Search for light charged Higgs bosons in top-quark decays with the ATLAS experiment

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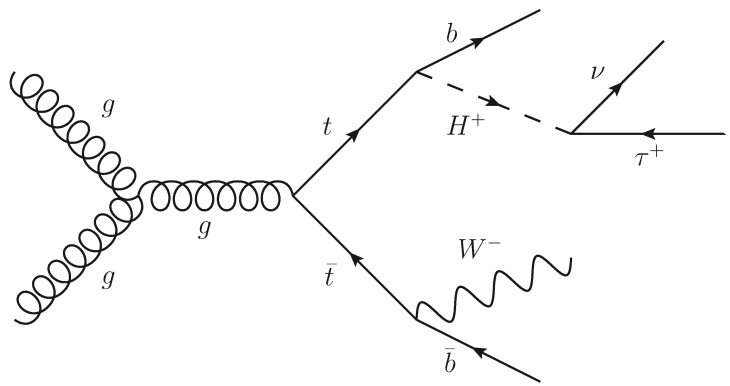
Light charged Higgs boson production at the LHC

- Many extensions to the Standard Model predict the existence of a charged Higgs boson.
- A light ($m_{H^+} < m_{top}$) charged Higgs boson can appear in the decays of top quarks.
- At the LHC, top quarks are main produced as $t\bar{t}$ pairs.



Studies of the following channels are presented here:

- $t\bar{t} \to b\bar{b}WH^+ \to \tau_{lep} + q\bar{q}$ (single lepton)
- $t\bar{t} \to b\bar{b}WH^+ \to \tau_{lep} + l$ (di-lepton)

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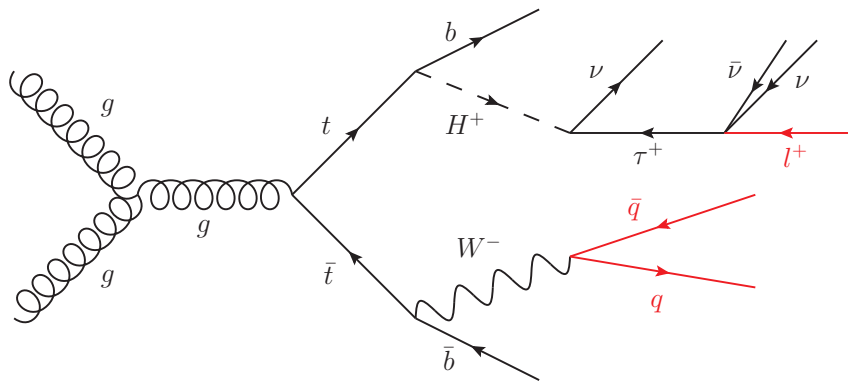

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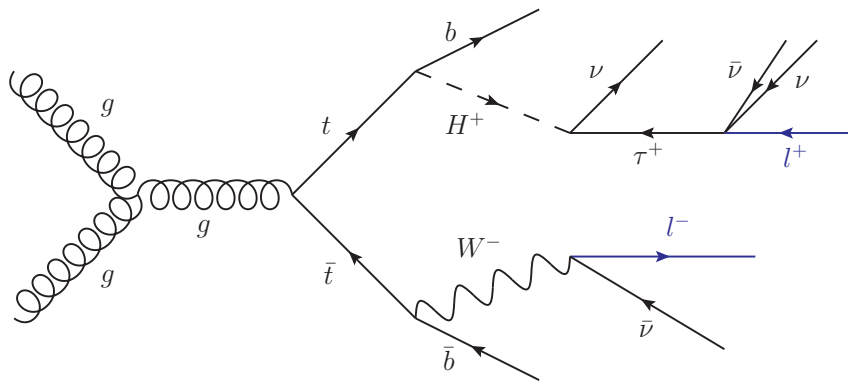

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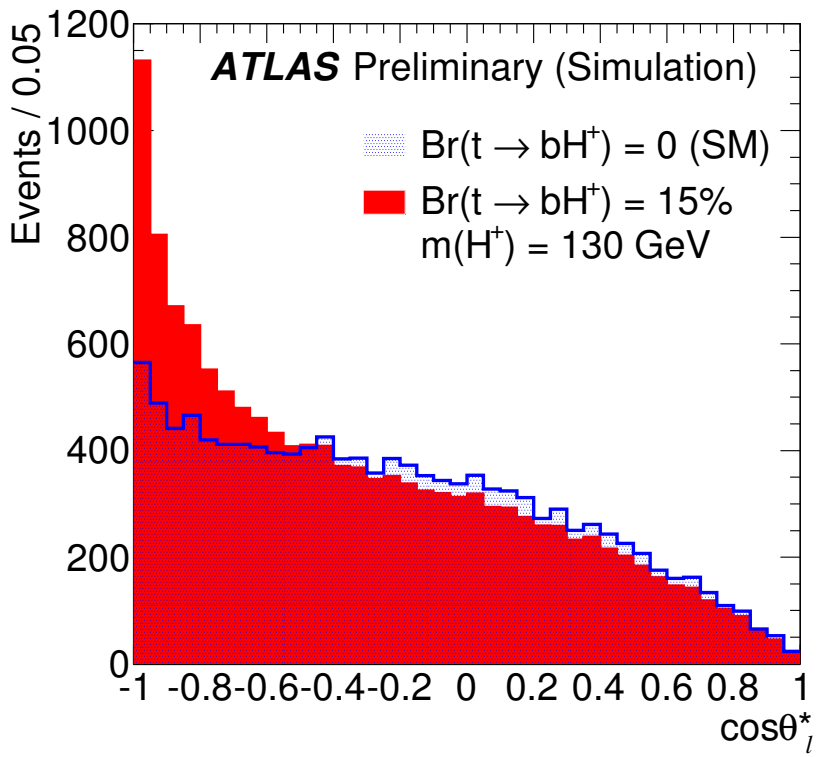
Discriminating variable $\cos\theta_l^*$

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

(with p^l and p^b being the 4-momenta of a lepton and corresponding b-quark)



Transverse masses

Ordinary W transverse mass:

$$(m_T^W)^2 = \min_{\left\{ \begin{array}{c} p_z^{miss},\ E^{miss} \\ (p^{miss})^2 = 0 \end{array} \right\}} [(p^l + p^{\text{miss}})^2]$$

Single lepton H^+ events - charged Higgs transverse mass:

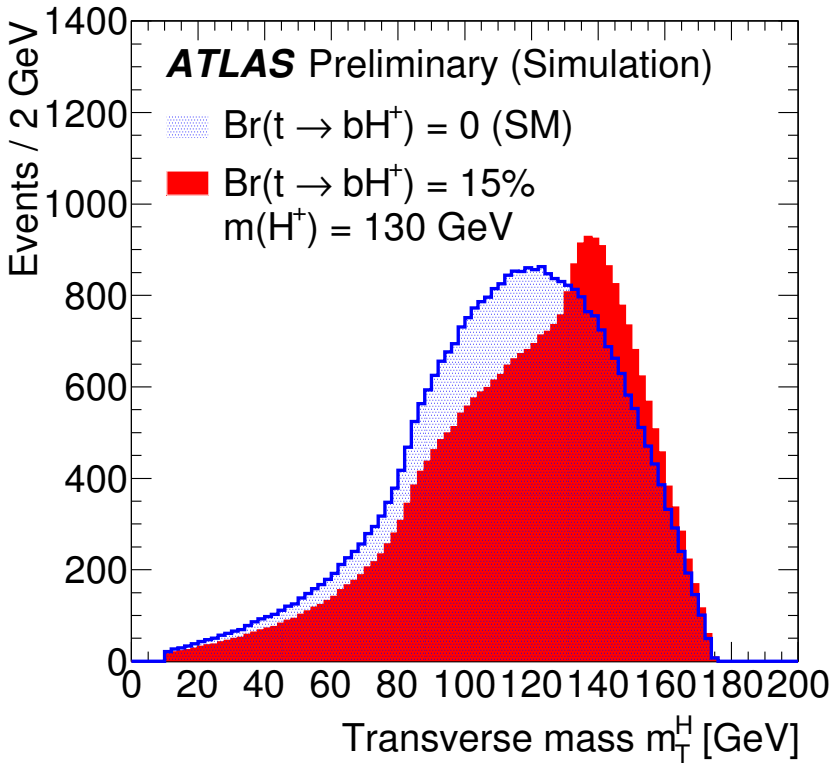
$$(m_T^H)^2 = \max_{\left\{ \begin{array}{c} p_z^{miss},\ E^{miss} \\ (p^{miss} + p^l + p^b)^2 = m_{top}^2 \end{array} \right\}} [(p^l + p^{\text{miss}})^2]$$

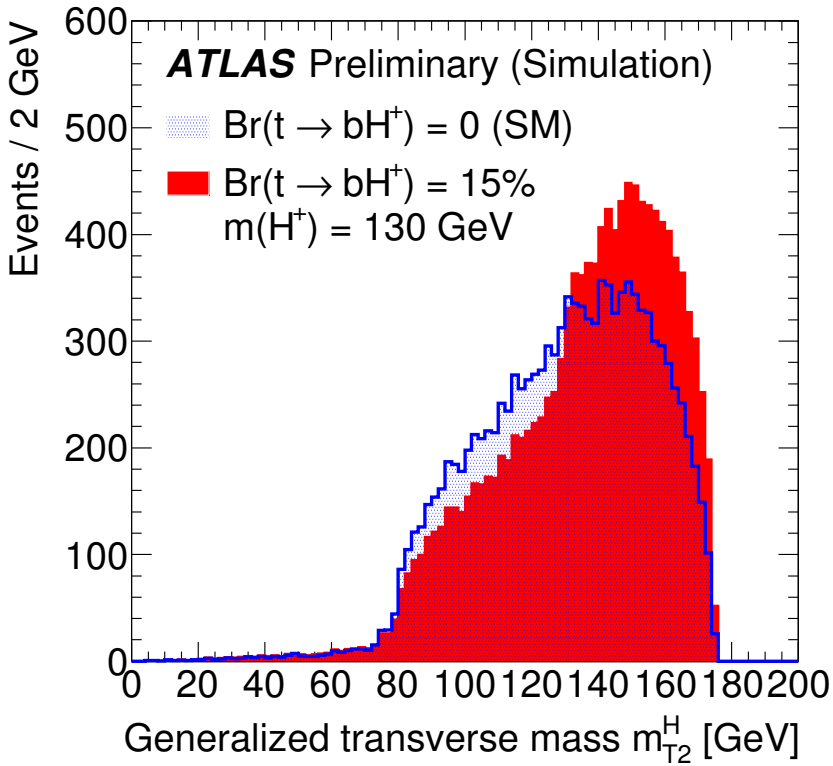
Dilepton H^+ events - generalized charged Higgs transverse mass:

$$(m_{T2}^H)^2 = \max_{\left\{ \begin{array}{c} p^{H^+},\ p^{\bar{\nu}l} \\ (p^{H^+} + p^b)^2 = m_{\text{top}}^2, \\ (p^{\ell^-} + p^{\bar{\nu}_\ell})^2 = m_W^2, \\ (p^{\ell^-} + p^{\bar{\nu}_\ell} + p^{\bar{b}})^2 = m_{\text{top}}^2, \\ (p^{\bar{\nu}_\ell})^2 = 0, \\ \vec{p}_T^{\,H^+} - \vec{p}_T^{\,\ell^+} + \vec{p}_T^{\,\bar{\nu}_\ell} = \vec{p}_T^{\,\text{miss}} \end{array} \right\}} [\left(\sqrt{m_{\text{top}}^2 + (\vec{p_T}^{H^+} + \vec{p_T}^{b})^2} - p_T^b \right)^2 - \left(\vec{p_T}^{H^+} \right)^2]$$

$$m_{H^+} < m_T^H \ , m_{T2}^H < m_{top}$$

(Generalized) charged Higgs boson transverse mass shapes





Event selection - one lepton

- One $E_T > 25$ GeV electron or $p_T > 20$ GeV muon.
- No additional $E_T > 15$ GeV electron or $p_T > 15$ GeV muon.
- At least 4 jets with $p_T > 20$ GeV, including exactly 2 b-jets.
- At least $E_T^{miss} > 40$ GeV (more if lepton and E_T^{miss} are aligned).

- Reconstruct the hadronic side of the event by minimizing:

$$\chi^2 = \frac{(M_{jjb} - M_{top})^2}{\sigma_{top}^2} + \frac{(M_{jj} - M_W)^2}{\sigma_W^2}$$

- Discard events with $\chi^2 > 5$.

$t\bar{t}$ ($bbWW$)	Single top-quark	W+jets	Z+jets	Diboson	QCD	$\sum$ SM	Data	130 GeV H^+ $\mathcal{B}(t \to bH^+) = 10\%$
3081	88	85	5.2	2.0	56	3317	3421	190

Event selection - two leptons

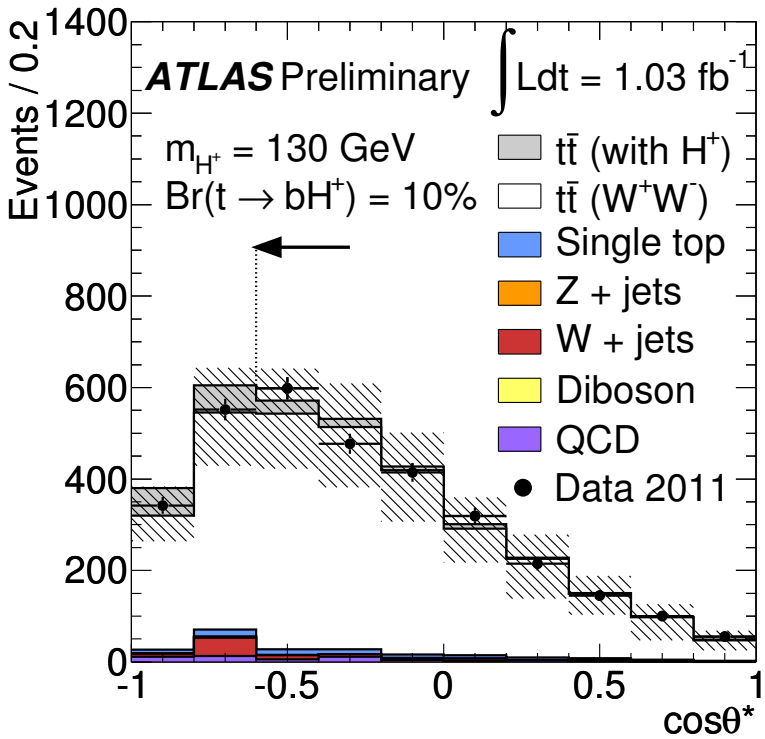
- Exactly two opposite charged leptons, including at least one $E_T > 25$ GeV electron or $p_T > 20$ GeV muon.
- At least 2 jets with $p_T > 20$ GeV, including exactly 2 b-jets.
- $e\mu$ events: $\sum E_T(leptons, jets) > 130$ GeV.
- ee and $\mu\mu$: $m_{ll} > 15$ GeV, $|m_{ll} - m_Z| > 10$ GeV and $E_T^{miss} > 40$ GeV.

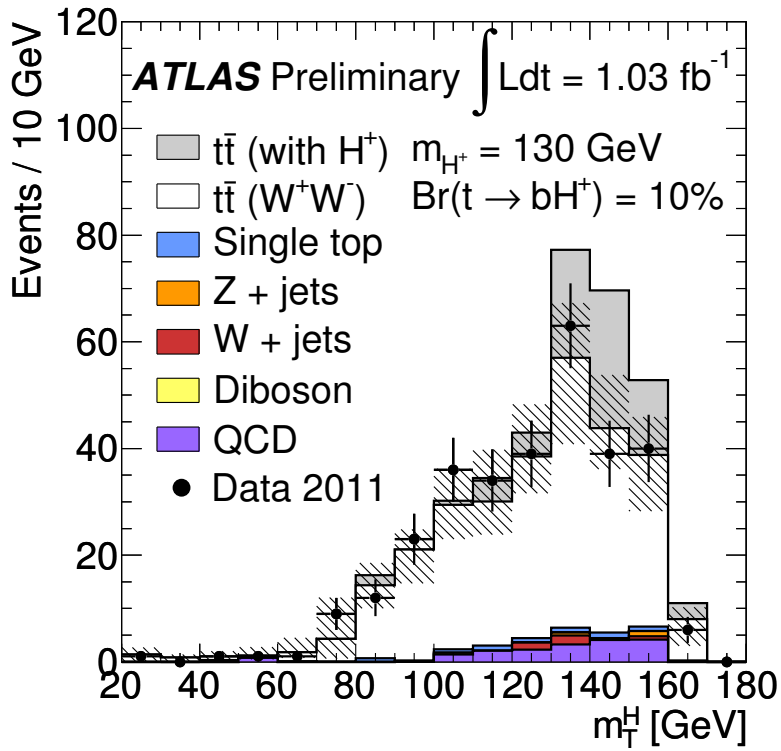
- Assign the leptons with the correct b-jets:
  1. Some events have an easy to find incorrect pairing ($\cos\theta_l^* > 1$), in which case we choose the other lepton-b combination,
  2. if both combinations are physical, choose the one that minimizes $\Delta R(l,b)_{pair1} + \Delta R(l,b)_{pair2}$ in the $\eta\phi$-plane,
  3. assign the pair with the smallest $\cos\theta_l^*$ to the H^+-side of the event,
  4. reject events with unphysical M_{T2}^H value.

$t\bar{t}$ ($bbWW$)	Single top-quark	Z+jets	Diboson	QCD and W+jets	$\sum$ SM	Data	130 GeV H^+ $\mathcal{B}(t \to bH^+) = 10\%$
864	18	1.5	0.3	40	924	992	115

Results - one lepton

- SM-like $t\bar{t} \to b\bar{b}W^+W^-$ MC scaled to match data in the control region $\cos\theta^*_l > -0.2$.
- M_T^H distribution computed for events in the signal region defined by $\cos\theta^*_l < -0.6$ and $m_T^W < 60\,\text{GeV}$.





Results - two leptons

- SM-like $t\bar{t} \to b\bar{b}W^+W^-$ MC scaled to match data in the control region $\cos\theta_l^* > -0.4$.
- M_{T2}^H distribution computed for events in the signal region defined by $\cos\theta_l^* < -0.6$.