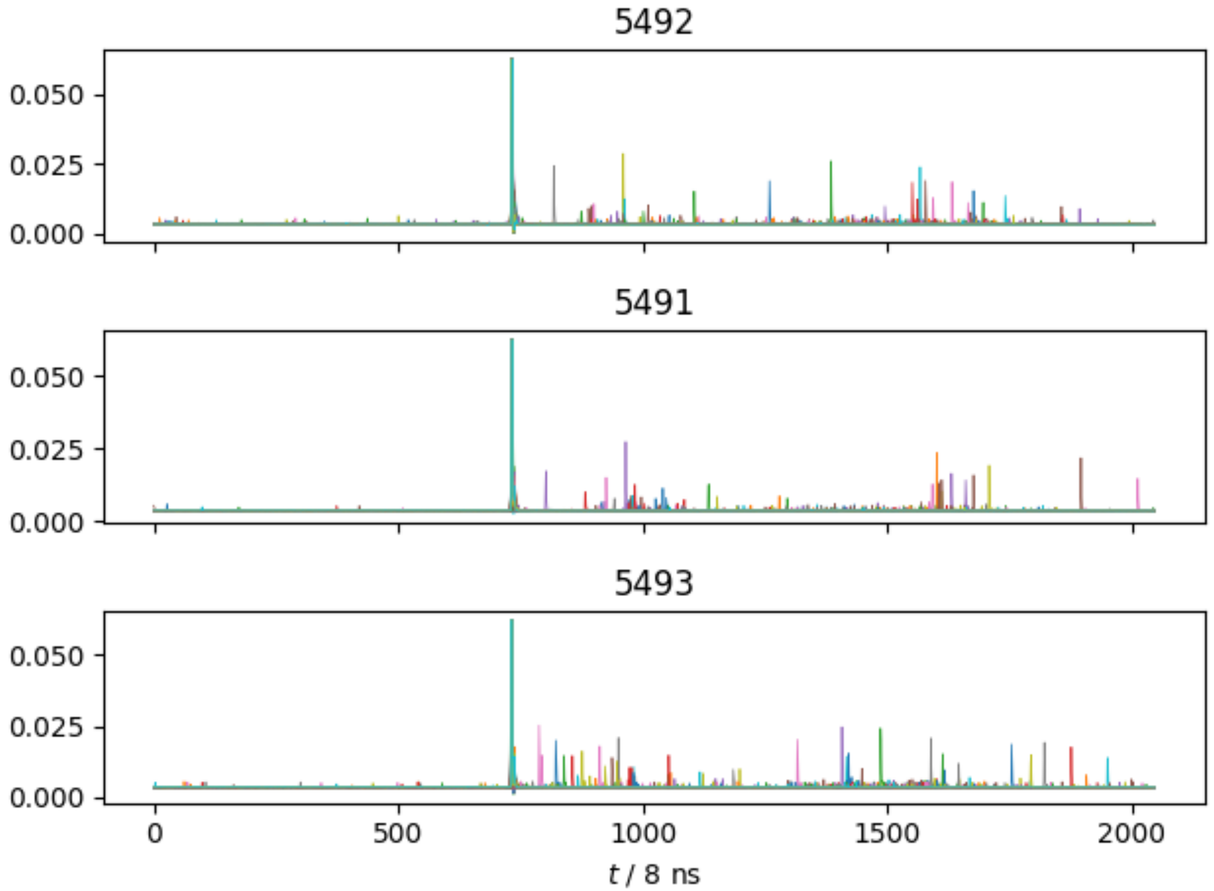
- Afterpulses can be an indication of gas contamination inside the glass envelope
- We performed these measurements using the UUB as the acquisition system.
- This way we could test 3 PMTs simultaneously.
- Lower sampling rate (120 MHz) —> 8 ns bin instead of 2ns



Afterpulses

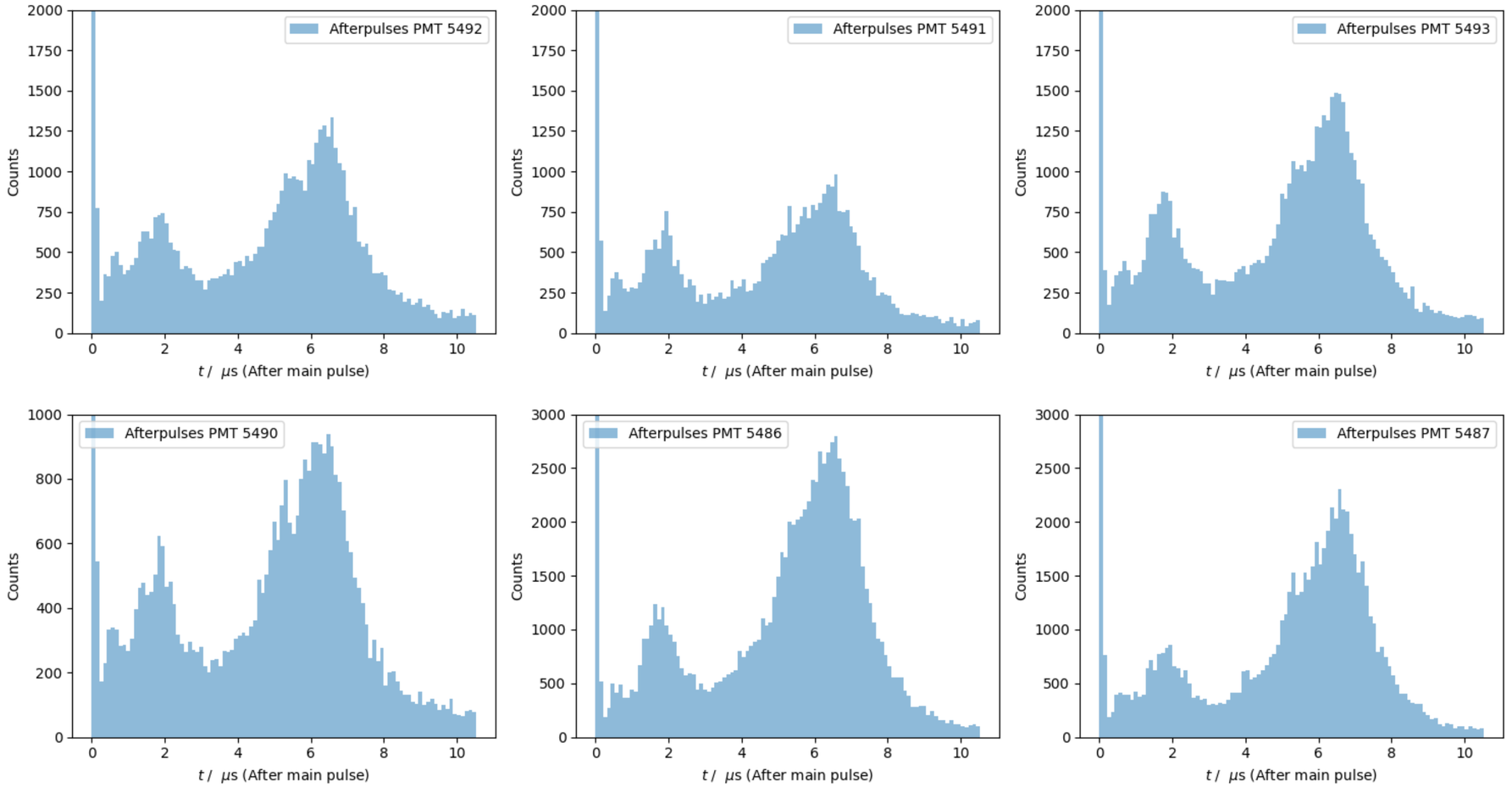
- First 100 traces for each PMT





Afterpulse

- Time distributions of peaks (>3σ noise level)
- Peaks at ~2 and ~6 μ s after main peak
- Differences in the counts between PMTs, not correlated with the PMT gain…



Conclusions and outlook

- Amazing lab at FZU, thanks to Martina and her group!
- Gain of $\sim 1.9 \times 10^6$ at 1200 V, with a (preliminary) spread between the 6 PMTs of ~27%
- Linearity up to 50 mA (2.5 V), half the value than for Photonis 9-inch PMTs. Is this good enough? In principle yes for the 3 prototypes, but what about the full PEPS config?
- Afterpulses time distributions show peaks at ~2 and ~6 μs, analysis ongoing to estimate after pulse charge-time distribution and signal intensity dependence.
- Are there any other PMT options we can investigate?

Backup Slides

Auger Base

- PMT SA5487 and SA5493 were also tested with another base

PMT	Gain $[\times 10^6]$	σ_G [%]
SA5487	2.12± 0.04	48
SA5493	1.74± 0.03	36