GSI2021 Analysis Updates

Giacomo Ubaldi

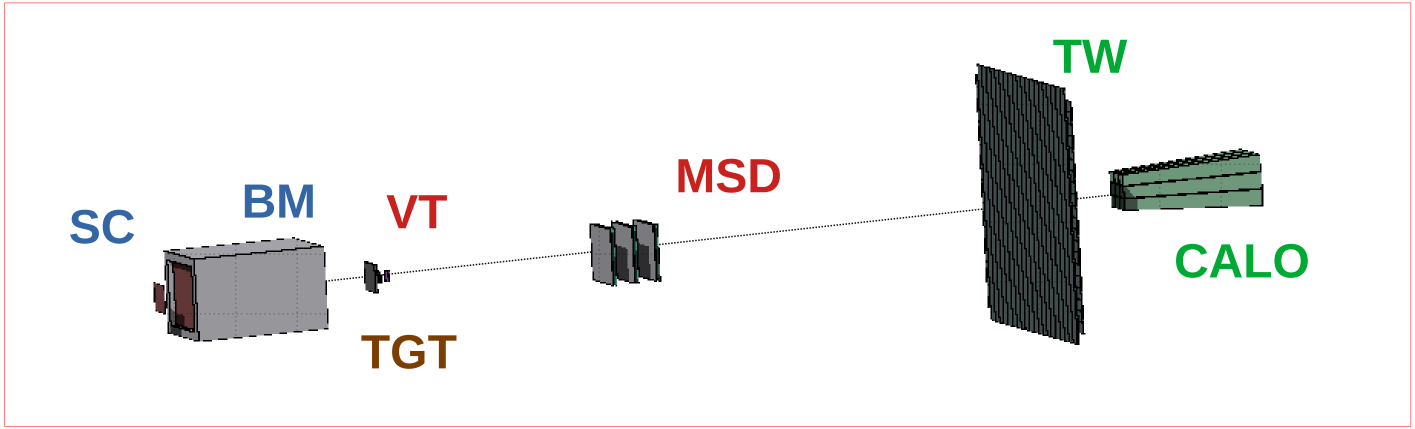
XV FOOT Collaboration Meeting

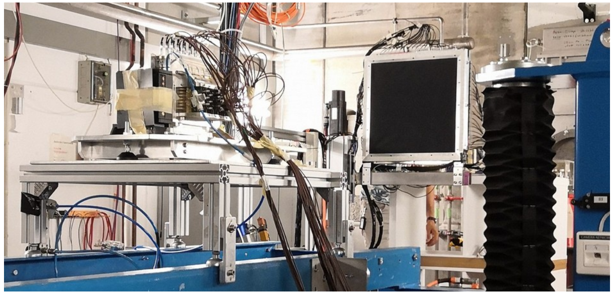
Trento

12/12/2023

GSI 2021 Analysis

- Data-taking at GSI (Darmstadt, Germany) in 2021
- **^{16}O 400 MeV/u** on 5 mm **C target**
- Partial setup: no magnet, only one module of calorimeter





- **VT, MSD, TW** considered
- Analysis based on **Global tracking**
- **MC considerations**

Analysis strategy

In the analysis, I am considering the following levels:

MC DATASET

MC TRUTH LEVEL

N_Reference (MC)

all TAMCParticles

- primary beams
- primary fragments generated in the TG

- which cross the end of TW

(all the particle inside the geometrical acceptance of the setup without secondary fragmentation beneath the detectors)

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In the analysis, I am considering the following levels:

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N_RECO

All reconstructed tracks by GENFIT + cuts

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RECO LEVEL → **N_RECO**

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N_RECO

All reconstructed tracks by GENFIT + cuts

I take the **MC_ID** of the track *(most frequent id)*

N_Good Reco

(Tracks with MC_ID which satisfies MC GENERATION requests)

Analysis strategy

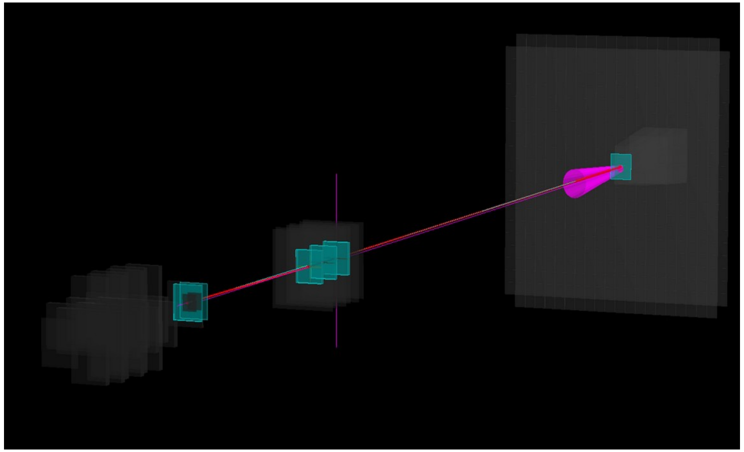
To compute angular differential cross section:

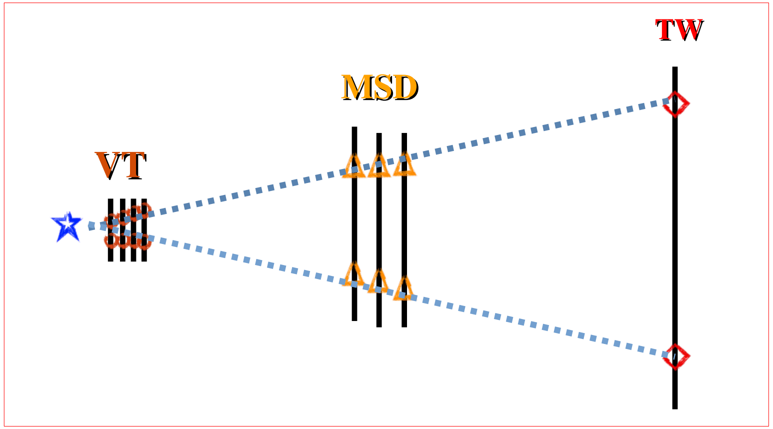
$$\frac{d\sigma}{d\theta}(Z,\theta) = \frac{Y(Z,\theta)}{N_{beam}\ N_{target}\ \Omega_\theta\ \epsilon(Z,\theta)}$$

where:

Y:	fragment counts	N_RECO
N_{beam}:	n° of primary events	
N_{target}:	n° of scattering centers per unit area	
ε:	efficiency	N_Good Reco / N_Reference (MC)
Ω_ϑ:	angular phase space	

Global Tracking strategy





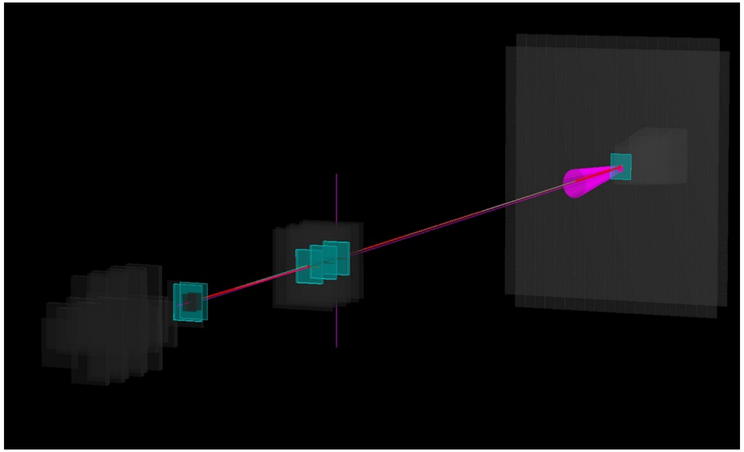
N_RECO

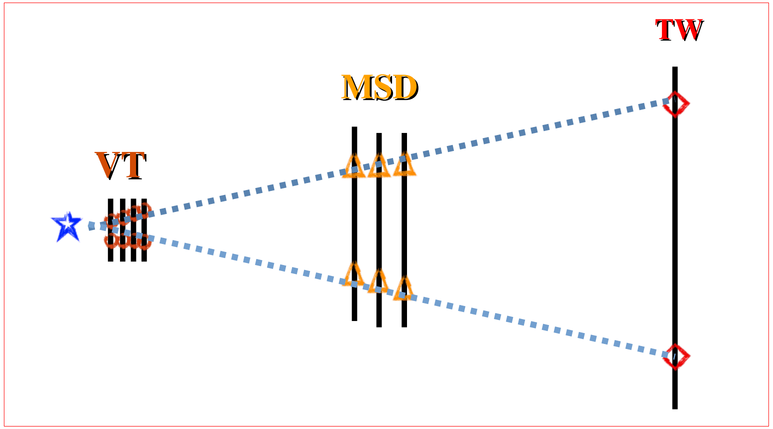
Tracks generated using a
Kalman Filter-based algorithm (GENFIT).

- Use info from trackers (VT, MSD) and TW via clusters
  - at least **7 clusters required**
- Start from VT tracklets
  - **Good vertex point required**
  - **BM-VT match required**
  - **only 1 track in BM required**
- Projection and extrapolation to further detector
- Z obtained from TW
  - **TW point required**
- Fit of the track candidate

thanks to Roberto Z.

Global Tracking strategy





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Tracks are not too optimized in order to be refined in analysis.
Then, the first attempt was a tuning:

N_RECO + **QUALITY CUT**

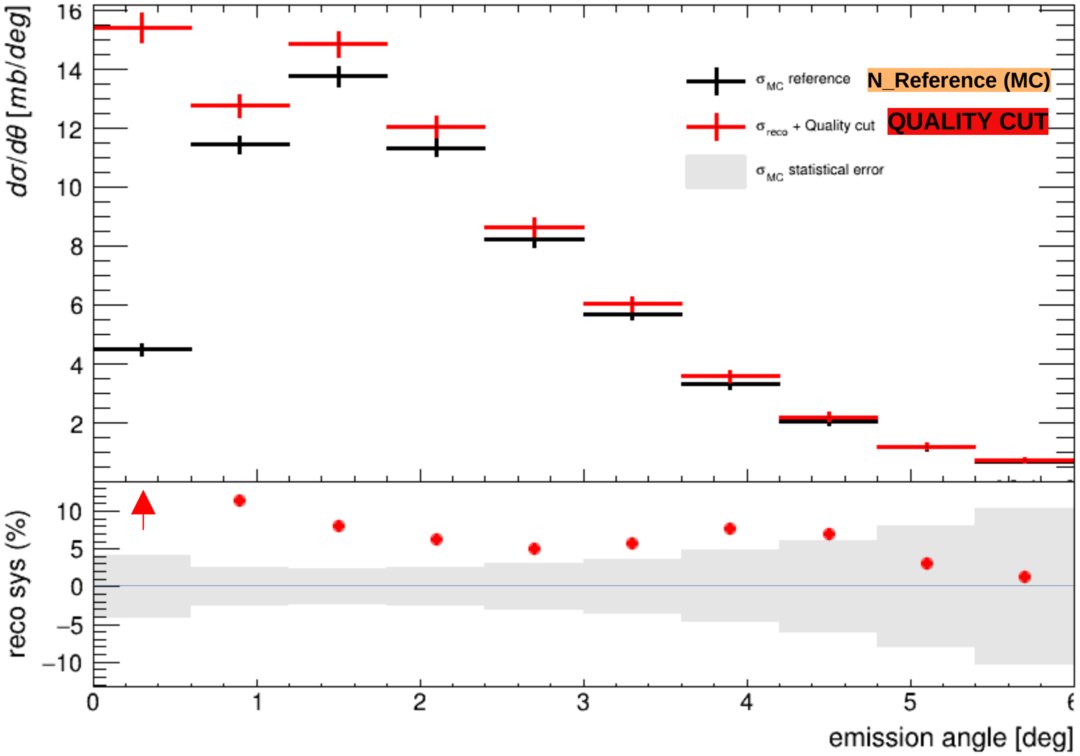
- χ^2 **/ ndof < 2**
- **worst residual < 0.01 cm**

see Yun et al. talk 04/10/23
https://agenda.infn.it/event/37822/

Quality cut – cross section

- I will start my considerations showing the plot of **Beryllium (Z=4) differential cross section** (all the other plots will be reported at the end of the presentation)

Z=4 Angular Differential Cross section



- Cross sections computed using the formula:

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- Systematical impact studied with the **reco ratio**:

$$reco\ sys = \frac{\sigma_{reco} - \sigma_{MC}}{\sigma_{MC}}$$

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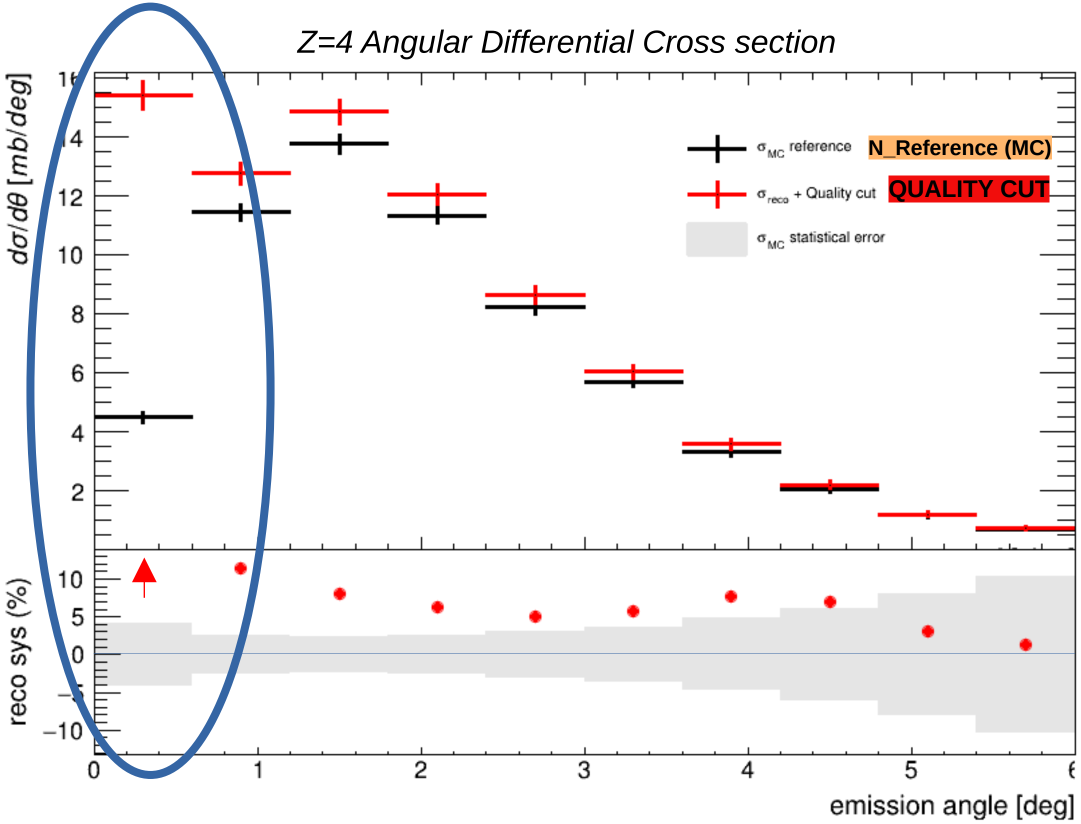

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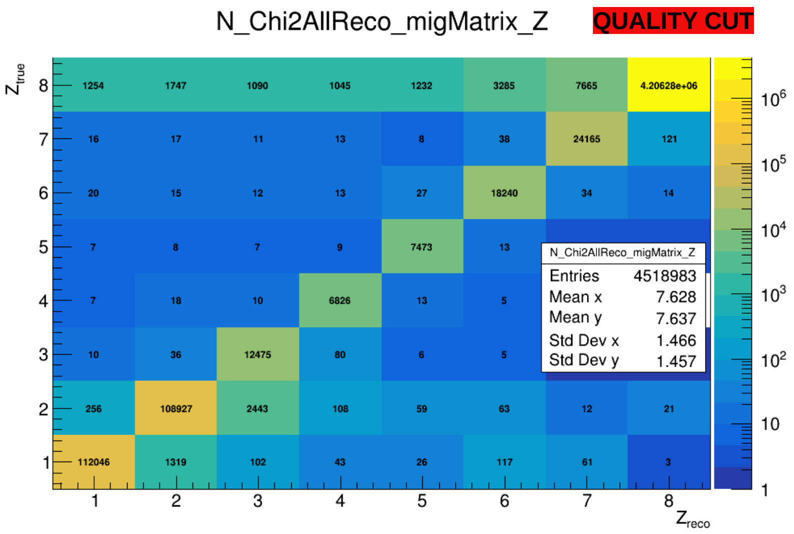
- There is a systematical overestimation of the cross section values
- **Worst reconstruction at lower angle**

  → **out of target fragmentation**

out of target fragmentation



Let's consider the CMM, where:

- $\mathbf{Z_{reco}}$ is the charge reconstructed by the TW for every track
- $\mathbf{Z_{true}}$ is the MC charge of the most frequent particle in the track

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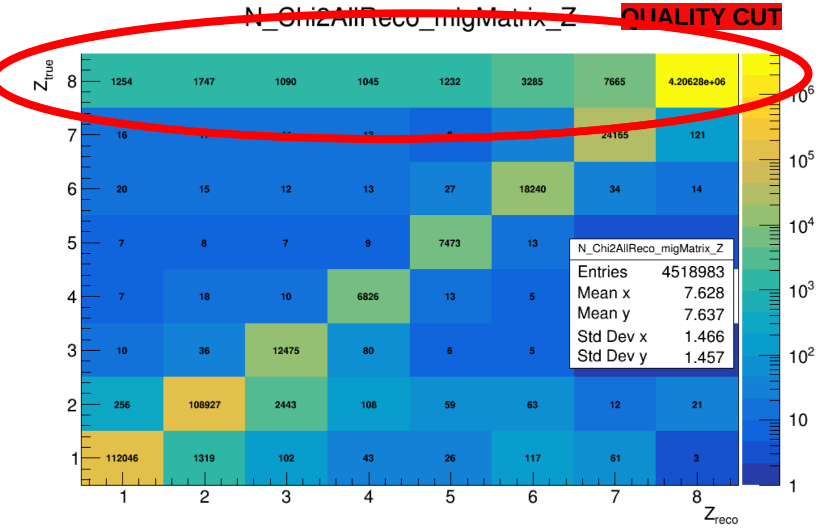

Let's consider the CMM, where:

- **Z_{reco}** is the charge reconstructed by the TW for every track
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Let's consider **Z_{true} = 8** :

- If the beam has a fragmentation out of the target:

  Z_{true} remains 8 because the most frequent particle in the track

  Z_{reco} would be the one of the fragment crossing the TW

  → this explains the **Z_{true} = 8 row**

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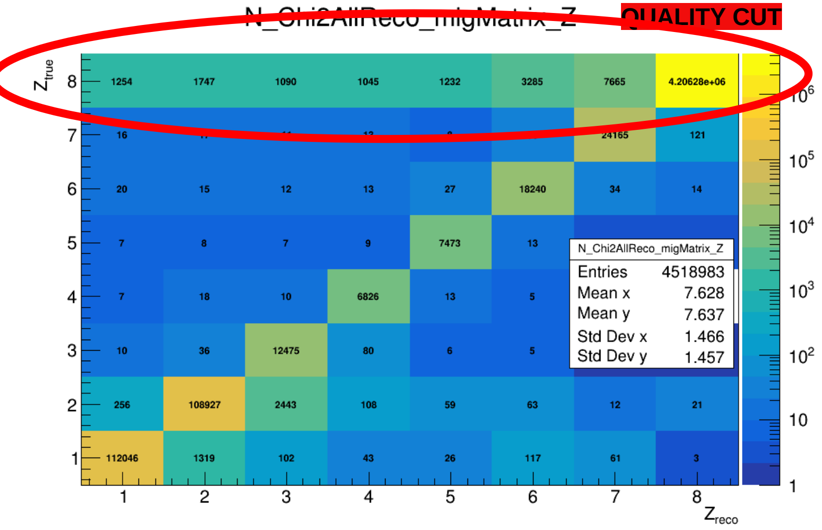

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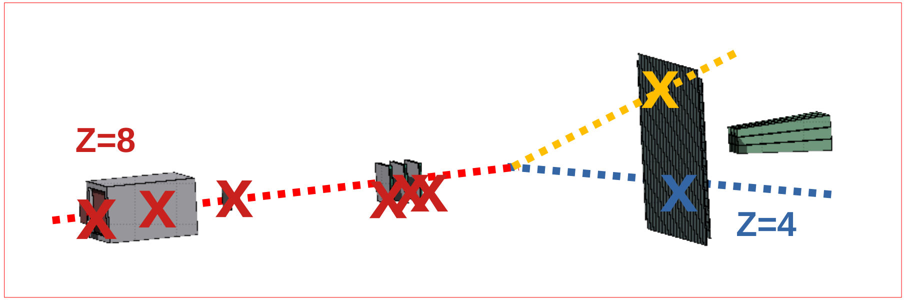
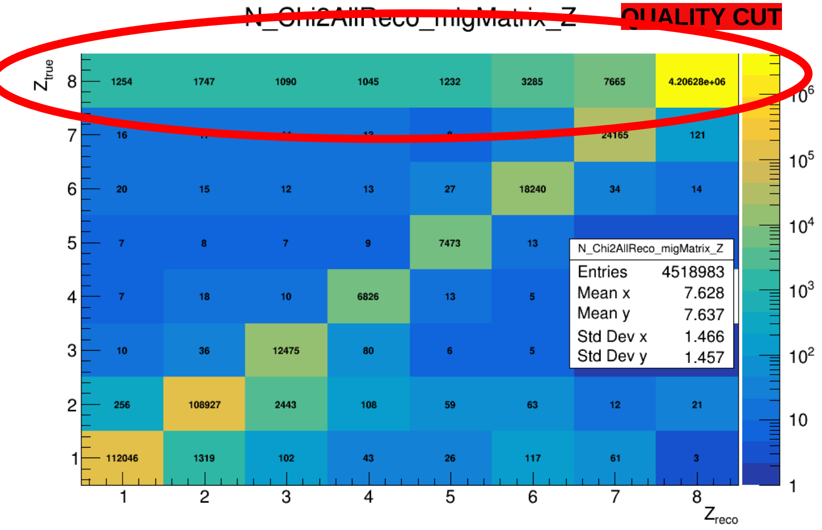
According to how global tracking works,
out of target fragmentation follows this pattern:



- Since there was only a track in the vertex, the global tracking will reconstruct 1 track at most
- using the closer TW point



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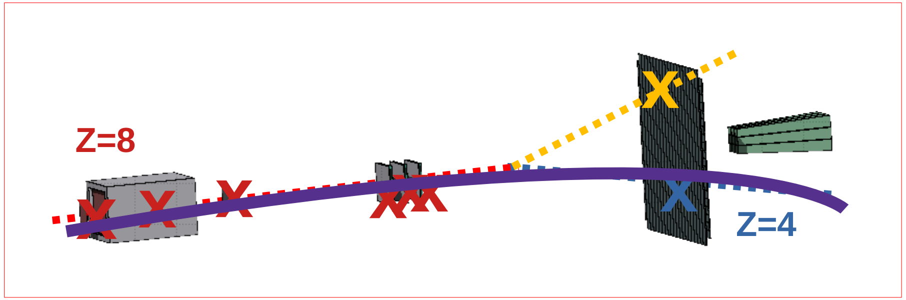

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only 1 glb track:
$\mathbf{Z_{reco} = 4}$
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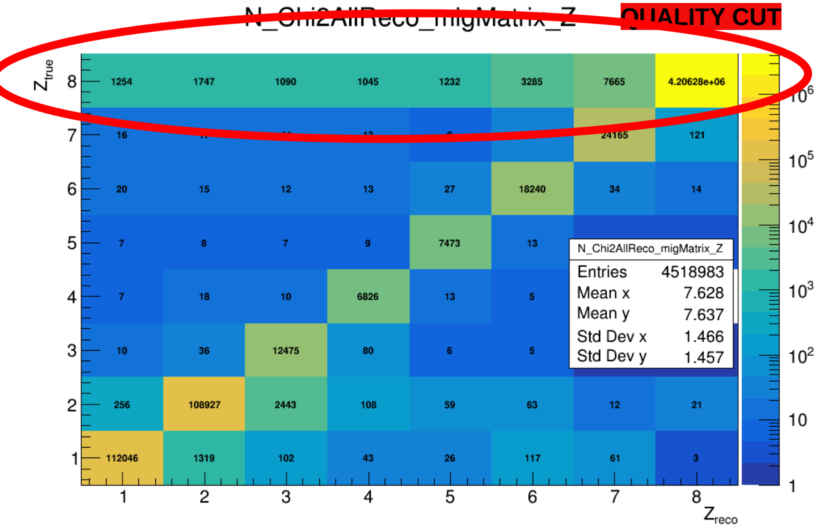

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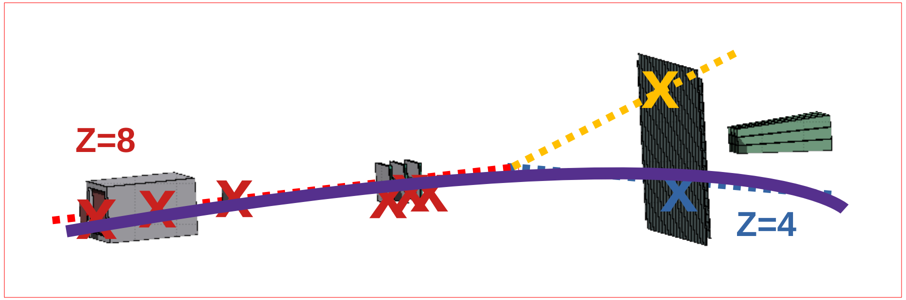

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only 1 glb track:
Z_{reco} = 4
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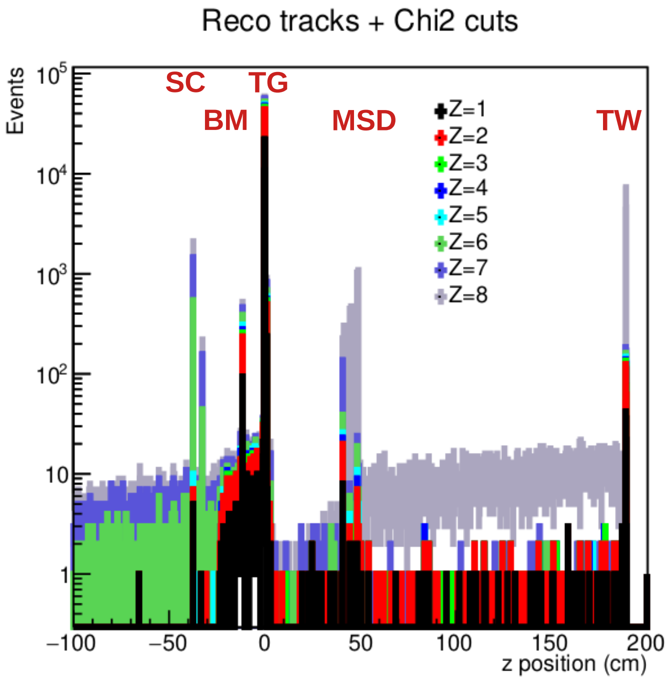
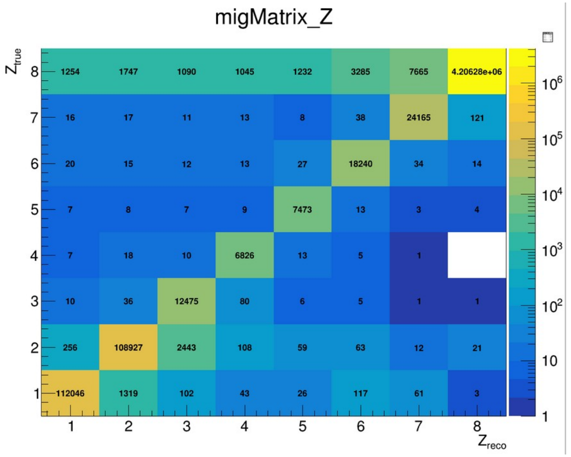
- Let's apply a cut for all the events with only one reco track:

MULTITRACK CUT **$n_{global\ tracks}$>1**

Multitrack cut – observations





Origin of the fragment crossing the TW for a specific track signed with Z_{true}

- As said, the highest amount of fragmentation is given by the primary, before and after TG

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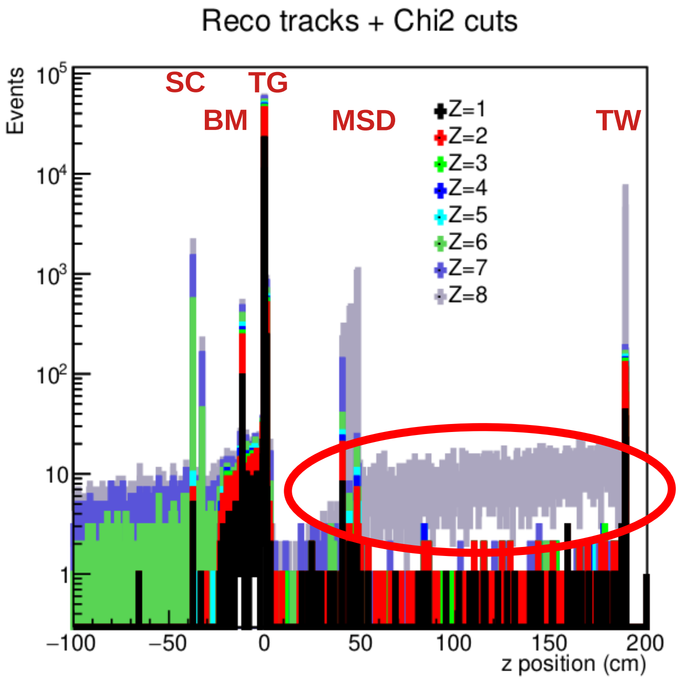

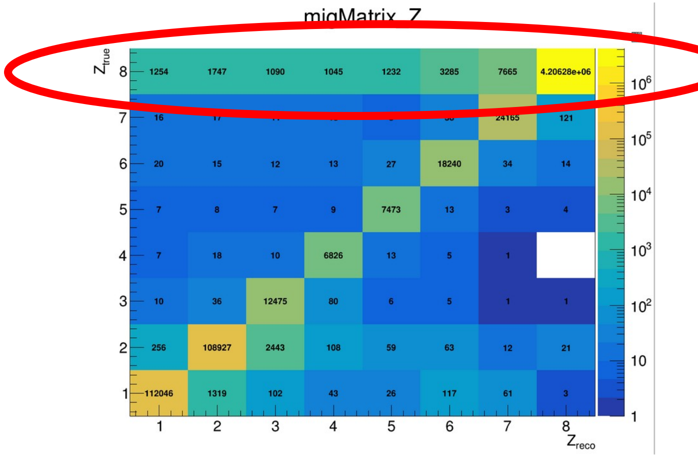

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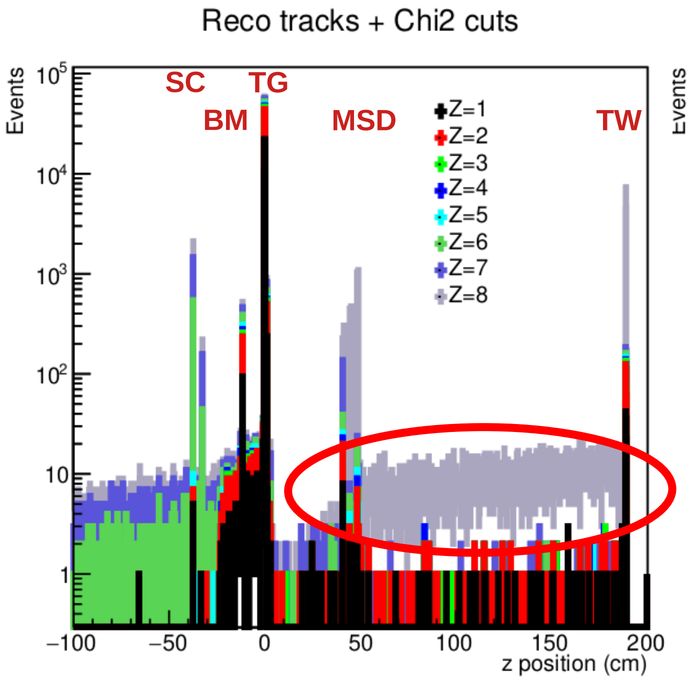
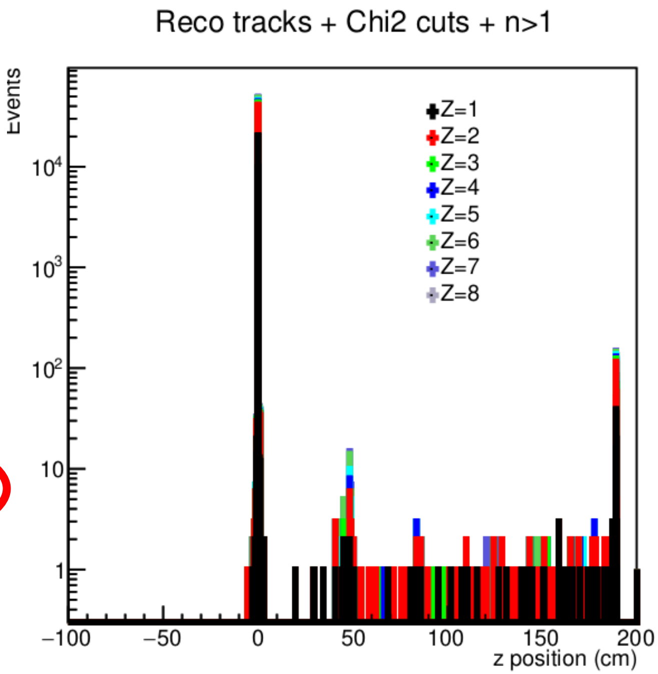
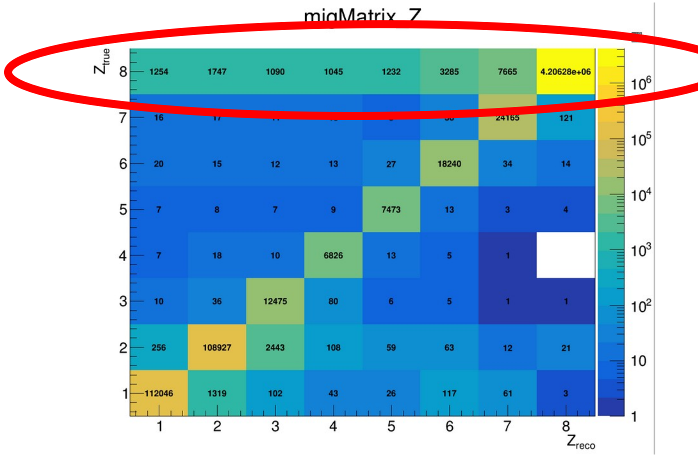
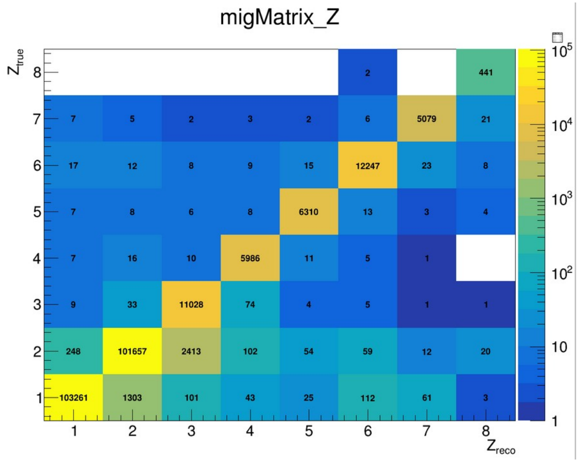






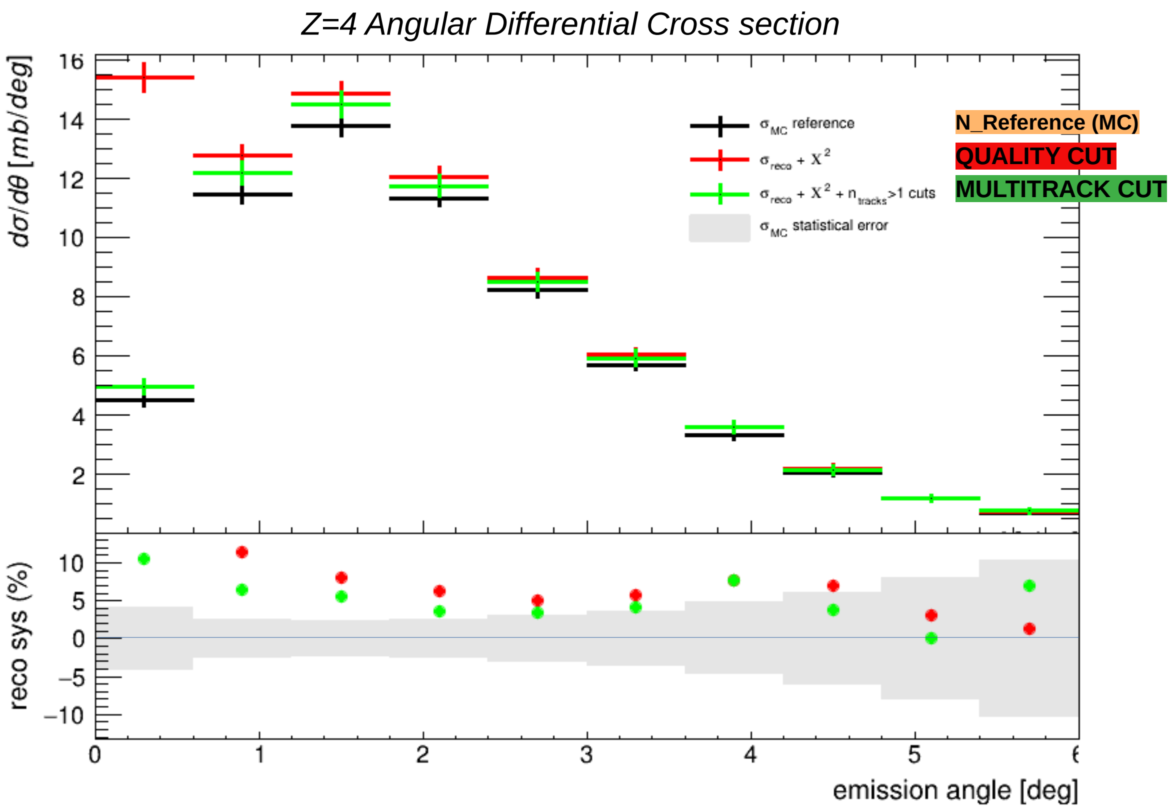


Origin of the fragment crossing the TW for a specific track signed with Z_{true}

- As said, the highest amount of fragmentation is given by the primary, before and after TG
- Applying the cut, the $\mathbf{Z_{true} = 8}$ row has been removed from CMM (and not only)

Multitrack cut – cross section

- Let's see the plot of **Boron (Z=4) differential cross section** with the new cuts



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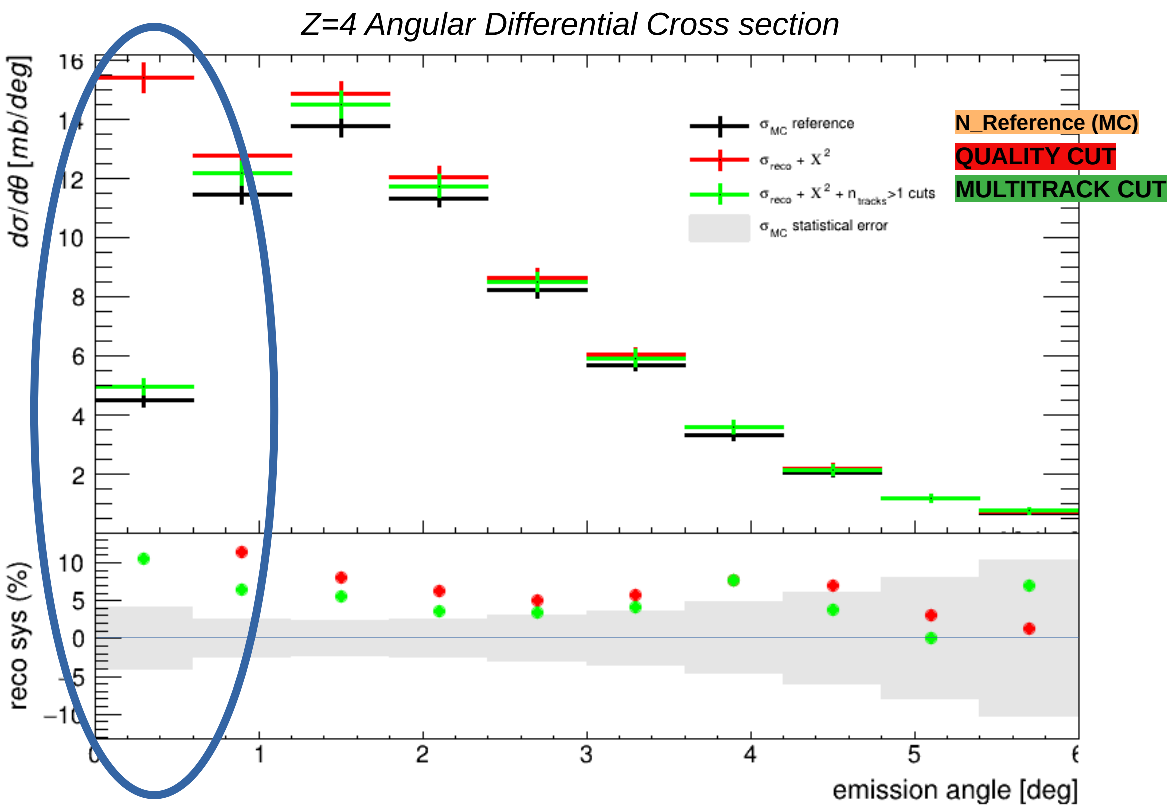

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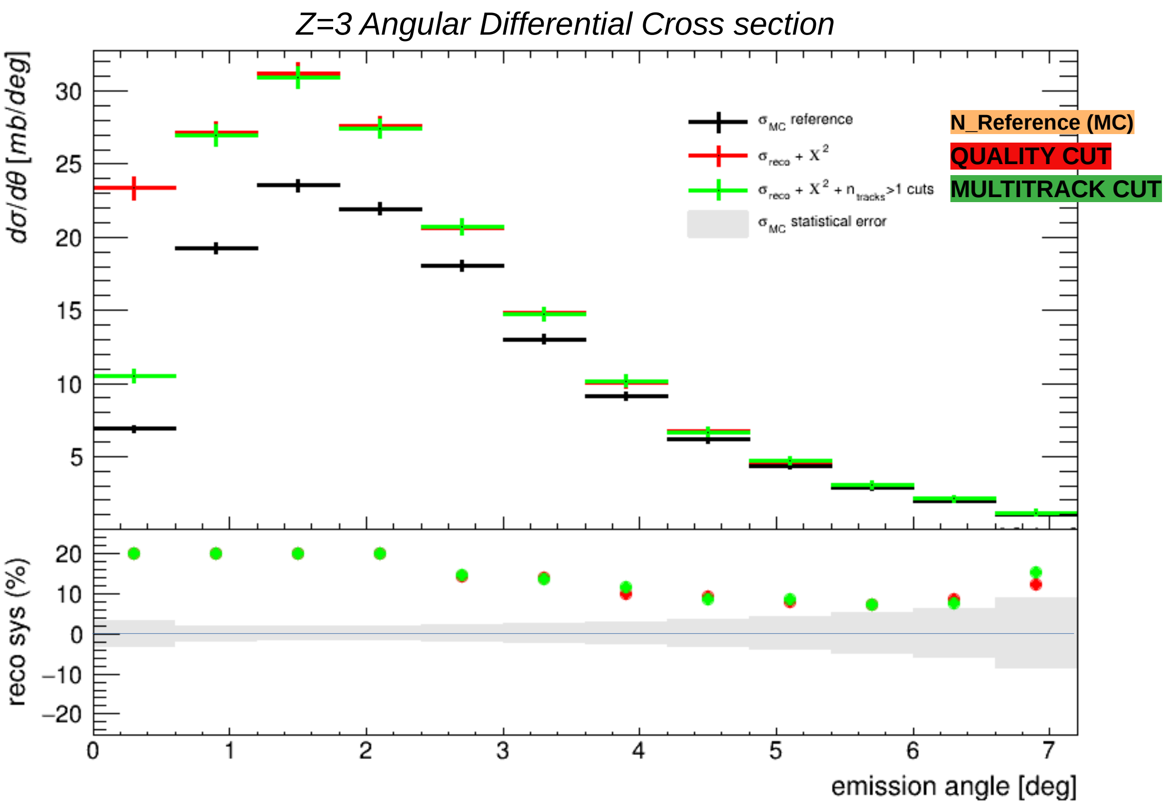

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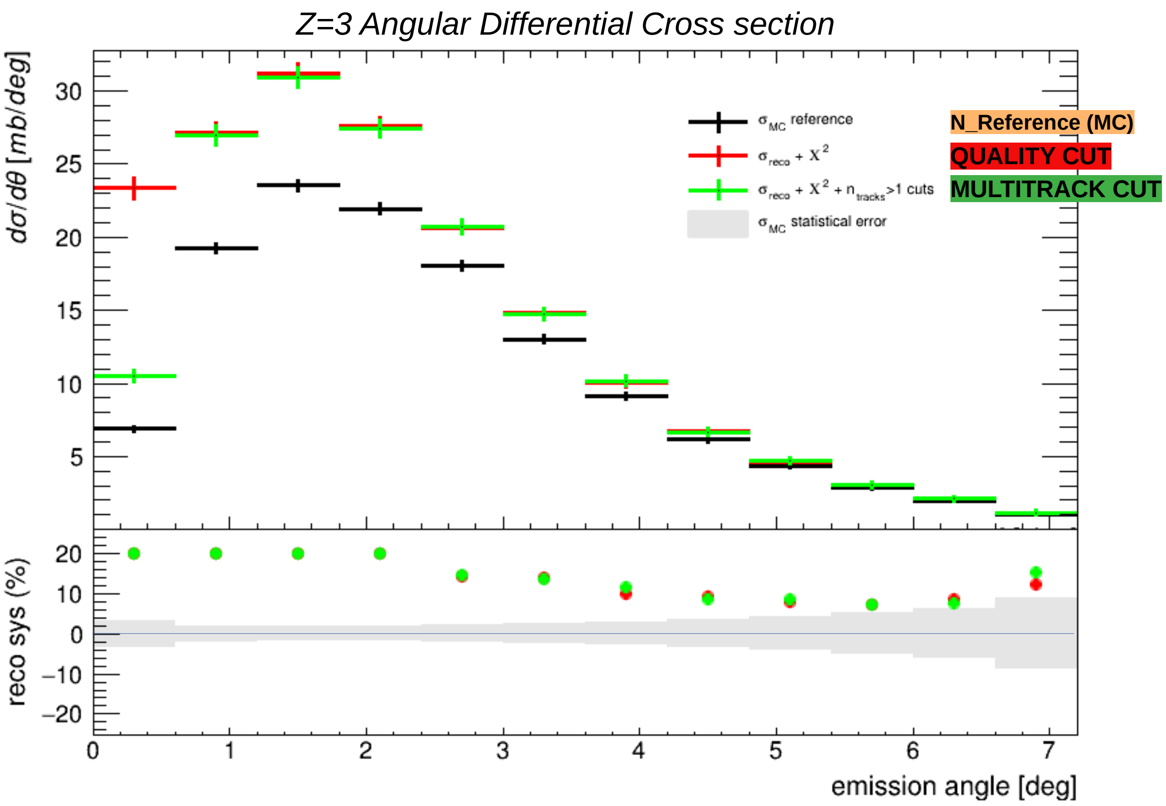

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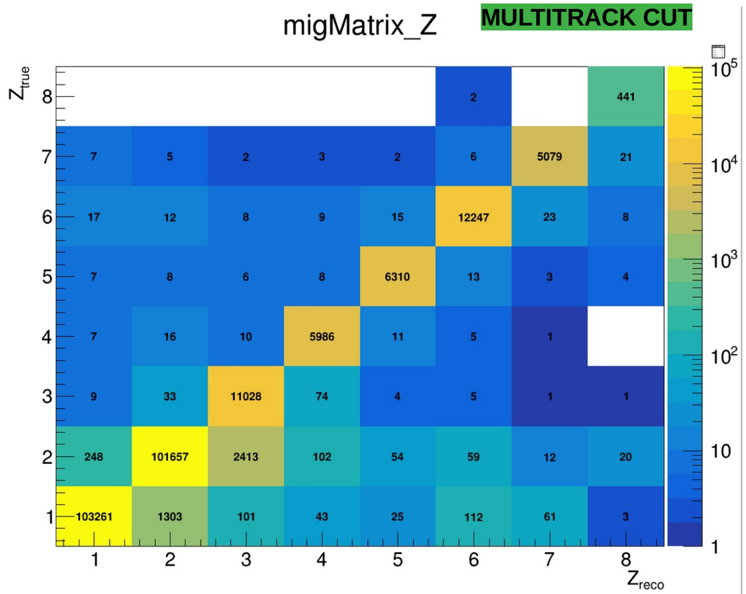

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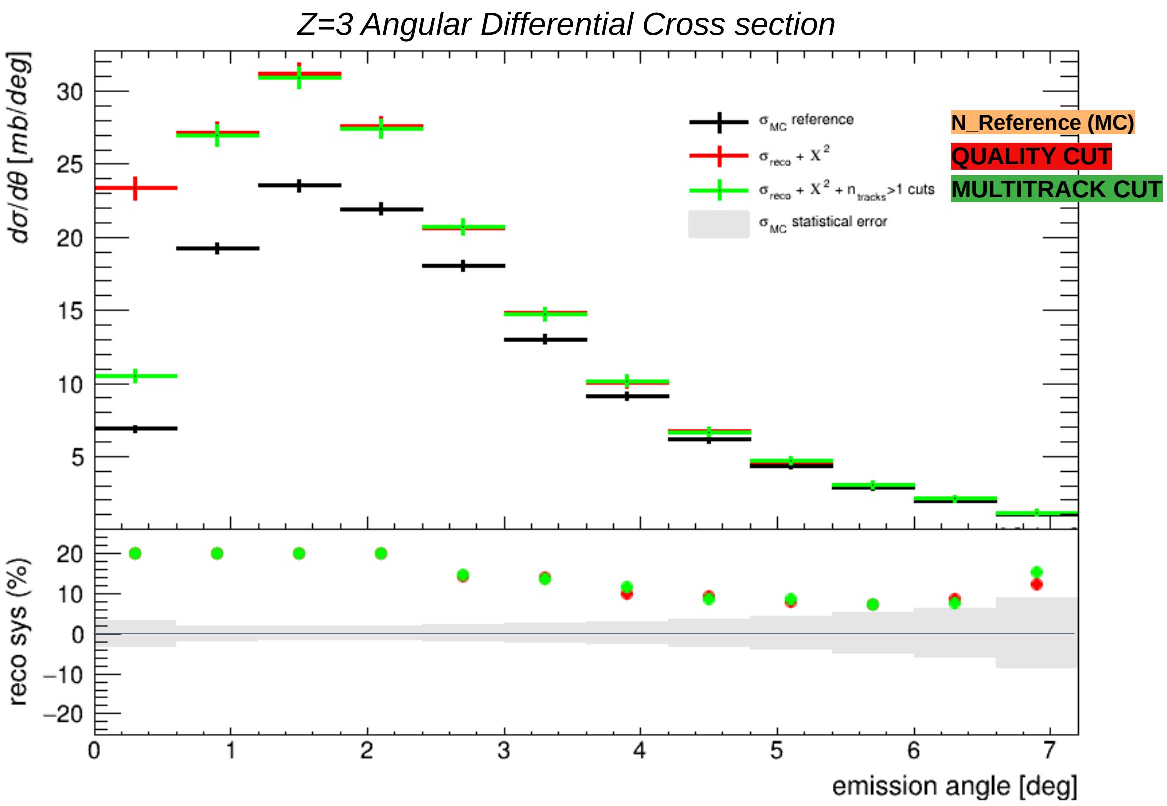

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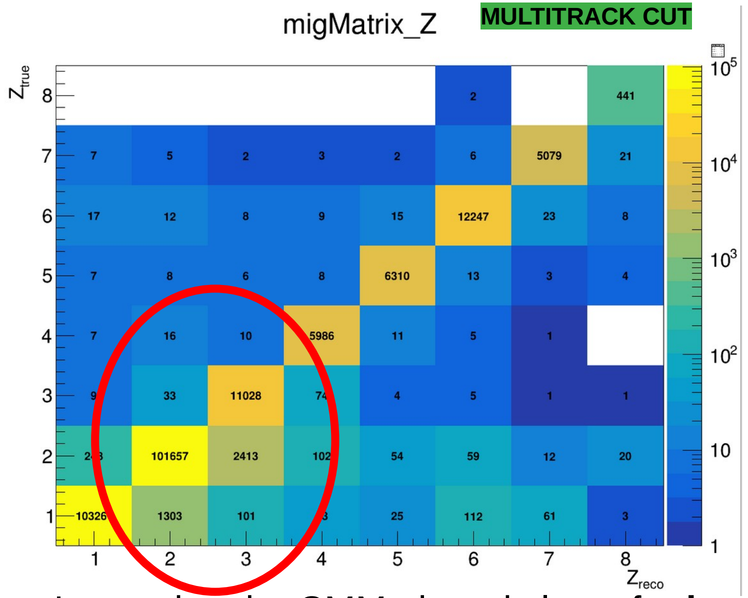

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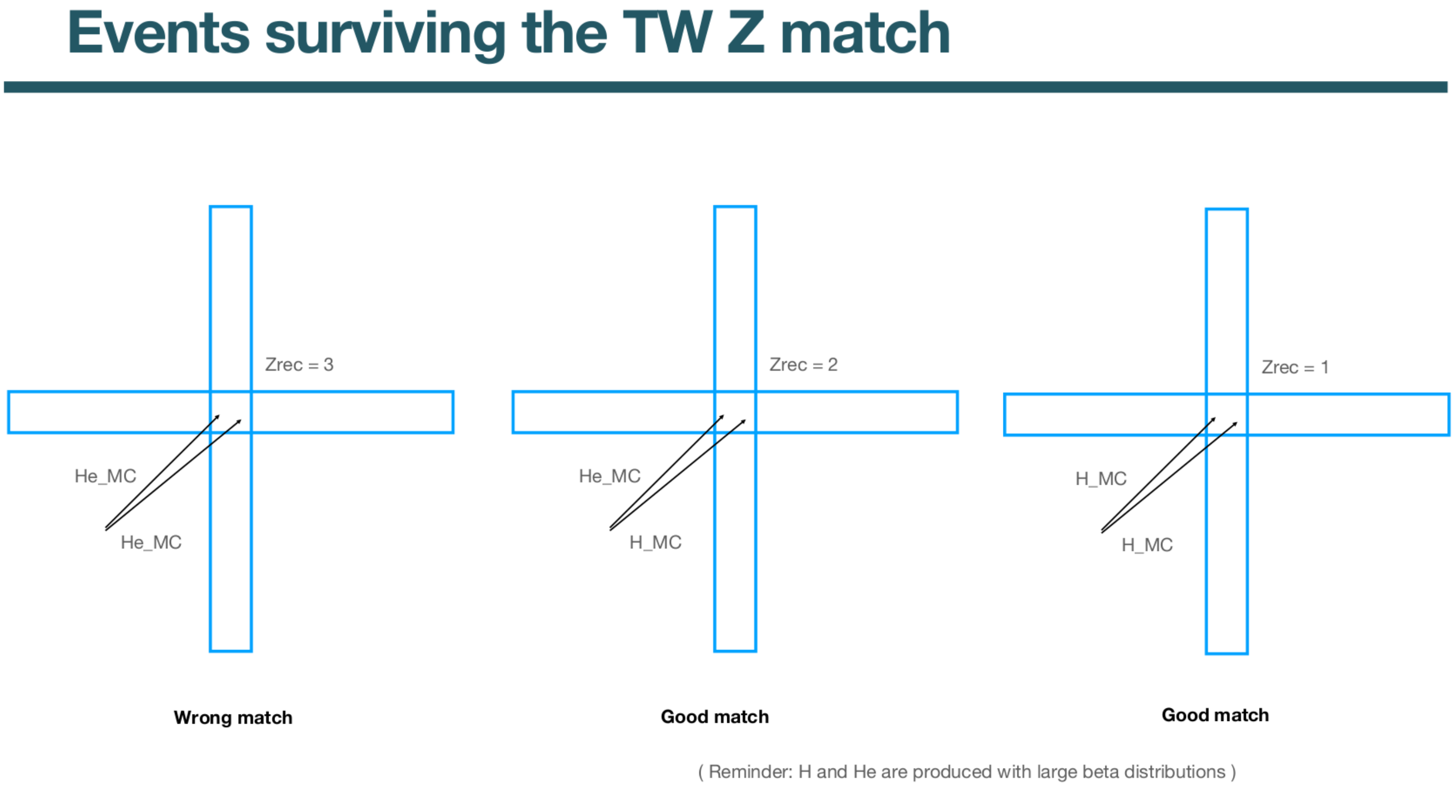
→ **due to TW reconstruction?**

TW point reconstruction

https://agenda.infn.it/event/35352/contributions/201148/

- From Marco T.'s talk at GM of Bergamo:



- It is possible that more than one fragment pass through the same TW cross, misreconstructing the charge.
  → **High impact for misreconstructed Z_{true} = 2 charges into Z_{reco} = 3.**

TW point reconstruction

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CMM matrix: GSI2021_MC(16O_C_400_1)

Concluding:

- The CMM as built here is showing the intrinsic limit of TW in identifying standalone the Z
- The result depend on TW granularity and the physics we're studying (fragmentation models in FLUKA)
- Help can come from:
  - 1) ZID from other detectors (MSD, VTX?)
  - 2) global tracking in disentangle close tracks
- Unfolding of the Z from the CMM cannot be done: the purity correction have to be used, but there is stll a dependence on the FLUKA MC models
- Correlation of the multiplicity of tracks in the same bar with the production angle of the fragments?

Purity = N(Zrec=Ztrue) / N (Zrec)

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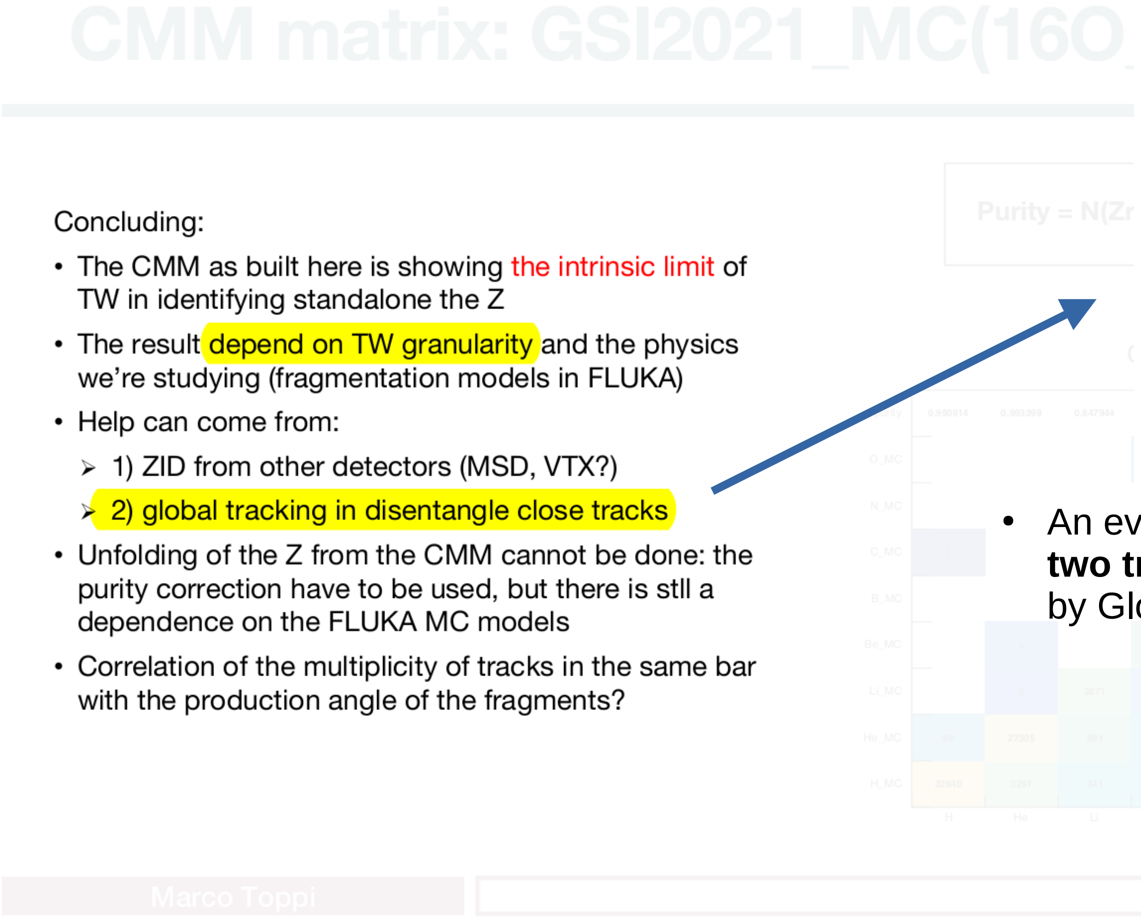

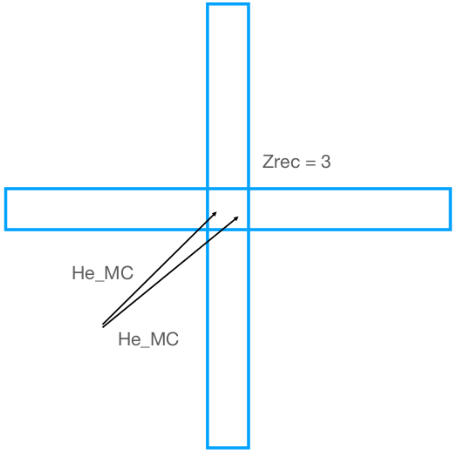

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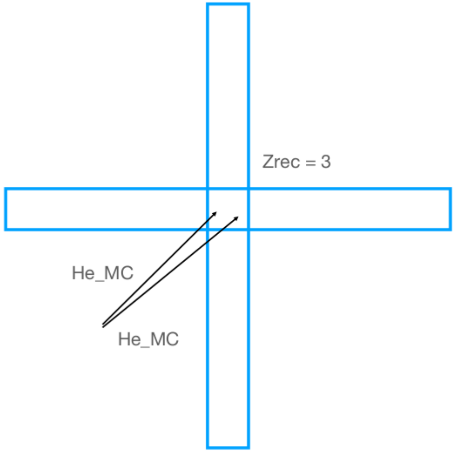
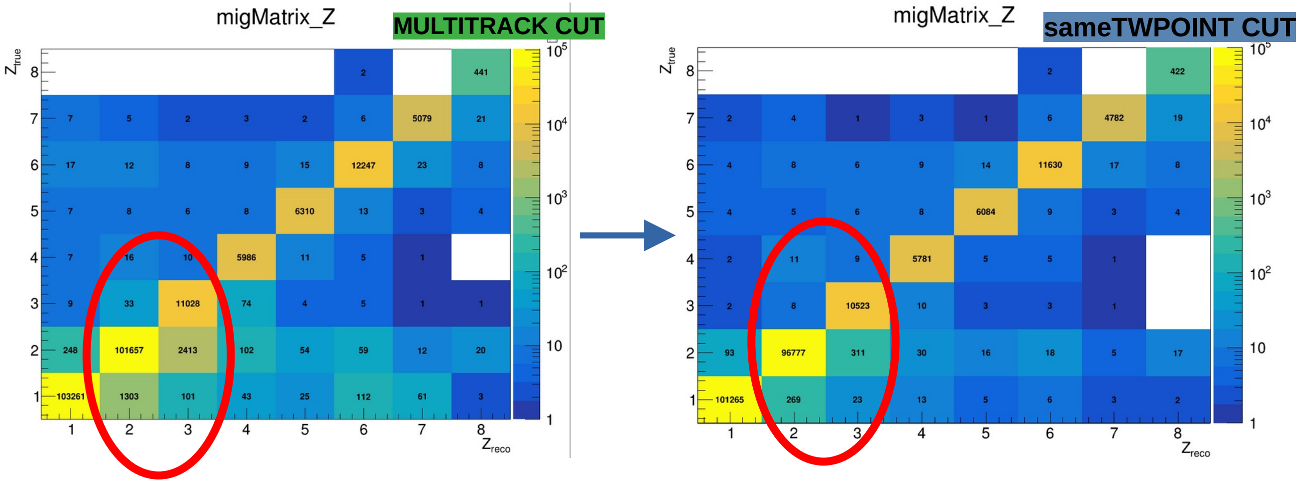


- An event like this can be reconstructed as **two tracks with the same TWPoint** by Global Tracking

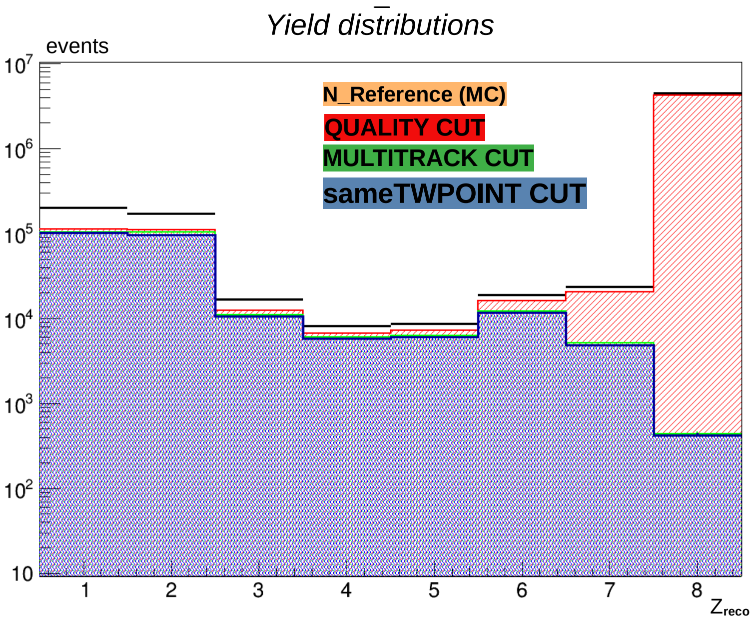
- Let's apply a cut in which all these reco tracks are omitted:

sameTWPOINT CUT



As expected:

- the reconstructed events out of diagonal for Z=2 and Z=3 are considerably reduces (and not only)
- Improvement of diagonalization of MM
- limited loss of statistics



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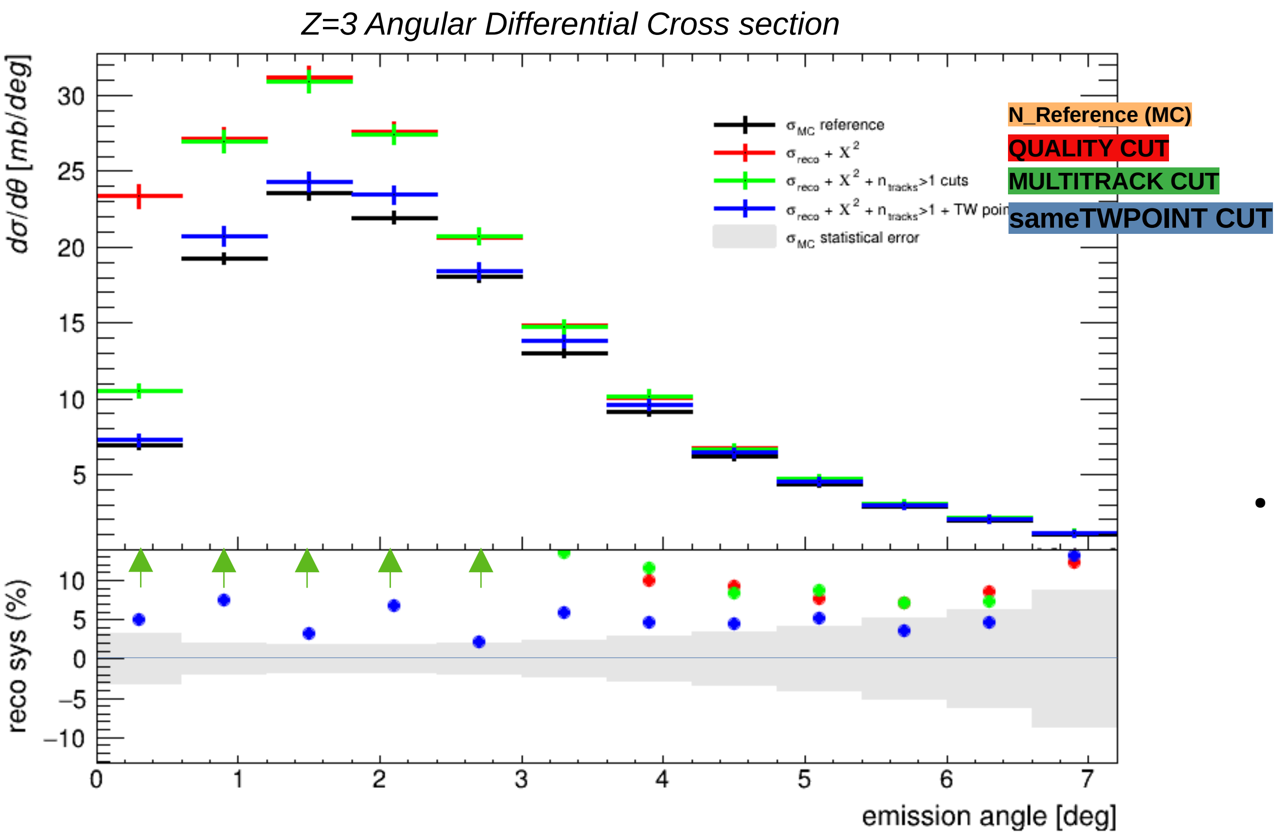
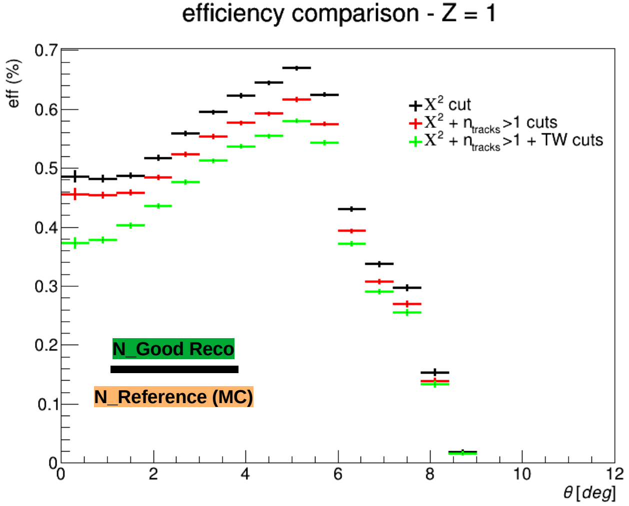
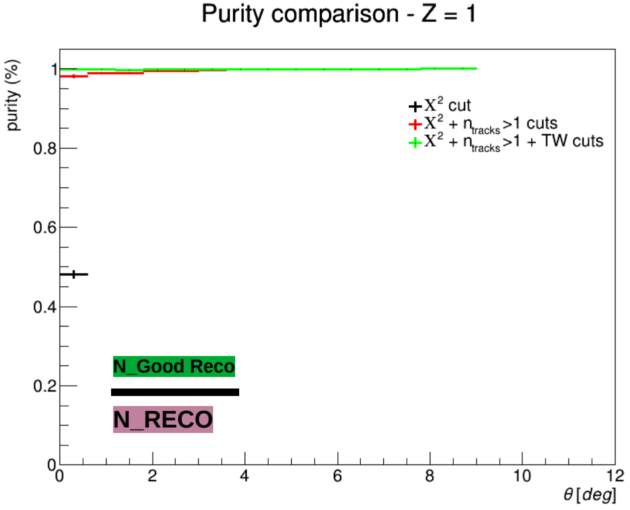
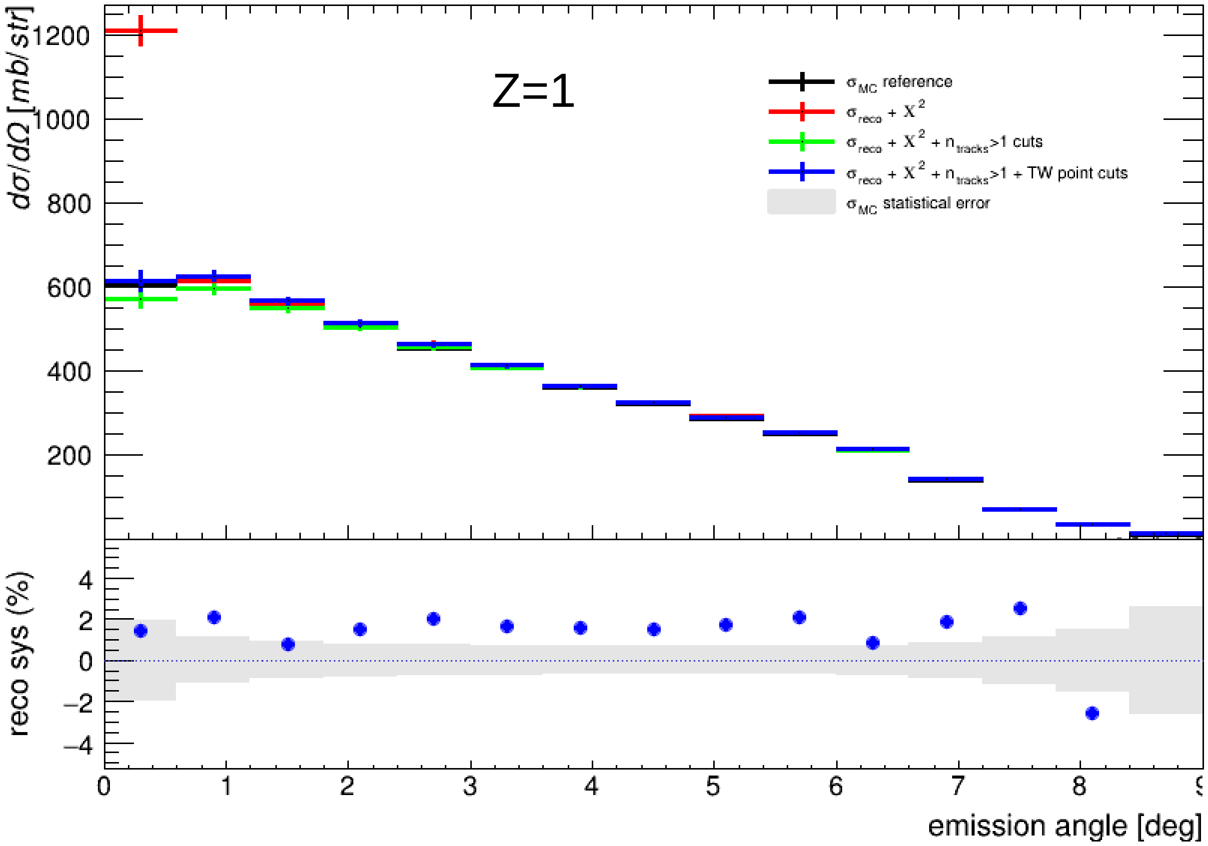


- The systematics decrease up to **5%**

Results – Angular Differential Cross Sections







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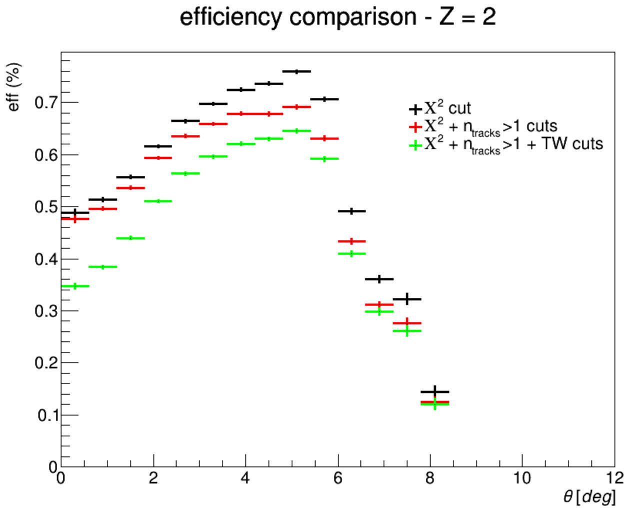
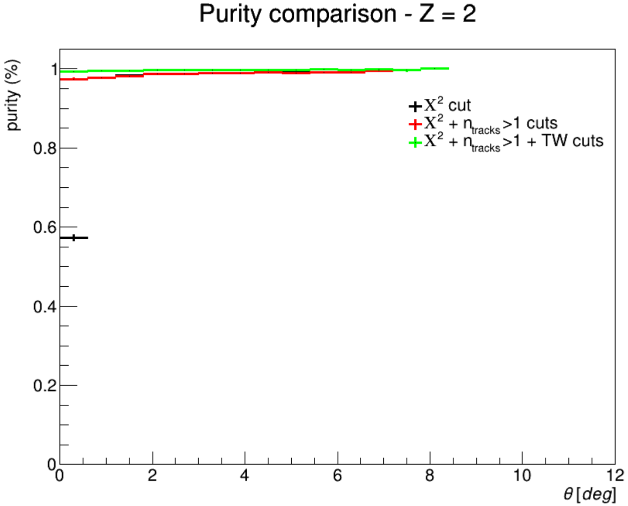
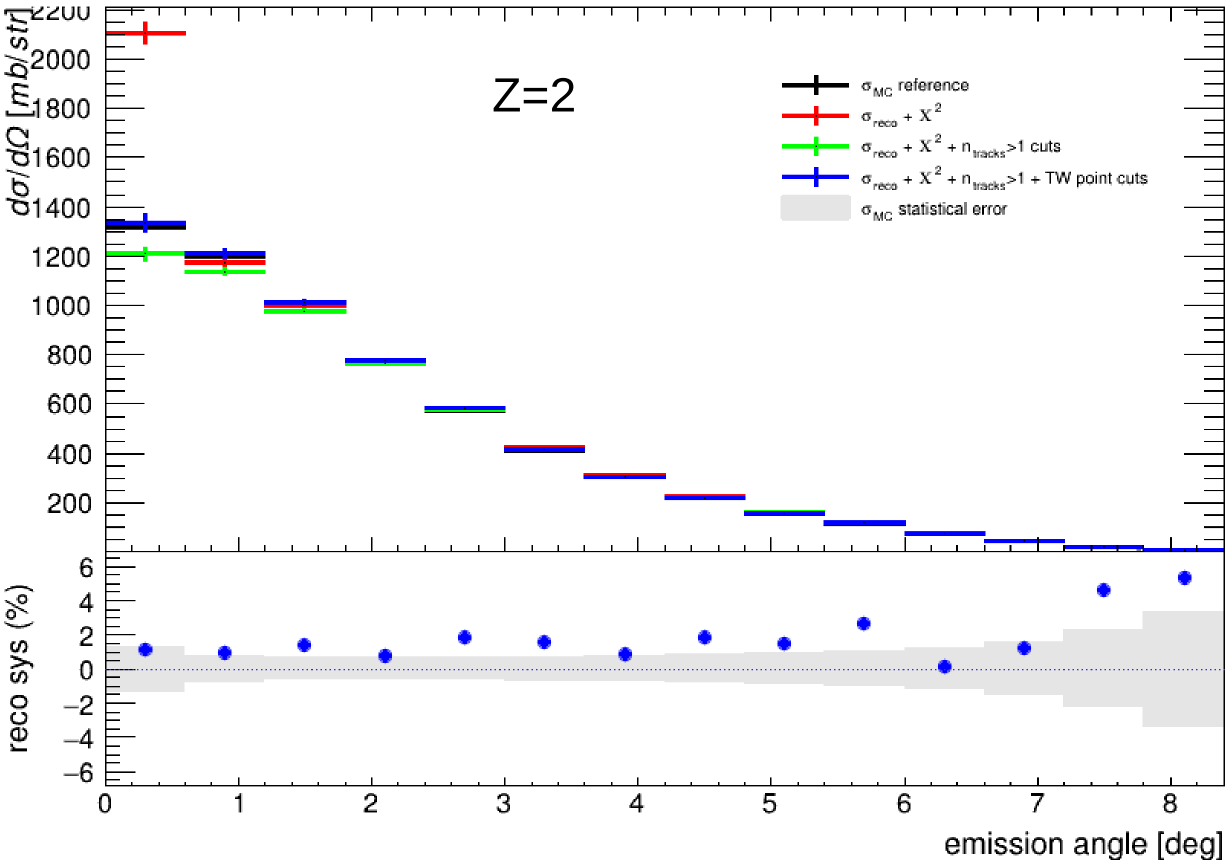
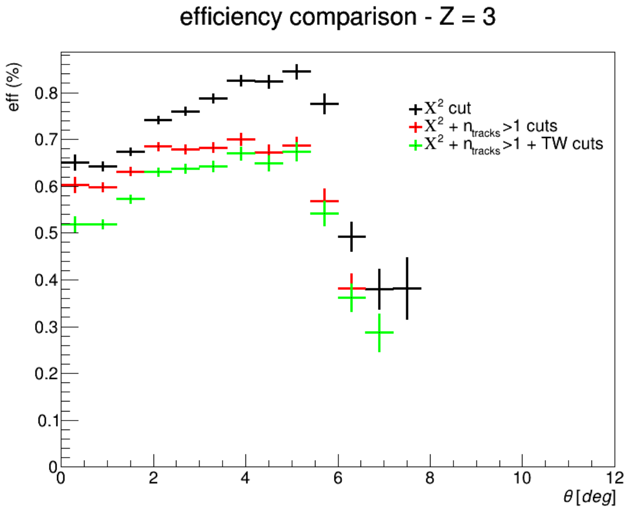
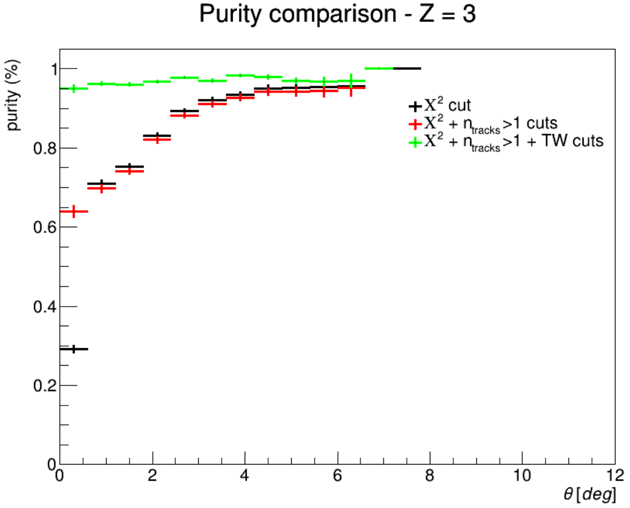


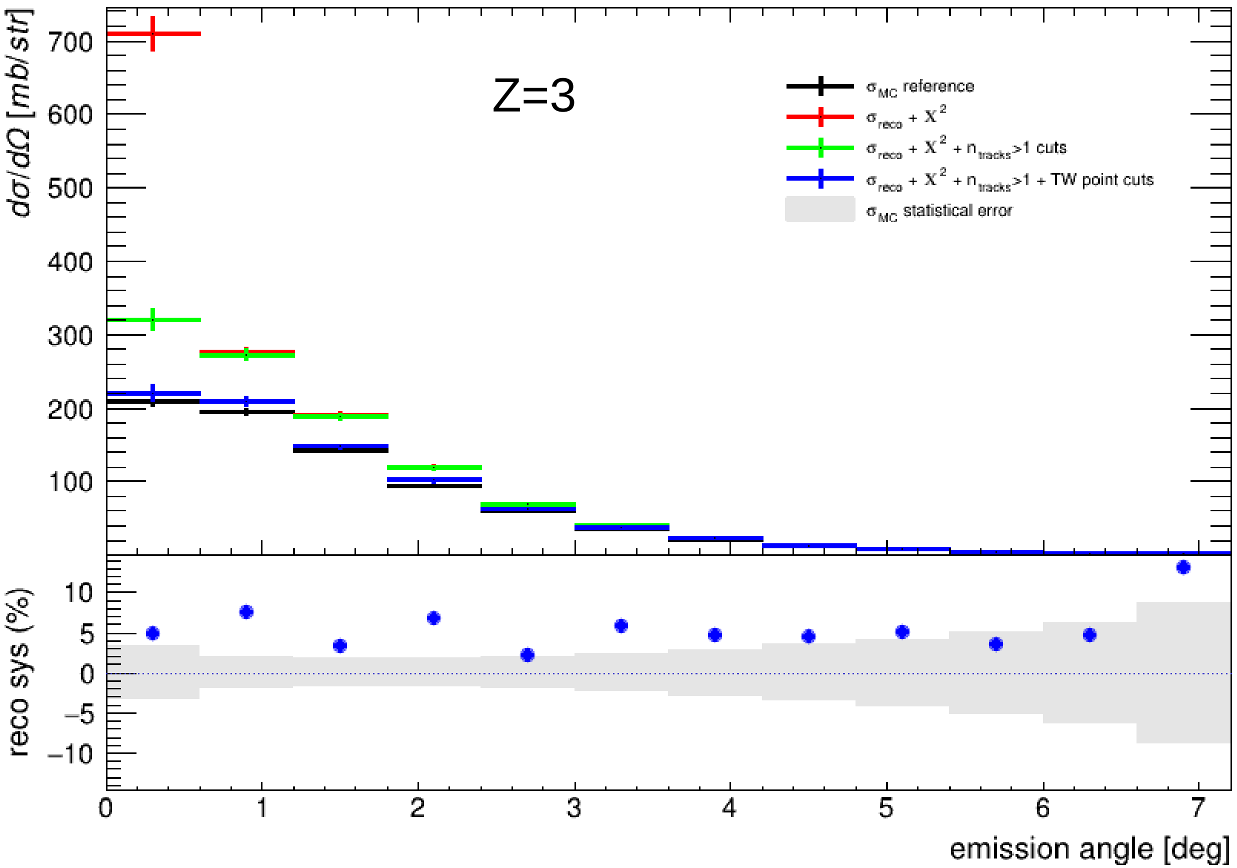




Results – Angular Differential Cross Sections







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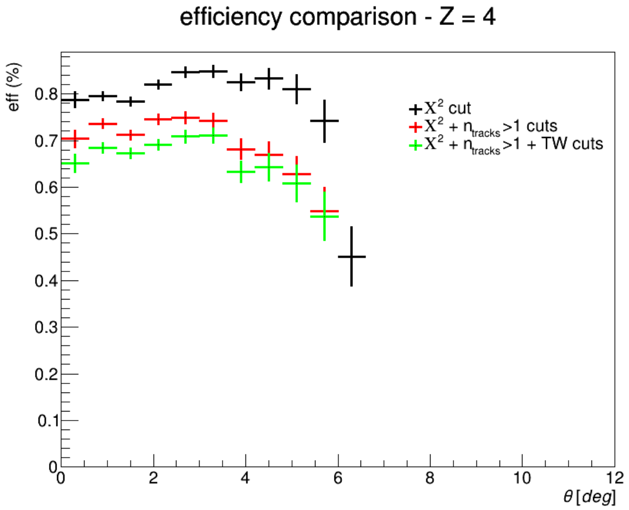

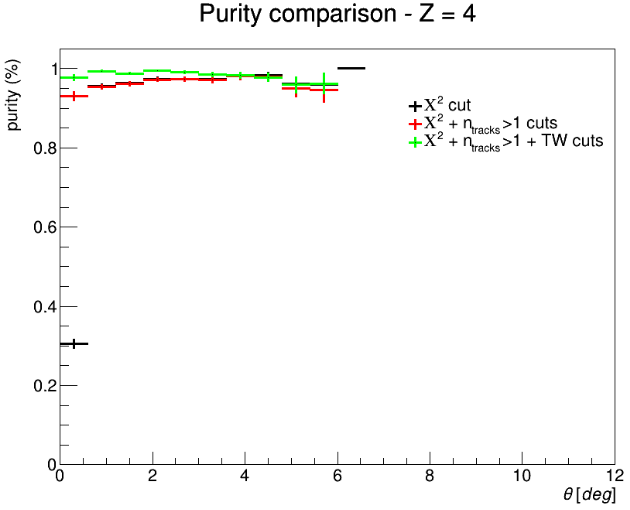

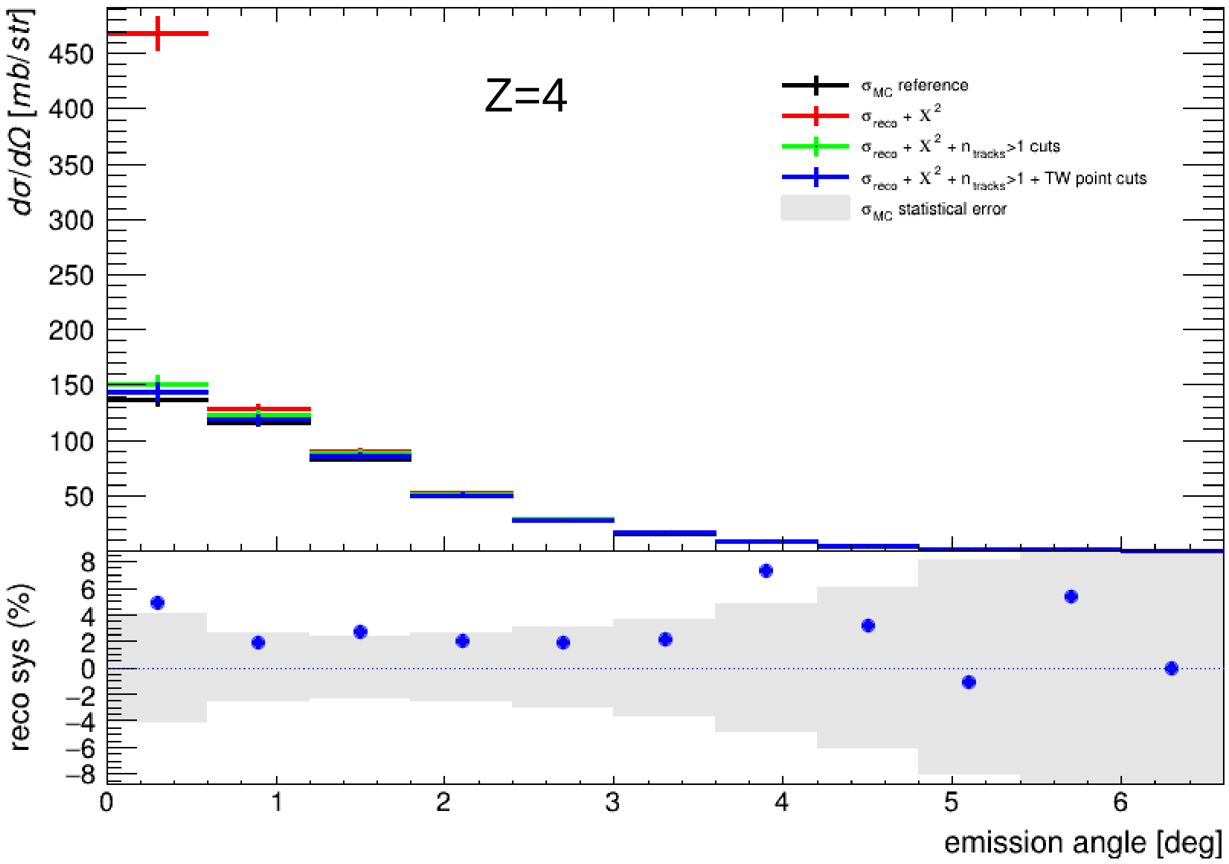

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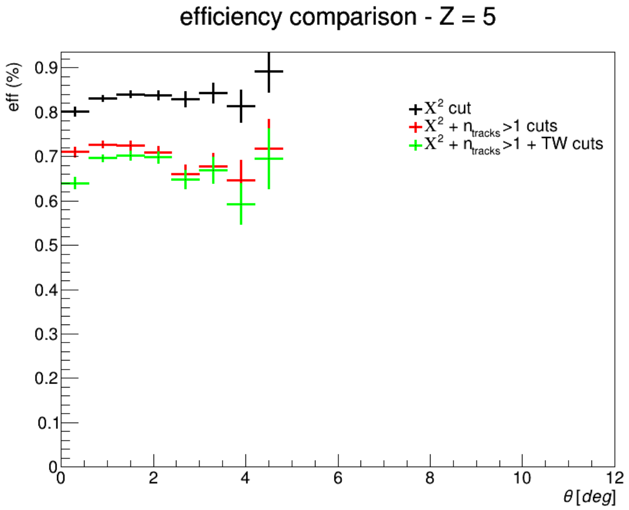

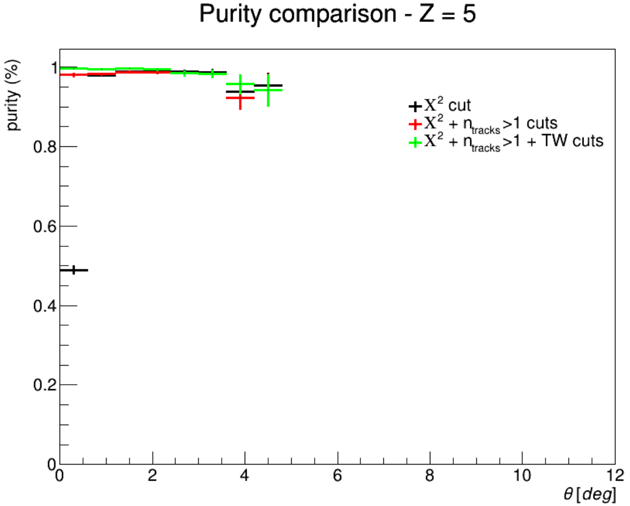

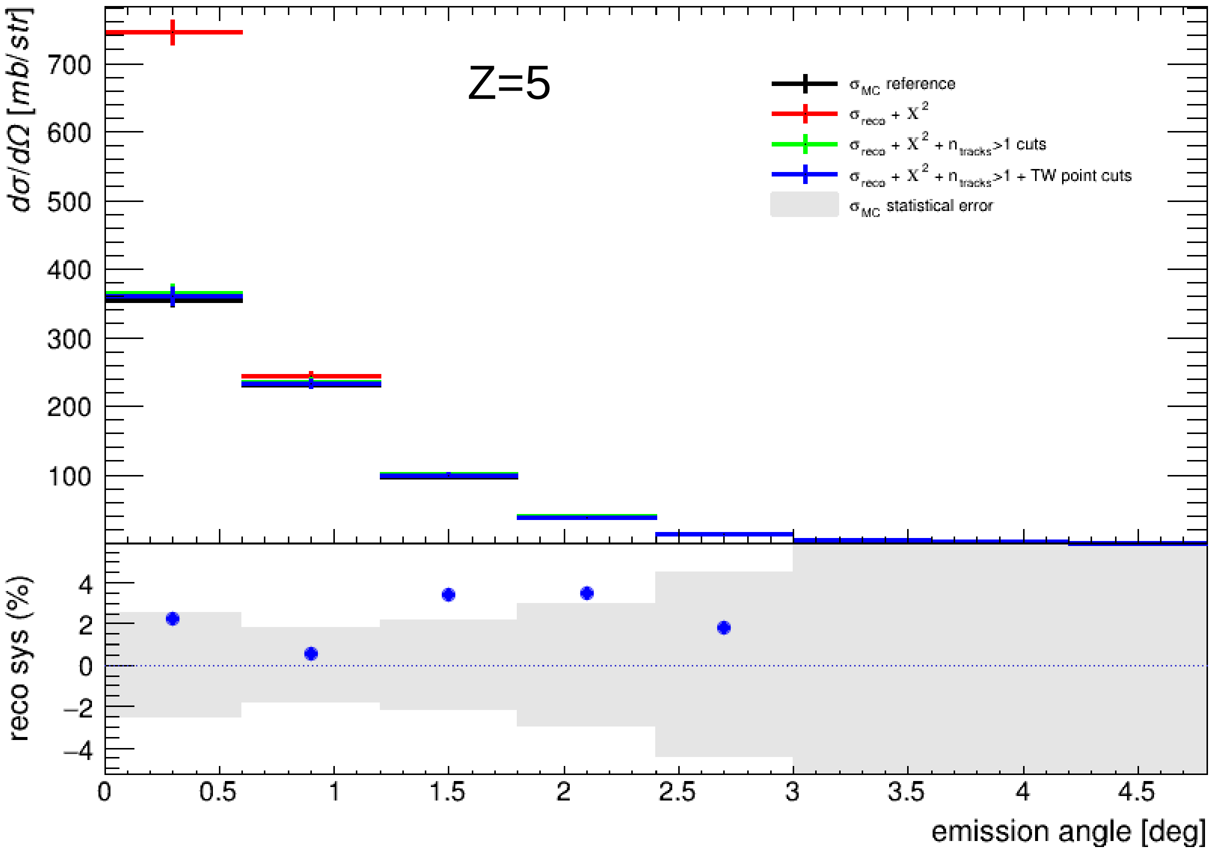

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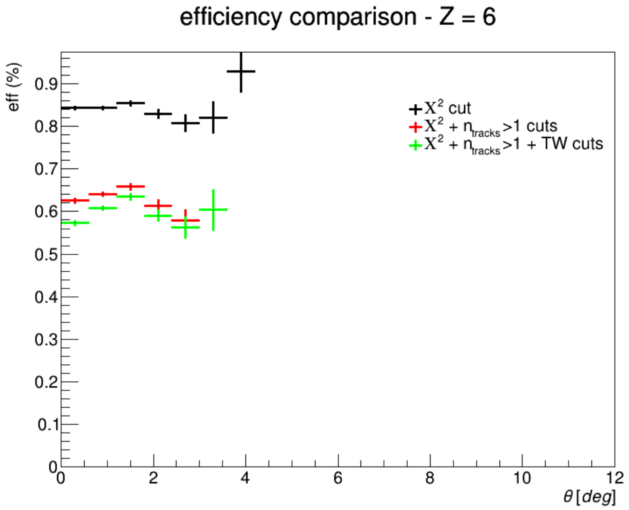

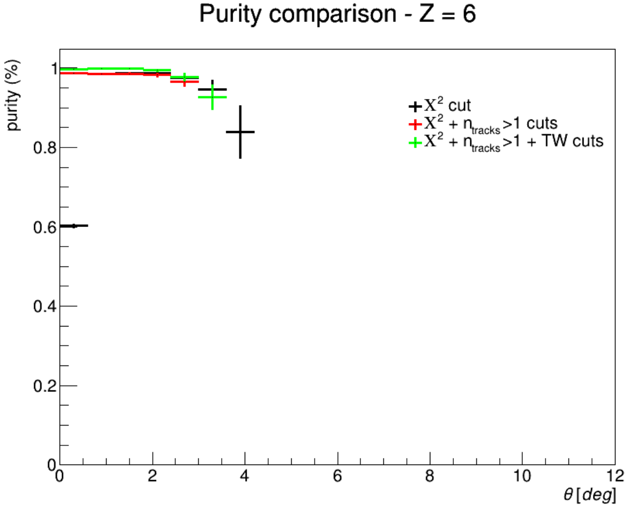

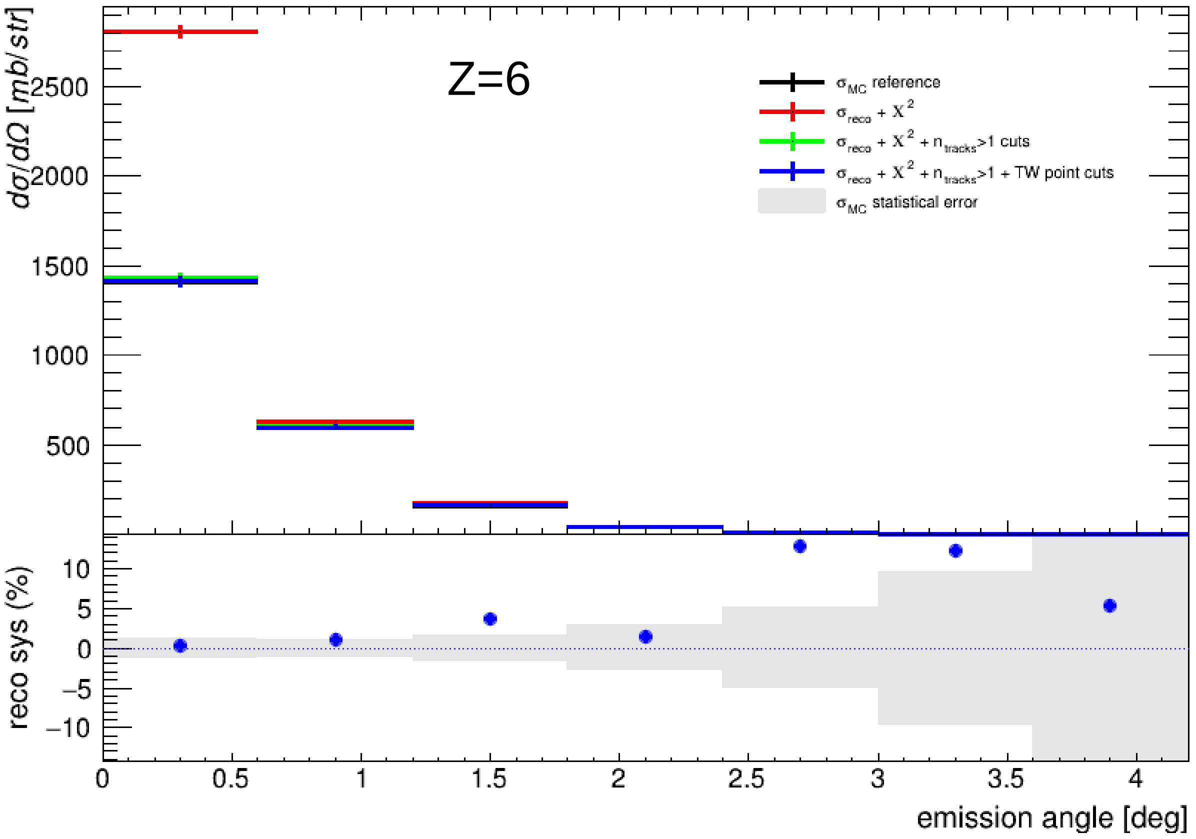

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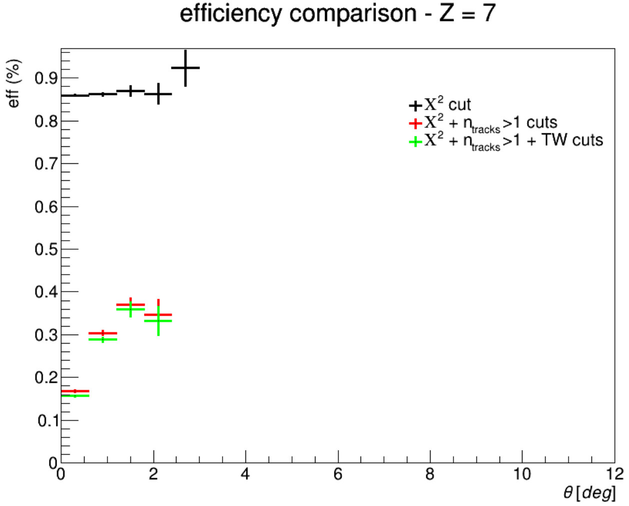
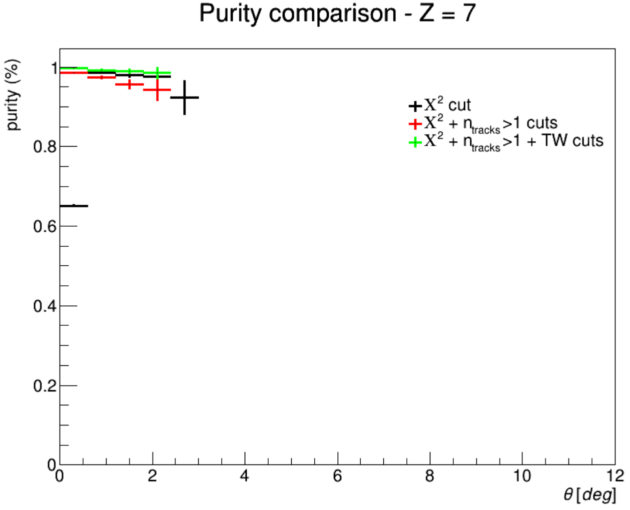
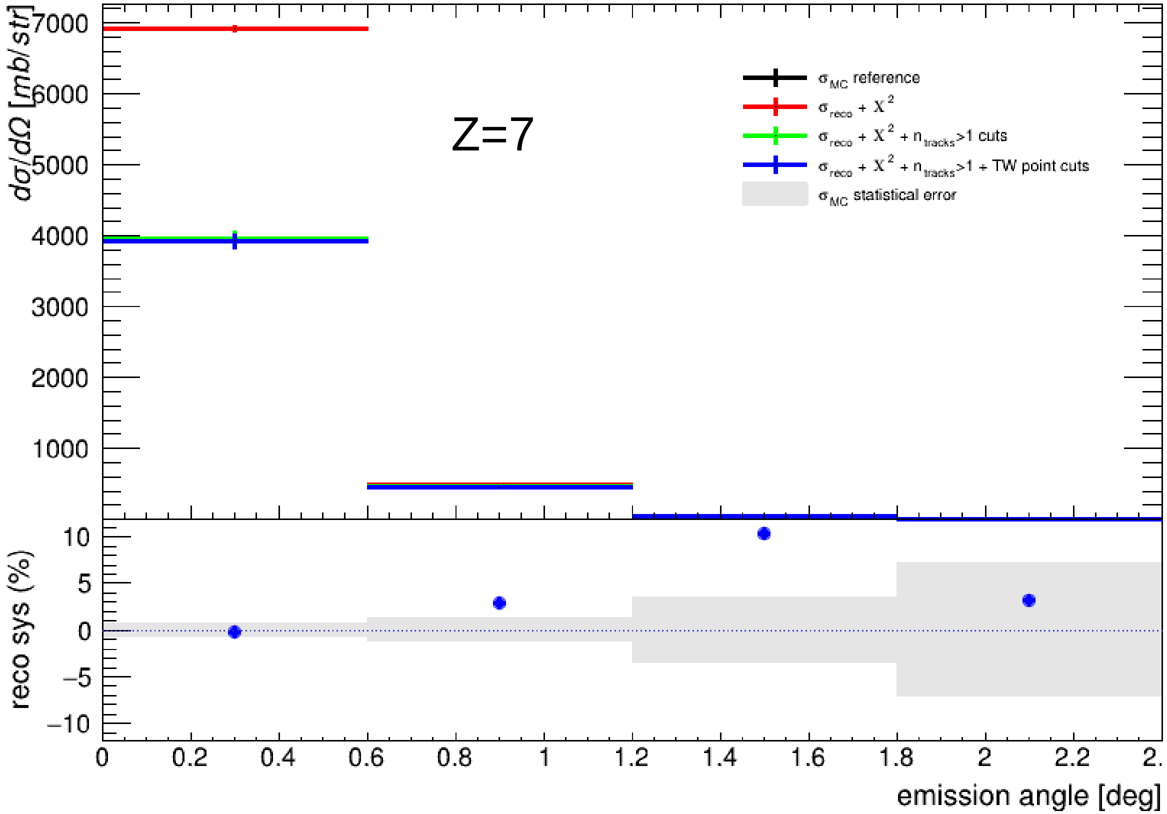
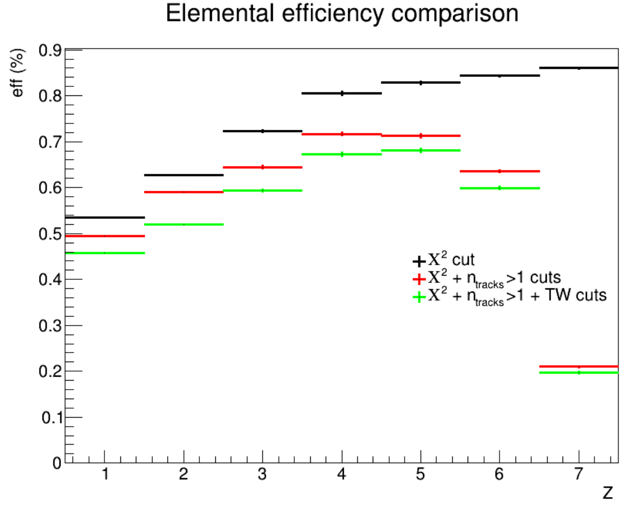
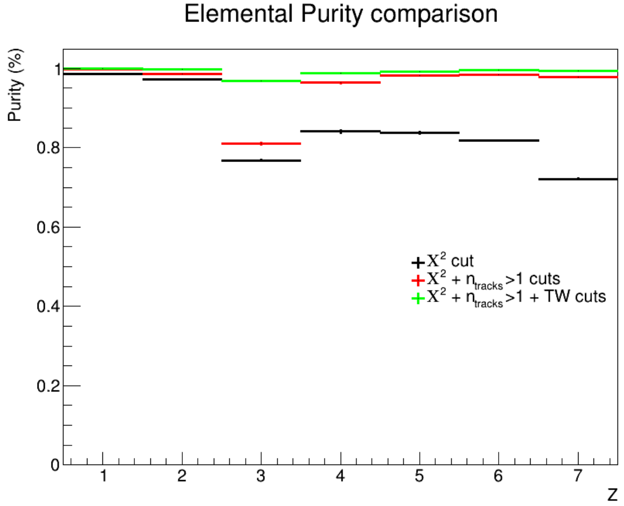


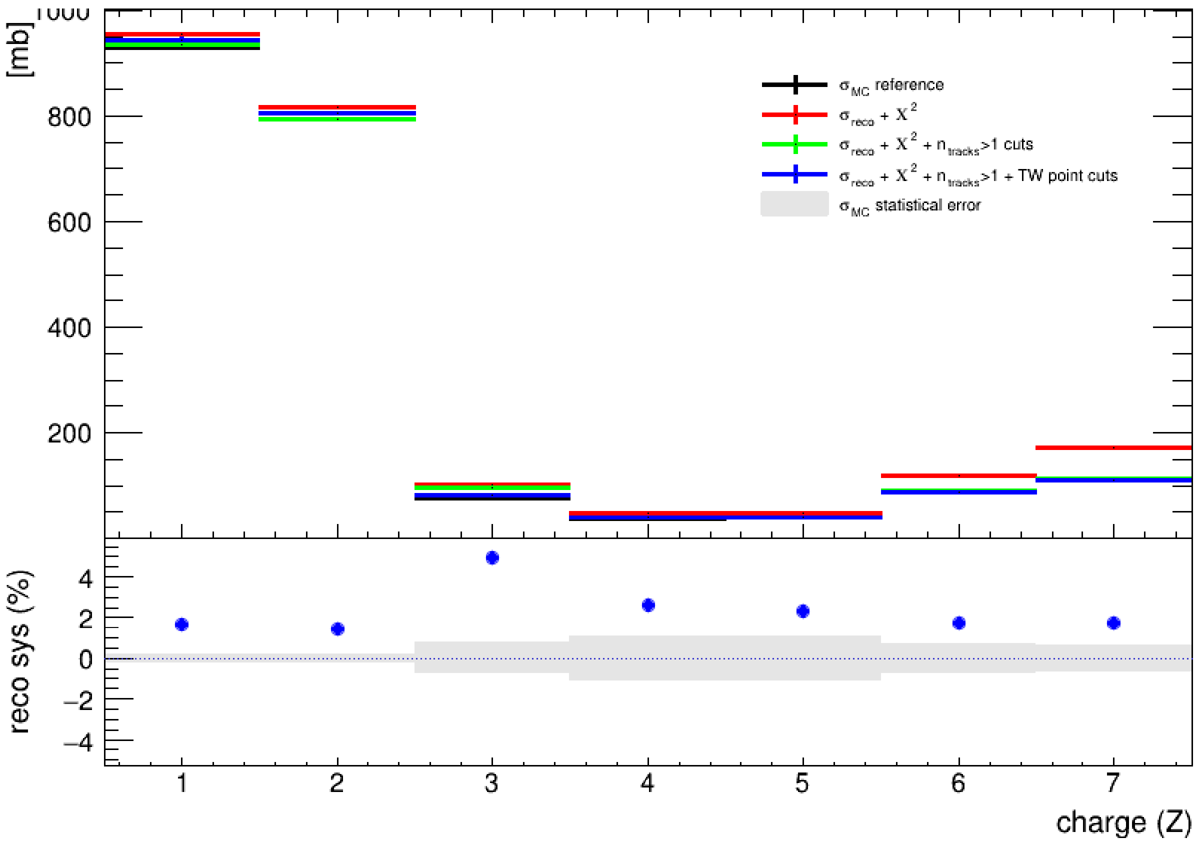




Results – Integral Elemental Cross Sections







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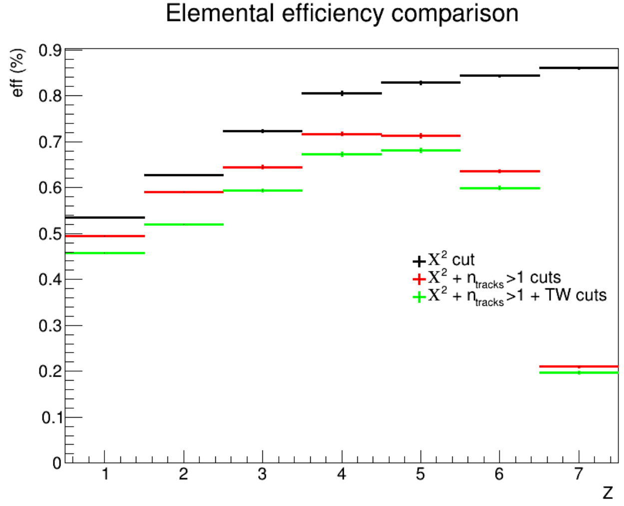
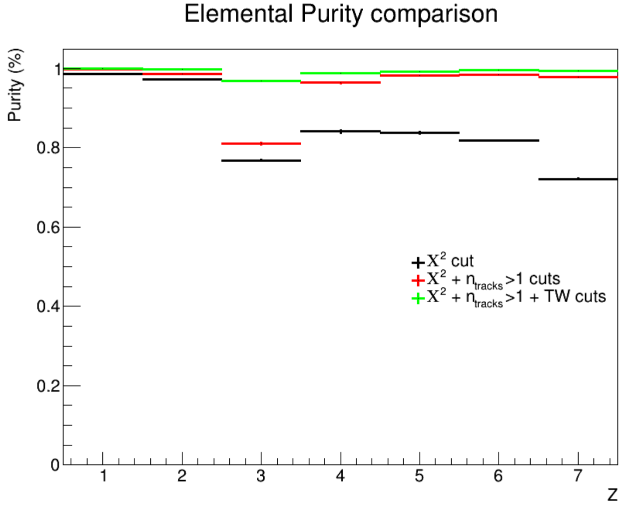
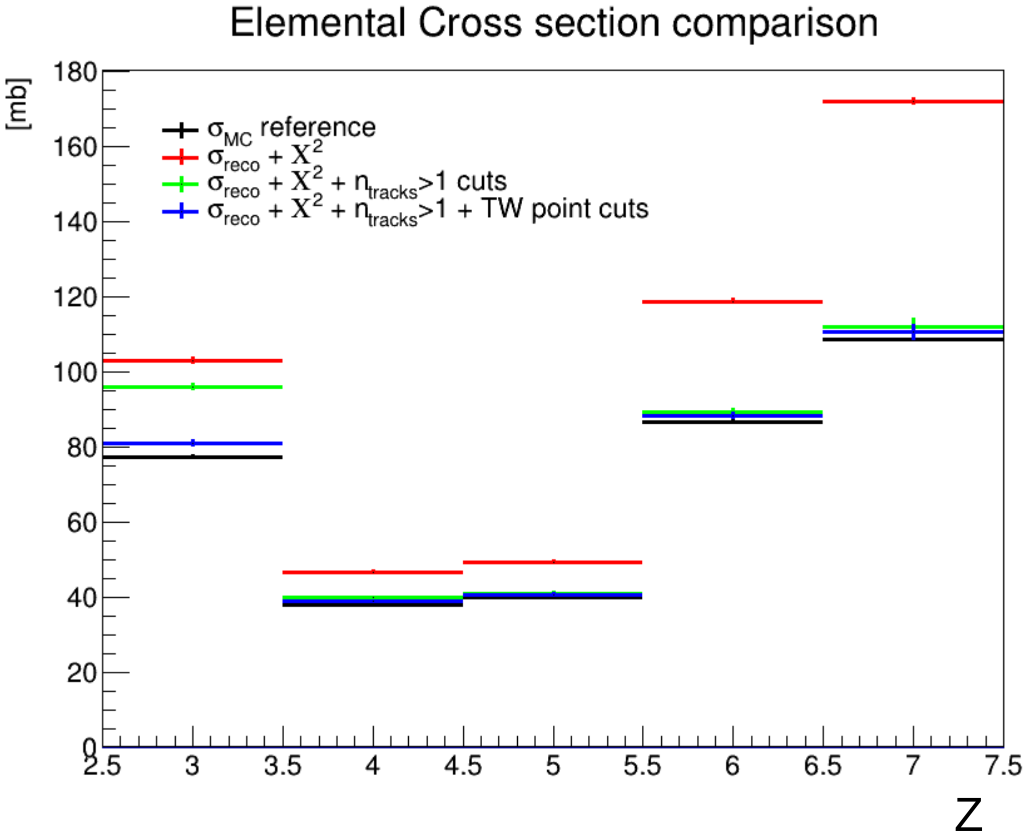






Conclusions

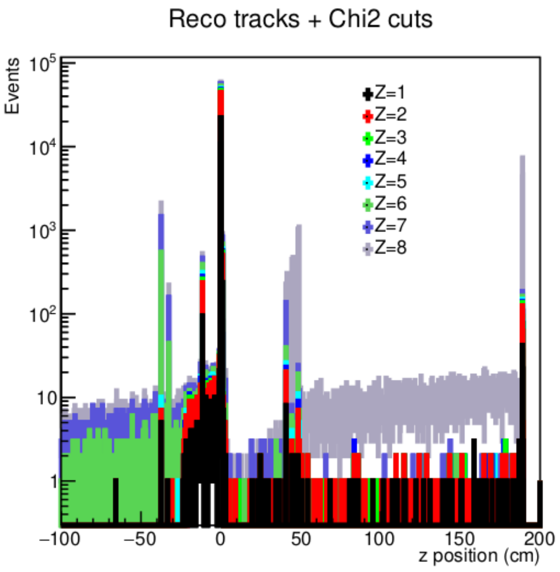
- Applying **Quality Cut**, **Multitrack Cut** and **same TWpoint Cut a discrepancy of ~ 5 %** is achieved in a **MC closure test** for angular differential cross section and elemental cross section reconstruction vs the true cross section.
- Such discrepancy can be accounted as a **systematic error** in our reconstructed cross section.

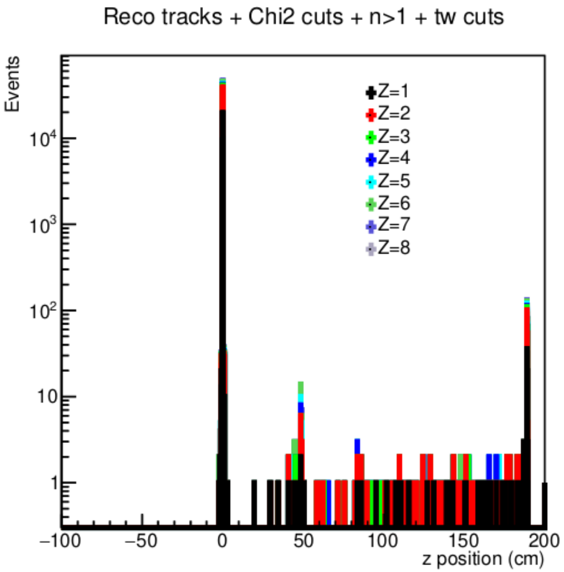
Conclusions

- Applying **Quality Cut**, **Multitrack Cut** and **same TWpoint Cut** **a discrepancy of ~ 5 %** is achieved in a **MC closure test** for angular differential cross section and elemental cross section reconstruction vs the true cross section.
- Such discrepancy can be accounted as a **systematic error** in our reconstructed cross section.

- the **background** (out of target, combinatorial and cross feed) is almost t**otally rejected** with the found selection criteria
- the **purity** of the selected track strongly **increased**

  → **no need of background subtraction technique?**





Conclusions

How to further improve our reconstructed XS and reduce systematics?

- Main criticalities to be faced for cross section measurements using Global Tracking:
  - **Fragmentation out of target** → investigate more feature of secondary fragments tracks
  - **TW instrinsic limits** → **MSD charge reconstruction** could be of help (to be checked with MC truth before implementing reconstruction)
    → $E_{kinetic}$ measured by **calorimeter** should be very different for fragments in the same TW cross!
- check how using the **Z information from other detecto**r (VTX and MSD) improve track quality and so background rejection
- Check if **angular unfolding** is needed

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What's next?

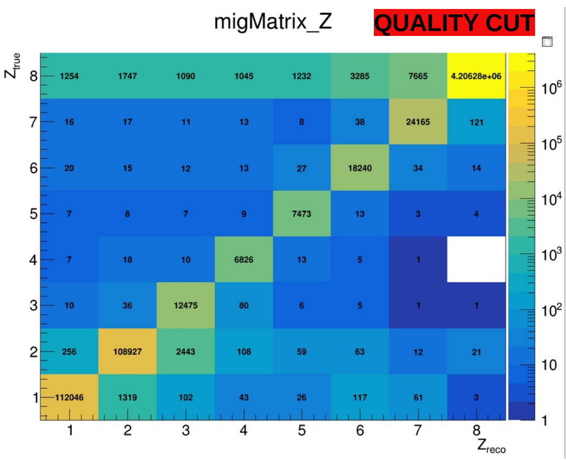
- Let's move to **real data** of GSI2021 campaign
- study thresholds and detector efficiencies in **data** for MSD and VTX and tune MC accordingly
- studying the MC reconstructed cross section as a function of **beta** bins
- Let's move to MC dataset with **full setup**
  (in preparation for CNAO2023...)

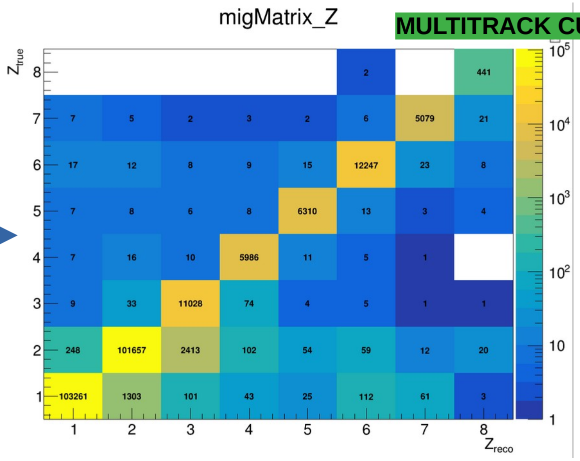
Conclusions

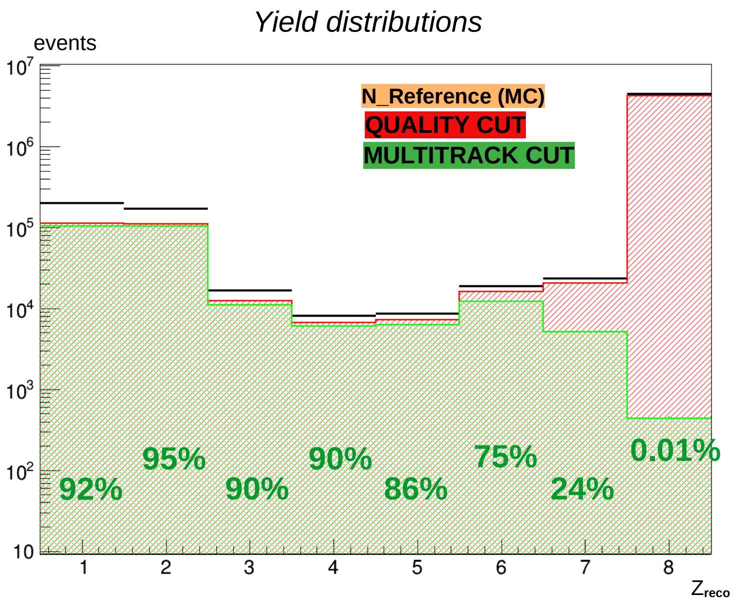
Thanks for the attention!

Back-up slides

Multitrack cut – observations



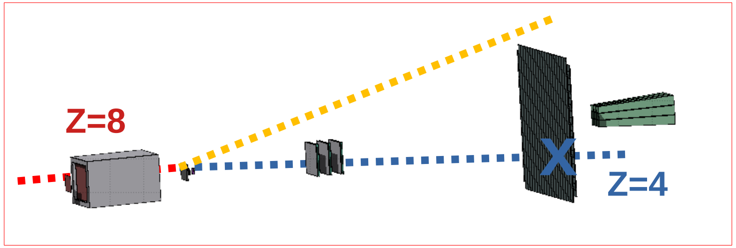




As expected:

- the $\mathbf{Z_{true} = 8}$ row has been removed
- the highest amount of cut yields are from Z=8 and bad Z_{reco}
- N.B.: this cut introduces a bias in events where there is
- fragmentation in target but only one fragment is revealed.

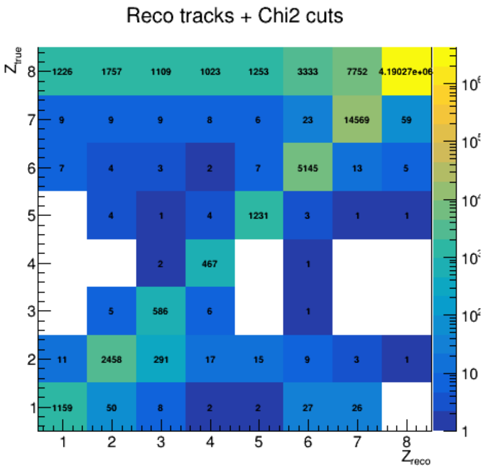
Bias on good event which is cut:

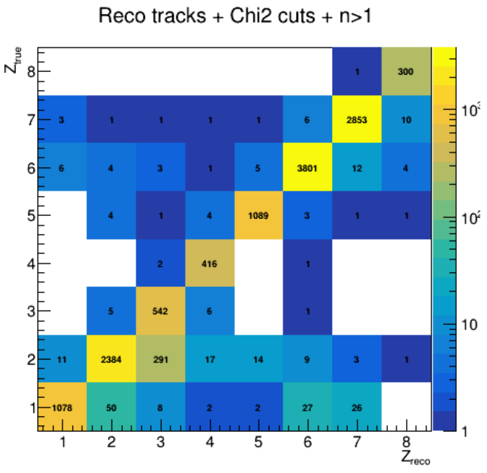


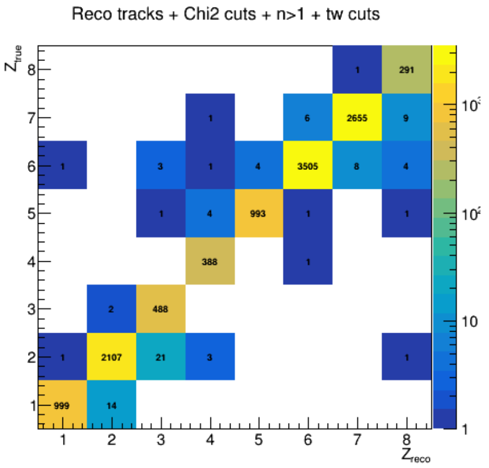
However, it is still taken into account when computing the efficiency, since:

$$\varepsilon = \frac{\text{N\_Multitrack Good Reco}}{\text{N\_Reference (MC)}}$$

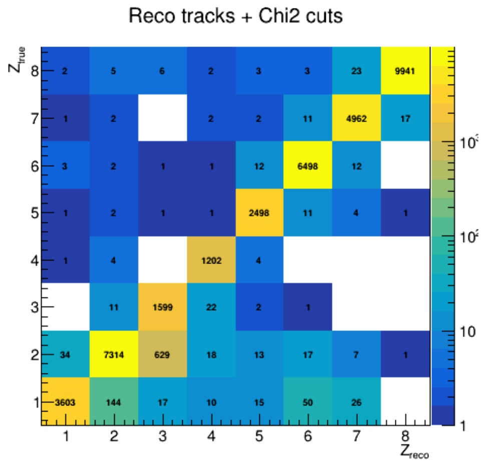
CMM wrt angular emission

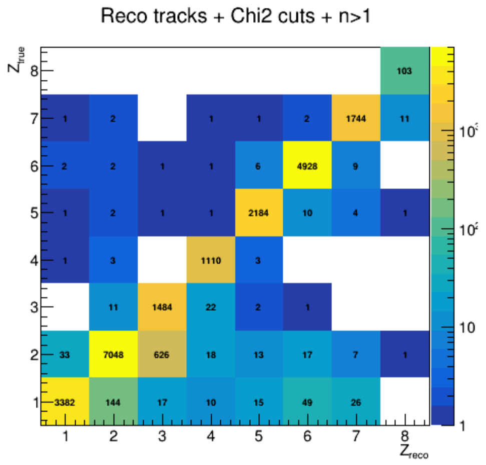


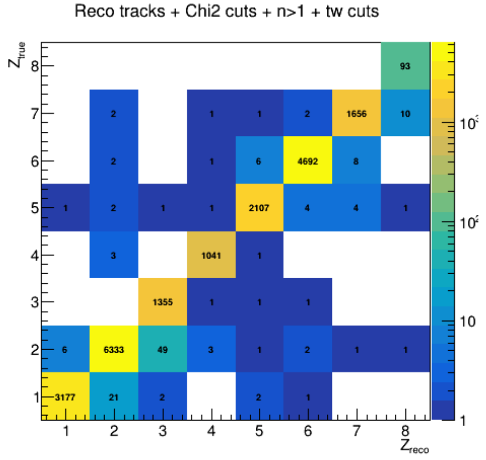




migMatrix_Z with theta < 0.600000

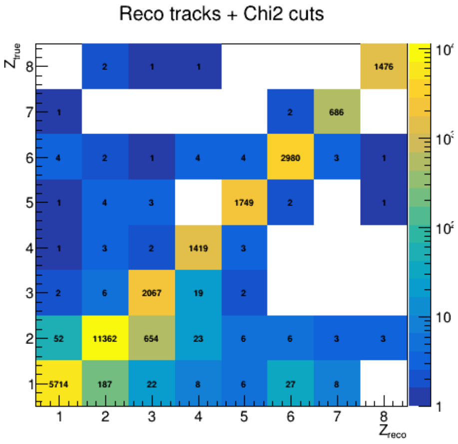


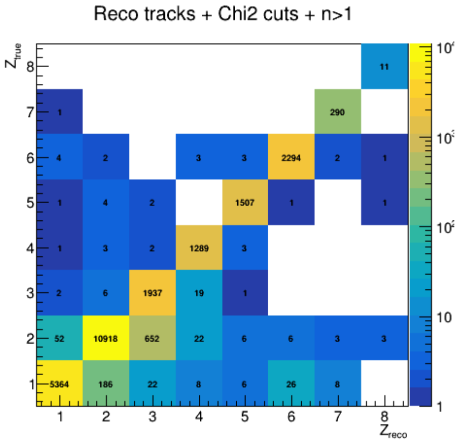


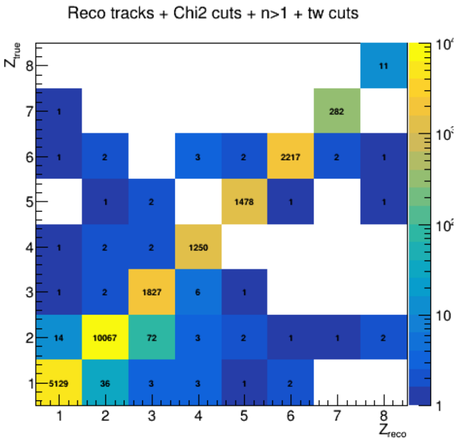


migMatrix_Z with theta < 1.200000

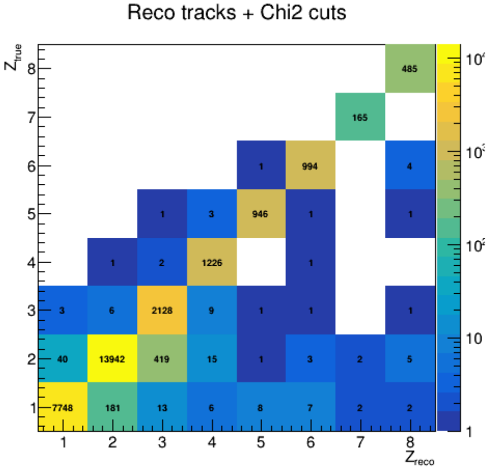
CMM wrt angular emission

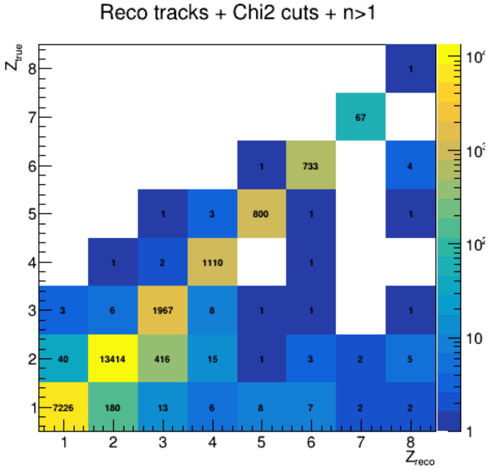


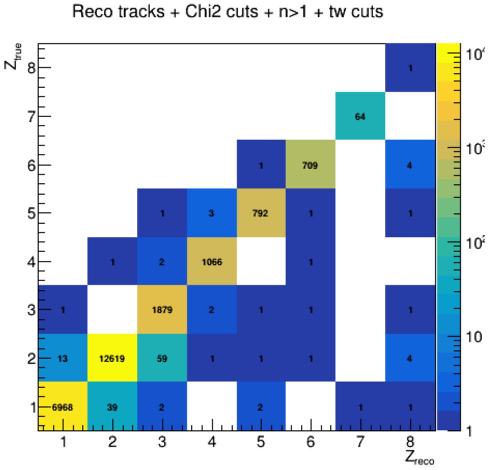




migMatrix_Z with theta < 1.800000



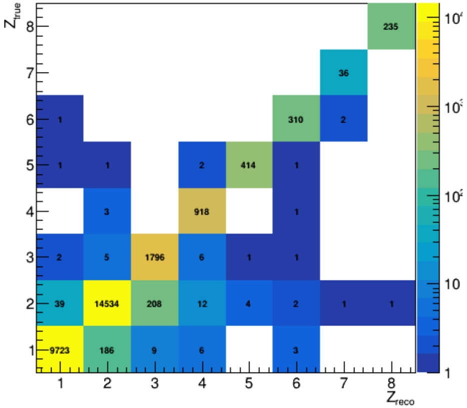




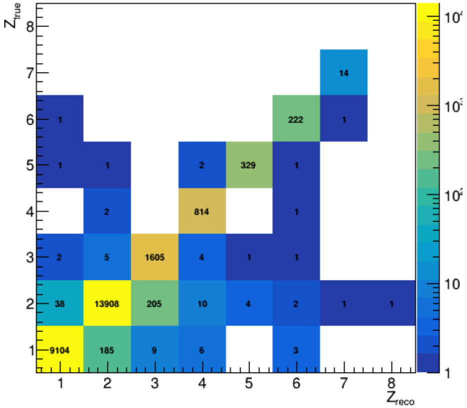
migMatrix_Z with theta < 2.400000

CMM wrt angular emission

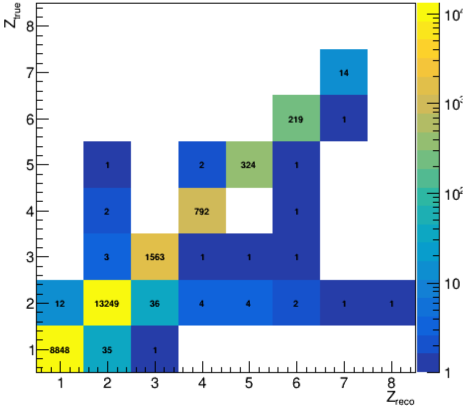
Reco tracks + Chi2 cuts



Reco tracks + Chi2 cuts + n>1

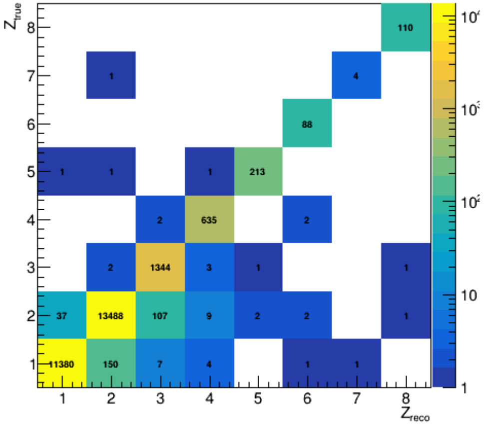


Reco tracks + Chi2 cuts + n>1 + tw cuts

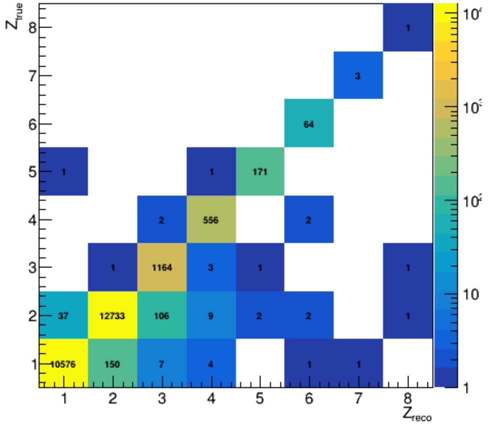


migMatrix_Z with theta < 3.000000

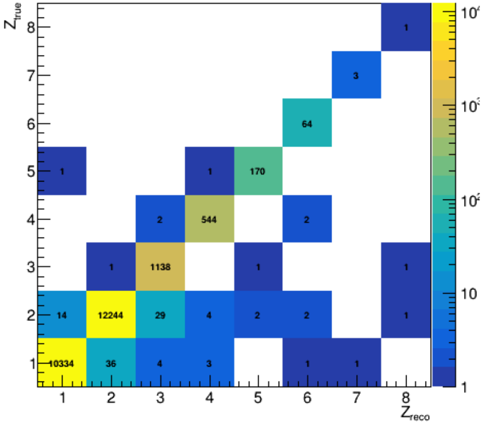
Reco tracks + Chi2 cuts



Reco tracks + Chi2 cuts + n>1

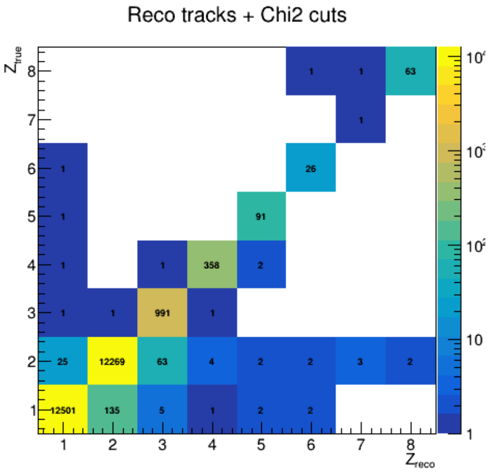


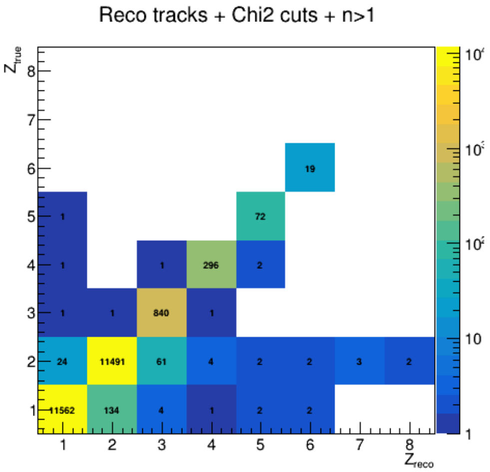
Reco tracks + Chi2 cuts + n>1 + tw cuts

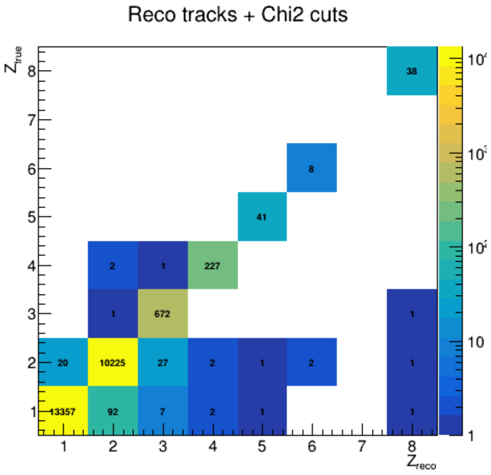


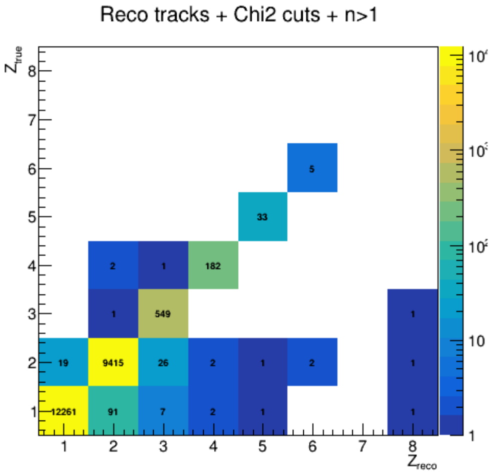
migMatrix_Z with theta < 3.600000

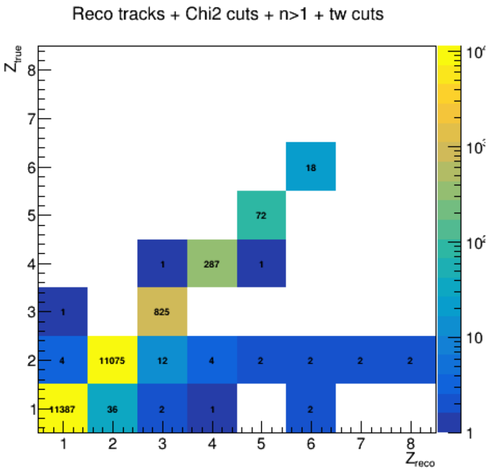
CMM wrt angular emission



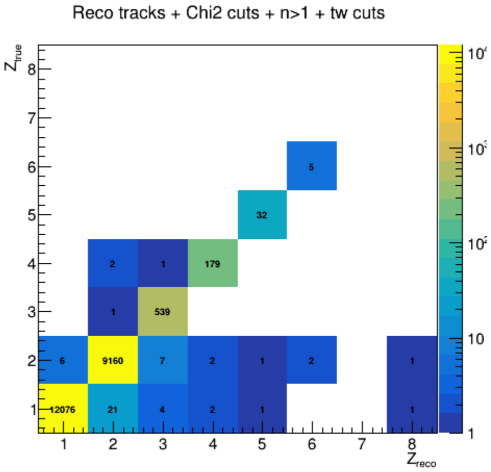






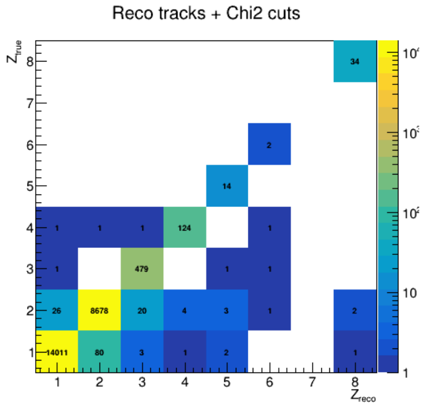


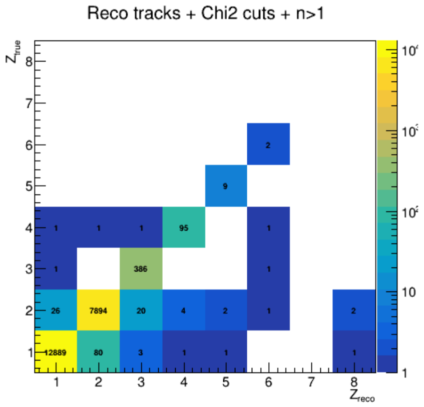
migMatrix_Z with theta < 4.200000

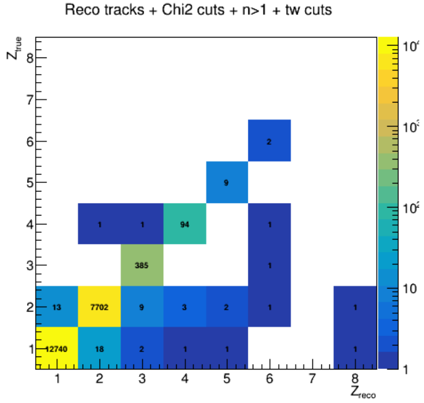


migMatrix_Z with theta < 4.800000

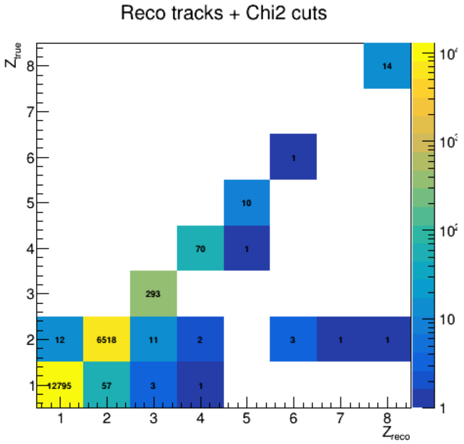
CMM wrt angular emission

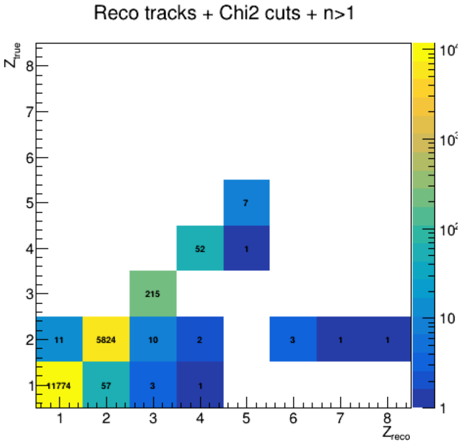


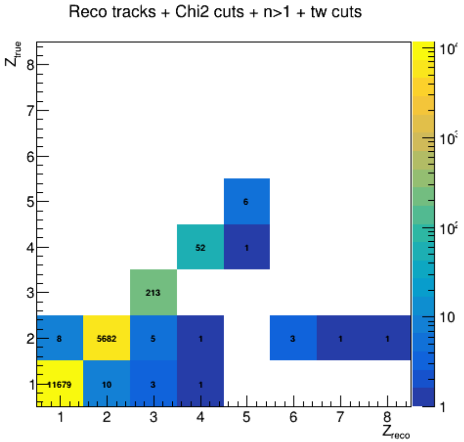




migMatrix_Z with theta < 5.400000

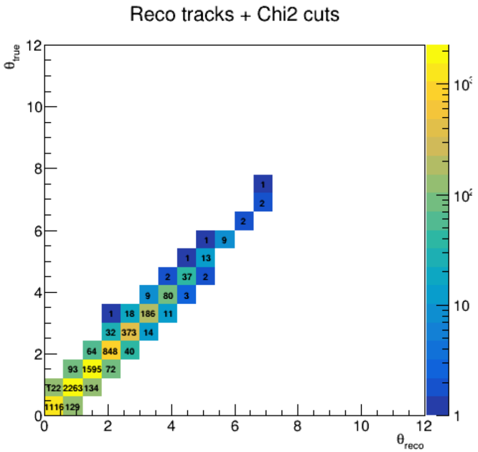


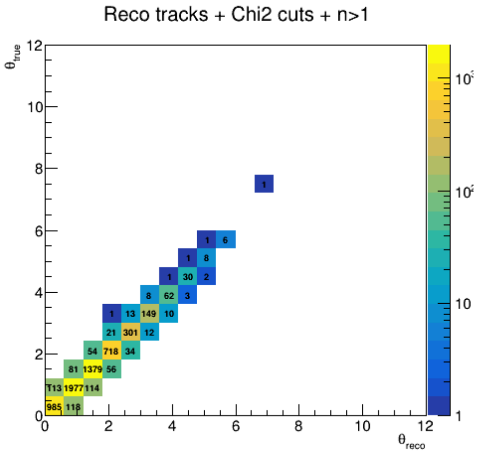


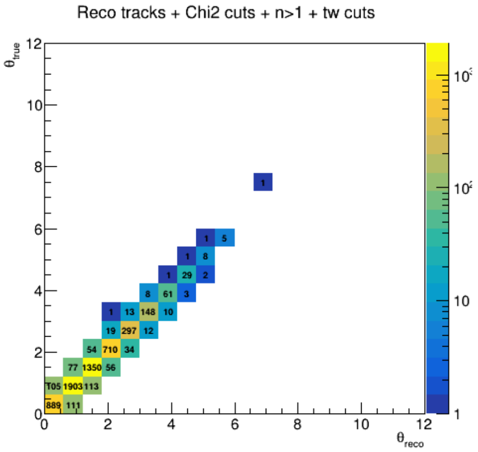


migMatrix_Z with theta < 6.000000

Angular MM







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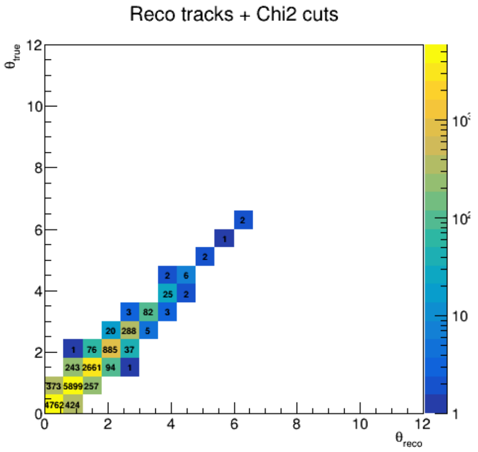

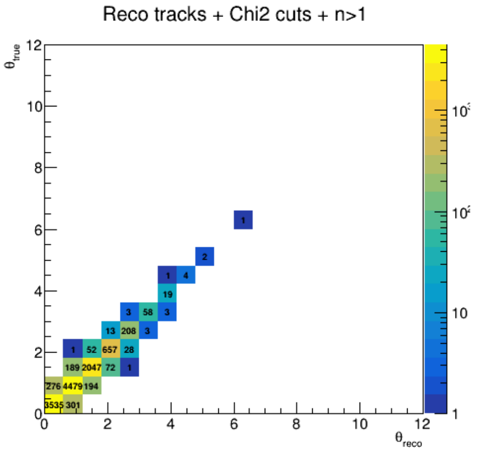

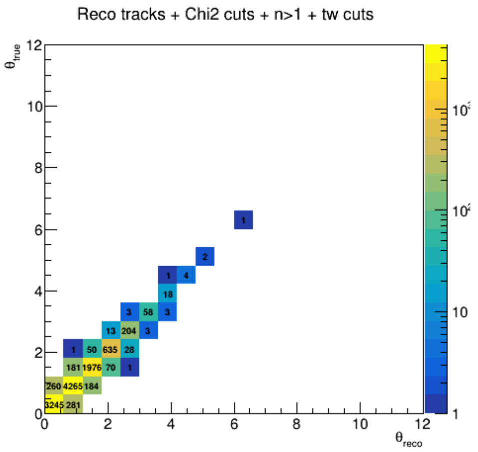

migMatrix_theta_Z=6