Xe doping analysis update

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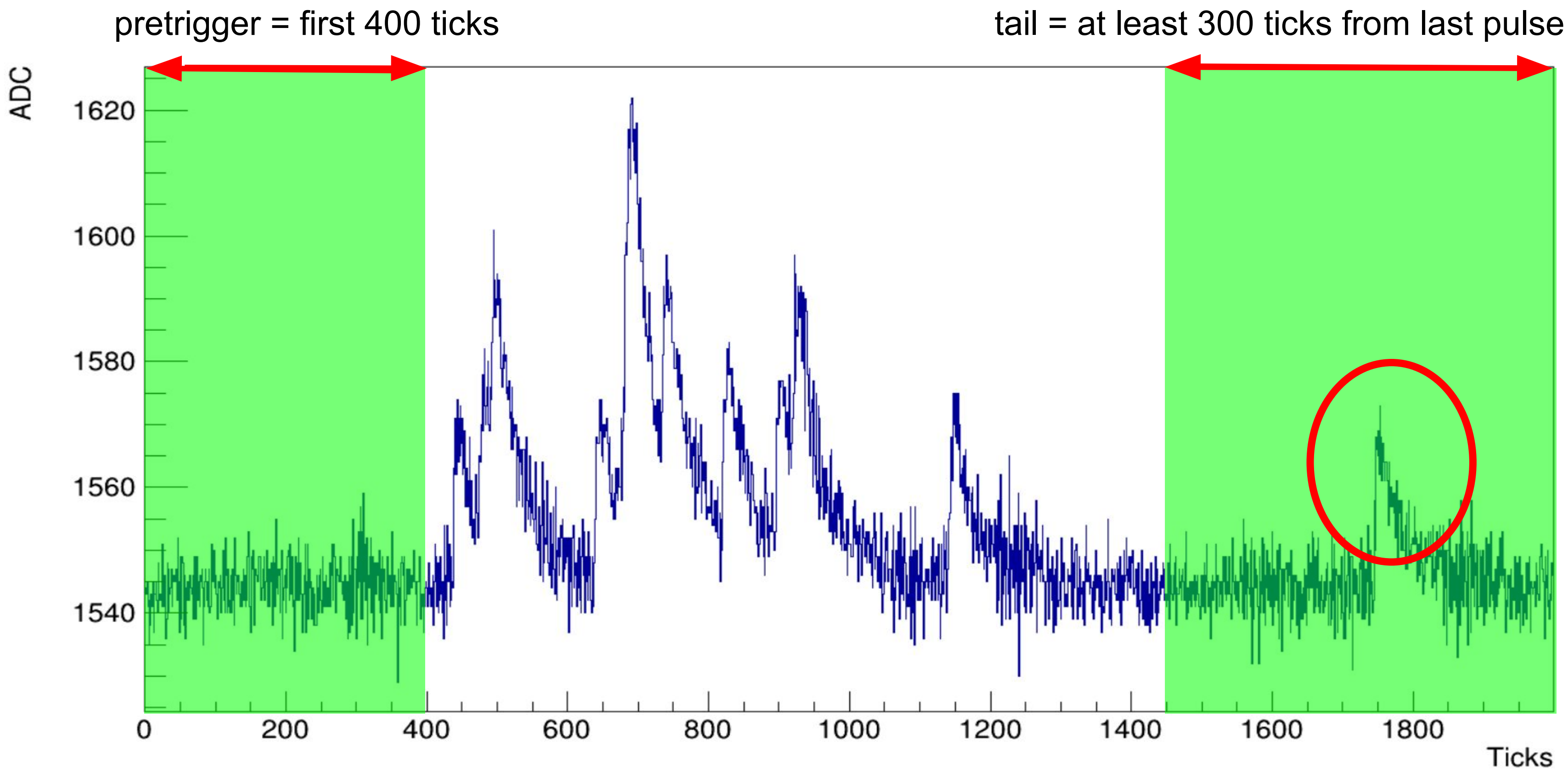
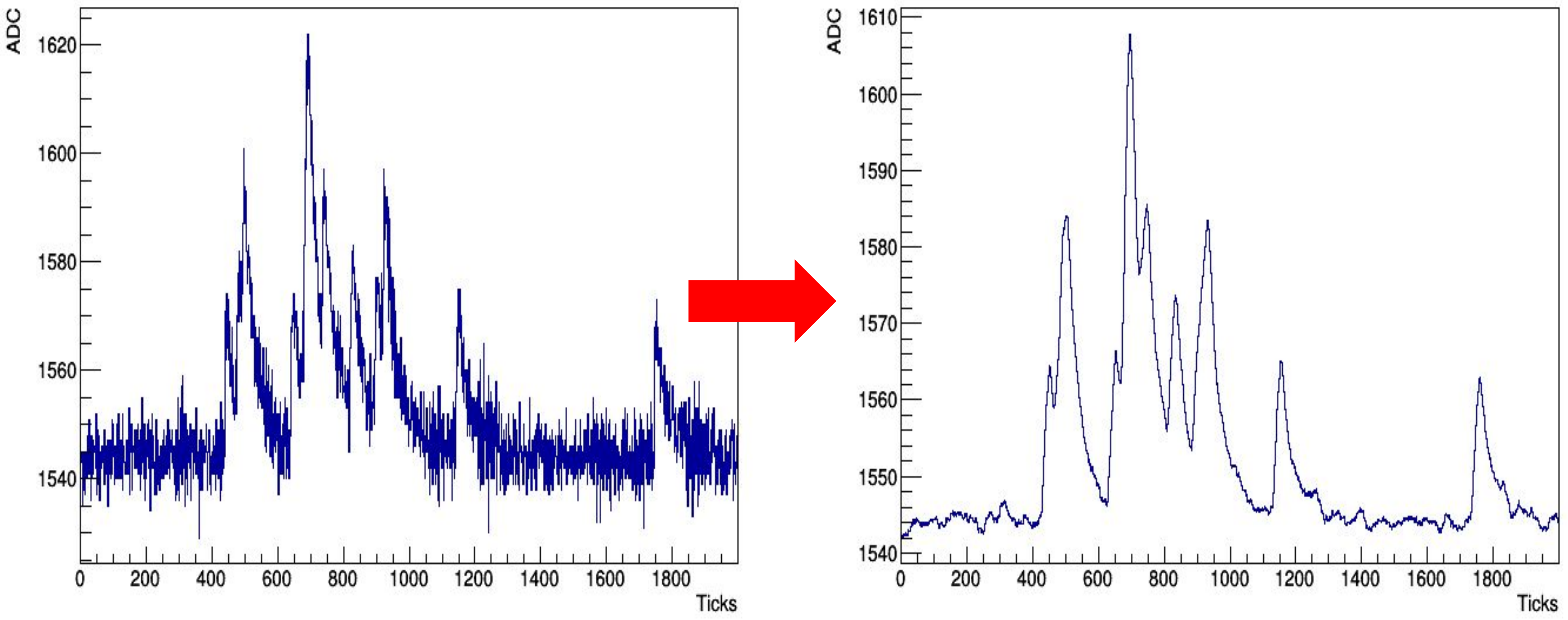
Looking for SPE pulses in the pretrigger and tail of each event

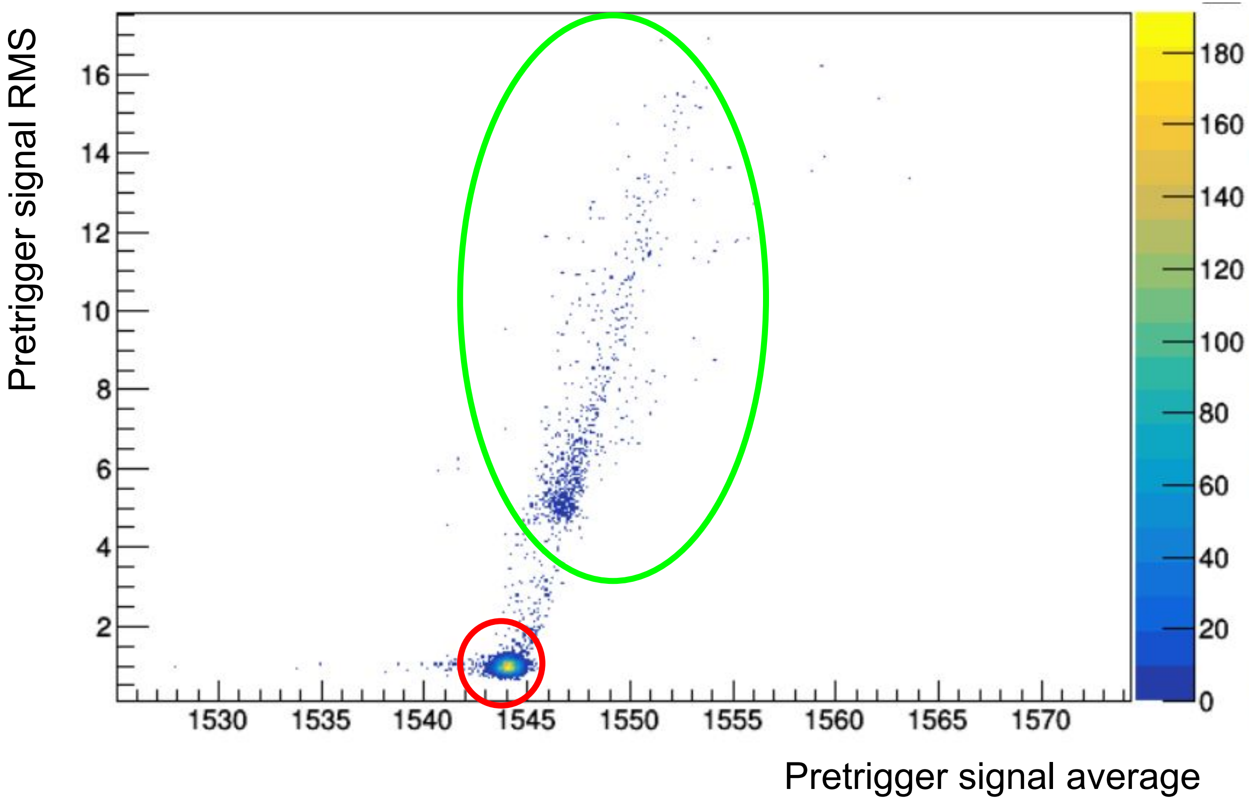


Step 1: smoothing the raw waveform



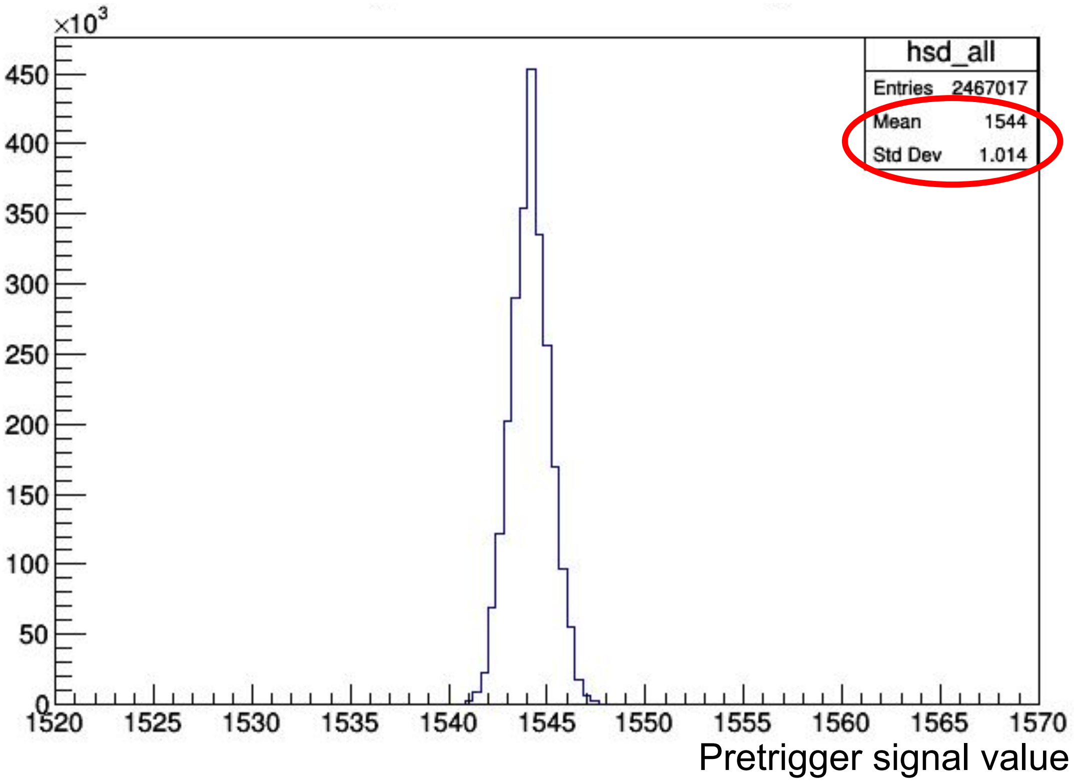
Smoothing performed with a **13 tick-wide moving average** filter

Step 2: study of the pretrigger to select baseline and signal events



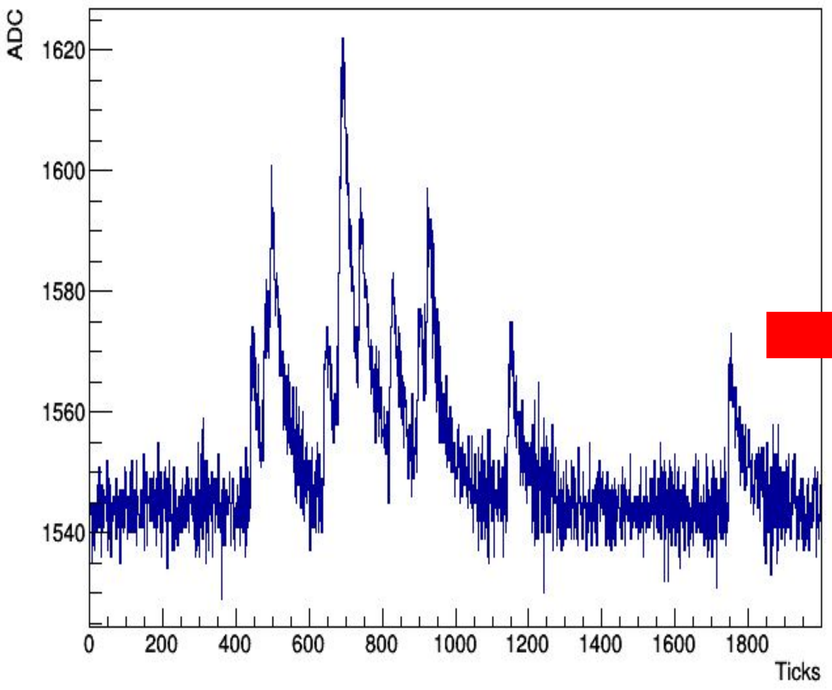
- in each pretrigger signal, compute signal average and RMS
- 2 data sets emerge
- **"baseline"** events (no signal in the pretrigger)
- **"signal"** events (some signal is present in the pretrigger)

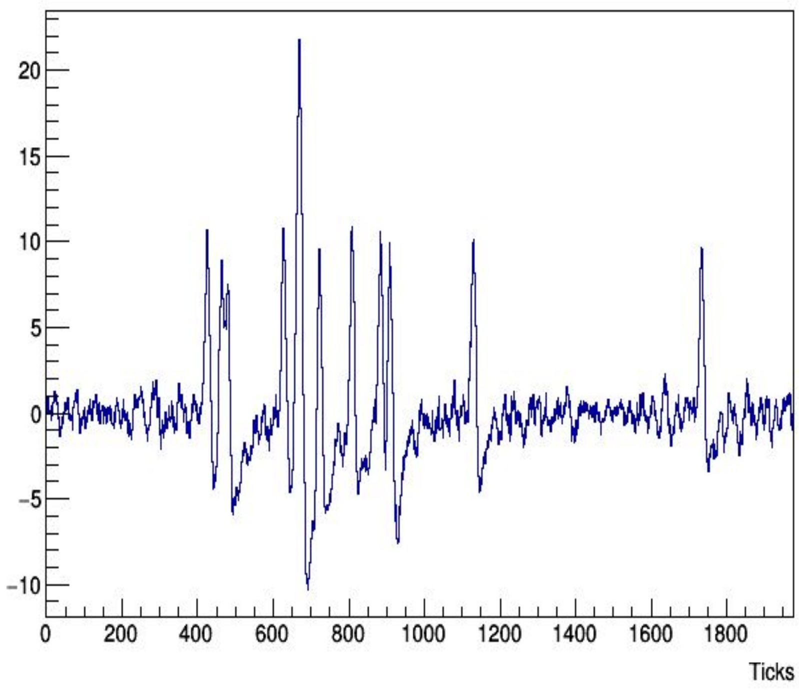
Step 3: get the baseline average and rms



- from the pretrigger of the **"baseline"** events, make the **smoothed** waveform value distribution
- get **mean and rms of the baseline**

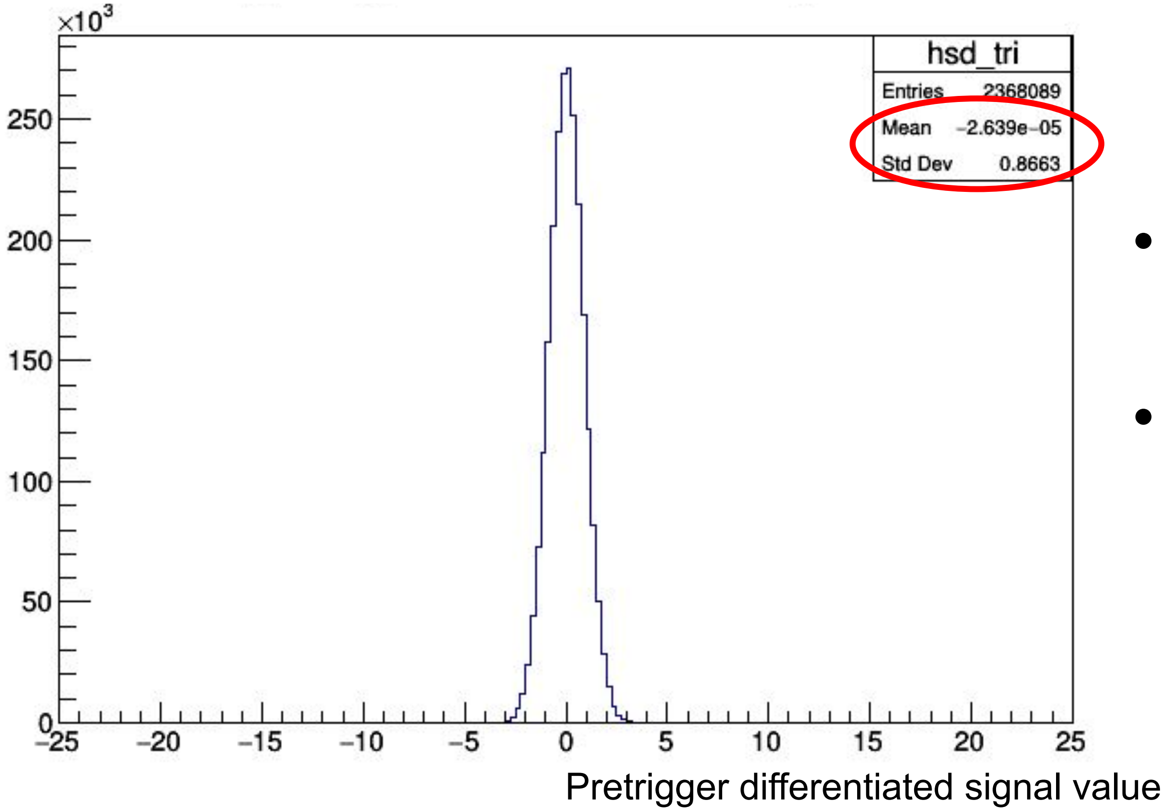
Step 4: back to the full waveform - apply a differentiating filter





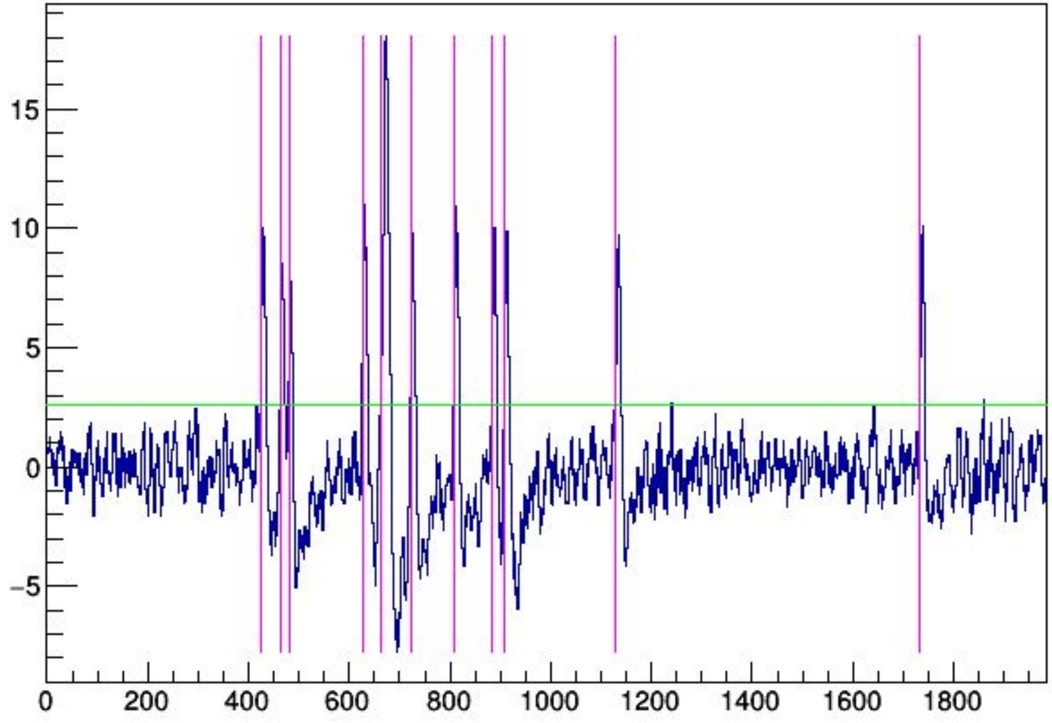
Differentiation performed with a **16 tick-wide 0 area triangle** filter

Step 5: establish a cut on the differentiated waveform



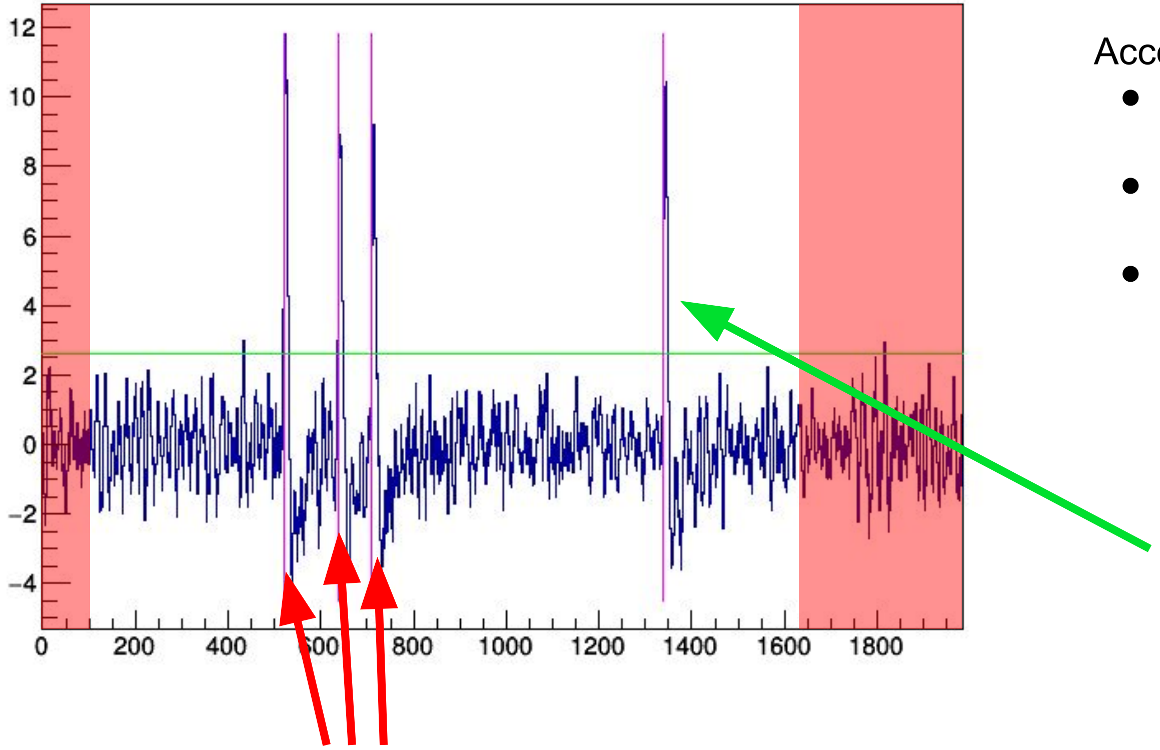
- from the pretrigger of the **"baseline"** events, make the **differentiated** waveform value distribution
- get **mean and rms of the differentiated baseline**

Step 6: find the signal onset



- put a **threshold** at **3 sigma from the differentiated baseline**
- find the **onset** of every signal in the waveform

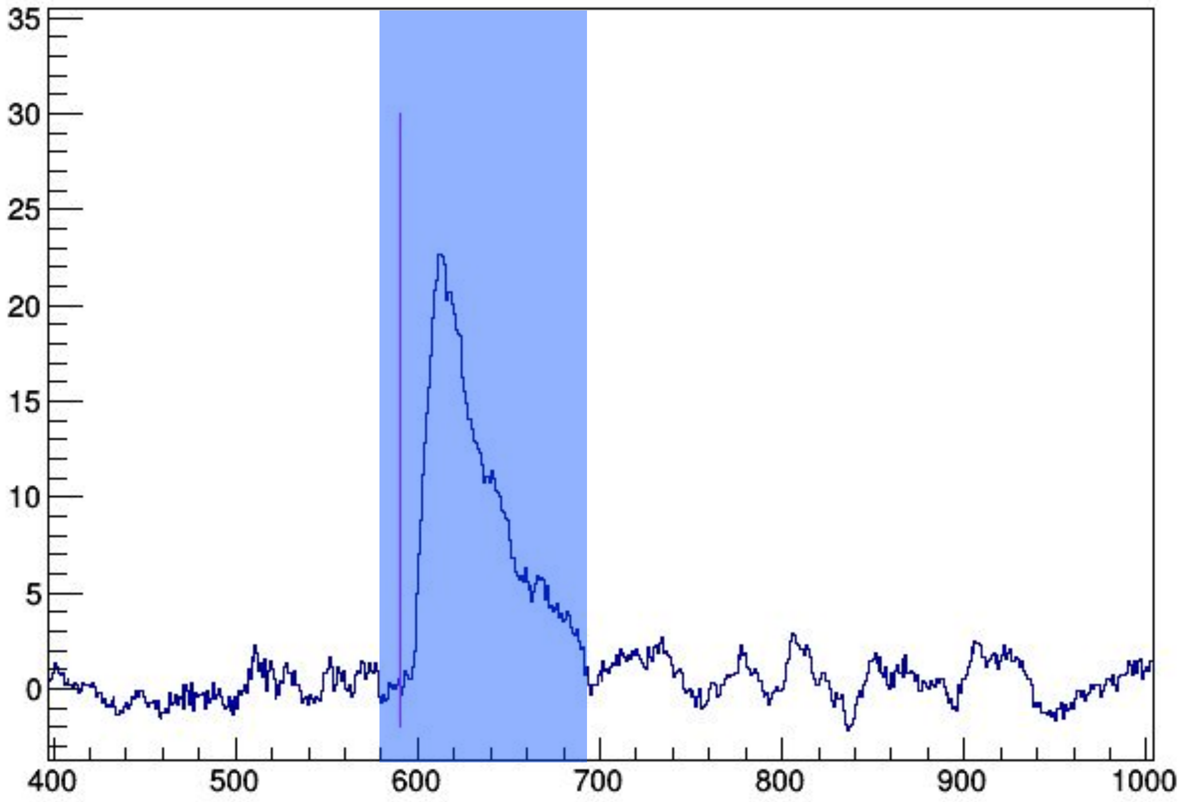
Step 7: signal selection based on timing



Accept signals if:

- onset is >= 50 ticks from waveform start
- onset is <= 300 ticks from waveform end
- onset is >= 300 ticks from any previous or following onset

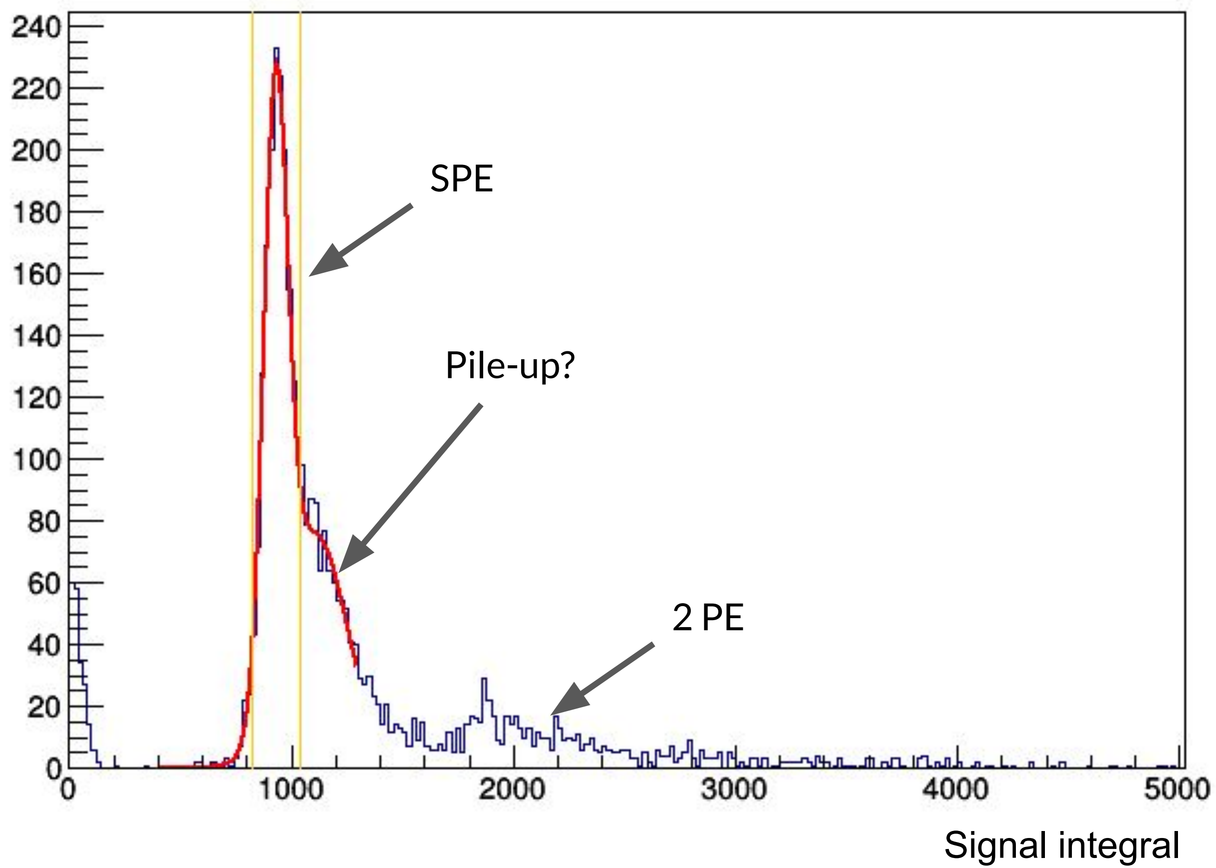
Step 8: compute the integral of accepted signals



Compute the **integral of the smoothed accepted signals**

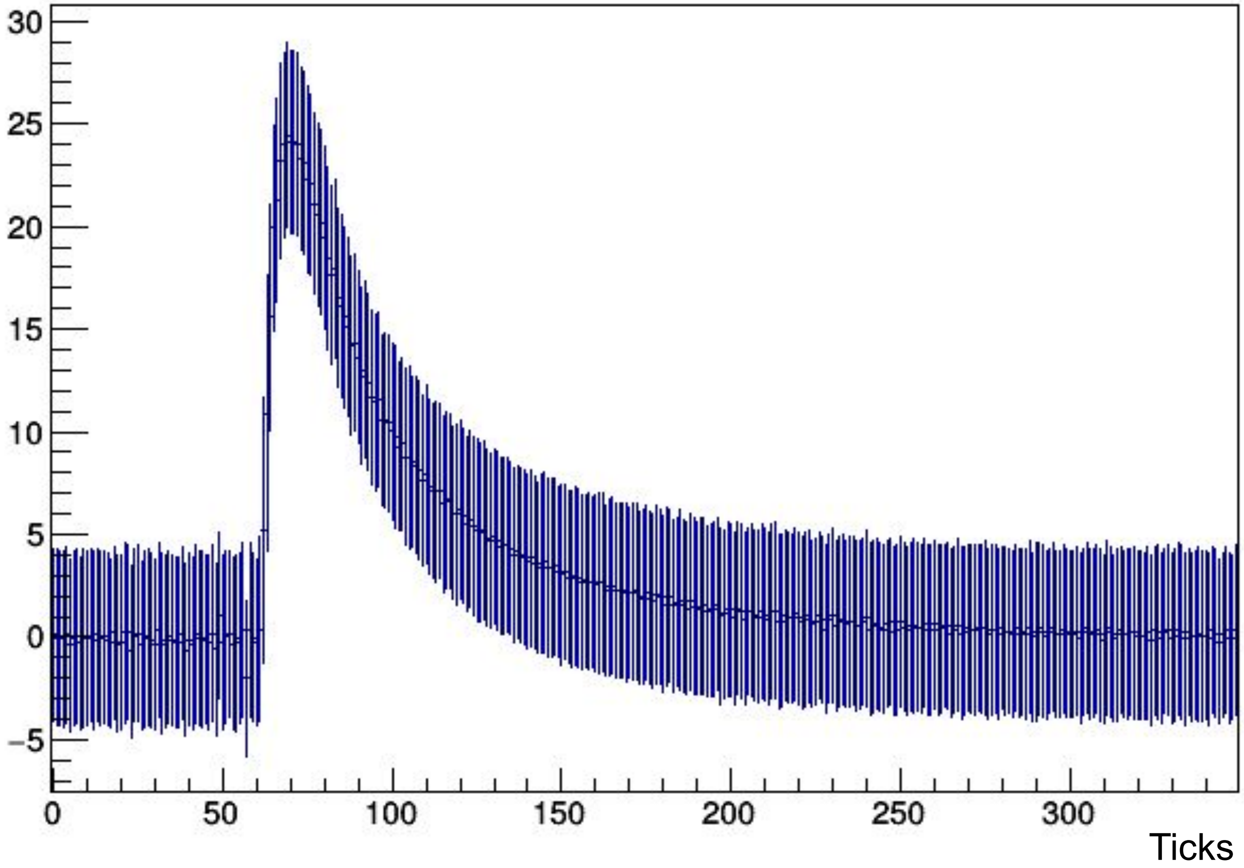
- start 10 ticks before the onset
- stop 100 ticks after the onset

Step 9: signal integral distribution



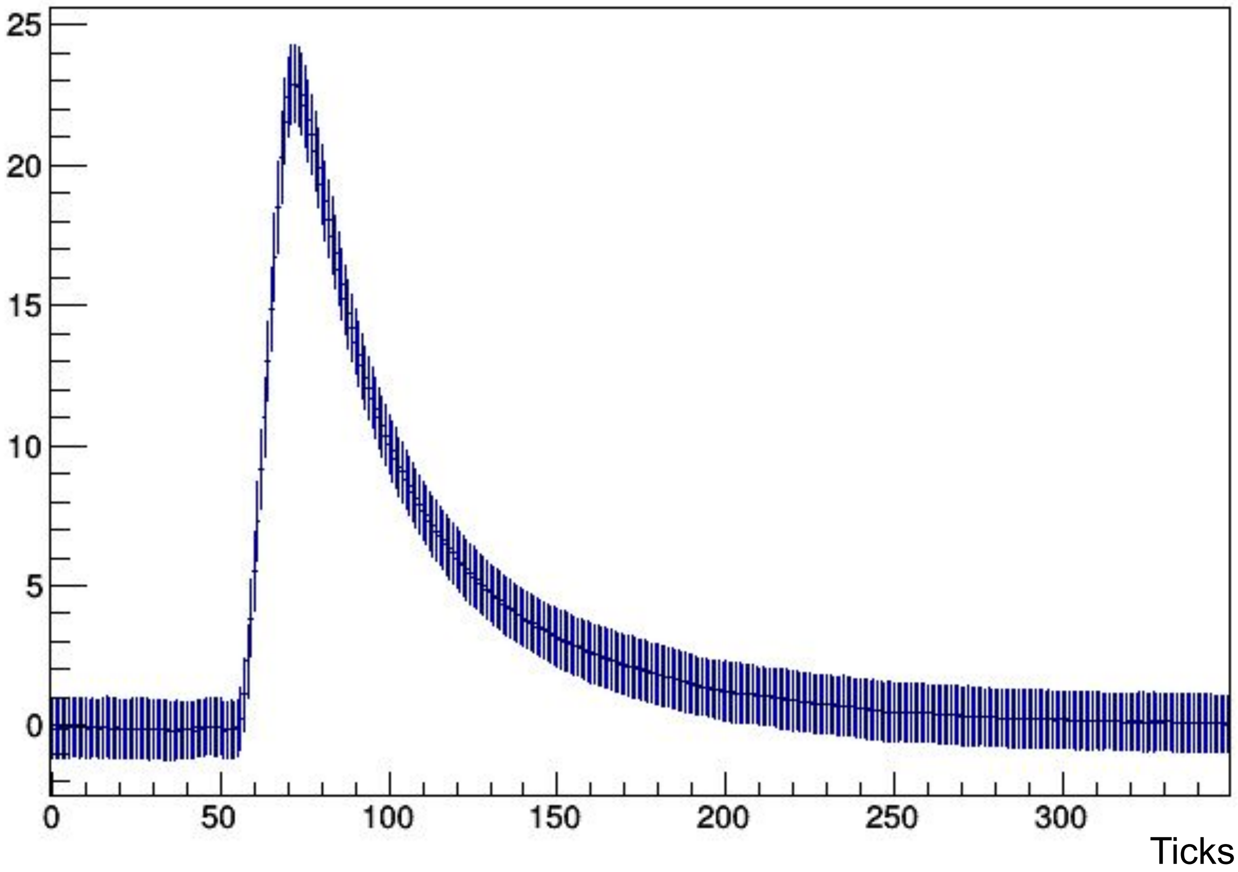
- From the **integral distribution**, single PE and (scarcely populated) double PE peaks are apparent
- fit the SPE peak with a gaussian to **establish a cut on the integral** at 2 sigma

Step 10: average raw SPE (run Dope3_ext_08_Ch5)



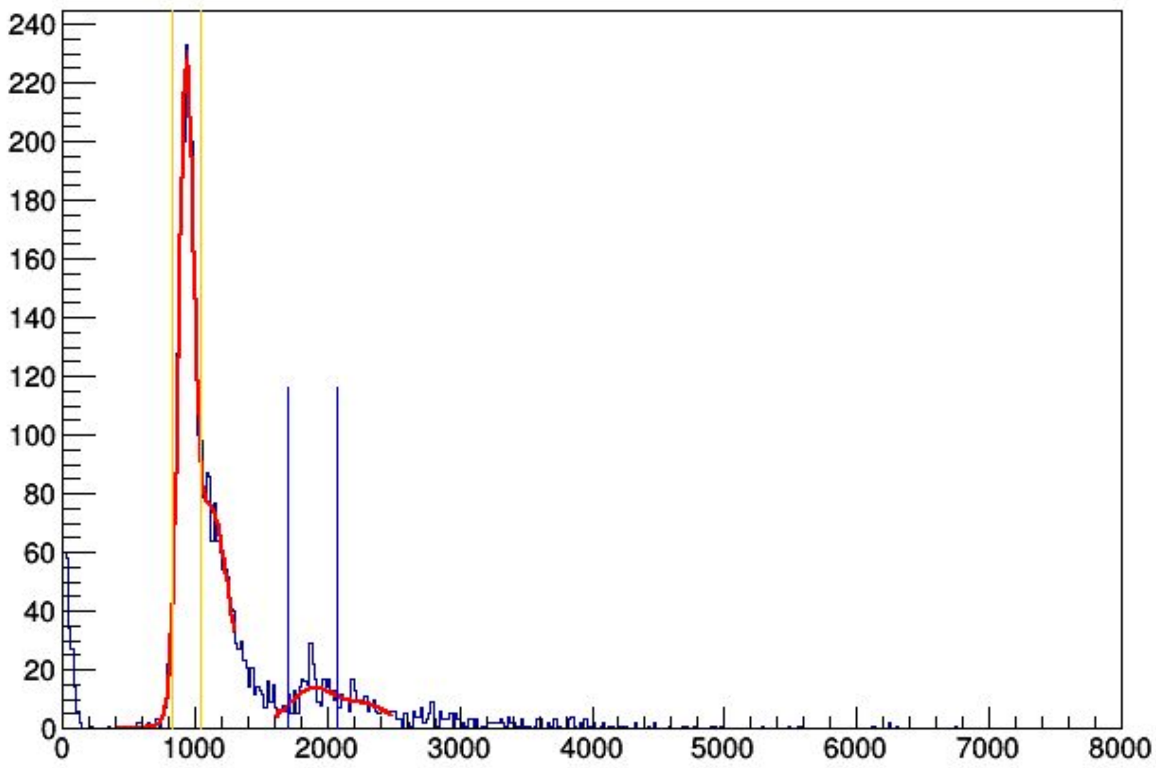
- from the SPE population, **synchronize and average** all the baseline-subtracted **raw** signals
- average error ~4 ADC
- ***Def.:***
  $\sigma_{<SPE>\ i}$ = std. dev. of i-th point in <SPE>

Step 11: average smoothed SPE (run Dope3_ext_08_Ch5)



- from the SPE population, **synchronize and average** all the baseline-subtracted **smoothed** signals
- average std dev ~1.1 ADC (reduction of a factor ~ √13)
- the signal is slightly low-passed

Consistency check: cut on double PE

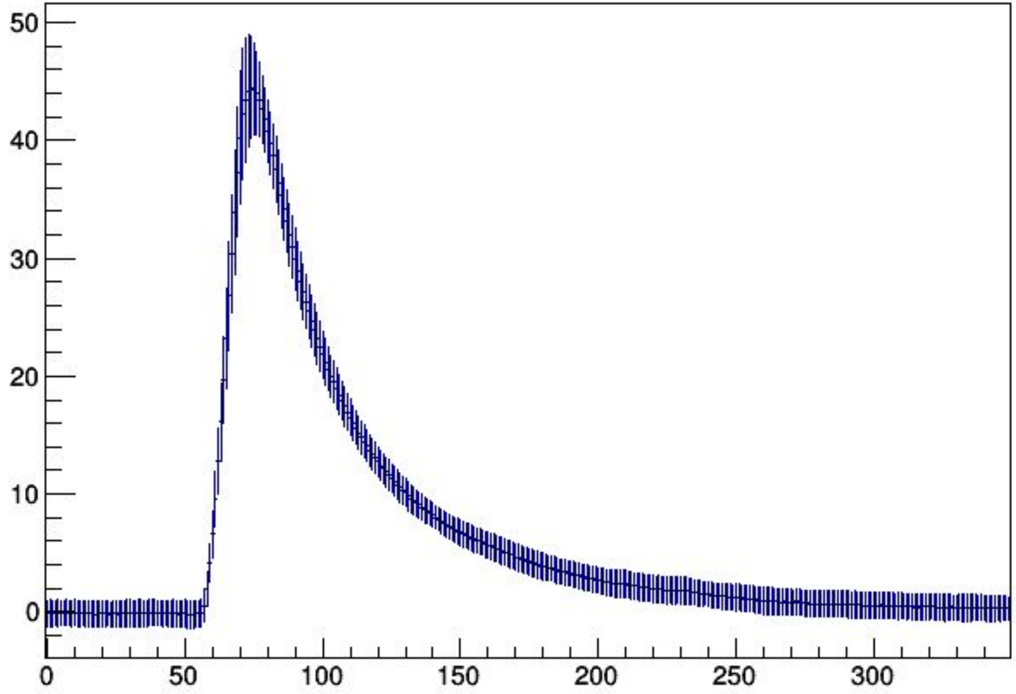


Signal integral

fit the DPE peak with a gaussian to **establish a cut on the integral** at 1 sigma

Consistency check: average DPE

find the **average DPE smoothed signal**

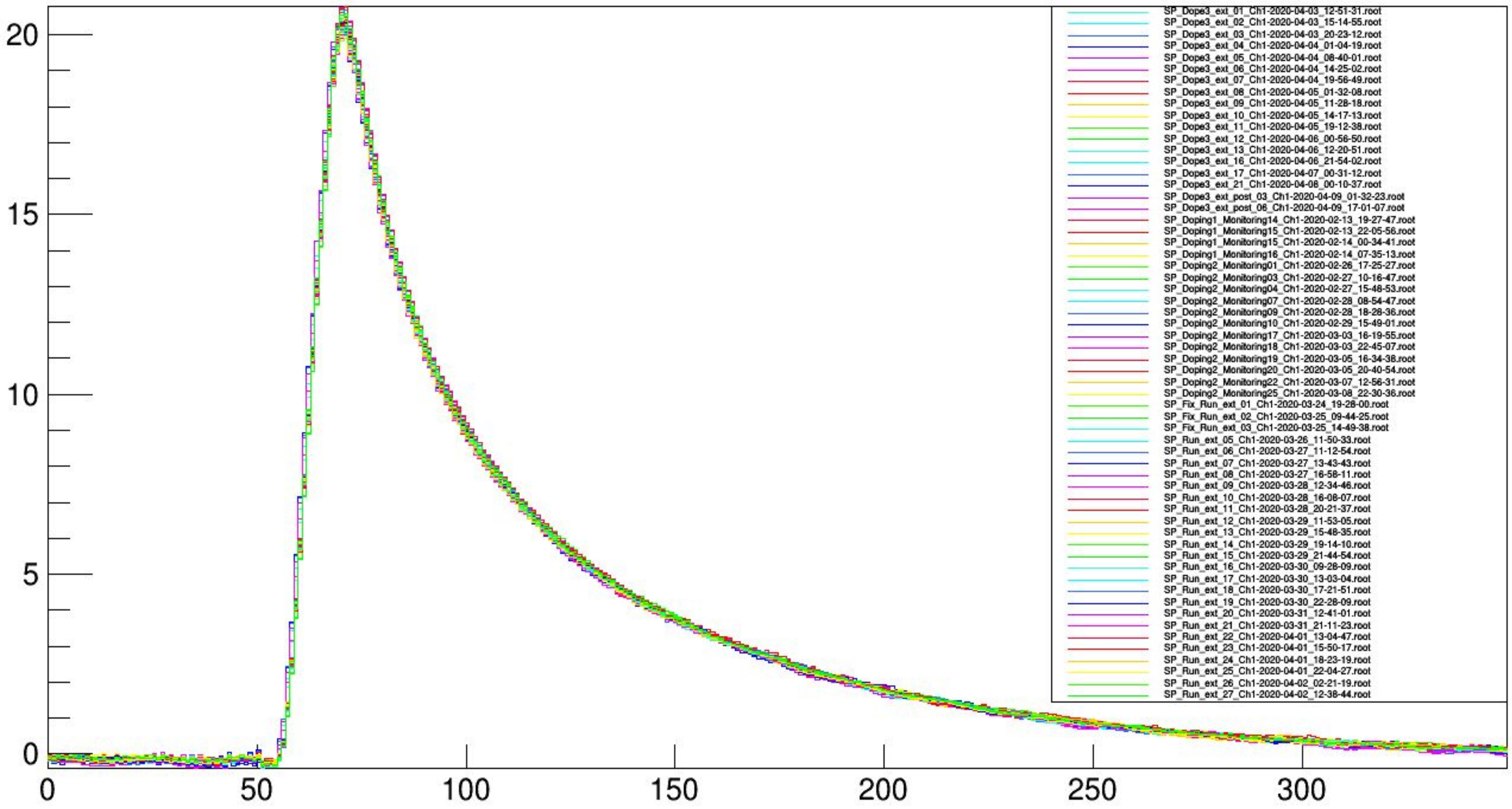


Ticks

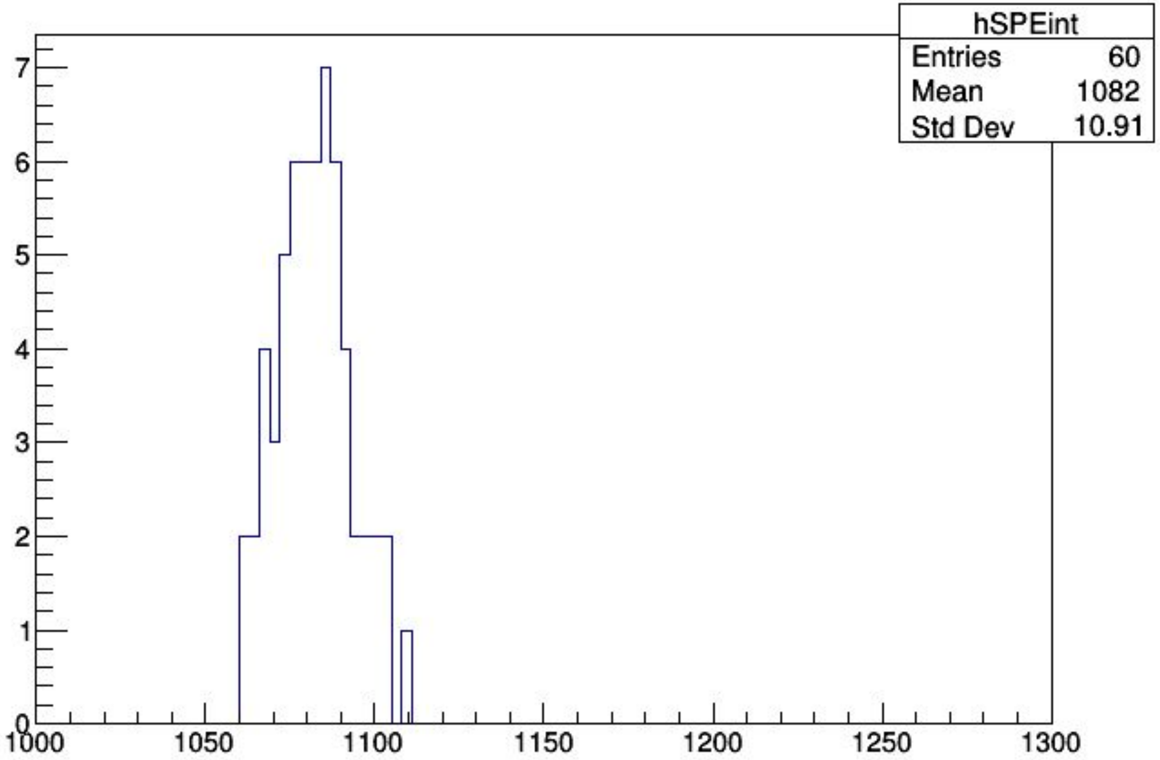
Run Dope3_ext_08_Ch5

	SPE	DPE
Pulse Height	22.9 ± 1.4	44.5 ± 4.4
Integral	1106 ± 20	2267 ± 30

Channel 1: superposition of <SPE> for 60 runs

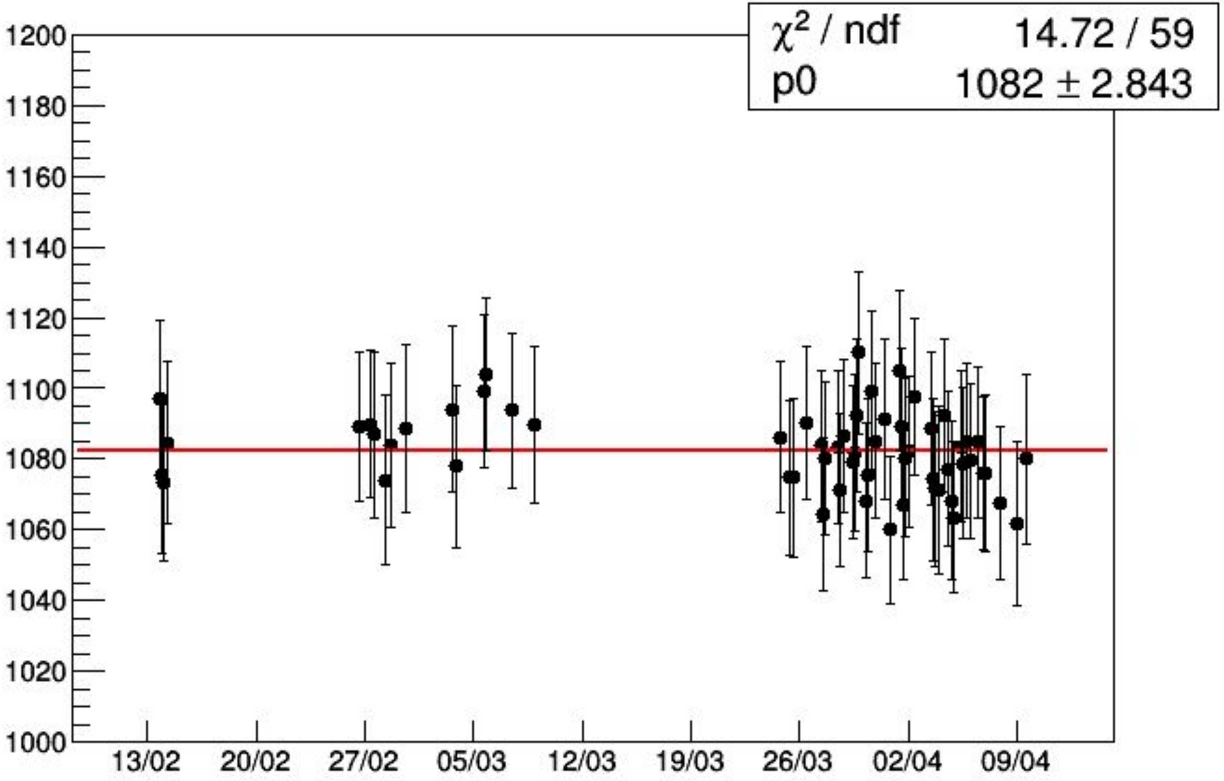


Survey of Ch1 stability: <SPE> integral distribution



σ = 10.91
→ 2σ is within the error bars

Survey of Ch1 stability: <SPE> integral vs time



- Average std dev ~22 ADC → **about 2%**

Def.:

$\text{Integral}_{\text{<SPE>}} = \sum_{i=1}^{300} \text{<SPE>}_i$

Def.:

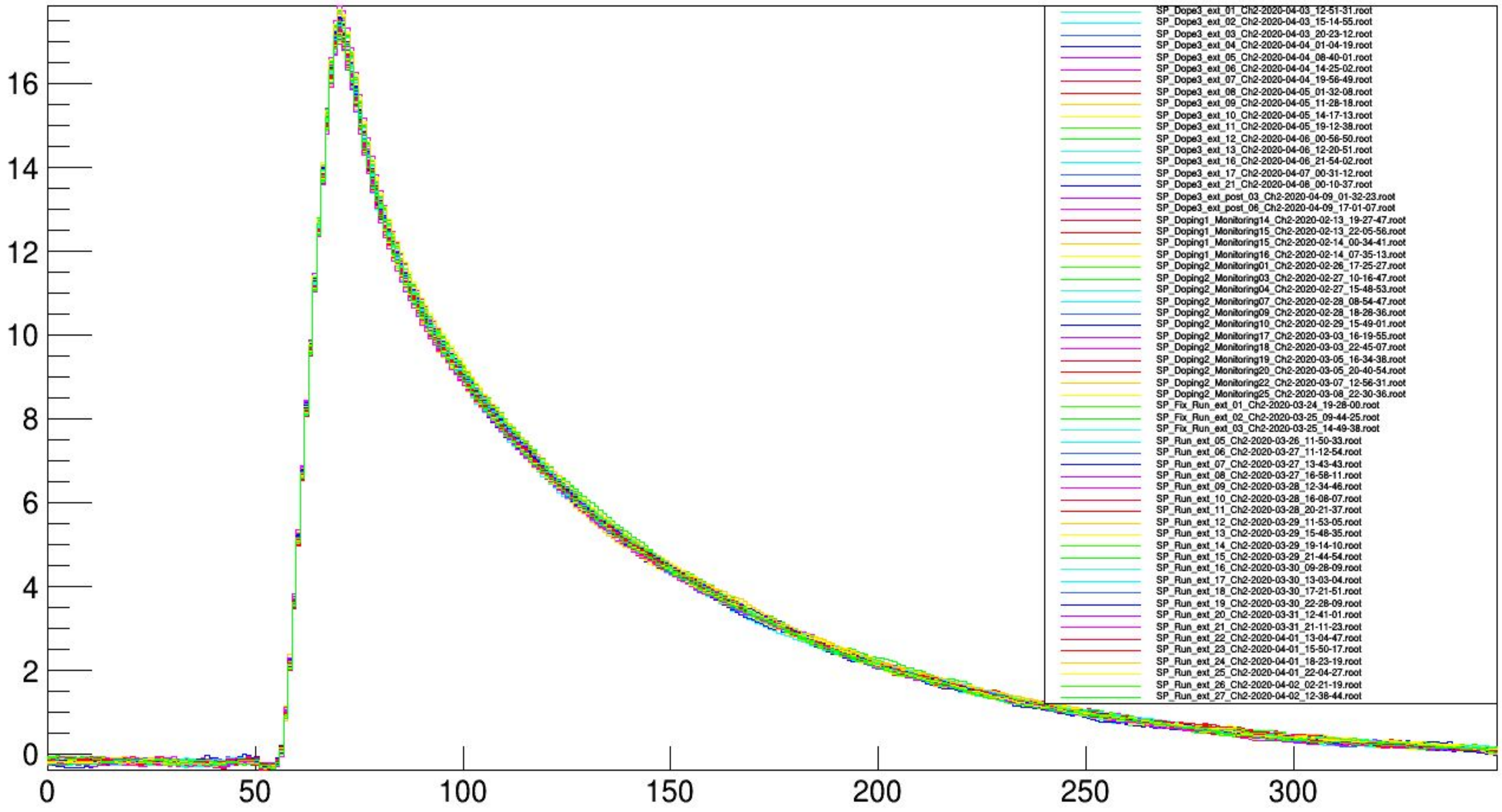
$\sigma\ \text{Integral}_{\text{<SPE>}} = \sqrt{\left(\sum_i \sigma_{\text{<SPE>}i}^2 \right)}$

Survey of response stability: comparison between all chs

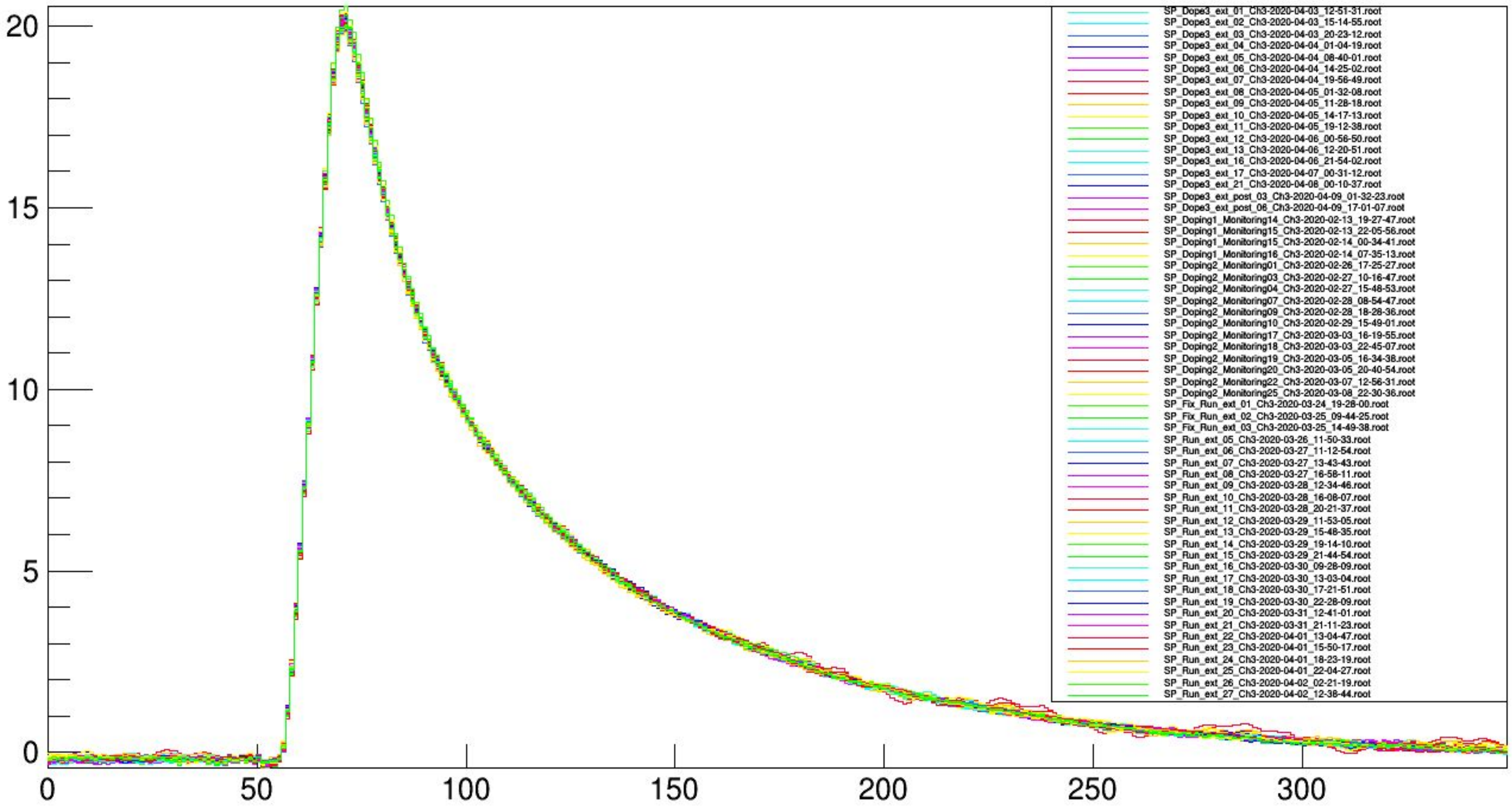
- std dev of individual <SPE>-integral ~ 2% for all channels and runs
- time distribution of <SPE>-integral consistent with constant (most recent data must be added & time-weighted fit implemented(?))
- <SPE>-integral distribution ~ gaussian for all Chs, with some variability in the distribution width (6 to 17)

	<SPE> PH mean (σ)	fit with a constant mean (+/-) [χ^2/ndf]	mean (σ) of distribution of 60 <SPE> integrals
Ch1	20.3 (0.2)	1082 (2.9) [15/59]	1082 (11)
Ch2	17.3 (0.2)	1085 (2.8) [38/59]	1086 (17)
Ch3	20.1 (0.2)	1092 (2.8) [17/59]	1086 (12)
Ch4	20.9 (0.3)	1092 (3.4) [7/59]	1092 (9)
Ch5	22.8 (0.2)	1110 (2.7) [4/59]	1110 (6)
Ch7	20.2 (0.2)	1089 (2.6) [10/59]	1089 (8)

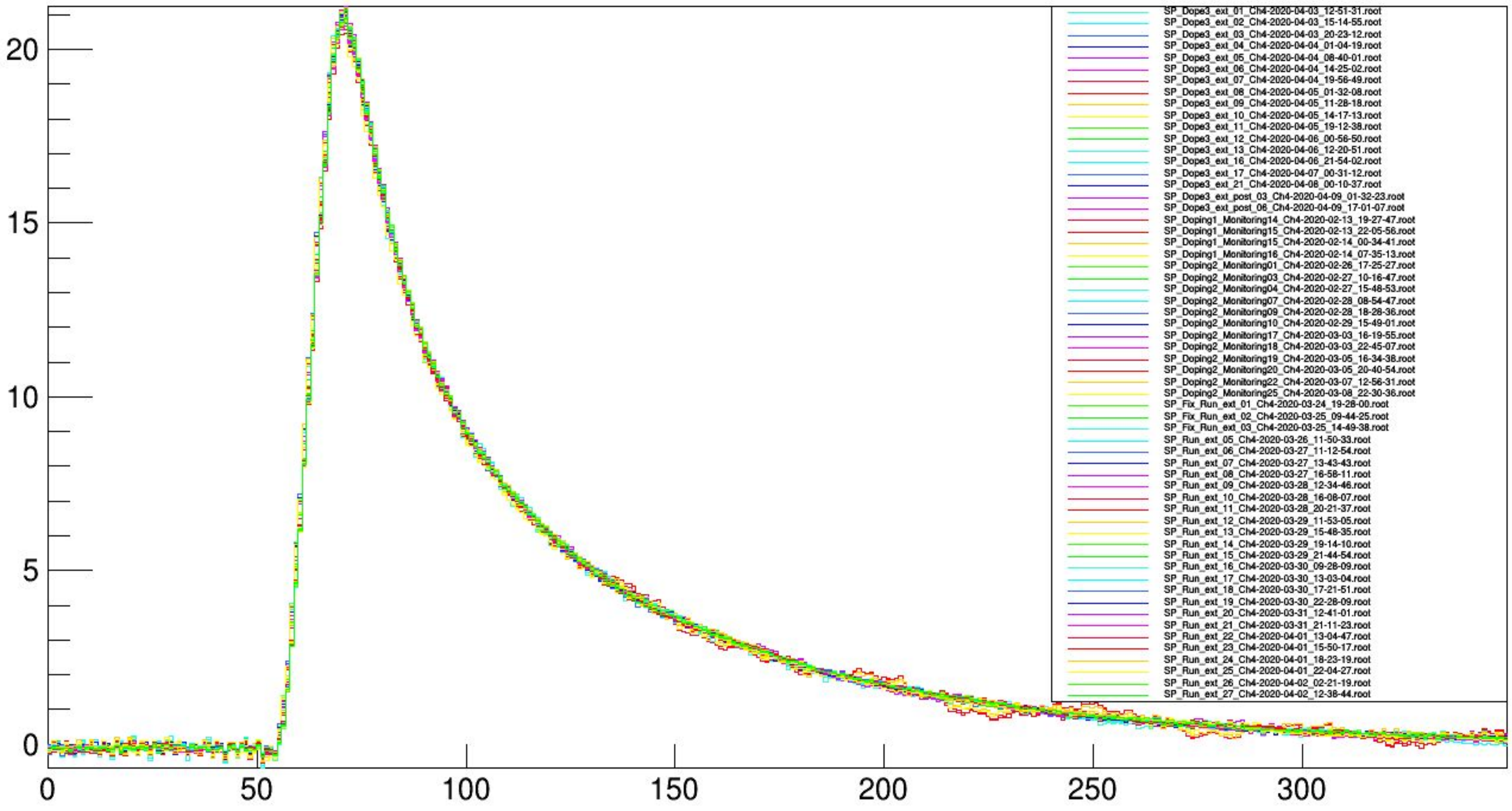
Channel 2: superposition of <SPE> for 60 runs



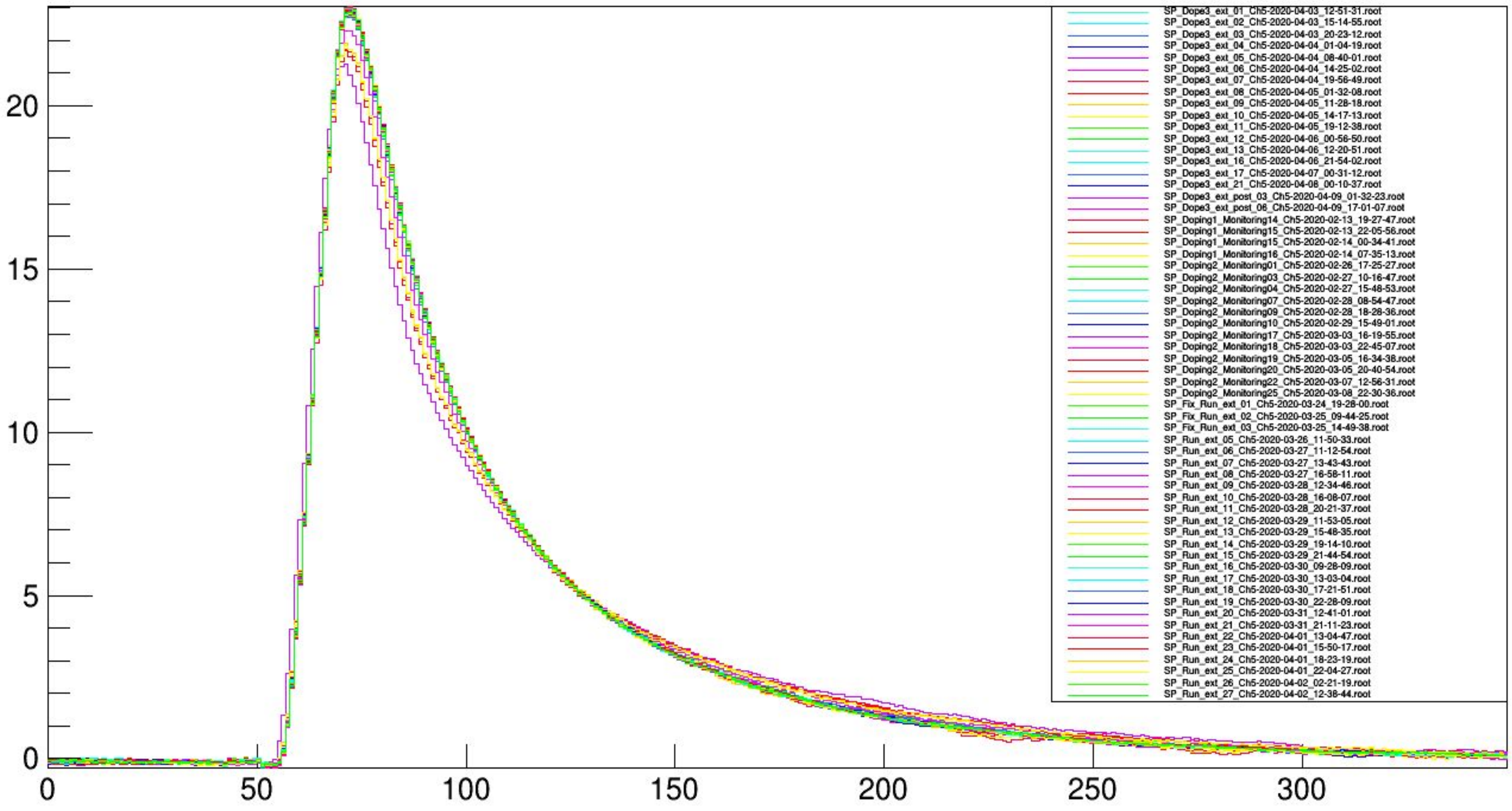
Channel 3: superposition of <SPE> for 60 runs



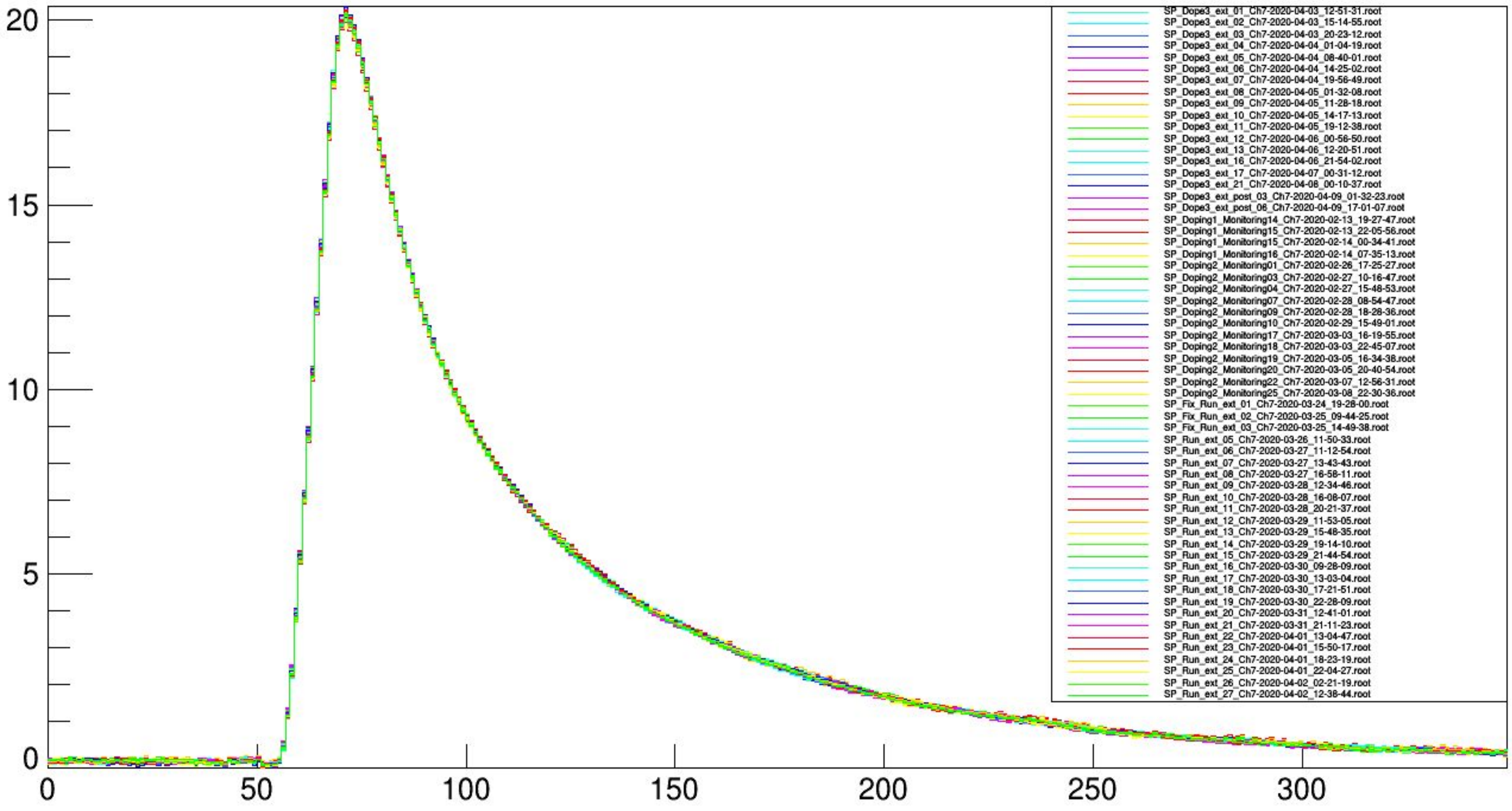
Channel 4: superposition of <SPE> for 60 runs



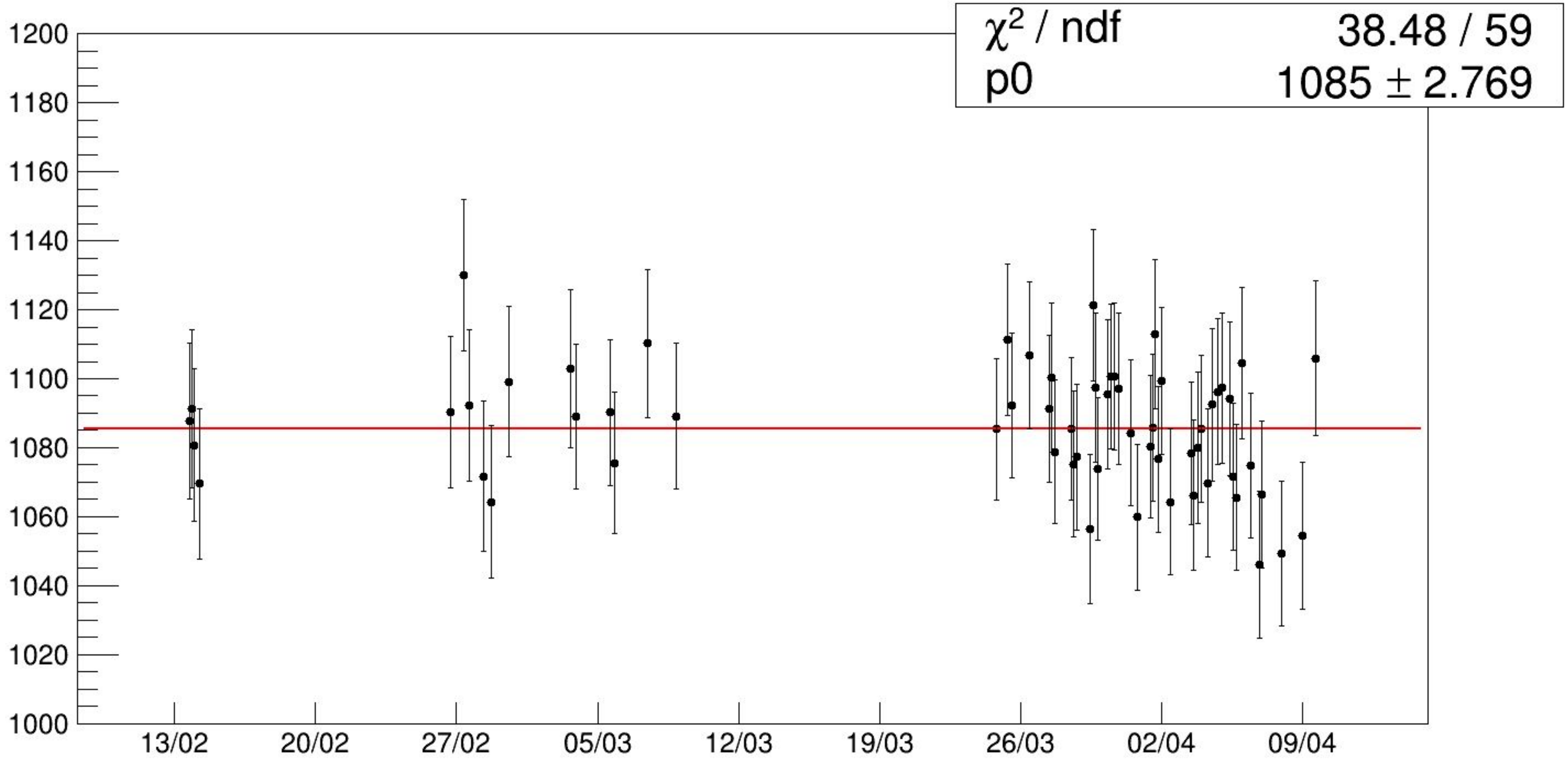
Channel 5: superposition of <SPE> for 60 runs



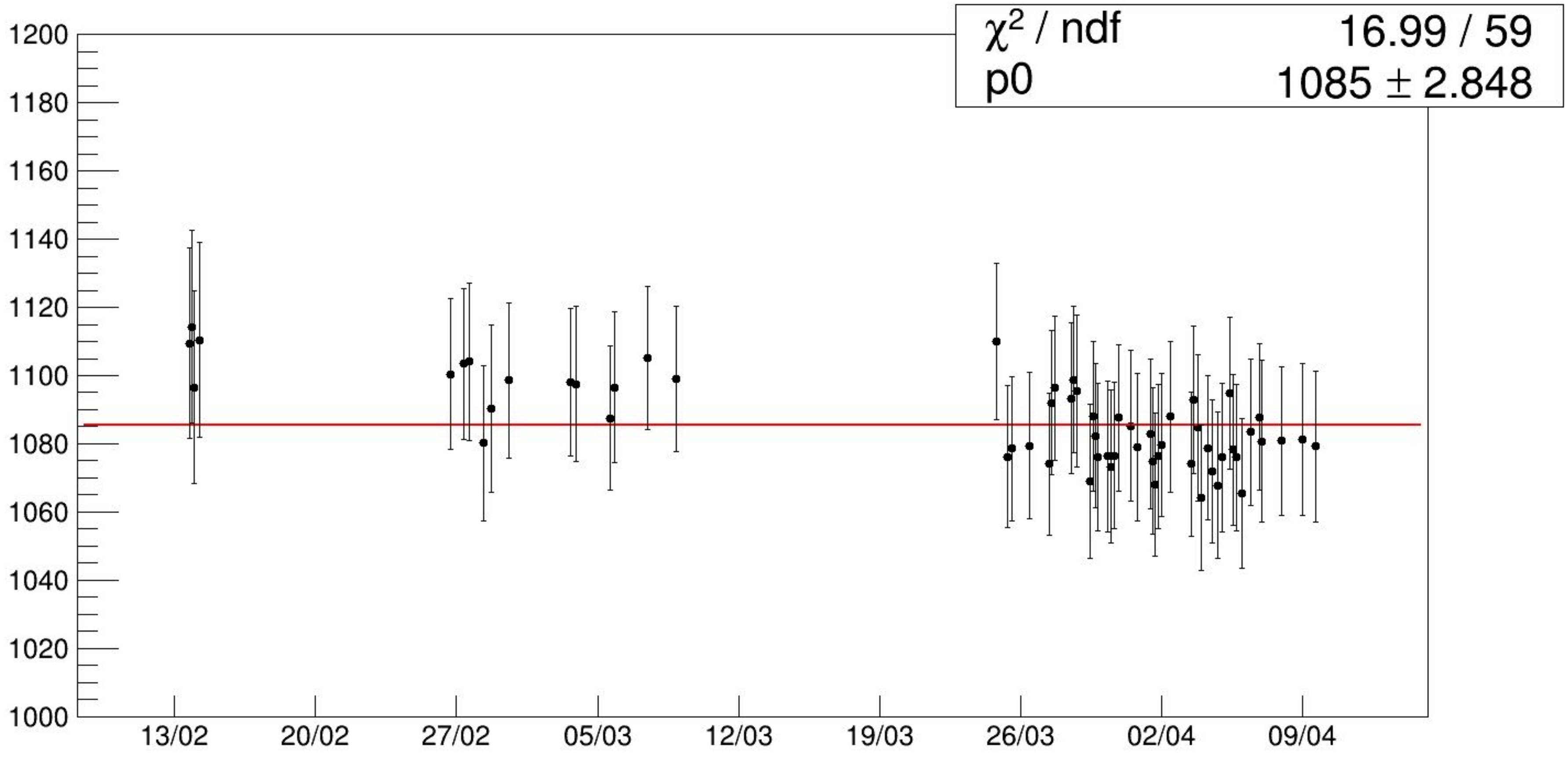
Channel 7: superposition of <SPE> for 60 runs



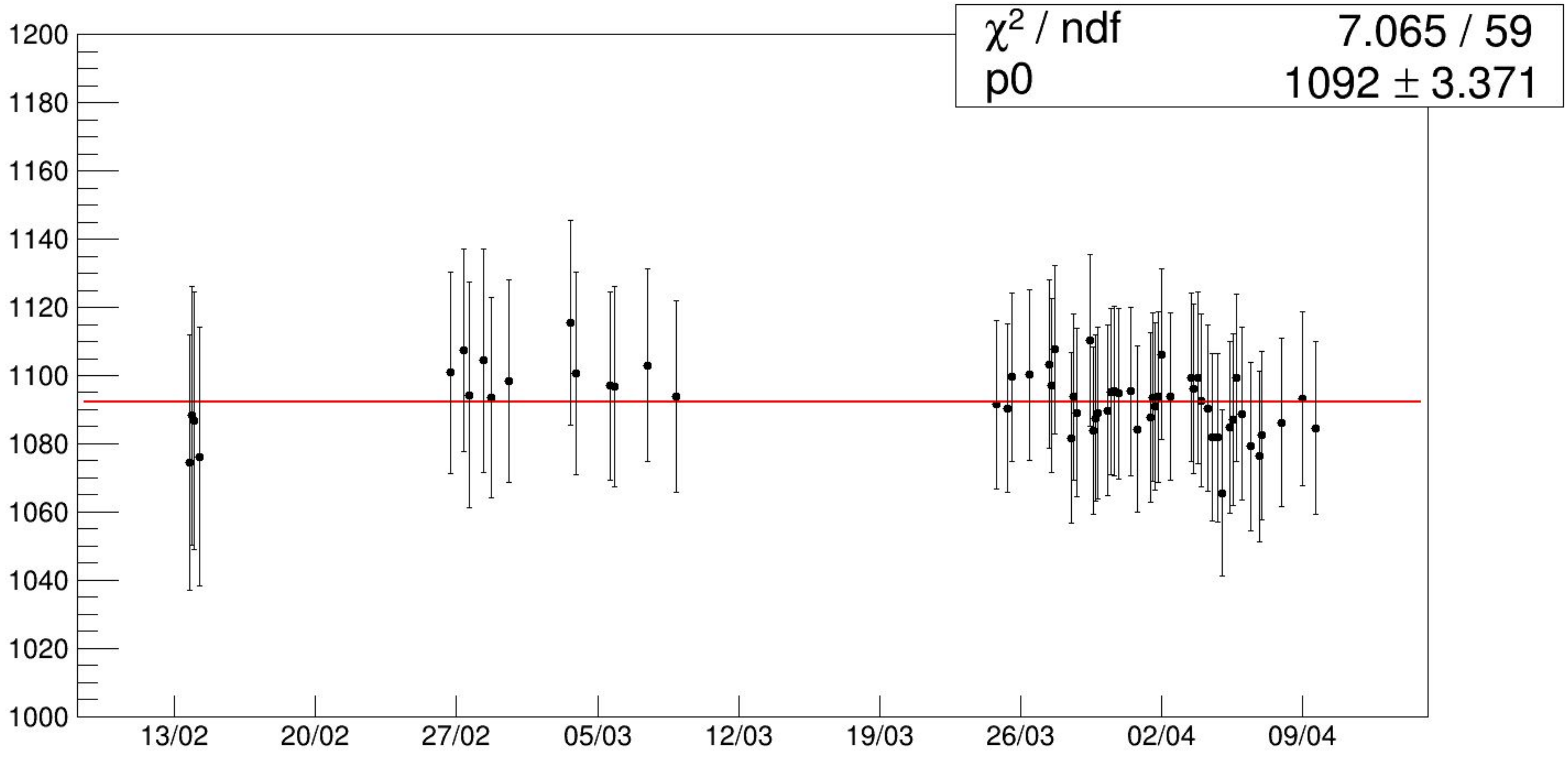
Ch2 <SPE> integral vs time



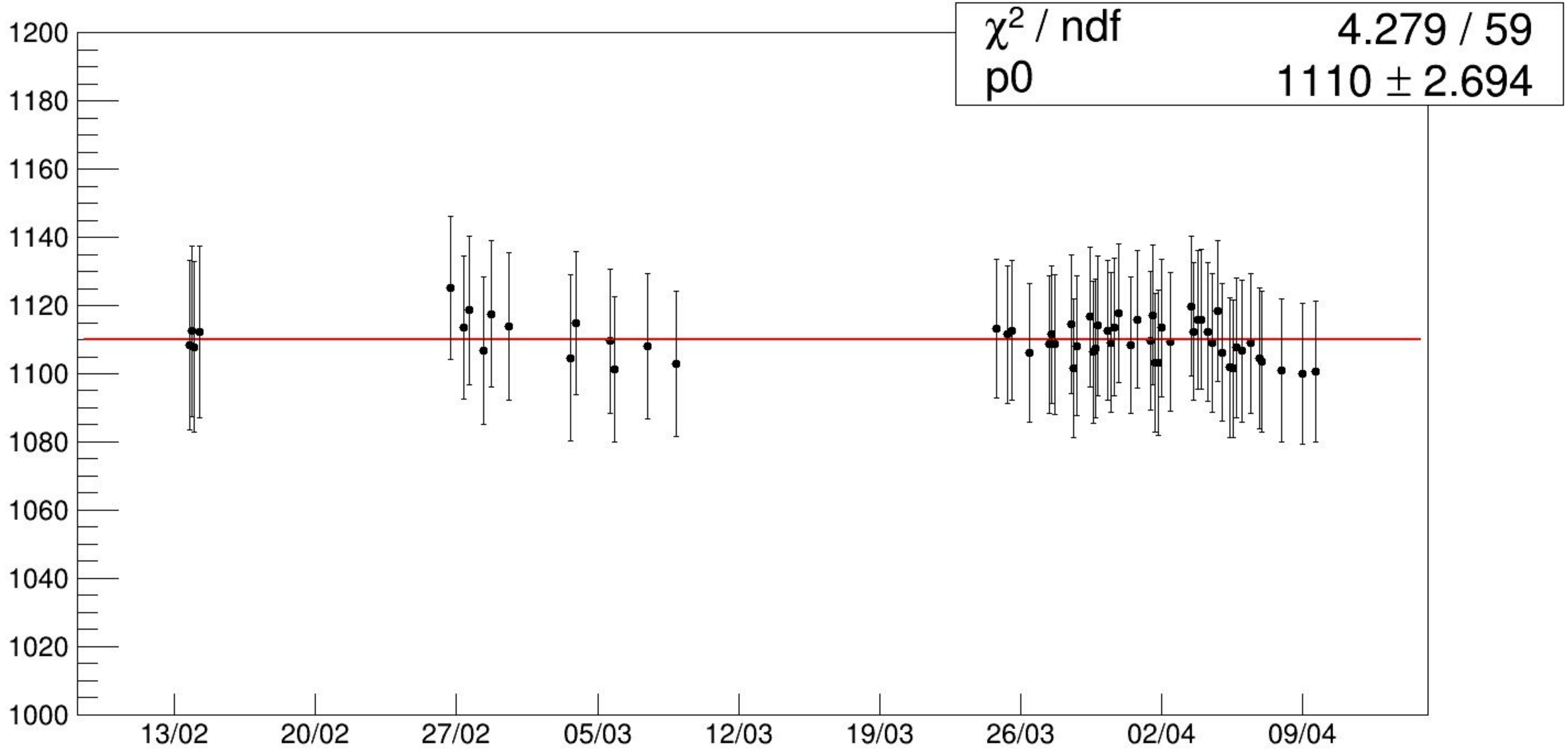
Ch3 <SPE> integral vs time



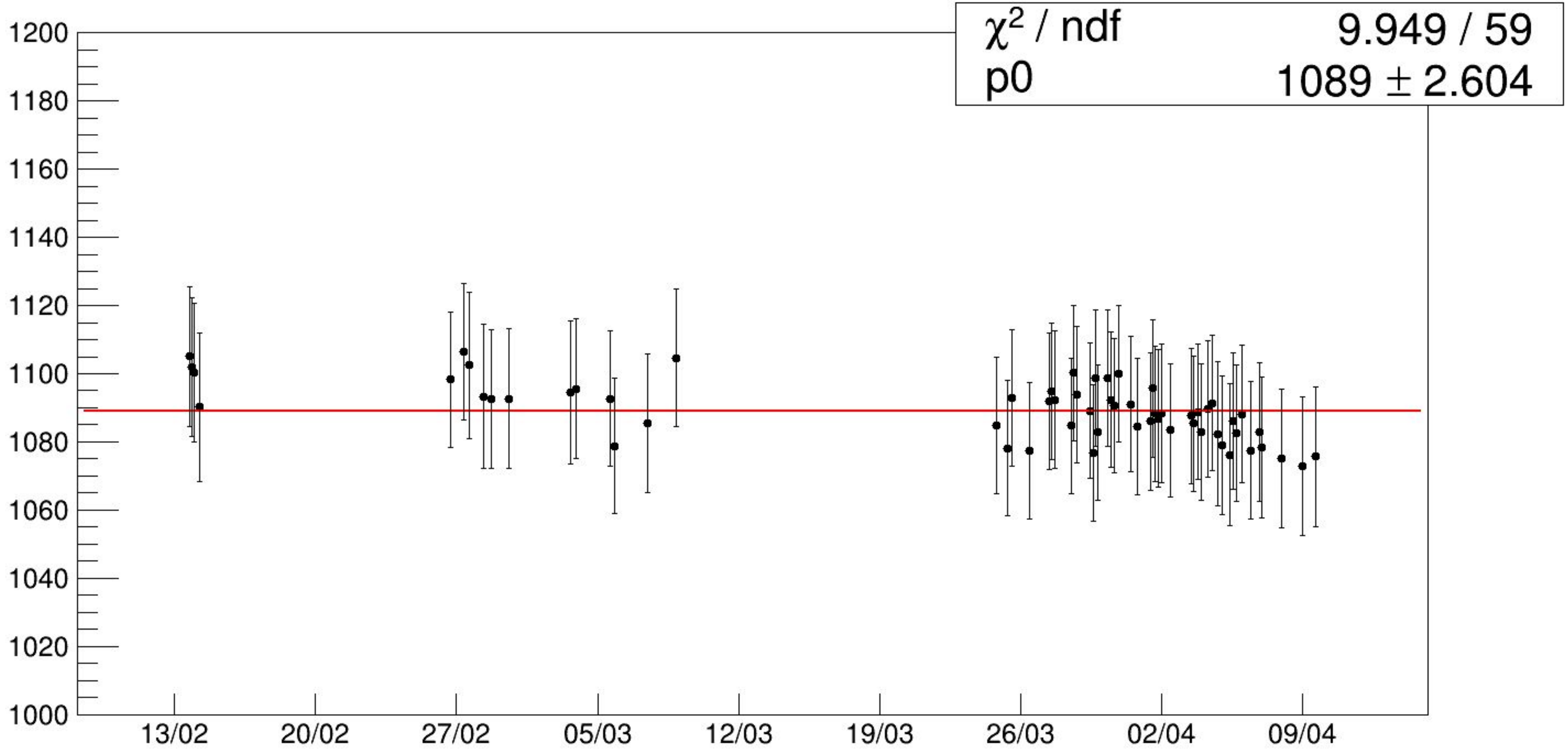
Ch4 <SPE> integral vs time



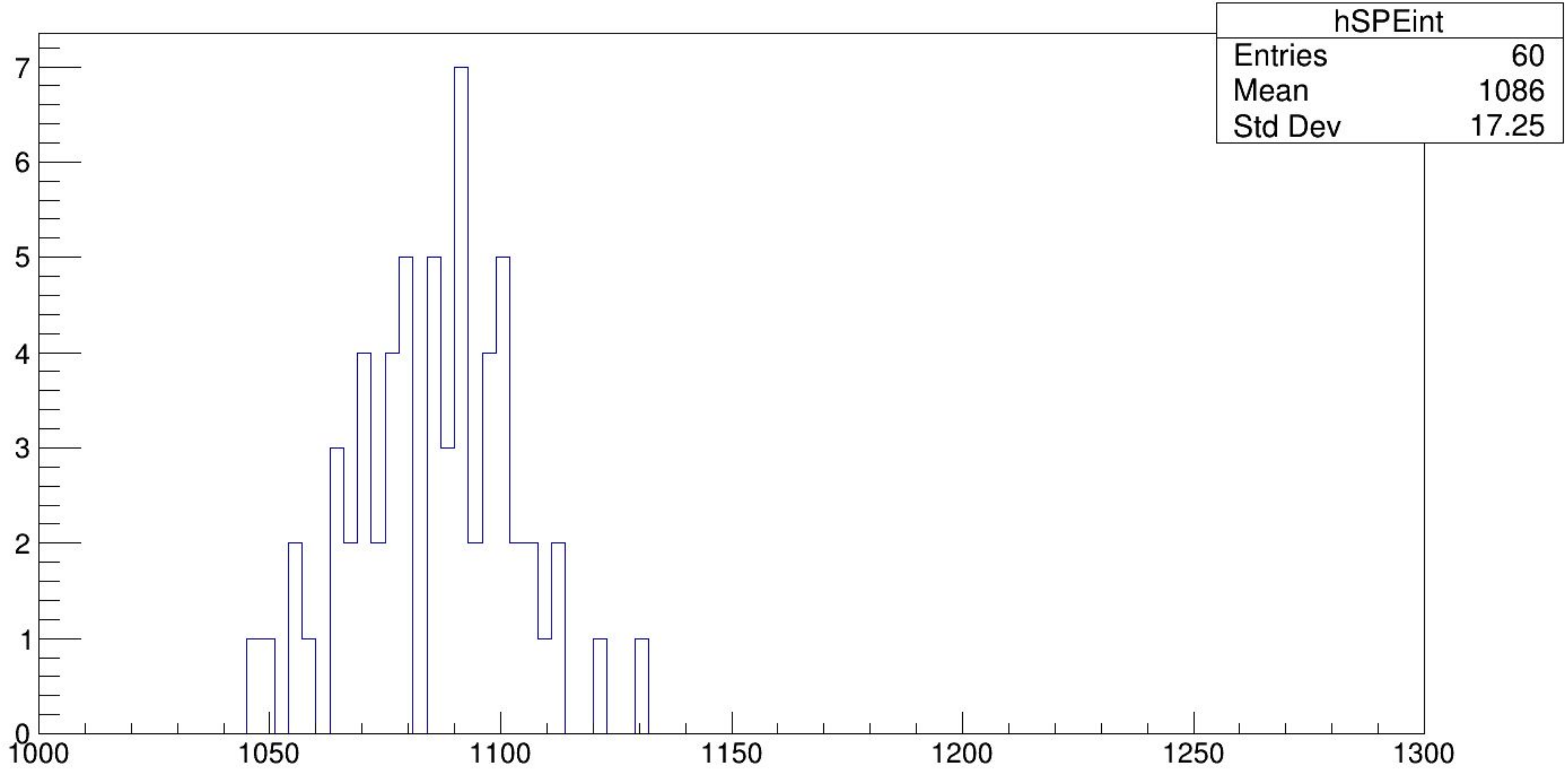
Ch5 <SPE> integral vs time



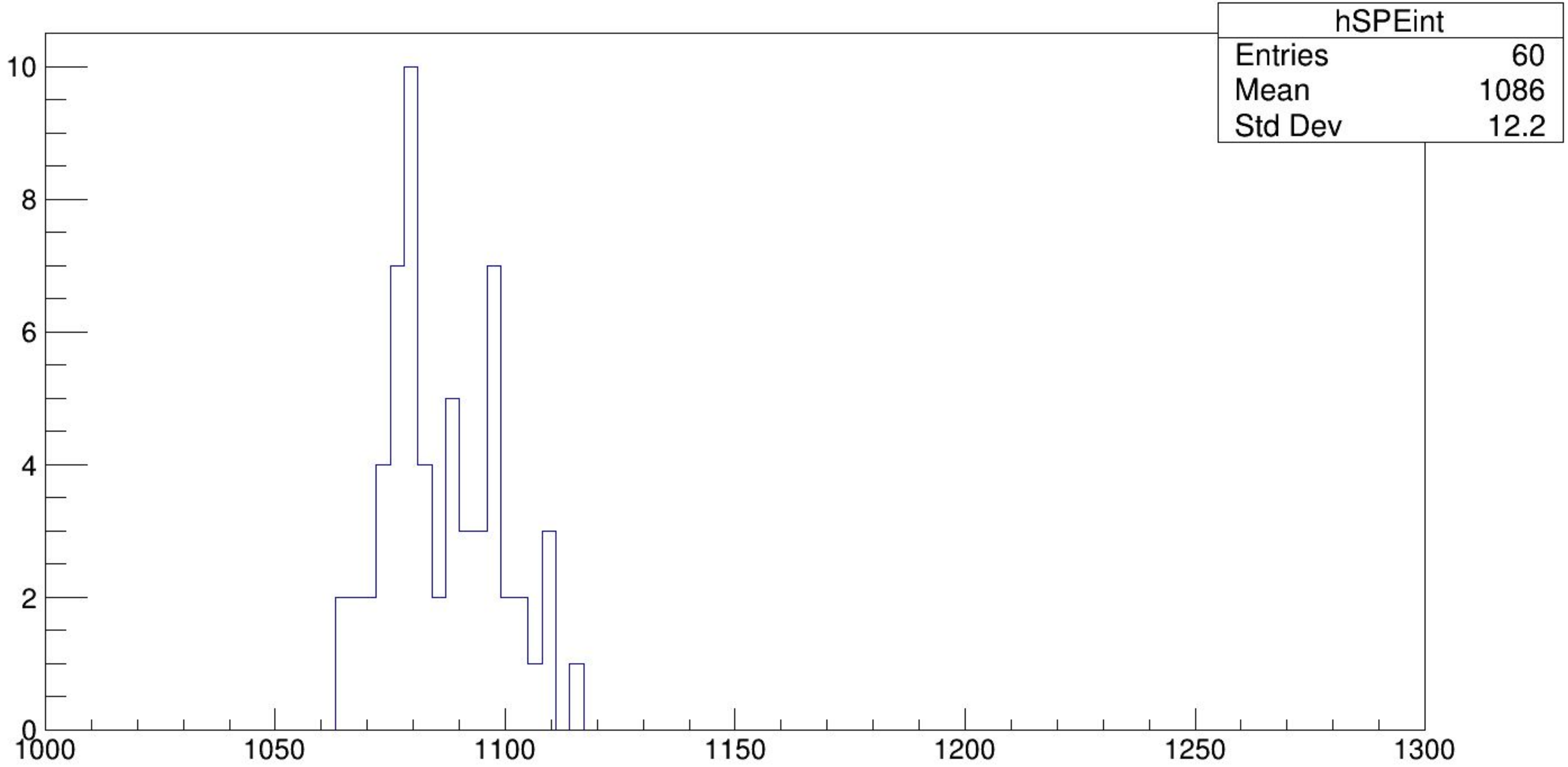
Ch7 <SPE> integral vs time



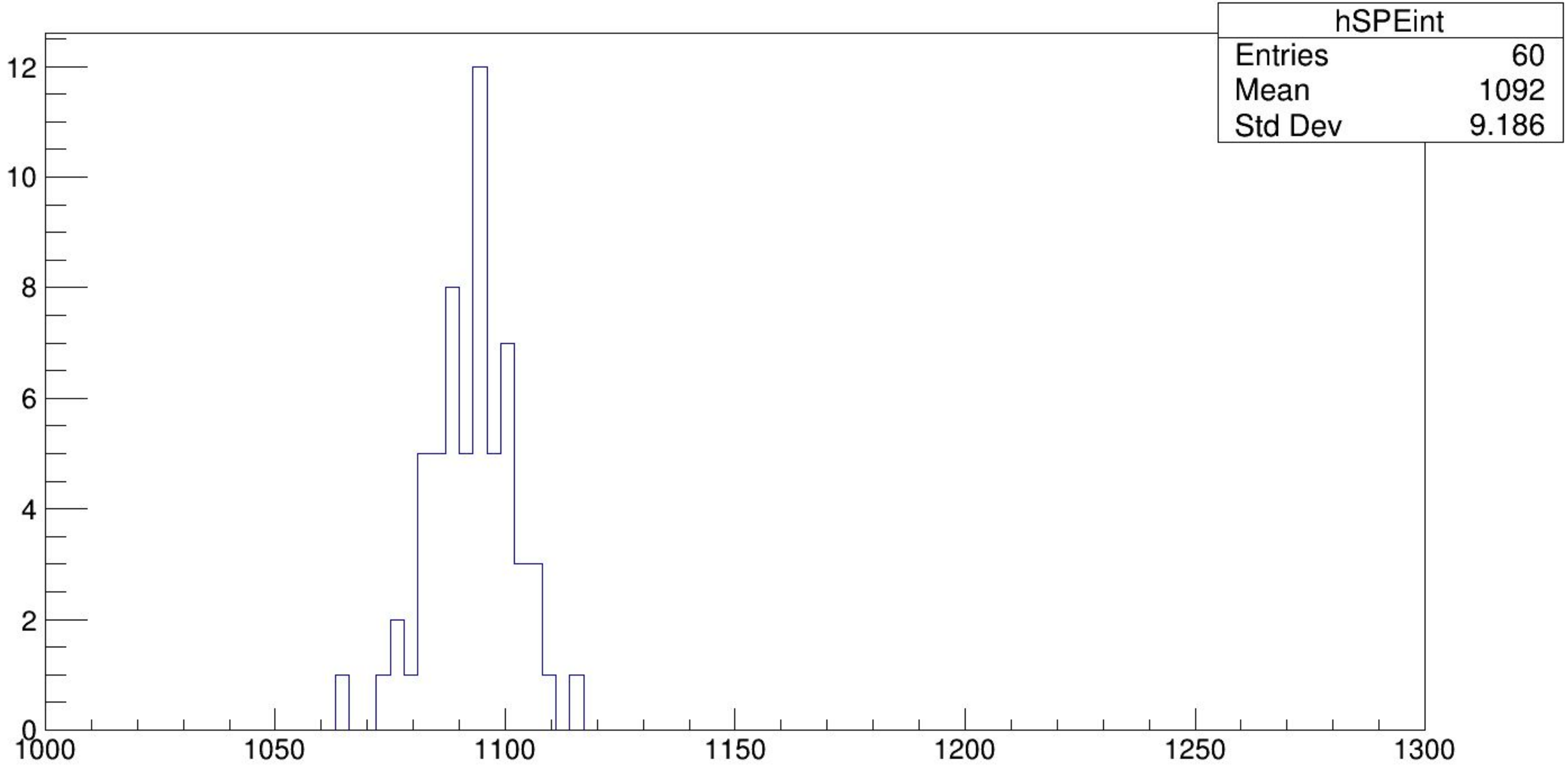
Ch2 <SPE> integral distribution



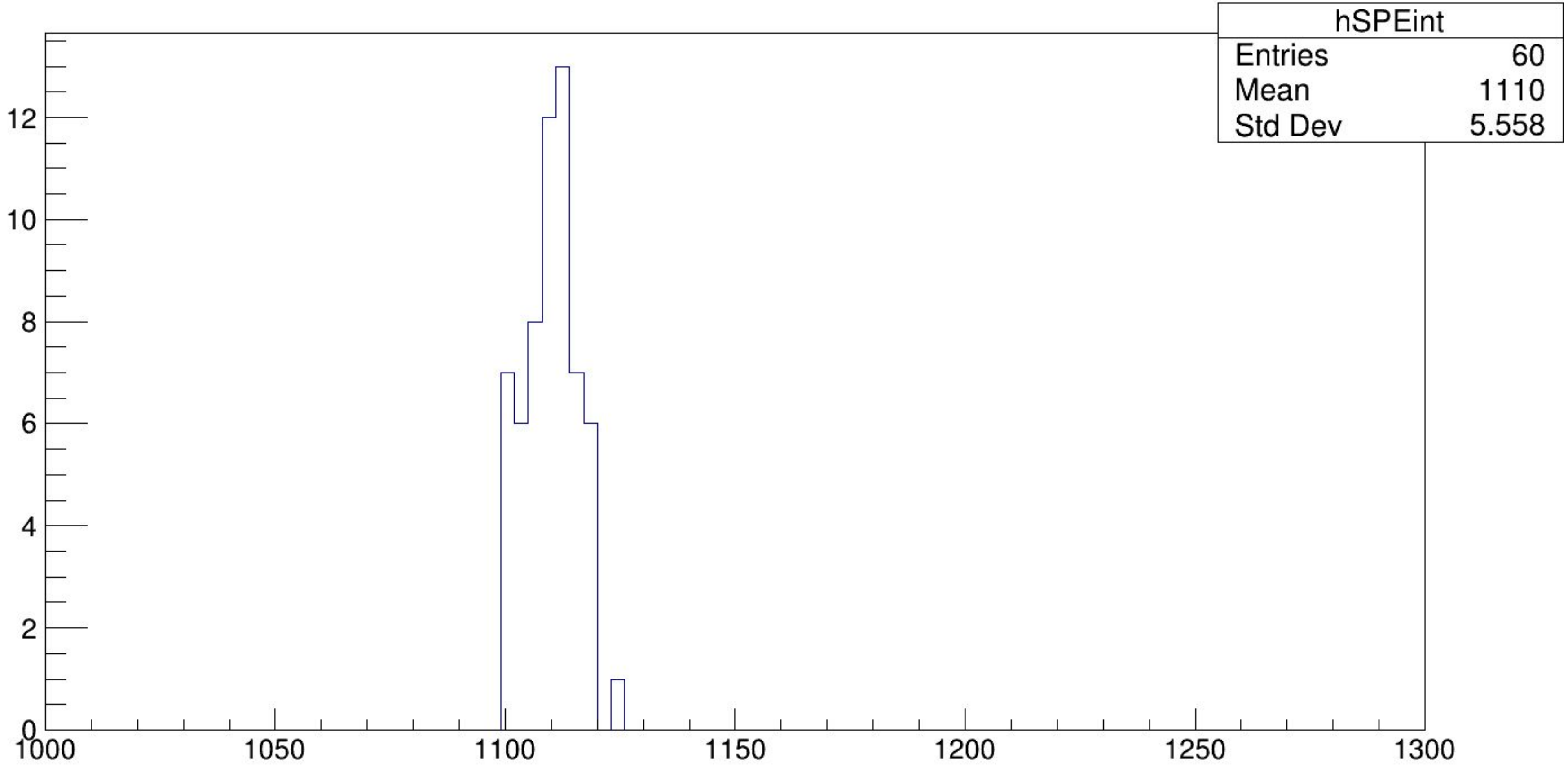
Ch3 <SPE> integral distribution



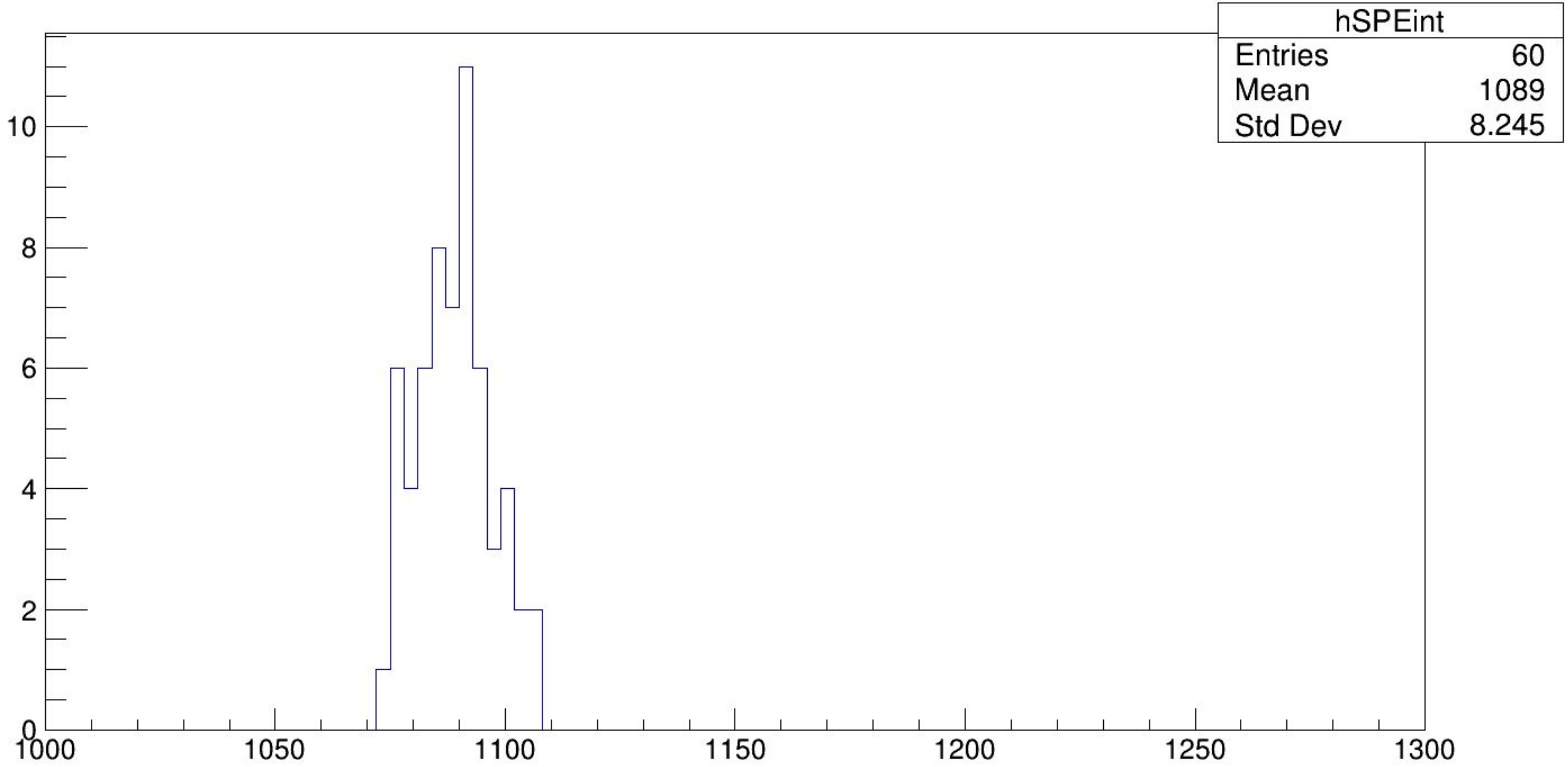
Ch4 <SPE> integral distribution



Ch5 <SPE> integral distribution

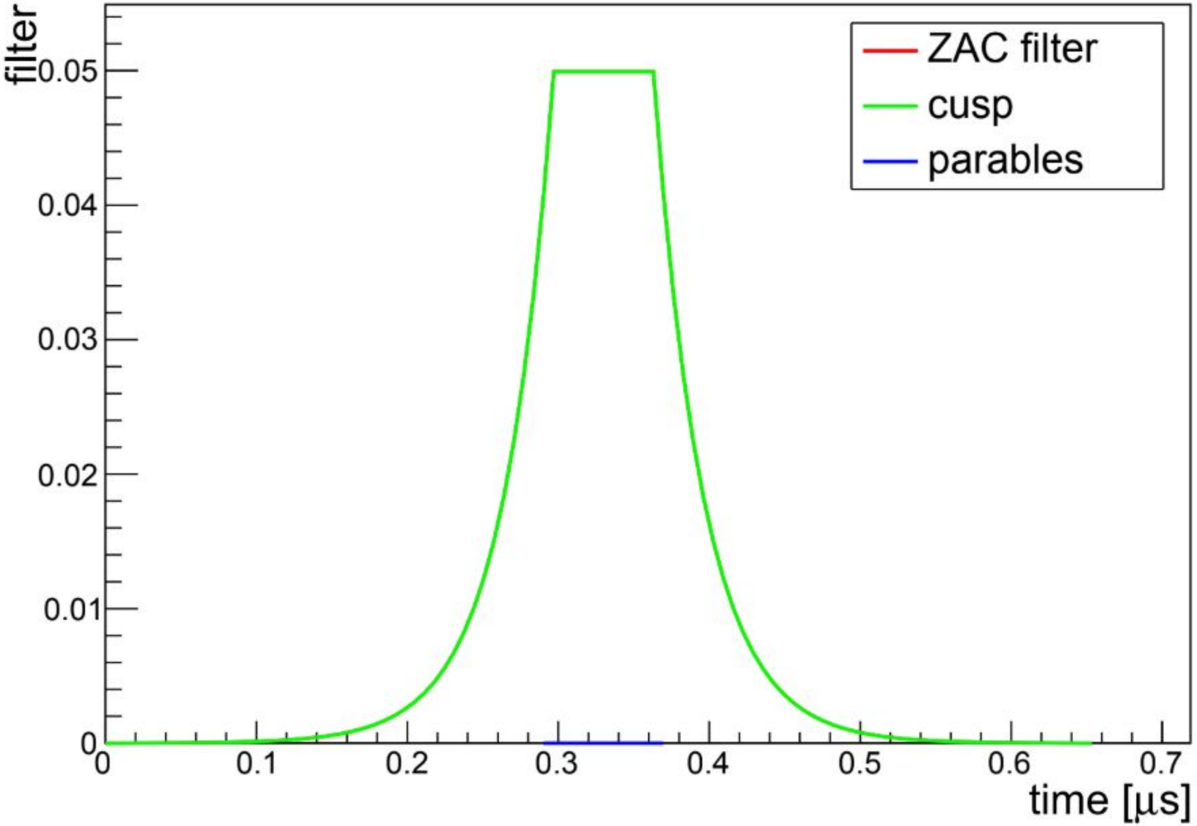


Ch7 <SPE> integral distribution



A FIR filter to integrate and smooth the signals

WORK IN PROGRESS



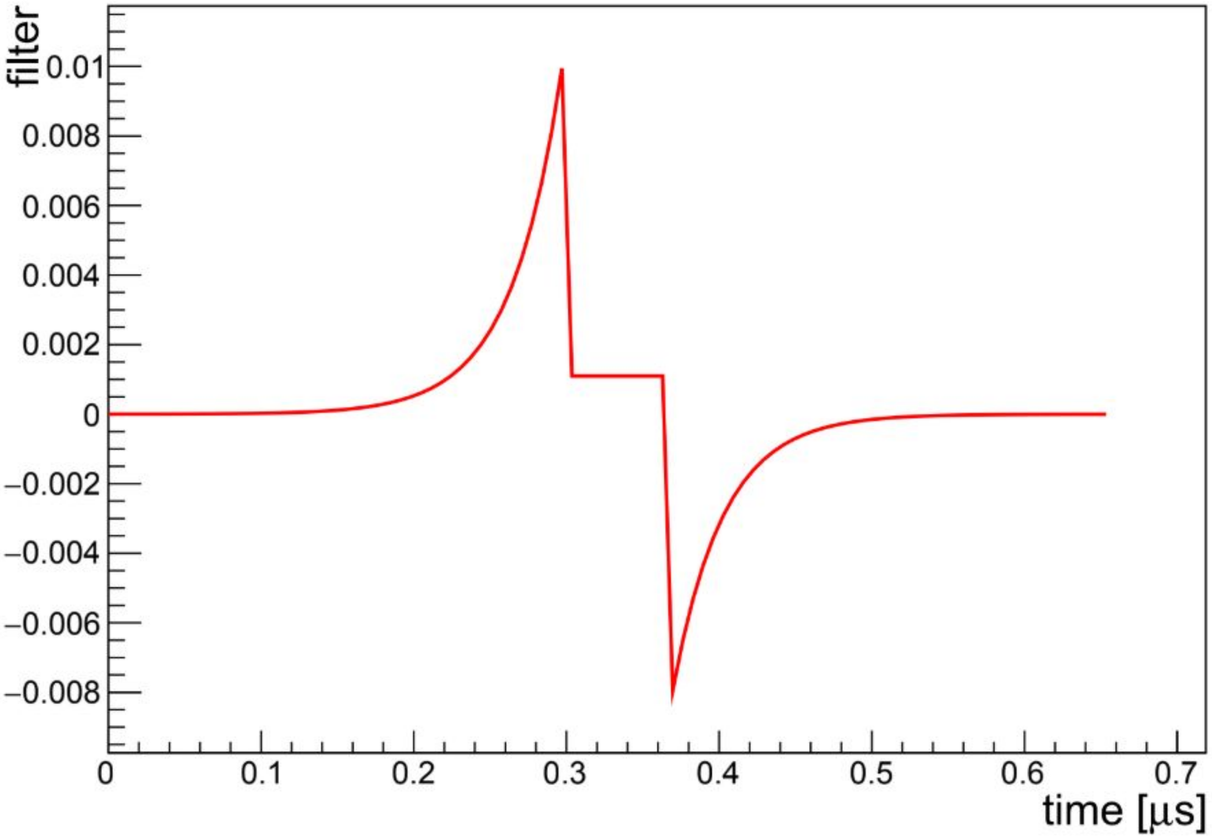
weighting function: truncated cusp

- 660 ns (100 ticks) length
- 33 ns shaping factor
- 66 ns flat top

the cusp parameters are preliminar: optimized only on Ch1 and on Dope3 first run. They may(should) be optimized on a channel and run basis

A FIR filter to deconvolve signals

WORK IN PROGRESS



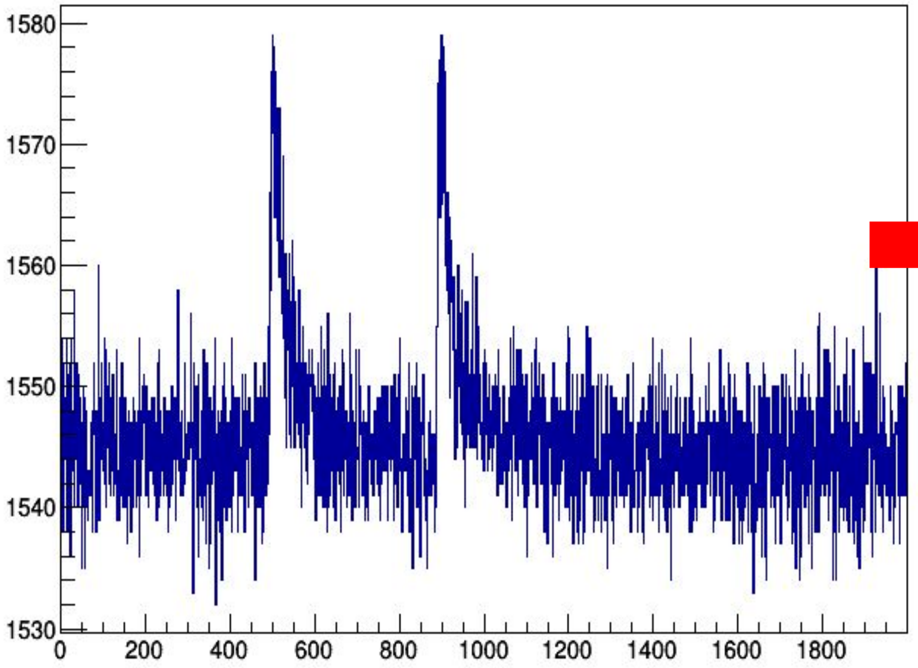
The cusp is then convolved with the SiPMs RC exponential decay (τ is now set to 300 ns, but a second RC decay component may be added)

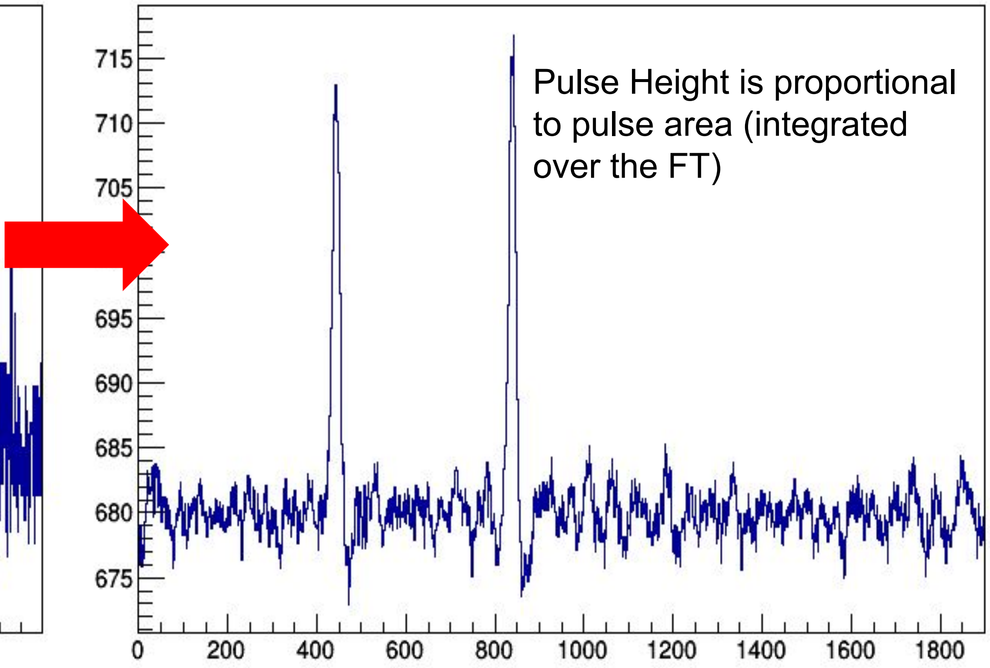
the τ parameter is now = 300 ns for all the Chs:

- we know it may differ (ch2) among channels
- pulse decay it is not an unique exp decay (from fit of the SPE)

It has been derived from Ch1 Dope3 run.
It may(should) be optimized on a channel (and run) basis

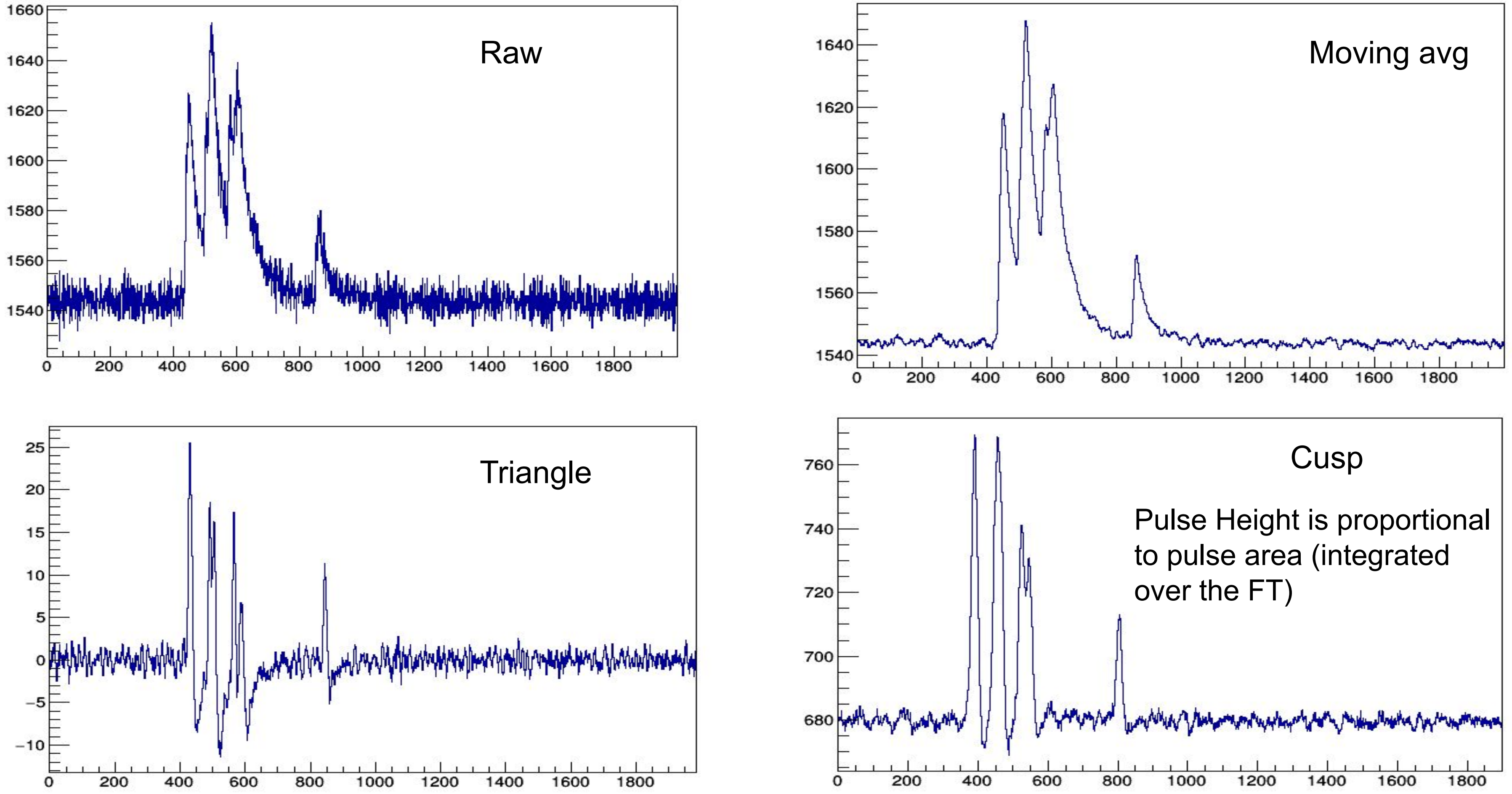
Filtered waveforms CH5: 2 SPE



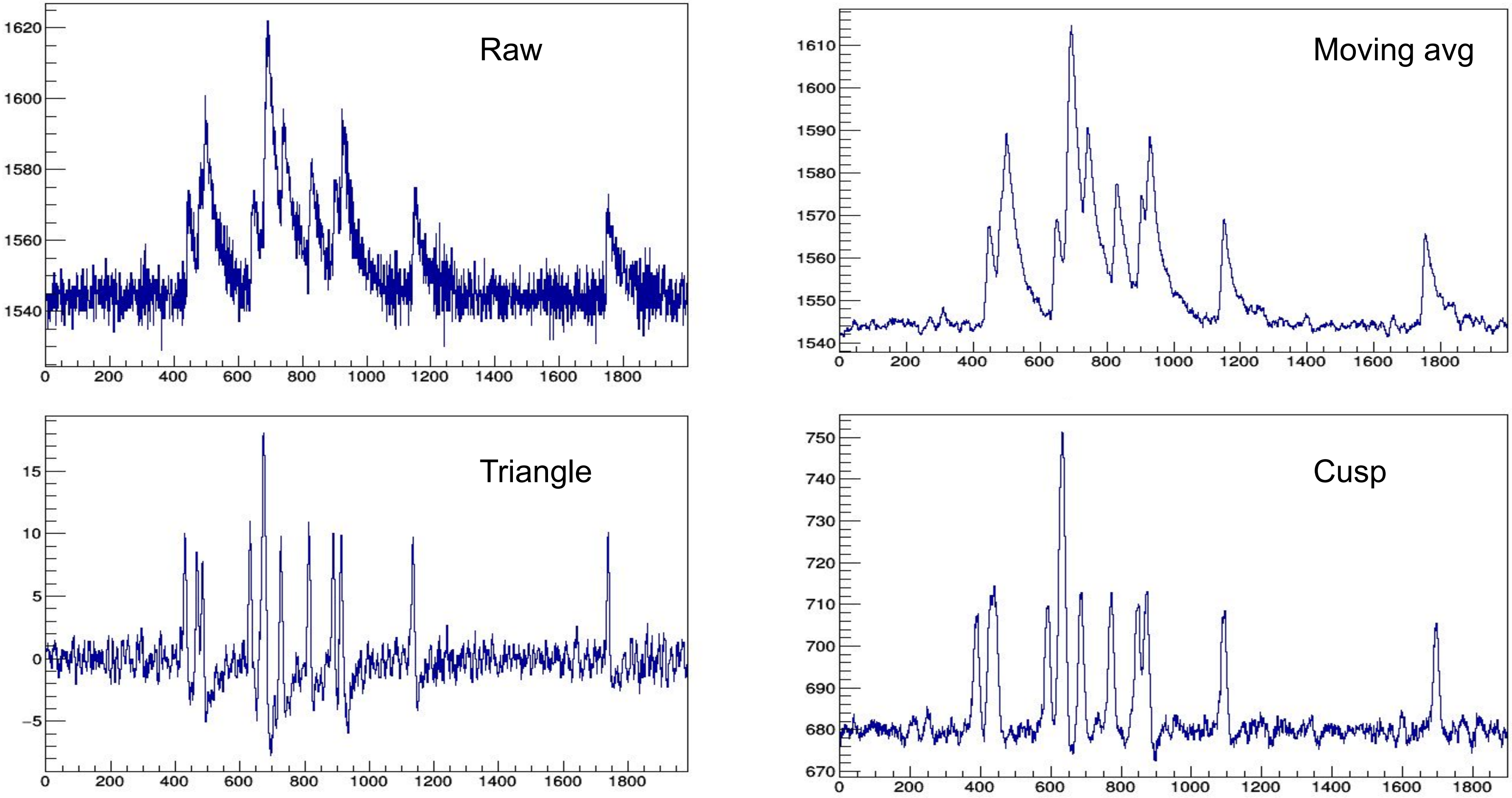


Pulse Height is proportional to pulse area (integrated over the FT)

Filtered waveforms: a multiPE event

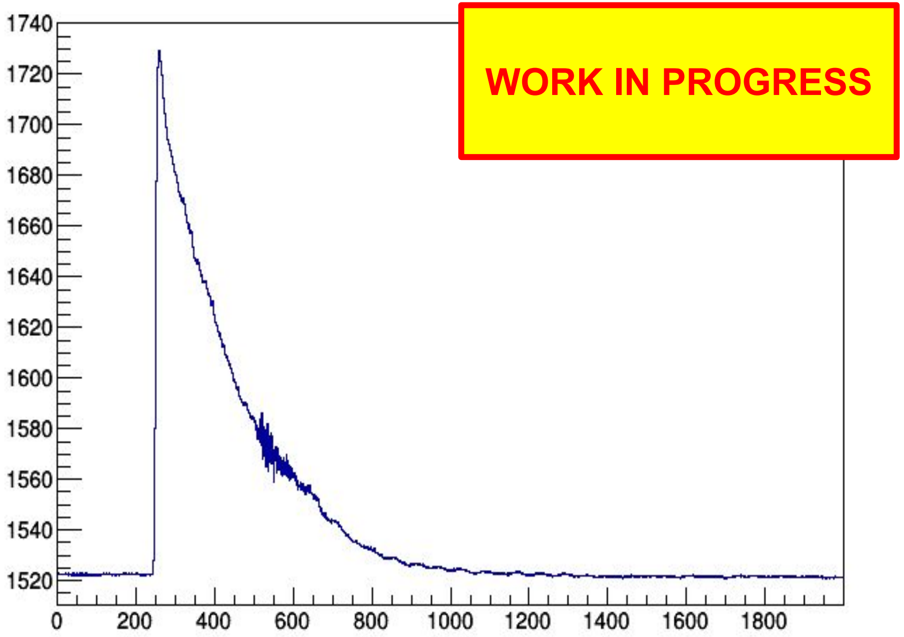


Filtered waveforms

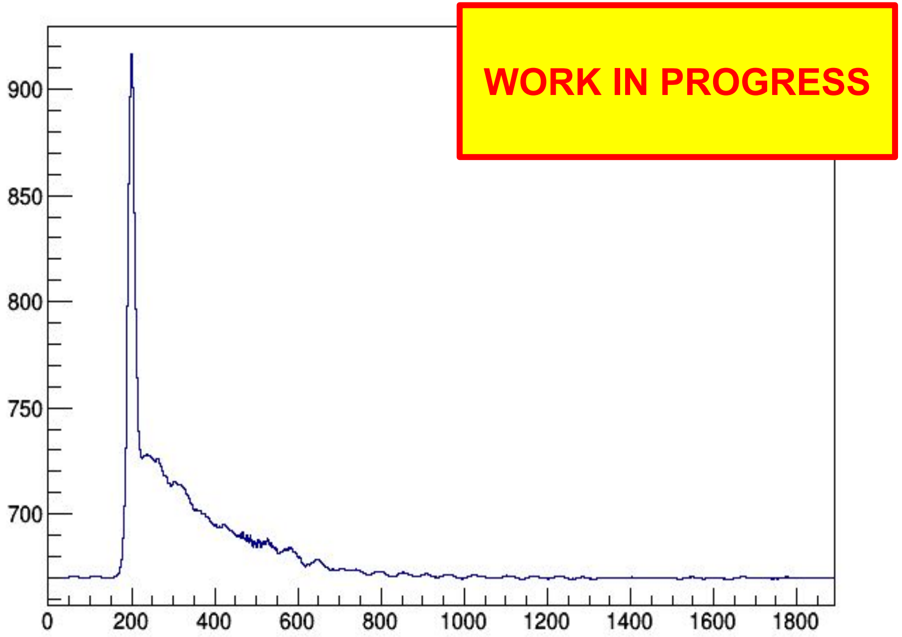


Averaged deconvolved wfs - before doping - no quartz

Average raw waveform



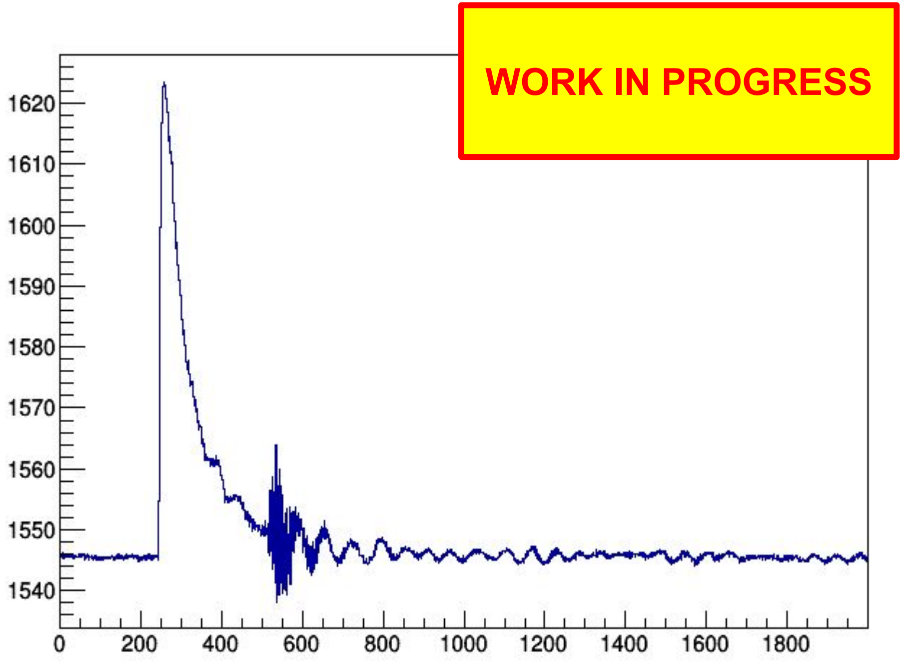
Average filtered waveform



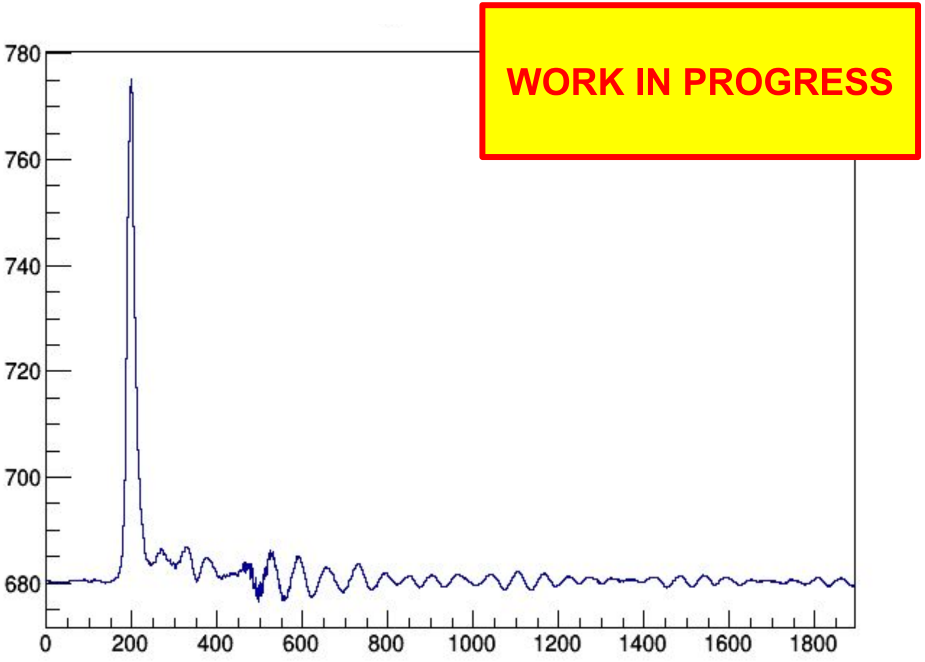
- so far the wfms are filtered on individual basis and then added: once the parameters are optimized, the filter may be passed at once on the raw-<wfm>

Averaged deconvolved wfs - before doping - quartz

Average raw waveform

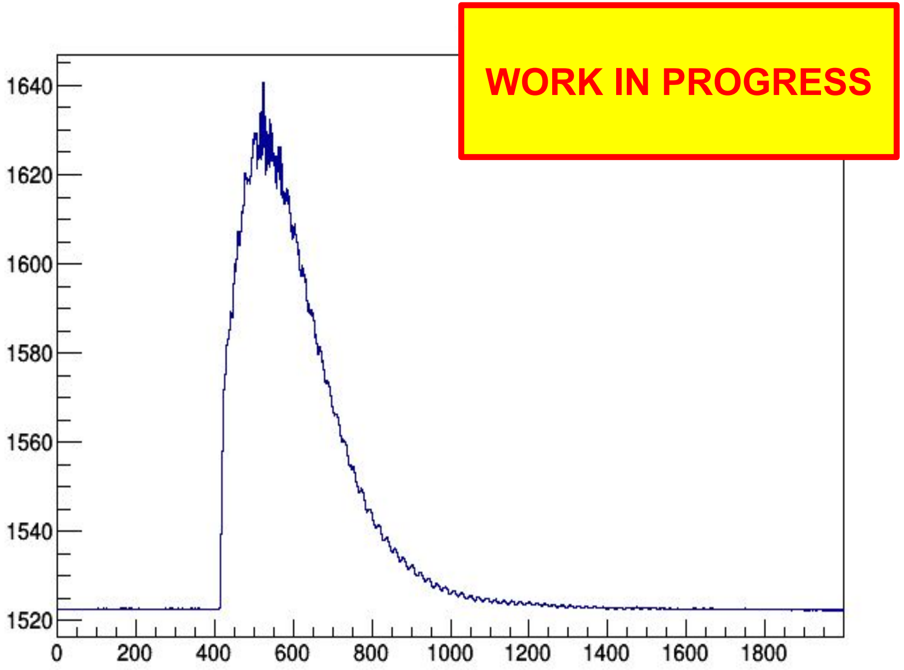


Average filtered waveform

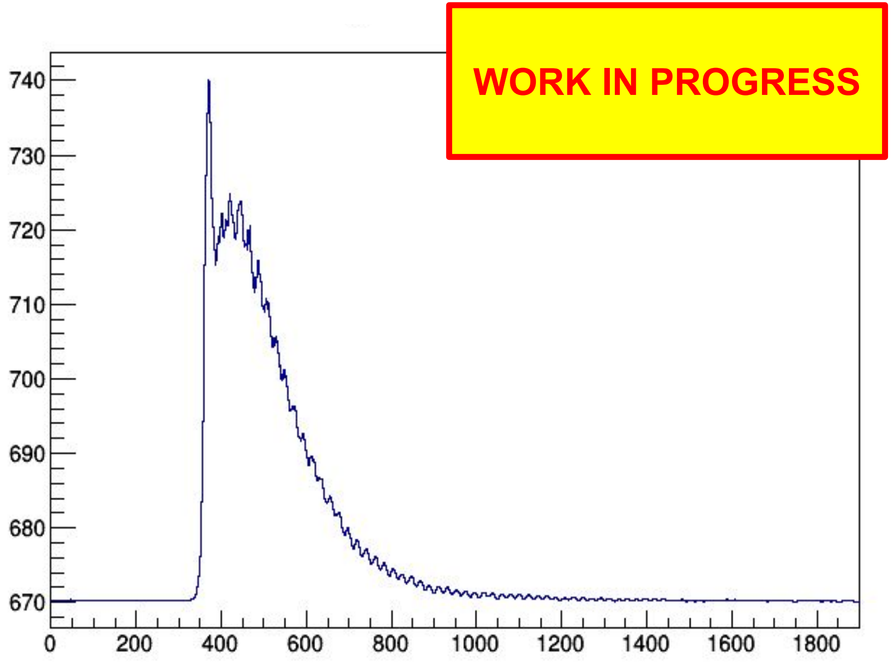


Averaged deconvolved wfs - after 3rd doping - no quartz

Average raw waveform

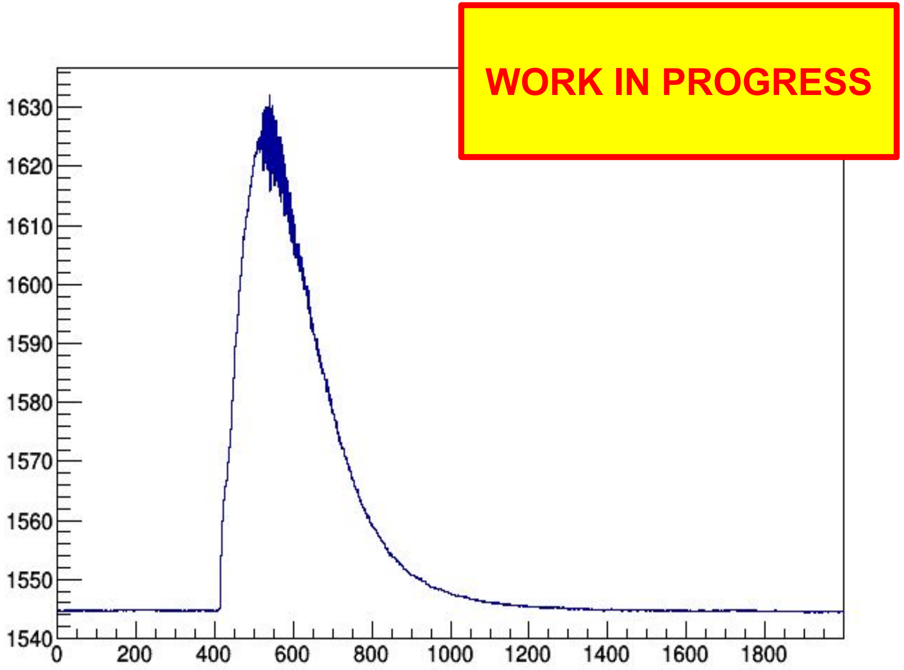


Average filtered waveform

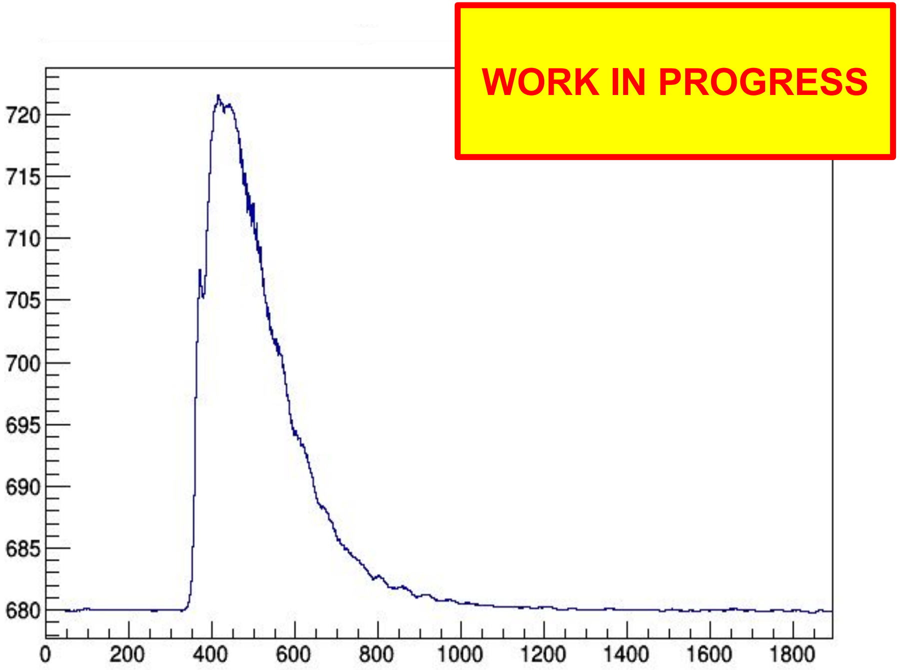


Averaged deconvolved wfs - after 3rd doping - quartz

Average raw waveform



Average filtered waveform



Conclusions

- <BL> and BL_rms are evaluated on the wfm pretrigger samples
- SPE and DPE pulses identified in the whole wfms thanks to FIR differentiator and requirements on dt between pulse onsets
- synchronized SPEs are averaged in each run.
  - The <SPE>-integrals (INT <SPE>) are plotted to survey the stability of the system (electronics)
  - The std dev of the <INT <SPE>> is found to be ~2%
- Time distribution of <SPE> is consistent with flat (but recentest runs not yet included) for all the channels
- A FIR filter to smooth, integrate and deconvolve the pulse exponential decay (due to SiPM RC) has been designed: it allows to identify the amplitude and timing of the detected photons
- the filtered-<wfm> is built and compared to the raw-<wfm> (work in progress) and ready for the evaluation of slow-fast components (time/amplitude)

To do:

- Add more data
- Include most recent runs in the SPE time survey
- optimize parameters of the FIR filter
- add second τ_{RC} to the filter
- characterize via fit the slow component of deconvolved average wvfs for each doping period