Searches for light $H^{\pm}$ decaying to a hadronic tau in the one lepton mode with ATLAS

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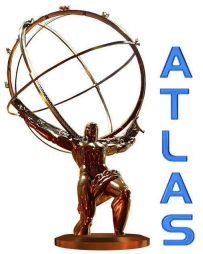

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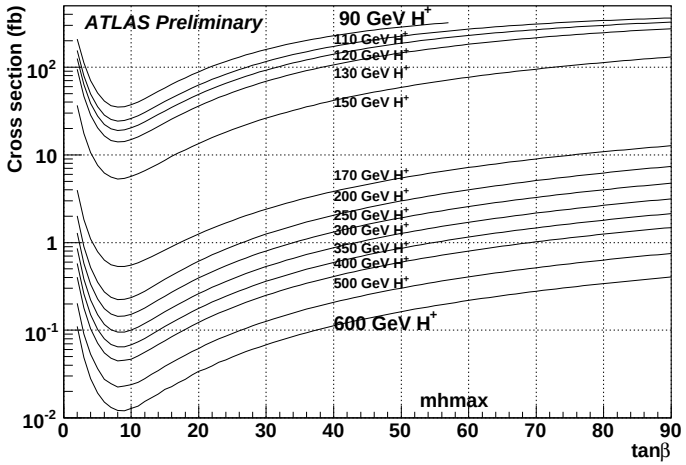
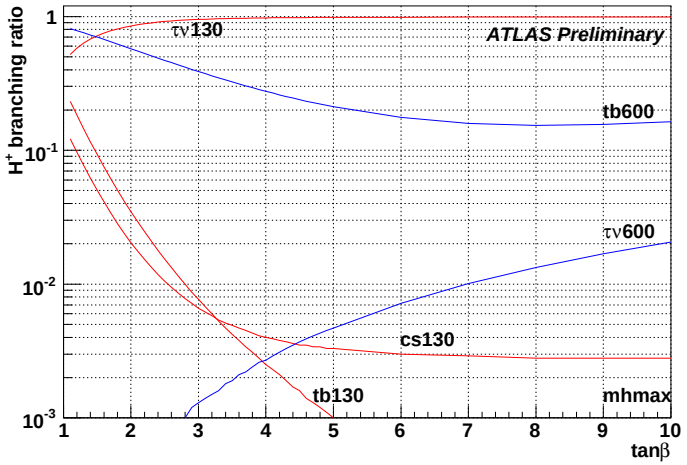
PHYSICS AT THE TERA SCALE
Helmholtz Alliance

FSP 101 ATLAS

Charged Higgs Production and Decay

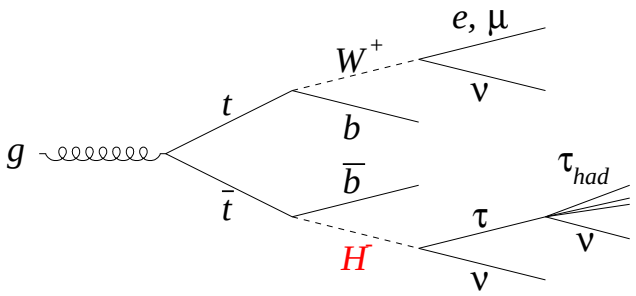
- charged Higgs bosons occure in:
  - models with > 1 Higgs doublet (e.g. 2HDM, MSSM)
  - some Litte Higgs Models
  - models with Higgs tripletts
- in MSSM/2HDM one pair: $H^{\pm}$
- for $m_{H^{\pm}} < m_{top}$:
  - $t\bar{t} \rightarrow (Wb)(H^{\pm}b)$ [main production mode]
  - $H^{\pm} \rightarrow \tau\nu$ [BR$\sim$100%]
- for $m_{H^{\pm}} > m_{top}$:
  - $gb \rightarrow H^{\pm}t$; $gg \rightarrow H^{\pm}tb$
  - $H^{\pm} \rightarrow tb$; $H^{\pm} \rightarrow \tau\nu$ [dependent on $m_{H^{\pm}}$ and $\tan\beta$]



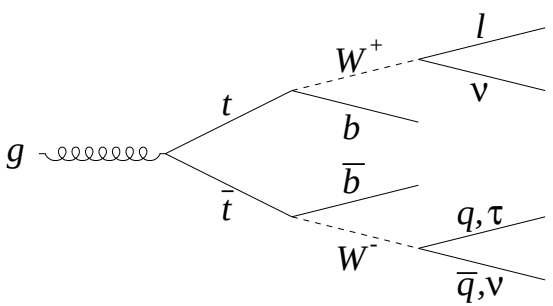


Signal and $t\bar{t}$ Background

Signal



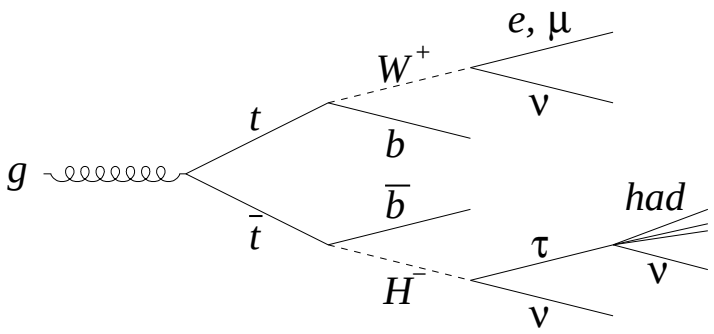
Main Background ($t\bar{t}$)



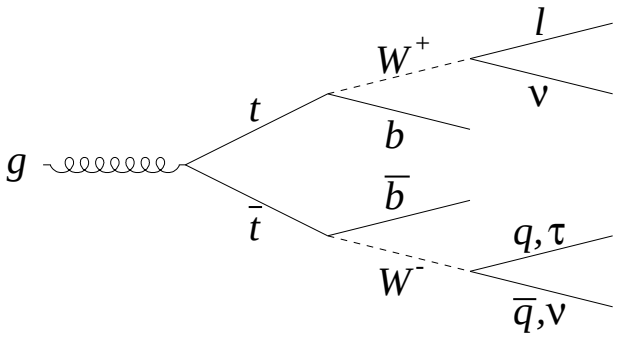
- in this talk:
  - $m_{H^\pm} < m_{top}$
  - $t\bar{t} \rightarrow (Wb)(H^\pm b)$
  - $H^\pm \rightarrow \tau\nu \rightarrow \tau$-jet $\nu\nu$
  - $W \rightarrow l\nu$
- no full event reconstruction possible (3ν; on both sides)
- signal observable as an excess of events over SM $t\bar{t}$
- same signature, but not covered in the signal MC sample:
  - $W \rightarrow \tau\nu$ in $t\bar{t} \rightarrow (Wb)(H^\pm b)$
  - $H^\pm$ in single top events

Backgrounds

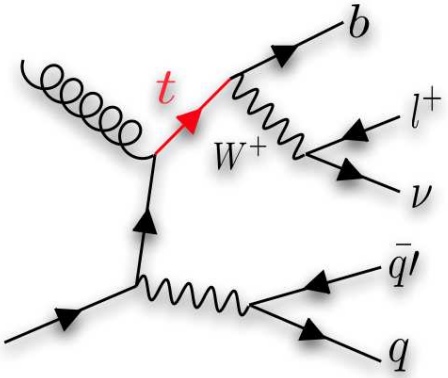
Signal, 62 pb^{-1}



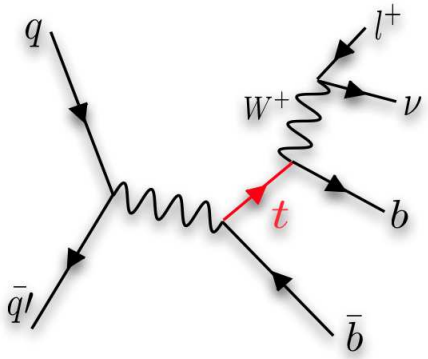
$t\bar{t}$ Background, 833 pb^{-1}



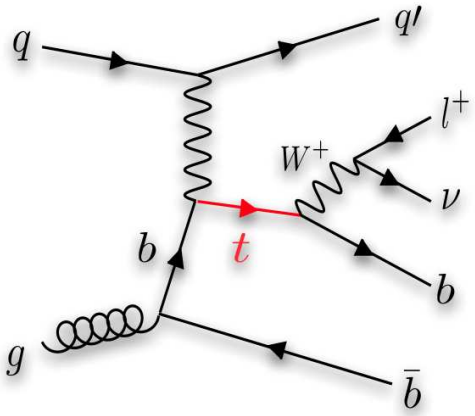
Wt, 66 pb^{-1}



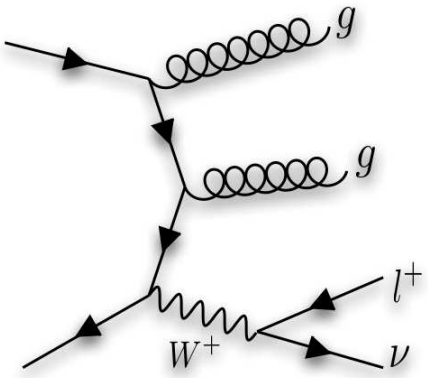
s-chan, 11 pb^{-1}



t-chan, 247 pb^{-1}



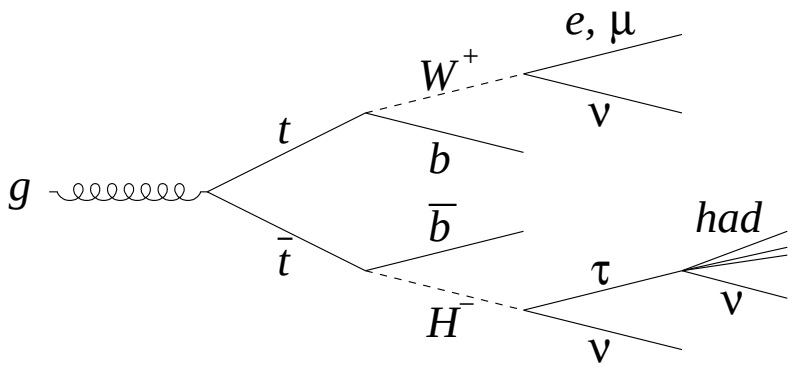
W+jets, 912 pb^{-1}



- all cross-sections are inclusive
- except W+Jets: 3 Jet filter, W$\rightarrow$e/$\mu/\tau + \nu$

Statistic and Trigger

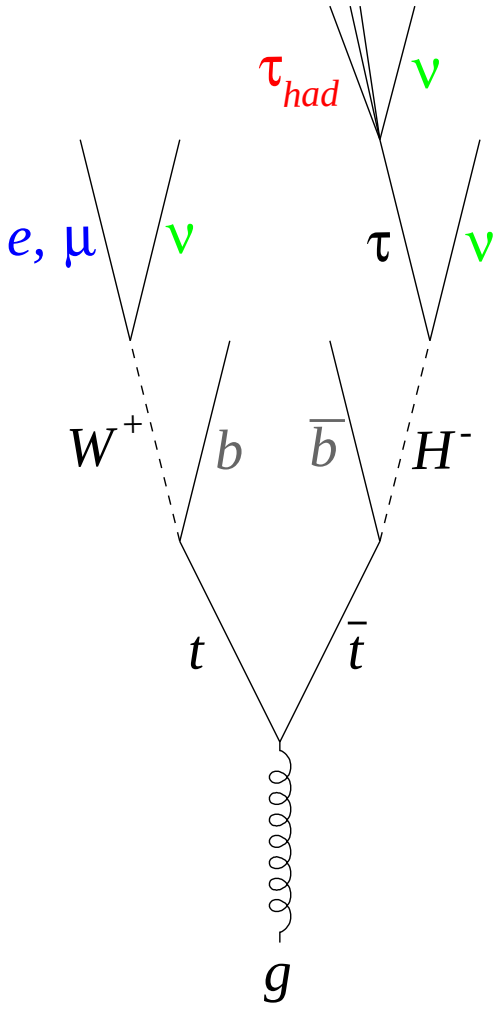
- Data Samples
  - Monte Carlo with fully simulated detector response
  - signal: Pythia $\mathcal{L} = 0.8$ - 4.3 fb^{-1}
    $t\bar{t}$: MC@NLO $\mathcal{L} = 0.9$ fb^{-1}
    single top: AcerMC $\mathcal{L} = 0.2$ - 2.8 fb^{-1}
    W+Jets: Alpgen/Jimmy $\mathcal{L} = 0.15$ - 0.5 fb^{-1}



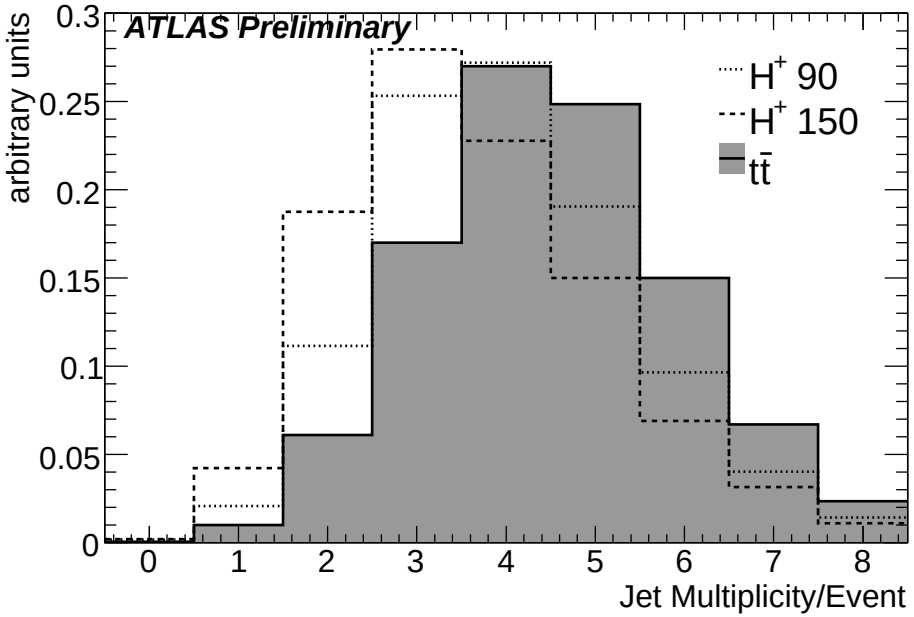
- Trigger
  - isolated electron,$p_T > 25$ GeV + $E_T^{miss} > 30$ GeV
  - isolated muon,$p_T > 20$ GeV + $E_T^{miss} > 30$ GeV
  - isolated τ-jet,$p_T > 35$ GeV + $E_T^{miss} > 40$ GeV + 3 jets (20 GeV)
  - isolated τ-jet,$p_T > 35$ GeV + $E_T^{miss} > 50$ GeV

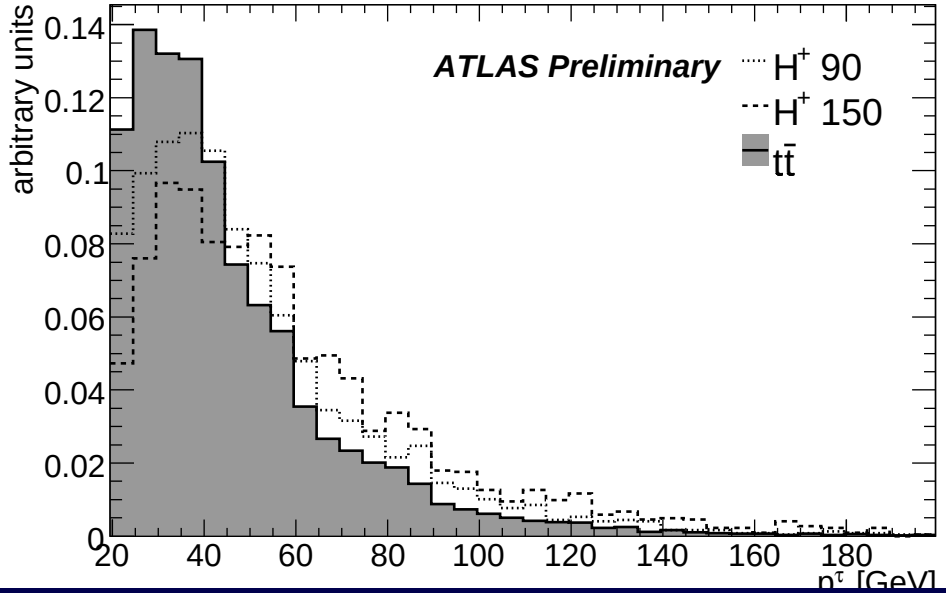
Event Selection

- $N_{e,\mu} \geq 1$
  - p_T>25 (e), 20 (μ) GeV
  - $|\eta|$ <2.5
  - isolation required
- $N_{jets}(=N_{light\ jets}+N_{b\text{-}\ jets}+N_{\tau\text{-}jets}) \geq 3$
  - p_T>20 GeV
  - $|\eta|$ <5
- $N_{\tau\text{-}jet} \geq 1$
  - $p_T^{\tau} > 40$ GeV
  - $|\eta|$ <2.5
  - refinement of τ selection: $\frac{E_T^{had}}{p_{T,\text{lead. track}}^{\tau}}$ >0.1
- $N_{b\text{-}jet} \geq 1$
  - $|\eta|$ <2.5
- charge(τ)=-charge(ℓ)
- $E_T^{miss} > 175$ GeV



Jets





- for high $H^{\pm}$ mass $m_{H^{\pm}} \sim 150$ GeV:
  - b-jet associated to $H^{\pm}$is very soft $p_T \sim 20$ GeV
  - often not even reconstructed
    $\Rightarrow$ require only one b-tag

- τ-jets more energetic due to $m_{H^{\pm}} > m_W$ and different polarizations

Cutflow (m_h-max Scenario, tanβ=20)

cross-sections [fb] and rel. cut efficiencies (ATLAS Preliminary)

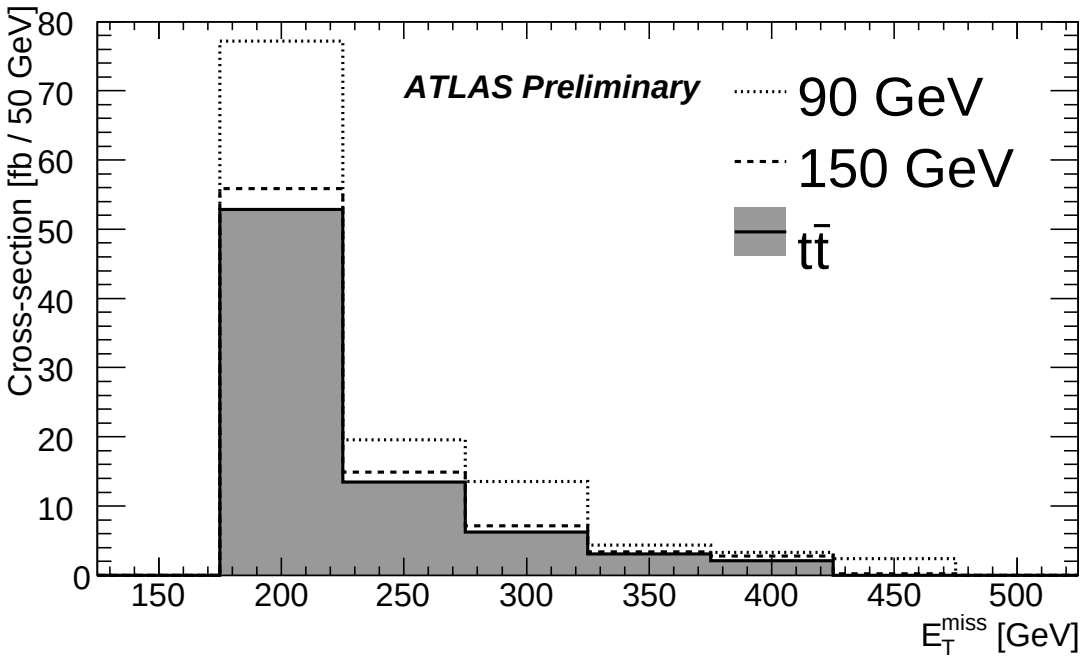
Channel		All ev.	Trigger	$\geq$1 e,μ	$\geq$3 jets	$\geq 1\tau$	$\geq$1 b	τ p_T	$\sum$ q	E_T^{miss}
$H^{\pm}$ (110 GeV)	[fb]	8570	4510	3534	2986	772	650	439	431	30
	[/]		*0.53*	*0.78*	*0.84*	*0.26*	*0.84*	*0.67*	*0.98*	*0.07*
$t\bar{t}$ (1 lep)	[fb]	452000	169612	137928	122547	4760	4006	1915	1730	78
	[/]		*0.37*	*0.81*	*0.89*	*0.04*	*0.84*	*0.48*	*0.90*	*0.04*
single top	[fb]	112500	30180	25065	18081	271	168	47	38	-
	[/]		*0.27*	*0.83*	*0.72*	*0.02*	*0.61*	*0.28*	*0.81*	-
W$\rightarrow$lν+jets	[fb]	769547	216556	166598	101473	1549	180	92	58	-
	[/]		*0.28*	*0.77*	*0.61*	*0.02*	*0.12*	*0.51*	*0.63*	-

- most significant $t\bar{t}$ reduction by τ tagging
- 45% of remaining $t\bar{t}$ contain τ faked by e and light jets
- p_T^{τ} and E_T^{miss} cut values optimized taking into account a systematic uncertainty on the background of 10%
- after all cuts (at $\mathcal{L}$=1 fb^{-1}):
  - 30 $H^{\pm}$ events
  - 78 (72) $t\bar{t}$ events in the case of SM (MSSM)

Missing Transverse Energy after All Cuts

- excess of events visible, especially for small masses (m_h-max Scenario)

$\tan\beta$=20



Systematic Uncertainties

Theoretical uncertainties:

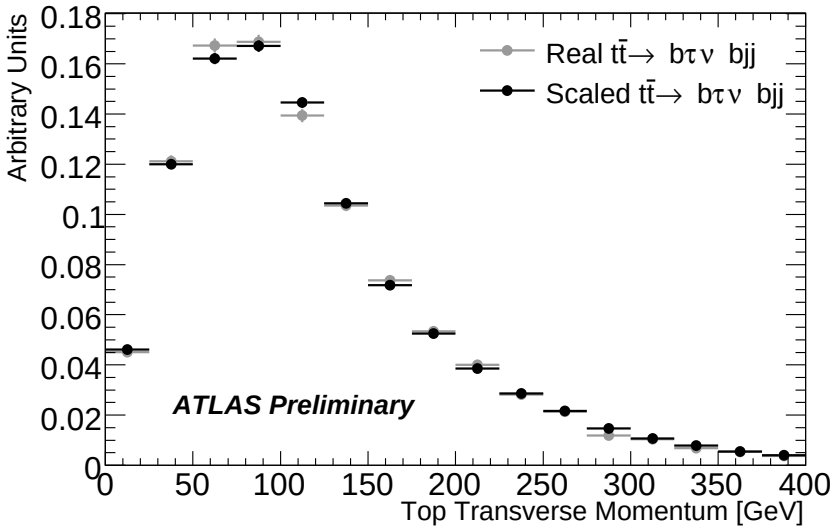
- cross-section $t\bar{t}$ background: 12%
- branching ratio $t \rightarrow H^{\pm}b$: $< 10\%$
- branching ratio $H^{\pm} \rightarrow \tau\nu$: $< 5\%$

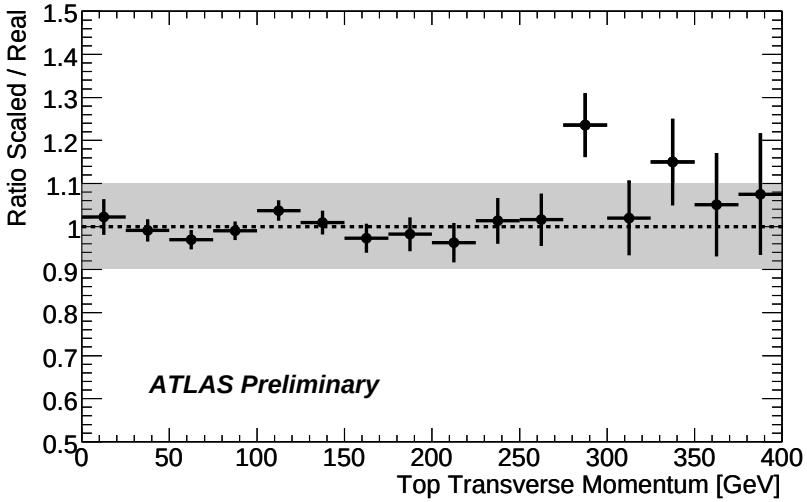
Dominating experimental uncertainties:

- jet energy scale (E_T^{miss}): $\sim 30 - 40\%$
- τ-jet energy scale: $\sim 10\%$
- τ-jet energy resolution: $\sim 10\%$

Background Estimation from Data

- use $t\bar{t} \rightarrow (bW)(bW) \rightarrow (b\mu\nu)(b\mu\nu)$
  - two isolated μ, $p_T > 20$ GeV
  - exclusion of Z region
  - $E_T^{miss} > 40$ GeV
    $\Rightarrow \epsilon_{sel} = 28\%$, purity$=71\%$
- replace μ by τ and scale 3-Vector to τ mass
- decay with TAUOLA
- full detector simulation and reconstruction



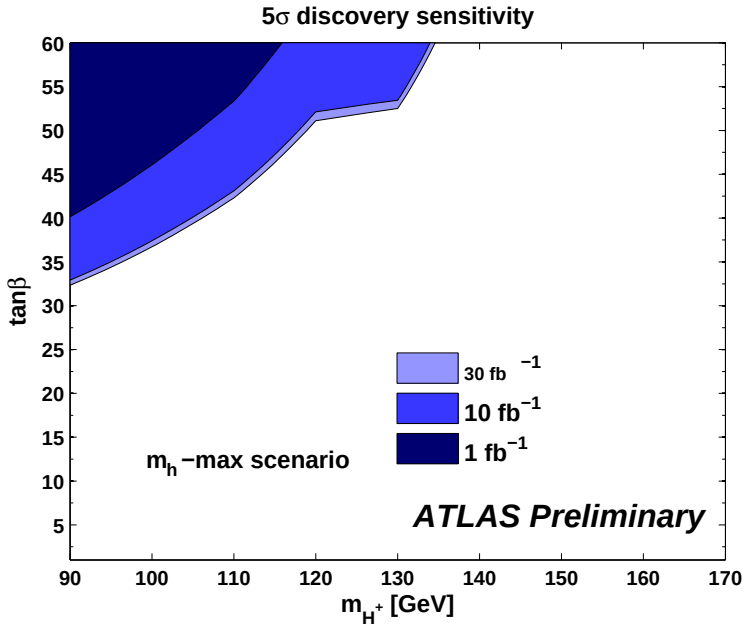


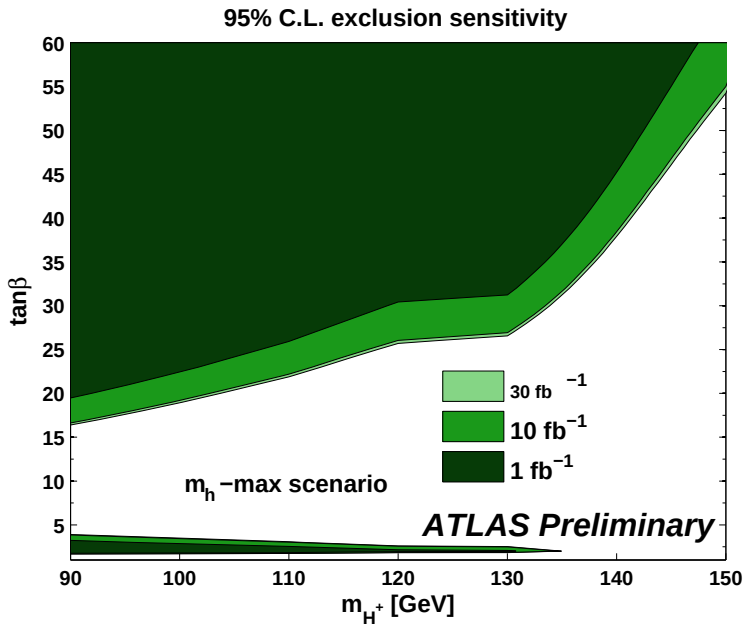
$\Rightarrow$ estimated uncertainty of $t\bar{t}$: $\mathcal{O}(10\%)$

Discovery and Exclusion Limits (m_h-max)

- results calculated using a profile likelihood method
- assumed systematic background uncertainty: 10%
  signal systematic uncertainty: 40%
- statistical uncertainties of MC taken into account

  $\Rightarrow$ limits for 30 fb^{-1} conservative

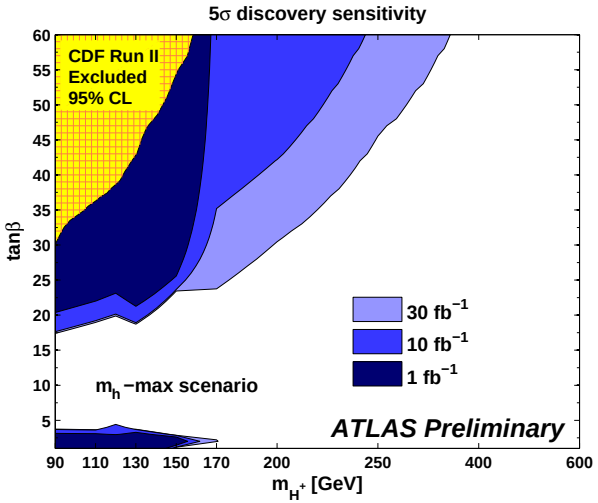


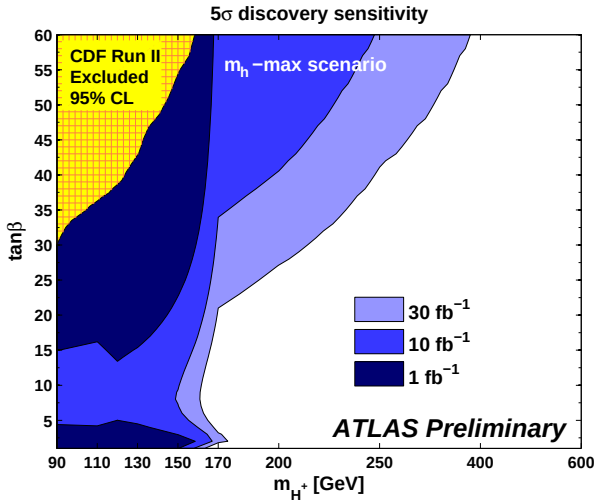


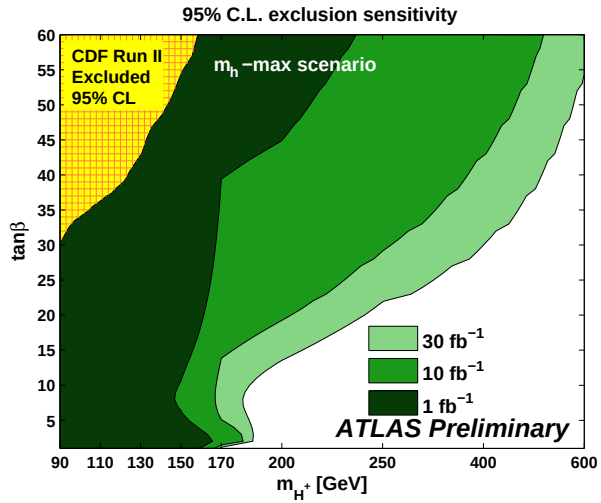
Combination with other $H^{\pm}$ Signatures (m_h-max)

Signatures investigated by ATLAS:

- light $H^{\pm}$($m_{H^{\pm}} < m_{top}$):
  - $t\bar{t} \rightarrow (H^{\pm}b)(Wb) \rightarrow (\tau_{had}\bar{\nu}_{\tau}\nu_{\tau}\ b)(\ell\nu_{\ell}\ b)$
  - $t\bar{t} \rightarrow (H^{\pm}b)(Wb) \rightarrow (\tau_{had}\bar{\nu}_{\tau}\nu_{\tau}\ b)(qq\ b)$
  - $t\bar{t} \rightarrow (H^{\pm}b)(Wb) \rightarrow (\ell\nu_{\ell}\bar{\nu}_{\tau}\nu_{\tau}\ b)(qq\ b)$
- heavy $H^{\pm}$($m_{H^{\pm}} > m_{top}$):
  - $H^{\pm} \rightarrow tb : gg/gb \rightarrow t[b]H^{\pm} \rightarrow W_{qq}b[b](\ell\nu_{\ell}bb)$
  - $H^{\pm} \rightarrow \tau\nu : gg/gb \rightarrow t[b]H^{\pm} \rightarrow W_{qq}b[b](\tau_{had}\bar{\nu}_{\tau}\nu_{\tau})$







infinite MC statistics

Conclusions

- The main keys towards a $H^{\pm}$ discovery are:
  - good understanding of the $t\bar{t}$ background down to $\sim 10\%$
  - powerful τ-identification
  - small uncertainty on E_T^{miss}
- Discovery of light $H^{\pm}$ bosons challenging for $\mathcal{L}$=10 fb^{-1}.
- Exclusion possible over a wide tanβ range,
  but intermediate region remains uncovered.