TOF-Wall Front/Real clustering

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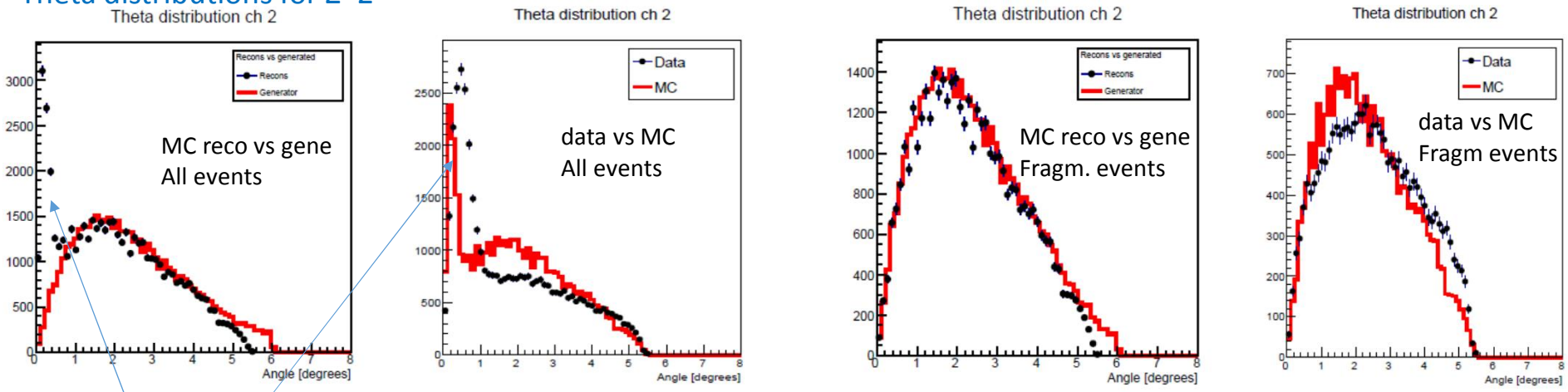
- Reconstruction issues
- TOF Front/Rear clustering
- Observations on vertexing and pile-up.

Introduction

FIRST analyses can be performed in two complementary ways:

1) use all the data/MC sample, identify and count particles in each energy/angle bin, correct for efficiencies and purities to extract cross sections.
   -> background from C misidentified events to be estimated from MC
2) select fragmentation events looking at the number of tracks from the vertex matching the BM track (much less background from C events)
   -> how well do we manage pile-up events in data ?

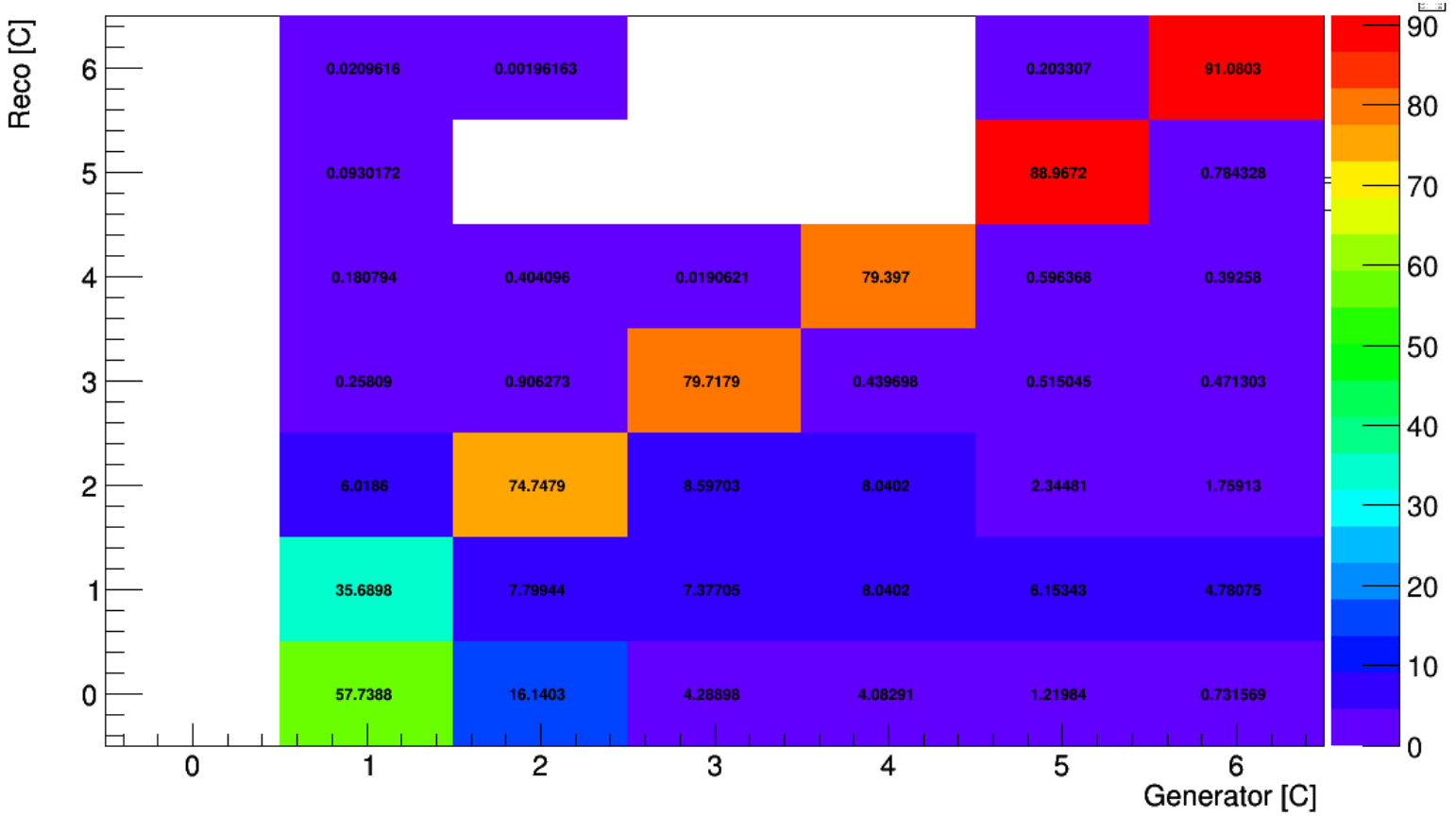
Theta distributions for Z=2



Contamination from carbons.

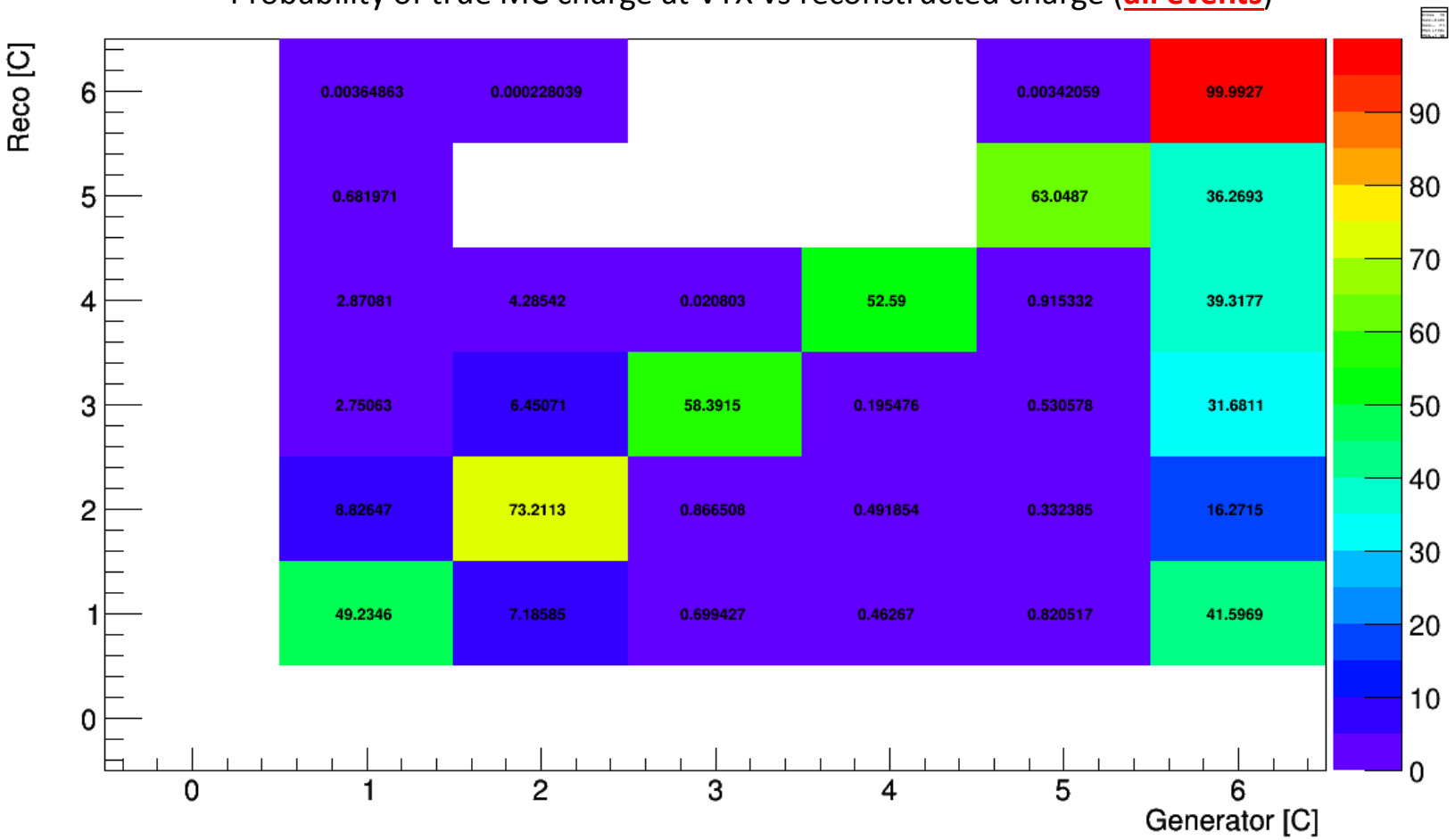
Same effect seen for example when the VTX cluster size is correlated with the charge of the global track.

Probability of global reconstruction charge vs MC true charge after the target (**all tracks all events**)



The probability that a C particle is reconstructed as a C track is >92%

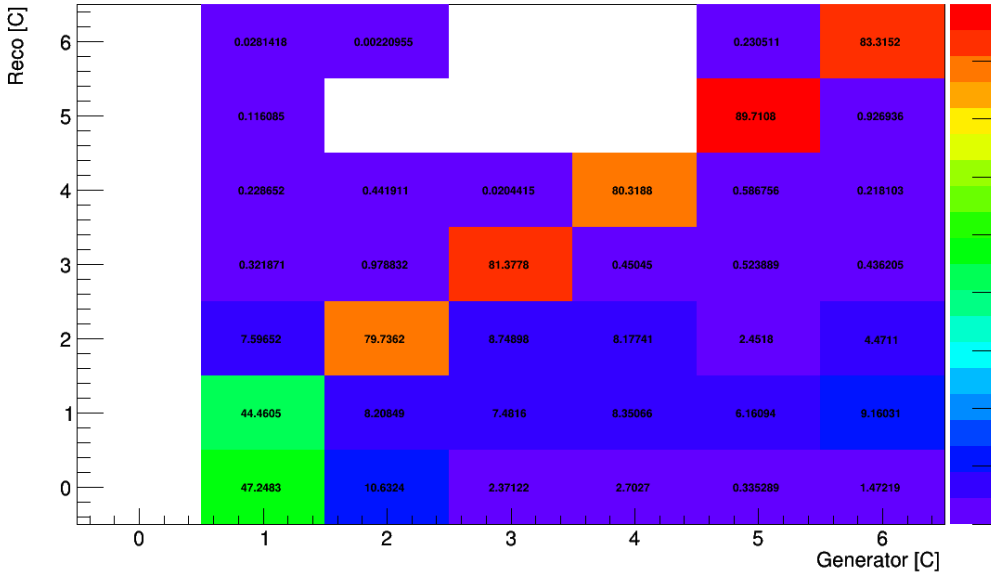
Probability of true MC charge at VTX vs reconstructed charge (**all events**)



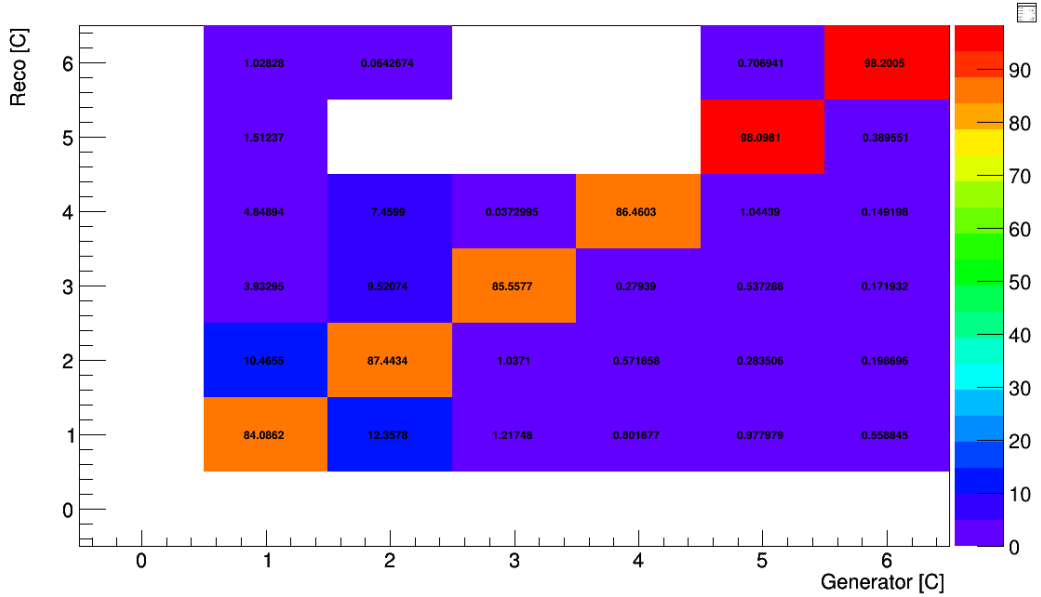
The large number of Carbons results in a large contamination when looking at fragments of lower charge. Corrections for purity efects needed in the cross-section extraction.

Fragmentation events (n.tracks from BM matched vertex > 1)

Probability of global reconstruction charge vs
MC true charge after the target (fragmentation events)



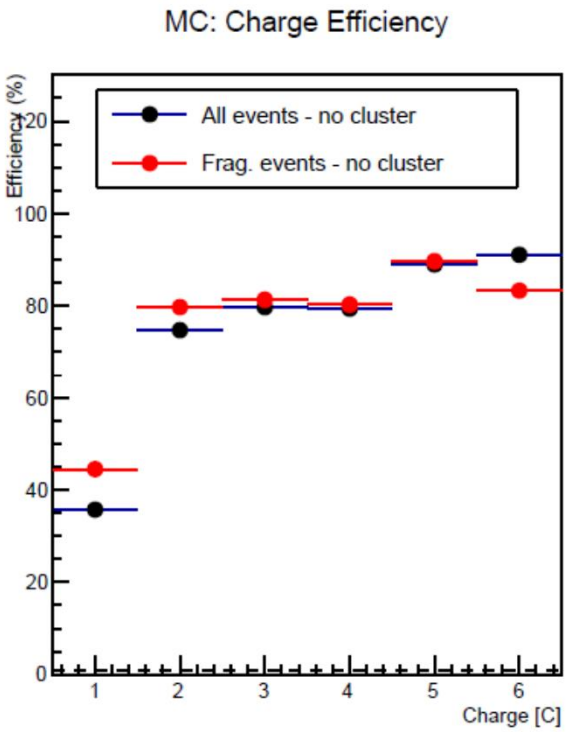
Probability of true MC charge at VTX vs
reconstructed charge (fragmentation events)

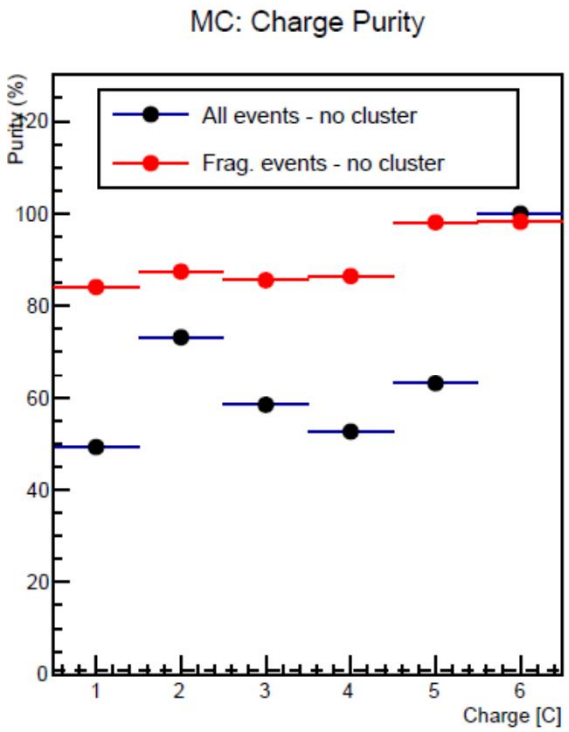


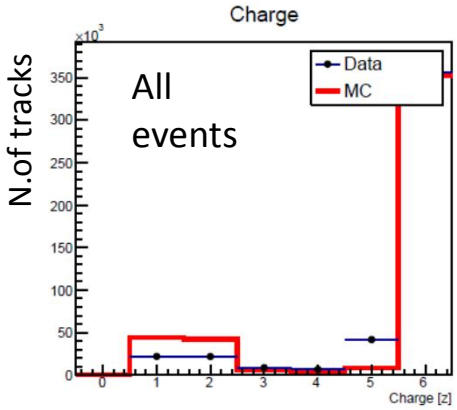
Background from misidentified Carbons strongly reduced.

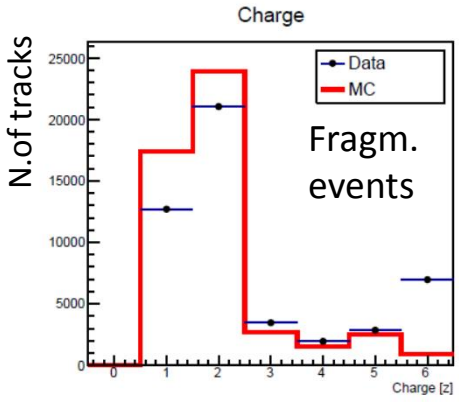
Efficiencies and purities for charge identification

Let's try to correct the number of measured fragments of each charge for the efficiency and purity estimated from MC (done separately for the complete event sample and for fragmentation events).

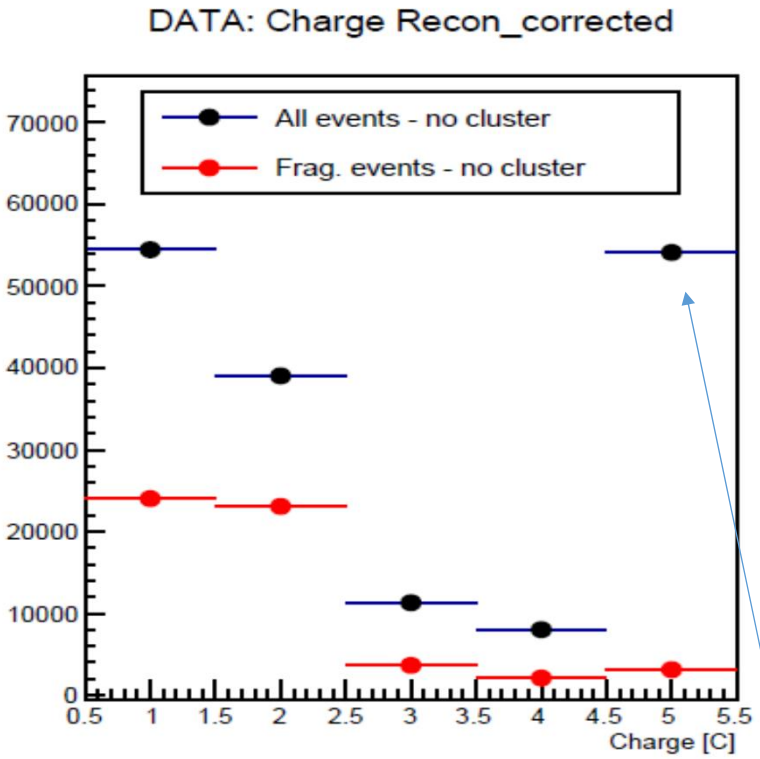








Same sample is used.



$$N_{corrected}(Z) = \frac{\text{efficiency}}{\text{purity}} \cdot N_{\text{n.vtx tracks(BM)}>1}$$

We expect the same number of reconstructed fragments
In the two samples when corrected for efficiencies and purity effects.

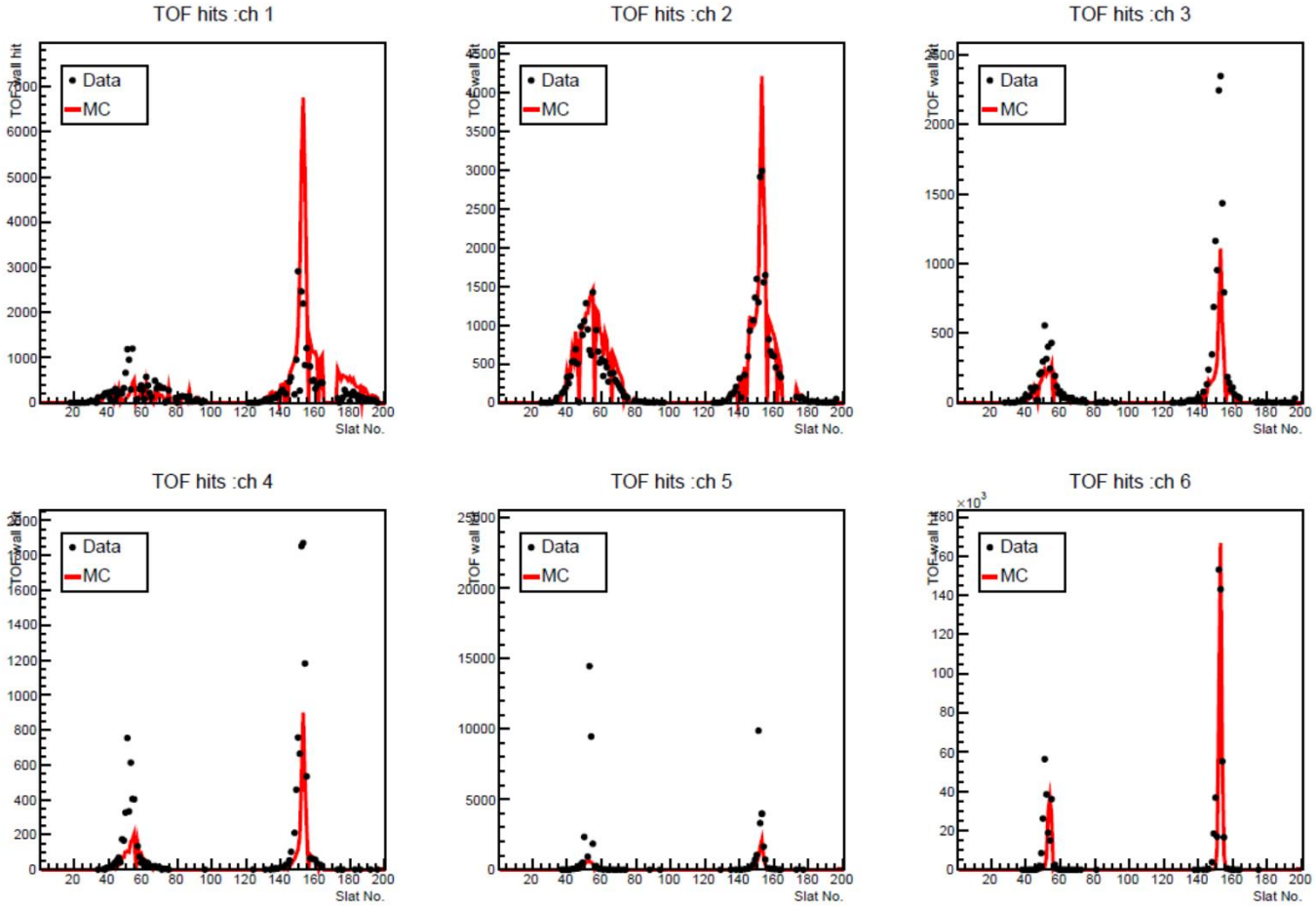
Fraction of fragmentation events
(events with n.vtx tracks(BM)>1)

Monte Carlo: 10,0 %
Data: 6,6 %

It seems the fragmentation selection at VTX level is too strong for data (see later).

The higher discrepancy at Z=5 seems to be related to the behaviour of the TOF around the carbon peak not well reproduced in the simulation (see later)
There si also a different angular distribution of Carbons between data and MC, still not understood.

Slat occupancy for each charge (DATA vs MC)



Slat occupancy for Z=5 more peaked around the C peak in data than in MC (maybe mis-reconstructed carbons, in such a case the purity is worse than MC estimation).

Two possibility to improve our confidence on the fragment identification and cross-section measurement

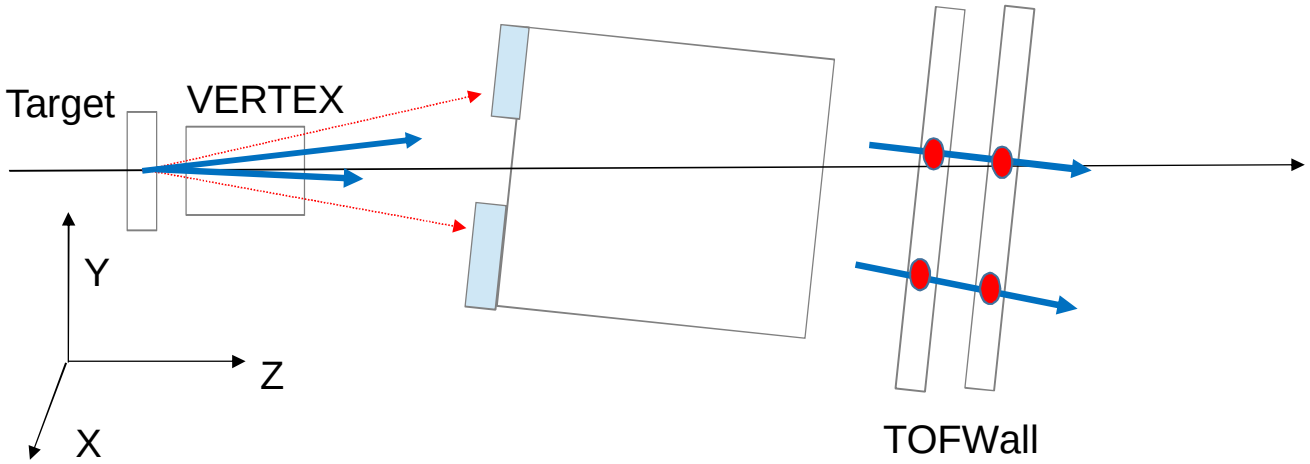
1) try our best to reduce the background from misidentificated carbons

- **study and improve TOF-VTX matching**
- **include the charge information from VTX to improve the matching**
- **careful study of the TOF behavior in the central slats**

2) study the performance of the vertexing algorithms in presence of pile-up with the simulation.

We present an attempt to match the TOF Front and Rear hits to improve some aspects of point 1.
The clustering between Front and Rear TOF hits is done in the global reconstruction algorithm after the tracking.
Some other improvements in the reconstruction algorithms included.
Doubts on the right way to use the VTX informations in the reconstruction code.

Global reconstruction algorithm



The global reconstruction algorithm currently implemented in the FIRST software tries to find the momentum for all the combinations of TOF hits and VTX tracks.
For example, in case 2 VTX tracks enter the magnet region and reach the TOF wall, up to 8 global tracks can be reconstructed.
For each VTX track, the global track having minimum difference between Y measured at TOF and Y extrapolated from the VTX is selected.

Weak points in the current algorithm:

1) TOF hits in the two plane produced by the same particle could be associated to different global tracks.
2) The sorting algorithm searches for the best Y match for each VTX track sequentially (the vertex tracks are not equivalent)
3) The resolution in Y could not be enough to solve all the ambiguities.
4) The algorithm does not take into account pile-up events (all the possible VTX tracks are considered).

Point 1) to 3) can be optimized using the Monte Carlo simulation.

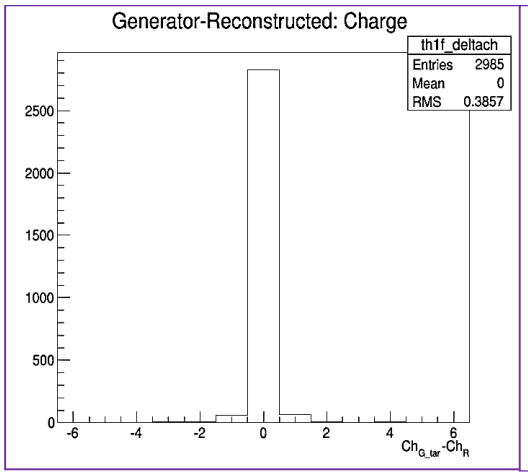
Point 4) is more delicate: there is no simulation of pile-up events, we can only rely on the correctness of the vertex association with the BM track (see later).

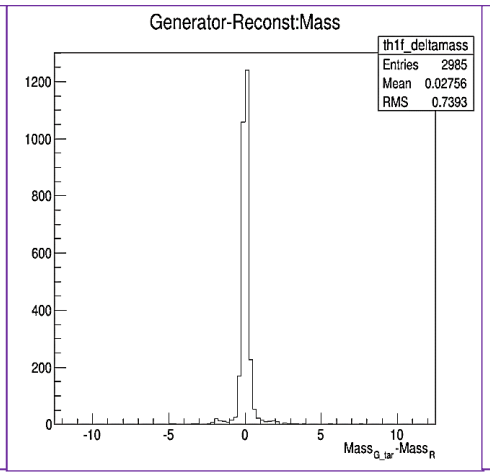
Monte Carlo study for clustering performed using fragmentation events.

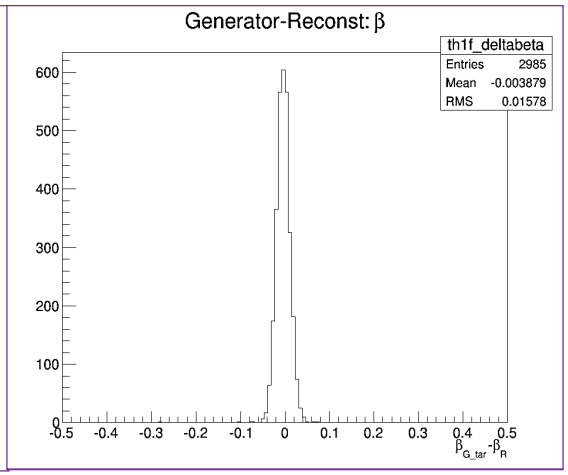
Each TOF hit is associated to a VTX track navigating in the MC track chain.

Probability a selected global track matches a TOF hit with a wrong VTX track is 16% (in fragmentation events)

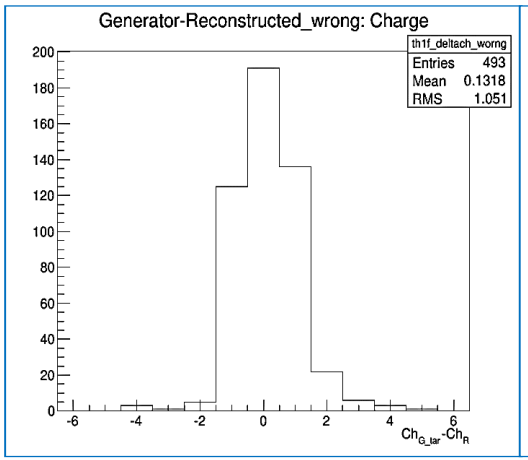
Right assignment

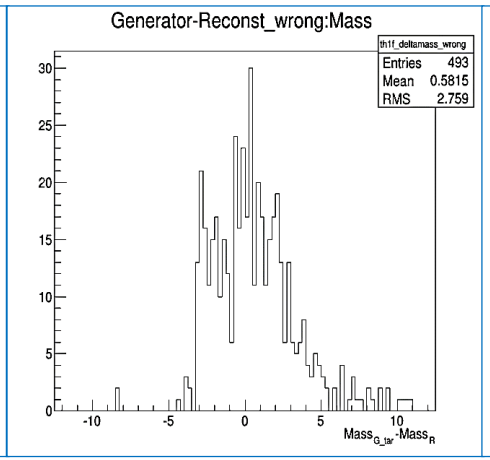


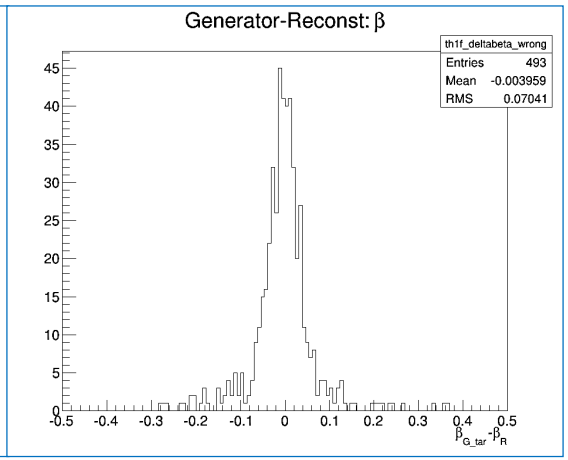




Wrong assignment







Wrong TOF/VTX assignments distort the reconstructed distributions.

In order to improve the TOF/VTX matching algorithm, the following algorithm has been tested with simulation events (algorithm implemented in GlobalTrack.cxx, not committed yet).

1) Search for the best VTX/TOF matching looking at minimum Yvtx-Ytof for all the global track candidates (like before but looking at all the VTX-TOF combinations)

2) Loop over the other global track associated to the same VTX track but with a hit in the opposite plane, if any (best selection could be based using all possible quantities, including reconstructed variables). Cluster the two hits in a single one, and repeat the tracking.

3) Continue the loop excluding the selected TOF hits and VTX track.

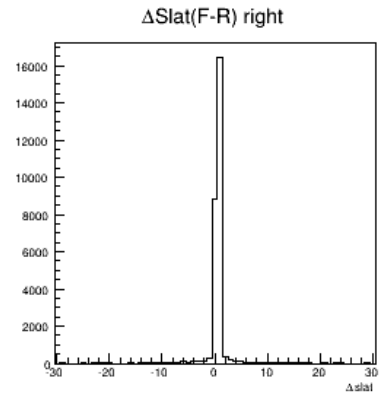
Advantages:

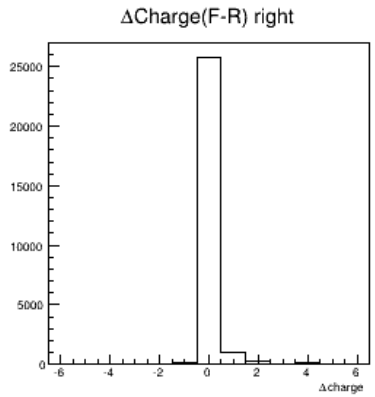
- TOF hits belonging to the same track in different planes can not be associated to different global tracks.
- no discrimination between VTX tracks (all the combinations are tested for each VTX track)
- the TOF cluster can provide more precise information for the reconstruction
- TOF/VTX matching and clustering criteria can be easily changed (including reconstructed quantities or i.e. adding the VTX charge informations for the TOF/VTX matching).

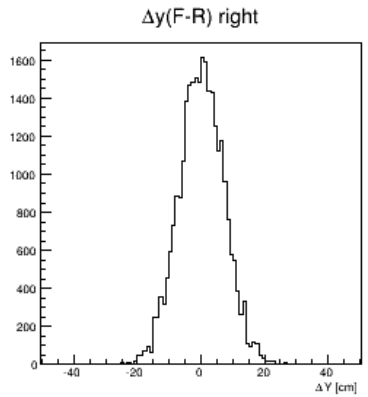
The clustering criteria has been studied in the simulation by looking at wrong or right TOF hit F/R combinations (based on MC track information, right combinations are 2 TOF hits in opposite planes associated to the same MC track).

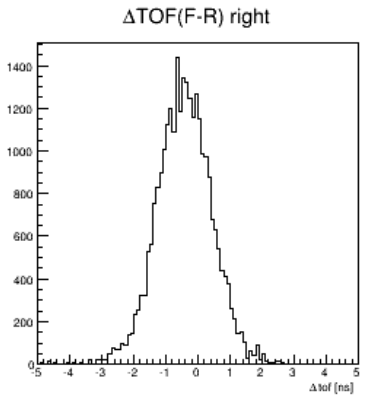
Front-Rear comparison for different TOF quantities for right and wrong clusters in the simulation.

Right assignment

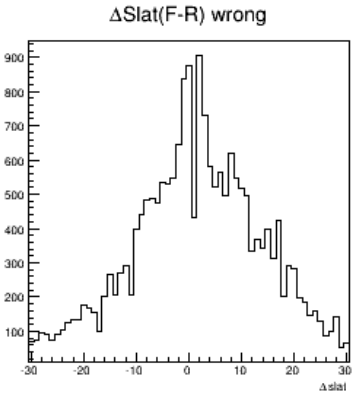


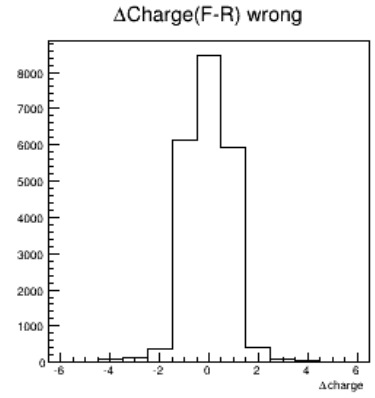


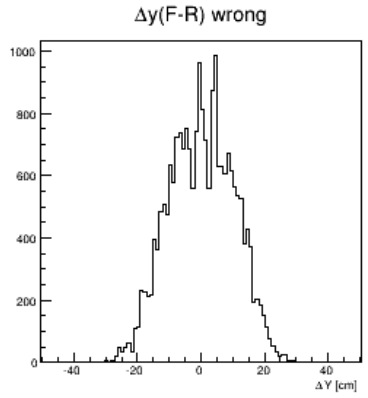


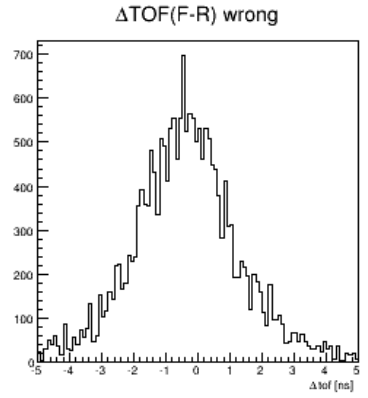


Wrong assignment



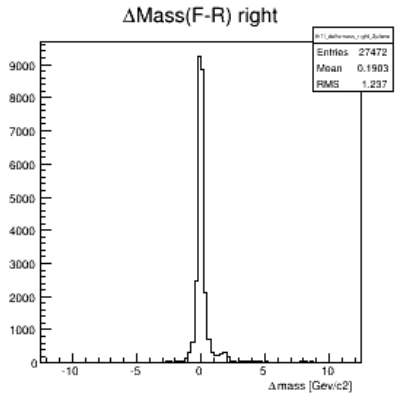


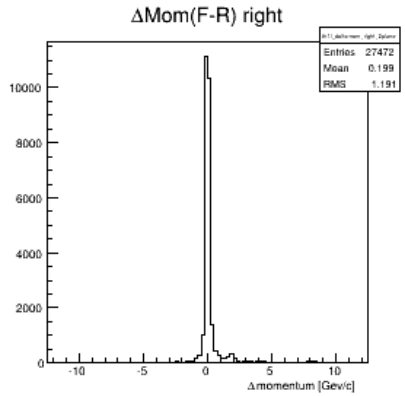


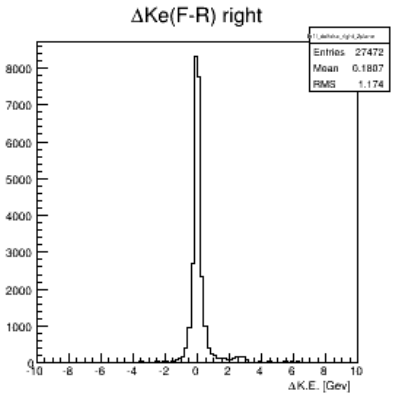


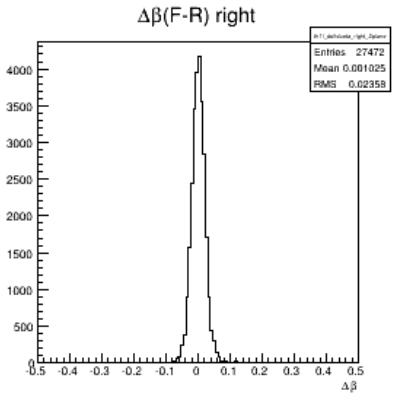
Front-Rear comparison for different reconstructed variables for right and wrong clusters in the simulation.

Right assignment

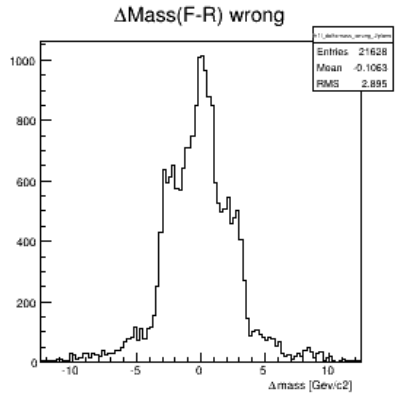


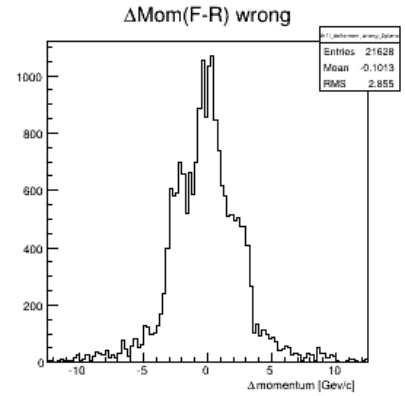


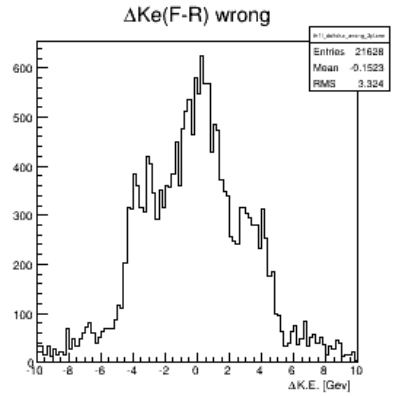


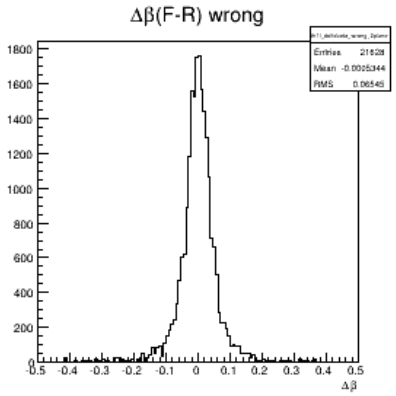


Wrong assignment

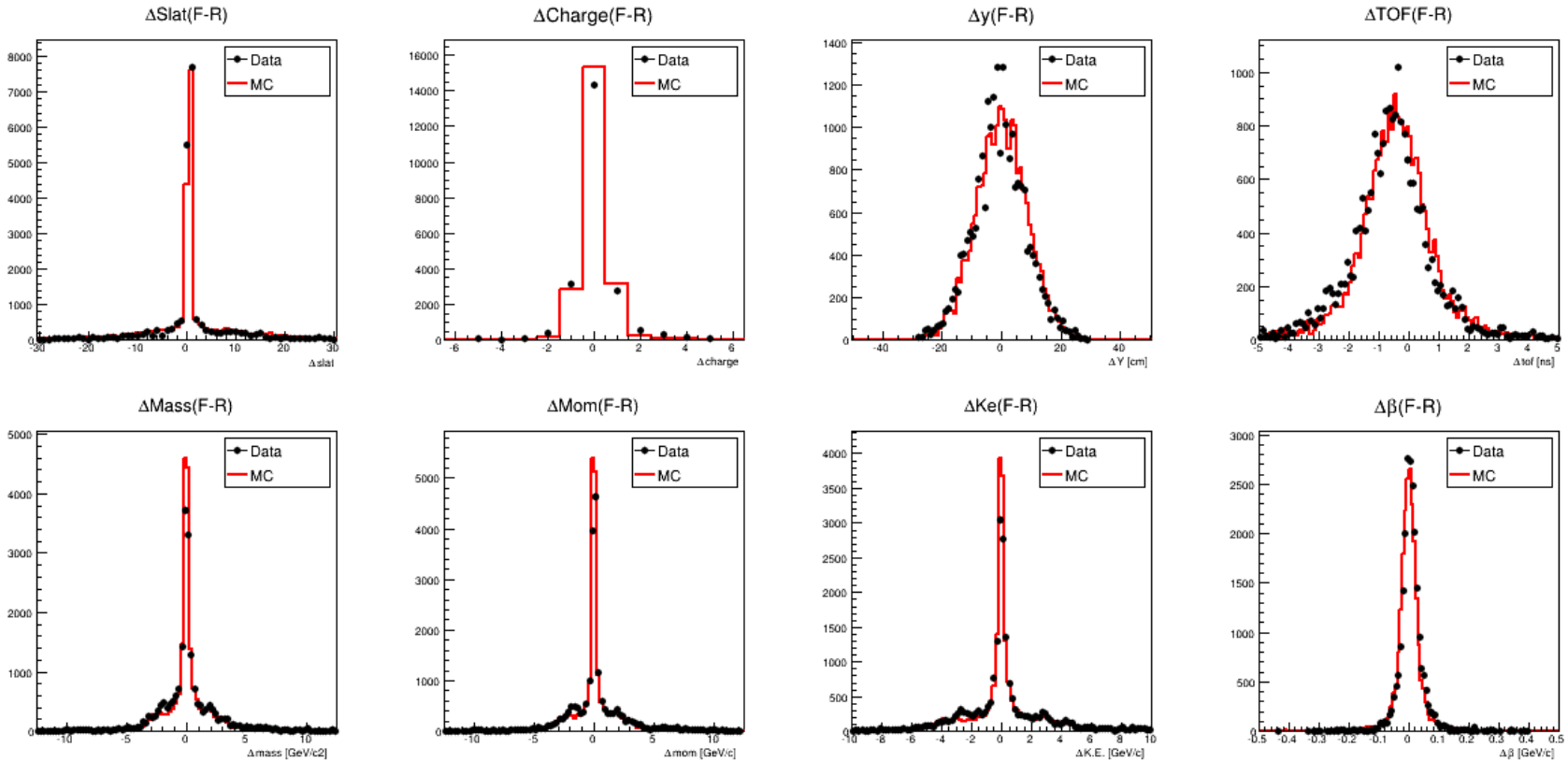








DATA/MC comparison for F-R distributions (done on all F/R hit combinations before the clustering).



Clustering scoring function (can be easily changed):

$$f(F,R) = \sqrt{\left(\frac{\Delta \text{slat}}{\sigma(\Delta \text{slat})}\right)^2 + \left(\frac{\Delta Y}{\sigma(\Delta Y)}\right)^2}$$

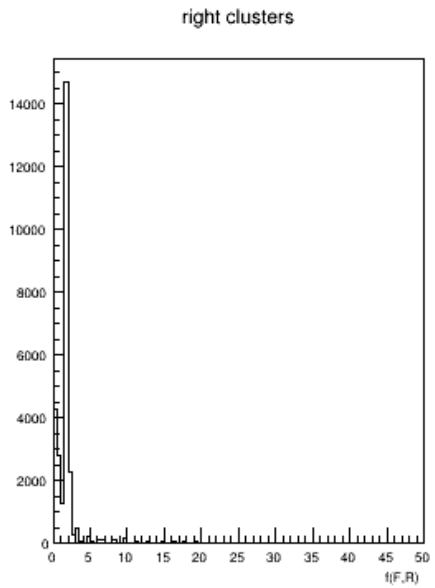
Δslat < 4

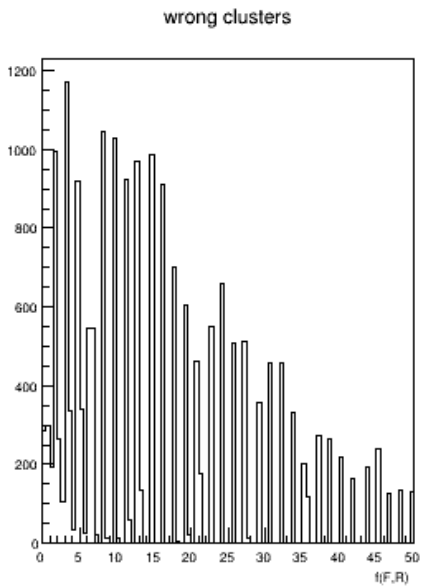
Δslat = slat(Front)-slat(rear)

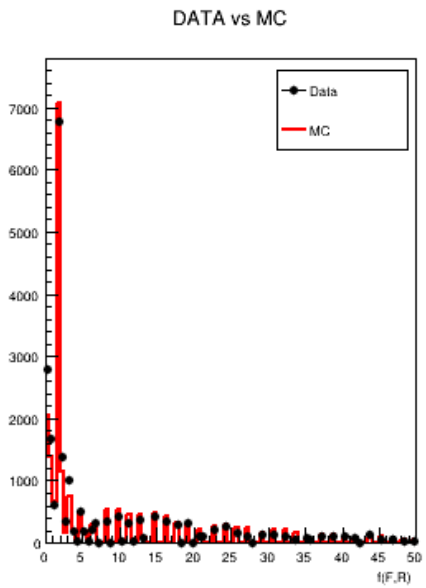
ΔY = Y(Front)-Y(rear)

$\sigma(\Delta\text{slat})$ = 0,62 (from distibution fits in data and MC)

$\sigma(Y)$ = 8,5 cm (from distibution fits in data and MC)







Fraction of wrong selected clusters in MC: 6 %.

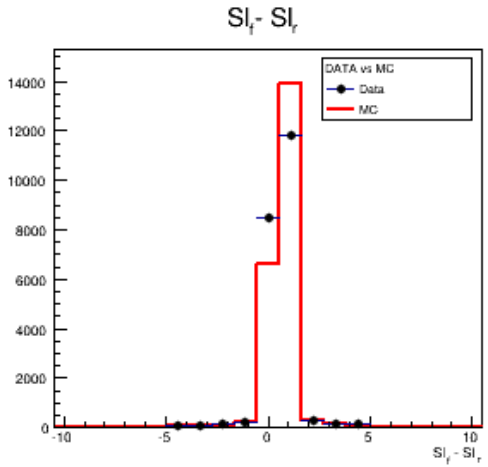
The track is refitted using the maximum charge of the two hits.

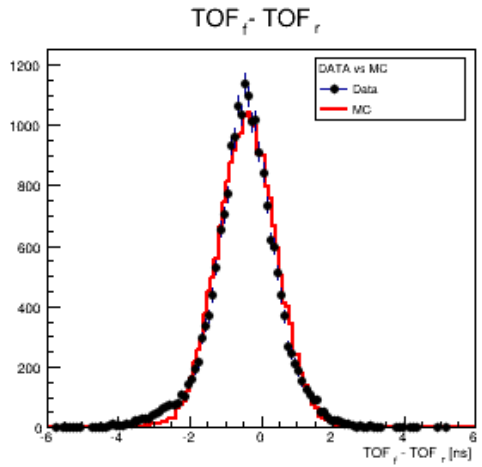
Fraction of wrong TOF/VTX matching:

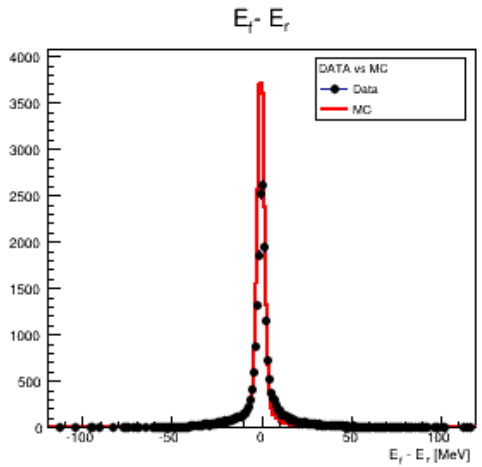
Change in the reconstruction code	Fraction of wrong TOF/VTX matches
Original algorithm	15,78 %
All combinatorials of VTX/TOF in the matching selection	14,71 %
+ TOF clustering	14,50 %
+ use of true MC VTX charge in the sorting (for test)	8,37 %

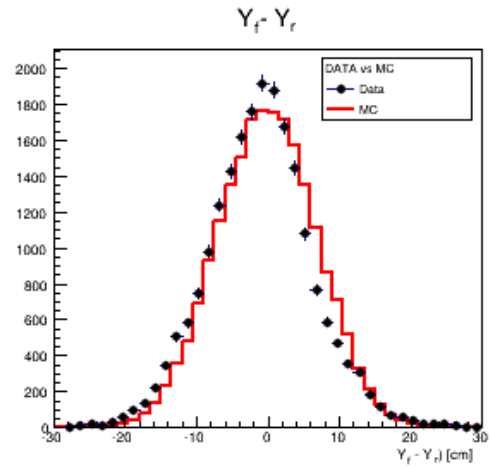
Probably the remaining errors are mainly due to secondary interactions (to be studied).

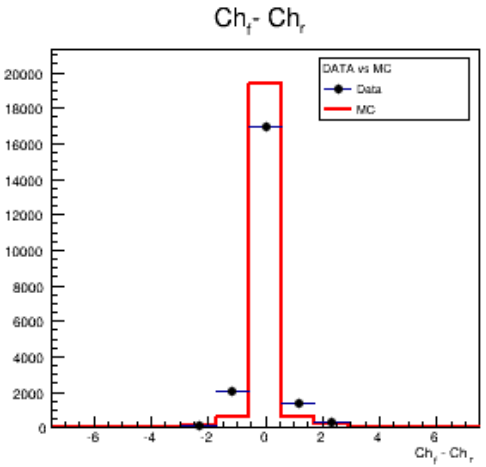
Comparison Front and Rear TOF distributions for clustered hits (**fragmentation events**)



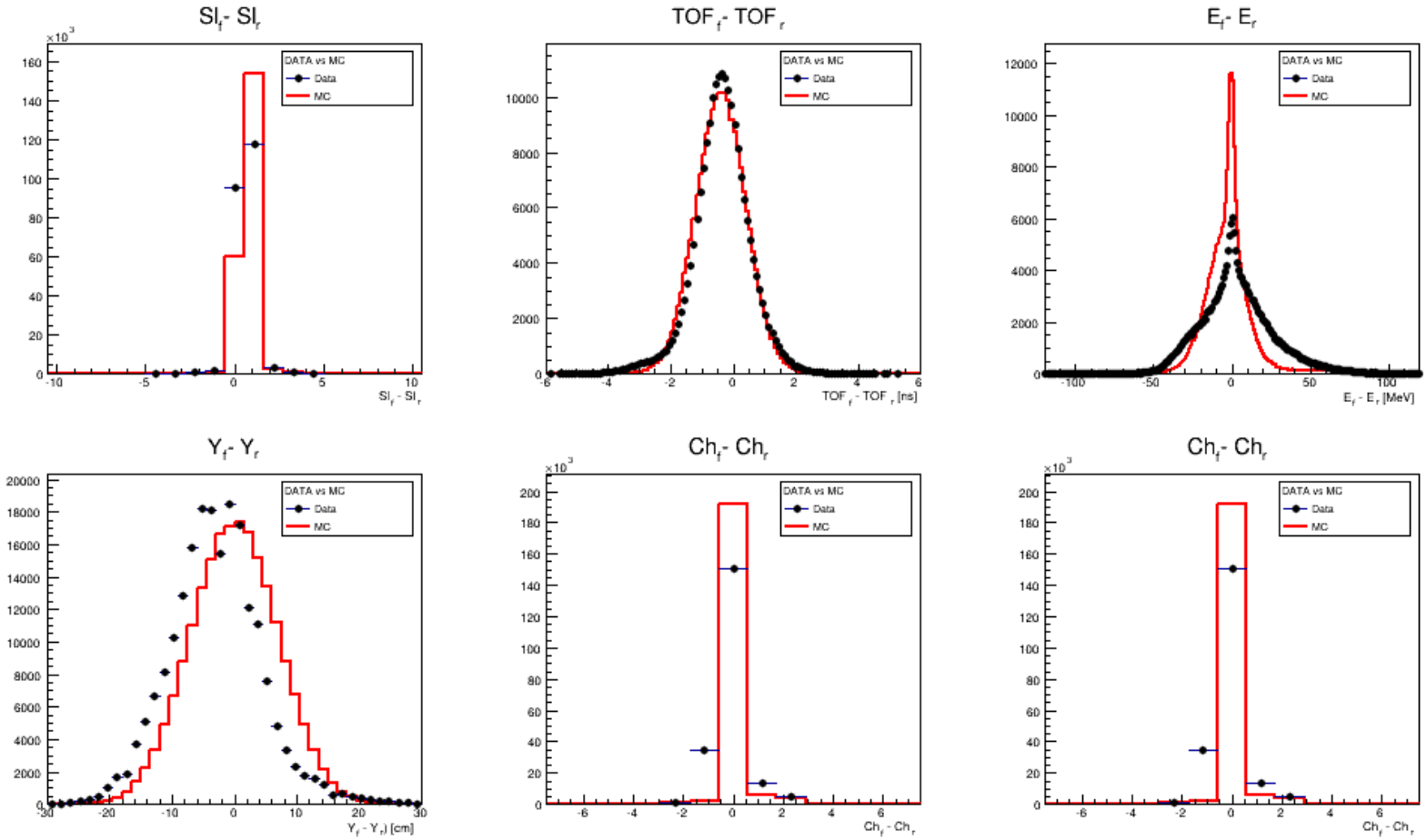






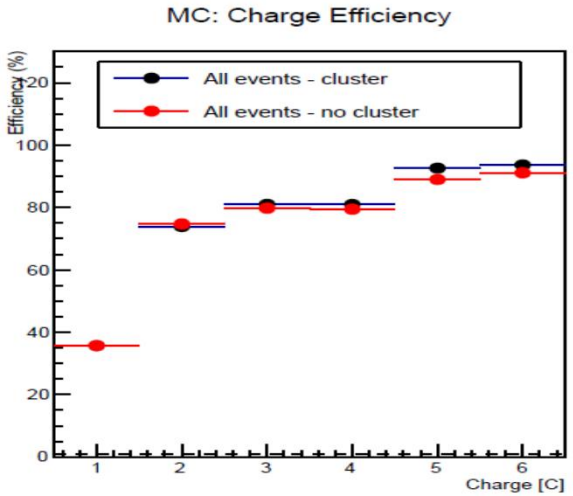


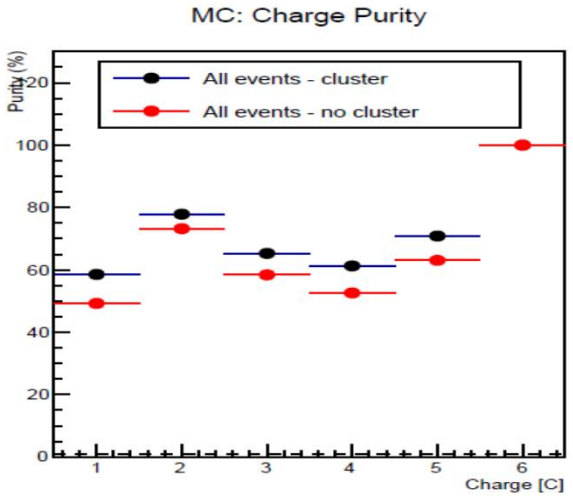
Some F-R comparisons are worse when **all the events** are considered:



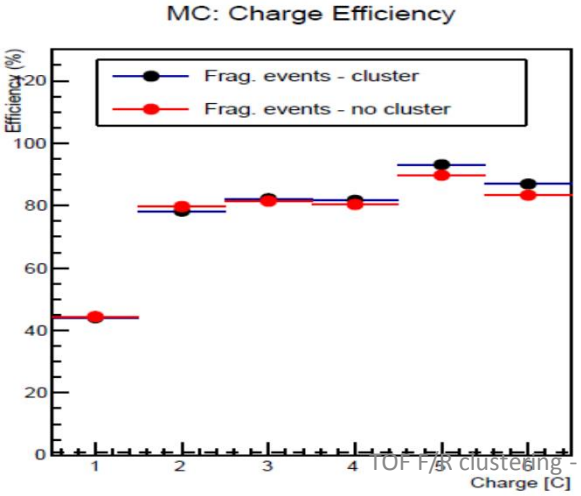
Improvement in efficiencies and purities with old algorithma and after the clustering.

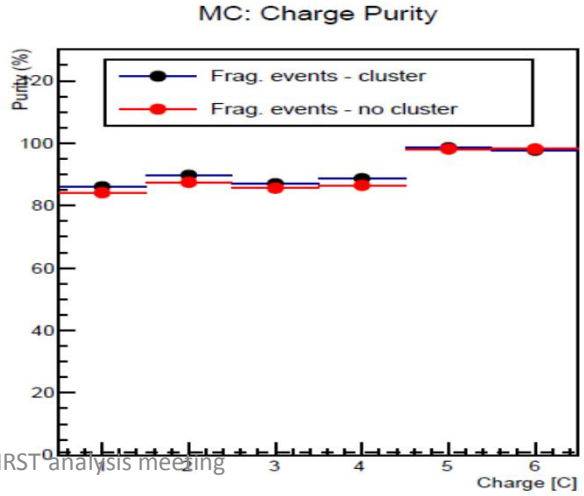
All events





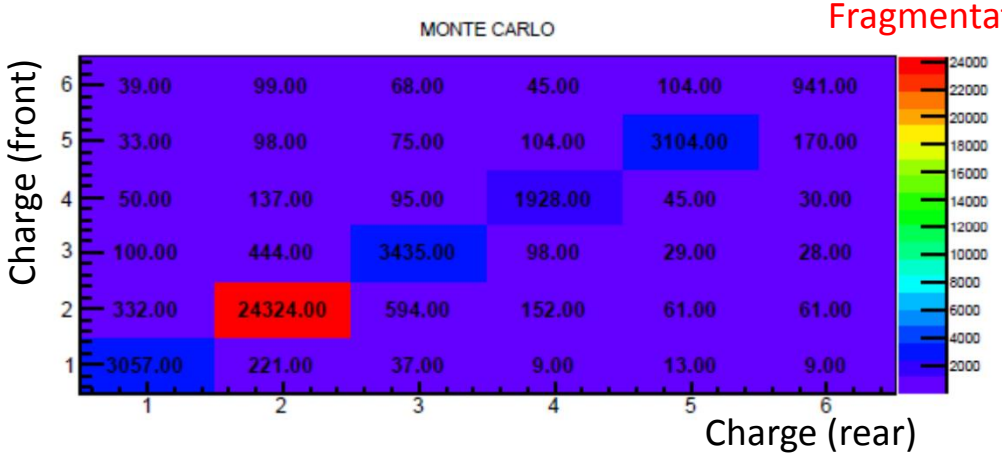
Fragmentation events

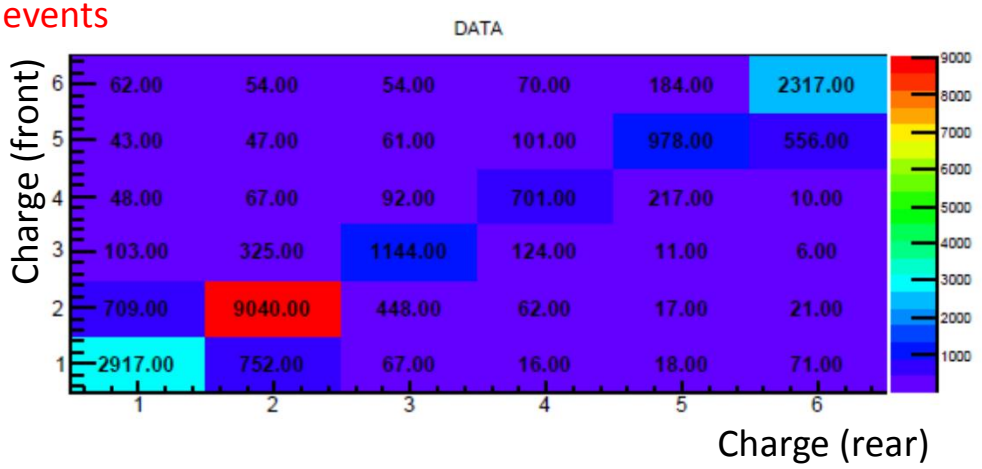




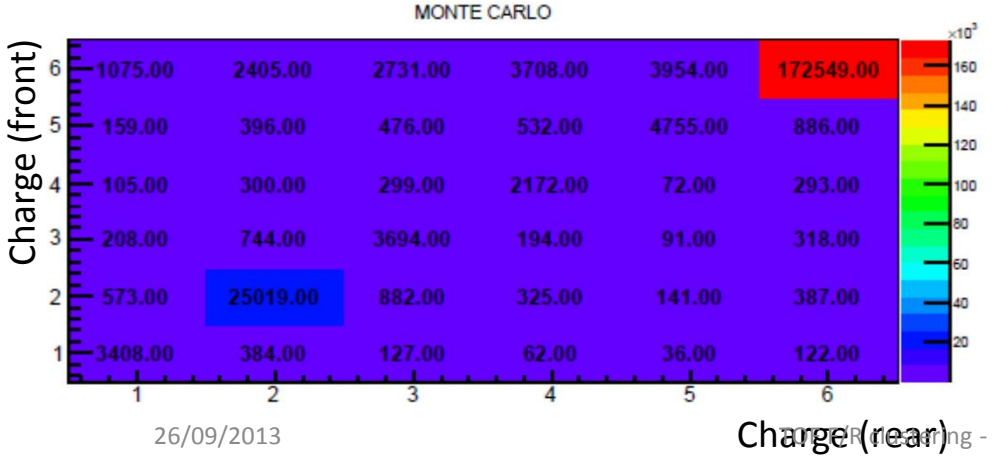
Charge(Front) vs Charge(Rear) for clustered hits

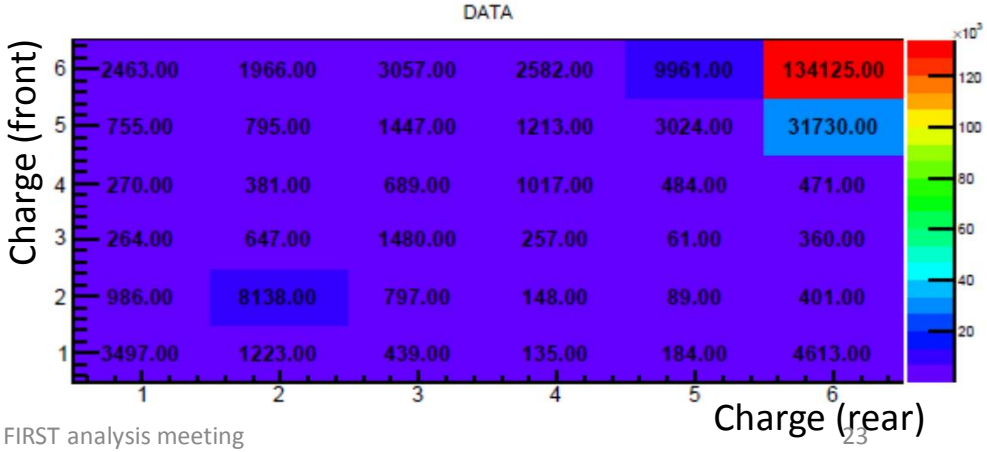
Fragmentation events





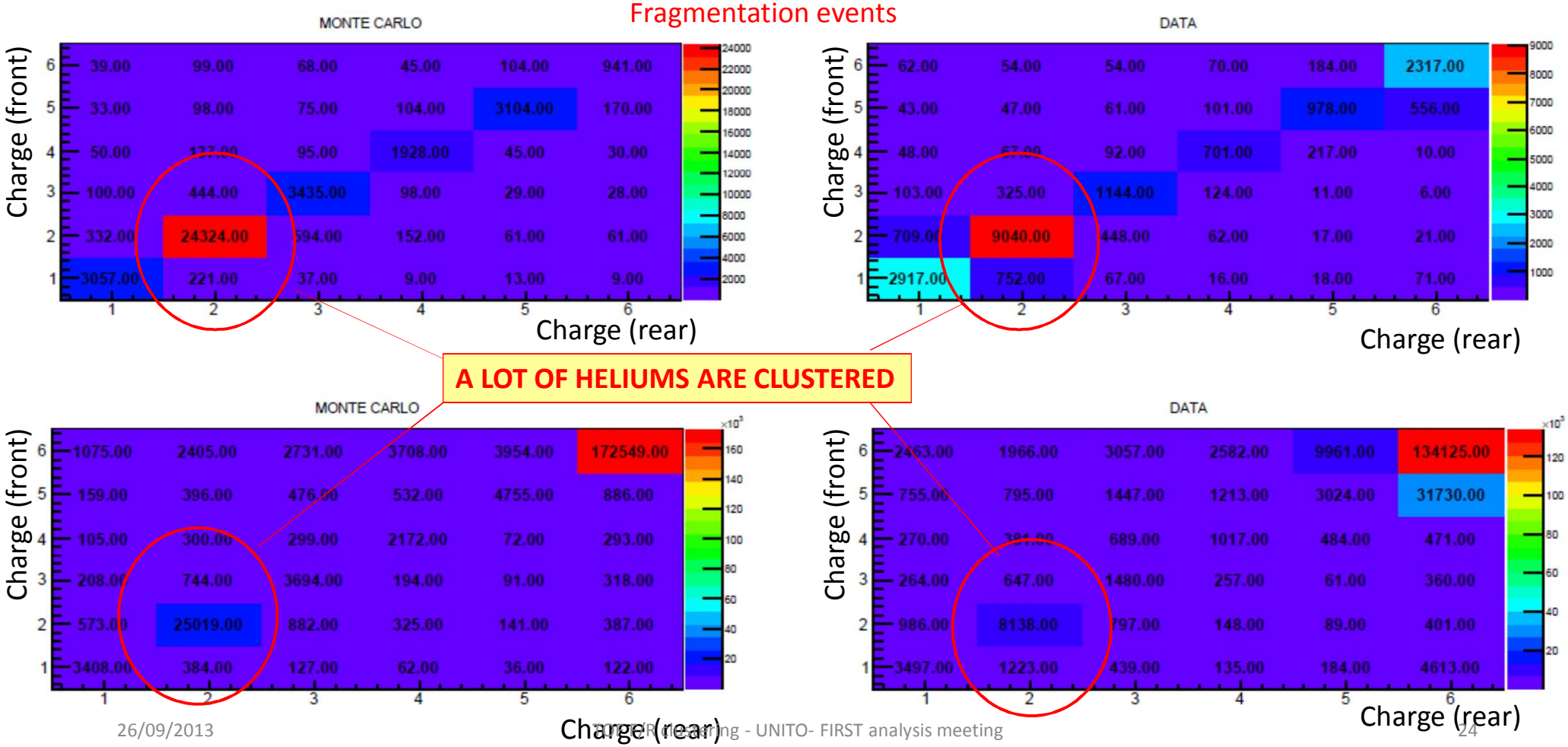
All the events



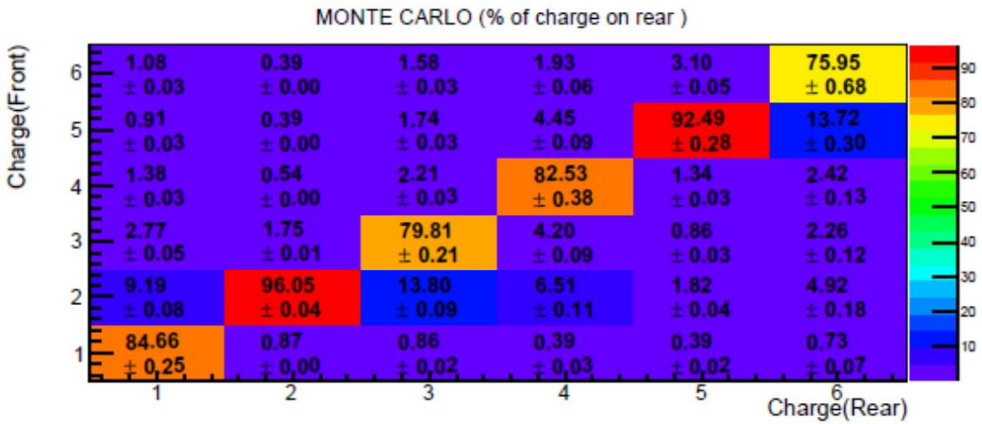


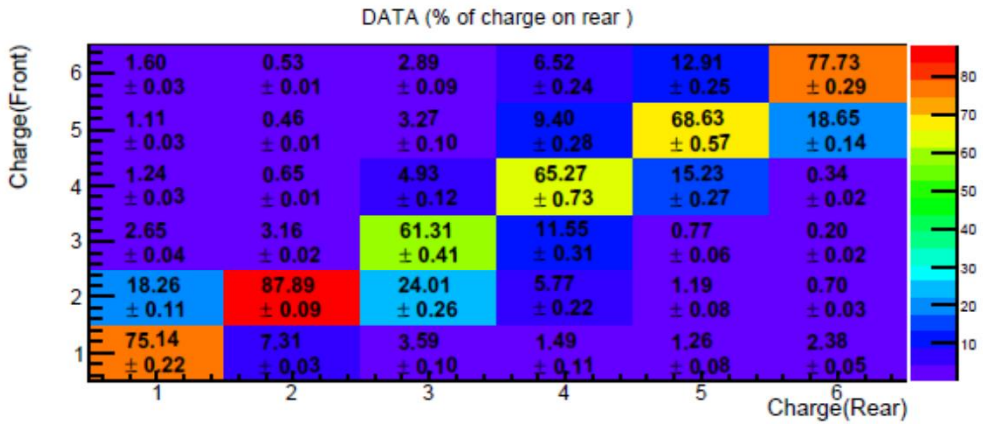
Charge(Front) vs Charge(Rear) for clustered hits

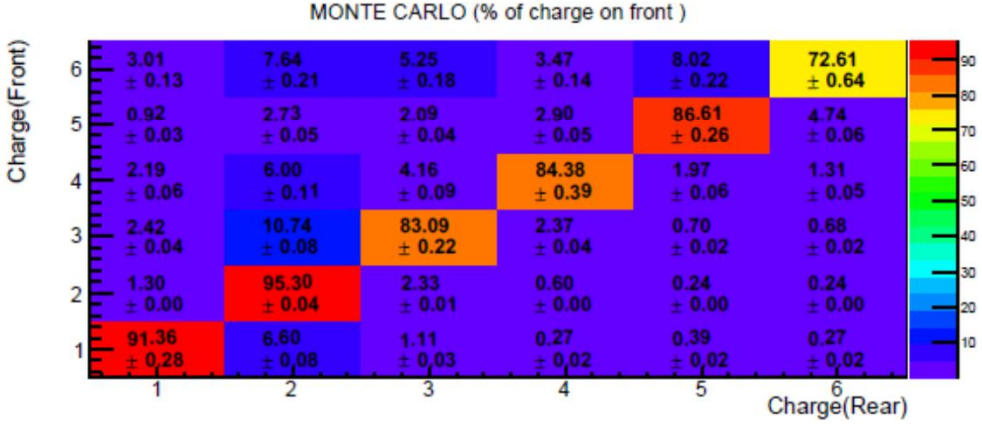
Fragmentation events

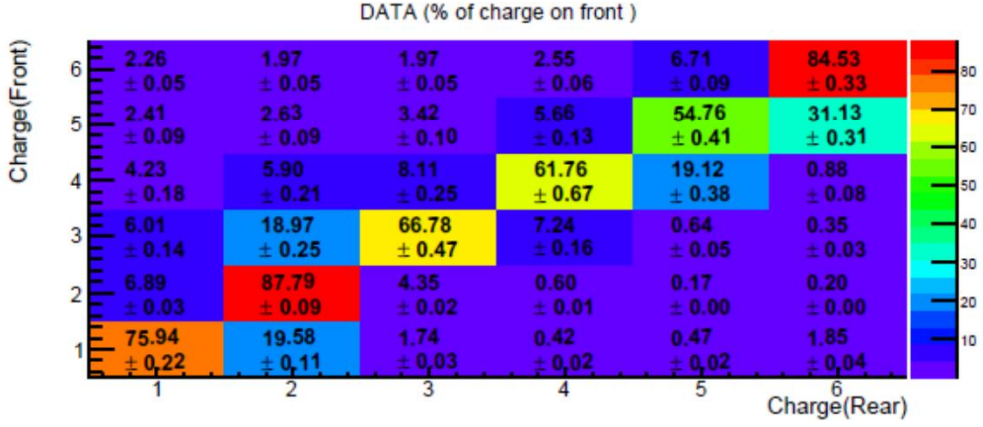


Charge(Front) vs Charge(Rear) for clustered hits
Probabilities for fragmentation events.



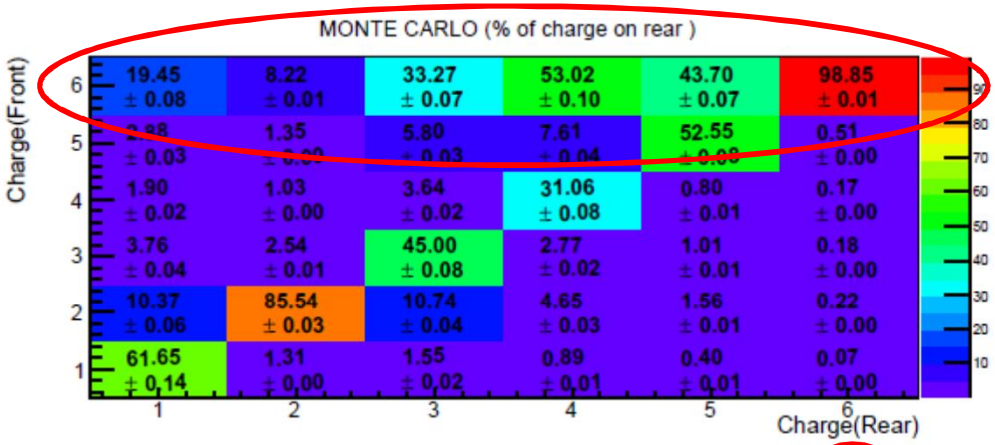


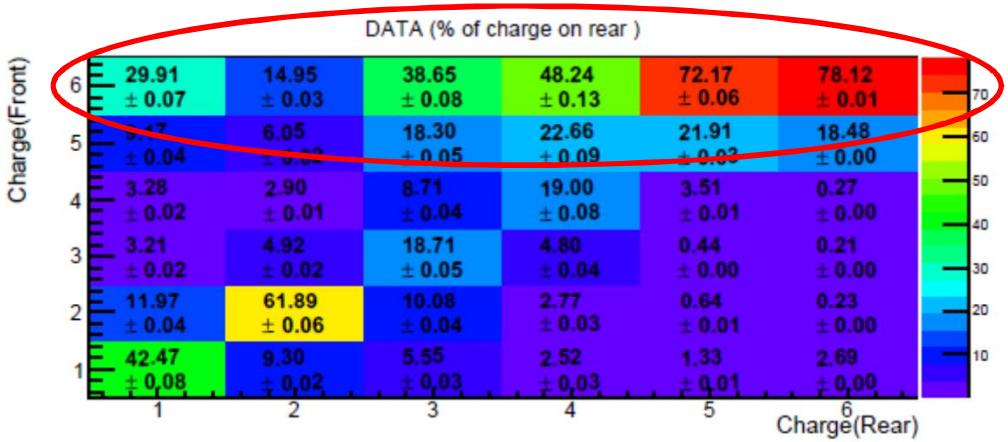


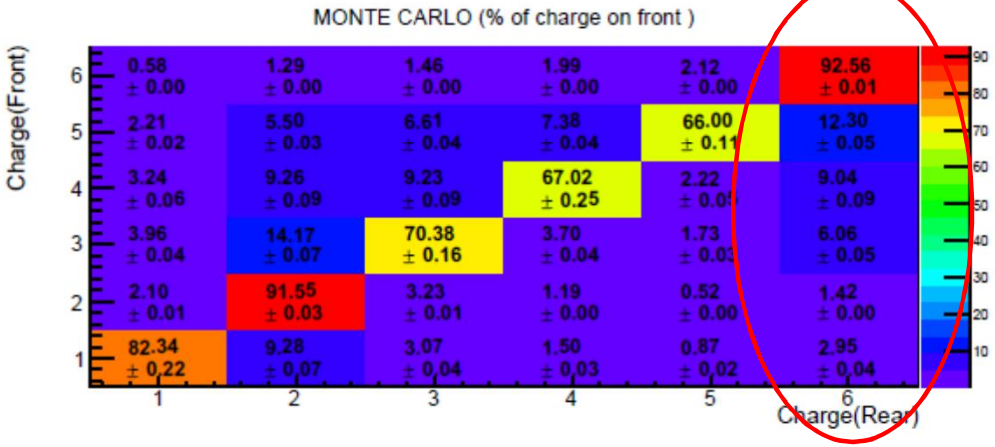


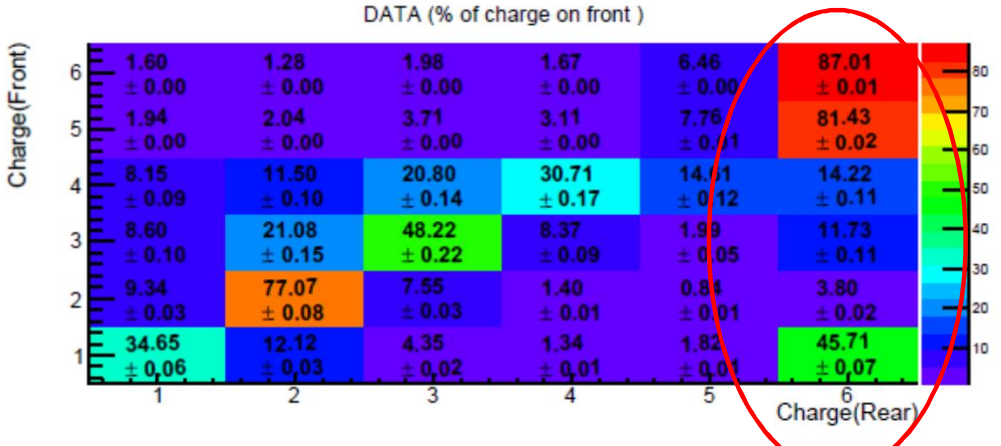
Correlation worse in data than in the simulation

Charge(Front) vs Charge(Rear) for clustered hits
Probabilities for <u>all the events</u>.







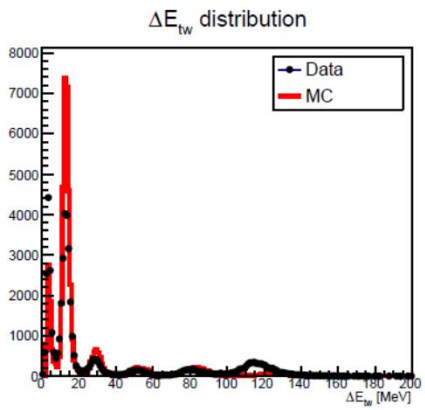


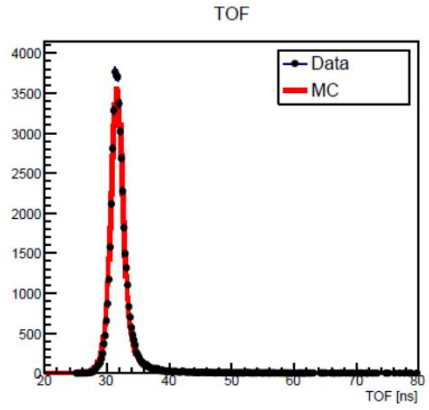
Fragmentation between front and real walls (worse in data) ?

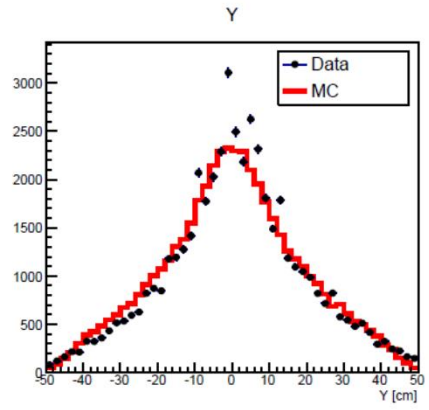
TOF data/MC comparisons (fragmentation events)

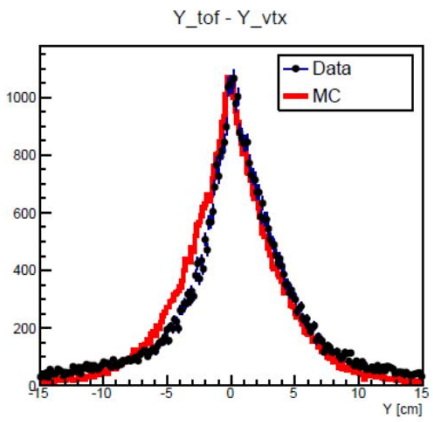
Å Data/MC comparison for different TOF quantities is quite good for fragmentation events.

Linear scale

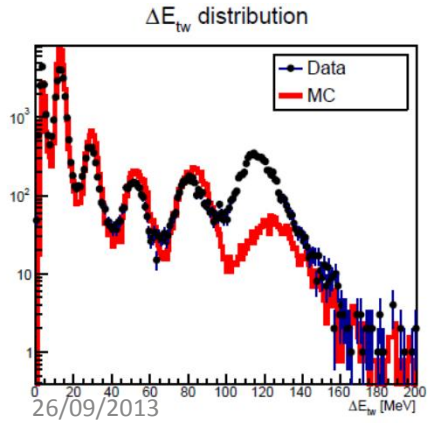


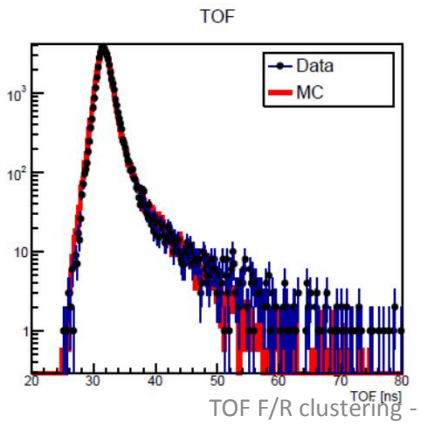


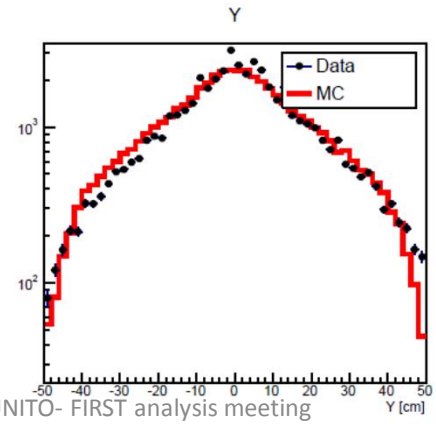




Logaritmic scale



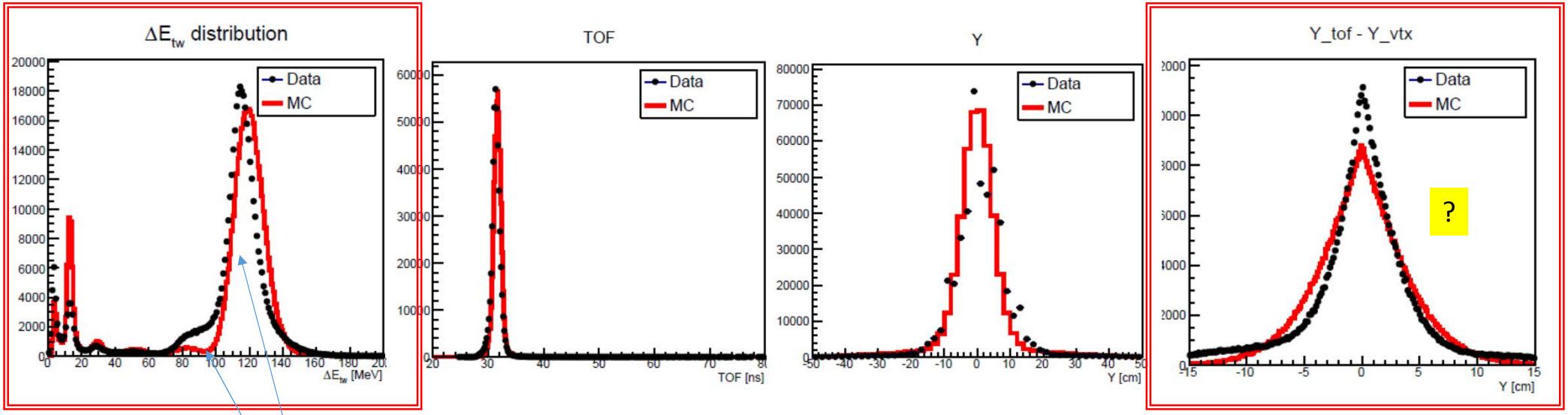




An old question:
Why we have this carbon peak
In fragmentation events ?
Are we handling the pile-up
In the correct way ?

TOF data/MC comparisons (all the events)

After many changes in the TOF calibration and simulation, we realize now that the agreement between data and MC for some TOF quantities is not so good close to the Carbon peak

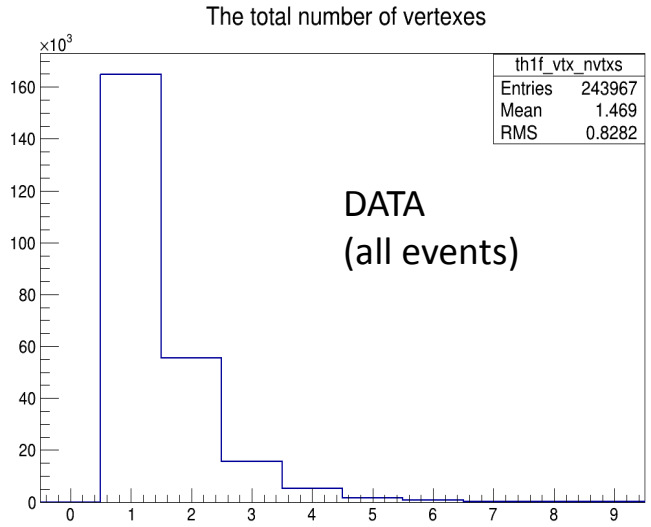


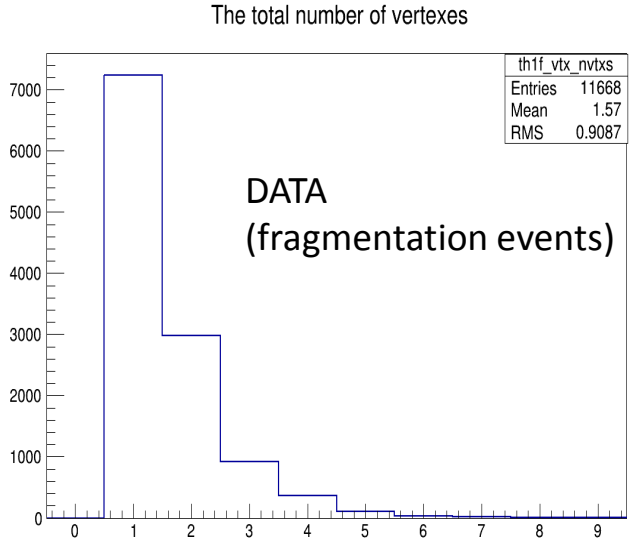
Peak shift + excess of Z=5

The region around the central slats is quite difficult to handle (hole in the front, additional module in the rear, different angular distributions in data and MC). We could try to retune the MC simulation in this region.

Pile-up in the reconstruction code

In the current reconstruction code all the VTX tracks are used, even if the event has more than 1 vertex.





Slight different number of vertices in the 2 cases (in principle it should be exactly the same)

In principle, in presence of more than 1 VTX, in the reconstruction we should use only the tracks from the vertex associated to the BM track. Suggestions needed for this part from VTX experts.

Examples of reconstructed events (with clustering)

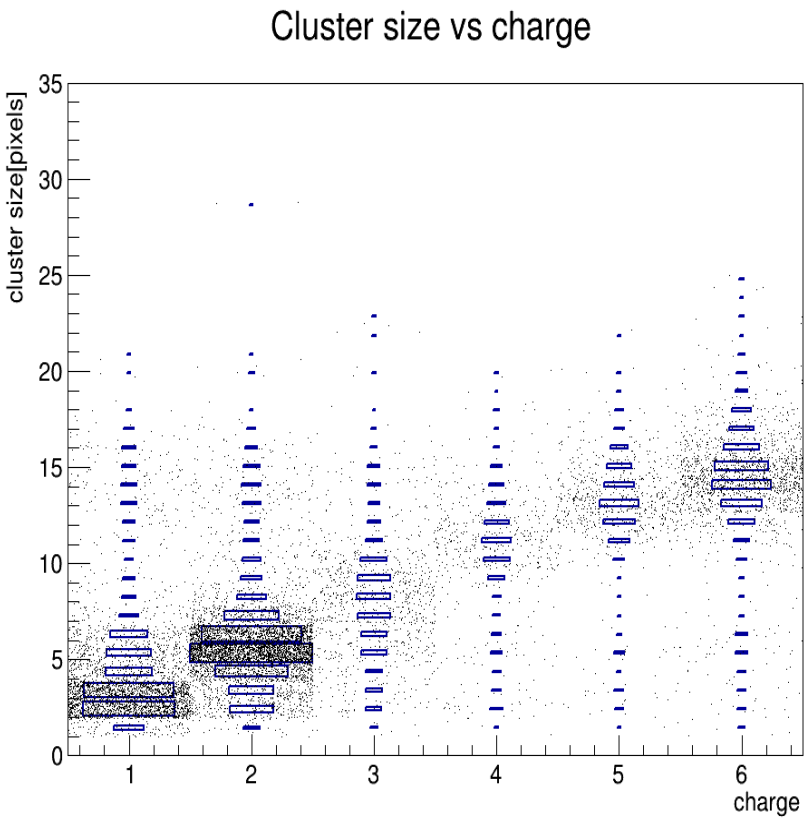
About 200 events analyzed «by eyes» to understand reconstruction/vertexing/TOF issues

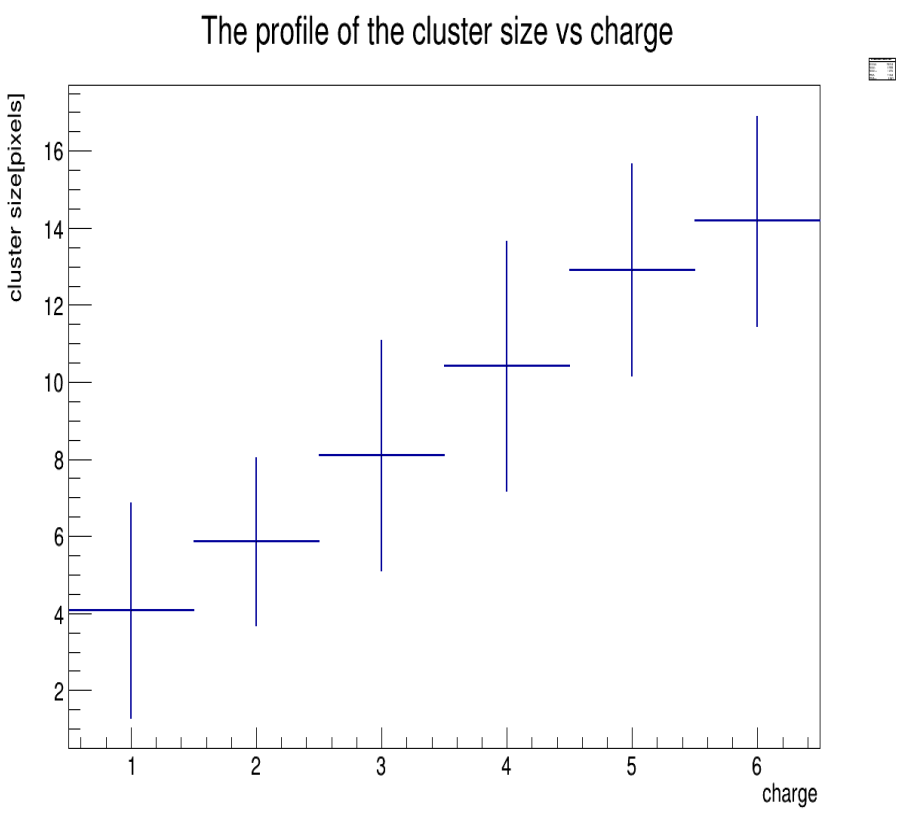
Examples shown for:

- unambiguos carbon events (well reconstructed)
- carbon events with pile-up (well reconstructed as carbon)
- events reconstructed with Z<6 but with no fragmentation in the TOF or in the VTX
- events with fragmentation close to the TOF wall
- fragmentation events

raw information on charge from VTX cluster size used to cross check

ÅVTX cluster size vs charge (fragmentation events)

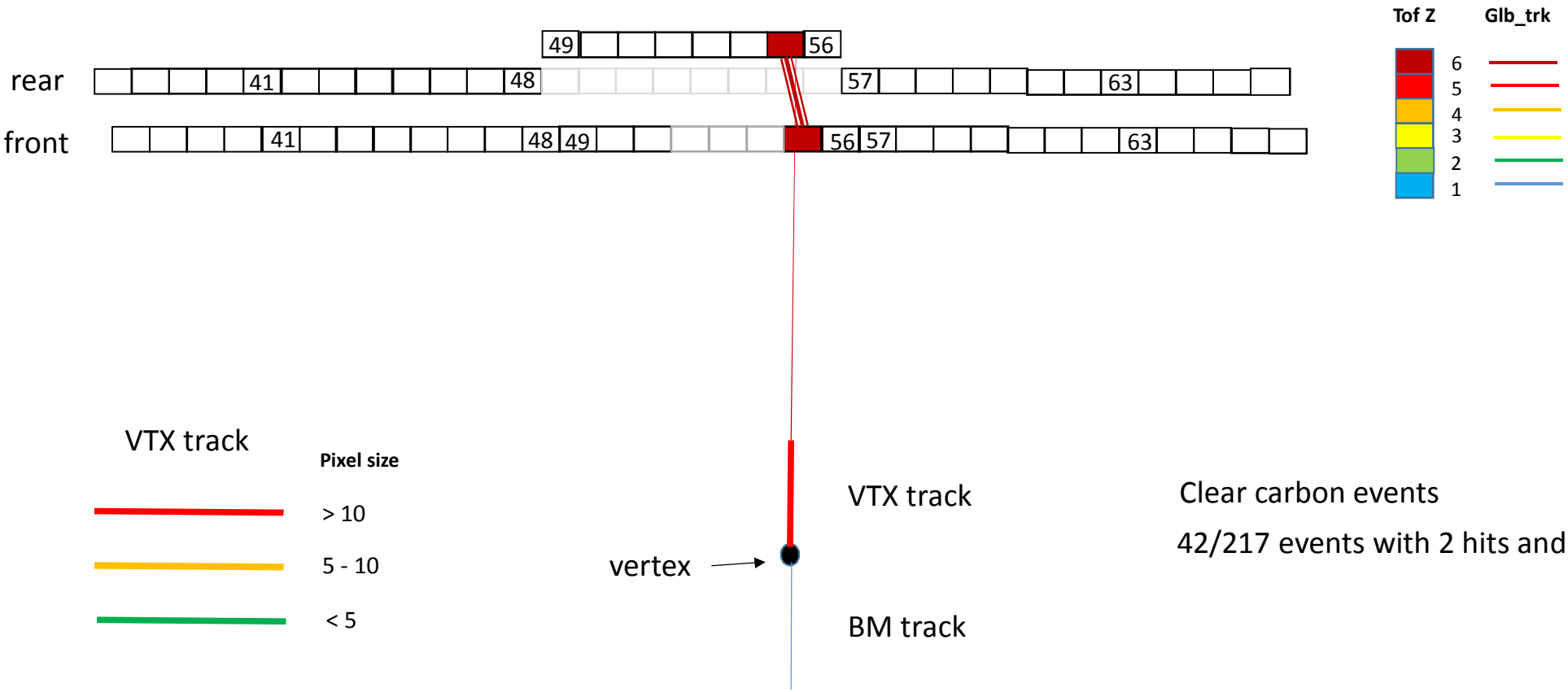




Error bars = RMS

Unambiguos Carbon events

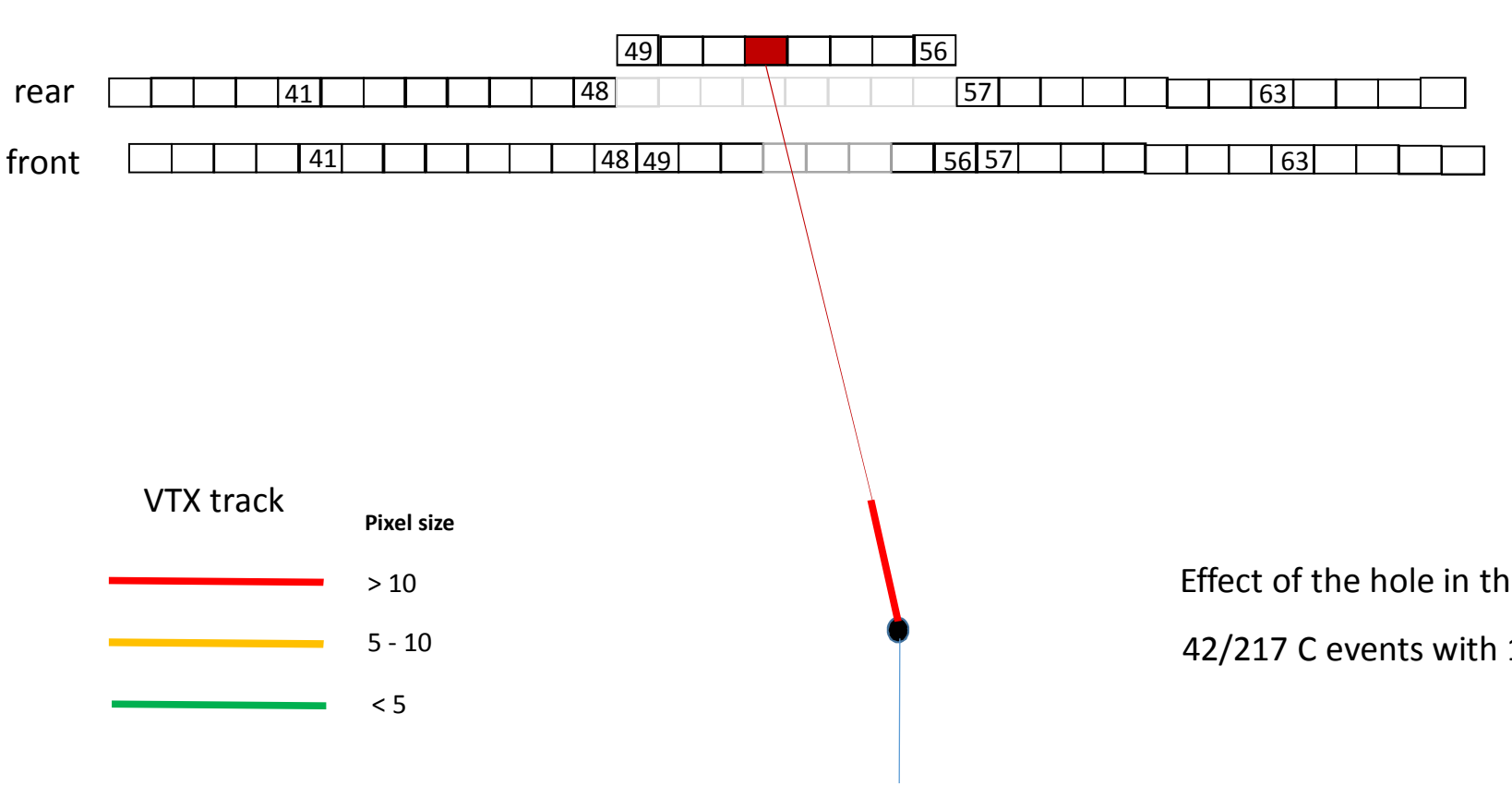
2 TOF hits carbon (clustered) – 1 VTX vertex – 1 VTX track



Clear carbon events

42/217 events with 2 hits and 1 VTX

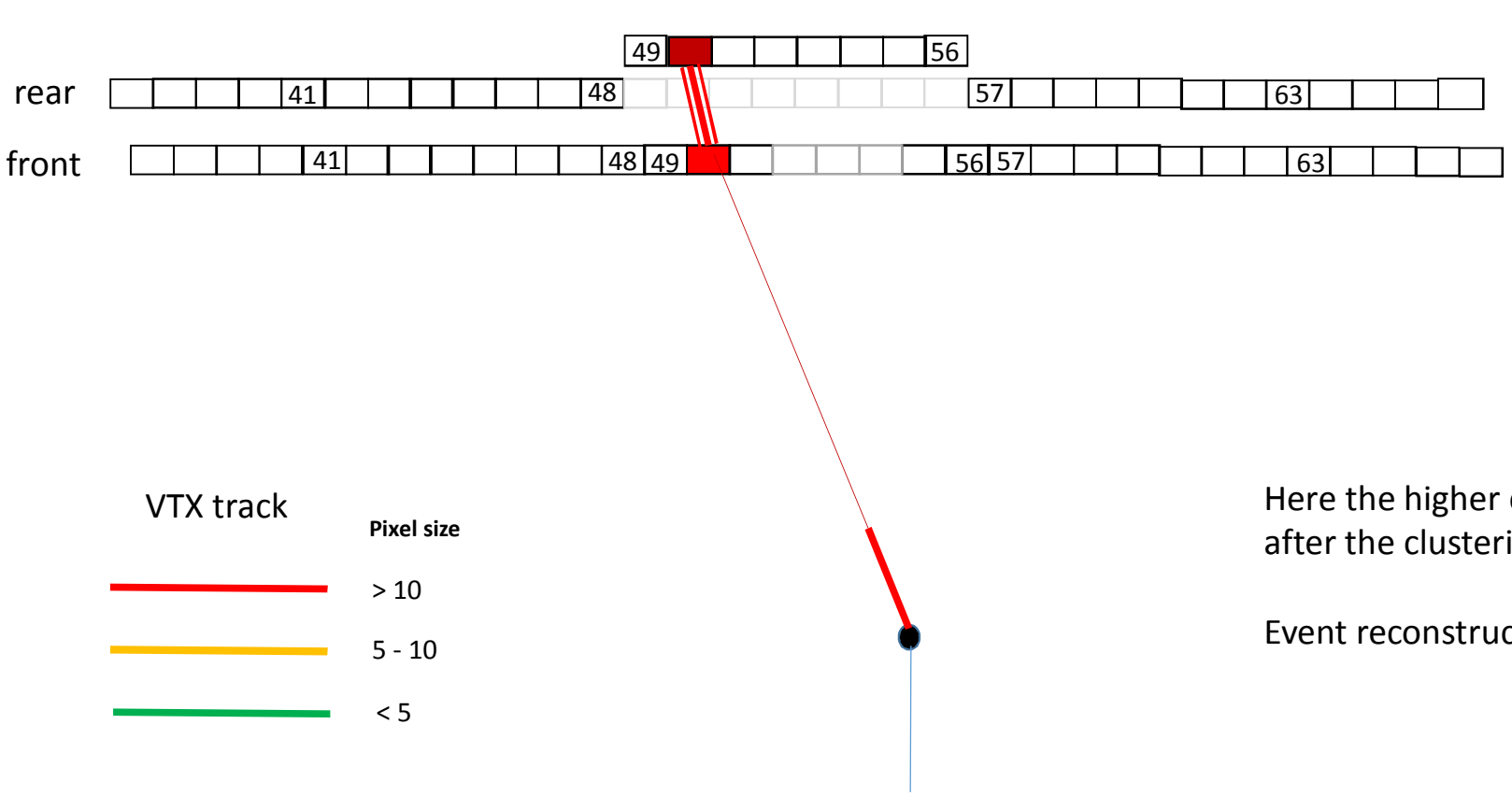
1 TOF hits carbon – 1 VTX vertex – 1 VTX track



Effect of the hole in the front plane

42/217 C events with 1 VTX + 1 TOF hit

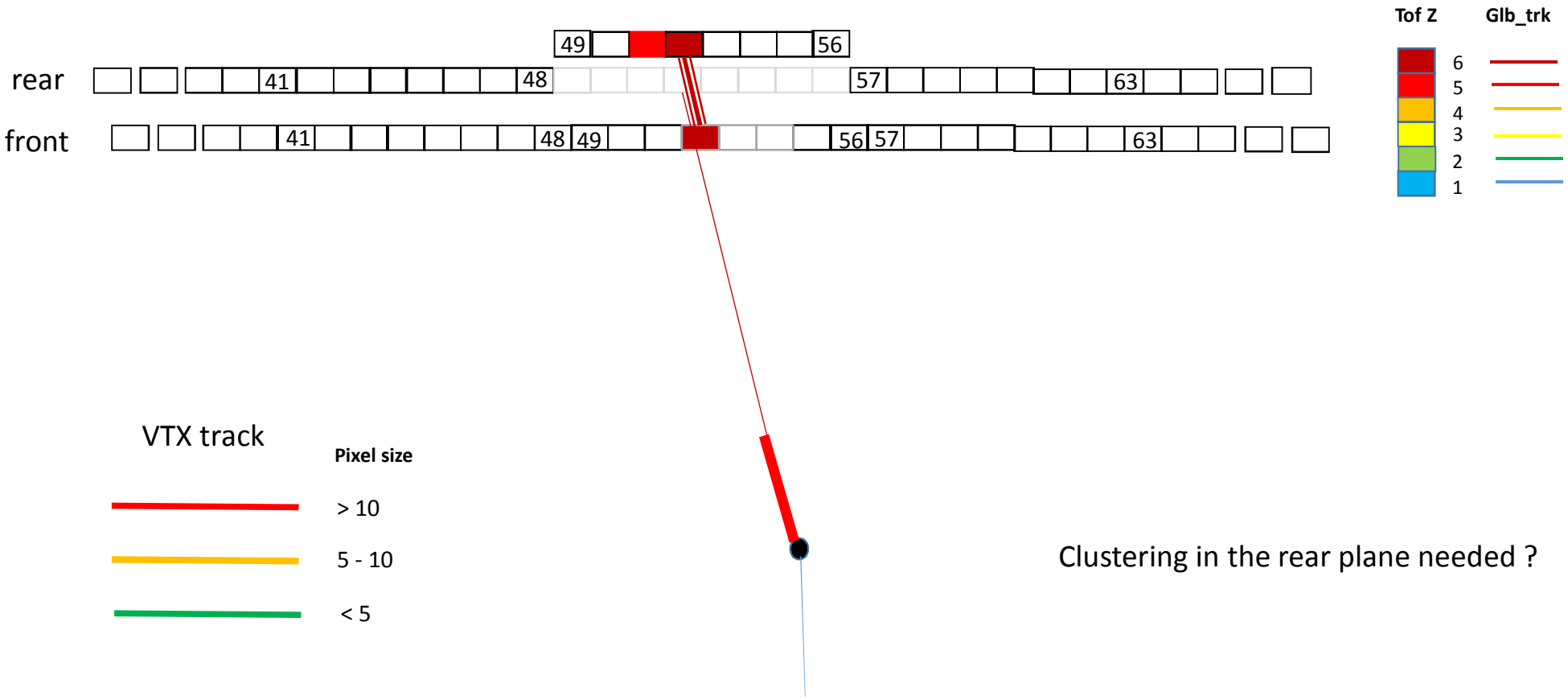
2 TOF hits carbon (clustered) – 1 VTX vertex – 1 VTX track



Here the higher charge is assigned after the clustering.

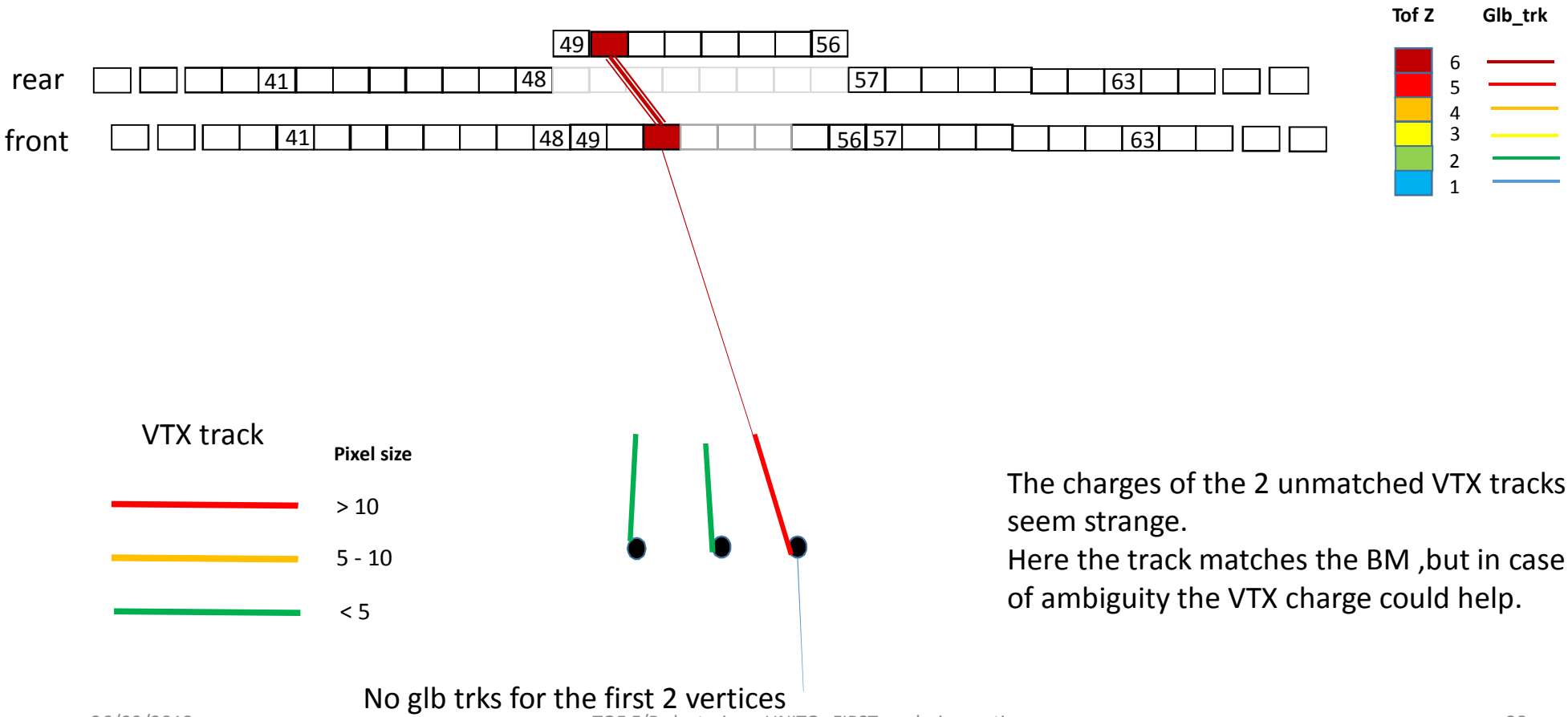
Event reconstructed as Carbon.

Caso C



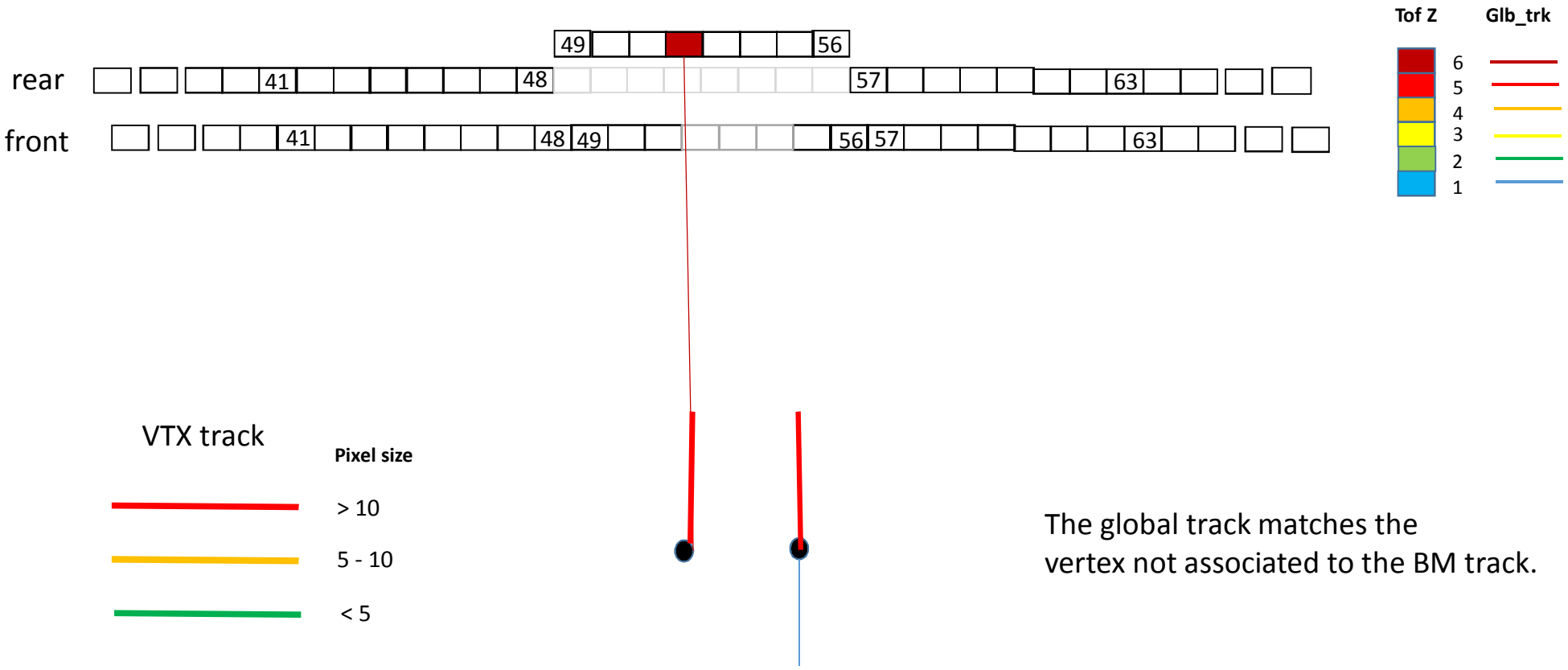
Clustering in the rear plane needed ?

Pile-up in Carbon events



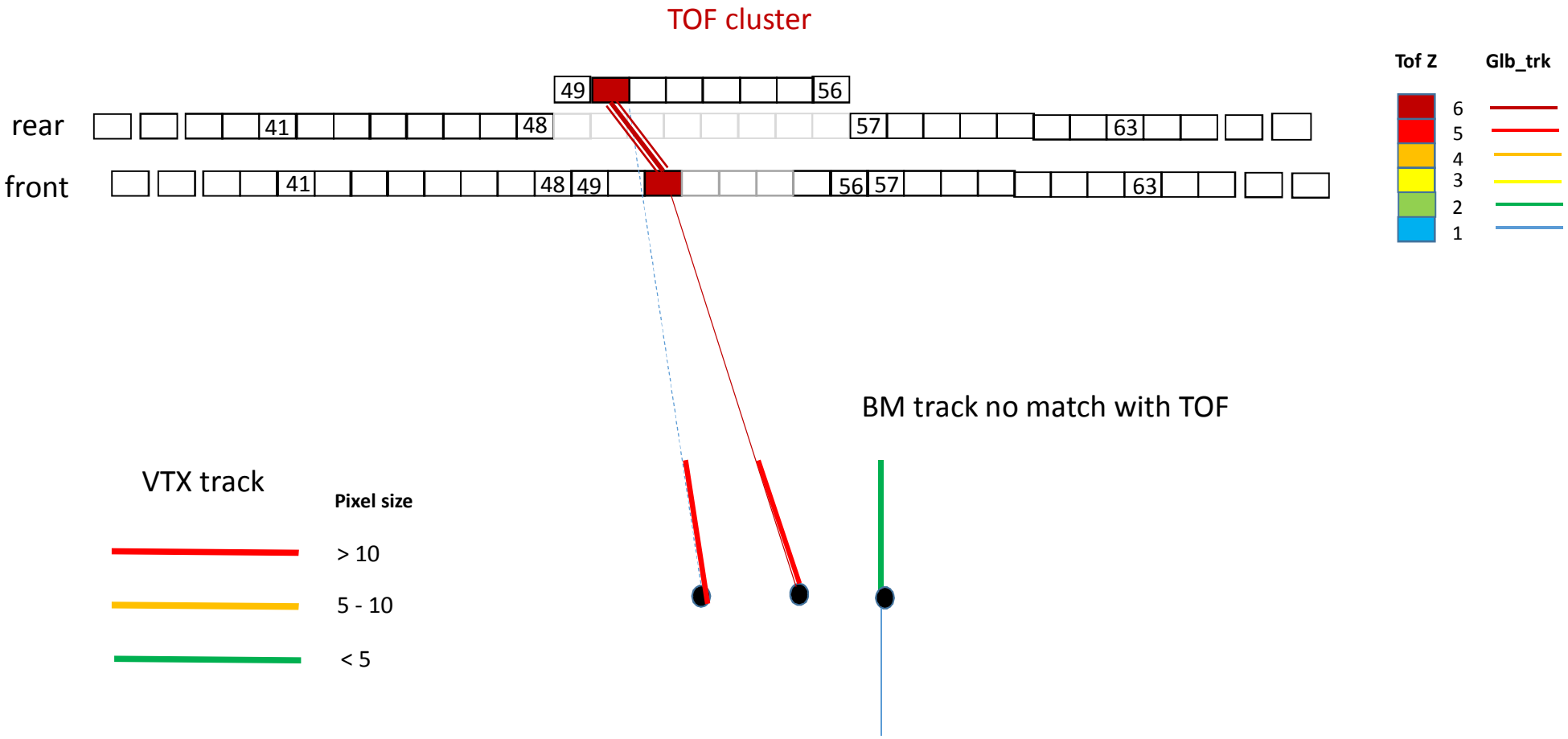
The charges of the 2 unmatched VTX tracks seem strange.
Here the track matches the BM ,but in case of ambiguity the VTX charge could help.

Case B2

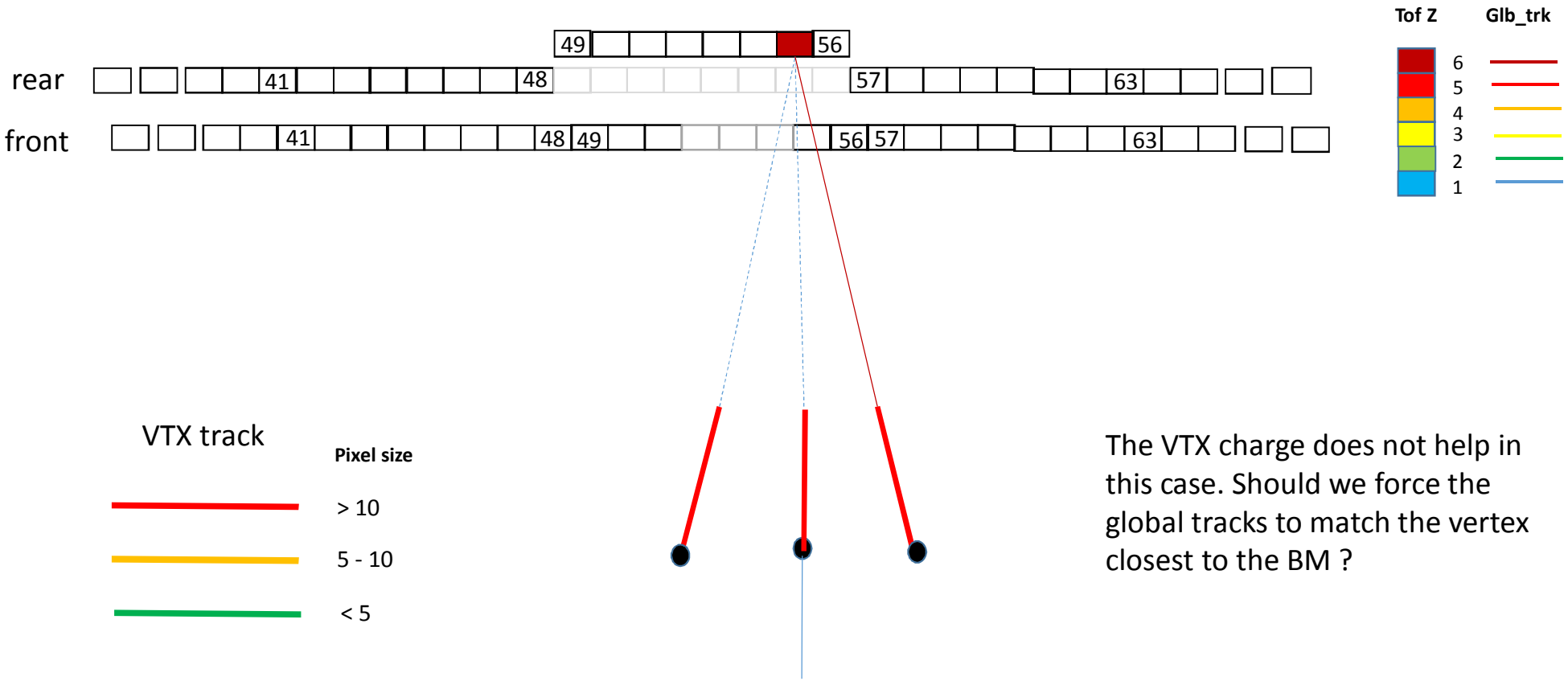


The global track matches the vertex not associated to the BM track.

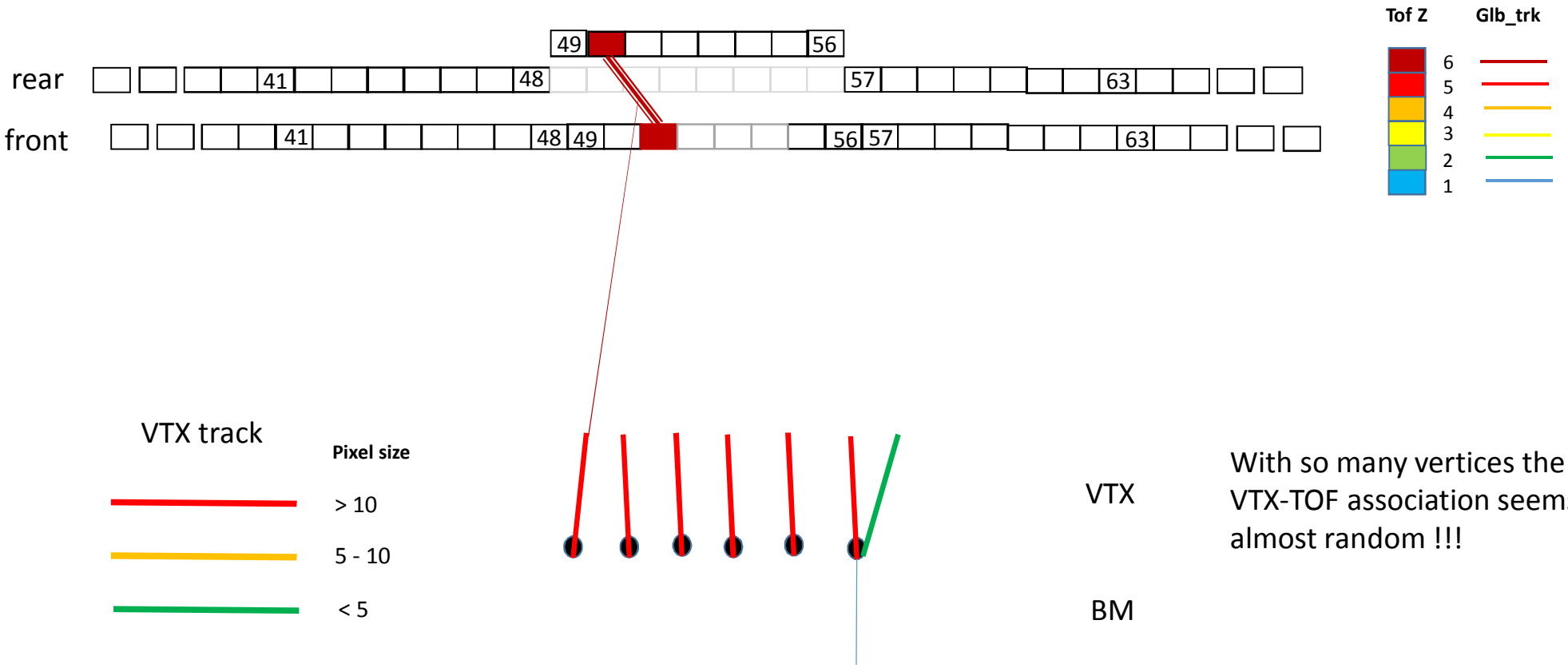
2 TOF hits carbon – > 1 VTX vertex – 1 VTX track for each vertex (match no BM track)



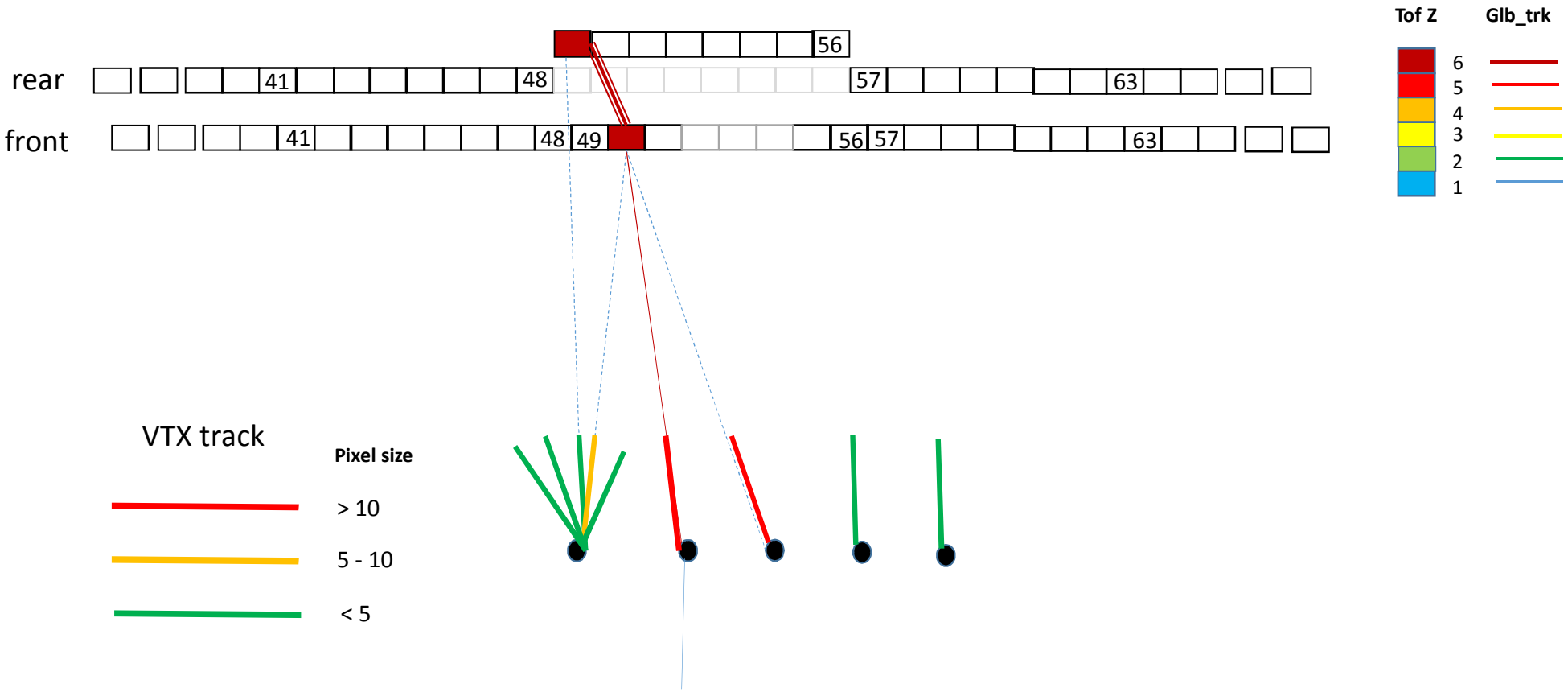
1 TOF hits carbon – > 1 VTX vertex – 1 VTX track for each vertex (match no BM track)



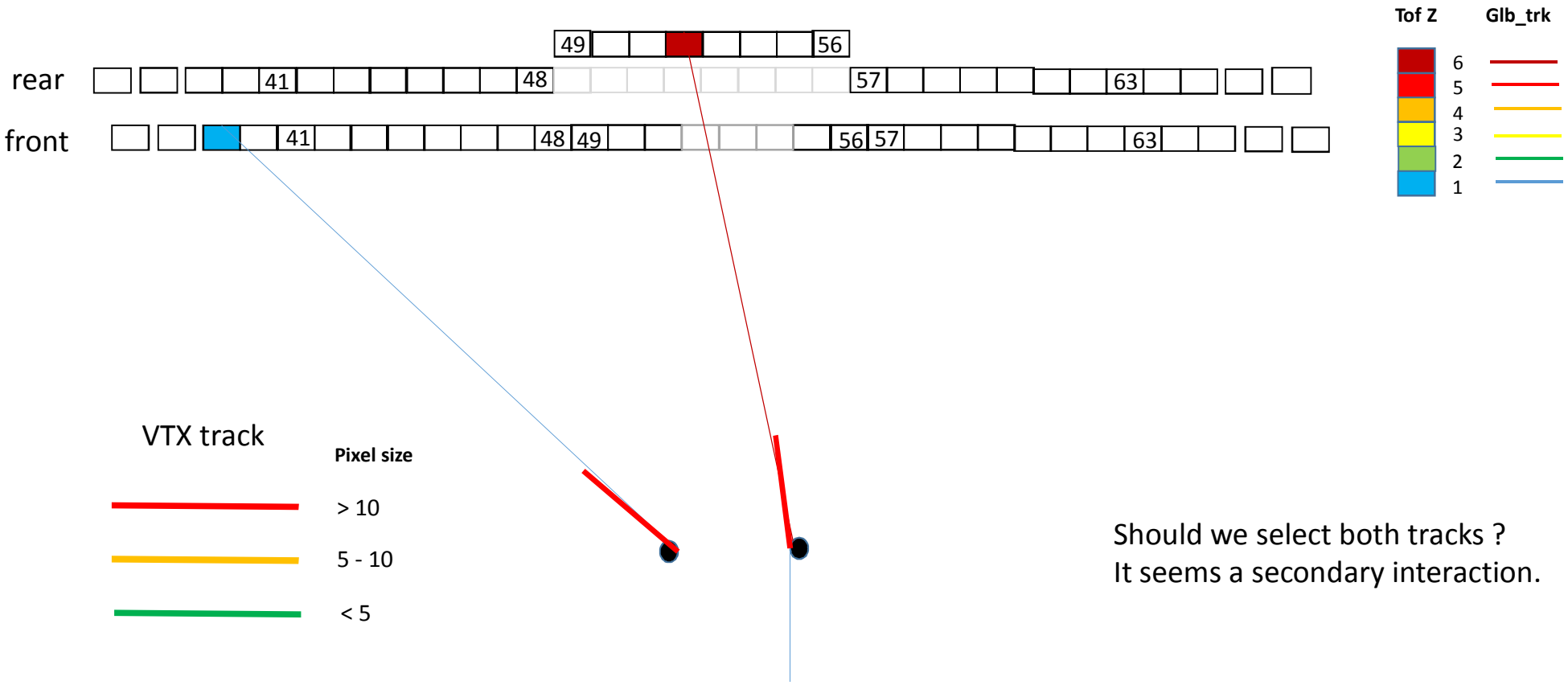
The VTX charge does not help in this case. Should we force the global tracks to match the vertex closest to the BM ?



With so many vertices the VTX-TOF association seems almost random !!!

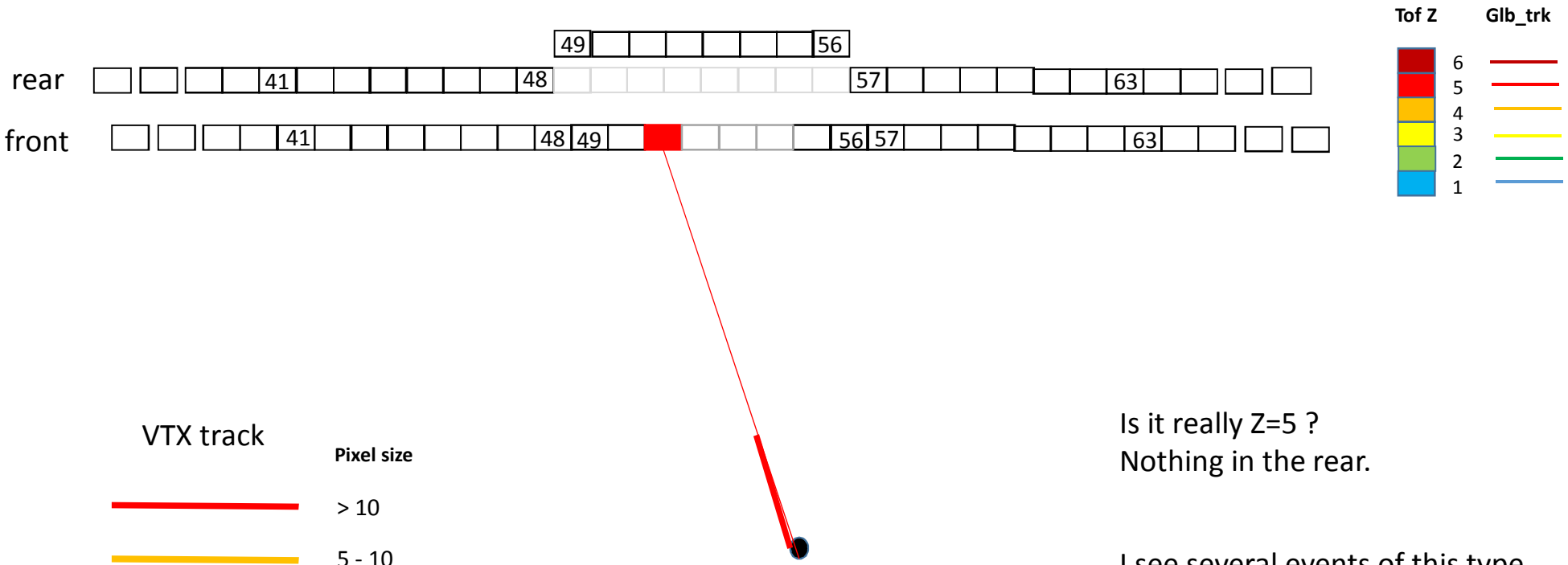

rear
front
41
48
56
57
63
49
Tof Z
Glb_trk
6
5
4
3
2
1
VTX track
Pixel size
> 10
5 - 10
< 5

Case F1



Should we select both tracks ?
It seems a secondary interaction.

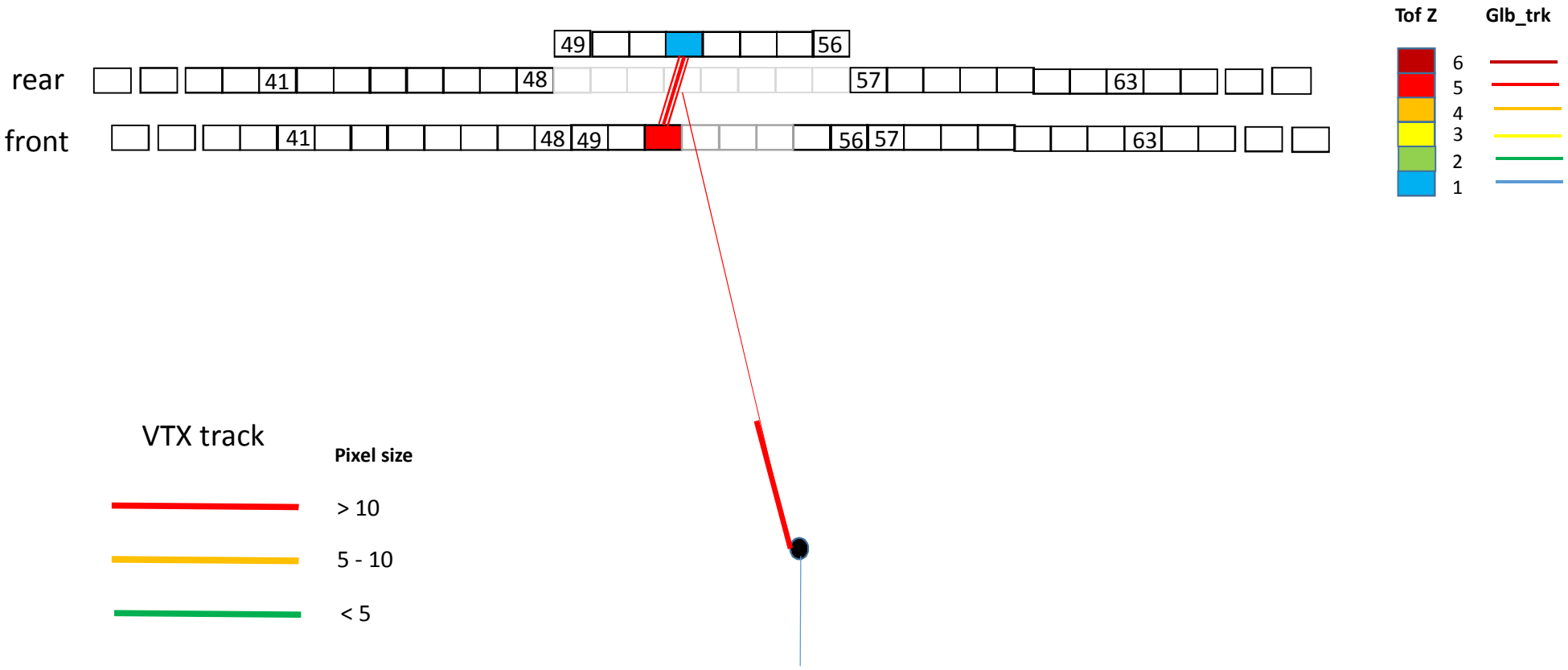
Events with charge < 6 and no apparent fragmentation
in the TOF or in the VTX
(charge wrongly assigned ?)

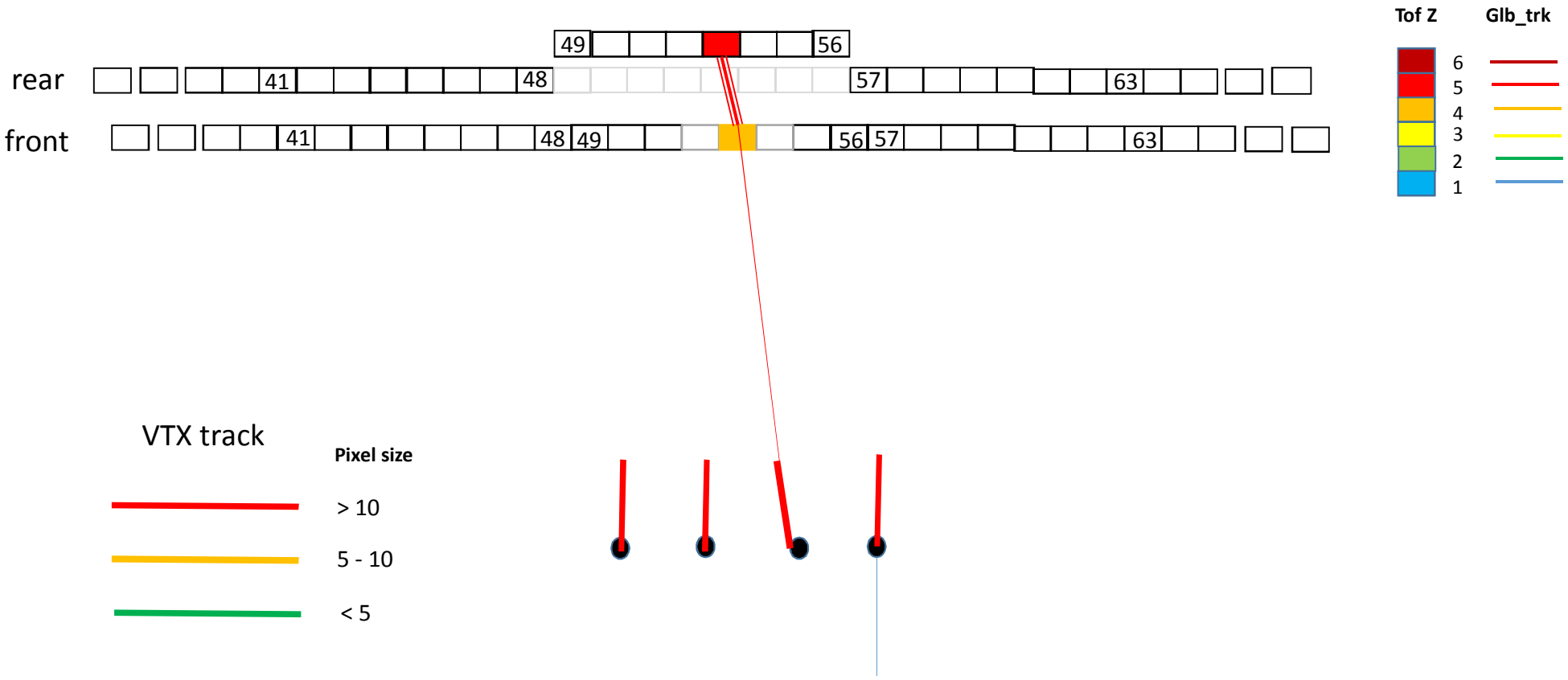


Is it really Z=5 ?
Nothing in the rear.

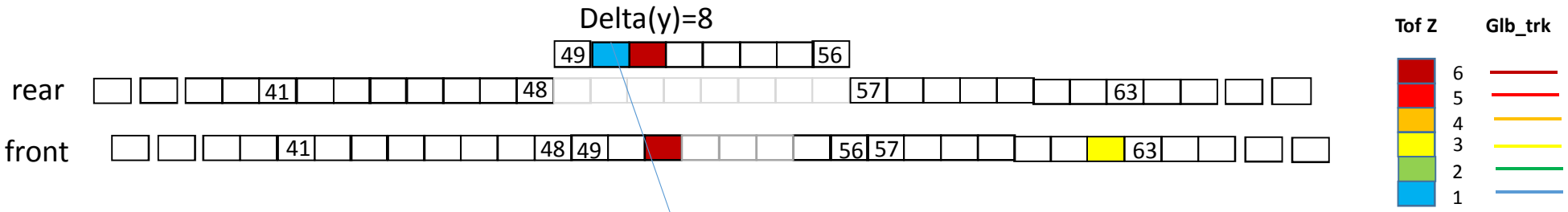
I see several events of this type
(4 with Z=5, 2 with Z=3)

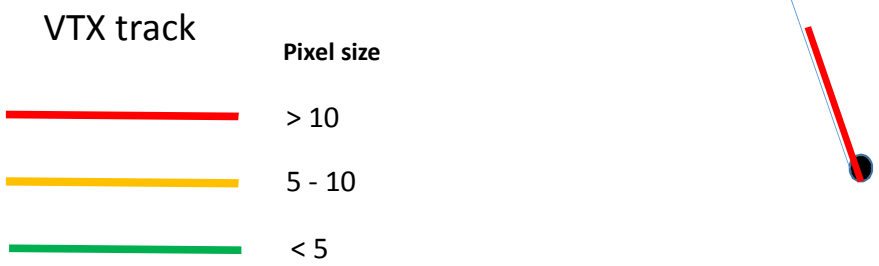
Case D3


rear
front
49
56
41
48
57
63
41
48
49
56
57
63
Tof Z
Glb_trk
6
5
4
3
2
1
VTX track
Pixel size
> 10
5 - 10
< 5


rear
front
49
56
41
48
57
63
Tof Z
Glb_trk
6
5
4
3
2
1
VTX track
Pixel size
> 10
5 - 10
< 5

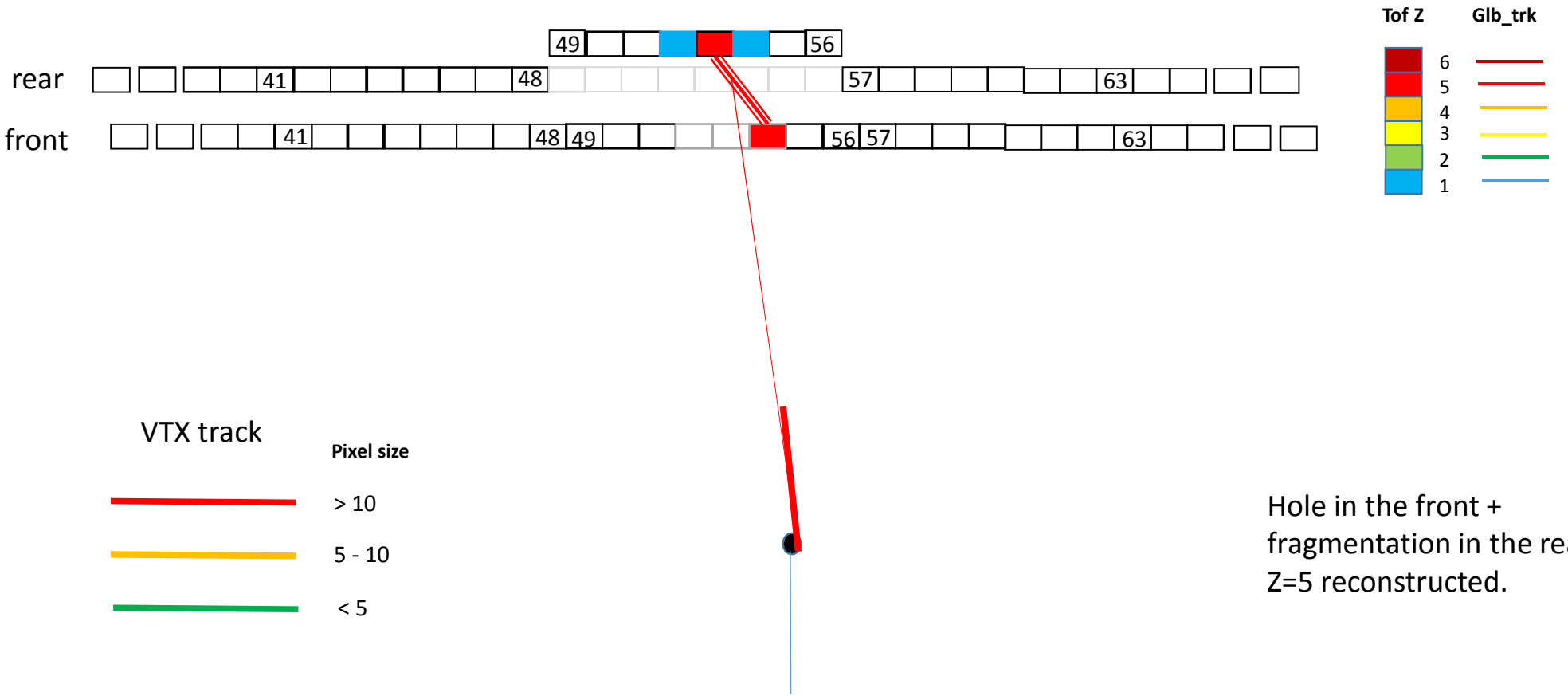
Caso F3)





The minimum Delta(y) is found
with slat 151 (Z=1).
The front hit (51) is not associated to any global track (Delta(y) cut ?).
The track has charge 1 but is clearly a carbon.
Release Delta(y) cut in reconstruction ?
VTX charge useful.

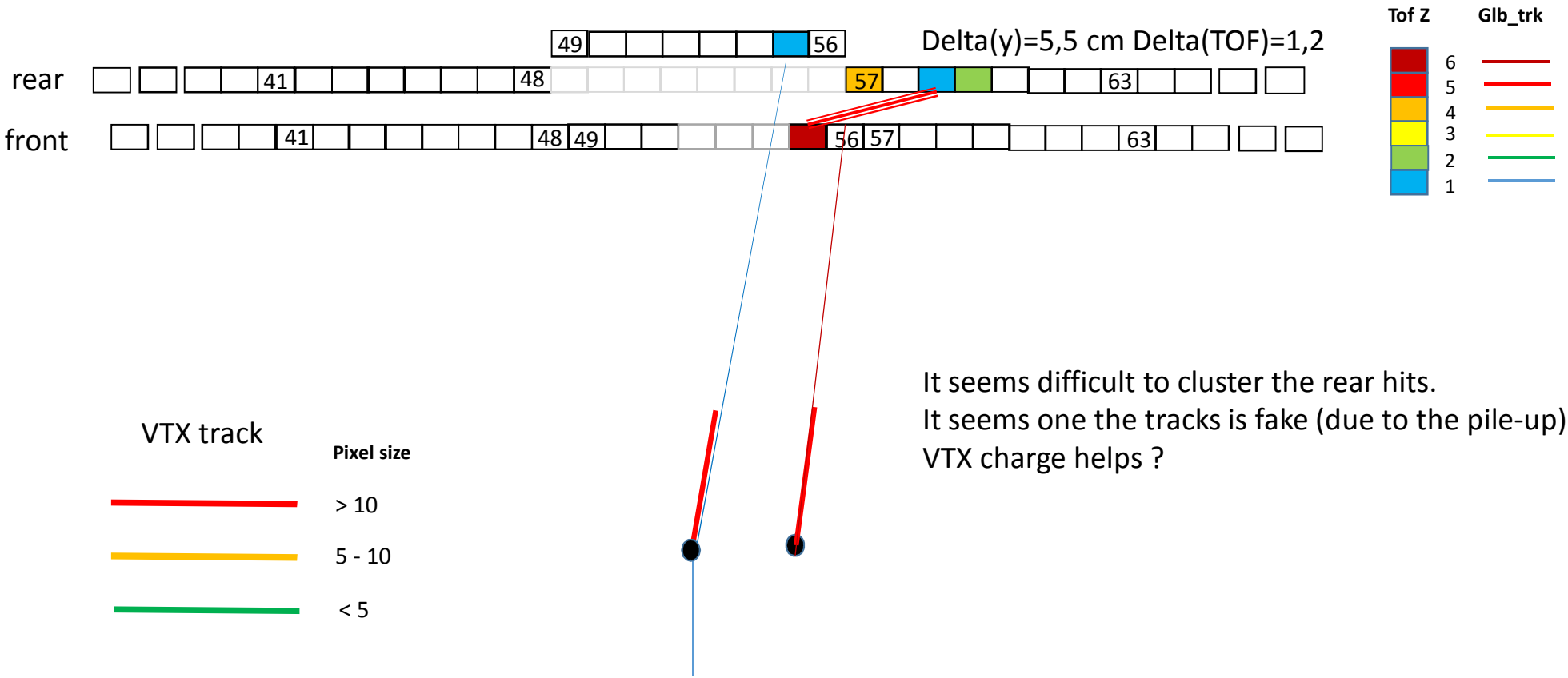
Caso C1



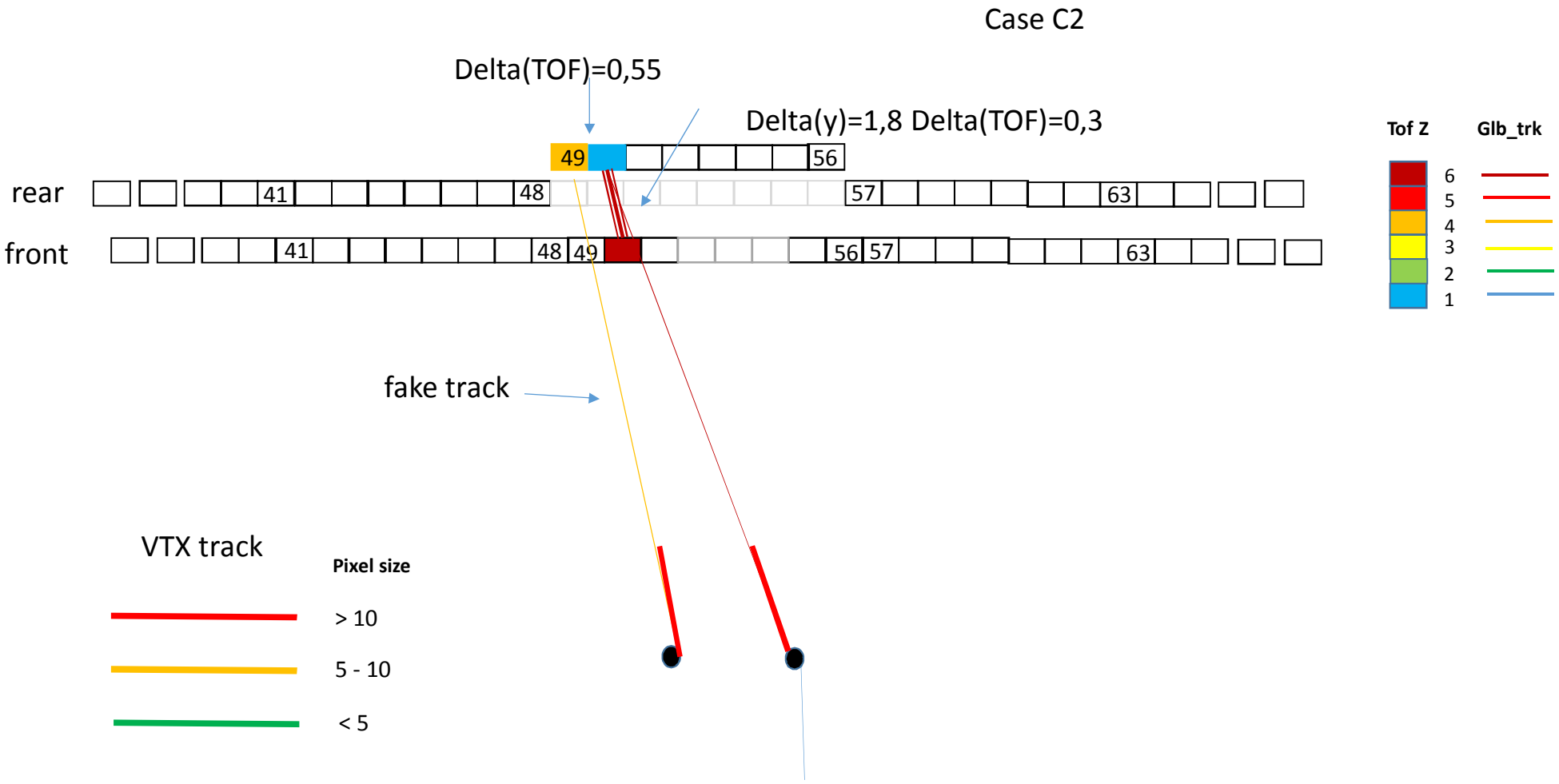
Hole in the front + fragmentation in the rear. Z=5 reconstructed.

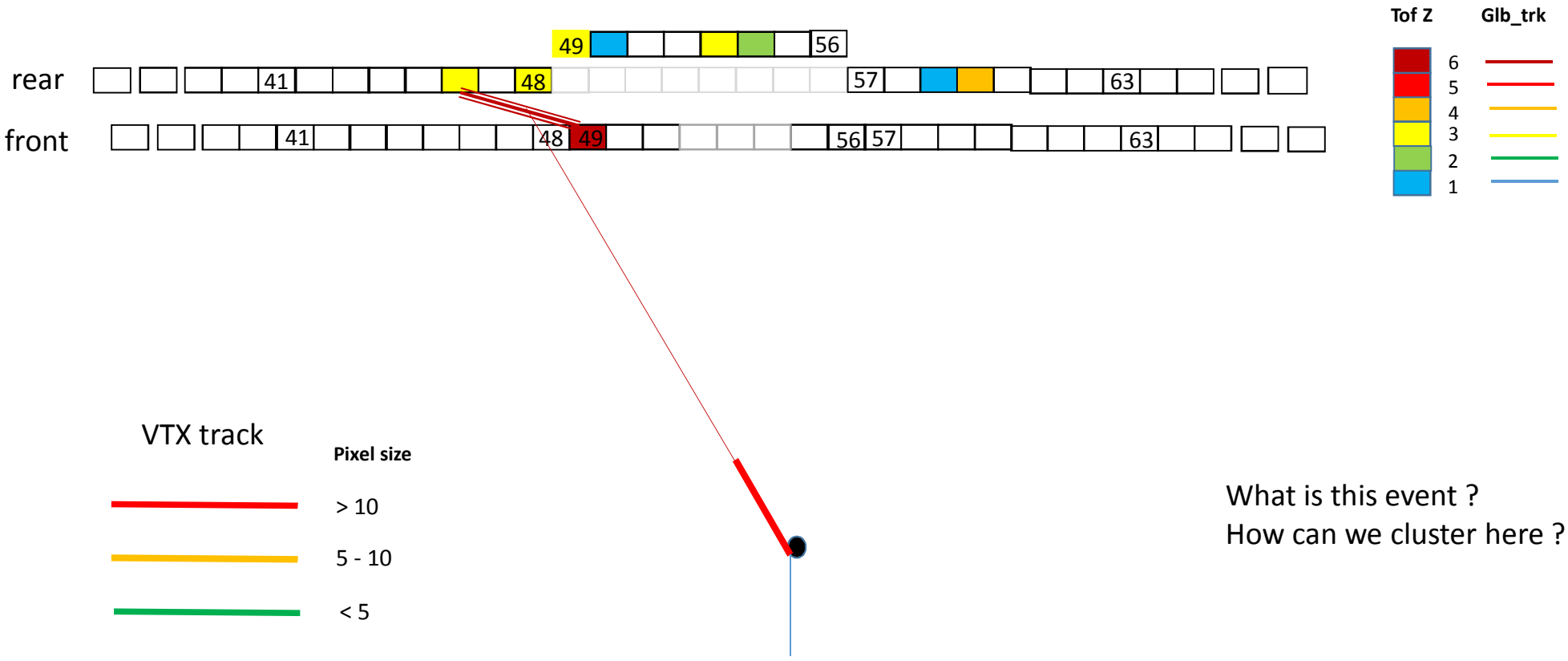
Fragmentation between front and rear wall

TOF multiple hits (fragmentation in the rear plane) - >1 vtx

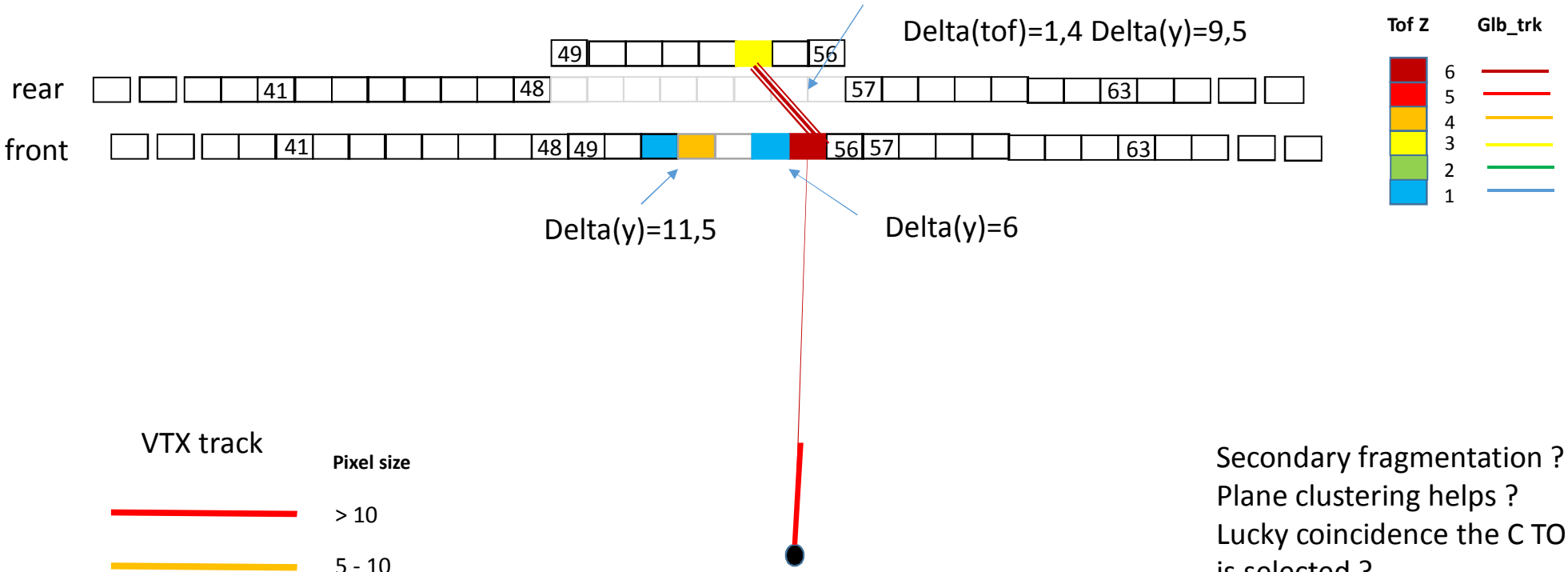


It seems difficult to cluster the rear hits.
It seems one the tracks is fake (due to the pile-up).
VTX charge helps ?

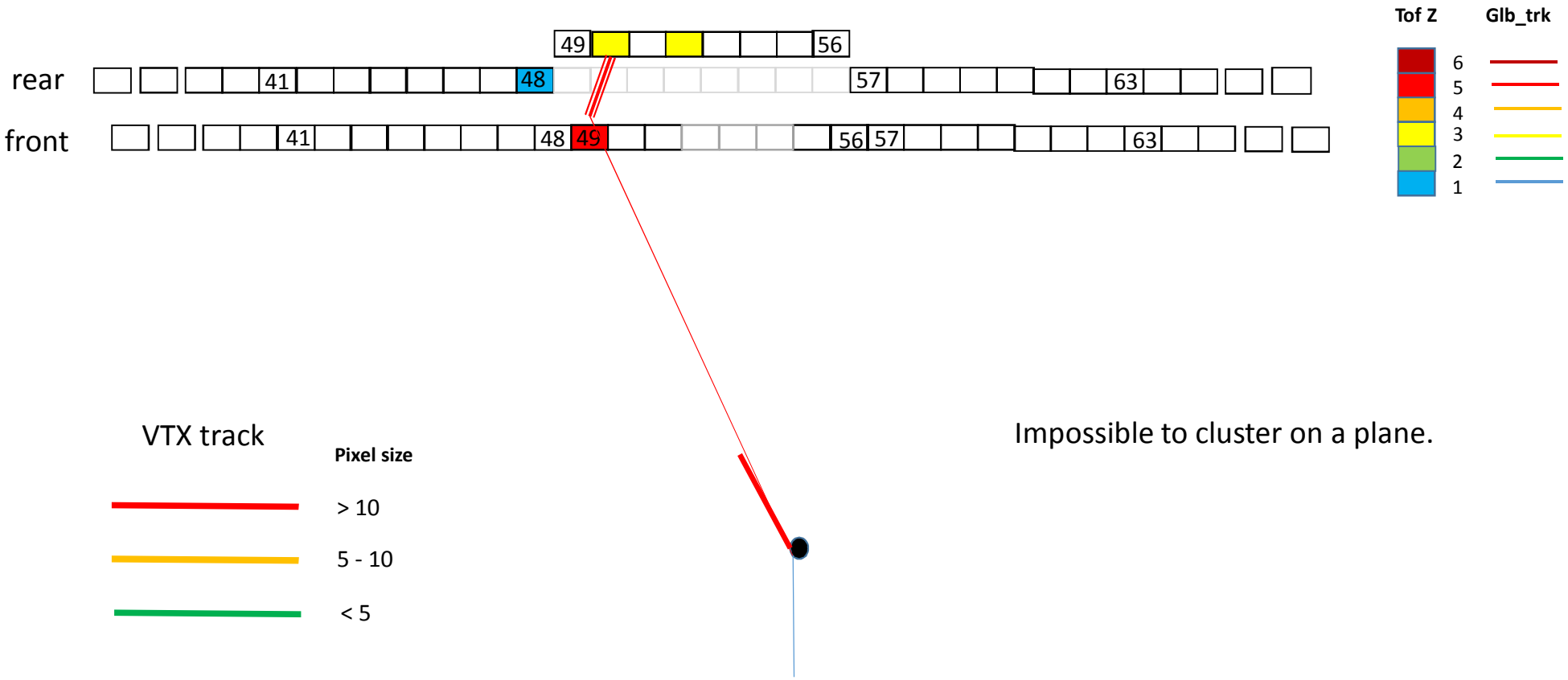

Case C2
Delta(TOF)=0,55
Delta(y)=1,8 Delta(TOF)=0,3
rear
front
49
56
41
48
57
63
fake track
Tof Z
Glb_trk
6
5
4
3
2
1
VTX track
Pixel size
> 10
5 - 10
< 5



What is this event ?
How can we cluster here ?

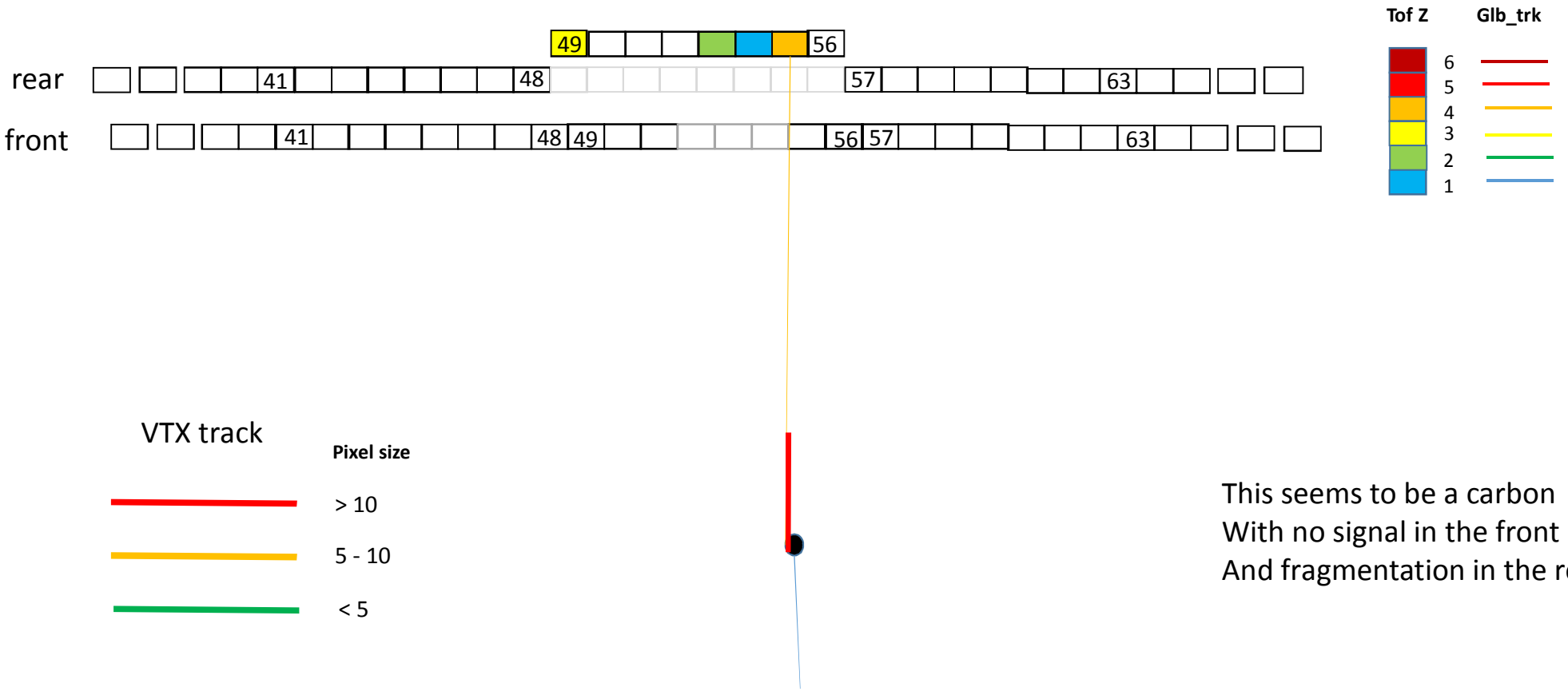


Secondary fragmentation ?
Plane clustering helps ?
Lucky coincidence the C TOF hit is selected ?



Impossible to cluster on a plane.

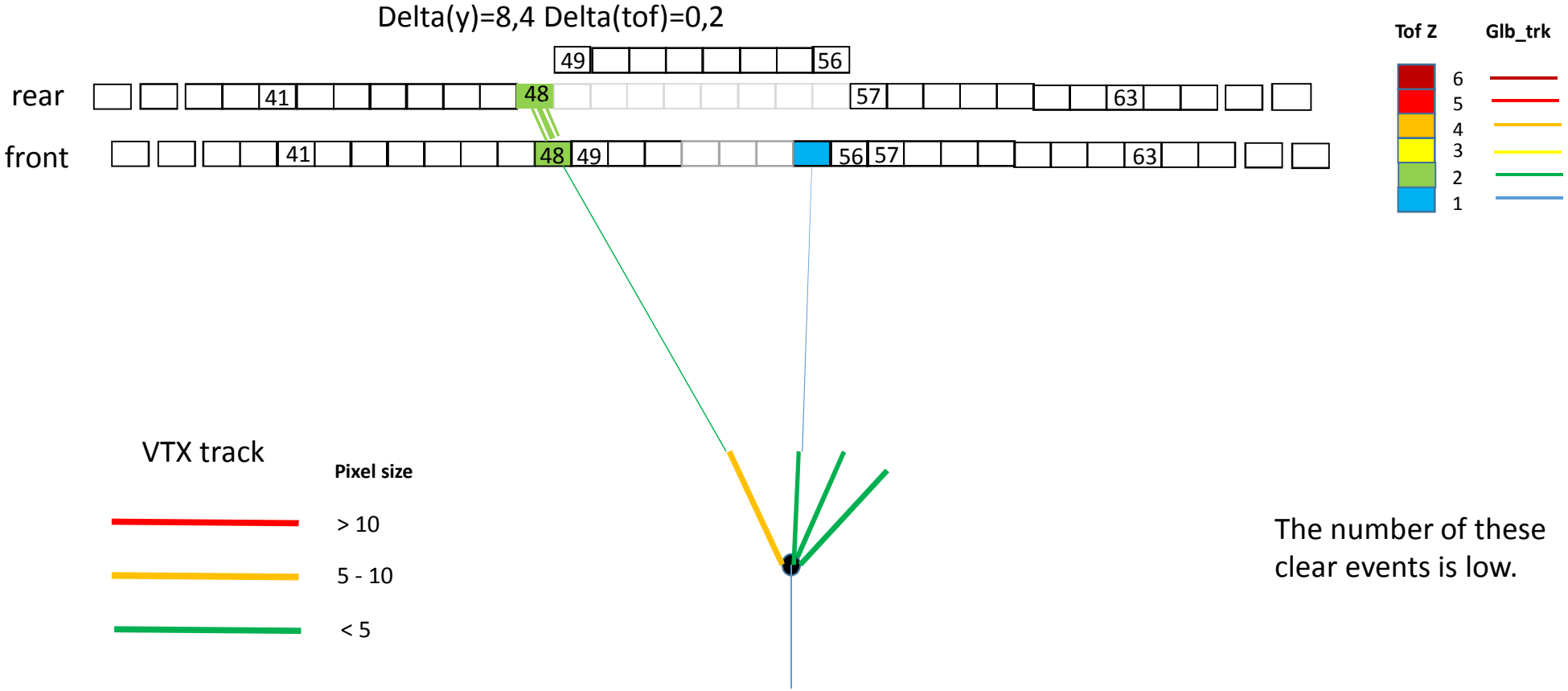
Case F3



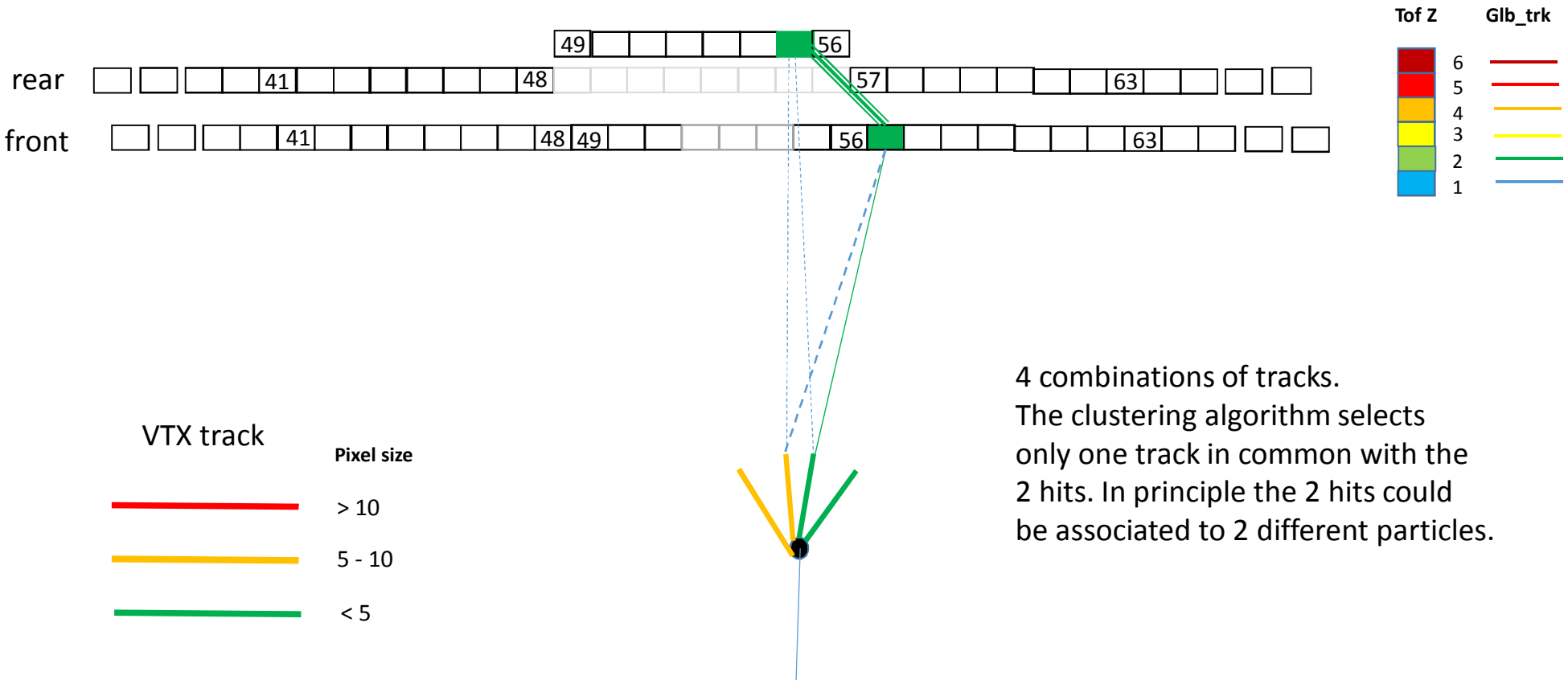
This seems to be a carbon
With no signal in the front
And fragmentation in the rear.

Fragmentation events

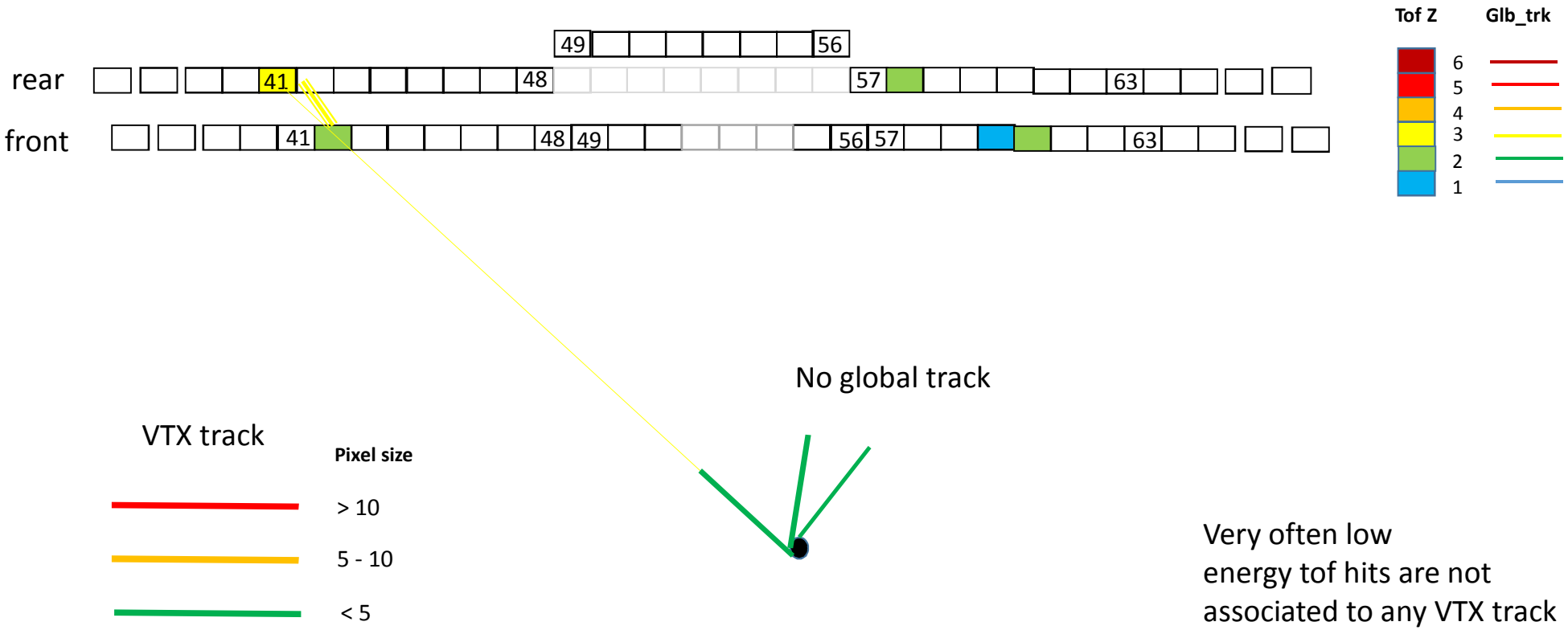
TOF fragmentation – 1 vtx (seems ok)



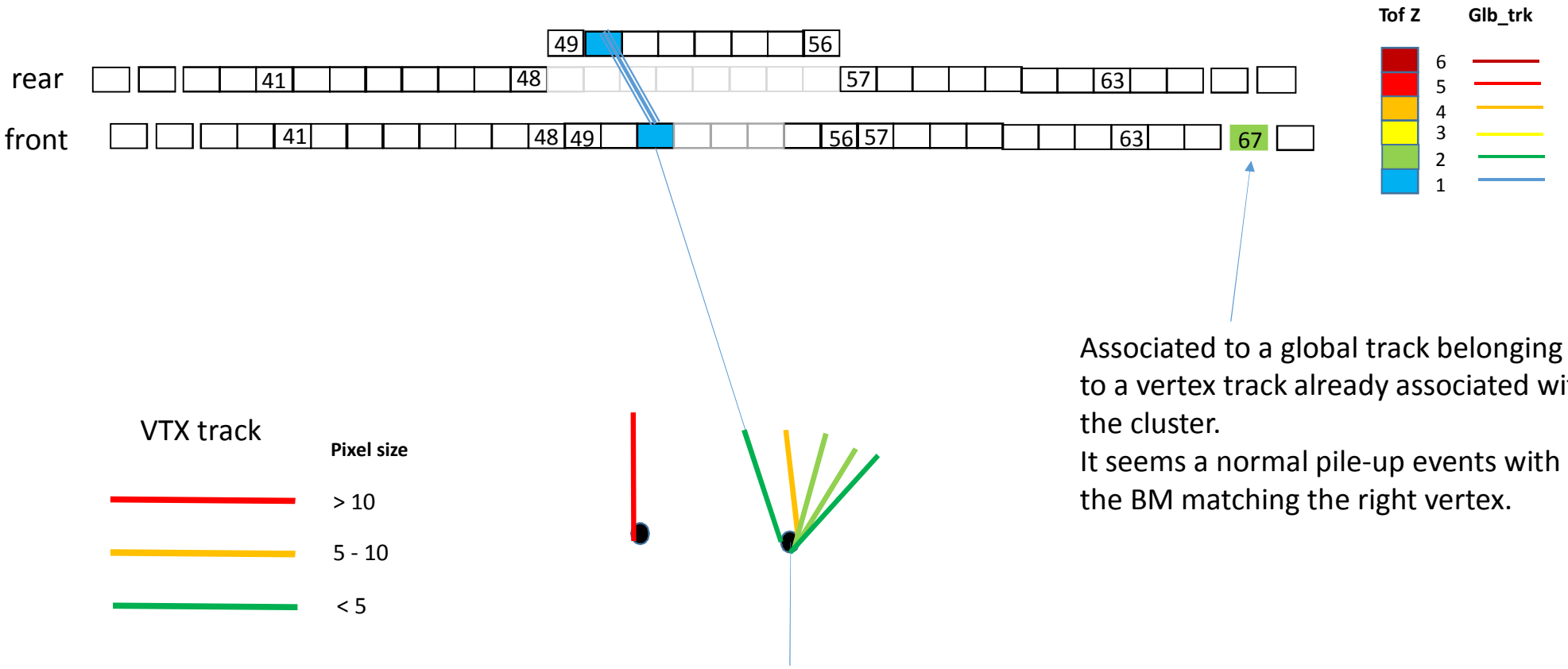
The number of these clear events is low.



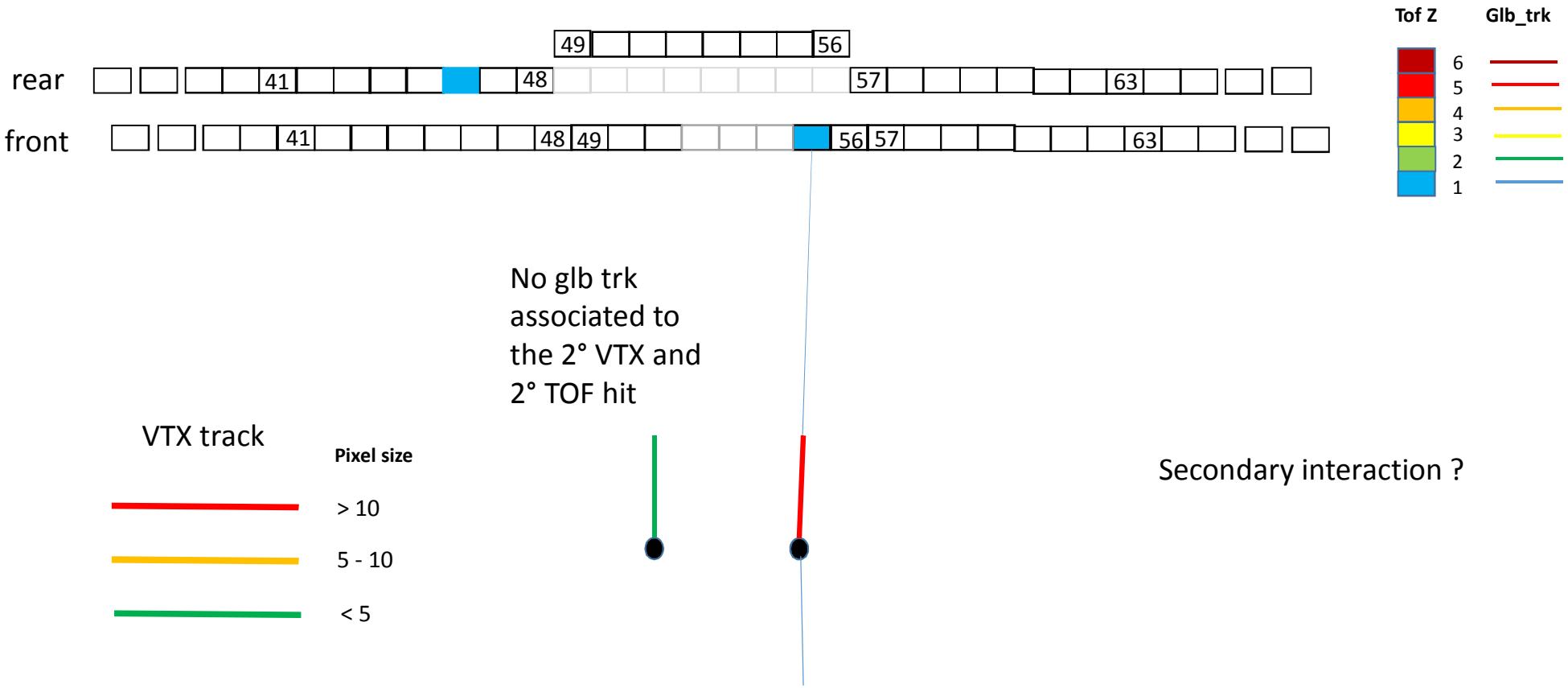
4 combinations of tracks.
The clustering algorithm selects only one track in common with the 2 hits. In principle the 2 hits could be associated to 2 different particles.



Very often low energy tof hits are not associated to any VTX track

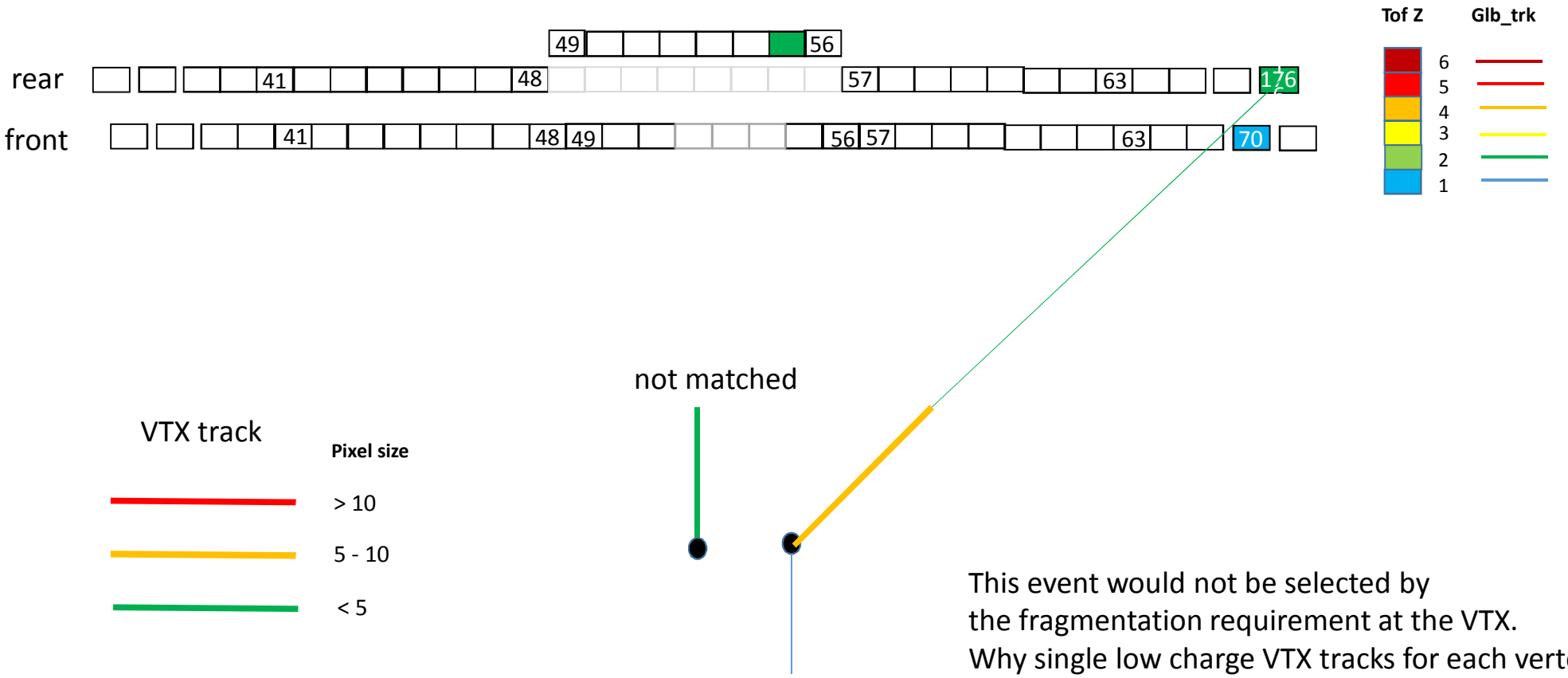


Associated to a global track belonging to a vertex track already associated with the cluster.
It seems a normal pile-up events with the BM matching the right vertex.


rear
front
49
56
41
48
57
63
Tof Z
Glb_trk
6
5
4
3
2
1
No glb trk associated to the 2° VTX and 2° TOF hit
VTX track
Pixel size
> 10
5 - 10
< 5
Secondary interaction ?

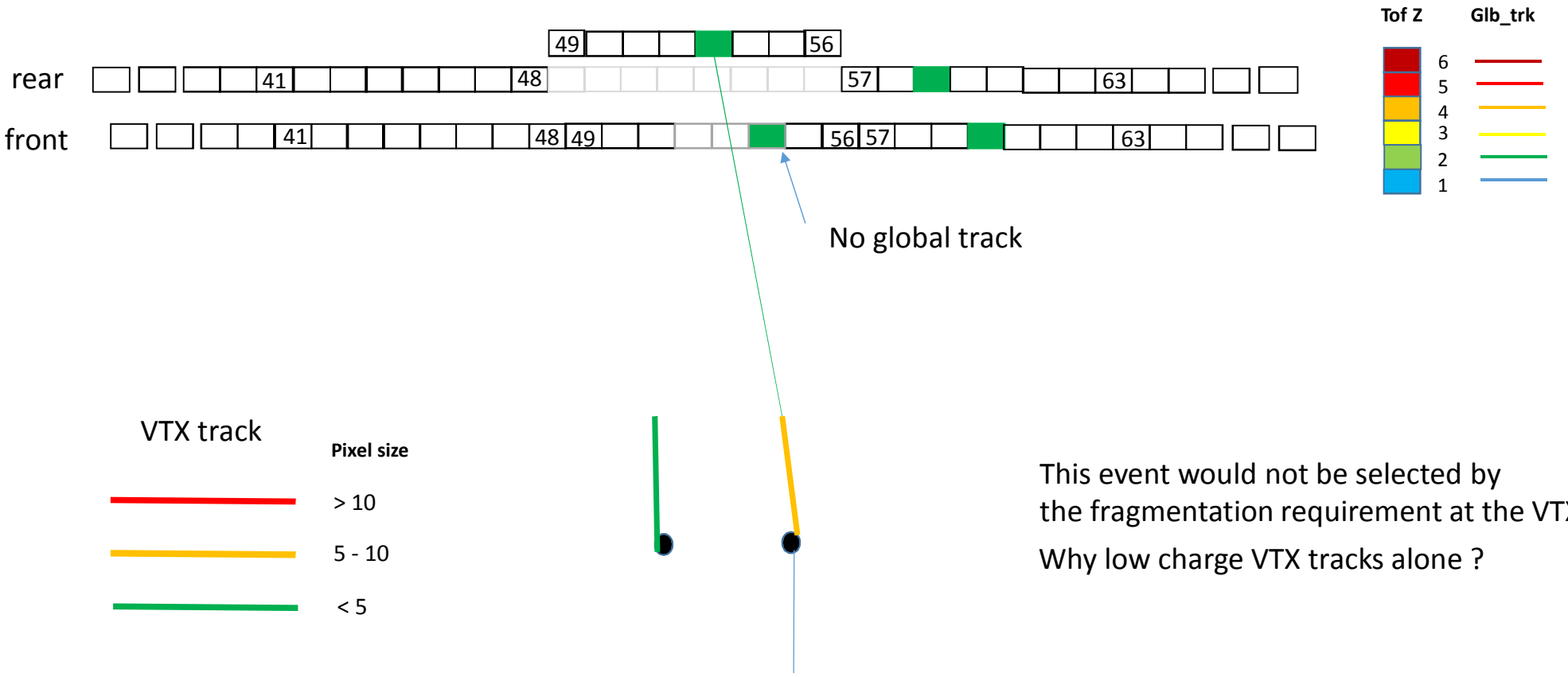
>1 TOF hits (fragm.) – >1 VTX vertex – 1 VTX track for each vertex (fragm)

Case F1



This event would not be selected by
the fragmentation requirement at the VTX.
Why single low charge VTX tracks for each vertex ?

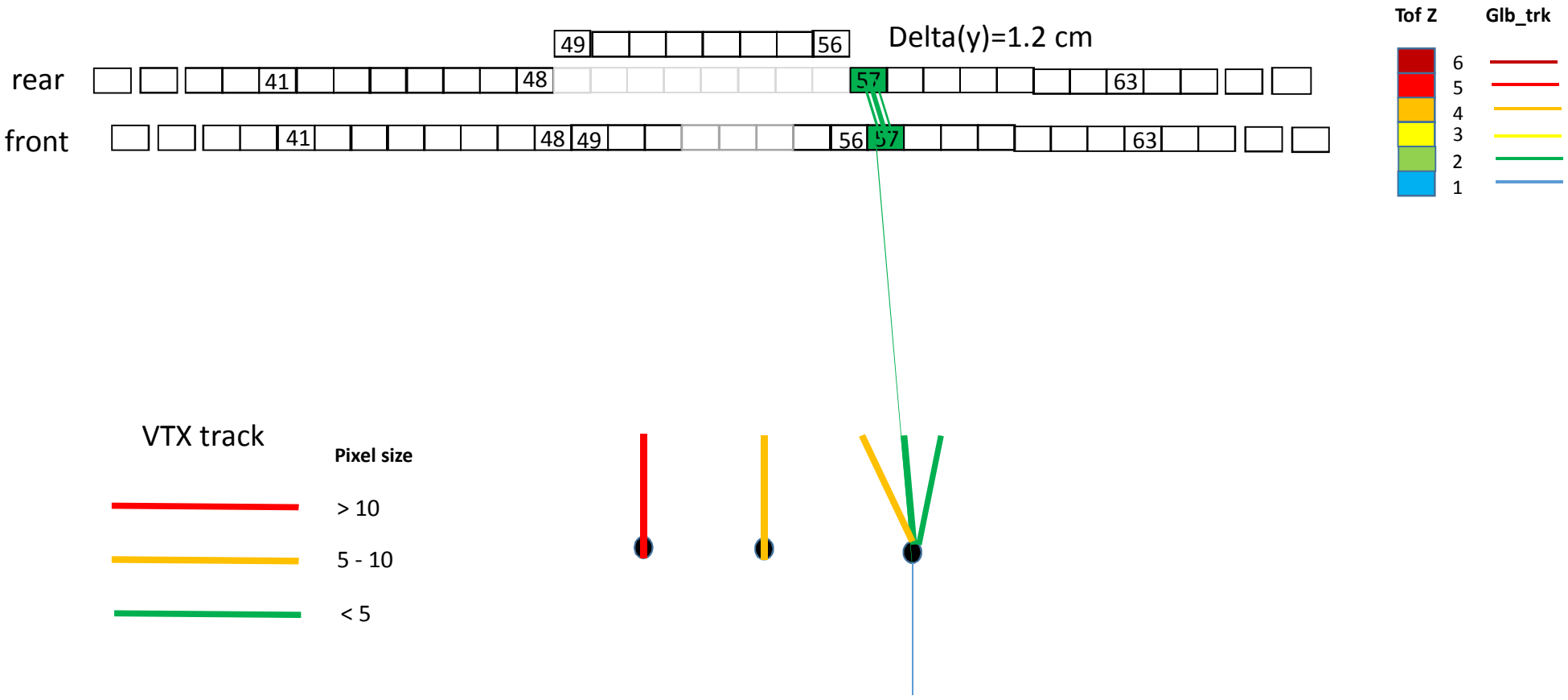
Case F1

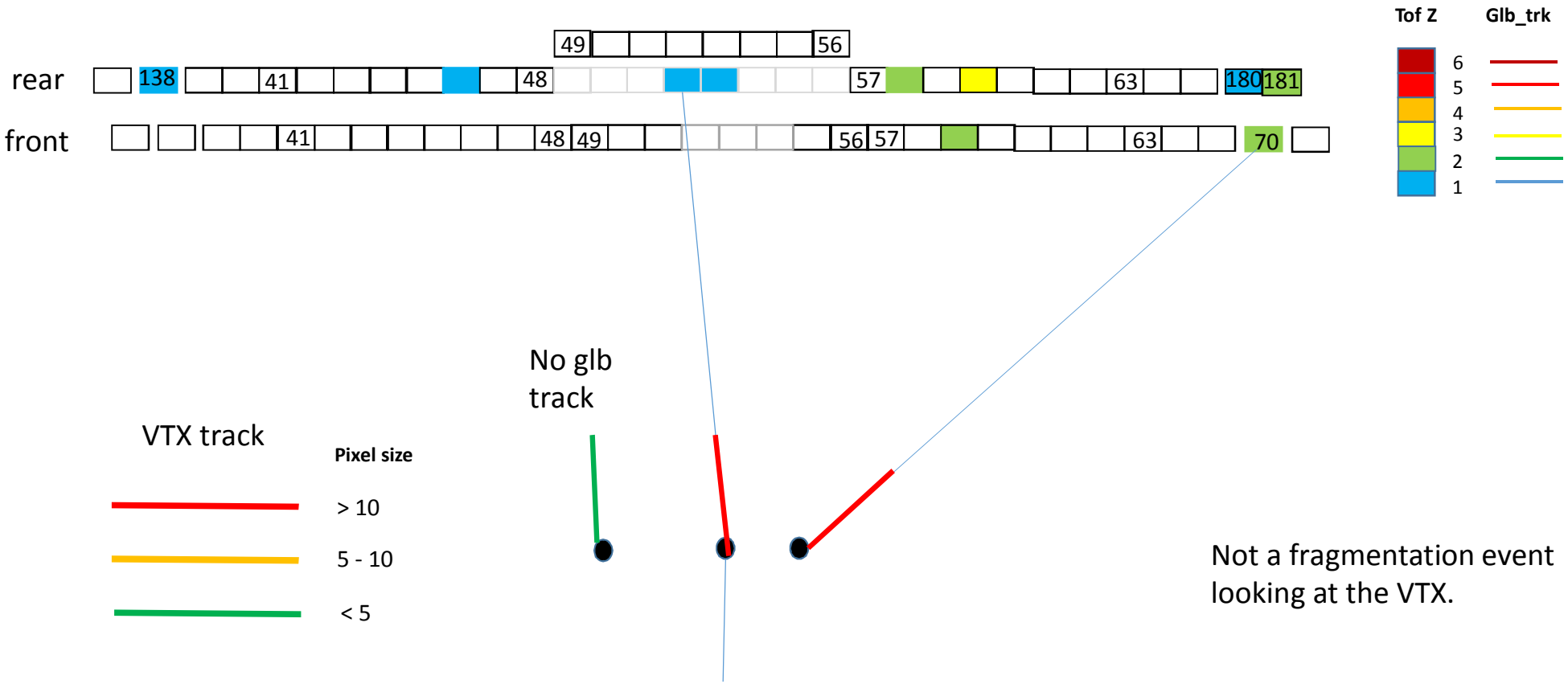


This event would not be selected by the fragmentation requirement at the VTX

Why low charge VTX tracks alone ?

TOF fragmentation – BM track fragmentation + pile-up





Not a fragmentation event looking at the VTX.

Event type	N. events	Comment
Carbons 1 vertex – 1 track reconstructed as Carbon	107	OK
Carbon >1 vertex – 1 track Reconstructed as Carbon	51	Clearly carbons, but 50% associated to the vertex not matching the BM
Carbon not reconstructed as carbons	12	
Fragmentation events with 1 vtx – 1 track	7	Some could be worngly reconstructed carbons or secondary interactions
Fragmentation events With >1 vtx but 1 trk/vtx	7	These events can not be selected as VTX-fragm.
Fragmentation events >=1 vtx > 1 track (OK)	5	OK
No global tracks/no TOF hits/no BM track	28	

I have the impression that about 50% of fragmentation events are not selected by requiring >1 track from the vertex matching the BM.

Conclusions

TOF Front/Rear clustering algorithms implemented. It reduces the reconstruction ambiguities and improve the purity of the selected fragments.
A major improvement expected using the cluster size from the VTX for the TOF/VTX matching.

Artefacts in TOF reconstruction around the central slats give problem to identify correctly fragments at low angles. Even if the probability to reconstruct a Carbon with lower charge is not so high, the high number of Carbons produce a high contamination in the selected samples. It seems the MC does not reproduce well the TOF wall behavior for Carbons in this central region.

The reconstruction algorithm needs to be improved to take into account the pile-up (tracks not associated to the BM should not be considered in the reconstruction code ?).
A simulation of pile-up events is necessary to understand the behaviour of the vertexing algorithms.