Update on integral and elemental cross sections with GSI data

Riccardo Ridolfi

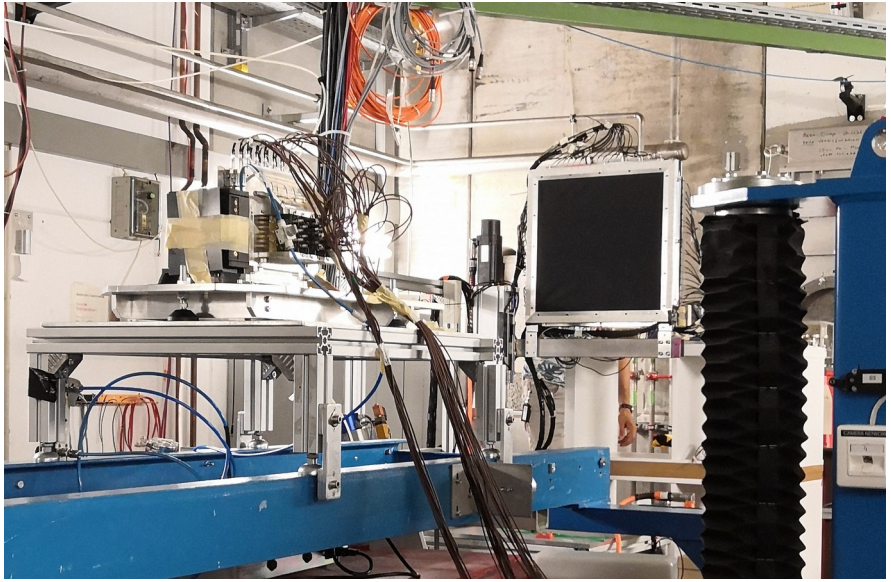
2 February 2021

Cross section measurements

400 MeV/u ^{16}O beam on 5mm Carbon target

Run	Trigger type	Target	Events
4305	MB	C	162102
4306	MB	C	577096
4307	MB	C	513370
4310	Frag + MB	C	1012099
4313	MB	no	57133

Table 6.1: Run list GSI2021.



Cross section measurements

400 MeV/u ^{16}O beam on 5mm Carbon target

With available data total integrated and angle differential cross section are achievable (no kinetic energy)

$$\Delta\sigma(Z) = \int_{E_{\min}}^{E_{\max}} \int_{0}^{\theta_{\max}} \left(\frac{\partial^2 \sigma}{\partial\theta \partial E_{\mathrm{kin}}} \right) \mathrm{d}\theta \mathrm{d}E_{\mathrm{kin}} = \frac{Y(Z)}{N_{\mathrm{prim}} \cdot N_{\mathrm{TG}} \cdot \varepsilon(Z)}$$

$$\frac{\mathrm{d}\sigma}{\mathrm{d}\theta}(Z) = \frac{Y(Z,\theta)}{N_{\mathrm{prim}} \cdot N_{\mathrm{TG}} \cdot \Delta\theta \cdot \varepsilon(Z,\theta)}$$

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Align FOOT detectors and estimate **angular acceptance**

Extract fragment yields from TW

Calculate MC efficiencies for fragments

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Calculate MC efficiencies for fragments

Cross section measurements

400 MeV/u ^{16}O beam on 5mm Carbon target

In this analysis trackers (VTX & MSD) are not included!

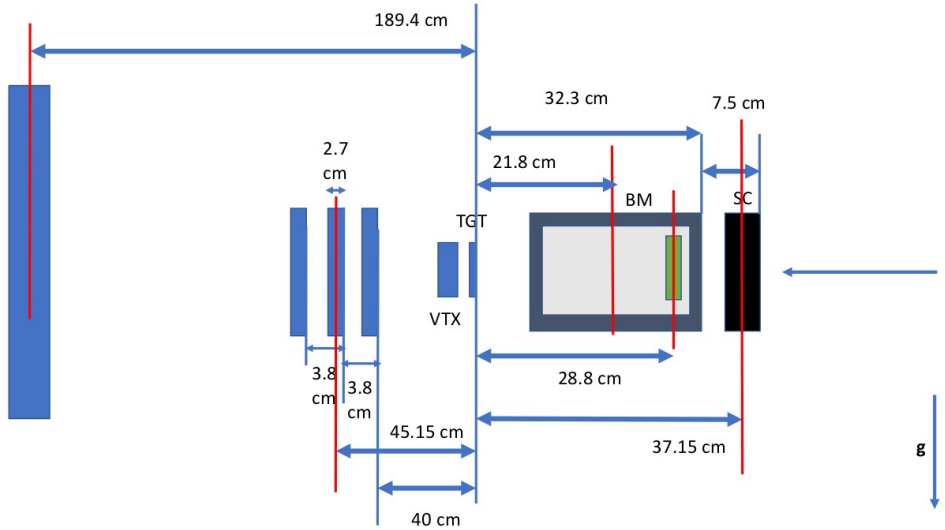
Fragmentation out of target will be estimated with no target runs

Data analysis carried out in GSI VIRGO cluster

Detector alignment

All the geometry was handled by **SHOE** TAGgeotrafo

To align BM and TW projections of beam particles were used



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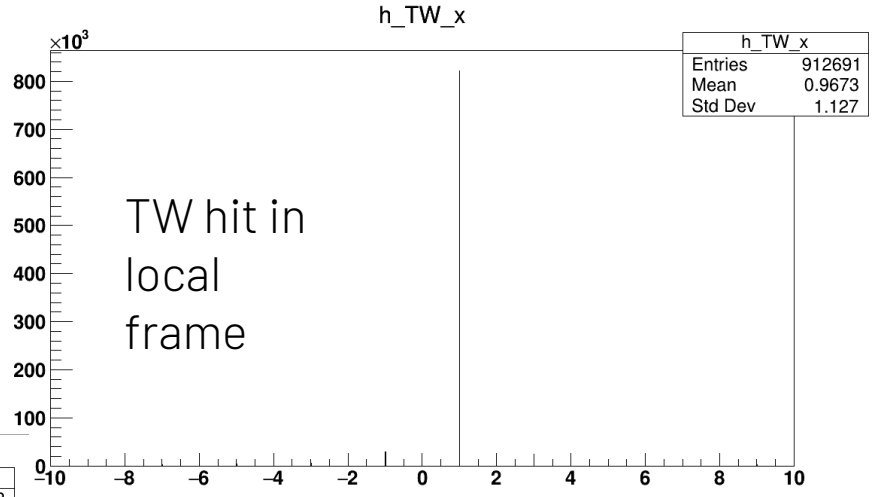

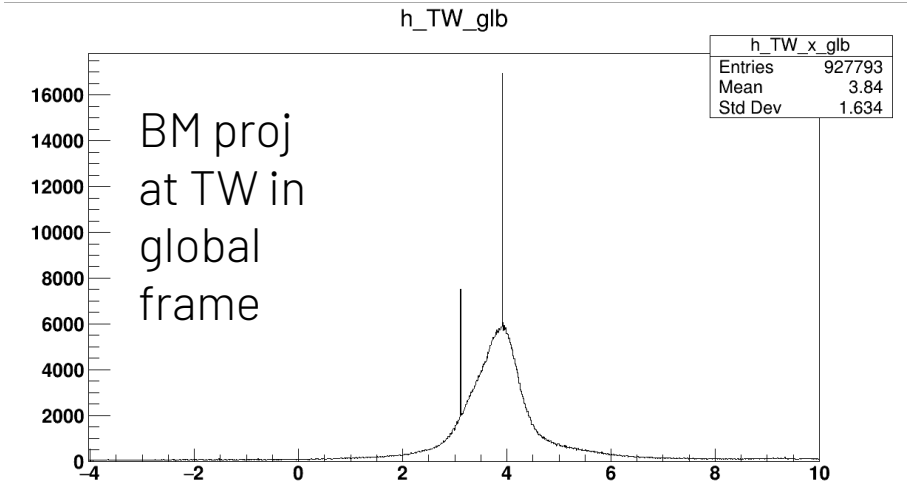

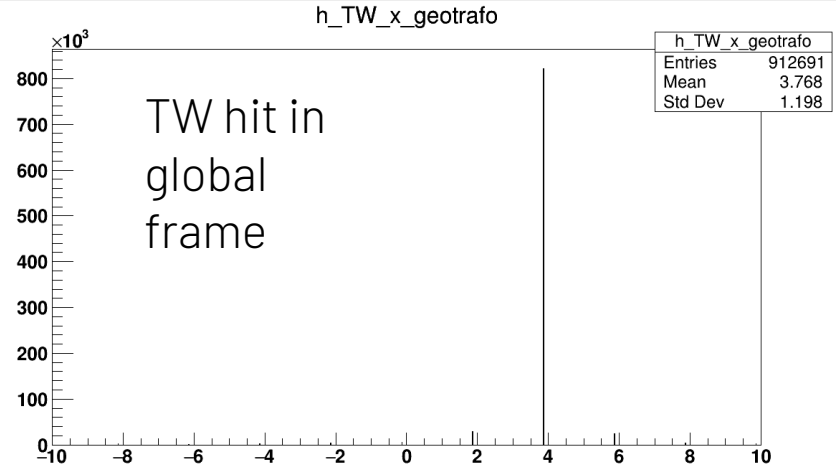

Detector alignment

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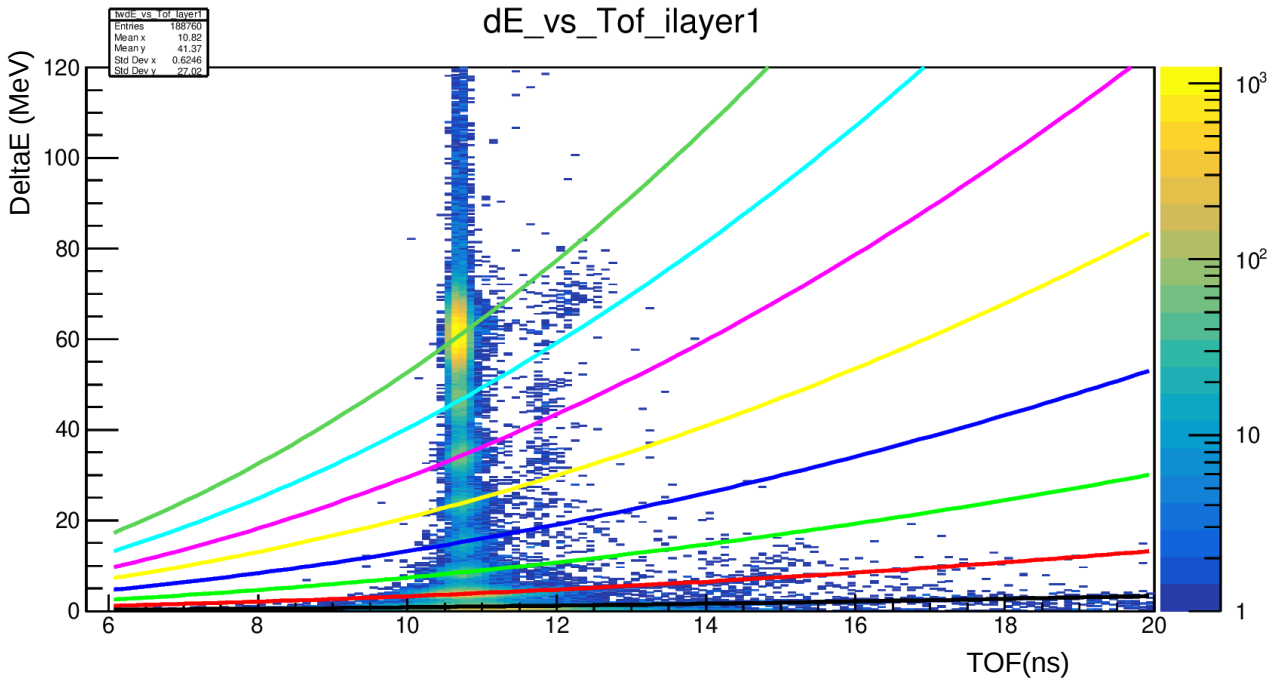
of beam particles were used

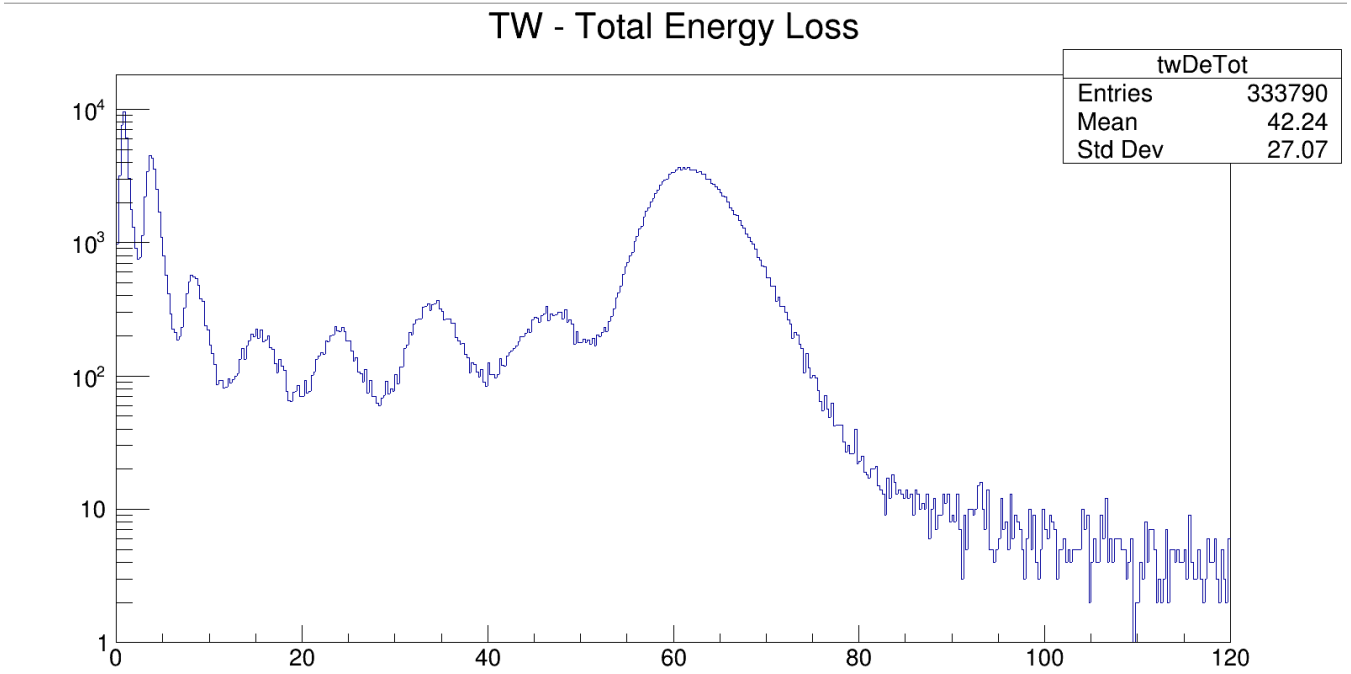
Due to the asymmetric shift of TW
acceptance θ max ≈4.85°

SHOE output (ZID)



Run 4310 + BB curve implemented in SHOE for 400 MeV/u

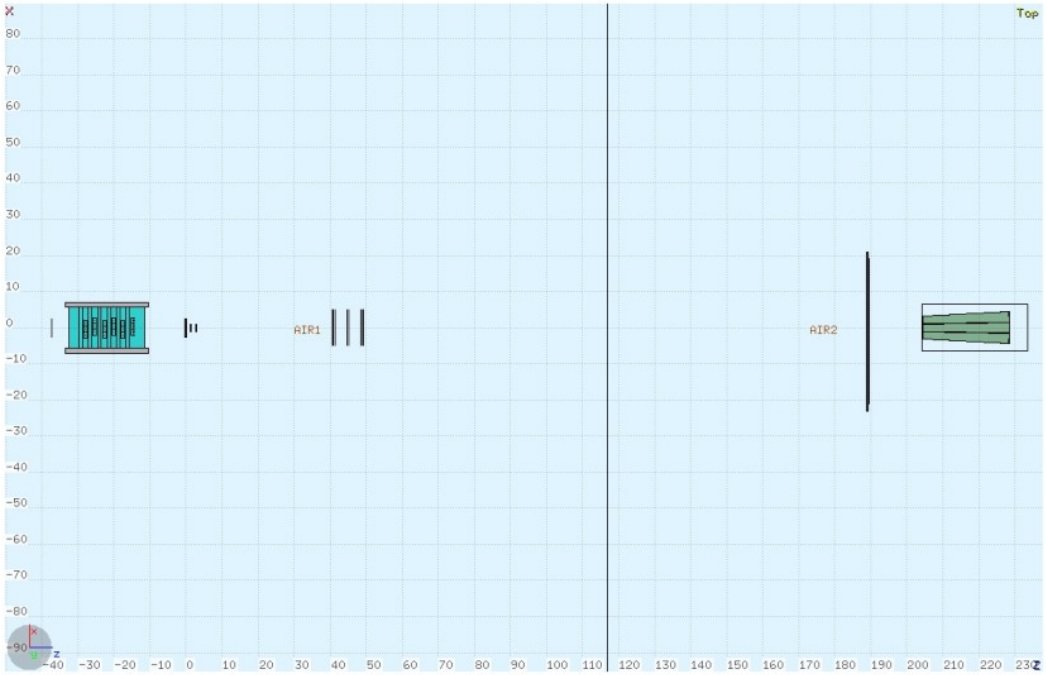
SHOE output (ZID)



Run 4310 + BB curve implemented in SHOE for 400 MeV/u

MC analysis

Updated layout

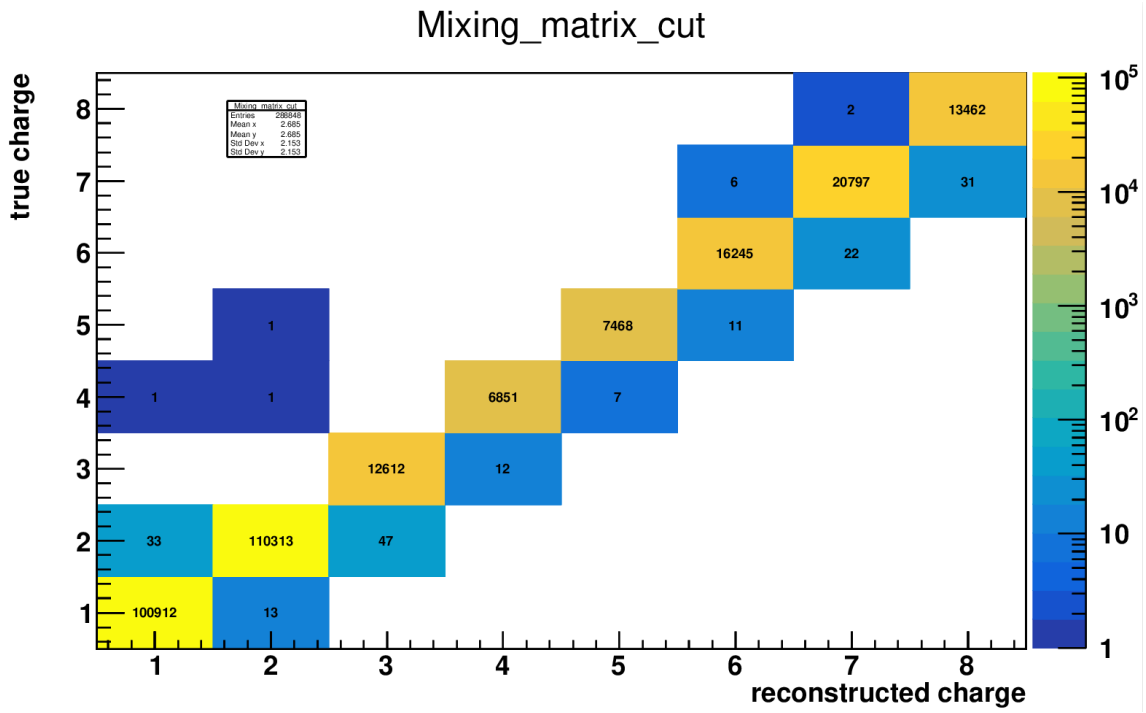


Using just the **newgeom branch**, for the moment, the geometrical layout of GSI2021_MC campaign has been updated according to the survey performed in cave A (as from the document uploaded in the Elog)

We have considered for the moment the case with all detectors centered in the XY plane (400 MeV/u runs)

Gaussian beam with σ_x = 2.3 mm
σ_y = 1.5 mm

MC analysis



Only particles with cut in Ekin, produced in target by primary beam inside TW acceptance

No unfolding up to now

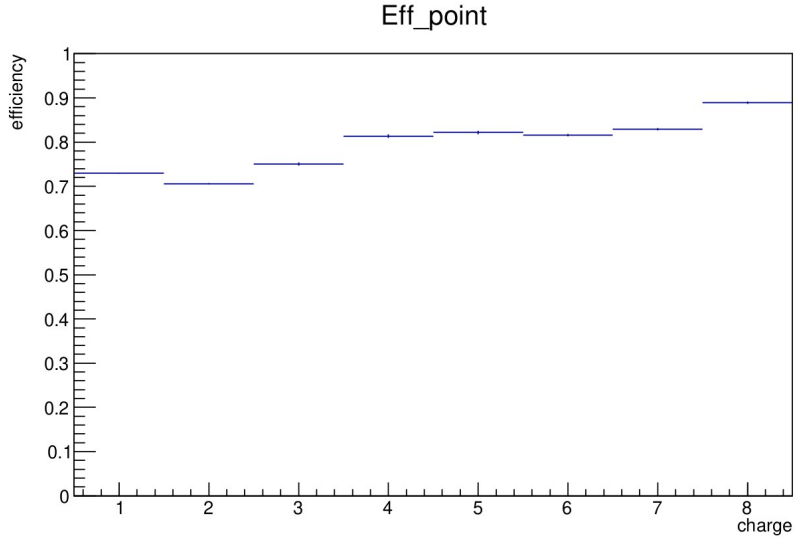
MC analysis

$$\varepsilon(Z) = \frac{N_{\mathrm{TW}}(Z) + 1}{N_{\mathrm{track}}(Z) + 2}$$

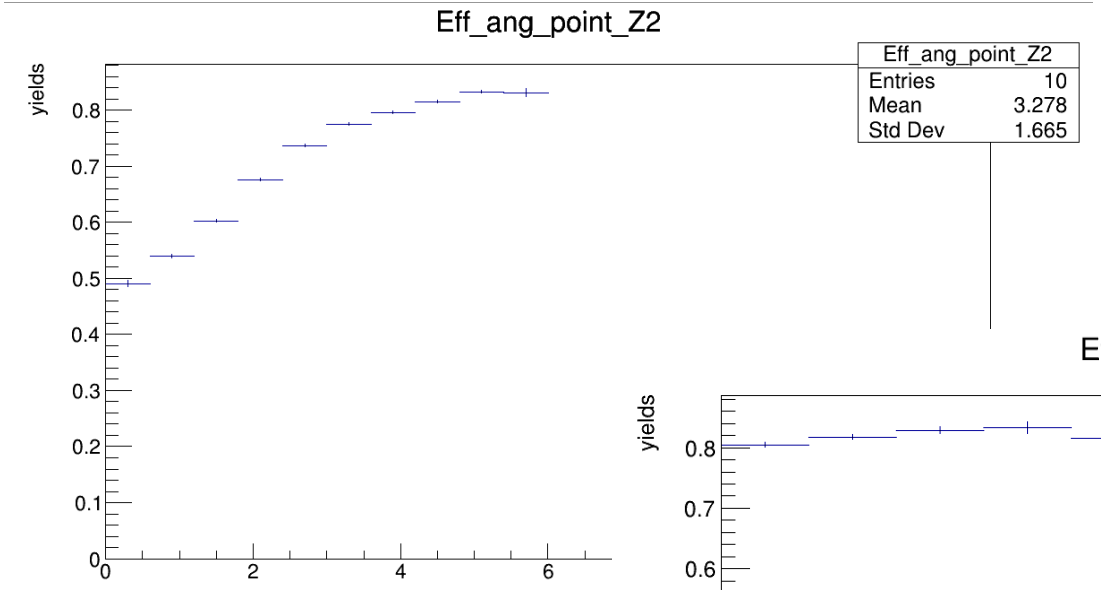
asking for a good TW point matched to a fragment produced in TG and kinetic energy between [100,600] MeV/u

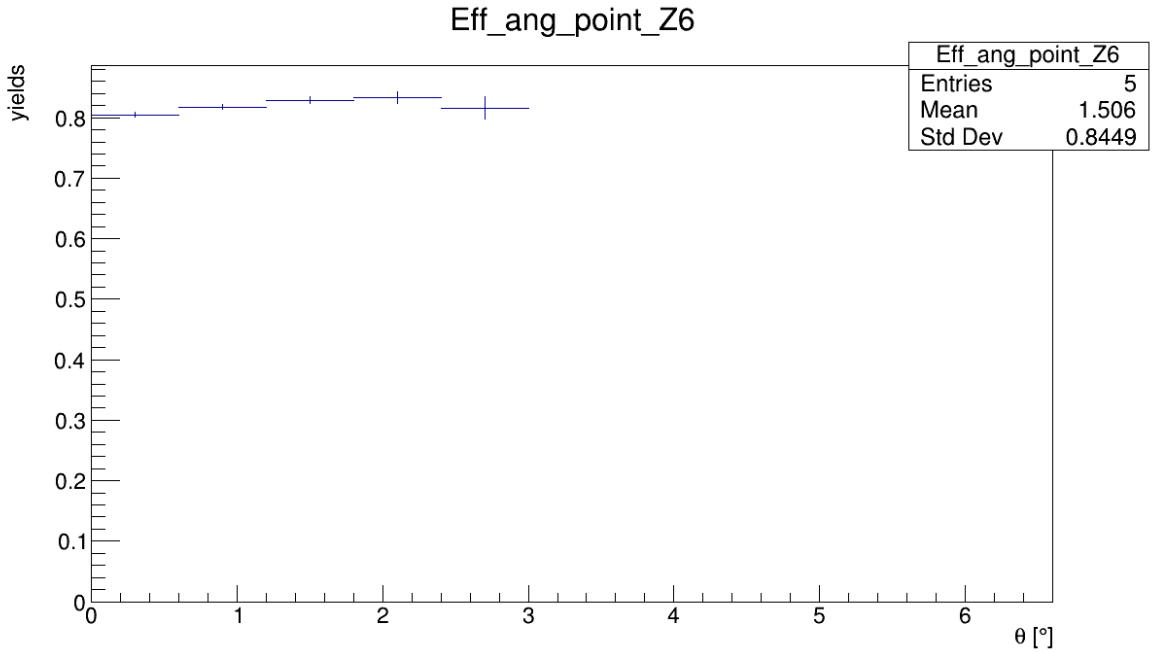
asking for a fragment produced in TG within TW acceptance and kinetic energy between [100,600] MeV/u

$$\epsilon_{\varepsilon}(Z) = \sqrt{\varepsilon(Z)\frac{N_{\mathrm{TW}}(Z) + 2}{N_{\mathrm{track}}(Z) + 3} - \varepsilon(Z)^2}.$$

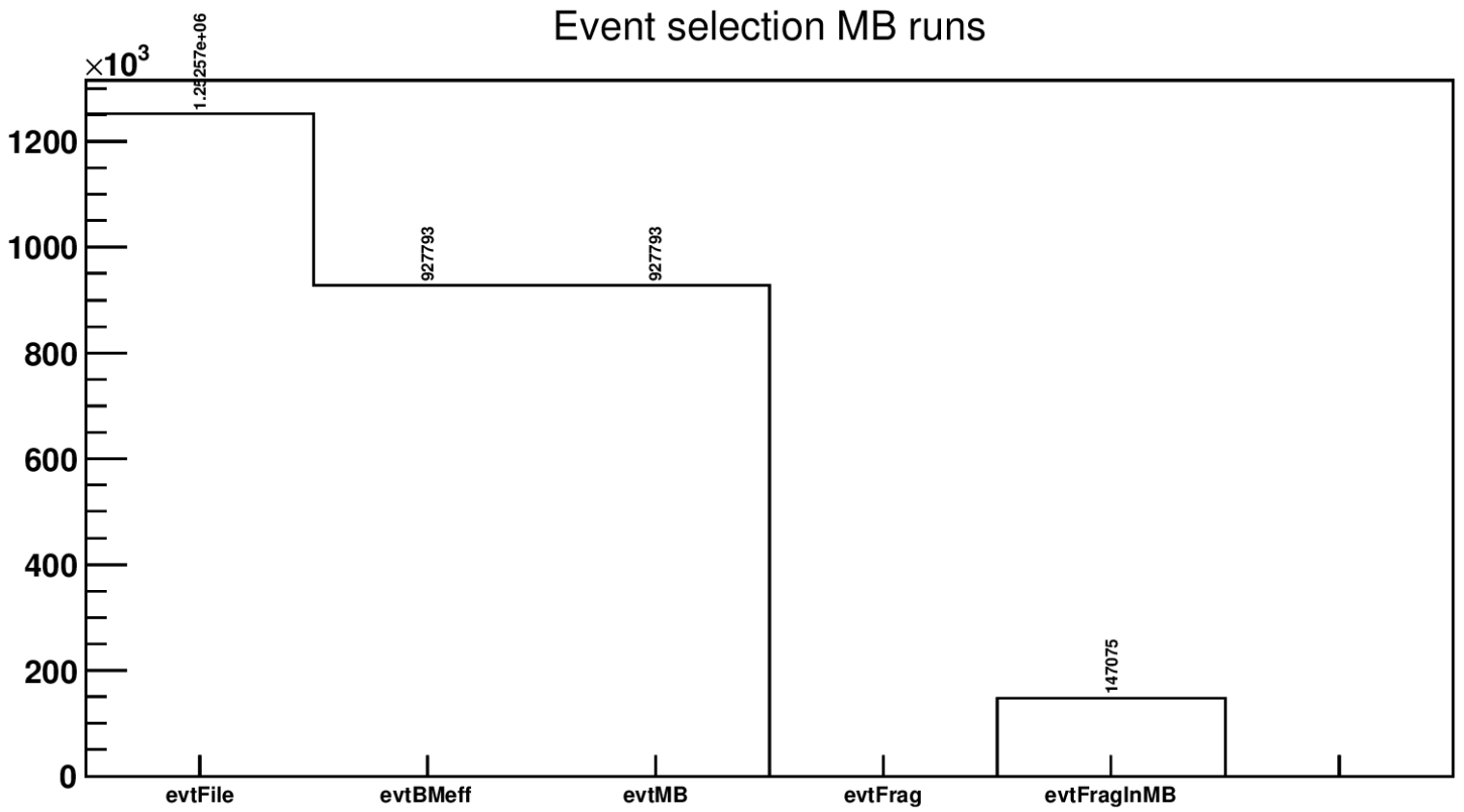


MC analysis

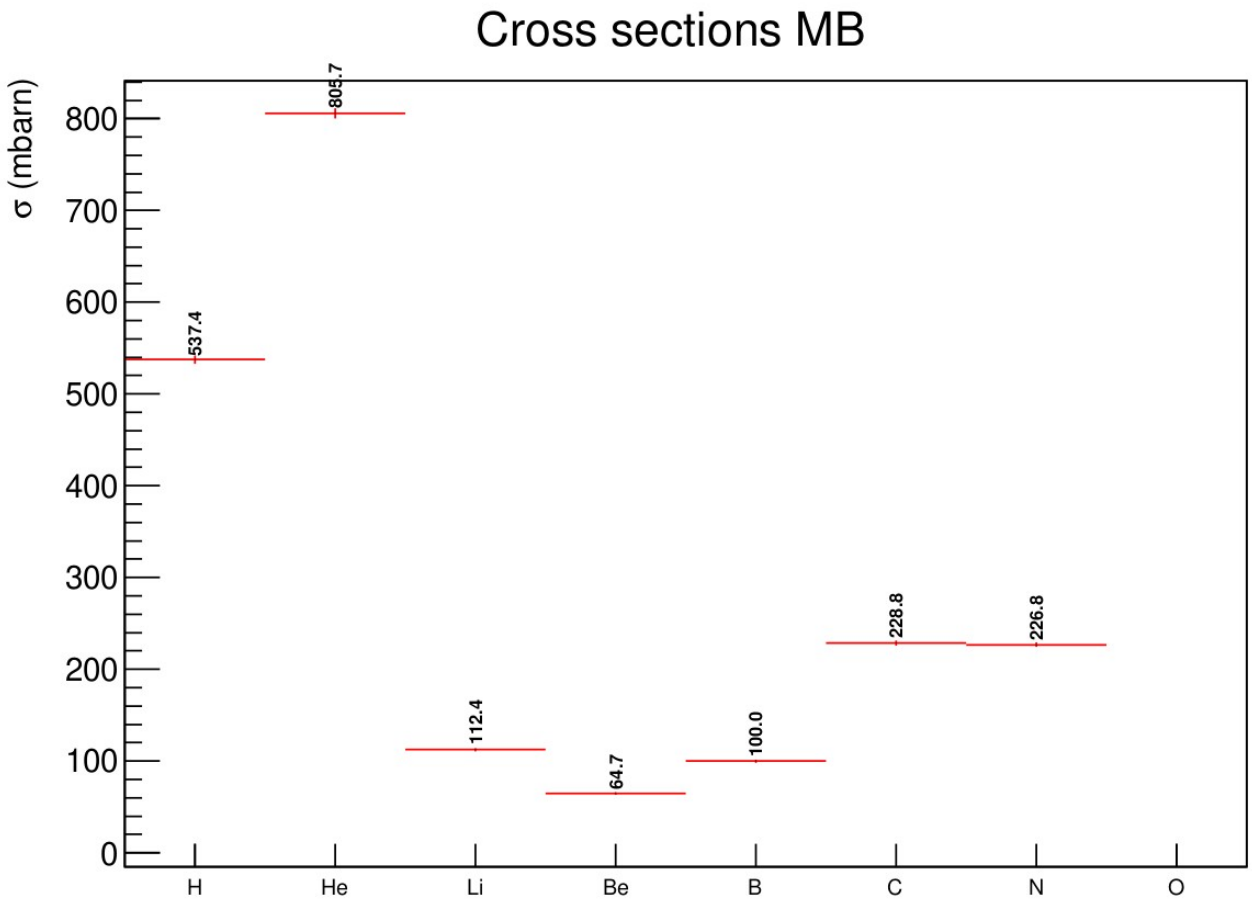

Eff_ang_point_Z2
yields
Eff_ang_point_Z2
Entries 10
Mean 3.278
Std Dev 1.665
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0
2
4
6


Eff_ang_point_Z6
yields
Eff_ang_point_Z6
Entries 5
Mean 1.506
Std Dev 0.8449
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0
1
2
3
4
5
6
θ [°]

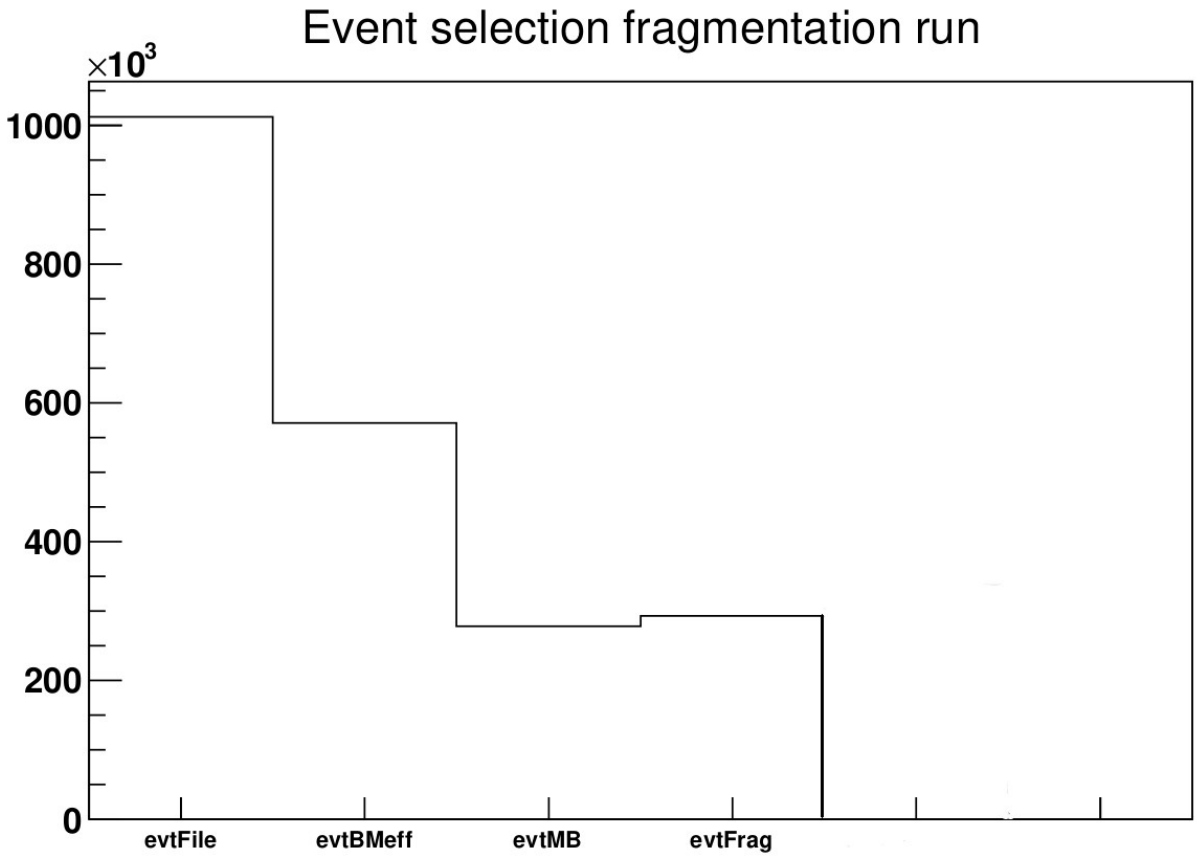
Cross section measurement MB (4305-6-7)



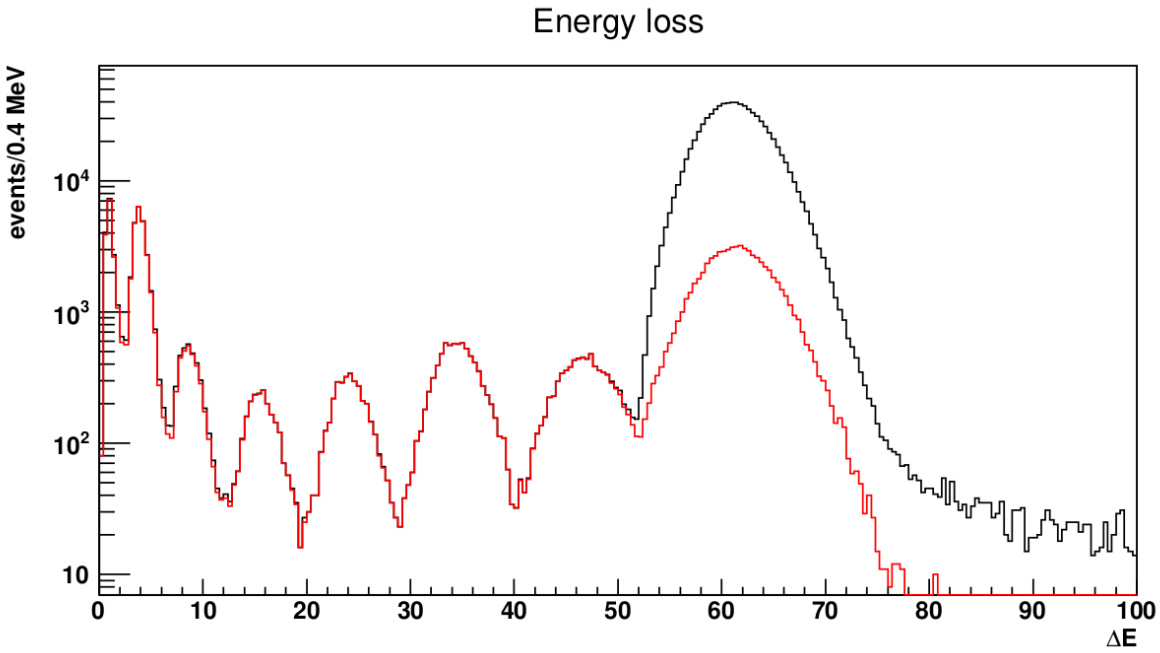
Cross section measurement MB (4305-6-7)

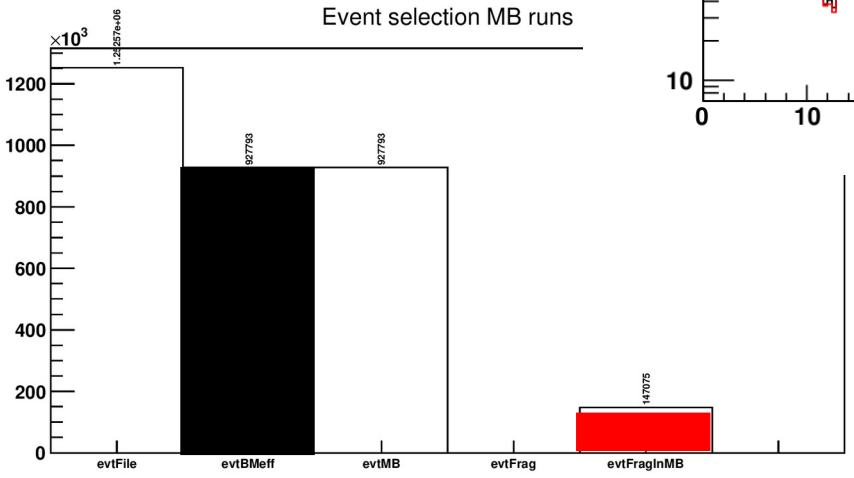


Cross section measurement frag (4310)



Number of primaries estimation (4310)



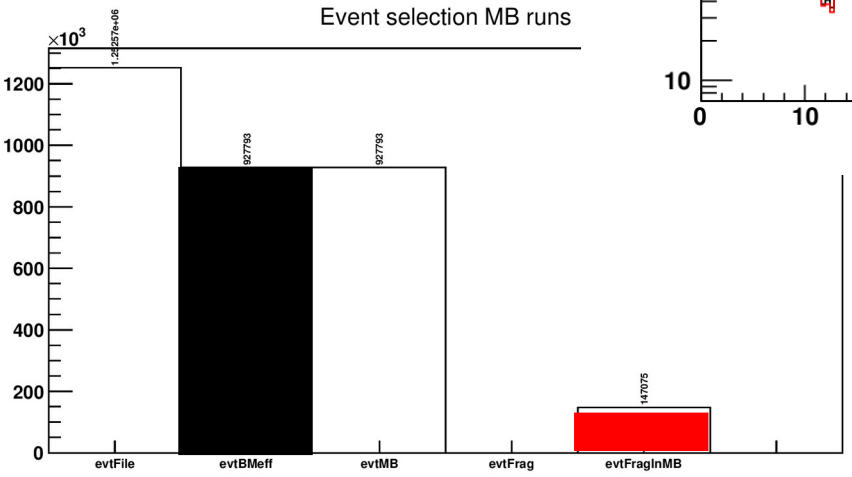


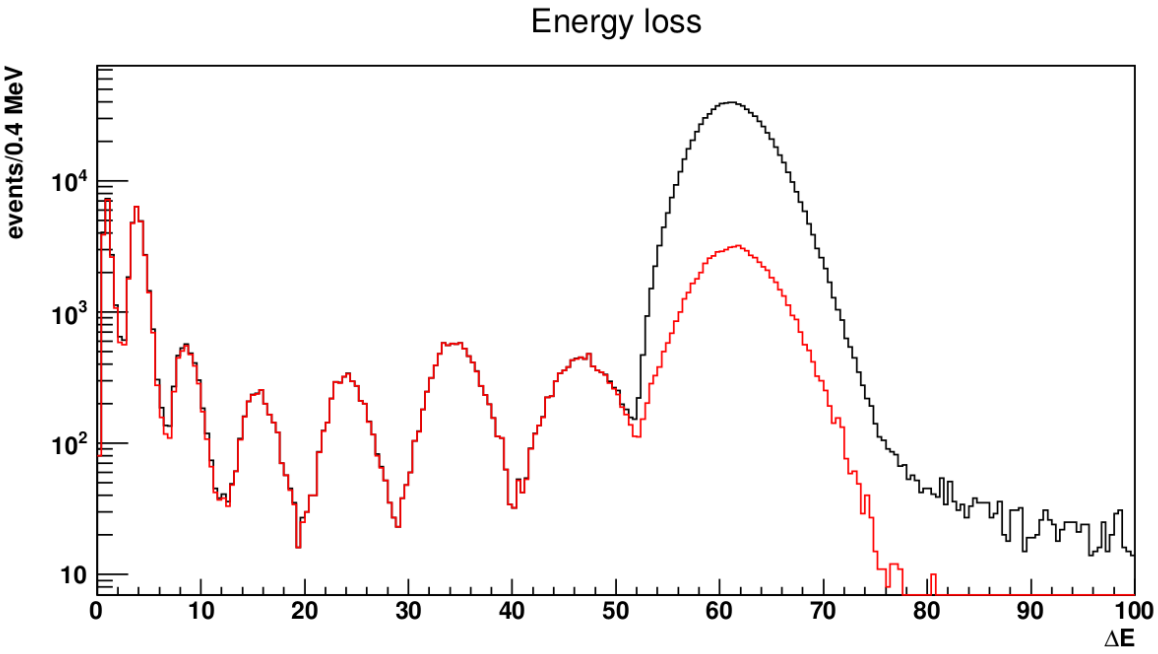
Number of primaries estimation (4310)

$$R = \frac{N_{\text{evtFragInMB}}}{N_{\text{evtMB}}} \approx 0.1585$$

$$\varepsilon_{\text{frag}}(Z) = \frac{N_{\text{evtFragInMB}}(Z)}{N_{\text{evtMB}}(Z)}.$$

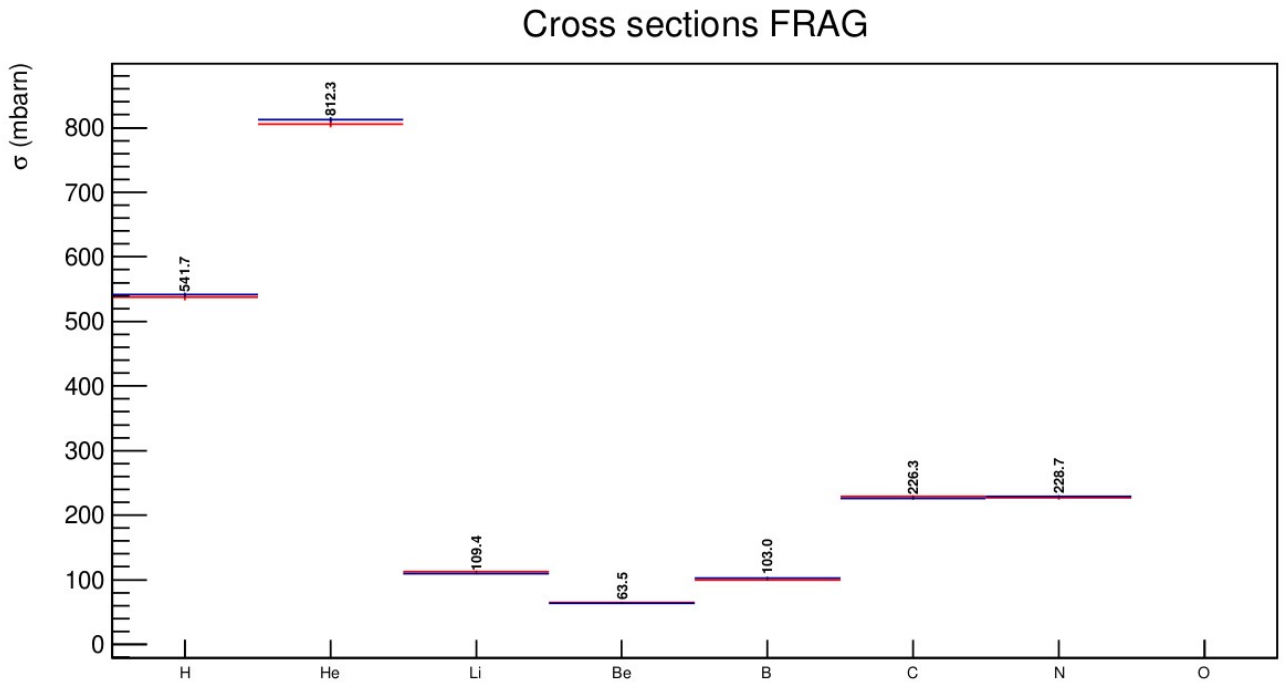
H	He	Li	Be
95.7 ± 0.2	98.2 ± 0.1	99.1 ± 0.2	99.3 ± 0.2
B	C	N	O
99.6 ± 0.1	99.8 ± 0.1	98.2 ± 0.1	8.46 ± 0.03



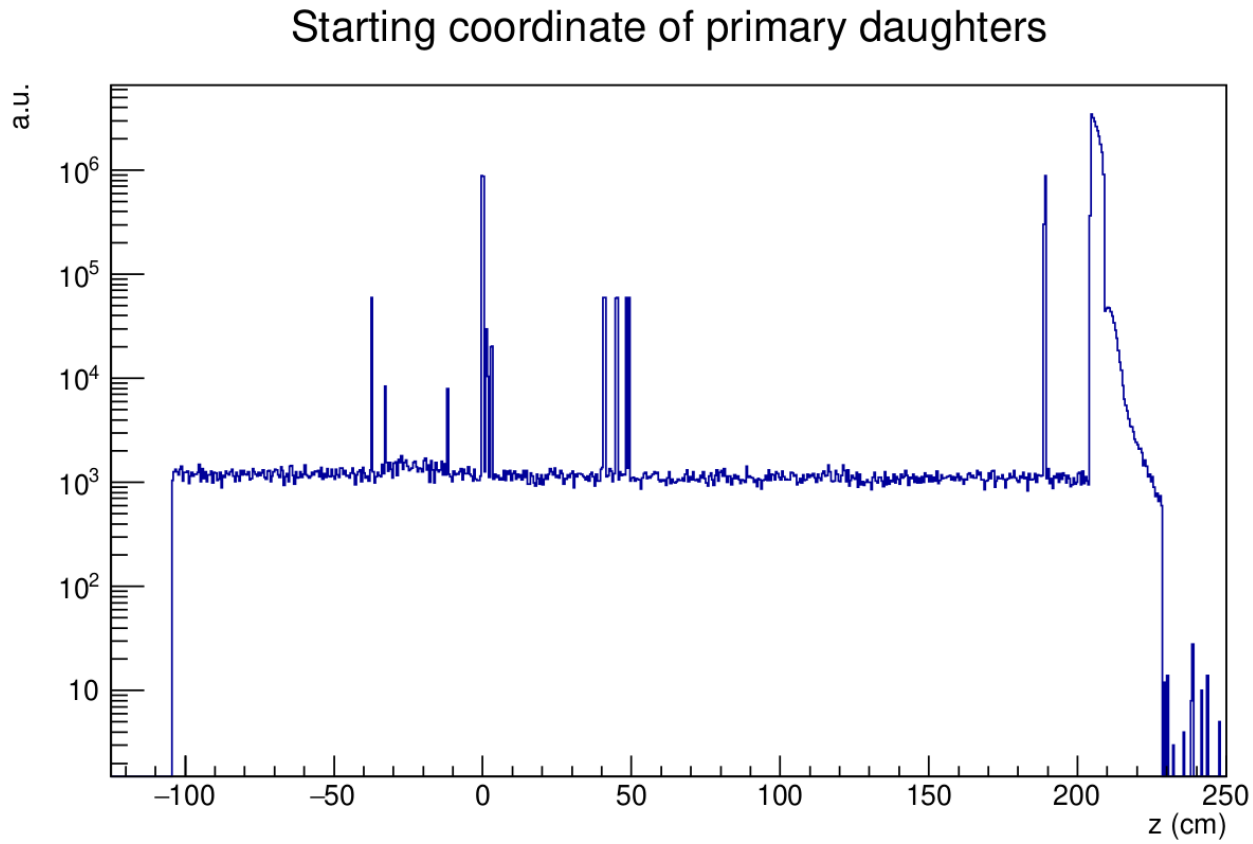


$$N_{\text{prim}} = N_{\text{frag}}/R$$
$$Y(Z) \to Y(Z)/\varepsilon_{\text{frag}}(Z).$$

Cross sections

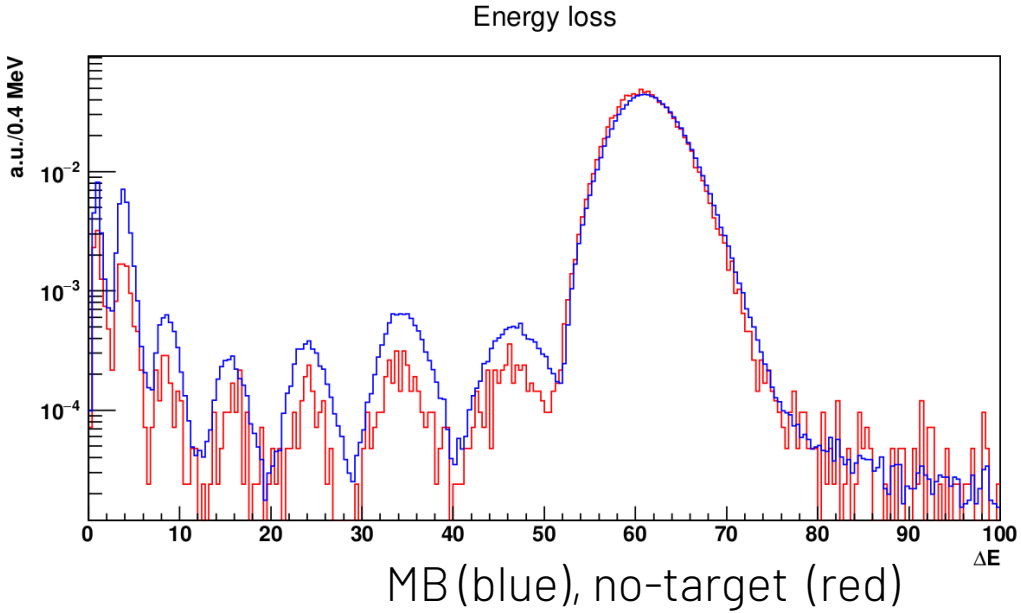


Background subtraction



Background subtraction (4313)

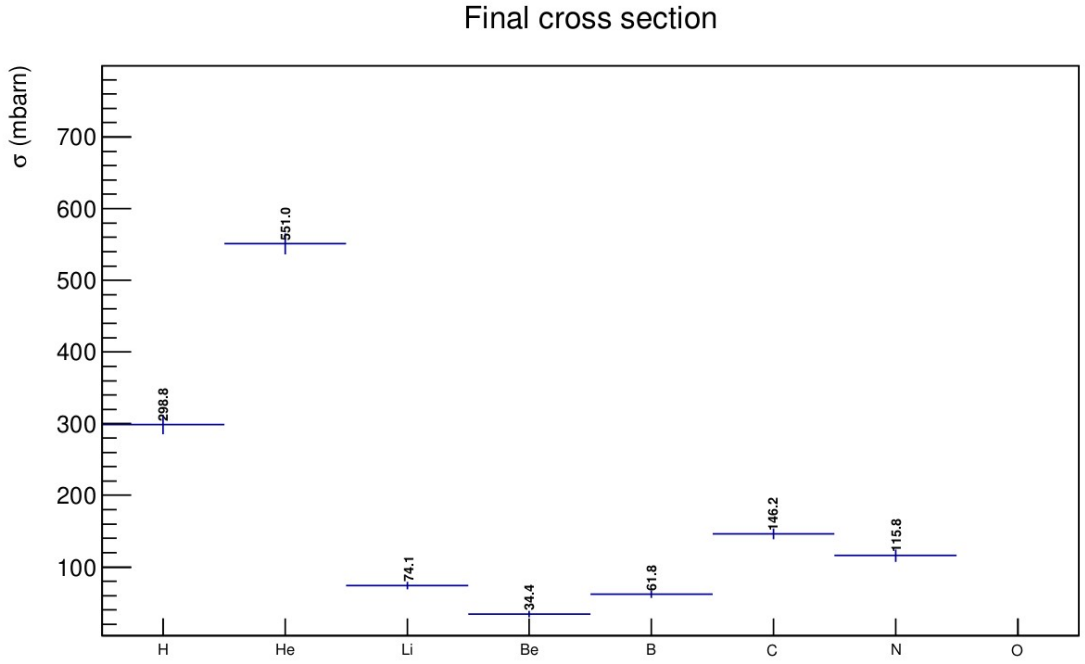
Fragment	Y^{sig}	Y^{bkg}
H	16696 ± 129	339 ± 18
He	24213 ± 156	350 ± 19
Li	3591 ± 60	56 ± 8
Be	2242 ± 47	48 ± 7
B	3497 ± 59	61 ± 8
C	7944 ± 89	131 ± 11
N	8004 ± 89	179 ± 13
O	846504 ± 920	40603 ± 202



MB (blue), no-target (red)

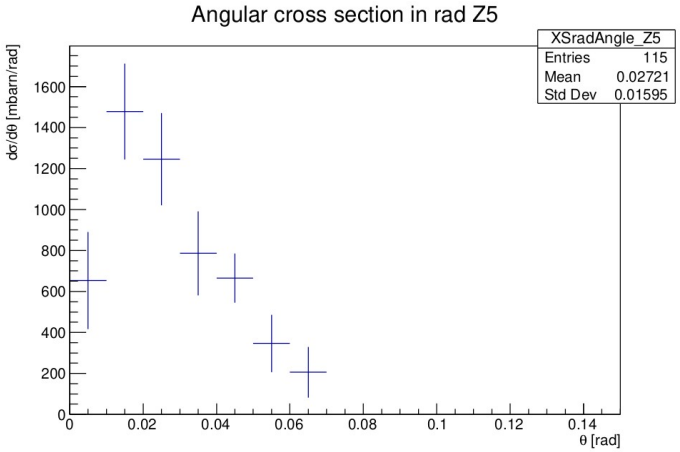
$$\Delta\sigma(Z) = \frac{1}{N_{\mathrm{TG}} \cdot \varepsilon(Z)} \left(\frac{Y^{\mathrm{sig}}(Z)}{N^{\mathrm{sig}}_{\mathrm{prim}}(Z)} - \frac{Y^{\mathrm{bkg}}(Z)}{N^{\mathrm{bkg}}_{\mathrm{prim}}(Z)} \right)$$

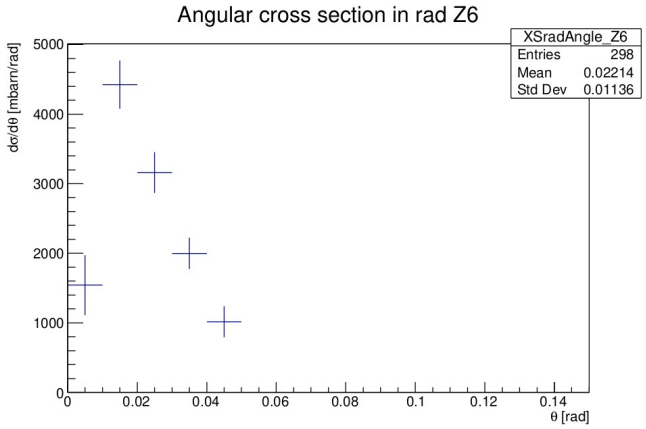
Background subtraction

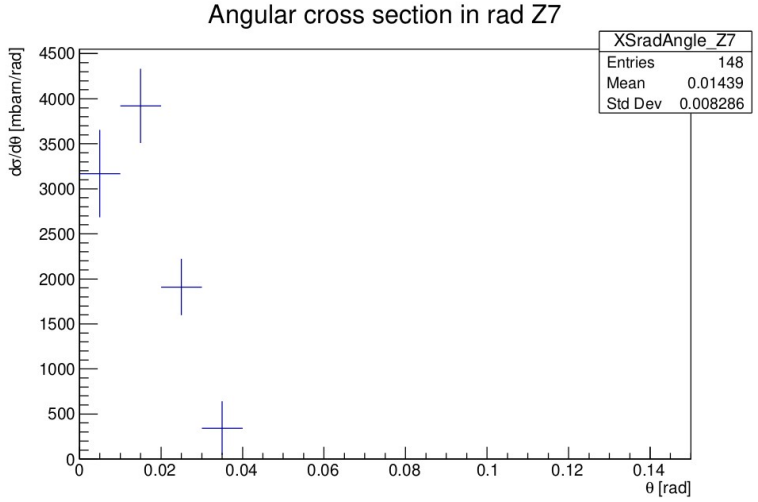


H	He	Li	Be
299 ± 14	551 ± 15	74.1 ± 5.5	34.4 ± 4.6
B	C	N	
61.8 ± 5.2	146.2 ± 7.7	115.8 ± 8.7	

Differential cross sections







Comparison with literature

PHYSICAL REVIEW C **83**, 034909 (2011)

Fragmentation of ^{14}N, ^{16}O, ^{20}Ne, and ^{24}Mg nuclei at 290 to 1000 MeV/nucleon

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(Received 27 October 2010; revised manuscript received 20 January 2011; published 24 March 2011)
10.1103/PhysRevC.83.034909

We report fragmentation cross sections measured at 0° for beams of ^{14}N, ^{16}O, ^{20}Ne, and ^{24}Mg ions, at energies ranging from 290 MeV/nucleon to 1000 MeV/nucleon. Beams were incident on targets of C, CH_2, Al, Cu, Sn, and Pb, with the C and CH_2 target data used to obtain hydrogen-target cross sections. Using methods established in earlier work, cross sections obtained with both large-acceptance and small-acceptance detectors are extracted from the data and, when necessary, corrected for acceptance effects. The large-acceptance data yield cross sections for fragments with charges approximately half of the beam charge and above, with minimal corrections. Cross sections for lighter fragments are obtained from small-acceptance spectra, with more significant, model-dependent corrections that account for the fragment angular distributions. Results for both charge-changing and fragment production cross sections are compared to the predictions of the Los Alamos version of the quark gluon string model (LAQGSM) as well as the NASA Nuclear Fragmentation (NUCFRG2) model and the Particle and Heavy Ion Transport System (PHITS) model. For all beams and targets, cross sections for fragments as light as He are compared to the models. Estimates of multiplicity-weighted helium production cross sections are obtained from the data and compared to PHITS and LAQGSM predictions. Summary statistics show that the level of agreement between data and predictions is slightly better for PHITS than for either NUCFRG2 or LAQGSM.

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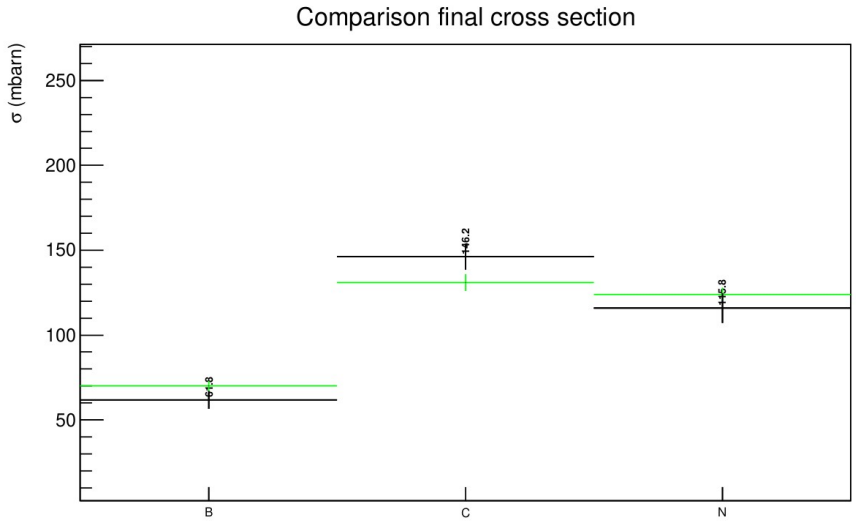
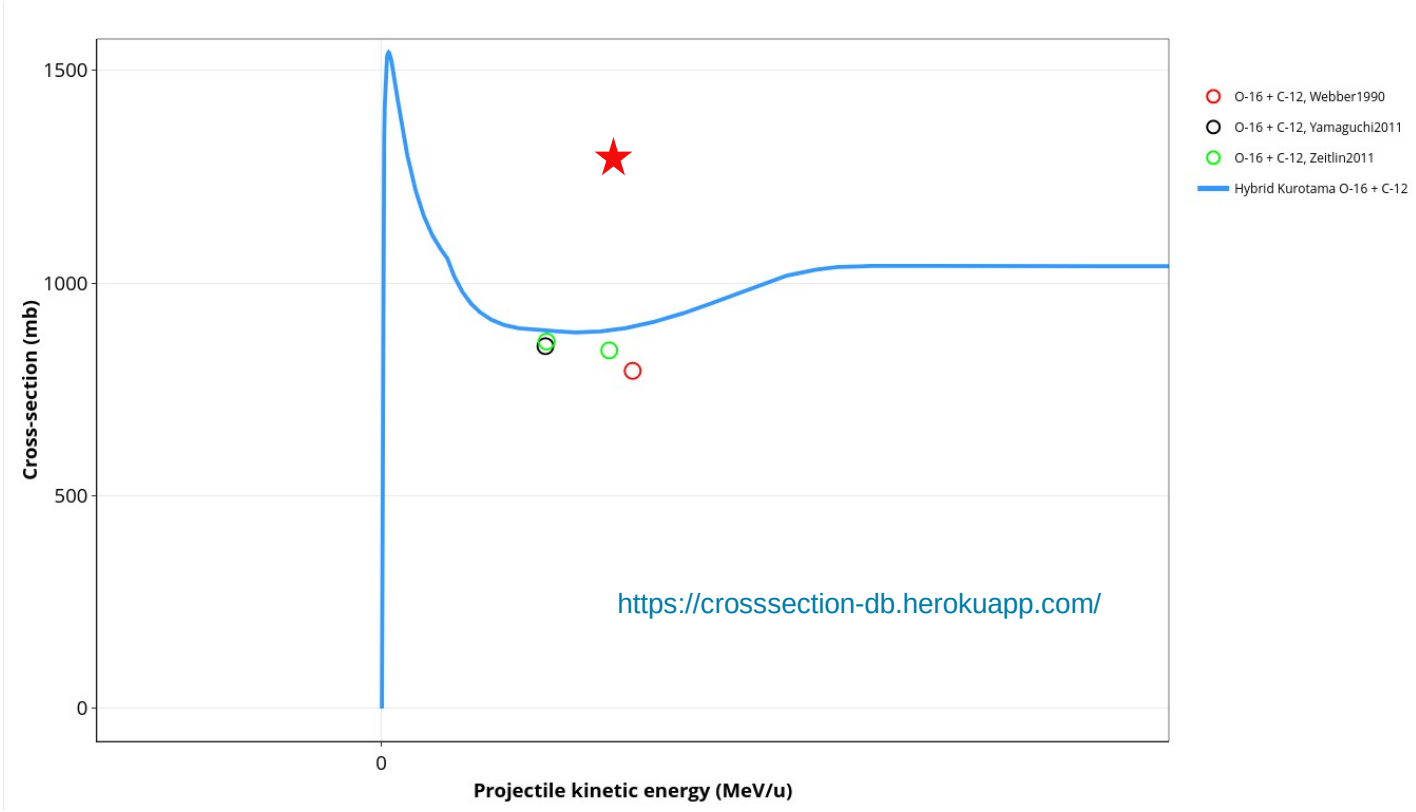


	This work	Ref.[69]	Weighted average	t
B	62 ± 5	70 ± 3	68.0 ± 2.6	-1.37
C	146 ± 8	131 ± 5	135.5 ± 4.2	1.66
N	116 ± 9	124 ± 4	122.6 ± 3.6	-0.86

Comparison


1500
1000
500
0
Cross-section (mb)
0
Projectile kinetic energy (MeV/u)
O-16 + C-12, Webber1990
O-16 + C-12, Yamaguchi2011
O-16 + C-12, Zeitlin2011
Hybrid Kurotama O-16 + C-12
https://crosssection-db.herokuapp.com/

Conclusions

First elemental cross sections with 400 MeV/u ^{16}O beam on 5mm Carbon target were shown

No trackers included

Difference between fragmentation and MB runs solved

Low-Z cross sections seem to be too high

Systematics to be done

Not to far from other data!

Thanks for your attention!