Dark count and correlated noise in tile 21

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https://github.com/Gattocrucco/sipmfilter

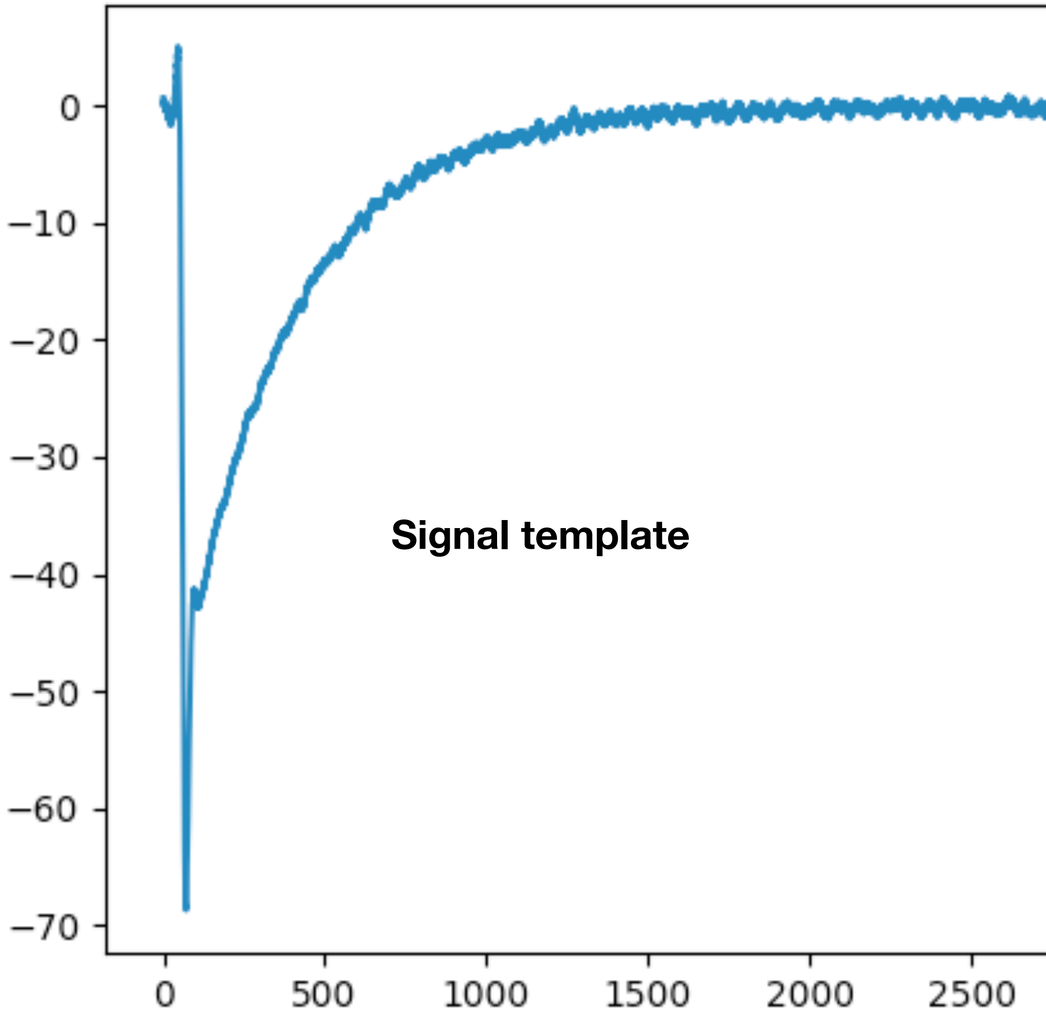
Data (1/2)

LNGS LN laser data.

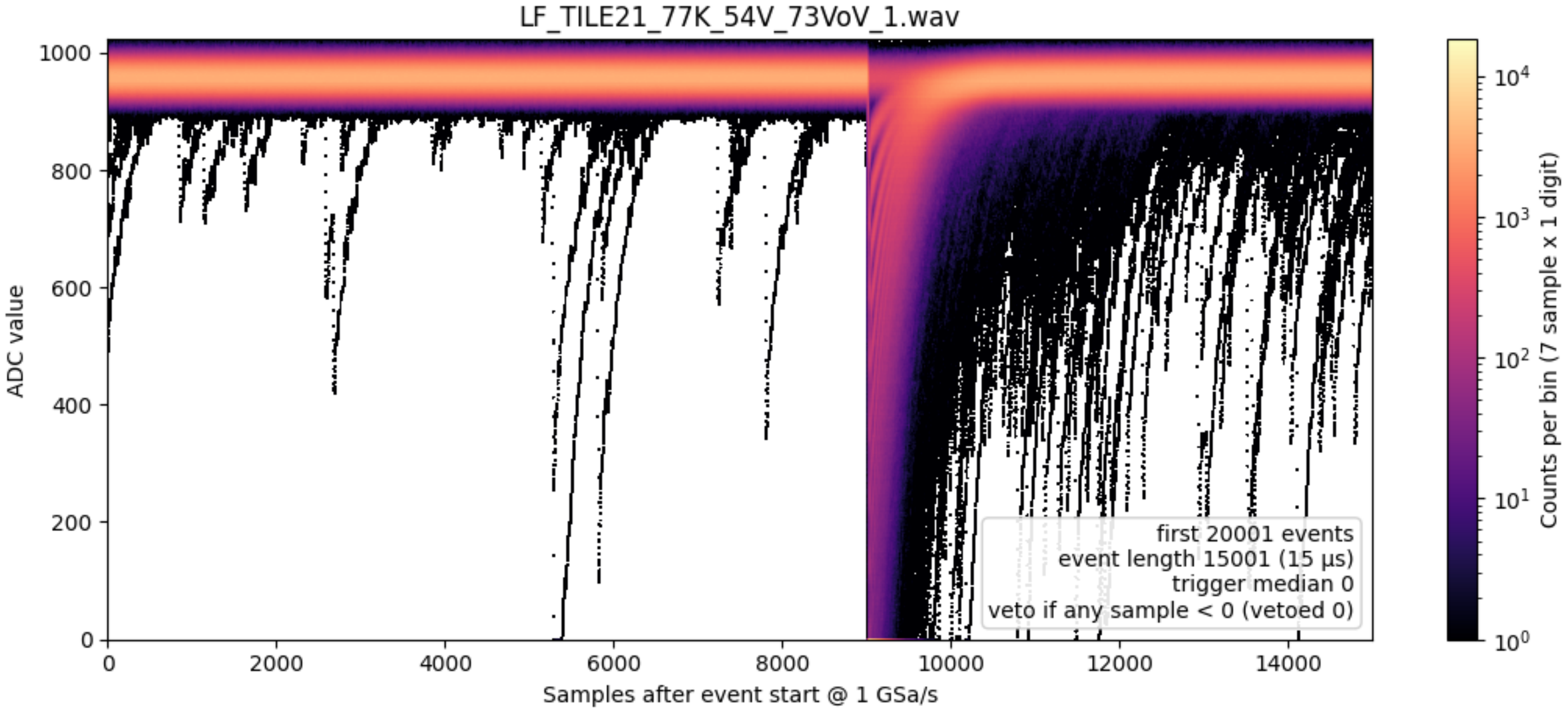
http://ds50tb.lngs.infn.it:2180/SiPM/Tiles/LFOUNDRY/pre-production-test/TILE_21/

We search for pulses using a cross-correlation filter and a prominence-based peak finder. The filter template is obtained from the mean of 1 pe laser-induced pulses.

We use all files (1–10).



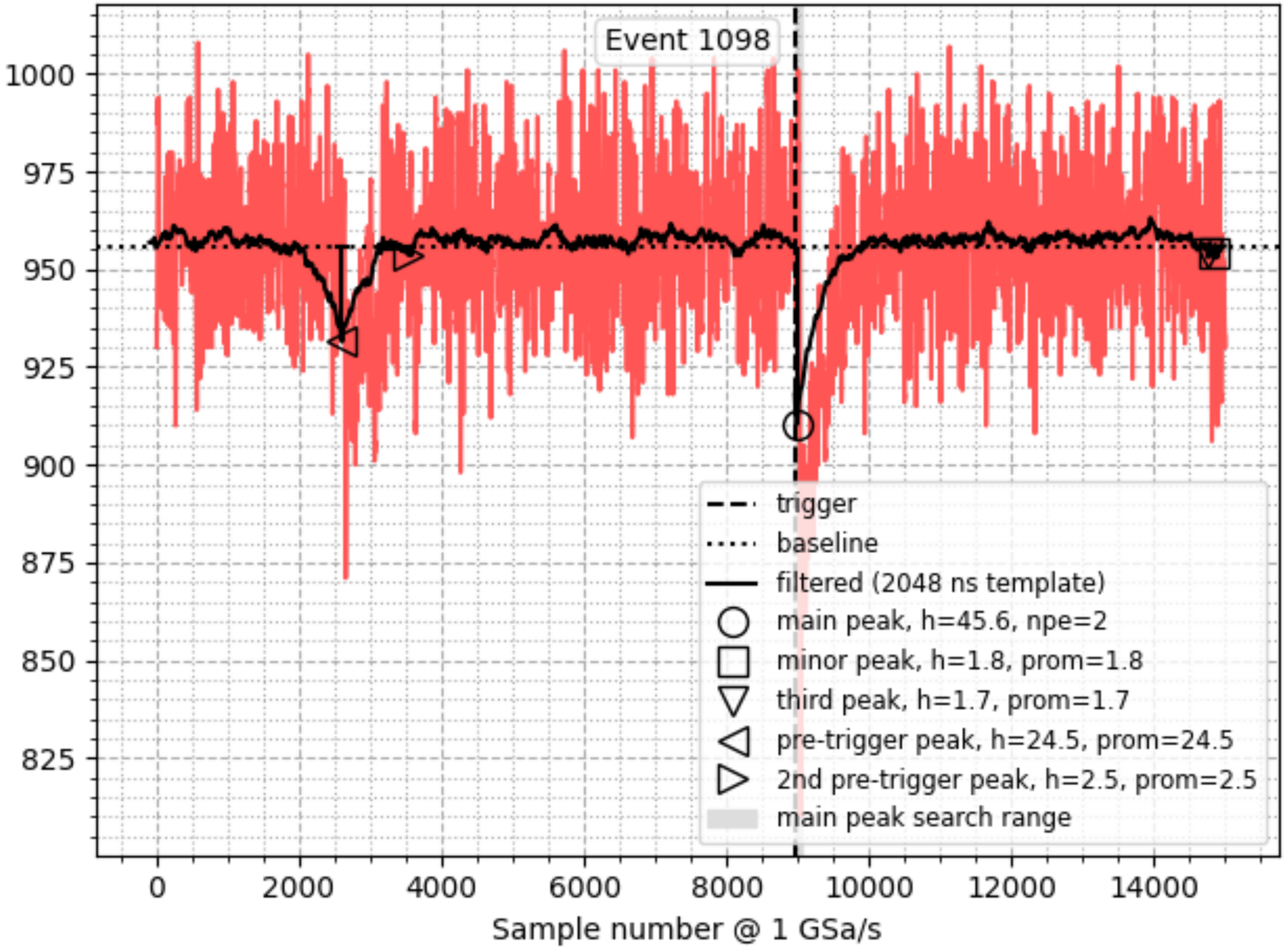
Data (2/2)


LF_TILE21_77K_54V_73VoV_1.wav
ADC value
Samples after event start @ 1 GSa/s
Counts per bin (7 sample x 1 digit)
first 20001 events
event length 15001 (15 µs)
trigger median 0
veto if any sample < 0 (vetoed 0)

Dark count (1/4)

We use the pre-trigger region to search for dark counts.

(This example plot and all the other example plots will be at 5.5 VoV.)

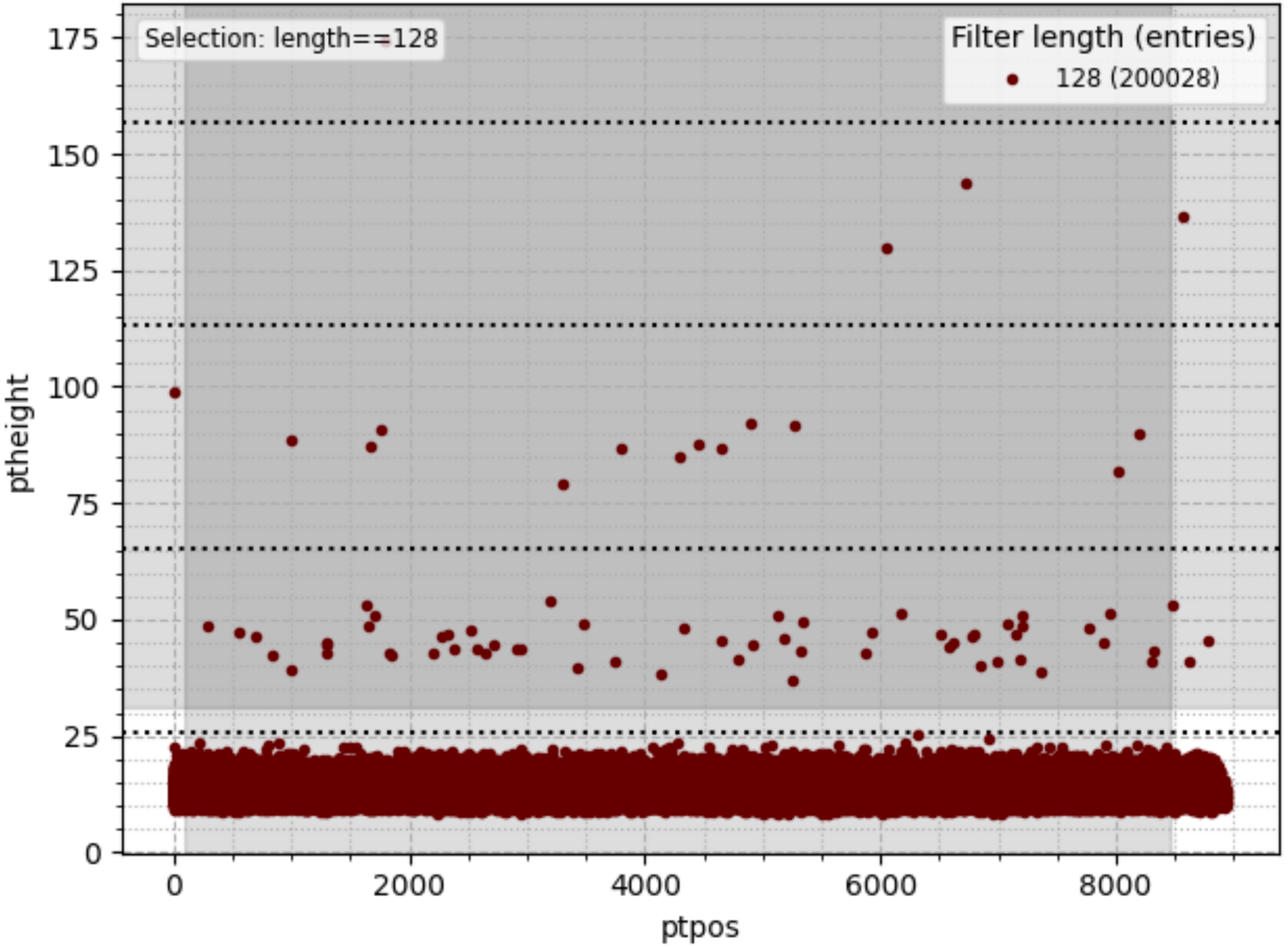


Dark count (2/4)

Scatterplot peak height vs. peak temporal position.

For the highest peak before the trigger in each event (so we don't count afterpulses for the dark count rate).

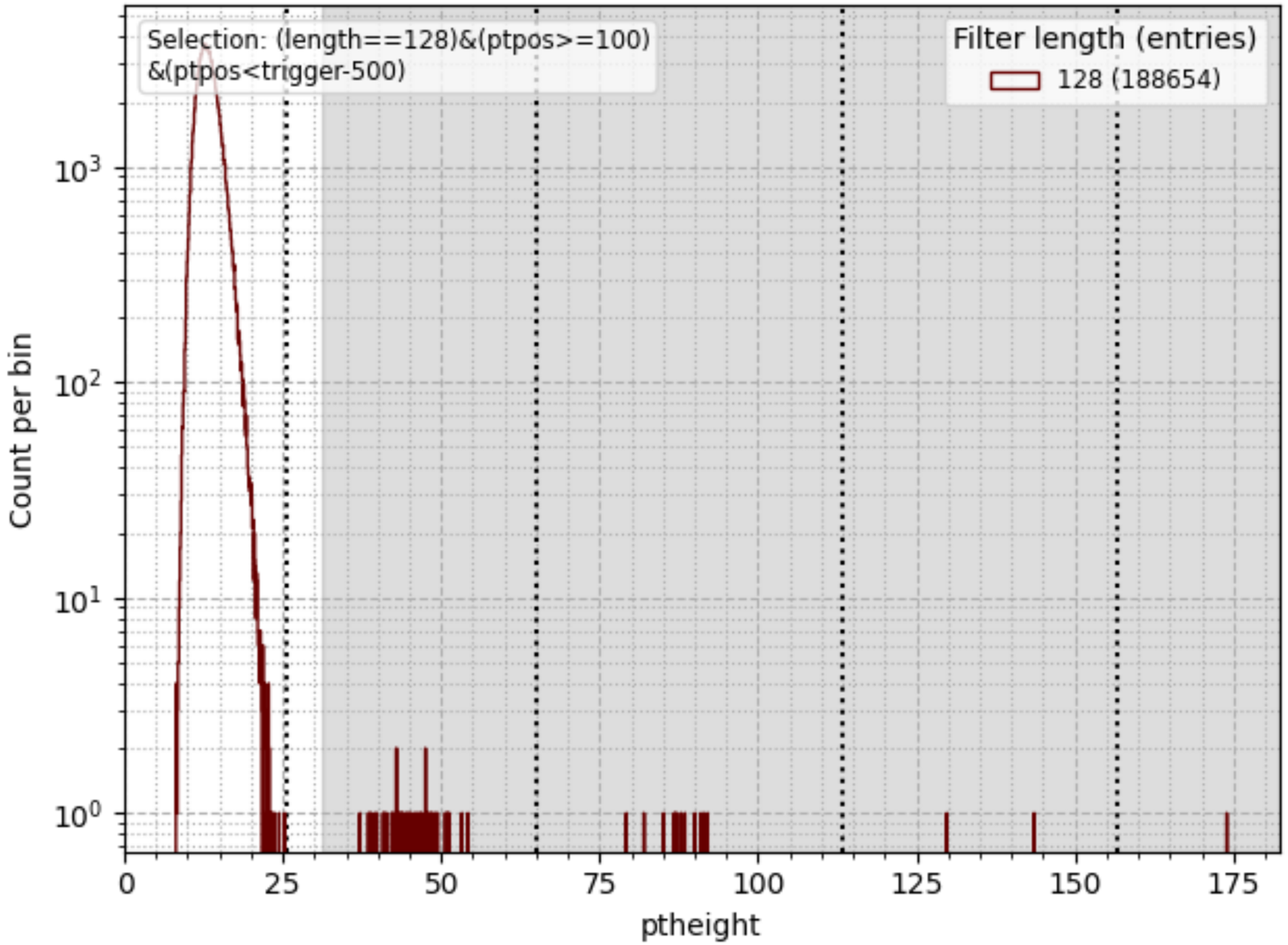
We select pulses in the dark gray rectangle.



Dark count (3/4)

Histogram of pre-trigger pulses height.

The separation between random peaks and 1 pe is clear already at 5.5 VoV (lowest available) so there won't be problems.

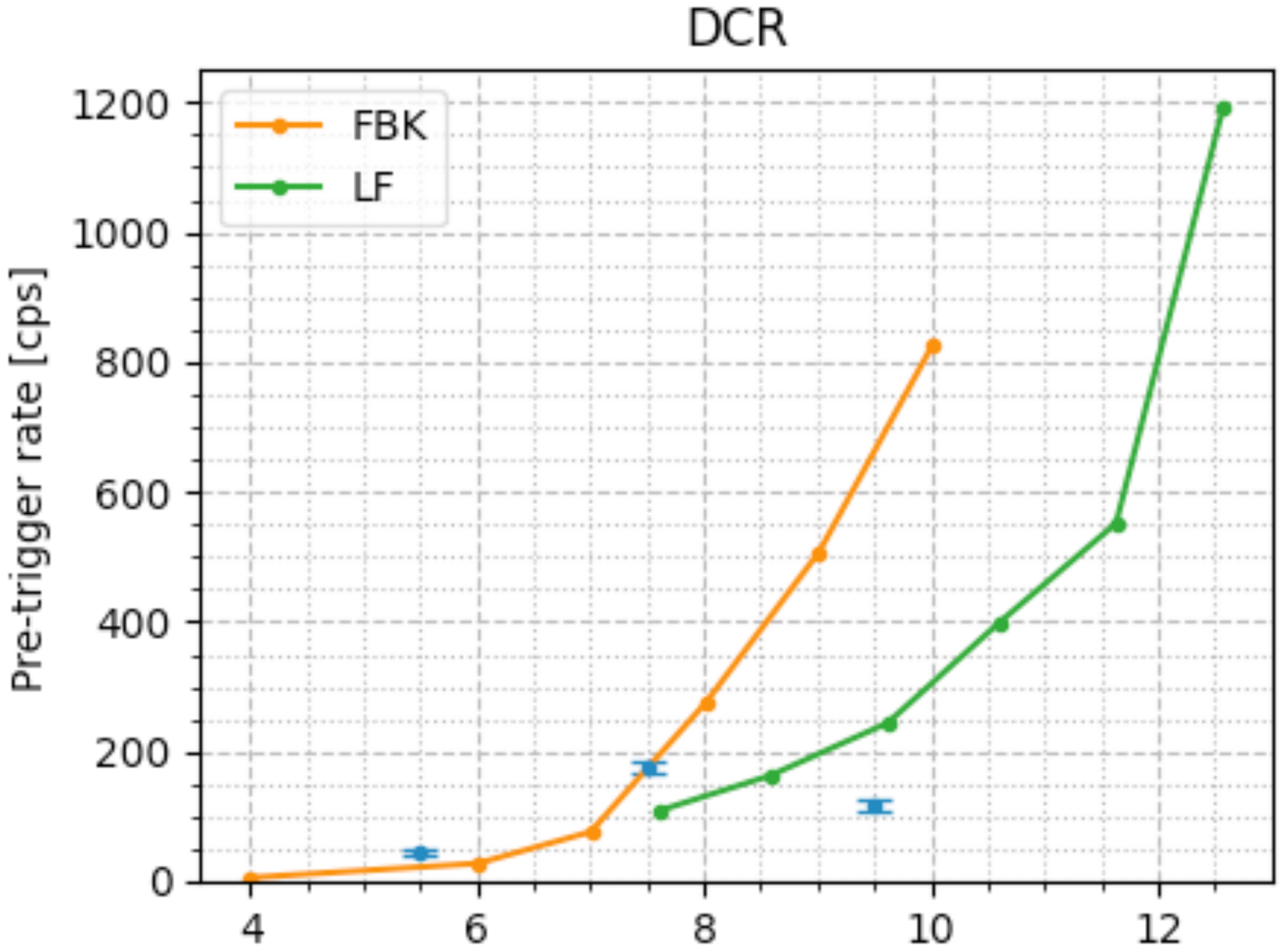


Dark count (4/4)

Results for the dark count rate.

Lines are copied from some old slides.

Since the rate is not monotonic with overvoltage, we think that the measurements are not light-tight, so these are upper bounds.

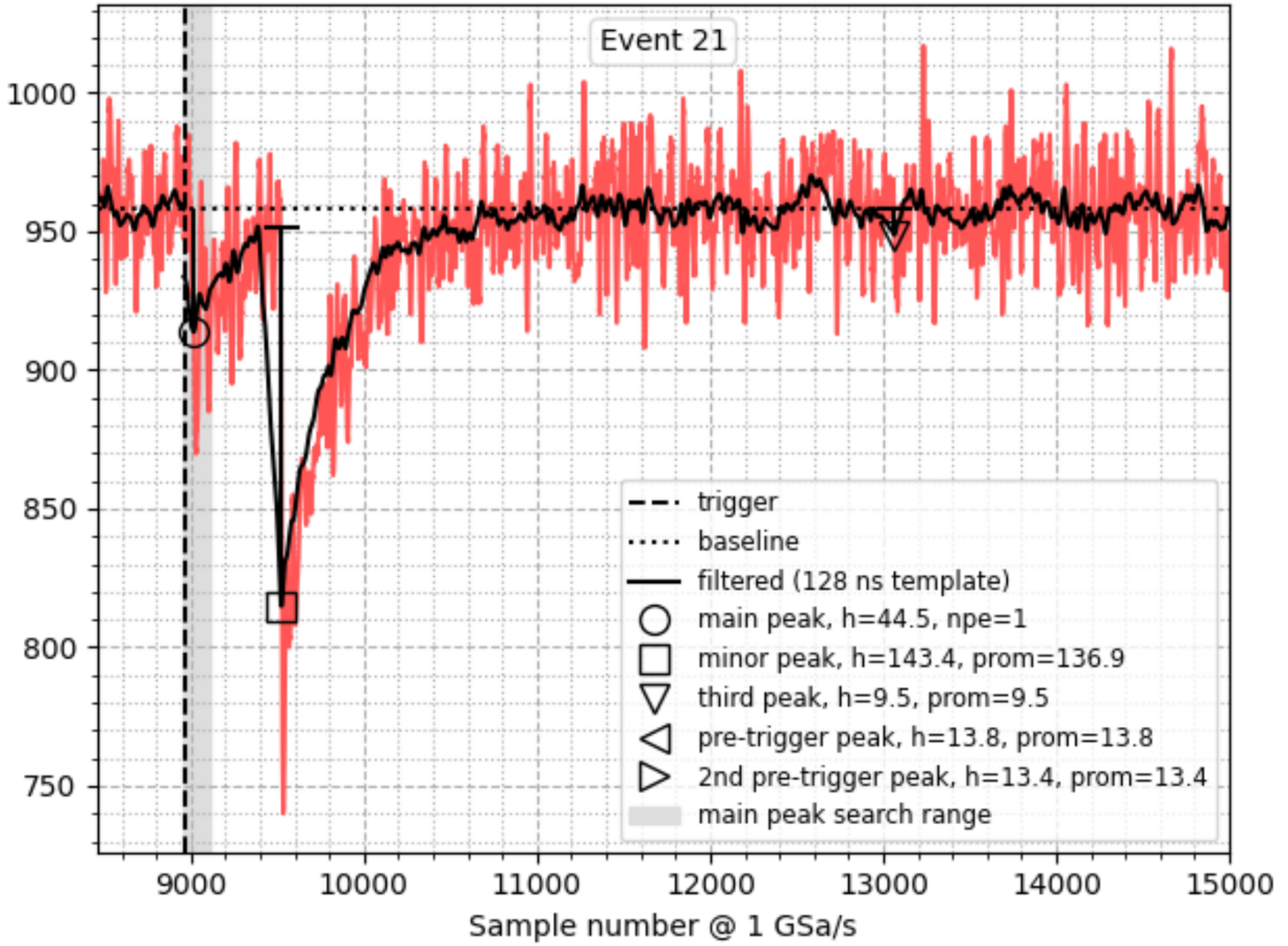


Afterpulses (1/4)

We search for afterpulses after 1 pe laser-induced pulses.

We only use the highest peak after the laser one, so we don't count multiple afterpulses.

(But we search for them so we can check later if needed.)



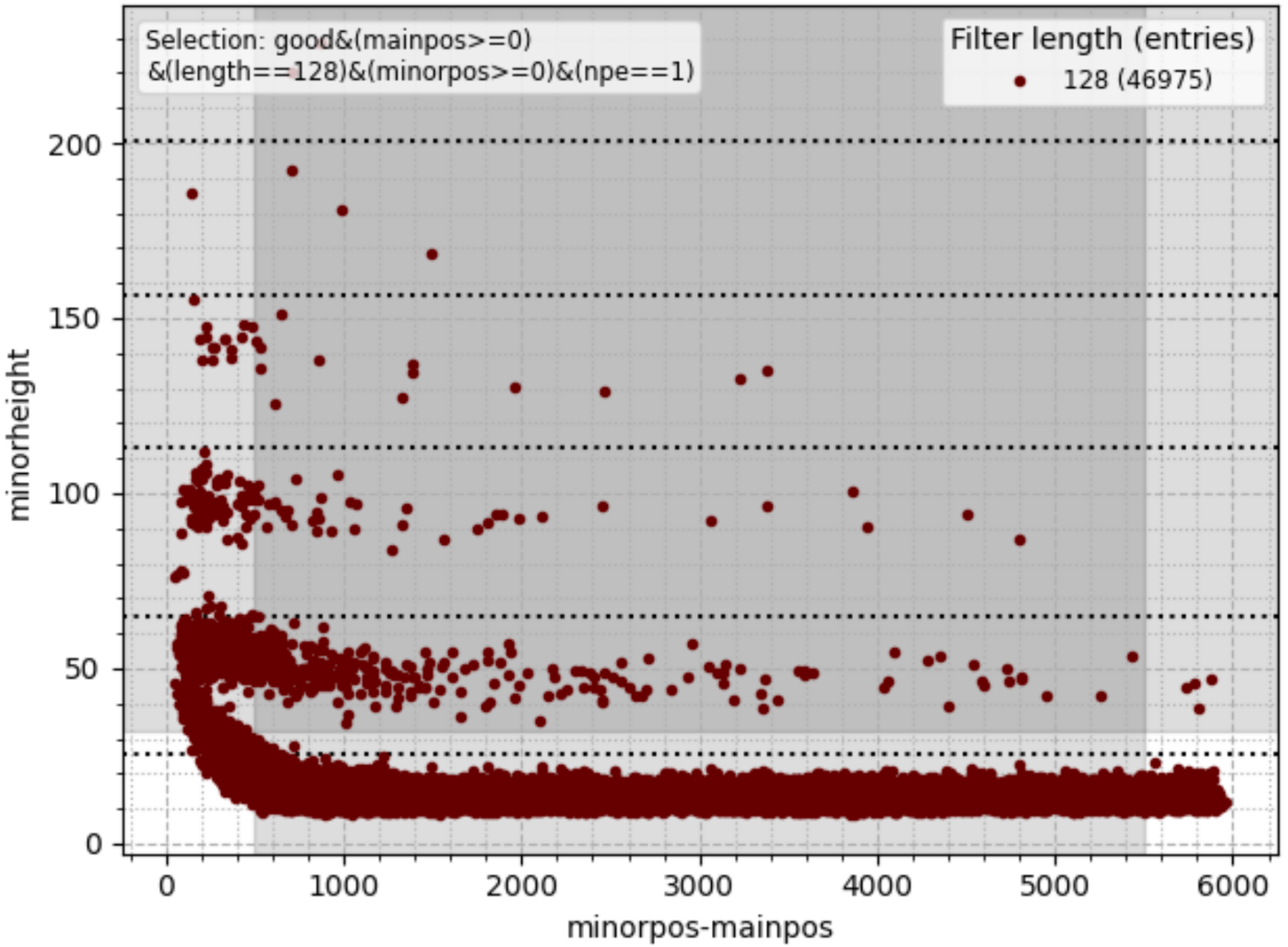
Afterpulses (2/4)

Scatterplot pulse height vs. delay from the laser peak.

The height is relative to the baseline, i.e. we are not subtracting the tail of the laser peak.

We select delay > 500 ns to separate well random from 1 pe.

The filter is short (≤ 128 ns) because a long filter can miss afterpulses.

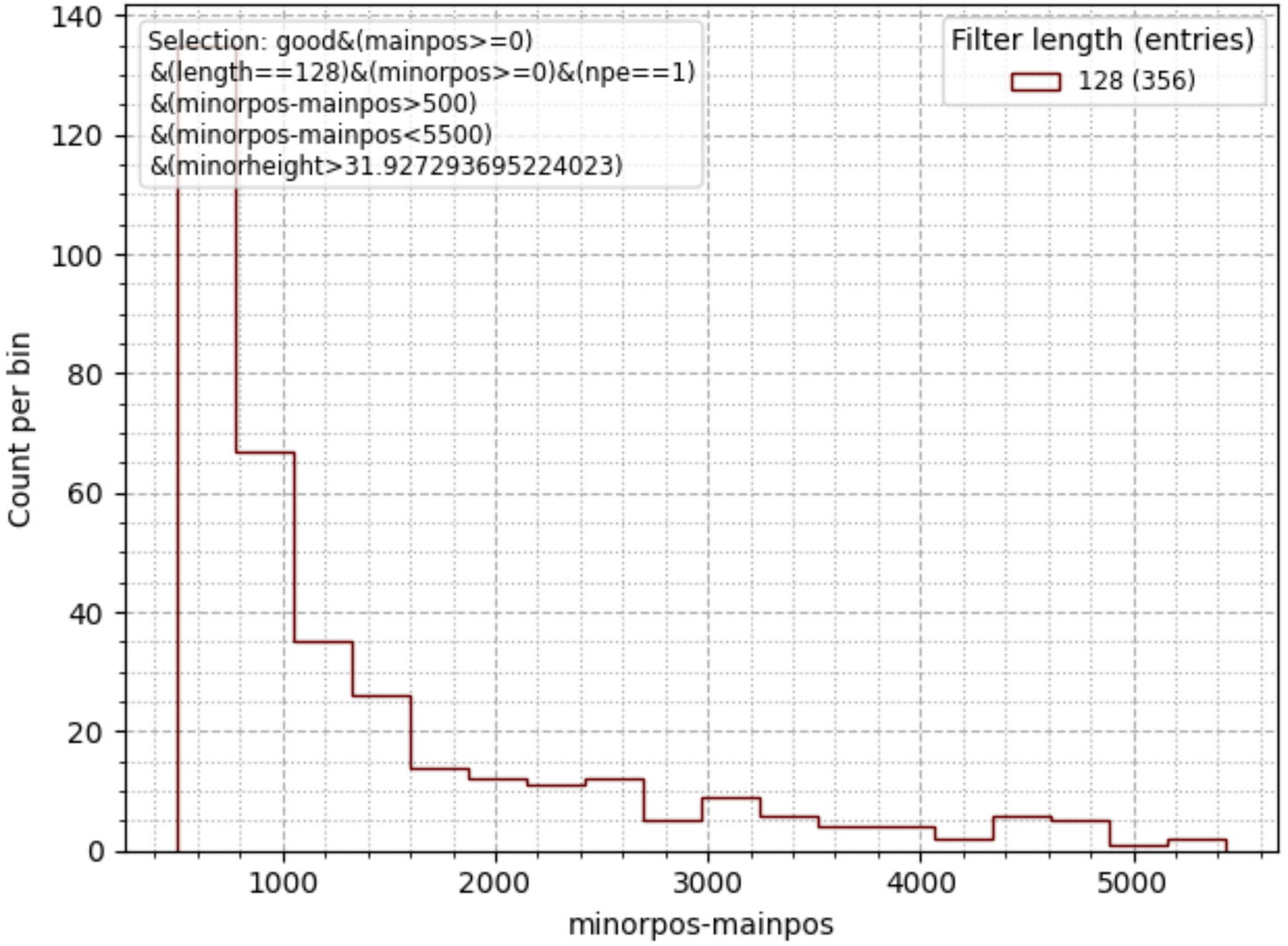


Afterpulses (3/4)

Temporal distribution of selected afterpulses.

Assuming exponential, the taus are: 880(60) ns @ 5.5 VoV, 1040(60) ns @ 7.5 VoV, 870(50) ns @ 9.5 VoV.

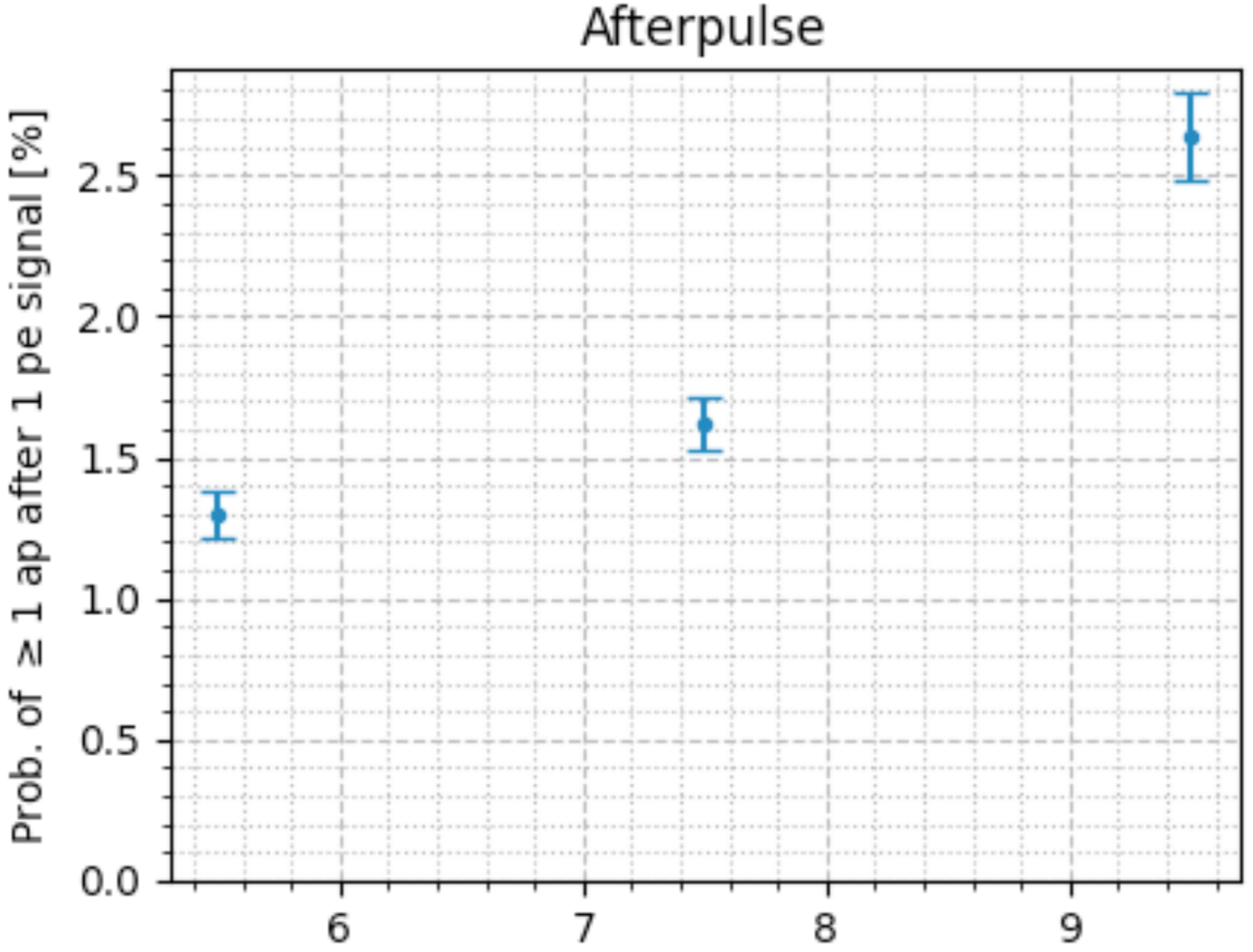
The distribution is needed to correct for the temporal cuts.



Afterpulses (4/4)

Afterpulse probabilities at all overvoltages.

We repeated with different filter lengths, difference << error.



Direct cross talk model

Poisson branching process: each pulse generates a poisson count of child pulses with mean μ_B. The total number of pulses (root + descendants) is Borel distributed:

$$P(n;\mu_B) = \exp(-\mu_B n)\frac{(\mu_B n)^{n-1}}{n!}$$

If the initial number of pulses is poisson-distributed with mean μ_P, the total with cross talk is:

$$P(n;\mu_P,\mu_B) = \exp(-(\mu_P + n\mu_B))\frac{\mu_P(\mu_P + n\mu_B)^{n-1}}{n!}$$

References: 1109.2014, 1609.01181.

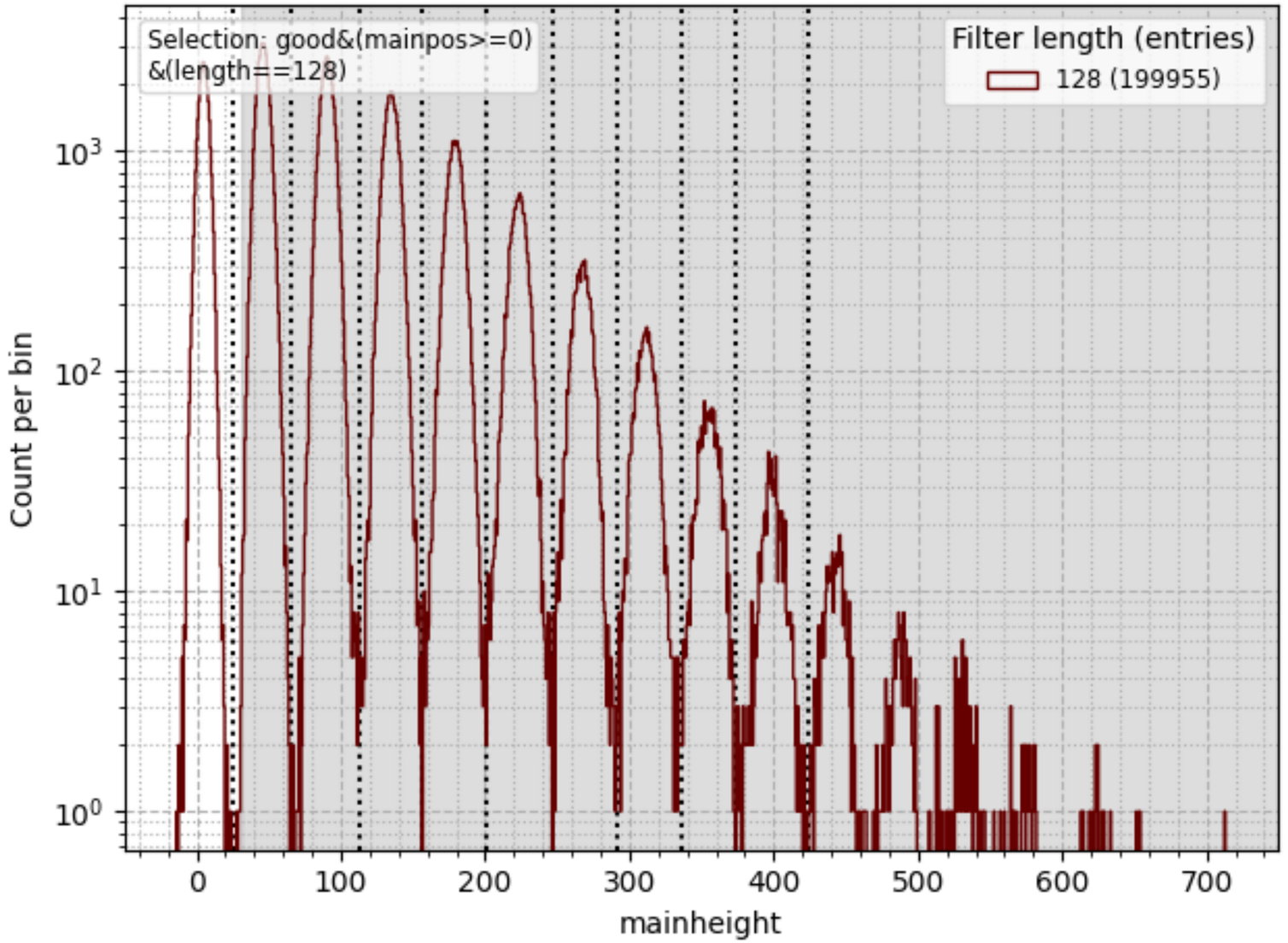
Cross talk

Fingerplot used to determine the pe bins.

The dotted lines are the bin boundaries.

They are the midpoints between the two most distant consecutive height samples between two peaks.

Pulses higher that the last boundary are counted in a single overflow bin.

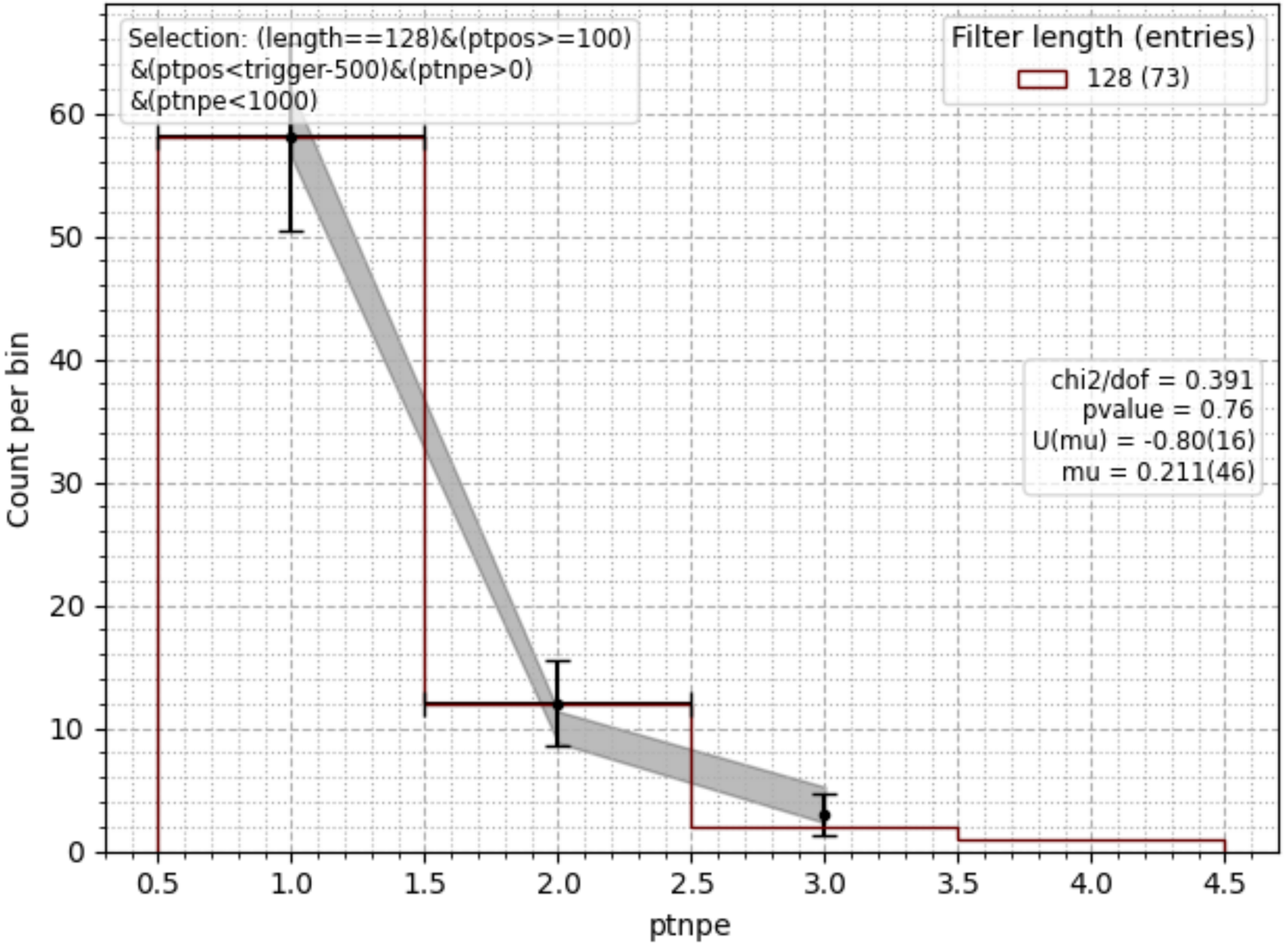


Cross talk in dark count

Fit of histogram of height binned by number of pe with the Borel distribution.

U(mu) = transformed parameter for the minimization because mu in [0, 1].

The red histogram is the data, the actually fitted counts are the black datapoints, and the point without horizontal bars is the overflow bin + low tail bins (least squares needs count ≥ 3).

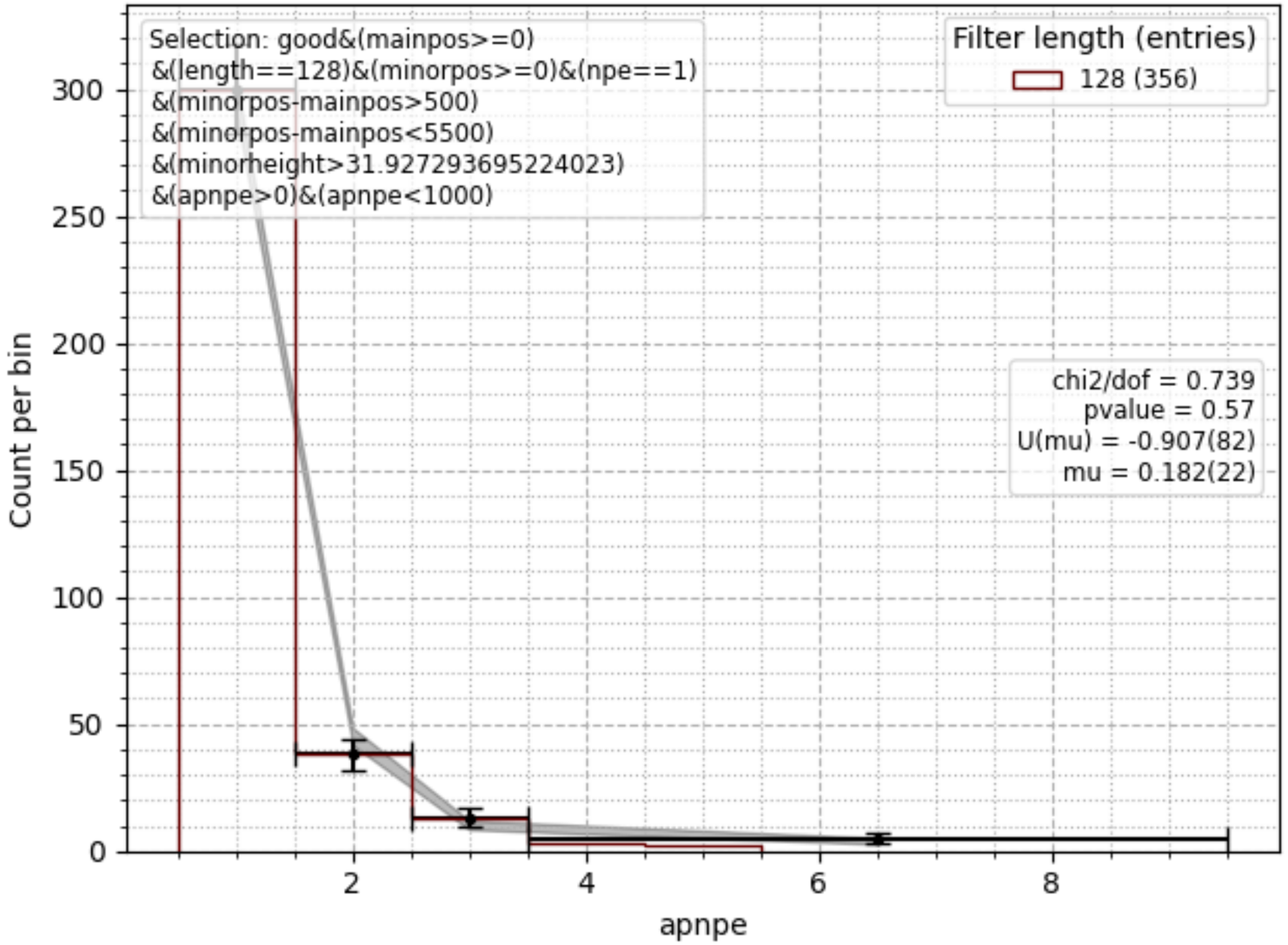


Cross talk in afterpulses

Like previous slide but for afterpulses.

There may be an upward bias because as said before we have not corrected the height for the influence of the laser peak.

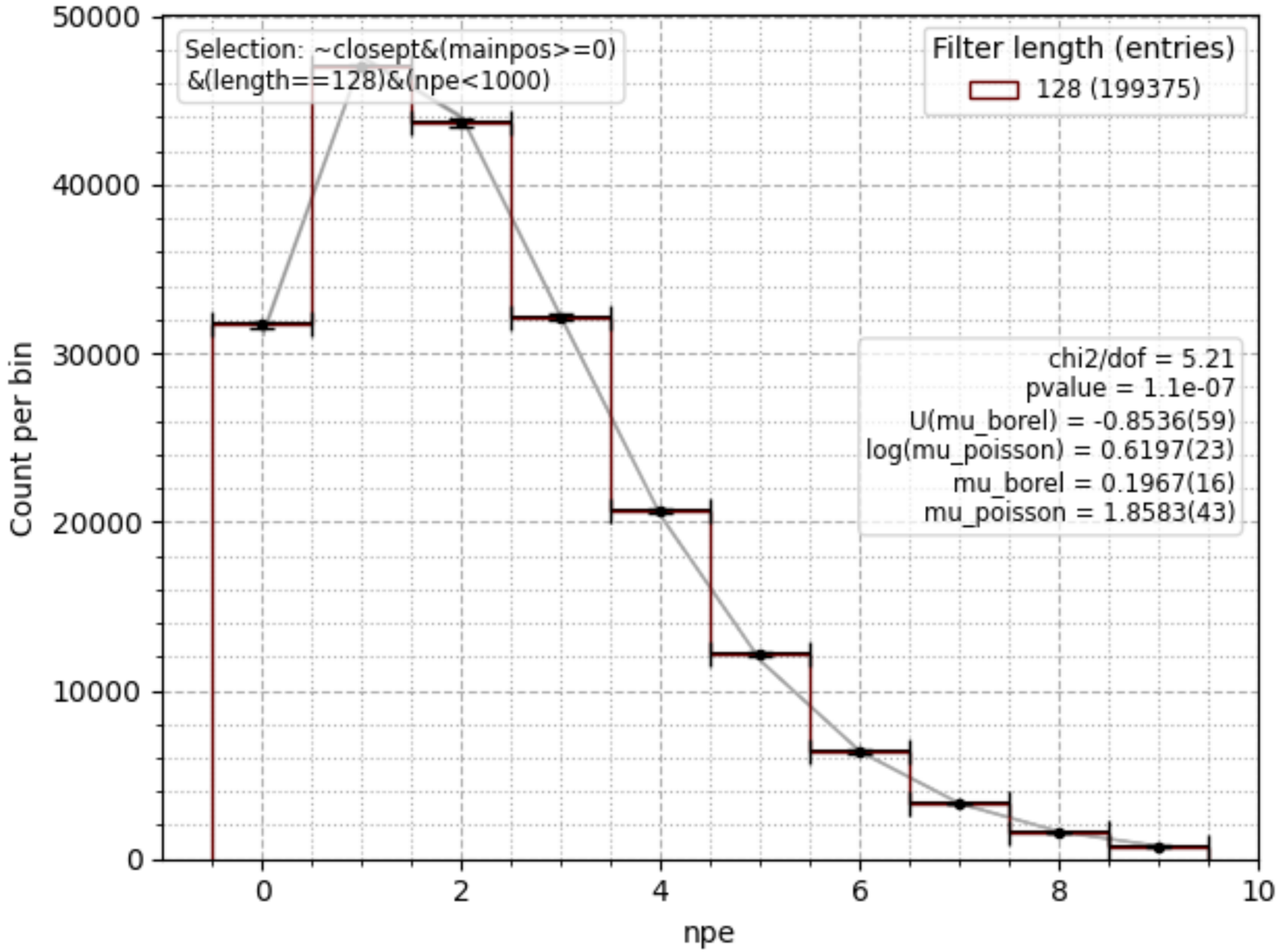
Here there's a larger last bin but no overflow bin (we'll talk later about these choices).



Cross talk in laser pulses

Here we fit poisson+Borel.

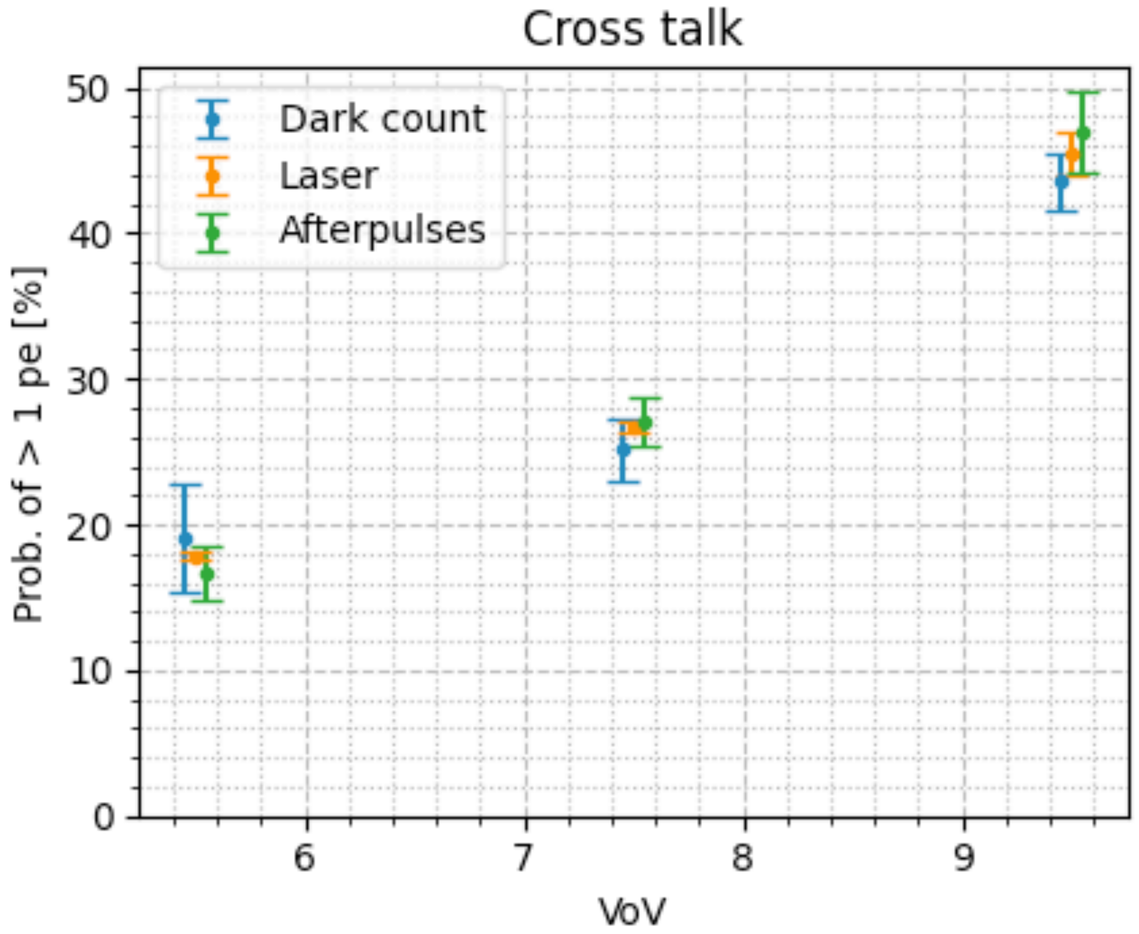
No overflow bin.

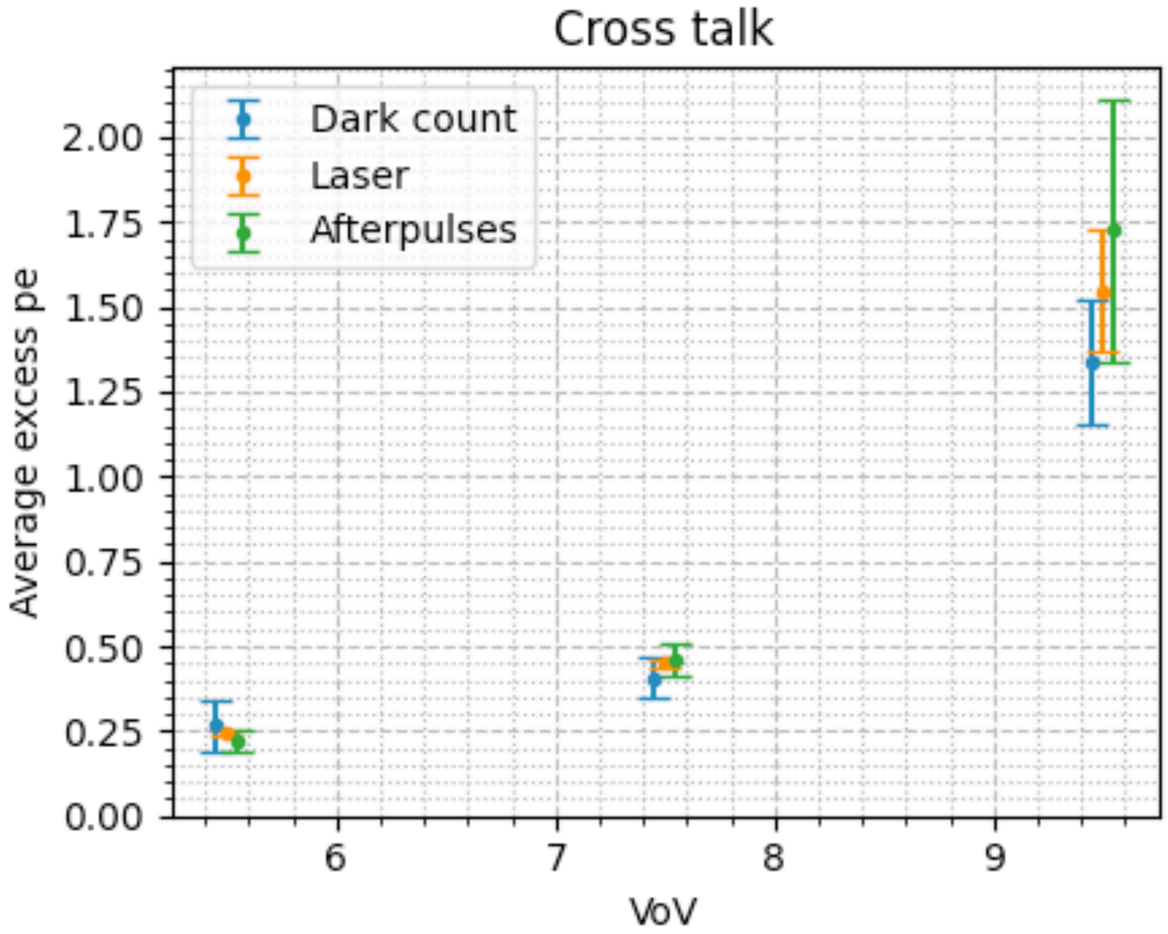


Cross talk results

P(>1 pe) = 1 – exp(–mu_B)

Mean[pe – 1] = 1 / (1 – mu_B) – 1





Cross talk results

Laser, dark count and afterpulses are consistent.

Some errorbars are PDG-corrected: when pvalue < 0.01, we rescale the error by sqrt(chi2/dof).

Apart from dark count, we have not fitted the overflow bin. The overflow bin counts all heights higher that the last pe bin and is fitted with the survival function of the distribution.

Fitting the overflow bin gives inconsistent results, still maybe good at 5.5 VoV but gets worse increasing overvoltage. Worse discrepancy for poisson+Borel fit.

Assuming we didn't mess up anything, this means that the model is decent for low cross-talk probabilities. There may be saturation effects since the model is reasonable if we don't fit the tail of the distribution and fitting the tail lowers the mu_B obtained.

Conclusions

The cross talk model is not good at high overvoltage.

(Sorry, I've not saved the plots with the overflow bin included that show how much exactly it goes wrong.)

Should try other models, or avoid high overvoltages.

The afterpulse probability and DCR seem good.