GSI2021 analysis without tracking

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25 June 2024 - XVI FOOT
Collaboration Meeting

Cross section measurement

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

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

Align FOOT detectors and estimate angular acceptance

Extract fragment yields from TW

Calculate MC efficiencies for fragments

Evaluate the beta range from data and put in MC for efficiency calculations

Cross section measurement

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

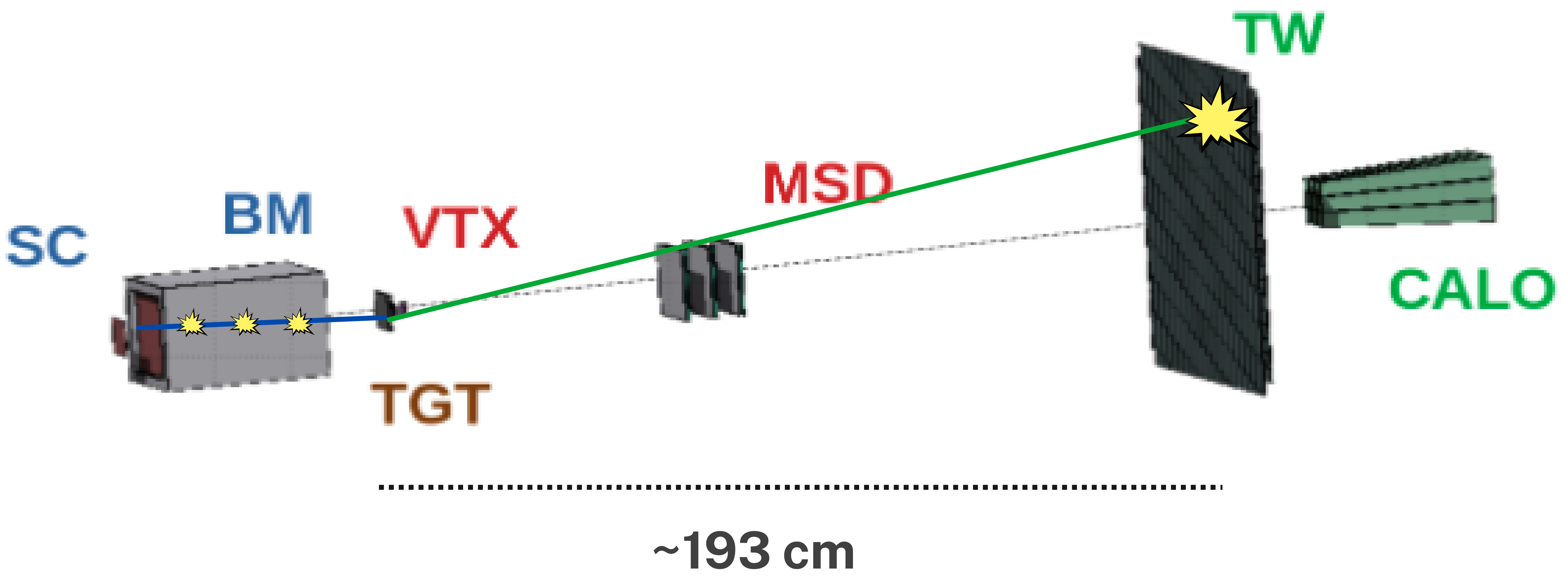
$$\frac{\mathrm{d}\sigma}{\mathrm{d}\theta}(Z) = \frac{Y(Z,\theta)}{N_{\mathrm{prim}} \cdot N_{\mathrm{TG}} \cdot \Delta\theta \cdot \varepsilon(Z,\theta)}$$

Align FOOT detectors and estimate **angular acceptance**

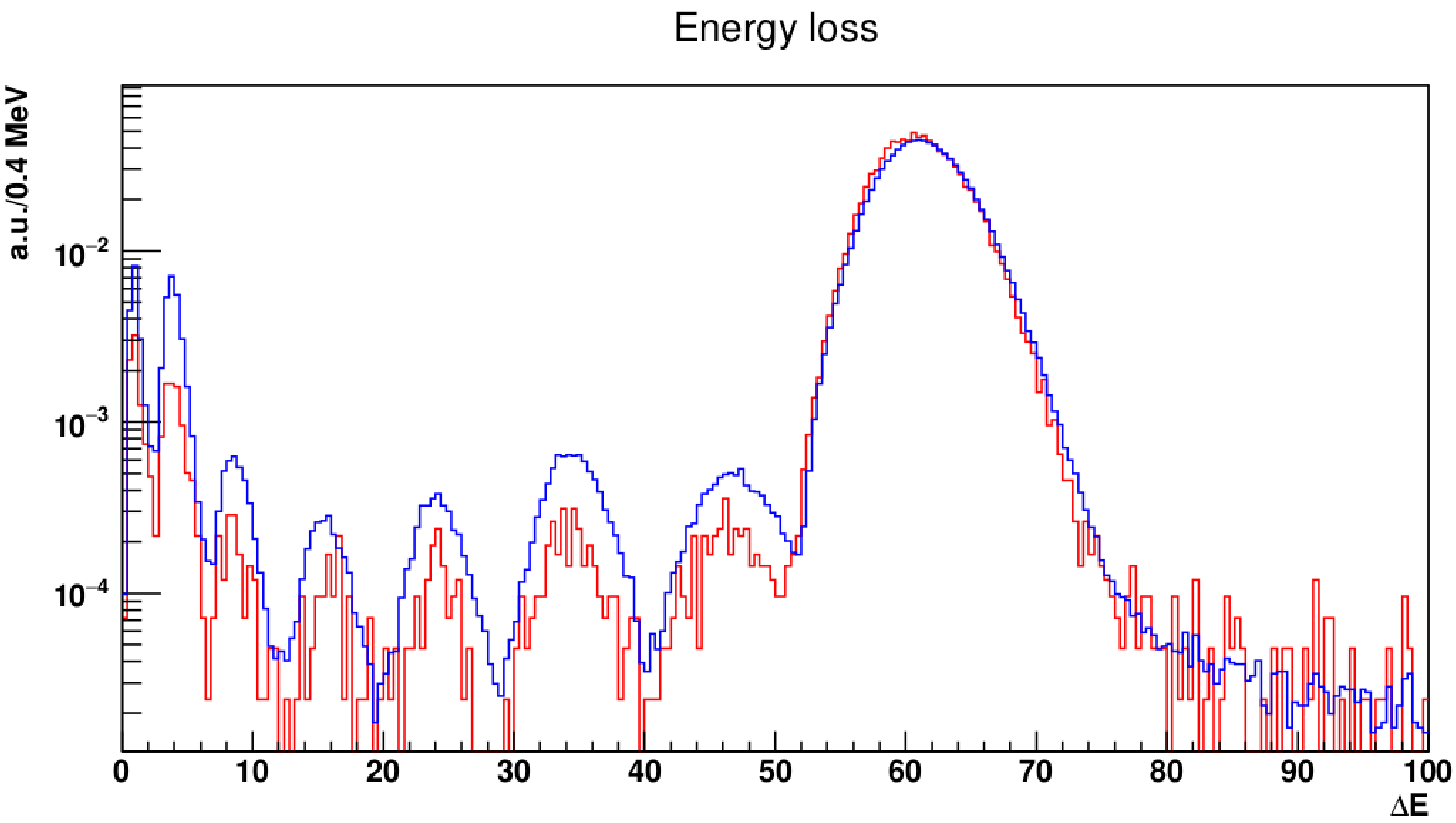
Extract fragment yields from TW

Calculate MC efficiencies for fragments

Angle measurement



Why background subtraction?



from Trento
GM

Conclusions

Background subtraction strategy seems to work also for angle differential cross sections

Purity correction implemented(very important for Li and Be)

Good agreement in MC closure test except for first bin of C and N

Angle unfolding machinery ready to be performed

Very few statistics for background reduces final number of bins

Comparison with “with tracking analysis” ongoing (and promising!) (Giacomo’s talk)

Conclusions

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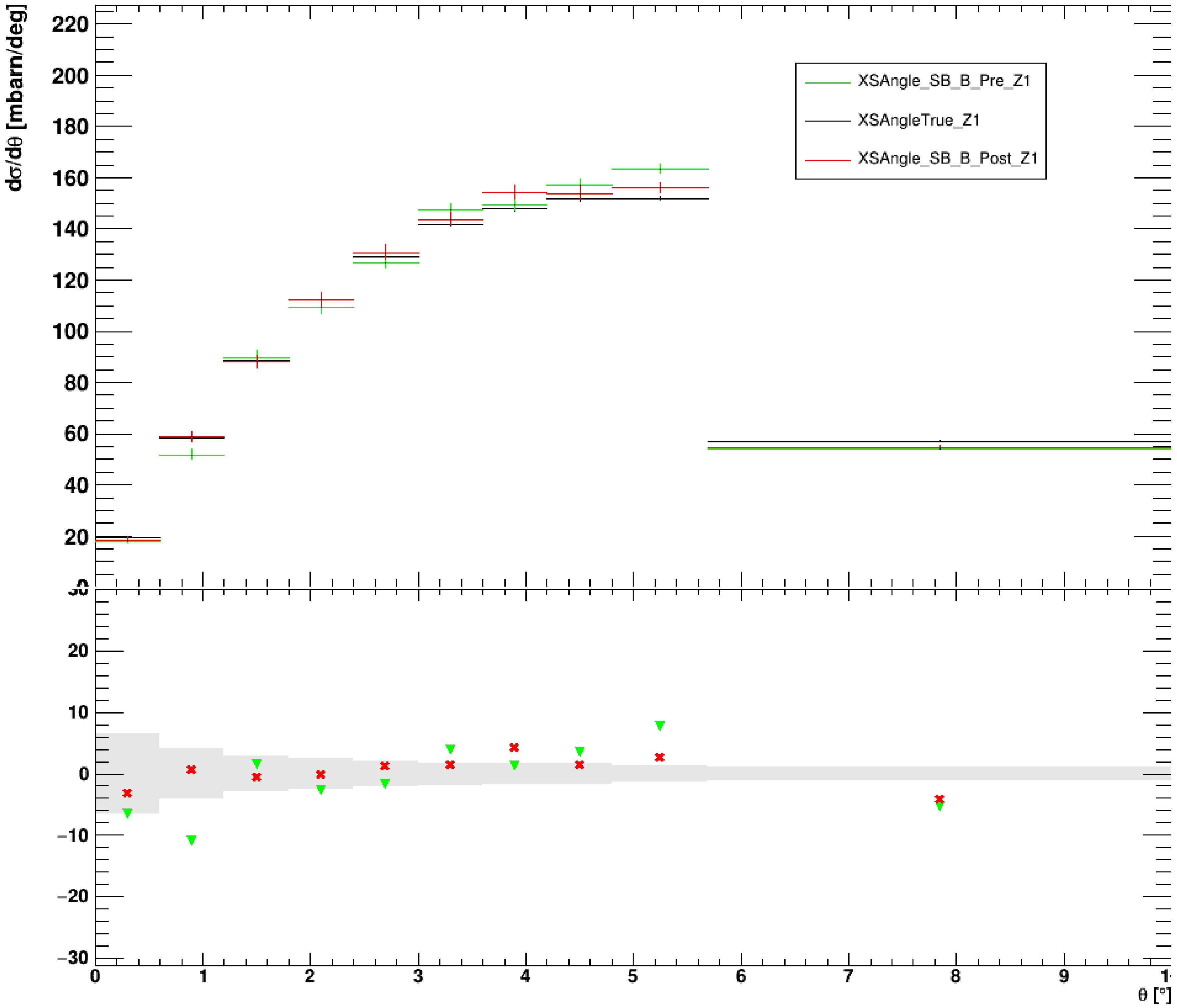
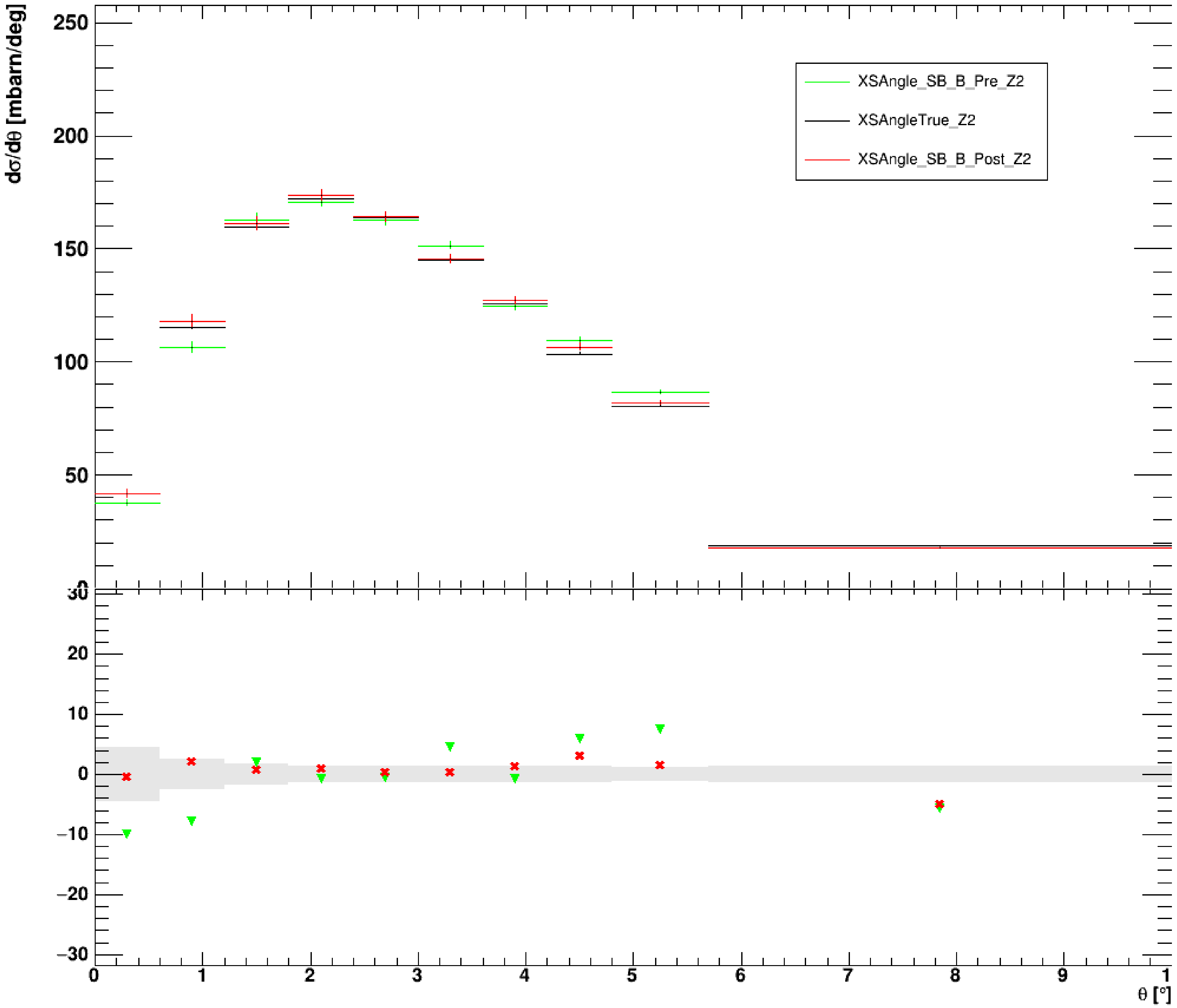
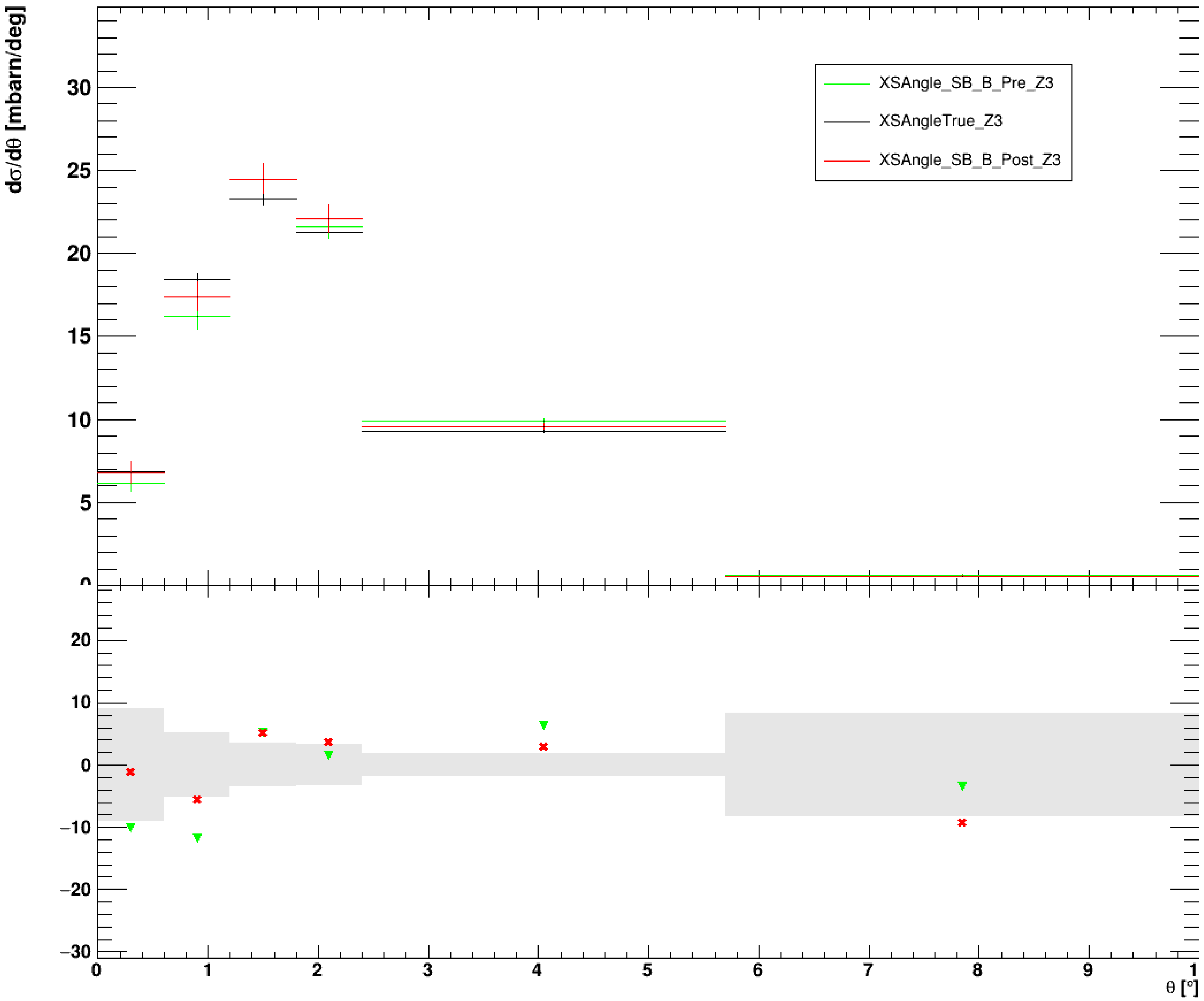


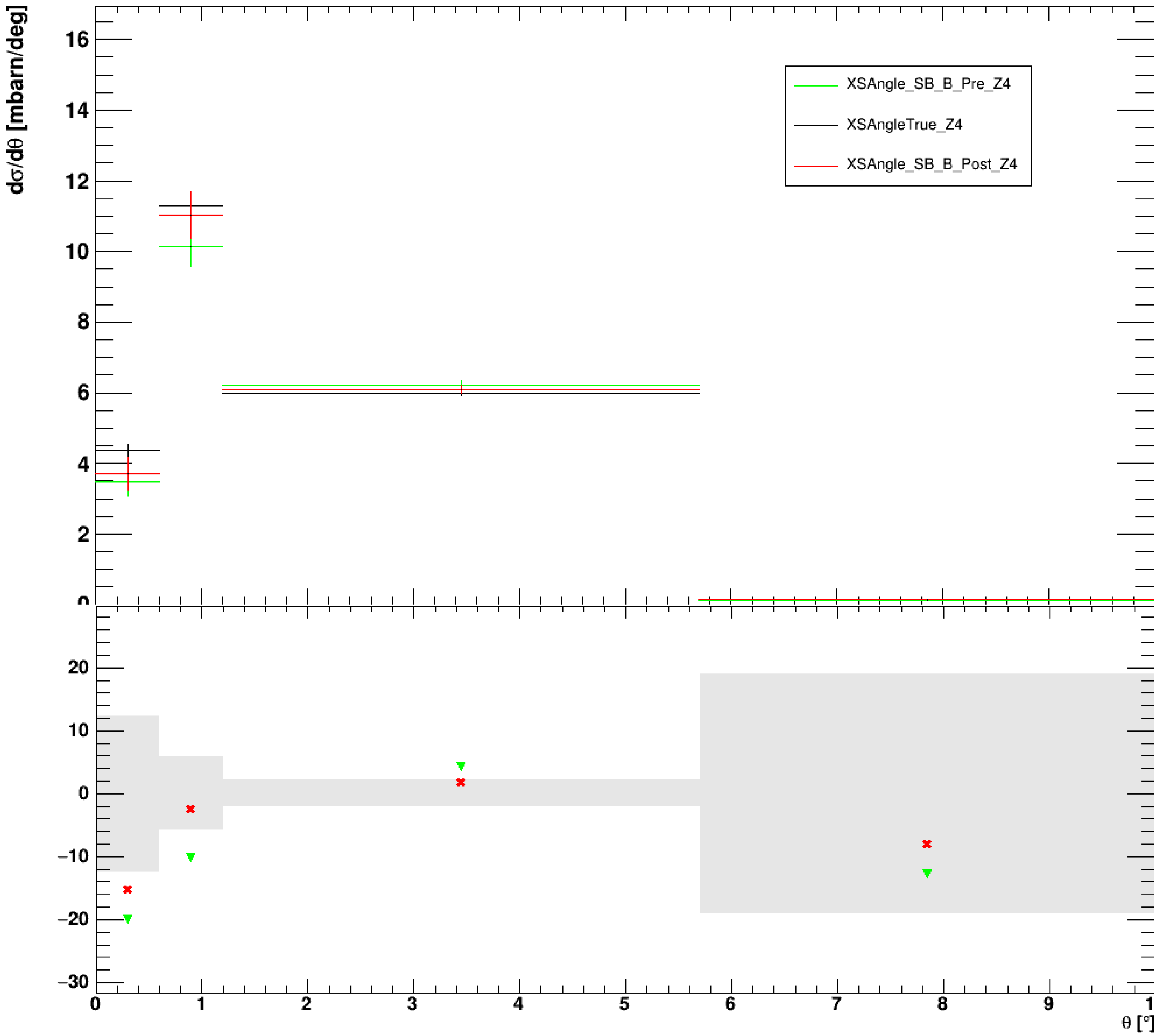
dσ/dθ [mbarn/deg]
XSAngle_SB_B_Pre_Z1
XSAngleTrue_Z1
XSAngle_SB_B_Post_Z1
θ [°]



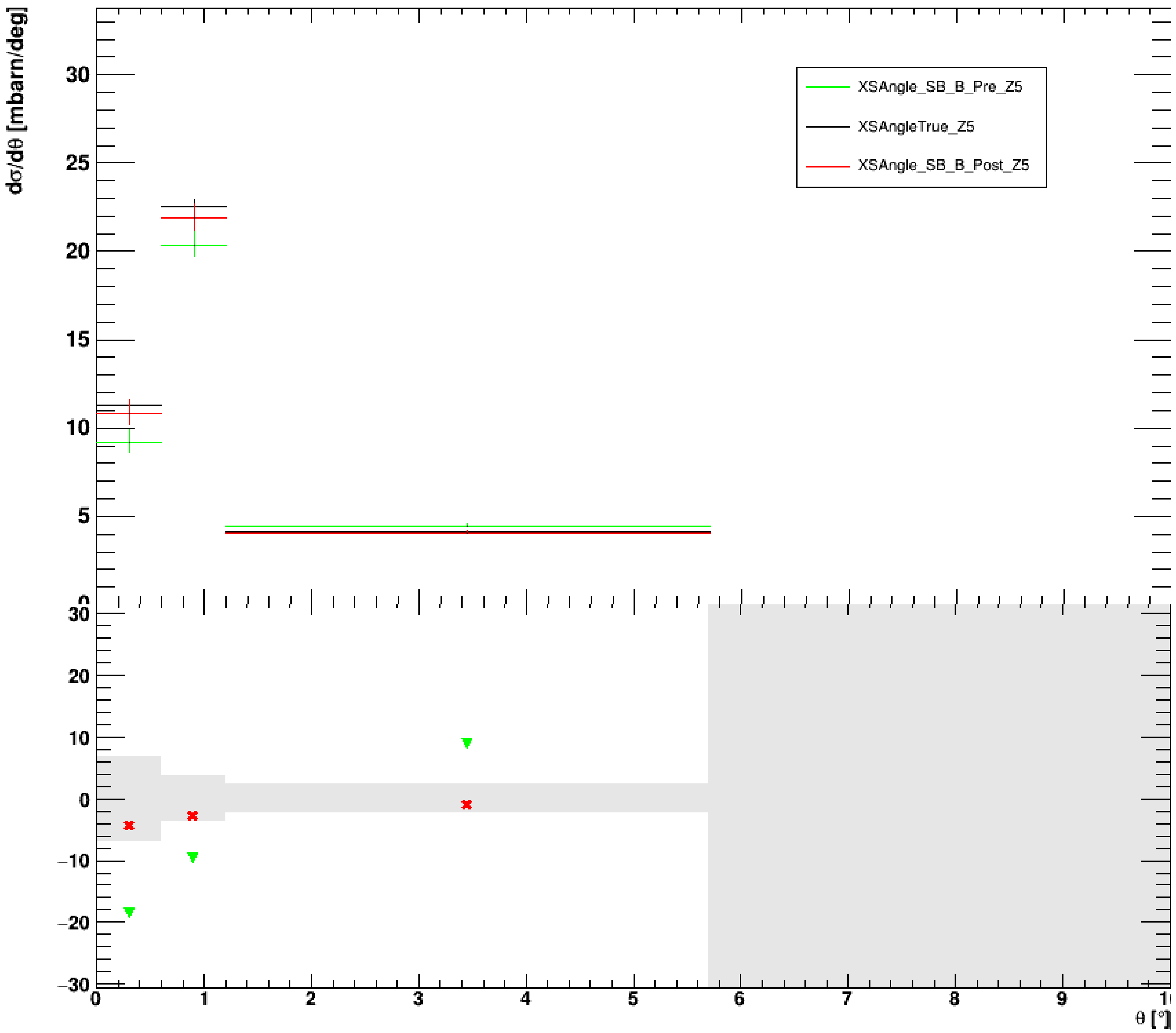
dσ/dθ [mbarn/deg]
XSAngle_SB_B_Pre_Z2
XSAngleTrue_Z2
XSAngle_SB_B_Post_Z2
θ [°]

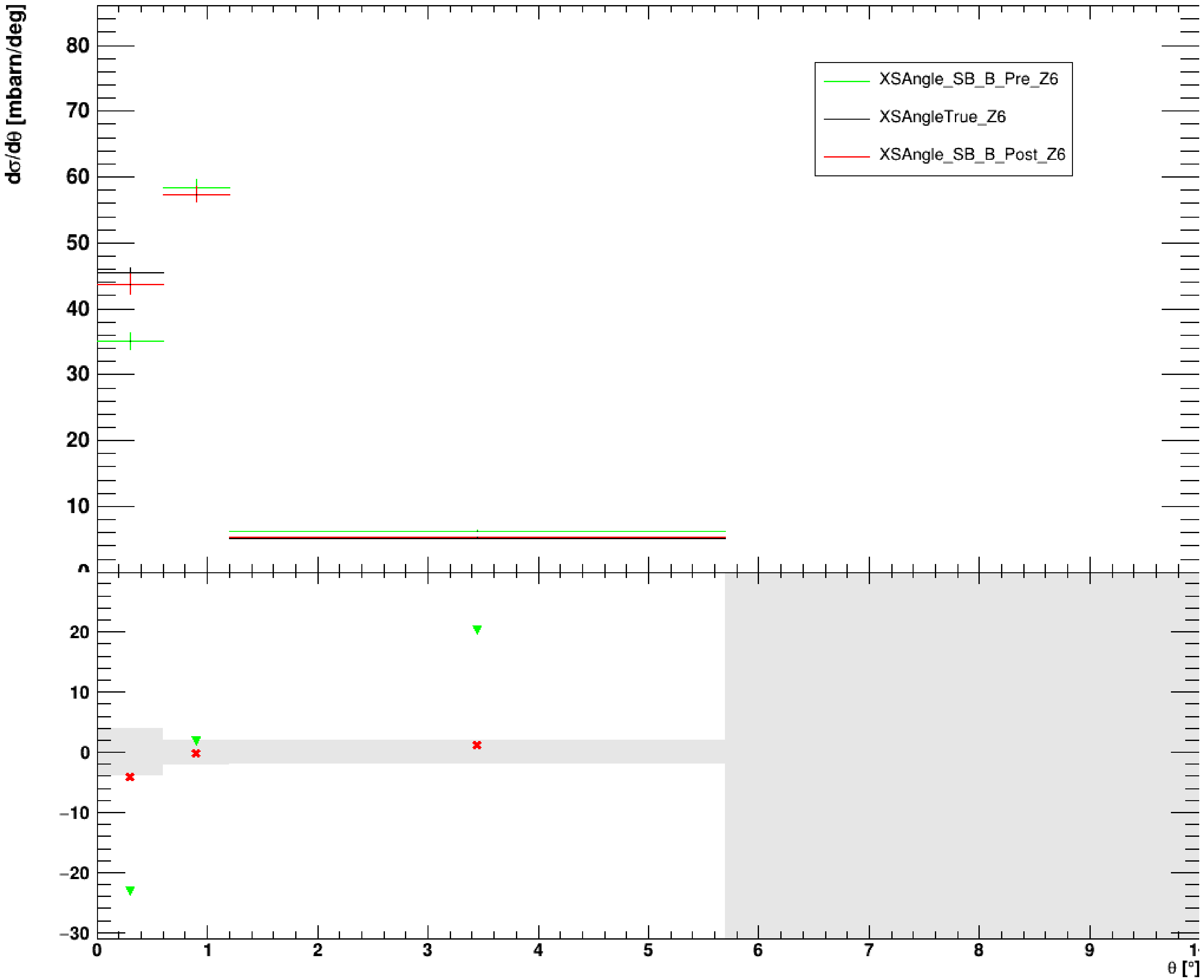


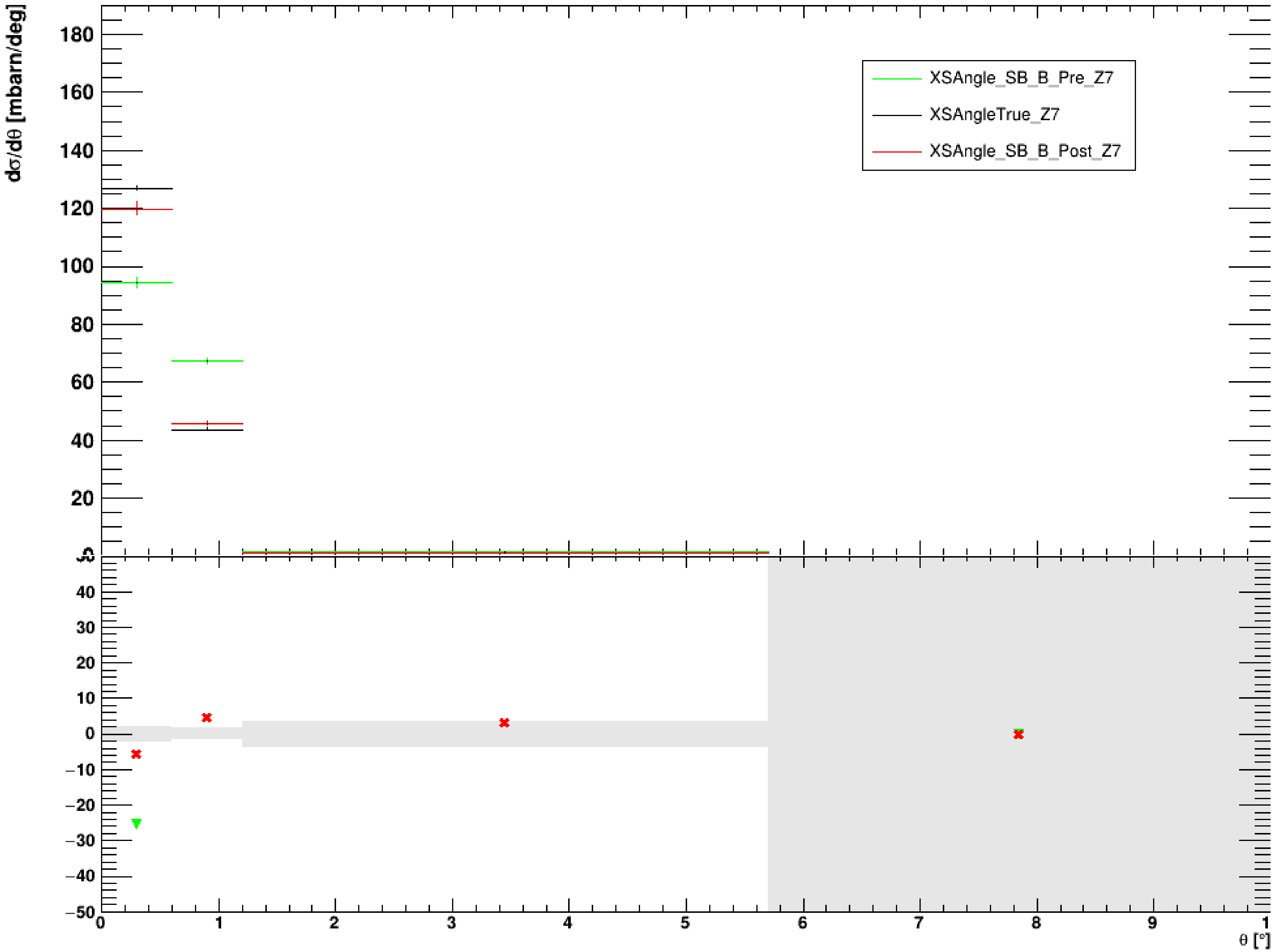
XSAngle_SB_B_Pre_Z3
XSAngleTrue_Z3
XSAngle_SB_B_Post_Z3
dσ/dθ [mbarn/deg]
θ [°]



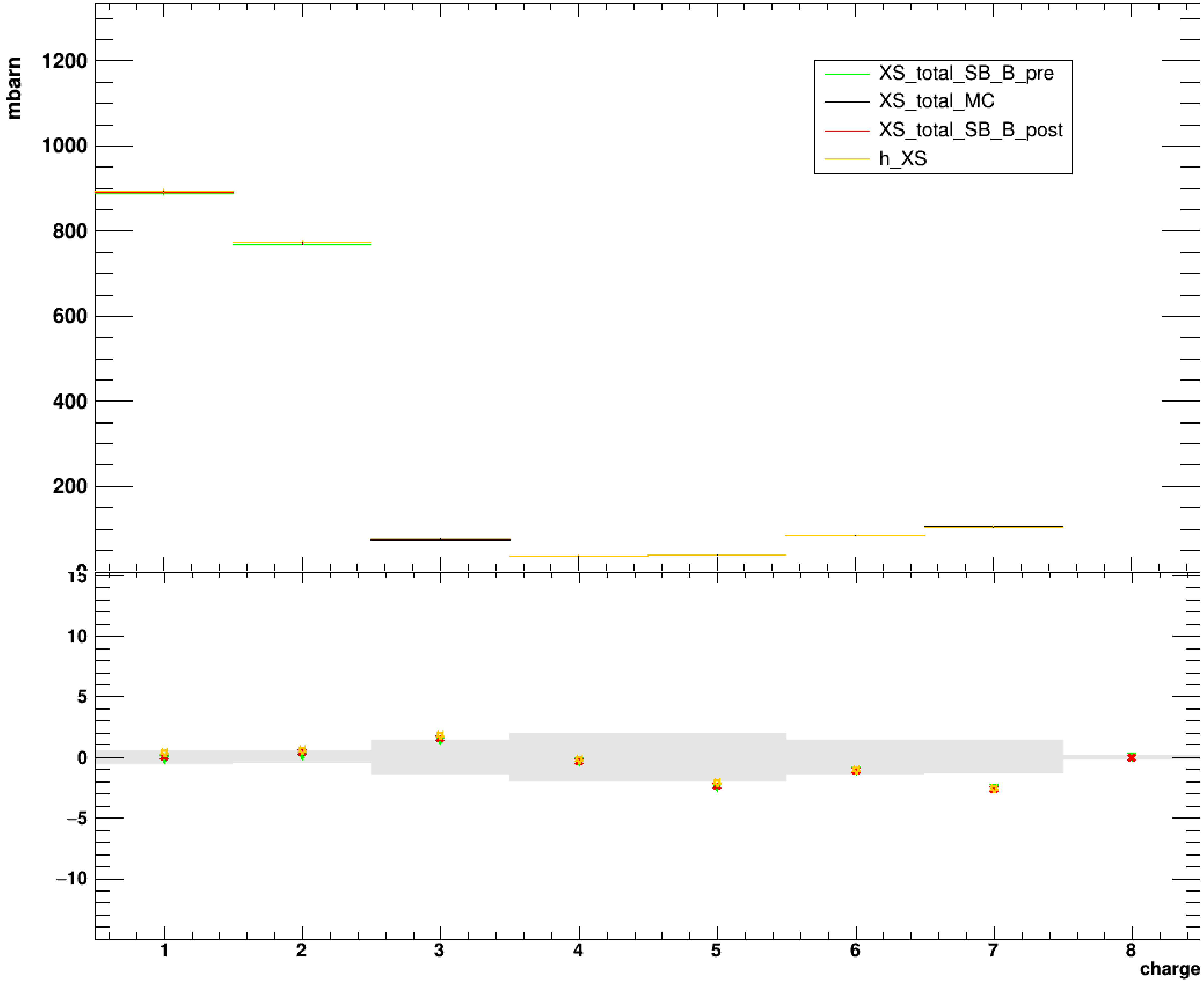
XSAngle_SB_B_Pre_Z4
XSAngleTrue_Z4
XSAngle_SB_B_Post_Z4
dσ/dθ [mbarn/deg]
θ [°]


dσ/dθ [mbarn/deg]
XSAngle_SB_B_Pre_Z5
XSAngleTrue_Z5
XSAngle_SB_B_Post_Z5
θ [°]


dσ/dθ [mbarn/deg]
XSAngle_SB_B_Pre_Z6
XSAngleTrue_Z6
XSAngle_SB_B_Post_Z6
θ [°]



dσ/dθ [mbarn/deg]
180
160
140
120
100
80
60
40
20
XSAngle_SB_B_Pre_Z7
XSAngleTrue_Z7
XSAngle_SB_B_Post_Z7
40
30
20
10
0
−10
−20
−30
−40
−50
0
1
2
3
4
5
6
7
8
9
1
θ [°]

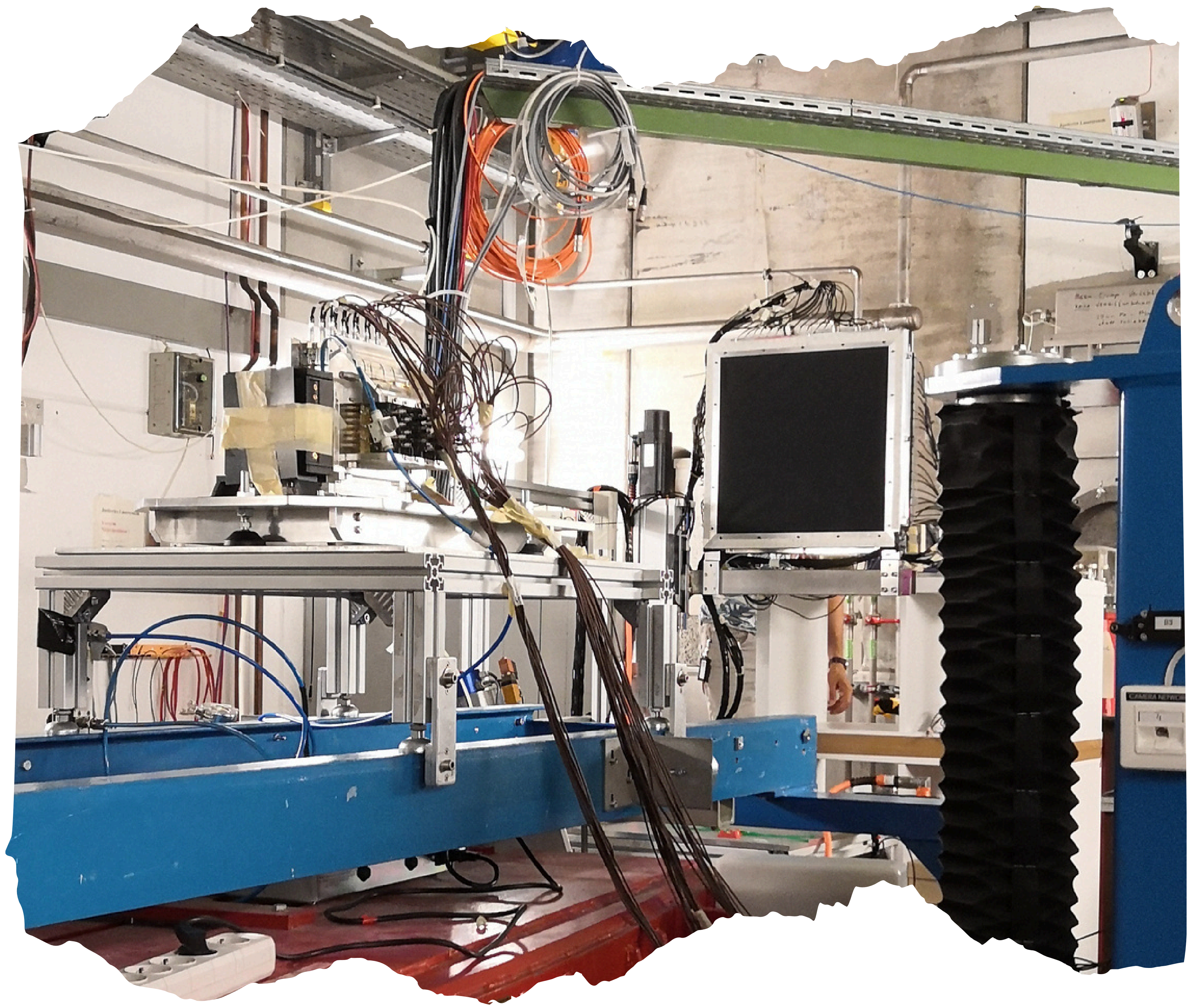

XS_total_SB_B_pre
XS_total_MC
XS_total_SB_B_post
h_XS
mbarn
1200
1000
800
600
400
200
0
15
10
5
0
−5
−10
1
2
3
4
5
6
7
8
charge

Data analysis

Run on data with the same steps of MC analysis

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
4308	Frag + MB	C	510169
4309	Frag + MB	C	531812
4310	Frag + MB	C	1012099
4313	MB	no	57133



New analysis flow

Evaluate **efficiencies** and **purities**

Repeat for with and w/o target samples

Apply reconstruction cuts (SC, BM)

Normalize yields and **subtract** background

Apply efficiency and **purity** for fragmentation in target

Unfolding

Calculate angular **cross sections**

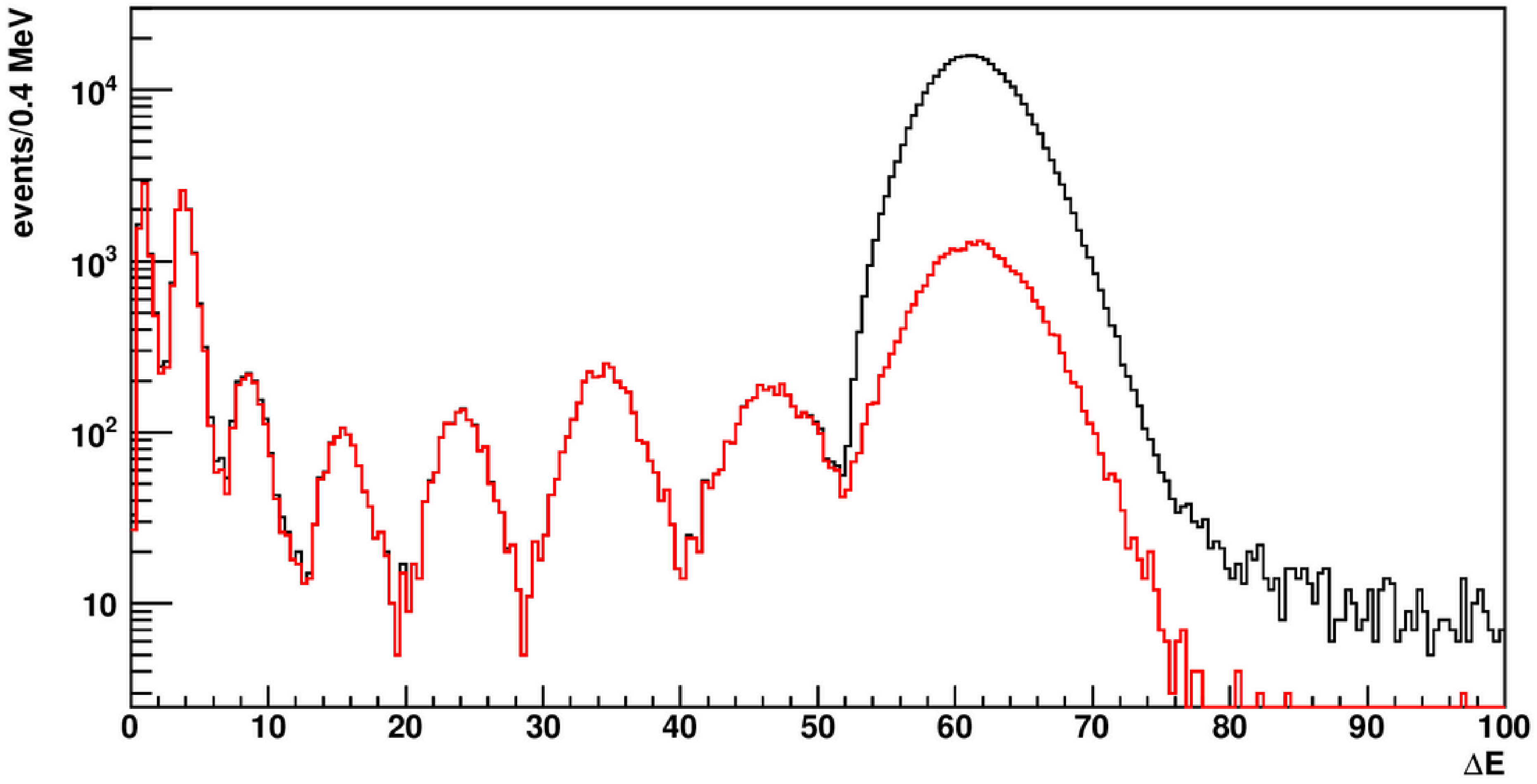
Add systematics uncertainties

Data analysis

In MB runs the number of primaries is the number of events passing selection cuts

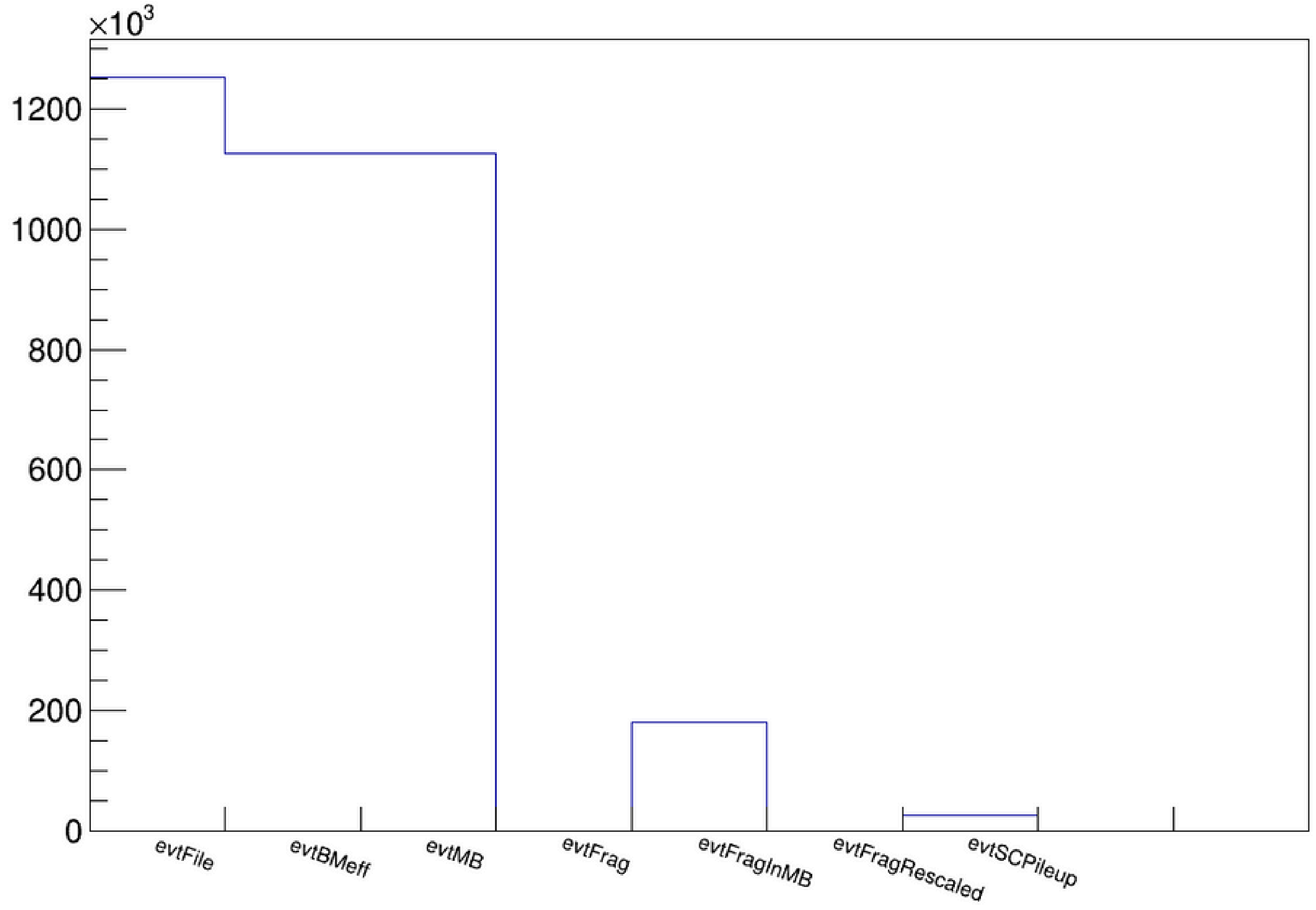
In fragmentation runs the number of primaries has to take into account the **trigger rejection factor**

It can be evaluated from MB runs (fragmentation flag: ON)

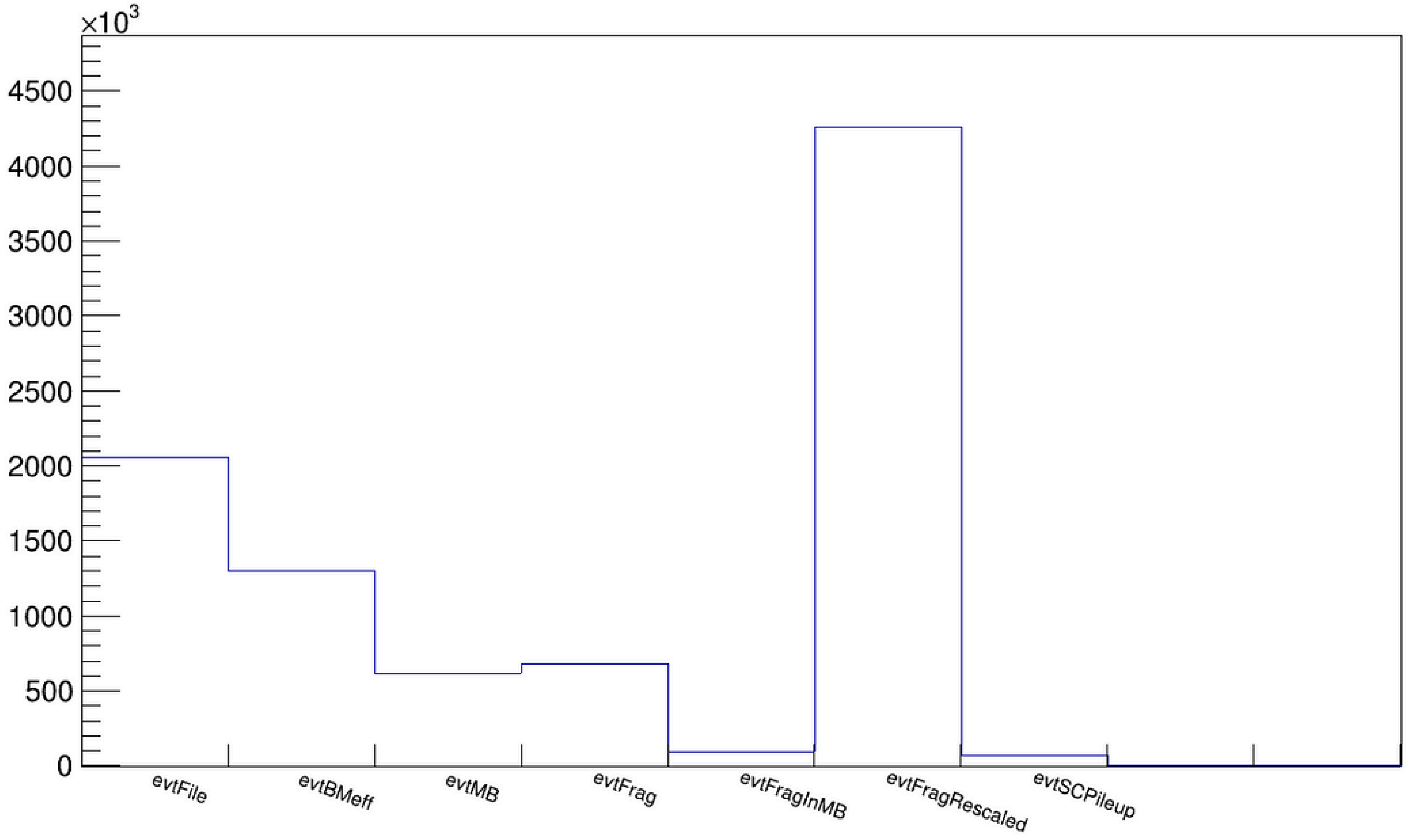


Number of events

Minimum bias (4305,4306,4307)

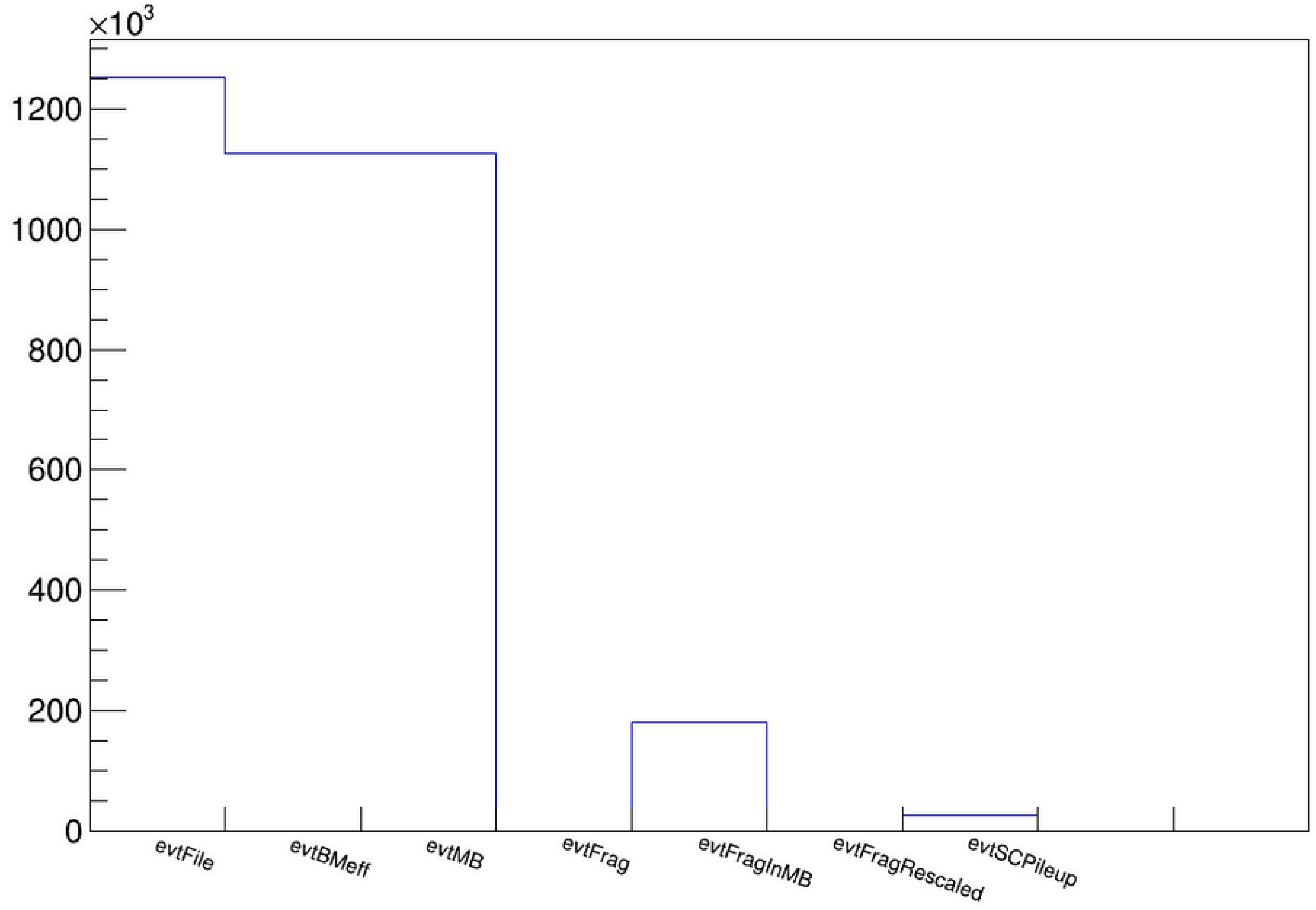


Fragmentation+MB (4308, 4309, 4310)



Number of events

Minimum bias (4305,4306,4307)



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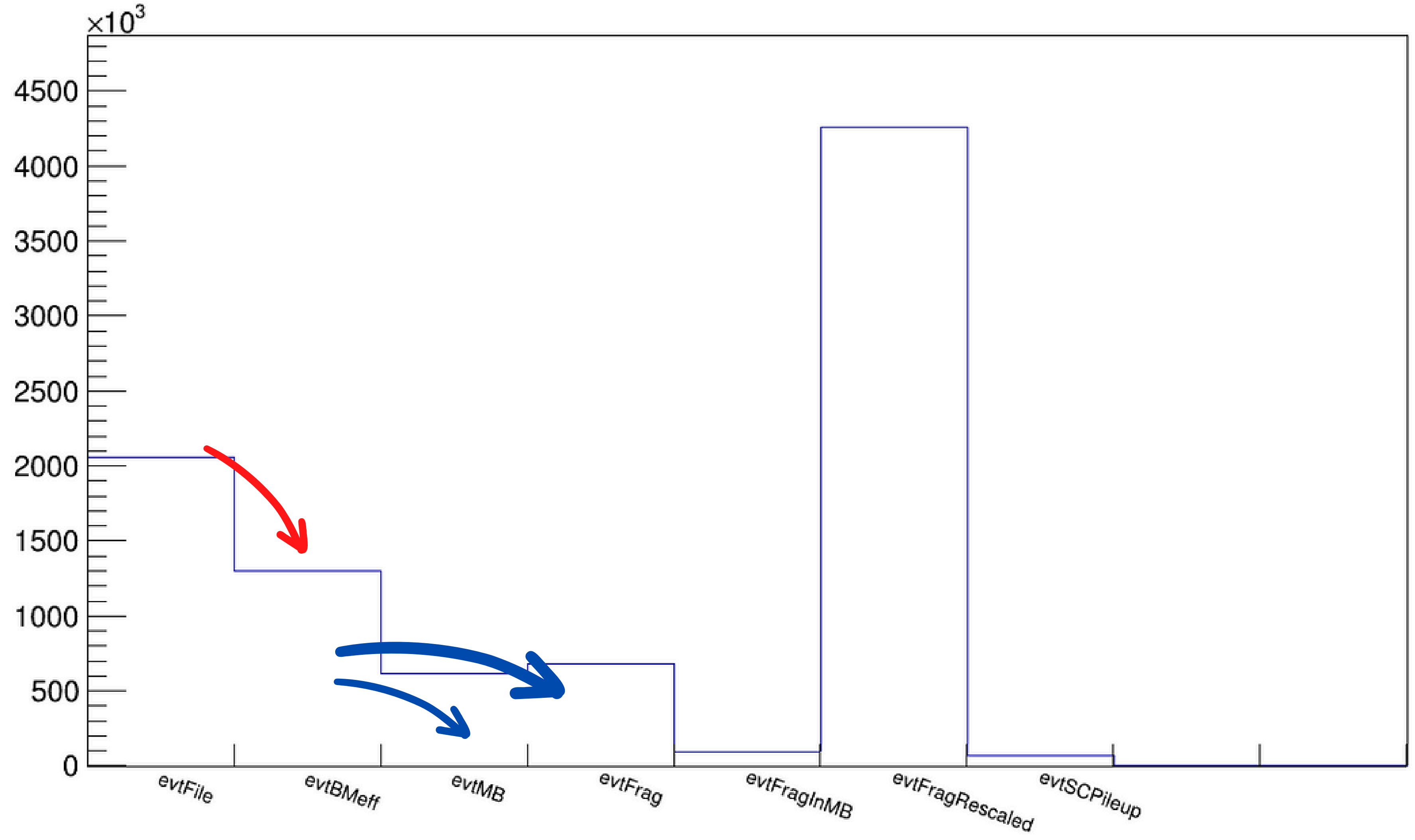
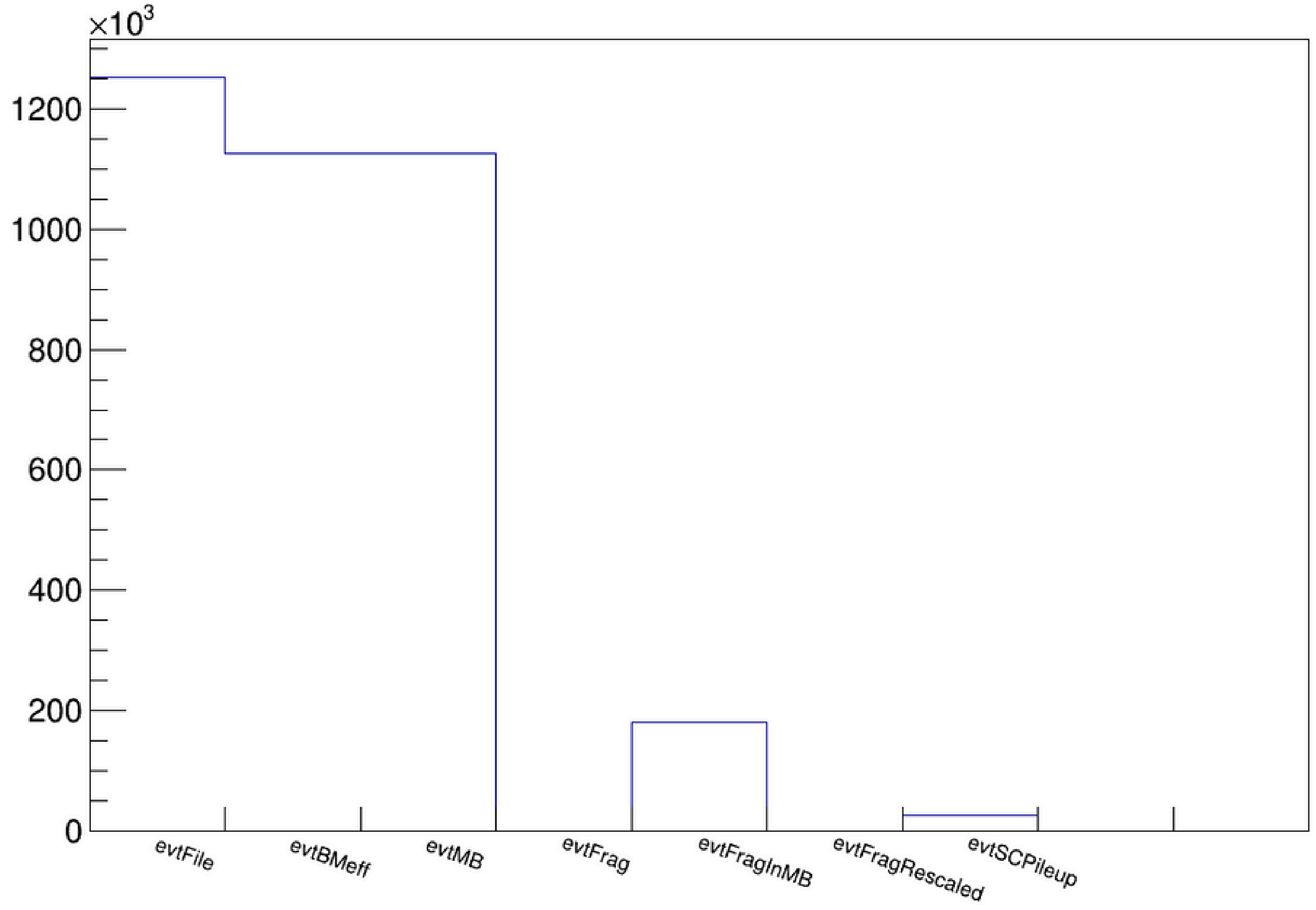


Number of events

Minimum bias (4305,4306,4307)



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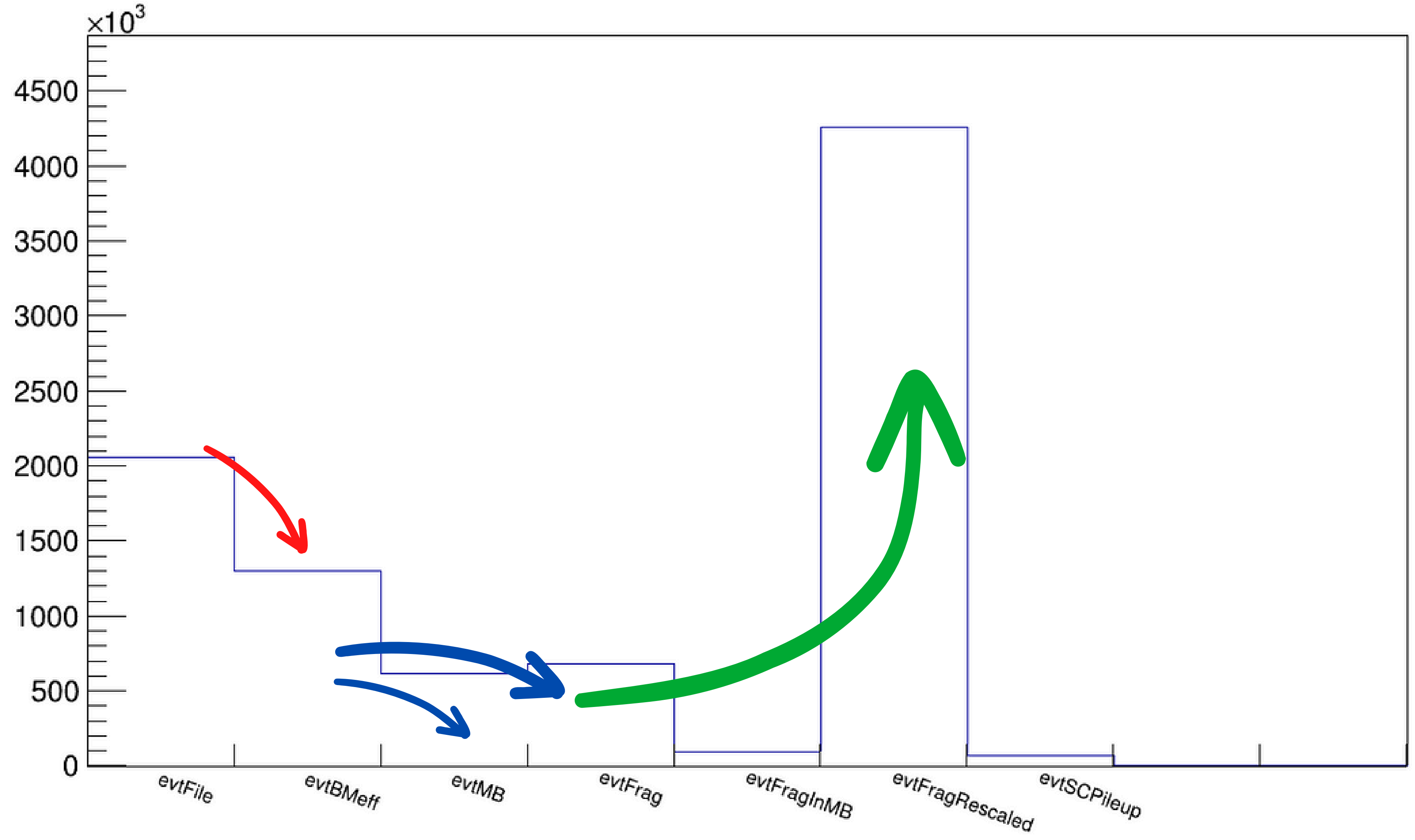
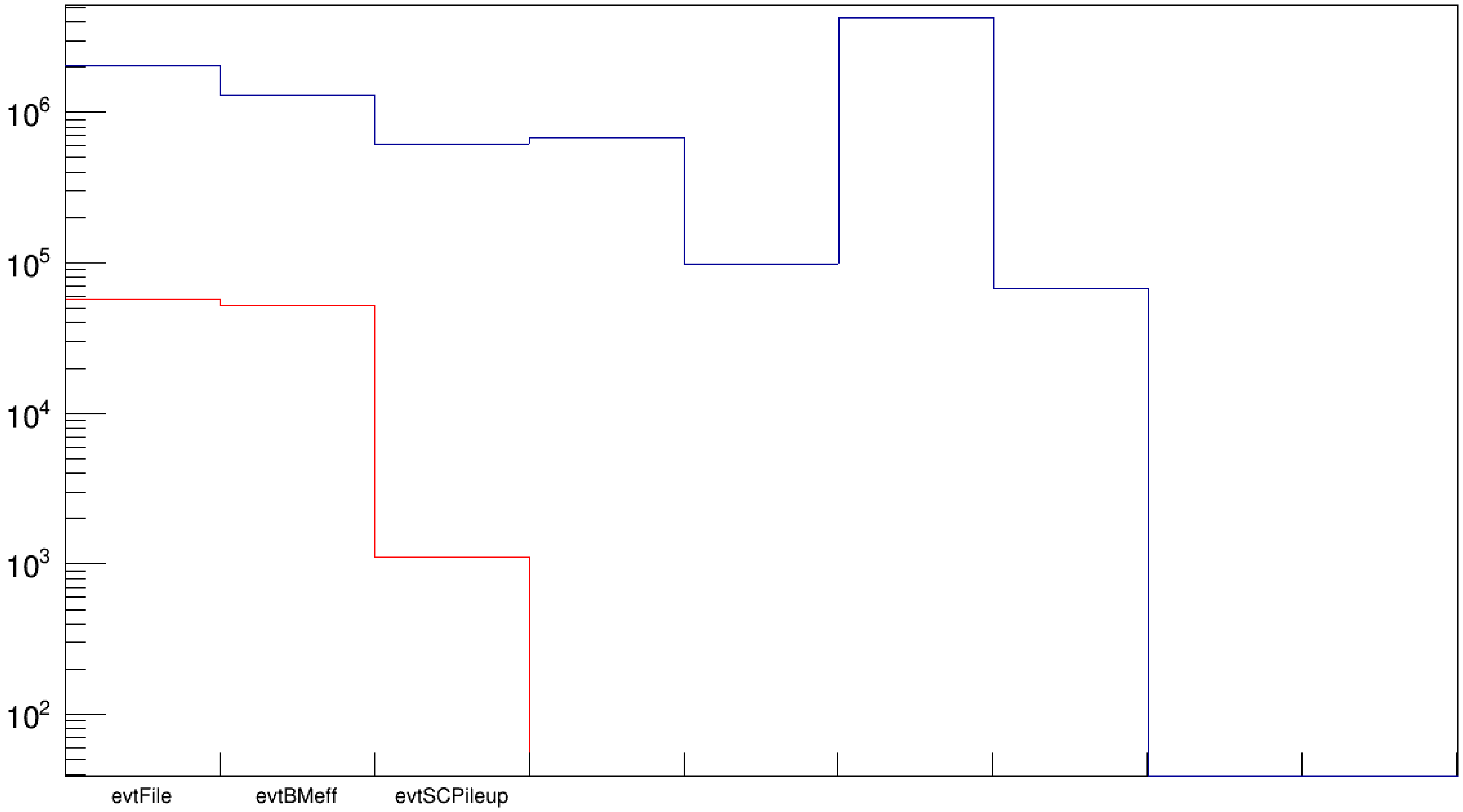


Number of events

Fragmentation+MB (4308, 4309, 4310)

Background MB (4313)



Impact of statistics on XS resolution

Relative uncertainties in XS (only stat)

$$\sigma(Z) = \frac{1}{N_{\mathrm{TG}} \cdot \varepsilon(Z)} \cdot \left(\frac{Y_S(Z)}{N_S} - \frac{Y_B(Z)}{N_B} \right) = \frac{1}{N_{\mathrm{TG}} \cdot \varepsilon(Z)} \cdot (S(Z) - B(Z))$$

$$\frac{\Delta\sigma}{\sigma} \approx \left(\frac{1}{S - B} \right) \cdot \sqrt{S^2 \cdot \left[\left(\frac{\Delta Y_S}{Y_S} \right)^2 + \left(\frac{\Delta N_S}{N_S} \right)^2 \right] + B^2 \cdot \left[\left(\frac{\Delta Y_B}{Y_B} \right)^2 + \left(\frac{\Delta N_B}{N_B} \right)^2 \right]}$$

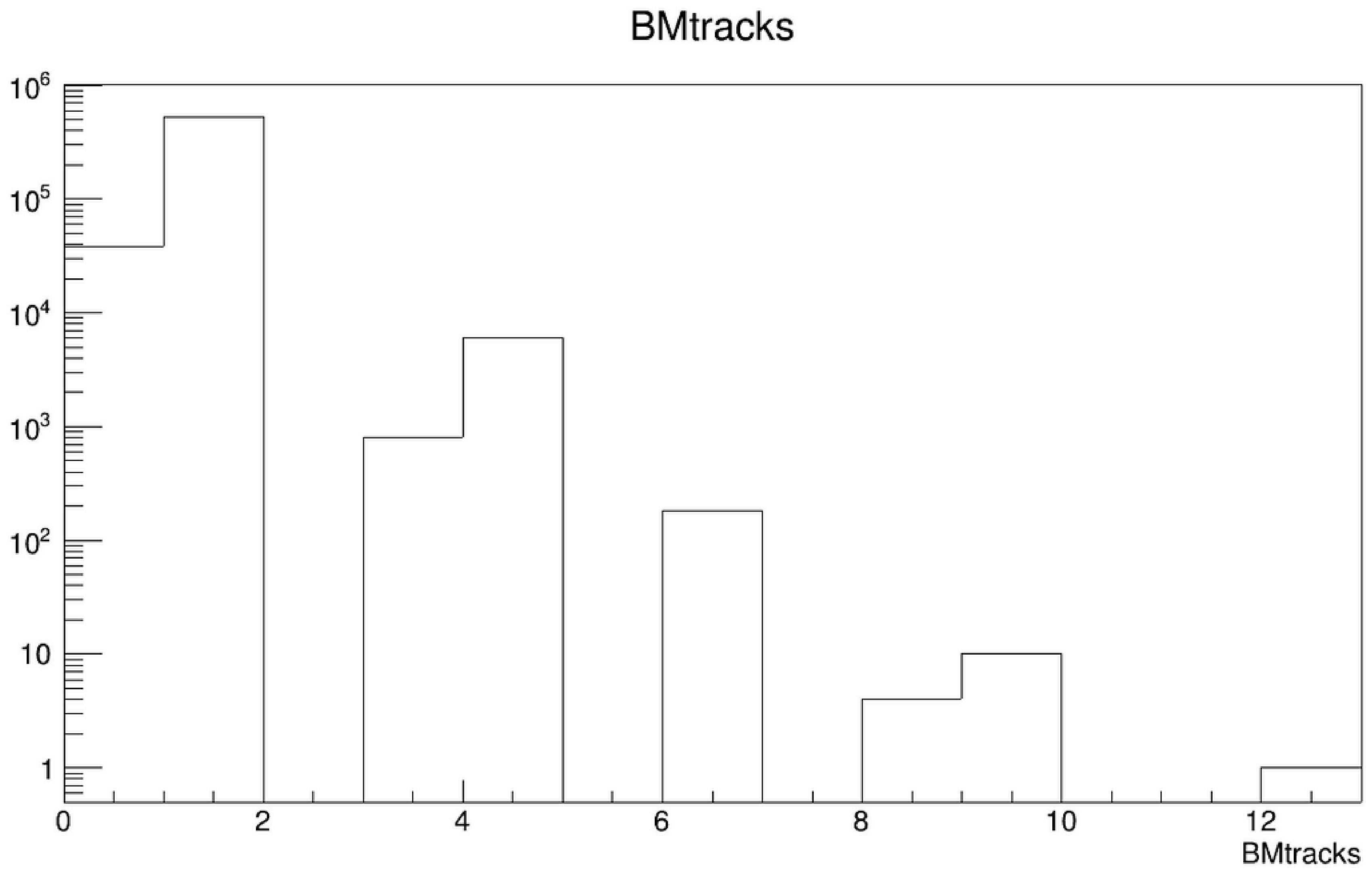
Fragmentation physics **Available Statistics**

$$S = \frac{Y_S}{N_S} \qquad B = \frac{Y_B}{N_B}$$

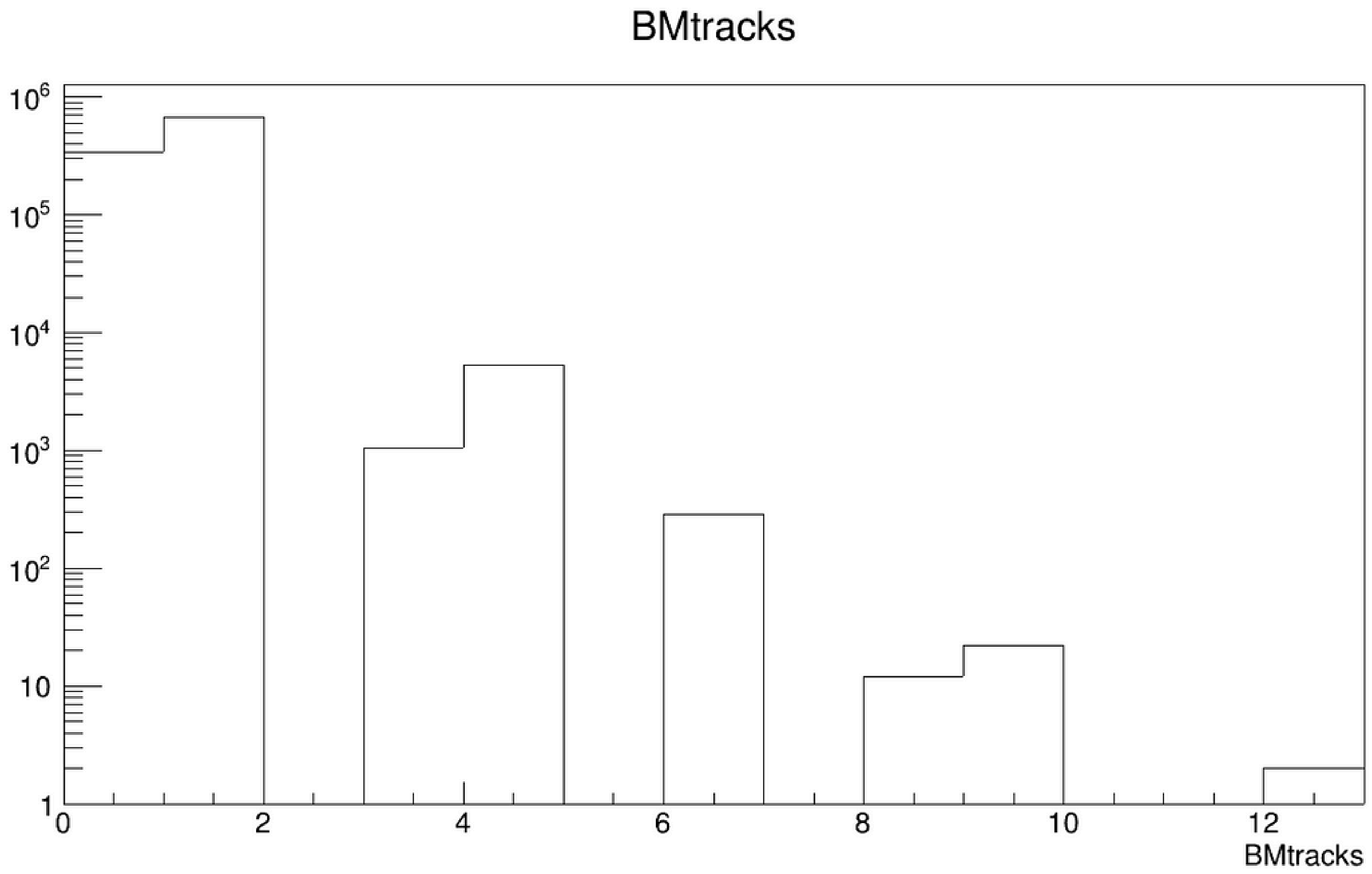
- Y_S fragments yields in TG runs (S->S+B)
- N_S primaries in TG runs (S->S+B)
- Y_B fragments yields in NO TG runs
- N_B primaries in NO TG runs

Selection cuts

Minimum bias (4306)

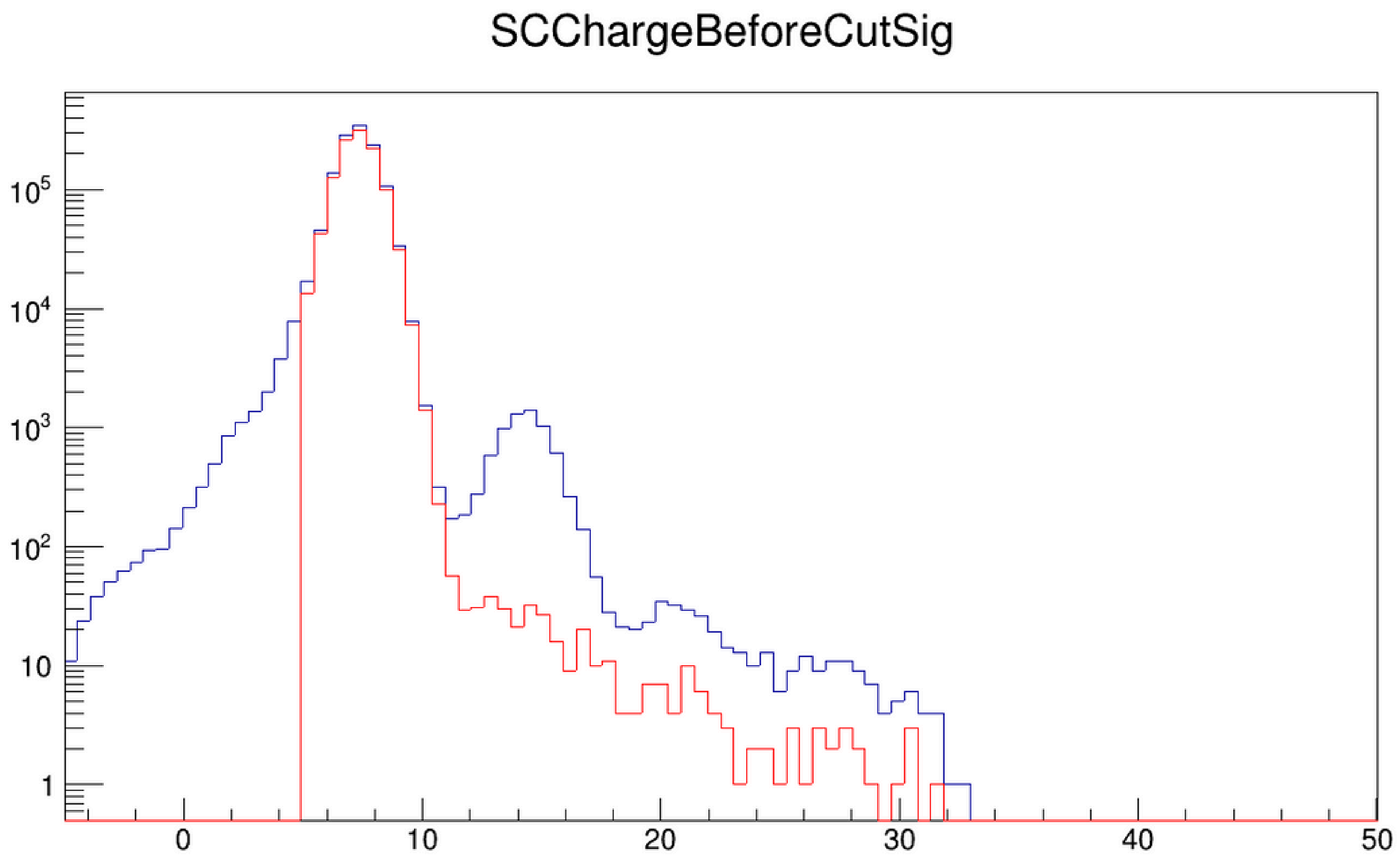


Fragmentation+MB (4310)

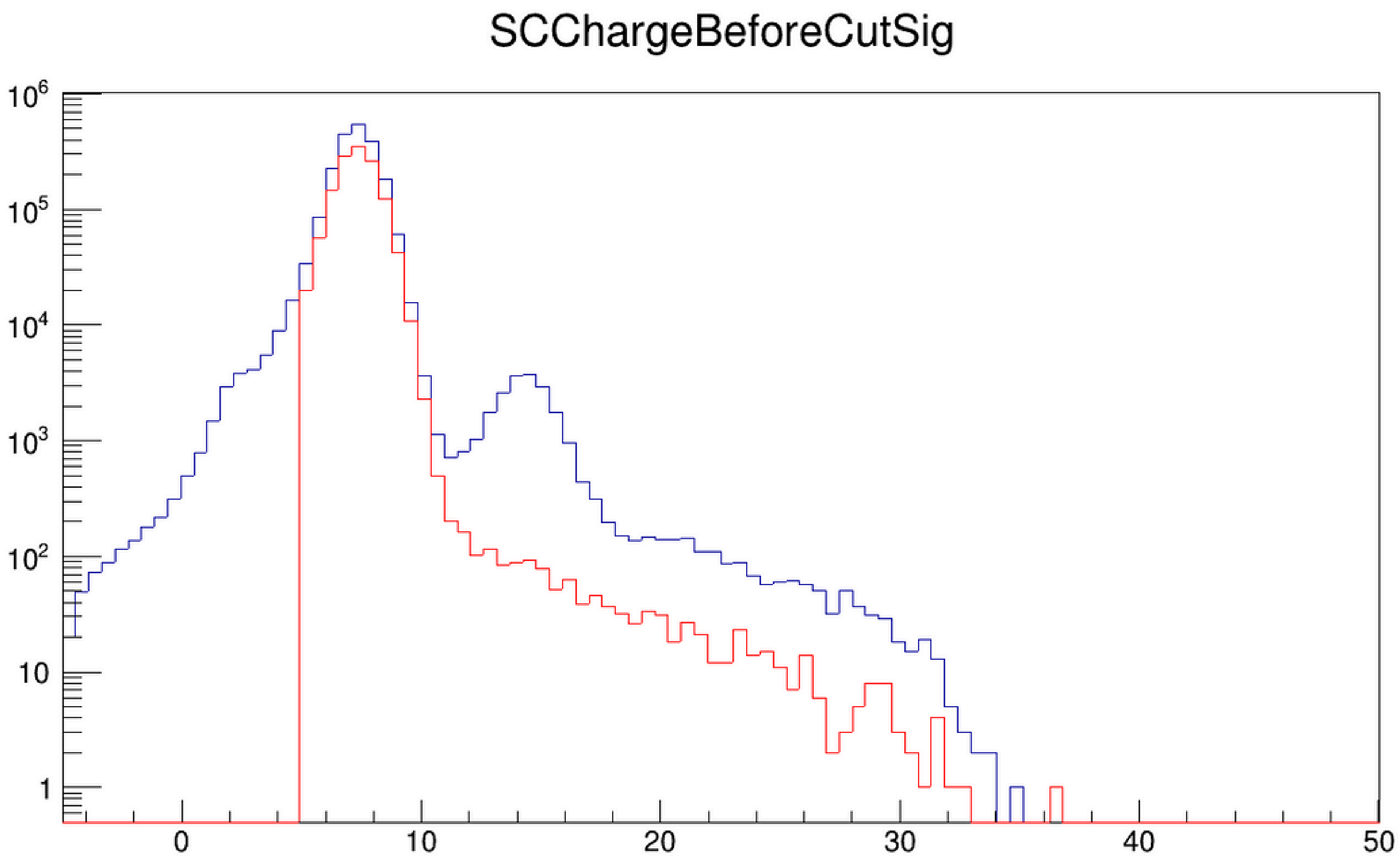


Selection cuts

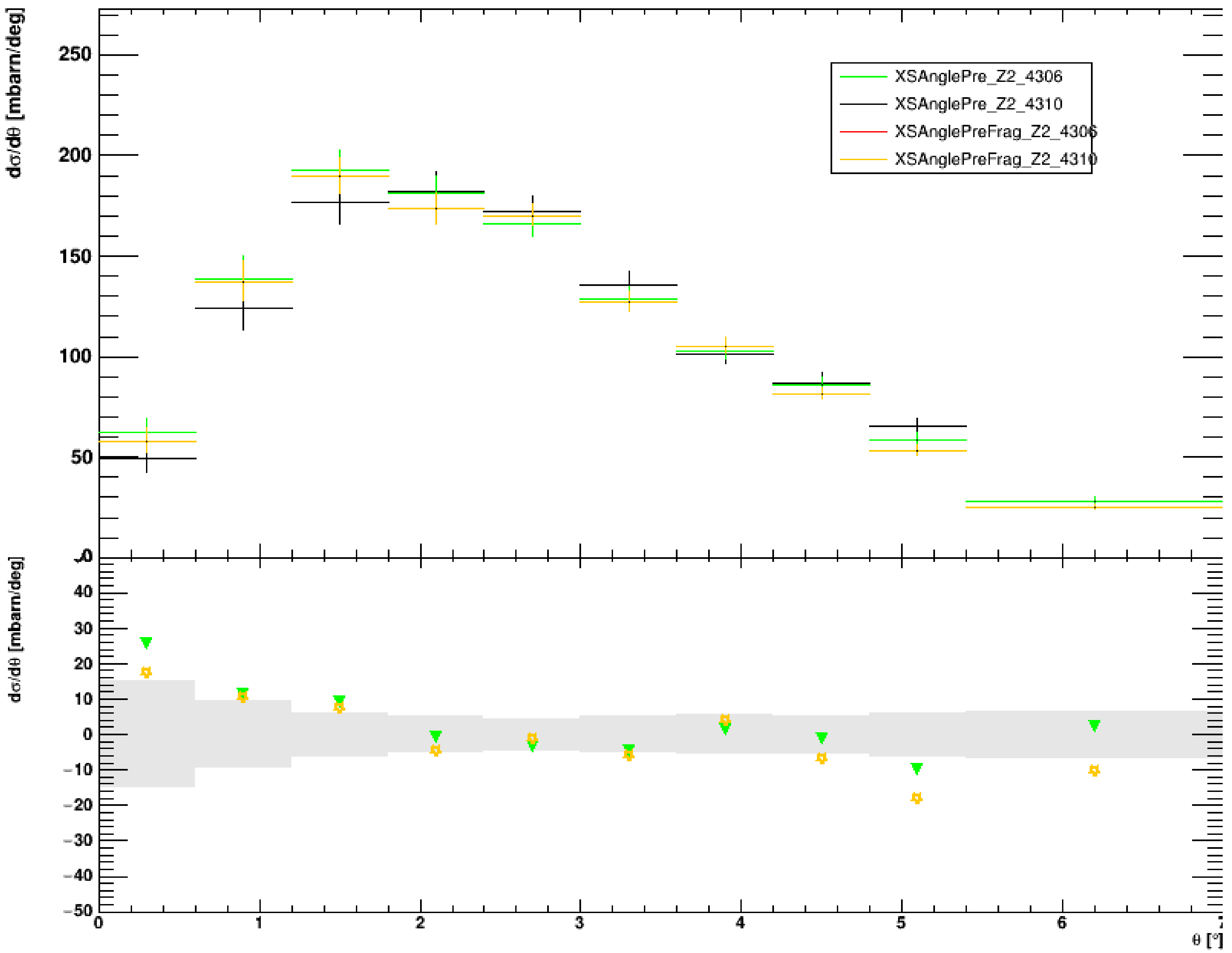
Minimum bias (4305, 4306, 4307)

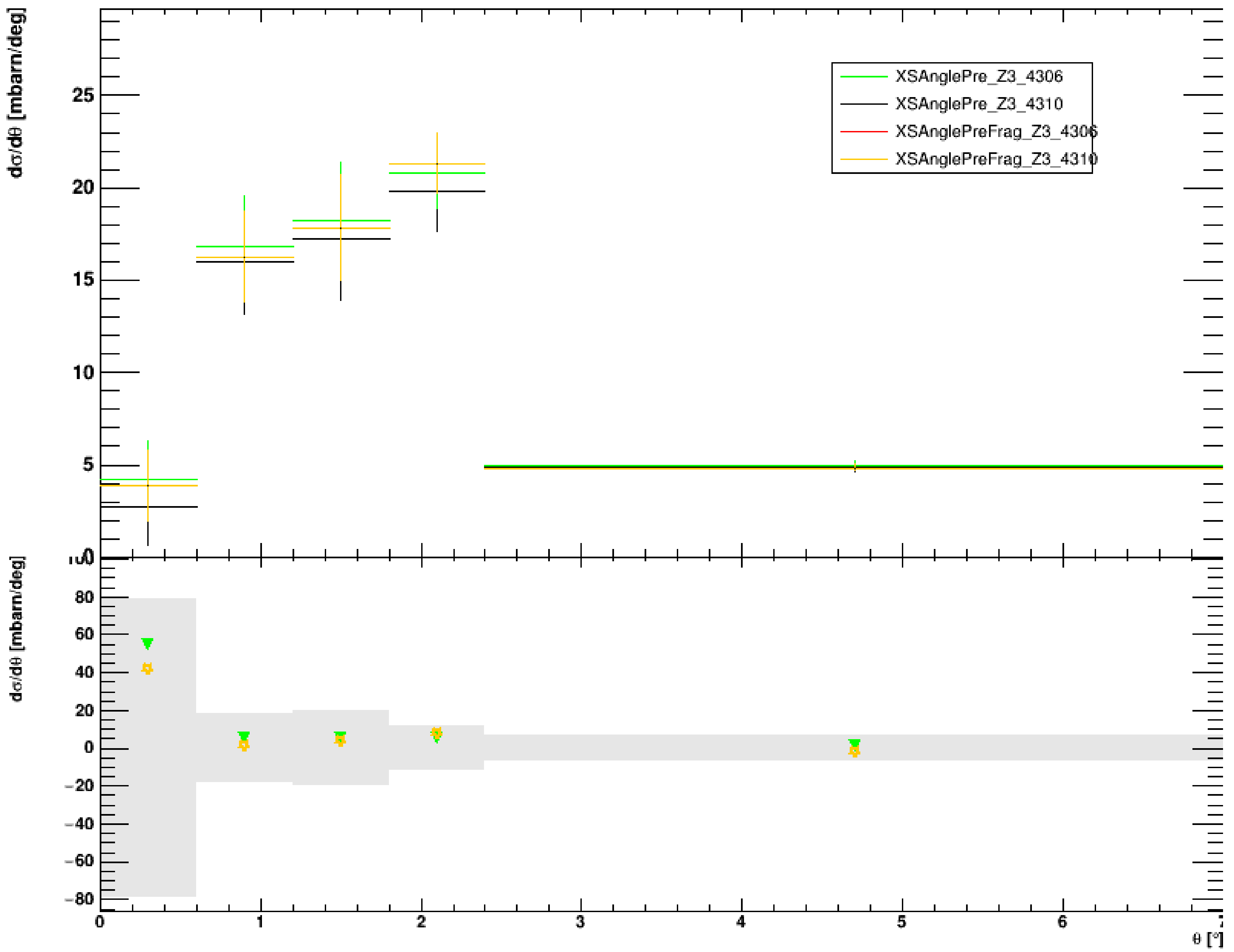


Fragmentation+MB (4308, 4309, 4310)



Consistency checks on data





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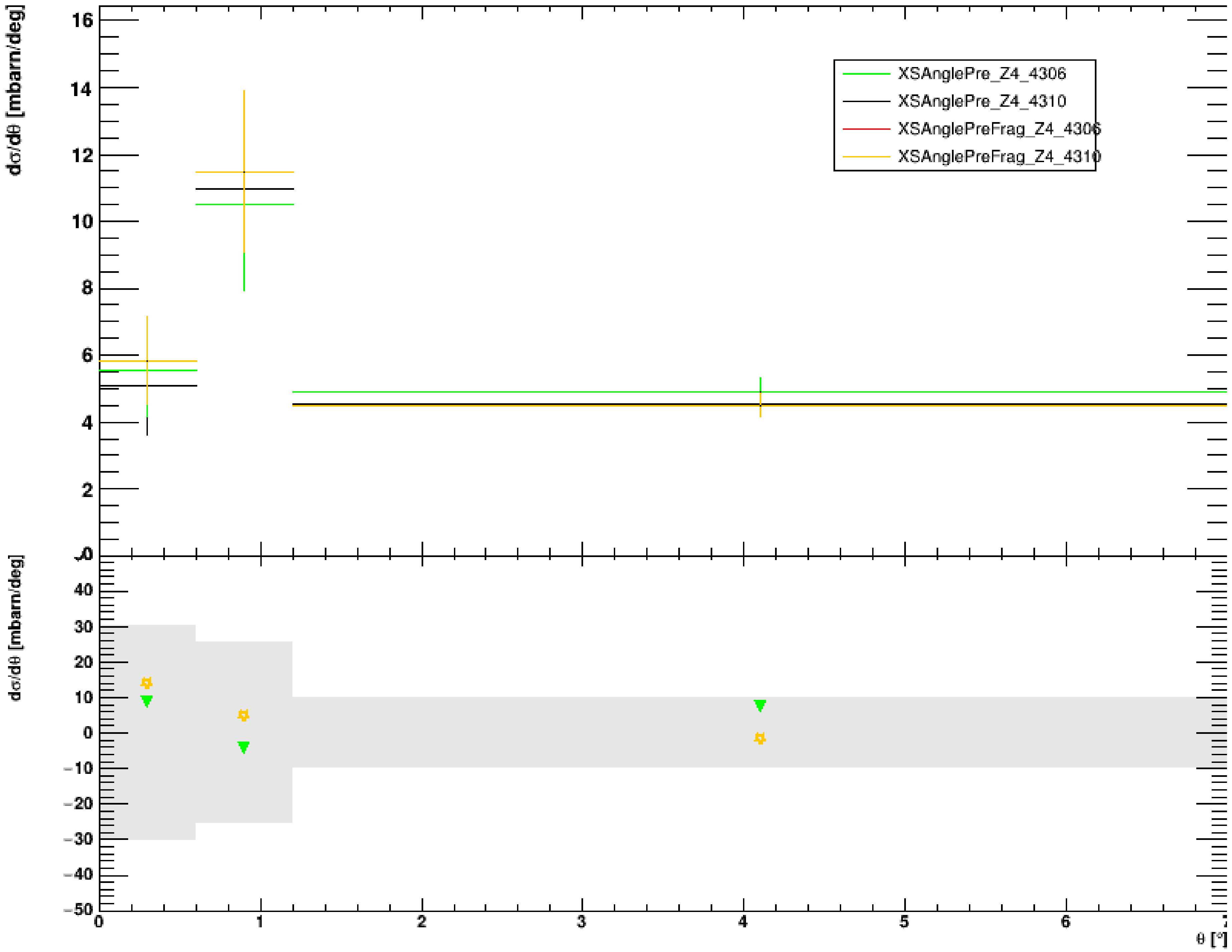
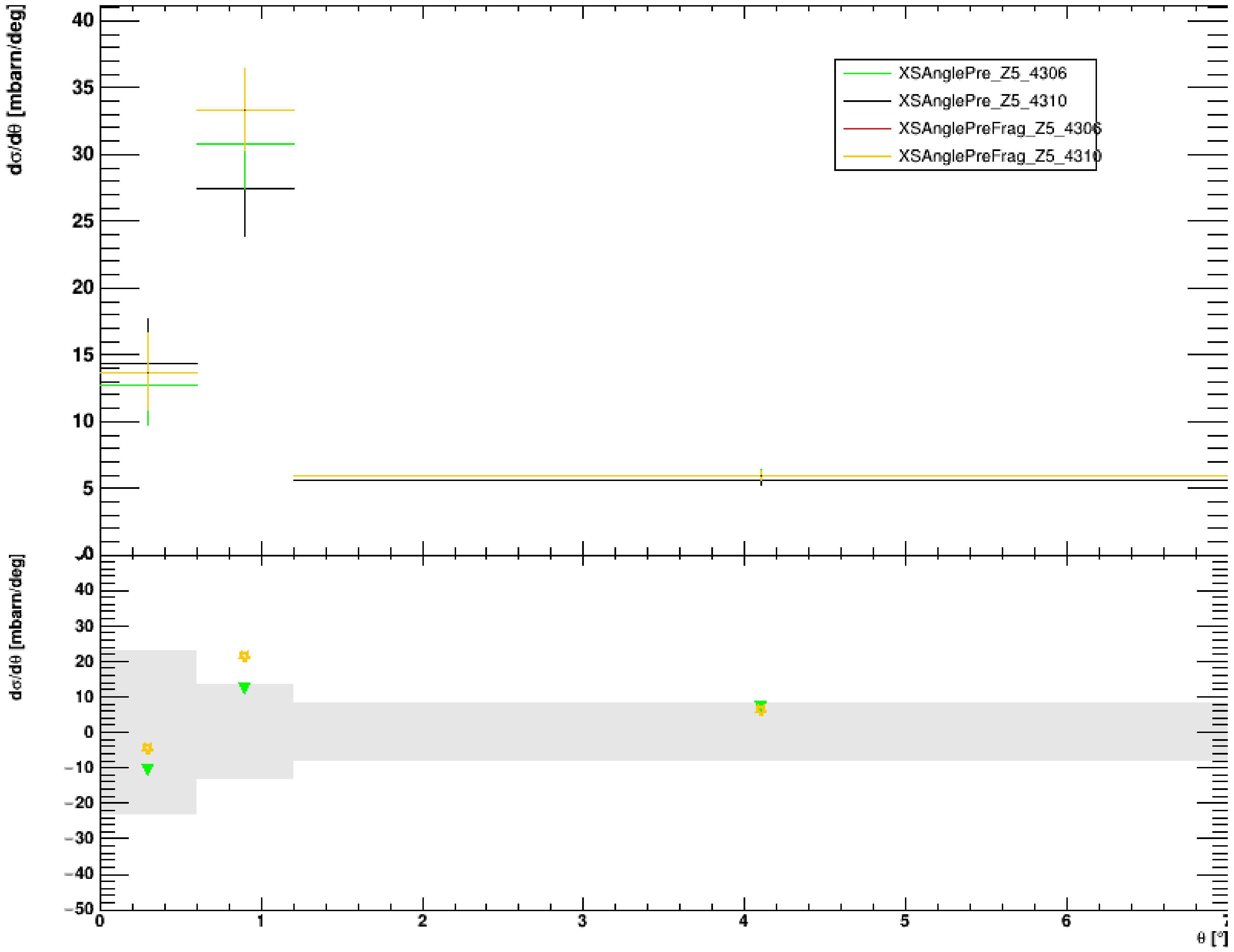
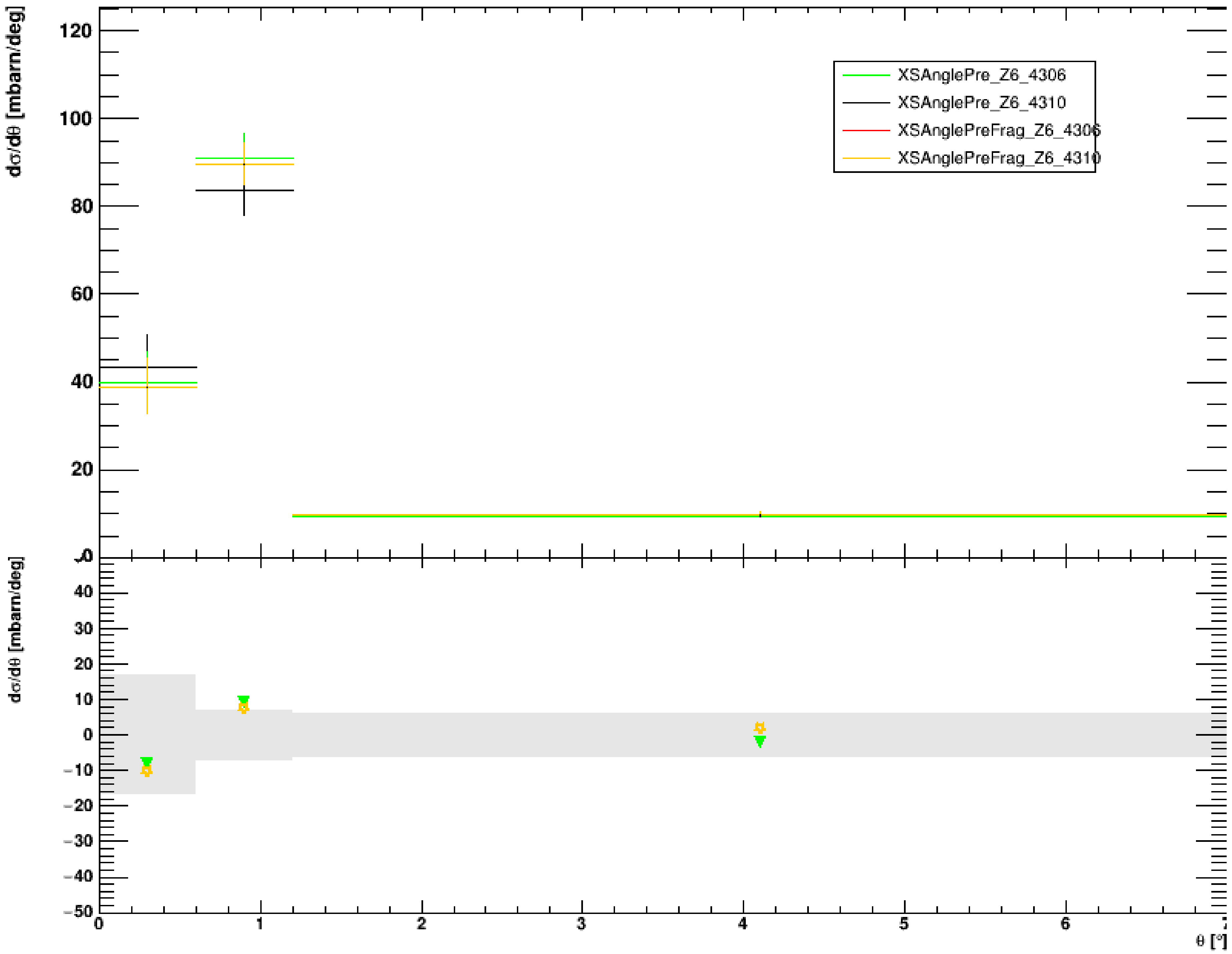
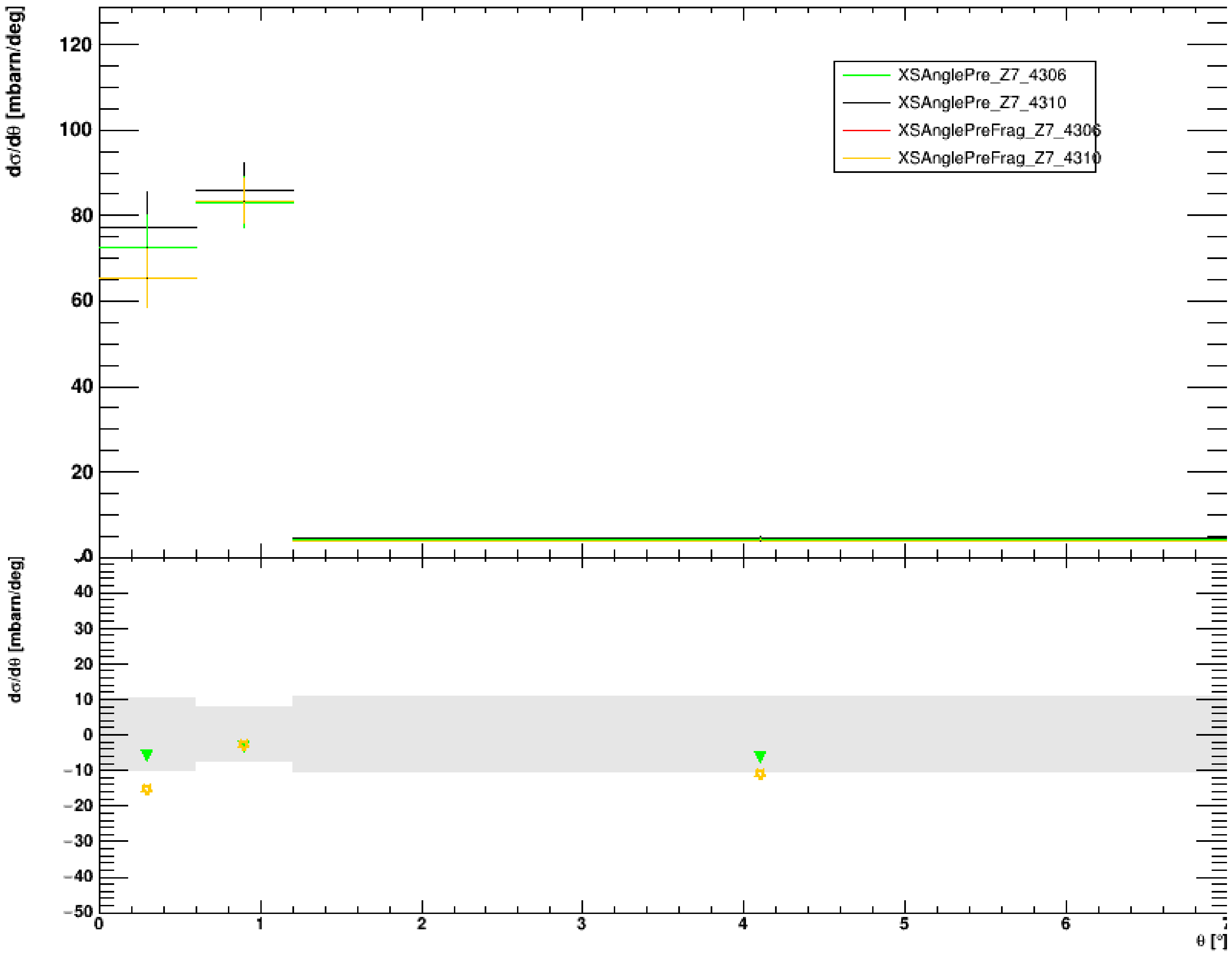


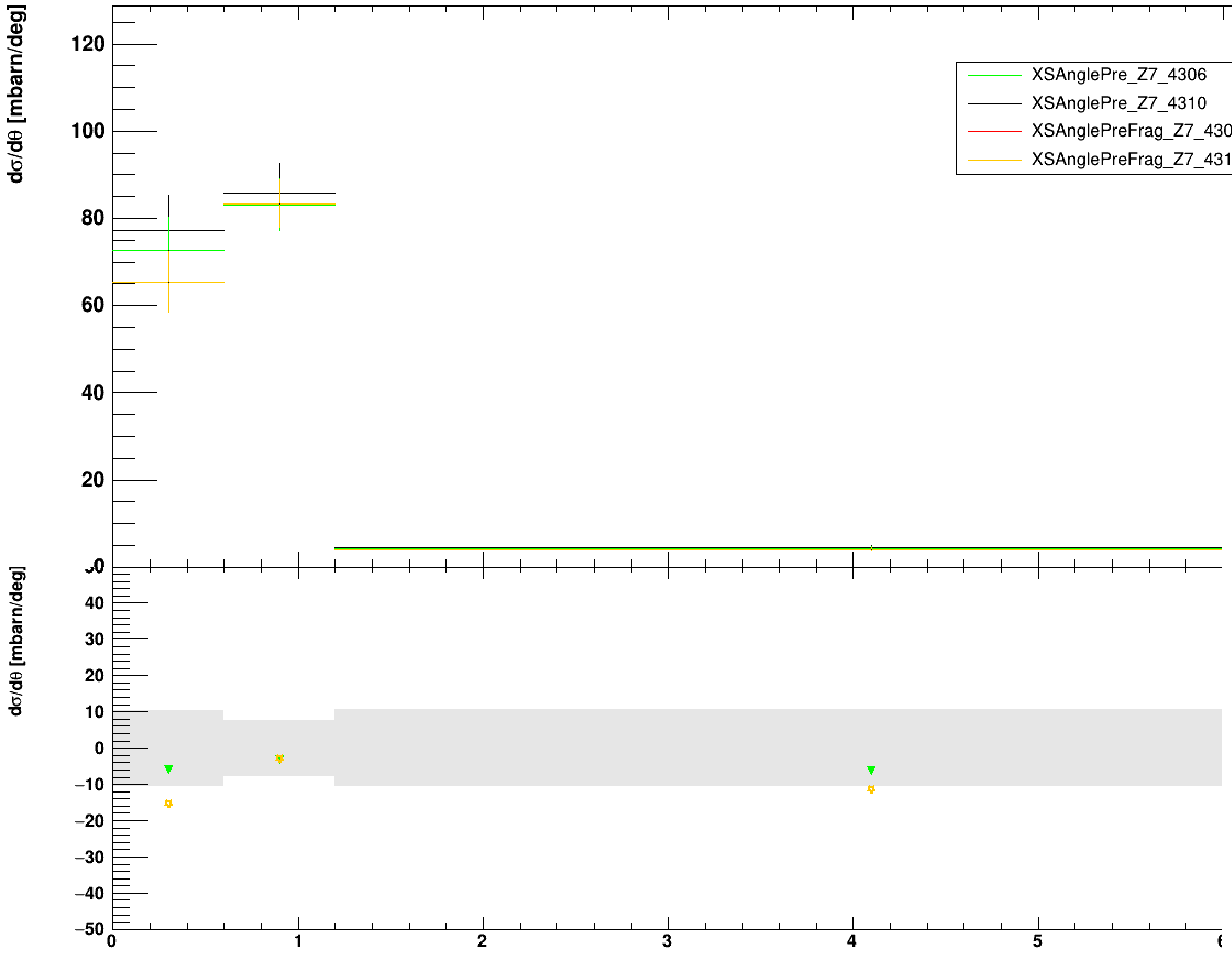


Consistency checks on data

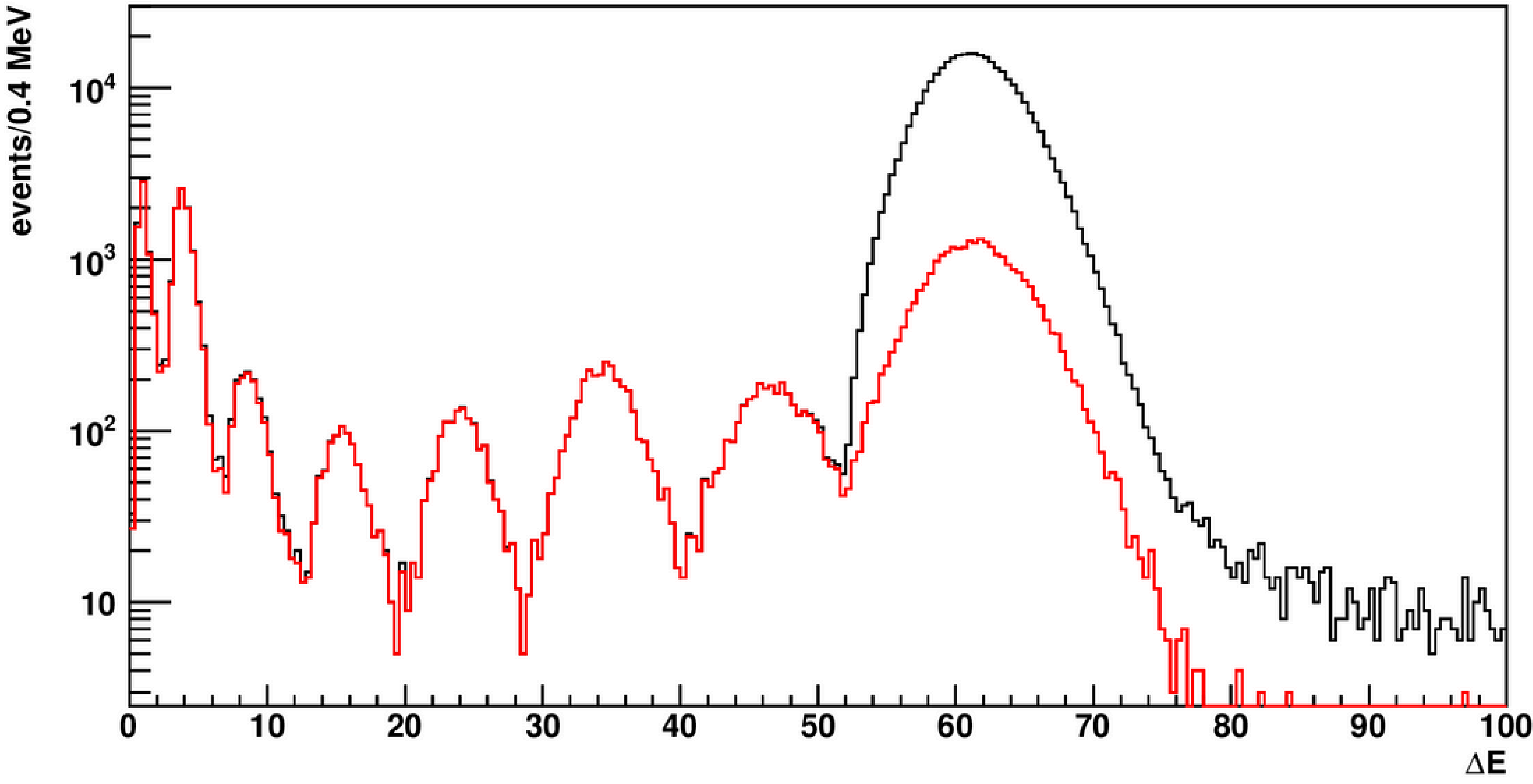




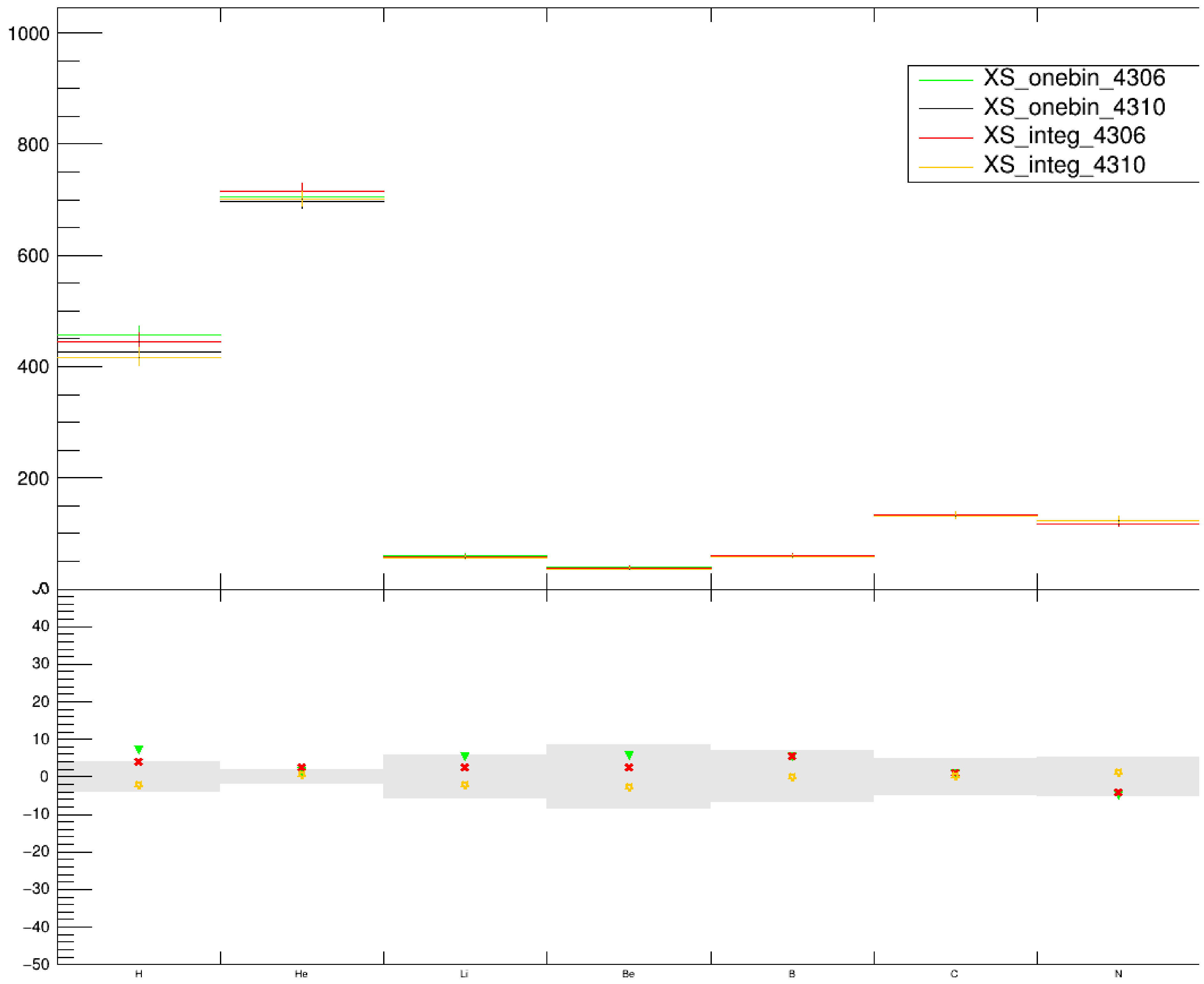
Consistency checks on data

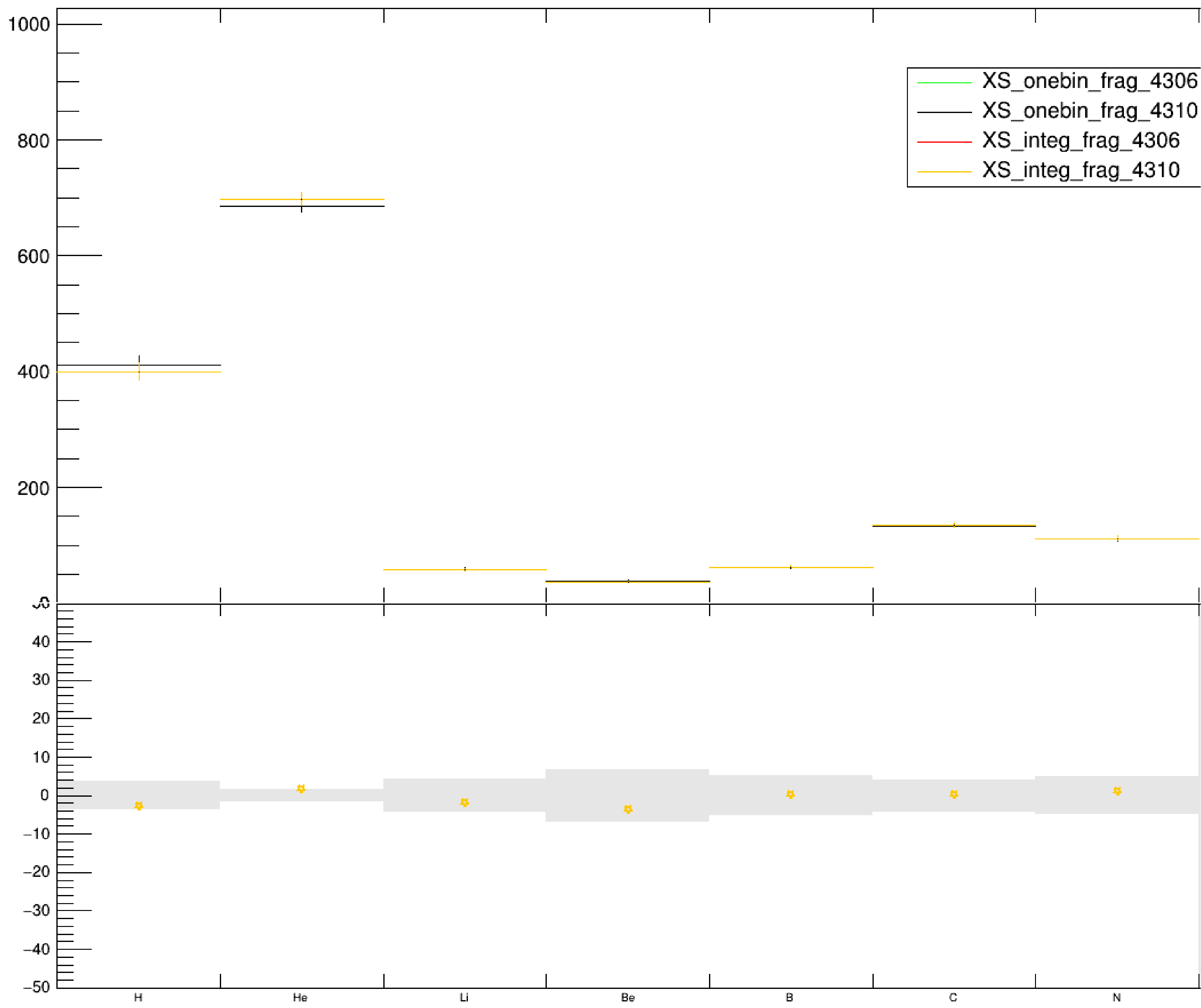


Fragment rescaling maybe useful for N if outside our uncertainties (it seems not)



Consistency checks on data

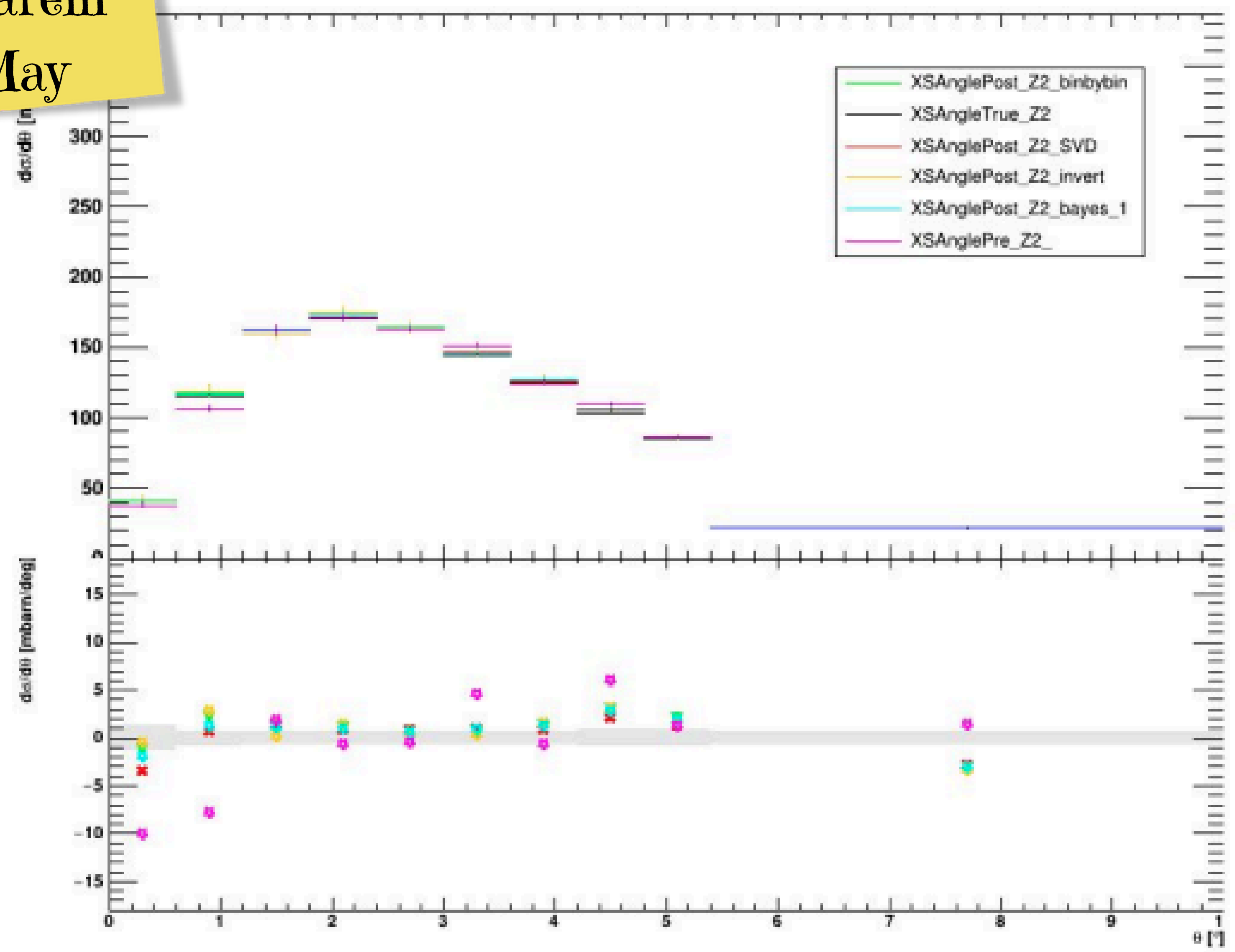




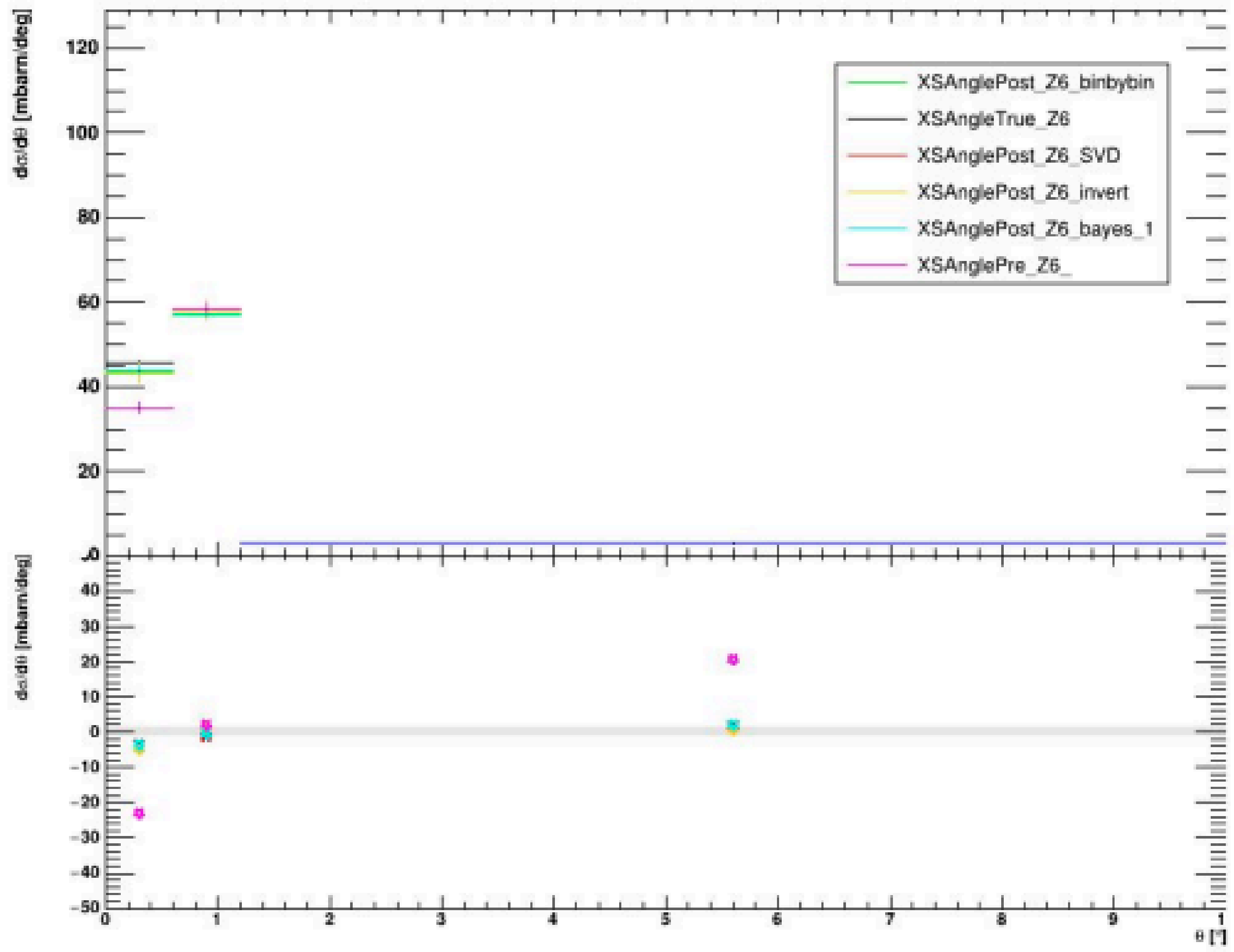
Unfolding Method Comparison

Alberto Mengarelli 21 May

Z=2



Z=6



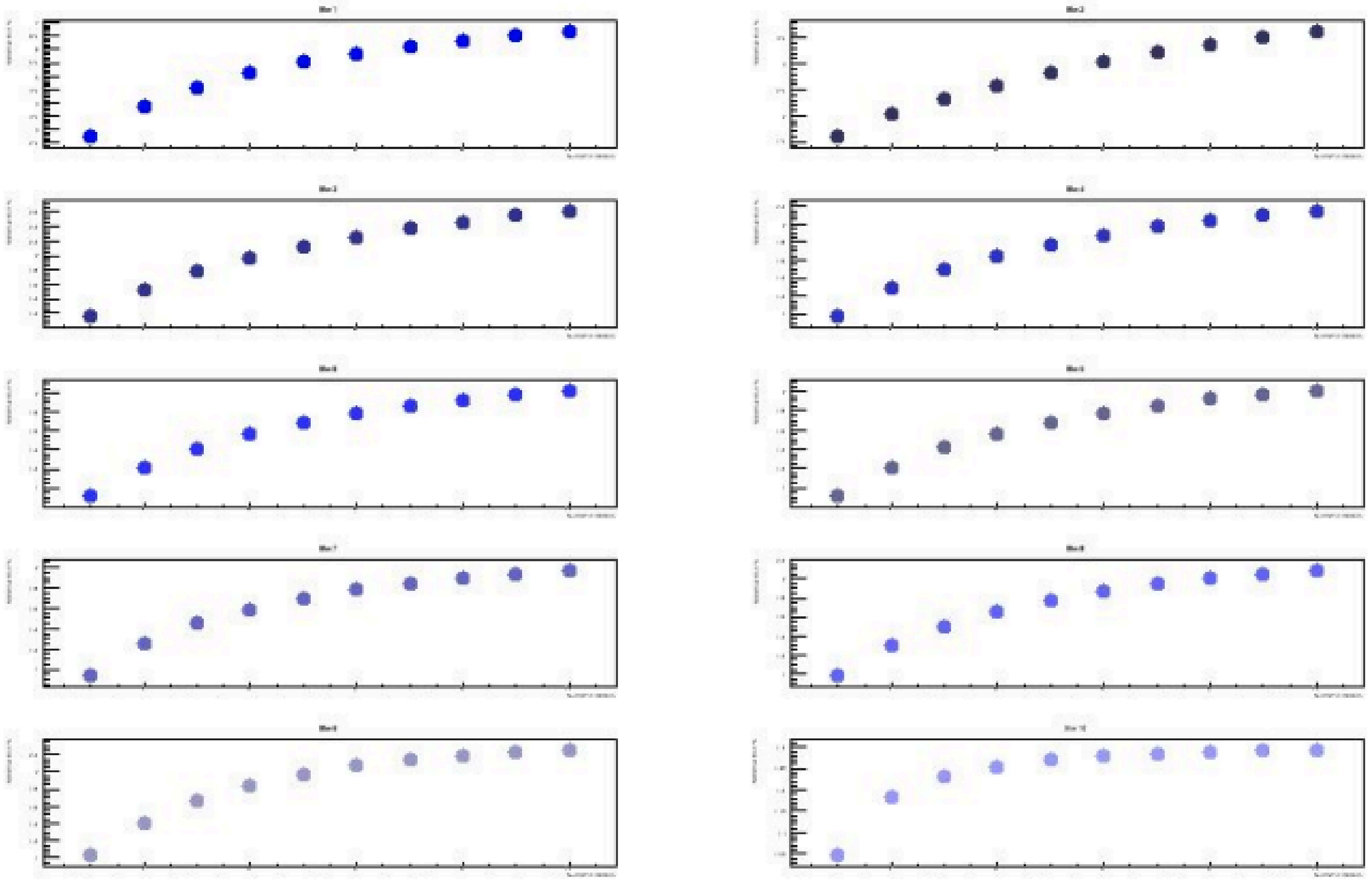
Different methods behave the same way → Bayes Iterative method chosen

Alberto
Mengarelli
21 May

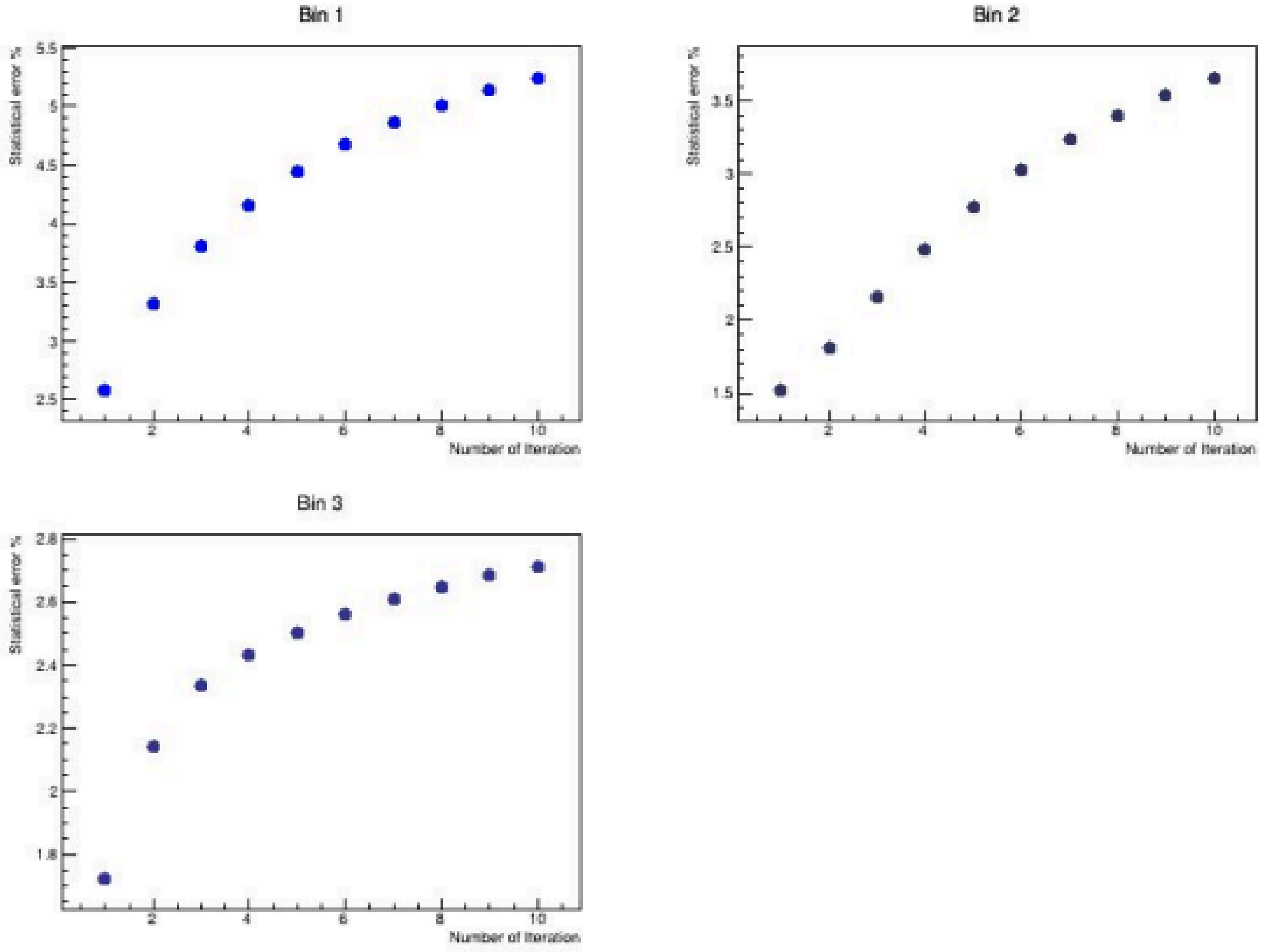
Studies on the number of iterations: Statistical uncertainty

The degree of convergence of the iterative procedure is checked by comparing each iteration to the previous one. In particular, the parameters taken into account are the bin-wise statistical error (it increases with the number of iterations, reaching a sort of plateau)

Z=2



Z=6



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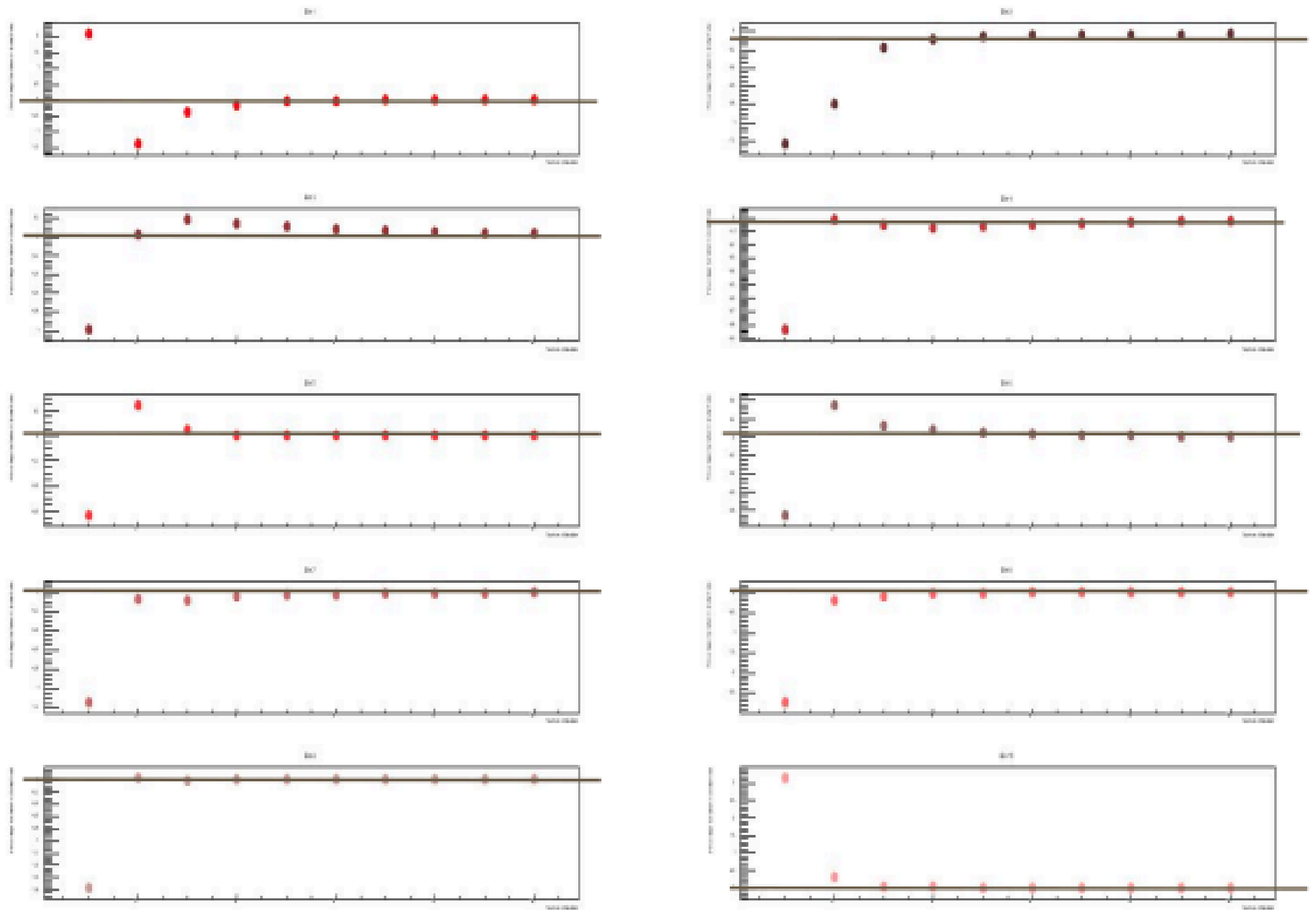
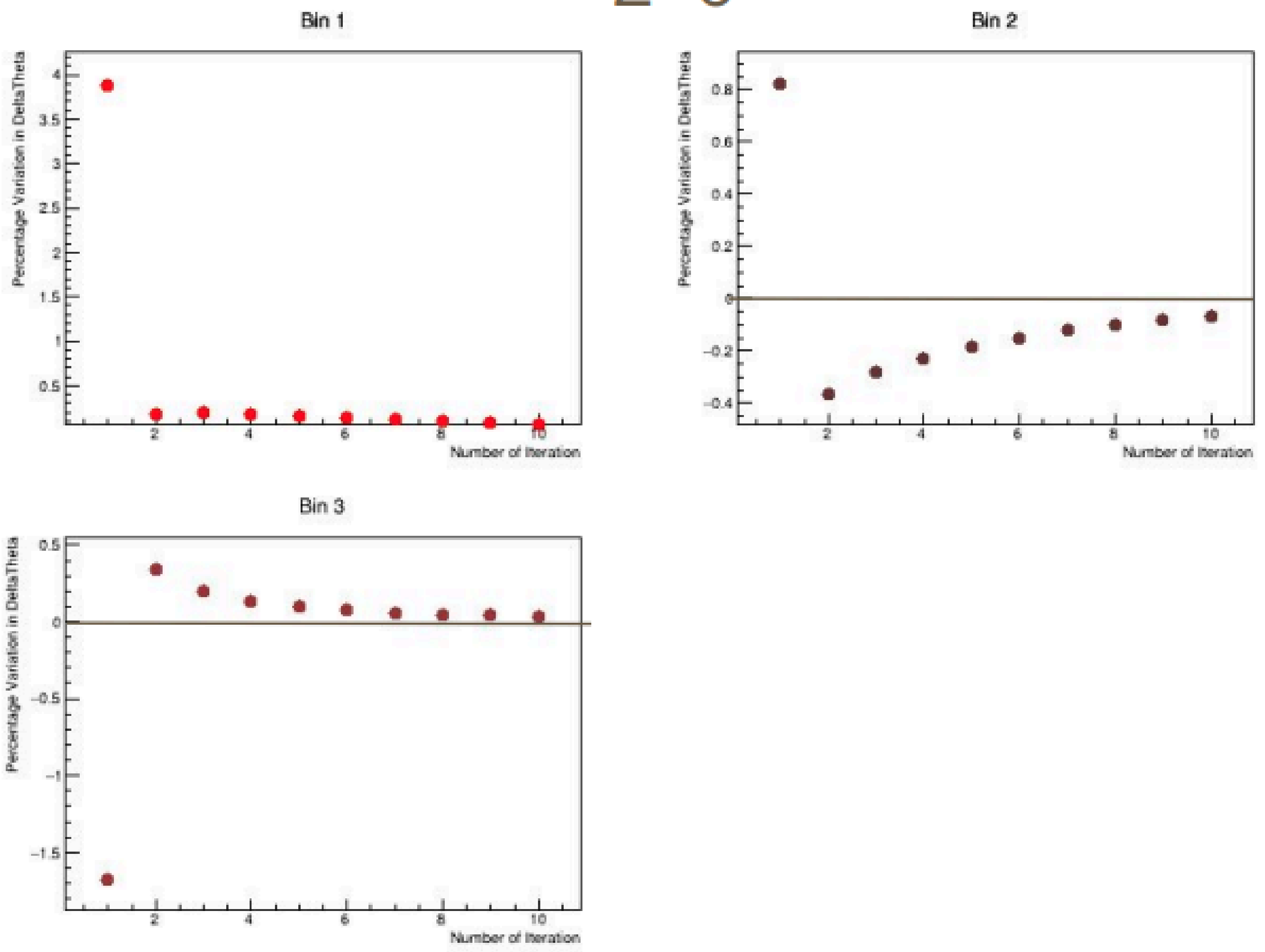
Studies on the number of iterations: bin residuals

bin-wise residuals (the bin-by-bin difference between the unfolded distribution at the i-th iteration and the unfolded distribution at the $i-1$-th iteration, which must converge to 0).

Z=2



Z=6



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Studies on the number of iterations: Average correlation

An optimal choice of the regularization parameter is the one that minimizes the average correlation factor:

$$\rho_{\text{avg}} = \frac{1}{M_x} \sum_{j=1}^{M_x} \rho_j .$$

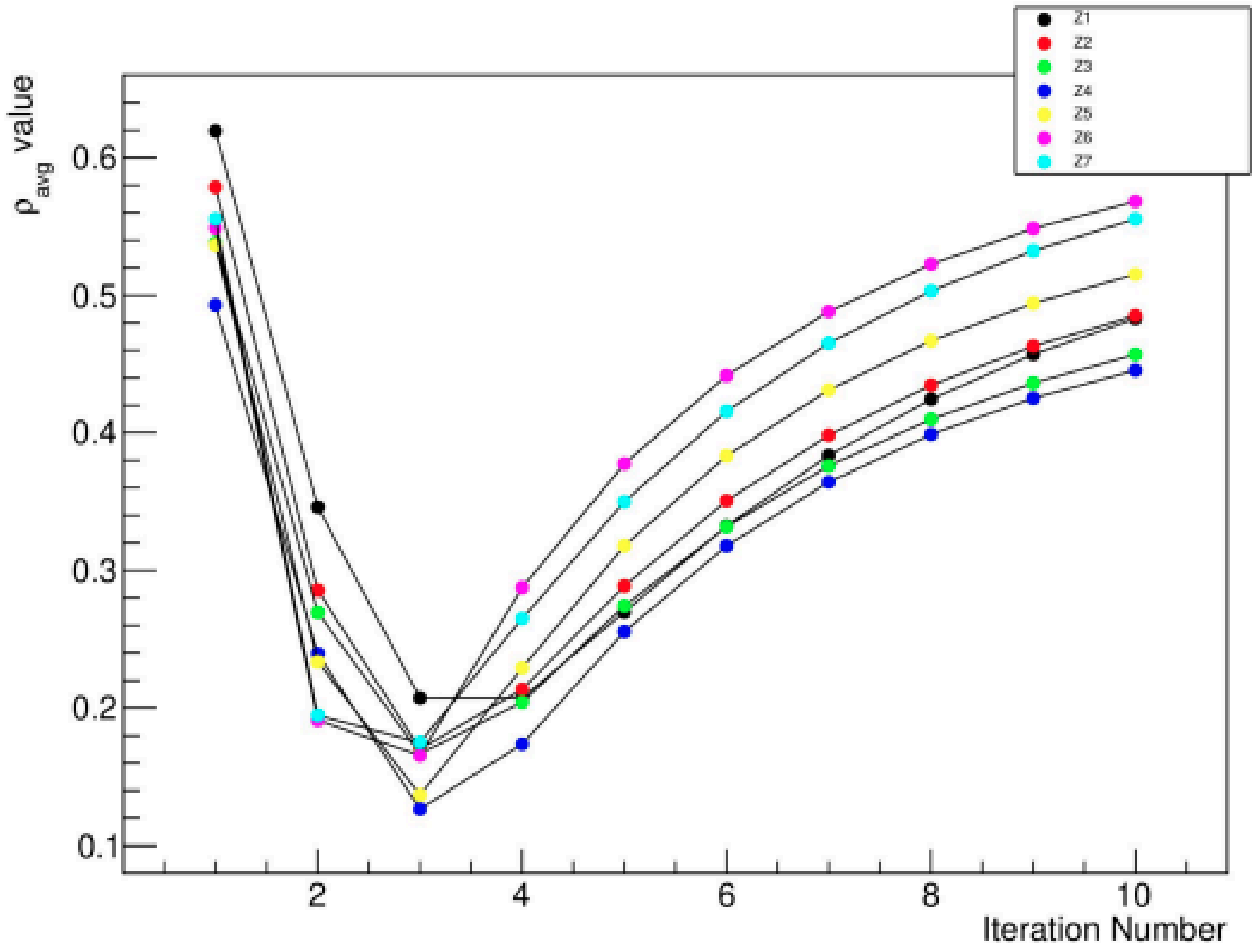
where ρ_j global correlation coefficient of bin j is defined as

$$\rho_j = \sqrt{1 - \left((\boldsymbol{V_{xx}})_{jj} \left(\boldsymbol{V_{xx}}^{-1} \right)_{jj} \right)^{-1}} .$$

M_x : ndof ; V_{xx} : Cov. matrix

$$\rho_{\text{avg}} = \frac{1}{N_{\text{bins}}} \sum_{i=1}^{N_{\text{bins}}} \rho_i \qquad \rho_i = \sqrt{1 - \left[C_{ii} \left(C^{-1} \right)_{ii} \right]^{-1}} .$$

S. Schmitt, Data Unfolding Methods in High Energy Physics, EPJ Web Conf. 137 (2017) 11008, ed. by Y. Foka, N. Brambilla and V. Kovalenko, arXiv: 1611.01927



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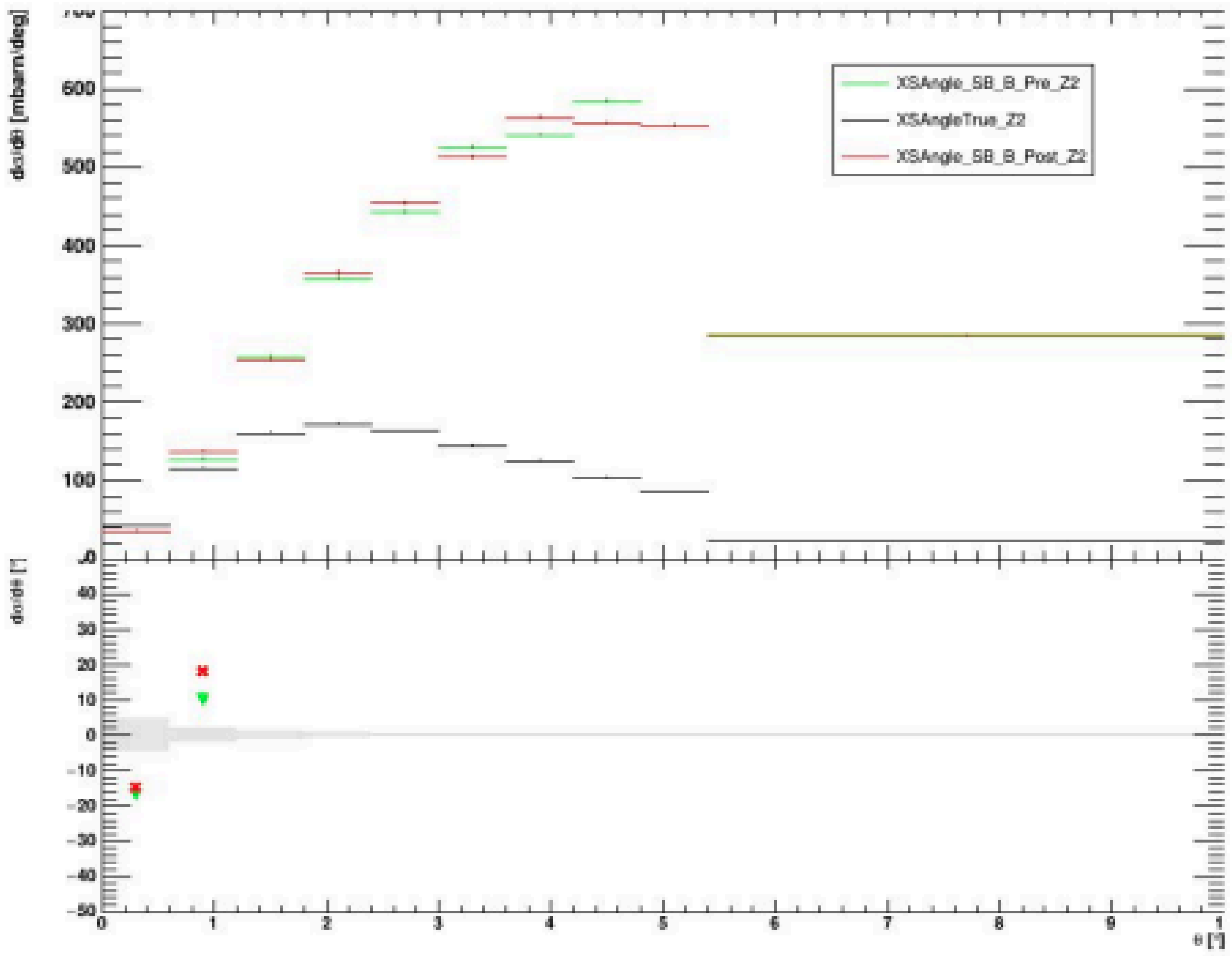
Mengarelli
21 May

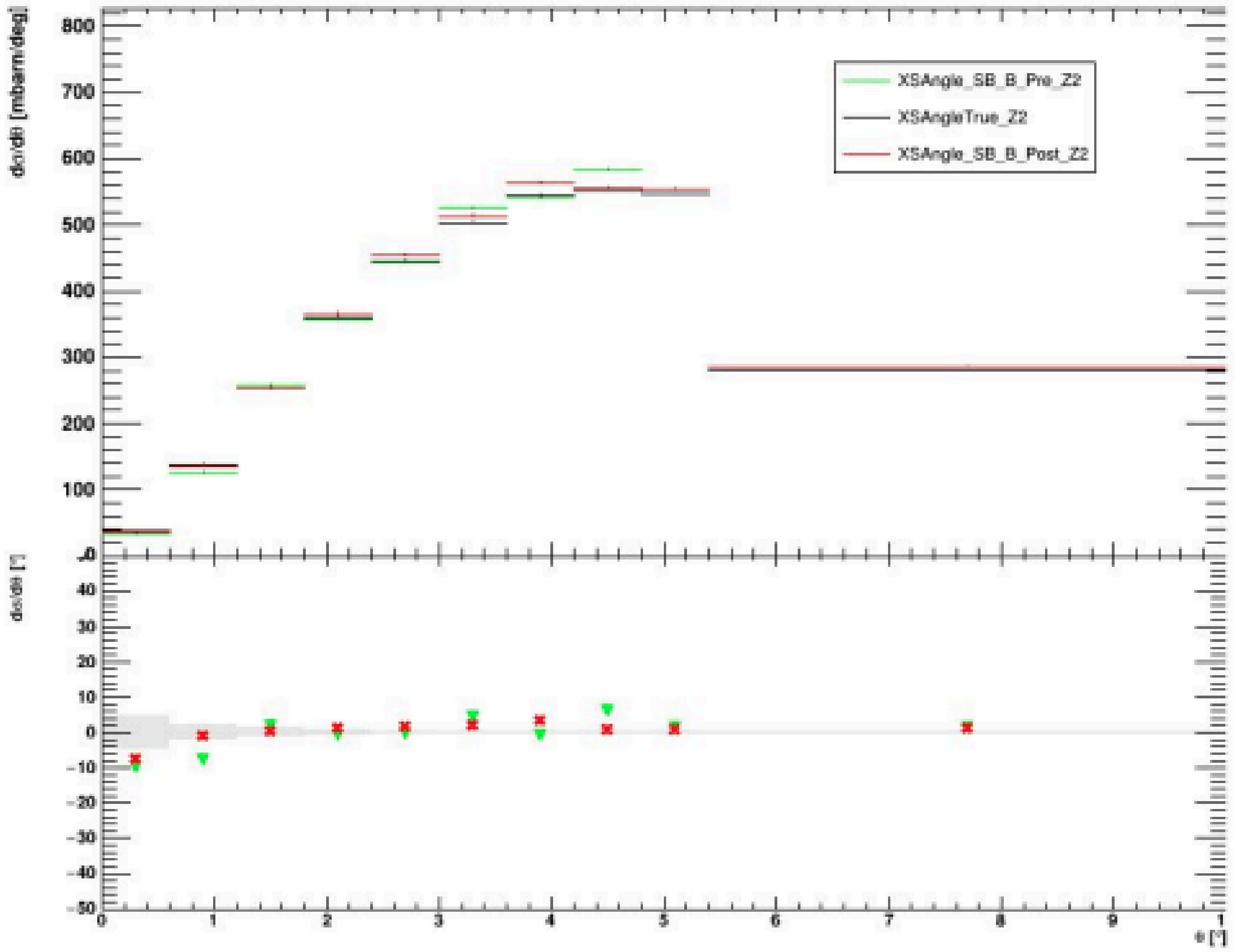
Stress tests

Due to the specific choice of the Monte Carlo sample for the training of the unfolding, it is necessary to check whether this choice could introduce a bias via the unfolding. To do this check the MC reweighting is required, in order to change the shapes of the distributions and get a varied distribution used as pseudo-data.

Only pseudo-data reweighted

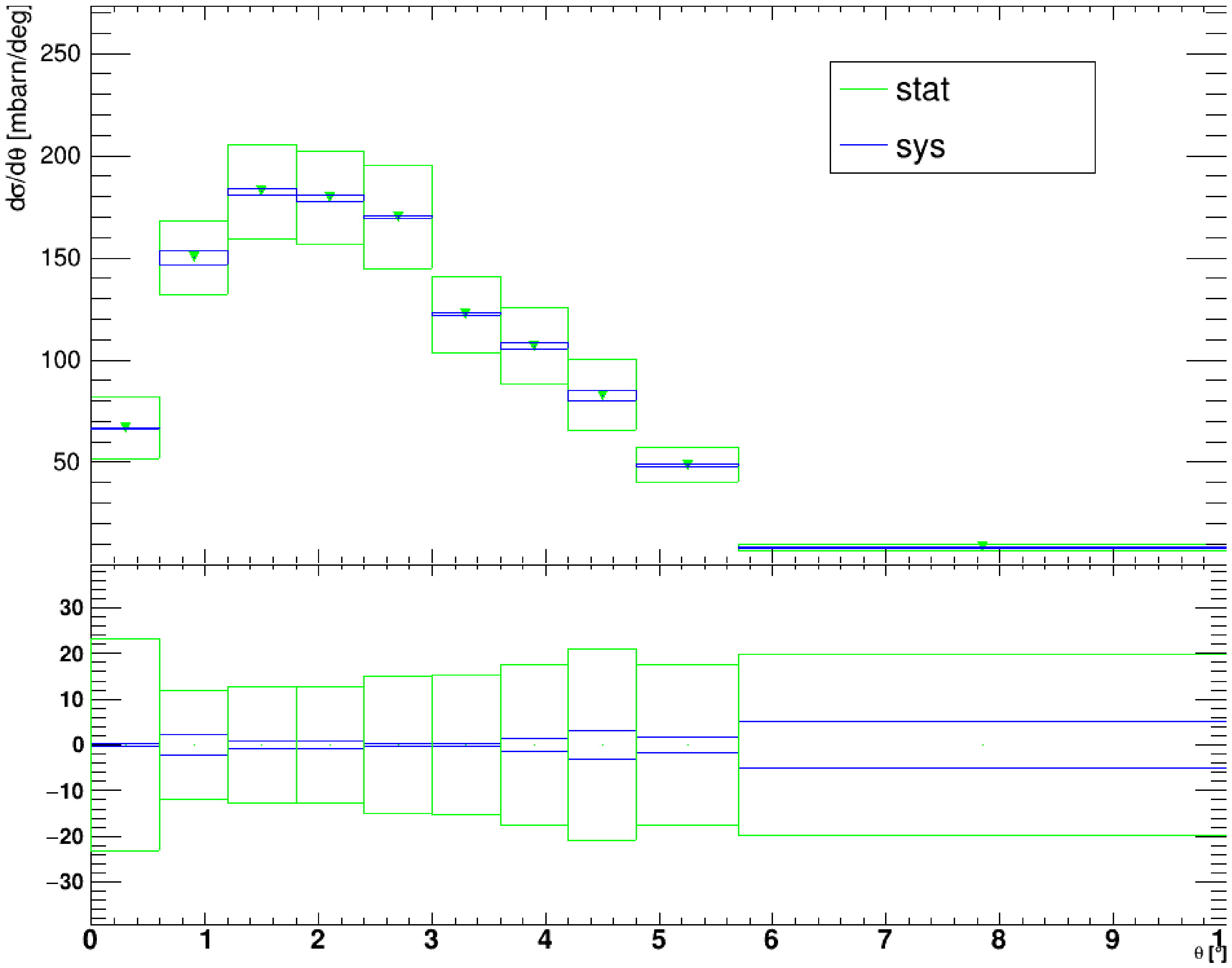


Both pseudo-data and truth reweighted

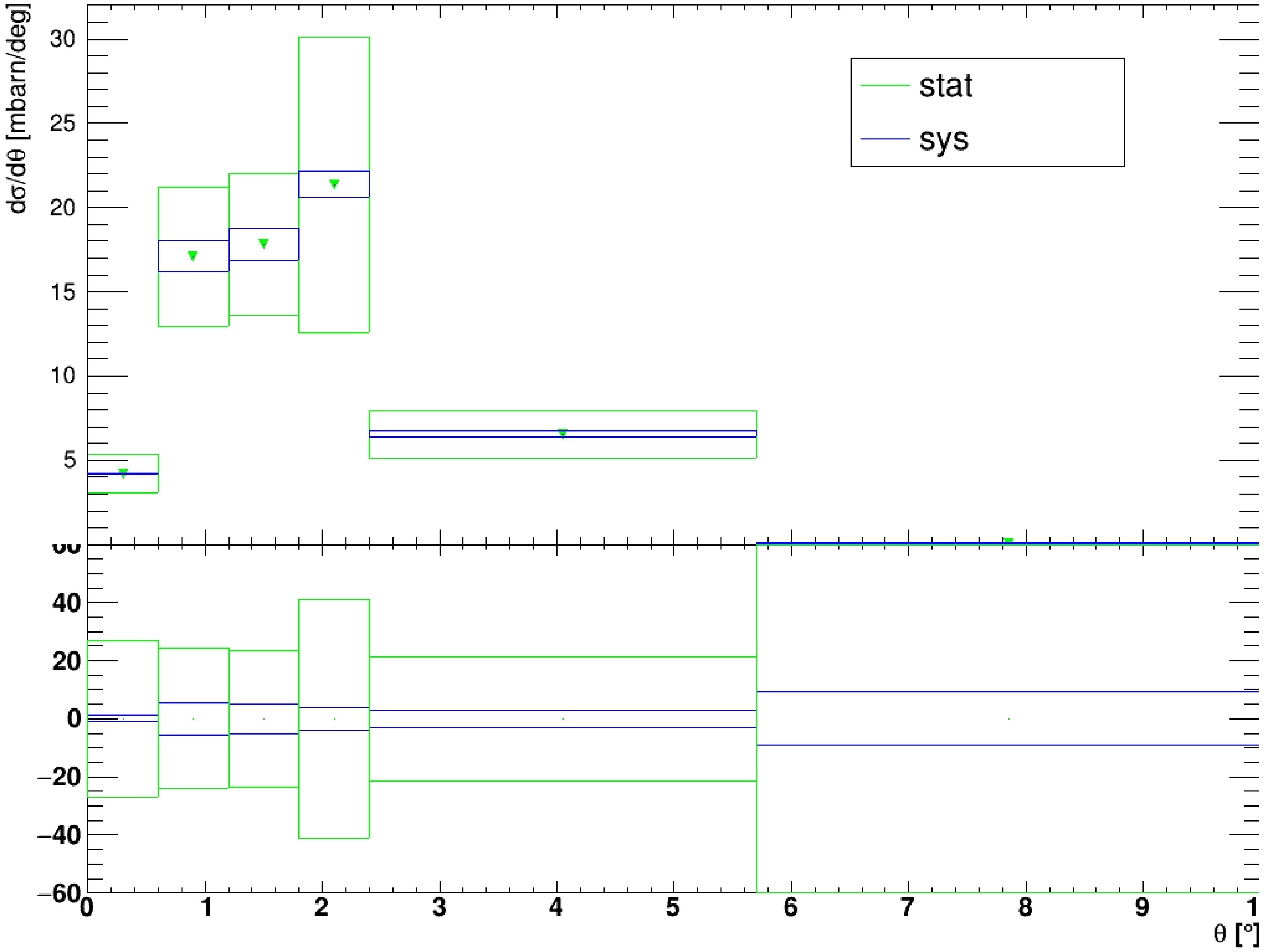


Merge all statistics

Z=2

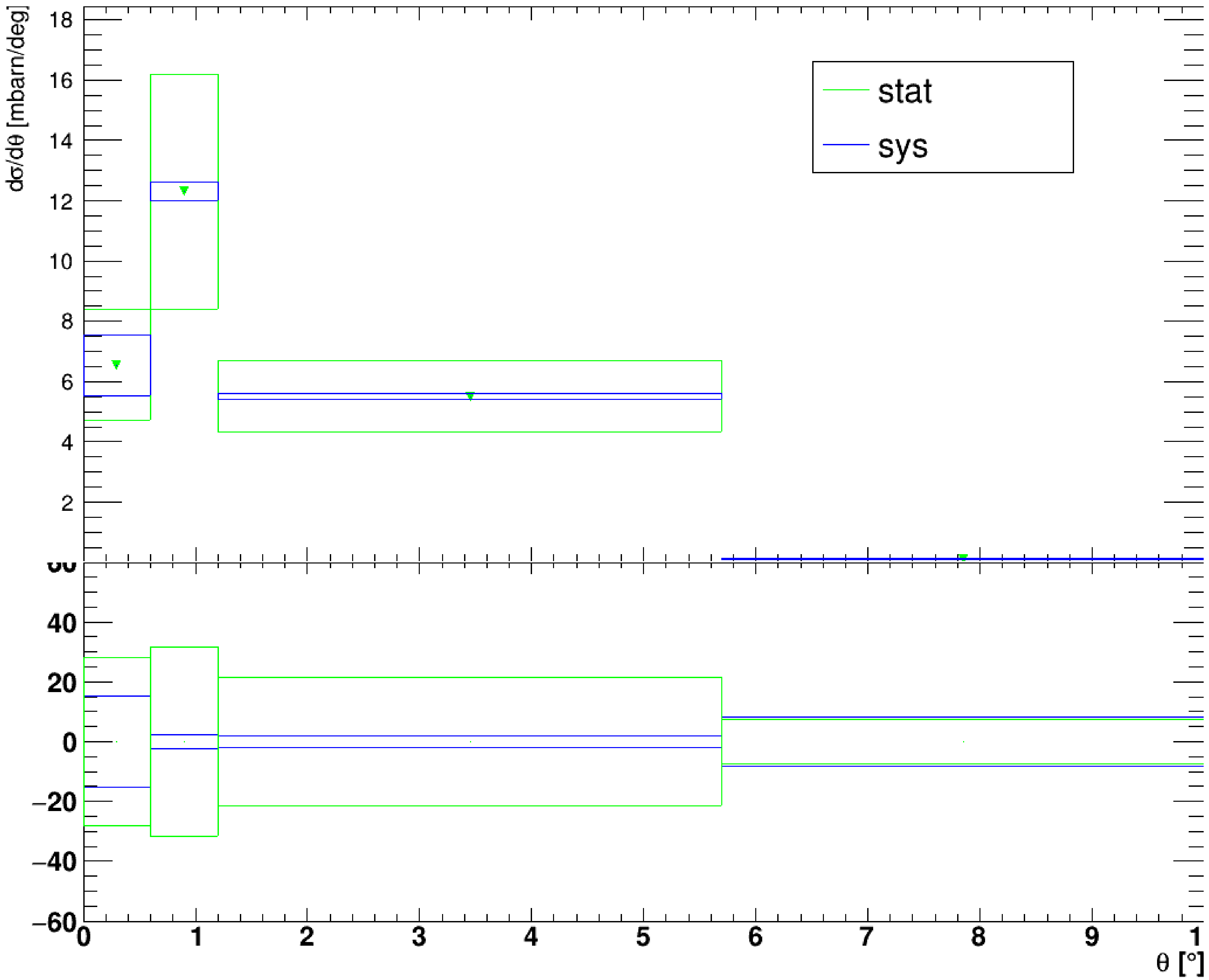


Z=3

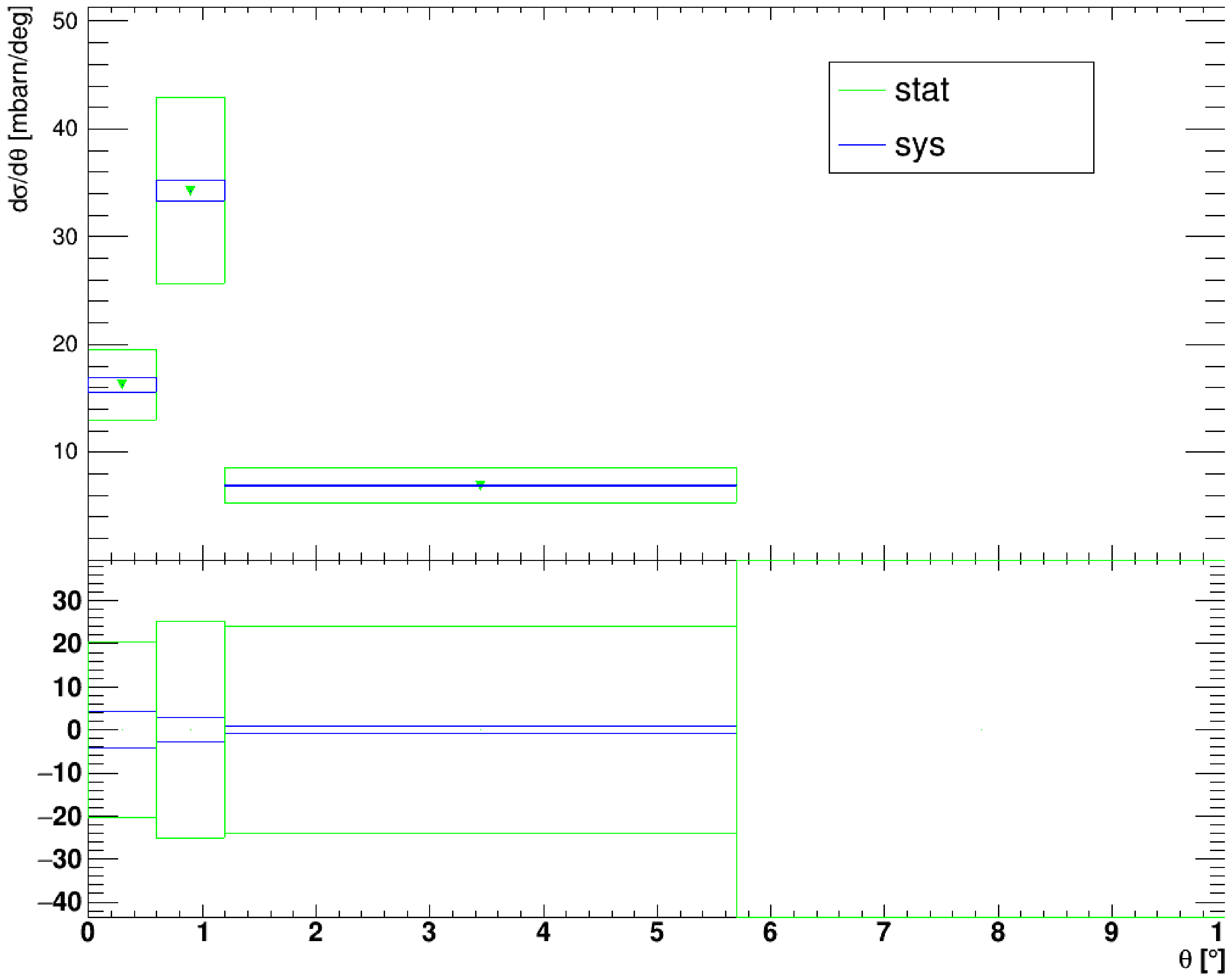


Merge all statistics

Z=4

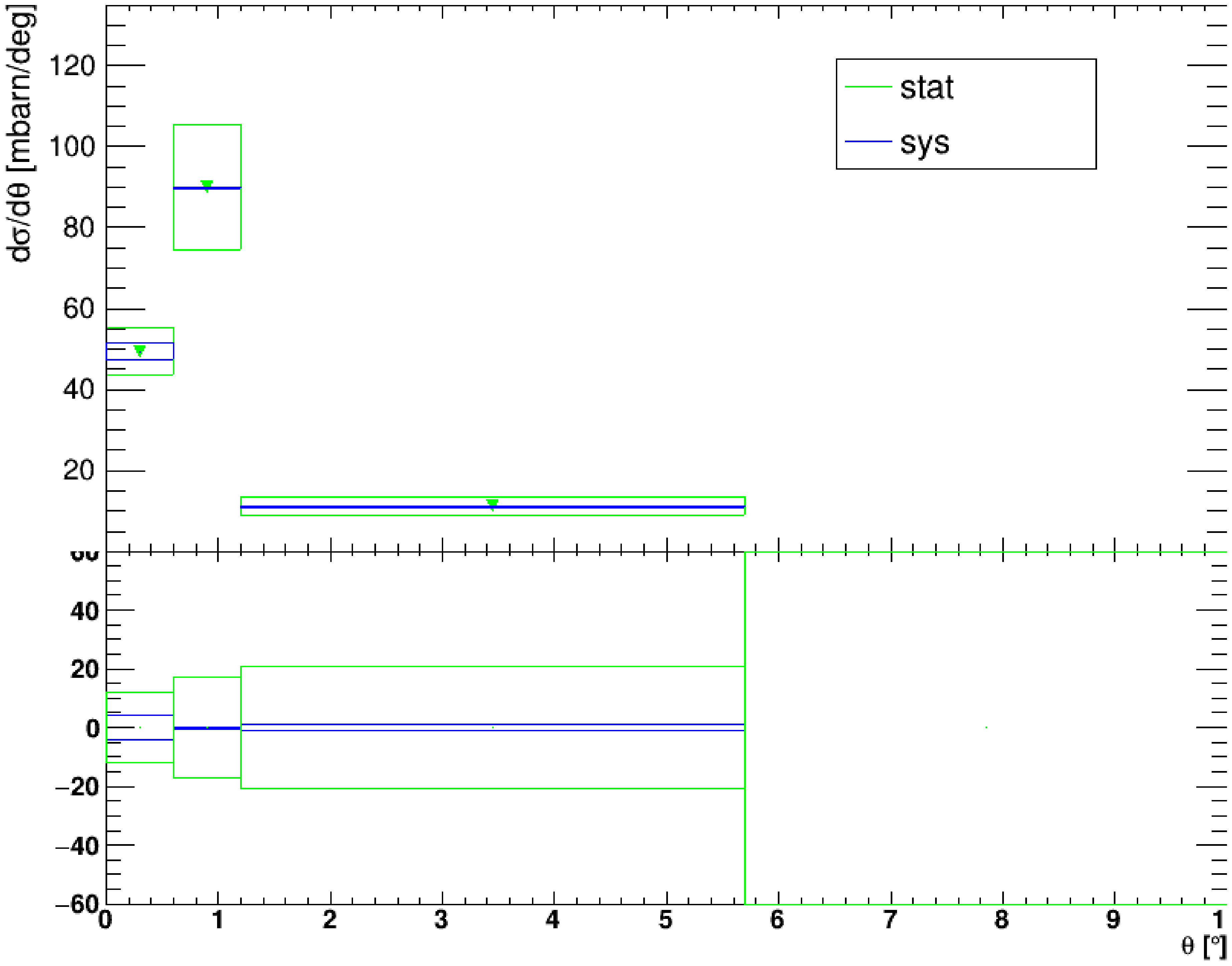


Z=5

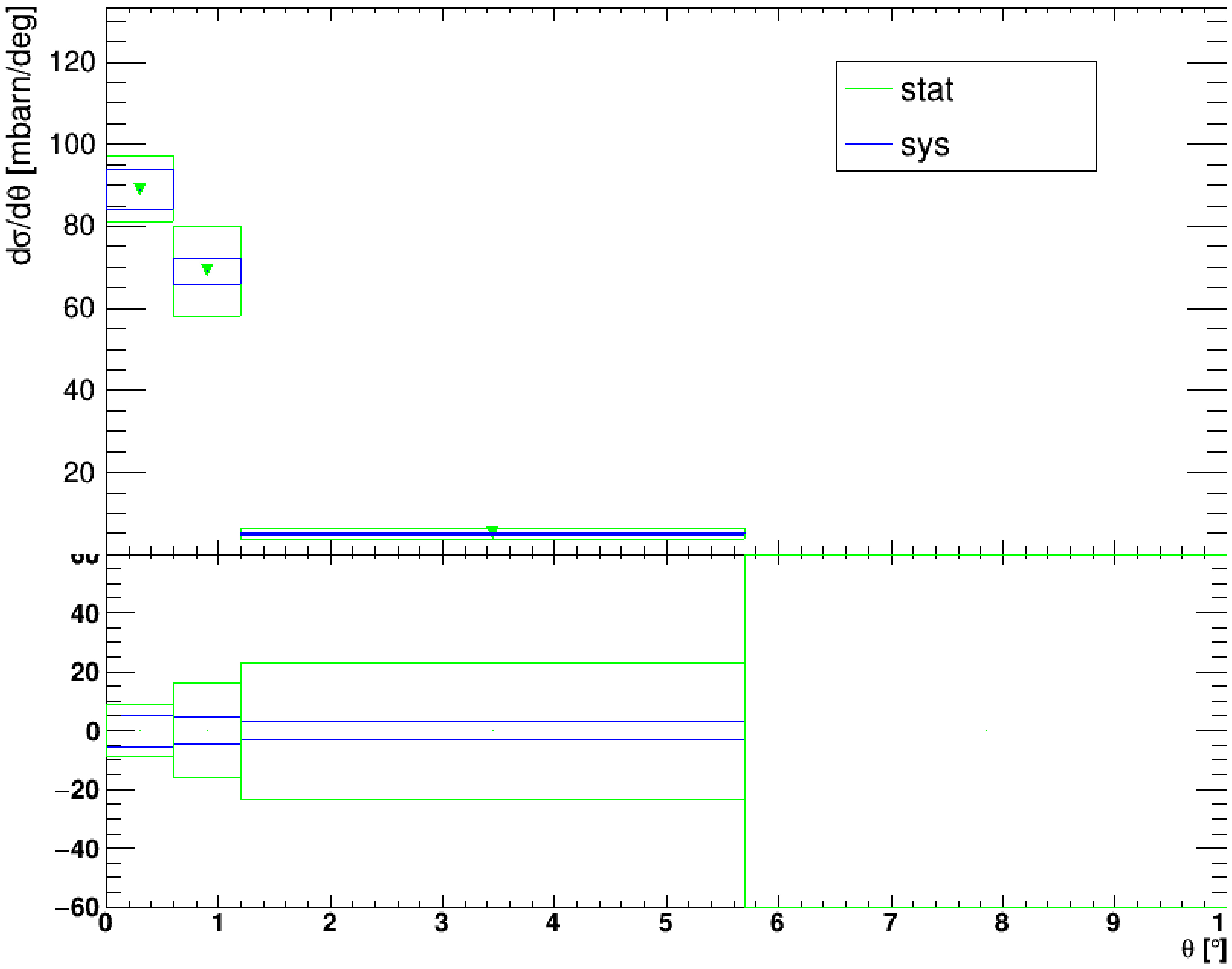


Merge all statistics

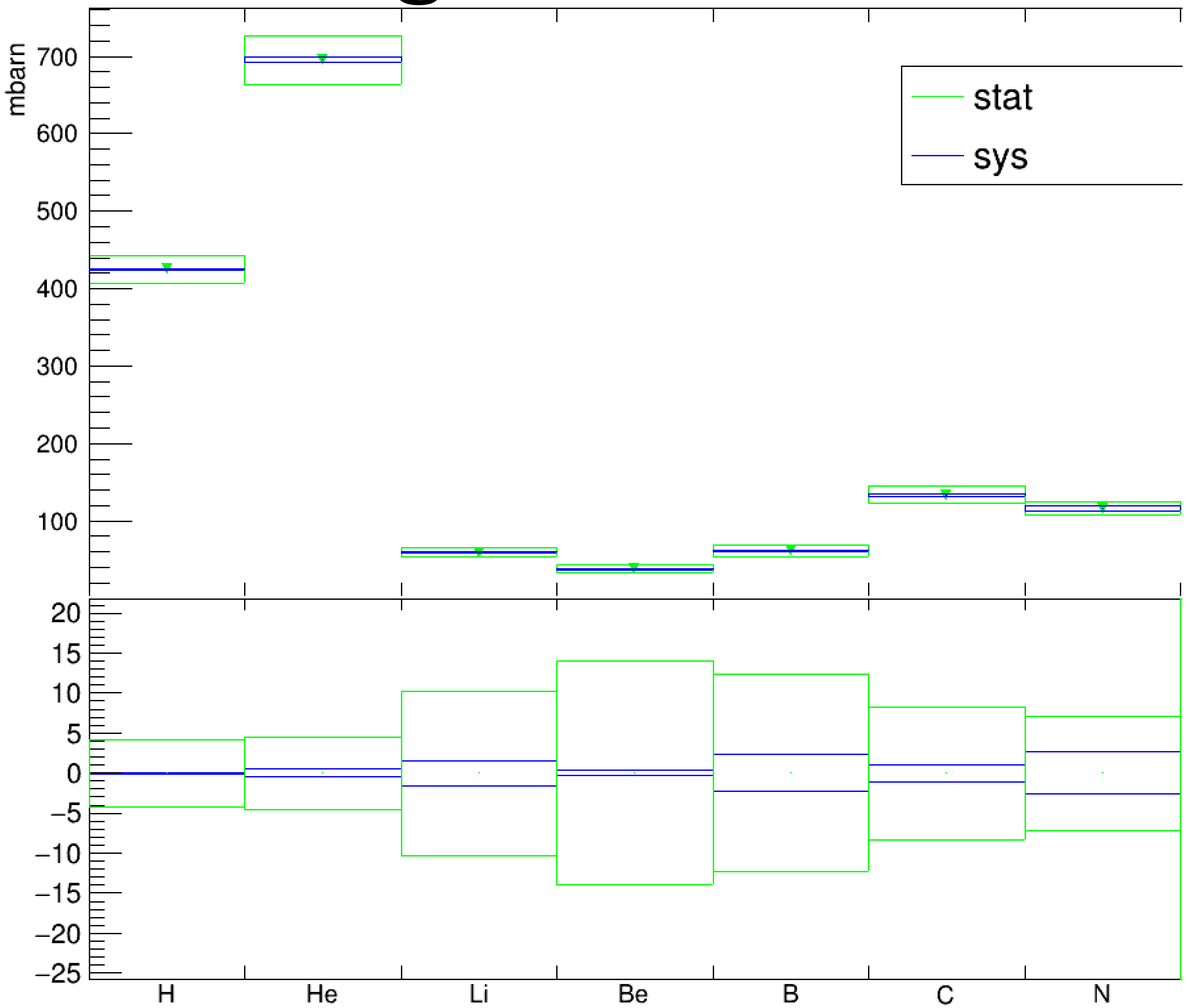
Z=6



Z=7



Merge all statistics



Comparison with our GSI2019 article

TABLE 4 Elemental fragmentation cross sections measured in this work, for a 400 MeV/u ^{16}O beam interacting with a 5 mm graphite target. The energy of the ^{16}O beam at target center is 393 MeV/u. The results are compared with FLUKA MC predictions (last column).

Element	$\sigma_{frag} \pm\Delta_{stat} \pm\Delta_{sys}$ [mbarn]	$\Delta_{stat}/\sigma_{frag}$	$\Delta_{sys}/\sigma_{frag}$	σ_{MC} [mbarn]
He	789 ± 35 ± 67	4.4%	8.5%	705 ± 2
Li	101 ± 13 ± 10	12.5%	10.4%	74.9 ± 0.6
Be	33 ± 9 ± 3	26%	10.3%	37.5 ± 0.4
B	78 ± 11 ± 6	14%	8.5%	41.8 ± 0.4
C	131 ± 14 ± 4	11%	2.8%	87.7 ± 0.6
N	117 ± 14 ± 6	12%	4.8%	110.3 ± 0.7

He	**695±31±4**
Li	**59±6±1**
Be	**38±5±1**
B	**61±8±2**
C	**134±11±2**
N	**116±8±3**

Conclusions and perspectives

Data seem to agree among runs

Merged all the statistics with target

Added systematics of the subtraction method

Bayes selected as unfolding method, others in systematics

To add: geometric efficiency for Z=2

We started writing!

Thanks for listening!