Physics Searches with Tau Final States at ATLAS

Stan Lai

Universität Freiburg

on behalf of the
ATLAS Collaboration

Workshop on Tau Lepton Decays
Cracow, Poland
17. May 2012

FSP 101 ATLAS

Bundesministerium
für Bildung
und Forschung

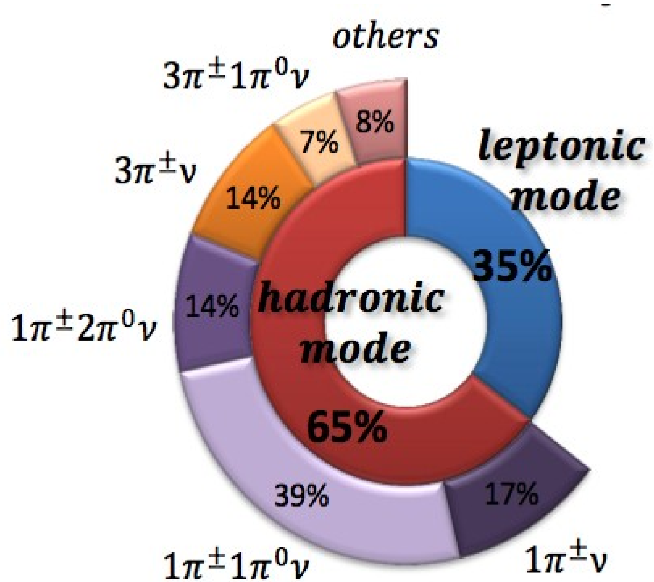
The Tau Lepton

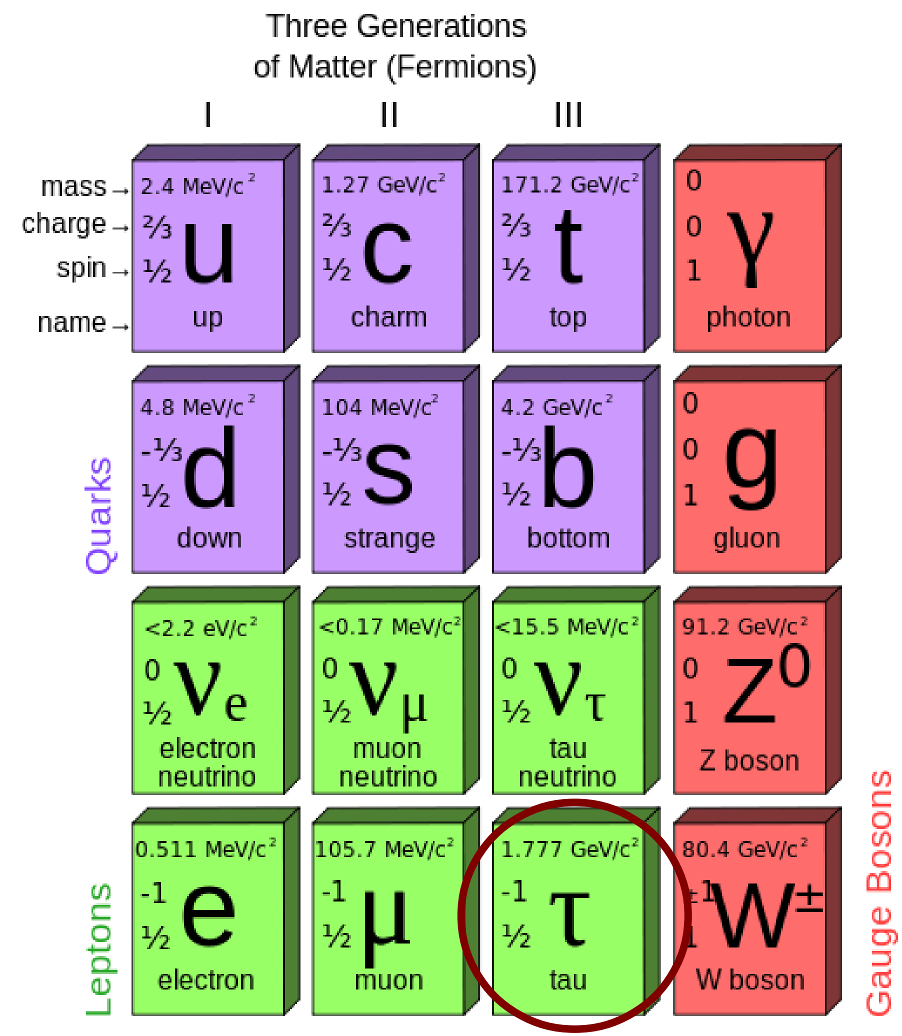
The tau lepton: heaviest lepton observed,
excellent probe of new physics (m_τ = 1.78 GeV)

- good probe for new particles whose couplings increase with mass

- tau polarization observables can test predictions of particle decays to left/right-handed tau leptons

Tau identification is challenging at hadron colliders
(see talk by M. Flechl)

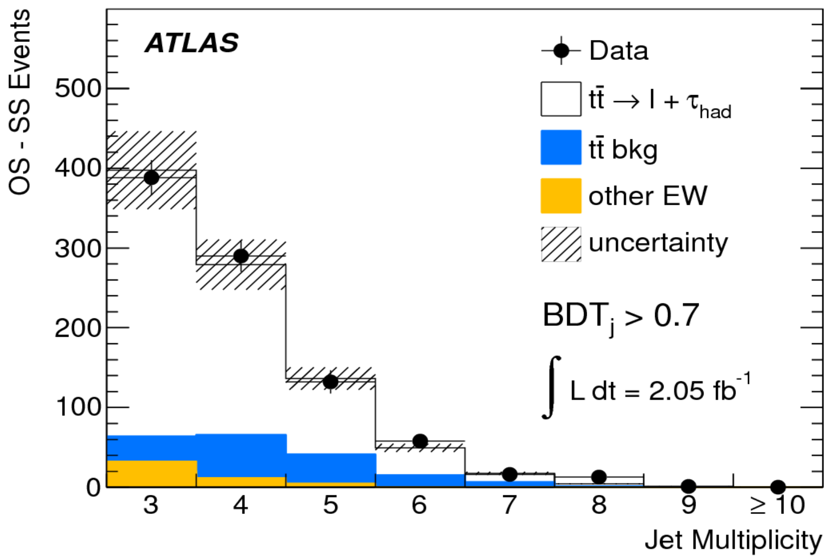


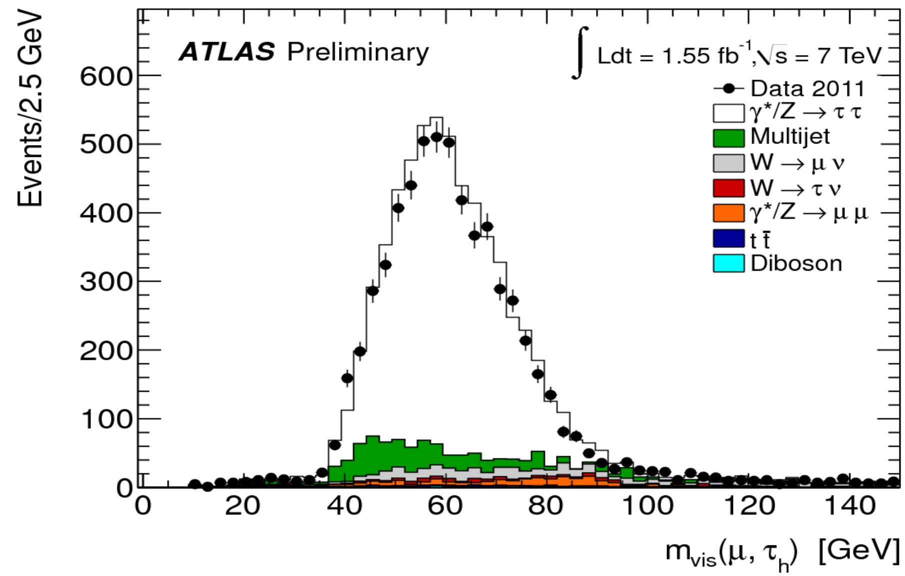


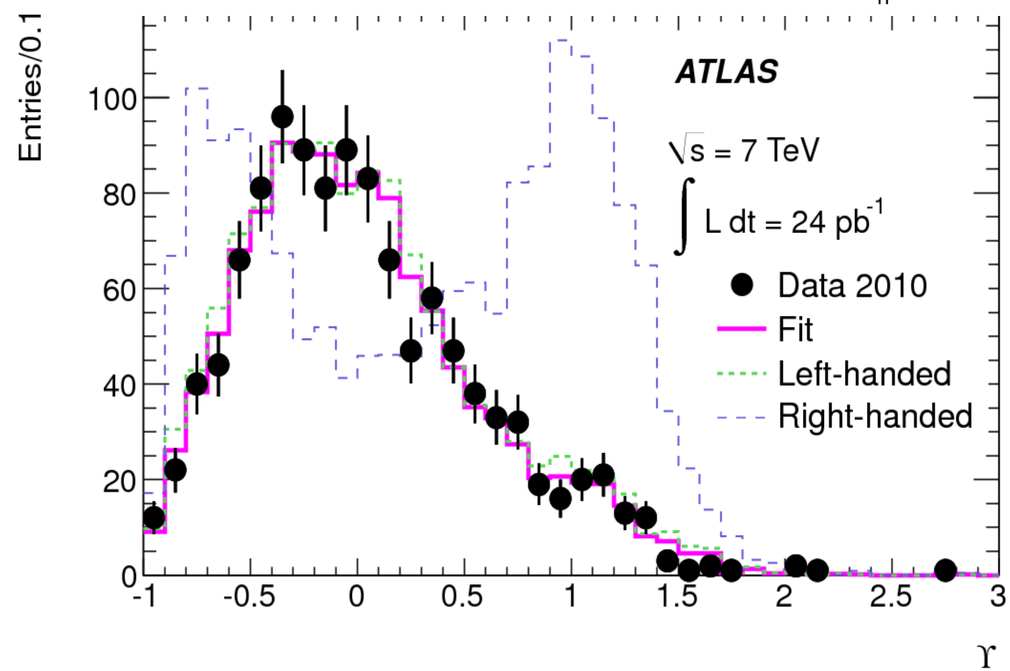
The ATLAS Tau Physics Program

ATLAS tau physics program includes:

- cross-section measurements for SM processes
- tau polarization measurement (W decays)







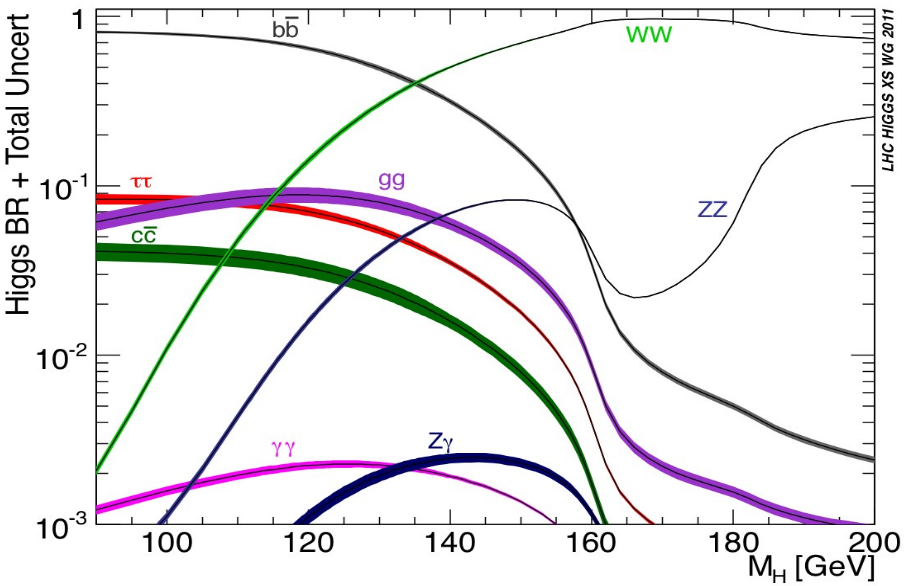
This talk focuses on searches

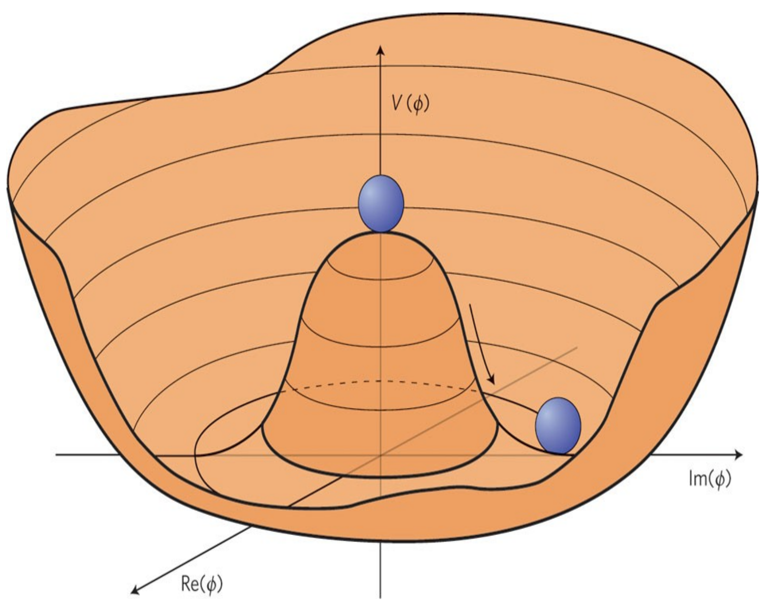
- Standard Model Higgs bosons
- supersymmetry with tau final states
- MSSM Higgs bosons (charged/neutral)

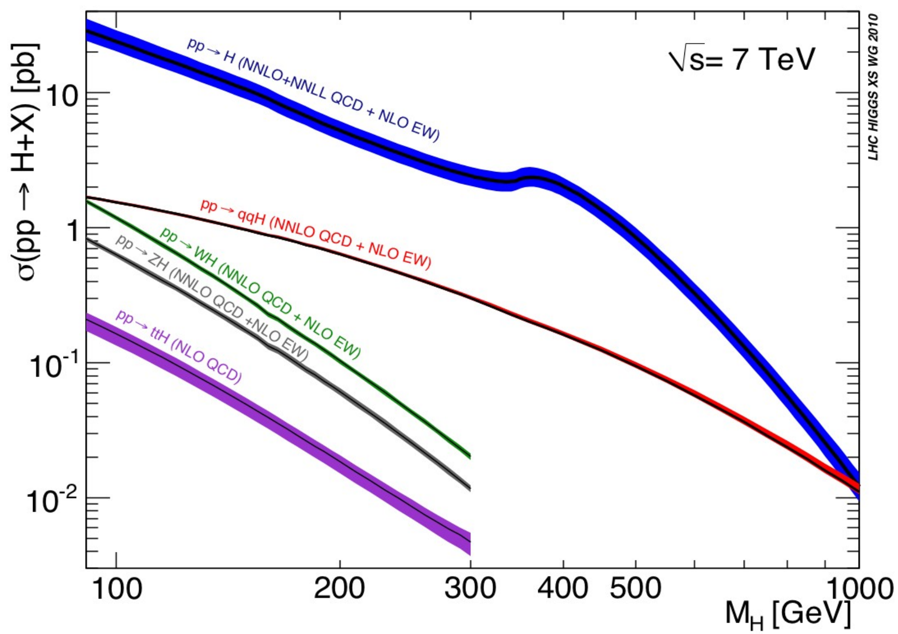
The Standard Model Higgs Boson

Higgs mechanism:

- minimal SM electroweak symmetry breaking
- provides mass to vector bosons (and fermions)
- physical manifestation of scalar field:
  Higgs boson







Standard Model $H \to \tau\tau$ Search

lepton-lepton	lepton-hadron	hadron-hadron
ee/μμ/eμ	$e\tau_h/\mu\tau_h$	$\tau_h\tau_h$

Further division of channels based on additional jets in event:

- 0 jets (lep-lep, lep-had)
- 1-jet (lep-lep, lep-had, had-had)
- 2-jet VBF selection (lep-lep, lep-had)
- 2-jet VH selection (lep-lep)

Background estimation:

- multi-jet background from data
- misidentified tau decays: corrected using data
- Z+jets events: embed tau leptons in $Z \to \mu\mu$ events

Mass Reconstruction for ττ

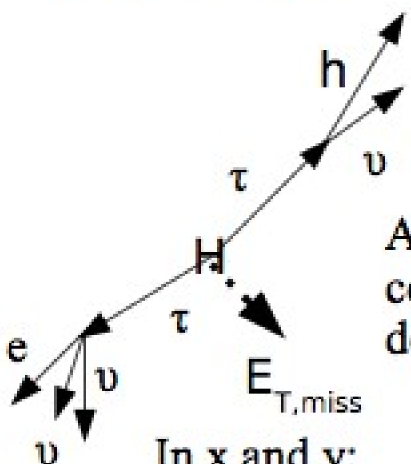
Three mass reconstruction methods used for the different H→ττ

Effective mass

$$m_{\tau\tau}^{\text{effective}} = \sqrt{(p_e + p_\mu + p_{E_T^{miss}})^2}$$

$$p_{E_T^{miss}} = (E_T^{miss}, E_x^{miss}, E_y^{miss}, 0)$$

Collinear Mass



Assume neutrinos are collinear to visible decay products

In x and y:
Sum of neutrino momenta equal to $E_{T,miss}$
→ 2 equations, 2 unknowns

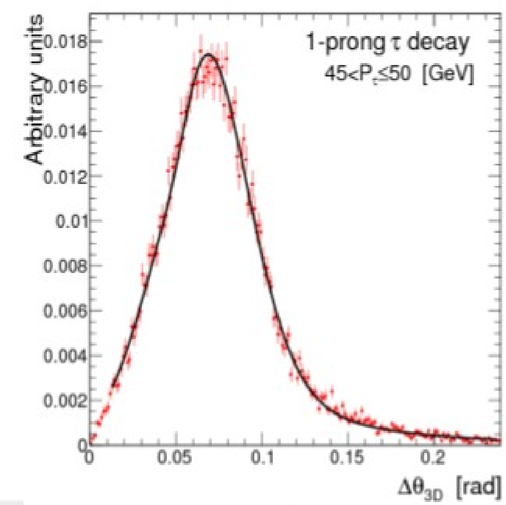
MMC Mass

Elagin et al., NIM A654 (2011) 481

Collinearity requirement relaxed
→ 7 unknowns,from neutrino 4 vector
→ 4 equations: 2x τ mass, $E_{x,miss}$ $E_{y,miss}$

Scan over
- mass(υ,υ)
- $\Delta\varphi_1$(υ, h),
- $\Delta\varphi_2$(υ, l)

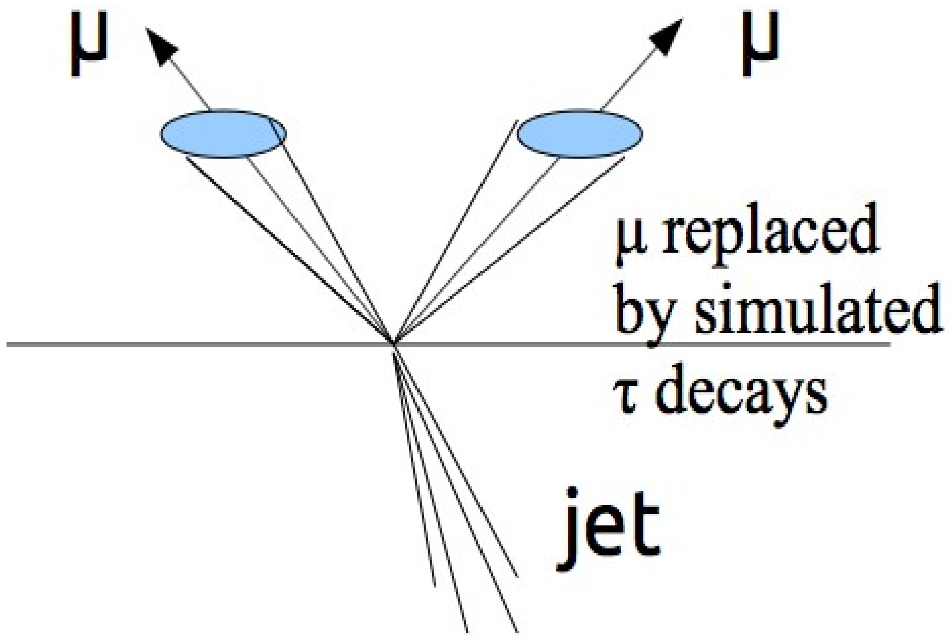
weight with PDF

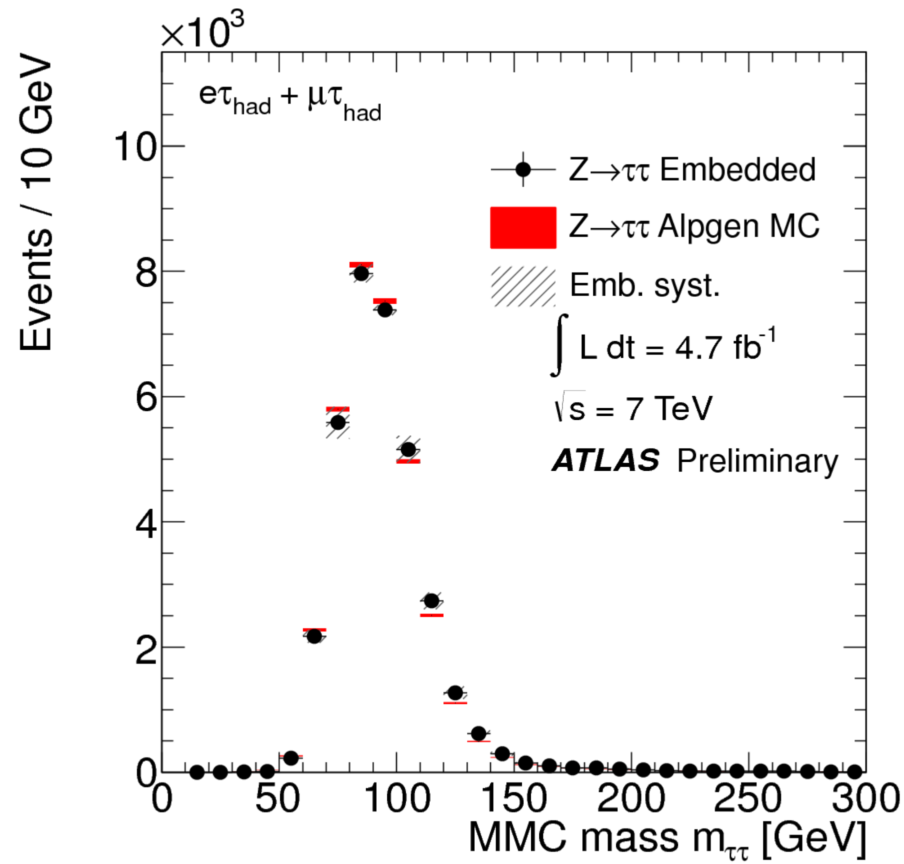


Z+jets Events and Embedding

Irreducible background from $Z \rightarrow \tau\tau$ + jets events

- usage of embedding reduces systematic uncertainties on missing transverse energy, pileup effects, underlying event, jet multiplicity, etc.





SM $H \rightarrow \tau\tau \rightarrow ll + 4\nu$

Subchannels:

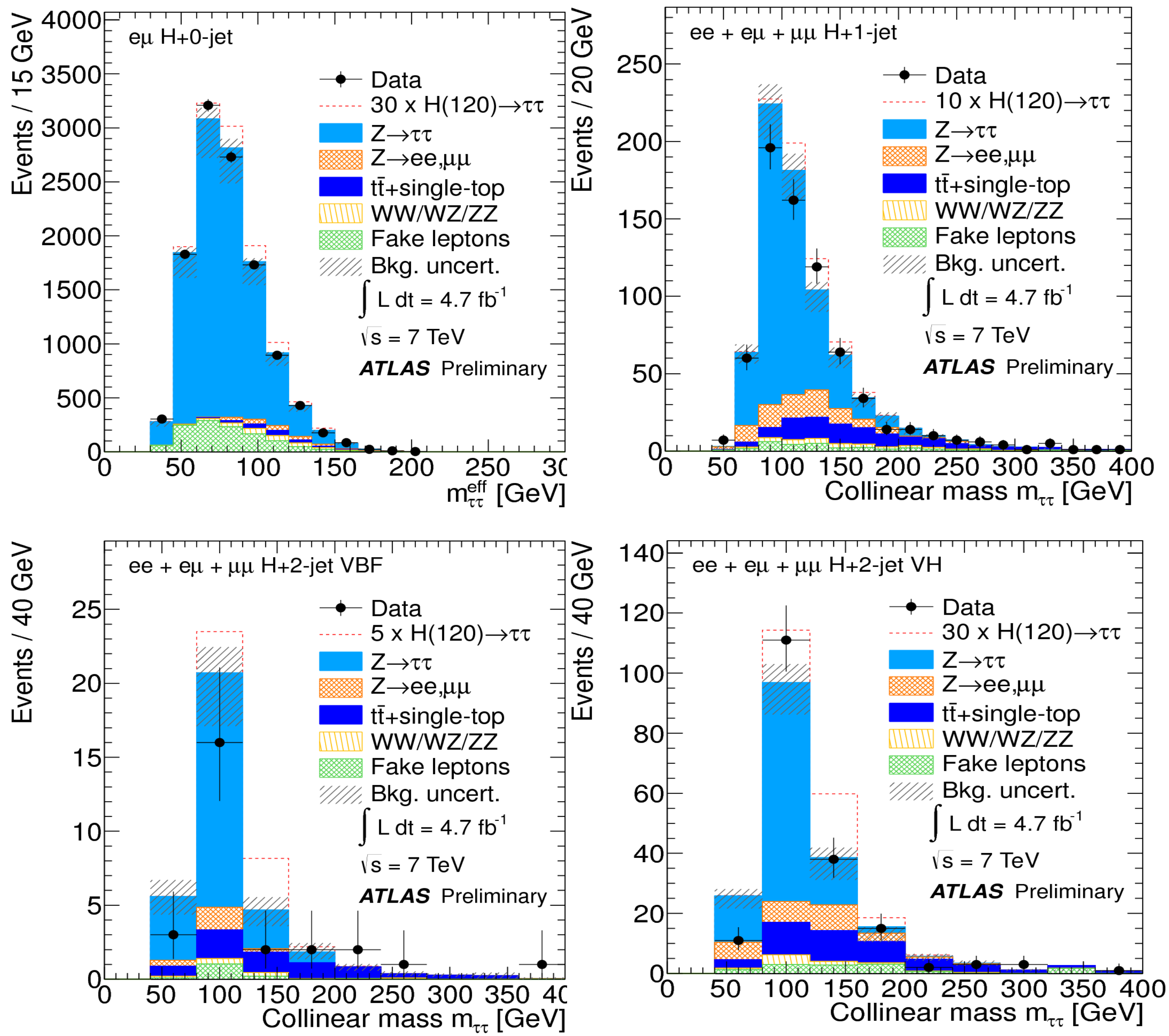
0-jet: eμ, m_{eff}
$p_T^e + p_T^\mu + E_T^{miss} < 120$ GeV

1-jet: ee,μμ,eμ
$p_T^{jet} > 40$ GeV, $m_{\tau\tau j} > 225$ GeV

2-jet VBF: ee,μμ,eμ
$p_T^{jet} > 40/25$ GeV, $\Delta\eta_{jj} > 3$,
central jet veto, $m_{jj} > 350$ GeV

2-jet VH: ee,μμ,eμ
$p_T^{jet} > 40/25$ GeV, $\Delta\eta_{jj} < 2$,
$50 < m_{jj} < 120$ GeV

fake lepton backgrounds:
template fit on lepton isolation



SM $H \rightarrow \tau\tau \rightarrow l\tau_h + 3\nu$

Subchannels:

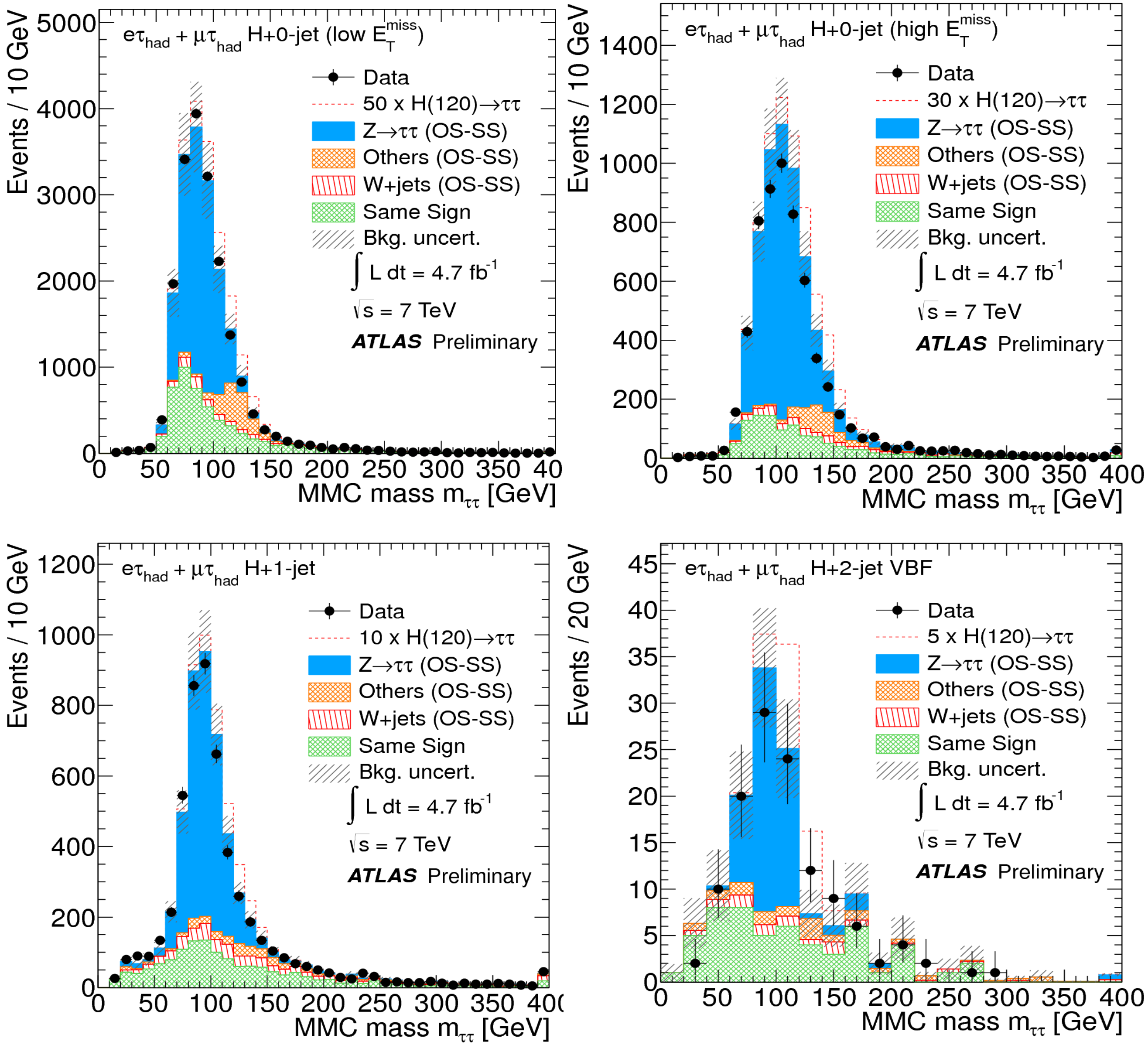
0-jet: consider separately
$E_T^{miss} > 20$ and $E_T^{miss} < 20$ GeV

1-jet: $p_T^{jet} > 20$ GeV
$E_T^{miss} > 20$ GeV

2-jet VBF: $p_T^{jets} > 20$ GeV
$\Delta\eta_{jj} > 3$, $m_{jj} > 300$ GeV
(jets in opposite hemisphere)

multi-jet backgrounds:
evaluate using same-sign region

W+jets MC corrected by
scaling factor in high m_T-region

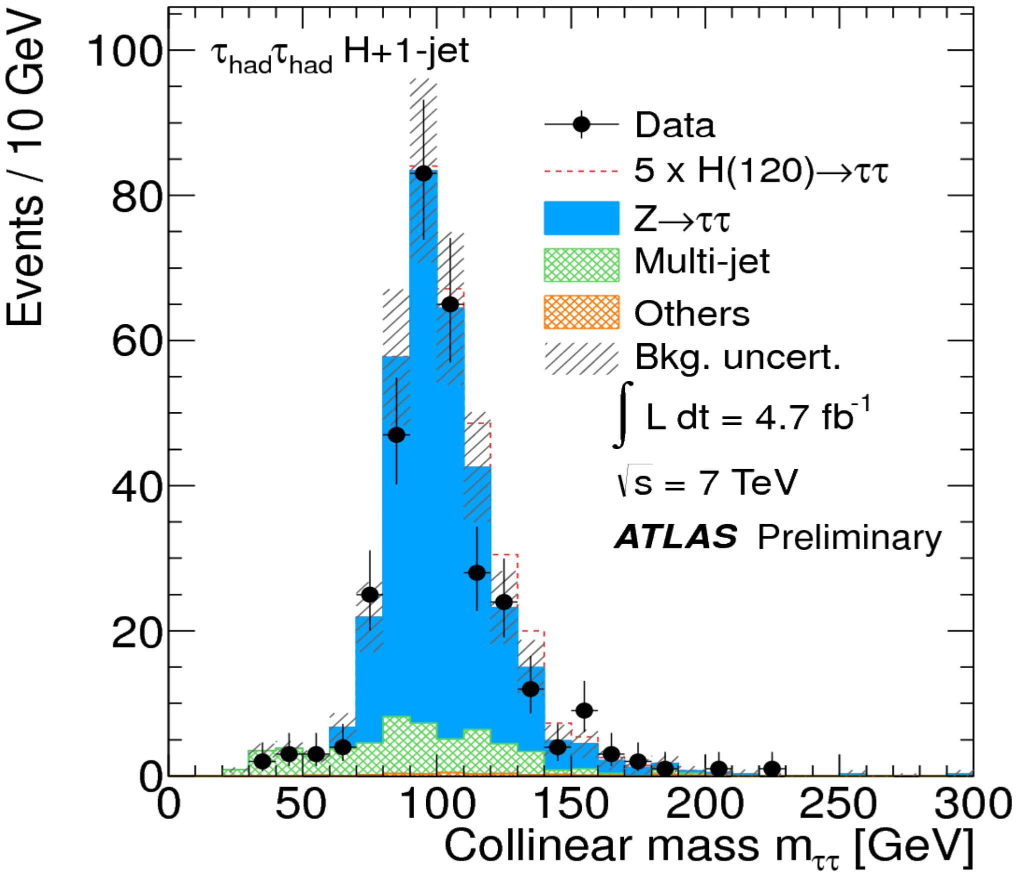


SM $H \rightarrow \tau\tau \rightarrow \tau_h \tau_h + 2\nu$

Trigger: double τ_h trigger (τ_{h1} > 35, τ_{h2} > 25 GeV)

1 jet selection:

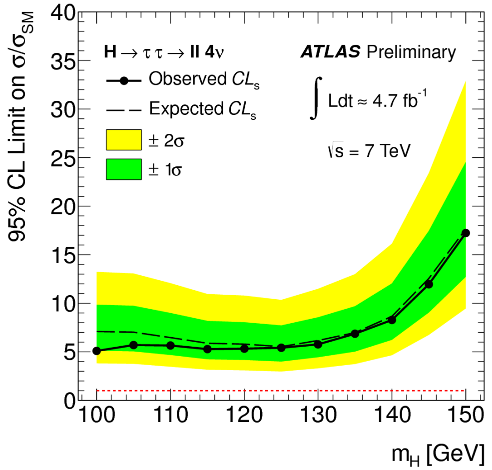
- jet p_T > 40 GeV
- E_T^{miss} > 20 GeV
- $m_{\tau\tau j}$ > 225 GeV
- collinear mass: physical solution required

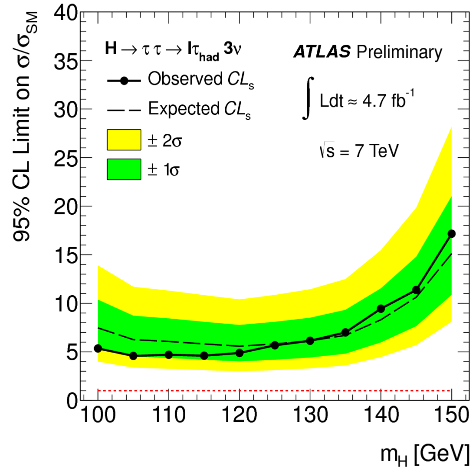


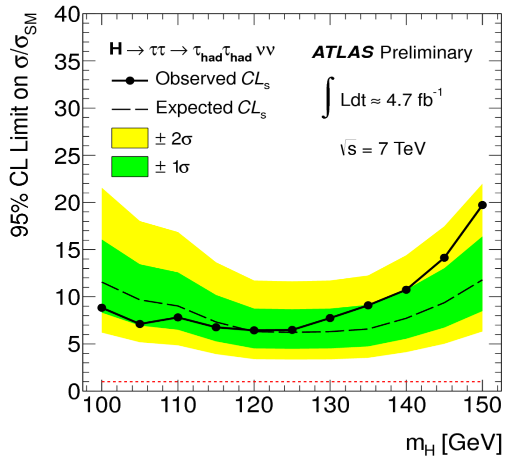
Multijet background estimation:

- 2D template fit of tau track multiplicity for both tau candidates

Standard Model H→ττ Limits

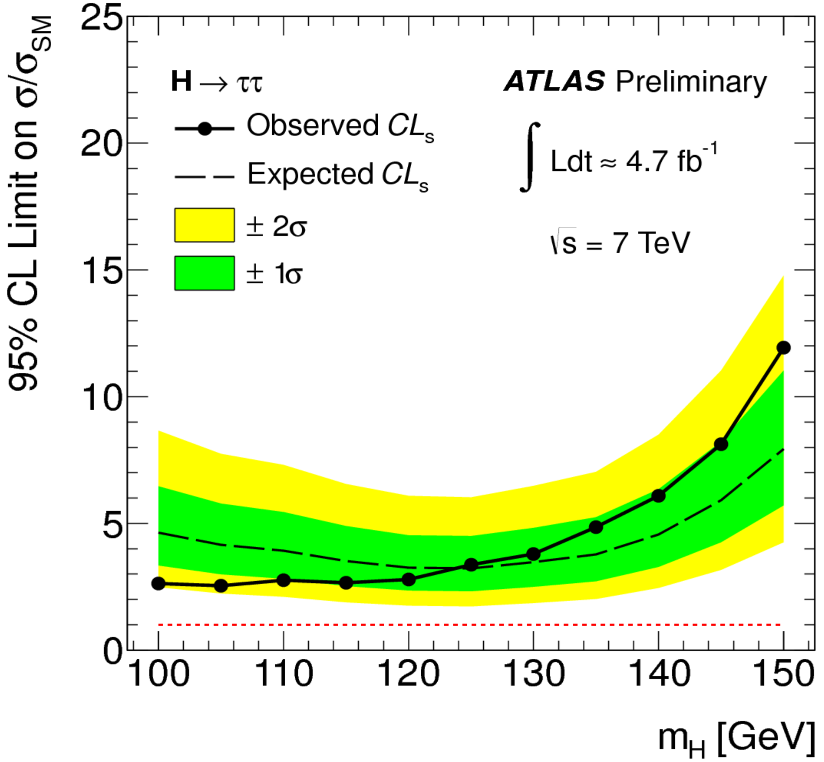




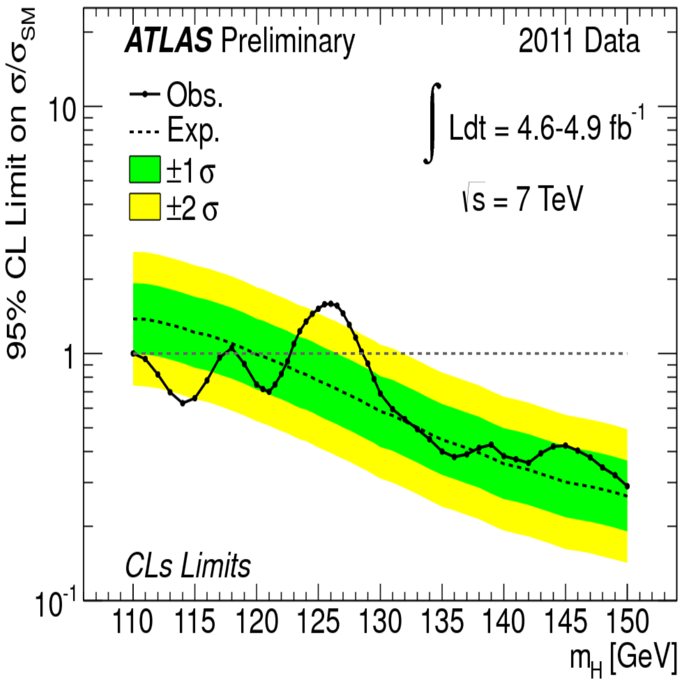


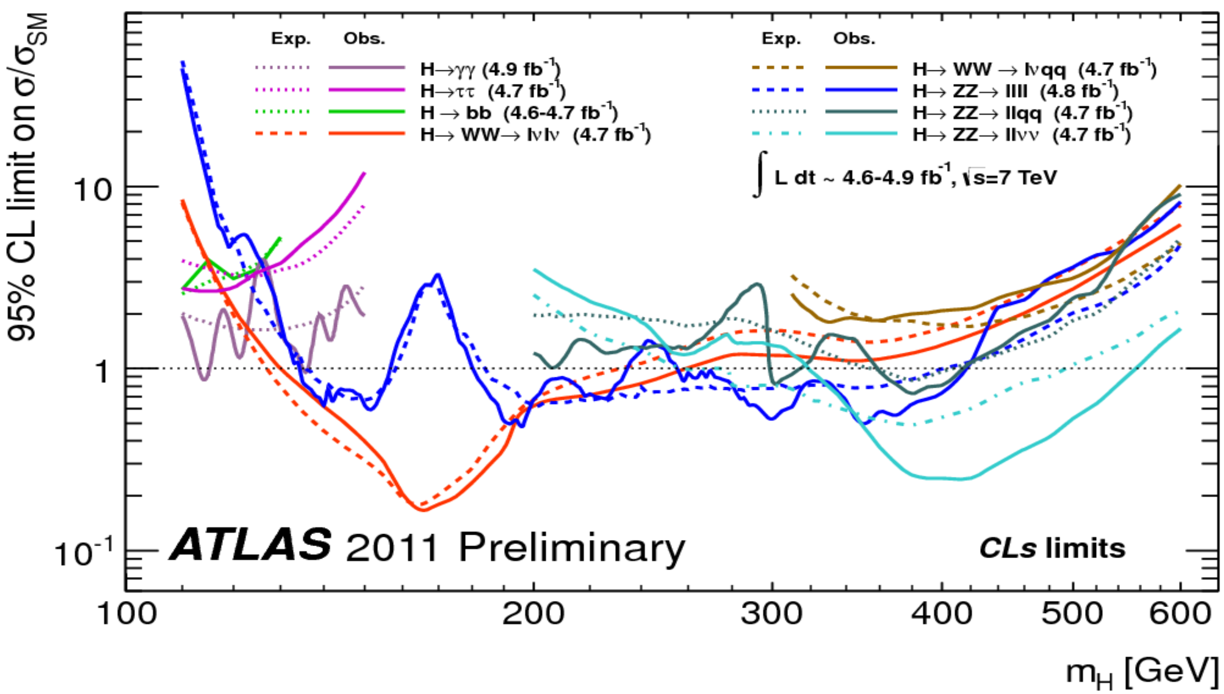
No excess of events seen in any channel

95% CL_S limits set as a function of m_H



Standard Model Higgs Limits

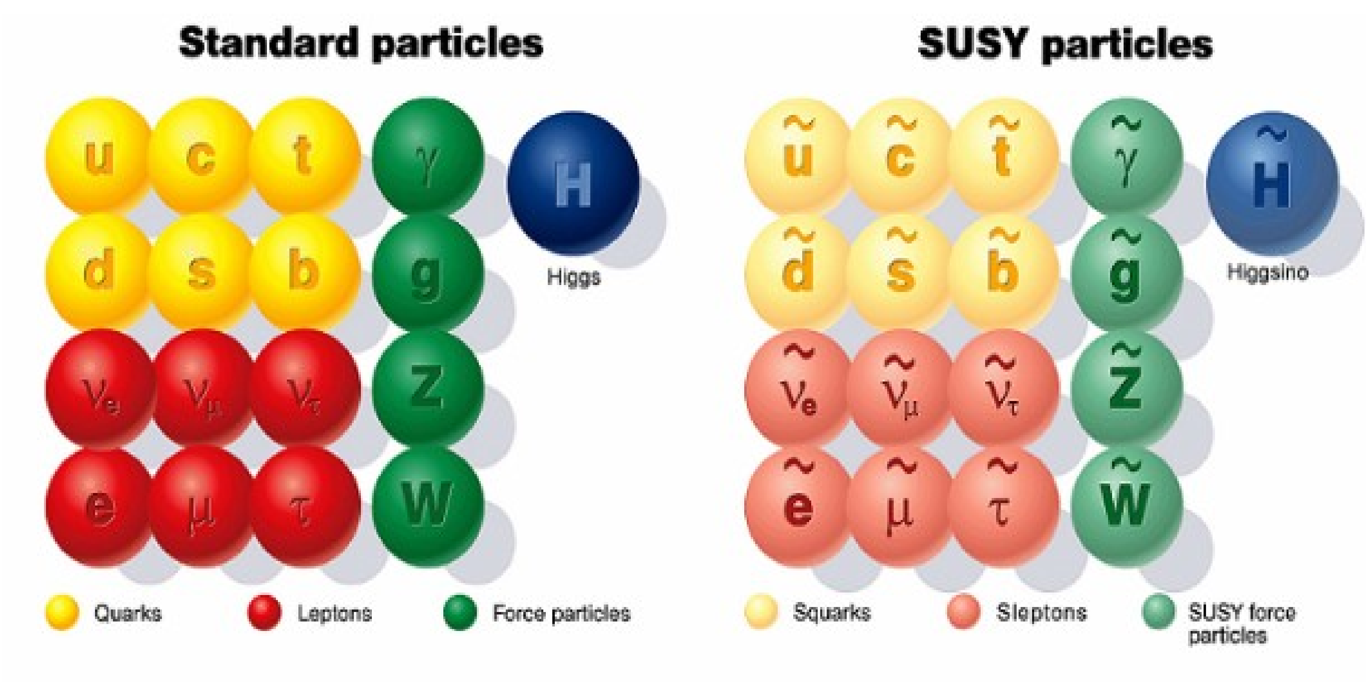




Supersymmetry

SUSY: well-studied extension of the Standard Model
- all SM particles have "superpartners" (same properties except spin differing by $\hbar/2$)
- broken symmetry, since we have not yet observed SUSY particles

Properties
- can provide suitable dark matter candidate (Lightest SUSY Partner)
- can naturally reduce fine-tuning in hierarchy problem
  [provided relevant mass scales are O(1 TeV)]



Phenomenology dependent on SUSY breaking mechanism

mSUGRA
- SUSY breaking mediated by gravitational-sector (LSP: gravitino)

GMSB
- SUSY breaking mediated by gauge interactions of a messenger sector

Supersymmetry and Tau Leptons

The 3rd generation in SUSY can provide for interesting phenomenology:

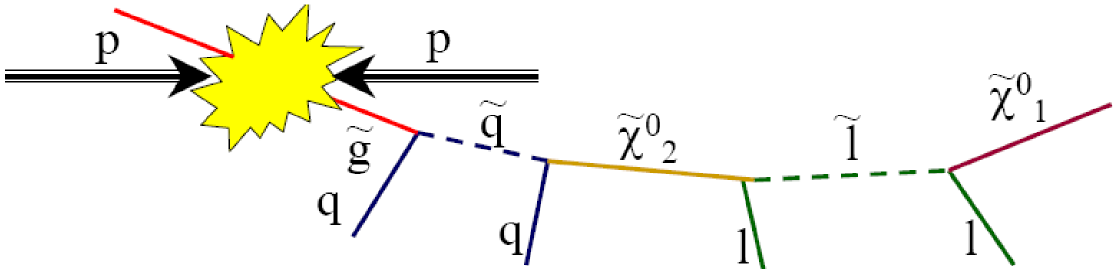
large mixing between left- and right-handed sfermions

→ lightest slepton is the stau (often the NLSP in GMSB models)

→ LSP becomes the gravitino or neutralino

tau final states provide access to:

- stau masses
- polarization information and couplings of neutralinos, stau, other partners



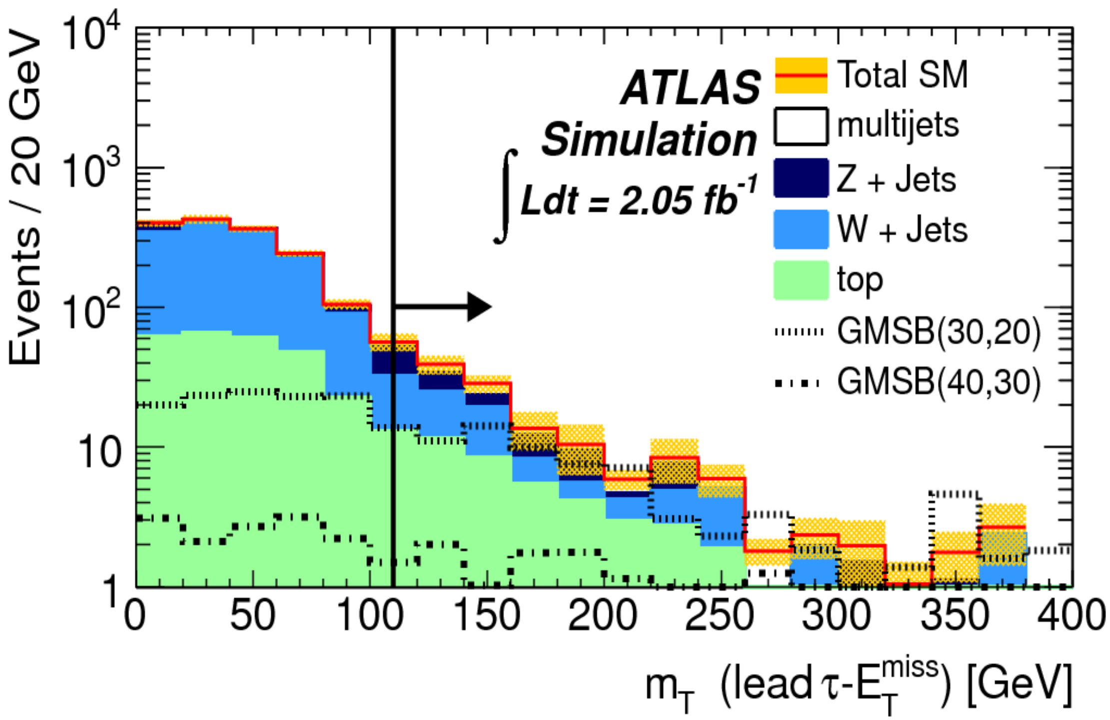
1-tau inclusive SUSY Search: Selection

Object selection:

- Events selected using jet + E_T^{miss} trigger
- one or more tau candidates: p_T > 20 GeV
- p_T^{jet1} > 130 GeV, p_T^{jet2} > 30 GeV
- E_T^{miss} > 130 GeV

Topological selection:

- E_T^{miss} / m_{eff} > 0.25
- $m_T (E_T^{miss}, \tau)$ > 110 GeV
- m_{eff} > 600 GeV



effective mass:

$m_{eff} = p_T^{\tau} + p_T^{jet1} + p_T^{jet2} + E_T^{miss}$

1-tau inclusive SUSY Search: Backgrounds

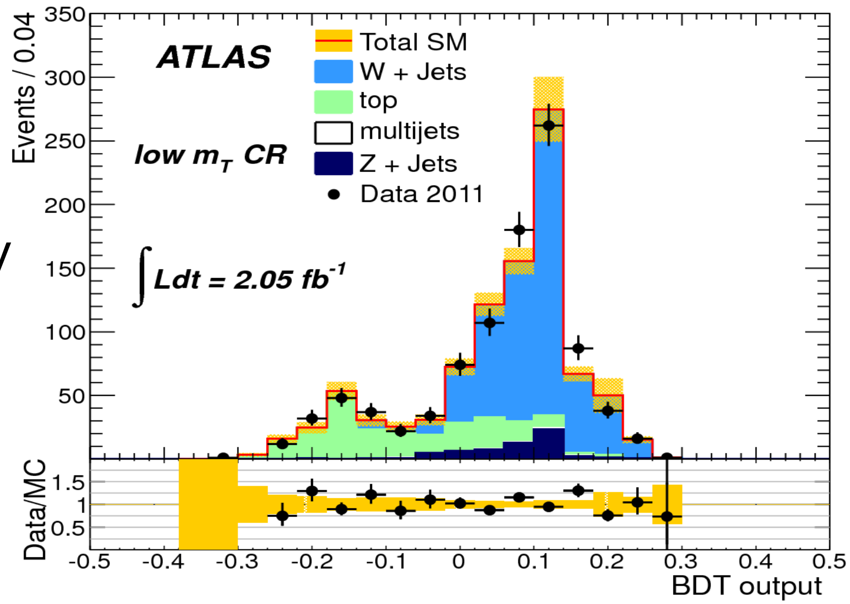
Real tau lepton background: use m_T < 70 GeV

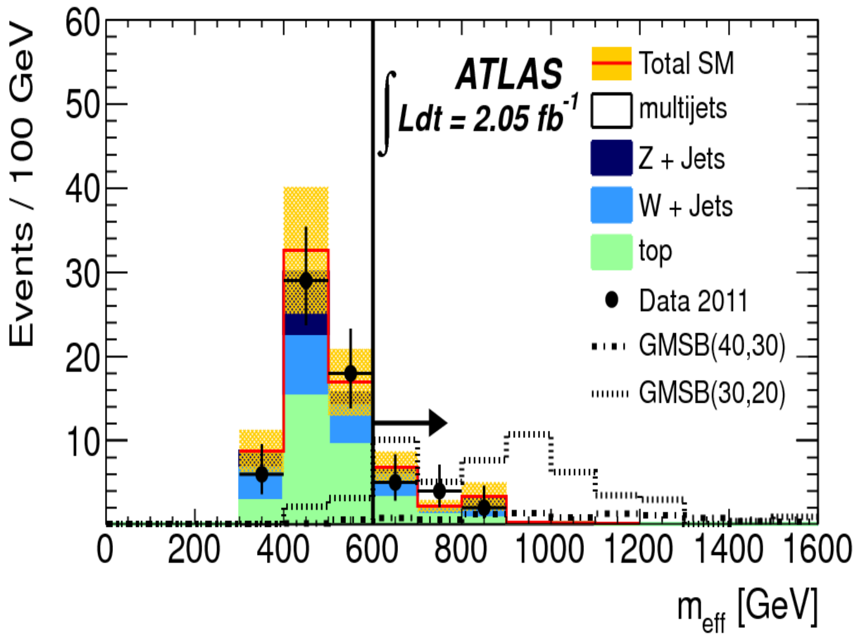
- separate scaling for W+jets and top processes using a BDT output fit to signal region

Fake tau lepton background: m_T < 110 or m_{eff} < 600 GeV

- scaling factor for fake tau candidate events determined

Multijet background only ~1%





Event yields in 2.05 fb^{-1}:

Top	$W+$jets	$Z+$jets	Multijet	Σ_{SM}	Data
5.6 ± 1.4	4.7 ± 1.5	2.4 ± 0.7	0.5 ± 0.6	13.2 ± 4.2	11

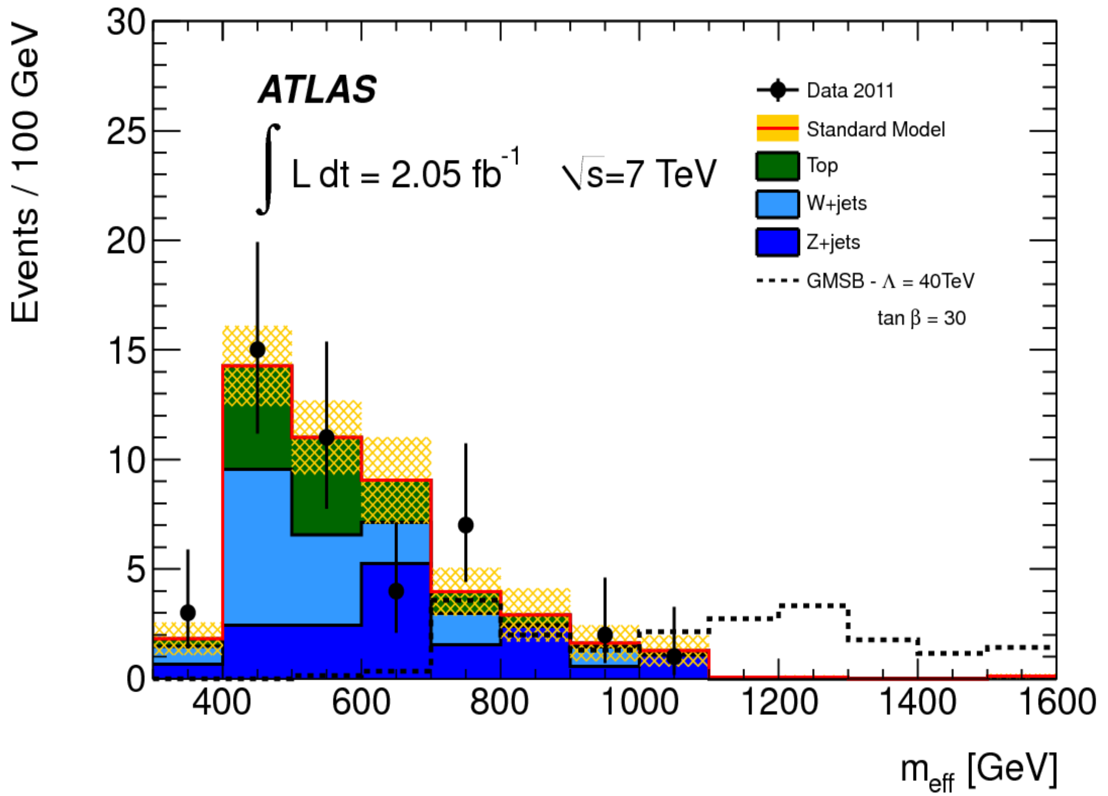
2-tau inclusive SUSY Search: Selection

Object selection:

- Events selected using jet + E_T^{miss} trigger
- at least two tau candidates: $p_T > 20$ GeV
- $p_T^{jet1} > 130$ GeV, $p_T^{jet2} > 30$ GeV
- $E_T^{miss} > 130$ GeV

Topological selection:

- $m_T(E_T^{miss}, \tau_1) + m_T(E_T^{miss}, \tau_2) > 80$ GeV
- $m_{eff} > 700$ GeV
- $\Delta\phi\,(E_T^{miss}, jets) > 0.4$



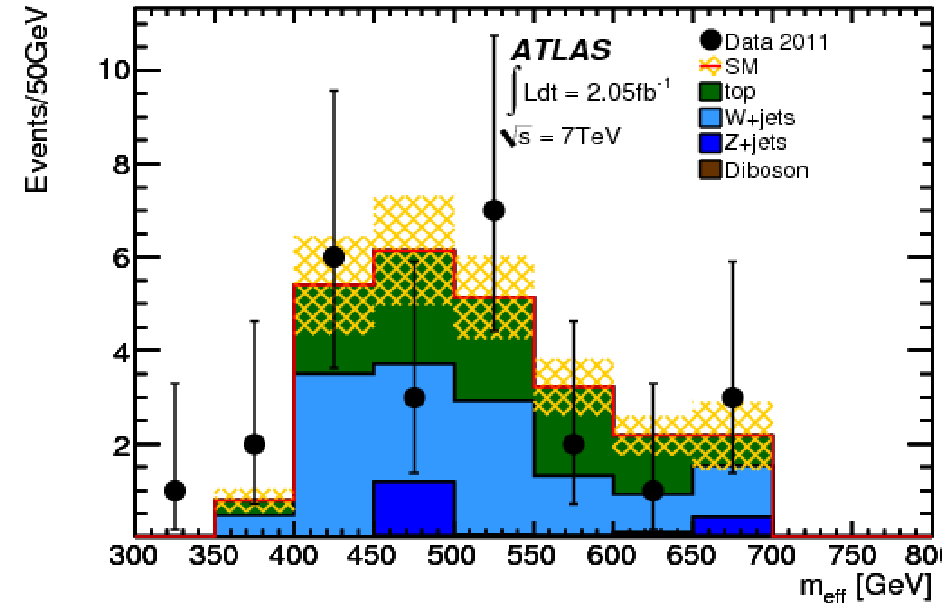
effective mass:

$m_{eff} = \Sigma p_T^{\tau} + p_T^{jet1} + p_T^{jet2} + E_T^{miss}$

2-tau inclusive search: Backgrounds and Results

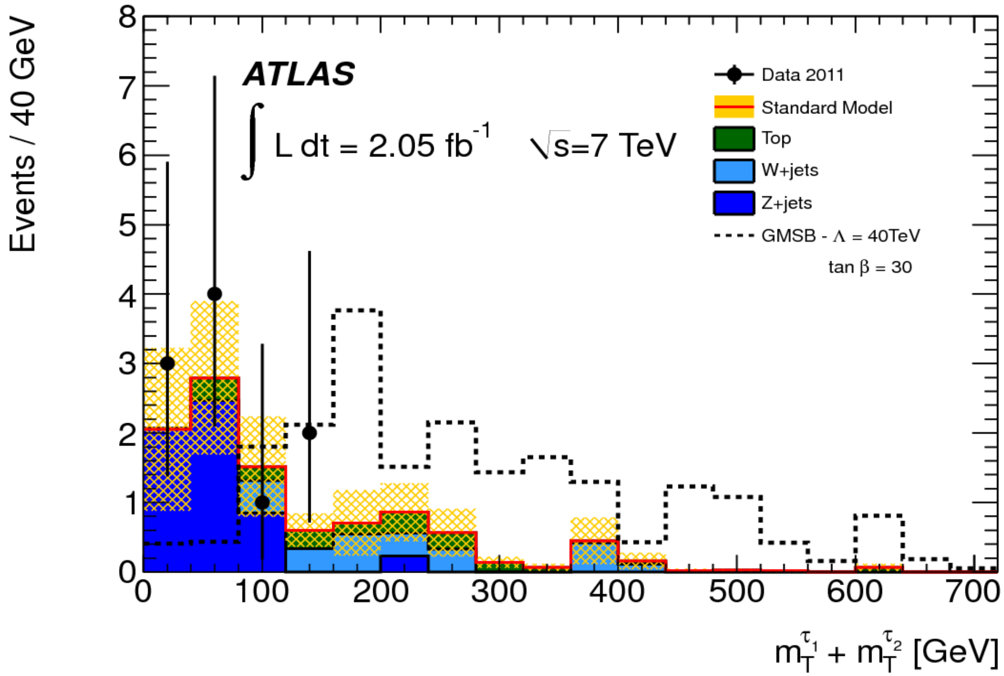
Top and W+jets background estimated by scaling number of events in a control region

- invert m_{eff} cut to obtain top/W-enriched region



Multi-jet background is negligible

- confirmed in control region with $\Delta\phi < 0.4$, $m_{eff} < 700$ GeV, $E_T^{miss}/m_{eff} < 0.4$



Process	Exp. no. events in SR
Data	3
Total background	$5.3 \pm 1.3(\text{stat}) \pm 2.2(\text{sys})$
Drell-Yan	$0 \pm 0 \pm 0$
Di Bosons	$0.135 \pm 0.054 \pm 0.026$
QCD	< 0.01
Z+jets	$1.08 \pm 0.70 \pm 0.63$
Top scaled	$1.57 \pm 0.42 \pm 0.75$
W+jets scaled	$2.5 \pm 1.0 \pm 1.2$

SUSY with taus: Limits

No excess of events observed

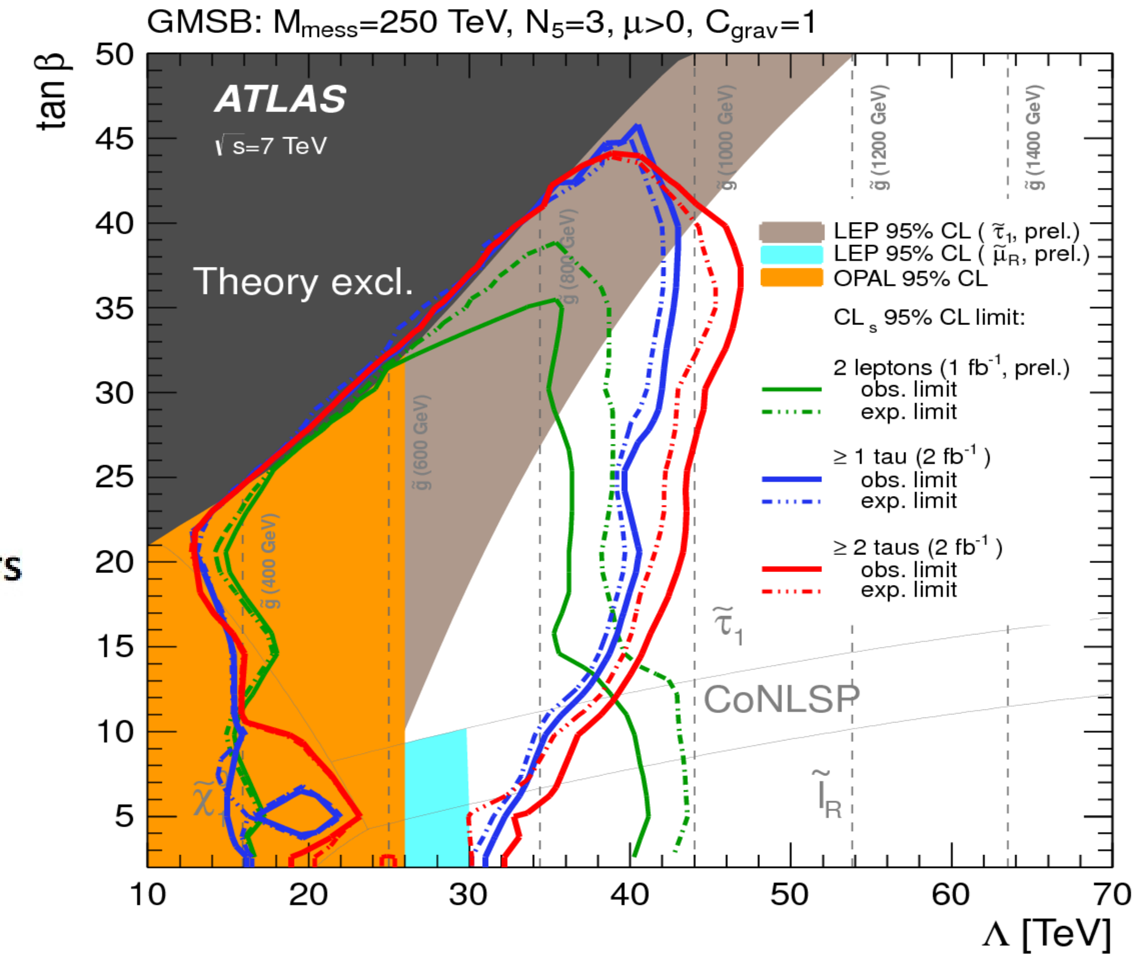
95% CL_S limits set in GMSB parameter-plane

Model considered:

- LSP : Gravitino $(\tilde{G})$ with mass ~keV
- NLSP can be $\tilde{\tau}_1, \tilde{\ell}_R, \tilde{\chi}_1^0, \tilde{\nu}$
- Relevant phenomenological parameters
  - Λ : Signal cross section
  - $\tan\beta$: NLSP

- hypothesis:

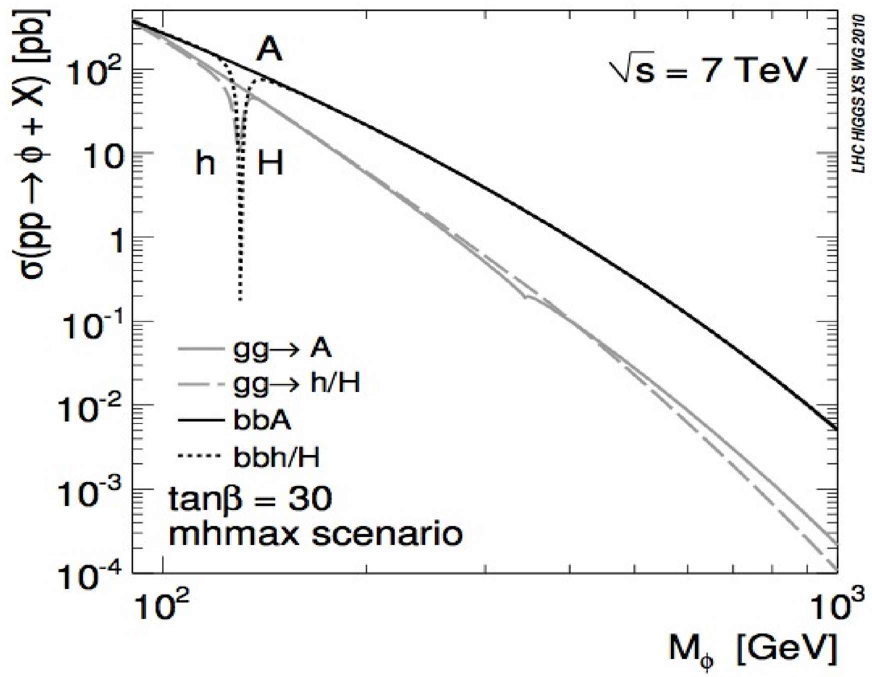
$M_{mess} = 250$ TeV, $N_5 = 3$, $\mu > 0$, $C_{grav} = 1$



The MSSM Higgs Sector

Two Higgs Doublets → 5 Higgs bosons:
- h, H (CP = +1)
- A (CP = -1)
- $H^{\pm}$

Soft-breaking parameters are fixed in benchmark scenarios (i.e. m_H-max)



Neutral MSSM Higgs bosons:

benchmark scenarios (m_H^{max}) constrain model to m_A and tan β

At medium/high tan β:
- decays with BR ~10% to ττ, (~90% to bb)
- production modes: gluon-fusion and b-quark associated production

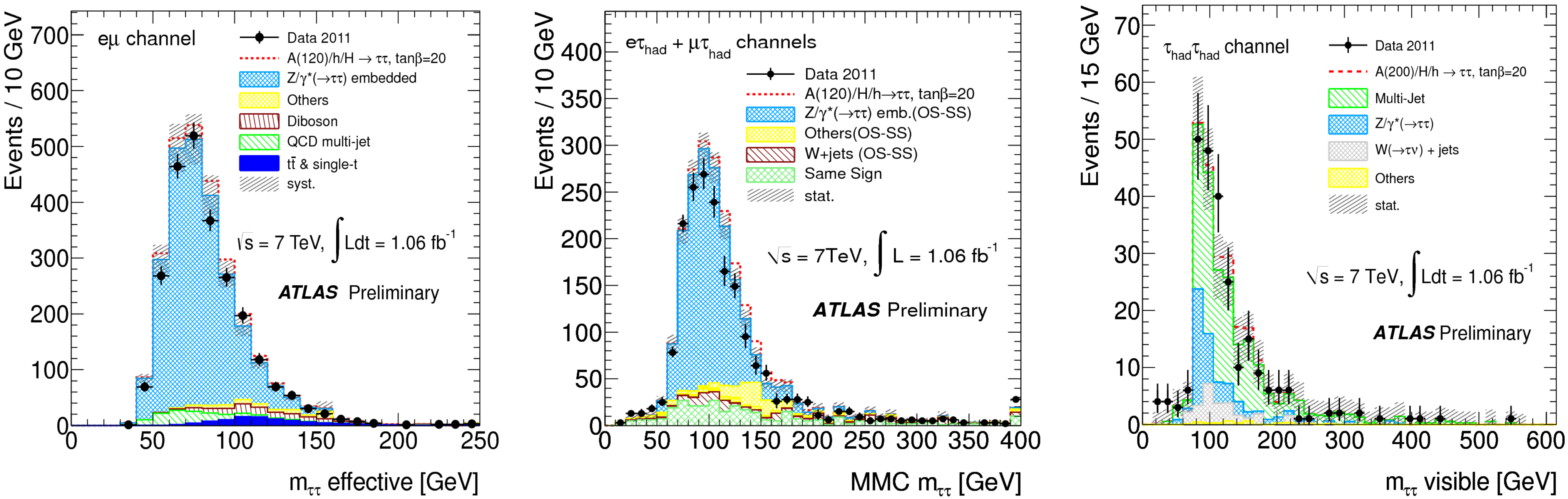
Charged MSSM Higgs bosons:

For $m_{H+} < m_t$:
Production via top quark decays ($t \rightarrow H^+ b$)

$H^+ \rightarrow \tau\nu$ decays preferred for tan β > 3

Neutral MSSM H→ττ

Inclusive selection (no categories based on additional jets)

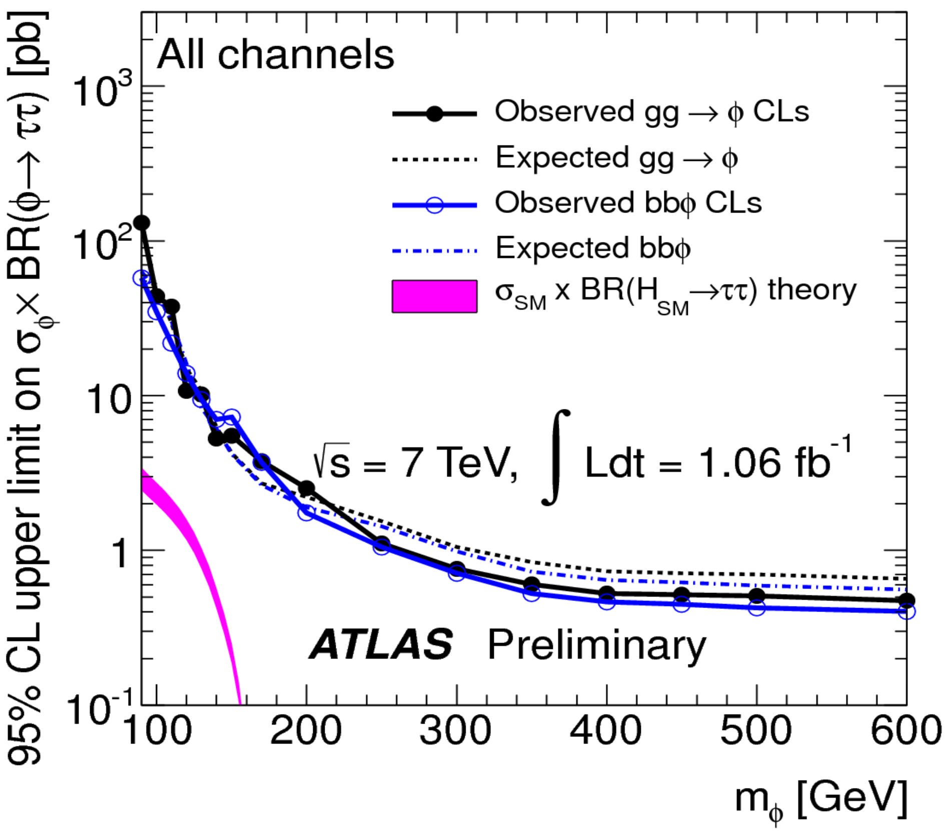


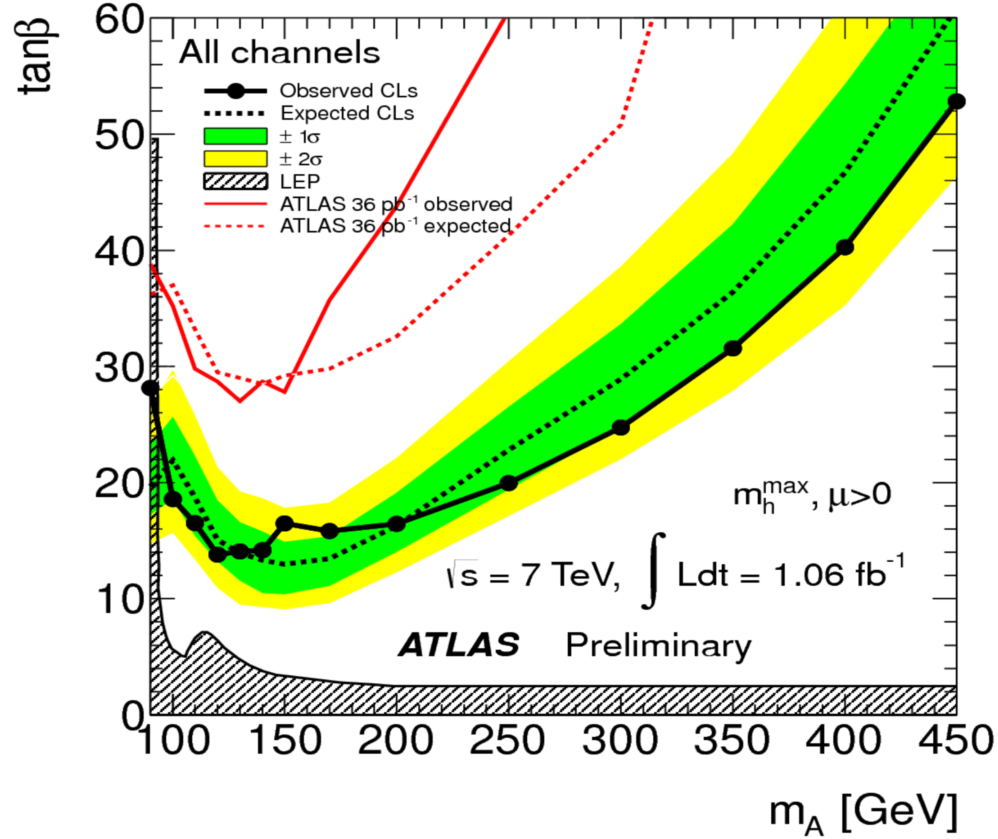
Enhanced branching ratio to ττ for large values of tanβ

Embedding crucial to model irreducible Z→ττ background

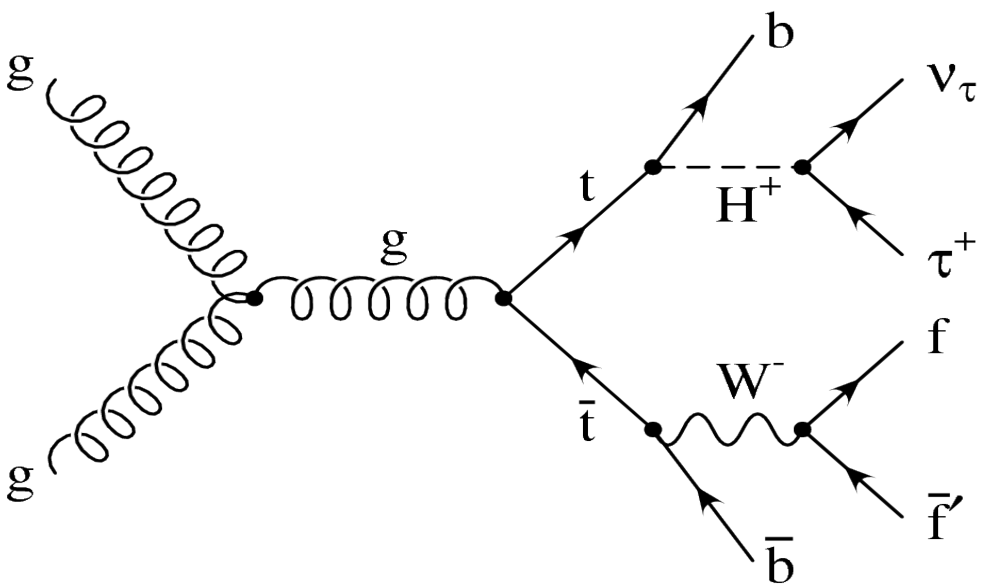
Neutral MSSM H→ττ Limits

MSSM limits on neutral Higgs in 1.1 fb^{-1}





Charged Higgs Search



For $m_{H+} < m_t$ produced via top quark decays ($t \to H^+ b$)

Analysis channels:

$t\bar{t} \to b\bar{b}H^{\pm}W^{\mp} \to b\bar{b}(\tau_{lep}\nu)(q\bar{q})$: *lepton + jets* — single lepton trigger

$t\bar{t} \to b\bar{b}H^{\pm}W^{\mp} \to b\bar{b}(\tau_{had}\nu)(\ell\nu)$: *tau + lepton* — single lepton trigger

$t\bar{t} \to b\bar{b}H^{\pm}W^{\mp} \to b\bar{b}(\tau_{had}\nu)(q\bar{q})$: *tau + jets* — tau + E_T^{miss} trigger

Charged Higgs: lepton+jets

Basic Selection:

- one lepton p_T > 25/20 GeV (e/μ)
- four jets (2 b-tags) p_T > 20 GeV
- E_T^{miss} > 40 GeV
- top reconstruction (hadronic-side)

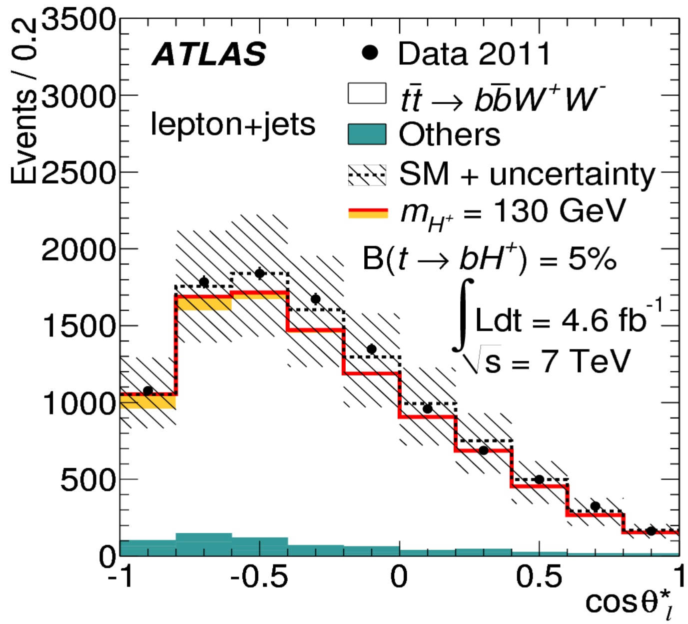
Additional discrimination against direct $W \rightarrow l\nu$:

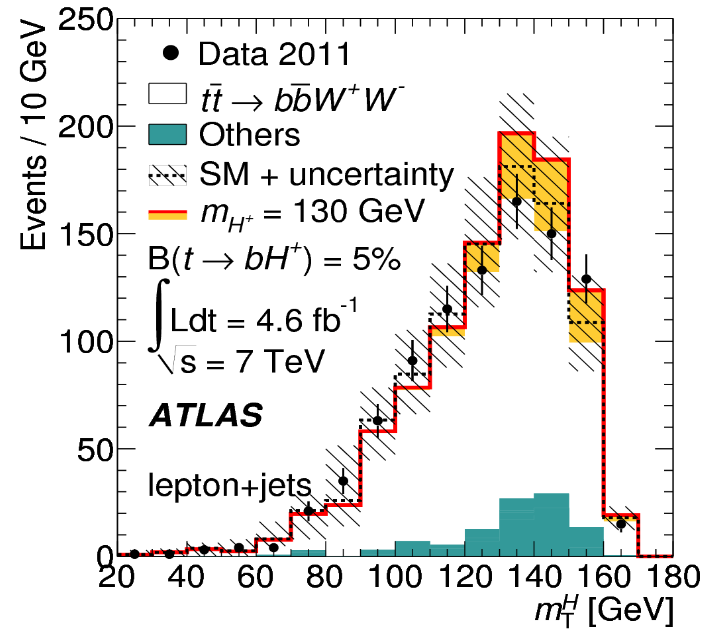
$$\cos\theta_l^* = \frac{2m_{bl}^2}{m_{\text{top}}^2 - m_W^2} - 1 \simeq \frac{4\, p^b \cdot p^l}{m_{\text{top}}^2 - m_W^2} - 1$$

$$(m_T^H)^2 = \left(\sqrt{m_{\text{top}}^2 + (\vec{p_T}^l + \vec{p_T}^b + \vec{p_T}^{\text{miss}})^2} - p_T^b\right)^2 - \left(\vec{p_T}^l + \vec{p_T}^{\text{miss}}\right)^2$$

$\cos\theta_l^*$ also defines control region for top background

Sample	Event yield (lepton+jets)
$t\bar{t}$	840 ± 20 ± 150
Single top quark	28 ± 2 $^{+8}_{-6}$
W+jets	14 ± 3 $^{+6}_{-3}$
Z+jets	2.1 ± 0.7 $^{+1.2}_{-0.4}$
Diboson	0.5 ± 0.1 ± 0.2
Misidentified leptons	55 ± 10 ± 20
$\sum$ SM	940 ± 22 ± 150
Data	933
$t \rightarrow bH^+$ (130 GeV)	120 ± 4 ± 25
Signal+background	990 ± 21 ± 140





Charged Higgs: tau + lepton

Basic Selection:

- one lepton p_T > 25/20 GeV (e/μ)
- opposite signed tau p_T > 20 GeV
- >2 jets (>1 b-tag) p_T > 20 GeV
- Σp_T^{tracks} > 100 GeV

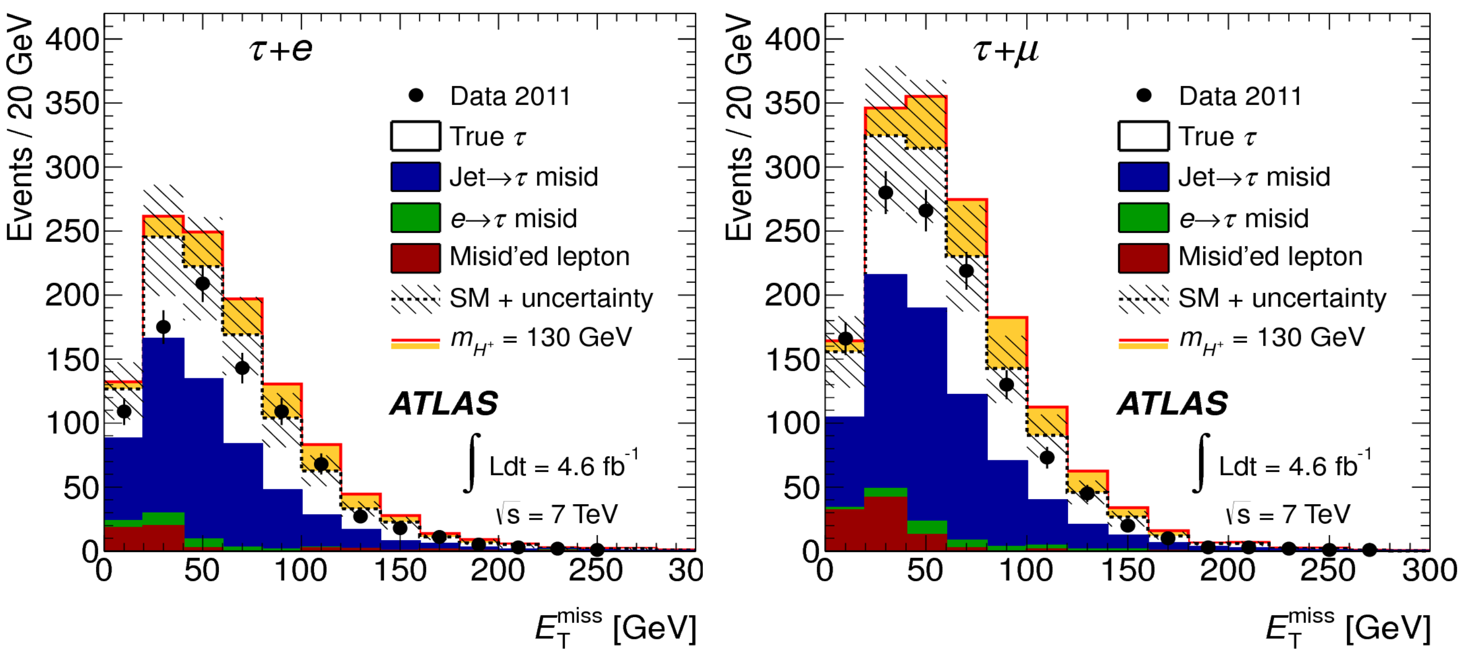
Sample	Event yield (τ+lepton) $\tau + e$	$\tau + \mu$
True τ+lepton	$430 \pm 14 \pm 59$	$570 \pm 15 \pm 75$
Misidentified jet $\to \tau$	$510 \pm 23 \pm 86$	$660 \pm 26 \pm 110$
Misidentified $e \to \tau$	$33 \pm 4 \pm 5$	$34 \pm 4 \pm 6$
Misidentified leptons	$39 \pm 10 \pm 20$	$90 \pm 10 \pm 34$
$\sum$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

Backgrounds

e→τ fakes: apply mis-id rates obtained from Z→ee

jet→τ fakes: apply mis-id rates obtained from W+jets control region

lepton fakes: determined from loose isolated lepton sample



Charged Higgs: tau+jets

Basic Selection:

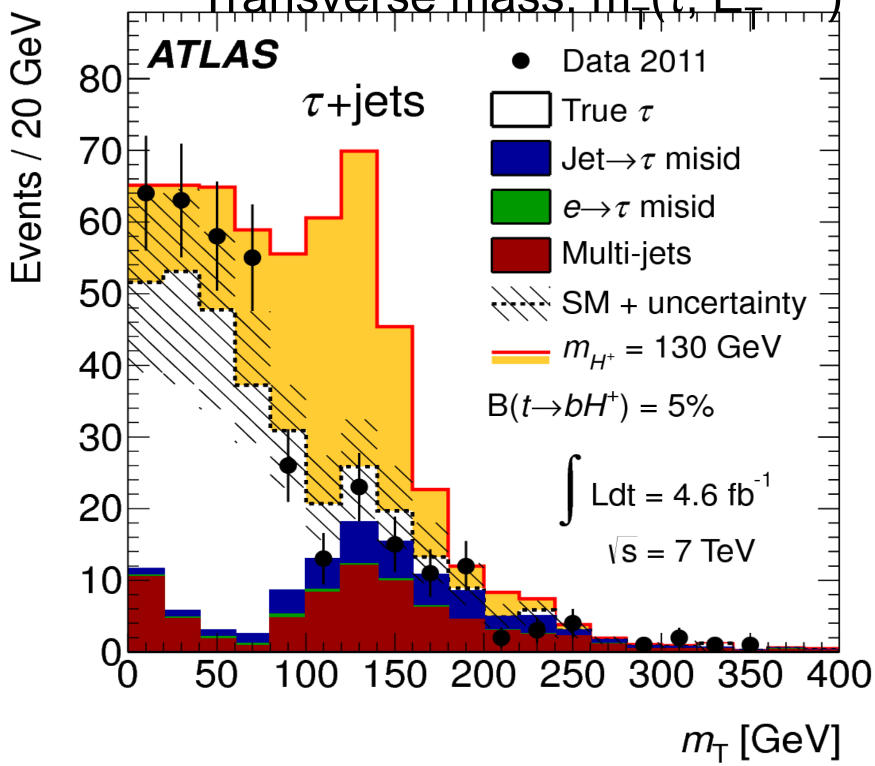
- identified tau p_T > 40 GeV
- >4 jets (>1 b-tag) p_T > 20 GeV
- E_T^{miss} > 65 GeV
- E_T^{miss} / 0.5 GeV$^{1/2}$ $\sqrt{\Sigma p_T^{tracks}}$ > 13
- mass window on hadronic top decay

Backgrounds

- true tau: embed top-pair events ($\mu\nu$ b qq b)
- multijets: fit ETmiss distribution obtained from control region
- fake taus: same method as tau+lepton channel

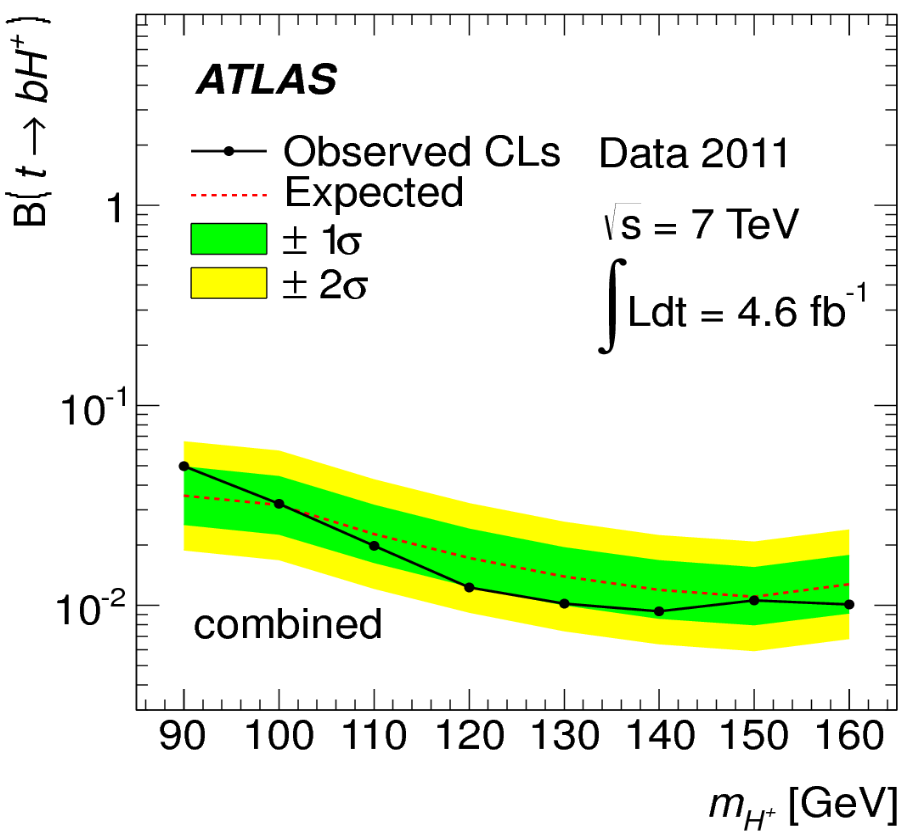
Sample	Event yield (τ+jets)
True τ (embedding method)	$210 \pm 10 \pm 44$
Misidentified jet $\to \tau$	$36 \pm 6 \pm 10$
Misidentified $e \to \tau$	$3 \pm 1 \pm 1$
Multi-jet processes	$74 \pm 3 \pm 47$
$\sum$ SM	$330 \pm 12 \pm 65$
Data	355
$t \to bH^+$ (130 GeV)	$220 \pm 6 \pm 56$
Signal+background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

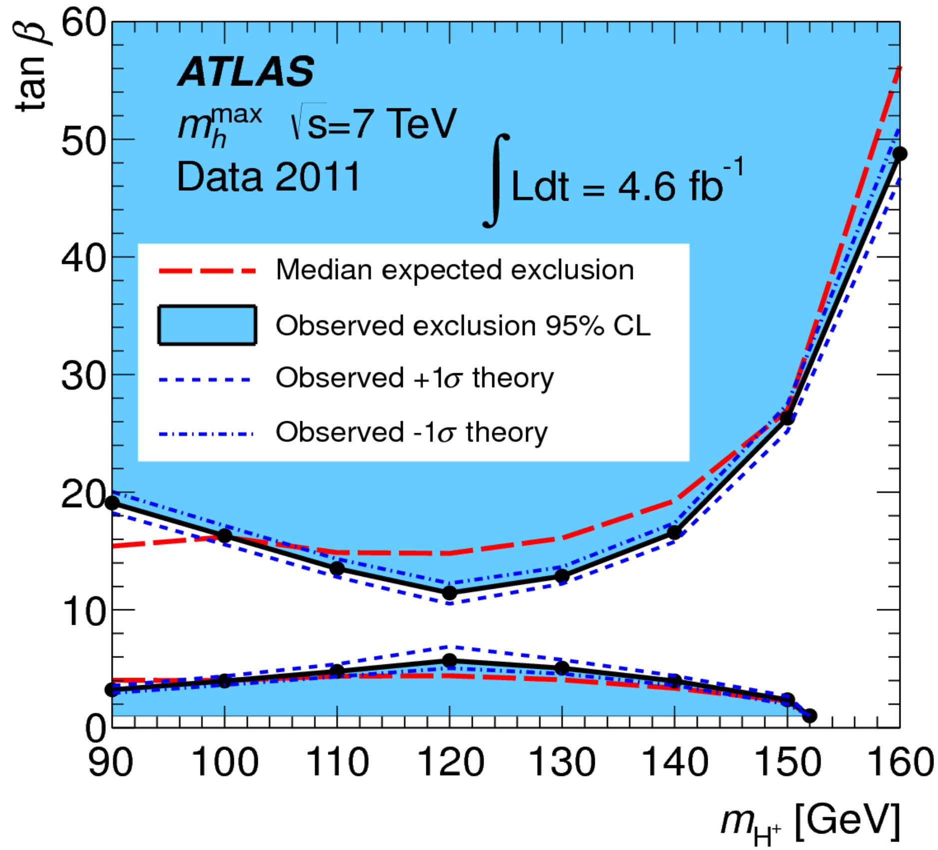
Transverse mass: $m_T(\tau, E_T^{miss})$



Charged Higgs Limits

Combined limits in all three channels (95% CL)





Profile likelihood ratio for m_T^H (lep+jets), E_T^{miss} (tau+lep), m_T (tau+jets) used to obtain CL_S limit

Summary and Outlook

ATLAS has a very extensive physics program utilizing tau lepton final states

- Standard Model Higgs Searches
- Beyond the Standard Model Higgs Searches (neutral and charged)
- Supersymmetric Signatures with tau final states
- Tau polarization and cross-section measurements in SM processes

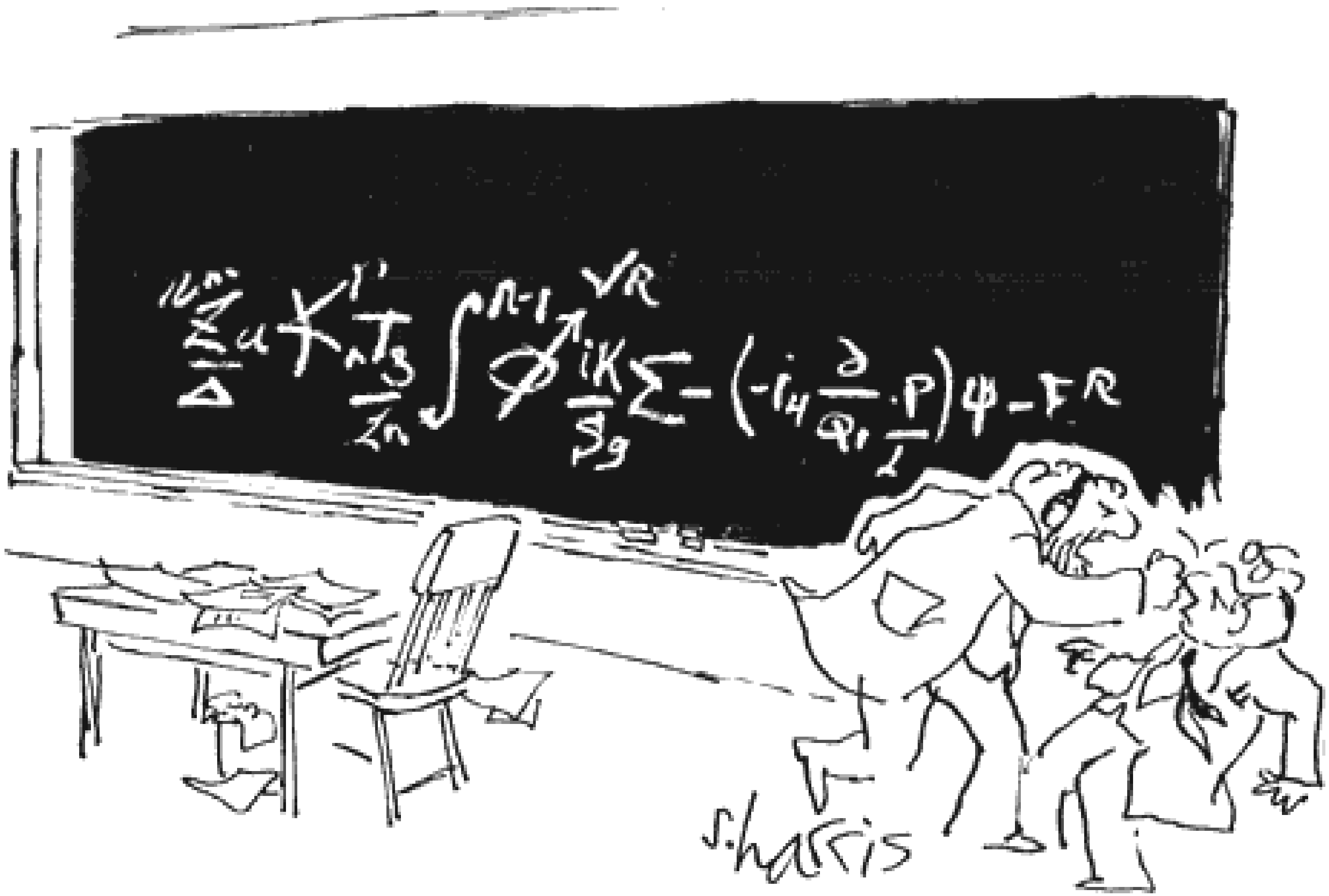
Increase of LHC E_{CM} = 8 TeV and luminosity projections for 2012
→ 2012 searches with tau final states even more relevant and exciting

Other exotic scenarios can also involve tau final states:

- heavy gauge bosons
- third generation lepto-quarks
- other exotic signatures

Crucial to maintain a high-performing tau identification algorithm in high luminosity environment

More Slides for Your Reading Pleasure



"You want proof? I'll give you proof!"

References

Standard Model Higgs: ATLAS-CONF-2012-014

SUSY with 1 tau: arXiv: 1204.3852v1

SUSY with 2 taus: arXiv: 1203.6580v1

MSSM Neutral Higgs: ATLAS-CONF-2011-132

MSSM Charged Higgs: arXiv:1204.2760v1

SM $H \to \tau\tau \to ll + 4\nu$

	$ee + \mu\mu + e\mu$ H +2-jet VBF	$ee + \mu\mu + e\mu$ H +2-jet VH	$ee + \mu\mu + e\mu$ H +1-jet	$e\mu$ H +0-jet
$gg \to H$ signal	0.26±0.06±0.10	0.8±0.1±0.2	3.9±0.2±1.0	23±1±3
VBF H signal	1.08±0.03±0.11	0.10±0.01±0.01	1.15±0.03±0.01	0.75±0.03±0.06
VH signal	0.01±0.01±0.01	0.53±0.02±0.07	0.40±0.02±0.03	0.52±0.02±0.04
$Z/\gamma^* \to \tau^+\tau^-$	24±3±2	107±12±9	$(0.52\pm0.01\pm0.04)\cdot10^3$	$(9.68\pm0.05\pm0.07)\cdot10^3$
$Z/\gamma^* \to \ell^+\ell^-$ (ℓ=e,μ)	2±1±1	25±4±9	80±10±30	185±11±14
$t\bar{t}$ +single top	7±1±2	41±2±6	95±3±12	169±4±14
$WW/WZ/ZZ$	0.9±0.3±0.3	6±1±1	21±1±3	221±3±18
Fake leptons	1.3±0.8±0.6	13±2±5	30±4±12	$(1.2\pm0.5)\cdot10^3$
Total background	34±3±4	191±7±20	$(0.75\pm0.01\pm0.05)\cdot10^3$	$(11.4\pm0.5)\cdot10^3$
Observed data	27	185	702	11420

- p_T thresholds for lepton are trigger-dependent (lowest is 15/10 GeV for electron/muon)
- $30 < m_{e\mu} < 100$ GeV and $30 < m_{ll} < 75$ GeV
- $\Delta\phi$ (l,l) > 2.5

SM $H\to\tau\tau\to l\tau_h + 3\nu$

	H +0-jet (low E_T^{miss})		H +0-jet (high E_T^{miss})	
	Electron	Muon	Electron	Muon
ggH signal	11 ± 1 ± 2	17 ± 1 ± 4	7.1 ± 0.8 ± 1.5	9.8 ± 0.9 ± 2.1
VBF H signal	0.08 ± 0.02 ± 0.12	0.11 ± 0.03 ± 0.03	0.09 ± 0.02 ± 0.02	0.14 ± 0.03 ± 0.03
VH signal	0.07 ± 0.02 ± 0.05	0.10 ± 0.03 ± 0.01	0.08 ± 0.0 2± 0.01	0.08 ± 0.02 ± 0.01
n^{all}_{SS}	$(3.3 \pm 0.2 \pm 0.7) \cdot 10^3$	$(2.0 \pm 0.1 \pm 0.4) \cdot 10^3$	$(0.69 \pm 0.06 \pm 0.14) \cdot 10^3$	$(0.47 \pm 0.04 \pm 0.09) \cdot 10^3$
n^{W+jets}_{OS-SS}	$(0.34 \pm 0.02 \pm 0.04) \cdot 10^3$	$(0.52 \pm 0.02 \pm 0.07) \cdot 10^3$	$(0.15 \pm 0.01 \pm 0.02) \cdot 10^3$	$(0.18 \pm 0.01 \pm 0.03) \cdot 10^3$
$n^{Z\to\tau\tau}_{OS-SS}$	$(3.70 \pm 0.06 \pm 0.62) \cdot 10^3$	$(7.49 \pm 0.06 \pm 1.25) \cdot 10^3$	$(1.55 \pm 0.04 \pm 0.24) \cdot 10^3$	$(3.22 \pm 0.04 \pm 0.49) \cdot 10^3$
n^{other}_{OS-SS}	$(0.97 \pm 0.04 \pm 0.22) \cdot 10^3$	$(0.59 \pm 0.04 \pm 0.14) \cdot 10^3$	$(0.27 \pm 0.02 \pm 0.08) \cdot 10^3$	$(0.14 \pm 0.02 \pm 0.04) \cdot 10^3$
Total background	$(8.3 \pm 0.2 \pm 0.8) \cdot 10^3$	$(10.6 \pm 0.2 \pm 1.3) \cdot 10^3$	$(2.66 \pm 0.07 \pm 0.27) \cdot 10^3$	$(4.01 \pm 0.06 \pm 0.49) \cdot 10^3$
Observed data	8363	10911	2545	3570
Altern. estimate	$(8.7 \pm 0.1 \pm 0.8) \cdot 10^3$	$(10.7 \pm 0.1 \pm 1.0) \cdot 10^3$	$(2.76 \pm 0.05 \pm 0.33) \cdot 10^3$	$(3.75 \pm 0.05 \pm 0.47) \cdot 10^3$

	H +1-jet		H +2-jet VBF
	Electron	Muon	Electron + Muon
ggH signal	8.1 ± 0.7 ± 1.6	10.8 ± 0.8 ± 2.2	0.9 ± 0.2 ± 0.3
VBFH signal	1.6 ± 0.1 ± 0.1	1.9 ± 0.1 ± 0.1	2.2 ± 0.1 ± 0.2
VH signal	1.1 ± 0.1 ± 0.1	1.4 ± 0.1 ± 0.1	0.02 ± 0.01 ± 0.01
n^{all}_{SS}	$(0.93 \pm 0.07 \pm 0.19) \cdot 10^3$	$(0.49 \pm 0.04 \pm 0.10) \cdot 10^3$	54 ± 8 ± 11
n^{W+jets}_{OS-SS}	$(0.26 \pm 0.01 \pm 0.03) \cdot 10^3$	$(0.27 \pm 0.01 \pm 0.04) \cdot 10^3$	9 ± 1 ± 3
$n^{Z\to\tau\tau}_{OS-SS}$	$(1.25 \pm 0.03 \pm 0.18) \cdot 10^3$	$(1.87 \pm 0.03 \pm 0.27) \cdot 10^3$	57 ± 6 ± 8
n^{other}_{OS-SS}	$(0.20 \pm 0.02 \pm 0.03) \cdot 10^3$	$(0.16 \pm 0.01 \pm 0.02) \cdot 10^3$	12 ± 3 ± 3
Total background	$(2.63 \pm 0.08 \pm 0.22) \cdot 10^3$	$(2.79 \pm 0.05 \pm 0.29) \cdot 10^3$	132 ± 11 ± 14
Observed data	2610	2711	122
Altern. estimate	$(2.63 \pm 0.05 \pm 0.25) \cdot 10^3$	$(2.72 \pm 0.04 \pm 0.28) \cdot 10^3$	131 ± 11 ± 23

- p_T thresholds are 20 GeV (μ,τ) and 25 GeV (e)
- m_T (l, E_T^{miss}) < 30 GeV

SM $H \rightarrow \tau\tau \rightarrow \tau_h \tau_h + 2\nu$

	$\tau_{had}\tau_{had}\,\nu\nu$ H +1-jet
$gg \rightarrow H$ signal	$3.1 \pm 0.2 \pm 0.6$
VBF H signal	$1.51 \pm 0.05 \pm 0.18$
VH signal	$0.61 \pm 0.04 \pm 0.06$
$Z/\gamma^* \rightarrow \tau^+\tau^-$	$287 \pm 23 \pm 34$
W+jets / Z+jets	$6.1 \pm 1.3 \pm 1.4$
$t\bar{t}$ +single top	$1.9 \pm 0.3 \pm 0.4$
$WW/WZ/ZZ$	$2.1 \pm 0.4 \pm 0.4$
Multi-jet	$54 \pm 21 \pm 12$
Total background	$348 \pm 31 \pm 36$
Observed data	317

Charged Higgs: Individual Limits