

Search for MSSM Higgs bosons in ATLAS

Martin Flechl (Freiburg)
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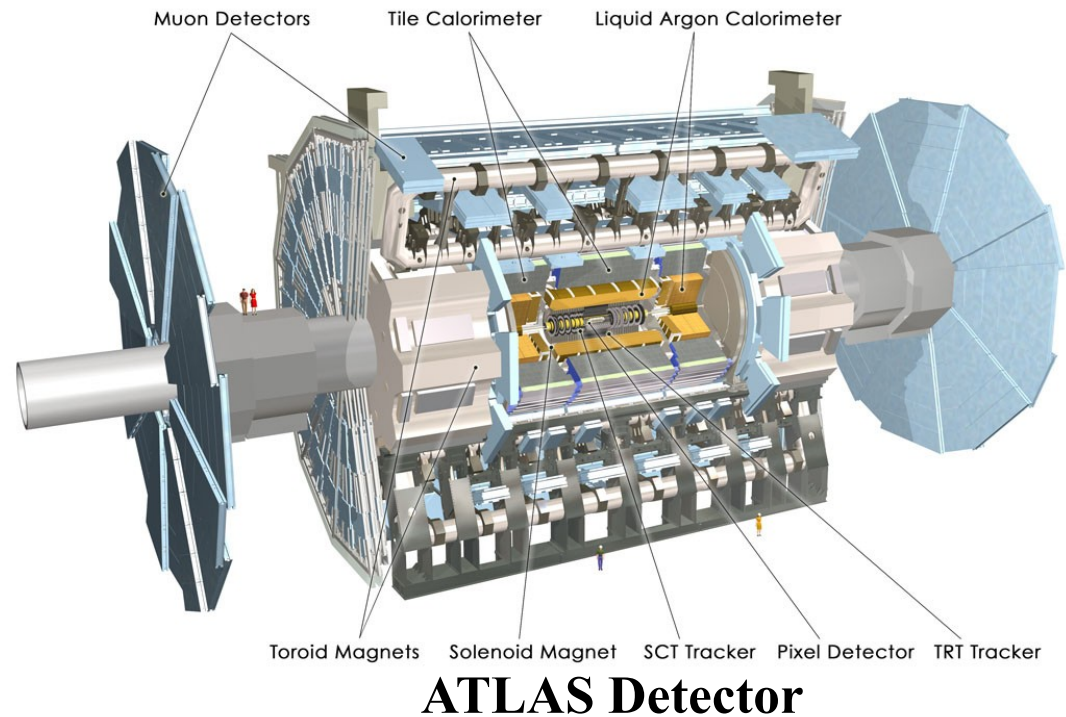
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Outline

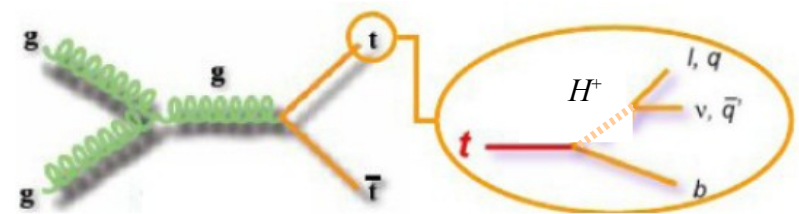
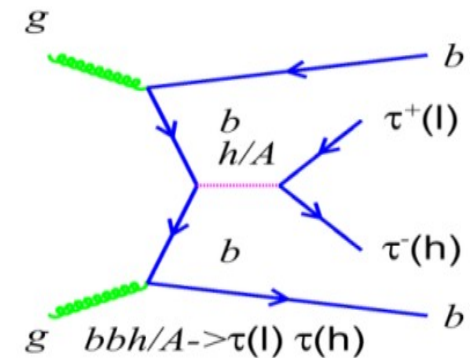
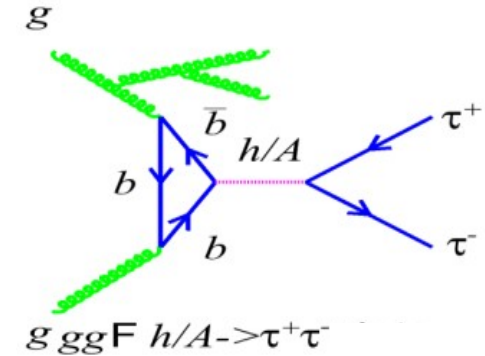
- $H^+ \rightarrow c\bar{s}$
- $H^+ \rightarrow \tau\nu$
 - Leptonic τ decays
 - Hadronic τ decays
- MSSM $H \rightarrow \tau\tau$ searches
 - Lepton-hadron mode
 - Lepton-lepton mode



- MSSM Higgs sector
 - 5 bosons $h/H/A, H^+, H^-$
 - Higgs sector: determined by two parameters at tree level: $\tan \beta$ and m_A (or m_{H^\pm})

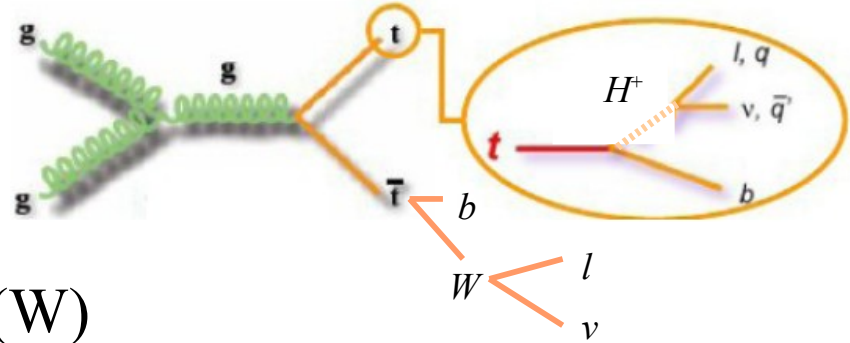
- Major production modes:
 - $h/H/A$: gg -fusion, b -associated
 - Light H^\pm : top quark decays
 - *[Heavy H^\pm : gg/gb -fusion]*

- Dominant decay modes
 - $h/H/A \rightarrow \tau\tau$
 - $H^+ \rightarrow \tau\nu$, for small $\tan \beta$: $H^+ \rightarrow c\bar{s}$

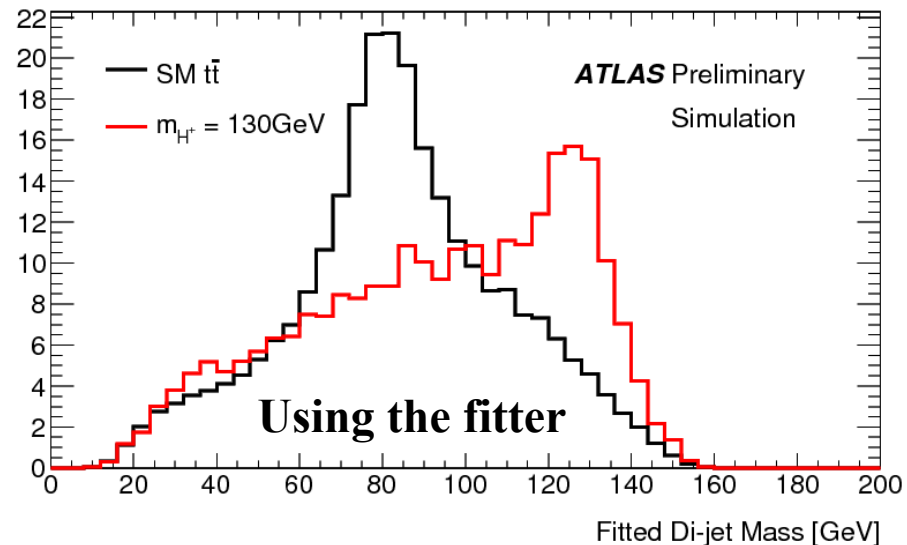
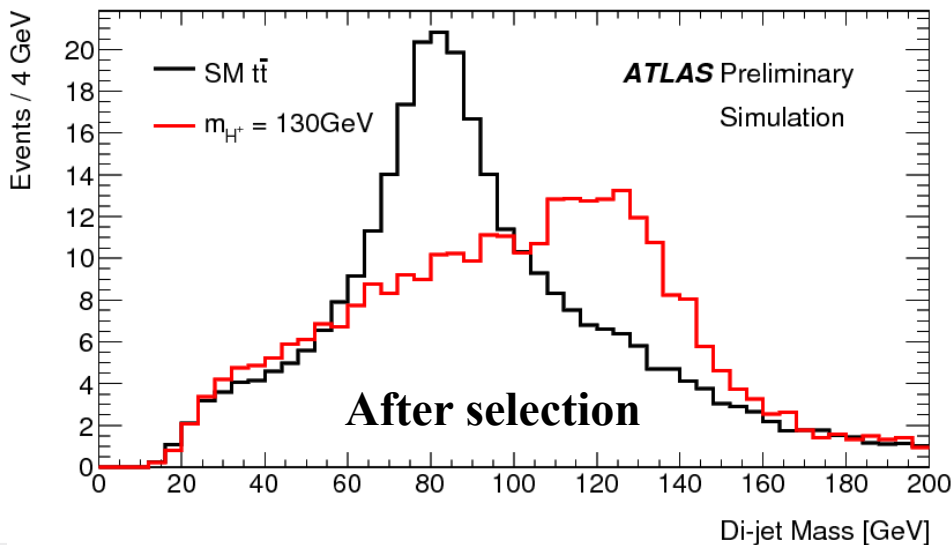


$$H^+ \rightarrow c\bar{s}$$

- Full reconstruction of the H^+ candidate possible
- Selection: isolated lepton, $E_T(\text{miss})$, ≥ 4 jets, ≥ 1 b -tag, $m_T(W)$
Use a χ^2 fitter for the whole event

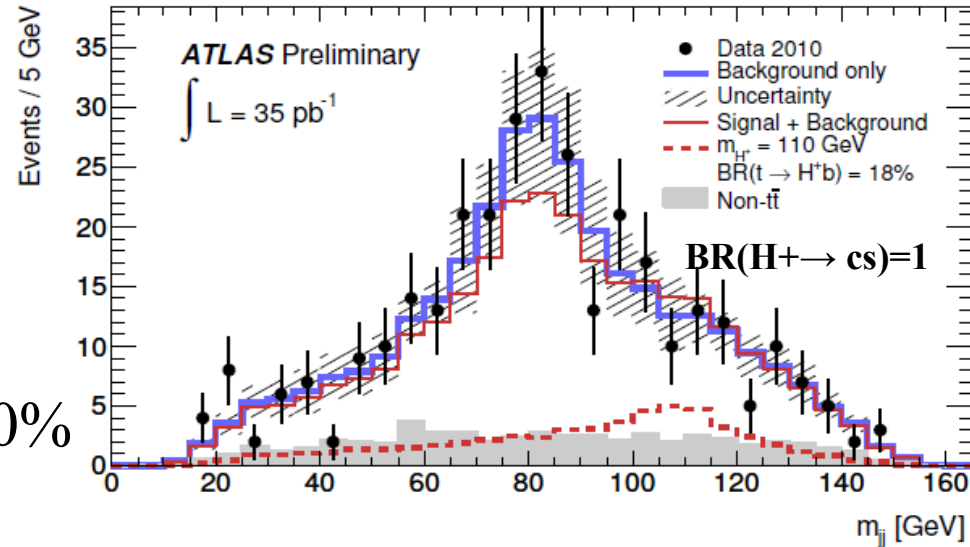


■ *Below: Mass peak of the dijet system: MC expectation*



Dijet mass spectrum

- Strategy: Look for a 2nd peak in the dijet mass spectrum in $t\bar{t}$ (lepton+jets) events
- Signal would lead to depletion
- $t\bar{t}$ background after selection >80%
- QCD estimated from data



- Event yield agrees with SM expectation
- Dominant systematic uncertainties:
 - Jet energy scale ($\approx 10\%$)
 - b-tagging efficiency (5-10%)
 - $t\bar{t}$ cross section ($\approx 9\%$)

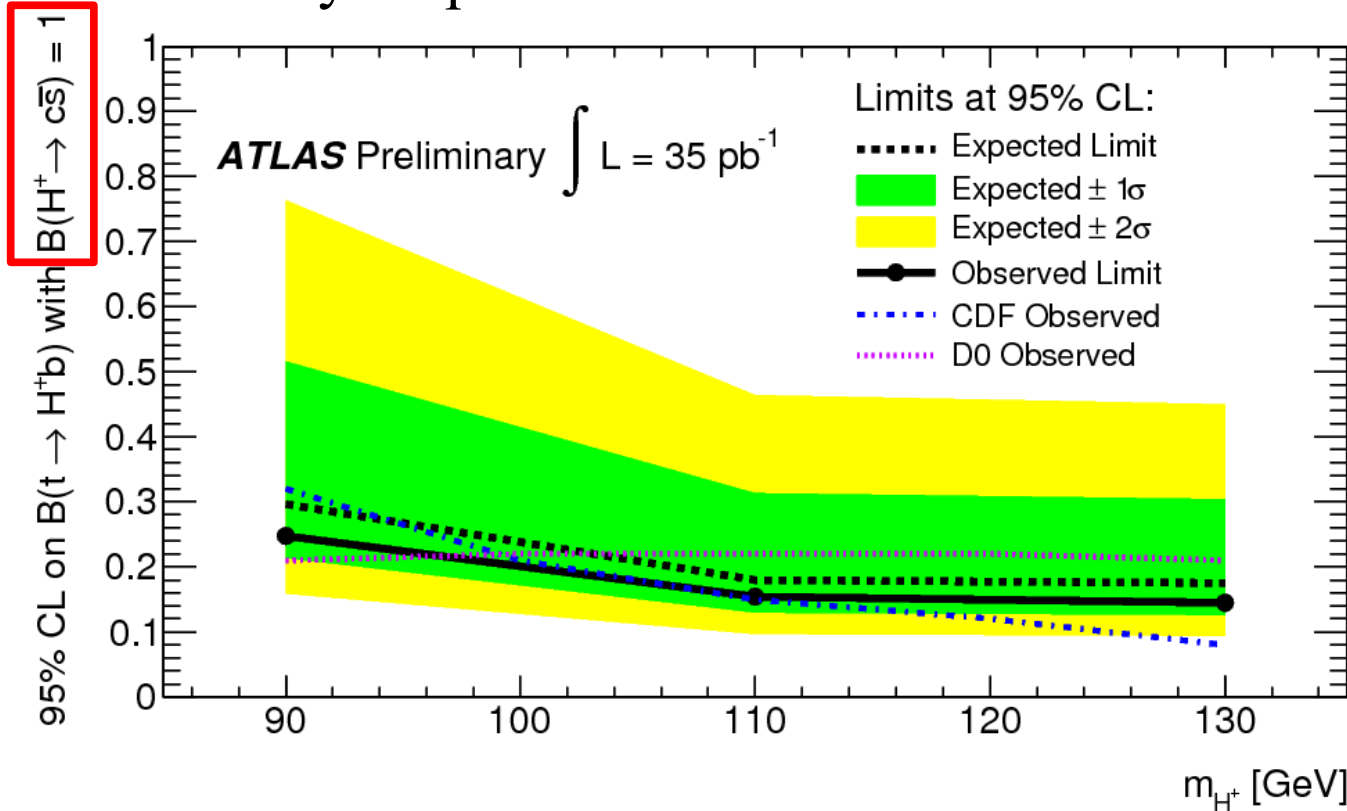
Channel	Muon	Electron
Data	193	130
SM $t\bar{t} \rightarrow W^+bW^-\bar{b}$	156^{+24}_{-29}	106^{+16}_{-20}
W/Z + jets	17 ± 6	9 ± 3
Single top	7 ± 1	5 ± 1
Diboson	0.30 ± 0.02	0.20 ± 0.02
QCD multijet	11 ± 4	6 ± 3
Total Expected (SM)	191^{+26}_{-30}	127^{+17}_{-21}
$\mathcal{B}(t \rightarrow H^+b) = 10\% :$		
$t\bar{t} \rightarrow H^+bW^-\bar{b}$	20^{+3}_{-4}	14^{+2}_{-2}
$t\bar{t} \rightarrow W^+bW^-\bar{b}$	127^{+19}_{-23}	86^{+13}_{-16}
Total Expected ($\mathcal{B} = 10\%$)	181^{+21}_{-25}	120^{+14}_{-17}

$H^+ \rightarrow c\bar{s}$: Limit

- Limit on $BR(t \rightarrow bH^+)$ [CL_s]
- Competitive with Tevatron results with only 35 pb^{-1}

Limit on $B(t \rightarrow bH^+)$ assuming $B(H^+ \rightarrow c\bar{s})=1$

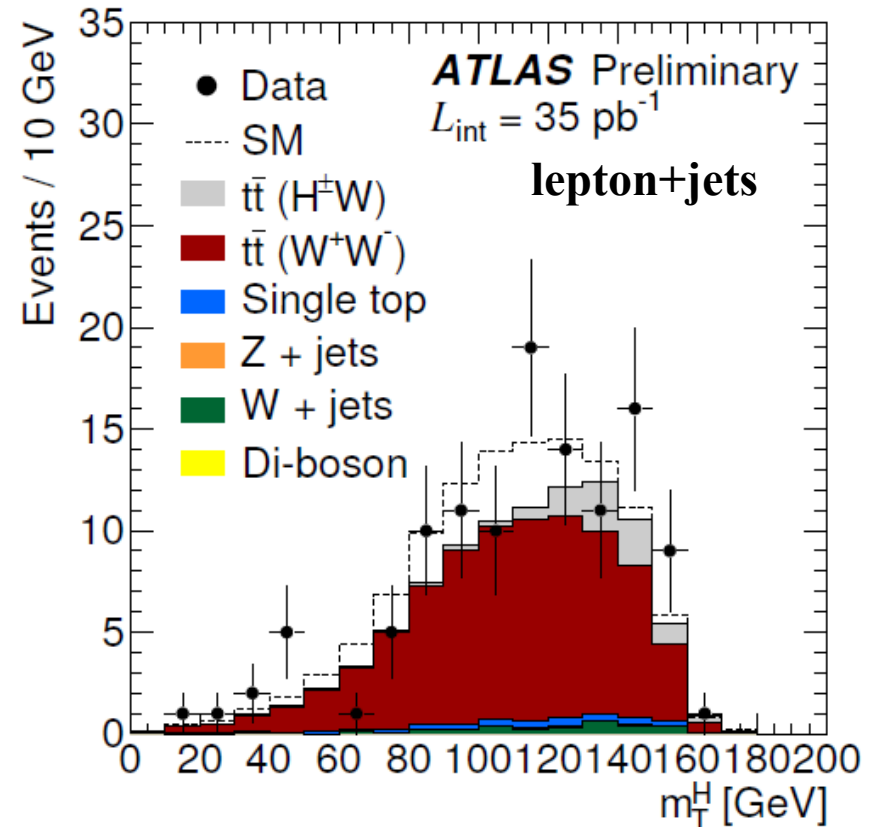
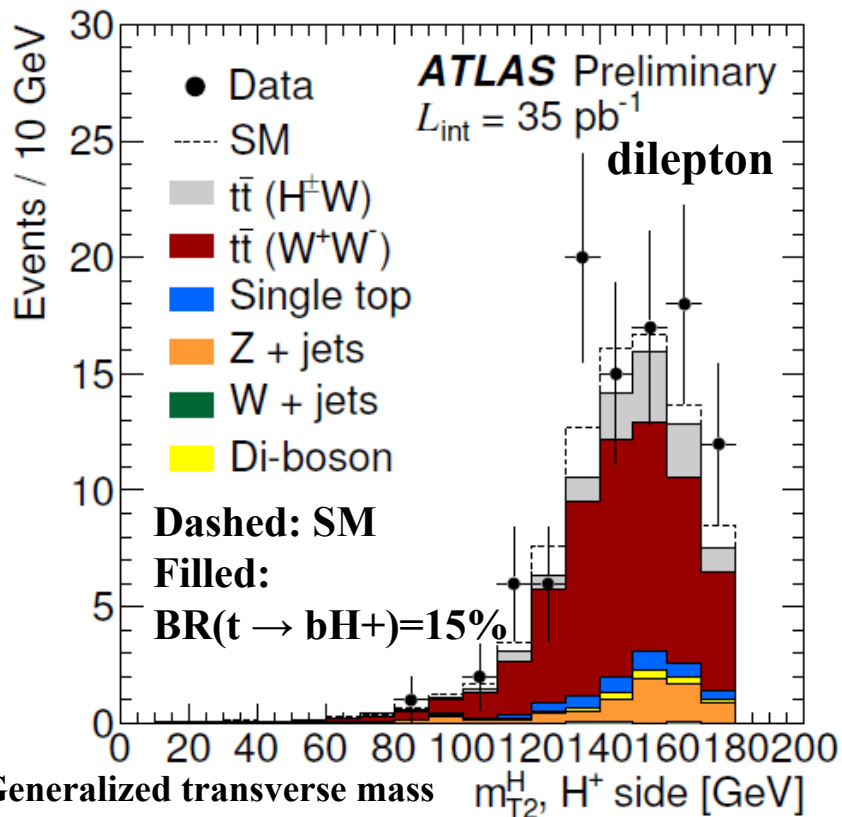
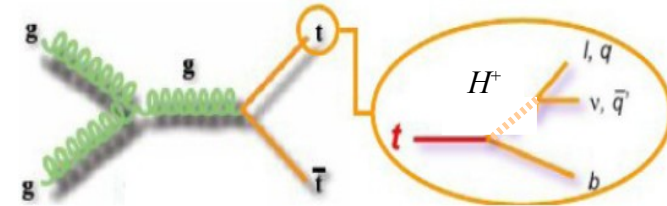
Higgs Mass	Expected limit	Observed limit
90 GeV	0.30	0.25
110 GeV	0.18	0.15
130 GeV	0.17	0.14



See poster by
**Alex
Martyniuk**

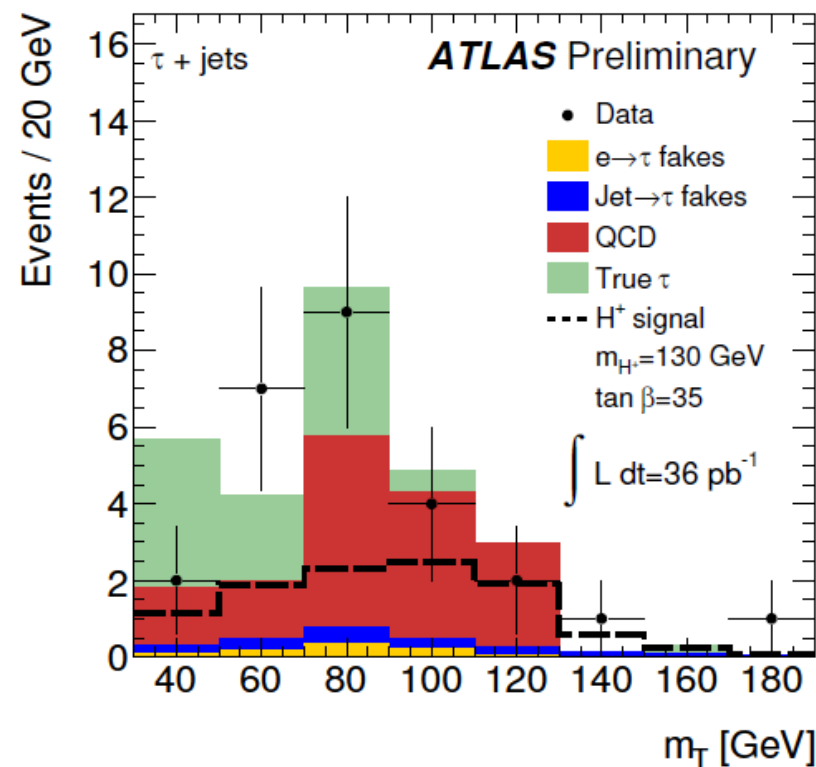
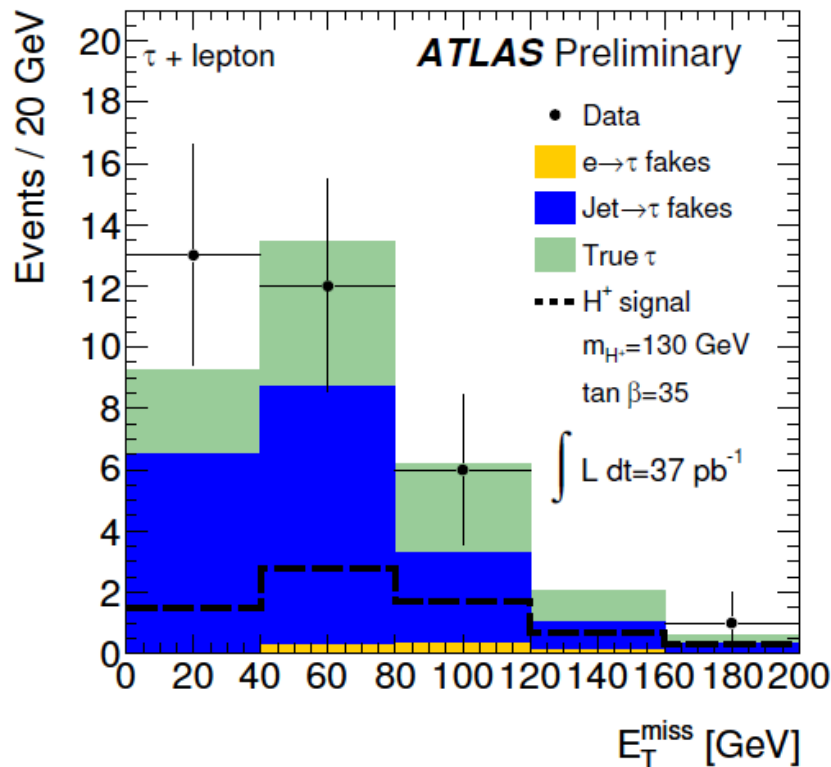
$H^+ \rightarrow \tau\nu$ with leptonic τ decays

- Test of data-driven background estimates and new discriminating variables
- Fair agreement data/MC, will proceed to produce limits



$H^+ \rightarrow \tau\nu$ with hadronic τ decays

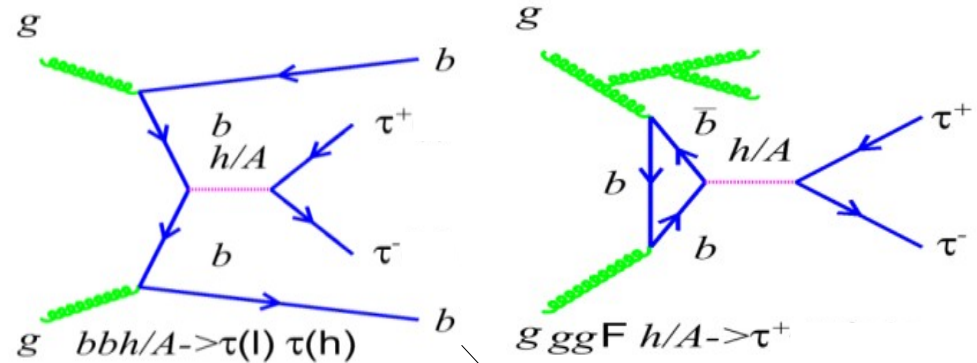
- Background estimates are all either fully data-driven or use data-driven estimates (except true τ in τ +lepton)
- Fair agreement with data. Final discriminants:



Signal expectation shown for $BR(t \rightarrow bH^+) = 6\%$ (current limit: $\approx 15\%$)

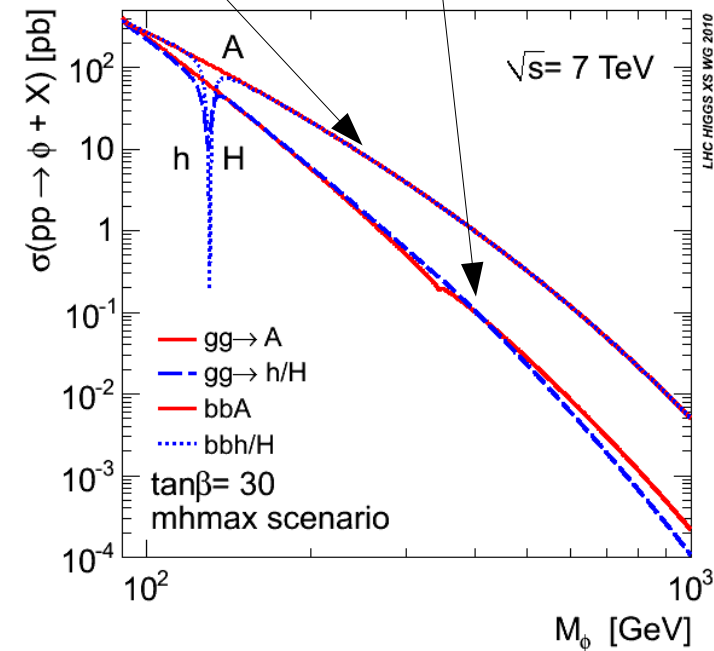
MSSM $H \rightarrow \tau\tau$

- Enhanced cross section wrt SM for large $\tan\beta$
- Production: b-associated, gg-fusion



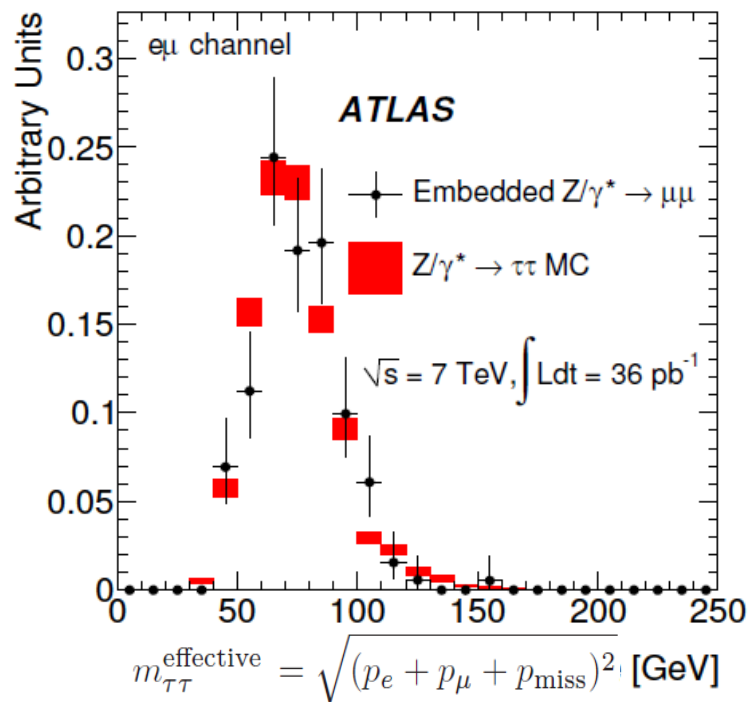
- Backgrounds: $Z \rightarrow \tau\tau$ (irreducible), $W + \text{jets}$, $t\bar{t}$, $Z \rightarrow l l$
- Event selection:

- | | |
|---|---|
| <ul style="list-style-type: none"> Lepton-hadron: <ul style="list-style-type: none"> 1 isolated lepton 1 τ jet ($q_1 \times q_{\tau} = -1$) $E_T(\text{miss}) > 20$ GeV $m_T(l, \text{miss}) < 30$ GeV | <ul style="list-style-type: none"> Lepton-lepton <ul style="list-style-type: none"> 1 μ, 1 e, isolated $q_e \times q_{\mu} = -1$ $p_T^{l1,2} + E_T^{\text{miss}} < 120$ GeV $\Delta\phi(e, \mu) > 2$ rad |
|---|---|



Background estimation

- Validation of the $Z \rightarrow \tau\tau$ shape
 - Select $Z \rightarrow \mu\mu$ in data, replace both μ with τ from simulation
 - Apply event selection to embedded events
 - Data agrees well with $Z \rightarrow \tau\tau$ simulation (within uncertainties)



- QCD ($\tau_L \tau_L$): ABCD method**

- Assume lepton charge product (SS/OS) and isolation are uncorrelated
- EW & $t\bar{t}$ background subtracted
- Estimated QCD in signal region: $n_B \cdot n_C / n_D = 2.1^{+3.1}_{-2.1}(\text{stat})$

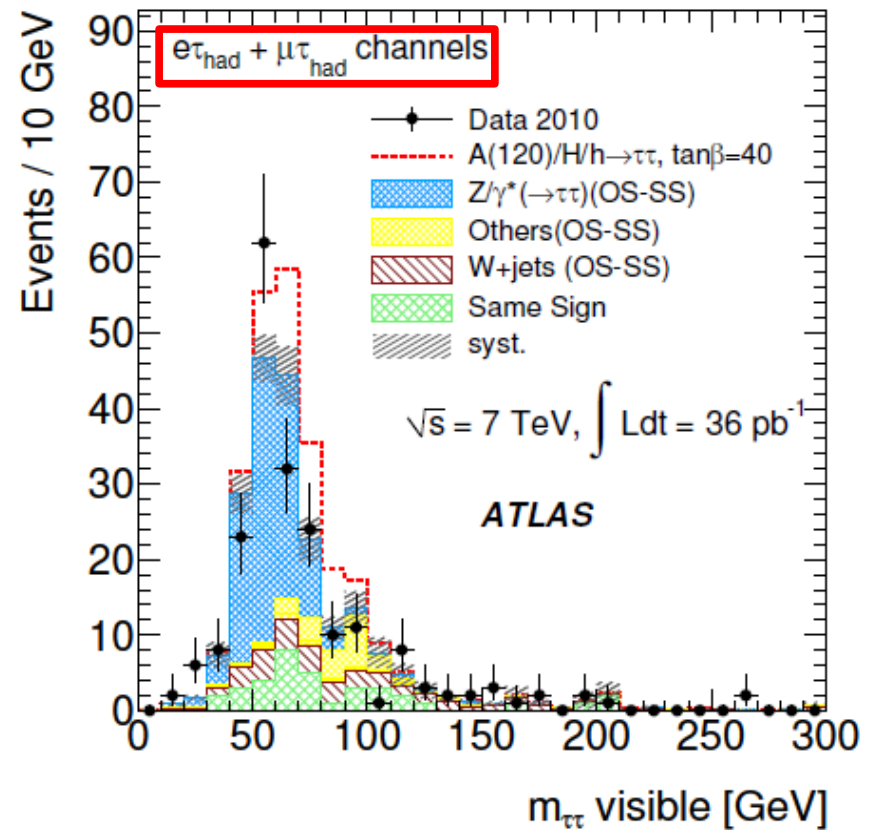
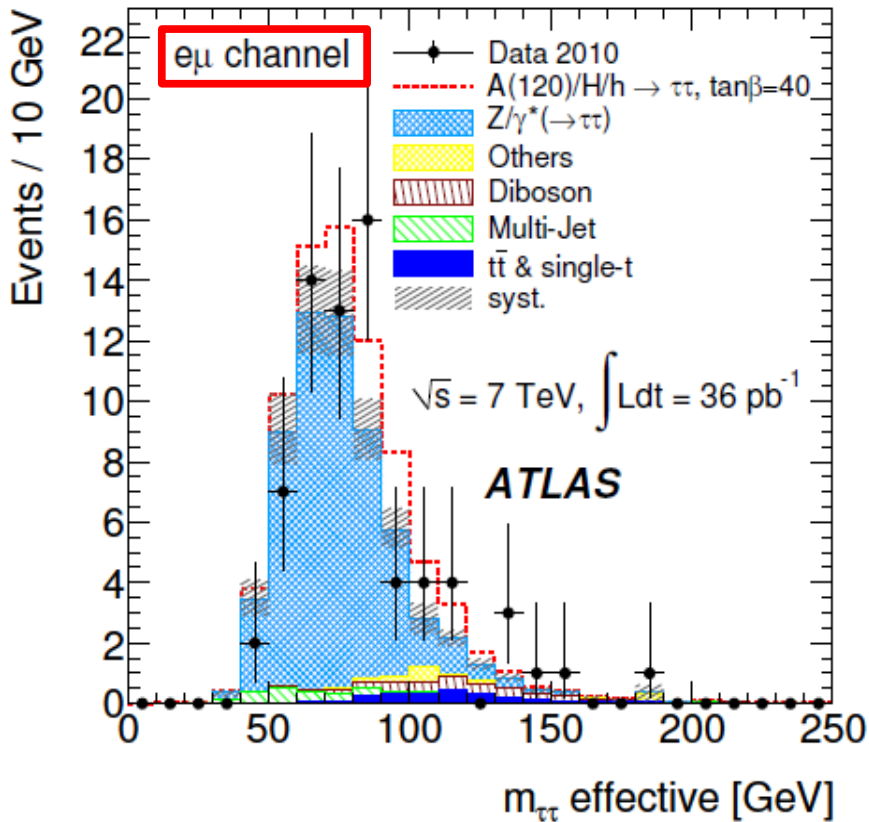
	$e\&\mu$ iso.	$e\&\mu$ \not{iso}	e iso, μ \not{iso}
OS	A 70	C 857	G 92
SS	B 1	D 433	H 33

- W+jets, QCD ($\tau_L \tau_H$)**

$$n_{OS}^{Bkg} = n_{SS}^{Bkg} + \underbrace{n_{OS-SS}^{QCD}}_{\approx 0} + n_{OS-SS}^{W+Jets} + n_{OS-SS}^Z + n_{OS-SS}^{other}$$

- Assumption: $n_{OS} = n_{SS}$ for fake backgrounds
- Use n_{SS} shape for QCD
- Correction factor needed for W+jets: from n_{OS-SS} from control region; shape from MC

$H \rightarrow \tau\tau \rightarrow e\mu / 1\tau_{\text{had}}$ mass spectra

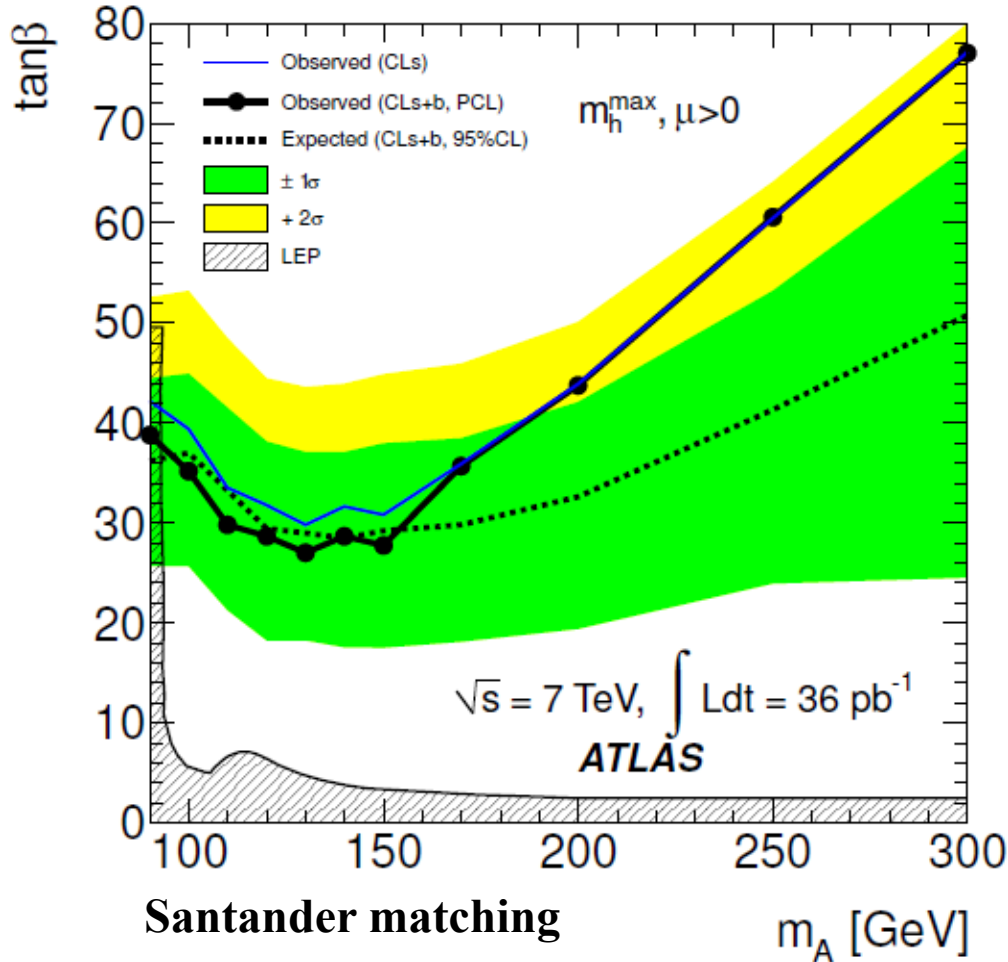


Dominating Systematic uncertainties

- Energy scales, resolution (1τ , Z: $\approx 30\%$, signal: 19%)
- electron efficiency ($e\mu$, 8%), τ efficiency (1τ , 4%)
- Cross section (backgrounds: $\approx 5\%$, signal: 14%)
- Acceptance (Z: 14% , signal: $\approx 5\%$)
- Luminosity (3.4%)
- W/QCD estimate: $\approx 20\%$ (1τ)

MSSM limit (mh-max)

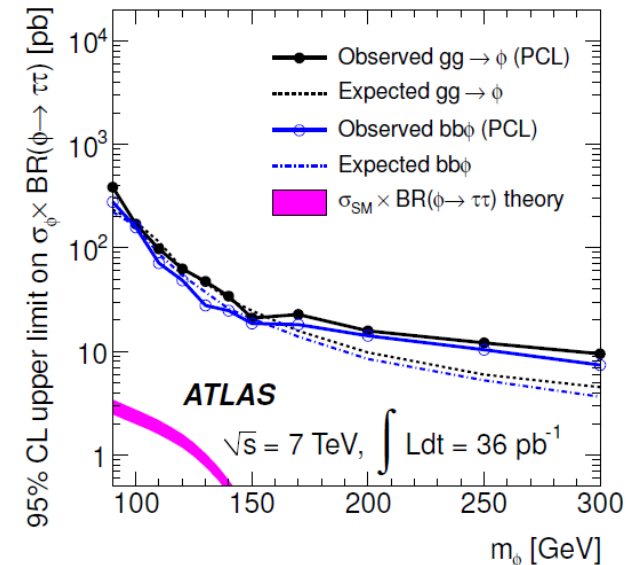
Combined limit $H \rightarrow \tau_1 \tau_h / H \rightarrow \tau_e \tau_\mu$



Expected background and data (combined statistical and systematic uncertainties)

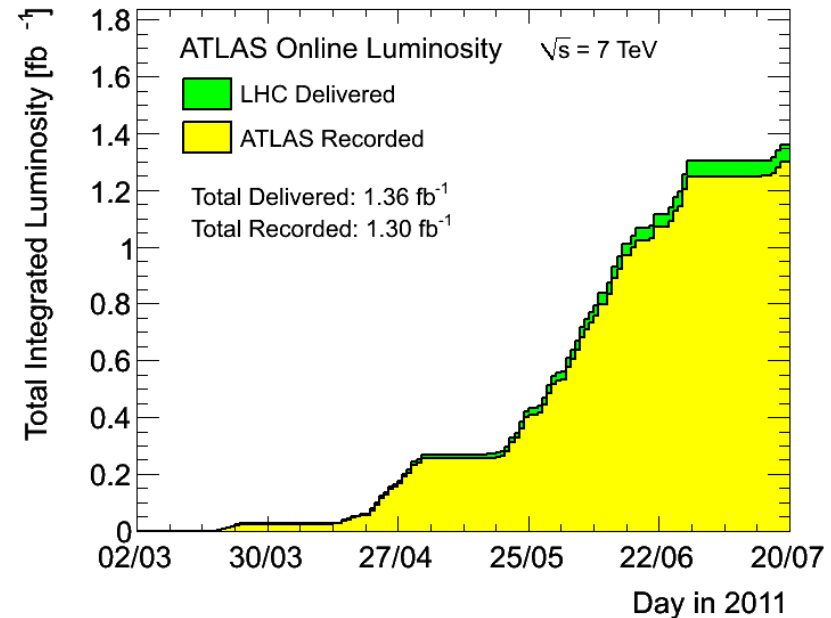
Final state	Exp. Background	Data
$e\mu$	63 ± 7	70
$\ell\tau_{had}$	206 ± 35	206
Sum	269 ± 36	276

Model-independent limit



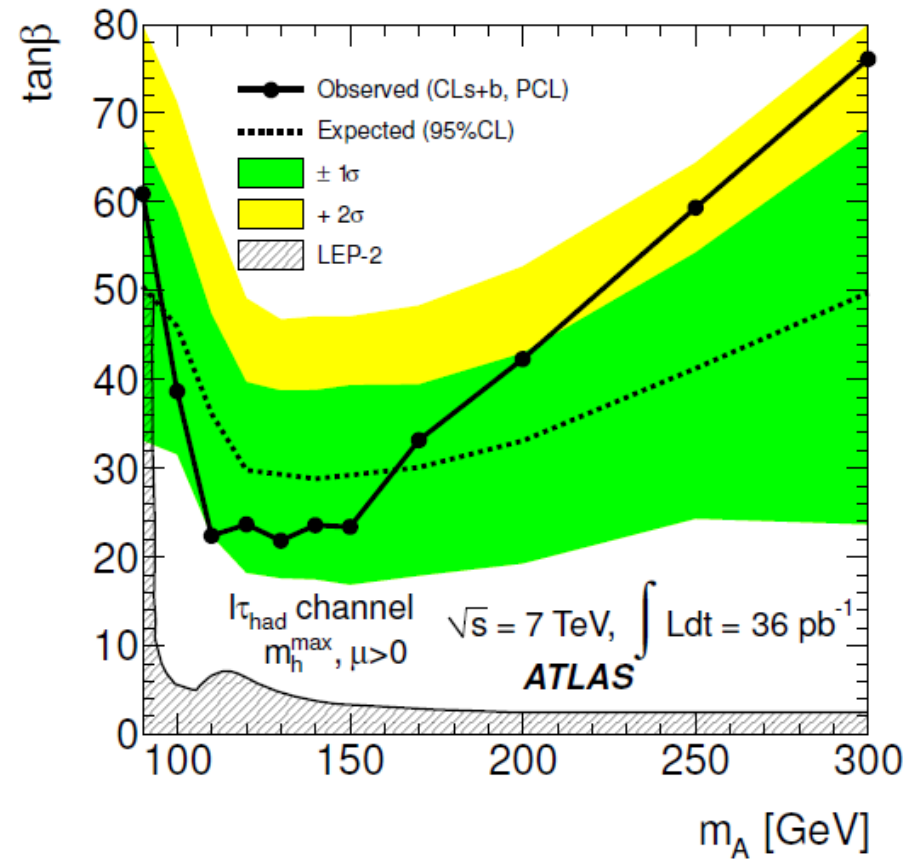
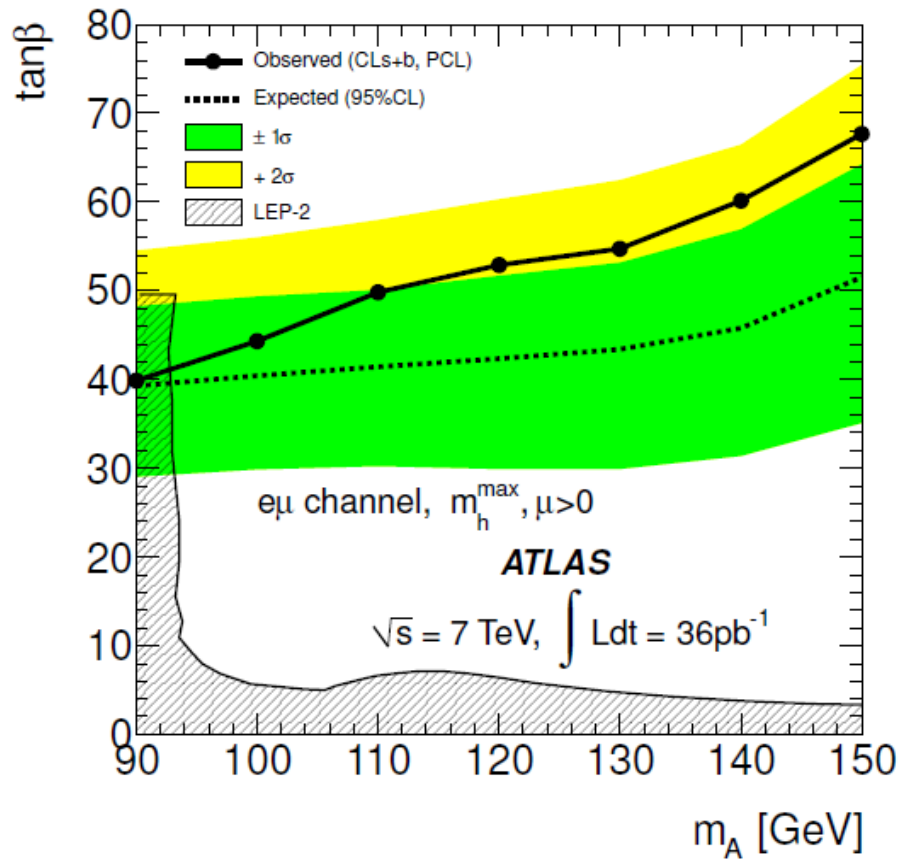
Conclusions

- ATLAS detector performs well
 - Agreement expectation / observation
- So far, 36 pb^{-1} analyzed for MSSM Higgs searches
- Results already competitive with Tevatron results
 - $H \rightarrow \tau\tau$
 - $H^+ \rightarrow c\bar{s}$
- Constraints on MSSM with heavy Higgs ($A/H/H^+$) masses below 200 GeV are getting tighter
 - Exclusion down to $\tan \beta \approx 30$ for $m_A = 110\text{-}160 \text{ GeV}$ (mh-max)
- The current dataset of $1\text{-}2 \text{ fb}^{-1}$ could exclude a much larger region
 - ...or lead to a discovery

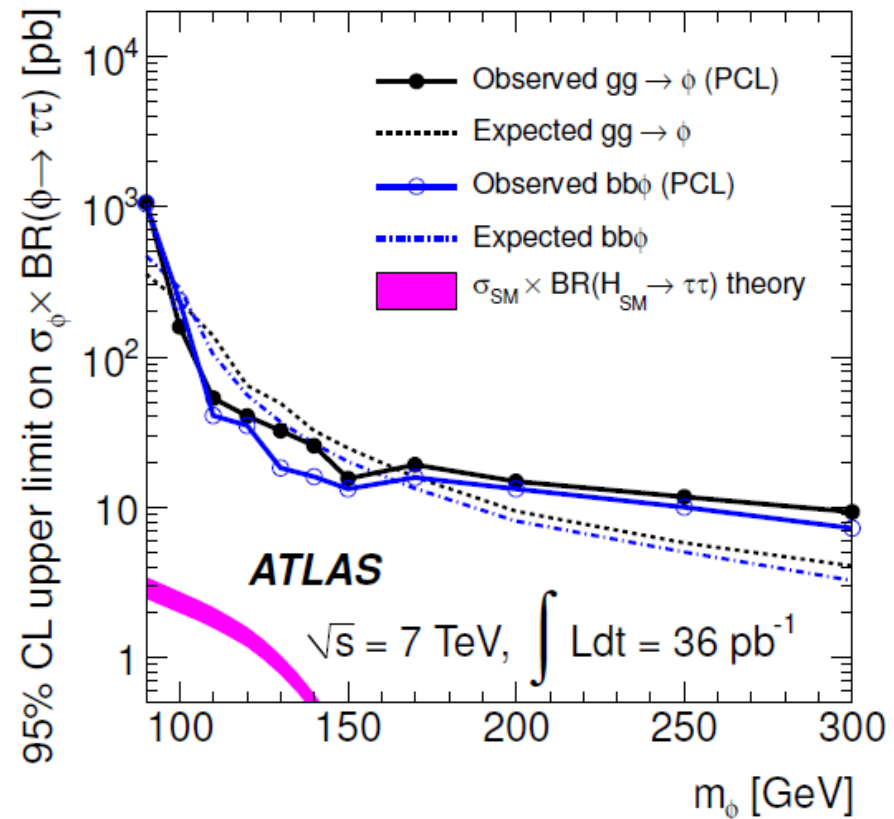
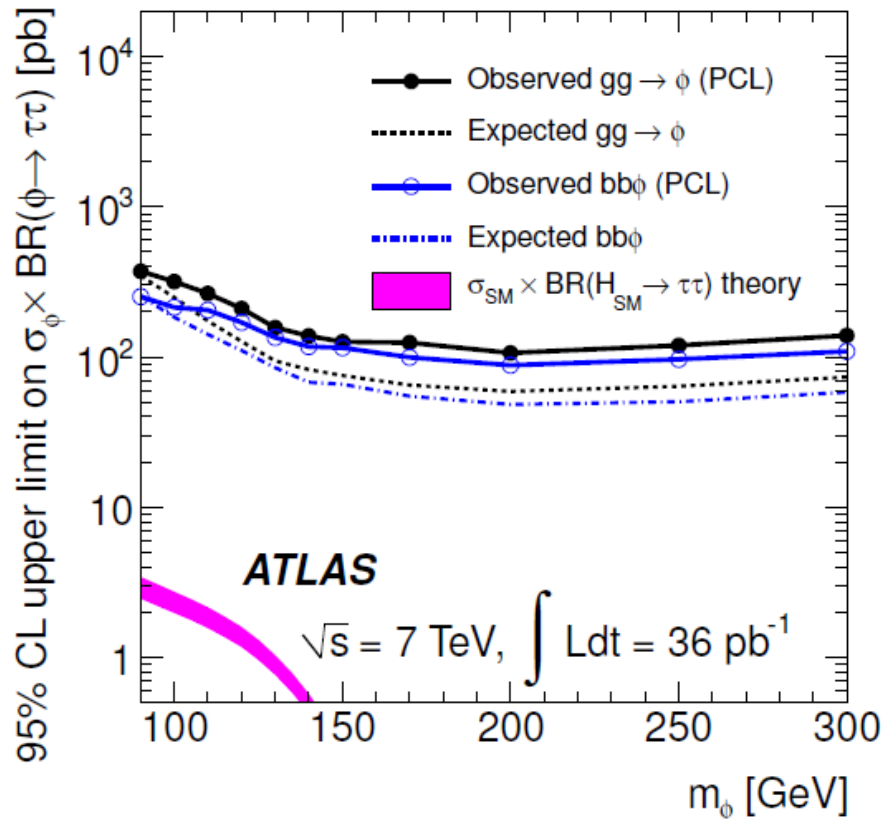


- References:
 - ATLAS-CONF-2011-018 [$H^+ \rightarrow \text{tau}(\text{lep})$]
 - ATLAS-CONF-2011-051 [$H^+ \rightarrow \text{tau}(\text{had})$]
 - ATLAS-CONF-2011-094 [$H^+ \rightarrow \text{cs}$]
 - Submitted to Phys. Lett. B [$h/H/A \rightarrow \text{tautau}$]

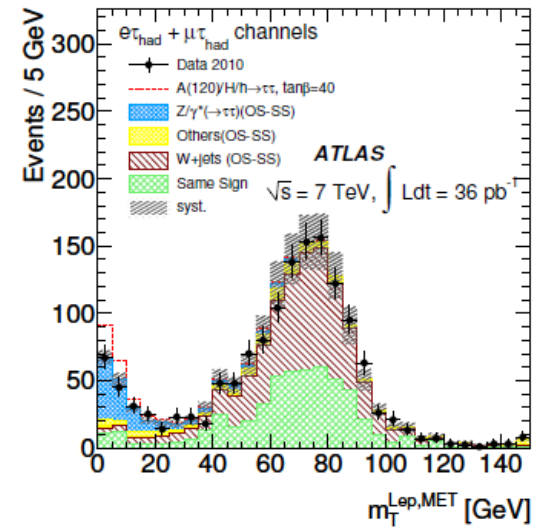
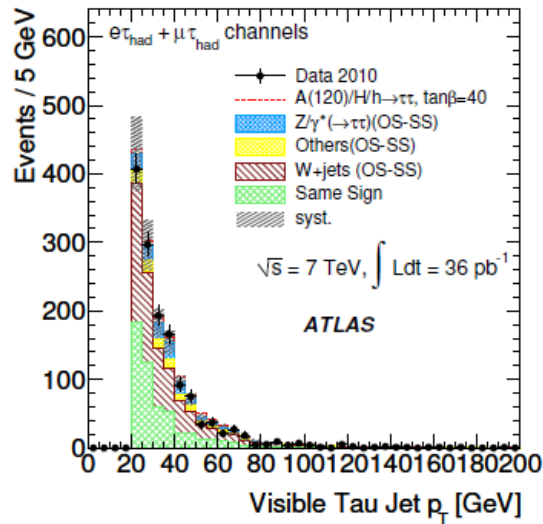
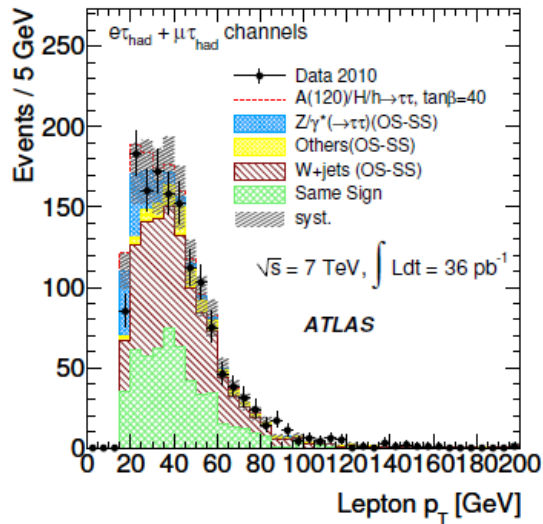
H → ττ: Limits per channel



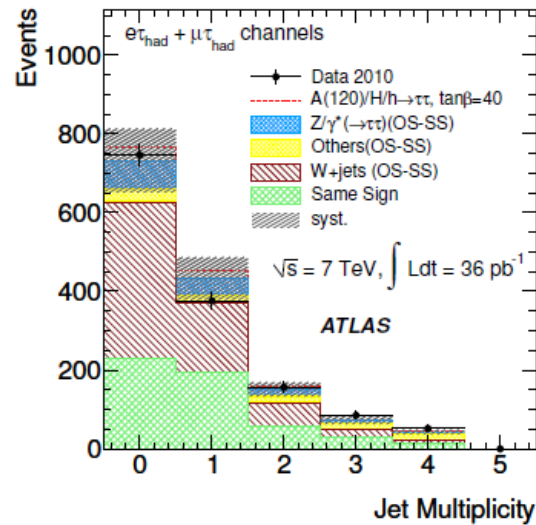
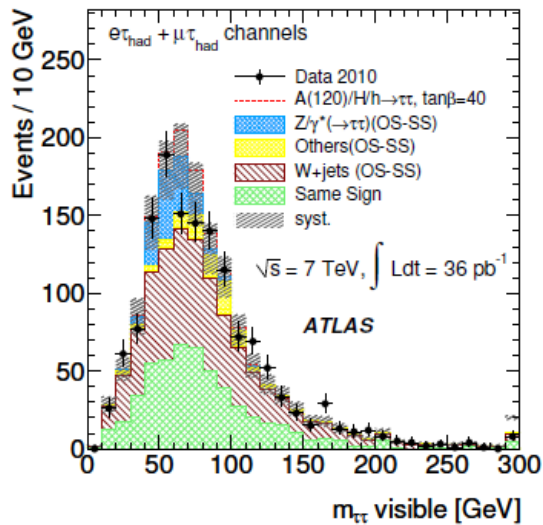
H → ττ: Model-independent limits per channel



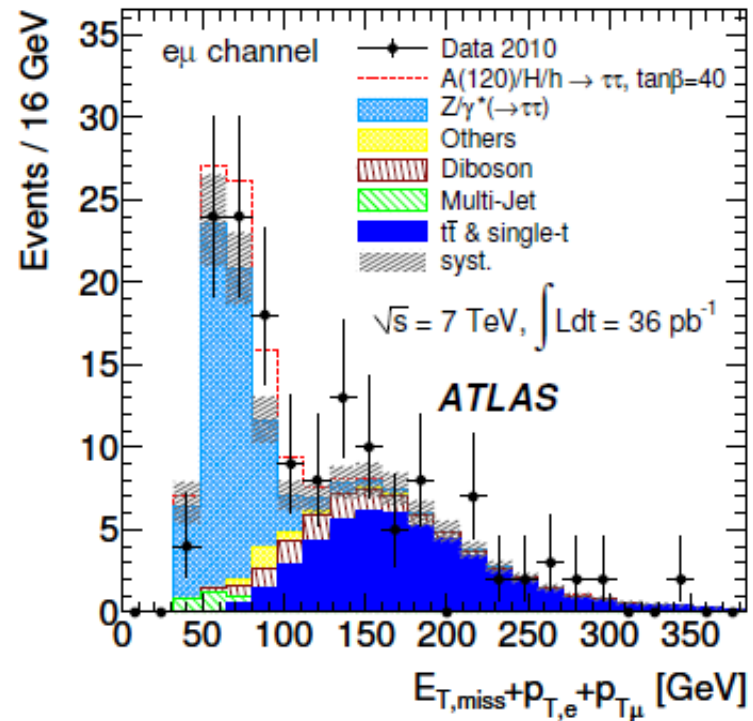
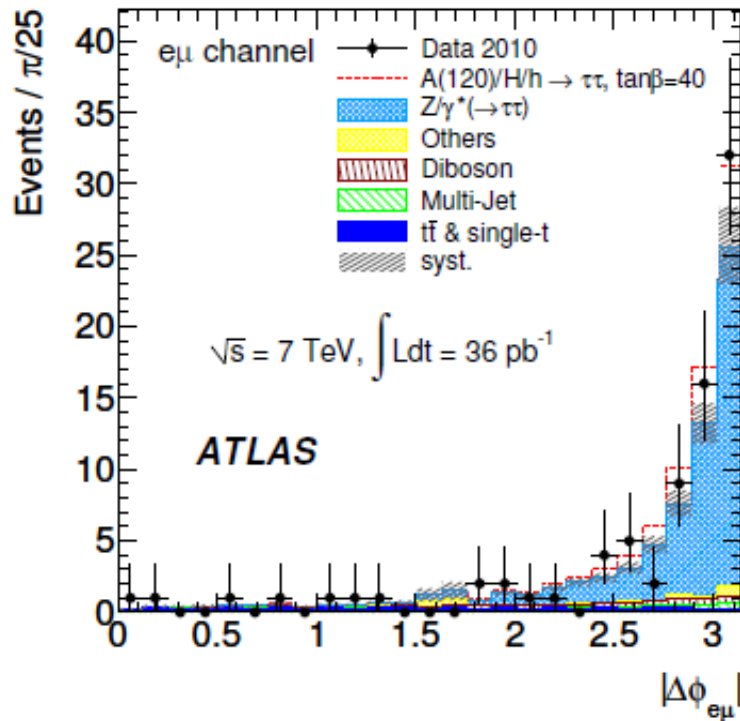
$H \rightarrow \tau_L \tau_H$ control plots



Kinematic distributions for the $\ell\tau_{had}$ final states for the selection without a requirement on m_T



$H \rightarrow \tau_L \tau_L$ control plots



Kinematic distributions for the $e\mu$ final state for the full selection

H⁺ → cs: χ² fitter

- Allowed measured values to vary within uncertainties

$$\begin{aligned}\chi^2 = & \sum_{i=l,4jets} \frac{(p_T^{i,fit} - p_T^{i,meas})^2}{\sigma_i^2} \\ & + \sum_{j=x,y} \frac{(p_j^{UE,fit} - p_j^{UE,meas})^2}{\sigma_{UE}^2} \\ & + \sum_{k=bjj,bl\nu} \frac{(M_k - M_{top})^2}{\sigma_{top}^2}.\end{aligned}$$

H⁺ → cs channel: mass spectra

