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

Frank Sauerburger[a,*] **on behalf of the ATLAS Collaboration**

[a] *Physikalisches Institut, Albert-Ludwigs-Universität Freiburg*
Hermann-Herder-Str. 3, Freiburg, Germany

E-mail: f.sauerburger@cern.ch

The coupling of the Higgs boson to τ-leptons is one of the most precise measured coupling of the Higgs boson to fermions. Its coupling strength is measured using the decays of the Higgs boson into two τ-leptons in the gluon-fusion and vector boson fusion production channels. This poster presents results from the latest measurements of the Higgs boson coupling to τ-leptons by the ATLAS experiment using 36 fb^{-1} of proton–proton collision data at $\sqrt{s}$ = 13 TeV at the LHC. Machine-learning techniques have been applied in a measurement of CP properties.

40th International Conference on High Energy physics - ICHEP2020
July 28 - August 6, 2020
Prague, Czech Republic (virtual meeting)

[*] Speaker

PoS(ICHEP2020)106

1. Introduction

In the Standard Model (SM) of particle physics, the Higgs boson decays into a pair of τ-leptons in approximately 6% of the cases. One can differentiate two different decay types of the τ-lepton. In the leptonic case, the τ-lepton (τ_{lep}) decays into an electron or a muon and two neutrinos, while in the hadronic case, the τ-lepton (τ_{had}) decays into a neutrino and a pair of quarks which subsequently hadronize.

This poster documents the latest measurements by the ATLAS experiment [1] of the Higgs boson coupling to τ-leptons by studying $H \to \tau\tau$ decays [2]. This measurement analyzes proton–proton collision data delivered by the LHC at $\sqrt{s} = 13$ TeV, corresponding to an integrated luminosity of 36 fb^{-1}. The τ-lepton decay modes give rise to three analysis channels: $\tau_{\text{lep}}\tau_{\text{lep}}$, $\tau_{\text{lep}}\tau_{\text{had}}$, and $\tau_{\text{had}}\tau_{\text{had}}$. Hadronically decaying τ-leptons are reconstructed using a dedicated algorithm. The event selections are tailored to the different background composition in each channel. The analyses use dedicated signal regions to target the gluon fusion and the vector boson fusion (VBF) Higgs production modes. The two main backgrounds, $Z \to \tau\tau$ and events with jets misidentified as hadronically decaying τ-leptons, are estimated with simulation and data-driven techniques, respectively.

2. Cross-section measurement

Due to the presence of the neutrinos in the final state, the invariant mass of the Higgs boson cannot be measured directly. It is rather estimated using the likelihood-based Missing Mass Calculator (MMC). The MMC algorithm takes the measured four-momenta of all visible τ-decay products and missing transverse energy into account to find the most likely mass of the initial $\tau\tau$ system. Figure 1a shows the mass distribution in all signal regions of the analysis described in Ref. [2]. The difference between measured events (Data) and expected background events shows a clear excess of events compatible with the prediction of the SM Higgs boson.

The measured total cross-section is $\sigma_{H\to\tau\tau} = 3.77^{+0.60}_{-0.59}\,(\text{stat})^{+0.87}_{-0.74}\,(\text{syst})$. The dominant systematic uncertainties are the uncertainties on the theory predictions for the signal production ($^{+0.51}_{-0.33}$ pb) and the statistical uncertainties of the background estimate ($^{+0.41}_{-0.37}$ pb).

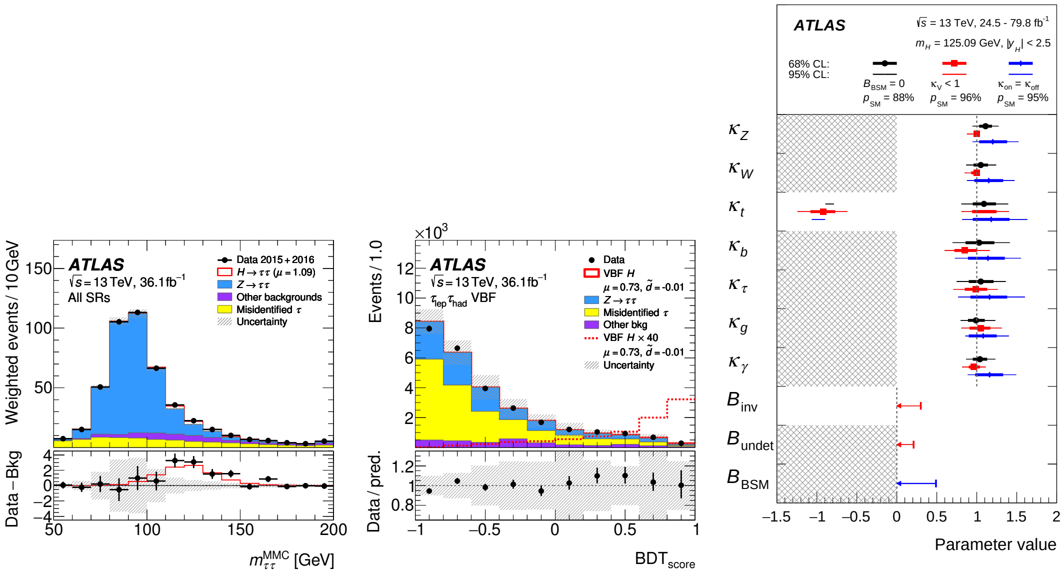
3. Machine-learning approaches

The use of machine-learning approaches for the study of the $H \to \tau\tau$ decay has been investigated in Ref. [3]. This analysis uses Boosted Decision Trees (BDT) to test the CP invariance in the VBF Higgs boson production mode. The requirement of $\text{BDT}_{\text{score}} > 0.86$ defines a signal region enriched in VBF-signal with a background efficiency of 0.4% while maintaining a signal efficiency of 29%. The $\text{BDT}_{\text{score}}$ distribution in the $\tau_{\text{lep}}\tau_{\text{had}}$ channel is shown in Figure 1b. The classifier has been validated in control regions. The coupling parameter $\tilde{d}$ describing the strength of CP violation has been constrained to the interval $[-0.090, 0.035]$ at 68% confidence level.

4. Coupling measurement

The result of the measurement of the $H \to \tau\tau$ decays [2] has been combined with other ATLAS measurements to measure the Higgs boson couplings to fermions and bosons [4].

PoS(ICHEP2020)106



(a) **(b)** **(c)**

Figure 1: Overview of important distributions and results from the analyses presented in this document: (a) The $\tau\tau$ mass distribution of all signal regions with an excess of measured data compatible with the expectation of the SM Higgs boson [2], (b) the output score of the BDT trained in the $\tau_{\mathrm{lep}}\tau_{\mathrm{had}}$ decay channel [3] and (c) the measurement results of various coupling strengths in the κ-framework [4].

The measured strength of the coupling of τ-leptons to the Higgs boson in the so-called κ-framework is $1.05^{+0.16}_{-0.15}$ times the SM prediction, assuming no BSM effects, see Figure 1c. The measurement is in agreement with the SM prediction for all Higgs decay channels. The results from the $H \to \tau\tau$ measurement contribute also to the combination in the STXS framework, in particular to the measurements of the VBF production mode, and of the low-p_{T}^{H} and high-p_{T}^{H} gluon-fusion production mode.

References

[1] ATLAS Collaboration, *The ATLAS Experiment at the CERN Large Hadron Collider*, *JINST* **3** (2008) S08003.

[2] ATLAS Collaboration, *Cross-section measurements of the Higgs boson decaying into a pair of τ-leptons in proton–proton collisions at $\sqrt{s}$ = 13 TeV with the ATLAS detector*, *Phys. Rev. D* **99** (2019) 072001 [1811.08856].

[3] ATLAS Collaboration, *Test of CP invariance in vector-boson fusion production of the Higgs boson in the $H \to \tau\tau$ channel in proton–proton collisions at $\sqrt{s}$ = 13 TeV with the ATLAS detector*, *Phys. Lett. B* **805** (2020) 135426 [2002.05315].

[4] ATLAS Collaboration, *Combined measurements of Higgs boson production and decay using up to 80 fb^{-1} of proton–proton collision data at $\sqrt{s}$ = 13 TeV collected with the ATLAS experiment*, *Phys. Rev. D* **101** (2020) 012002 [1909.02845].