Current work on D0 reconstruction using a μvertex code a.k.a *MuKpi* macro

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The goal of this document is to give (for us) a current status of where we are, what we have studied concerning *MuKpi* macro.
A comparison between D0 variables from the reconstructed code will also be compared to the parameters given as input in the simulation (GEANT).

1 Brief introduction to the code

This μvertex macro is used to associate positive and negative tracks in order to built the invariant mass of the D0, via the decay channel :

$$D0 \rightarrow K^- + \pi^+ \tag{1}$$

(which branching ratio is 3.8$\%$)
We use 3 different datasets :

- pure D0 sample, where only 1 D0 is generated by event ($\simeq$ 950 files)
- D0 mix sample : 1 D0 embedded with Cu+Cu at $\sqrt{s}$ = 200 GeV Hijing ($\sim$ 250 files)
- real data from STAR run V Cu+Cu collisions

MuKpi macro acts like :

- it has several loops on event structure stored in MuDst.root file
  file $\rightarrow$ event $\rightarrow$ number of vertex $\rightarrow$ number of tracks
- we use an event selection using a z_{vertex} cut at |20| cm
- the loop over tracks applies also quality cut :
  1. number of TPC fits hits
  2. transverse momentum p_T
  3. pseudorapidity η

4. dEdx track length

These cuts are applied for both positive and negative daughters. The identification of K^-, π^+ is done using energy loss from the TPC and by applying cuts on $N_\sigma^{(K^-,\pi^+)}$. Once a positive and negative track is found, one calculates :

- the decay length using a weighted average of length obtained from projection of each track on $K^-.\pi^-$ total momentum (direction)
- the invariant mass defined as :

$$M_{inv}^2 = M_+^2 + M_-^2 + 2(E_+E_- - \vec{p_+}\vec{p_-}) \tag{2}$$

1.1 Description of the different steps in *MuKpi macro*

1. selection of files to be analyzed is done by opening a text file containing the paths of these root files
2. definition of histograms and trees
3. loop over file, beginning at *while (iter.Next)*
4. loop over vertices : index = **l**
5. cut on the z_{vertex} position less than 20 cm in absolute value and cut on its resolution in Z : $0 \leq \sigma_{vertex} \leq 800 \mu$m
6. definition of η_{min} and η_{max} relative to the edge of the SSD
7. first loop over primary tracks collection : index is **k**. If the primary vertex index of the **k** track is different from **l**, drop the event.
8. set to **kg** the index **k** : it is used to get the corresponding global track
9. multiple cuts are done on :
   (a) the number of fit hits in TPC (N$\geq$15)
   (b) the transverse momentum p_T ($\geq$0.1 MeV/c^{-1})
   (c) the pseudorapidity η : $\eta_{min} \leq \eta \leq \eta_{max}$
   (d) on the tracklength ($\geq$ 40 cm)

2 Investigation of cuts

2.1 pure D0 sample

In this sample, a D0 is decaying according to eq.1. However, there are others tracks generated in a given event.
The D0 parameters have been set ; we can check[1], for example, that the position of the z_{vertex} has been done between -30 $\leq z_{vertex} \leq$ 30 (cm). (The red line indicates here our cut). A flat distribution is observed in Fig. 1, left. We also see that the D0's were generated with $0 \leq p_T \leq 5$ (GeV/c) (Fig. 1 from the right)

[1]Fig. 1 and Fig. 5 come from running MC data only : no match with *MuKpi* macro os used

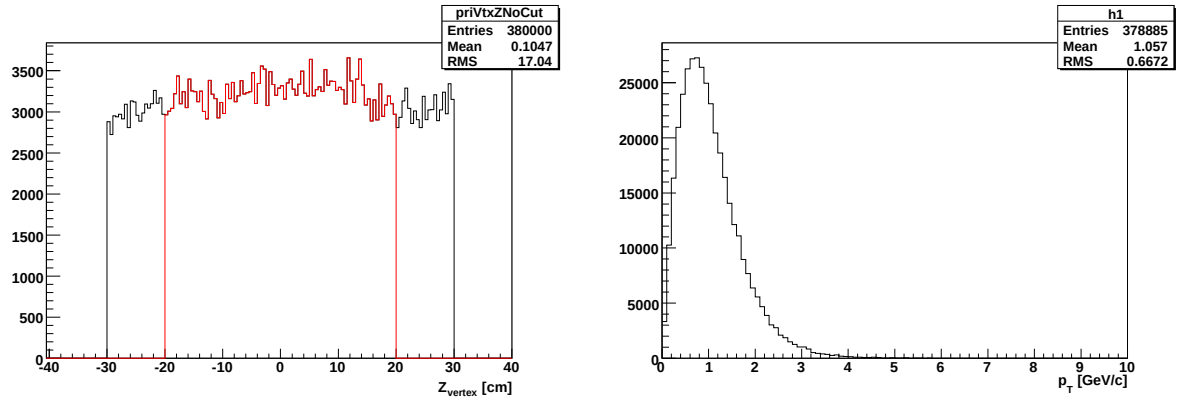

Figure 1: Position (cm) of the z_{vertex} (left); p_T of D0 generated

2.2 Study based on the number of hits used for daughters

First we can look at the reconstructed daughters tracks parameters for each D0.

The correlation between TPC hits and Si may not be trivial : in deed as shown in Fig. 2, one can find that positive tracks (plot on the left) with the maximum number of TPC hits (45) have equally 2,3 or 4 Si hits. The same remark is available for negative tracks (plot on the right).
The 2 plots on the top show the correlation between the p_T of positive and negative tracks as a function of their silicon hits. The same conclusion can be made : a mean $<p_T> \sim 1$ GeV/c for 2,3 and 4 silicon hits is found. (The actual distribution of p_T is shown in Fig. 4)

Concerning the daughters, the reconstructed transverse momentum p_T do not show any unexpected behavior (see Fig. 3 : blue line stands for positive, red for negative tracks).
No selection on Si hits is done here.

In details for the positive and negative tracks with 1,2,3 and 4 silicon hits. We can see that ,for this simulation, most of the tracks have 1,2 or 3 silicon hits. The number of tracks with 4 silicons hits appears to be a bit lower and at the limit, tracks with no silicon hits are much lower

This can be found also by plotting the distribution of silicon hits per tracks (cf Fig. 5)

Some observations :

- the distribution looks different from Fig. 4 because here we consider oly the input from GEANT
- no selection on η is done, so it can explained the number of tracks with no silicon hits
- tracks with more than 1 (3) hit(s) for SSD (SVT) are found

3 Matching the reconstruction and the GEANT data

The second step of the work was to match the reconstruction and the input data.
For this, we :

1. run *MuKpi* macro and collect the D0 reconstructed (which run number, file)

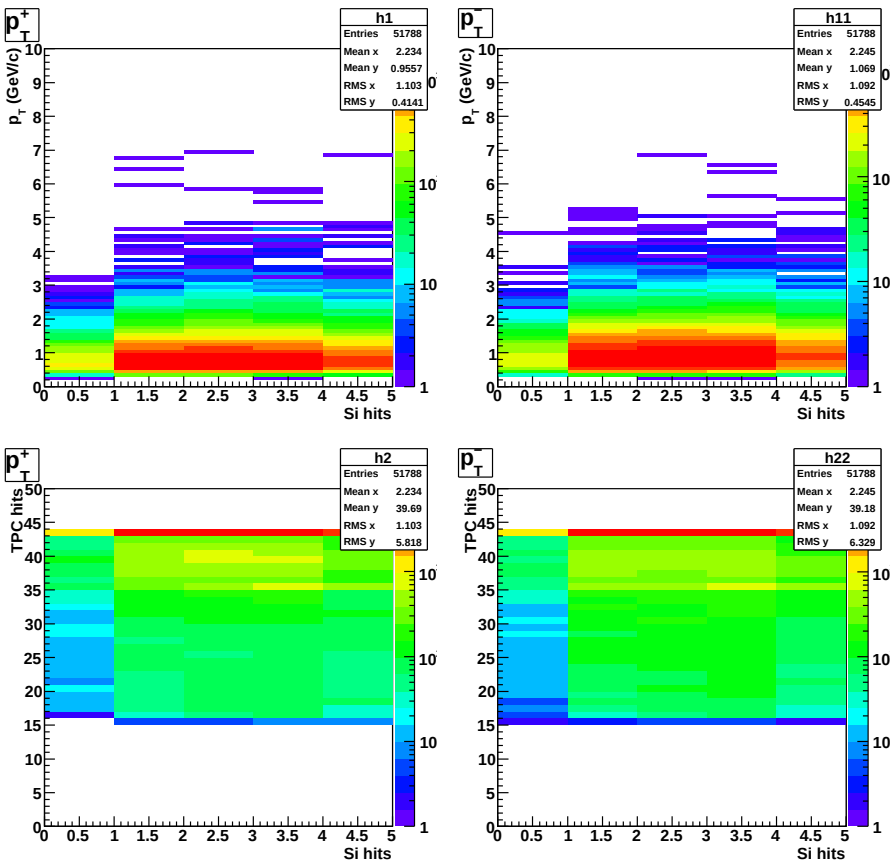

Figure 2: *top* : transverse momentum p_T vs. number of Si hits ; *bottom* : number of TPC hits vs. number of si hits for posititive and negative daughters

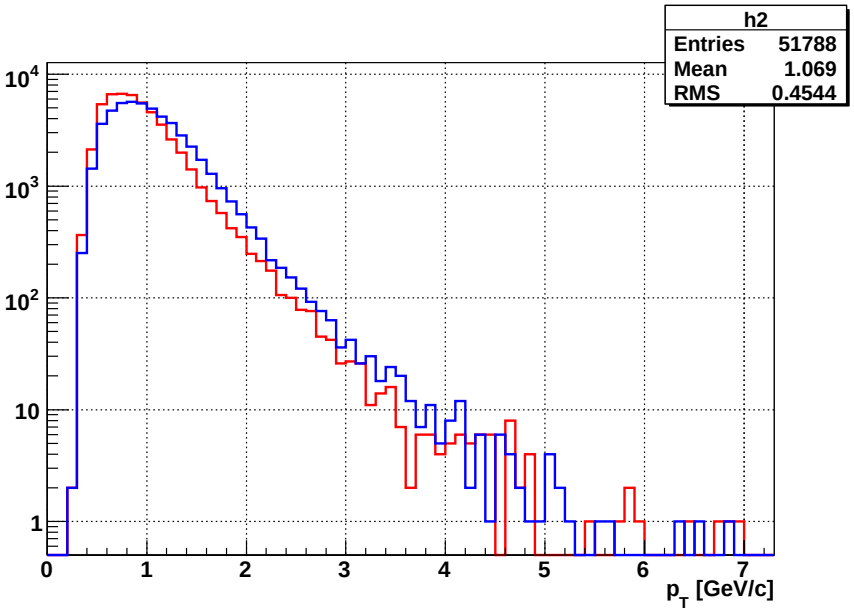

Figure 3: transverse momentum p_T of daughters

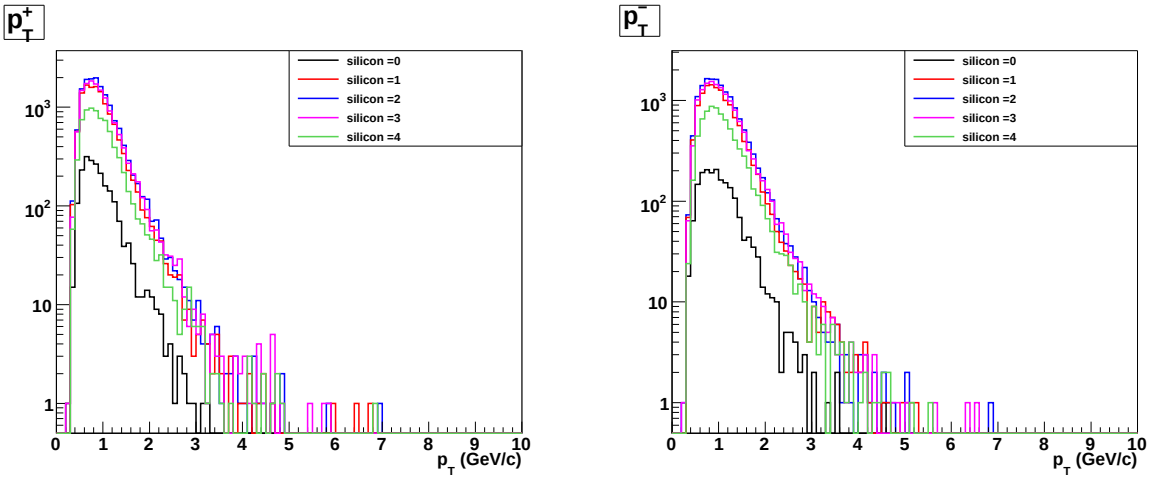

Figure 4: left (right) : transverse momentum p_T of positive (negative) daughters for different configurations of silicon hits

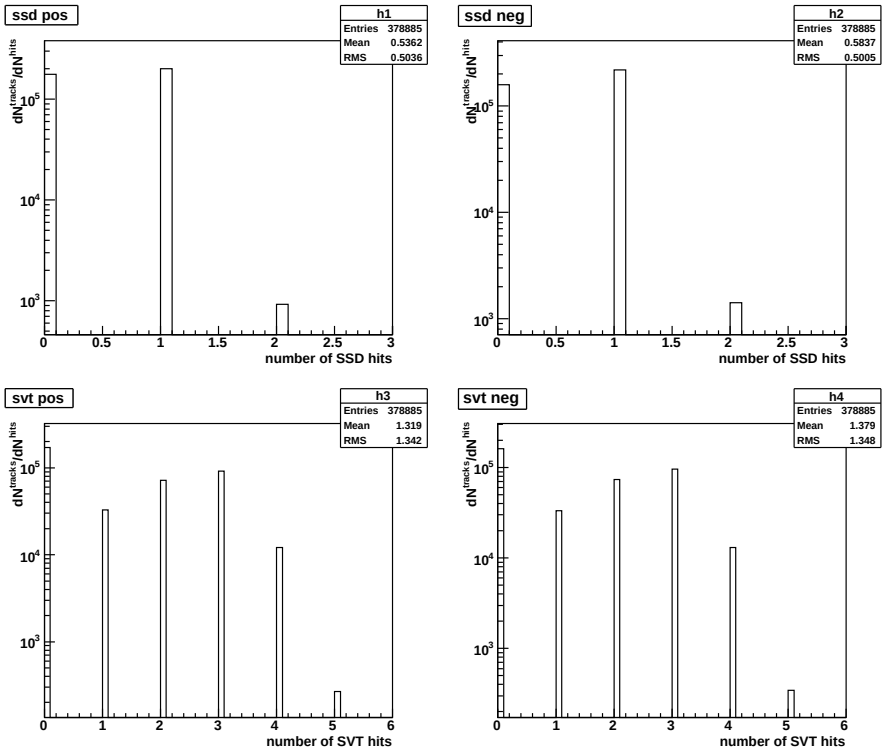

Figure 5: Number of Si hits for charged daughters from the D0

2. run over the same GEANT file and get the information for this D0
3. compare them
4. We also investigated how the previous parameters can affect the D0 mass peak

We noted that, in *MuKpi* macro, the first 2 tracks are the decaying daughters, whereas tracks with index $\geq$1 are the tracks generated due to secondary interactions ($e^{\pm}, \mu^{\pm}$).
This was a change with initial version of the macro from Yuri.
The following figure is obtained using no additionnal cut than those defined originally in *MuKpi* macro : it represents the invariant mass M_{D0} for the mix data available. No background substraction is done and a gaussian fit is applied to this distribution.

From the fit we obtain :

$$M_{D0} = (1.86 \pm 0.01097) MeV \tag{3}$$

Fig. 6 right shows that it seems to have background in the tracks associations. Investigation of cuts will help us to minimize this effect. For this study, we plotted the invariant mass as a function of a given parameter in a 2D histogram and fitted with a gaussian the projection on the mass axis in order to get the parameter of the fit (mean,). The next panel (Fig. 7) shows the invariant mass as a function of its p_T for

- no cuts applied (panel a)

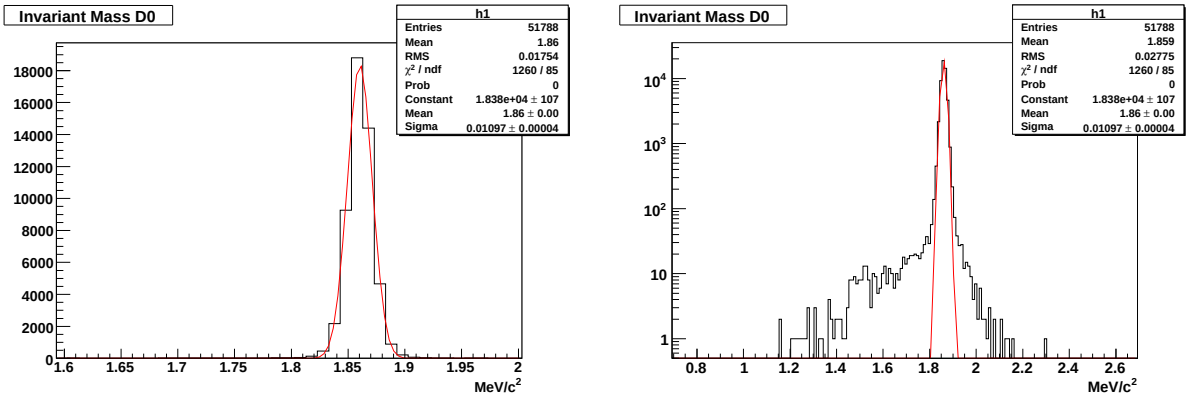

Figure 6: D0 invariant mass (left); represented in a log scale (right)

- cut on the number of fits hits in TPC ($\geq$40 for both positive and negative tracks associated to the D0)(panel b)
- cut on the number of silicon Si hits ($\geq$2 for both positive and negative tracks associated to the D0) (panel c)
- combined cut on the number of TPC and Si hits (with the values quoted above associated to the D0) (panel d)

The panel a) show that the background we saw on Fig. 6 is for the D0 with low transverse momentum. Once we applied a individual cut on the number of TPC or Si hits (panel b and c respectively), these associations are removed ; it has more effect when using a cut on the Si hits. A side effect is that we also decreased the number of D0 using those cut.
Ultimately, using a combined cut (panel d), we get a clean mass vs. p_T correlation but decreasing the statistic by a factor of 10.

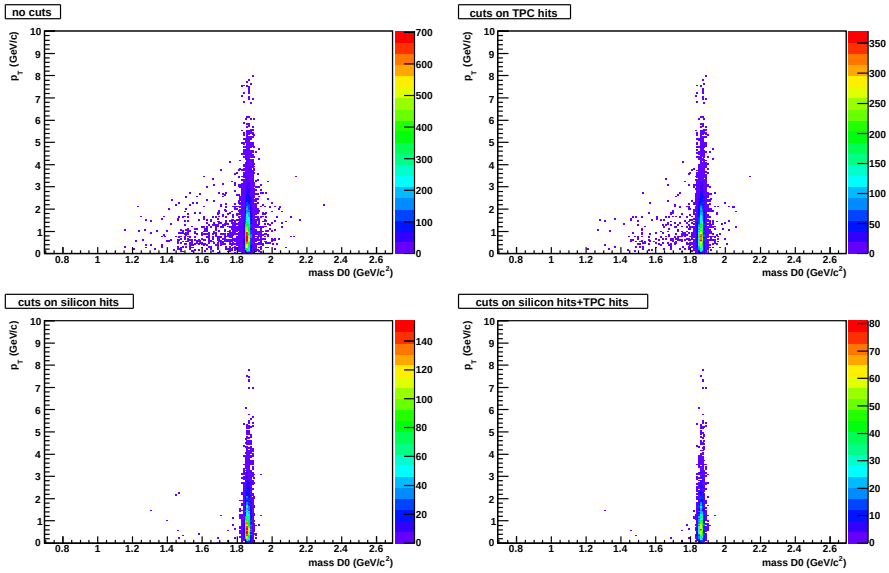

Figure 7: mass of D0 as a function of its transverse momentum p_T using cuts

A fit of the mass projection is shown in Fig. 8

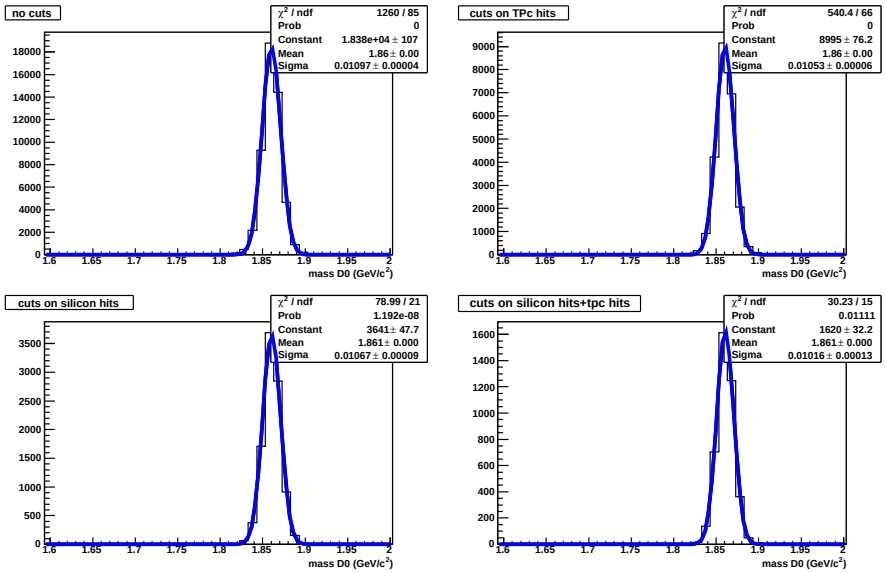

Figure 8: Fit of the mass of D0 using cuts

Cut	Entries	Mass	σ_{Mass}
none	51788	1.86037	0.01093
TPC hits	24274	1.86043	0.01052
Si hits	9815	1.86063	0.01066
TPC+Si	4155	1.86072	0.01015

Table 1: Fit results

3.1 Details for the cut on the number of TPC hits

Here I change the cut on the number of TPC hits from 20 to 40, for positive and negative separately and combined

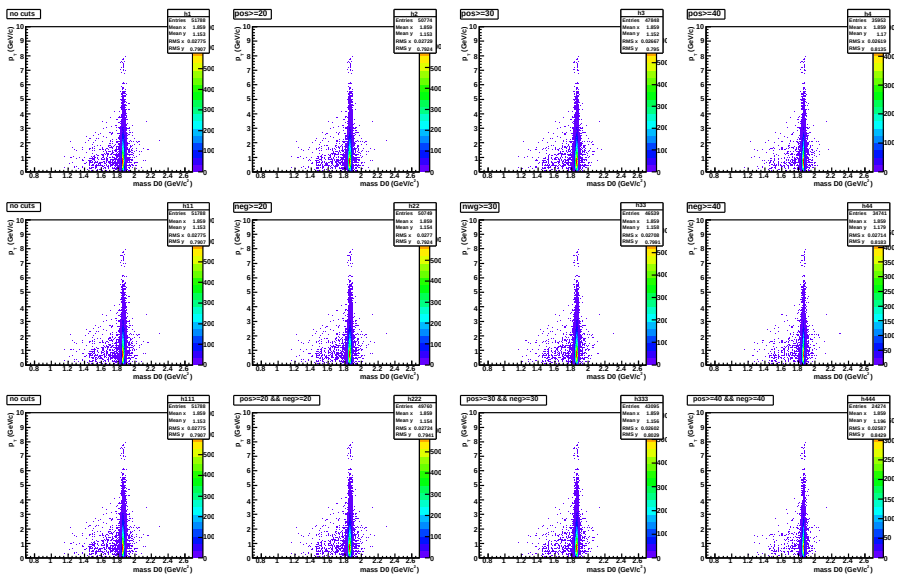

Figure 9: mass of D0 as a function of its transverse momentum p_T using cuts based on number of hits in TPC for the daughters

Number of Points for TPC tracks	20	30	40
positive	50774	47848	35953
negative	50749	46539	34741
positive and negative	49760	43095	24274

Table 2: Number of D0 after TPC hits cut

3.2 Details for the cut on the number of Si hits

Here I change the cut on the number of Si hits from 2 to 4, for positive and negative separately and combined

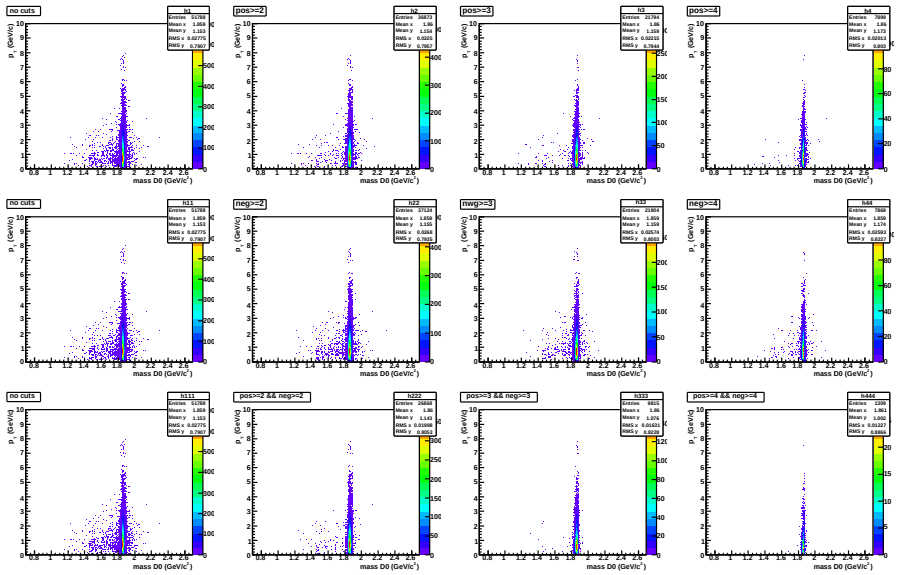

Figure 10: mass of D0 as a function of its transverse momentum p_T using cuts based on number of silicon hits for the daughters

Number of Points for Si tracks	2	3	4
positive	36873	21794	7899
negative	37124	21904	7869
positive and negative	26868	9815	1309

Table 3: Number of D0 after Si hits cut

Number of Si Hits	no cuts	2	3	4
positive	1.86037±0.0109692	1.86053± 0.0108802	1.86056±0.0108085	1.8607±0.0106959
negative	1.86037±0.0109692	1.86047±0.0108572	1.86057±0.0108255	1.86059±0.0108413
positive and negative	1.86037±0.0109692	1.86061±0.0107418	1.86063±0.0106677	1.86068±0.0110117

Table 4: Mass of D0 (mean,resolution) after Si hits cut

The corresponding plots are :

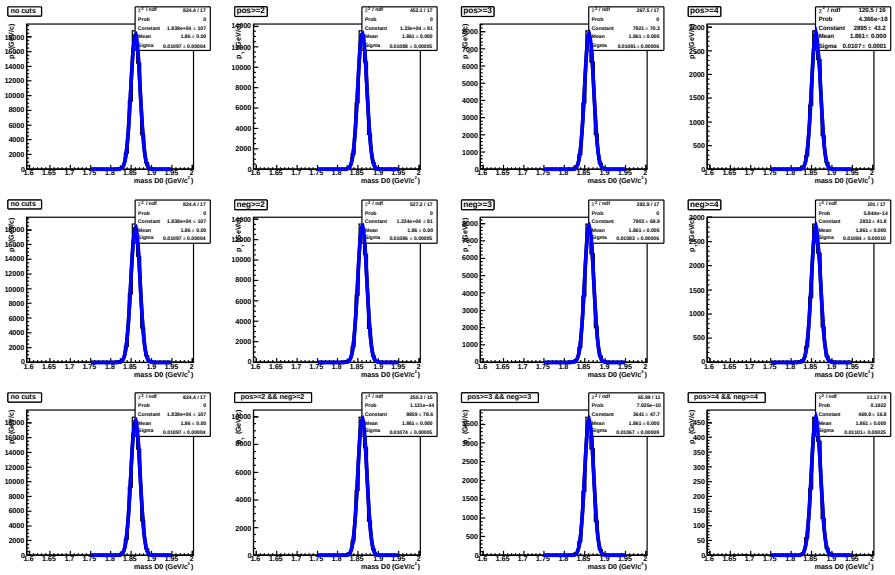

Figure 11: mass of D0 as a function of its transverse momentum p_T using cuts

3.3 Cuts on the pseudorapidity η of tracks

The following plot shows the pseudorapidity η of daughters of the D0 reconstructed. Lower and uper limit are $\sim |\eta|$<1.2, corresponding to the enveloppe of the SSD.

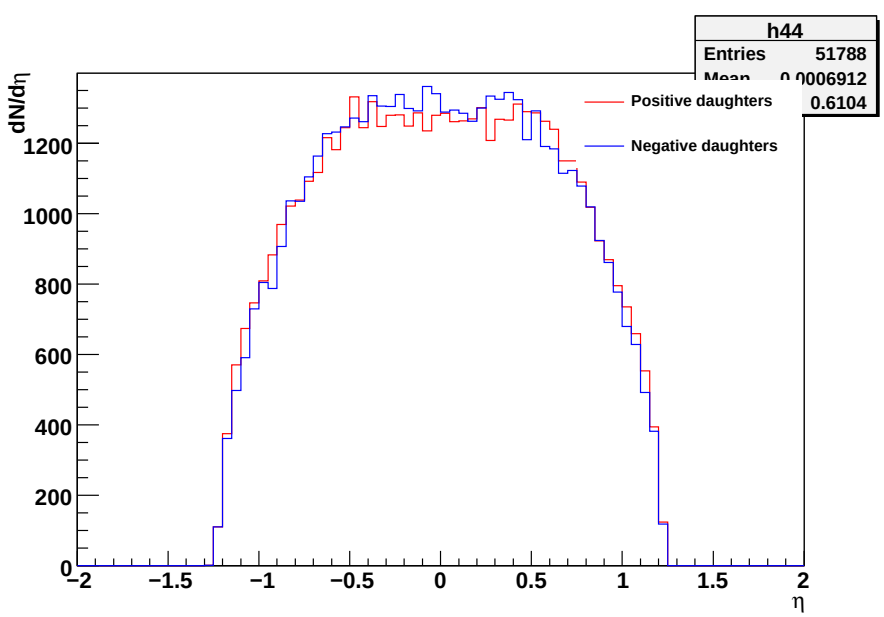

Figure 12: η distribution of D0's daughters

In details, these 2 plots show the correlation between the pseudorapidity of tracks and the number of silicon hits in those tracks.

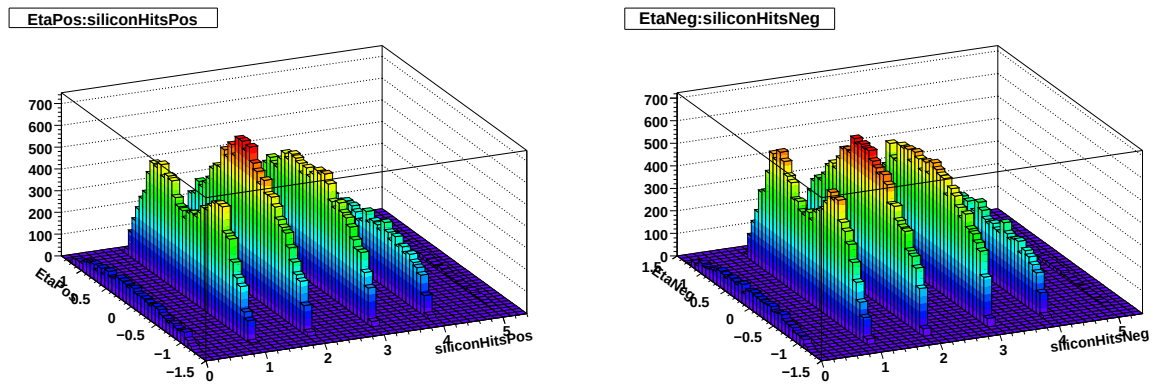

Figure 13: left (right) : η of positive (negative) tracks vs. the number of silicon hits

We can see a slight gap for tracks having only 1 silicon hits. However, this case is the result of tracks having 1 SSD hit and no SVT hits or no SSD hits and 1 SVT hits [2]. Another quantity interesting for the D0 reconstruction is to look at the η correlation between daughters :

$$\Delta\eta = \eta_{pos} - \eta_{neg} \tag{4}$$

The following plot shows the correlation between the pseudorapidity of the positive daughter (η_{pos}) and the negative daughter (η_{neg})

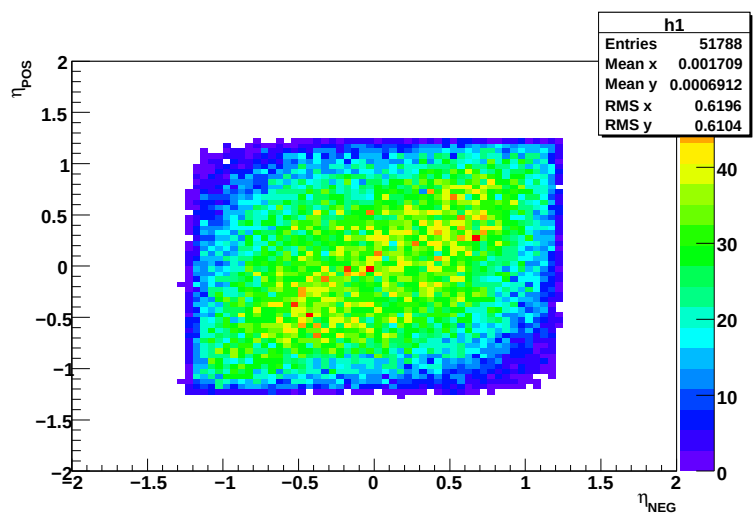

Figure 14: η_{pos} of the positive daughter as a function of η_{neg} of the negative daughter

We can see from 14 that the range of the pseudorapidity is correct, meaning that if one of the 2 daughters has it's pseudorapidity at $\eta\pm1.2$, the range for the associated opposite sign daughter will be also ±1.2. We find more entries (i.e stronger correlation) for :

[2] we don't disentangle these 2 cases actually when we fill the NTuple, maybe we have to

- if eta_{neg} is $\sim \pm$ 1, then η_{pos} is in the range η = [$\pm$1,0]

The 2 following plots show $\Delta\eta$ as a function of $\eta_{pos,neg}$

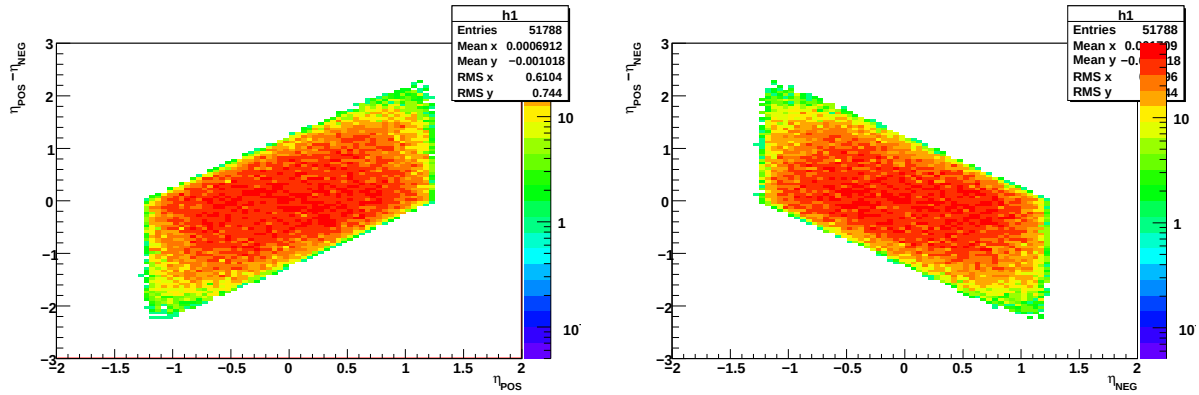

Figure 15: left (right) : $\Delta\eta$ as a function of $\eta_{pos,neg}$

We see, that at the limit of the range of pseudorapidity ($\pm$1.2), the maximum value is $|\Delta\eta| \sim 2.2$, which is in agreement with the detector (SSD) acceptance. That also means that we could find D0 (or a positive and negative tracks association) having this