Summer Student Report: Studies of the Higgs-boson mass reconstruction in the tH ML channel

Lars Kolk
Supervisor: André Sopczak

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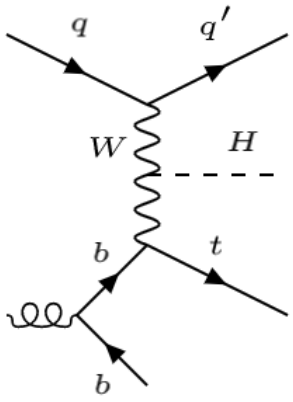
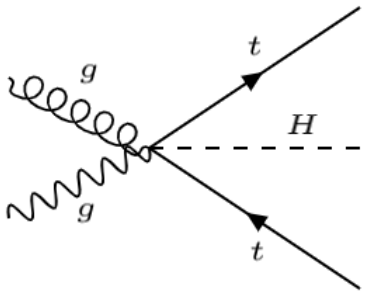
1 Introduction

In 2012, the ATLAS und CMS Collaborations discovered a particle consistent with a neutral scalar particle which was predicted by the Standard Model of particle physics (SM), the Higgs boson. After its discovery, the properties of the Higgs boson have to be examinated so it can be compared with the SM expectations. One of these properties is the Yukawa coupling Y_t^{SM} between the top-quark and the Higgs boson.
This coupling can be measured directly in processes where both Higgs boson and real top quarks are present. There are two processes that would allow this direct measurement of Y_t^{SM}. The first one is the production of the Higgs boson with a top anti-top pair (ttH), while the second process is the production of the Higgs boson with a single top-quark (tHq). For each process, a Feynman diagram on tree level is shown in figure 1.



(a) tHq



(b) ttH

Figure 1: Feynman diagrams on tree level for tH and ttH.

Since the tH and ttH process are quite similar to each other, it is an interesting question to ask if the methods used to examinate the ttH properties[1] can be adapted to the tH process.
In order to study if these methods can be adapted to the tH process, truth information have been added to tHq Monte Carlo samples. These information can be used in further studies to study the tH process even further.

[1] tH mass reconstruction implemented by Petr Urban: `https://gitlab.fit.cvut.cz/urbanp13/masters-thesis---petr-urban`.

2 Adding Truth Information

In order to add the truth information to the Monte Carlo files, the *SingletopAnalysis* framework is used. The framework uses *TopAnalysis* which is modified to add tH truth information. Thereto the files *CalcThqPartonHistory.cxx* and *CalcThqPartonHistory.h* have been added. As seen in table 1, the implemented code is adapted to the $H \to \tau\tau$ channel.

Table 1: Added variables for the tHq channel. For each variable, the particles mass m, transversal momemtum p_t, η and ϕ are stored. If the name of the variable does not give any information about the particle-type, the pdgId is stored aswell.

Higgs-Variables	Top-Variables	b-quark
MC_Higgs	MC_t_beforeFSR	MC_b
MC_tau1_from_Higgs	MC_t_afterFSR	-
MC_tau2_from_Higgs	MC_W_from_t	-
MC_nu_from_tau1	MC_b_from_t	-
MC_nu_from_tau2	MC_Wdecay1_from_t	-
MC_Wdecay1_from_tau1	MC_Wdecay2_from_t	-
MC_Wdecay2_from_tau1	-	-
MC_Wdecay1_from_tau2	-	-
MC_Wdecay2_from_tau2	-	-

However, these variables are not specified to the hadronic or leptonic channel and therefore include both of them. In case a tau-lepton decays leptonically, the respective *MC_Wdecay1_from_tau*-variable stores the information about the light lepton (electron e or muon μ), while the information about the respective neutrino will be stored in the *MC_Wdecay2_from_tau*-variable.
Due to confinement the simulated tau-leptons decay directly into multiple pions. However, the number of pions can vary. Because of this the hadronic final states are not saved. Instead, the 4-vector of the virtual W-boson is calculated as the difference between the 4-vector of a tau and its respective neutrino. The result is then saved into the respective *MC_Wdecay1_from_tau*-variable. In this case, the pdgId is either set to 24 or -24, depending on the pdgId of the respective *MC_nu_from_tau*-variable.
In the hadronic channel, all attributes of the respective *MC_Wdecay2_from_tau* are set to zero. This way, the hadronic and leptonic channel can be seperated with ease.

3 Conclusion and Outlook

Studies on the ttH and tHq process are essential to study the Yukawa coupling Y_t^{SM} between the top-quark and the Higgs boson. To support studies on the tHq process - including mass reconstruction - truth information about the tHq process have been added. These contain information about the $H \to \tau\tau$ channel considering leptonically and hadronically decaying tau-leptons.

With these additonal information on truth-level, the methods used for ttH mass reconstruction can be applied to the tHq process. This might help with further studies of the Yukawa coupling Y_t^{SM}.
The developed code has now been implemented in the official ATLAS athena framework and can be used automatically for the next production of the tH group ntuple.