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Searches for charged Higgs bosons in ATLAS

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Summary. — The presented analyses were performed by the Higgs to Complex States Working Group of the ATLAS Collaboration, using *pp* collisions data taken by the ATLAS detector in 2010 and 2011 at the LHC. An outline of the analysis and the result of the charged Higgs in the $c\bar{s}$ final state, which uses kinematic fitting algorithms, was presented. Upper limits on $\mathcal{B}(t \to bH^+) \times \mathcal{B}(H^+ \to c\bar{s}) = 0.25$ to 0.14 for $m_{H^\pm} = 90$ to 130 GeV have been derived. In the second part the charged Higgs in the hadronic τ final state analysis, which utilizes different techniques to estimate all background contributions from the data, was summarized. Values of the product of branching ratios $\mathcal{B}(t \to bH^+) \times \mathcal{B}(H^+ \to \tau + \nu)$, larger than 0.03 to 0.10 have been excluded in the $H^\pm$ mass range 90 to 160 GeV.

PACS 14.65.Ha – Top quarks.

1. – Introduction

The charged Higgs boson is predicted by many extended Higgs scenarios, such as models containing Higgs triplets and Two-Higgs-Doublet Models (2HDM). The observation of charged Higgs bosons, $H^\pm$, would indicate physics beyond the Standard Model (SM). Both analyses presented here [1] consider the type-II 2HDM, which is also the Higgs sector of the Minimal Supersymmetric Standard Model (MSSM). For charged Higgs boson masses, $m_{H^\pm}$, smaller than the top quark mass, m_t, the dominant production mode at the LHC for $H^\pm$ is through top quark decay via $t \to bH^+$. The dominant source of top quarks at the LHC is $t\bar{t}$ production (fig. 1).

2. – The $c\bar{s}$ + jets final state

The goal of this analysis is to search for $H^+ \to c\bar{s}$ decays. In the absence of a signal signature in data, exclusion limits for the top decay branching ratio to a light charged Higgs boson $\mathcal{B}(t \to bH^+) \times \mathcal{B}(H^+ \to c\bar{s})$ are derived from early ATLAS data. A kinematic fit improves the sensitivity for a possible signal and allows to set very good limits, using only 35 pb^{-1}.

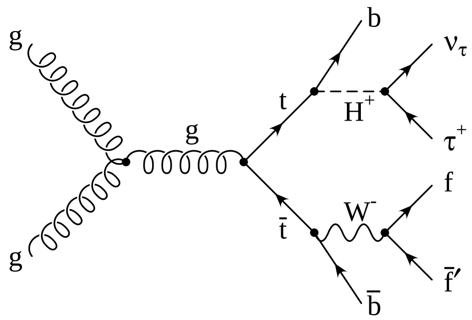

Fig. 1. – Example for a leading-order Feynman diagram for the production of a charged Higgs boson through gluon fusion in $t\bar{t}$ decays.

2˙1. *The kinematic fit.* – In lepton plus four jets events, the two jets originating from decays of H^+ need to be identified in order to reconstruct the mass of H^+ candidates. A kinematic fitter [2] is used to identify and reconstruct the mass of dijets from W/H^+ candidates, by fully reconstructing the $t\bar{t}$ system. In the kinematic fitter, the lepton, the missing transverse energy, $E_{\mathrm{T}}^{\mathrm{miss}}$, (from the neutrino), and four jets are assigned to the decay partons from the $t\bar{t}$ system.

2˙2. *Result and limits.* – The sensitivity of the analysis presented in [4] is comparable to the limits obtained at the Tevatron, where datasets with more than twenty-five times the integrated luminosity were used. The limits are shown in fig. 2 where the extracted limits are compared with the previous limits from the Tevatron [2,3].

3. – The τ + jets final state

The goal of this analysis is to search for the light charged Higgs bosons in the decay channel $H^+ \to \tau + \nu$, all the backgrounds of the selection are estimated from data using data-driven techniques [5]. Only a selection of the methods applied is presented below. In absence of a significant signal, limits on the branching ratio of $\mathcal{B}(t \to bH^+) \times \mathcal{B}(H^+ \to \tau + \nu)$ are derived.

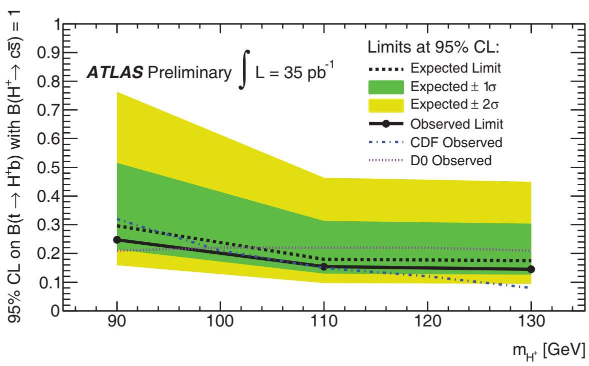

Fig. 2. – The extracted 95% CL upper limits on $\mathcal{B}(t \to bH^+)$ from the ATLAS data are compared with the expected results and results from the Tevatron. These results assume $\mathcal{B}(H^+ \to c\bar{s}) = 100\%$. The ATLAS limits shown are calculated using the CL_S limit setting procedure.

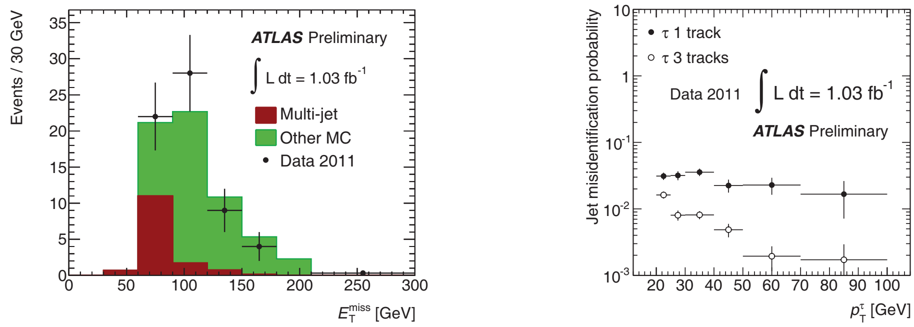

Fig. 3. – Left: multi-jet estimate: A fit to the E_T^{miss} distribution in data after all selection cuts using two shapes (one for the multi-jet model, and one for all other background processes, dominated by $t\bar{t}$ and W+jets) is shown. The multi-jet fraction estimated after all selection cuts is $(23 \pm 10)\%$. Right: jet $\to \tau$ misidentification probabilities measured from γ+jet events for 1-track and 3-track tight likelihood based τ identification, *versus* p_T, using an integrated luminosity of $1.03\,\text{fb}^{-1}$ are shown.

3·1. *Multi-jet background estimation and jet-to-τ misidentification probability*. – The multi-jet background is estimated by fitting its E_T^{miss} shape to data (fig. 3 (left)). In order to study this shape in a data-driven way, a control region is defined by inverting the τ identification and b-tagging requirements. A measurement of the probability for a jet to be misidentified as a hadronically decaying τ lepton is used to predict the yield of jet-to-τ misidentification events (fig. 3 (right))from the most important SM backgrounds with intrinsic E_T^{miss}.

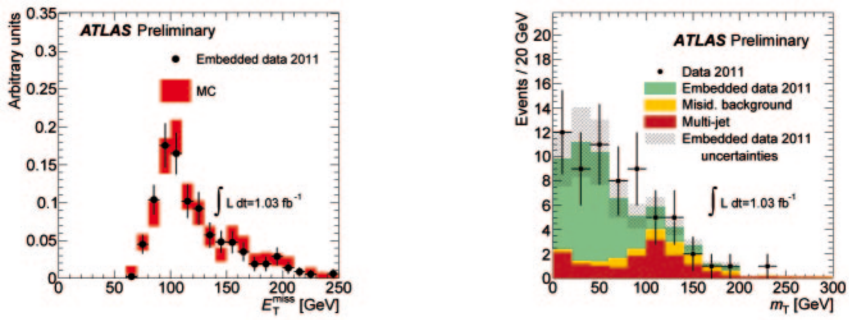

Fig. 4. – Left: The embedded data E_T^{miss} shape, normalized to unit area, is compared to $t\bar{t}$ simulation after applying the H^+ selection (shaded area indicates the statistical uncertainties on the MC simulation). Right: Comparison of the m_T shape for embedded events *versus* collision data. The prediction using the embedding method is stacked on top of the expected backgrounds with objects misidentified as τ jets: MC expectation for $t\bar{t}$ and electroweak processes, and the data-driven estimate for multi-jet events. The comparison is done after the H^+ event selection and after normalizing the m_T distribution of embedded events to the data distribution in the range 0–40 GeV (gray area indicates the statistical and systematic uncertainties of the embedding method estimate).

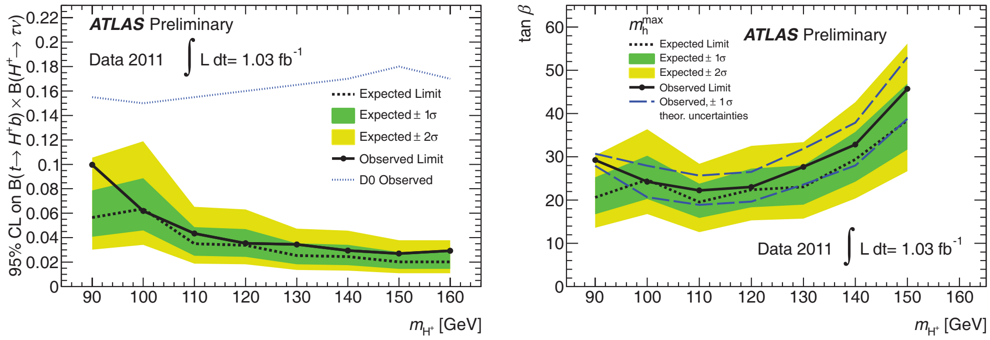

Fig. 5. – Left: Expected and observed 95% CL exclusion limits for charged Higgs boson production from top quark decays as a function of m_{H^+} in terms of $\mathcal{B}(t \to H^+ b) \times \mathcal{B}(H^+ \to \tau^+ \nu)$. For comparison, the best limit provided by the Tevatron experiments is shown [3]. Right: Limit for charged Higgs boson production from top quark decays in the m_{H^+}-$\tan\beta$ plane. Results are shown for the MSSM scenario $m_h^{\max}$.

3·2. *The embedding method.* – The method consists of collecting a control sample of real $t\bar{t}$, single-top and W+jets events with a muon and replacing the detector signature of this muon with that of a simulated τ lepton. The reconstruction is re-applied to the new hybrid events which are then used to estimate the true-τ background of the selection (fig. 4). The whole event (except for the τ jet) is taken directly from data, including the underlying event and pile-up, missing energy, b quark jets and light quark jets.

3·3. *Result and limits.* – Using data-driven background estimates, no statistically significant excess of events is observed in 1.03 fb^{-1} of collision data. Exclusion limits are set on the branching ratio $t \to bH^+$ (fig. 5 (left)), and in the $m_{H^+} - \tan\beta$ plane (fig. 5 (right)), by rejecting the signal hypothesis at the 95% confidence level applying the CL$_S$ procedure [6, 7]. A profile likelihood ratio [8] is used with the m_{T} distribution as the discriminating variable. The final limits are based on the asymptotic distribution of the test statistic [8].

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