Searches for Beyond-Standard Model Higgs bosons at ATLAS

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The results of the searches for Higgs bosons beyond the Standard Model with the ATLAS detector, based on the 2011 proton-proton collision data recorded at the Large Hadron Collider (LHC) at a centre-of-mass energy of 7 TeV are reported. No significant excess is observed and exclusion limits are set on the production cross section times branching ratio of neutral Higgs bosons from a fermiophobic benchmark model and the minimal supersymmetric model (MSSM), as well as singly and doubly-charged Higgs bosons.

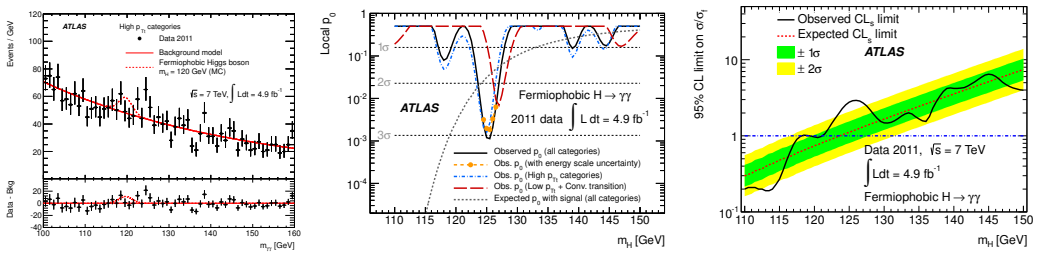
Introduction

In order to reveal the mechanism responsible for the electroweak symmetry breaking, the ATLAS experiment [1] has carried out an extensive program of searches for Higgs bosons using LHC collision data recorded in 2011. In addition to the search for the Standard Model (SM) scalar boson, the existence of Higgs particles predicted by two Higgs doublet [2] (in particular the MSSM [3]), Higgs triplet [4] models and others was investigated. Results of the searches for fermiophobic Higgs bosons, neutral MSSM Higgs bosons, charged and doubly-charged Higgs bosons are presented below.

1 Fermiophobic Higgs boson

A fermiophobic benchmark model, in which the Higgs field does not couple to fermions while the couplings to bosons are kept at their SM values, allows a generic investigation of scenarios in which the Higgs field couplings to some or all fermion generations are suppressed. ATLAS has looked for fermiophobic Higgs bosons, produced via vector boson fusion or associated with W or Z bosons, in the diphoton decay channel using 4.9 fb^{-1} of collision data [5].

The overal sensitivity is dominated by events with high diphoton transverse momentum with respect to the thrust axis ($p_{\mathrm{Tt}} > 40$ GeV). The corresponding diphoton invariant mass spectrum in the range 100 – 160 GeV is shown in Fig. 1a. The background model from an exponential function and the expected signal (with a resolution of about 1.5 GeV), modelled by the sum of a Crystal-Ball and a wide Gaussian, are also shown. The largest excess with respect to the background-only hypothesis is found at 125.5 GeV (Fig. 1b), with a local significance of 2.9 standard deviations, which reduces to 1.6 standard deviations when taking into account the look-elsewhere effect. The data exclude the fermiophobic Higgs model in the ranges 110.0 – 118.0 GeV and 119.5 – 121.0 GeV at 95% confidence level (CL), as shown in Fig. 1c.



(a) (b) (c)

Figure 1: (a) Diphoton invariant mass spectrum for the high p_{Tt} categories, overlaid with the background model and the expected fermiophobic Higgs boson signal ($m_H = 120$ GeV) [5]. (b) Observed and median expected local p_0 and (c) 95% CL exclusion limits normalised to the fermiophobic cross section times branching ratio expectation σ_{f} as a function of the fermiophobic Higgs boson mass m_H [5].

2 Neutral MSSM Higgs bosons

A search for neutral MSSM Higgs bosons ($A/H/h$) decaying to pairs of τ-leptons was performed using 1.06 fb^{-1} of integrated luminosity [6]. Four final states with opposite-charged τ-lepton candidates, reconstructed by their decays to leptons (electrons or muons, $\ell = e, \mu$) or hadrons (τ_{had} in the following), were considered ($e\mu$, $e\tau_{\mathrm{had}}$, $\mu\tau_{\mathrm{had}}$ and $\tau_{\mathrm{had}} + \tau_{\mathrm{had}}$).

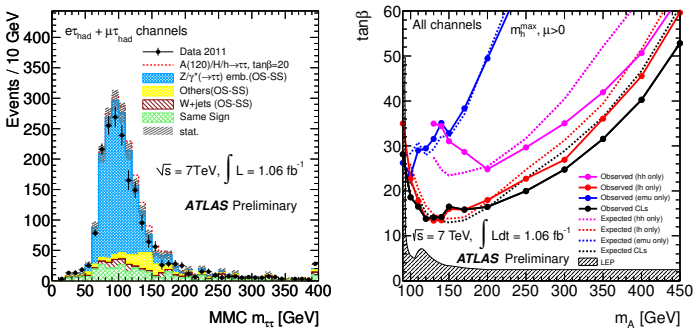
Background events from QCD processes and Z boson decays were suppressed by requiring a minimum amount missing transverse energy, while specific cuts depending on the final state were applied to reject processes like W + jets, diboson and top-quark decays. Data-driven techniques were used in the estimation of the background from QCD processes and the irreducible background from $Z \to \tau\tau$ decays. The presence of a possible signal was investigated using the di-τ invariant mass spectrum, reconstructed using different techniques for each final state. The sum of the spectra of the $e\tau_{\mathrm{had}}$ and $\mu\tau_{\mathrm{had}}$ final states, reconstructed using the Missing Mass Calculator (MMC), is shown in Fig. 2a.

The observed number of events in each final state and their sum are consistent with the expected background. Exclusion limits for the production of MSSM $A/H/h$ bosons as a function of the parameters m_A and $\tan\beta$ in the maximal mixing scenario ($m_{\mathrm{h}}^{\mathrm{max}}$) [7] are shown in Fig. 2b.

3 Charged Higgs bosons

ATLAS has performed a model-independent search for charged Higgs bosons ($H^{\pm}$) using 4.6 fb^{-1} of collision data [8]. Charged Higgs bosons with masses in the range 90 – 160 GeV could be produced in top-quark pair events ($t\bar{t} \to b\bar{b}H^{\pm}W^{\mp}$) and can decay via $H^+ \to \tau\nu$. Both leptonically or hadronically decaying τ-leptons and W bosons were considered, except for both τ and W decaying leptonically, leading to the final states e/μ + jets, $\tau_{\mathrm{had}} + e/\mu$ and τ_{had}+ jets.

A dedicated event selection for each final state was applied in order to reject non-$t\bar{t}$ backgrounds. The discrimination between W and H^+ decays relied on the amount of missing transverse energy ($E_{\mathrm{T}}^{\mathrm{miss}}$) or on the transverse mass (m_{T}) of the τ-lepton and the $E_{\mathrm{T}}^{\mathrm{miss}}$. The

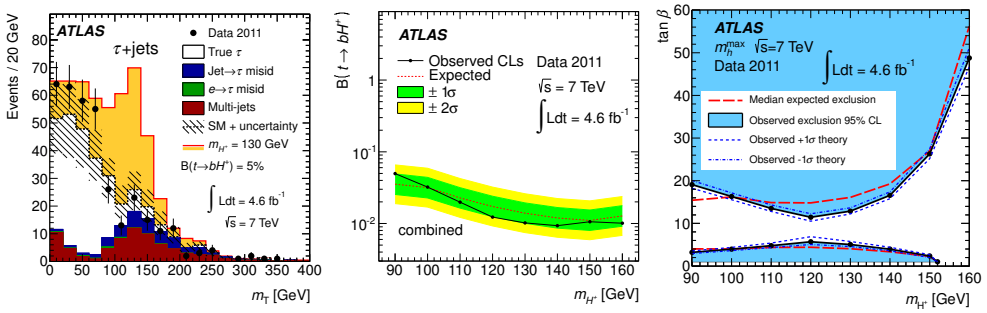


(a) (b)

Figure 2: (a) MMC mass distribution for the sum of the $e\tau_{\rm had}$ and $\mu\tau_{\rm had}$ final states, compared with the background expectation and overlaid with the expected MSSM signal for $m_A = 120$ GeV, $\tan\beta = 20$ [6]. (b) Expected and observed 95% CL exclusion limits in the $m_A - \tan\beta$ plane of the MSSM for the individual $e\mu$, $e\tau_{\rm had} + \mu\tau_{\rm had}$ (ℓh) and $\tau_{\rm had}\tau_{\rm had}$ (hh) analyses and their combination [6].

$m_{\rm T}$ distribution for the $\tau_{\rm had}$+ jets final state is shown in Fig. 3a. Data-driven methods were used in the estimation of the multi-jet background, backgrounds with misidentified leptons or hadronically decaying τ-leptons, as well as backgrounds with true τ-leptons.

Assuming a branching ratio of the charged Higgs boson to a τ-lepton and a neutrino $B(H^+ \to \tau\nu) = 100\%$, upper limits on the branching ratio of top-quark decays to a b-quark and a charged Higgs boson are set between 5% and 1% for charged Higgs boson masses ranging from 90 GeV to 160 GeV, respectively (Fig. 3b). In the context of the MSSM $m_{\rm h}^{\rm max}$ scenario, values of $\tan\beta$ above 12 – 26, as well as between 1 and 2 – 6, are excluded for charged Higgs boson masses between 90 GeV and 150 GeV (Fig. 3c).



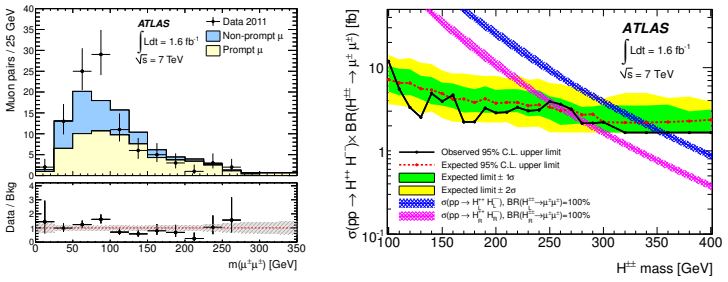
(a) (b) (c)

Figure 3: (a) Distribution of $m_{\rm T}$ in the τ+jets channel, overlaid with the expected background and signal ($m_{H^+} = 130$ GeV, $B(t \to bH^+) = 5\%$) [8]. (b) Expected and observed 95% CL exclusion limits as a function of m_{H^+} on $B(t \to bH^+)$ assuming $B(H^+ \to \tau\nu) = 100\%$ [8]. (c) Expected and observed 95% CL limits on $\tan\beta$ for the $m_{\rm h}^{\rm max}$ scenario [8].

4 Doubly-charged Higgs bosons

A search for doubly-charged Higgs bosons decaying to same-sign dimuons was performed using 1.6 fb^{-1} of collision data [9], looking for a narrow resonance in the dimuon invariant mass spectrum. The contribution of SM processes giving rise to high-p_{T} prompt (from τ-lepton, W or Z-boson decays) like-sign dimuons, such as WZ, ZZ, $W^{\pm}W^{\pm}$ and $t\bar{t}W$, was estimated using Monte Carlo simulations. The background from semi-leptonic b- or c-hadron decays, muons from pion or kaon decays in flight, and misidentified muons from hadronic showers in the calorimeter was estimated from data. Backgrounds where the charge of one of the two muons is misidentified are negligible in the relevant mass range.

The distribution of the invariant mass of the muon pair $m(\mu\mu)$, shown in Fig. 4a, is found to agree well with the background expectation. Limits on the cross section times branching ratio of pair production of doubly-charged Higgs bosons ($pp \to H^{++}H^{--}$) via a virtual Z/γ^* exchange are shown in Fig. 4b, for the doubly-charged Higgs boson mass range 100 – 400 GeV. The observed upper limit is 11 fb (1.7 fb) at $m(H^{++}) = 100$ GeV (400 GeV). The lower mass limit on doubly-charged Higgs bosons with a 100% (33%) branching ratio to muons is 355 (244) GeV and 251 (209) GeV for H^{++} bosons coupling to left-handed and right-handed fermions, respectively.



(a) (b)

Figure 4: (a) Distribution of the dimuon invariant mass for $\mu^{\pm}\mu^{\pm}$ pairs [9]. (b) Upper limit at 95% CL on the cross section times branching ratio for pair production of doubly-charged Higgs bosons decaying to two muons [9].

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