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Trigger studies for the Higgs pair production in the $WWbb$ final state at $\sqrt{s} = 13$ TeV with the ATLAS detector

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Summary. — In this 2nd year of my PhD I committed myself to the analysis of data collected by ATLAS and such an activity will be the subject of my PhD dissertation. The analysis in which I am involved is about the study of the search for the Higgs boson pair production where one Higgs boson decays via $h \to b\bar{b}$ and the other via $h \to WW^* \to lvqq$. The search is performed on a full data set 2015 ($3.2\,\text{fb}^{-1}$) plus 2016 ($33.3\,\text{fb}^{-1}$) of proton-proton collision data at the center-of-mass energy of 13 TeV recorded with the ATLAS detector at the LHC.

1. – Introduction

In this work we describe the search for the Higgs boson pair production where one Higgs boson decays via $h \to b\bar{b}$ and the other via $h \to WW^* \to lvqq$. The search is performed on a full data set 2015 ($3.2\,\text{fb}^{-1}$) plus 2016 ($33.3\,\text{fb}^{-1}$) of proton-proton collision data at the center-of-mass energy of 13 TeV recorded with the ATLAS detector at the LHC [1].

The SM predicts the interaction of the Higgs boson with itself. This mechanism contributes to the non-resonant Higgs boson pair production through Yukawa interaction. Figures 1(a) and (b) show the schematic diagram of the non-resonant Higgs boson pair production.

2. – Motivation

Di-Higgs production can proceed also through BSM physics, like the exchange of a heavy Higgs boson (H) (see fig. 2).

3. – Di-Higgs branching ratios

There are six decay channels under study by ATLAS and $WWbb$ is the second largest branching ratio among them after $4b$. The full hadronic decay of the WW pair has higher branching ratio with respect to the semi-leptonic one, but it is affected by larger QCD background.

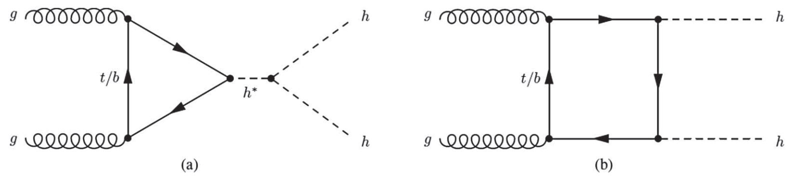

Fig. 1. – Leading-order Feyman diagrams for non-resonant production of Higgs boson pairs in the Standard Model through (a) the Higgs boson self-coupling and (b) the Higgs-fermion Yukawa interaction.

4. – Signal *vs.* background

The signal topology consists of one charged lepton, four jets two of which are b-jets, missing transverse energy and $t\bar{t}$ is the largest and irreducible background. Other backgrounds are W+jets, Z+jets and Di-bosons. Nevertheless the decay kinematics can be used to distinguish between signal and background and the largest separation is expected when $m_{hh} \gg m_{t\bar{t}} = 350\,\text{GeV}$.

5. – Used triggers

The following triggers are used to increase the signal acceptance by adding lepton plus multi-jet triggers in addition to one-lepton triggers.

One-lepton triggers (lepton and muon) are: passHLT_e26_lhmedium_nod0_ivarloose which triggers on electron of threshold 26 GeV and passHLT_mu26_ivarmedium triggers on muon of threshold 26 GeV. One-lepton and three-jet triggers are passHLT_e15_lhtight_ivarloose_3j20_L1EM13VH_3J20 which triggers on tight electron and jets of threshold 15 and 20 GeV and passHLT_mu14_ivarloose_3j20_L1MU10_3J20 triggers on muon and jets of threshold 14 and 20 GeV respectively. The isolation criteria are applied to the lepton in all triggers, with the muon+jet trigger applying a looser isolation than the corresponding single muon trigger. The ivarloose and ivarmedium are the looser and tighter criterias applied at the HLT level.

6. – Cuts applied

The following selections are used at preselection level: one muon with $|\eta| < 2.5$ and $p_T > 15\,\text{GeV}$ or one electron with $p_T > 16\,\text{GeV}$ and $|\eta| < 2.47$. $h \to bb = 2$: Jets are required to be b-tagged to identify the $h \to bb$ decay.

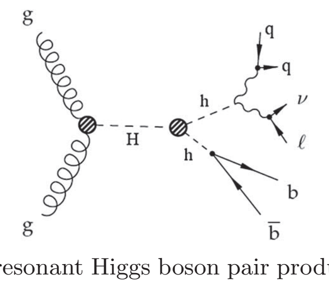

Fig. 2. – Schematic diagram of resonant Higgs boson pair production with the subsequent Higgs and W boson decays.

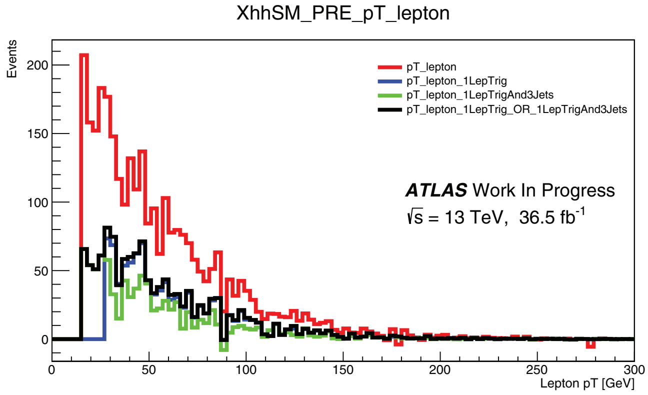

Fig. 3. – Lepton transverse momentum distribution with different triggers. The p_T threshold due to the used triggers is visible in the figure.

Table I. – *Trigger efficiencies calculated using signal samples. Different cuts presented are used in the analysis and their relative gain is shown.*

Trigger efficiencies				
Cuts	1LepTrigg	1LepAnd3JetsTrigg	1Lep _or_ 1LepAnd3JetsTrig	Relative gain (%)
Presel	0.330 ± 0.013	0.284 ± 0.013	0.422 ± 0.014	27
$hh \to bb$	0.330 ± 0.013	0.284 ± 0.013	0.423 ± 0.014	28
nCentralLightJets $\geq$2	0.330 ± 0.015	0.310 ± 0.015	0.432 ± 0.016	30
bJets$\geq$2	0.200 ± 0.013	0.205 ± 0.013	0.265 ± 0.014	32
Selection	0.397 ± 0.01	0.601 ± 0.095	0.606 ± 0.095	52

- *nCentralLightJets*≥ 2: This requirement asks for jets from the W decay which are detected in the central part of the detector. Jets are reconstructed with the antiKt algorithm with radius 0.4, the 85% efficiency working point is used for b-tagging.
- *Selection:* $p_T(bb) > 150\,\text{GeV}$, $\Delta R(bb) < 1.1$, $\Delta R(WW) < 0.9$, $105 < m(bb) < 135\,\text{GeV}$.

Figure 3 shows the p_T distributions of different triggers, different thresholds and efficiencies in table I.

7. – Conclusion

By adding lepton plus jets trigger, we get about 52% efficiency gain over the single lepton trigger alone.

REFERENCES

[1] Higgs Cross Section Working Group, HH subgroup, tech. rep., url: https://twiki.cern.ch/twiki/bin/view/LHCPhysics/LHCHXSWGHH#NEW_Gluon_fusion.