TOF-Wall detector

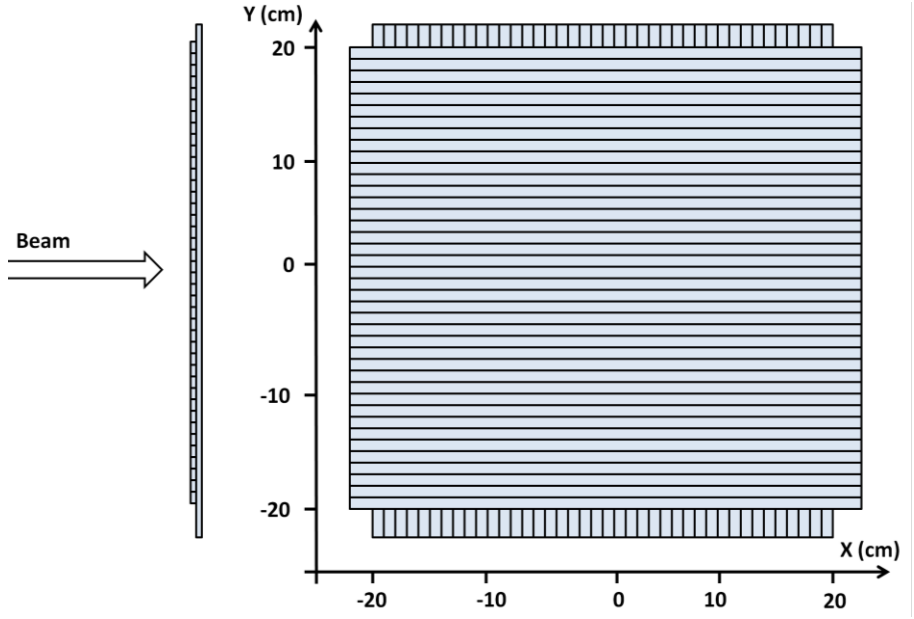
Matteo Morrocchi

XVII FOOT Collaboration Meeting

16-18 / 12/2024 Monastero di Cherasco – Cherasco (CN)

A brief recap of the TOF-Wall detector: TW structure

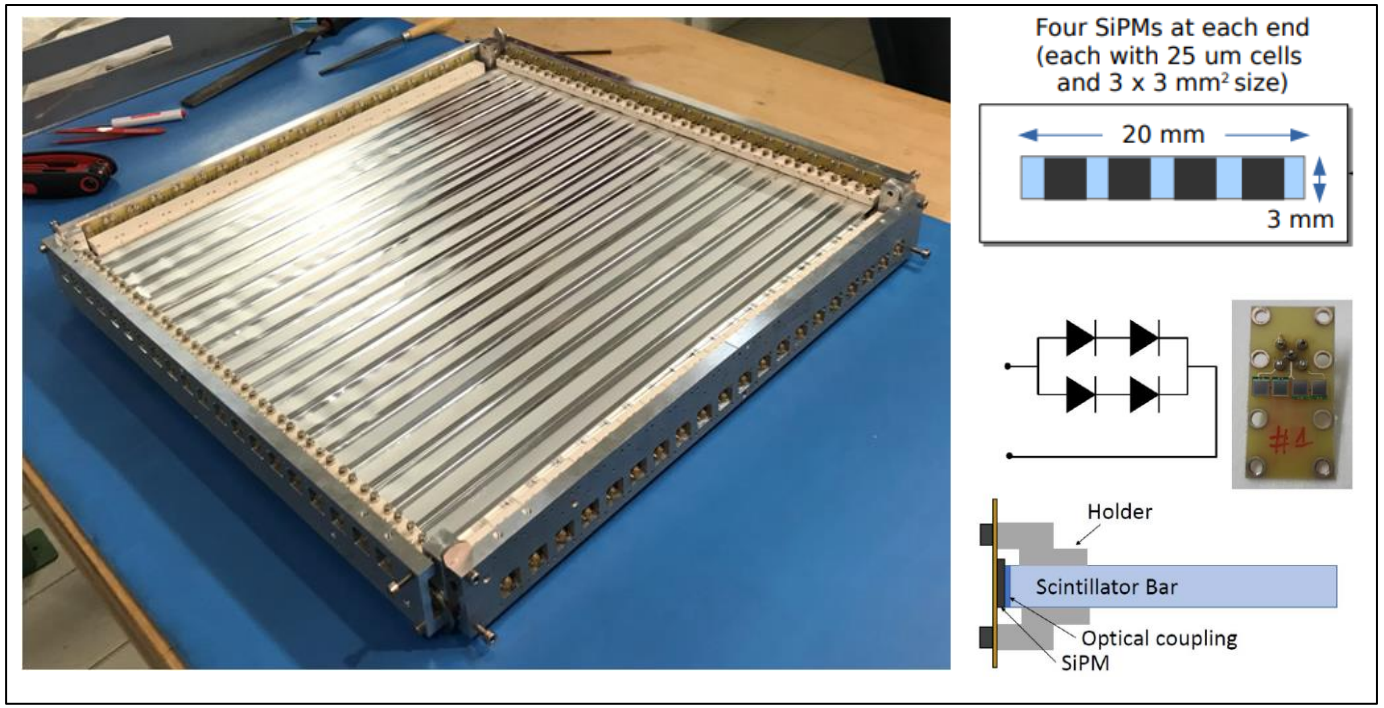
20 + 20 plastic scintillating bars (EJ200)
Each one with size 440 mm x 20 mm x 3 mm



- The two layers are orthogonally arranged to identify the interaction position
- Total active area of 40 x 40 cm^2
- 80 analog channels in total

Purpose of the detector:

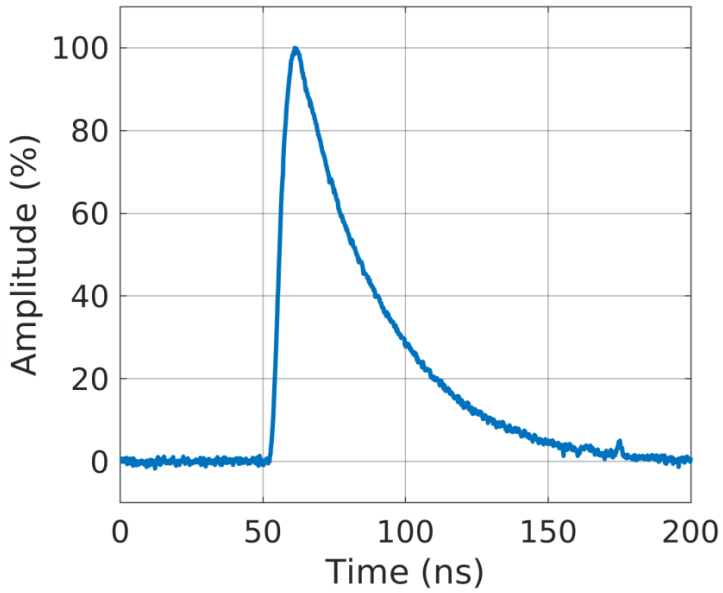
- Act as second Time-of-Flight detector right before the calorimeter
- Measure the ΔE of the fragments
- Mainly suited for high-Z fragments, not totally efficient with protons.



A brief recap of the TOF-Wall detector: Signal readout

The signal is acquired and digitized with DRS4 (1024 samples) using the WaveDAQ system

Bias, trigger & DAQ
WaveDAQ (PSI & INFN)



Each layer provides a timestamp given by the combination of the two timestamps at the two ends of the triggered bar

$$T_H = \frac{T_L + T_R}{2}$$

$$T_V = \frac{T_B + T_T}{2}$$

The timestamp of the TOF-Wall is evaluated by combining the two layers

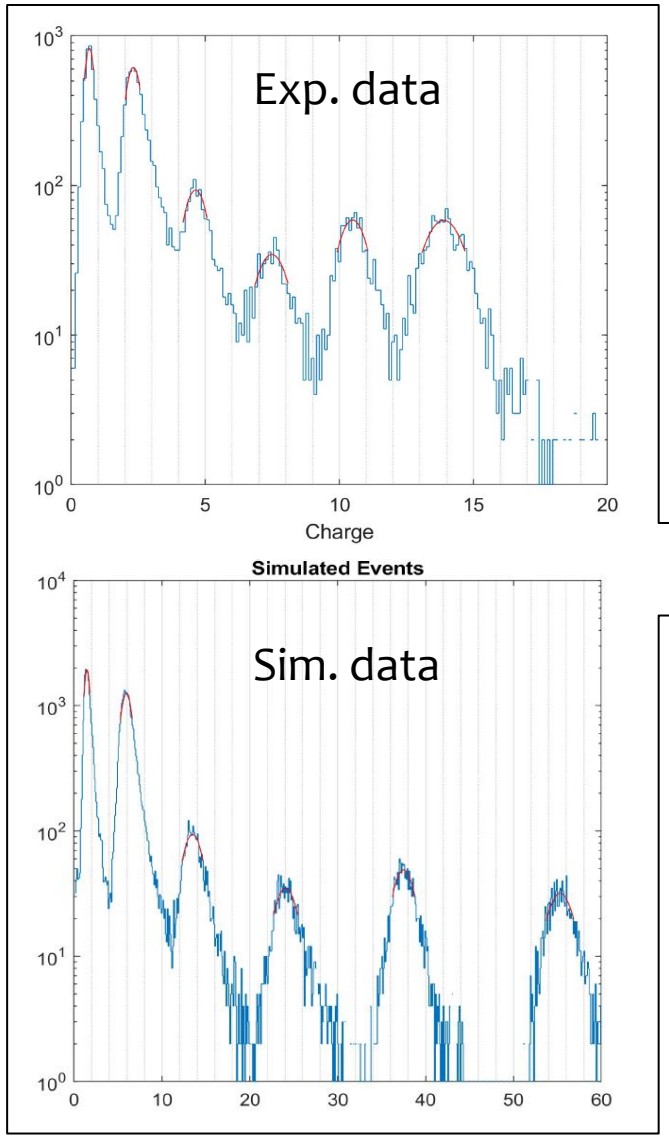
$$T_{\Delta E-TOF} = \frac{T_H + T_V}{2}$$

$$TOF = T_{\Delta E-TOF} - T_{SC}$$

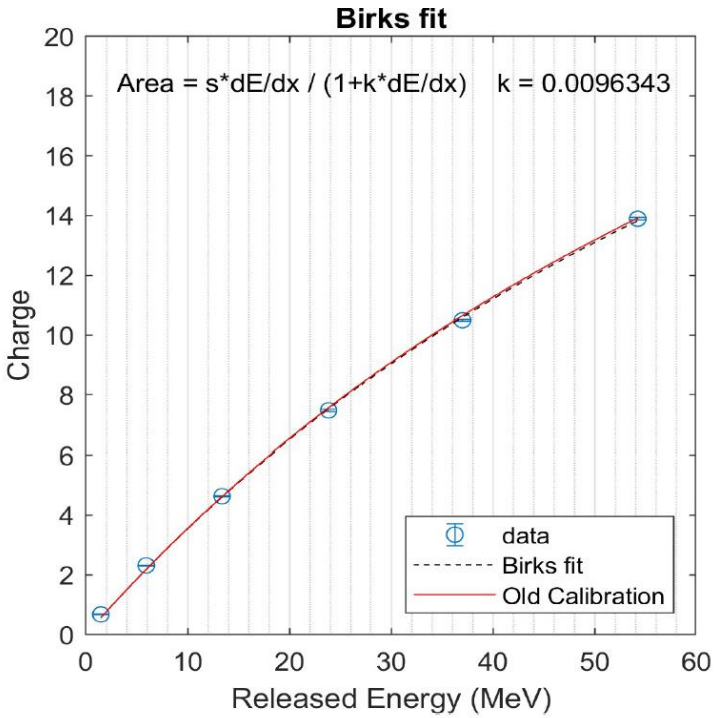
The same system is used also to digitize the waveforms of Start Counter and Calorimeter

Waveforms of both start counter and triggered channels of TOF-Wall are stored and analyzed off-line

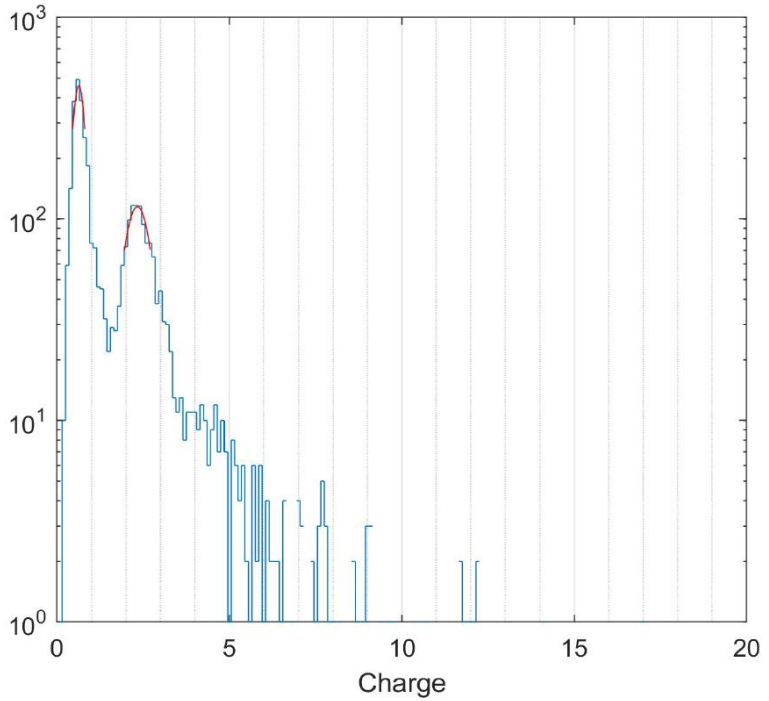
A brief recap of the TOF-Wall detector: Energy calibration



The calibration is performed using data with the target to improve the number of fragments in the histogram, and comparing the collected signal with the simulation

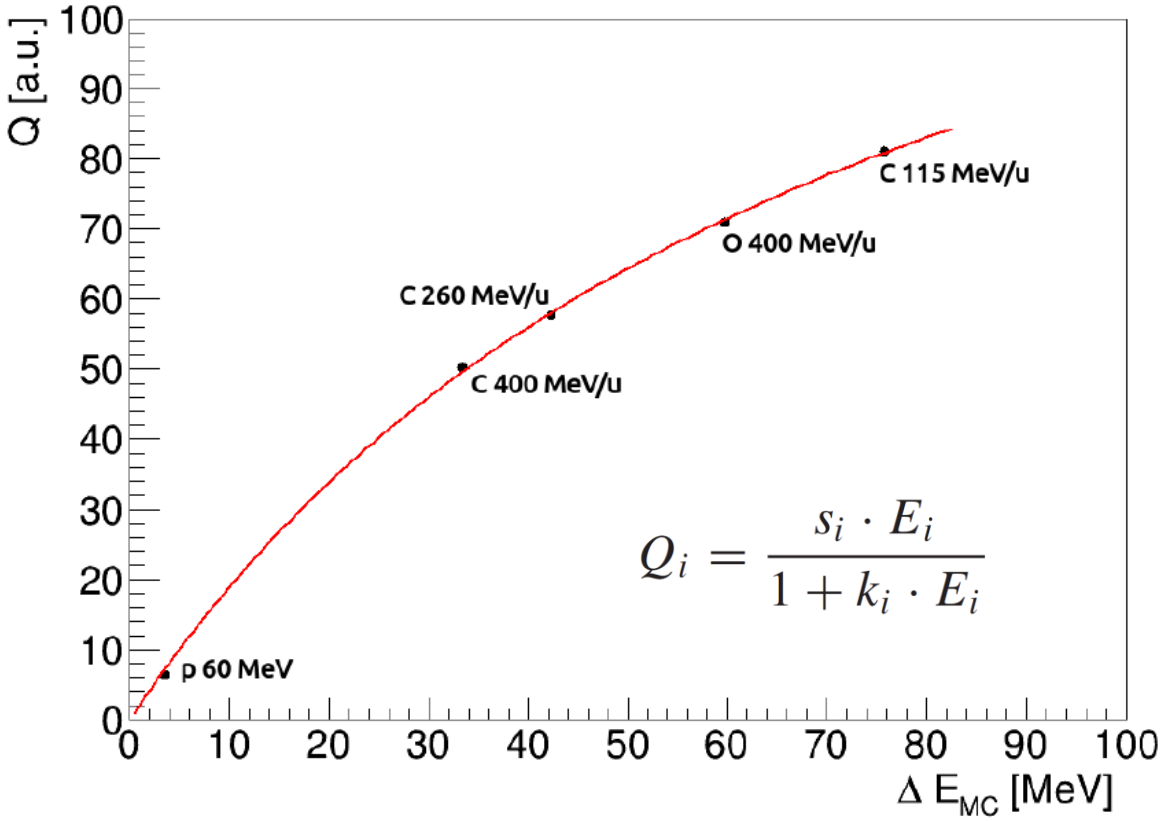


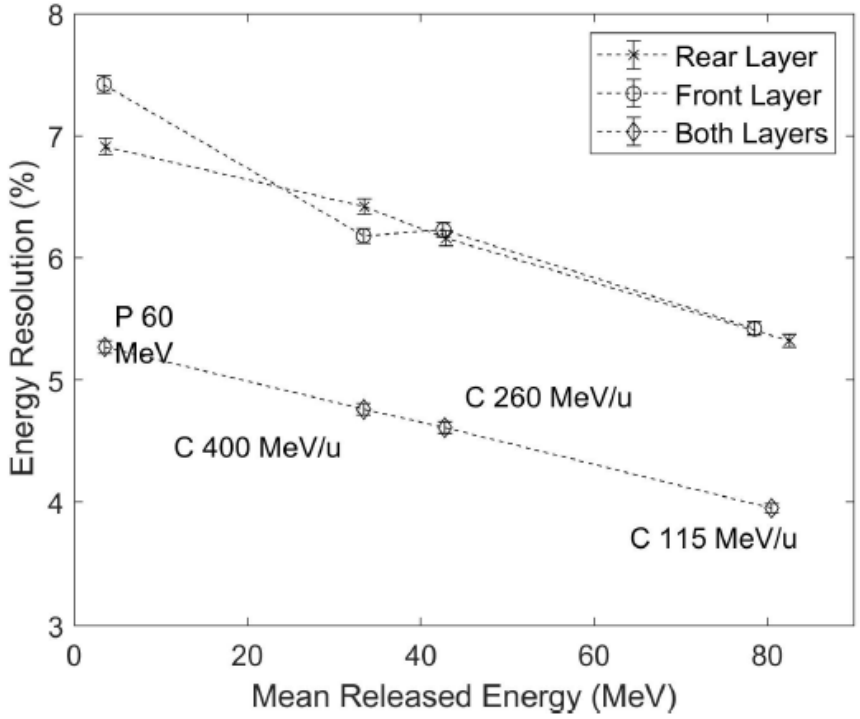
This way, unfortunately, the most lateral bars collect only lighter ions, but they are the only ions for which the response needs to be calibrated



A brief recap of the TOF-Wall detector: Energy response

The energy response of the TOF-Wall detector needs to be calibrated to account for the scintillator saturation, according to Birks' law. An individual calibration for each bar is performed.

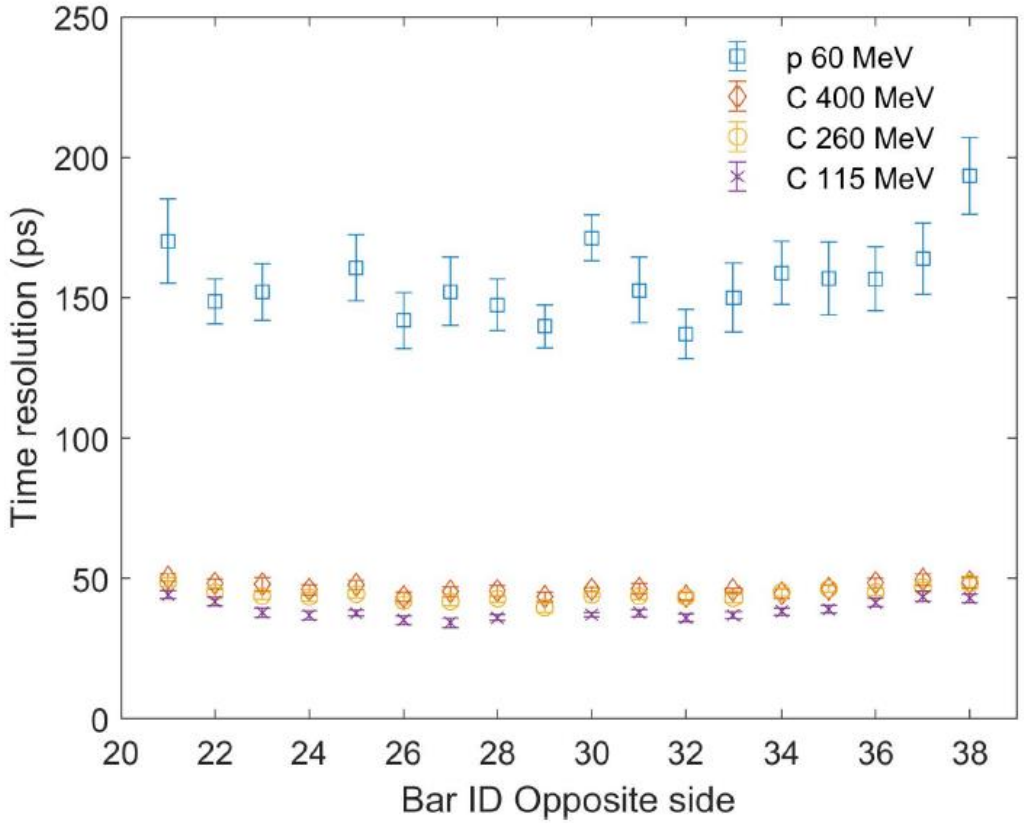




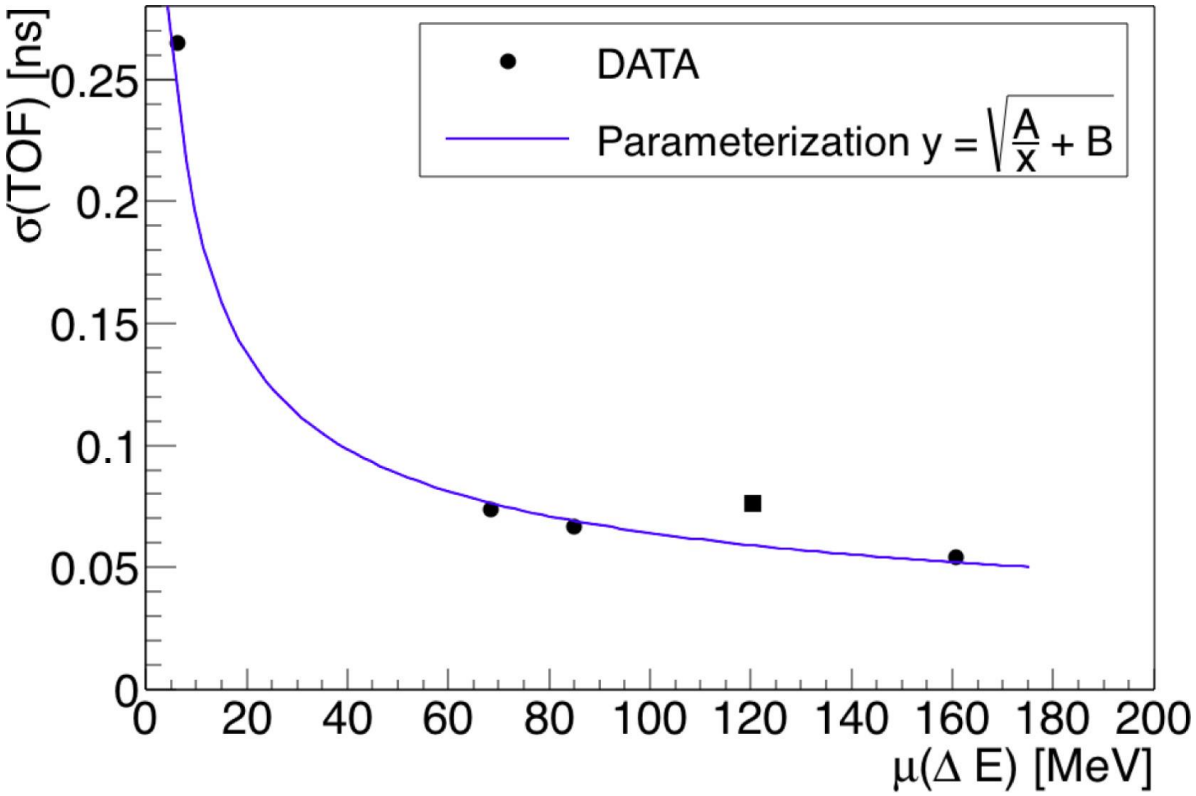
Particle	E_{beam} [MeV/u]	$\mu(Z)$	$\sigma(Z)$	$\sigma(Z)/\mu(Z)$ [%]
p	60	0.96	0.06	6.10 ± 0.02
^{12}C	115	6.17	0.15	2.51 ± 0.01
^{12}C	260	6.01	0.21	3.52 ± 0.01
^{12}C	400	6.07	0.24	3.85 ± 0.01
^{16}O	400	8.07	0.22	2.67 ± 0.02

A brief recap of the TOF-Wall detector: Timing performance

Contribution of TW to the TOF resolution can be evaluated by comparing the resolution between the two layers (shown below). TW contribution can be obtained dividing these values by a factor 2.

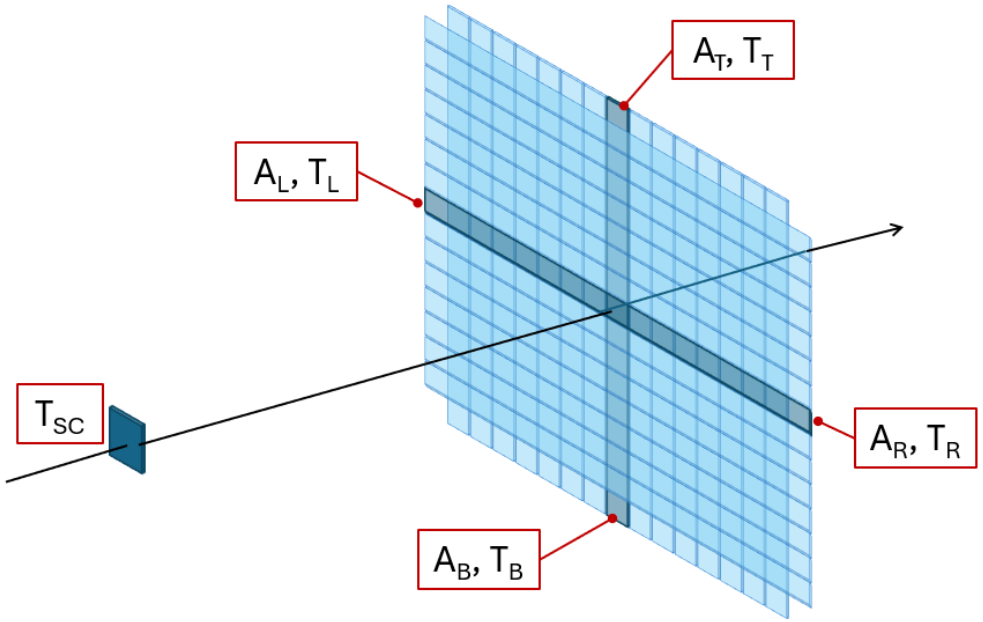


The total TOF resolution is determined both by the SC and the TW. The SC has a very reduced thickness to minimize fragmentation, so usually its contribution is dominant for heavy fragments.

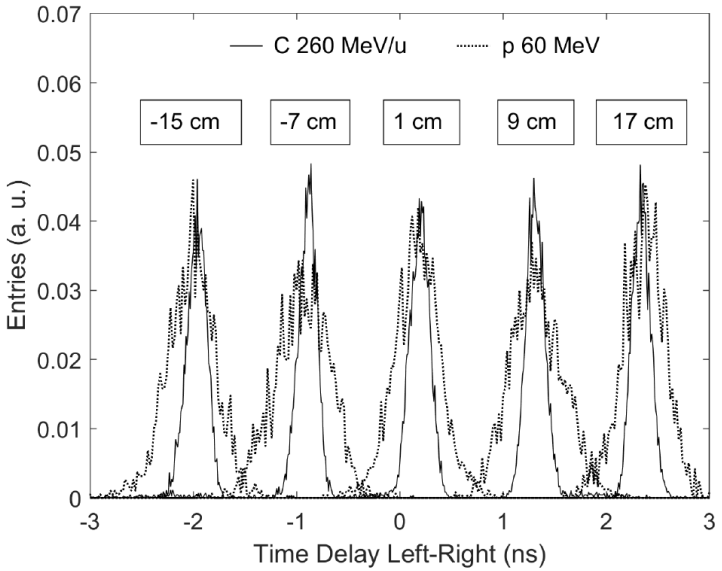


A brief recap of the TOF-Wall detector: Interaction position reconstruction

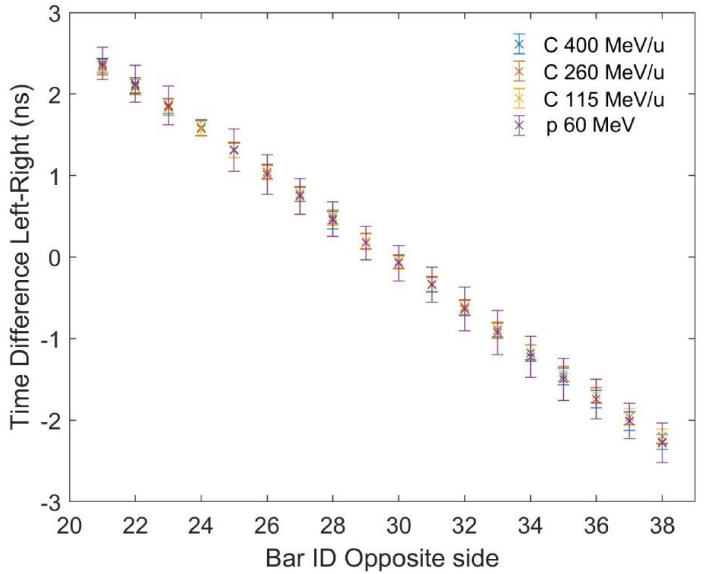
In case that a single particle hits the TW, a bar for each layer is triggered and the interaction position can be reconstructed with the resolution of the bar pitch



If more than one fragment hit the TW at the same time, the reconstruction of the interaction position may be ambiguous and the scintillation position along the bar can be reconstructed according to the difference in the time measured at the two ends of the bar.

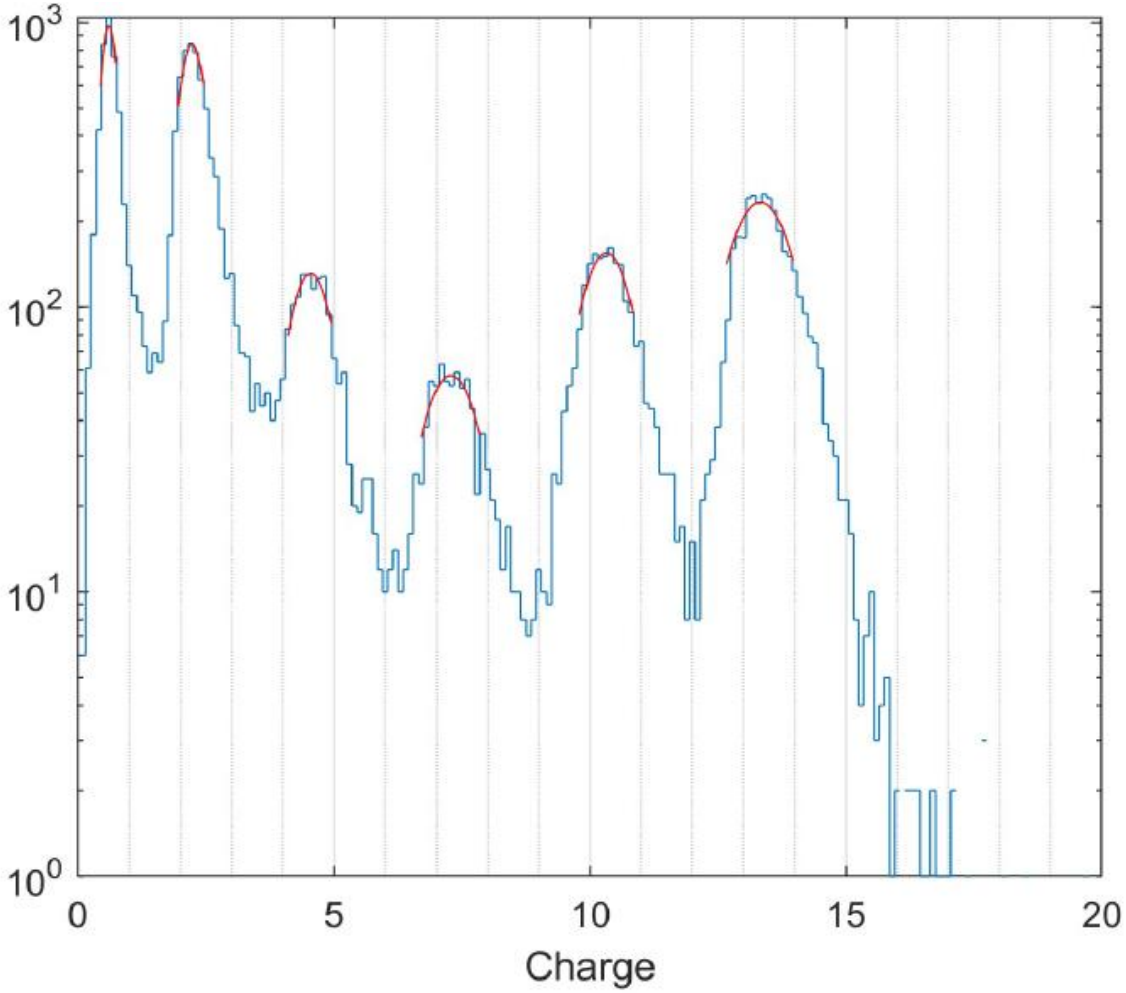


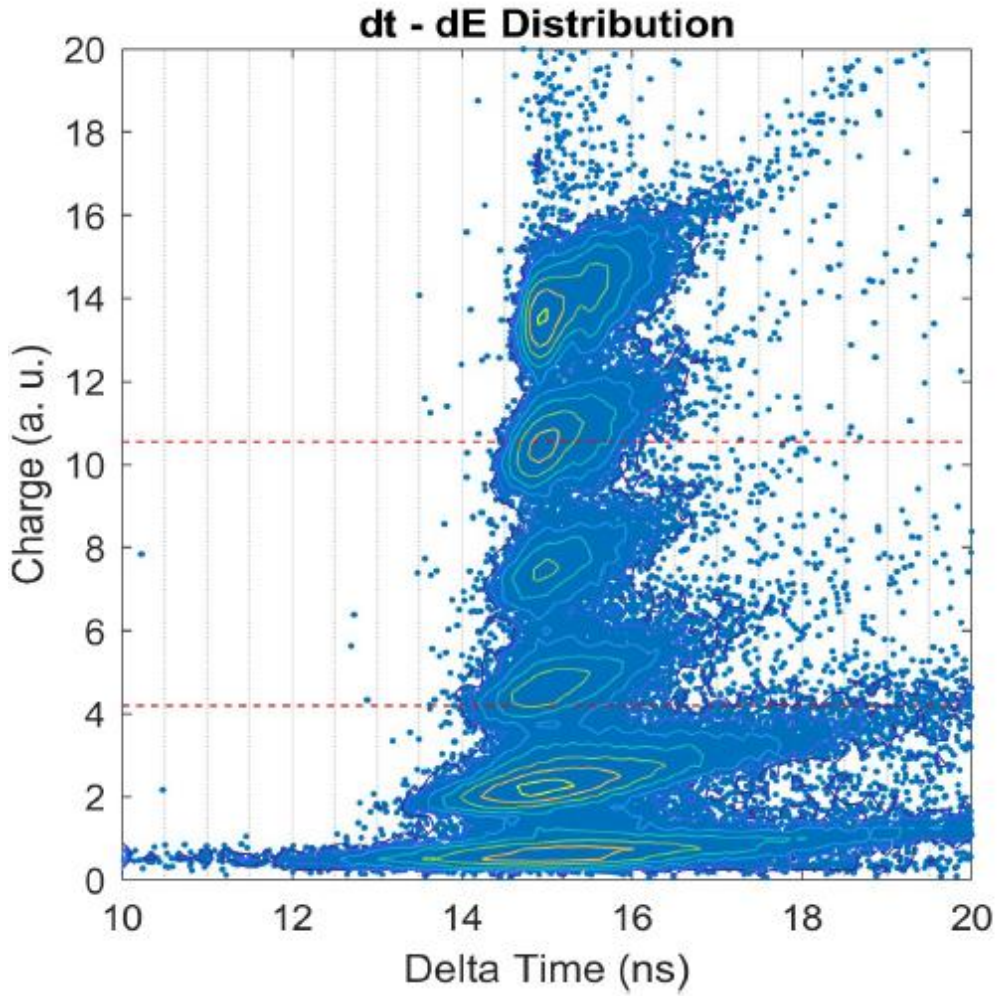
The resolution on the position depends on the amount of collected signal, therefore this method is more precise with heavier ions



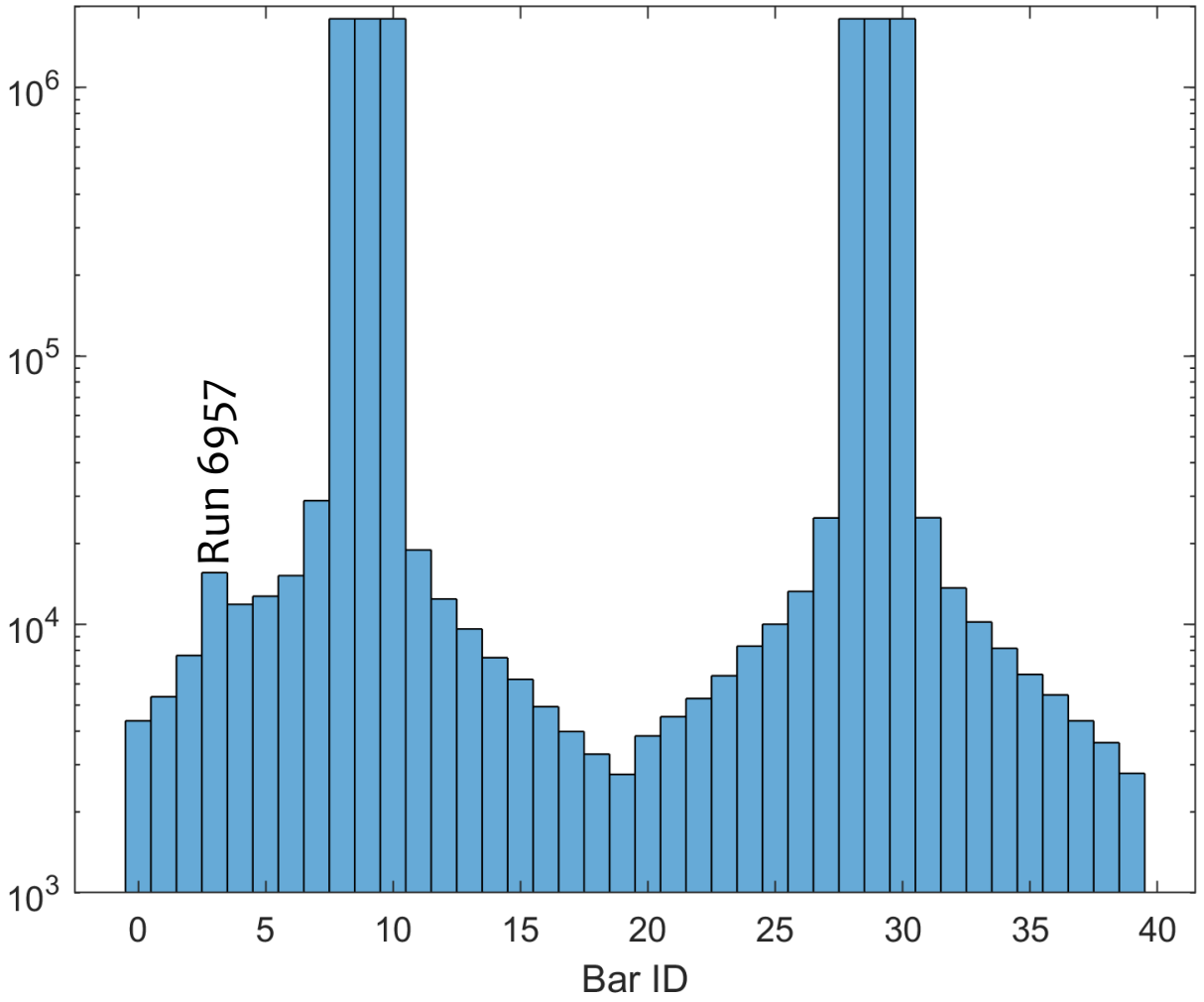
There is a linear dependence between the detected time difference and the interaction position

A brief recap of the TOF-Wall detector





Some results from CNAO2024 campaign



All the bars seem to work properly, the zero suppression was deactivated in the central bars for all the acquisitions

- Not a problem, but maybe not necessary
- Just some more data without events that will be filtered out with a SW threshold

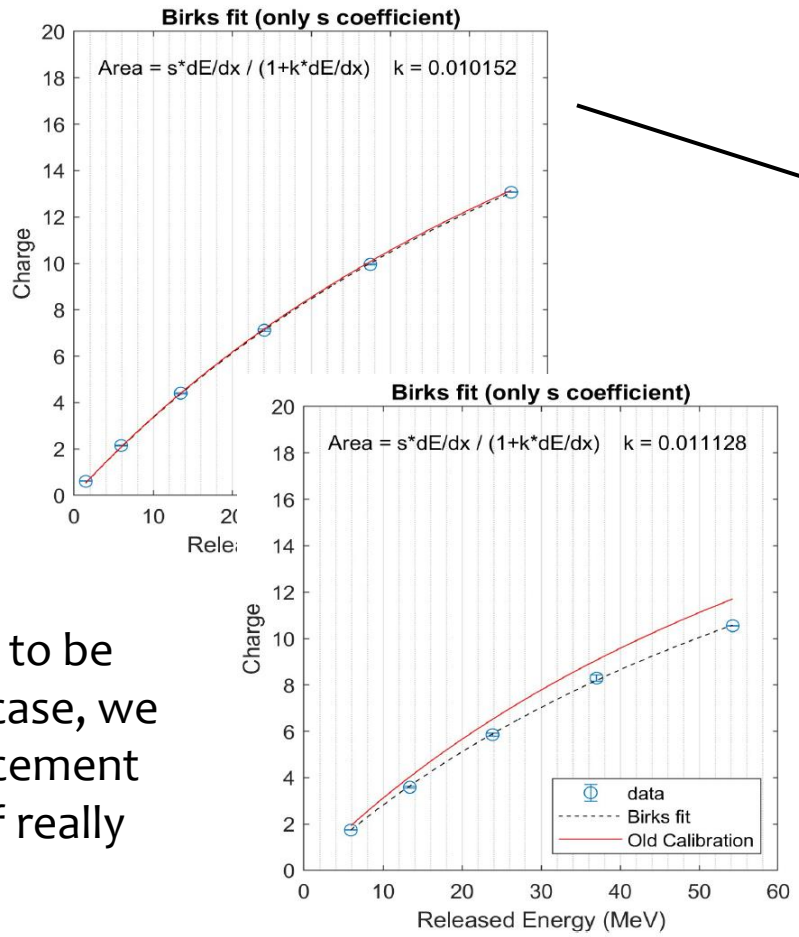
Some results from CNAO2024 campaign

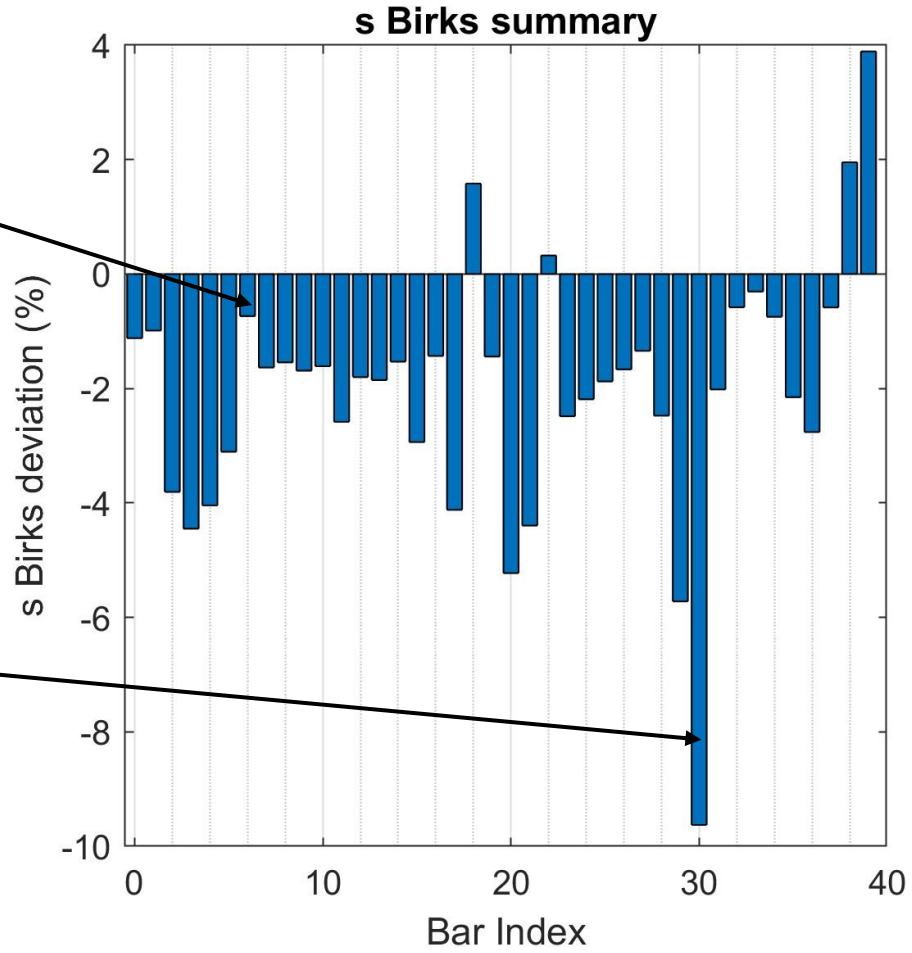
* Obtained using CNAO2023 simulations for comparison, so maybe this still needs to be fully optimized

Comparison of the bar response between 2023 and 2024 campaign, k_B was kept fixed and only the *s* parameter was changed.

Less than 5% deviation with respect to last year in the bar response (except for a higher reduction in the signal in the central bar of one layer!)

The situation needs to be monitored, and, in case, we can foresee a replacement in the future (only if really really needed)



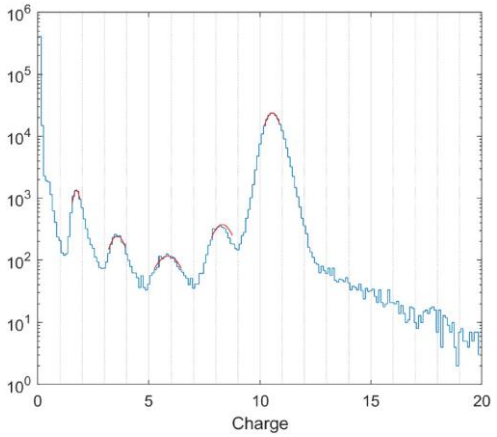


Some results from CNAO2024 campaign

* Obtained using CNAO2023 simulations for comparison, so maybe this still needs to be fully optimized

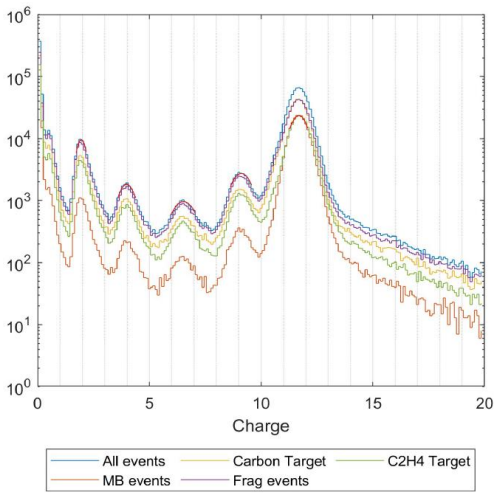
Bar 30 - 2024

Ion	Peak_pos
H	NaN
He	1.74 +/- 0.008
Li	3.59 +/- 0.05
Be	5.86 +/- 0.06
B	8.3 +/- 0.1
C	10.552 +/- 0.003

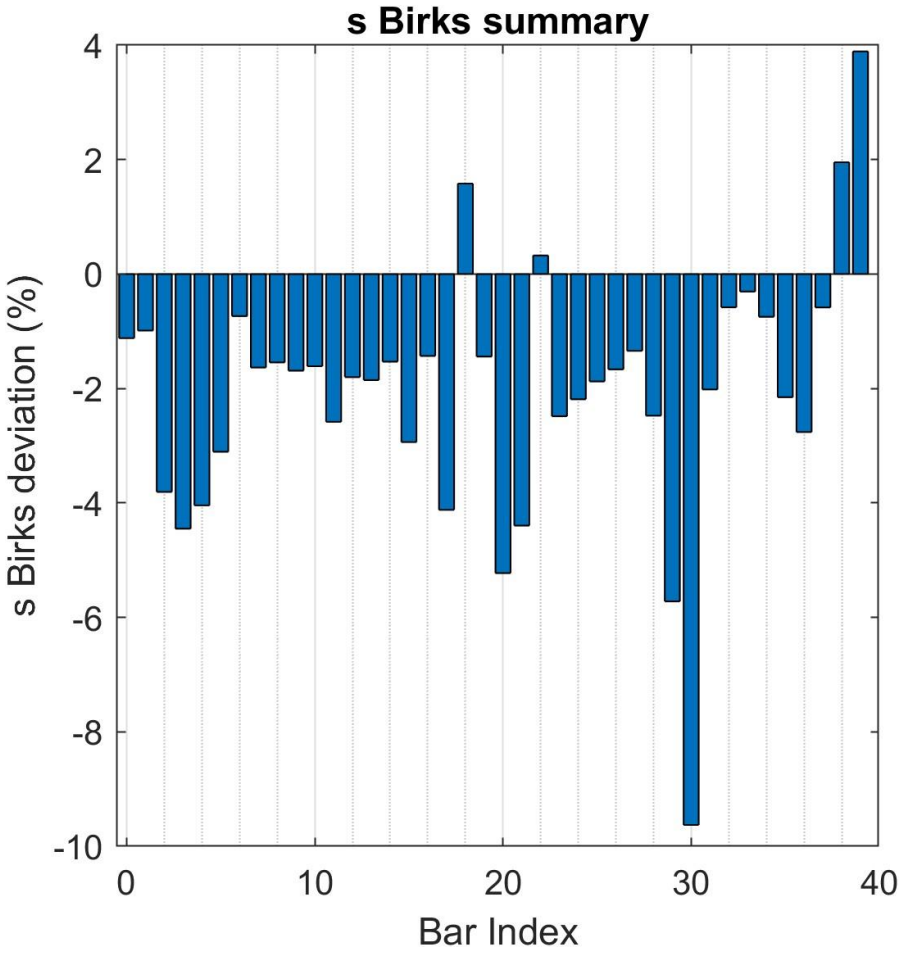


Bar 30 - 2023

Ion	Peak_pos
H	NaN
He	1.96 +/- 0.01
Li	3.98 +/- 0.01
Be	6.53 +/- 0.01
B	9.12 +/- 0.01
C	11.69 +/- 0.005



Comparison of the bar response between 2023 and 2024 campaign, k_B was kept fixed and only the *s* parameter was changed.



TW calibration status

Status of the TW calibrations:

- CNAO 2024: temporary energy calibration with 2023 simulations, time calibration to be implemented
- CNAO 2023: energy and time calibration done
- CNAO 2022: energy calibration done, time calibration generated and to be tested
- HIT 2022: working on it (see Lorenzo's presentation)

TW future work

I already talked about the problem with the WaveDAQ faced @ CNAO, action items:

- Replacement of the switch
- Long runs in January to verify if the problem can be reproduced

Changes in the mechanic of the TW to:

- add references for the laser tracker alignment
- Verify if it is possible to have an integration with the mechanic of the calorimeter or of the table, also in this case to reduce the degree of freedom during the alignment and to ease the installation
  → Discussion about this at the beginning of next year