Charged Higgs searches in ATLAS: Ratio method and $H^+ \rightarrow t\bar{b}$

update and status report

UPPSALA UNIVERSITET

Alexander Madsen

ILCP general meeting

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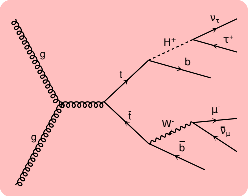
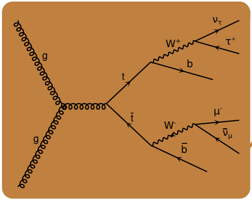
Introduction

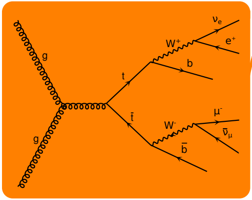
Since last time...

- A Higgs(?) boson has been discovered!
  - Taking this into account, a light charged Higgs boson is now strongly disfavored in our standard benchmark (M_h-max) MSSM scenario.
- The "Ratio method" analysis covered last meeting has been finished.
  - Currently undergoing ATLAS internal review.
- The hunt is on for heavy ($m_{H^+} > m_{top}$) charged Higgs bosons!
  - Will introduce $H^+ \rightarrow t\bar{b}$ today.

Ratio method review







- This is a search for light charged Higgs bosons decaying to $\tau\nu$.
- Can gain sensitivity over previous results, especially in the $m_{H^+} \approx m_W$ region.
- The idea is to test lepton universality in $t\bar{t}$ decays by measuring the ratios

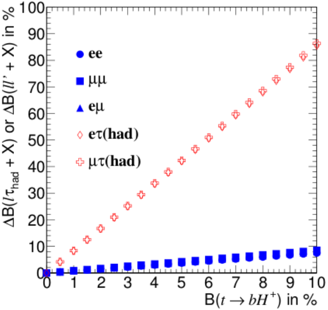
$$\frac{\mathcal{N}(t\bar{t} \rightarrow b\bar{b} + \mu\tau_{had})}{\mathcal{N}(t\bar{t} \rightarrow b\bar{b} + \mu e)} \text{ and } \frac{\mathcal{N}(t\bar{t} \rightarrow b\bar{b} + \mu\tau_{had})}{\mathcal{N}(t\bar{t} \rightarrow b\bar{b} + \mu e)}.$$

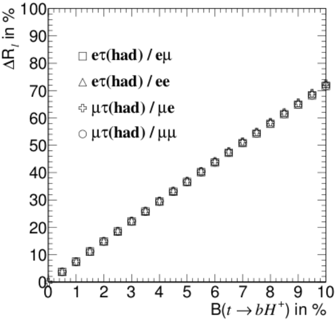
Many systematics cancel in the ratios!

- The amount of fake taus remains as a large systematic uncertainty...

Ratio method: Effects of a charged Higgs boson

Expect relatively more τ events with increasing $\mathcal{B}(t \to H^+)$!





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 electron trigger ($e\mu$ and $e\tau$ events) or single muon trigger (μe and $\mu\tau$ events) 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 $p_T > 20$ GeV and vertex fraction > 0.75, including exactly 2 b-tagged jets.
4. Either exactly one τ jet with $p_T >$25 GeV 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.
6. A well defined generalized transverse mass, m_{T2}^H (arXiv:0907.5367).

How to deal with fake taus?

- In simulated events, $\sim 46\%$ of reconstructed taus come from quark- or gluon-jets. The fake rate is different for each type of jet, and we don't know the correct fraction of jet types...
- True 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.

  $\rightarrow$ This cancels the contribution of gluon and heavyt flavor jets!
- Now use a selection of OS-SS W + >2 jets (0 b-tag) events in data to derive the probability that a fake tau candidate passes tight tau idenfication criteria, and apply to simulation.
  - Bin by p_T, N^{τ}_{track} and N^{iso}_{track} with the latter being the number of tracks within $0.2 < \Delta R < 0.4$ of the τ.
- Also derive scale factors for number of tracks of the fake tau candidates.

Ratio method: Conclusion

Other data driven background estimates:

- $e \to \tau$ fake rates: Measured using Z→ee events.
- Misidentified leptons: Matrix method.

Limits on $\mathcal{B}(t \to bH^+)$:

- Can be calculated using M_{T2}^{H} distribution alone.
- But more powerfully, using the ratio of event yields. The combined ratio is:

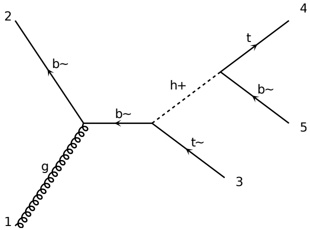
$$R_{e+\mu} = \frac{N(e+\tau_{had}) + N(\mu+\tau_{had})}{[N(e+\mu) + N(\mu+e)] \times [1-\delta_{e\mu}]}$$

(where $\delta_{e\mu}$ is the fraction of overlapping dilepton events).

Outlook:

- Want to extend the ratio method to include heavy charged Higgs.
- Most of the machinery is already in place!

New study: $H^+ \to t\bar{b}$



A search for heavy H^+:

- Looks like SM ttbar with 3 or 4 b-jets.
- We will use the semileptonic decay channels.
- If a solution for the neutrino can be found, a full event reconstruction is possible, giving the mass of the charged Higgs boson.

Workflow:

- Follow event selection used by the SM semileptonic ttbar studies.
- "TopRootCore" codebase by ATLAS Top WG will be used to produce analysis ntuples with all energy corrections, etc, applied.
- Reconstruct the event topology using
  - Simple χ^2 fit *or*
  - Kinematic Fitter tool *or*
  - MVA.
- Enhance signal / background using an MVA discriminator.

MVA based event reconstruction

Problem: How to assign each object to its proper place in the decay chain?

$$N_{combinations} = N_b! \times \binom{N_j}{2} \times N_\nu \times 2$$

Define two classes: The correct combination and all the wrong ones.

- Variables suggested by earlier sensitivity studies ([1], [2]):
  - Invariant masses: m_{jj}, m_{jjb}, $m_{l\nu b}$
  - Transverse momentum of b-jets: $p_T(b_{H^+})$, $(p_T(b_0))$
  - Angular separations: $\Delta R(j, j)$, $\Delta R(jj, b)$, $\Delta R(l, \nu)$, $\Delta R(b_{H^+}, t_{H^+})$
- Will keep trying new ideas!
- Variables are typically mass dependent - will have to train MVAs separately for each mass point.

Using the W mass constraint, candidate solutions for the longitudinal momentum of the neutrino can be obtained. In 25% of cases no real solution is found: Neglect imaginary part or adopt colinear approximation $p_z(\nu) = p_z(l)$.

Summary

- Ratio method
  - Currently under internal review.
  - To be published fall 2012.
- $H^+ \to t\bar{b}$
  - Work is starting.
  - Aiming for Moriond 2013.

Backup

Moriond 2012 constraints on $H^+ \to \tau\nu$