Optimization of the rejection of the $t\bar{t}$ background for the search of SuperSymmetry

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1 Analysis of the L1_Met trigger

Before we begin to look for a way to optimize the reduction of the background we first need to look at the trigger on the Met that we will use after. This trigger is the L1_Met. We are going to use it because it select the events with a large missing energy, which is the case when you have neutralinos. What we want to determine is the percentage of events that go through the trigger in function of the Met of those events.We are then going to look for the cut to be applied on Met to have a trigger fully efficient.

To do that we are going to take the events that have been selected by an other trigger which is orthogonal to L1_Met, and look for those events which are also accepted by L1_Met. Knowing that the L1_Met trigger does not use the information from the muon chamber we are going to use the L1_MU20 trigger which is a trigger that accept all the events with at least one muon.

We are then going to compare the number of events that have been accepted by L1_MU20 with the number of events that have been accepted by both L1_MU20 and L1_Met and plot it in function of the Met calculated after the complet reconstruction (the trigger do his selection using a Met calculated before the complete reconstruction so it is less precise). This allows us to draw the graph that you can see below (Fig. 1). It is important to note that we need to add the impulsion of the muons to the Met to correct for the fact that the the muons are not use in the calculation of the Met in the L1_Met trigger.

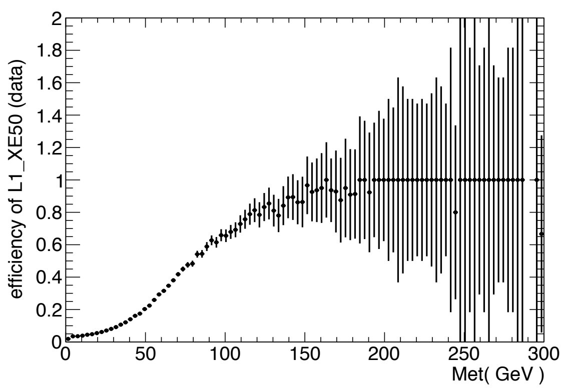


Figure 1
Efficiency of the L1_Met50 trigger

Now that we have drawn the efficiency of the trigger for the data, it could be a good idea to look if the graph is different for the Monte Carlo (Fig. 2). We can see that the two curves of the efficiency are almost the same and reach the plateau at the same Met value. This mean that we are going to be able to use those Monte Carlo data to look at the efficiency for different triggers threshold on the Met.

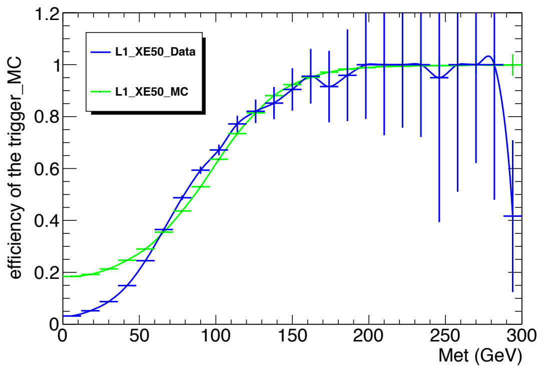


Figure 2
Comparison of the efficiency between the data and the Monte Carlo

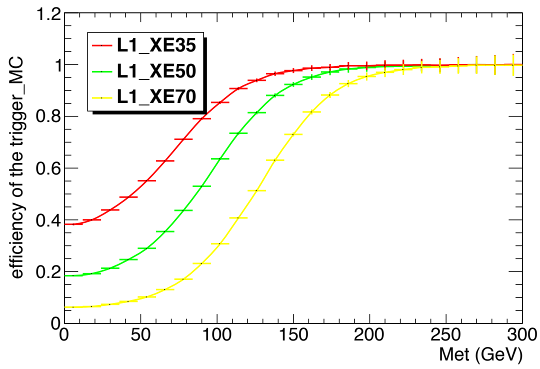


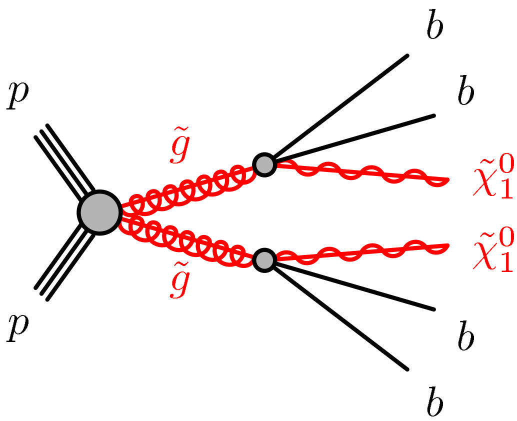
Figure 3
Comparison of the efficiency of the different L1_Met trigger

Now we want to compare the curve of efficiency of three triggers on the Met : L1_Met35, L1_Met50 and L1_Met70 (Fig. 3), the value after the trigger representing the threshold of this trigger. What we can see is that the lower this threshold is the sonner the curve reach the plateau. If we look at the the L1_Met50 trigger (which is the trigger that we are going to use later) we can see that it reach the plateau for a Met of 200 GeV. So we will do a preselection on the Met at 200 GeV so that we do not have worry about the difference in the trigger turn-on curve between data and Monte Carlo.

2 Optimization of the rejection of the $t\bar{t}$ background

2.1 Introduction

We are working on Susy events where two gluinos are produced and then decay into a 2 b quarks and the LSP (lightest supersymmetric particle) as we can see in the Feynman diagram below. The objective of this analysis is to optimize the selection of the events so that we can maximize the signal over background ratio. We are going to work on one the reduction of the $t\bar{t}$ background which is the main background for this signal.



To do that we are going to first look at different variables to compare their distribution for the $t\bar{t}$ background and the signal to determine if it is possible to use them for discriminating the signal from the background.
It is important to notice that each one of those distribution are going to be normalized to the unity. But all the other graph will be renormalized using the theoretical cross section of the process and a luminosity of $5fb^{-1}$.

2.2 Preselection

Before I show the result, of all those analyse I first need to present the different cut done in the preselection :

- 0 lepton or muon muon with $pt > 20GeV$
- ≥ 4 $jets$ with $pt \geq 30$ GeV
- ≥ 3 $jets$ b with $pt \geq 30$ GeV
- Met>200 GeV
- $\Delta\phi$ min (Met, jets) > 0.4

We use a veto on the lepton to reject all events with electrons and muons because the final state does not contain any of them. That way we could normally reduce the background without affecting the signal. In a same way we can ask to have at least 4 jets because that is what we are suppose to see in the final state but we only ask for 3 b jets because the efficiency of the reconstruction is only 85%, so there is a probability of only 50% that the 4 b coming from $\tilde{g}\tilde{g}$ are identified as b jets.

We then cut on the Met, keeping only events with a Met greater than 200 GeV. That way we are at the maximum of efficiency of trigger on the Met. We use this preselection because the LSP are neutralinos which does not interact with the detector, creating a large Missing energy.

To finish we are doing a preselection on the angle $\Delta\phi$ between the Met and the 4 leading jets . This preselection is use to reject the multijet background. In this background the Met is created by a jet energy mismesurement such that the Met is aligned with the jet Pt.

2.3 Comparaison of variable that can be used to reduce the background

For this comparison we are going to look at four variables to see we we can use them to discriminate on the signal and the background that in order to increase the significance.

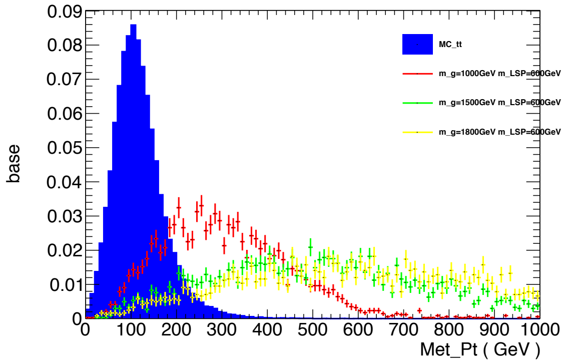


Figure 4
Number of event in function of Met_Pt

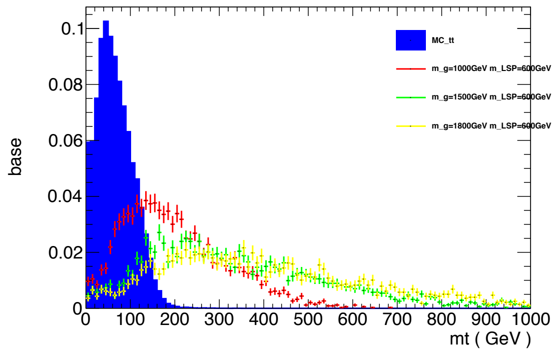


Figure 5
Number of event in function of mt_b^{min}

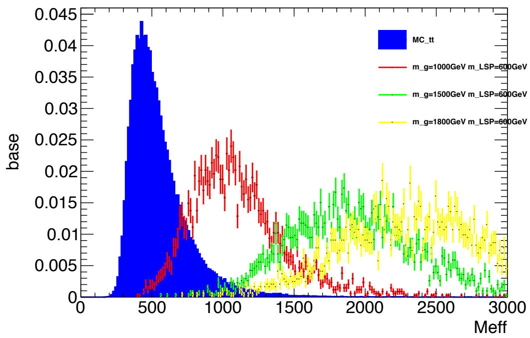


Figure 6
Number of event in function of M_{eff}

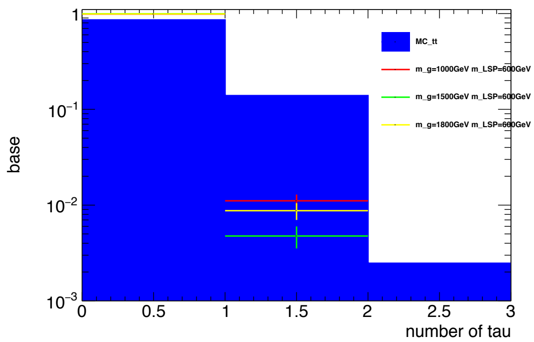


Figure 7
Percentage of events with a τ

Those four variables are the Missing transverse energy (Met_Pt) (Fig. 4), the transverse mass between the three b jets with the higher pt and the Met (mt_b^{min}) (Fig. 5), the effective mass (M_{eff}) (Fig. 6) which is the sum of the impulsion of the 4 jets with the higher pt and of the Met and the presence or not of tau.

What we can see in the three cases is that the background reaches its maximum before every signal point (we define a signal point as a combination of a gluino mass and an LSP mass for which we have generated a signal). So because of that we know that we are going to be able to cut on those three variables to minimize the background. The optimization of those cut will be explain in more detail later in this report. It is also interesting to optimize the reduction of the background using tau lepton.

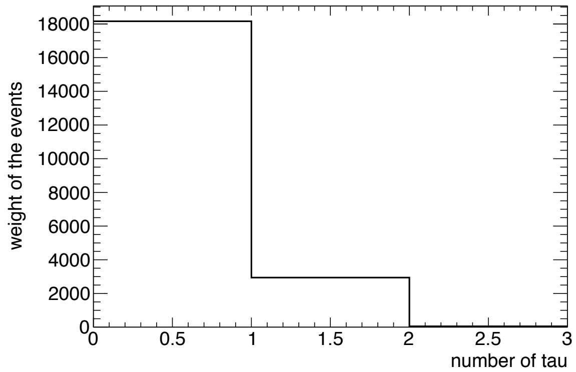


Figure 8
number of τ reconstruits

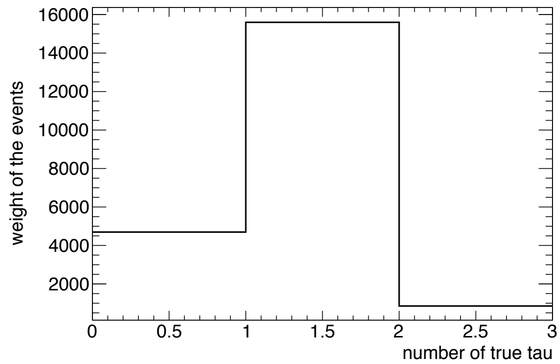


Figure 9
Number of τ

The first plot (Fig. 7) show that while only 1% of the signal events have a je misstated as a tau approximately 10% of the events contains tau. The two other plots (Fig. 8)(Fig. 9) show that only 15% of the true taus are identified which will reduce the efficiency of the tau veto.

2.4 Composition of the $t\bar{t}$ background before and after the cut on mt_b^{min}

We want to know the nature of the jet that form mt_b^{min}, the proportion of the jets that have this nature and the value of mt_b^{min} associate to know if we can make a link between a type of jet in particular and the values of mt_b^{min} lower than 160 GeV

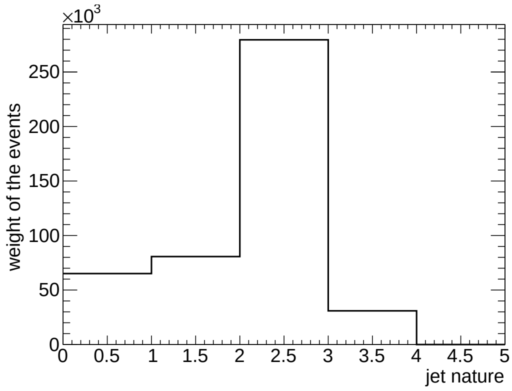


Figure 10
Nature of the jet forming mt_b^{min}

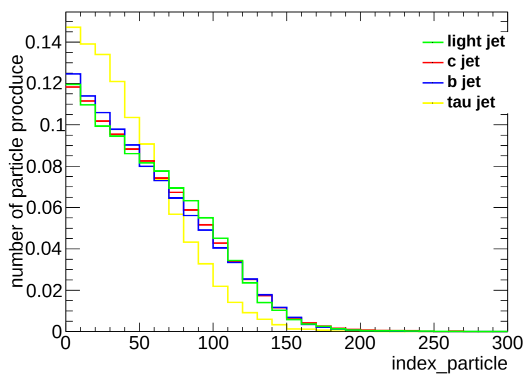


Figure 11
Number of events in fonction of mt_b^{min}

$0 \rightarrow$ light quark ; $1 \rightarrow$ quark c ; $2 \rightarrow$ quark b ; $3 \rightarrow$ tau

We can see in the first plot (Fig. 10) that approximately 7% of the jets forming mt_b^{min} are taus and if we look at the second one (Fig. 11) we can see that the value of mt_b^{min} are smaller for the taus, so a lot of them are going to be remove after the selection on mt_b^{min}.

It could also be interesting to look at the composition of the $t\bar{t}$ background. To do that we first need to understand the desintegration of the top quark. It can decay into a W boson and a b quark and the W boson decays into a 2 quarks or into a pair charged lepton / neutrino. We can see in the plot below the respective quantity of the different pairs of elementary particles produced by the decay of the two W. The first one (Fig. 12) shows those quantities for the event before the cut on mt_b^{min} and the second one (Fig. 13) shows those quantities after the cut.

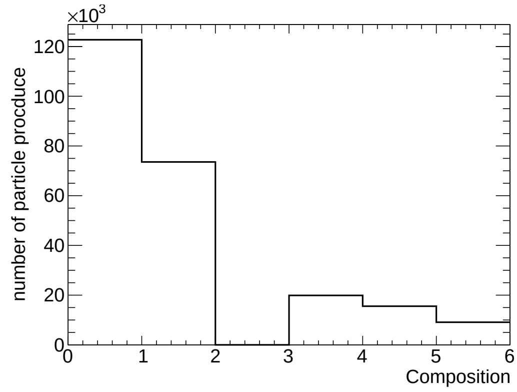


Figure 12
Composition of the events before the cut on mt_b^{min}

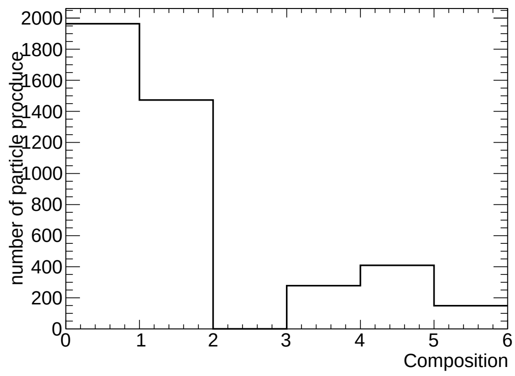


Figure 13
Composition of the events before the cut on mt_b^{min}

0 → light quark + lepton ; 1 → light quark + tau ; 2 → light quark + light quark ;
3 → lepton + lepton ; 4 → lepton + tau ; 5 → tau + tau

With those plots we can see that the cut on mt_b^{min} removes almost all the taus that were forming the mt_b^{min}, but even with this suppression, the number of tau stays high. The fact is that events were a tau forms mt_b^{min} are relatively rare compared to the one were a b jet forms the mt_b^{min} so a great number of taus come from those events. That is why the use of tau veto is justified.

2.5 Optimization

Now that we have all those informations, we are going to optimize the cuts on the signal and the background. To do that we are going for each signal point to look at which combination of the different cuts on Met, M_{eff} and mt_b^{min} give us the best significance. To be precise, we are going to scan the cut on Met from $200GeV$ to $500GeV$ with step of $50GeV$ and for M_{eff} we are going to test cuts between $500GeV$ and $2000GeV$ with a step of $100GeV$. It is also important to precise that for mt_b^{min} we are only going to look what is the most effective between mt_b^{min}>160 and no cut on mt_b^{min}.

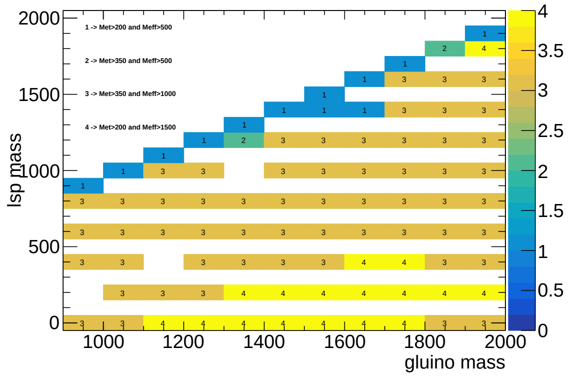


Figure 14
Zones of cut

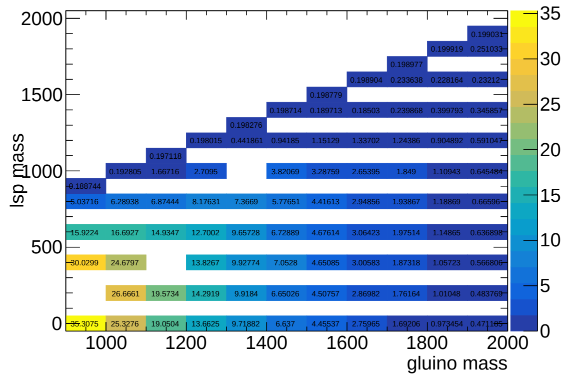


Figure 15
Significance for each signal point

The plot on the left (Fig. 14) show us the existence on some zones of cut where all the signal point have the same cut on Met and M_{eff}, we do not specify the cuts on mt_b^{min} because they are always at 160 GeV, except on the diagonal where there are at 0.

The plot on the left (Fig. 15) show us the significance for each signal point after the different cuts. We can see that the significance decrease when the mass of the gluino increases. This is expected because when its mass increase the cross section of his production increase to.

Once we have done all those plots we can now apply the tau veto and redo an other optimization using the others variable and the tau veto (Fig. 16) (Fig. 17).

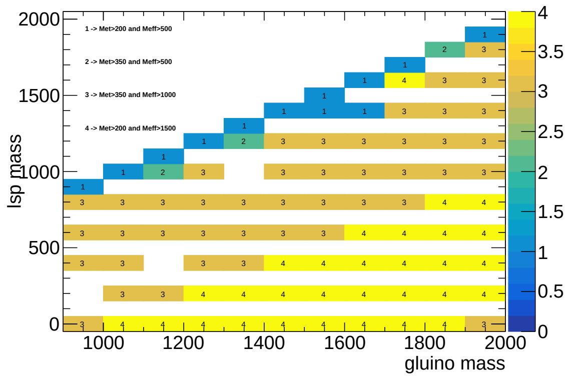


Figure 16
Zones of cut

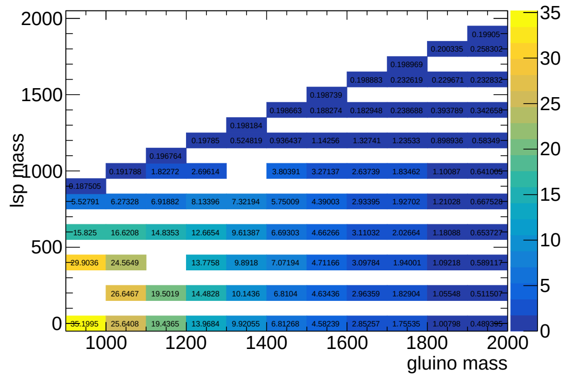


Figure 17
Significance of the signal point

As we can see, this new optimization slightly changes the old zones of cut and increases by 2 ou 3% the significance for some zones of the signal, and for some points reduces it of less than 1%. We are going to talk a bit more about those gain in the next part which is about the gain.

2.6 Theoretical and effective gain of the tau veto

Now that we have acces to the significance with and without tau veto we can have access to the gain of significance for each of the signal point. We are going to compare this gain (Fig. 18) to the maximum gain (Fig. 19) which is obtained by getting rid of all events in $t\bar{t}$ that contain taus. Those tau are the true, tau from Monte Carlo, not the tau after reconstruction. That is the reason why we have a difference between the theoretical gain and the real one, not all the taus are reconstruct.

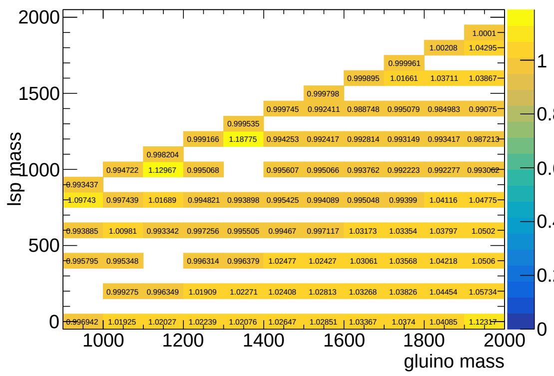


Figure 18
Gain after the use of tau veto

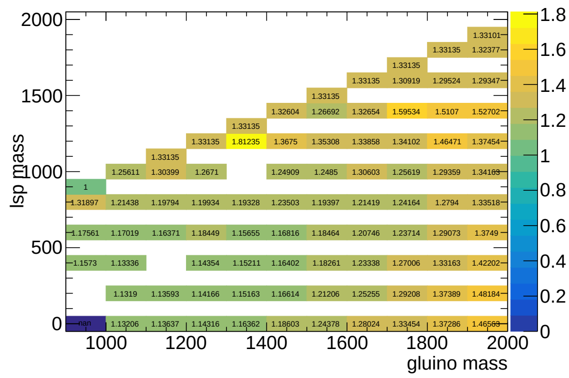


Figure 19
Maximum gain

What we can see is that the tau veto is only efficient for the low mass LSP. But if it is used in this zone it can allow us to gain some percents on the significance. If we compare this gain to the maximum gain, we can see that if we could improve the reconstruction of the taus we could gain a lot of significance.

2.7 Study of others variables

Now that we have seen the effect of the tau veto on the significance, it can be interesting to see if we can use other variables to improve the significance. In particular we are going to try two variables : jet_{pt}^{max} (Fig. 20) which is the impulsion of the more energetic jet and $4jets_{pt}$ (Fig. 21) which is the impulsion that the 4 jets that we use in the cut (which is the same thing as the impulsion of the 4^{st} leading jet). The graph below show those two variables for the signal and the background.

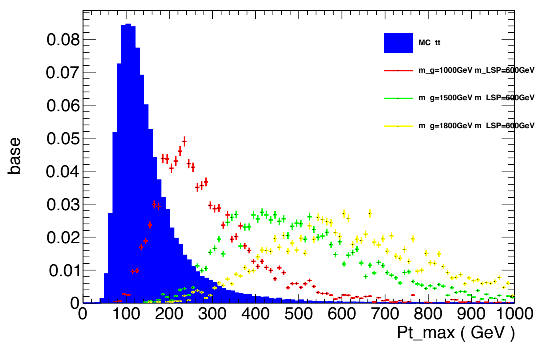


Figure 20
Number of events as a function of jet_{pt}^{max}

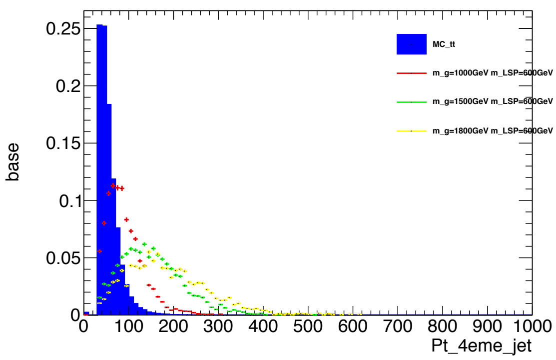


Figure 21
Number of events as a function of $4jets_{pt}$

As you can see the optimization seems possible for the two variables because the maximum of the background is reach beforeed the maximum of the background. We can now redo the optimization, we use the same variables as before but this time we also test cut on Pt^{max} between $30GeV$ and $210GeV$ with step of $30GeV$, and a cut on $4jets_{pt}$ between $30GeV$ et $90GeV$ with a step of $30GeV$.

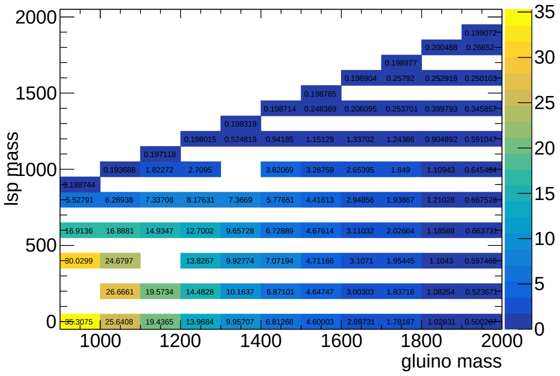


Figure 22
Significance for the signal point after the optimization on jet_{pt}^{max}

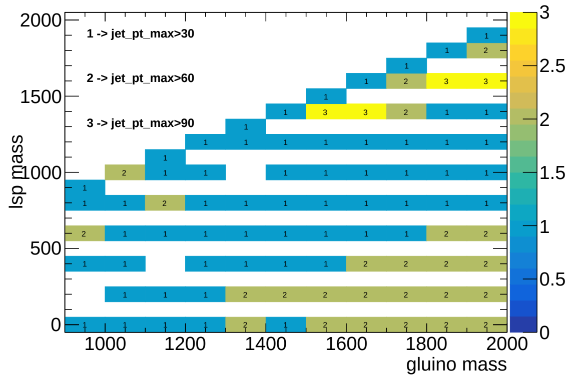


Figure 23
Zones of cut on jet_{pt}^{max}

As we can see this cut seems to have an effect on the zone where we were applying the tau veto (Fig. 23). This new cut allow us to get a small effect gain of 1% or 2% on the significance (Fig. 22). But as the graph below shows, when we use the cut on Pt^{max} the tau veto is not used anymore (Fig. 25), except for a few point.

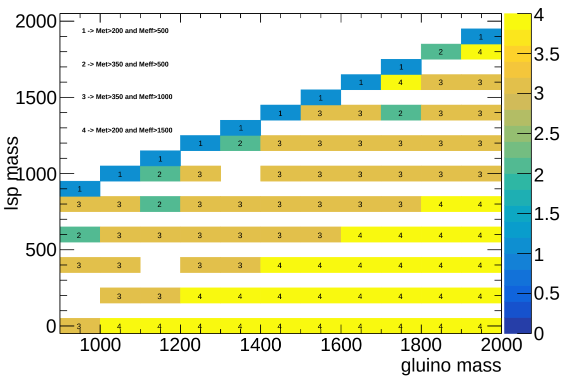


Figure 24
Zones of cut after the optimization on jet_{pt}^{max}

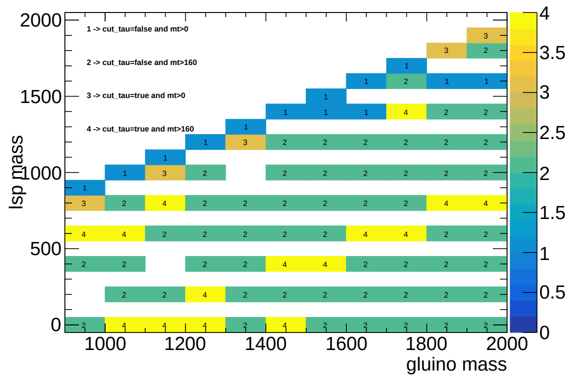


Figure 25
Zones of tau veto after the optimization on jet_{pt}^{max}

2.8 Impact of the luminosity on the optimization

Until now we have been using a luminosity of $5fb^{-1}$ for our analysis, so it could be interesting to see what kind of effect the luminosity could have on the optimization and the significance. On the left you can see the plots with $L = 1fb^{-1}$ (Fig. 26) and on the right the plots for $L = 10fb^{-1}$ (Fig. 27).

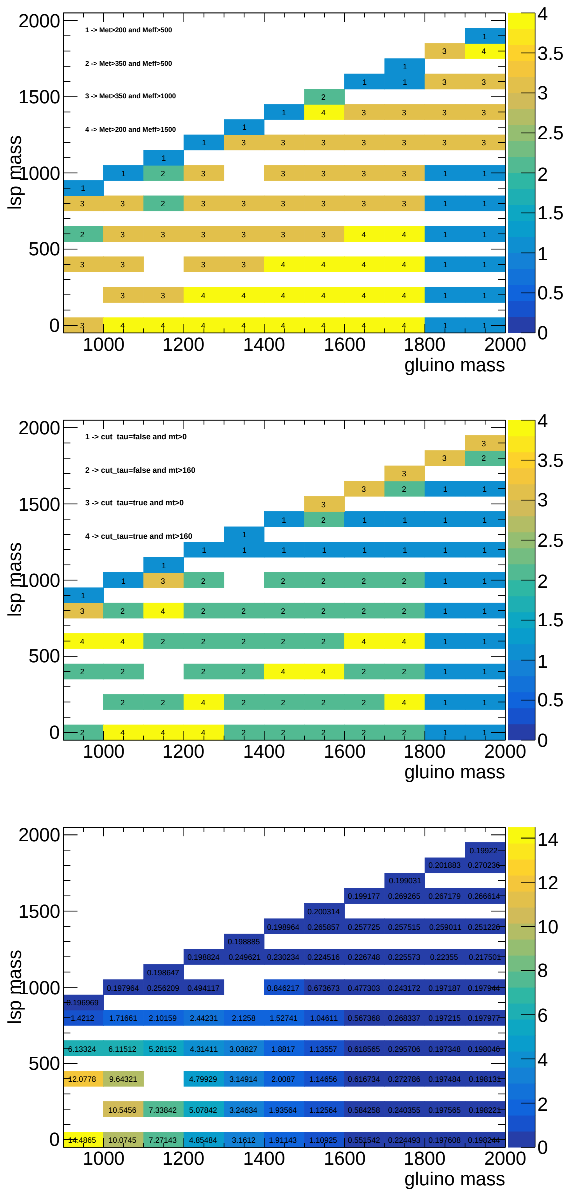


Figure 26
Plot for $L = 1fb^{-1}$

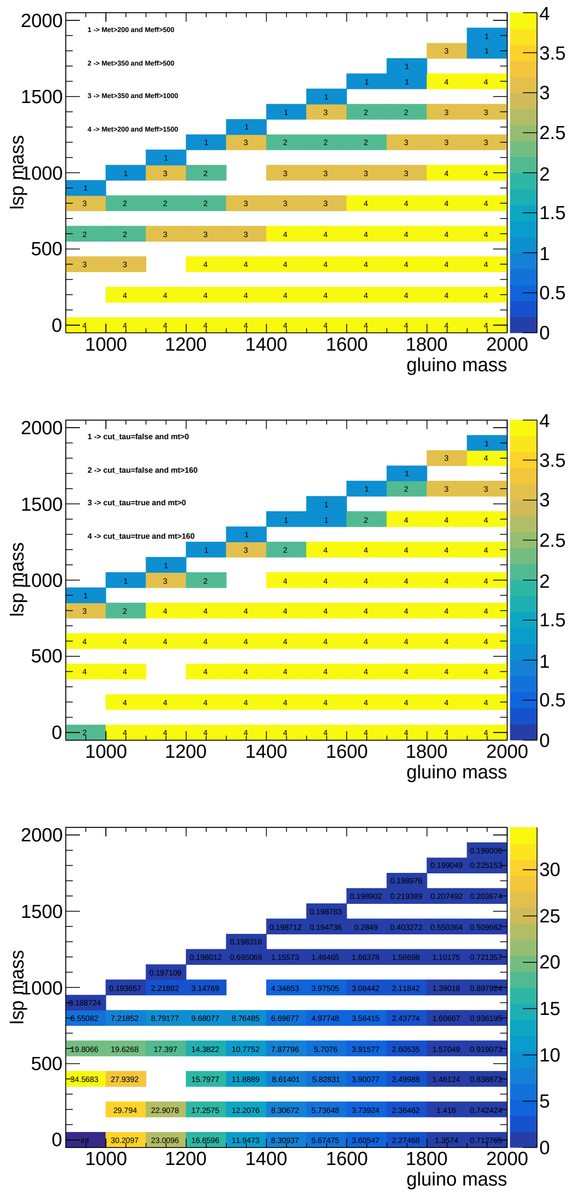


Figure 27
Plot for $L = 10fb^{-1}$

As we can see on those plots, when we increase the luminosity, using the tau veto becomes useful and allows us to increase the significance by a few percents.

2.9 Conclusion

In conclusion, we can say that the tau veto is not very useful in the curent situation and that we should use instead a combination of cut on Met, M_{eff}, mt_b^{min} et jet_{pt}^{max}. Currently using the tau veto does not remove any tau that the other variables have not already cut. But if we can increase the luminosity or improve the way the taus are identify, the tau veto could become really interesting because there are still a lot of events with tau in the background.