First attempt to study α-clustering fragmentation in GSI2021 data at 400 MeV/u

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Introduction

- At the Collaboration meeting in Naples, we reported the 1st MC study of multi-α tracking for the GSI2021 data concerning ^{16}O fragmentation at 400 MeV/u, C target (GSI21PS_MC campaign), in view of the possibility of using global track reconstruction on real GS2021 experimental data:

https://agenda.infn.it/event/40055/contributions/233767/attachments/122536/179388/GBatt_AlphaGSI21.pdf

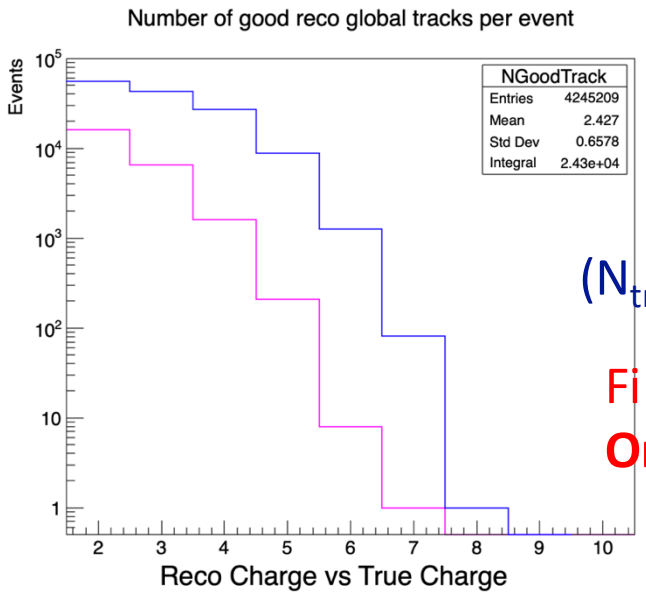
- The GenFit reconstruction was used, implementing Event and Track selection cuts defined during the discussions in the Physics and Analysis group

- Here we report about the 1st (overdue…) attempt to perform this reconstruction and analysis on the real data

- Goal: start data analysis for α -clustering with the electronic spectrometer beginning from the simplest case (no magnet) for ^{16}O fragmentation (more interesting that ^{12}C)

Summary of main results from MC study presented last year

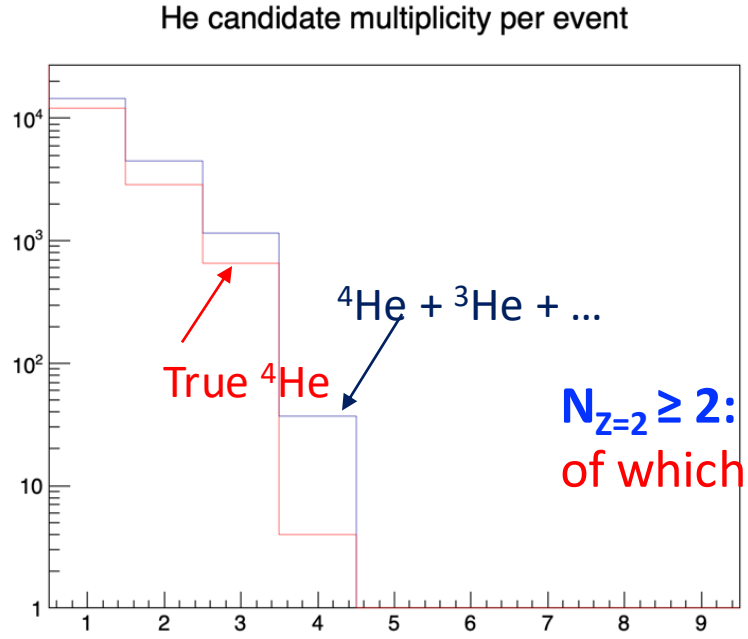
5 10^6 primary events



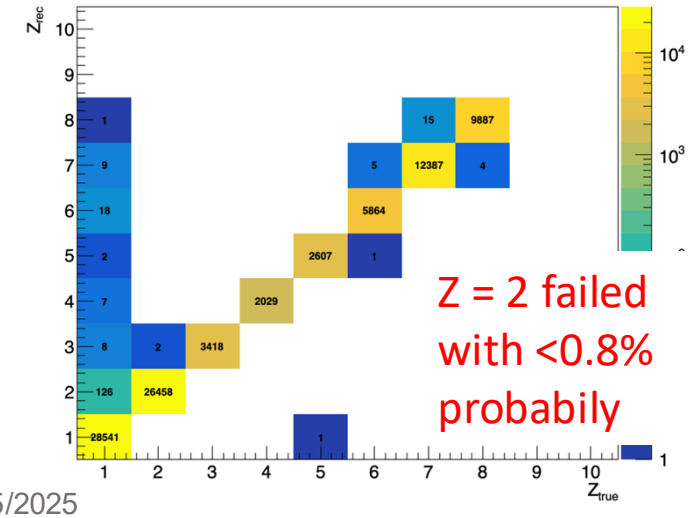
After event and track selection:

True Events
(N_{track}>1 at TW): 135 715

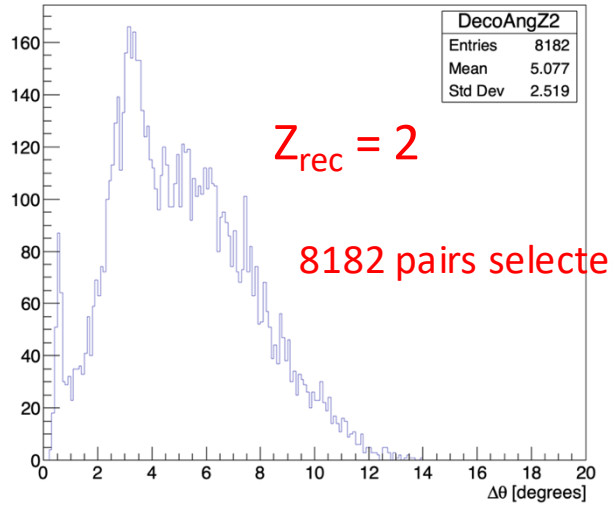
Final Selected Events
Only 24 299 events left!



$N_{Z=2} \geq 2$: 5685 event
of which 3542 are true ^{4}He



Z = 2 failed with <0.8% probabily



Z_{rec} = 2

8182 pairs selected

GSI2021 Run selection at 400 MeV/u

Run	Trigger type	n. events
4305	Min. bias	162110
4306	Min. bias	577120
4307	Min. bias	513365
4308	Fragm.	513391
4309	Fragm.	531838
4310	Fragm.	1012148
	Total:	3309972

Data Selection and Reconstruction

Following suggestions received by R.Z, M.T, Y.D, we excluded MSD (for the time being) from tracking: only VT + TW

New option: EnableBMVTmatch yes

Data reconstruction:

- We have at first tried GenFit, both Standard and Linear: we failed to achieve a satisfactory results. Some results were presented at a physics meeting. Updated material on this is available here in the backup slides.

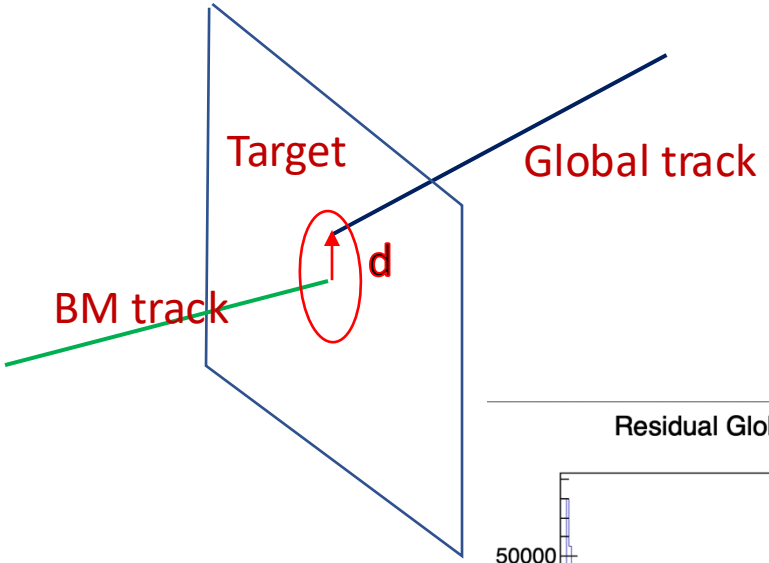
- In a second attempt we used Straight Line Reconstruction achieving much better results. Here we present this approach

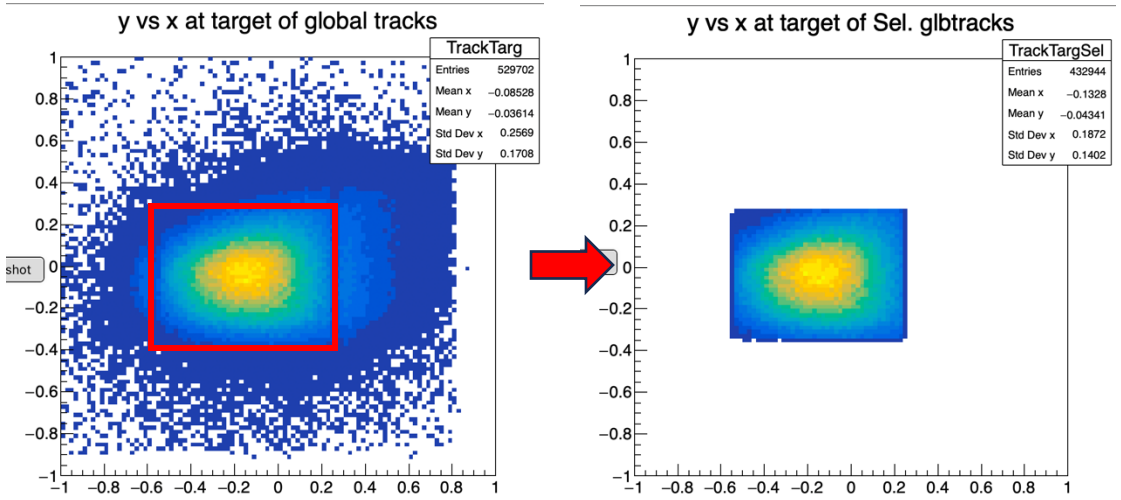
Straight Line Reconstruction: Event Selection

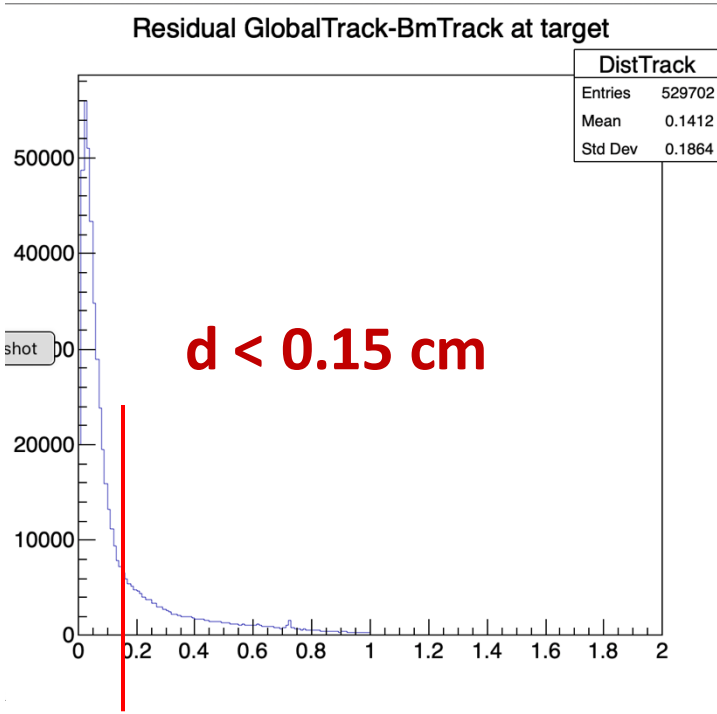
- MSD were excluded from tracking by unsetting them in FootGlobal.par
- Pile-up rejection: excluding events with more than one pulse in the SC acq. time window
- 1 BM track $\otimes$ ≥1 track with TW-point
- Following experience from previous work by G. Ubaldi et al, we also ask for N_{track}≥2 to get rid of primary contamination

Track selection in the event

- by default, after event selection, in each Global Track there are at least 3 VTX point and 1 TW point: tracks can have just 4 o 5 points in total
- Selection on the matching between BM track and Global Track on the x-y plane at z=0 (center of target)
- Selection on x-y position of primary beam at z=0
- In Straight Line Reconstruction there is no available P(χ^2) in Shoe to be used for track quality selection



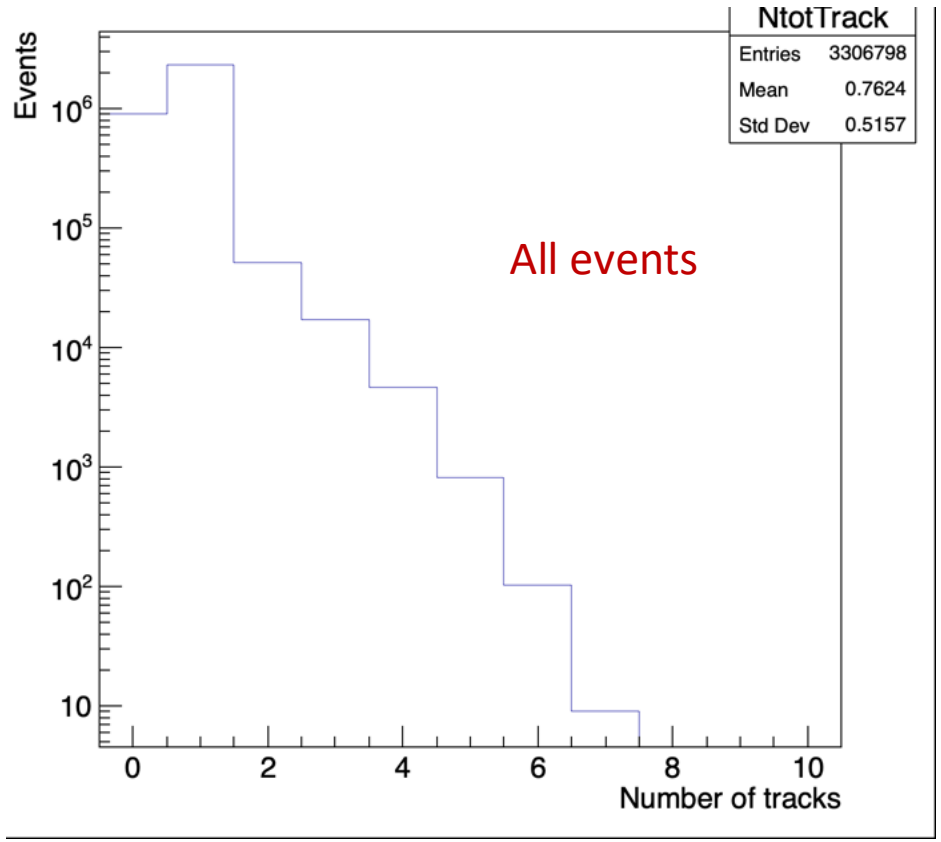


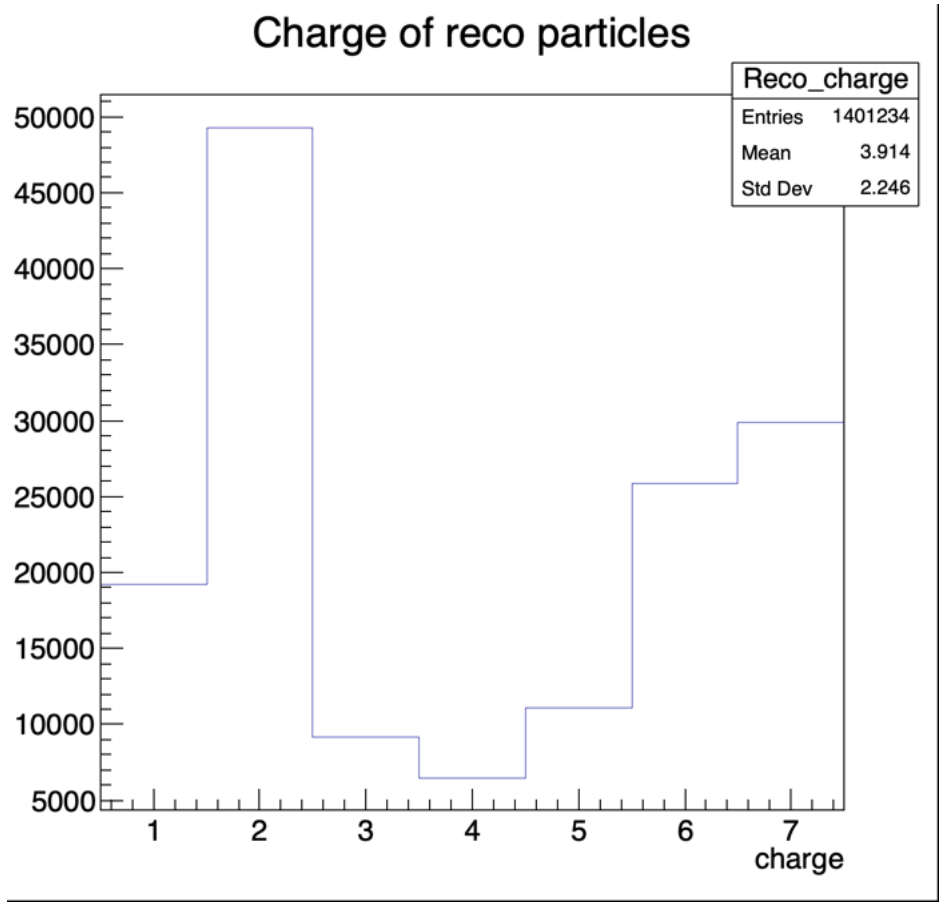


Straight Line Reconstruction

Exp. Data: all selected runs

Track multiplicity/event

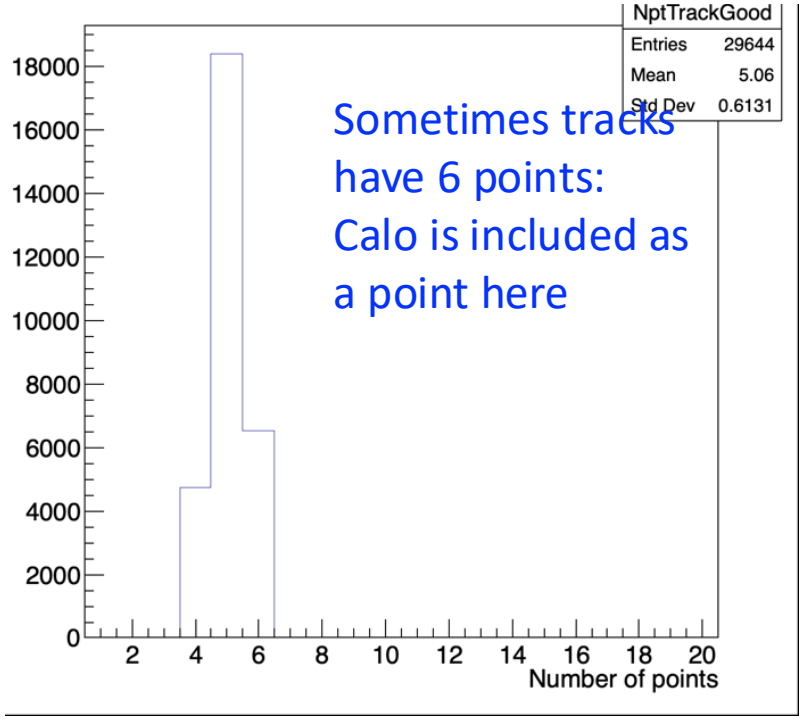




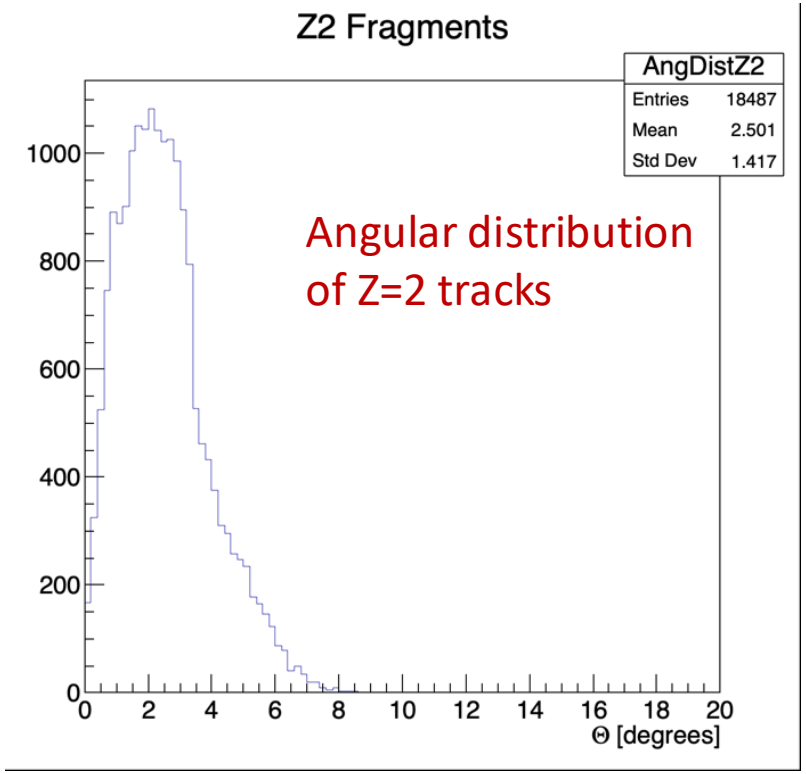
Straight Line Reconstruction with $N_{track} \geq 2$

Exp. Data: all selected runs

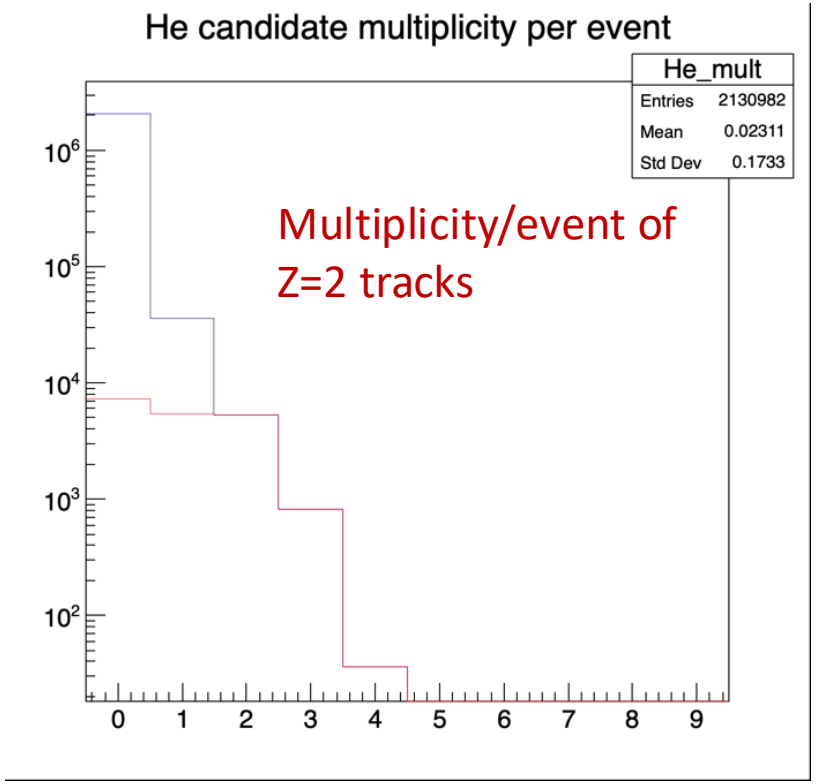
No. of points per selected track



Sometimes tracks have 6 points: Calo is included as a point here



Angular distribution of Z=2 tracks



Multiplicity/event of Z=2 tracks

Final statistics:

Processed Events: 3306798 Rejected Events: 1175816 (35.6%) Events with 0 Tracks: 745337 (22.5%)

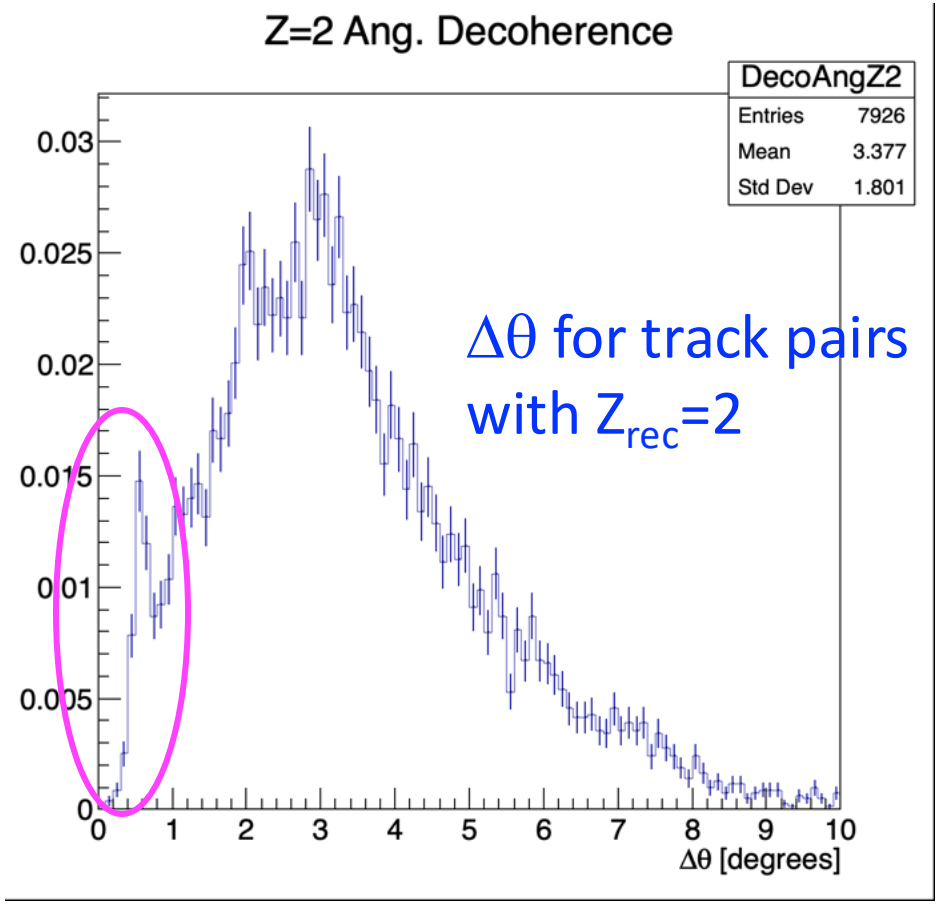
Total no. of Global Tracks: 2521223 (1.82 track/event)

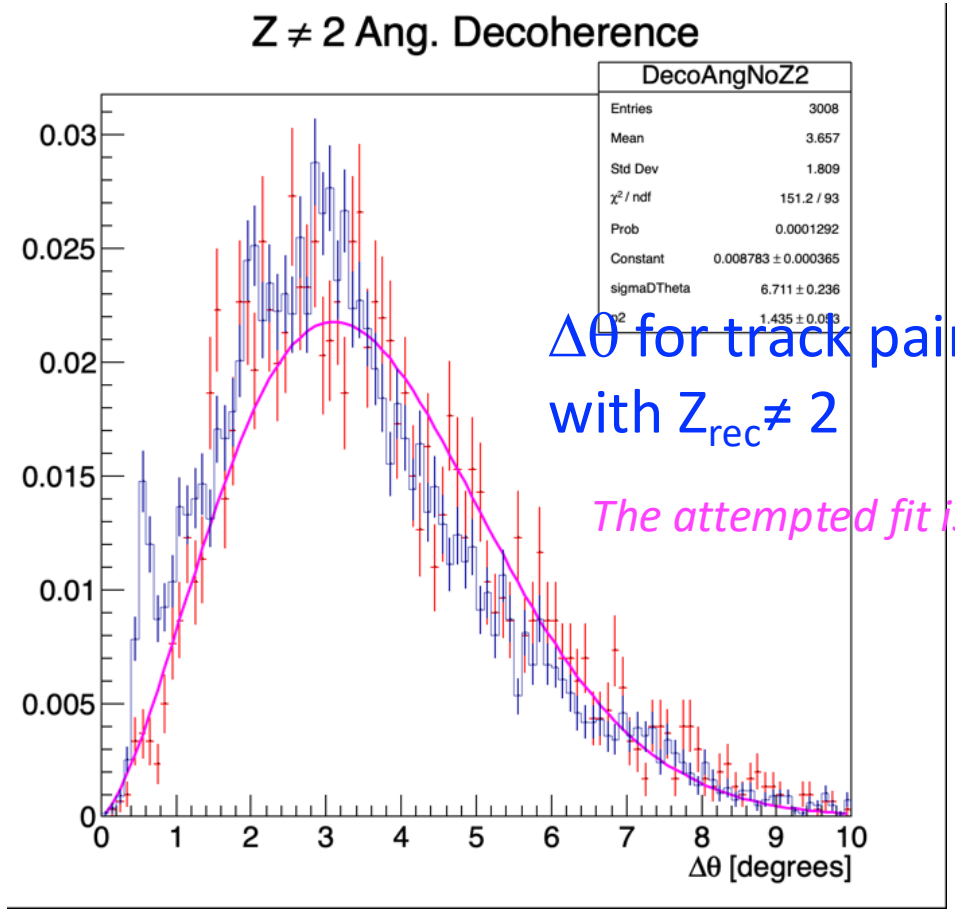
Tracks with 1 TW point: 2105796 (83.5%) Tracks accepted after matching with BM target: 1401234 (66.5%)

Remaining tracks after $N_{track} \geq 2$ selection: 29644 (1.2%), of which Z=2 Tracks: 18487 (62.3% of accept. tracks)

Present Results:
angular separation of Z=2 tracks and search for ^{8}Be peak

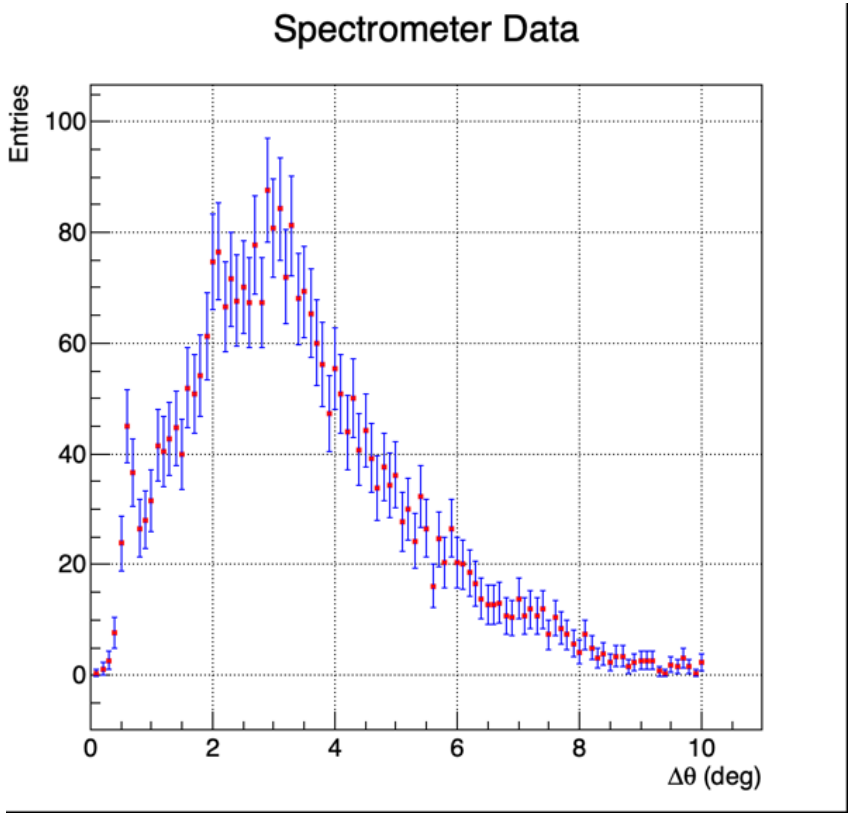
Exp. Data: all selected runs

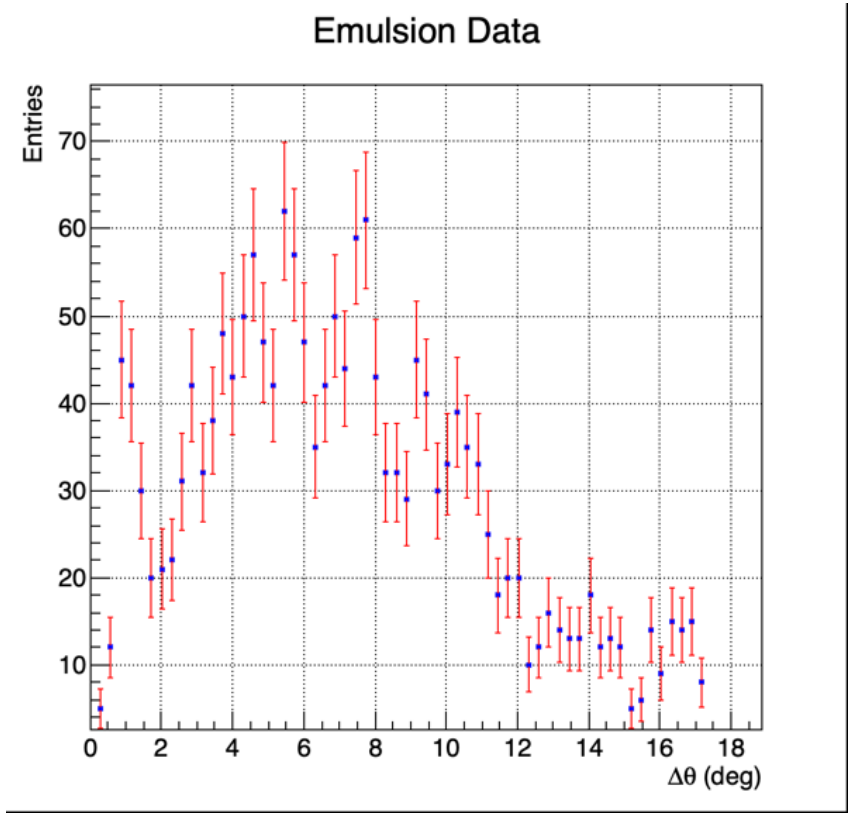




Both normalized to Integral = 1

Comparison to Emulsion Data at 200 MeV/u



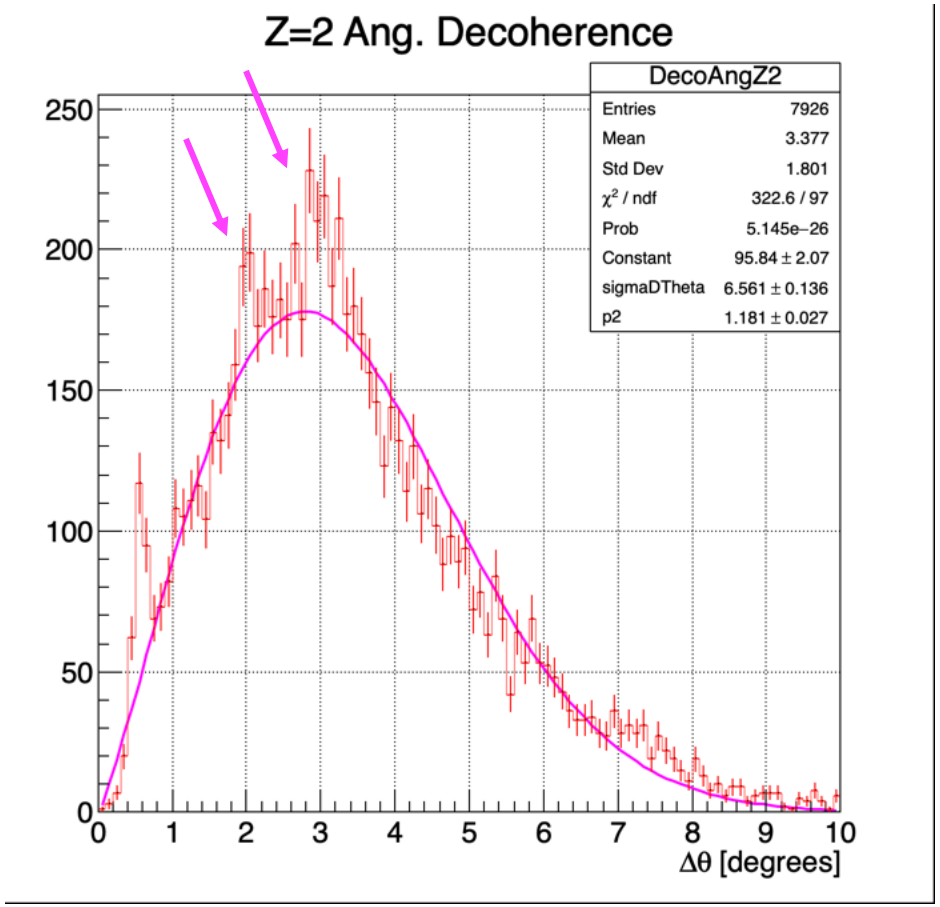


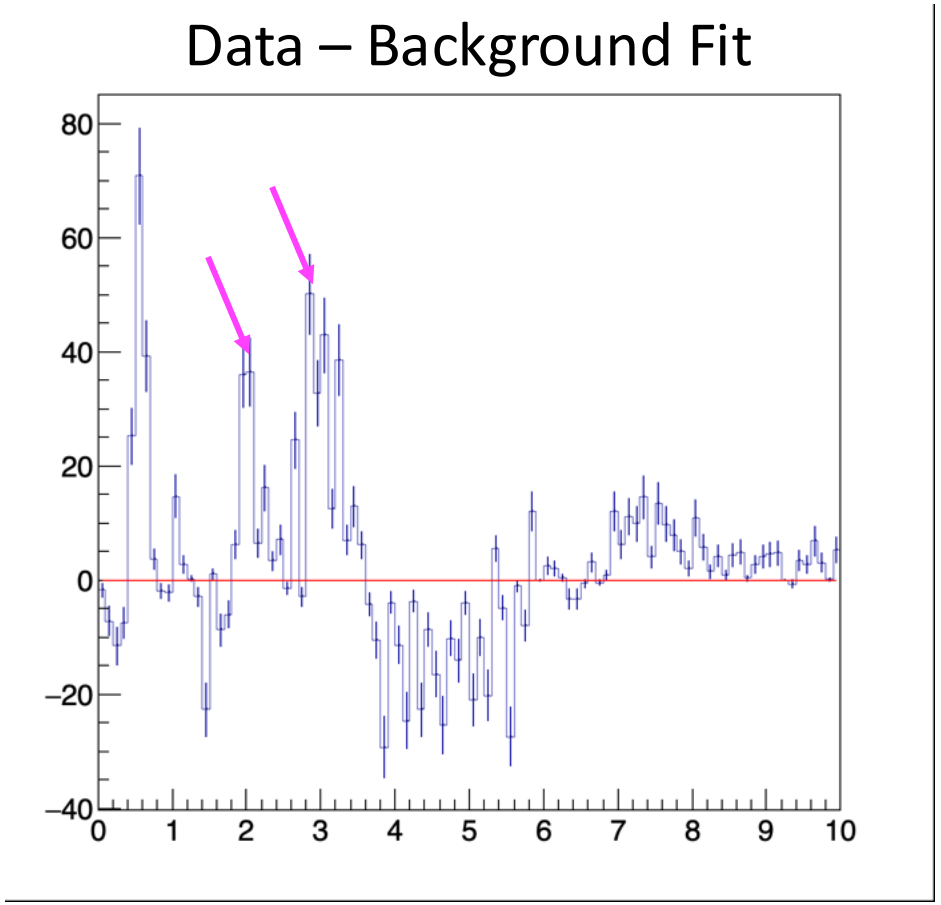
2 possible comments:

a) at 200 MeV/u you indeed expect a wider angular separation

b) in the electronic setup, small angular separations are penalized: superposition on the same TW bar

Observation of other possible structures and their interpretation





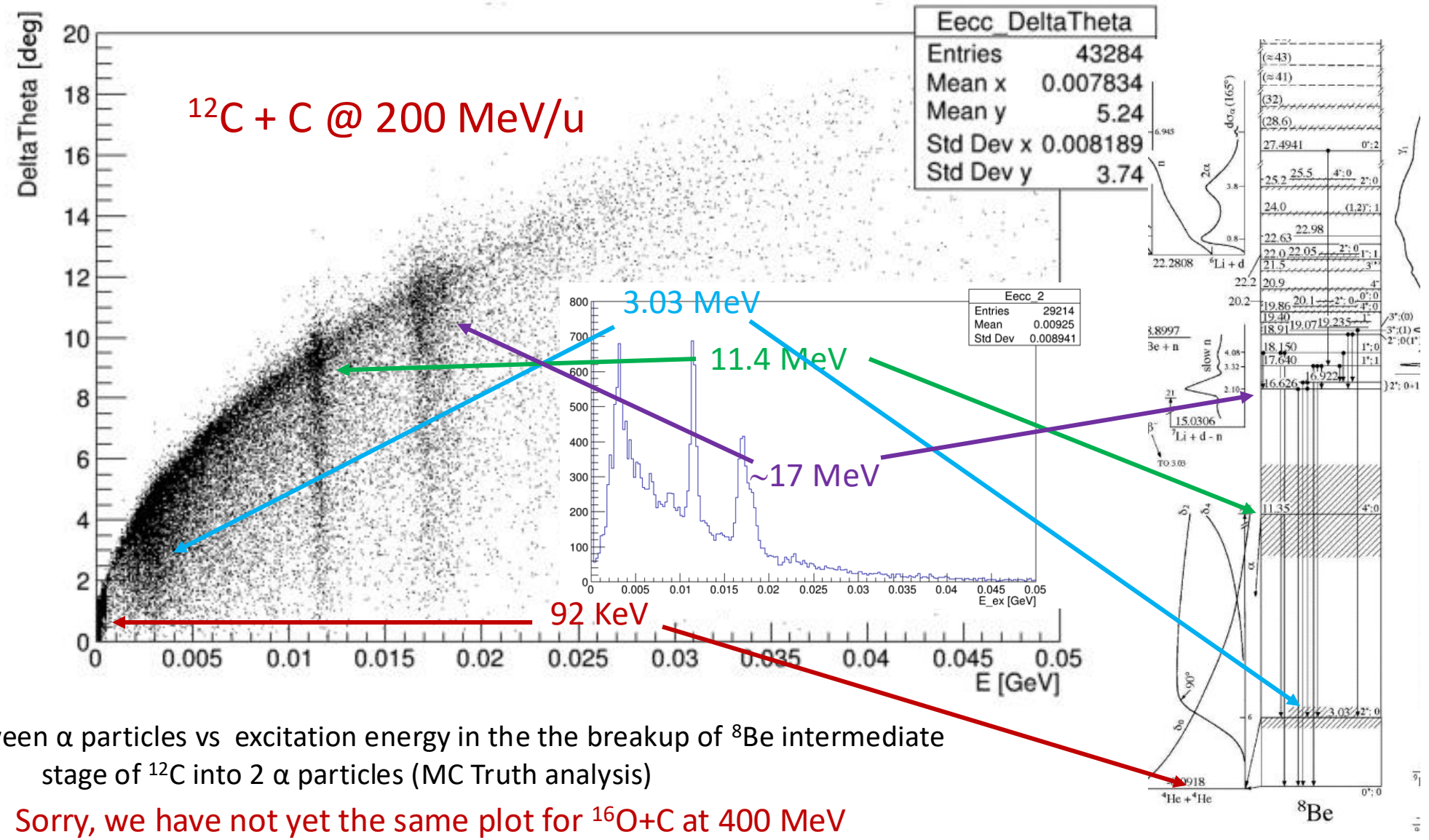
These structures could reflect other very interesting nuclear physics processes (➔ including the higher excited levels of ^{8}Be!!) , but, at the same time, they could also point to possible contaminations in the Z_{rec}=2 sample.

Δθ vs Excitation energy for ^{8}Be

^{12}C(α, ^{8}Be)

MC Truth

Extracted from A. Caglioni's talk at dec. 2023 meeting in Trento



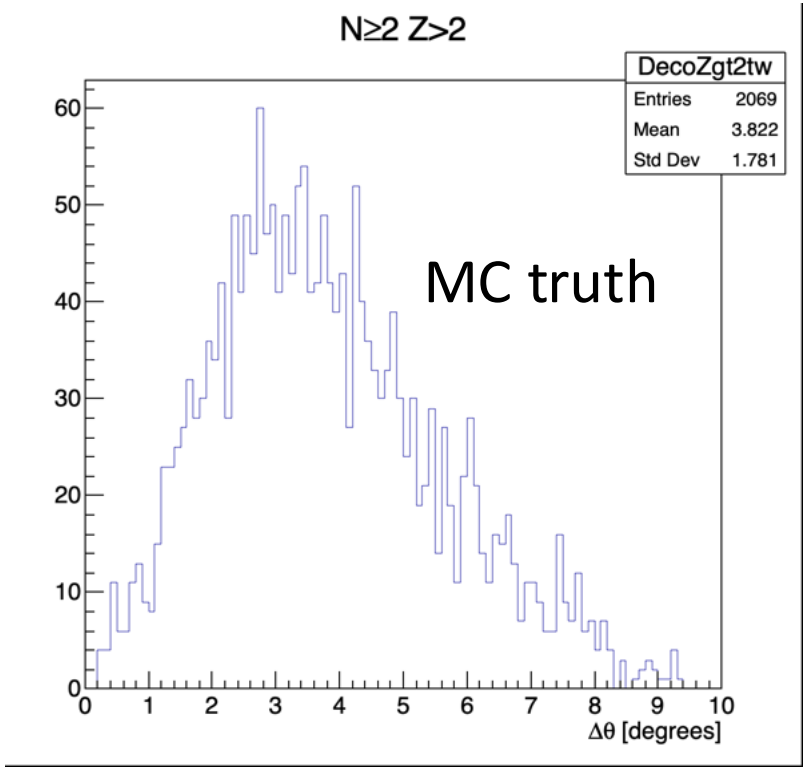
Opening angle between α particles vs excitation energy in the the breakup of ^{8}Be intermediate stage of ^{12}C into 2 α particles (MC Truth analysis)

Sorry, we have not yet the same plot for ^{16}O+C at 400 MeV

What we just learned from MC (MC truth)

GSI21PS_MC simulation campaign

- The only distribution with no visible structures comes from the coupling of Z>2 particles

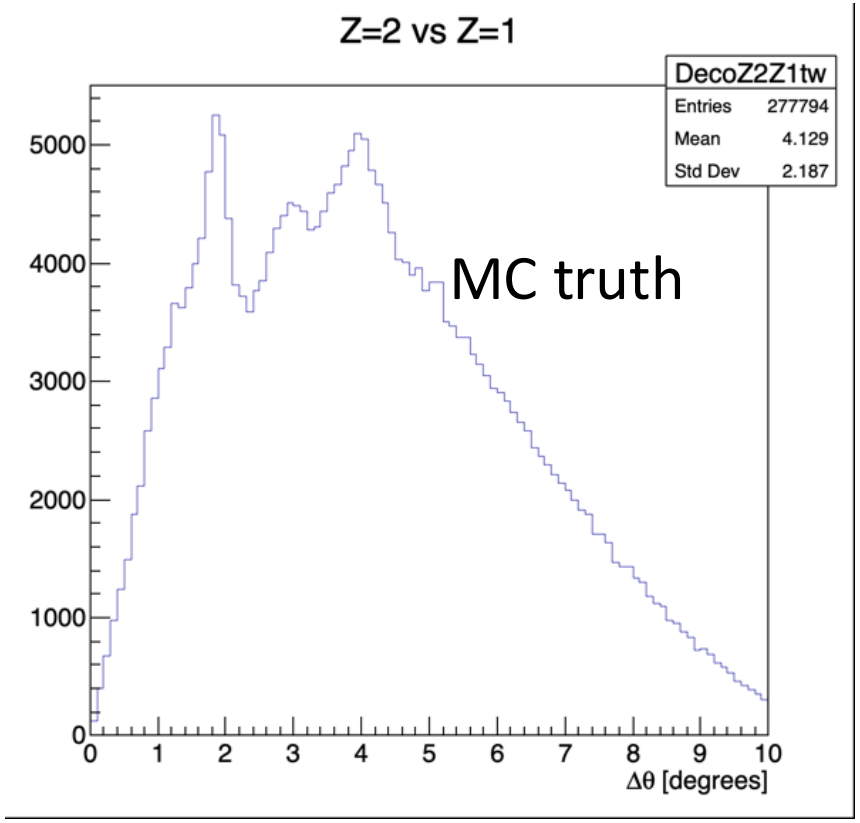


Instead, important structures are predicted when considering the pairing of Z=2 and Z=1 particles

What we just learned from MC (MC truth)

GSI21PS_MC simulation campaign

Angular separation of Z=2 and Z=1 particles

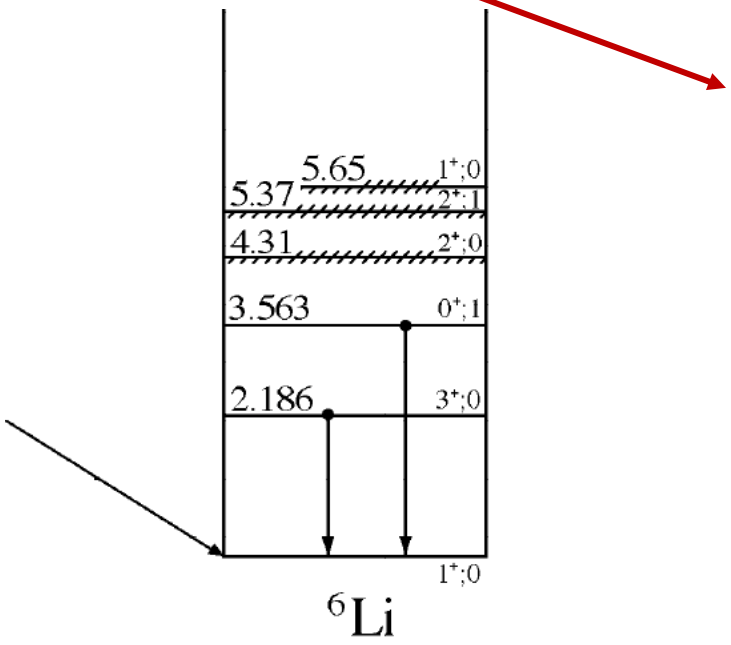


What are these structures?

➔ There are other nuclei exhibiting prompt decay similarly ton the ^{8}Be case

Interesting prompt decay cases:

1. $^{4}Li \rightarrow {}^{3}He + p$ $\tau = 9.10\ 10^{-23}$ s $M(^{4}Li) = 4.0255$ u
2. $^{5}Li \rightarrow {}^{4}He + p$ $\tau = 3.04\ 10^{-22}$ s $M(^{5}Li) = 5.0109$ u
3. $^{6}Li^{*} \rightarrow {}^{4}He + d$ $\tau = 7.6\ 10^{-23}$ s $M(^{6}Li) = 5.6031$ u



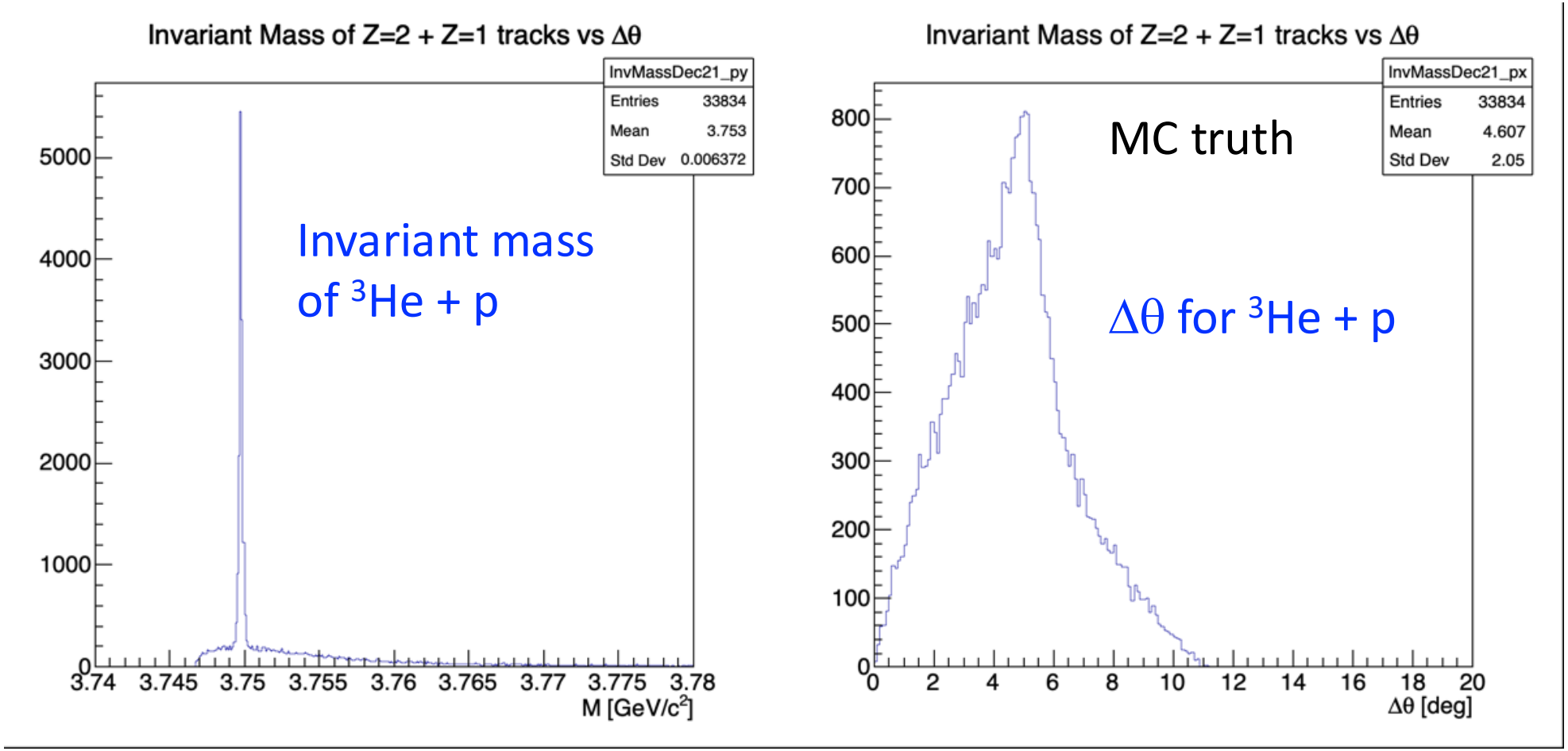
^{6}Li is stable, but his excited levels can have a strong prompt decay:

$M(^{6}Li\ g.s.) = 5.6015\ GeV/c^2$; $M(^{4}He) + M(^{2}H) = 5.6030\ GeV/c^2$

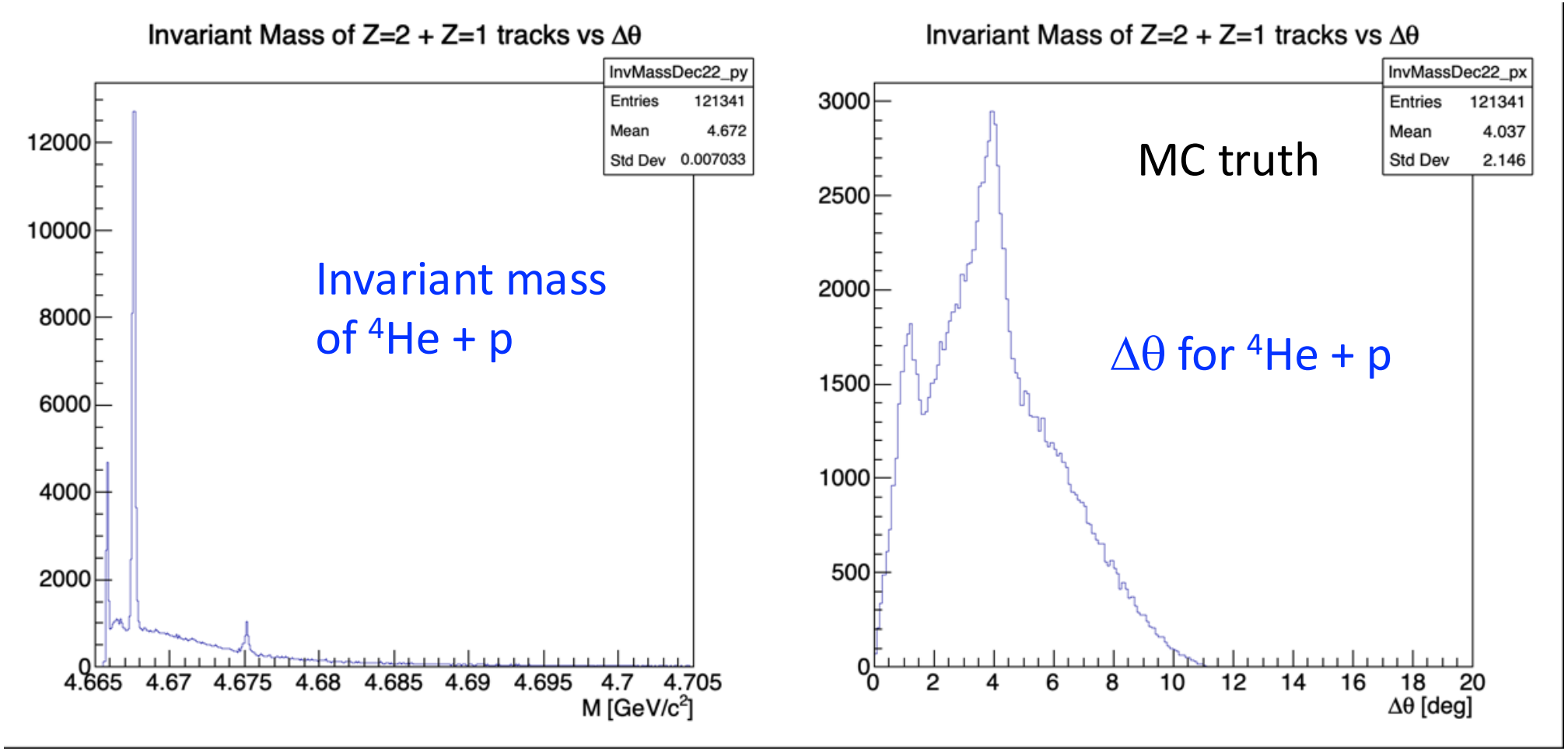
➔$\Delta M = 1.47\ MeV/c^2$

(excluding the 0^+ 3.563 MeV level because of quantum numbers)

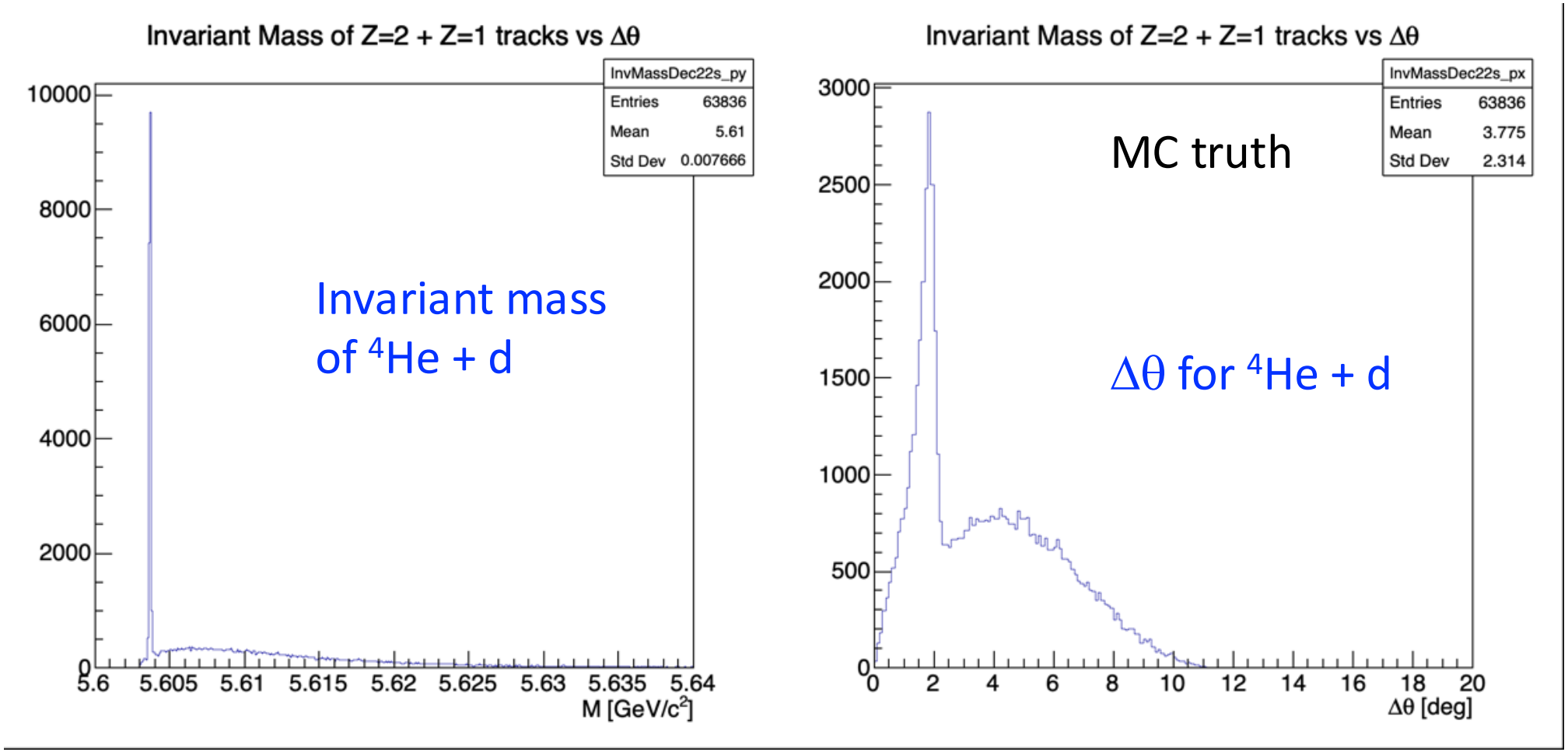
MC truth analysis: ^{4}Li region

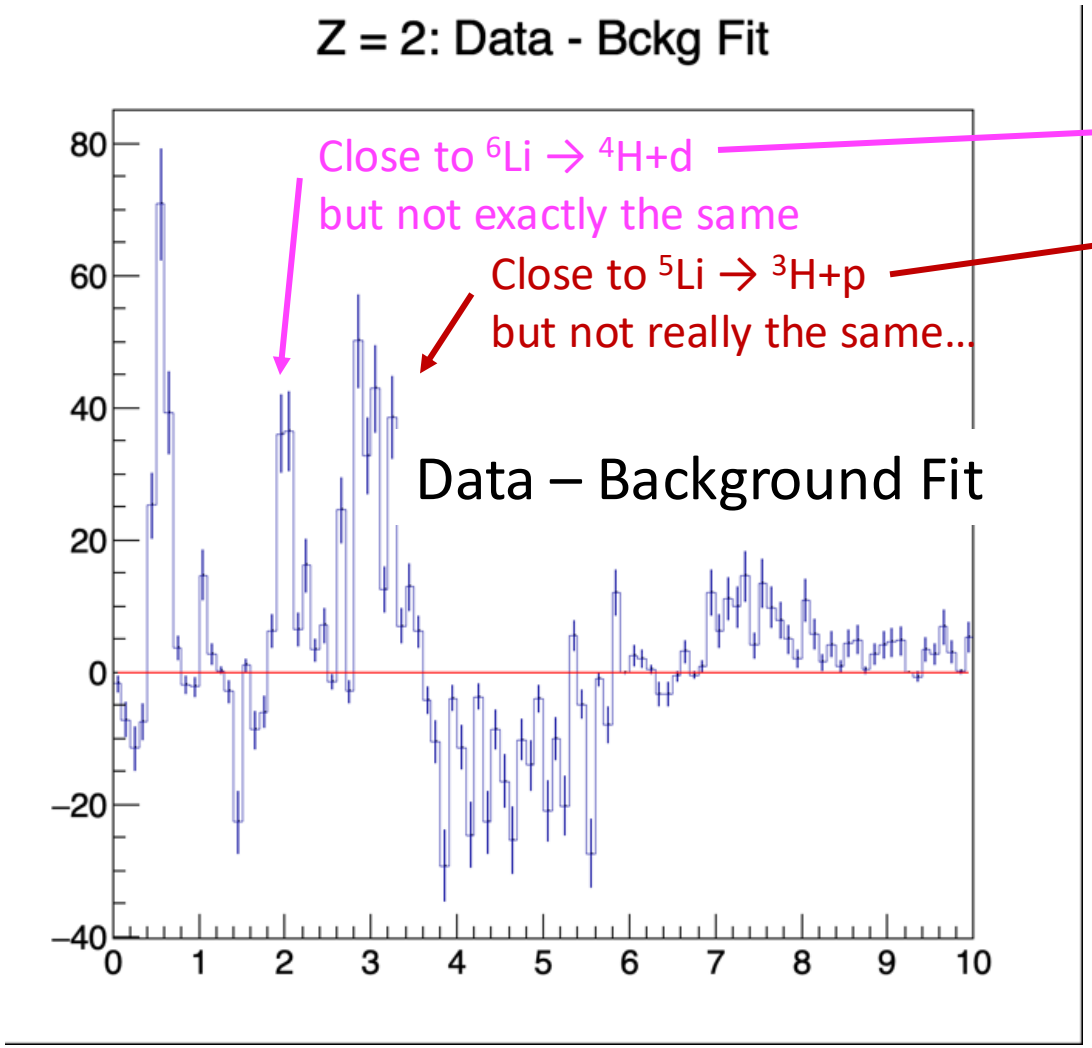


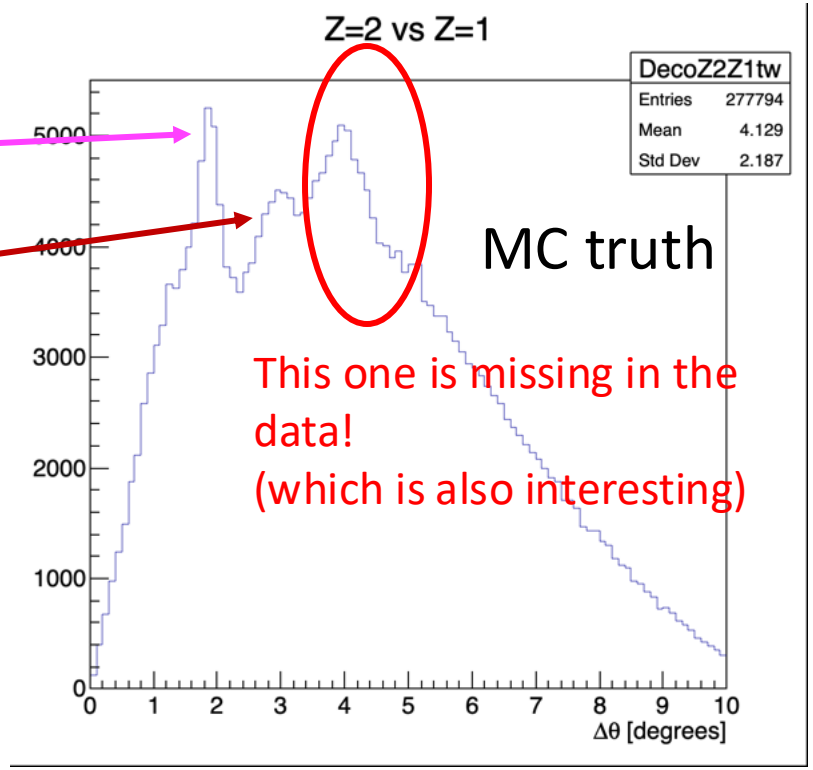
MC truth analysis: ^{5}Li region



MC truth analysis: ^{6}Li region







All this is very preliminary, but also intriguing…

However, the Z=1 contamination hypothesis remains a plausible scenario

Comparison with reconstructed MC

- Having switched to Straight Line Reconstruction, all the numbers presented in Naples are no more valid
- We have reprocessed MC using Straight Line Rec. applying the same cuts used for exp. data
- 2 10^6 events processed.
- It immediately appears how this tracking is more efficient on MC than for real data:

Processed Events: 2000000 Rejected Events: 123061 (6.2%) Events with 0 Tracks: 213650 (10.7%)
Total no. of Global Tracks: 2220655 (1.5 track/event)
Tracks with 1 TW point: 2086994 (94%) Tracks accepted after matching with BM target: 1717282 (77%)
Remaining tracks after $N_{track} \geq 2$ selection: 90048 (4%), of which Z=2 Tracks: 37465 (41.6% of accepted tracks)

Comparison summary

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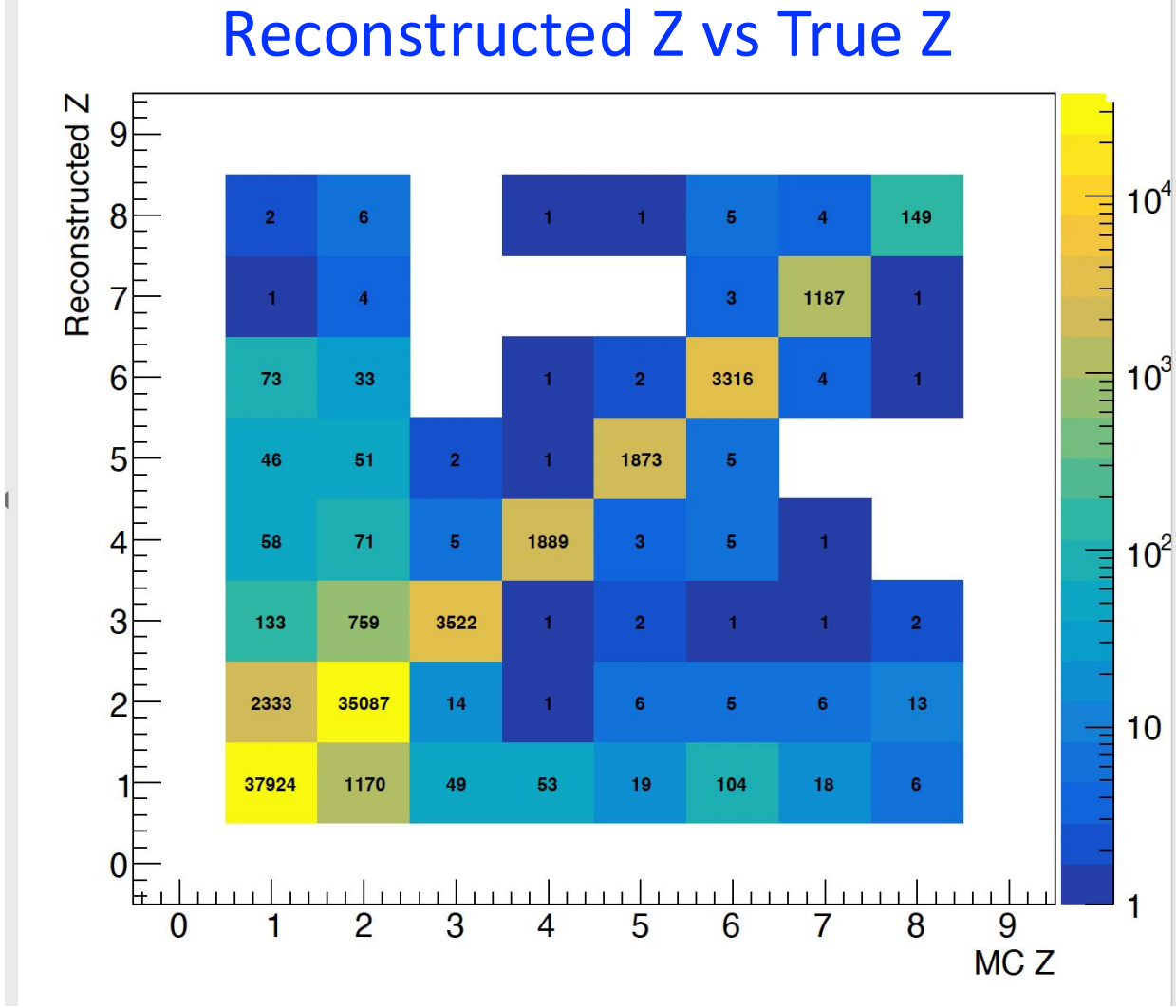
Can we really compare MC to data?

This is not just a question about the nuclear physics model

Comparison with reconstructed MC

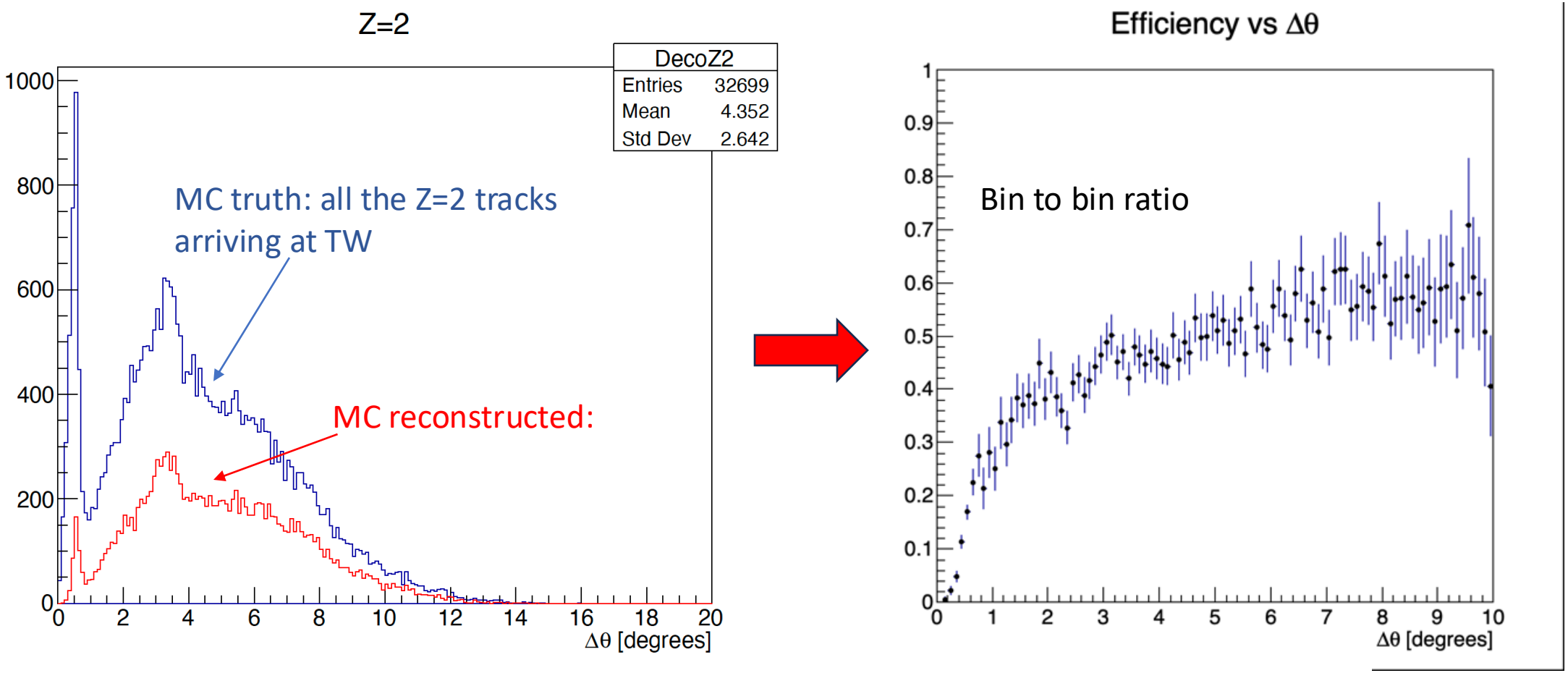


This matrix is essentially diagonal, but the sample of Z=2 tracks has a contamination of Z=1 of the order of ~6.5%

It is unclear if we can trust this prediction: at present we are not including in MC the inefficiency of VT for Z=1 particles

Comparison with reconstructed MC

Estimate of efficiency in the measurement of angular separation

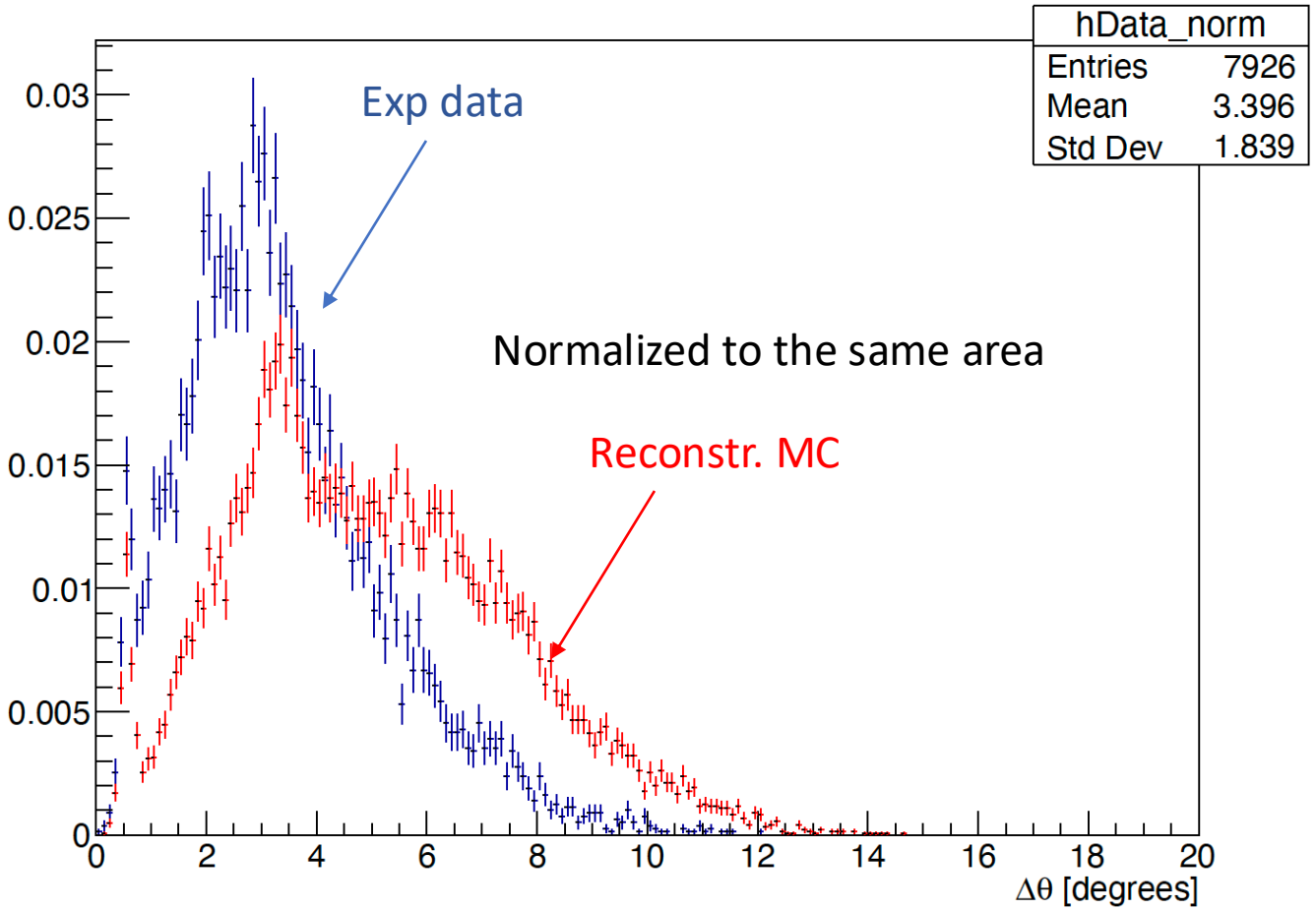


The $^{8}Be_{g.s.}$ peak at small angular separation is strongly penalized

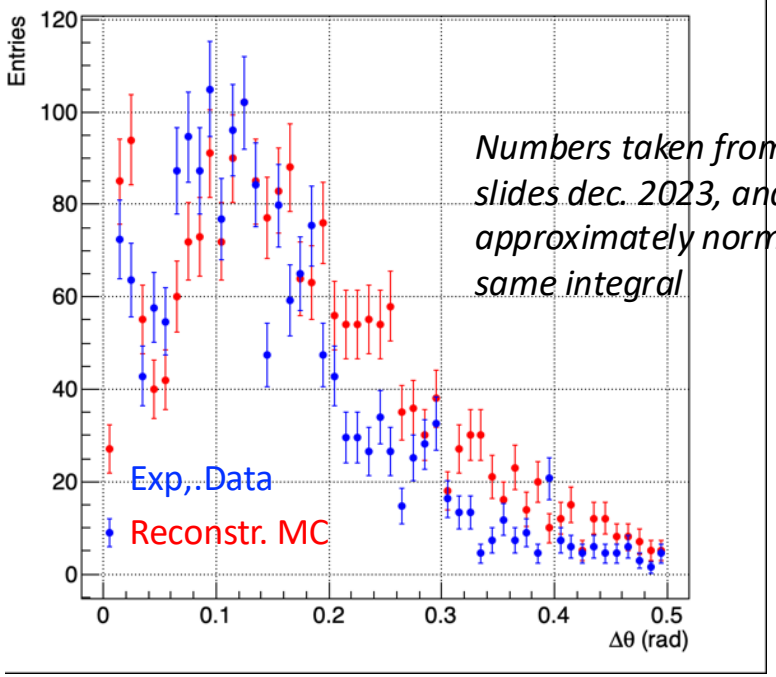
In this respect 400 MeV/u is worse than 200 MeV/u: narrower distributions

Comparison of data with reconstructed MC

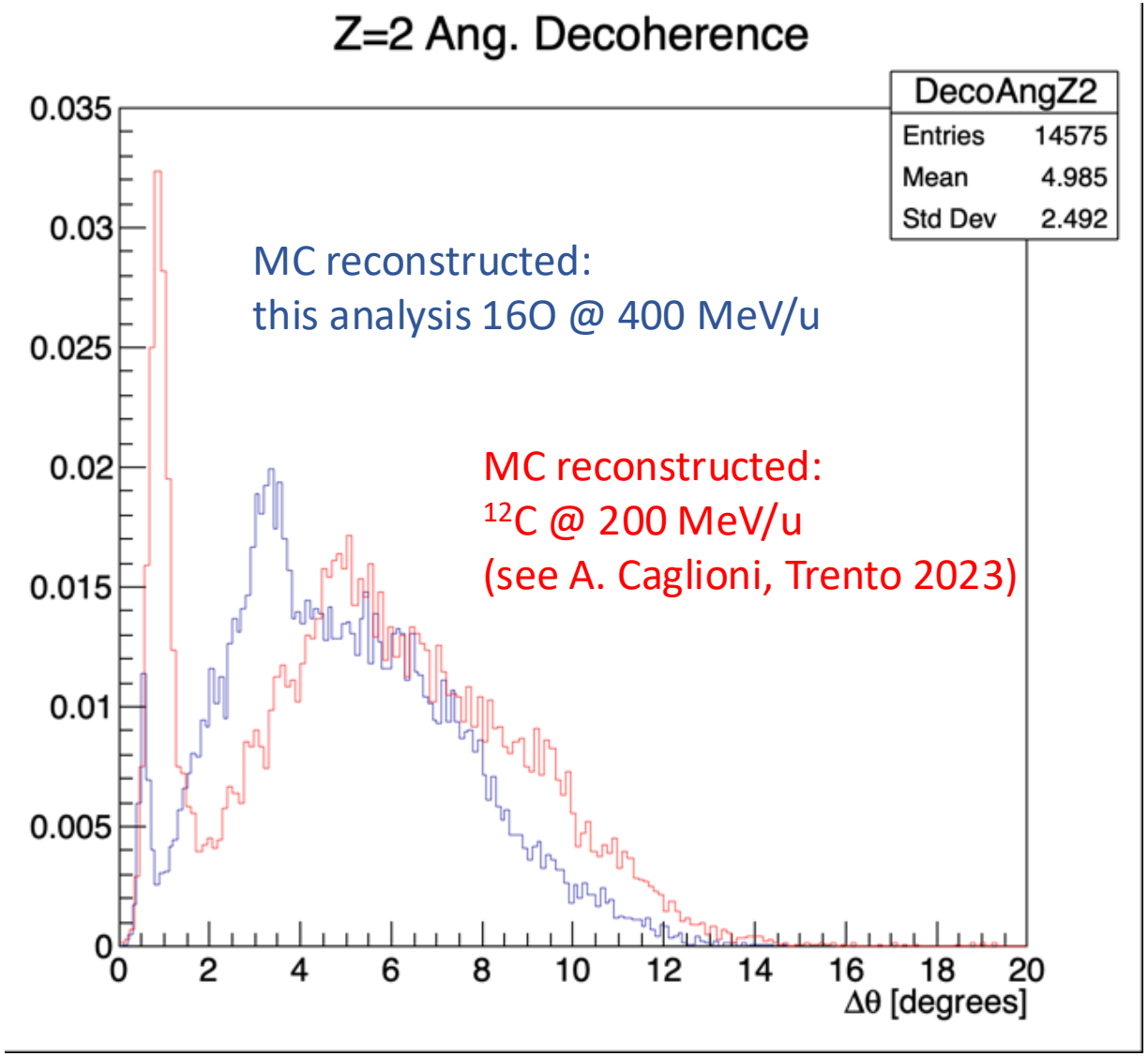
There are strong differences between MC and data!



In the case of emulsion data at 200 MeV/u MC prediction and exp. data were much closer:



About energy and projectile in the MC



Warning:

In FLUKA MC the $^{12}C \rightarrow$ 3 α fragmentation is already considered in detail with probability taken from existing data

This is not the case for ^{16}O fragmentation

Conclusions

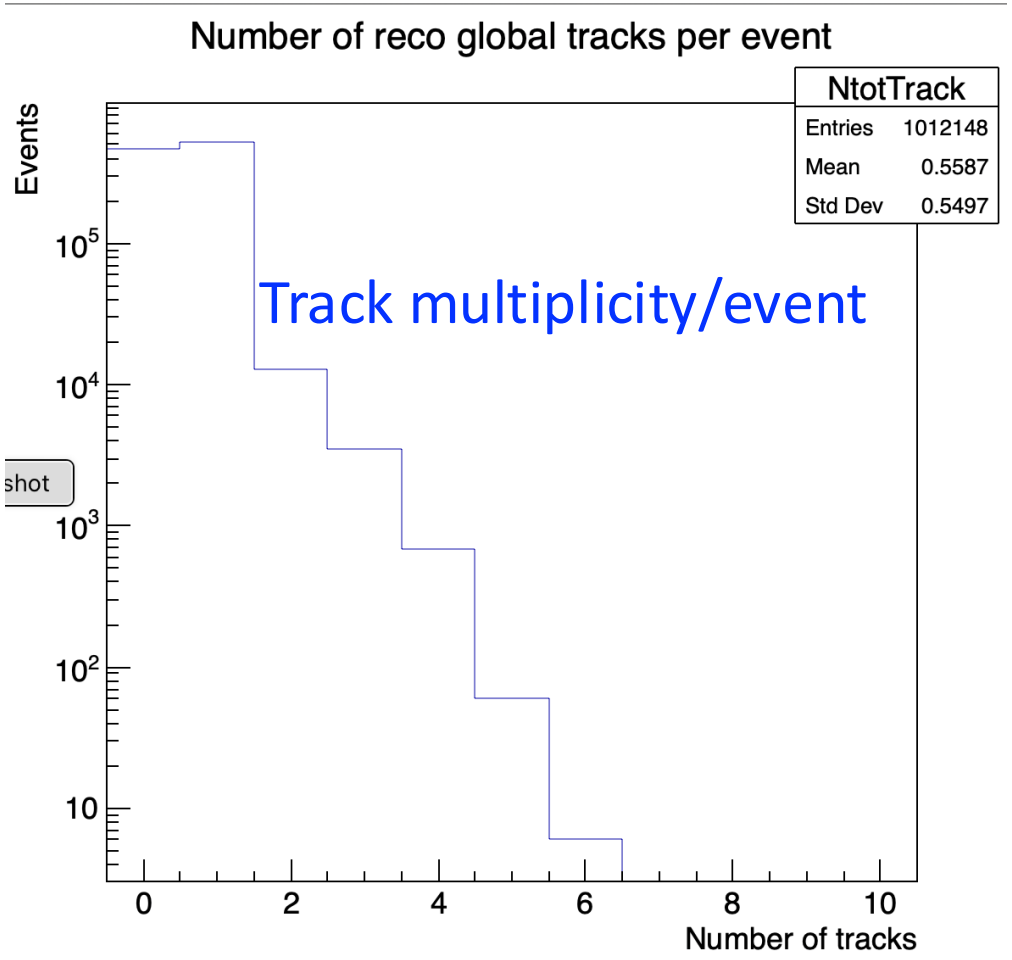
- The analysis of GSI2021 data turned out to be not easy at all, and there is a penalty from large pile-up.
- Apparently, there are problems in using GenFit. Straight Line Reconstruction seems to work better. The analysis strategy studied one year ago had to be totally rebuilt
- There are still a lot of uncertainties that cannot be simply solved without additional information. For instance, the reliability of Z reconstruction and the amount of Z=1 contamination
- MSD had to be taken away from reconstruction, for the time being. They could be very helpful in this situation
- There are important disagreements in the comparison of data and MC, and there are surely differences with respect to the 200 MeV/u case:
  - At the moment it is unclear if there are issues in the physics model (which indeed might depend on energy) or if the simple reconstruction used in this analysis in faulty or introducing biases
  - It is however clear that there are instrumental inefficiencies at small angle separation which must be more evident when energy increases

Take home messages

- Hints of other interesting nuclear physics processes are emerging. They must be taken into account for our future analyses!
- The structures in Z1-Z2 correlation should be explored also with emulsions
- It is anyway of fundamental important that both electronic spectrometer and emulsion analyze these phenomena at the same energy
- This means that it's probably necessary to analyze also GSI2021 data at 200 MeV/u (and run the simulation as well…)
- For the electronic spectrometer: in order to understand better our systematics and to give answers to the many questions arising from GSI2021 data, it is ot the outmost importance to analyze ^{12}C data taken with full detector and lower energy. Is CNAO2024 the most viable data set?

Backup Slides

1) GenFit Reconstruction test with run 4310



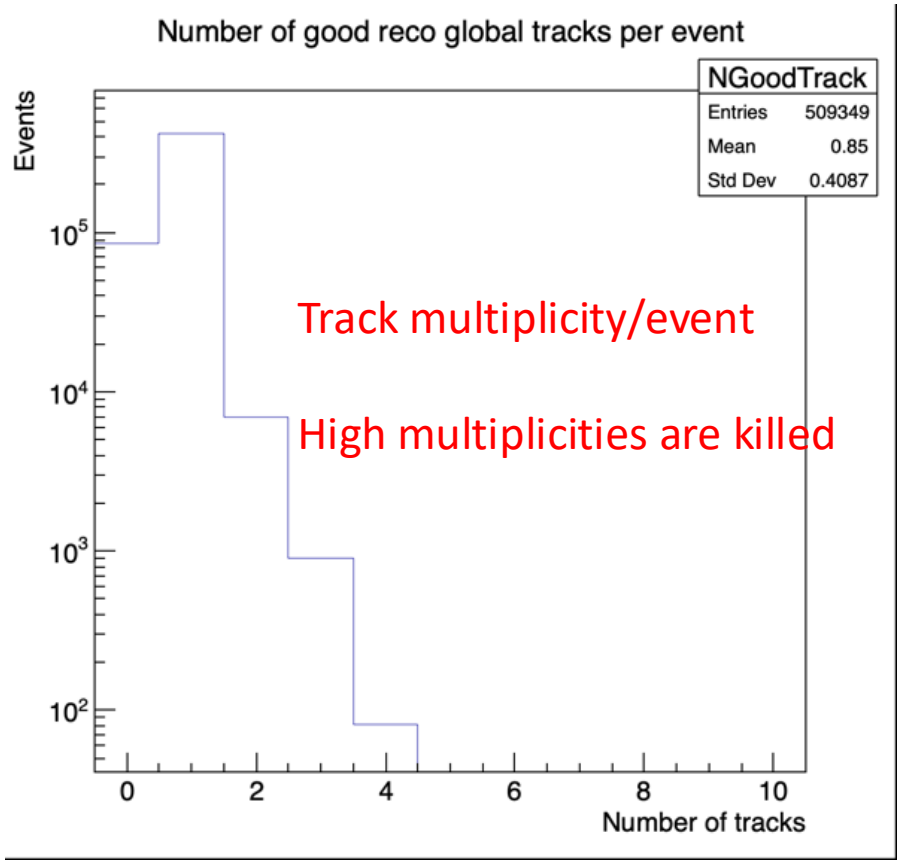
No track selection!

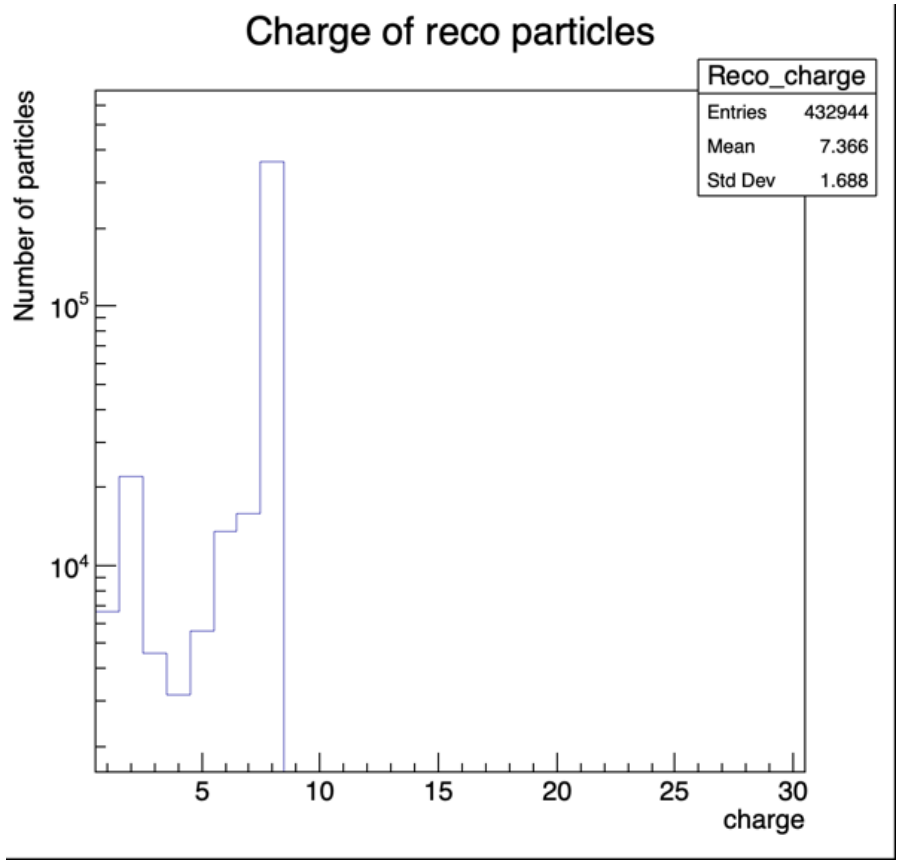
468828 events with 0 reconstructed tracks

1 track: 526166 events
2 tracks: 12940 events
3 tracks: 3465 events
4 tracks: 682 events
5 tracks: 61 events
6 tracks: 6 events

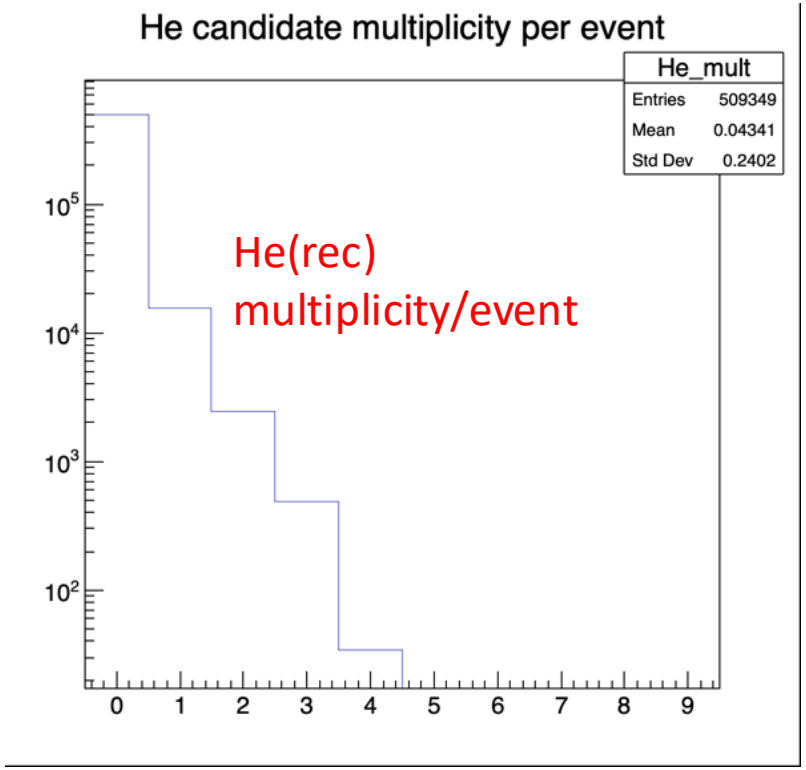
In 1 track events there are mainly non interacted primaries

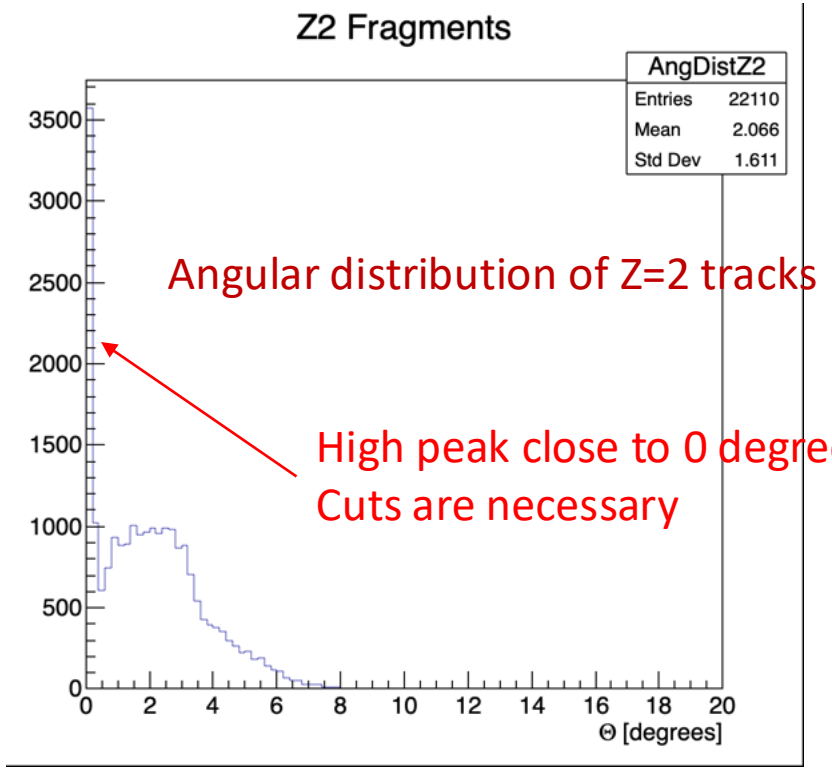
GenFit run 4310 after track selection



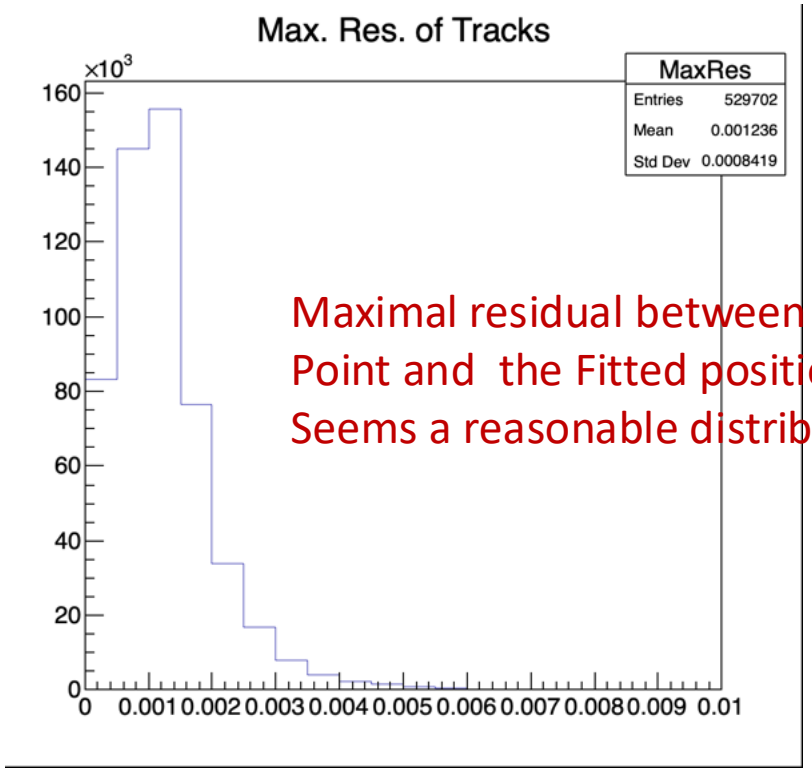


GenFit run 4310 after track selection



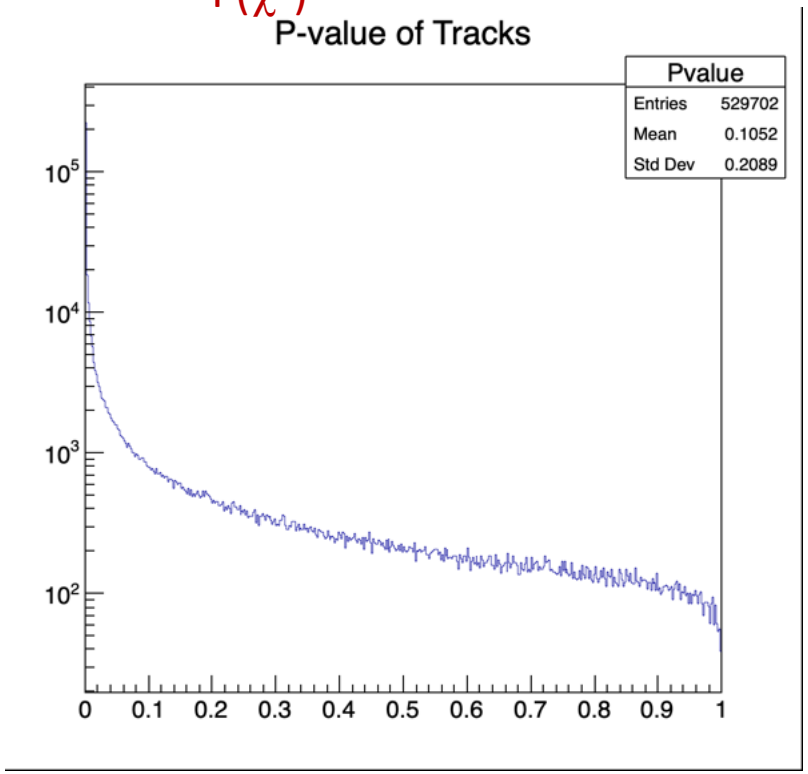


GenFit run 4310 after track selection



Maximal residual between a Track Point and the Fitted position: Seems a reasonable distribution

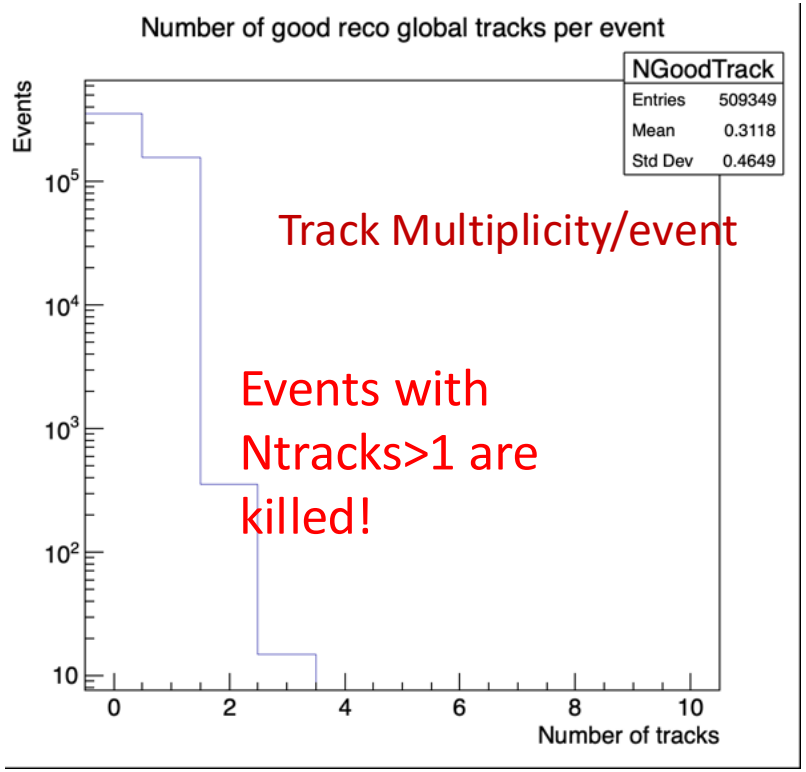
$P(\chi^2)$

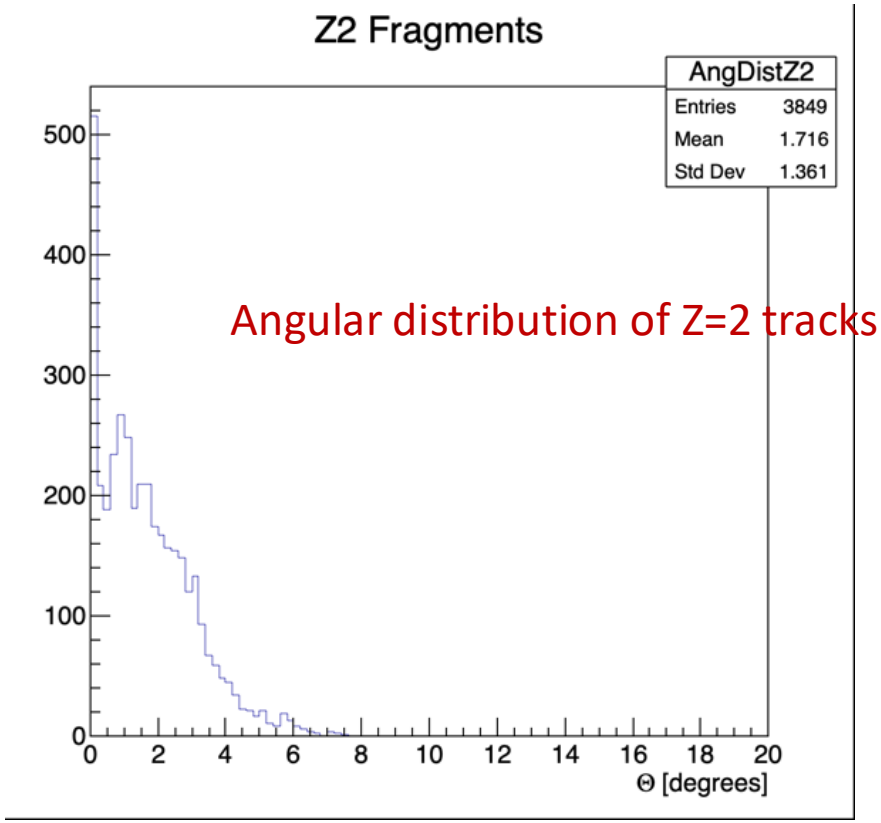


Attempting standard (loose) quality cuts

- $P(\chi^2) > 0.02$

run 4310

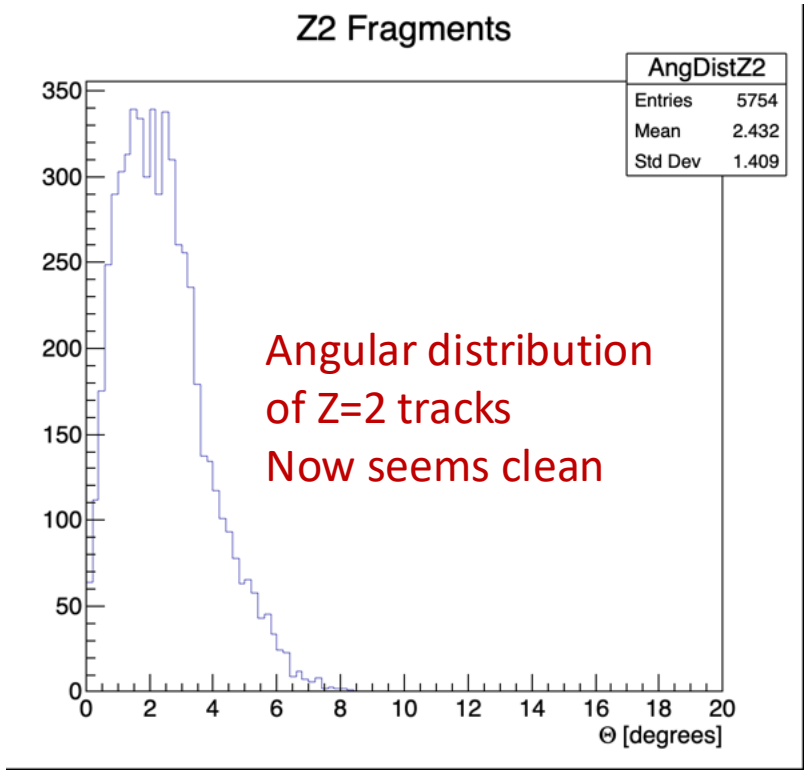


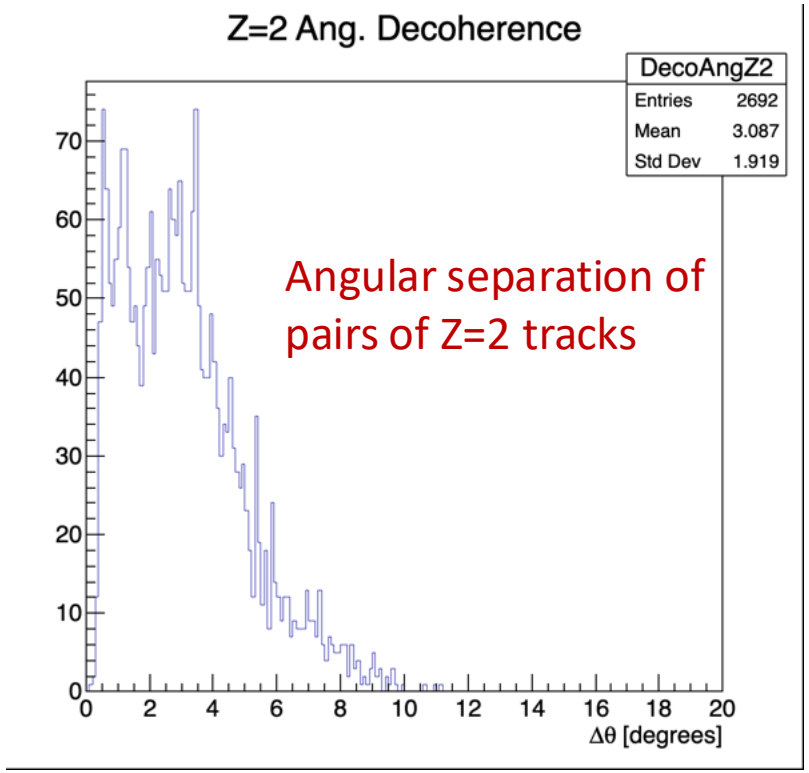


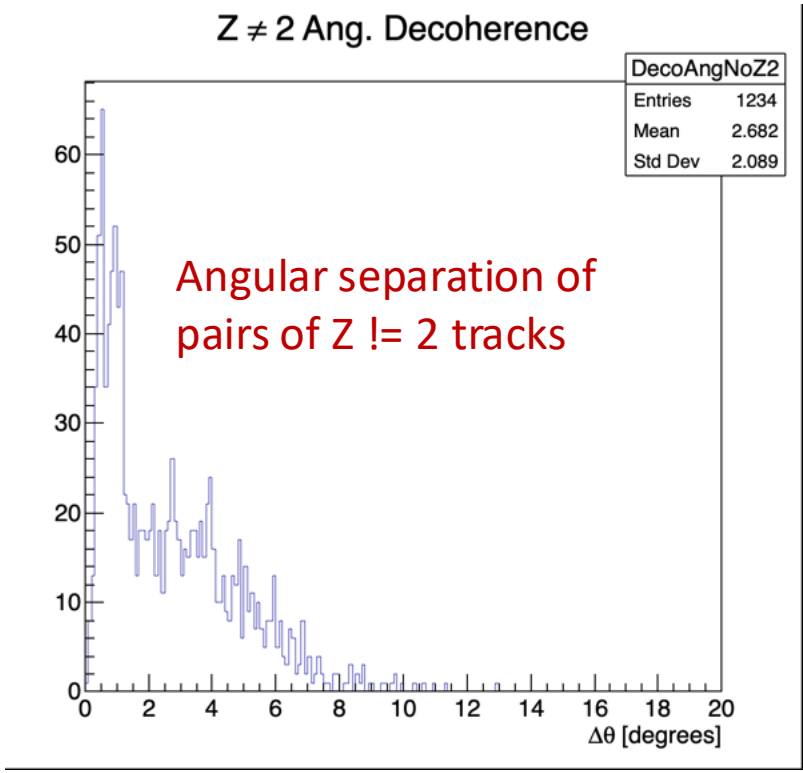
Number of events with Z=2 is also strongly reduced using the P-value cut

Dismissing cut on P(χ^2) and requiring $N_{track} \geq 2$

run 4310







Weird distributions…