TOF Wall data-MC comparisons CNAO and GSI data

Pisa group

Introduction

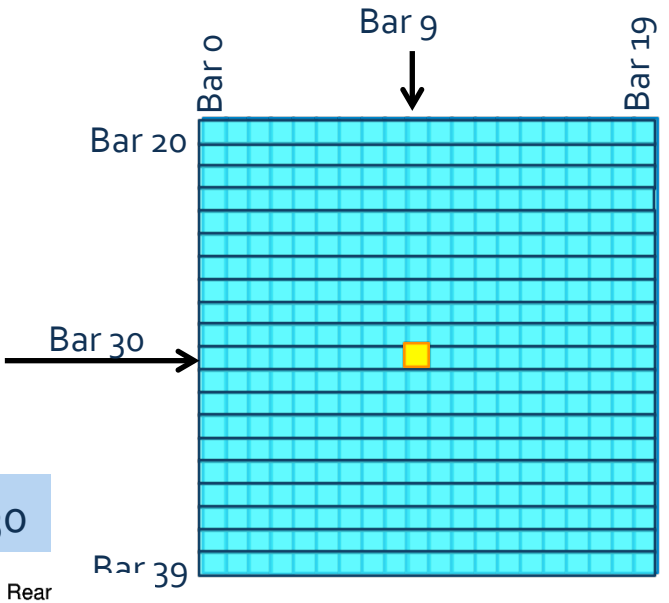
- Last time: December 2019: showed preliminary energy and time calibration using Pisa stand-alone ΔE-TOF software :
  - CNAO data only
  - No MC simulations analyzed
- Today:
  - Quick reminder of energy and time calibration strategy
  - New energy calibrations including also oxygen data
  - Calibration methods compared (mean, median, MPV…)
  - MC simulations analyzed
  - Using new calibrations, data-MC comparisons performed of CNAO and GSI data
    - With target (GSI)
    - Without target (CNAO and GSI)

Data and MC samples

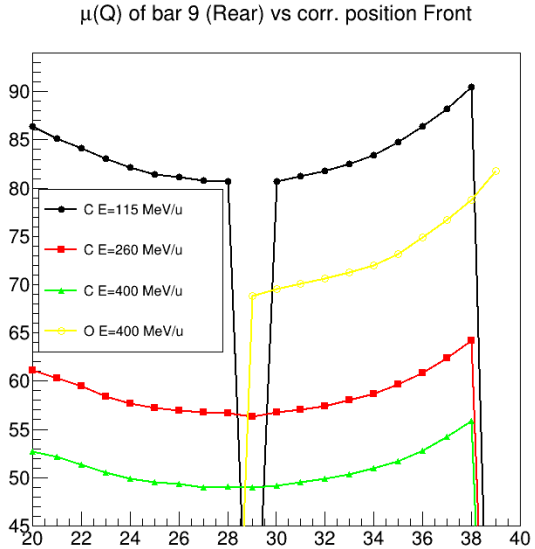
- Delta-E TOF detector system with 40 bars
- Data samples:
  - 4 acquisitions from CNAO (March 2019):
    - Carbon: 115, 260, 400 MeV/u
    - Protons: 60 MeV/c
  - 2 acquisitions from GSI (April 2019):
    - Oxygen 400 MeV/u: no target: Run 2242
    - Oxygen 400 MeV/u with 3 mm C target: Run 2239, 2240, 2241
  - Data processed with Stand Alone Pisa software
- MC simulations:
  - GSI Setup from Giuseppe, changed the y coordinate of the beam position, so irradiation was mostly on bar 30 (as data showed) (SHOE)
  - CNAO setup: from GSI but putting all irrelevant components to air
  - AnaFOOT used to extract MC results. Note that all MC results are obtained in the same way as data (so include events with more bars hit, etc)
  - No cuts applied

Energy calibration

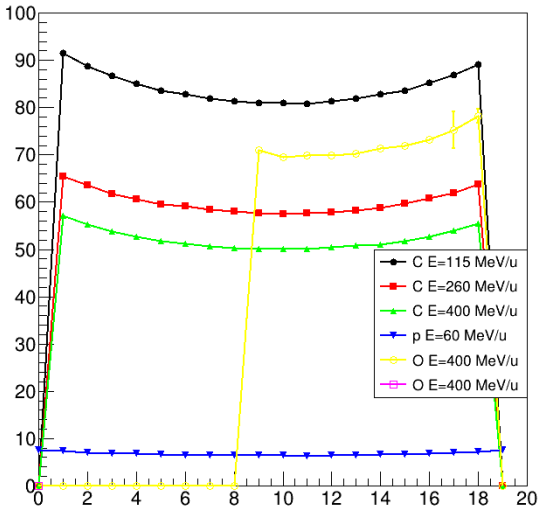
- **Since charge changes along the bar, we cannot calibrate bar-per-bar** but have to calibrate **position-by-positio**n
  - see also meeting December 2019
  - GSI data added on these plots!



mu(Q) along bar 9



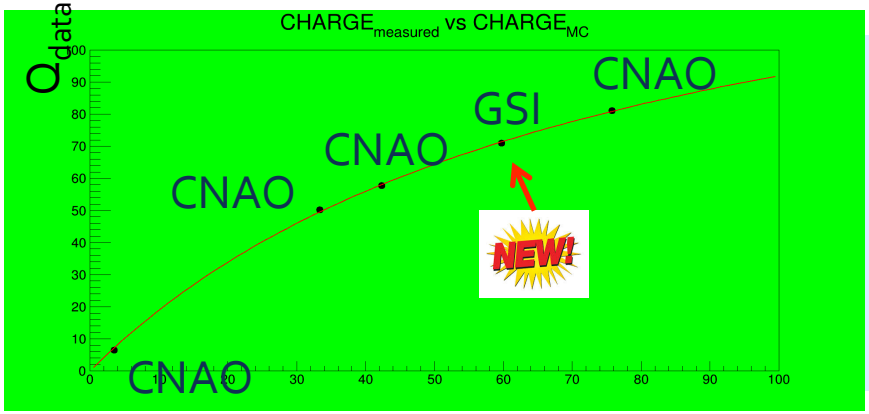
mu(Q) along bar 30



- Up to 15% difference
- New: 400 MeV/u oxygen curve
- Behaviour not exactly predictable, so safest option is to calibrate position-by-position

Position-per-position calibration

- Relate detected charge in data to a real value in MeV
- Done with MC
- Can use mean, median, most probable value (mode), … ? This plot: median
- Q versus expected (MC) energy deposit in central position



Birks' law:

$$\frac{dE}{dx} = S\frac{\frac{dE}{dx}}{1 + k_B \frac{dE}{dx}} \qquad Q_{data} = [0]\frac{\Delta E_{depos,MC}}{1 + [1]\Delta E_{depos,MC}}$$

See presentation December for more details

- Fits OK with Birks' law: GSI oxygen point falls more or less on the curve.
- What to use? Mean? Medium? MPV? → test all and check who is best
  - We want to approximately get back the MC value which we used to calibrate!
  - Compare energy deposition distributions
  - Next plots are when taking median value (all other
- Repeat in 400 positions, front and rear separately

Position-per-position calibration: **front**

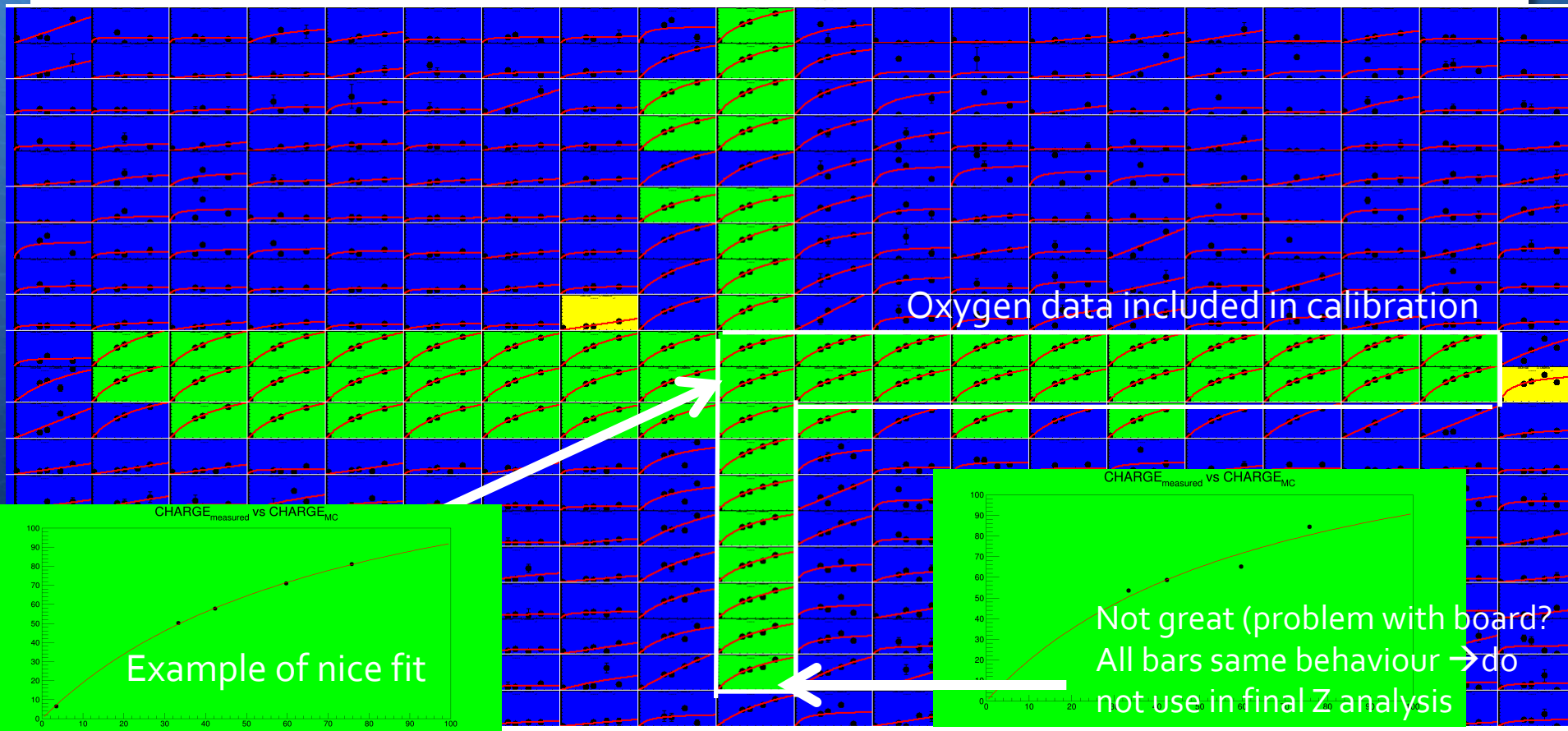
- Repeat fit in all positions. Remember:
  - At CNAO only cross was irradiated
  - At GSI only a few bars
- **Positions with oxygen are new**

NEW!

Bad statistics (<20 ev/point)

Statistics ok, but fit parameters strange

Ok: calibrated!

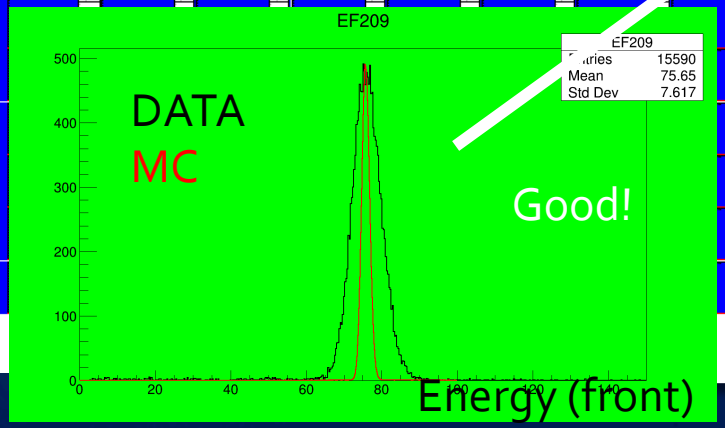


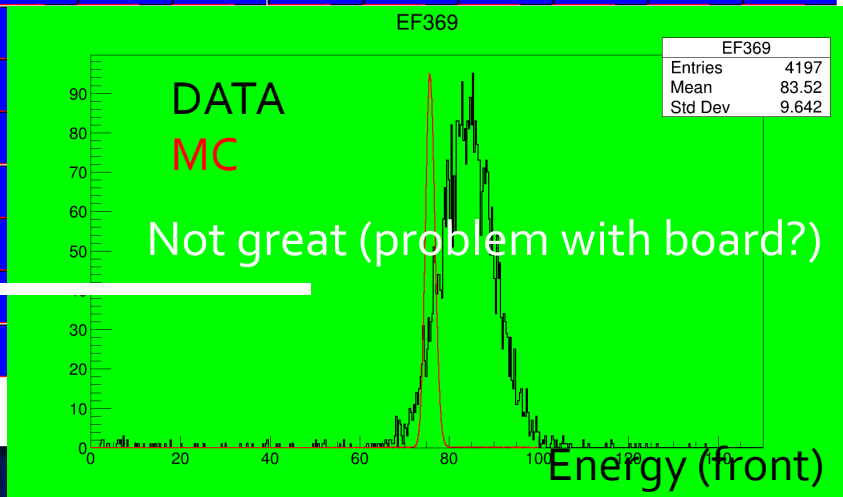
Validation of energy calibration front: 115 MeV/u C

Check the calibration: apply the extracted parameters (for 5 or 4 energies) p_0 and p_1 on each energy separately: do we get back the MC result?

Mostly OK!

Oxygen data included in calibration



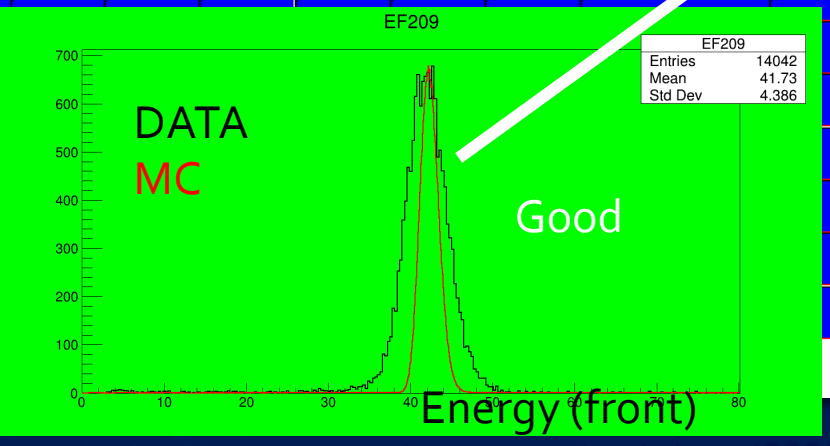


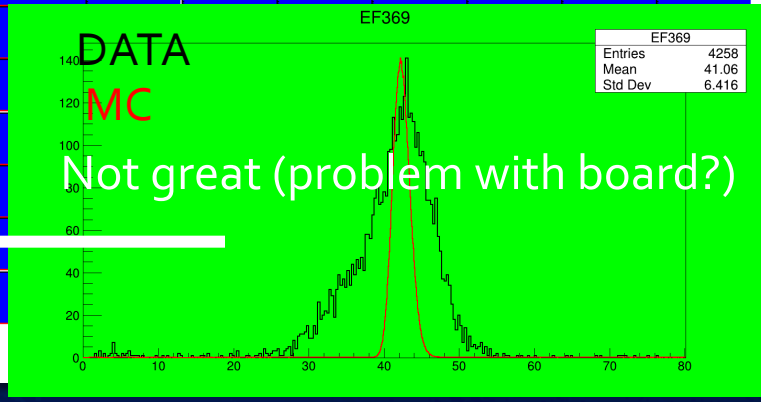
Validation of energy calibration front: 260 MeV/u C

Check the calibration: apply the extracted parameters (for 5 or 4 energies) p_0 and p_1 on each energy separately: do we get back the MC result?

Mostly OK!

Oxygen data included in calibration



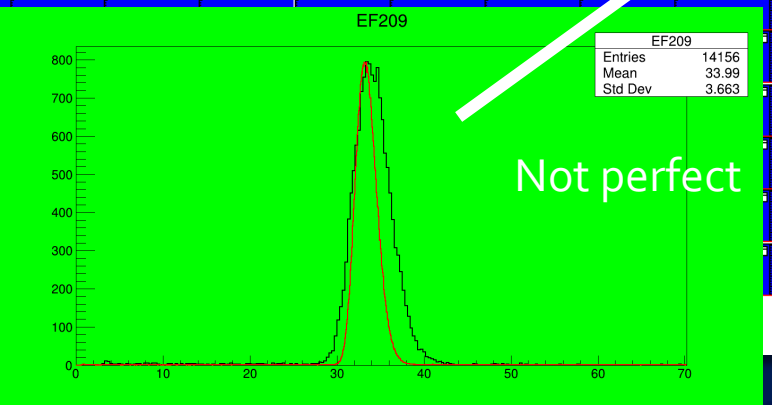


Validation of energy calibration front: 400 MeV/u C

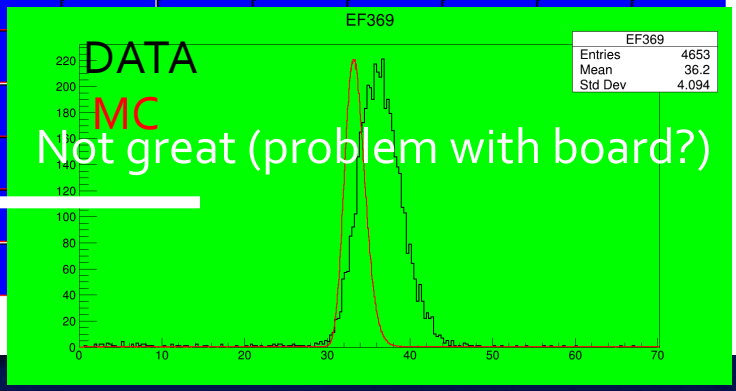
Check the calibration: apply the extracted parameters (for 5 or 4 energies) p_0 and p_1 on each energy separately: do we get back the MC result?

Mostly OK!

Oxygen data included in calibration



Not perfect



DATA

MC

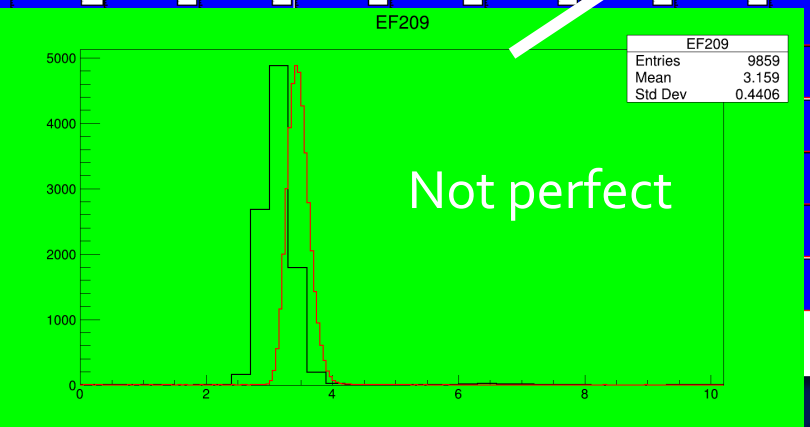
Not great (problem with board?)

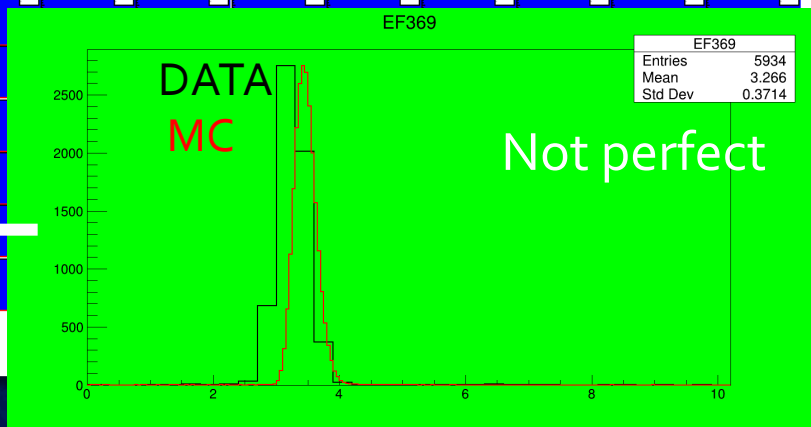
Validation of energy calibration front: 60 MeV/u p

Check the calibration: apply the extracted parameters (for 5 or 4 energies) p_0 and p_1 on each energy separately: do we get back the MC result?

Not perfect for protons
Can't get it better when using 4 or 5 points for calibration…

Oxygen data included in calibration



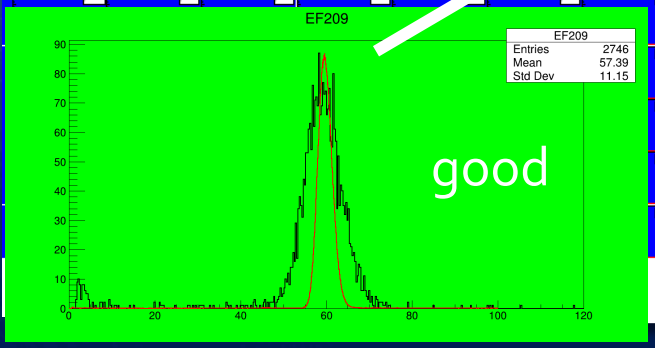


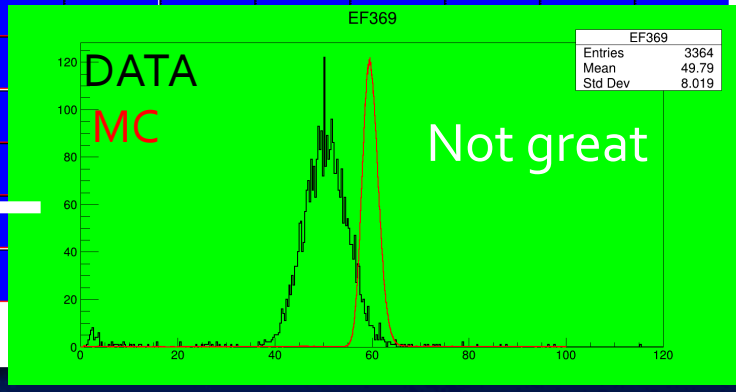
Validation of energy calibration front: 400 MeV/u O

Check the calibration: apply the extracted parameters (for 5 or 4 energies) p_0 and p_1 on each energy separately: do we get back the MC result?

Mostly OK

Oxygen data included in calibration

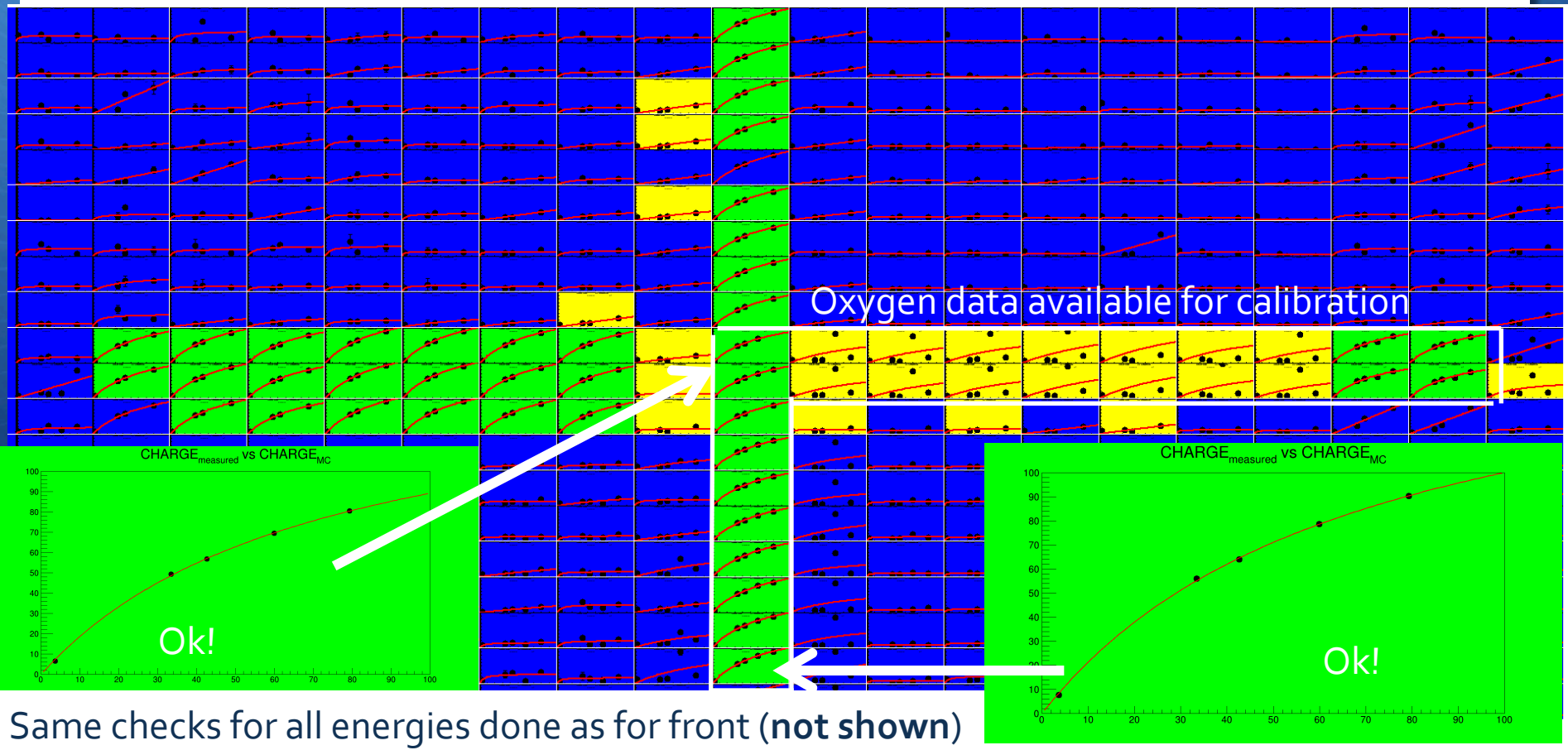




Position-per-position calibration: **rear**

- Repeat fit in all positions. Remember:
  - At CNAO only cross was irradiated
  - At GSI only a few bars
- **Positions with oxygen are new**

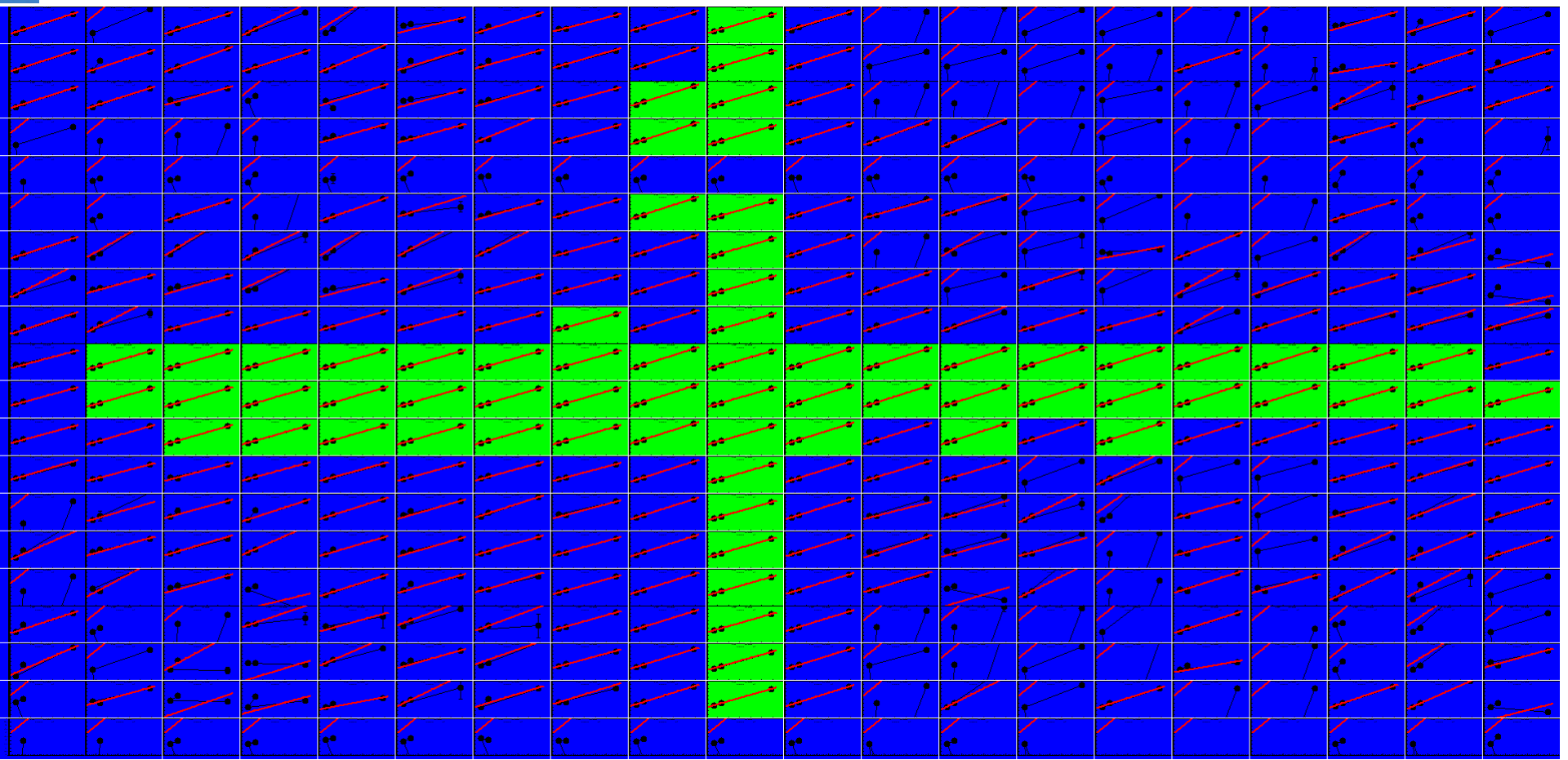
Bad statistics (<20 ev/point)
Statistics ok, but fit parameters strange
Ok: calibrated!



Same checks for all energies done as for front (**not shown**)

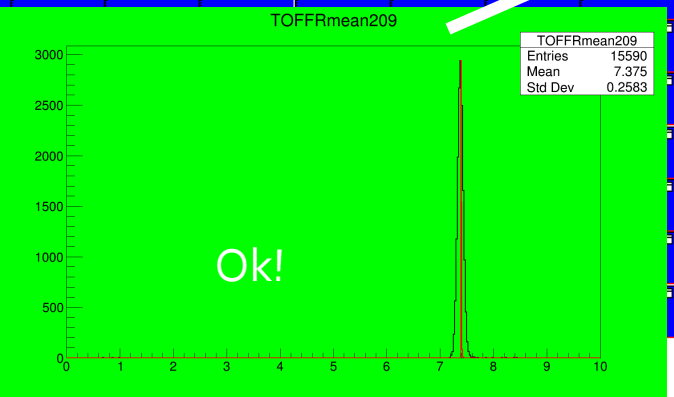
TOF calibration

- TOF calibration for cables: data used: C 260 MeC, C 400 MeV/u, and p 60 MeV
- Front and rear together: plot measured TOF vs expected MC TOF → get cable offset
- Carbon 115 MeV/u: not usable (not aligned in time): calibrate separately
- Oxygen data: not used, different cables, calibrate separately



Validation of TOF calibration: C 115 MeV/u

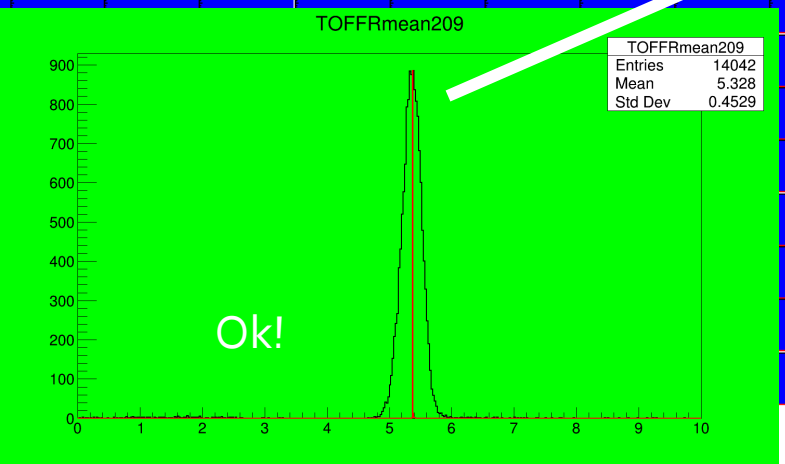
Separately calibrated: do we get back the MC result?



Everywhere excellent

Validation of TOF calibration: C 260 MeV/u

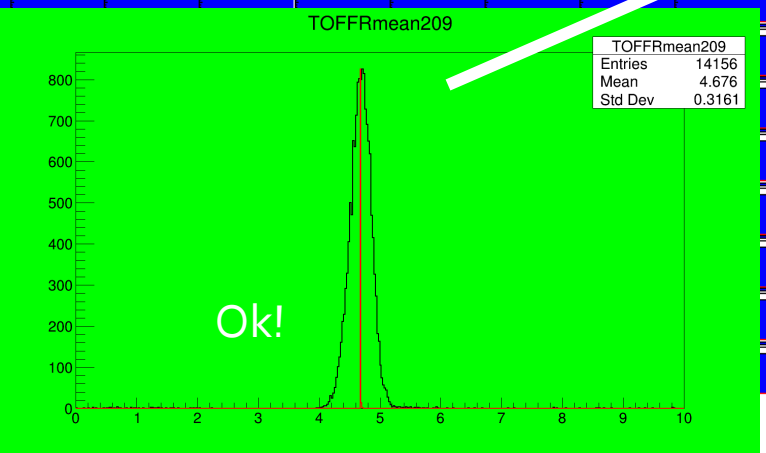
Separately calibrated: do we get back the MC result?



Everywhere excellent

Validation of TOF calibration: C 400 MeV/u

Separately calibrated: do we get back the MC result?

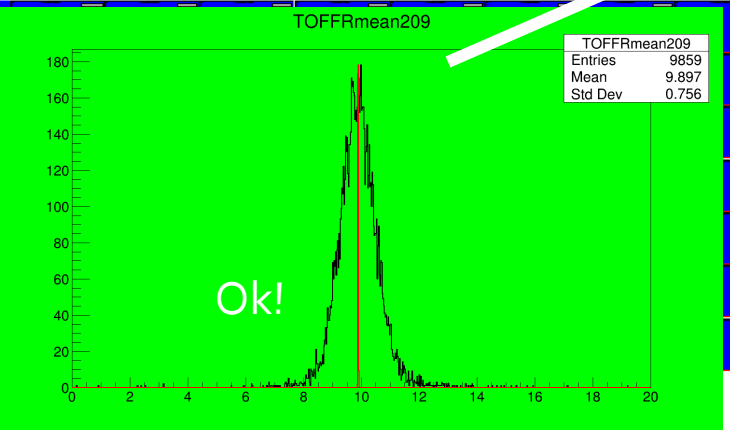


Everywhere excellent

Validation of TOF calibration: p 60 MeV

Separately calibrated: do we get back the MC result?

Oxygen calibration data available



Everywhere excellent

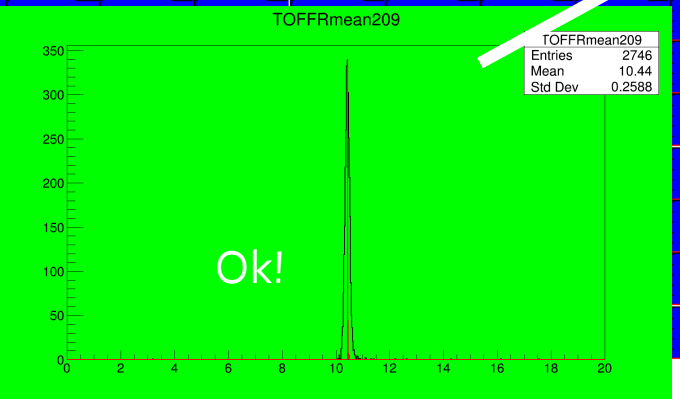
Validation of TOF calibration: O 400 MeV

Separately calibrated: do we get back the MC result?

Oxygen calibration data available

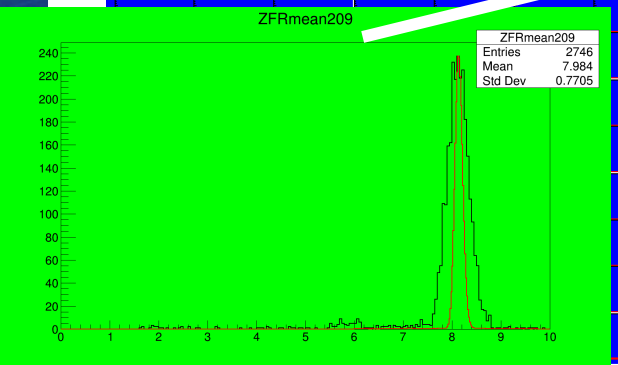
Everywhere excellent

Ok!



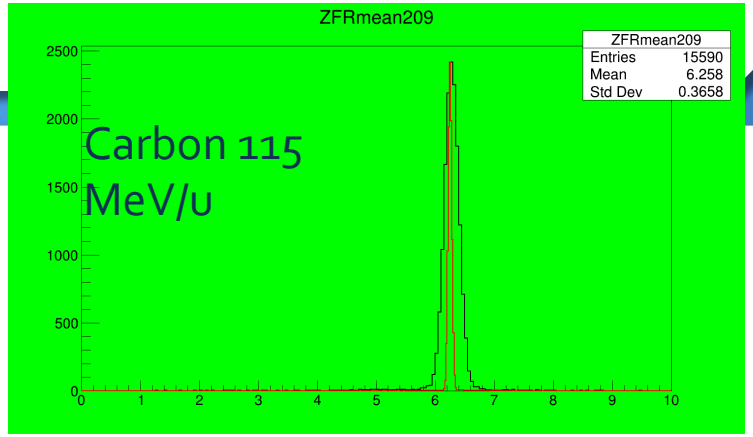
Validation of Z values: O400 MeV/u

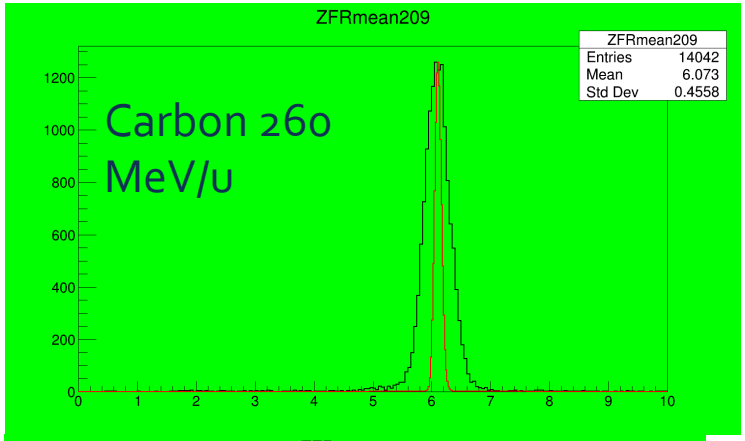
- Energy: use mean of front and rear energy, except for yellow positions in rear (use front) and those positions in front that were bad. (board 79 and 82, respectively)
- TOF calculation: from front and rear together (that is calibrated together)
- Z values checked again in all positions, example here of oxygen (Run 2242)

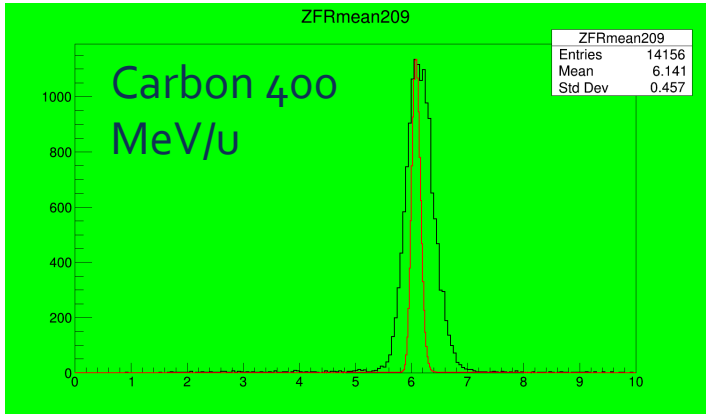


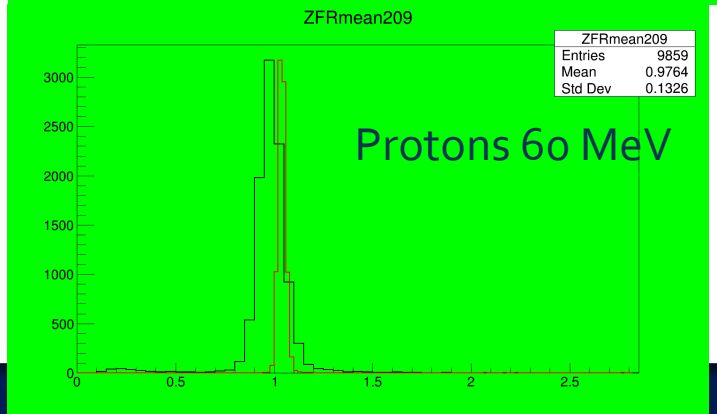
Z-plots

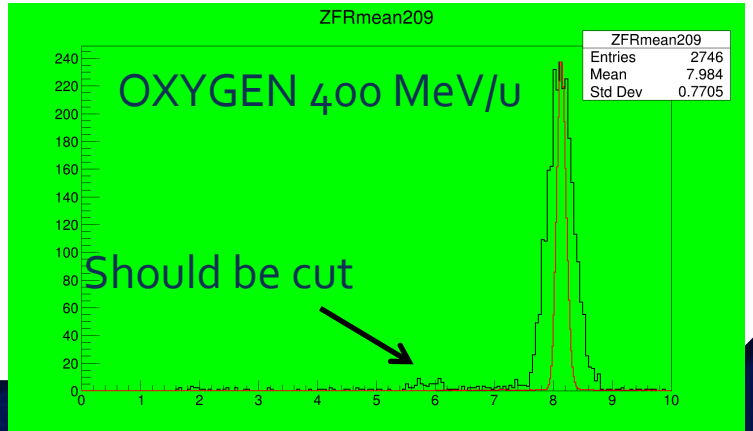
- Example of Z plots in central position (not in all positions result is so good)
- **No cuts at all in data nor in MC!**
- MC result approximately reproduced, as we expected











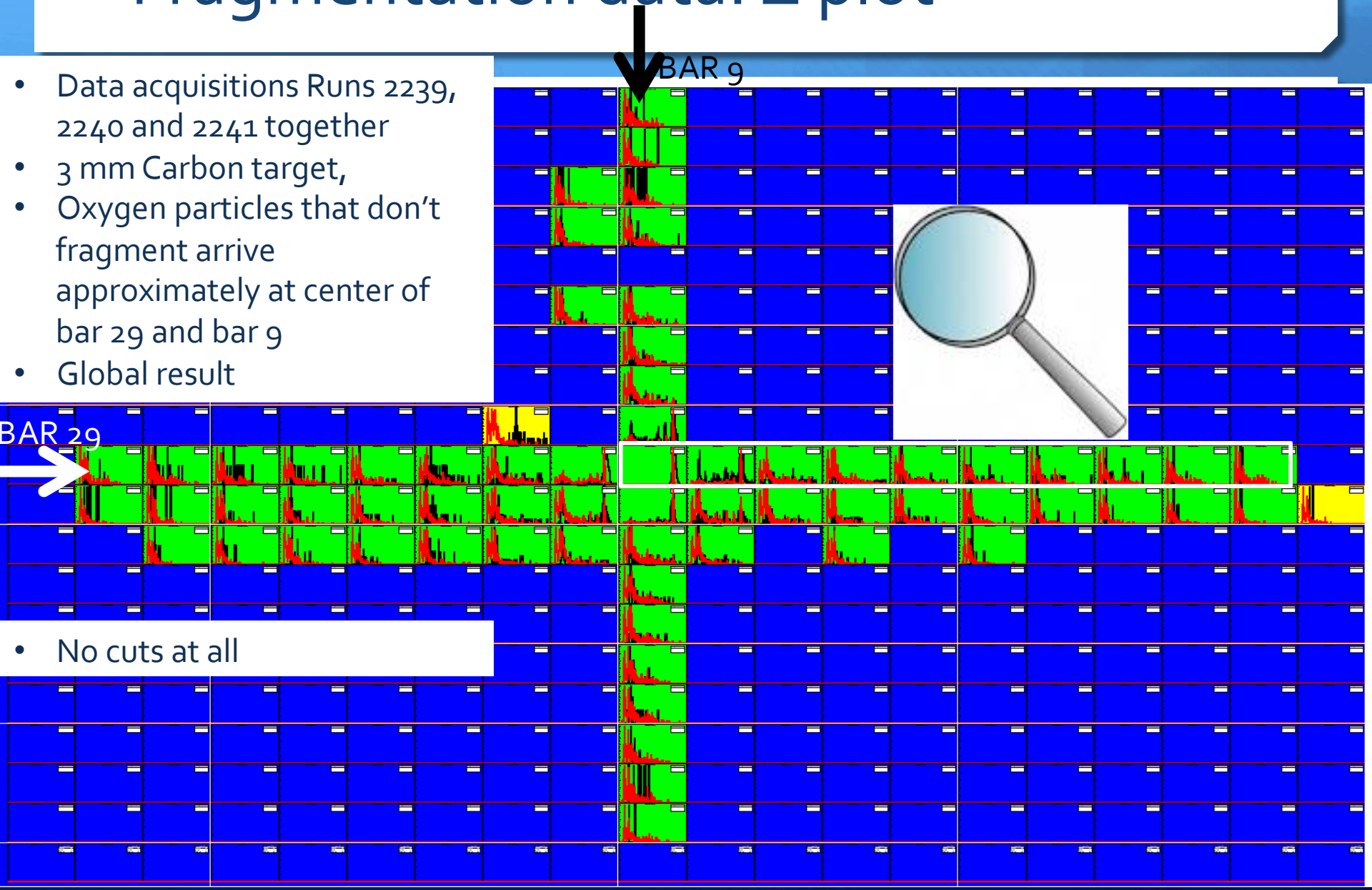
Comparisons between calibration methods

- We have to relate measured charge with deposited energy
- Compare data charge and TOF distribution with mean of MC. Evaluated all above results for:
  - **Mean** of distributions: disadvantage is that data outliers influence results: NO
  - **Mu (fit with gaussian)** distributions: was OK
  - **Median** of distribution: was BEST
  - **MPV** (mode=most probable value) of distributions: was OK
  - Also the way the 5 (4) data points are fitted to Birks' function can slightly influence results
  - For final calibration with new data, should try all options
  - All plots shown today: **median** was used, gave globally the best results (but should be quantified better, for instance by plotting measured-true distributions for all positions, maybe apply some basic cuts before doing the calibration, etc)

Calibration is pretty solid→ Ready to look at the fragmentation data where Z is unknown!

Fragmentation data: Z plot

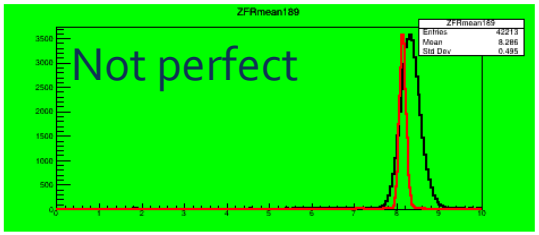
- Data acquisitions Runs 2239, 2240 and 2241 together
- 3 mm Carbon target,
- Oxygen particles that don't fragment arrive approximately at center of bar 29 and bar 9
- Global result

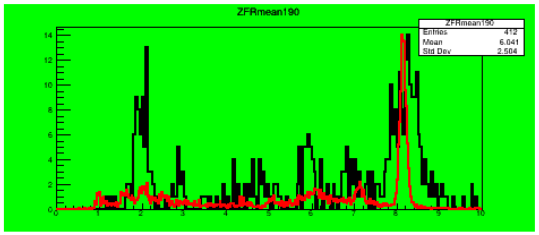


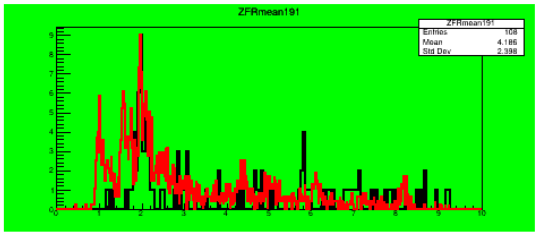
- No cuts at all

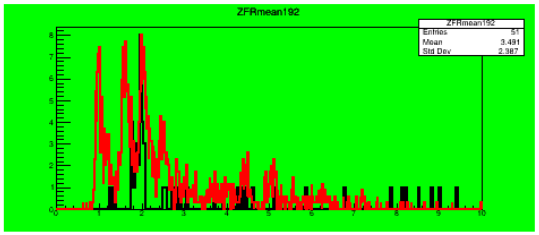
Fragmentation data: Z plot

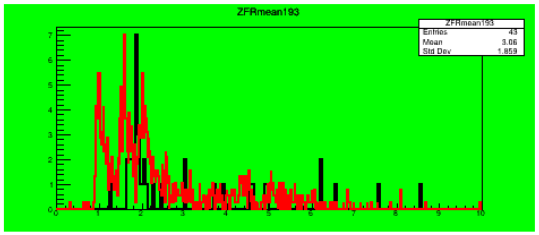
- Close-up of the 10 plots in white region from previous slide (positions 189-198)

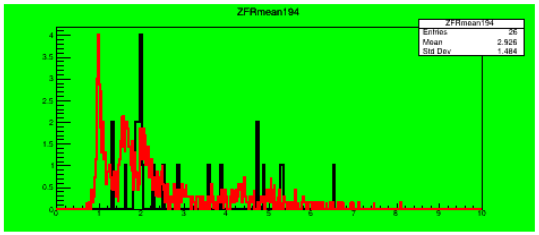


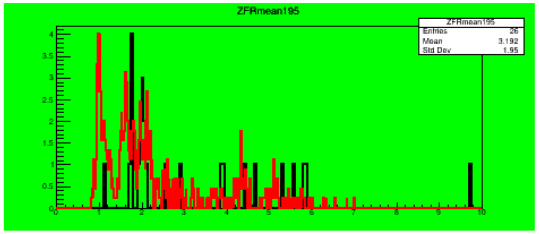


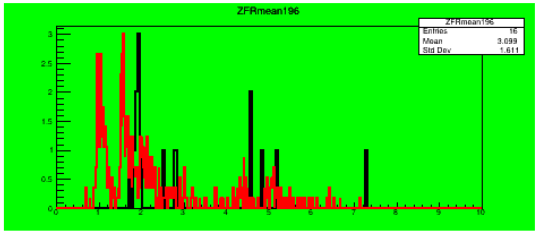


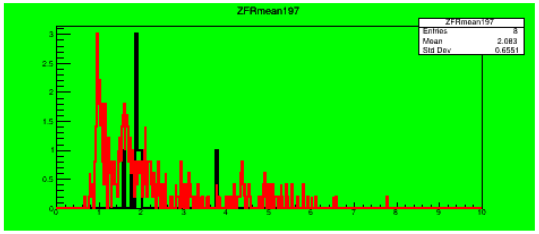


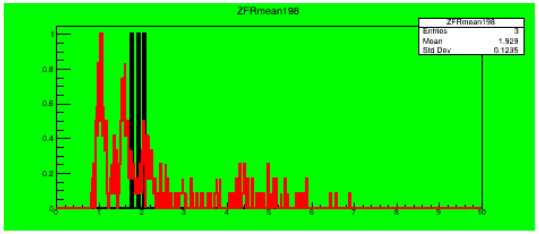










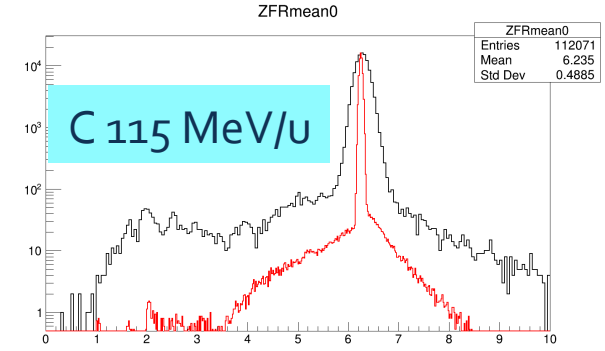


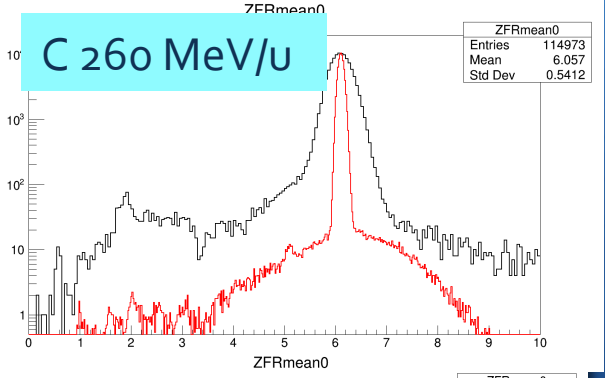
Comparison difficult:

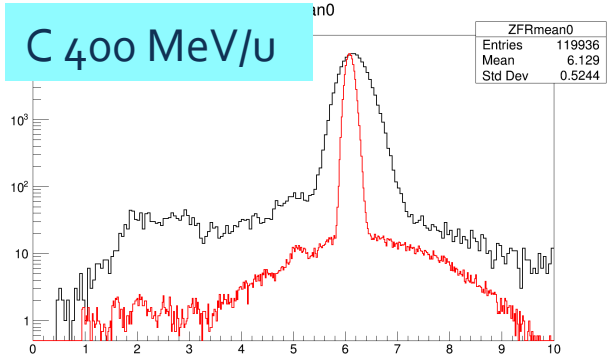
- Beam width not known
- Entrance position not precisely
- Should cut out ghost entries in data and MC (next)

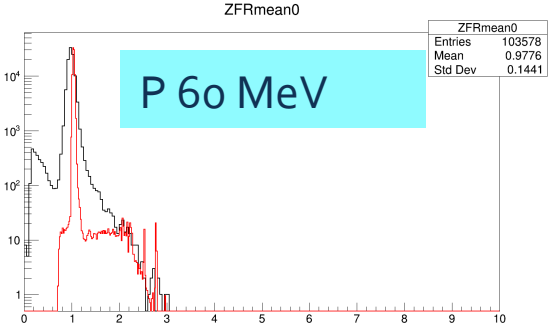
Fragmentation data: Z plot (no cuts)

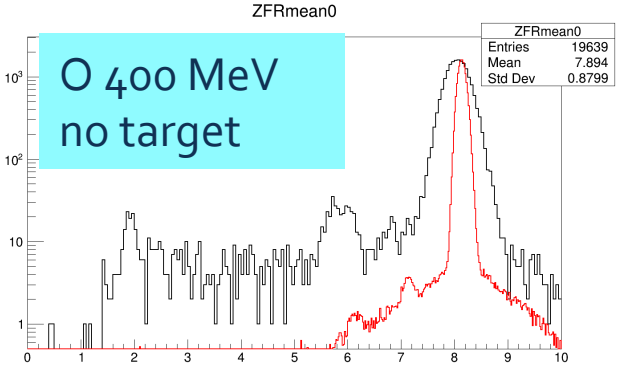
- Histograms of Z of all well calibrated positions added together (Front-Rear mean); logarithmic scale
- In plots, normalized max of MC to max of data (should still apply resolutions in MC)
- No cuts applied

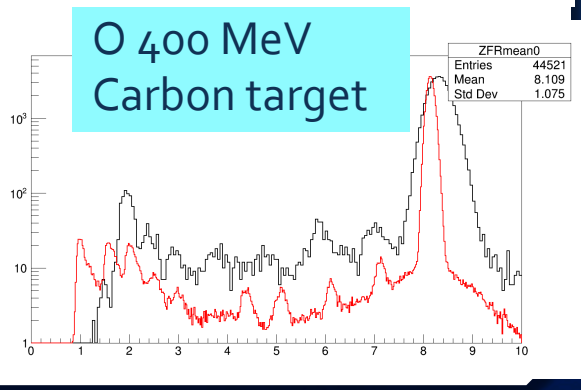












Conclusion and plans

- ✓ Calibration of bars done (preliminary)
  - ✓ As accurate as possible.
  - ✓ Oxygen data included in calibration
    - ✓ OK for many irradiated positions
    - ✓ A few positions showed problems: coupling to SiPM during transport?
  - ✓ Should calibrate just before taking data (same location)
  - ✓ Maybe try other models to fit better the hydrogen point
  - ✓ Apply cuts to remove ghost hits before doing the calibration?
- ✓ GSI data fragmentation data analyzed: data MC comparisons performed
- ✓ Plans: SHOE? Yields? cross sections? → define a strategy together