Single-differential cross sections with matrix inversion

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Classification of tracks

MC reconstructed global tracks are divided into 3 categories:

1) Tracks with a right VTX/TOF match and charge(reconstructed)==charge(generated)

2) Tracks with a wrong VTX/TOF match OR charge(reconstructed)!=charge(generated)

3) Reconstructed tracks not associated to a track generated at the target (track fragmented before the target or associated to a VTX track from pileup).

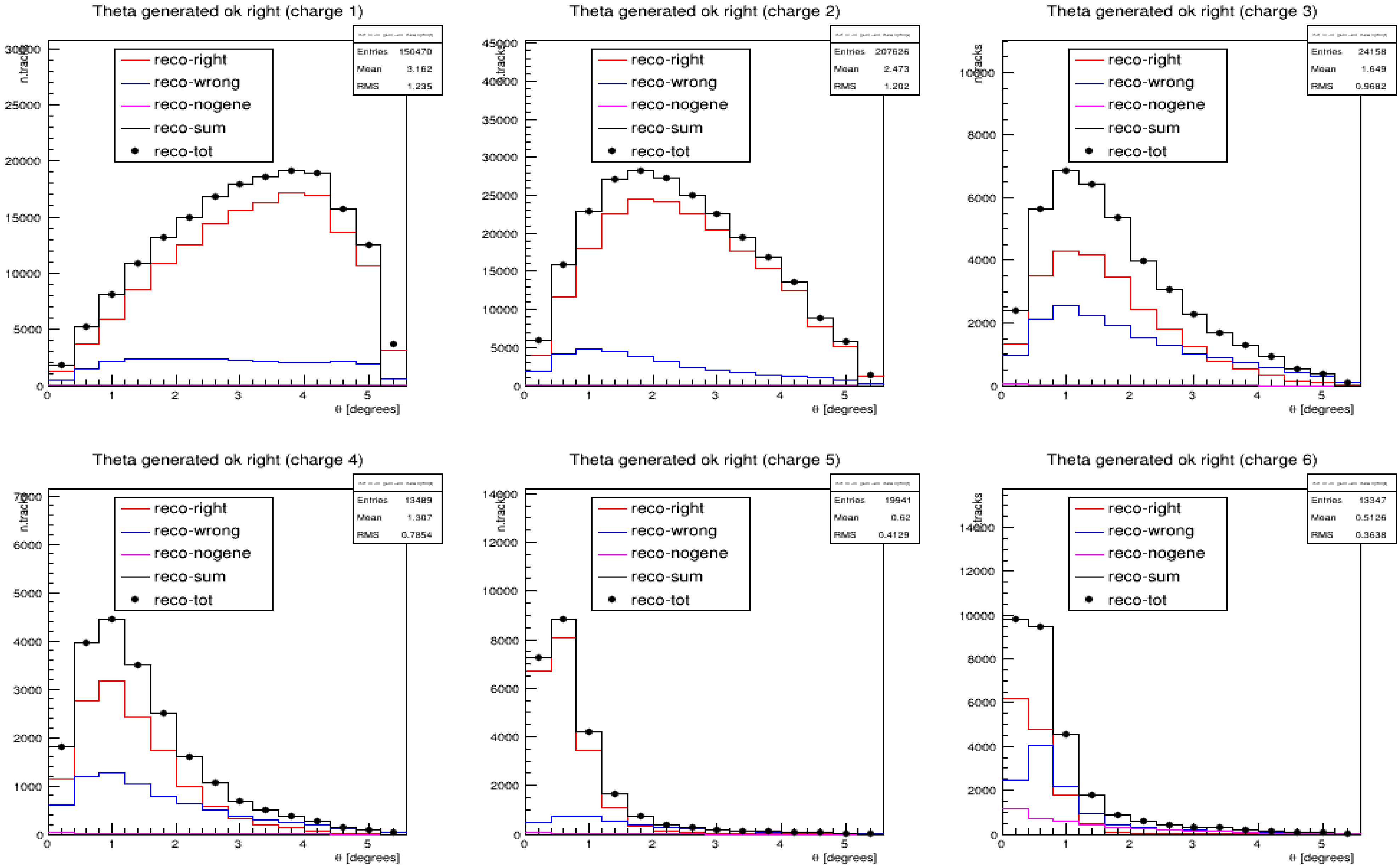
2) and 3) are taken as background estimated from MC for each bin and subtracted.

TOF charge misidentification probability is taken into account in the background definition. For each charge, the X-feed matrix is inverted and applied to the distributions corrected for background contributions.

Example shown for angular differential cross-sections (but done also for beta and ke/A)

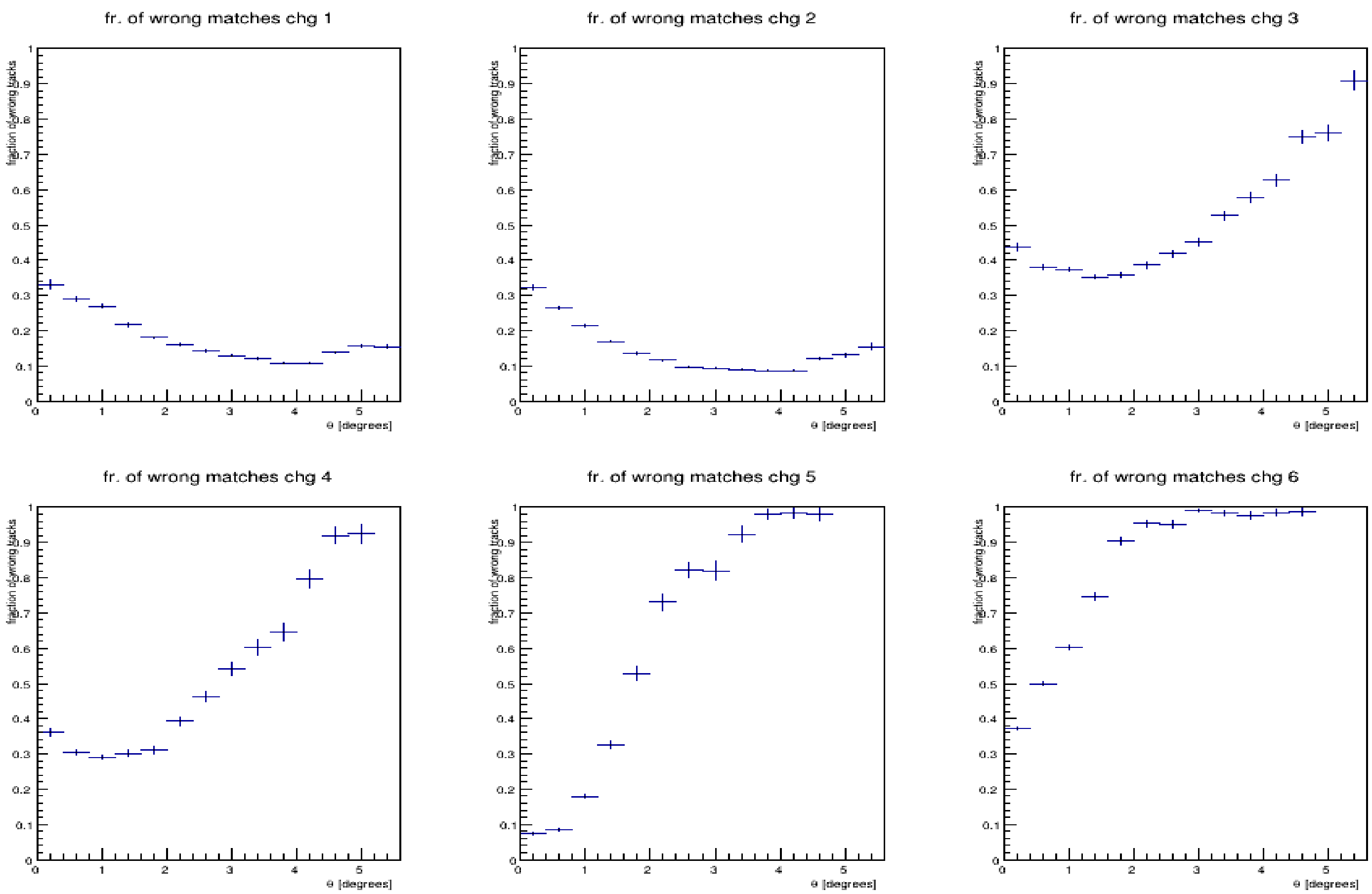
VTX charge used in the reconstruction for TOF/VTX matches
Only VTX tracks matching a BM track used in the reconstruction.
N.of events used = 3,7 M (MC), 2,8 M (DATA)

Classification of tracks



Fraction of “wrong” tracks

w(b,Z)

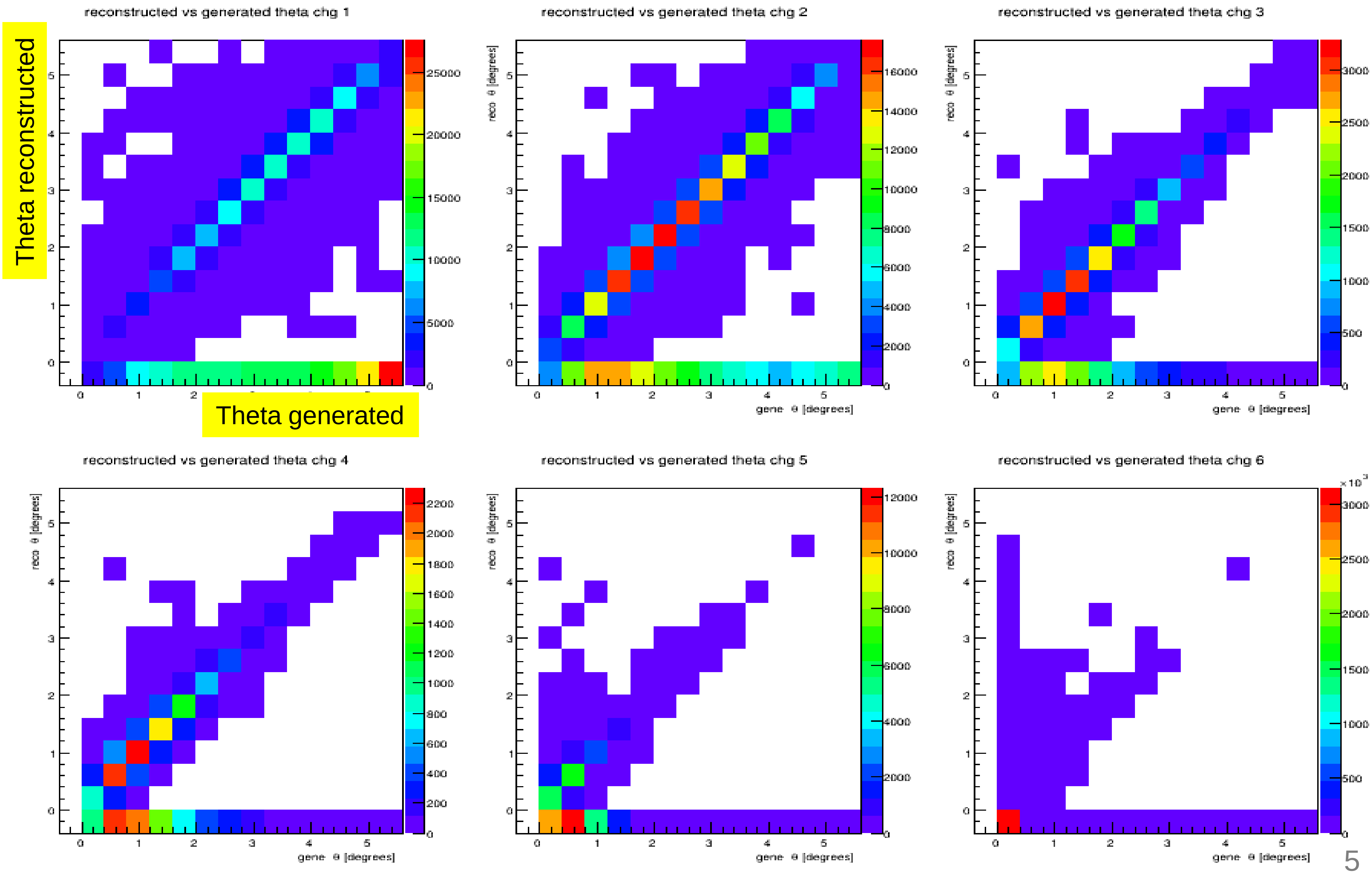


$$N_{reco-right}(b, Z) = (1 - w(b, Z)) \cdot N_{reco}(b,Z)$$

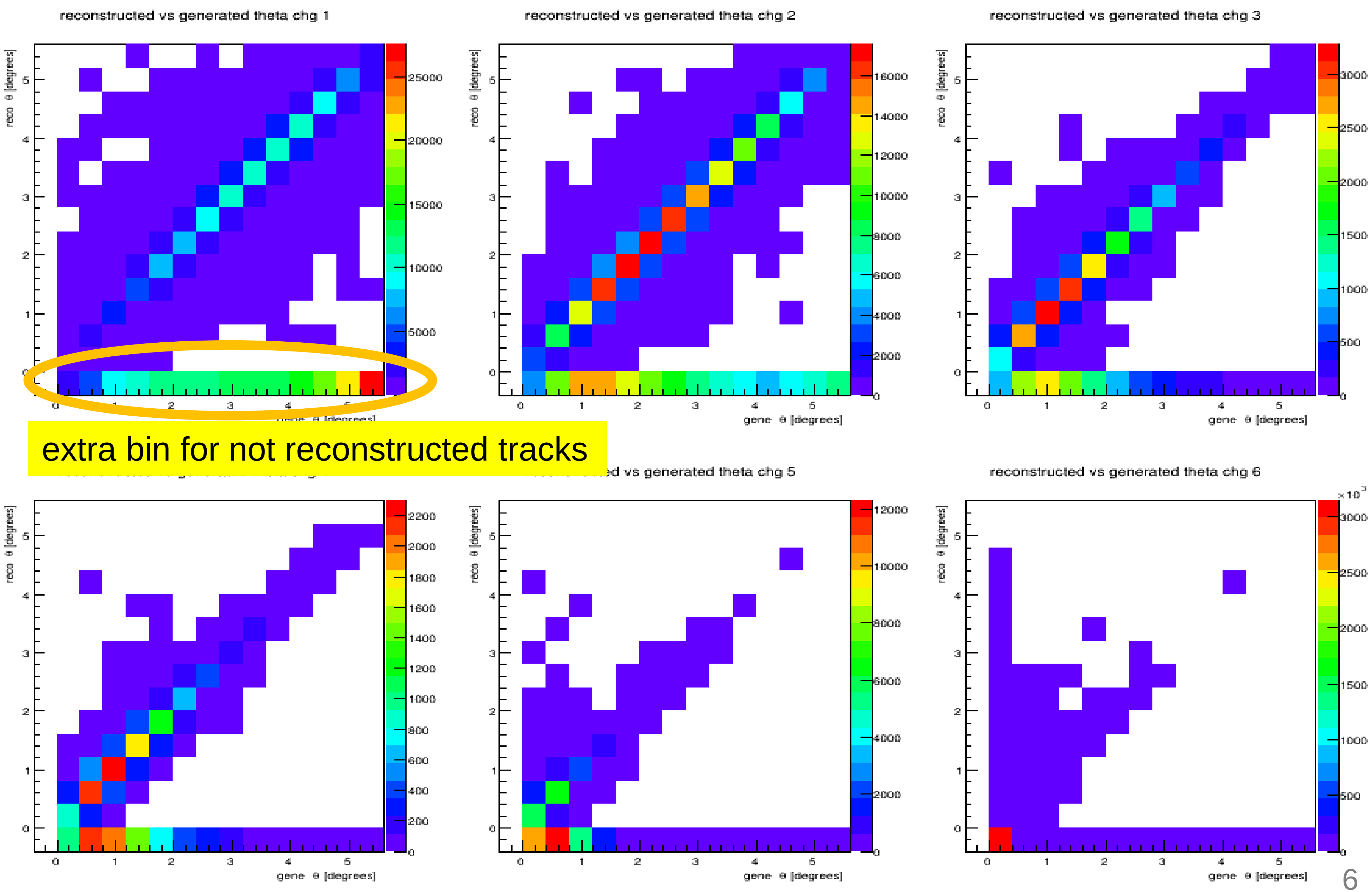
The number of tracks in each bin is corrected for the fraction of background

Correlation matrix reconstructed vs generated

Built only for right matches

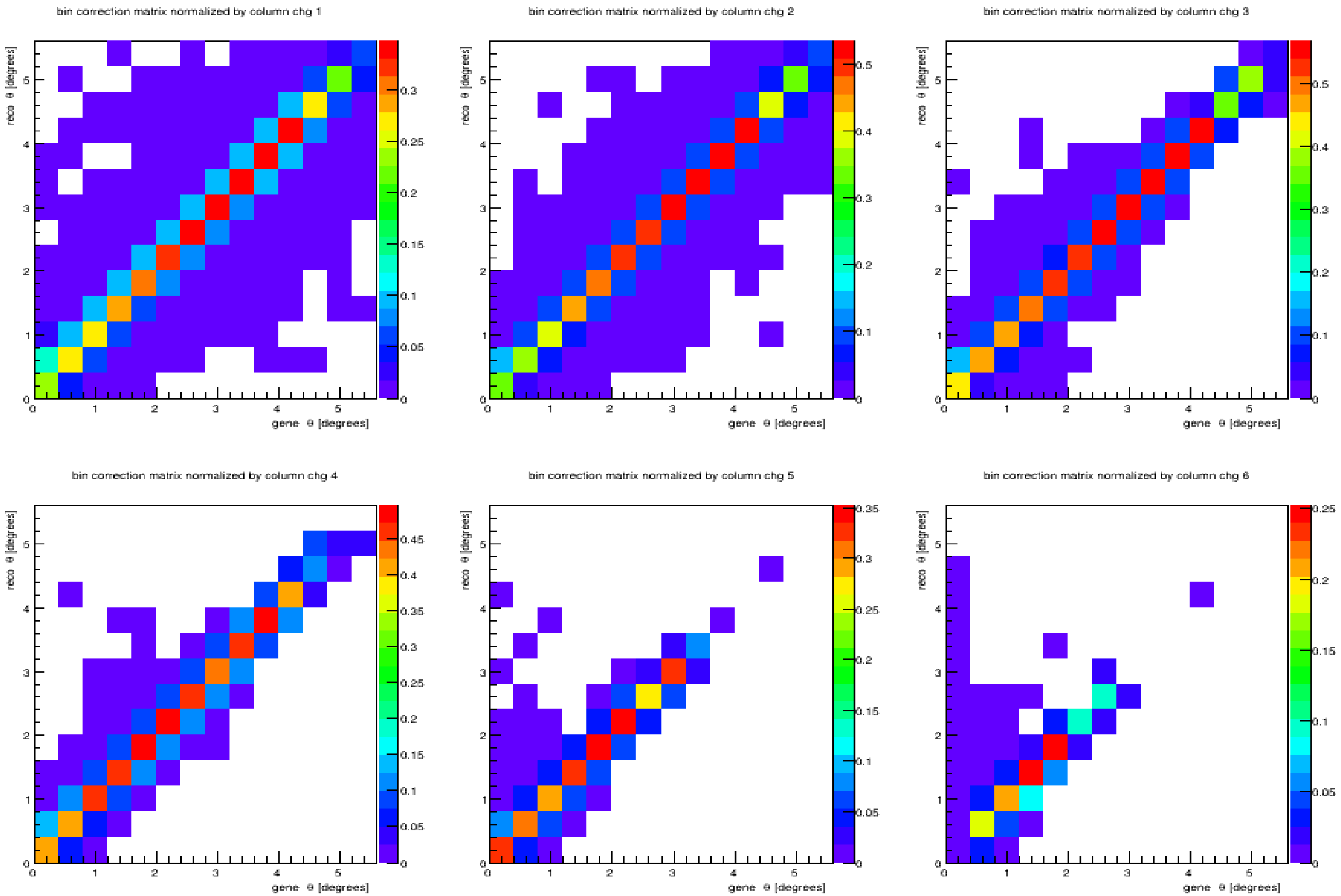


Correlation matrix reconstructed vs generated



Correlation matrix normalized to number of generated tracks

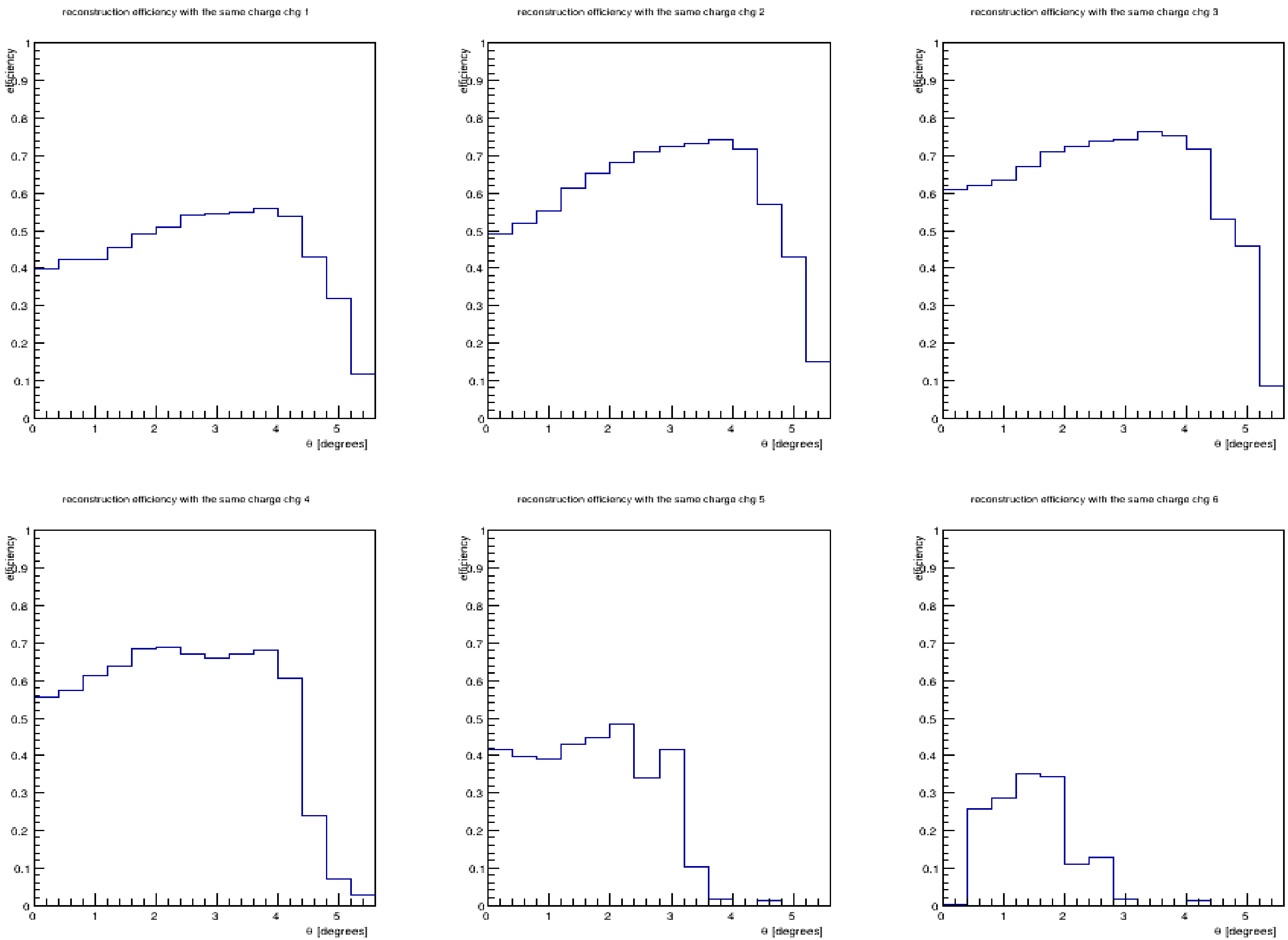
$$A(b, b', Z) = \frac{N(\mathrm{recoright}(Z, b) \& \mathrm{gen}(b', Z))}{N(\mathrm{gene}(b', Z))}$$



The diagonal elements are the bin efficiency used in the simpler method considering uncorrelated bins. These are the matrixes to be inverted.

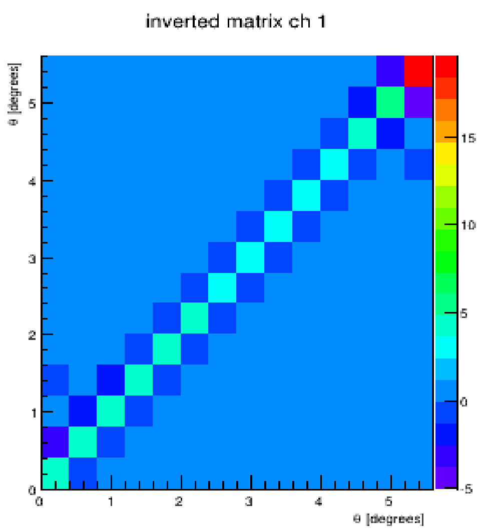
Efficiencies

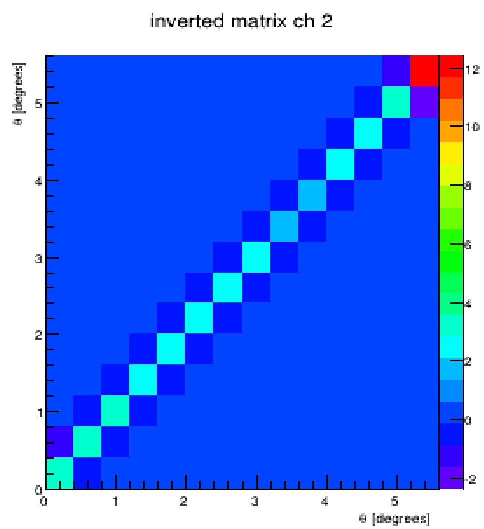
Efficiency to reconstruct the track with a right VTX/TOF match and with the right charge regardless the reconstructed bin (projection in the X axis of the previous matrices)

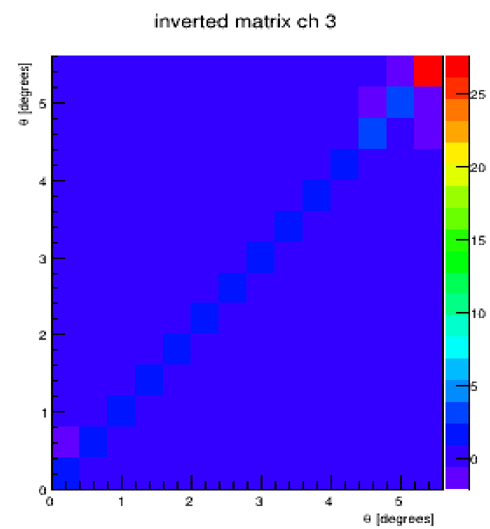


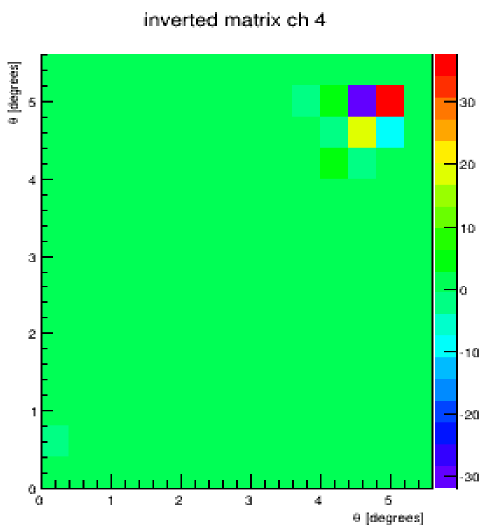
Inverted matrices

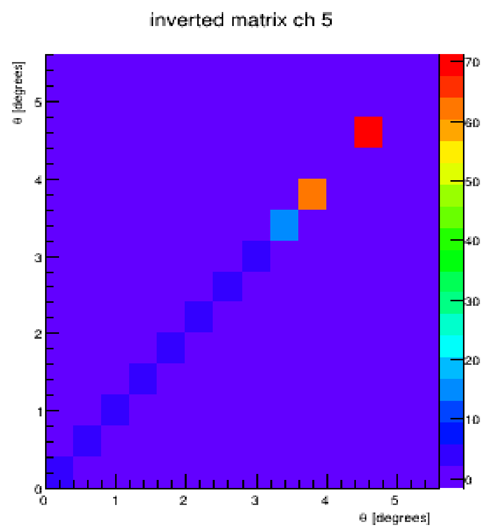
Most of the matrices are singular.
Attempt to remove empty rows and columns, invert the matrix and insert the empty rows and columns again (“dirty” procedure).

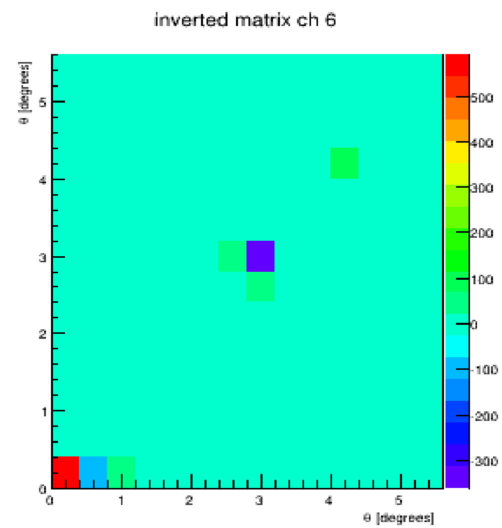






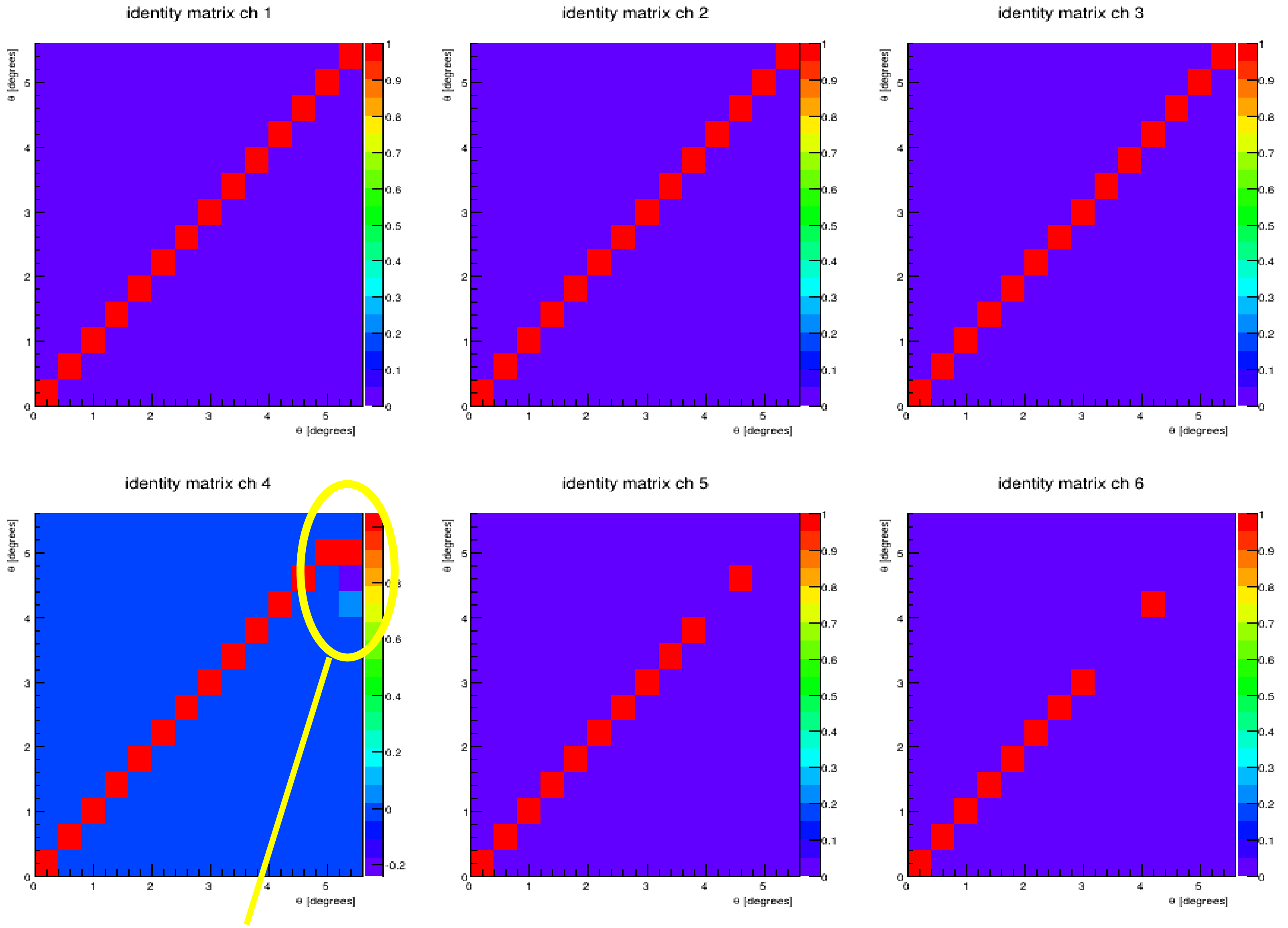






Check of matrix inversion

$A^{-1} \cdot A = I$



Some issues to be understood.

Corrected yields

$$\mathbf{N_{corrected}(Z) = A(Z)^{-1} \cdot N_{reco-right}(Z)}$$

$N_{reco\text{-}right}(Z) = (1\text{-}w(Z)) \cdot N_{reco}(Z)$ (vector with n.of reconstructed tracks for each bin with Z charge)

$N_{corrected}(Z)$ (vector with n.of reconstructed tracks corrected for efficiencies and bin migrations)

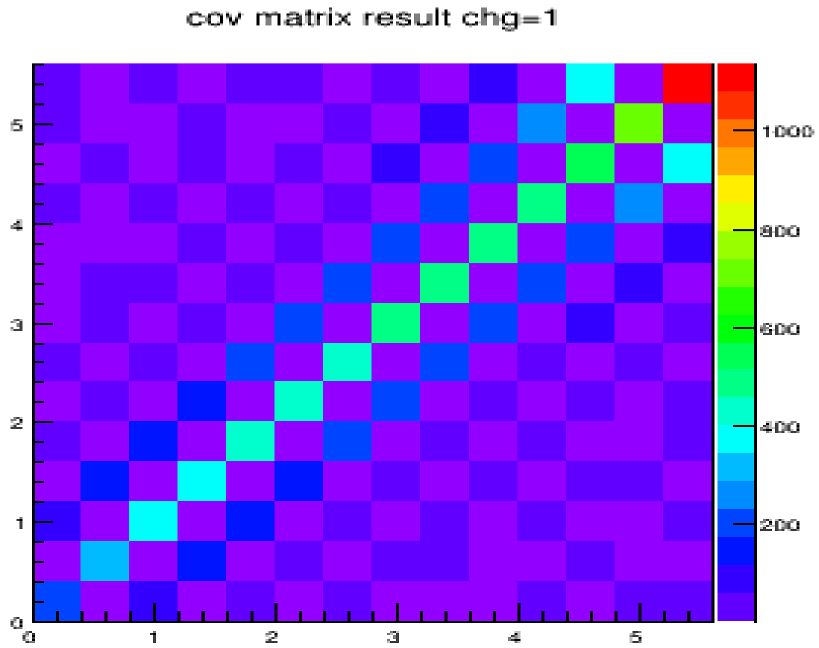
$$\mathbf{V_{corr} = A^{-1} V_{reco-right} \left(A^{-1}\right)^{T}}$$

$V_{reco\text{-}right}$ = covariance matrix for N_{right}

V_{corr} = covariance matrix for $N_{corrected}$

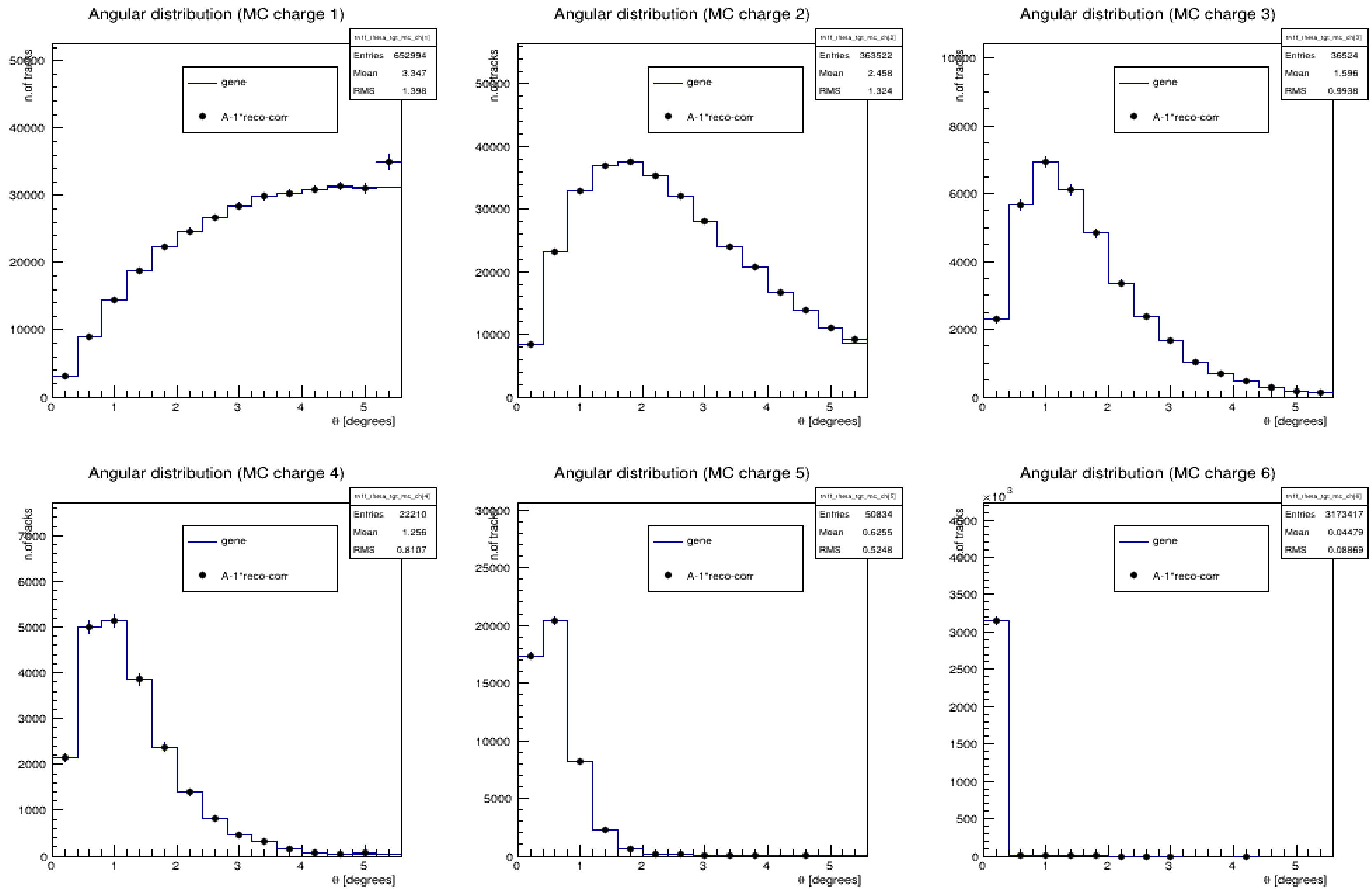
Diagonal elements of V_{corr} used for errors on the elements of the $N_{corrected}$ vector

Example of V_{corr} covariance matrix for chg=1



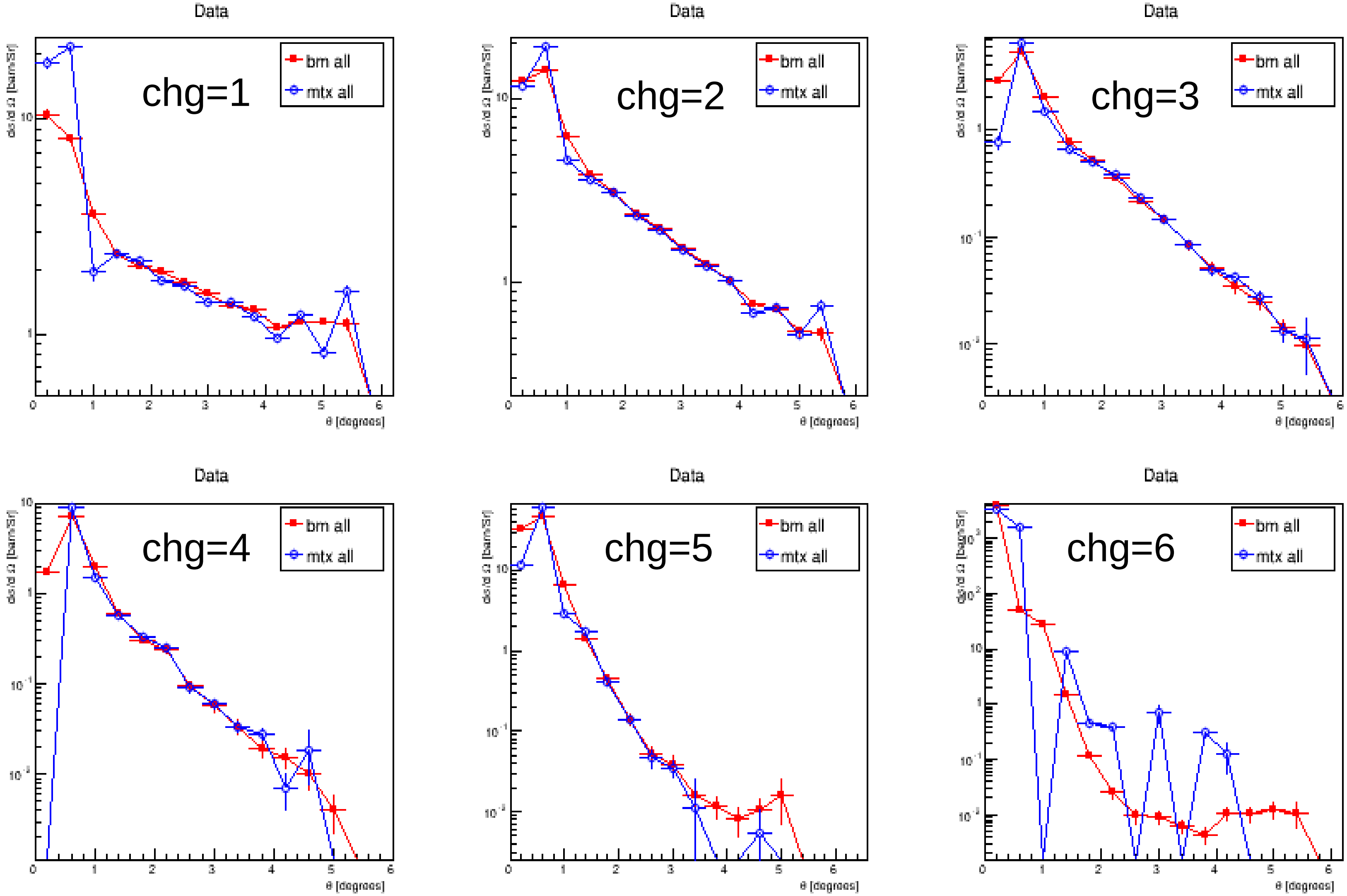
MC check (yields)

The inverted matrix, applied to the number of MC reconstructed events corrected for the fraction of wrong tracks, should reproduce the distributions of generated events.



Cross sections (all events)

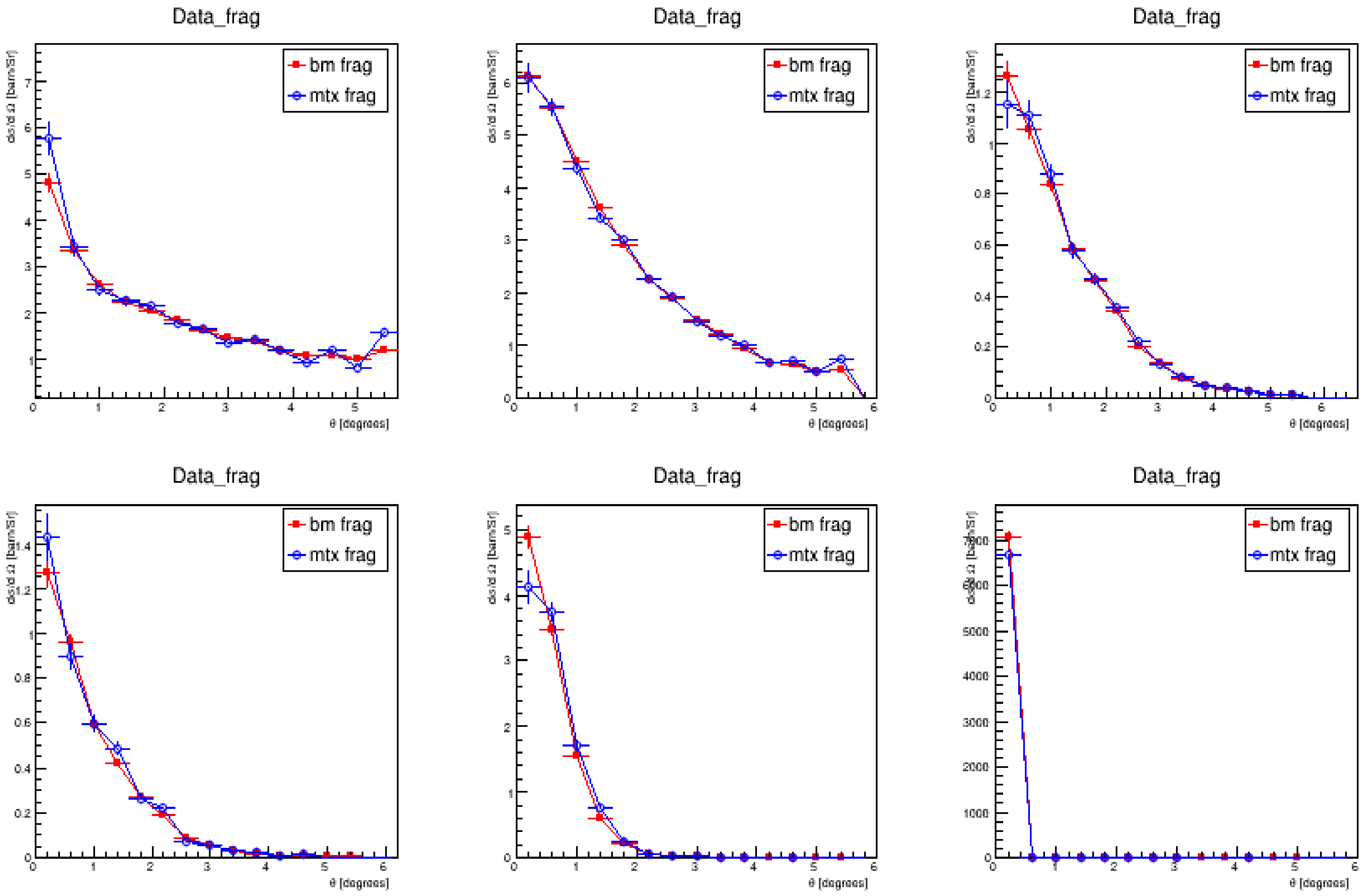
Cross sections with matrix inversion (blue) compared to the cross sections extracted with simpler method using efficiencies and purities defined for each bin (red).



Log scale. Discrepancy at low angle.

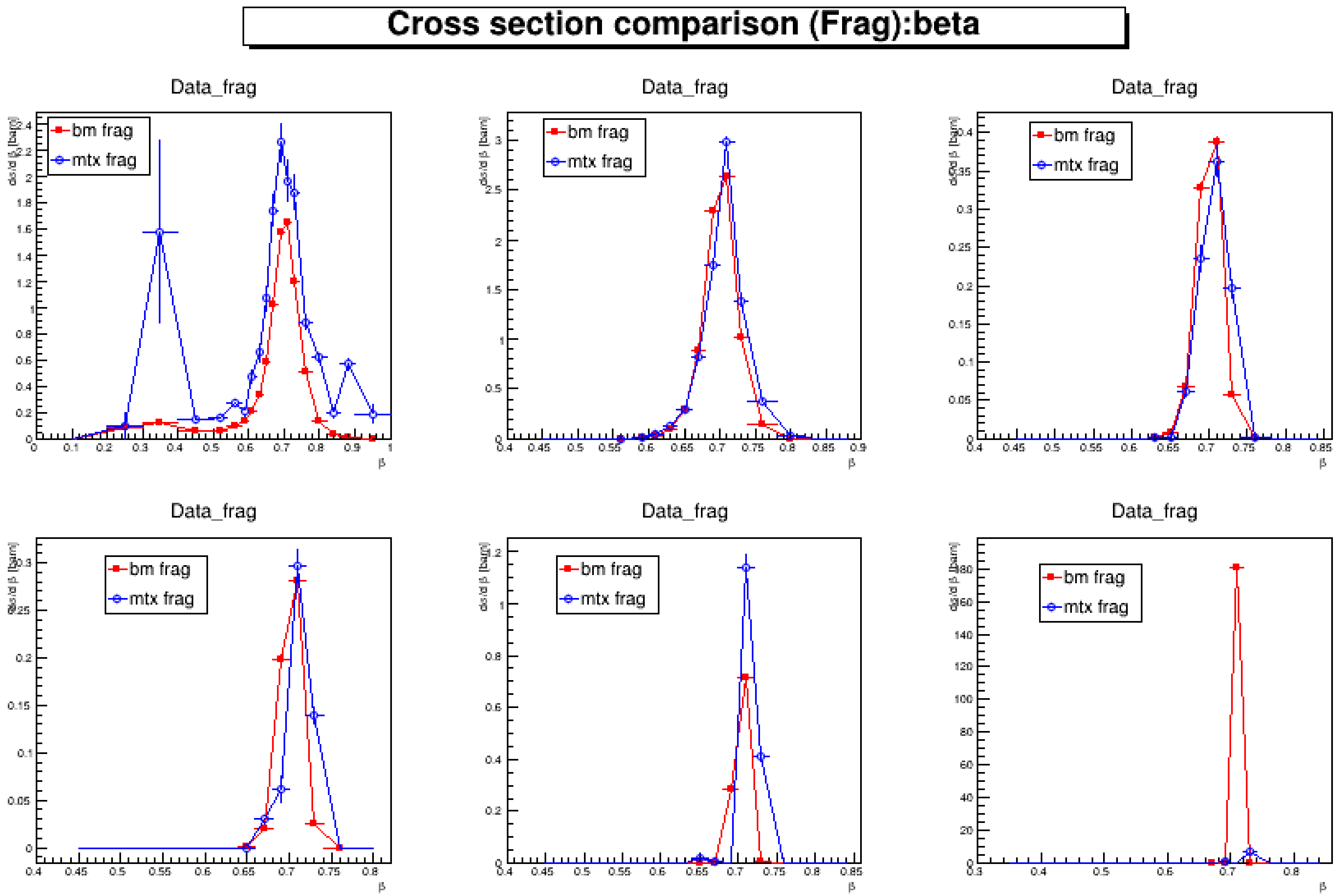
Cross sections (fragmentation events)

Cross sections with matrix inversion (blue) compared to the cross sections extracted with simpler method using efficiencies and purities defined for each bin (red).



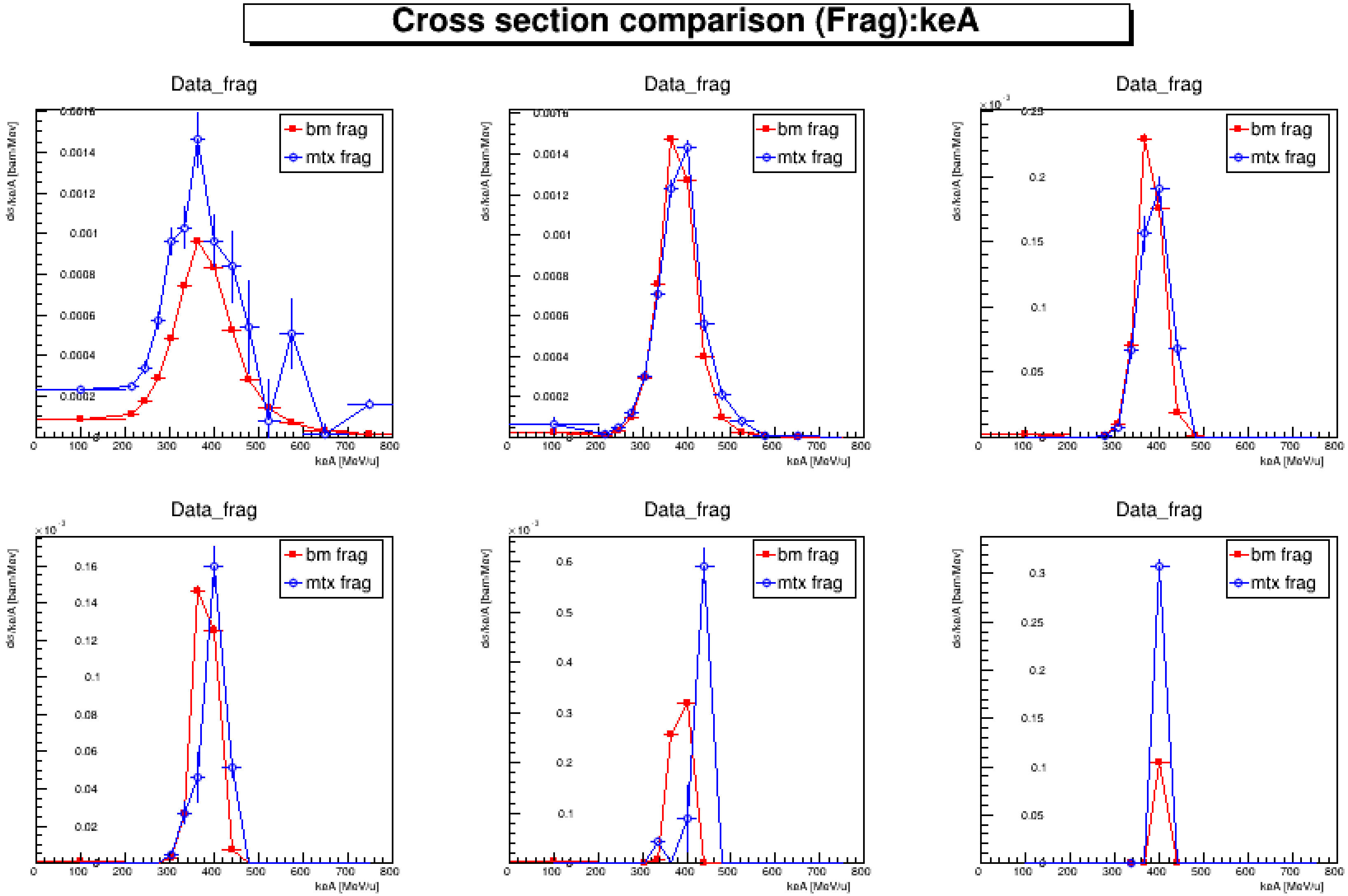
Linear scale

Cross sections (beta)



Fragmentation events. Excess of protons with the matrix inversion.
Differencies to be investigated (matrix inversion more difficult with few bins)

Cross sections (ke/A)



Fragmentation events. Excess of protons with the matrix inversion.
Differencies to be investigated (matrix inversion more difficult with few bins)

Simple matrix deconvolution done separately for each charge, considering the wrongly reconstructed tracks (wrong TOF/VTX match or wrong charge assignment) as a background subtracted to the number of reconstructed tracks.

This is the only way I have found to disentangle the migrations between different values of charges from bin migrations. Another possibility is to use huge matrices with the different charge values as additional entries.

The results seem to be in quite good agreement with the results obtained with a simpler method without considering correlations between different bins.

Possible issues related to the matrix inversion not investigated yet.

With matrix inversion I expect more stability with respect to changes to be applied for evaluation of systematic errors.

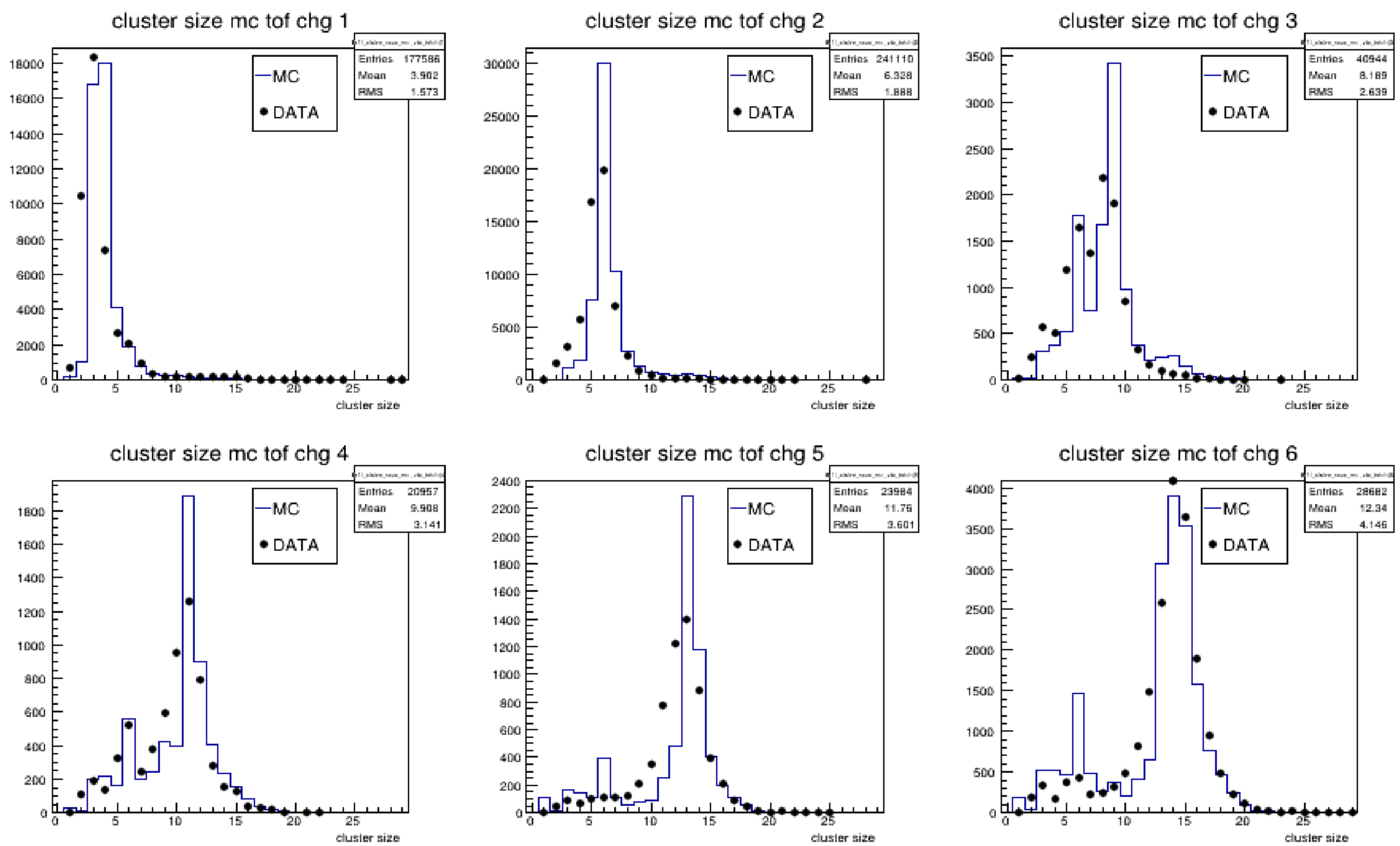
Once the differences obtained for beta and ke/A are understoof, it should be easy to extend to double differential cross-sections.

Maybe it could be possible to increase the number of bins (but I expect difficulties when the migrations become too high with respect to the bin sizes)

BUT WHY THE MEASURED CROSS SECTIONS ARE LOWER THAN WHAT IS IMPLEMENTED IN FLUKA ?

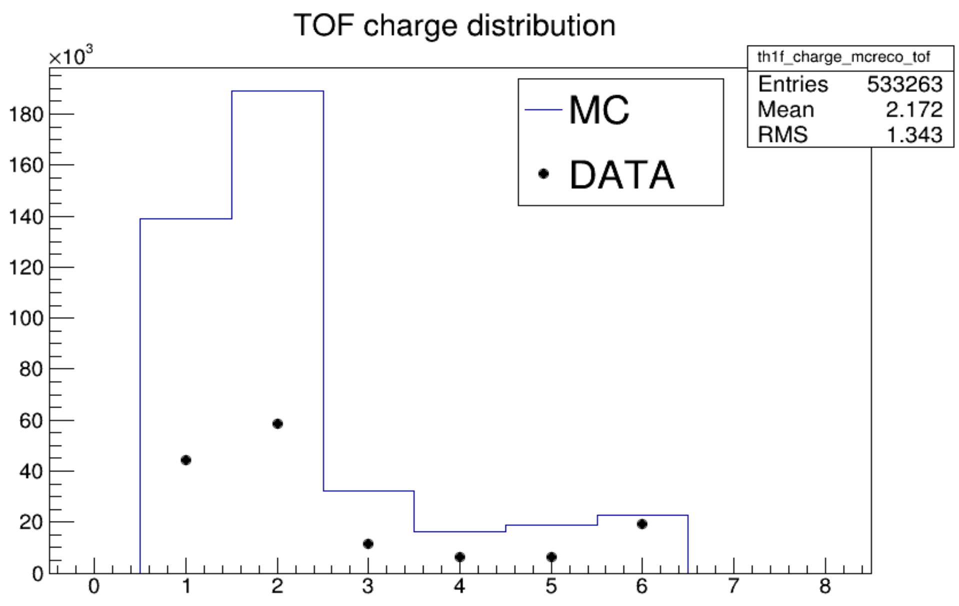
Attempt to extract cross section using only the VTX

VTX charge distribution for data and MC vs TOF charge (fragmentation events)

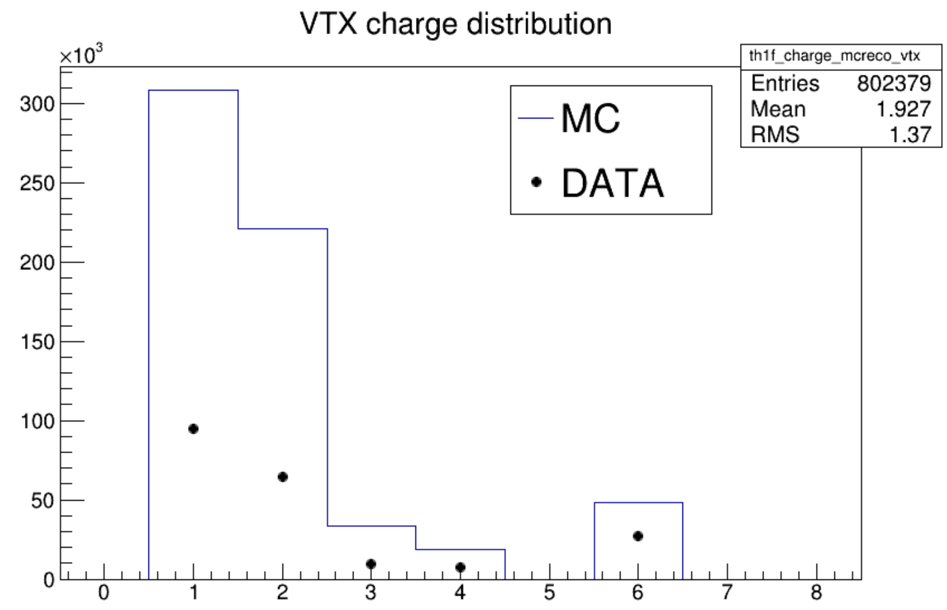


Attempt to apply the same procedure shown before for p and He using only the VTX tracks (no reconstruction or TOF info used) to check the scale of the cross section.
All VTX tracks with theta<6 degrees and matching a BM track are used.

TOF charge distribution of
global tracks (fragm.events)



VTX charge distribution of
all VTX tracks (fragm.events)



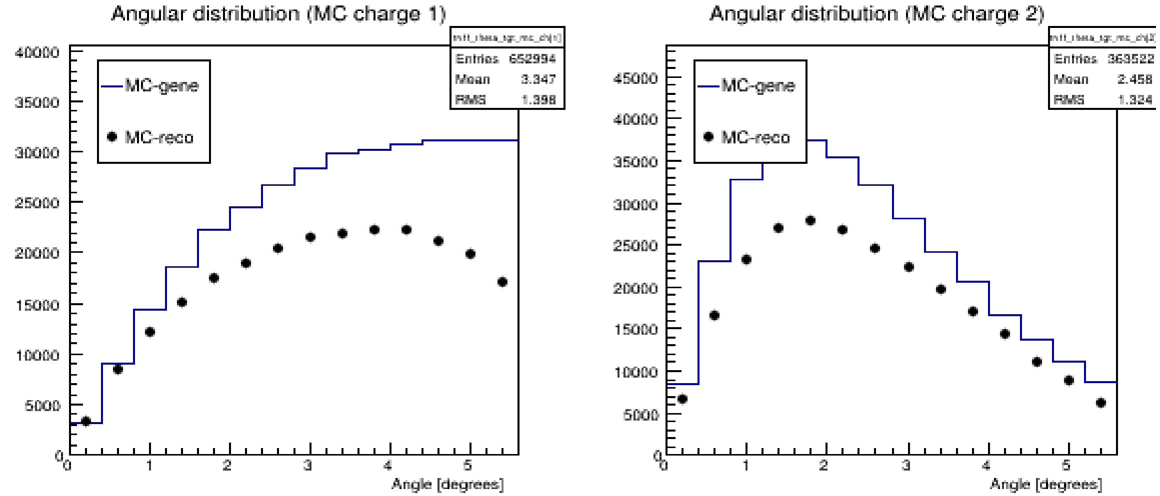
Distributions normalized to the same number of triggers.

Even if we look only at the tracks at the VTX without using the reconstruction, the number of tracks is lower in the DATA than in MC.

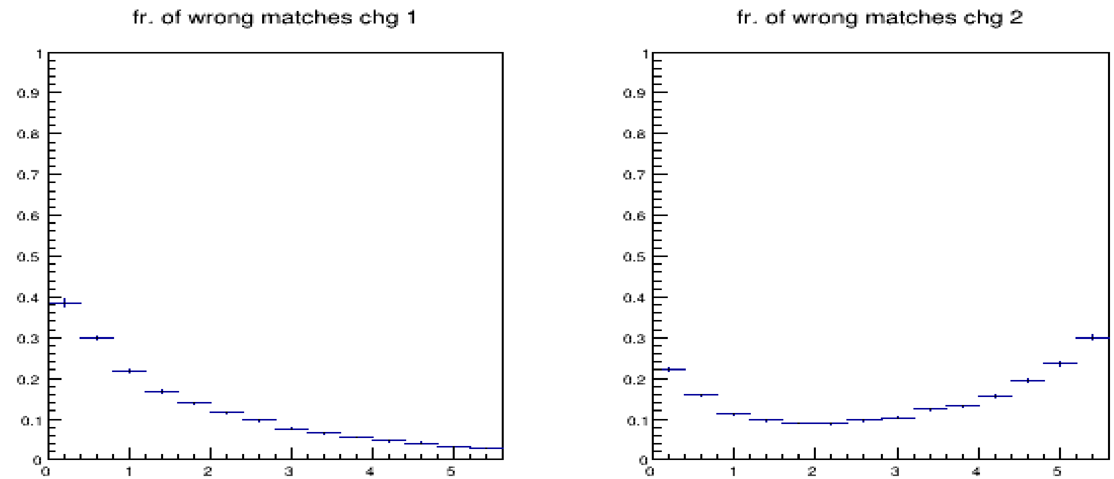
WARNING: no boron fragment found using the charge of VTX track with

TAVTtrack->GetChargeWithMaxProbaNorm();

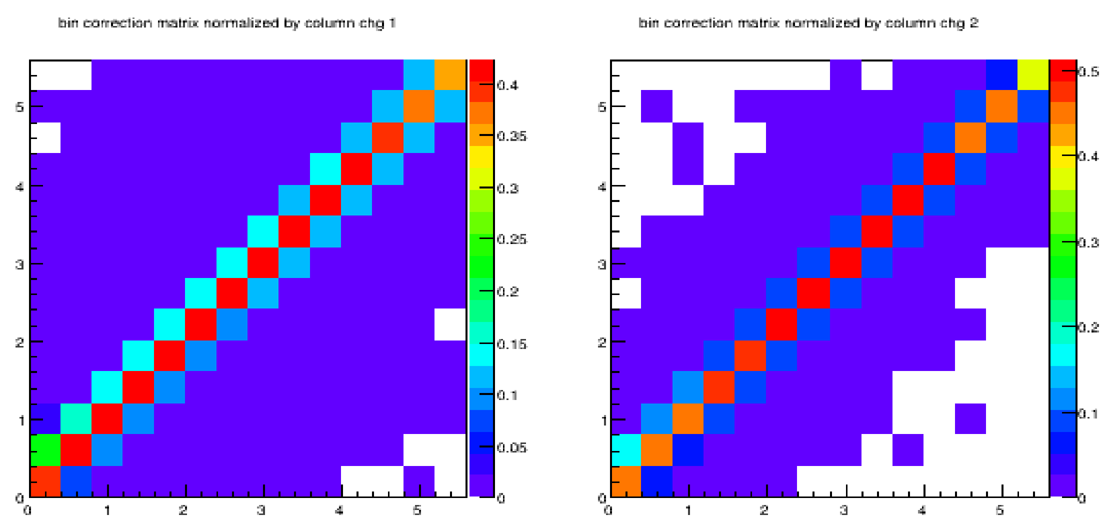
Reconstructed and generated MC distributions



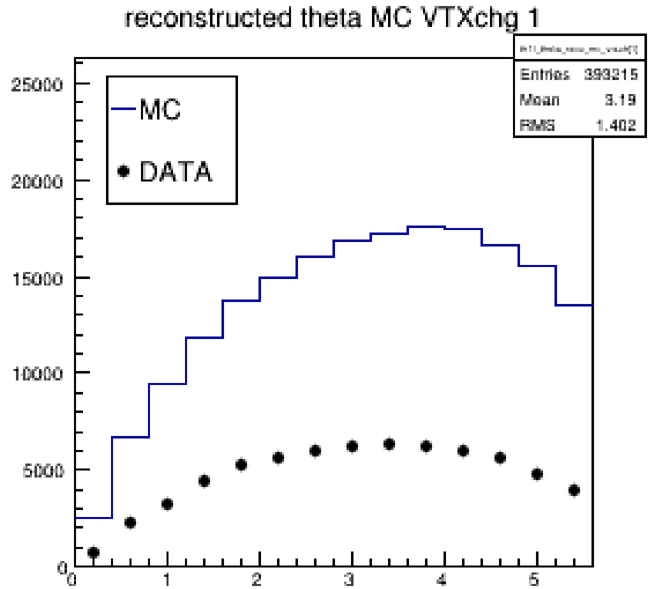
Fraction of tracks with wrong charge assignemnt

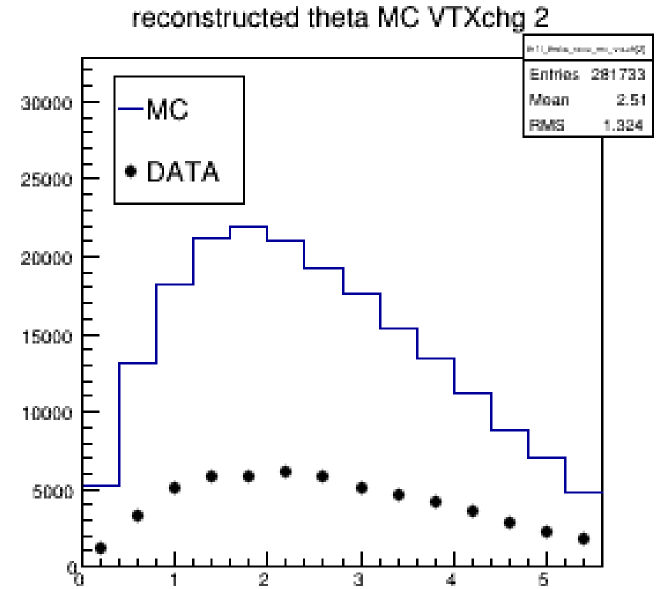


Efficiency matrix A(Z) (almost diagonal)



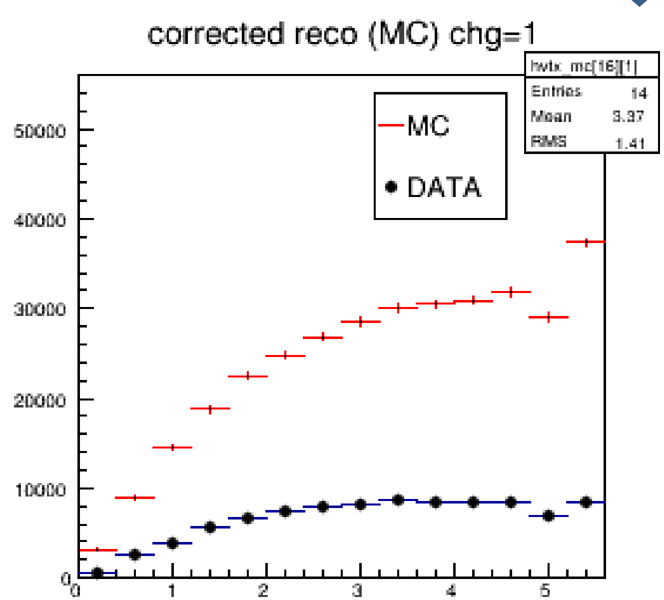
Original distributions

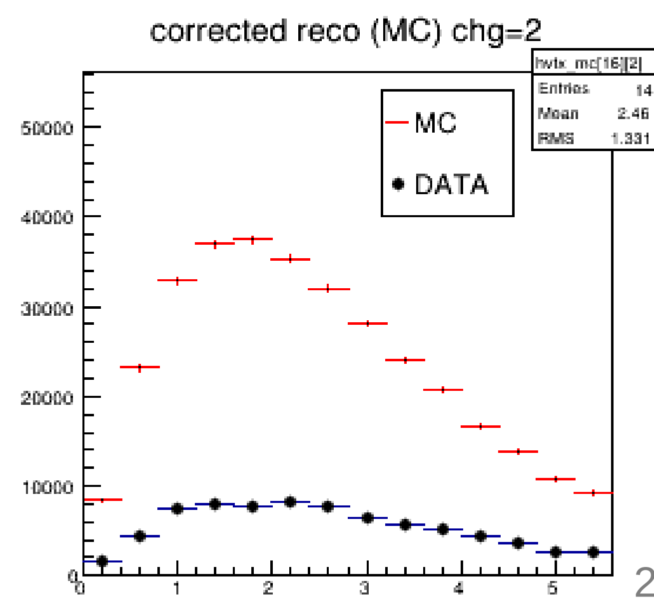




$$\mathbf{N_{corrected}(Z) = A(Z)^{-1} \cdot \big(1 - \boldsymbol{w}(\boldsymbol{Z})\big)\boldsymbol{N}\ (Z)}$$

Yields after the corrections.

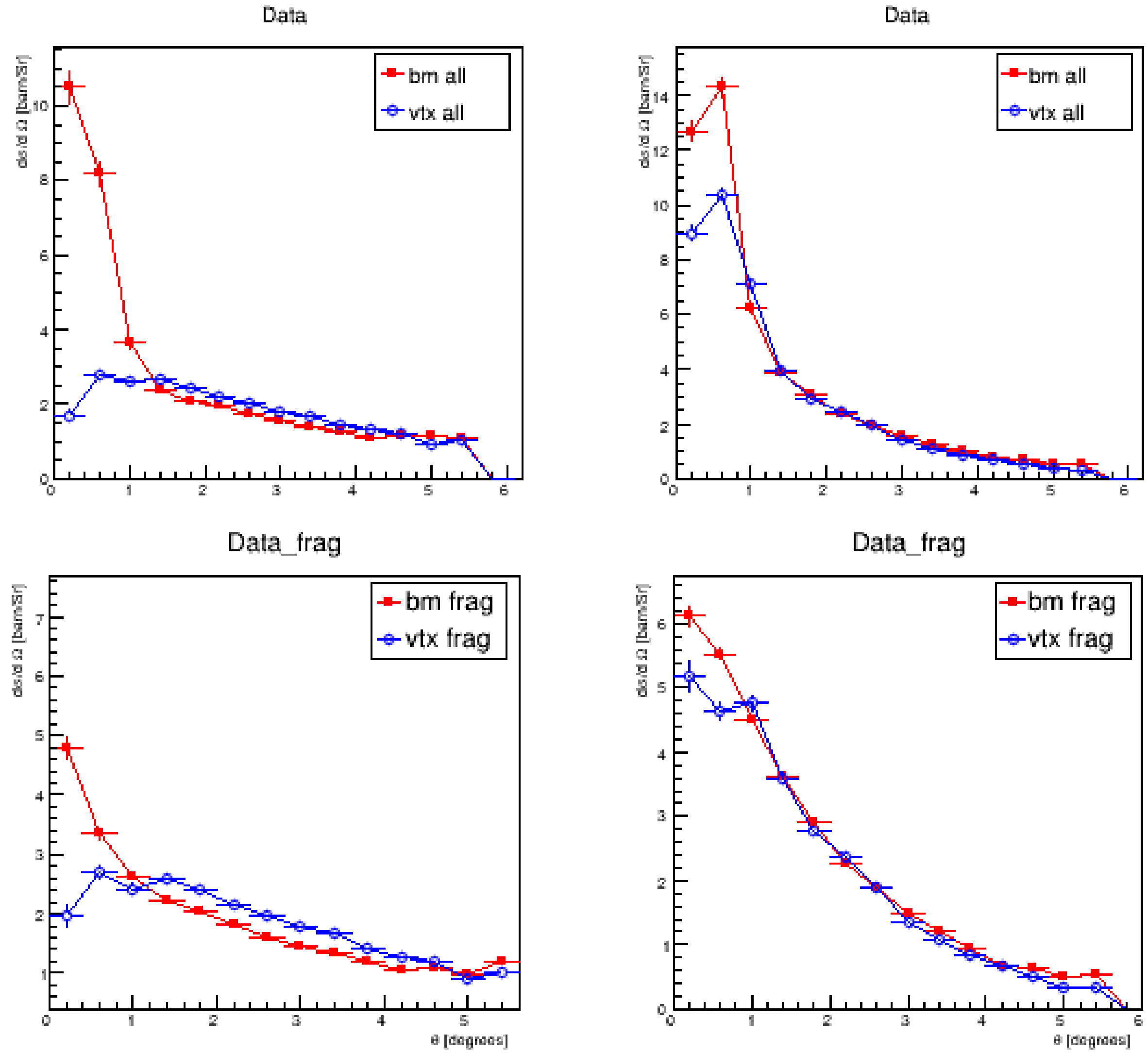




Cross sections using only VTX tracks and matrix inversion (blue) compared to the cross sections extracted using efficiencies and purities defined for uncorrelated bin (red).

All events

Fragmentation events



For theta>1 degree the cross sections obtained using only the VTX information is close to the values obtained using fully reconstructed tracks.

The peak at low angles seen for protons when all the events are considered seems to disappear (understimation of wrong match with pile-up track in the MC ?)

Comments

It looks strange that the cross sections are much lower than in the MC (the total charge-changing cross section in Fluka should be right, according to some pubblications).

Looking only at the number of VTX tracks with chg 1 and 2, the values for the cross section are similar to those obtained using the full reconstruction. The low cross section values seem not to be related to unefficiencies in the reconstruction or in the TOF not reproduced in the MC.

One possibility for low cross sections in the data could be the efficiency for BM reconstruction not correctly simulated in the MC (to be checked) or some issue in the matching of VTX tracks with a BM matched vertex.

Another possibility is that inefficiencies in the global reconstruction in the data are hidden in the method used now to select the VTX tracks from the vertex matching the BM track. In the current output files from hlreco, the information on the BM matched vertex and associated tracks is accessible from the list of GlobalTracks (if no global track associated to the BM matched vertex is reconstructed, this vertex and the corresponding tracks are lost).

IT WOULD BE USEFUL TO HAVE THE POSSIBILTY TO ACCESS THE FULL INFORMATION OF THE VTX IN THE OUTPUT OF HLRECO.