CoMPASS DAQ Pulse Height Algo

MEMO

In terminal → CoMPASS

Project folder structure → *Runs Folder=DAQ/ {RAW/, FILTERED/, OFFLINE/, UNFILTERED/, SCREENSHOTS/,settings.xml, run.info}$_{perRun}$*

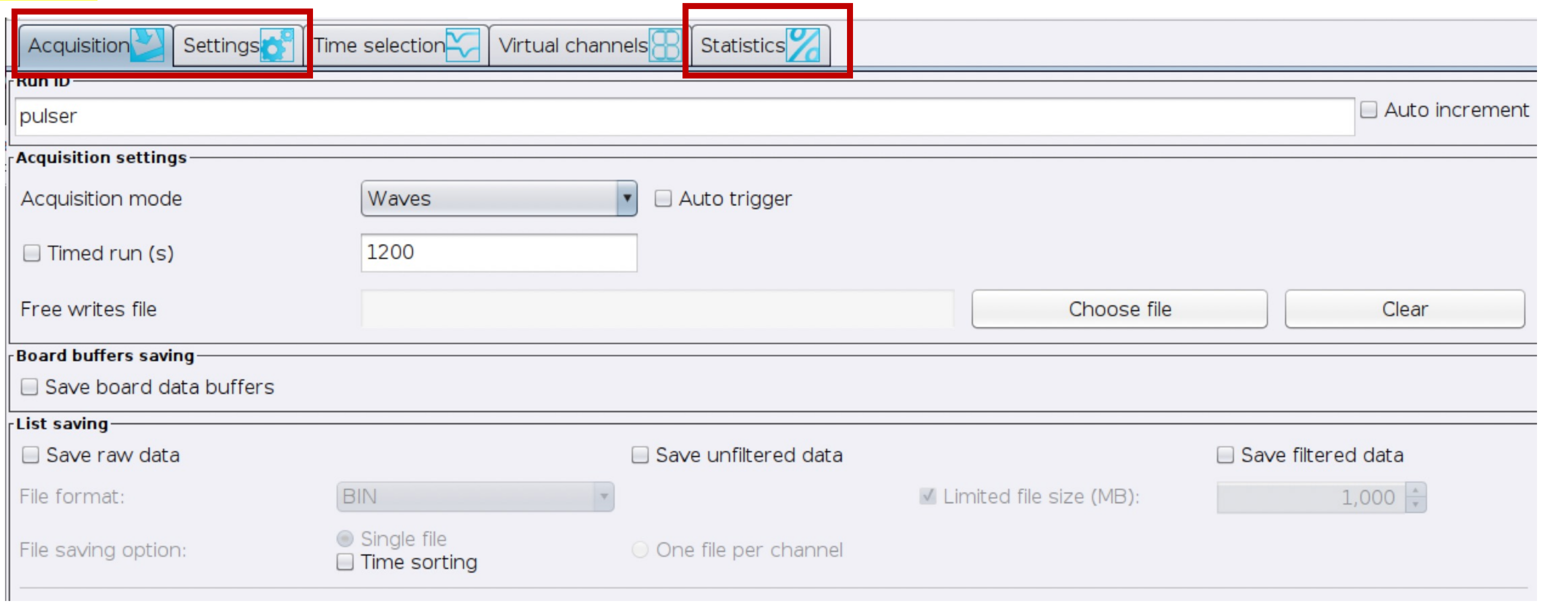
DAQ settings = .compass

Saving on same run name will erase everything from previous

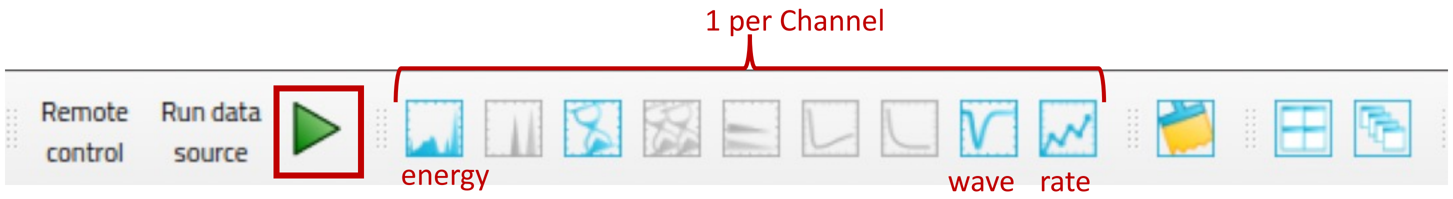
2 windows → Acquisition/Setting

Stats. (rate…)

Overview all board-channel rates



→ Start/Plots



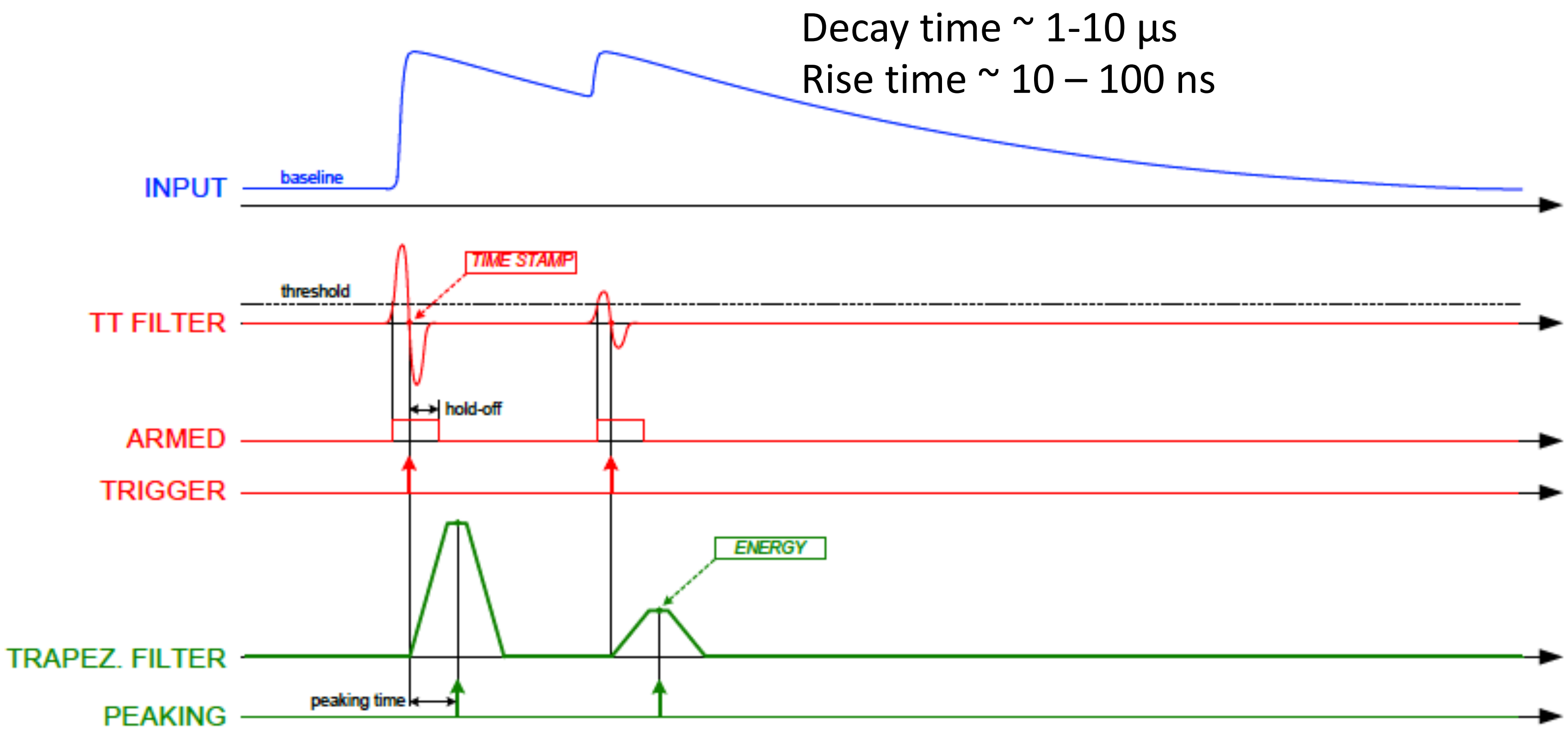


Fig. 4.11: Simplified signals scheme of the Trigger and Timing filter (red) and the Trapezoidal Filter (green). In blue the input pulses from Preamplifier.

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Discriminator -- RC-CR2 Filter → time conversion (event Timestamp)

Trapezoid Filter → energy conversion (event "raw" Energy)

Ref. → *Compass Quick start guide p 57--67*

0. **Observe phys. signal on the scope** (amplitude > 2V will be saturating in DAQ, get count/freq. measure)

Step by Step (iterative process) ➔ on the waveforms

1. Input

- *Coase gain* x4 if low phys. signal (<<500mv), input in Compass always >0 ⇔ *Polarity* set at phys. signal
- *Record length* >~ phys. signal decay time (e.g. reasonable pile up ~ 10%@MUSIC_40kHz)
- *DC offset* as low as possible (to avoid input saturation) ⇔ 10-20%
- *Pre-trigger* long enough for baseline calculations, i.e. > 16 ns x *Nsamp_baseline*
  Nsamp_baseline such baseline cst ~ 0 (+*DC offset*)

2. Discrimination Trigger

- *Fast Discri smooth:* starting value=16 Ns. (32 – 64 if high freq. noise in phys. signal)
- *Input rise time* such RC-CR2 height~input height
- *Trig. Holdoff* = RC-CR2 width (after 0 crossing)
- *Threshold* to adjust such line just above RC-CR2 noise level
  Limits {max ⇔ channel freq. ~ phys. signal frequency, min ⇔ E_{min} just after noise-peak~0}
- Timestamp defined at RC-CR2 zero crossing after *Threshold* → improving the time resolution by adjusting *Input rise time* & *Threshold*

➔ look at Count Rate Spectrum / Statistics window w.r.t. phys. signal expectations ok / no

3. Trapezoid (compromise between energy resolution and dead time)

- *Pole Zero:* start value = input decay time
- *Rise time:* start value with 1 µs. for rates>20kHz, decrease it
- *Peaking time* high 70% - 90% (to be set before *Flat top*)
- *Flat top* (start value < 0.8**Rise time*) → such that trapezoid top is flat-constant
- *Pole Zero* fine tune such that trapezoid top is flat-constant
- *Nsamp* low as possible while keeping good resolution (<16)
- *Fine gain* of use >1 if low phys. signals (10s mv)

➔ look at Energy w.r.t peak resolution ok / no

- If dead time&pile up high, decrease
  Nsamp & Width of trapezoid = *2 Rise time + Flat top* while keeping top flat

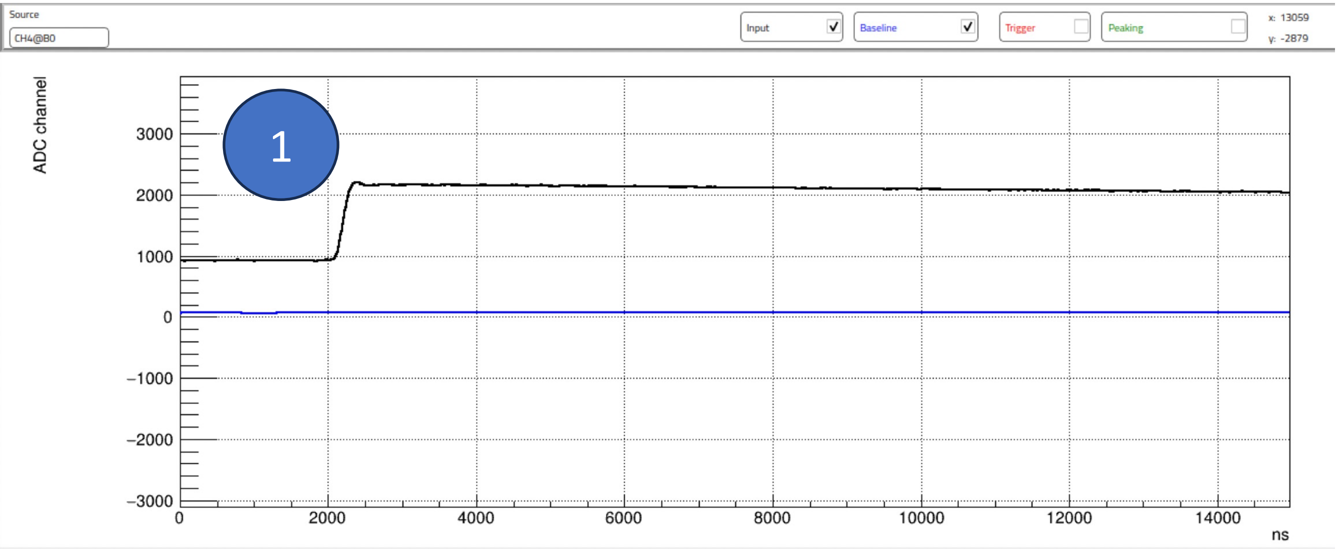
MEMO

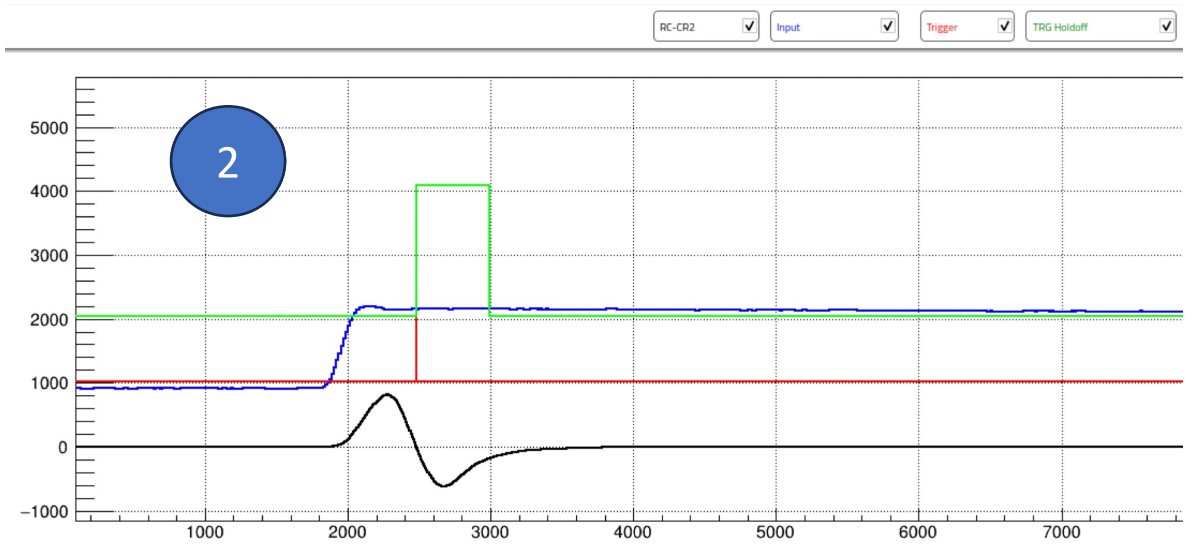
Regular saving of CoMPASS project

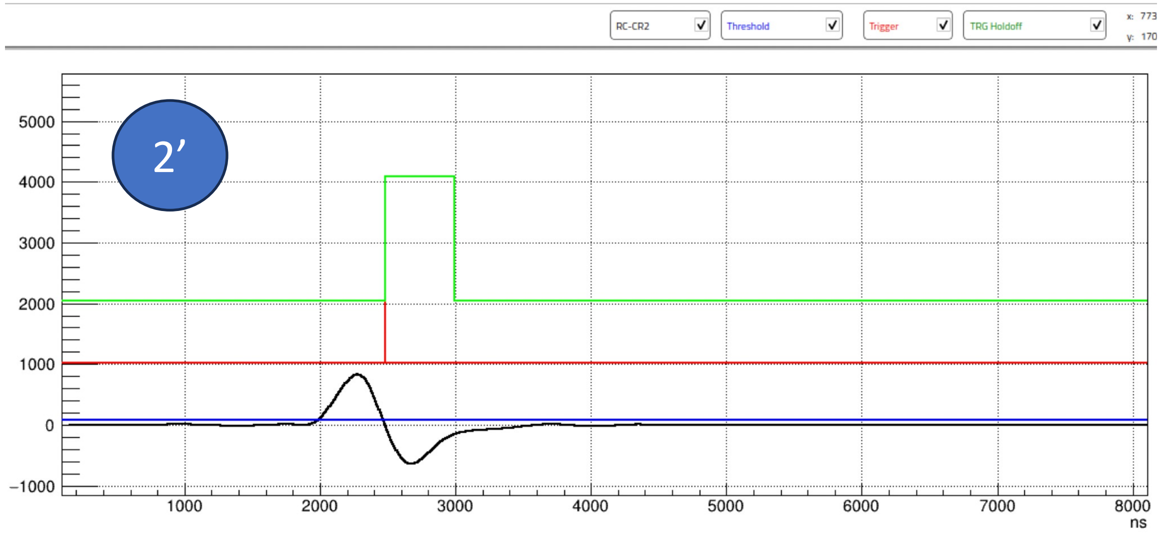
Production Mode@High-Rates

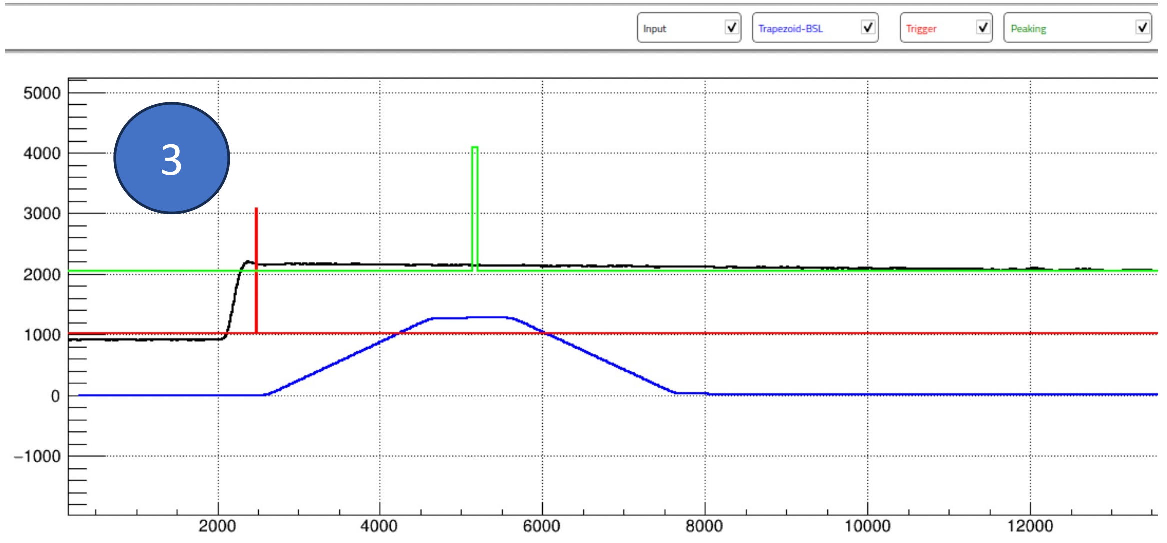
Rate Optimization = 511 (Miscellaneous),
Acquisition **List only**, Saved data RAW, **.BIN**

Step by Step ➔ on the waveforms (illustrated)





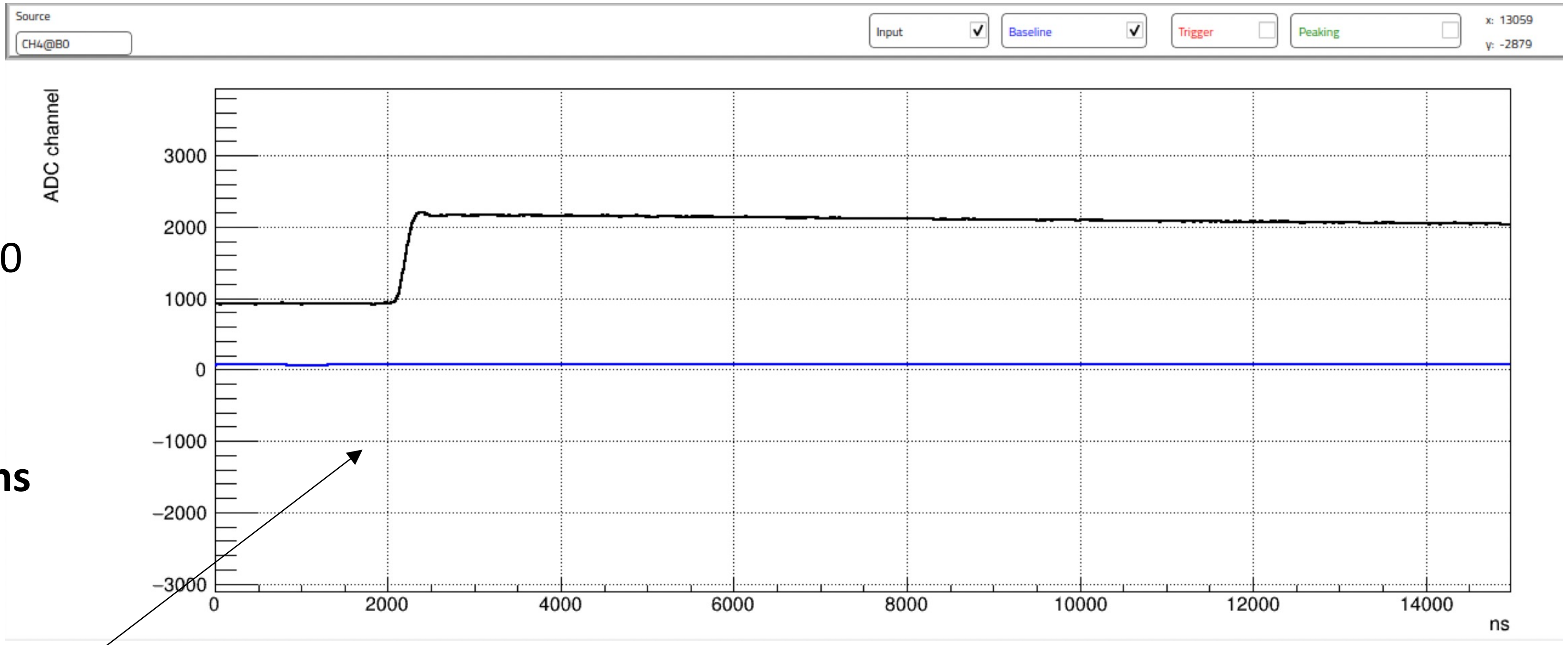




Input

Input	Discriminator	Trapezoid

Parameter	Board	
Enable	☑	
Record length	12000 ns	max=20000
Pre-trigger	2496 ns	
Polarity	Negative	
N samples baseline	64 samples	**1 Ns = 16 ns**
DC Offset	20.000 %	
Coarse gain	1x	(x1 – x4)



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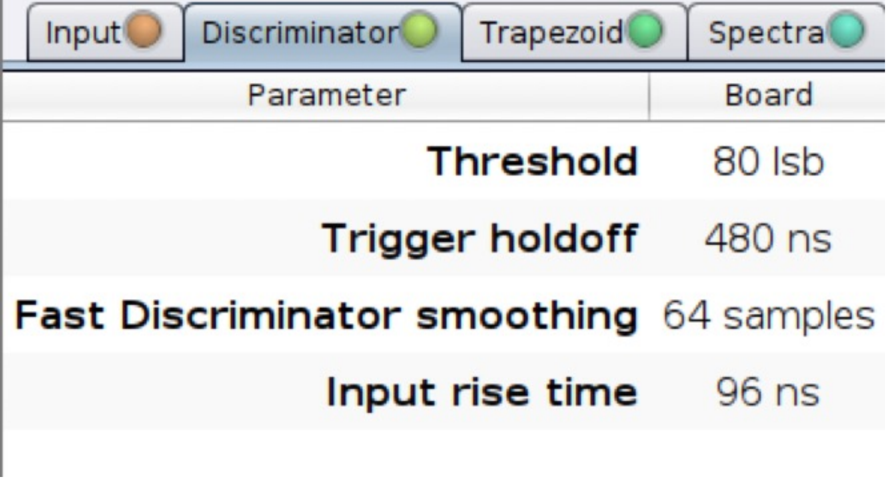
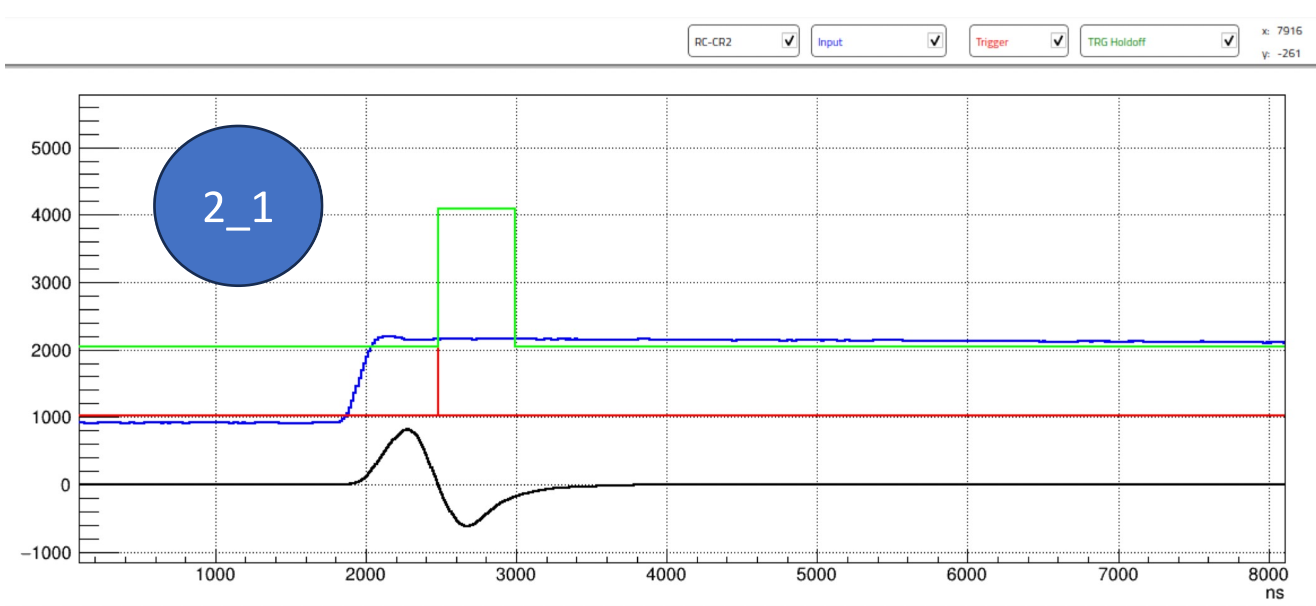
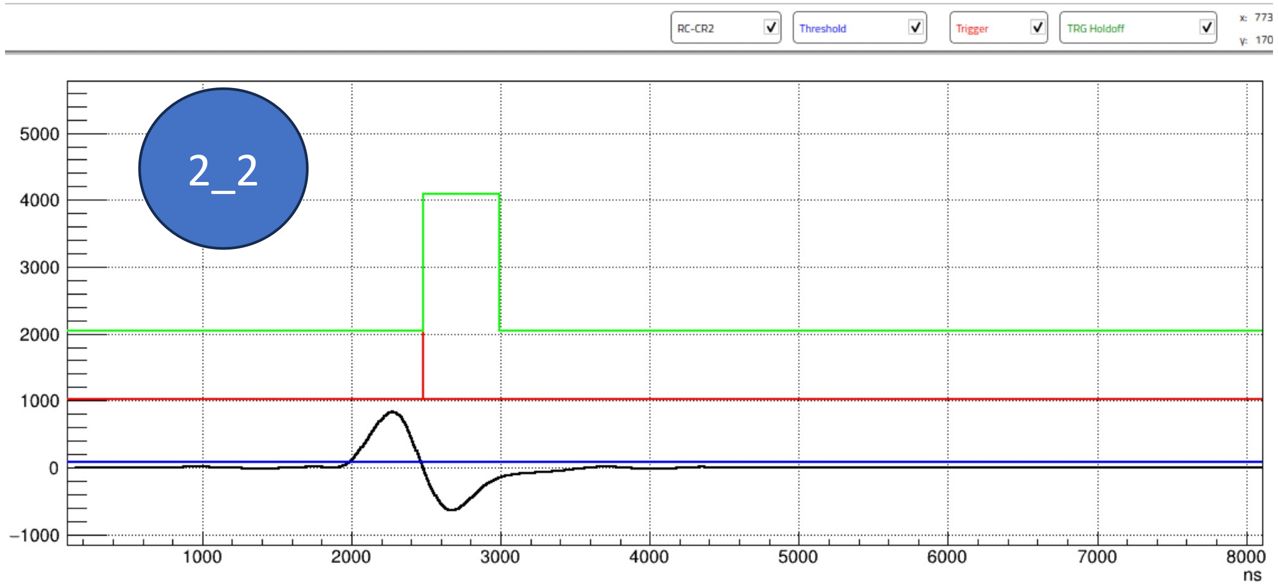
Plots in waveform to be looked → {input, baseline}
Jumpy Baseline → reduce *Nsamp_baseline*
Noisy Baseline → increase *Nsamp_baseline*
***Pre-trigger* length > *Nsamp_baseline* * 16ns**
Disable un-used channels
Decrease of *DC Offset* → input not saturate at 0 ⇔ dead time increases



Parameter	Board
Threshold	80 lsb
Trigger holdoff	480 ns
Fast Discriminator smoothing	64 samples
Input rise time	96 ns

RC-CR2 Filter





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Plots in waveform → 1. {input, RC-CR2, *Trigger-Holdoff*}
2. {RC-CR2, *Threshold*}

The aim of the Trigger and Timing Filter (TTF) is to identify the input pulses, generate a digital signal called *trigger* that identifies the pulse, and calculate the time of occurrence of the event (trigger time stamp). The TTF performs a digital RC-CR^2 filter, whose zero crossing corresponds to the trigger time stamp. In analogy with a CFD – Constant Fraction Discrimination – the RC-CR^2 signal is bipolar and its zero crossing is independent of the pulse amplitude. The integrative component of the RC-CR^2 is a smoothing filter based on a moving average filter that reduces the high frequency noise and prevents the trigger logic to generate false triggers on spikes or fast fluctuation of the signals. The derivative component allows to subtract the baseline, so that the trigger threshold is not affected by the low frequency fluctuation. Moreover the pile up effect is significantly reduced (see Sec. **Pile-up Rejection**).

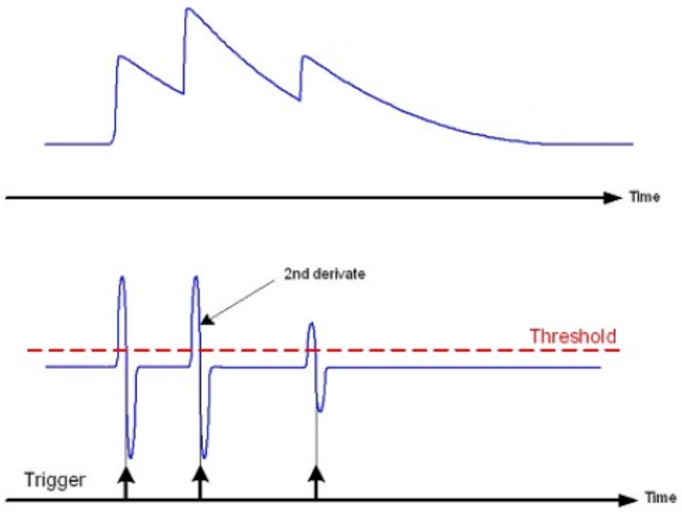


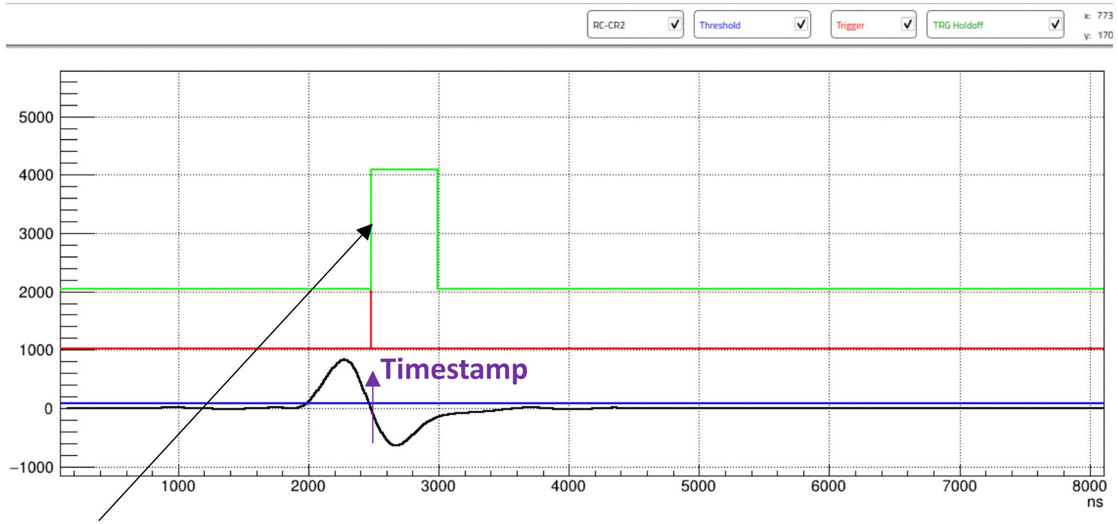
Fig. 4.9: The Trigger and Timing Filter allows to detect pulses on the zero-crossing of the RC-CR^2 signal, which corresponds to a 2nd derivative of the input pulse. The derivative component of the RC-CR^2 subtracts the baseline and makes easier to perform a zero-crossing calculation.

The trigger logic gets armed at the **Threshold** crossing, then it generates the trigger signal at the RC-CR^2 zero crossing. Setting the threshold value corresponds to set the LLD (lower level discrimination) of the energy spectrum. The user can check from the histogram which value corresponds to the set threshold level. Another important parameter for the trigger logic is the **RC-CR^2 smoothing**, corresponding to the number of samples used for the RC-CR^2 signal formation. Increasing this parameter may help in reducing high frequency noise, but have the drawback to make the signal slower and smaller, due to the smoothing. Finally the **Input Rise Time** is the time the RC-CR^2 reaches its maximum value. This value should correspond to the input rise time, in such a way the RC-CR^2 peak value corresponds to the height of the input signal.

Trigger fires at zero-crossing of RC-CR2 signal after *Threshold* crossing

All settings must be set according to *Fast Discri. Smoothing*
If high freq. noise, *Fast Discri. Smoothing* >32—64 Ns
Input rise time such RC-CR2 height ~ input height
Threshold must be adjusted such line just above RC-CR2 noise level
Limits: -max ⇔ channel rate~ phys. signal frequency
-min ⇔ E_{min} just after noise-peak~0
→ decrease *Threshold* until noise peak seen then set its value just slightly higher

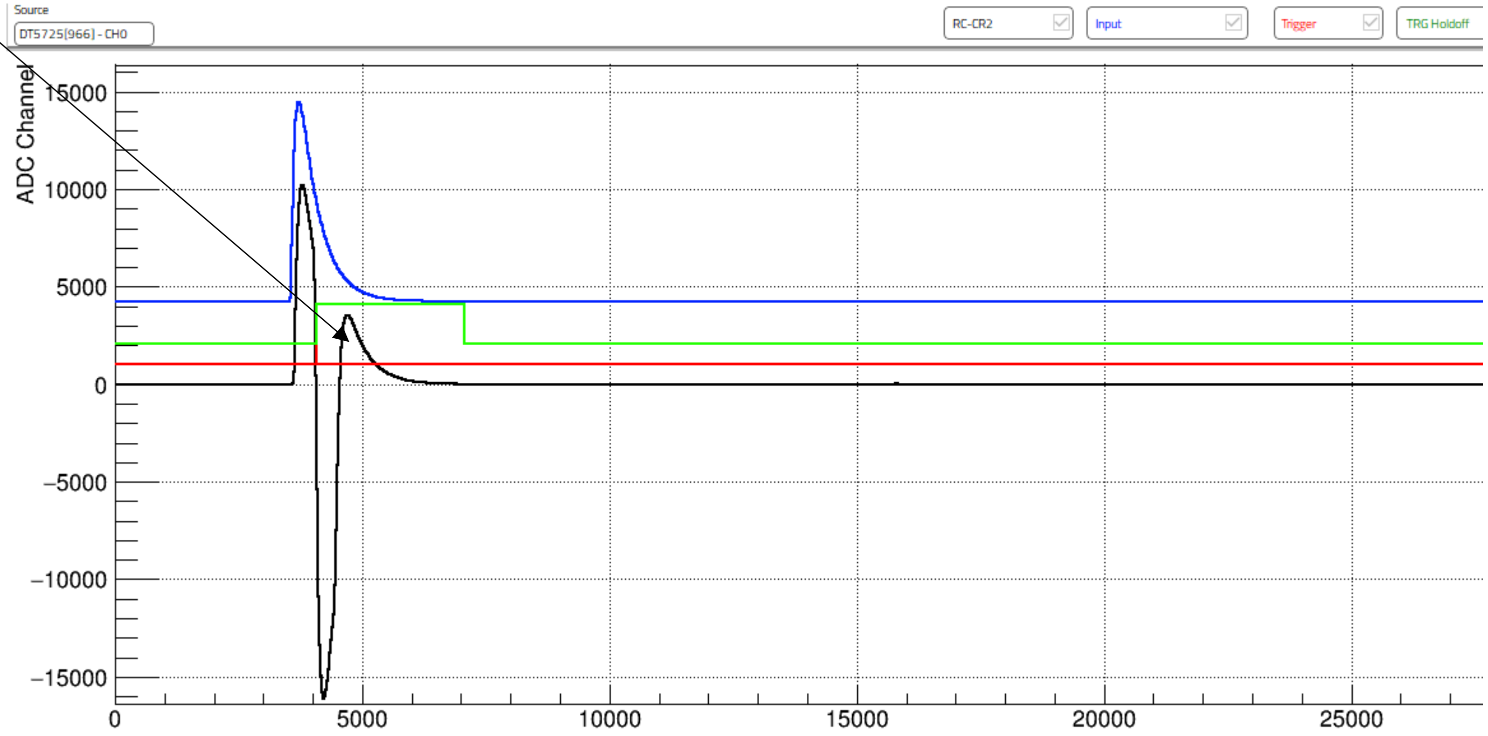
Timestamp at RC-CR2 zero crossing after *Threshold*
→ improving time resolution by adjusting *Input rise time & Threshold*



Trigger holdoff must cover RC-CR2 signal
If there is an overshot, increase *Trigger holdoff* to include it

Examples of unproper values for *Input rise time*

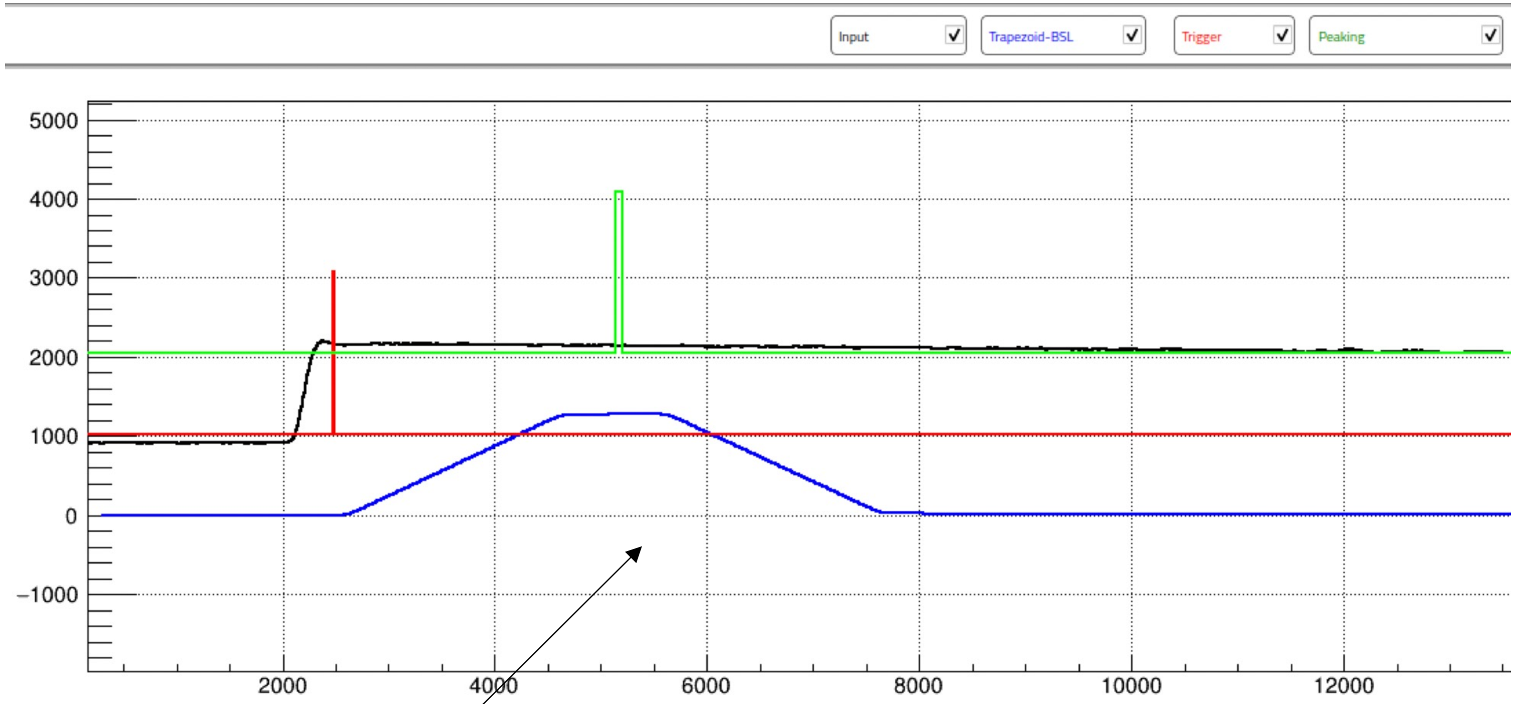
Example of overshoot exclusion thanks to *Trigger holdoff*



Trapezoid filter @High Rate (>kHz)

Input | Discriminator | Trapezoid | S

Parameter	Board	CH
Trap. rise time	0.192 µs	0.19
Trap. flat top	2.496 µs	2.49
Trap. pole zero	40.000 µs	40.00
Peaking time	40.4 %	40.
N samples peak	16 samples	16 sa
Peak holdoff	0.496 µs	0.49
Energy fine gain	1.000	1.0



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Plots in waveform → {input, trapezoid, trigger, peaking}

High rate ⇔ compromise resolution and dead time

Baseline of trapezoid **must be 0**

Rise time + *Flat top* <= 16 µs

Some literature

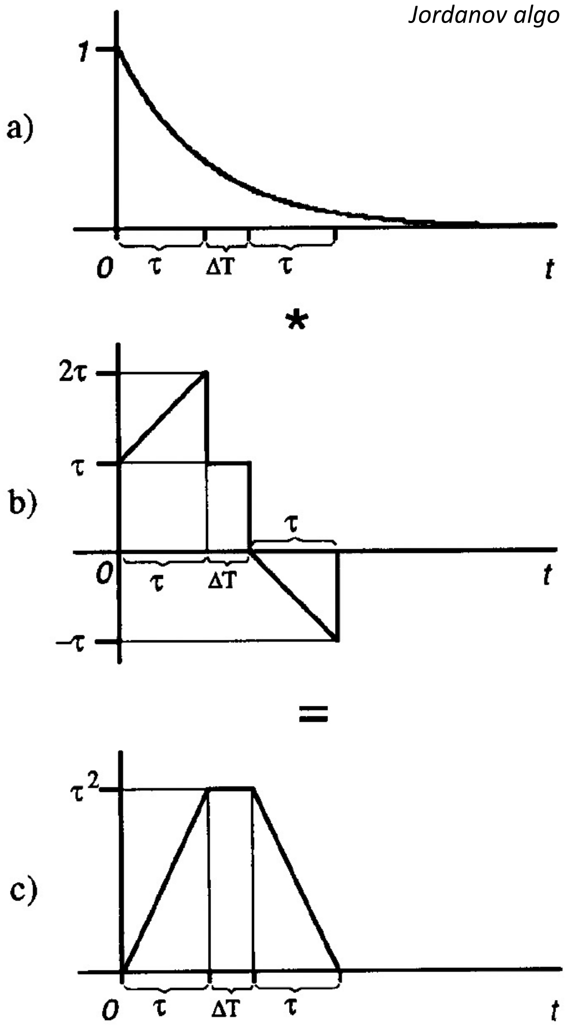


Fig. 3. Convolution of an exponential input signal (a) with trapezoidal shaper impulse response (b) and the output response of the system (c).

The algorithm implemented in the digitizer FPGA is based on the Jordanov trapezoidal filter **[RD12]** and it is called **DPP-PHA (Digital Pulse Processing for Pulse Height Analysis)**. The trapezoidal filter is a filter able to transform the typical exponential decay signal generated by a charge sensitive preamplifier into a trapezoid whose flat top height is proportional to the amplitude of the input pulse (that is to the energy released by the particle in the detector) (see Fig. **4.7**). The trapezoid plays almost the same role of the shaping amplifier in a traditional analog acquisition system. There is an analogy between the two systems: both have a "shaping time" constant and must be calibrated for the pole-zero cancellation. For both, a long shaping time gives a better resolution but has higher probability of pile-up. Both are AC coupled with respect to the output of the preamplifier whose baseline is hence removed, but both have their own output DC offset and this constitutes another baseline for the peak detection.

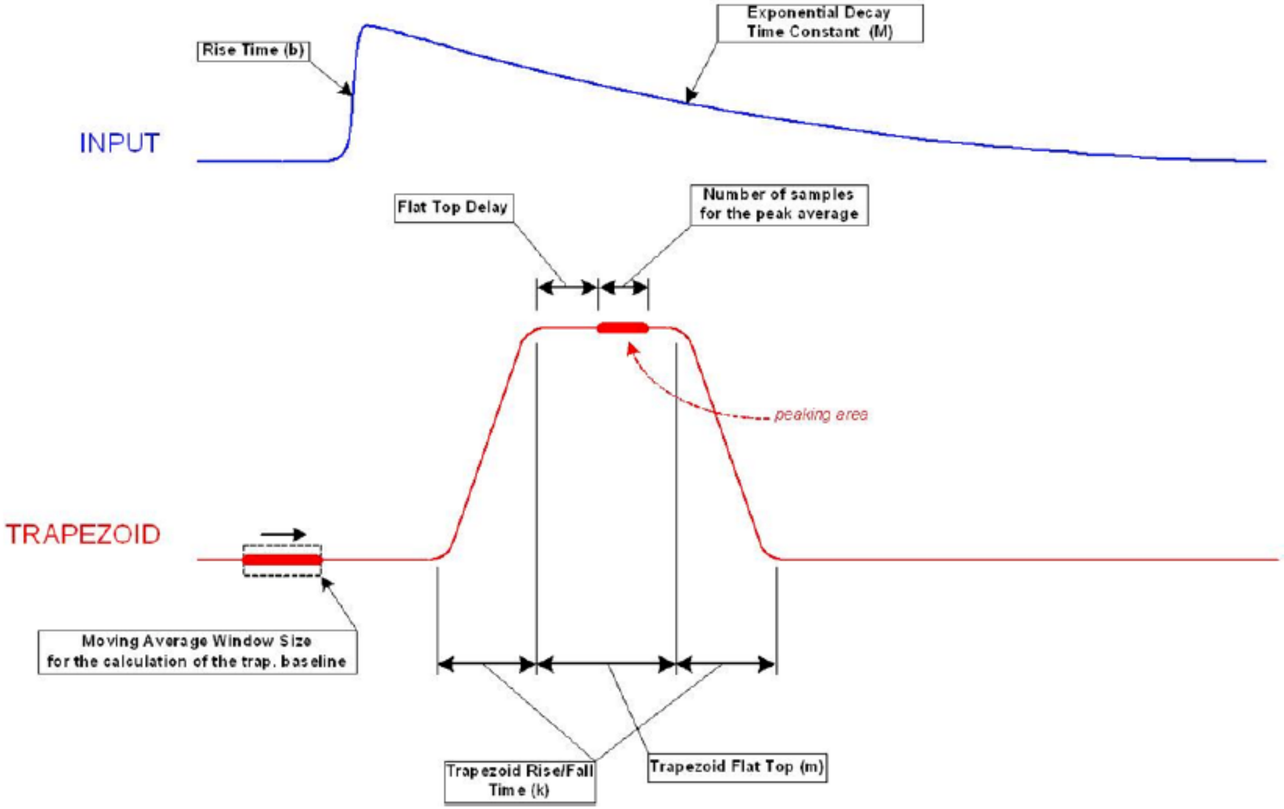
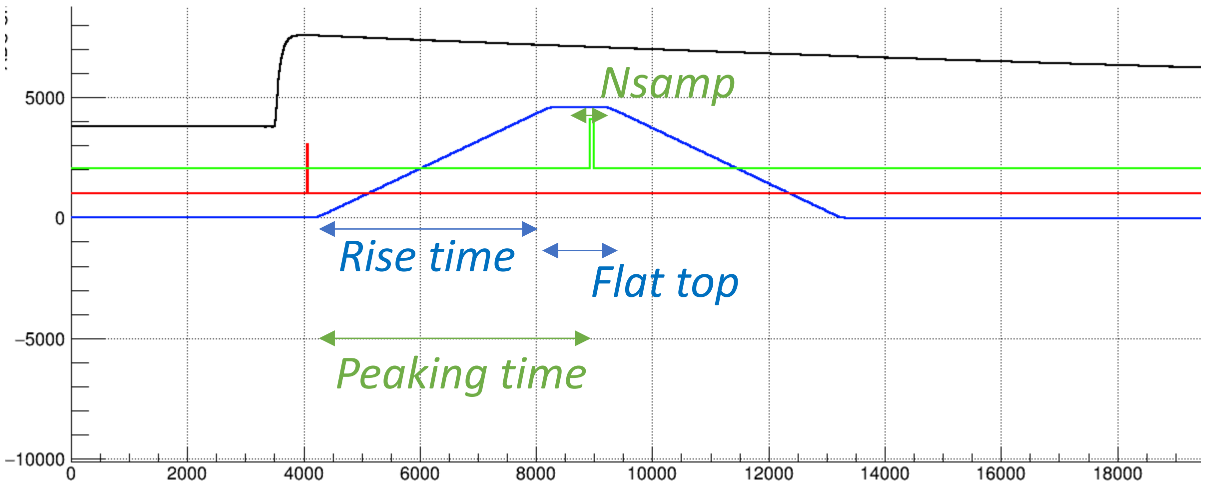


Fig. 4.7: Pulse Height Analysis with Trapezoid Method.

As in the traditional analog chain, the Shaping Amplifier is able to convert the exponential shape from the Charge Sensitive Preamplifier into a Gaussian shape whose height is proportional to the pulse energy, in the same way the Trapezoidal filter is able to transform it into a trapezoidal signal whose amplitude is proportional to the input pulse height (energy). In this analogy, the **Trapezoid Rise Time** corresponds to the Shaping Time times a factor of 2/2.5. Therefore for an analog shaping of 3us the user can set a trapezoid rise time of 7-8 us (see also **[RD13]**).

In case of high rate signal, the trapezoid rise time value should be reduced in order to avoid pile-up effects (see Sec. **Pile-up Rejection**), choosing a compromise between high resolution (high value of trapezoid rise time) and pile-up rejection (and corresponding dead time).

The energy value of the input pulse is evaluated as the height of the trapezoid in its **Flat Top** region. The user must take care that the flat top is really flat and that the **Peaking** (i.e. the samples used for the energy calculation) is in the flat region. Moreover, the correct setting of flat top and peaking helps in the correct evaluation of the energy especially when large volume detectors are involved and the ballistic deficit may cause a significant error in the energy calculation. In this case, it may be convenient to increase the flat top duration and delay the peaking time to wait for the full charge collection.



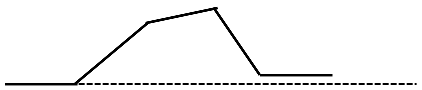
Start with *Pole zero* = input decay time

Then *Rise time* [1 – 4] µs, **for rates>20kHz, decrease it below 1 µs**
Flat Top and Pole zero must be adjusted such top region = flat
Width of trapezoid *is =2xRise time + Flat top* while

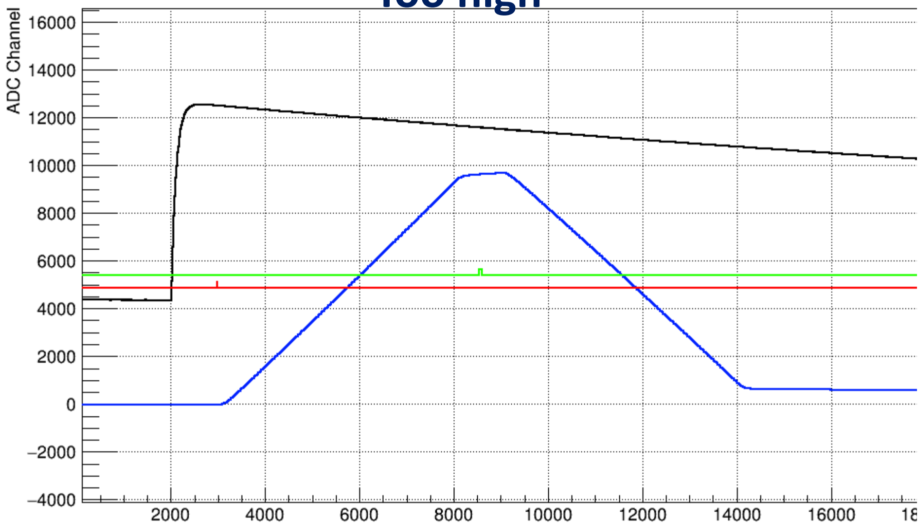
Nsamp as low as possible while keeping good resolution (<16)

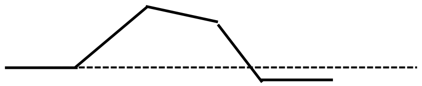
<u>Special configurations</u>
If need to wait full charge collection
→ increase *Flat top* and *Peaking time*
If dead time & pile up high (for high rates)
→ decrease *Nsamp* & Width of trapezoid = *2 Rise time + Flat top* while keeping top flat

Pole zero adjustment → *Trap. Pole zero*

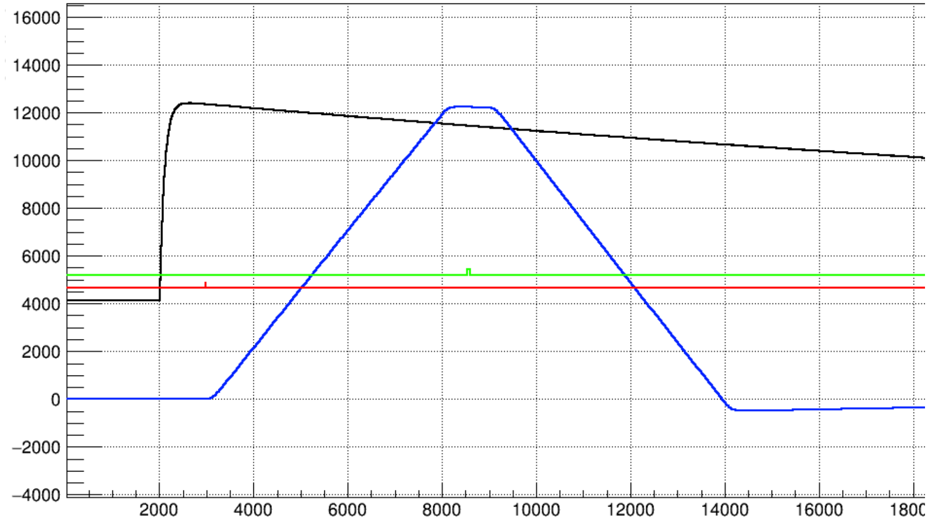


Too high

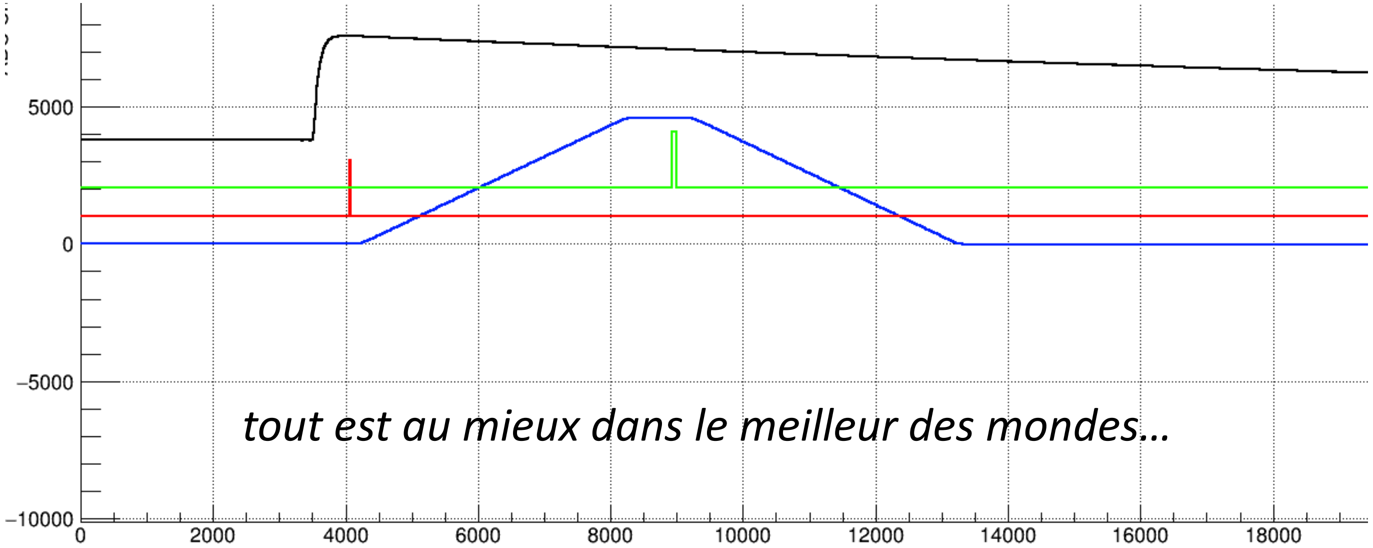




Too low



GOAL



tout est au mieux dans le meilleur des mondes…

Dead time visualisation → in energy spectrum