Search for $H^{\pm} \rightarrow \tau_{had} + \nu$ in ATLAS

cHarged 2012

Prospects for Charged Higgs Discovery at Colliders
Uppsala University, Sweden, 8-11 October 2012

Patrick Czodrowski
Institute of Nuclear and Particle Physics

OUTLINE

- Light charged Higgs searches in ***ATLAS*** with τs(*)
  - Background estimation techniques
  - **$H^{\pm}$** → **τυ** + jets
  - **$H^{\pm}$** → **τυ** + leptons
- Conclusion(s)

(*) in this talk **τ** denotes hadronically decaying tau leptons $\tau^{\pm}_{\mathbf{had}}$

$H^{\pm} \rightarrow \tau\nu$

this talk covers 2/3 analyses published here:

JHEP
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Search for charged Higgs bosons decaying via $H^{\pm} \rightarrow \tau\nu$ in $t\bar{t}$ events using pp collision data at $\sqrt{s} = 7$ TeV with the ATLAS detector

The ATLAS collaboration

the other one will be covered by Catrin after the coffee

$H^{\pm} \rightarrow \tau\nu$

- both presented analyses use the full **2011 4.6 fb^{-1}** data recorded by the ***ATLAS*** detector at $\sqrt{s}$ = **7 TeV**

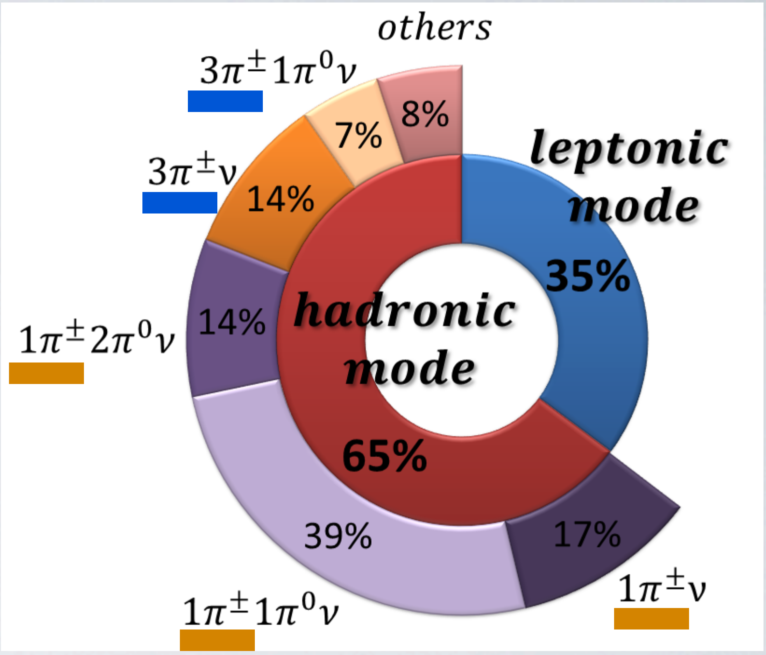
- so far LHC searches focused on light$^{(*)}$ charged Higgs (stemming from top decays) searches

- currently ***ATLAS*** searches for the **heavy** $H^{\pm}$ are in progress

$^{(*)}$ $m_{H^{\pm}} < m_t$ (here considering range: 90 – 160 GeV)

$H^{\pm} \rightarrow \tau\nu$

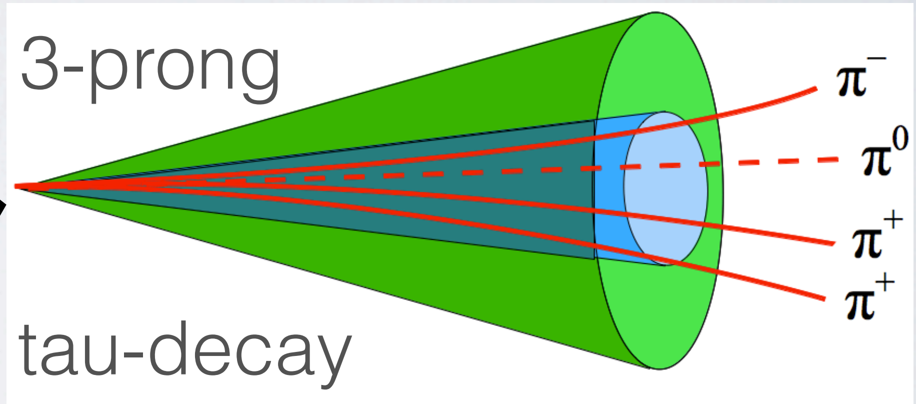
lets talk about τ

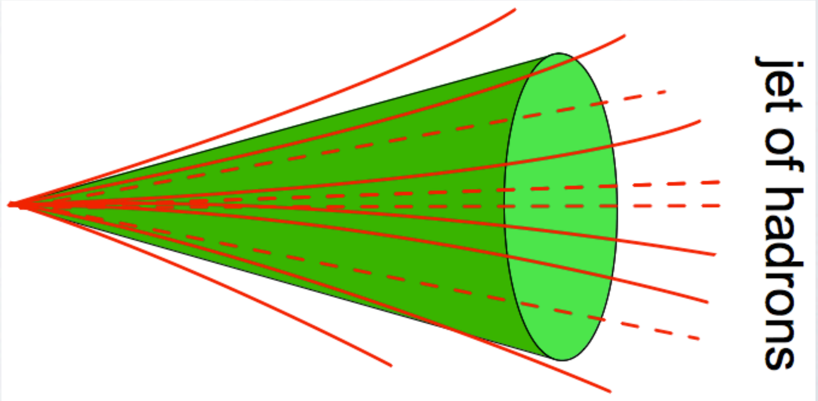


hadronic τs are hard to identify!

- chosen working point:
  1 or 3 prongs
  30% efficiency with
  jet rejection factors of
  ~100 – 1000
  (p_{T} and η dependent)

See also Stefania's talk!





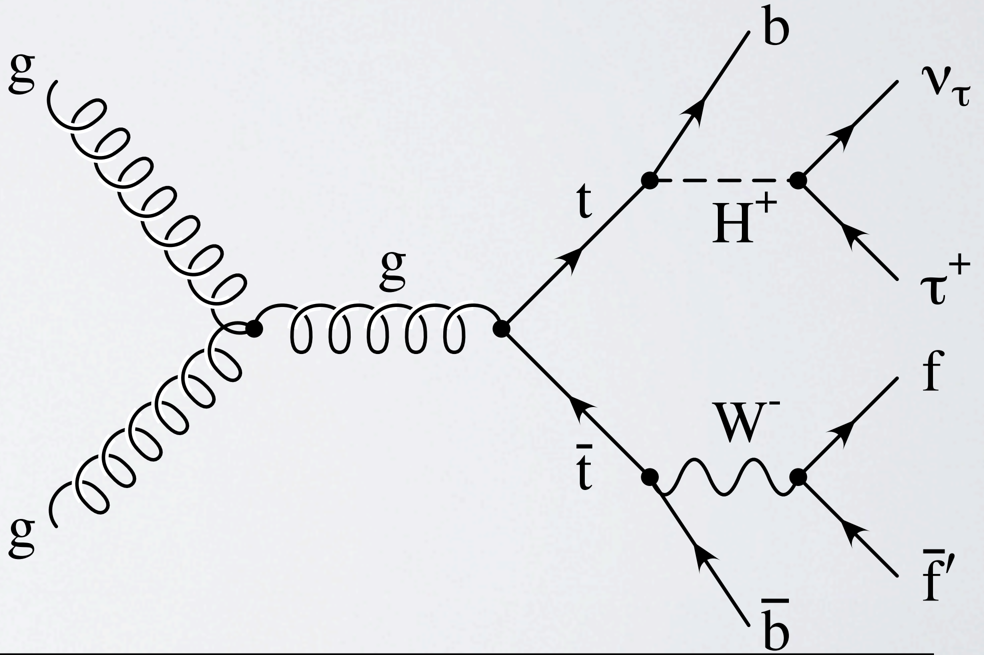
(ATLAS-CONF-2011-152)

background estimations

Don't miss Yoram's talk

- main contribution from **irreducible** $t\bar{t}$ events
- QCD multi-jet events contribute in τ+jets analysis
- backgrounds for $H^{\pm}$ (τ_{had}) analyses are categorized in:

  1. true τs
  2. jets and electrons faking τs
  3. multi-jet events



light $H^{\pm}$ from top decay

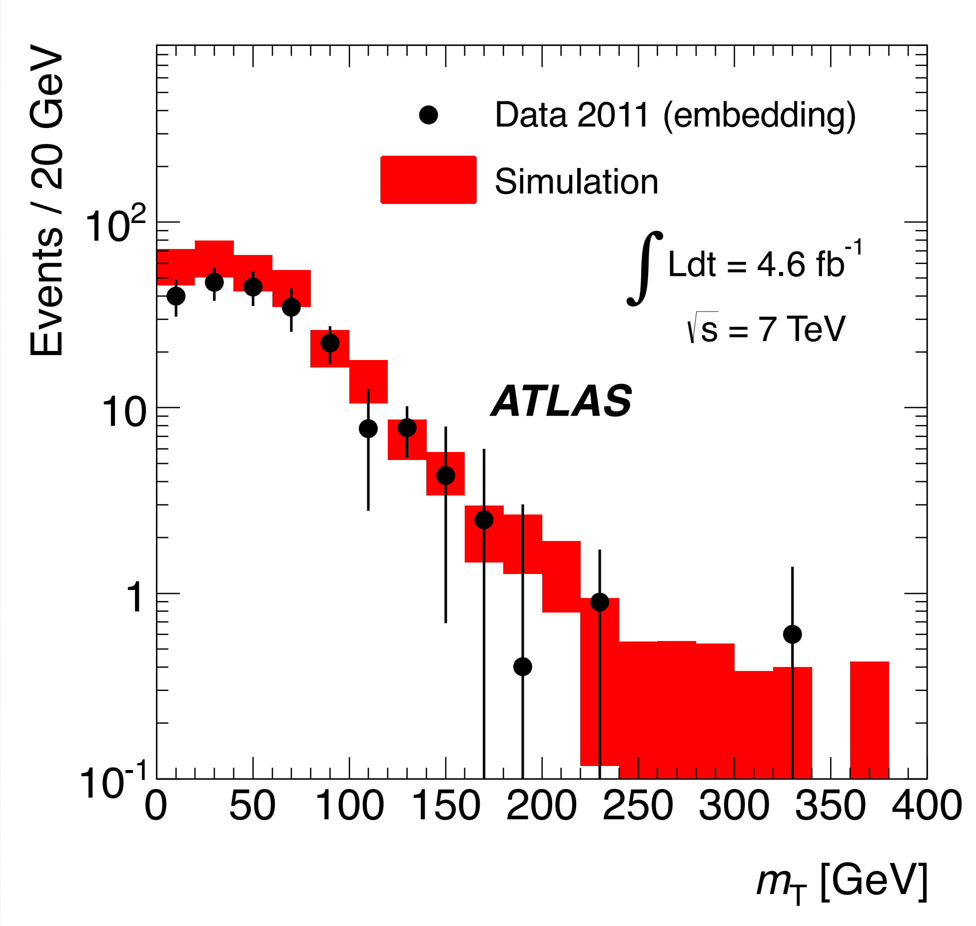
1. true τ estimation

embedding method:

more details: here

- in data: loose selection of $t\bar{t}$ events with at least one μ in the final state

- identified μ replaced with simulated τs in order to estimate the contribution from $t\bar{t}$ with correctly reconstructed τ_{had}'s



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2. fake τ estimation

fake rate method:

more details: here

- applying **data-derived** misidentification rates to simulation to determine contribution of **misidentified τs from jets** (W+jets) & **electrons** ($Z \to ee$)

Sample	Data-driven method [events]	Simulation [events]
$t\bar{t}$	900 ± 15	877 ± 6
W+jets	150 ± 3	145 ± 9
Single top quark	81 ± 1	61 ± 2
Z/γ^*+jets	44 ± 1	69 ± 4
Diboson	6 ± 1	8 ± 1

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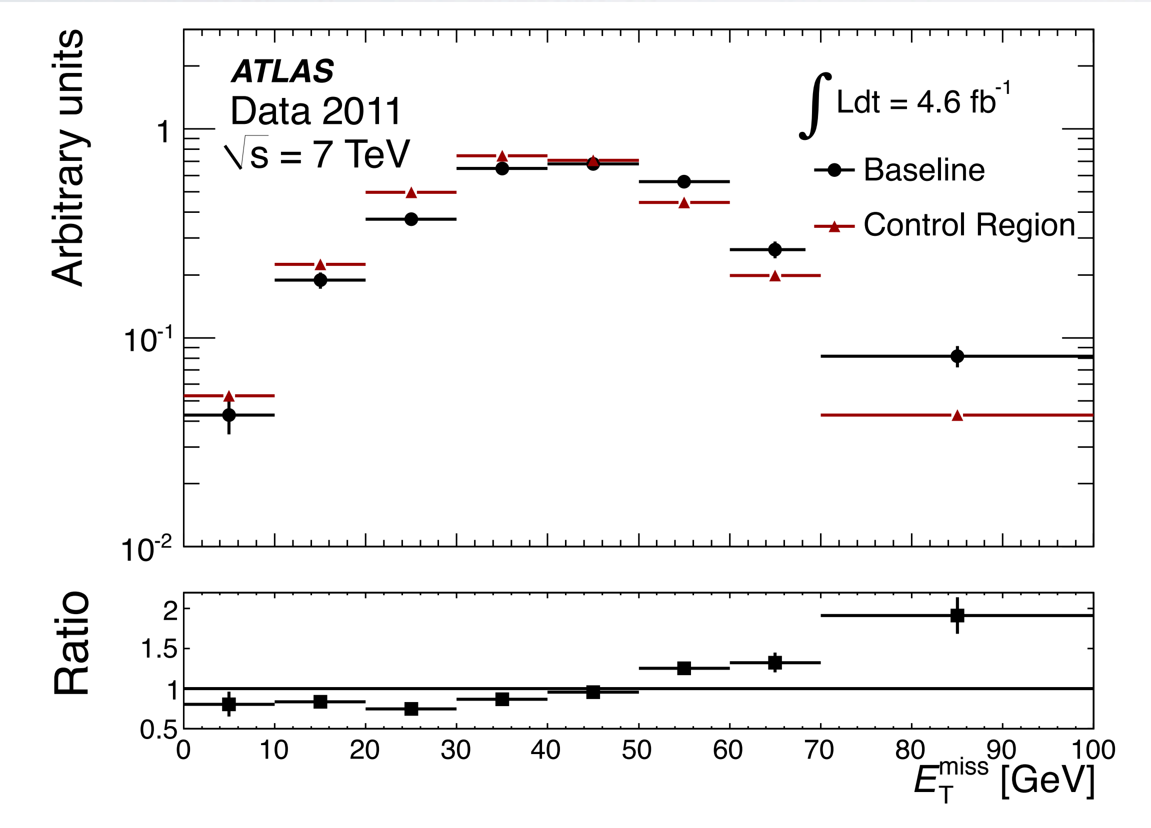
Table: yield of the jet→τ estimation for τ+lepton analysis

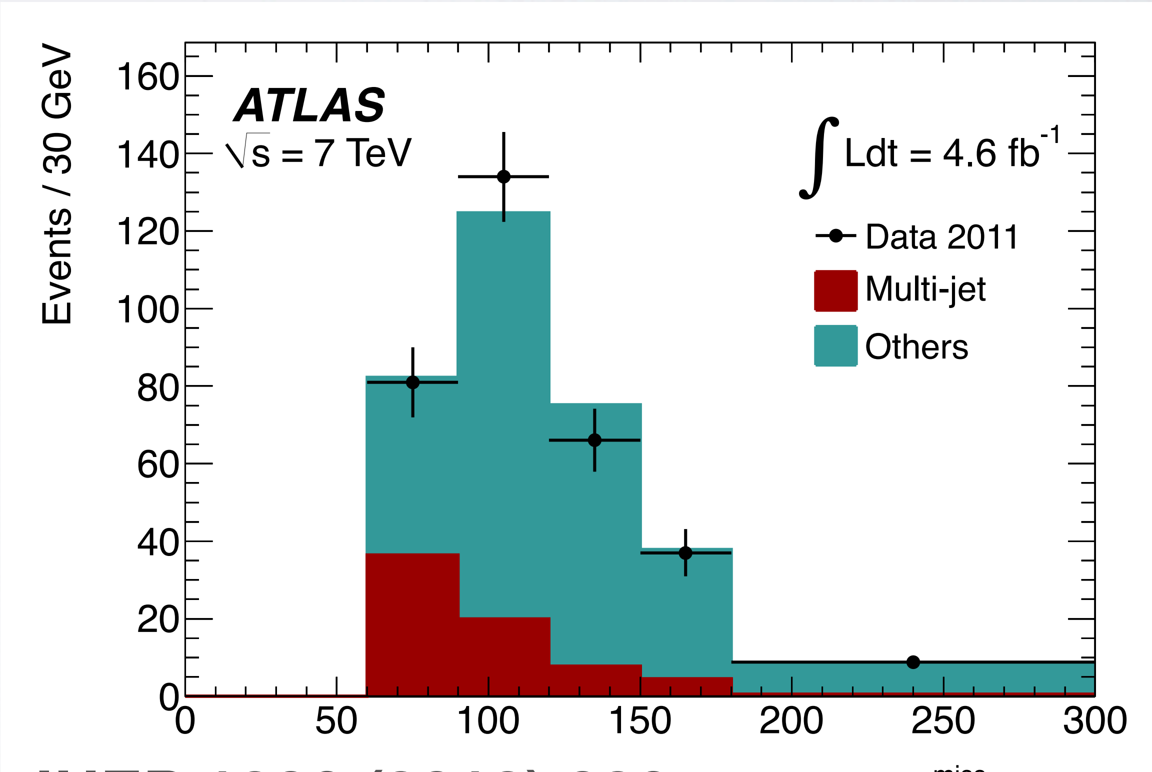
3. multi-jet estimation

fitting of E_T^{miss} shape:

more details: here

- data-driven **multi-jet** background estimated by fitting the E_T^{miss} distribution in a control region (no b-tagged jet and passing loose but not tight τ-ID)





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$H^{\pm} \rightarrow \tau\upsilon$ + jets

for further details see: **arXiv:1204.2760v1 [hep-ex]**

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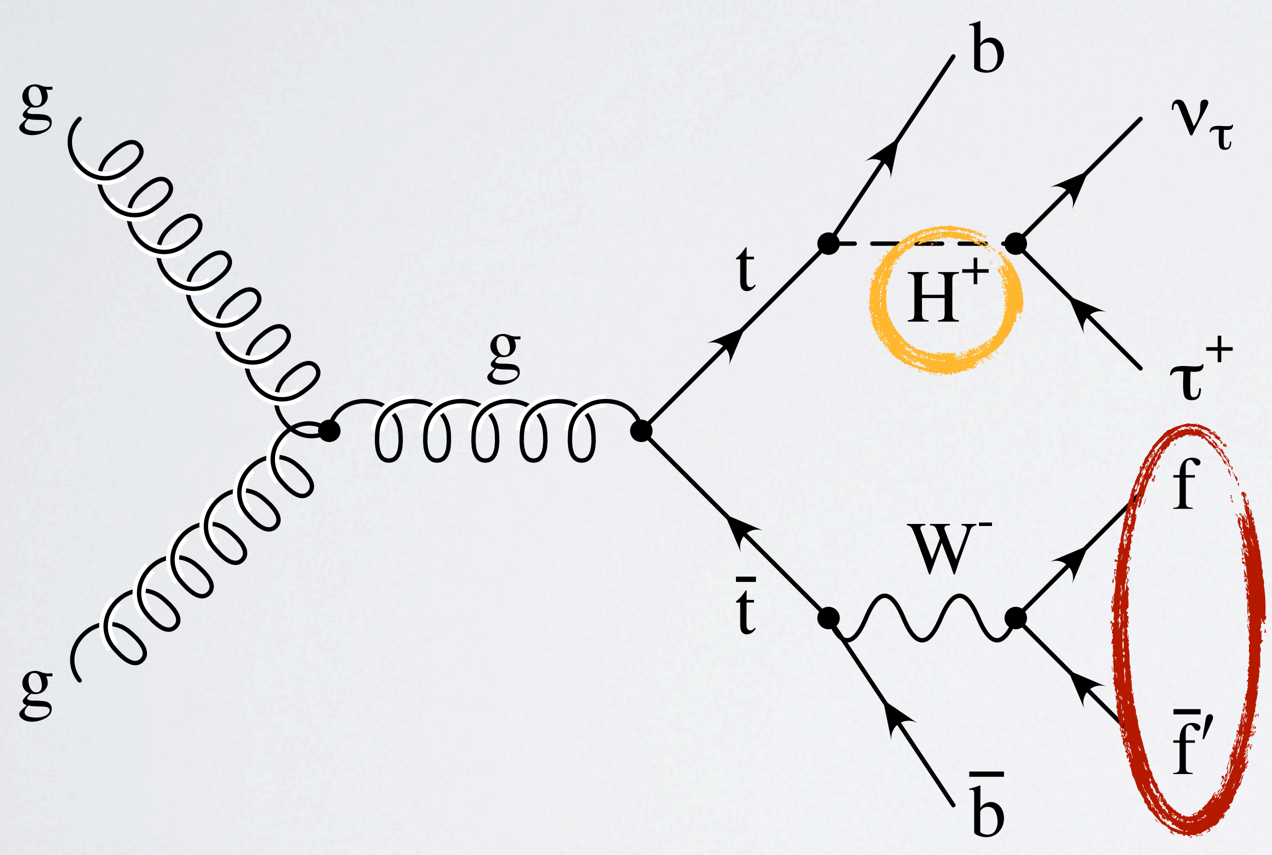


this is the “jets” side

$H^{\pm} \to \tau\nu$ + jets

Analysis **strategy**:

- make use of the neutrino-free "$W \to$jets" side to reconstruct the top for better background reduction
- use transverse mass $\boldsymbol{m_{\mathrm{T}}}$ to distinguish $\boldsymbol{W^{\pm}}$ bosons from $\boldsymbol{H^{\pm}}$ signal – very efficient due to mass difference

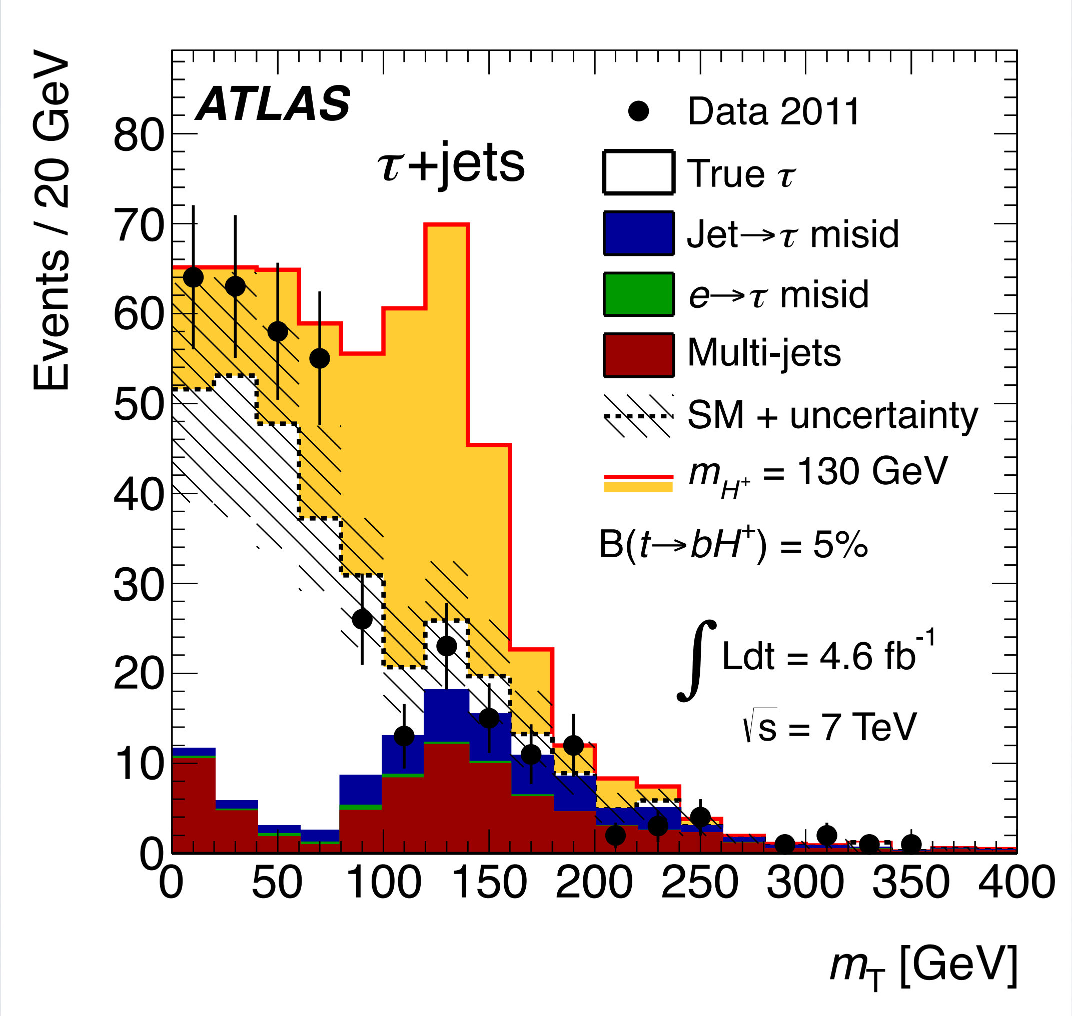
$$m_{\mathrm{T}} = \sqrt{2 p_{\mathrm{T}}^{\tau} E_{\mathrm{T}}^{\mathrm{miss}} (1 - \cos \Delta\phi_{\tau,\mathrm{miss}})}$$

$H^{\pm} \rightarrow \tau\nu$ + jets

Event Selection

- trigger: `tau29_medium_xe35_noMu`, `tau29T_medium_xe35_noMu_3L1J10`
- ≥4 jets (not identified as τ_{had}) and ≥1 b-tagged jet
- exactly one high p_{T} (> 40 GeV) τ_{had} and no μ or e
- missing transverse energy, $E_{\mathrm{T}}^{\mathrm{miss}}$ > 65 GeV
- $E_{\mathrm{T}}^{\mathrm{miss}}$ significance > 13 $\left(\frac{E_{\mathrm{T}}^{\mathrm{miss}}}{0.5\ \mathrm{GeV}^{1/2} \cdot \sqrt{\sum p_{\mathrm{T}}}} \right)$
- **topology** consistent with **top**-quark **decay** (invariant mass, m_{jjb}, of the combination with highest p_{T} has to lie within a range of 120 – 240 GeV)

$H^{\pm} \rightarrow \tau\upsilon$ + jets



Event Yield

Sample	Event yield (τ+jets)
True τ (embedding method)	$210 \pm 10 \pm 44$
Misidentified jet $\to \tau$	$36 \pm 6 \pm 10$
Misidentified $e \to \tau$	$3 \pm 1 \pm 1$
Multi-jet processes	$74 \pm 3 \pm 47$
All SM backgrounds	$330 \pm 12 \pm 65$
Data	355
$t \to bH^+$ (130 GeV)	$220 \pm 6 \pm 56$
Signal+background	$540 \pm 13 \pm 85$

with $\mathcal{B}(t \to bH^+) = 5\%$ and $\mathcal{B}(H^+ \to \tau\nu) = 100\%$

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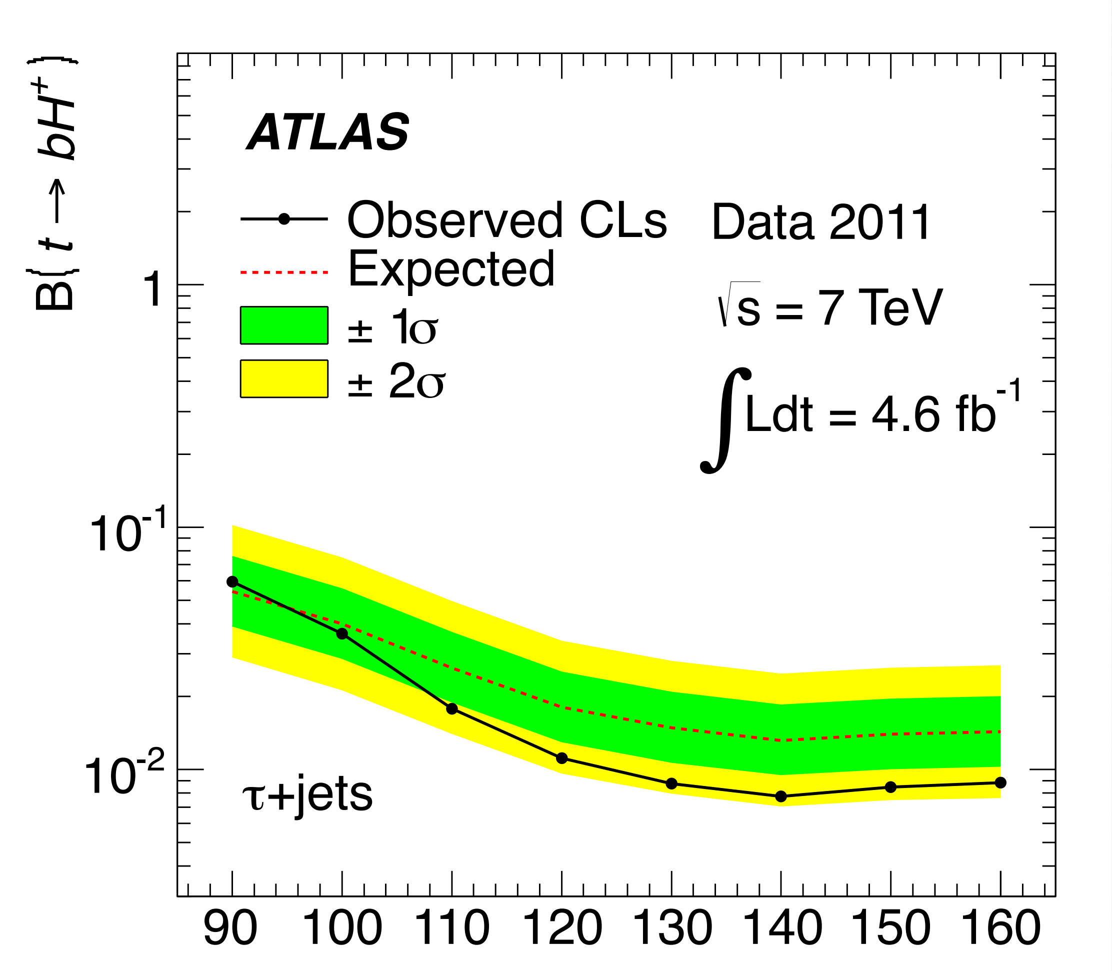
$H^{\pm} \rightarrow \tau\upsilon$ + jets

B($t \rightarrow bH^{+}$) **limits** and **MSSM** interpretation of search results



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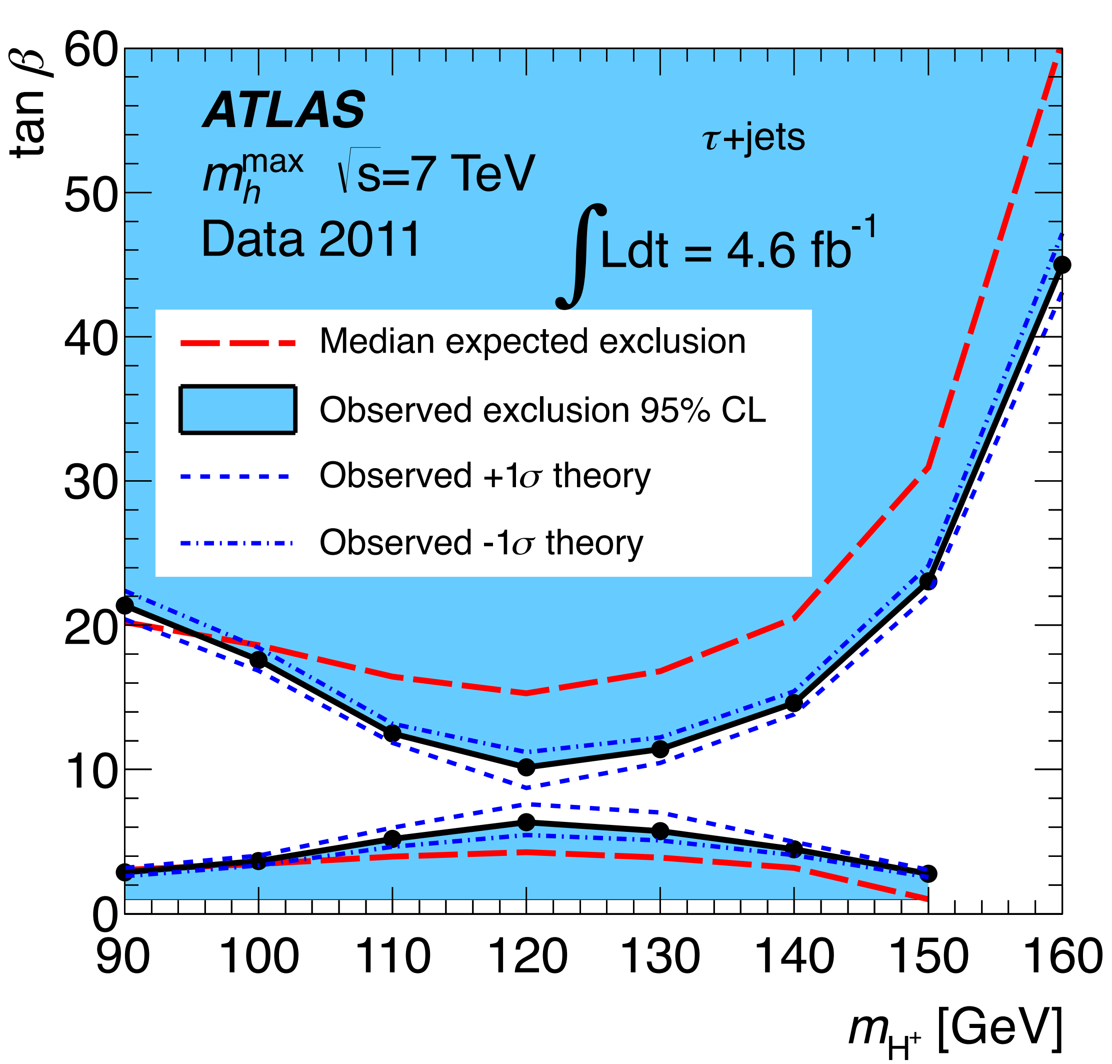

assuming $\mathcal{B}(H^{+} \rightarrow \tau\nu) = 100\%$: as for all further BR-limit plots shown in this talk

$H^{\pm} \rightarrow \tau\nu$ + lepton

for further details see: **arXiv:1204.2760v1 [hep-ex]**

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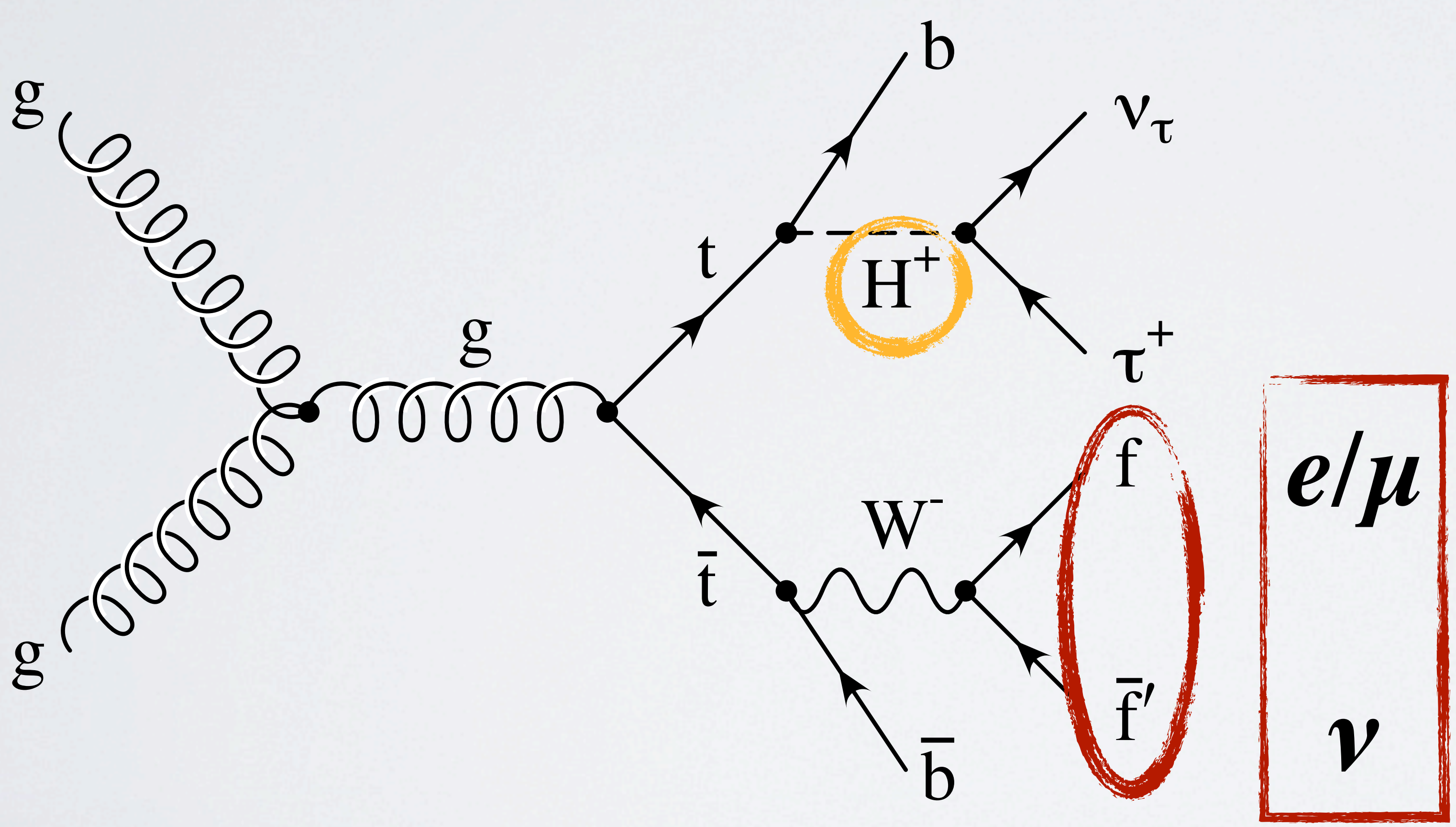

the “lepton” side

$H^{\pm} \to \tau\nu$ + lepton

Analysis **strategy**:

- measure the **missing transverse energy** (E_T^{miss}) if top quark decays mediated via $H^{\pm}$ boson neutrinos are very likely to carry away more energy

$H^{\pm} \rightarrow \tau\nu$ + lepton

Event Selection

- electron trigger: e20_medium, e22_medium, e22vh_medium1
- muon trigger: mu_18, mu18_medium
- exactly one lepton, having $E_{\mathrm{T}} > 25$ GeV (electron) or $p_{\mathrm{T}} > 20$ GeV (muon) and matched to the corresponding trigger object, and no other electron or muon;
- exactly one τ jet having $p_{\mathrm{T}} > 20$ GeV and an electric charge opposite to that of the lepton;
- at least two jets having $p_{\mathrm{T}} > 20$ GeV, including at least one b-tagged jet;
- $\sum p_{\mathrm{T}} > 100$ GeV in order to suppress multi-jet events, where $\sum p_{\mathrm{T}}$ is the sum of the transverse momenta of all tracks associated with the primary vertex. Tracks entering the sum must pass quality cuts on the number of hits and have $p_{\mathrm{T}} > 1$ GeV. As this variable is based on tracks from the primary vertex (as opposed to energy deposits in the calorimeter), it is robust against pile-up.

$H^{\pm} \rightarrow \tau\nu$ + lepton

Event Yields

Sample	Event yield (τ+lepton)	
	$\tau + e$	$\tau + \mu$
True τ+lepton	$430 \pm 14 \pm 59$	$570 \pm 15 \pm 75$
Misidentified jet $\rightarrow \tau$	$510 \pm 23 \pm 86$	$660 \pm 26 \pm 110$
Misidentified $e \rightarrow \tau$	$33 \pm 4 \pm 5$	$34 \pm 4 \pm 6$
Misidentified leptons	$39 \pm 10 \pm 20$	$90 \pm 10 \pm 34$
All SM backgrounds	$1010 \pm 30 \pm 110$	$1360 \pm 30 \pm 140$
Data	880	1219
$t \rightarrow bH^{+}$ (130 GeV)	$220 \pm 6 \pm 29$	$310 \pm 7 \pm 39$
Signal+background	$1160 \pm 30 \pm 100$	$1570 \pm 30 \pm 130$

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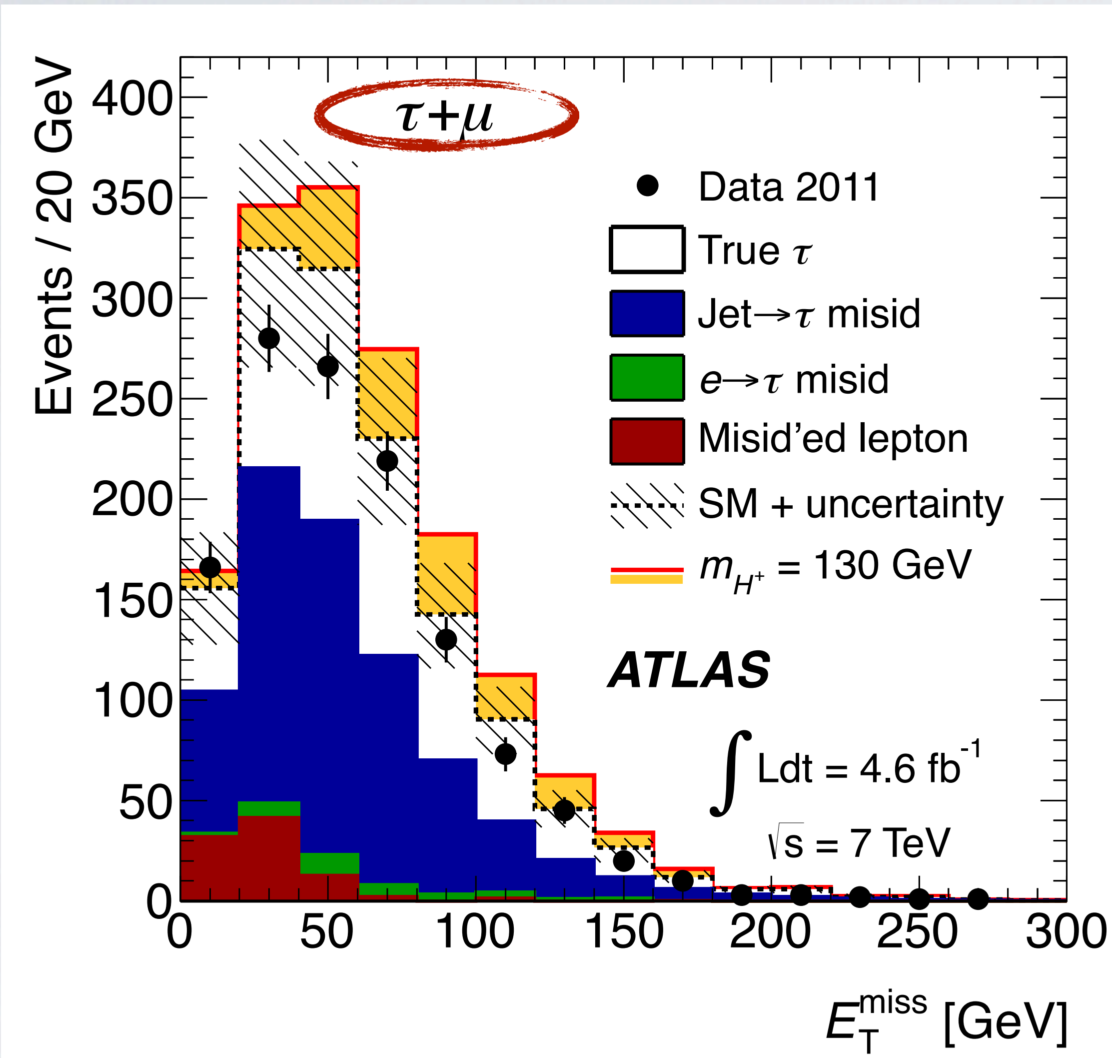
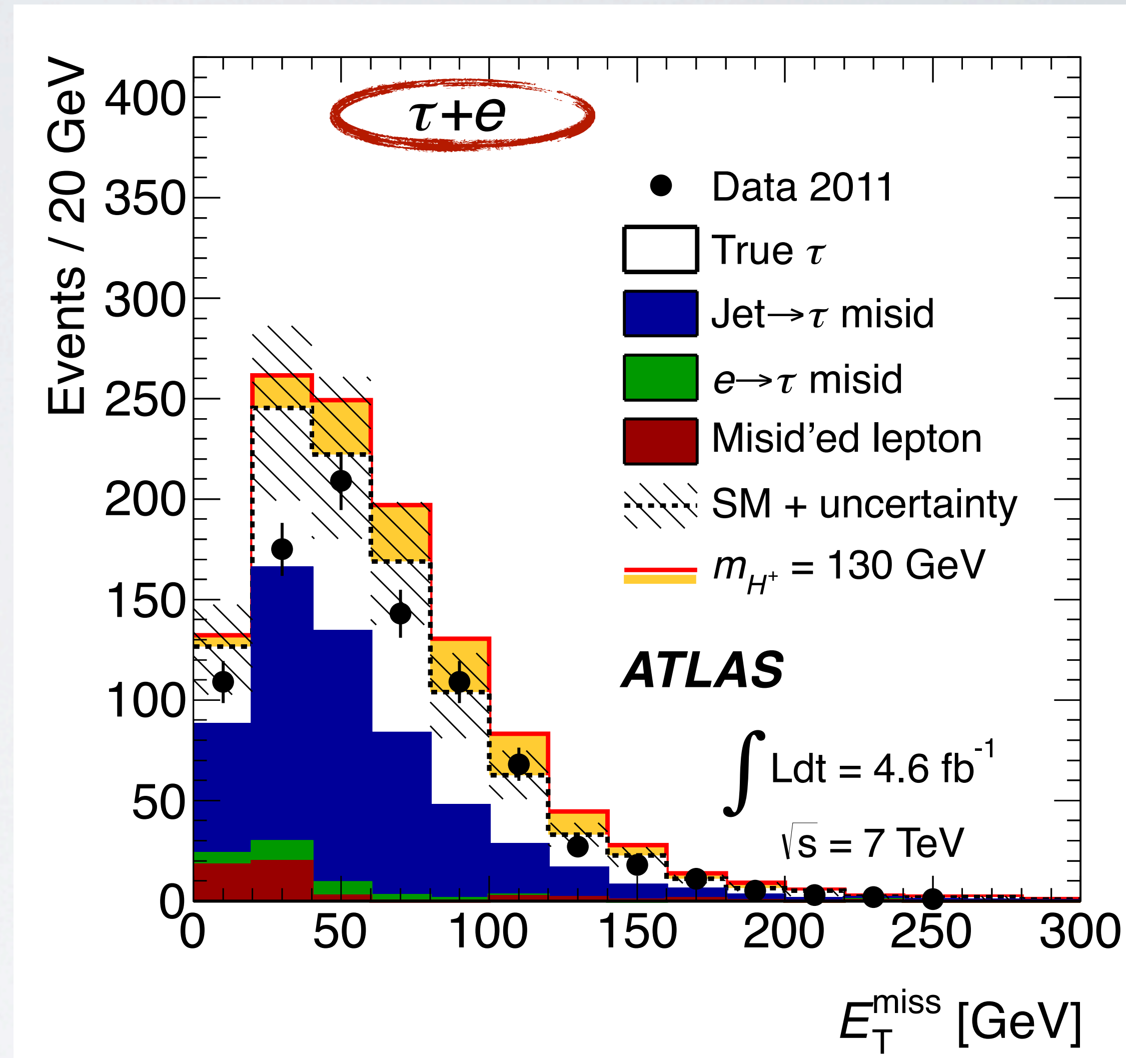
$H^{\pm} \to \tau\nu$ + lepton

Event Yields





example $H^{\pm}$ signal at 130 GeV with $\mathcal{B}(t \to bH^{+}) = 5\%$ and $\mathcal{B}(H^{+} \to \tau\nu) = 100\%$

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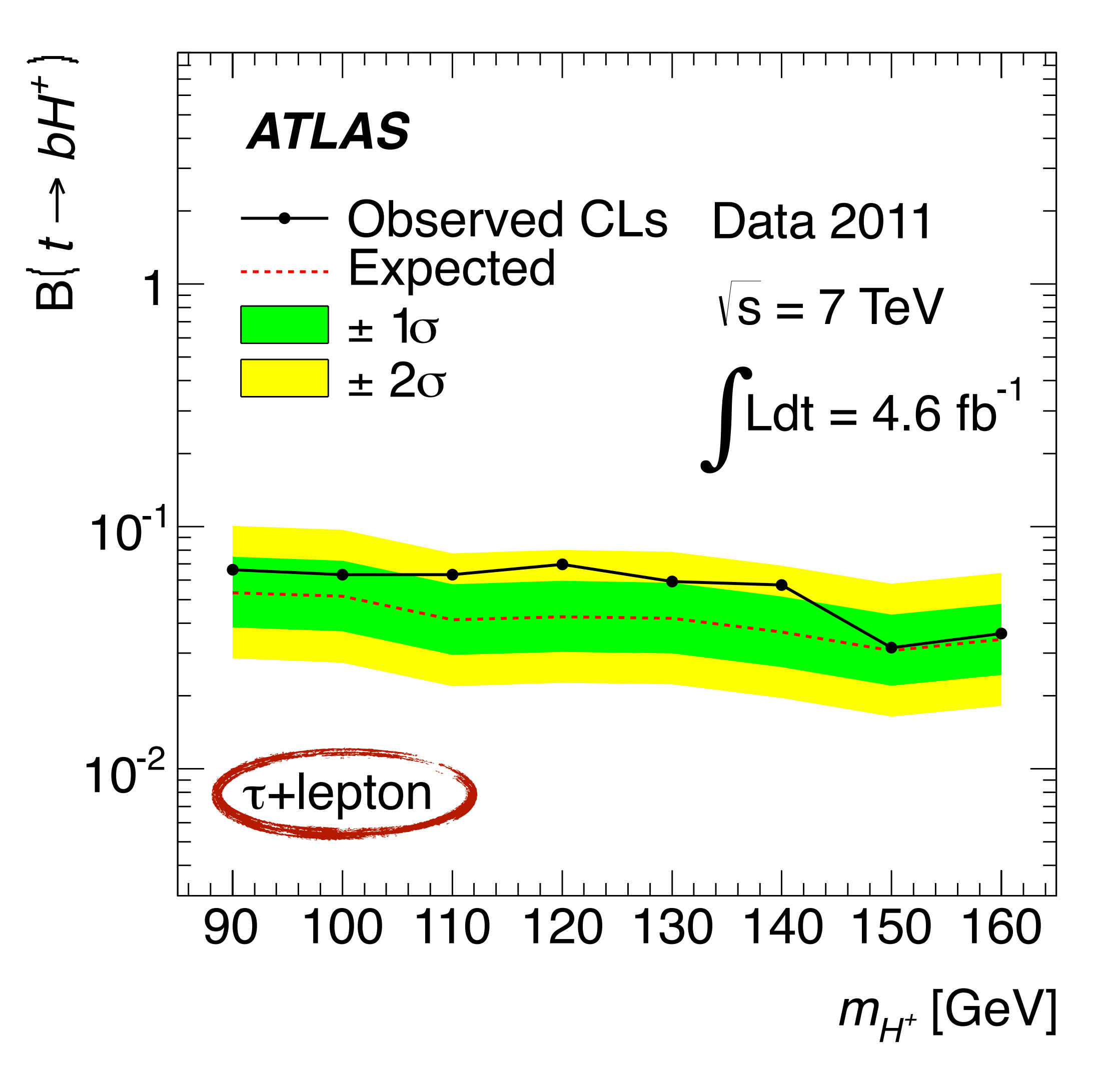
$H^{\pm} \rightarrow \tau\upsilon$ + lepton

B($t \rightarrow bH^{+}$) **limits**



assuming $\mathcal{B}(H^{+} \rightarrow \tau\nu) = 100\%$

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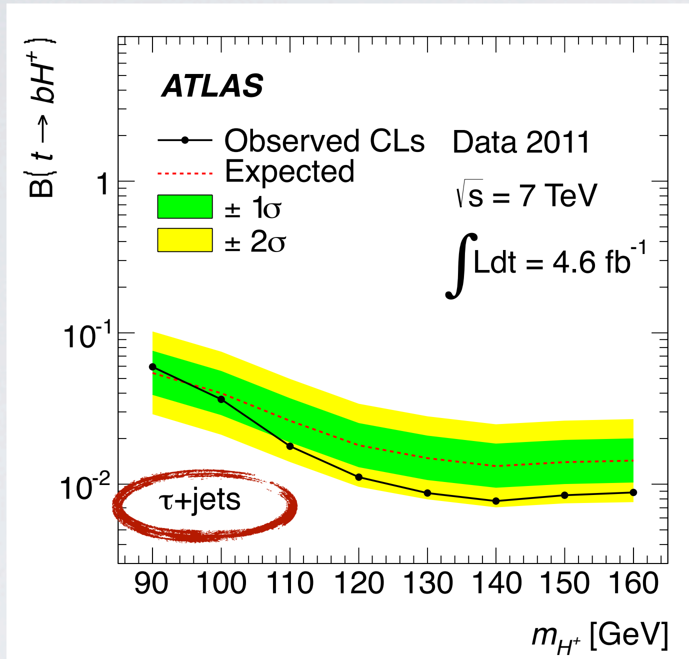
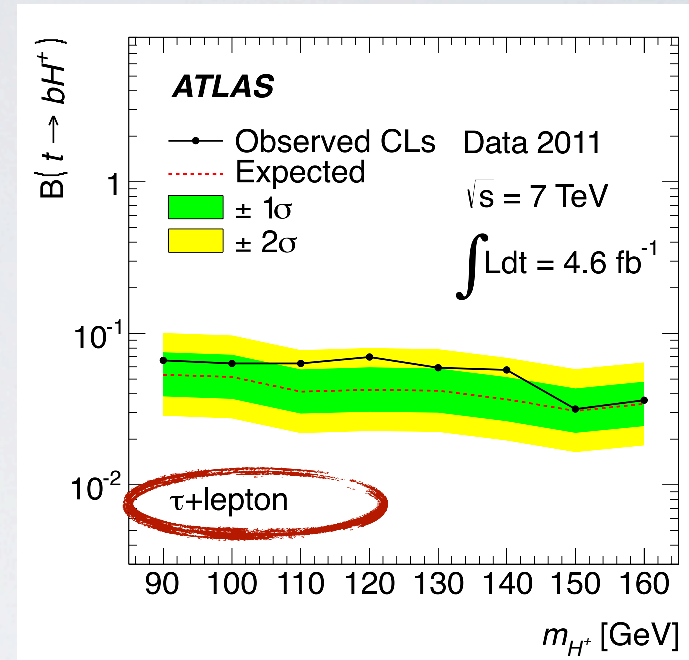
$B(t \rightarrow b\mathbf{H}^{\pm})$ limit combination





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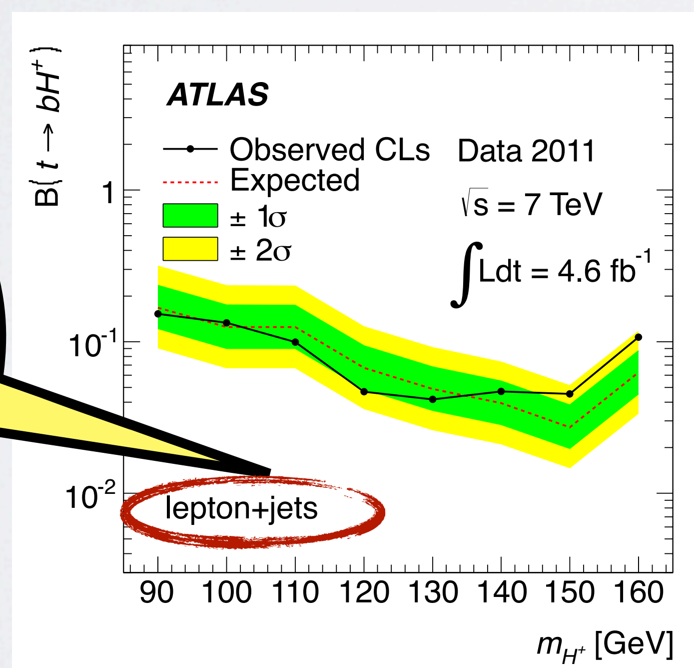
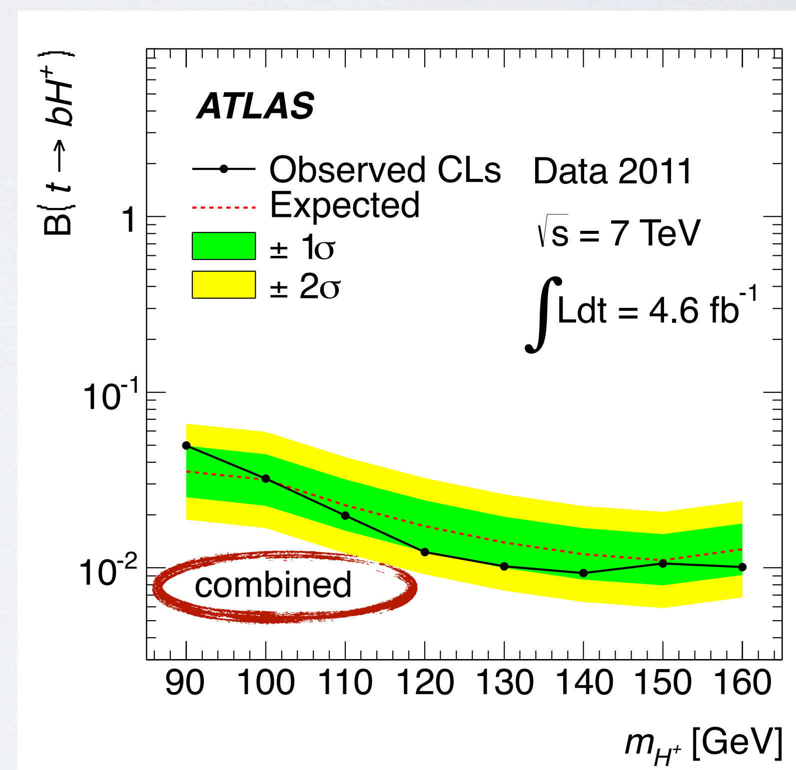


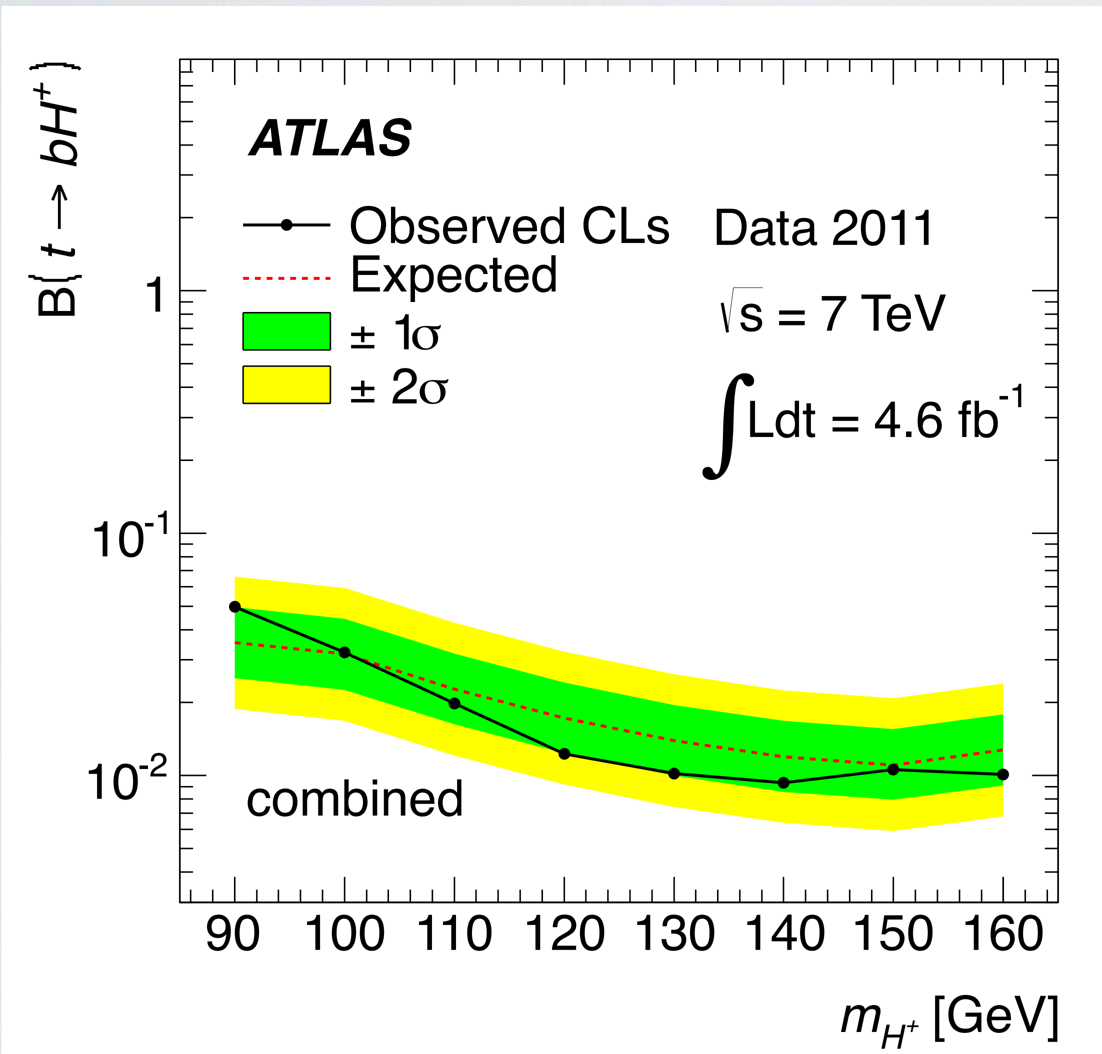


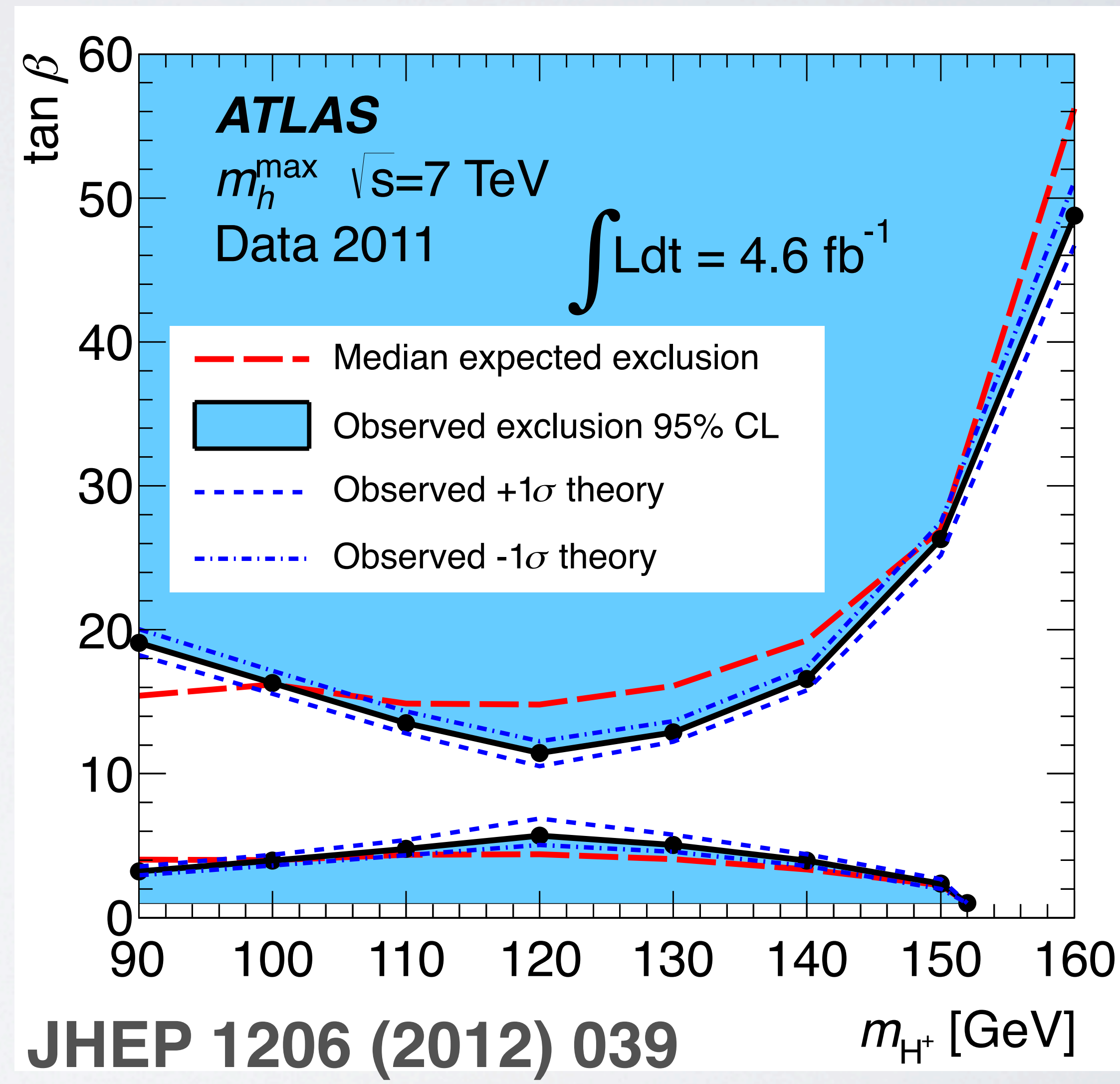
See Catrin's talk!

assuming $\mathcal{B}(H^+ \rightarrow \tau\nu) = 100\%$

$B(t \to bH^{\pm})$ limit

$B(t \to bH^{+})$ **limits** and **MSSM** interpretation of search results





assuming $\mathcal{B}(H^{+} \to \tau\nu) = 100\%$

CONCLUSION(S)

- in the mass range between: **90** $\leq m_{H^\pm} \leq$ **160** GeV upper **limits** on the branching ratio B($t \rightarrow bH^+$) between **5 % – 1 %** can be set

- in context of the m_h^{max} scenario of the MSSM tan β above **12 – 26** (and **1 to 2 – 6**) can be excluded within **90** $\leq m_{H^\pm} \leq$ **150** GeV

- looking forward to updated results with the 2012 data collected at $\sqrt{s}$ = 8 TeV - already now ~3x the statistics of 2011 collected and especially the heavy $H^\pm$ search (I bet You are too!)

THANK YOU FOR YOUR ATTENTION !

(and of course all the hard-working analyzers - rock on!)

Backup slides following

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$H^{\pm} \rightarrow \tau\nu$ + jets Uncertainties

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Source of uncertainty	Normalisation uncertainty	Shape uncertainty
τ+jets: true τ		
Embedding parameters	6%	3%
Muon isolation	7%	2%
Parameters in normalisation	16%	-
τ identification	5%	-
τ energy scale	6%	1%
τ+jets: jet $\rightarrow \tau$ misidentification		
Statistics in control region	2%	-
Jet composition	12%	-
Purity in control region	6%	1%
Object-related systematics	21%	2%
τ+jets: $e \rightarrow \tau$ misidentification		
Misidentification probability	22%	-
τ+jets: multi-jet estimate		
Fit-related uncertainties	32%	-
$E_{\mathrm{T}}^{\mathrm{miss}}$-shape in control region	16%	-

$H^{\pm} \to \tau\nu$ + lepton Uncertainties

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Source of uncertainty	Normalisation uncertainty	Shape uncertainty
τ+lepton: jet $\to \tau$ misidentification		
Statistics in control region	2%	-
Jet composition	11%	-
Object-related systematics	23%	3%
τ+lepton: $e \to \tau$ misidentification		
Misidentification probability	20%	-
τ+lepton: lepton misidentification		
Choice of control region	4%	-
Z mass window	5%	-
Jet energy scale	14%	-
Jet energy resolution	4%	-
Sample composition	39%	-