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The associated production of $t\bar{t}H$ in ATLAS

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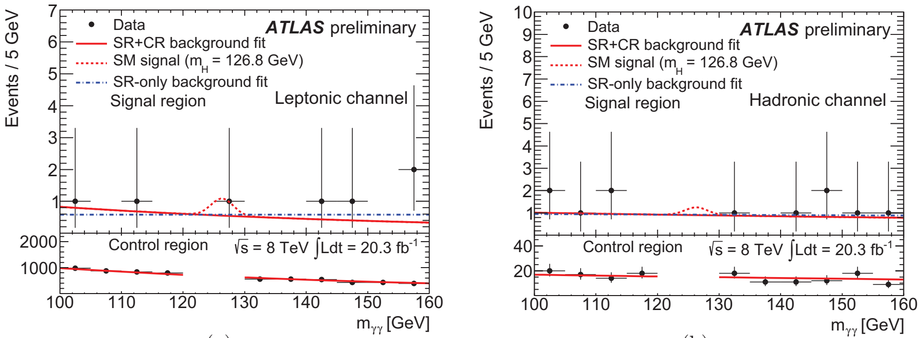
Summary. — Since its discovery in July 2012, it has become mandatory to study the couplings of the Higgs boson with other Standard Model particles. The associated production of Higgs and top-antitop pairs ($t\bar{t}H$) gives direct access to the Higgs-top couplings. Due to the different decay modes of the $t\bar{t}$ pairs and of the Higgs boson, the process displays a large variety of decay channels involving in the final state, $b\bar{b}$ pairs, $\gamma\gamma$ and multileptonic (including τ) states. Although the sensitivity is still limited by the Run I statistics, the assessment of the analysis methods will be essential for constraining the t-H coupling using the data collected from 2015 at ATLAS at LHC. These include background estimation, selection optimization and systematics control.

PACS 14.80.Bn – Standard-model Higgs bosons.
PACS 14.65.Ha – Top quarks.
PACS 14.65.Fy – Bottom quarks.
PACS 14.70.Bh – Photons.

1. – Introduction

The final pieces of the Standard Model of particle physics, the top quark and the Higgs boson, have been discovered respectively in 1995 [1, 2] and 2012 [3]. The Higgs field is responsible for the mass of the other fundamental particles, so the decay and production rates of the associated Higgs boson are directly proportional to the mass of the fermionic decay products and interacting particles. The main production process of the Higgs Boson at the LHC is the gluon fusion, that couples through a t or W loop with the Higgs, while the main decay channels are $b\bar{b}$, WW, ZZ and $\tau\tau$. From these productions and decays we can study the coupling coefficients with the fermions and bosons, in particular k_f is defined as $\sigma_f \sim k_f M_f$. The study of the associated production $t\bar{t}H$ is essential to obtain a precise value of k_f. k_f has been extracted from the gluon fusion process, that is sensitive to perturbative loops containing particles Beyond the Standard Model (BSM). A significant discrepancy between k_fs calculated through gluon fusion and $t\bar{t}H$ production would be an evidence of BSM physics, while a good agreement would impose strict limits on the production cross-sections of these phenomena. In these proceedings we present



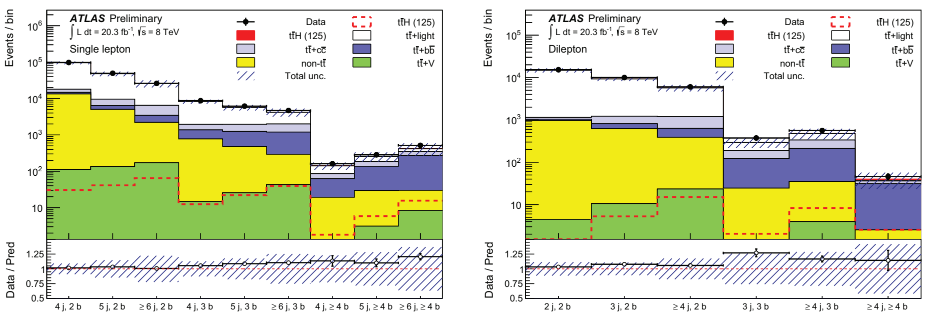
(a) (b)

Fig. 1. – The observed number of signal and background events in the $t\bar{t}H$, $H \to \gamma\gamma$ channel, together with the expected signal from the theory. Leptonic and hadronic refer to $t\bar{t}$ decays.

the analysis results obtained in the $t\bar{t}H$ production channel for the 2012 ATLAS dataset, divided into three main Higgs decay channels: $H \to \gamma\gamma$ [4], $H \to b\bar{b}$ [5] and multi-lepton decays, coming from $H \to WW/ZZ/\tau\tau$. These analyses are important test benches for the 2015 data: at 13/14 TeV the $t\bar{t}H$ production cross-section is the most enhanced (a factor of ~ 5), thus increasing the significance of the results together with the increased luminosity, addressing the questions concerning the Higgs fermionic couplings.

2. – The $H \to \gamma\gamma$ channel

The $H \to \gamma\gamma$ channel is considered the "golden" one for single-Higgs due to the clean signature given by the two almost back-to-back clusters in the Electromagnetic Calorimeter. The low branching ratio, on the other hand, reduces the statistic gathered by the experiment. Depending on top decays we distinguish between leptonic (single and double) and pure hadronic channels. The cut-based analysis of the 20.3 fb^{-1} data gathered in 2012 yields the results in fig. 1, where we observe no excess over the background foreseen by the Standard Model. A combined 95% CL limit is set on $t\bar{t}H$ ($H \to \gamma\gamma$) production cross-section 5–6 times the SM prediction.



(a) (b)

Fig. 2. – The observed number of signal and background events in the $t\bar{t}H$, $H \to b\bar{b}$ channel, for the different analysis signatures.

3. – The $H \to b\bar{b}$ channel

The main decay channel of the Higgs boson yields high statistics but a high background due to $t\bar{t}+$ jet (in particular $b\bar{b}$) events. Due to the complicated background, multi-variate methods have been exploited. In particular, Neural Networks using the NeuroBayes [6] package have been used. The events have been categorized on three bases: number of jets, number of b-jets and single lepton and di-lepton distinction. Figure 2 shows no excess from Standard Model predictions, as in the previous case. An observed 95% confidence level limit is observed 4.1 times the SM cross-section prediction.

4. – Multi-leptonic channels

To improve the sensitivity the analysis is being extended to multi-leptonic channels, that derive from $H \to WW$, $H \to ZZ$ and $H \to \tau\tau$ decays. We distinguish the different signal regions based on jet, lepton and τ multiplicities: two lepton with same sign, three leptons and four leptons; all with or without τ leptons. These channels can have a good signal-to-background ratio (expected $s/\sqrt{b} \sim 0.8$ per channel) and need different signal optimization and background estimation.

5. – Conclusions

The Higgs boson production, especially in the $t\bar{t}H$ production channel, could give important signals of what lies beyond our current knowledge of physics. The analysis of the 2012 data have shown that we can control the backgrounds and systematics of the various decay channels. Thanks to this, with the higher statistic available in the next years, the $t\bar{t}H$ channel will become essential in the search for new physics and the Standard Model measurements.

REFERENCES

[1] Abe F. *et al.* (CDF Collaboration), *Phys. Rev. Lett.*, **74** (1995) 2626.
[2] Abachi S. *et al.* (D0 Collaboration), *Phys. Rev. Lett.*, **74** (1995) 2632.
[3] ATLAS Collaboration, *Phys. Lett. B*, **716** (2012) 1.
[4] ATLAS Collaboration, ATLAS, CONF (2013) 080.
[5] ATLAS Collaboration, ATLAS, CONF (2014) 011.
[6] Feindt Michael, *Neurobayes, a neural bayesian estimator for conditional probability densities Techincal Report*, IEKP (KA/01) 1.