# Search for a Light Charged Higgs Boson in $H^+ \to c\bar{s}$ Channel Using ATLAS Data

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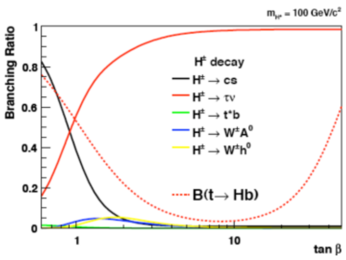
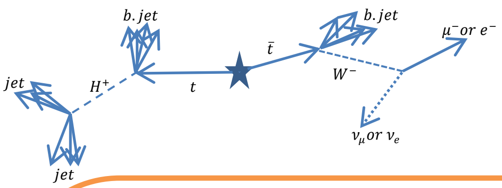
## Introduction:

- The Standard Model (SM) predicts a neutral massive gauge boson (the Higgs boson)
- Beyond the SM, two Higgs-doublet models (2HDM) such as the Minimal Supersymmetric Standard Model (MSSM) -> five physical Higgs bosons; $h^0$, $H^0$, $A^0$, $H^{\pm}$.
- Discovery of neutral Higgs boson -> which one?
- Any evidence of $H^{\pm}$ is an evidence of new physics beyond the SM.
- LEP excluded any charged Higgs boson up to 80GeV.
- In Hadron Colliders, search for charged Higgs boson in association of the top quark has been performed.
- Tevatron limits on the branching ratio of the top quark decay to $b+H^{\pm} \approx$ 10-20% (depending on the $H^{\pm}$ mass).
- LHC limits are: $H^+ \to \tau\nu$ channel between 7-1% (ATLAS) but $H^+ \to c\bar{s}$ channel still 20-10% (depending on the $H^{\pm}$ mass).

## The Analysis in Brief

- Search for charged Higgs boson ($H^+$) from top quark decays where $H^+$ decays to $c\bar{s}$ producing two jets in the detector.
- Complementary to $\tau\nu$ channel which is dominant at high tanβ.
- Select semi-leptonic ttbar events: use high $p_T$ lepton (e/μ), large $E_T^{miss}$ with 4 jets two (1 or 2-btag)
- Fully reconstruct the $t\bar{t}$ event using kinematic χ2 fitter to improve the di-jet mass resolution and increase signal-background separation power.





## Event Selection, Reconstruction and the Fitter

- Use MC samples for signal and background
- The $H^+$ signal are 90, 100, 110, 120, 130, 140 & 150 GeV mass points.
- Major backgrounds include; SM $t\bar{t}$, Single Top, W+jets (light jets and heavy flavour jets), di-boson and QCD.
- Apply a set of optimized event selection cuts.
- Selected events are used as an input to the kinematic $\chi^2$ fitter.

***In The Fitter:***

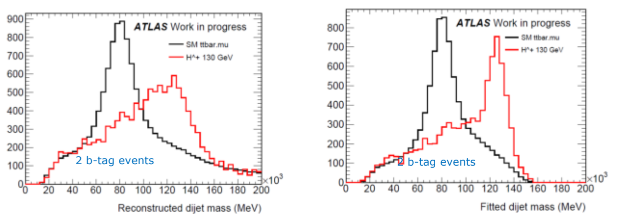
- Constrain the values of the Leptonic W boson mass and the top pair masses to be their PDG values.
- Allow the measured $P_T$ values to vary within their uncertainties.
- Use information to provide a neutrino $p_z$ solution and correct jet combination.
- Allow combinations where the 5th jet swaps the 3rd or 4th jet (if not b-tagged)

***From the Fitter:***

- Remove badly reconstructed ttbar events using a cut on the $\chi^2$ value.
- Significantly reduce the background events.
- Provide a greater resolving power between ttbar and signal MC.

***The $\chi^2$ function:***

- $$\chi^2 = \Sigma_{i=l,4jets}\frac{(p_T^{i,fit}-p_T^{i,meas})^2}{\sigma_i^2} + \Sigma_{j=x,y}\frac{(p_j^{SEJ,fit}-p_j^{SEJ,meas})^2}{\sigma_{SEJ}^2} + \Sigma_{k=jjb,blv}\frac{(M_k-M_{top})^2}{\sigma_{top}^2} + \frac{(M_{lv}-M_W)^2}{\sigma_W^2}$$
- First term is to allow the $p_T$ of the jets and lepton be changed within their resolutions.
- Second term allows the rescaling of the sum of extra jets energy (SEJ) defined as a quantity absorbing all jet $E_T$ not associated with the lepton or the four leading jets and is used to re-calculate the $E_T^{miss}$.
- Third term constrains the masses of the top pair to $M_{top}$ = 172.5 GeV.
- Fourth term constrains the mass of the leptonic W to $M_W$ = 80.42 GeV.



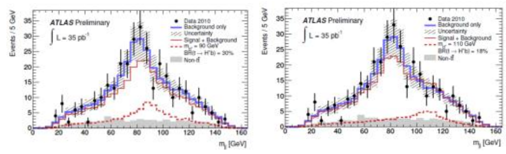

*The improvement in the reconstructed di-jet mass due to the fitter for SM $t\bar{t}$ and signal $m_{H^+}$ = 130 GeV (MC)*

## Analysis with 35pb$^{-1}$ of ATLAS Data (≥ 1 b-tag)

- In 2010 ATLAS recorded more than 35pb-1 of physics data.
- Apply a ≥ 1 b-tag and loser χ2 cut to enhance our signal.
- Total data events (323) agree with the SM expectation within error.
- The expected number of SM ttbar, non-ttbar background and the case of $m_{H^+}$ = 110GeV signal with Br = 10% are shown in the following table.
- Expected and observed limits are comparable with the Tevatron limits with a factor of 30 to 60 less luminosity.

| Channel | Muon | Electron |
|---|---|---|
| Data | 193 | 130 |
| SM $t\bar{t} \to W^+bW^-\bar{b}$ | $156^{+24}_{-29}$ | $106^{+16}_{-20}$ |
| $W/Z$ + jets | $17\pm6$ | $9\pm3$ |
| Single top | $7\pm1$ | $5\pm1$ |
| Diboson | $0.30\pm0.02$ | $0.20\pm0.02$ |
| QCD multijet | $11\pm4$ | $6\pm3$ |
| Total Expected (SM) | $191^{+26}_{-30}$ | $127^{+17}_{-21}$ |
| $\mathcal{B}(t\to H^+b)$ = 10% : | | |
| $t\bar{t} \to H^+bW^-\bar{b}$ | $20^{+3}_{-4}$ | $14^{+2}_{-3}$ |
| $t\bar{t} \to W^+bW^-\bar{b}$ | $127^{+19}_{-23}$ | $86^{+13}_{-16}$ |
| Total Expected ($\mathcal{B}$ = 10%) | $181^{+21}_{-25}$ | $120^{+14}_{-17}$ |

***Data-MC Comparison***




- Dijet mass distributions of the data is compared with the SM expectaion (MC) (left) with Br = 0.30 for $m_{H^+}$ = 90 GeV;(right) with Br = 0.18 for $m_{H^+}$ = 110GeV

| Higgs Mass | Expected limit | Observed |
|---|---|---|
| 90 GeV | 0.30 | 0.25 |
| 110 GeV | 0.18 | 0.15 |
| 130 GeV | 0.17 | 0.14 |

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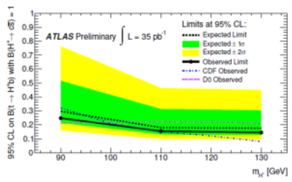


## Analysis with 35pb$^{-1}$ of ATLAS Data (2 b-tag)

- The efficiency of the 2 b-tag cut is about 30% for both channels.
- Total data events 92
- Good discriminating power for some backgrounds (single top, W + jets).
- Good agreement between data and SM expectation in both channels (electron left and muon right).
- Statistically limited

## Prospects of Analysis with 4.7fb$^{-1}$ of ATLAS Data

- Sufficiently high statistics to apply 2b-tag and a tighter ($\chi^2$ < 10) cut to reduce the background rate and improve signal-background separation power (expect ~14K events).
- However, the effect of systematic uncertainties becomes dominant.
- Many sources of systematic uncertainties that affect the signal acceptance and/or the shape of the reconstructed di-jet mass.
- Try different techniques to estimate the effect of these uncertainties.
- The expected limits will be between several percent to 1% depending on the $H^+$ mass.
- Results are in the collaboration review and will be public within a month.