Prospects for a Charged Higgs Search with Early ATLAS Data

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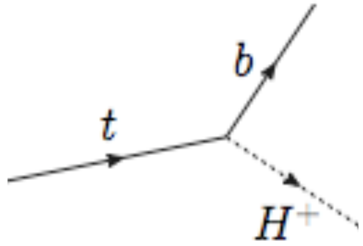
- Charged Higgs in top decays
- Event selection
- Analysis method
- Expected upper limits on $B(t \rightarrow H^{+}b)$ with 200 pb^{-1} of 10 TeV data.

Charged Higgs in Top Decays

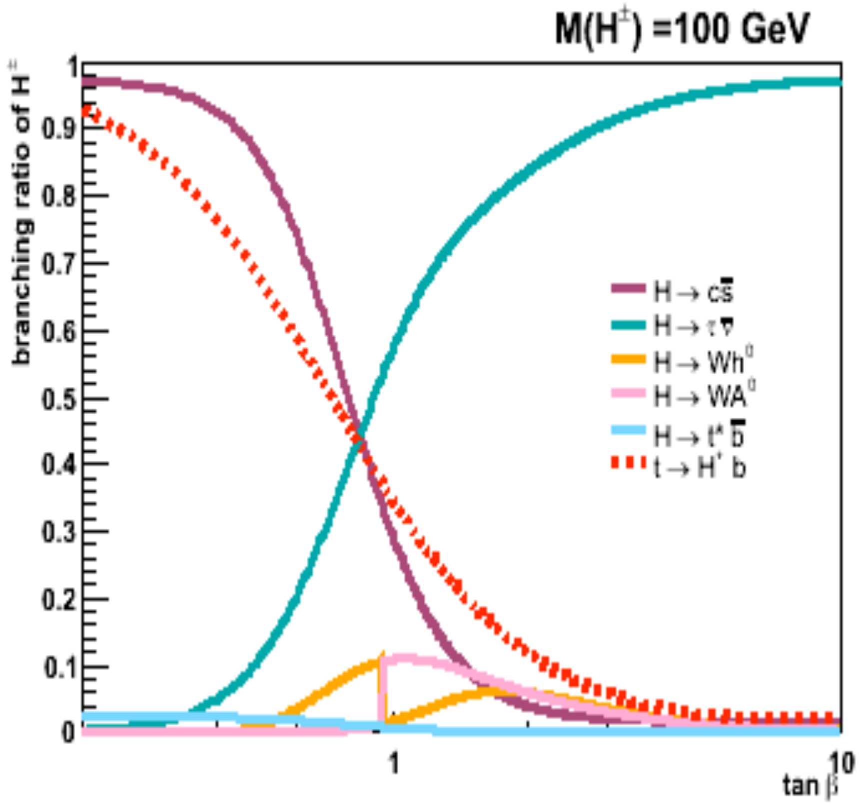
- The minimal supersymmetric extension to the standard model, together with a two higgs doublet model, predicts five higgs bosons: H, h, A, $H^{\pm}$.
- Discovery of a new charged boson would be direct evidence for new physics.



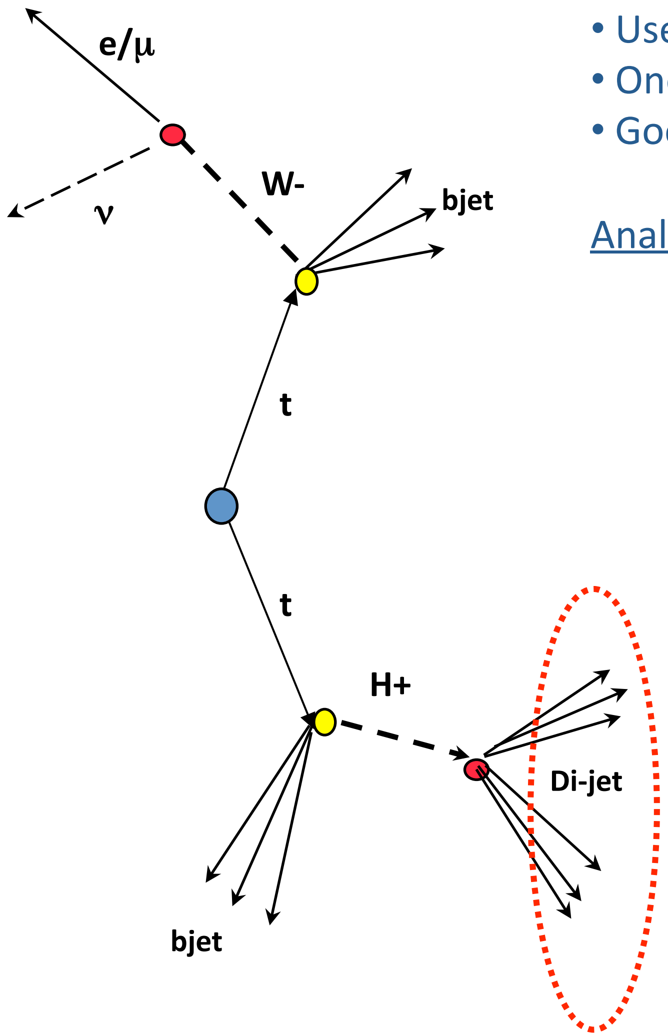
- Production mechanism for H^+ depends on the mass.
- For a light H^+ (lighter than $M_t - M_b$), then the main production mechanism would be via the decay of a top quark.

- Predicted branching ratio t -> H^+b depends on tanβ (experimentally difficult at medium tanβ).

- Decay mode of H^+ also depends on tanβ.



Decay Channel



- Use semi-leptonic ttbar decay.
- One W boson is replaced by a H^+ and decays to two jets.
- Good candidate decay for MSSM at low tanβ.

<u>Analysis strategy</u>:

– Reconstruct di-jet from H^+ and look for a second peak in the SM W mass distribution.
– Assume B(H^+->csbar) = 1 and try to set limits on B(t->H^+b).

- Analysis has already been done at the Tevatron (CDF)

Charged Higgs mass (GeV)	B(t->H^+b) Upper Limit @ 95% CL
90	0.22
110	0.14
130	0.08
150	0.12

- LHC σ_{tt} ~ two orders of magnitude larger than Tevatron
- Expect lots of ttbar events.
- With a small amount of data we have the potential to compete with the Tevatron results.

Signal and Backgrounds: Event Selection

- The SM ttbar decay in the semi-leptonic channel is an irreducible background.
- Other backgrounds are single top and W + jets.
- QCD background is not considered and will be estimated from data.

- Signal samples generated at 90, 110, 130, 150 GeV using Pythia.
- ttbar background generated with MC@nlo

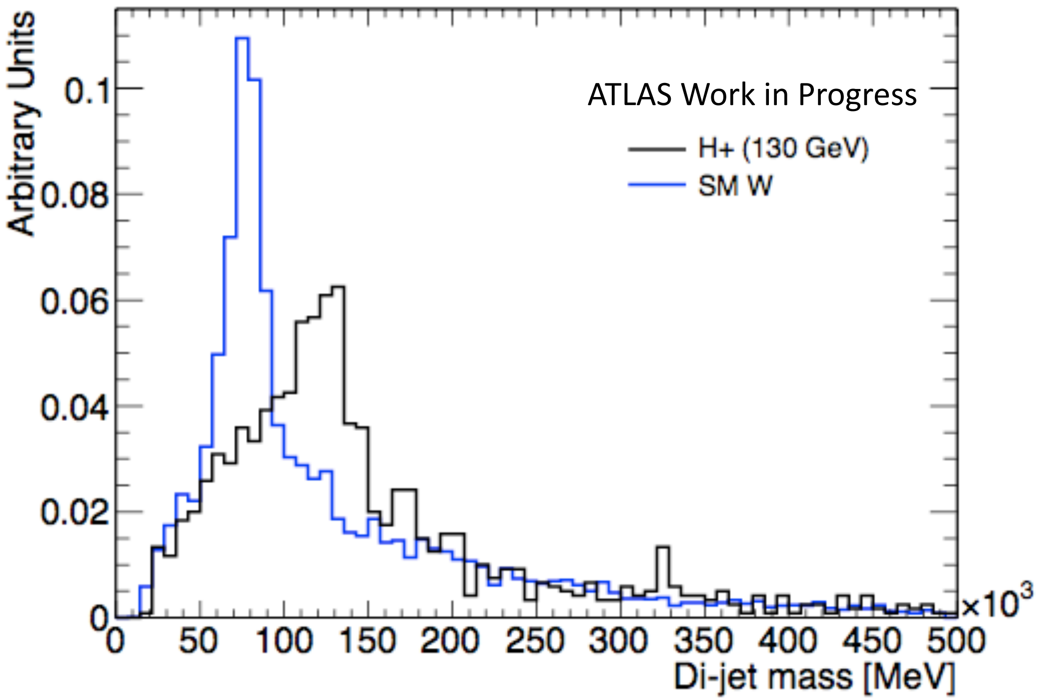
- Analysis assumes a 10 TeV centre of mass energy.

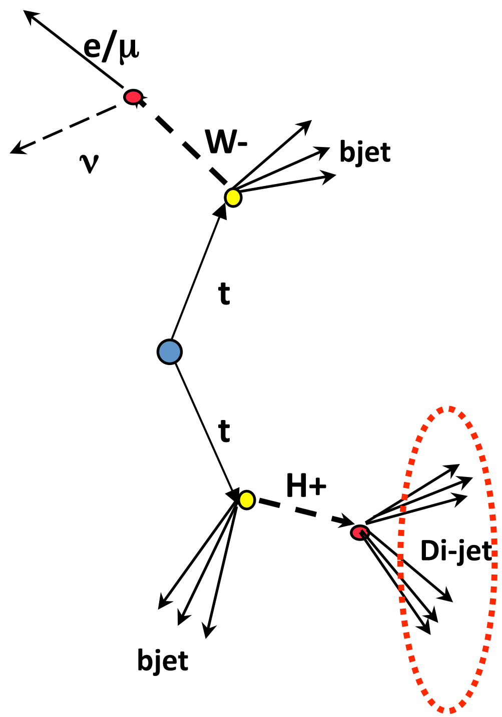
Event selection cuts:

- Exactly 1 electron or muon with $p_T > 20$ GeV, $|\eta| < 2.5$. Isolation 6 GeV in a cone 0.2
- Missing $E_T > 20$ GeV
- At least 4 jets with $p_T > 20$ GeV
- 2 of the 4 leading jets are b-tagged.

Di-jet Reconstruction

- Combining the two untagged jets from the four leading jets…





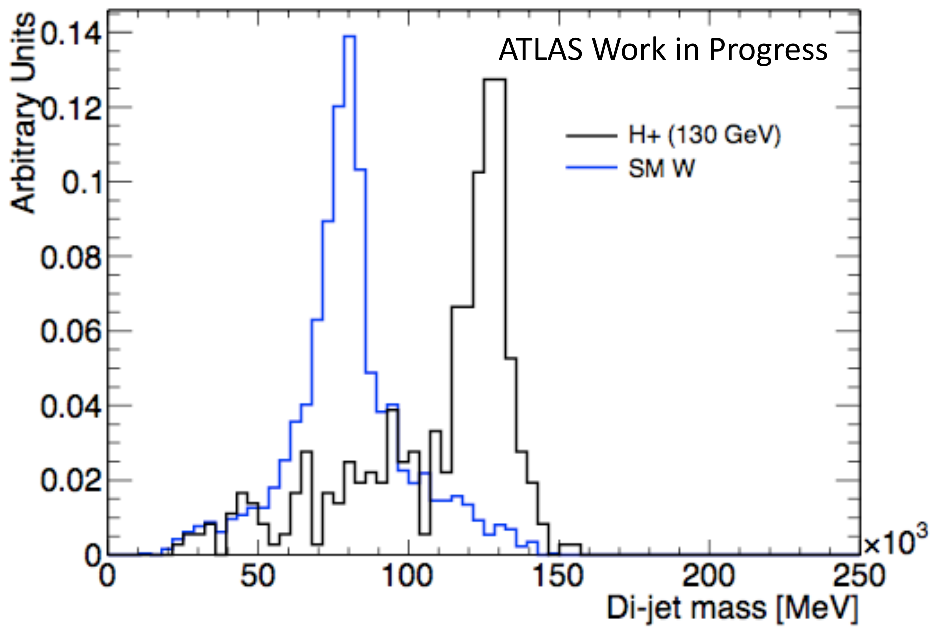
- Resulting distributions are wide and have long tails.
- Want better separation between signal and background.

The Kinematic Fit

- Define a χ^2 function that describes the event, and minimise, allowing jet and lepton energies to vary in the fit within experimental resolutions.

$$\chi^2 = \sum_{\substack{i=lepton,\\ 4\ jets}} \frac{\left(p_T^{i,fit} - p_T^{i,meas}\right)^2}{\sigma_i^2} + \sum_{j=x,y} \frac{\left(p_j^{UE,fit} - p_j^{UE,meas}\right)^2}{\sigma_{UE}^2} + \sum_{j=jjb,lvb} \frac{\left(M_k - M_{top}\right)^2}{\sigma_{top}^2} + \frac{\left(M_{lv} - M_W\right)^2}{\sigma_W^2}$$

- Have constraints on the reconstructed top and W mass – the χ^2 reflects how much the event looks like a ttbar event.



- Fitted distributions requiring $\chi^2 < 10$ and on the hadronic side of the decay M_{top} before fitting < 195 GeV.

- Improves separation between signal and ttbar background.

- χ^2 cut is also powerful to remove non-ttbar background events

For 200 pb^{-1} Scenario at 10 TeV

- Cut flow for the signal and main backgrounds.

Process	No Cuts (N events)	Lepton	MET	4 jets	2 btags	trigger	$\chi^2 < 10$	Mtop < 195 GeV
H+ (90 GeV)	4757	0.395	0.897	0.624	0.254	0.880	0.379	0.831 **(74)**
H+ (110 GeV)	4757	0.401	0.901	0.620	0.221	0.881	0.404	0.857 **(72)**
H+ (130 GeV)	4757	0.403	0.894	0.605	0.181	0.878	0.345	0.860 **(49)**
H+ (150 GeV)	4757	0.413	0.891	0.553	0.125	0.884	0.308	0.845 **(28)**
SM ttbar no all had	43680	0.390	0.906	0.507	0.270	0.883	0.425	0.860 **(683)**
Single Top	11792	0.407	0.894	0.172	0.195	0.882	0.236	0.800 **(24)**
W + jets	55220	0.367	0.860	0.333	0.008	0.894	0.190	0.750 **(6)**

Signal

– Numbers of events assume B(t -> H^+b) = 0.1 and B(H^+->csbar) = 1.

Limit Setting (Maximum Likelihood)

- Assume no signal and use binned maximum likelihood based on template mass distributions.

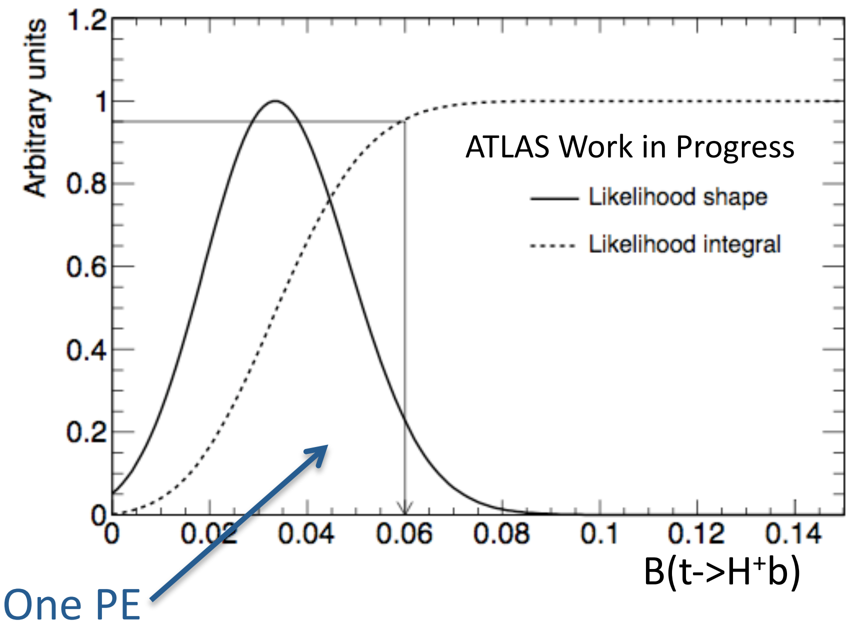
$$LH = \prod \frac{\nu_i^{n_i} \times e^{-\nu_i}}{n_i!} \otimes G(N_{bkg}, \sigma_{Nbkg})$$

Non-ttbar backgrounds Estimated from MC. Gaussian constrained in LH fit.

- Three fit parameters:
  - $B(t \to H^+ b)$
  - Total N_{tt} (into all decay modes: over all normalisation uncertainties absorbed)
  - N_{bkg} (Total number of non-ttbar background)

- Test LH fit performance using set of 1000 PE (PE).
- LH shape gives information for limit setting.

  1. Maximise LH to fit 3 parameters.
  2. Scan LH from $B(t \to H^+ b) = 0$ to 1 with fitted values of N_{tt} and N_{bkg} to obtain 95% CL upper limit on $B(t \to H^+ b)$.



Systematic Uncertainties

- Systematic uncertainties have two effects on the limit setting:
  - Acceptance changes
  - Shape of di-jet mass distribution

Nominal $B(t \to H^+ b) = 0.0584$

- Model the effect of each systematic uncertainty in the MC
- Use new distributions to create pseudodata.
- Repeat LH fit, but fit to nominal templates and check the effect on the upper limit.

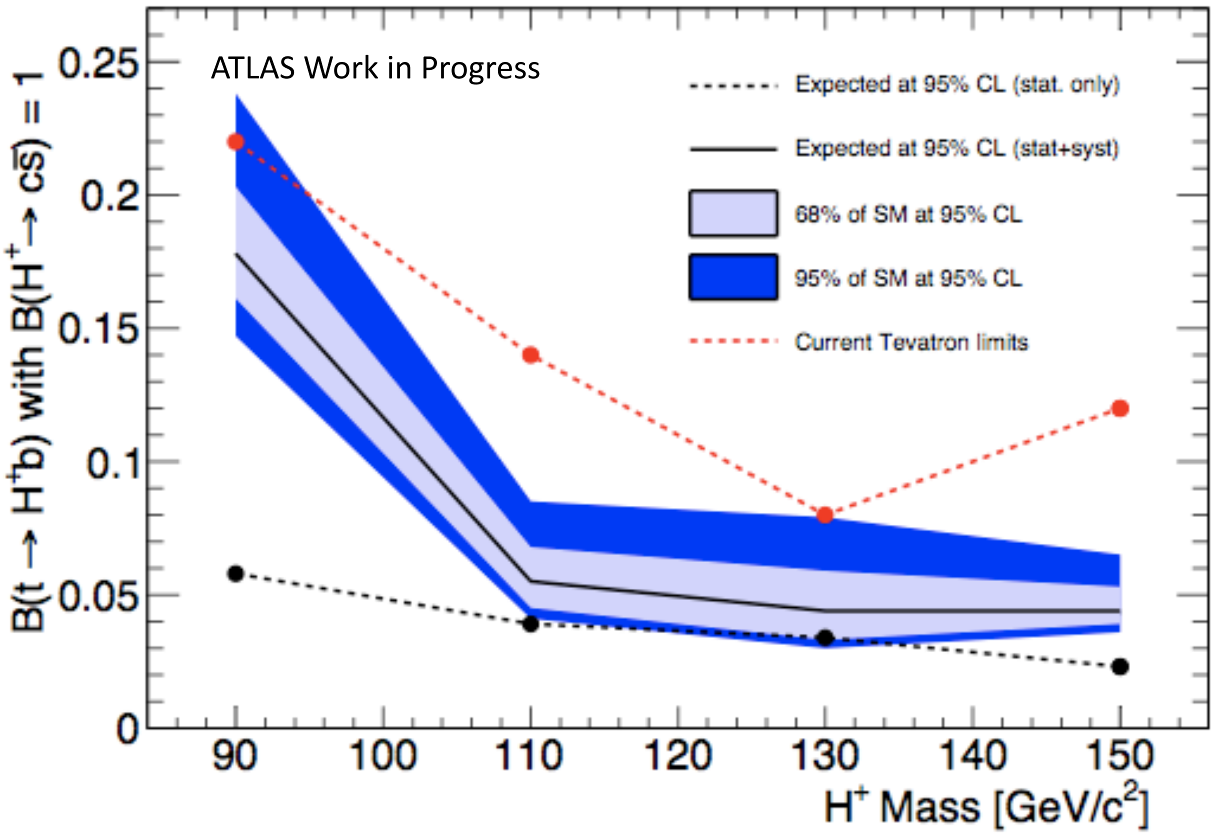
- An example case for 90 GeV H^+.

Systematic	**$\Delta(B)$**
Jet Energy Resolution	0.0584
Jet Energy Scale	0.0011
MC Generator	0.0180
ISR/FSR	0.0550
b-jet Energy Scale	0.0327
Lepton Energy Scale	0.0015
Combination	**0.0942**

- Systematic due to Jet Energy Scale (JES) is small
- Have applied a recalibration to the jet energies based on the position of the W mass peak in SM ttbar decays.

Final Limits

- For final limits including systematics use a smeared LH.
- Convolute LH with a Gaussian whose width describes the combination of all systematics.



Summary

- For $m_{H+} < m_t - m_b$ can search for a charged Higgs produced in top decays.

- The LHC will produce tops at an unprecedented rate.

- A kinematic fit gave better separation between signal and background events.

- A likelihood fit method was used to put expected upper limits on $B(t \to H^+b)$ at 95% confidence level.

- Can expect to improve on the current Tevatron limits with 200 pb^{-1} data at 10 TeV.