Evidence for Higgs Boson Decays to $\tau^+\tau^-$ Final State with the ATLAS Detector

ATLAS CONFERENCE NOTE

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- Data preselection
- Analysis technique
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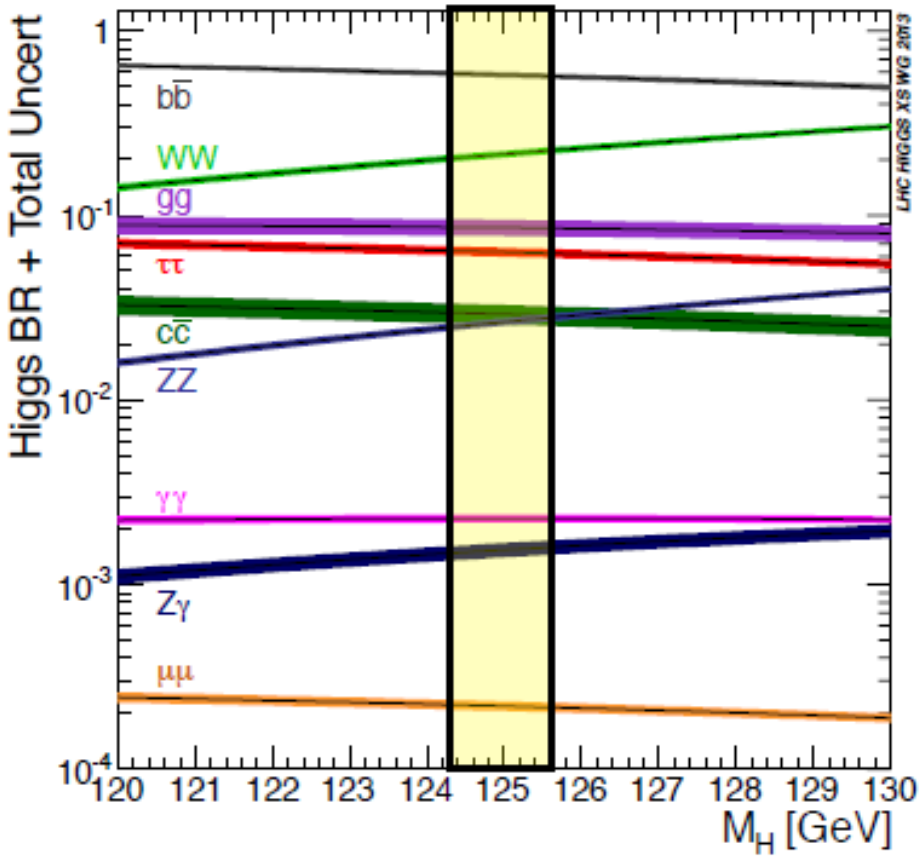
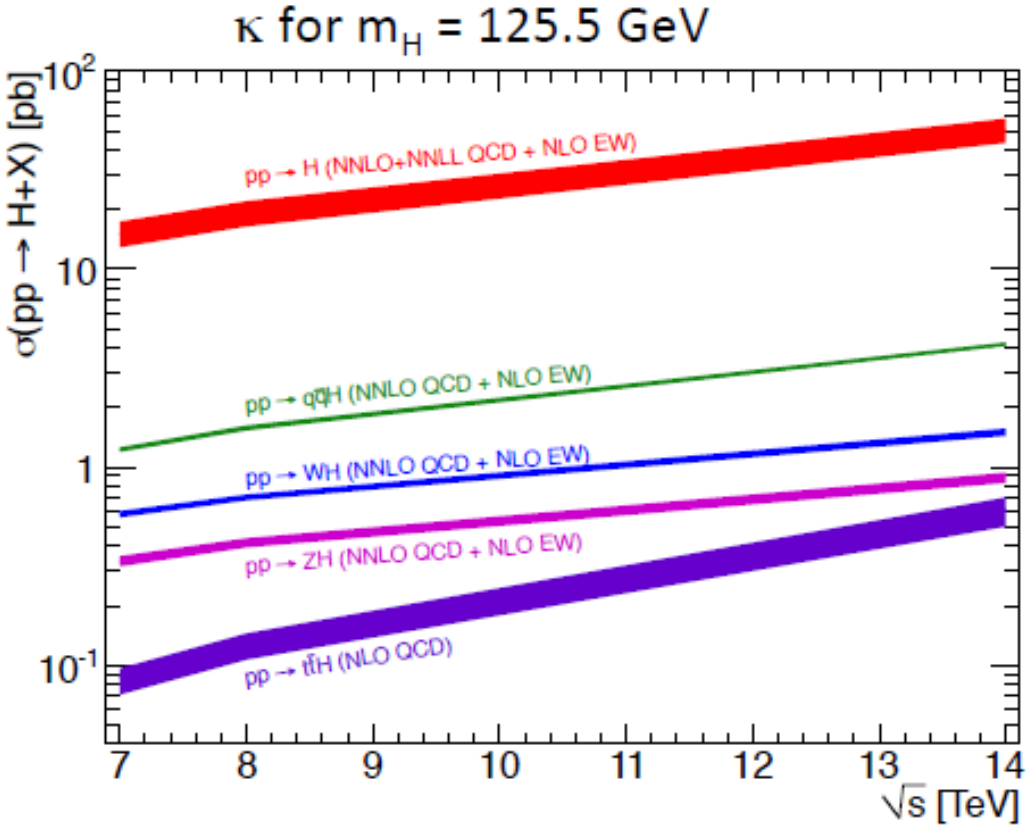
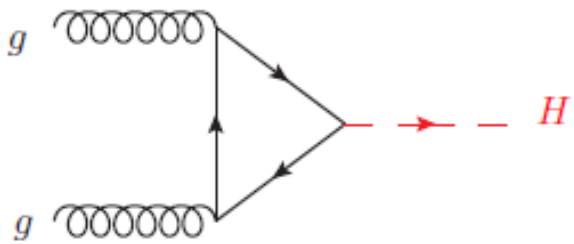
Higgs decay channels

- bb channel (57%)
- WW channel (22%)
- $\tau^+\tau^-$ channel (6.3%)
- ZZ channel (3%)
- cc channel (3%)
- $\gamma\gamma$ channel (0.2%)



Higgs production modes

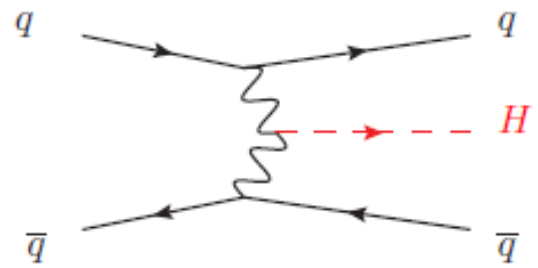




Gluon fusion process

NNnLO ~O(10%)

~0.5 M events produced



Vector Boson Fusion

NLO TH uncertainty ~O(5%)

Two forward jets and a large rapidity gap

~40 k events produced

$H \rightarrow \tau\tau$

Reoptimised 7+8 TeV analysis

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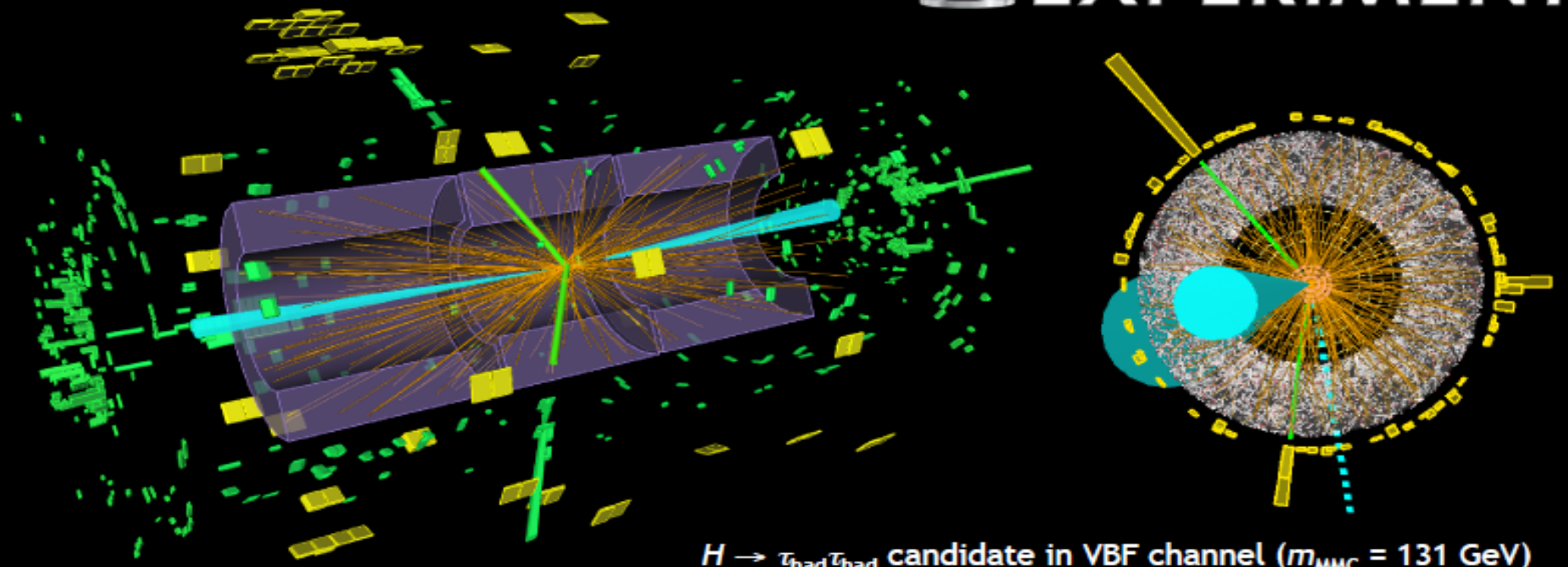
ATLAS EXPERIMENT



$H \rightarrow \tau_{had}\tau_{had}$ candidate in VBF channel (m_{MMC} = 131 GeV)

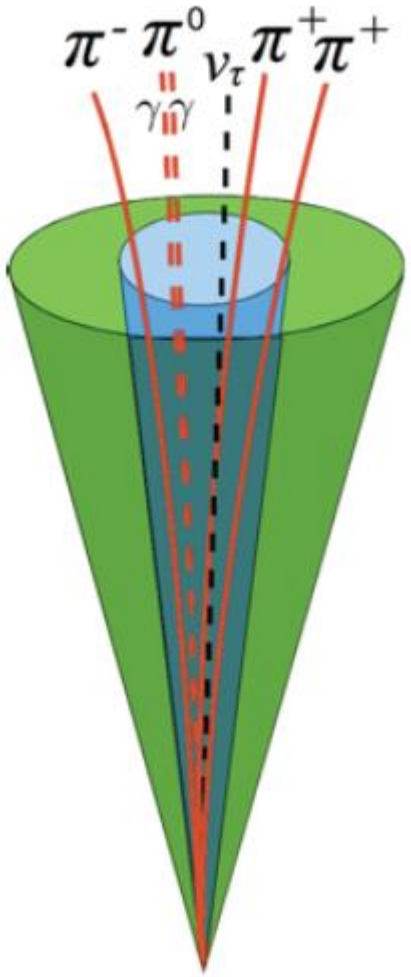
ττ channel basic facts sheet :

Signal (SM)	Signal purity s/b	Main backgrounds	Production	7 & 8 TeV $\int L\,dt$
~330	0.3% - 30%	ZZ, Z+jets, top	VBF, Hgg, VH	4.9 & 13 fb^{-1}

$H \rightarrow \tau^{+}\tau^{-}$

- Consistent with a SM Higgs of 125 GeV.
- Strong evidence that fermions acquire their mass through the Higgs mechanism, as it provides a direct measurement of the coupling of the Higgs to fermions.
- Data collected in pp collisions at $\sqrt{s} = 8$ TeV and $\mathcal{L} = 20.3\ fb^{-1}$.
- It is not possible to detect the τ particle directly (it is decaying)

$\tau^+\tau^-$ decay channels

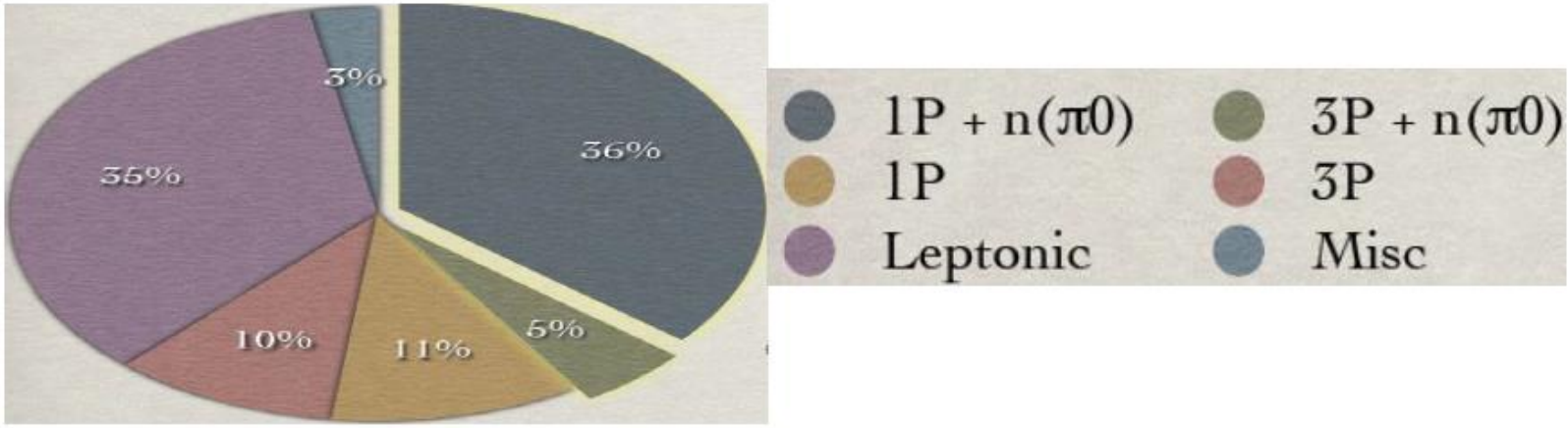


Lep-lep channel: H→ττ→2l+4ν, Br=12.4%

Lep-had channel: H→ττ→l+τ_{had}+3ν, Br=45.6%

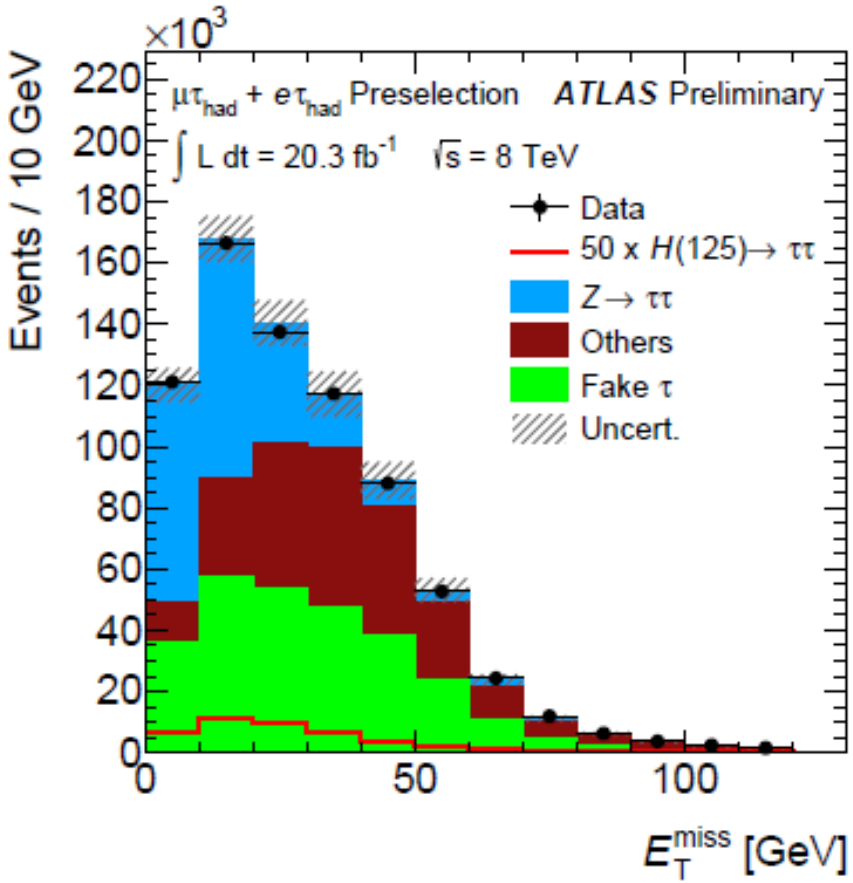
Had-had channel: H→ττ→2τ_{had}+2ν, Br=42%

Tau decay modes



Background estimation

- Derived from a mixture of simulated samples and data.
- Dominant $Z \rightarrow \tau^{+}\tau^{-}$ background, which is modelled by $Z \rightarrow \mu^{+}\mu^{-}$ taken from data.



Preselection

Lep lep channel

- Two isolated leptons of opposite sign charges required
- Events containing τ_{had} candidate are discarded
- Two leptons must satisfy
  - $30 < m_{\tau\tau}^{vis} < 100$ GeV in $e^{+}\mu^{-}$ channel
  - $30 < m_{\tau\tau}^{vis} < 75$ GeV in $e^{+}e^{-}$ and $\mu^{+}\mu^{-}$ channels
  - $p_T(l_1) + p_T(l_2) > 35$ GeV

Lep Had channel

- One lepton and one τ_{had} candidate with opposite charges
- Transverse mass reconstructed from the lepton and $\mathrm{E_T}^{miss}$ is $m_T > 70$ GeV (to reduce W+jects background)
- τ_{had} candidates $p_T > 20$ GeV
- τ_{had} candiates $|\eta| < 2.47$

Had Had channel

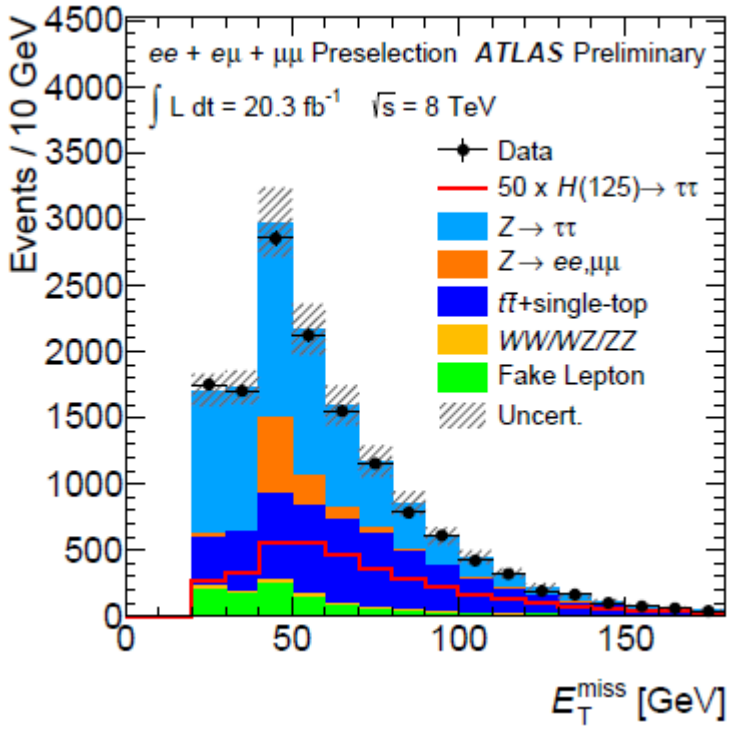
- Two τ_{had} candidates with opposite charge are required
- Events with electron or muon candidates are rejected
- Transverse momentum thresholds:
  - $p_T(\tau_{had1}) > 35$ GeV
  - $p_T(\tau_{had2}) > 25$ GeV
- Separation criteria:
  - $0.8 < \Delta R < 2.8$
  - $\Delta\eta(\tau_{had}, \tau_{had}) < 1.5$

Analysis Categories

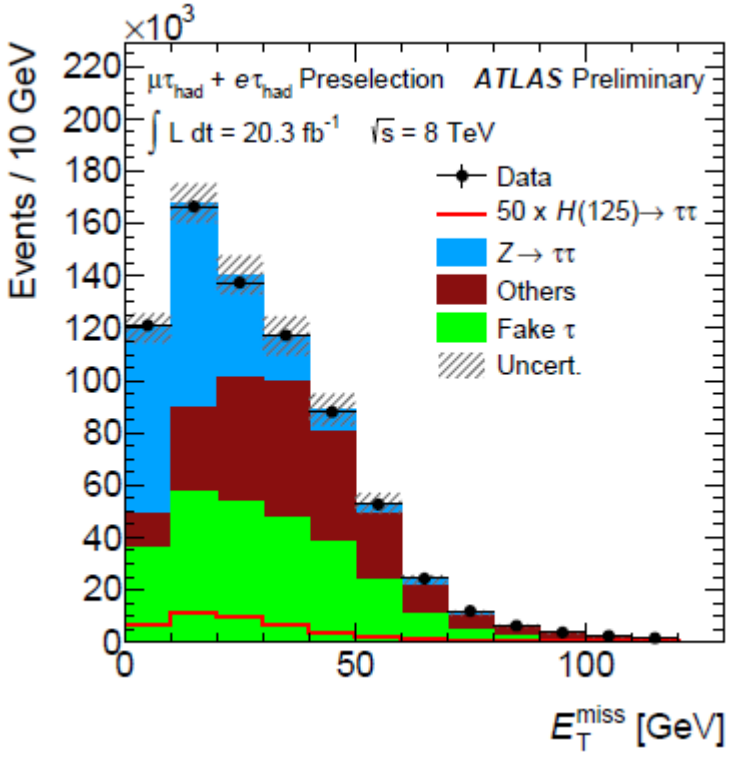
Category	Selection	$\tau_{\text{lep}}\tau_{\text{lep}}$	$\tau_{\text{lep}}\tau_{\text{had}}$	$\tau_{\text{had}}\tau_{\text{had}}$
VBF	$p_{\text{T}}(j_1)$ (GeV)	40	50	50
	$p_{\text{T}}(j_2)$ (GeV)	30	30	30/35
	$\Delta\eta(j_1, j_2)$	2.2	3.0	2.0
	b–jet veto for jet p_{T} (GeV)	25	30	-
	p_{T}^{H} (GeV)	-	-	40
Boosted	$p_{\text{T}}(j_1)$ (GeV)	40	-	-
	p_{T}^{H} (GeV)	100	100	100
	b–jet veto for jet p_{T} (GeV)	25	30	-

- VBF – targeted at the vector boson fusion Higgs production mechanism. Characterized by two jets with a large pseudorapidity separation.
- Boosted – targeted at events with boosted Higgs boson from the gluon fusion production mechanism. It includes only events which fail the VBF category definition. This category selects Higgs boson candidates which have larger $p_T(p_T^H > 100\ GeV)$.

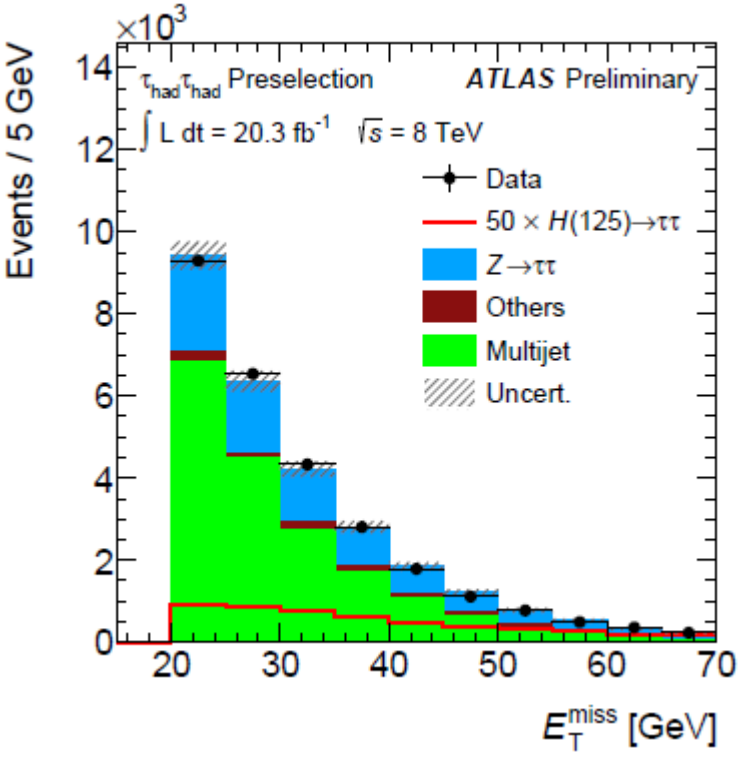
Missing energy



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

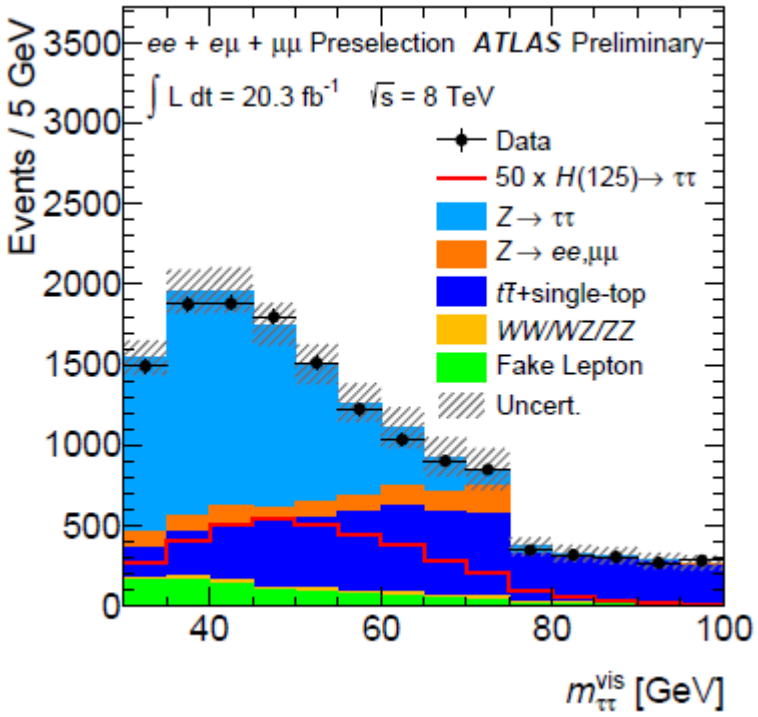


$\tau_{lep}\tau_{had}$

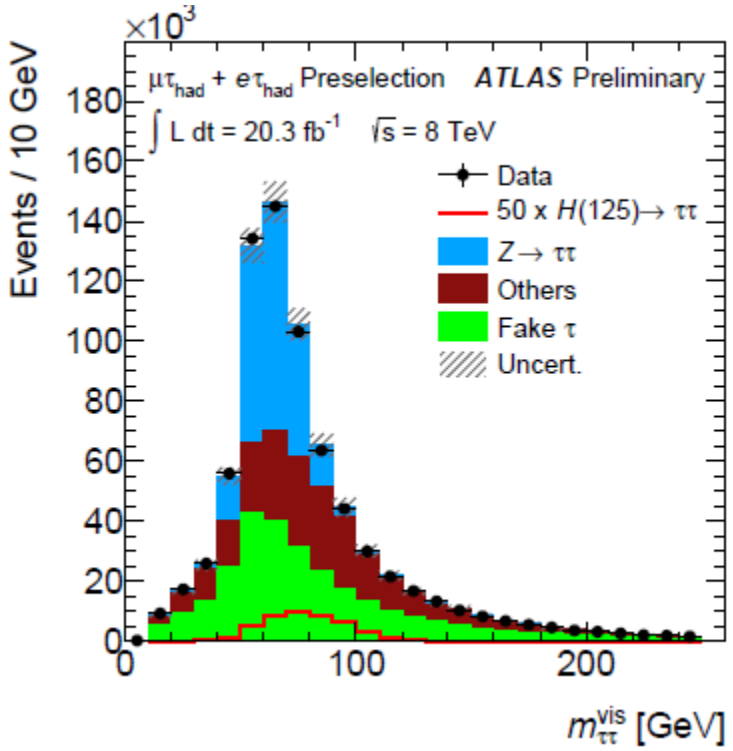


$\tau_{had}\tau_{had}$

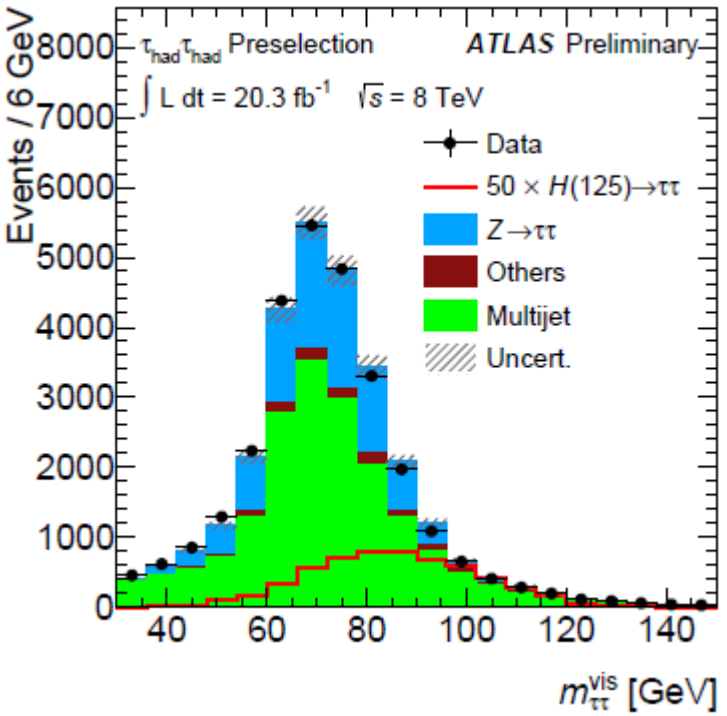
$m_{\tau\tau}^{vis}$



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



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



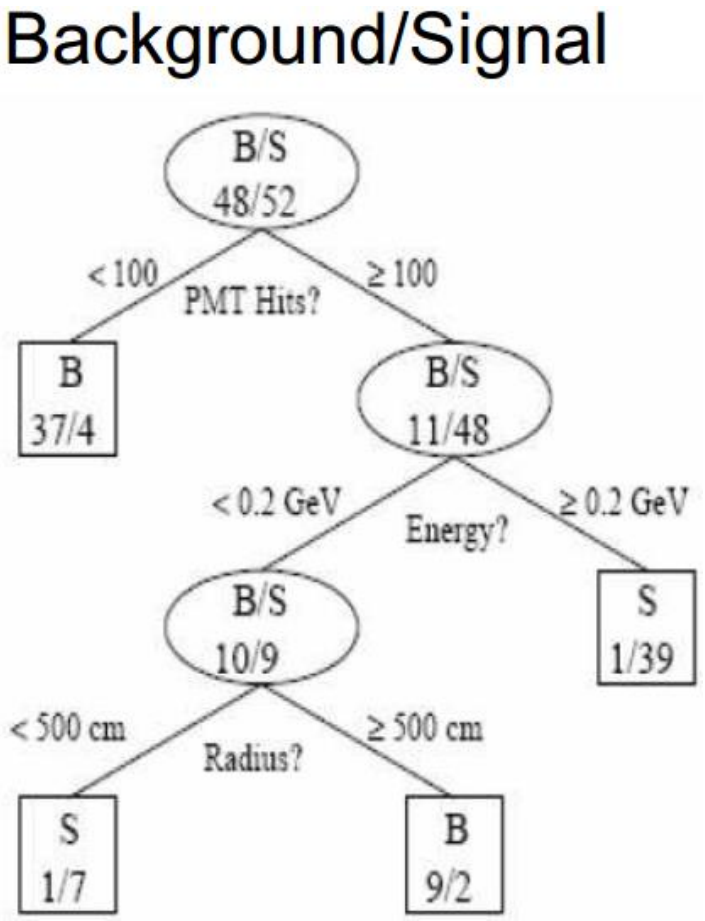
$\tau_{had}\tau_{had}$

Boosted decision trees

Decision Trees are particularly sensitive to statistical fluctuations in the data making up their Training Sets.

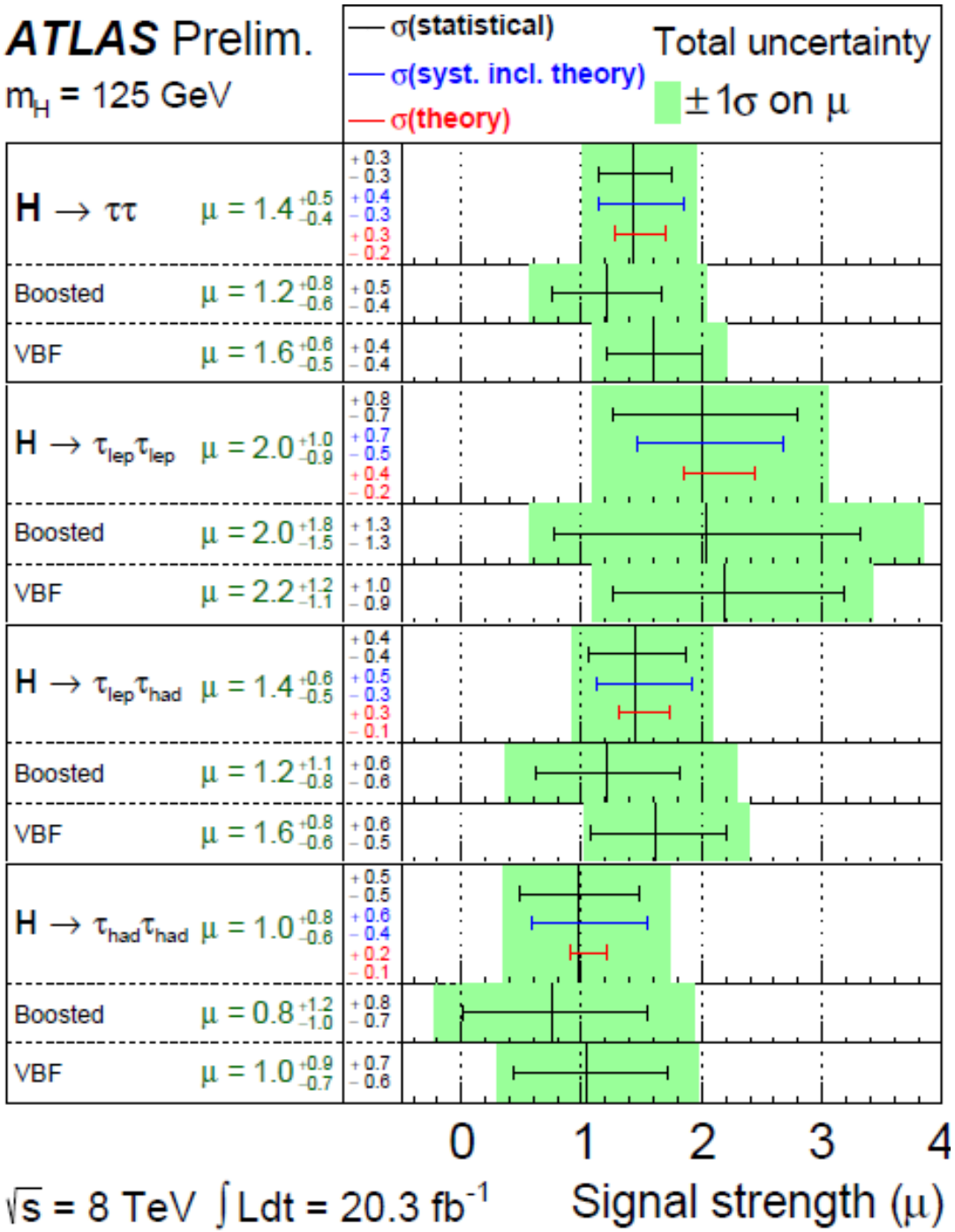
Solution – boosting.

Idea: Built many trees O(1000), so that the weighted average over all trees is insensitive to fluctuations.



Results

- The observed signal strength $\mu = \frac{\sigma_{measured}}{\sigma_{SM}} = 1.4^{+0.5}_{-0.4}$ is compatible with the SM expectation.
- For m_H=125 GeV, the observed p_0 value is 2.0×10^{-5}, which corresponds to a deviation from the background-only hypothesis of 4.1 standard deviations. This can be compared to an expected p_0 value of 6.6 × 10−4 (3.2 standard deviations). This is direct evidence for $H \to \tau^+\tau^-$ decays.



Conclusions

- A search for a Higgs boson of mass 125 GeV decaying into the $\tau^+\tau^-$ final state has been performed using the full ATLAS 2012 dataset, corresponding to an integrated luminosity of L = 20.3 fb^{-1} of pp collisions at a centre-of-mass energy of 8 TeV.
- A signal has been measured with a significance of 4.1 standard deviations, compared with an expected significance of 3.2 standard deviations.
- This constitutes direct evidence of the decay of the Higgs boson to fermions. The observed signal strength $\mu = 1.4^{+0.5}_{-0.4}$ is compatible with the Standard Model expectation.

Thank You