

# ATLAS tau Physics News

## 13th Workshop of the tau Analysis Working Group

03.12.2014

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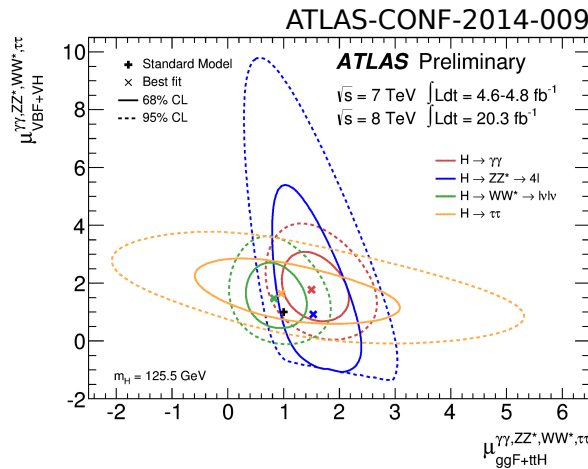
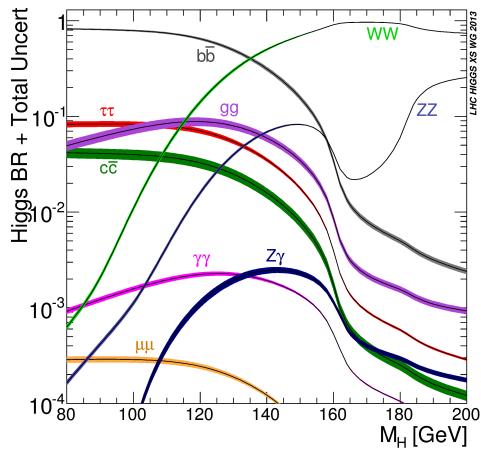


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# SM $H \rightarrow \tau\tau$

- Evidence for SM Higgs boson in the  $H \rightarrow \tau\tau$  decay mode
- $\int L dt = 4.5 \text{ fb}^{-1}$  at  $\sqrt{s} = 7 \text{ TeV}$
- $\int L dt = 20.3 \text{ fb}^{-1}$  at  $\sqrt{s} = 8 \text{ TeV}$
- ATLAS-CONF-2014-061
- Multivariate analysis using BDTs

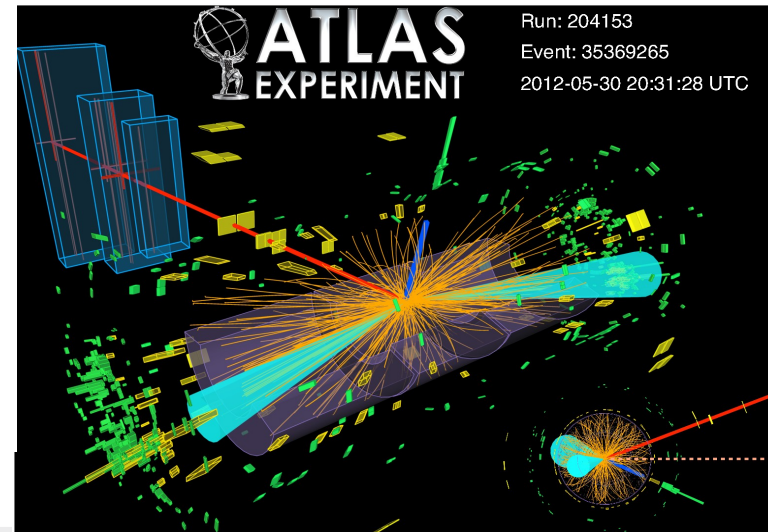


## Evidence for Higgs boson Yukawa couplings in the $H \rightarrow \tau\tau$ decay mode with the ATLAS detector

The ATLAS Collaboration

### Abstract

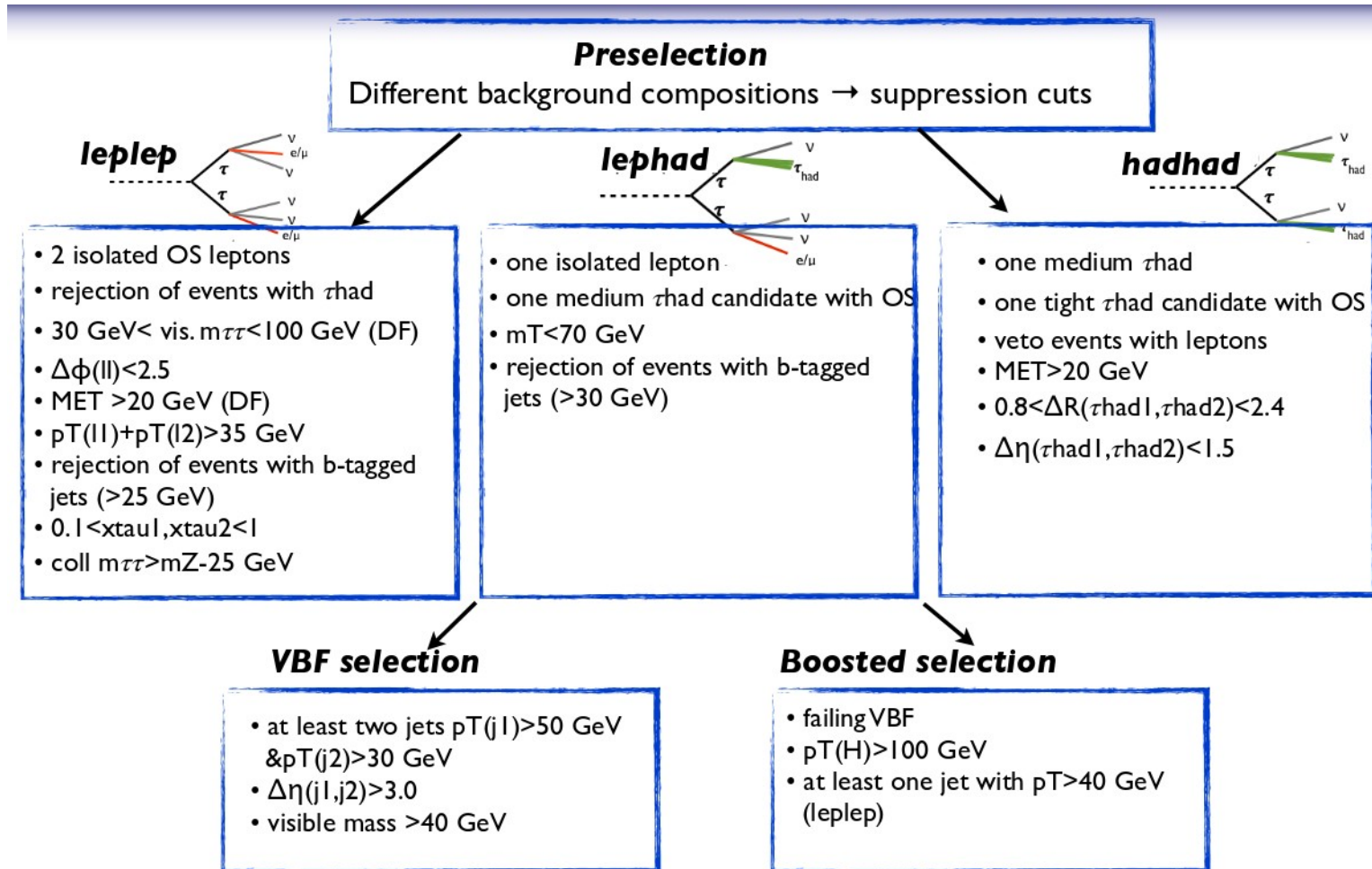
Results of a search for  $H \rightarrow \tau\tau$  decays are presented, based on the full set of proton-proton collision data recorded by the ATLAS experiment at the LHC during 2011 and 2012. The data correspond to integrated luminosities of  $4.5 \text{ fb}^{-1}$  and  $20.3 \text{ fb}^{-1}$  at centre-of-mass energies of  $\sqrt{s} = 7 \text{ TeV}$  and  $\sqrt{s} = 8 \text{ TeV}$  respectively. All combinations of leptonic ( $\tau \rightarrow \ell\nu\bar{\nu}$  with  $\ell = e, \mu$ ) and hadronic ( $\tau \rightarrow \text{hadrons } \nu$ ) tau decays are considered. An excess of events over the expected background from other Standard Model processes is found with an observed (expected) significance of 4.5 (3.5) standard deviations. This excess provides evidence for the direct coupling of the recently discovered Higgs boson with mass  $m_H = 125 \text{ GeV}$  to fermions. The measured signal strength, normalised to the Standard Model expectation, of  $\mu = 1.42^{+0.44}_{-0.38}$  is consistent with the predicted Yukawa coupling strength in the Standard Model.



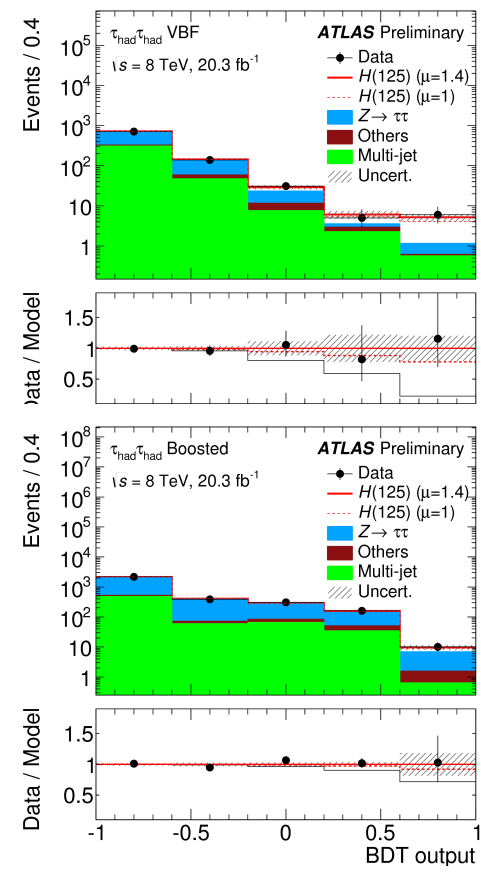
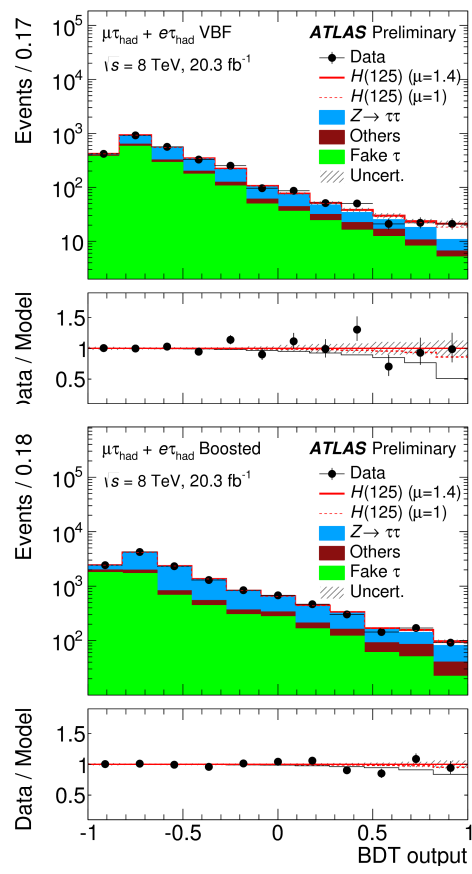
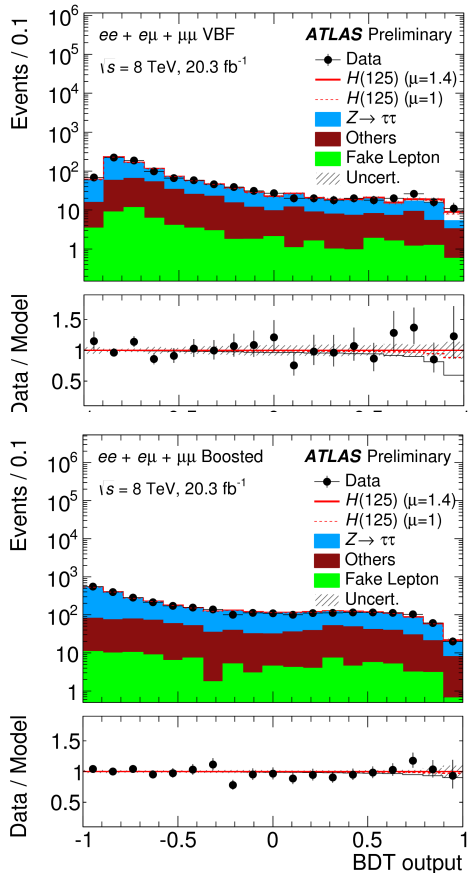
# Analysis strategy



More details can be found in yesterday's talk by Jessica [link](#)



# Final discriminant (8TeV)

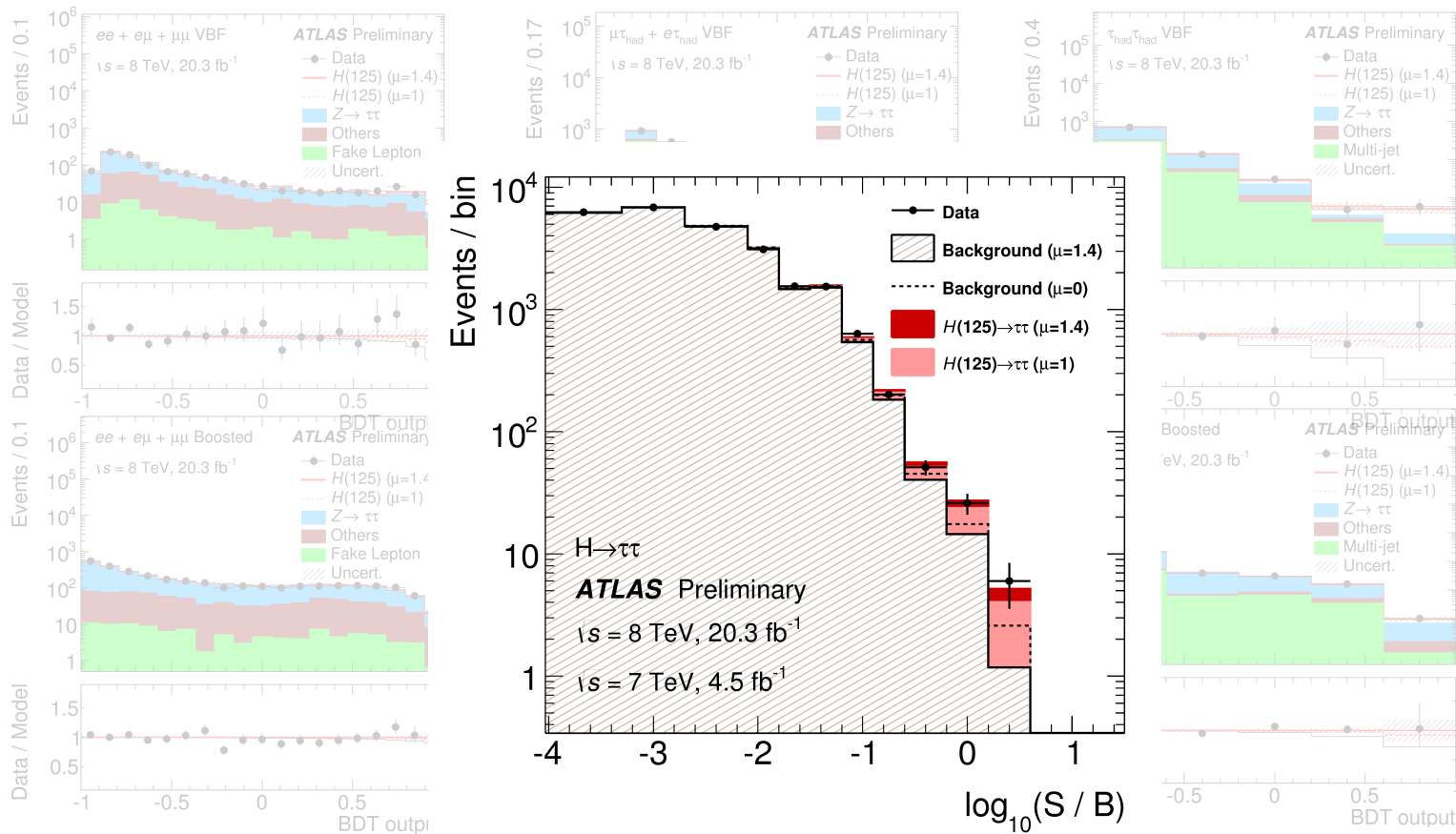


$\tau_{\text{lep}} \tau_{\text{lep}}$

$\tau_{\text{lep}} \tau_{\text{had}}$

$\tau_{\text{had}} \tau_{\text{had}}$

# Analysis strategy

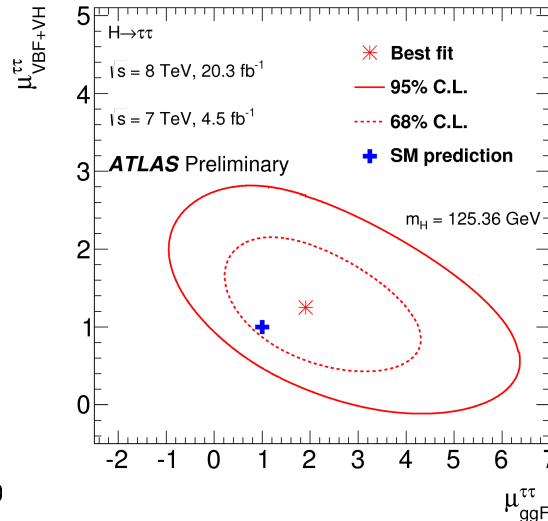
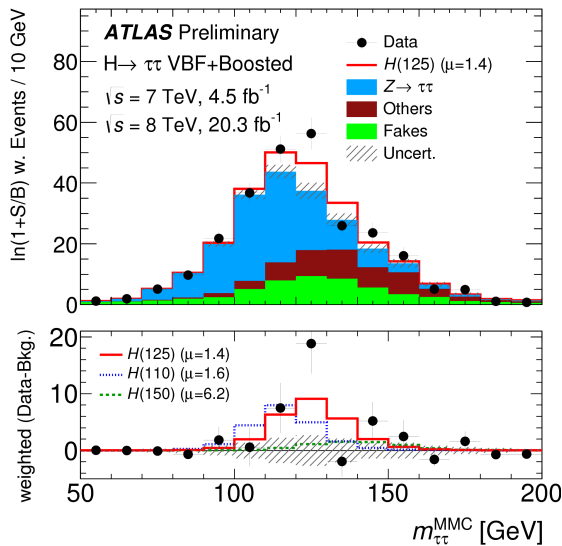


Excess seen in signal like BDT bins

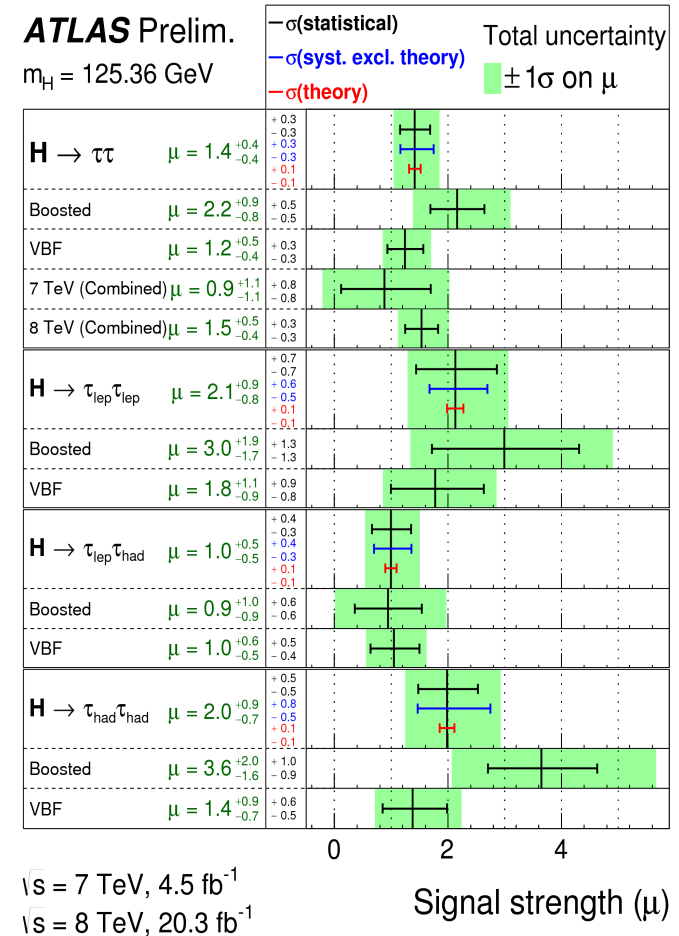
# Results



- Combined **signal strength**  $\mu = 1.42^{+0.27}_{-0.26}$  (stat) $^{+0.32}_{-0.24}$  (sys)  $\pm 0.10$  (theory)
- Observed (expected) **significance** 4.5 (3.5)  $\sigma$
- Evidence for Higgs boson **coupling to fermions**
- Mass compatibility** with 125 GeV
- Cut-based approach shows consistency  $\mu = 1.37^{+0.57}_{-0.48}$



**ATLAS Prelim.**  
 $m_H = 125.36 \text{ GeV}$





# MSSM $h/H/A \rightarrow \tau\tau$

- Search for neutral Higgs bosons in the MSSM  
 $\int L dt = 19.5 - 20.3 \text{ fb}^{-1}$  at  $\sqrt{s} = 8 \text{ TeV}$
- CERN-PH-EP-2014-210
- Supersymmetric extension of SM  
 Two Higgs doublets
  - 2 CP-even  $h/H$
  - 1 CP-odd  $A$
  - 2 charged  $H^{\pm}$
- 2 additional parameters wrt SM at tree level  
 $m_A$  and  $\tan\beta$  (ratio of vacuum exp. values)
- Higgs boson coupling to down-type fermions enhanced
- Higgs boson production through gluon fusion or b-quark associated
- Lorenz Hauswald's talk yesterday [link](#)



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Search for neutral Higgs bosons of the minimal supersymmetric standard model in  $pp$  collisions at  $\sqrt{s} = 8 \text{ TeV}$  with the ATLAS detector



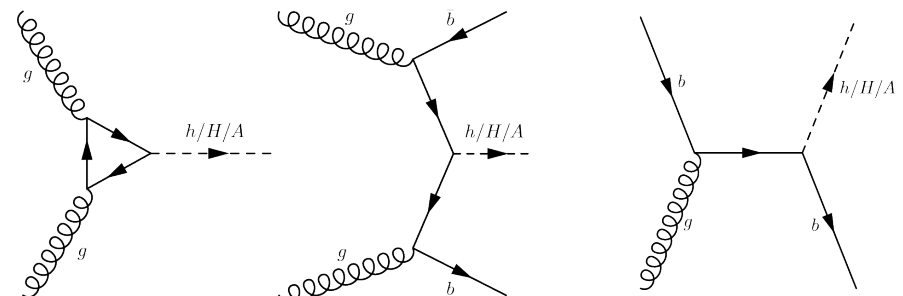
The ATLAS collaboration

E-mail: [atlas.publications@cern.ch](mailto:atlas.publications@cern.ch)

ABSTRACT: A search for the neutral Higgs bosons predicted by the Minimal Supersymmetric Standard Model (MSSM) is reported. The analysis is performed on data from proton-proton collisions at a centre-of-mass energy of 8 TeV collected with the ATLAS detector at the Large Hadron Collider. The samples used for this search were collected in 2012 and correspond to integrated luminosities in the range 19.5–20.3  $\text{fb}^{-1}$ . The MSSM Higgs bosons are searched for in the  $\tau\tau$  final state. No significant excess over the expected background is observed, and exclusion limits are derived for the production cross section times branching fraction of a scalar particle as a function of its mass. The results are also interpreted in the MSSM parameter space for various benchmark scenarios.

KEYWORDS: Hadron-Hadron Scattering

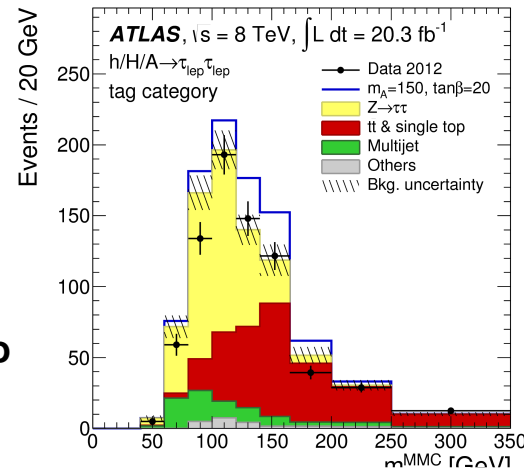
ARXIV EPRINT: [1409.6064](https://arxiv.org/abs/1409.6064)



JHEP11(2014)056

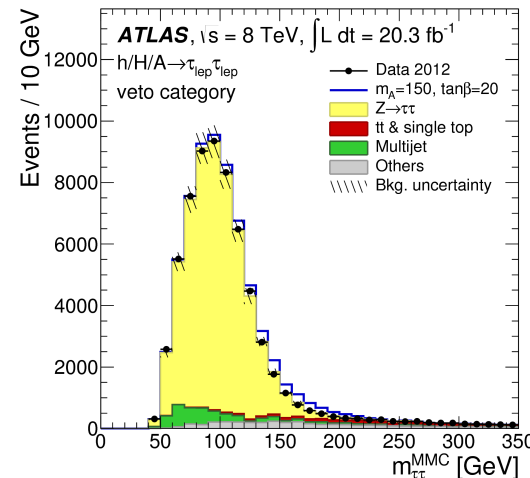
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- Branching ratio 6%
- One isolated **electron** ( $p_T^{\text{el}} > 15 \text{ GeV}$ ) and **muon** ( $p_T^\mu > 10 \text{ GeV}$ ) with opposite charge
- If  $p_T^{\text{el}} > 25 \text{ GeV}$ : sgl-el-trigger else: el-mu-trigger
- Veto events with loose  $\tau_{\text{had}}$
- **Low mass categories** ( $m_A < 200 \text{ GeV}$ ) **tag & veto**
- Background estimation
  - Z $\rightarrow\tau\tau$  embedded sample
  - ttbar from MC (normalization from 2 b-jets CR)
  - W+jets, sgl-top, dibosons from MC
  - QCD multijet bkg from data (ABCD method using charge and isolation)
- **MMC** mass as final discriminant



### Low mass tag

- Exactly one b-tagged jet
- $\Delta\phi(e, \mu) > 2$
- $\Sigma \cos \Delta\phi(l, \text{MET}) > -0.2$
- $\Sigma p_T^{\text{jet}} < 100 \text{ GeV}$
- $p_T^{\text{el}} + p_T^\mu + \text{MET} < 125 \text{ GeV}$

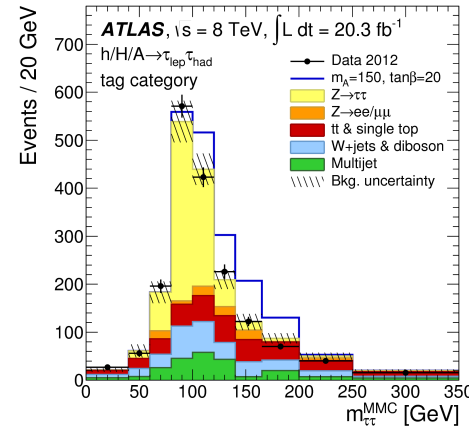


### Low mass veto

- No b-tagged jet
- $\Delta\phi(e, \mu) > 1.6$
- $\Sigma \cos \Delta\phi(l, \text{MET}) > -0.4$

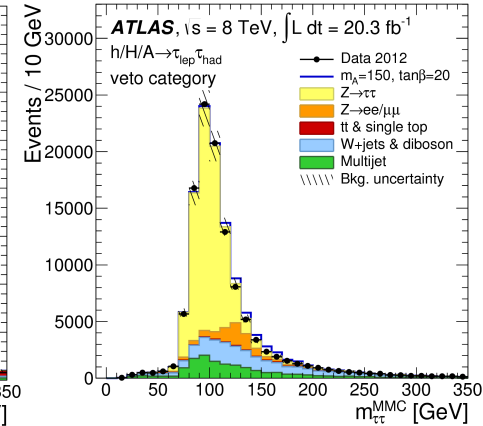


- Branching ratio 23% respectively
- One isolated **electron or muon** ( $p_T^{e/\mu} > 26\text{GeV}$ ) and one **medium tau** ( $p_T^\tau > 20\text{GeV}$ ) with opposite charge
- sgl-el-trigger or sgl-mu-trigger
- No additional electrons or muons in event
- **Low mass categories** ( $m_A < 200\text{GeV}$ ) **tag & veto**
- **High mass category** ( $m_A \geq 200\text{GeV}$ )
- Background estimation
- Z $\rightarrow\tau\tau$  embedded sample
- W, Z, Top from MC (normalization from CRs)
- Dibosons from MC
- QCD multijet bkg from data (2D sideband method using charge and isolation)
- **MMC** mass as final discriminant



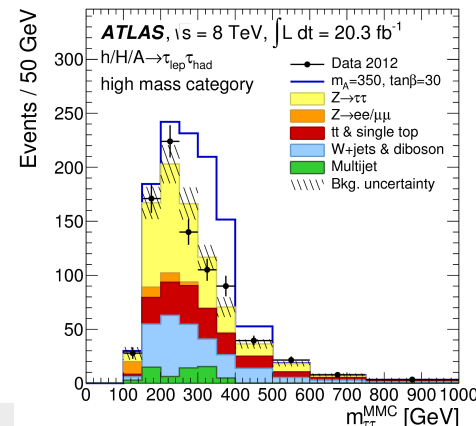
**Low mass tag**

At least one b-tagged jet  
 No  $\geq 1$  jet with  $p_T^{jet} > 30\text{GeV}$   
 $m_T(e/\mu, MET) < 45\text{ GeV}$



**Low mass veto**

No b-tagged jet  
 $\Sigma\Delta\phi(\tau, MET) < 3.3$   
 $m_T(e/\mu, MET) < 60\text{ GeV}$



**High mass**

$\Delta\phi(\tau, MET) < 3.3$   
 $\Delta\phi(\tau_{e/\mu}, \tau_{had}) > 2.4$   
 $p_T^{had} - p_T^{e/\mu} > 45\text{ GeV}$

- Branching ratio 46%
- At least 2 loose tau leptons ( $p_{\tau}^{\tau} > 50\text{GeV}$ ) with opposite charge and  $\Delta\phi(\tau_{\text{had}} \tau_{\text{had}}) > 2.7$
- No electrons and muons in the event
- **High mass categories** ( $m_A \geq 200\text{GeV}$ ) **STT & DTT**

- Background estimation

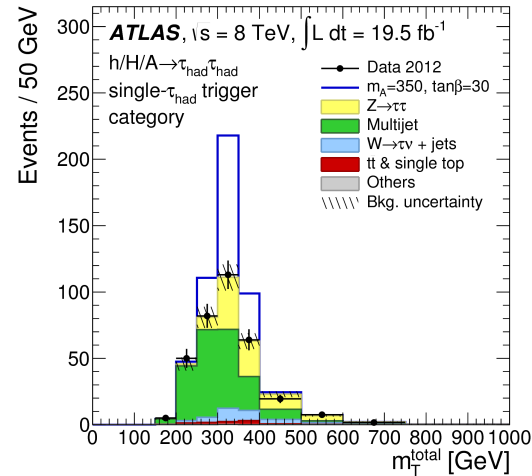
QCD multijet bkg from data:

- STT shape and norm from high purity CR using jet to tau fake data efficiencies
- DTT 2D sideband method using charge and MET

Non-multijet processes from MC

- Final discriminant is **total transverse mass**

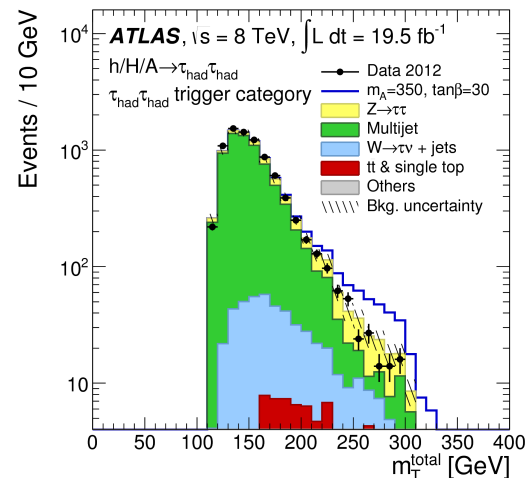
$$m_{\tau}^{\text{total}} = \sqrt{[m_{\tau}^2(\tau_1, \tau_2) + m_{\tau}^2(\tau_1, \text{MET}) + m_{\tau}^2(\tau_2, \text{MET})]}$$



## STT

sgl-tau-trigger

$p_{\tau}^{\text{tau}} > 150\text{ GeV}$



## DTT

di-tau-trigger

$p_{\tau}^{\text{tau}} < 150\text{ GeV}$

medium taus

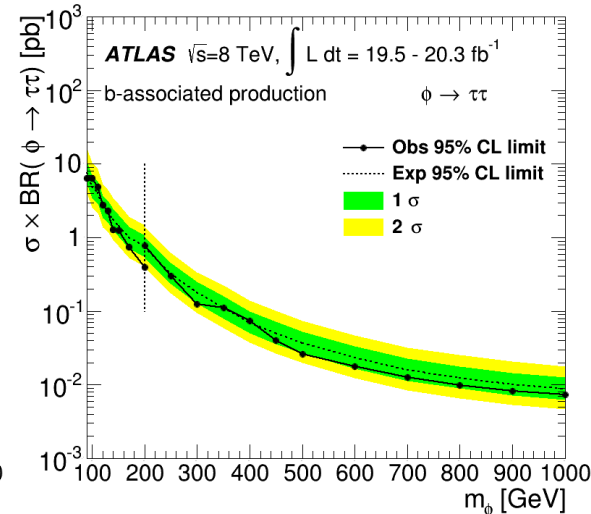
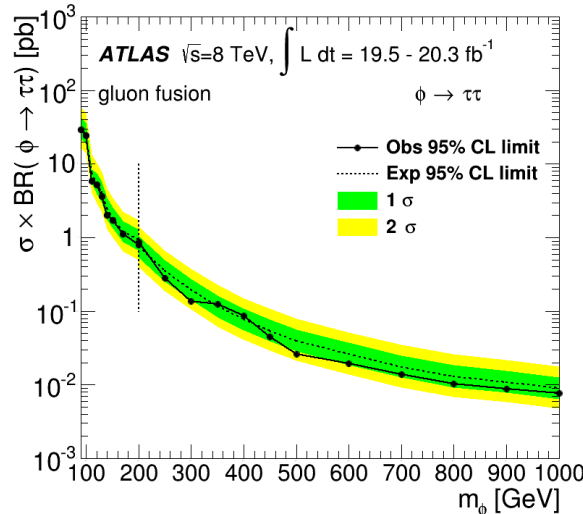
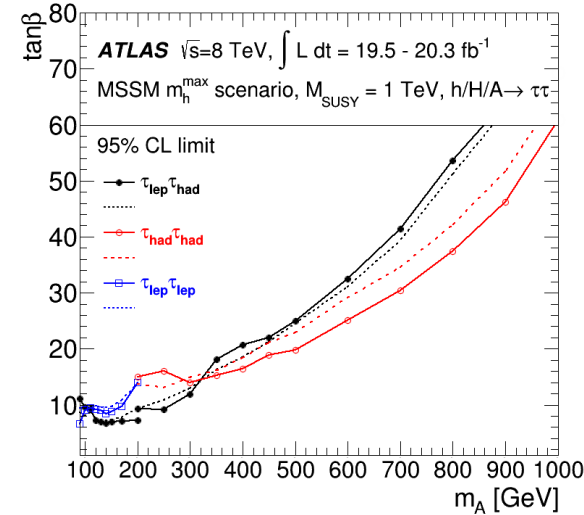
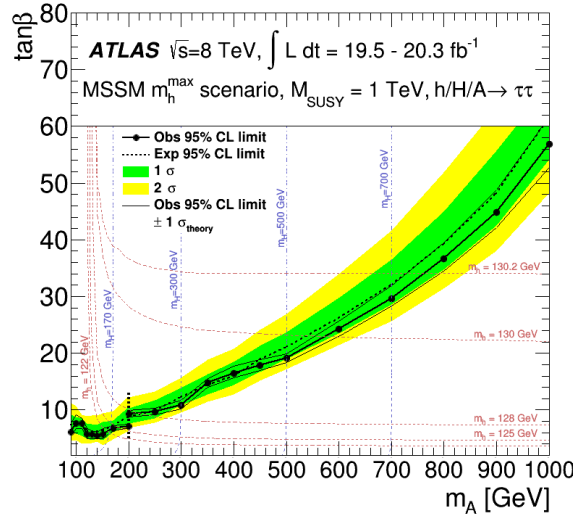
$\text{MET} > 10\text{ GeV}$

$\Sigma E_{\tau} > 160\text{ GeV}$

# Results



- Data in good agreement with background only expectation
- Calculating **limits** (95% CIs)
- Categorisation based on boson mass & production mechanism (**low** and **high** mass region)
- Here  $m_h^{\max}$  scenario shown
- Lowest exclusion  $\tan\beta > 5.4$  for  $m_A = 140\text{GeV}$
- Upper limit on  $\sigma$  times BR ranges from 30pb to 7fb
- If CP-even Higgs boson  $h$  identified with discovered boson at 125GeV  
 $\rightarrow$  Exclusion of  $m_A < 160\text{ GeV}$  and  $\tan\beta < 4$  and  $\tan\beta > 10$



# SSM $Z' \rightarrow \tau_{\text{had}} \tau_{\text{had}}$



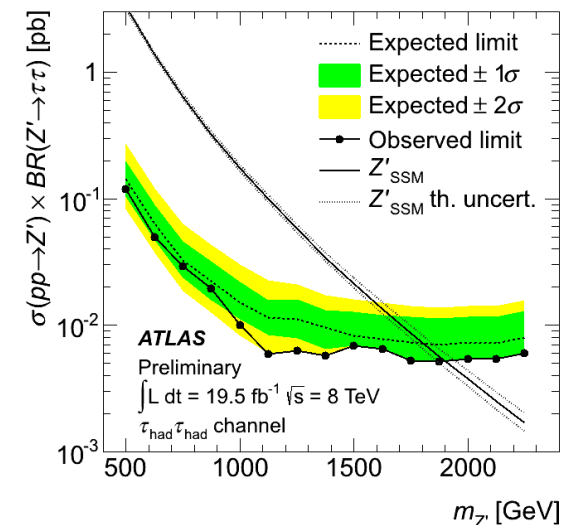
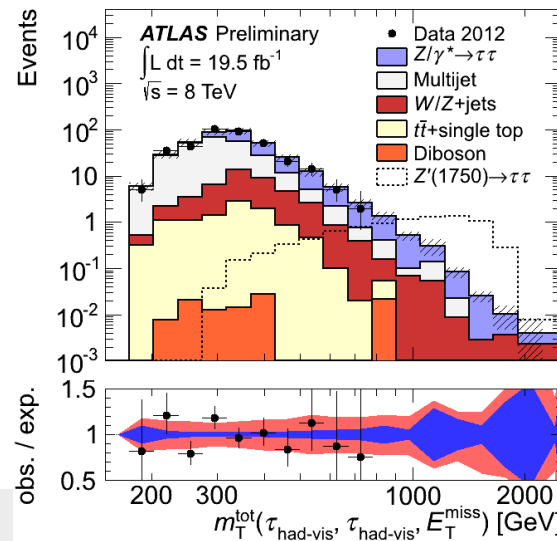
- Search for high-mass ditau resonance  
 $\int L dt = 19.5 \text{ fb}^{-1}$  at  $\sqrt{s} = 8 \text{ TeV}$
- ATLAS-CONF-2013-066
- Sequential Standard Model (SSM)** contains heavy neutral gauge boson  $Z'$  with SM fermion couplings
- $\geq 2$  **loose tau-leptons** ( $p_{T}^{\tau} > 50 \text{ GeV}$ ) with opposite charge ( $\Delta\phi(\tau_1, \tau_2) > 2.7$  &  $p_{T, \text{lead}}^{\tau} > 150 \text{ GeV}$  & no  $e/\mu$ )
- Non-multijet bkg from MC  
Multijet data driven
- Observed (expected) limit at 95% credibility  
 $m_{Z'} < 1.9 (1.8) \text{ TeV}$

A search for high-mass ditau resonances decaying in the fully hadronic final state in  $pp$  collisions at  $\sqrt{s} = 8 \text{ TeV}$  with the ATLAS detector

The ATLAS Collaboration

## Abstract

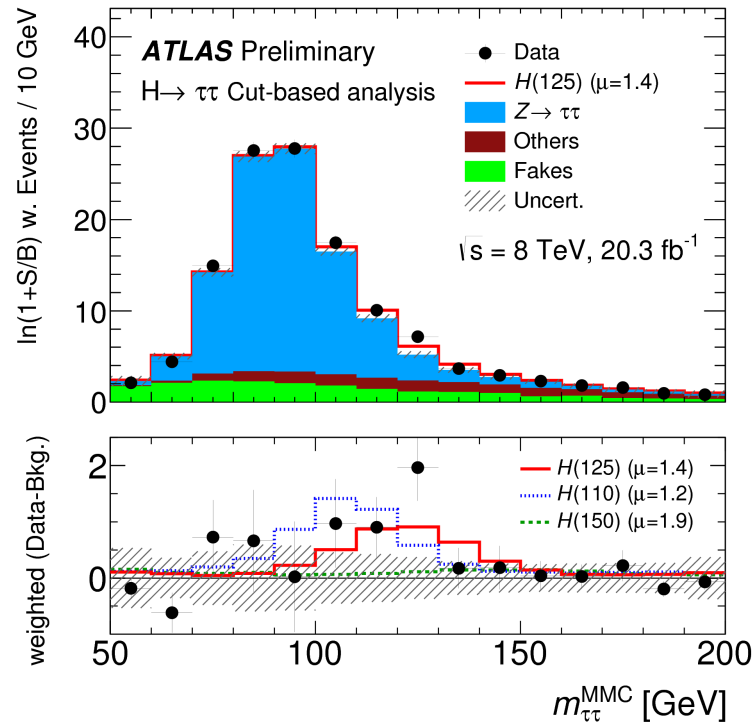
This note presents a search for high-mass ditau resonances decaying in the fully hadronic final state using proton-proton collisions at  $\sqrt{s} = 8 \text{ TeV}$  produced by the Large Hadron Collider. The data were recorded with the ATLAS detector and correspond to an integrated luminosity of  $19.5 \text{ fb}^{-1}$ . No statistically significant excess above the Standard Model expectation is observed; 95% credibility upper limits are set on the cross section times branching fraction of  $Z'$  resonances decaying into  $\tau^+ \tau^-$  pairs as a function of the resonance mass. As a result,  $Z'$  bosons of the Sequential Standard Model with masses less than  $1.90 \text{ TeV}$  are excluded at 95% credibility.





# Backup

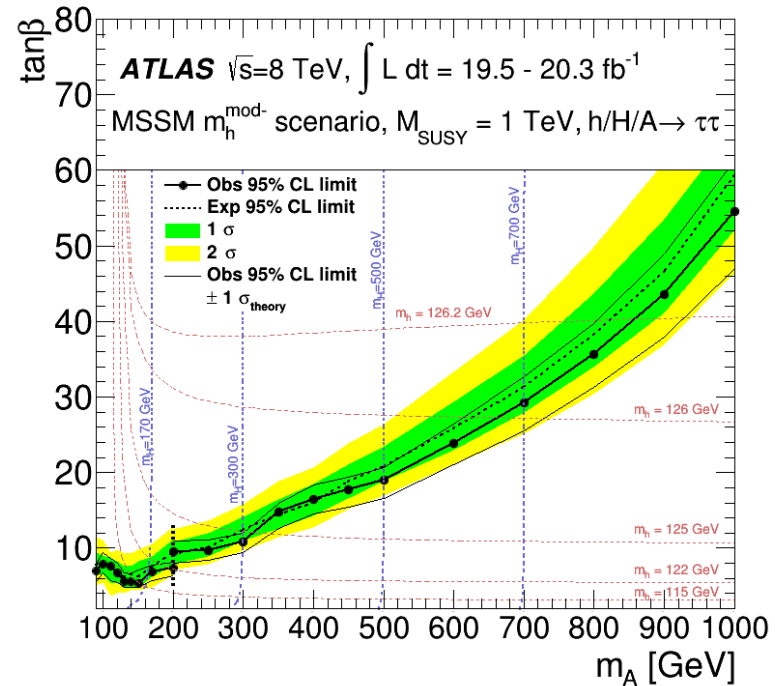
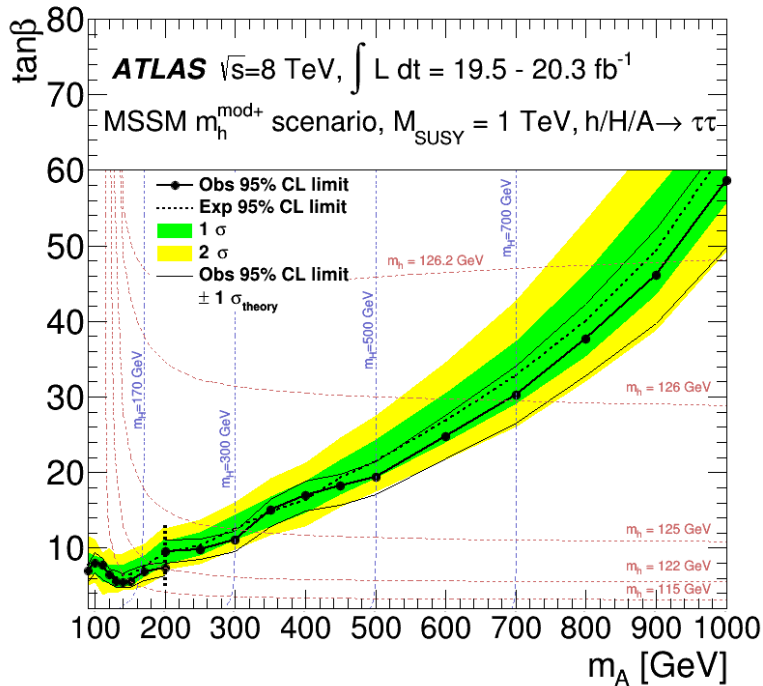
# SM $H \rightarrow \tau\tau$



- Cut based analysis
- Final discriminant MMC



# MSSM $h/H/A \rightarrow \tau\tau$



- MSSM  $m_h^{\text{mod}\pm}$  scenarios