

Searches for additional charged Higgs bosons in the MSSM

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Searches for a charged Higgs boson in various decay channels using 36.1 fb^{-1} of pp collision data at a centre-of-mass energy of 13 TeV collected with the ATLAS detector at the Large Hadron Collider are presented. No significant excess above the background-only hypothesis is observed and upper limits on the production cross-section times the branching ratio of the charged Higgs boson as a function of its mass are derived. The results are interpreted in benchmark scenarios of the Minimal Supersymmetric Standard Model.

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No charged fundamental scalar bosons exist in the Standard Model (SM), but many theories beyond the SM include an extended Higgs sector with at least one pair of charged Higgs bosons. In CP-conserving two-Higgs-doublet models (2HDM) the properties of the charged Higgs boson¹ depend on its mass, the mixing angle of the neutral CP-even Higgs bosons, α , and the ratio of the vacuum expectation values of the two Higgs doublets, $\tan\beta$. In these proceedings, a search for H^+ production in pp collisions at a centre-of-mass-energy of 13 TeV collected with the ATLAS detector [1] at the Large Hadron Collider (LHC) is presented. The analysis uses 36.1 fb^{-1} of pp data recorded during 2015 and 2016, and targets the $H^+ \rightarrow \tau\nu$ [2] and $H^+ \rightarrow tb$ [3] decays.

Depending on the assumption made for the decay mode of the W boson originating from the top-quark produced together with the H^+ , two final states are studied in the $H^+ \rightarrow \tau\nu$ search: τ +jets if the W boson decays into a quark pair, or τ +lepton if the W boson decays into an electron or muon and neutrino(s). Only τ -leptons decaying to hadrons are considered. Events with τ +jets are recorded using a missing transverse energy (E_T^{miss}) trigger with varying threshold depending on the data-taking period, and only events with at least one τ candidate with transverse momentum (p_T) larger than 40 GeV are accepted. The events must contain at least three jets with p_T larger than 25 GeV of which at least one has originated from a b -quark, have E_T^{miss} larger than 150 GeV, and transverse mass of the highest- p_T τ candidate and E_T^{miss} larger than 50 GeV. No electrons or muons with p_T larger than 20 GeV are allowed. τ +lepton events are recorded using single-lepton triggers and only events with exactly one electron or muon with p_T larger than 30 GeV matched to the trigger object are considered. Exactly one τ -lepton candidate with p_T larger than 30 GeV and electric charge opposite to that of the lepton, and at least one jet with p_T larger than 25 GeV and identified as originating from a b -quark must be present in the event. Finally, the E_T^{miss} must exceed 50 GeV. Backgrounds with prompt taus, like those in $W \rightarrow \tau\nu$ and $t\bar{t}$ events, are modelled with simulation, and the normalisation of the latter is corrected with data. Backgrounds with electrons misidentified as taus are estimated with simulation and validated in a $Z \rightarrow e^+e^-$ control region (CR). Backgrounds where jets are misidentified as taus are estimated from data using a data-driven fake-factor method [2].

The search is performed in the 90–2000 GeV mass region, including for the first time the mass region around the top-quark mass [4]. Multivariate techniques are used to separate signal from background and the parameters of interest, e.g. $\sigma(pp \rightarrow tbH^+) \times \mathcal{B}(H^+ \rightarrow \tau\nu)$, are obtained from a simultaneous fit together with several nuisance parameters that encode statistical and systematic uncertainties. The compatibility of the data with background-only and signal+background hypotheses is computed from a profile likelihood ratio. Three signal regions (SR), τ +jets, τ +electron and τ +muon, and one CR enriched in $t\bar{t}$ events are considered simultaneously in the fit. The fitted distributions are binned boosted decision tree (BDT) scores in the SR and the number of events in the CR.

Data are found to be consistent with the background-only hypothesis and exclusions limits are set at the 95% confidence level (CL) by using the CL_S procedure [5] on $\sigma(pp \rightarrow tbH^+) \times \mathcal{B}(H^+ \rightarrow \tau\nu)$ for the full mass range and on $\mathcal{B}(t \rightarrow bH^+) \times \mathcal{B}(H^+ \rightarrow \tau\nu)$ in the low H^+ mass range. Figure 1 shows the expected and observed exclusion limits as a function of the H^+ mass hypothesis.

¹For simplicity in the following charged Higgs bosons are denoted H^+ , with the charge-conjugate H^- always implied.

The observed limit on the $\sigma(pp \rightarrow tbH^+) \times \mathcal{B}(H^+ \rightarrow \tau\nu)$ ranges from 4.2 pb to 2.5 fb at 90 GeV and 2000 GeV, respectively, and the limit on $\mathcal{B}(t \rightarrow bH^+) \times \mathcal{B}(H^+ \rightarrow \tau\nu)$ from 0.25% to 0.031% at 90 GeV and 160 GeV, respectively.

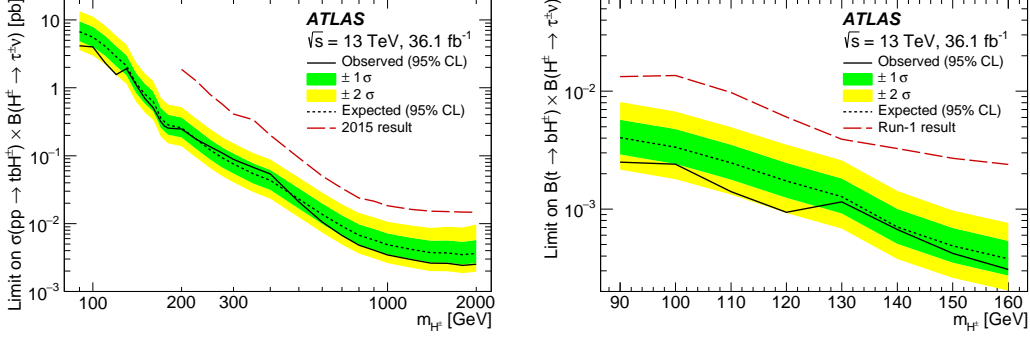


Figure 1: Observed and expected 95% CL exclusion limits on $\sigma(pp \rightarrow tbH^+) \times \mathcal{B}(H^+ \rightarrow \tau\nu)$ (left) and $\mathcal{B}(t \rightarrow bH^+) \times \mathcal{B}(H^+ \rightarrow \tau\nu)$ (right) as a function of the H^+ boson mass [2].

Charged Higgs decaying to a top-quark and a bottom-quark are recorded with single-lepton triggers. Events are required to have one or two electrons or muons, with the leading lepton matched to the lepton trigger and a p_T larger than 27 GeV. The second lepton must have opposite charge and p_T larger than 10 GeV (15 GeV in events with two electrons). At least three (five) jets are required in the events with two (one) leptons, of which at least two (three) must have originated from a b -quark. In the ee and $\mu\mu$ channels the dilepton invariant mass must be incompatible with the J/ψ and Z masses. The selected events are classified into SR and CR according to the multiplicity of the jets and that of jets originated from a b -quark. The signal fraction is very small even in the most sensitive regions, and $t\bar{t}$ +jets events constitute the largest background. To improve its modelling, it is subdivided into $t\bar{t}$ +light, $t\bar{t} \geq 1c$ and $t\bar{t} \geq 1b$ categories, and the latter is reweighted to an NLO prediction of $t\bar{t}b\bar{b}$ including parton shower and hadronisation. A second type of reweighting is performed on several kinematical variables sequentially. Finally, since the number of events with high leading jet p_T is overestimated in the simulation, a reweighting function for the leading jet p_T is derived by comparing simulation and data [3]. Multi-jet events are modelled with data using a matrix method in events with one lepton and with simulation in events with two leptons. A different discriminant BDT is defined for each H^+ mass hypothesis and SR, which are used, together with the overall normalisation in the CR, in a profile likelihood as in the $H^+ \rightarrow \tau\nu$ analysis. For mass hypotheses up to 300 GeV, the BDTs for events with one lepton include a kinematic discriminant that reflects the compatibility of a given event with the H^+ and $t\bar{t}$ hypotheses. The search is performed in the 200–2000 GeV mass region. No significant excess above the background-only hypothesis is observed and exclusion limits are derived for $\sigma(pp \rightarrow tbH^+) \times \mathcal{B}(H^+ \rightarrow tb)$ as a function of the H^+ mass, which range from 2.9 pb at 200 GeV to 0.070 pb at 2000 GeV. Figure 2 shows the expected and observed exclusion limits as a function of the H^+ mass hypothesis.

Figure 3 shows 95% CL exclusion limits set on $\tan\beta$ for the m_h^{mod-} and the hMSSM scenarios.

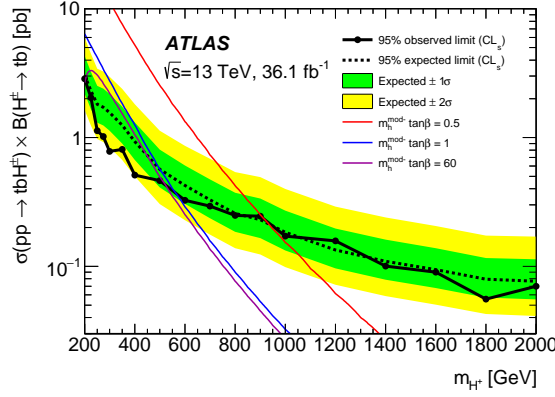


Figure 2: Observed and expected 95% CL exclusion limits on $\sigma(pp \rightarrow tbH^+) \times \mathcal{B}(H^+ \rightarrow tb)$ as a function of the H^+ mass [3].

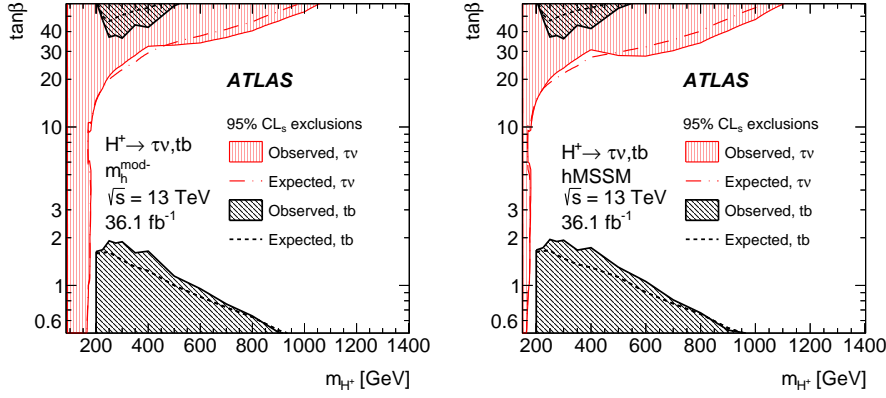


Figure 3: Observed and expected 95% CL exclusion limits on $\tan\beta$ as a function of m_{H^+} in the m_h^{mod-} (left) and the hMSSM (right) scenarios. Limits are shown for $\tan\beta$ values in the range 0.5–60 where predictions are available for both scenarios [3].

References

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