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

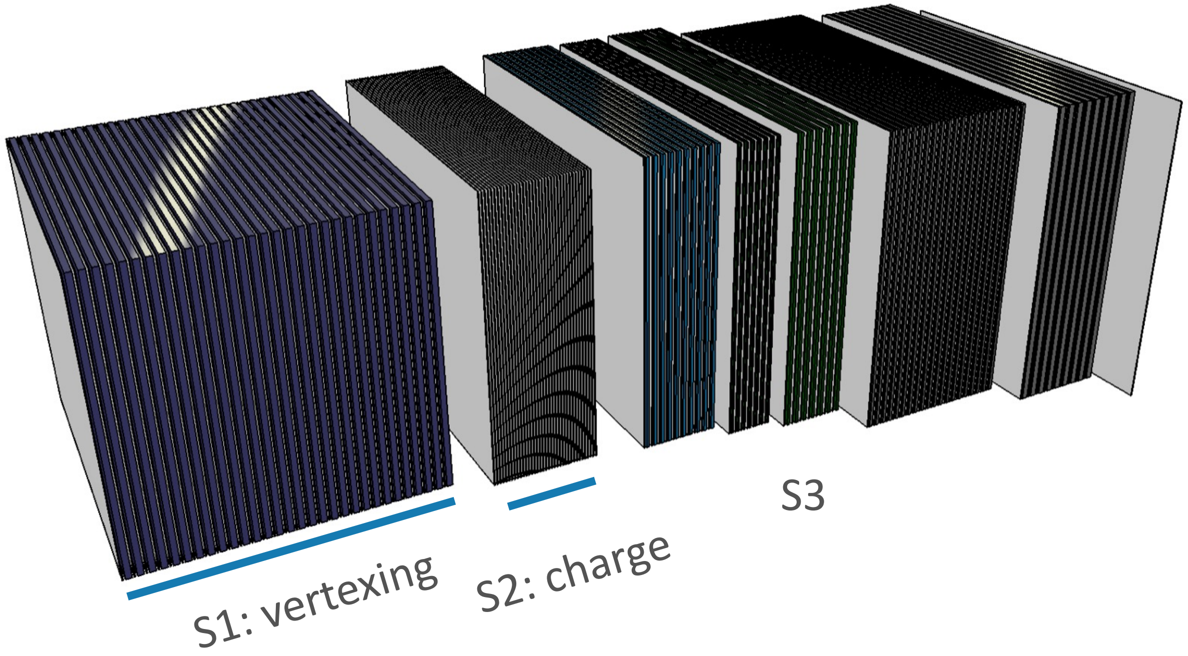
A. Alexandrov, V. Boccia, A. Di Crescenzo, G. De Lellis, G. Galati,
A. Iuliano, A. Lauria, M. C. Montesi, A. Pastore, V. Tioukov

Università di Napoli "Federico II", INFN Napoli

Università di Bari "Aldo Moro", INFN Bari

13/12/2022, XIII General FOOT Meeting
Perugia, Sangallo Palace Hotel

Summary

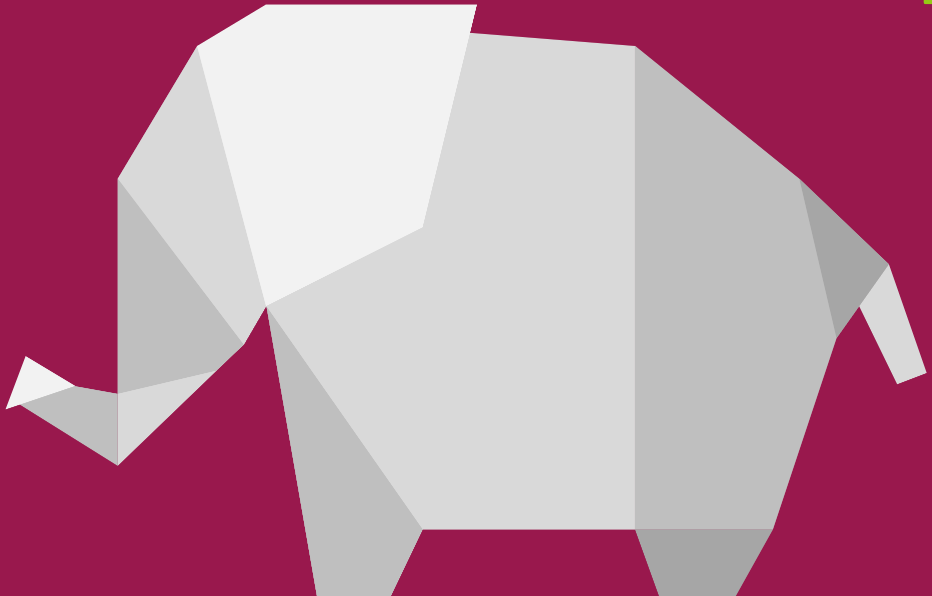


TARGET \ BEAM	2019	
	Oxygen 200 MeV/n	Oxygen 400 MeV/n
Carbon	GSI1	GSI3
Polyethylene	GSI2	GSI4

- Reconstruction of vertices from Oxygen interactions in Section 1 (S1)
- Charge measurement in Section 2 (S2)

Reconstruction improvements

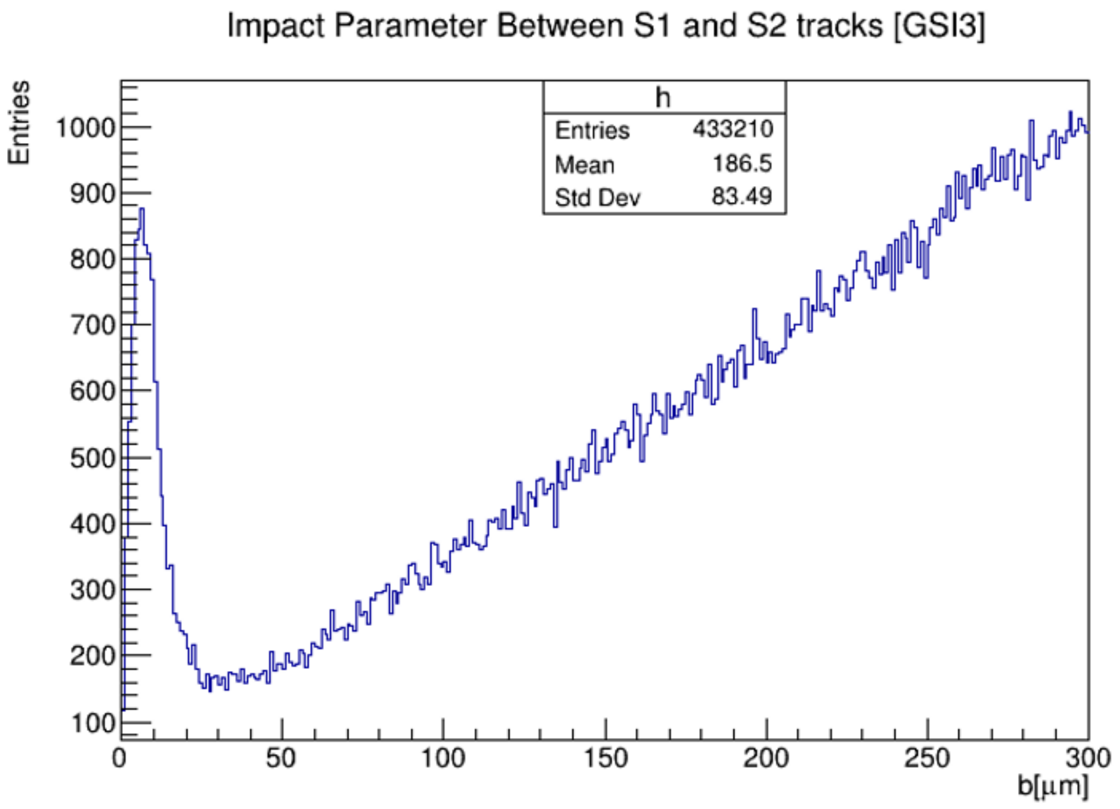
- vertices reconstruction (bug + improvements)
- Merging procedure between different sections
- Charge evaluation

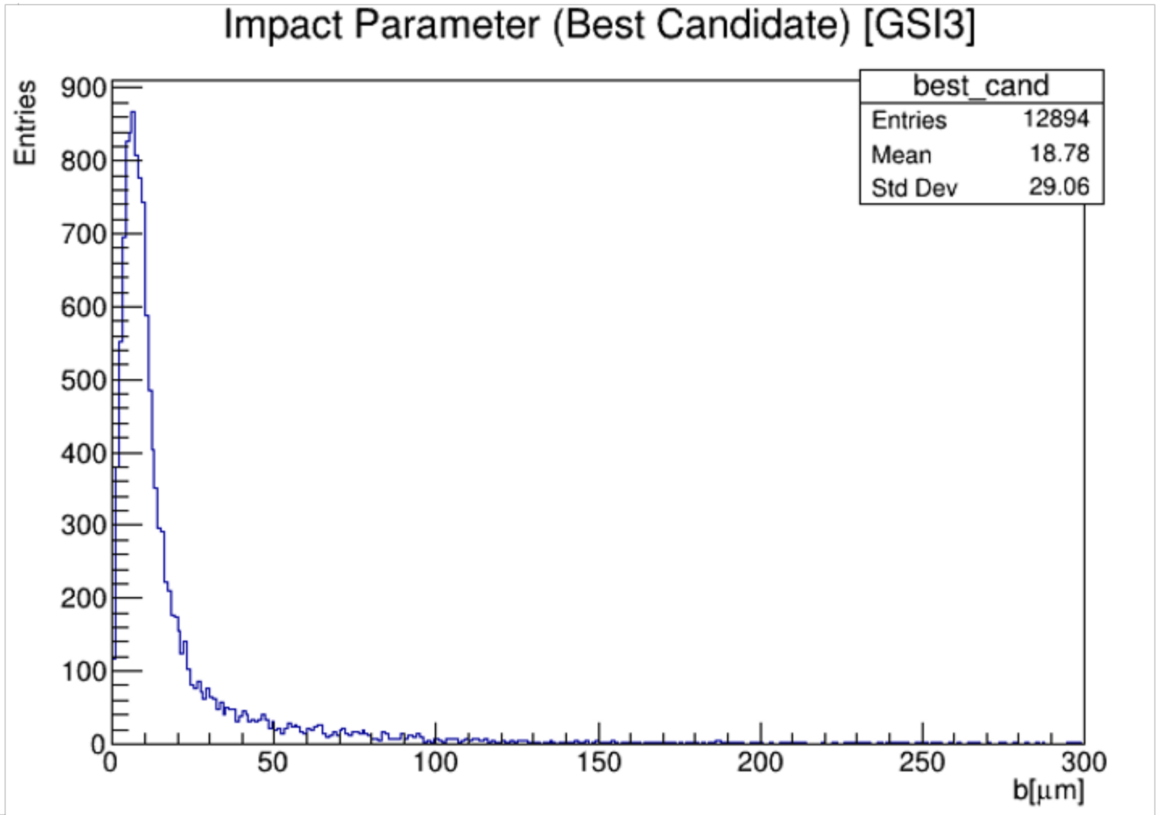


Merging procedure between different sections

- Each section is characterised by its own parameters (material density, thickness…): tracking algorithm applied to each section separately → Different reference systems for each section

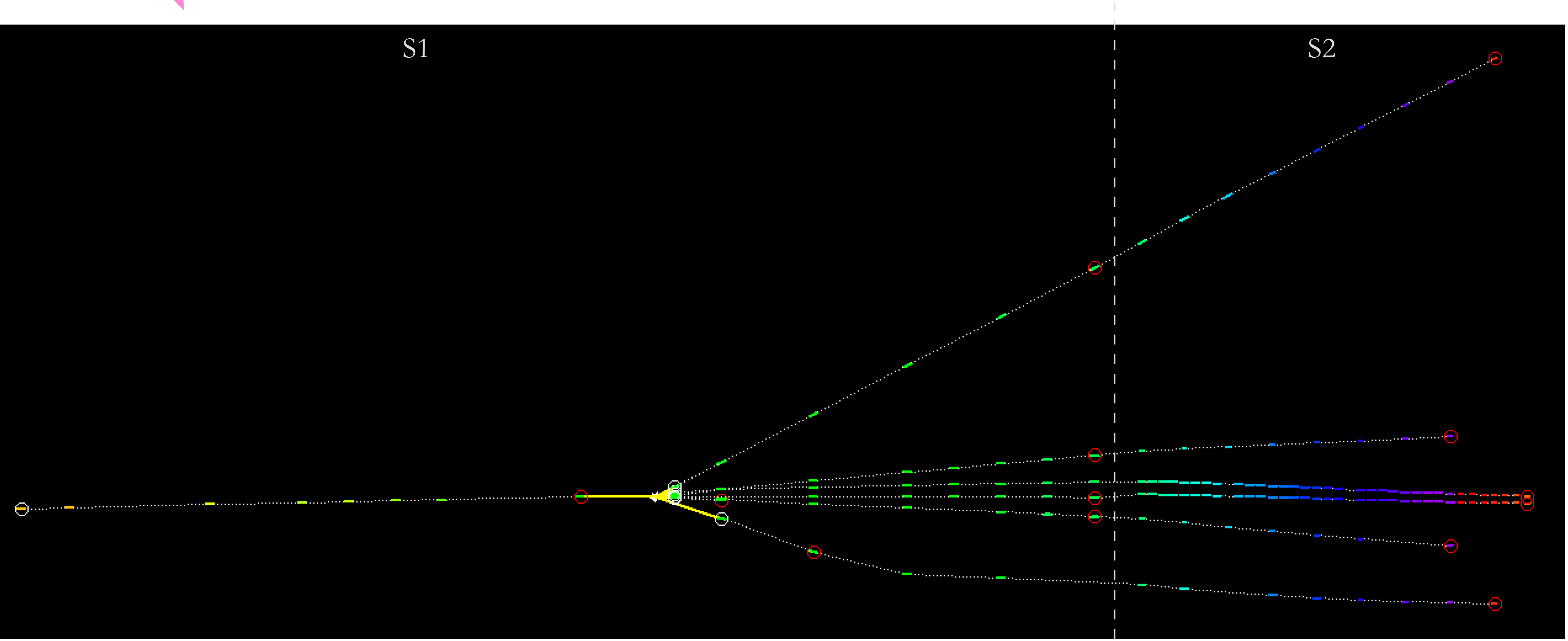
- Improved procedure to align two sections and transform coordinates into a global system
- In GSI3 about 90% of the tracks with more than 5 segments have a candidate with impact parameter<50μm





EXAMPLES TAKEN FROM GSI3 DATA

Merging procedure between different sections

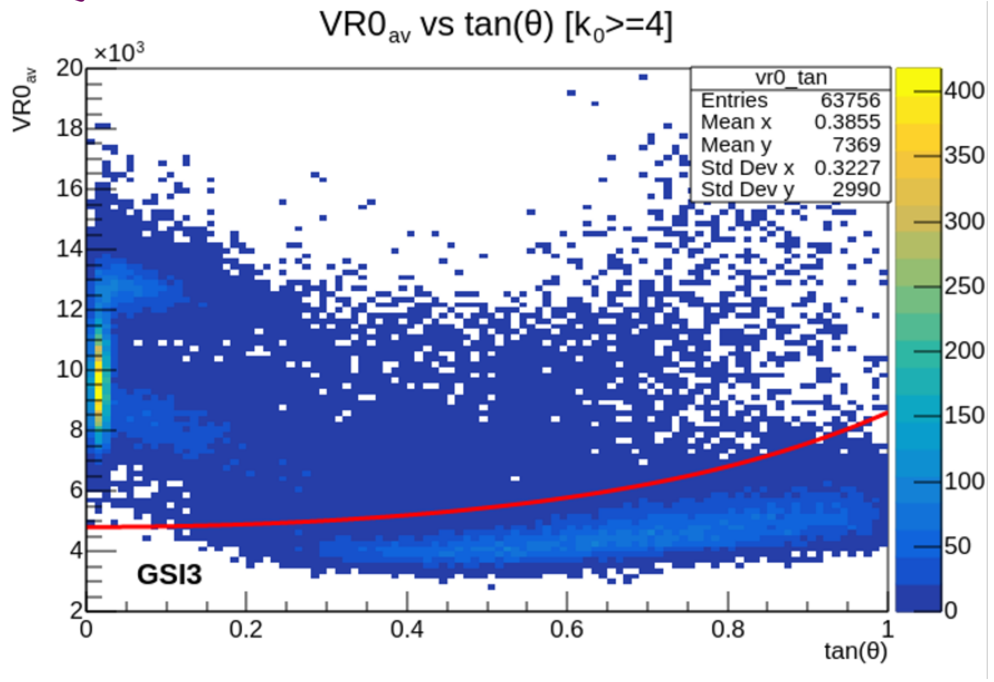


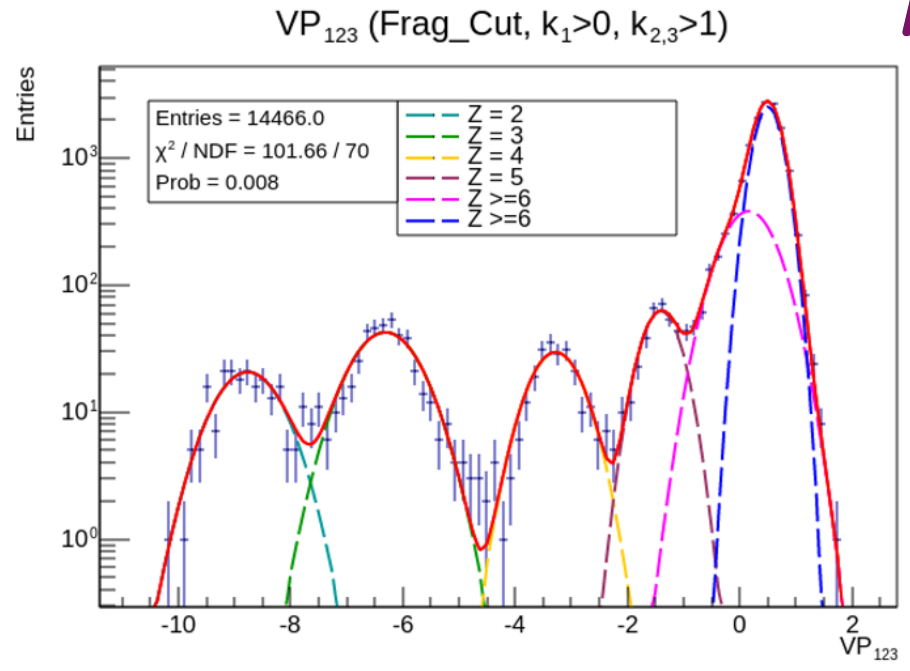
Example taken from GSI3 data

Retrieving the charge from S2

- S2 =9 cells × 4 thermal conditions (R0 to R3) leading to 4 "volume variables" ($< VR_i >$)
- Cut based analysis combining the slope of the tracks and their $< VR_0 >$
- PCA based analysis to identify charges $Z \geq 2$

- For Oxy@200 MeV/n (GSI1 & GSI2) charges were identified up to Z=4
  For Oxy@400 MeV/n (GSI3) charges were identified up to Z=6

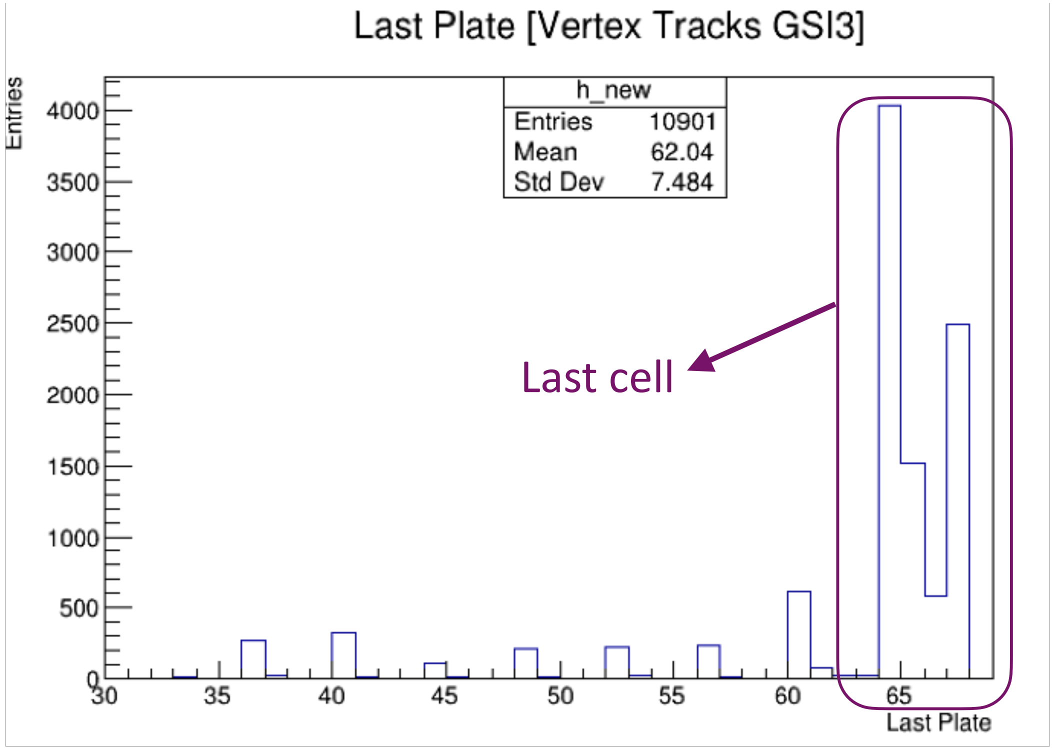


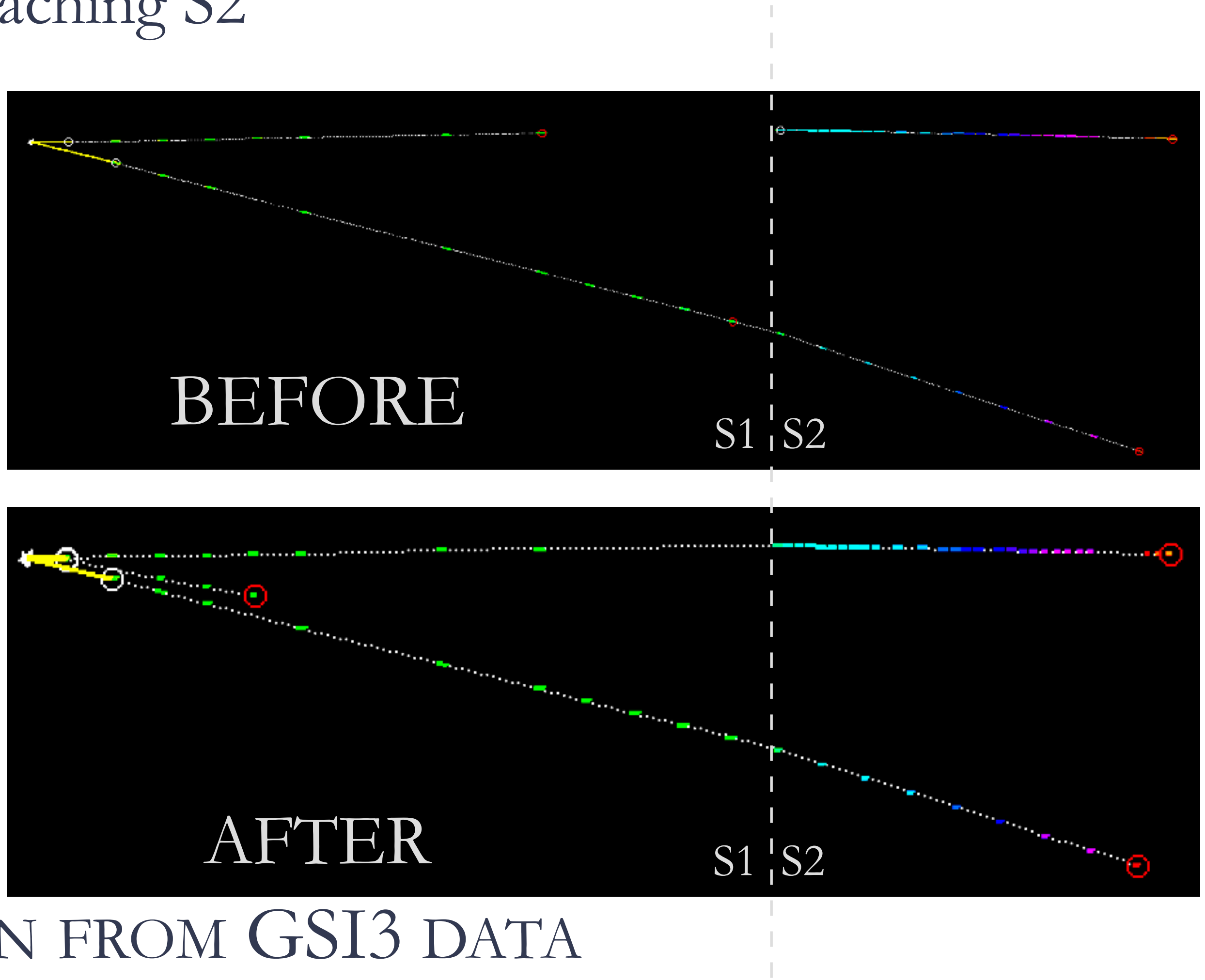


EXAMPLES TAKEN FROM GSI3 DATA

Improvements in retrieving the charge from S2

- Improved method to select the best candidate to extend tracks
- Dedicated procedure to extend tracks with gaps longer than 5 passive layers
- ~ 1000 additional fragmentation tracks reaching S2

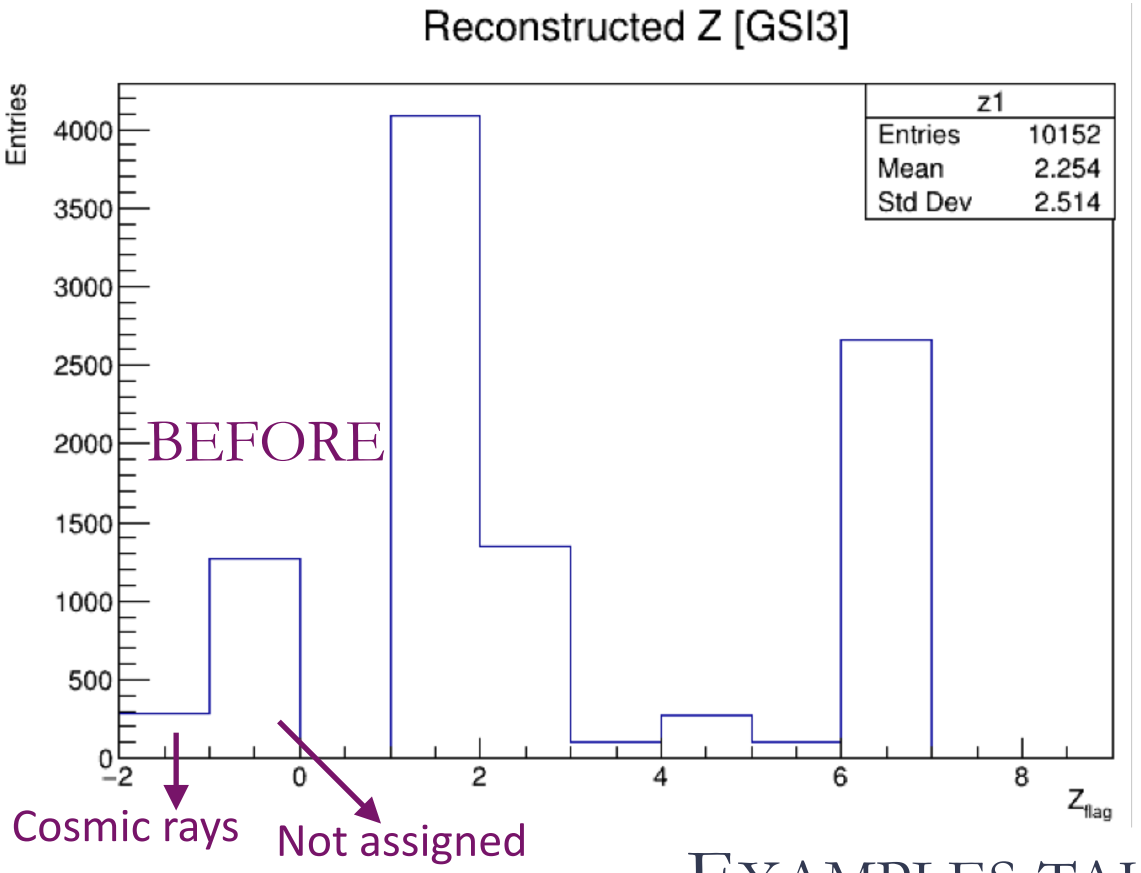


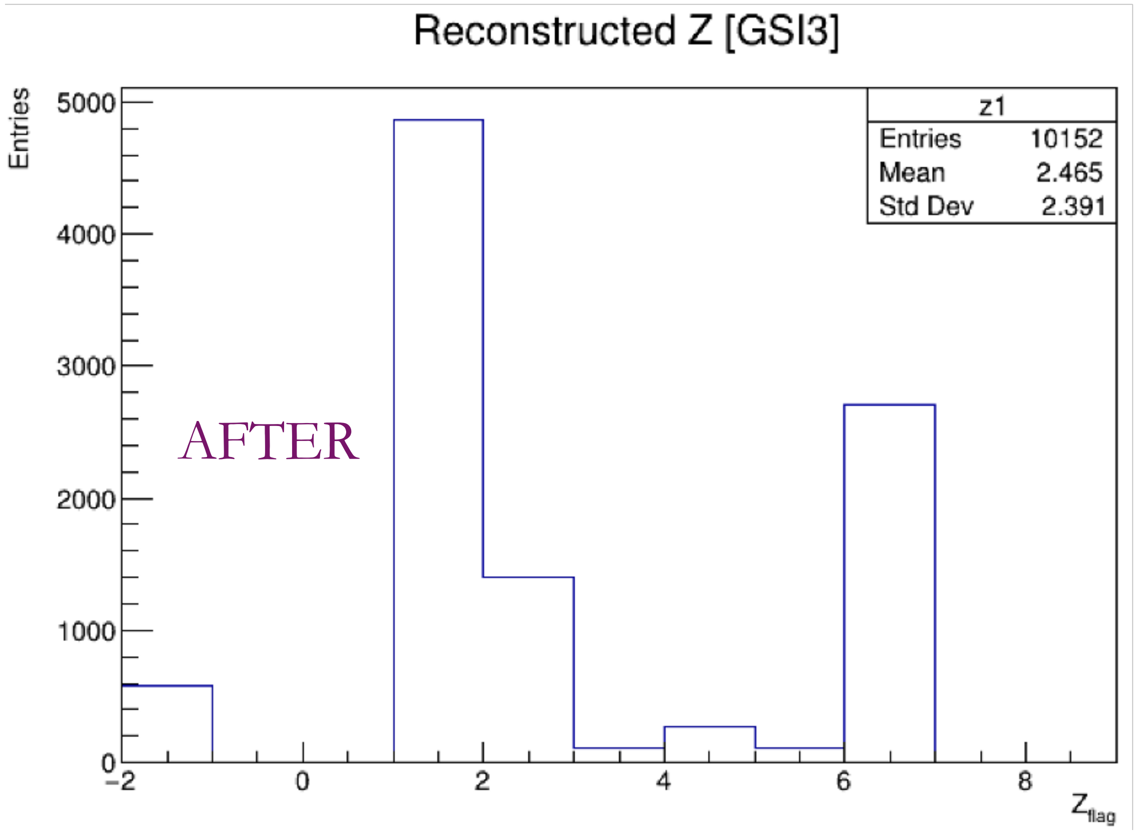


EXAMPLES TAKEN FROM GSI3 DATA

Improvements in retrieving the charge from S2

- Initially some of the tracks connected to vertices had not been classified in S2 because they did not satisfy some requirement (example: minimum number of segments to avoid background)
- These tracks have been added to the charge identification procedure

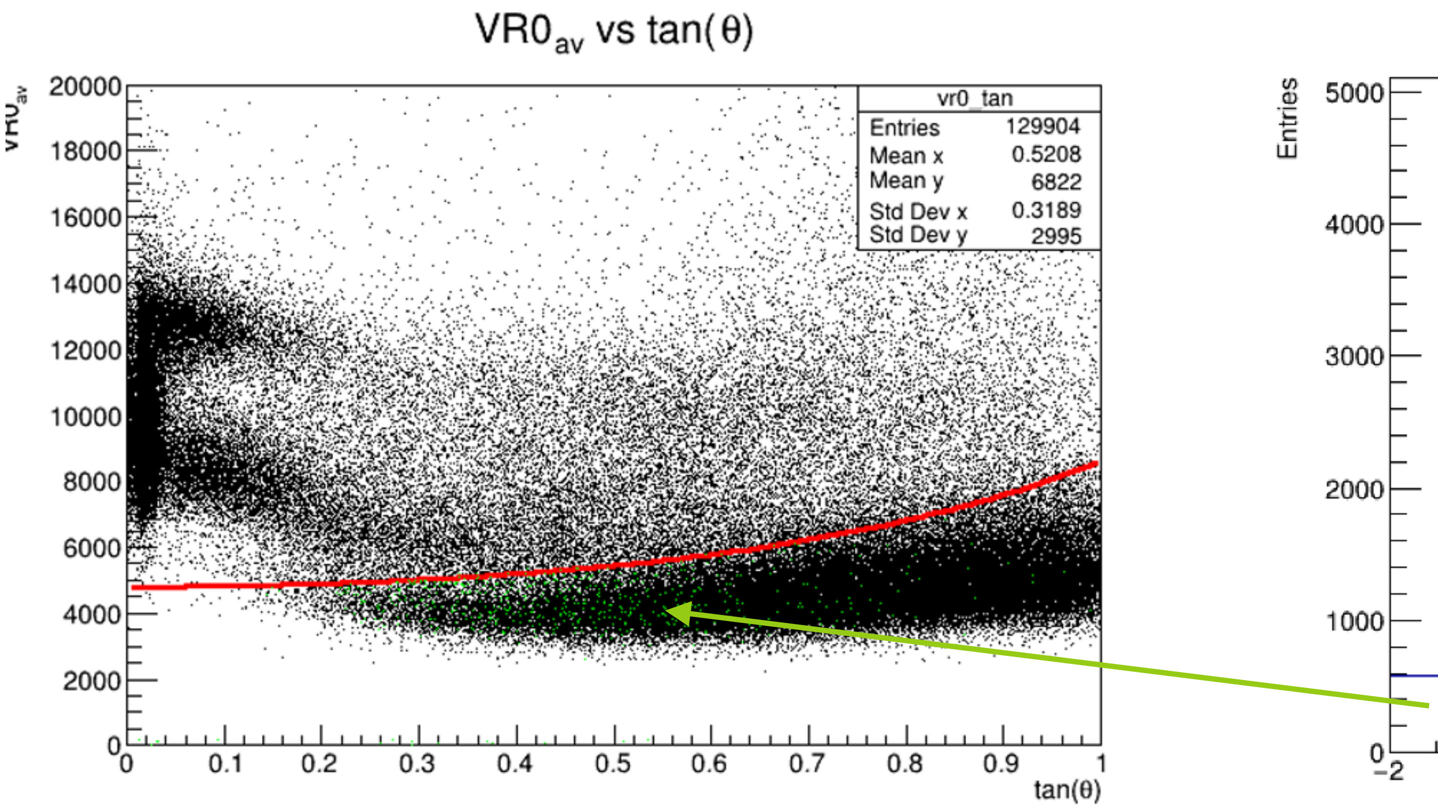


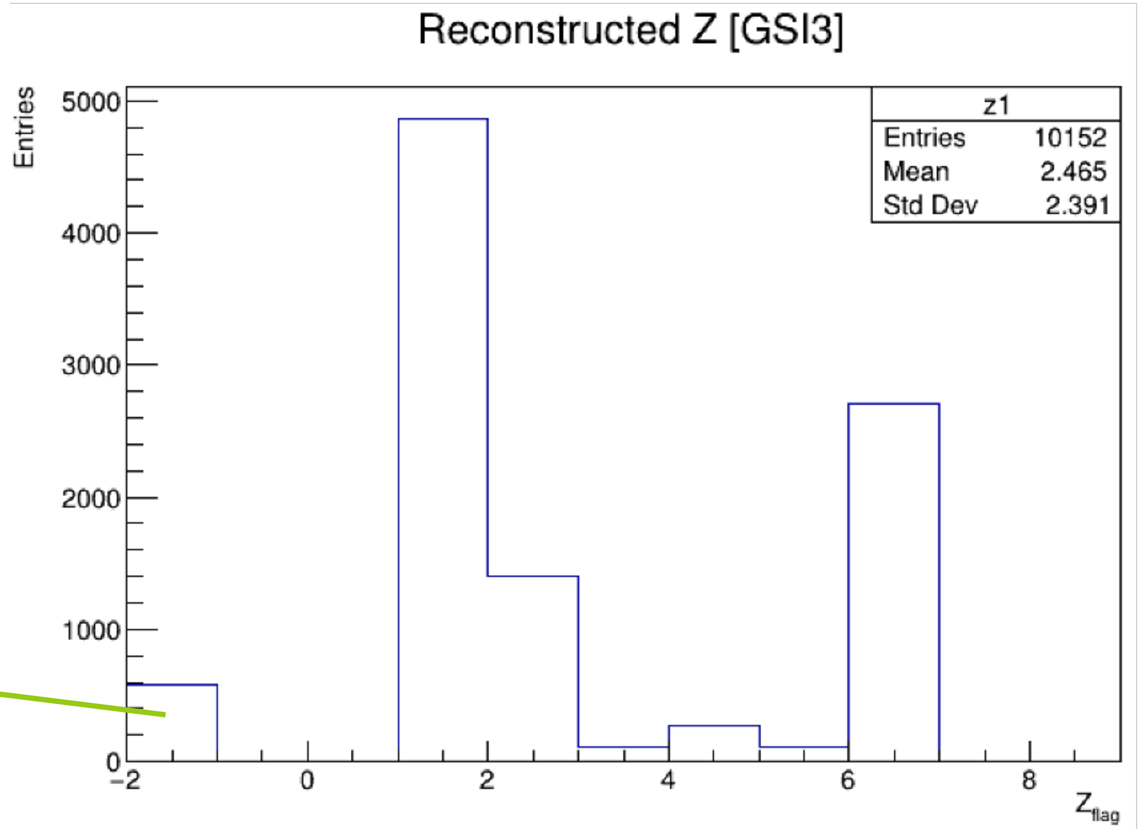


EXAMPLES TAKEN FROM GSI3 DATA

Improvements in retrieving the charge from S2

- All tracks are now classified
- $\sim 5\,\%$ of tracks connected to a vertex are classified as cosmic rays: further checks on-going → if confirmed as comics tracks are removed from the vertex





EXAMPLES TAKEN FROM GSI3 DATA

Improvements in retrieving the charge from S2

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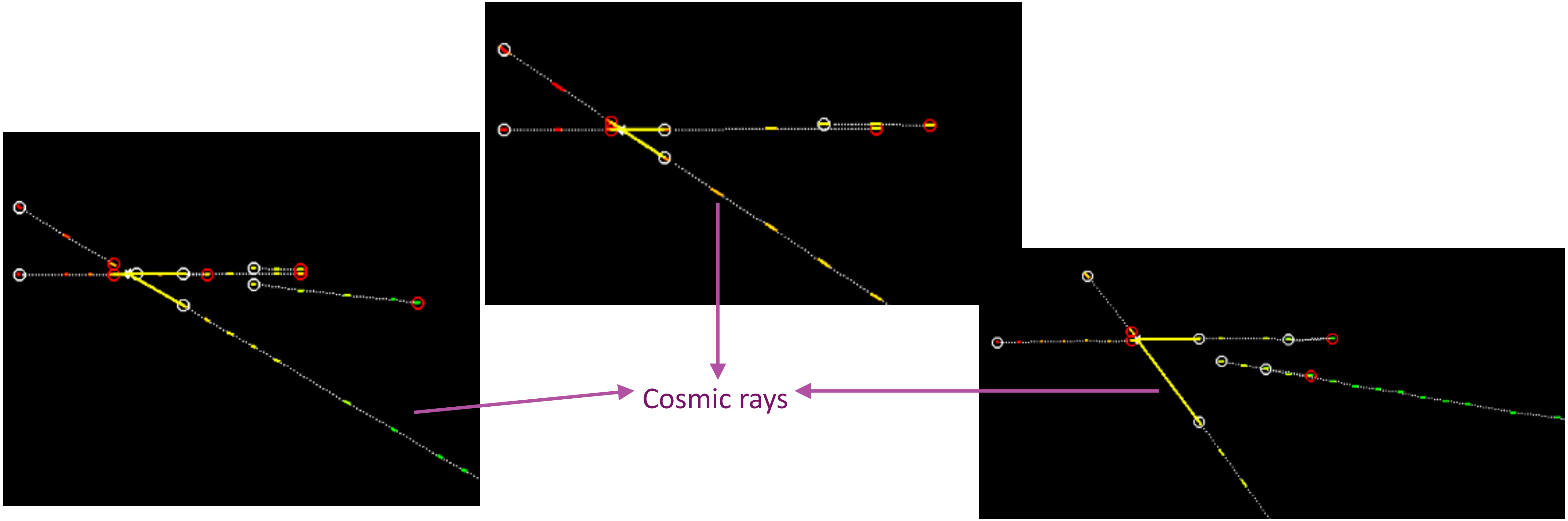


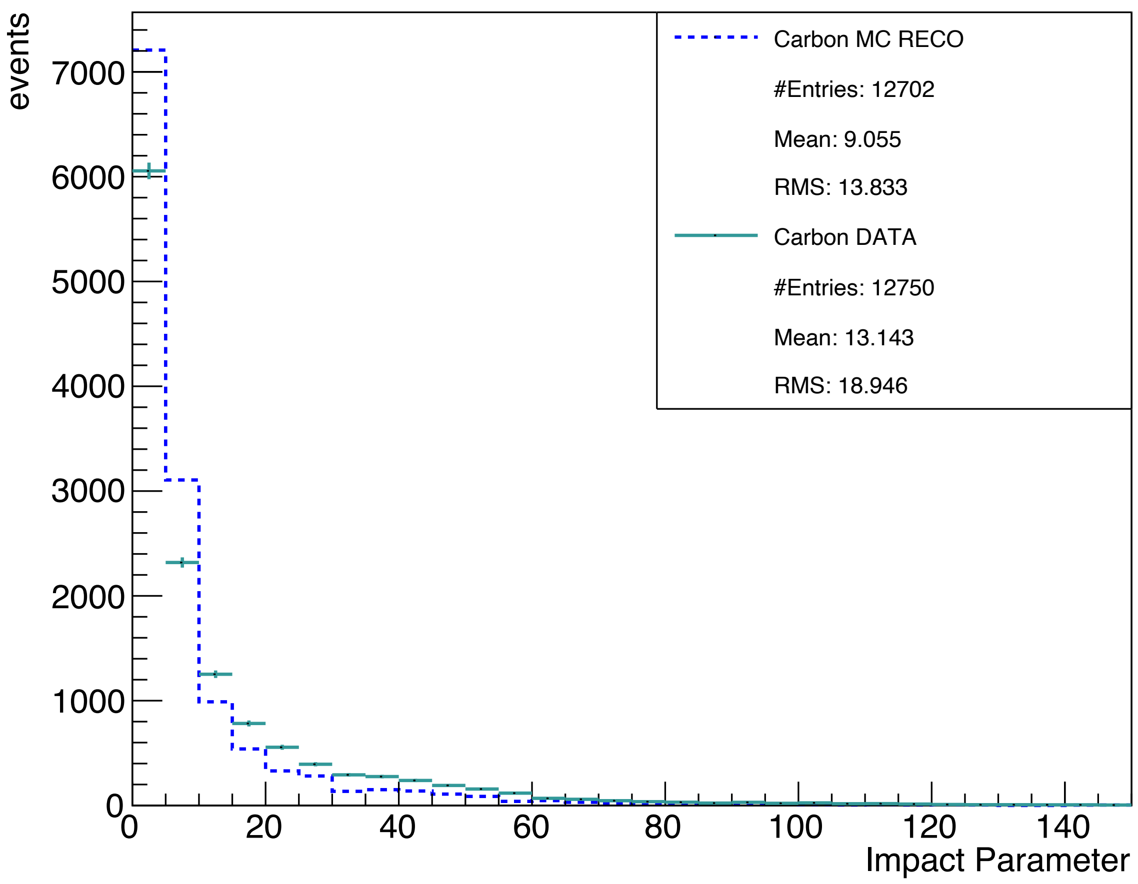
EXAMPLES TAKEN FROM DATA

Data analysis

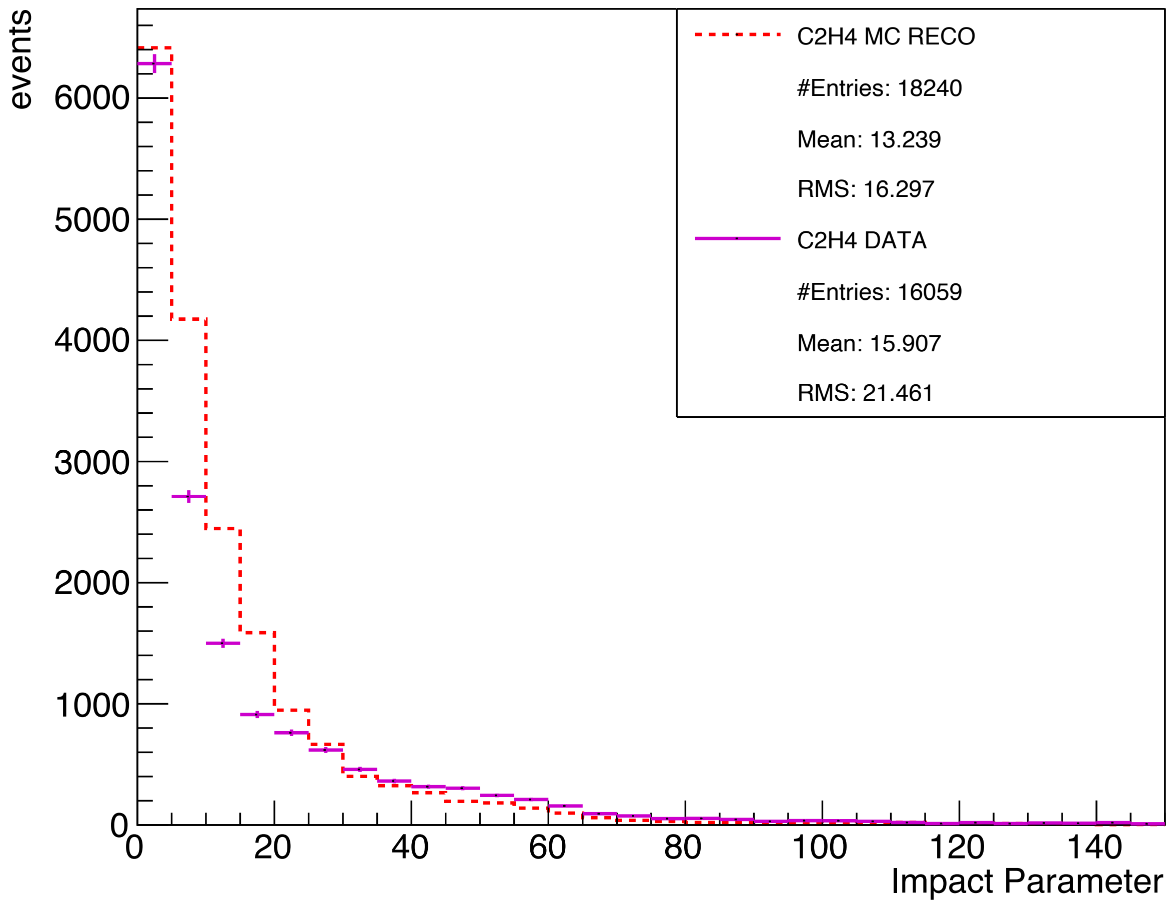
- GSI1: Oxy@200 MeV/n on C target
- GSI2: Oxy@200 MeV/n on C_2H_4 target
- GSI3: Oxy@400 MeV/n on C target

GSI1: Oxy@200 MeV/n

GSI1 (C target)



GSI2 (C2H4 Target)

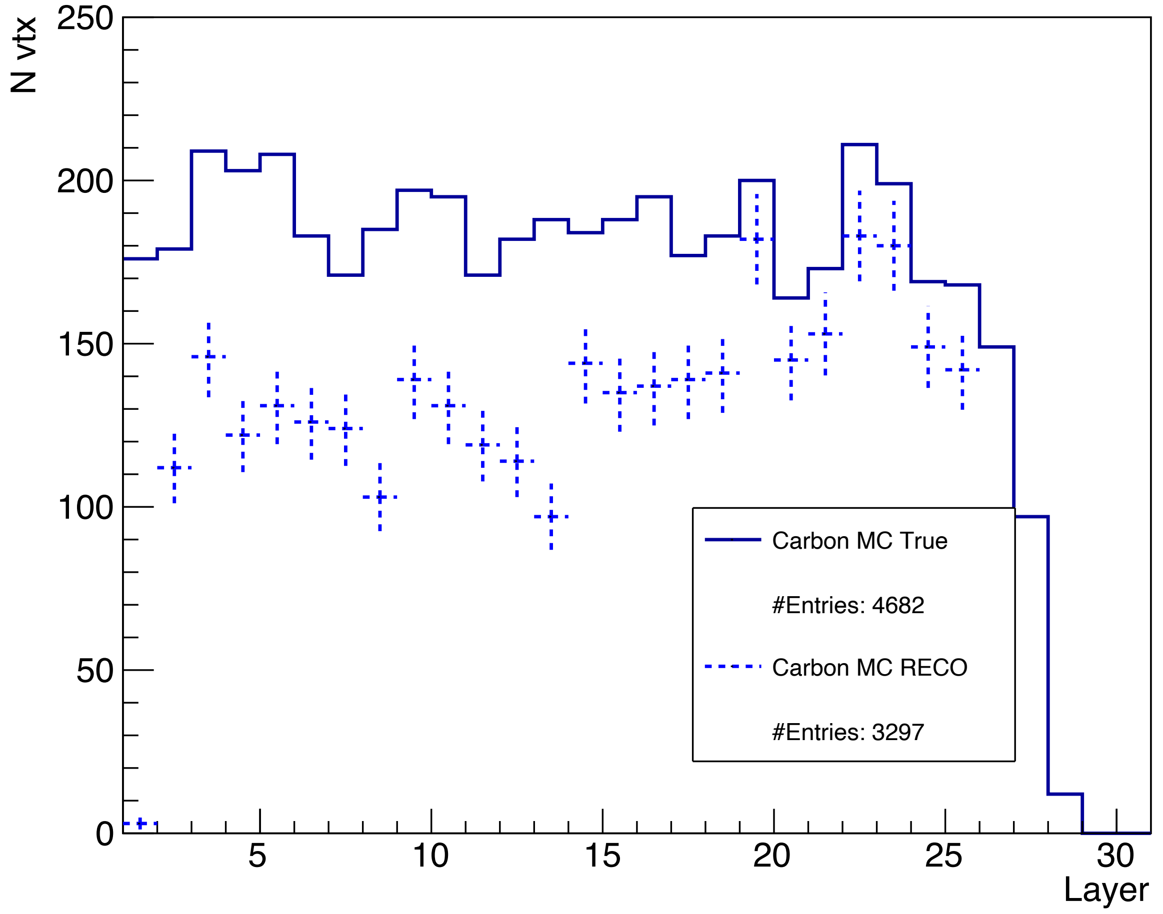


Distributions normalised to beam particles

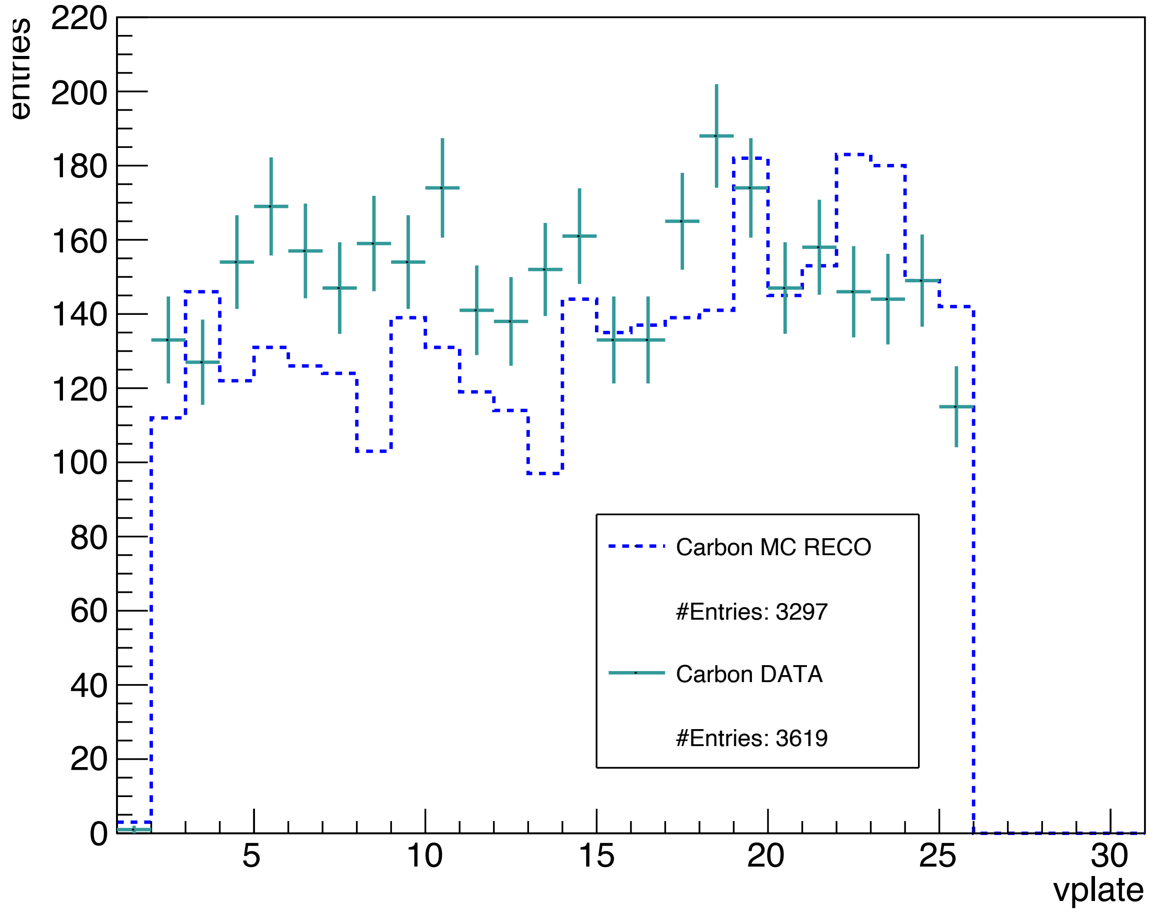
GSI1: Oxy@200 MeV/n on C target

N vertices per layer

MC TRUE vs MC RECO



MC RECO vs DATA

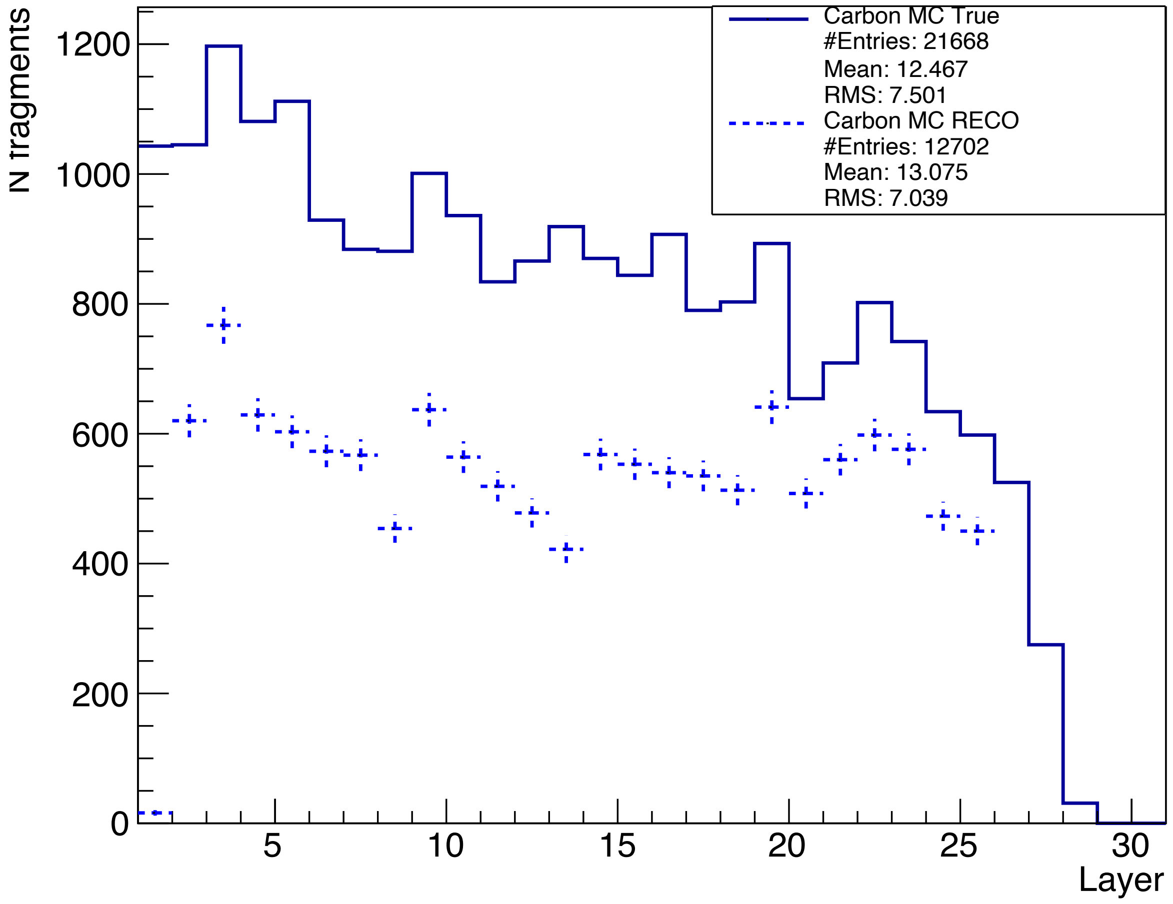


Distributions normalised to beam particles

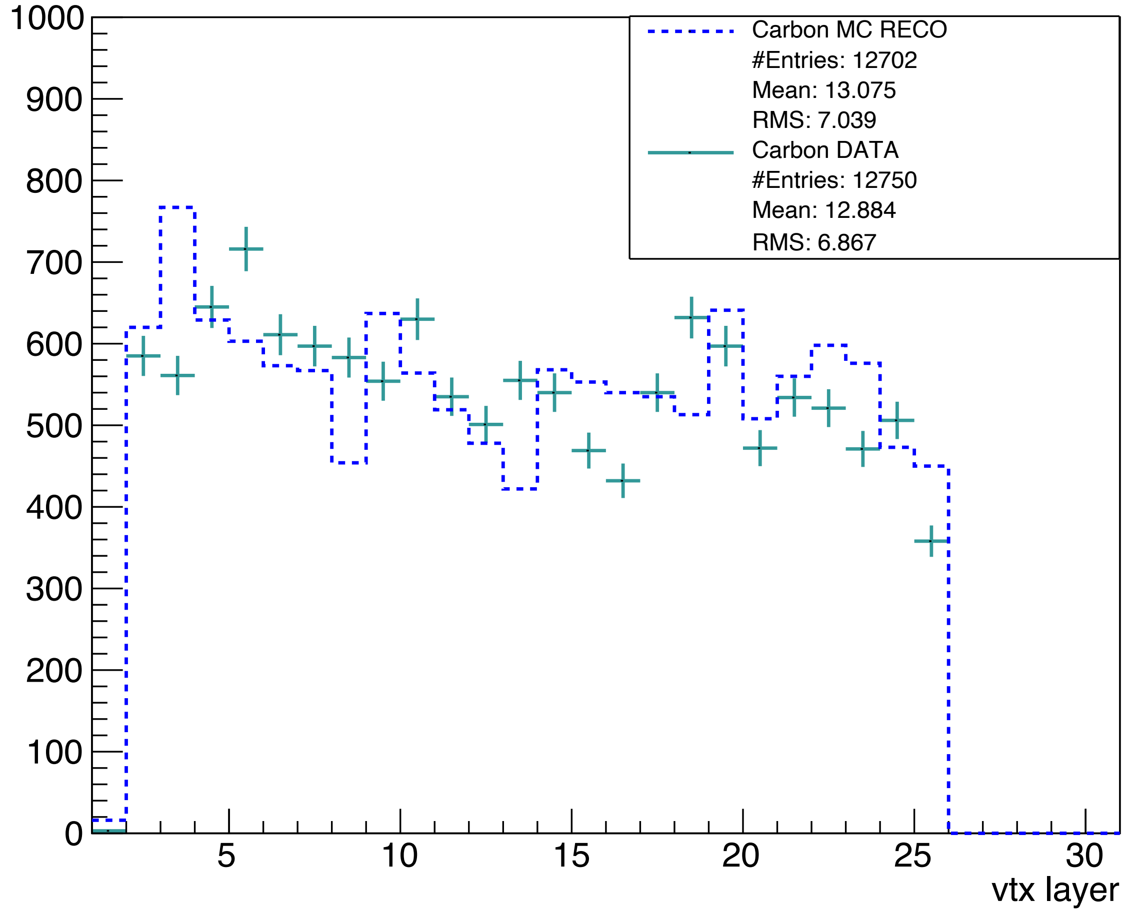
GSI1: Oxy@200 MeV/n on C target

N fragments per layer

MC TRUE vs MC RECO



MC RECO vs DATA



Distributions normalised to beam particles

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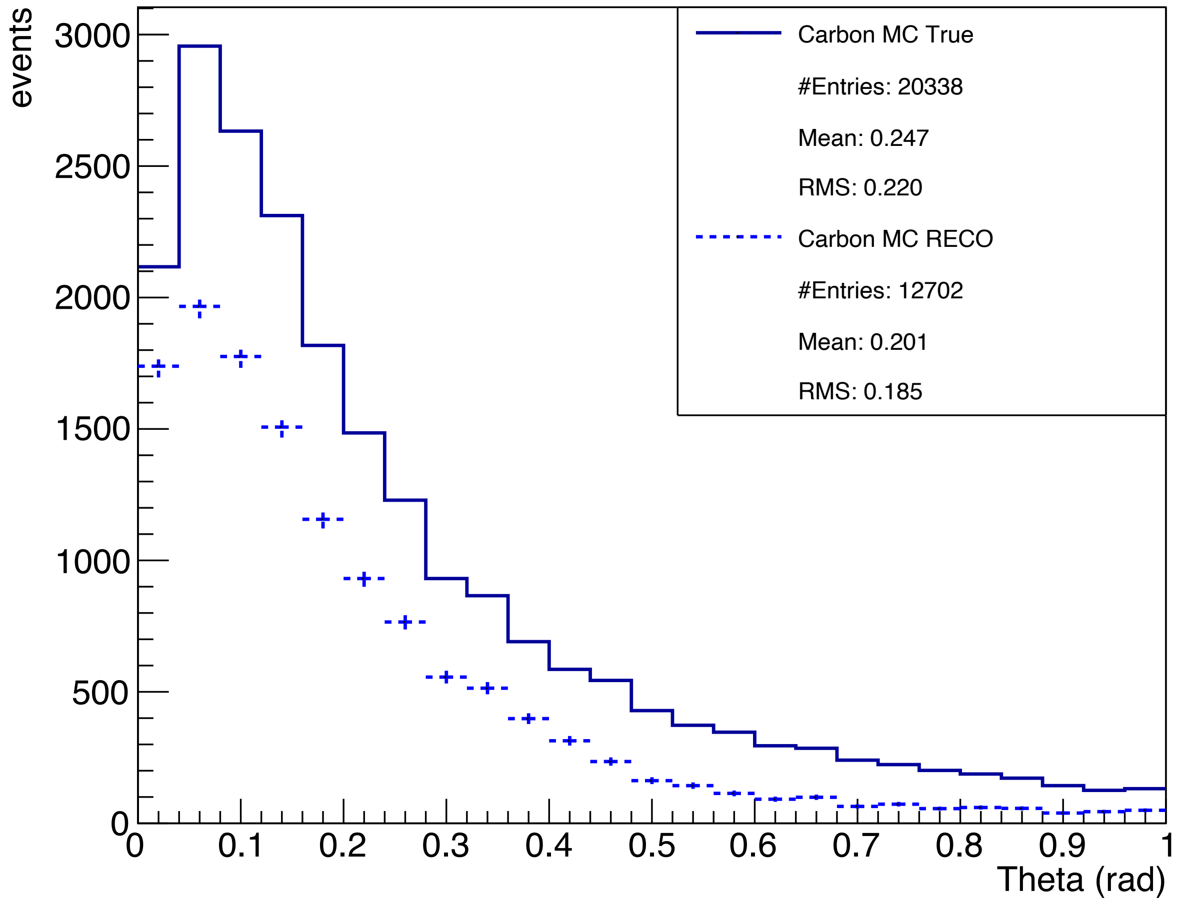
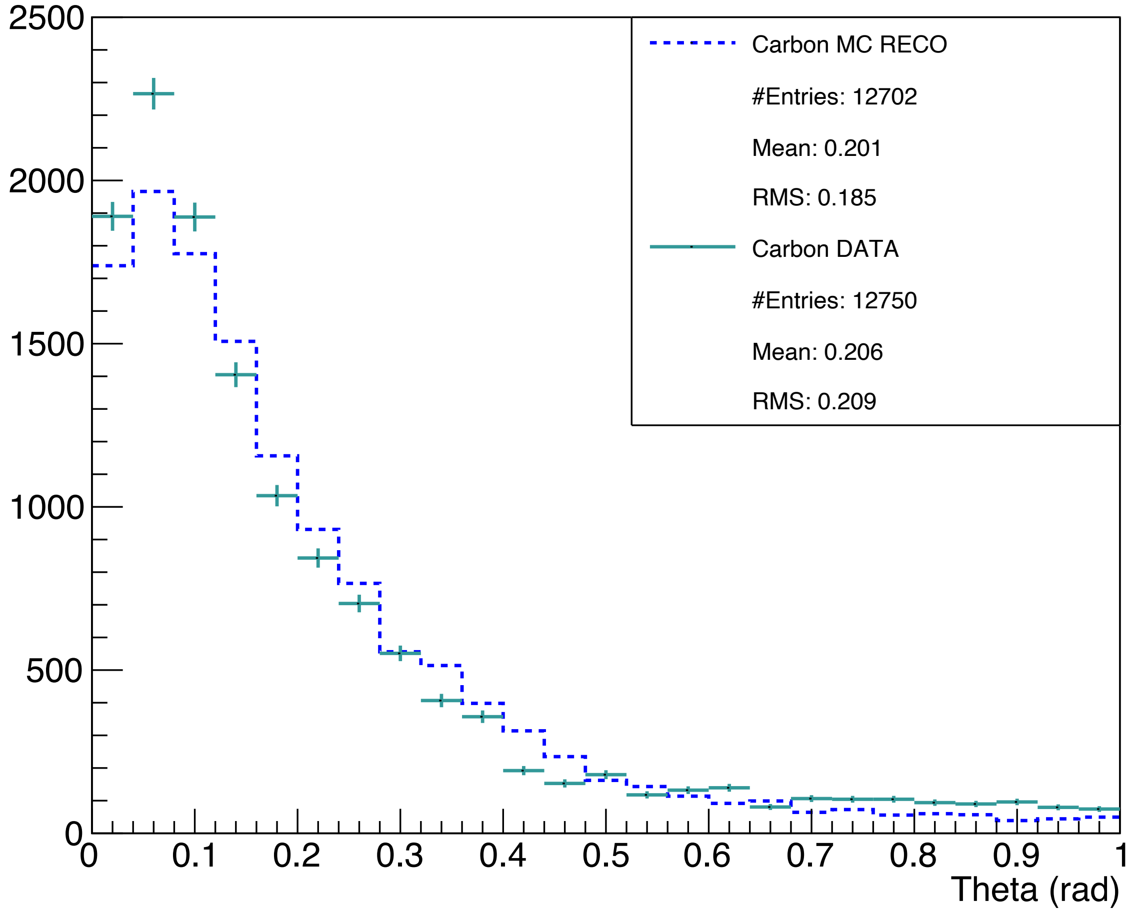
N fragments per layer

MC TRUE vs MC RECO



MC RECO vs DATA

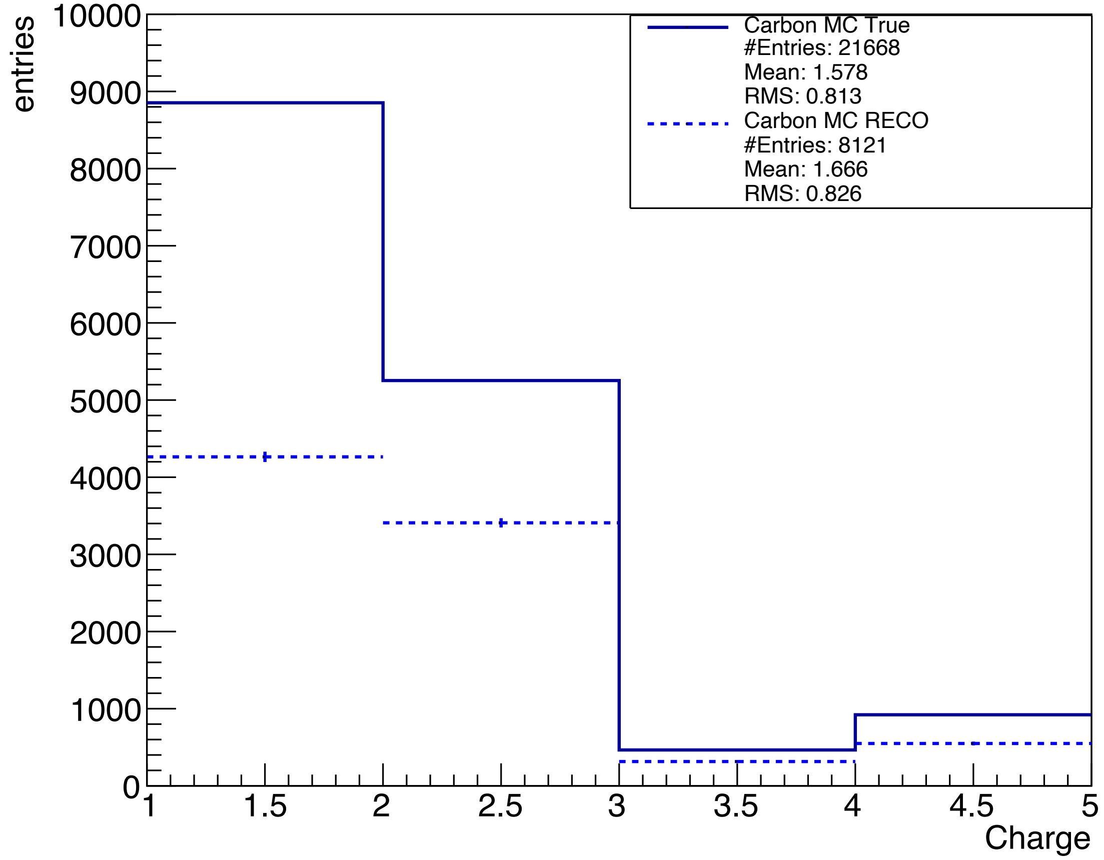


Distributions normalised to beam particles

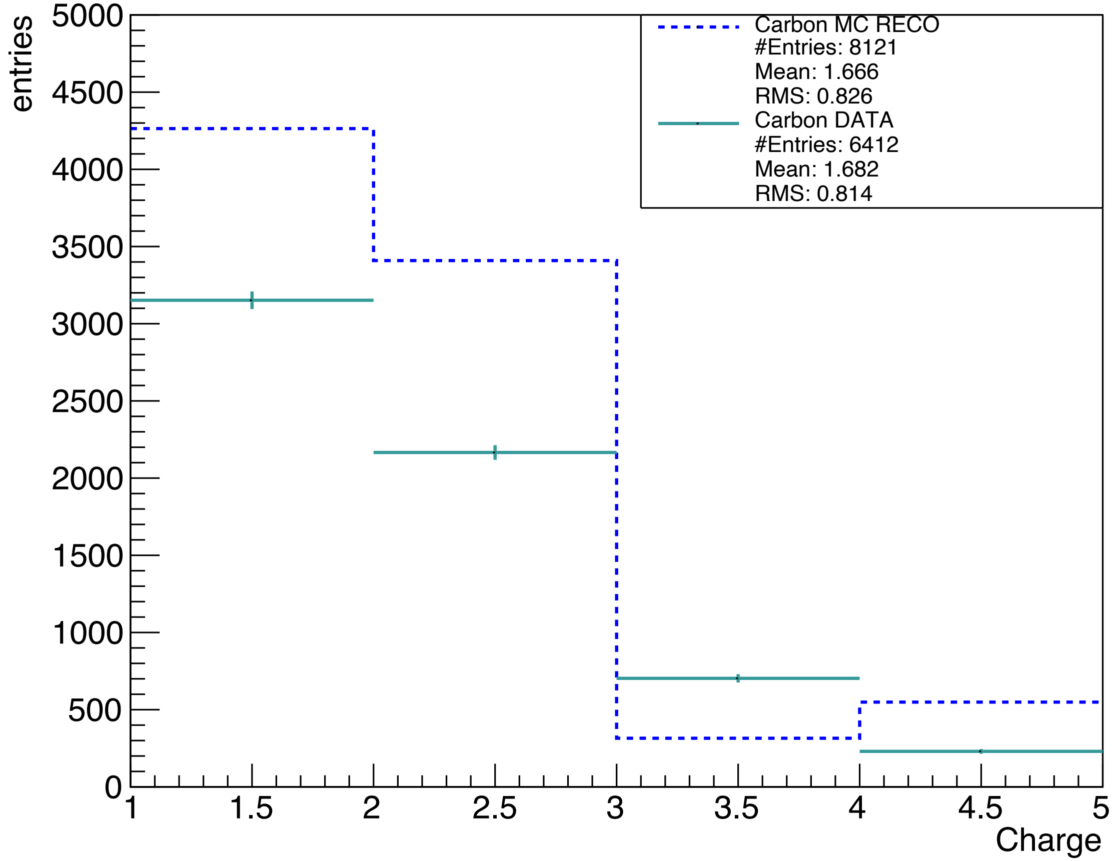
GSI1: Oxy@200 MeV/n on C target

Fragments' charge

MC TRUE vs MC RECO



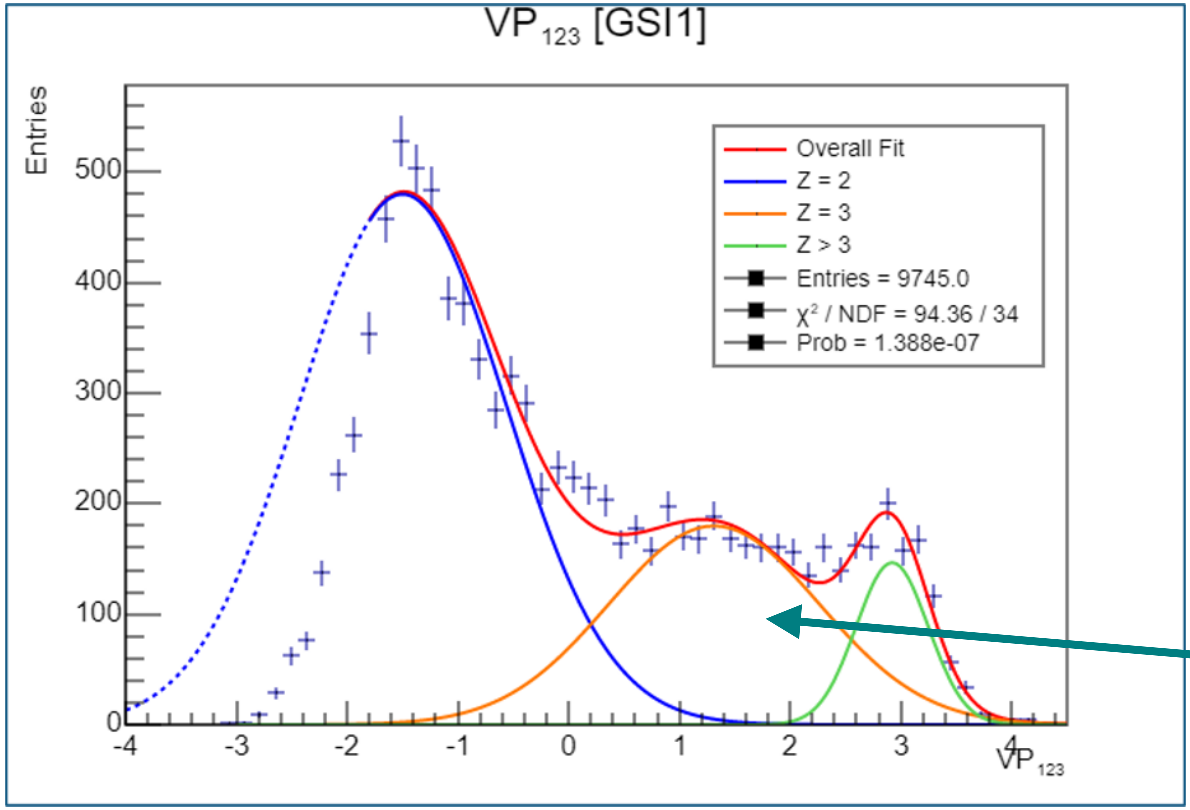
MC RECO vs DATA



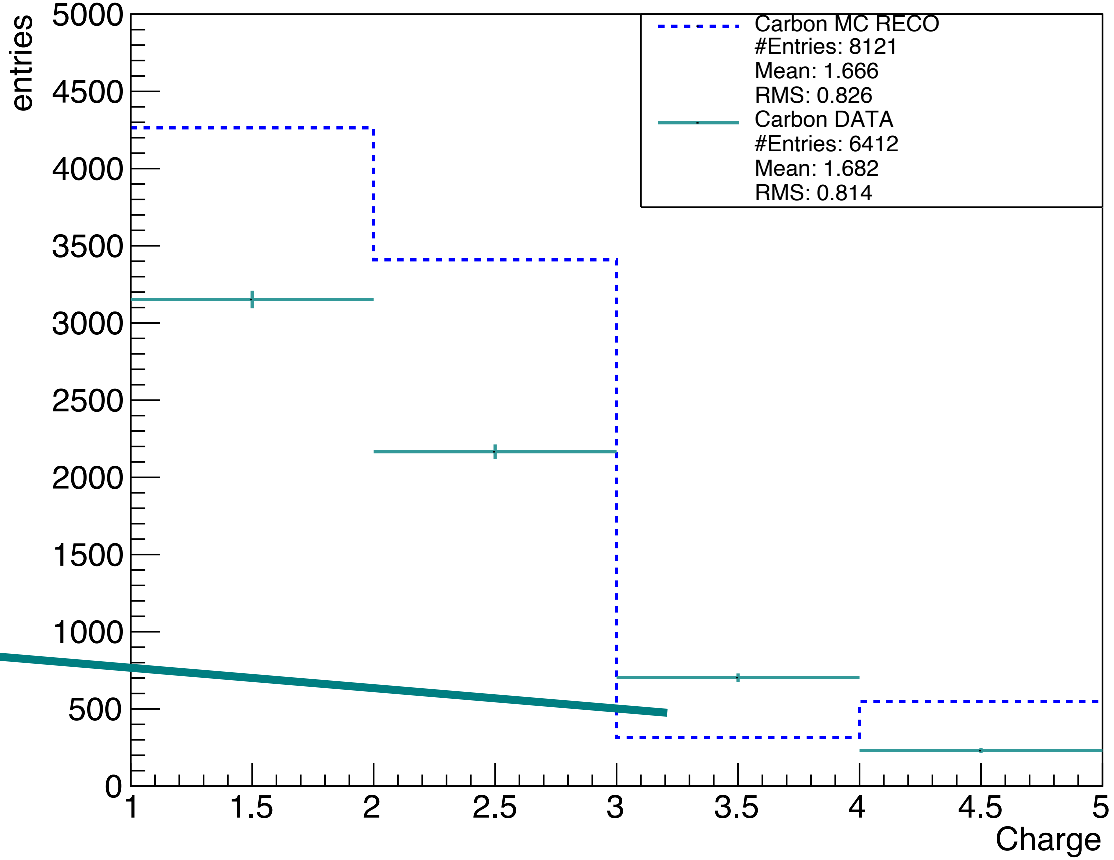
Distributions normalised to beam particles

GSI1: Oxy@200 MeV/n on C target

Fragments' charge



MC RECO vs DATA

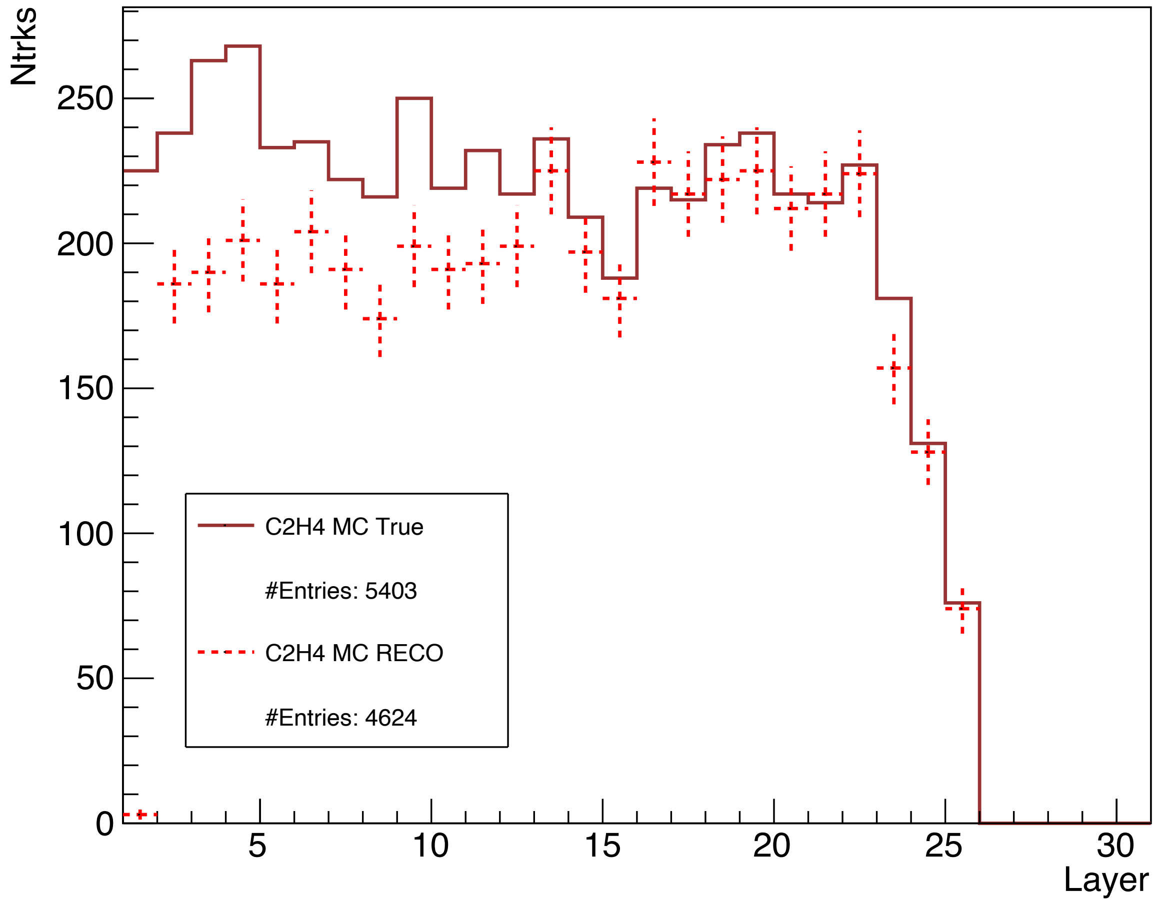


Distributions normalised to beam particles

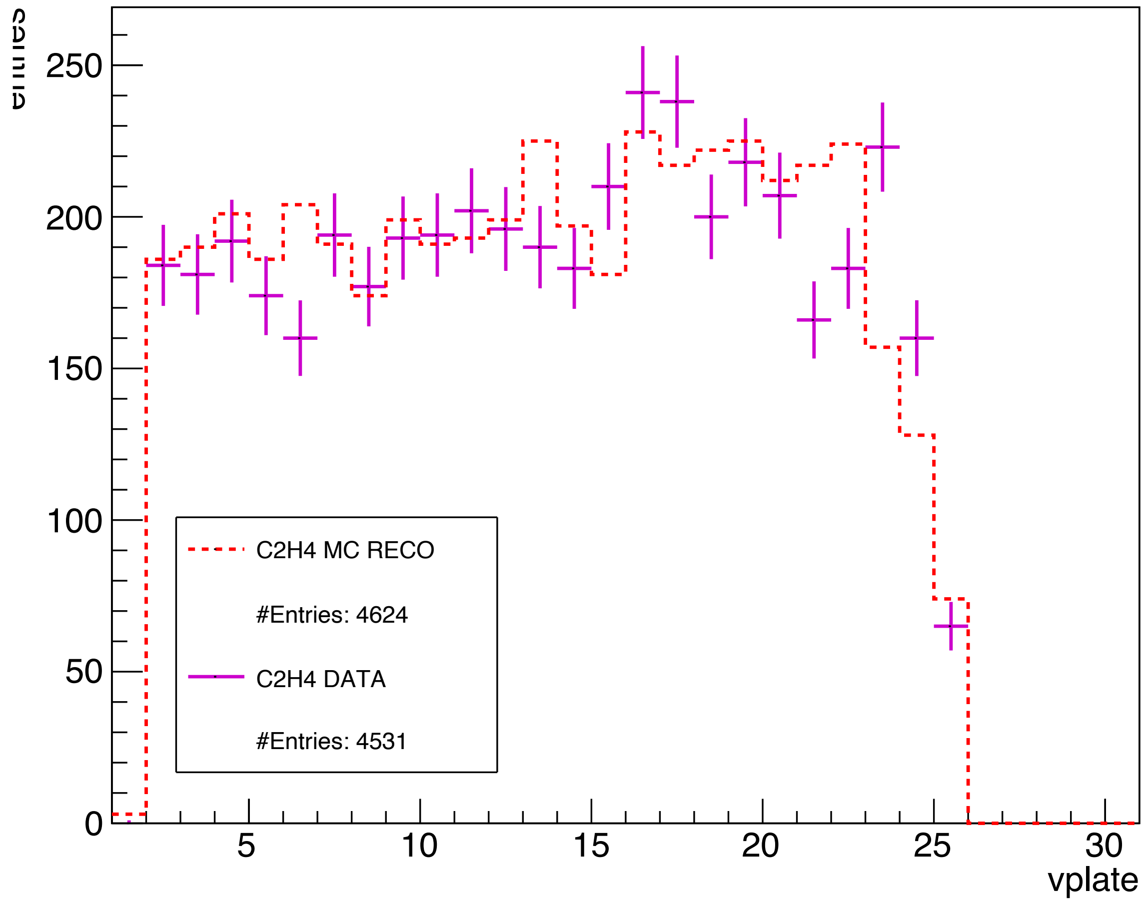
GSI2: Oxy@200 MeV/n on C2H4 target

N vertices per layer

MC TRUE vs MC RECO



MC RECO vs DATA

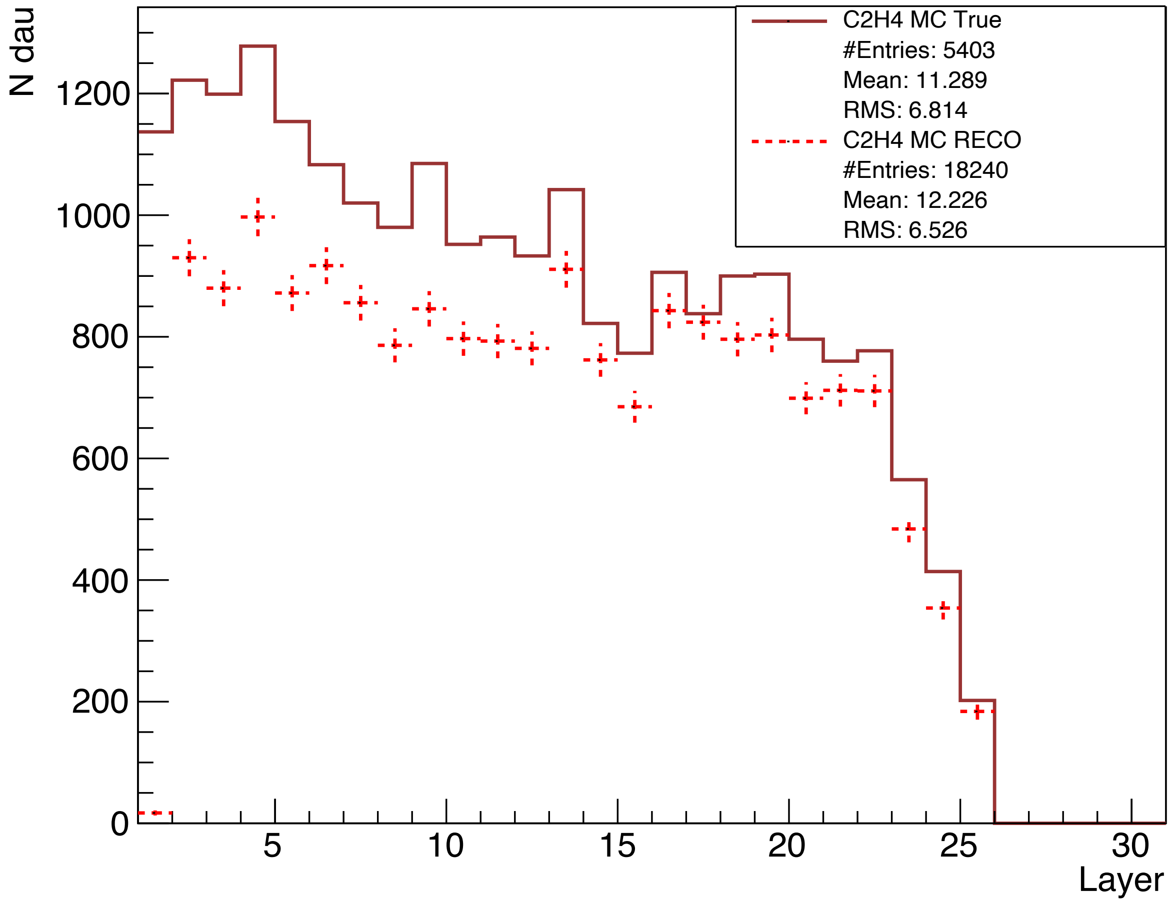


Distributions normalised to beam particles

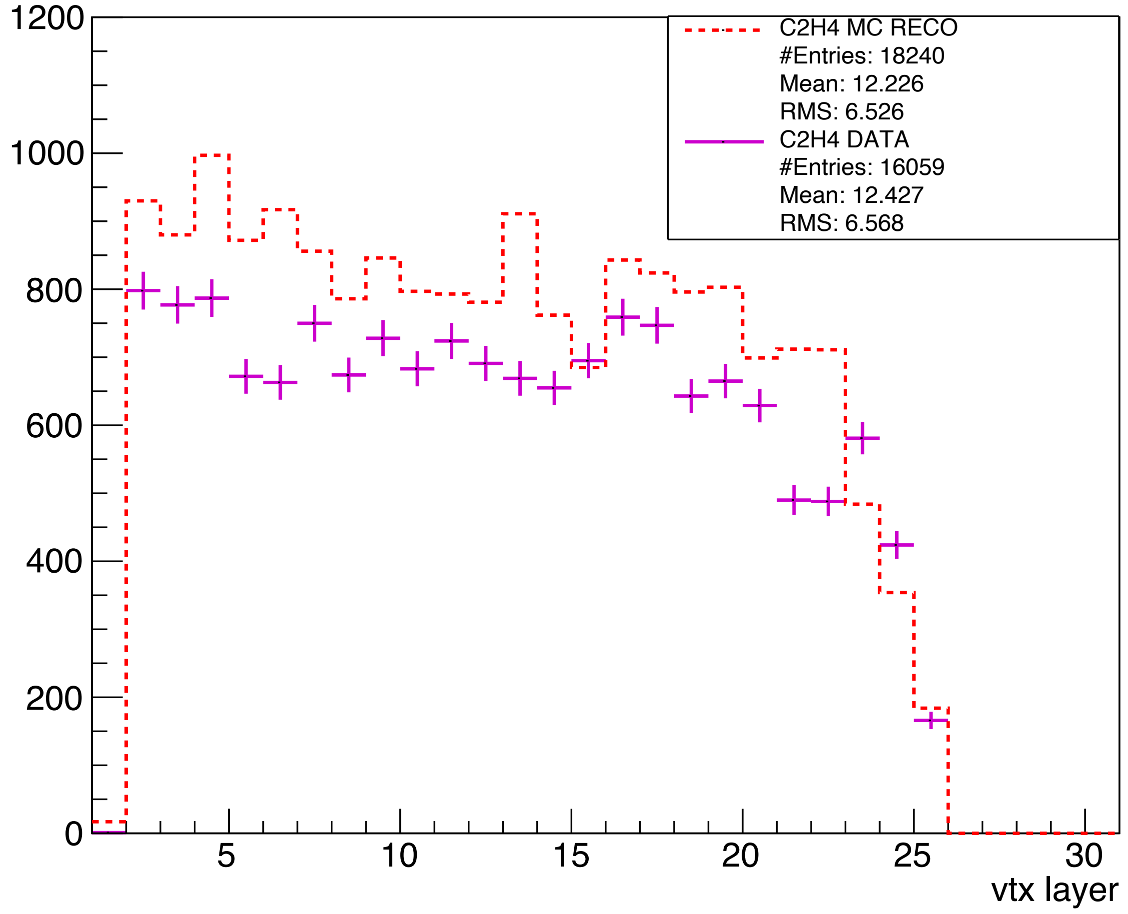
GSI2: Oxy@200 MeV/n on C2H4 target

N fragments per layer

MC TRUE vs MC RECO



MC RECO vs DATA

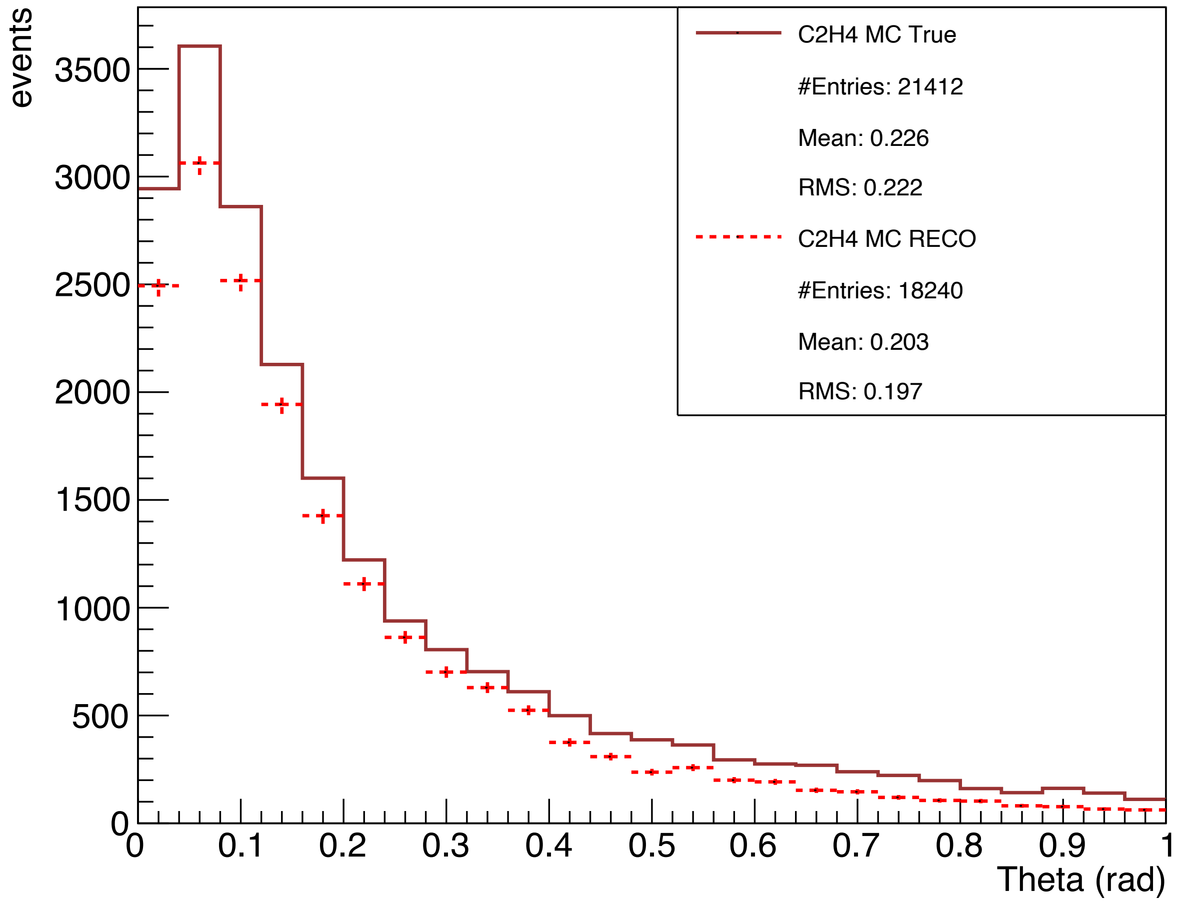


Distributions normalised to beam particles

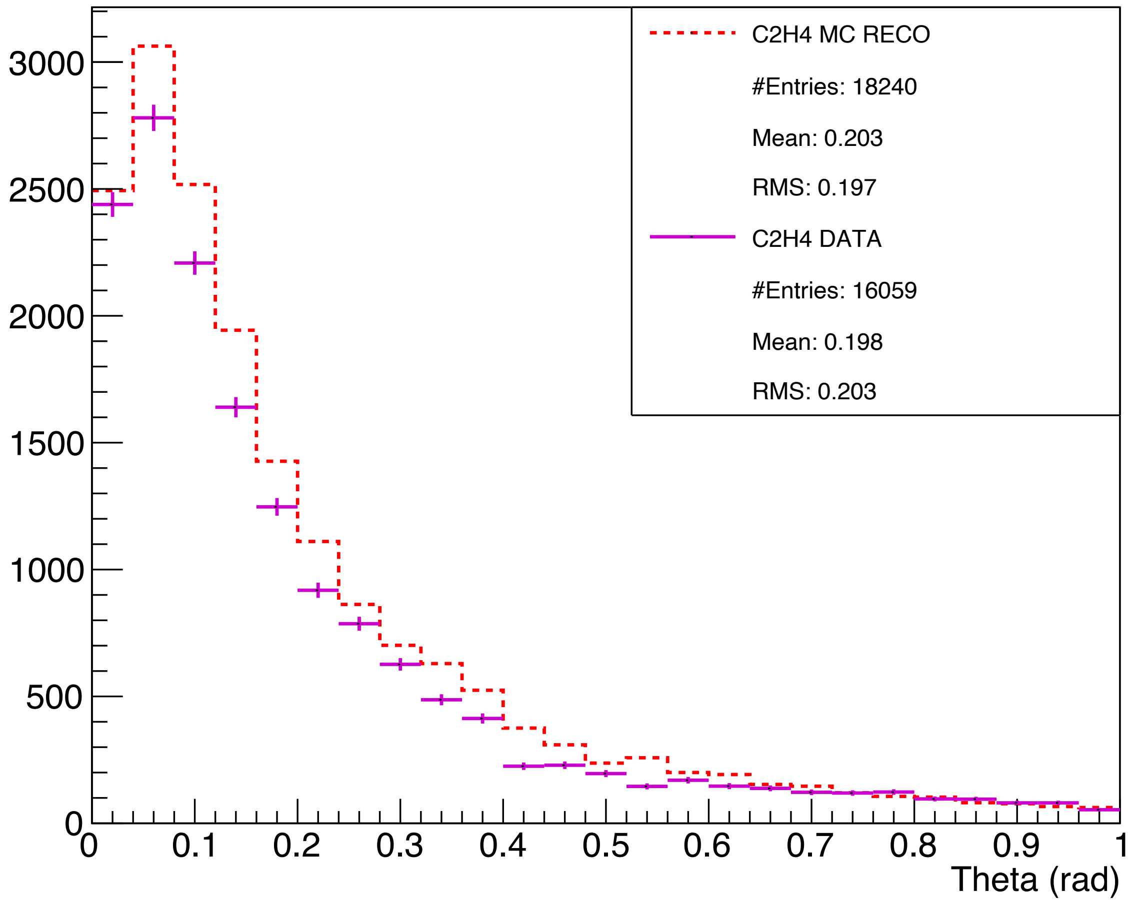
GSI2: Oxy@200 MeV/n on C2H4 target

N fragments per layer

MC TRUE vs MC RECO



MC RECO vs DATA

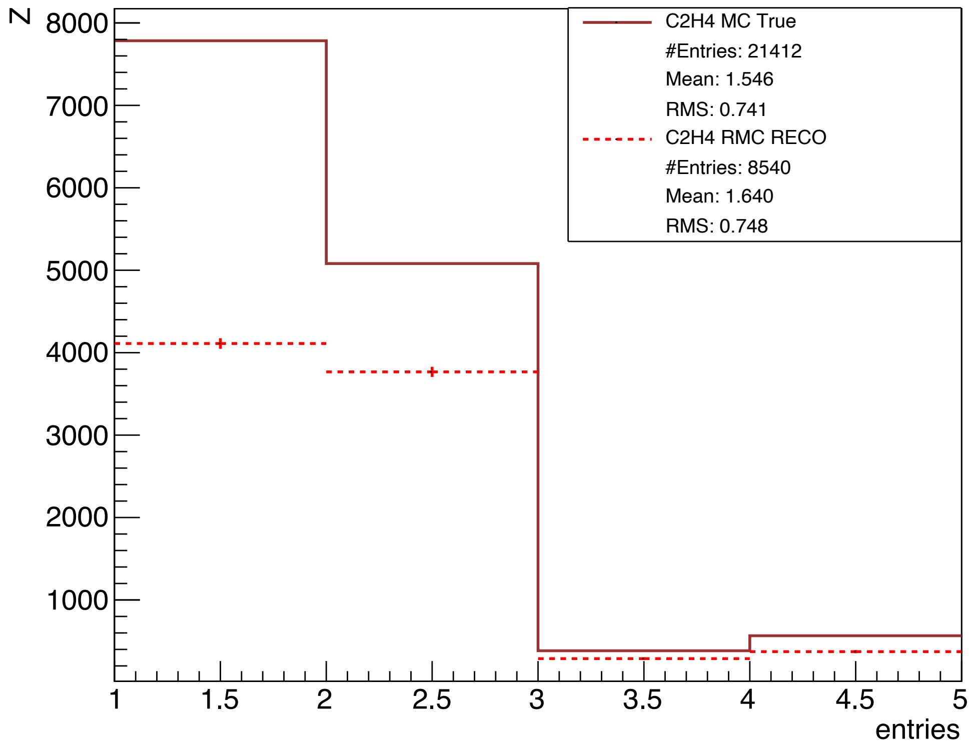


Distributions normalised to beam particles

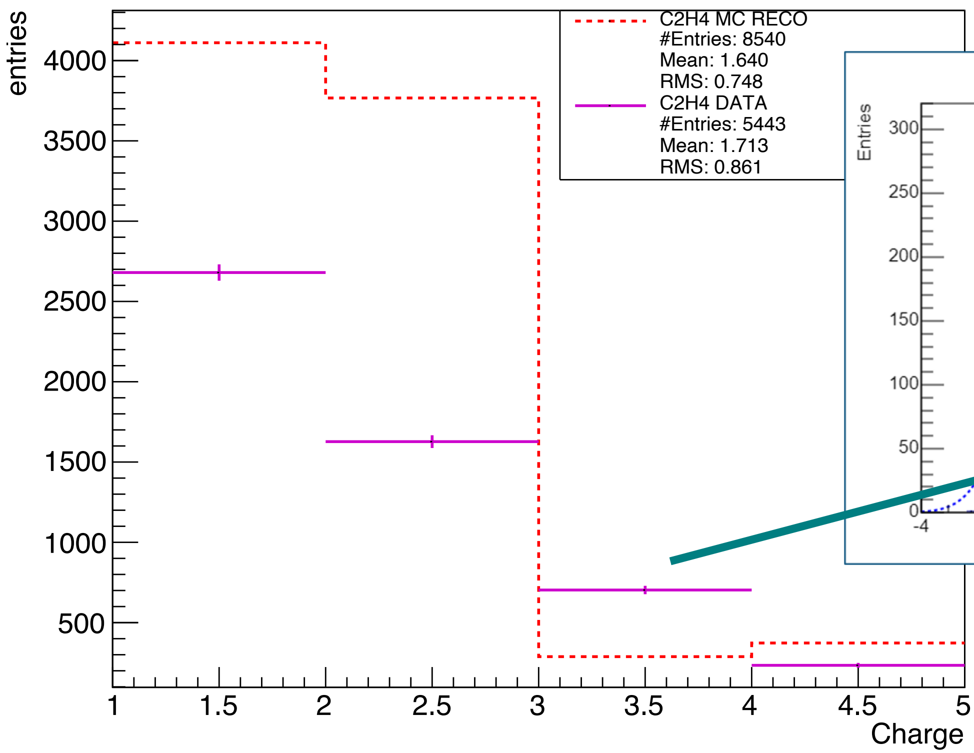
GSI2: Oxy@200 MeV/n on C2H4 target

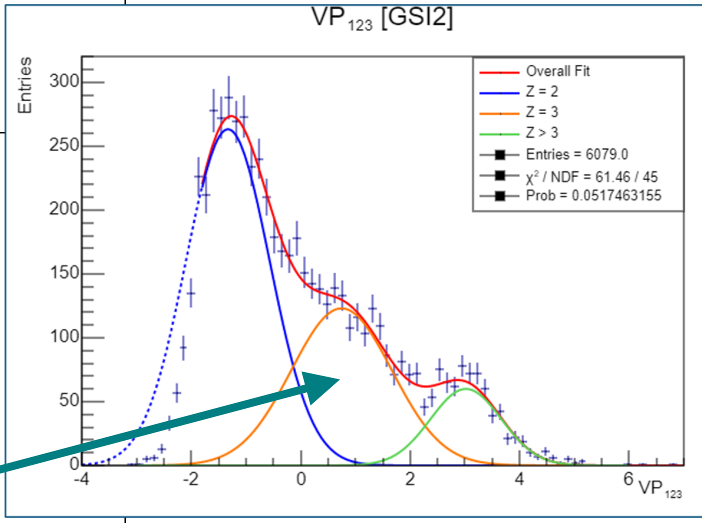
Fragment's charge

MC TRUE vs MC RECO



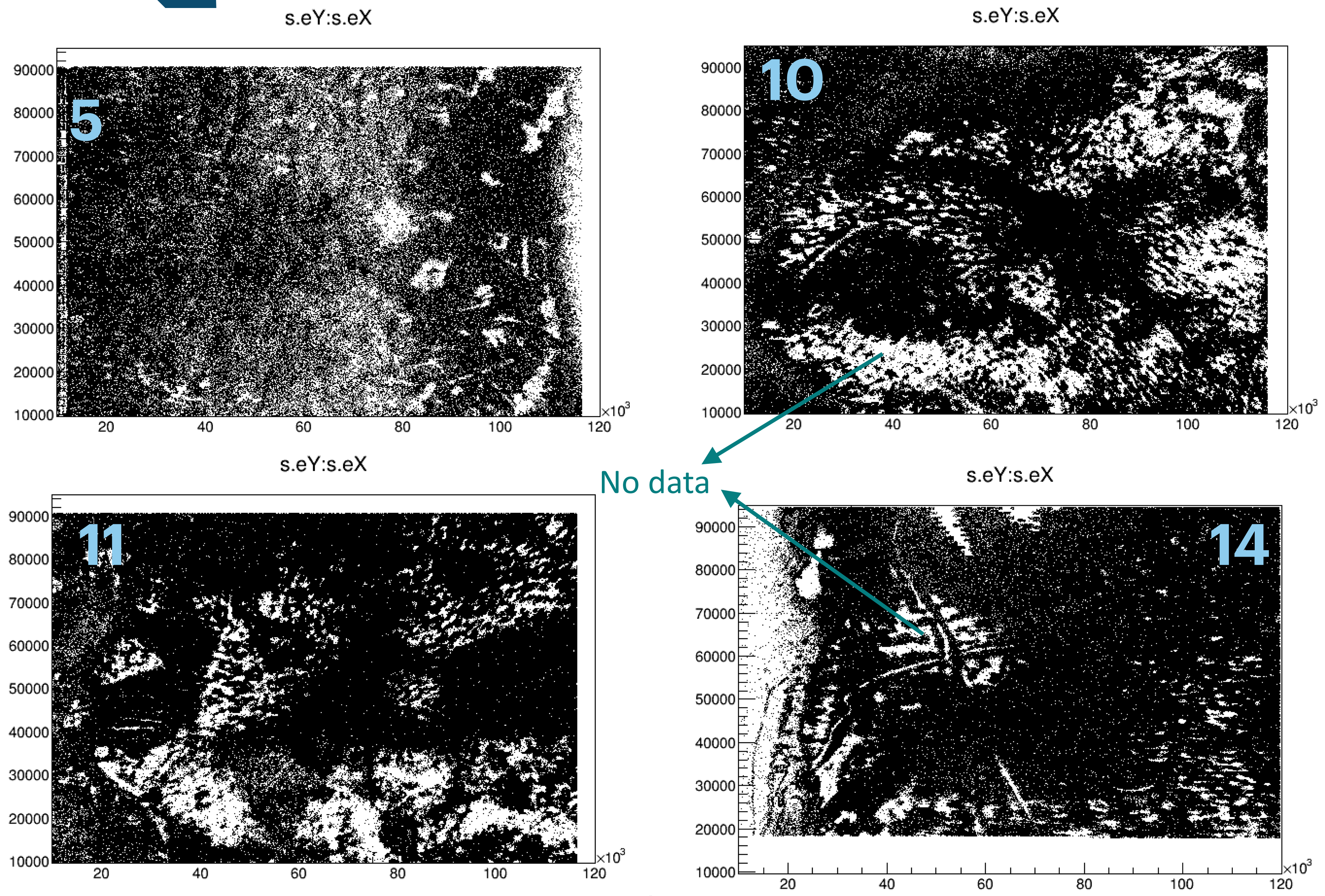
MC RECO vs DATA





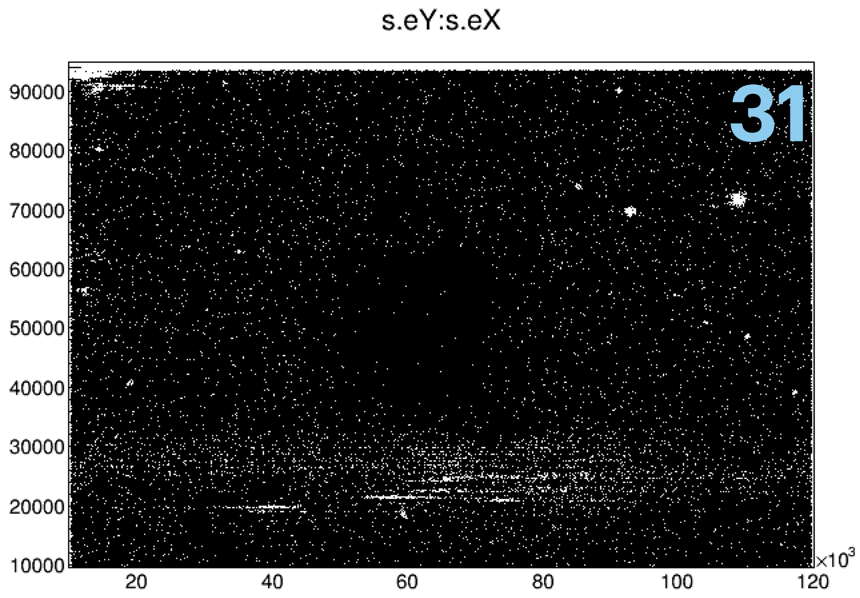
Distributions normalised to beam particles

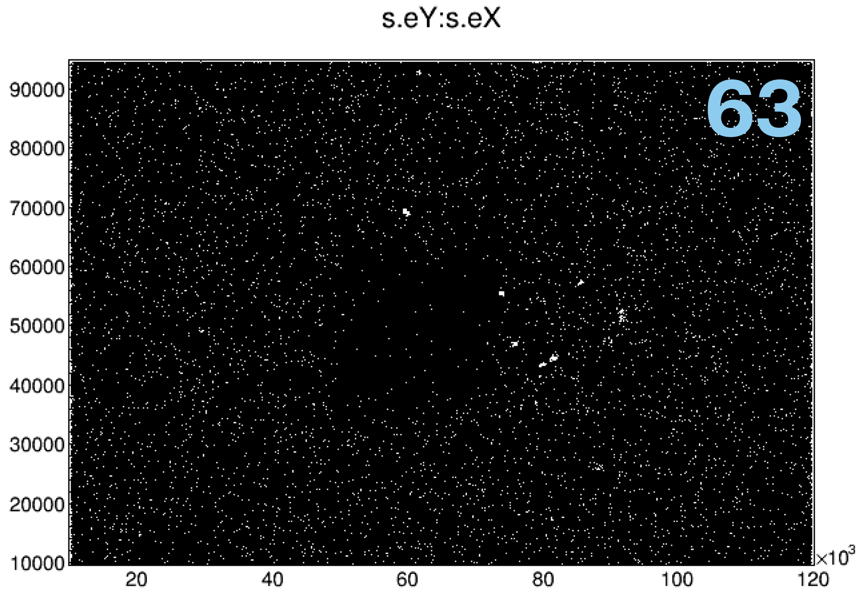
GSI3 - Emulsions Quality Check S1



- Bad emulsions quality for 30% of S1 emulsions
- S1 were made by Slavich company, S2 and following by Nagoya emulsions
- GSI3 and GSI4 batch different from GSI1’ and GSI2’ one
- S1 reconstruction performed without emulsions # 3, 6, 9, 23, 25

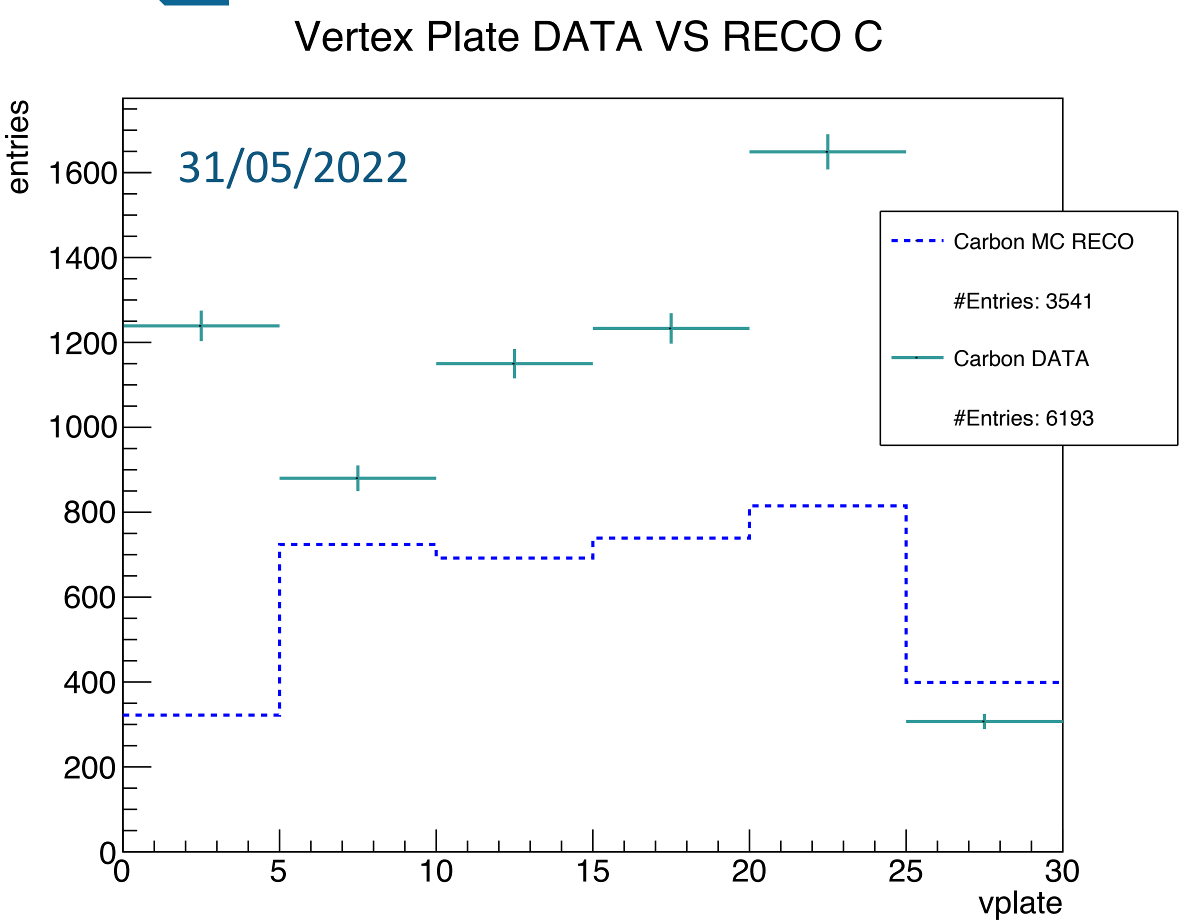
GSI3 - Emulsions Quality Check S2

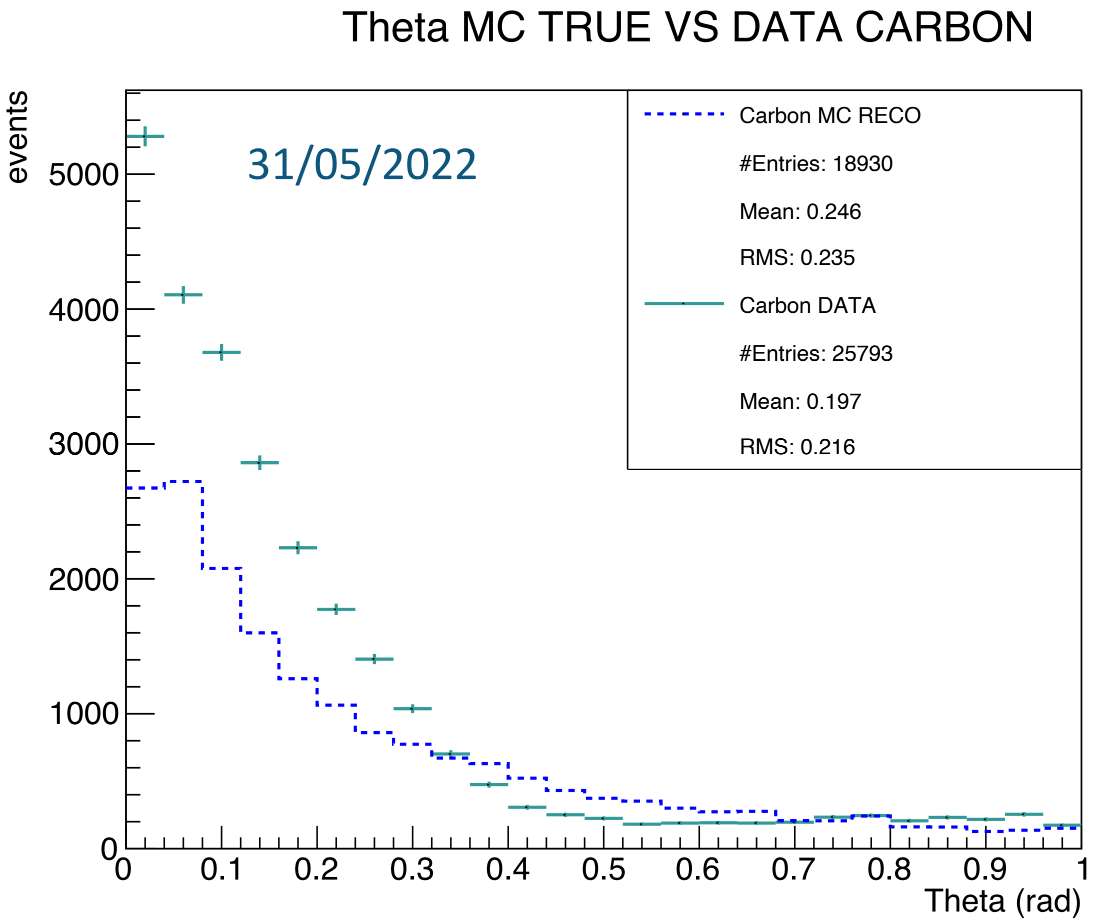




- No problems in S2 (emulsions produced in Nagoya)

GSI3 DATA vs MC RECO Comparison @ XII General Meeting





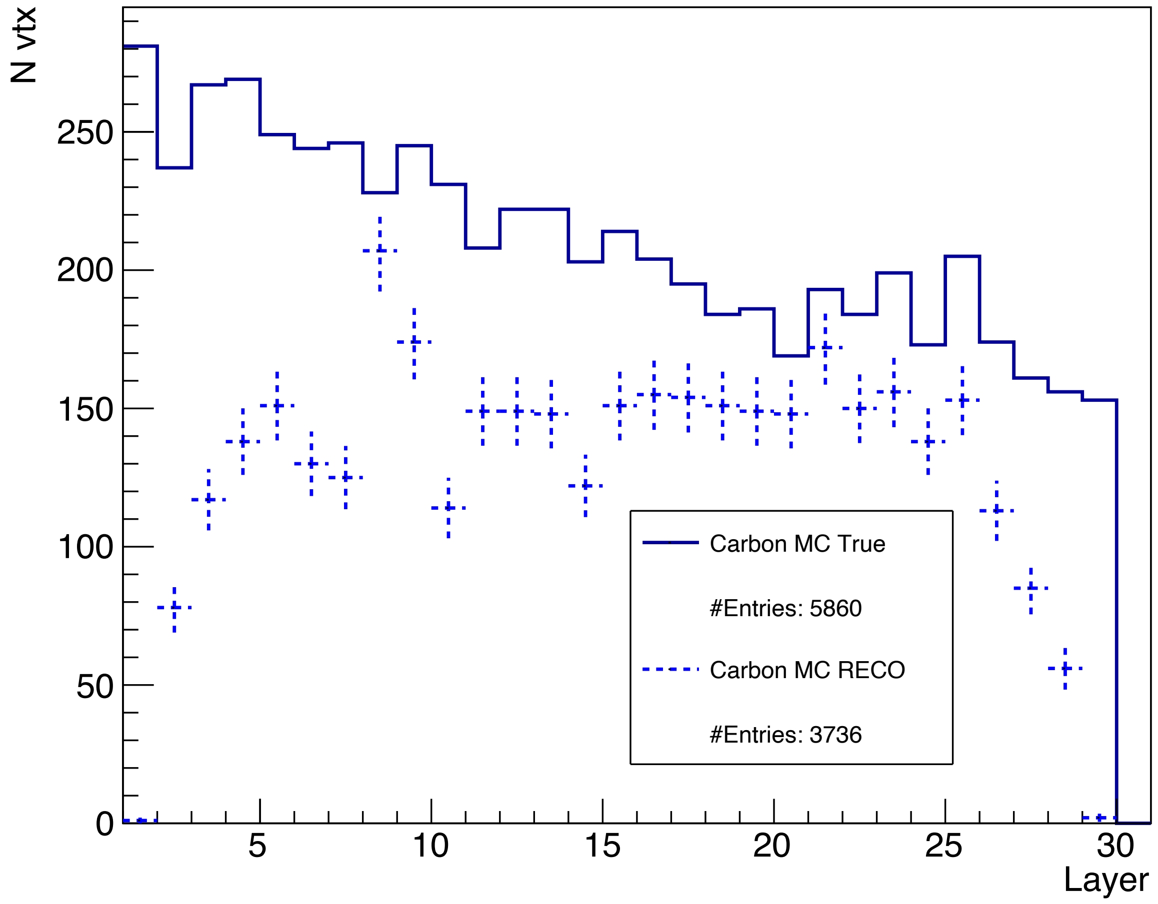
Distributions normalised to beam particles, requirement of at least 3 tracks in the vertex.

In GSI3 (1mm C target) there were several discrepancies between data and reconstructed MC **due to bad quality nuclear emulsions film**

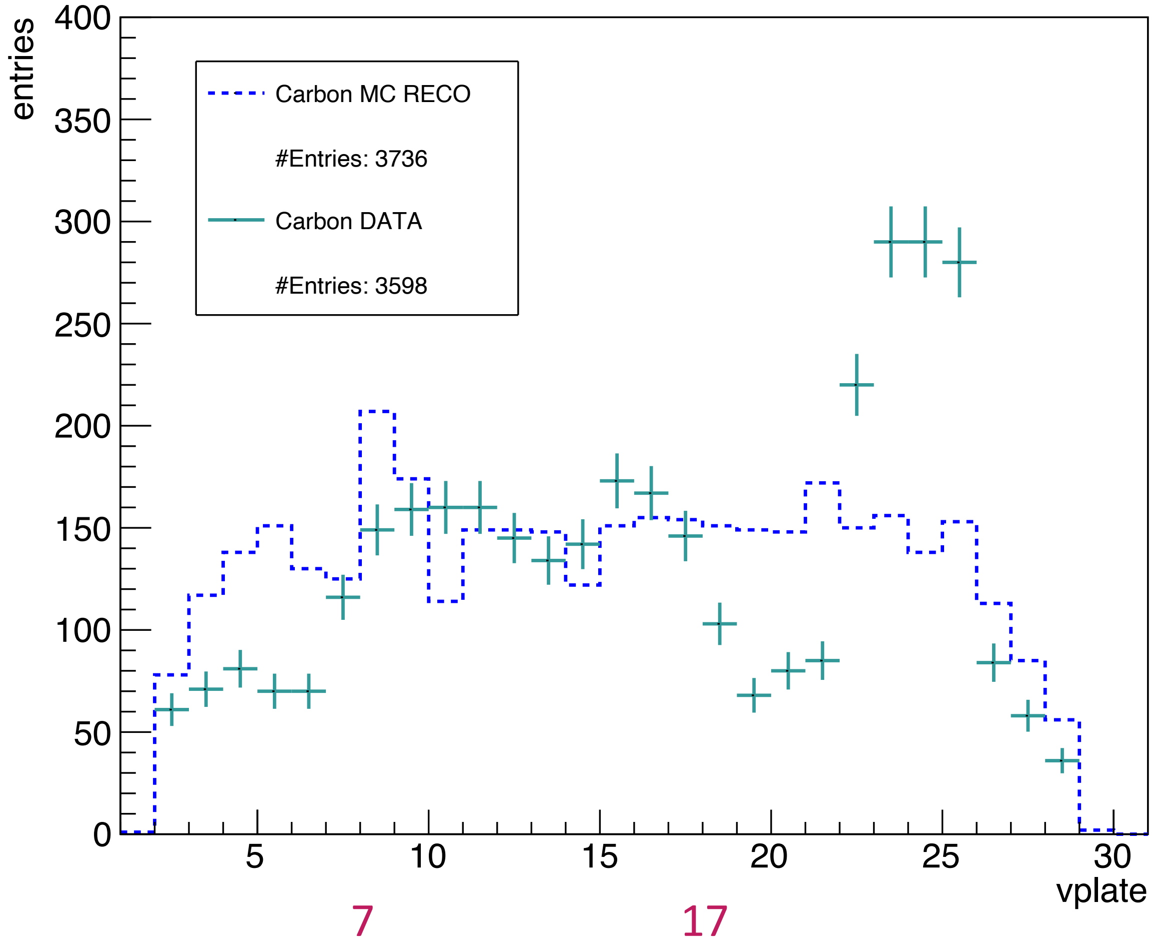
GSI3: Oxy@400 MeV/n on C target

N vertices per layer

MC TRUE vs MC RECO



MC RECO vs DATA

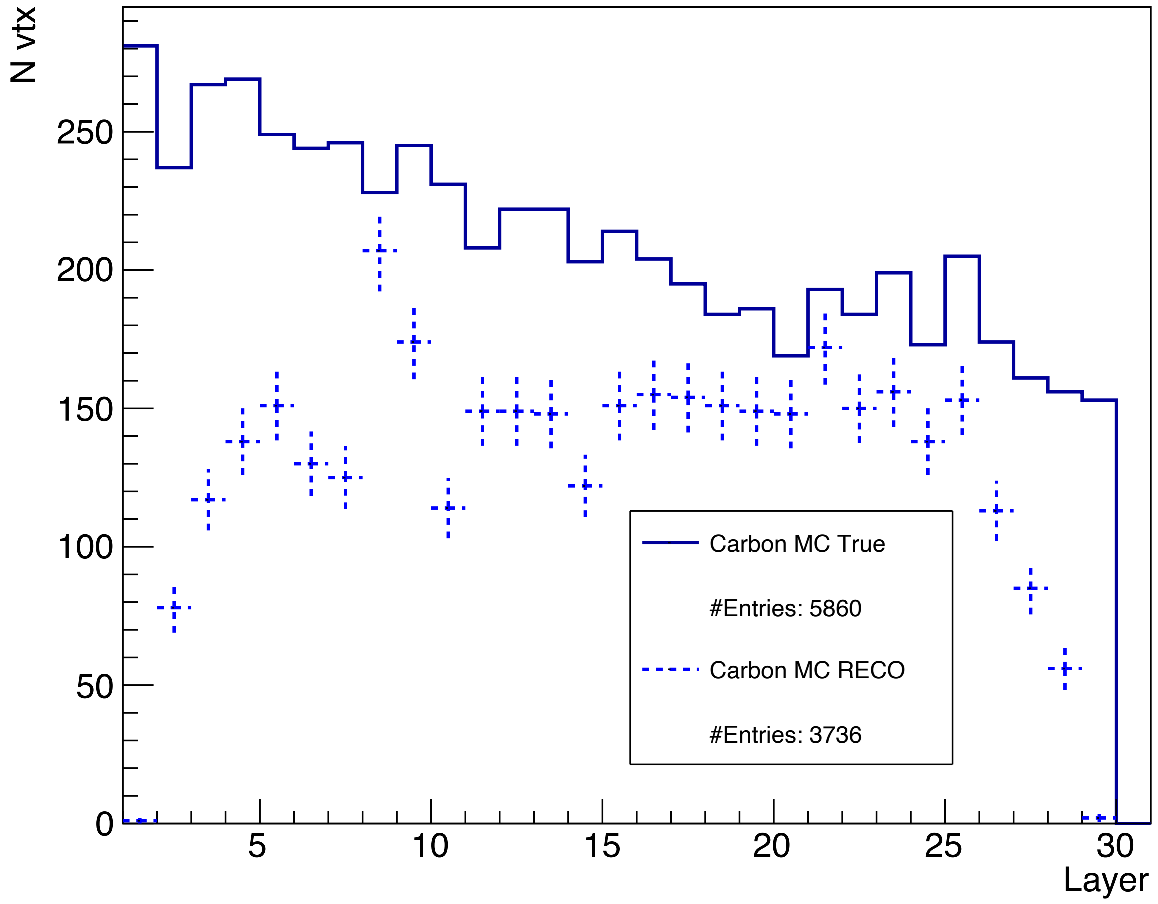


Distributions normalised to beam particles

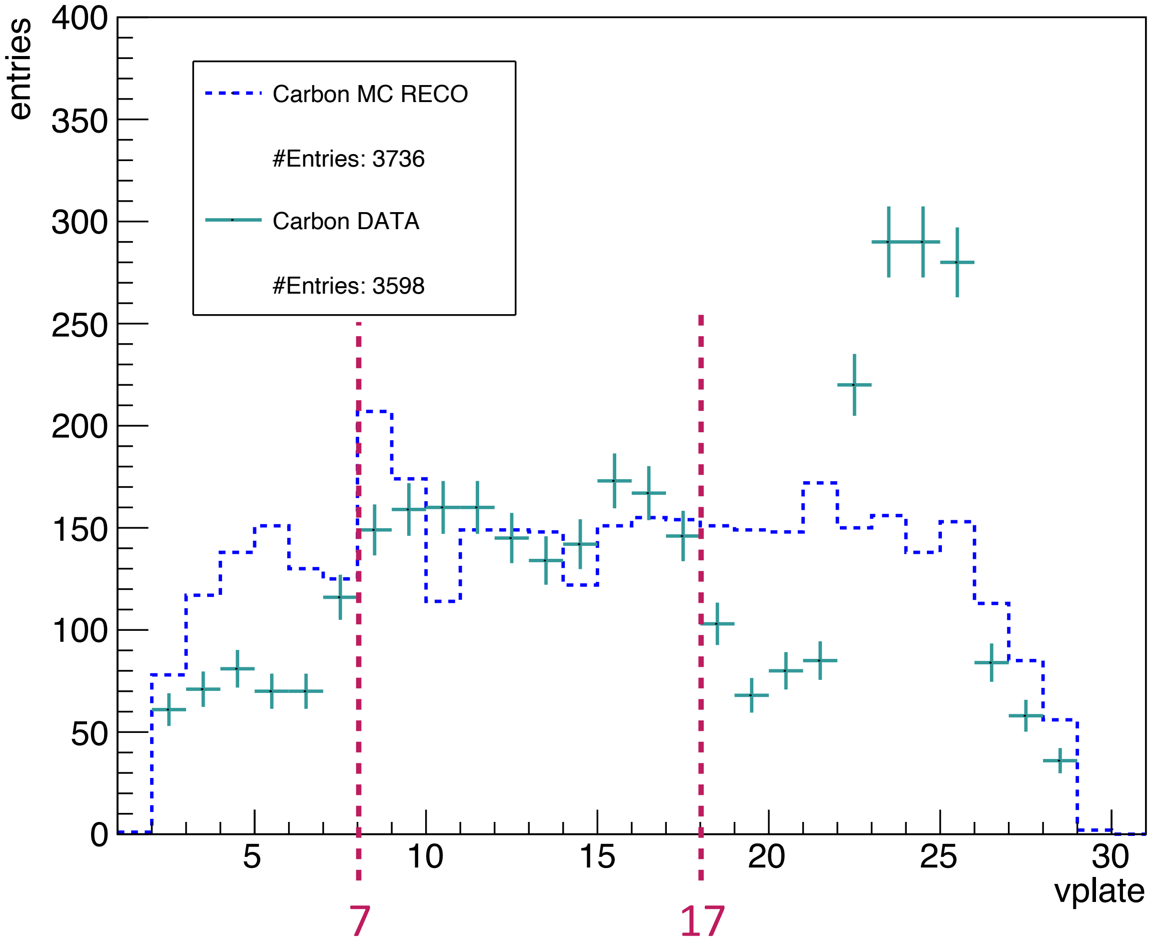
GSI3: Oxy@400 MeV/n on C target

N vertices per layer

MC TRUE vs MC RECO



MC RECO vs DATA

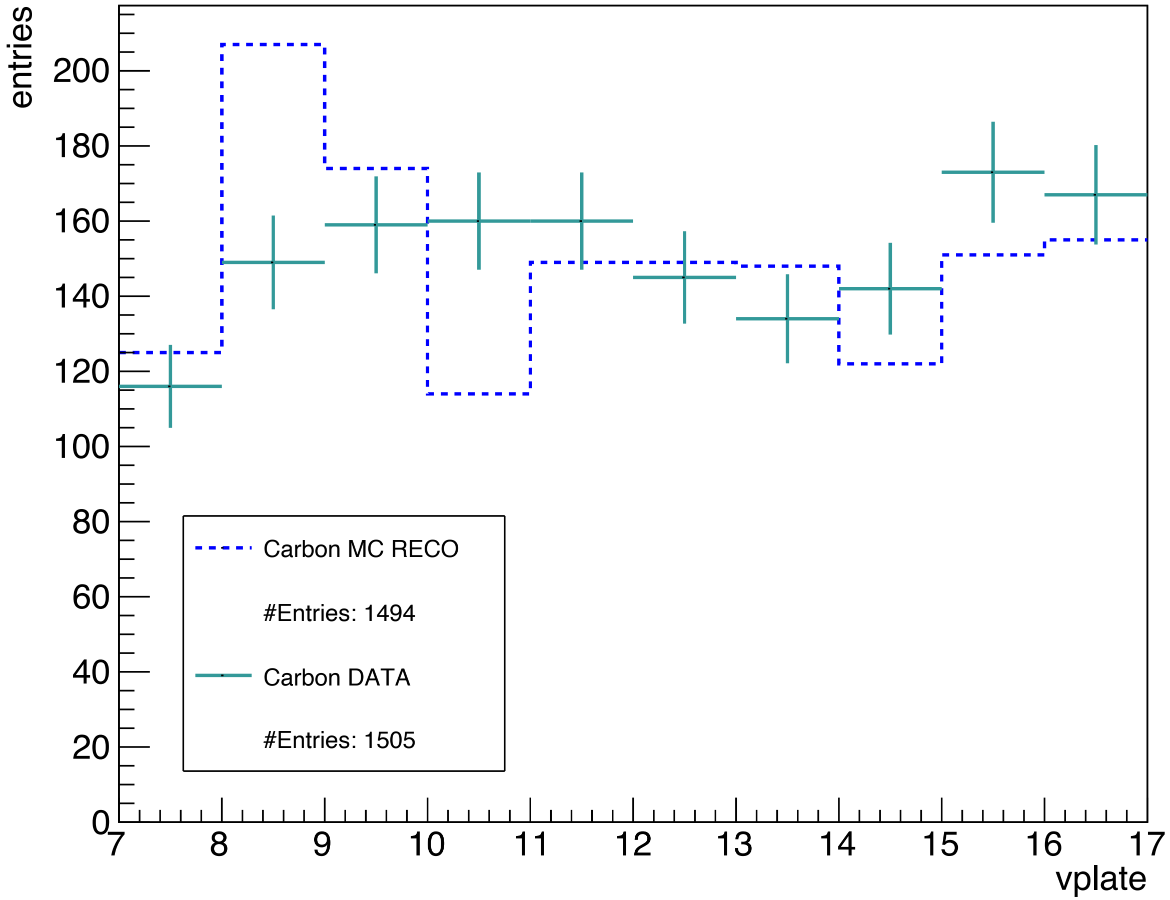


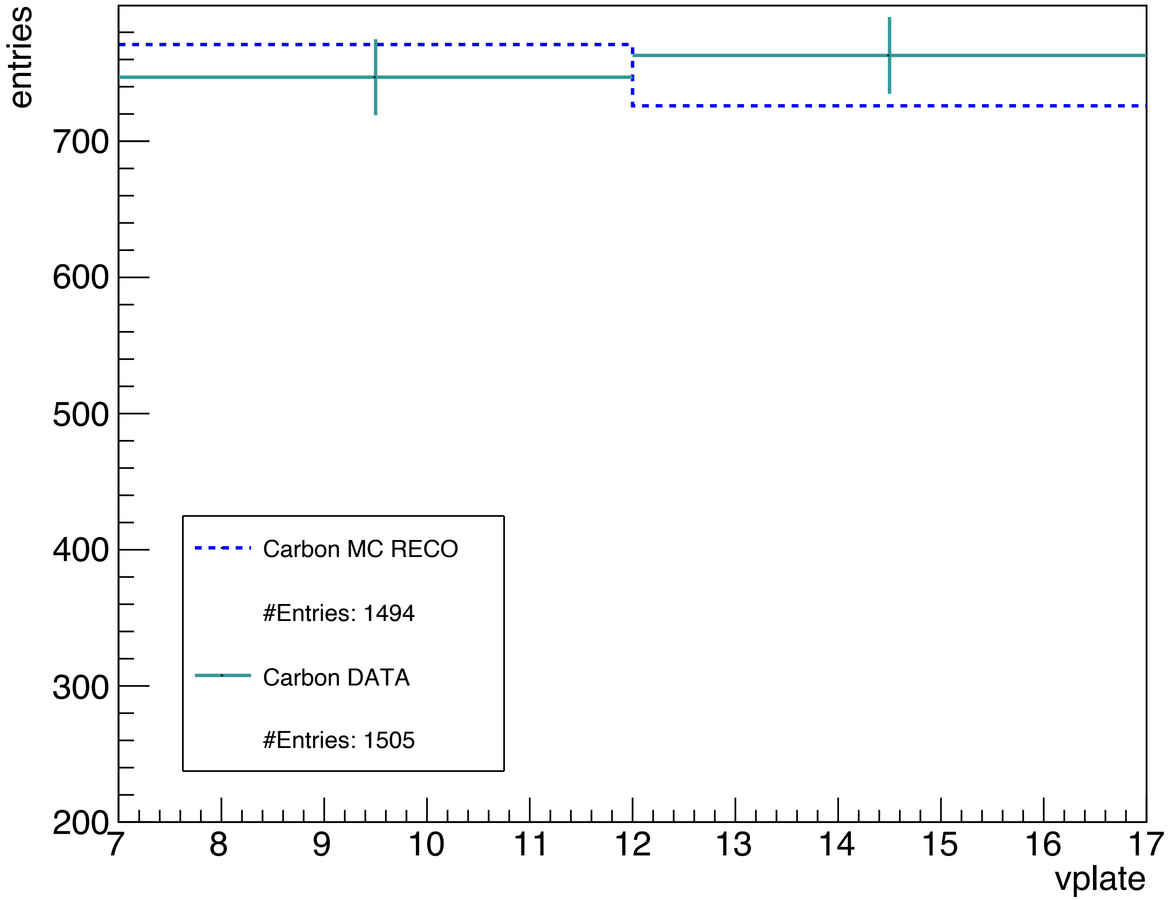
Distributions normalised to beam particles

GSI3: Oxy@400 MeV/n on C target

N vertices per layer

MC RECO vs DATA



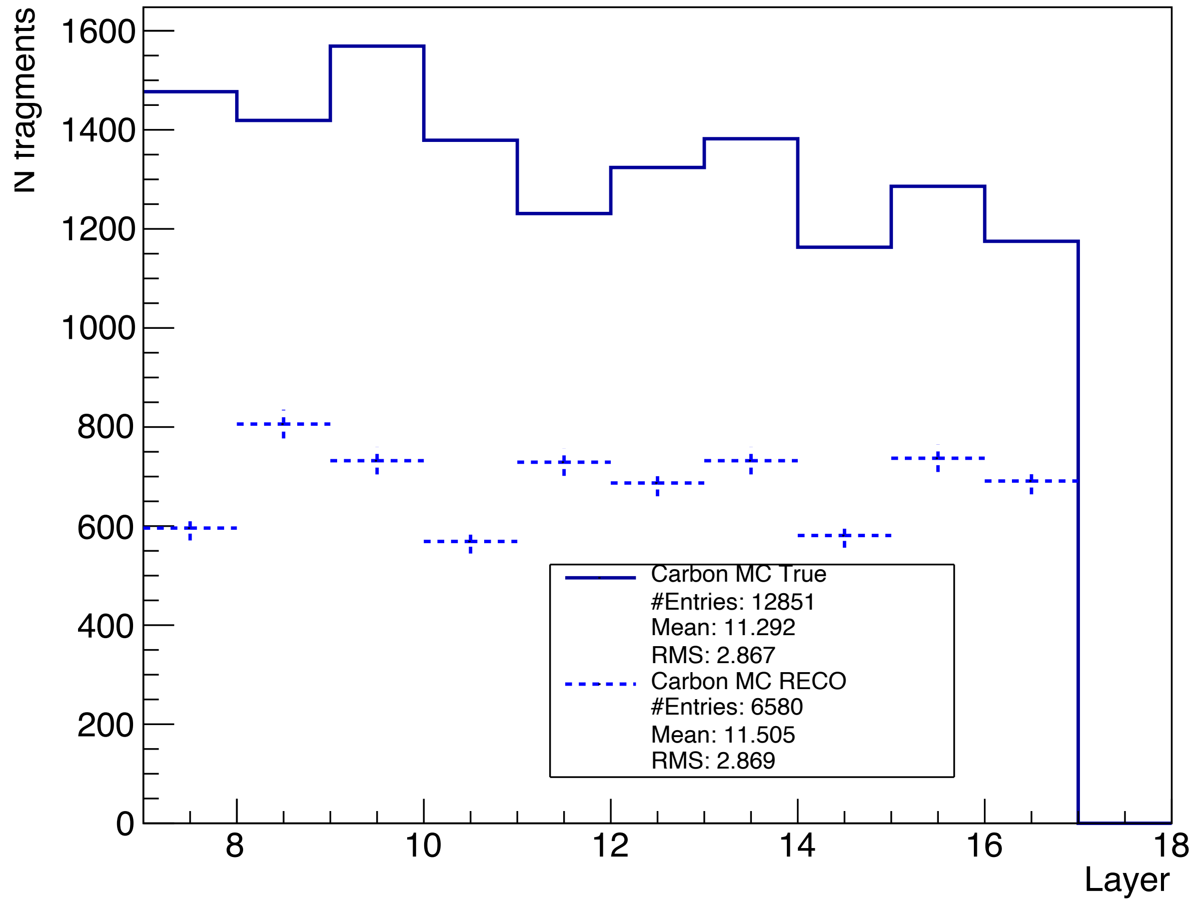


Distributions normalised to beam particles

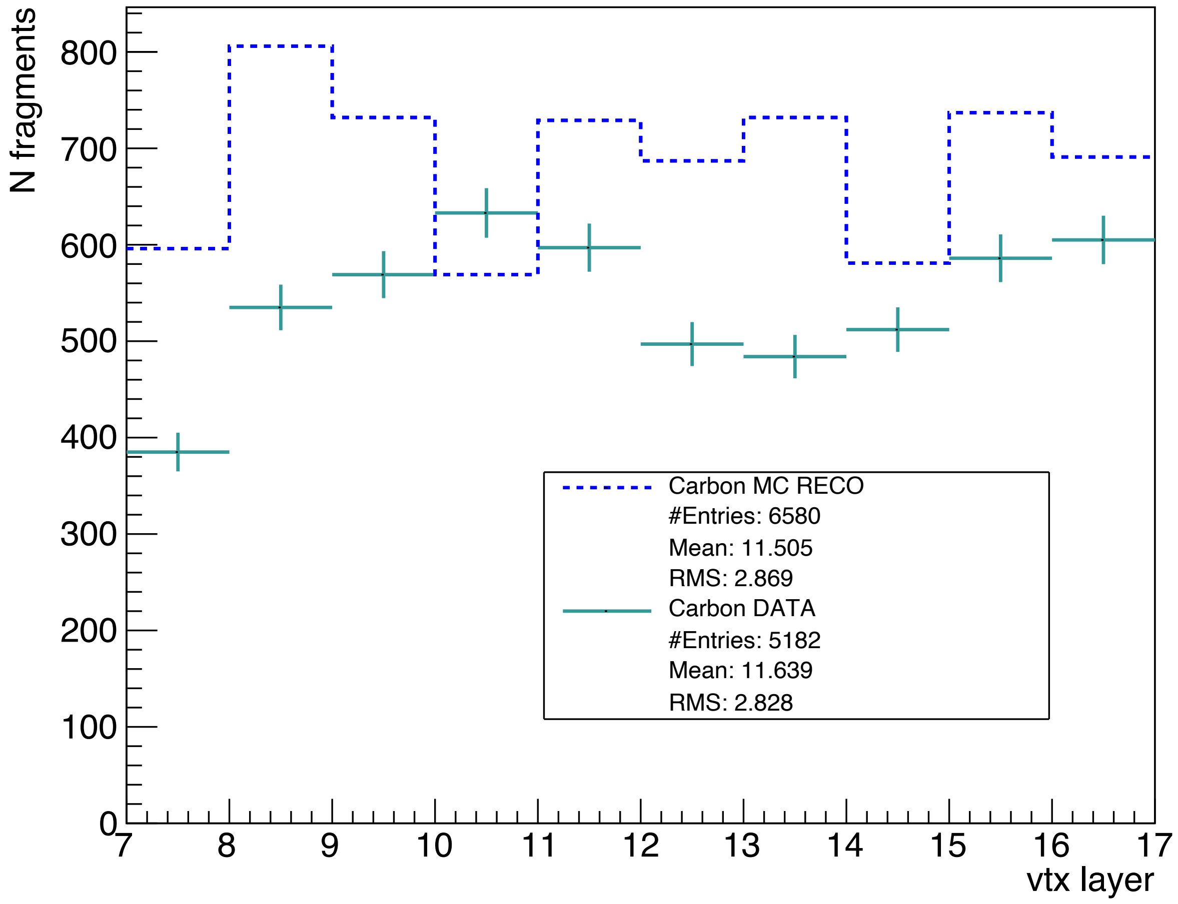
GSI3: Oxy@400 MeV/n on C target

N fragments per layer

MC TRUE vs MC RECO



MC RECO vs DATA

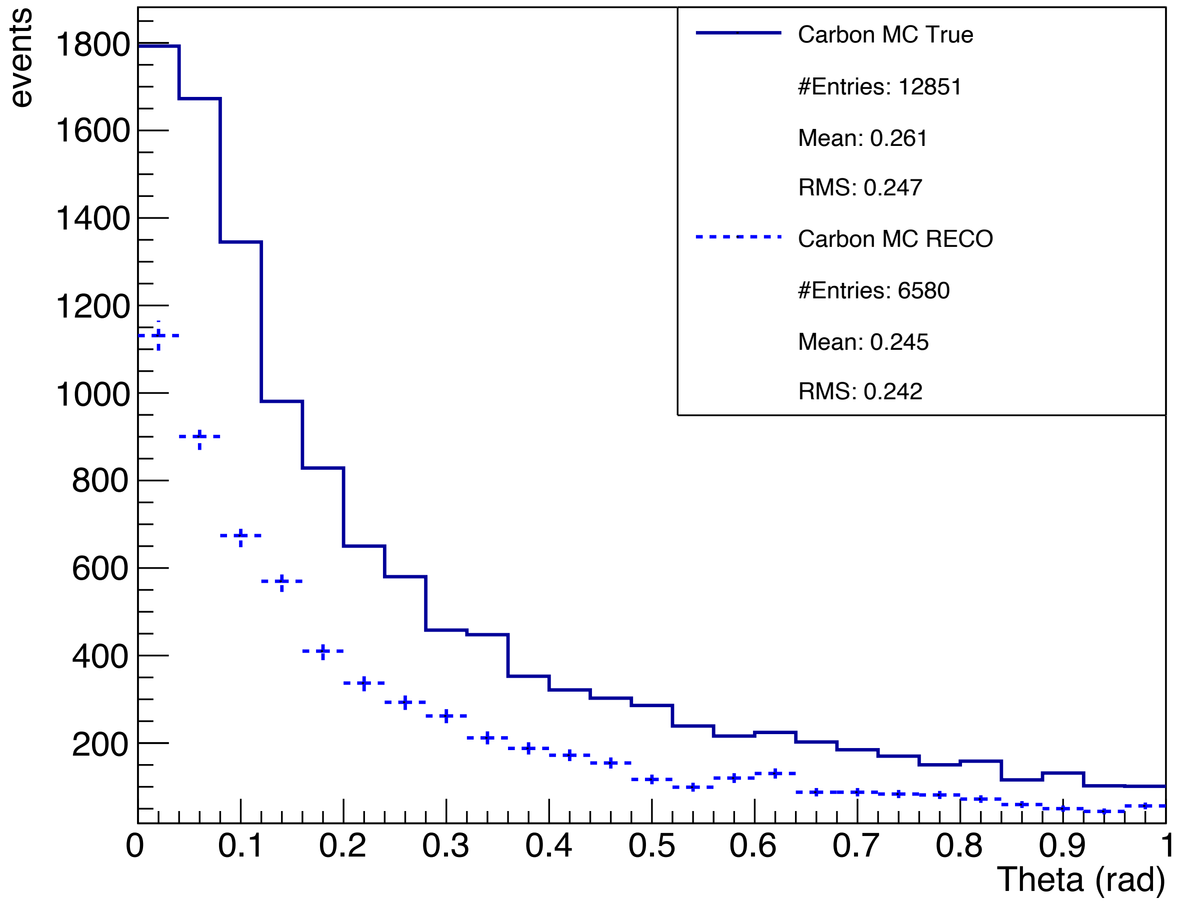


Distributions normalised to beam particles

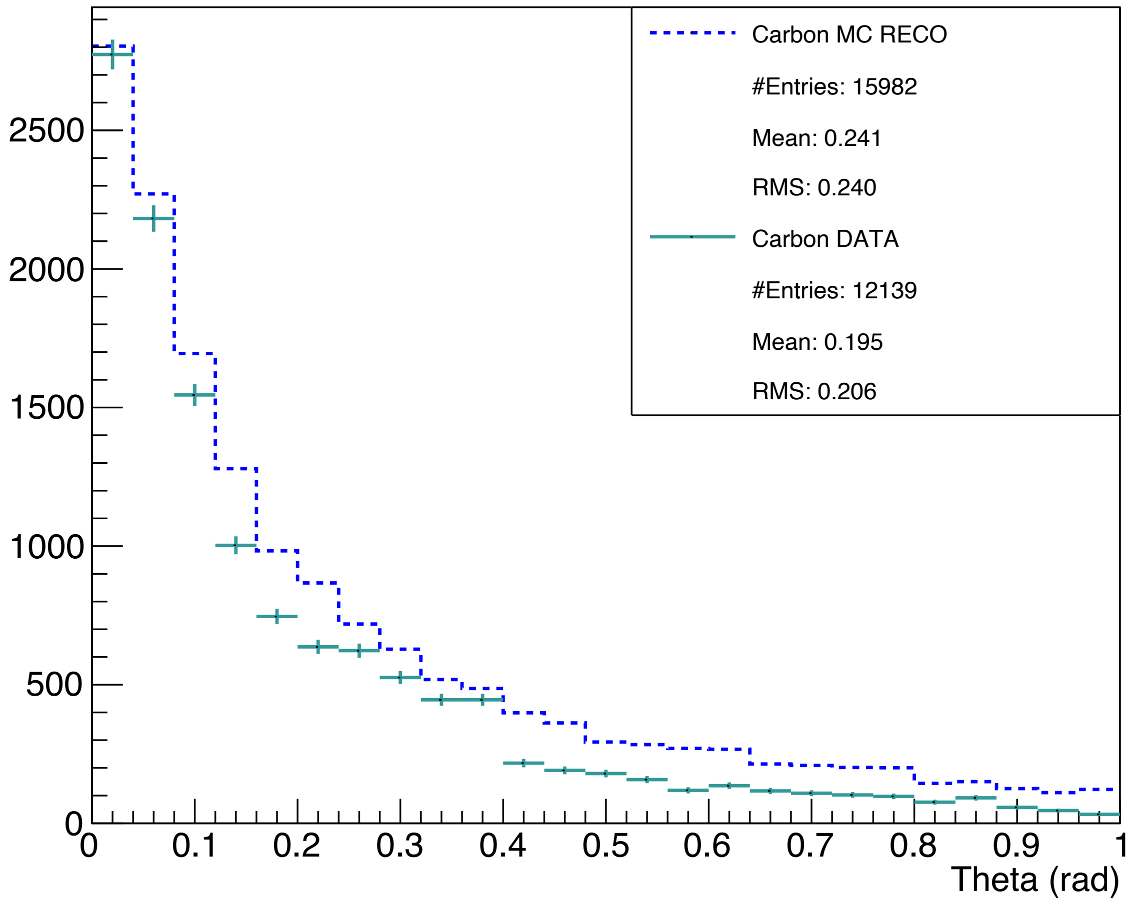
GSI3: Oxy@400 MeV/n on C target

N fragments per layer

MC TRUE vs MC RECO



MC RECO vs DATA

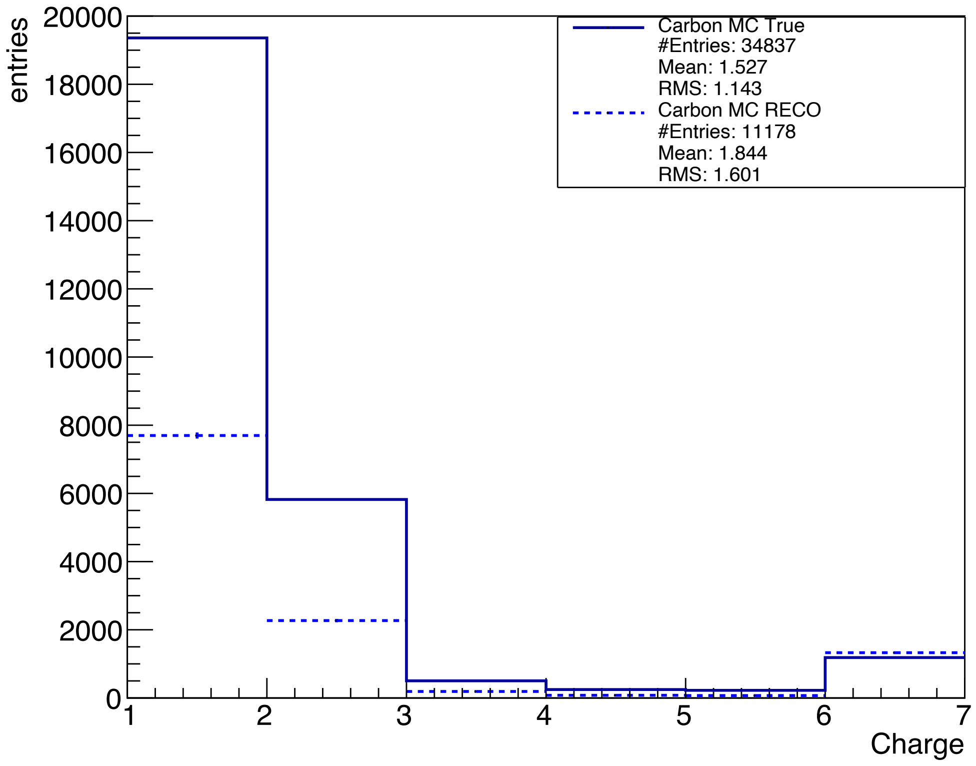


Distributions normalised to beam particles

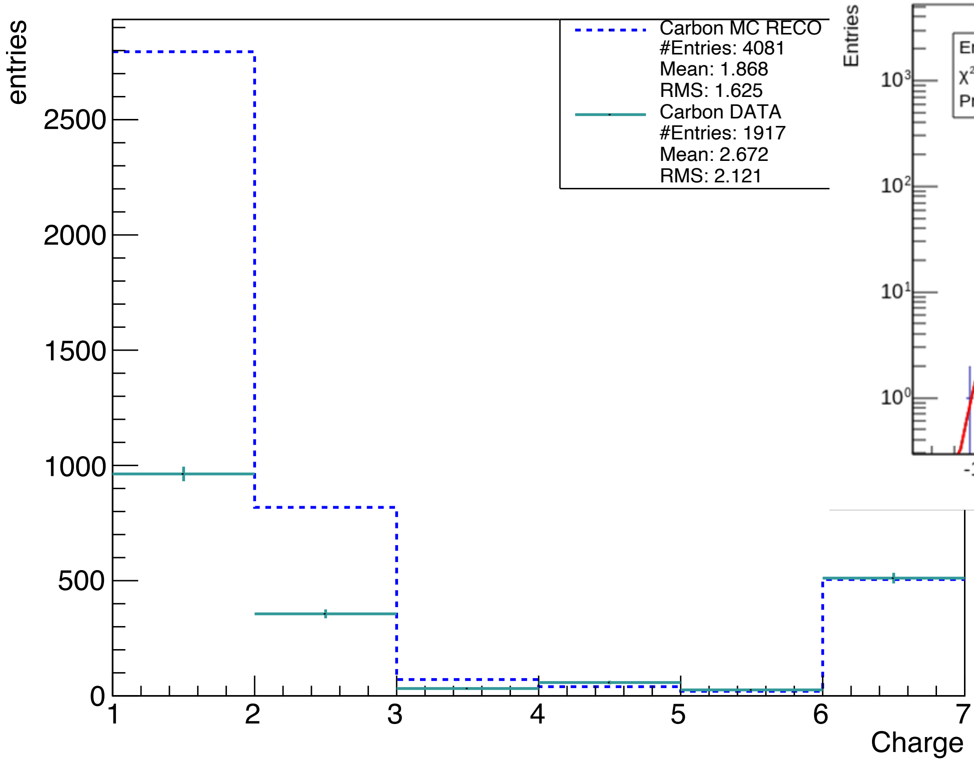
GSI3: Oxy@400 MeV/n on C target

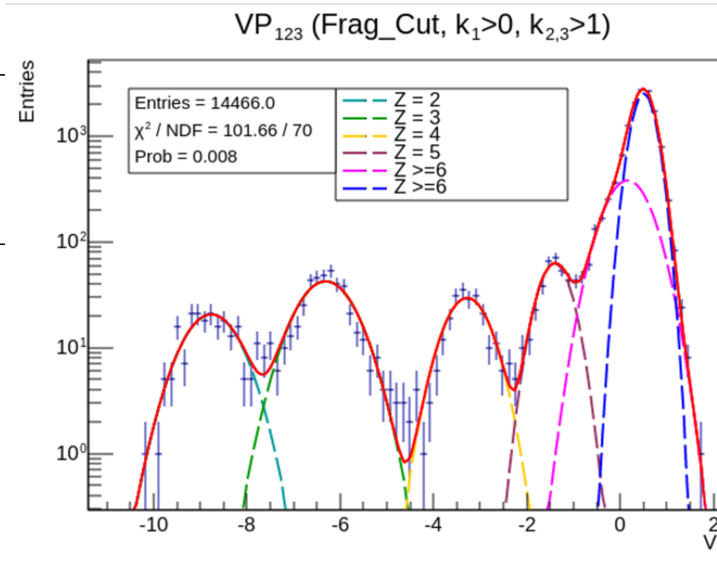
MC TRUE vs MC RECO

MC TRUE vs MC RECO



MC RECO vs DATA



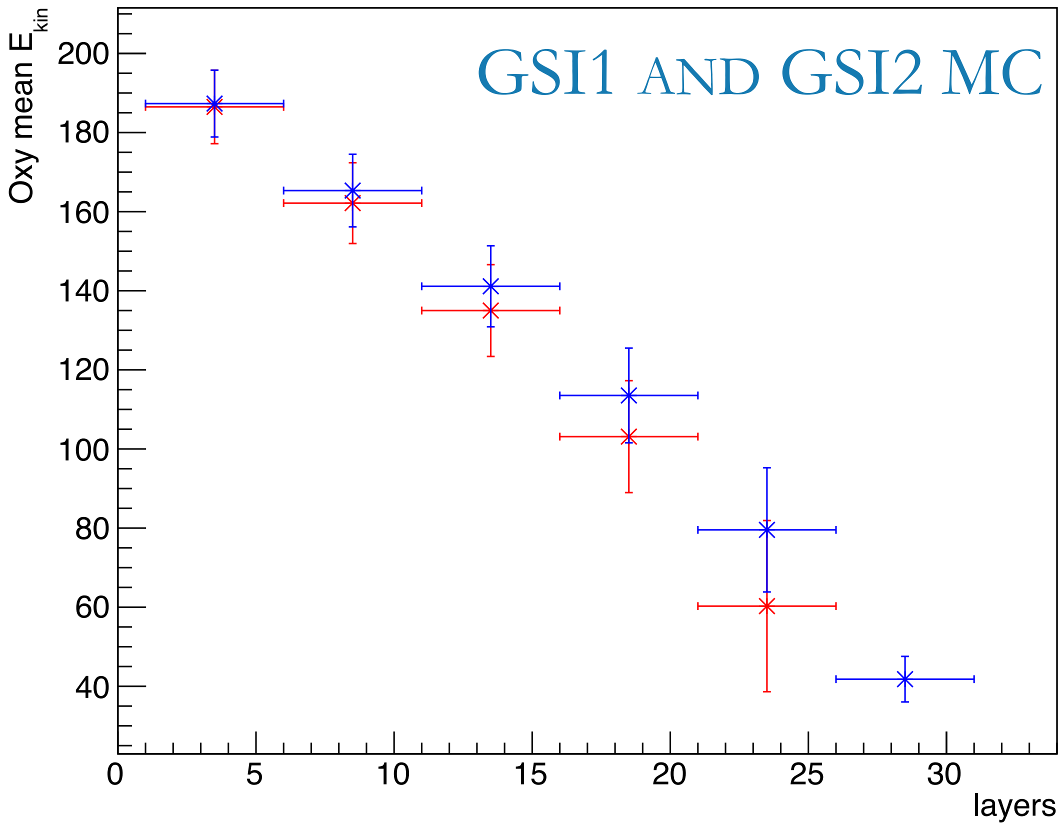


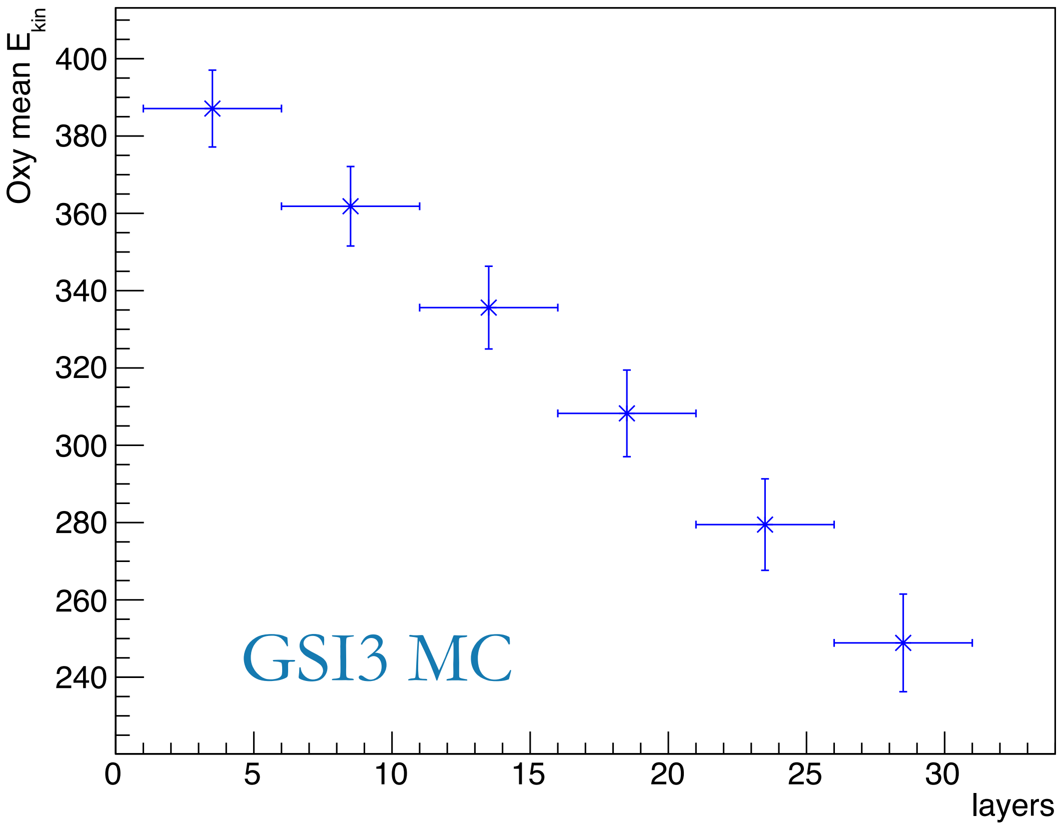
Distributions normalised to beam particles

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:
    $A_C = 12 g/mol$
    $A_{C2H4} = 28 g/mol$
    $A_H = 1 g/mol$
- Δx = x bin
- ϵ^i_{reco} = reconstruction efficiency

The problem of N_B evaluation

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

G. De Lellis et al. / Nuclear Physics A 853 (2011) 124–134

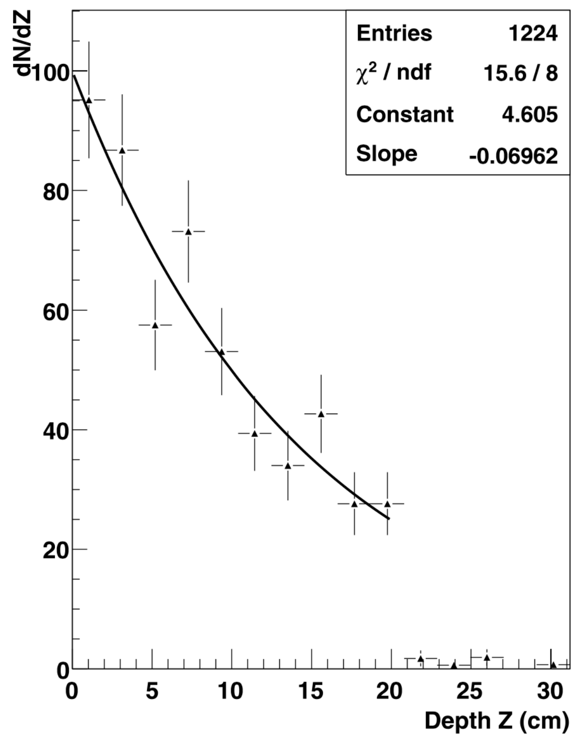
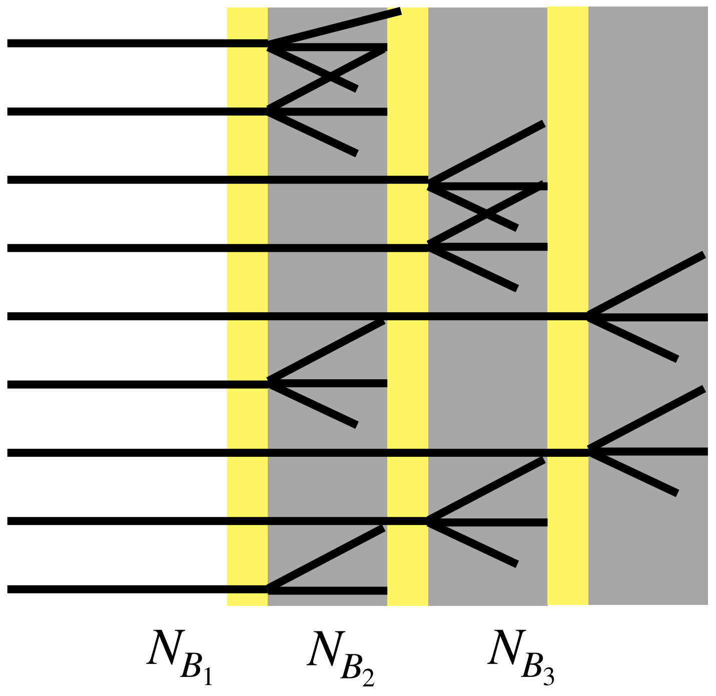
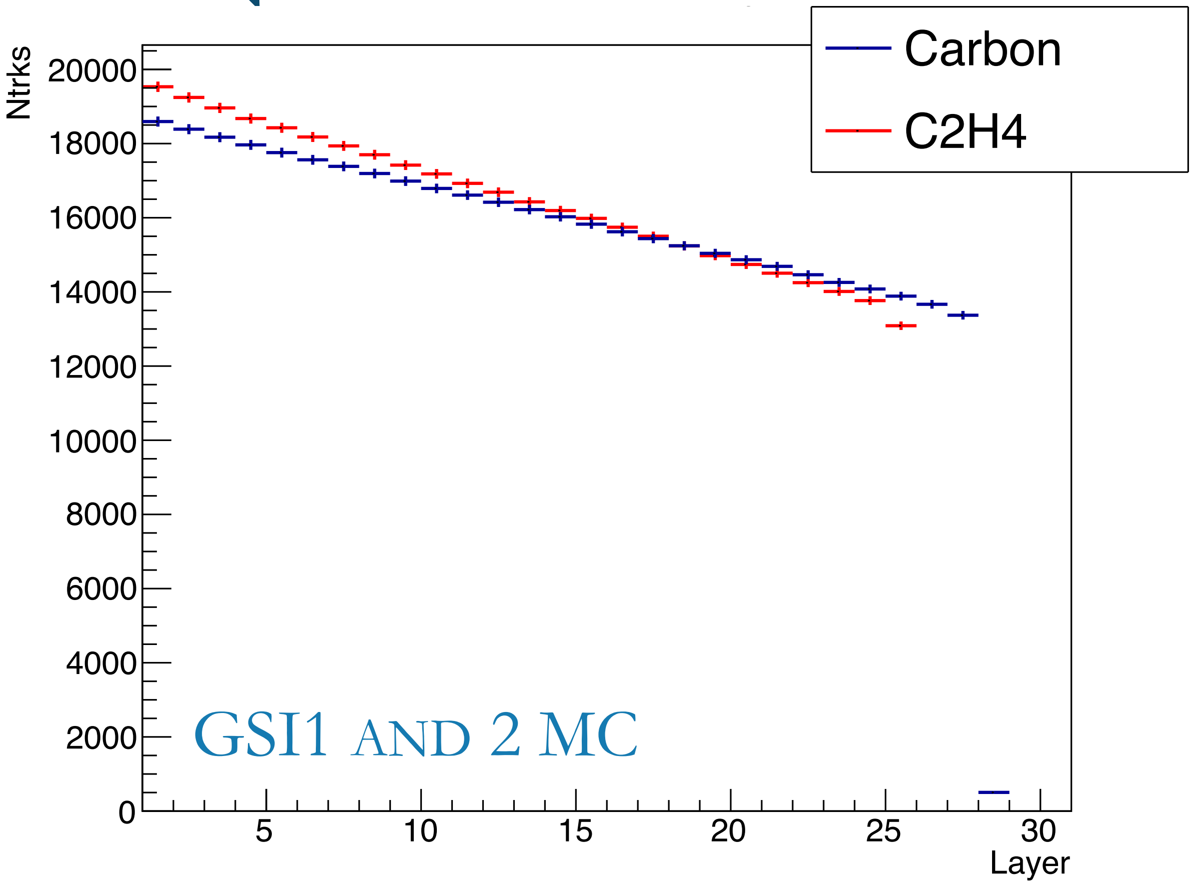


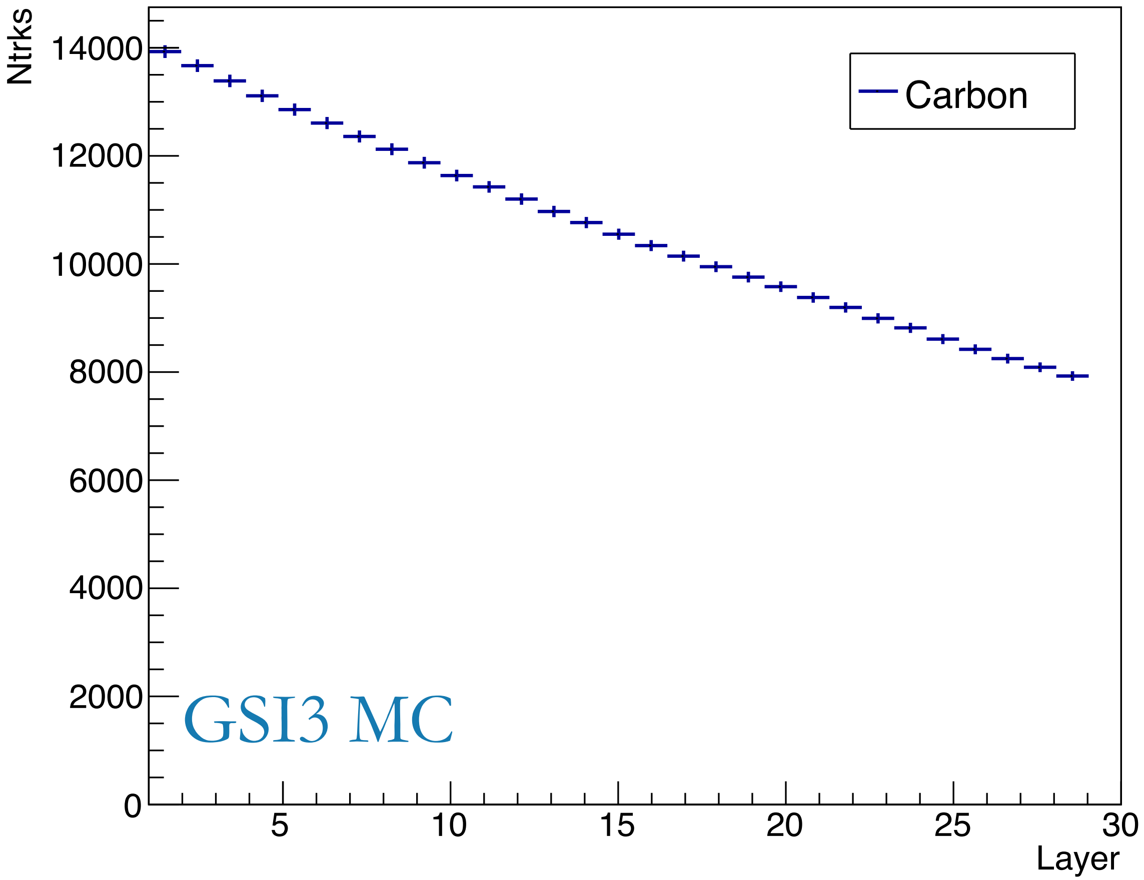
Fig. 2. Fraction of the remnant Carbon beam as a function of the traversed ECC material.



- 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
- This efficiency has not been taken into account at present
- We'll try to estimate it from data (as done in previous publications) or through other methods

The problem of N_B evaluation

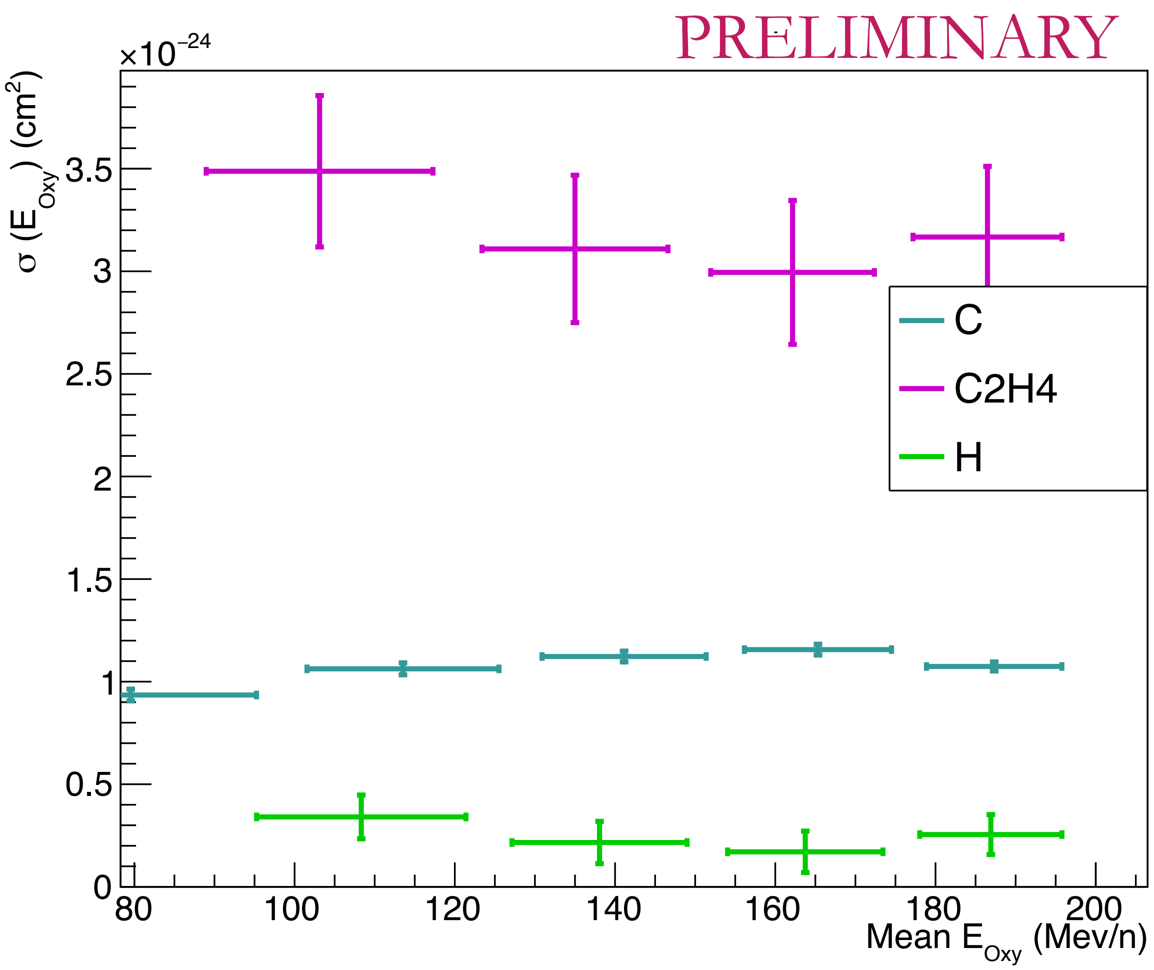




Integrated cross section Oxy@200MeV/n

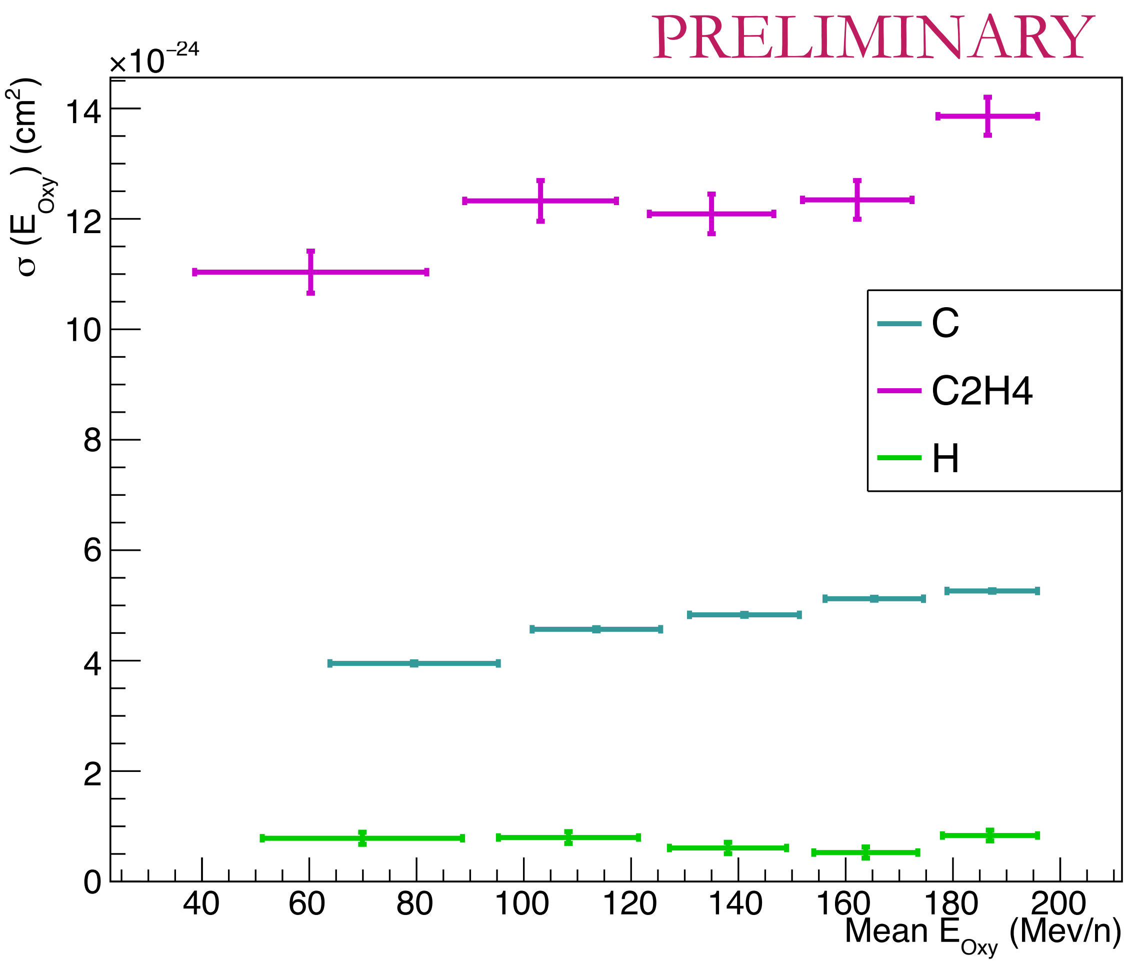
DATA

Total reaction cross section



$Y_i = \#$ of vertices

Total production cross section



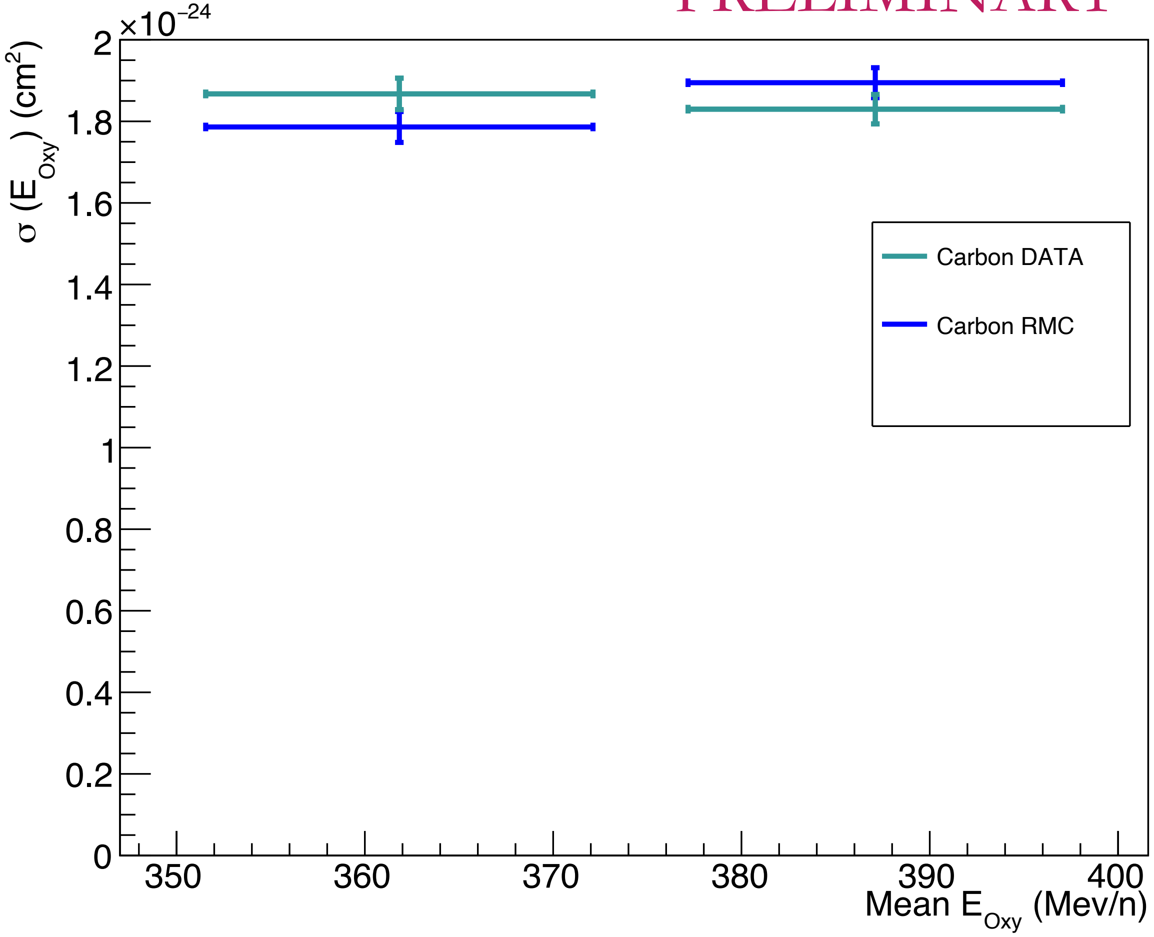
$Y_i = \#$ of fragments

Integrated cross section Oxy@400MeV/n

MC RECO vs DATA

Total reaction cross section

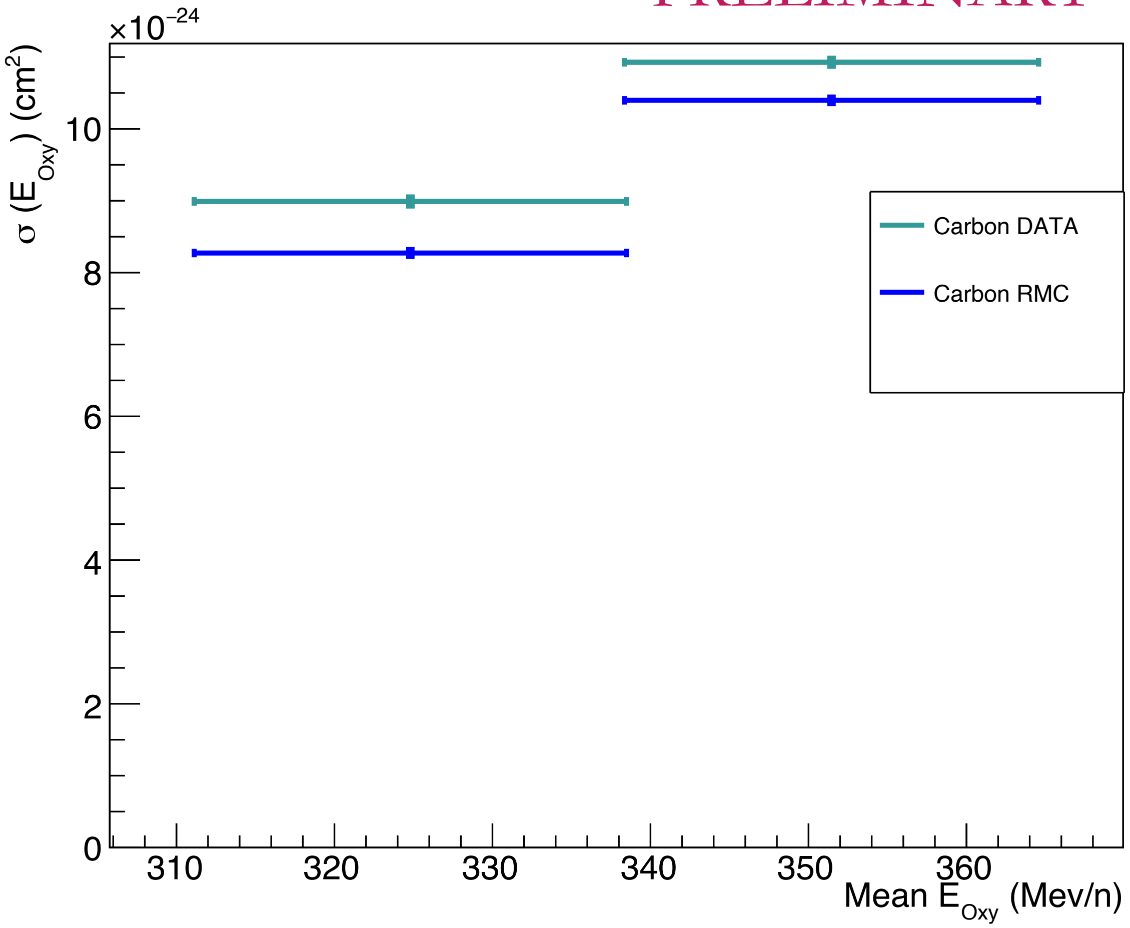
PRELIMINARY



$Y_i = \#$ of vertices

Total production cross section

PRELIMINARY



$Y_i = \#$ of fragments

Conclusions

- Several improvements on vertices reconstruction, merging procedure between different sections, charge evaluation.

Oxygen @ 200 MeV/n on C

- Reconstruction of vertices completed
- Charge measurement completed (a publication is in program with S2 stand alone, as for GSI2)
- Connection between Sections still to be improved

Oxygen @ 400 MeV/n on C

- Bad emulsions quality: efforts made to recover data reconstruction.
- Partial reconstruction without 5 nuclear emulsions films
- Data reconstruction on-going: preliminary results are encouraging (especially for 10 films)

THANK YOU!

BACK UP SLIDES

Number of reconstructed vertices

		GSI1 C target	GSI2 C2H4 target	GSI3 C target
MC	Beam particles	18990	19988	14375
	True vertices	3547	5403	5860
	Reco vertices	3140	4624	3591
DATA	Beam particles	19375	20625	14375
	Data vertices	3519	4686	3462

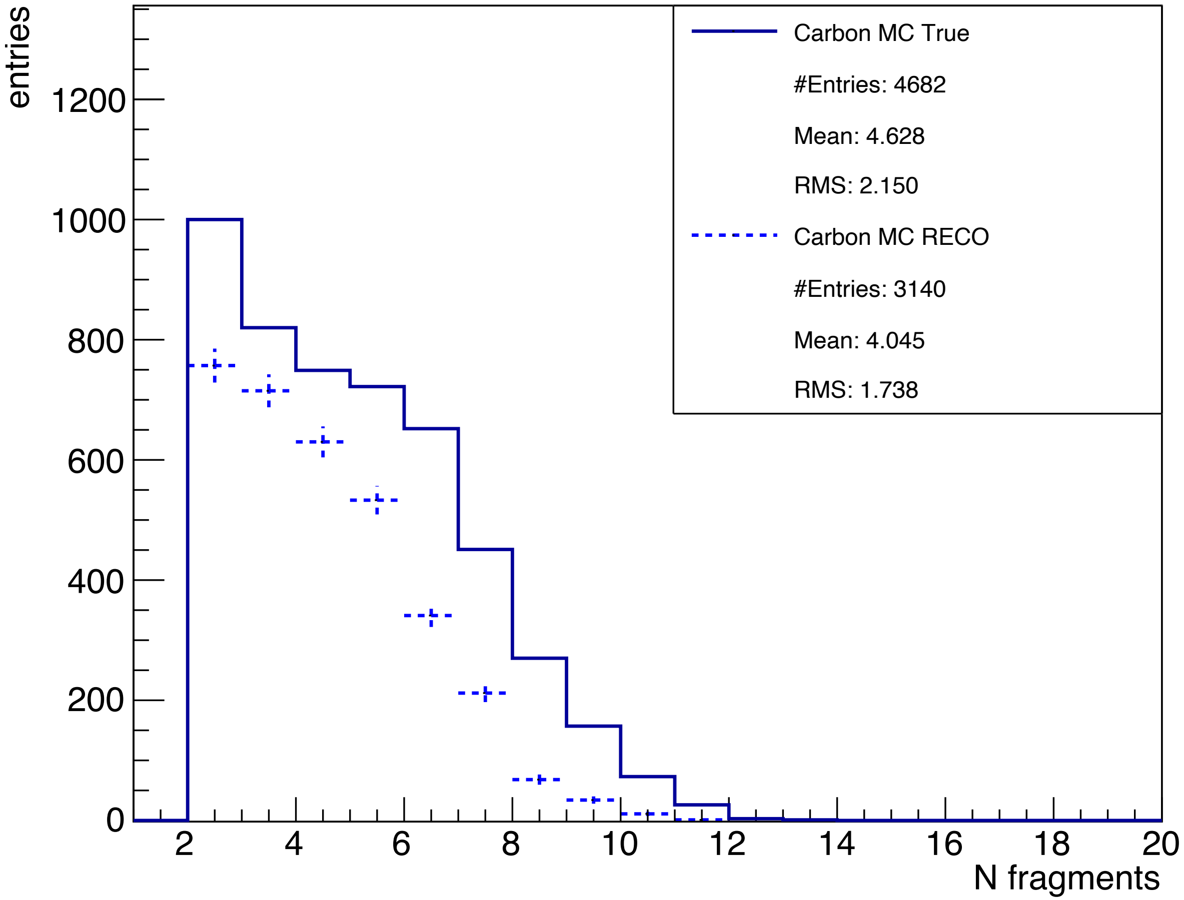
Cuts for vertices selection:

- $n \geq 3$, n = number of tracks (parent + daughters)
- At least 2 daughters with at least 3 segments

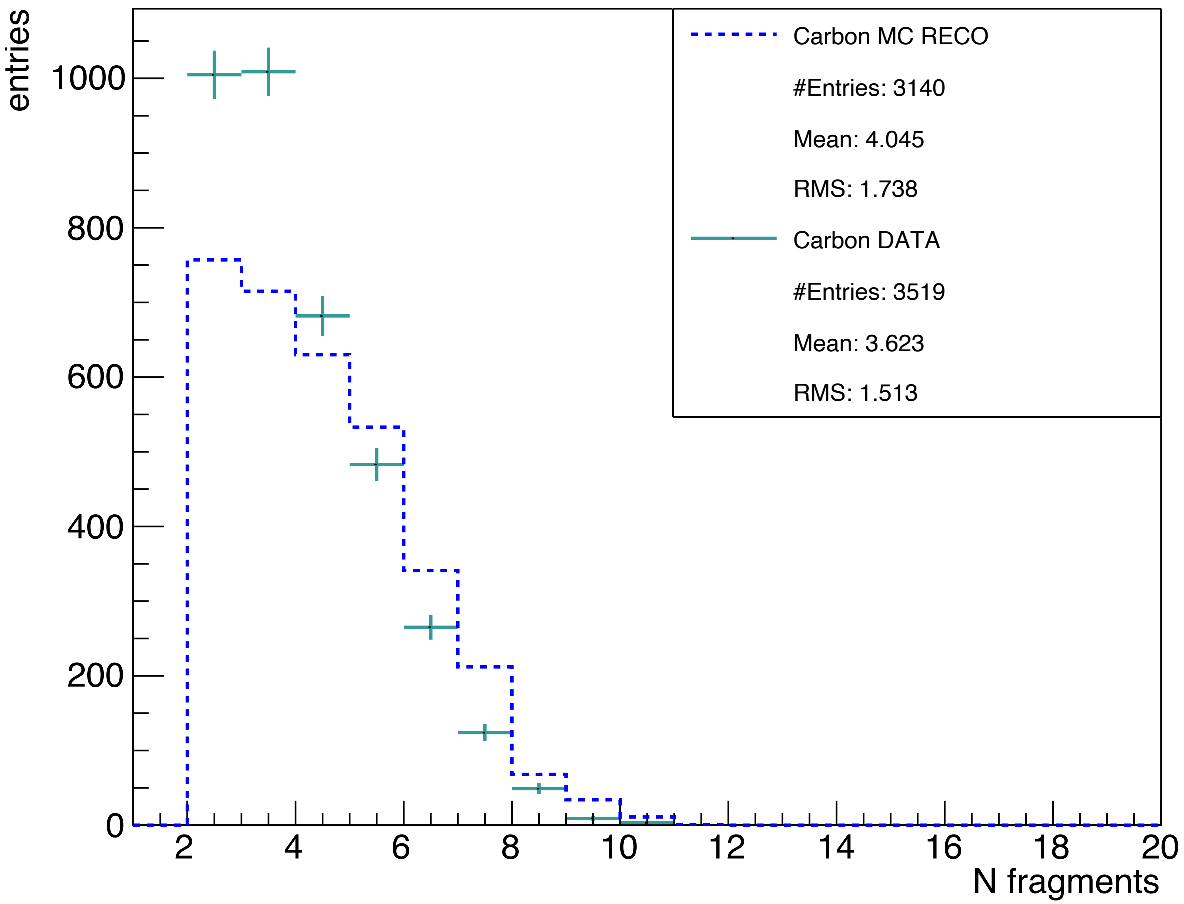
GSI1: Oxy@200 MeV/n on C target

Fragments' Multiplicity

MC TRUE vs MC RECO



MC RECO vs DATA

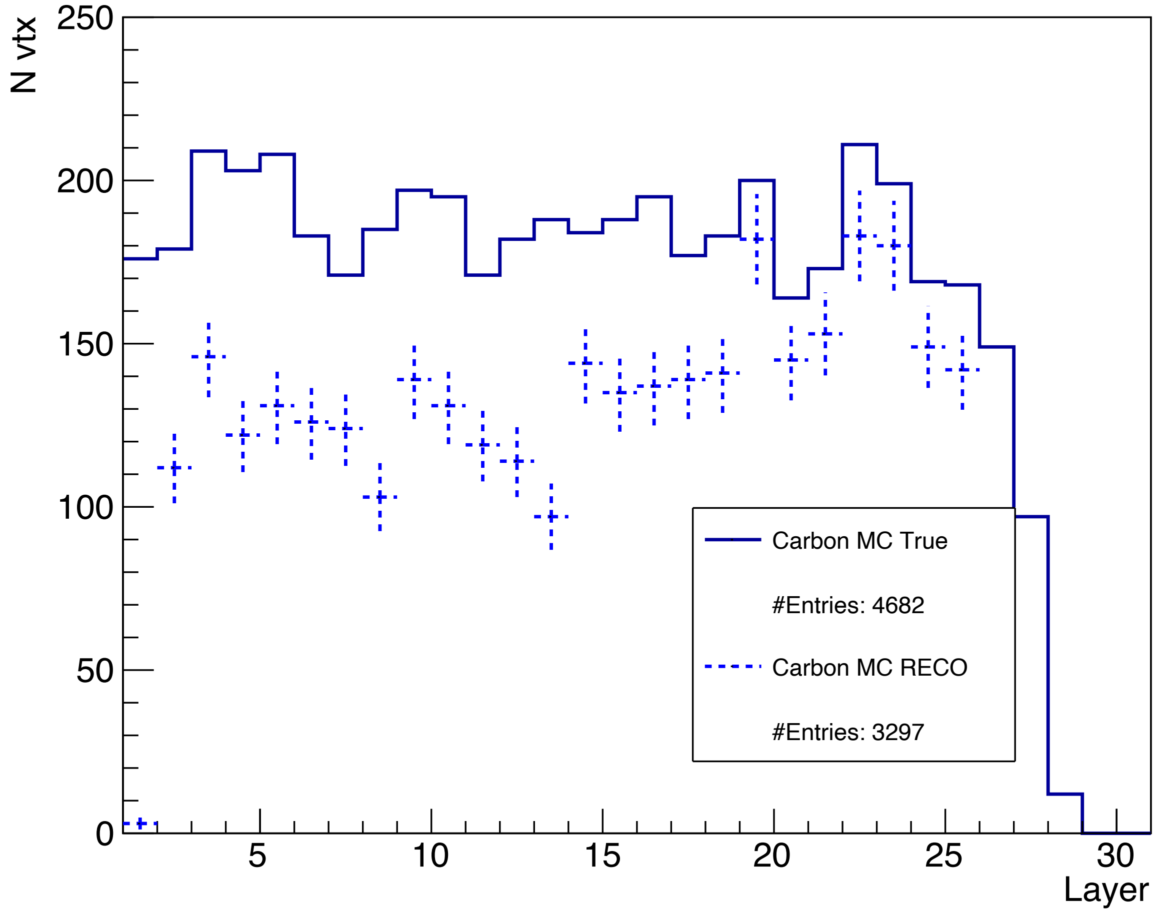


Distributions normalised to beam particles

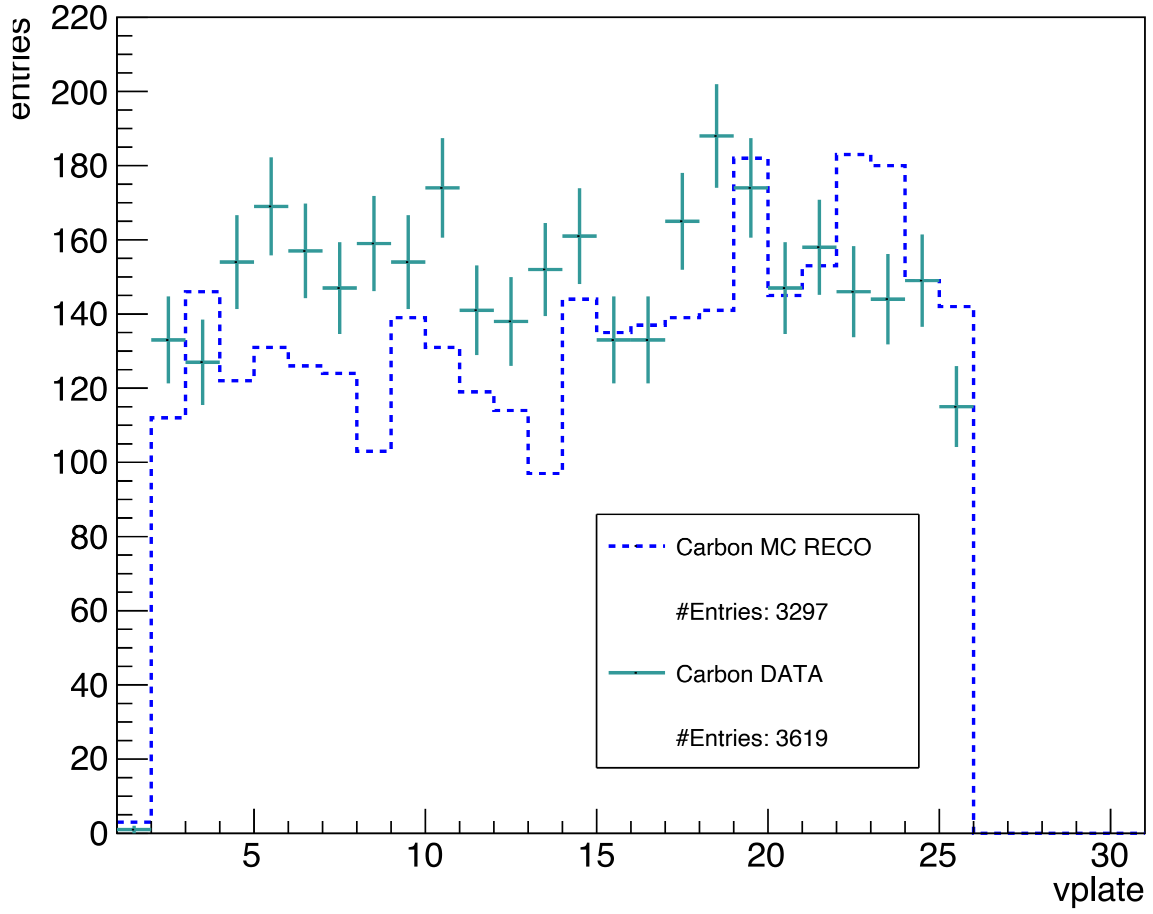
GSI1: Oxy@200 MeV/n on C target

N vertices per layer

MC TRUE vs MC RECO



MC RECO vs DATA

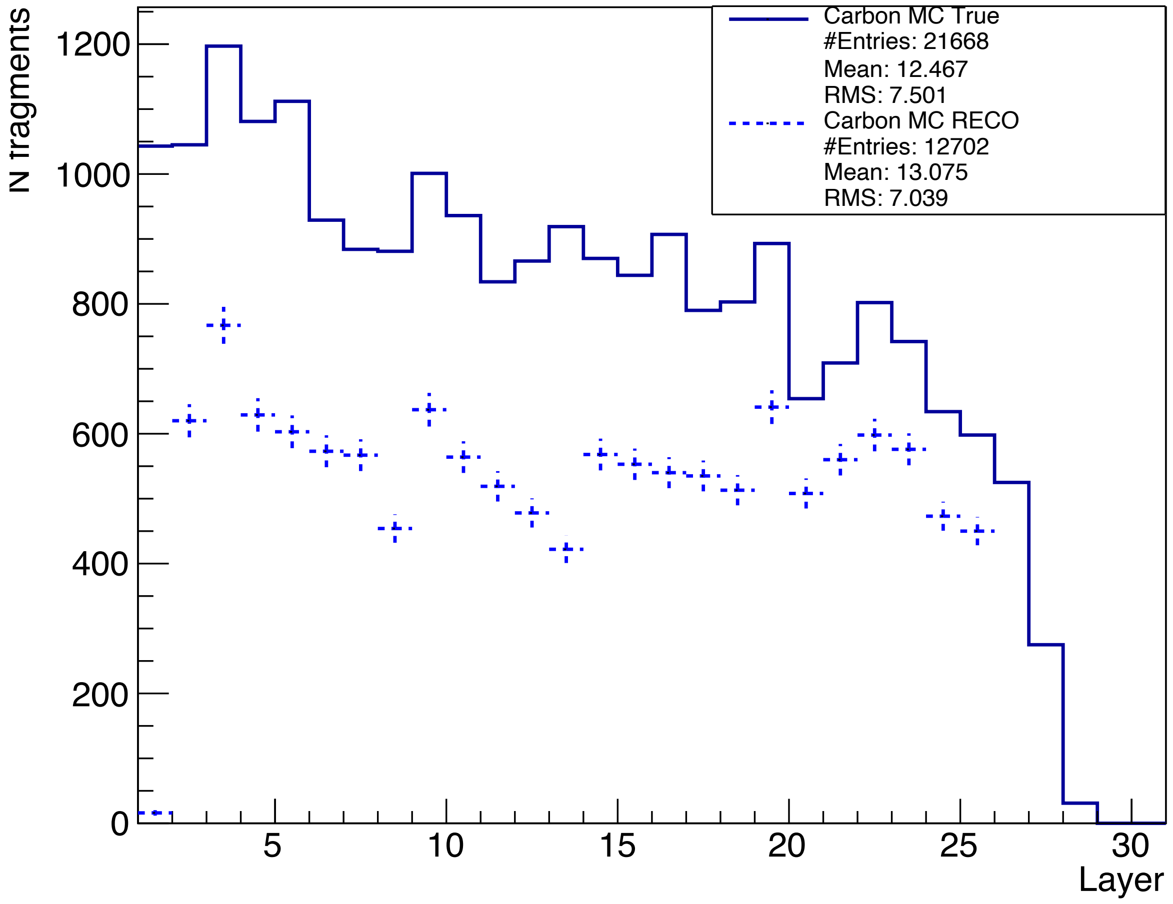


Distributions normalised to beam particles

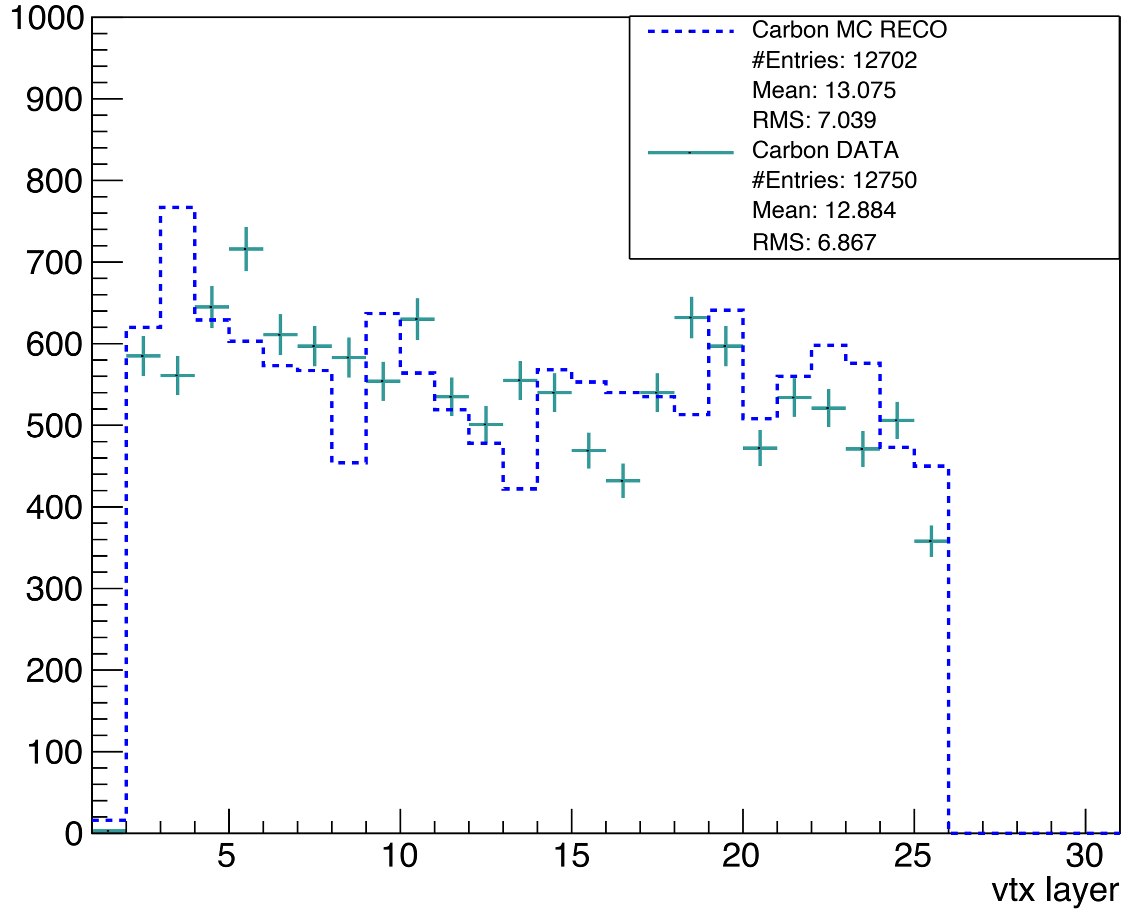
GSI1: Oxy@200 MeV/n on C target

N fragments per layer

MC TRUE vs MC RECO



MC RECO vs DATA

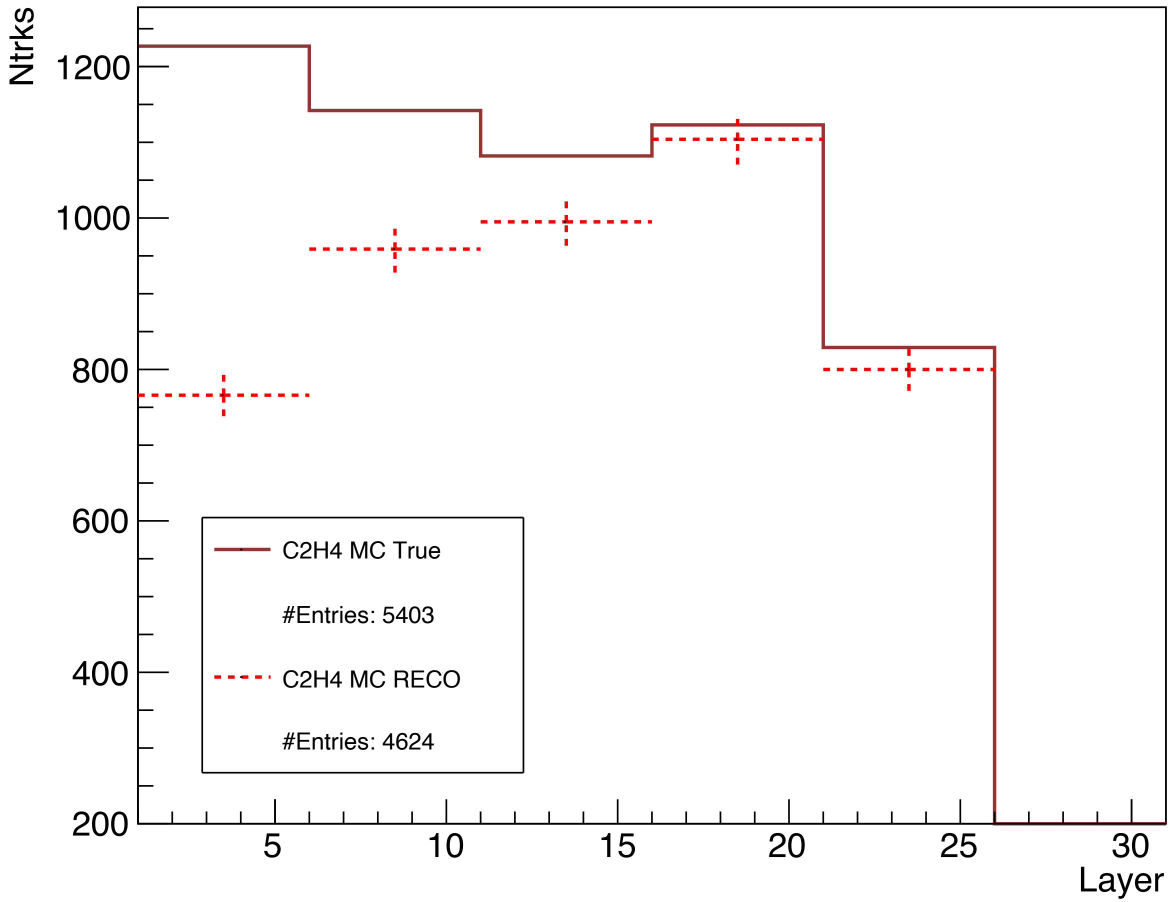


Distributions normalised to beam particles

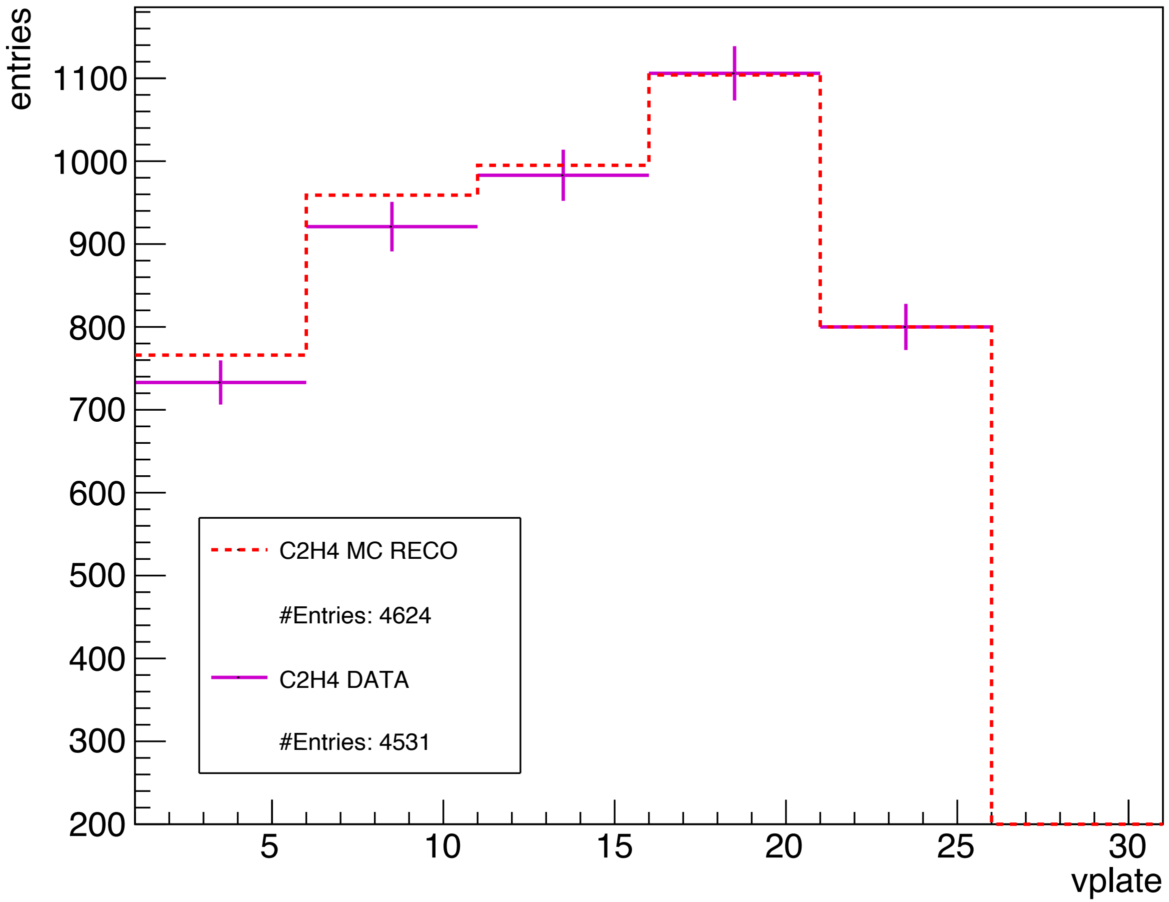
GSI2: Oxy@200 MeV/n on C2H4 target

N vertices per layer

MC TRUE vs MC RECO



MC RECO vs DATA

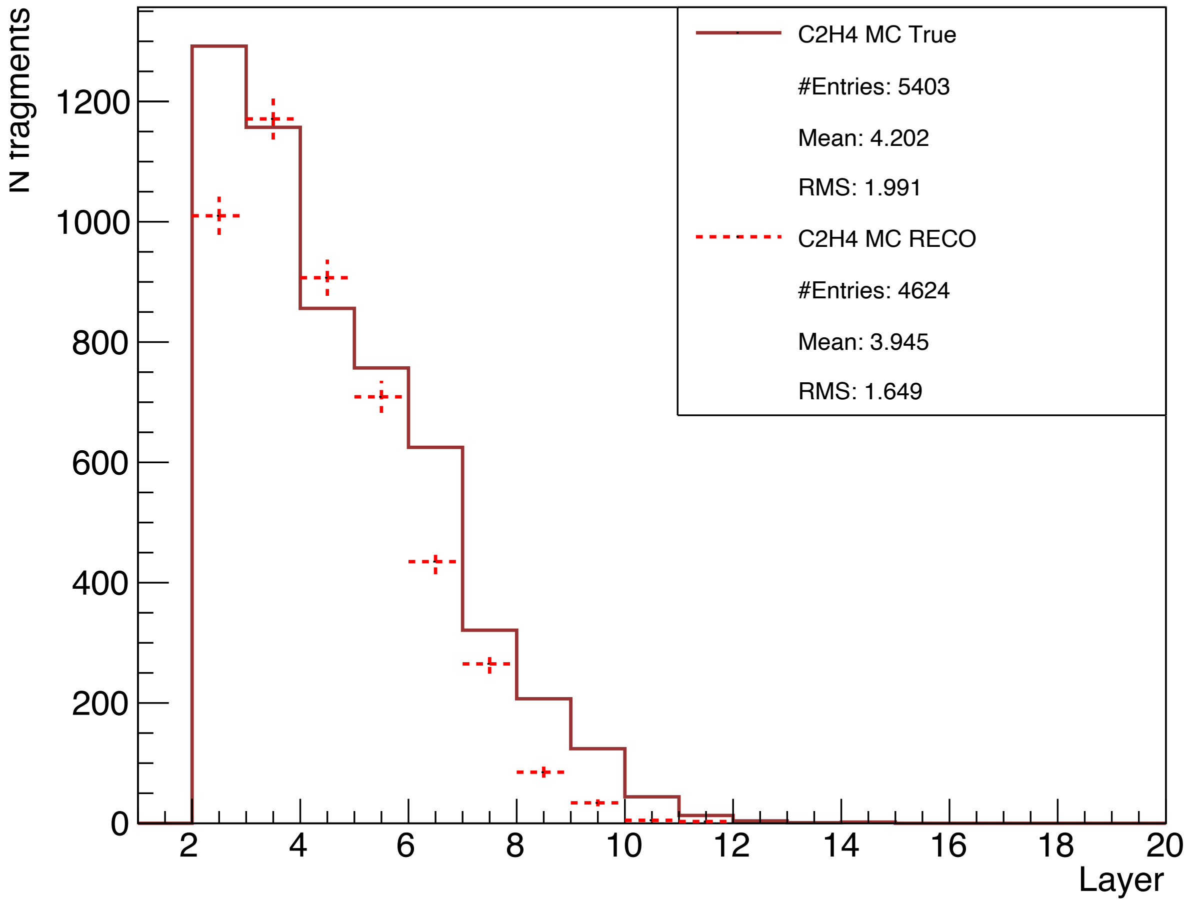


Distributions normalised to beam particles

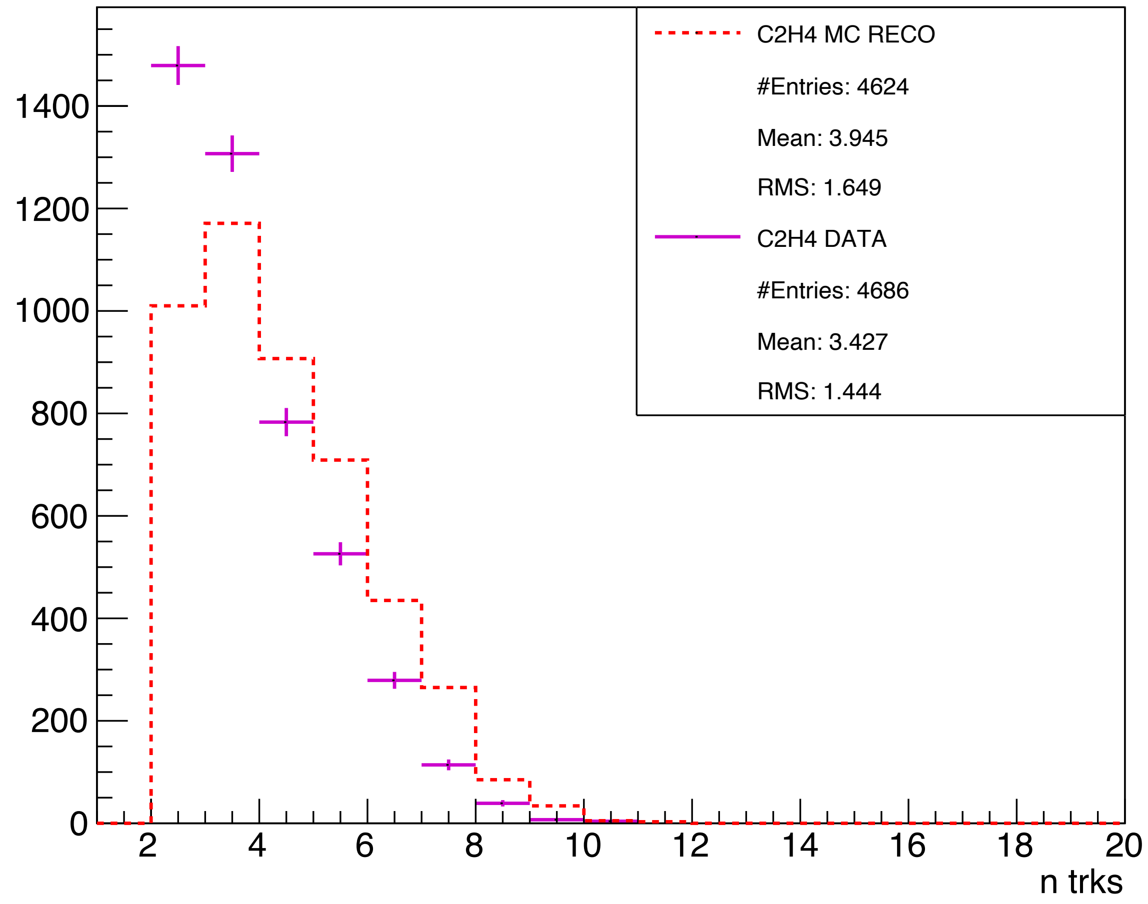
GSI2: Oxy@200 MeV/n on C2H4 target

Fragments' Multiplicity

MC TRUE vs MC RECO



MC RECO vs DATA

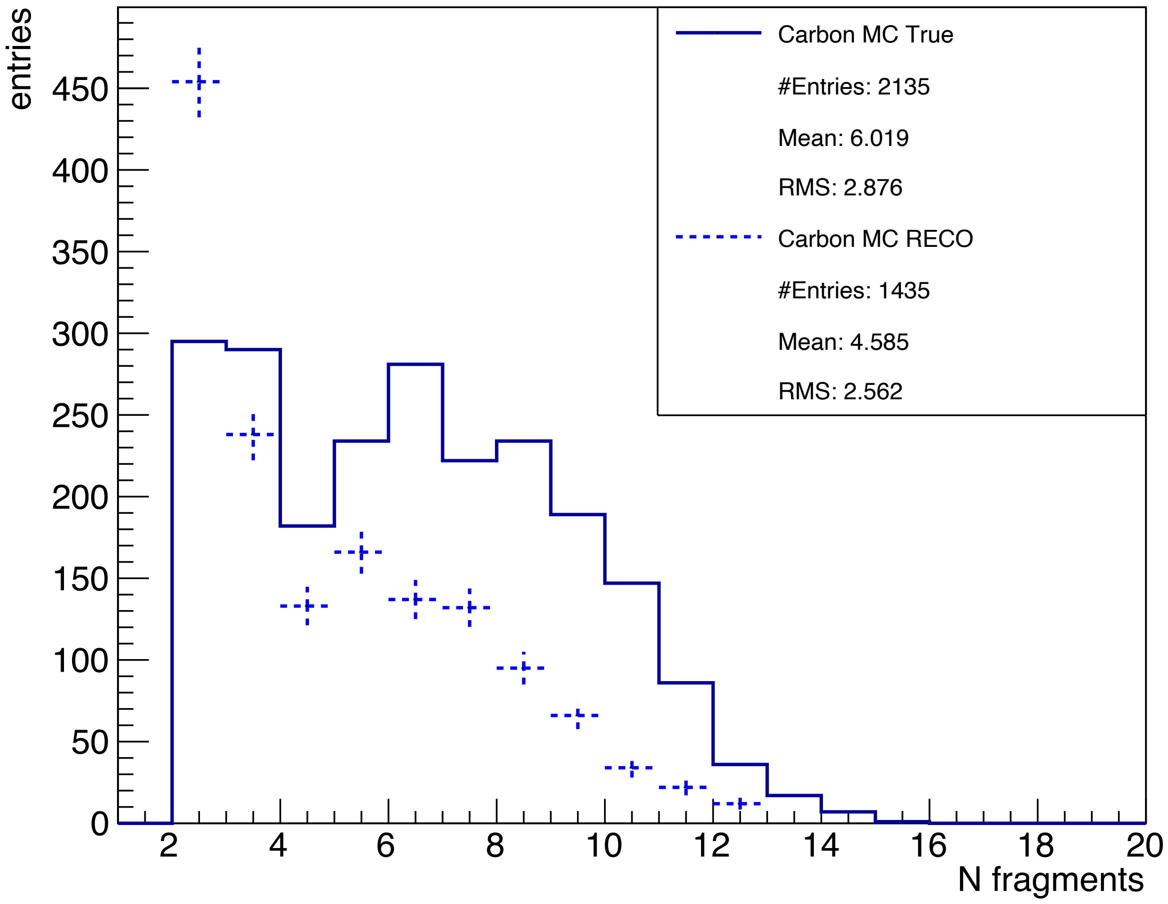


Distributions normalised to beam particles

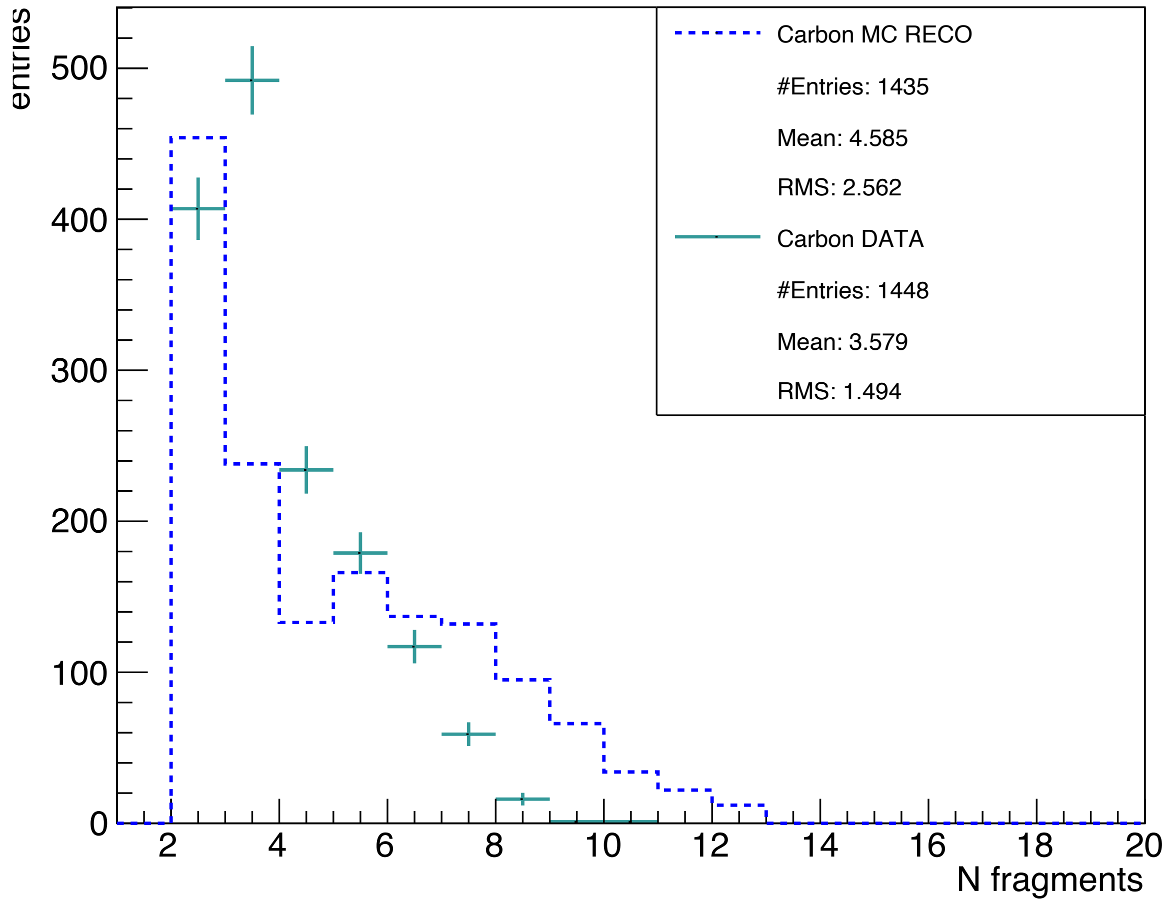
GSI3: Oxy@400 MeV/n on C target

Fragments' Multiplicity

MC TRUE vs MC RECO



MC RECO vs DATA



Distributions normalised to beam particles

Detector Structure