Studies for the efficiency and performance of the triggers and the dilepton cuts as a pre-selection stage in the ttHH production mode.

Miguel Ángel García Ruíz
CERN SUMMER SCHOOL REPORT
Supervisors:
Giulia Di Gregorio
Valentina Cairo
Stefano Manzoni

Abstract

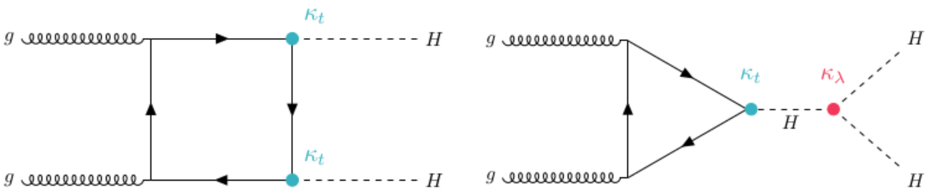
The exploration of the Higgs self-coupling could give a promising way to answer some fundamental questions within the framework of the Standard Model, providing a better comprehension of the model. Additionally, studying the way in which the Higgs boson couples with other particles, particularly with gauge bosons, serves as a crucial way towards unraveling the mysteries underlying the electroweak symmetry breaking mechanism and the observable asymmetry between matter-antimatter. In this written report, we study the efficiency of leptons and multijets triggers, which are characteristic objects for the $ttHH$ process in its final state. This process, which is relatively unexplored at LHC, has the possibility to enable the simultaneous study for both the t quark and Higgs sectors. The $ttHH$ channel considers each Higgs boson decaying into two quarks b while the two W bosons (coming from the top quarks decays) are allowed to decay leptonically, hadronically or semileptonically (one W boson decays leptonically and the other one does so hadronically). In order to optimize the analysis, we consider the number of accepted events and the significance values derived from applying all the triggers to both signal and background MC samples. By identifying the regions for high overlapping of events being triggered by certain groups of triggers, we choose the triggers that boosts the significance while preserves a substantial quantity of signal events, prioritizing the statistic robustness of signal events for future pre-selection stages in the analysis. Subsequently, a loose pre-selection criterion is applied to the events passing the triggers. This approach focuses around the use of dilepton cuts, where the main requirement is to select events with only two leptons in the final state, and is carried out to determine the behavior of the distributions for some kinematic variables, as well as the identification of some possible inconsistencies within the dataset used.

Keywords

Triggers efficiency, Significance, Higgs self-coupling, $ttHH$ process.

1 Introduction

The Higgs self-coupling, denoted as λ, is involved in the shape of the Higgs potential. Furthermore, a study of the manner in which the Higgs boson interacts with other particles, specially with gauge bosons, can help us to understand how the electroweak symmetry breaking mechanism works and why we observe the asymmetry between matter-antimatter in the universe. One possible way to test the Higgs self-coupling relies on the search for HH pairs productions, where the couplings of the Higgs bosons are present with other particles, such as gauge bosons, and with itself (the trilinear coupling HHH). Considering these reasons, it is a good idea to study the Higgs self-coupling through the different modes for the HH pairs.



(a) Box Diagram (b) Triangle Diagram

Figure 1: Feynman diagrams for the ggF HH pair production mode [1].

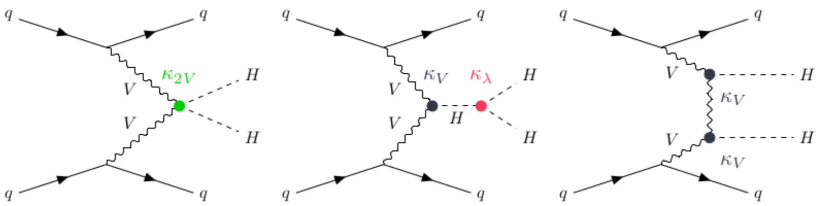


Figure 2: Feynman diagrams for the VBF HH pair production mode [2].

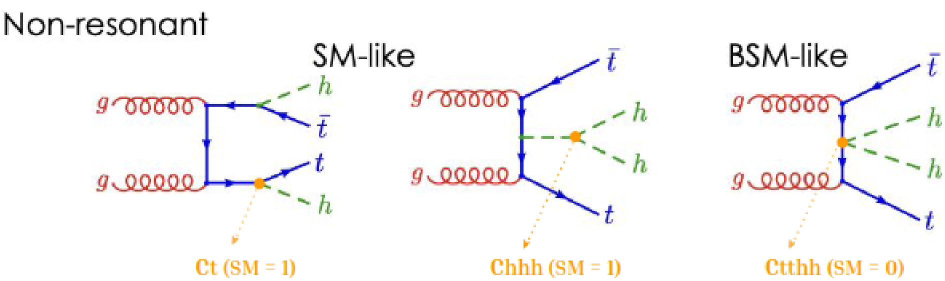


Figure 3: Feynman diagrams for the $ttHH$ HH pair production mode [3].

Among the various HH pair production modes in the Standard Model, the most dominant ones are the gluon-gluon fusion and vector boson fusion processes (they Feynman diagrams to leading order can be seen in the figures [1] and [2]), which have the higher cross sections compared with the others. The next production mode corresponds to the $ttHH$ process (characterized by $\kappa_\lambda = \lambda/\lambda_{SM}$), with the third highest cross section in the standard model case (green line in the figure [4]). The use of the $ttHH$ process provides interesting advantages, such as the presence of the coupling for the Higgs self-coupling vertex (see the figure [3]), a lower fluctuation of the cross section with respect to κ_λ (see the green line in the image [4]), the possibility of getting insights in the t and H sectors simultaneously, as well as the possibility to study a largely unexplored channel at LHC. In contrast, this approach presents certain drawbacks, being the most notable the lower cross section which produces the few amount of signal events to be observed. Besides, the computational effort required to delve into this process is also highly demanding.

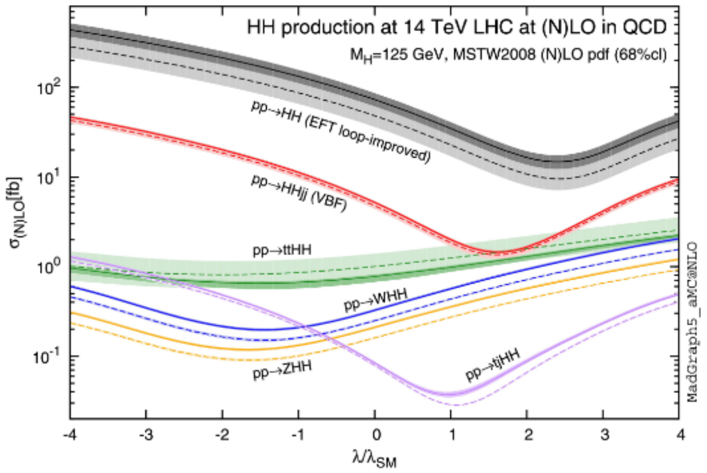


Figure 4: κ_λ dependency of the cross sections for some of the HH pair production modes [4].

2 Description of the MC samples used and the List of Triggers

Our objective is to assess the efficiency of the triggers for the $ttHH$ process, identifying which are most suitable at accepting signal events while filtering out background events. Evaluating the performance and efficiency of these triggers requires the use of MC samples to generate the signal and background events. Due to the lower cross-section of the $ttHH$ process, we decide to explore only the channel where the HH pairs decay into 4 b-quarks. This selection is influenced by the high probability of the Higgs boson decay into two b quarks (the branching ratio for $H \to bb$ is around 58%, making it the channel with the highest probability of decaying for the Higgs boson). Consequently, we heighten the probability of obtaining a signal event and increase our statistics when compared with the available data. Apart from the b quarks coming from the HH pairs, we also account for the fact that the top quark always decays into a b-quark and a W boson, so our signal channel yields a minimum of 6 b-quarks in the final state. However, numerous processes in the standard model produce a 6b quarks configuration in the final state, thereby contributing to the background events. Thus, this background contribution includes at least seven processes to consider, which are: $ttHZ$, $ttZZ$, $tttt$, $ttHjj$, $ttZjj$, $ttbbbb$ and tt.

Ideally, we would use all of these background MC samples, but we only had access to the $t\bar{t}$ samples at the moment of the analysis (and some samples for the ttH samples). However, opposite to one might think due to the lack of the MC samples we are not considering yet, the $t\bar{t}$ MC samples are a good starting point for the background contribution, since this process has the higher cross-section of all the background MC samples involved in the analysis, with around six orders of magnitude higher than the signal cross-section. In the table [1] we can see an estimate of the number of expected events for the $ttHH$ signal channel and the $t\bar{t}$ background for the Run 2, although it is expected that using the Run 3 and the data from the HL-LHC, the number of signal events increase as a consequence of the increase in the luminosity. Consequently, given the low rate of expected signal events compared with the background events, the triggers must preserve many events as possible, while reduce the number of background events at the same time.

One of the main characteristics of our chosen channel for the $ttHH$ process is that this involves the decay of the two W bosons. Each W boson have two possible options, decay hadronically $W \to qq'$ or leptonically $W \to l\nu$. As a result, there are three possible combinations for the products of the decays

Run 2 Dataset [13TeV]	L_{int} $[fb^{-1}]$	σ $[fb]$	N_{events}
$ttHH$	150	$7.75 \cdot 10^{-1}$	116
$t\bar{t}$	150	$8.32 \cdot 10^{5}$	$1.24 \cdot 10^{8}$

Table 1: Number of expected events for signal and background samples.

that involve both W bosons, which are the full hadronic decay (both W boson decay hadronically), semileptonic decay (one W boson decays hadronically and the other one decays leptonically) and full leptonic (both W boson decay leptonically). Each combination produces a different number of leptons in the final state, so we would have 0, 1 or 2 leptons for the full hadronic, semileptonic and full leptonic respectively. Therefore, we classify the signal into three categories by using the number of leptons in the final state, as: $ttHHfullhad$, $ttHHsemilep$ and $ttHHdilep$. By splitting the signal samples into these three categories, we are able to study the behavior of these three different decays modes by separated, allowing us to determine certain characteristics that are proper from each W decay mode and study the effect of applying the triggers on each category.

In the other hand, we need to use the triggers that can make an online-selection of events that are likely to be signal events. Given that we have many objects in the final state, mainly leptons, jets and b-jets, the triggers to be used need to accept events containing these objects in the final state. For this reason, the whole list of triggers can be separated into groups of leptons and multijets triggers (or a combination of both of them). The list of all the trigger that were considered during the analysis are given in the table [2], where the triggers are grouped by the kind of objects which are likely to be identified. Thus, we have 5 groups of triggers, listed as: e/mu+jets , multi-jet small R, single-lepton and dilepton triggers. In order to study the efficiency and performance of these triggers, the study is done over the different groups instead of individual triggers, so we can identify better which groups of triggers fit better with the signal channel and which objects are more significant to be considered in our analysis.

3 Number of Accepted Events and Significance Plots

As was mentioned in the previous section, the idea is to reduce the number of groups of triggers we were using and select only the groups that can increase the significance while preserve the higher number of signal events as much as possible. With this in mind, we need to plot the number of events that are accepted by all of these triggers when these are applied to the MC samples (signal and background). Once we have found the number of signal and background events, we could compute the significance for these triggers and study the effect of using them in the study for the $ttHH$ analysis.

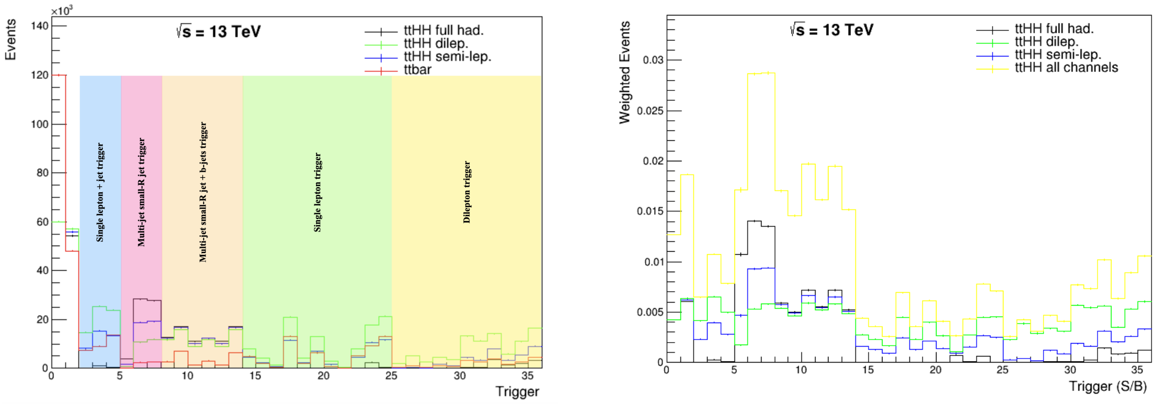
The first approach to the study of the efficiency of these triggers is given by the number of events plots, which provides information of how many initial events are considered for all MC samples before applying the triggers, and how many of them are accepted by these triggers. The figure [5a] shows us the general plot for the accepted number of events when consider the whole list of triggers, from the bin 2 to 36 (the colour regions determines which bins corresponds to a certain group of triggers), the bin 0 gives us the initial number of events before applying any trigger. Each MC sample contains a total of $60k$ events, $20k$ per each campaign, but we have $120k$ events for the $t\bar{t}$ sample since we are considering the two possible contributions to this background process, where the two W bosons decay full hadronically (both W bosons decay into 2 quarks) or semileptonically (one W boson decay into 2 quarks and the other decays into one lepton and one neutrino), there is no possible contribution for the $t\bar{t}$ background events when the two W boson decays leptonically, since we wouldn't have at least 4 jets and b-jets in the final state. Finally, the bin number 1 shows us the number of events that passed at least one of all the triggers. Here, we can see that in general, we can observe a considerable decrease in the number of background events compared with the signal events, with an initial number of events equal to $120k$ to the accepted

Chain of triggers	List of Triggers
e/mu+jets for VH	HLT_e20_lhtight_nod0_ivarloose_3j20_L1EM18VHI_3J20
	HLT_mu14_ivarloose_3j20_L1MU10_3J20
	HLT_mu20_ivarmedium_L1MU10_2J15_J20
Multi-jet small R	HLT_10j40_L14J15
	HLT_7j45_L14J15
	HLT_6j55_0eta240_L14J15
Multijets+b-jets	HLT_j100_2j55_bmv2c2060_split
	HLT_2j35_bmv2c2060_split_2j35_L14J15.0ETA25
	HLT_j110_gsc150_boffperf_split_2j35_gsc55_bmv2c1070_split_L1J85_3J30
	HLT_2j15_gsc35_bmv2c1040_split_2j15_gsc55_boffperf_split_L14J15.0ETA25
	HLT_j110_gsc150_boffperf_split_2j45_gsc55_bmv2c1070_split_L1J85_3J30
	HLT_2j35_bmv2c1060_split_2j35_L14J15.0ETA25
Single-lepton	HLT_e24_lhmedium_L1EM20VH
	HLT_e60_lhmedium
	HLT_e120_lhloose
	HLT_e26_lhtight_nod0_ivarloose
	HLT_e60_lhmedium
	HLT_e60_lhmedium_nod0
	HLT_e140_lhloose_nod0
	HLT_e300_etcut
	HLT_mu20_iloose_L1MU15
	HLT_mu50
	HLT_mu26_ivarmedium
Dilepton	HLT_2e12_lhloose_L12EM10VH
	HLT_2e17_lhvloose_nod0
	HLT_2e24_lhvloose_nod0
	HLT_e17_lhloose_mu14
	HLT_e7_lhmedium_mu24
	HLT_e17_lhloose_nod0_mu14
	HLT_e7_lhmedium_nod0_mu24
	HLT_2mu10
	HLT_mu18_mu8noL1
	HLT_2mu14
	HLT_mu22_mu8no_L1

Table 2: List of Triggers used during the efficiency and performing analysis.

number of events around $50k$ for the $t\bar{t}$, whereas the initial number of events for the signal samples start from $60k$ and the number of accepted events varies from $55k$ to $58k$.

Apart from the accepted number of events plots, we also have the significance plots, in which we can see how the significance (defined as $S/\sqrt{B}$, where S is the number of signal events and B the number of background events when the triggers are applied) is affected by the use of the triggers. The figure [5b)] shows us the significance for all the triggers in the list individually, given in the bins 2 to 36 as are listed in the table [2]. The bin 0 is the initial significance we would have by only considering the initial events for signal and background, while the bin 1 represents the significance once we have applied all the triggers and considering those events that passed at least one of the triggers in the list. As we can observe, the significance is higher once we use the complete set of triggers, since we have seen that in general, the application of these triggers produces a higher decrease in the number of background events



(a) Number of accepted events for all the triggers in the list.

(b) Significance for all the triggers in the list

Figure 5: Number of accepted events and significance plots for all the triggers.

compared with the signal events. Having said that, we want to reduce the groups of triggers without affecting significantly the number of accepted events and the significance, but we are not able to select them by only comparing these two plots at the first glance.

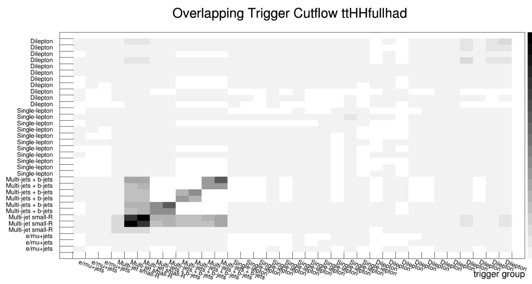
Considering that we are applying all the triggers at the same time, it is difficult to us to determine what are the effects of removing certain set of triggers from the study. For instance, we need to consider the possibility that some signal events are been triggering by different triggers at the same time (especially among similar groups of triggers such as multijets or leptons triggers), presenting an overlapping of these signal events. When there is a higher overlapping among these triggers, the significance would change significantly depending on the background events that are passing these triggers. In this way, we can optimize the analysis by removing the groups of triggers presenting a higher overlapping, saving time in the online-selection when the detector is taking data and it is needed to stored interesting events for our signal process, so the next step is to find a way to study this overlapping among the different groups of triggers we are considering.

4 Overlapping Regions

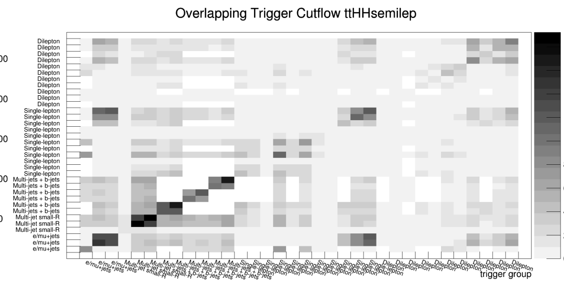
The overlapping among the different groups of triggers is done by using a 2D histogram. In order to do that, we create a 2d histogram in which the X and Y bins corresponds to the list of triggers ordered in the same order that are in the table [2]. Therefore, each square bin represents two individual triggers at the same time, and the information given by each square bin is the number of events that pass both triggers at the same time. By doing this, we can observe which groups of triggers are accepting the same events easier, so we can identify better the regions of higher overlapping, understanding by regions the combinations of two or more groups of triggers (darkest regions on each overlapping plots). Additionally, each overlapping plot contains a color bar in gray scale with the range of the minimum and maximum overlapping values, so we can identify what are the ranges of number of events accepted in different regions. While the regions between different triggers are useful to identify the higher values of overlapping, the diagonal of each plot provide not relevant information, since the diagonal square bins corresponds to the same individual trigger in the X and Y axis, with a 100% of accepted events.

In our study, we considered the overlapping per each signal MC sample (3 plots) and the overlapping for the whole signal MC sample ($ttHHfullhad$, $ttHHsemilep$ and $ttHHdilep$ at the same time). These three plots can be seen in the figure [6]. The figure [6a)] shows us that in the full hadronic channel, the groups of triggers that present the higher overlapping correspond to the multijets triggers (multijet small R and multijets+b-jets triggers), which makes sense since most of our generated events in this channel must contain more jets and b-jets rather than leptons in the final state. From the figure [6b)], we can see that there are regions of higher overlapping corresponding to the multijets triggers (multijet small R and multijets+b-jets triggers) and lepton triggers (single-lepton and dilepton triggers), which also makes sense since we have many events with the combination of leptons and jets in the final state for the semilepton channel. Similarly, from the figure [6c)] we can see that the region of higher overlapping correspond to the lepton triggers (such as the single-lepton and dilepton triggers, or e/mu+jets and dilepton triggers), since most of the events in this channel contains 2 leptons in the final state.

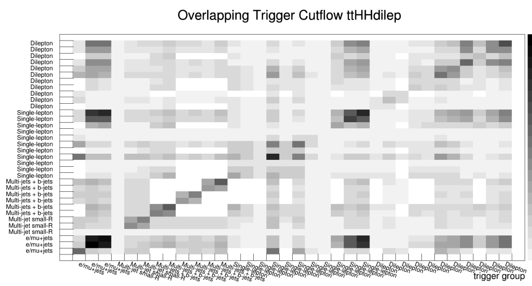
In general, when we consider the three signal channels at the same time, we get the overlapping plot given by the image [6d)]. This image shows us at least two main regions of higher overlapping. The first region corresponds to the multijets triggers multijet small R and multijets+b-jets triggers), and the second region corresponds to the lepton triggers (single-lepton and dilepton triggers). Once we have identified these two regions, we can study the number of events and the significance for both groups and compare their results with their respective pairs in order to remove less useful group from the analysis. Additionally, it is important to underline that due to the fact that the e/mu+jets triggers were not used during some campaigns of data-taking, we consider to omit them from the analysis from this part, leaving only for main groups of triggers, two for the multijets triggers and two for the lepton triggers.



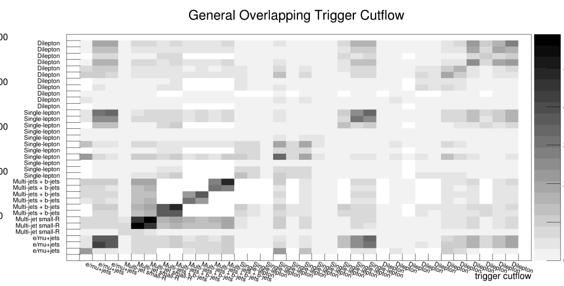
(a) Overlapping plot for the full hadron channel.



(b) Overlapping plot for the semilepton channel.



(c) Overlapping plot for the dilepton channel.



(d) Overlapping plot for the complete signal sample.

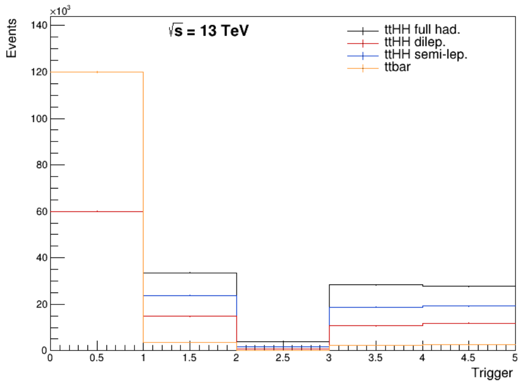
Figure 6: Overlapping plots for the individual signal samples and the general signal sample.

5 Efficiency Comparison Among the Groups of Triggers Resulting From The Overlapping Criteria

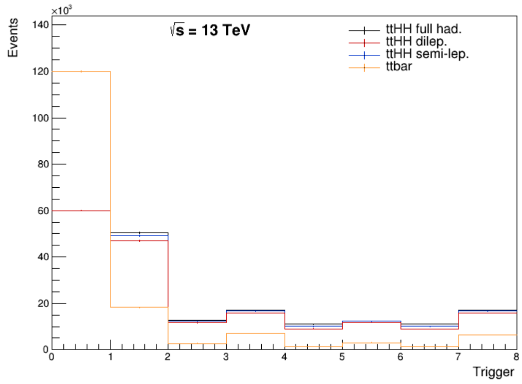
Once we have found the regions of higher overlapping, we want to use this information to optimize the analysis and reduce the number of triggers we are using. Since we are using a group of triggers that are selecting similar events, presenting a higher overlapping of events, we would like to choose between these two pairs of groups for the multijets and leptons triggers, the most useful to use to select likely events for signal in the online-selection. To do that, per each pair of groups we are going to study which of the two groups of triggers provides the higher significance, by comparing the significance plots when only these group of triggers are used individually and both at the same time.

Firstly, we can start by comparing the number of accepted events and the significance plots for the multijet group of triggers (multi-jet small R and multi-jets+b-jets triggers) individually. The images [7] and [8] show us the number of accepted events and the significance for the multijets triggers when these are applied individually. Similarly to the description of these plots in their corresponding section, the bin 0 determines the number of initial number of events / significance before applying the triggers, while the bin 1 determines the number of accepted events / significance after applying the triggers for the number of accepted events and significance plots respectively. The difference in the number of bins corresponds to the difference in the number of triggers for each multijet trigger group (3 triggers for the multijet small R group and 6 for the multijet+b-jet group, as can be seen from the table [2]).

Some initial considerations about these two plots are that the multijets small R triggers group provides a higher significance than the multijets + b-jets triggers, as we can see when we compare the two significance plots from each group individually (see figure [8]. When we do that, we can see that the bin 1 in the multijets small R reaches a weighted value of ~ 0.040, while the multijets + b-jets reaches a weighted value of ~ 0.032. Besides, we can compare the number of events plots (see figure [7]) and observe that the acceptance of events when we use the multijets small R triggers is lower than the multijets + b-jets triggers. So even if the multijets small R triggers removes more background events than the multijets + b-jets triggers, the amount of signal events is higher for the last group.



(a) Number of accepted events for the multi-jet small R triggers group.



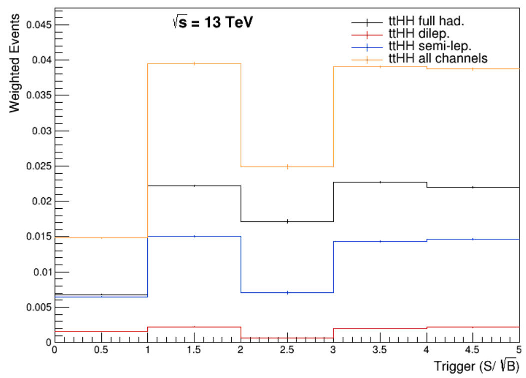
(b) Number of accepted events for the multi-jet+b-jet triggers group.

Figure 7: Number of accepted events plots for the multijets triggers by considering them individually.

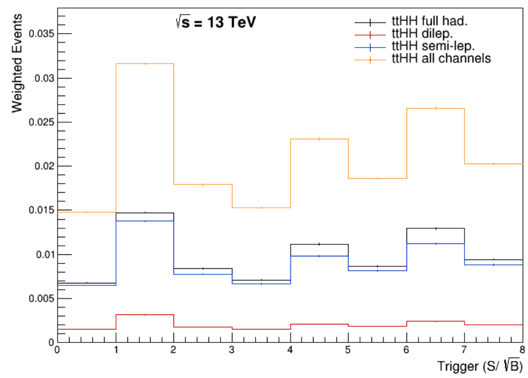
Similarly as we did for the multijets triggers groups, we can apply the same method for the leptons triggers groups (single-lepton and dilepton triggers groups) and analyze the results for each group individually. In the images [9] and [10] we can see the number of accepted events and the significance for both leptons triggers individually.

Something we would expect is that the ttHHdilep signal channel has an increase in the significance after applying all the lepton triggers, since the leptonic decay of the two W bosons adds two leptons in the final state. However, for the other signals channels (ttHHsemilep and ttHHfullhad) the significance decreased, and moreover, the total significance decreased too (compare the values for the significance in bin 0 and 1 in the image [10]), in which the only increase in the significance was for the dilepton channel, in contrast with the full hadronic and semileptonic channels. This behaviour was not present during the analysis of the efficiency in the multijets triggers groups, for which the significance increased in general with the use of both multijets triggers groups.

To sum up, along this section we have seen that the multijets triggers presents a better selection for the signal channels, as well as these triggers discard many background events, producing and increase in the significance values. However, as we also want to preserve as many signal events for future

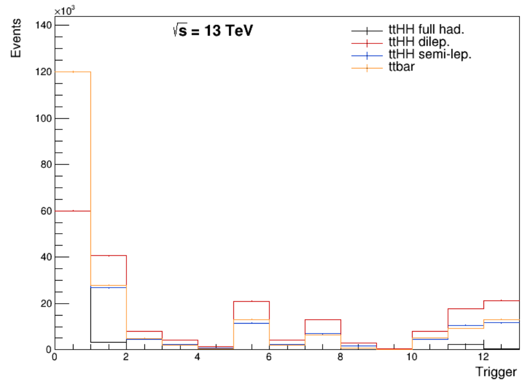


(a) Significance plot for the multi-jet small R triggers group.

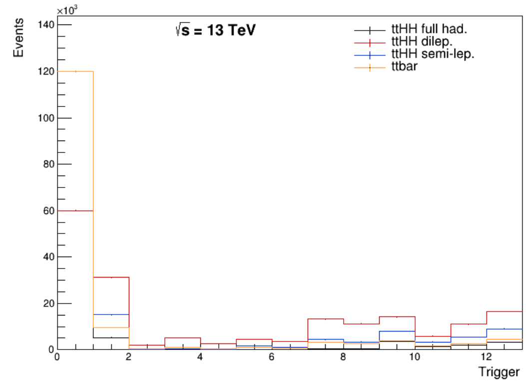


(b) Significance plot for the multi-jet+b-jets triggers group.

Figure 8: Significance plots for the multijets triggers by considering them individually.



(a) Number of accepted events for the single-lepton triggers group.



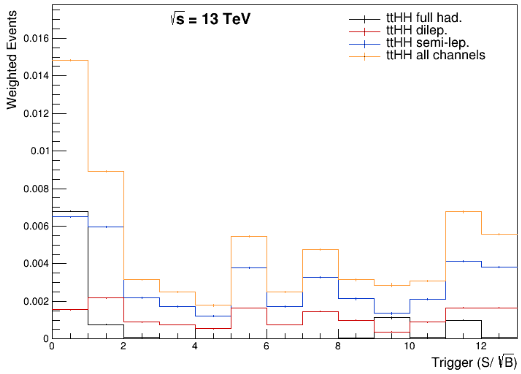
(b) Number of accepted events for the dilepton triggers group.

Figure 9: Number of accepted events plots for the leptons triggers by considering them individually.

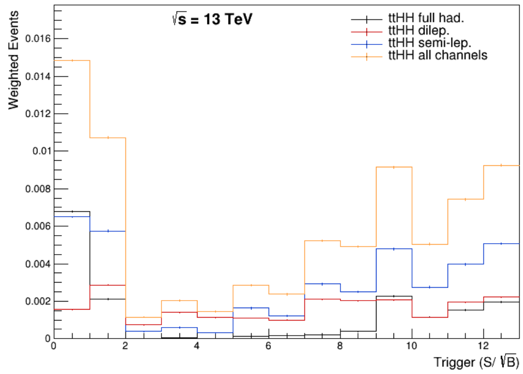
pre-selection cuts, we can see that the multijets+b-jets triggers fullfils this requirement better than the multijets small R jets. In other hand, the lepton triggers seems to present an opposite behavior, since even if the use of these groups of triggers reduces the background events, these are also reducing in a higher proportion the number of signal events, reducing the significance except for the dilepton channel. Considering all of these reasons, it could be wise to continue working only with the multijets+b-jets triggers for future analyses in the pre-selection stages when tighter cuts will be applied on the MC samples.

6 Dilepton Cuts Approach

Now that we have chosen the group of triggers that fits better with the objectives of the analysis for the $ttHH$ signal channel, the idea is to study the behavior for some kinematic variables, such as the jet p_T, MET (Missing Transverse Energy), number of reconstructed jets and b-jets distributions, etc. In order to do that, we consider to apply a pre-selection criteria for the MC samples, which means to study what happens when some additional cuts are applied to the dataset. In general, the main idea is to apply a common pre-selection and then categorize the events according to the number of charged leptons in the final state. In this report, the results are given only for the dilepton channel as a first approach to the



(a) Significance plot for the single-lepton triggers group.



(b) Significance plot for the dilepton triggers group.

Figure 10: Significance plots for the leptons triggers by considering them individually.

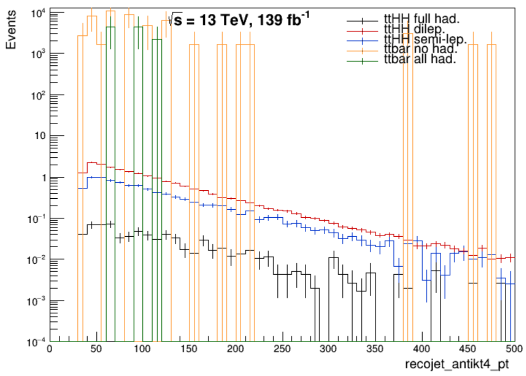
future pre-selection stages. As a consequence of this new approach, we want to determine how these cuts affects the kinematic distributions of some characteristic variables for each MC sample, and be able to distinguish which contributions comes from the different channels for signal and background, by observing similar behaviors or inconsistencies in the distribution of these variables.

During this part of the analysis, the MC background samples were divided into the two possible contributions, which are the $t\bar{t}$ non-all hadronic (where only one of the two W boson decays hadronically, while the other one decays leptonically) and the $t\bar{t}$ all hadronic (where the two W bosons decays hadronically). The cuts applied over these MC samples are given in the table [3], where we can see that the selection criteria is not so strict for jets and b-jets, while the number of leptons in the final state must be equal to 2 (which is basically the two leptons coming from the W bosons decaying leptonically). This pre-selection criteria of events will allow us to keep a good number of signal events while applying the most meaningful cut for the dilepton channel, which is the final number of leptons.

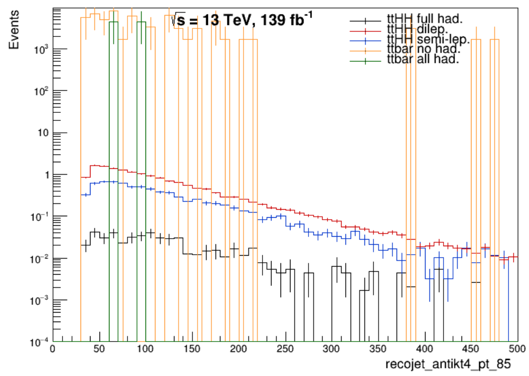
Kinematic variable	**Cut**
Jet p_T	$p_T > 35GeV$
Jet η	$\|\eta\| < 2.4$
Number of jets	≥ 4
Number of b-jets	≥ 4
Number of leptons	$= 2$

Table 3: Pre-selection for the dilepton channel.

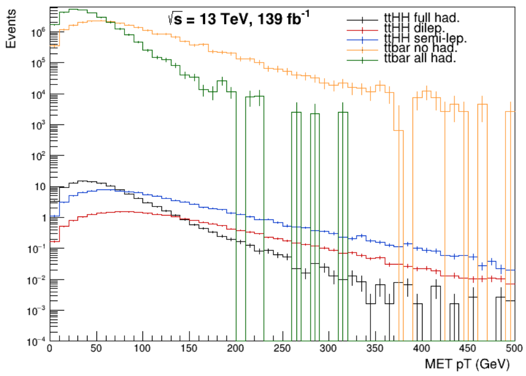
After applying this pre-selection criteria using the dilepton cuts, some kinematic variables were plotted (see images [11]). As we can observe, in some distributions, specially for the p_T of the jets and b-jets, the behavior of the $t\bar{t}$ is not so coherent at all, since this shows peaks in some regions that are not present for the other channels, which makes suggest that some inconsistencies are present in the $t\bar{t}$ MC samples we are using at the moment. Additionally, we can observe that most of the contribution comes from the $t\bar{t}$ samples, compared with the signal samples, due to the fact that we are considering the cross-section and the luminosity to weight each event. Since the $t\bar{t}$ process has a higher cross-section than the $ttHH$ process, most of the events passing this pre-selection comes from the background. Therefore, in order to make a better comparison, these plots are using the log scale in the Y axis.



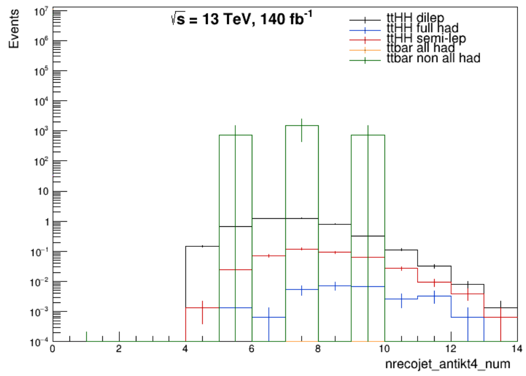
(a) p_T distribution for jets.



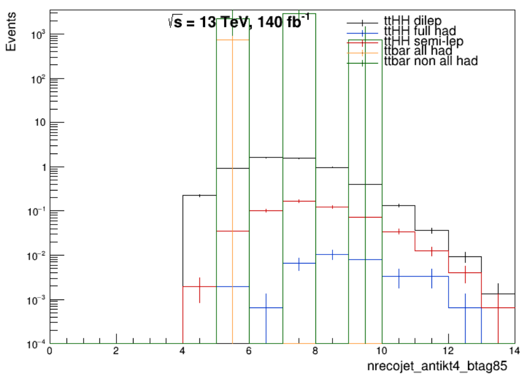
(b) p_T distribution for b-jets.



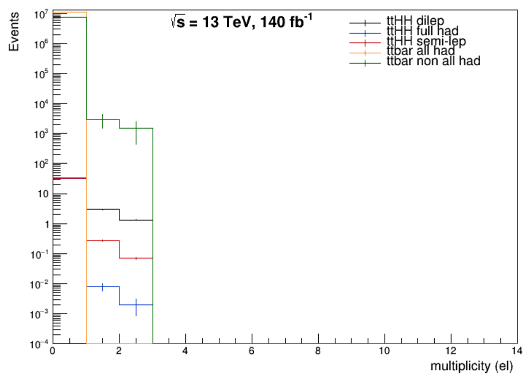
(c) Missing Transverse Energy Distribution.



(d) Number of jets distribution.



(e) Number of b-jets distribution.



(f) Number of electrons distribution.

Figure 11: Some kinematic variable distributions after applying the dilepton cuts.

Finally, it is important to consider that these results are the first approximations we have done with a simple preselection of events after the application of the multijets+b-jets triggers and the dilepton cuts, so further analysis should be done to be able to get conclusive conclusions about this part of the pre-selection stage using this approach.

7 Conclusion and Final Remarks

The study of the trigger efficiency and their performance is highly important for each research group at LHC, since this is the first stage where a selection of likely interesting events is done when the detector is working and the data must be stored in the Data acquisition system. The optimization and selection of the triggers that are most suitable for each analysis allow us to heighten the probabilities of observing the signal processes we want to study, especially when these processes have a lower section.

Identifying the regions of high overlapping values of signal events within all the trigger groups offered us the opportunity to evaluate those that share an analogous selection criteria. This assessment proves valuable in streamlining the trigger selection process, leading to a reduction in the number of triggers required during the analysis without affecting too much the significance while preserving the number of signal events. By considering both the significance and the number of signal events accepted by the trigger groups, we could make decisions about which groups yield comparable outcomes, thereby optimizing the selection procedure to the most suitable group of triggers for the $ttHH$ channel production mode.

Additionally, at the end of the work we decide to use the multijets+b-jets triggers over the multijets small R triggers, since the first ones allow us to keep a higher number of signal events to be used for future pre-selection stages of the analysis, while provide a high significance value. These information was obtained by comparing the number of accepted events and significance plots done individually per each group of triggers.

Regarding with the dilepton channel pre-selection study, it is important to underline that the presented outcomes represent initial approximations, starting from a basic selection criteria of events after applying the multijets+b-jets triggers, where the most strict criteria required the two leptons in the final state. Even so, this approach allow us to identify common behaviors in the distribution of some kinematic variables for the $ttHH$ and $t\bar{t}$ channels, as well as to identify possible inconsistencies that can be considered in future implementations. In conclusion, further studies are essential to arrive at definitive conclusions regarding with this pre-selection stage, by including the missing sources of background MC samples, once these are available, and the use of a more robustness dataset that can be provided for the RUN 3 and HL-LHC future plans.

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