

Mu2e : A Search for Charged Lepton Flavour Violation in Muons

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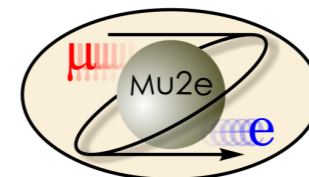
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University of Pisa, INFN Pisa

INTENSE : particle physics experiments at the intensity frontier

Monthly Meeting

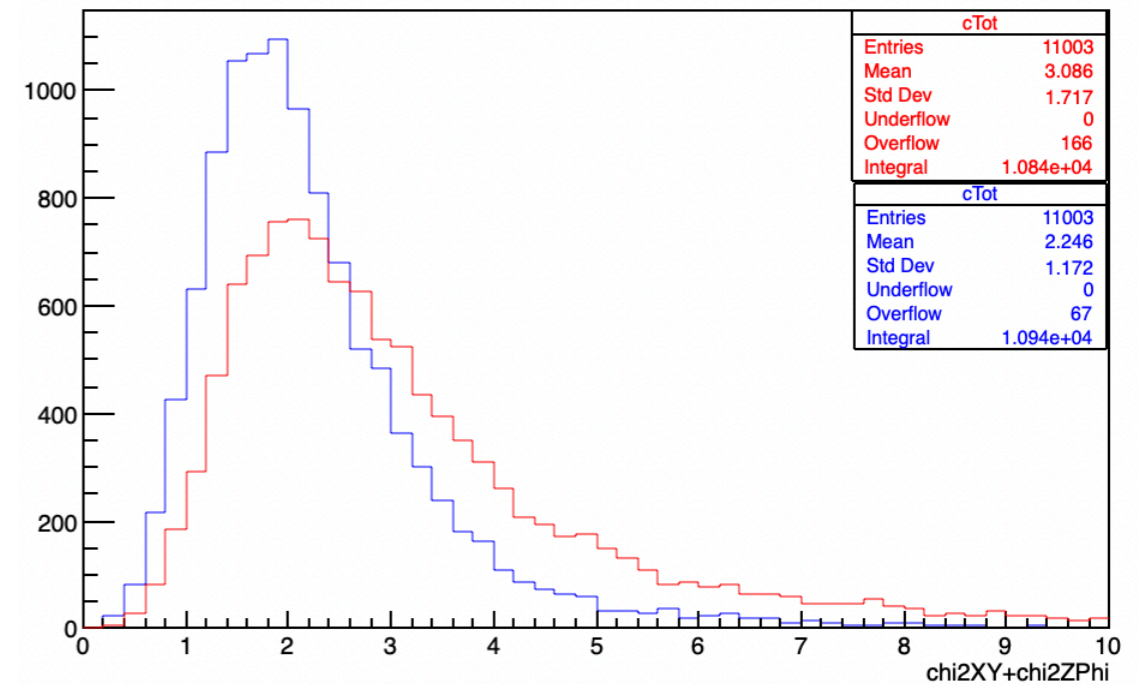
14 Sep 2022



MergeHelices

Study of the original and the new algorithm with the mixed dataset

- Data :
dig.mu2e.CeEndpointMixTriggered.MDC2
020n_10pc.art
- No. Of events : 10000
- Histograms produced with the information of the selected helices at the MergeHelices stage.
- The changes made and studied are :
 1. Uniform χ^2 calculation. The method followed in CalPatRec (LsqSums) was adopted for the TrkPatRec helices as well (explained in docdb 41019)
 2. If the difference in the no. of hits between the 2 helices < 5 , use the χ^2 value as the selection parameter.



chi2Total/dof

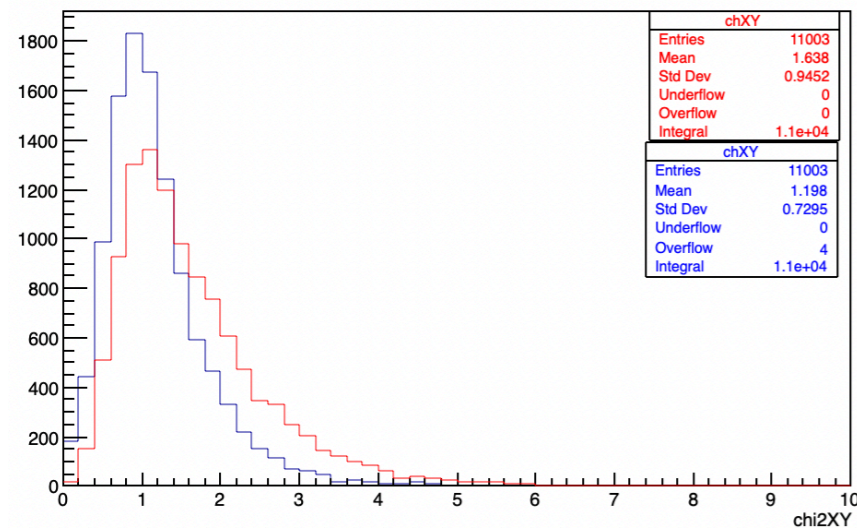
red = Original, blue = New

Mixed Data

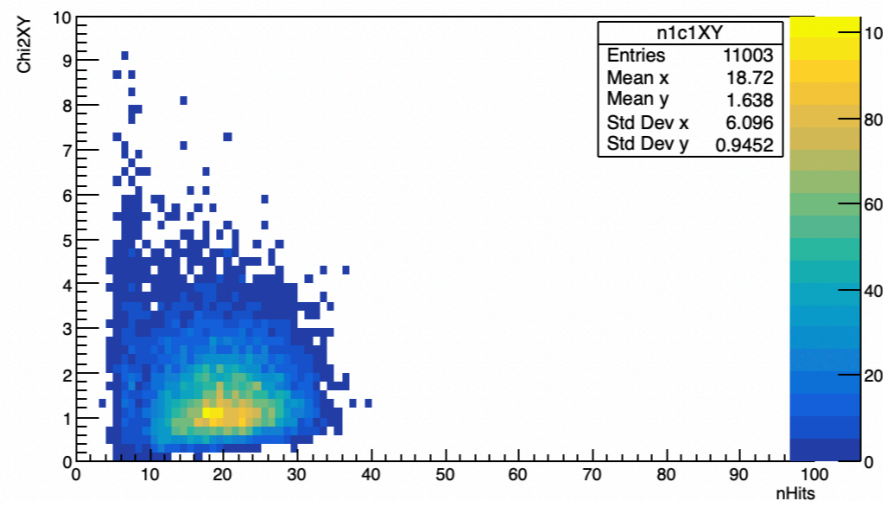
Red = Original Blue = New, uniform

$$\chi^2 + \Delta nHits = 5$$

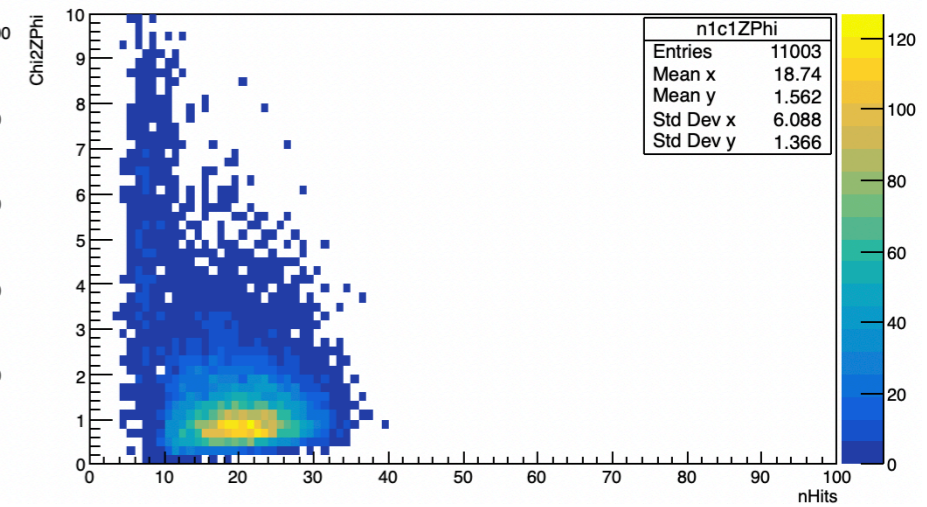
- About 11000 helices are selected for a run of 10000 events.
- The χ^2 distribution improves with the new algorithm.



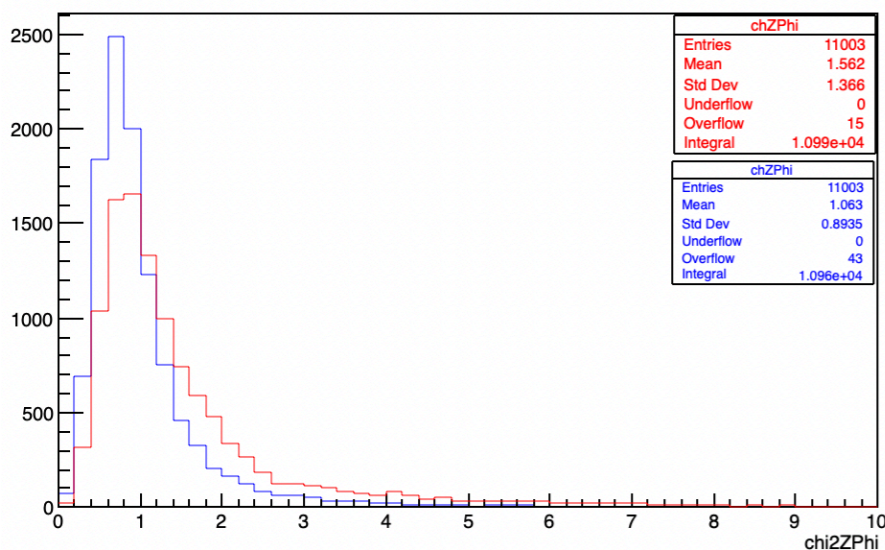
Chi2XY



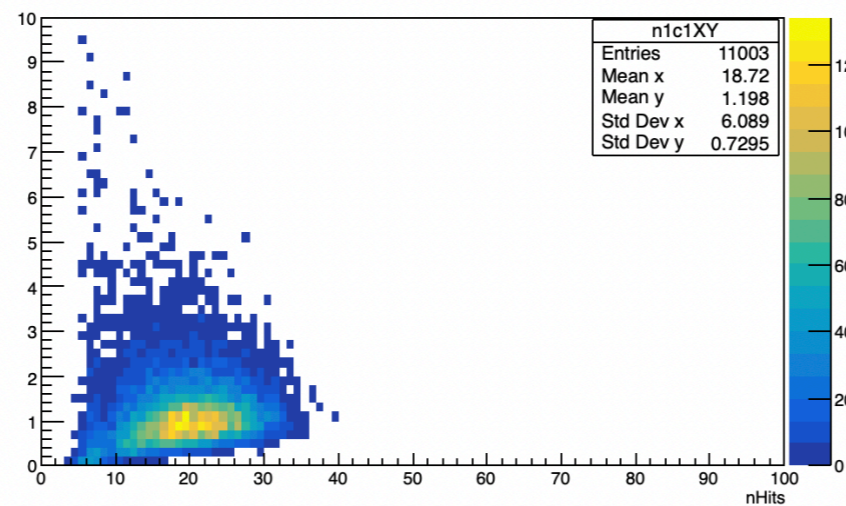
Original Chi2XY v/s nHits



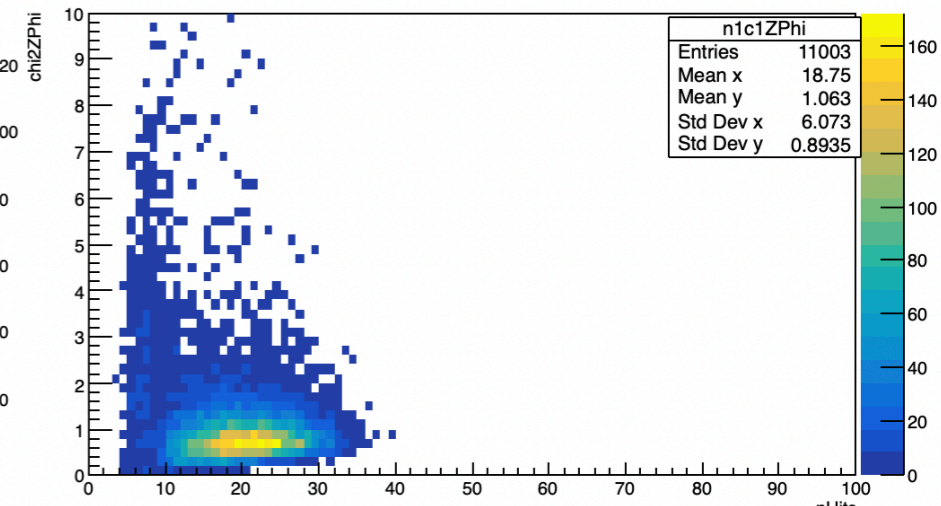
Original Chi2ZPhi v/s nHits



Chi2ZPhi



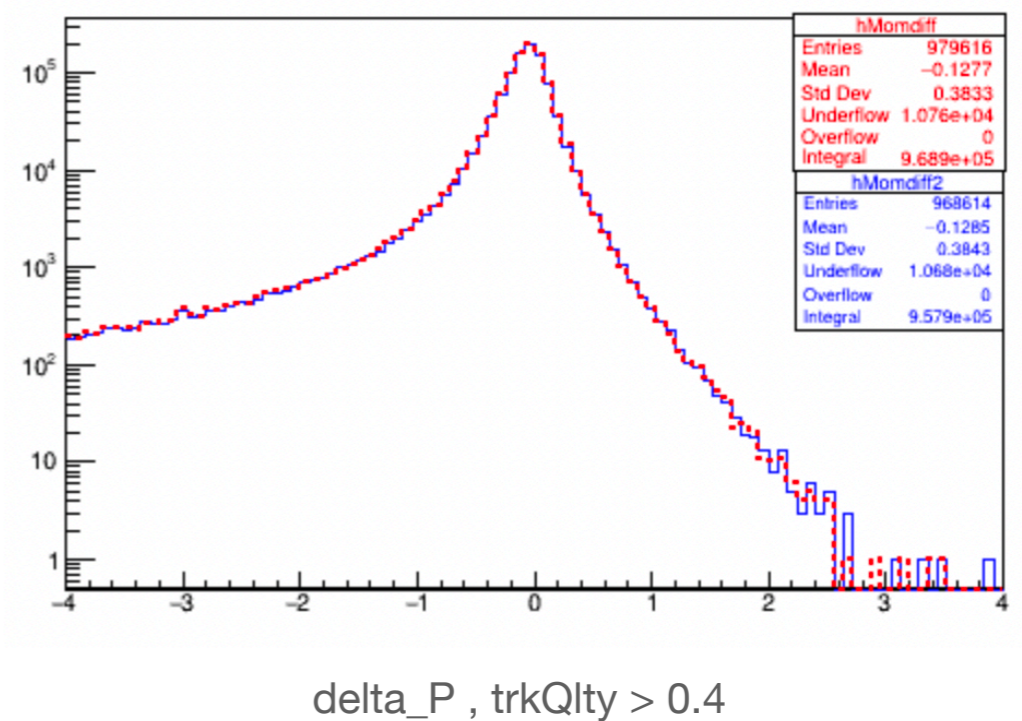
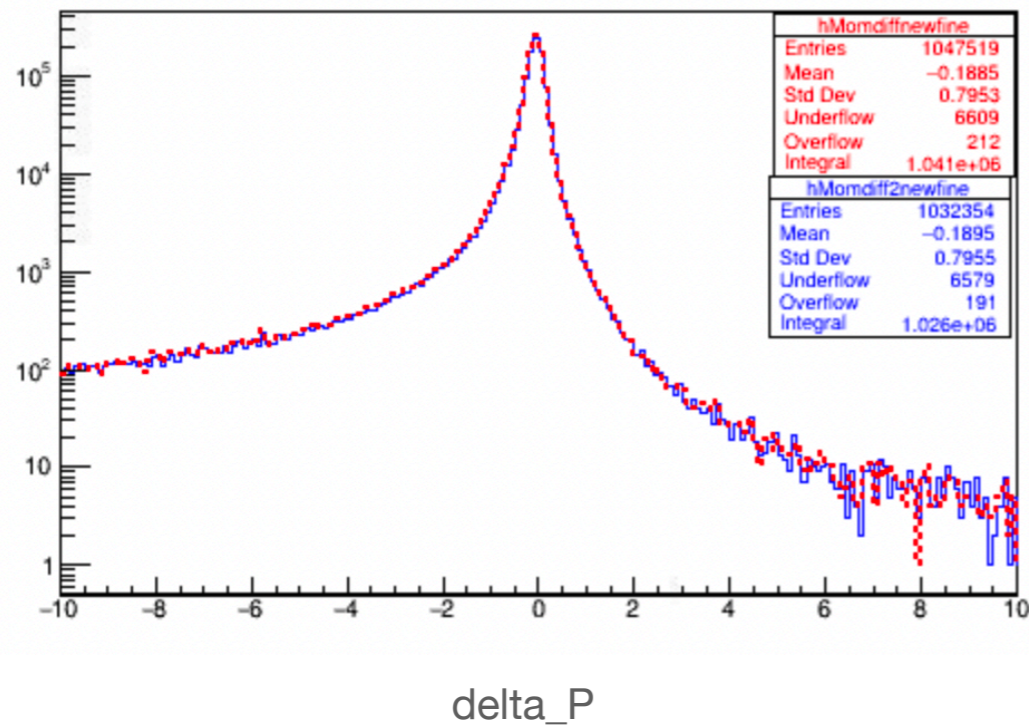
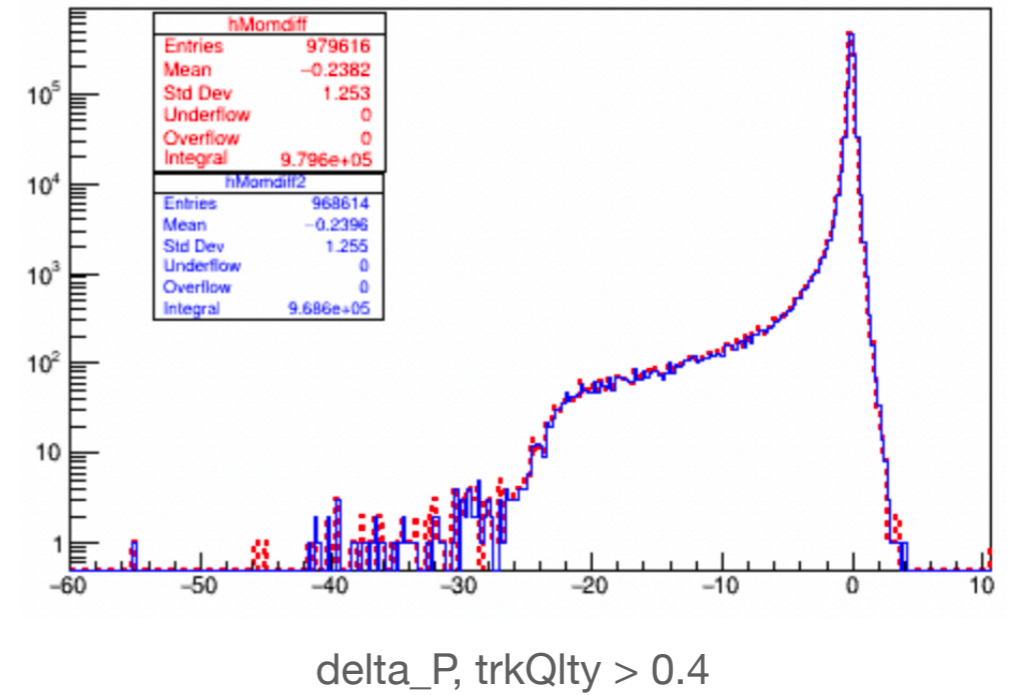
New Chi2XY v/s nHits



New Chi2ZPhi v/s nHits

Momentum Resolution assessment (No. Of events = 1 million)

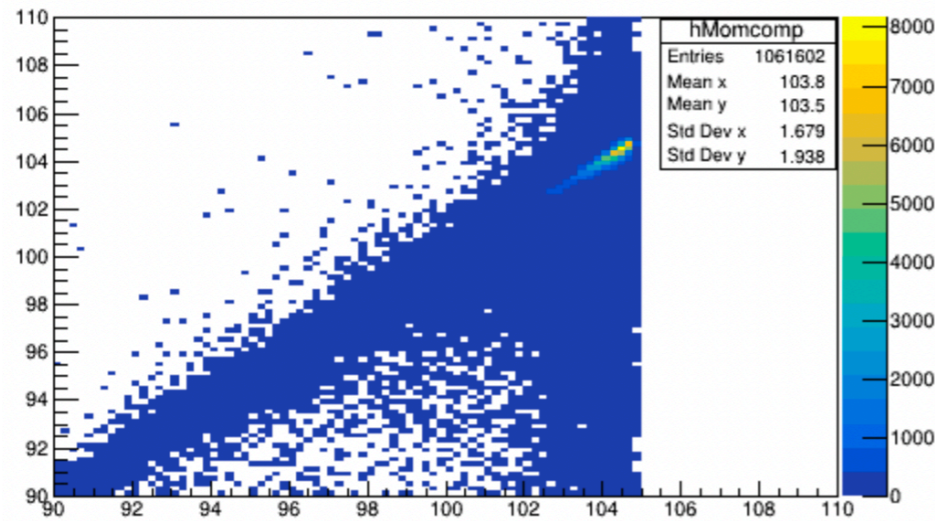
- The following plots are made utilising and customising the scripts available in TrkAna.
- The momentum distributions of the first segments of the track, the reconstructed and true momentum respectively are used.
- The TrkQlty parameter refers to the quality score of the track.
- We expected to see an improvement in the momentum resolution distribution, particularly at the high-end tail but it does not vary much from the present state.



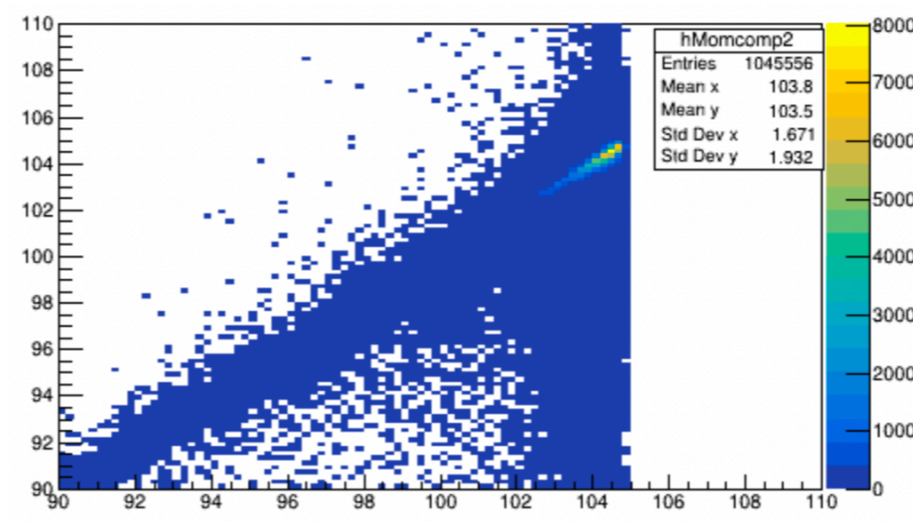
Δp comparison
Original = Red, New = Blue

Reconstructed momentum v/s MC truth momentum

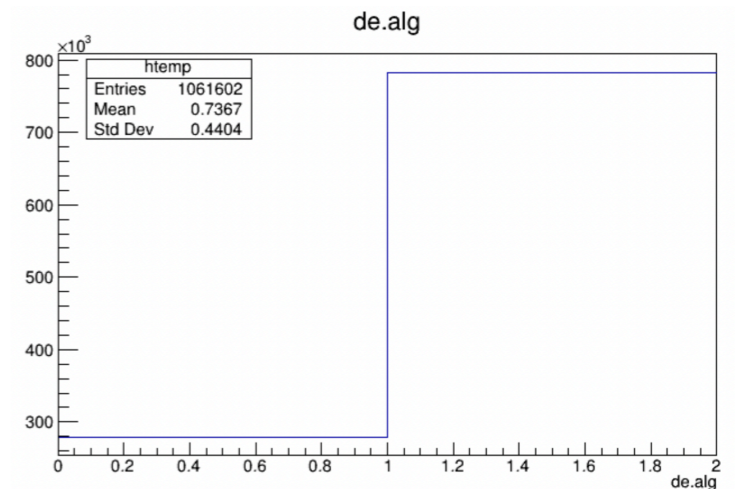
TPR or CPR



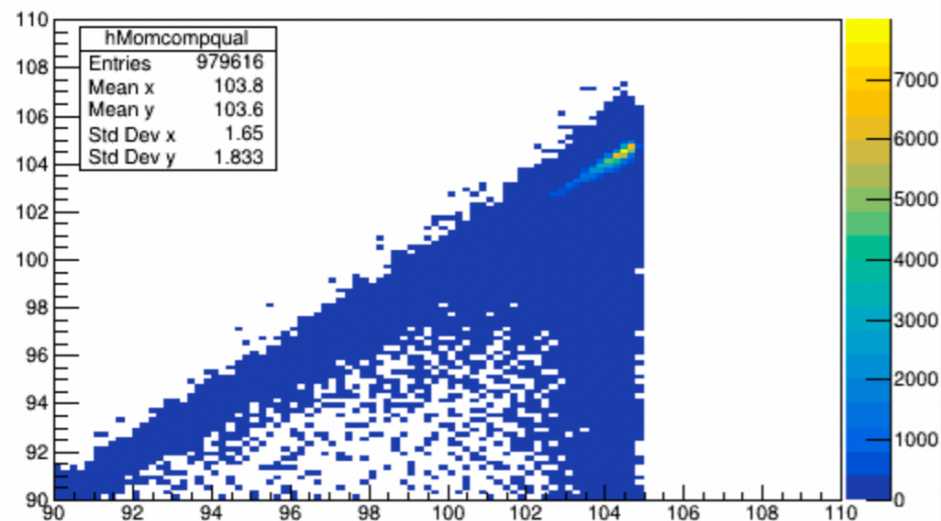
Reconstructed v/s True momentum, No TrkQlty cut



Reconstructed v/s True momentum, No TrkQlty cut

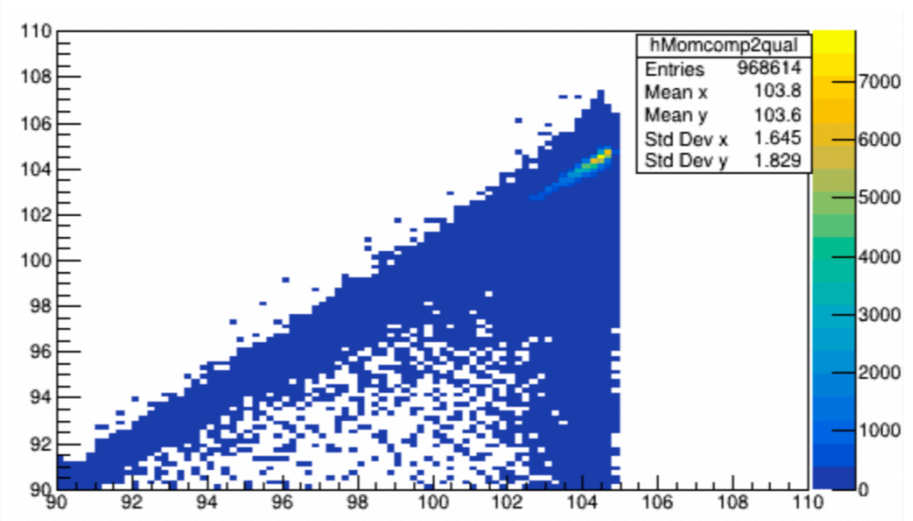


Original



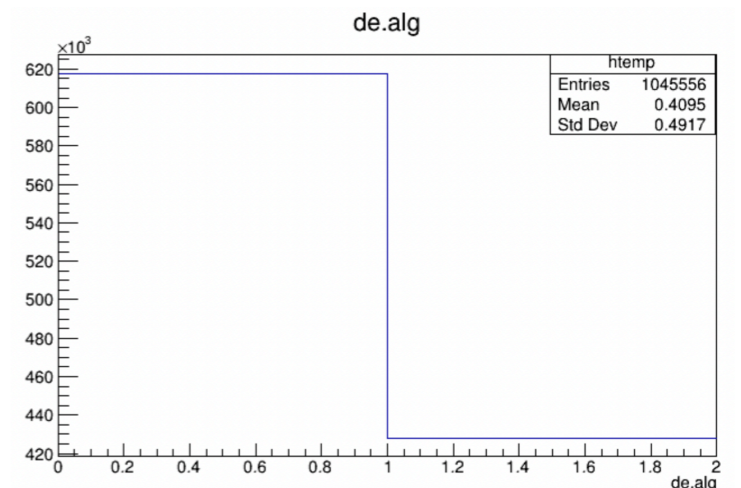
Reconstructed v/s True momentum, deQual > 0.4

Original



Reconstructed v/s True momentum, deQual > 0.4

New



New

1 = TrkPatRec and 2 = CalPatRec

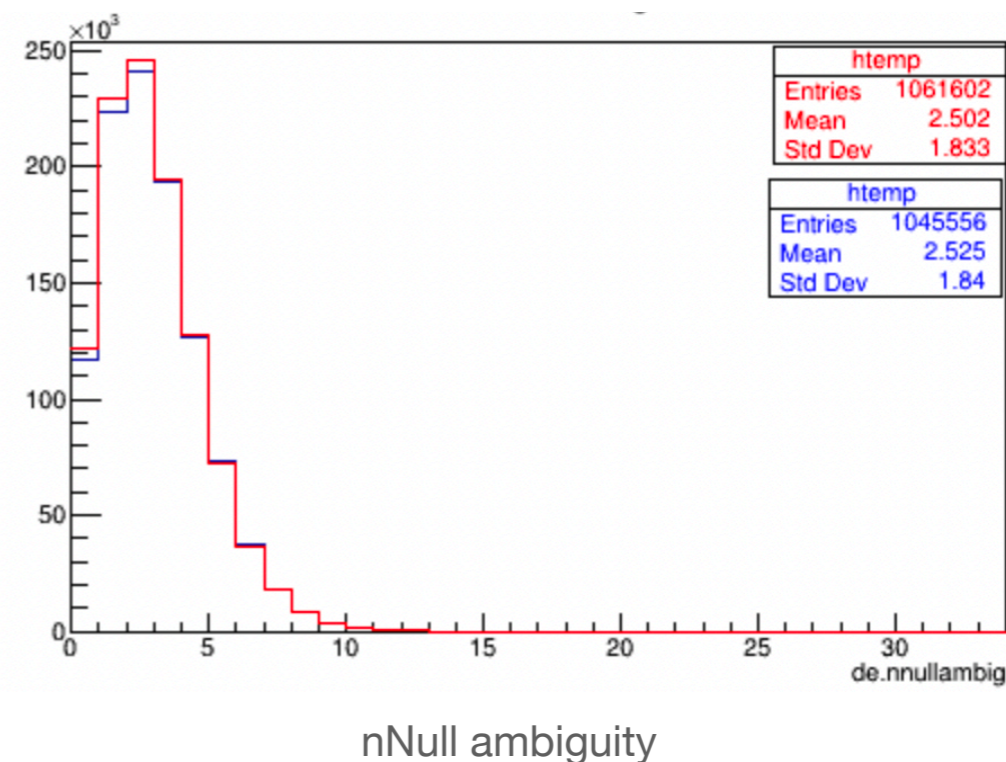
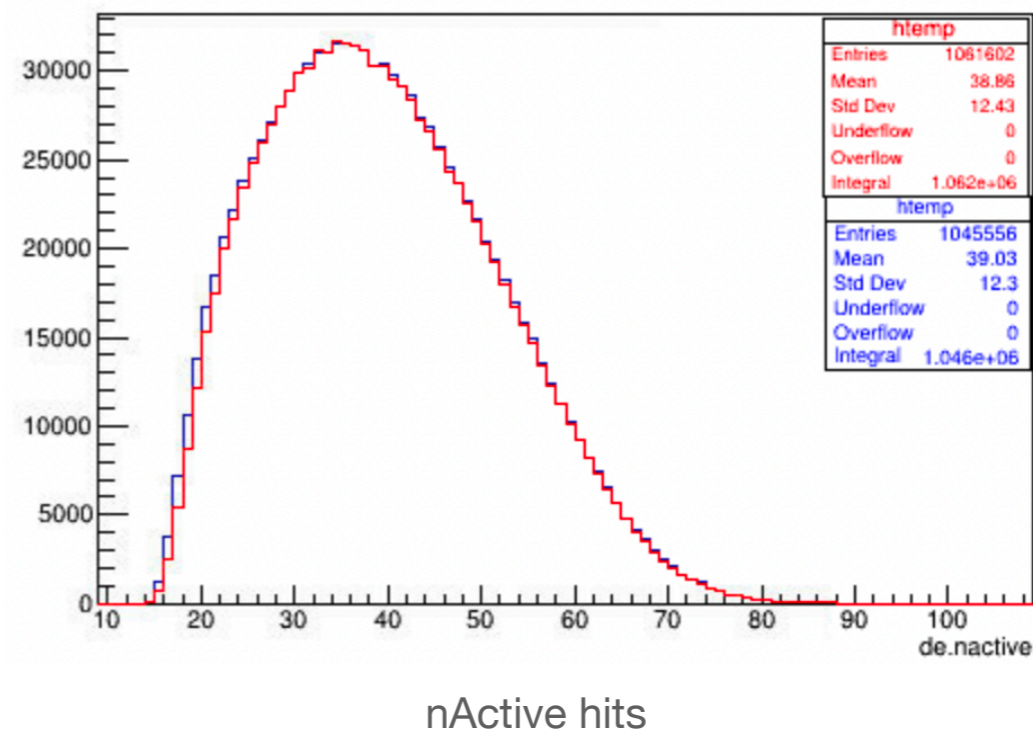
With the original MergeHelices about 73 % of the tracks come from the CalPatRec algorithm

With the New MergeHelices, about 40% of the tracks come from the CalPatRec algorithm.

nActive Hits and nNull ambiguity comparison

Red = Original Blue = New $\chi^2 + \Delta nHits = 5$

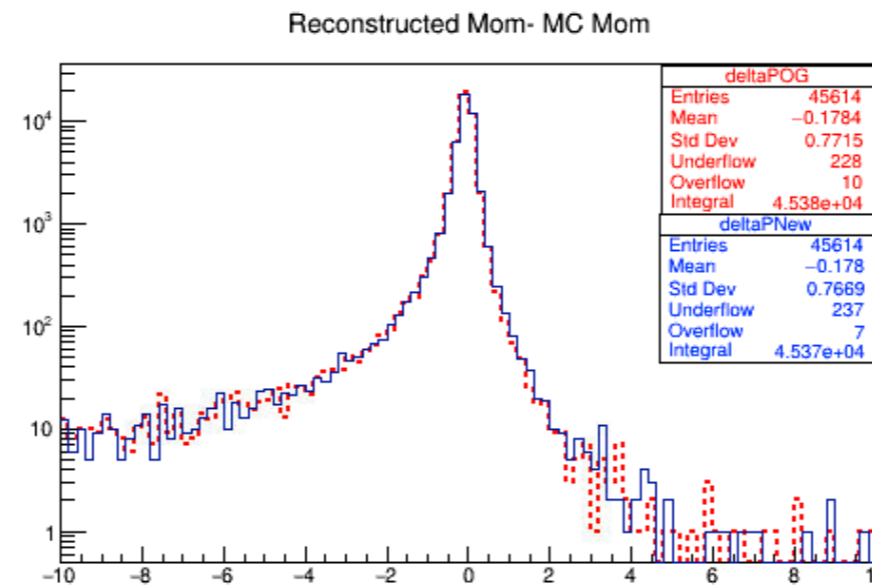
- Both, the number of active hits and the null ambiguity distributions does not vary much between the present and the new changes.
- About 33% of the helices changed teams, that is, if they were CalPatRec helices earlier, they are TrkPatRec ones now. But this does not seem to matter very significantly.
- From the momentum resolution, number of active hits and null Ambiguity distribution comparisons it looks like it does not matter much from which pattern recognition algorithm the helix is formed.



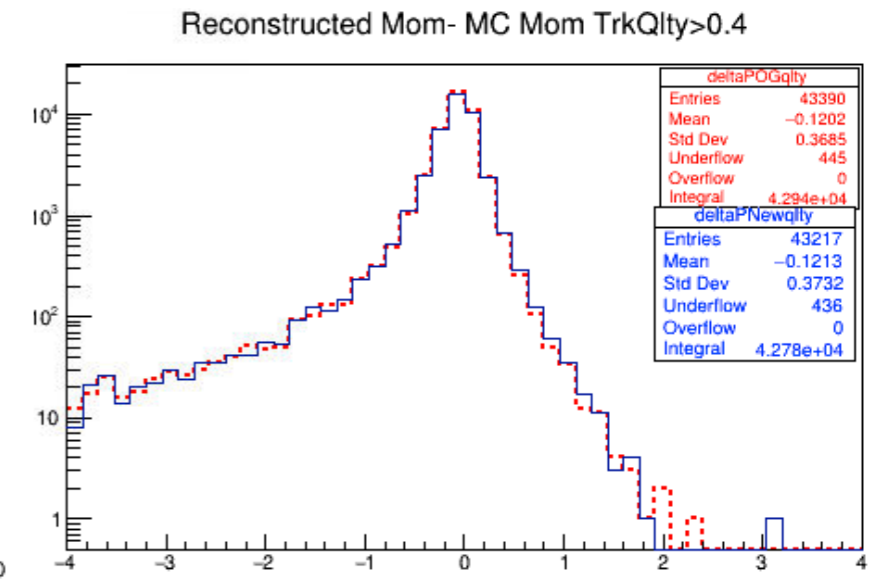
Momentum Resolution assessment of cases particularly where the pattern recognition algorithm changed because of the changes in MergeHelices

Red = Original Blue = New $\chi^2 + \Delta nHits = 5$

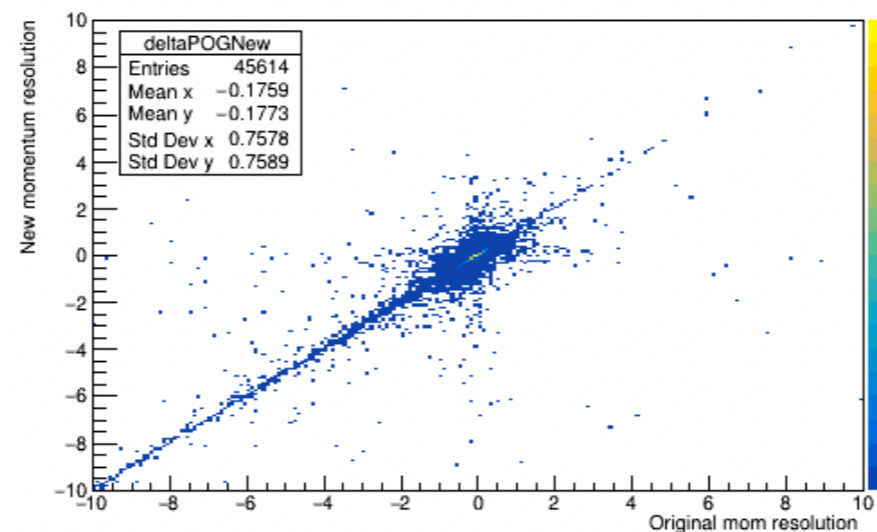
- No. Of events = 10^5
- Momentum resolution plots for cases where the new helix algorithm is different from the original one, the cases where originally a TrkPatRec helix was selected and now the CalPatRec one is selected and vice versa.
- I compare the **de.alg** variable of the original and the new helix for each event and if they are different i.e “1 0” or “0 1” they are inserted into the histogram.
- We did not observe any significant change here either where there was the maximum chance to see a change because these are particularly cases where the original and new helices are different from one another (in terms of their source)



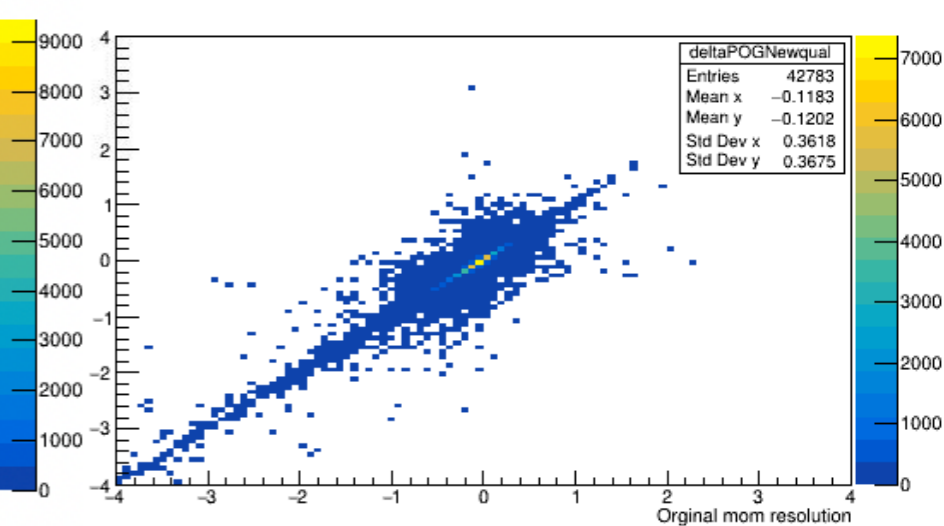
Momentum resolution



Momentum resolution, TrkQlty > 0.4



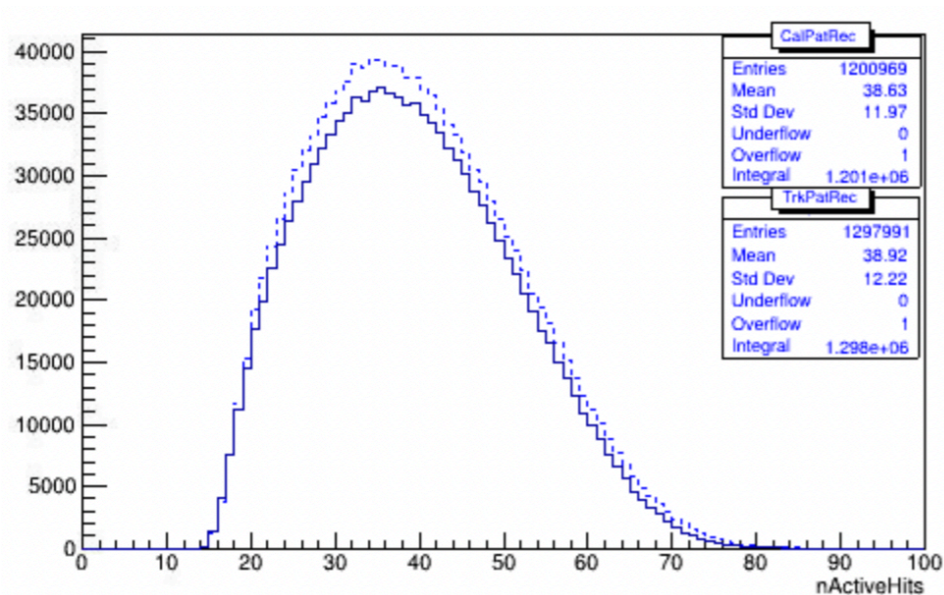
New v/s Original momentum resolution



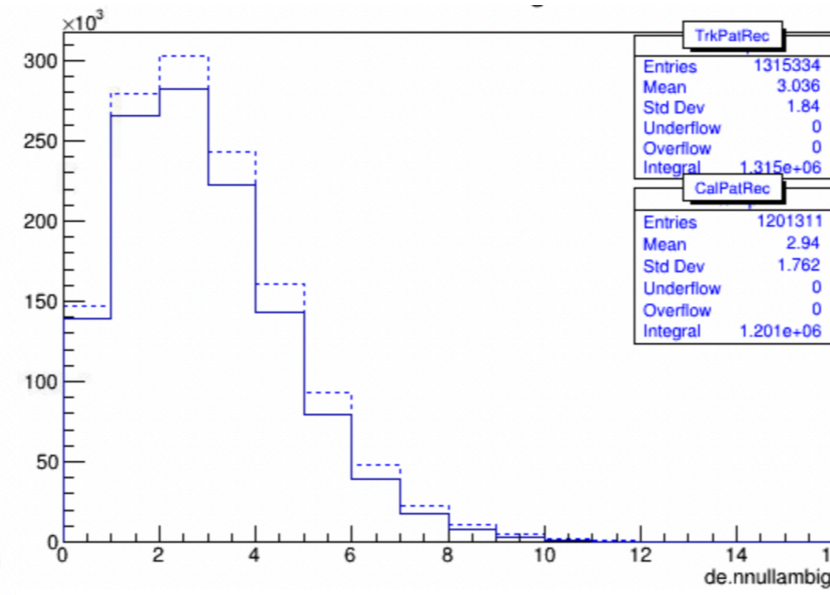
New v/s Original momentum resolution with TrkQlty > 0.4

Check with just CalPatRec and TrkPatRec helices

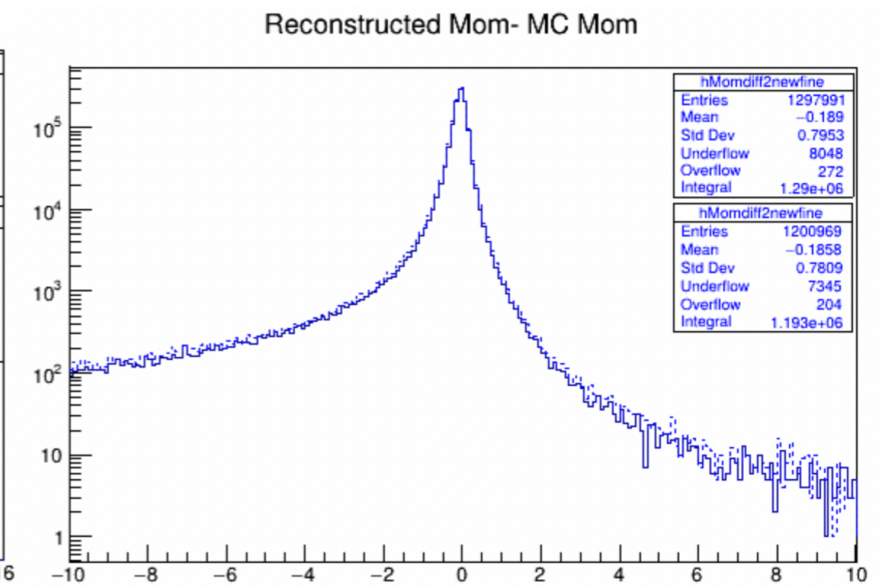
- The absence of a difference between the results using either of the helices led us to check the individual algorithms separately.
- — — — — is the TrkPatRec only tracks and ————— are the CalPatRec only tracks.
- From the histograms, it is evident that both the pattern recognition algorithms give very similar results.
- Note : The difference in the number of entries in the histograms is only due to the fact that some of the files did not run completely when I submitted the jobs in the grid (the CalPatRec only case).



nActiveHits



nNullAmbiguity



Momentum resolution

Conclusion

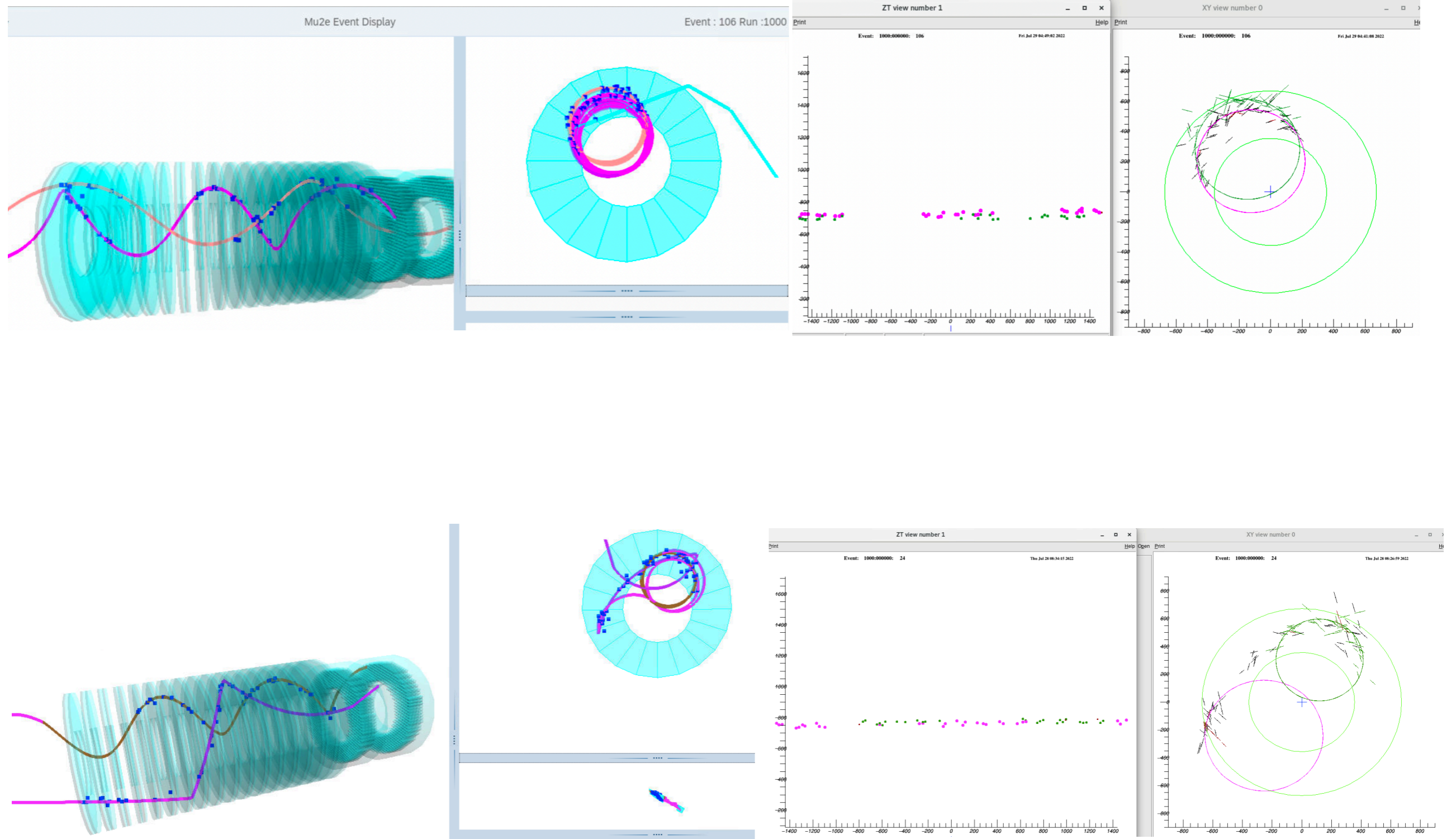
- The number of hits and the chi-squared values of the helix are the two important parameters for helix selection. Earlier, there was a bias in selection due to the different modes of chi-square calculation for TrkPatRec and CalPatRec helices.
- Now, a uniform chi-square calculation is implemented for all helices irrespective of the algorithm they are generated from.
- Now about 60% of the helices selected come from the TrkPatRec algorithm which was about 27% earlier.
- This change in helices does not seem to effect the final momentum resolution of the tracks much. We checked with data that contained only “TrkPatRec” and only “CalPatRec” helices and noticed that the momentum resolution of the final tracks are not very different.
- The $\Delta nHits = 5$ criteria introduced means that if the difference in hits between two helix candidates is < 5 then the chi2 of the helices is used as the selection criteria.

Antiproton Background study

Motivation

- One of the potential backgrounds for the Mu2e experiment is the $p\bar{p}$ annihilation that could occur at the Stopping Target, resulting in conversion electron like events.
- There are absorbers and collimator placed at different points along the Transport Solenoid (TS) to block the antiprotons from entering the Detector Solenoid (DS).
- Most of the antiprotons are expected to hit the walls of the TS and not make it to the DS.
- About 4.4% events have two MC particle tracks and each track has > 20 Straw hits i.e possibly reconstructible 2 track events.
- 3.4% of the events have an electron track with > 20 Straw hits.
- 0.18% of the events have an electron track with > 20 Straw hits and in the momentum range 90-110 MeV.
- Successful reconstruction of the 2 track events could help to estimate the number of conversion electron like events contributed by the $p\bar{p}$ annihilation.

A visual inspection of some interesting events



Phi Cluster Finder : An attempt to identify two simultaneous particle tracks

- Introduce the phi cluster finder after the time clustering stage in reconstruction.
- Start the search if the input time cluster has number of hits > 20 .
- Calculate the phi of every hit and fill the phi histogram.
- Find the bin with the highest content and look for all the bins around it with content $>$ threshold (set to 2 right now).
- This gives the minimum and maximum phi values.
- Loop through the list of hits and flag the hits with phi within this range as “UsedHits”. This would form one phi cluster.
- Now go through the list of hits again and if they are not “Usedhits” repeat the above procedure for those hits.
- Save the phi clusters as time clusters if they have greater than 20 straw hits. These clusters would be the input for the next stage of reconstruction, the helix finder.

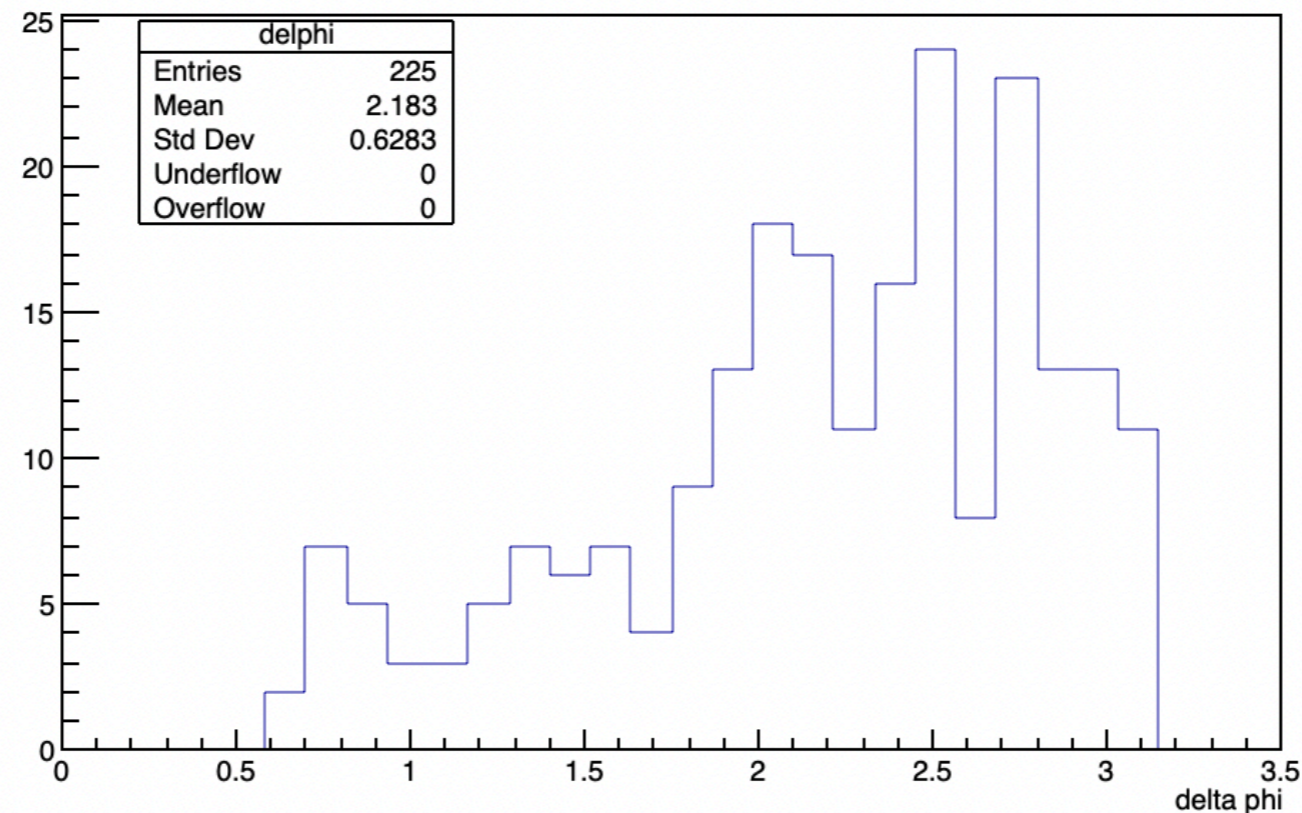
Delta phi

- Dataset : Pure ppbar annihilation events

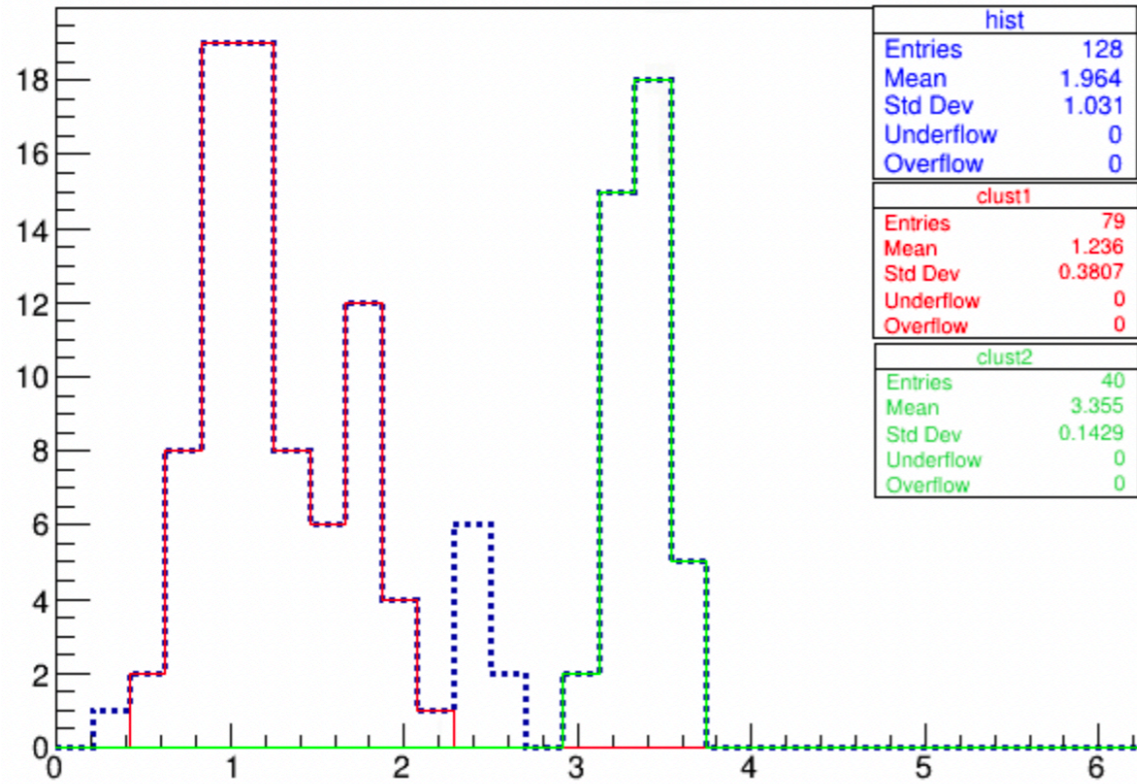
- No. Of events : 10,000

- $$\Delta\phi = \frac{\Sigma\phi_1}{n1} - \frac{\Sigma\phi_2}{n2}$$

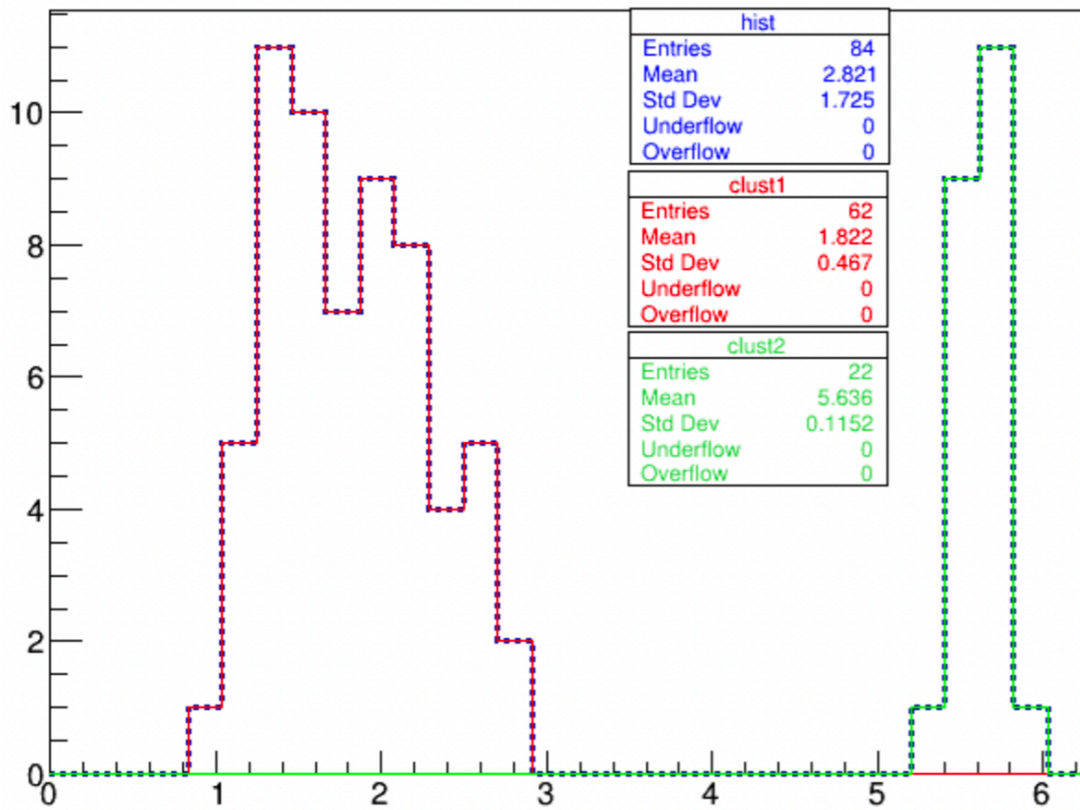
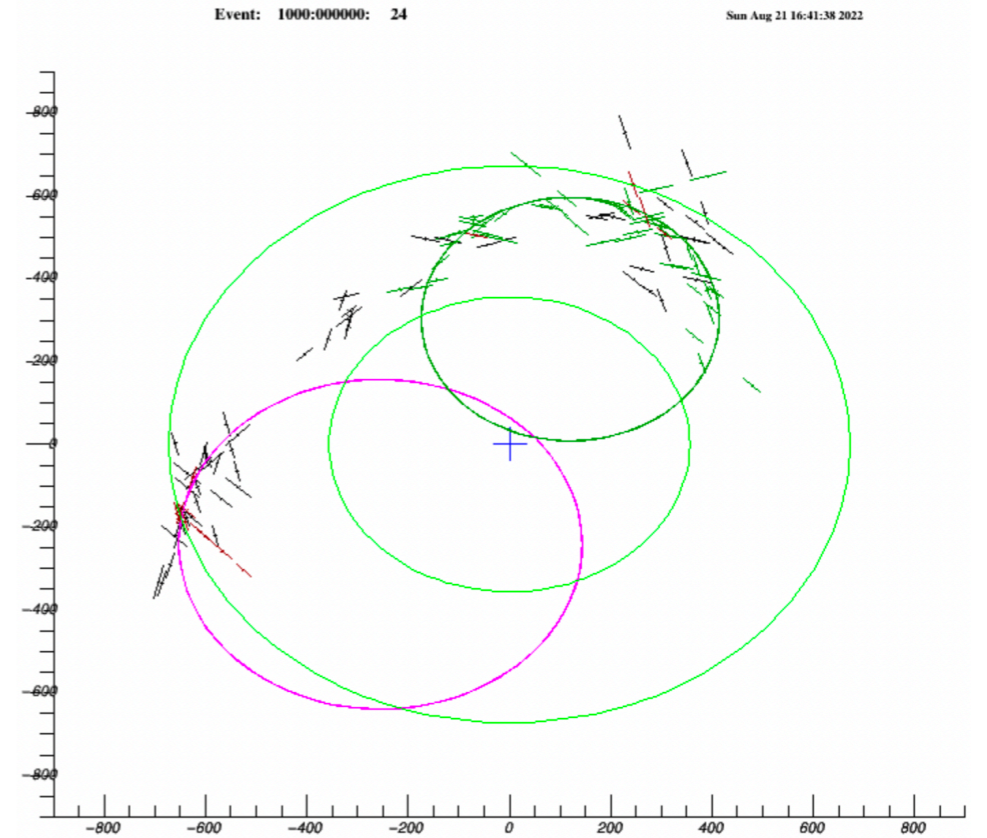
- No. Of potentially reconstructible events containing two particle tracks (after a selection cut at $\Delta\phi > 1.5$ rad) : 187



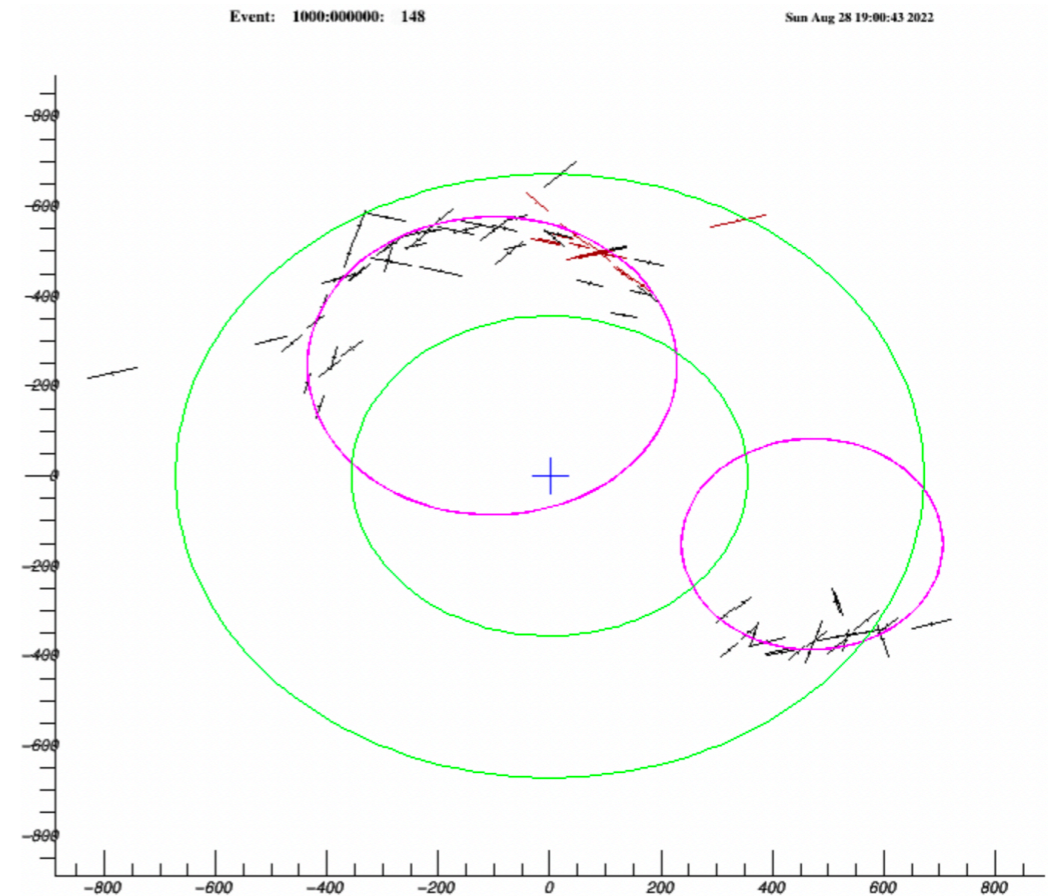
Some nice events

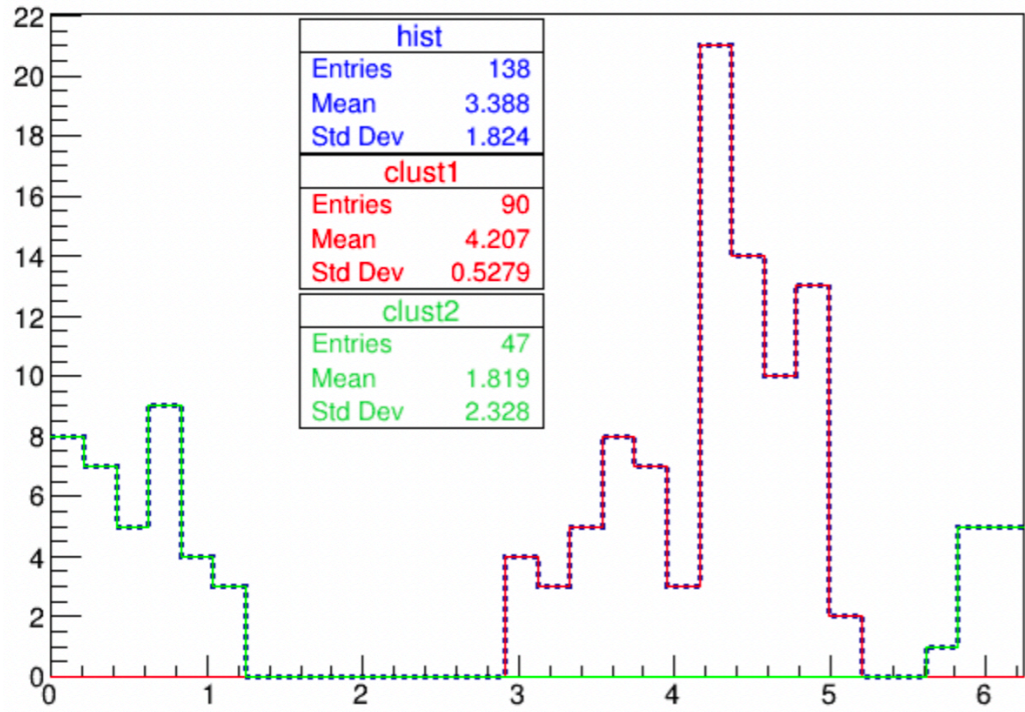


Event : 24 Delta phi : 2.11854

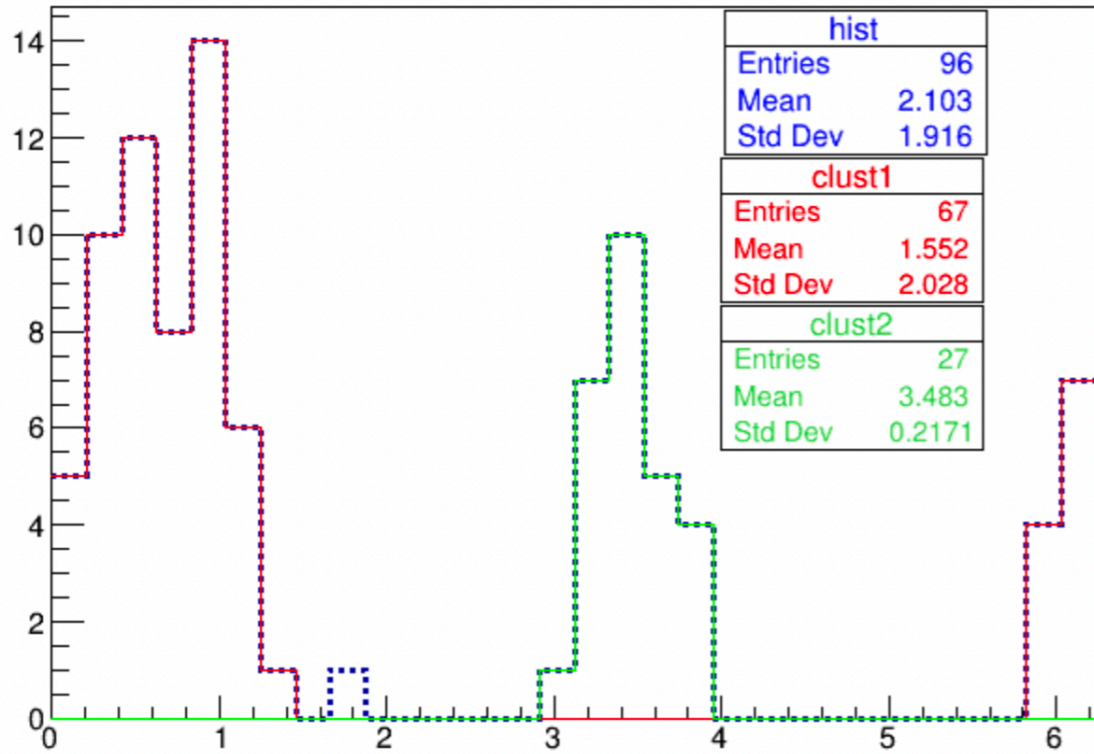
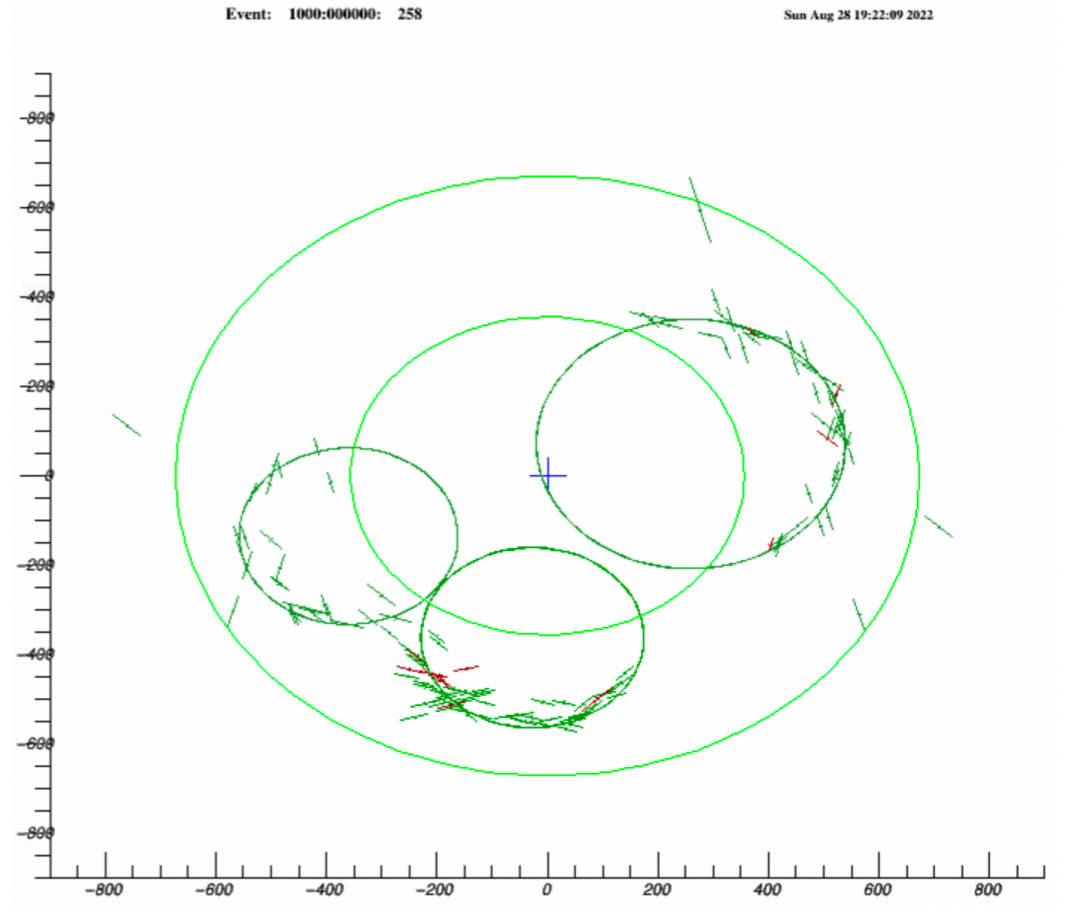


Event : 148 Delta phi : 2.46929

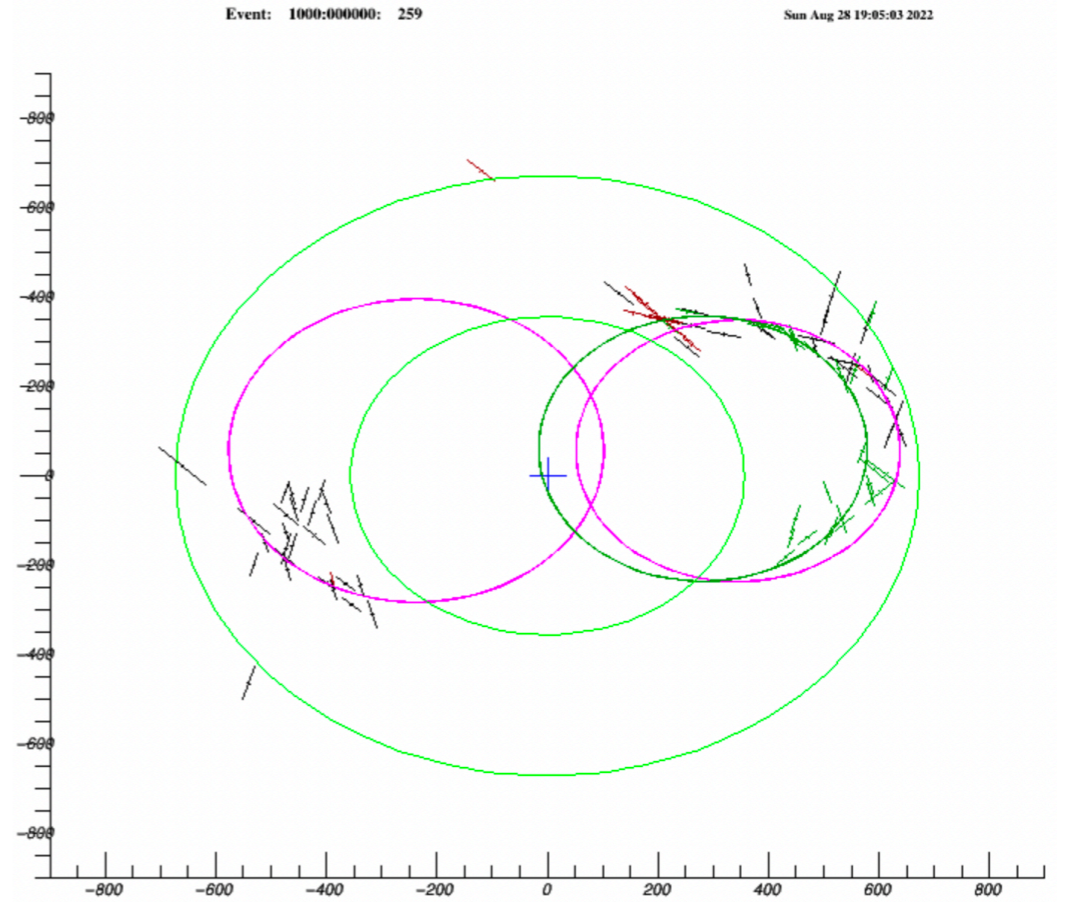




Event : 248 Delta phi : 2.42506

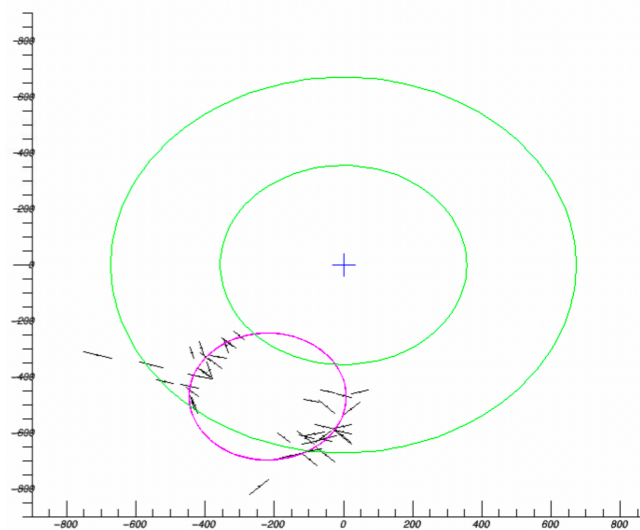
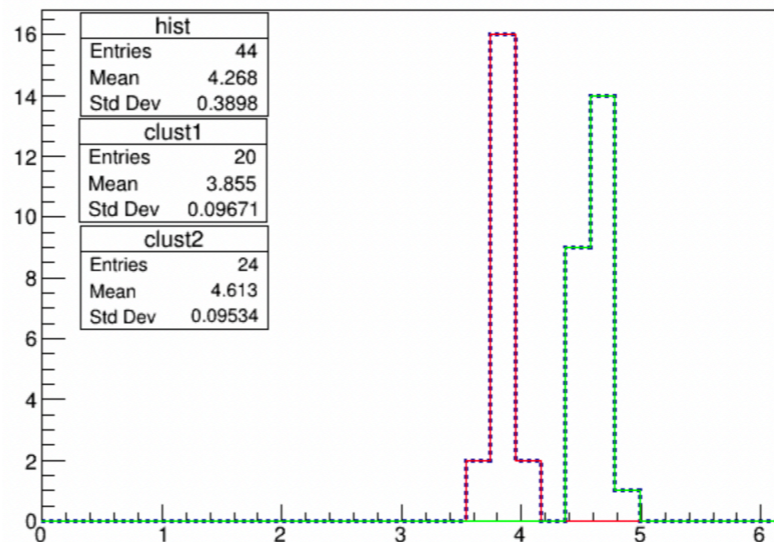
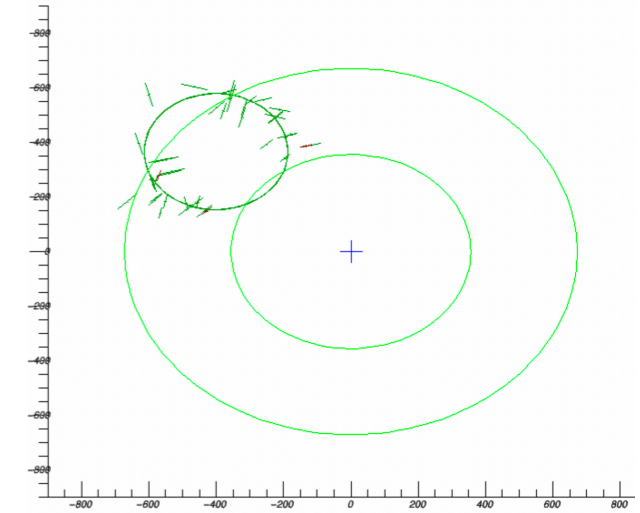
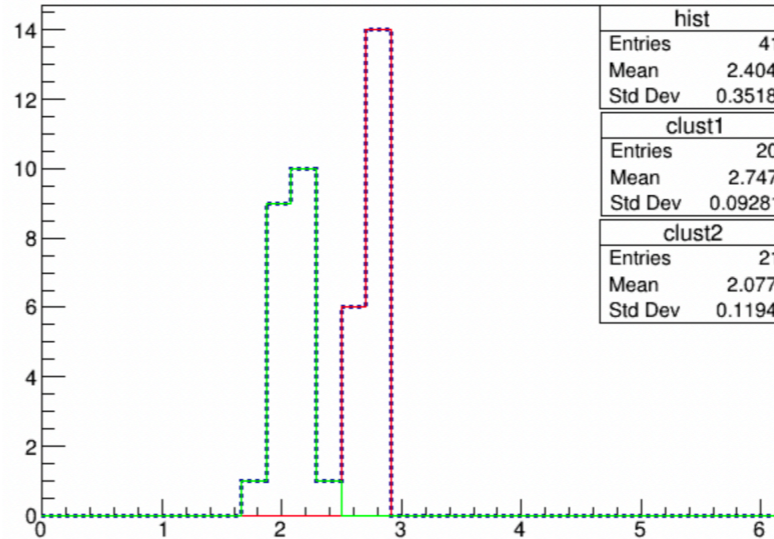
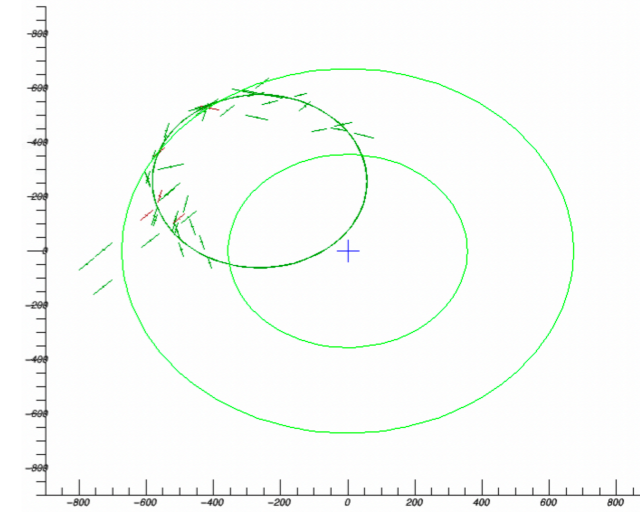
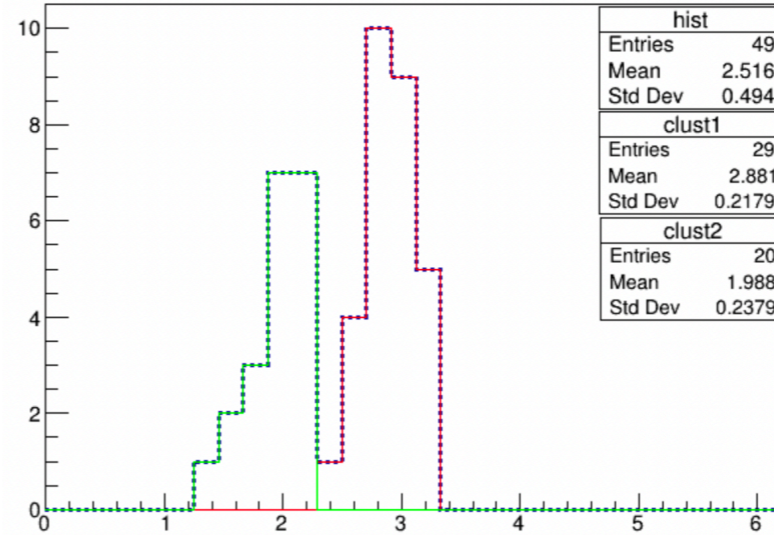


Event : 249 Delta phi : 2.96271



Events with delta phi < 1.0 investigated

- Event = 1507 Delta phi = 0.893319
- Event = 1737 Delta phi = 0.670281
- Event = 2099 Delta phi = 0.758703



Statistics

- Out of the 187 events with $\Delta\phi > 1.5$, 121 events are correctly matched 2 particle track events and 48 are ≥ 3 track events.
- Out of the 225 events, 138 events are correctly matched 2 particle track events and 50 are ≥ 3 track events.
- If a condition is placed to select events where 1 cluster has > 70 straw hits and a null second cluster 317 more events are selected.
- Out of the 317 events, 116 events are correctly matched 2 particle track events and 27 are ≥ 3 track events.
- But these events may be difficult to reconstruct.

Next steps

- Test the present reconstruction with the PhiClusterFinder stage introduced.
- Create and find better ways to reconstruct events with two simultaneous particle tracks. The present algorithm is designed particularly for the reconstruction of single conversion electron tracks.
- Study and test the algorithms with data containing background.

Conferences

- 54th Annual FNAL Users Meeting (August 2-6, 2021) Poster “Mu2e Event Display Development using the TEve Framework”
- New Perspectives 2021 Conference (August 16-19, 2021)Talk
- Congresso Nazionale della Società Italiana di Fisica (September 13-17, 2021) Talk “Mu2e Event Display Development using the TEve Framework”
- APS April Meeting 2022 (April 9-12, 2022) Talk “Mu2e Event Display Development : Using the TEve and REve Frameworks”
- 15th Pisa Meeting on Advanced Frontier Detectors (May 22-28, 2022) Poster
- 55th Annual FNAL Users Meeting (June 13-19, 2022) Poster “Mu2e Event Visualisation using TEve and Eve-7”
- New Perspectives 2022 Conference (June 16-22, 2022)Talk, Fermilab
- Mu2e Internal talks in the Comp-Soft and pbar2m meetings

Courses completed

- Statistical Analysis Lab by Prof. Punzi
- Introduction to Astrophysics by Prof. Del Posso, Prof. Shore et al
- Scientific Writing for Physicists
- PhD seminar about Plasma Wakefield Acceleration