Towards CNAO2025: check of momentum reconstruction quality with CNAO2024 data

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Towards CNAO2025 with full detector: how well do we reconstruct momentum?

- In the current month we are going to take data with full detector after having learned (hopefully) in September how to optimize both the positioning/alignement of our setup and the performance of our tracking detectors.
- It will be the chance of collecting a large sample of useful data for physics
- In this perspective it can be useful to try to understand a last important topic: which is the quality of our momentum reconstruction? (effective comprehension of the magnetic field of our system, material budget and track reconstruction)
- For this purpose, it can be useful to use 2024 data to perform some checks

A fast look to CNAO2024 data

- Run 7072, carbon ions at 200 MeV/u on C target ~400 k events
- GenFit reconstruction
- In the following test the main focus is on momentum reconstruction of primaries: no physics involved, beam energy well known.

➔ Event selection for primaries:

- 1 BM track with matched vertex with VTX
- Strictly 1 reconstructed track with TW point + >2 VTX pts + >2 MSD pts + $\chi^2<2$
- $Z_{rec} = 6$ (TW charge matched with MSD charge)

403936 events processed
313803 rec. tracks
156110 accepted ➔ 154685 with Z=6 TW-MSD matched

Expected P value

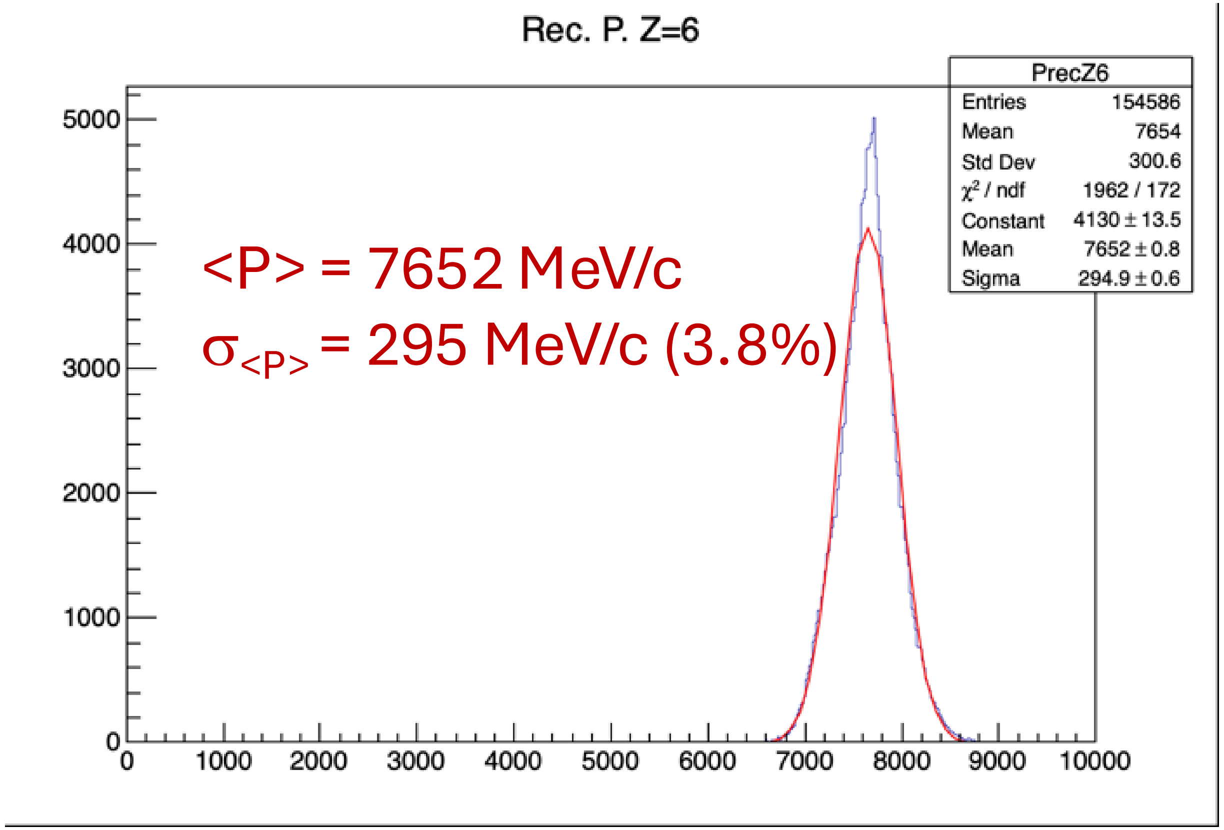
At 200 MeV/u ^{12}C has nomina initial P = 7707.97 MeV/c but we have energy loss in the path

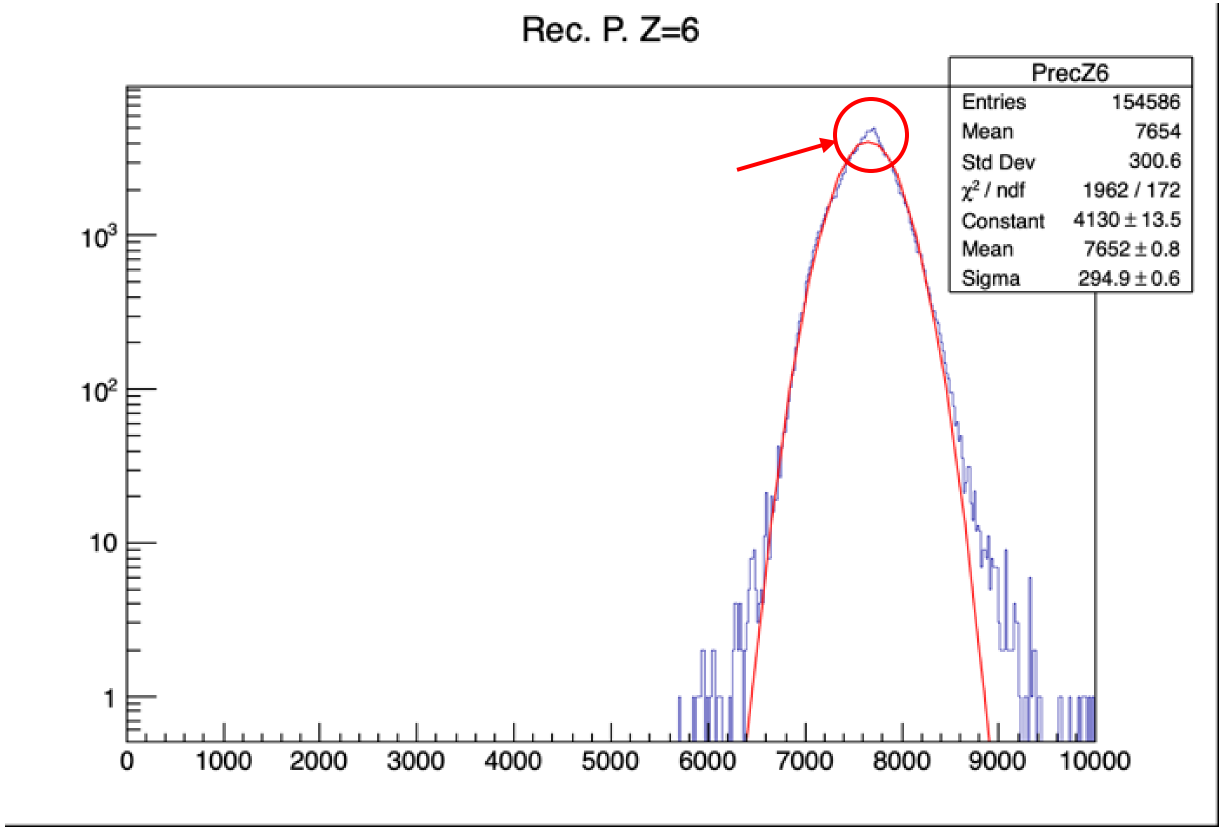
Considering 200 MeV/u, from MC we find that at target entrance energy is reduced in average to 198.5 MeV/u (P ~ 7675 MeV/c), while at target exit is in average 187.1 (P ~ 7432 MeV/c).

Since GenFit reconstructs tracks assuming to be originated in the target, we expect to have in average something in the range 7500-7600 MeV/c

Question: which energy were we using exactly? In CNAO library there are 197.91 MeV/u (P = 7662.84 MeV/c) and 200.61 MeV/u (P = 7719.97 MeV/c). Probably it was the last one. Can it be checked? I was not able to find this in the elog...

Exp. Data results





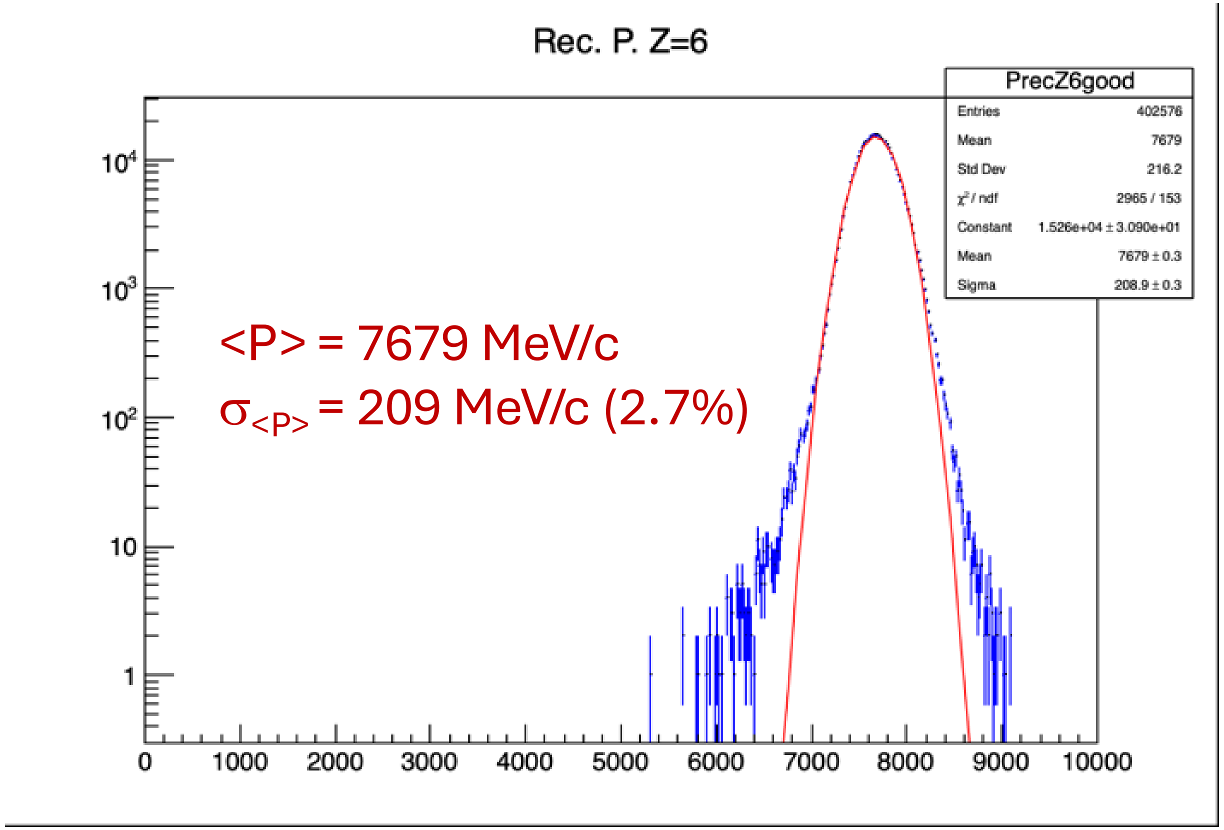
Not a gaussian shape

P resolution within the design goal

Maybe a slight excess of <P> with respect to expectation?

MC results (E_{beam} = 200 MeV/u)

Same reconstruction and analysis as exp. data



Shape is much closer to a gaussian in the core, but maybe the tails are a bit larger

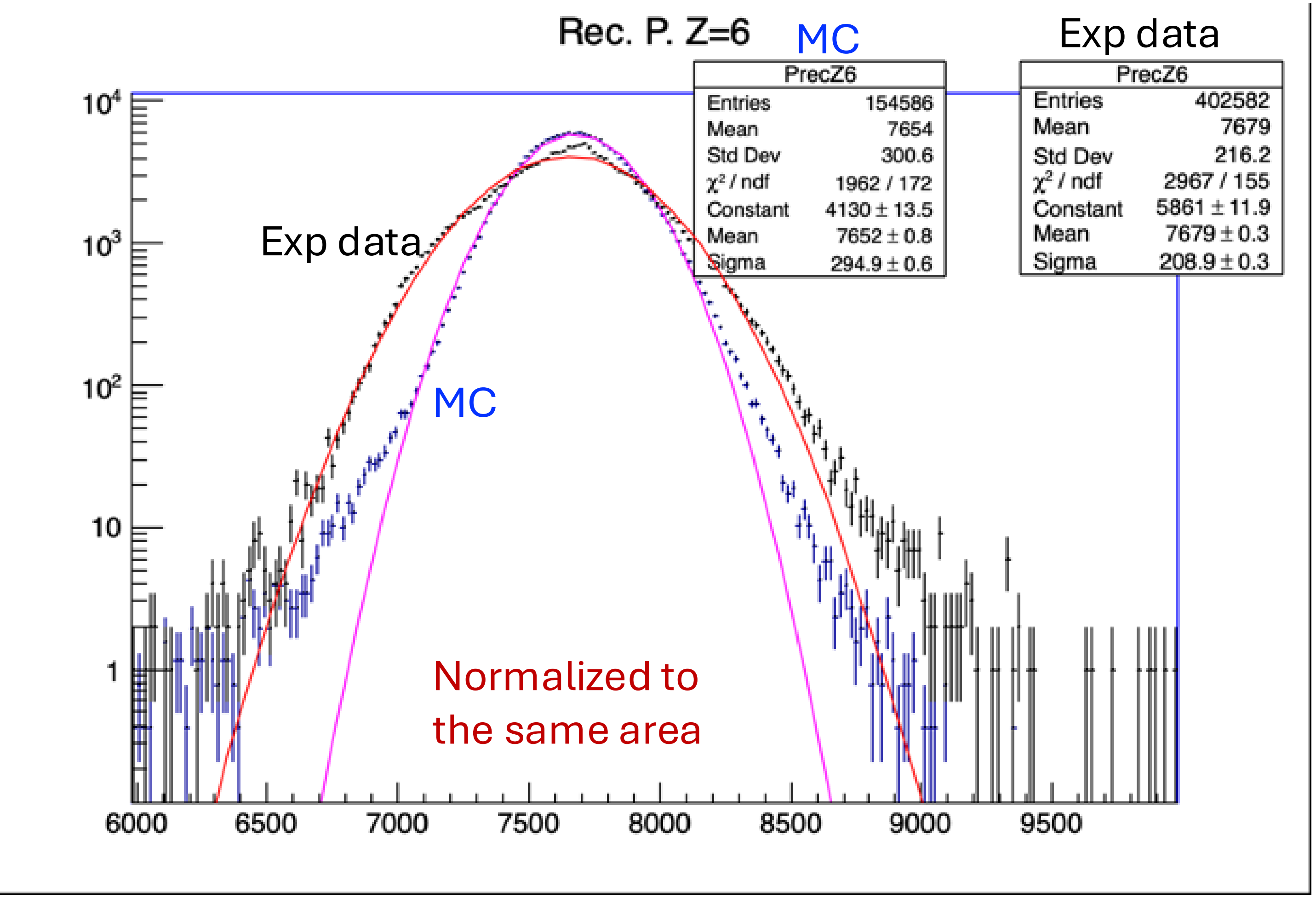
Average differs from data only by 0.35% *(but remember the question on exact energy...)*

r.m.s is significantly better than that of the exp. data:

$\sigma_{<P>\,(Data)} \sim 1.41\, \sigma_{<P>\,(MC)}$

Again,maybe, a slight excess of <P> with respect to expectation

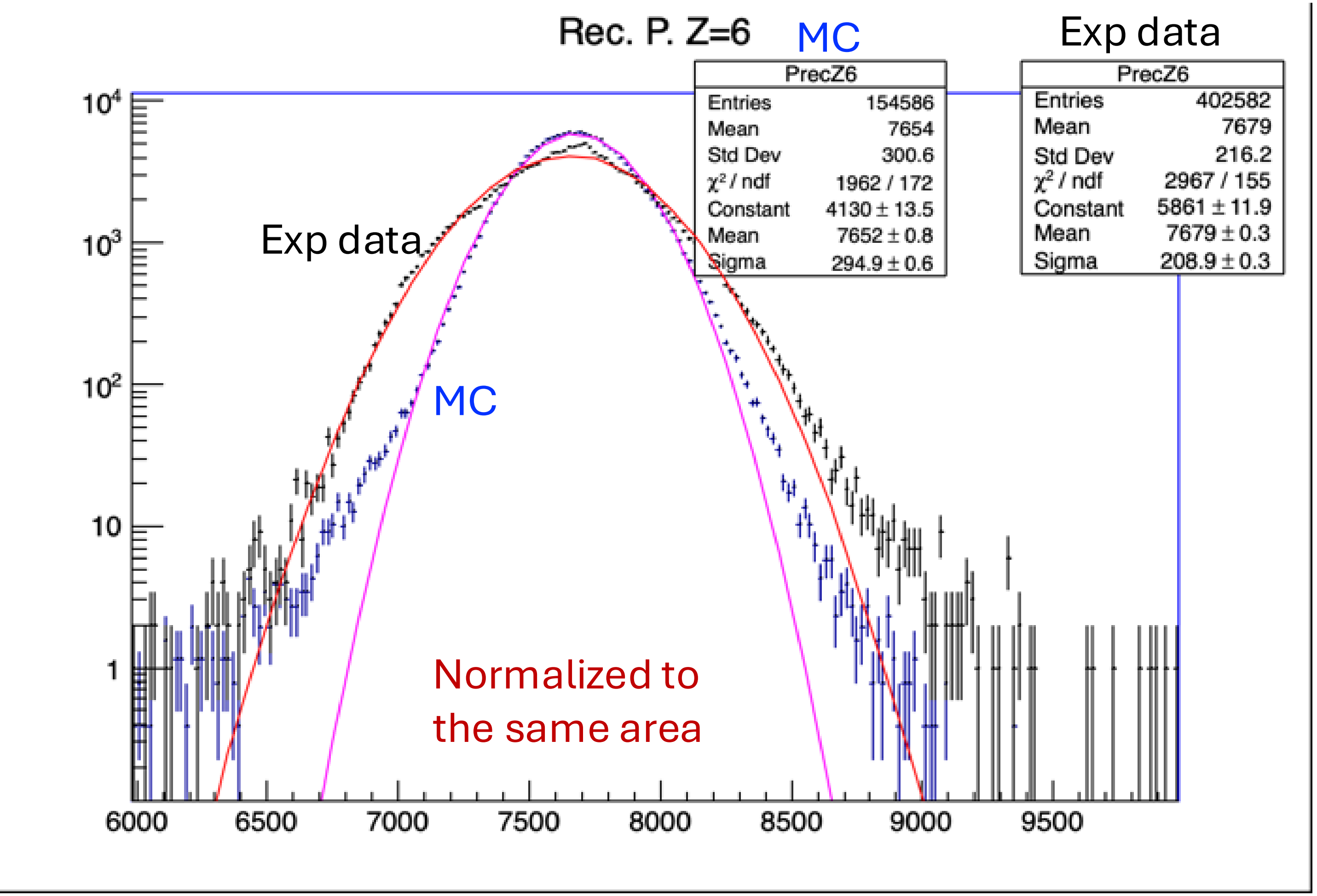
Data – MC comparison



The difference in the width of the reconstructed P of primaries may be originated by a number of different things.

My guess for the most probable hypothesis:
it could be due to some residual mis-alignments (or mis-positioning) of tracking detectors in real life

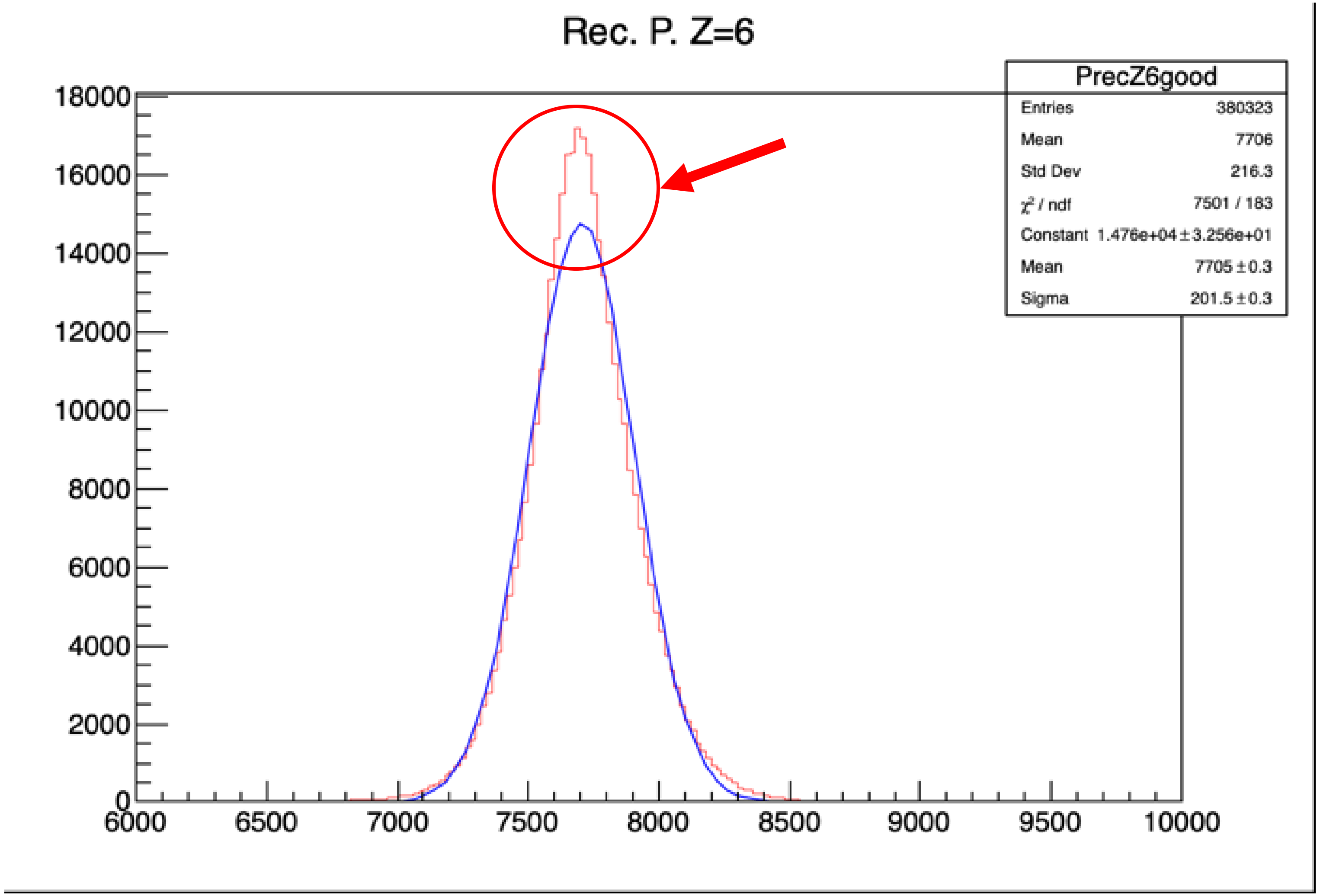
Data – MC comparison



However, it must be noticed that while in MC the IT is perfectly working, that was not the case for exp. data. No IT points in reconstructed tracks.

A new MC reconstruction without IT tracking was considered, so to be in the same conditions as in the experiment

MC results without IT in track reconstruction



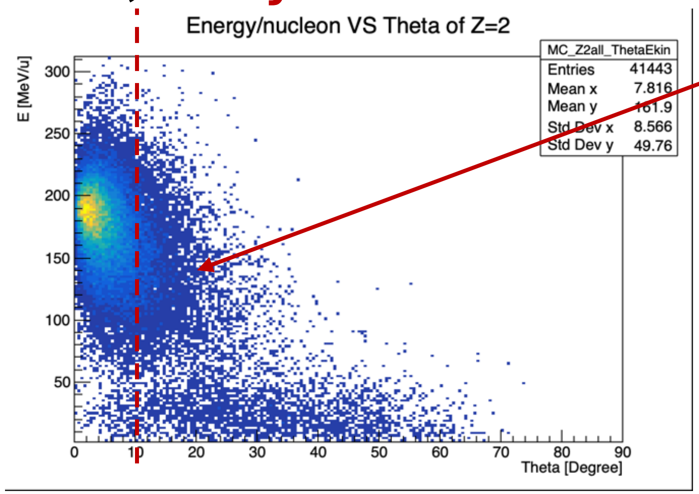
Now, also MC result deviates from gaussian in a very similar way as exp. data!

$\sigma_{<P>\,(MC)}$ however is unchanged: it remains smaller than that of data

Furthermore: without IT there is a loss of 6% in the number of reconstructed tracks

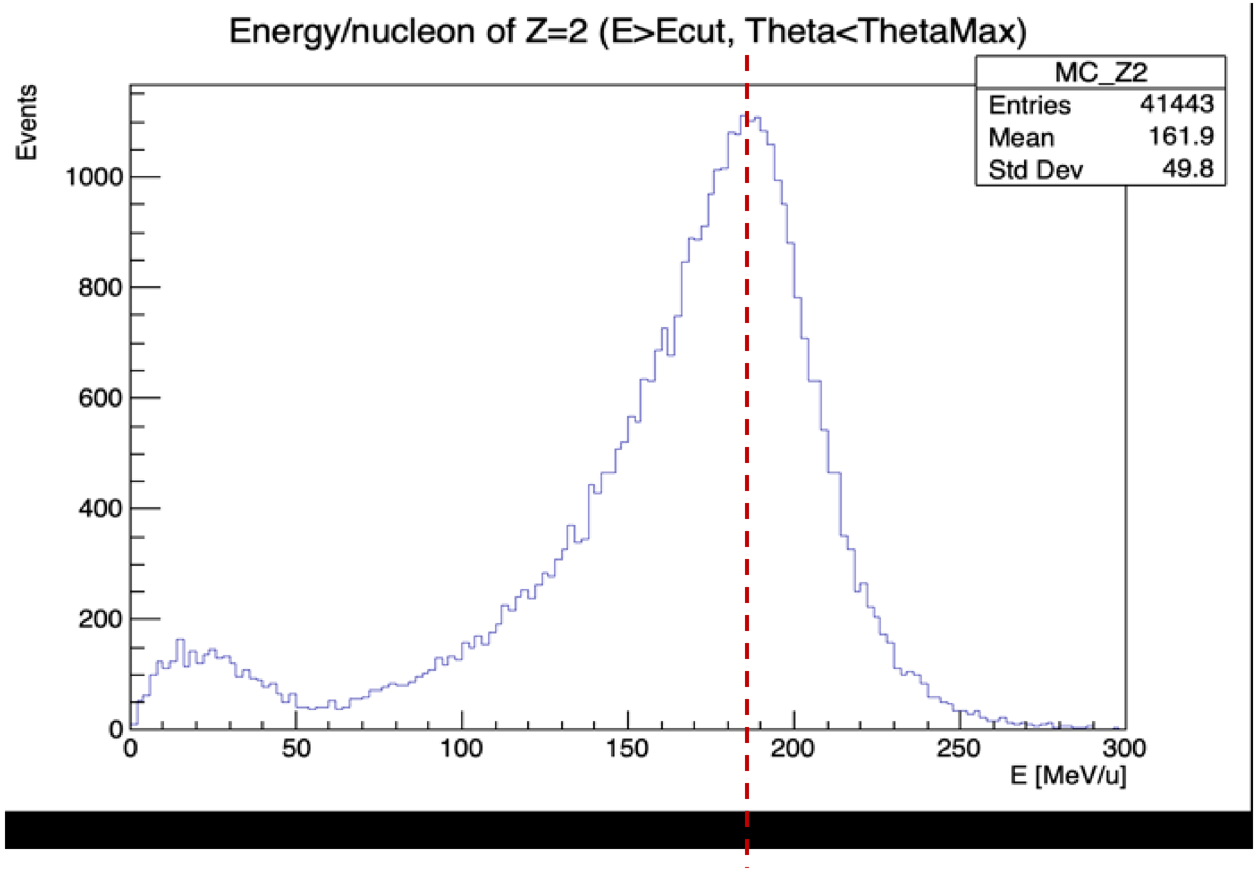
A preliminary check on secondary particles

- New reconstruction including events with ≥1 global track
- Selected Z=2 sample (again asking for TW-MSD Z_{id} match). The case of Z=2 is important since they are the most abundant and, differently from primaries, they cover the whole space inside the magnet system



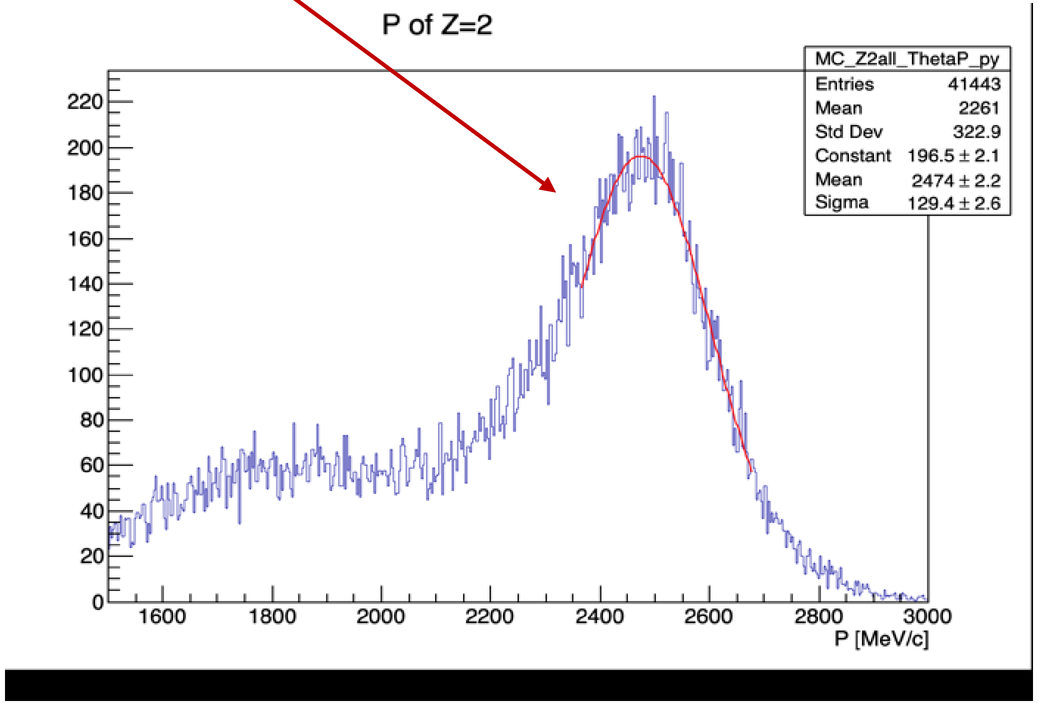
- In this case, however, both the peak of momentum and the width of the distribution are dominated by the physics of fragmentation

MC expectation

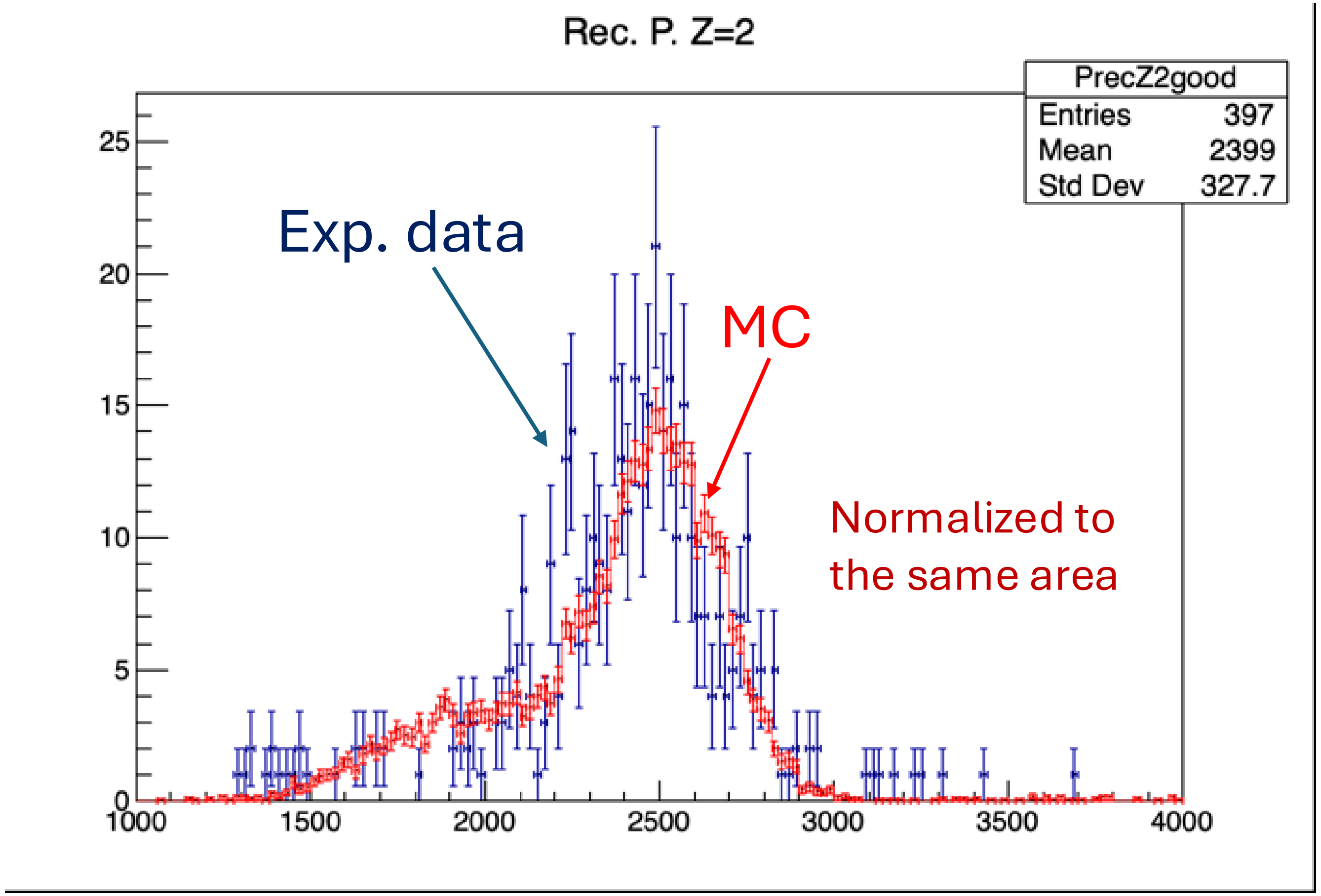


Peak of energy is expected at ~186 MeV/u

➔ P_{peak} ~ 2470 MeV/c



Data – MC comparison



Exp data:

P_{peak} ~ 2493 MeV/c

<P> = 2399 MeV/c

r.m.s = 327 "

MC:

P_{peak} ~ 2490 MeV/c

<P> = 2368 MeV/c

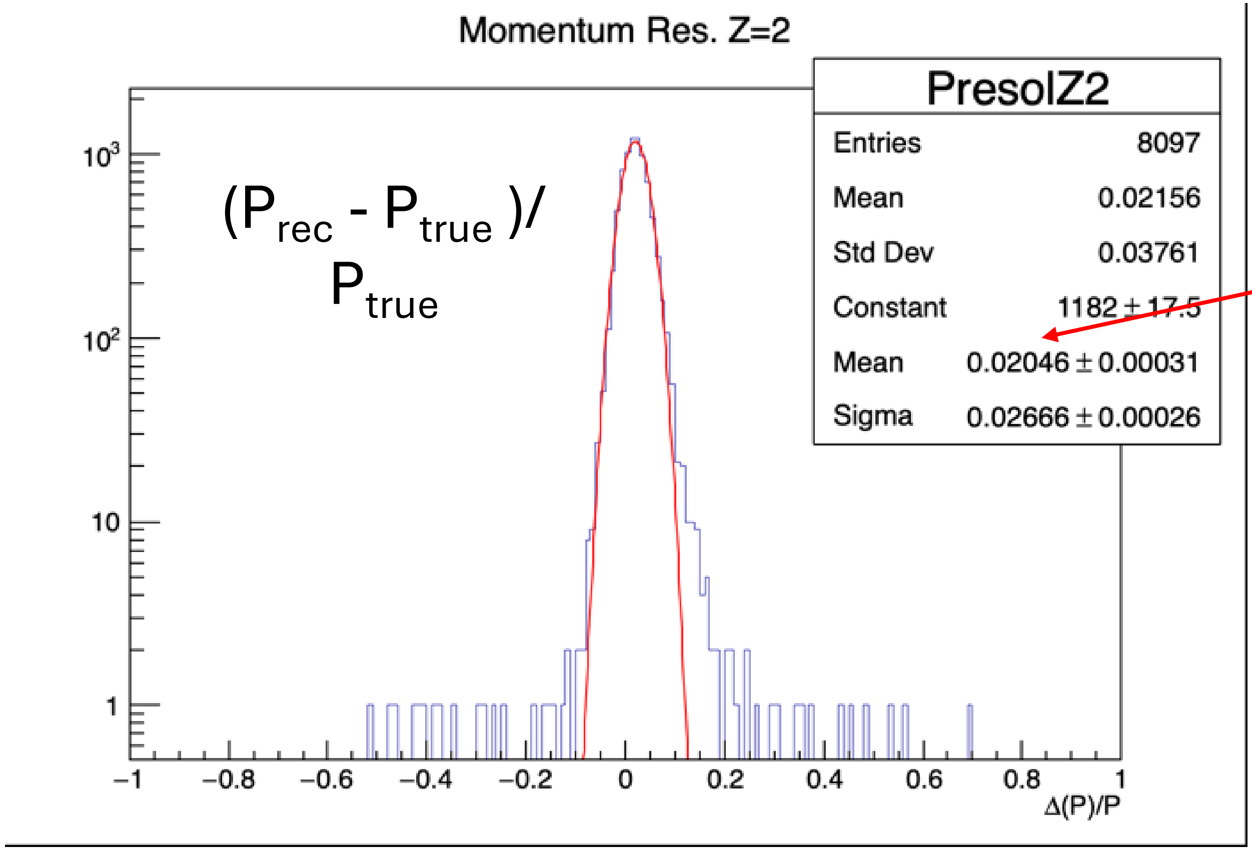
r.m.s = 334 "

The peak value of P exhibits an excellent agreement with expectations *(but the peak value is not reached in the whole angular space inside the magnet)*.

Comments on <P> and r.m.s are less significant: they mostly depend on the physics of fragmentation process

Bias on momentum reconstruction?

As reported in other meetings, MC says that considering the <u>whole range</u> of rec. P, $<P_{rec}>$ exceeds $<P_{true}>$



In the case of Z=2 we get an excess of ~2.0%

Without IT goes to 2.3%

This will deserve a more detailed and dedicated analysis, mainly at software level

Some preliminary conclusions

- This first check on primary momentum reconstruction is very satisfactory as far as <P> is concerned
- The first check on P of Z=2 particles is very good as well.
- The level of agreement between data and MC is an encouraging piece of news in the path of assessing our actual knowledge of the magnetic field and material budget of FOOT
- There is a significant difference in the width of the reconstructed P of primaries. It could be due to residual mis-alignments.
- We have to prepare for CNAO2025 data taking considering with the due attention at least two aspects:
    - Great care in alignment (detectors and axis of magnet system)
    - This study indirectly shows that IT has an importance for the quality of P reconstruction: it must work