ToF analysis update

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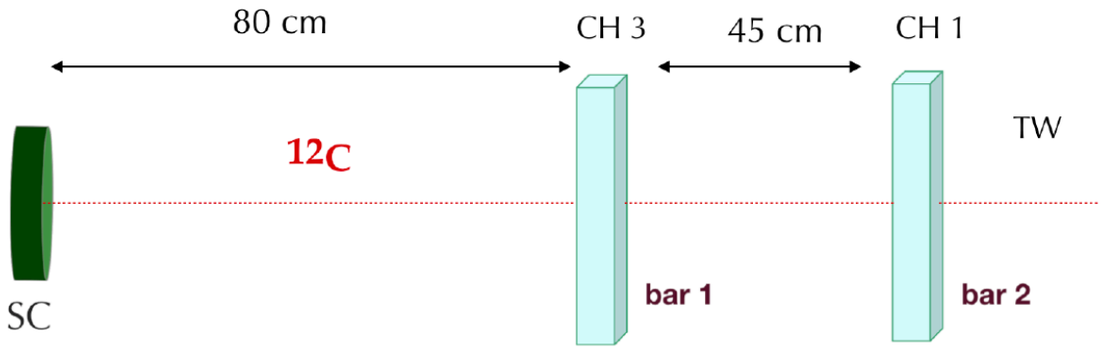
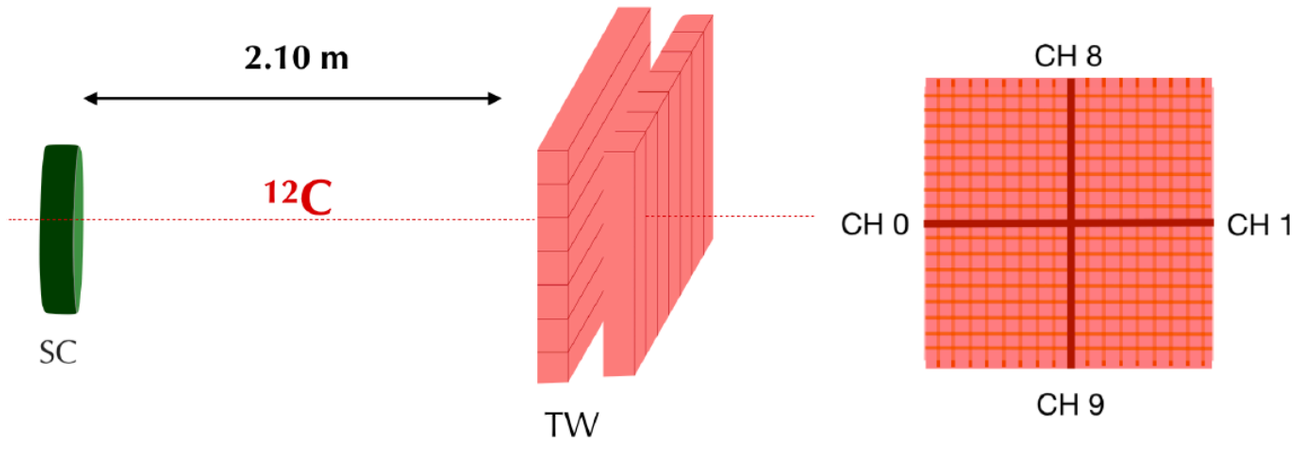
Experimental setup

1) CNAO1



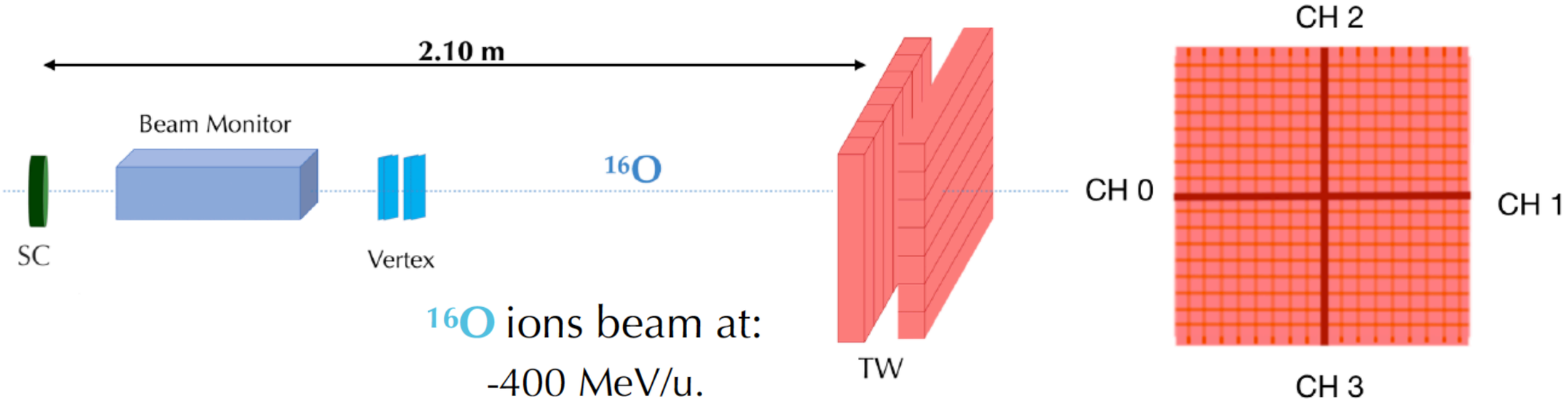
^{12}C ions beam at:
-115 MeV/u;
-151 MeV/u;
-221 MeV/u;
-280 MeV/u.

2)CNAO2



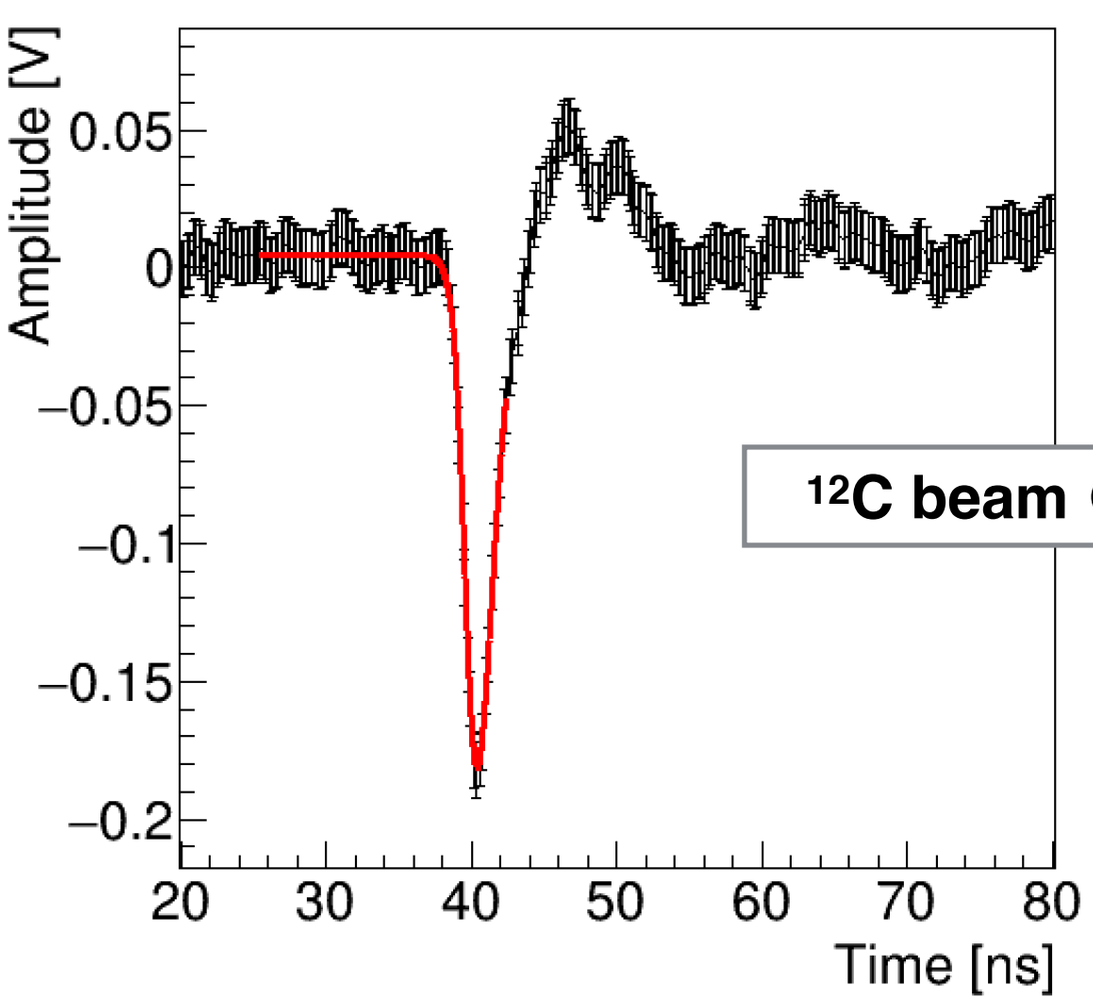
^{12}C ions beam at:
-115 MeV/u;
-260 MeV/u;
-400 MeV/u.

3) GSI

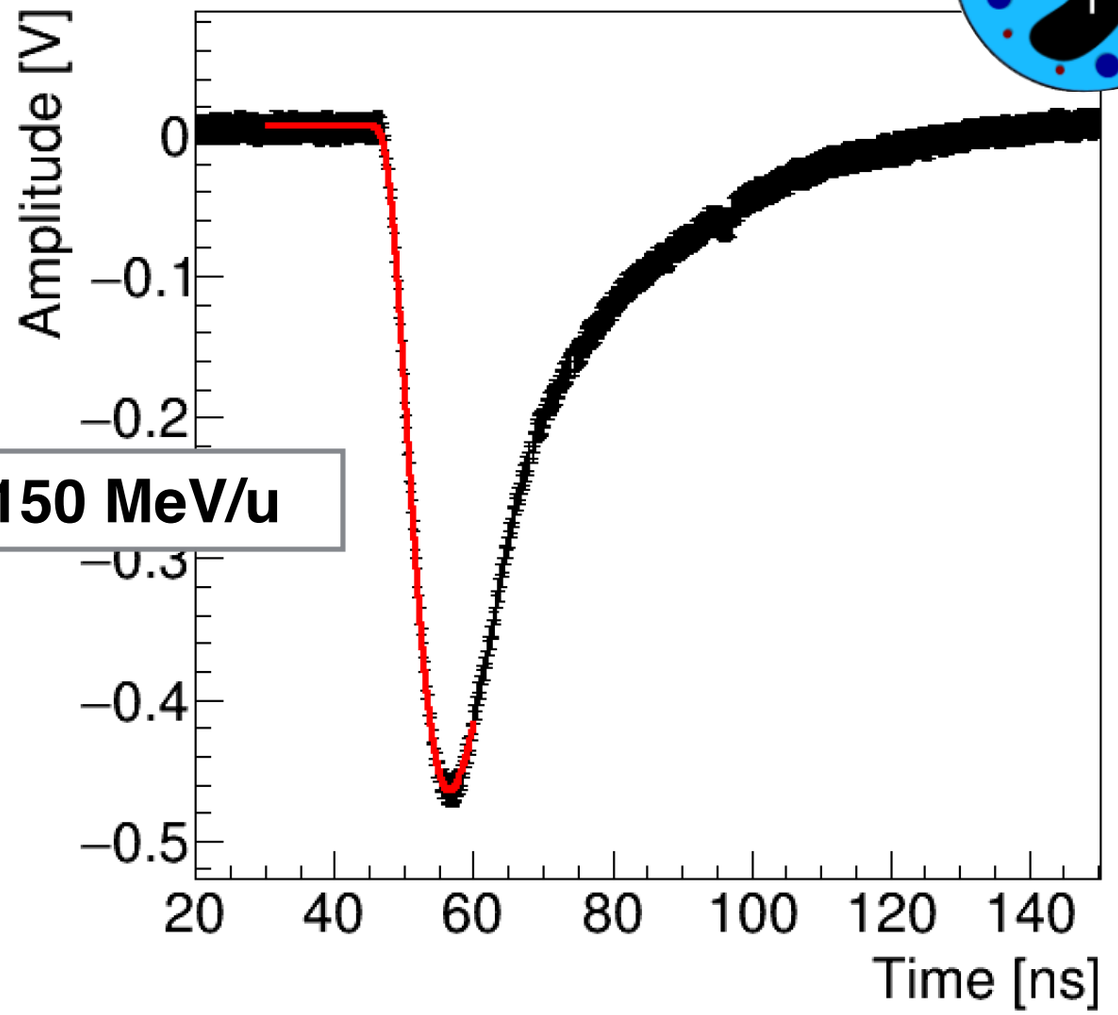


^{16}O ions beam at:
-400 MeV/u.

Waveform processing



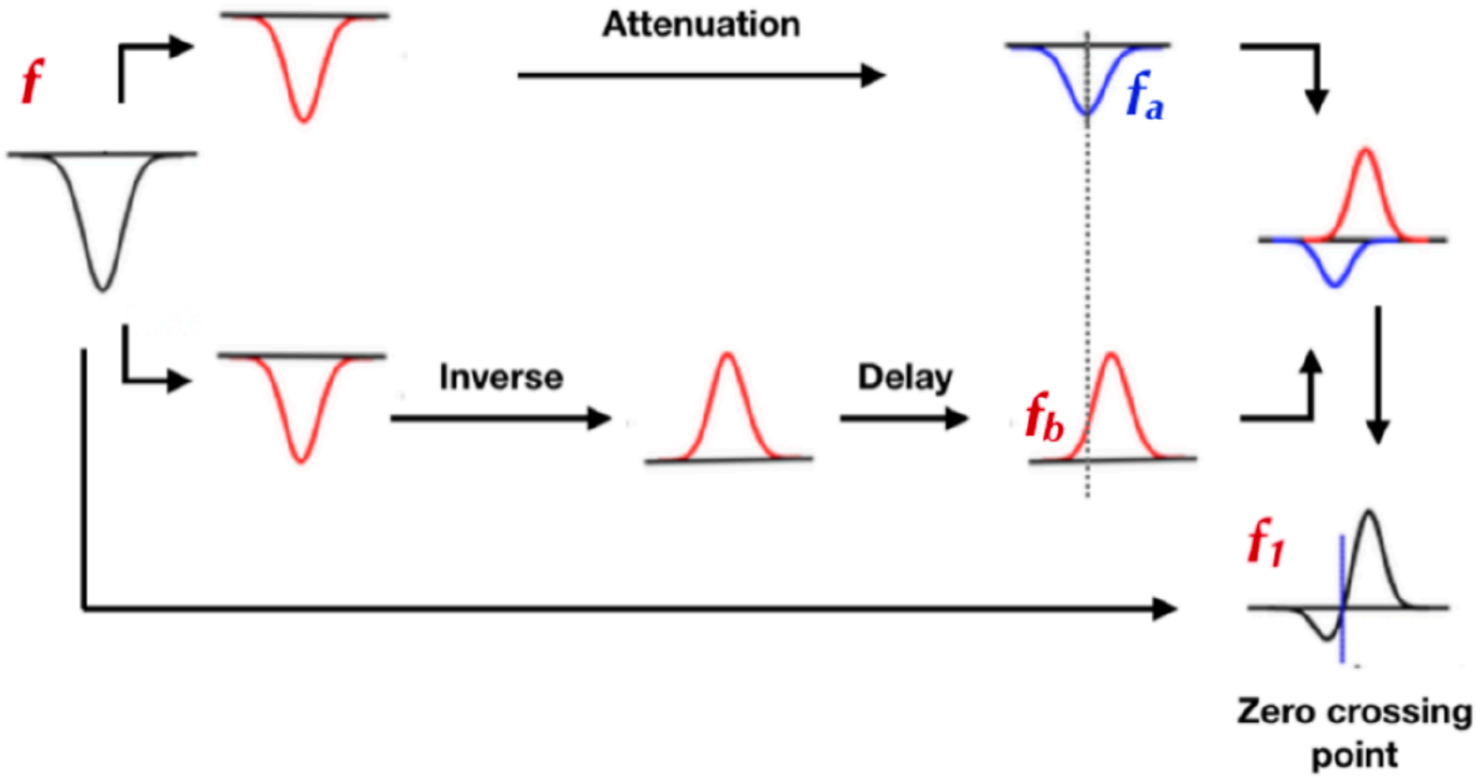
^{12}C beam @ 150 MeV/u



- Waveforms are fitted with double Fermi-Dirac (ST) and LogNormal distributions (TW)
- **CFD** algorithm to extract the arrival time of the single channels in the acquisition window (~200 ns)
- Start Counter time (**t_ST**)-> **weighted average** between channels according to their resolution
- ΔE - ToF time of single bar (**t_TW)**-> **arithmetic average** of the up-down channels

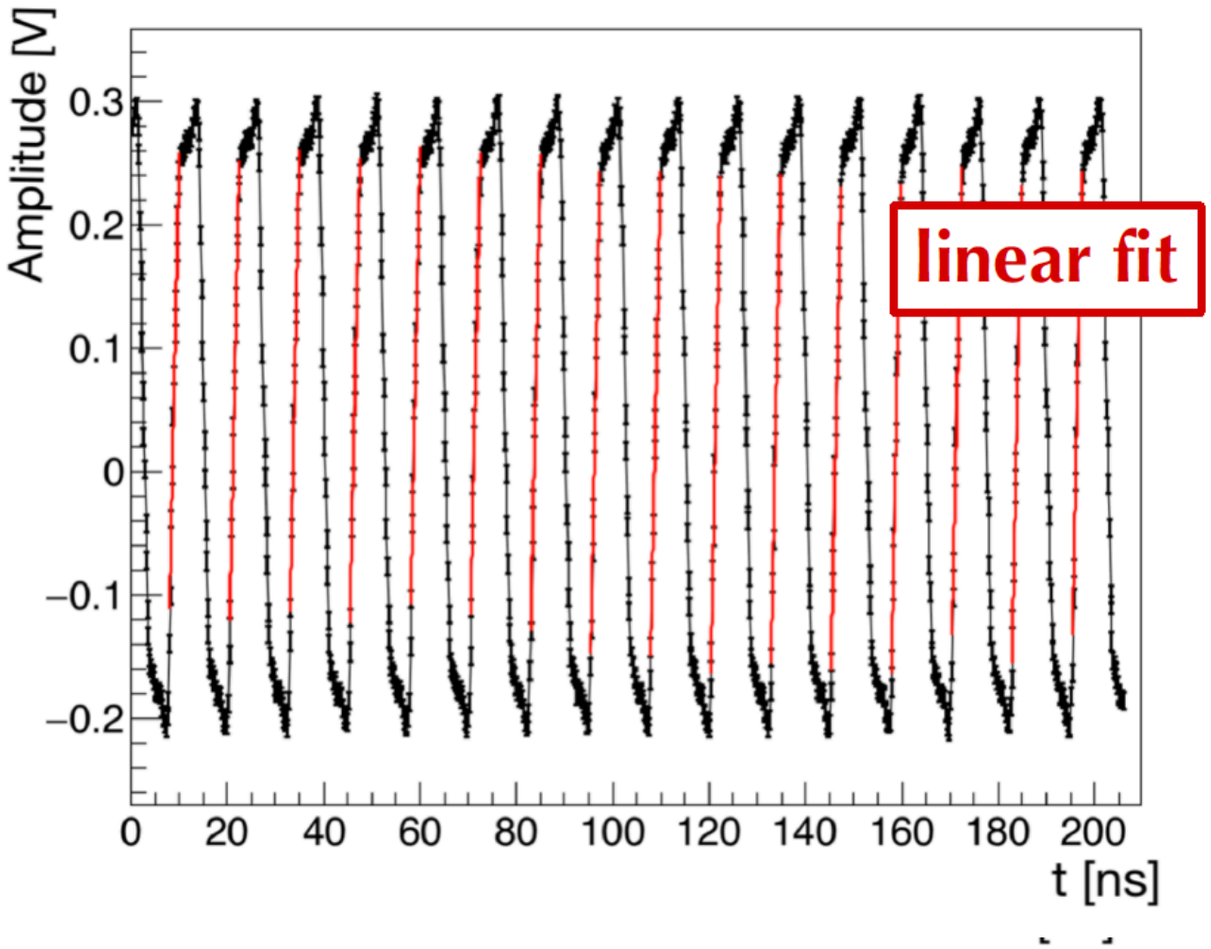
CFD Optimisation

- **Fraction** and **delay** parameters are tuned to optimise the time resolution

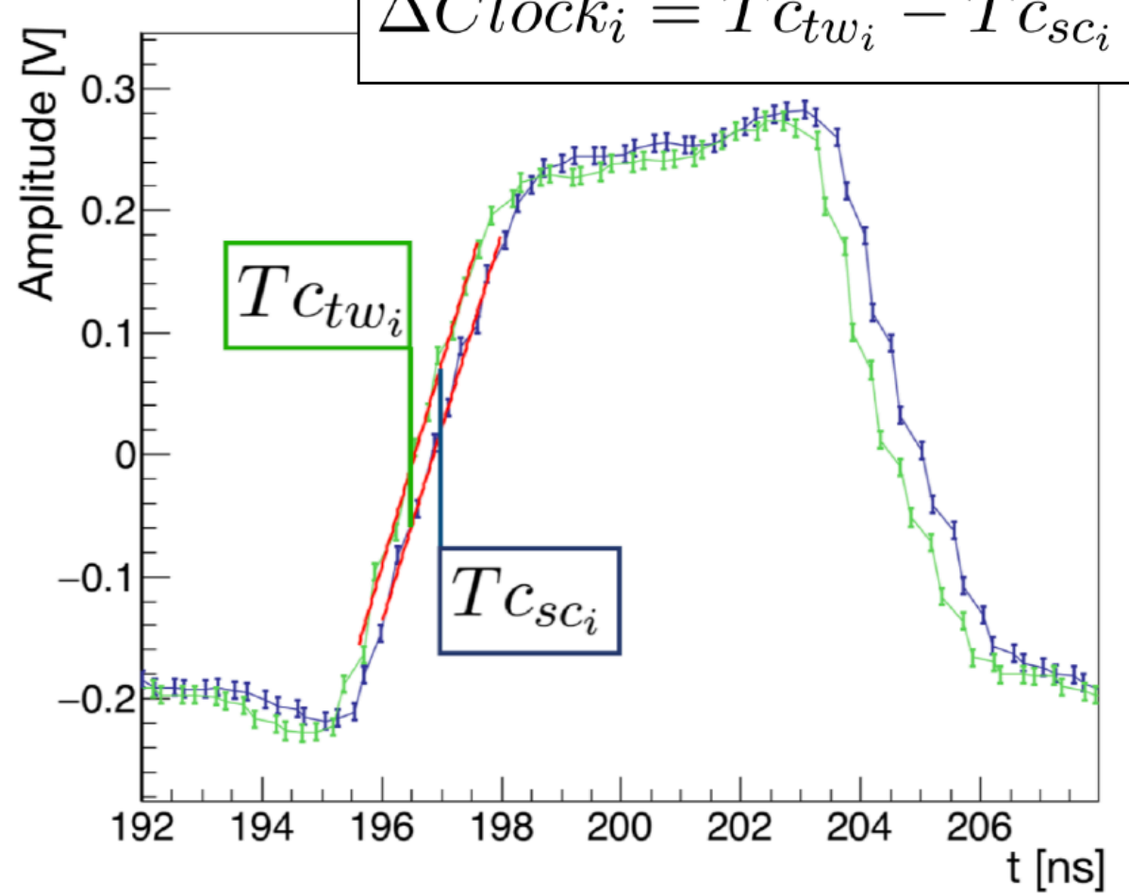


- ST: each channel is optimised studying the ToF resolution of the single channels (**varying in the range 120ps - 300ps** with 12C @ 115 MeV/u). Frac and del parameters are included in a configuration file.
- TW: each channel is optimised minimising the resolution of the Δt between the central bar time.

Clock jitter subtraction



$$\Delta Clock_i = Tc_{tw_i} - Tc_{sc_i}$$



$$\overline{\Delta Clock} = \overline{Tc_{tw}} - \overline{Tc_{sc}}$$

$$\overline{Tc_{tw}} = \frac{\sum_i Tc_{tw_i}}{N} \qquad \overline{Tc_{sc}} = \frac{\sum_i Tc_{sc_i}}{N}$$

- Linear fit of the clk rising edges
- ΔClock taken as the average difference between each zero-crossing time

ToF resolution

^{12}C-CNAO1

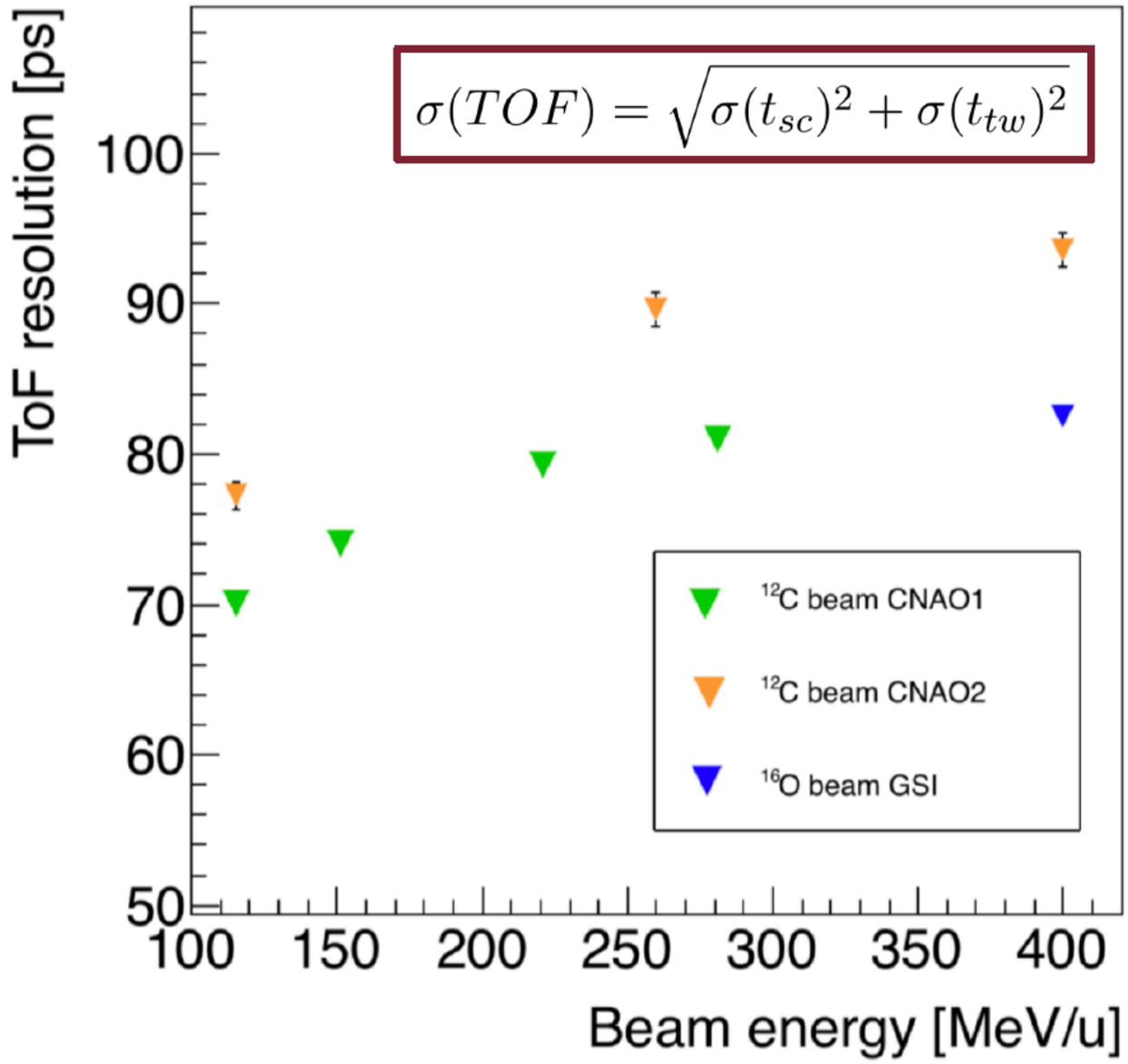
Energy [MeV/u]	$\sigma(TOF)$ [ps]
115	69.6 ± 0.6
151	73.6 ± 0.6
221	78.9 ± 0.7
280	80.1 ± 0.7

^{12}C-CNAO2

Energy [MeV/u]	$\sigma(TOF)$ [ps]
115	76.9 ± 1.0
260	88.9 ± 1.1
400	93.2 ± 1.1

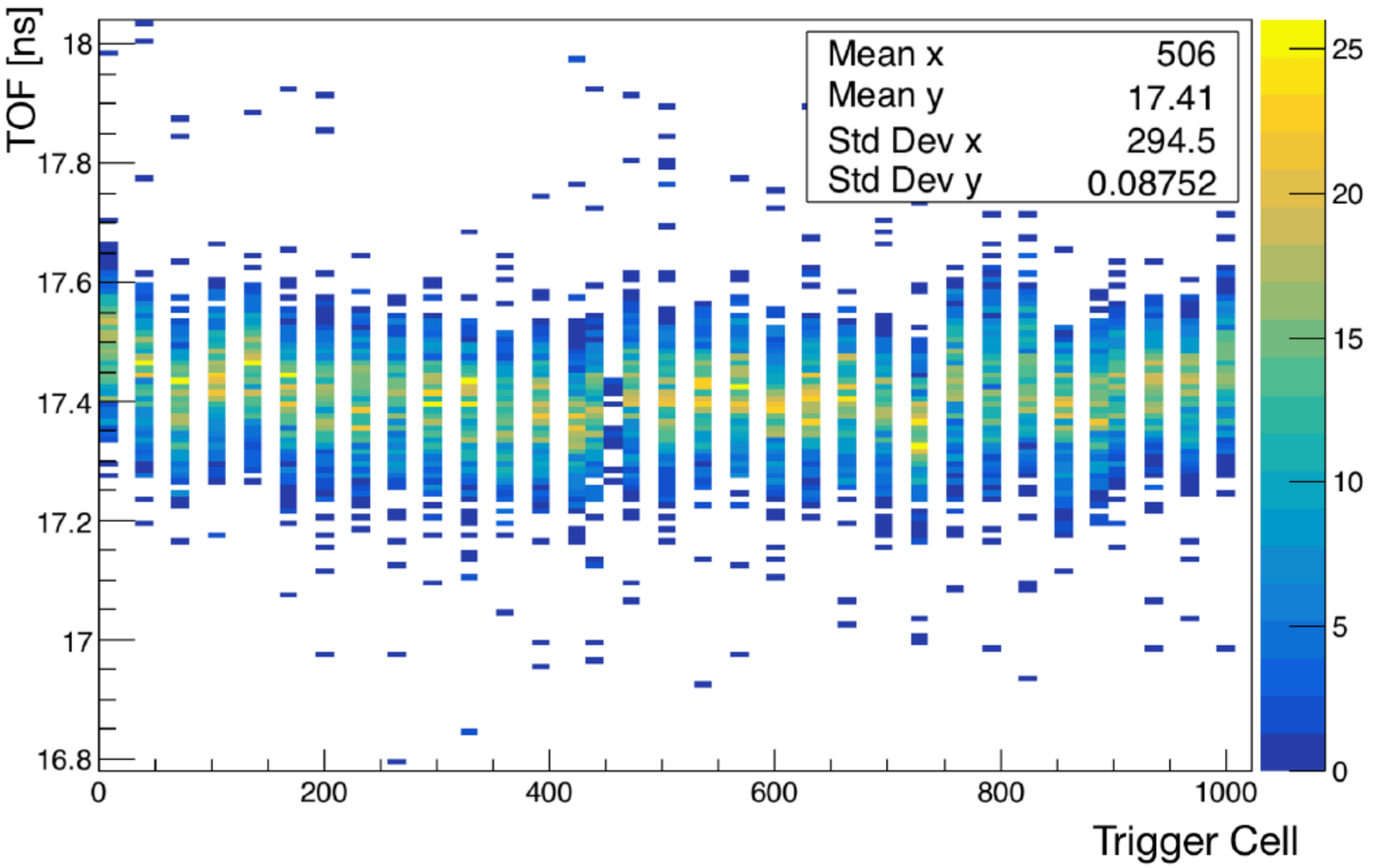
^{16}O-GSI

Energy [MeV/u]	$\sigma(TOF)$ [ps]
400	82.1 ± 0.7



- **A systematic discrepancy is observed between CNAO1 and CNAO2 data**

Trigger cell ToF equalisation



Since the time calibration is not uniform on all the buffer, the SC performance depends on the event **trigger cell** (**TC**) which is shared by its 8 channels.

Natural **correlation** that depends on the trigger cell position in the buffer.

Correction→ I have decided to correct the TOF measurements according to the activatec trigger cell: I have calculated, by setting a reference TC, the correction factors as the difference between the average TOF obtained for a **given trigger cell** and the one obtained for a **reference trigger cell**

$$\delta_{TC_i} = \overline{TOF}_r - \overline{TOF}_i \quad \Rightarrow \quad TOF^f = \overline{T}_{tw} - \overline{T}_{sc} - \delta_{TC_i}$$

ToF vs Ekin

Final TOF and SC resolutions

^{12}C-CNAO1 Energy [MeV/u]	BEFORE $\sigma(TOF)$ [ps]	BEFORE $\sigma(\overline{T}_{sc})$ [ps]	AFTER $\sigma(TOF^f)[ps]$	AFTER $\sigma(\overline{T}^f_{sc})$ [ps]
115 MeV/u	69.6 ± 0.6	68.1 ± 0.7	64.2 ± 0.5	56.3 ± 0.6
151 MeV/u	73.6 ± 0.6	71.6 ± 0.7	68.3 ± 0.6	61.1 ± 0.6
221 MeV/u	78.9 ± 0.7	73.6 ± 0.7	73.9 ± 0.7	66.8 ± 0.6
280 MeV/u	80.1 ± 0.7	76.9 ± 0.8	76.1 ± 0.7	69.5 ± 0.6

^{12}C-CNAO2 Energy [MeV/u]	BEFORE $\sigma(TOF)$ [ps]	BEFORE $\sigma(\overline{T}_{sc})$ [ps]	AFTER $\sigma(TOF^f)[ps]$	AFTER $\sigma(\overline{T}^f_{sc})$ [ps]
115 MeV/u	76.9 ± 1.0	70.9 ± 1.2	61.5 ± 0.8	53.8 ± 0.9
260 MeV/u	88.9 ± 1.1	83.4 ± 1.2	75.1 ± 1.0	69.2 ± 0.9
400 MeV/u	93.2 ± 1.1	86.8 ± 1.2	82.5 ± 1.0	75.2 ± 0.9

^{16}O-GSI Energy [MeV/u]	BEFORE $\sigma(TOF)$ [ps]	BEFORE $\sigma(\overline{T}_{sc})$ [ps]	AFTER $\sigma(TOF^f)[ps]$	AFTER $\sigma(\overline{T}^f_{sc})$ [ps]
400 MeV/u	82.1 ± 0.7	78.0 ± 0.7	68.5 ± 0.6	63.7 ± 0.6

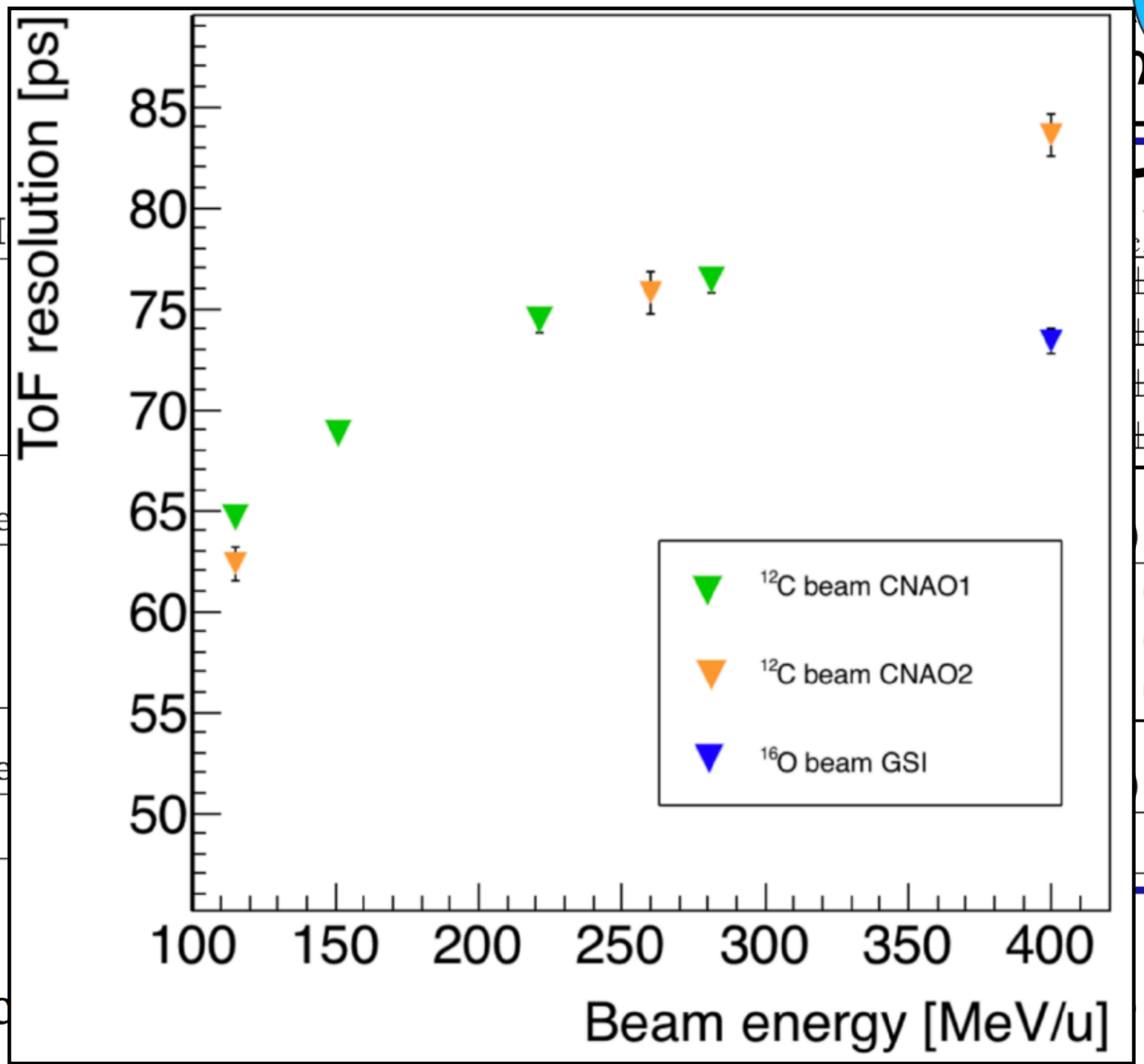
The trigger cell correction has improved significantly the time resolution!!

ToF vs Ekin

^{12}C-CNAO1 Energy [M	) [ps]
115 MeV/u	± 0.6
151 MeV/u	± 0.6
221 MeV/u	± 0.6
280 MeV/u	± 0.6

^{12}C-CNAO2 Energy [Me	[ps]
115 MeV/u	0.9
260 MeV/u	0.9
400 MeV/u	0.9

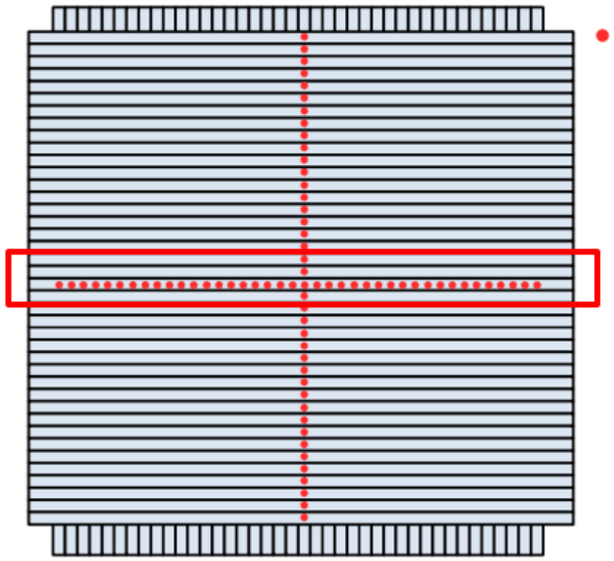
^{16}O-GSI Energy [Me	[ps]
400 MeV/u	0.6



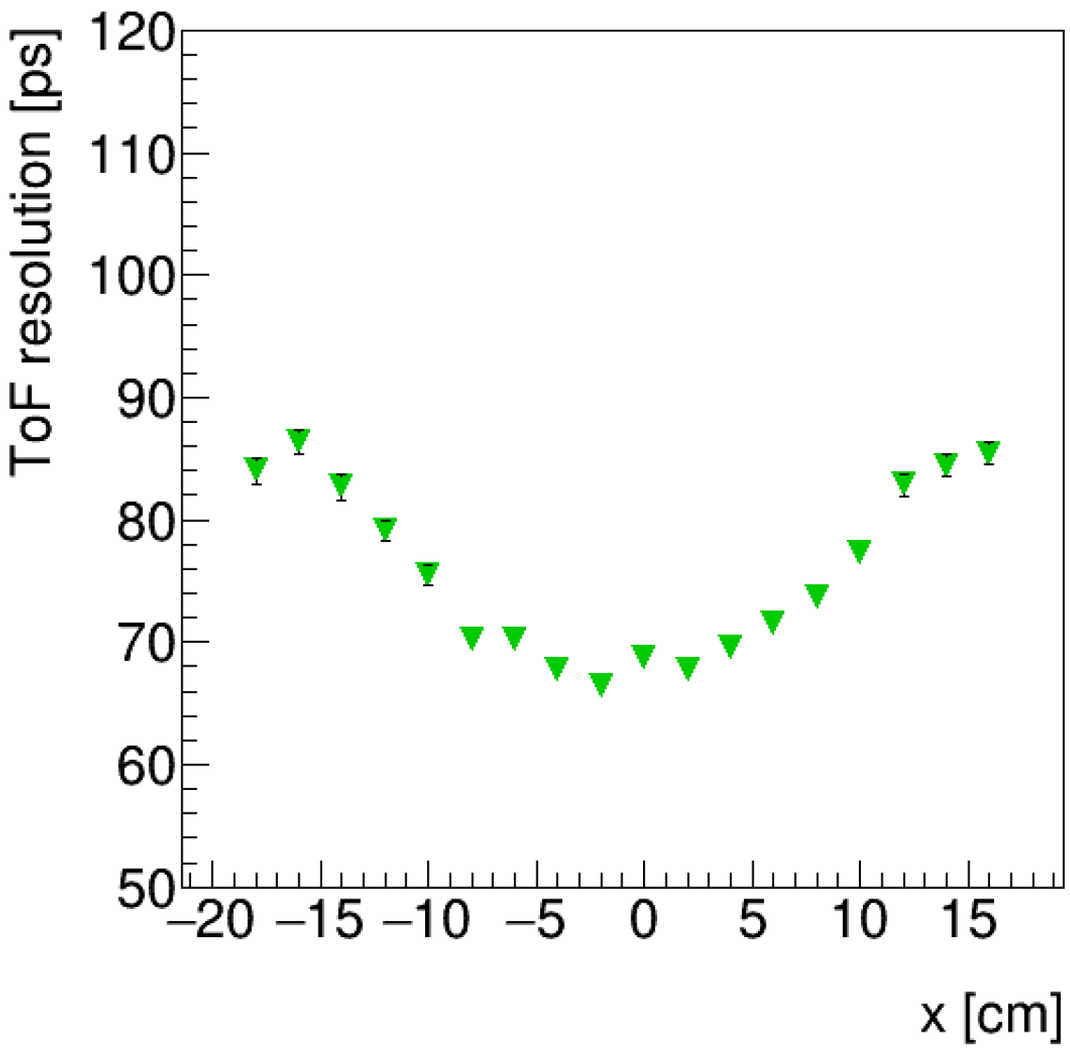
The trigger c

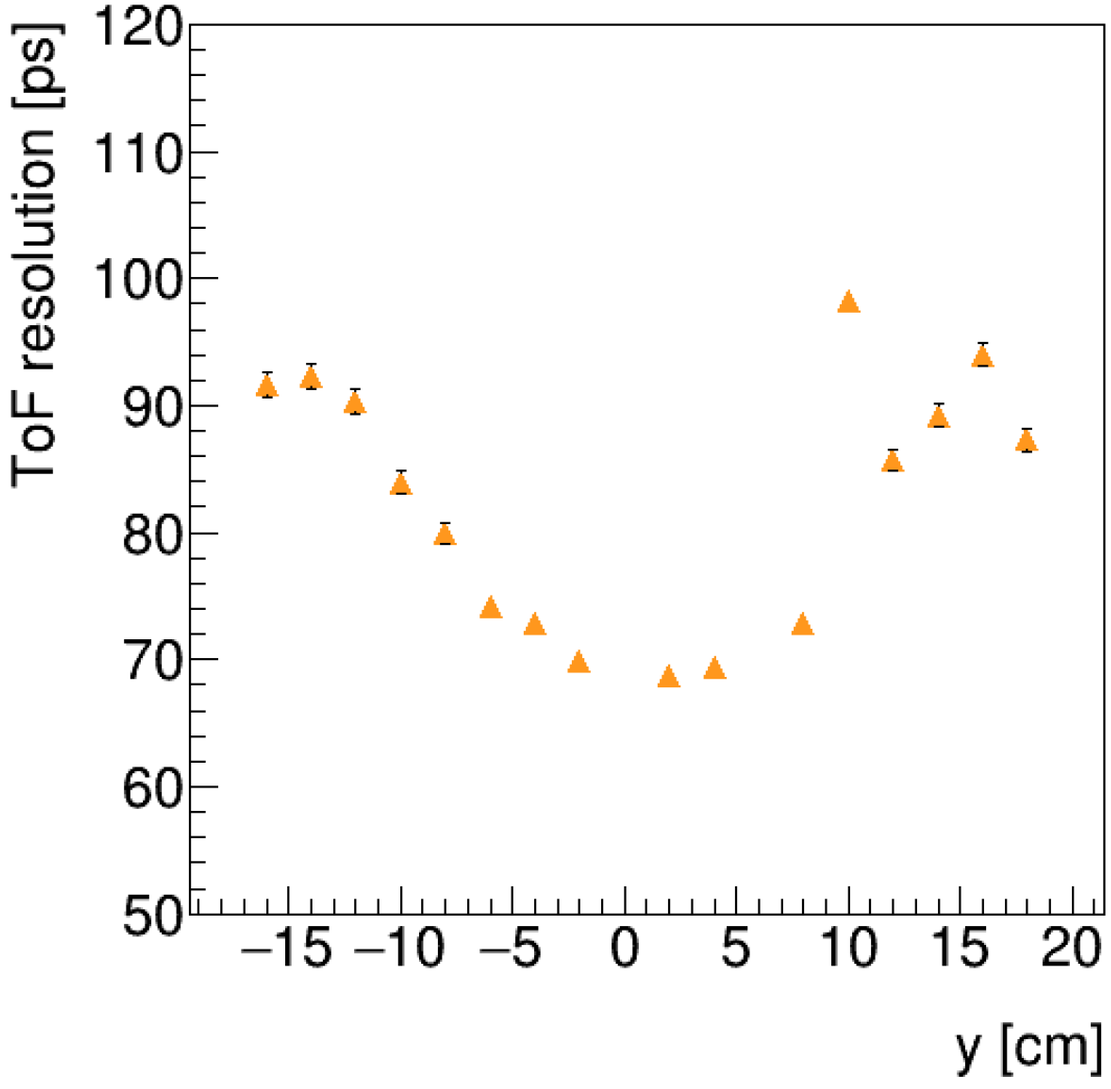
resolution!!

ToF vs position

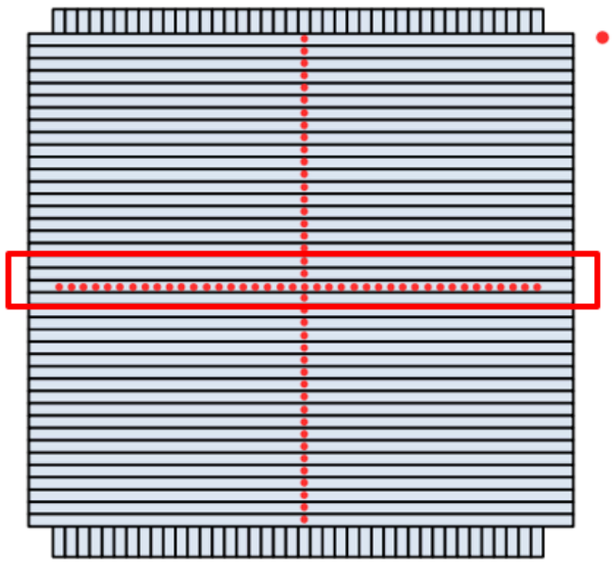


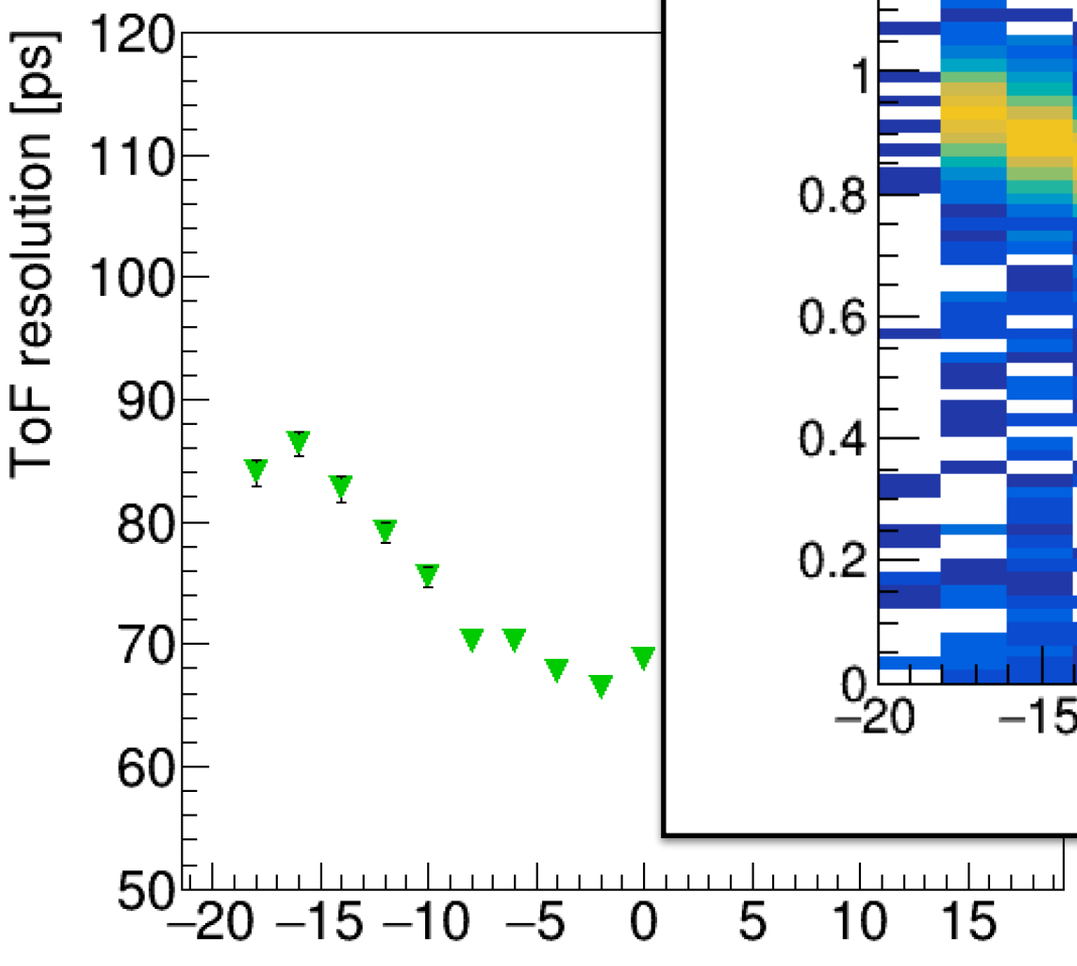
- The ToF resolution is not uniform on the TW surface
- Effect is still not understood and it seems to be related to the signal asymmetry in the bar when hit near to the extremities

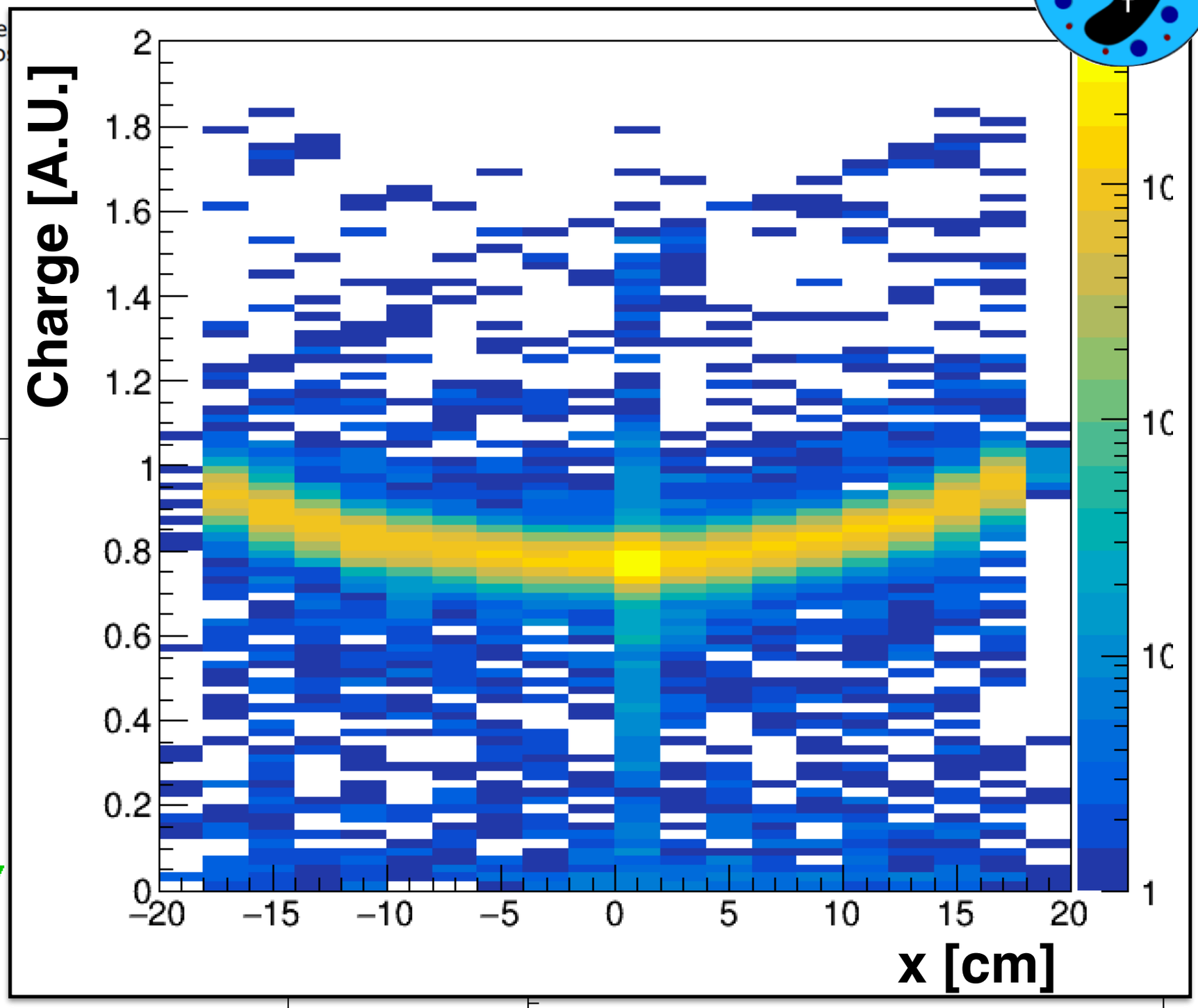


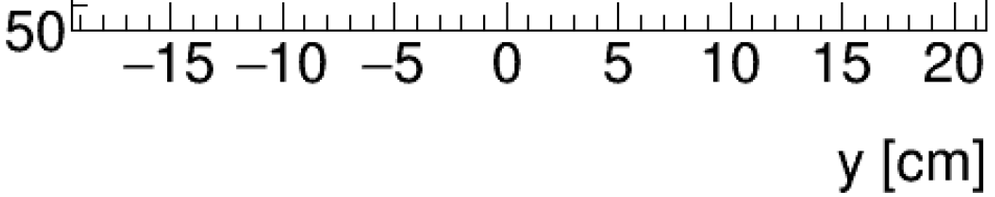


ToF vs position



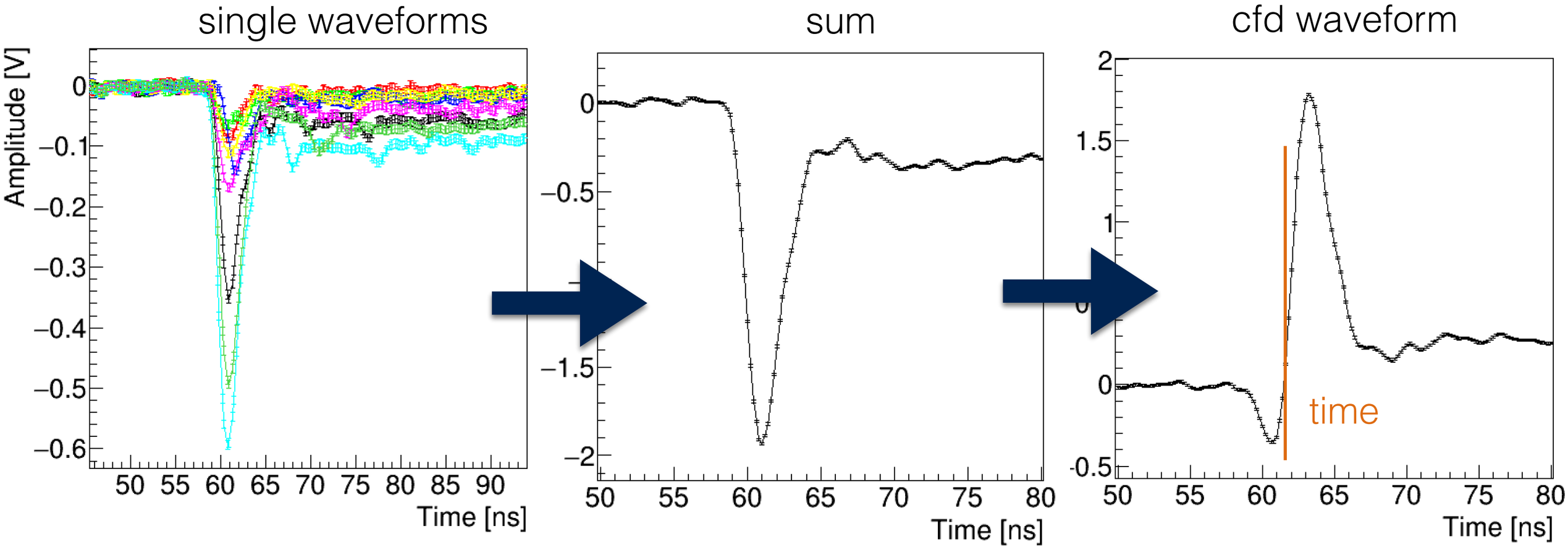






New processing method

- We are studying a different method to reduce the time consumption, avoiding of using fit



- Both waveform summing and time extraction are performed using linear interpolation between points
- Time resolution seems to be comparable to the old method
- **We gain a factor 3 in the processing rate**
- **It will be soon implemented in shoe!**

Summary and conclusions

- The results in terms of Time Of Flight resolution are robust, we don't expect any significant improvement with new software tricks.
- Performances of the ST are actually good (**time resolution between 55 ps-75 ps**) but some detector features are still not understood, i.e. the different response of single channels (maybe some effect of SiPM- scintillator coupling?)

Open issues:

- Significant differences in the response of the ST channels (HW issues?)
- Spatial dis-uniformity of the ToF resolution (can a different CFD algorithm help?)
- Finalize the implementation of the new faster method for waveform processing in shoe