PROCEEDINGS OF SCIENCE

Searching for lepton-flavour-violating decays of the Higgs boson with the ATLAS detector

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A search for lepton-flavour-violating decays of the Higgs boson into a tau lepton and either an electron or a muon is presented. The analysis uses data from proton–proton collisions at the Large Hadron Collider at $\sqrt{s}$ = 13 TeV, collected by the ATLAS detector and corresponding to an integrated luminosity of 36.1 fb^{-1}. The uncertainties in the results are dominated by the systematic error related to the fake-tau background calculation, which involved a data-driven technique. No significant excess of events is found over the Standard Model expectation and upper limits at 95% CL are placed in the branching ratios Br($H \to e\tau$) and Br($H \to \mu\tau$) of 0.47% and 0.28%, respectively. These limits are a big improvement with respect to previous ATLAS results, from Run 1.

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1. Introduction

The observation of neutrino oscillations indicates that lepton flavour violation (LFV) occurs in nature and that lepton flavour is not an exact symmetry. However, no observation has been made in the charged sector, which would be a clear indication of physics Beyond the Standard Model (BSM). There are BSM models which predict LFV decays of the Higgs boson into a pair of leptons with different flavours such as models with more than one Higgs doublet, composite Higgs models, models with flavour symmetries, Randall-Sundrum models and many more.

In this analysis [1] we search for the decays $H \to e\tau$ and $H \to \mu\tau$, independently, and we split the search depending on the decay mode of the tau lepton, leptonically ($\ell\tau_\ell$) or hadronically ($\ell\tau_{\text{had}}$). We use data from proton–proton collisions at the Large Hadron Collider at $\sqrt{s}$ = 13 TeV, collected by the ATLAS detector [2] and corresponding to an integrated luminosity of 36.1 fb^{-1}.

The composition of the Standard Model (SM) background depends on the channel; for both channels $Z \to \tau\tau$ is the dominant background while the second dominant background is top-quark for $\ell\tau_\ell$ and jets mis-identidied as taus for $\ell\tau_{\text{had}}$. There are smaller contributions from vector-bosons and $H \to \tau\tau$. The background from mis-identified leptons is derived with data-driven techniques, while the rest are calculated from Monte Carlo simulation.

In the $\ell\tau_\ell$ channel, events must contain exactly one electron and one muon of opposite-sign (OS) electric charges. In the $\ell\tau_{\text{had}}$ channel, a lepton and a τ_{had} of OS electric charges are required. In both cases, a veto on the presence of b-jets is applied to reduce the top-quark background.

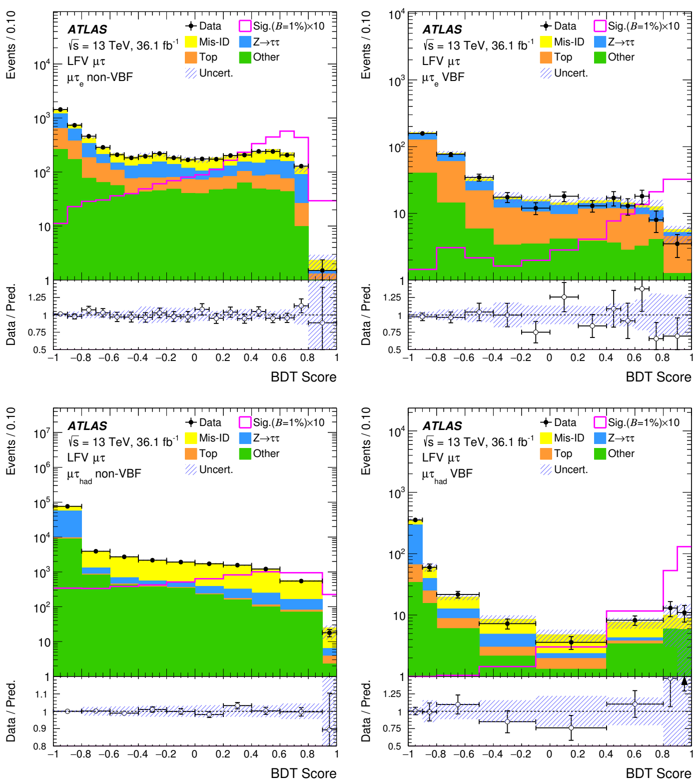

Figure 1: BDT score distributions for the $H \to \mu\tau$ search, after the signal-plus-background fit. The LFV signal is overlaid assuming a branching ratio of 10% for visibility [1].

Two categories are defined in each channel to exploit different production modes of the Higgs boson. The "VBF" category, which exploits the vector-boson fusion production mode, is defined by requiring at least two high-p_{T} jets with large invariant mass and large pseudorapidity. The "nonVBF" category fails the VBF selection and is dominated by Higgs bosons produced by gluon-gluon fusion.

In each channel and category, a Boosted Decision Tree (BDT) was trained to discern the LFV signal from the SM background using different kinematic variables. Figure 1 shows the BDT score distributions for the $H \to \mu\tau$ search.

2. Results

A statistical analysis was performed using a binned likelihood function. The BDT scores of all signal regions are analysed, plus control regions to constrain the normalisation of the $Z \to \tau\tau$ and top-quark backgrounds. The main systematic uncertainties impacting the fit are those related to jet kinematics, mis-identified leptons and, in the case of $H \to \mu\tau$, muon-related systematic uncertainties.

No significant excess of events was found over the SM expectation and upper limits at 95% CL were placed in the branching ratios Br($H \to e\tau$) and Br($H \to \mu\tau$) of 0.47% and 0.28%, respectively. These limits are a big improvement with respect to previous ATLAS results from Run 1, which were 1.04% and 1.43%, respectively . The limits can be converted to limits on off-diagonal Yukawa coupling matrix elements $Y_{\tau\ell}$ and $Y_{\ell\tau}$ for comparison to other results, as shown in Figure 2.

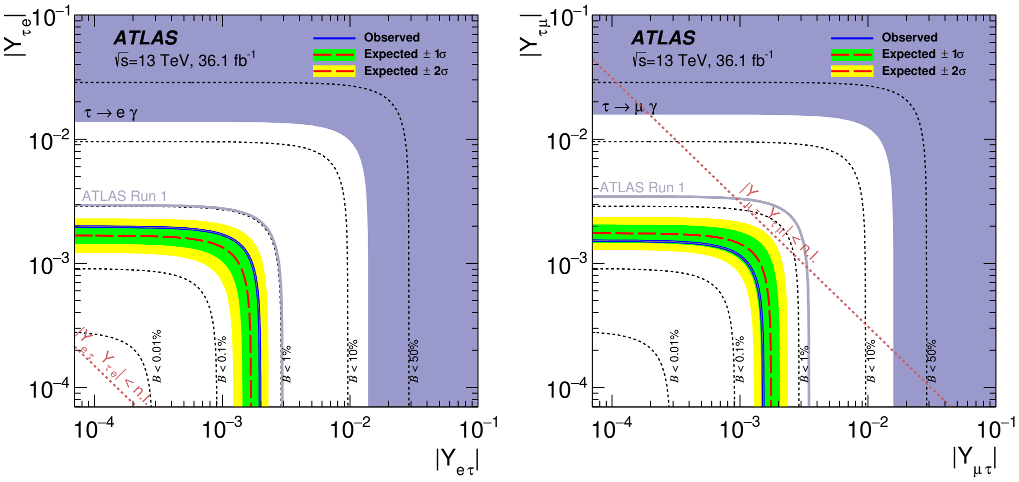

Figure 2: Upper limits on the absolute value of the couplings $Y_{\tau\ell}$ and $Y_{\ell\tau}$ together with the limits from the ATLAS Run 1 analysis and the most stringent indirect limits from $\tau \to \ell\gamma$ searches [1].

References

[1] ATLAS Collaboration, *Searches for lepton-flavour-violating decays of the Higgs boson in* $\sqrt{s}$ *= 13 TeV pp collisions with the ATLAS detector*, *Physics Letters B* **800** (2020) 135069

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

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