PROCEEDINGS OF SCIENCE

Measurement of the Higgs boson coupling to τ-leptons in proton–proton collisions at $\sqrt{s}$ = 13 TeV with the ATLAS detector at the LHC

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The Standard Model decay of the Higgs boson to leptons has been observed in the decay to a pair of τ-leptons. The cross section for $H \to \tau\tau$ is measured to $\sigma^{\text{obs}}_{H\to\tau\tau} = 2.90 \pm 0.21\,(\text{stat.})\,^{+0.37}_{-0.32}\,(\text{syst.})$ pb using Higgs boson decays into two τ-leptons in multiple Higgs production channels. The result is in agreement with the Standard Model prediction of 3.15 ± 0.09 pb. The sensitivity of the analysis is improved using machine-learning techniques. The analysis uses the full Run 2 proton-proton collision dataset corresponding to an integrated luminosity of 139 fb^{-1} recorded at a centre-of-mass energy $\sqrt{s}$ = 13 TeV with the ATLAS detector at the LHC.

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1. Introduction

According to the Standard Model (SM) of particle physics, the Higgs boson decays to a pair of τ-leptons with a branching ratio of BR($H \to \tau\tau$) $\approx 6\%$. Two classes of τ-lepton decay modes can be distinguished: the leptonic case where a τ-lepton (τ_{lep}) decays to a light, charged lepton (ℓ, electron or muon) and two neutrinos, and the hadronic case where the τ-lepton (τ_{had}) decays into a neutrino and a small number of hadrons.

This poster summarizes the latest measurement of the $H \to \tau\tau$ cross section [1] with the ATLAS detector [2] at the LHC. The analysis uses the full Run 2 proton–proton collision dataset with an integrated luminosity of $139\,\mathrm{fb}^{-1}$ recorded at a centre-of-mass energy of $\sqrt{s} = 13\,\mathrm{TeV}$. The analysis has specific signal regions to target the four main production modes of the Higgs boson at the LHC: gluon fusion (ggF), vector boson fusion (VBF), and associated production with a vector boson (VH) or a top quark (ttH). The decay of the two τ-leptons give rise to three analysis channels: $\tau_e\tau_\mu$, $\tau_{\mathrm{lep}}\tau_{\mathrm{had}}$, $\tau_{\mathrm{had}}\tau_{\mathrm{had}}$. The same-flavour, fully leptonic channel is not considered in this analysis. Hadronically decaying τ-leptons are reconstructed with a specialized algorithm. The contribution of events with an electron or a jet that is misidentified as a hadronically decaying τ-lepton is estimated with data-driven methods. The main background $Z \to \tau\tau$ is normalized to kinematically embedded $Z \to \ell\ell$ control regions. The invariant mass m_{MMC} of the di-τ system is reconstructed with the Missing Mass Calculator [3].

2. Machine learning

Boosted decision trees are used to target three production modes. In the VBF signal region, a boosted decision tree is trained to identify events with a VBF signature using jet kinematics. As shown in Figure 1a, a requirement on the BDT score defines a very pure signal region with more signal events than background events in the most sensitive m_{MMC} bins. Similar methods have been employed for the signal regions that target VH and ttH. In the case of ttH, one BDT is trained to reject events originating from background with a Z boson, and one BDT to reject events from $t\bar{t}$ background.

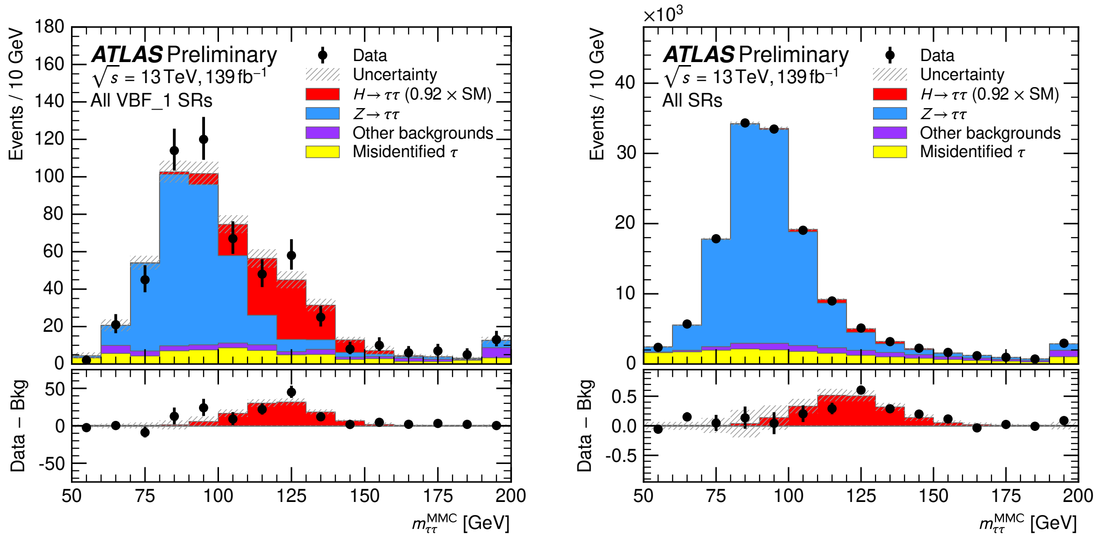
3. Cross section measurement

The cross section for the Higgs boson decay to τ-leptons has been measured to

$$\sigma^{\mathrm{obs}}_{H\to\tau\tau} = 2.90 \pm 0.21\,(\mathrm{stat.})\,^{+0.37}_{-0.32}\,(\mathrm{syst.})\,\mathrm{pb} \tag{1}$$

which is in agreement with the SM prediction of 3.15 ± 0.09 pb. The individual observed cross sections per signal region category and their compatibility with the SM are summarized in Figure 2. Additionally, the cross section has been measured in 9 categories of the Simplified Template Cross Sections [4]. Due to the high purity in the VBF signal regions, this analysis was able to observe the $H \to \tau\tau$ process in the VBF production mode with a significance of 5.3σ. The largest contribution to the systematic uncertainties arises from signal theory uncertainties (8.1%). The largest experimental uncertainties are related to Jet / $E_{\mathrm{T}}^{\mathrm{miss}}$ (4.2%).

PoS(EPS-HEP2021)573



(a) (b)

Figure 1: Invariant mass distributions m_{MMC} of the di-τ system in (a) the VBF signal region with a requirement on the BDT score, and (b) the combination of all signal regions [1].

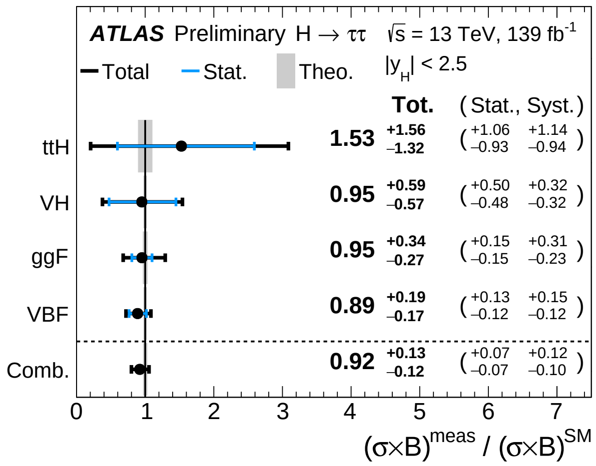


Figure 2: Measured cross sections in the production mode specific signal regions and the combined cross section. The cross sections are scaled to the SM expectation. The result is compatible with the SM prediction [1].

References

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PoS(EPS-HEP2021)573

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PoS(EPS-HEP2021)573