TOF Wall Software Validation and Energy Calibration

Pisa group

Introduction

- Pisa stand-alone ΔE-TOF software re-structured and improved
- New features:
  - Event-by event structure→ MC-data comparisons possible!
  - New structure including 40 bars!
  - Charge distributions recovered (where possible)
  - STC information included → Delta TOF available! (thanks to Giacomo Traini for help)
  - Details of code structure: see presentation 29-10-2019
- Today:
  - Used new Pisa software for TOF reconstruction and private analysis code
    - At present no trigger cell correction
  - Single bar studies → see Matteo's presentation
  - Extraction of TOF → see presentation by Roberto Zarrella
  - Here:
    - Energy calibration
    - Performance and first validation of code

Energy calibration

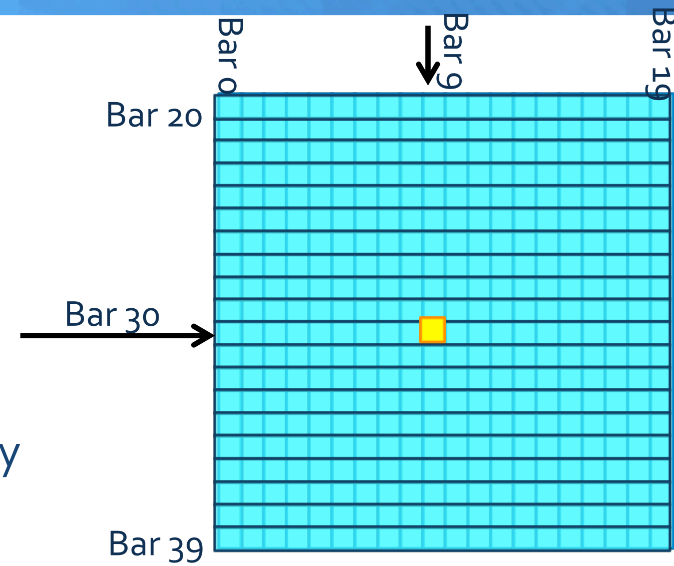
- Do we need to do the calibrate energy **bar-per-bar** or **position-by-position**??

- Depends…
  - Does energy deposition depend on **where** bar was hit?
    - If no→ can calibrate bar-per-bar
    - If yes, can it be predicted? (behaviour same for all bars?)
      - Yes→ parameterize it and calibrate bar-per-bar
      - No→ calibrate position-per-position
- We currently have full scans of 2 bars (energy deposition and TOF), so enough to investigate position dependence and decide the strategy
- Final goal: extract parameters to find relationship between deposited charge and true MC deposited energy for all positions, where a fragment deposited charge

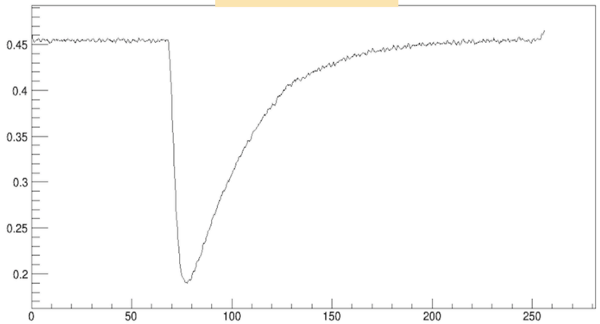
→ let's have a look at the charge distributions

Charge distributions

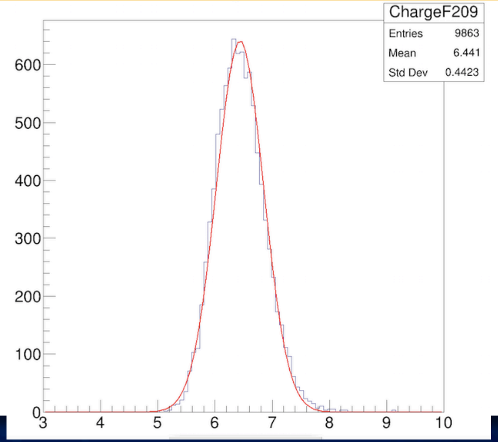
- Run over all files CNAO 2019, using TW and STC
  - Protons 60 MeV
  - Carbon 115 GeV/u
  - Carbon 260 MeV/u
  - Carbon 400 MeV/u
- For each event, identify hit position by crossing point of bars front and rear (charge in each bar >0)
- Example of waveform



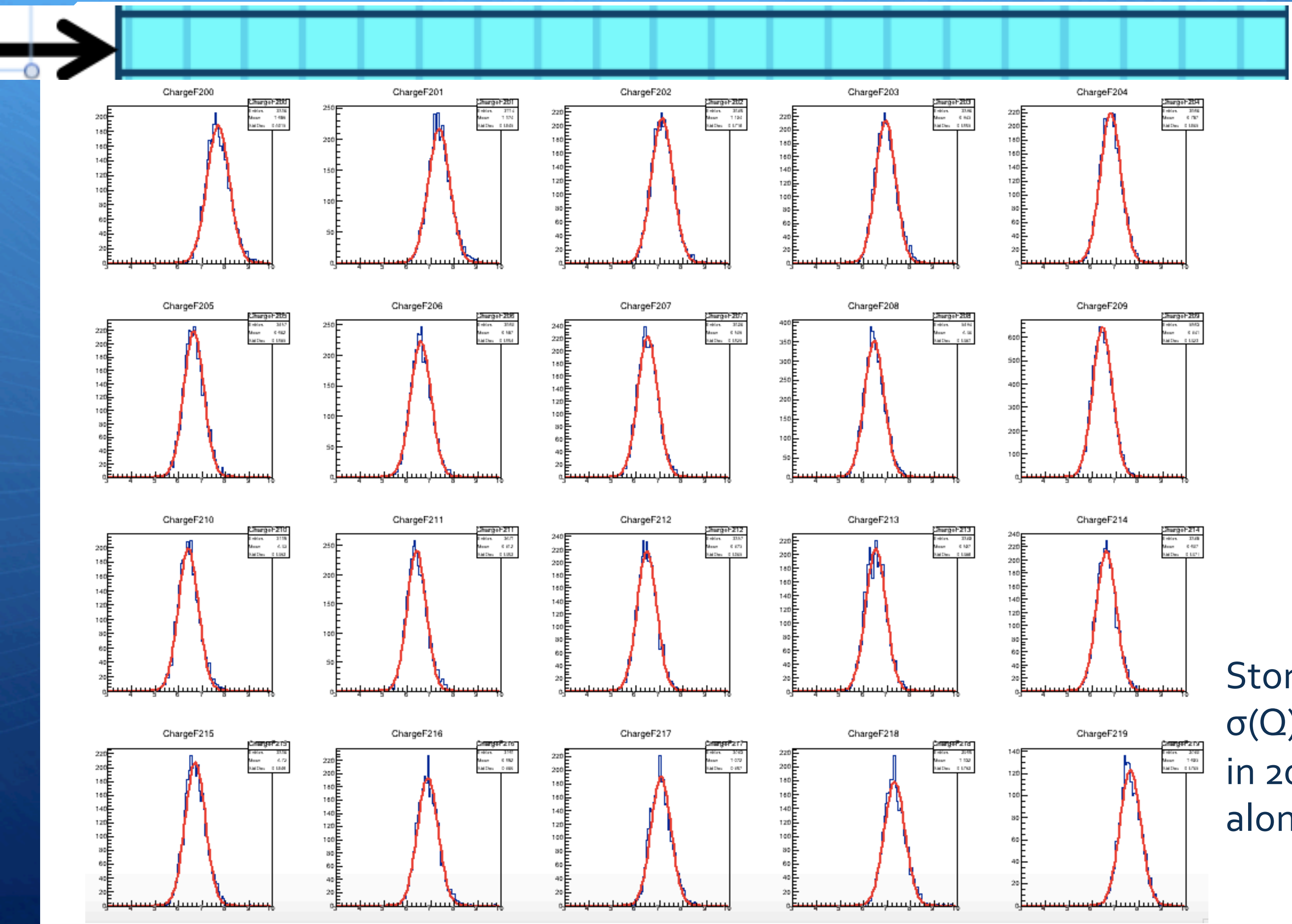
1 event



Charge distribution in bar 30 in central position (protons) of N events

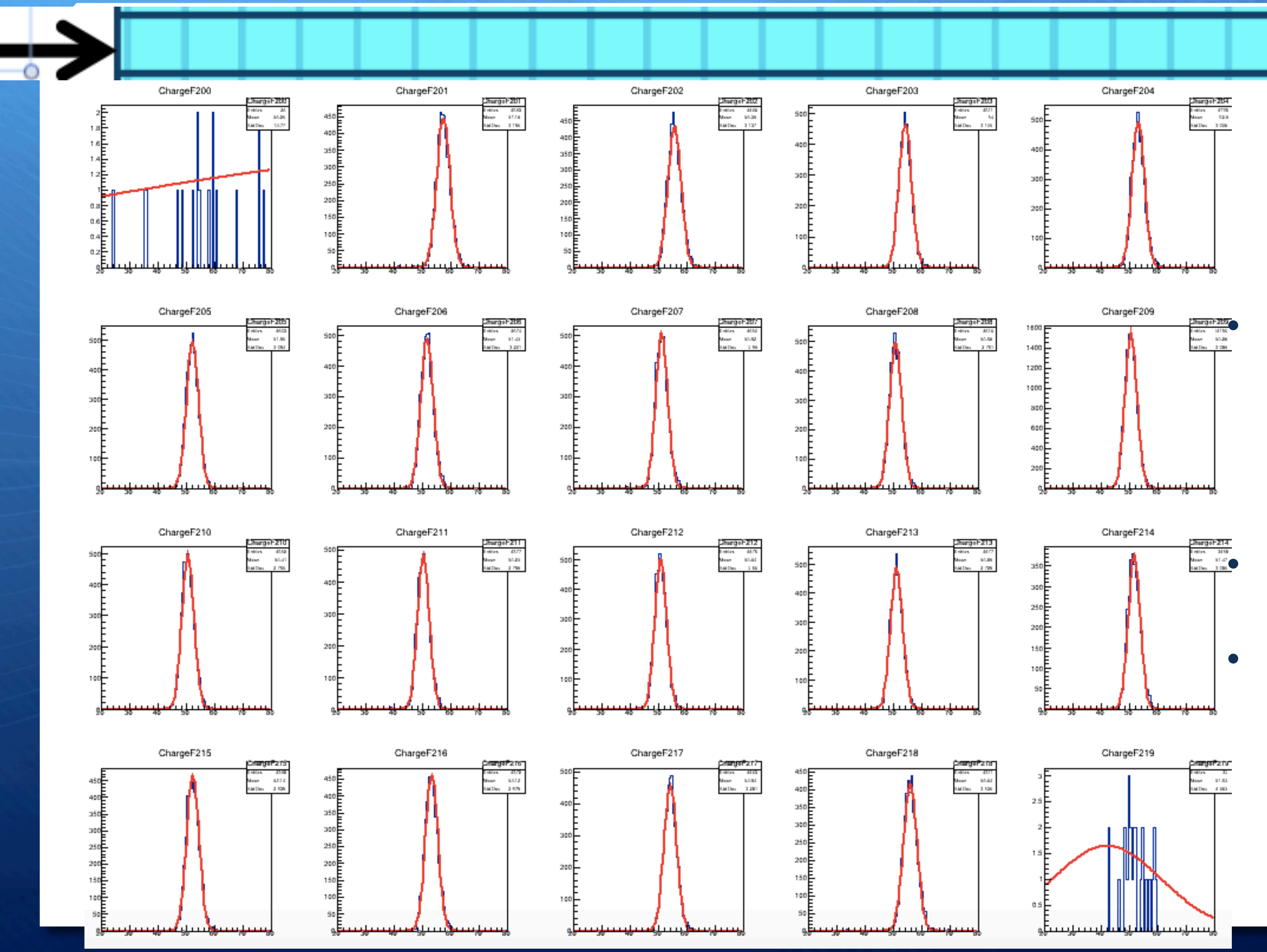


Protons 60 MeV along bar 30



Store μ(Q) and σ(Q) sigma of fit in 20 positions along a bar

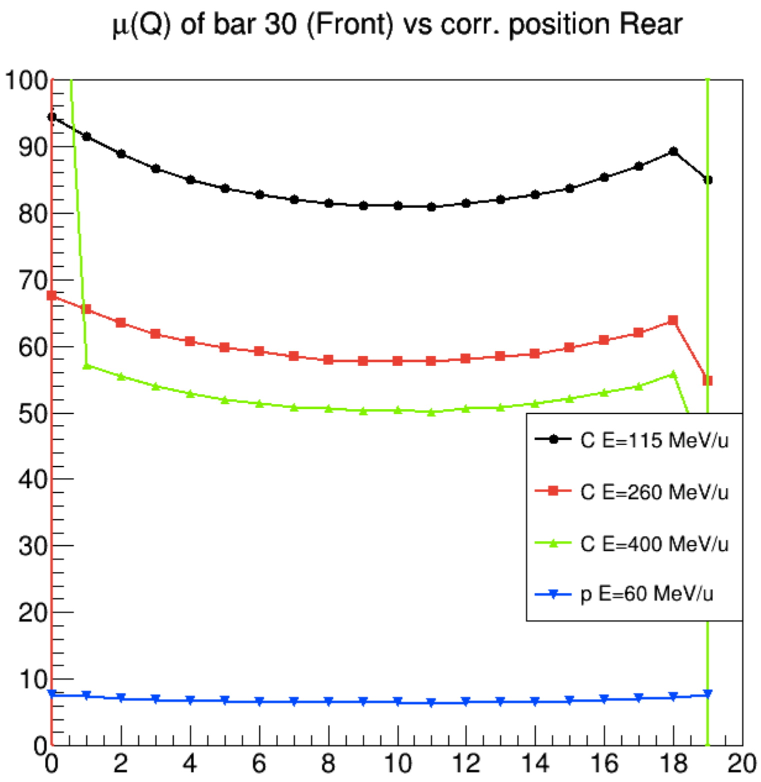
Carbon 260 MeV/u along bar 30

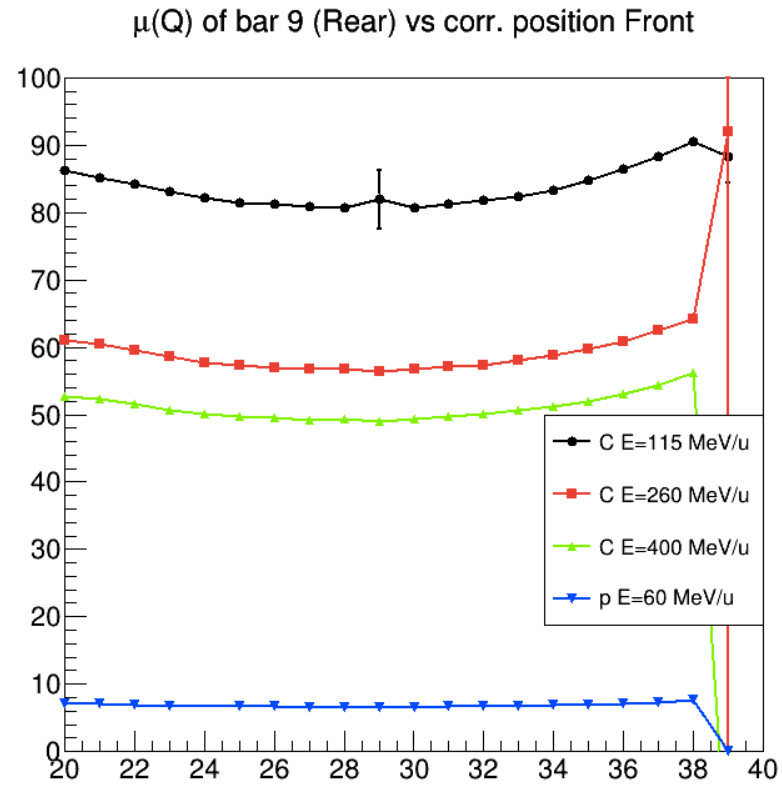


- Store μ(Q) and σ(Q) sigma of fit in 20 positions along a bar
- Repeat for bar all energies
- Repeat for bar 9

Charge dependence on hit position

- Mean charge (μ(Q)) along bar 9 and bar 30

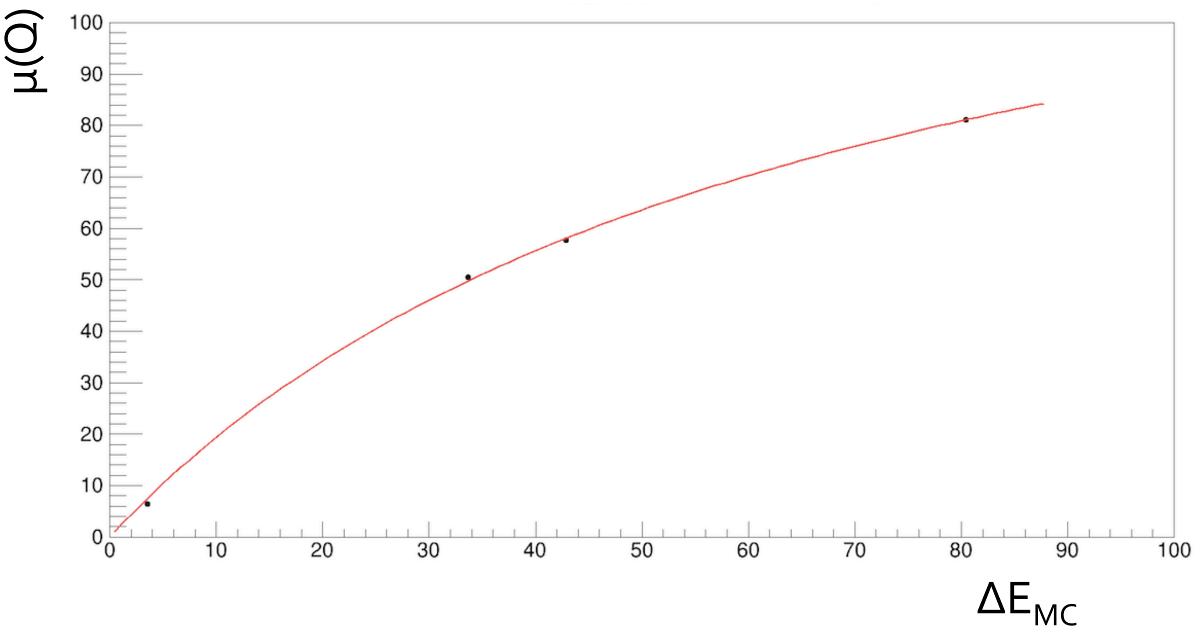




- Position dependence: up to **15%** charge difference with hit position!
- Not easily parameterizable (optical coupling, wrapping, saturation, …)→ **position-per-position energy calibration seems necessary, and front and rear separately**
- σ/μ roughly constant: values from 2% (115 MeV/c carbon) to 6% (60 MeV protons)

Position-per-position calibration

- Mean detected charge (μ(Q)) versus expected (MC) energy deposit in central position (bar30 and bar 9 hit)



Birks' law:

$$\frac{dE}{dx} = S\frac{\frac{dE}{dx}}{1+k_B\frac{dE}{dx}}$$

$$\mu(Q) = [0]\frac{\Delta E_{MC}}{1+[1]\Delta E_{MC}}$$

- Remember:
  - [0]: to describe the nominal scintillation efficiency, the wrapping, transport, and the optical coupling to the photo-detectors.
  - [1]: related to scintillator quenching and photo-detector saturation effects.
- Fits nicely with Birks' law
- Repeat in 400 positions, **Front and Rear separately**

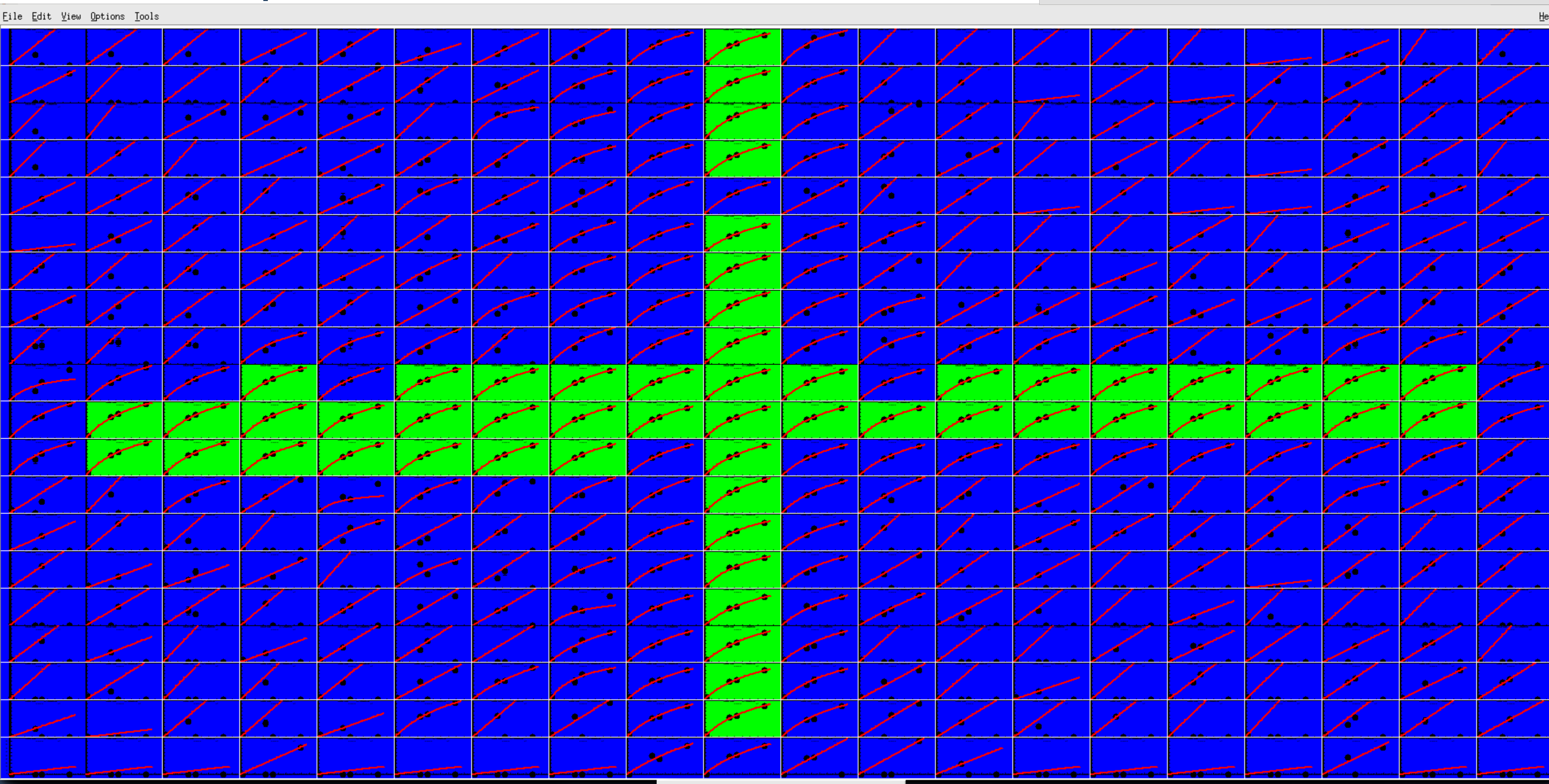
Position-per-position calibration

- Repeat fit in all positions (remember only cross was irradiated)
- **Extract parameters of front ONLY**

Bad statistics (<100 ev/point)

Statistics ok, but fit parameters strange

Ok: calibrated!



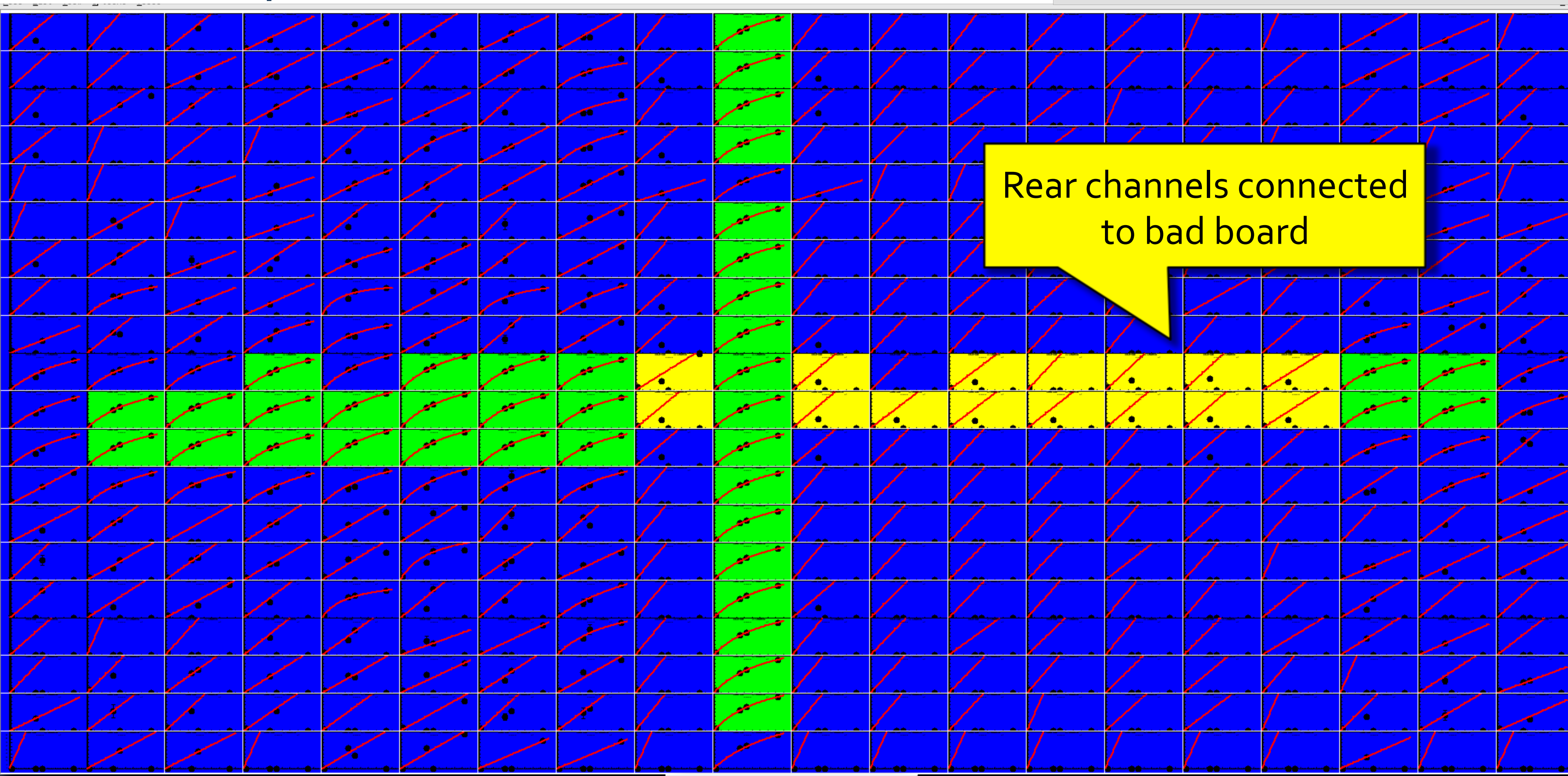
Position-per-position calibration

- Repeat fit in all positions (remember only cross was irradiated!)
- **Extract parameters of rear ONLY**

Bad statistics (<100 ev/point)

Statistics ok, but fit parameters strange

Ok: calibrated!

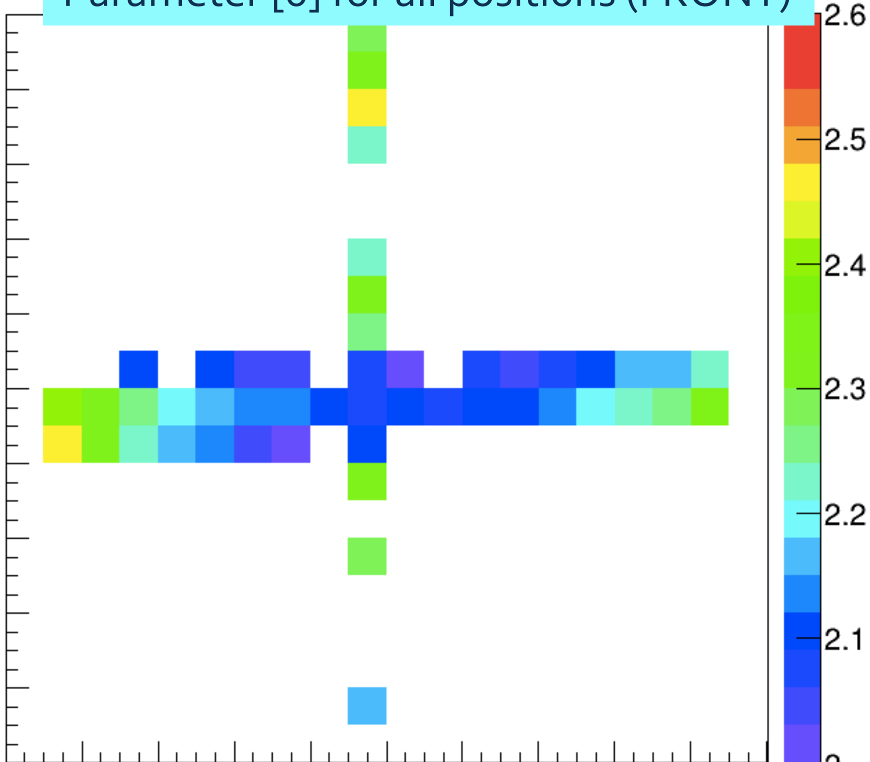


Position-per-position calibration

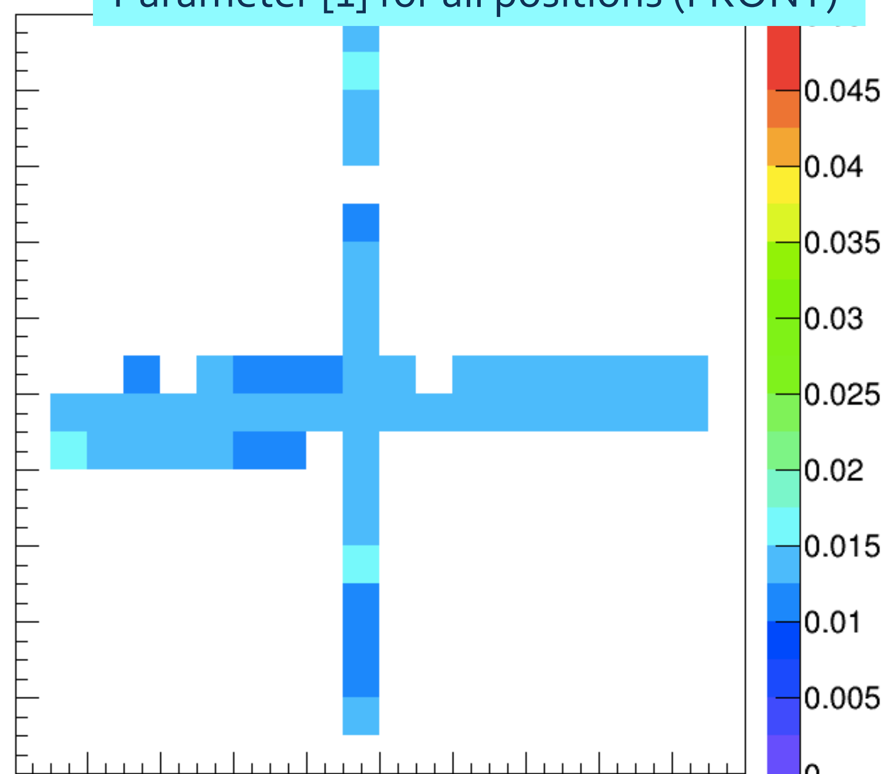
- All parameters stored in text file
- [0]: describes scintillation efficiency, wrapping, transport, optical coupling to photo-detectors → variation between bars, some dependence on position
- [1]: scintillator quenching, photo-detector saturation effects→ similar for all bars

$$\mu(Q) = [0]\frac{\Delta E_{MC}}{1 + [1]\Delta E_{MC}}$$

Parameter [0] for all positions (FRONT)



Parameter [1] for all positions (FRONT)

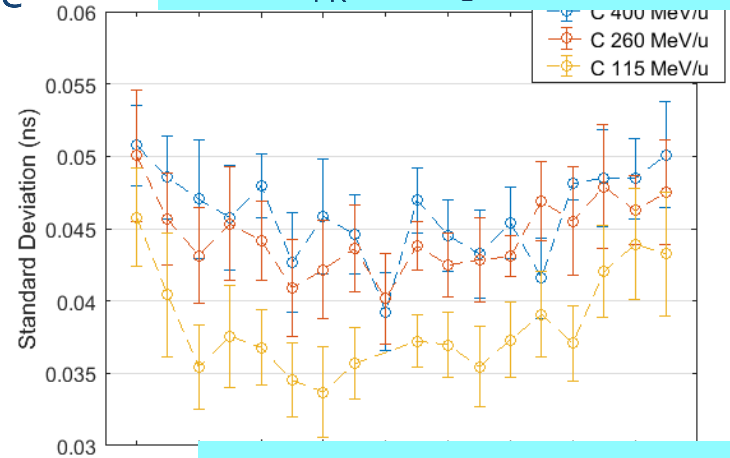


Tof Wall only: time resolution validation

- Before extraction of final TOF, compare time resolution σ (TOF_{FR}) with Matteo's results

$$TOF_{FR} = t_{TW,plane\ 1} - t_{TW,plane\ 2}$$

σ (TOF_{FR}) along bar 9 (Matteo)

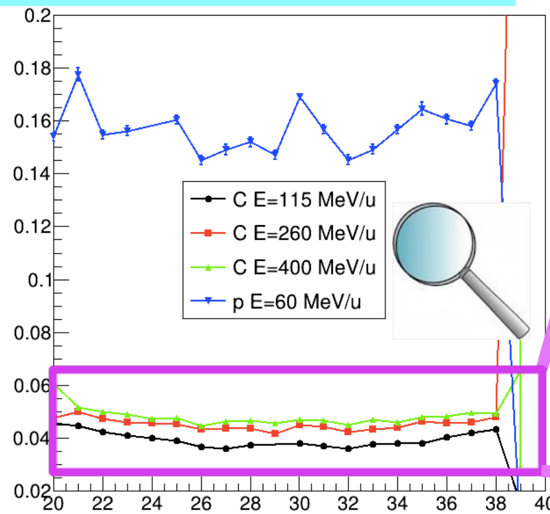


TW resolutions

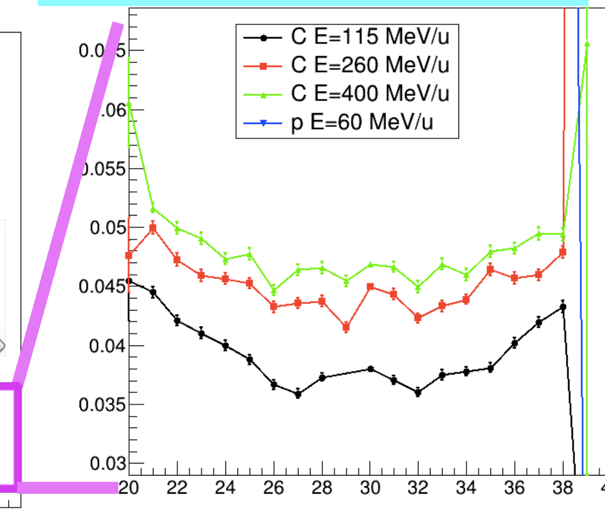
Carbon:
σ (TOF_{FR})=35 to 60 ps
(**agree with Matteo**)

Protons:
σ (TOF_{FR})=160 ps

σ (TOF_{FR}) along bar 9 (new)



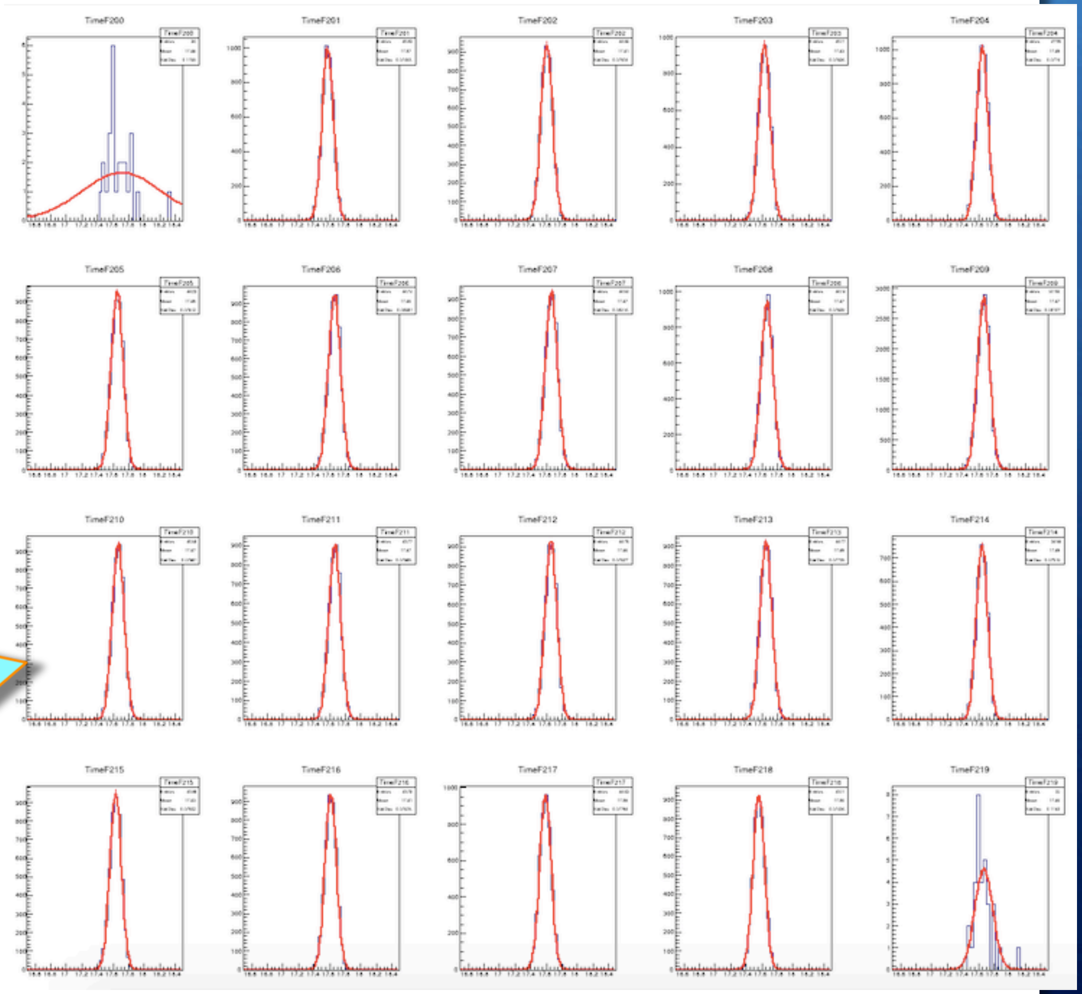
σ (TOF_{FR}) along bar 9 (new)



Time-Of-Flight between TW and STC

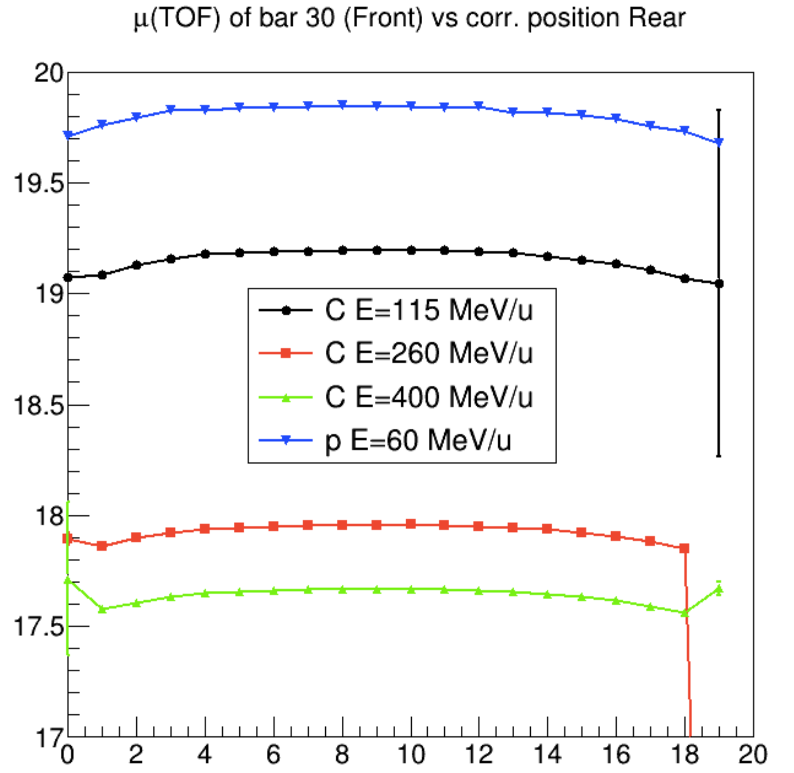
- Extraction of final TOF including clock correction
- Details on how to extract TOF see presentation by Roberto Zarrella!
- Here just a global validation to check whether distributions are globally as expected

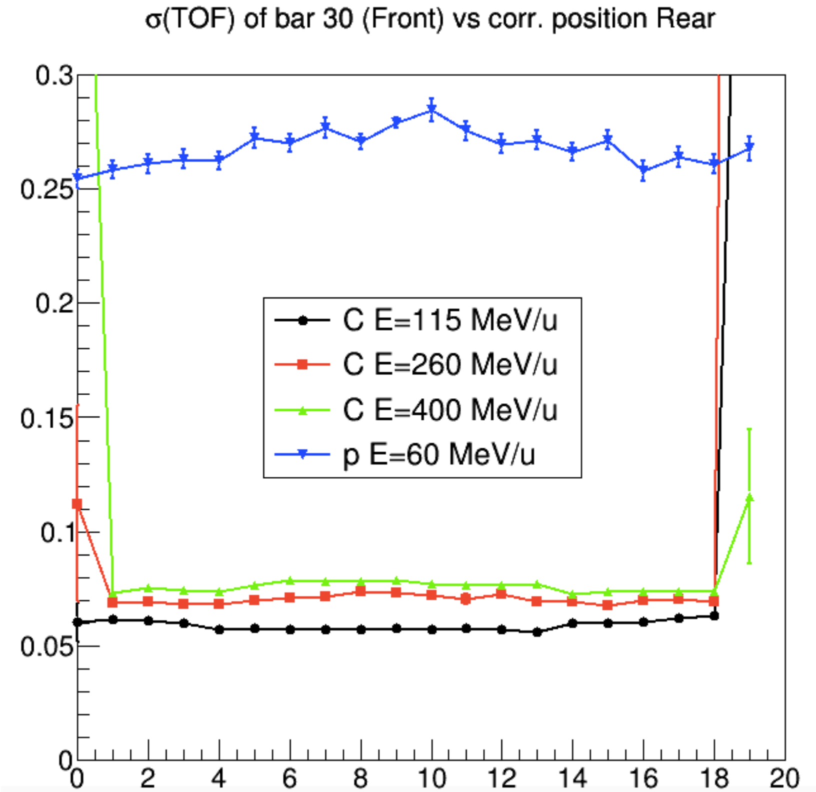
Example of TOF distribution measured along bar 30 (USING ONLY BAR 30) (for 260 MeV/u Carbon) (no cabling correction in this plot)



Time-Of-Flight between TW and STC

- For each energy, extract μ(TOF) and σ(TOF)
- Example of μ(TOF) and σ(TOF) along bar 30 **USING ONLY FRONT (BAR 30 itself)**

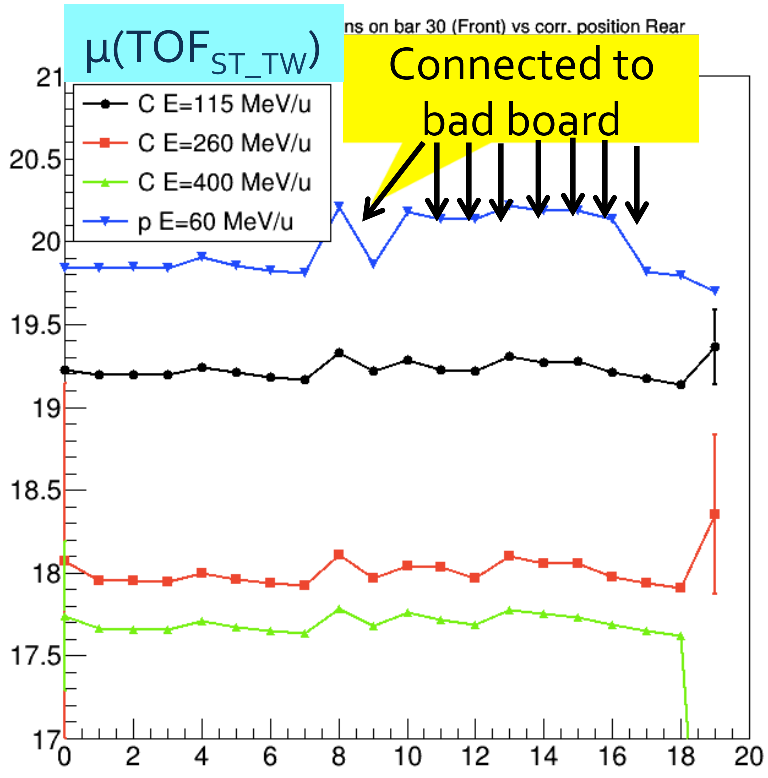


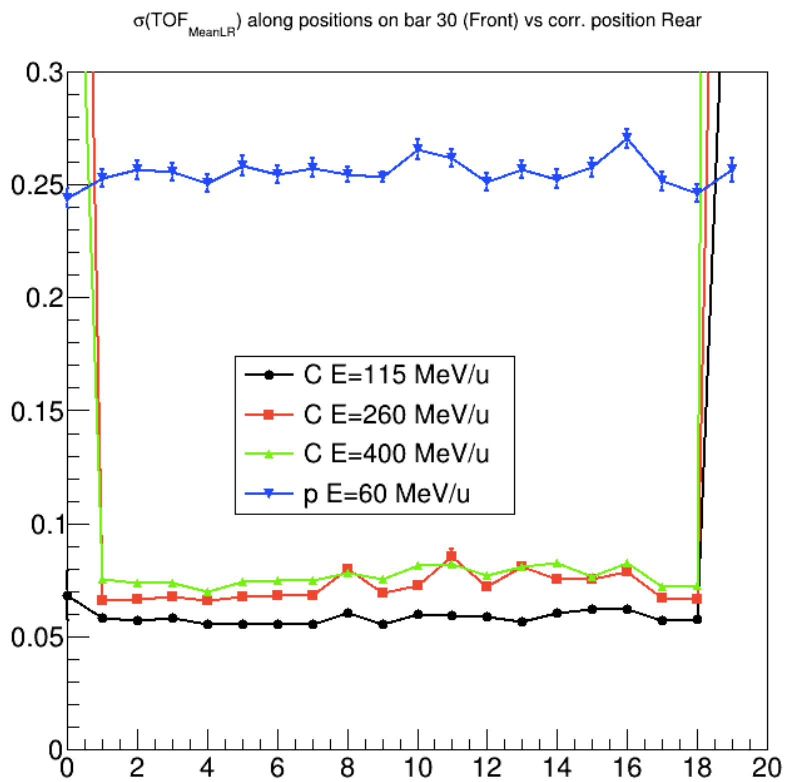


- Carbon: σ (TOF)=60 to 80 ps (using only FRONT)
- Protons: σ (TOF)=250 to 280 ps (using only FRONT)
- Shape of resolution plot different from slides by Giacomo (29-10-2019) and Gaia (today)…

Time-Of-Flight between TW and STC

- For each energy, extract μ(TOF) and σ(TOF)
- Example of μ(TOF) and σ(TOF) along same positions but **USING FRONT AND REAR**

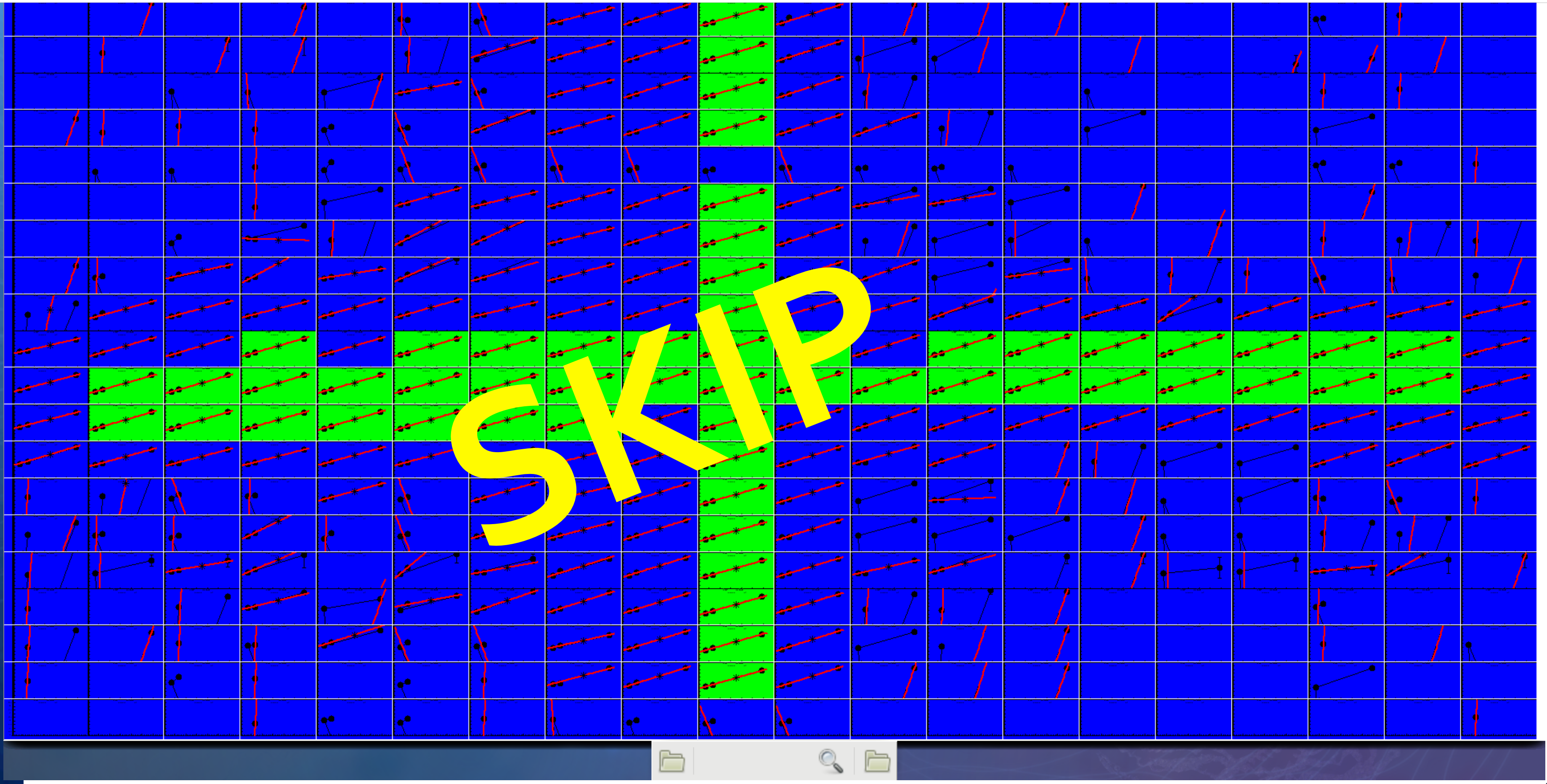




- Carbon: σ (TOF)=55 to 80 ps (using FRONT+REAR)
- Protons: σ (TOF)=250 to 270 ps (using only FRONT+REAR)
- To be repeated with full working detector… in any case resolution dominated by STC

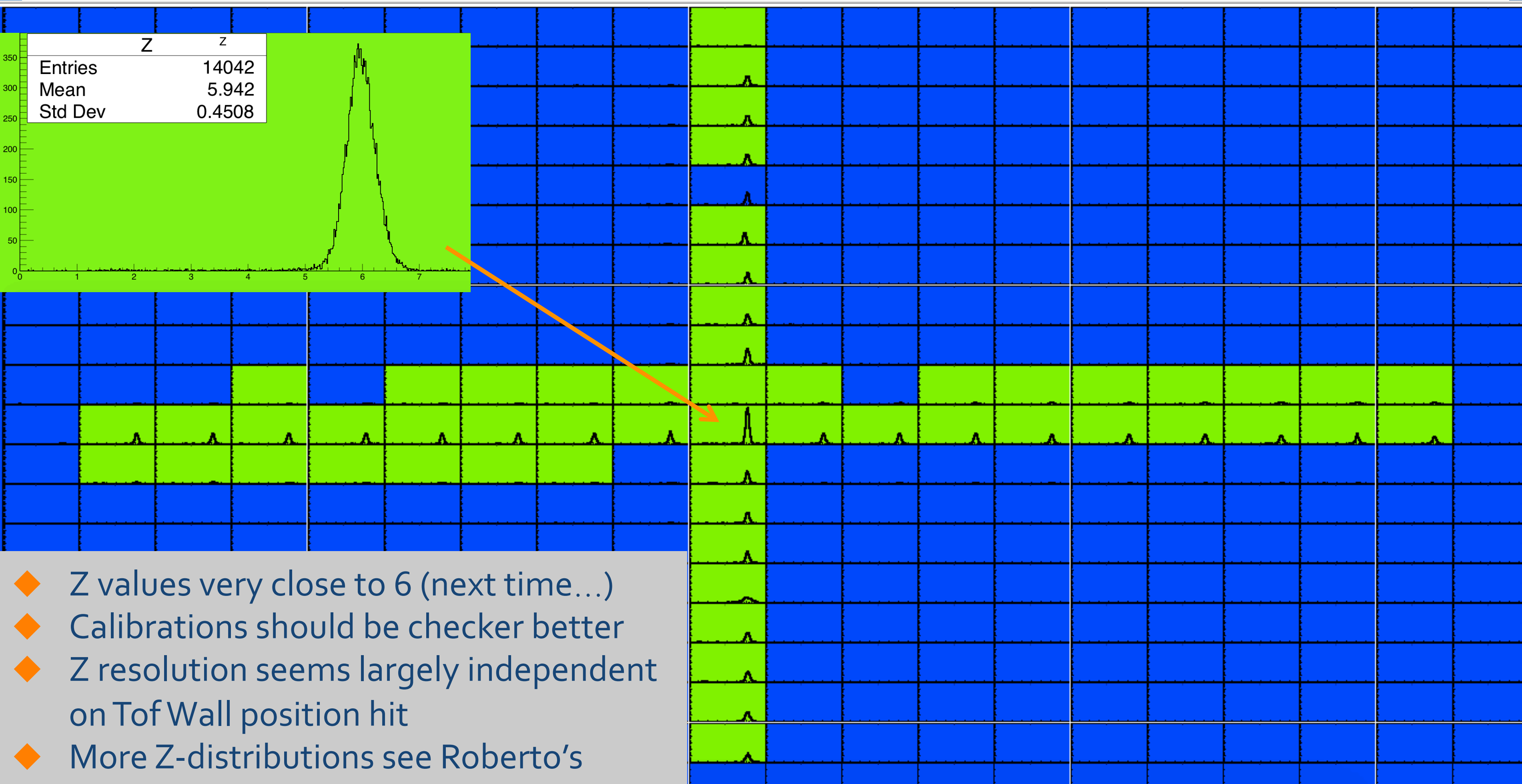
TOF between TW and STC

- Calibrated TOF position-by-position now, using front+rear average .
- Final strategy to be decided (see more information and another method in Roberto's presentation)



Evaluated Z position-per position

- Using energy and TOF calibration, extract Z with Bethe-Bloch formula
- Example of Z distributions on plane for well-calibrated bars (here carbon, E=260 MeV/u)
- Used only front energy in this plot



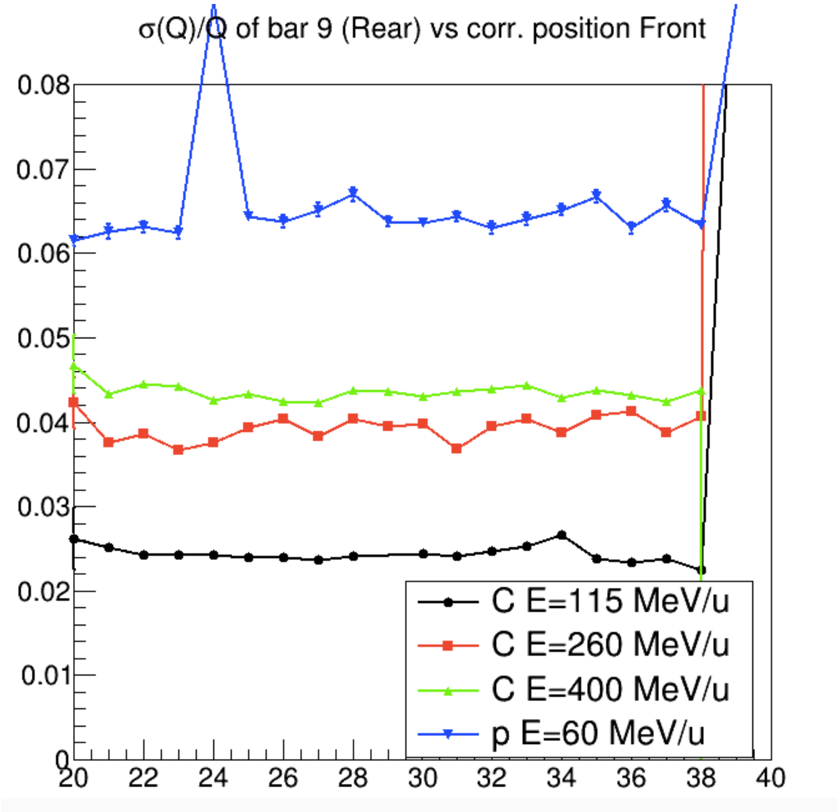
- Z values very close to 6 (next time…)
- Calibrations should be checker better
- Z resolution seems largely independent on Tof Wall position hit
- More Z-distributions see Roberto’s presentation

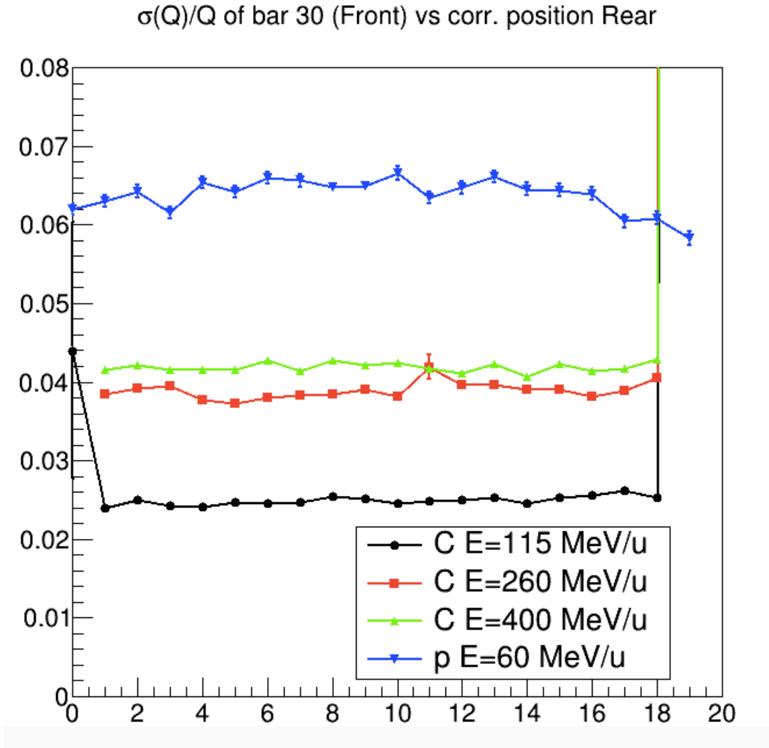
Conclusion and plans

- ✓ Pisa stand-alone ΔE-TOF software re-structured and improved
  - ✓ 40 bars
  - ✓ Allows for direct data-MC comparison (event-by-event structure)
  - ✓ Fully validated with Matteo;s plots independently obtained
  - ✓ Includes STC information
  - ✓ Includes time and energy calibration
- → Master thesis of Roberto Zarrella.
- → Will be used in all stand-alone data takings at CNAO and to check GSI data analysis with SHOE

- To be done:
  - Check TOF calibration, energy calibration, and evaluation of Z
    - Include effect of CNAO nozzle on energy
  - MC-data comparison (Z, nbars hits, …)

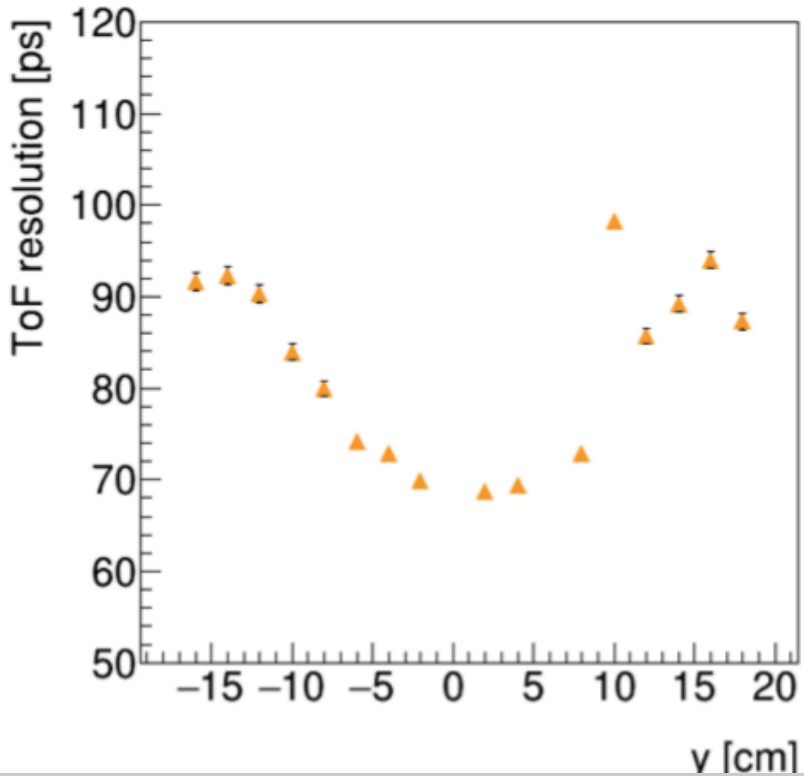
Backup: sigma(Q)/Q

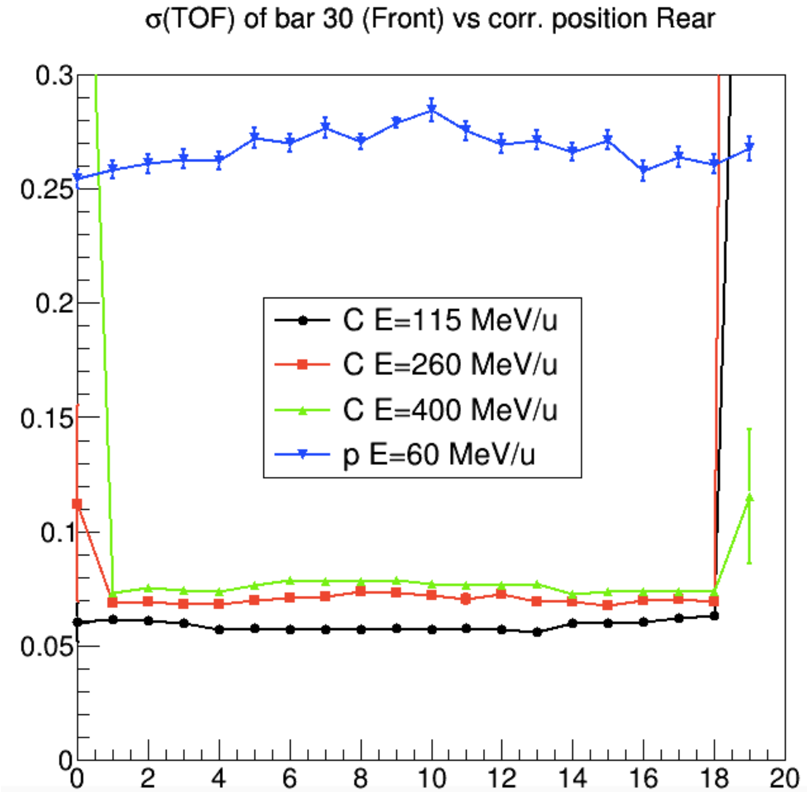




Time-Of-Flight between TW and STC

- For each energy, extract μ(TOF) and σ(TOF)
- Example of μ(TOF) and σ(TOF) along bar 30 **USING ONLY FRONT (BAR 30 itself)**





Disagreement