Analysis status and strategy

XIV FOOT collaboration meeting
06/06/2023

Marco Toppi

Data available and analysis tasks

- **GSI2021 data**: ^{16}O+C,C_2H_4 → physics runs with VTX-MSD (most of the 400 MeV/u data), runs without VTX (most of the 200 MeV/u data), essentially no calo-> elemental fragmentation cross section in theta/beta bins
- **Emulsions:** ^{16}O + C, C_2H_4 @ 200 and 400 MeV/u
- **HIT2022 data**: ^{4}He (@ 100, 140, 200, 220 MeV/u) and p beams → good for calorimeter and MSD. Mass spectra with TW/calo calibration. Cross section for ^{3}He production and p, d and t.
- **CNAO2022 data**: C + C @ 200 MeV/u and p beams → if calo calibrated mass identification and corresponding cross sections. Need to wait for calib/config files from detector groups
- **Full / partial setup MC analysis**

Work in progress for the Analysis

- **Analysis working group:**
  - Many people involved (regular weekly meetings every Wednesday morning at 9.30, everyone is invited to join)
  - First milestone: to have as soon as possible a full reconstruction "under control" able to produce cross sections and verify them with a MC closure test.
  - At this moment FOOT doesn’t know what is the precision it can reach in measuring MC cross section (and for data will be worse
  - Ongoing analysis for GSI2021 data→ talks of Riccardo and Giacomo (Ubaldi)
- **TW working group:**
  - Matteo/Esther -> studying thresholds and resolutions for GSI 2021 campaign -> talk today
  - Aafke -> taking care of TW calibration @ CNAO2022 -> talk today
  - Tino/Miriam -> taking care of TW calibration @ HIT2022 -> talk today
  - RobZ-> Already provided positions calibrations for all campaigns -> talk today
  - me -> taking care of TW reco in shoe and fix/update in order to have performance plots ok for every campaign

Work in progress for the Analysis

- **CALO working group:**
  - CALO guys provided calibration @ CNAO and HIT 2022 -> talk today
  - Alessandro/Francesca/Tino candidate for TW-calo match for HIT2022 to produce mass distributions (following calo and TW calib)
- **MSD working group:**
  - Matteo/new master student-> new clustering + eta function @ HIT2022
  - Leonello/Benedetto -> MSD efficiencies with protons @ Trento
  - Gianluigi/Lucia -> working on pedestals @ HIT2022 → talk today
  - Tino -> efficiencies @ HIT2022
- **MC group:**
  - Giuseppe and Silvia produced all the MC campaigns relative to data taking and full setup

Work in progress for the Analysis

- **BM:**
  - Yun is working on improvement of BM tracking algorithm -> talk today
- **SC:**
  - Giacomo already made everything working :)
- **VTX:**
  - Giacomo Ubaldi with Chris supervision is taking care of studying VTX algorithm performances –> talk today
- **Glb tracking:**
  - Rob, Giacomo Ubaldi and Matteo studying performances of Glb tracking and methods to reject bkg -> talk today

Work in progress for the Analysis

- **Emulsions:**
  - Momentum evaluation -> Giovanni's talk
  - GSI 2019 Cross section measurement -> Giuliana' talk

- **On June 23 meeting with the FOOT referees. Milestones:**
  - GSI2021 analysis (+ a possible publication date)
  - Emulsion analysis
  - Something of HIT2022 (it could be mass distributions and calo calibration)

Strategy

- In order to have a ready machinery for XS we need to have under control for each detector and for global tracking (and for each campaign):
  - Study the performaces of local (each detector) and global reconstruction
  - Efficiency, purity and resolutions for local and global reconstructed quantities
  - Comparison of the same quanties with data
  - Introduce systematics for local and global reconstructed quantities (sys on the geometry due to uncertanties in detector position, on tracking, clustering, ZID and mass identification, and so on…)
  - Background rejection through global reconstruction (efficiency and systematics) vs background subtraction→ (how many physics and background events)
  - Combinatorial background
  - In most of the cases such things have to be done in bin in which we want to perform the measurement (theta, beta, ekin) so this means also take under control migration between bins --> implement an unfolding procedure

Strategy

- In order to have a ready machinery for XS we need to have under control for each detector and for global tracking (and for each campaign):
  - Study the performaces of local (each detector) and global reconstruction
  - Efficiency, purity and resolutions for local and global reconstructed quantities

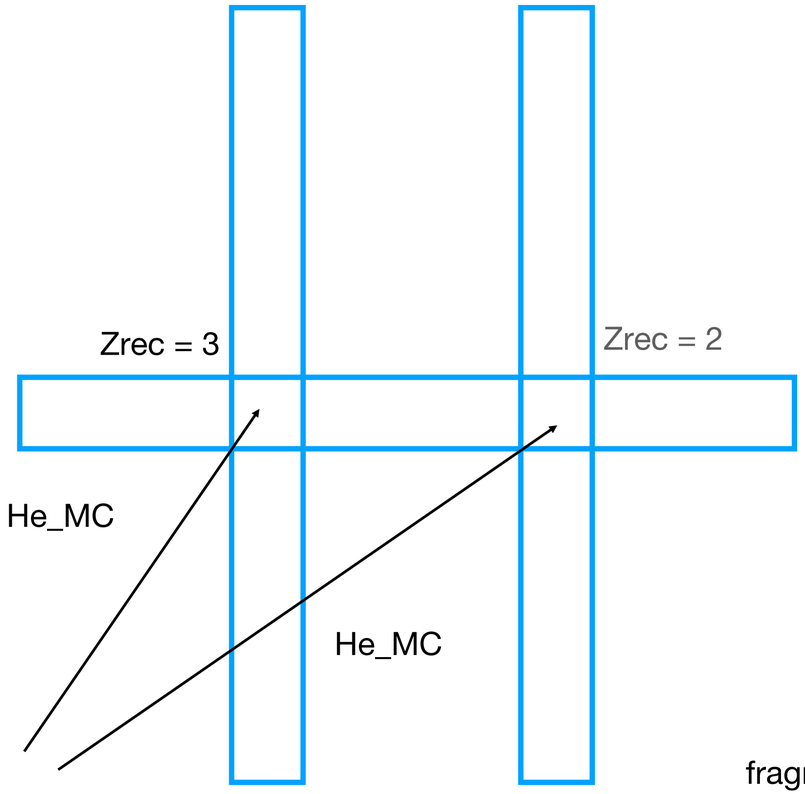
Be carefull:

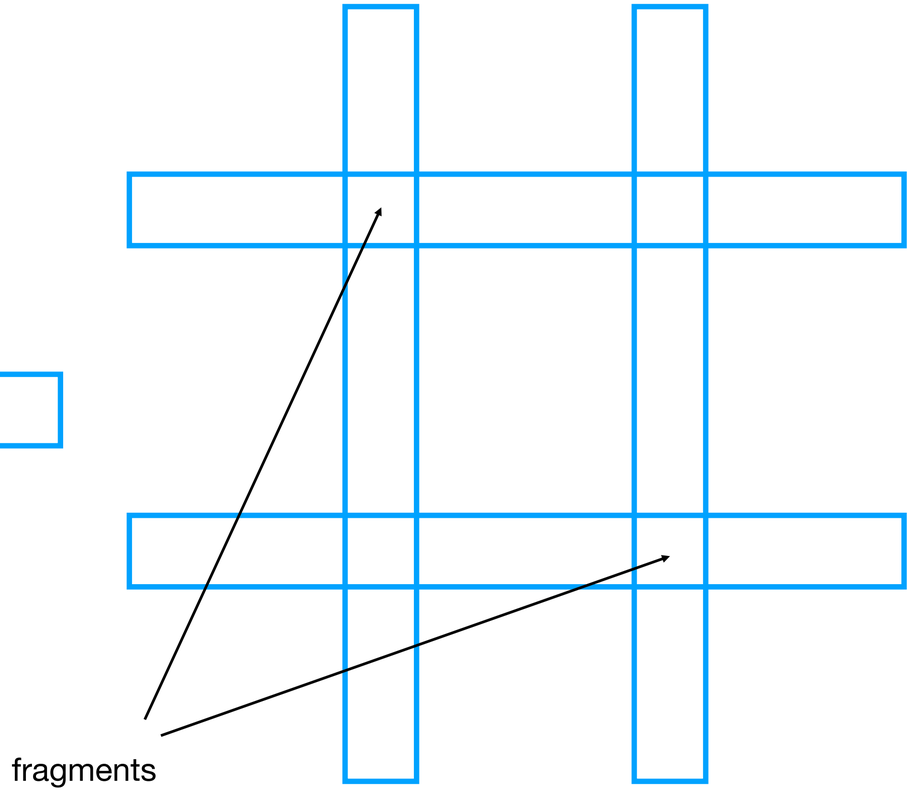
- **Starting to do MC reco/true comparison, MC/data comparison and introducing systematics there is the risk to enter in infinite loops to have the best agreement**
- **This should be avoided keeping in mind what are the goal precision, let's keep small effects (small means < of our stat uncertainty) out or put them at the end of the list.**
- **Let's concentrate our effort on the bigger one first :)**
- **Somehow systematics will drive the needed statistics during data taking and vice versa statistics will set a limit to the study of our systematics**

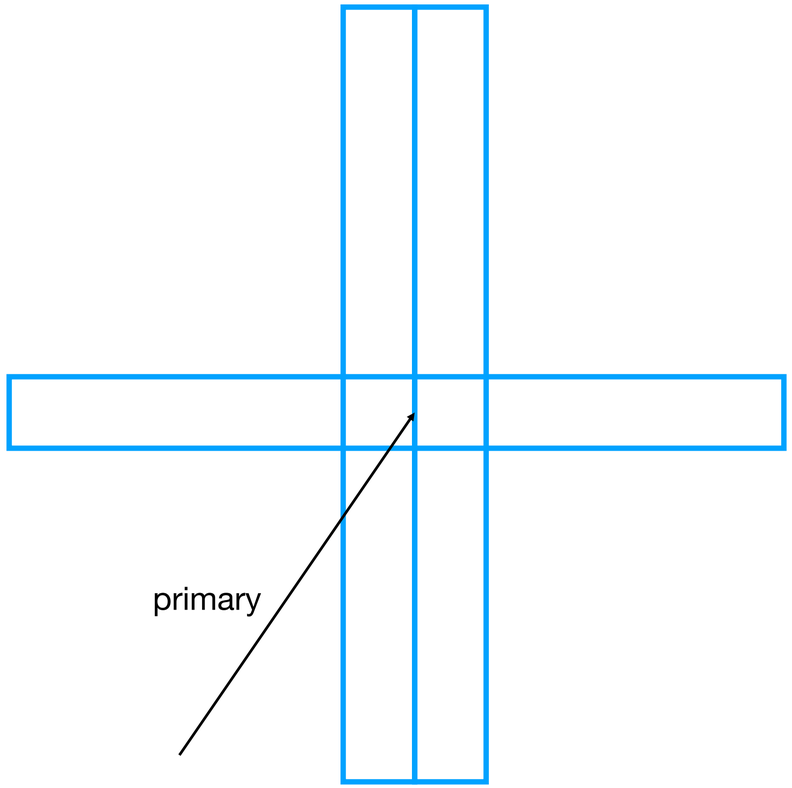
Motivation for TW

- Check the TW reco, optimized for GSI2019, for all the campaigns (resolutions in Eloss and Tof, ZID algorithm, positions and hit matching for a point)
- Open points from people working with it (giuseppe, yun, roberto, matteo, riccardo):
- Charge Mixing Matrix
- Reconstruction efficiency low
- TW Z match
- Error on the assigned Z
- Unfolding of the Z from the CMM

TW reco and TW Z match

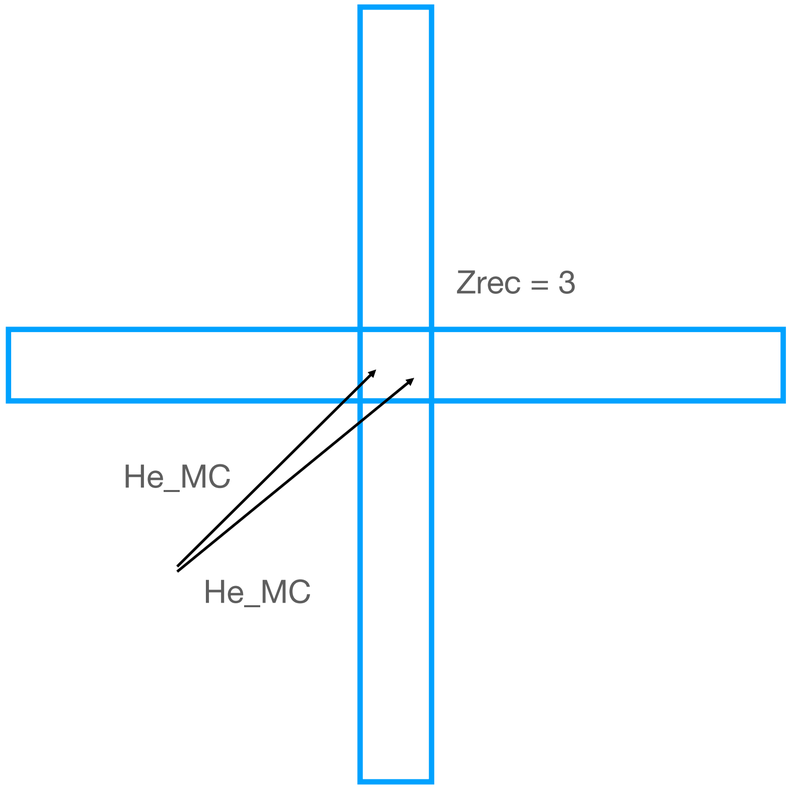


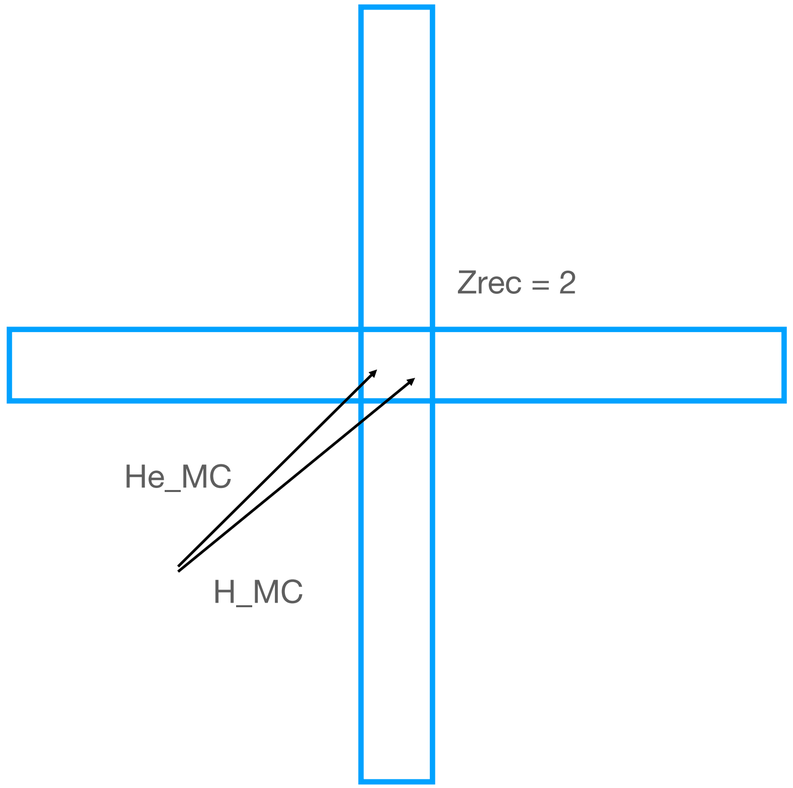




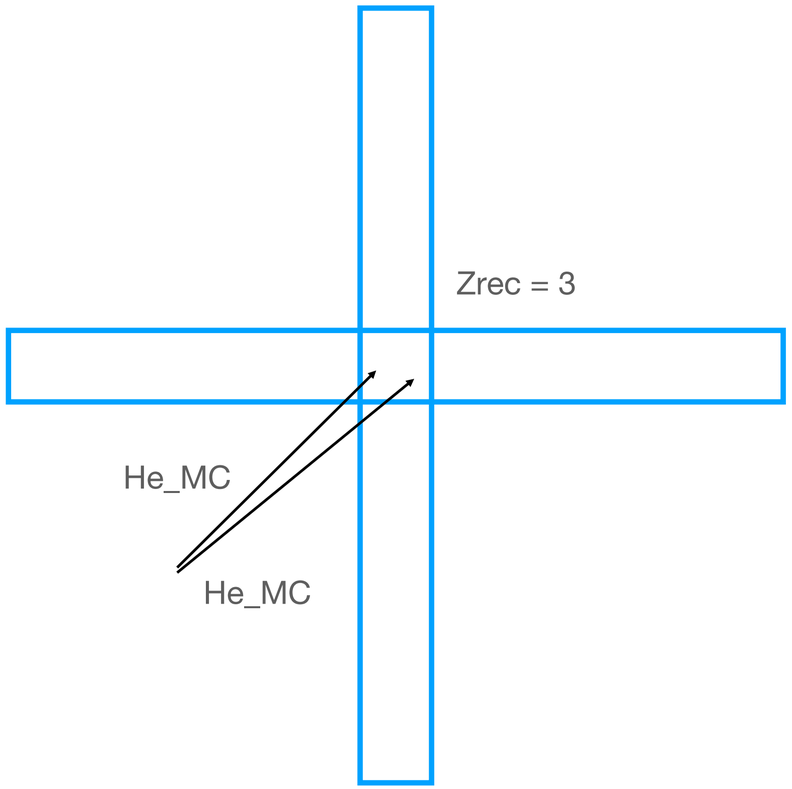
Ghosts are managed measuring the position from deltaTime along the TW bar→ See RobZ's talk

Events surviving the TW Z match



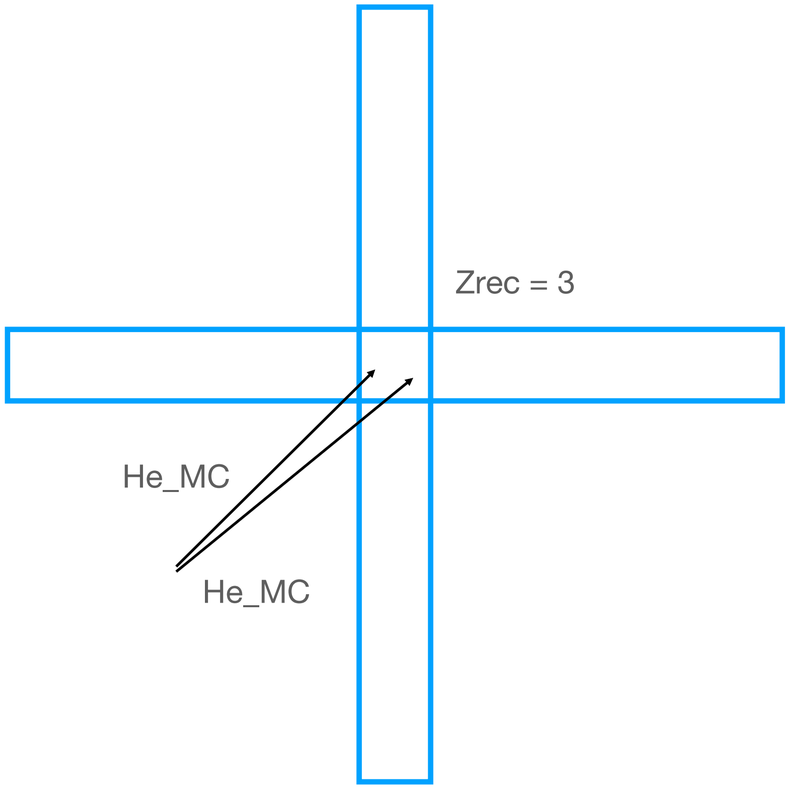


How to manage? (to study CMM, purity and efficiencies)

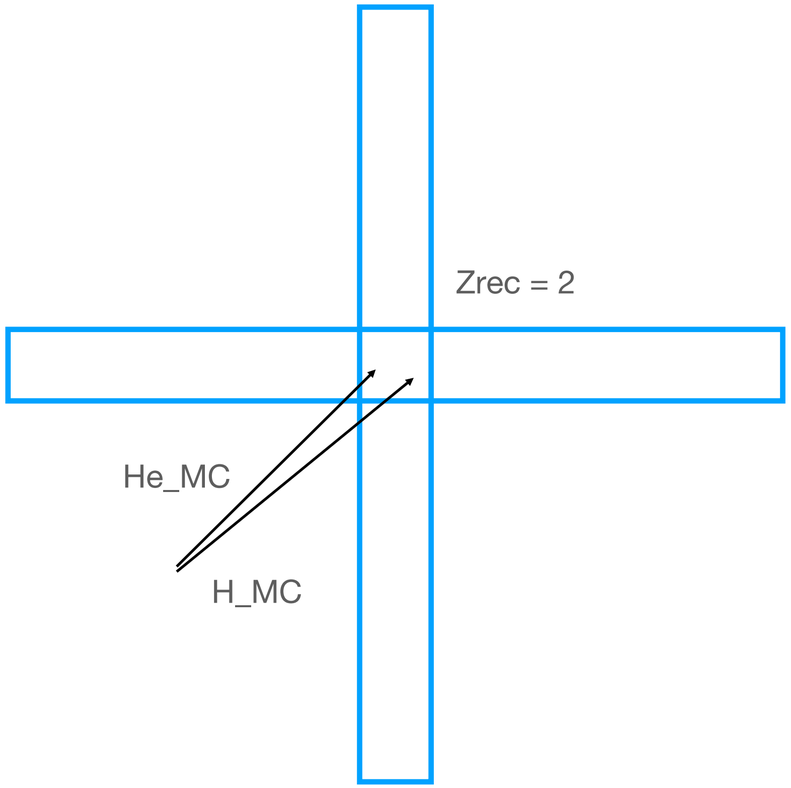


- Needed the matching of the trkId for each track crossing the TW and the one related to the TW points
- In the case of more tracks hitting the same bar check if the vector of trkIds associated to the TWpoints contains at least trkId of the impinging tracks
- If this is the case assign:
  - Good match if Zrec==Zmc
  - Wrong match if Zrec!=Zmc

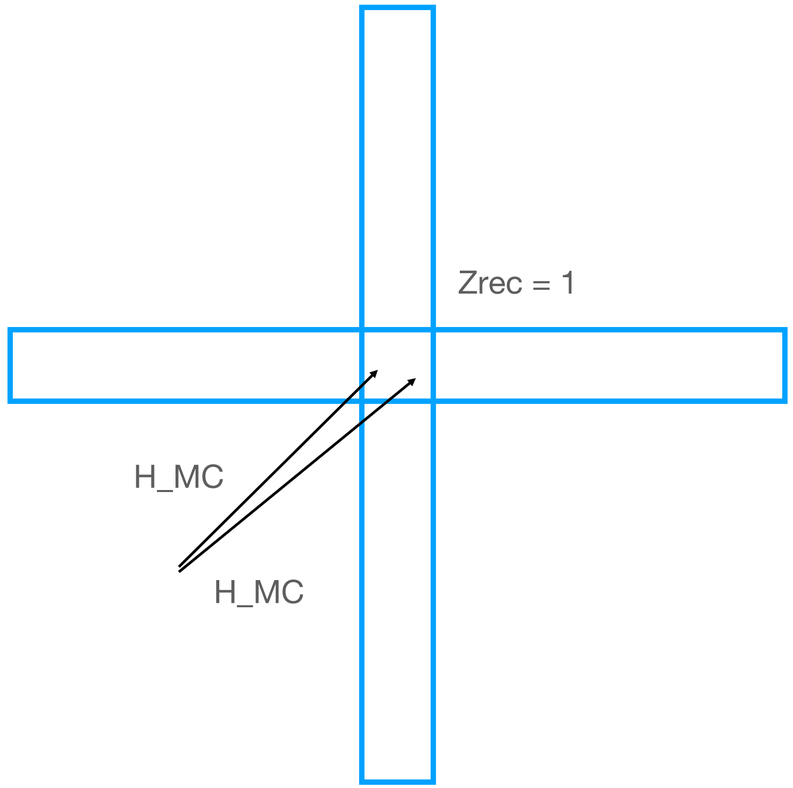
Events surviving the TW Z match



Wrong match



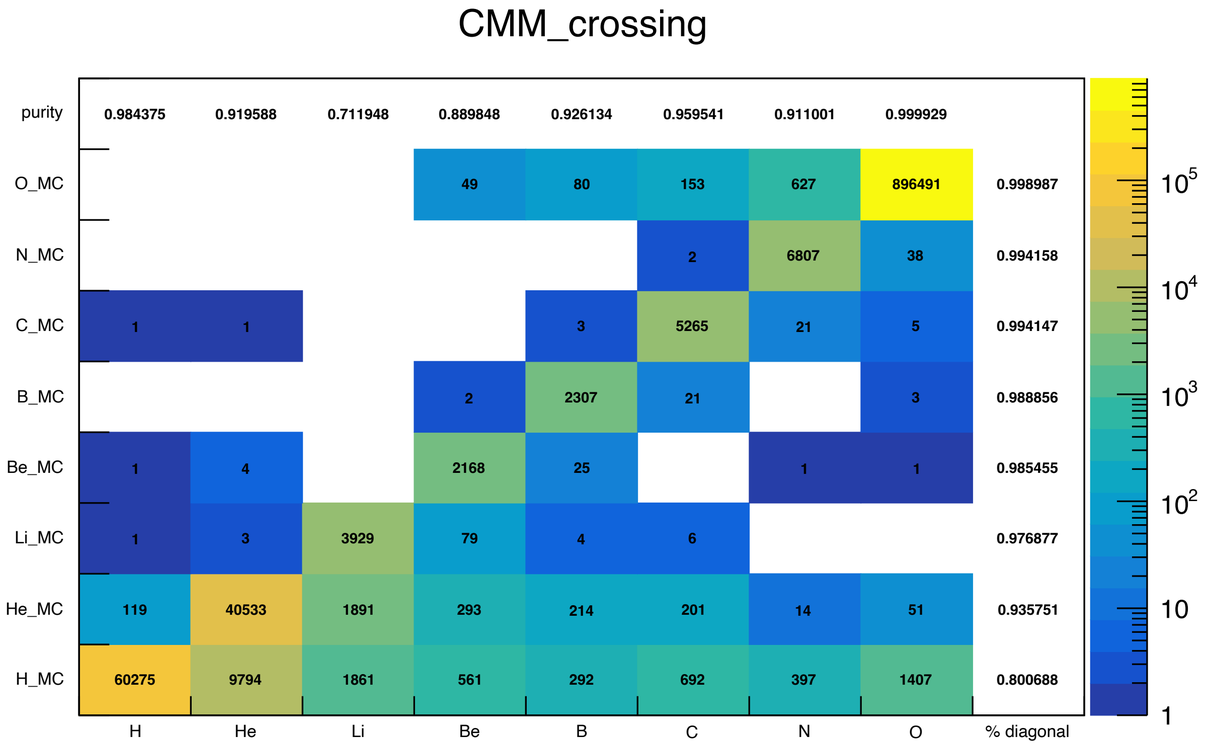
Good match



Good match

(Reminder: H and He are produced with large beta distributions)

CMM matrix: GSI2021_MC(16O_C_400_1)



Purity = N(Zrec=Ztrue) / N (Zrec) = Ngood / (Ngood + Nwrong)

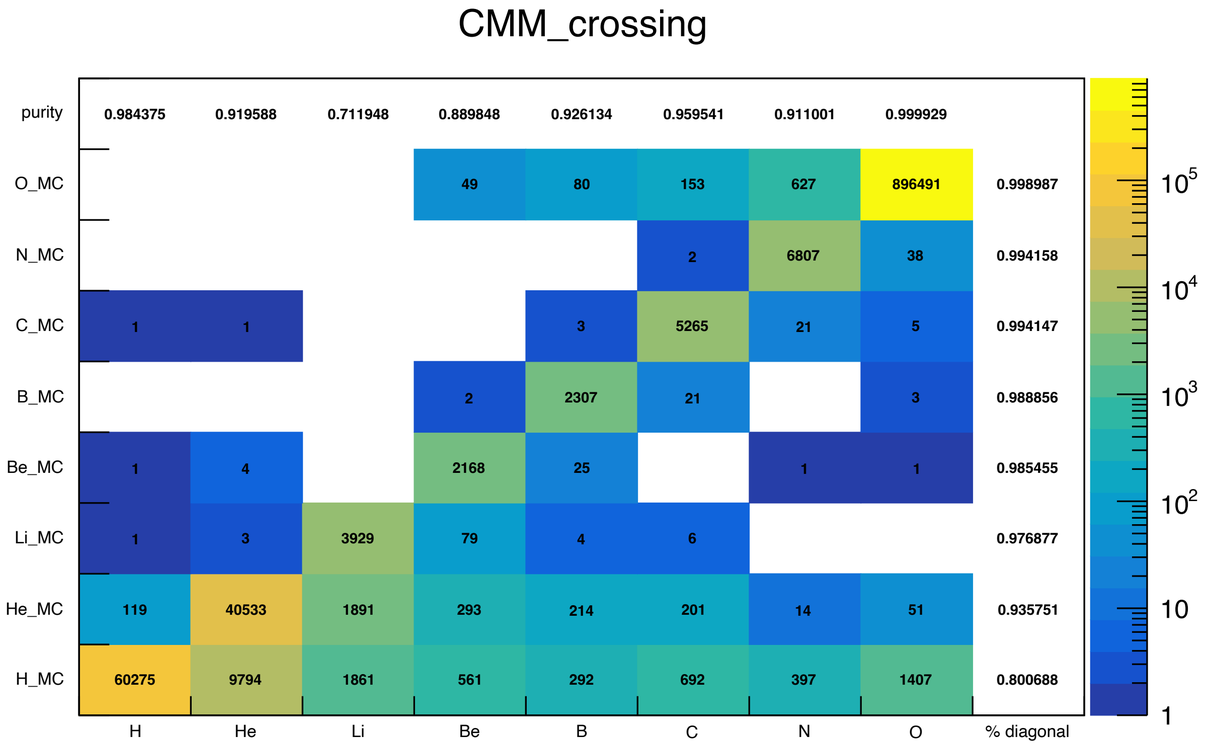
(The row is normalized not the column !)

1. **Is this CMM coming from wrong ZID algorithm assignment? (No, see later – but Eloss and Tof resolutions play an important role)**
2. **Where did all these fragmentation events come from?**

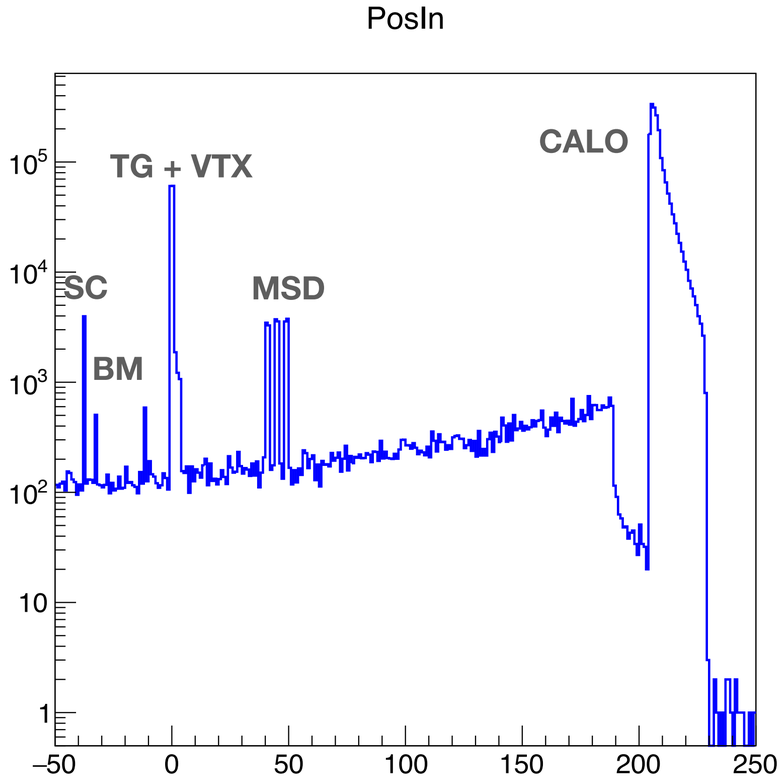
Some selections not included which clean the CMM and so the purity:

- E_{THR} included in TW hit reco not optimized wrt data
- No cut in beta (driven by data)
- No cut in angle (nor angular bin selected)
- Correlation of the multiplicity of tracks in the same bar with the production angle of the fragments

CMM matrix: GSI2021_MC(16O_C_400_1)



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



Tracks at the TW crossings

Some selections not included which clean the CMM and so the purity:

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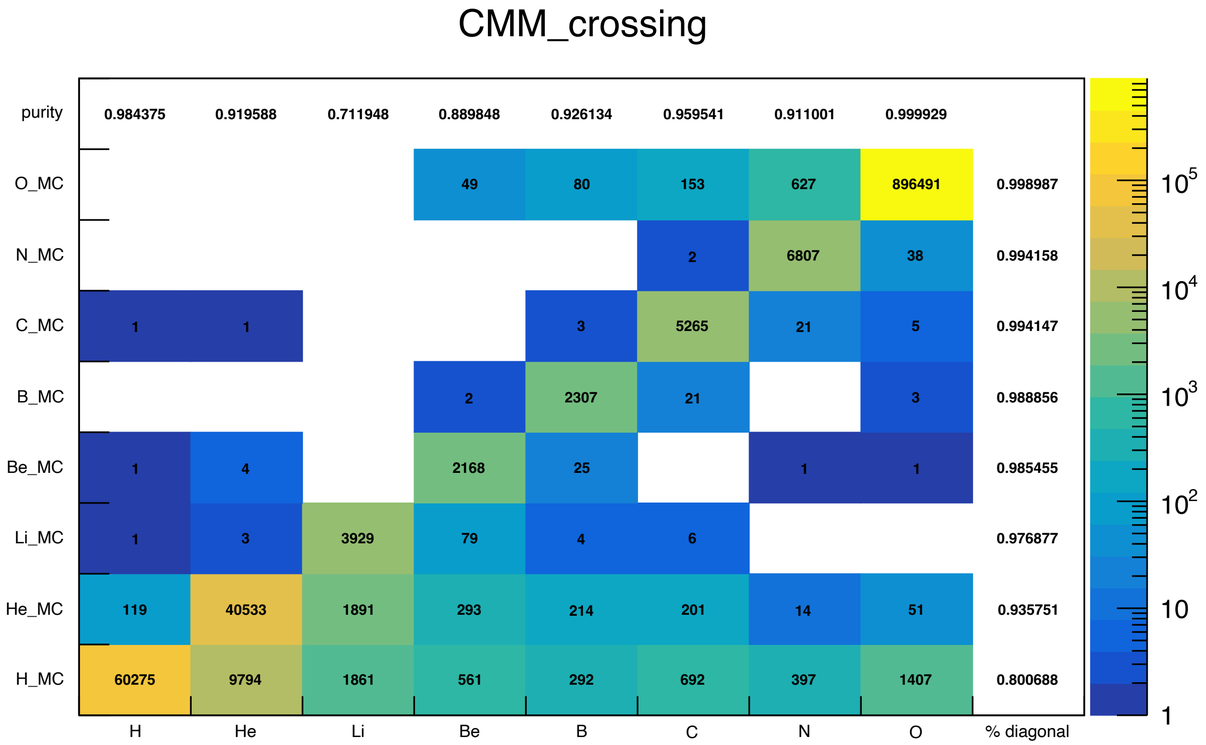

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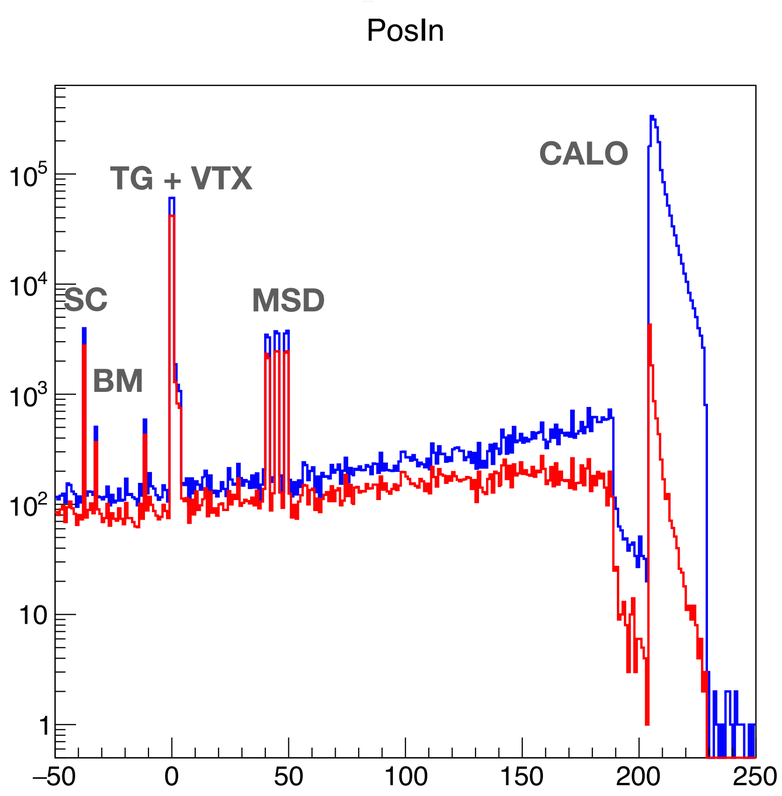

Tracks at the TW crossings

Tracks matched to TW

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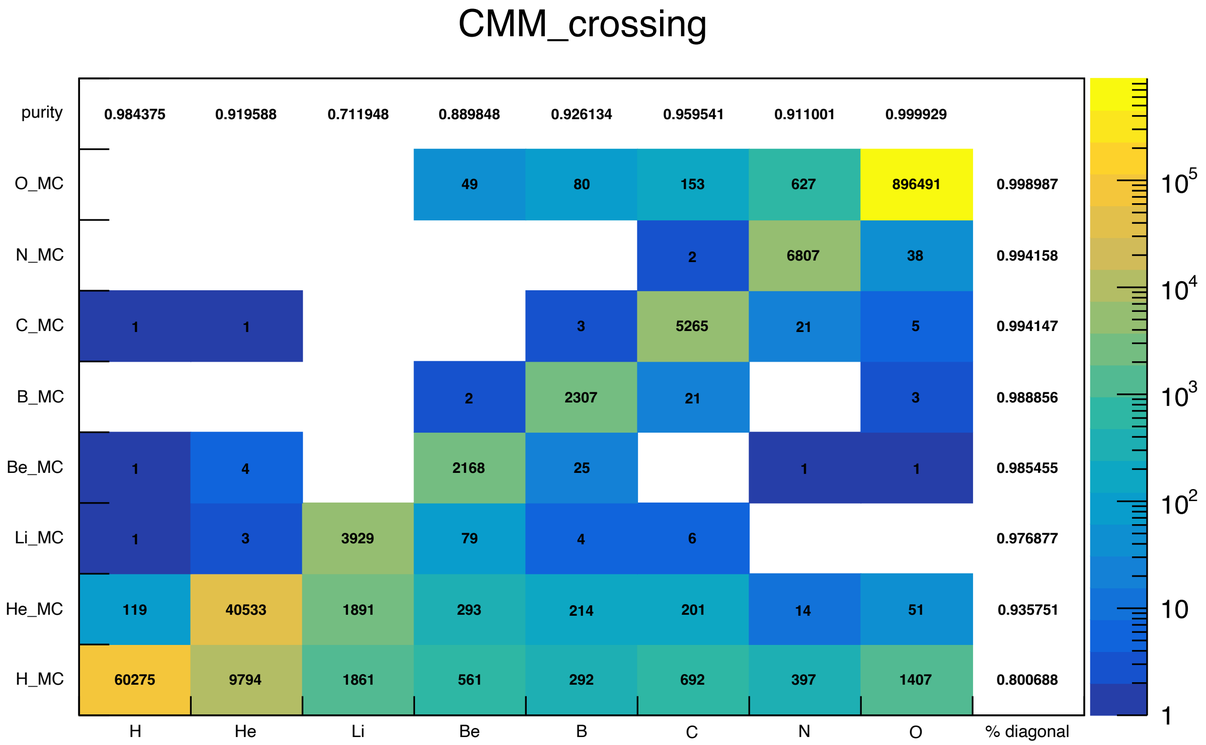
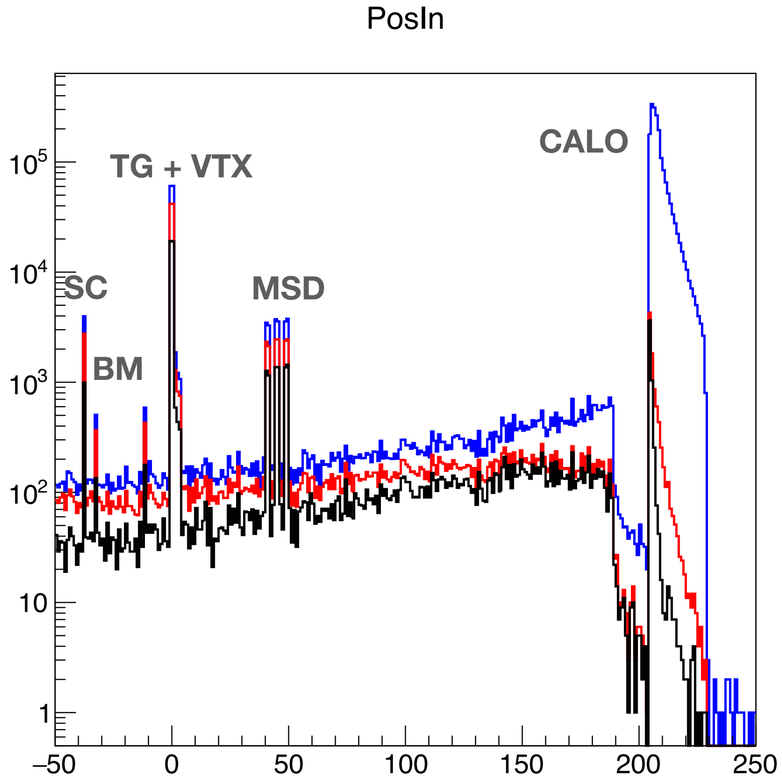
CMM matrix: GSI2021_MC(16O_C_400_1)



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



Tracks at the TW crossings

Tracks matched to TW

Protons matched to TW

Some selections not included which clean the CMM and so the purity:

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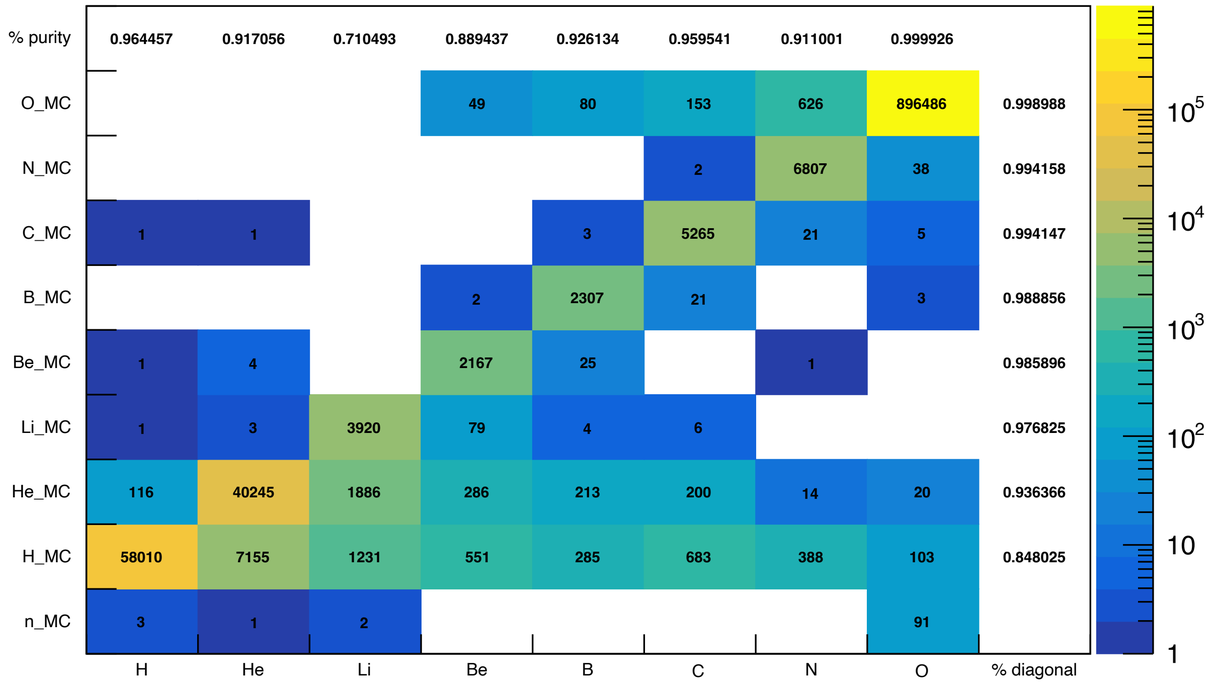
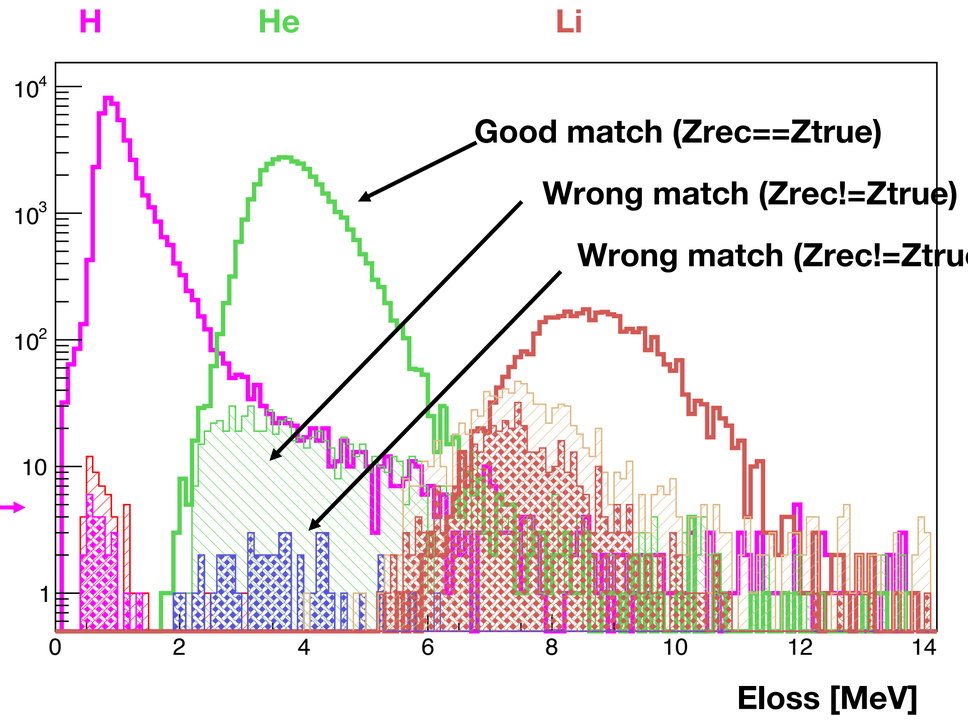
- No cut in beta (driven by data)
- No cut in angle (nor angular bin selected)
- Correlation of the multiplicity of tracks in the same bar with the production angle of the fragments

CMM matrix: GSI2021_MC(16O_C_400_1)



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

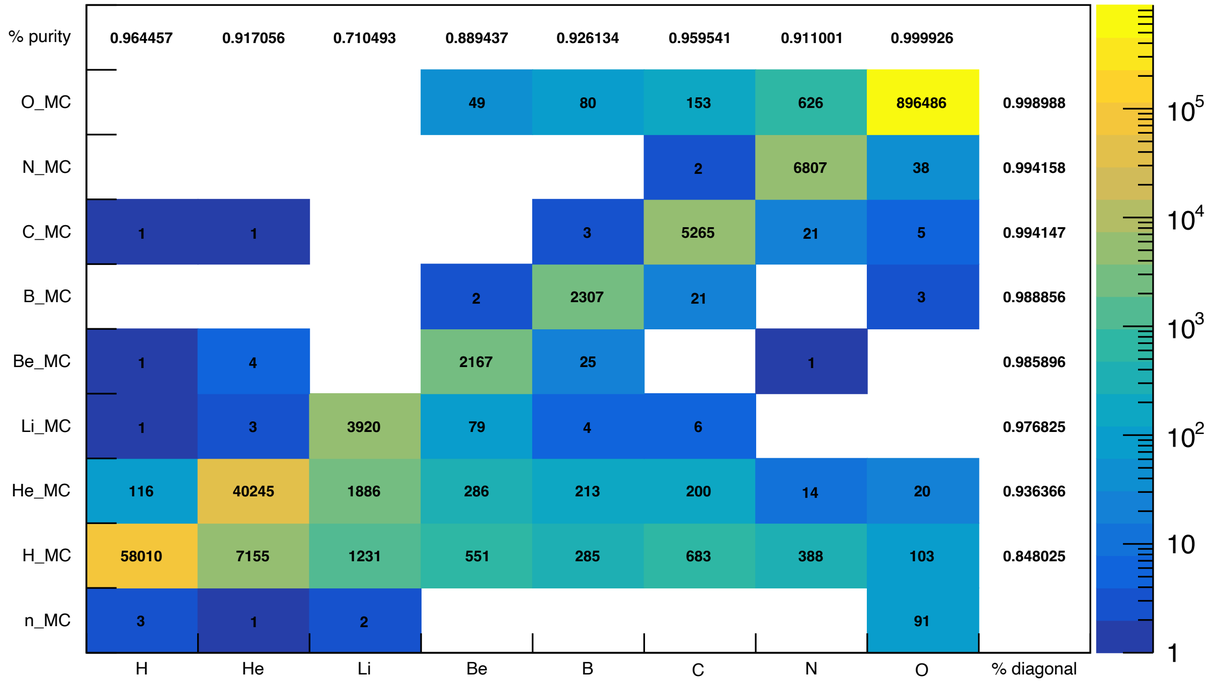
Reconstructed Eloss for H, He and Li:



Some selections not included which clean the CMM and so the purity:

- E_{THR} included in TW hit reco not optimized wrt data→ See Matteo's talk
- No cut in beta (driven by data)
- No cut in angle (nor angular bin selected) → See Riccardo's talk
- Correlation of the multiplicity of tracks in the same bar with the production angle of the fragments

CMM matrix: GSI2021_MC(16O_C_400_1)



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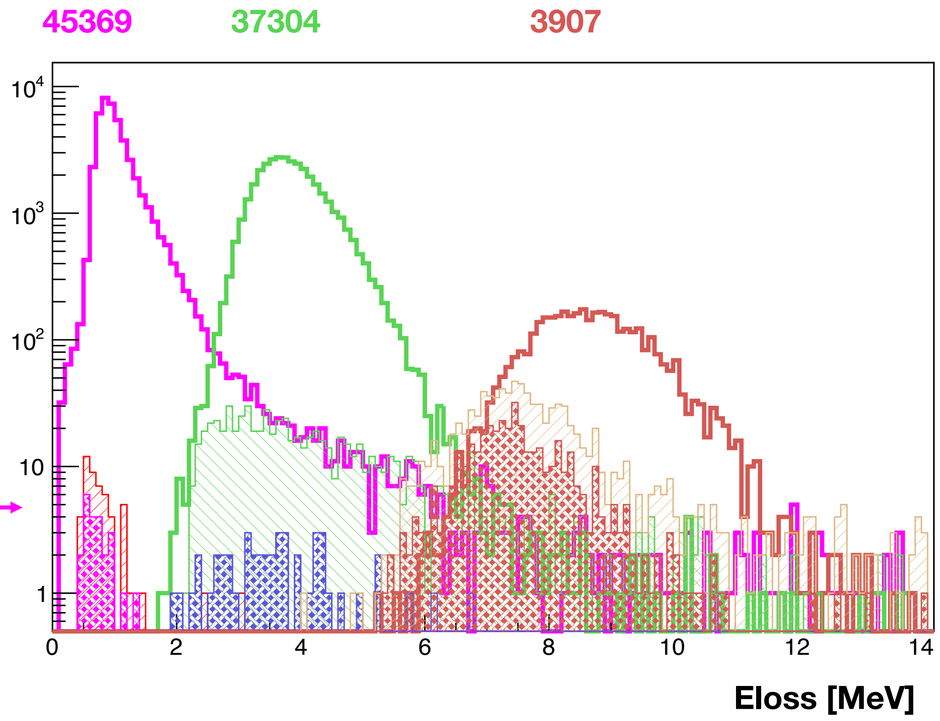
Reconstructed Eloss for H, He and Li:



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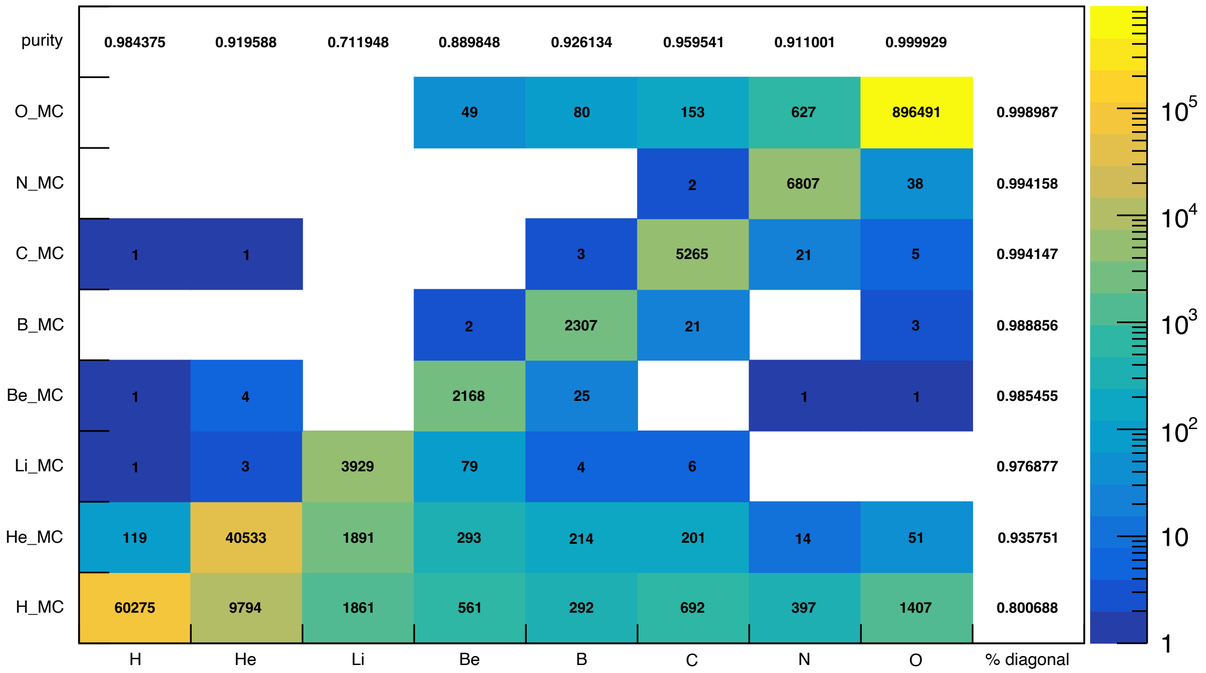
- No cut in angle (nor angular bin selected) → See Riccardo's talk
- Correlation of the multiplicity of tracks in the same bar with the production angle of the fragments

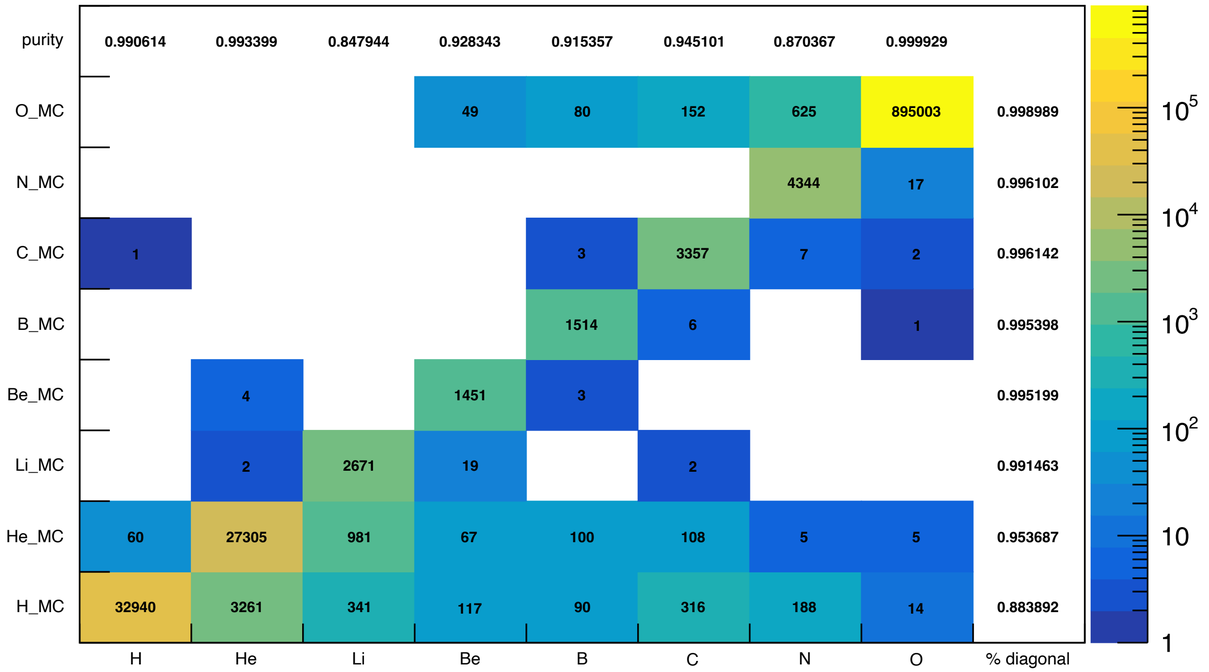
CMM matrix: GSI2021_MC(16O_C_400_1)

CMM_crossing



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

CMM_crossing_inTG



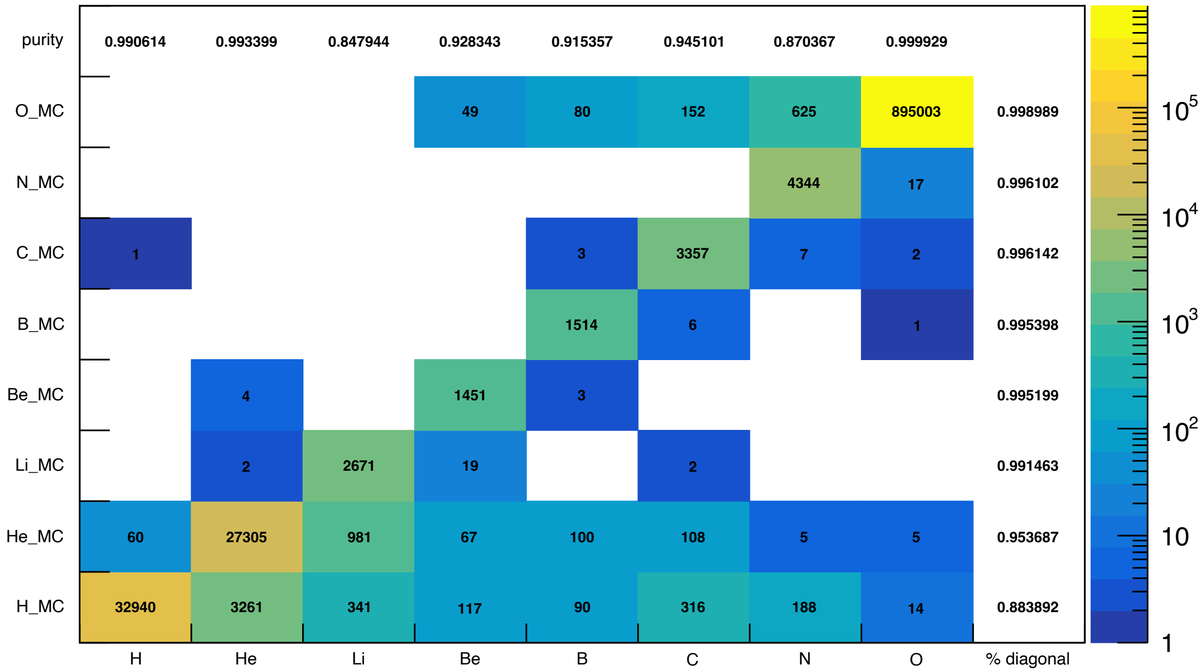
CMM matrix: GSI2021_MC(16O_C_400_1)

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)

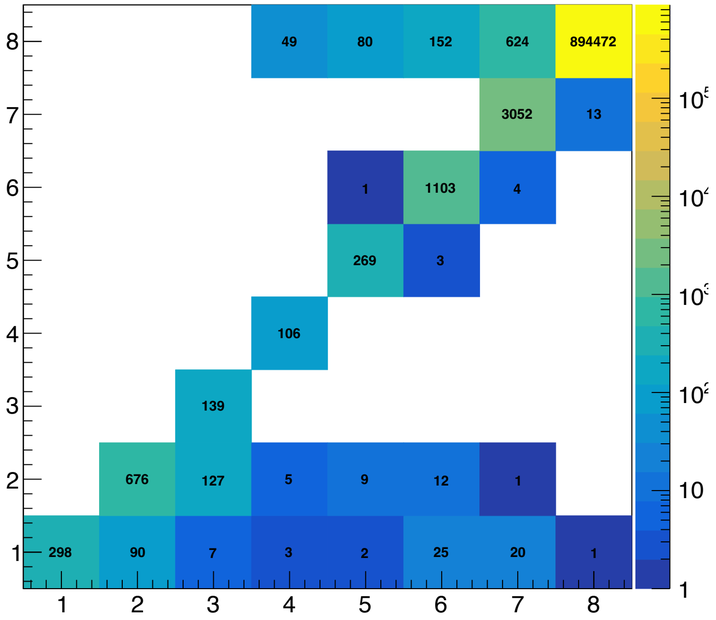
CMM_crossing_inTG



CMM matrix: GSI2021_MC(16O_C_400_1)

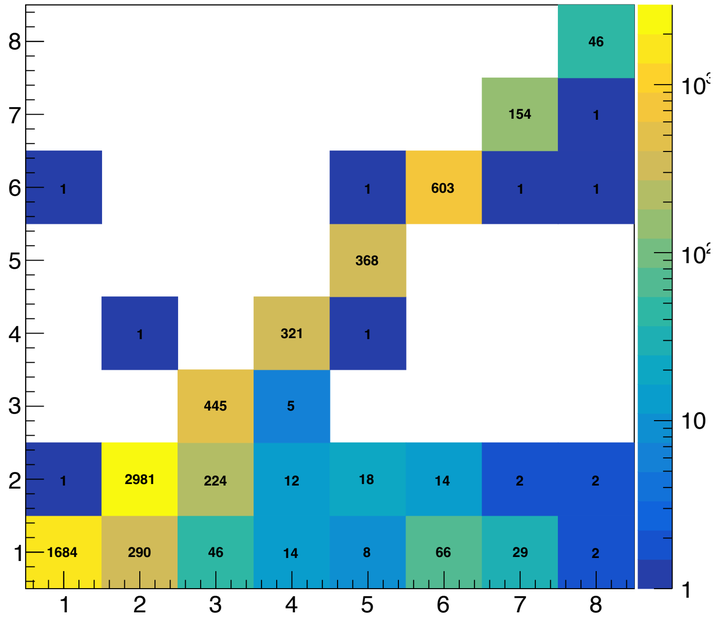
- Correlation of the multiplicity of tracks in the same bar with the production angle of the fragments?

CMM_AngleBin_0



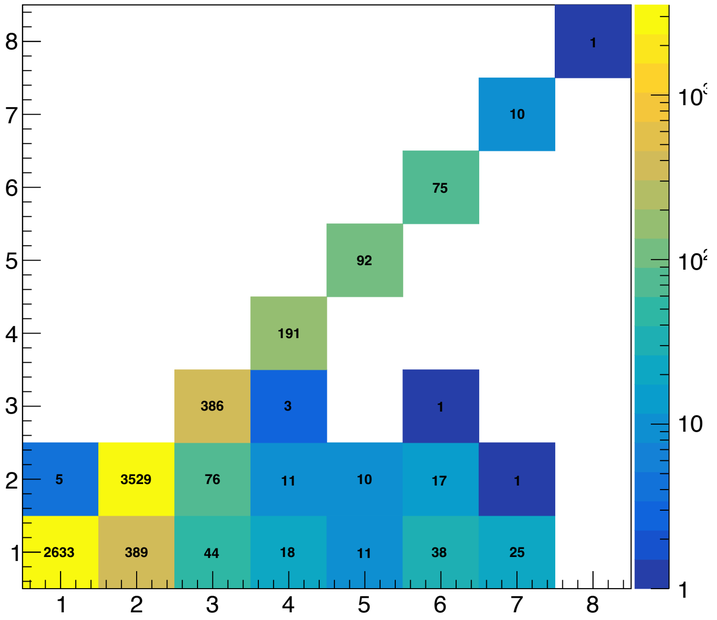
[0°-0.6°]

CMM_AngleBin_2



[1.2°-1.8°]

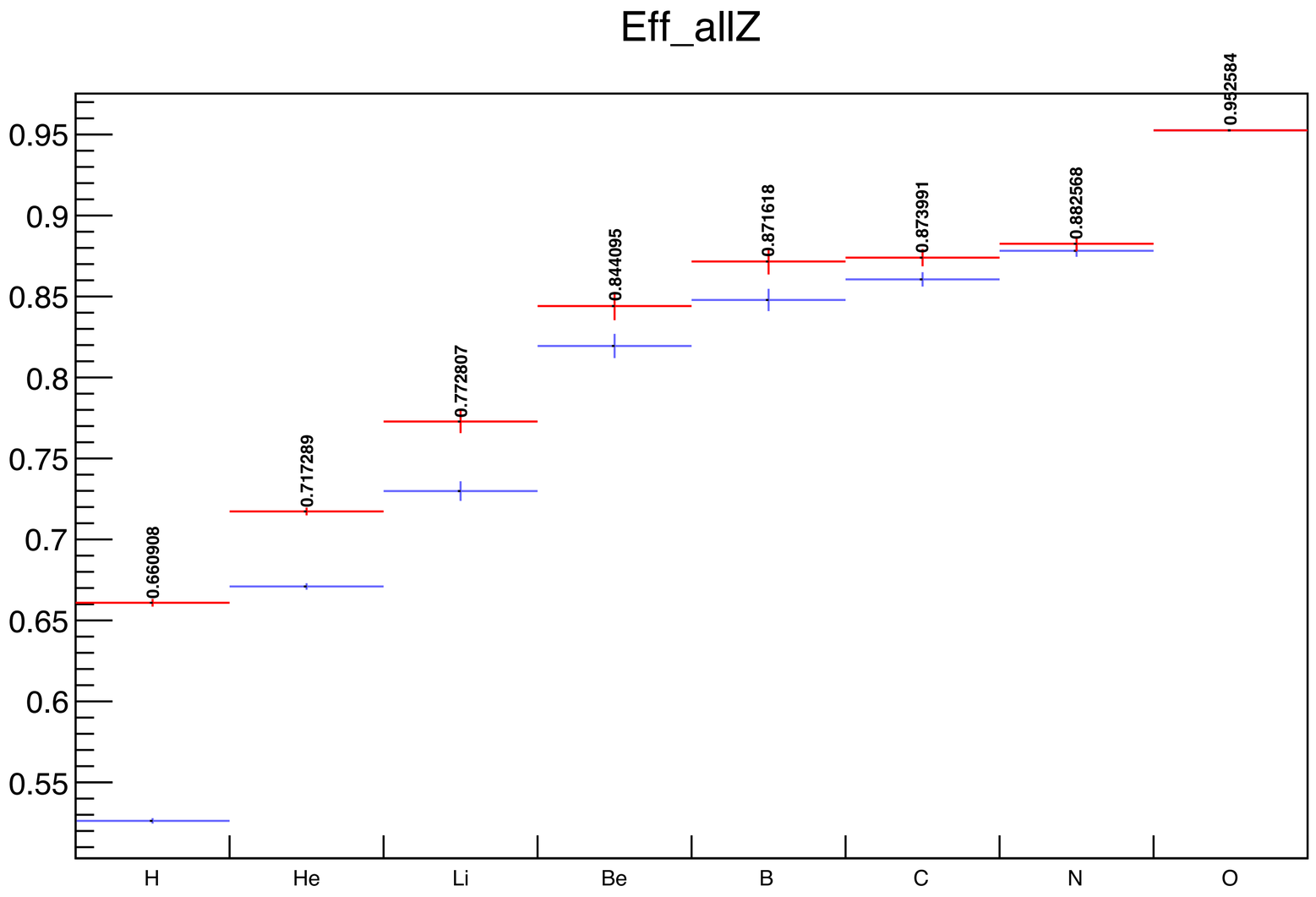
CMM_AngleBin_4



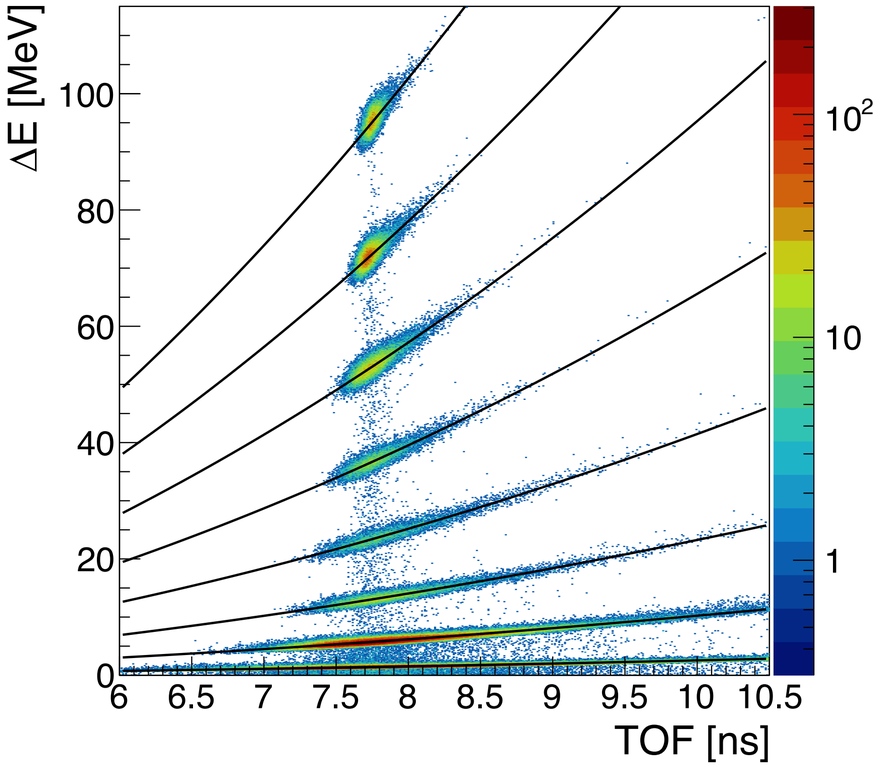
[2.4°-3.0°]

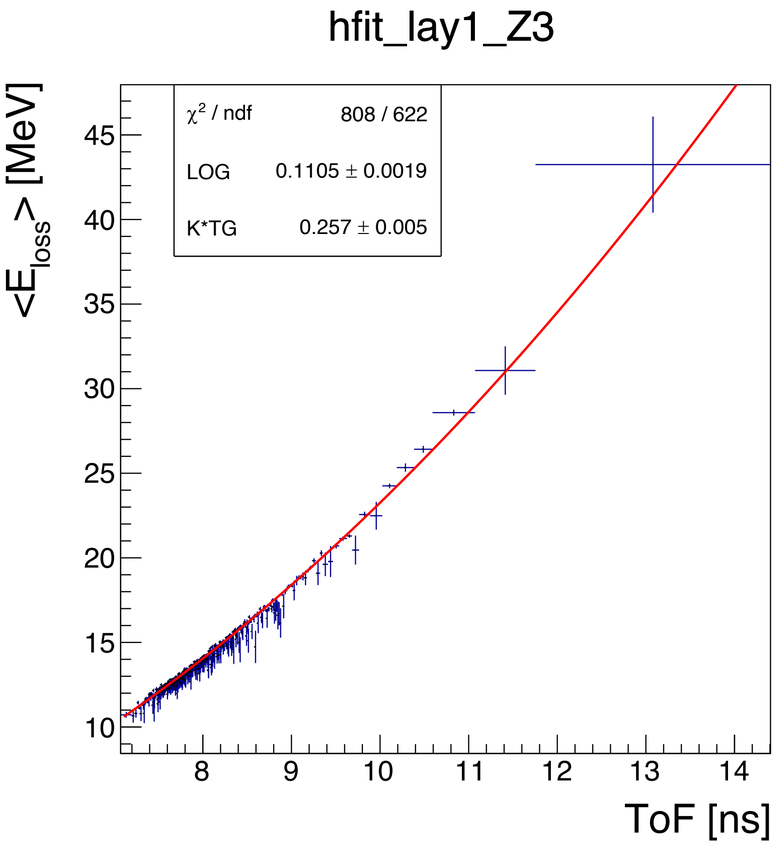
- The correlation is clear but the contribution doesn't disappear at ~3°

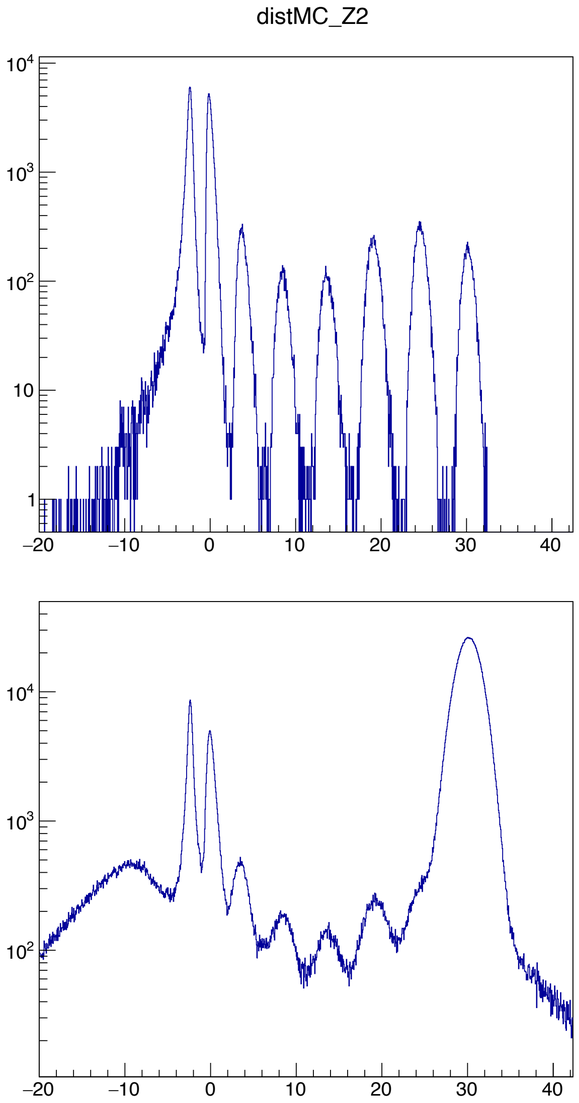
Reconstruction efficiencies: GSI2021_MC



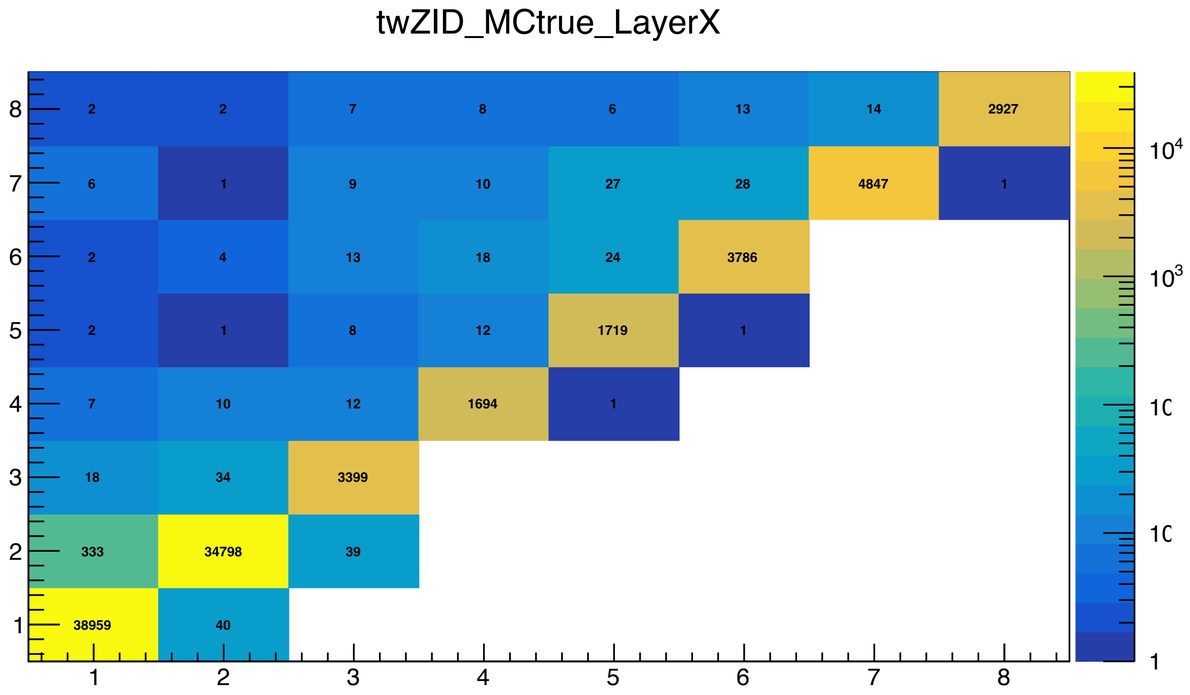
Systematics and possible improvements on ZID algorithm

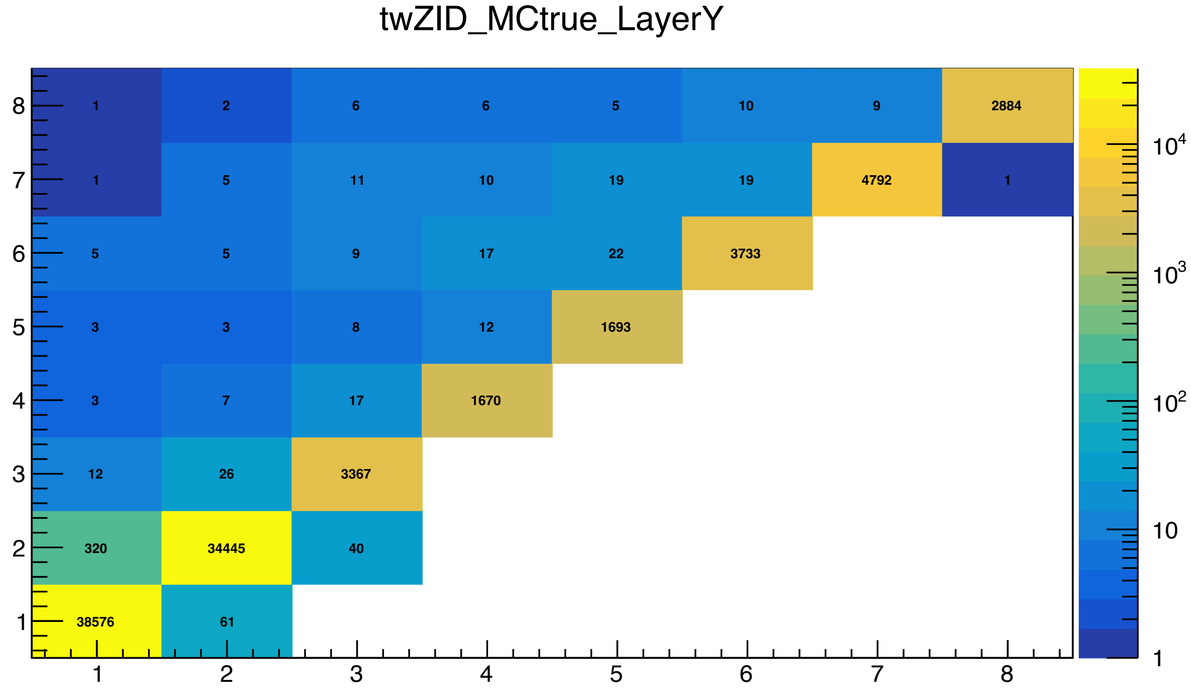






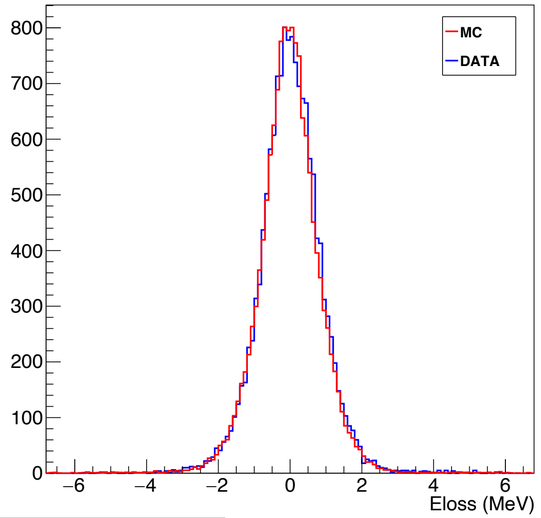
CMM matrix: GSI2021_MC(16O_C_400_1)



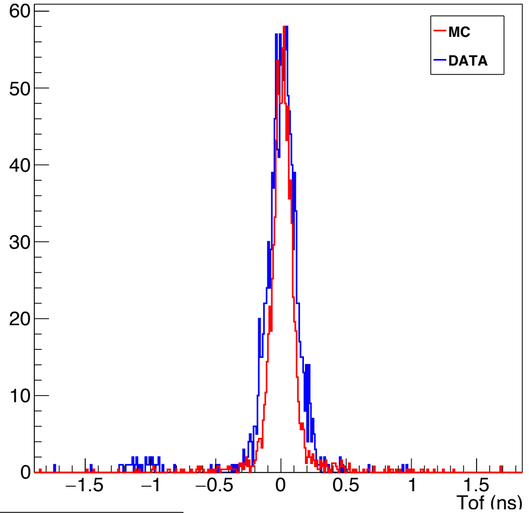


Data / MC comparison

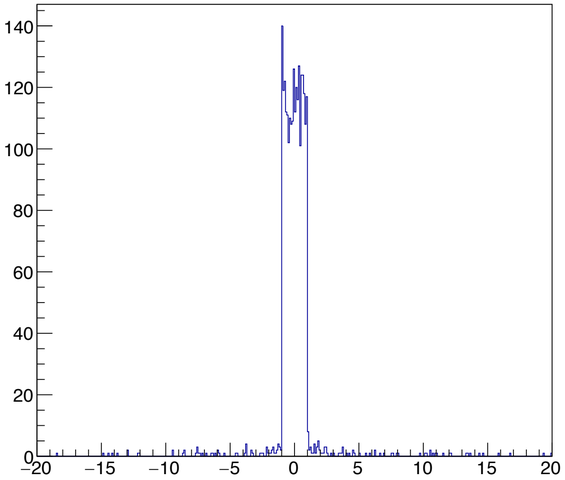
twDeltaE_Z2



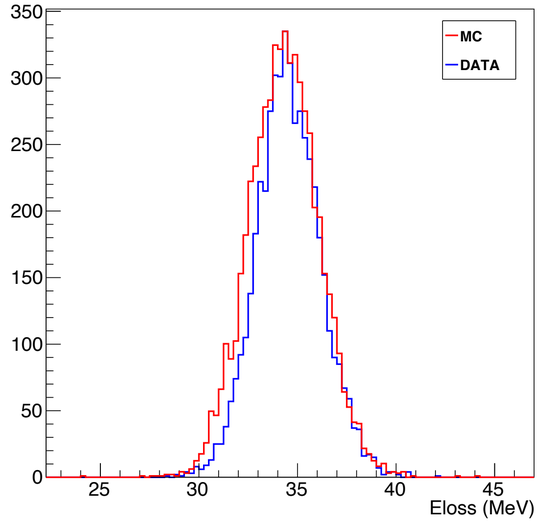
twDeltaTof_Z4



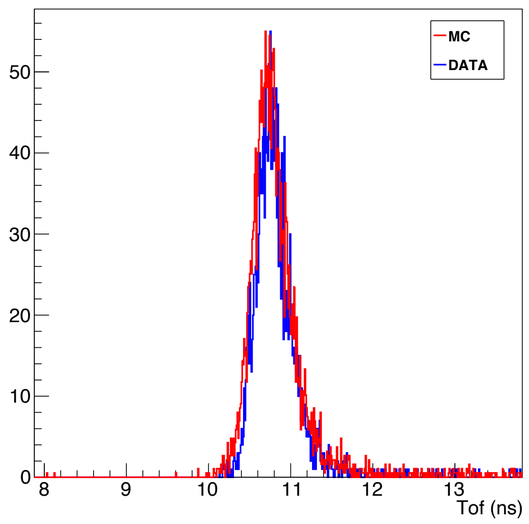
DeltaPosY_Z4



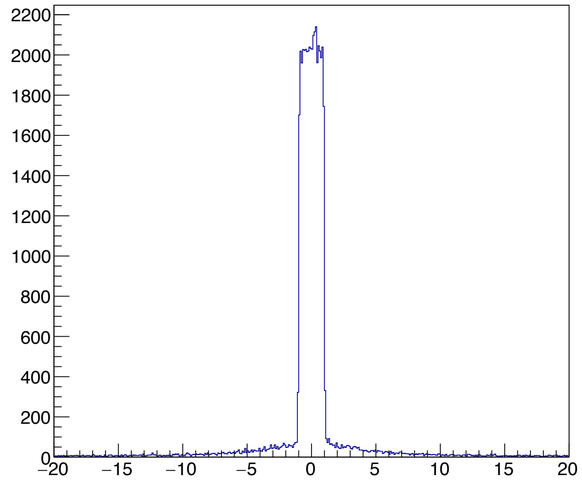
twElossMean_Z6



twTofMean_Z3

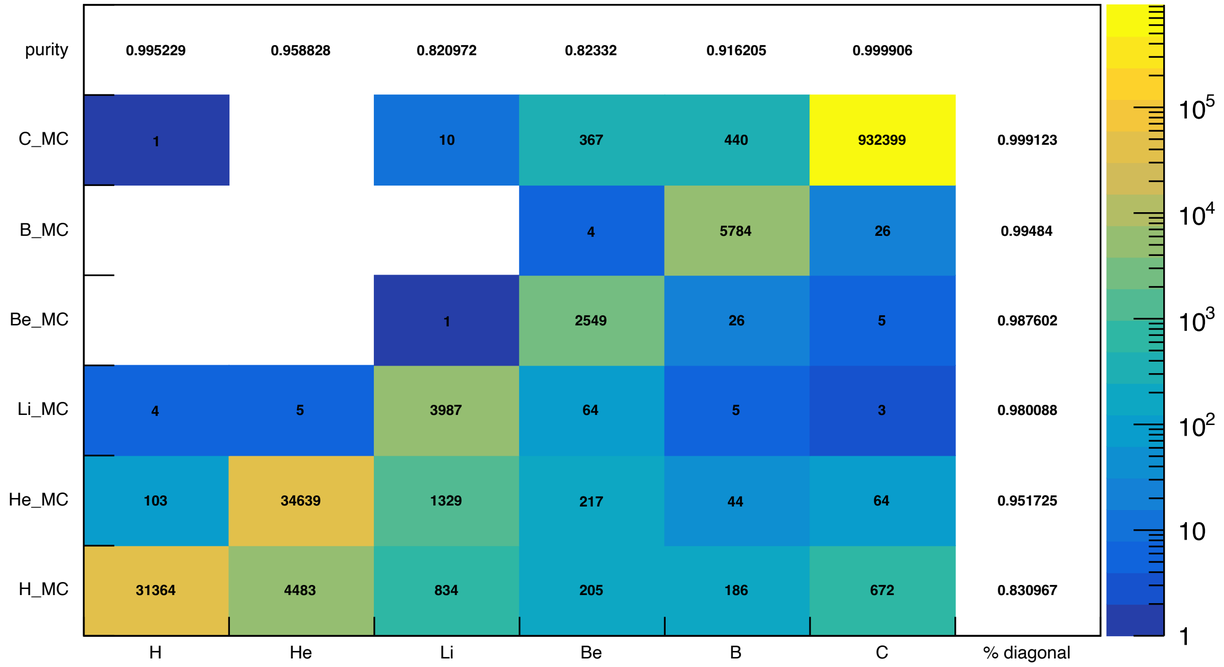


DeltaPosX_Z1



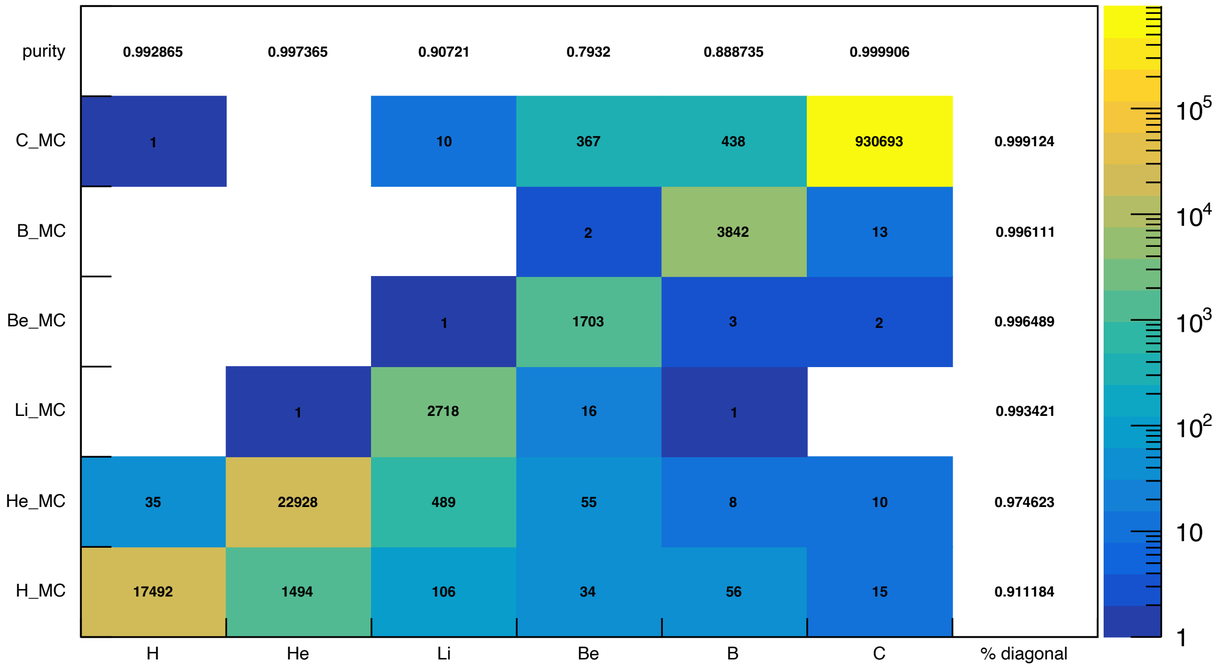
CMM matrix: CNAO2022_MC(12C_C_200dec)

CMM_crossing



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

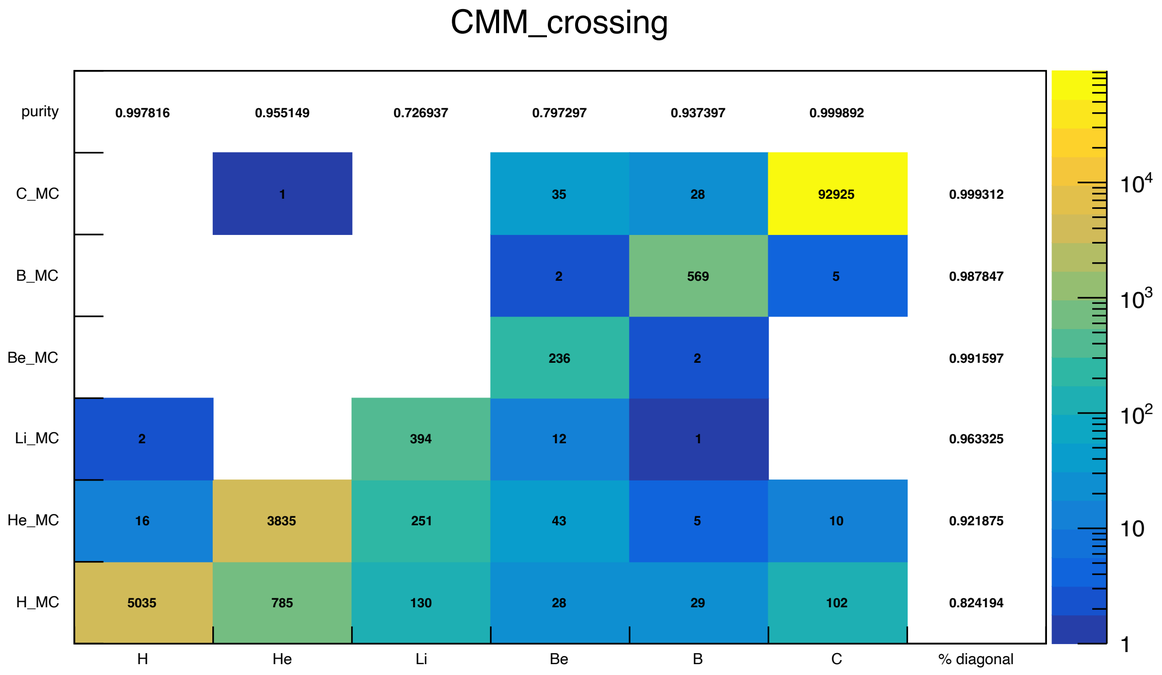
CMM_crossing_inTG



Some selections not included which clean the CMM and so the purity:

- E_{THR} included in TW hit reco not optimized wrt data
- No cut in beta (driven by data)
- No cut in angle (nor angular bin selected)
- Correlation of the multiplicity of tracks in the same bar with the production angle of the fragments

CMM matrix full setup: 12C_200_2023_MC



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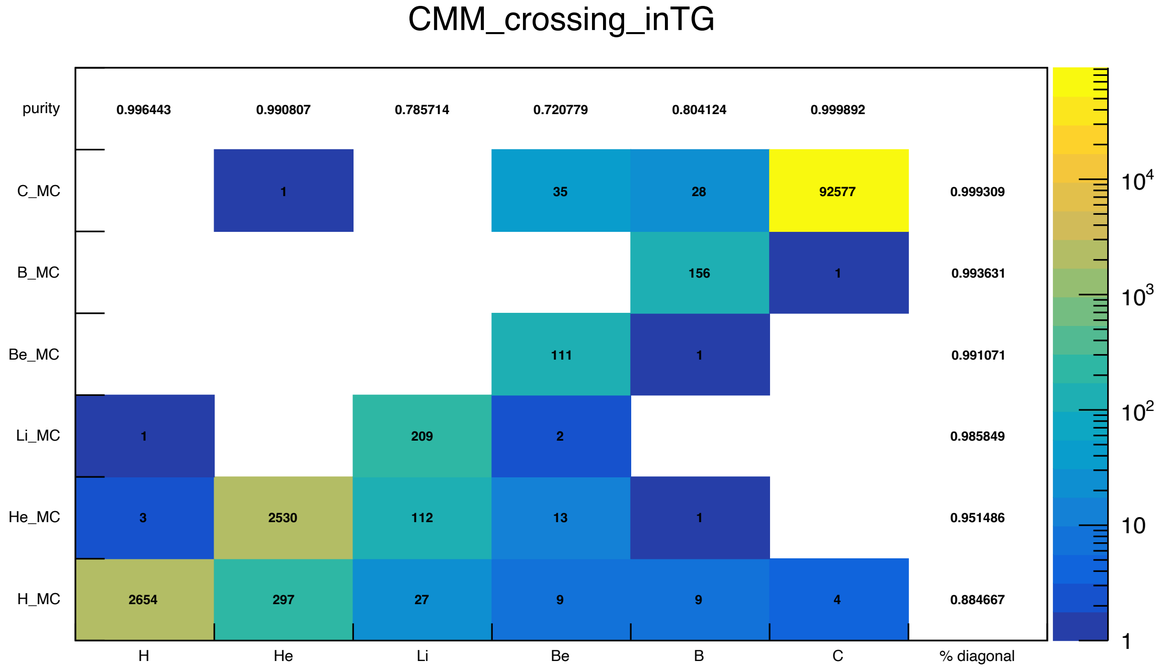

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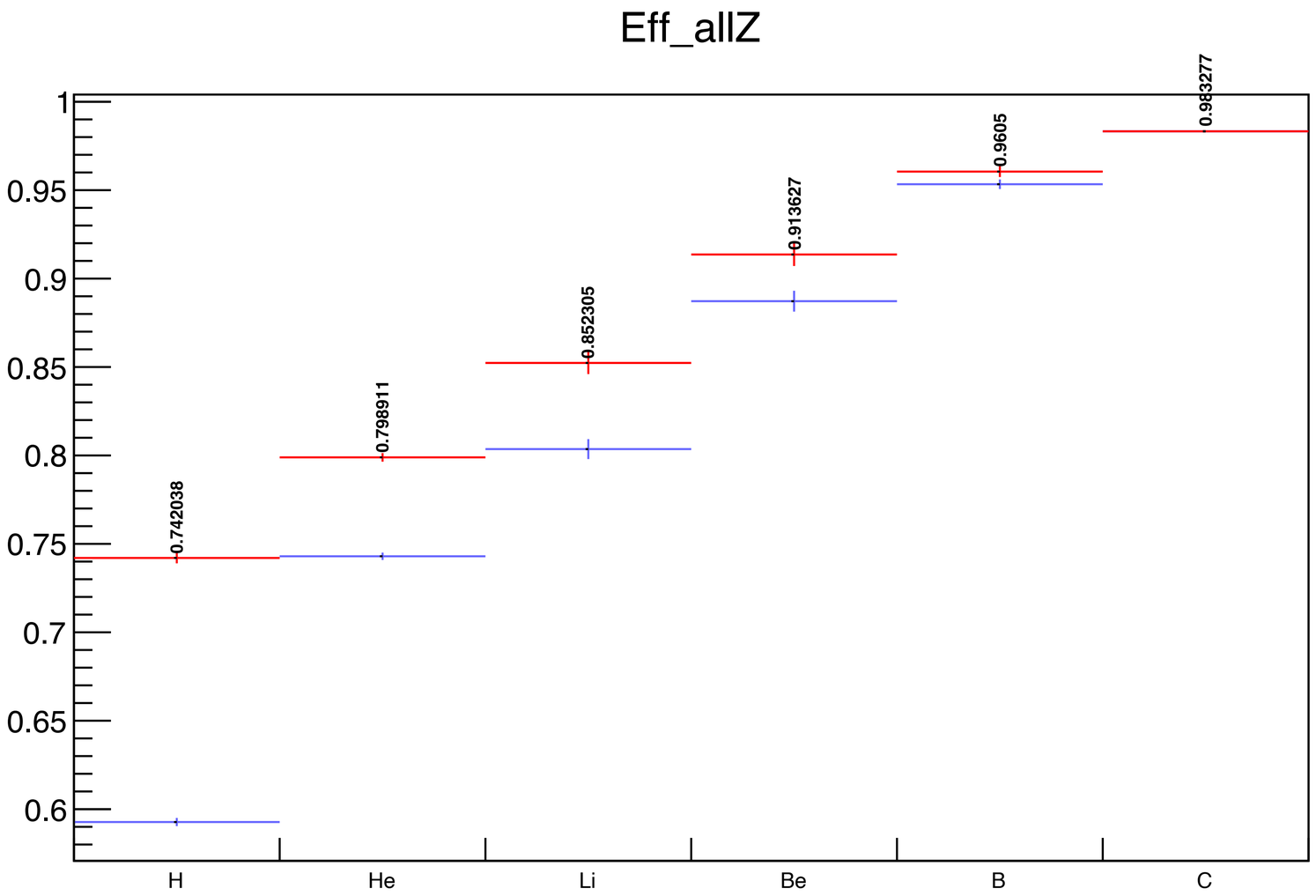
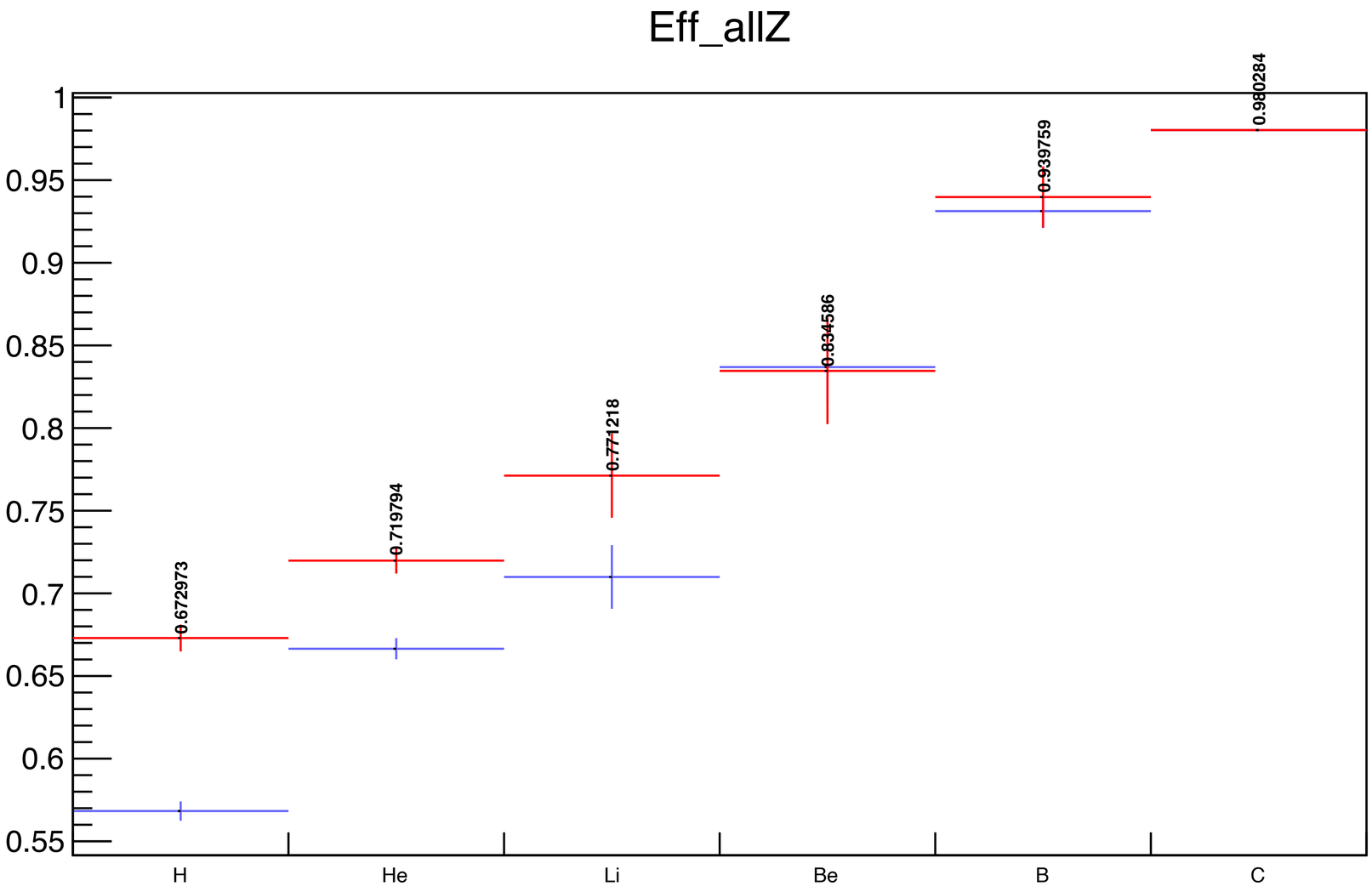
Reconstruction efficiencies: CNAO2022 _MC



Reconstruction efficiencies: full



Conclusions

- Check the TW reco, optimized for GSI2019, for all the campaigns (resolutions in Eloss and Tof, ZID algorithm, positions and hit matching for a point)
- Charge Mixing Matrix populated by multiple fragments events surviving the TW Z match
- Reconstruction efficiency low due to Tw Z match
- TW Z match→ don’t touch until we don’t have new ZID algorithms
- Error on the assigned Z→systematics on the BB fit
- Unfolding of the Z from the CMM cannot be done
- Still some improvement needed in GSI2021 campaign for H and He resolutions and H calibration. Also observed a shift of the ^{16}O peak to be verified→ same things to be checked for the others campaigns

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come fai..SBAI

Energies of interest for RPS