Update on the Analysis of GSI ^{16}O Data Taking

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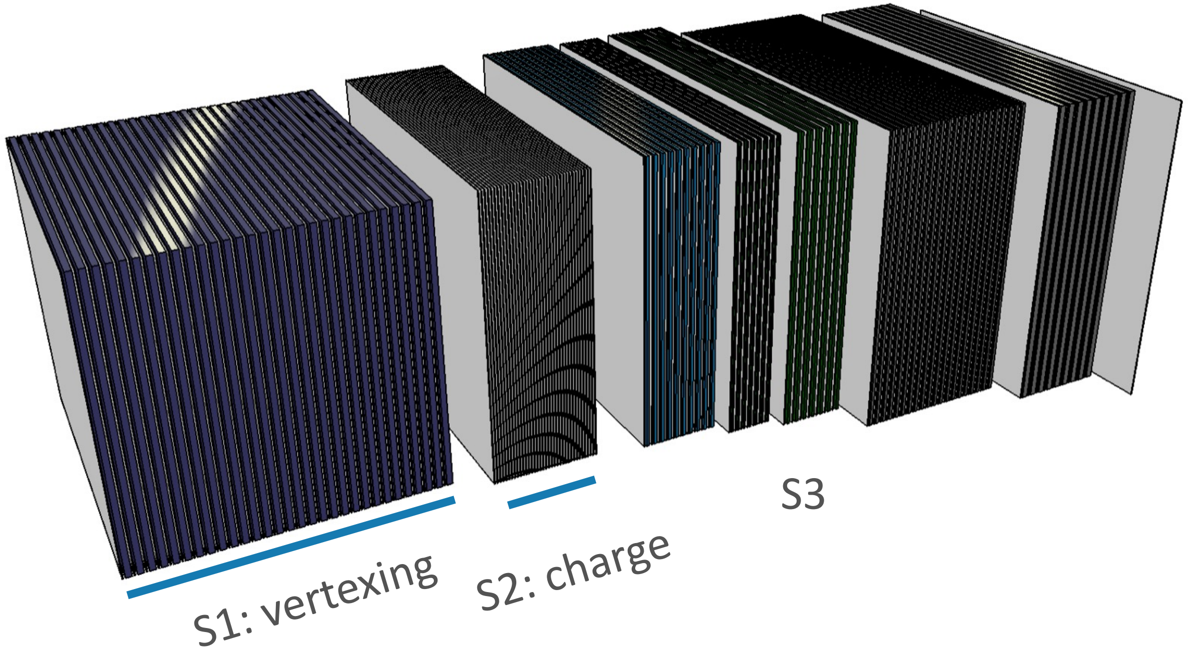
Bergamo, Giovanni XXIII Congress Centre

Summary

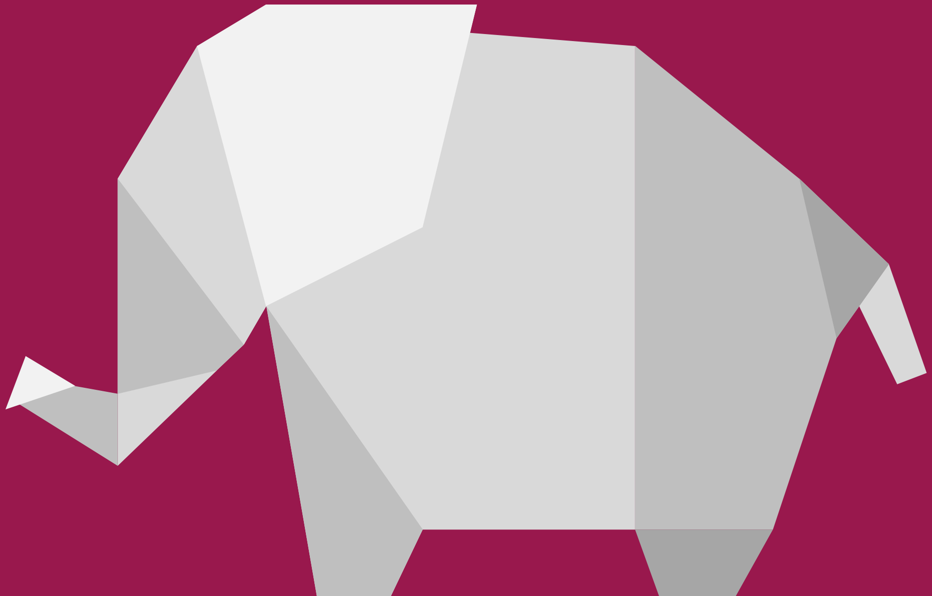


Target	Beam: 2019 Oxygen 200 MeV/n	Beam: 2019 Oxygen 400 MeV/n
Carbon	GSI1	GSI3
Polyethylene	GSI2	GSI4

- Reconstruction of vertices from Oxygen interactions in Section 1 (S1)
- Charge measurement in Section 2 (S2)
- Momentum measurement in Section 3 (S3) [see G. Lorusso's talk]

Reconstruction improvements

- MC description of detector response ("MC Reco")
- Merging procedure between different sections
- Vertices reconstruction
- Procedure to attach unconnected tracks in S2 to vertices



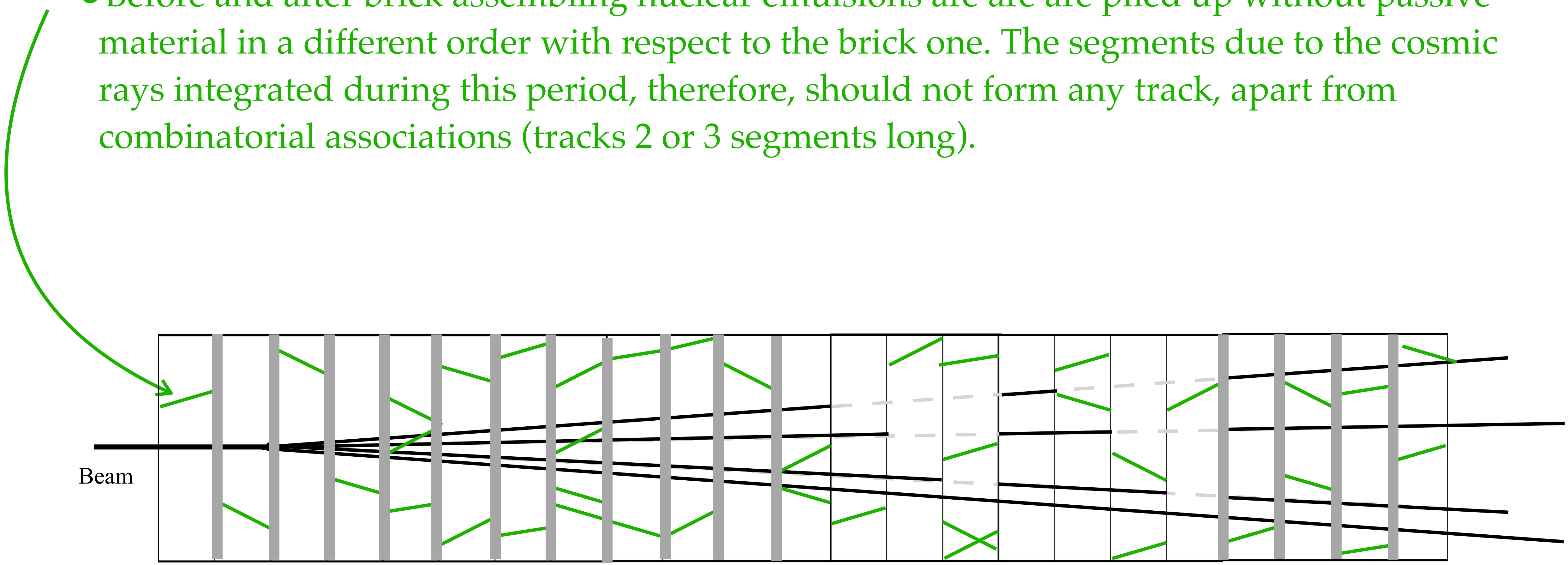
Improvements of detector response in MC description ("MC Reco")

- Efficiencies for cross section measurement is obtained comparing True and Reconstructed Monte Carlo
- Reconstructed Monte Carlo has to reproduce detector response
- Effects already present:
  - angle smearing
  - data-driven inefficiencies
  - data-driven random background
- Effects added:
  - misalignments
  - data-driven long cosmic rays background

Background in Monte Carlo Simulation

- Nuclear emulsions integrate cosmic rays since their production up to their development

- Before and after brick assembling nuclear emulsions are are are piled up without passive material in a different order with respect to the brick one. The segments due to the cosmic rays integrated during this period, therefore, should not form any track, apart from combinatorial associations (tracks 2 or 3 segments long).



Passive material not to scale

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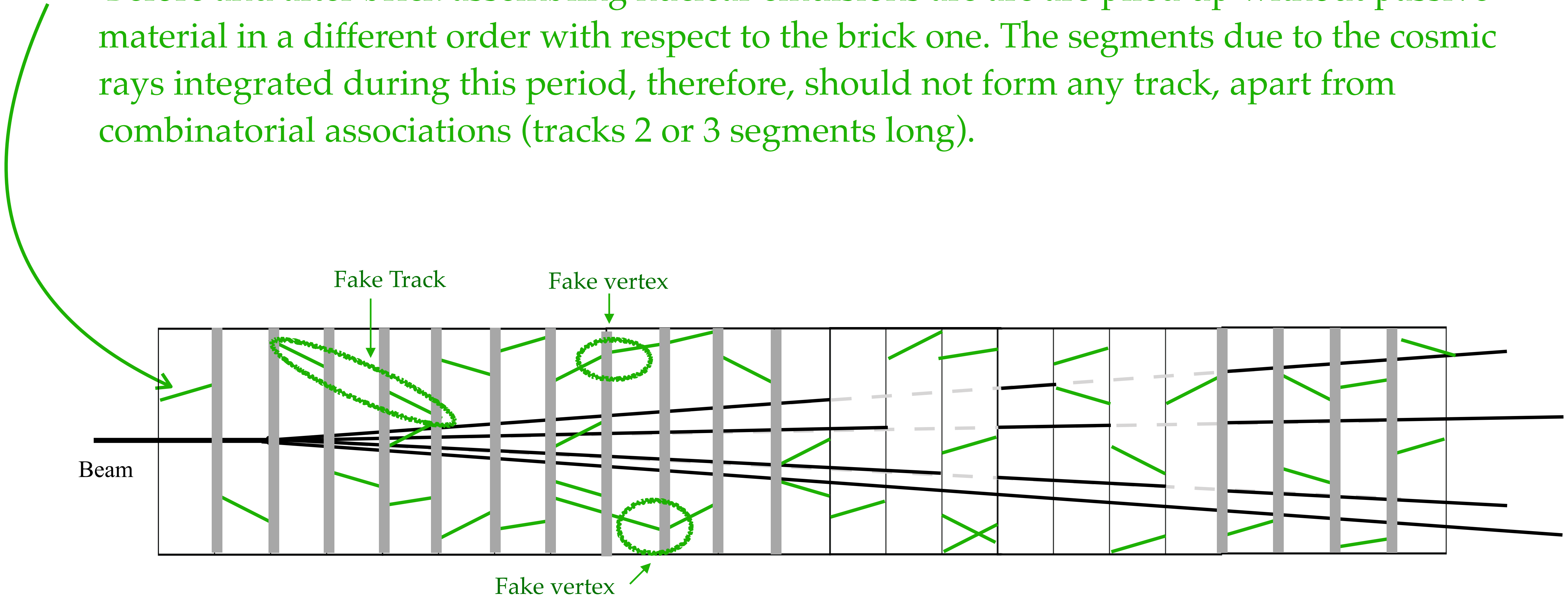

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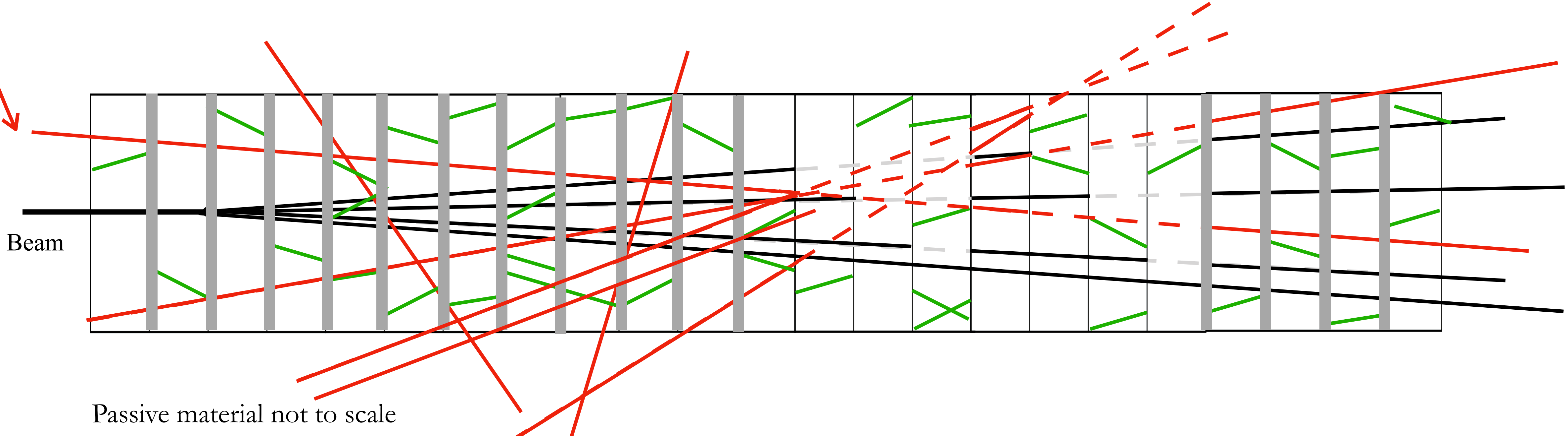
Background in Monte Carlo Simulation

- Nuclear emulsions integrate cosmic rays since their production up to their development
- When the brick is assembled, it integrates cosmic rays that are then reconstructed as long tracks. These could mimic a vertex or be associated to a true vertex if they're reconstructed as more than one track
- Penetrating cosmic rays now included in MC Reco simulation
- Basetracks belonging to cosmic rays tagged from S2 Charge identification analysis in DATA are "copied" in MC Reco



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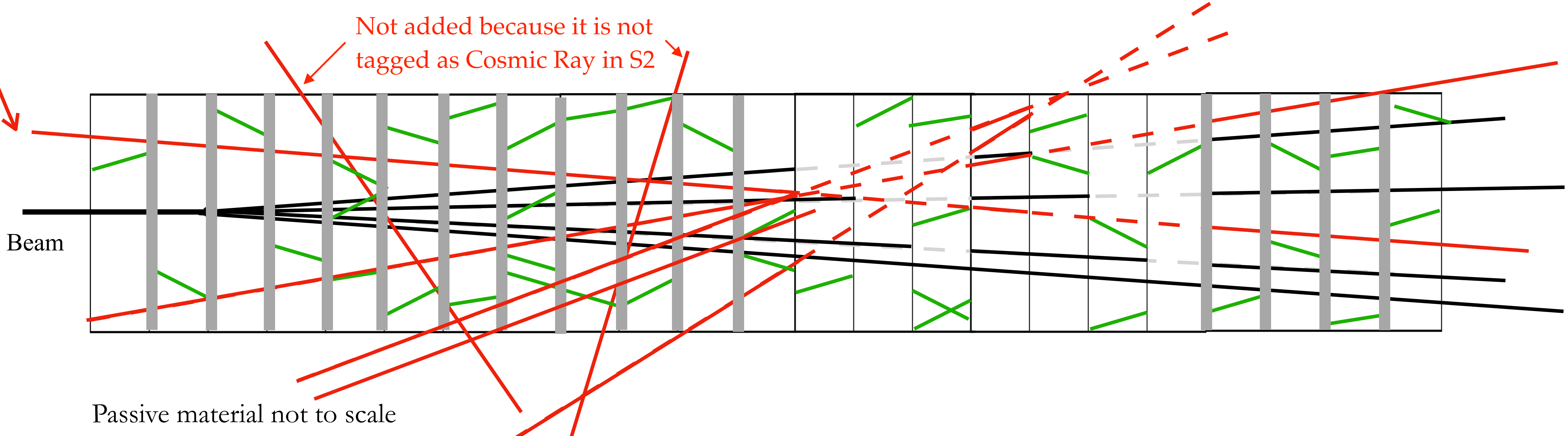

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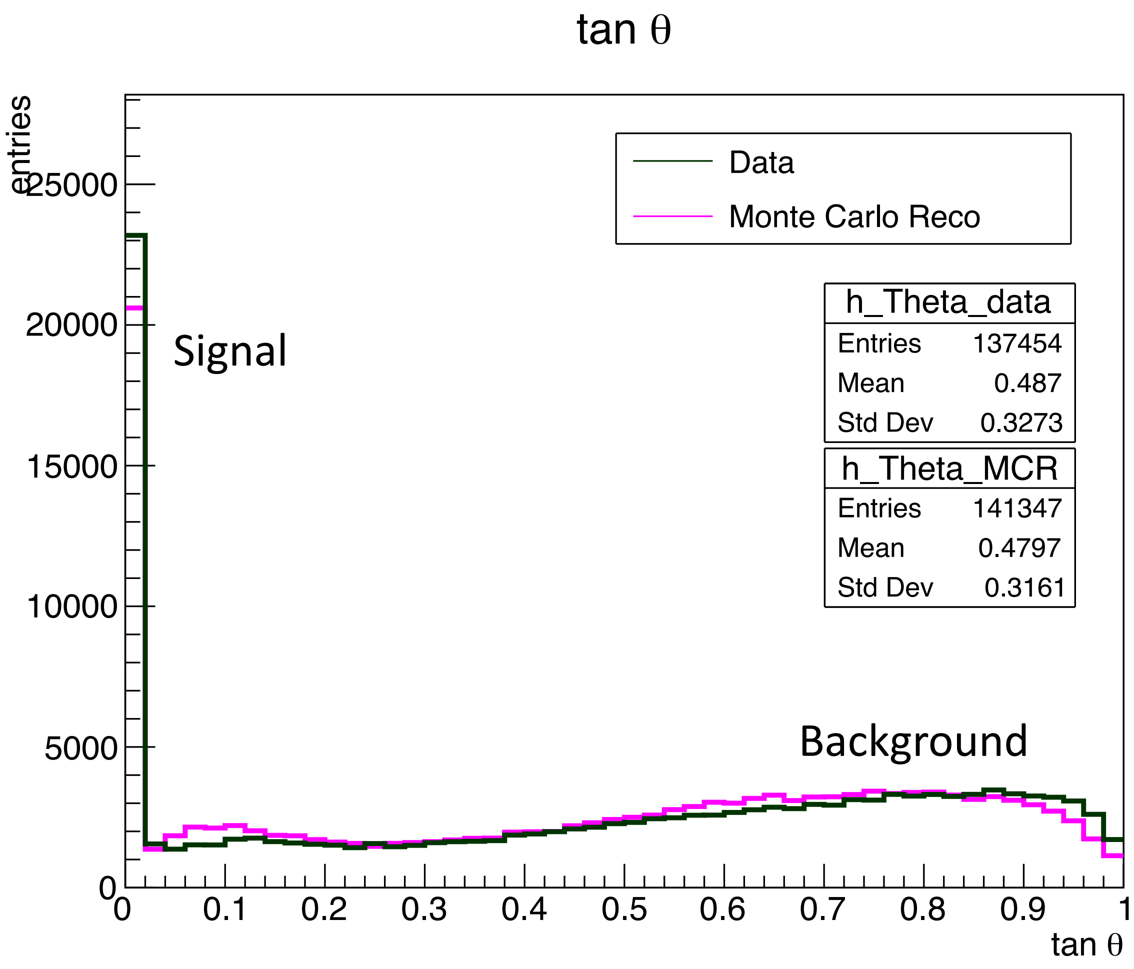
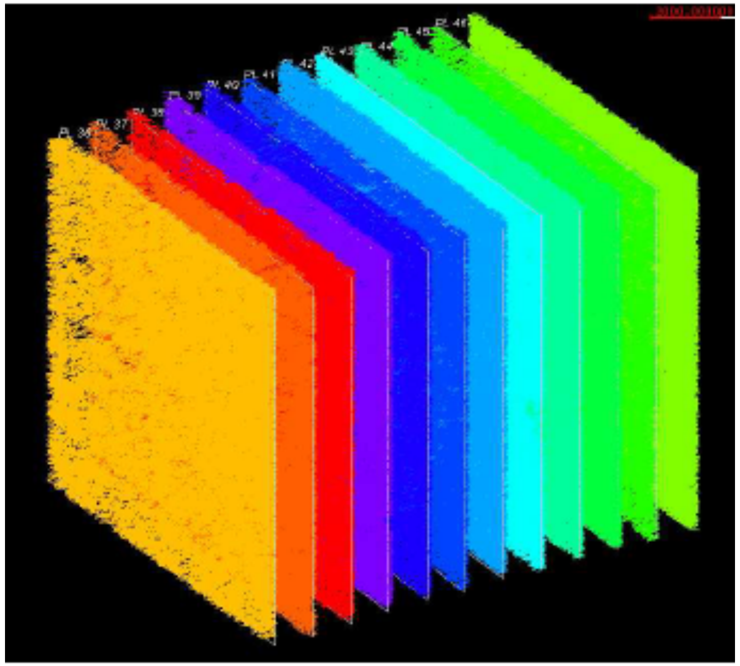
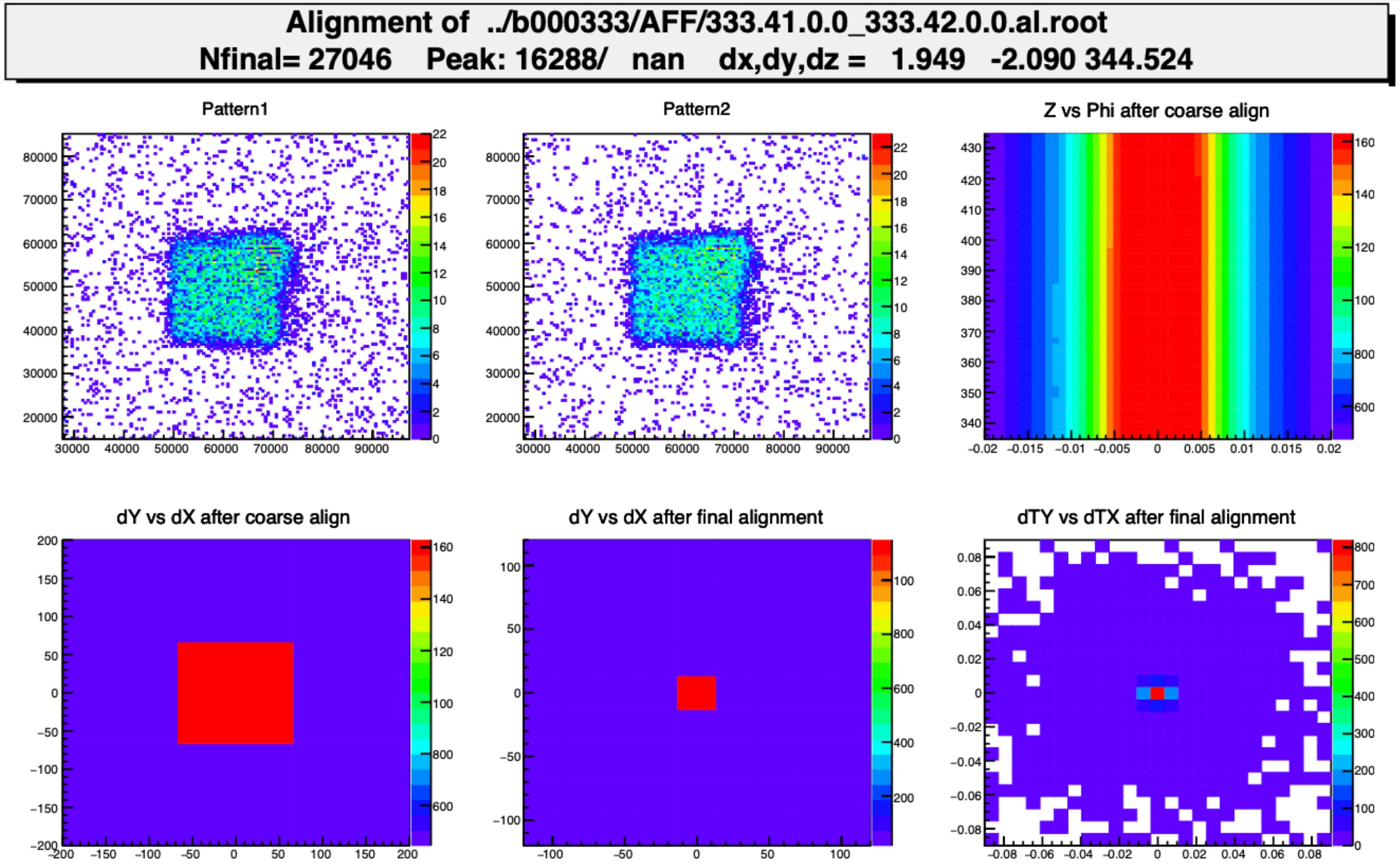


Example taken from GSI2

Nuclear emulsion films alignment

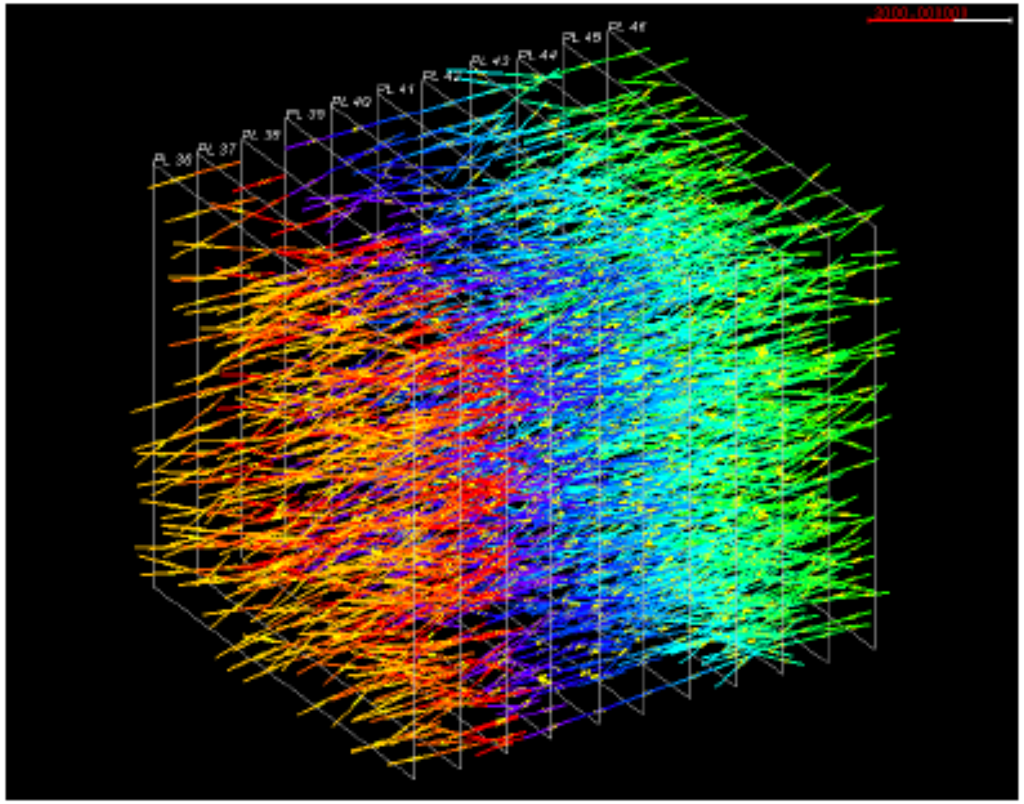
- **STEP 1**: align couples of consecutive plates (~3 interactions with more stringent parameters)





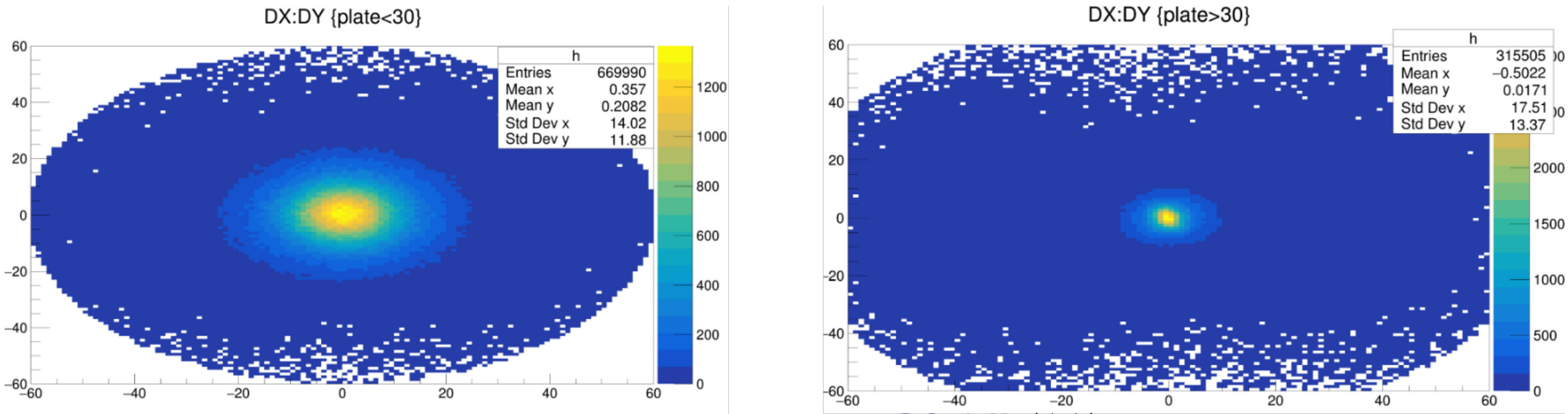
Nuclear emulsion films alignment

- Residual (small) misalignment are present in the global reconstruction
- **STEP 2**: re-alignment of the whole stack, taking into consideration long tracks to improve the global alignment
- Final tracks reconstruction



Misaligments in MC Reco

- Introduction of a smearing on X and Y positions that reproduces the residual misalignments:
  - 5 micron in all stacks with exception of S2
  - 2 micron in S2 (no passive material)
- Re-alignment procedure (**step 2**)



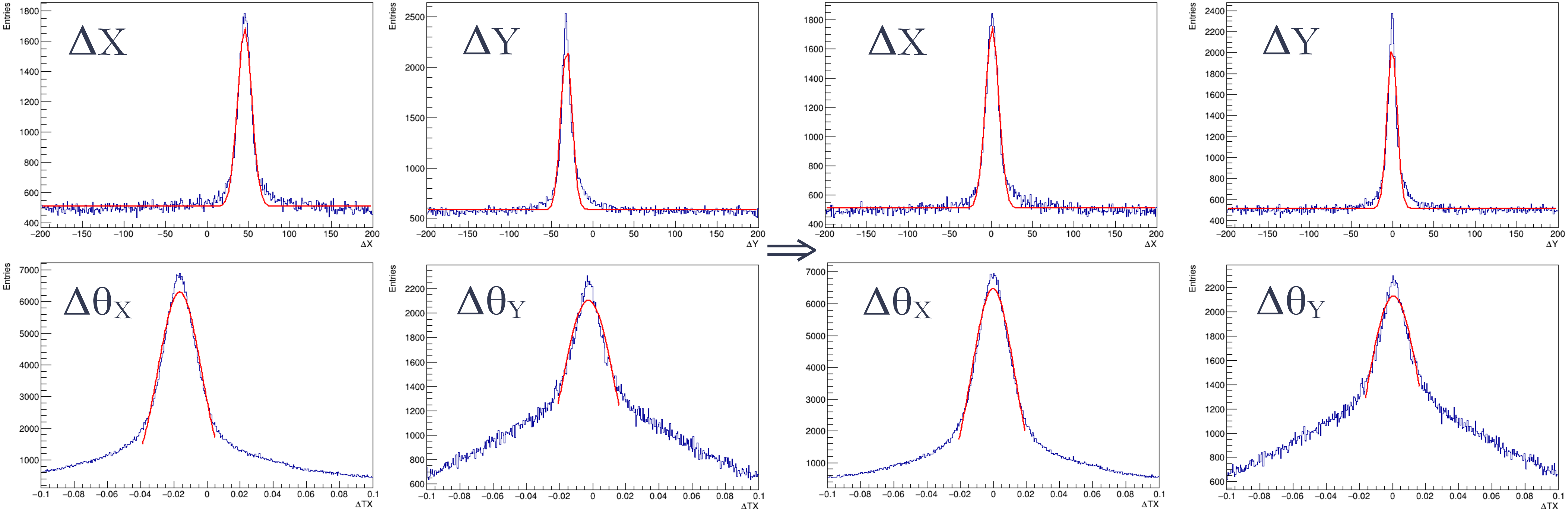
EXAMPLE TAKEN FROM GSI2 DATA

- Future plan: understand if it possible to introduce systematic shifts between plates (needed?)

Merging procedure between different sections

- Each section is characterised by its own parameters (material density, thickness…): tracking algorithm applied to each section separately → Different reference systems for each section
- Optimised procedure to put tracks in the same reference system
- Improved final XY shift + rotation to correct the offsets

Before corrections **After corrections**

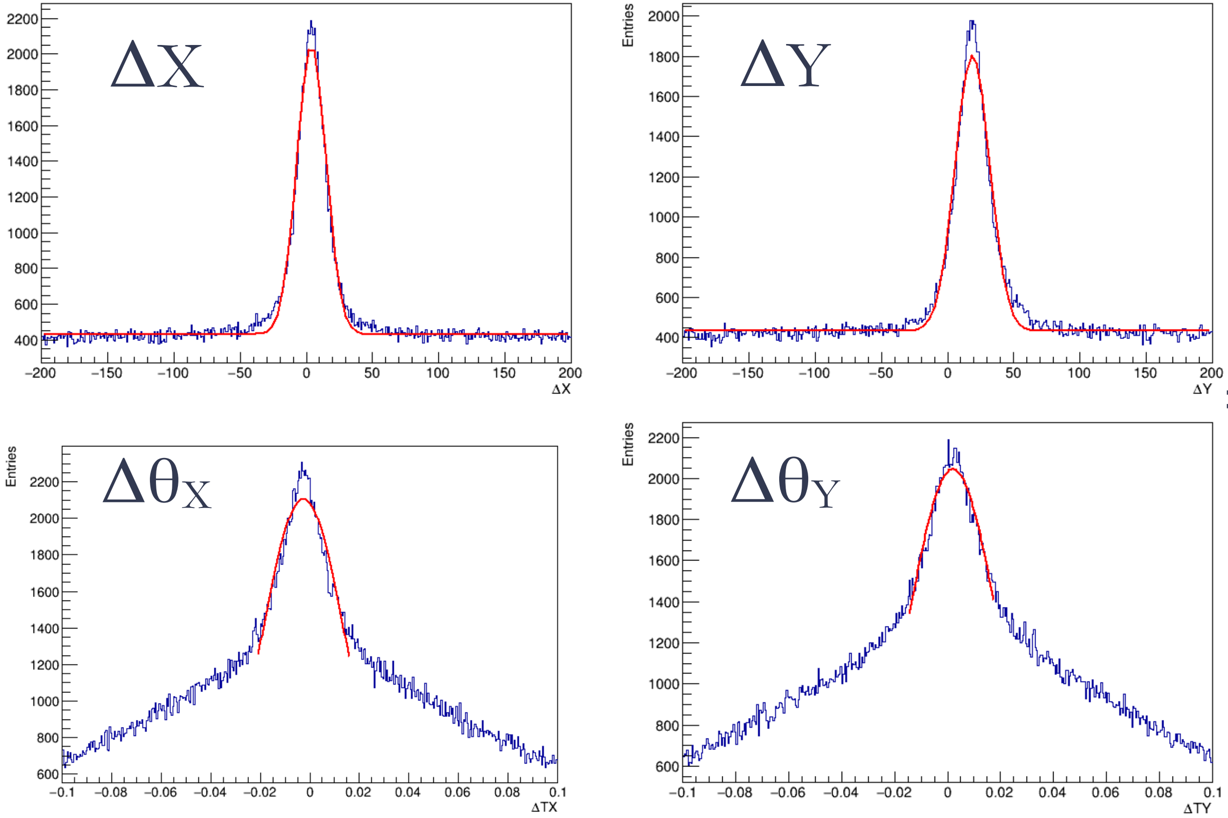


EXAMPLE TAKEN FROM GSI3 DATA S1→S2

Merging procedure between different sections

- Application to all stacks (S1-S7) for the first time

Before corrections | **After corrections**



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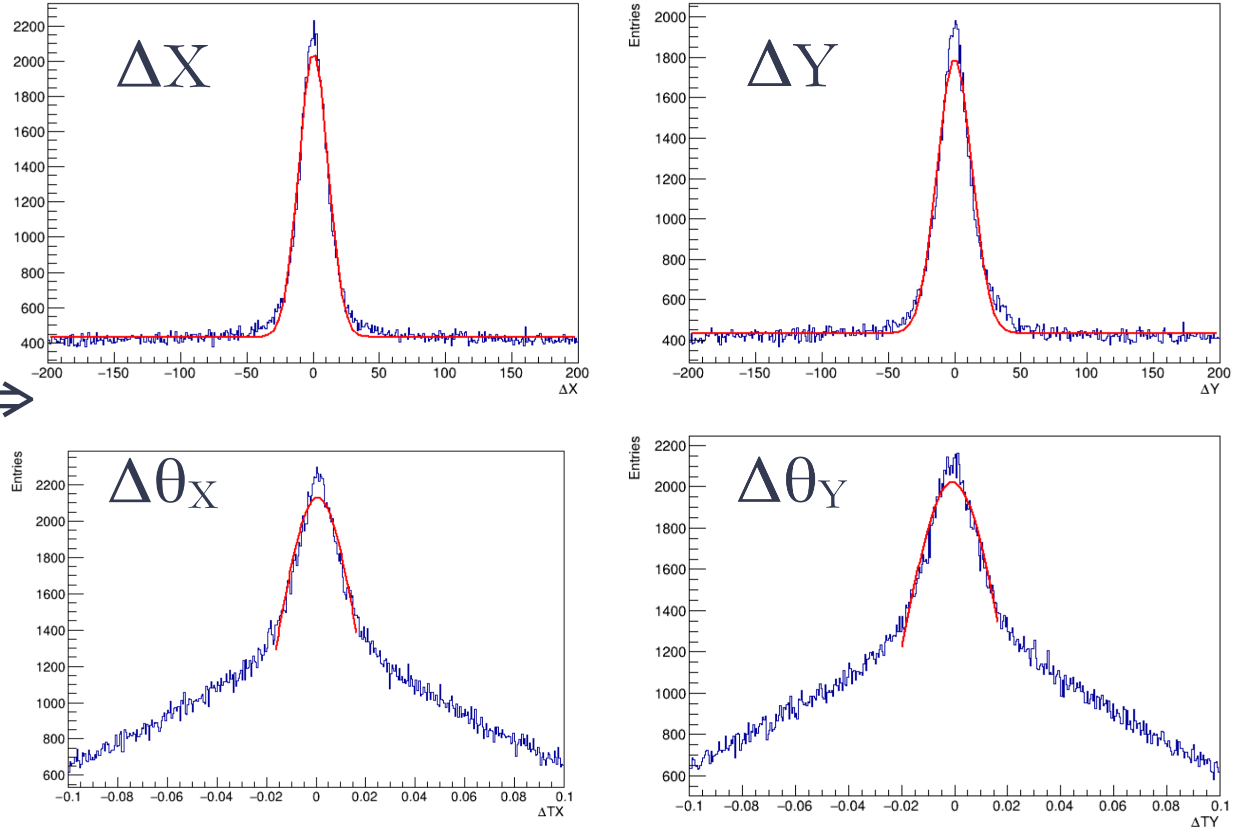
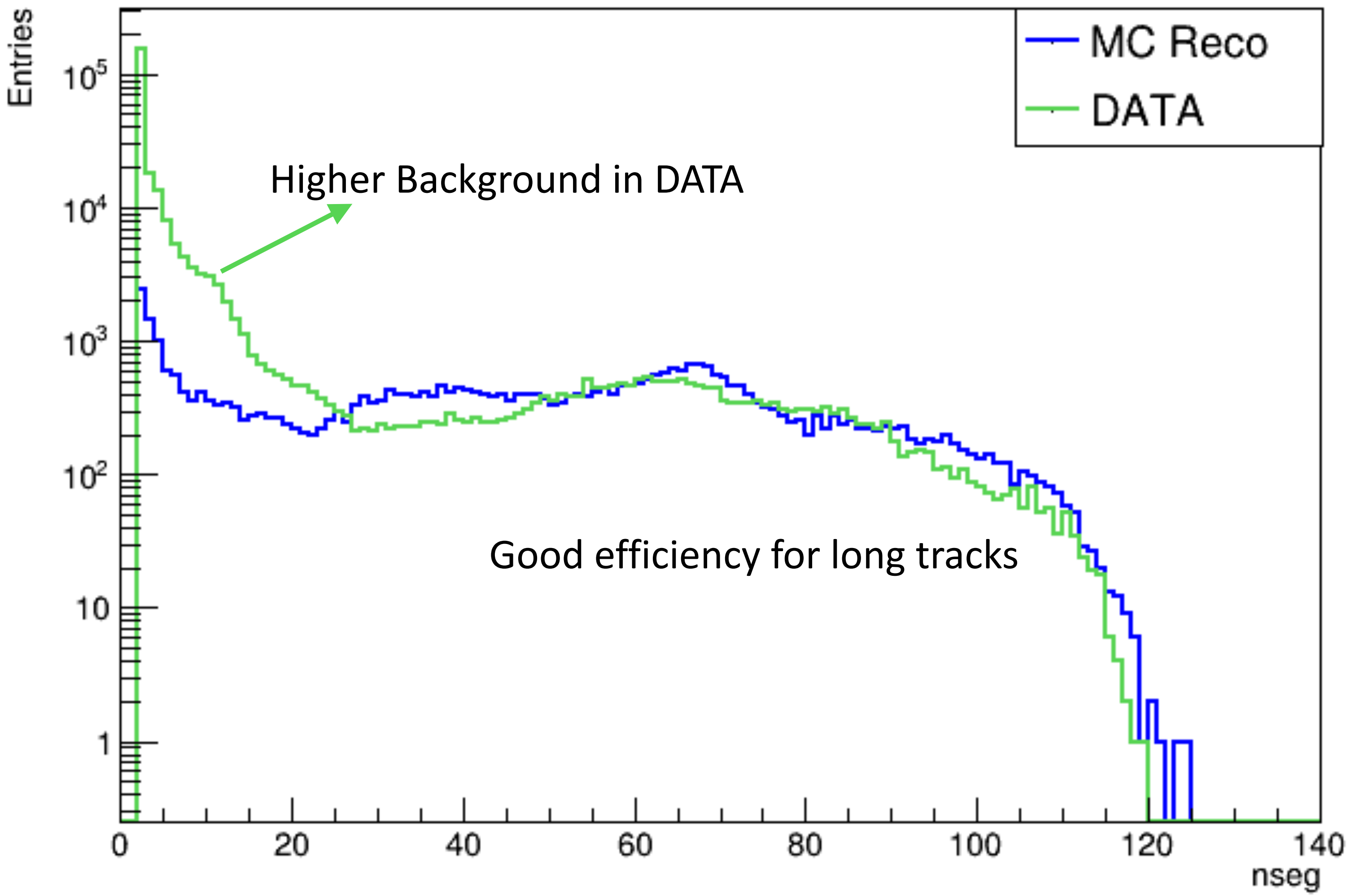


EXAMPLE TAKEN FROM GSI3 DATA S5→S6

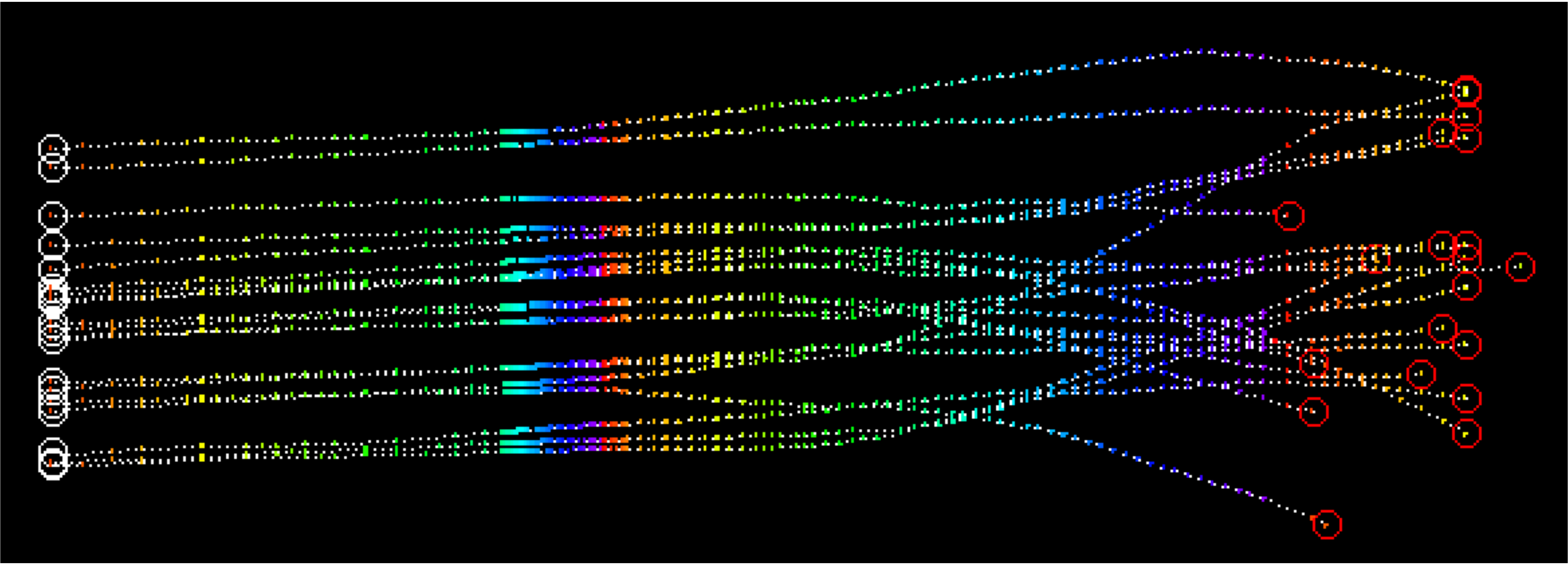
Tracks connections

- New algorithm to connect tracks once they are in the same reference system



EXAMPLE TAKEN FROM GSI3

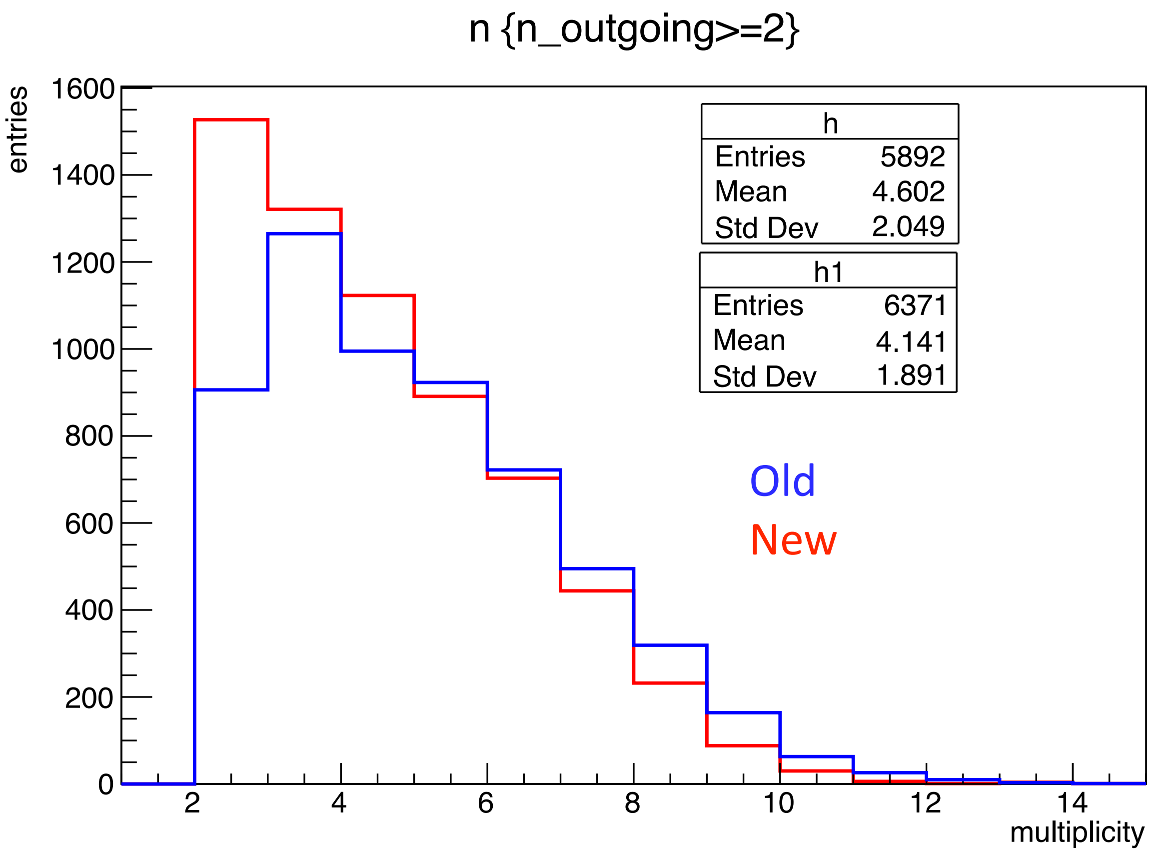
Merging procedure between different sections

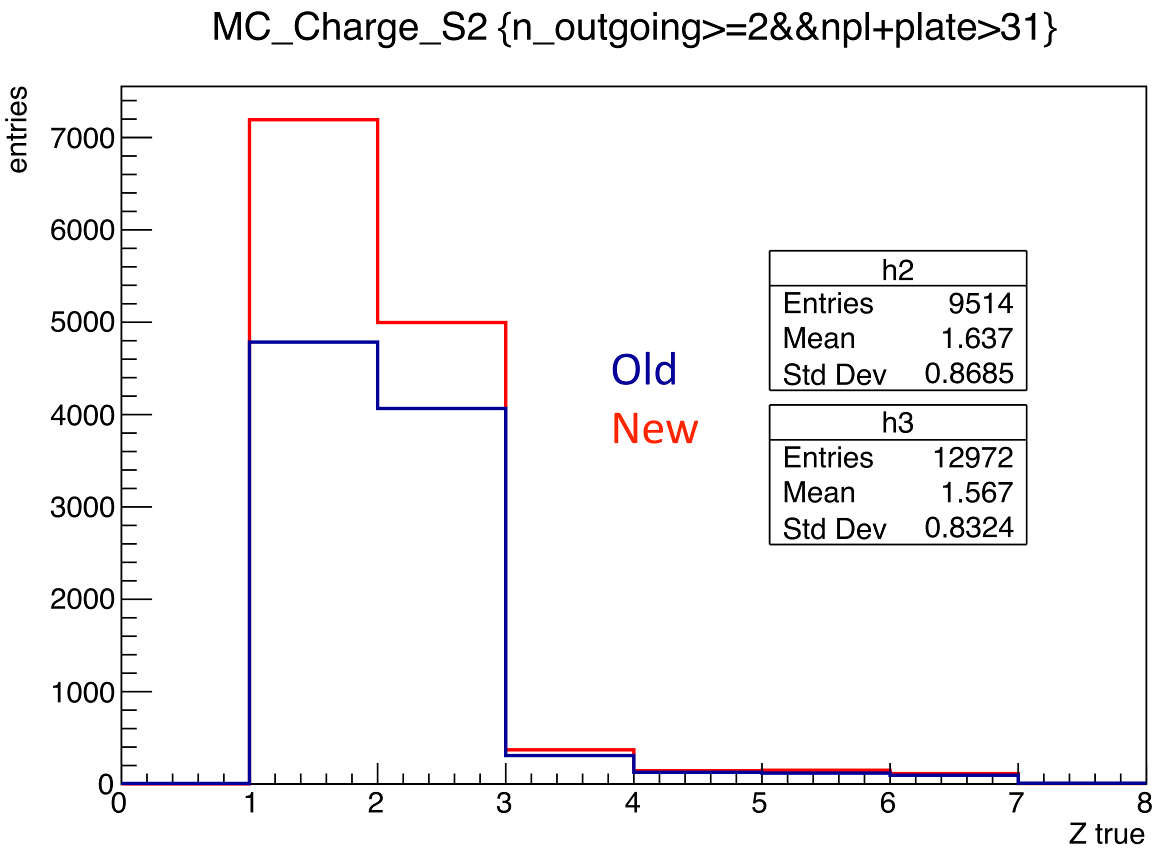


EXAMPLE OF LONG TRACKS (NSEG>100) TAKEN FROM GSI3 DATA

Vertices reconstruction

- New vertexing procedure to give a higher score to vertices with longer tracks



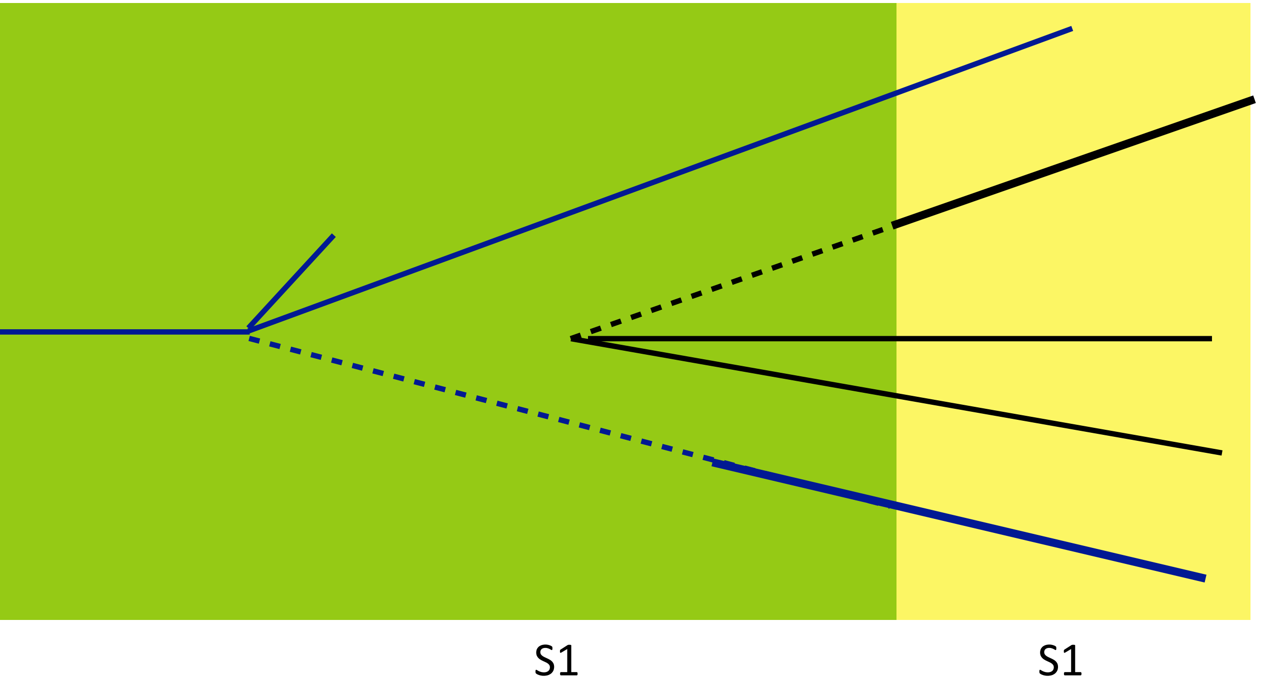


- Higher number of vertices (even though sometimes with lower multiplicity) but more tracks arriving in S2

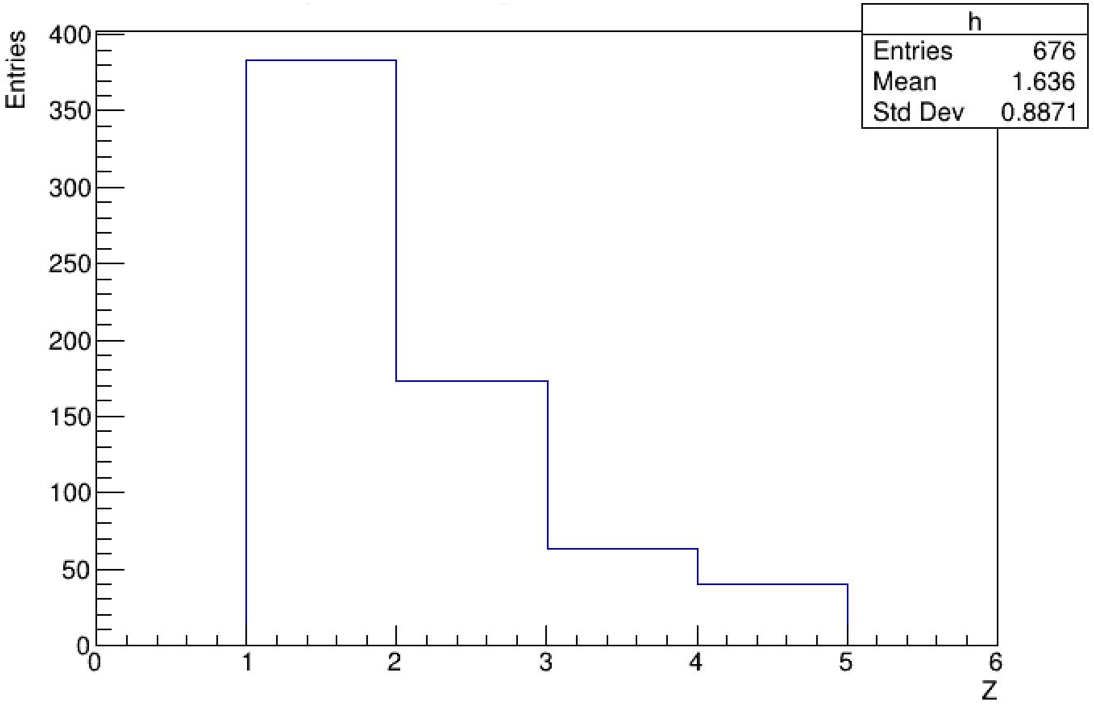
EXAMPLE TAKEN FROM GSI3

Procedure to attach unconnected tracks in S2 to vertices

- Analysis on tracks arriving in the first plate of S2 not connected to vertices
- Evaluation of impact parameter and distances between their projection at vertices Z
- Attaching the track if cuts are satisfied



(not in scale)



- ~ hundreds tracks recovered

Data analysis

- GSI1: Oxy@200 MeV/n on C target
- GSI2: Oxy@200 MeV/n on C_2H_4 target

OLD - GSI1: Oxy@200 MeV/n on C target

Fragments' charge

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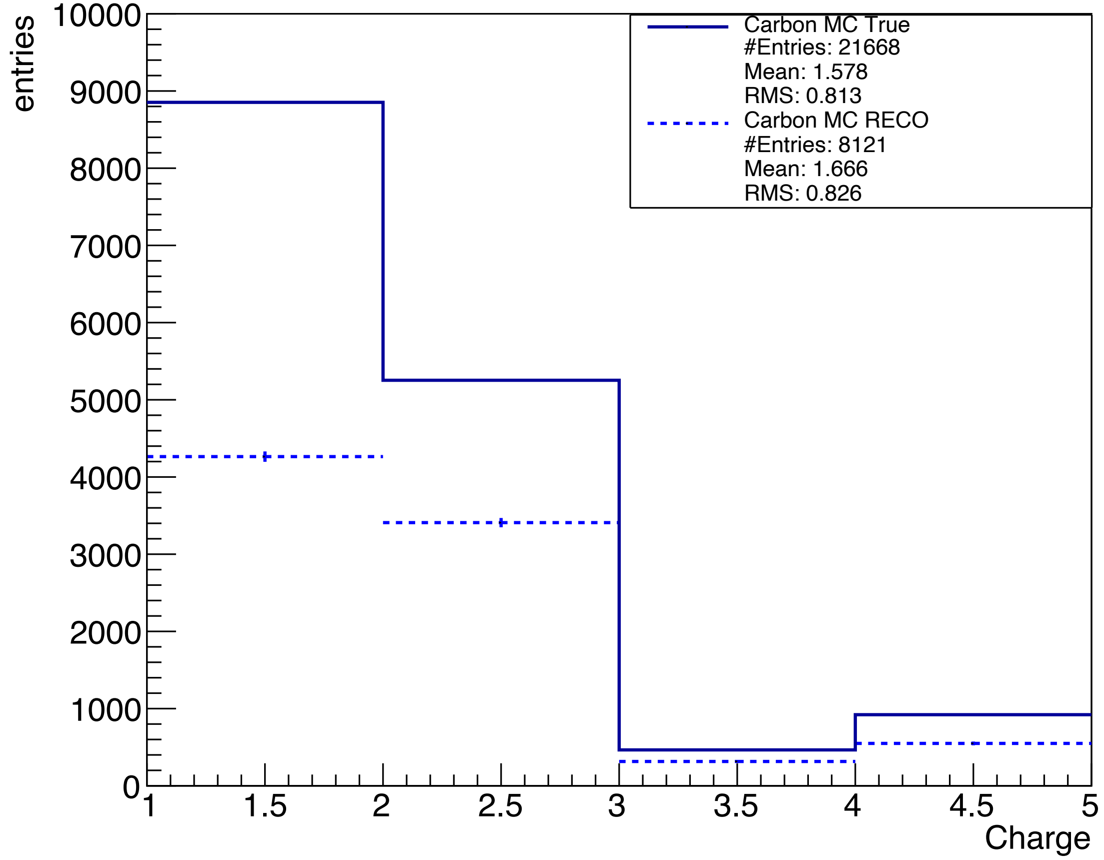
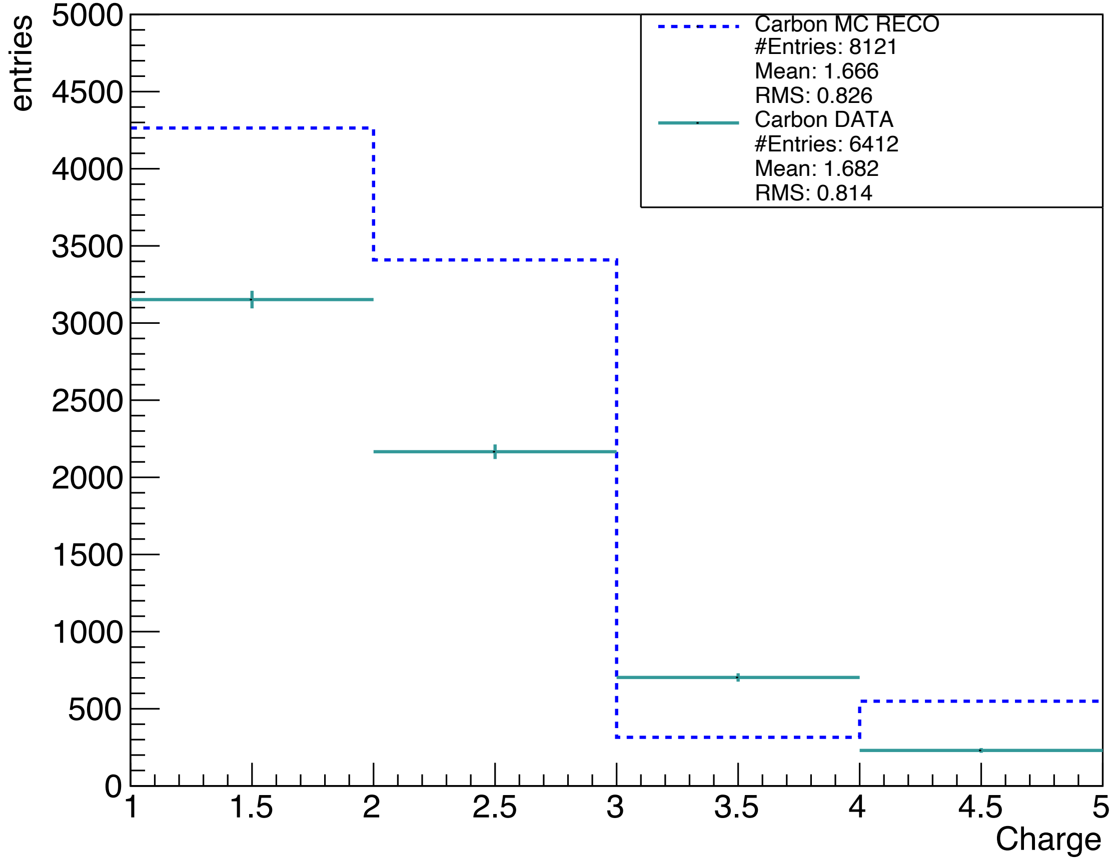
MC TRUE vs MC RECO



MC RECO vs DATA

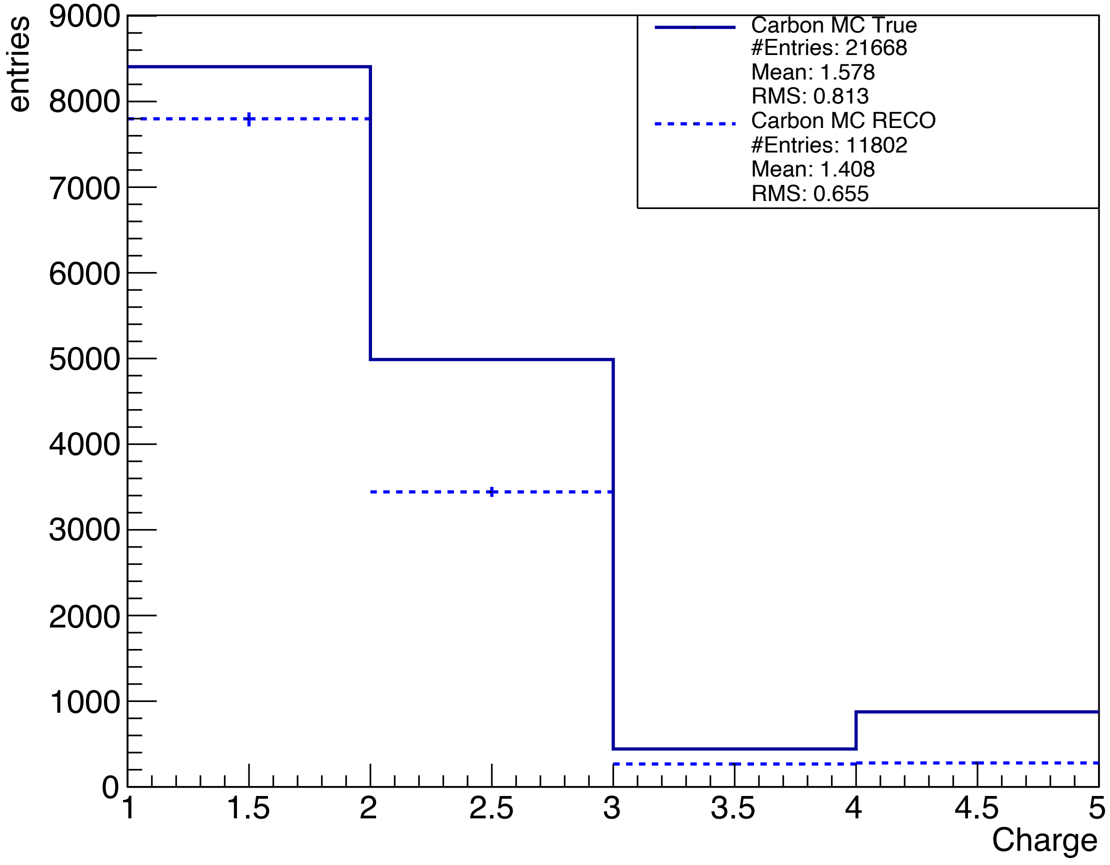


Distributions normalised to beam particles

GSI1: Oxy@200 MeV/n on C target

Fragments' charge (no misalignment in MC RECO)

MC TRUE vs MC RECO



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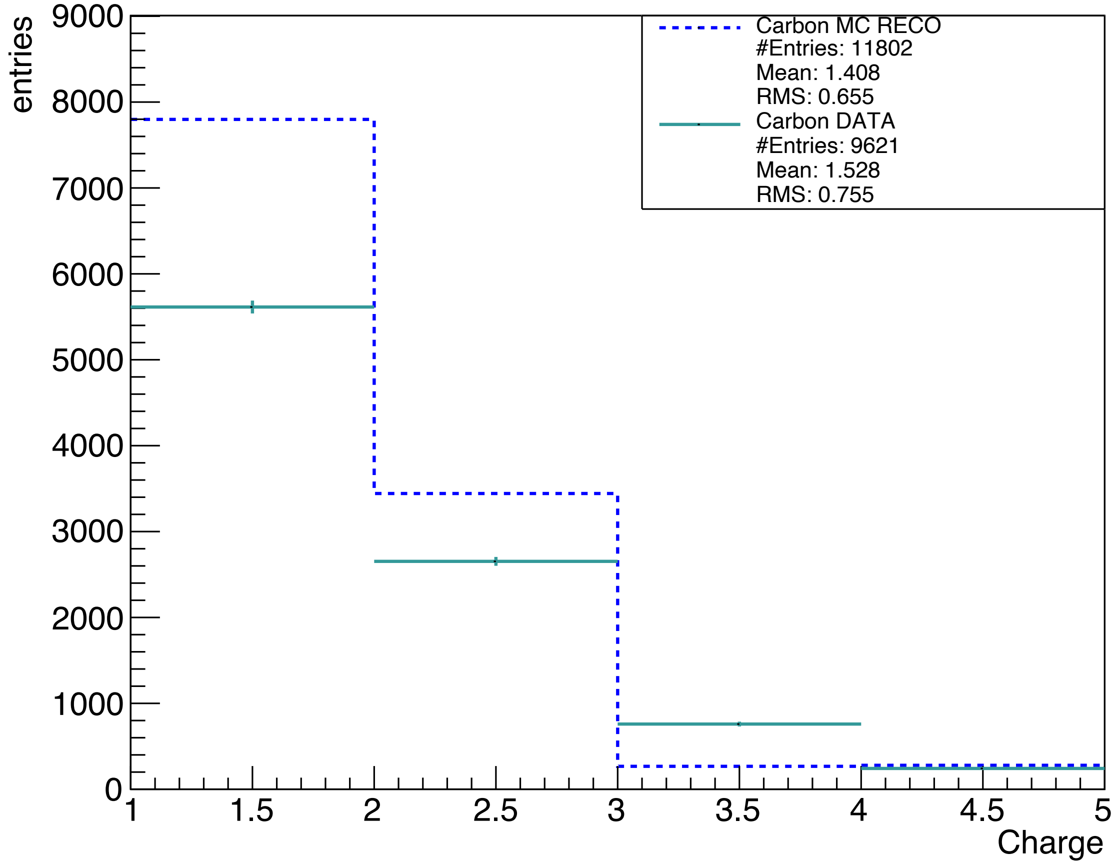

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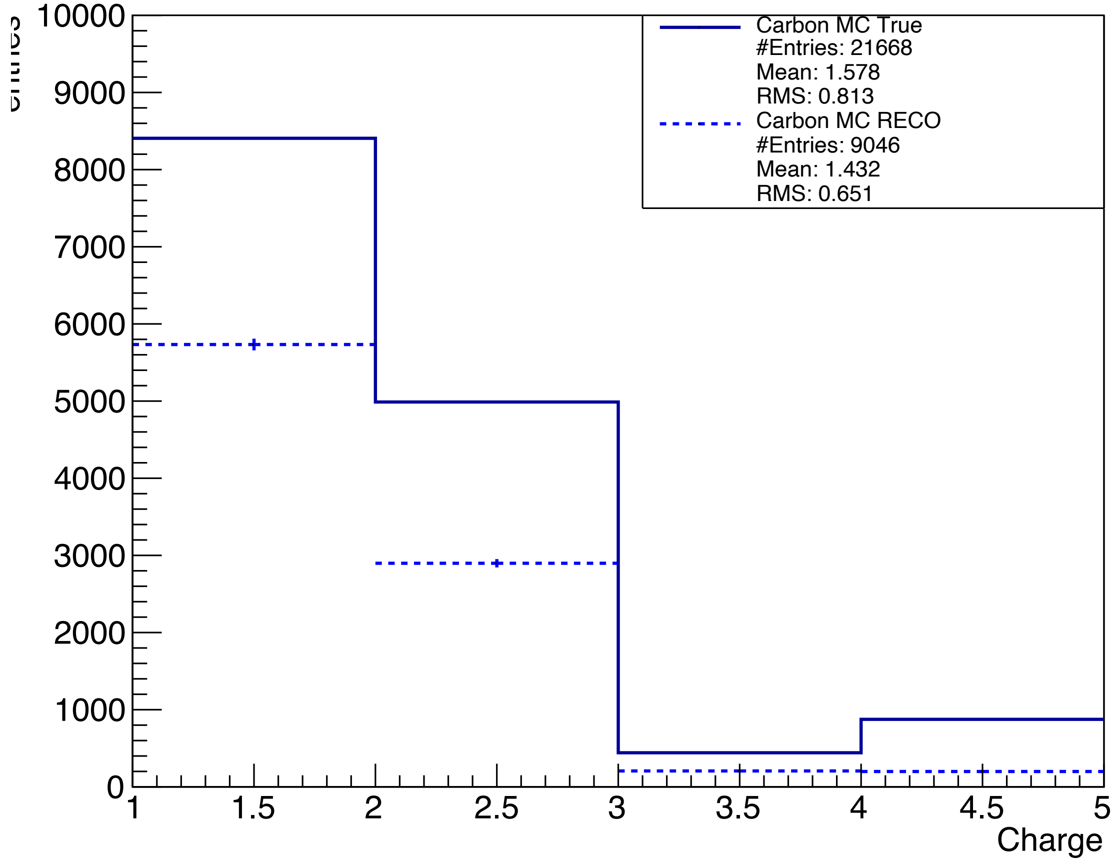

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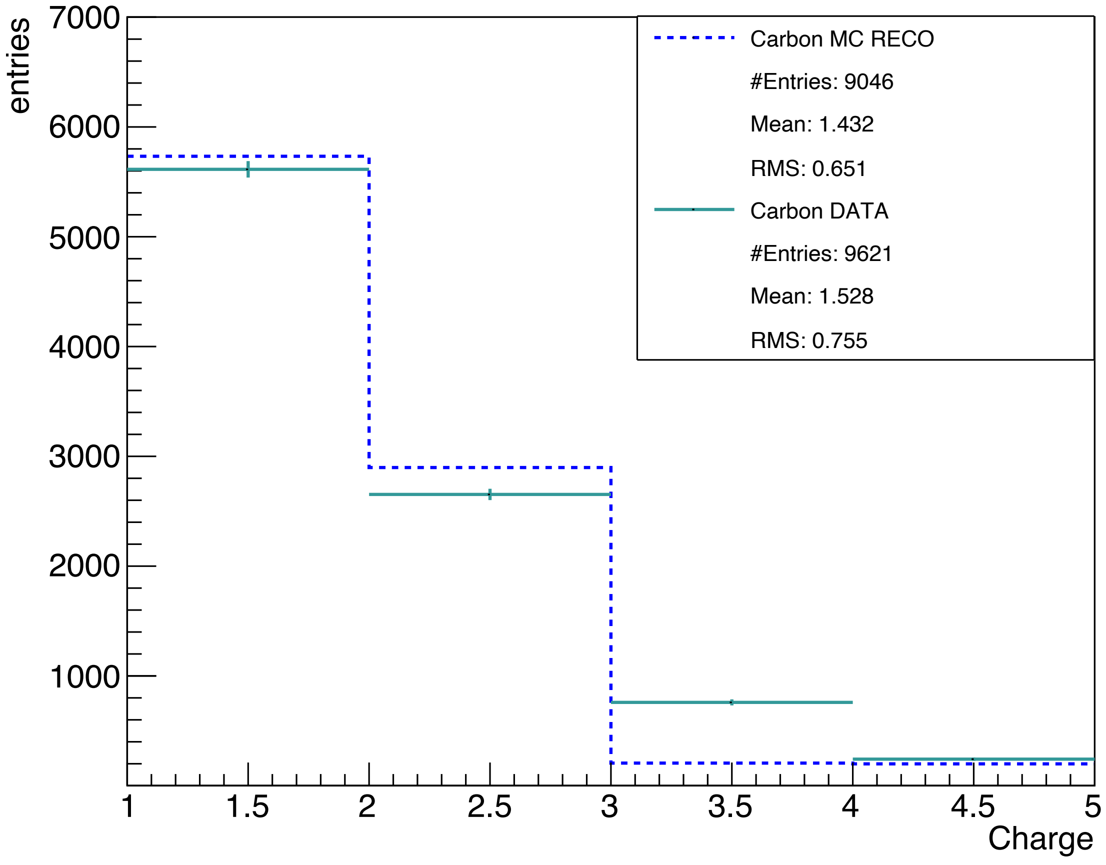

Distributions normalised to beam particles

OLD - GSI2: Oxy@200 MeV/n on C2H4 target

Fragment's charge

MC TRUE vs MC RECO

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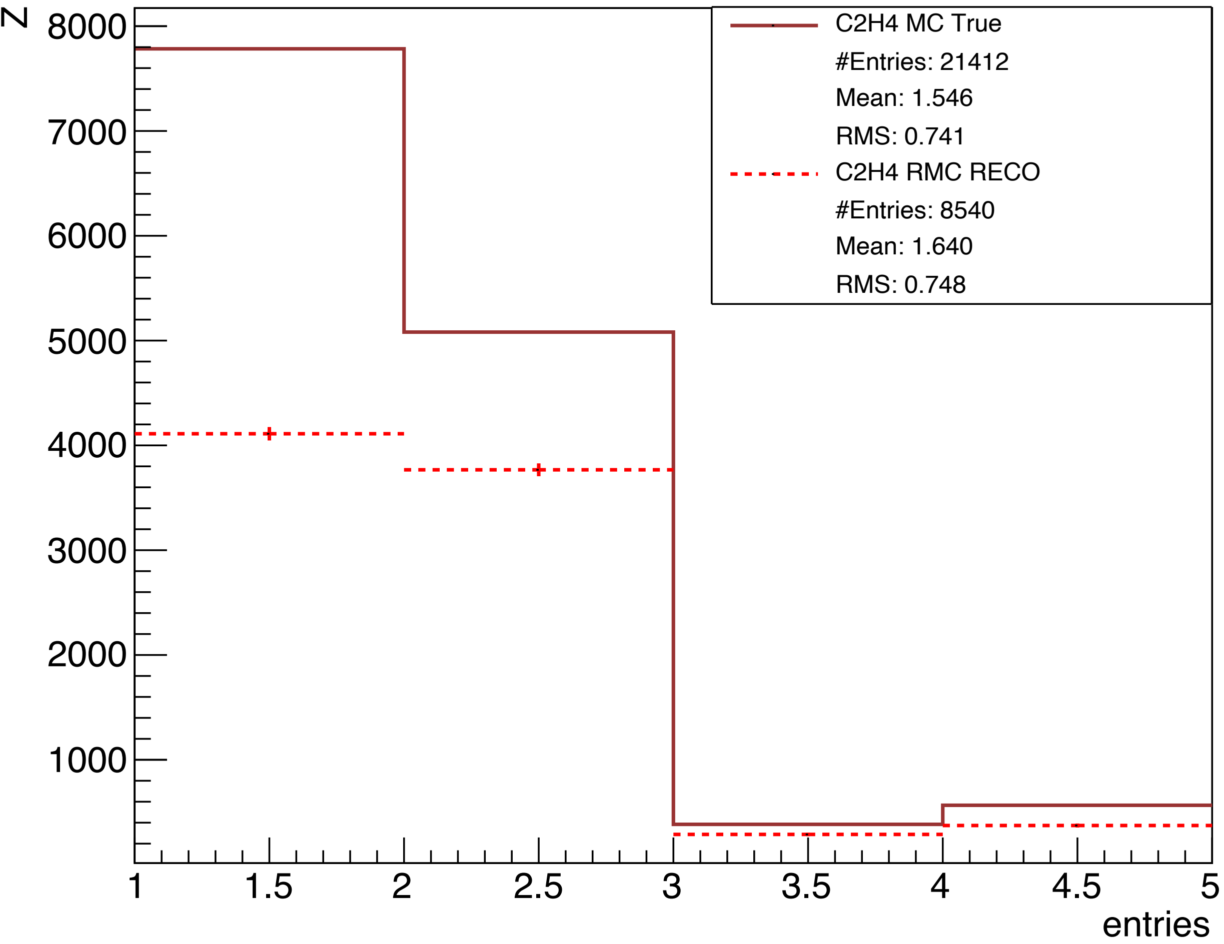
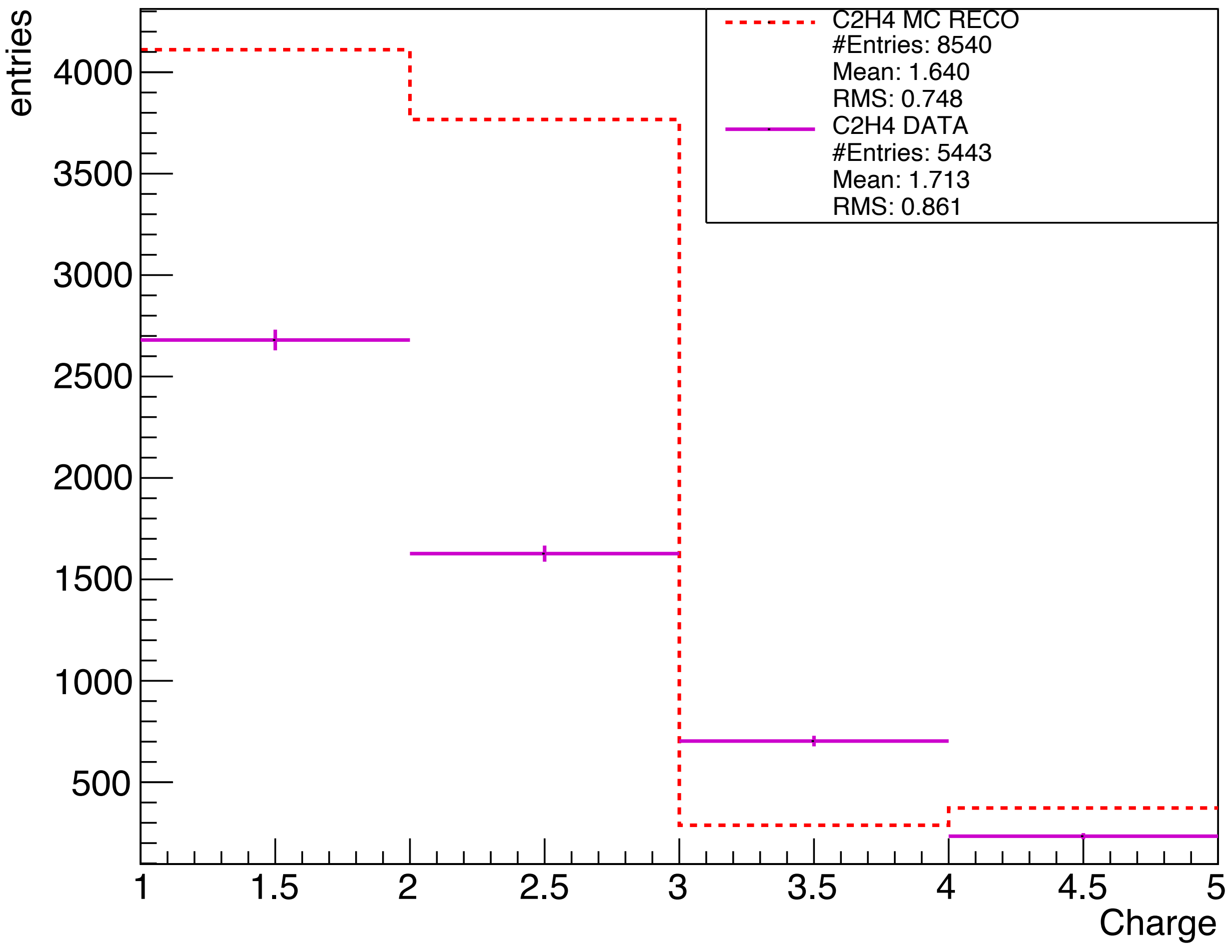
MC RECO vs DATA



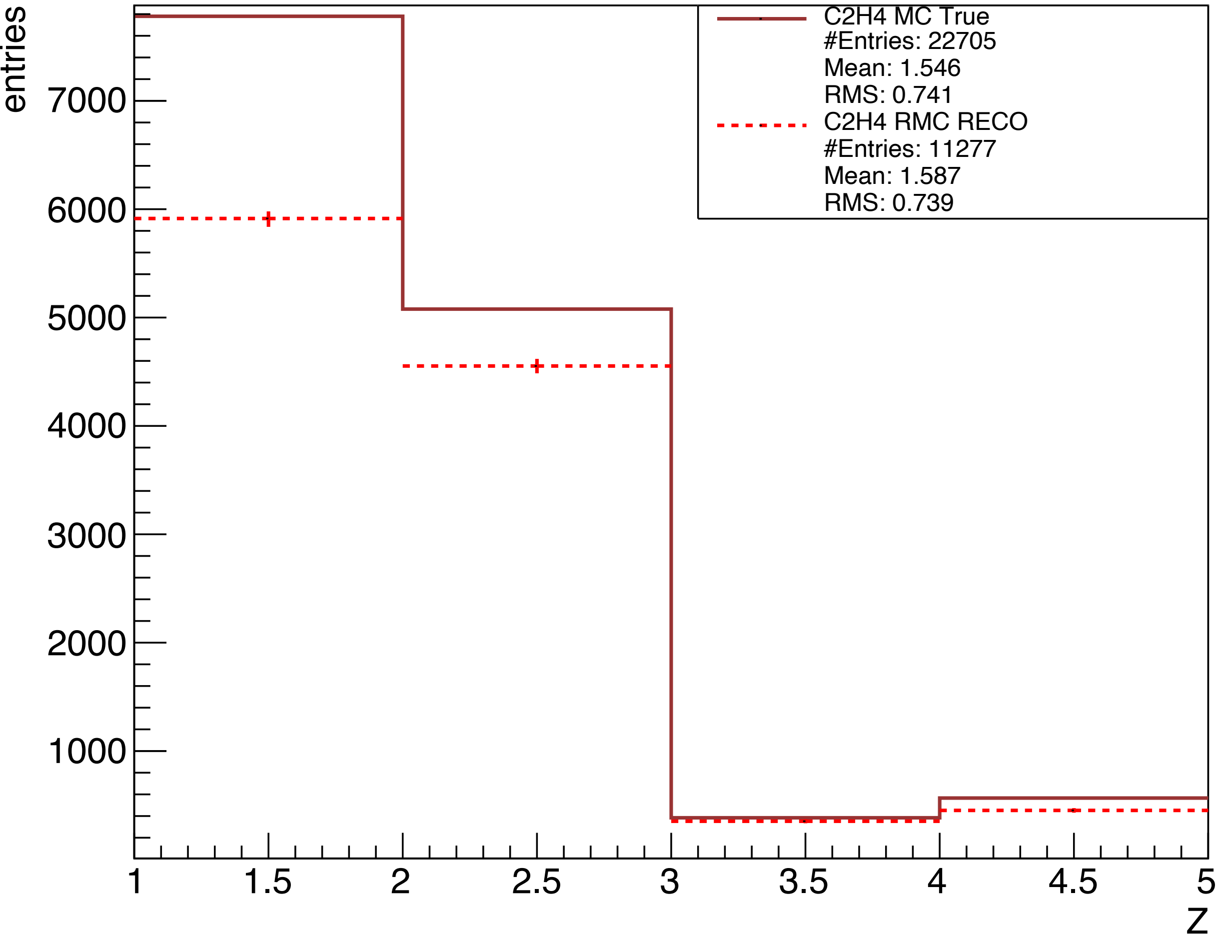


Distributions normalised to beam particles

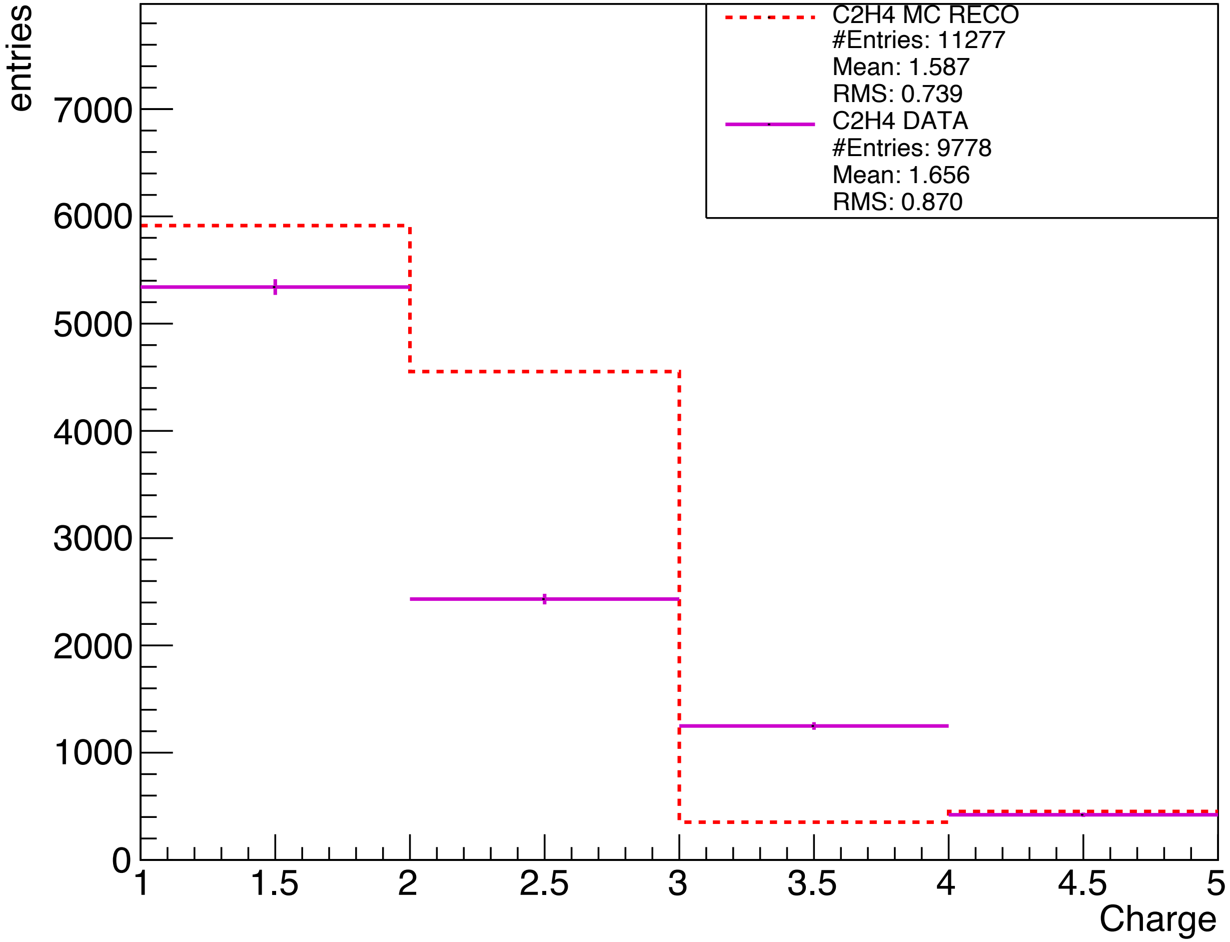
GSI2: Oxy@200 MeV/n on C2H4 target

Fragments' charge (no misalignment in MC RECO)

MC TRUE vs MC RECO



MC RECO vs DATA



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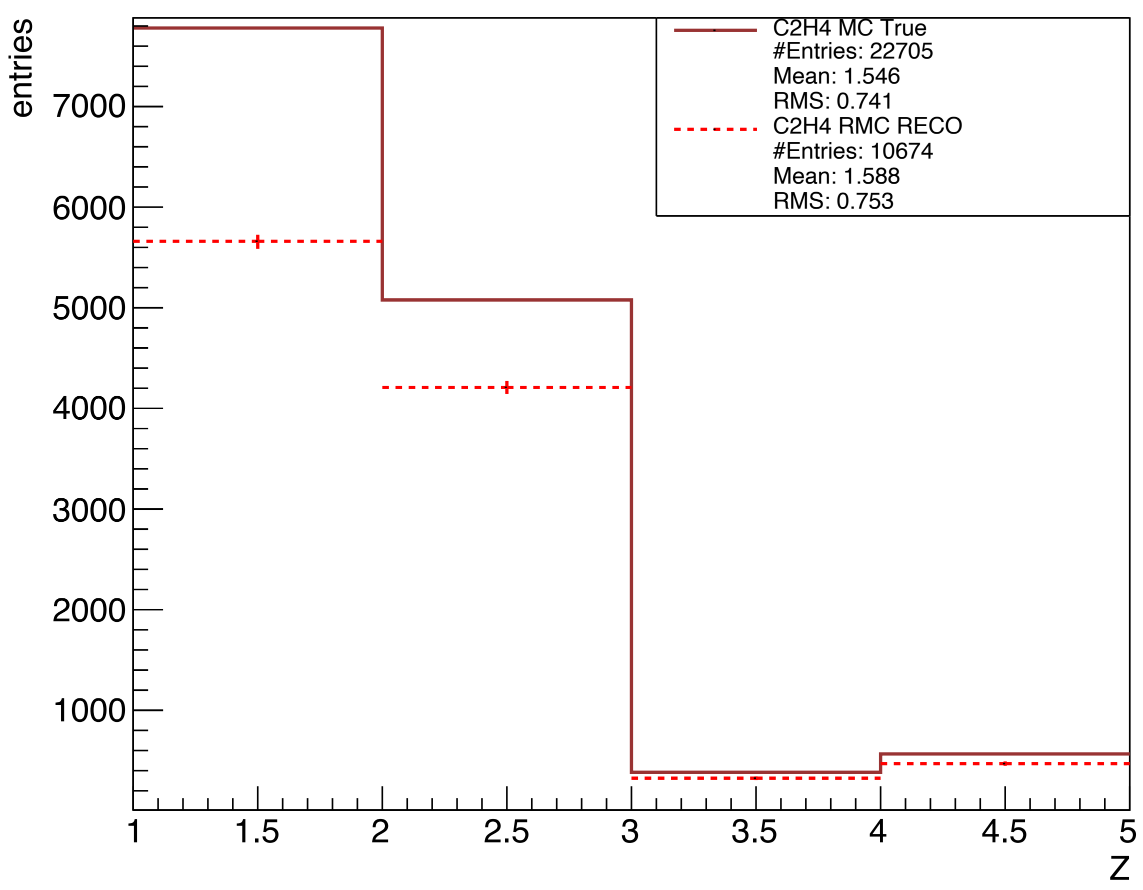
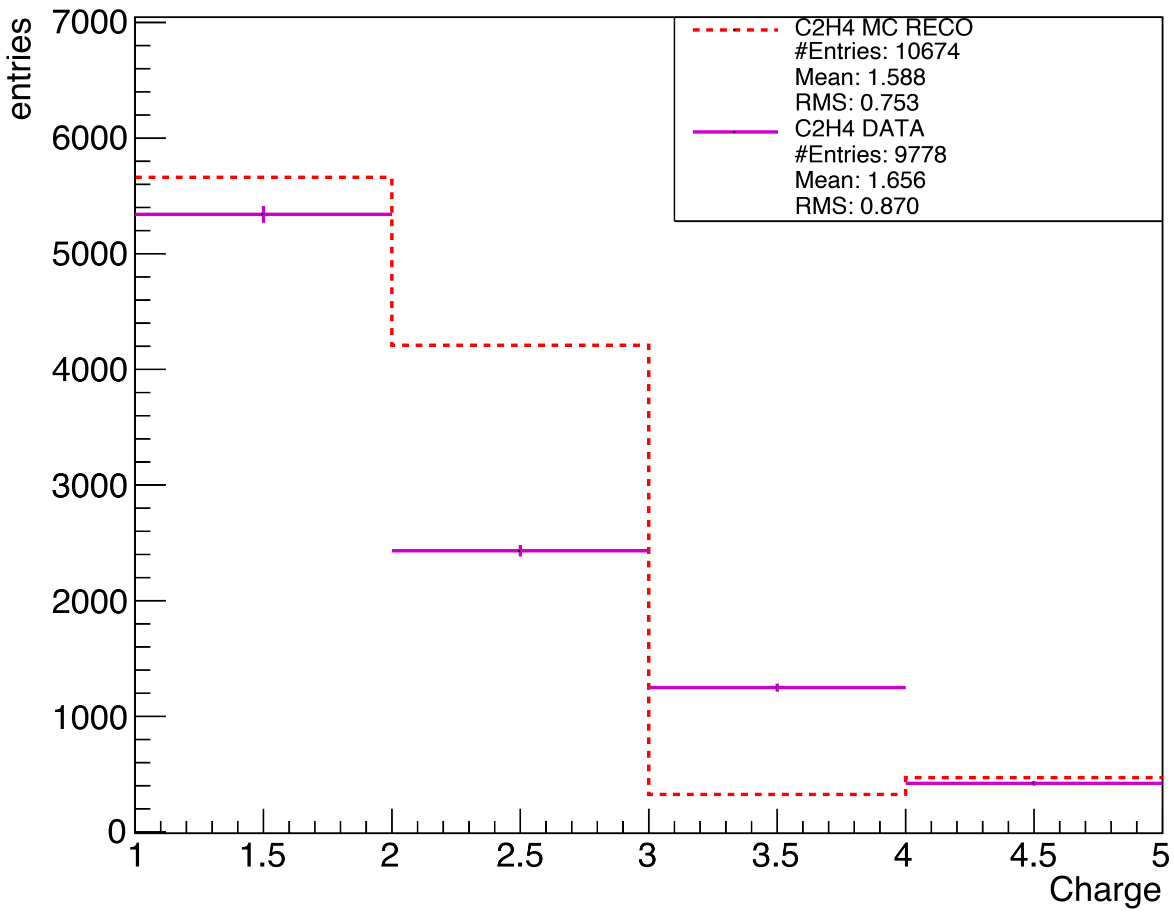


MC RECO vs DATA

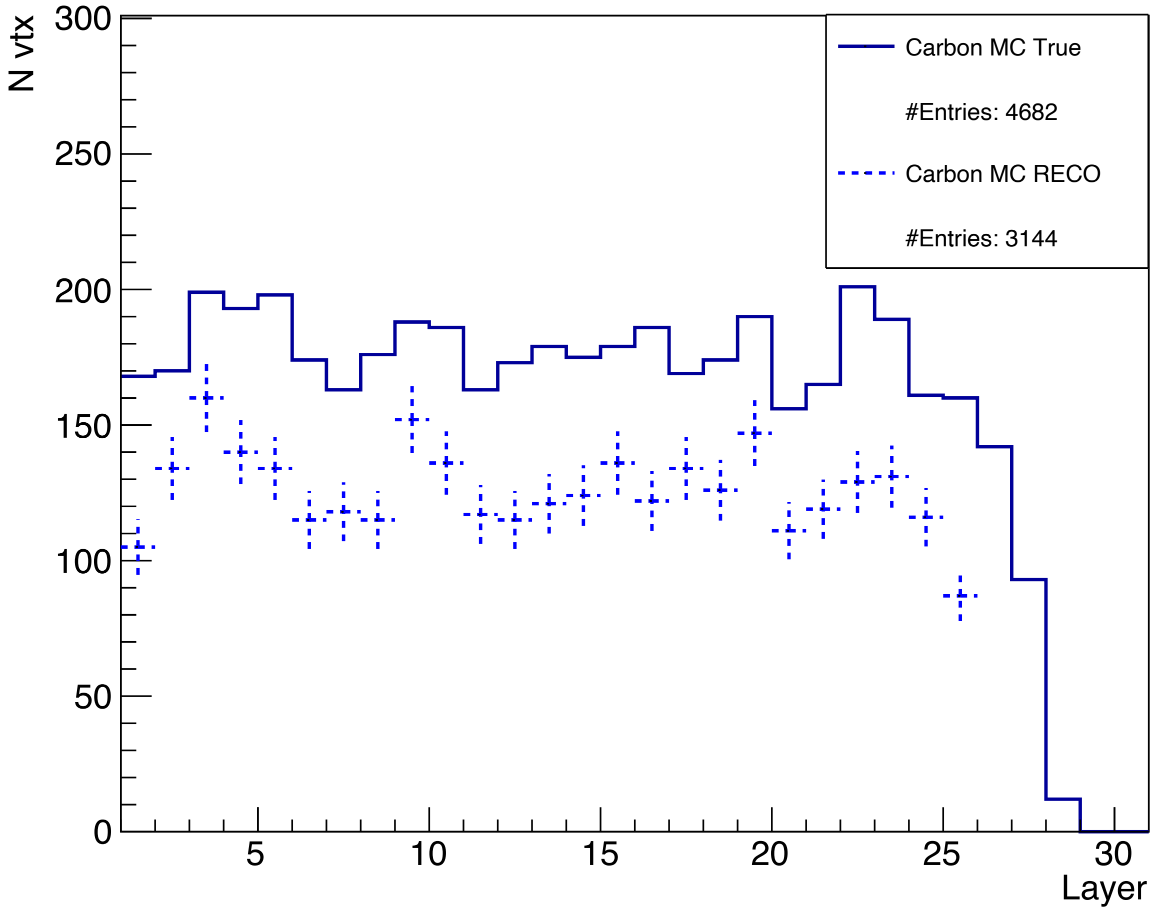


Distributions normalised to beam particles

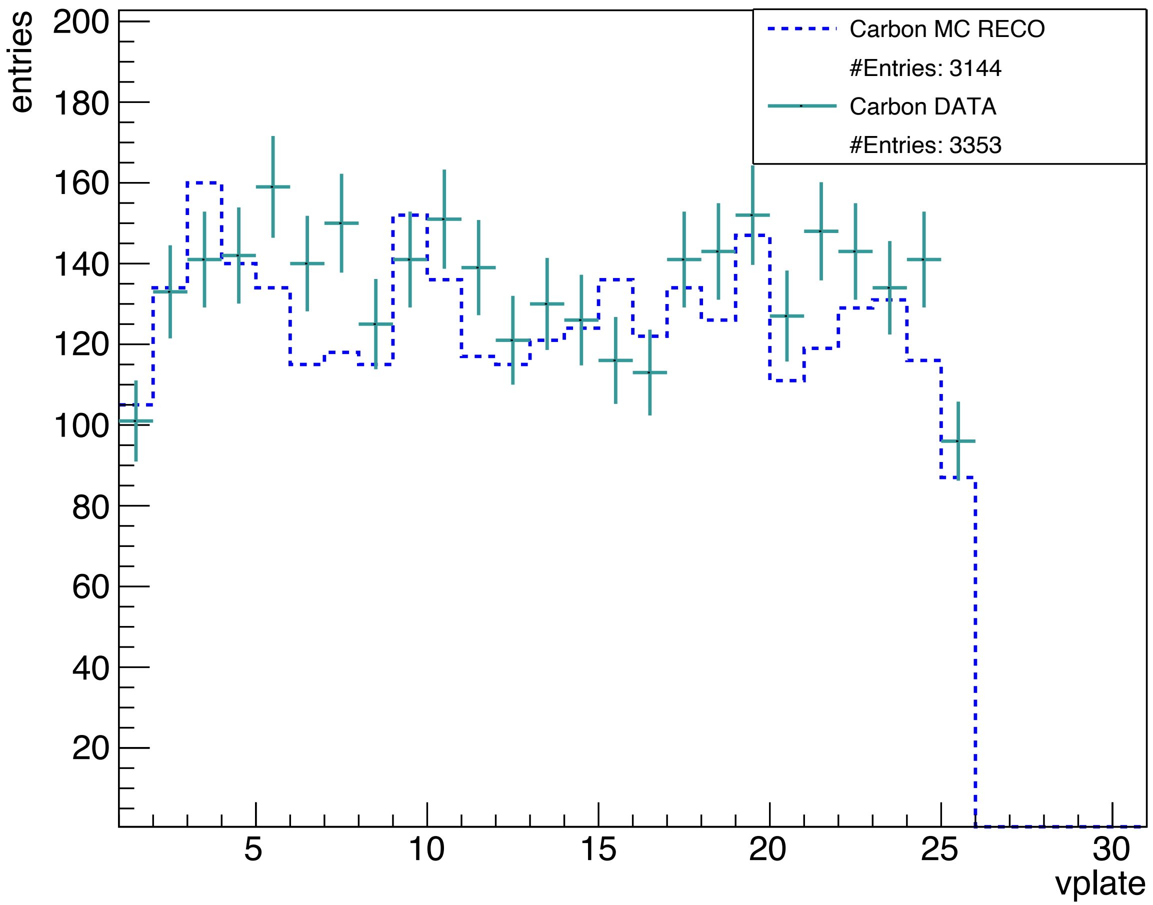
GSI1: Oxy@200 MeV/n on C target

N vertices per layer

MC TRUE vs MC RECO



MC RECO vs DATA



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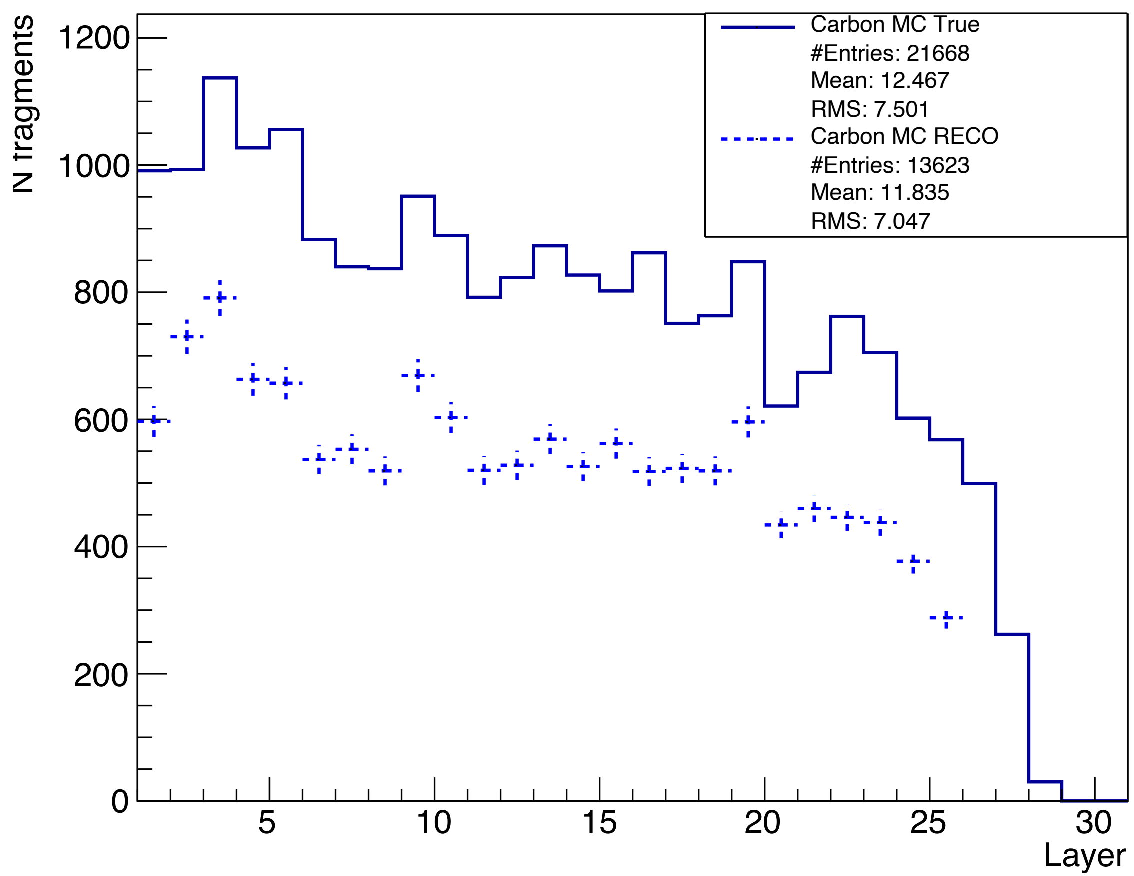
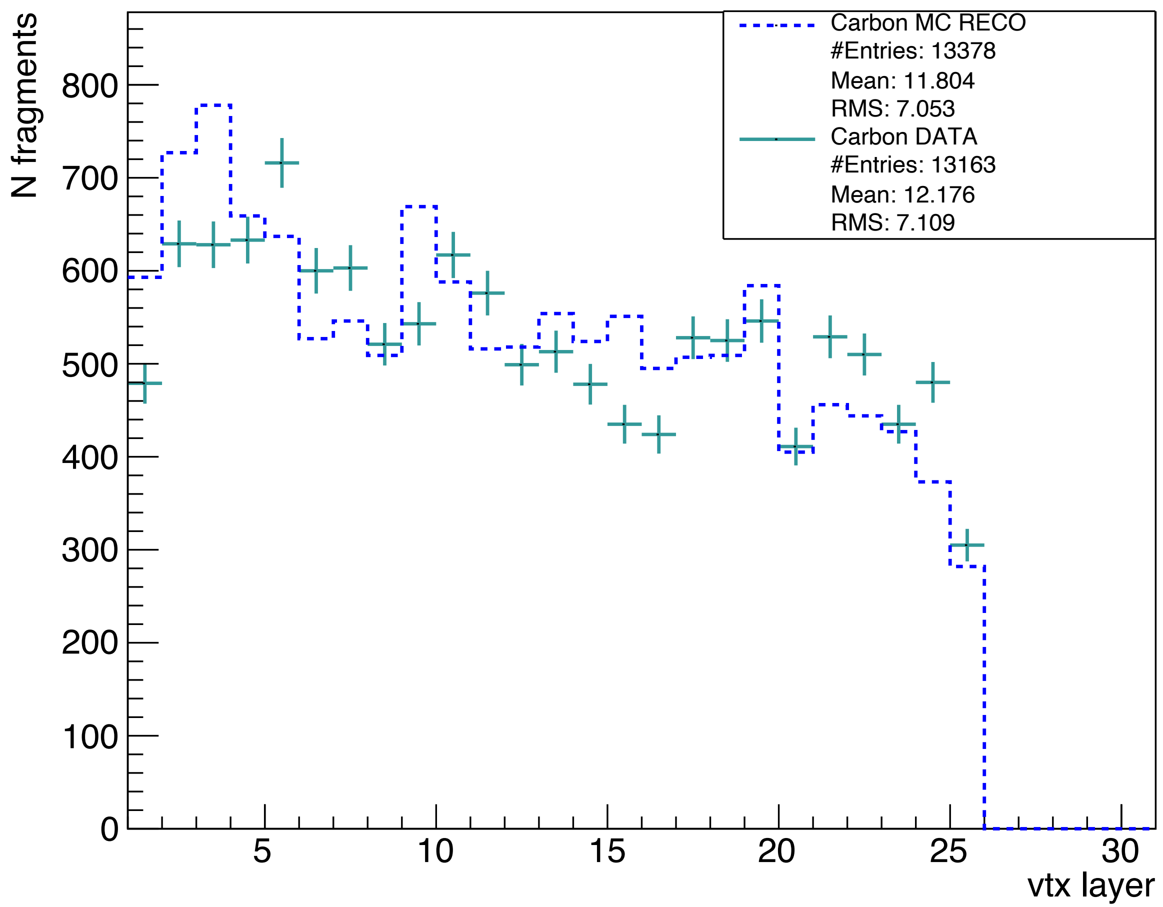


MC RECO vs DATA



Distributions normalised to beam particles

GSI2: Oxy@200 MeV/n on C2H4 target

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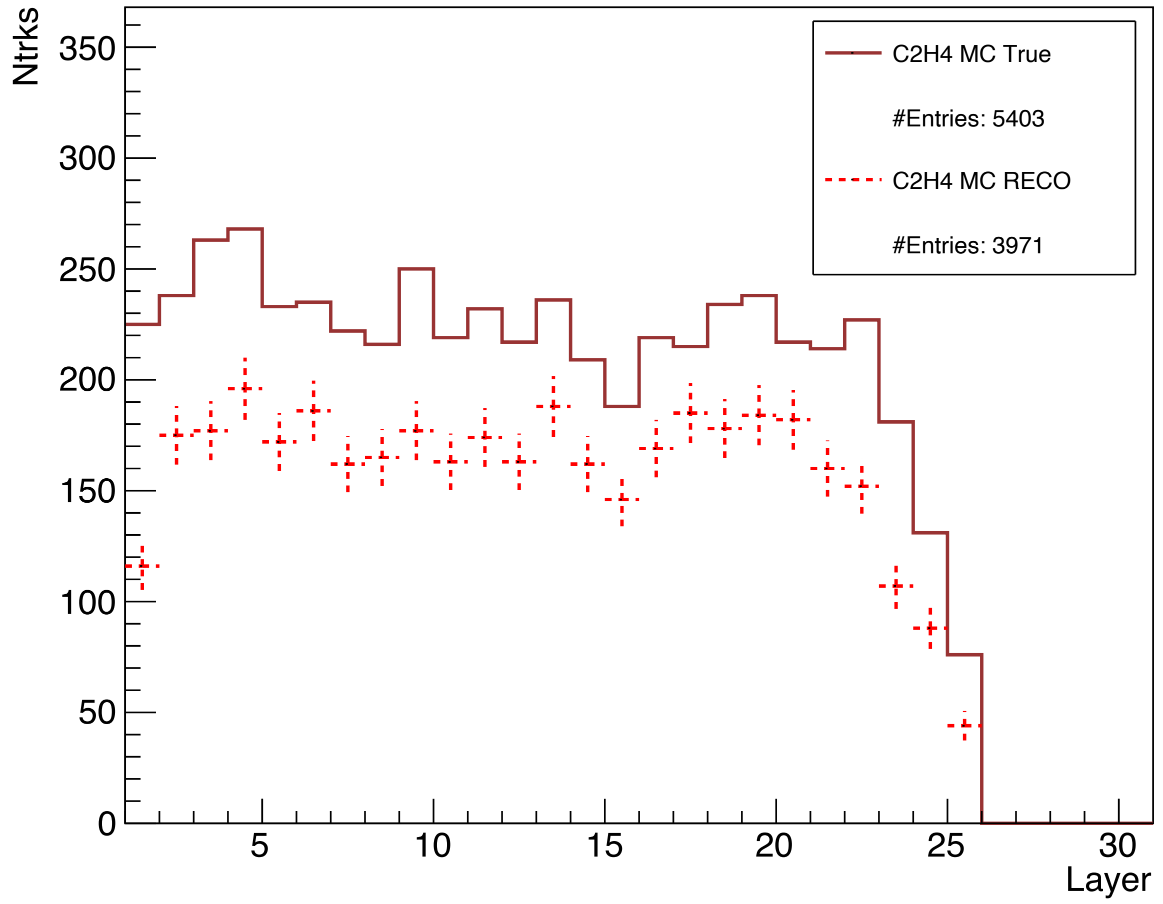

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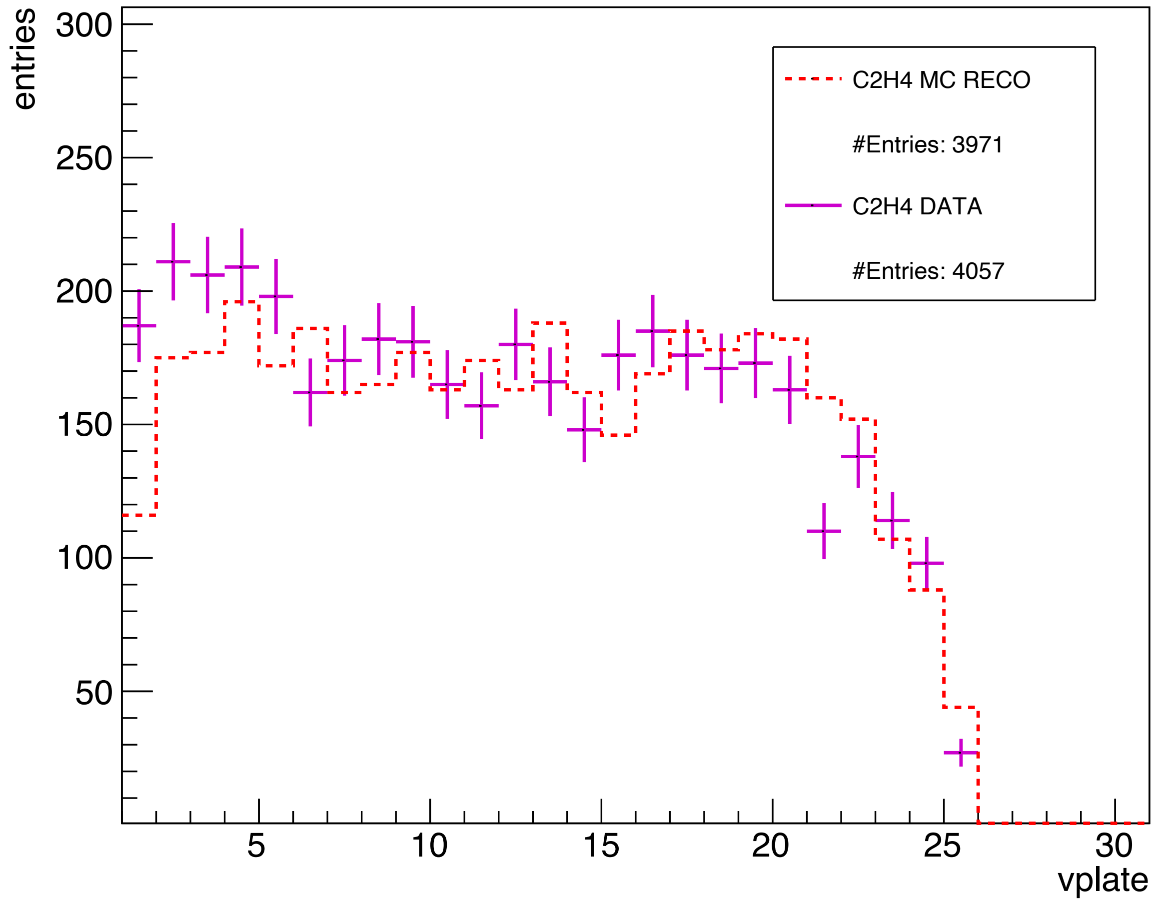

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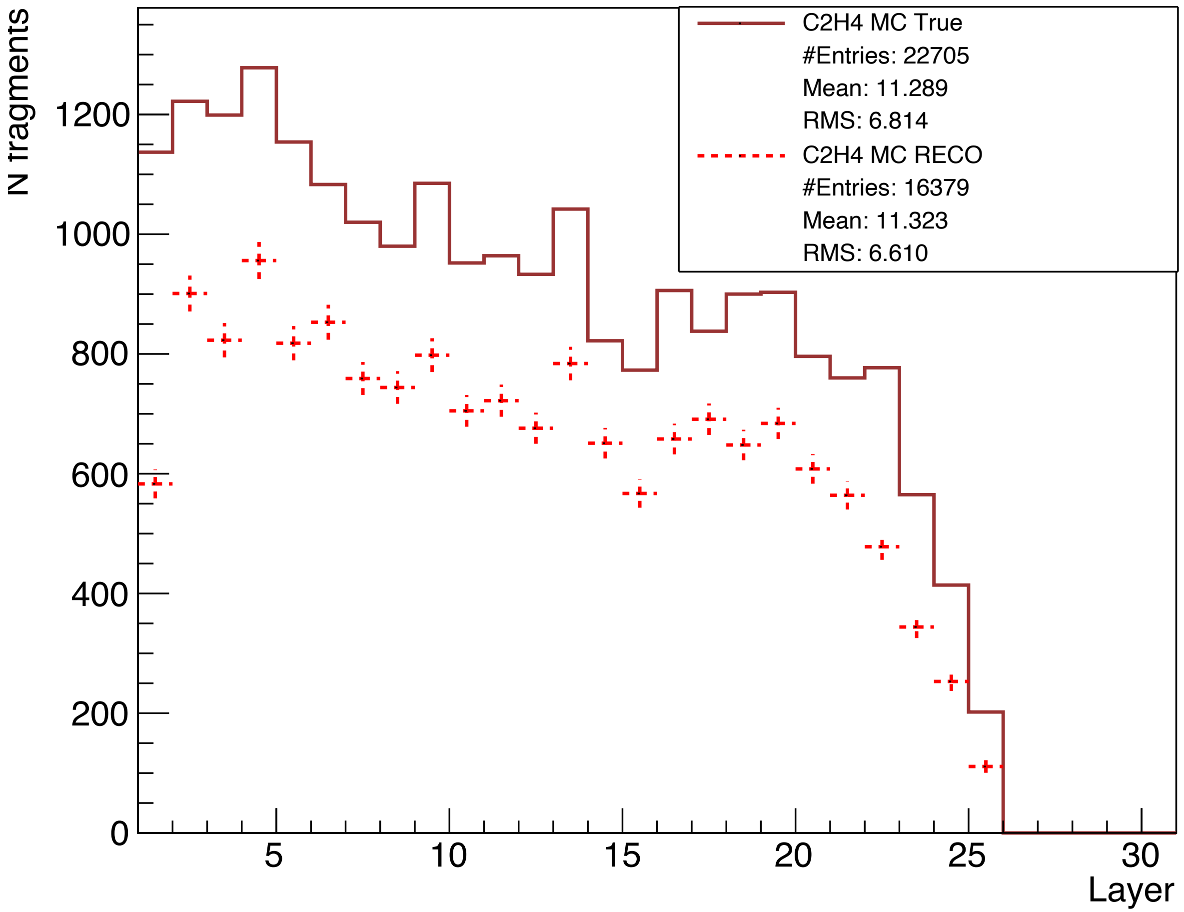

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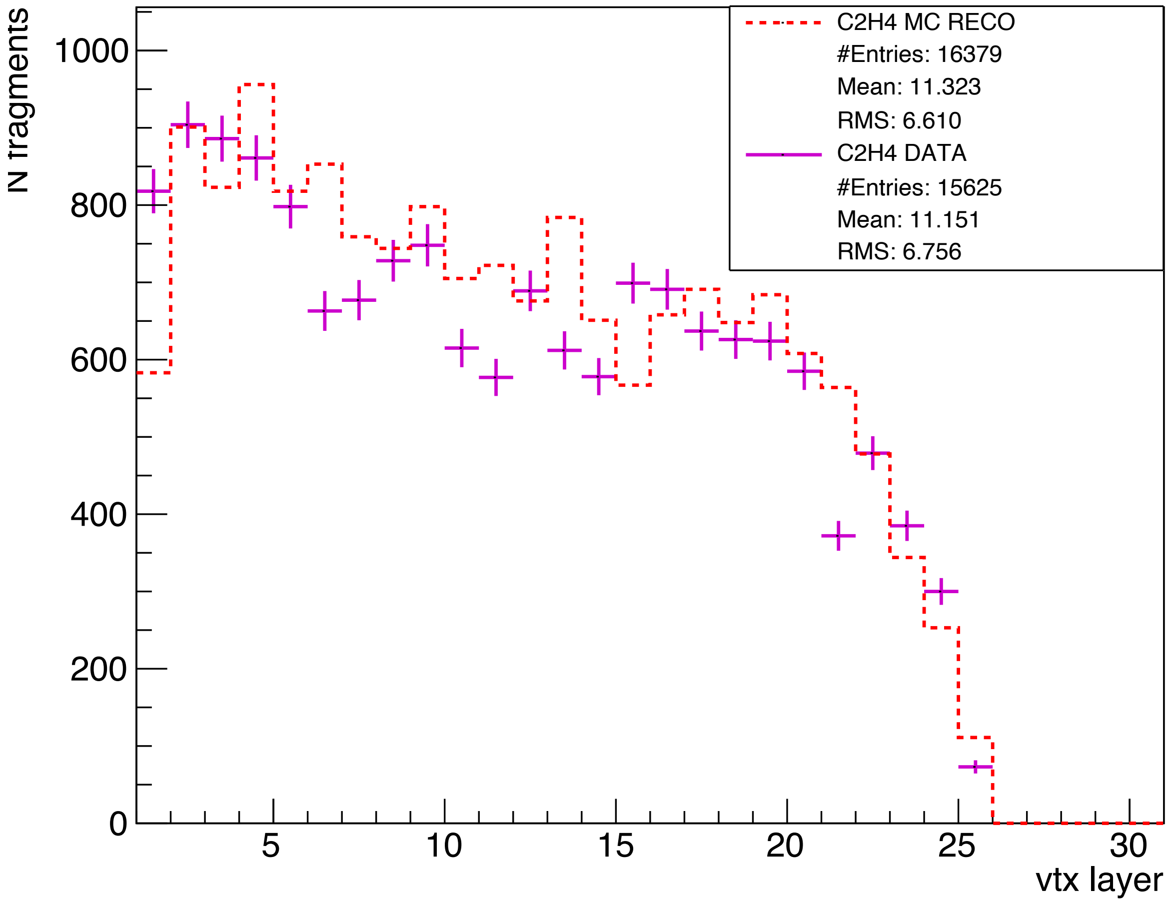
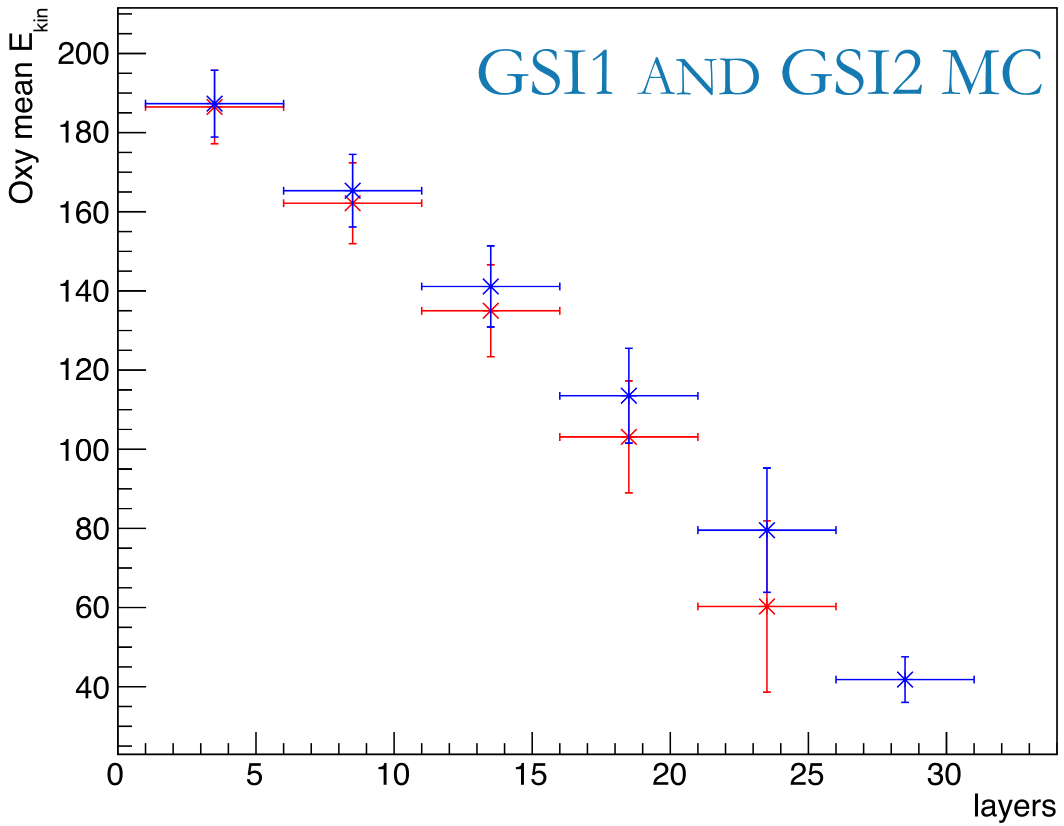


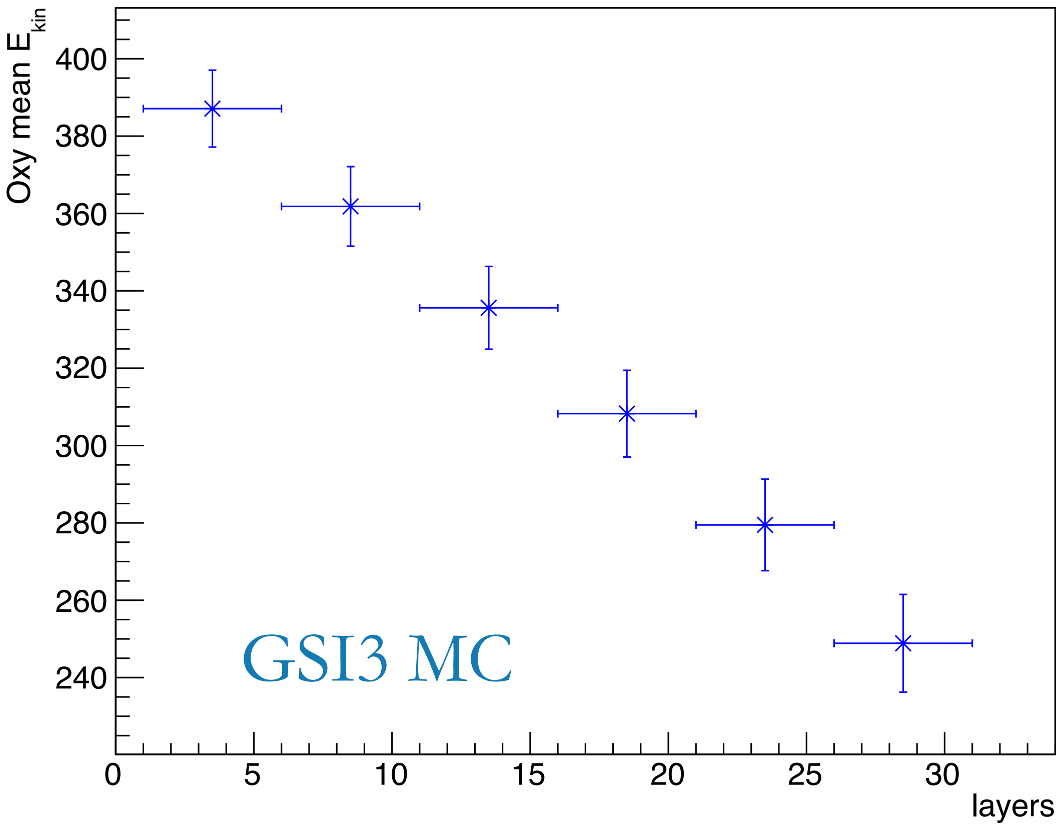
Distributions normalised to beam particles

Cross section evaluation

One detector… many measurements!

- The energy loss within S1 is not negligible
- We can divide S1 into sub-sections of 5 layers and obtain many measurements in different energy ranges!





Cross Section Measurement

$$\left.\frac{d\sigma(x)}{dx}\right|_{C\ or\ C_2H_4} = \frac{Y_i(x)}{N_B N_{TG} \Delta x \epsilon^i_{reco}(x)}$$

$$\left.\frac{d\sigma(x)}{dx}\right|_{H} = \frac{1}{4}\left(\left.\frac{d\sigma(x)}{dx}\right|_{C_2H_4} - 2\left.\frac{d\sigma(x)}{dx}\right|_{C}\right)$$

- Y_i = # of fragments in the interval Δx
- N_B = # of ions colliding on the target
- N_{TG} = # of particles in the target: $\frac{\rho d N_A}{A}$, with:
  - ρ = target density:
    $\rho_C = 2.26 g/cm^3$
    $\rho_{C_2H_4} = 0.94 g/cm^3$
    $\rho_H = 0.0708 g/cm^3$
  - d = target thickness:
    $d_C = 0.1 cm$ per layer
    $d_{C_2H_4} = 0.2 cm$ per layer
  - $N_A = 6.022 \cdot 10^{23}/mol$
  - A = molar mass:
    $A_C = 12 g/mol$
    $A_{C2H4} = 28 g/mol$
    $A_H = 1 g/mol$
- $\Delta x = x$ bin
- ϵ^i_{reco} = reconstruction efficiency

The problem of N_B evaluation

$$\left.\frac{d\sigma(x)}{dx}\right|_{C\ or\ C_2H_4} = \frac{Y_i(x)}{N_B N_{TG} \Delta x \epsilon^i_{reco}(x)}$$

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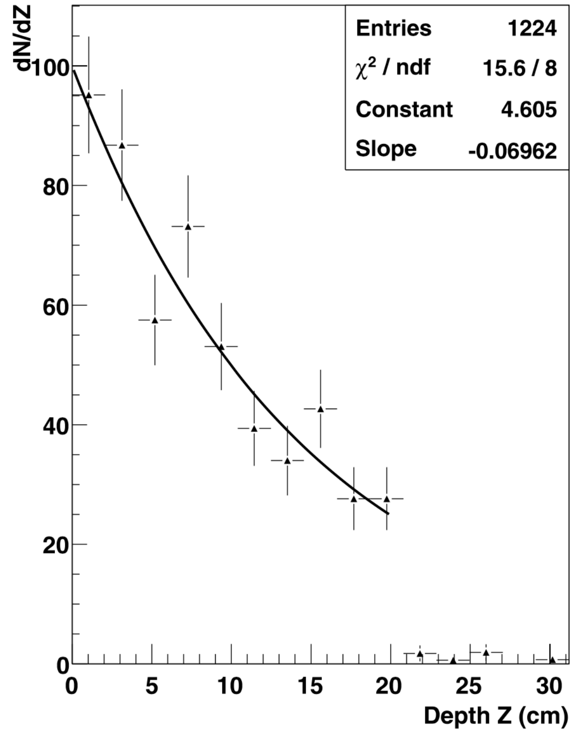
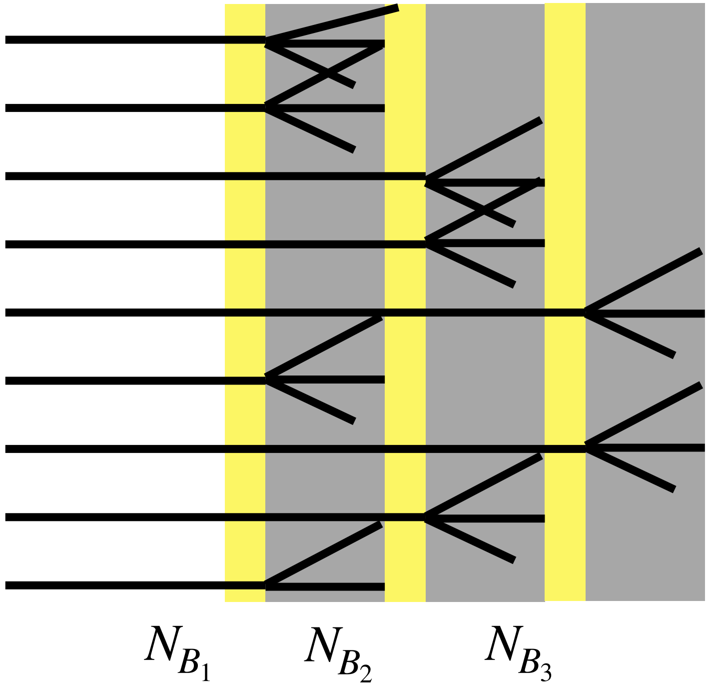


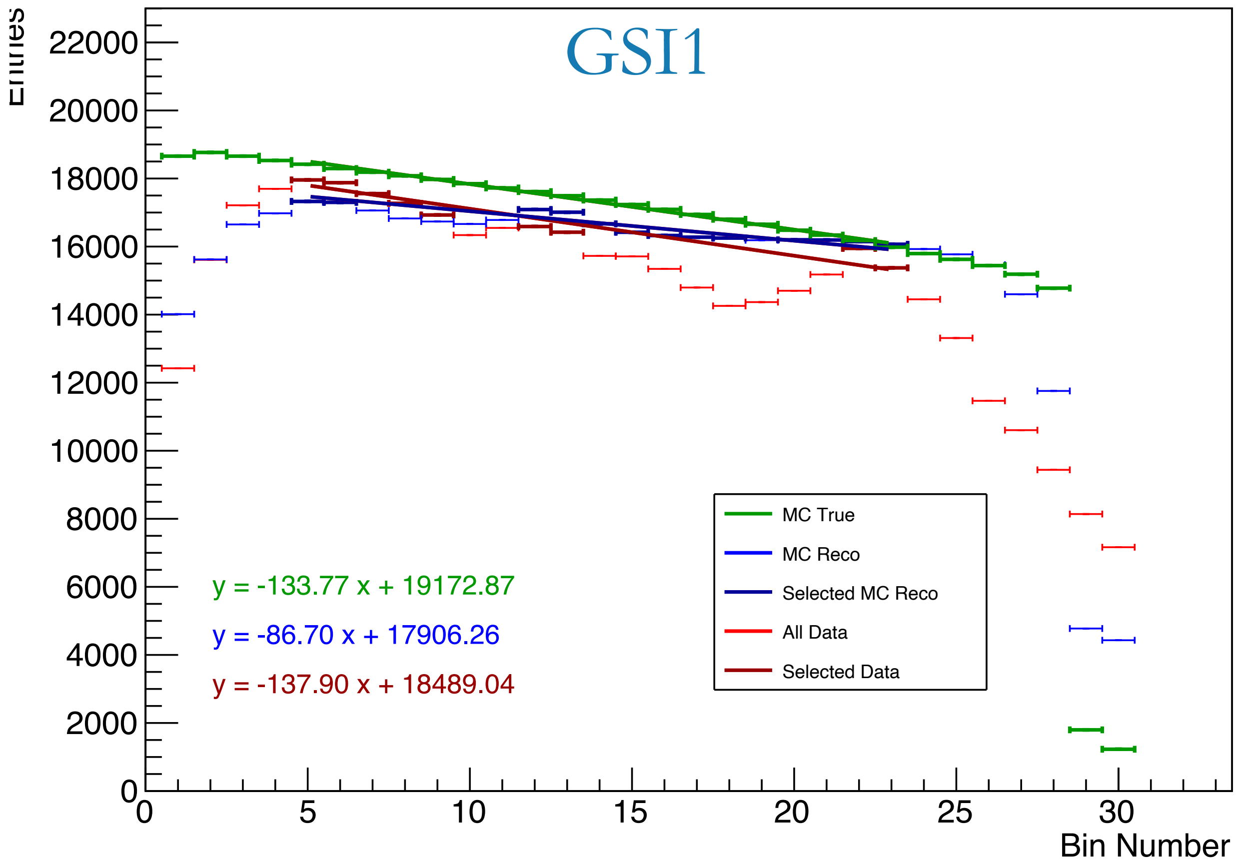
Fig. 2. Fraction of the remnant Carbon beam as a function of the traversed ECC material.

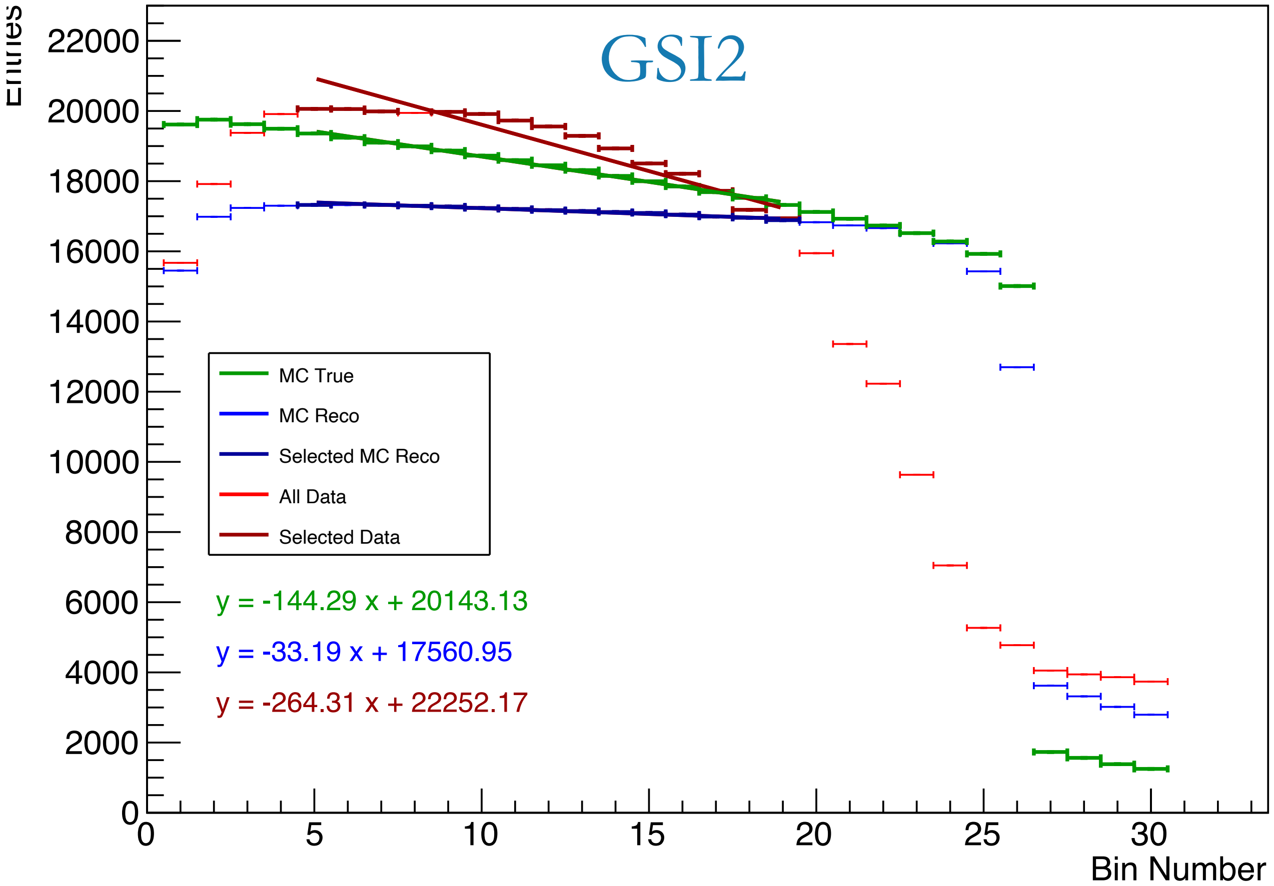


- Each passive material layer can be considered a "new measurement"
- The number of incident beam particle on each layer has to be evaluated and is affected by its efficiency
- New approach: estimation from oxygen tracks

The problem of N_B evaluation

- Oxygen: tracks with $\tan\theta \leq 0.03$ rad
- Missing basetracks in a track filled to recover inefficiencies
- Fit of all bins that do not have a higher bin afterwards
- N_B of a specific film evaluated from the fit

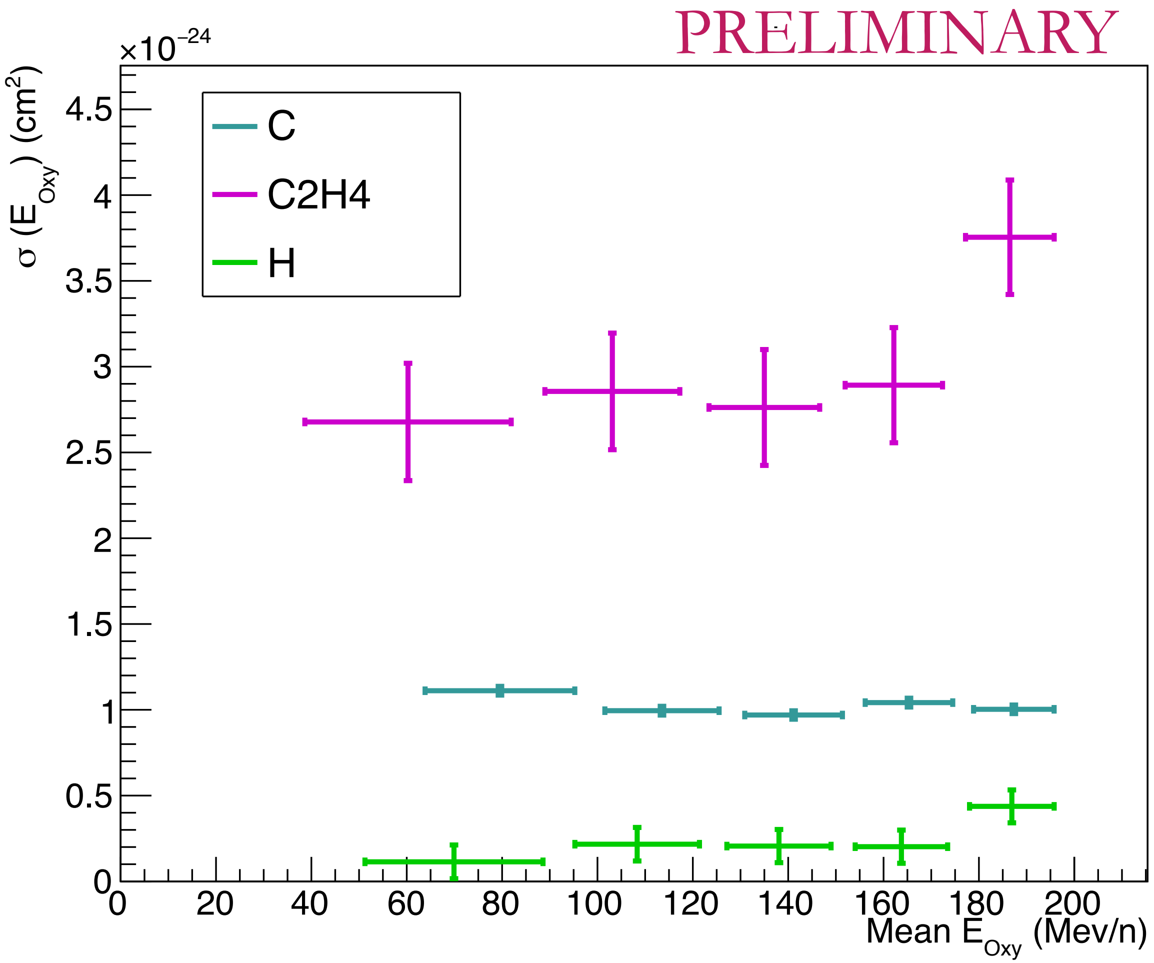




Integrated cross section Oxy@200MeV/n

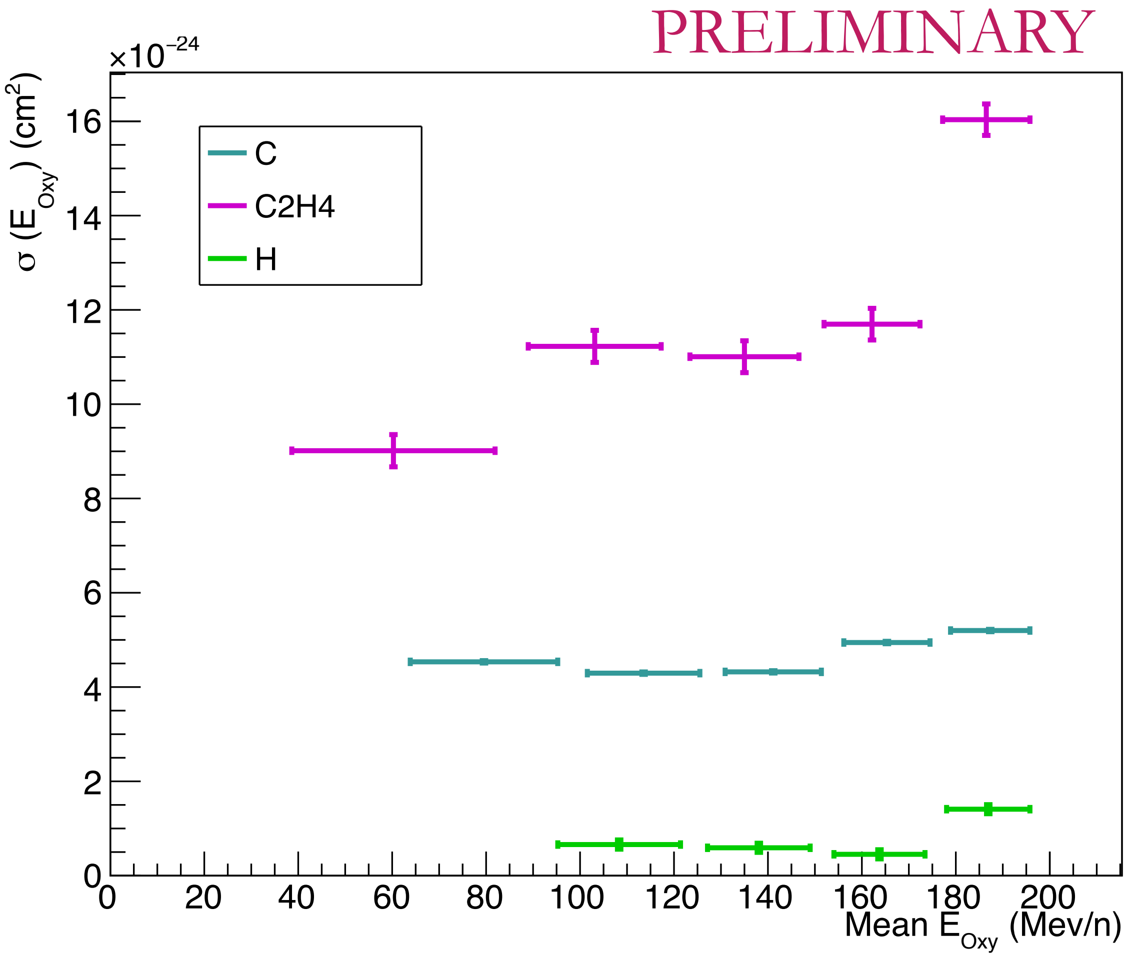
DATA

Total reaction cross section



$Y_i = \#$ of vertices

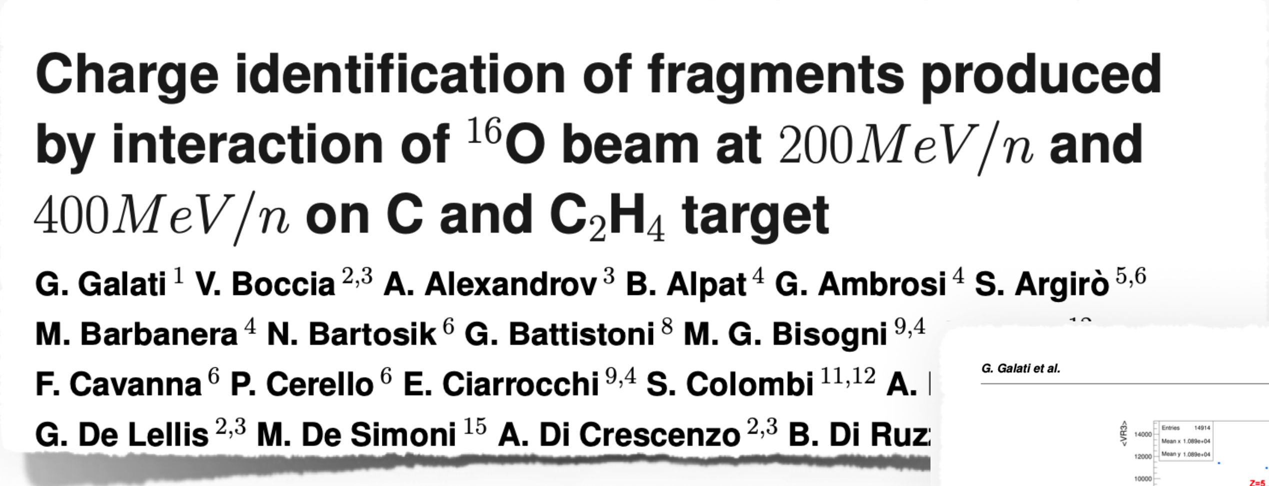
Total production cross section



$Y_i = \#$ of fragments

New paper!

New paper almost ready!



Charge identification of fragments produced by interaction of ^{16}O beam at $200 MeV/n$ and $400 MeV/n$ on C and C_2H_4 target

G. Galati [1] V. Boccia [2,3] A. Alexandrov [3] B. Alpat [4] G. Ambrosi [4] S. Argirò [5,6]
M. Barbanera [4] N. Bartosik [6] G. Battistoni [8] M. G. Bisogni [9,4]
F. Cavanna [6] P. Cerello [6] E. Ciarrocchi [9,4] S. Colombi [11,12] A.
G. De Lellis [2,3] M. De Simoni [15] A. Di Crescenzo [2,3] B. Di Ruz

- New article on charge evaluation in S2 for all GSI2019 data takings
- Article already reviewed by the EB
- Almost ready to be shared with the collaboration (next week)

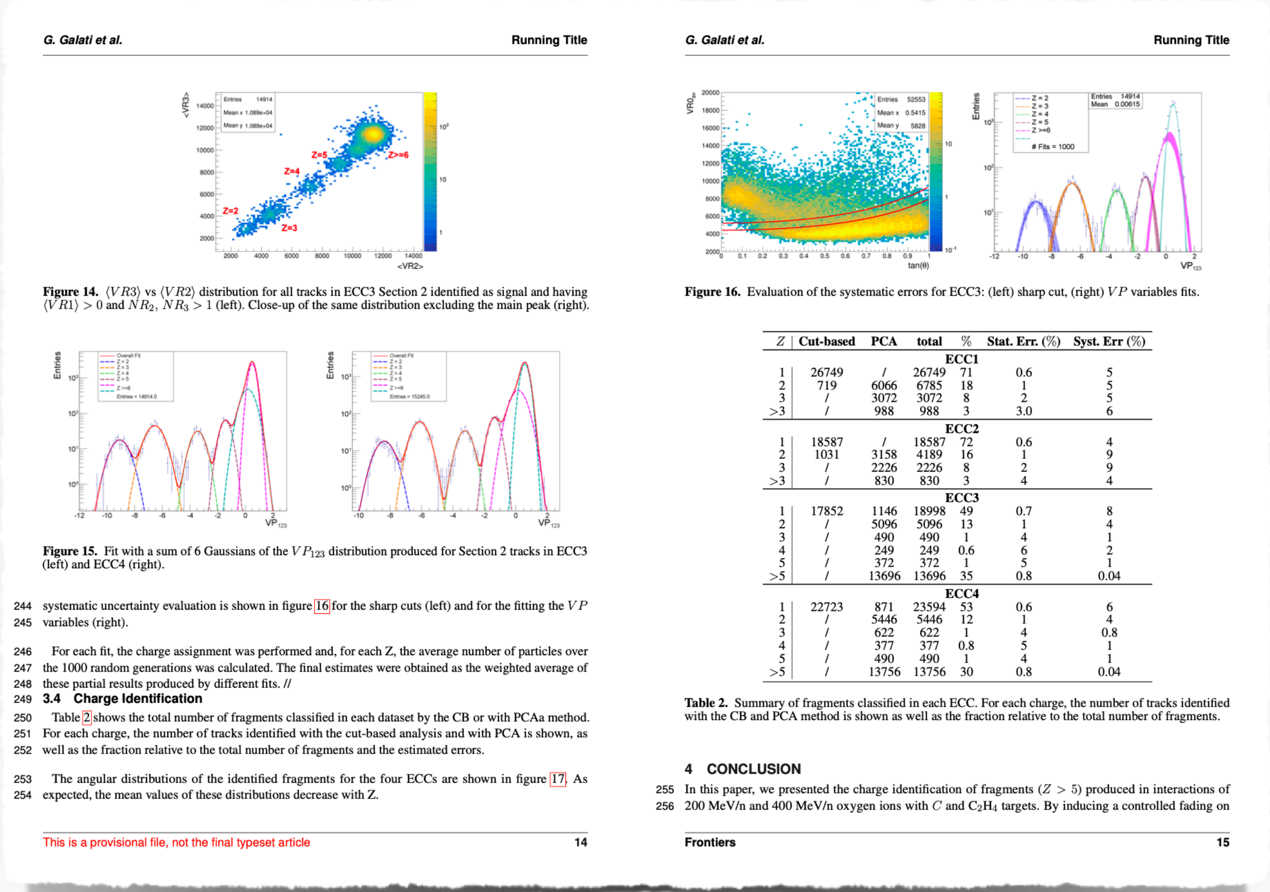


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Figure 14. $\langle VR3 \rangle$ vs $\langle VR2 \rangle$ distribution for all tracks in ECC3 Section 2 identified as signal and having $\langle VR1 \rangle > 0$ and NR_2, $NR_3 > 1$ (left). Close-up of the same distribution excluding the main peak (right).

Figure 15. Fit with a sum of 6 Gaussians of the VP_{123} distribution produced for Section 2 tracks in ECC3 (left) and ECC4 (right).

systematic uncertainty evaluation is shown in figure 16 for the sharp cuts (left) and for the fitting the VP variables (right).

For each fit, the charge assignment was performed and, for each Z, the average number of particles over the 1000 random generations was calculated. The final estimates were obtained as the weighted average of these partial results produced by different fits. //

3.4 Charge Identification

Table 2 shows the total number of fragments classified in each dataset by the CB or with PCAa method. For each charge, the number of tracks identified with the cut-based analysis and with PCA is shown, as well as the fraction relative to the total number of fragments and the estimated errors.

The angular distributions of the identified fragments for the four ECCs are shown in figure 17. As expected, the mean values of these distributions decrease with Z.

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Figure 16. Evaluation of the systematic errors for ECC3: (left) sharp cut, (right) VP variables fits.

Z	Cut-based	PCA	total	%	Stat. Err. (%)	Syst. Err (%)
			ECC1			
1	26749	/	26749	71	0.6	5
2	719	6066	6785	18	1	5
3	/	3072	3072	8	2	5
>3	/	988	988	3	3.0	6
			ECC2			
1	18587	/	18587	72	0.6	4
2	1031	3158	4189	16	1	9
3	/	2226	2226	8	2	9
>3	/	830	830	3	4	4
			ECC3			
1	17852	1146	18998	49	0.7	8
2	/	5096	5096	13	1	4
3	/	490	490	1	4	1
4	/	249	249	0.6	6	2
5	/	372	372	1	5	1
>5	/	13696	13696	35	0.8	0.04
			ECC4			
1	22723	871	23594	53	0.6	6
2	/	5446	5446	12	1	4
3	/	622	622	1	4	0.8
4	/	377	377	0.8	5	1
5	/	490	490	1	4	1
>5	/	13756	13756	30	0.8	0.04

Table 2. Summary of fragments classified in each ECC. For each charge, the number of tracks identified with the CB and PCA method is shown as well as the fraction relative to the total number of fragments.

4 CONCLUSION

In this paper, we presented the charge identification of fragments ($Z > 5$) produced in interactions of 200 MeV/n and 400 MeV/n oxygen ions with C and C_2H_4 targets. By inducing a controlled fading on

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Conclusions

- Several improvements on:
  - MC description of detector response ("MC Reco"): long cosmic rays + misalignments
  - Merging procedure between different sections
  - Vertices reconstruction
  - Procedure to attach unconnected tracks in S2 to vertices

Oxygen @ 200 MeV/n

- Comparison between MC True, MC Reco and DATA improved
- New estimation of the number of incoming oxygens in each S1 "sub-section"
- Cross section evaluation at different energies

Oxygen @ 400 MeV/n

- Analysis on C target (GSI3) on-going: bad quality emulsions
- Analysis on C2H4 target (GSI4) just started

- **New paper almost ready on charge measurement for all GSI2019 bricks**

THANK YOU!

BACK UP SLIDES

Detector Structure