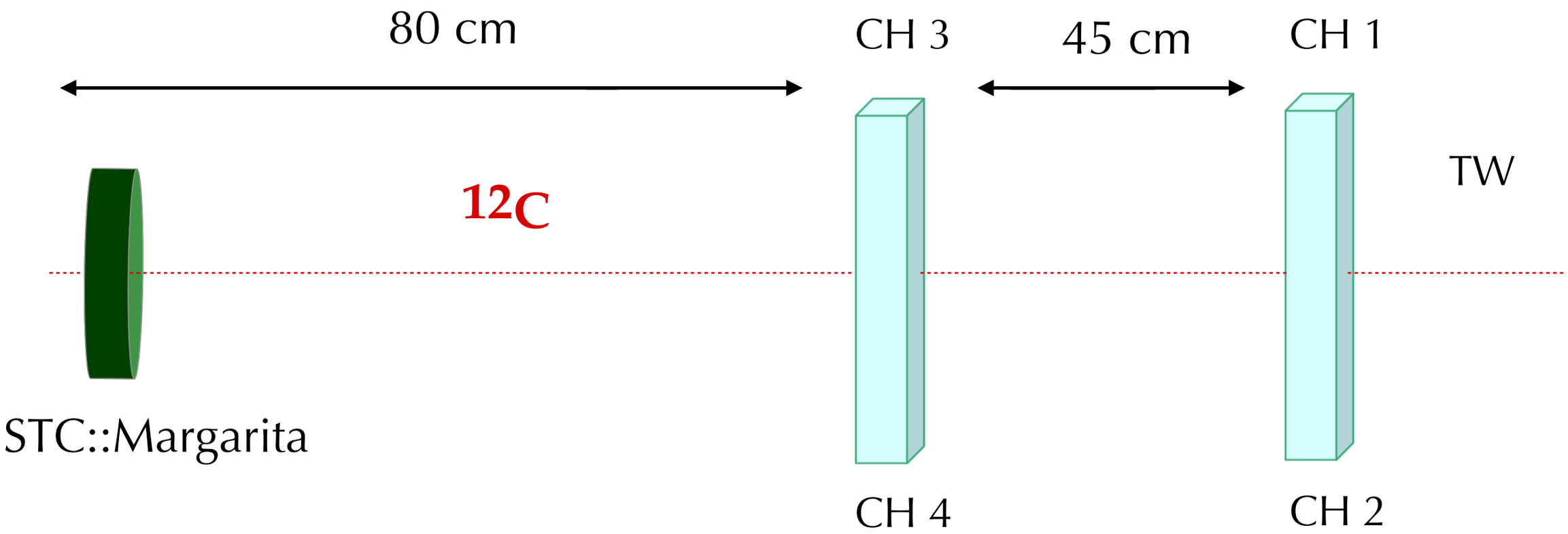
Study of the Margarita performance: a first look to the Time-of-Flight (ToF) resolution

Gaia Franciosini, Giacomo Traini

06-06-2019

Beam test @ CNAO 2018



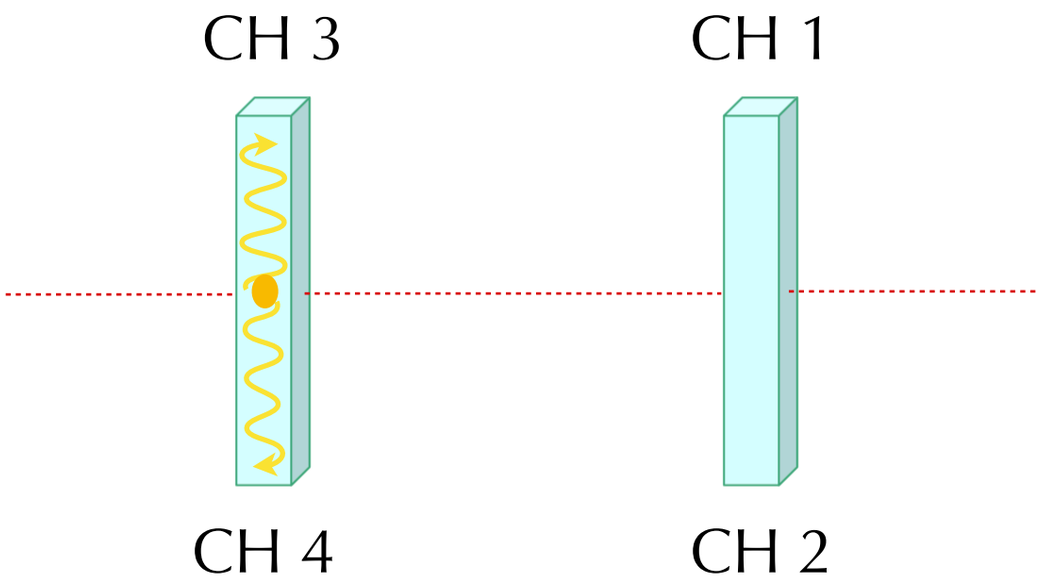
Run:
1. ^{12}C beam at 115 MeV/n;
2. ^{12}C beam at 151 MeV/n;
3. ^{12}C beam at 221 MeV/n;
4. ^{12}C beam at 280 MeV/n;

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 3 and CH 4 are averaged. The arrival time on the TW is evaluated as the average arrival times measured by the two channels.

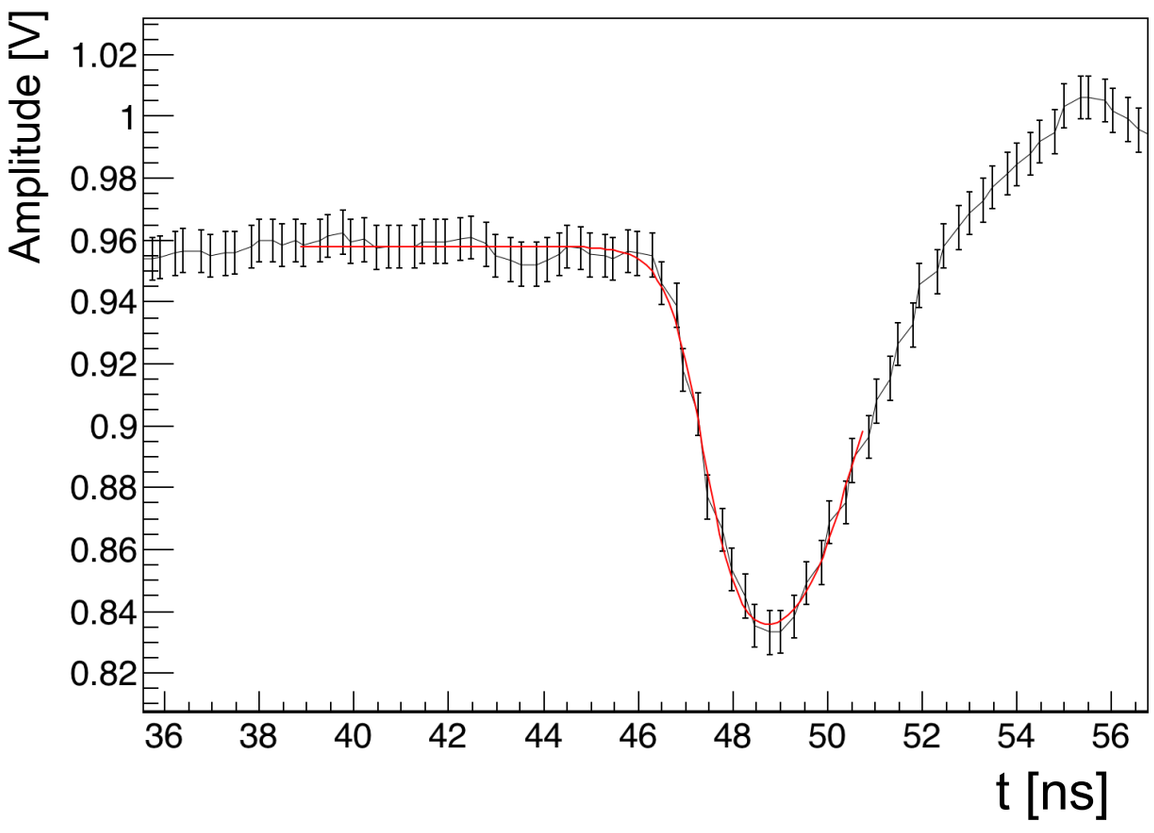
Single channel arrival time evaluation @ CNAO

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

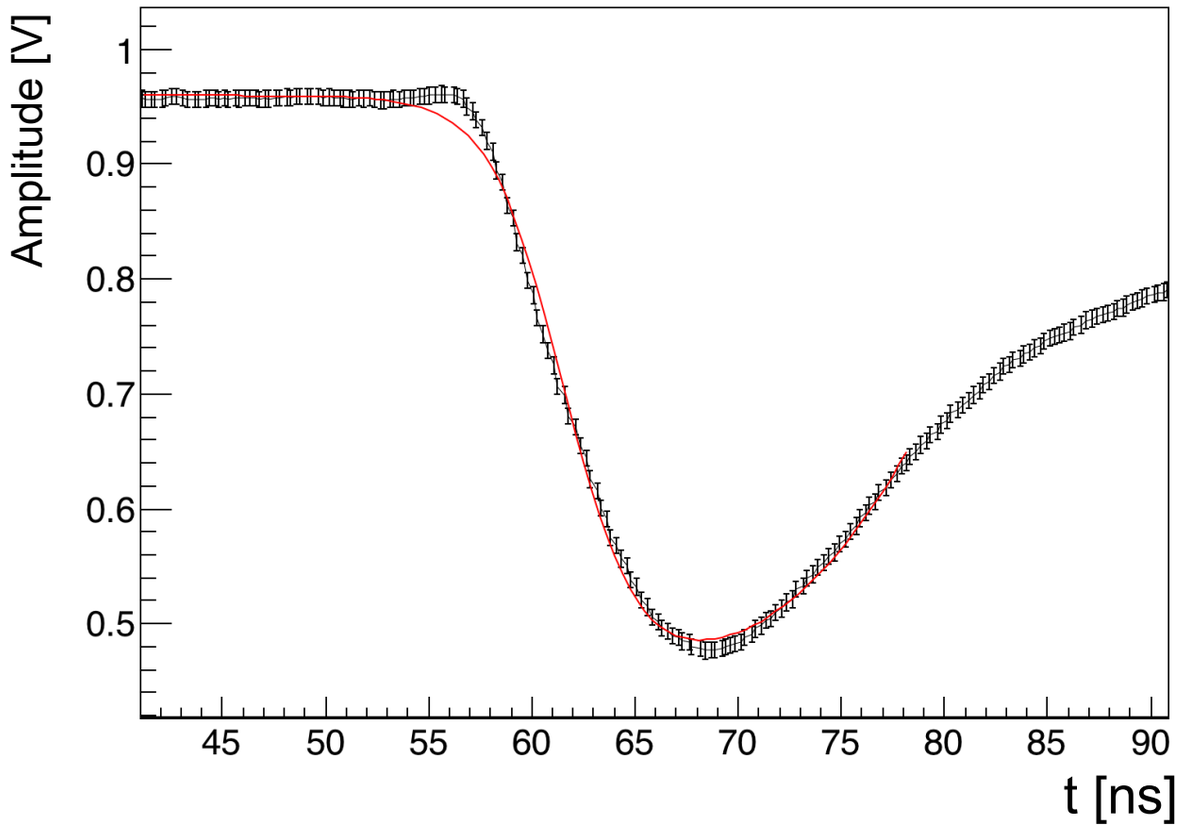
$$f = -\frac{[0]}{1+e^{-\frac{x-[1]}{[2]}}}\frac{[1]}{1+e^{-\frac{x-[3]}{[4]}}} + [5]$$

Waveforms as measured from the digitizer

Margarita



TOF Wall



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

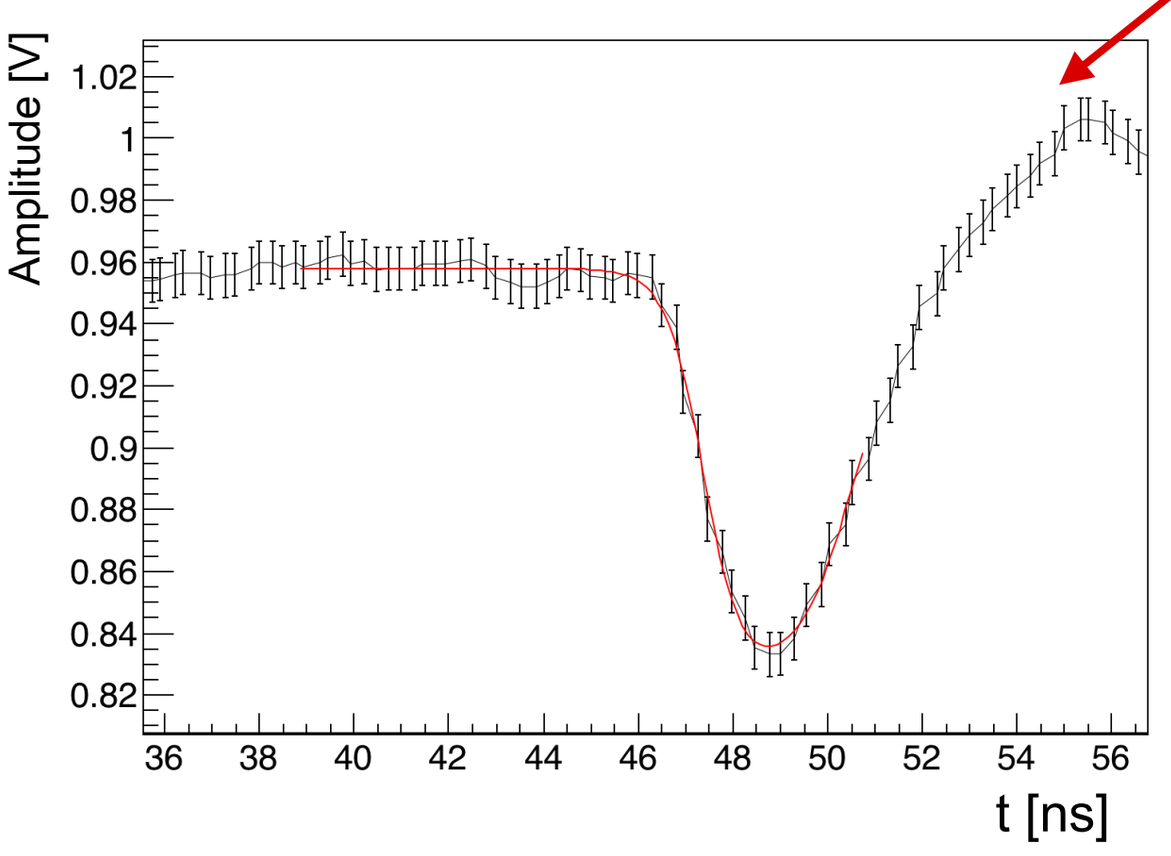
Single channel arrival time evaluation @ CNAO

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

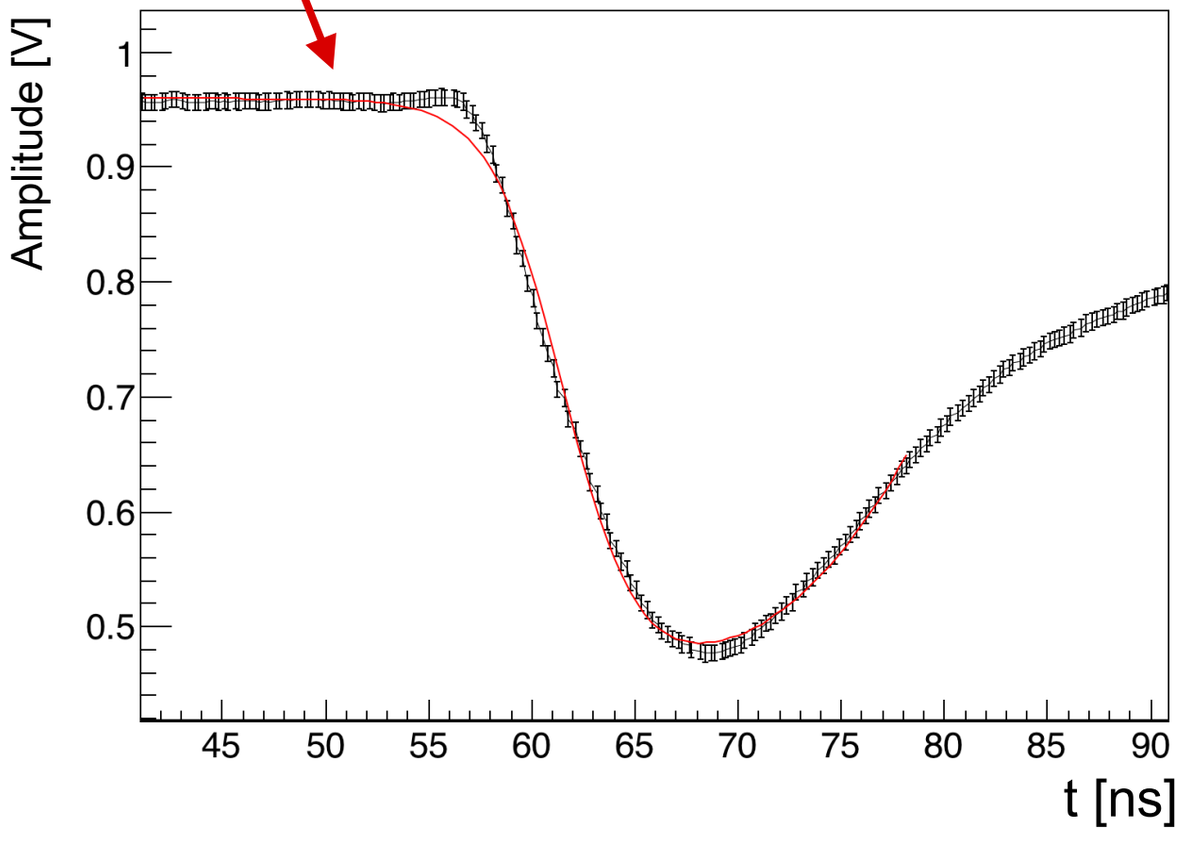
$$f = -\frac{[0]}{1+e^{-\frac{x-[1]}{[2]}}}\frac{[1]}{1+e^{-\frac{x-[3]}{[4]}}}$$

The uncertainties for both Margarita and TW signals are assigned as the baseline fluctuations.

Margarita



TOF Wall



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

Arrival time evaluation

@ CNAO

In order to obtain the best configuration, each arrival time and TOF calculation has been performed using the Constant fraction discriminator (CFD) method:

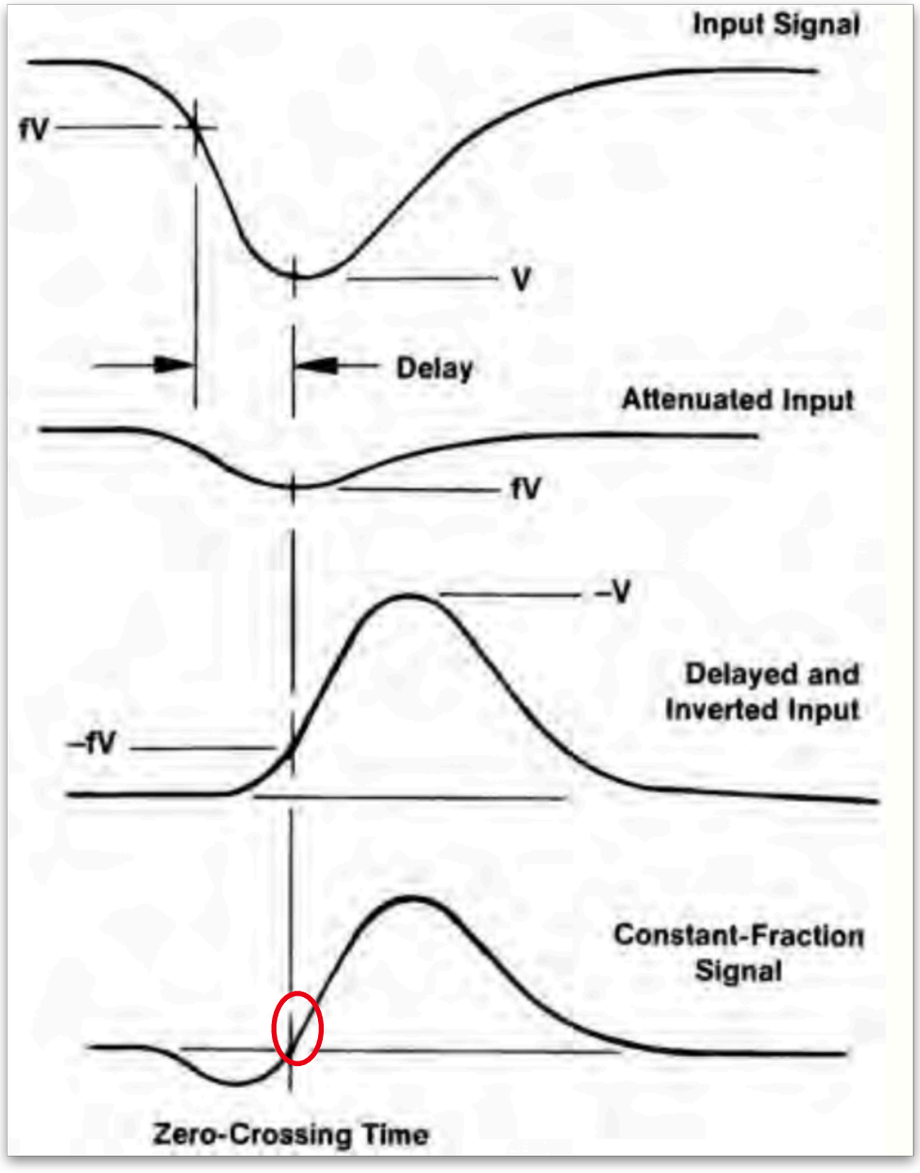
The function f, used for the fit to the Margarita output signals, is either attenuated by a **frac** factor or delayed by a **del** factor and than inverted. The f_1 function is then obtained from the sum of these two curves.

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

After a brief analysis on each Margarita channel ToF we decided to choose:

1. **frac** = 0.5 and **del** = 2 ns for CH 9 and CH 10;
2. **frac** = 0.2 and **del** = 2 ns for CH 8 and CH11 to CH 15;

f_1 →



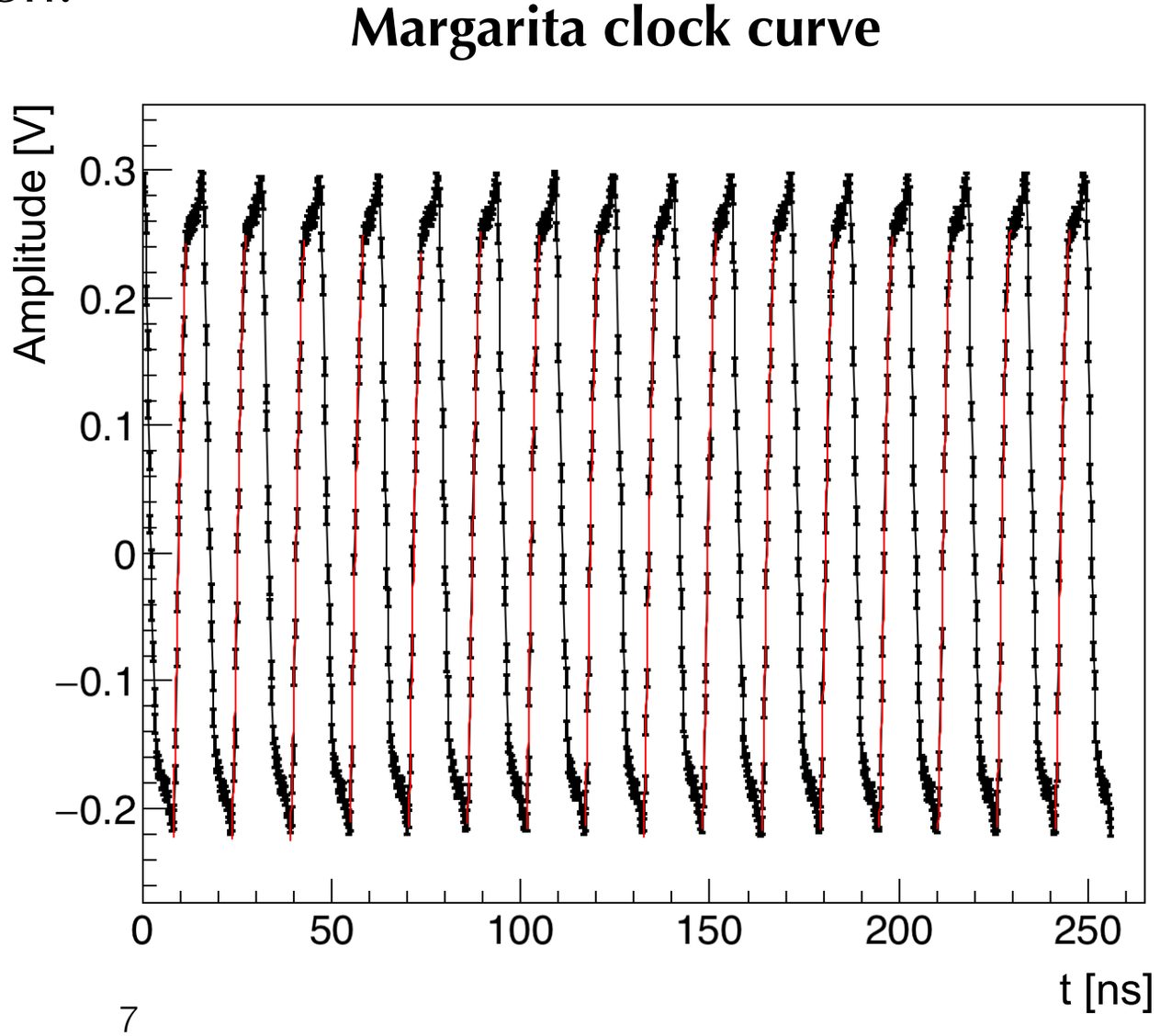
Time jitter: ΔClock calculation

@ CNAO

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.

The rising edges of the clock waveforms are parametrized with the function f_c, obtained by the Fermi-Dirac distribution.

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



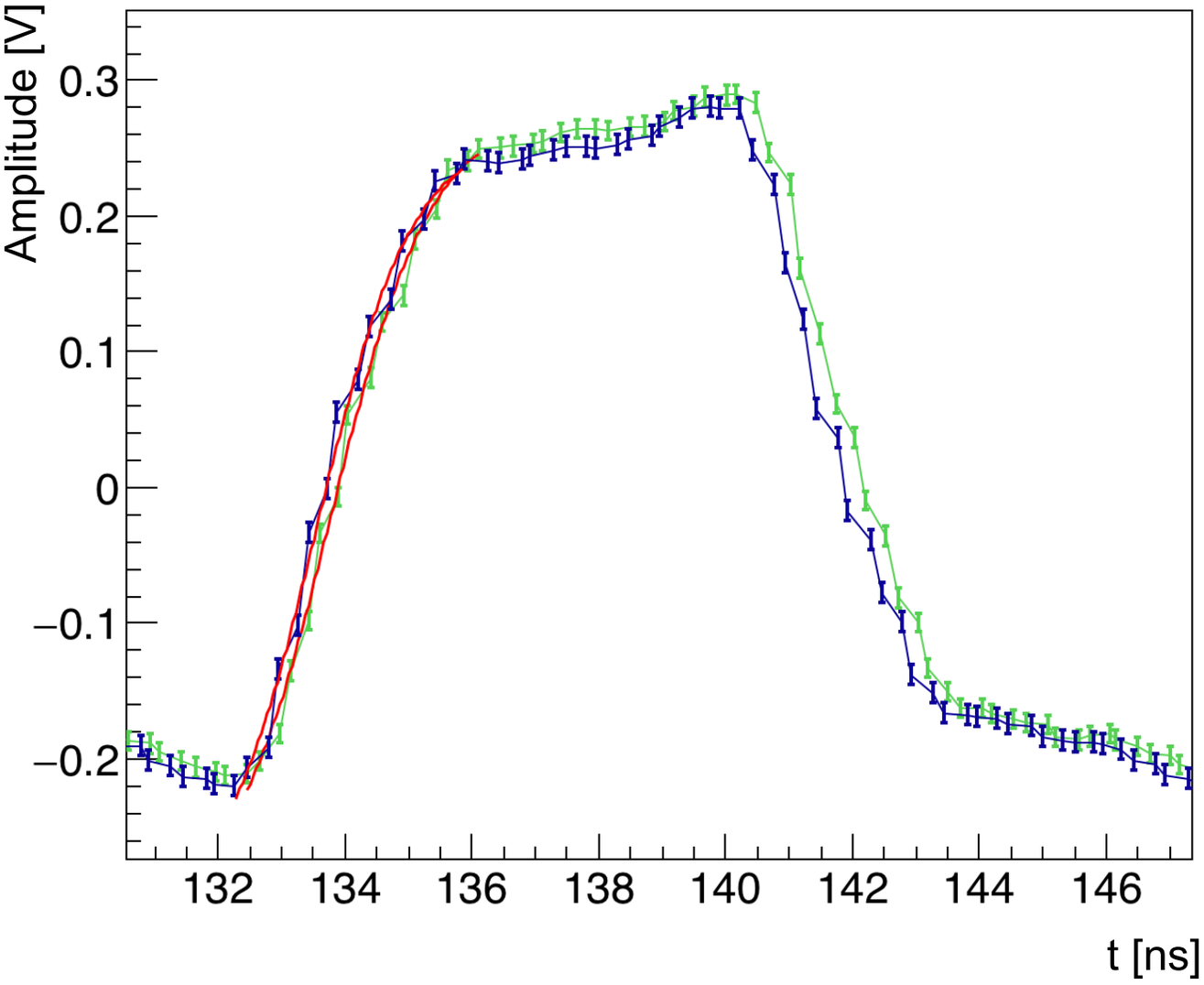
Time jitter: ΔClock calculation

@ CNAO

TW … iven by CH 16 and CH 17 res… computing the Time of Flight this…

The … etrized with the function f_c, obt…

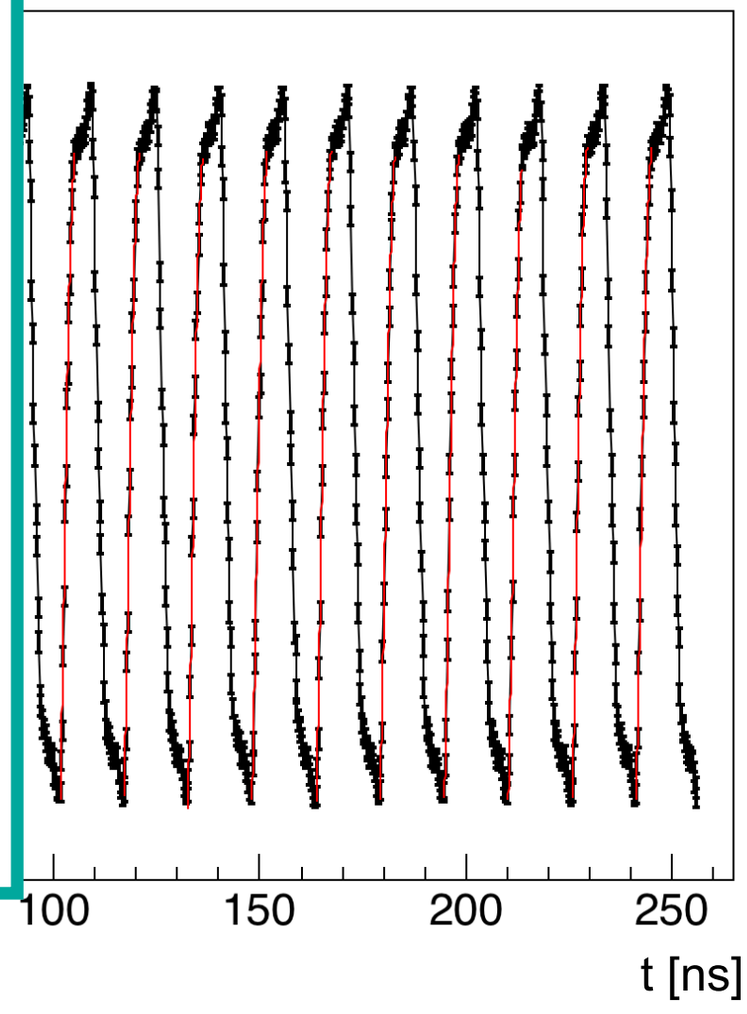
Margarita and TW clock curves



TW: green curve

Margarita: blu curve

…rita clock curve



Time jitter: ΔClock calculation

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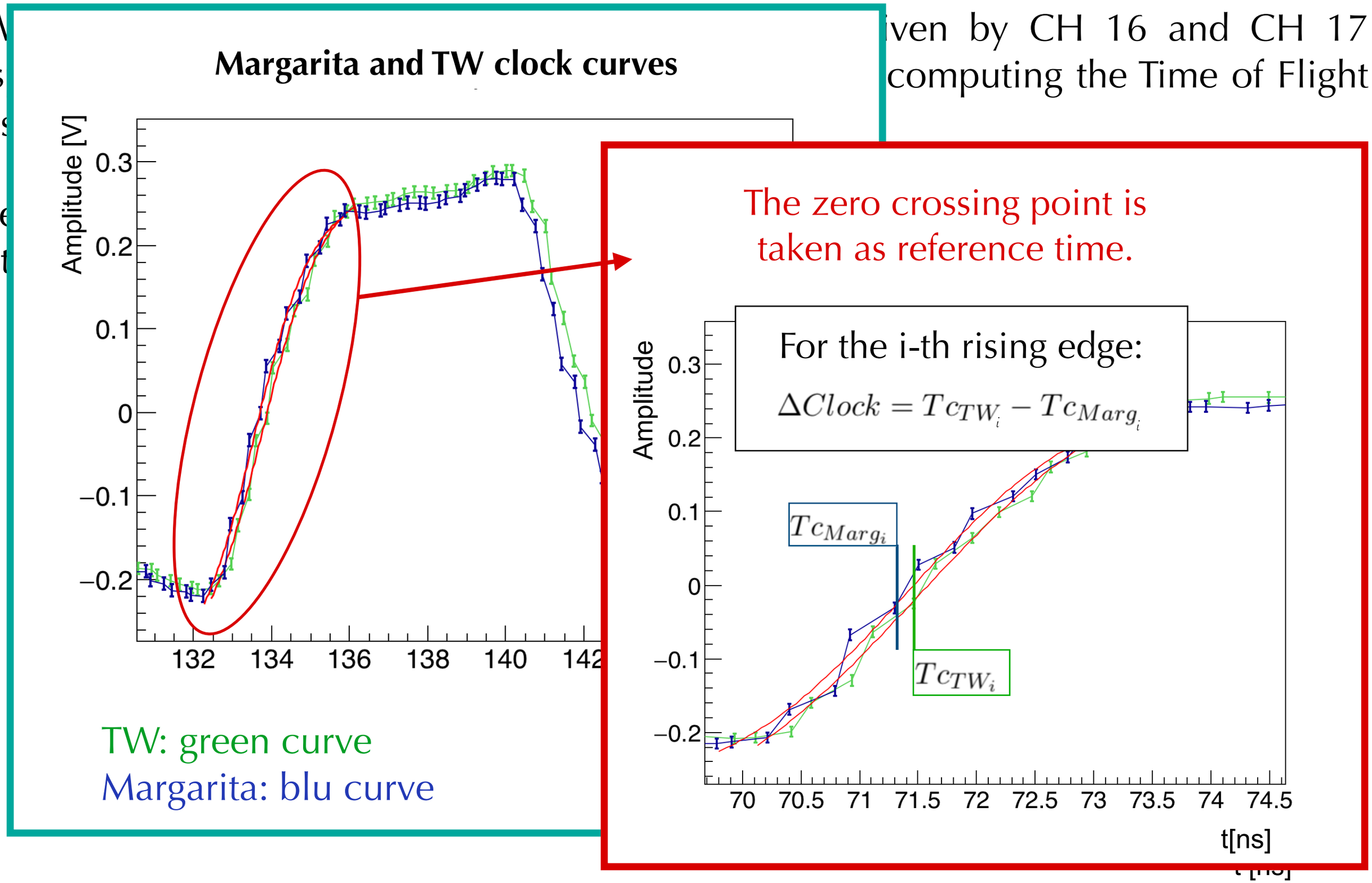
TW … iven by CH 16 and CH 17 res… computing the Time of Flight this…

The… obt…



Time jitter: ΔClock calculation

@ CNAO

We decided to fit all the Margarita and TW rising edges, than the ΔClock is evaluated as the difference between the average clock times of the TW and the one of the Margarita.

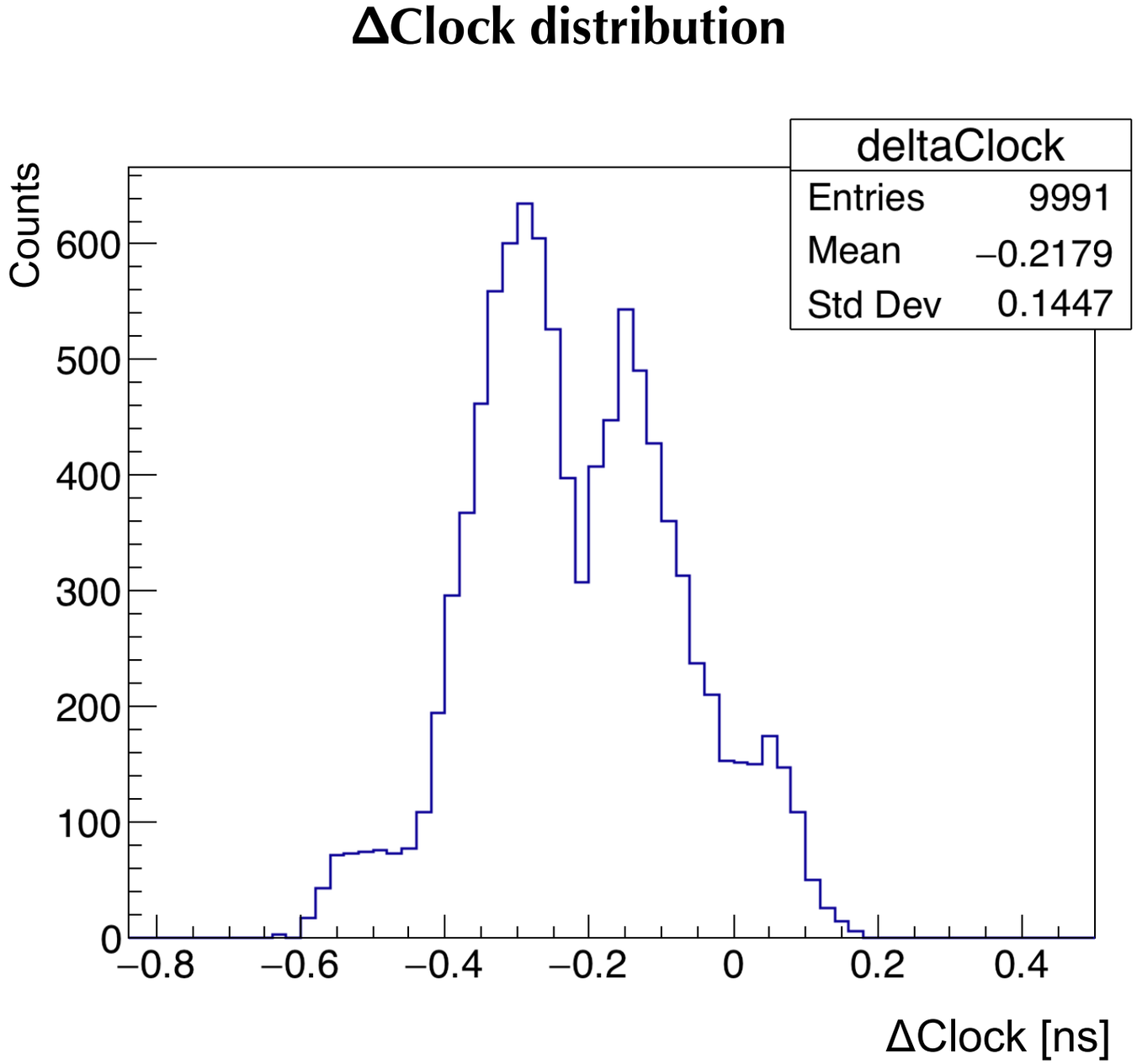
$$\Delta Clock = \overline{Tc_{TW}} - \overline{Tc_{Marg}}$$

with

$$\overline{Tc_{Marg}} = \frac{\sum Tc_{Marg_i}}{N}$$

$$\overline{Tc_{TW}} = \frac{\sum Tc_{TW_i}}{N}$$

The peaks have to be still understood



Time of Flight resolution evaluation

@ CNAO

Time of Flight 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:

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

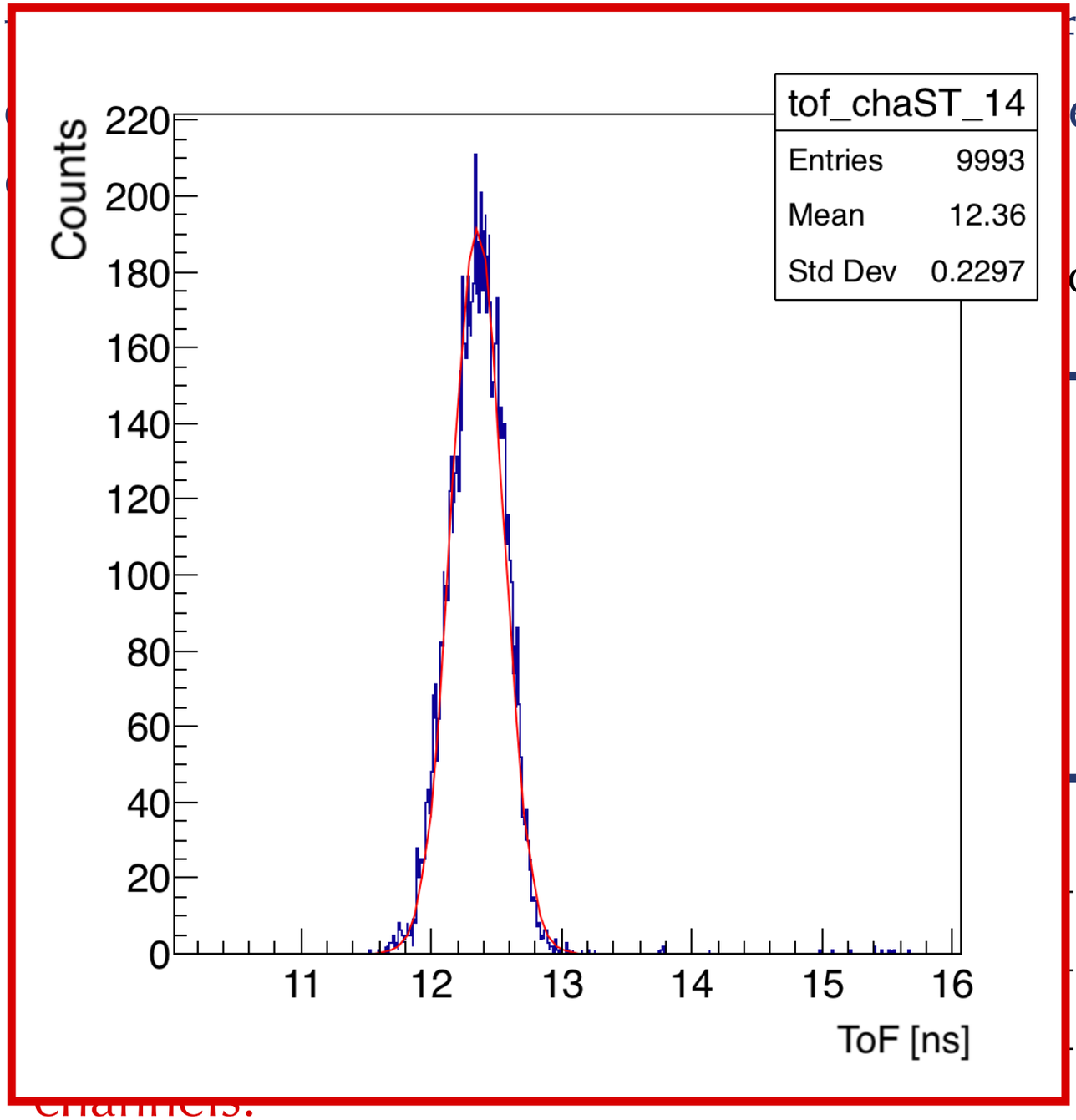
The σ values are the ones extracted from the ToF distribution measured by each Margarita channels.

CH	σ	CH	σ
8	0.165 ns	**12**	0.219 ns
9	0.230 ns	**13**	0.152 ns
10	0.248 ns	**14**	0.147 ns
11	0.210 ns	**15**	0.147 ns

E = 115 MeV/n

Time of Flight resolution evaluation

@ CNAO



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

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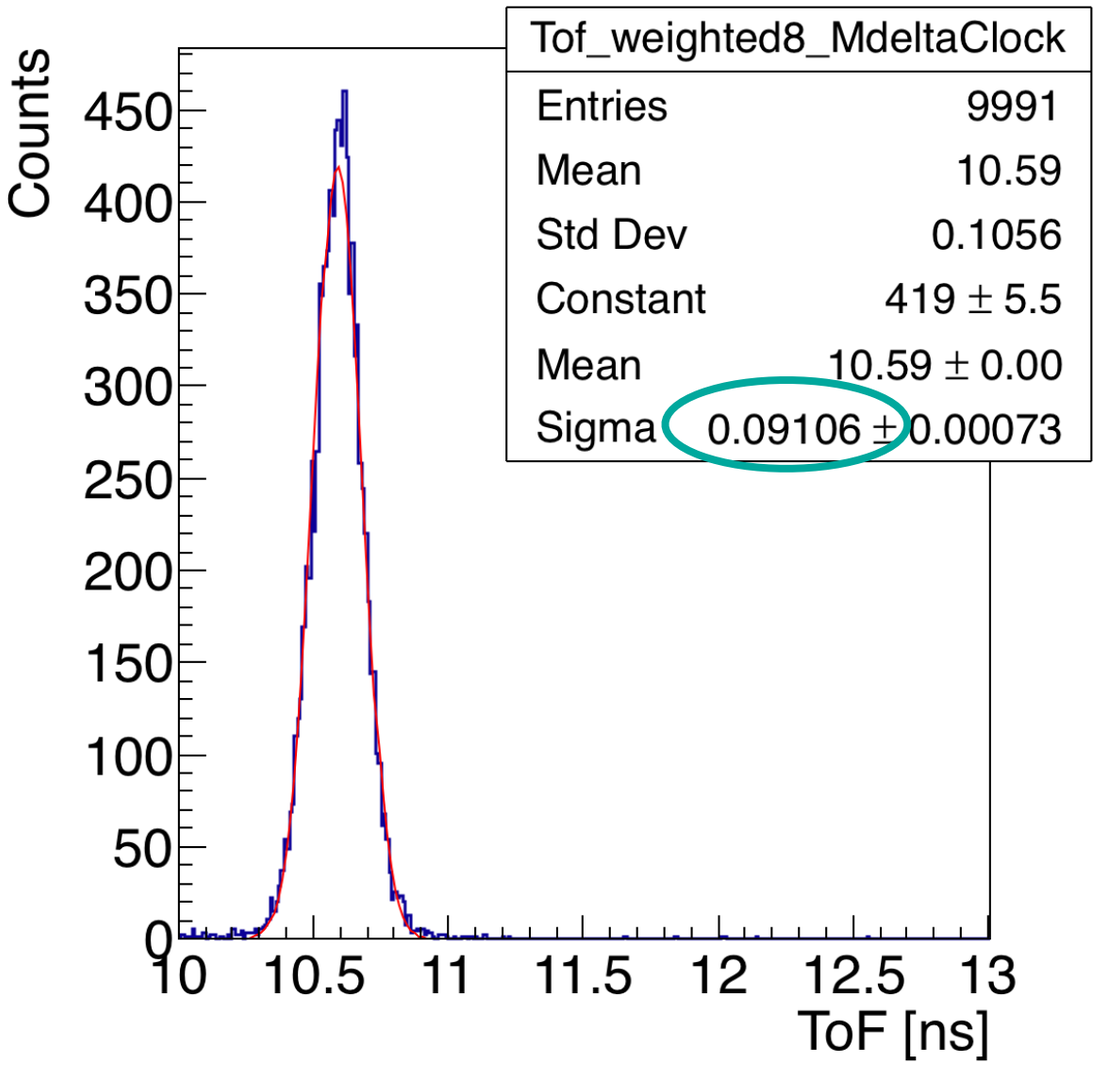
E = 115 MeV/n

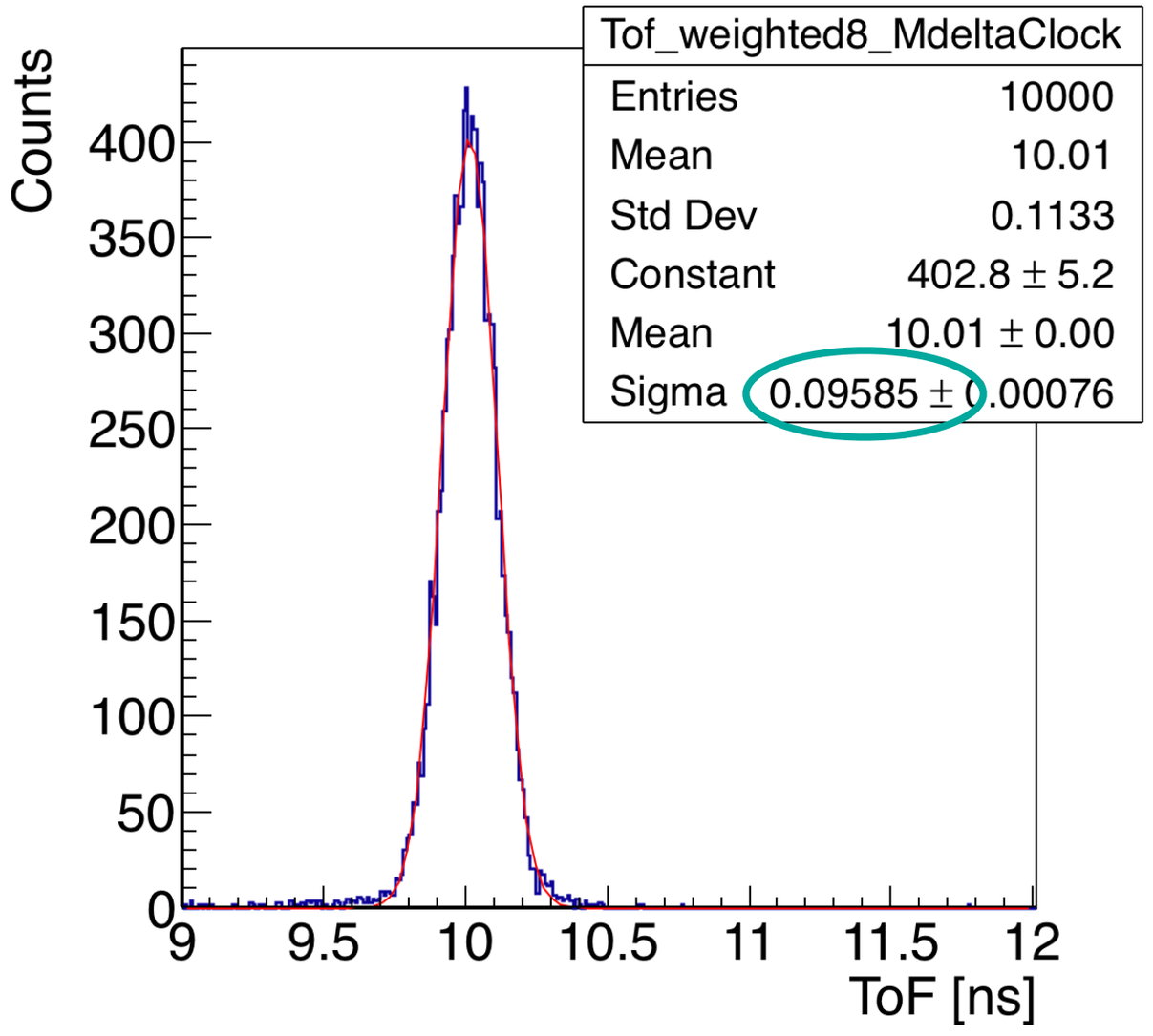
Time of Flight resolution evaluation

@ CNAO

115 MeV/n



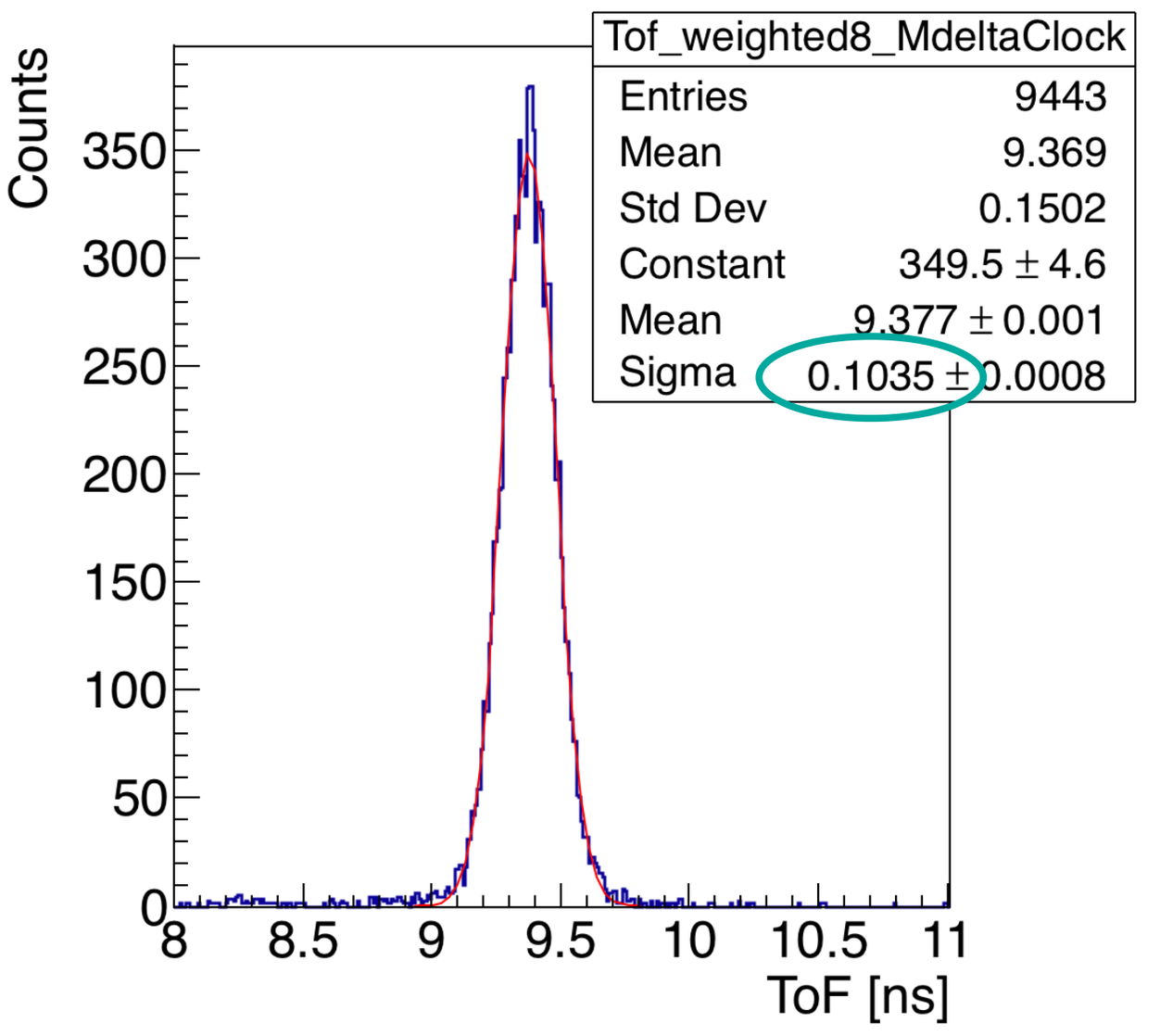
151 MeV/n



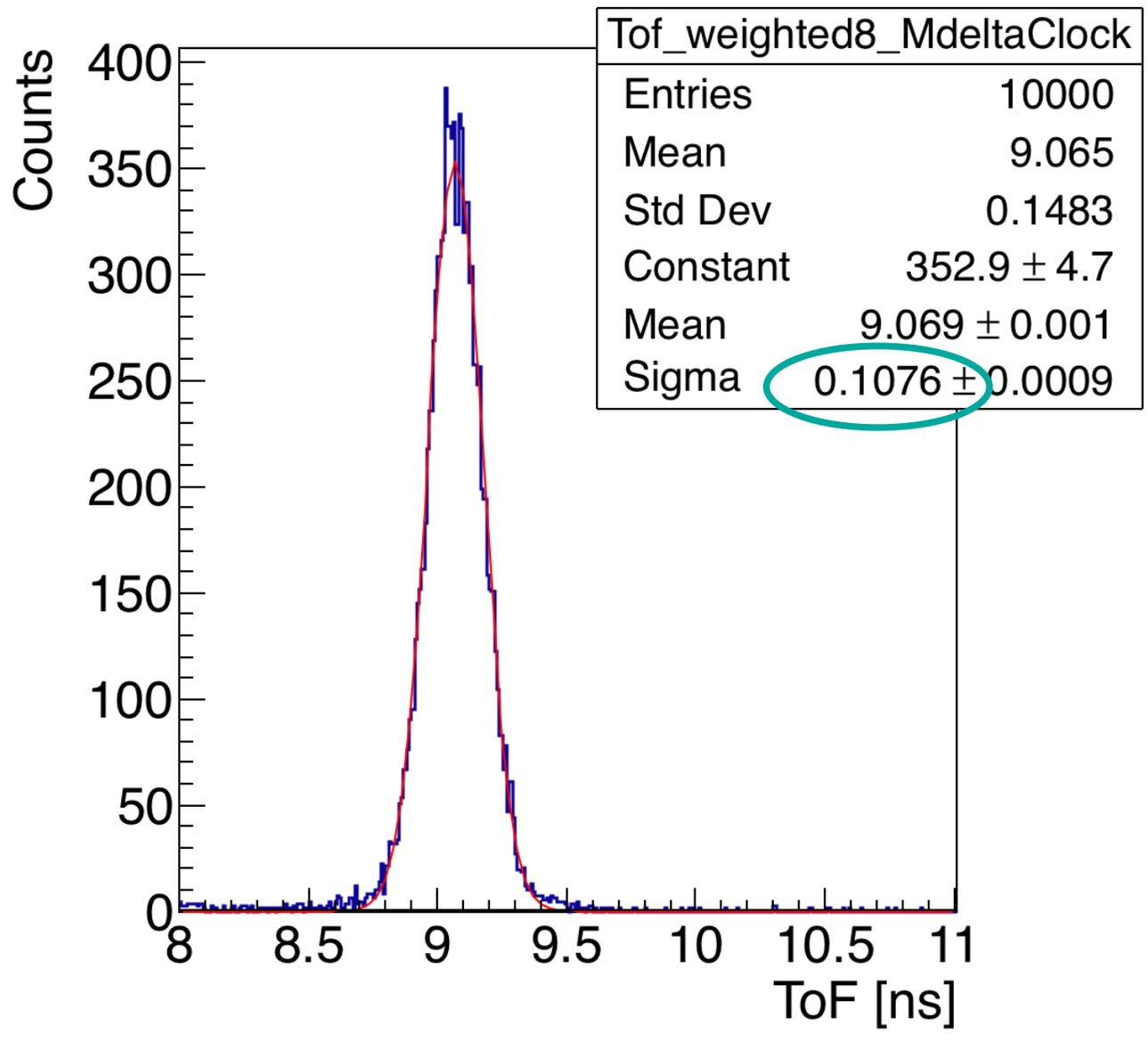
Time of Flight resolution evaluation

@ CNAO

221 MeV/n



280 MeV/n



ToF resolution (Carbon)

@ CNAO

Energy [MeV/n]	σ(ToF) [ns]	σ(Margarita) [ns]
115 MeV/n	0.091 ns	0.082 ns
151 MeV/n	0.095 ns	0.086 ns
221 MeV/n	0.103 ns	0.094 ns
280 MeV/n	0.108 ns	0.100 ns

The Margarita resolution has been evaluated assuming the TW resolution of the order of 40 ps.

Based on the statistics, since the arrival time on the Margarita is evaluated as the weighted average of the arrival times measured by each channel, the expected resolution for the Margarita is given by:

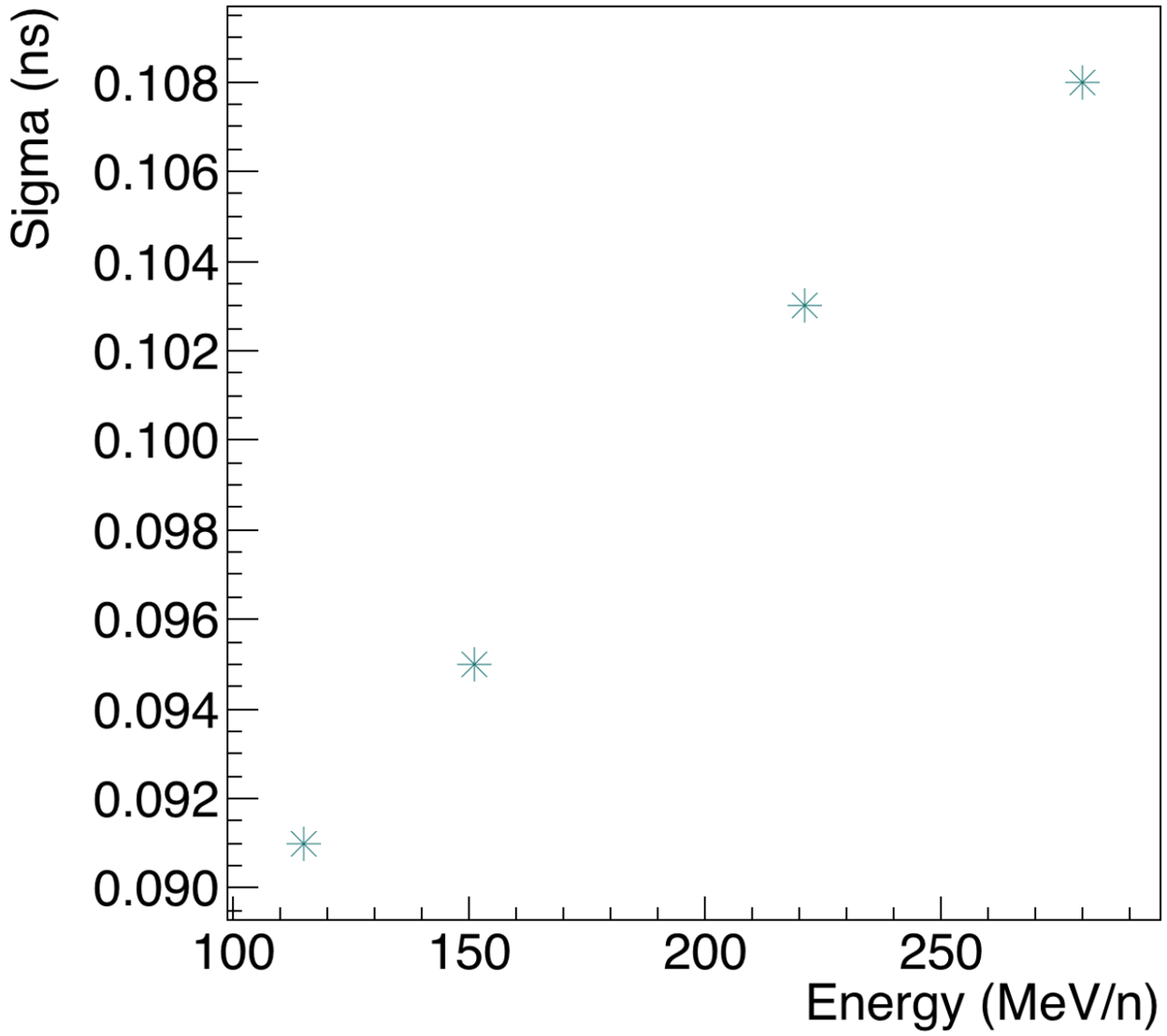
$$\overline{Marg} = \frac{\sum \frac{marg_i}{\sigma_i}}{\sum \frac{1}{\sigma_i^2}} \qquad \sigma[\overline{Marg}] = \frac{\sqrt{\sum \frac{1}{\sigma_i^2}}}{\sum \frac{1}{\sigma_i^2}} = \sqrt{\frac{1}{\sum \frac{1}{\sigma_i^2}}}$$

The expected Margarita σ is: 60-80 ps

ToF resolution (Carbon)

@ CNAO

Energy [MeV/n]	σ(ToF) [ns]
115 MeV/n	0.091 ns
151 MeV/n	0.095 ns
221 MeV/n	0.103 ns
280 MeV/n	0.108 ns



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the order of 40 ps.

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average of the arrival times measured
resolution for the Margarita is given b

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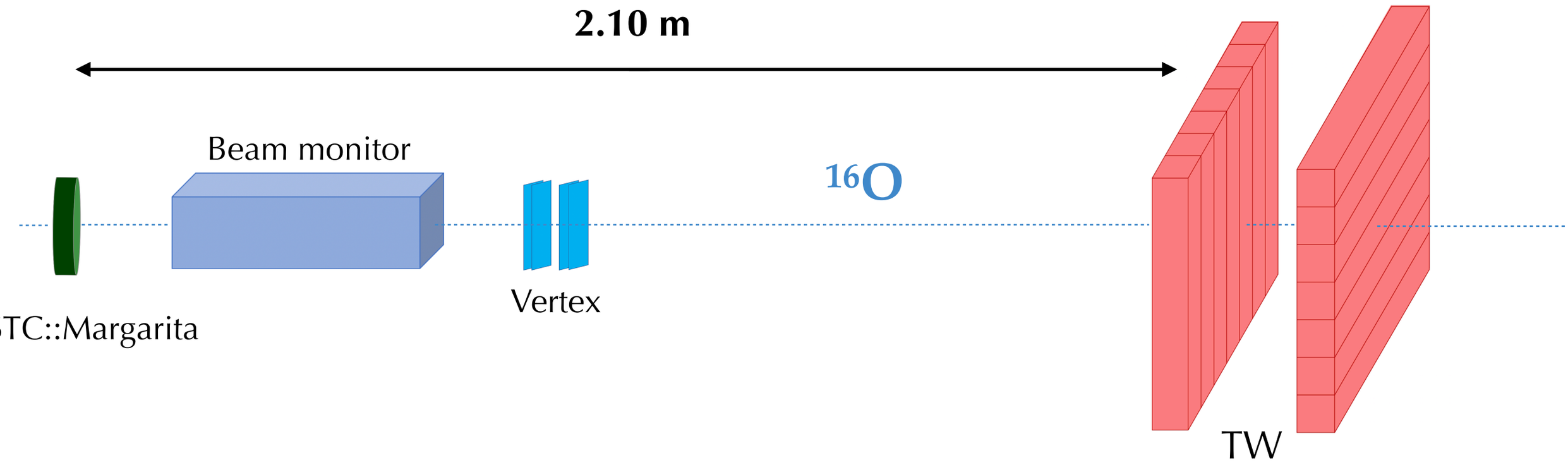
the expected
Margarita σ is: 60 ps

Beam test @ GSI 2019



Run:
^{16}O beam at 400 MeV/n, NO TARGET.

The results presented hereafter are only related to the run at 400 MeV/n: the other runs are currently being processed.

`run_wd_00002210.data`

Beam test @ GSI 2019

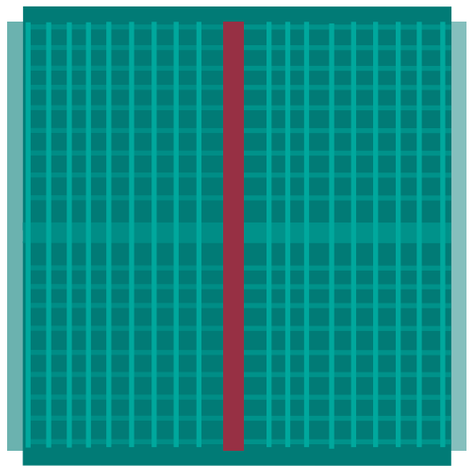
@ GSI

Electronic Setup:

7 boards:

1. Six for the TW (boards 78, 86, 80, 81,82 and 94): each of them contains 15 readout channels (CH 0- CH 15) and one clock channel (CH 16).
2. One for the Margarita (board 27): 8 readout channels (CH 0-CH 7) and one clock channel (CH 17).

In this analysis only the central barrel of the first layer is consider. The arrival time on the TW is evaluated as the average arrival times measured by the two central barrel channels.



GSI data were analyzed using the same method shown in the previous slides for CNAO data.

Arrival time evaluation

@ GSI

As has been done for the data taking @ CNAO, the arrival time is estimated with the CFD method.

After a brief analysis on each Margarita channel ToF we decided to choose:

1. **frac** = 0.4 and **del** = 2 ns for CH 0;
2. **frac** = 0.2 and **del** = 2 ns for CH1 and CH3 to CH7;
3. **frac** = 0.5 and **del** = 2 ns for CH2;

With these parameters, we obtained the following time resolutions evaluated from the ToF distribution measured by each Margarita channel.

CH	σ	CH	σ
0	0.213 ns	**4**	0.136 ns
1	0.229 ns	**5**	0.124 ns
2	0.389 ns	**6**	0.167 ns
3	0.207 ns	**7**	0.151 ns

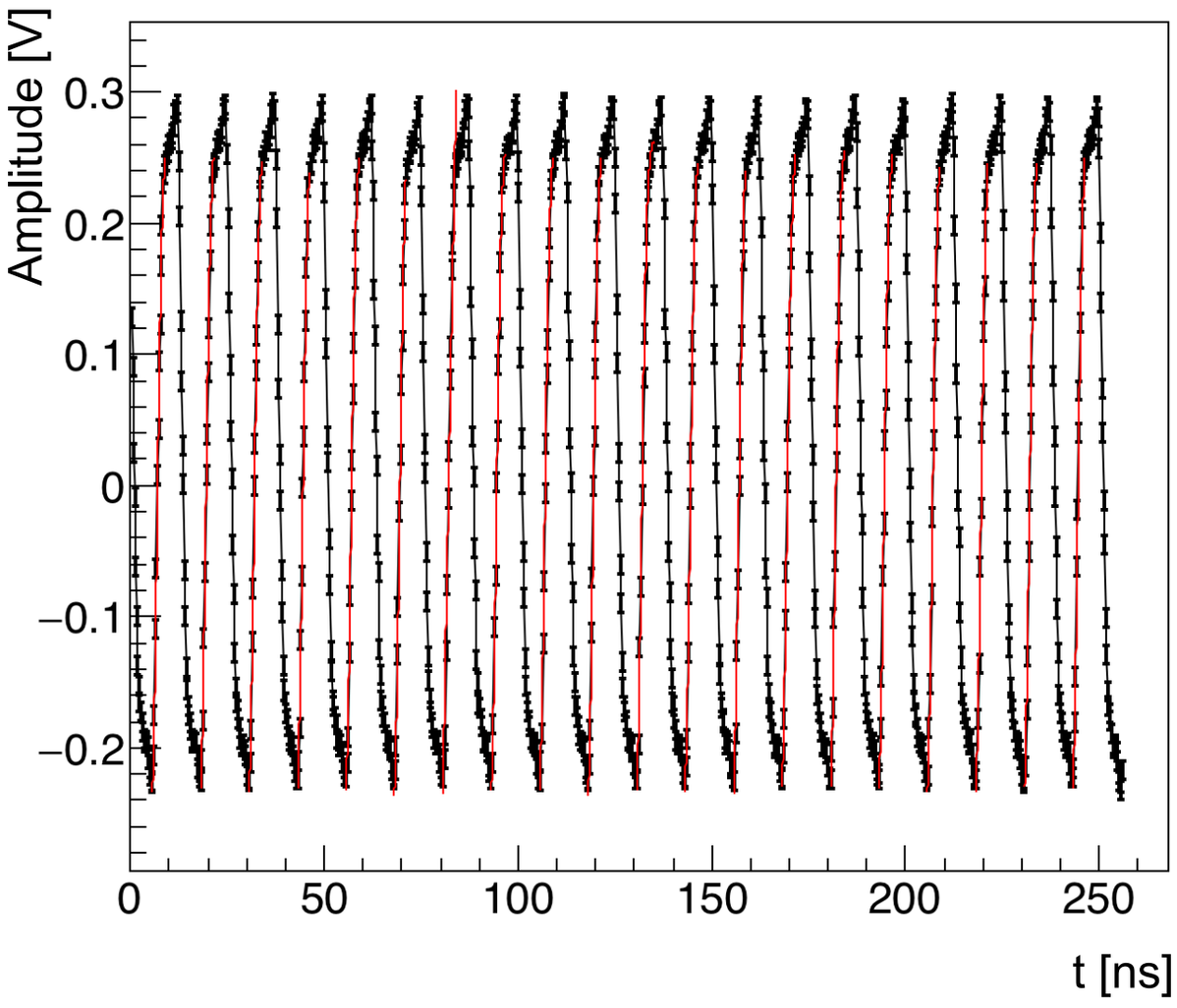
$$ToF_{Marg_i} = \overline{TW} - T_{Marg_i}$$

Time jitter: ΔClock calculation

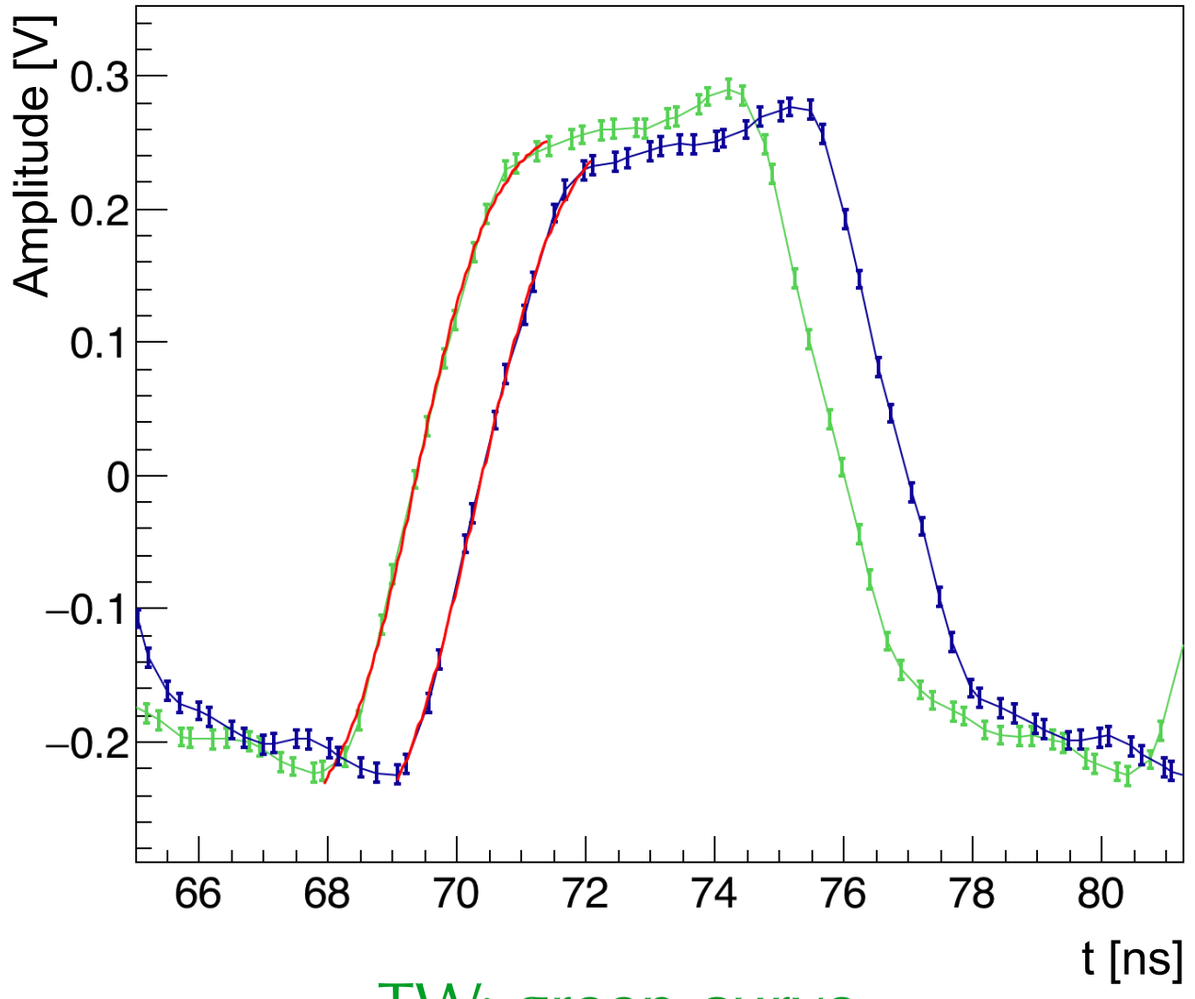
@ GSI

The time jitter is evaluated with the same method used for the data taking @ CNAO.

Margarita clock curve



Margarita and TW clock curves



TW: green curve

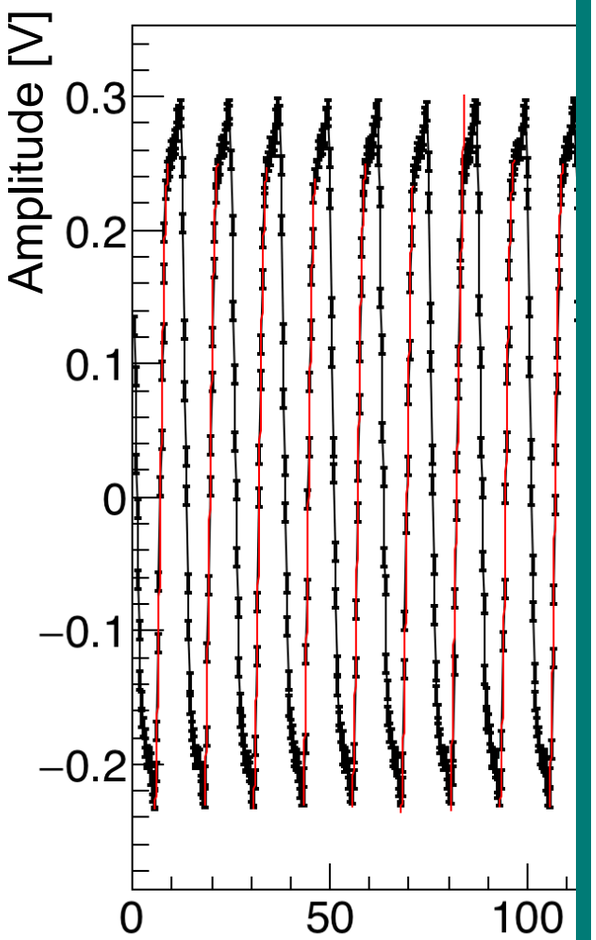
Margarita: blu curve

Time jitter: ΔClock calculation

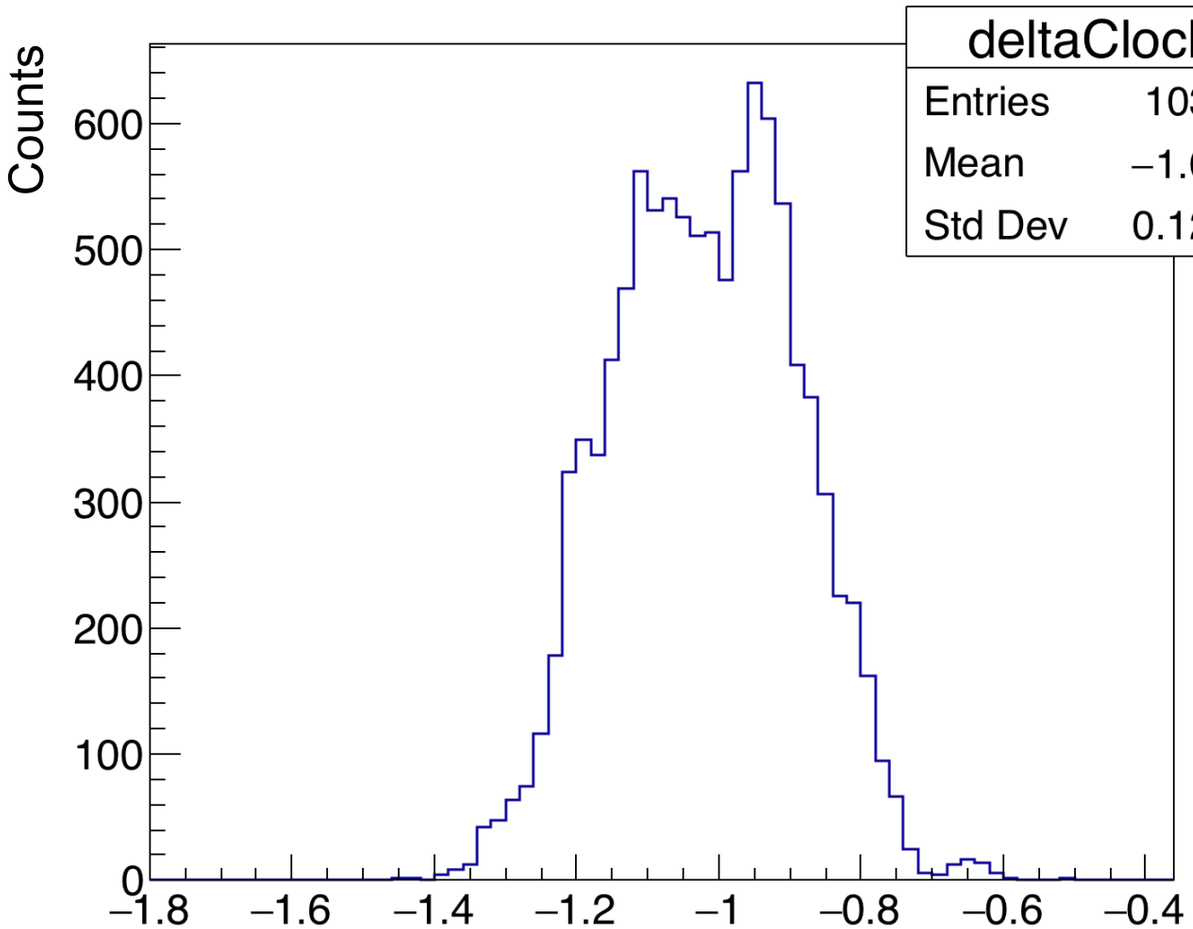
@ GSI

The time jitter is evaluated with the same method used for the data taking @ CNAO.

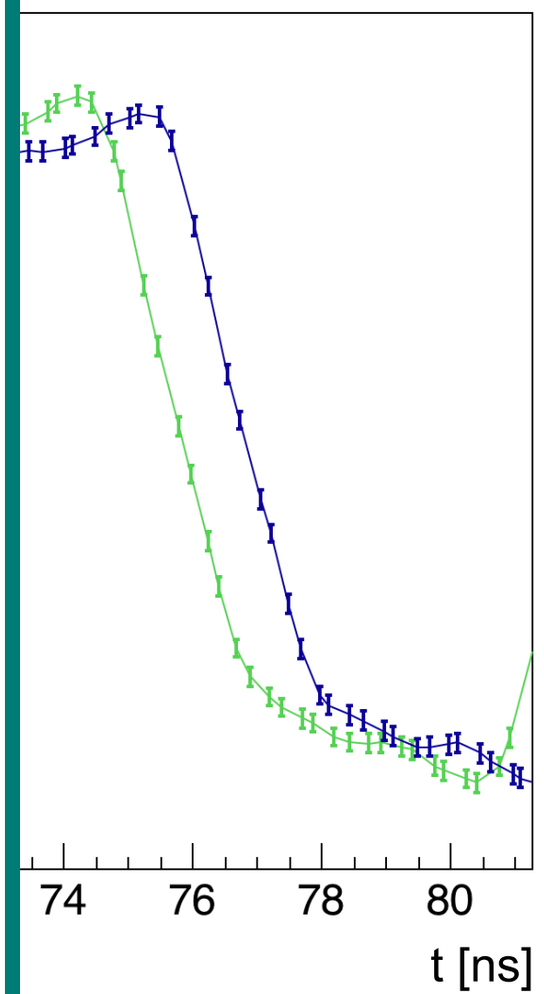
Margarita



ΔClock distribution



TW clock curves

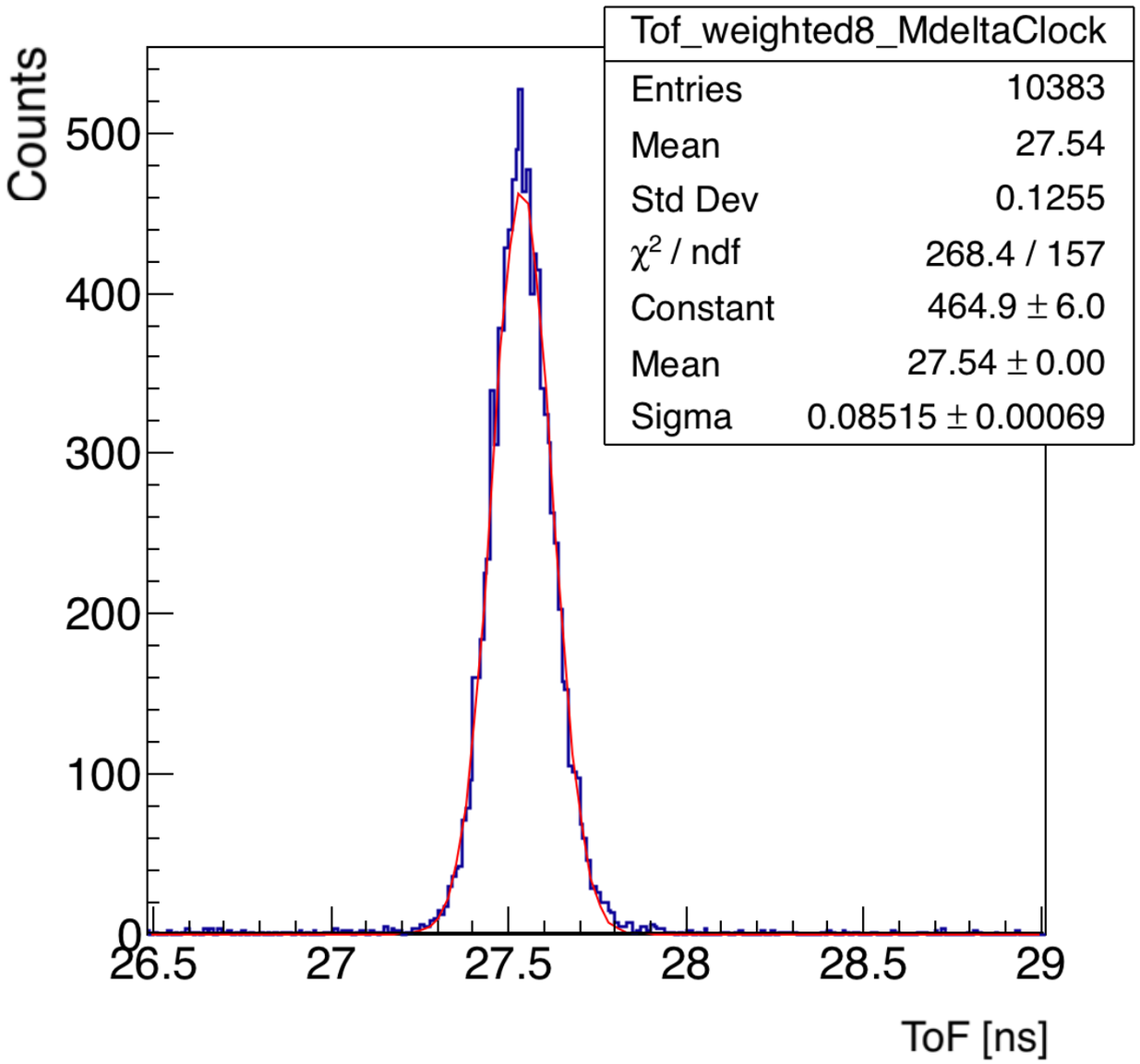


curve

Margarita: blu curve

Time of Flight resolution evaluation

@ GSI



Time of Flight 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.

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

ToF resolution (Oxygen)

@ GSI

Energy [MeV/n]	σ(ToF) [ns]	σ(Margarita) [ns]
400 MeV/n	0.085 ns	0.075 ns

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

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

The expected Margarita σ is: 61 ps

Conclusions

We obtained the following ToF and Margarita resolutions:

Ion	Energy [MeV/n]	σ(ToF) [ns]
^{12}C	**115 MeV/n**	**0.091 ns**
	151 MeV/n	**0.095 ns**
	221 MeV/n	**0.103 ns**
	280 MeV/n	**0.108 ns**
^{16}O	**400 MeV/n**	**0.085 ns**

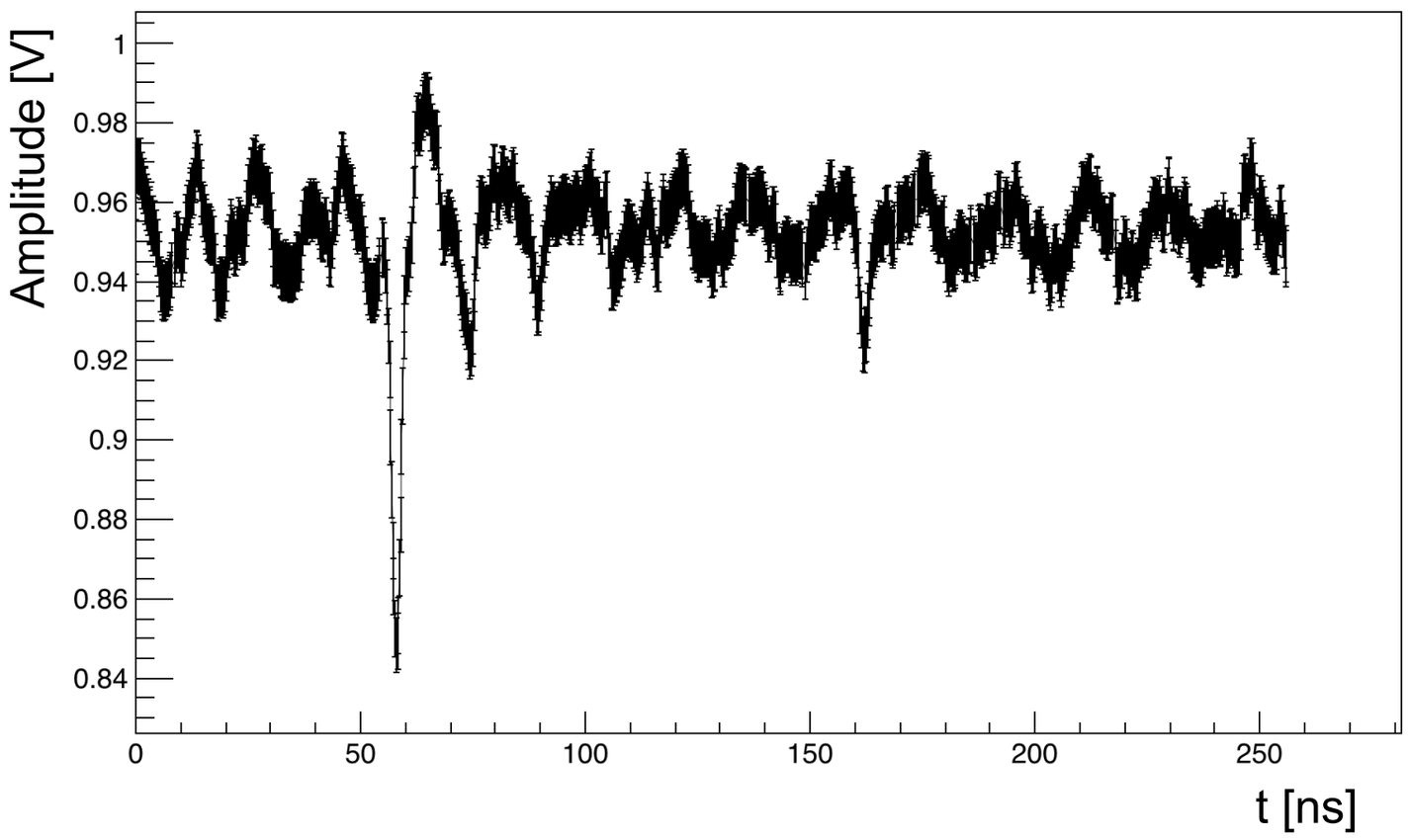
1. The resolution for the oxygen at 400 MeV/n should be of consistent with that of carbon at ~ 200 MeV/n, but at present we find a different result that has to be understood.

2. We are still working in order to recover the expected resolution (~ 60-80 ps).

Conclusions

3. We need to improve the clock curve parametrization and the ΔClock evaluation;

4. Concerning the oxygen, at GSI we observed a relevant noise superimposed to the signals in ~ 3-4% of the events.

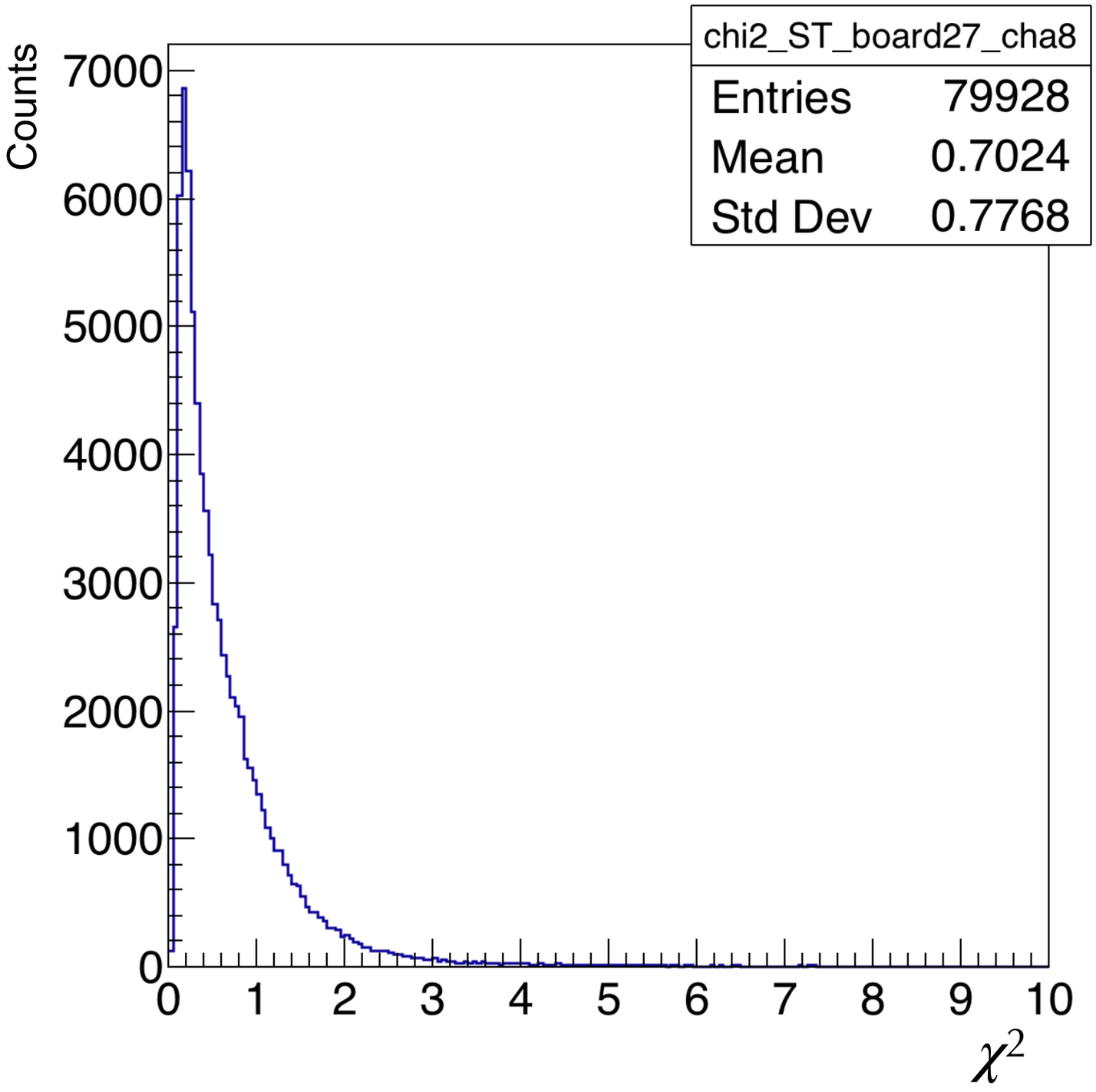


So far the noise has not been taken into account: we do not expected a big impact on the final conclusions but we will implement the proper noise subtraction ASAP.

SPARE SLIDES

Fit goodness: χ^2 distribution

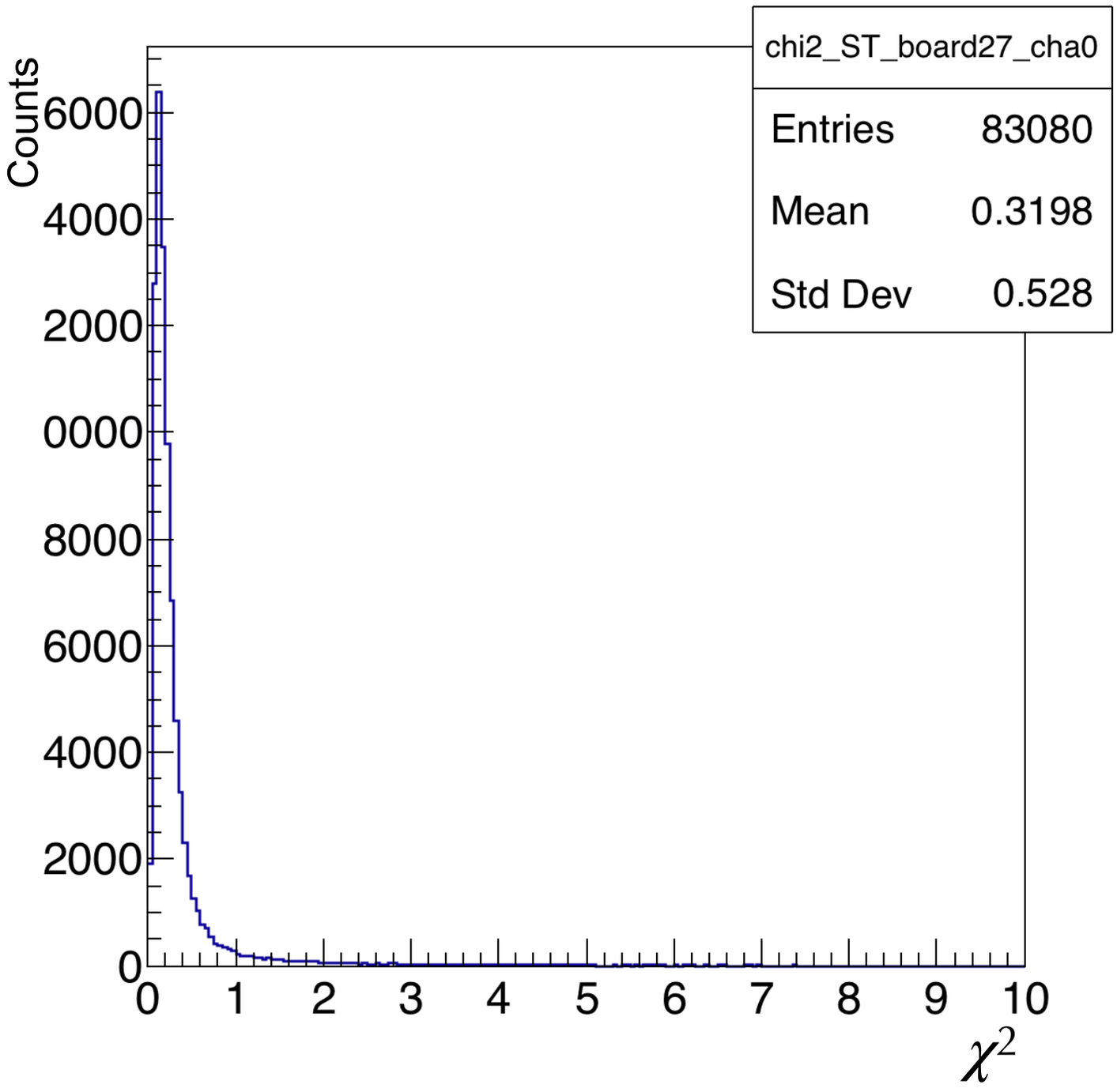
@ CNAO



χ^2 distribution for all Margarita channels

Fit goodness: χ^2 distribution

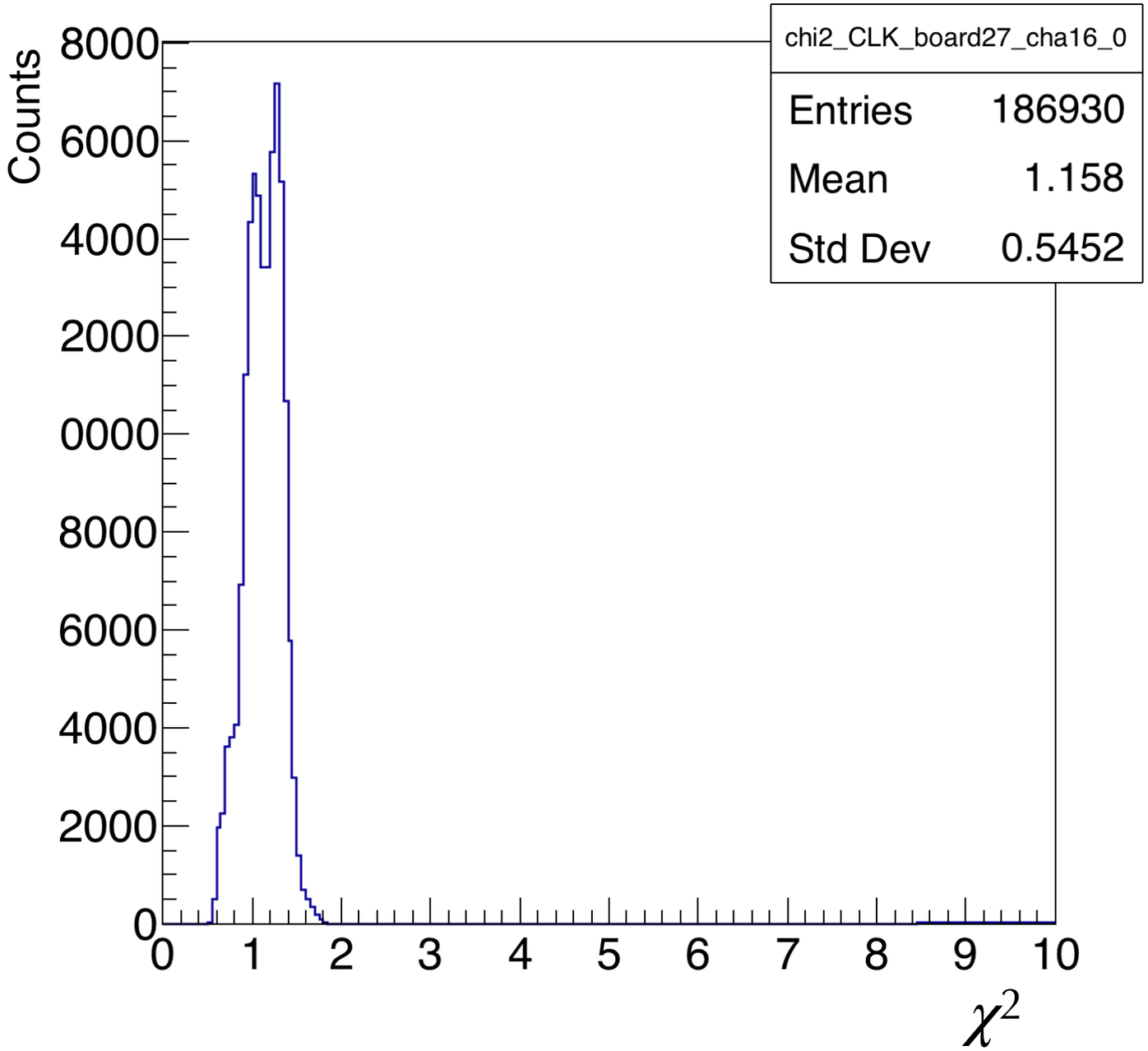
@ GSI



χ^2 distribution for all Margarita channels

Fit goodness: χ^2 distribution

@ GSI



χ^2 distribution for all the rising edge of the Margarita clock curves.