Search for Higgs bosons decaying into tau leptons with ATLAS

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Abstract. In these proceedings the status of the searches for Higgs bosons decaying with tau leptons (τ) in the final state using the ATLAS detector are presented. The analyses search for Higgs bosons using up to $\int L\ \mathrm{d}t = 4.6\ \mathrm{fb}^{-1}$ of pp collision data at $\sqrt{s} = 7$ TeV provided by the Large Hadron Collider (LHC). No excess is observed above the expected background, and results are interpreted as limits on production cross sections excluded regions in the $\tan\beta$ vs $m_A/m_{H^\pm}$ planes.

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Introduction

Many scenarios beyond the Standard Model (SM) include several Higgs bosons. A popular model is the minimal supersymmetric (MSSM) extension of the SM [1]. Searches for both neutral and charged Higgs bosons that use τ and missing energy signatures are performed using the ATLAS detector [2]. Various ATLAS subsystems allow the reconstruction of charged and neutral electromagnetic particles with high precision.

Hadronically decaying τ candidates manifest as narrow jet-like objects in the calorimeter subsystems and in tracks in a narrow cone with little surrounding activity. Algorithms are seeded using a list of jet candidates, and τ candidates are identified using a cone of $\Delta R < 0.2$ (where $\Delta R^2 = \Delta\eta^2 + \Delta\phi^2$) surrounded by an isolation annulus of $0.2 < \Delta R < 0.4$ [3]. Several methods of background and efficiency estimation are used, including embedding Monte Carlo simulation (MC) into data, the tag and probe method using W/Z bosons, the opposite sign vs same sign method, and the ABCD double-sideband method [4, 5].

Neutral MSSM Higgs search

This analysis uses $\int L\ \mathrm{d}t = 1.06\ \mathrm{fb}^{-1}$ of data [4]. The following final states are considered: $\tau\tau \to e\mu 4\nu$, $\tau\tau \to \ell\tau_{\mathrm{had}}3\nu$, $\tau\tau \to \tau_{\mathrm{had}}\tau_{\mathrm{had}}2\nu$, where τ_{had} refers to a reconstructed hadronic τ candidate. The minimum transverse energies or momenta for electron, muon, and hadronically decaying τ candidates are $E_{\mathrm{T}}^{e} > 15$ GeV, $p_{\mathrm{T}}^{\mu} > 15$ GeV, and $p_{\mathrm{T}}^{\tau} > 20$ GeV, respectively. Events are triggered using single electron or muon triggers, with thresholds of $E_{\mathrm{T}}^{e} > 20$ GeV, and $p_{\mathrm{T}}^{\mu} > 18$ GeV, or double τ triggers with thresholds of $p_{\mathrm{T}}^{\tau_1} > 20$ GeV, $p_{\mathrm{T}}^{\tau_2} > 20$ GeV.

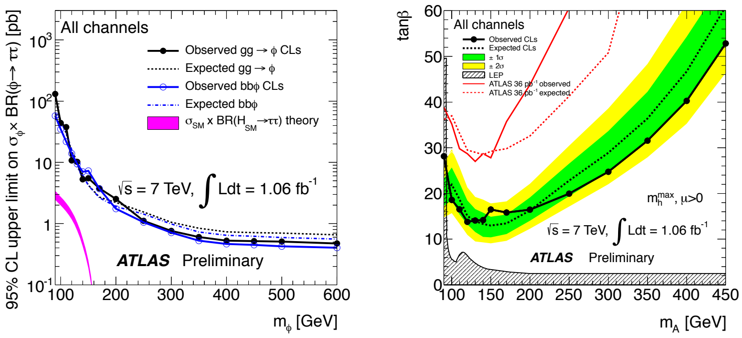

FIGURE 1. Limits on (left) the production cross section and (right) exclusion in the $\tan\beta$ vs m_A plane for the neutral Higgs search [4].

In all final states the sizes of signal and background components are estimated using a profile likelihood ratio to a pseudo-mass variable. In the $e\mu 4\nu$ final state the effective mass is used as defined as $(m^{\text{eff}}_{\tau\tau})^2 = (p_{\tau^+} + p_{\tau^-} + p_{\text{miss}})^2$, where p_{miss} is the missing momentum, assumed to come from the neutrinos from both τ decays, obtained using conservation of momentum in the transverse plane, and p_{τ^+}, p_{τ^-} are the momenta of the τ candidates. In the $\ell\tau_{\text{had}}$ final state the missing mass spectrum [7] is used. In the $\tau_{\text{had}}\tau_{\text{had}}$ final state the visible mass is used. Dominant systematic uncertainties come from the production cross section $(14-16\%)$, and energy scale and resolution on both signal and background MC samples$(12-50\%)$. No excess of events beyond the background expectation is observed and the results are interpreted as limits on the production cross section, and exclusions in the $\tan\beta$ vs m_A plane. The results are combined across the final states to improve sensitivity across a wide spectrum of m_A. The results are shown in Figure 1.

Charged MSSM Higgs search

This analysis uses $\int L\, \mathrm{d}t = 4.6\ \text{fb}^{-1}$ of data and considers charged Higgs bosons where the mass is $m_H^{\pm} < 150$ GeV [5]. The dominant production process is gg fusion to $t\bar{t}$ where one of the top quarks decays via charged Higgs emission, $t \to bH^{\pm}$, and the other top quark decays via W emission, $t \to bW^{\pm}$. The following final states are considered: $t\bar{t} \to b\bar{b}q'\bar{q}\tau_{\text{lep}}\nu$ (lepton+jets), $t\bar{t} \to b\bar{b}\ell\nu_\ell\tau_{\text{had}}\nu$ (τ+lepton), and $t\bar{t} \to b\bar{b}q'\bar{q}\tau_{\text{had}}\nu$ (τ+jets), where τ_{lep} refers to a purely leptonically decaying τ.

The minimum transverse energies or momenta for electron, muon, and hadronically decaying τ candidates are $E_{\text{T}}^{e} > 20$ GeV, $p_{\text{T}}^{\mu} > 15$ GeV, and $p_{\text{T}}^{\tau} > 20$ GeV respectively. Events are triggered using single electron or muon triggers, with thresholds of $E_{\text{T}}^{e} > 20-22$ GeV (depending on the running period), $p_{\text{T}}^{\mu} > 18$ GeV, or single τ triggers, $p_{\text{T}}^{\tau} > 35$ GeV, in association with missing transverse energy, $E_{\text{T}}^{\text{miss}} > 29$ GeV.

In all final states the sizes of the signal and background components are estimated using a profile likelihood ratio to a kinematic variable. In the lepton+jets mode a signal region is defined by requiring $\sqrt{2p_{\text{T}}^{\ell}E_{\text{T}}^{\text{miss}}(1-\cos\phi_{\ell,\text{miss}})} < 60$ GeV, where the T

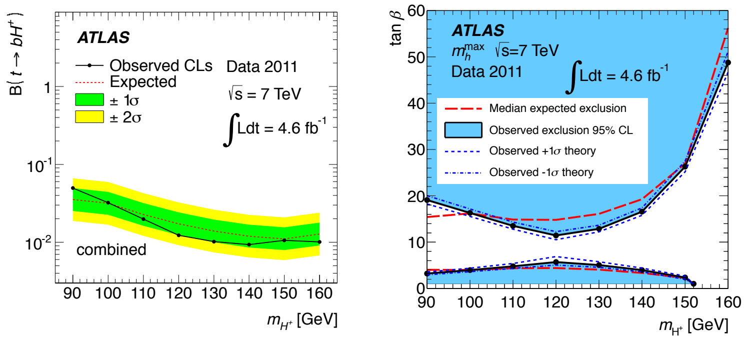

FIGURE 2. Limits on (left) the production cross section and (right) exclusion in the $\tan\beta$ vs $m_{H^\pm}$ plane for the charged Higgs search [5].

subscript refers to projections of momenta onto the transverse plane, and the lepton helicity angle $\cos\theta^*_\ell < -0.6$, where $\cos\theta^*_\ell = 4p_b \cdot p_\ell/(m^2_{\mathrm{T}} - m^2_W) - 1$, p_b, p_ℓ are the four momenta of the b-jet and lepton, and m_{T}, m_W are the nominal masses of the top quark and W boson. Signal and background components are estimated by fitting to the transverse mass, $(m^H_{\mathrm{T}})^2 = (\sqrt{m^2_t + (\vec{p}^{\,\ell}_{\mathrm{T}} + \vec{p}^{\,b}_{\mathrm{T}} + \vec{p}^{\,\mathrm{miss}}_{\mathrm{T}})} - p^b_{\mathrm{T}})^2 - (\vec{p}^{\,\ell}_{\mathrm{T}} + \vec{p}^{\,\mathrm{miss}}_{\mathrm{T}})^2$, where $\vec{p}^{\,\mathrm{miss}}_{\mathrm{T}}$ is the missing transverse momentum, assumed to come from the neutrinos from the τ decay [6]. In the τ+lepton mode, the missing transverse energy is used to discriminate signal from background, and in the τ+jets the transverse mass of the charged Higgs candidate is used. Dominant systematic uncertainties come from the signal efficiency $(13-25\%)$, and QCD background estimations $(14-15\%)$. No excess of events beyond the background expectation is observed and the results are interpreted as limits on the production cross section, and exclusions in the $\tan\beta$ vs m_A plane. The results are combined to improve sensitivity across a wide spectrum of the mass of the charged Higgs boson, $m_{H^\pm}$. The results are shown in Figure 2.

Summary

Results of the searches for neutral and charged Higgs bosons decaying with τ leptons in the final states show no excess beyond the expected background. Results have been interpreted as limits on production cross sections and excluded regions in the $\tan\beta$ vs $m_A/m_{H^\pm}$ planes.

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