Hit sharing studies in multi-track CRAFT data

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The 2_2_5-reprocessed CRAFT sample

- Compare with the plots of the talk I gave on Jan 23rd and Mar 6th:
  - http://indico.cern.ch/getFile.py/access?contribId=2&resId=1&materialId=slides&confId=50704
  - http://indico.cern.ch/getFile.py/access?contribId=5&resId=0&materialId=slides&confId=54035

- /Cosmics/Commissioning08_CRAFT_ALL_V9_**225**-v2/RECO
  - CRAFT at B = 3.8 T
  - runs n.

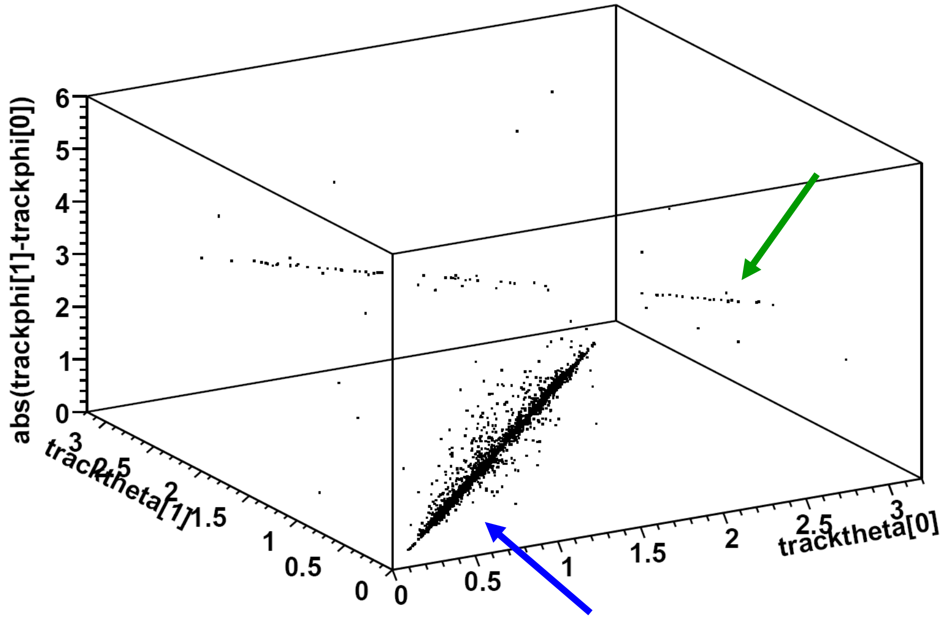
    69892,69874,69850,69800,69797,69788,69750,69564,69557,69522

- Now I've run with CMSSW_**2_2_6**

- Reconstruction performed with CTF (ctfWithMaterialTracksP5)

Why hit sharing studies?

Δφ vs (θ_1, θ_0) (2-track events)



While studying ***2-track events***, I found strong theta, phi and IP correlations between the two tracks:

either $\begin{cases} \theta_1 = \theta_0 \\ \varphi_1 = \varphi_0 \\ dxy_1 = dxy_0 \end{cases}$

or $\begin{cases} \theta_1 = \pi - \theta_0 \\ |\Delta\varphi| = \pi \\ dxy_1 = - dxy_0 \end{cases}$

Track quality cuts applied:

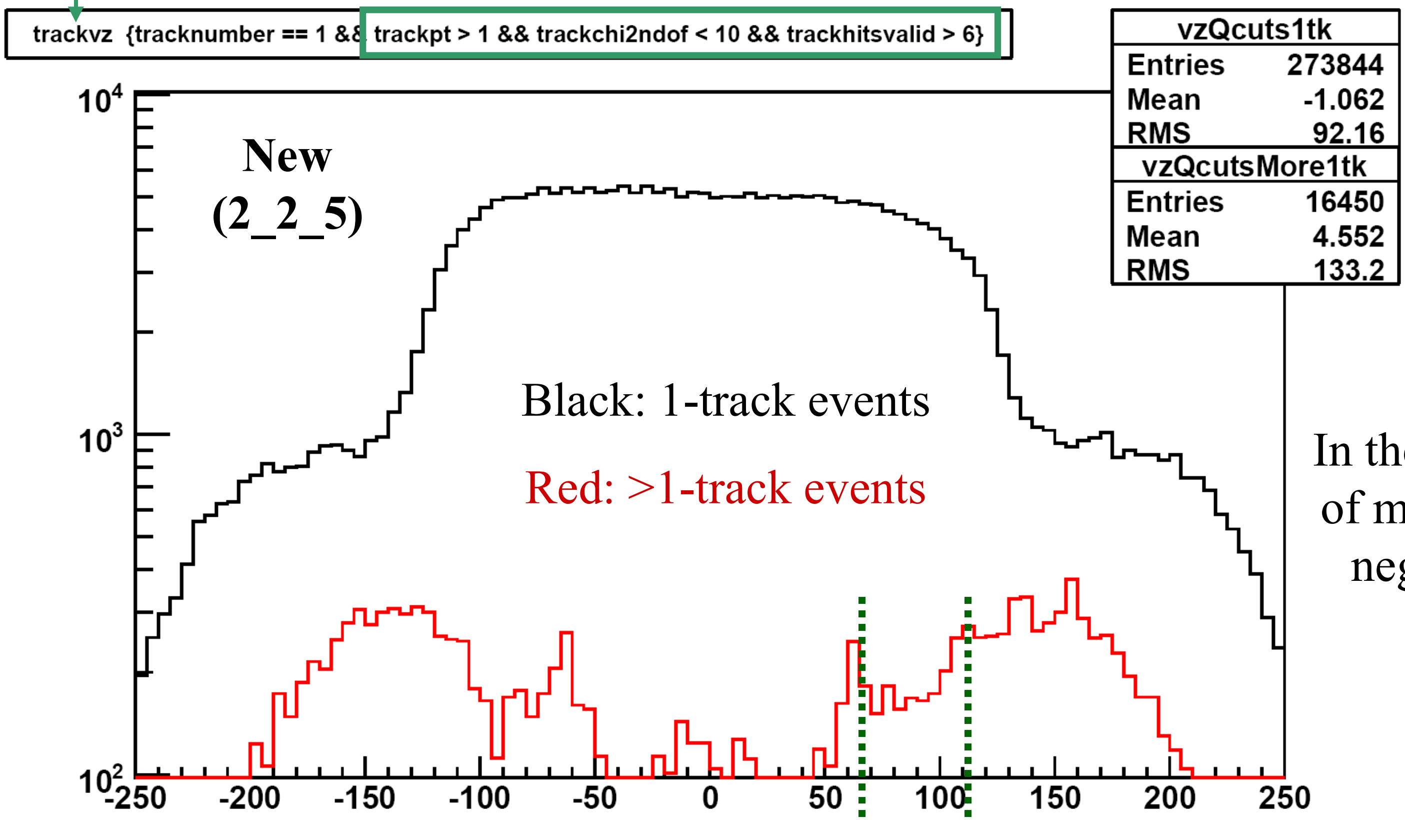
$\begin{cases} (\chi^2/ndof)_{0,1} < 10 \\ p_{T\,0,1} > 1\ GeV \\ N_{hits\ 0,1} > 6 \end{cases}$

One of the possible explanations took into account the eventual presence of '***split tracks***'.

I started to look at some of these events with IGUANA and to analyze them at RecHit level.

v_z distribution

z-coordinate of the PCA of tracks



trackvz {tracknumber == 1 && trackpt > 1 && trackchi2ndof < 10 && trackhitsvalid > 6}

vzQcuts1tk	
Entries	273844
Mean	-1.062
RMS	92.16

vzQcutsMore1tk	
Entries	16450
Mean	4.552
RMS	133.2

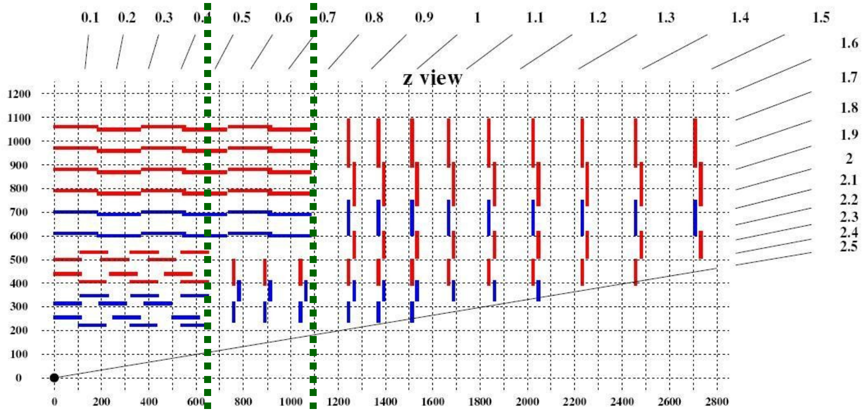
New (2_2_5)

Black: 1-track events

Red: >1-track events

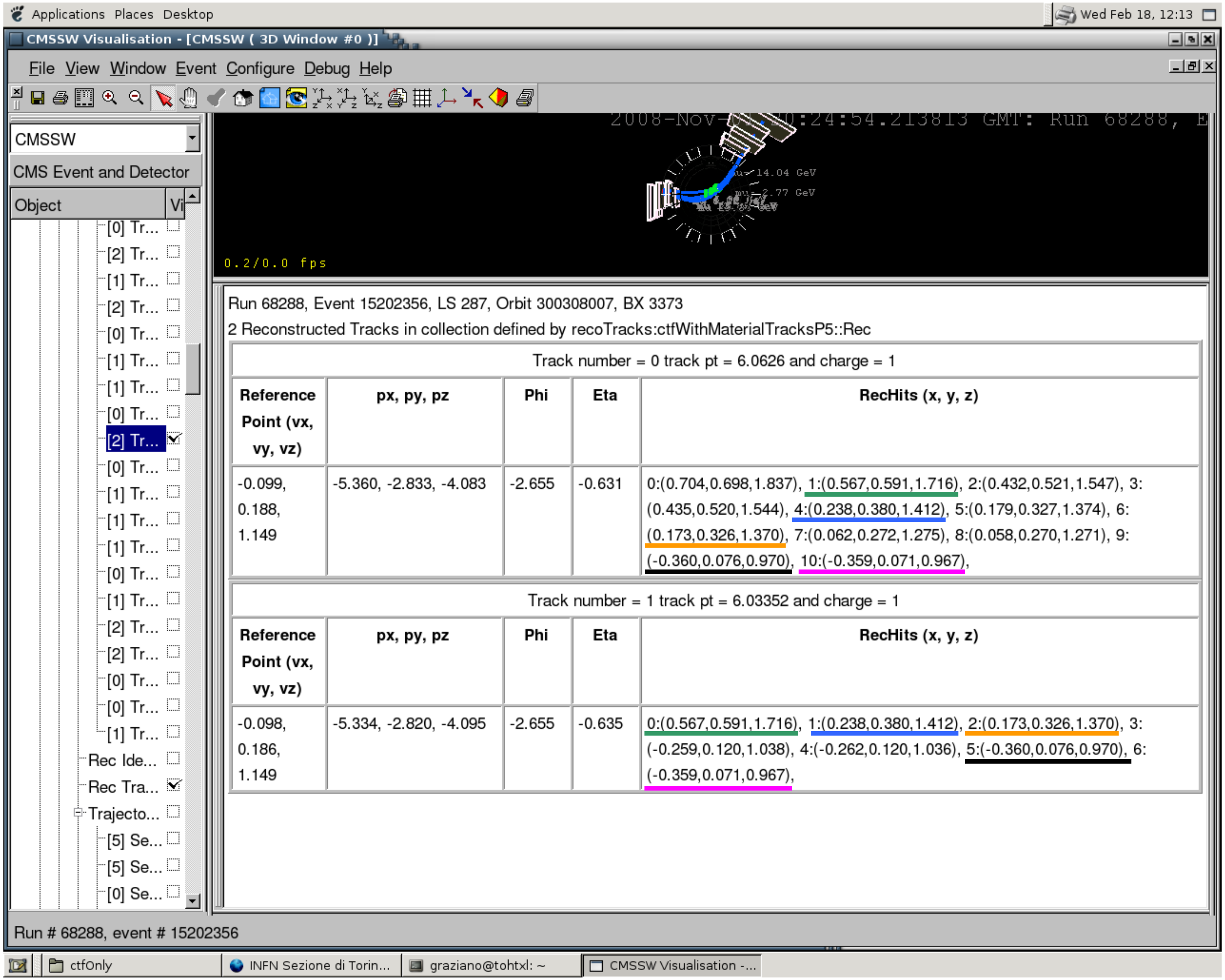
The presence of multi-track events is more frequent in TEC than in the barrel

In these regions the number of multi-track events is not negligible (~10% of the single-track ones)



Run **68288,**

event **15202356**



Run 68288, Event 15202356, LS 287, Orbit 300308007, BX 3373

2 Reconstructed Tracks in collection defined by recoTracks:ctfWithMaterialTracksP5::Rec

Track number = 0 track pt = 6.0626 and charge = 1

Reference Point (vx, vy, vz)	px, py, pz	Phi	Eta	RecHits (x, y, z)
-0.099, 0.188, 1.149	-5.360, -2.833, -4.083	-2.655	-0.631	0:(0.704,0.698,1.837), 1:(0.567,0.591,1.716), 2:(0.432,0.521,1.547), 3:(0.435,0.520,1.544), 4:(0.238,0.380,1.412), 5:(0.179,0.327,1.374), 6:(0.173,0.326,1.370), 7:(0.062,0.272,1.275), 8:(0.058,0.270,1.271), 9:(-0.360,0.076,0.970), 10:(-0.359,0.071,0.967),

Track number = 1 track pt = 6.03352 and charge = 1

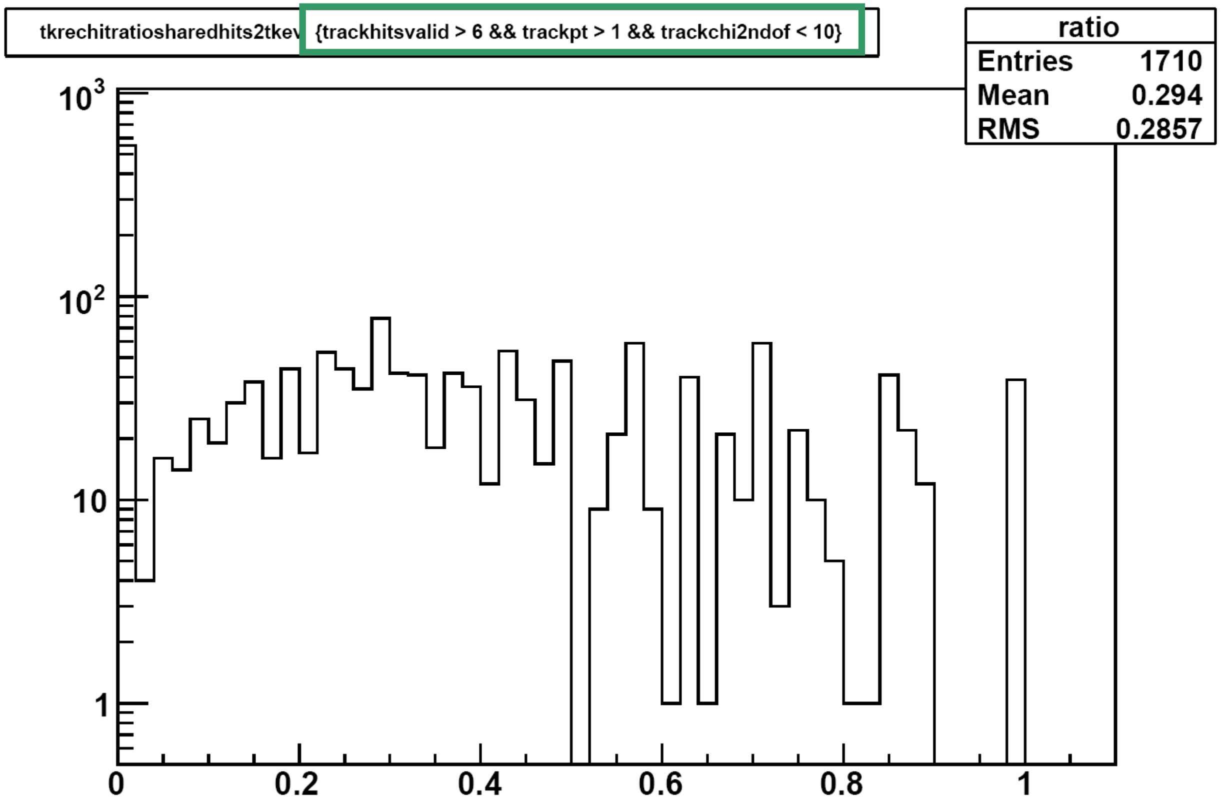
Reference Point (vx, vy, vz)	px, py, pz	Phi	Eta	RecHits (x, y, z)
-0.098, 0.186, 1.149	-5.334, -2.820, -4.095	-2.655	-0.635	0:(0.567,0.591,1.716), 1:(0.238,0.380,1.412), 2:(0.173,0.326,1.370), 3:(-0.259,0.120,1.038), 4:(-0.262,0.120,1.036), 5:(-0.360,0.076,0.970), 6:(-0.359,0.071,0.967),

Only ***ctfWithMaterialTracksP5*** tracks considered.

Rather than ‘split’ tracks, it seems that ‘**overlapping**’ tracks are there

The two tracks **share many RecHits**

Fraction of shared hits (2-track events)



In 2-track events, a new variable can be defined for each track:

$$\frac{\#(\text{hits shared by both tracks})}{\#(\text{hits of each track})}$$

SiStripRecHit2D hits are counted;
events in which tracks have pixel hits are not considered

Warning: both tracks of the event are plotted (→ same numerator: a correlation is introduced)

Hit sharing occurs very often!
(in more than half of the events)

What’s new?

- The TrajectoryCleaning code applies a check on the number of shared hits:

  nShared(1,2) > min(nHits1, nHits2) * fraction ?

  where fraction = **0.5**

  (see TrackingTools/TrajectoryCleaning/src/TrajectoryCleanerBySharedHits.cc)

- If the answer is yes, only one track is kept out of two:
  - the one with more hits
  - if nHits1 = nHits2, the one with smaller chi2

- This means that we shouldn’t see any track with a ratio

$$\frac{\#(\text{hits shared})}{\#(\text{track hits})} > 0.5$$

…but we do…

⇩

Is there a **bug** in the TrajectoryCleaning code?

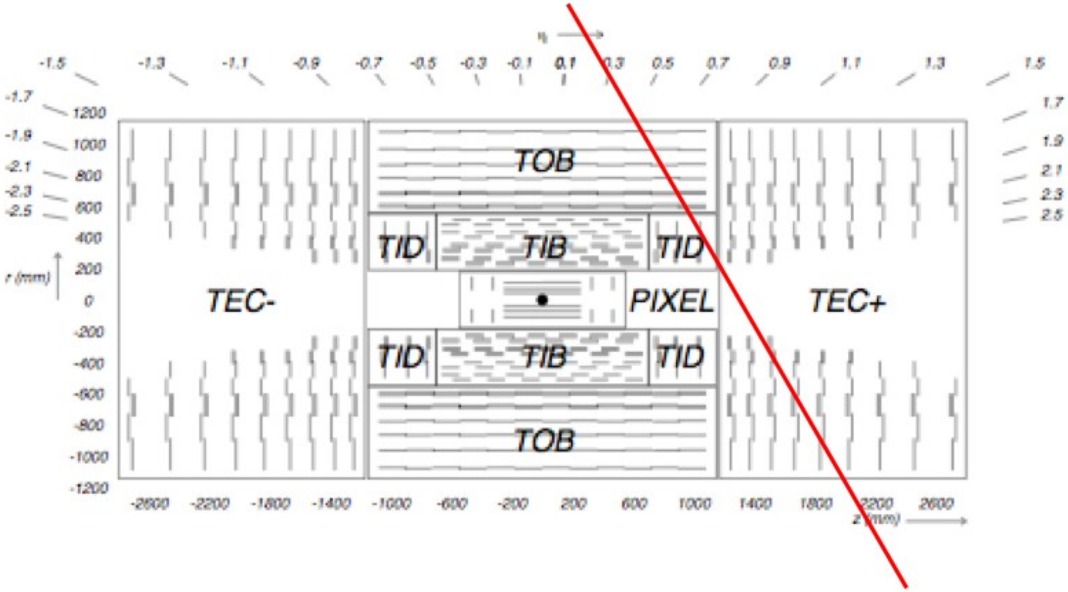
Kevin’s and Boris’ suggestions (1)

- Consider the SiStripMatchedRecHit2D hits
  - they are extrapolated from an rphi and a stereo RecHits
  - with CTF, at the end of the TrajectoryCleaning, they’re split into the two single hits which they come from
- The TrajectoryCleaning code performs the check on shared hits **before** splitting the matched rechits…
  - it counts both mono and matched hits
- … whereas I was looping over the final RecHits, i.e. **after** that splitting
  - both the number of track hits and that of shared ones have changed

I’ve repeated my analysis with matched hit splitting **turned off**

Kevin’s and Boris’ suggestions (2)

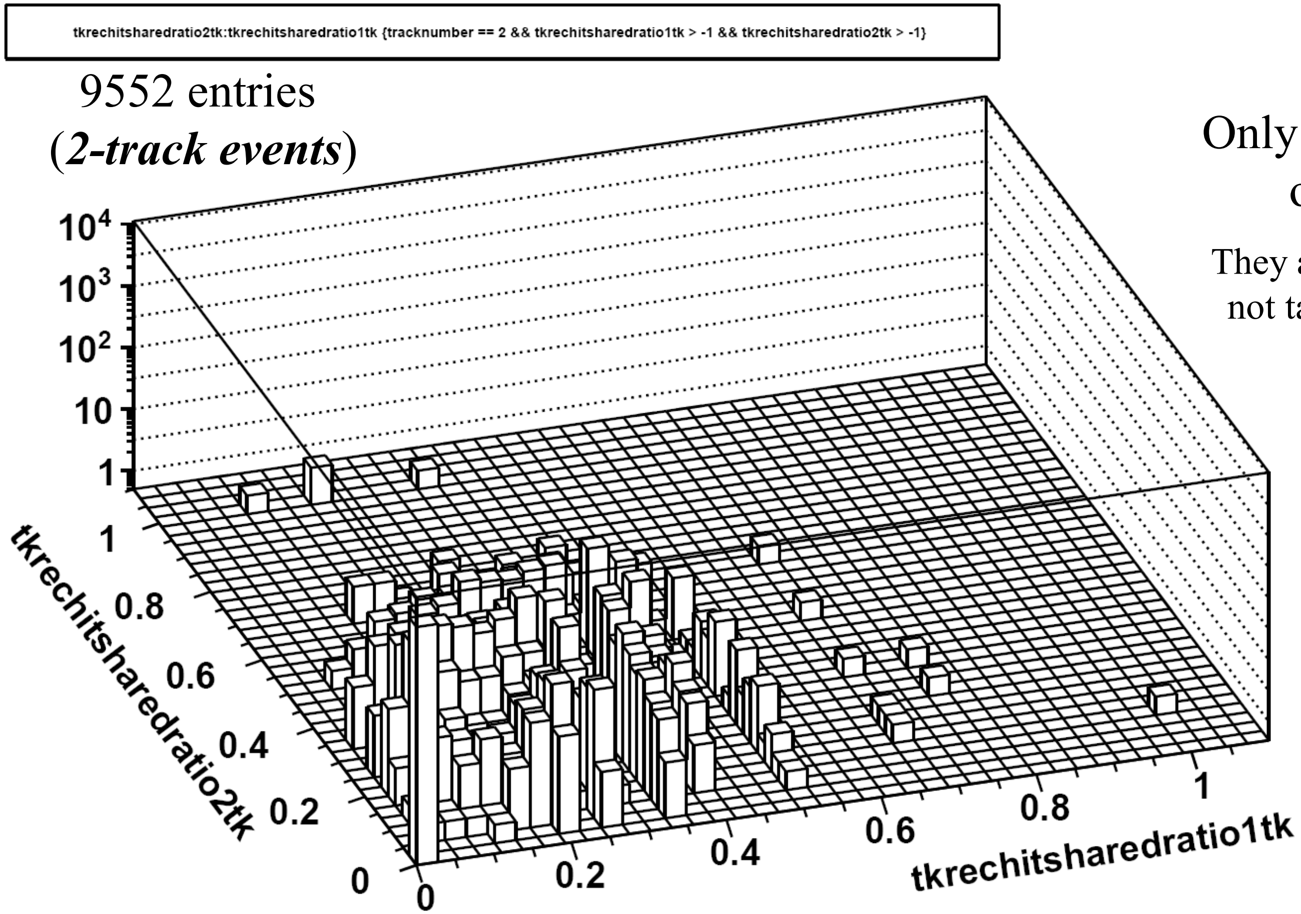
- In addition, Boris has provided me with a slightly modified version of RecoTracker/TkDetLayers/src/ForwardDiskSectorBuilderFromWedges.cc
- A fix to the following issue is tried: (I quote Boris’ explanation)
  - “As you can see, for some combination of eta and z, cosmic particles can link TOB/TID layers with TECn (n>=3) layers, skipping all the innermost TEC layers. This is a problem because the current implementation of the trajectory builder does **not** have a link between such sets of fwd layers. There is a chance that the same trajectory is split in 2 segments”.



My results (1)

Matched hit splitting off and fix included

This plot shows the ratio of shared hits to track hits for both tracks, w/o matched hit splitting



9552 entries (***2-track events***)

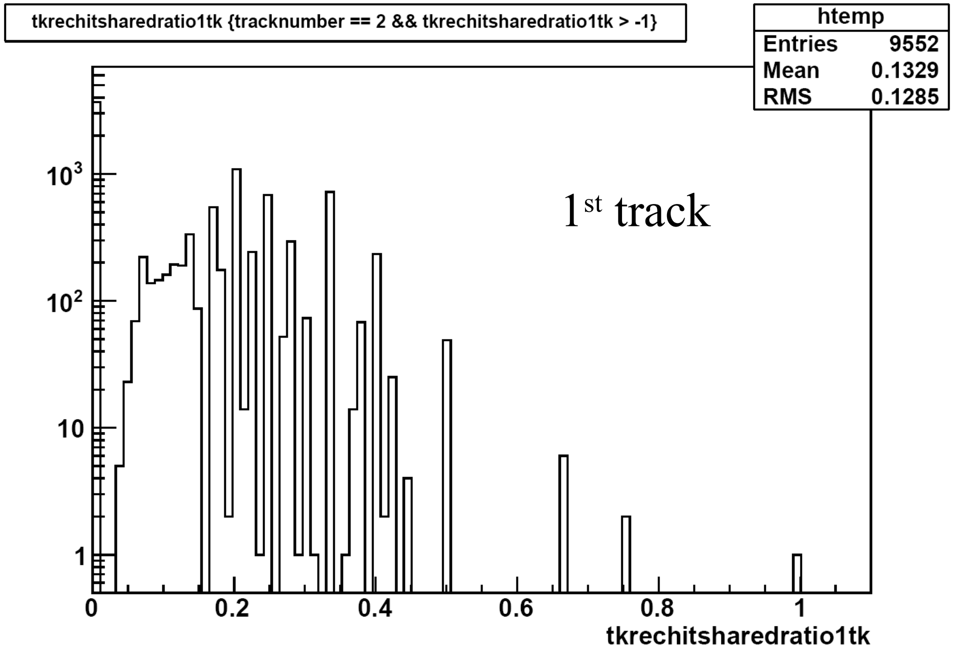
Only very few events are left out of the (0.5 x 0.5) square

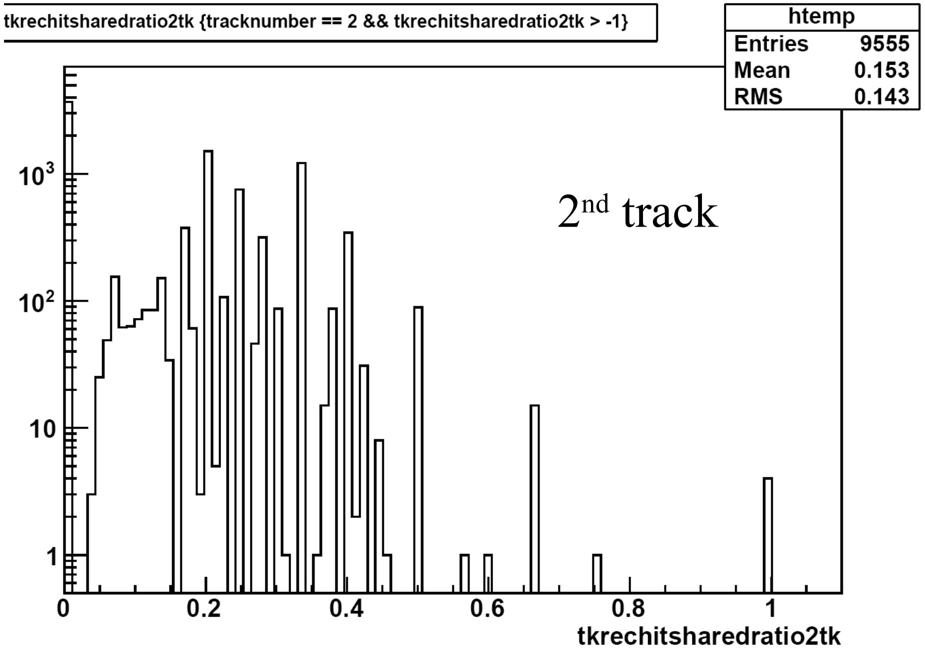
They are maybe due to some minor cases not taken into account in my code (e.g. SiStripProjectedRecHit2D)

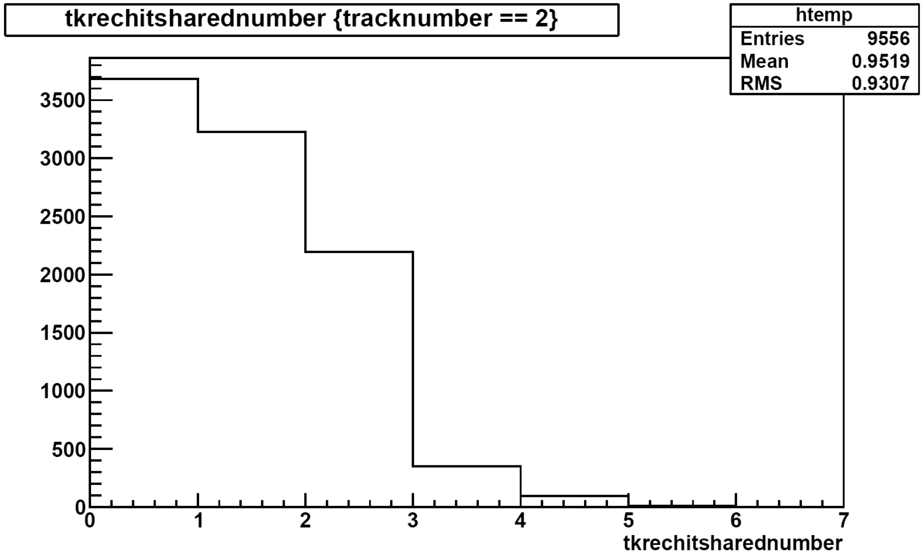
There is **no bug** in the TrajectoryCleaning code

Most events show no hit sharing at all

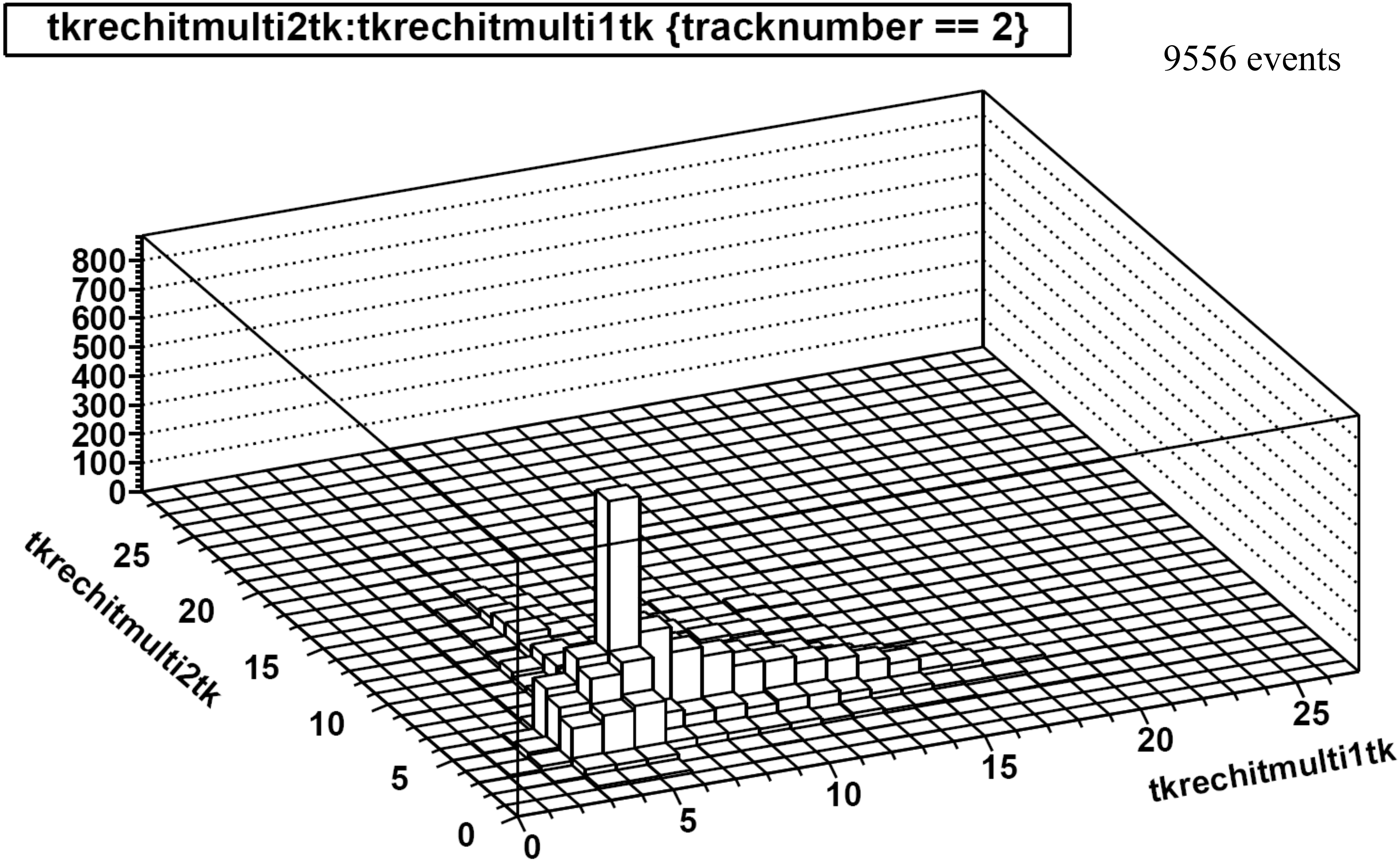
My results (2)


tkrechitsharedratio1tk {tracknumber == 2 && tkrechitsharedratio1tk > -1}
htemp
Entries 9552
Mean 0.1329
RMS 0.1285
1st track
10^3
10^2
10
1
0
0.2
0.4
0.6
0.8
1
tkrechitsharedratio1tk


tkrechitsharedratio2tk {tracknumber == 2 && tkrechitsharedratio2tk > -1}
htemp
Entries 9555
Mean 0.153
RMS 0.143
2nd track
10^3
10^2
10
1
0
0.2
0.4
0.6
0.8
1
tkrechitsharedratio2tk

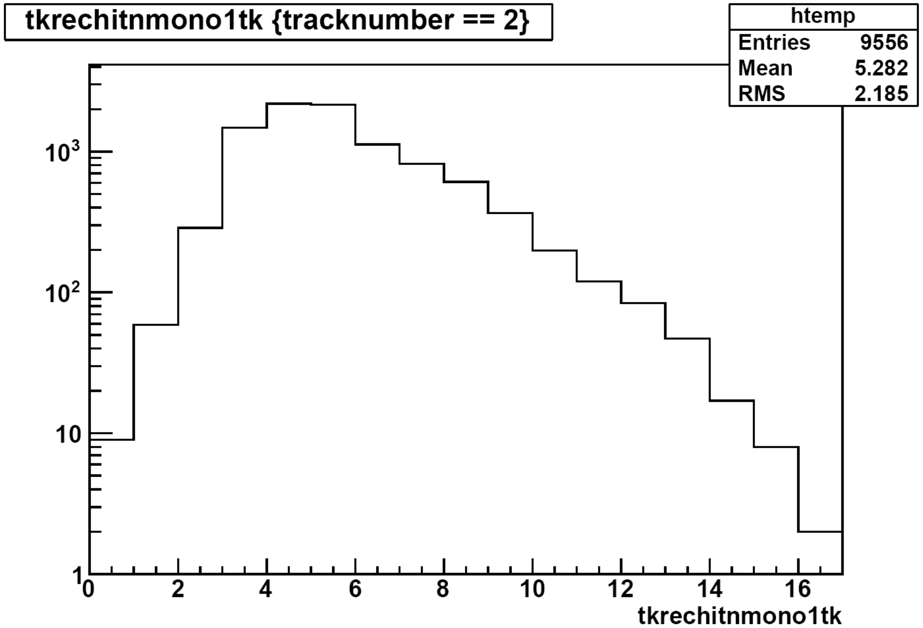

tkrechitsharednumber {tracknumber == 2}
htemp
Entries 9556
Mean 0.9519
RMS 0.9307
3500
3000
2500
2000
1500
1000
500
0
0
1
2
3
4
5
6
7
tkrechitsharednumber

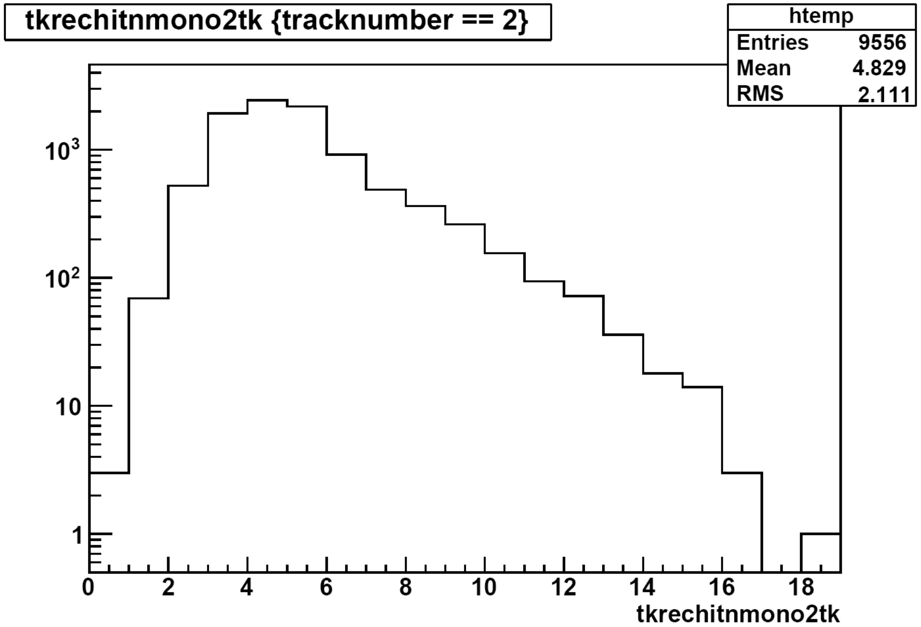
RecHit multiplicity per track (2-track events)

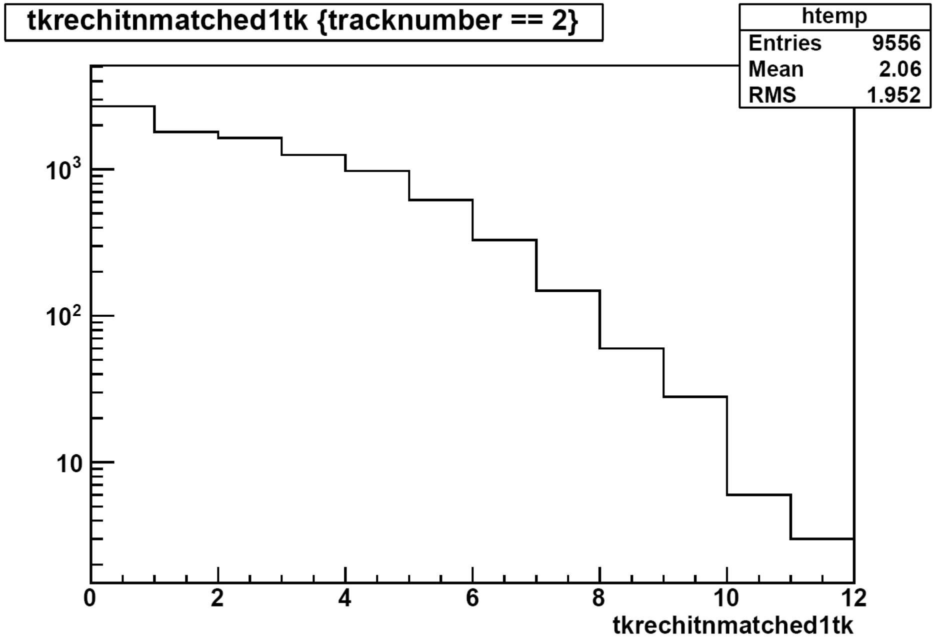


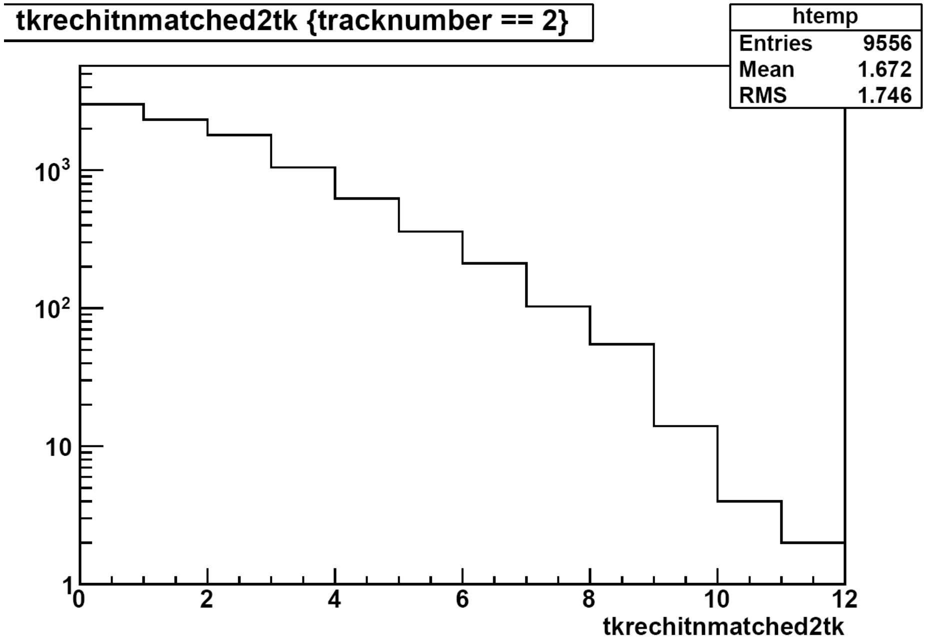
9556 events

Number of mono & matched hits per track









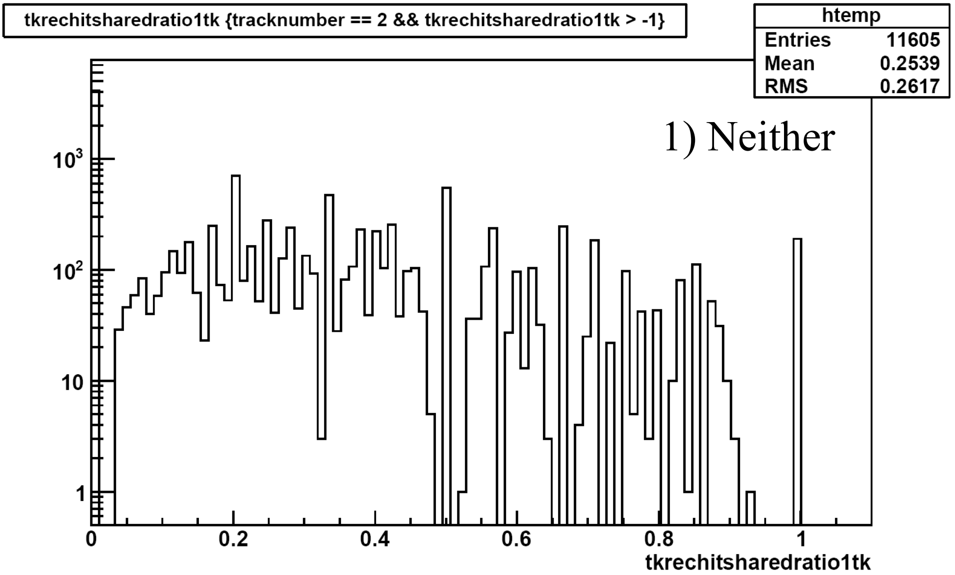
Disentangling the two contributions

- I’ll show the same plots in 4 cases:
  1. neither suggestion applied
  2. only matched rechit splitting turned off
  3. only fix included
  4. both suggestions applied

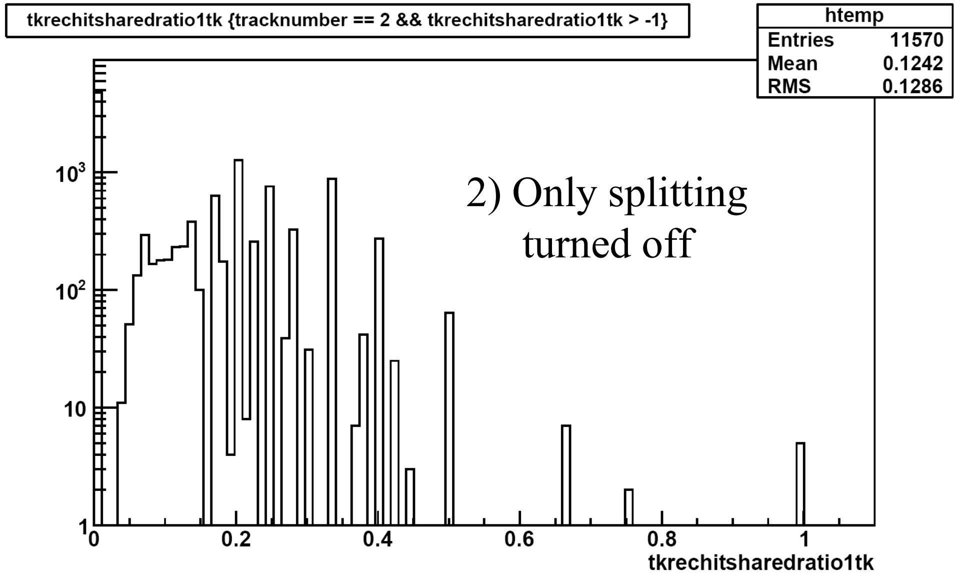
Warning: the number of entries is not exactly the same (but comparable)

Case 1	Case 2
Case 3	Case 4

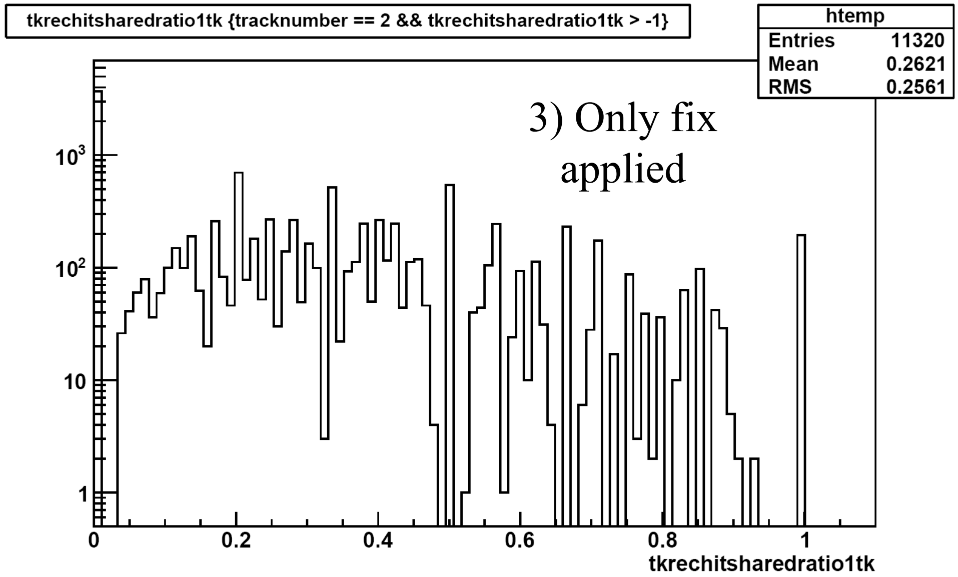
Shared hit ratio – 1st track



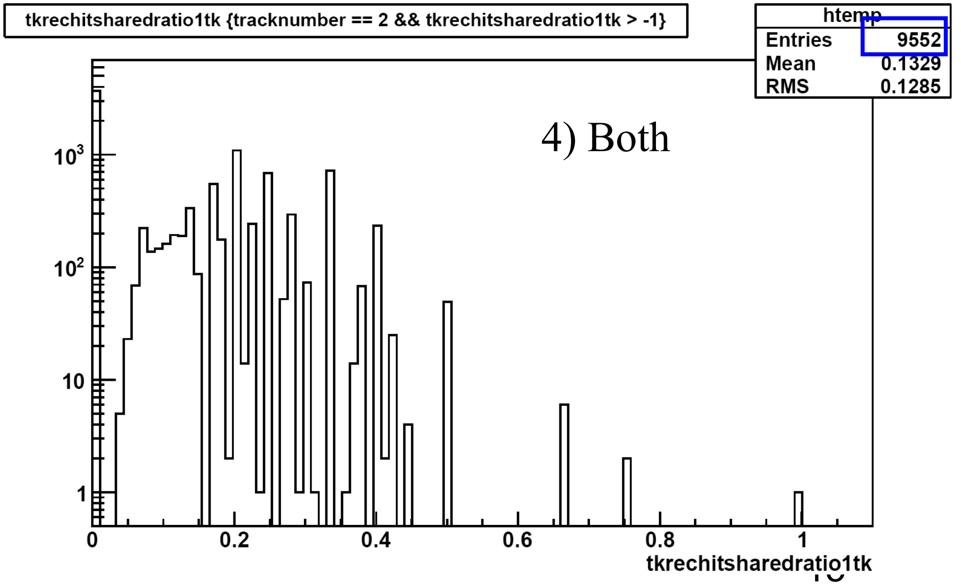
1) Neither



2) Only splitting turned off

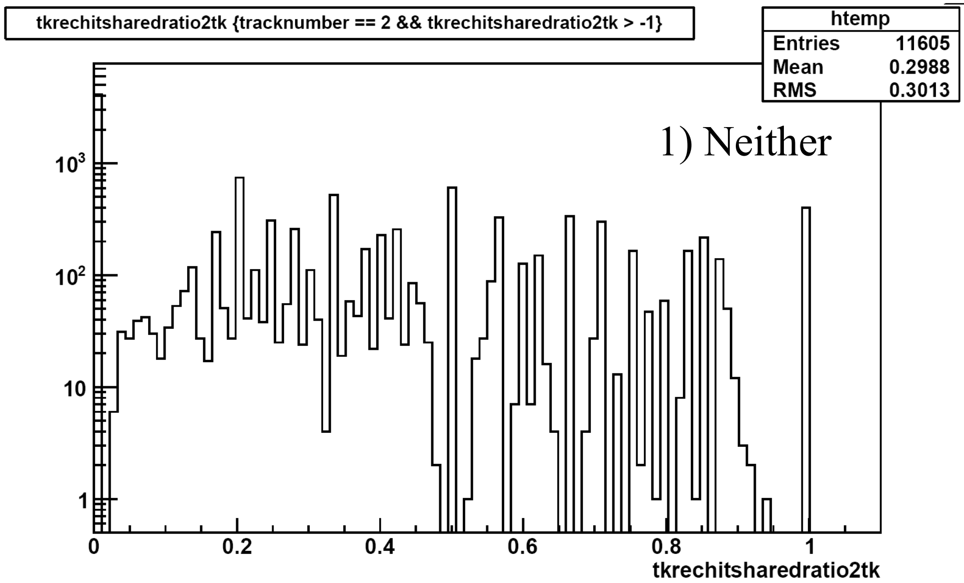


3) Only fix applied

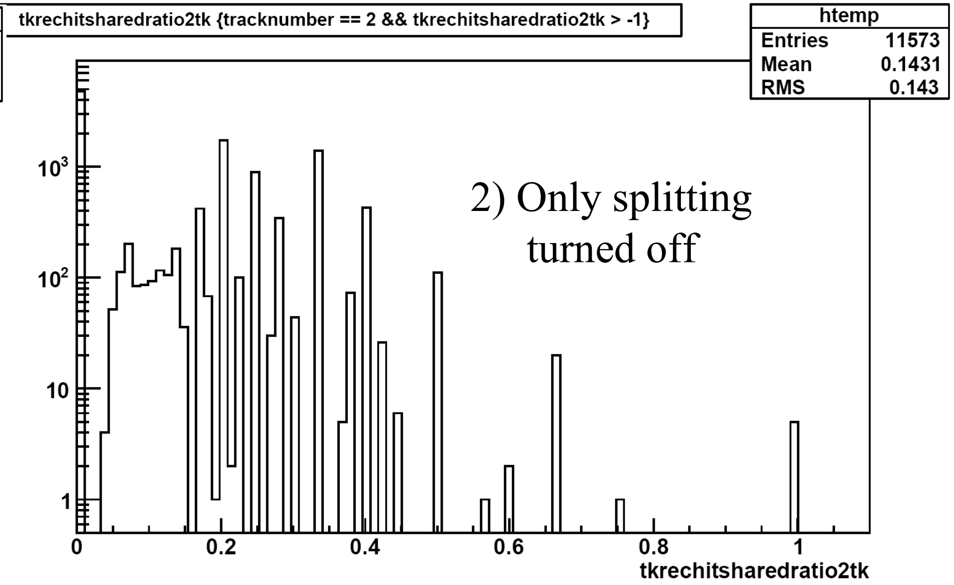


4) Both

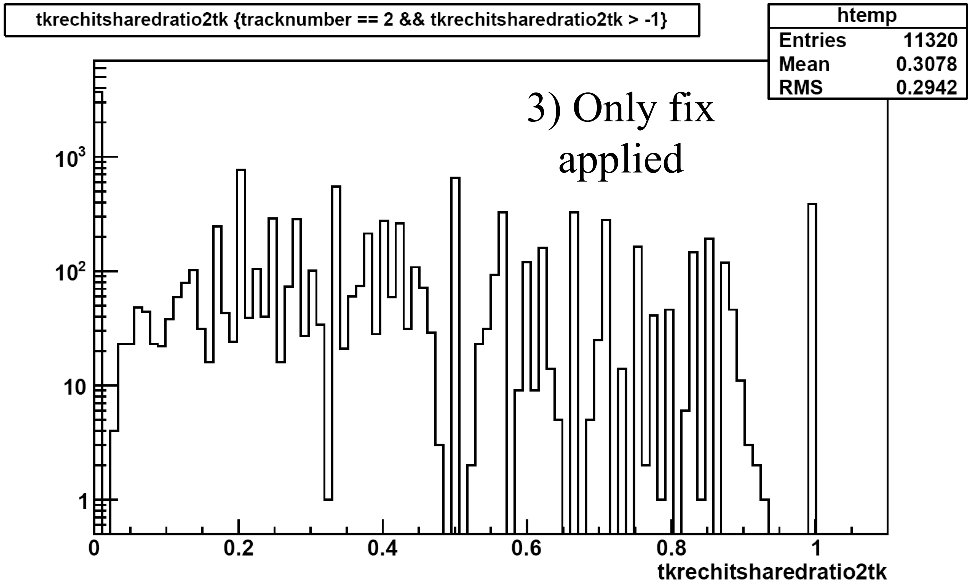
Shared hit ratio – 2nd track



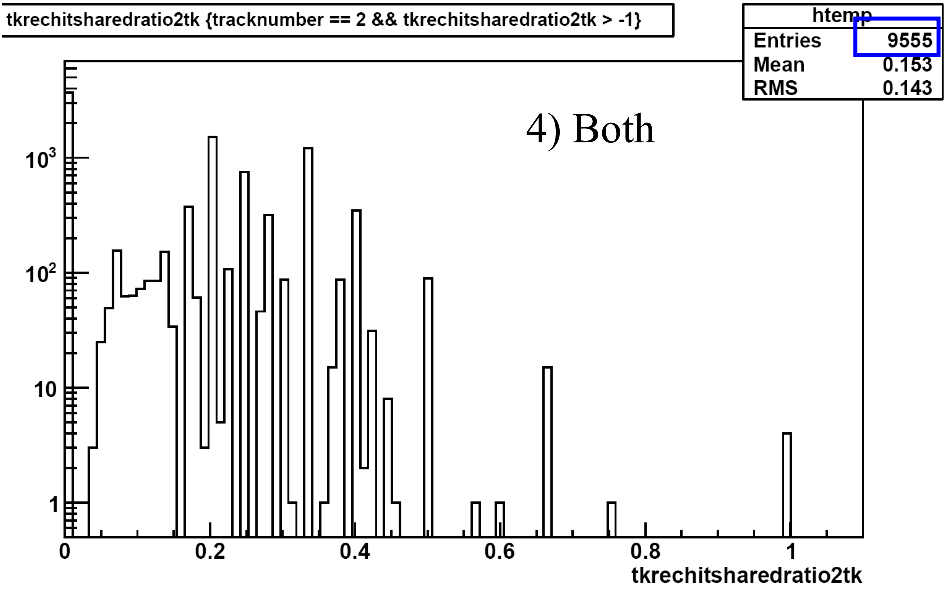
1) Neither



2) Only splitting turned off

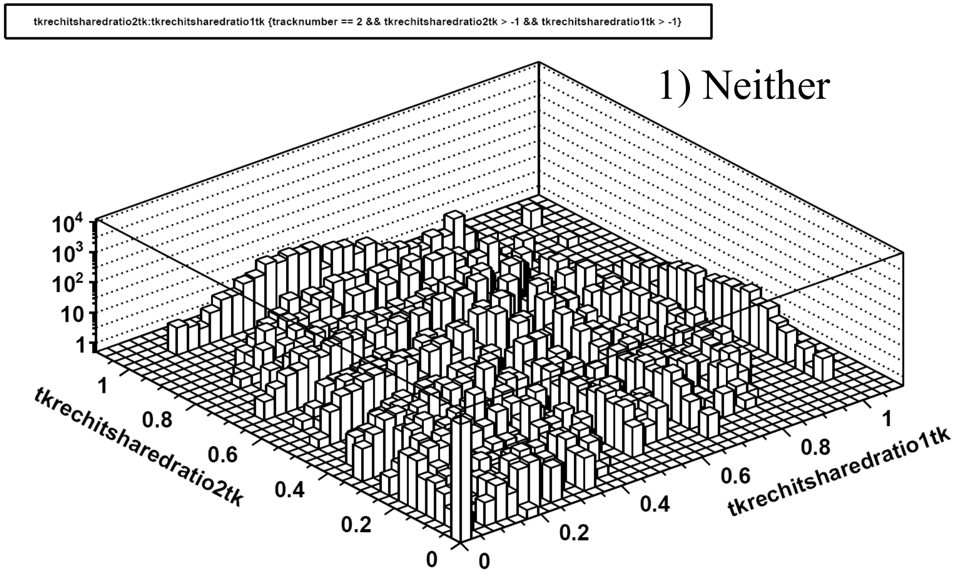


3) Only fix applied

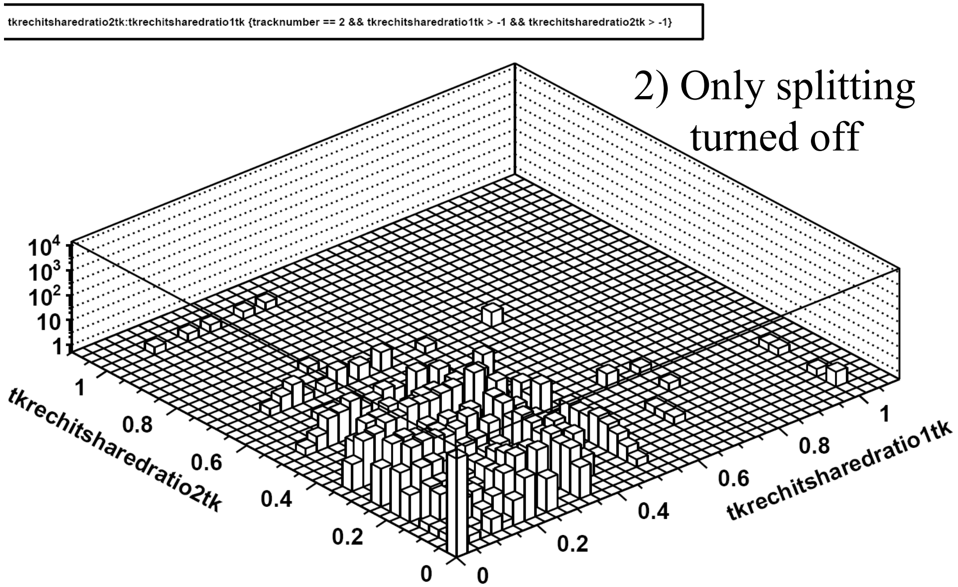


4) Both

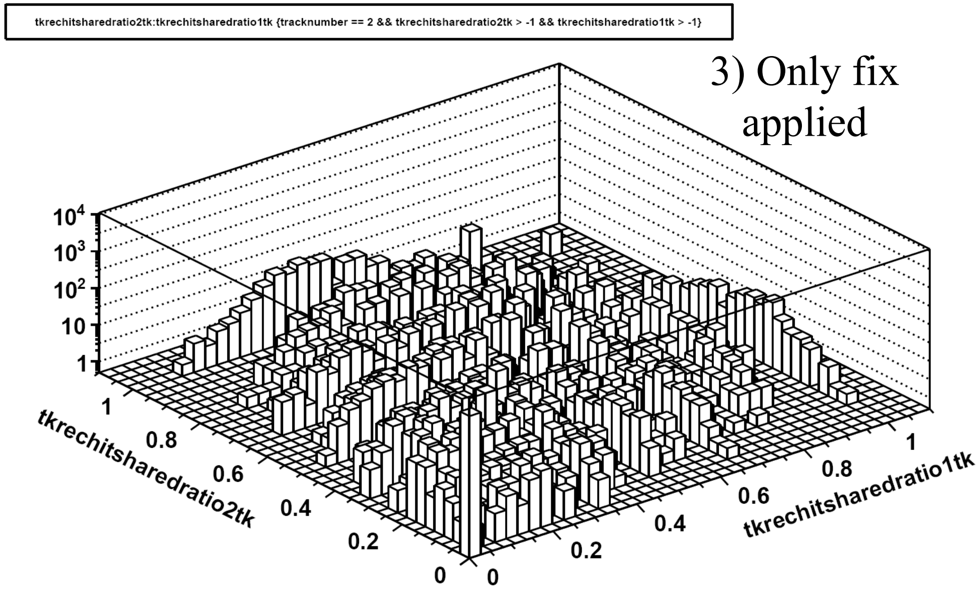
2D shared hit ratio distribution



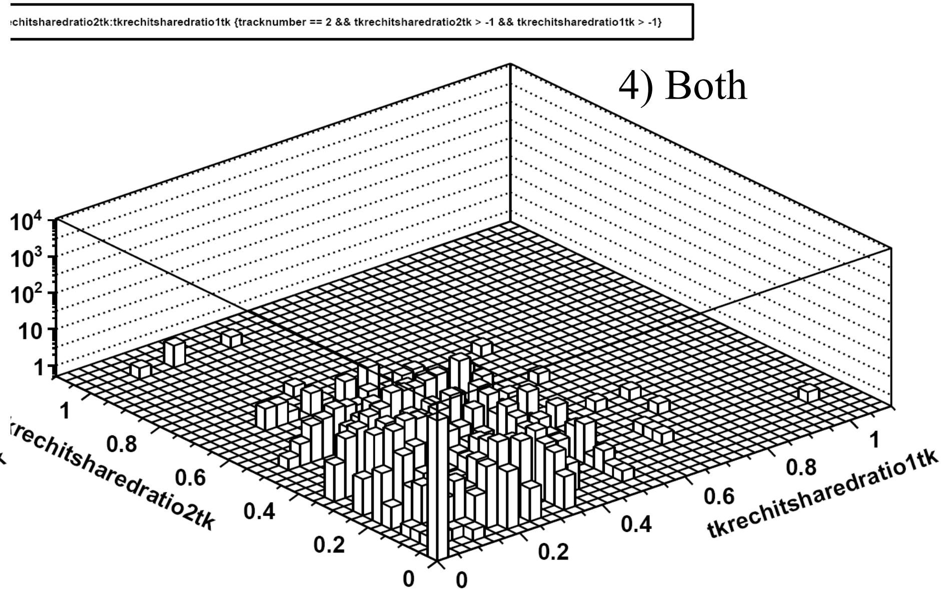
1) Neither



2) Only splitting turned off

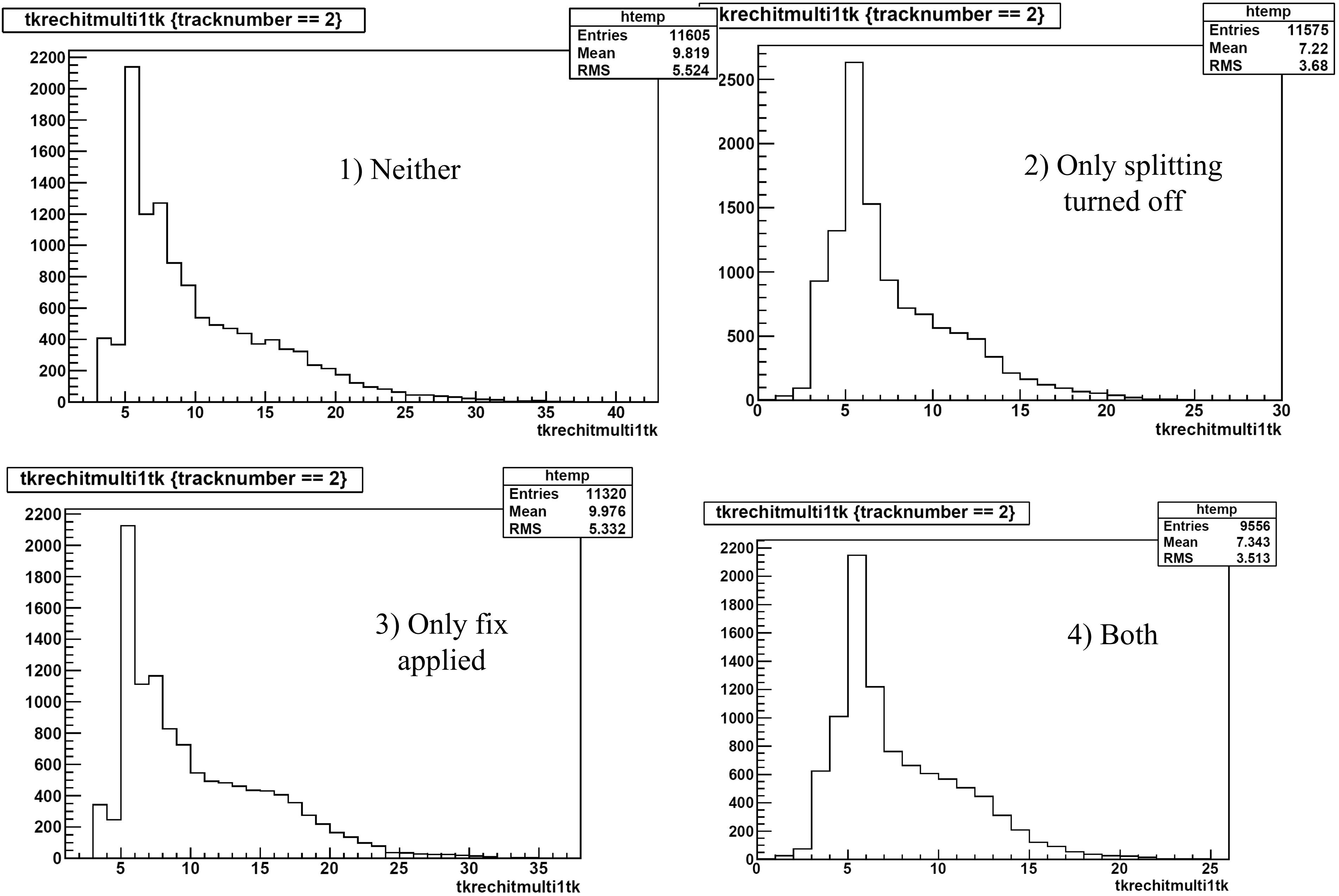


3) Only fix applied



4) Both

Hit multiplicity – 1st track



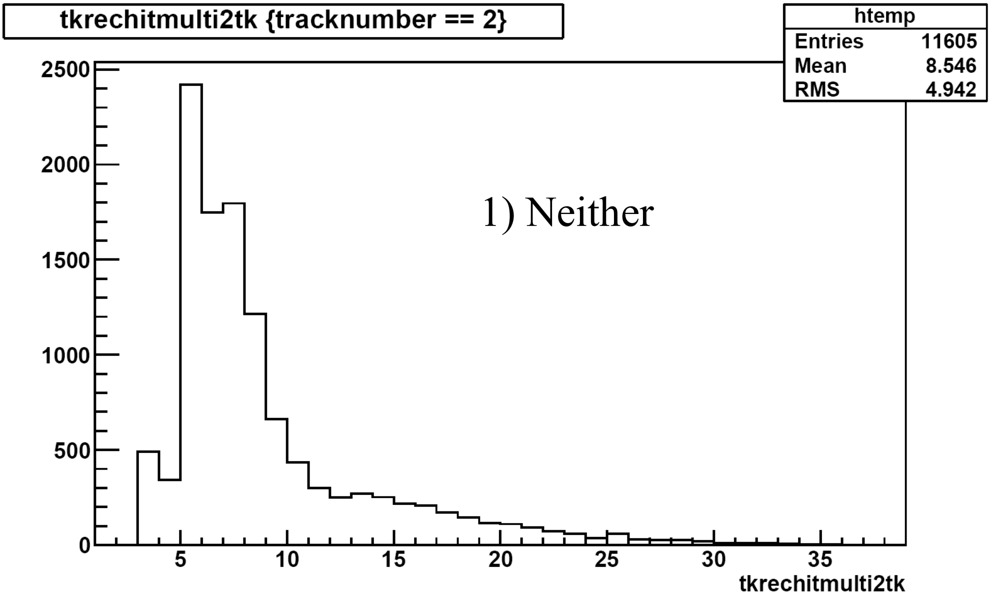
1) Neither

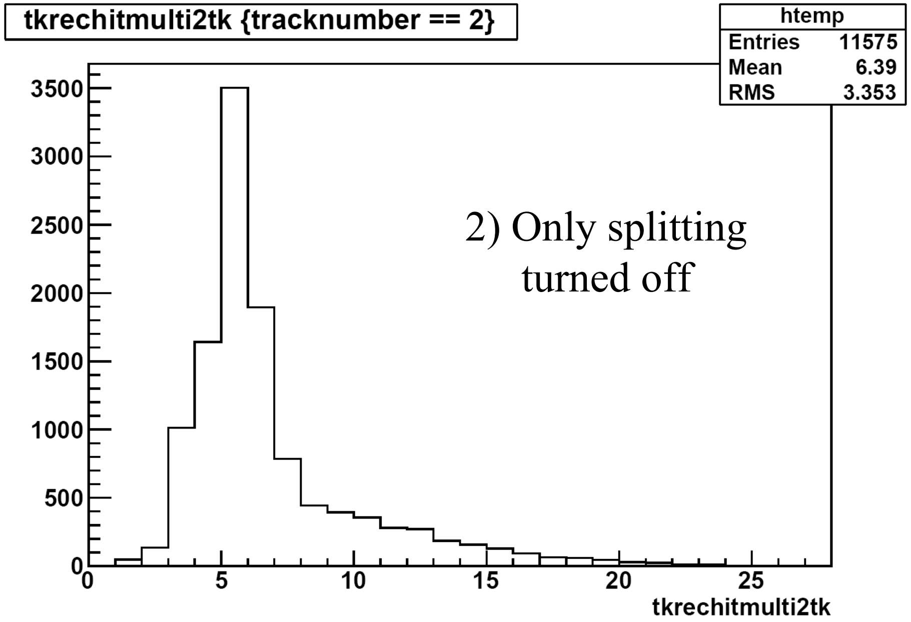
2) Only splitting turned off

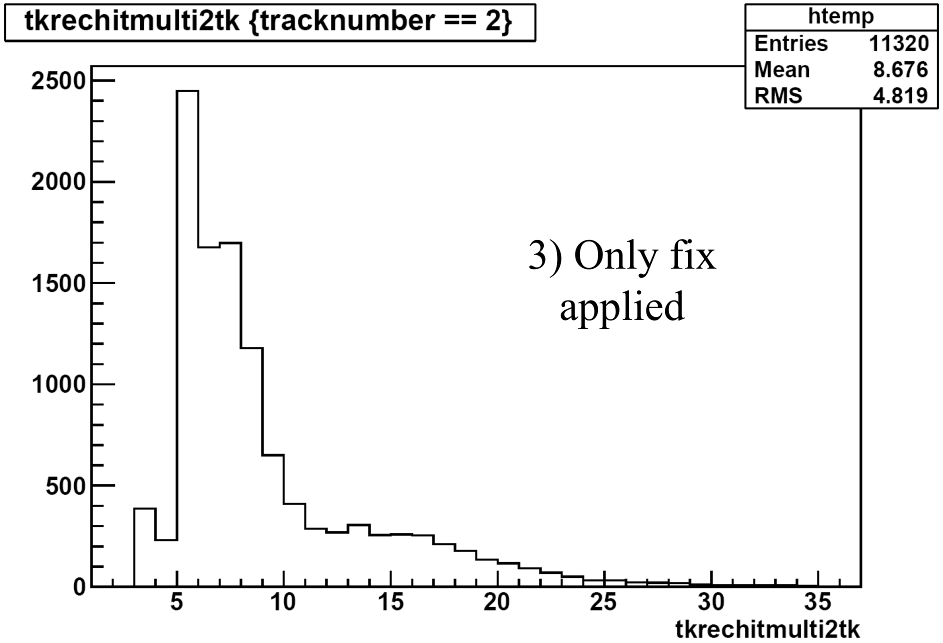
3) Only fix applied

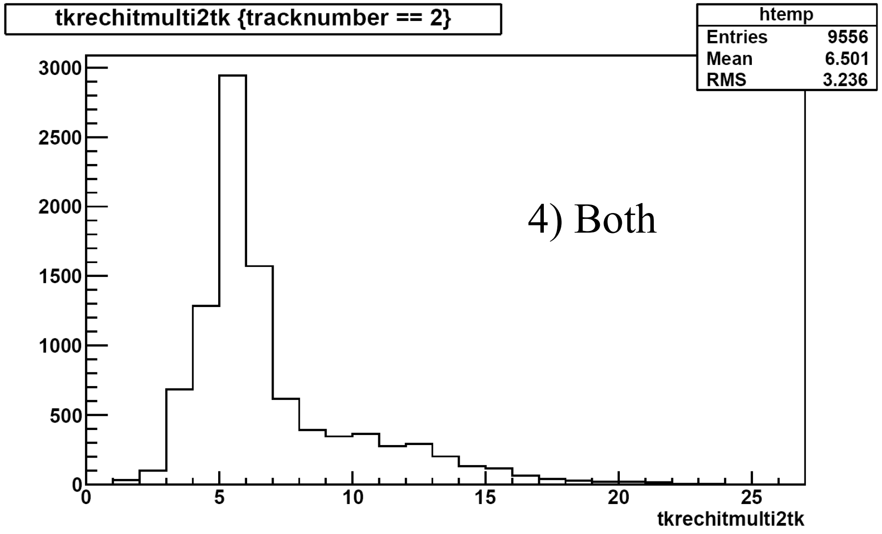
4) Both

Hit multiplicity – 2nd track

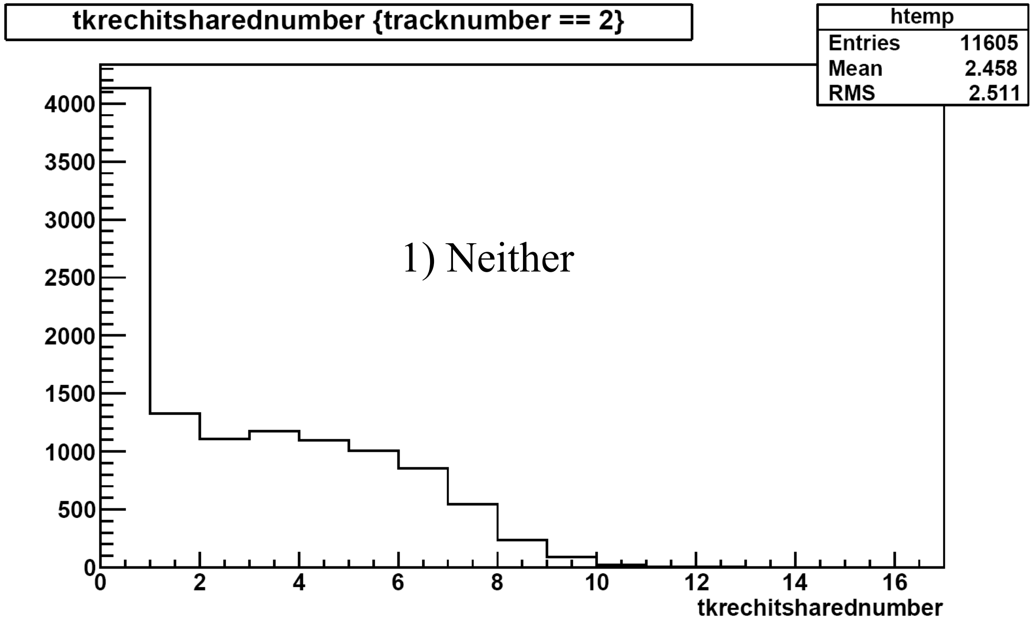

1) Neither


2) Only splitting turned off

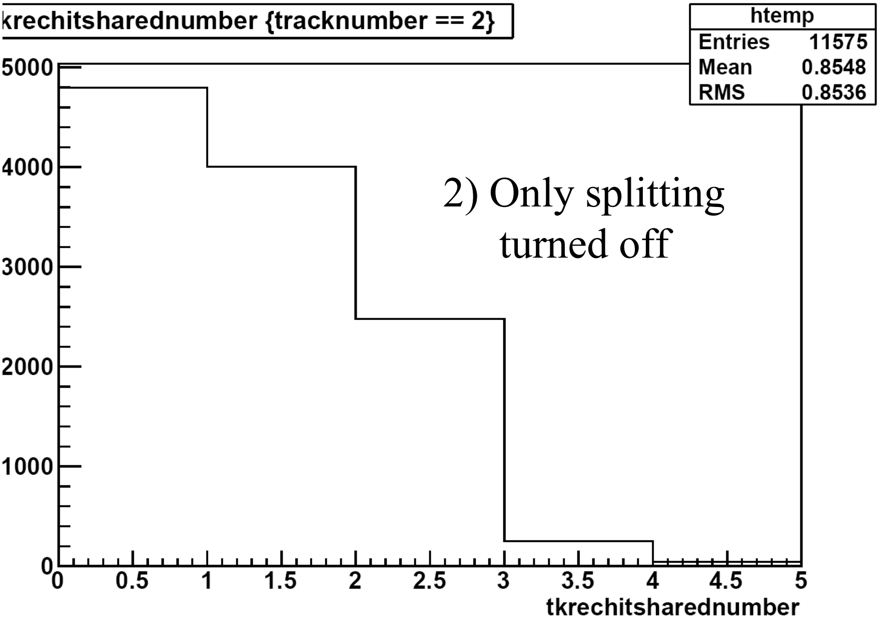

3) Only fix applied


4) Both

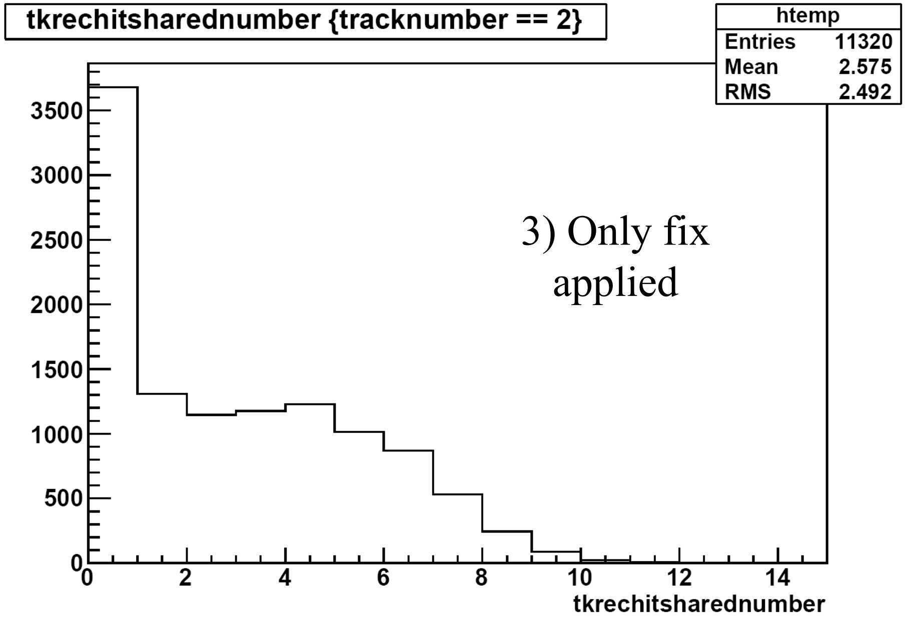
Shared hit multiplicity



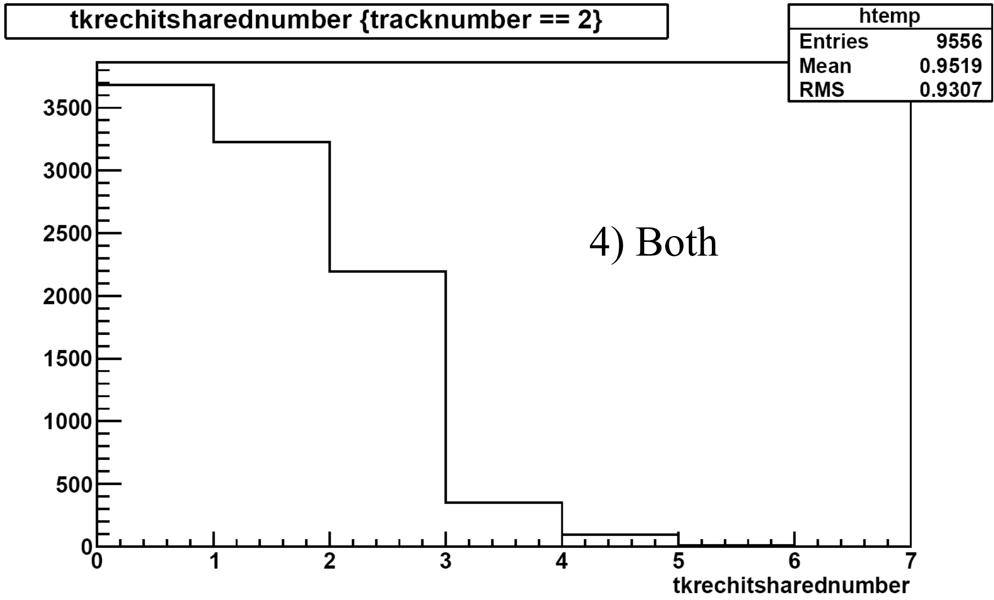
1) Neither



2) Only splitting turned off



3) Only fix applied



4) Both

Conclusions and outlook

- There is no bug in the TrajectoryCleaning code
- Just keep in mind that the new results have been produced **after turning off** the splitting of the SiStripMatchedRecHit2D
  - the ratio of shared hits after this splitting is larger
- Tracks with pixel hits haven't been taken into account
  - in fact, this wasn't needed to check if the TrajectoryCleaning is OK

- The 'TOB-TEC fix' has little or no impact on hit sharing
  - is it needed? Maybe yes, but not for this kind of studies

- The theta, phi and IP correlations (slide n.3) still have to be understood:
  - overlapping tracks?
  - split tracks?
  - two real tracks?

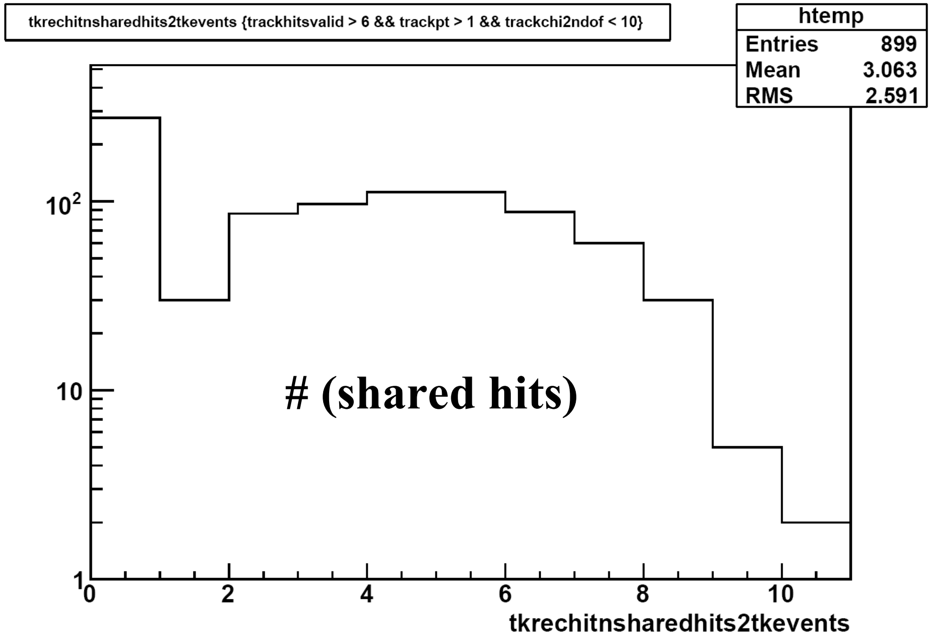
Many thanks to Burton A. Betchart for the big help in writing the code and to Regina Demina and Marco Costa for the useful comments and suggestions!

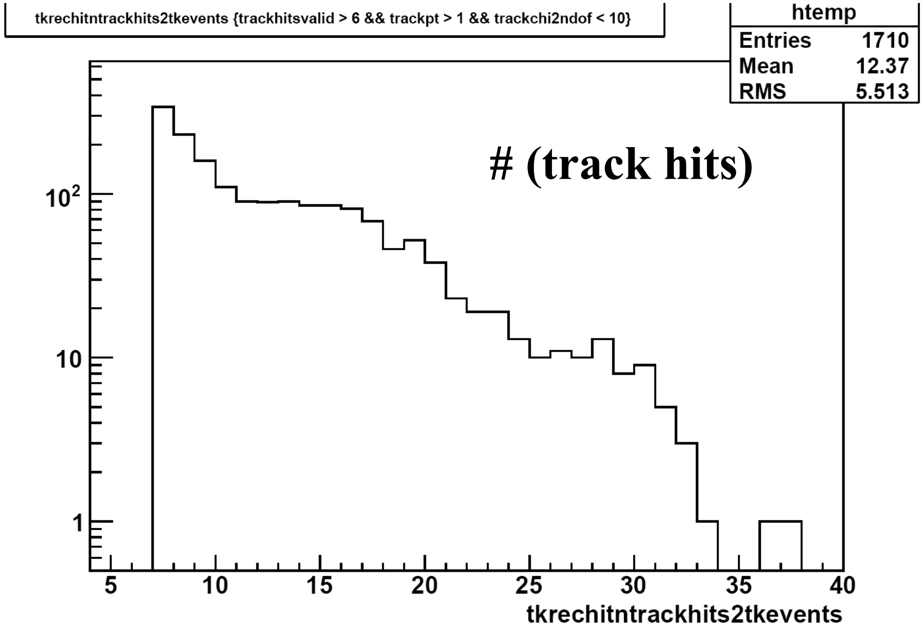
Backup slides

Considering the SiStripRecHit2D hits

- In some events, tracks share some hits
  - unphysical, due to combinatorics
  - looking for a criterion to distinguish among:
    - real multi-track events
    - ‘split-track’ events
    - ‘overlapping-track’ events
- Only strip RecHits considered at the moment…
  - pixel RecHits not added yet

Numerator and denominator separately





Would it be possible to modify the track reconstruction algorithm in order to avoid the hit-sharing?

This could help in reducing the number of multi-track events.