Update of Cross Sections measurement from 2019 GSI data taking and TW algorithms in SHOE

Angelica De Gregorio, Federica Murtas, Marco Toppi

IX FOOT Collaboration Meeting – 10/12/2020

Steps for cross sections measurement

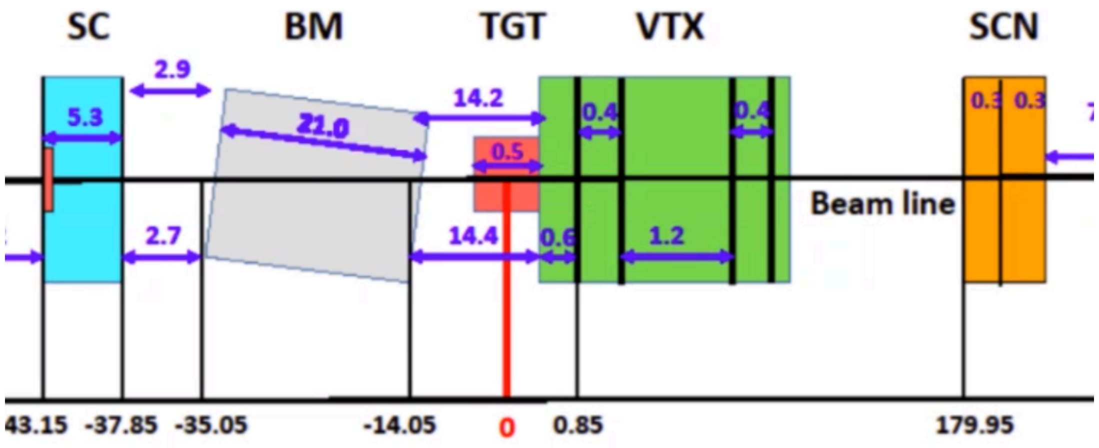
- Align FOOT detector at GSI and select angular acceptance for cross section integration (thanks Yun)
- Apply Pisa group calibration performed at CNAO on GSI data (thanks Aafke and Roberto)
- Extract the fragments yields from ZID and TW clustering algorithms
- Tune MC on Data (Tof and Eloss resolutions, energy thresholds, dead channels plus some rough digitization) to compute MC efficiencies
- Correct for fragment charge misidentification
- Estimate secondary fragmentation out of target for total charge changing cross section
- Systematics study

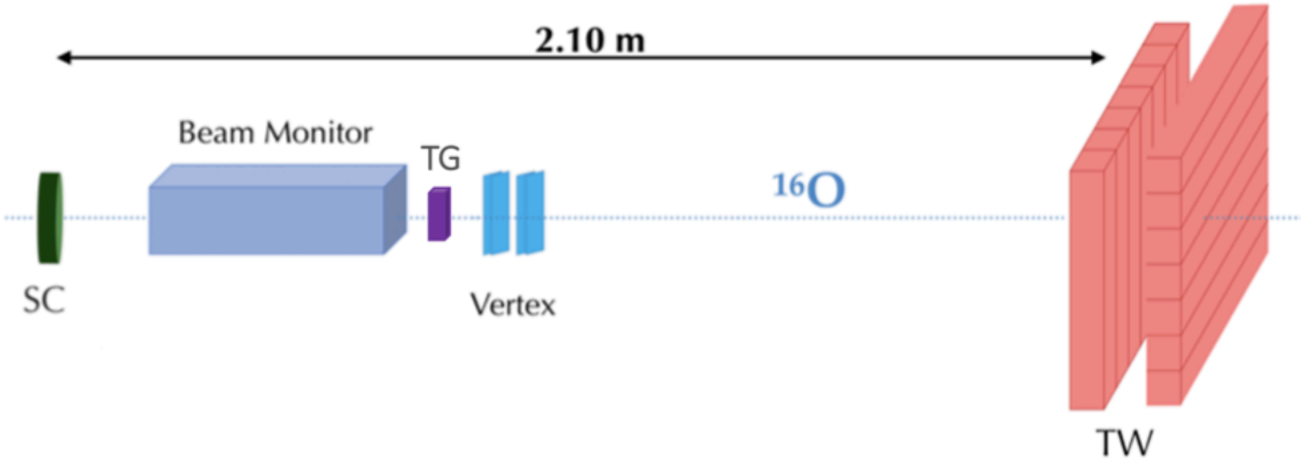
Available data @ GSI

- **^{16}O beam @ 400 MeV/nucleon on a 5 mm Carbon TG**
- Available detectors: SC + BM + (VTX) + TW
- Available runs with TG: 2239, 2240, 2241, 2251
- Available runs without TG: 2242

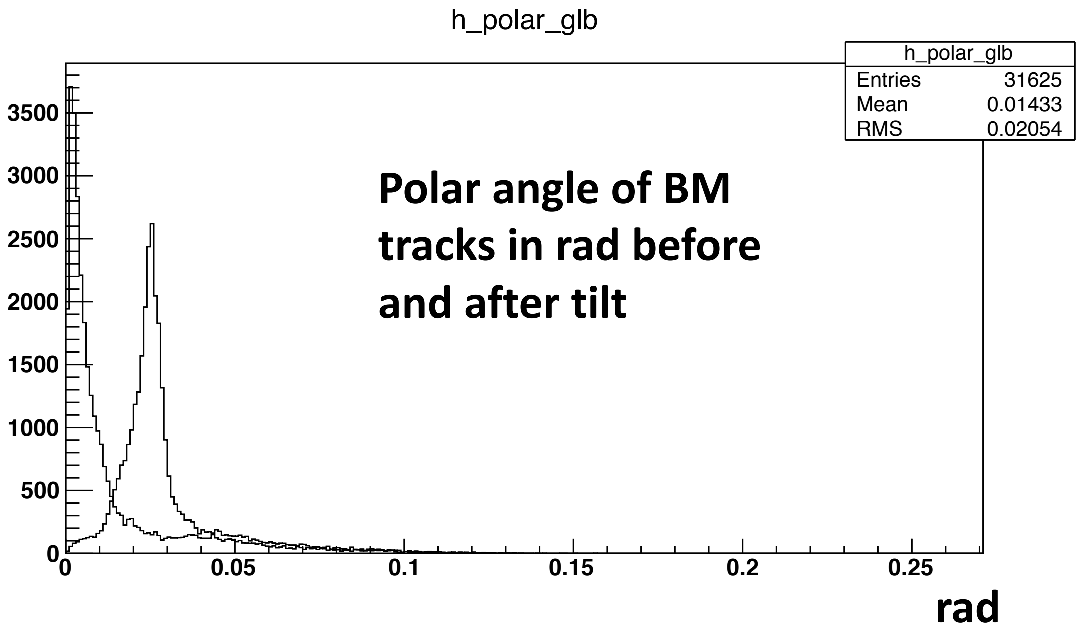
- Analysed runs with TG: 2239, 2240, 2241 (~ 20k evt/run)
- Now also included run 2251 (~ 6kevts)→ shift in ToF now calibrated
- **Very low statistics and no detectors for mass identification -> only the measurement of elemental (charge-changing) cross section integrated in angular and kinetic energy interval is feasible**

Beam and Beam Monitor at GSI



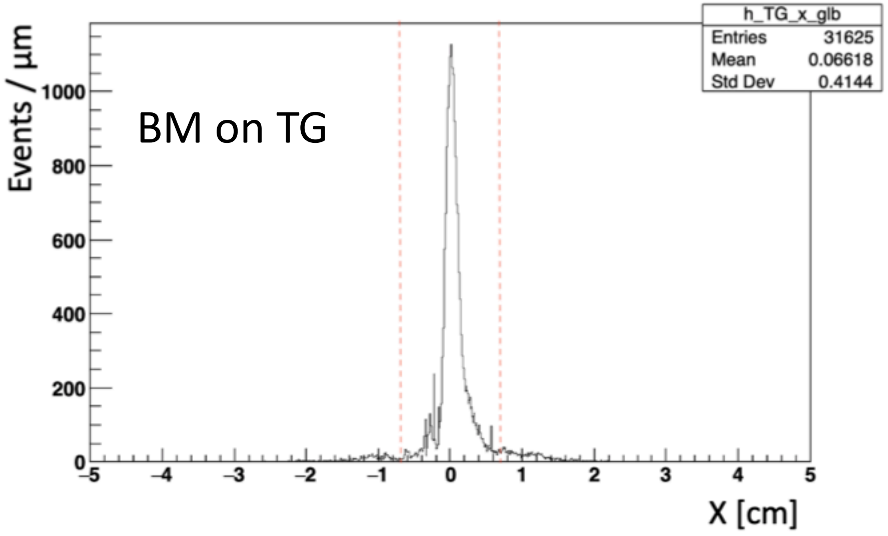


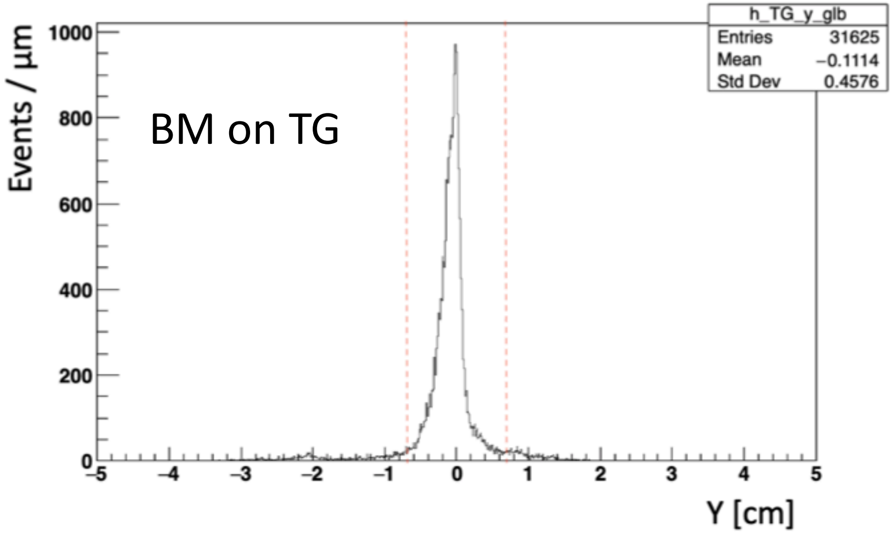
GSI setup (BM/TW) aligned using run 2242 -> straight oxygen ions without TG



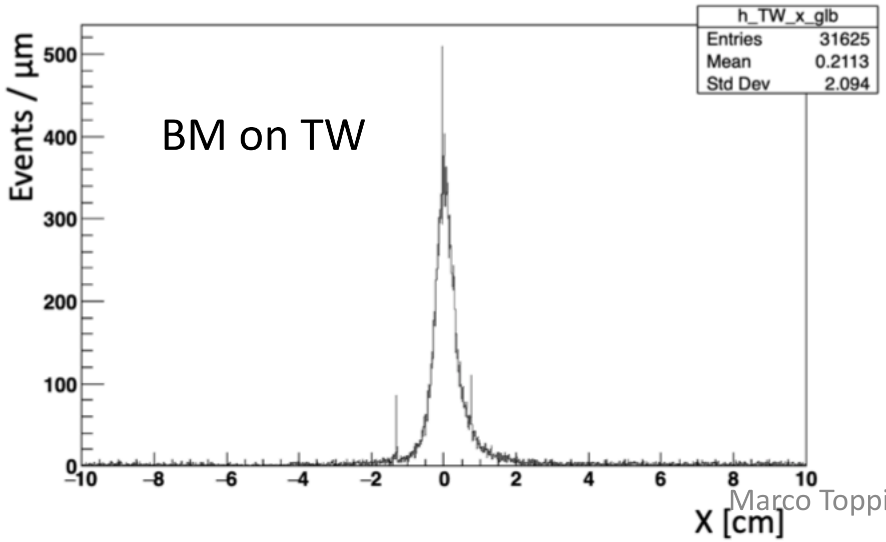
Angular resolution from TW bars crossing < 1.2mrad (0.6°)

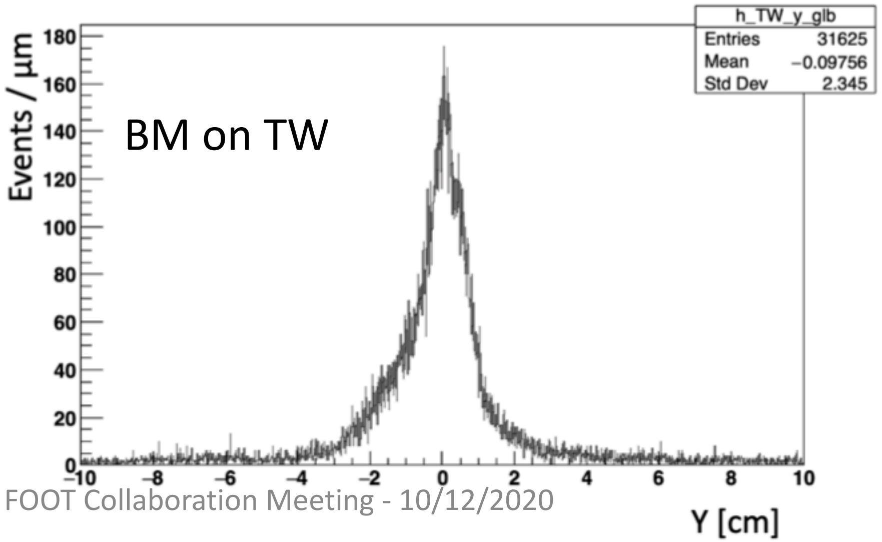
Beam and Beam Monitor at GSI





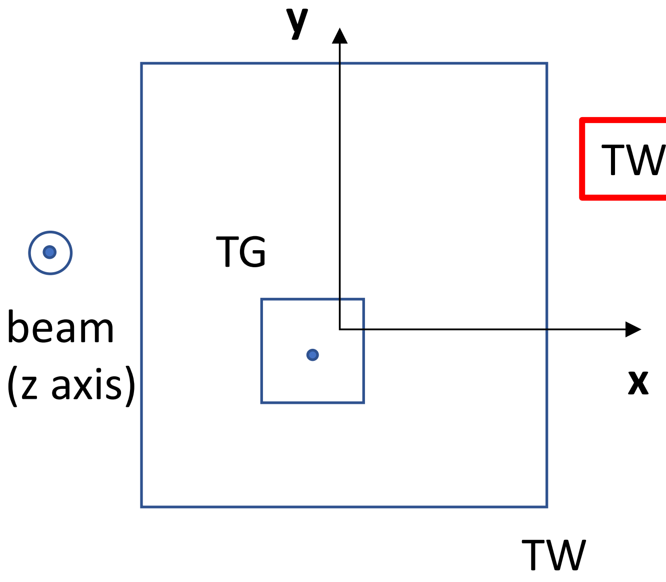
The beam structure, even if not Gaussian, is centered at (x,y) = (0,0) in the global reference frame





The broadening of the distribution on the TW shows a divergence of the beam of ~ 5 mrad (about 0.3°) in X and Y → to be considered in systematics

Angular acceptance



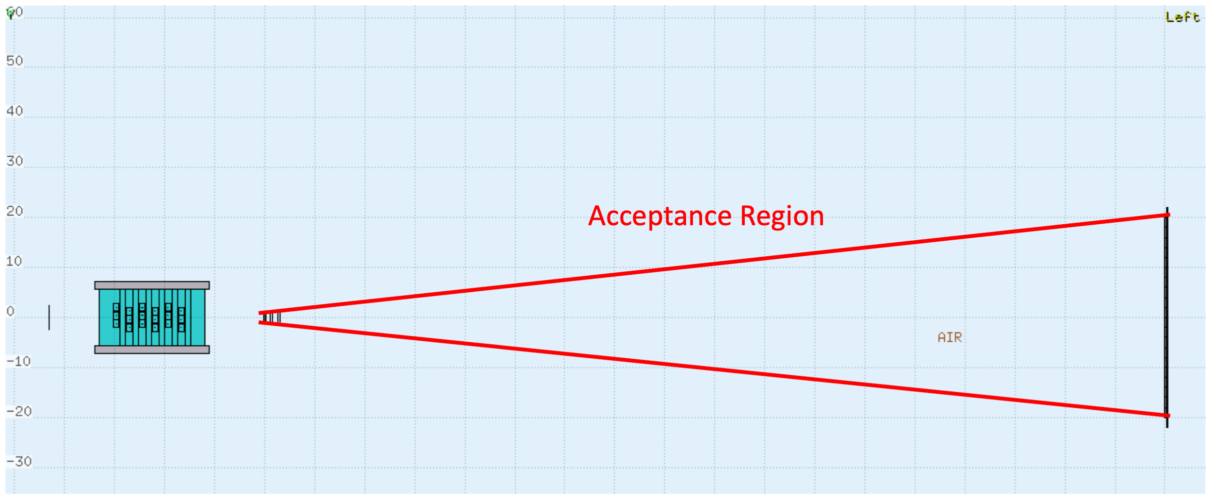
TW center glb ~ [-1,-1]

Small shift between BM and TW

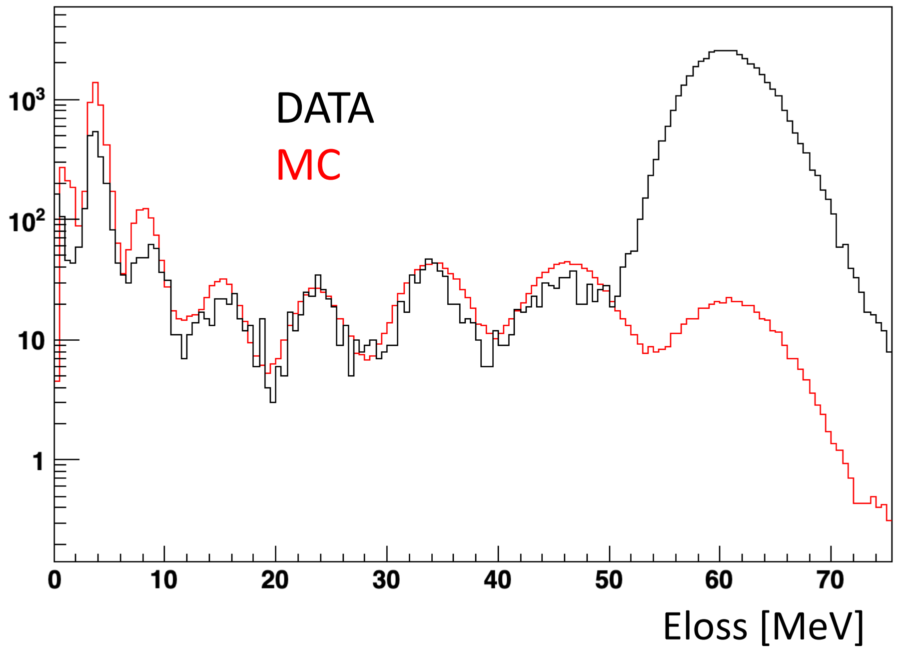
$0° \leq \theta \leq 5.7°$

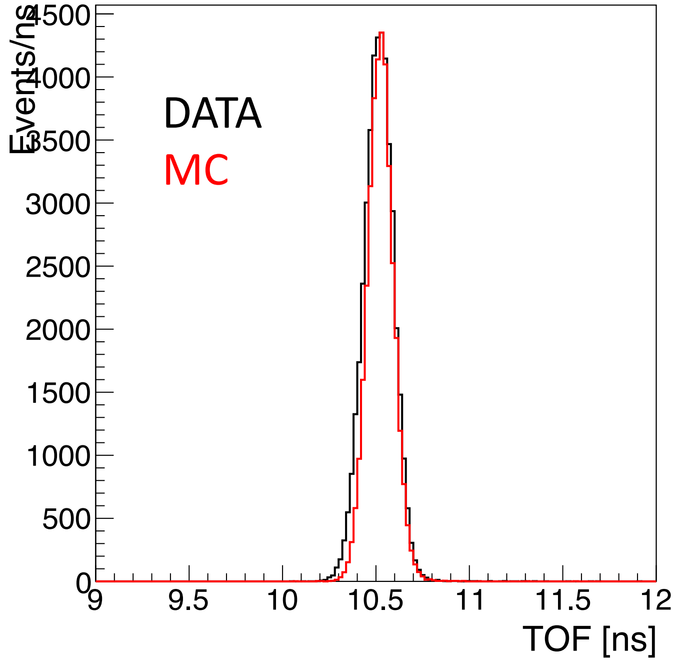
Selecting fragments from TG region [-0.7,0.7] cm

$0° \leq \varphi \leq 360°$



Calibration and tuning of MC on GSI DATA





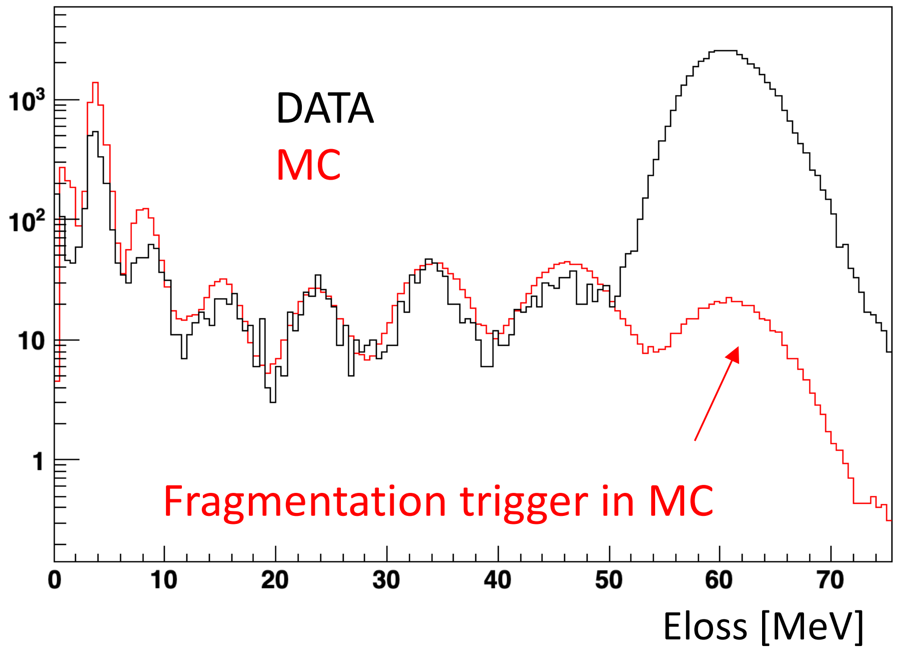
Eloss Calibration:

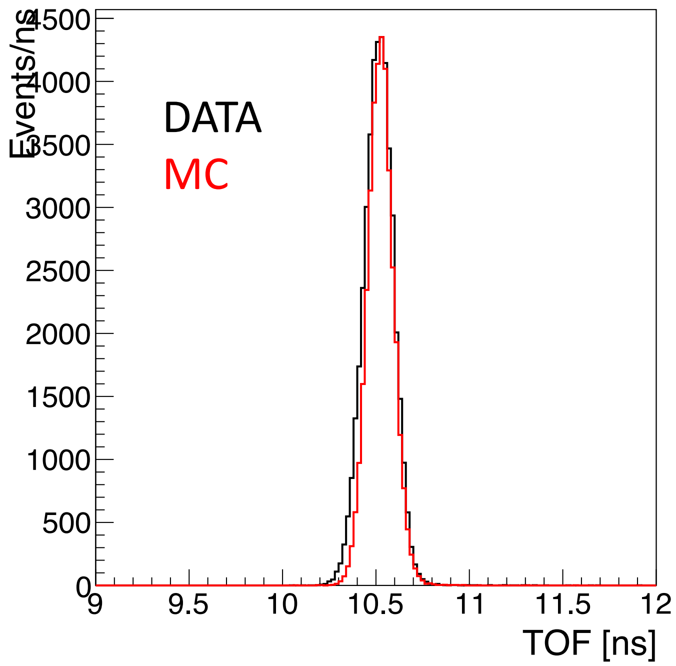
- "Tuned" and applied CNAO Pisa-calibration to GSI data
- Cross-checked with a GSI standalone calibration

ToF calibration:

- Calibration from 2242 for runs 2239,2240,2241
- Standalone calibration for run 2251

Calibration and tuning of MC on GSI DATA





Eloss Calibration:

- "Tuned" and applied CNAO Pisa-calibration to GSI data
- Cross-checked with a GSI standalone calibration

ToF calibration:

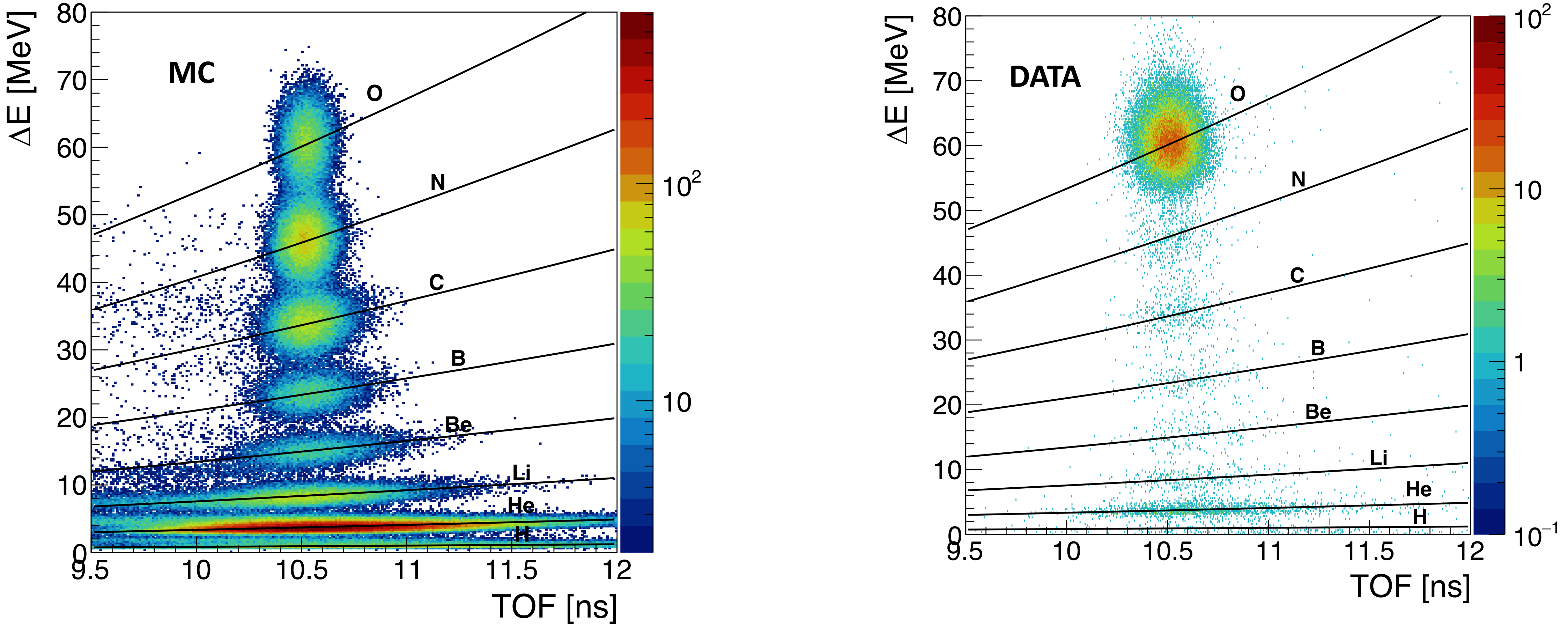
- Calibration from 2242 for runs 2239,2240,2241
- Standalone calibration for run 2251

In SHOE implemented reconstructed MC takes into account:

- Eloss, Tof and t_{TW} resolutions from CNAO data. Eloss threshold (cut away most of the protons) and dead bars @ GSI
- Time and position reconstruction from times Ta and Tb (data-like)
- Pile-up (multi-hit in the same bar per event) and fragment charge from ZID algorithm.

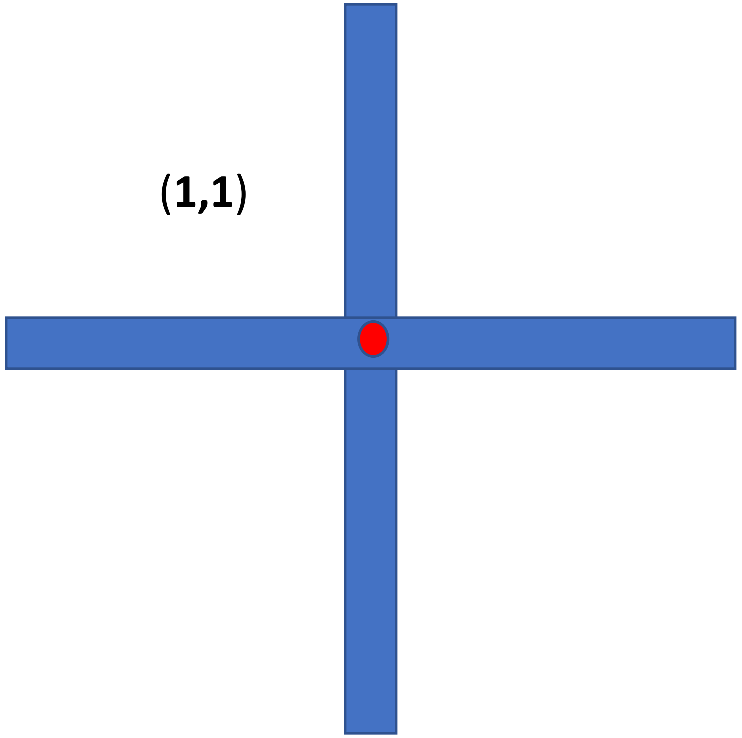
Charge identification (ZID) algorithm

Implemented in SHOE: need to be tuned for each new MC production (otherwise Zrec = Ztrue)



Yields extraction and TW Clustering

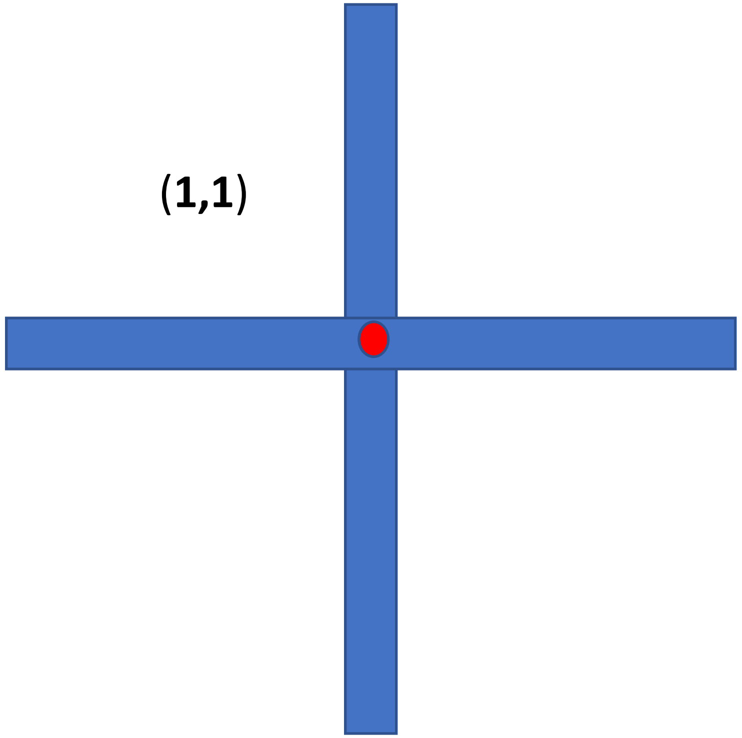
In order to extract fragment yields from cross sections measurement front and rear TW hits have to be clusterized.
New algorithm implemented in SHOE.



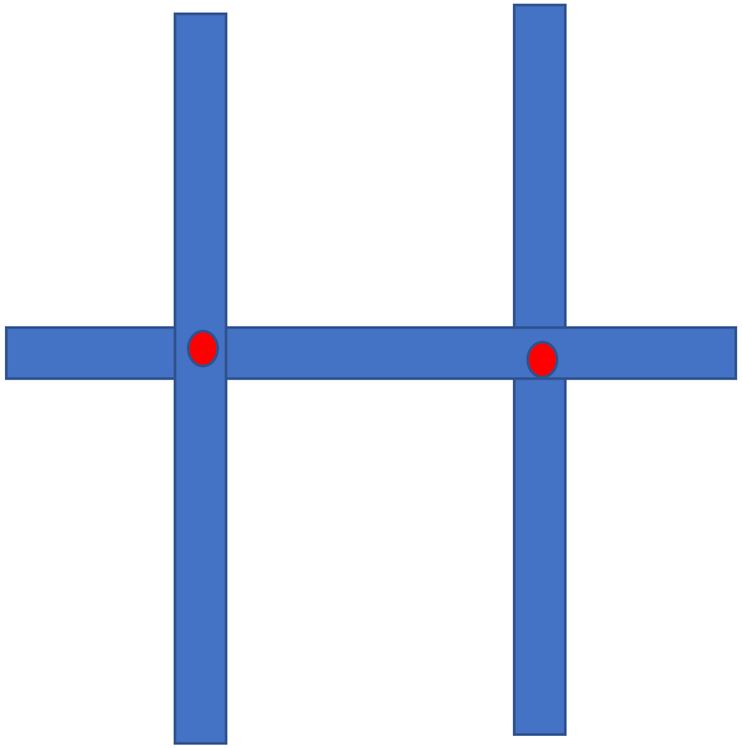
Yields extraction and TW Clustering

In order to extract fragment yields from cross sections measurement front and reat TW hits have to be clusterized.
New algorithm implemented in SHOE.

(1,1)



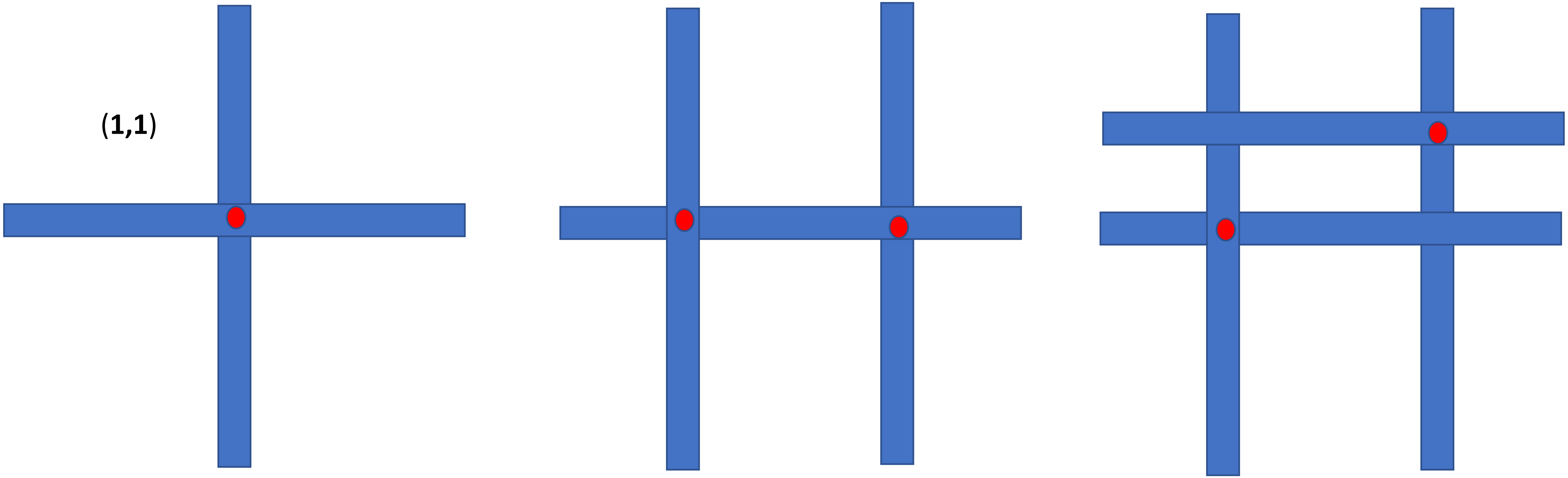
(1,N), (N,1), with N>1



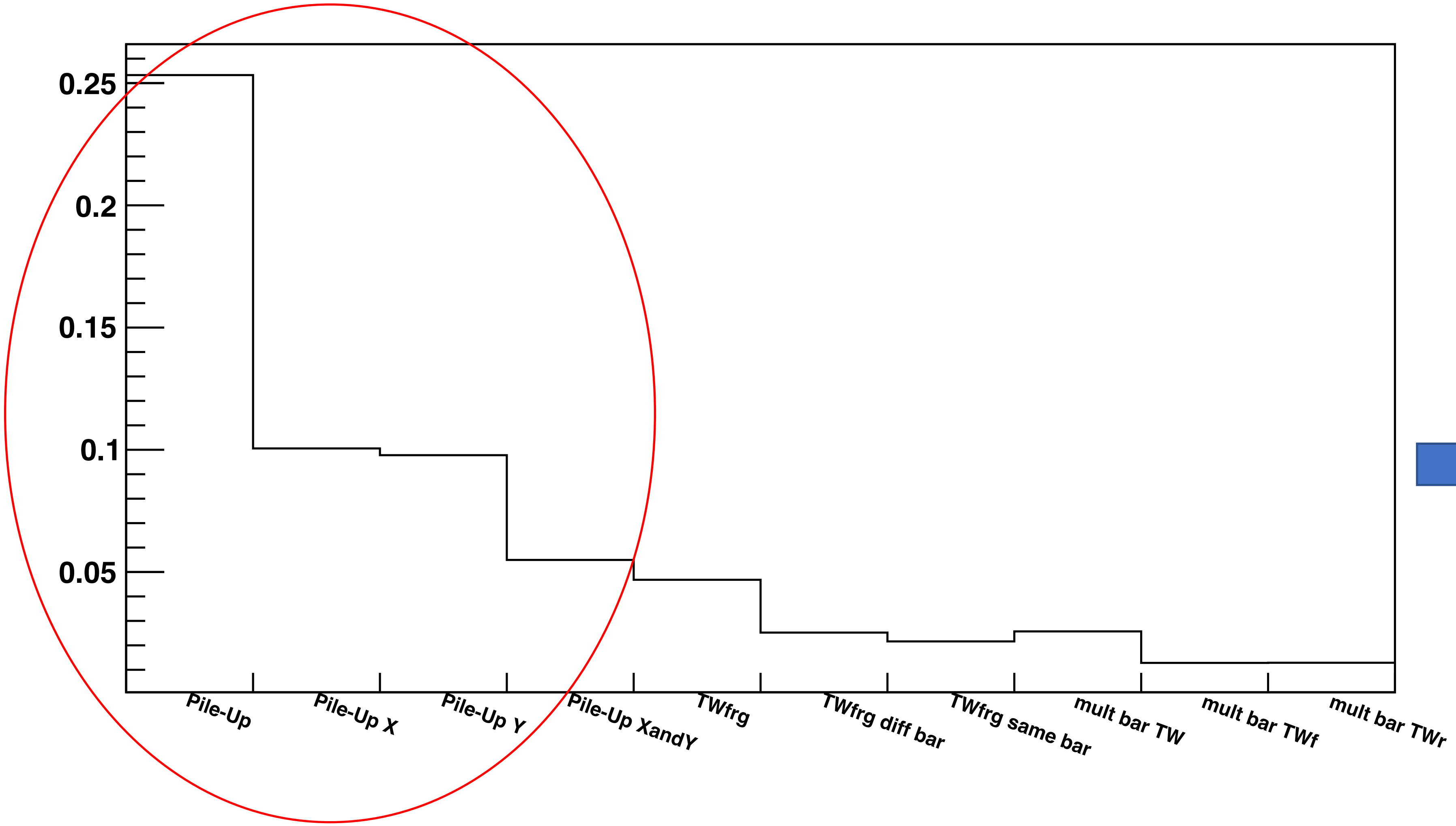
Yields extraction and TW Clustering

In order to extract fragment yields from cross sections measurement front and reat TW hits have to be clusterized.
New algorithm implemented in SHOE.

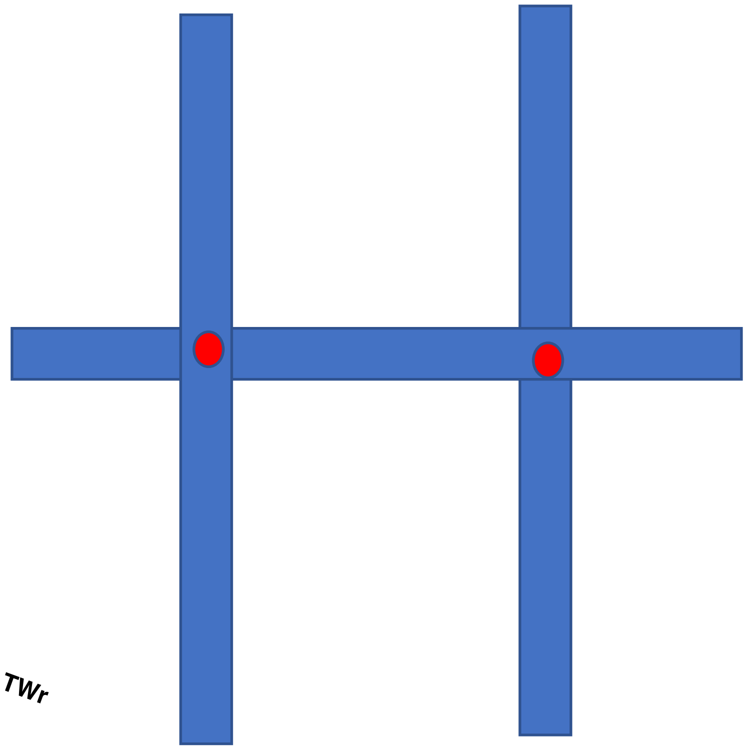
(1,N), (N,1), with N>1 **(N,M), (M,N), with N,M>1**



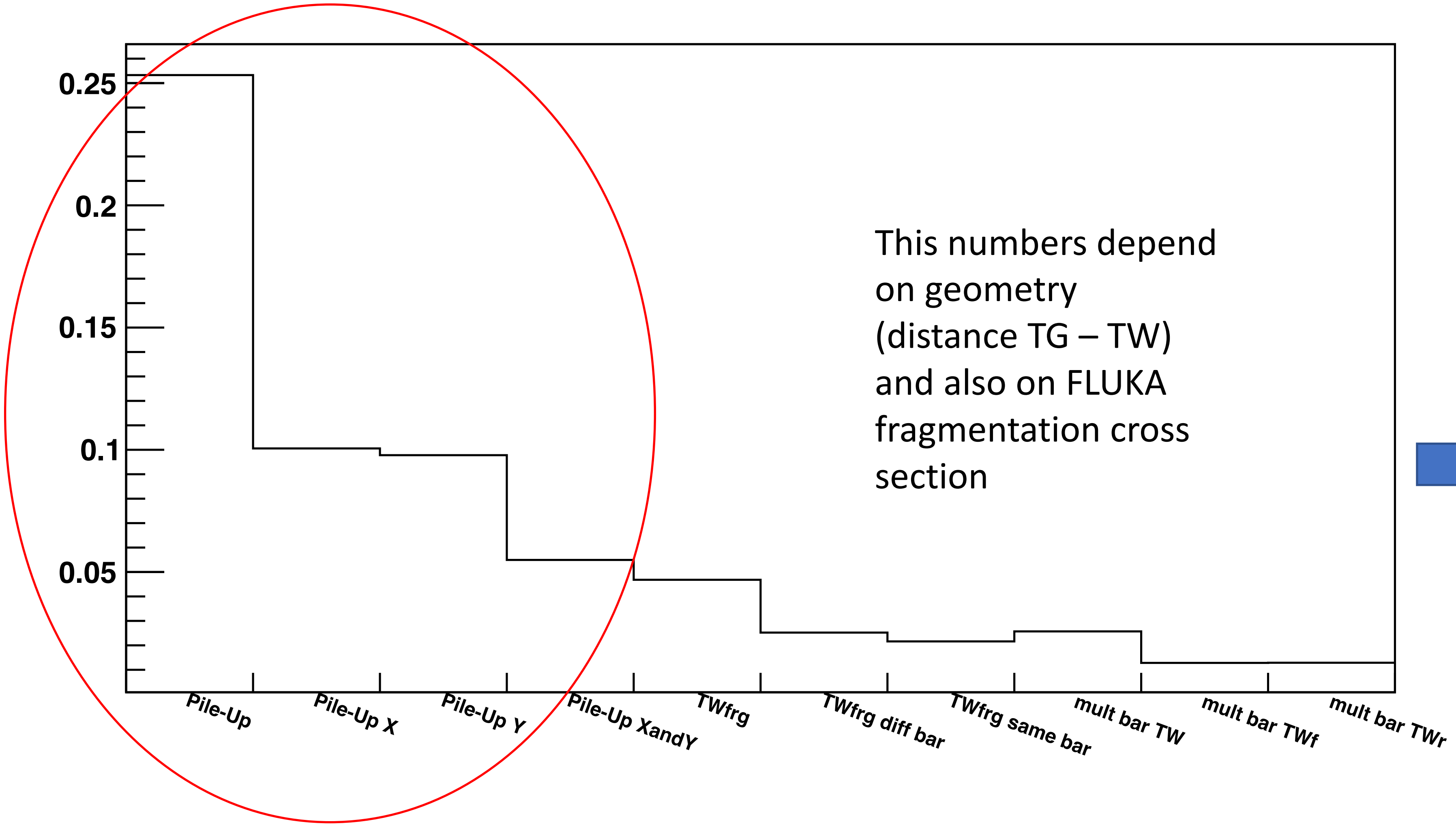
Yields extraction and TW Clustering



Pile-Up (multi-hits)

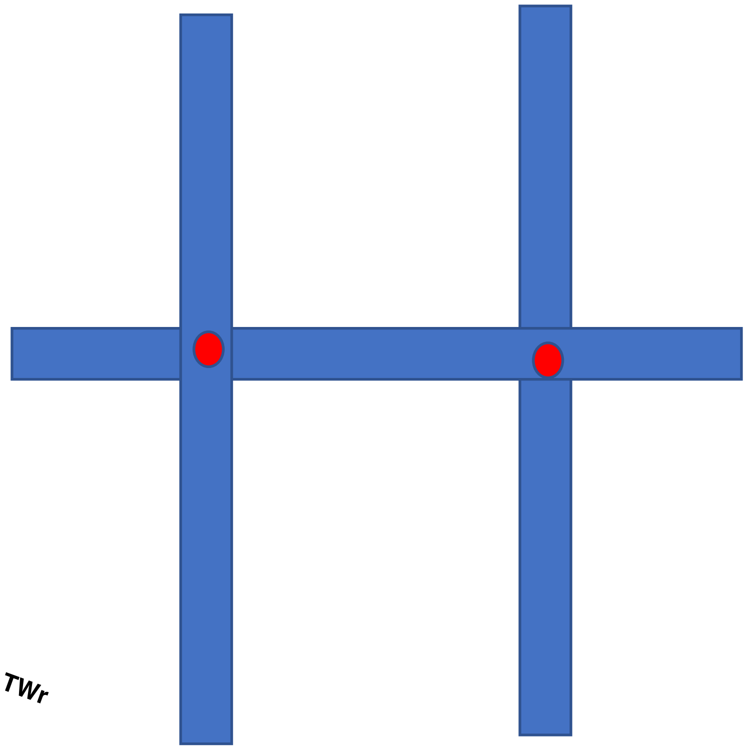


Yields extraction and TW Clustering

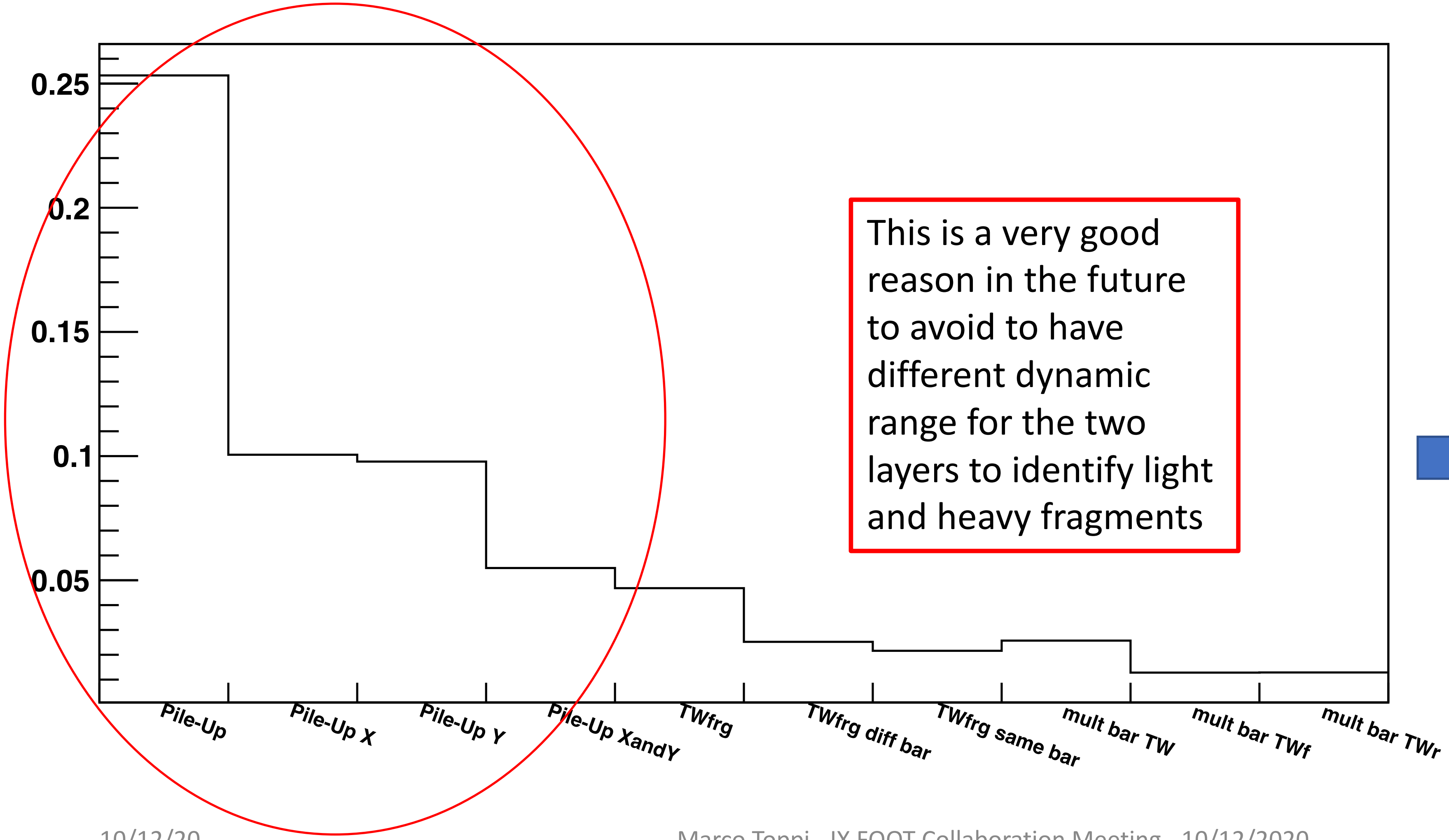


This numbers depend on geometry (distance TG – TW) and also on FLUKA fragmentation cross section

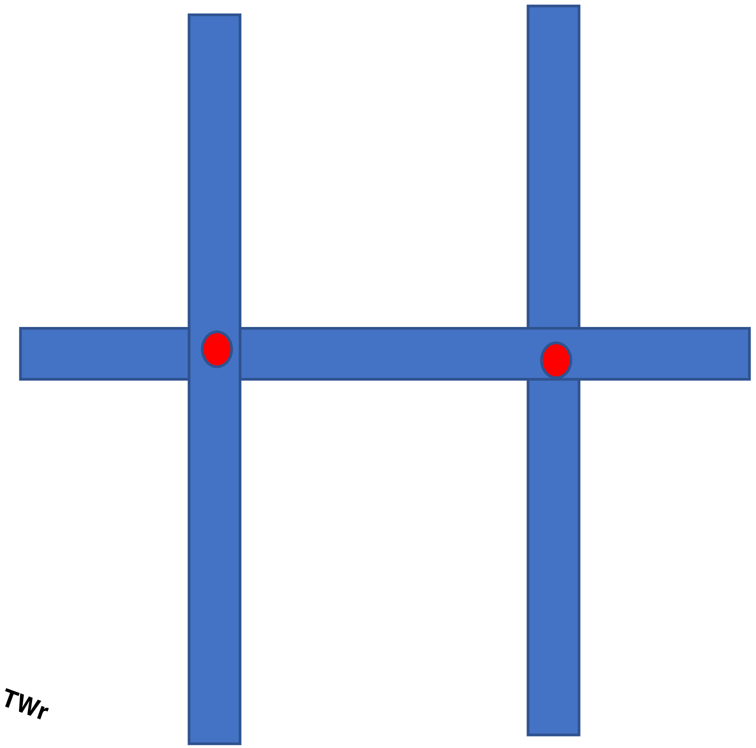
Pile-Up (multi-hits)



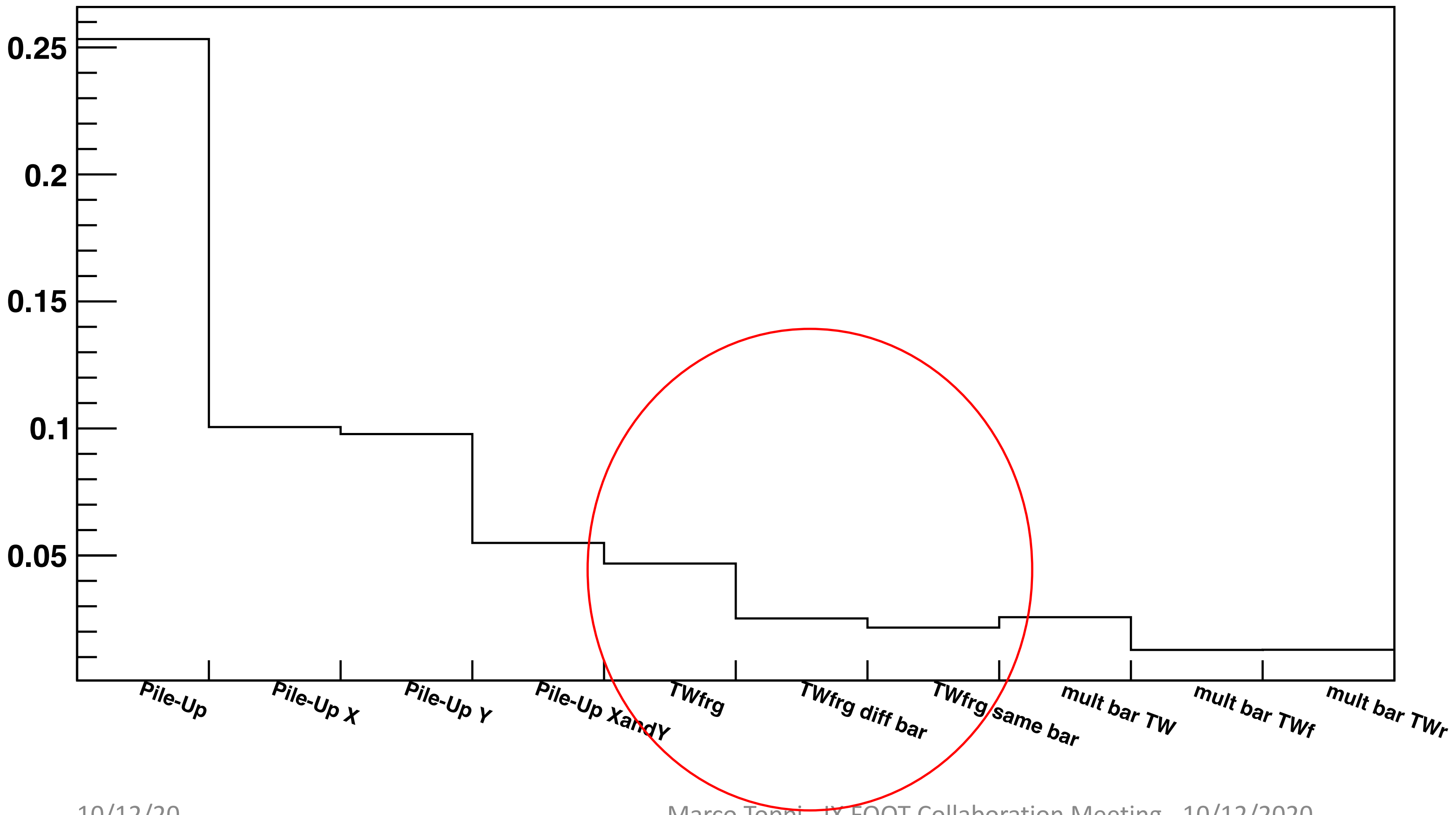
Yields extraction and TW Clustering



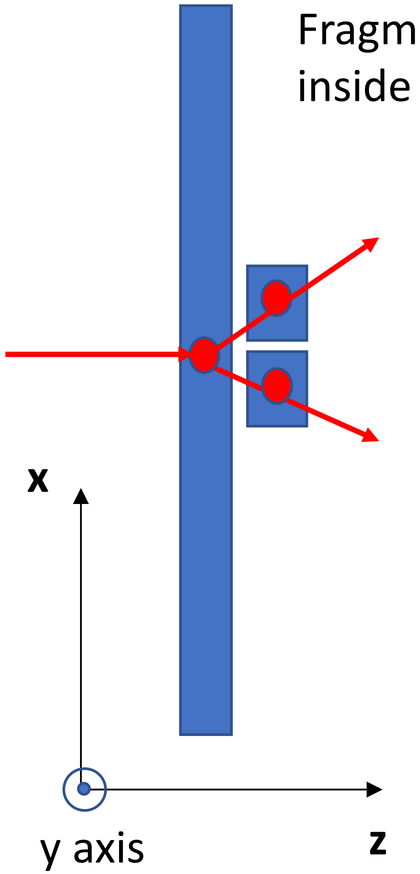
Pile-Up (multi-hits)



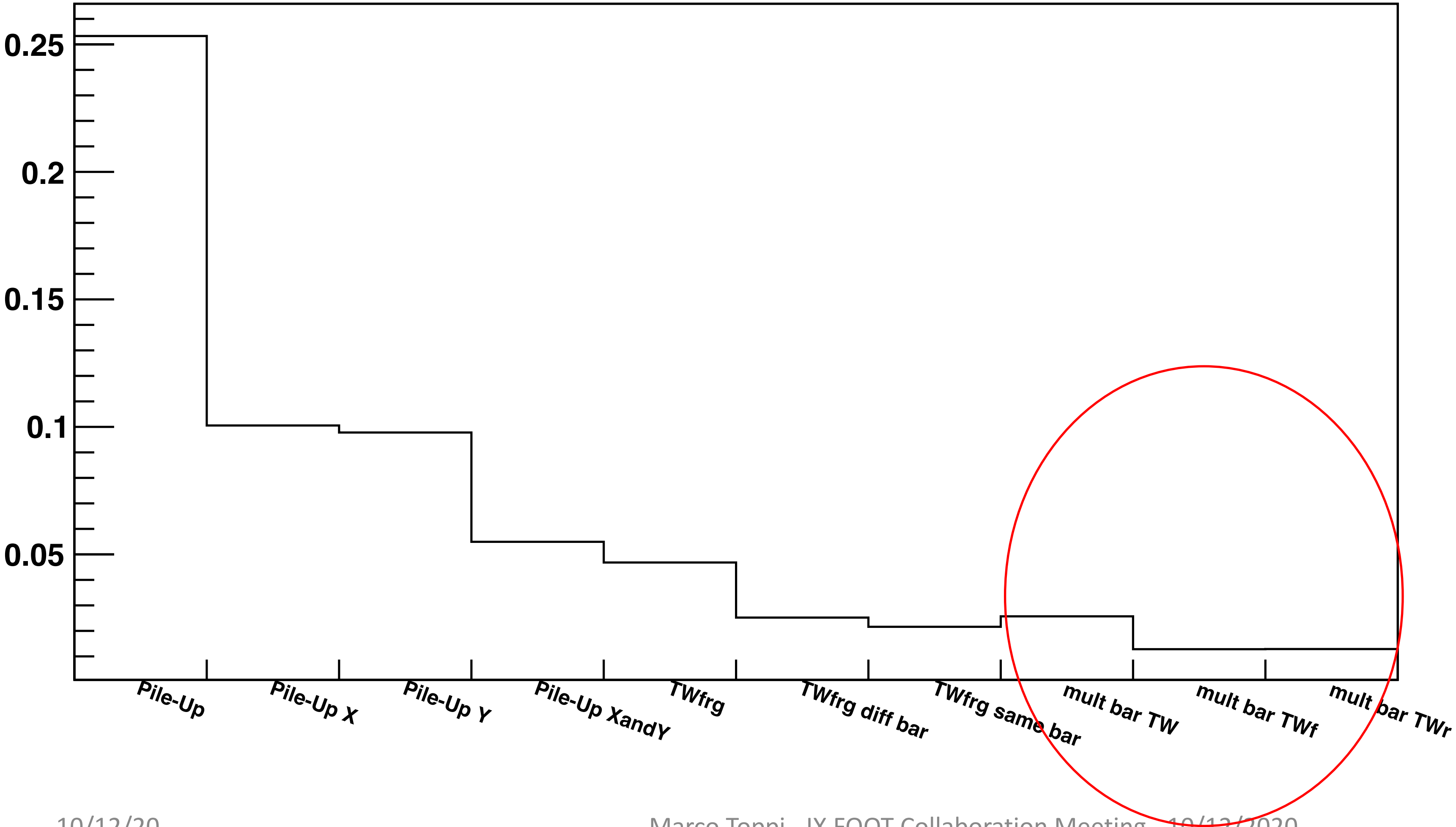
Yields extraction and TW Clustering

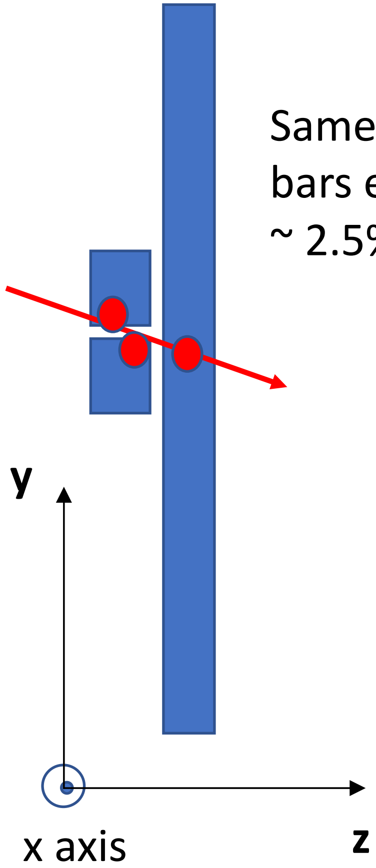


Fragmentation inside TW ~ 2.5%



Yields extraction and TW Clustering

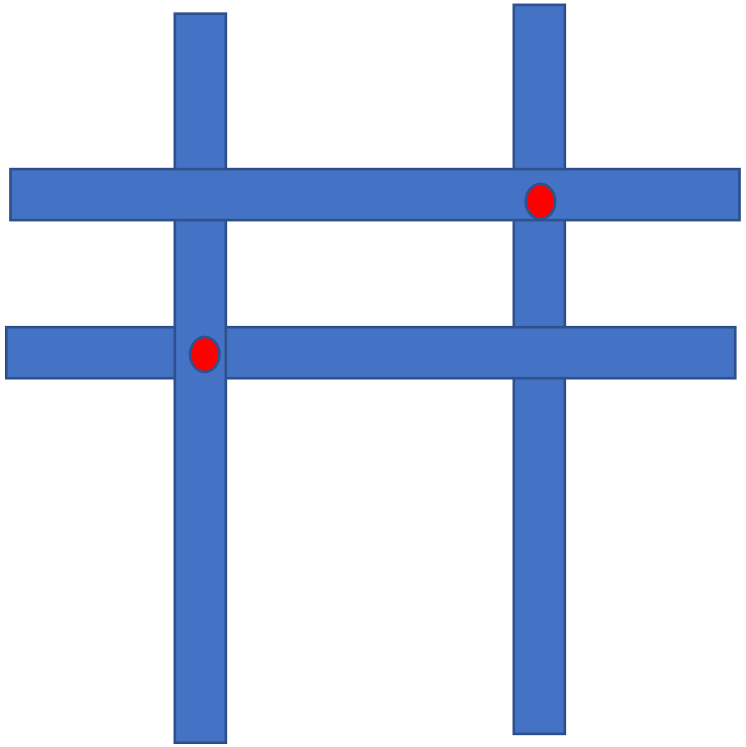




Same layer multi-bars events
~ 2.5%

Yields extraction and TW Clustering

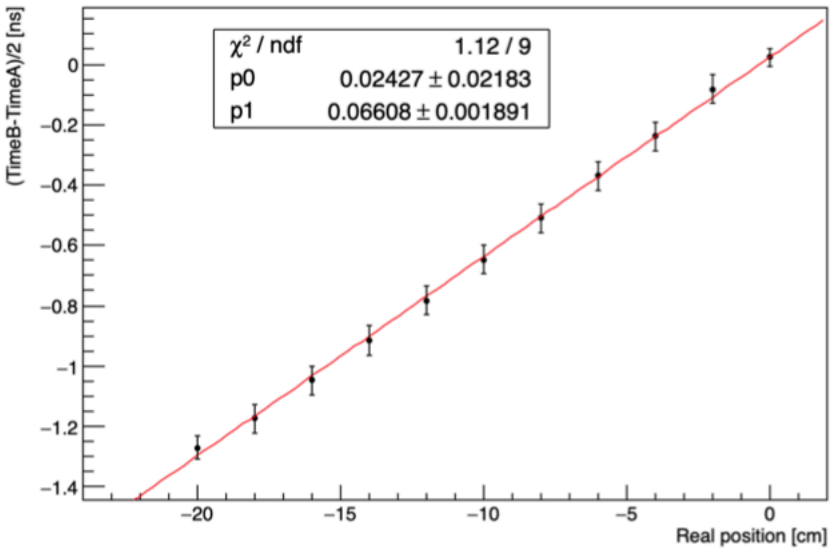
Same situation of above + problem of the ghosts→ to be managed with measurement of the position along the bar exploiting the time difference DeltaT at the edges of the bar



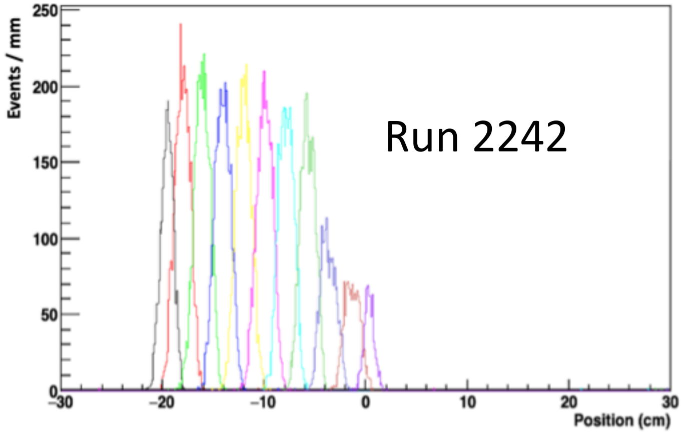
(N,M), (M,N), with N,M>1

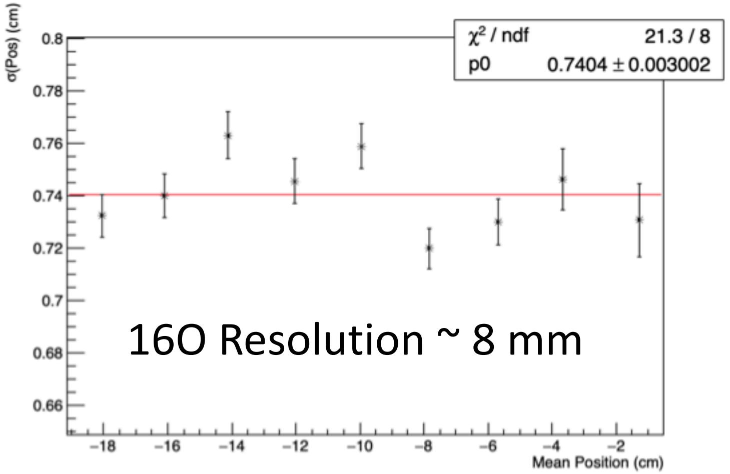
Yields extraction and TW Clustering

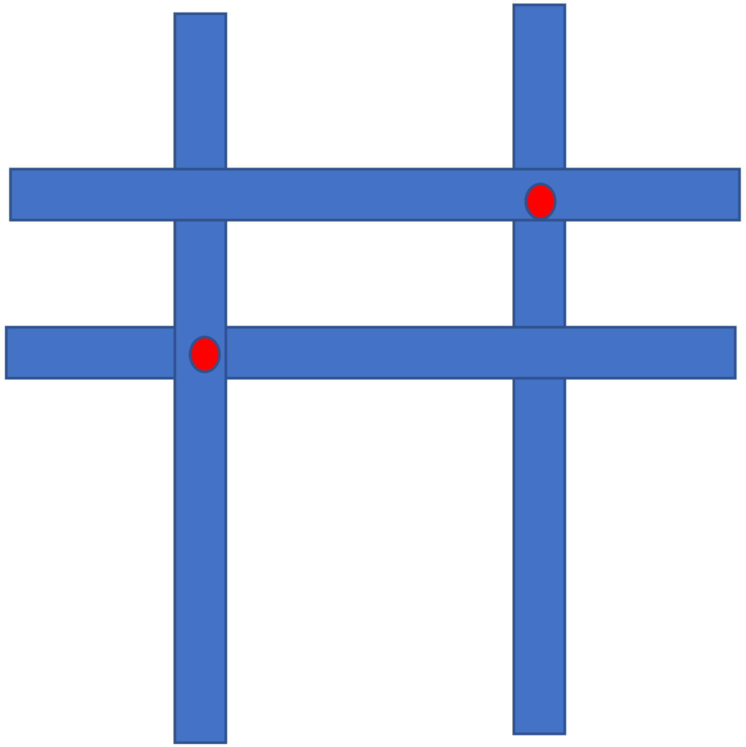
Same situation of above + problem of the ghosts→ to be managed with measurement of the position along the bar exploiting the time difference DeltaT at the edges of the bar



Light speed in the bars v:
1/v ~ 66 ps/cm







(N,M), (M,N), with N,M>1

TW Clustering algorithm

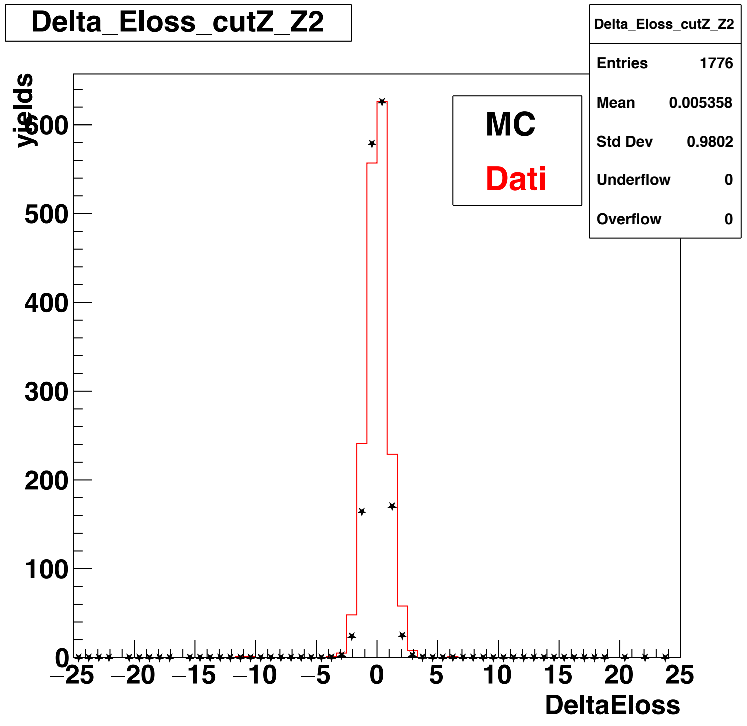
- From these simple observations I follow the simple idea to train the TW cluster/point with the hits from the TW layer with higher occupancy to avoid to drop 25% of events due to pile-up
- When there is the same number of hits in the two layers the front hits train the clusters
- Noise can be further strongly reduced asking Zfront = Zrear (best choice in the end)

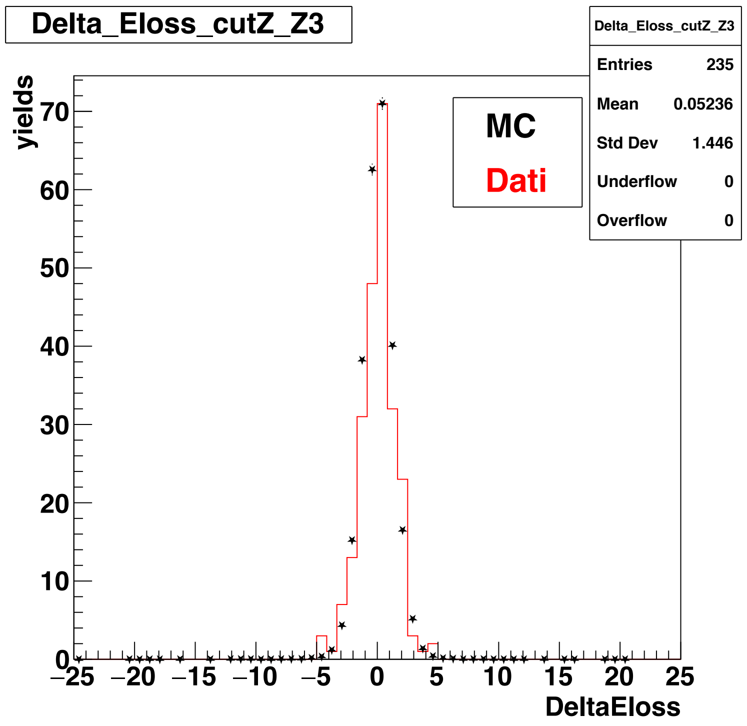
In SHOE: for each TWpoint the charge of the training hit and its MC track ID (useful for efficiencies evaluation) are assigned to the point

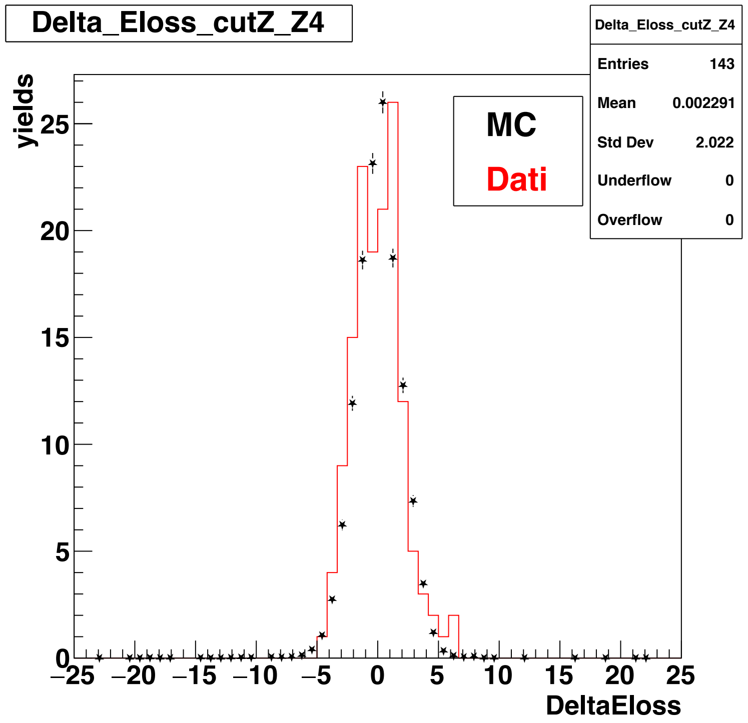
This fact, matched with the good position resolution from deltaT (better than bar crossing resolution), is a good reason in the future to keep as in GSI horizontal bars in the front layers and vertical in rear → actually this study should be repeated in presence of the magnetic field

Implementation of TW Clustering in SHOE

Checking algorithm comparing Eloss and Tof of hits matched to the cluster

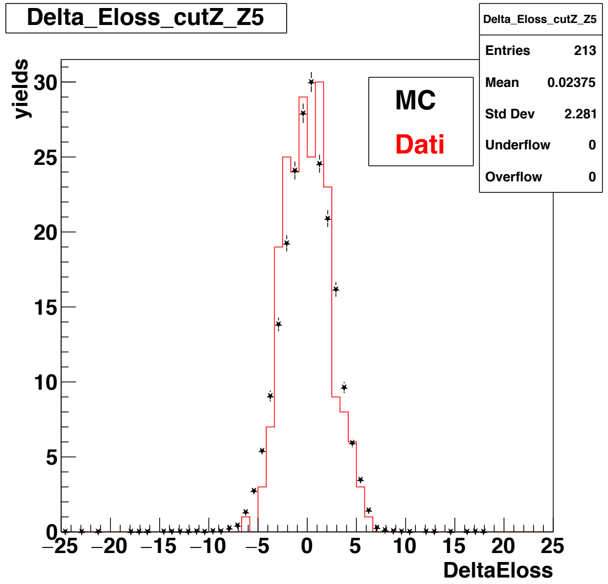


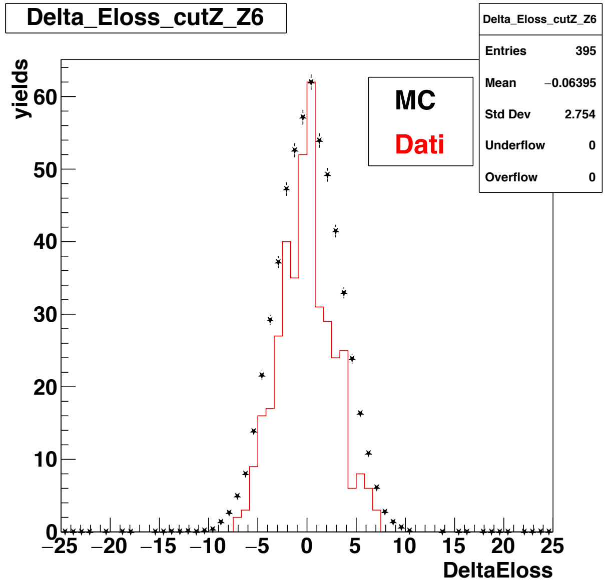


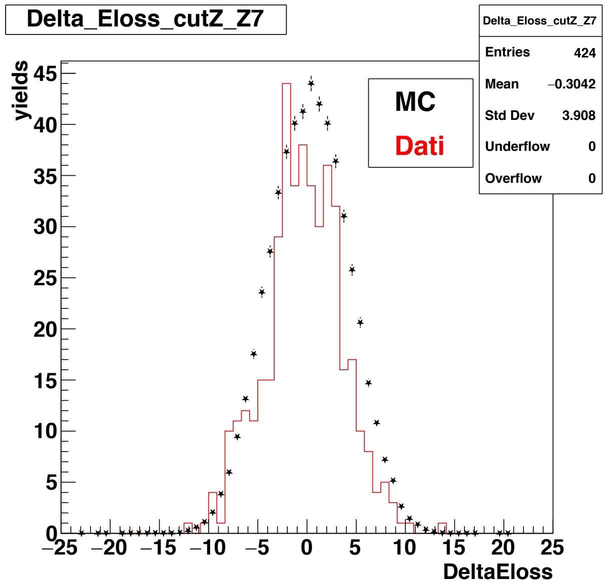


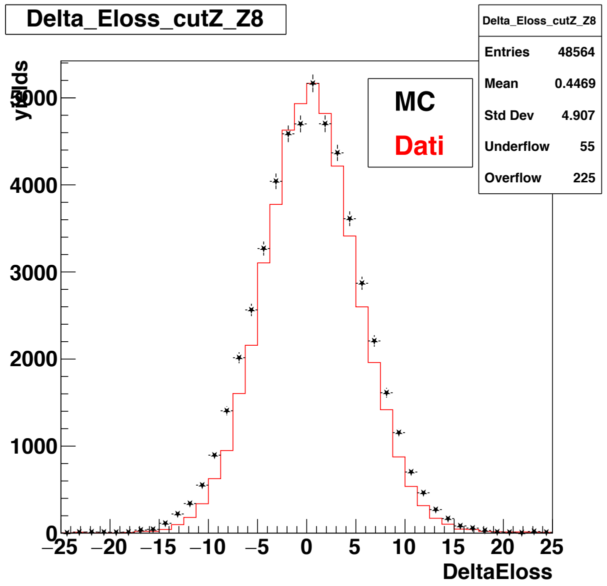
Implementation of TW Clustering in SHOE

Checking algorithm comparing Eloss and Tof of hits matched to the cluster



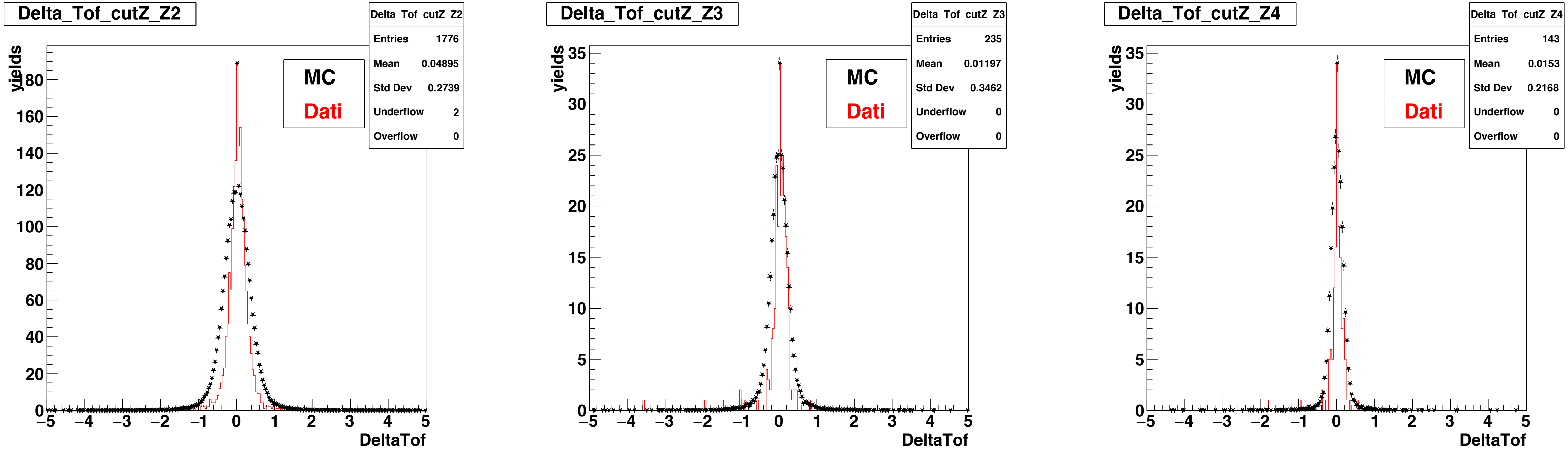






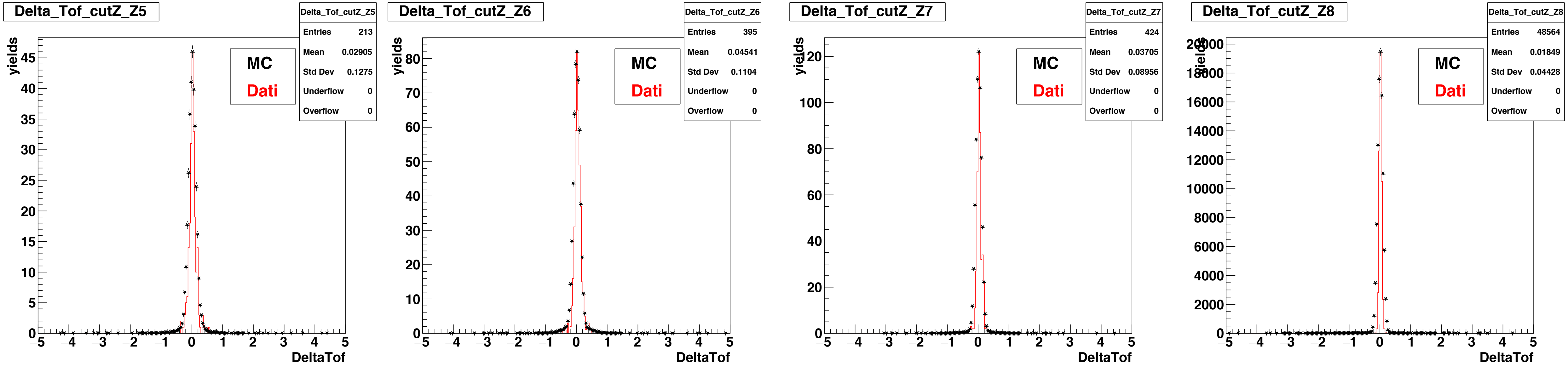
Implementation of TW Clustering in SHOE

Checking algorithm comparing Eloss and Tof of hits matched to the cluster

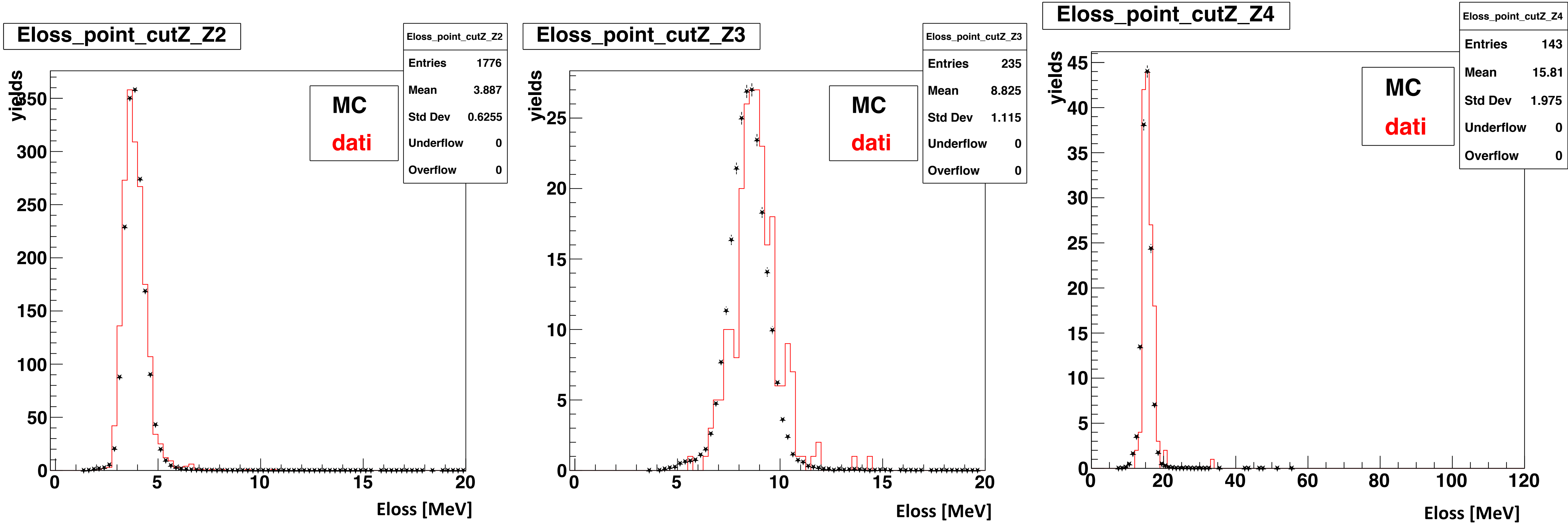


Implementation of TW Clustering in SHOE

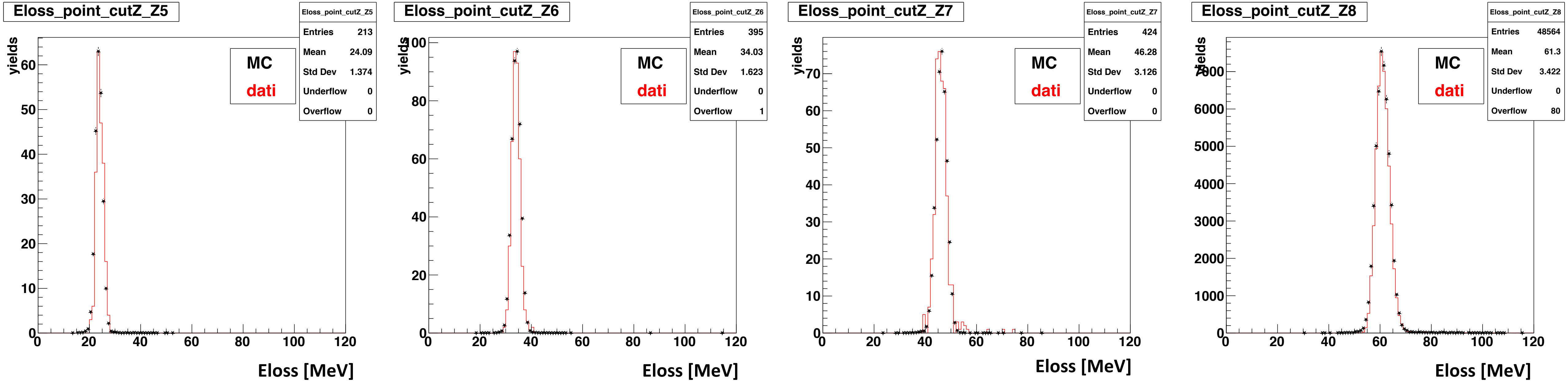
Checking algorithm comparing Eloss and Tof of hits matched to the cluster



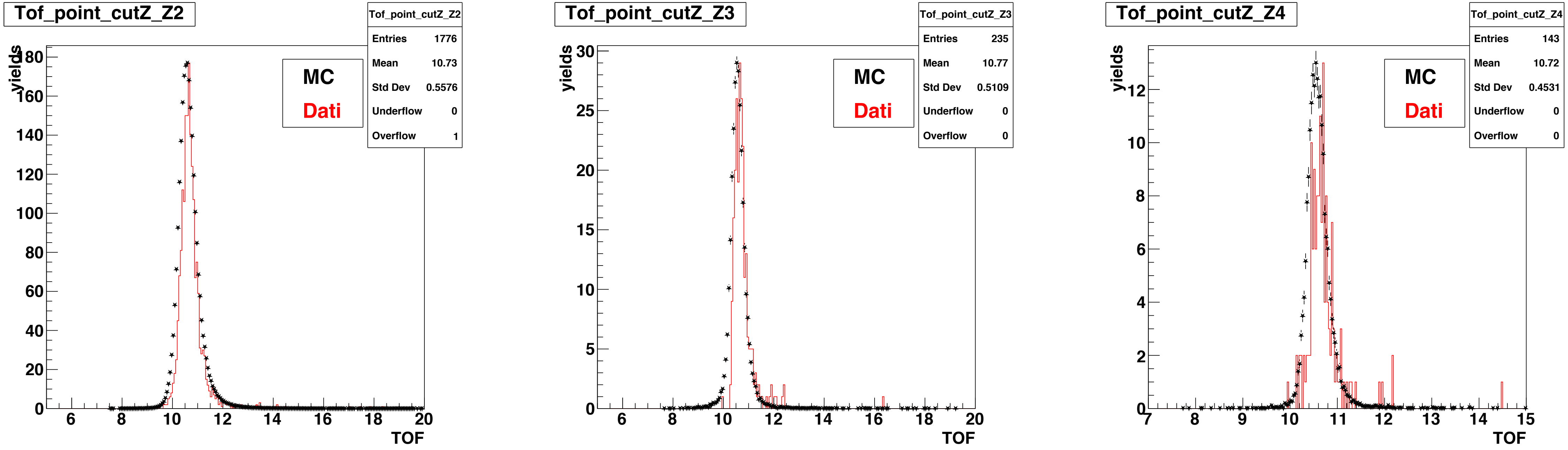
Implementation of TW Clustering in SHOE



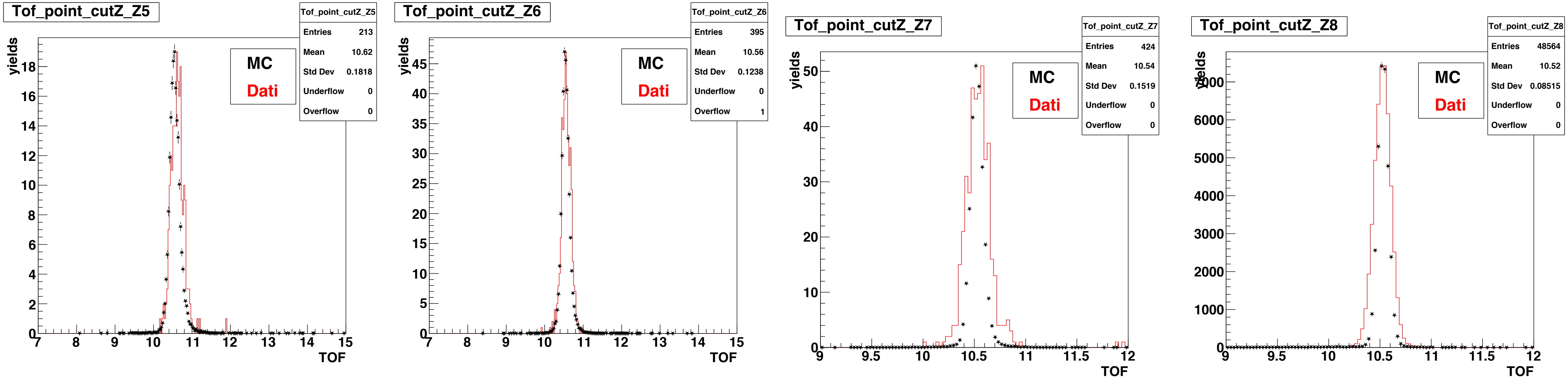
Implementation of TW Clustering in SHOE



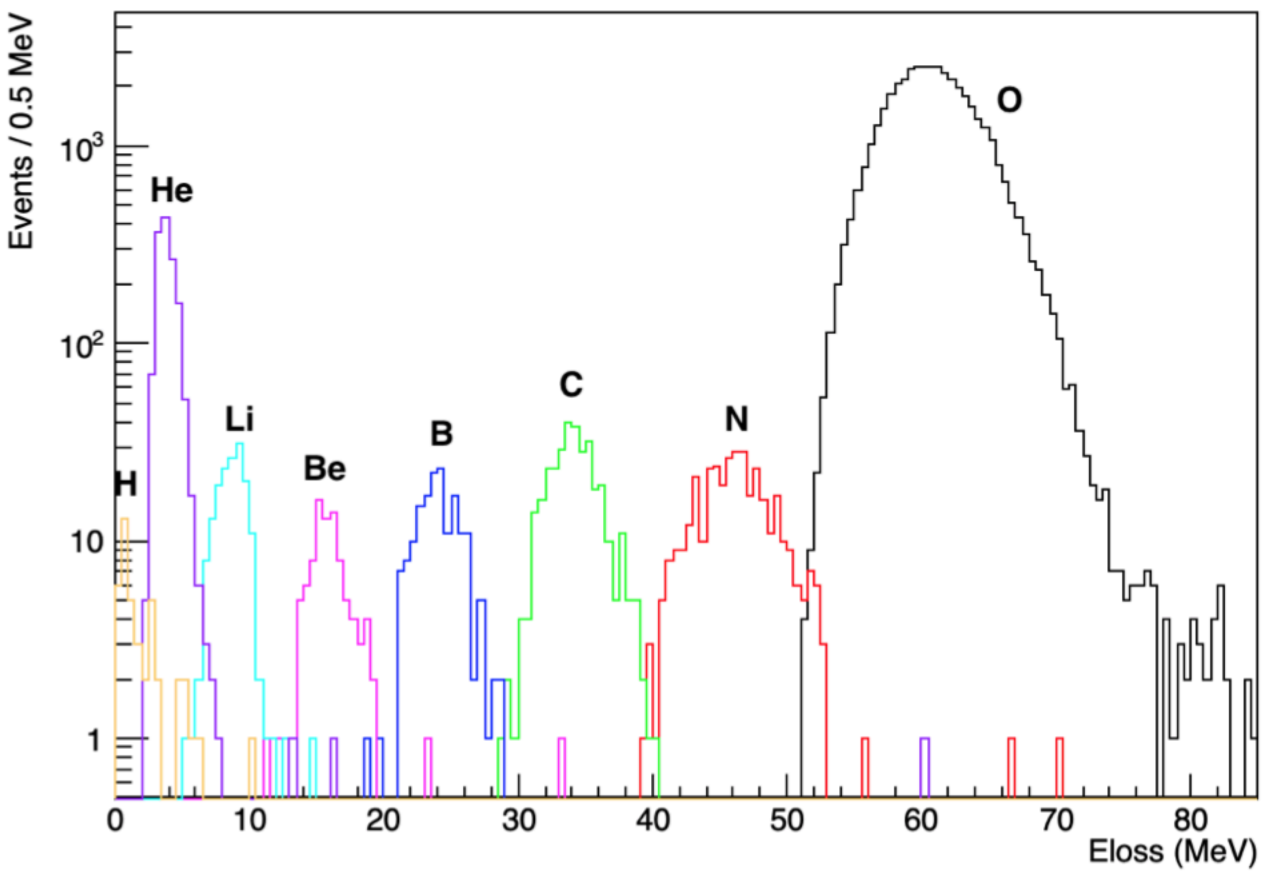
Implementation of TW Clustering in SHOE



Implementation of TW Clustering in SHOE



Implementation of TW Clustering in SHOE

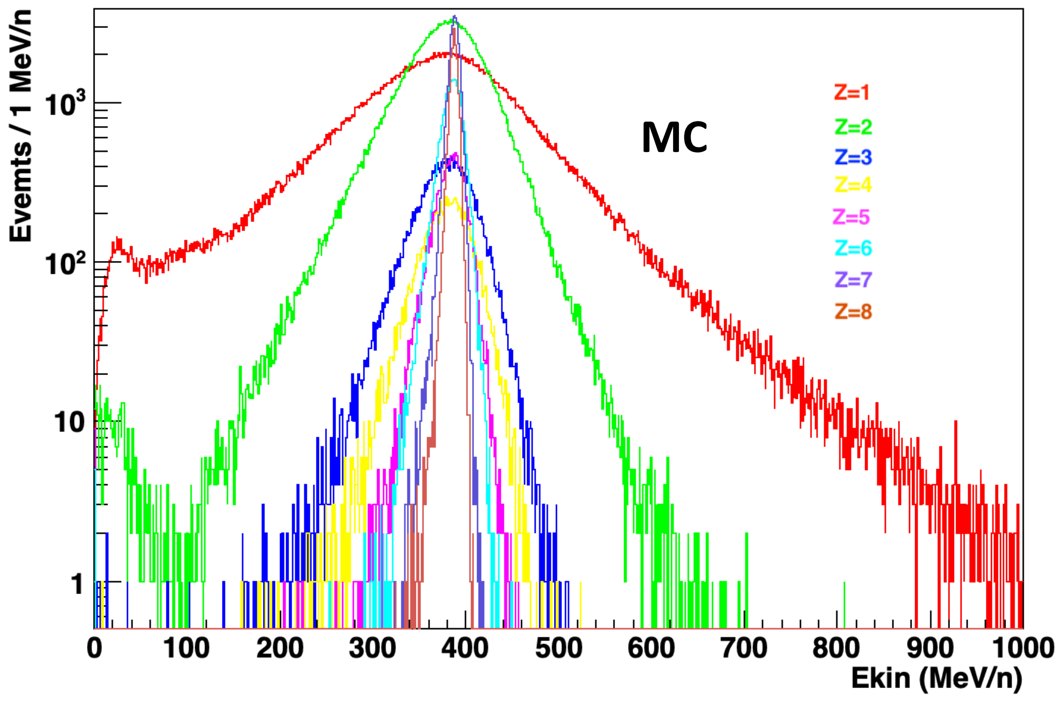


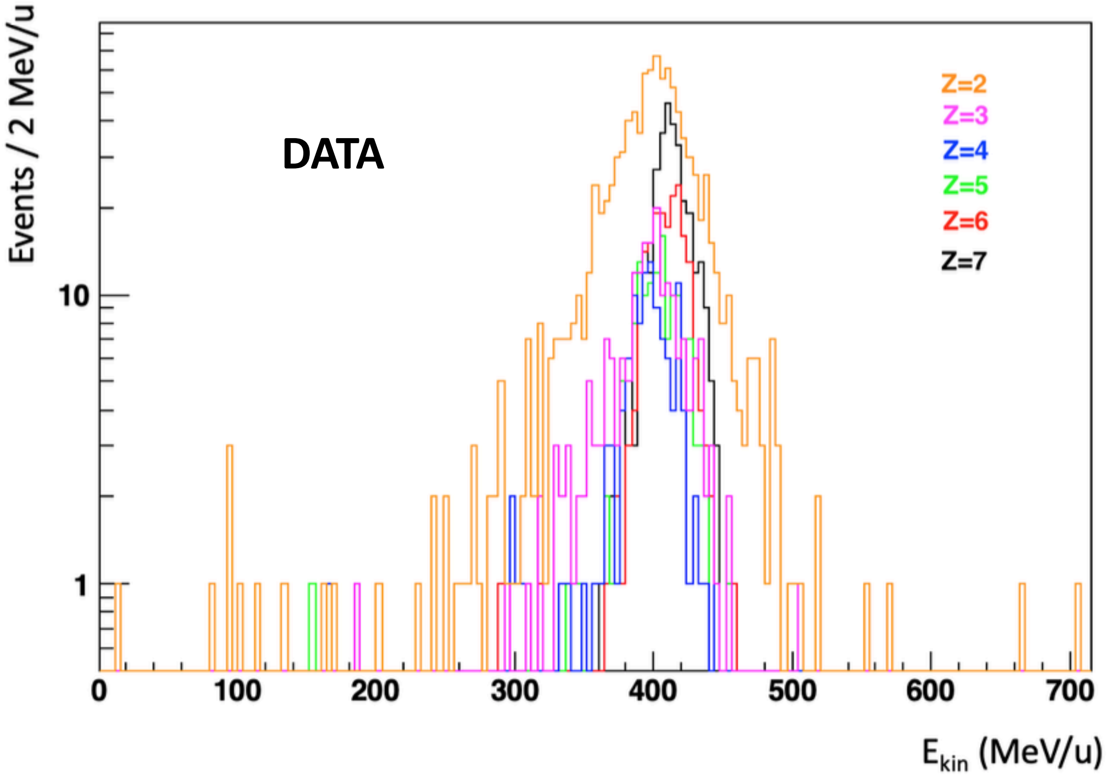
The combination of the Z identification and clustering algorithms implemented in SHOE provide a very good fragment charge identification on an event-by-event basis (DATA!!)

Provide the fragment yields for the measurement of the cross section

Efficiencies: denominator

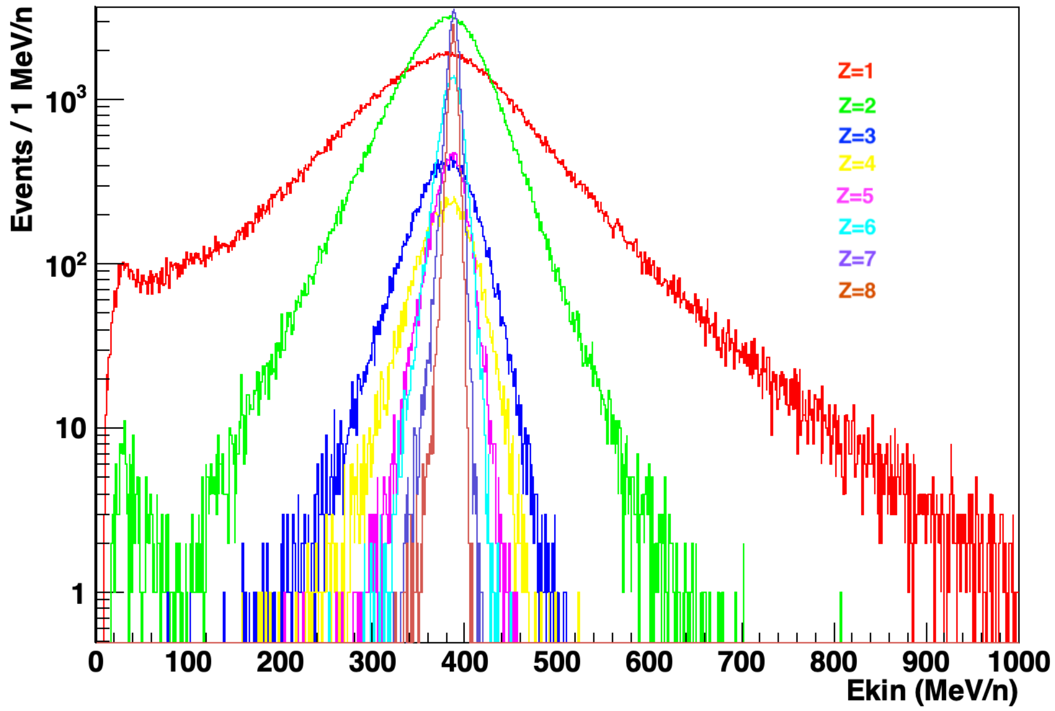
Production E_{kin} distribution of fragments out of TG





<u>Denominator</u>: Asking for only primary fragments with origin in Target produced on the TG in [-0.7,0.7] and escaping from it with θ<5.7° and an Ekin in the interval 200-600 MeV/n (from data distribution)

Efficiencies: numerator

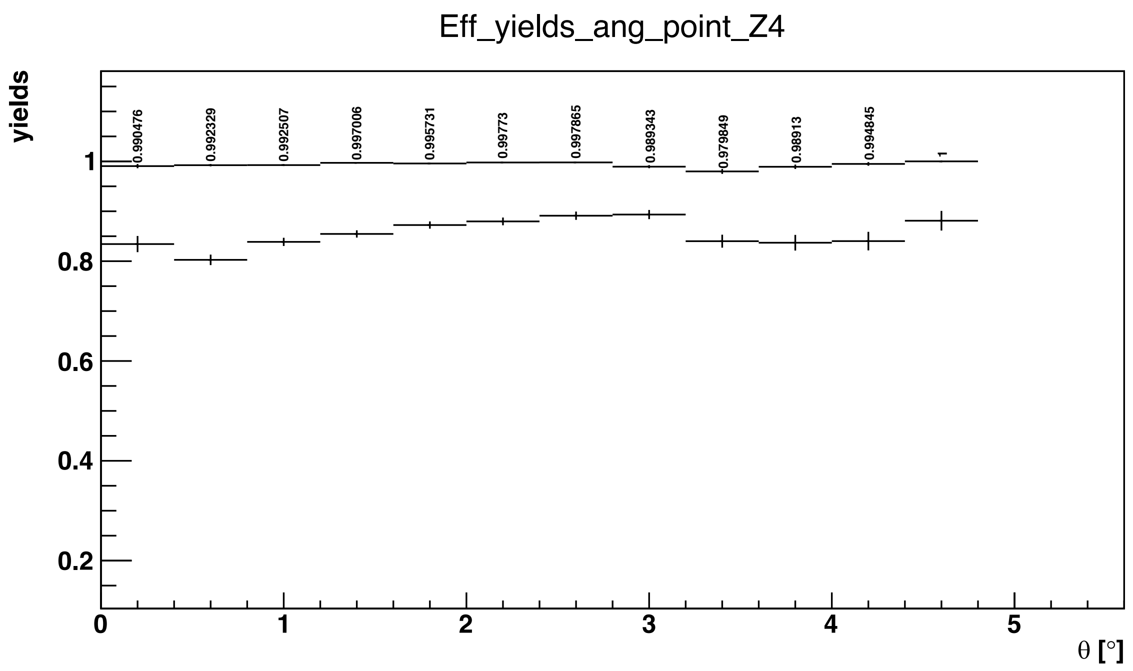


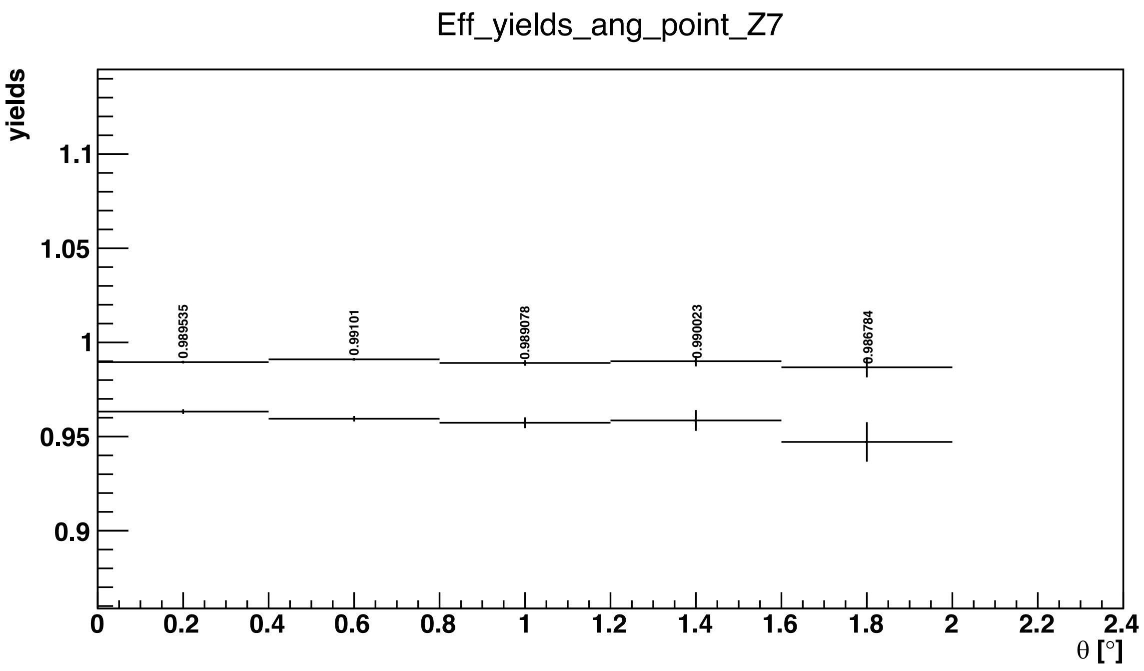
<u>Numerator</u>: Asking for a good TWpoint matched to primary fragments with origin in Target with production angle < 5.7° , beam projection on TG in [-0.7,0.7] and production Ekin in the range [200,600] MeV/n.

In reconstructed MC **Pile-Up is switched off and Z=Ztrue** (not reconstructed Z)

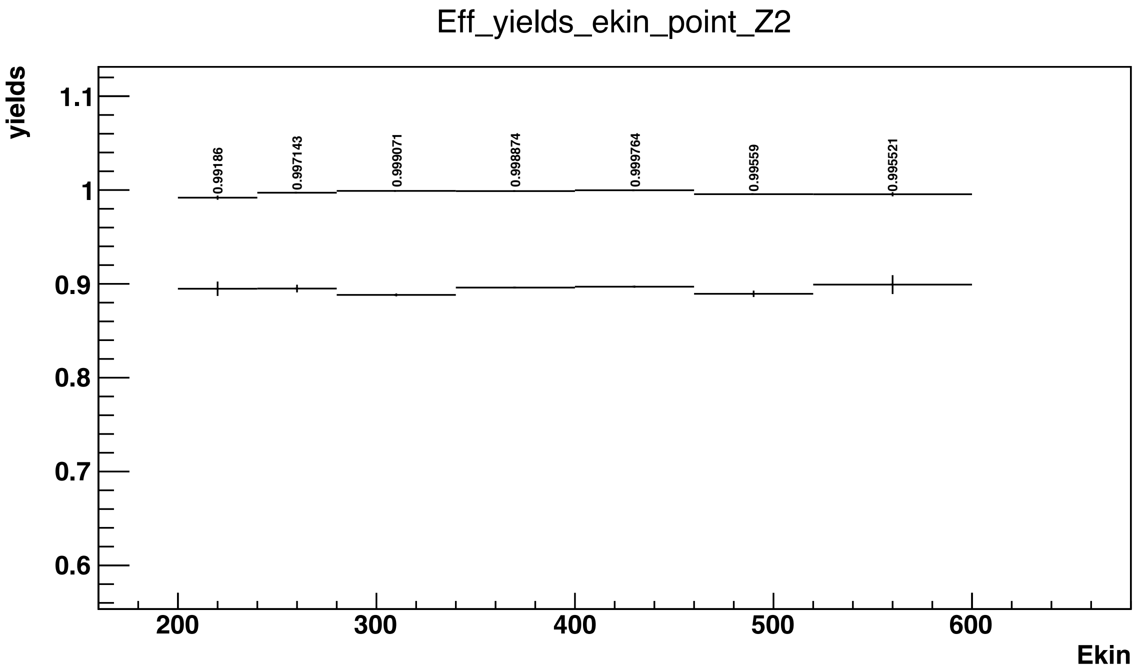
ON/OFF Request: Z_front = Z_rear

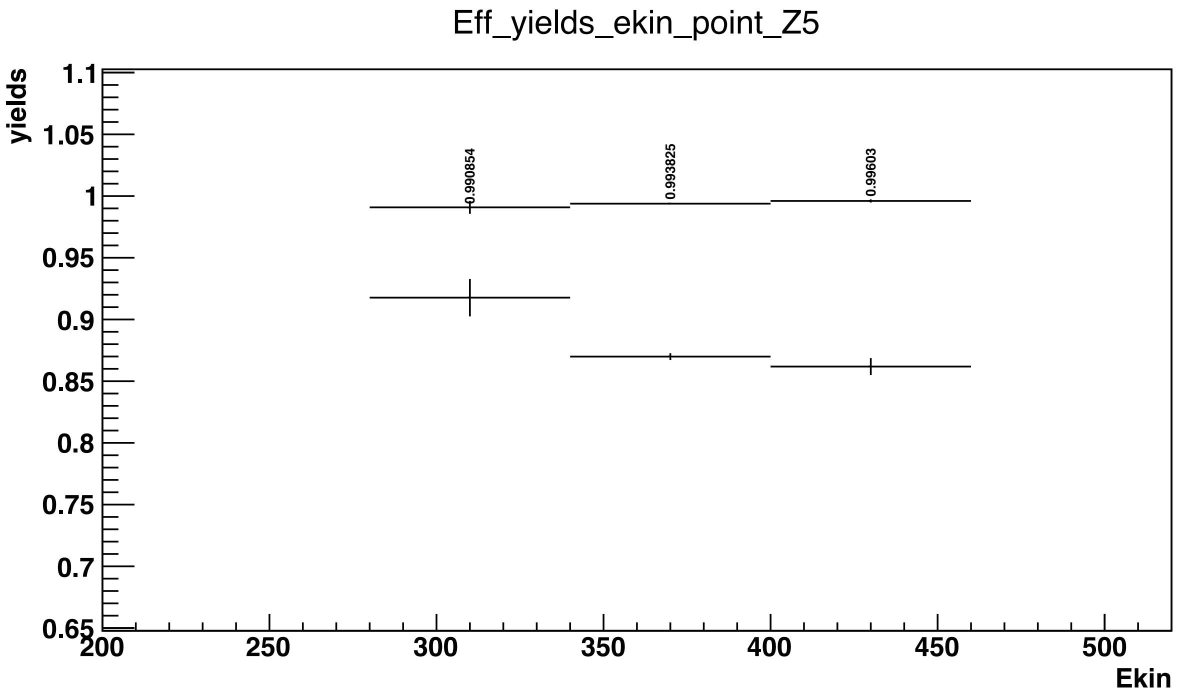
Angular efficiencies



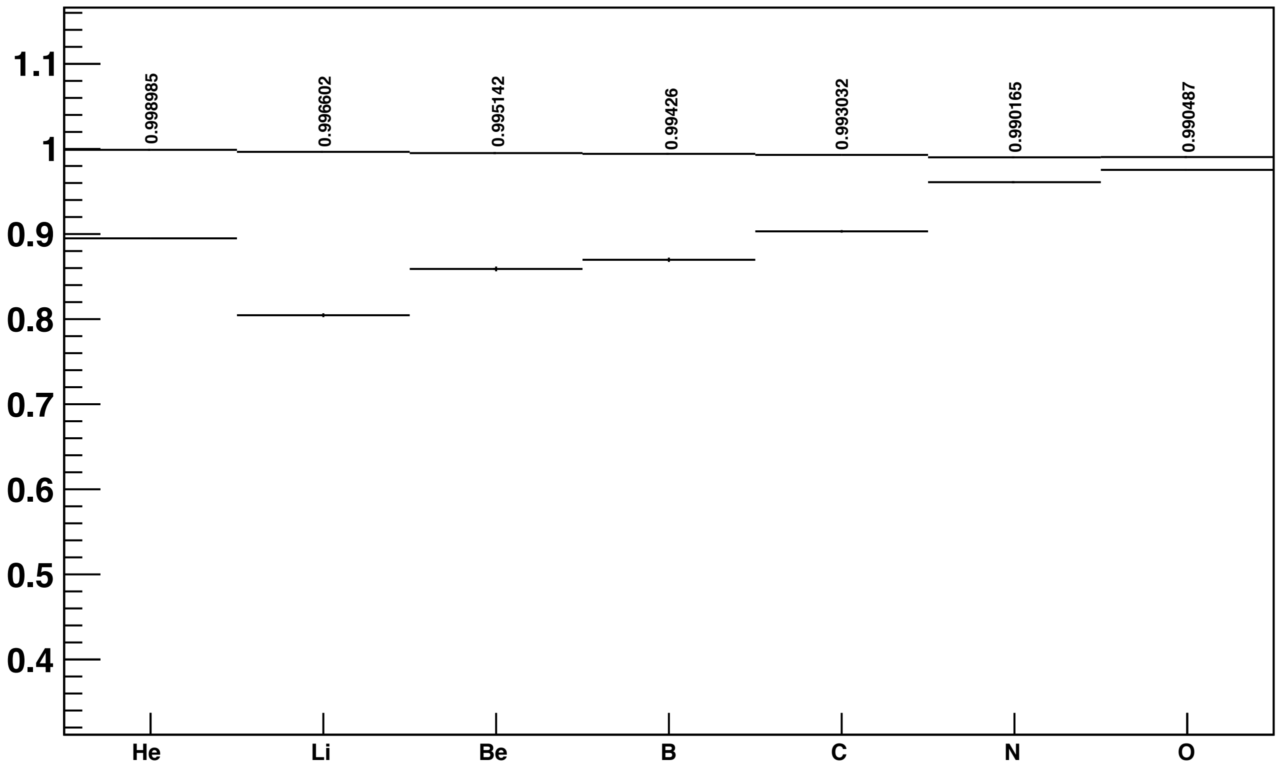


Energy efficiencies



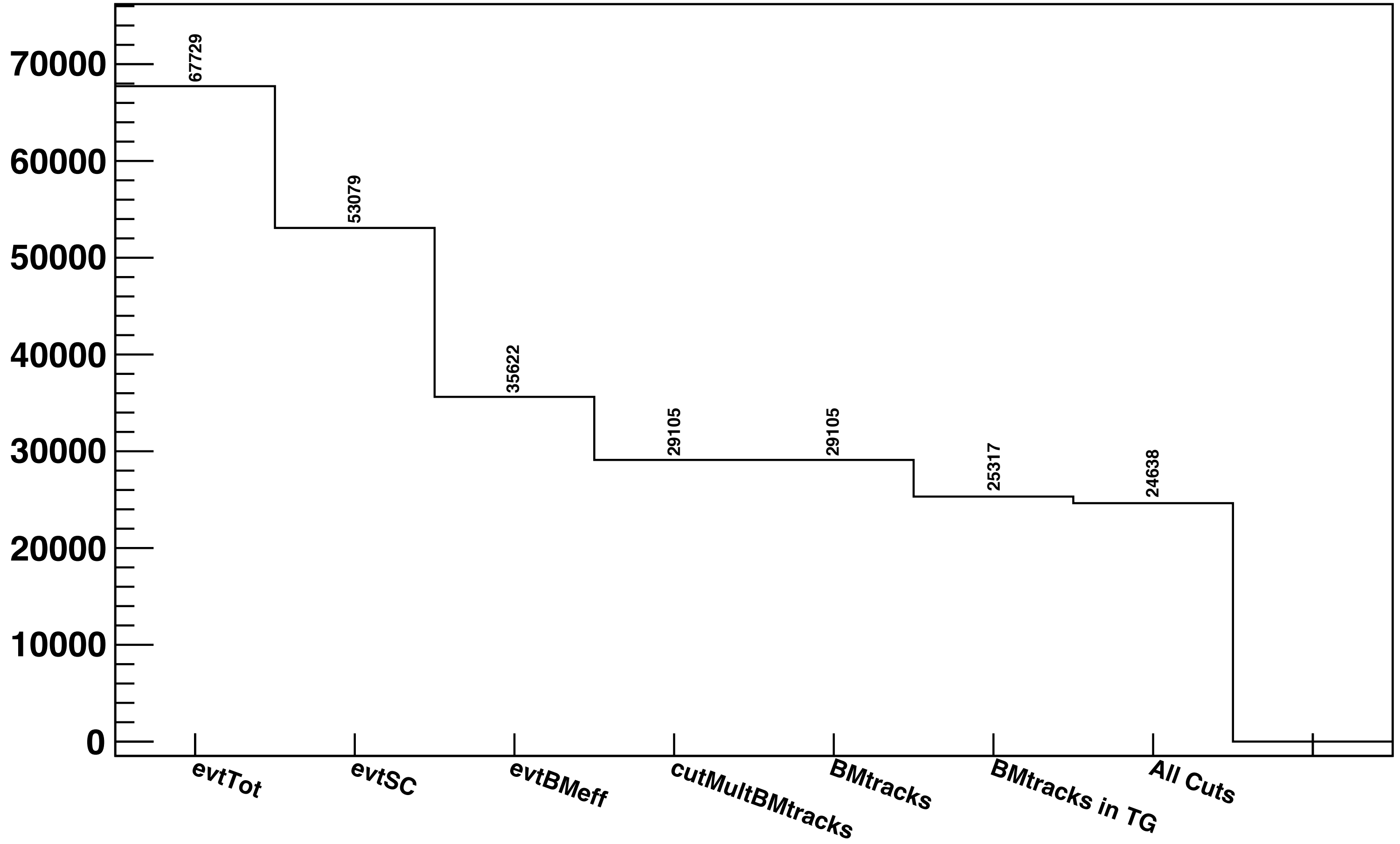


"Integral" efficiencies



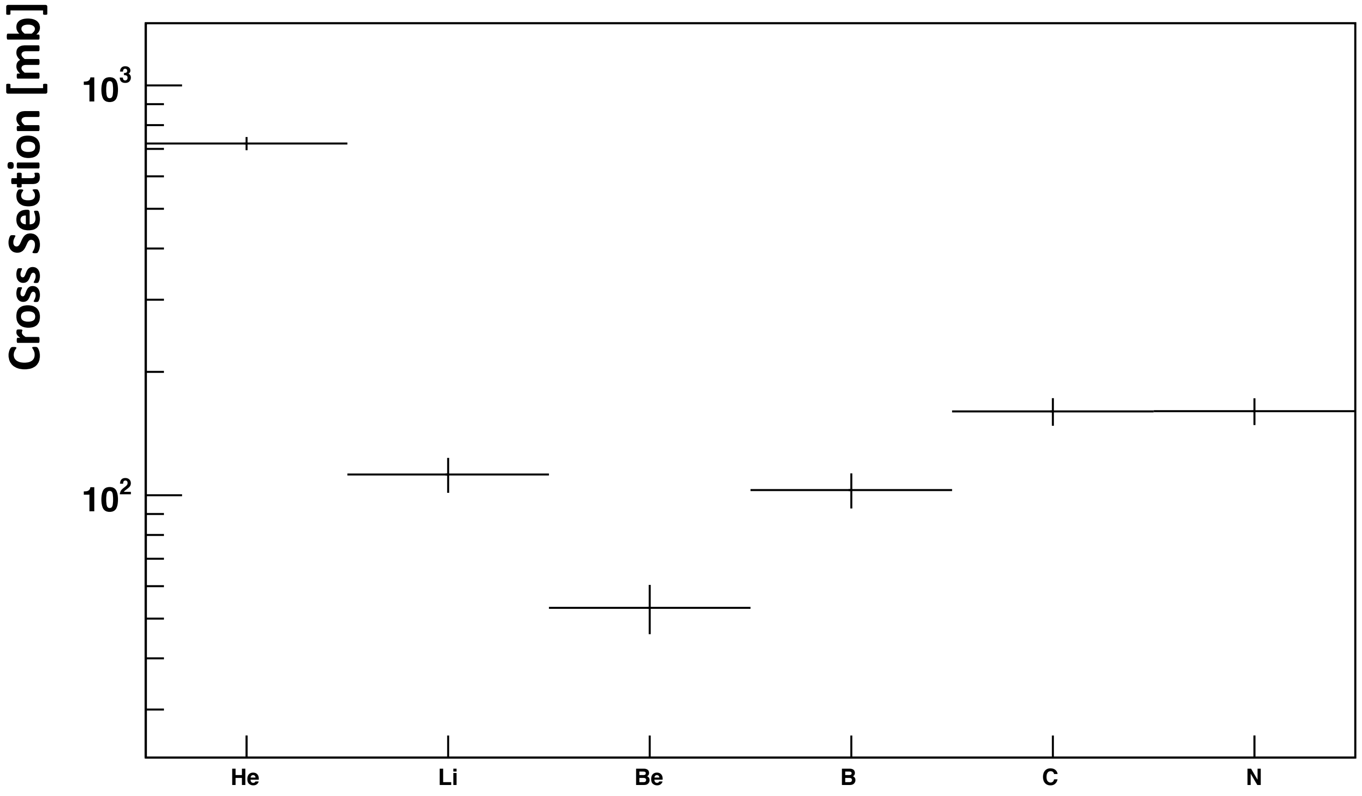
Intrinsic efficiencies folded with TW clustering efficiency

Selections and available statistics



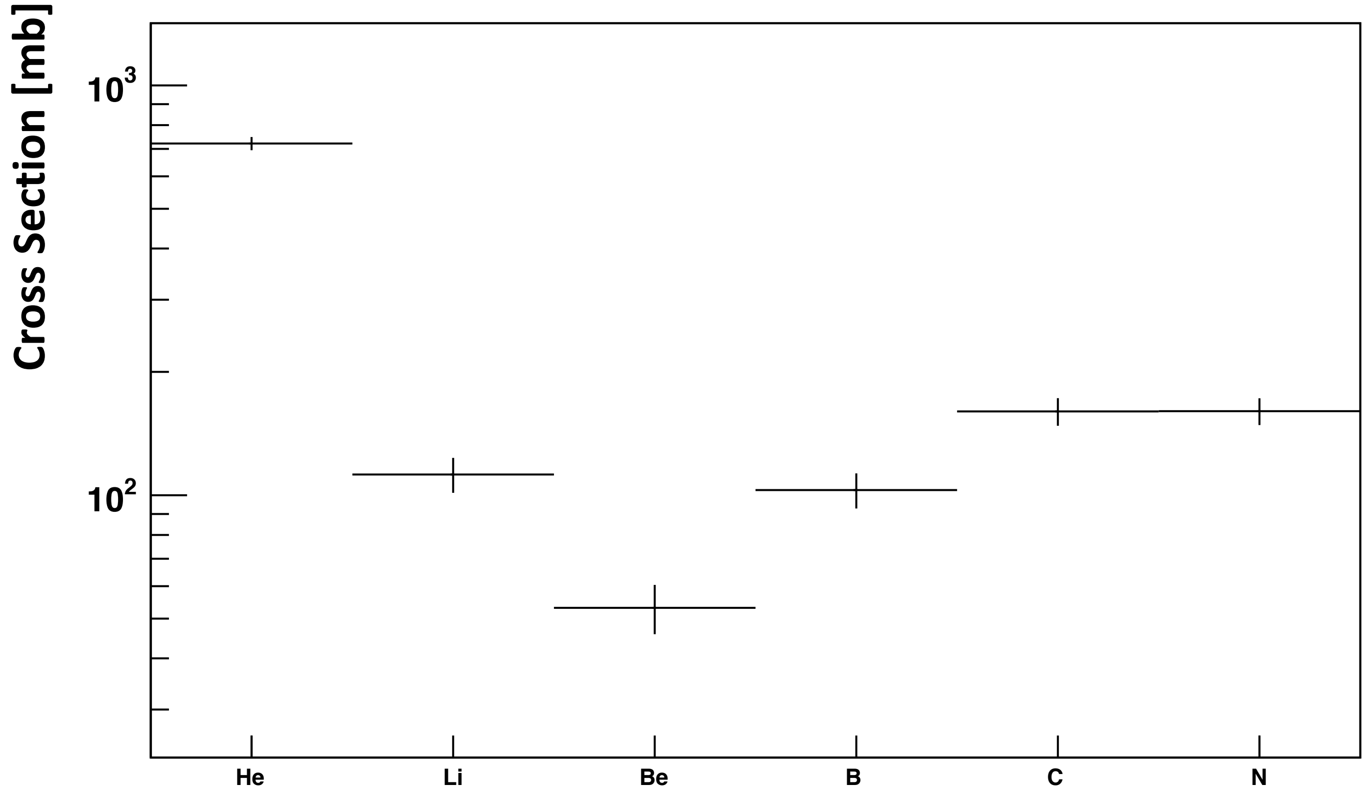
Detected “Primary” 16O: 23236
→ **Overall fragmentation 5.7%**

Charge-Changing cross sections
16O+C @ 400 MeV/n



Z2: (721 +/- 27) mb
Z3: (112 +/- 11) mb
Z4: (53 +/- 7) mb
Z5: (103 +/- 10) mb
Z6: (160 +/- 12) mb
Z7: (160 +/- 12) mb

Integrated Elemental cross sections 16O+C @ 400 MeV/n



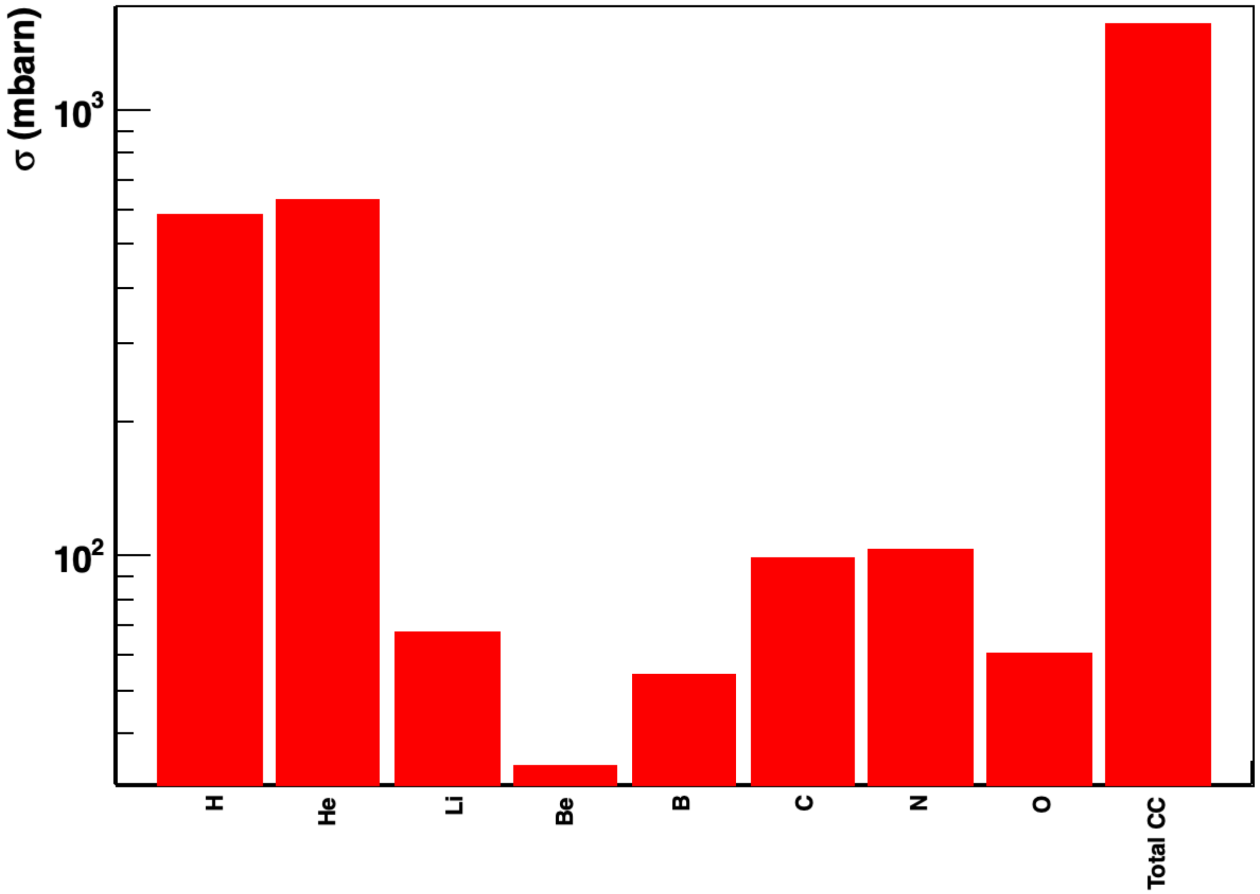
Z2: (721 +/- 27) mb
Z3: (112 +/- 11) mb
Z4: (53 +/- 7) mb
Z5: (103 +/- 10) mb
Z6: (160 +/- 12) mb
Z7: (160 +/- 12) mb

In literature (Webber, PRC, vol 41, N 2 (1990):

16O+C @ 441 MeV/n:

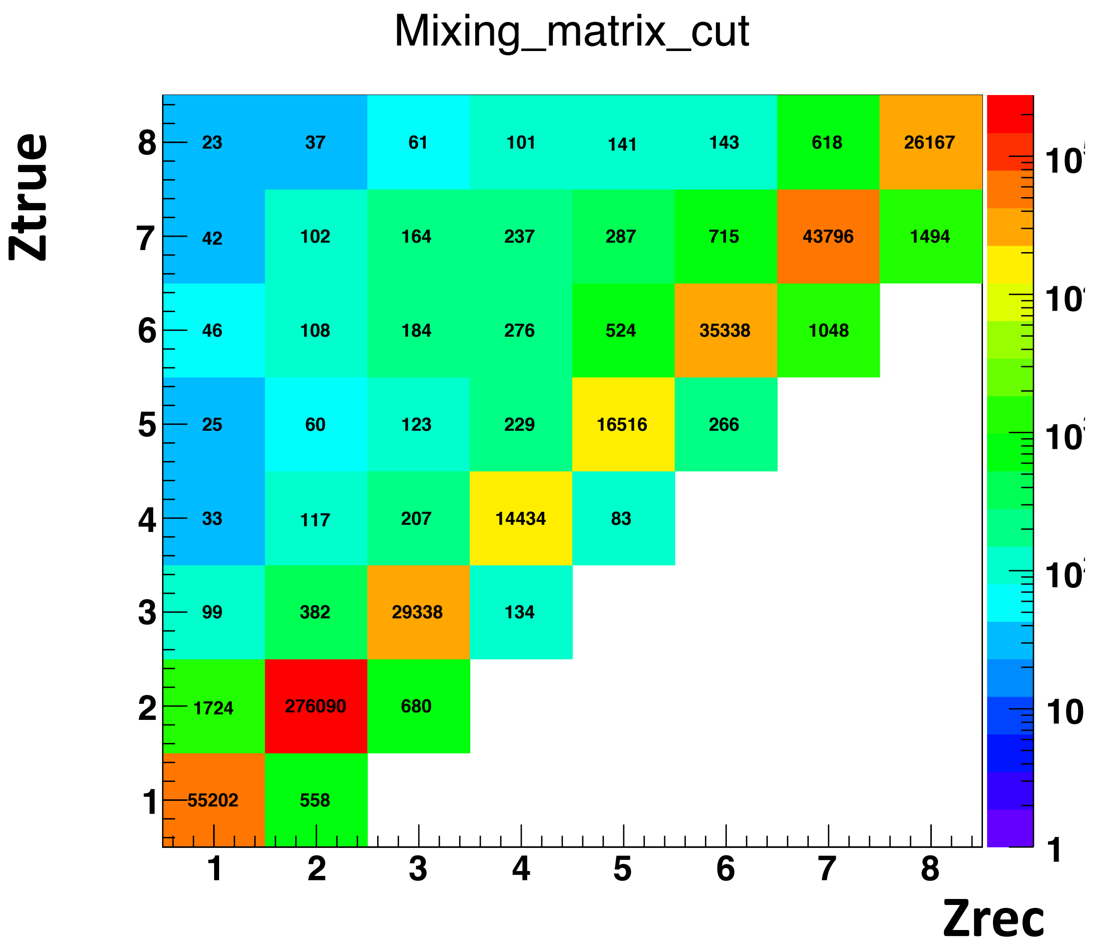
Z6: (162 +/- 2) mb
Z7: (160 +/- 2) mb

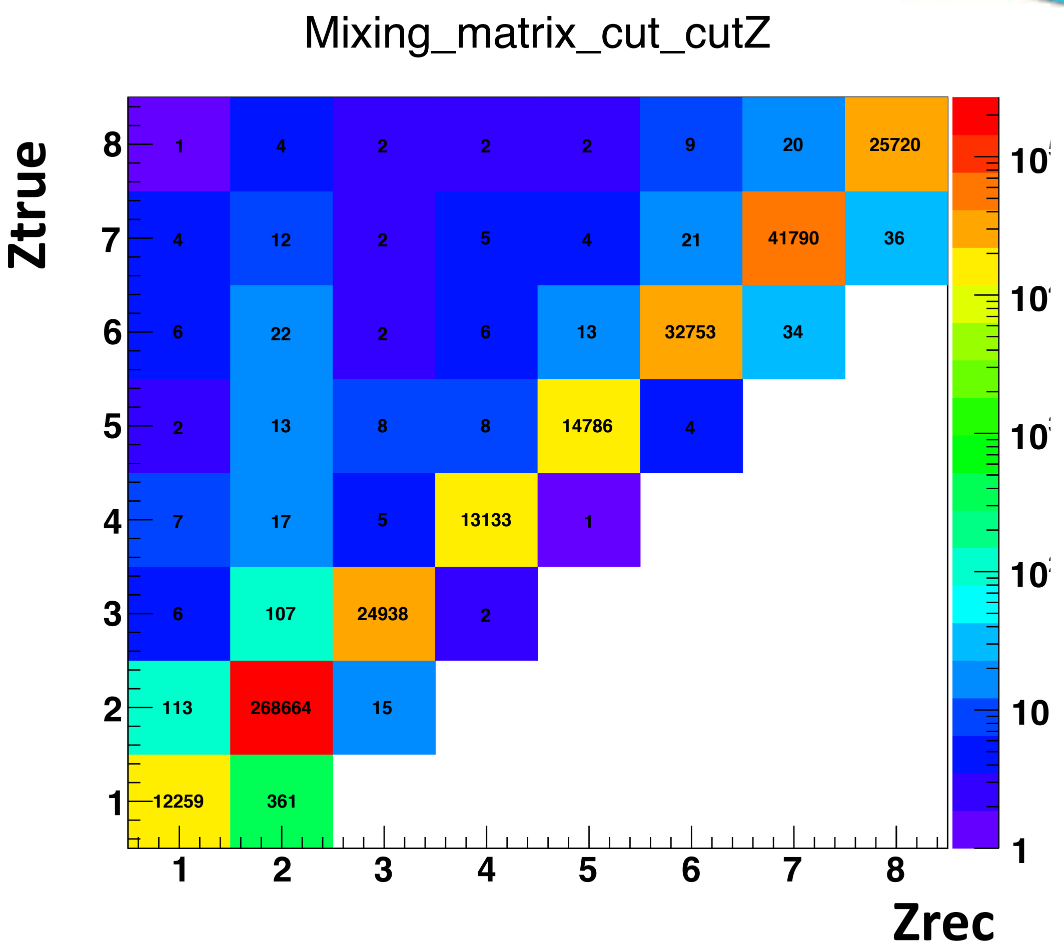
Charge-changing XS in FLUKA



Charge	Cross section (mbarn)	Rescaled to data (Z=7) [mb]
1	582.237098	-
2	624.328050	960
3	67.443612	104
4	33.971387	52
5	54.391275	84
6	98.731728	152
7	103.810543	160
8	60.529448	-
Total CC	1564.913692	-

What is missing: charge mixing matrix





Conclusions

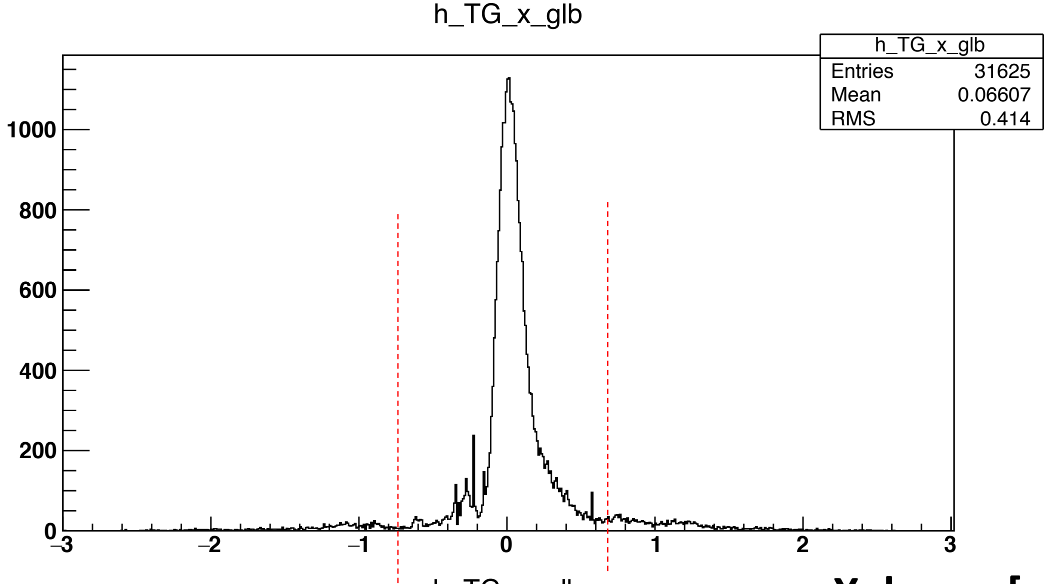
- Preliminary measurement of the GSI cross section O+C at 400 MeV/n has been shown → very nice agreement with literature and similar ratio btw fragments of FLUKA
- Some algorithms developed in SHOE for this analysis, useful for the future

What is missing:

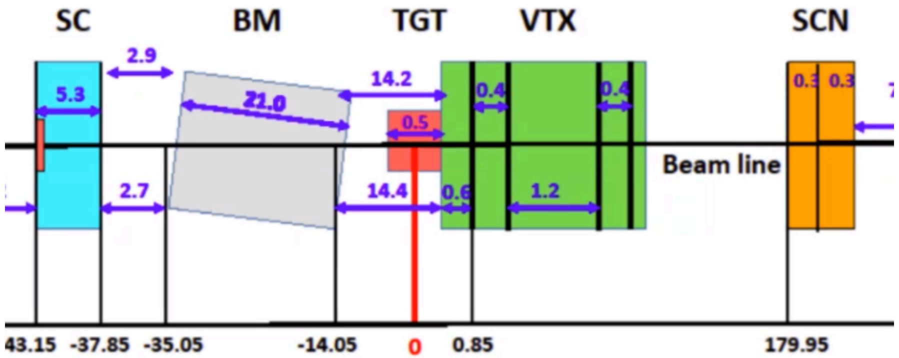
- Perform all systematics studies
- Cross check measurement trying to enlarge the data sample
- (Apply Charge mixing matrix)
- Check “flat” MC efficiencies (to be produced with Giuseppe)
- From run 2242 estimate secondary fragmentation in VTX and air and compute CC cross section

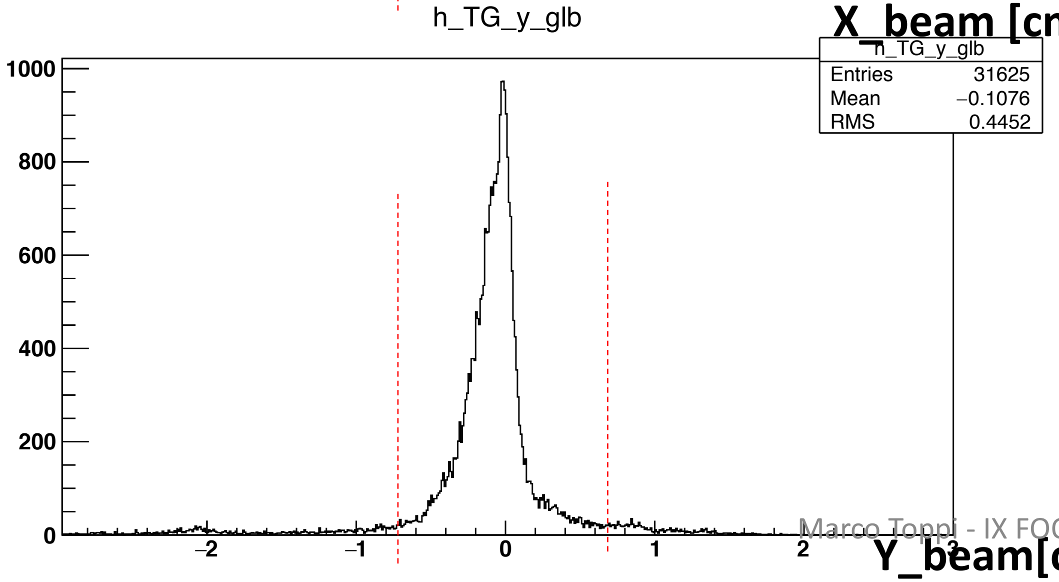
Spare slides

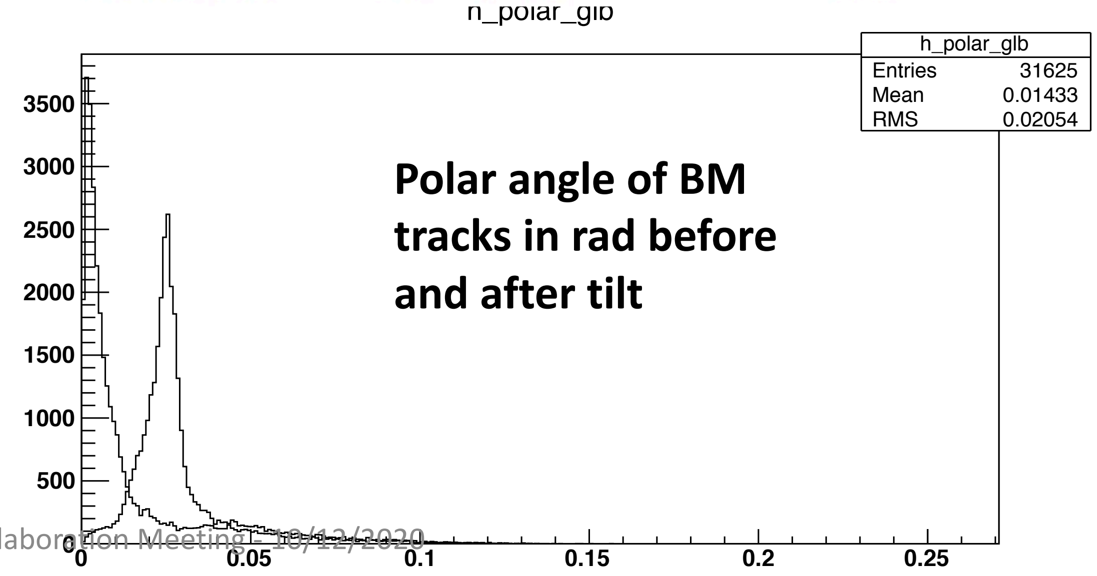
Beam and Beam Monitor at GSI -



Thanks to Yun GSI setup (BM/TW) aligned

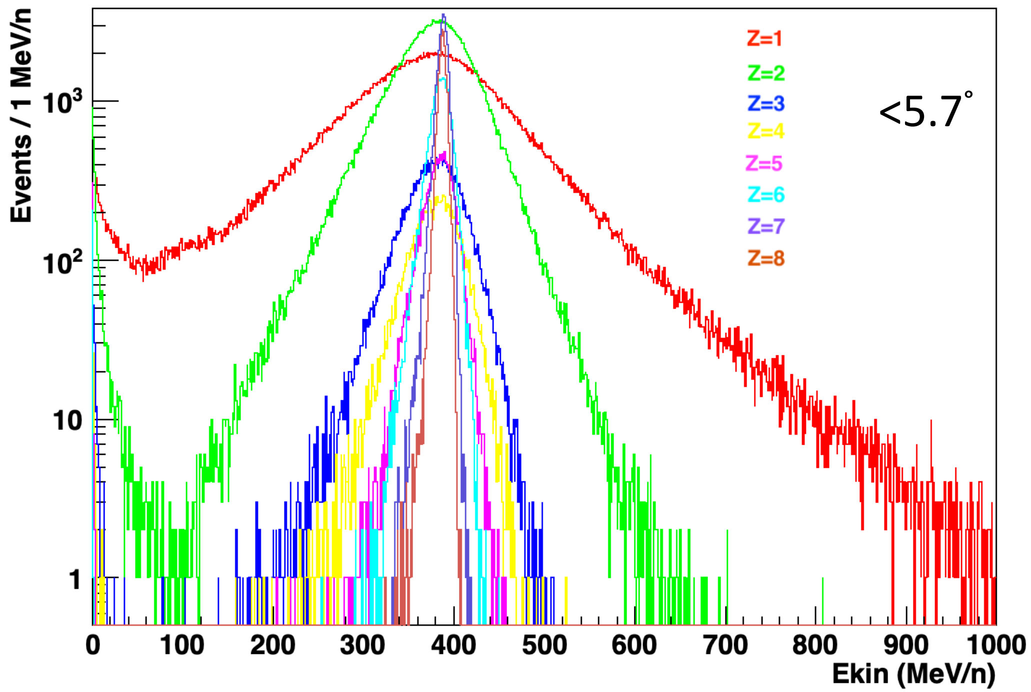


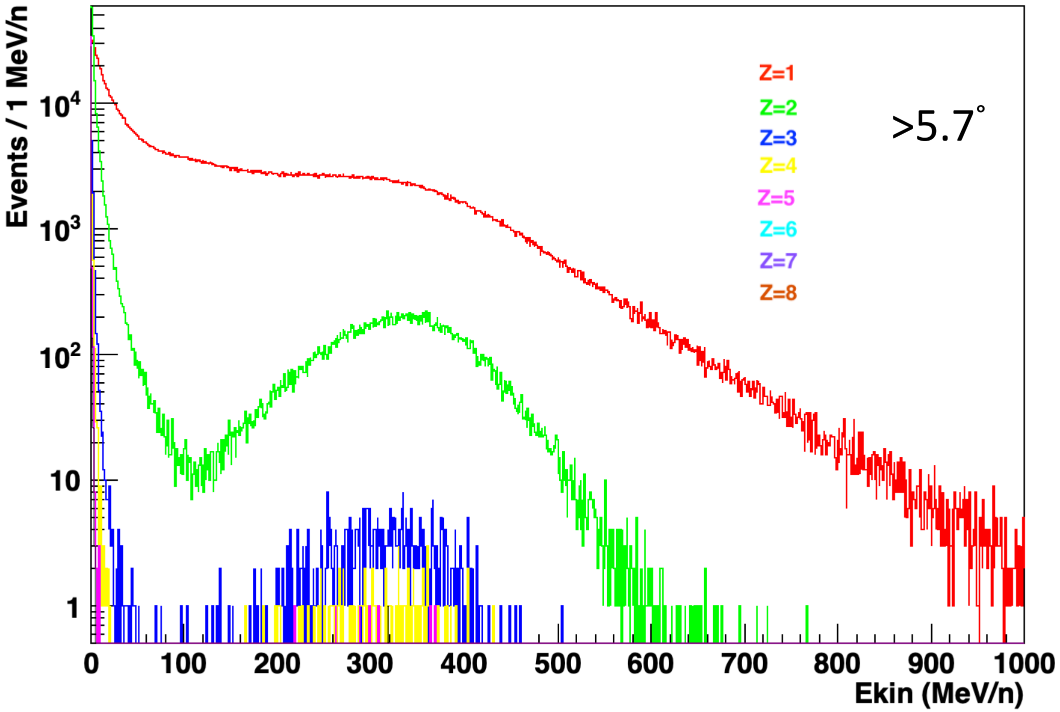




Polar angle of BM tracks in rad before and after tilt

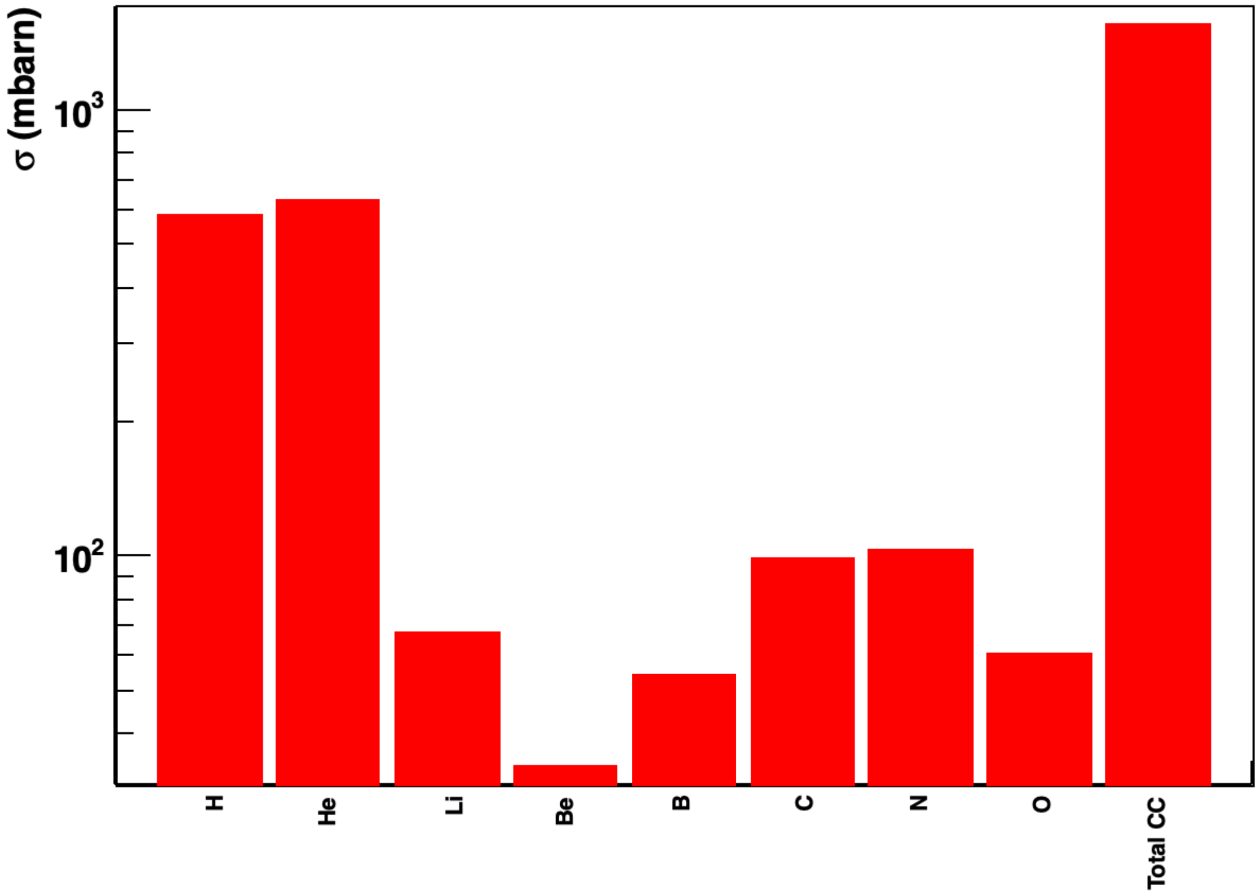
FLUKA: E_{kin} distribution fragments in TG





Asking for only primary fragments with origin in Target

$\sigma_{Production}$ in TG (between 0° and 5.7°)

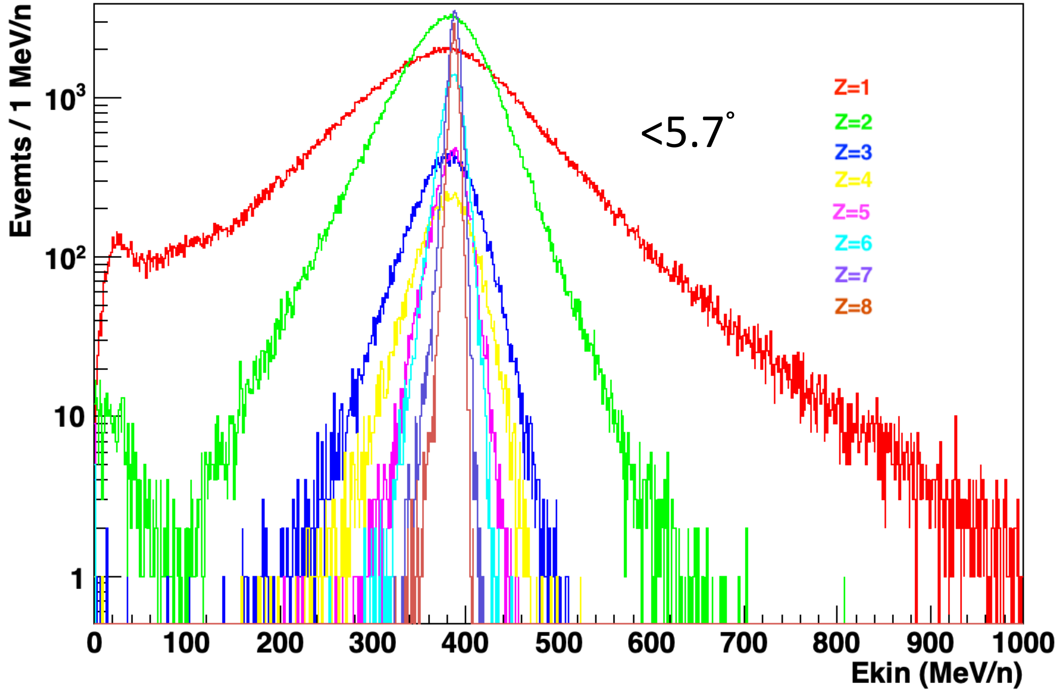


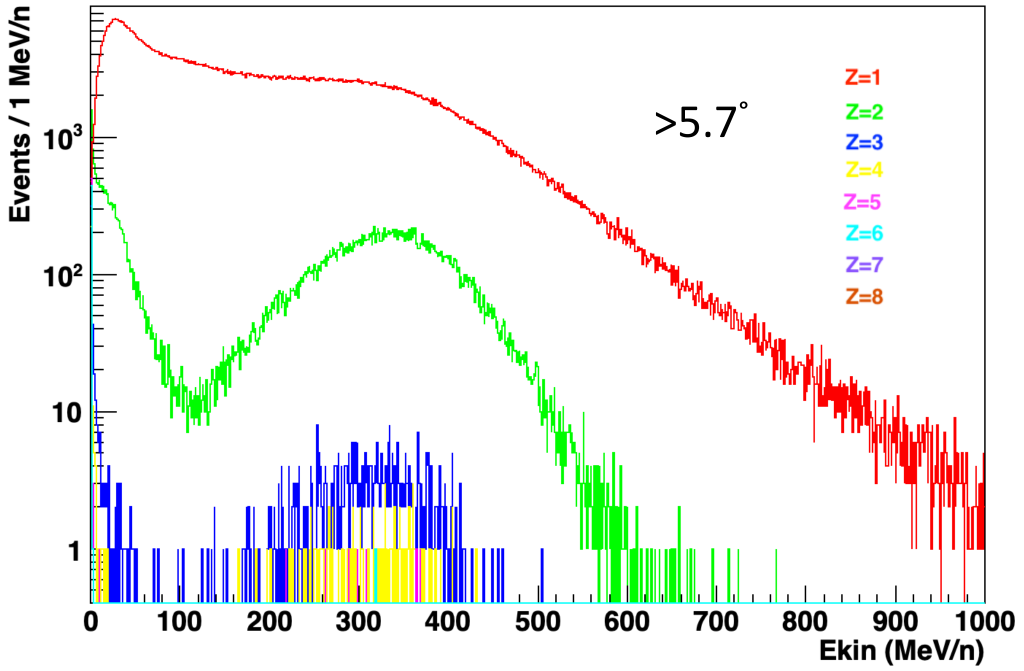
$$\sigma = \int_{0°}^{7°} \frac{d\sigma}{d\theta}\Big|_{0°-7°} d\theta = \frac{N_f}{N_{oxy} * N_t}$$

Where: $N_t = \frac{\rho * dx * N_A}{A}$

Charge	Cross section (mbarn)
1	582.237098
2	624.328050
3	67.443612
4	33.971387
5	54.391275
6	98.731728
7	103.810543
8	60.529448
Total CC	1564.913692

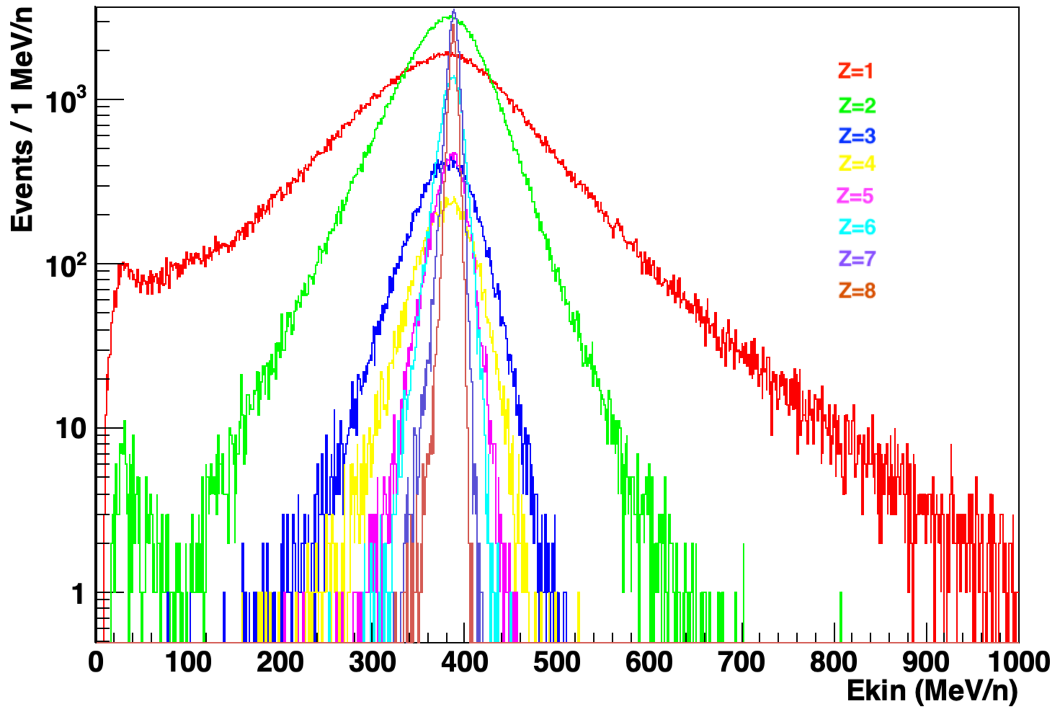
E_{kin} distribution fragments out TG





Asking for only primary fragments with origin in Target produced on the TG in [-0.7,0.7].

E_{kin} distribution TW hit

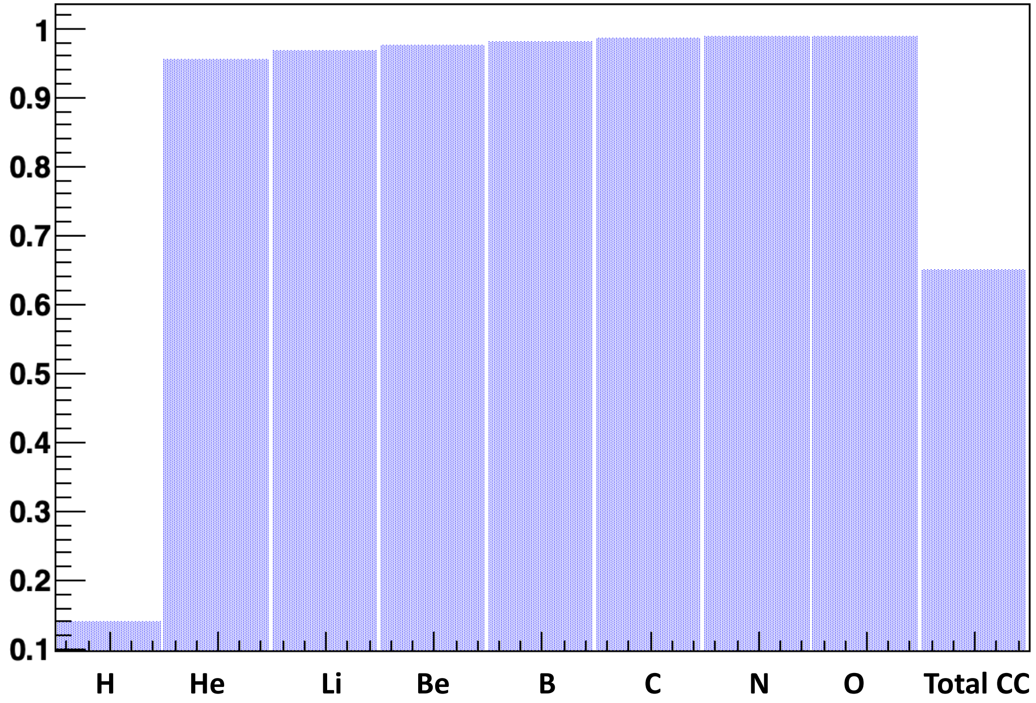


E_{kin} production

Asking for only primary fragments with origin in Target (over threshold) with production angle < 5.7° and beam progection on TG in [-0.7,0.7] matching a TW hit

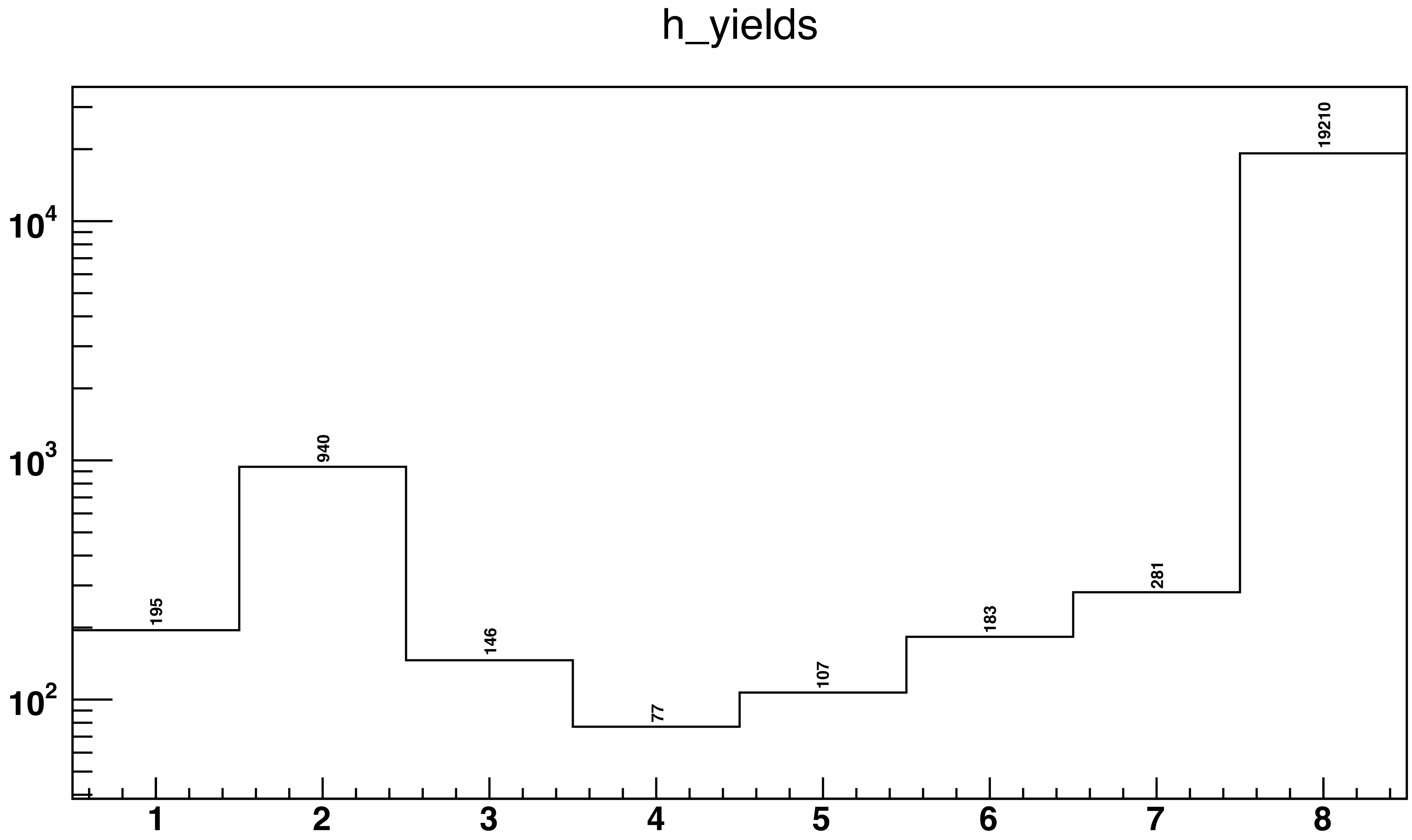
Intrinsic efficiency for TW hits:

Charge	Efficiency
1	0.140197 +/- 0.000674
2	0.955599 +/- 0.000386
3	0.968819 +/- 0.000997
4	0.977083 +/- 0.001220
5	0.982057 +/- 0.001002
6	0.987662 +/- 0.000565
7	0.990215 +/- 0.000451
8	0.990277 +/- 0.000589
Total CC	0.651769 +/- 0.000570



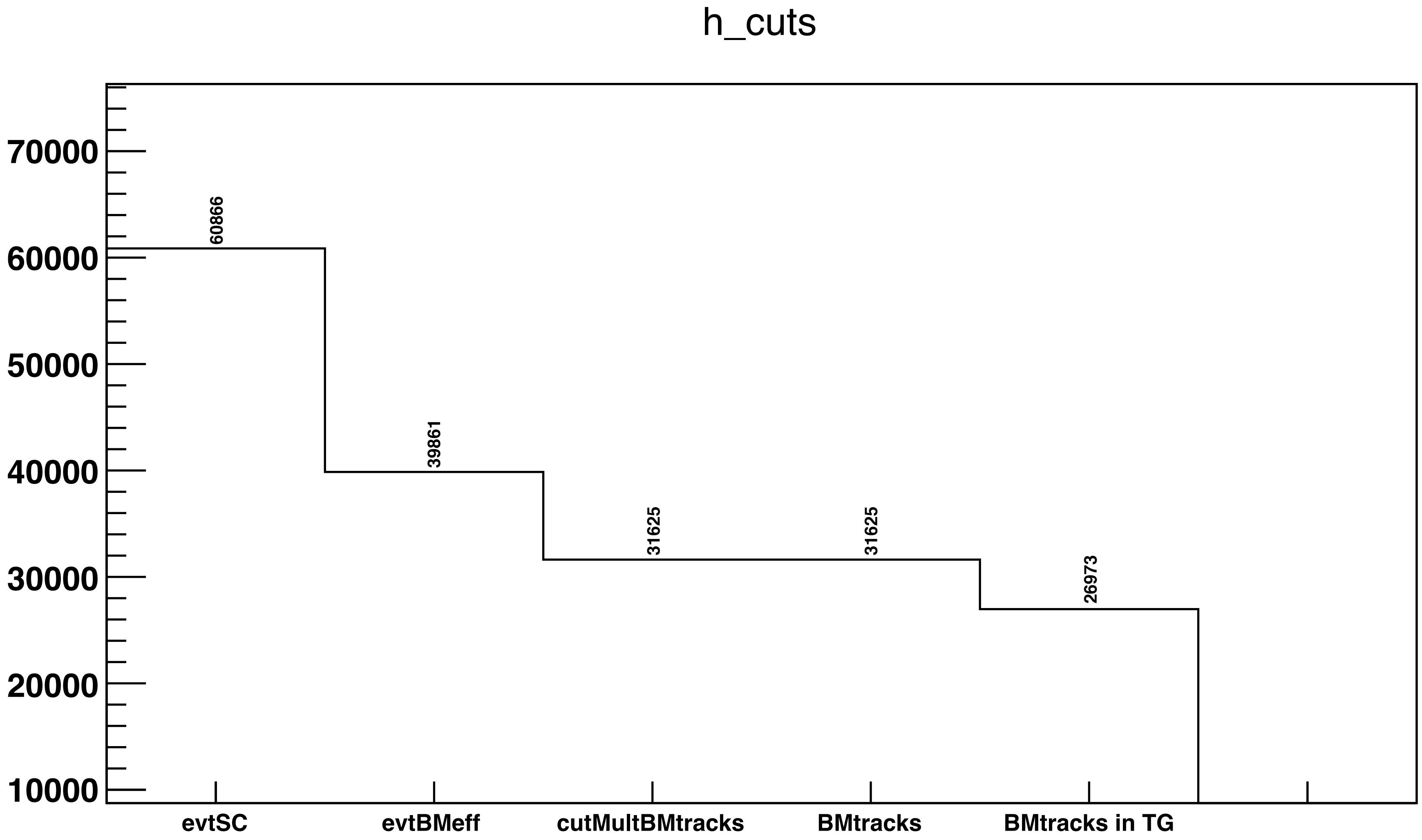
Efficiencies from MC triggered. Values in range of 3-5% of difference obtained with flat simulations

But…Yields measuremnts

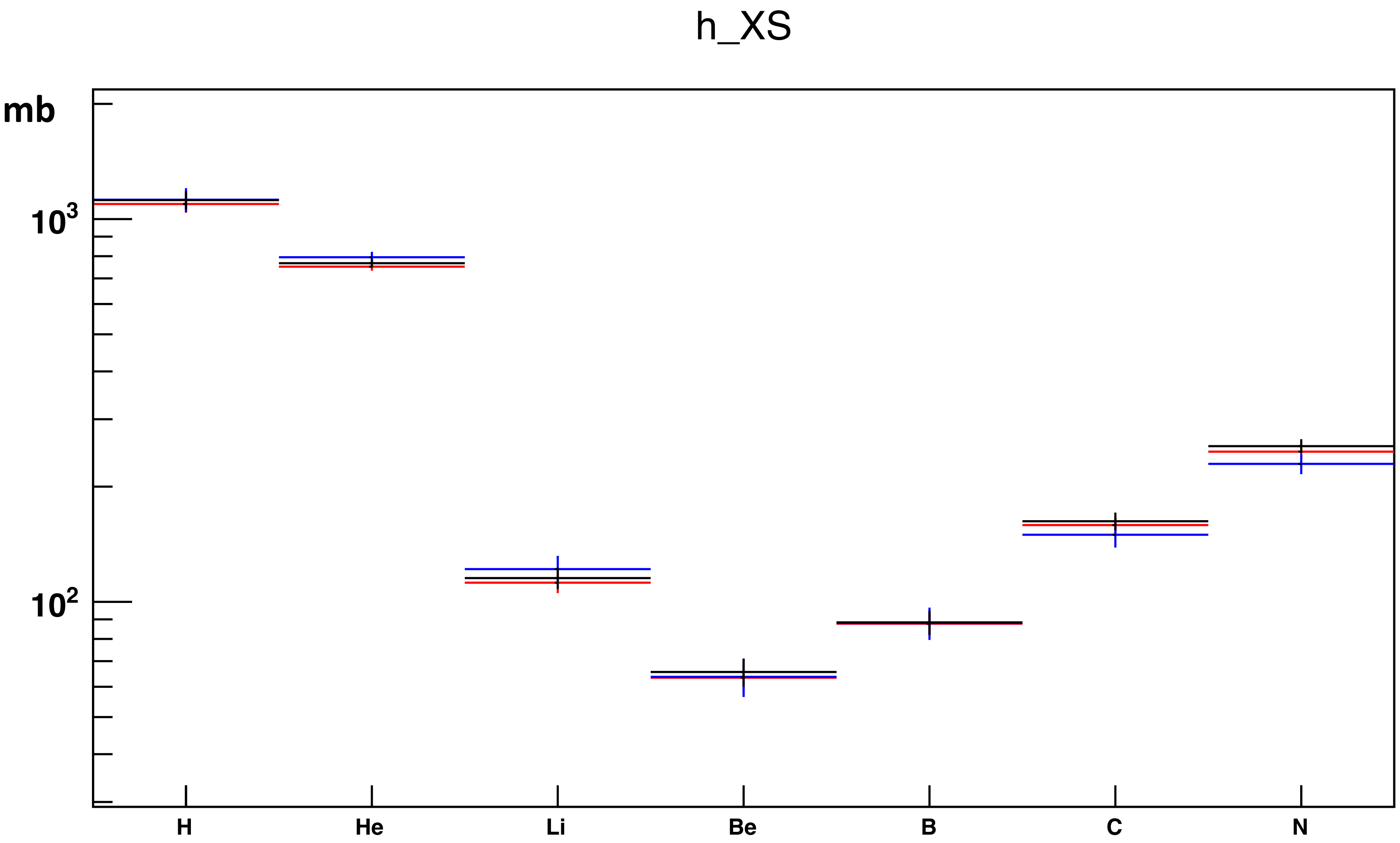


N of Oxygen make me feel bad…

Selections and N of primaries:

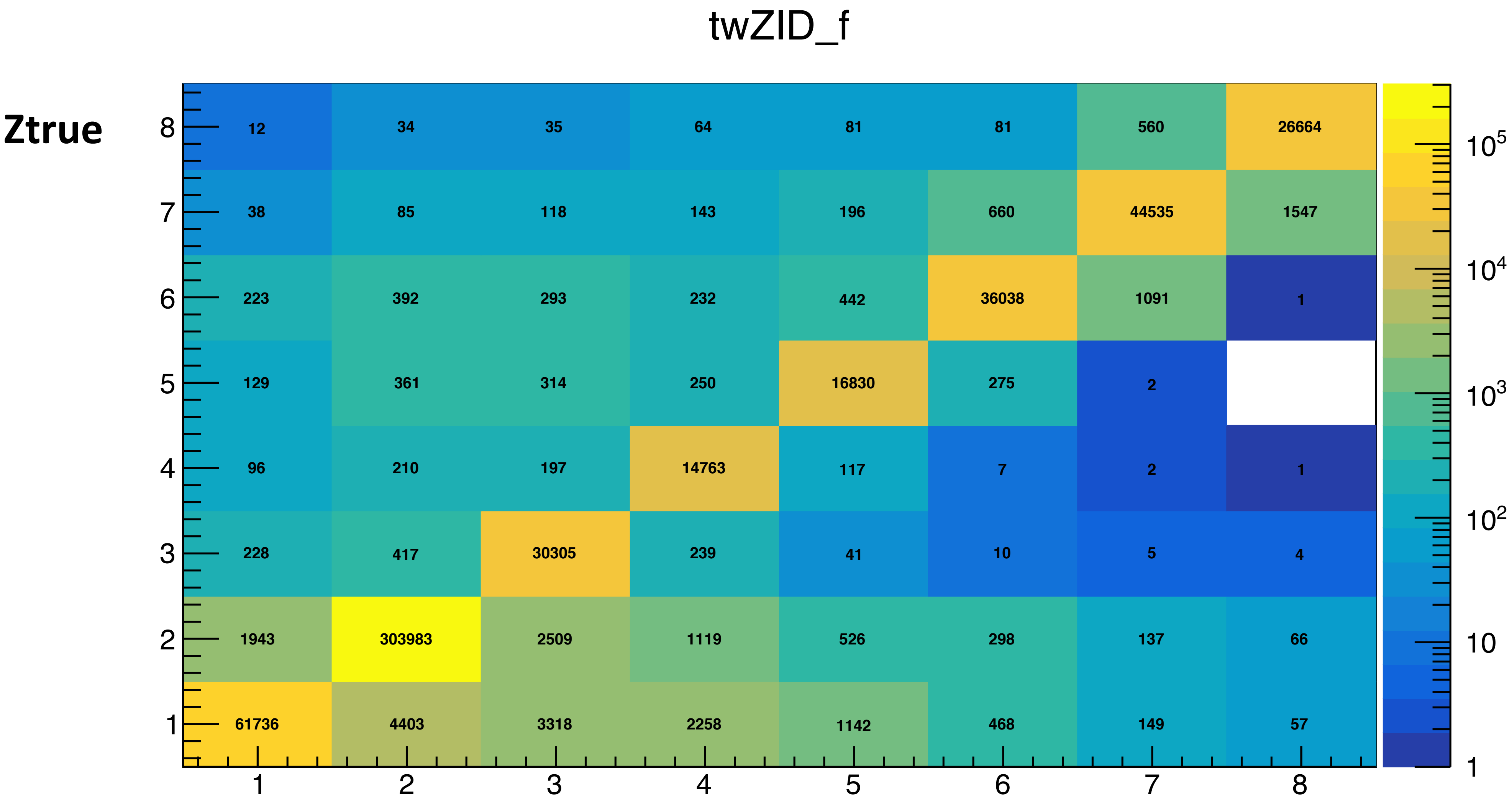


Raw cross sections



Z1: (1124+/- 81) mb
Z2: (795 +/- 26) mb
Z3: (122 +/- 10) mb
Z4: (64 +/- 7) mb
Z5: (88 +/- 8) mb
Z6: (150 +/- 11) mb
Z7: (229 +/- 14) mb

Charge mixing matrix for TW hits



Zrec