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# Searches for lepton-flavour-violating decays of the Higgs boson in $\sqrt{s} = 13$ TeV $pp$ collisions with the ATLAS detector

The ATLAS Collaboration

This Letter presents direct searches for lepton flavour violation in Higgs boson decays,  $H \rightarrow e\tau$  and  $H \rightarrow \mu\tau$ , performed with the ATLAS detector at the LHC. The searches are based on a data sample of proton–proton collisions at a centre-of-mass energy  $\sqrt{s} = 13$  TeV, corresponding to an integrated luminosity of  $36.1 \text{ fb}^{-1}$ . No significant excess is observed above the expected background from Standard Model processes. The observed (median expected) 95% confidence-level upper limits are  $0.47\%$  ( $0.34^{+0.13}_{-0.10}\%$ ) and  $0.28\%$  ( $0.37^{+0.14}_{-0.10}\%$ ) for  $H \rightarrow e\tau$  and  $H \rightarrow \mu\tau$ , respectively.

# 1 Introduction

The search for processes beyond the Standard Model (SM) is one of the main goals of the Large Hadron Collider (LHC) programme at CERN. A possible sign of such processes is lepton flavour violation (LFV) in decays of the Higgs boson [1, 2]. Many beyond-SM theories predict LFV decays of the Higgs boson, such as extensions of the Higgs sector or warped extra dimension models [3–6].

In this Letter, searches for LFV decays of the Higgs boson,  $H \rightarrow e\tau$  and  $H \rightarrow \mu\tau$ , at the LHC with the ATLAS experiment are presented. Studies are based on proton–proton ( $pp$ ) collision data recorded in 2015–2016 at a centre-of-mass energy  $\sqrt{s} = 13$  TeV. The dataset corresponds to an integrated luminosity of  $36.1 \text{ fb}^{-1}$ .

Previous ATLAS searches [7, 8] placed an upper limit of 1.04% (1.43%) on the  $H \rightarrow e\tau$  ( $H \rightarrow \mu\tau$ ) branching ratio ( $\mathcal{B}$ ) with a 95% confidence level (CL) using Run 1 data collected at  $\sqrt{s} = 8$  TeV, corresponding to an integrated luminosity of  $20.3 \text{ fb}^{-1}$ . The CMS Collaboration recently provided 95% CL upper limits on these branching ratios of 0.61% and 0.25%, respectively, using data collected at  $\sqrt{s} = 13$  TeV, with an integrated luminosity of  $35.9 \text{ fb}^{-1}$  [9].

The searches presented here involve both leptonic ( $\tau \rightarrow \ell' \nu \bar{\nu}^1$ ) and hadronic ( $\tau \rightarrow \text{hadrons} + \nu$ ) decays of  $\tau$ -leptons, denoted  $\tau_{\ell'}$  and  $\tau_{\text{had}}$  respectively. Only pairs of different-flavour leptons are considered in the dilepton final states  $\ell\tau_{\ell'}$ . Two channels are considered for each of the two searches:  $e\tau_{\mu}$  and  $e\tau_{\text{had}}$  for the  $H \rightarrow e\tau$  search,  $\mu\tau_e$  and  $\mu\tau_{\text{had}}$  for the  $H \rightarrow \mu\tau$  search. The analysis is designed such that any potential LFV signal overlap between the  $H \rightarrow e\tau$  and  $H \rightarrow \mu\tau$  searches is negligible. Many methods are reused from the measurement of the Higgs boson cross-section in the  $H \rightarrow \tau\tau$  final state [10].

The ATLAS detector<sup>2</sup> is described in Refs. [11–13]. It consists of an inner tracking detector covering the range  $|\eta| < 2.5$ , surrounded by a superconducting solenoid providing a 2 T axial magnetic field, high-granularity electromagnetic ( $|\eta| < 3.2$ ) and hadronic calorimeters ( $|\eta| < 4.9$ ), and a muon spectrometer (MS) which covers the range  $|\eta| < 2.7$  and includes fast trigger chambers ( $|\eta| < 2.4$ ) and superconducting toroidal magnets.

## 2 Simulation samples

Samples of Monte Carlo (MC) simulated events are used to optimize the event selection, and to model the signal and several of the background processes. The samples were produced with the ATLAS simulation infrastructure [14] using the full detector simulation performed by the GEANT4 [15] toolkit. The Higgs boson mass was set to  $m_H = 125$  GeV [16]. The four leading Higgs boson production mechanisms are considered: the gluon–gluon fusion (ggF), vector-boson fusion (VBF) and two associated production modes ( $WH$ ,  $ZH$ ), while the others give negligible contributions and are ignored. The cross-sections of all Higgs boson production processes were fixed to the SM predictions [17]. The LFV Higgs boson decays as well as the  $H \rightarrow \tau\tau$  and  $H \rightarrow WW$  background decays were modelled with Pythia 8 [18]. Other background processes involve electroweak production of  $W/Z$  bosons via VBF, Drell–Yan production of

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<sup>1</sup> Unless explicitly mentioned otherwise, leptons (denoted by  $\ell$  or  $\ell'$ ) refer to electrons or muons.

<sup>2</sup> ATLAS uses a right-handed coordinate system with its origin at the nominal interaction point in the centre of the detector and the  $z$ -axis along the beam pipe. The azimuthal angle  $\phi$  runs around the beam pipe, the pseudorapidity is defined in terms of the polar angle  $\theta$  as  $\eta \equiv -\ln \tan(\theta/2)$ . Angular distance in the  $\eta$ – $\phi$  space is defined as  $\Delta R \equiv \sqrt{(\Delta\eta)^2 + (\Delta\phi)^2}$ .

$W/Z$  in association with jet(s) as well as diboson, single top-quark and top-quark pair ( $t\bar{t}$ ) production. The MC generators used for the SM  $H \rightarrow \tau\tau$  cross-section measurement [10] were also employed here for all background components. The generators and parton shower models used to simulate different processes are summarized in Table 1.

Table 1: Generators used to describe the signal and background processes, parton distribution function (PDF) sets for the hard process, and models used for parton showering, hadronization and the underlying event (UEPS). The orders of the total cross-sections used to normalize the events are also given. More details are given in Ref. [10].

| Process        | Generator                         | PDF                 | UEPS              | Cross-section order                    |
|----------------|-----------------------------------|---------------------|-------------------|--|
| ggF            | Powheg-Box v2 [19–23] NNLOPS [24] | PDF4LHC15 [25] NNLO | Pythia 8.212 [18] | N <sup>3</sup> LO QCD + NLO EW [26–29] |
| VBF            | Powheg-Box v2 MiNLO [23]          | PDF4LHC15 NLO       | Pythia 8.212      | ~NNLO QCD + NLO EW [30–32]             |
| $WH, ZH$       | Powheg-Box v2 MiNLO               | PDF4LHC15 NLO       | Pythia 8.212      | NNLO QCD + NLO EW [33–35]              |
| $W/Z$ +jets    | Sherpa 2.2.1 [36]                 | NNPDF30NNLO [37]    | Sherpa 2.2.1 [38] | NNLO [39, 40]                          |
| $VV/V\gamma^*$ | Sherpa 2.2.1                      | NNPDF30NNLO         | Sherpa 2.2.1      | NNLO                                   |
| $t\bar{t}$     | Powheg-Box v2 [19–21, 41]         | CT10 [42]           | Pythia 6.428 [43] | NNLO+NNLL [44]                         |
| Single $t$     | Powheg-Box v1 [45, 46]            | CT10                | Pythia 6.428      | NLO [47–49]                            |

### 3 Object reconstruction

The correct identification of  $H \rightarrow \ell\tau$  events requires reconstruction of most objects (electrons, muons, and jets, including those initiated by hadronic decays of  $\tau$ -leptons) and the missing transverse momentum  $\vec{p}_T^{\text{miss}}$ , whose magnitude is called  $E_T^{\text{miss}}$ .

Electrons are reconstructed by matching tracks in the inner detector to clustered energy deposits in the electromagnetic calorimeter [50]. Loose likelihood-based identification [51],  $p_T > 15$  GeV and fiducial volume requirements ( $|\eta| < 2.47$ , excluding the transition region between the barrel and the endcap calorimeters  $1.37 < |\eta| < 1.52$ ) are applied. Medium identification and gradient isolation [51] criteria are imposed for the baseline electron selection.

Muons are identified by tracks reconstructed in the inner detector and matched to tracks in the MS. Loose identification [52],  $p_T > 10$  GeV and  $|\eta| < 2.5$  requirements are applied. Medium identification and gradient isolation [52] criteria are imposed for the baseline muon selection.

Jets are reconstructed using the anti- $k_t$  algorithm [53] as implemented by the FastJet [54] package. The algorithm is applied to topological clusters of calorimeter cells [55] with a radius parameter  $R = 0.4$ . Only jets with  $p_T > 20$  GeV and  $|\eta| < 4.5$  are considered. Jets from other  $pp$  interactions in the same and neighbouring bunch crossings (pile-up) are suppressed using jet vertex tagger (JVT) algorithms [56, 57]. Jets containing  $b$ -hadrons ( $b$ -jets) are identified by the MV2c20 algorithm [58, 59] in the central region ( $|\eta| < 2.4$ ). A working point corresponding to 85% average efficiency determined for  $b$ -jets in  $t\bar{t}$  simulated events is chosen.

The reconstruction of the object formed by the visible products of the  $\tau_{\text{had}}$  decay ( $\tau_{\text{had-vis}}$ ) begins from energy deposits in the calorimeter, processed by the anti- $k_t$  jet algorithm with a radius parameter  $R = 0.4$ . Information from the inner detector tracks associated with the energy deposits in the calorimeter is incorporated in the reconstruction. Only  $\tau_{\text{had-vis}}$  candidates with  $p_T > 20$  GeV and  $|\eta| < 2.5$  are considered.<sup>3</sup> One or three associated tracks with an absolute total charge  $|q| = 1$  are required. An

<sup>3</sup> The transition region in  $\eta$  is excluded, similarly to electrons.

Table 2: Baseline event selection and further categorization for the  $\ell\tau_{\ell'}$  and  $\ell\tau_{\text{had}}$  channels. The same criteria are also used for the control region (CR) definitions in the  $\ell\tau_{\ell'}$  channel (Section 5), but one requirement of the baseline selection is inverted to achieve orthogonal event selection. There is no CR in the  $\ell\tau_{\text{had}}$  channel.

| Selection                   | $\ell\tau_{\ell'}$   | $\ell\tau_{\text{had}}$  |
|-----------------------------|--|--|
| Baseline                    | exactly 1e and 1 $\mu$ , OS<br>$p_{\text{T}}^{\ell_1} > 45$ GeV<br>$p_{\text{T}}^{\ell_2} > 15$ GeV<br>$30 \text{ GeV} < m_{\text{vis}} < 150$ GeV<br>$p_{\text{T}}^e(\text{track})/p_{\text{T}}^e(\text{cluster}) < 1.2$ ( $\mu\tau_e$ only)<br>$b$ -veto (for jets with $p_{\text{T}} > 25$ GeV and $ \eta  < 2.4$ ) | exactly 1 $\ell$ and 1 $\tau_{\text{had-vis}}$ , OS<br>$p_{\text{T}}^{\ell} > 27.3$ GeV<br>$p_{\text{T}}^{\tau_{\text{had-vis}}} > 25$ GeV, $ \eta^{\tau_{\text{had-vis}}}  < 2.4$<br>$\sum_{i=\ell, \tau_{\text{had-vis}}} \cos \Delta\phi(i, E_{\text{T}}^{\text{miss}}) > -0.35$<br>$ \Delta\eta(\ell, \tau_{\text{had-vis}})  < 2$ |
|                             |  | Baseline<br>$\geq 2$ jets, $p_{\text{T}}^{j_1} > 40$ GeV, $p_{\text{T}}^{j_2} > 30$ GeV<br>$ \Delta\eta(j_1, j_2)  > 3$ , $m(j_1, j_2) > 400$ GeV<br>–<br>$p_{\text{T}}^{\tau_{\text{had-vis}}} > 45$ GeV  |
| Non-VBF                     |  | Baseline plus fail VBF categorization  |
|                             |  | $m_{\text{T}}(\ell_1, E_{\text{T}}^{\text{miss}}) > 50$ GeV –<br>$m_{\text{T}}(\ell_2, E_{\text{T}}^{\text{miss}}) < 40$ GeV –<br>$ \Delta\phi(\ell_2, E_{\text{T}}^{\text{miss}})  < 1.0$ –<br>$p_{\text{T}}^{\tau}/p_{\text{T}}^{\ell_1} > 0.5$ –  |
| Top-quark CR                | inverted $b$ -veto:  |  |
| VBF and non-VBF             | $\geq 1$ $b$ -tagged jet ( $p_{\text{T}} > 25$ GeV and $ \eta  < 2.4$ )  |  |
| $Z \rightarrow \tau\tau$ CR | inverted $p_{\text{T}}^{\ell_1}$ requirement:  |  |
| VBF and non-VBF             | $35 \text{ GeV} < p_{\text{T}}^{\ell_1} < 45$ GeV  |  |

identification algorithm [60, 61] based on boosted decision trees (BDT) [62–64] is used to reject  $\tau_{\text{had-vis}}$  candidates arising from misidentification of jets or from decays of hadrons with  $b$ - or  $c$ -quark content. Unless otherwise indicated, a tight identification (ID) working point is used for the  $\tau_{\text{had-vis}}$ , corresponding to an efficiency of 60% (45%) for 1-prong (3-prong) candidates. The  $\tau_{\text{had-vis}}$  candidates with one track overlapping with an electron candidate with high ID score, as determined by a multivariate (MVA) approach, are rejected. Leptonic  $\tau$ -decays are reconstructed as electrons or muons.

Single-lepton triggers with  $p_{\text{T}}$  thresholds between 21 and 27 GeV, depending on the lepton type and data-taking period, and variable isolation requirements are used for both the  $\ell\tau_{\ell'}$  and  $\ell\tau_{\text{had}}$  final states [65, 66].

## 4 Event selection and categorization

Events selected in the  $\ell\tau_{\ell'}$  channel contain exactly one electron and one muon of opposite-sign (OS) charges. Similarly in the  $\ell\tau_{\text{had}}$  channel, a lepton and a  $\tau_{\text{had-vis}}$  of OS charges are required, and events with more than one baseline lepton are rejected. The selection criteria are summarized in Table 2 for the analysis categories as well as the control regions (CRs), which are described in Section 5.

In the  $\ell\tau_{\ell'}$  channel,  $\ell_1$  and  $\ell_2$  denote the leading and subleading lepton in  $p_T$ , respectively. Events where the leading lepton is an electron (muon) are used in the search for  $H \rightarrow e\tau_\mu$  ( $H \rightarrow \mu\tau_e$ ). A requirement on the dilepton invariant mass, equal to the invariant mass of the lepton and the visible  $\tau$ -decay products,  $m_{\text{vis}}$ , reduces backgrounds with top quarks, and the criterion applied to the track-to-cluster  $p_T$  ratio of the electron reduces the  $Z \rightarrow \mu\mu$  background where a muon deposits a large amount of energy in the electromagnetic calorimeter and is misidentified as an electron in the  $\mu\tau_e$  channel. The contribution from the  $H \rightarrow \tau\tau$  decay is reduced by the asymmetric  $p_T$  selection of the two leptons.

In the  $\ell\tau_{\text{had}}$  channel, the criterion based on the azimuthal separations of lepton– $E_T^{\text{miss}}$  and  $\tau_{\text{had-vis}}-E_T^{\text{miss}}$ ,  $\sum_{i=\ell, \tau_{\text{had-vis}}} \cos \Delta\phi(i, E_T^{\text{miss}})$ , reduces the  $W$ +jets background whereas the requirement on  $|\Delta\eta(\ell, \tau_{\text{had-vis}})|$  reduces backgrounds with misidentified  $\tau_{\text{had-vis}}$  candidates.

For both channels, a  $b$ -veto requirement reduces the single-top-quark and  $t\bar{t}$  backgrounds. Events are further categorized into VBF (with a focus on the VBF production of the Higgs boson) and non-VBF categories. The VBF selection is based on the kinematics of the two jets with the highest  $p_T$ , where  $j_1$  and  $j_2$  denote the leading and subleading jet in  $p_T$ , respectively. The variables  $m(j_1, j_2)$  and  $\Delta\eta(j_1, j_2)$  stand for the invariant mass and  $\eta$  separation of these two jets. The non-VBF category contains events failing the VBF selection. Additional selection criteria in  $\ell\tau_{\ell'}$ , as described in Table 2, are applied to further reject background events in this category, in which  $m_T$  stands for the transverse mass<sup>4</sup> of the two objects listed in parentheses, and  $p_T^\tau$  represents the magnitude of the vector sum of  $p_T^{\ell_2}$  and  $E_T^{\text{miss}}$ . The requirement on  $p_T^\tau/p_T^{\ell_1}$  reduces the background arising from jets misidentified as leptons. The VBF and non-VBF categories in each of the  $\ell\tau_{\ell'}$  and  $\ell\tau_{\text{had}}$  channels give rise to four signal regions in each search.

The analysis exploits BDT algorithms to enhance the signal separation from the background in the individual searches, channels and categories. First, the components of the four-momenta of the analysis objects as well as derived event variables (e.g. invariant masses and angular separations) are the input variables of the BDT discriminant. These variables are ranked according to their discrimination power [67, 68]. The list of variables is then optimized, removing the lowest-ranked variables. The final list of variables is presented in Table 3 for each channel and category. The invariant mass of the Higgs boson reconstructed under the  $H \rightarrow \ell\tau$  decay hypothesis exhibits the highest signal-to-background separation power and it helps to distinguish LFV signal from  $H \rightarrow \tau\tau$  and  $H \rightarrow WW$  backgrounds. For the  $\ell\tau_{\ell'}$  channel the invariant mass is reconstructed with the MMC algorithm [69] and is denoted by  $m_{\text{MMC}}$ ; for the  $\ell\tau_{\text{had}}$  channel it is reconstructed with the collinear approximation [69] and is denoted by  $m_{\text{coll}}$ . The analysis CRs are used to validate the level of agreement between data and simulated distributions of the BDT score and input variables, as well as their correlations.

<sup>4</sup> The transverse mass of two objects is defined as  $m_T = \sqrt{2p_{T1}p_{T2}(1 - \cos \Delta\phi)}$ , where  $p_{Ti}$  are the individual transverse momenta and  $\Delta\phi$  is the angle between the two objects in the azimuthal plane.

Table 3: BDT input variables used in the analysis. For each channel and category, used input variables are marked with HR (indicating the five variables with the highest rank) or a bullet. Analogous variables between the two channels are listed on the same line.

| $\ell\tau_{\ell'}$                                 |     |         | $\ell\tau_{\text{had}}$   |     |         |
|--|-----|---------|---|-----|---------|
| Variable   | VBF | non-VBF | Variable  | VBF | non-VBF |
| $m_{\text{MMC}}$                                   | HR  | HR      | $m_{\text{coll}}$   | HR  | HR      |
| $p_{\text{T}}^{\ell_1}$                            | •   | •       | $p_{\text{T}}^{\ell}$   | •   | HR      |
| $p_{\text{T}}^{\ell_2}$                            | HR  | HR      | $p_{\text{T}}^{\tau_{\text{had-vis}}}$  | •   | HR      |
| $\Delta R(\ell_1, \ell_2)$                         | HR  | •       | $\Delta R(\ell, \tau_{\text{had-vis}})$   | •   | •       |
| $m_{\text{T}}(\ell_1, E_{\text{T}}^{\text{miss}})$ | •   | HR      | $m_{\text{T}}(\ell, E_{\text{T}}^{\text{miss}})$                                      | HR  | •       |
| $m_{\text{T}}(\ell_2, E_{\text{T}}^{\text{miss}})$ | HR  | •       | $m_{\text{T}}(\tau_{\text{had-vis}}, E_{\text{T}}^{\text{miss}})$                     | HR  | HR      |
| $\Delta\phi(\ell_1, E_{\text{T}}^{\text{miss}})$   | •   | •       | $\Delta\phi(\ell, E_{\text{T}}^{\text{miss}})$  | HR  | •       |
| $\Delta\phi(\ell_2, E_{\text{T}}^{\text{miss}})$   |     | HR      | $\Delta\phi(\tau_{\text{had-vis}}, E_{\text{T}}^{\text{miss}})$                       | •   |         |
| $m(j_1, j_2)$                                      | •   |         | $m(j_1, j_2)$   | •   |         |
| $\Delta\eta(j_1, j_2)$                             | HR  |         | $\Delta\eta(j_1, j_2)$  | •   |         |
| $p_{\text{T}}^{\tau}/p_{\text{T}}^{\ell_1}$        |     | HR      | $\sum_{i=\ell, \tau_{\text{had-vis}}} \cos \Delta\phi(i, E_{\text{T}}^{\text{miss}})$ | •   | •       |
|  |     |         | $E_{\text{T}}^{\text{miss}}$  | HR  | •       |
|  |     |         | $m_{\text{vis}}$  |     | HR      |
|  |     |         | $\Delta\eta(\ell, \tau_{\text{had-vis}})$   |     | •       |
|  |     |         | $\eta^{\ell}$   |     | •       |
|  |     |         | $\eta^{\tau_{\text{had-vis}}}$  |     | •       |
|  |     |         | $\phi^{\ell}$   |     | •       |
|  |     |         | $\phi^{\tau_{\text{had-vis}}}$  |     | •       |
|  |     |         | $\phi(E_{\text{T}}^{\text{miss}})$  |     | •       |

## 5 Background modelling

The most significant backgrounds in the search are from events with  $Z \rightarrow \tau\tau$  decays or with (single or pair-produced) top quarks, especially in the  $\ell\tau_{\ell'}$  channel, as well as from events with misidentified objects, which are estimated using data-driven techniques. The relative contribution from misidentified objects to the total background yield is 5–25% in the  $\ell\tau_{\ell'}$  channel and 25–45% in the  $\ell\tau_{\text{had}}$  channel, depending on the search and the analysis category. The shapes of distributions from the  $Z \rightarrow \tau\tau$  and top-quark (single-top-quark and  $t\bar{t}$ ) processes are modelled by simulation in both the  $\ell\tau_{\ell'}$  and  $\ell\tau_{\text{had}}$  decay channels. In the  $\ell\tau_{\ell'}$  channel, the relative contributions of  $Z \rightarrow \tau\tau$  and top-quark production processes are 20–35% and 20–55%, respectively; the top-quark background dominates in the VBF category. In the  $\ell\tau_{\text{had}}$  channel, the top-quark background fraction is 1–10%, while the  $Z \rightarrow \tau\tau$  process contributes to 45–55% of the total background. The individual contributions are listed in Tables 4 and 5. Smaller background components are also modelled by simulation and are grouped together:  $Z \rightarrow \mu\mu$ , diboson production,  $H \rightarrow \tau\tau$  and  $H \rightarrow WW$ .

Good modelling of the background is demonstrated in Figure 1 for a selection of important BDT input variables. Details of the background estimation techniques are given below.

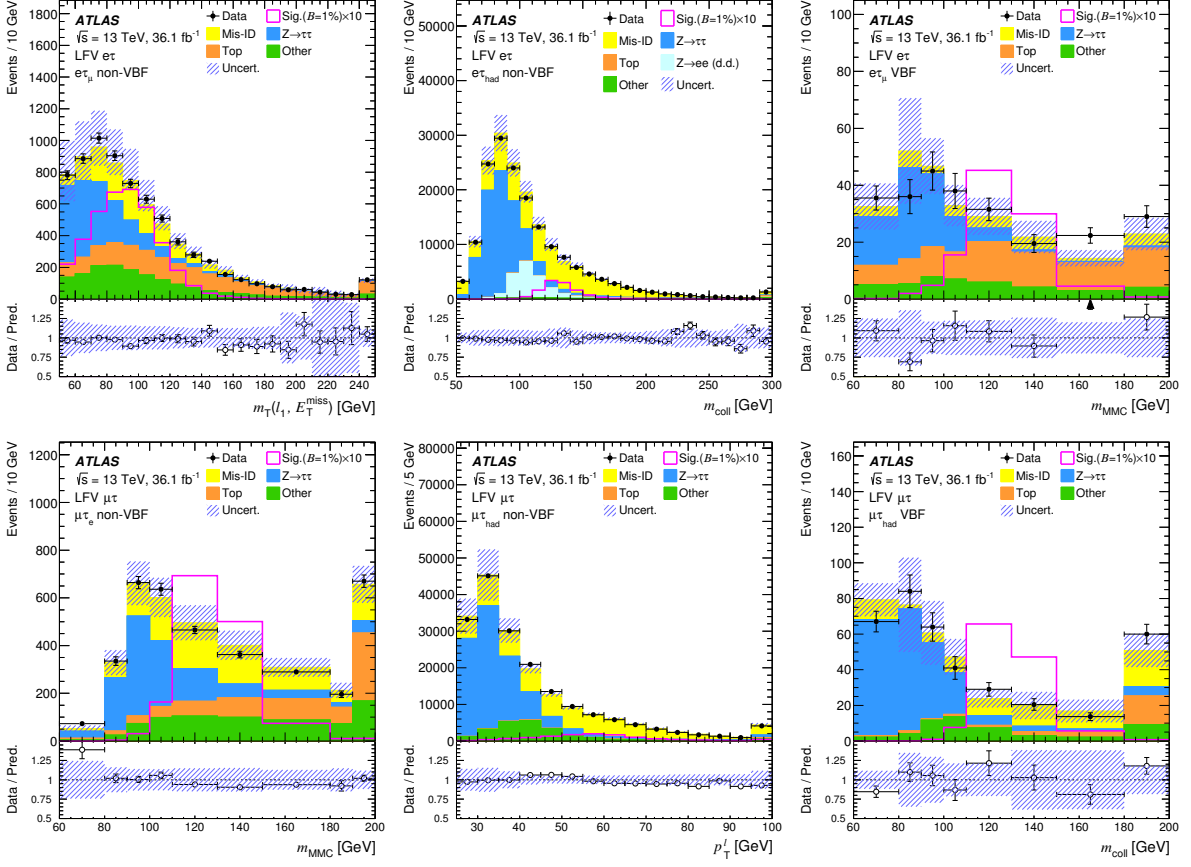


Figure 1: Pre-fit distributions of representative kinematic quantities for different searches, channels and categories. Top row: transverse mass  $m_T(\ell_1, E_T^{\text{miss}})$  ( $e\tau_\mu$  non-VBF), collinear mass  $m_{\text{coll}}$  ( $e\tau_{\text{had}}$  non-VBF) and  $m_{\text{MMC}}$  ( $e\tau_\mu$  VBF). Bottom row:  $m_{\text{MMC}}$  ( $\mu\tau_e$  non-VBF), muon  $p_T$  ( $\mu\tau_{\text{had}}$  non-VBF) and  $m_{\text{coll}}$  ( $\mu\tau_{\text{had}}$  VBF). Entries with values that would exceed the  $x$ -axis range are included in the last bin of each distribution. The size of the combined statistical, experimental and theoretical uncertainties in the background is indicated by the hatched bands. The  $H \rightarrow \ell\tau$  ( $H \rightarrow \mu\tau$ ) signal overlaid in top (bottom) plots assumes  $\mathcal{B}(H \rightarrow \ell\tau) = 1\%$  and is enhanced by a factor 10. In the data/background prediction ratio plots, points outside the displayed  $y$ -axis range are shown by arrows.

## 5.1 $\ell\tau_{\ell'}$ channel

Two sets of CRs, as defined in Table 2, are used to constrain the normalization of  $Z \rightarrow \tau\tau$  and top-quark background components. These CRs inherit their definitions from the corresponding analysis category but invert one requirement to ensure orthogonality with the nominal selection. The normalization factors are determined during the statistical analysis by fitting the event yields in all signal and control regions simultaneously. For each search, separate  $Z \rightarrow \tau\tau$  normalization factors are used for the VBF and non-VBF categories. In the case of the top-quark background, in which leading jets are produced at a lower order of the perturbative expansion of the scattering process, a combined normalization factor across the two categories is used in the  $\ell\tau_{\ell'}$  channel.

Top-quark CRs are almost exclusively composed of top-quark backgrounds: the purity is 95% across both searches and categories, with  $t\bar{t}$  process accounting for more than 90% of the top-quark backgrounds. The  $Z \rightarrow \tau\tau$  CRs achieved a purity of  $\sim 80\%$  in the non-VBF categories, while a lower purity of  $\sim 60\%$  is



observed in the VBF categories. The contributions of all other background components are set to their SM predictions when the likelihood fit (Section 7) is applied.

The shape and normalization of diboson and  $Z \rightarrow \mu\mu$  background distributions are validated with data in dedicated regions where their contributions are enhanced. The latter process only contributes sizeably in the  $\mu\tau_e$  channel, where it represents up to 10% of the total background.

Another source of background comes from  $W$ +jets, top-quark and multi-jet events, where jets are misidentified as leptons. This background is estimated directly from OS data events where an inverted isolation requirement is imposed on the subleading lepton [10]. Normalization factors are applied to correct for the inverted isolation requirement. The normalization factors are derived in a dedicated region where the leptons are required to have same-sign (SS) charges. Additional corrections are derived from data in terms of  $\Delta\phi(\ell_1, E_T^{\text{miss}})$  and  $\Delta\phi(\ell_2, E_T^{\text{miss}})$  in the SS region to improve the modelling of azimuthal angles between leptons and the  $E_T^{\text{miss}}$  direction. These corrections also improve the modelling of  $m_T(\ell_2, E_T^{\text{miss}})$  in the SS region. A similar improvement is observed in the nominal OS region. In most of the cases, the misidentified jet mimics the lepton of lower  $p_T$ ,  $\ell_2$ , while the fraction of events where both leptons are misidentified varies between 2% to 8% across categories. The systematic uncertainties of the estimation of the misidentified lepton background include contributions from closure tests in SS and OS regions enriched with misidentified leptons, from the corrections made to the  $\Delta\phi$  distributions, and from the composition of the misidentified lepton background.

## 5.2 $\ell\tau_{\text{had}}$ channel

The main background contributions come from the  $Z \rightarrow \tau\tau$  process and events where either a jet or an electron is misidentified as  $\tau_{\text{had-vis}}$ . The shape of the  $Z \rightarrow \tau\tau$  background distribution is modelled by simulation, and the corresponding normalization factors are determined from the simultaneous fit of the event yields in all signal and control regions. The  $Z \rightarrow \tau\tau$  normalization factors are fully correlated with those of the  $\ell\tau_{\nu}$  channel, in each VBF and non-VBF category. Top-quark production represents less than 1% of the total background in the  $\ell\tau_{\text{had}}$  channel and is determined by simulation, including its normalization, which is kept fixed in the fit.

The main contributions to jets misidentified as  $\tau_{\text{had-vis}}$  come from multi-jet events and  $W$ -boson production in association with jets, and a fake-factor method is used to estimate the contribution of each component separately. A fake factor is defined as the ratio of the number of events where the highest- $p_T$  jet is identified as a tight  $\tau_{\text{had-vis}}$  candidate to the number of events where the highest- $p_T$  jet fails to satisfy this  $\tau$ -ID criterion but satisfies a looser criterion. The procedure, including systematic uncertainties, is described in Ref. [10]. Since a different  $\tau$ -ID working point is considered in this analysis, fake factors are re-derived as a function of  $p_T$  and track multiplicity of the  $\tau_{\text{had-vis}}$  candidate.

Electrons misidentified as  $\tau_{\text{had-vis}}$ , denoted by “ $Z \rightarrow ee$  (d.d.)” in the following figures and tables, represent another background component in the  $e\tau_{\text{had}}$  channel, with a contribution about five times smaller than that of jets misidentified as  $\tau_{\text{had-vis}}$ . While the rate of electrons misidentified as 3-prong  $\tau_{\text{had-vis}}$  makes a negligible contribution and is modelled by simulation, the rate of electrons misidentified as 1-prong  $\tau_{\text{had-vis}}$  is determined with a fake-factor method. This time, the fake factor is defined as the ratio of the number of events with tight  $\tau$ -ID to the number of events with anti-identified  $\tau_{\text{had-vis}}$  (such a candidate satisfies all criteria but the requirement on the high electron ID score is inverted). These fake factors are derived in a dedicated  $Z \rightarrow ee$  enriched region defined by  $|m_{\text{vis}} - m_Z| < 5 \text{ GeV}$ ,  $m_T(\ell, E_T^{\text{miss}}) < 40 \text{ GeV}$ , and  $m_T(\tau_{\text{had-vis}}, E_T^{\text{miss}}) < 60 \text{ GeV}$ , where the  $\tau_{\text{had-vis}}$  candidate satisfies the medium  $\tau$ -ID but not the tight  $\tau$ -ID



criterion to avoid overlap with the  $\ell\tau_{\text{had}}$  signal region. These fake factors are applied to signal-like events with the anti-identified  $\tau_{\text{had-vis}}$  to determine the background contribution in the categories of the analysis. The systematic uncertainties include the statistical uncertainty of the fake factors and account for looser  $\tau$ -ID in the  $Z \rightarrow ee$  enriched region as well as for the subtraction of the not misidentified components in this region.

## 6 Systematic uncertainties

The systematic uncertainties affect the normalization of signal and background, and/or the shape of their corresponding final discriminant distributions. Each source of systematic uncertainty is considered to be uncorrelated with the other sources. The effect of each systematic uncertainty is fully considered in each category, including control regions. Correlations of each systematic uncertainty are maintained across processes, channels, categories and regions. The size of the systematic uncertainties and their impact on the fitted branching ratio are discussed in Section 7. The main sources of systematic uncertainties are related to the estimation of the backgrounds originating from mis-identified leptons/jets and to the jet energy scale uncertainties.

Experimental uncertainties include those originating from the reconstruction, identification, tagging and triggering efficiencies of all physics objects as well as their momentum scale and resolution. These include effects from leptons [50–52],  $\tau_{\text{had-vis}}$  [61], jets [56, 57, 70] and  $E_{\text{T}}^{\text{miss}}$  [71]. Uncertainties affecting the kinematics of the physics objects are propagated to the BDT input variables. The corresponding shape and normalization variations of the BDT discriminant are considered in the statistical analysis. Uncertainties of the luminosity measurement [72], pile-up modelling and uncertainties specific to mis-identified background estimation techniques mentioned in Section 5 are included.

The procedures to estimate the uncertainty of the Higgs boson production cross-sections follow the recommendations of the LHC Higgs Cross-Section Working Group [73]. Theoretical uncertainties affecting the ggF signal originate from nine sources [17]. Two sources account for yield uncertainties, which are evaluated by an overall variation of all relevant scales and are correlated across all bins of the BDT discriminant distribution [74]. Another two sources account for migration uncertainties of zero to one jet and one to at least two jets in the event [74–76], two for Higgs boson  $p_{\text{T}}$  shape uncertainties, one for the treatment of the top-quark mass in the loop corrections, and two for the acceptance uncertainties of ggF production in the VBF phase space from selecting exactly two and at least three jets, respectively [77, 78]. For VBF and  $WH$ ,  $ZH$  production cross-sections, the uncertainties due to missing higher-order QCD corrections are estimated by varying the factorization and renormalization scales up and down by factors of two around the nominal scale. For all signal samples, PDF uncertainties are estimated using 30 eigenvector variations and two  $\alpha_s$  variations using the default PDF set PDF4LHC15 [25]. Uncertainties related to the simulation of the underlying event, hadronization and parton shower are estimated by comparing the acceptances when using Pythia 8.212 [18] or Herwig 7.0.3 [79, 80].

The sources of modelling uncertainties considered for the  $Z \rightarrow \tau\tau$  process are the same as in Ref. [10] and their effect on the event migrations between categories and on the shape of the BDT discriminant are considered, since the overall normalizations are determined from data in the statistical analysis. These systematic uncertainties include variations of PDF sets, factorization and renormalization scales, CKKW matching [81], resummation scale and parton shower modelling. The other background processes are either normalized using data (processes with top-quarks and mis-identified leptons and  $\tau_{\text{had-vis}}$  candidates) or their

cross-section uncertainties have negligible impact and therefore are not included. The shape uncertainties of these backgrounds originate from experimental uncertainties only.

## 7 Statistical analysis

The searches for  $H \rightarrow e\tau$  and  $H \rightarrow \mu\tau$  are treated independently. For each search, the analysis exploits the four signal regions and the two control regions specified in Table 2. The BDT score distributions of all signal regions are analysed to test the presence of a signal, simultaneously with the event yields in control regions, which are included to constrain the normalizations of the major backgrounds estimated from simulation. The statistical analysis uses a binned likelihood function  $\mathcal{L}(\mu, \theta)$ , constructed as a product of Poisson probability terms over all bins considered in the search. This function depends on the parameter  $\mu$ , defined as the branching ratio  $\mathcal{B}(H \rightarrow \ell\tau)$ , and a set of nuisance parameters  $\theta$  that encode the effect of systematic uncertainties in the signal and background expectations. All nuisance parameters are implemented in the likelihood function as Gaussian or log-normal constraints. The normalization factors of the single-top-quark and  $t\bar{t}$  backgrounds in the  $\ell\tau_{\ell'}$  channel and of the  $Z \rightarrow \tau\tau$  background component are unconstrained parameters of the fit. Estimates of the parameters of interest are calculated with the profile-likelihood-ratio test statistic  $\tilde{q}_\mu$  [82], and the upper limits on the branching ratios are derived by using  $\tilde{q}_\mu$  and the  $\text{CL}_S$  method [83].

The discriminant distributions after the fit in each channel are shown in Figures 2 and 3. Good agreement between data and the background expectation is observed. The event yields after the background-only fit are summarized in Tables 4 and 5. The larger yields in  $\ell\tau_{\text{had}}$  non-VBF than in  $\ell\tau_{\ell'}$  non-VBF are due to the looser selection criteria defined for the former channel (Section 4). Table 6 shows a summary of the uncertainties of  $\mathcal{B}(H \rightarrow \ell\tau)$ . The uncertainties associated with misidentified leptons and  $\tau_{\text{had-vis}}$  candidates and those related to the jet energy scale and resolution exhibit the highest impact on the best-fit branching ratios in both searches. The combined impact from all systematic uncertainties and the data statistics ranges from 0.17% to 0.19%.

Table 4: Event yields and predictions as determined by the background-only fit in different signal regions of the  $H \rightarrow e\tau$  analysis. Uncertainties include both the statistical and systematic contributions. ‘‘Other’’ contains diboson,  $Z \rightarrow \ell\ell$ ,  $H \rightarrow \tau\tau$  and  $H \rightarrow WW$  background processes. For the  $e\tau_{\text{had}}$  channel the ‘‘ $Z \rightarrow ee$  (d.d.)’’ component corresponds to electrons misidentified as  $\tau_{\text{had-vis}}$ . This contribution is summed with ‘‘Other’’ since there are few events in the VBF category. The uncertainty of the total background includes all correlations between channels. The normalizations of top-quark ( $\ell\tau_{\ell'}$  channel only) and  $Z \rightarrow \tau\tau$  background components are determined by the fit, while the expected signal event yields are given for  $\mathcal{B}(H \rightarrow e\tau) = 1\%$ .

|                           | $e\tau_\mu$ non-VBF | $e\tau_\mu$ VBF | $e\tau_{\text{had}}$ non-VBF | $e\tau_{\text{had}}$ VBF |
|---------------------------|---------------------|-----------------|------------------------------|--------------------------|
| Signal                    | $379 \pm 31$        | $19.8 \pm 2.7$  | $1180 \pm 110$               | $25 \pm 4$               |
| $Z \rightarrow \tau\tau$  | $2470 \pm 230$      | $221 \pm 34$    | $73\,800 \pm 1900$           | $290 \pm 40$             |
| Top-quark                 | $1640 \pm 140$      | $490 \pm 40$    | $1580 \pm 190$               | $56 \pm 12$              |
| Mis-identified            | $1330 \pm 250$      | $73 \pm 33$     | $74\,400 \pm 1600$           | $140 \pm 50$             |
| $Z \rightarrow ee$ (d.d.) |                     |                 | $15\,900 \pm 1800$           | $82 \pm 13$              |
| Other                     | $1700 \pm 80$       | $220 \pm 15$    | $2960 \pm 200$               |                          |
| Total background          | $7130 \pm 100$      | $1003 \pm 33$   | $168\,700 \pm 1000$          | $570 \pm 40$             |
| Data                      | 7128                | 992             | 168 883                      | 572                      |

Table 5: Event yields and predictions as determined by the background-only fit in different signal regions of the  $H \rightarrow \mu\tau$  analysis. Uncertainties include both the statistical and systematic contributions. “Other” contains diboson,  $Z \rightarrow \ell\ell$ ,  $H \rightarrow \tau\tau$  and  $H \rightarrow WW$  background processes. The uncertainty of the total background includes all correlations between channels. The normalizations of top-quark ( $\ell\tau_{\ell'}$  channel only) and  $Z \rightarrow \tau\tau$  background components are determined by the fit, while the expected signal event yields are given for  $\mathcal{B}(H \rightarrow \mu\tau) = 1\%$ .

|                          | $\mu\tau_e$ non-VBF | $\mu\tau_e$ VBF | $\mu\tau_{\text{had}}$ non-VBF | $\mu\tau_{\text{had}}$ VBF |
|--------------------------|---------------------|-----------------|--------------------------------|----------------------------|
| Signal                   | $287 \pm 23$        | $14.6 \pm 1.9$  | $1200 \pm 120$                 | $25 \pm 5$                 |
| $Z \rightarrow \tau\tau$ | $1860 \pm 130$      | $144 \pm 26$    | $96\,100 \pm 2000$             | $274 \pm 33$               |
| Top quark                | $1260 \pm 130$      | $390 \pm 34$    | $1620 \pm 210$                 | $51 \pm 10$                |
| Misidentified            | $1340 \pm 210$      | $41 \pm 21$     | $63\,900 \pm 1600$             | $149 \pm 33$               |
| Other                    | $1180 \pm 140$      | $168 \pm 18$    | $23\,000 \pm 1000$             | $104 \pm 15$               |
| Total background         | $5640 \pm 100$      | $743 \pm 29$    | $184\,500 \pm 1200$            | $580 \pm 30$               |
| Data                     | 5664                | 723             | 184\,508                       | 583                        |

Table 6: Summary of the systematic uncertainties and their impact on the best-fit value of  $\mathcal{B}$  in the  $H \rightarrow e\tau$  and  $H \rightarrow \mu\tau$  searches. The measured values are obtained by the fit to data, while the expected values are determined by the fit to a background-only sample.

| Source of uncertainty                     | Impact on $\mathcal{B}(H \rightarrow e\tau)$ [%] |             | Impact on $\mathcal{B}(H \rightarrow \mu\tau)$ [%] |             |
|---|--|-------------|--|-------------|
|   | Measured   | Expected    | Measured   | Expected    |
| Electron                                  | +0.05/−0.05                                      | +0.06/−0.06 | +0.03/−0.03  | +0.02/−0.02 |
| Muon                                      | +0.04/−0.04                                      | +0.04/−0.04 | +0.10/−0.10  | +0.08/−0.10 |
| $\tau_{\text{had-vis}}$                   | +0.02/−0.02                                      | +0.02/−0.02 | +0.04/−0.04  | +0.04/−0.05 |
| Jet                                       | +0.09/−0.08                                      | +0.09/−0.09 | +0.11/−0.12  | +0.11/−0.12 |
| $E_{\text{T}}^{\text{miss}}$              | +0.02/−0.02                                      | +0.02/−0.03 | +0.05/−0.08  | +0.03/−0.05 |
| $b$ -tag                                  | +0.02/−0.03                                      | +0.03/−0.03 | +0.01/−0.01  | +0.01/−0.01 |
| Mis-ID backg. ( $\ell\tau_{\ell'}$ )      | +0.08/−0.07                                      | +0.09/−0.08 | +0.07/−0.07  | +0.07/−0.07 |
| Mis-ID backg. ( $\ell\tau_{\text{had}}$ ) | +0.12/−0.11                                      | +0.11/−0.12 | +0.11/−0.11  | +0.10/−0.10 |
| Pile-up modelling                         | +0.02/−0.01                                      | +0.01/−0.01 | +0.05/−0.03  | +0.08/−0.06 |
| Luminosity                                | < 0.01   | < 0.01      | < 0.01   | < 0.01      |
| Background norm.                          | +0.05/−0.04                                      | +0.05/−0.03 | +0.04/−0.02  | +0.05/−0.03 |
| Theor. uncert. (backg.)                   | +0.04/−0.03                                      | +0.04/−0.03 | +0.08/−0.07  | +0.09/−0.09 |
| Theor. uncert. (signal)                   | +0.01/−0.01                                      | +0.01/−0.01 | +0.04/−0.02  | +0.02/−0.02 |
| MC statistics                             | +0.04/−0.04                                      | +0.03/−0.03 | +0.04/−0.04  | +0.05/−0.04 |
| Full systematic                           | +0.17/−0.16                                      | +0.17/−0.17 | +0.18/−0.18  | +0.19/−0.20 |
| Data statistics                           | +0.07/−0.07                                      | +0.07/−0.07 | +0.07/−0.07  | +0.08/−0.08 |
| Total                                     | +0.18/−0.17                                      | +0.18/−0.18 | +0.19/−0.19  | +0.20/−0.21 |

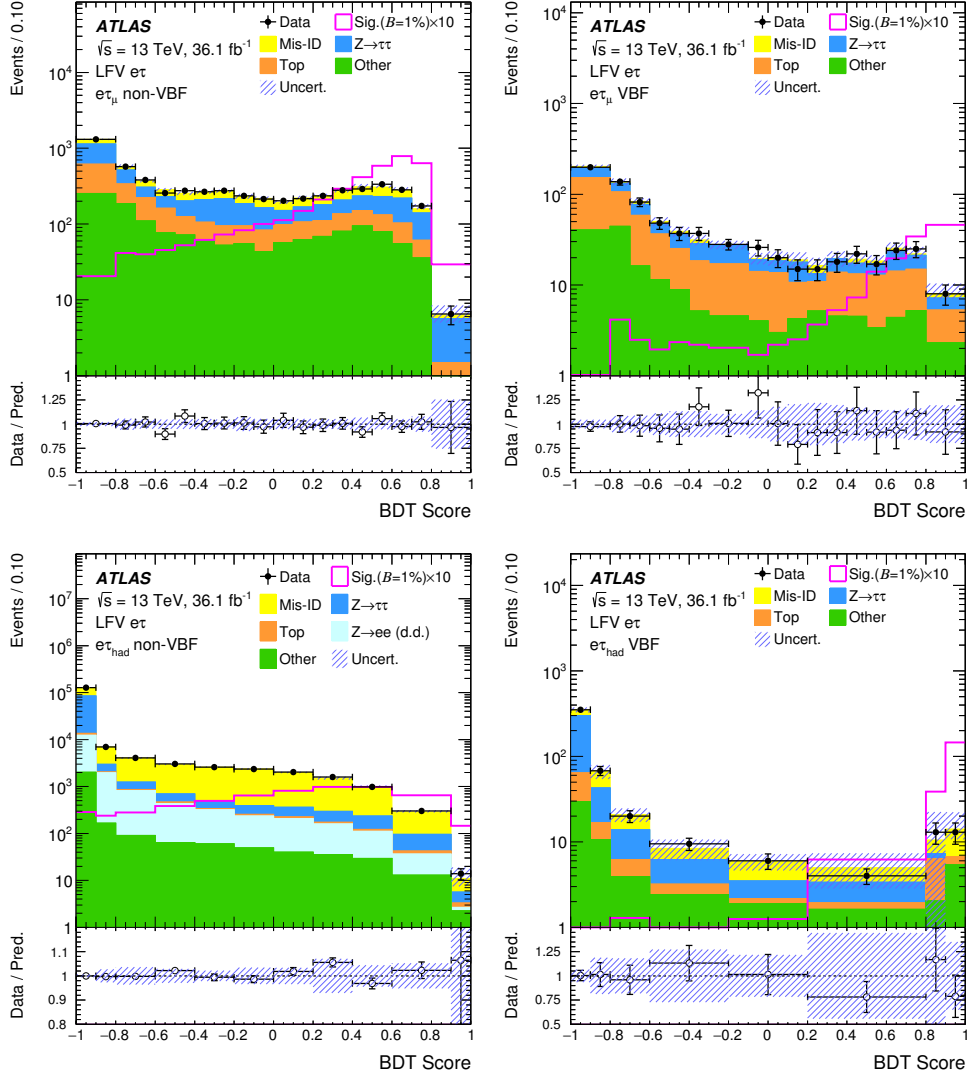


Figure 2: Distributions of the BDT score after the background+signal fit in each signal region of the  $e\tau$  search, with the LFV signal overlaid, normalized with  $\mathcal{B}(H \rightarrow e\tau) = 1\%$  and enhanced by a factor 10 for visibility. The top and bottom plots display  $e\tau_\mu$  and  $e\tau_{\text{had}}$  BDT scores respectively, the left (right) column corresponds to the non-VBF (VBF) category. The size of the combined statistical, experimental and theoretical uncertainties of the background is indicated by the hatched bands. The binning is shown as in the statistical analysis.

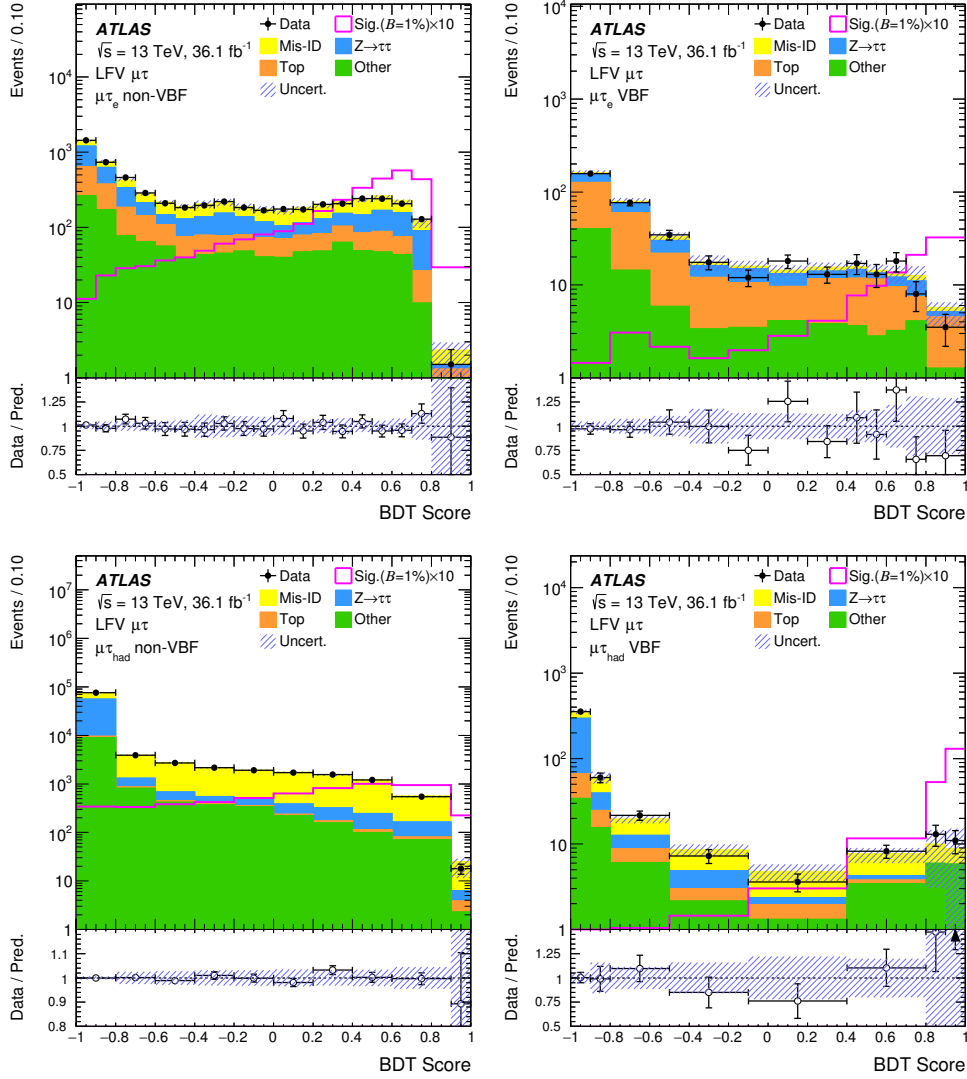


Figure 3: Distributions of the BDT score after the background+signal fit in each signal region of the  $\mu\tau$  search, with the LFBV signal overlaid, normalized with  $\mathcal{B}(H \rightarrow \mu\tau) = 1\%$  and enhanced by a factor 10 for visibility. The top and bottom plots display  $\mu\tau_e$  and  $\mu\tau_{had}$  BDT scores respectively, the left (right) column corresponds to the non-VBF (VBF) category. The size of the combined statistical, experimental and theoretical uncertainties of the background is indicated by the hatched bands. The binning is shown as in the statistical analysis. In the data/background prediction ratio plots, points outside the displayed y-axis range are shown by arrows.

## 8 Results

The best-fit branching ratios and upper limits are computed while assuming  $\mathcal{B}(H \rightarrow \mu\tau) = 0$  for the  $H \rightarrow e\tau$  search and  $\mathcal{B}(H \rightarrow e\tau) = 0$  for the  $H \rightarrow \mu\tau$  search. The best-fit values of the LFV Higgs boson branching ratios are equal to  $(0.15^{+0.18}_{-0.17})\%$  and  $(-0.22 \pm 0.19)\%$  for the  $H \rightarrow e\tau$  and  $H \rightarrow \mu\tau$  search, respectively. In the absence of a significant excess, upper limits on the LFV branching ratios are set for a Higgs boson with  $m_H = 125$  GeV. The observed (median expected) 95% CL upper limits are 0.47% ( $0.34^{+0.13}_{-0.10}\%$ ) and 0.28% ( $0.37^{+0.14}_{-0.10}\%$ ) for the  $H \rightarrow e\tau$  and  $H \rightarrow \mu\tau$  searches, respectively. These limits are significantly lower than the corresponding Run 1 limits of Refs. [7, 8]. The breakdown of contributions from different signal regions is shown in Figure 4.

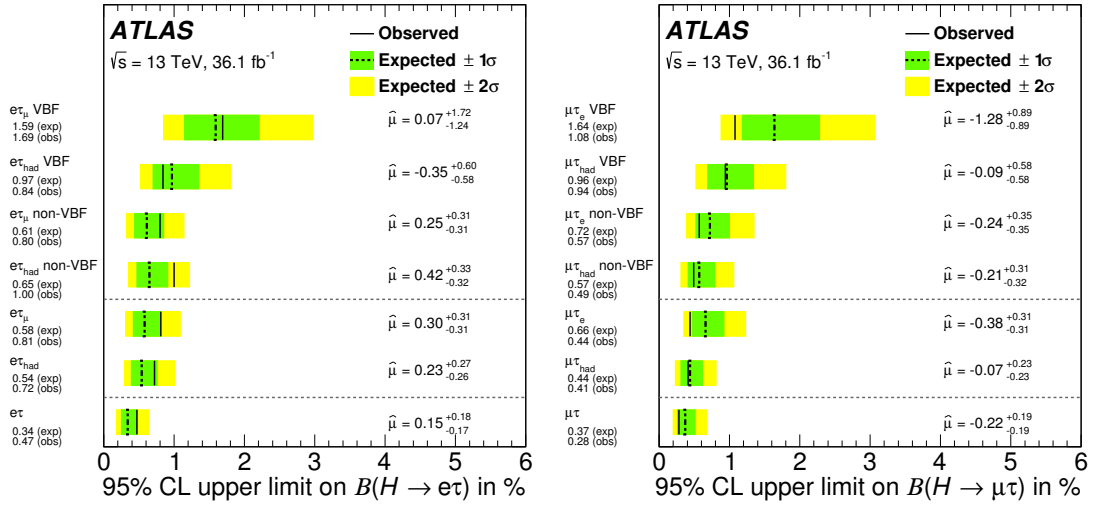


Figure 4: Upper limits at 95% CL on the LFV branching ratios of the Higgs boson,  $H \rightarrow e\tau$  (left) and  $H \rightarrow \mu\tau$  (right), indicated by solid and dashed lines. Best-fit values of the branching ratios ( $\hat{\mu}$ ) are also given, in %. The limits are computed while assuming that either  $\mathcal{B}(H \rightarrow \mu\tau) = 0$  (left) or  $\mathcal{B}(H \rightarrow e\tau) = 0$  (right). First, the results of the fits are shown, when only the data of an individual channel or of an individual category are used; in these cases the signal and control regions from all other channels/categories are removed from the fit. These results are finally compared with the full fit displayed in the last row.

The branching ratio of the LFV Higgs boson decay is related to the non-diagonal Yukawa coupling matrix elements [84] by the formula

$$|Y_{\ell\tau}|^2 + |Y_{\tau\ell}|^2 = \frac{8\pi}{m_H} \frac{\mathcal{B}(H \rightarrow \ell\tau)}{1 - \mathcal{B}(H \rightarrow \ell\tau)} \Gamma_H(\text{SM}),$$

where  $\Gamma_H(\text{SM}) = 4.07$  MeV [85] stands for the Higgs boson width as predicted by the Standard Model. Thus, the observed limits on the branching ratio correspond to the following limits on the coupling matrix elements:  $\sqrt{|Y_{\tau e}|^2 + |Y_{e\tau}|^2} < 0.0020$ , and  $\sqrt{|Y_{\tau\mu}|^2 + |Y_{\mu\tau}|^2} < 0.0015$ . Figure 5 shows the limits on the individual coupling matrix elements  $Y_{\tau\ell}$  and  $Y_{\ell\tau}$  together with the limits from the ATLAS Run 1 analysis and from  $\tau \rightarrow \ell\gamma$  searches [84, 86].

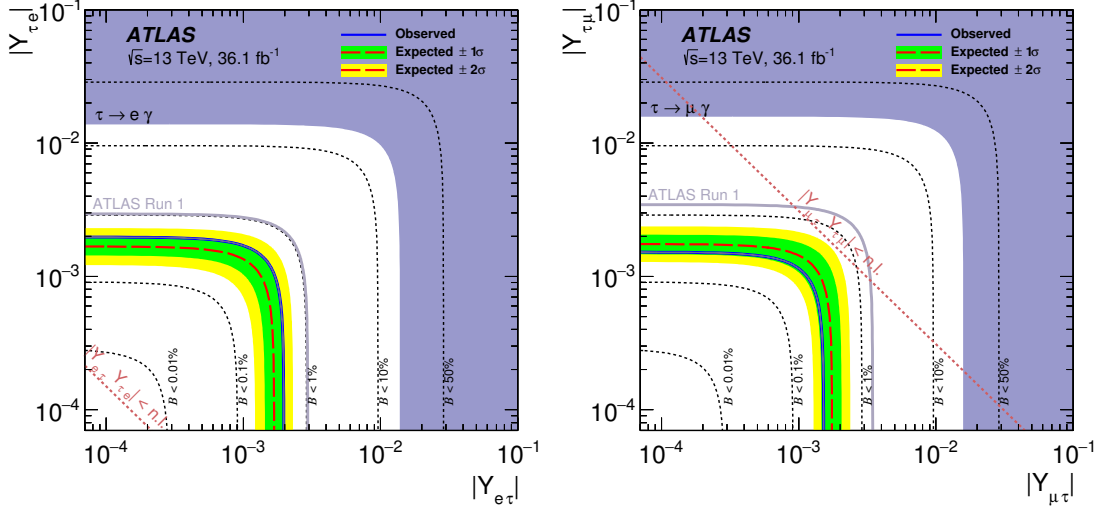


Figure 5: Upper limits on the absolute value of the couplings  $Y_{\tau\ell}$  and  $Y_{\ell\tau}$  together with the limits from the ATLAS Run 1 analysis (light grey line) and the most stringent indirect limits from  $\tau \rightarrow \ell\gamma$  searches (dark purple region). Also indicated are limits corresponding to different branching ratios (0.01%, 0.1%, 1%, 10% and 50%) and the naturalness limit (denoted n.l.)  $|Y_{\tau\ell}Y_{\ell\tau}| \lesssim \frac{m_{\tau}m_{\ell}}{v}$  [84] where  $v$  is the vacuum expectation value of the Higgs field.

## 9 Conclusions

Direct searches for the decays  $H \rightarrow e\tau$  and  $H \rightarrow \mu\tau$  are performed with proton–proton collisions recorded by the ATLAS detector at the LHC corresponding to an integrated luminosity of  $36.1 \text{ fb}^{-1}$  at a centre-of-mass energy of  $\sqrt{s} = 13 \text{ TeV}$ . No significant excess is observed above the expected background from Standard Model processes. The observed (expected) upper limits at 95% confidence level on the branching ratios of  $H \rightarrow e\tau$  and  $H \rightarrow \mu\tau$  are 0.47% ( $0.34^{+0.13}_{-0.10}$ %) and 0.28% ( $0.37^{+0.14}_{-0.10}$ %), respectively. These limits are more stringent by a factor of 2 (5) than the corresponding limits for the  $H \rightarrow e\tau$  ( $H \rightarrow \mu\tau$ ) decay determined by ATLAS at  $\sqrt{s} = 8 \text{ TeV}$ .

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## References

- [1] ATLAS Collaboration, *Observation of a new particle in the search for the Standard Model Higgs boson with the ATLAS detector at the LHC*, *Phys. Lett. B* **716** (2012) 1, arXiv: [1207.7214 \[hep-ex\]](#).
- [2] CMS Collaboration, *Observation of a new boson at a mass of 125 GeV with the CMS experiment at the LHC*, *Phys. Lett. B* **716** (2012) 30, arXiv: [1207.7235 \[hep-ex\]](#).
- [3] A. Arhrib, Y. Cheng and O. C. Kong, *Comprehensive analysis on lepton flavor violating Higgs boson to  $\mu^\mp\tau^\pm$  decay in supersymmetry without R parity*, *Phys. Rev. D* **87** (2013) 015025, arXiv: [1210.8241 \[hep-ph\]](#).
- [4] K. Agashe and R. Contino, *Composite Higgs-mediated flavor-changing neutral current*, *Phys. Rev. D* **80** (2009) 075016, arXiv: [0906.1542 \[hep-ph\]](#).
- [5] M. E. Albrecht, M. Blanke, A. J. Buras, B. Duling and K. Gemmler, *Electroweak and flavour structure of a warped extra dimension with custodial protection*, *JHEP* **09** (2009) 064, arXiv: [0903.2415 \[hep-ph\]](#).
- [6] A. Goudelis, O. Lebedev and J.-h. Park, *Higgs-induced lepton flavor violation*, *Phys. Lett. B* **707** (2012) 369, arXiv: [1111.1715 \[hep-ph\]](#).
- [7] ATLAS Collaboration, *Search for lepton-flavour-violating  $H \rightarrow \mu\tau$  decays of the Higgs boson with the ATLAS detector*, *JHEP* **11** (2015) 211, arXiv: [1508.03372 \[hep-ex\]](#).
- [8] ATLAS Collaboration, *Search for lepton-flavour-violating decays of the Higgs and Z bosons with the ATLAS detector*, *Eur. Phys. J. C* **77** (2017) 70, arXiv: [1604.07730 \[hep-ex\]](#).
- [9] CMS Collaboration, *Search for lepton flavour violating decays of the Higgs boson to  $\mu\tau$  and  $e\tau$  in proton–proton collisions at  $\sqrt{s} = 13$  TeV*, *JHEP* **06** (2018) 001, arXiv: [1712.07173 \[hep-ex\]](#).
- [10] ATLAS Collaboration, *Cross-section measurements of the Higgs boson decaying to a pair of tau leptons in proton–proton collisions at  $\sqrt{s} = 13$  TeV with the ATLAS Detector*, *Phys. Rev. D* **99** (2019) 072001, arXiv: [1811.08856 \[hep-ex\]](#).
- [11] ATLAS Collaboration, *The ATLAS Experiment at the CERN Large Hadron Collider*, *JINST* **3** (2008) S08003.

- [12] ATLAS Collaboration, *ATLAS Insertable B-Layer Technical Design Report*, ATLAS-TDR-19, 2010, URL: <https://cds.cern.ch/record/1291633>, *ATLAS Insertable B-Layer Technical Design Report Addendum*, ATLAS-TDR-19-ADD-1, 2012, URL: <https://cds.cern.ch/record/1451888>.
- [13] B. Abbott et al., *Production and integration of the ATLAS Insertable B-Layer*, *JINST* **13** (2018) T05008, arXiv: [1803.00844](https://arxiv.org/abs/1803.00844) [[physics.ins-det](#)].
- [14] ATLAS Collaboration, *The ATLAS Simulation Infrastructure*, *Eur. Phys. J. C* **70** (2010) 823, arXiv: [1005.4568](https://arxiv.org/abs/1005.4568) [[physics.ins-det](#)].
- [15] S. Agostinelli et al., GEANT4 Collaboration, *GEANT4—a simulation toolkit*, *Nucl. Instrum. Meth. A* **506** (2003) 250.
- [16] ATLAS and CMS Collaborations, *Combined Measurement of the Higgs Boson Mass in pp Collisions at  $\sqrt{s} = 7$  and 8 TeV with the ATLAS and CMS Experiments*, *Phys. Rev. Lett.* **114** (2015) 191803, arXiv: [1503.07589](https://arxiv.org/abs/1503.07589) [[hep-ex](#)].
- [17] D. de Florian et al., LHC Higgs Cross Section Working Group, *Handbook of LHC Higgs cross sections: 4. Deciphering the nature of the Higgs sector*, (2017), arXiv: [1610.07922](https://arxiv.org/abs/1610.07922) [[hep-ph](#)].
- [18] T. Sjöstrand et al., *An introduction to PYTHIA 8.2*, *Comput. Phys. Commun.* **191** (2015) 159, arXiv: [1410.3012](https://arxiv.org/abs/1410.3012) [[hep-ph](#)].
- [19] P. Nason, *A new method for combining NLO QCD with shower Monte Carlo algorithms*, *JHEP* **11** (2004) 040, arXiv: [hep-ph/0409146](https://arxiv.org/abs/hep-ph/0409146).
- [20] S. Frixione, P. Nason and C. Oleari, *Matching NLO QCD computations with parton shower simulations: the POWHEG method*, *JHEP* **11** (2007) 070, arXiv: [0709.2092](https://arxiv.org/abs/0709.2092) [[hep-ph](#)].
- [21] S. Alioli, P. Nason, C. Oleari and E. Re, *A general framework for implementing NLO calculations in shower Monte Carlo programs: the POWHEG BOX*, *JHEP* **06** (2010) 043, arXiv: [1002.2581](https://arxiv.org/abs/1002.2581) [[hep-ph](#)].
- [22] E. Bagnaschi, G. Degrossi, P. Slavich and A. Vicini, *Higgs production via gluon fusion in the POWHEG approach in the SM and in the MSSM*, *JHEP* **02** (2012) 088, arXiv: [1111.2854](https://arxiv.org/abs/1111.2854) [[hep-ph](#)].
- [23] K. Hamilton, P. Nason and G. Zanderighi, *Finite quark-mass effects in the NNLOPS POWHEG+MiNLO Higgs generator*, *JHEP* **05** (2015) 140, arXiv: [1501.04637](https://arxiv.org/abs/1501.04637) [[hep-ph](#)].
- [24] K. Hamilton, P. Nason, E. Re and G. Zanderighi, *NNLOPS simulation of Higgs boson production*, *JHEP* **10** (2013) 222, arXiv: [1309.0017](https://arxiv.org/abs/1309.0017) [[hep-ph](#)].
- [25] J. Butterworth et al., *PDF4LHC recommendations for LHC Run II*, *J. Phys. G* **43** (2016) 023001, arXiv: [1510.03865](https://arxiv.org/abs/1510.03865) [[hep-ph](#)].
- [26] C. Anastasiou, C. Duhr, F. Dulat, F. Herzog and B. Mistlberger, *Higgs Boson Gluon-Fusion Production in QCD at Three Loops*, *Phys. Rev. Lett.* **114** (2015) 212001, arXiv: [1503.06056](https://arxiv.org/abs/1503.06056) [[hep-ph](#)].
- [27] C. Anastasiou et al., *High precision determination of the gluon fusion Higgs boson cross-section at the LHC*, *JHEP* **05** (2016) 058, arXiv: [1602.00695](https://arxiv.org/abs/1602.00695) [[hep-ph](#)].
- [28] S. Actis, G. Passarino, C. Sturm and S. Uccirati, *NLO electroweak corrections to Higgs boson production at hadron colliders*, *Phys. Lett. B* **670** (2008) 12, arXiv: [0809.1301](https://arxiv.org/abs/0809.1301) [[hep-ph](#)].
- [29] C. Anastasiou, R. Boughezal and F. Petriello, *Mixed QCD-electroweak corrections to Higgs boson production in gluon fusion*, *JHEP* **04** (2009) 003, arXiv: [0811.3458](https://arxiv.org/abs/0811.3458) [[hep-ph](#)].

- [30] M. Ciccolini, A. Denner and S. Dittmaier, *Strong and Electroweak Corrections to the Production of a Higgs Boson + 2 Jets via Weak Interactions at the Large Hadron Collider*, *Phys. Rev. Lett.* **99** (2007) 161803, arXiv: [0707.0381 \[hep-ph\]](#).
- [31] M. Ciccolini, A. Denner and S. Dittmaier, *Electroweak and QCD corrections to Higgs production via vector-boson fusion at the LHC*, *Phys. Rev. D* **77** (2008) 013002, arXiv: [0710.4749 \[hep-ph\]](#).
- [32] P. Bolzoni, F. Maltoni, S.-O. Moch and M. Zaro, *Higgs Boson Production via Vector-Boson Fusion at Next-to-Next-to-Leading Order in QCD*, *Phys. Rev. Lett.* **105** (2010) 011801, arXiv: [1003.4451 \[hep-ph\]](#).
- [33] O. Brein, A. Djouadi and R. Harlander, *NNLO QCD corrections to the Higgs-strahlung processes at hadron colliders*, *Phys. Lett. B* **579** (2004) 149, arXiv: [hep-ph/0307206](#).
- [34] L. Altenkamp, S. Dittmaier, R. V. Harlander, H. Rzehak and T. J. E. Zirke, *Gluon-induced Higgs-strahlung at next-to-leading order QCD*, *JHEP* **02** (2013) 078, arXiv: [1211.5015 \[hep-ph\]](#).
- [35] A. Denner, S. Dittmaier, S. Kallweit and A. Mück, *Electroweak corrections to Higgs-strahlung off W/Z bosons at the Tevatron and the LHC with Hawk*, *JHEP* **03** (2012) 075, arXiv: [1112.5142 \[hep-ph\]](#).
- [36] T. Gleisberg et al., *Event generation with SHERPA 1.1*, *JHEP* **02** (2009) 007, arXiv: [0811.4622 \[hep-ph\]](#).
- [37] R. D. Ball et al., *Parton distributions for the LHC Run II*, *JHEP* **04** (2015) 040, arXiv: [1410.8849 \[hep-ph\]](#).
- [38] S. Schumann and F. Krauss, *A parton shower algorithm based on Catani-Seymour dipole factorisation*, *JHEP* **03** (2008) 038, arXiv: [0709.1027 \[hep-ph\]](#).
- [39] K. Melnikov and F. Petriello, *Electroweak gauge boson production at hadron colliders through  $O(\alpha_s^2)$* , *Phys. Rev. D* **74** (2006) 114017, arXiv: [hep-ph/0609070](#).
- [40] C. Anastasiou, L. J. Dixon, K. Melnikov and F. Petriello, *High precision QCD at hadron colliders: Electroweak gauge boson rapidity distributions at NNLO*, *Phys. Rev. D* **69** (2004) 094008, arXiv: [hep-ph/0312266 \[hep-ph\]](#).
- [41] S. Alioli, S.-O. Moch and P. Uwer, *Hadronic top-quark pair-production with one jet and parton showering*, *JHEP* **01** (2012) 137, arXiv: [1110.5251 \[hep-ph\]](#).
- [42] H.-L. Lai et al., *New parton distributions for collider physics*, *Phys. Rev. D* **82** (2010) 074024, arXiv: [1007.2241 \[hep-ph\]](#).
- [43] T. Sjöstrand, S. Mrenna and P. Z. Skands, *PYTHIA 6.4 physics and manual*, *JHEP* **05** (2006) 026, arXiv: [hep-ph/0603175](#).
- [44] M. Czakon and A. Mitov, *Top++: A program for the calculation of the top-pair cross-section at hadron colliders*, *Comput. Phys. Commun.* **185** (2014) 2930, arXiv: [1112.5675 \[hep-ph\]](#).
- [45] S. Alioli, P. Nason, C. Oleari and E. Re, *NLO single-top production matched with shower in POWHEG: s- and t-channel contributions*, *JHEP* **09** (2009) 111, arXiv: [0907.4076 \[hep-ph\]](#).
- [46] E. Re, *Single-top Wt-channel production matched with parton showers using the POWHEG method*, *Eur. Phys. J. C* **71** (2011) 1547, arXiv: [1009.2450 \[hep-ph\]](#).
- [47] M. Aliev et al., *HATHOR - HAdronic Top and Heavy quarks crOss section calculatoR*, *Comput. Phys. Commun.* **182** (2011) 1034, arXiv: [1007.1327 \[hep-ph\]](#).

- [48] P. Kant et al., *HATHOR for single top-quark production: Updated predictions and uncertainty estimates for single top-quark production in hadronic collisions*, *Comput. Phys. Commun.* **191** (2015) 74, arXiv: [1406.4403 \[hep-ph\]](#).
- [49] N. Kidonakis, *Two-loop soft anomalous dimensions for single top quark associated production with a  $W^-$  or  $H^-$* , *Phys. Rev. D* **82** (2010) 054018, arXiv: [1005.4451 \[hep-ph\]](#).
- [50] ATLAS Collaboration, *Electron and photon energy calibration with the ATLAS detector using 2015–2016 LHC proton–proton collision data*, *JINST* **14** (2019) P03017, arXiv: [1812.03848 \[hep-ex\]](#).
- [51] ATLAS Collaboration, *Electron reconstruction and identification in the ATLAS experiment using the 2015 and 2016 LHC proton–proton collision data at  $\sqrt{s} = 13$  TeV*, (2019), arXiv: [1902.04655 \[hep-ex\]](#).
- [52] ATLAS Collaboration, *Muon reconstruction performance of the ATLAS detector in proton–proton collision data at  $\sqrt{s} = 13$  TeV*, *Eur. Phys. J. C* **76** (2016) 292, arXiv: [1603.05598 \[hep-ex\]](#).
- [53] M. Cacciari, G. P. Salam and G. Soyez, *The anti- $k_t$  jet clustering algorithm*, *JHEP* **04** (2008) 063, arXiv: [0802.1189 \[hep-ph\]](#).
- [54] M. Cacciari, G. P. Salam and G. Soyez, *FastJet User Manual*, *Eur. Phys. J. C* **72** (2012) 1896, arXiv: [1111.6097 \[hep-ph\]](#).
- [55] ATLAS Collaboration, *Topological cell clustering in the ATLAS calorimeters and its performance in LHC Run 1*, *Eur. Phys. J. C* **77** (2017) 490, arXiv: [1603.02934 \[hep-ex\]](#).
- [56] ATLAS Collaboration, *Tagging and suppression of pileup jets with the ATLAS detector*, ATLAS-CONF-2014-018, 2014, URL: <https://cds.cern.ch/record/1700870>.
- [57] ATLAS Collaboration, *Identification and rejection of pile-up jets at high pseudorapidity with the ATLAS detector*, *Eur. Phys. J. C* **77** (2017) 580, arXiv: [1705.02211 \[hep-ex\]](#), Erratum: *Eur. Phys. J. C* **77** (2017) 712.
- [58] ATLAS Collaboration, *Performance of b-jet identification in the ATLAS experiment*, *JINST* **11** (2016) P04008, arXiv: [1512.01094 \[hep-ex\]](#).
- [59] ATLAS Collaboration, *Optimisation of the ATLAS b-tagging performance for the 2016 LHC Run*, ATL-PHYS-PUB-2016-012, 2016, URL: <https://cds.cern.ch/record/2160731>.
- [60] ATLAS Collaboration, *Reconstruction, Energy Calibration, and Identification of Hadronically Decaying Tau Leptons in the ATLAS Experiment for Run-2 of the LHC*, ATL-PHYS-PUB-2015-045, 2015, URL: <https://cds.cern.ch/record/2064383>.
- [61] ATLAS Collaboration, *Measurement of the tau lepton reconstruction and identification performance in the ATLAS experiment using pp collisions at  $\sqrt{s} = 13$  TeV*, ATLAS-CONF-2017-029, 2017, URL: <https://cds.cern.ch/record/2261772>.
- [62] L. Breiman, J. Friedman, R. Olshen and C. Stone, *Classification and Regression Trees*, Chapman & Hall, 1984 358.
- [63] Y. Freund and R. E. Schapire, *A Decision-Theoretic Generalization of On-Line Learning and an Application to Boosting*, *J. Comput. Syst. Sci.* **55** (1997) 119, ISSN: 0022-0000.
- [64] J. Friedman, *Stochastic gradient boosting*, *Comput. Stat. Data Anal.* **38** (2002) 367.
- [65] ATLAS Collaboration, *Performance of the ATLAS trigger system in 2015*, *Eur. Phys. J. C* **77** (2017) 317, arXiv: [1611.09661 \[hep-ex\]](#).

- [66] ATLAS Collaboration, *Trigger Menu in 2016*, ATL-DAQ-PUB-2017-001, 2017, URL: <https://cds.cern.ch/record/2242069>.
- [67] A. Hoecker et al., *TMVA - Toolkit for Multivariate Data Analysis*, 2007, arXiv: [physics/0703039](https://arxiv.org/abs/physics/0703039) [[physics.data-an](https://arxiv.org/abs/physics/0703039)].
- [68] T. Chen and C. Guestrin, ‘XGBoost: A Scalable Tree Boosting System’, *Proceedings of the 22nd ACM SIGKDD International Conference on Knowledge Discovery and Data Mining*, 2016, URL: <https://dl.acm.org/citation.cfm?doid=2939672.2939785>.
- [69] A. Elagin, P. Murat, A. Pranko and A. Safonov, *A new mass reconstruction technique for resonances decaying to  $\tau\tau$* , *Nucl. Instrum. Meth. A* **654** (2011) 481, arXiv: [1012.4686](https://arxiv.org/abs/1012.4686) [[hep-ex](https://arxiv.org/abs/1012.4686)].
- [70] ATLAS Collaboration, *Jet energy scale measurements and their systematic uncertainties in proton–proton collisions at  $\sqrt{s} = 13$  TeV with the ATLAS detector*, *Phys. Rev. D* **96** (2017) 072002, arXiv: [1703.09665](https://arxiv.org/abs/1703.09665) [[hep-ex](https://arxiv.org/abs/1703.09665)].
- [71] ATLAS Collaboration, *Performance of missing transverse momentum reconstruction with the ATLAS detector using proton–proton collisions at  $\sqrt{s} = 13$  TeV*, *Eur. Phys. J. C* **78** (2018) 903, arXiv: [1802.08168](https://arxiv.org/abs/1802.08168) [[hep-ex](https://arxiv.org/abs/1802.08168)].
- [72] ATLAS Collaboration, *Luminosity determination in pp collisions at  $\sqrt{s} = 13$  TeV using the ATLAS detector at the LHC*, ATLAS-CONF-2019-021, 2019, URL: <https://cds.cern.ch/record/2677054>.
- [73] S. Dittmaier et al., LHC Higgs Cross Section Working Group, *Handbook of LHC Higgs Cross Sections: 1. Inclusive Observables*, (2011), arXiv: [1101.0593](https://arxiv.org/abs/1101.0593) [[hep-ph](https://arxiv.org/abs/1101.0593)].
- [74] W. Stewart, F. J. Tackmann, J. R. Walsh and S. Zuberi, *Jet  $p_T$  resummation in Higgs production at NNLL'+NNLO*, *Phys. Rev. D* **89** (2014) 054001, arXiv: [1307.1808](https://arxiv.org/abs/1307.1808) [[hep-ph](https://arxiv.org/abs/1307.1808)].
- [75] X. Liu and F. Petriello, *Reducing theoretical uncertainties for exclusive Higgs-boson plus one-jet production at the LHC*, *Phys. Rev. D* **87** (2013) 094027, arXiv: [1303.4405](https://arxiv.org/abs/1303.4405) [[hep-ph](https://arxiv.org/abs/1303.4405)].
- [76] R. Boughezal, X. Liu, F. Petriello, F. J. Tackmann and J. R. Walsh, *Combining resummed Higgs predictions across jet bins*, *Phys. Rev. D* **89** (2014) 074044, arXiv: [1312.4535](https://arxiv.org/abs/1312.4535) [[hep-ph](https://arxiv.org/abs/1312.4535)].
- [77] I. W. Stewart and F. J. Tackmann, *Theory uncertainties for Higgs mass and other searches using jet bins*, *Phys. Rev. D* **85** (2012) 034011, arXiv: [1107.2117](https://arxiv.org/abs/1107.2117) [[hep-ph](https://arxiv.org/abs/1107.2117)].
- [78] S. Gangal and F. J. Tackmann, *Next-to-leading-order uncertainties in Higgs+2 jets from gluon fusion*, *Phys. Rev. D* **87** (2013) 093008, arXiv: [1302.5437](https://arxiv.org/abs/1302.5437) [[hep-ph](https://arxiv.org/abs/1302.5437)].
- [79] M. Bähr et al., *Herwig++ physics and manual*, *Eur. Phys. J. C* **58** (2008) 639, arXiv: [0803.0883](https://arxiv.org/abs/0803.0883) [[hep-ph](https://arxiv.org/abs/0803.0883)].
- [80] J. Bellm et al., *Herwig 7.0/Herwig++ 3.0 release note*, *Eur. Phys. J. C* **76** (2016) 196, arXiv: [1512.01178](https://arxiv.org/abs/1512.01178) [[hep-ph](https://arxiv.org/abs/1512.01178)].
- [81] L. Lönnblad and S. Prestel, *Matching tree-level matrix elements with interleaved showers*, *JHEP* **03** (2012) 019, arXiv: [1109.4829](https://arxiv.org/abs/1109.4829) [[hep-ph](https://arxiv.org/abs/1109.4829)].
- [82] G. Cowan, K. Cranmer, E. Gross and O. Vitells, *Asymptotic formulae for likelihood-based tests of new physics*, *Eur. Phys. J. C* **71** (2011) 1554, arXiv: [1007.1727](https://arxiv.org/abs/1007.1727) [[physics.data-an](https://arxiv.org/abs/1007.1727)], Erratum: *Eur. Phys. J. C* **73** (2013) 2501.
- [83] A. L. Read, *Presentation of search results: the  $CL_S$  technique*, *J. Phys. G* **28** (2002) 2693.

- [84] R. Harnik, J. Kopp and J. Zupan, *Flavor violating Higgs decays*, [JHEP \*\*03\*\* \(2013\) 026](#), arXiv: [1209.1397 \[hep-ph\]](#).
- [85] LHC Higgs Cross Section Working Group, *Handbook of LHC Higgs Cross Sections: 3. Higgs Properties*, (2013), arXiv: [1307.1347 \[hep-ph\]](#).
- [86] B. Aubert et al., BaBar Collaboration, *Searches for Lepton Flavor Violation in the Decays  $\tau^\pm \rightarrow e^\pm \gamma$  and  $\tau^\pm \rightarrow \mu^\pm \gamma$* , [Phys. Rev. Lett. \*\*104\*\* \(2010\) 021802](#), arXiv: [0908.2381 \[hep-ex\]](#).
- [87] ATLAS Collaboration, *ATLAS Computing Acknowledgements*, ATL-GEN-PUB-2016-002, URL: <https://cds.cern.ch/record/2202407>.



## The ATLAS Collaboration

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Armstrong<sup>171</sup>, O. Arnaez<sup>167</sup>, H. Arnold<sup>120</sup>, A. Artamonov<sup>111,\*</sup>, G. Artoni<sup>135</sup>, S. Artz<sup>99</sup>, S. Asai<sup>163</sup>, N. Asbah<sup>59</sup>, E.M. Asimakopoulou<sup>172</sup>, L. Asquith<sup>156</sup>, K. Assamagan<sup>29</sup>, R. Astalos<sup>28a</sup>, R.J. Atkin<sup>33a</sup>, M. Atkinson<sup>173</sup>, N.B. Atlay<sup>19</sup>, H. Atmani<sup>132</sup>, K. Augsten<sup>142</sup>, G. Avolio<sup>36</sup>, R. Avramidou<sup>60a</sup>, M.K. Ayoub<sup>15a</sup>, A.M. Azoulay<sup>168b</sup>, G. Azuelos<sup>109,av</sup>, H. Bachacou<sup>145</sup>, K. Bachas<sup>67a,67b</sup>, M. Backes<sup>135</sup>, F. Backman<sup>45a,45b</sup>, P. Bagnaia<sup>72a,72b</sup>, M. Bahmani<sup>84</sup>, H. Bahrasemani<sup>152</sup>, A.J. Bailey<sup>174</sup>, V.R. Bailey<sup>173</sup>, J.T. Baines<sup>144</sup>, M. Bajic<sup>40</sup>, C. Bakalis<sup>10</sup>, O.K. Baker<sup>183</sup>, P.J. Bakker<sup>120</sup>, D. Bakshi Gupta<sup>8</sup>, S. 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