H^+ Searches in ATLAS

Overview and status report

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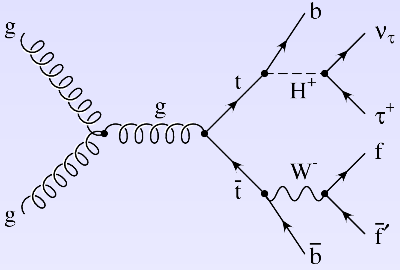
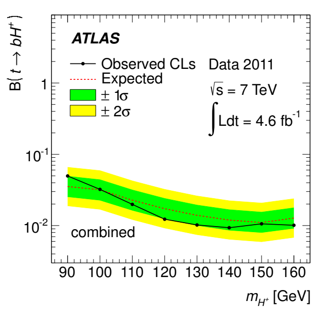
Introduction

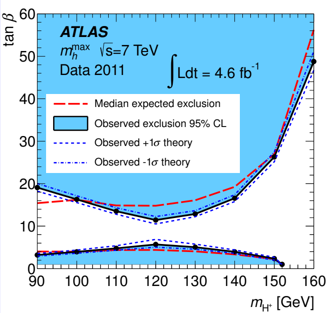
- In the Standard Model, one scalar Higgs field doublet is responsible for electroweak symmetry breaking $\rightarrow$ giving us one Higgs boson (and vector boson masses).
- The SM can be extended with an additional Higgs field, giving us in total 5 Higgs bosons: h^0, H^0, A^0, H^+, H^-.
- In particular, the MSSM Higgs sector is such a Two Higgs Doublet Model (2HDM).
- At tree level, it is fully determined by two parameters, e.g. m_{H^+} and $\tan\beta$ (ratio of Higgs field vacuum expectation values).

- Focus here on light charged Higgs bosons, $m_{H^+} < m_{top}$.
- The dominant decay mode is then $H^+ \rightarrow \tau\nu$ in most of the $\tan\beta$ range.
- A light charged Higgs can be produced in top decays.



Charged Higgs searches in ATLAS





$H^+ \to \tau^+\nu_\tau$ combination (3 channels)

- Results presented at Moriond 2012, paper submitted to JHEP (arXiv:1204.2760).
- 1%-5% upper limit on $\sigma(t \to H^+ b) \times \mathcal{B}(H^+ \to \tau^+\nu_\tau)$ for 90 GeV $< M_{H^+} <$ 160 GeV.

←plots: Assuming $\mathcal{B}(H^+ \to \tau\nu) = 100\%$.

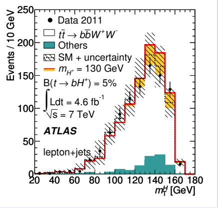
Also under preparation with full 2011 data

- $H^+ \to \tau\nu$ Ratio Method,
- $H^+ \to c\bar{s}$,
- $H^+ \to a_1 W^+$.

Not covered...

- Unusual production/decay modes,
- doubly charged Higgs, etc.

The Moriond 2012 $H^+ \to \tau\nu$ searches



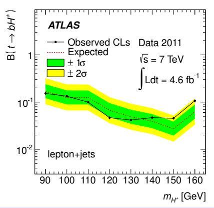
lepton+jets: $t\bar{t} \to b\bar{b}WH^+ \to b\bar{b}(q\bar{q}')(\tau_{lep}\nu)$

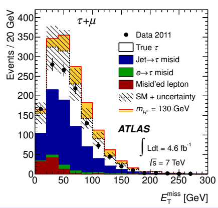
Cut on $\cos\theta_l^* = \frac{2m_{bl}^2}{m_{top}^2 - m_W^2} - 1 \simeq \frac{4\, p^b \cdot p^l}{m_{top}^2 - m_W^2} - 1$,

inverted cut on $m_T^W = \sqrt{2p_T^l E_T^{miss}(1 - \cos\Delta\phi_{l,miss})}$

reconstruct $t \to Wb$, find max $(m_T^H)^2 = (p^l + p^{miss})^2$

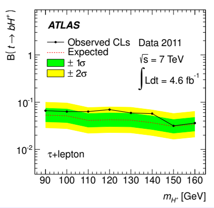
while requiring $(p^{miss} + p^l + p^b)^2 = m_{top}^2$.

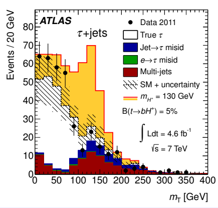




τ+lepton: $t\bar{t} \to b\bar{b}WH^+ \to b\bar{b}(l\nu)(\tau_{had}\nu)$

Use the E_T^{miss} distribution to distinguish between SM $t\bar{t}$ and H^+ mediated top decays, where neutrinos are expected to carry away more energy (as $m_{H^+} > m_W$).

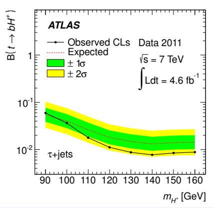




τ+jets: $t\bar{t} \to b\bar{b}WH^+ \to b\bar{b}(q\bar{q}')(\tau_{had}\nu)$

Reconstruct the fully hadronic top decay, require large E_T^{miss} as well as $E_T^{miss}/(0.5\sqrt{\sum p_T})$ to reduce the multi-jet background.

Use $m_T = \sqrt{2p_T^\tau E_T^{miss}(1 - \cos\Delta\phi_{\tau,miss})}$ to discriminate against SM $t\bar{t}$.

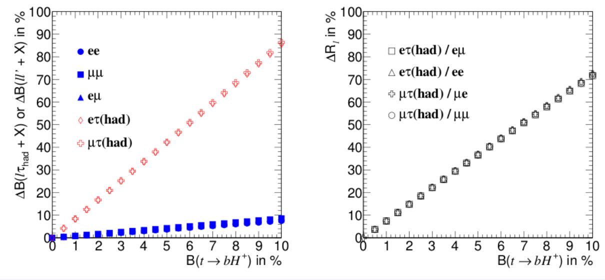


The Ratio Method

- Previous results are mainly limited by systematics
  $\rightarrow$ need a way to reduce the effect of these uncertainties.
- The ratio method aims to test lepton universality in $t\bar{t}$ events by measuring the ratios $\frac{\mathcal{B}(t\bar{t}\rightarrow b\bar{b}+\mu\tau_{had})}{\mathcal{B}(t\bar{t}\rightarrow b\bar{b}+\mu e)}$ and $\frac{\mathcal{B}(t\bar{t}\rightarrow b\bar{b}+e\tau_{had})}{\mathcal{B}(t\bar{t}\rightarrow b\bar{b}+e\mu)}$.
- Expect relatively more τ events with increasing $\mathcal{B}(t \rightarrow H^{+})$!
- Numerators and denumerators equally affected by uncertainties on e.g. luminosity, jet energy scale, b-tagging efficiency... these systematics cancel in the ratio!
- Can gain sensitivity over previous results, especially in the $m_{H^{+}} \approx m_{W}$ region.

Generator level plots:

Increase w.r.t. SM of the $t\bar{t}$ branching ratios involving either $e/\mu + \tau_{had}$ or $e + \mu$ (left) and the ratio between these branching ratios (right).
X stands for $b\bar{b}$ and ν's.



Ratio Method event selection

1. Single lepton (electron or muon) trigger and event quality cuts.
2. One trigger matched lepton with $E_T > 25$ GeV (electron) or $p_T > 25$ GeV (muon).
3. At least 2 jets with $p_T > 25$ GeV and vertex fraction > 0.75, including exactly 2 b-tagged jets.
4. Either exactly one τ jet or an electron (muon triggered events) or a muon (electron triggered events). Veto on any additional electrons or muons.
5. $E_T^{miss} > 40$ GeV.

For $e\mu$ events, require e trigger when comparing with $e\tau$ events and μ trigger when comparing with $\mu\tau$ events.

Taus are produced with opposite sign charge (OS) compared to the trigger lepton.
$\rightarrow$ Assign a negative weight to events in which the tau candidate has the same charge sign (SS) as the trigger lepton.

Data driven estimation of jet $\rightarrow \tau$ fakes

Tau identification in ATLAS

- Anti-Kt jets with 1 or 3 tracks are considered as tau candidates.
- A likelihood function based on the jet characteristics is used to discriminate between tau jets and quark- and gluon-initiated jets. $\rightarrow$ Use a cut-off value to define "tight" taus.

Fake τ model from data

- Obtain a sample of W+jet events in data and determine how often the non-tau jets identified as tau candidates also pass the "tight" criterion - the "fake rate". $\rightarrow$ Apply the fake rate as a weight to MC events with fake tau candidates.
- Alternatively: Fit the full likelihood distribution.

Problem: Different quark/gluon fraction of jets in W+jet and $t\bar{t}$ events

- Gluons (and b-jets) are equally likely to be produced with either charge.
  $\rightarrow$ These contributions should cancel out in the OS-SS subtraction!
- Remaining tau candidates are mainly true taus and light quarks.

Problem: W+jet is still not a perfect model of $t\bar{t}$ events...

- Bin/reweight by τ η/p_T, distance to closest jet, size and total energy of that jet...
- Currently under investigation what the best treatment is.

Outlook: Heavy charged Higgs

- Above the top quark mass, H^+ can be produced via gg or gb fusion.
- A new decay mode opens up, $H^+ \to t\bar{b}$.
  - Very difficult to distinguish from SM background.
- Both the $\tau\nu$ and $t\bar{b}$ decay channels will almost certainly be analyzed, but timescale still unclear.
- Large integrated luminosity needed for sensitivity to MSSM-like scenarios.