Charged Higgs Searches in ATLAS

$H^+ \to \tau\nu$ *and* $H^+ \to cs$

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on behalf of the ATLAS collaboration

Higgs Hunting
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UPPSALA
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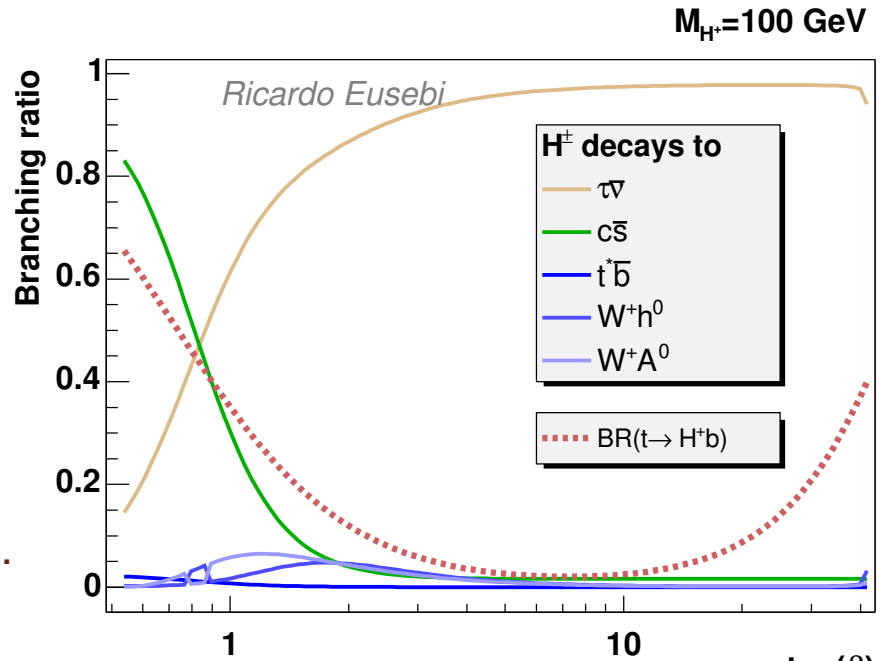
The Hunt is still on!

Charged Higgs?

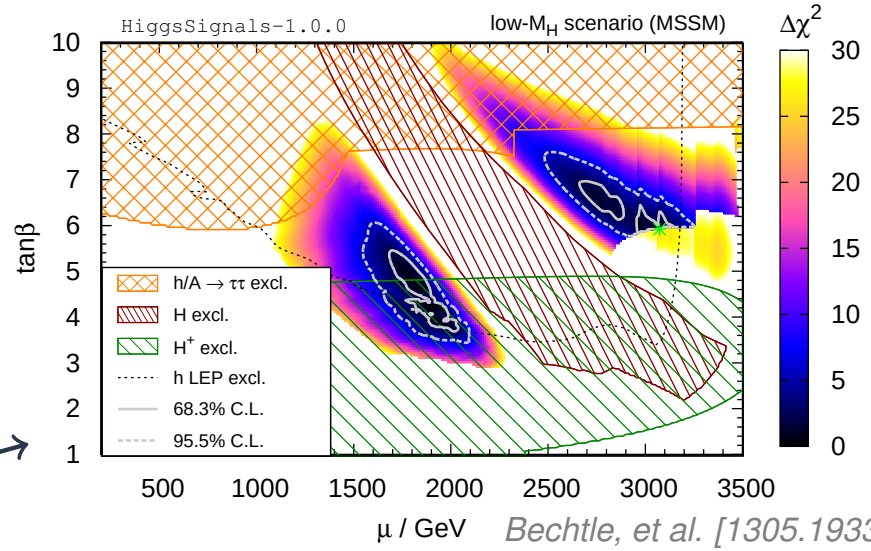
- Charged Higgs bosons appear in models with extended Higgs Sectors (e.g SUSY).
- So far using m_h^{max} in Type II 2HDM as benchmark scenario. For $m_{H^+} < m_{top}$:
  - Main production mode is $gg \to t\bar{t} \to H^+ bW^- \bar{b}$.
  - H^+ decays mainly to $c\bar{s}$ or $\tau\nu$.
- Results presented as limits on $Br(t \to H^+ b)$.
  - $\to$ Not model dependent.



Presented here: (7 TeV data)

- $H^+ \to c\bar{s}$ [Eur. Phys. J. C, 73 6 (2013) 2465].
  - Using the di-jet invariant mass.
- $H^+ \to \tau\nu$ [JHEP 03 (2013) 076].
  - Test of lepton universality in $t\bar{t}$ decays.

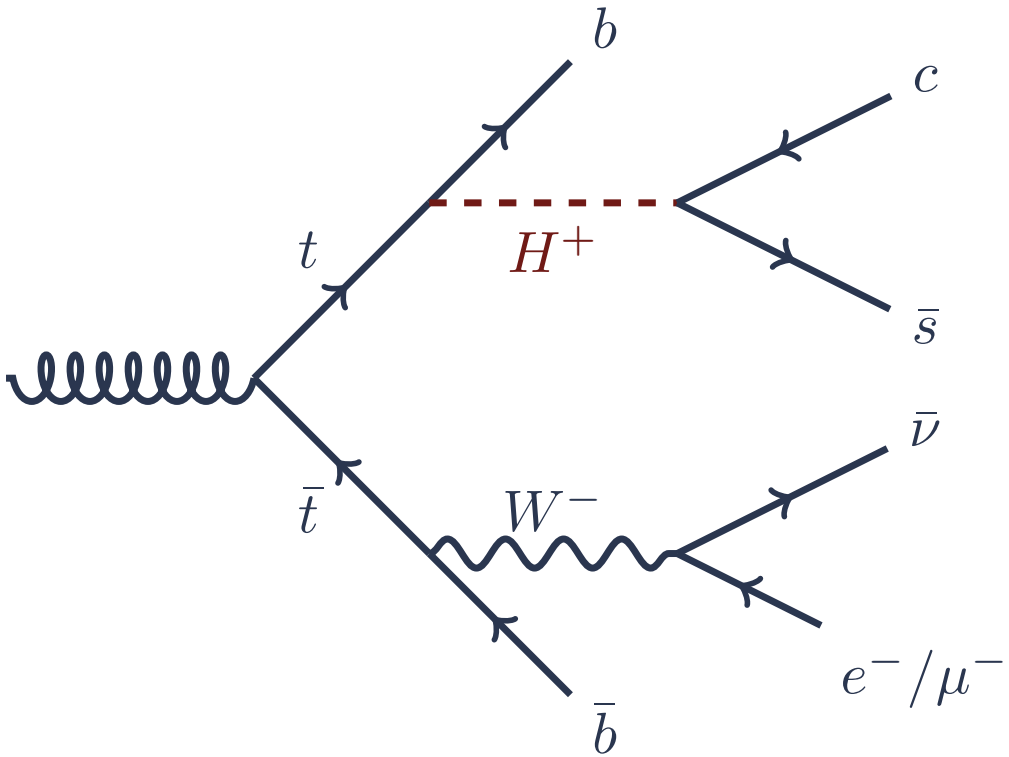
Adds sensitivity to scenarios not well covered by neutral Higgs searches. *Heavy MSSM Higgs H at 125 GeV, light h below LEP limit with reduced couplings??*



Bechtle, et al. [1305.1933]

$H^+ \to c\bar{s}$

➢ All hadronic decay of H^+ allows for full mass reconstruction.



- The QCD multijet background is determined by a fit to the E_{T}^{miss} distribution.
- The W+jets background is determined from data exploiting the charge asymmetry of such events.

Jet Selection

- At least **four jets**.
- At least **two b-tagged jets** (using an MVA algorithm with 70% efficiency).

Electron Channel

- 25 GeV electron.
- $E_{\mathrm{T}}^{miss} > 30$ GeV
- $m_{\mathrm{T}}^{e,miss} > 30$ GeV

Muon Channel

- 20 GeV muon.
- $E_{\mathrm{T}}^{miss} > 20$ GeV
- $E_{\mathrm{T}}^{miss} + m_{\mathrm{T}}^{\mu,miss} > 60$ GeV

Kinematic fitting

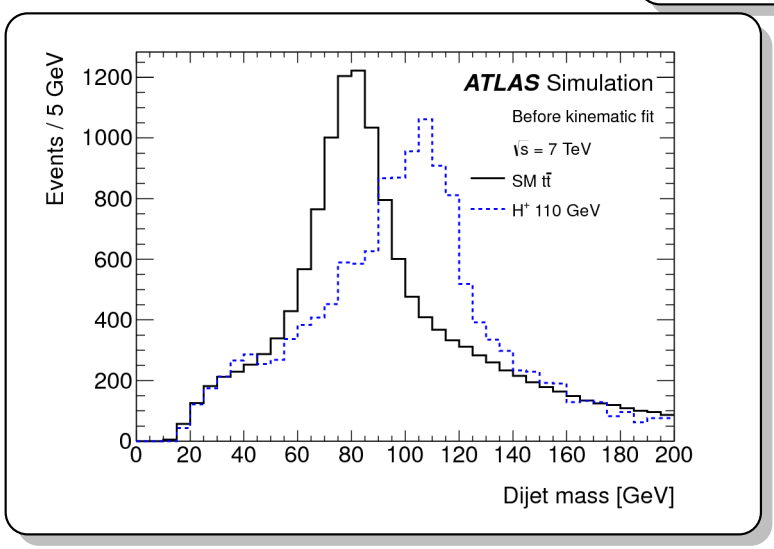
- Full reconstruction of the $t\bar{t}$ system - Neutrino p_z determined by fixing $m_W = 80.4$ GeV
- 5 highest p_T jets considered as possible $t\bar{t}$ decay products, 2 highest p_T jets always assumed to be $t\bar{t}$ decay products, b-tagged jets assumed to originate from b-quarks
- Find the best *bbjj* combination by minimizing:

$$\chi^2 = \sum_{i=l,4jets} \frac{(p_T^{i,fit} - p_T^{i,meas})^2}{\sigma_i^2} + \sum_{j=x,y} \frac{(p_j^{SEJ,fit} - p_j^{SEJ,meas})^2}{\sigma_{SEJ}^2} + \sum_{k=jjb,bl\nu} \frac{(m_k - m_t)^2}{\Gamma_t^2}$$

p_T of lepton and jets from $t\bar{t}$.

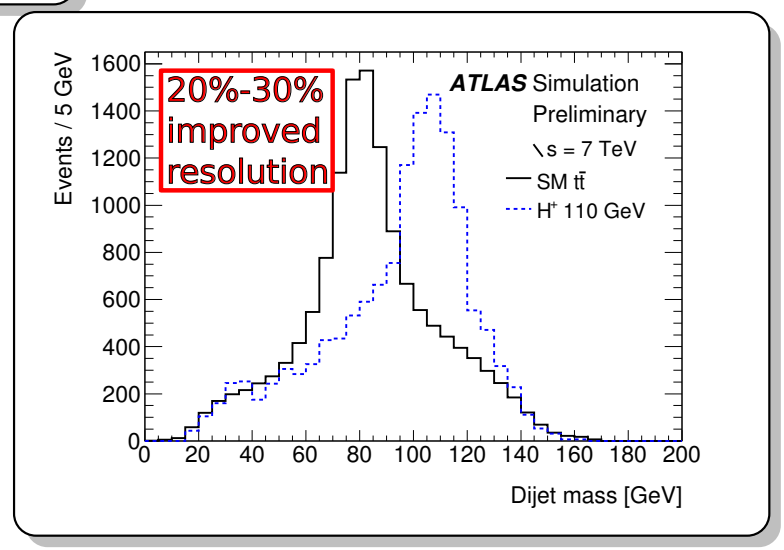
Vector sum of momenta of remaining jets, used to recalculate E_T^{miss}.

Reconstructed top quark masses.

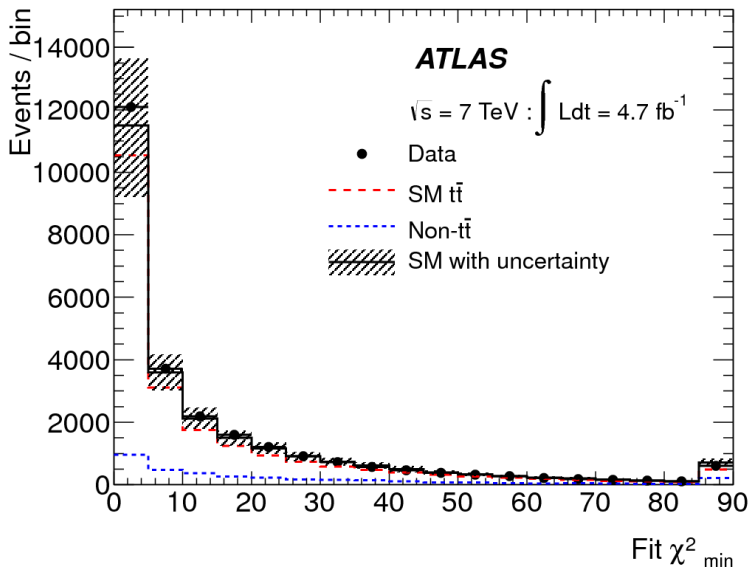


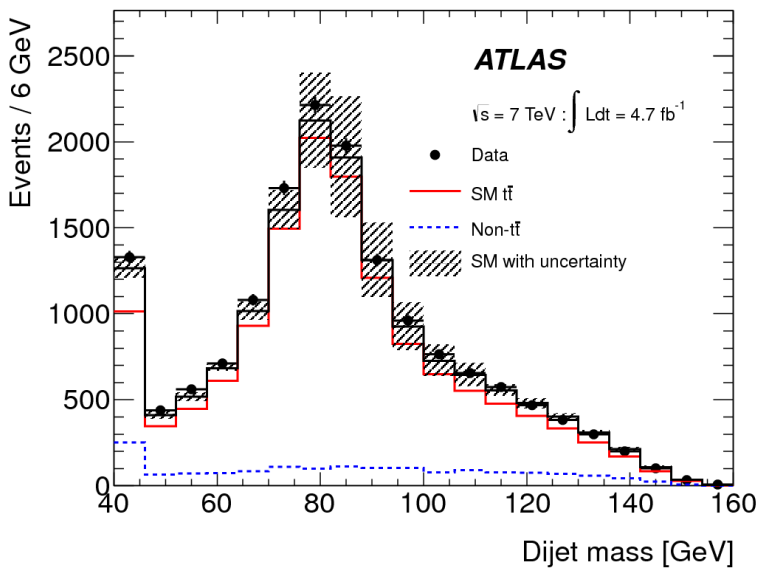
measured

post-fit

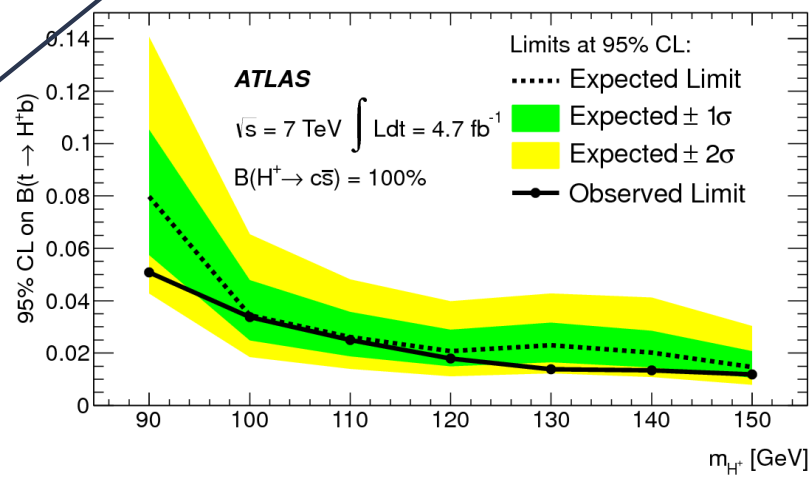


Results and limits



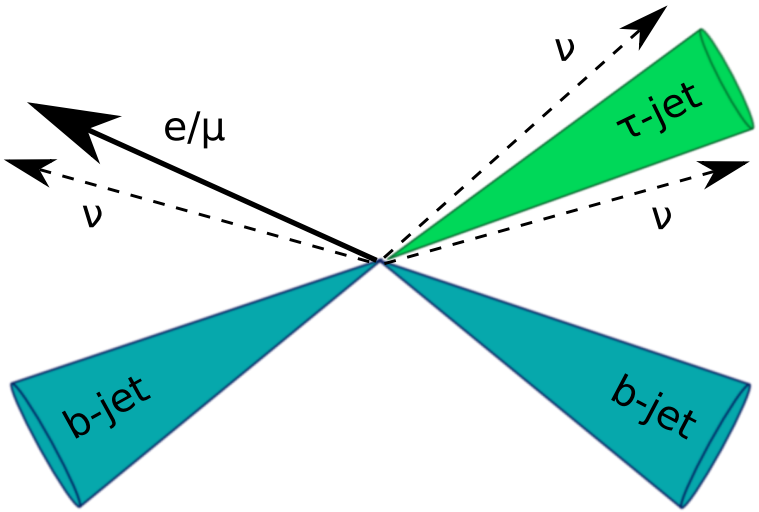


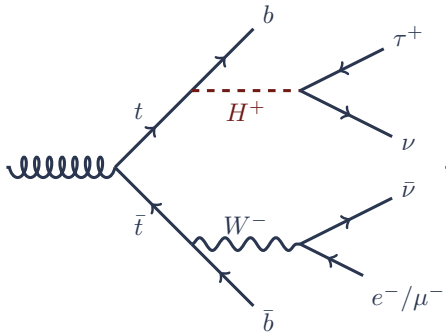
- Good mc/data agreement for χ^2_{min} distribution.
- Additional cut on $\chi^2_{min} < 10$ (63% efficiency for SM $t\bar{t}$).
- No peak except W observed in the di-jet distribution ➡ set limit.

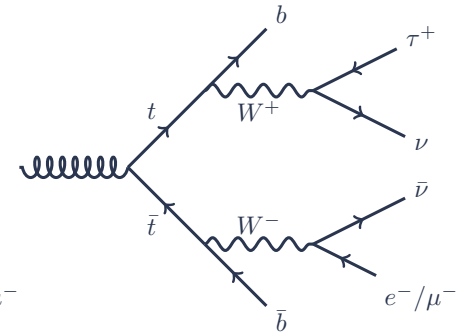


Largest uncertainties	$\Delta N(t\bar{t})$	Shape dep.
b-tagging eff.	11%	-
$t\bar{t}$ cross section	+10%, -11%	-
Jet energy scale	9.5%	✓

Test of lepton universality in $t\bar{t}$ events







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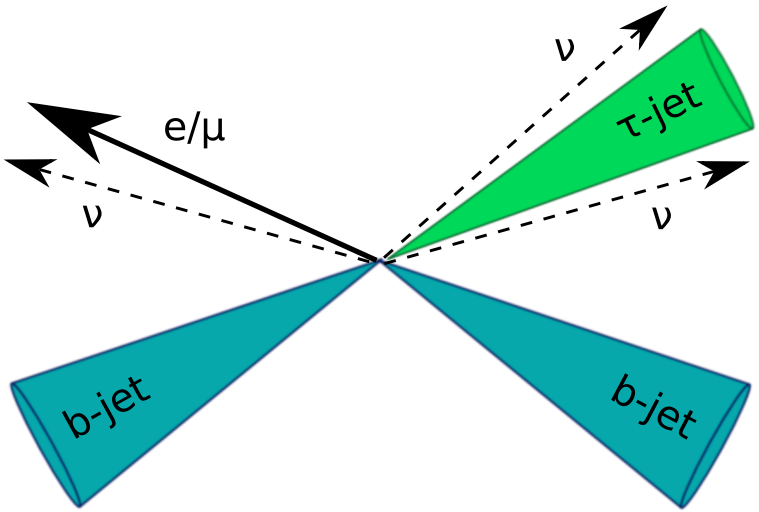
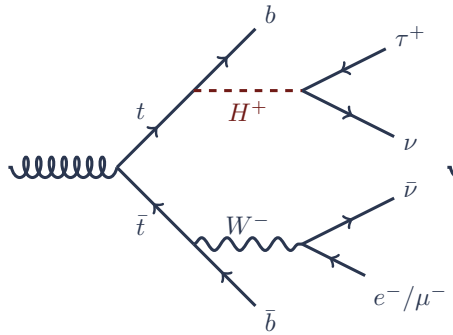
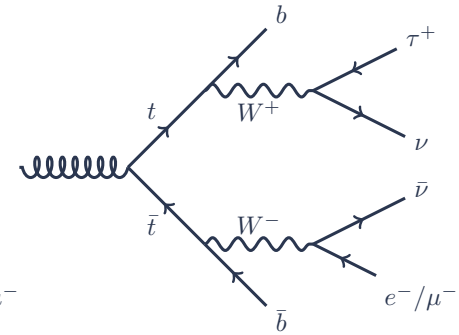
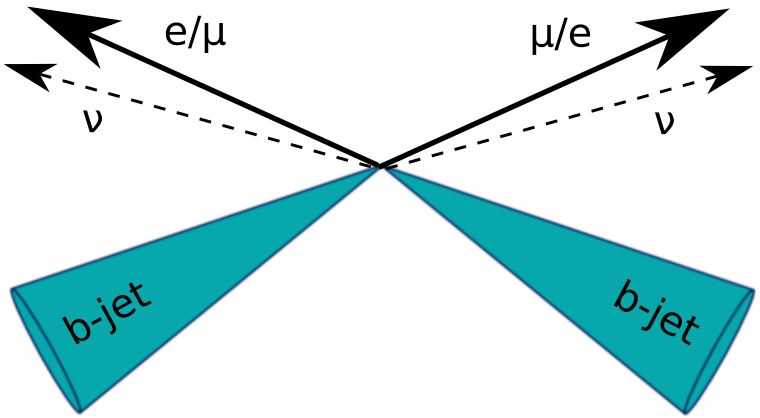
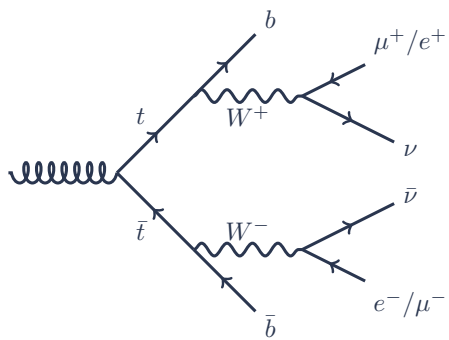


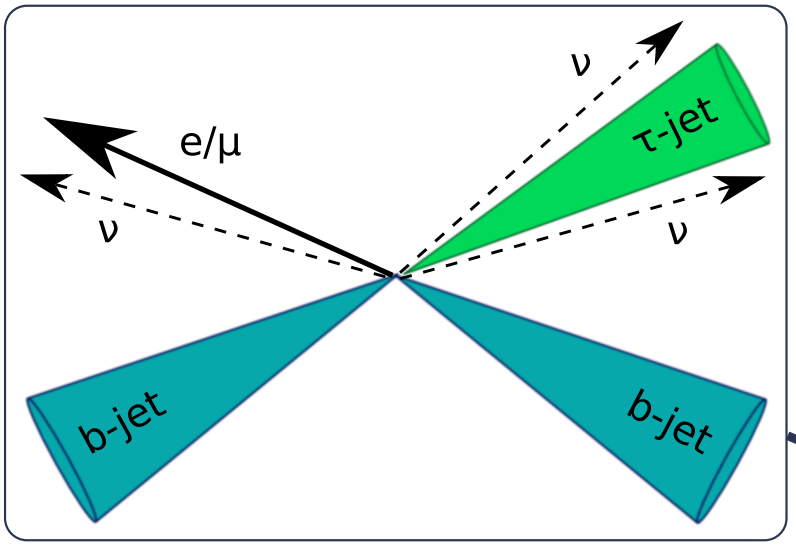


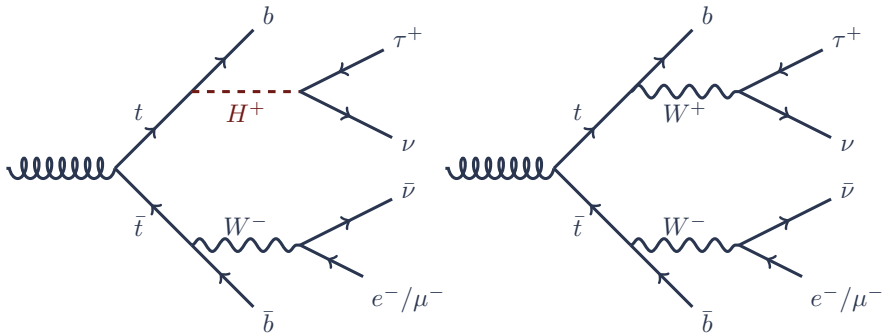






Test of lepton universality in $t\bar{t}$ events

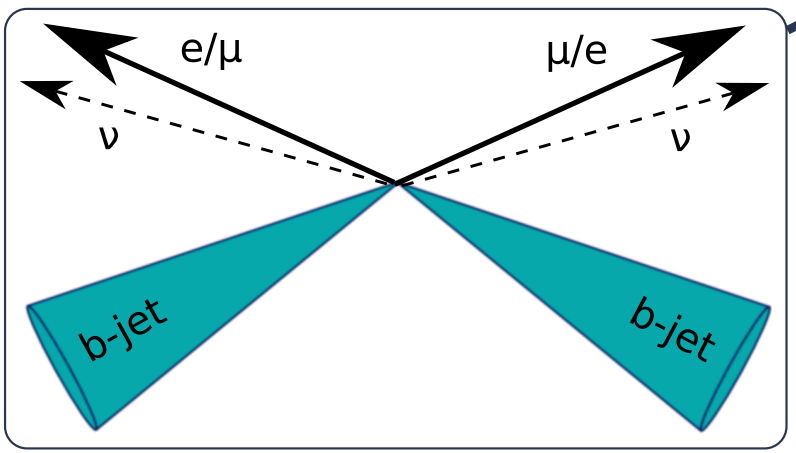


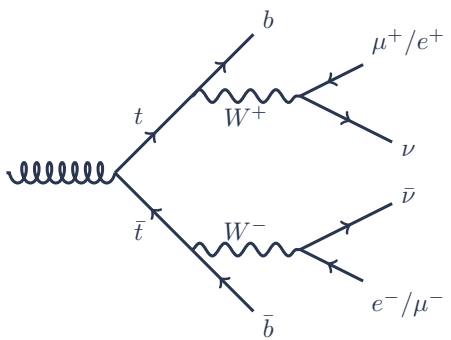


Select $t\bar{t}$ events and measure:

$$R_e = \frac{N(e+\tau+jets)}{N(e+\mu+jets)} \text{ and } R_\mu = \frac{N(\mu+\tau+jets)}{N(\mu+e+jets)}$$

R_e: using electron trigger, R_μ: using muon trigger





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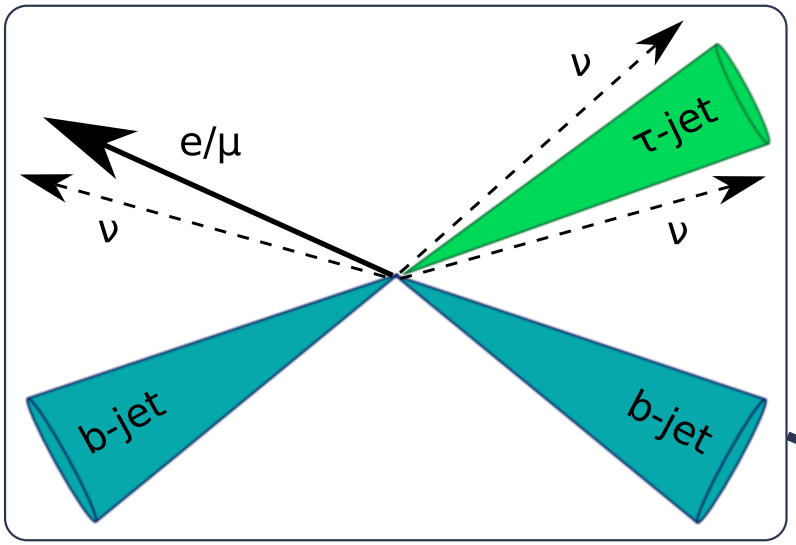

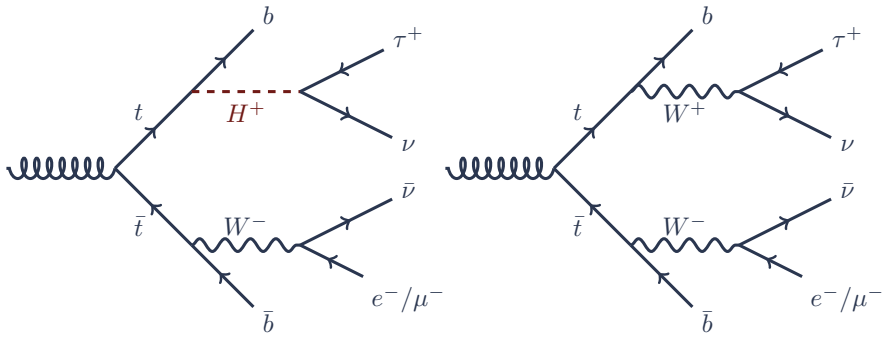

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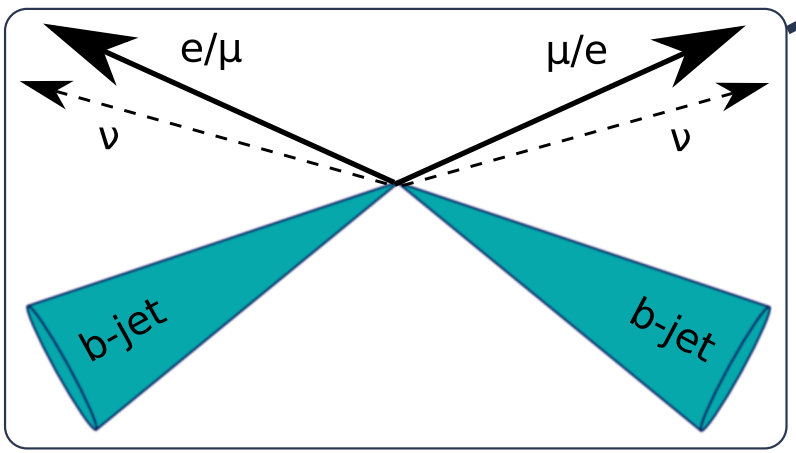
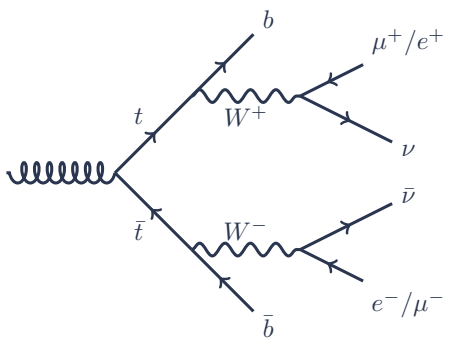
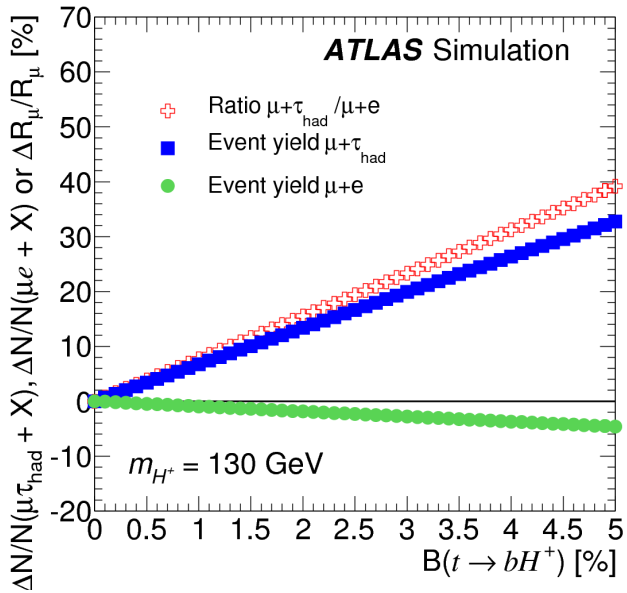




- R_e, R_μ mainly insensitive to b-tagging efficiency, jet energy...
- Good complement to direct searches.
- Works even if $m_H^+ \approx m_W$.



Analysis Outline

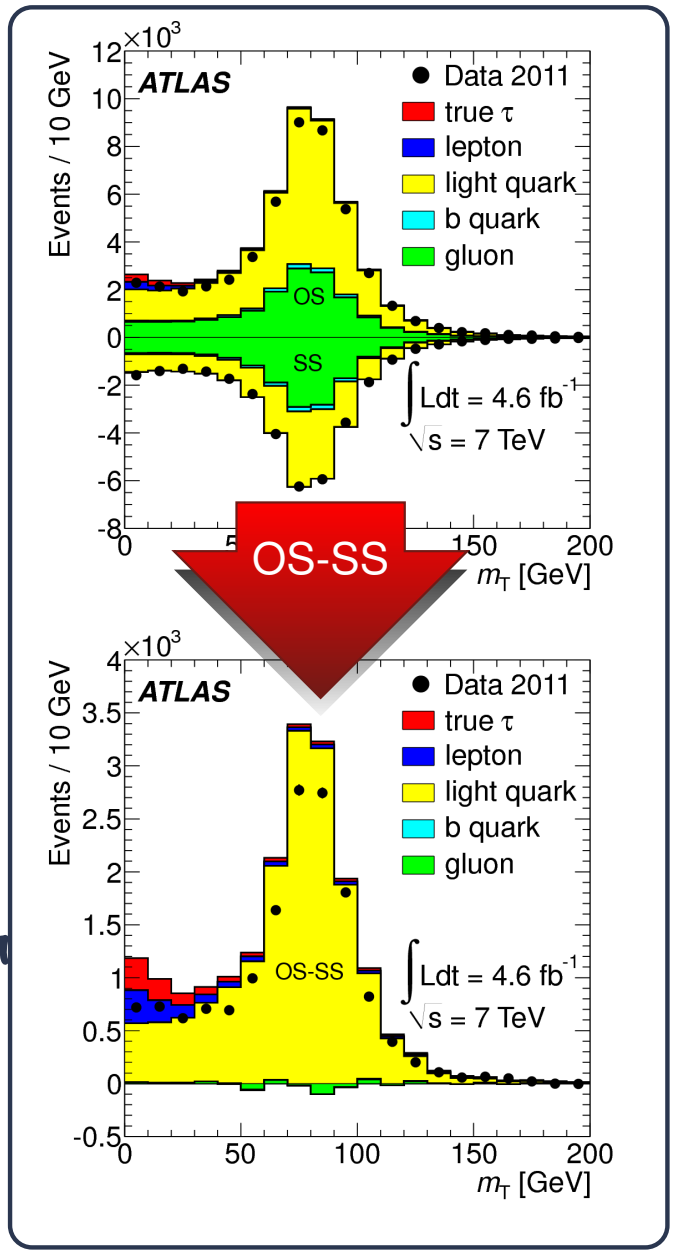
Event Selection

- Exactly one electron or muon having $p_T > 25$ GeV
- At least two jets having $p_T > 20$ GeV, exactly two b-tags.
- $E_T^{miss} > 40$ GeV.
- In addition one muon, electron or tau ($p_T > 25$ GeV)
- Separate events based on the tau charge: Same Sign (SS) or Opposite Sign (OS) as the lepton.

Subtracting Same Sign Events

- Tau misidentification rates differ between light quarks, heavy quarks, and gluons.
- Relative fractions of these contributions are not well known.
- Assume b quarks and gluons misidentified as taus contribute equally to SS and OS events.
- Assign negative weight to SS events - b quark and gluon contributions should cancel!

OS-SS procedure in a W+2 jets control region.
The poor data/mc agreement motivates using data driven methods.



Backgrounds

Misidentified taus

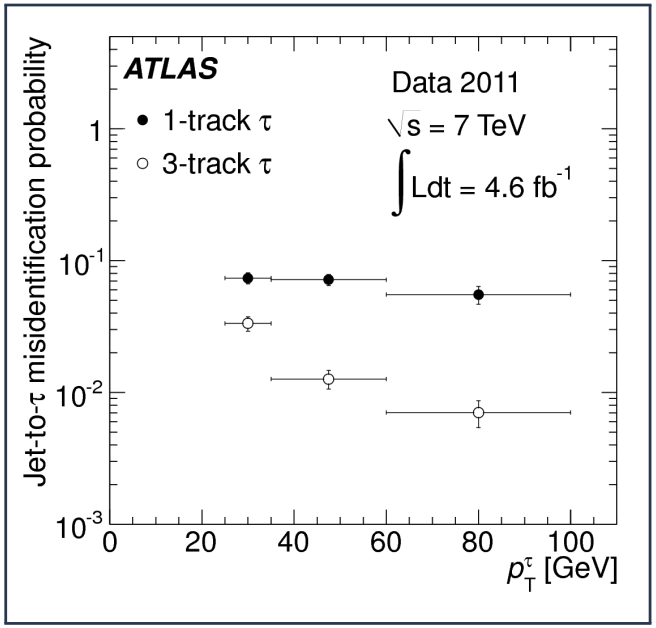
- 46% of taus in simulated SM $t\bar{t}$ events are actually quark- or gluon-initiated jets.
- Tau misidentification rates measured using W + 2 jets events in data:
  - Exactly one electron or muon
  - At least one tau candidate
  - At least two additional jets, no b-tags
  - $E_{\mathrm{T}}^{miss} > 40$ GeV
  - $m_{\mathrm{T}}^{lep,miss} > 30$ GeV
- Parametrized by tau p_{T}, number of tracks within $\Delta R < 0.2$ ($\mathrm{N}_{\tau}^{track}$) and within $\Delta R < 0.4$ (N_{iso}^{track}).
- Used to weight MC events with misidentified taus.

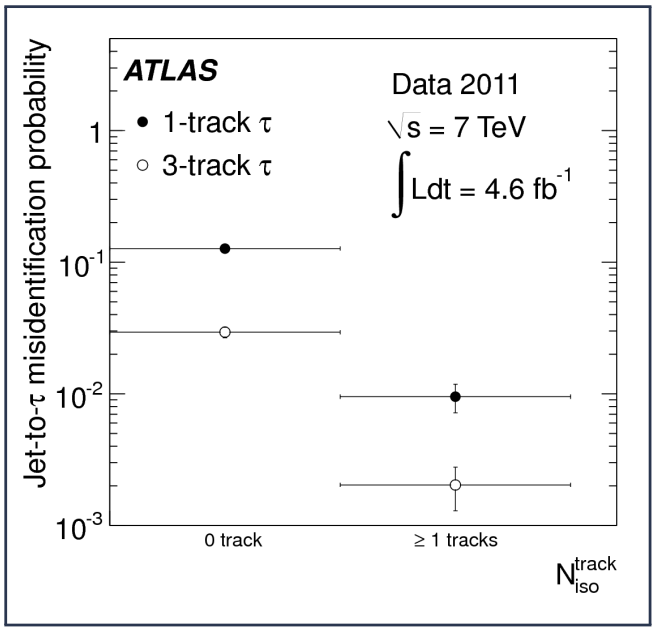
Misidentified leptons

- Small contribution from misidentified (non-isolated) leptons (e.g. QCD multijet events).
- Estimated using a matrix method also relying on (mis)identification efficiencies measured in control regions.

Backgrounds with real leptons and taus

- Taken from simulation.



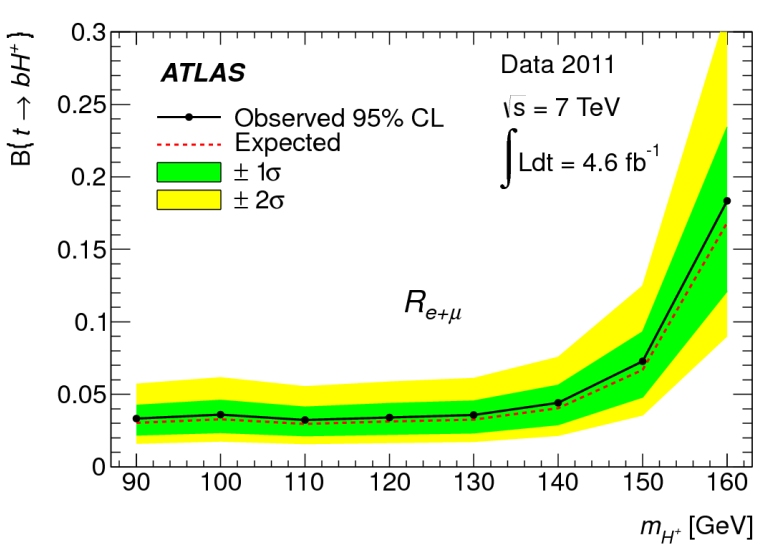


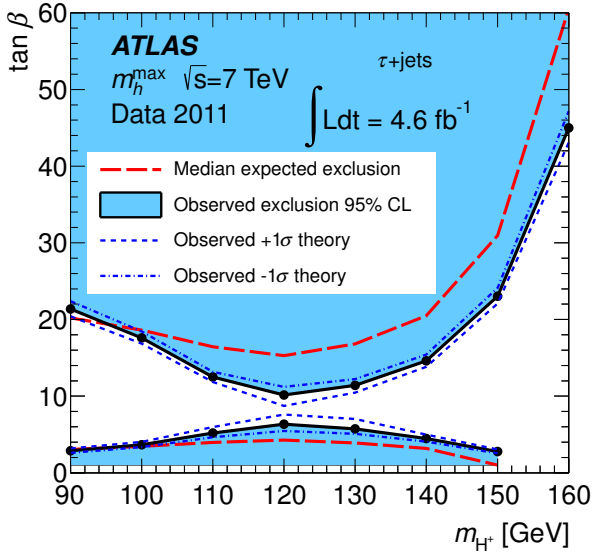
Exclusion limits

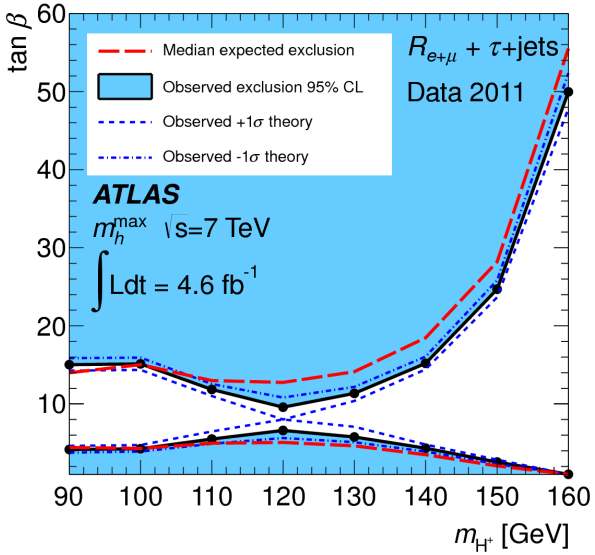
Ratio	R_e	R_μ
Background only	$0.105 \pm 0.004(stat) \pm 0.013(syst)$	$0.166 \pm 0.004(stat) \pm 0.026(syst)$
Measured value	$0.115 \pm 0.010(stat)$	$0.165 \pm 0.015(stat)$

- After accounting for dilepton events firing both triggers, a combination of both channels can be made.
- Limit on $B(t \to bH^+)$ placed at 2.9% (90 GeV) to 16.6% (160 GeV).
- Improvement over previous best result from direct search in tau+jes events [JHEP 1206 (2012) 039] at low mass (was $\approx$ 6% at 90 GeV).

Largest uncertainties	ΔR_e	ΔR_μ
mis-ID leptons	3.5%	4.3%
τ ID efficiency	3.9%	3.9%
τ mis-ID meas. (stat)	3.3%	3.2%
τ energy scale	2.9%	3.0%







Summary

- The 2012 discovery is perhaps just the beginning...
  - Many models predict additional Higgs bosons.
- ATLAS has searched for Charged Higgs bosons decaying to $c\bar{s}$ or $\tau\nu$ in the mass range 90 GeV< m_H^+ < 160 GeV.
  - $B(t \to bH^+) \times B(H^+ \to c\bar{s})$ < 1.2% - 5.1% (90-150 GeV).
  - $B(t \to bH^+) \times B(H^+ \to \tau\nu)$ < 0.9% - 3.4% (90-160 GeV).
- No LHC results with 8 TeV data
  - stay tuned for updates...