R5912 characterization

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2nd PEPS workshop | Osaka Metropolitan University

Hamamatsu R5912 characterization

Six photomultiplier tubes were tested at FZU (Prague), current crosschecks in Brussels

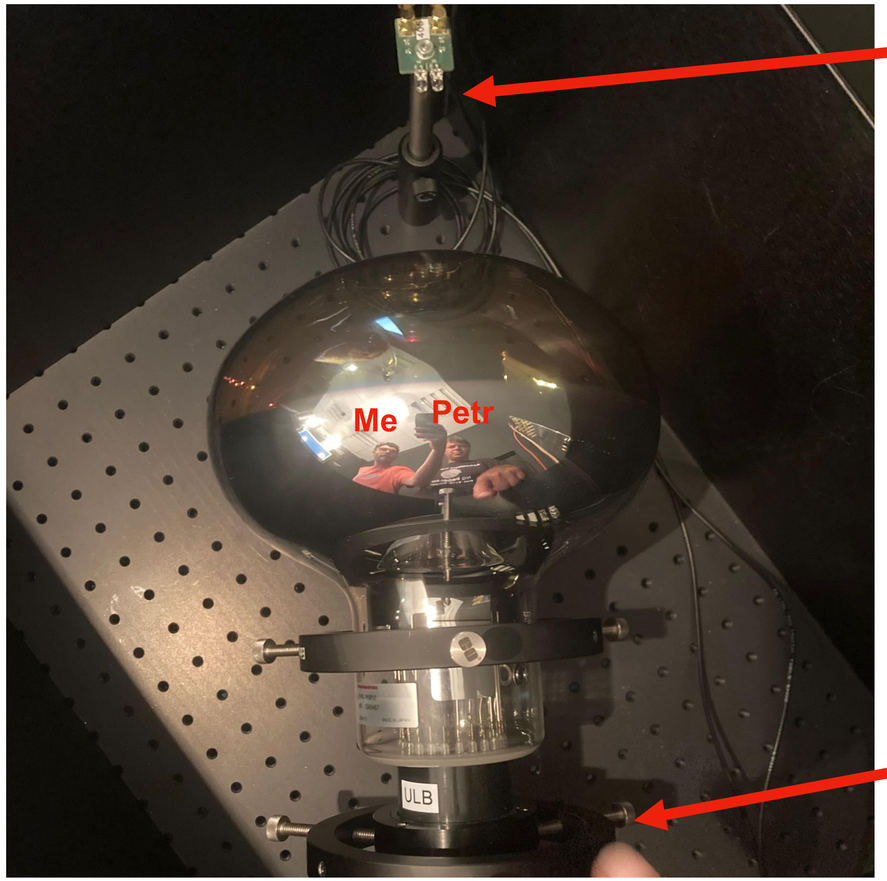
Tests:

- Single Photo Electron spectrum
- Gain VS high voltage
- Non-linearity
- Afterpulse analysis
- Dark rate

Experimental setup (@ FZU, Prague)

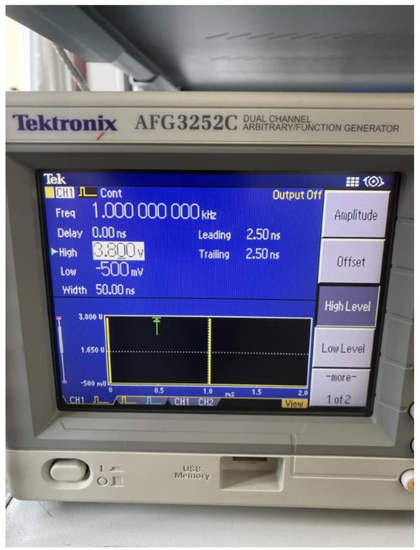
PMT placing inside the black box

2 LED (λ = 405 nm)

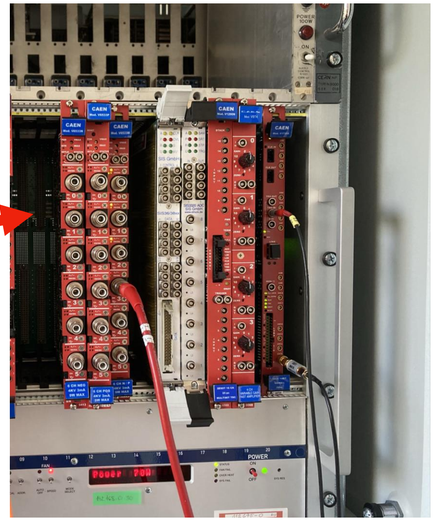


Hamamatsu base: HV input / signal readout

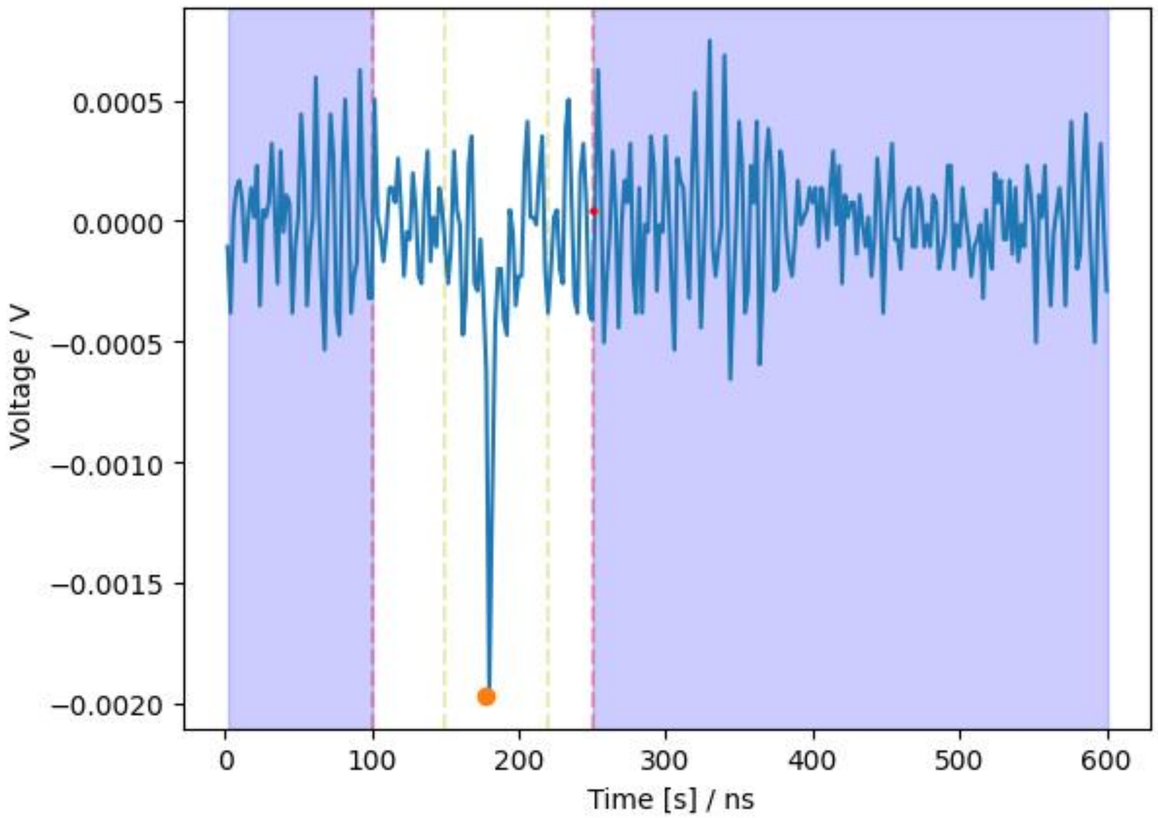
Signal generator: 1kHz, 50 ns steps

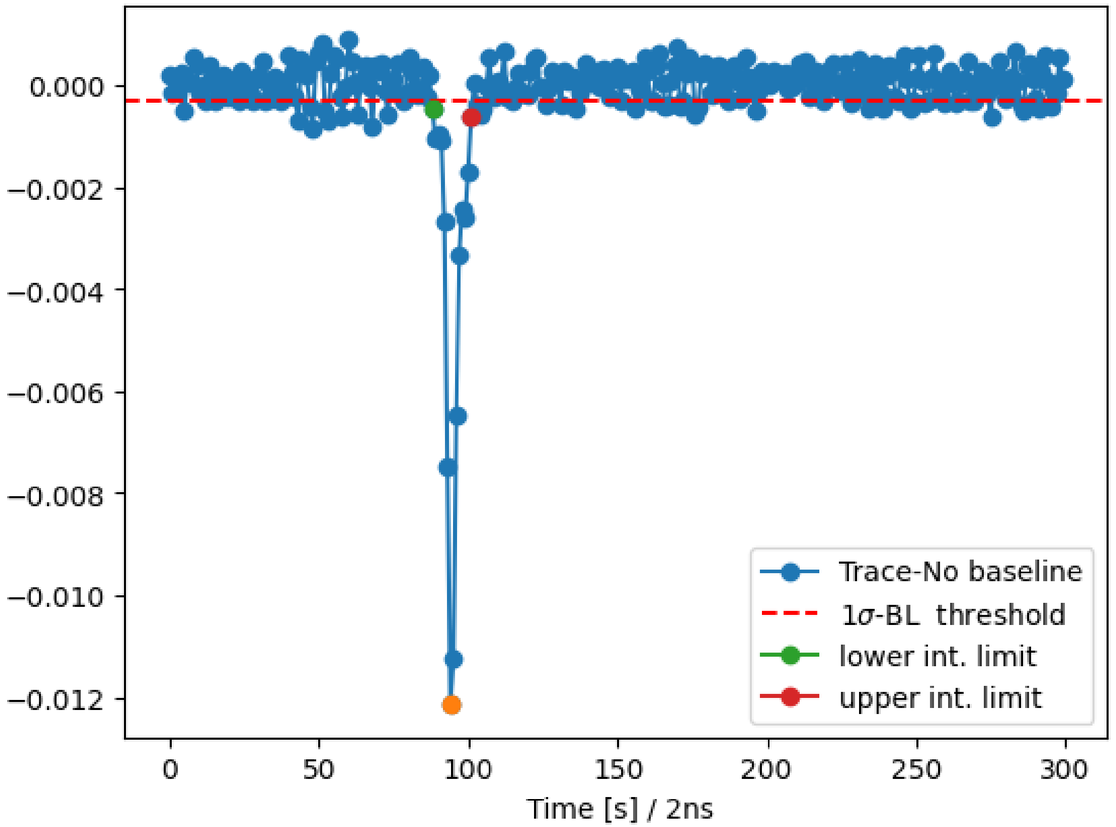


Power supply and signal digitizer (500 MHz)



Trace analysis





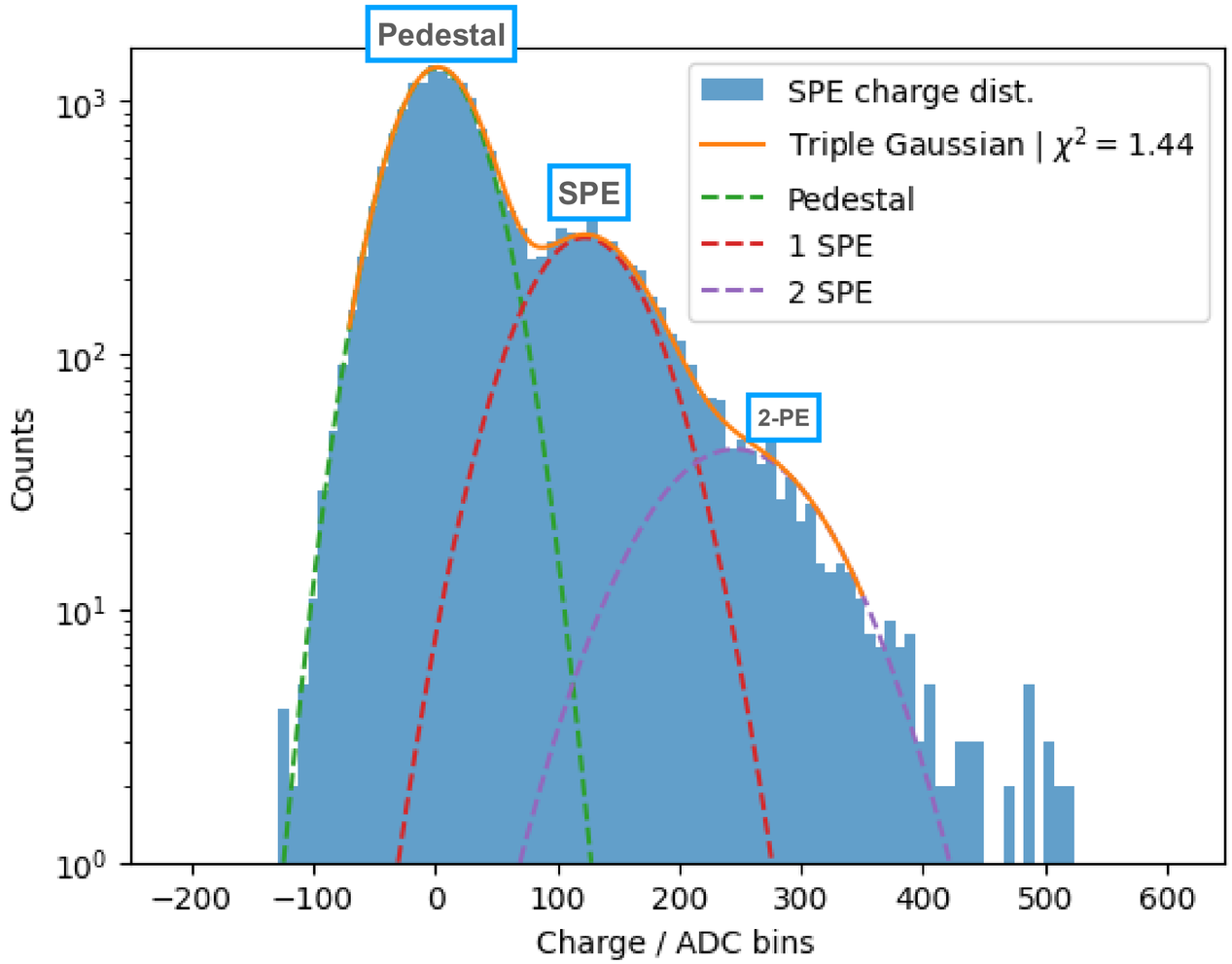
Selection cuts are applied to avoid high-noise traces

Integration window is calculated for each trace individually

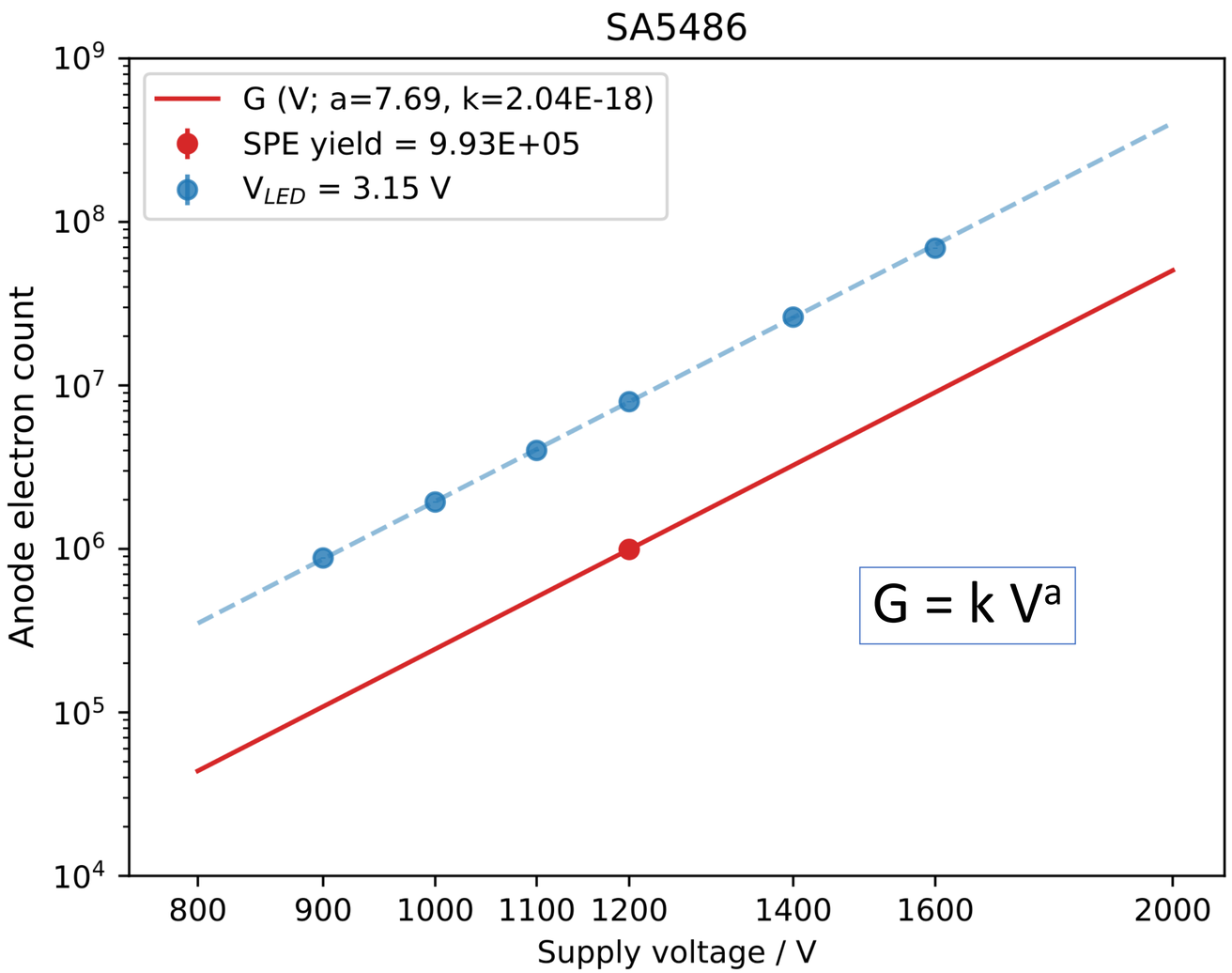
Single photo-electron (SPE) spectrum

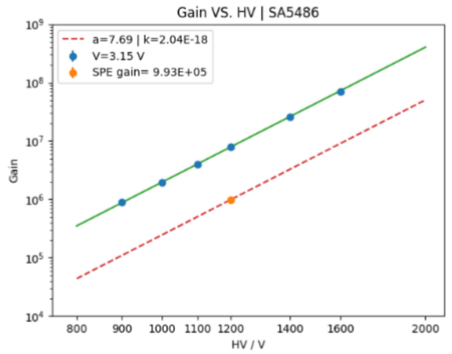
- Used a low light intensity for the LEDs
- The SPE, mean (μ_{SPE}) and variance (σ^2_{SPE}) are extracted from a fit of the full distribution
- The SPE gain and resolution are calculated for each PMT
- $G = \frac{1}{e}\left[\frac{\Delta V}{D} . \frac{\Delta t}{R}\right] \mu_{SPE}$

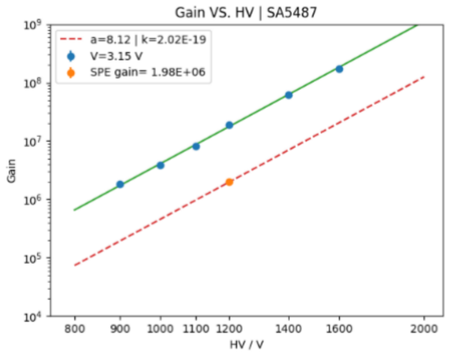
$G \sim 1.94 \times 10^6$

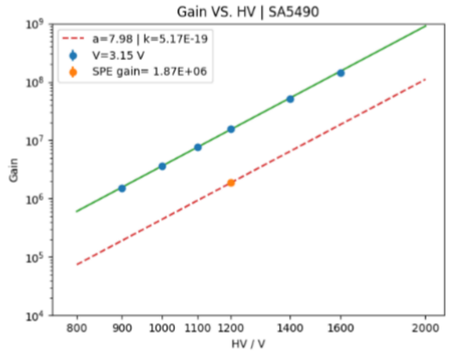


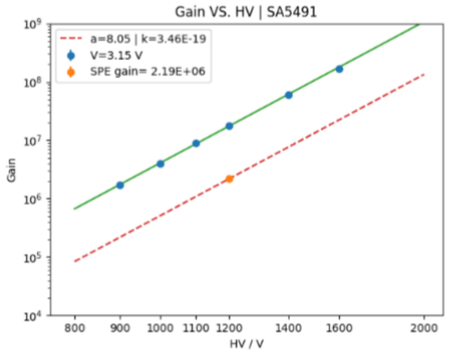
Gain VS. HV

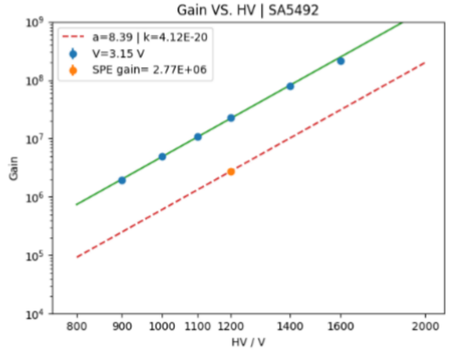

SA5486
G (V; a=7.69, k=2.04E-18)
SPE yield = 9.93E+05
V_{LED} = 3.15 V
G = k V^a
Anode electron count
Supply voltage / V

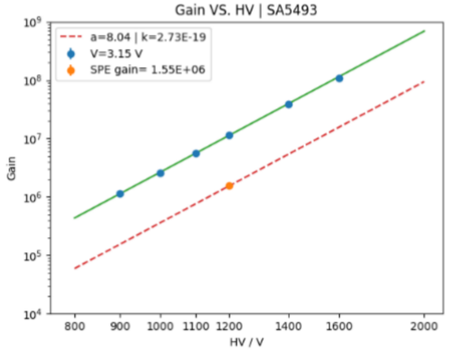

Gain VS. HV | SA5486
a=7.69 | k=2.04E-18
V=3.15 V
SPE gain= 9.93E+05
Gain
HV / V


Gain VS. HV | SA5487
a=8.12 | k=2.02E-19
V=3.15 V
SPE gain= 1.98E+06
Gain
HV / V


Gain VS. HV | SA5490
a=7.98 | k=5.17E-19
V=3.15 V
SPE gain= 1.87E+06
Gain
HV / V


Gain VS. HV | SA5491
a=8.05 | k=3.46E-19
V=3.15 V
SPE gain= 2.19E+06
Gain
HV / V


Gain VS. HV | SA5492
a=8.39 | k=4.12E-20
V=3.15 V
SPE gain= 2.77E+06
Gain
HV / V

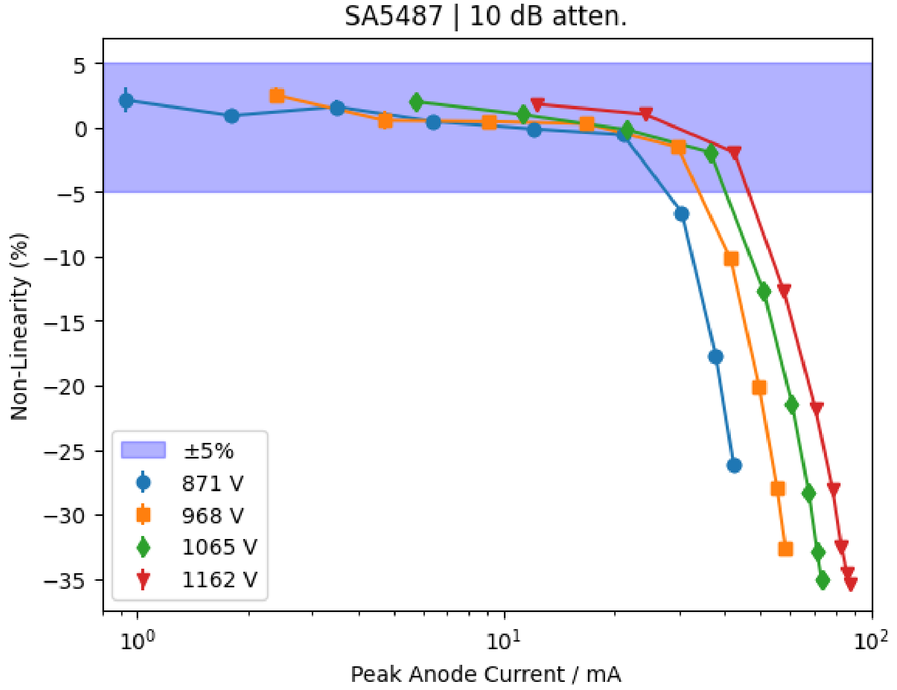

Gain VS. HV | SA5493
a=8.04 | k=2.73E-19
V=3.15 V
SPE gain= 1.55E+06
Gain
HV / V

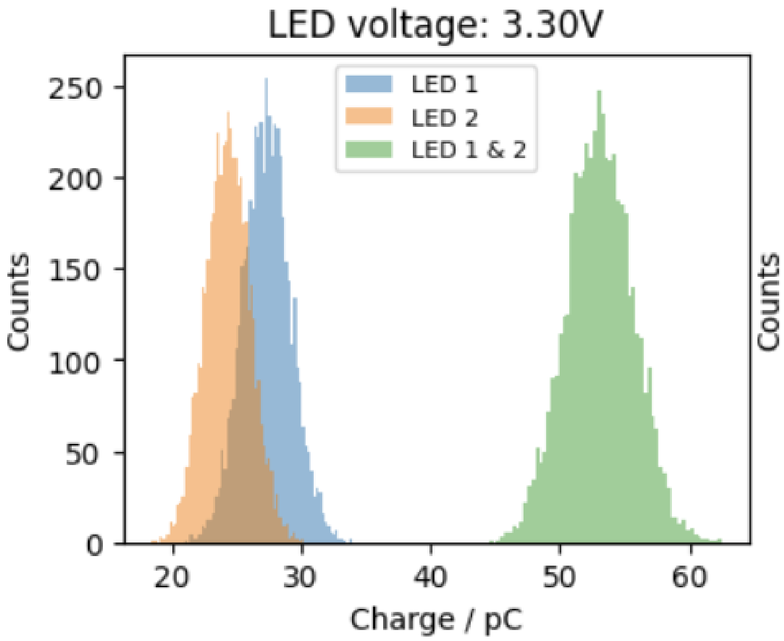
Non-linearity

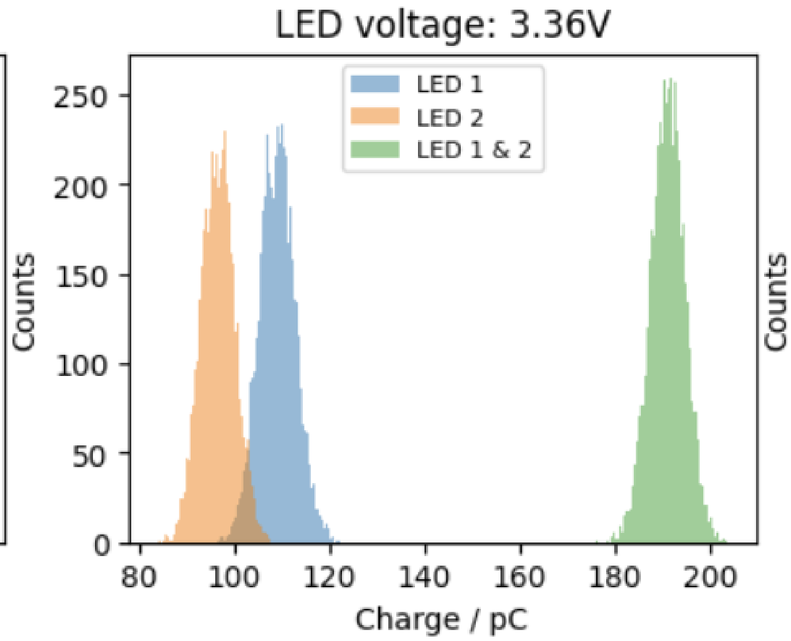
- Measurement procedure
  - LED A is fired.
  - LED B is fired.
  - LED A & B are fired.

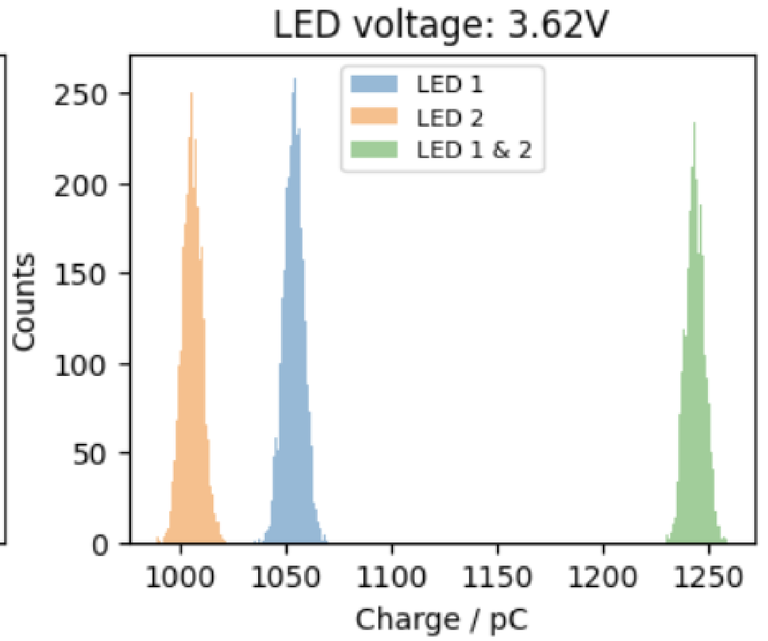
- Charge is estimated in each case by fitting a normal distribution.

- Non-linearity **within 5% up to 50 mA** (2.5 V)







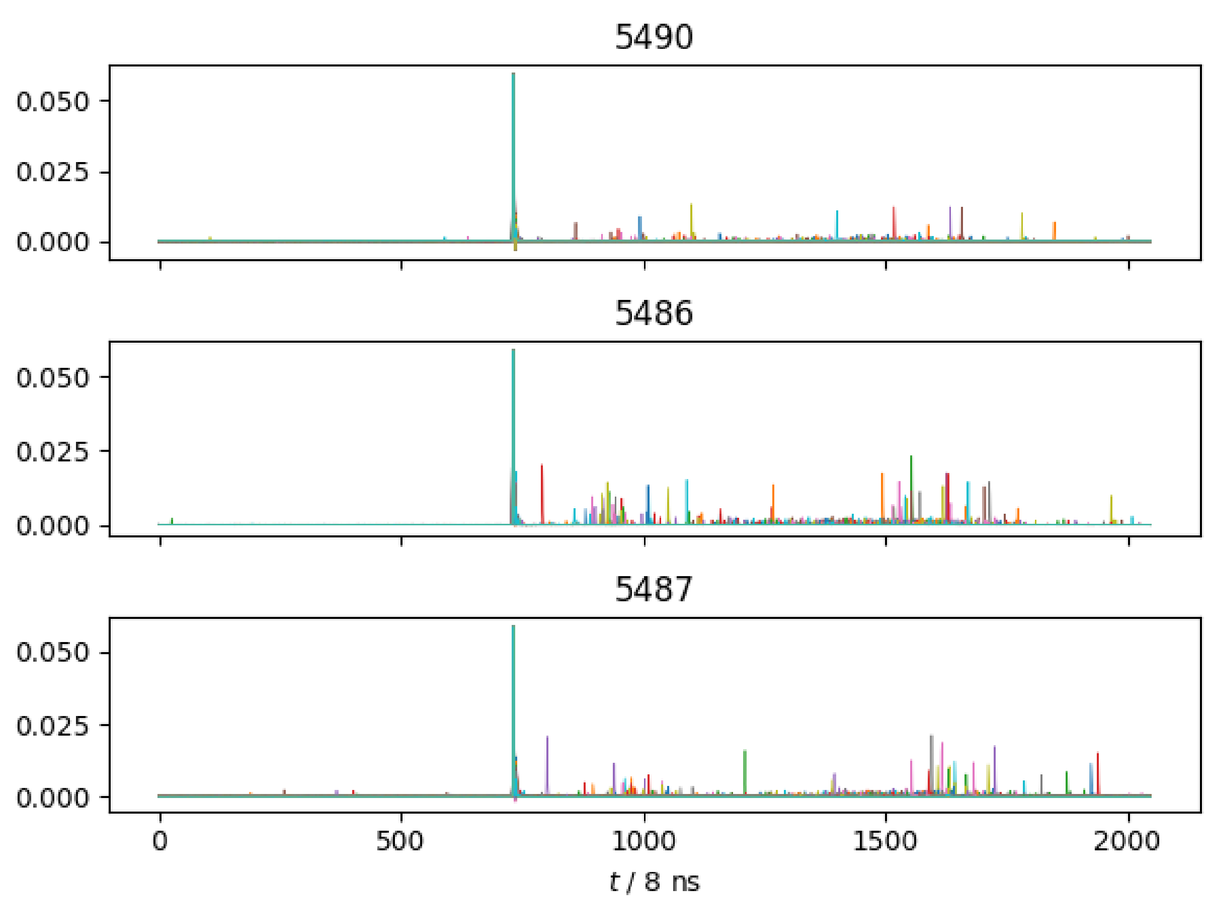


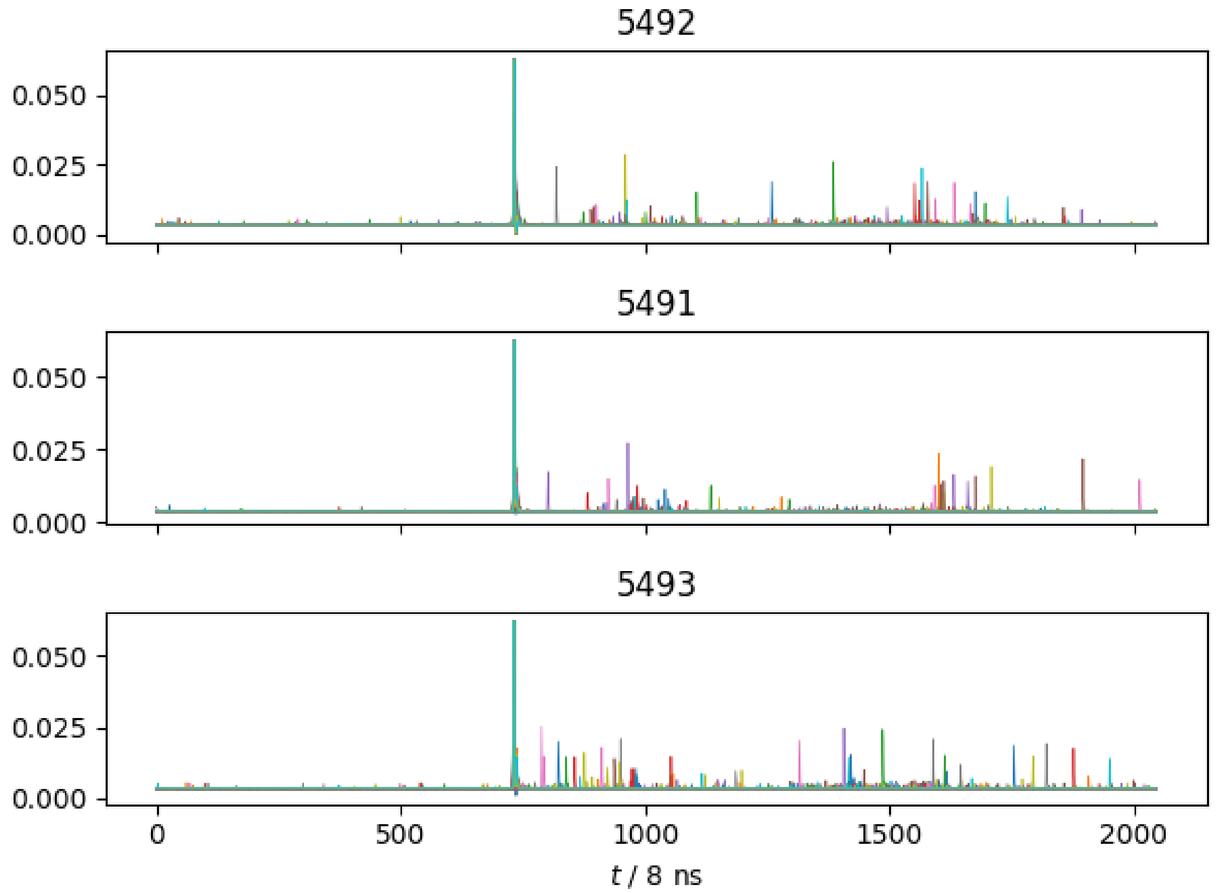
Afterpulses

PMT interior is not 100% vacuum --> ionized molecules can drift and generate secondary electron cascades (in the photocatode/dynode)

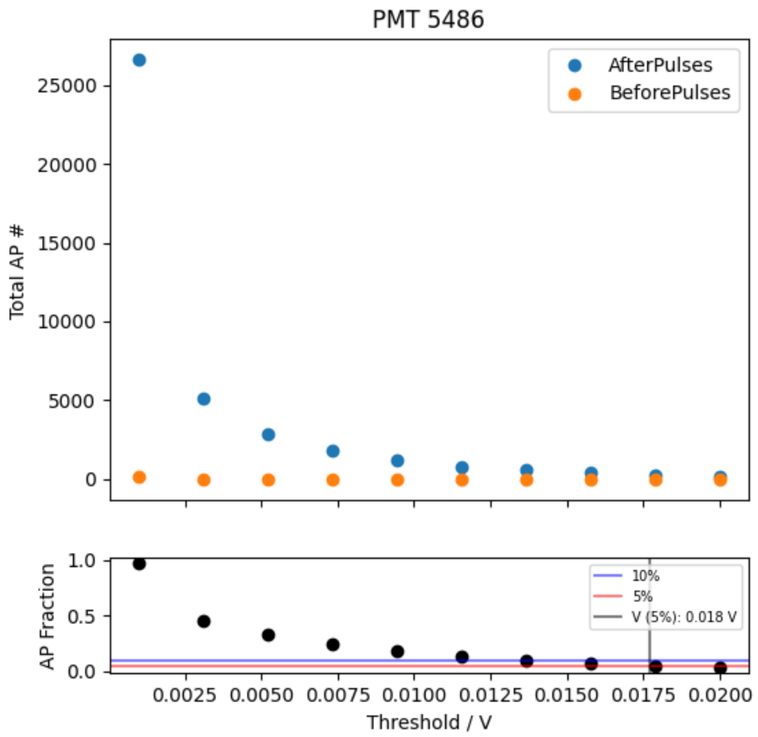
UUB used for acquisition (125 Ms/s)

We use the "beforepulse" fraction to define the **base-threshold --> 5 mV**



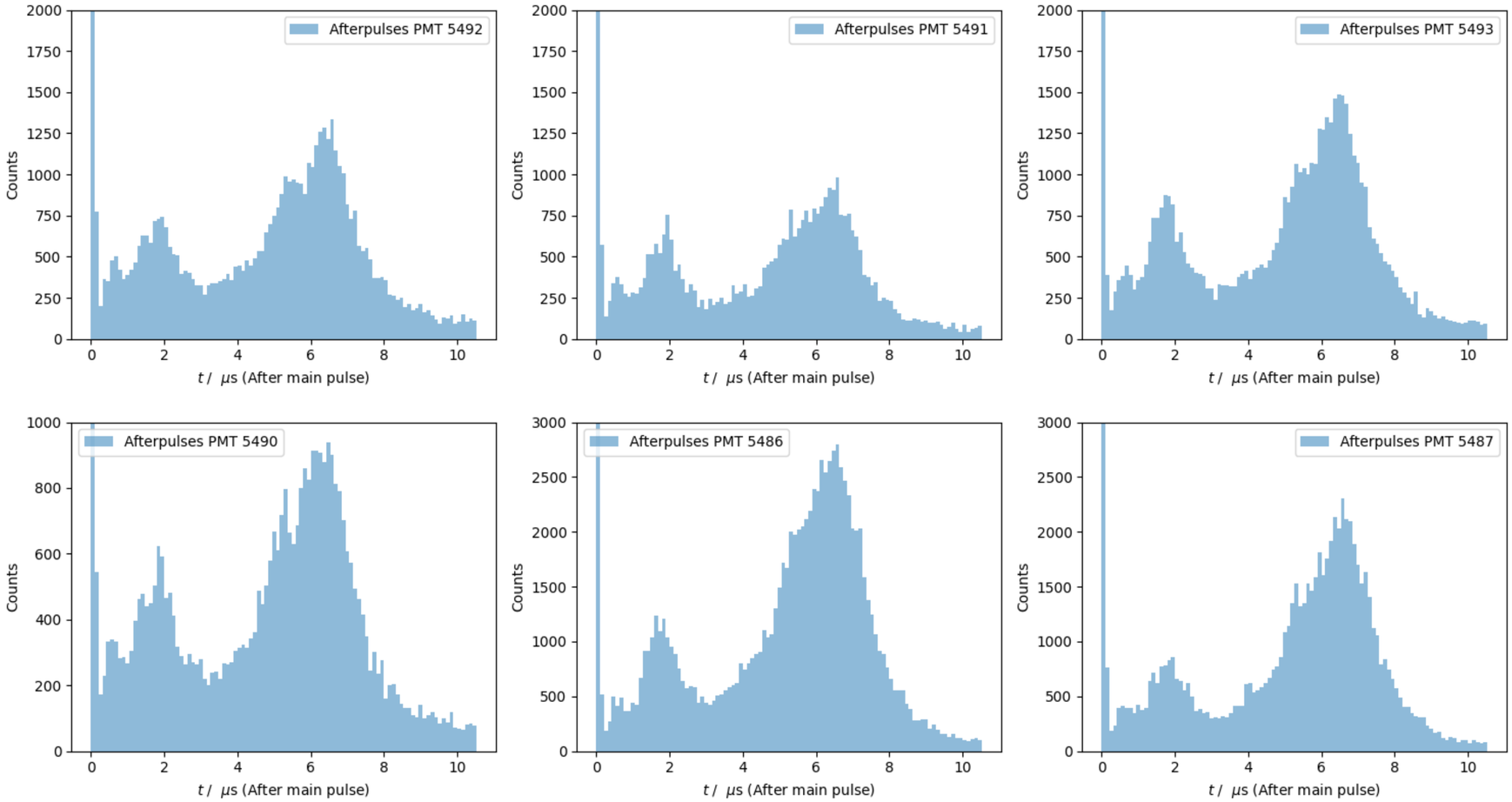


Afterpulses



AP fraction threshold dependence

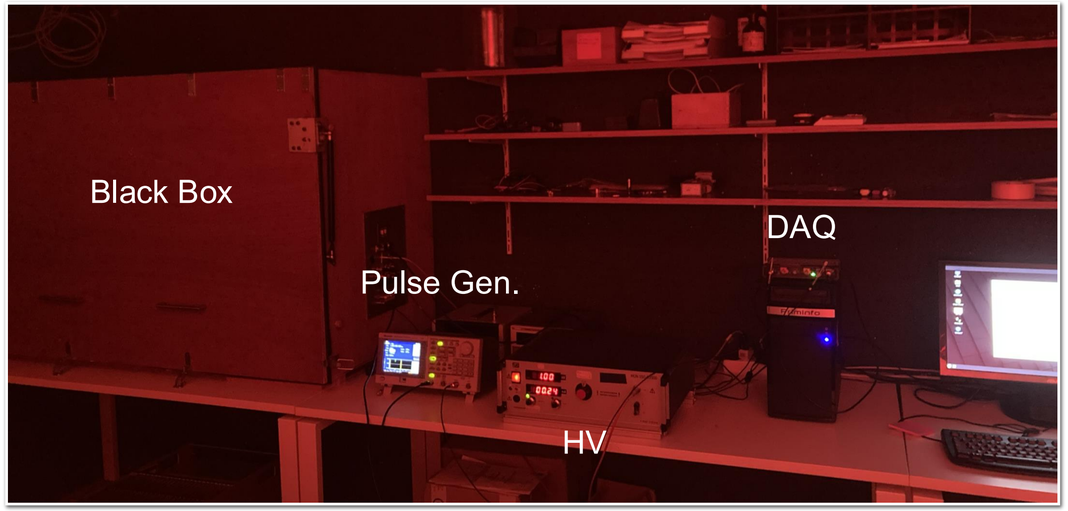
Drops below 5% above 15 mV

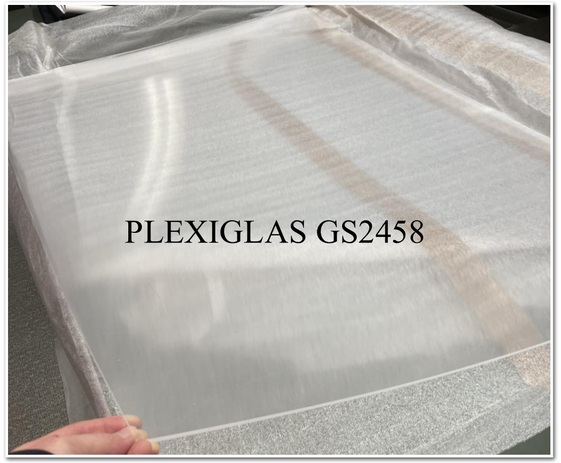


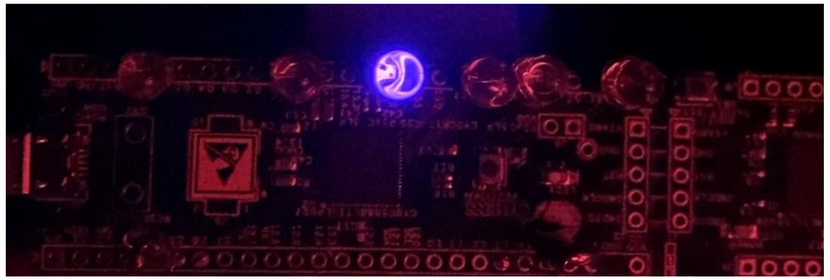
Time distributions with peaks @ 2 and 6 mus

PMT testbench development in Brussels

- Performing independent cross-checks and other tests on future PMTs (quantum eff.)
- Optical window: plexiglass GS2458 custom-made (thermoforming+laser cutting) also to be tested

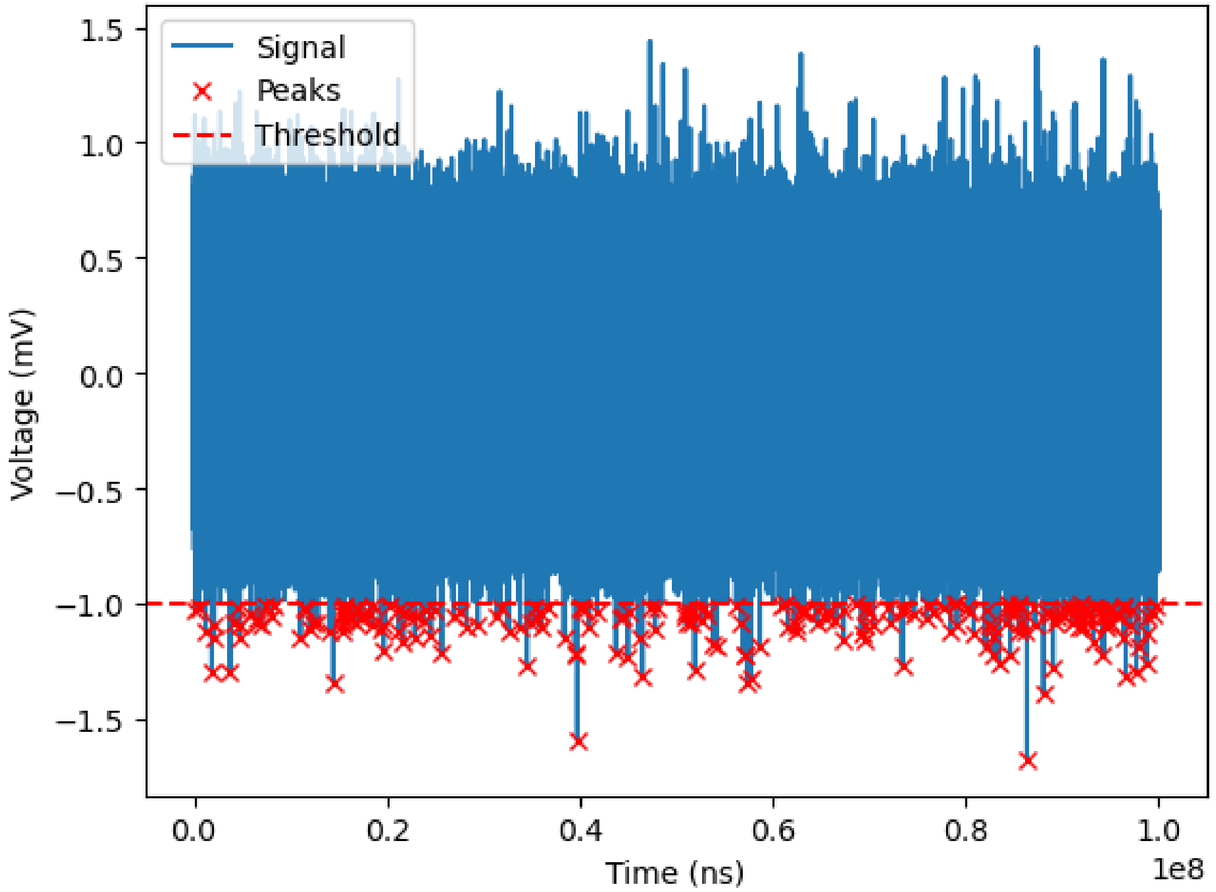






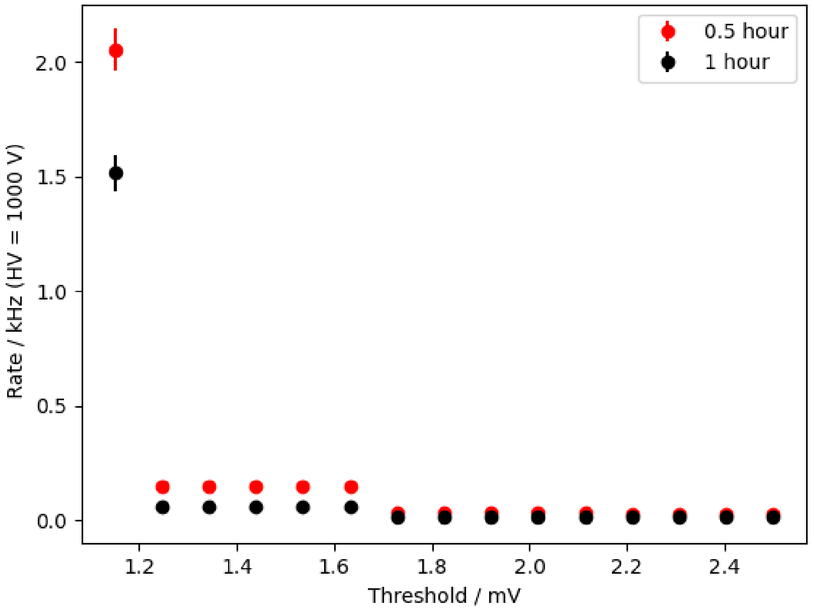
Dark rate measurements

- Dark rate: pulses above a certain threshold in the absence of light
- Mainly thermal noise and current leaks
- Sampling rate 250 MHz —> 4 ns
- 5000 traces
- Total time = 0.25 s (quite long)

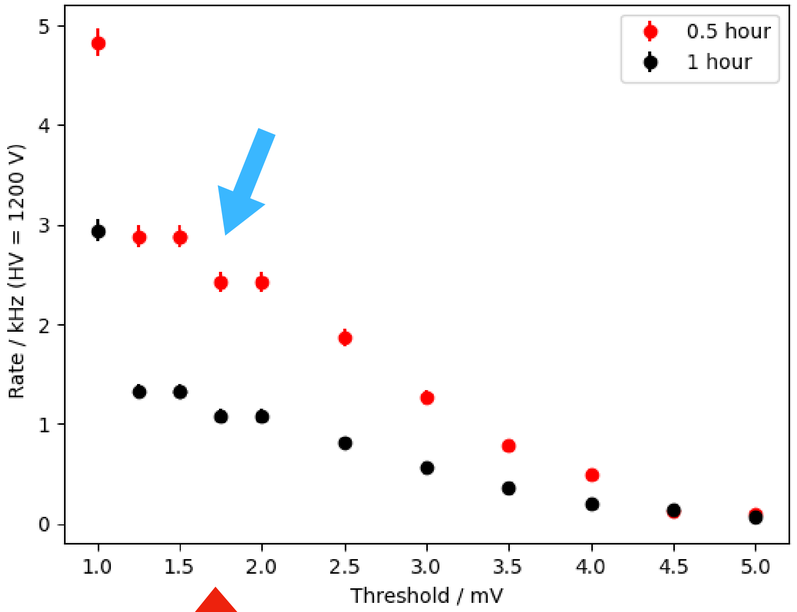


Dark rate vs. threshold

1000 V

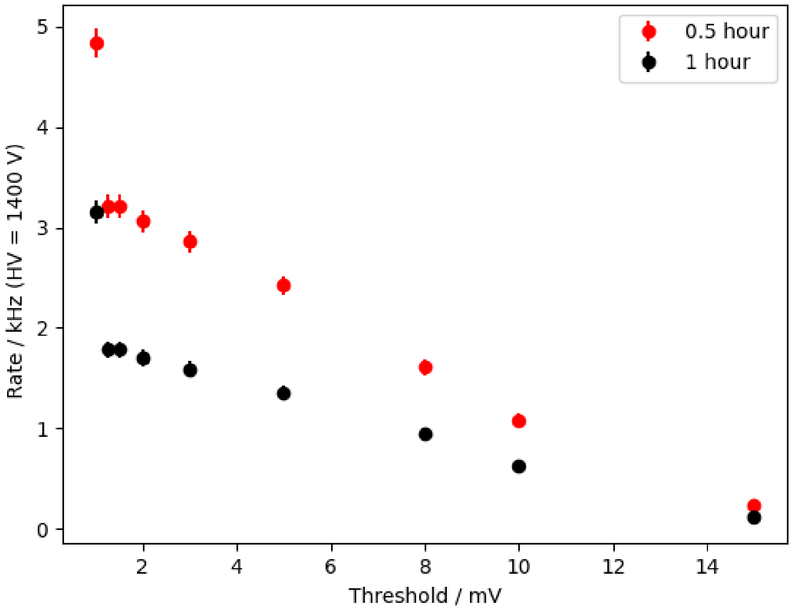


1200 V

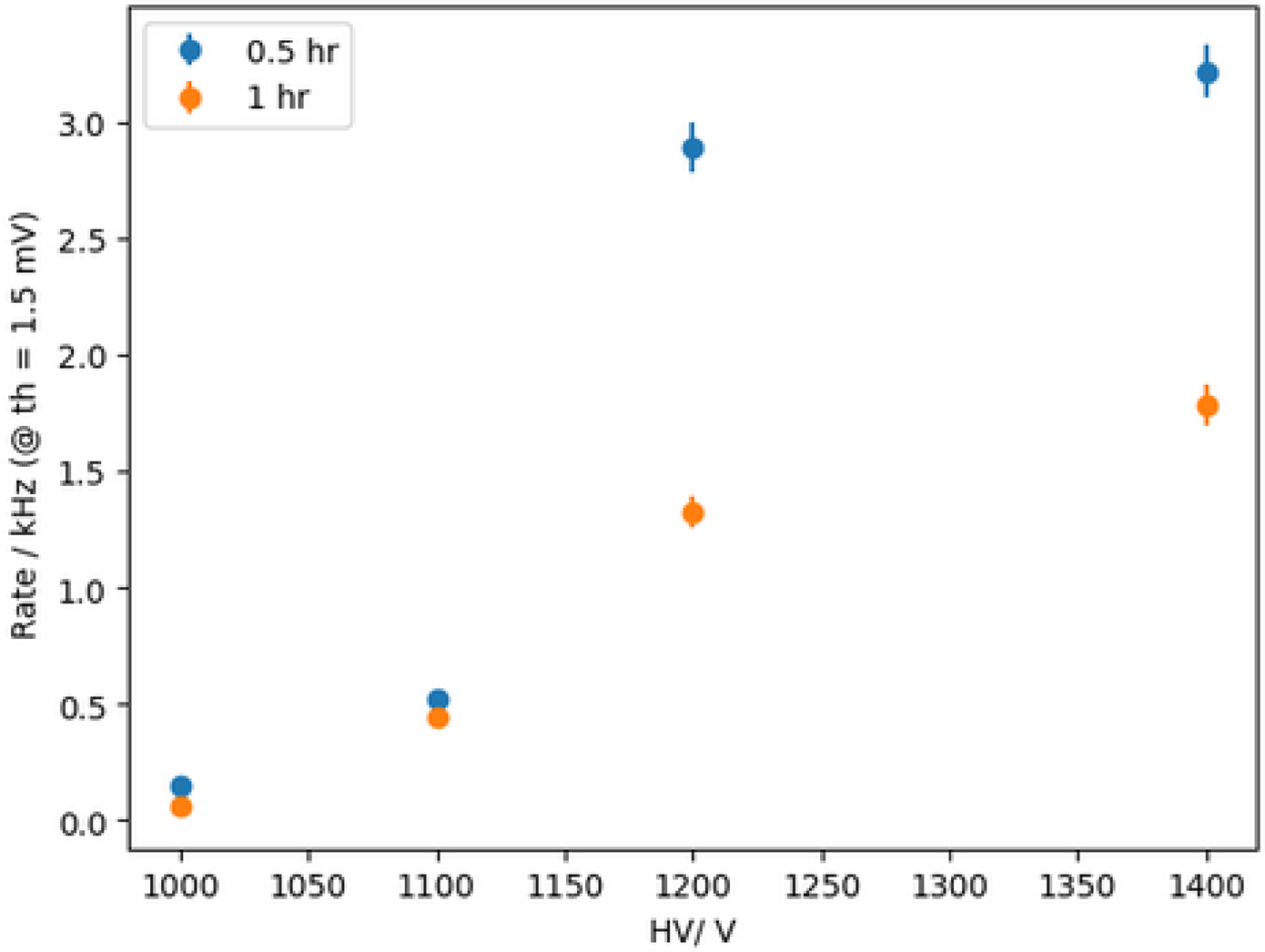


~ 1/4 p.e

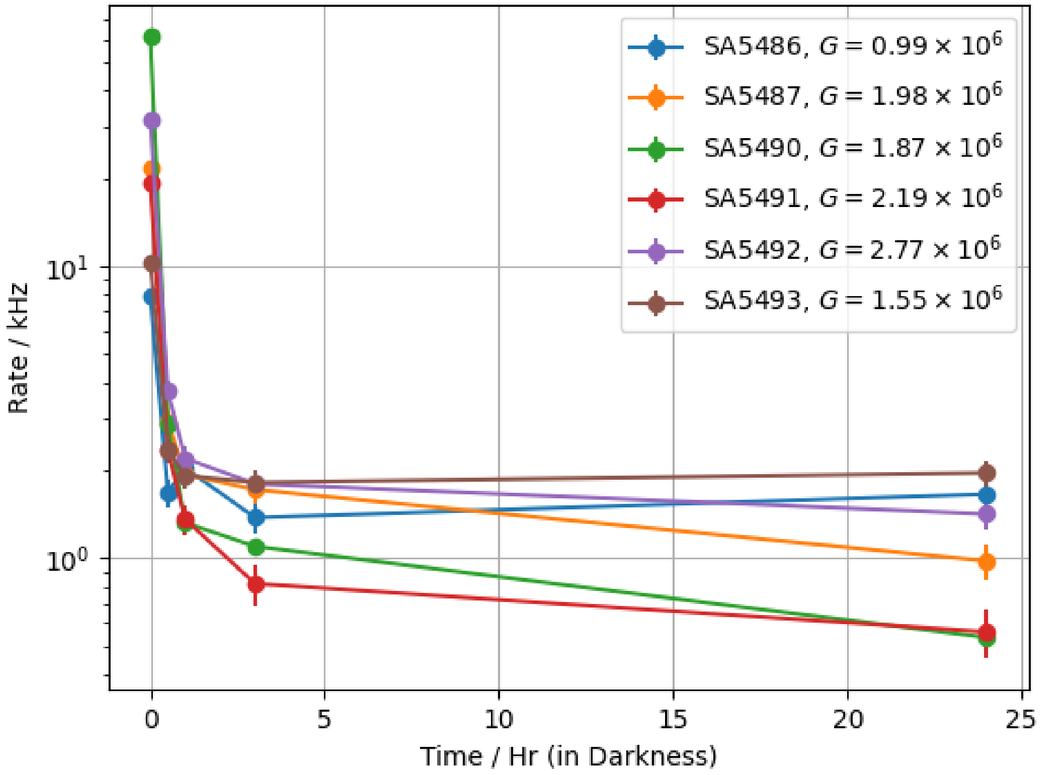
1400 V



Dark rate vs. HV (th = 1.5 mV)



Dark rate vs. time (in darkness)



Supply Voltage for Gain of 1×10^7		-	1500	2000	V
Anode Dark Current (after 30 min. storage in darkness)		-	100	1000	nA
Dark Count (after 24 hrs. storage in darkness) *1		-	4000	8000	s^{-1}
Time Response	Anode Pulse Rise Time	-	3.6	-	ns
	Electron Transit Time	-	54	-	ns
	Transit Time Spread (FWHM) *2	-	2	-	ns
P/V (Peak to Valley) Ratio *2		2.0	3.0	-	-
Pulse Linearity at +/-2% deviation		-	40	-	mA
Pulse Linearity at +/-5% deviation		-	60	-	mA
After Pulse		-	6	10	%

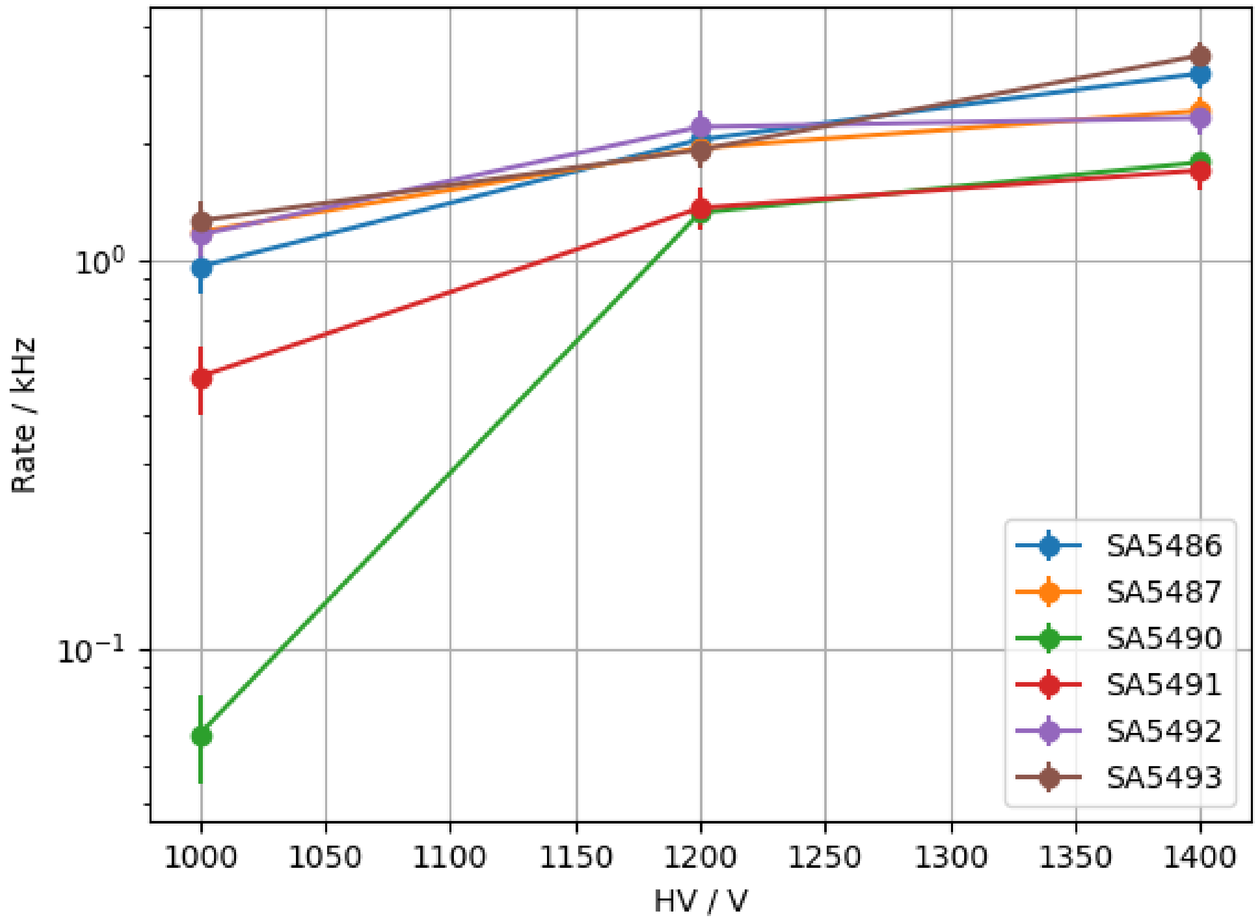
NOTES

* Anode characteristics are measured with the standard voltage distribution ratio.

*1 LLD : 1/4 p.e.

*2 at single p.e.

Dark rate vs. HV (60 min in darkness)



Summary

- 6 Hamamatsu R5912 PMTs were characterized in Prague and Brussels testbenches
- Average gain of ~$2x10^6$ with a 1-sigma spread of 30%
- Non- linearity: within 5% up to 50 mA – 2.5 V
- Afterpulse fraction below 5% for thresholds above 15 mV
- Dark rate around 1 kHz after 3 hours