Test beam drift chamber prototype

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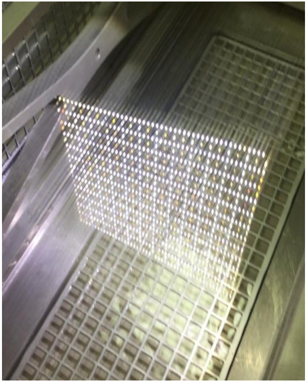
Introduction

- The chamber consists of 12 x 12 squared cell, with a side of 1 cm.
- The gas used is 90%He 10%iC_4H_{10}.
- The voltage applied to each wire is about 1475 V (depends by the runs).



During the test beam (2018), just 20 cells in the central core were read.
All data present some distortions due to different noise sources that make difficult subsequent analisys.
We are developing a filter algorithm to reduce the distortions.

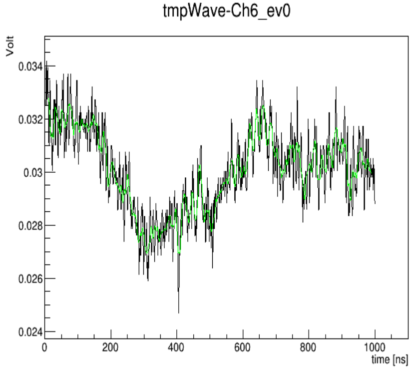
Filter procedure:

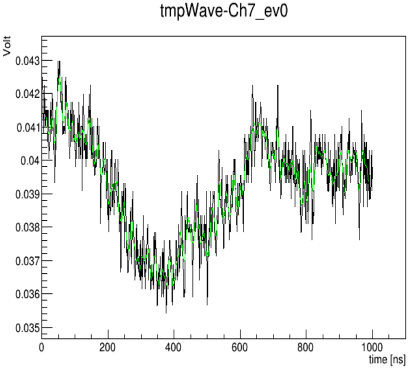
1. Filter for baseline restoring
2. Analisys of the frequency spectrum
3. Search of noise peaks
4. Notch filter
5. Different treatments for "difficult" noise distortions

Filter procedure: first distortion

We analyzed several runs and below we show some results about the *run*1000.*root*.

The first distortion under analysis:

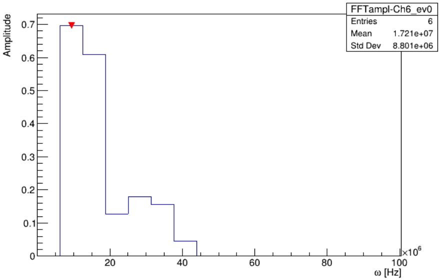


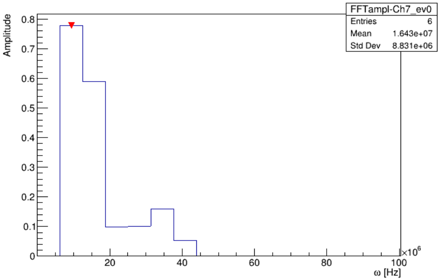


The shape of this particular distortion suggests a very "slow" noise component.

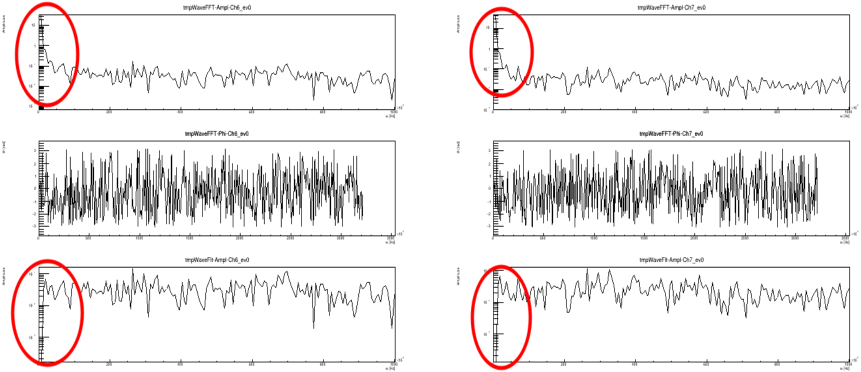
We try to use Notch filter:

- We search, in the waveform frequency spectrum, all possible noise peaks in the range between $\omega = 0$ and $\omega = 50MHz$, using TSpectrum (ω is angular frequency).
- We Notch the peaks found by TSpectrum in this range.
- We fix the stop-band amplitude at $20MHz$.

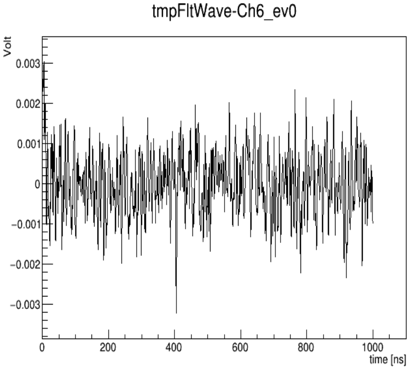


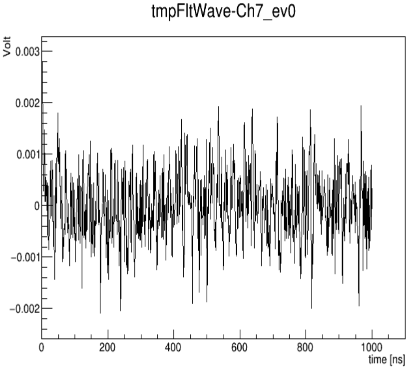


The frequency spectrum obtained with fast fourier transform (FFT), before and after the Notch filter, is:

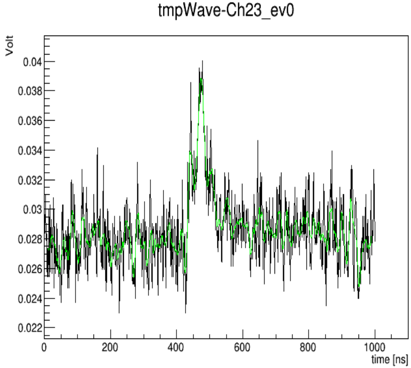


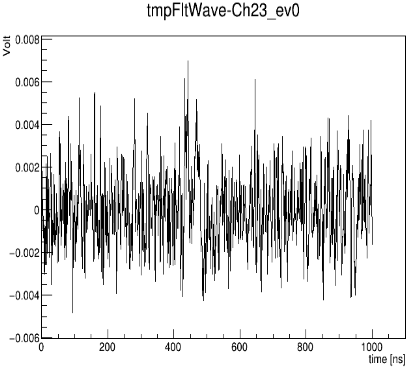
After this filter procedure, the distortion seems to be reduced.



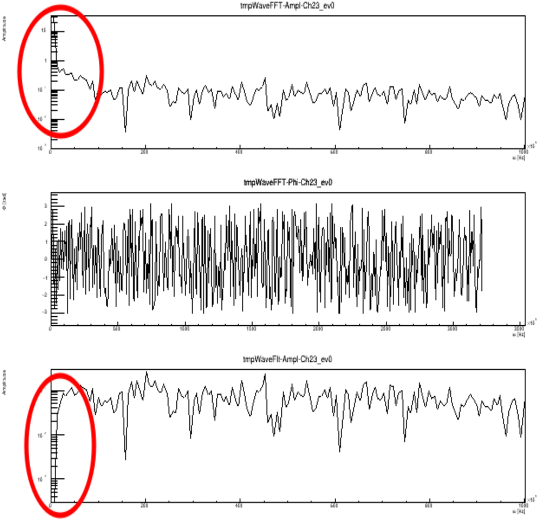


We apply the same procedure on a signal waveform, but the signal shape is deeply distorted.

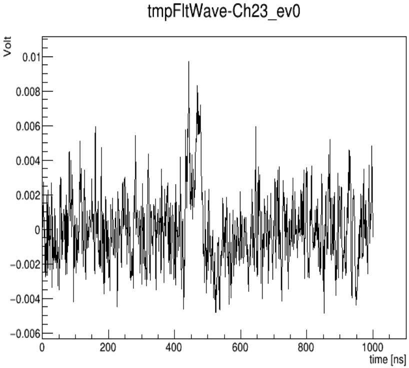


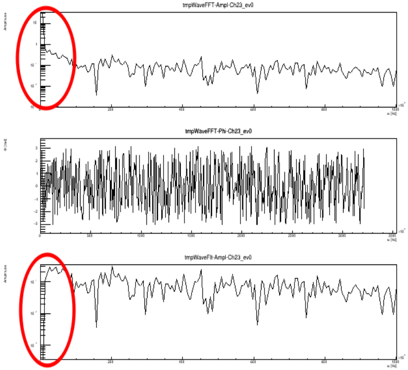


This is the FFT for the signal waveform: the noise frequency is very similar to the signal frequency.

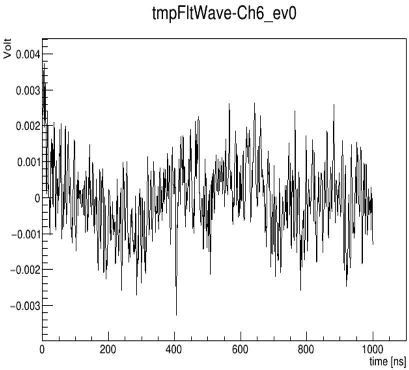


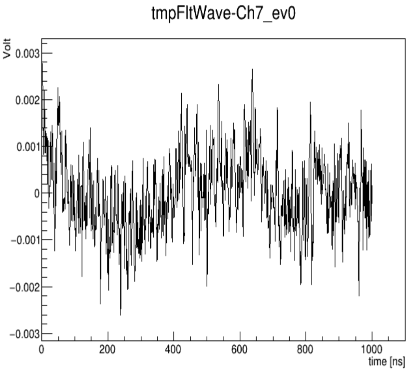
This effect could be reduce using a stop-band amplitude of $5MHz$.





Using this stop-band amplitude, the noise distortion is slightly restored in the two empty waveform under analysis:



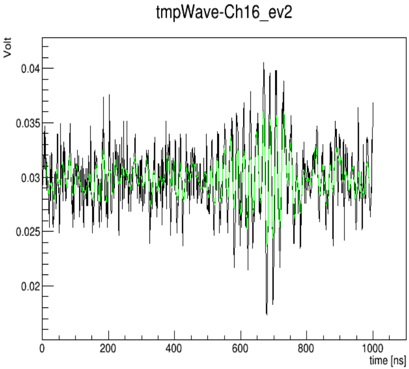


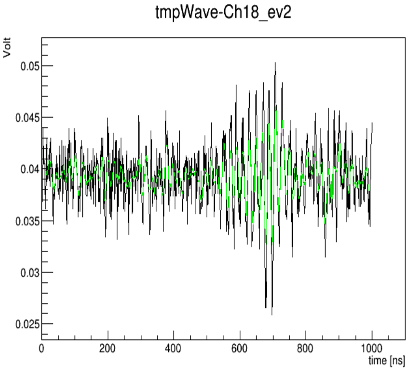
Analyzing other runs, we noticed the same kind of distortion in the 2 particular channels:
- channel 6
- channel 7

We came to the conclusion that there is a hardware problem and we need to exclude those 2 channel from analysis.

Filter procedure: second distortion

The second noise distortion under analysis is:

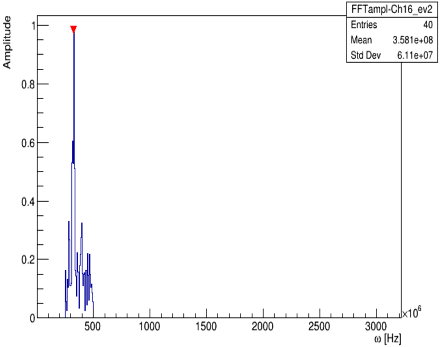


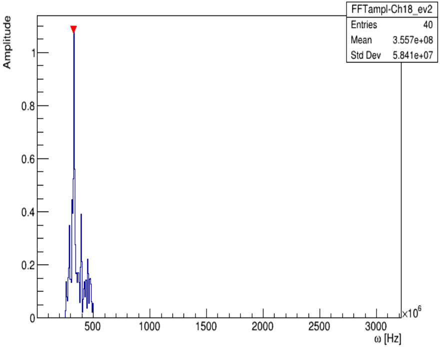


A rough estimate indicates that the noise angular frequency is around 300 MHz.

This means that we are enough away from signal angular frequency, so we can apply Notch filter.

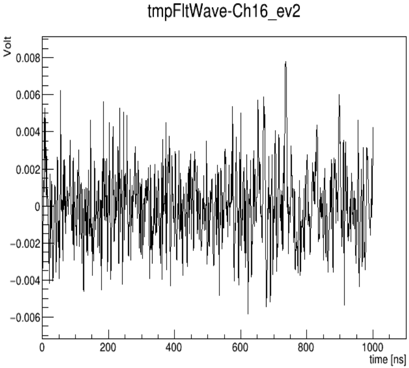
We use TSpectrum to search noise peaks in the region of **angular frequency** between 200 Mhz and 500 MHz.

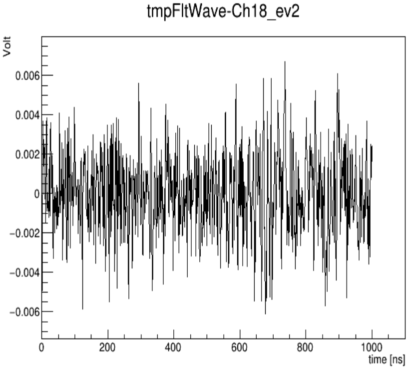




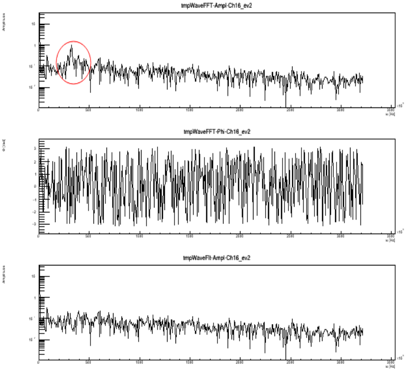
For now, we fix all the TSpectrum parameters in order to search for the highest peaks.

This procedure reduces efficiently the noise distortion.

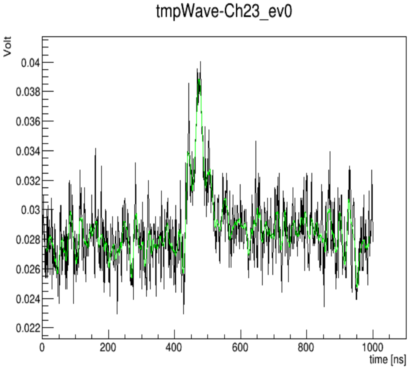


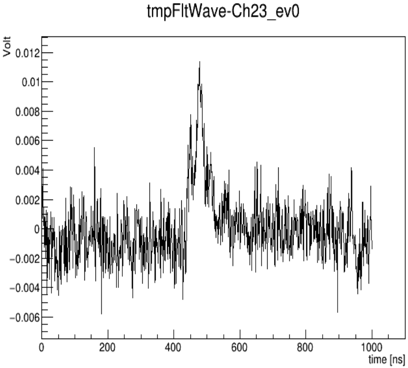


This is the FFT of the signals.
The two top graphs show the noise peak.
The last two graph show FFT of signals after Notch filter.



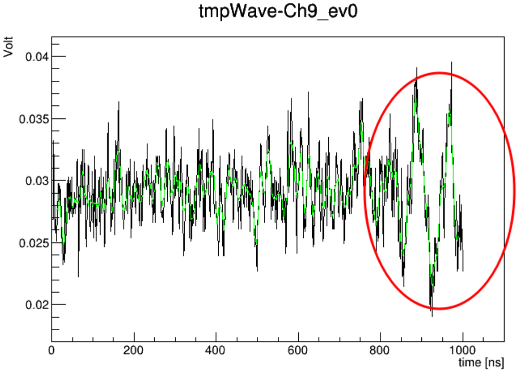
As we expected, this procedure does not distort the signal.





Filter procedure-third distortion: beat function

Some distortions in the waveforms are like this one:



This kind of distortions cannot be restored with Notch filter, because this distorts the signal.
Its shape reminds the beat function shape.

$$y_{tot} = 2A\cos 2\pi\left(\frac{f_1 - f_2}{2}\right)t \sin 2\pi\left(\frac{f_1 + f_2}{2}\right)t$$

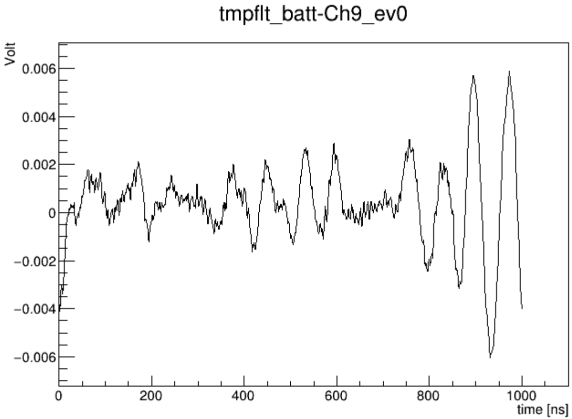
So we can fit the waveform with the beat funciton and subtract it from original waveform.

Procedure

- A rough estimate suggests that the noise frequency is around 15 MHz.
- We use a pass-band filter, selecting the noise frequency, to highlight the noise distortion.
- We fit the negative shape with a beat function.
- We subtract the fit function to the original one.

Band pass filter

After pass-band filter, we obtain the shape of the noise distortion.



Fit of the negative wave

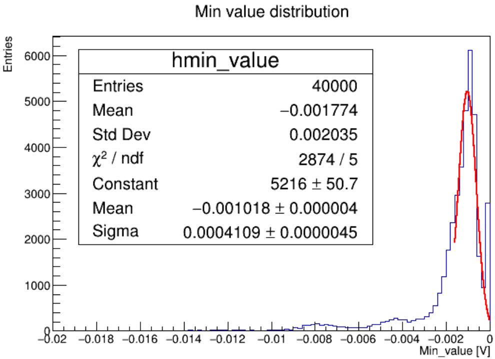
- We select the negative part of the waveforms after band pass filter, to reduce possible contributions from signal waveform.
- We apply the fit procedure just for those waveforms that pass a threshold on minimum value.

Choose of the threshoold

The beat distortion happens just in a small number of waveforms, so we need to select them.

We notice that the amplitude of the distorted wave is greater than a waveform that has other noise distortions (like white noise).

We study the distribution of minimum value for the negative waveforms.



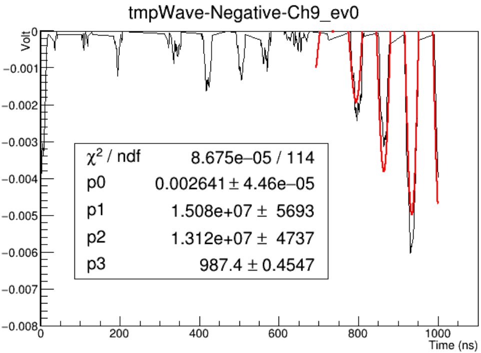
......Fit is really bad, but we are waiting for run with high statistics .....

Fit of the negative wave-Part 2

We fit the peak of the distribution with a gaussian function and choose the threshold as:

$$thr = mean - 3\sigma \quad (1)$$

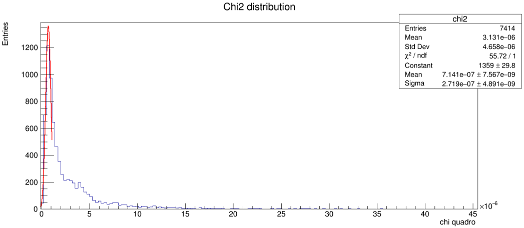
If a waveform passes this threshold, then it will be fitted.



As you see, the algorithm search for the correct range in which the distortion happens and fit just in this range.

Subtraction of the fit wave

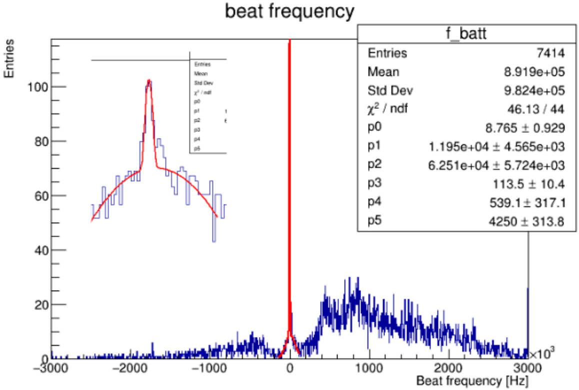
The signal waveforms pass the minimum threshold.
We find some thresholds to prevent the subtraction for the signal waveform.
1) The minimum threshold
2) The range of the beat distortion.
3) **The χ^2 distribution**: we select all the event that has a χ^2 less than the value suggested by study the χ^2 distribution.



......again fit is really bad, we are waiting for run with high statistics .....

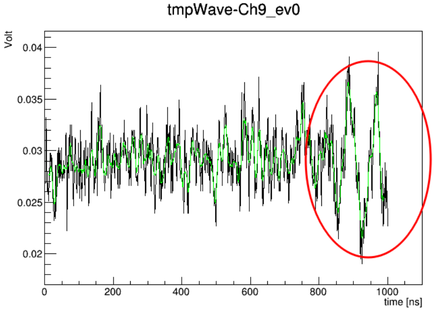
Subtraction of the fit wave-Part 2

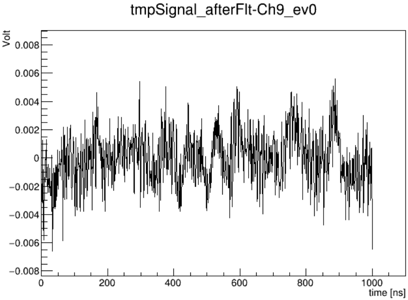
4) **The beat frequency distribution**: we cut all the event inside the peak distribution of beat frequency around 0.



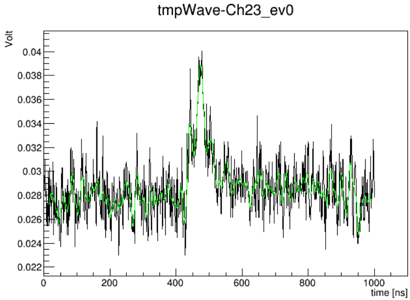
Subtraction of the fit wave-Part 3

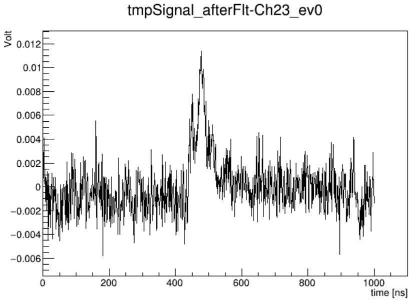
After the subtraction the waveform is:





As you can see, the filter does not affect signal waveforms:

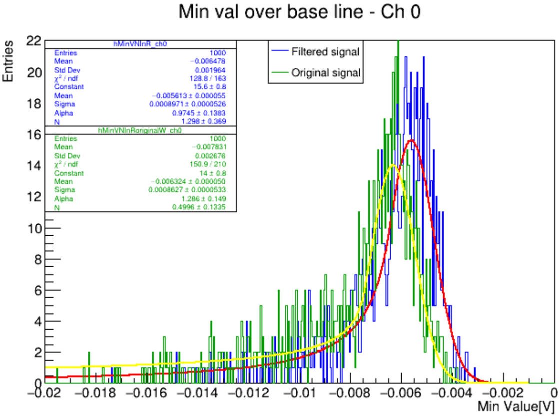




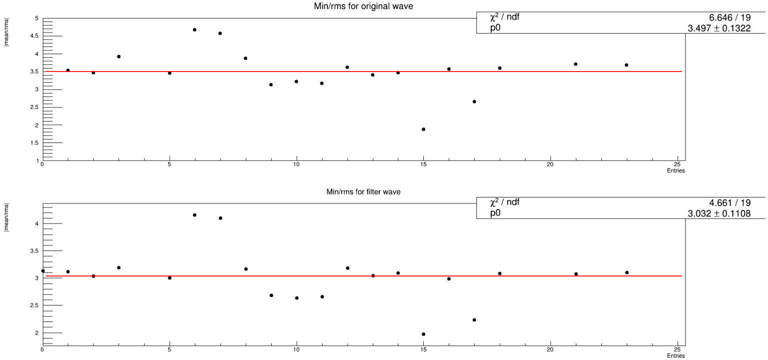
Quantitative analysis of filter procedure

To know the effect of the filter procedure, we study the minimum distribution for all events, channel per channel, for waveforms before and after filter application.

We fit the distribution with a crystall ball function.

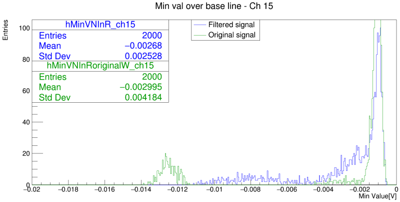


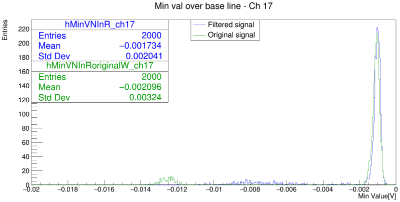
We study the value of mean over rms.
If we remove all the distortions correctly, we will have just white noise and the value will be around 3.



As you can see, channel 6 and 7 are the most noisy channel.
Channel 15 and 17 present a different behavior.

Take a look to channel 15 and 17





We observe from the green line :

- a peak around -0.012V, probably beat events.
- a peak near to zero that seems to have a gaussian shape.

We observe in the blue line:

- the peak around -0.0012 disappear, probably the beat filter works

BACK-UP

Notch filter

A notch filter is a band-stop filter with a narrow stopband, high Q factor.

$Q = \frac{f}{\Delta f}$

A. D. Inc. and H. Zumbahlen, Linear Circuit Design Handbook. Newnes, 2008.