TOF-track matching efficiency

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Abstract. This is part of a set of notes related to the run 10 analysis of ρ^0 meson production and the measurement of a diffraction pattern off the Au nuclei.

1. Paper title

Coherent Diffraction off Au Nuclei Measured at RHIC with ρ^0 Mesons Detected with the STAR Setup.

2. Introduction

The data collected during run 10 for Ultra Peripheral Collisions UPC was selected using two triggers: UPC_Main and UPC_Topo. Both triggers include signal originating in the Time Of Flight (TOF) detector system. The analysis the will be reported in the paper mentioned in the above uses events selected by the UPC_Main trigger. This trigger is defined by a multiplicity cut in the number of hits in TOF; at least 2 hits and no more than 6 hits. (At the level of information available to the trigger system a "TOF hit" is defined as a TOF module with signal, at most this defintion could translate into 6 TOF cells with signal above predetermined threshold).

The luminosity of the Au+Au run in 2010 was high and the information recorded in the TPC may include tracks originating from collisions that happened in bunch crossings before or after the triggered crossing. Other events may record multiple interactions in the same crossing, each interaction is clearly seen as a single vertex for collisions in the same bunch crossing or pairs of vertices for events from earlier or latter crossings. One of the first steps of the analysis consists on identifiying the triggered event vertex in the TPC, that connection is done using the match between TPC tracks and TOF hits during the overall reconstruction of the event. The condition imposed on the event forces at least one of tracks originating from a particular vertex to extrapolate onto a TOF cell which has signal above a predefined threshold. The resulting physics yields extracted from our analyses need to be corrected up because, as explained below, the matching is not perfect.

3. Datasets

In order to study the matching between TOF hits and TPC tracks we generated a set of UPC output trees (picoDst) which have the complete StMuTrack structure for the tracks in the selected UPC events. Global tracks that extrapolate to TOF hits are also stored as objects of the same class. We also stored the complete information about the vertices in each event as objects of the StMuPrimaryVertex class. The driver for the generation of these datasets is the xml file used to submit the jobs with STAR scheduler: ...UPC/run10AuAu200/ submitTracksFromFile.xml

```
<?xml version="1.0" encoding="utf-8" ?>
<job eventsPerHour="25000" minEvents="2000" maxEvents="84000" softLimits="true"
     fileListSyntax="xrootd" >
<command>
starnew
cd /star/u/ramdebbe/UPC/run10AuAu200
root4star -q -b /star/u/ramdebbe/UPC/run12_QA/doMuEventWithTracks.C\(\"$FILELIST\",
\"$SCRATCH/$JOBID.tree.root\"\)
</command>
      <stdout URL="file:/star/data05/scratch/ramdebbe/\$JOBID.out"/>
      <stderr URL="file:/star/data05/scratch/ramdebbe/\$JOBID.err"/>
<input URL="catalog:star.bnl.gov?production=P10ik,trgsetupname=AuAu200_production,
filetype=daq_reco_MuDst,storage=local,filename~st_upc,
runnumber[]11066001-11070043" nFiles="all" />$
      <output fromScratch="*.root" toURL="file:/star/data05/scratch/ramdebbe/" />
</job>
```

The output generated during those jobs produced 68 files stored at this moment in:
$/star/data05/scratch/ramdebbe/C21DD108E24819BB5678F471E04EB279\_*.tree.root$

4. Analysis

The output trees mentioned above are read with a root macro generated with the MakeClass method of the TTree class. The macro used in this analysis can be found in: .../UPC/run10AuAu200/TOFmatch/processData.C and .h files.

Prior to the extraction of the TOF matching efficiency one needs to define the geometrical acceptance of the TOF detector, to do that we use reconstructed tracks that have been matched succesfully to hits in TOF elements. The TOF detector is installed around the STAR TPC in the trays that used to house the CTB detector. The TOF detector consists of 120 "trays" 60 of them installed around the West TPC side and the same number on the East side. Five TOF trays overlap the azimuthal coverage of a TPC readout sector. Each TOF tray houses 32 "modules". A module is an actual MRPC (Multiple Resistive Plate Counter). The signal left by charged particles traversing a module is read out with 6 conductive pads which define further segmentation into the so called TOF "cells". Figure 1 shows the arrangement of modules inside one of the TOF trays. The polar angle orientation of the modules favors the detection of particles originating from the nominal interaction point (z=0).

Figure 2 shows the azimuthal angle at the end of the tracks versus the z coordinate of the yz projection of the track extrapolated to the nominal middle of the TOF detector. The outside radius of the TPC is 200 cm, the TOF trays are placed at radii of 207.8 cm and are 13.2 cm thich, the nominal middle of the TOF is thus at radius 214.4 cm. The location of the TPC six sector boundaries is clearly visible as horizontal lines, the HV membrane separating the two drift volumes of the TPC is also visible. The TOF modules are also visible in this figure. Their visibility is enhanced if one projects the distribution onto the horizontal axis (z coordinate of the intersection of extrapolated track and middle of the TOF detector). Such projection is shown in Fig. 3. The edge of the TOF detector along the z axis of the STAR setup is then defined by the tracks hitting the 32nd modules on both sides; $z \pm 230.$ cm. Because of the fast falling number of tracks at those edges we fix the TOF z limit arbitrarily at $z \pm 230$ cm.

The overall acceptance for the TOF detector has been calculated before. In particular, Fig. 4 shows the variation of that acceptance for a wide z vertex distribution ($\sigma_z = 100$ cm), z vertex coordinates extending widely: $|z_{vtx}| < 100$ cm and three pseudo-rapidity windows. These results are applicable to our analysis because we have a cut in vertex coordinate of $|z_{vtx}| < 100$ cm and we impose rapidity conditions on our selected pions $|y_\pi| < 1$.

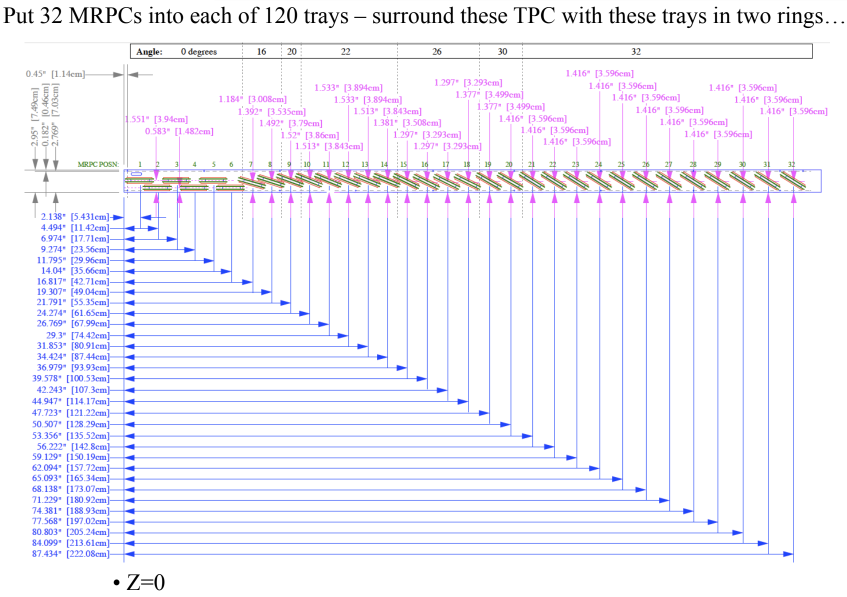

Figure 1. A diagram of the location of 32 TOF modules into one tray. (extracted from [1])

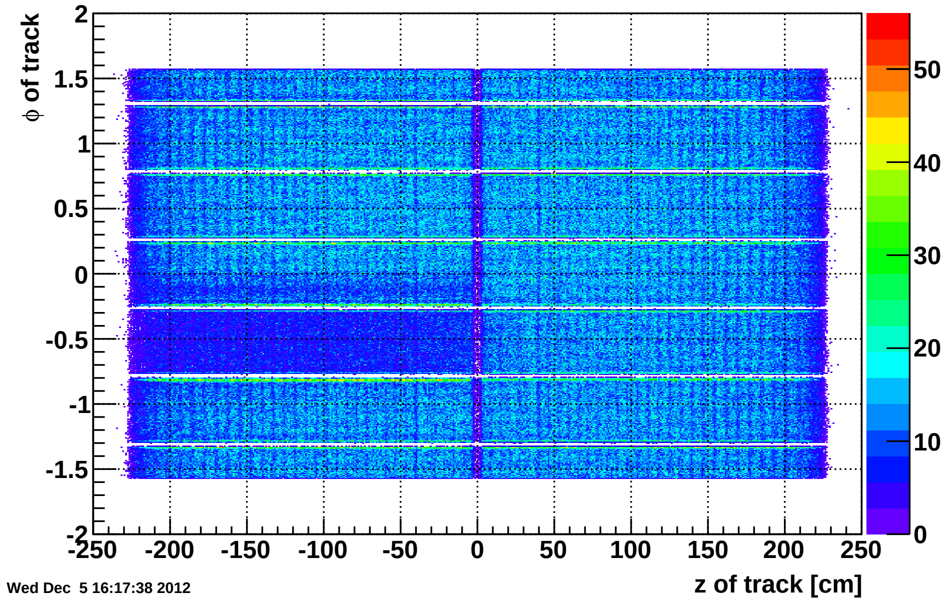

Figure 2. This figure shows the impact of charged particles on the nominal middle of the TOF detector. The vertical shows the azimuthal angle at the end point of the track that extrapolates to a live TOF cell, the horizontal axis shows the z coordinate of the intersection of the same tracks and a cylinder (R=214.4 cm) that defines the nominal middle of the TOF detector.

The one component of the geometrical acceptance of the TOF detector will thus be the cut on the z coordinate of extrapolated track intersecting the TOF middle cylinder (R=214.4 cm): $|z_{midTOF}| <= 220$ cm. From now on this component of the acceptance will be refered to as

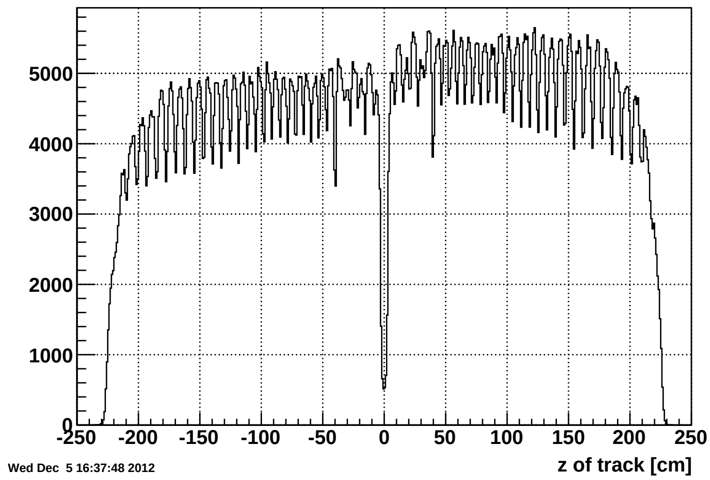

Figure 3. Projection of Fig. 2 over the horizontal axis (z coordinate of the track at intercept with the middle of the TOF detector (R=214.4cm). The first 31 modules per tray are clearly visible. Module 32 is only seen as change of slope on the rapidily falling counts at the edge to the TOF detector.

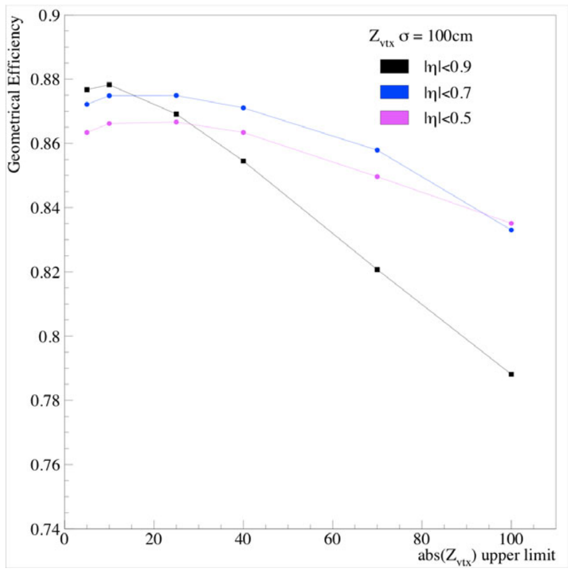

Figure 4. Geometrical acceptance of the TOF detector evaluated with a gaussian vertex distribution with σ_{vertex} = 100 cm. The horizontal axis shows the upper limit to the z coordinate of the vertices. The vertical axis shows the extracted geometrical acceptance for tracks emanating from those vertices within three different pseudo-rapidity windows. The point that is closer to the condition found in our UPC analyses is the one shown with black square markers ($|\eta| < 0.9$) at Z_{vtx} upper limit=100 which has the geometrical acceptance equal to 79%.(extracted from [1])

"TOF z acceptance". The rest of the TOF acceptance is determined by its segmentation. Such segmentation can be seen in Fig. 2 up to the “TOF module” granularity.

4.1. Track selection

The tracks that extrapolate to TOF active cells found in the muDsts have already been selected for at least two criteria: the number of hits used to construct them has a lower limit set at 14, and an implicit momentum appears at 100 MeV/c because particles with lower momenta would spiral in the magnetic field and will not reach the TOF elements. Figure 5 shows the correlation between the number of hits used to form the track and its measured momentum. Figure 6 shows the same distribution but this time for all primary tracks originating from vertices already selected as explained in the subsection below. In this figure one can see that the majority of tracks in these UPC analyses have low momenta ($p < 1$ GeV/c), the majotity of the tracks have in average ~ 35 hits, and tracks with number of hits smaller than 14 for a separate blob.

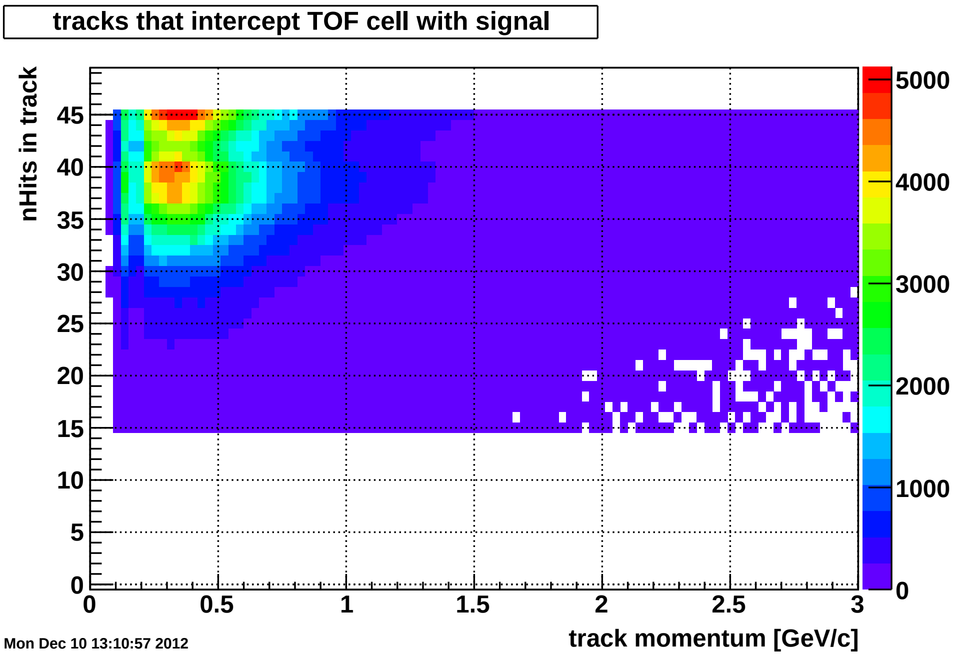

Figure 5. Number of hits used to build the track that extrapolated onto a TOF cell with signal correlated to the value of its measured momentum. The tracks found in the MuDst have already been cut on the minimum number of hits (14). Tracks with momenta as low as 100 MeV are included in this correlation. The majority of the tracks appear to be of good quality with more than 30 hits. The second “blob” at nHits=45 is not yet understood. These tracks originate from tracks with ratio $r \geq 0.02$ (see next subsection)

In summary, tracks used to extract the TOF matching efficiency had to originate from a selected vertex, they should have a minum number of hits set at 14, and finally, we also impose a low momentum cut at $p \geq 150$ MeV/c.

4.2. Vertex selection

To extract the TOF matching efficiency we count tracks originating from the same vertex separately for all vertices recorded in an event, the number of tracks that extrapolate onto a TOF cell with signal (refered as TOFtracks), as well as the number of tracks that extrapolate

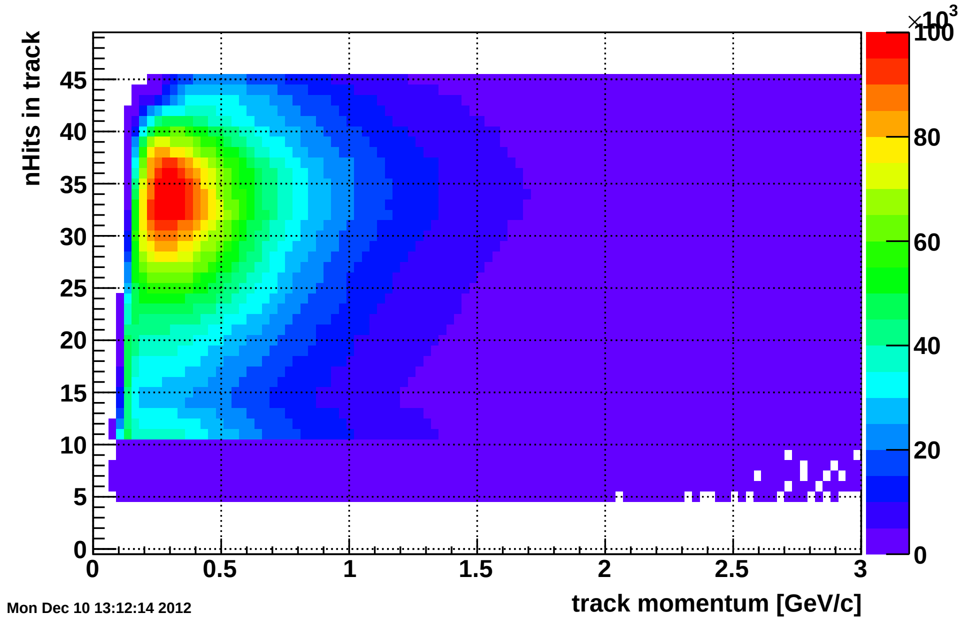

Figure 6. Same as Fig. 5 but this time the tracks are primaries from selected vertices ($r \geq 0.02$), they intercept the geometrical acceptance of the TOF detector. Tracks with low momentum and number of hits below 14 tend to be related to particles spiralling inside the TPC active volume.

into the TOF z acceptance (refered as TPCtracks). The ratio of those counts

$$r = (number\ of\ TOFtracks)/(number\ of\ TPCtracks)$$

for each vertex is shown in Fig. 7. The entries to the first bins of that plot have values that are so small as to be suspicious. The yz projection of tracks from a sample of those events has been saved in pdf format in the directory: .../UPC/run10AuAu200/TOFmatch/figuresLt01. Two of those events are shown in figures 8 and 9.

The efficiency for matching tracks to TOF hits in events like the ones included in our analysis where we put wide cuts in the z coordinate of the vertex and rapidity cuts $|\eta| < 1$ is expected to have the value $0.8 \times 0.9 \times 0.9 \sim 0.65$ where the first value is the TOF geometrical acceptance, the second one quantifies the TOF detector efficiency and the third one is related to the TPC detection and offline reconstruction efficiency. Vertices with one or two TOFtracks and up to hundreds of primary tracks are clearly spurious, they are more likely coincidences with TOF hits related to background. We have studied the TOF matching efficiency as function of the transverse momentum of the tracks for different cuts to the ratio r and found that we excluding vertices with r ranging from 0.01 to 0.2 produce an stable TOF match efficiency curve. We have then settle for the value r=0.02.

To contrast the display of events that are rejected from this analysis we also stored events that have a higher value of the ratio; r=0.5 Figures 10 and 11

5. Results and discussion

The ratio r extracted for each of the used vertices is assimilated to the TOF matching efficiency per track. Figure 12 shows that efficiency per track as function of the transverse momentum,

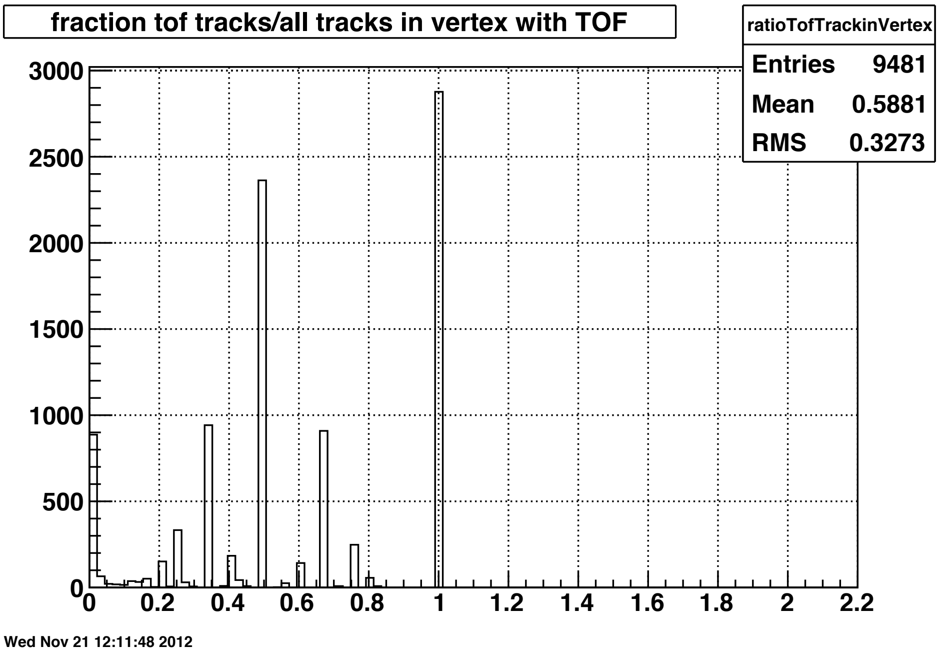

Figure 7. Ratio of number of tracks that extrapolate to a TOF hit over the number of all tracks in that particular vertex which extrapolate to the TOF z acceptance.

Fig. 13 shows similar results, the average value of r for all selected vertices, but this time expressed as function of the pseudo-rapidity of the tracks originating from it. Finally, Fig. 14 shows the TOF matching efficiency for ρ mesons as function of their rapidity. This last average is obtained from vertices that were found to have a ρ^0 meson decaying into two pions and no ther charged particles. The rapidity of the pions satisfies the condition $|y_\pi| < 1$ and the vertex has a wide distribution: $|z_{vtx}| < 100$ cm. At least one of those pions extrapolated onto a TOF cell with signal. Figure 15 shows the average value of r for similar vertices but this time their z coordinate is constrained to a narrow windod around 0 ($|z_{vtx}| < 5$cm). With such narrow vertex distribution the physical edges of the TOF detector are visible in rapidity space.

References

[1] Talk given at Juniors Session, STAR Analysis Meeting, BNL March 14, 2011 by W. Llope `http://wjllope.rice.edu/~WJLlope/-myPublications/JrsMtgTalk_20110314.pdf`.

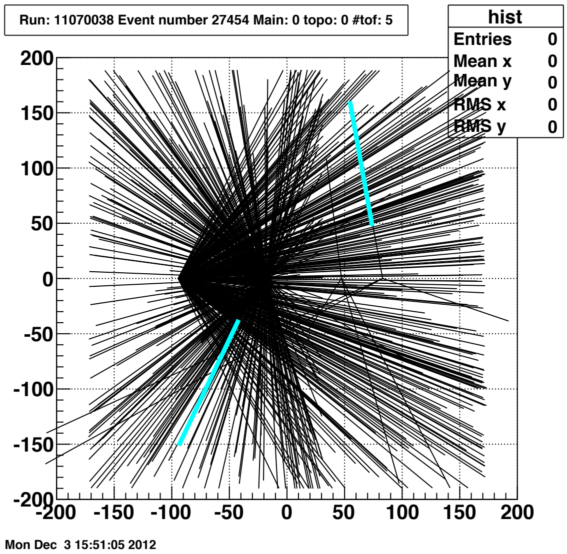

Figure 8. The yz projection of global tracks associated with a TOF hit are displayed in cyan color. The black lines show primary tracks in the event. In this event one can see at least four vertices, Two of those vertices have a big number of tracks that originate from them, in reality they for a single vertex from a collision that happened after the trigger. A single track originating from those events intercepts a live TOF cell, the value of the ratio r for that vertex is small. The third vertex has four tracks one of which connects to a TOF hit, the value of the ratio in this case would be 0.25. The fourth vertex at $z \sim 50$ cm does not have a track extending to a TOF cell with signal, it is thus not included in this analysis.

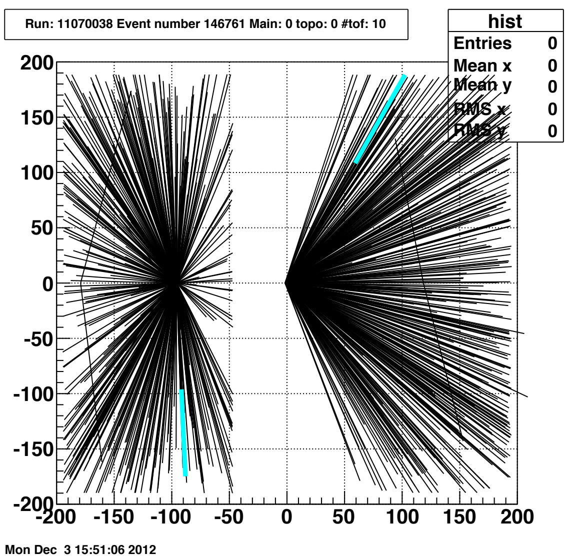

Figure 9. The yz projection primary tracks shown with black lines appear to originate from at least three vertices. What actually happened in this event is a collision before the trigger at $z_{vertex} \sim -50$ cm Ionization left by its tracks has drifted left and right by the time difference between its actual collison time and the trigger time. This event has two tracks connecting to TOF live cells but the value of the ratio r would be so small that it will be rejected from the analysis. Another vertex with two tracks is seen at z=-175 cm but it does not extrapolate to TOF cells.

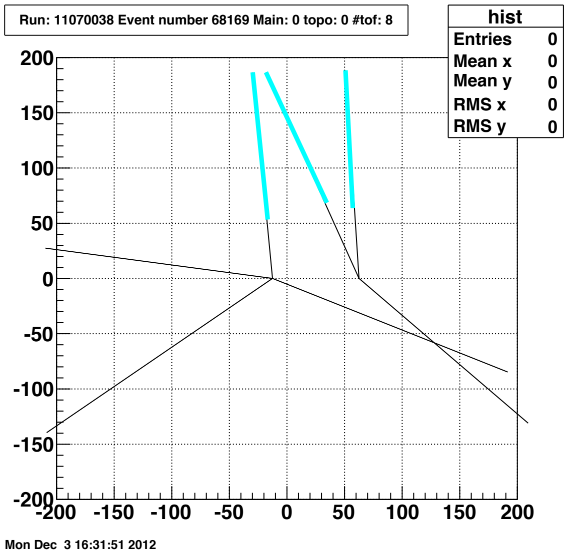

Figure 10. The yz projection of global tracks associated with a TOF hit are displayed in cyan color. The black lines show primary tracks in the event. This event has two vertices, both have tracks extrapolating to a TOF live cell, the value of the ratio r for both vertices is high and they will be included in the anlysis separately.

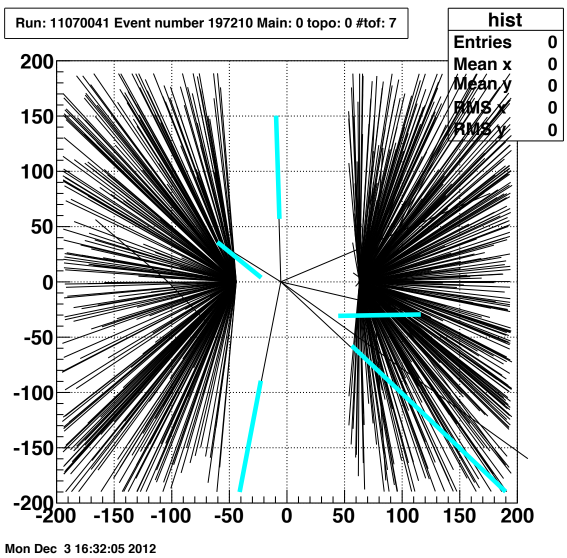

Figure 11. The yz projection of global tracks associated with a TOF hit are displayed in cyan color. The black lines show primary tracks in the event. In this event one can see at least three vertices. The one with z coordinate close to 0, has sevent tracks, four of them extrapolate to a TOF hit. This vertex is to be included in the TOF matching efficiency extraction. The other two vertices with $|z| \sim 50$ cm were recorded in an earlier bunch crossing and the drift of the ionization has produced the artificial split of the event. These "separated vertices" are not included in the analysis because none of their tracks connect to a live TOF cell.

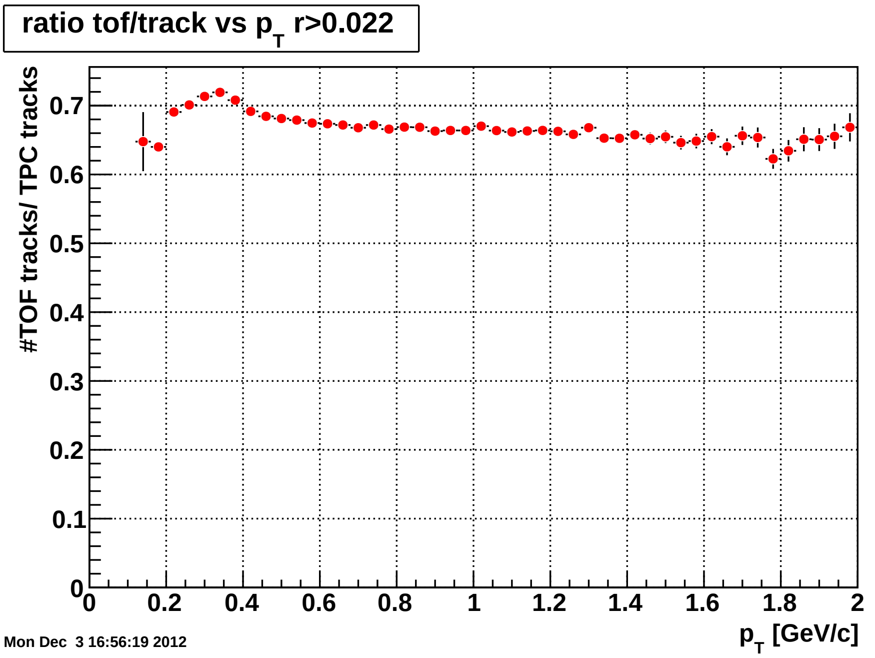

Figure 12. Average value of the ratio r of the vertex as function of the transverse momentum of the tracks originating from it. Vertices with $R \leq 0.02$ are excluded from the sample.

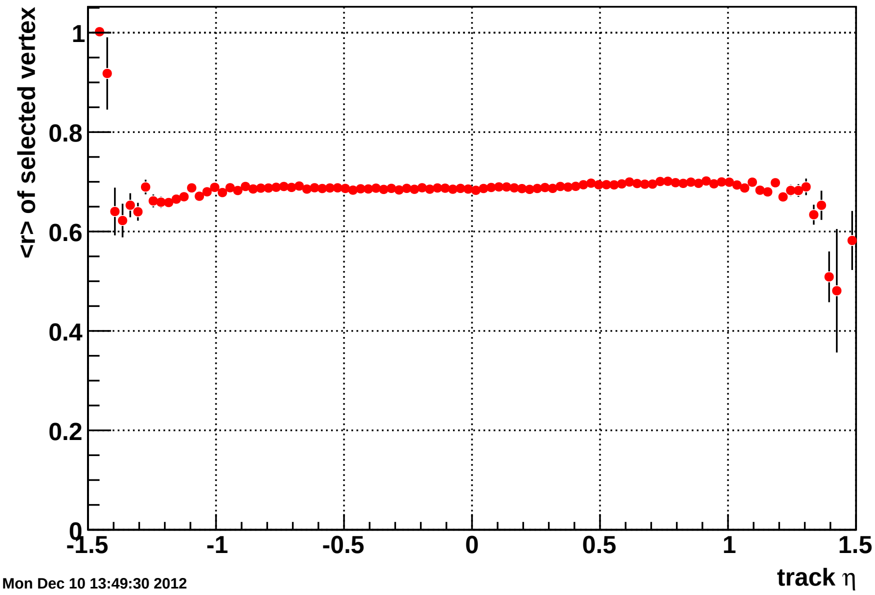

Figure 13. Average value of the ratio r of selected vertices as function of the pseudo-rapidity of the tracks originating from it. Vertices with $R \leq 0.02$ are excluded from the sample.

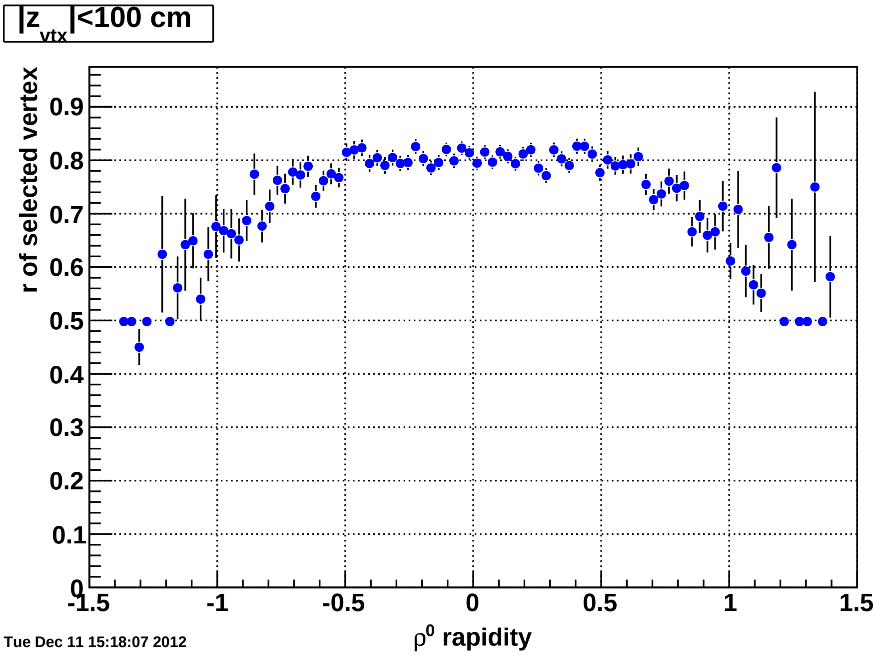

Figure 14. Average value of the ratio r of selected vertices as function of the rapidity of the ρ mesons candidates reconstructed them. The vertices included in this sample have only two tracks and the invariant mass of the pions related to them fall within the mass selection for a ρ meson $(0.5 \leq M_\rho \leq 1.0$ GeV.

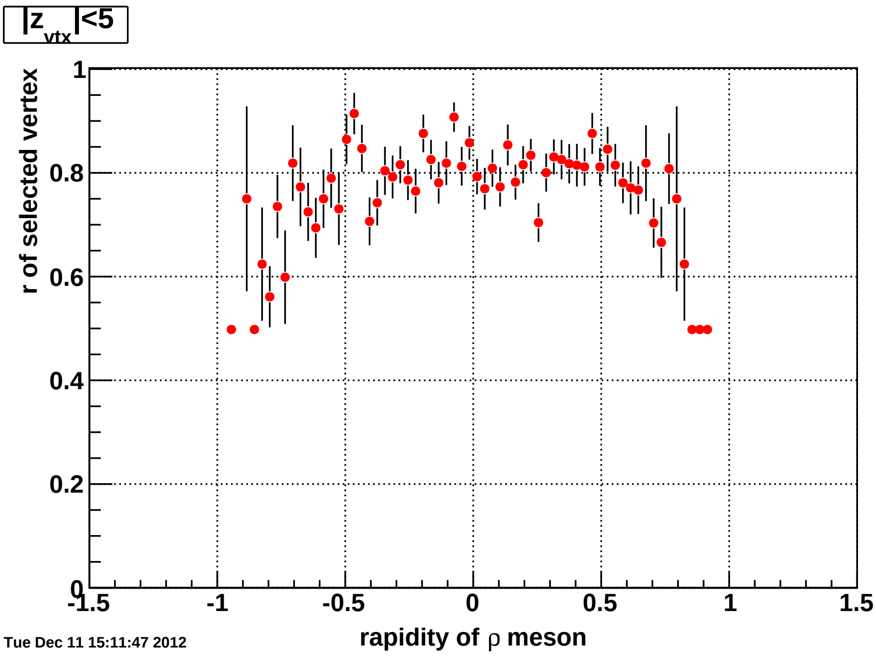

Figure 15. Average value of the ratio r of selected two track vertices as function of the rapidity of the ρ mesons candidates reconstructed in them. The distribution of z coordinate of those vertices is narrow: $|z_{vtx}| < 5$ cm. in it.