Study of the Margarita performance: a first look to the Time-of-Flight (ToF) resolution

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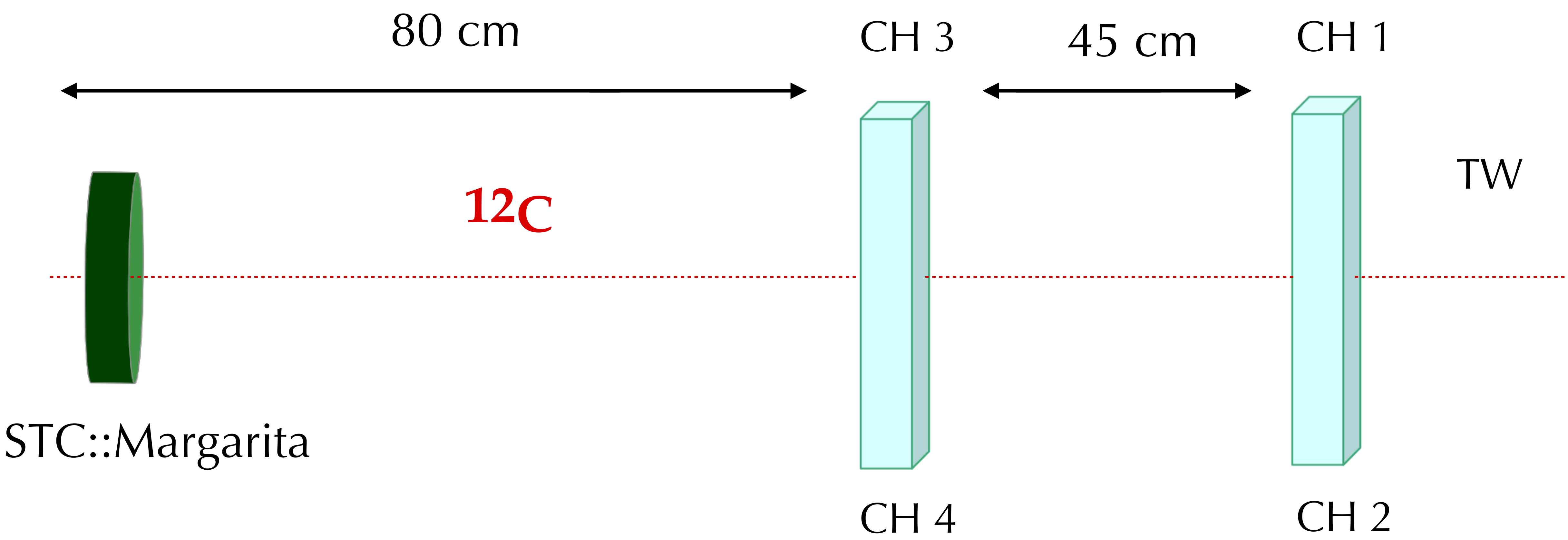
Foot meeting

17-05-2019

Beam test @ CNAO 2018



Run:
1. ^{12}C beam at 115 MeV/n;
2. ^{12}C beam at 151 MeV/n;
3. ^{12}C beam at 221 MeV/n;
4. ^{12}C beam at 280 MeV/n;
5. ^{12}C beam at 356 MeV/n;

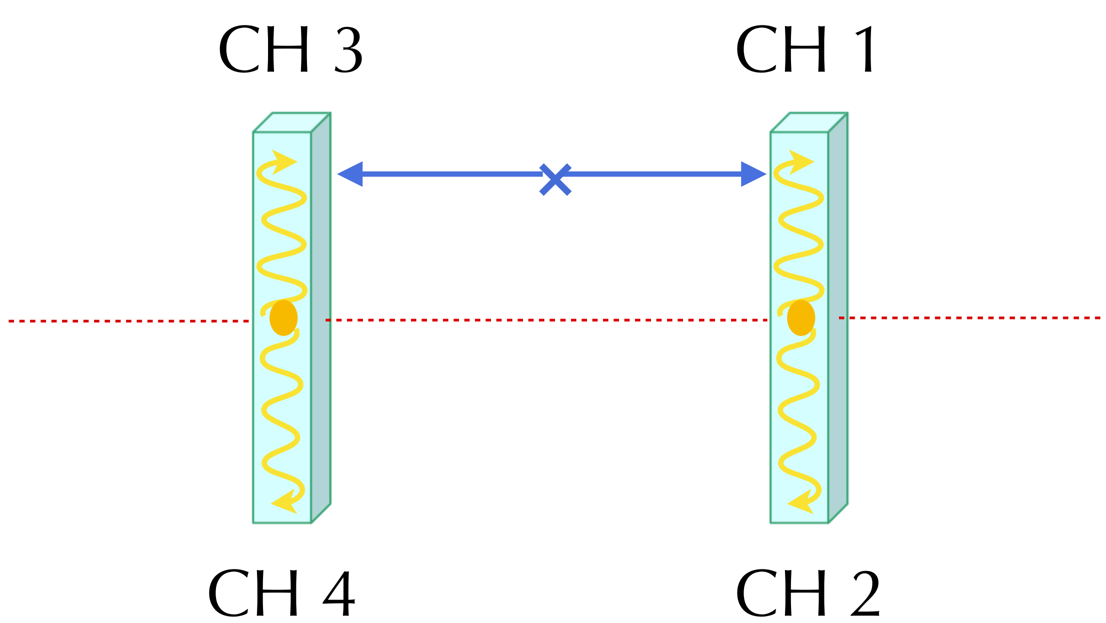
The results presented hereafter are only related to the first run (115 MeV/n): the other runs are currently being processed.

Beam test @ CNAO 2018

Electronic Setup:

One board with 2 chips:

1. One for the TW: 4 readout channels (CH 1- CH 4) and one clock channel (CH 16).
2. One for the Margarita: 8 readout channels (CH 8-CH 15) and one clock channel (CH 17).



Only CH 1 and CH 3 are averaged in order to have two independent measures.
The arrival time on the TW is evaluated as the average arrival times measured by CH 1 and CH 3.

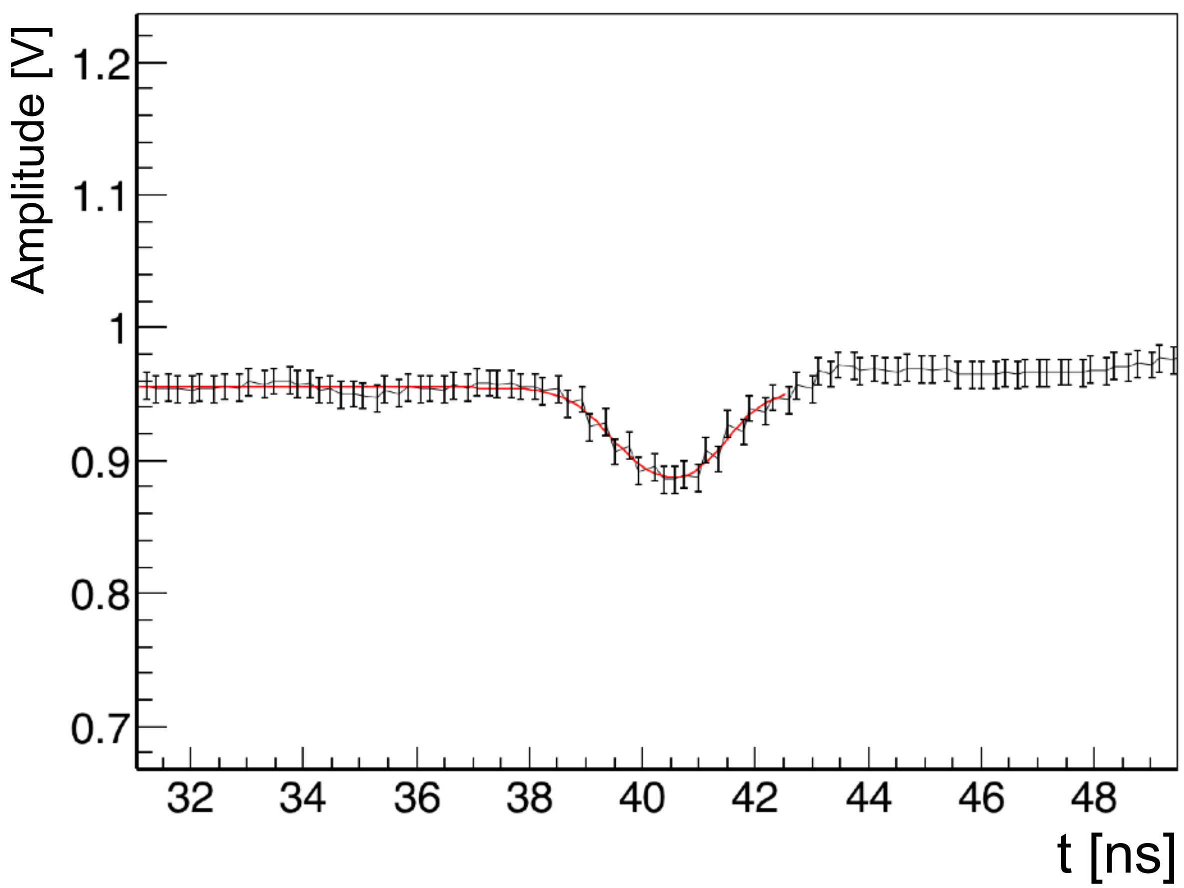
Single channel arrival time evaluation

The Margarita and TW signals have been fitted using the function [Fermi-Dirac distribution]:

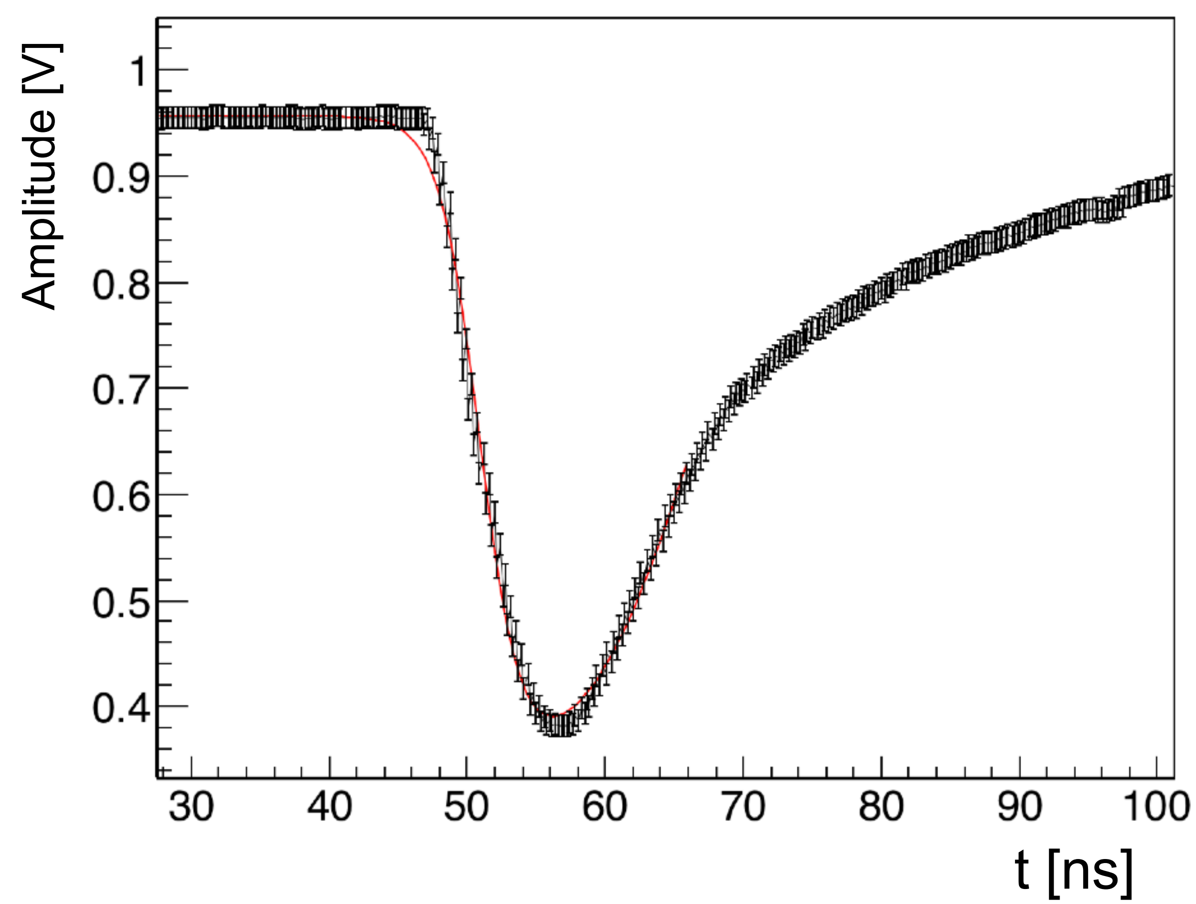
$$f = -\frac{[0]}{1+e^{-\frac{x-[1]}{[2]}}}\frac{[1]}{1+e^{-\frac{x-[3]}{[4]}}} + [5]$$

Waveforms as measured from the digitizer

Margarita



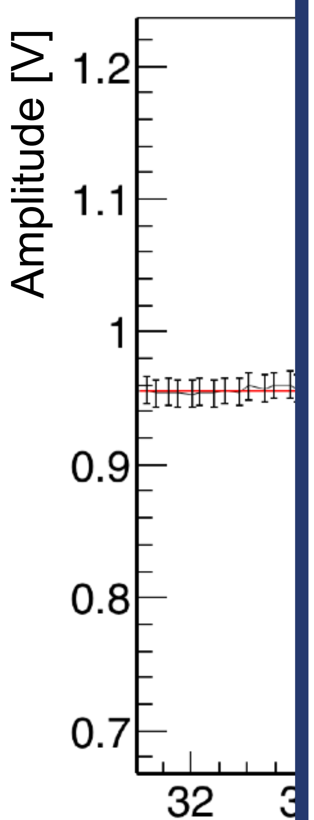
TOF Wall

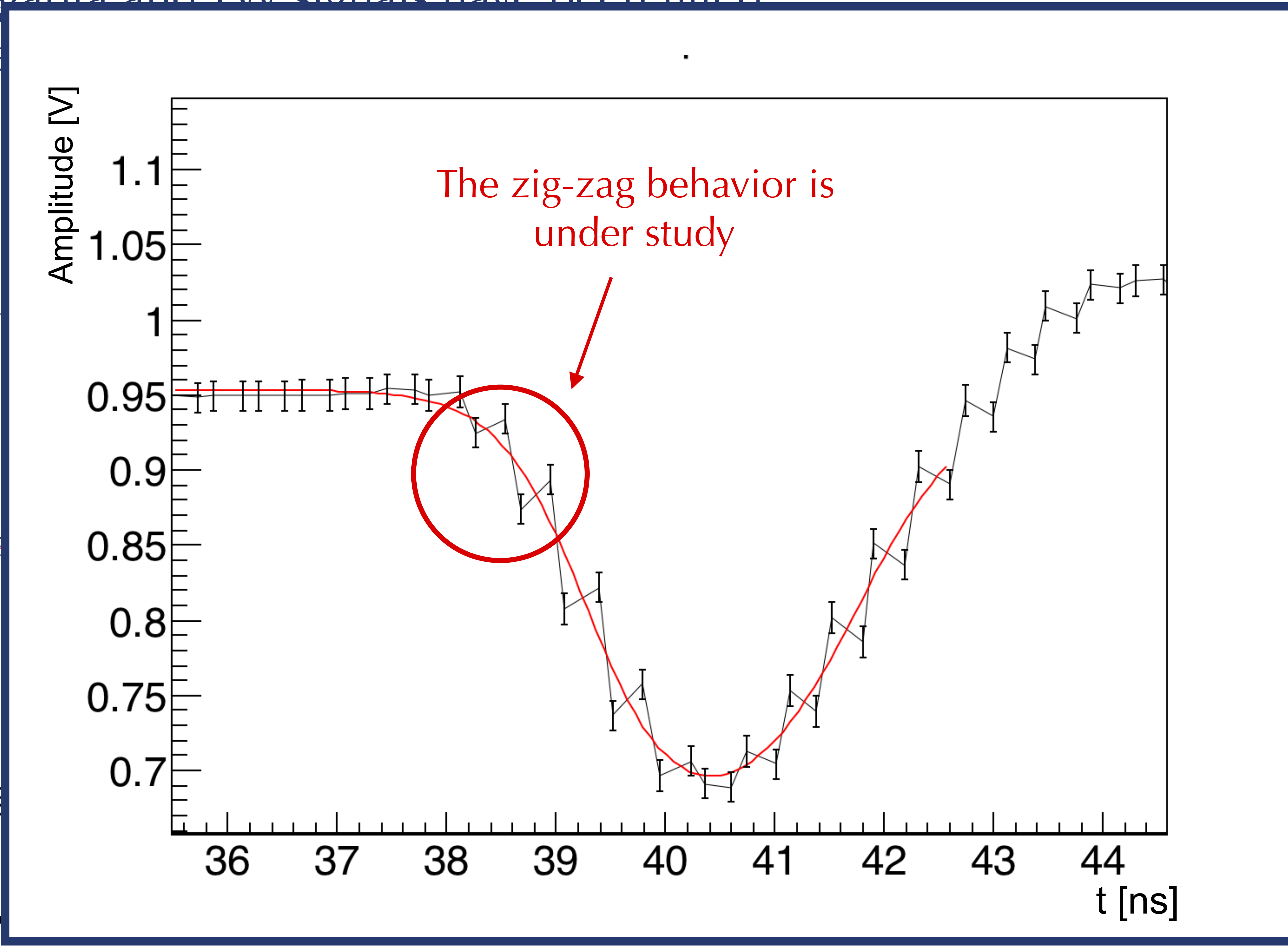


I verified the goodness of the fit performing the χ^2 test.

Single channel arrival time evaluation

The Margarita and TW signals have been fitted
using the





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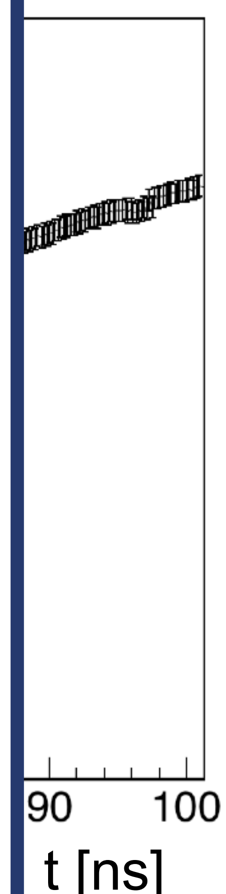

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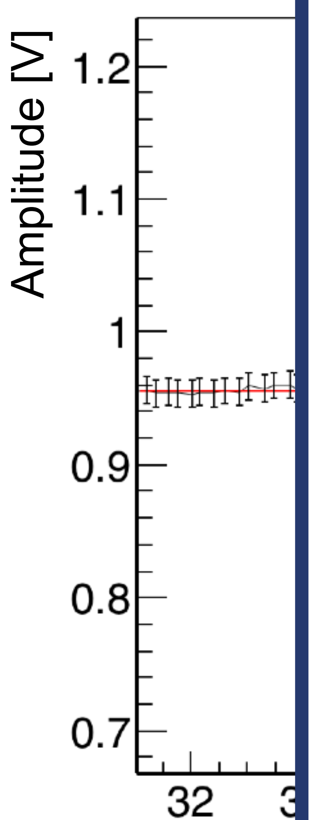
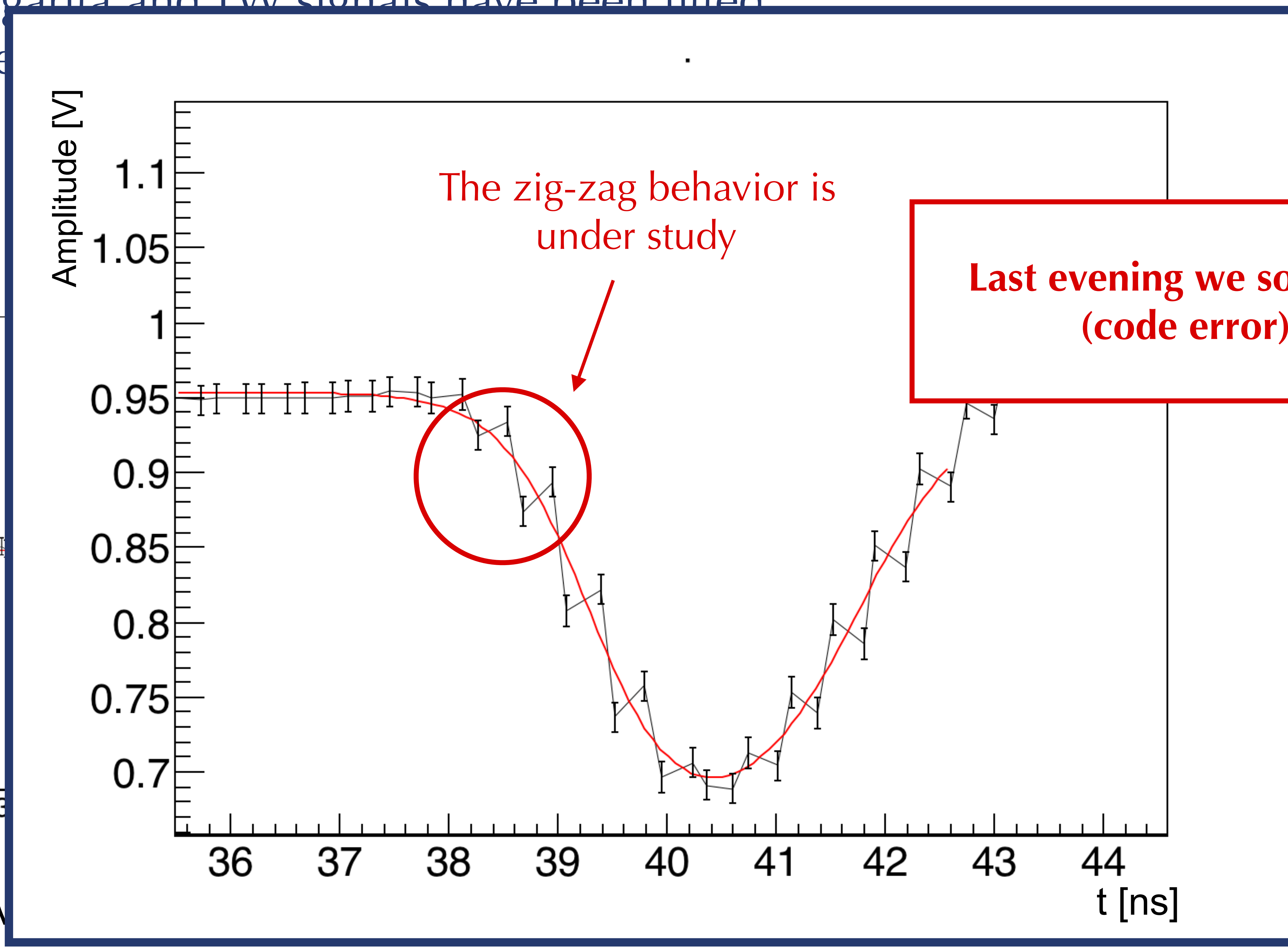
Single channel arrival time evaluation

The Margarita and TW signals have been fitted
using the





going
izer

Last evening we solved it
(code error)

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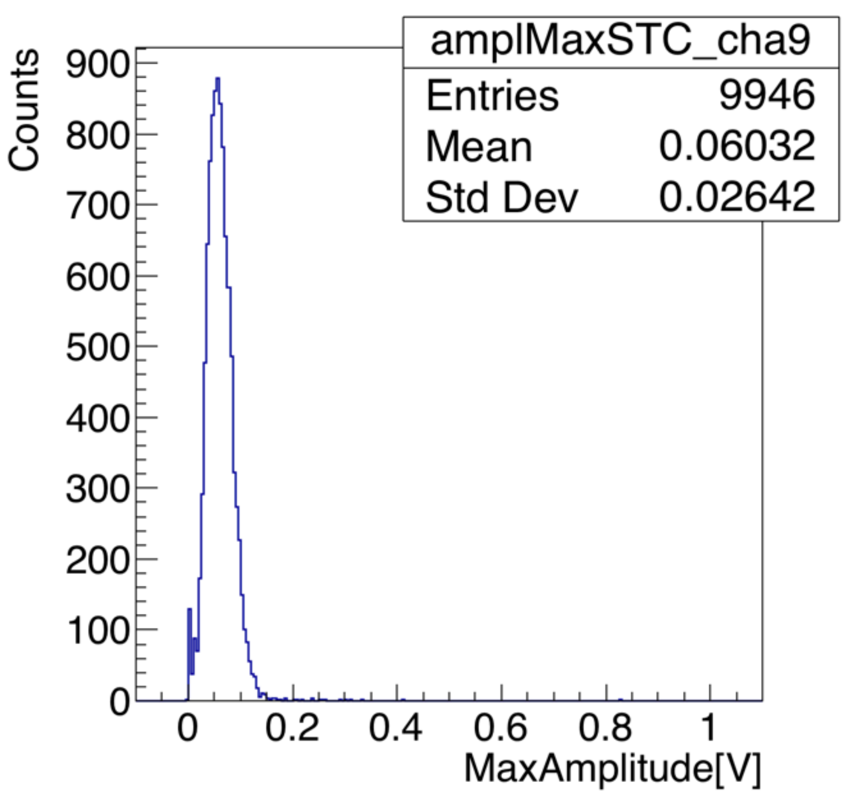
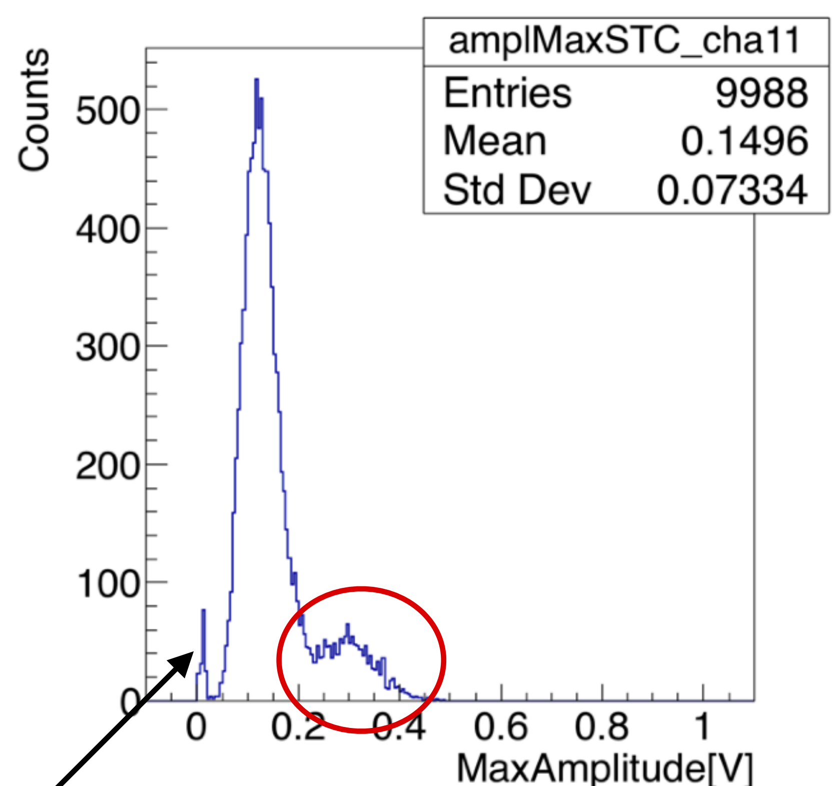
Max amplitude distribution

From the analysis of the max amplitudes histograms, obtained as the fit function peak, three different types of distributions have been obtained. Below are reported some examples:

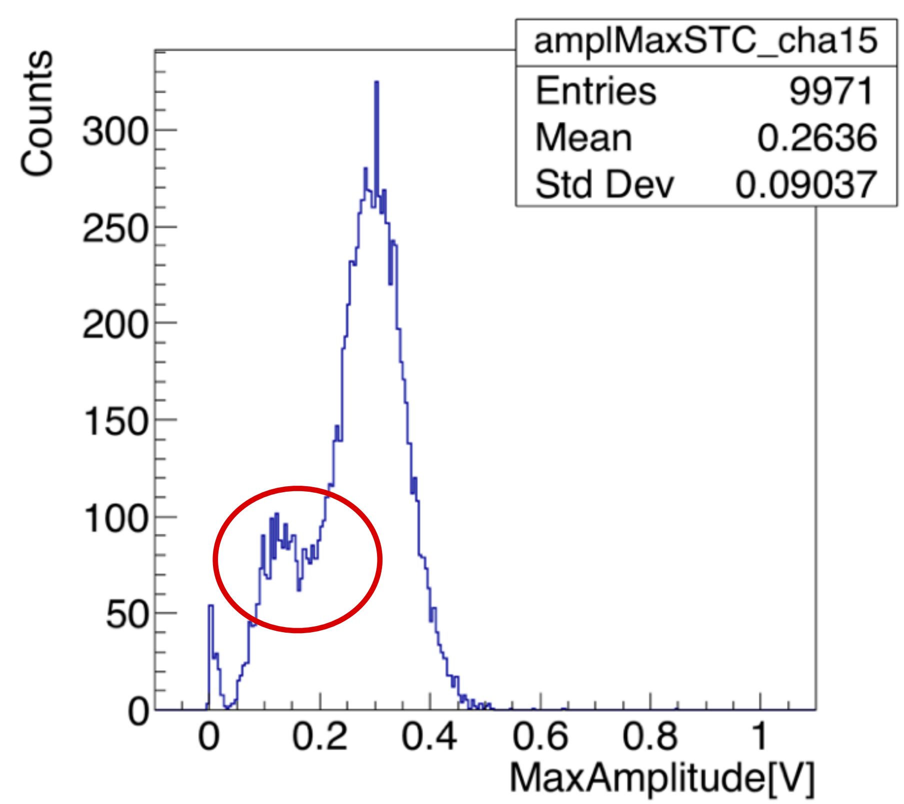
CH 9



CH 11



CH 15



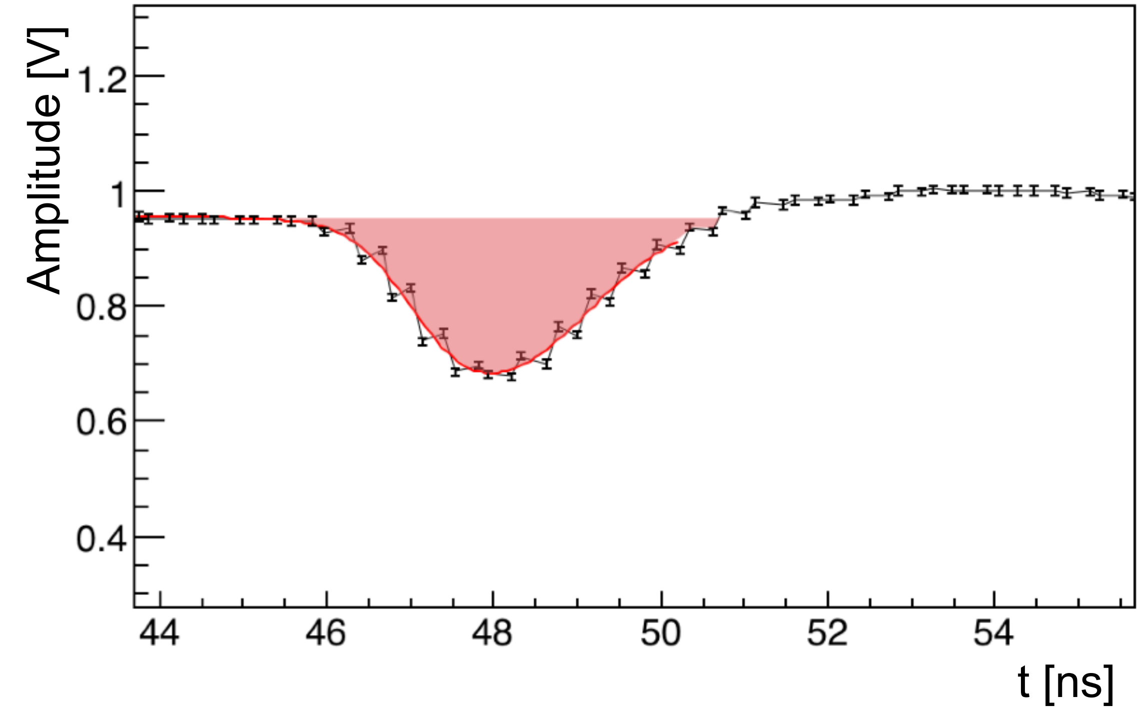
The peaks at zero are due to events triggered by the TW.

The presence of a double peak at the left or right of the principal peak is under study

Max amplitude-charge correlation

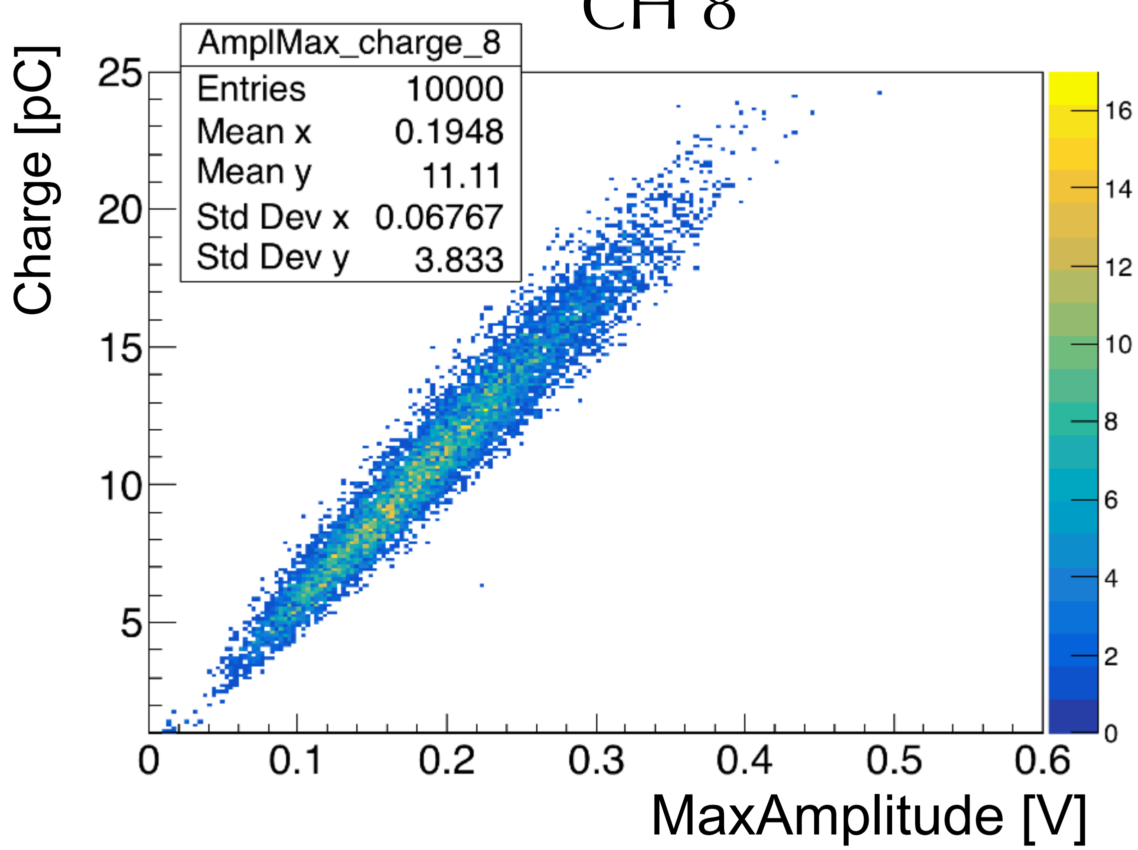
Preliminary check: study the max amplitude-charge correlation:

1. The charge is evaluated by an integral performed on each wave function, in the same range in which the fit is performed.
2. The max amplitude is the one extracted by the fit (previous slide).

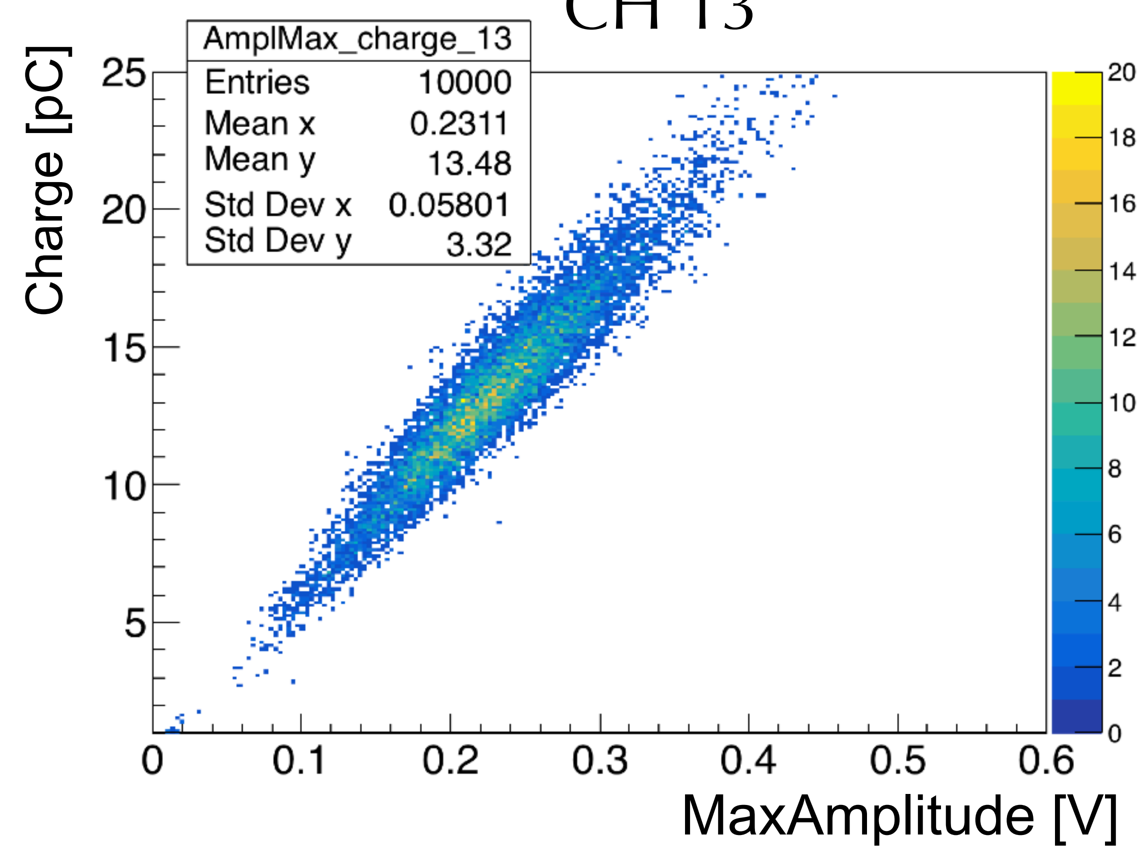


As an example the correlations measured between the charge and the max amplitude for CH 8 and CH 13 are reported:

CH 8



CH 13



Arrival time evaluation

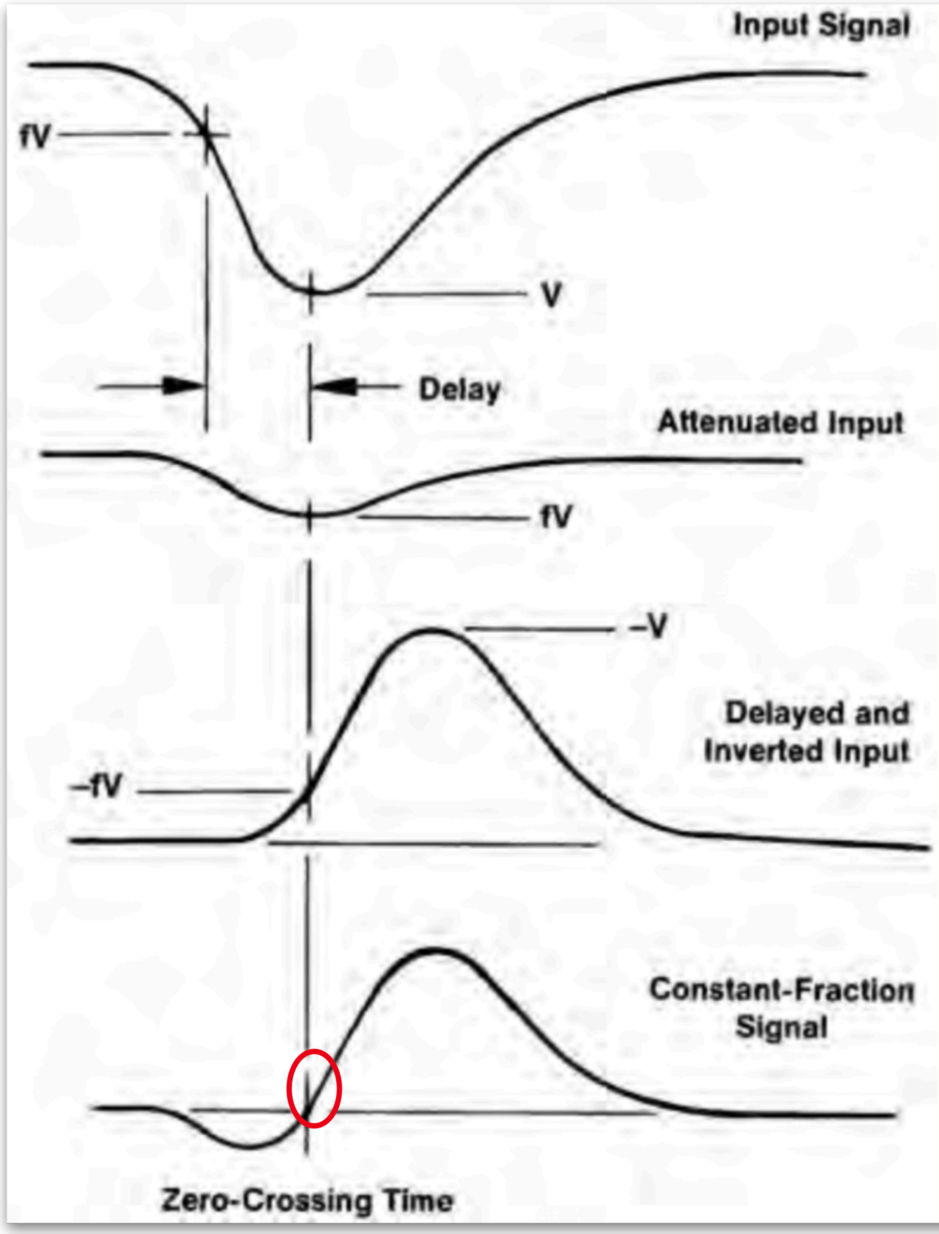
In order to obtain the best configuration, each arrival time and TOF calculation has been performed using two different methods:

1. Constant fraction discriminator (CFD)

The function f, used for the fit to the Margarita output signals, is either attenuated by a **frac** factor or delayed by a **del** factor and than inverted. The f_1 function is then obtained from the sum of these two curves.

Using f_1 the arrival time on the Margarita is set as the zero crossing point.

f_1

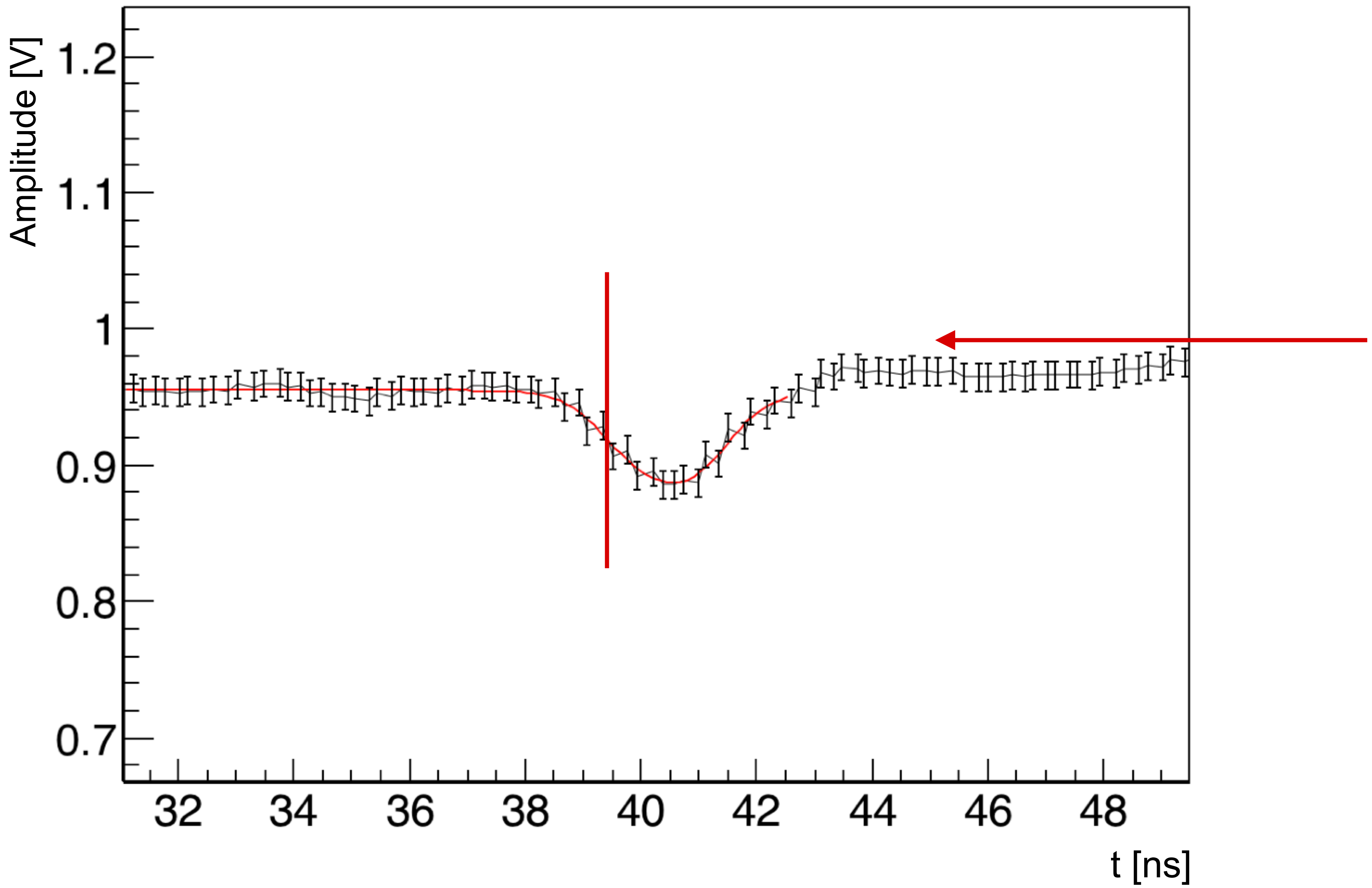


After a brief analysis **frac** = 0.5 and **del** = 2 ns are chosen

Arrival time evaluation

2. "Simple Constant fraction"

The arrival time is chosen as the x value corresponding to the half amplitude value.

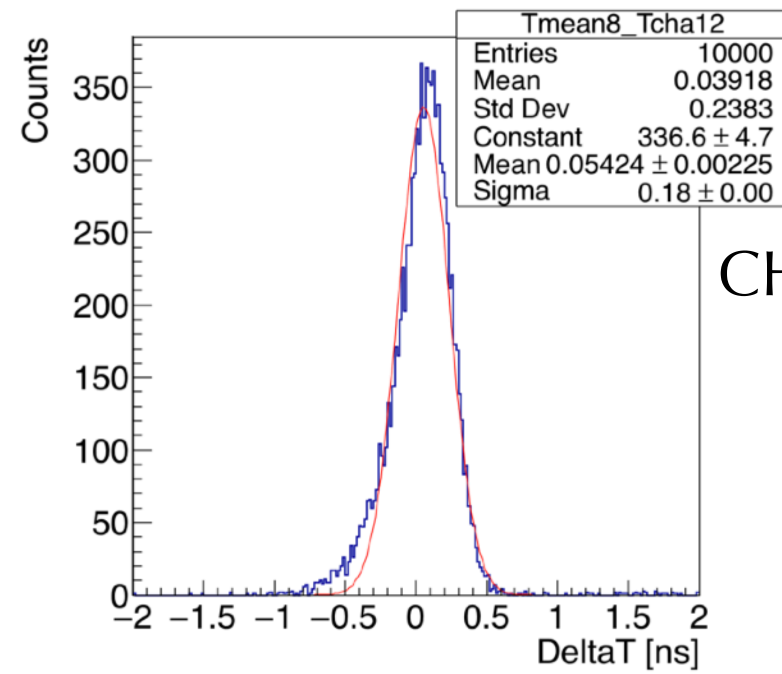


Constant Fraction Discriminator and Simple Constant Fraction

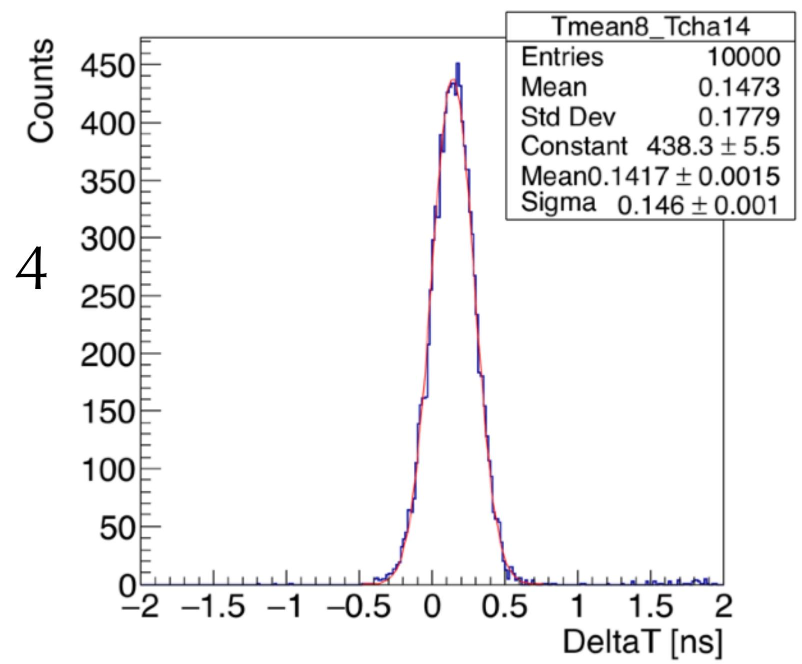
Some examples of histograms given by the difference between the average arrival time of the 8 Margarita's channels and the arrival time measured by each single channel for both methods are reported:

1. Constant Fraction Discriminator

CH 12

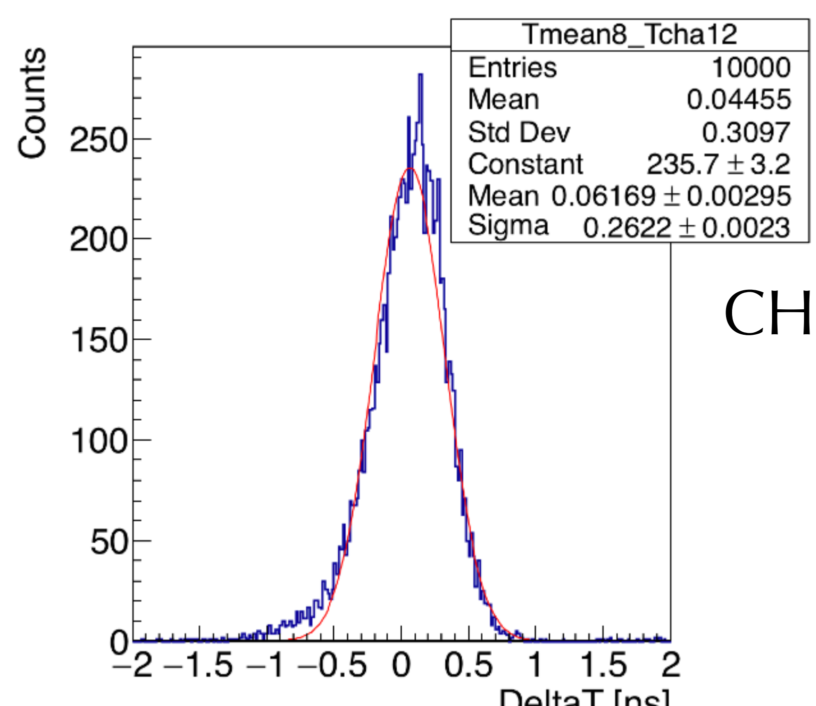


CH 14

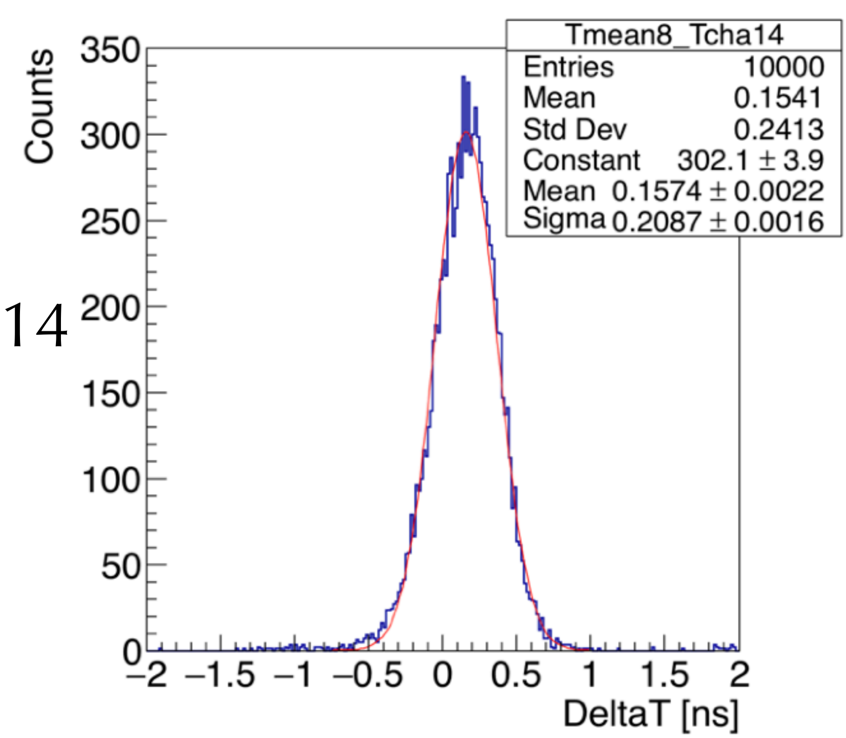


2. Simple Constant Fraction

CH 12



CH 14



Summary of the Margarita channels resolution σ

CFD method:

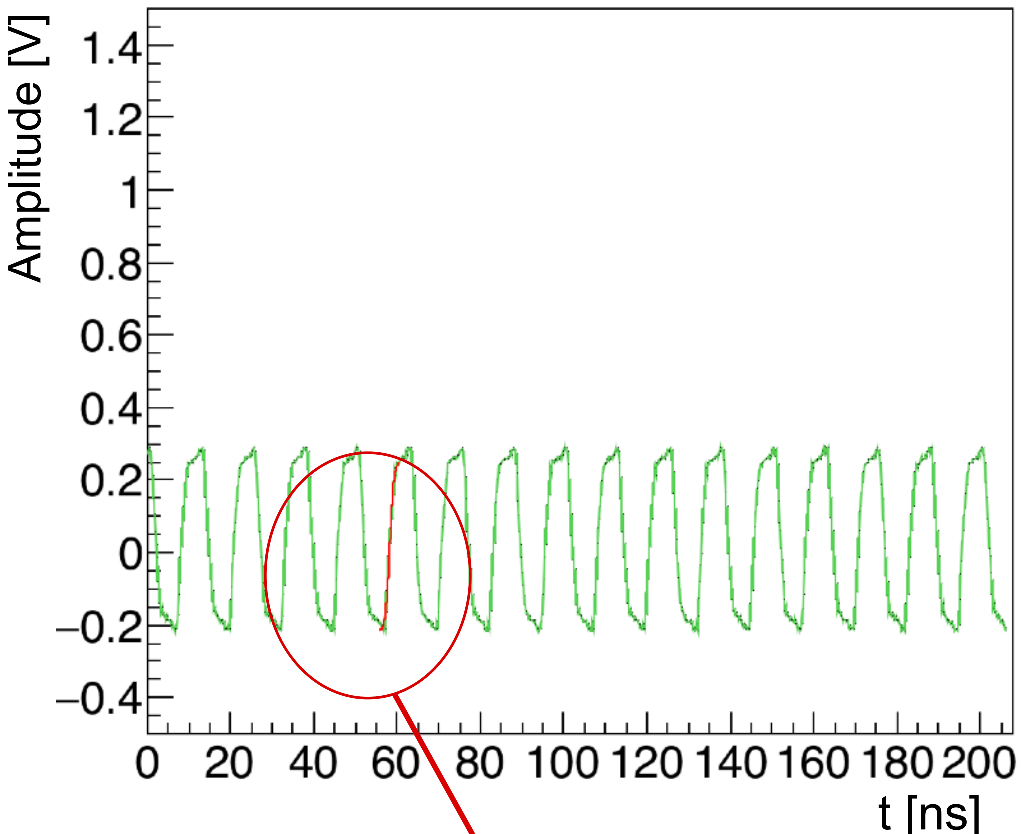
CH 8	0.147 ns	CH 12	0.180 ns
CH 9	0.280 ns	CH 13	0.137 ns
CH 10	0.247 ns	CH 14	0.146 ns
CH 11	0.180 ns	CH 15	0.135 ns

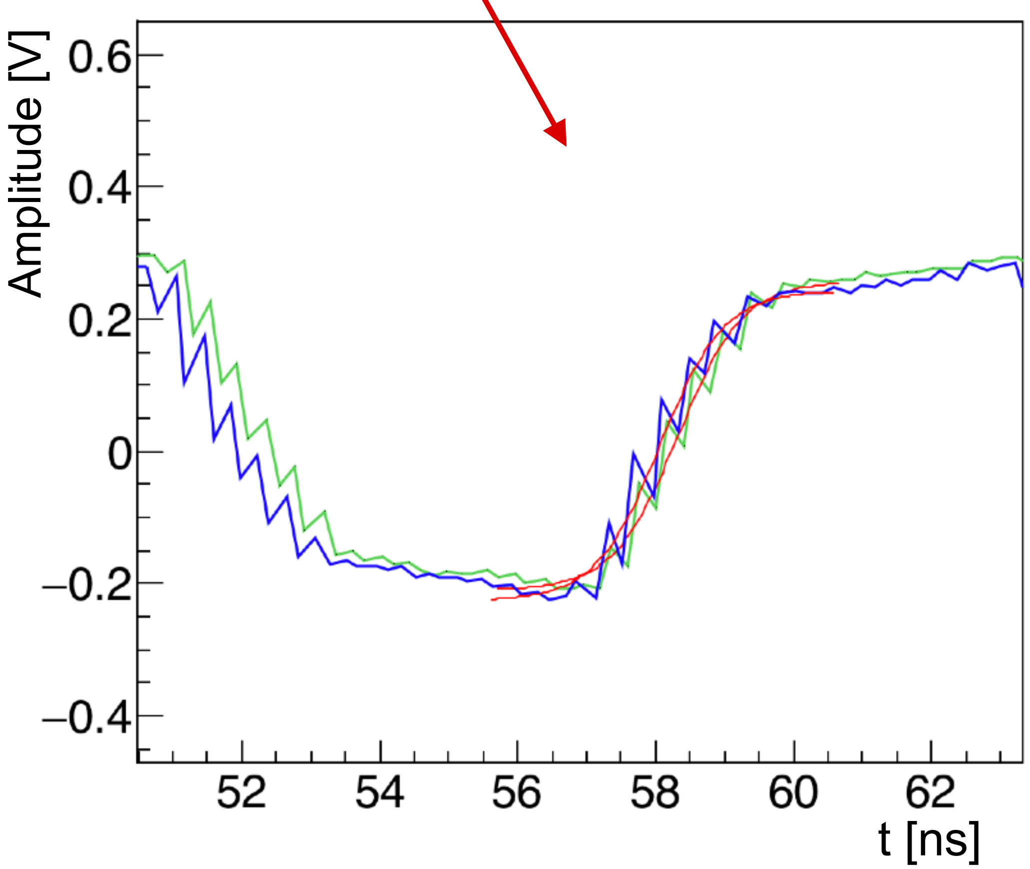
Simple constant fraction:

CH 8	0.233 ns	CH 12	0.262 ns
CH 9	0.334 ns	CH 13	0.211 ns
CH 10	0.328 ns	CH 14	0.208 ns
CH 11	0.264 ns	CH 15	0.205 ns

Comparing the two methods, I decided to use only the first one that results into an improvement of the time resolution.

Time jitter: ΔClock calculation





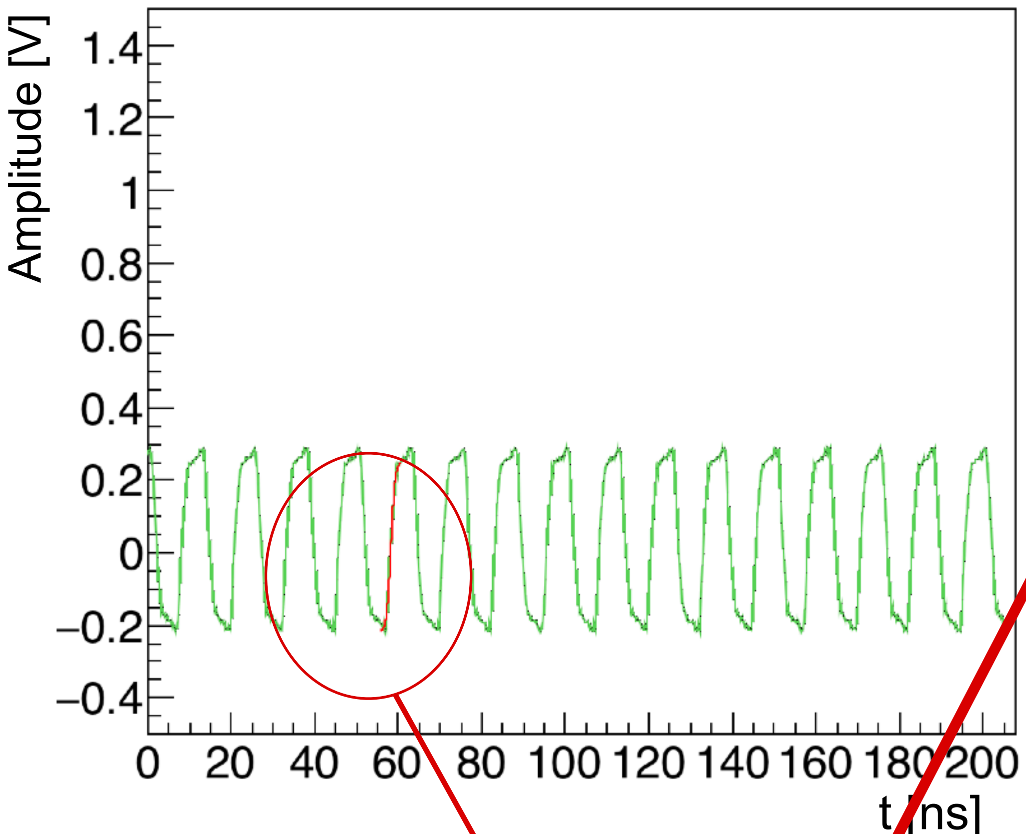
Margarita: green curve
TW: blue curve

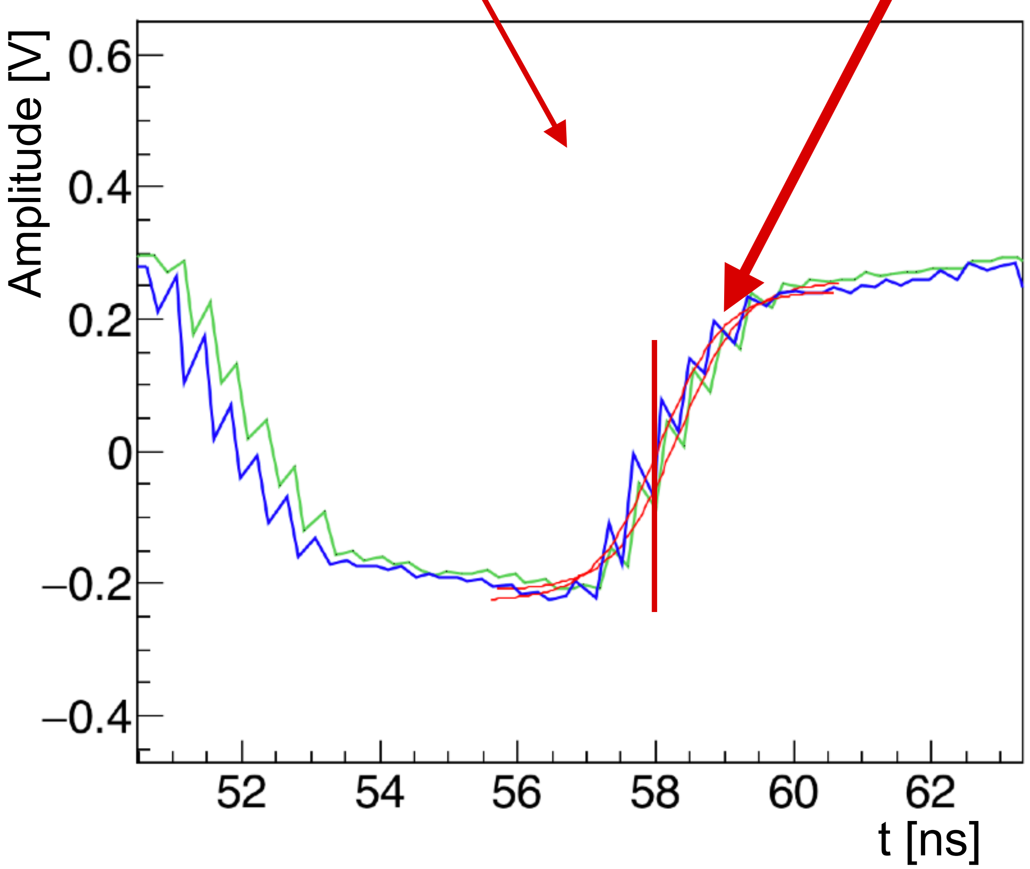
TW and Margarita have two different clock times, given by CH 16 and CH 17 respectively. Between them there is a time jitter. When computing the Time of Flight this ΔClock needs to be properly taken into account.

To fit the rising edge of the clock waveforms, the edge closest to the trig time is selected. The curve is parametrized with the Fermi-Dirac function.

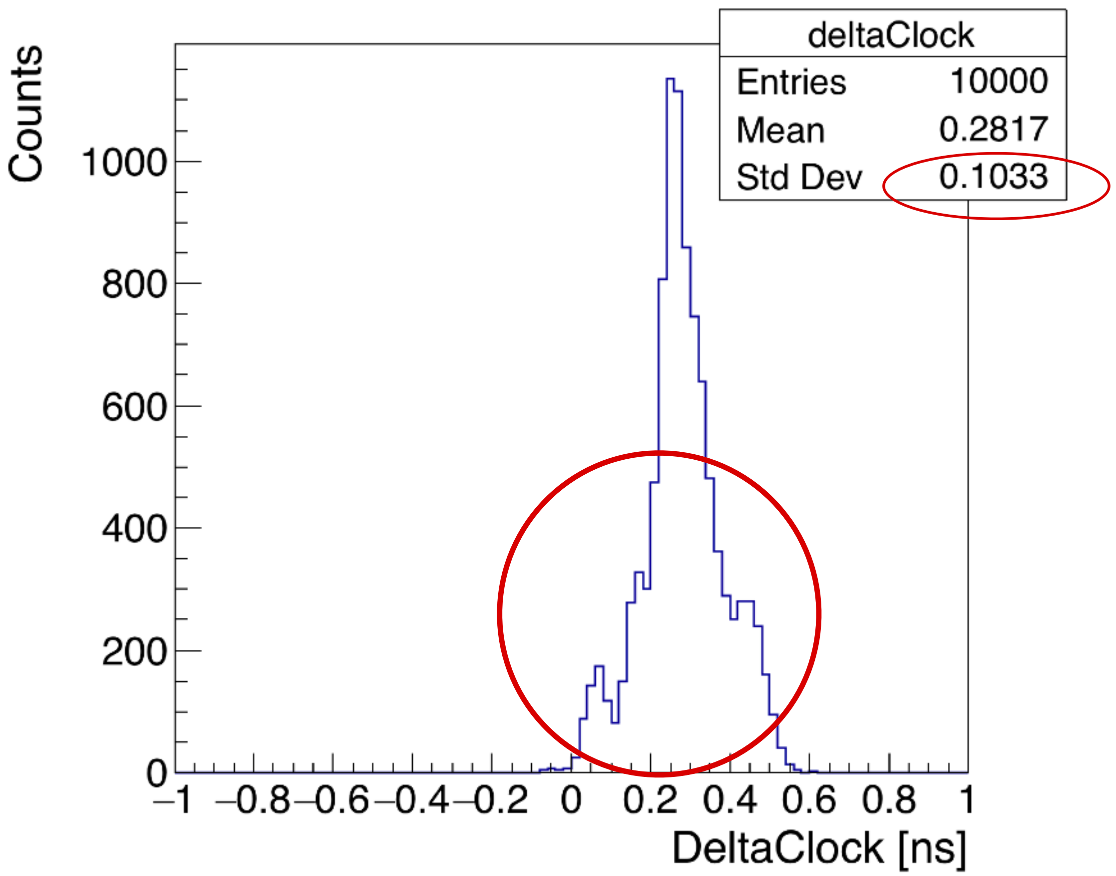
$$f_c = \frac{[0]}{1 + e^{-\frac{x-[1]}{[2]}}} - [3]$$

Time jitter: ΔClock calculation



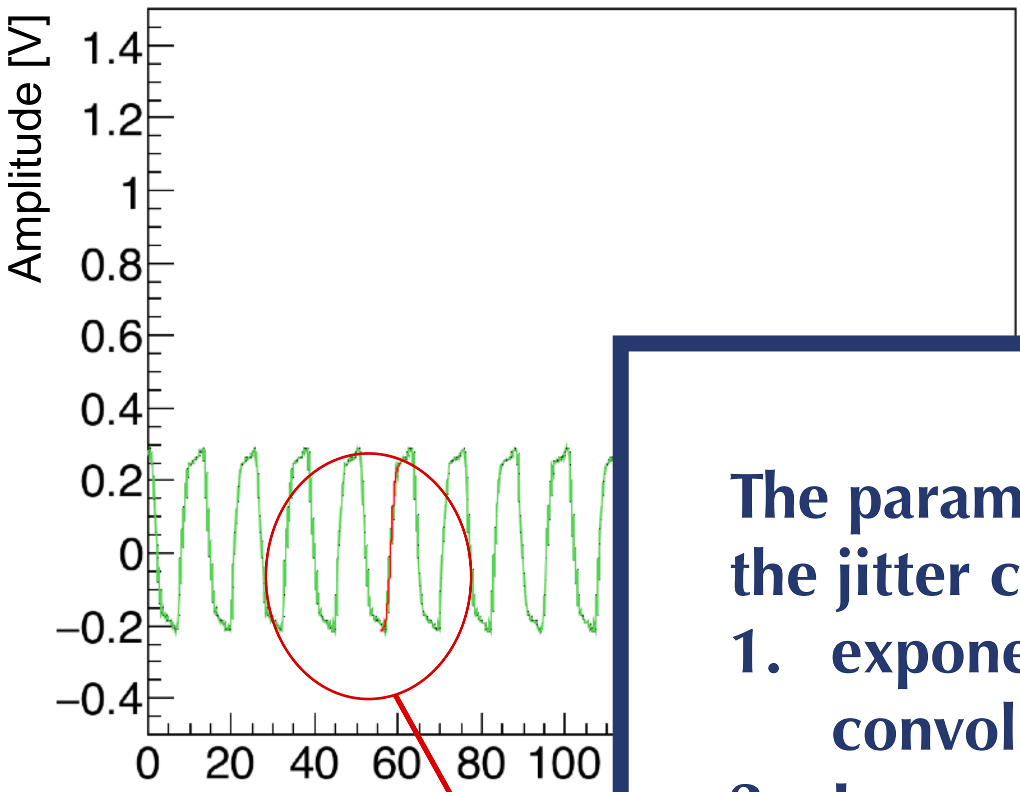


The zero crossing point is taken as reference time.

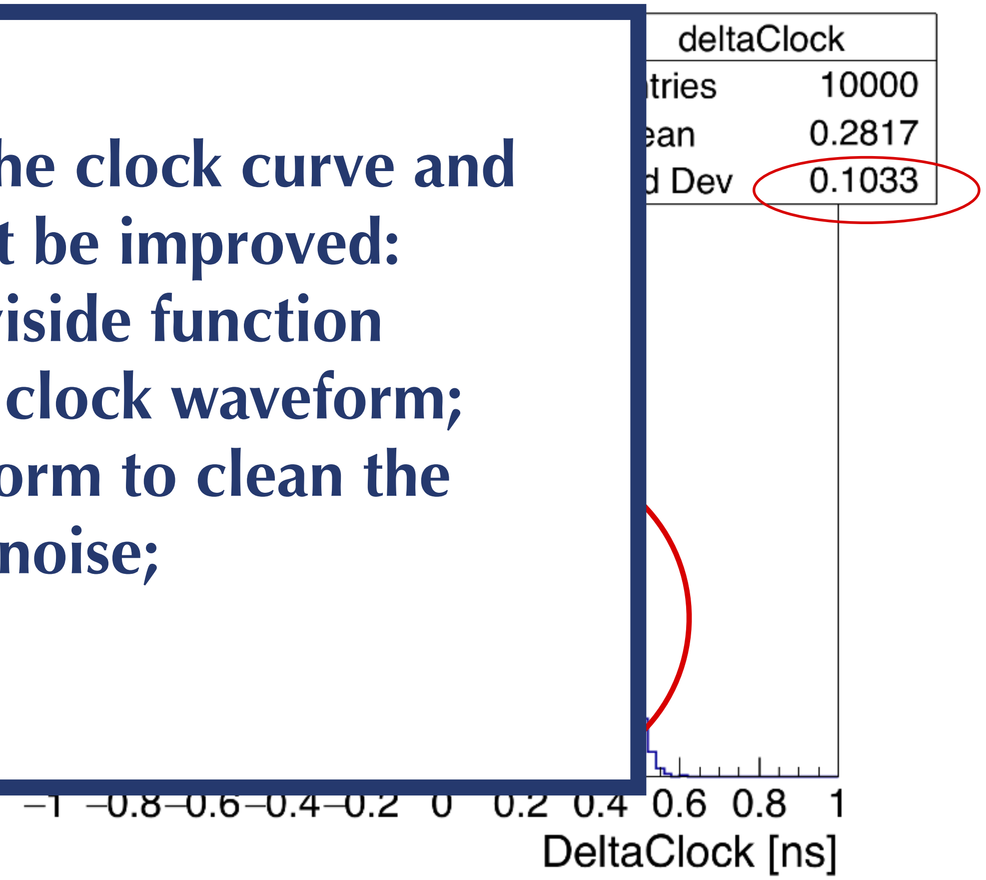


From now on the ΔClock is subtracted for each TOF calculation

Time jitter: ΔClock calculation

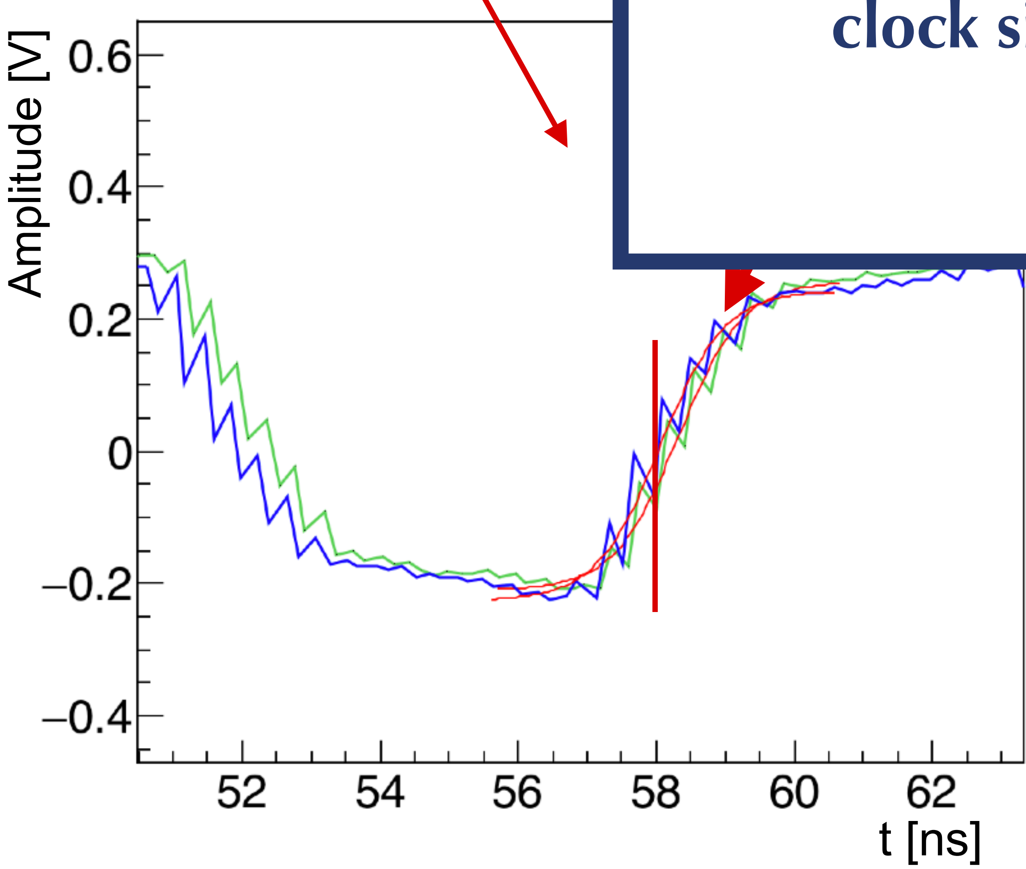


The zero crossing point is taken as reference time.



The parametrization of the clock curve and the jitter calculation must be improved:

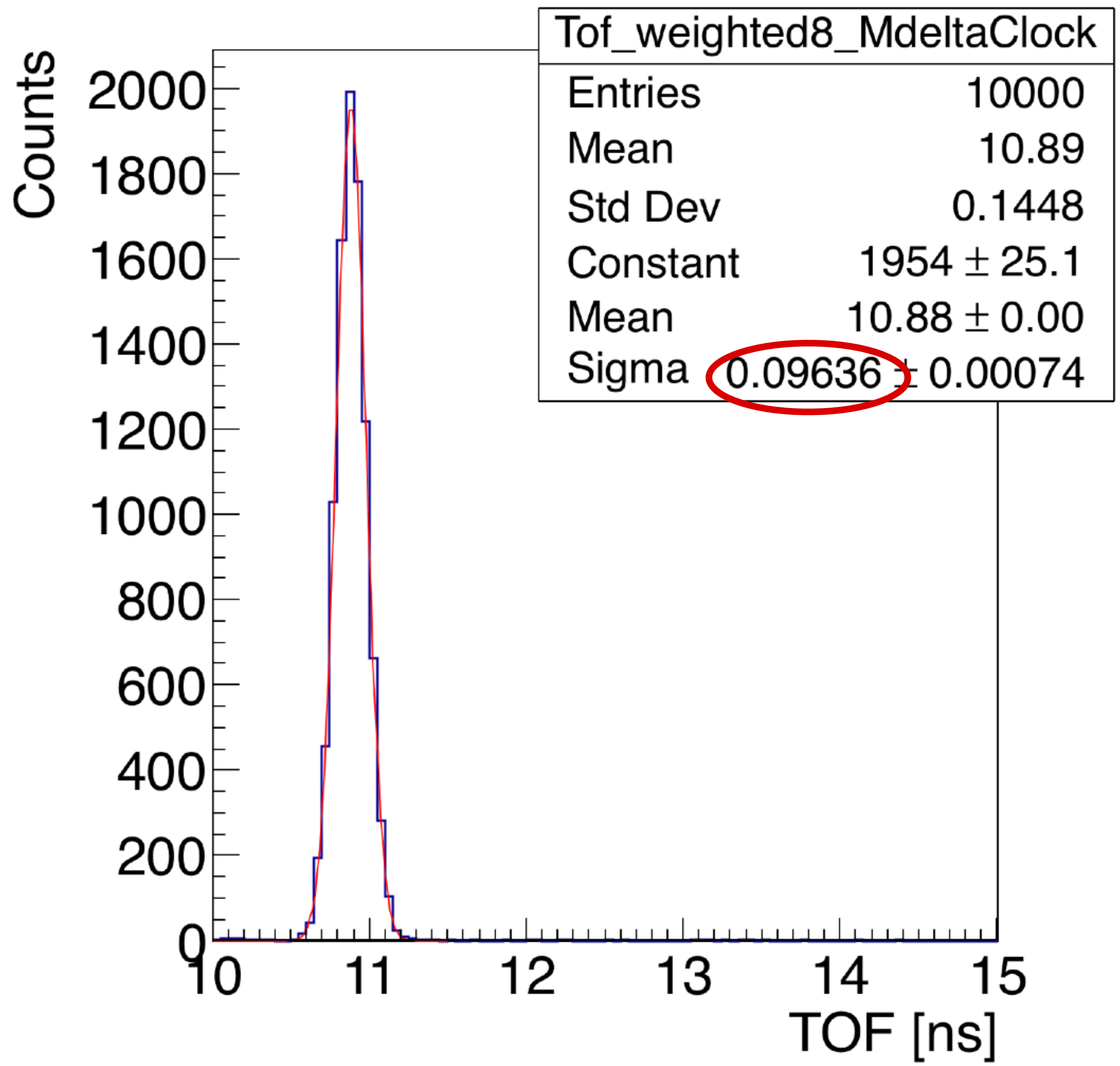
1. **exponential and Heaviside function convolution to fit the clock waveform;**
2. **Inverse Fourier transform to clean the clock signal from the noise;**



From now on the ΔClock is subtracted for each TOF calculation

Time of Flight resolution evaluation

TOF has been measured as the difference between the average arrival time of the 2 TW's channels and the weighted average arrival time of the 8 Margarita's channels



Weighted TOF:

$$\begin{cases} \overline{Marg} = \sum \frac{\omega_i marg_i}{\omega_i} \\ \overline{TW} = \frac{\sum tw_i}{2} \end{cases} \qquad \omega_i = \frac{1}{\sigma_i^2}*$$

$$\downarrow$$

$$\overline{TOF} = \overline{TW} - \overline{Marg}$$

* The σ values are the ones presented in slide 12 for each Margarita channel.

Expected Margarita Resolution

Based on the statistics, the expected resolution for the Margarita is given by:

$$\overline{Marg} = \frac{\sum \frac{marg_i}{\sigma_i}}{\sum \frac{1}{\sigma_i^2}}*$$

$$\longrightarrow \quad \sigma[\overline{Marg}] = \frac{\sqrt{\sum \frac{1}{\sigma_i^2}}}{\sum \frac{1}{\sigma_i^2}} = \frac{1}{\sum \frac{1}{\sigma_i^2}}$$

$$var[\overline{Marg}] = \sum \alpha_i^2 \sigma_i^2 = \frac{\sum \frac{1}{\sigma_i^2}}{\left(\sum \frac{1}{\sigma_i^2}\right)^2} \quad \text{with} \quad \alpha_i = \frac{\frac{1}{\sigma_i^2}}{\sum \frac{1}{\sigma_i^2}}$$

The expected Margarita σ is: 60 ps

The Margarita time resolution can be also evaluated from the TW resolution:

$$\sigma_{TOF}^2 = \sigma_{Marg}^2 + \sigma_{tw}^2$$

Since the TW resolution is 31 ps and the evaluated TOF sigma is 96 ps $\longrightarrow$

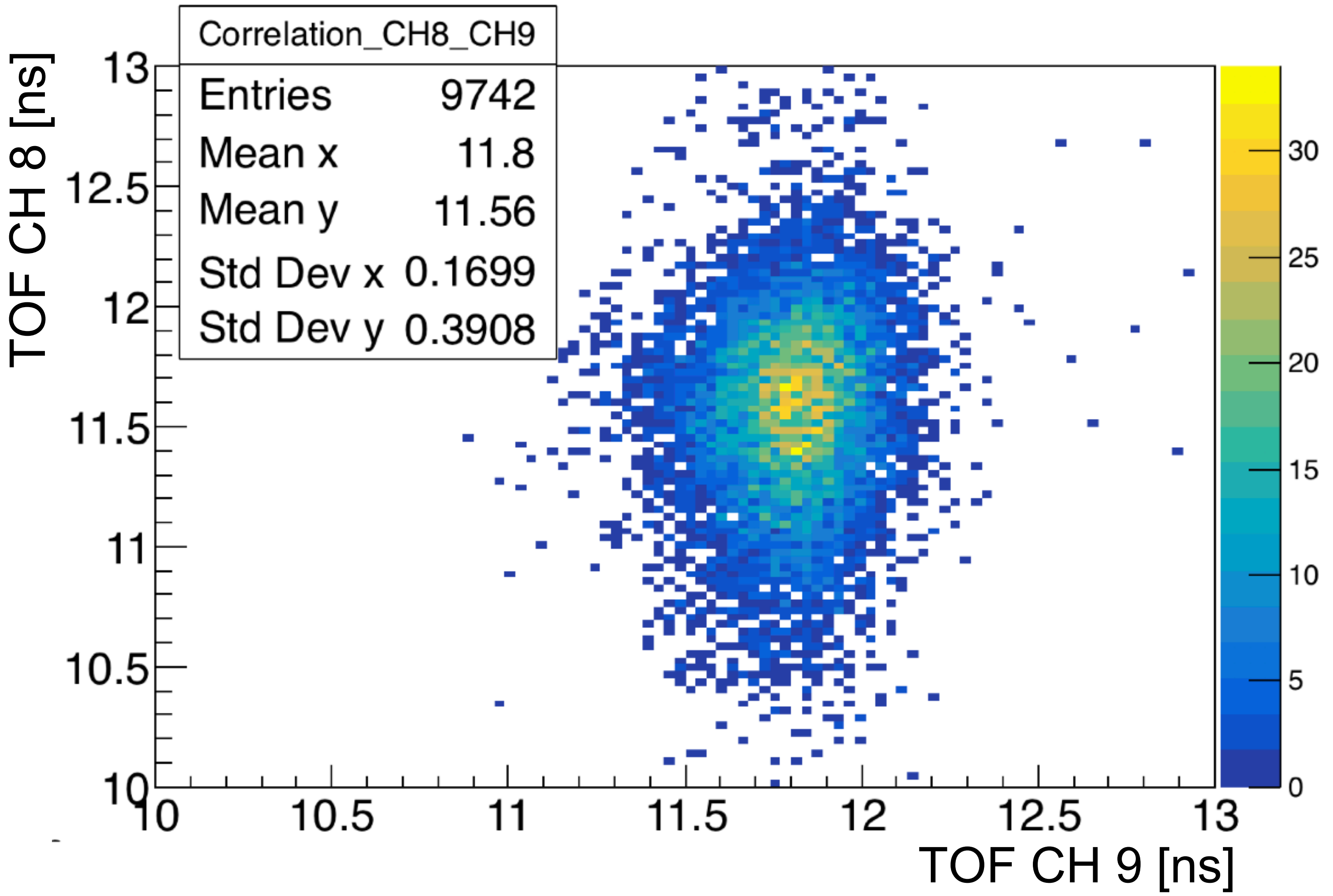
The Margarita σ is 90 ps

* The σ values are the ones presented in slide 12 for each Margarita channel.

Margarita channels correlation

When using all the information of the Margarita (all 8 channels) we would expect a significant improvement of the ToF resolution. As this is not currently the case we have start to look at systematic effects.

We have verified that there's no correlation between the TOF measured by the channels (e.g. the plot shows the results from CH 8 and CH 9):



As all the measurements share the common TW time subtraction, we are currently checking that the subtraction is properly done and that the ΔClock is not introducing an unwanted correlation.

Conclusions

We obtained a ToF resolution equal to 96 ps. This result is still unsatisfactory as our goal is σ_{TOF} = 60÷70 ps at 115 MeV/n.

For this purpose, we are working on the following items:

1. We need to check the impact of the last evening's fix on the obtained results;

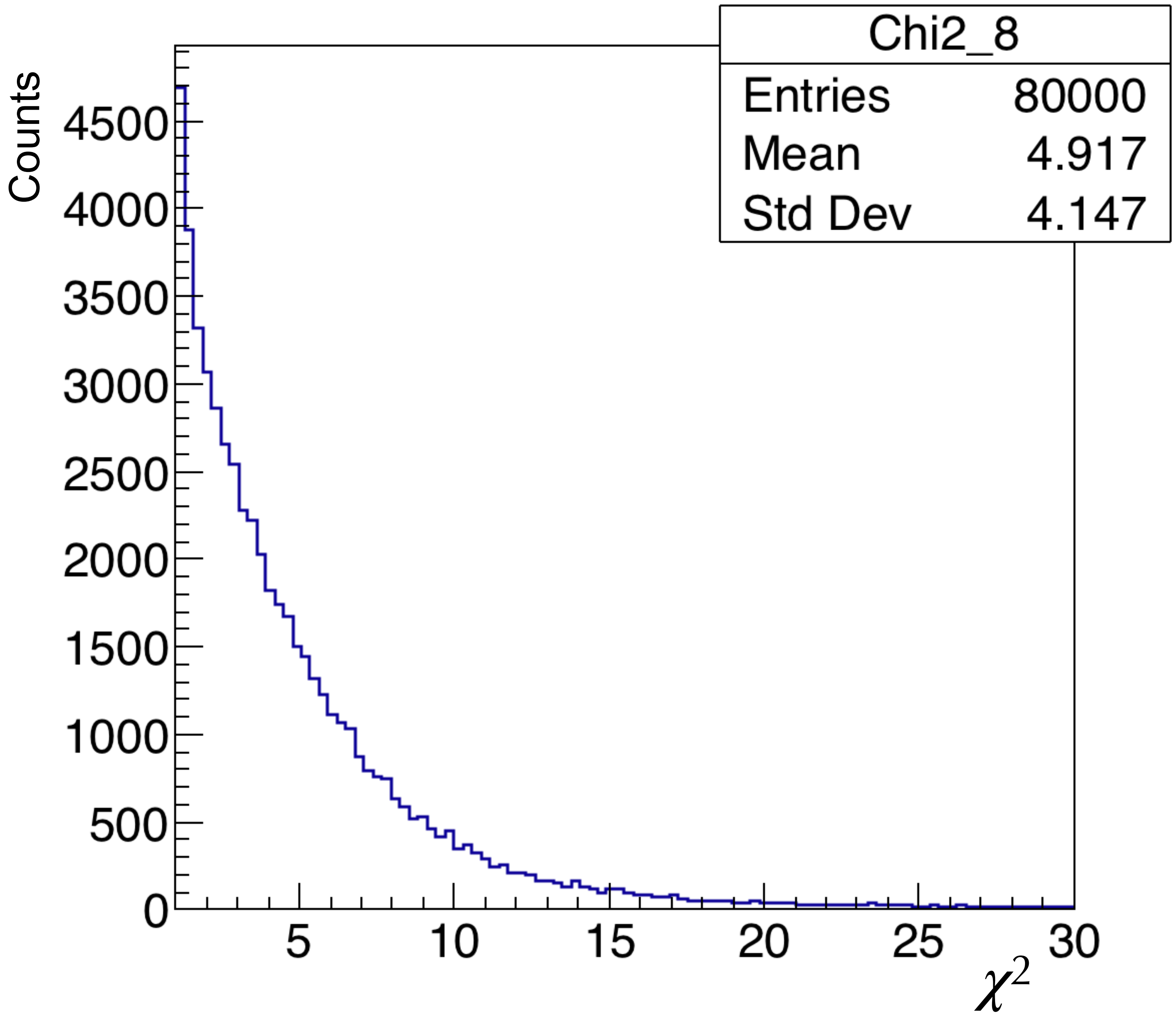
2. The clock signals parametrization has to be improved, using an exponential and Heaviside function convolution. We will also try to obtain a better clock curve to fit with the Heaviside function, using the inverse Fourier transform method;

3. We have to look at systematic effects.

SPARE SLIDES

Fit goodness: χ^2 distribution

Margarita channels:

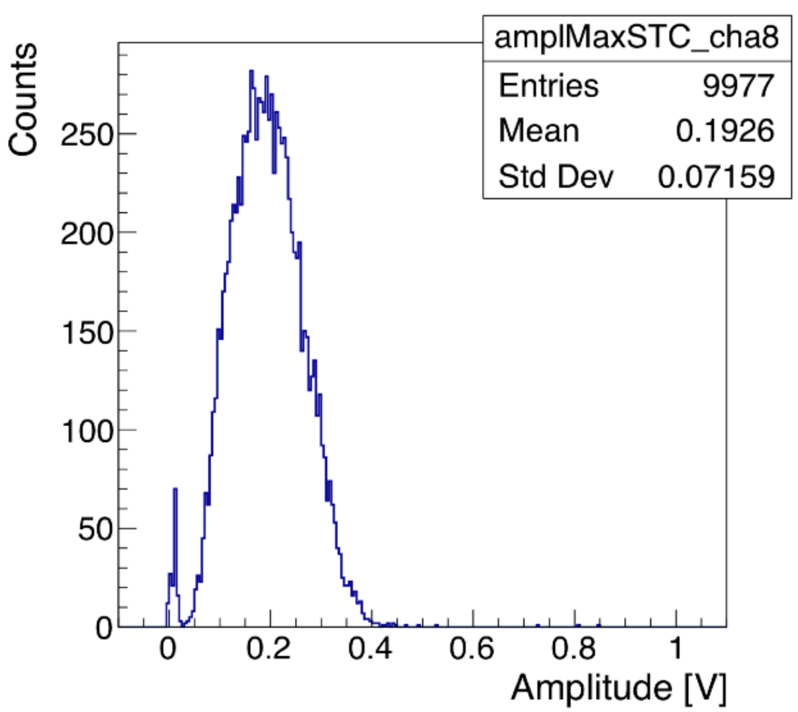


χ^2 distribution for all Margarita channels

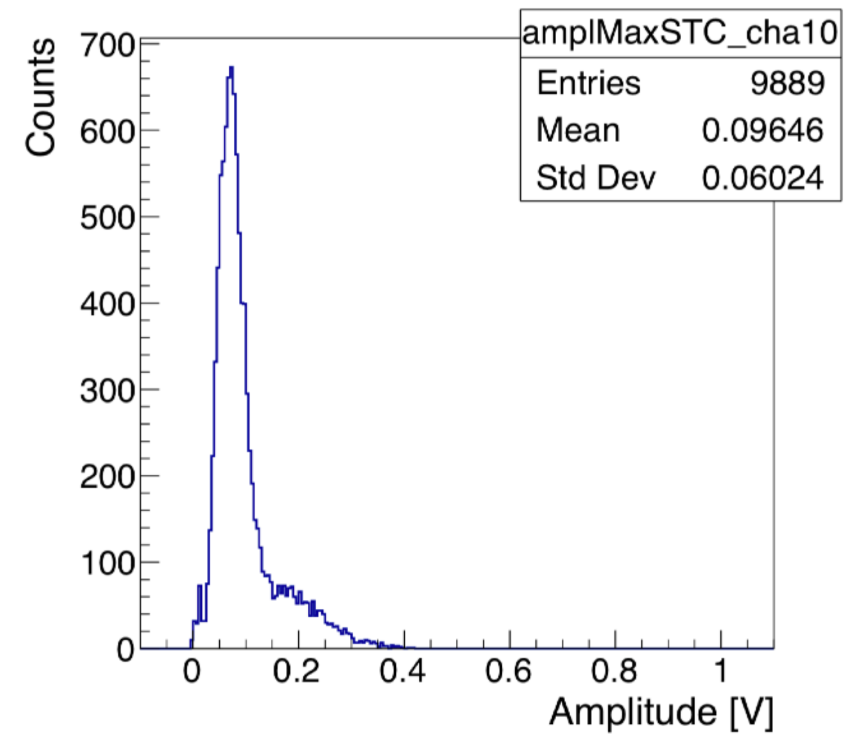
Max amplitude distribution

Histogram of the maximum amplitudes, obtained from the fit *f* as the peak of the 8 Margarita signals.

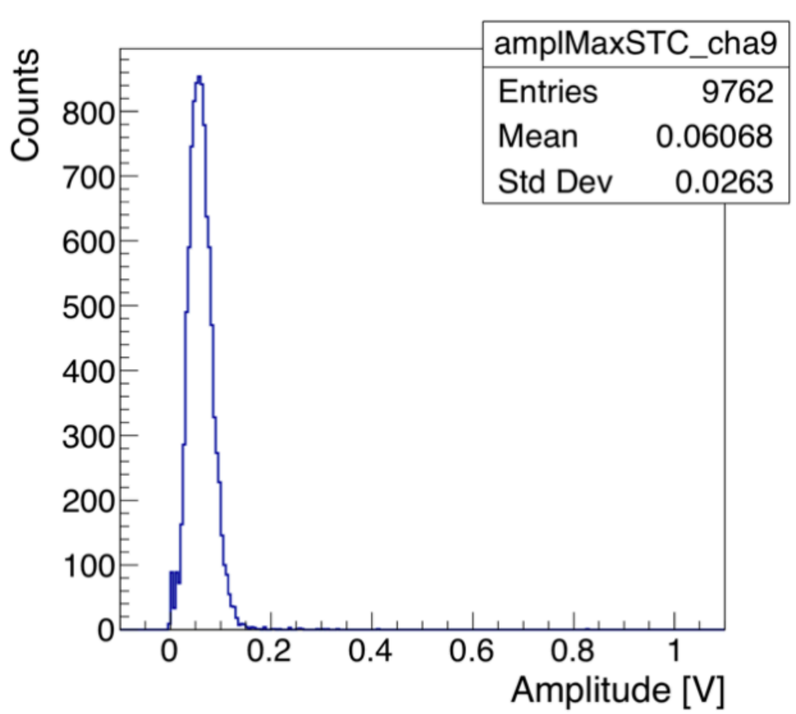
CH 8



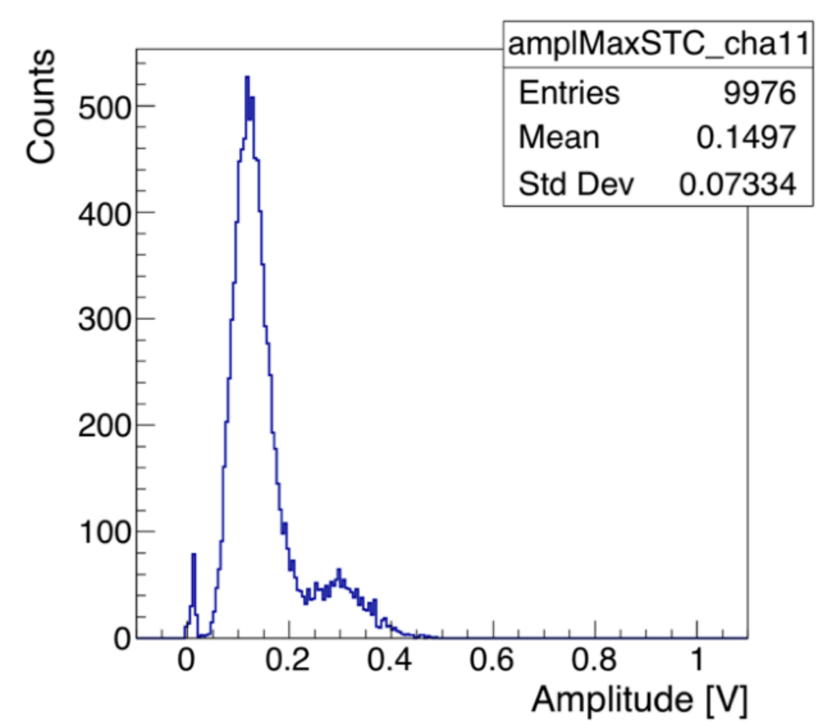
CH 10



CH 9

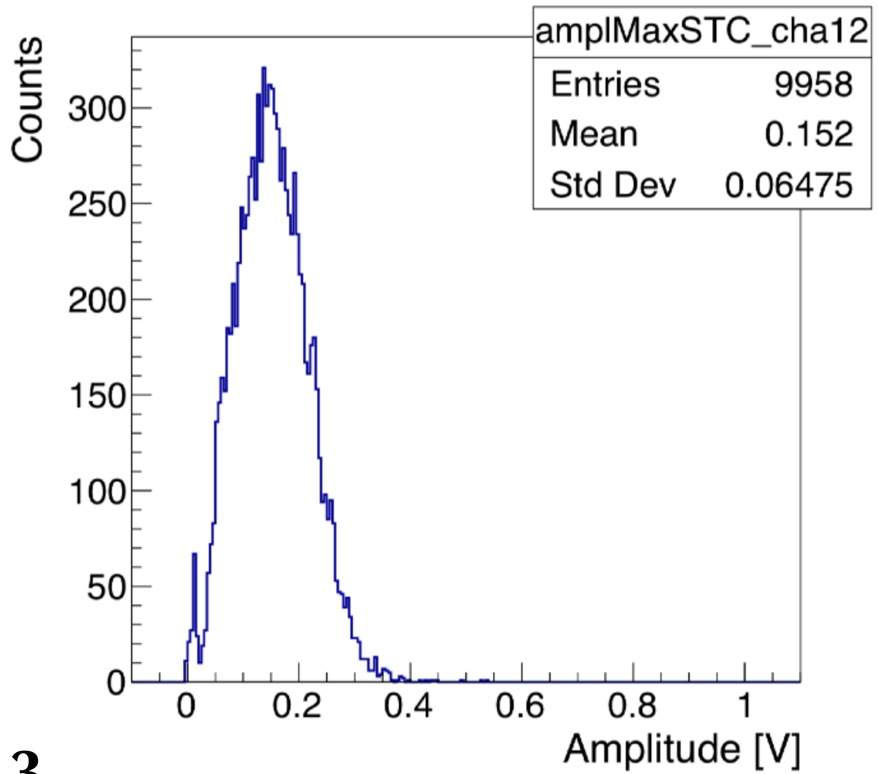


CH 11

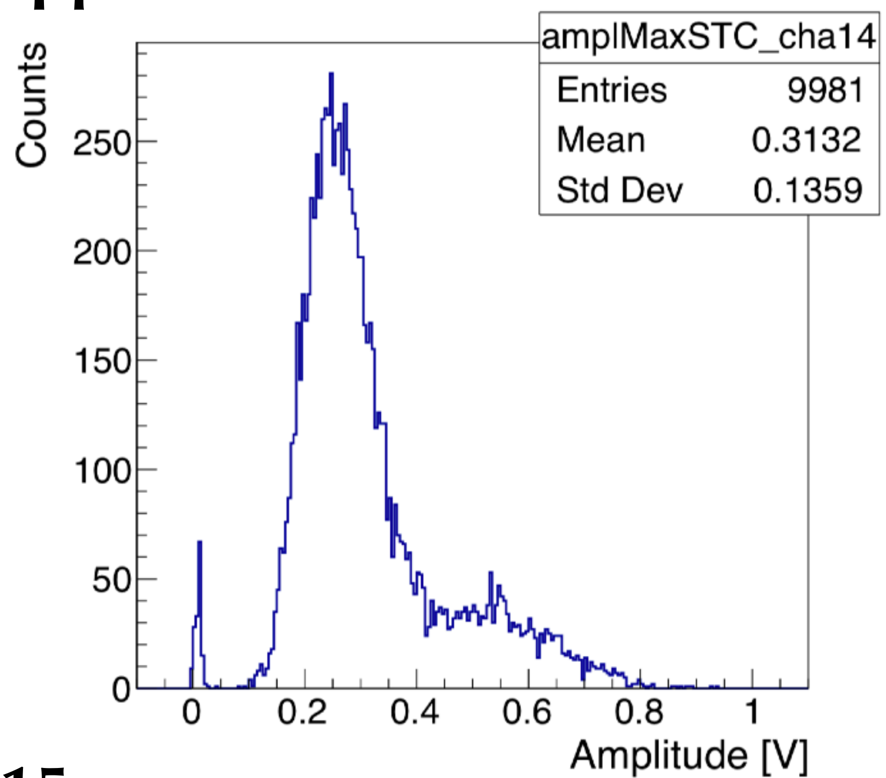


Max amplitude distribution

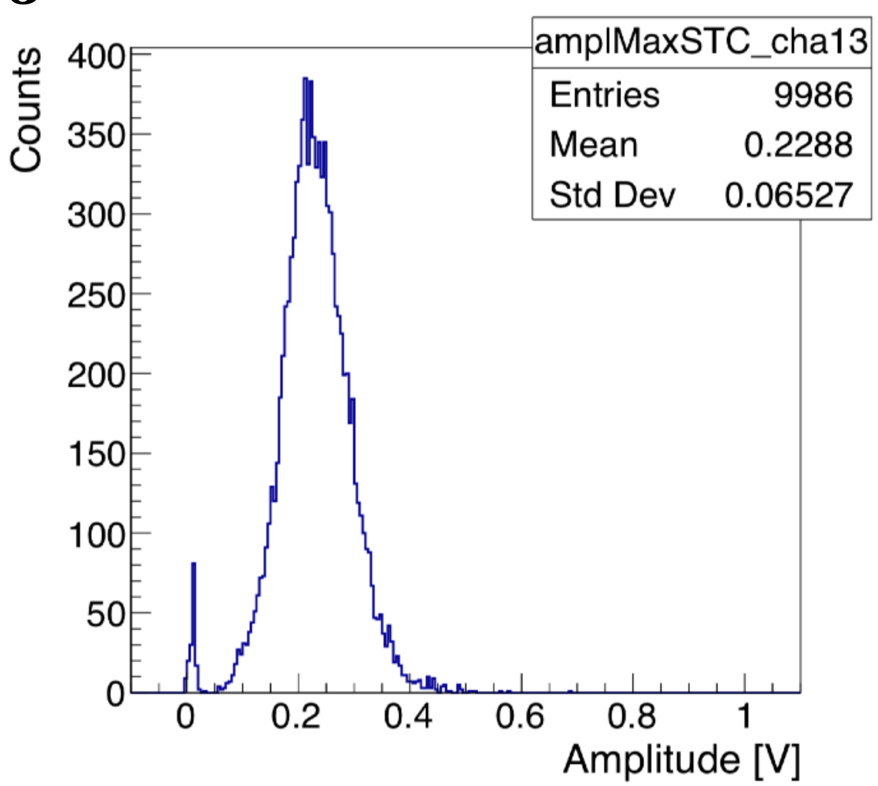
CH 12



CH 14



CH 13



CH 15