UPDATE ON THE ANALYSIS OF GSI2 ^{16}O DATA TAKING

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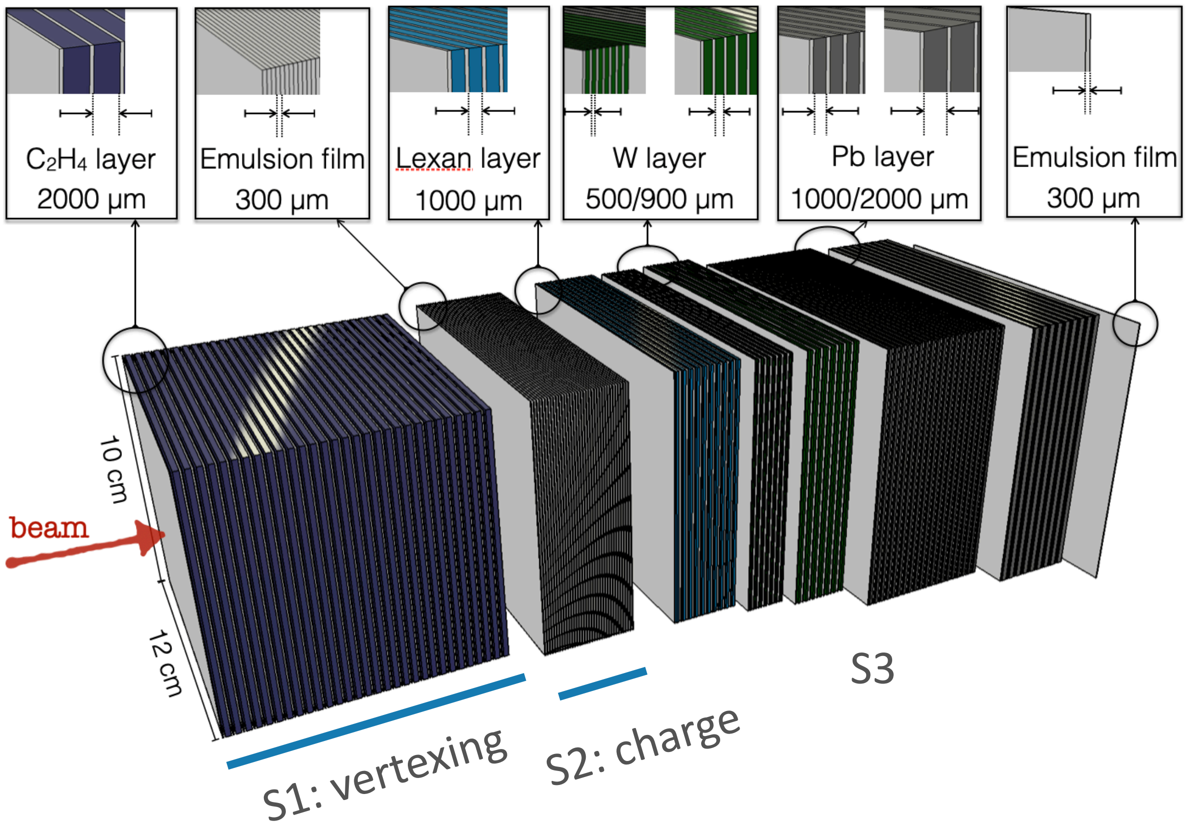
31/05/2022, XII General FOOT Meeting
Strasbourg, Amphitheatre Grünewald

Outline

- ECC reconstruction and improvements
    - Improvements in tracking algorithms
    - ECC reconstructions: GSI1, GSI2, GSI3 (NEW)
    - Comparison between: - true and reconstructed Monte Carlo
      - reconstructed Monte Carlo and DATA
- Cross section measurement for GSI1 and GSI2
    - Integrated
    - Differential for fragment's angles
    - Differential for charge

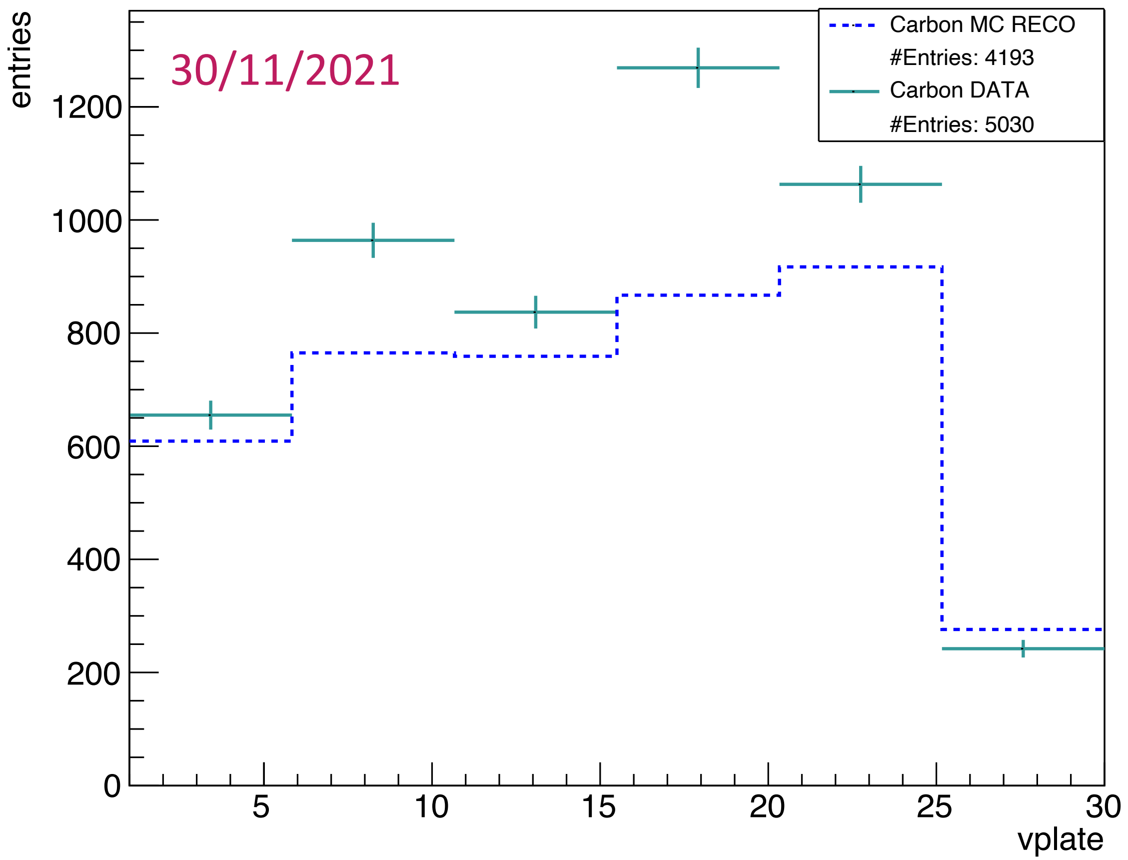
Summary



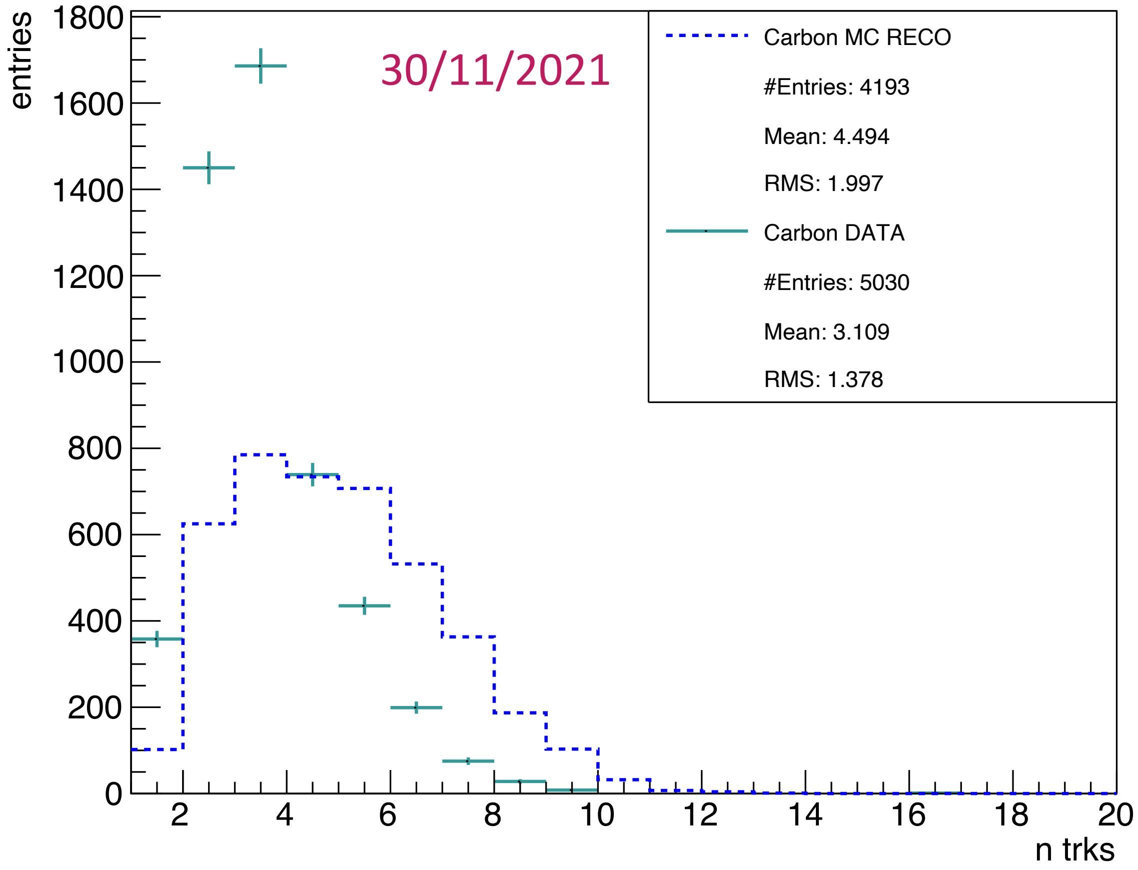
Target \ Beam	2019		2020
	Oxygen 200 MeV/n	Oxygen 400 MeV/n	Carbon 700MeV/n
Carbon	GSI1	GSI3	GSI5
Polyethylene	GSI2	GSI4	GSI6

GSI1 DATA vs MC RECO Comparison @ XI General Meeting

Vertex Plate



N daughters



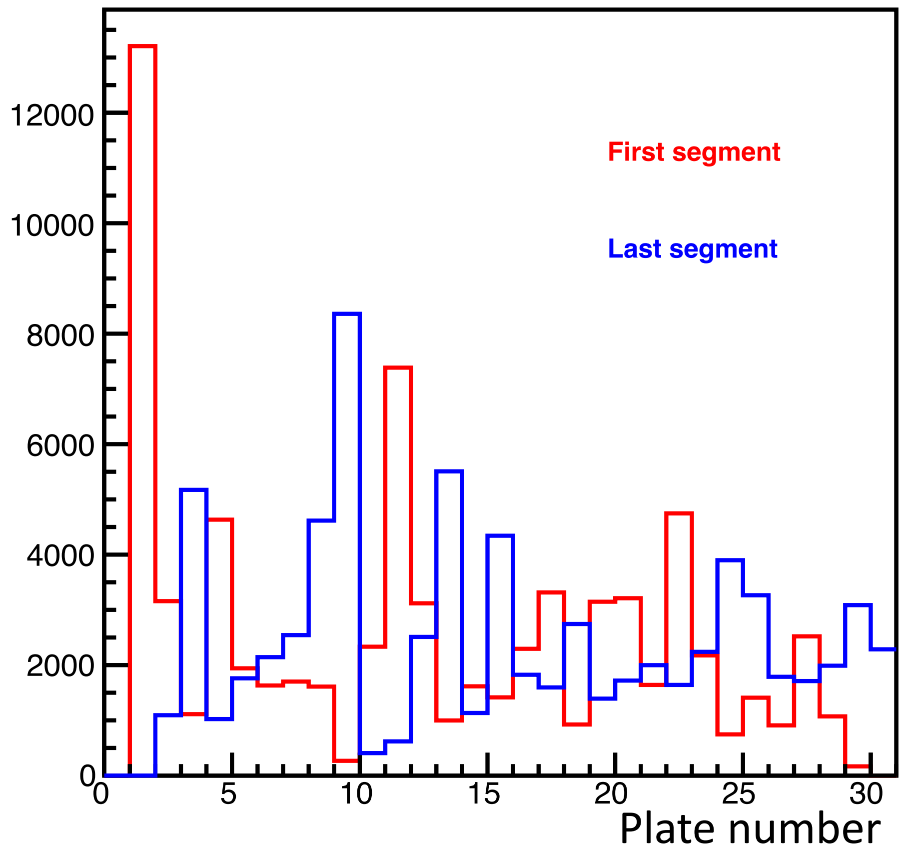
Distributions normalized to beam particles, requirement of at least 3 tracks in the vertex.

In GSI1 (1mm C target) there were several discrepancies between data and reconstructed MC, that we didn’t see in GSI2 (2mm C_2H_4 target).

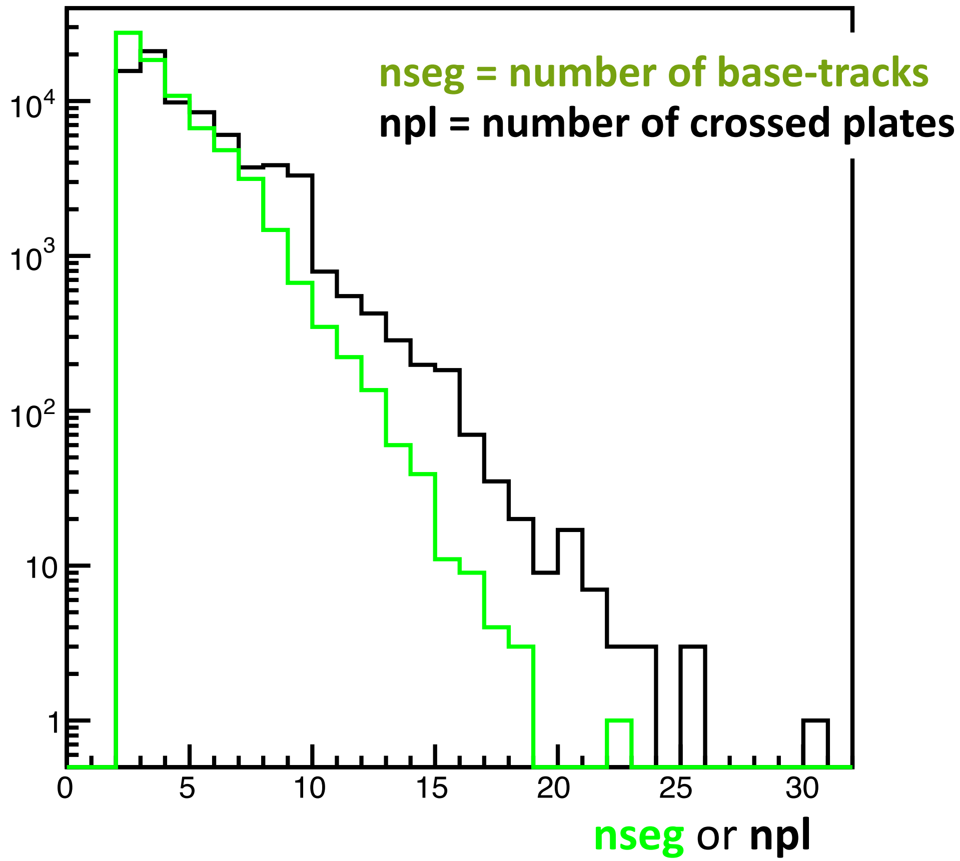
Hypothesis was that these discrepancies were due to alignment problems

GSI1 - S1 / BEFORE

First and last segment for “signal” tracks ($\theta_{X/Y} < 0.05rad$)

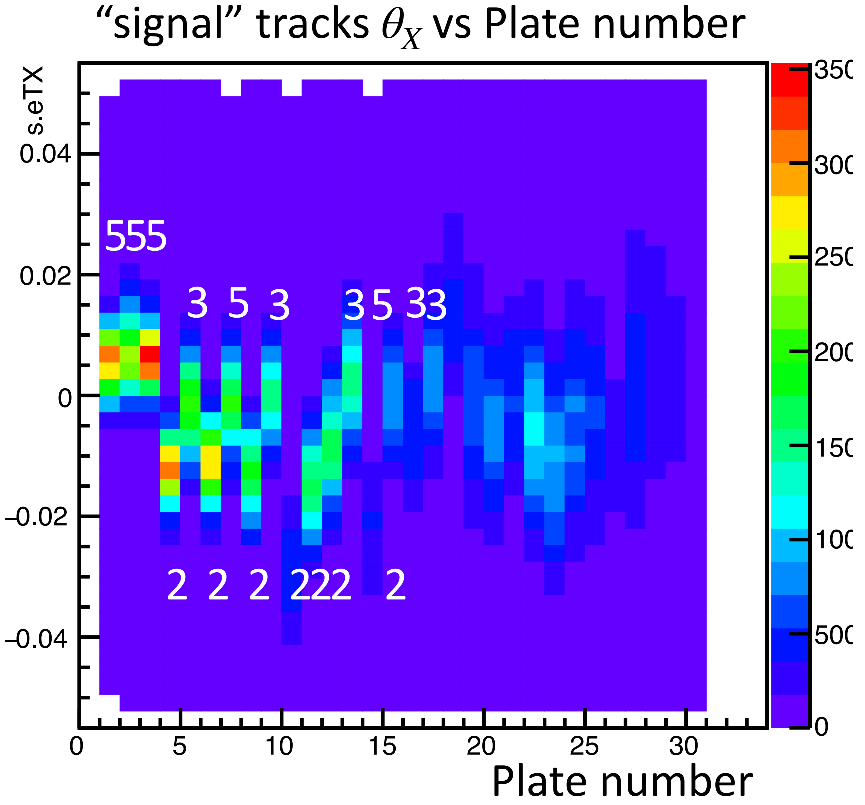


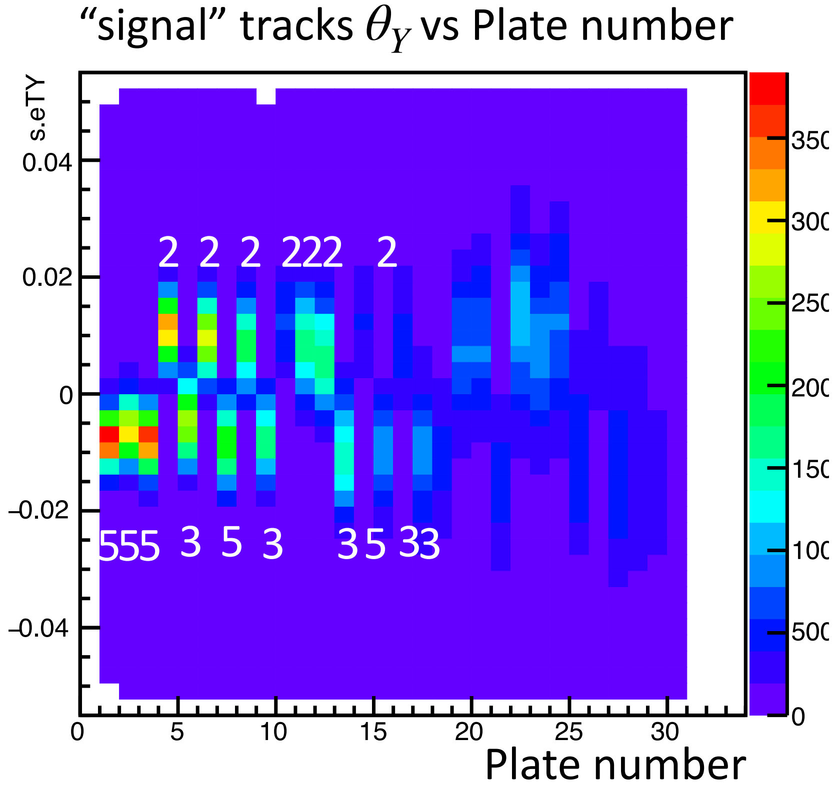
Number of segments or crossed plates for “signal” tracks ($\theta_{X/Y} < 0.05rad$)



- Several tracks interrupting and starting again even though alignment seemed to be fine
- Many short tracks ($\sim 10^4$ of only 2 base-tracks, ~ 10 of 15 base-tracks)

GSI1 - S1 / BEFORE

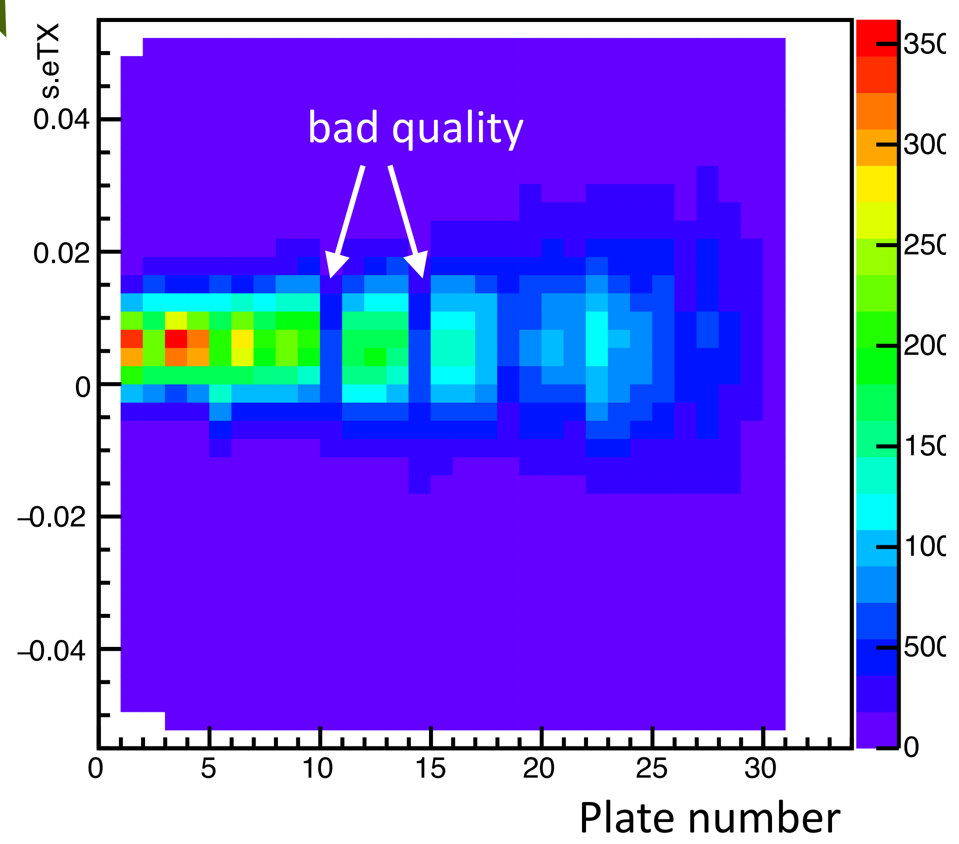




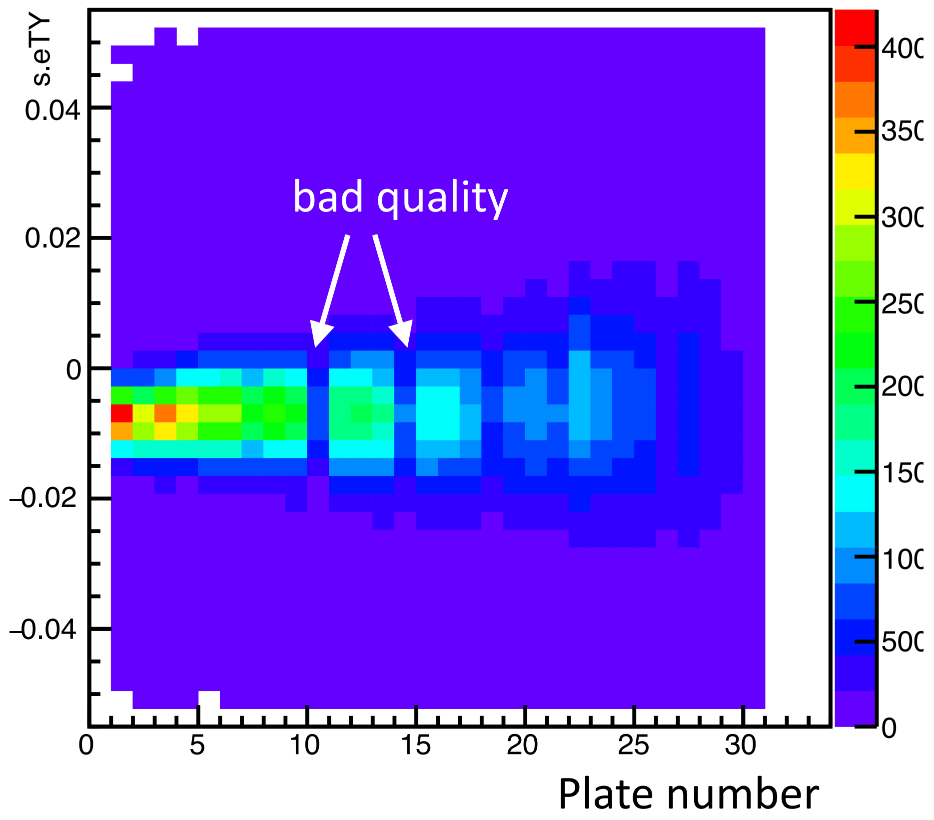
- Problem not with coordinates alignment, but with angle distributions! The distribution of $\theta_{X/Y}$ of “signal” tracks seemed to be centered on a different mean angle in each plate, probably due to scanning done on different microscopes
- Differences between consecutive base-tracks up to ~ 20 mrad, out of tolerances → match between consecutive base-tracks not found

GSI1 - S1 / AFTER θ CORRECTION

"signal" tracks θ_X vs Plate number



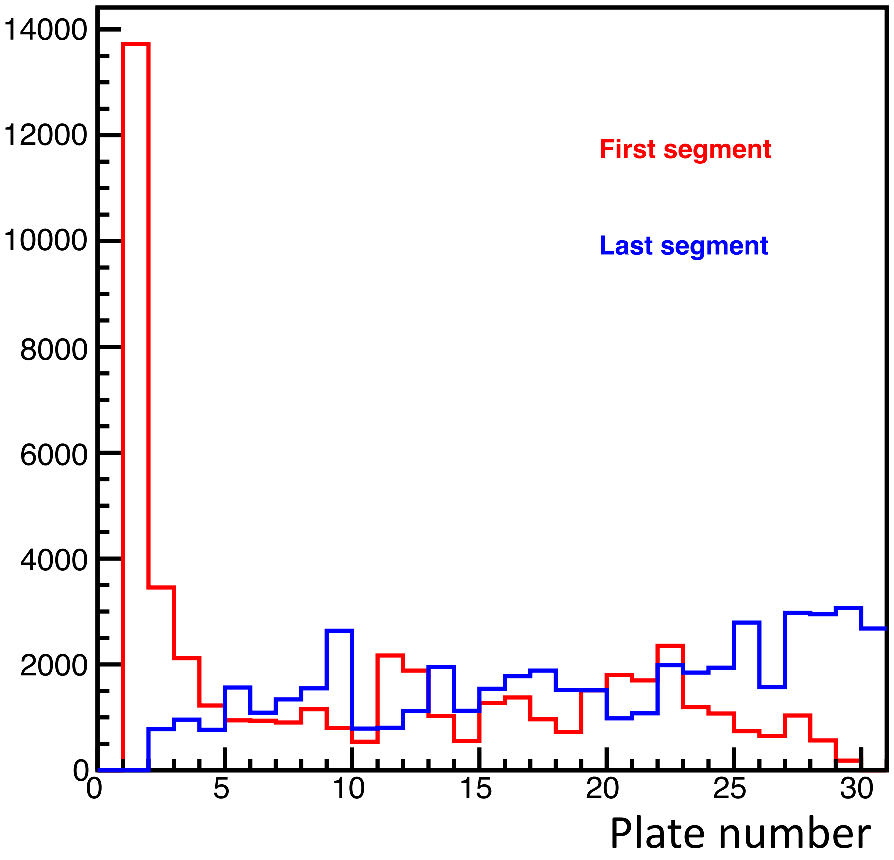
"signal" tracks θ_Y vs Plate number



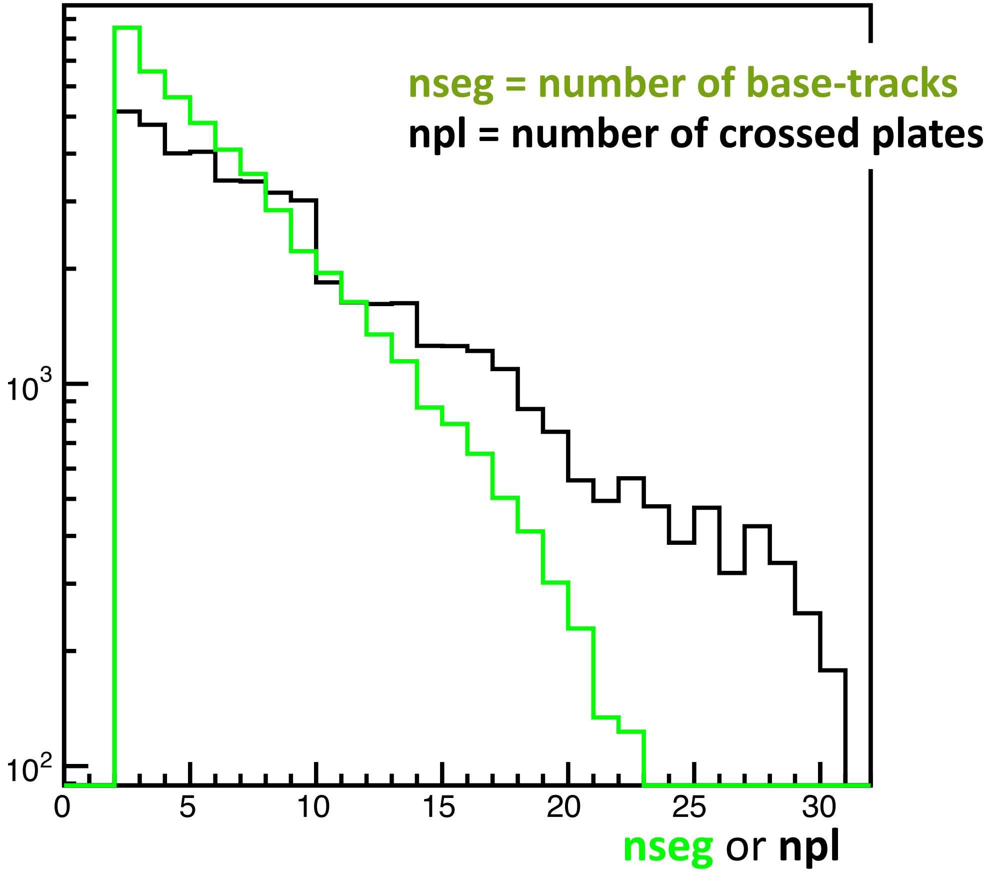
- Angles correction implemented in the last step of global alignment
- Now all distributions are centered to the mean of the first plate

GSI1 - S1 / AFTER θ CORRECTION

First and last segment for "signal" tracks ($\theta_{X/Y} < 0.05rad$)



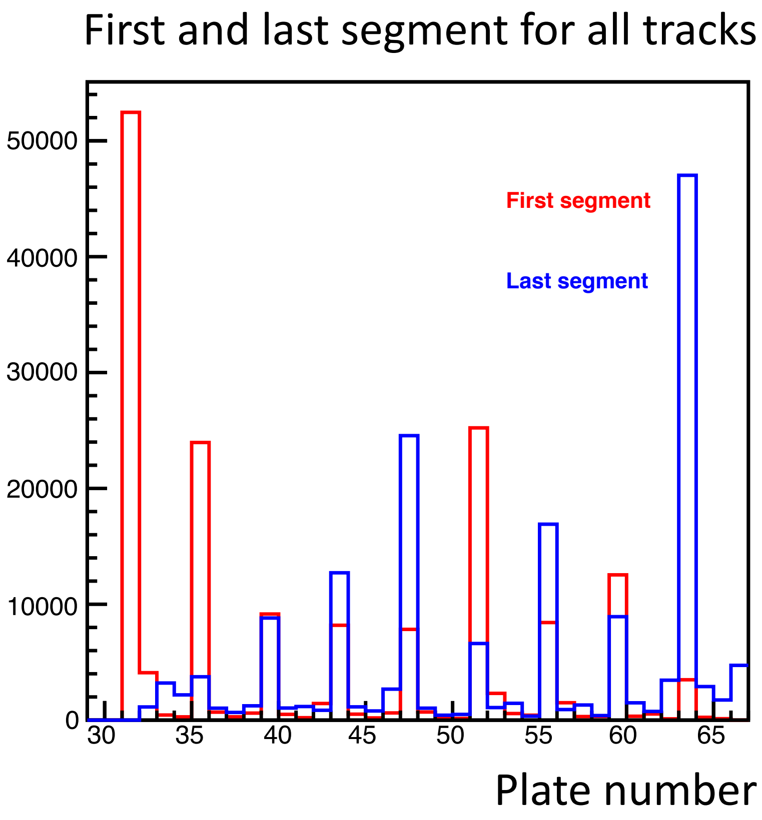
Number of segments or crossed plates for "signal" tracks ($\theta_{X/Y} < 0.05rad$)



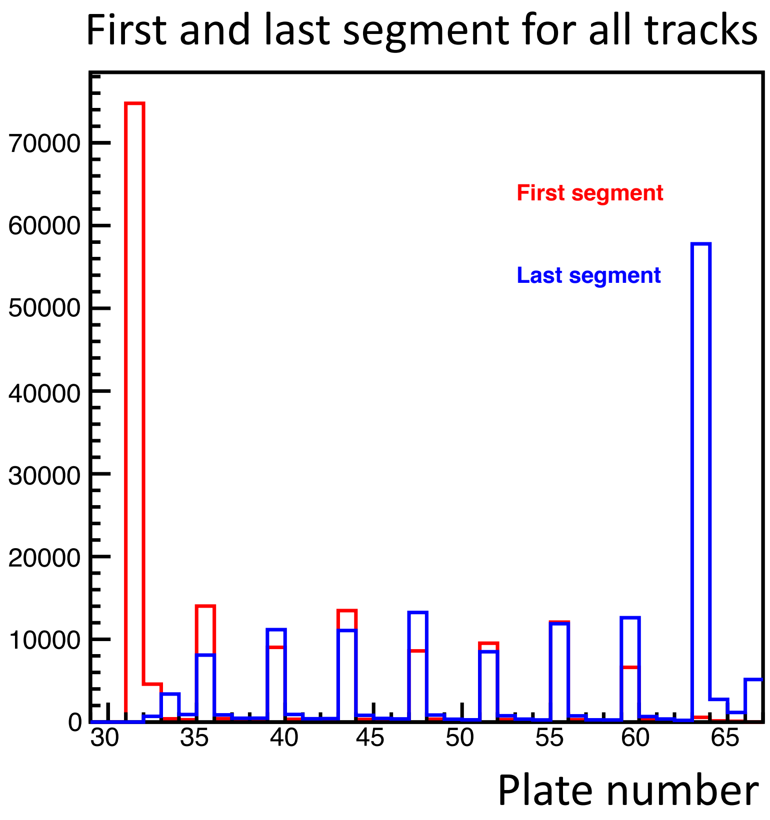
- Tracking significantly improved!
- $\sim 10^3$ tracks made of 15 base-tracks

GSI1 - S2 / Another example of improvements

BEFORE



AFTER

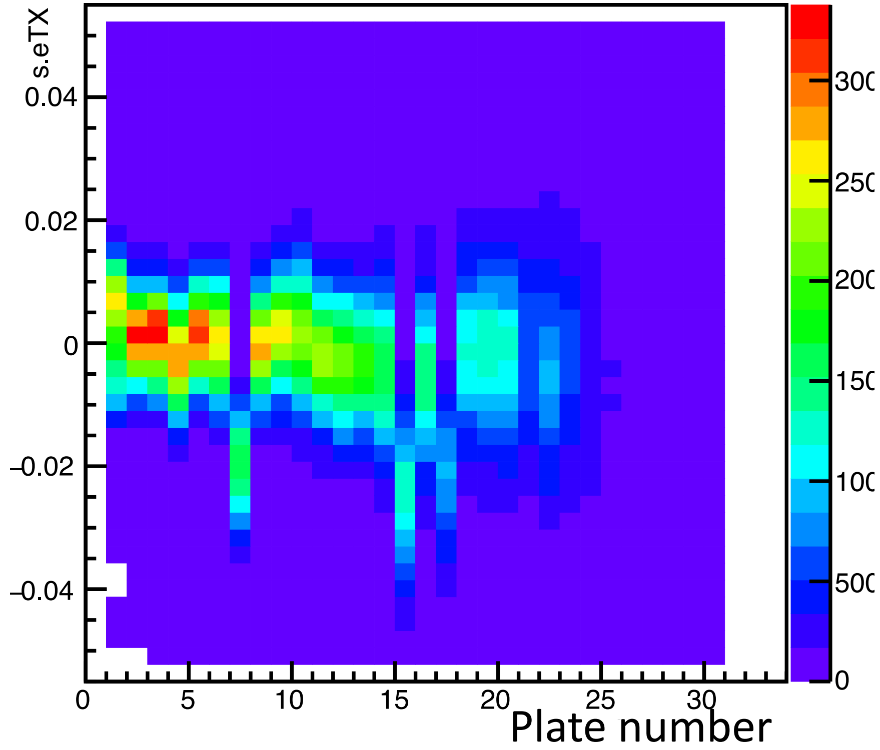


GSI2 - S1

- The same effect was less critical in GSI2 (2mm C_2H_4) because the emulsion films were scanned all on the same microscope with few exceptions

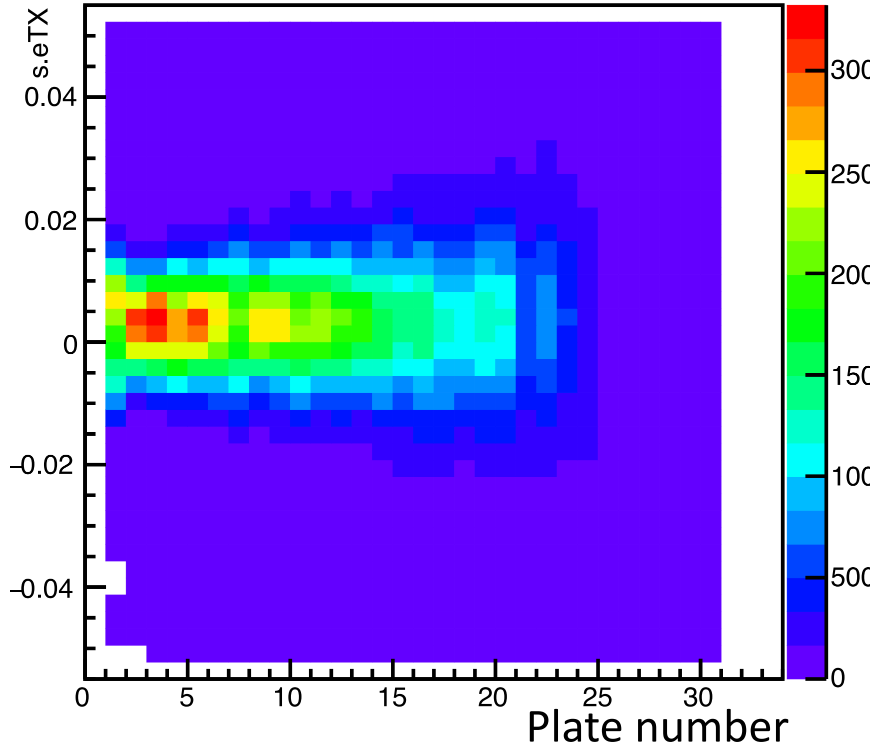
BEFORE

“signal” tracks θ_X vs Plate number



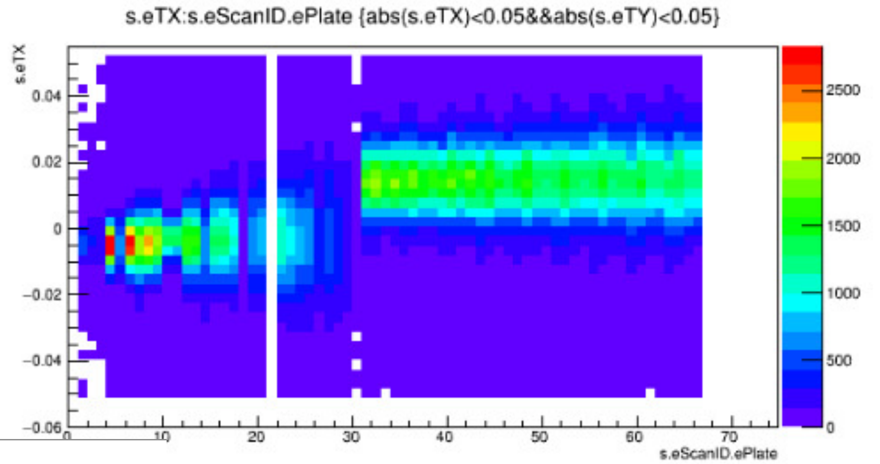
AFTER

“signal” tracks θ_X vs Plate number

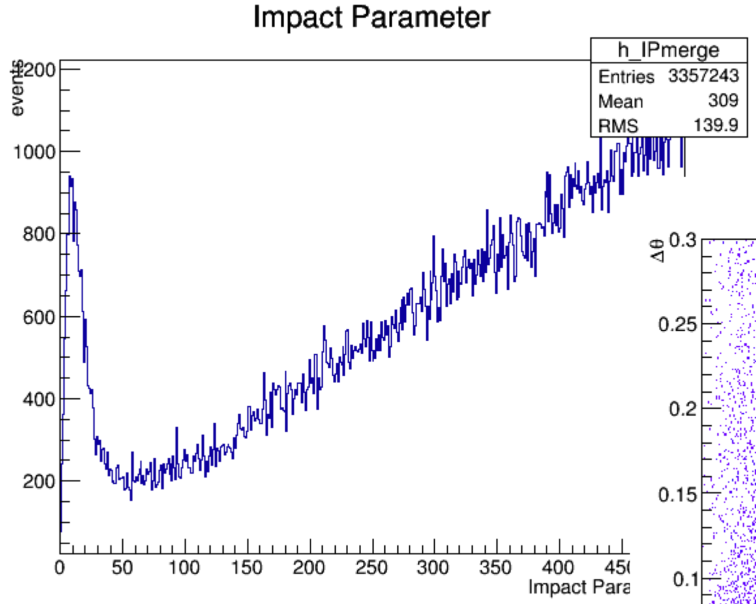


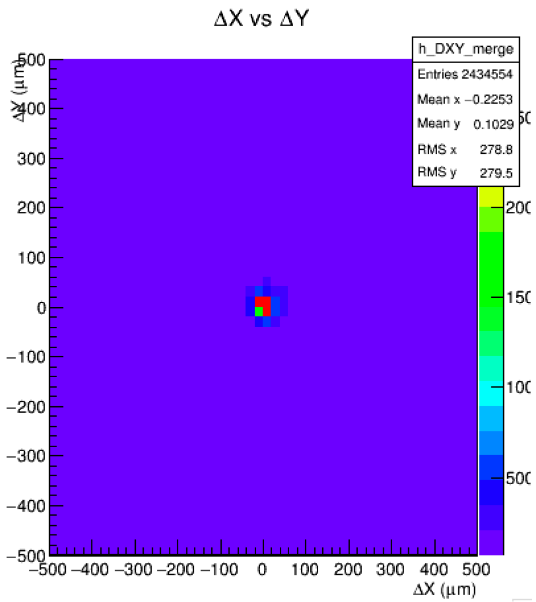
Merging stacks

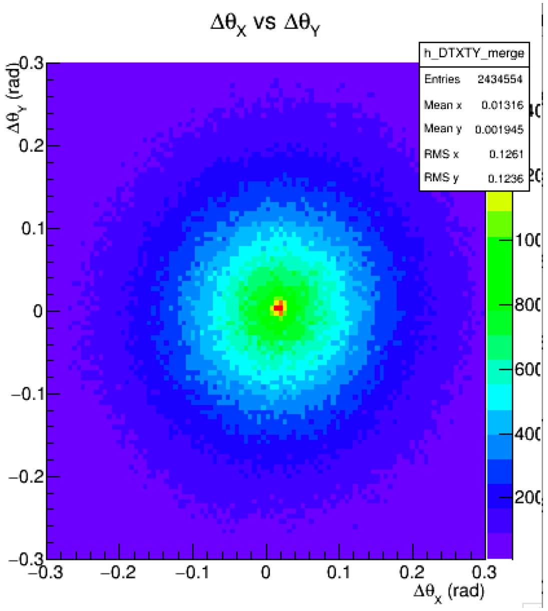
- Different reference systems in consecutive stacks both for coordinates and angles
- Efforts to align the two datasets
- New procedure (still to improve)

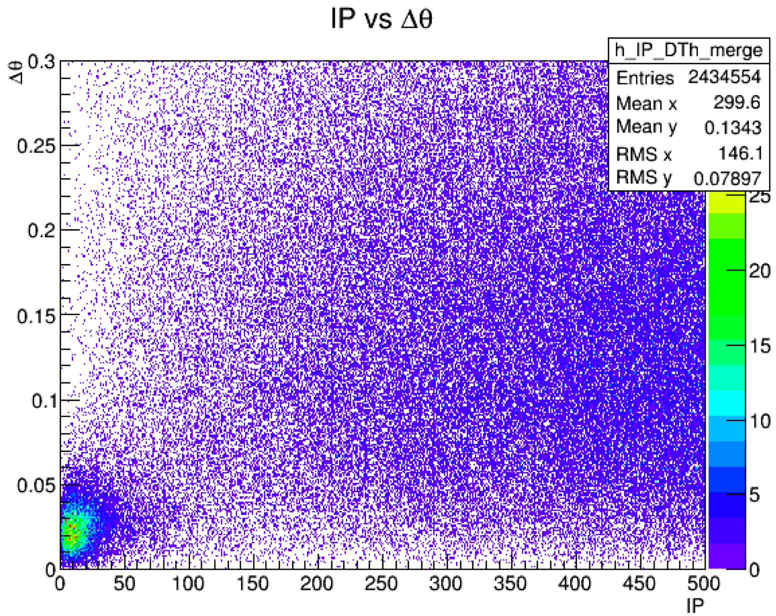


Example from GSI2 DATA:









Analysis of
Oxygen at 200 MeV/n on C and C_2H_4
GSI 1 & GSI2

Number of reconstructed vertices

		GSI1 C target	GSI2 C2H4 target
MC	Beam particles	18990	19988
	True vertices	4798	5567
	Reco vertices	4031	4753
DATA	Beam particles	19375	20625
	Data vertices	4086	5136

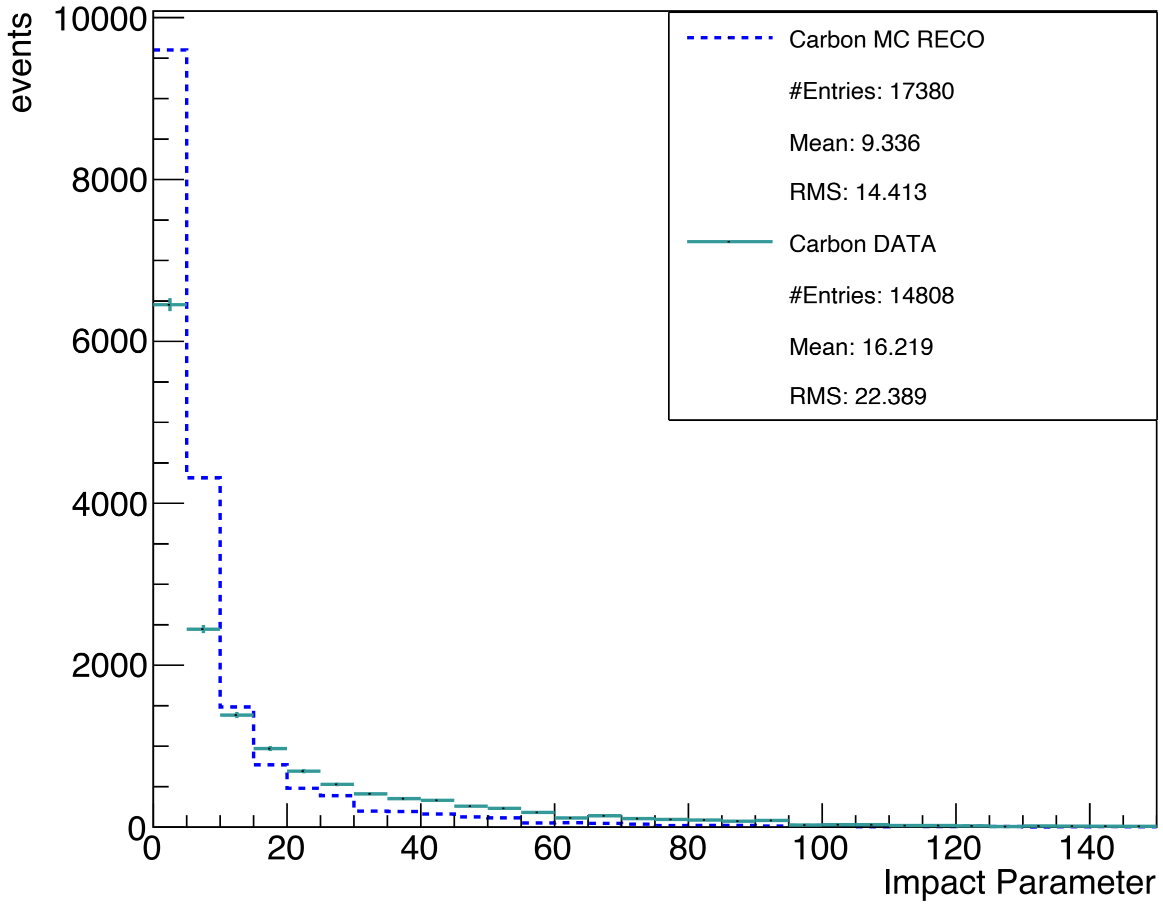
Cuts for vertices selection:

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

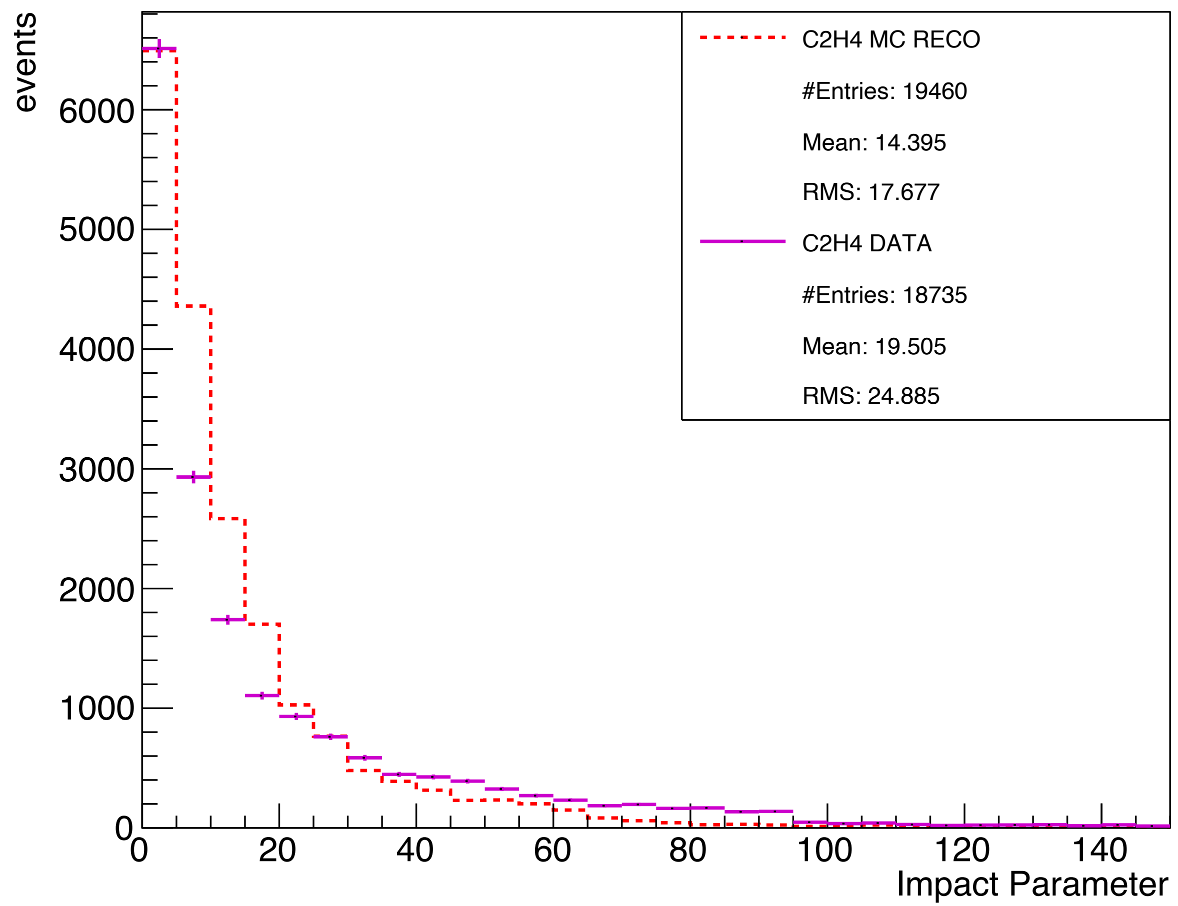
Daughters' impact parameters distribution

Distributions normalized to beam particles

Carbon



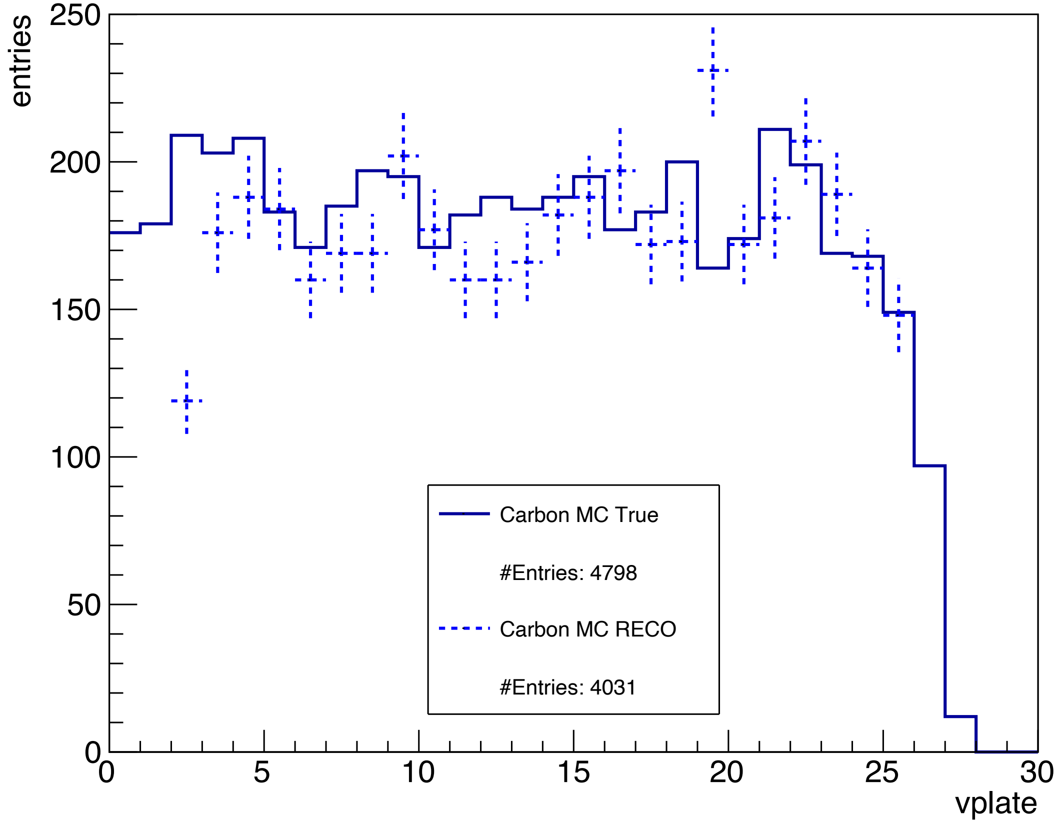
C_2H_4



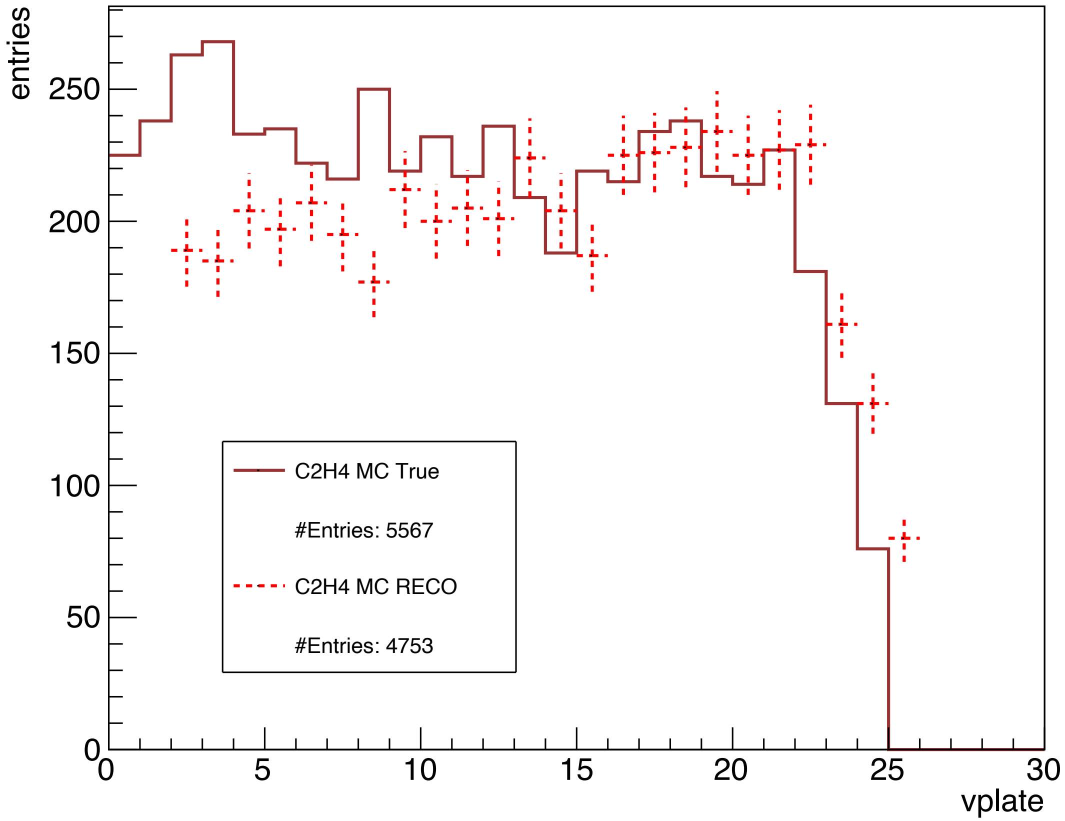
Vertex Plate distribution: MC RECO vs MC

Distributions normalized to beam particles

Carbon



C_2H_4

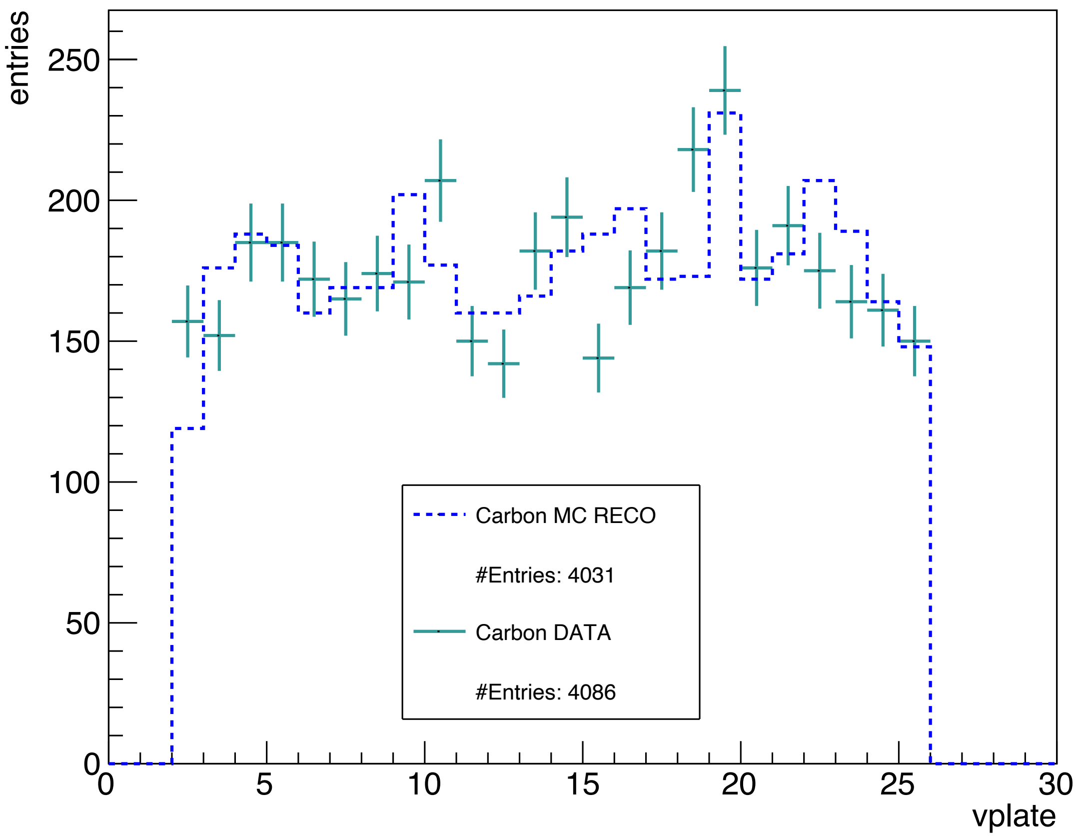


Since at least 3 tracks are required, efficiencies increases when the probability of fully reconstruct the incoming oxygen is higher. Smearing at Bragg peak.

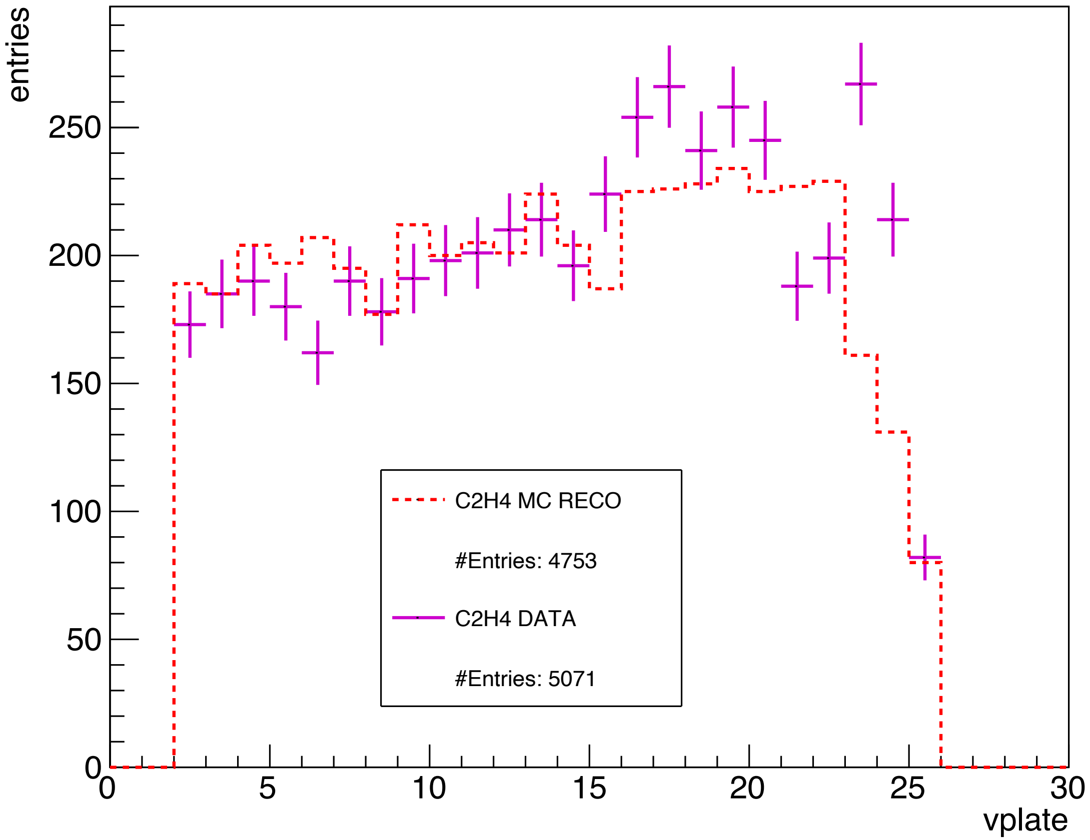
Vertex Plate distribution: DATA vs MC RECO

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

Carbon



C_2H_4

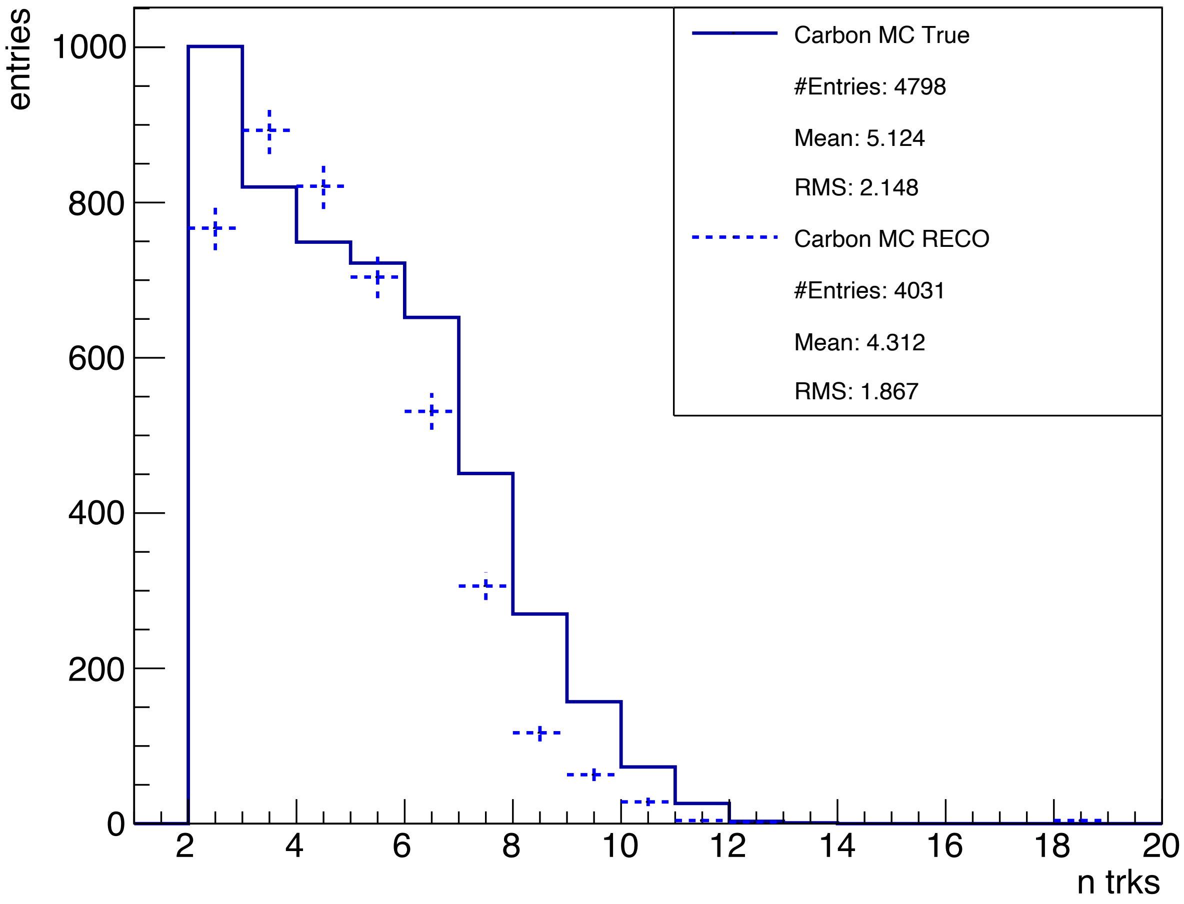


Trend is confirmed in DATA

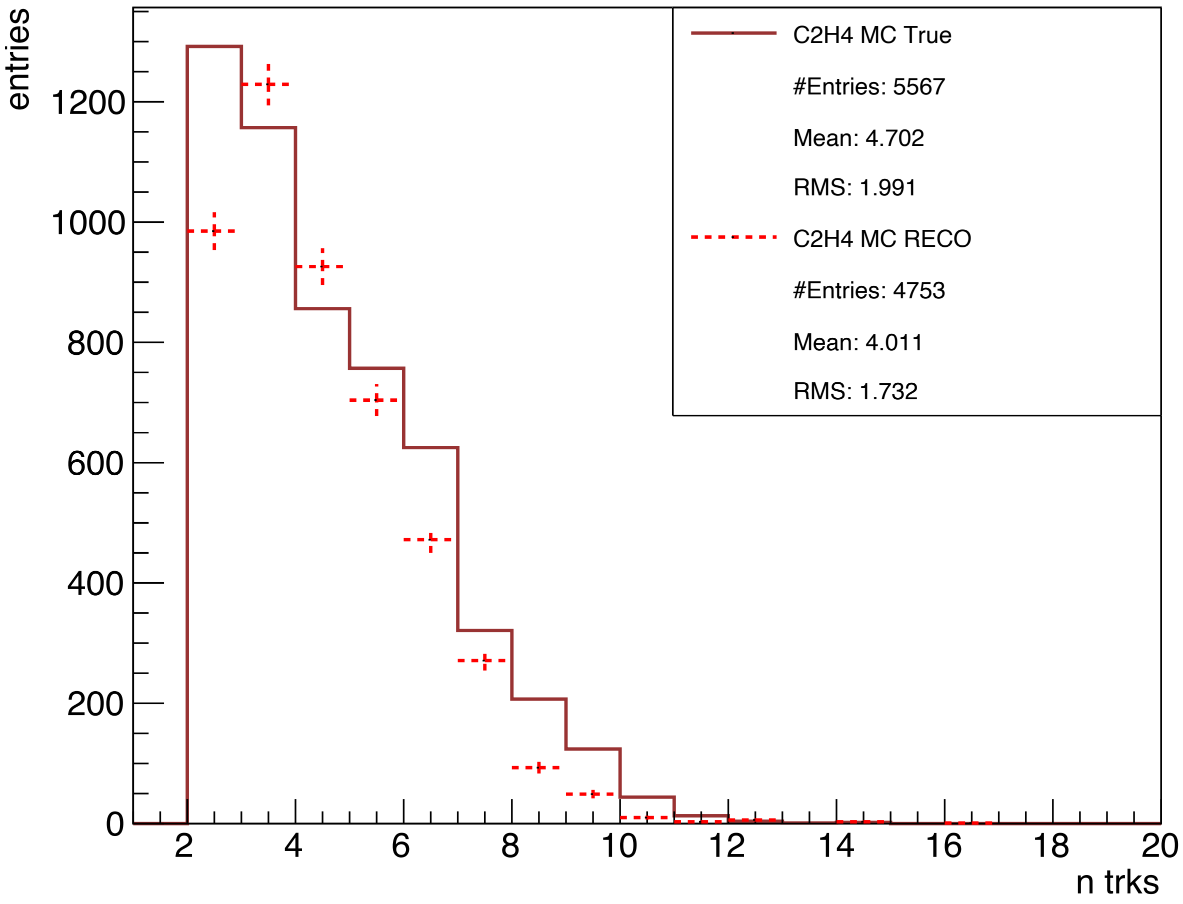
Fragments' multiplicity distribution: MC RECO vs MC

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

Carbon



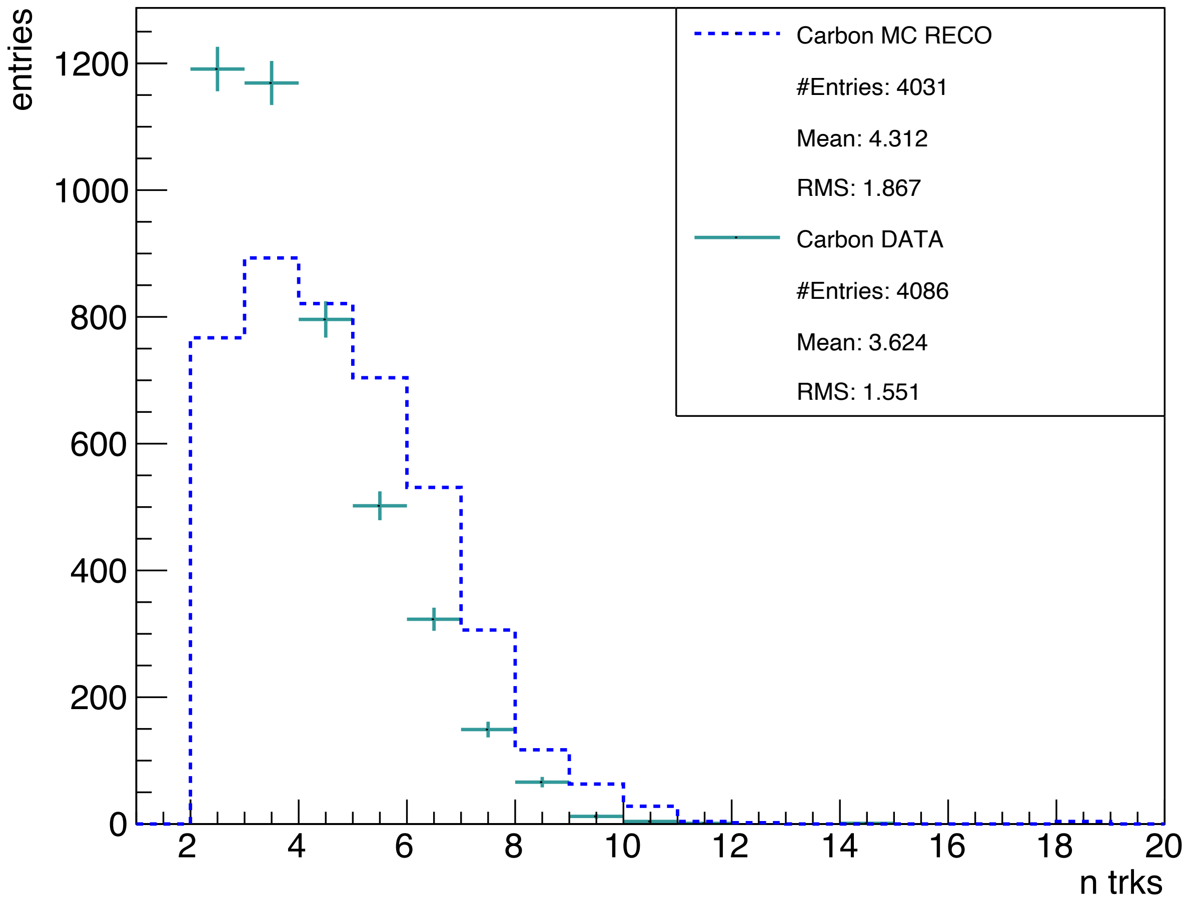
C_2H_4



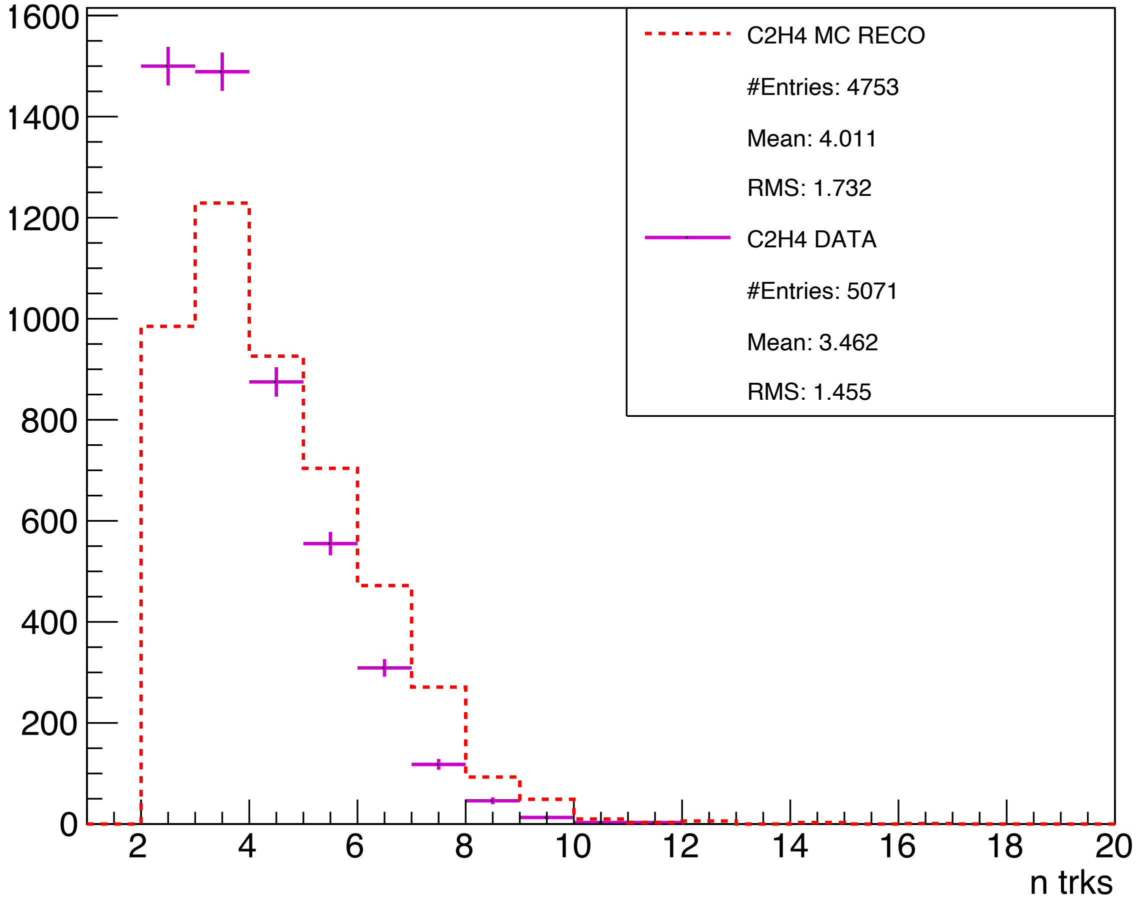
Fragments' multiplicity distribution: DATA vs MC reco

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

Carbon



C_2H_4

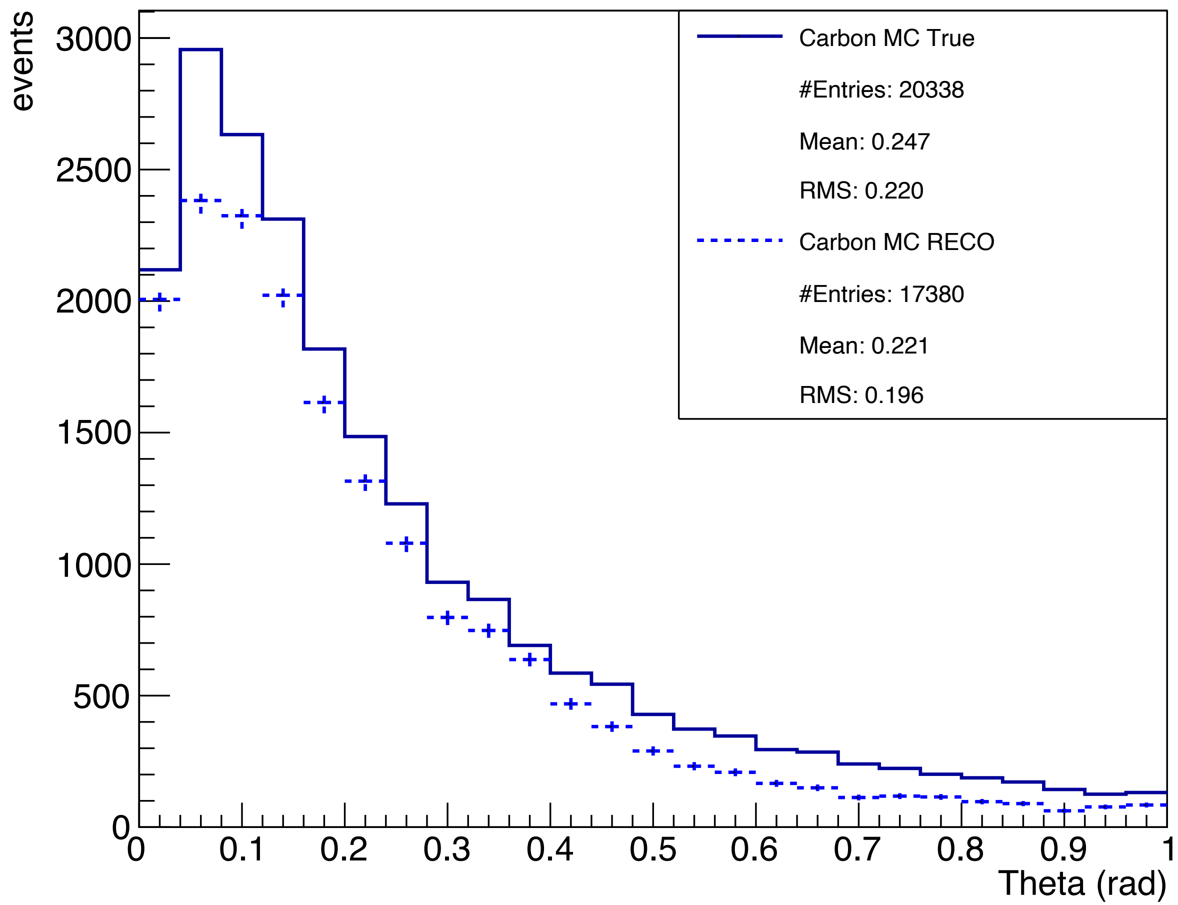


Still some effects to investigate, especially for GSI1 (C target)

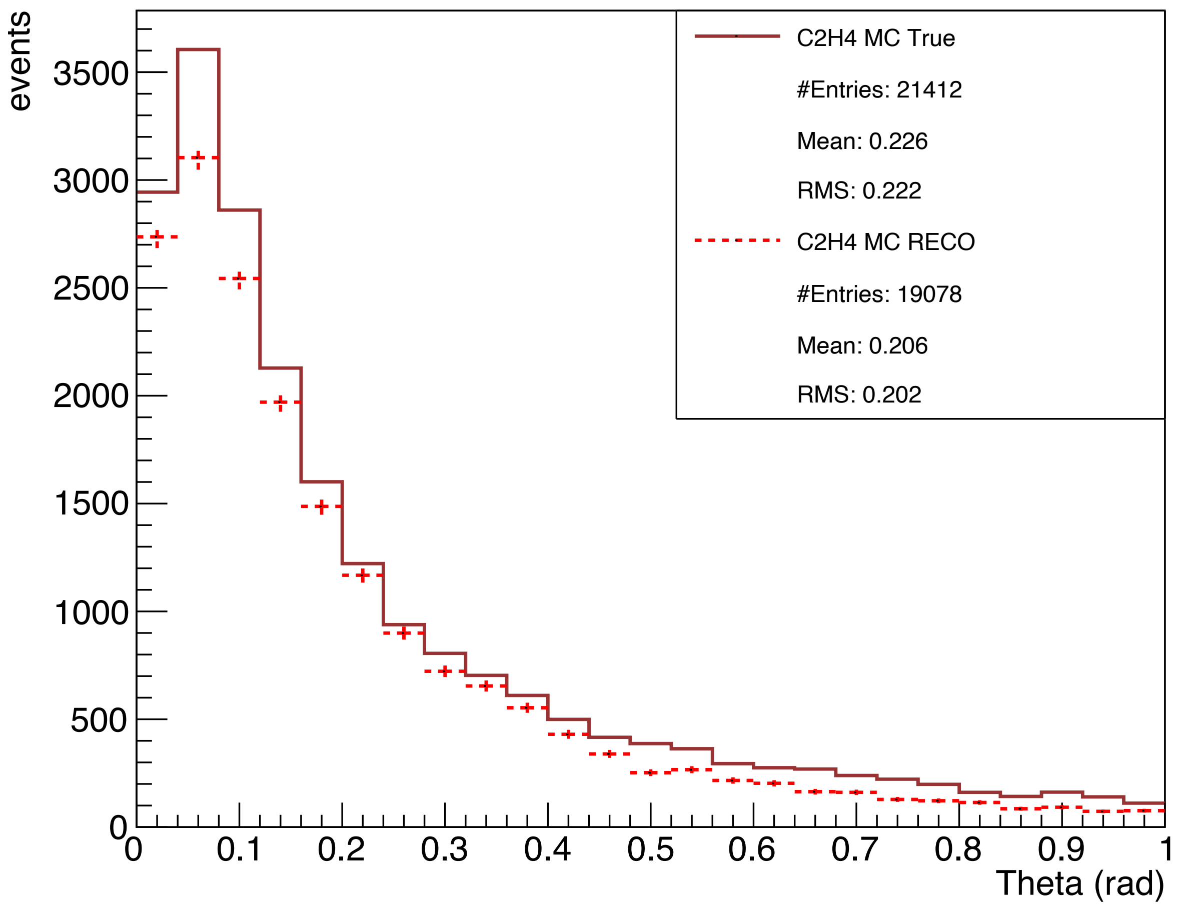
Fragments' angular distribution: MC RECO vs MC

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

Carbon



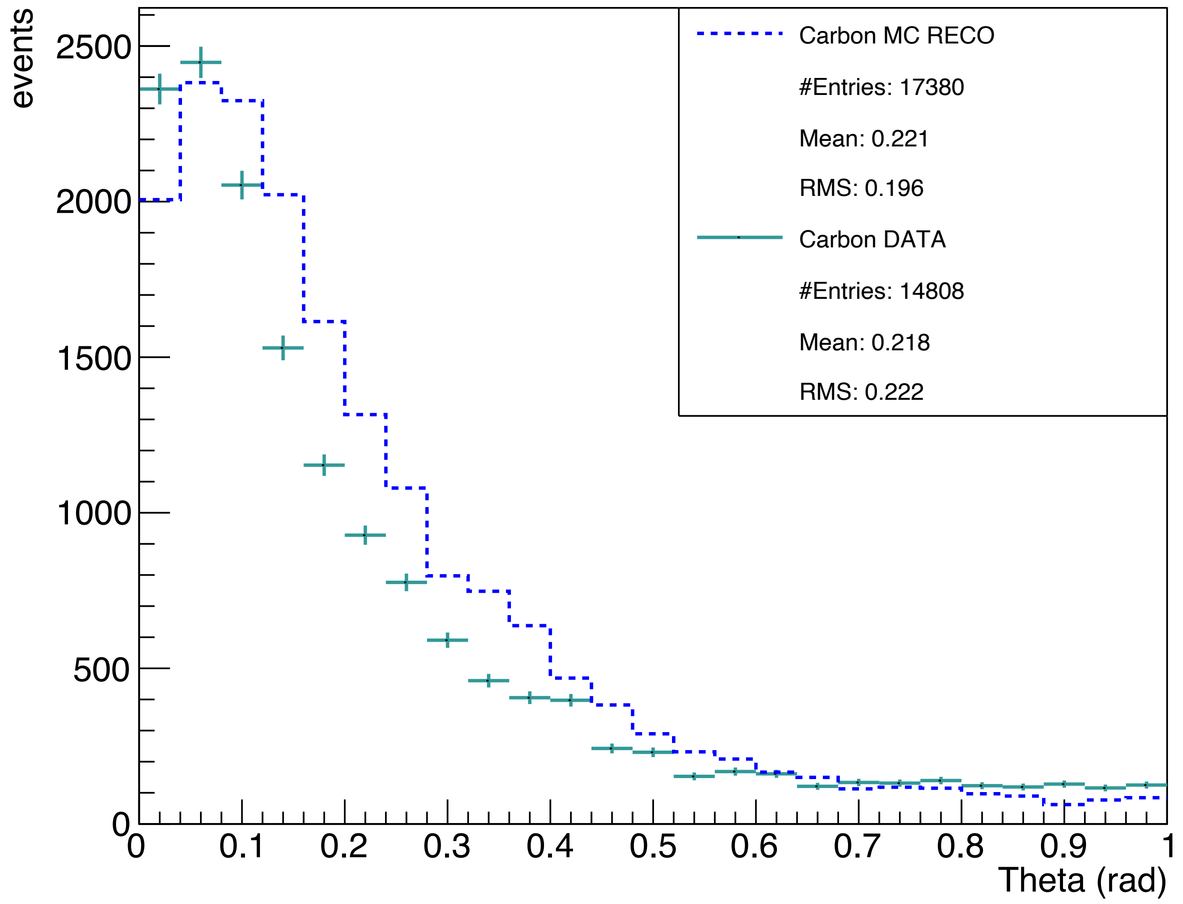
C_2H_4



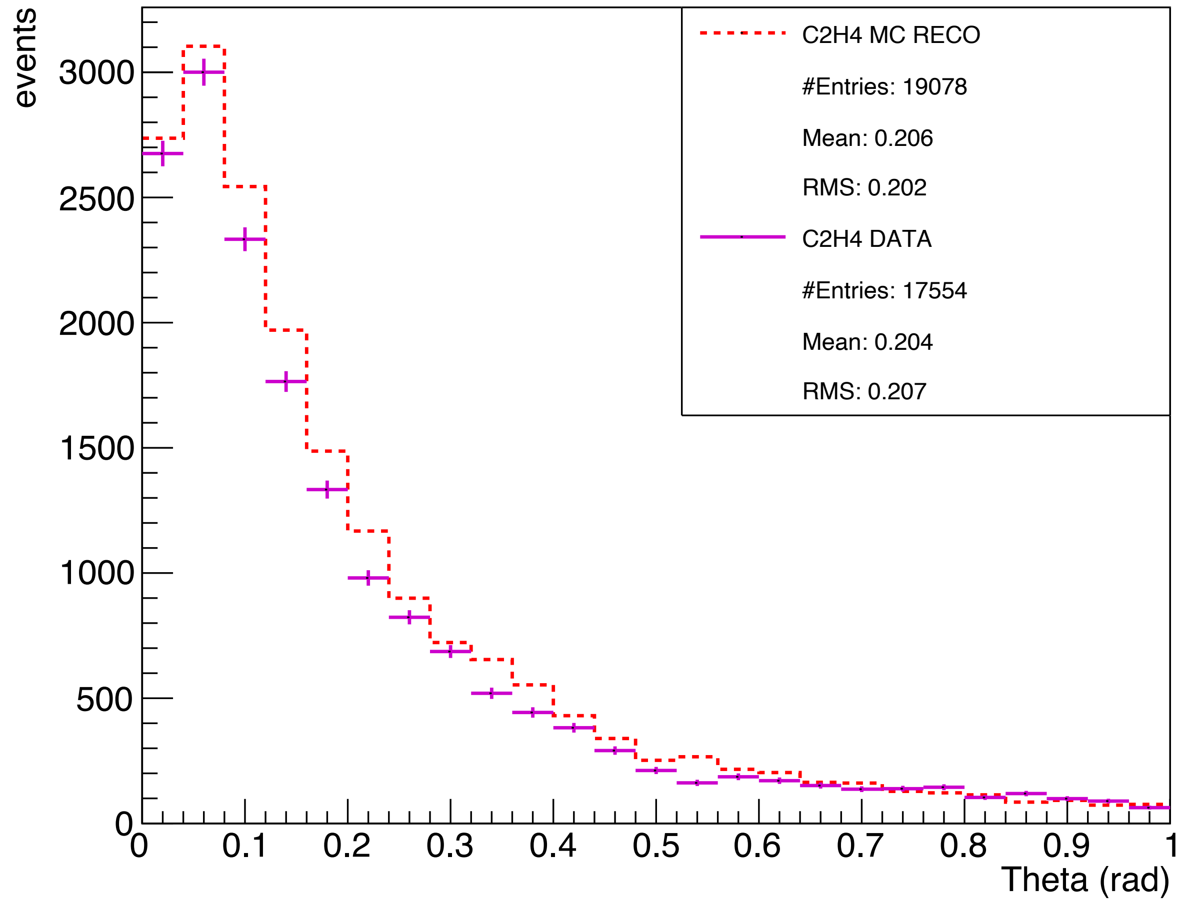
Fragment's angular distribution: DATA vs MC RECO

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

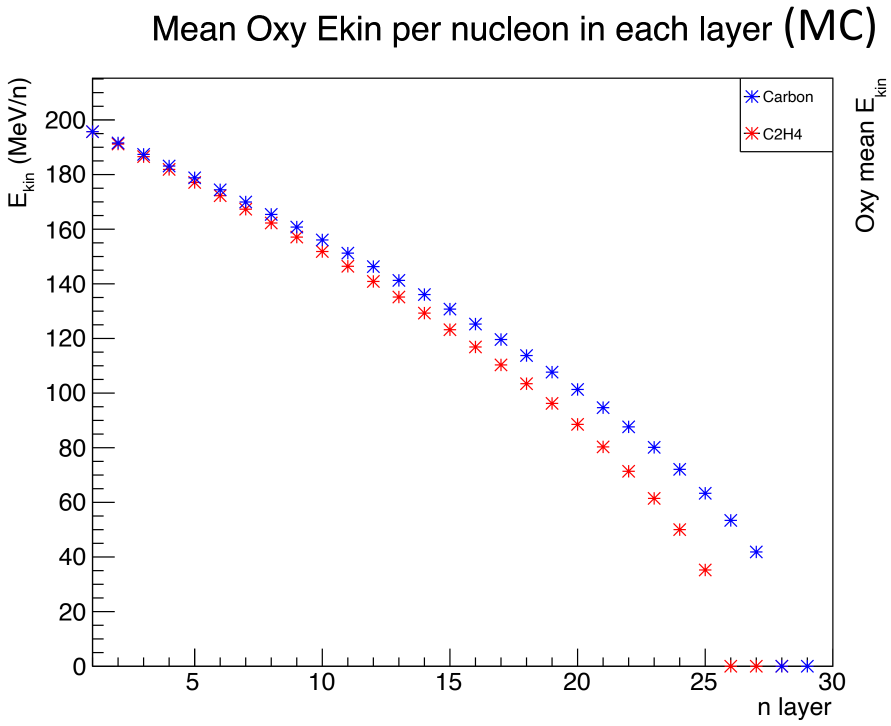
Carbon

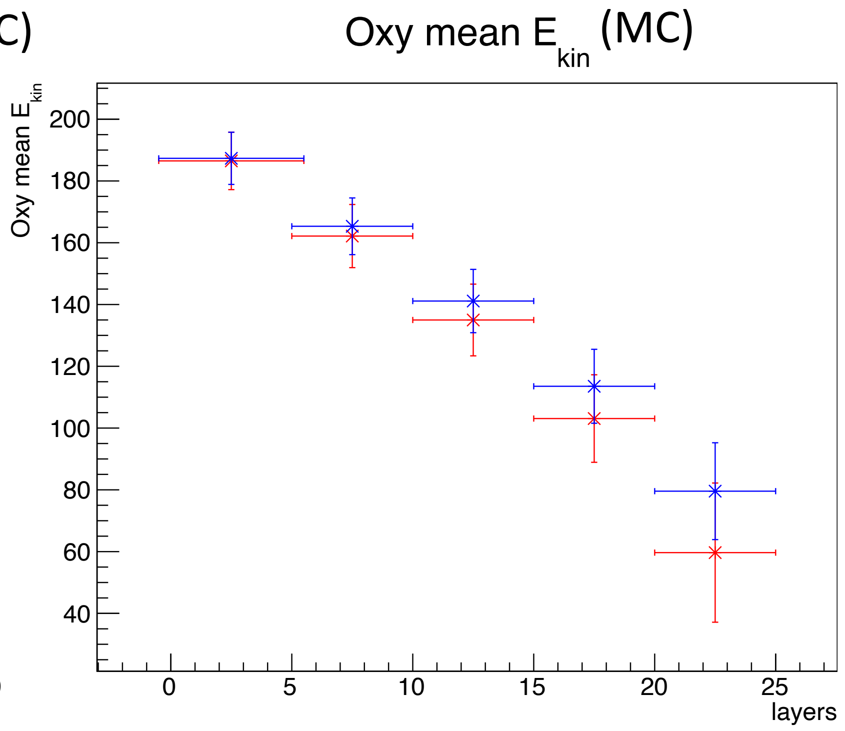


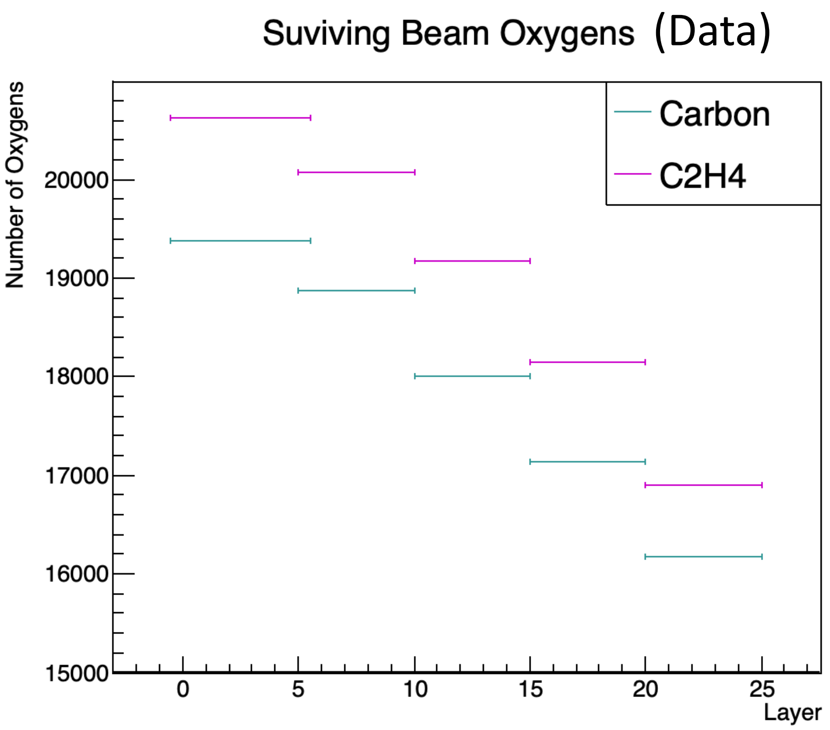
C_2H_4



Mean Oxygen Kinetic Energy per layer distribution (MC)







Cross Section Measurement

Integrated cross section:

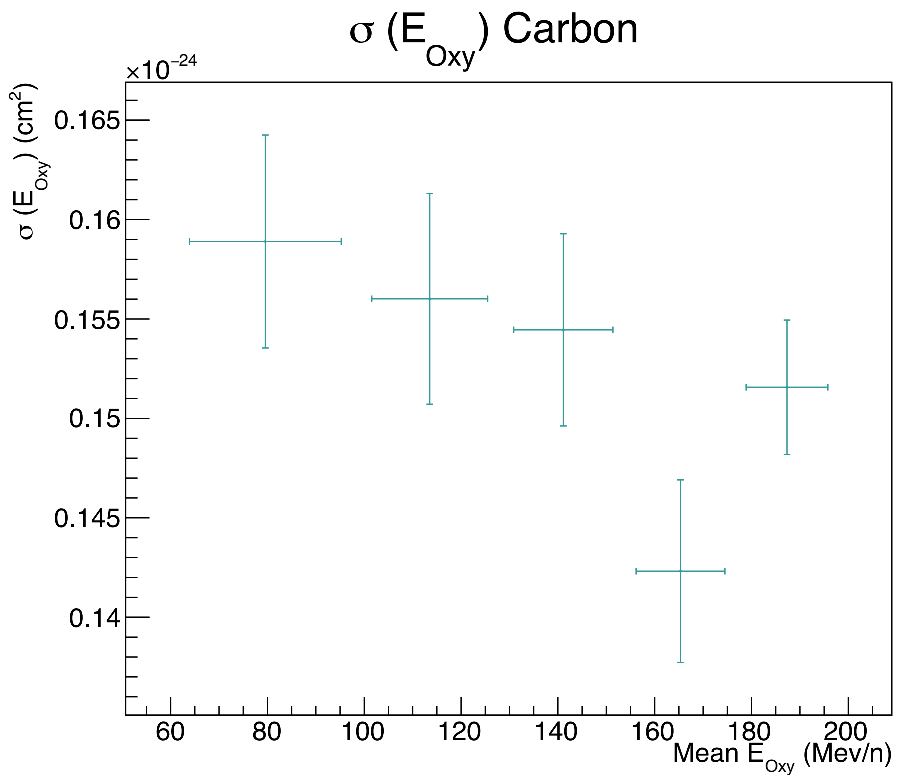
$$\sigma(E_{kin\ O})\Big|_{C\ or\ C_2H_4} = \frac{Y_i(E_{kin})}{N_B N_{TG} \epsilon^i_{reco}(E_{kin})}$$

$$\sigma(E_{kin\ O})\Big|_{H} = \frac{1}{4}\left(\sigma(E_{kin\ O})\Big|_{C_2H_4} - 2\sigma(E_{kin\ O})\Big|_{C}\right)$$

- Y_i = # of fragments in the interval $\Delta E_{kin\ Oxy}$
- 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:
    $\rho_C = 2.26g/cm^3$
    $\rho_{C_2H_4} = 0.94g/cm^3$
    $\rho_H = 0.0708g/cm^3$
  - d = target thickness:
    $d_C = 0.1cm$ per layer
    $d_{C_2H_4} = 0.2cm$ per layer
  - $N_A = 6.022 \cdot 10^{23}/mol$
  - A = molar mass:
    $A_C = 12g/mol$
    $A_{C2H4} = 28g/mol$
    $A_H = 1g/mol$
- ϵ^i_{reco} = reconstruction efficiency

Integrate cross section

1 Layer = 1mm C

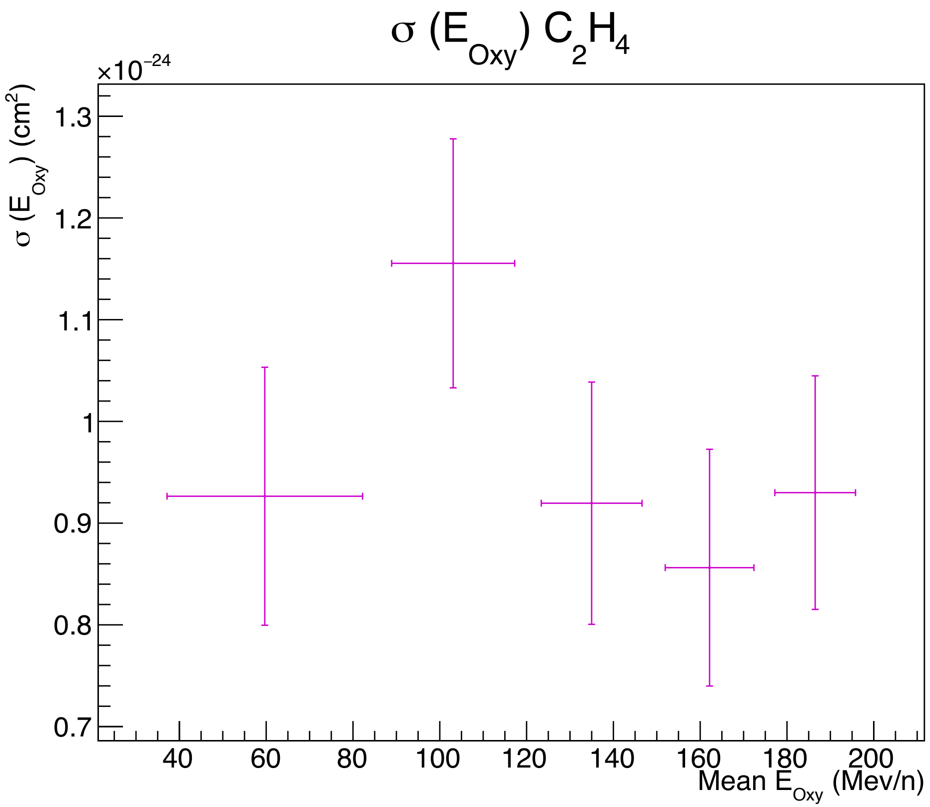


Projectile atomic number	Projectile mass number	Target atomic number	Target mass number	Target chemical formula	Projectile kinetic energy (MeV/u)	Cross-section type	Cross-section (mb)	Cross-section lower error (mb)	Cross-section upper error (mb)	First author of the publication	Year of publication
8	16	6	12	C	288	cc	852	17	17	Yamaguchi	2011
8	16	6	12	C	290	cc	863	20	20	Zeitlin	2011
8	16	6	12	C	400	cc	842	22	22	Zeitlin	2011

https://crosssection-db.herokuapp.com/

Integrate cross section

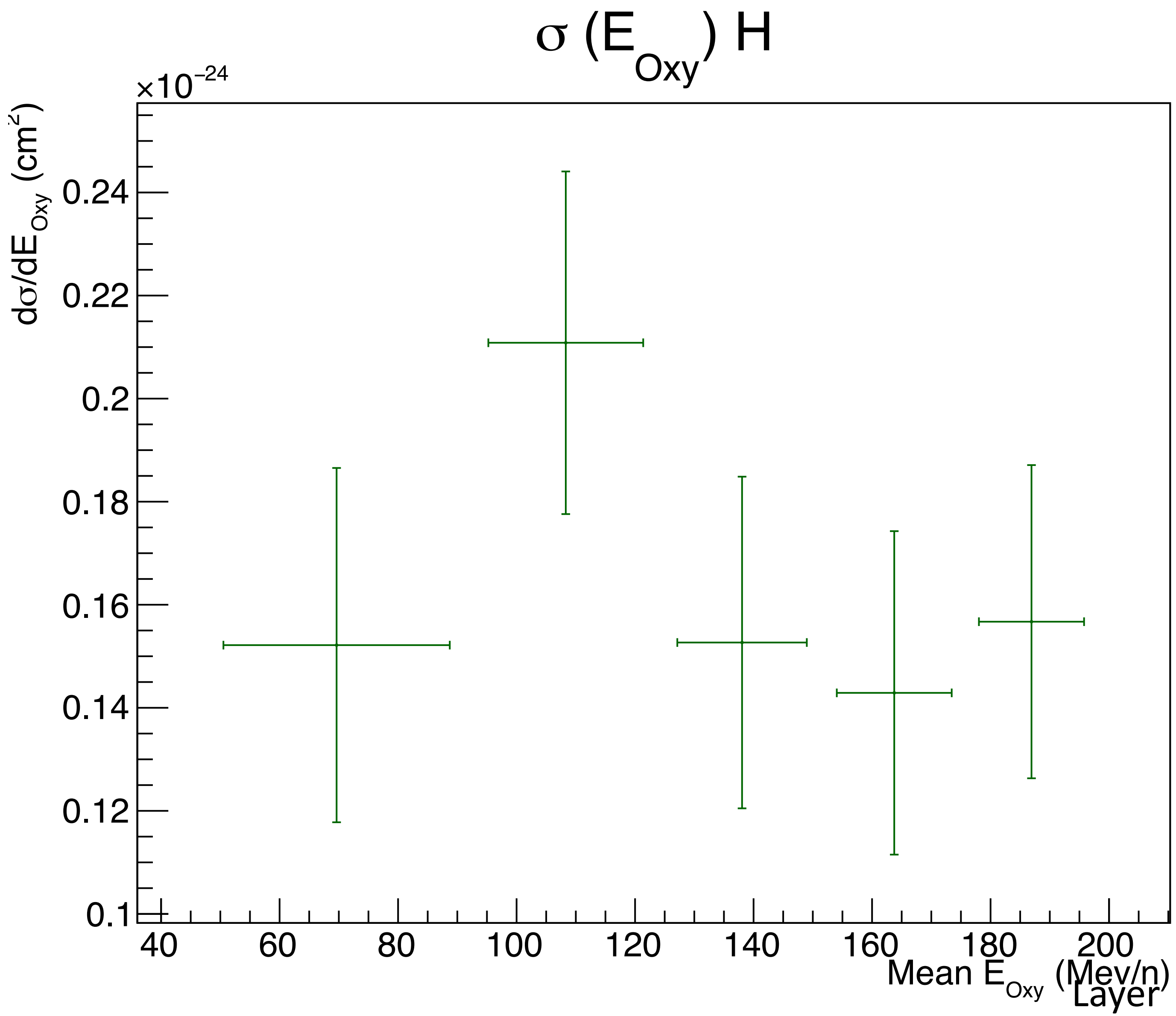
1 Layer = 2mm C_2H_4



Projectile atomic number	Projectile mass number	Target atomic number	Target mass number	Target chemical formula	Projectile kineti energy (MeV/u)	Cross-section type	Cross-section (mb)	Cross-section lower error (mb)	Cross-section upper error (mb)	First author of the publication	Year of publicati
8	16	5.44	14	CH2 (Polyethylene)	441	cc	1260	13	13	Webber	1990
8	16	5.44	14	CH2 (Polyethylene)	591	cc	1316	13	13	Webber	1990
8	16	5.44	14	CH2 (Polyethylene)	669	cc	1328	13	13	Webber	1990

https://crosssection-db.herokuapp.com/

Integrate cross section



Cross Section Measurement

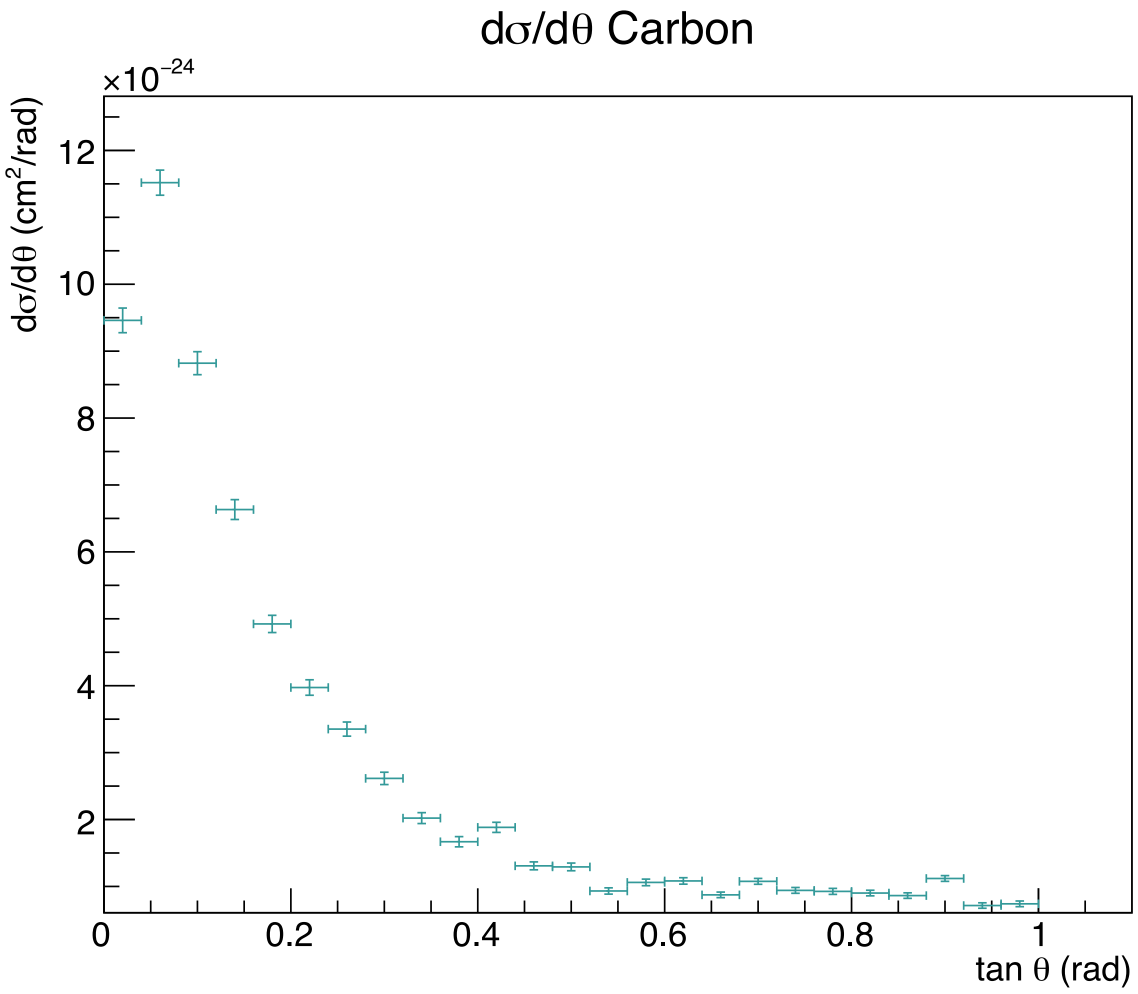
Starting from kinematic distributions it's possible to evaluate the differential cross section:

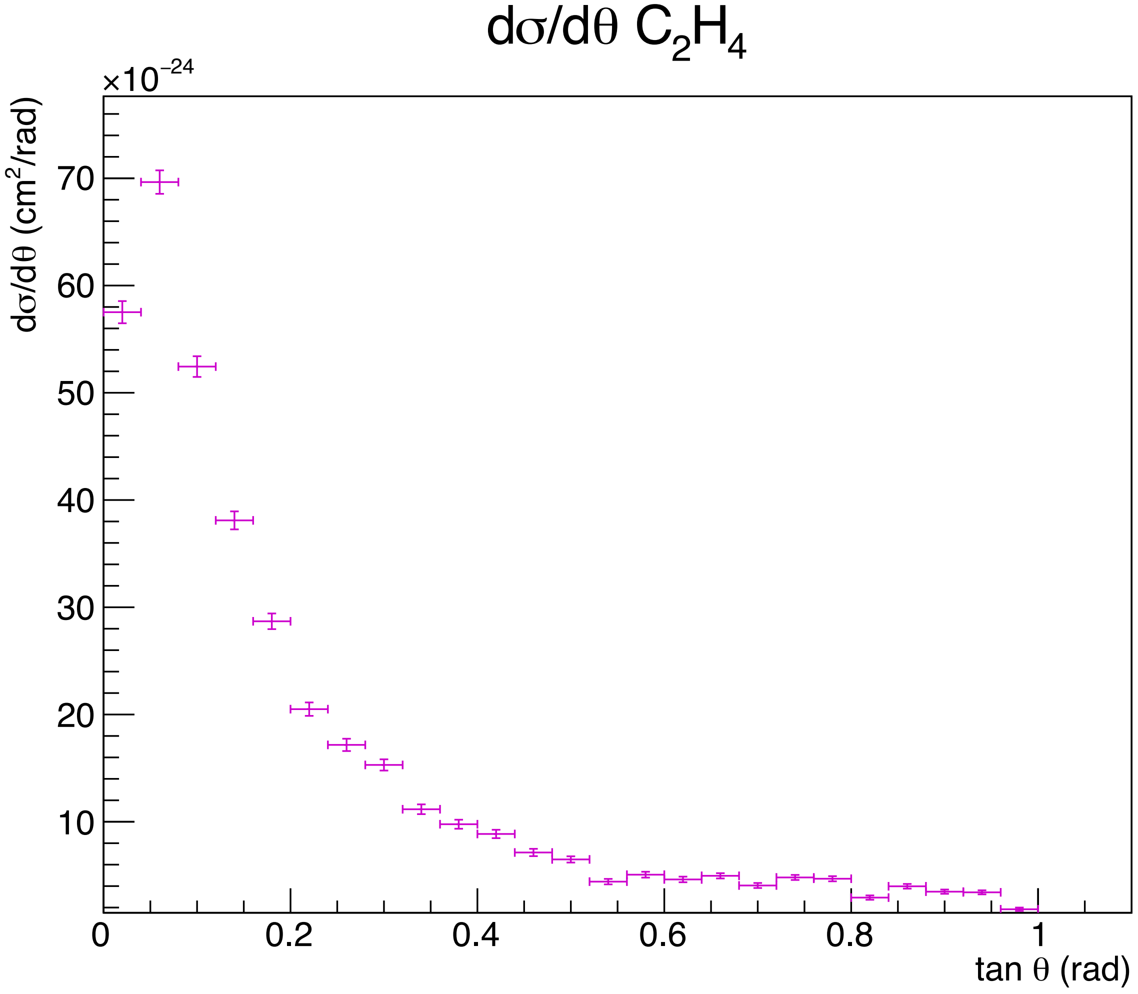
$$\left.\frac{d\sigma(\theta)}{d\theta}\right|_{C\ or\ C_2H_4} = \frac{Y_i(\theta)}{N_B N_{TG} \Delta\theta \epsilon^i_{reco}(\theta)}$$

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

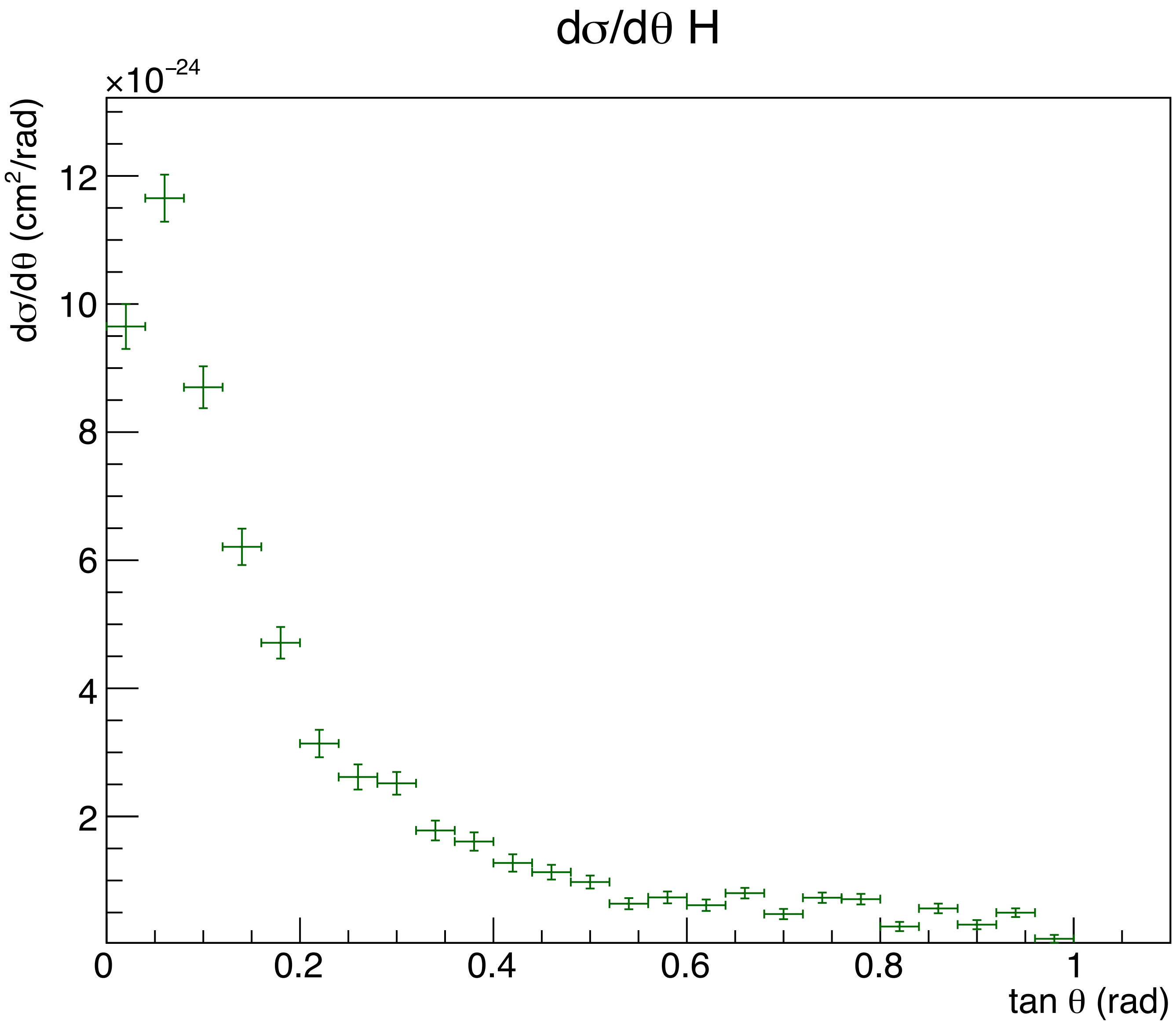
- Y_i = # of fragments in the interval $\Delta\theta$
- N_B = # of ions colliding on the target
- N_{TG} = # of particles in the target: $\frac{\rho d N_A}{A}$, with:
  - ρ = target density:
    $\rho_C = 2.26 g/cm^3$
    $\rho_{C_2H_4} = 0.94 g/cm^3$
    $\rho_H = 0.0708 g/cm^3$
  - d = target thickness: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

Differential cross section for angle (Mean Energy)





Differential cross section for angle (Mean Energy)

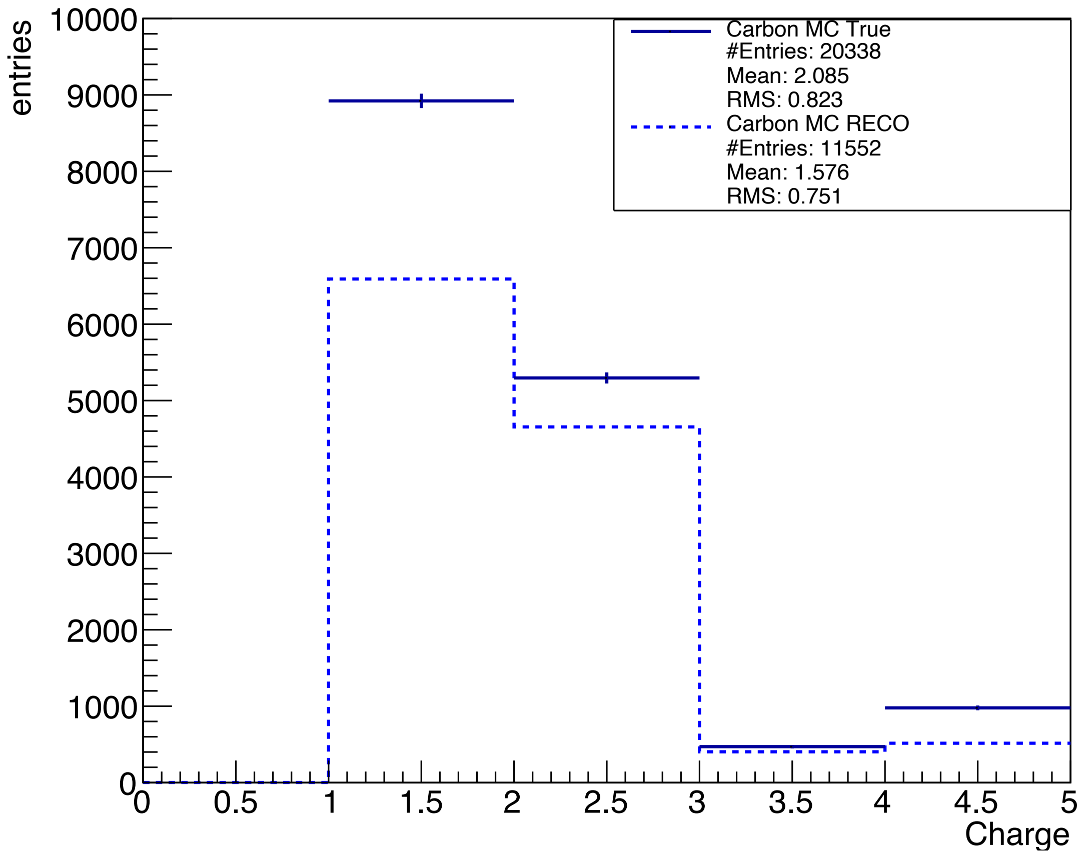


Charge distribution: MC RECO vs MC

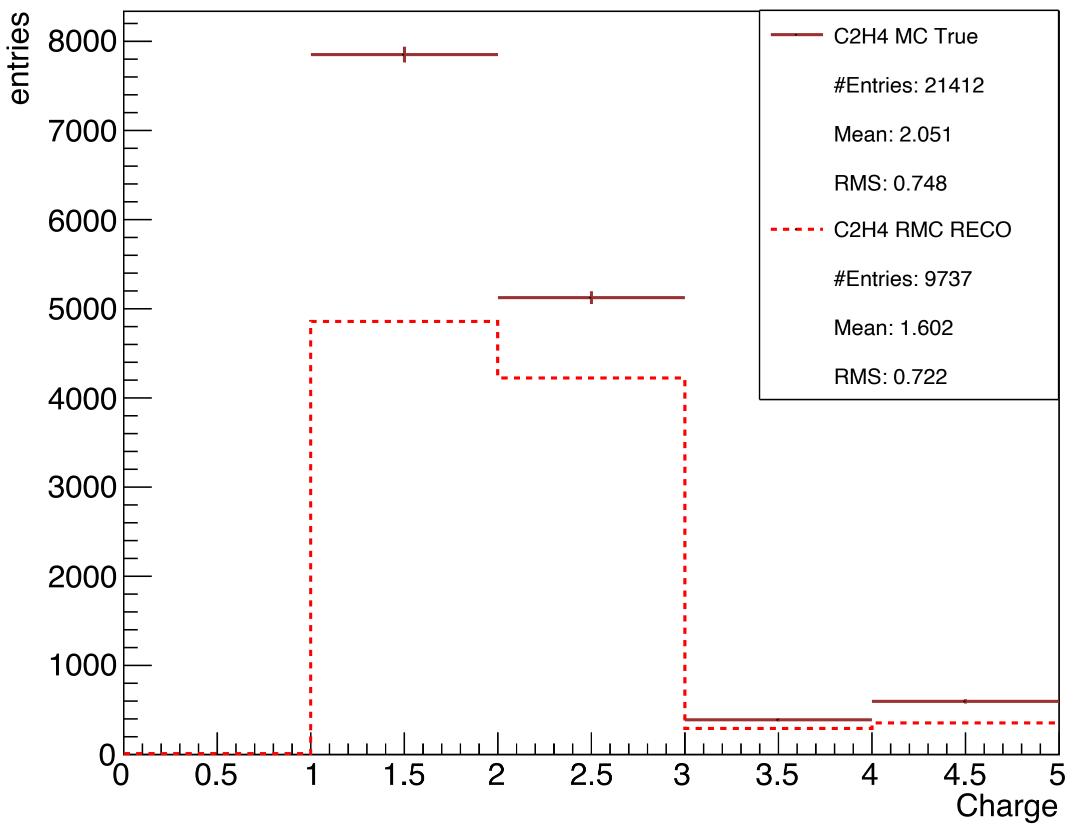
Distributions normalized to beam particles

PRELIMINARY

Carbon



C_2H_4



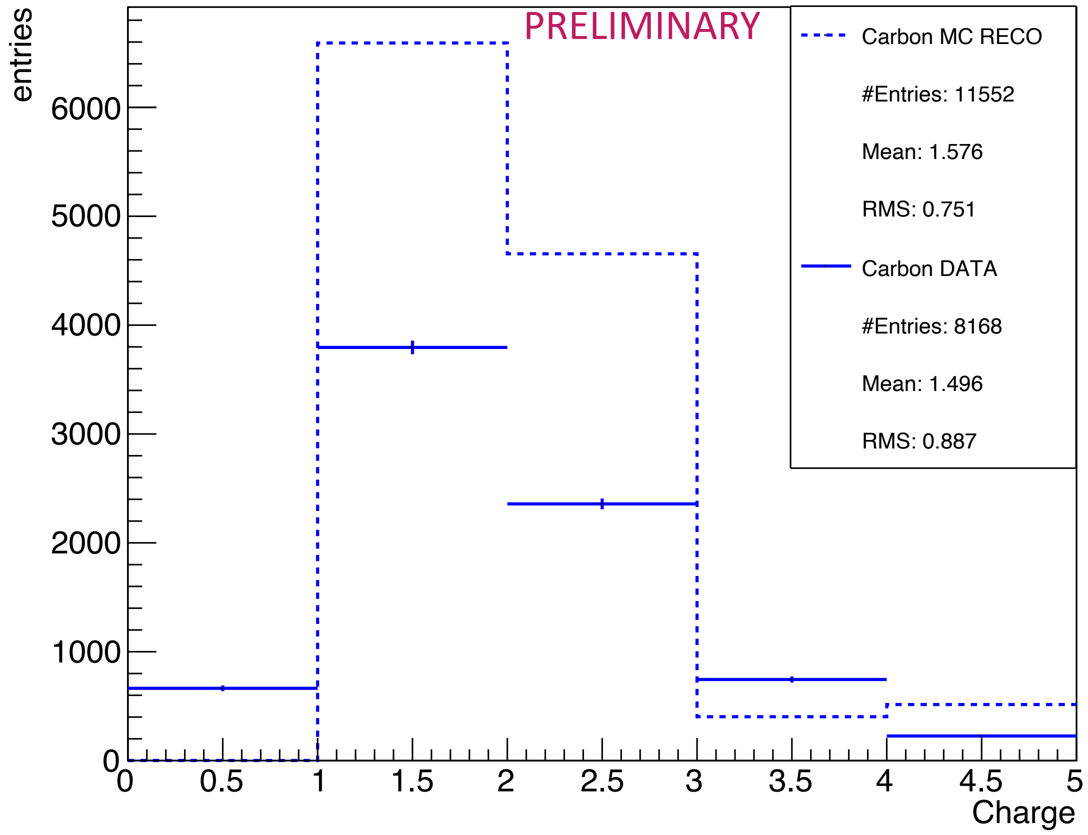
- Ionization and refreshing not simulated in MC: true charge used
- Efficiency of merging S1 and S2 to improve

Charge distribution: DATA vs MC RECO

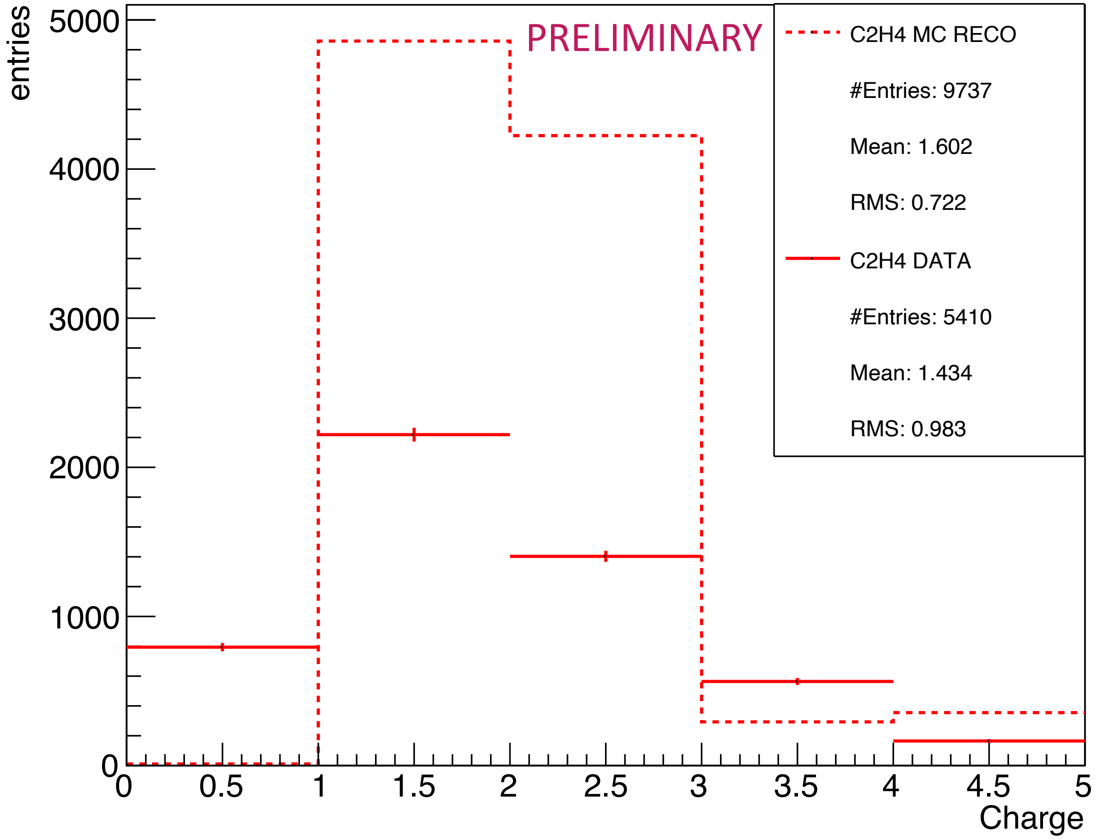
For charge evaluation see:
- https://doi.org/10.1515/phys-2021-0032
- V. Boccia's talk at Physics Meeting: https://agenda.infn.it/event/29377/contributions/149216/attachments/90378/121729/Update_ChargeID_GSI3_04_05_2022.pdf

Distributions normalized to beam particles

Carbon



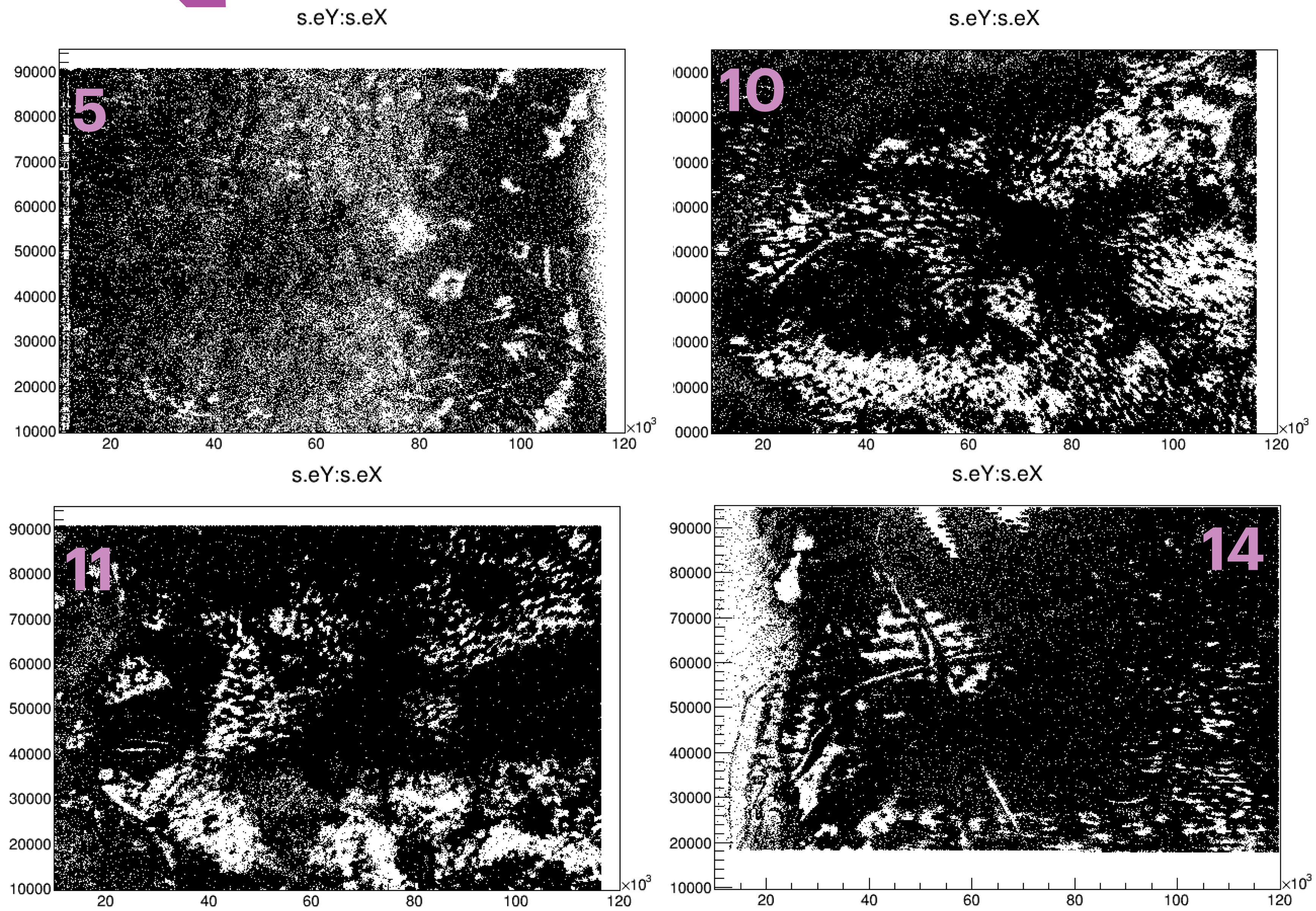
C_2H_4



- Efficiency of merging S1 and S2 to improve

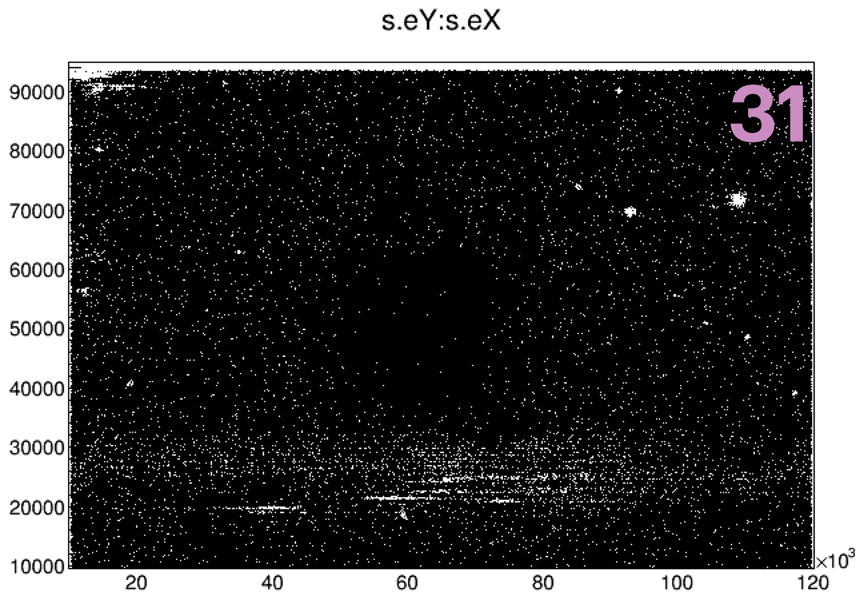
Analysis of
Oxygen at 400 MeV/n on C
GSI 3

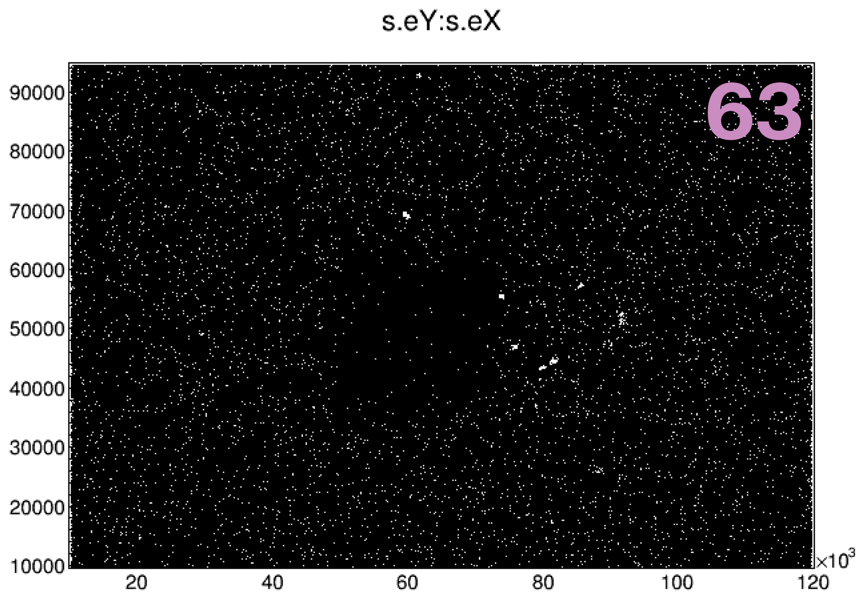
GSI3 - Emulsions Quality Check S1



- Bad emulsions quality
- S1 were made by Slavich company, S2 and following by Nagoya emulsions
- GSI3 and GSI4 batch different from GSI1' and GSI2' one

GSI3 - Emulsions Quality Check S2

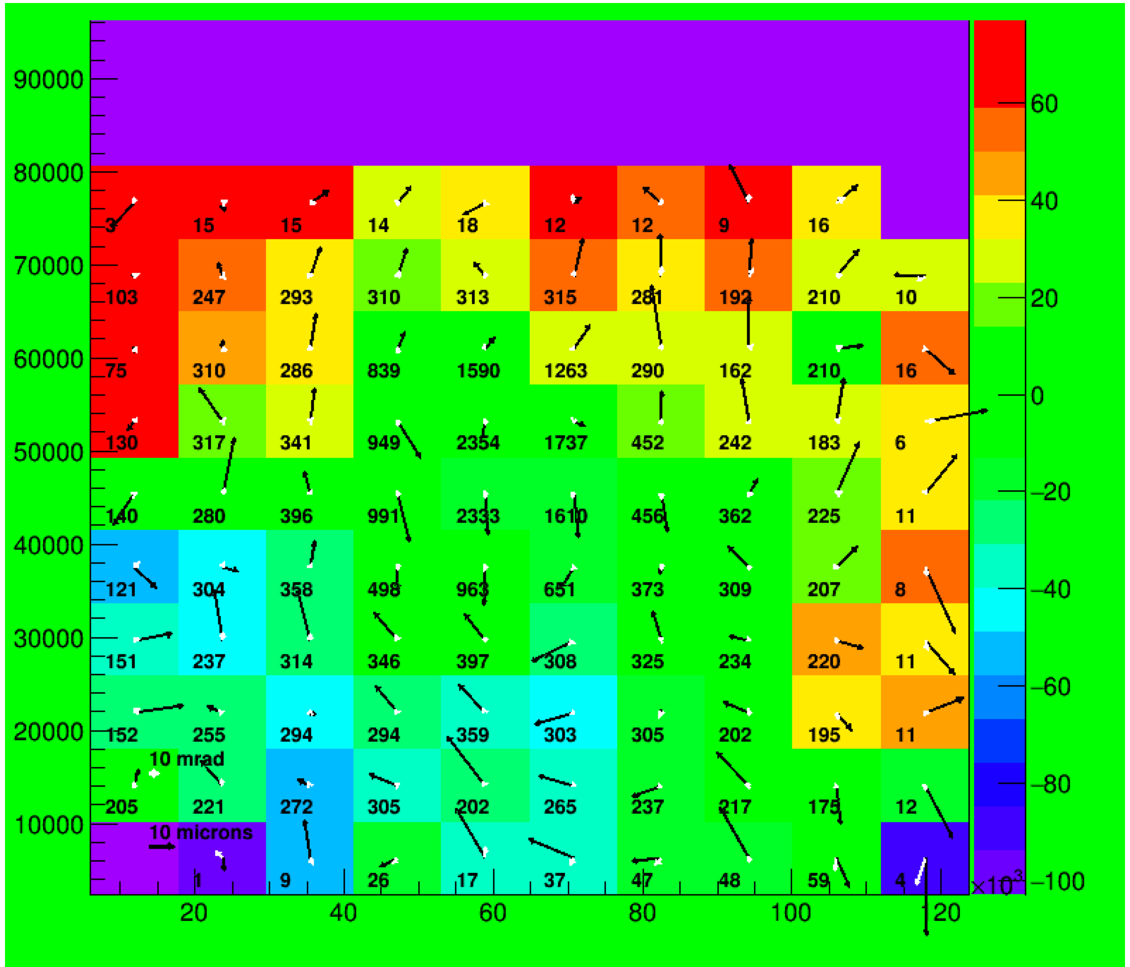


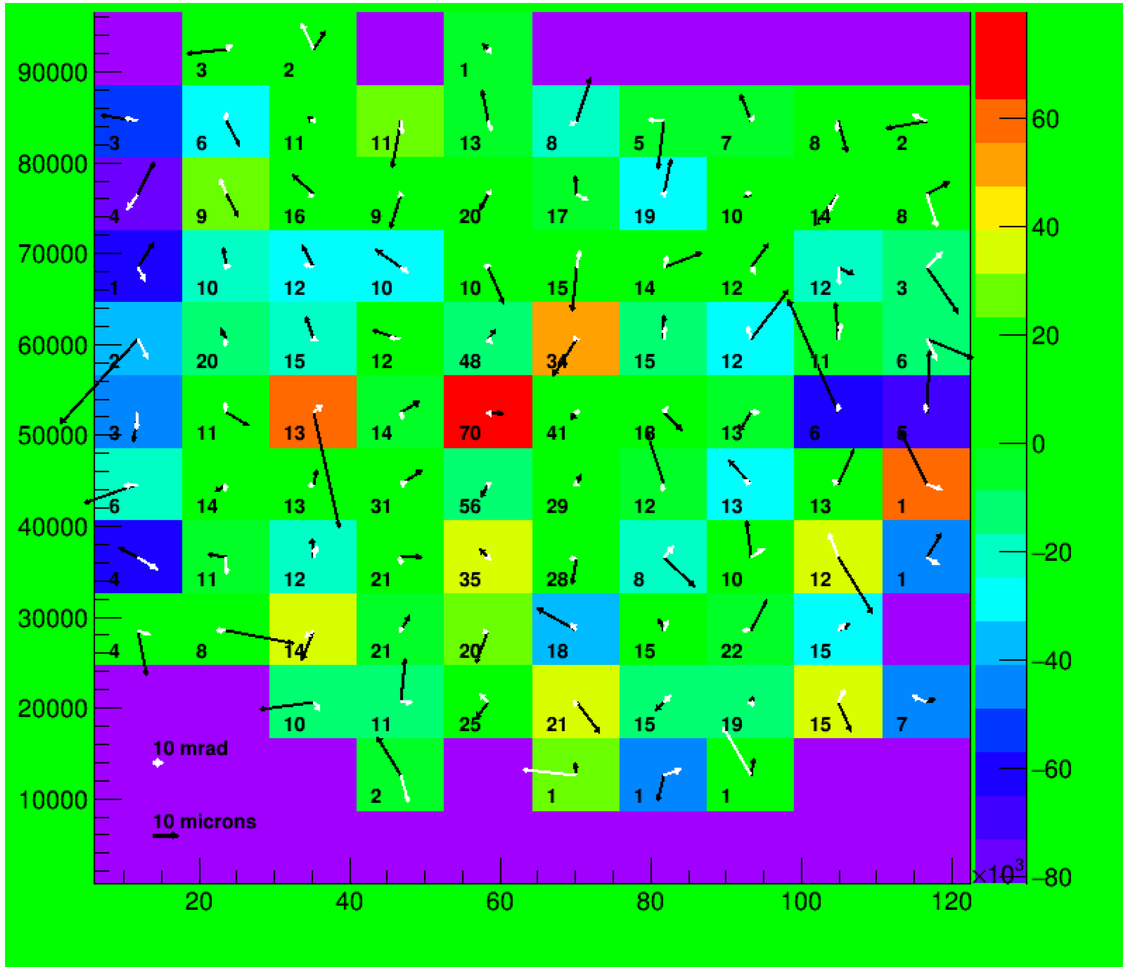


- No problems in S2 (emulsions produced in Nagoya)

Local alignment and shrinkage corrections

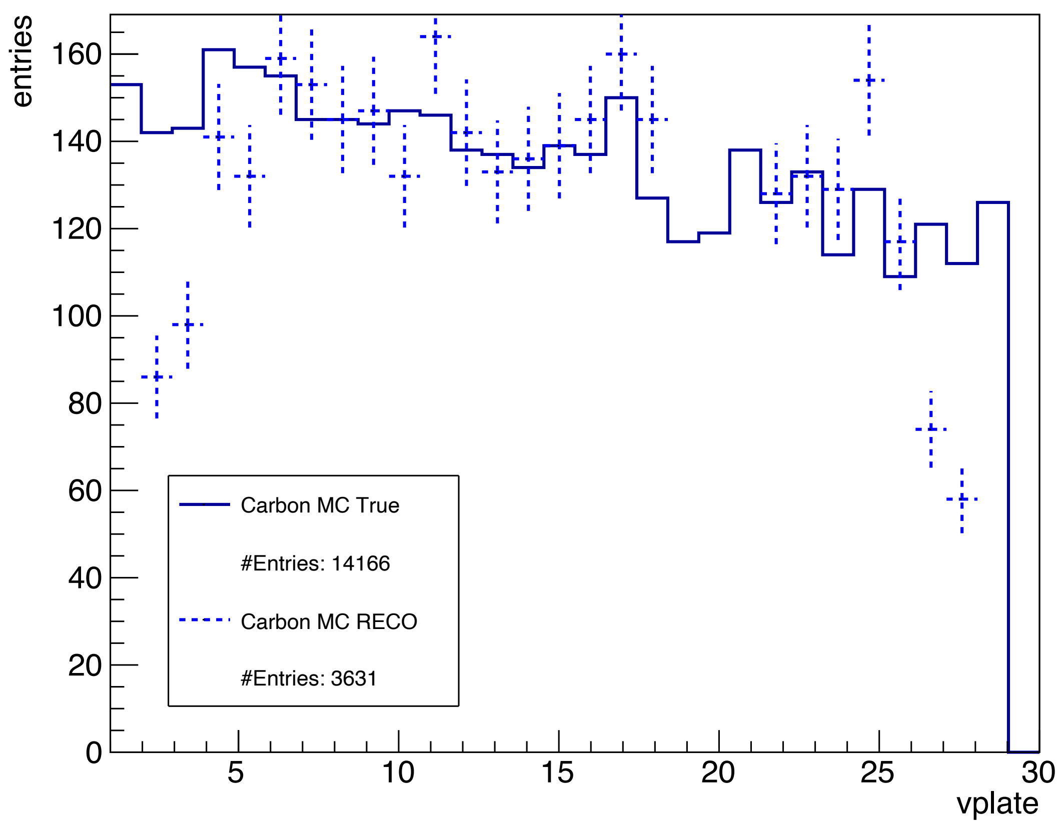
- Trials on-going to recover tracks and vertices reconstructions
- Trying to local align (corrections for each cm^2)

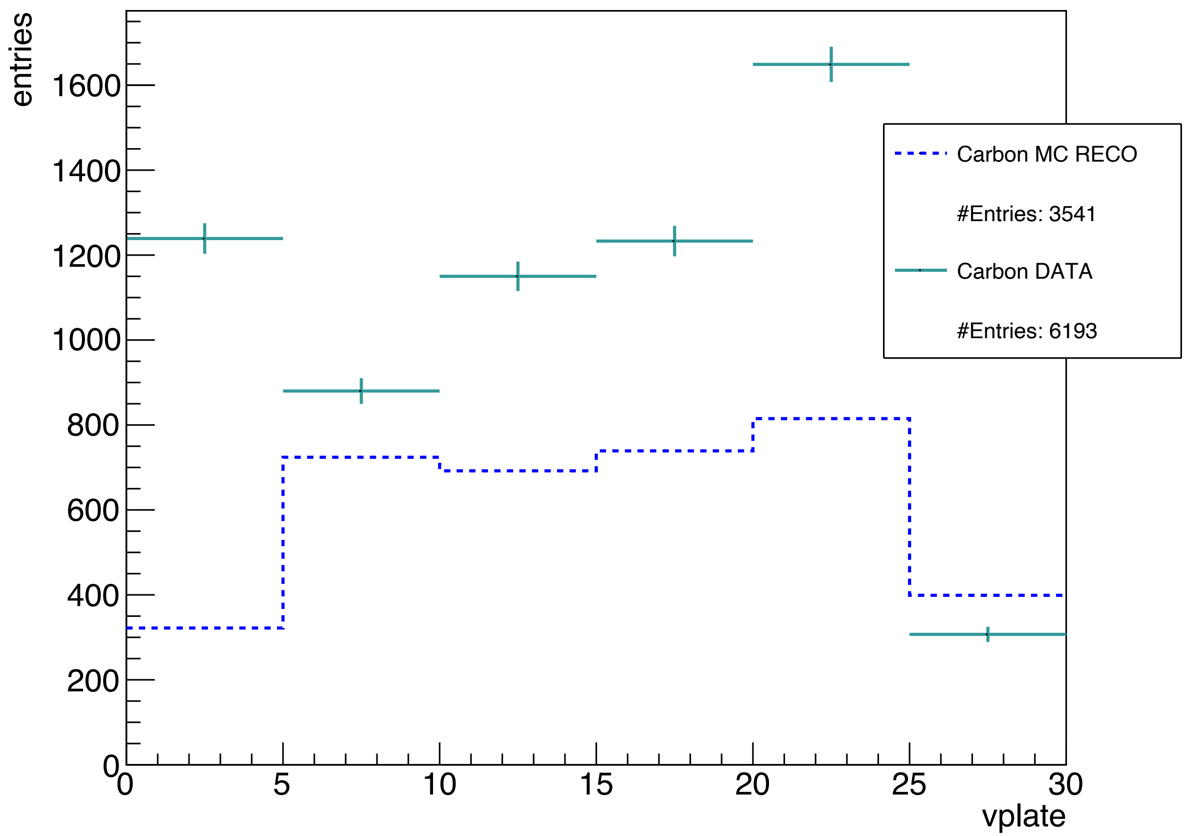




GSI3 Vertex Plate distribution

Distributions normalized to beam particles

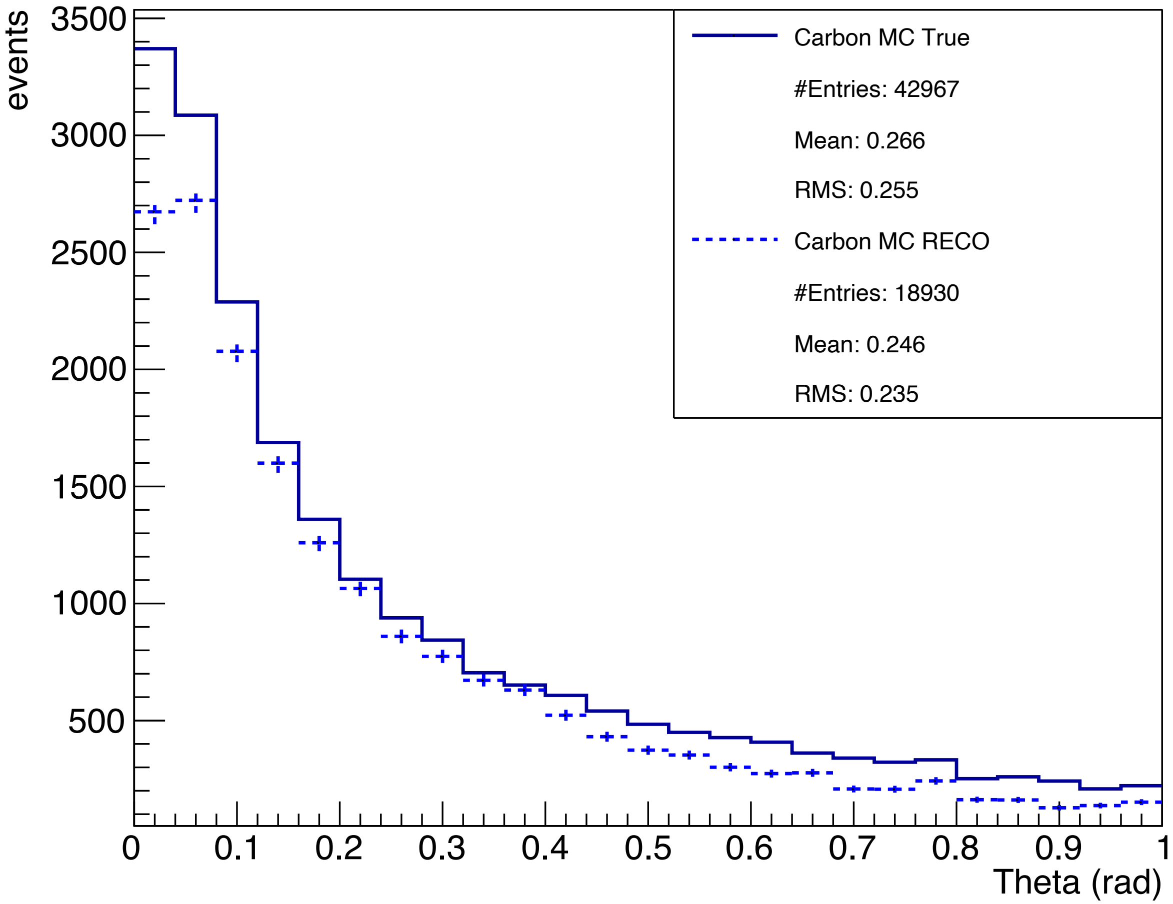


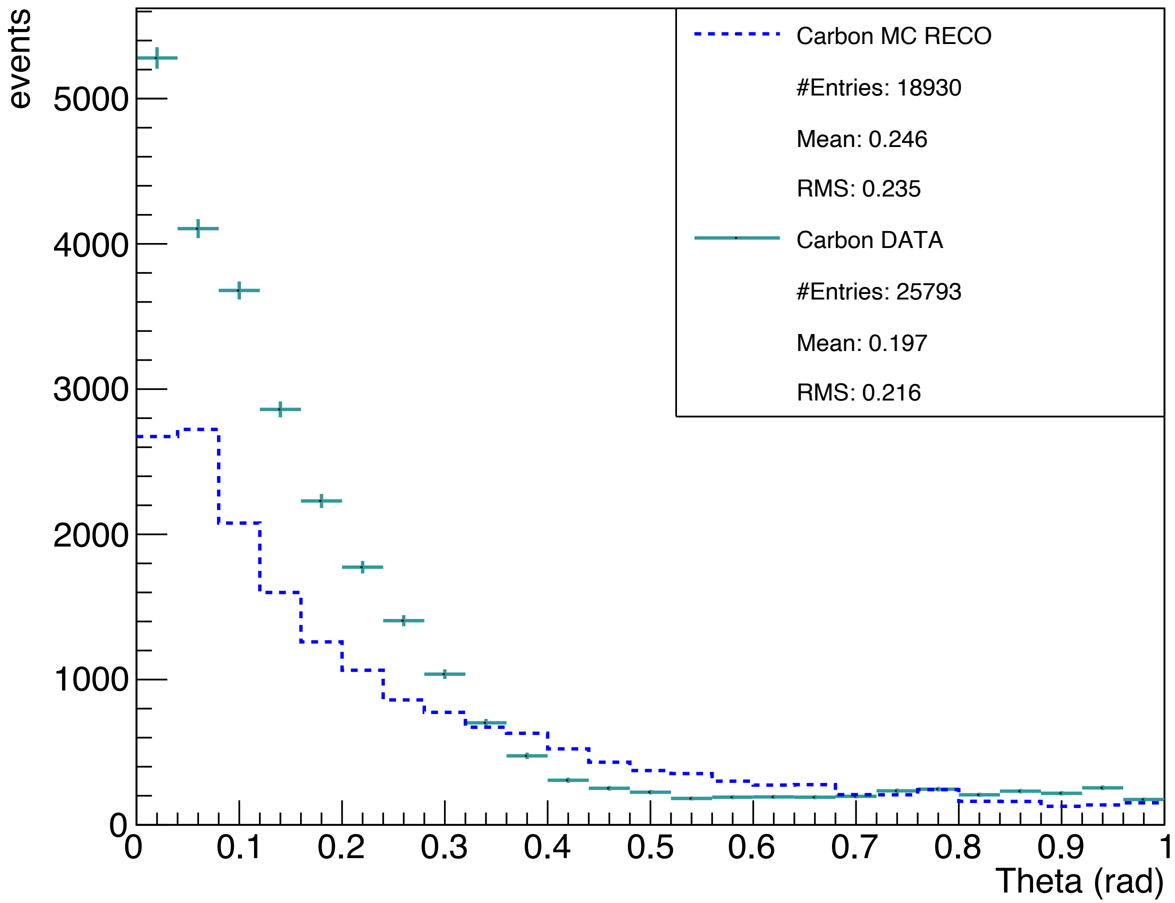


Still many fake or multiplied vertices

GSI3 Fragments' angular distribution

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





Conclusions

Oxygen @ 200 MeV/n on C and C2H4

- Integrated cross section evaluated
- Differential cross section evaluation on-going

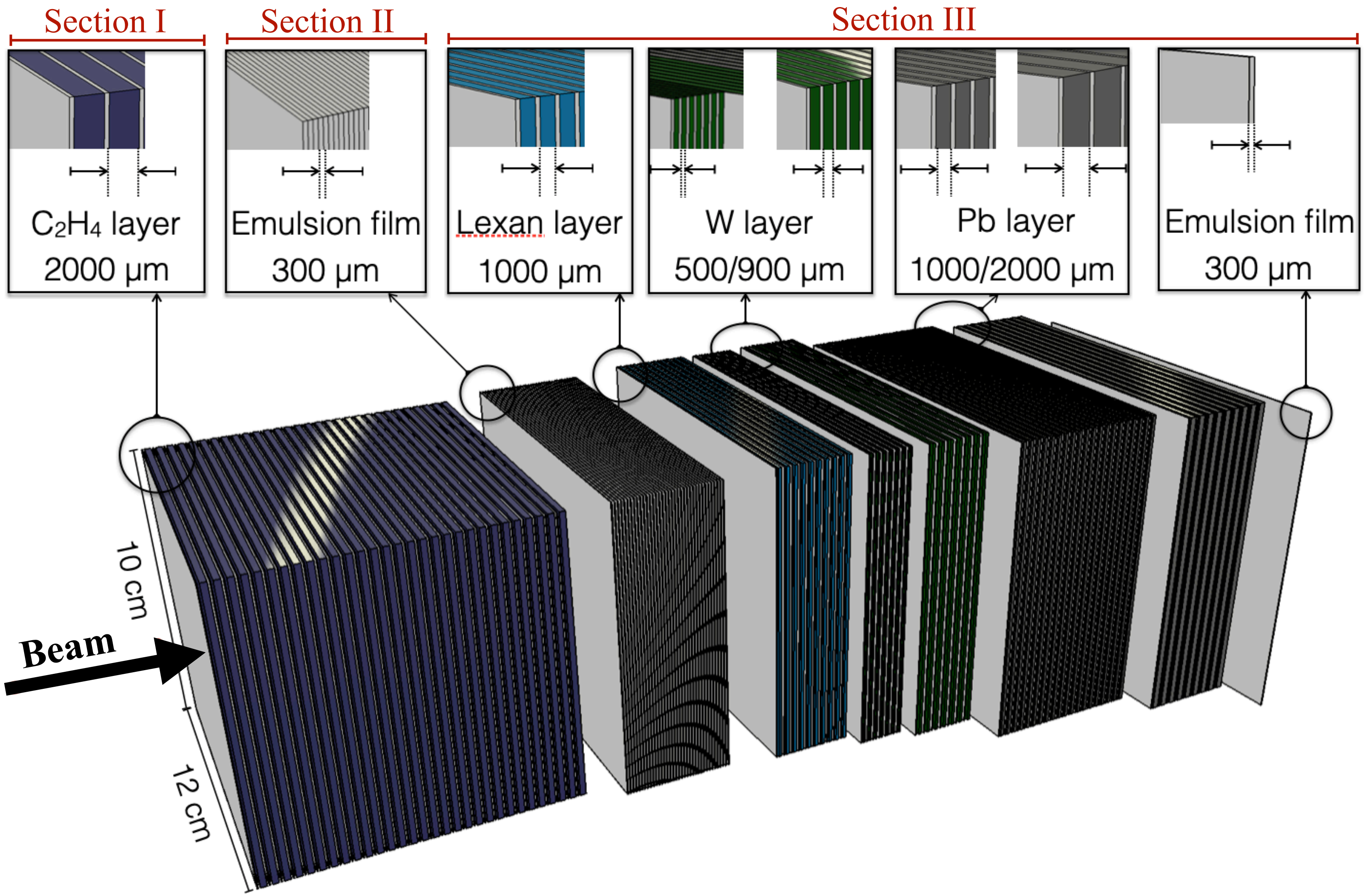
Oxygen @ 400 MeV/n on C

- Bad emulsions quality: efforts on-going to recover data reconstruction

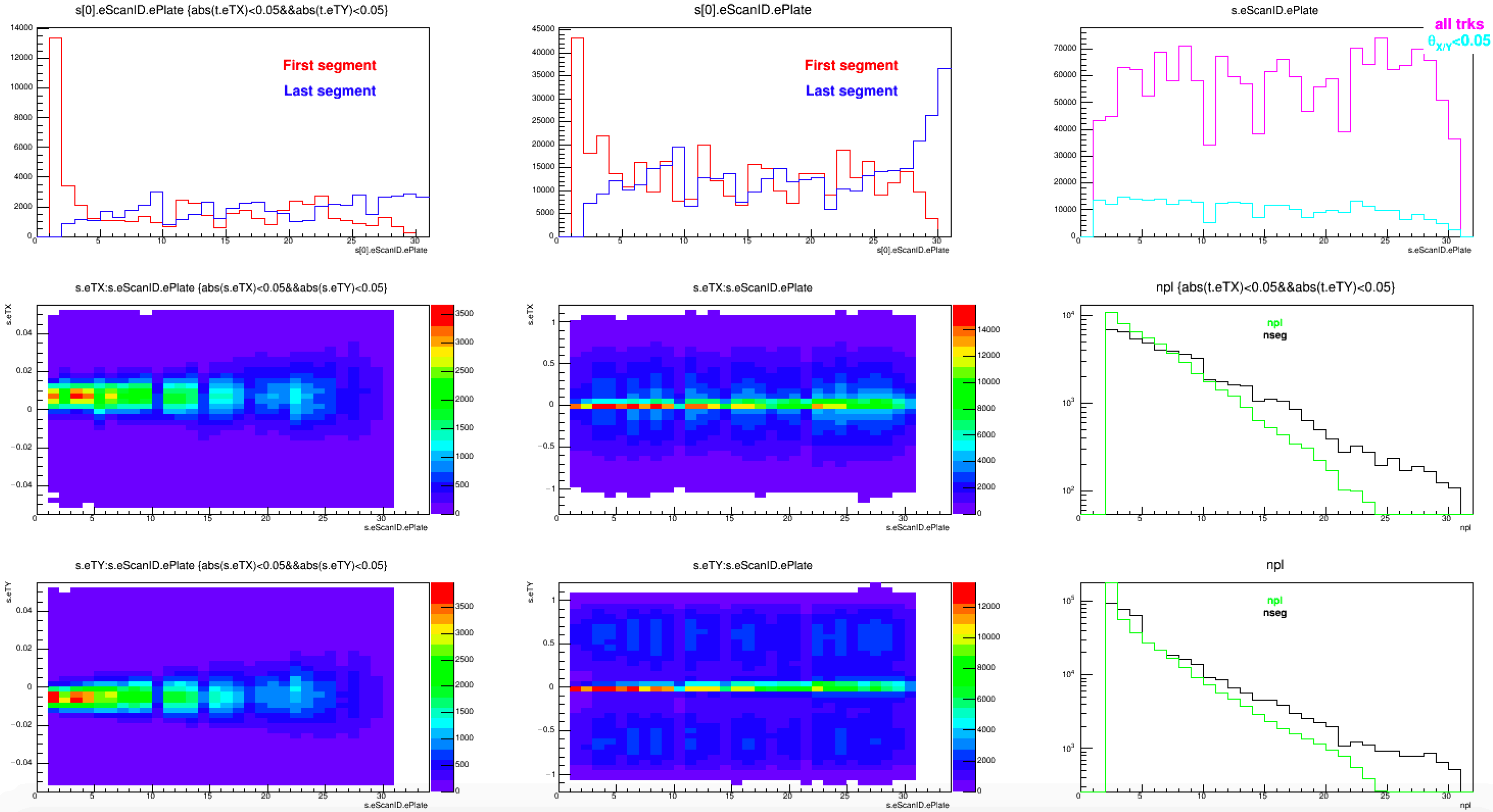
THANK YOU!

BACK UP SLIDES

Detector Structure

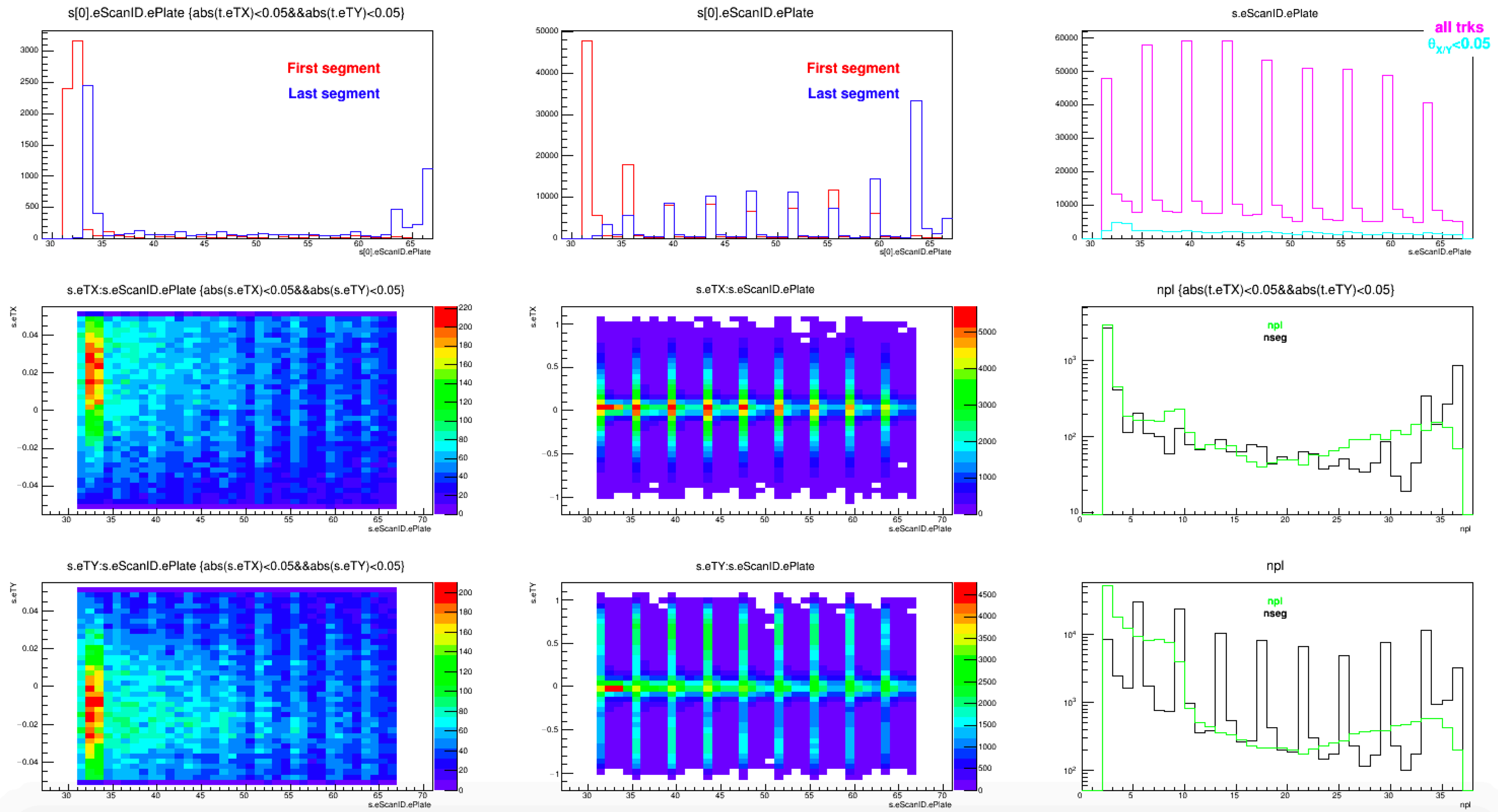


GSI1 - S1



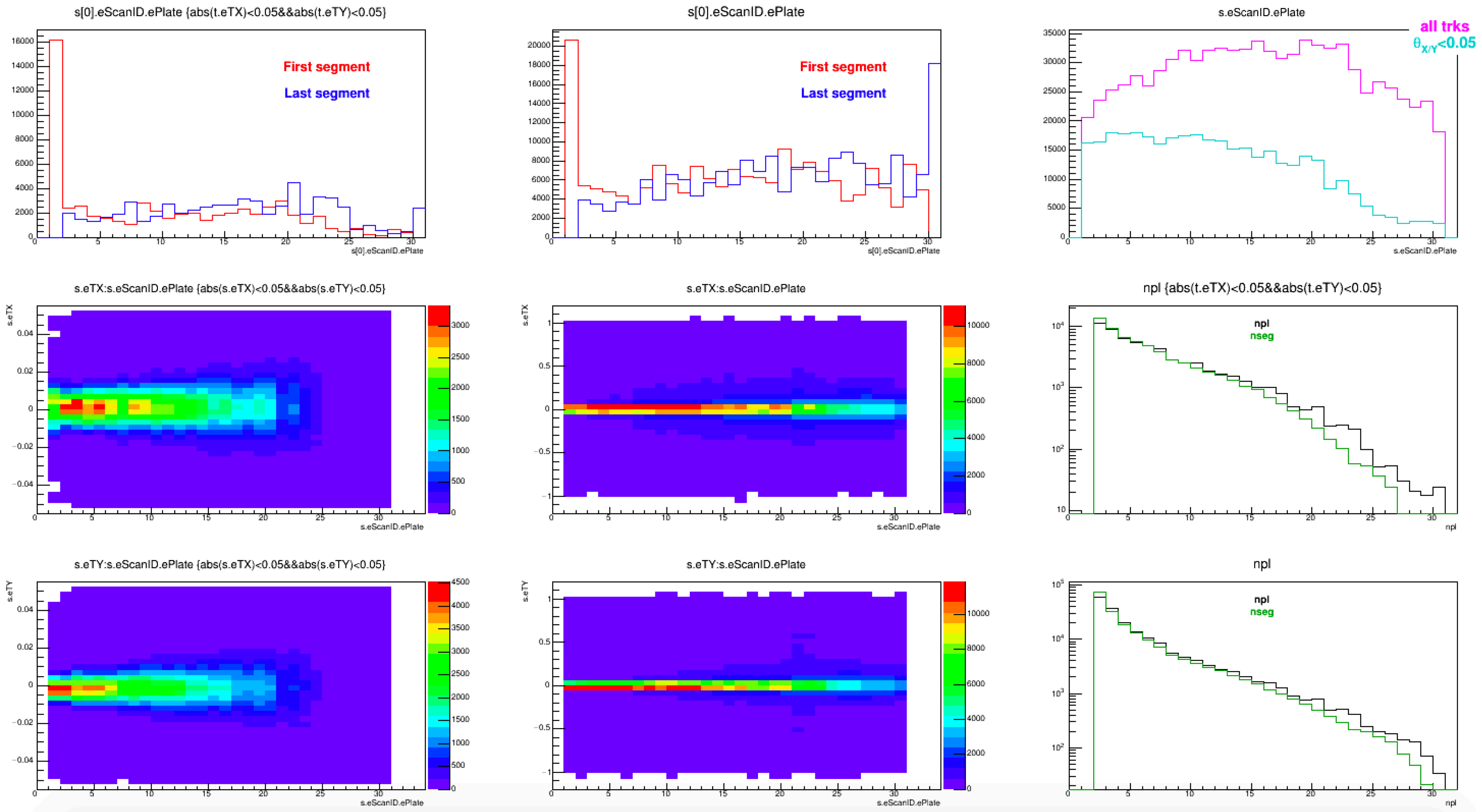
s[0].eScanID.ePlate {abs(t.eTX)<0.05&&abs(t.eTY)<0.05}
First segment
Last segment
s[0].eScanID.ePlate
First segment
Last segment
s.eScanID.ePlate
all trks
θX/Y<0.05
s.eTX:s.eScanID.ePlate {abs(s.eTX)<0.05&&abs(s.eTY)<0.05}
s.eTX:s.eScanID.ePlate
npl {abs(t.eTX)<0.05&&abs(t.eTY)<0.05}
npl
nseg
s.eTY:s.eScanID.ePlate {abs(s.eTX)<0.05&&abs(s.eTY)<0.05}
s.eTY:s.eScanID.ePlate
npl
npl
nseg

GSI1 - S2

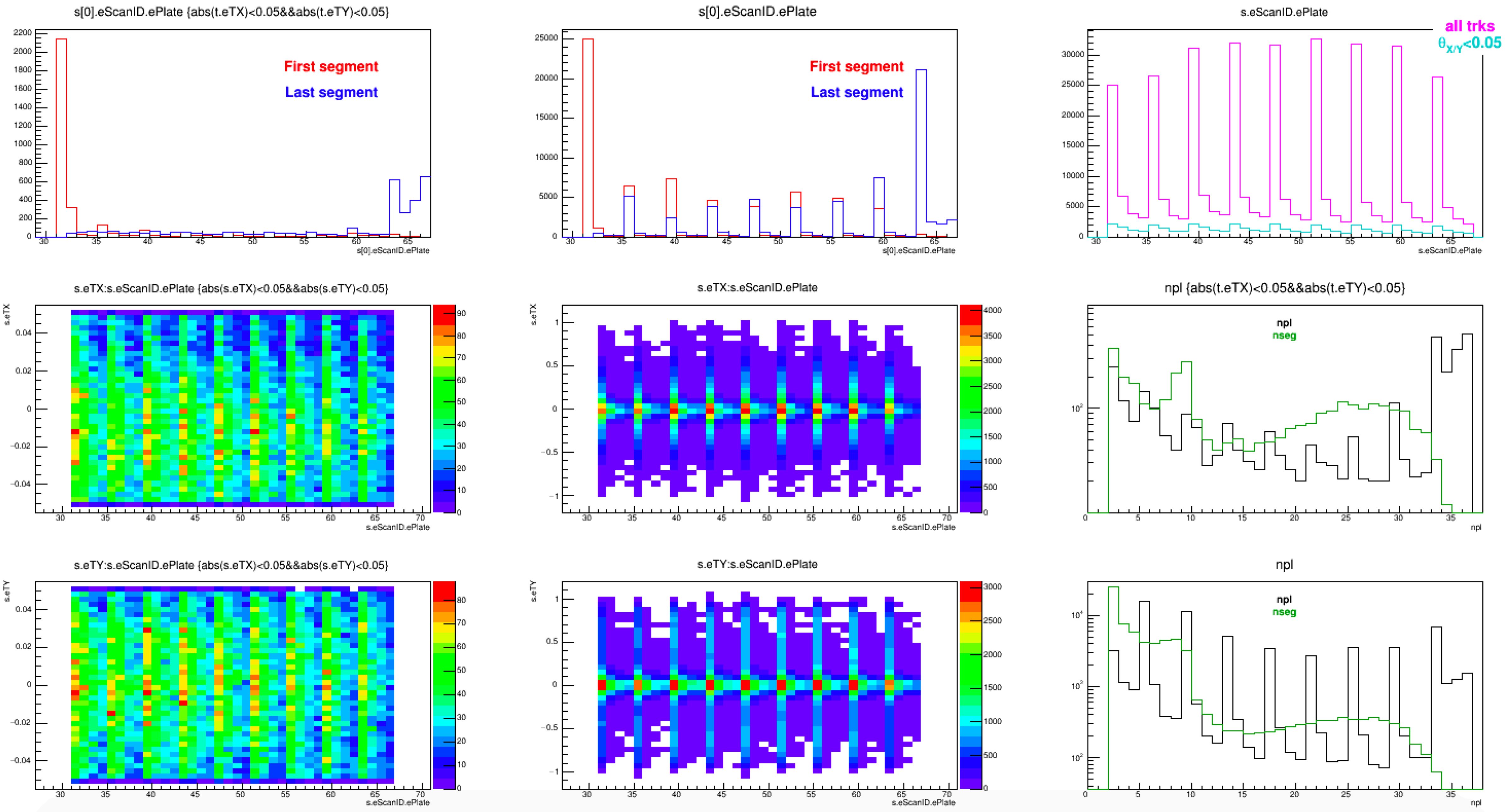


s[0].eScanID.ePlate {abs(t.eTX)<0.05&&abs(t.eTY)<0.05}
First segment
Last segment
s[0].eScanID.ePlate
First segment
Last segment
s.eScanID.ePlate
all trks
θX/Y<0.05
s.eTX:s.eScanID.ePlate {abs(s.eTX)<0.05&&abs(s.eTY)<0.05}
s.eTX:s.eScanID.ePlate
npl {abs(t.eTX)<0.05&&abs(t.eTY)<0.05}
npl
nseg
s.eTY:s.eScanID.ePlate {abs(s.eTX)<0.05&&abs(s.eTY)<0.05}
s.eTY:s.eScanID.ePlate
npl
npl
nseg

GSI2 - S1

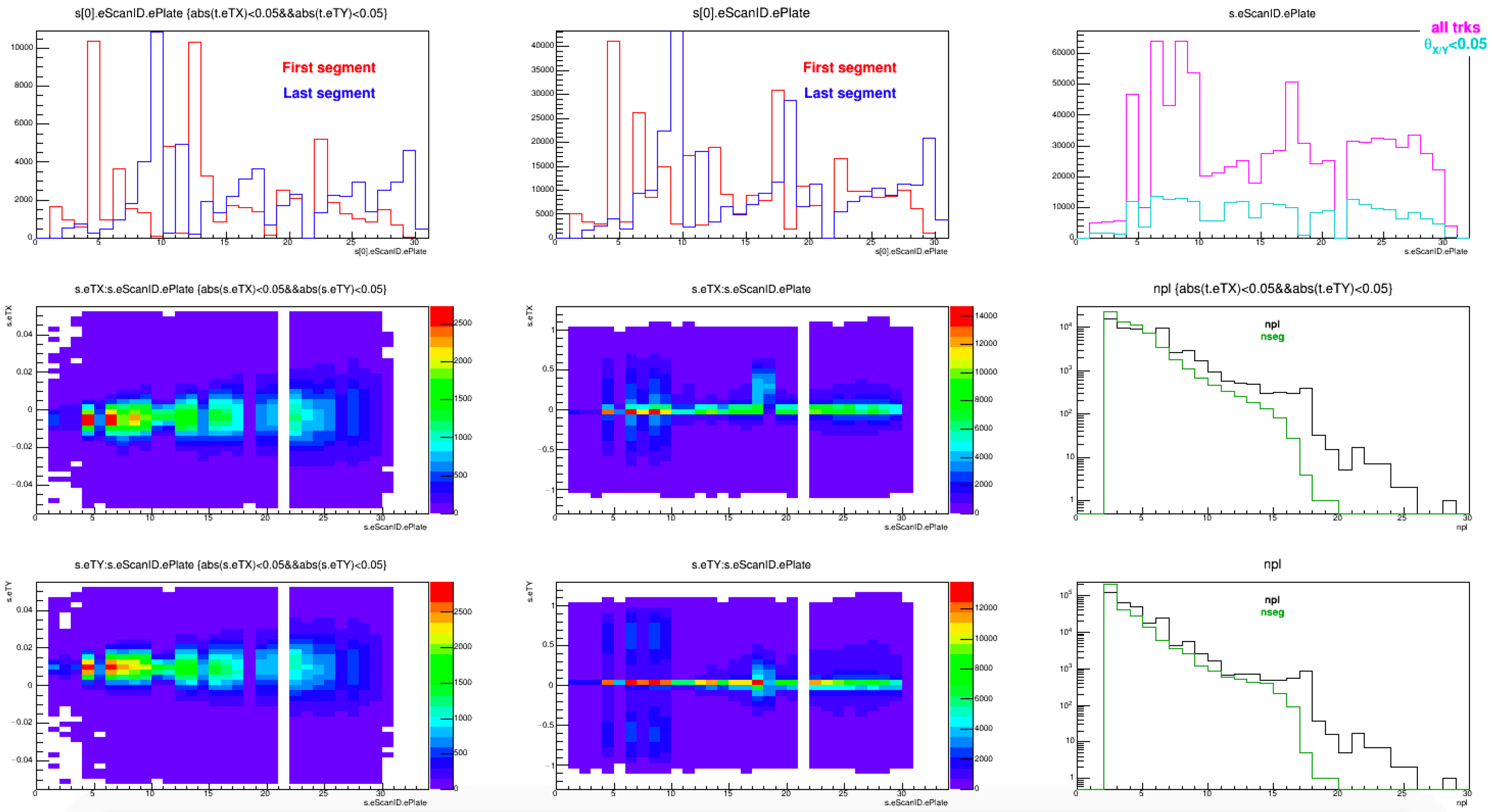

s[0].eScanID.ePlate {abs(t.eTX)<0.05&&abs(t.eTY)<0.05}
First segment
Last segment
s[0].eScanID.ePlate
s[0].eScanID.ePlate
First segment
Last segment
s[0].eScanID.ePlate
s.eScanID.ePlate
all trks
$\theta_{X/Y}$<0.05
s.eScanID.ePlate
s.eTX:s.eScanID.ePlate {abs(s.eTX)<0.05&&abs(s.eTY)<0.05}
s.eTX
s.eScanID.ePlate
s.eTX:s.eScanID.ePlate
s.eTX
s.eScanID.ePlate
npl {abs(t.eTX)<0.05&&abs(t.eTY)<0.05}
npl
nseg
npl
s.eTY:s.eScanID.ePlate {abs(s.eTX)<0.05&&abs(s.eTY)<0.05}
s.eTY
s.eScanID.ePlate
s.eTY:s.eScanID.ePlate
s.eTY
s.eScanID.ePlate
npl
npl
nseg
npl

GSI2 - S2



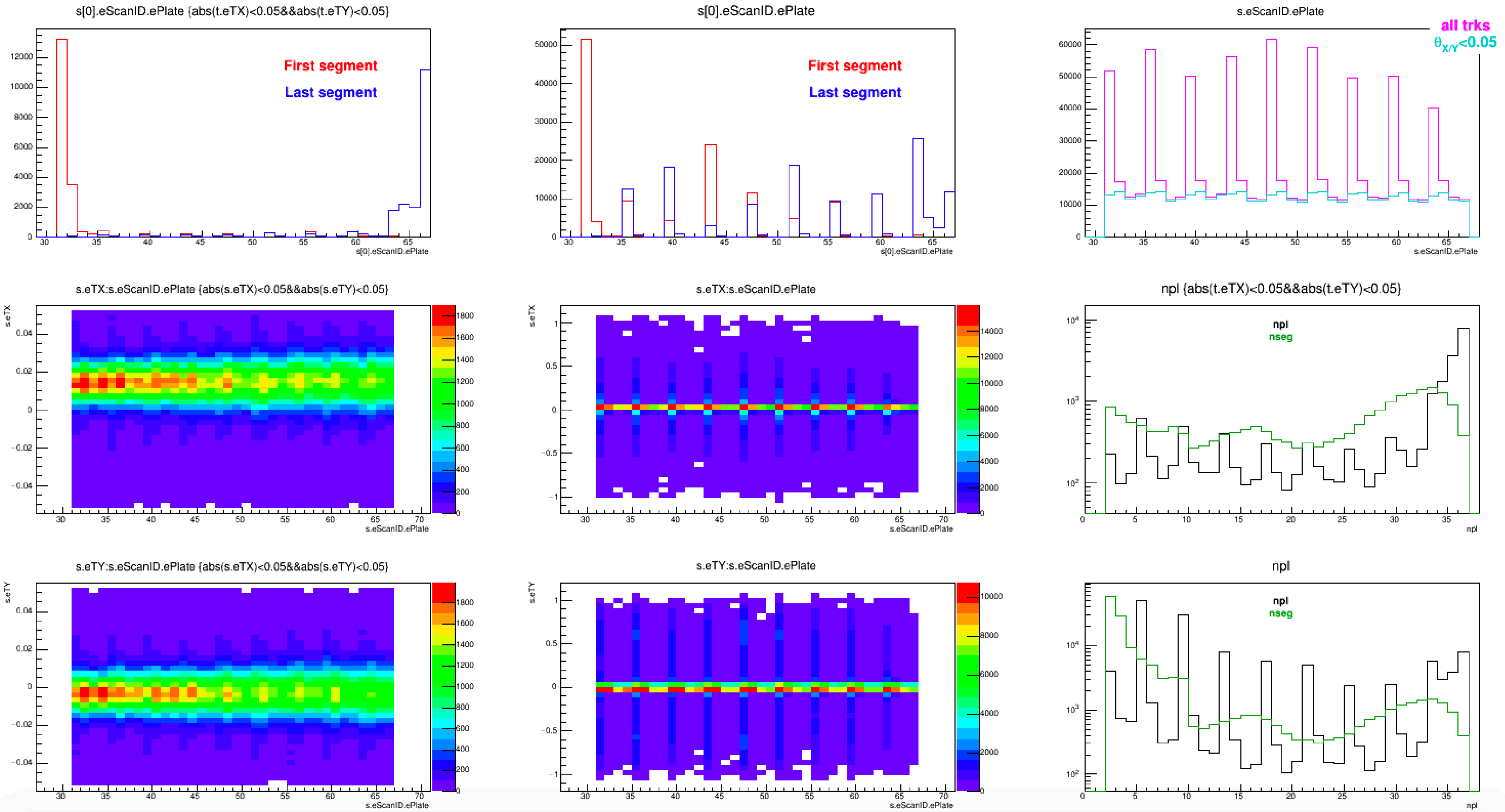
s[0].eScanID.ePlate {abs(t.eTX)<0.05&&abs(t.eTY)<0.05}
First segment
Last segment
s[0].eScanID.ePlate
s[0].eScanID.ePlate
First segment
Last segment
s[0].eScanID.ePlate
s.eScanID.ePlate
all trks
$\theta_{X/Y}$<0.05
s.eScanID.ePlate
s.eTX:s.eScanID.ePlate {abs(s.eTX)<0.05&&abs(s.eTY)<0.05}
s.eTX
s.eScanID.ePlate
s.eTX:s.eScanID.ePlate
s.eTX
s.eScanID.ePlate
npl {abs(t.eTX)<0.05&&abs(t.eTY)<0.05}
npl
nseg
npl
s.eTY:s.eScanID.ePlate {abs(s.eTX)<0.05&&abs(s.eTY)<0.05}
s.eTY
s.eScanID.ePlate
s.eTY:s.eScanID.ePlate
s.eTY
s.eScanID.ePlate
npl
npl
nseg
npl

GSI3 - S1



s[0].eScanID.ePlate {abs(t.eTX)<0.05&&abs(t.eTY)<0.05}
First segment
Last segment
s[0].eScanID.ePlate
s[0].eScanID.ePlate
First segment
Last segment
s[0].eScanID.ePlate
s.eScanID.ePlate
all trks
$\theta_{X/Y}$<0.05
s.eScanID.ePlate
s.eTX:s.eScanID.ePlate {abs(s.eTX)<0.05&&abs(s.eTY)<0.05}
s.eTX
s.eScanID.ePlate
s.eTX:s.eScanID.ePlate
s.eTX
s.eScanID.ePlate
npl {abs(t.eTX)<0.05&&abs(t.eTY)<0.05}
npl
nseg
npl
s.eTY:s.eScanID.ePlate {abs(s.eTX)<0.05&&abs(s.eTY)<0.05}
s.eTY
s.eScanID.ePlate
s.eTY:s.eScanID.ePlate
s.eTY
s.eScanID.ePlate
npl
npl
nseg
npl

GSI3 - S2


s[0].eScanID.ePlate {abs(t.eTX)<0.05&&abs(t.eTY)<0.05}
First segment
Last segment
s[0].eScanID.ePlate
First segment
Last segment
s.eScanID.ePlate
all trks
θX/Y<0.05
s.eTX:s.eScanID.ePlate {abs(s.eTX)<0.05&&abs(s.eTY)<0.05}
s.eTX:s.eScanID.ePlate
npl {abs(t.eTX)<0.05&&abs(t.eTY)<0.05}
npl
nseg
s.eTY:s.eScanID.ePlate {abs(s.eTX)<0.05&&abs(s.eTY)<0.05}
s.eTY:s.eScanID.ePlate
npl
npl
nseg