SM H→ττ with ATLAS

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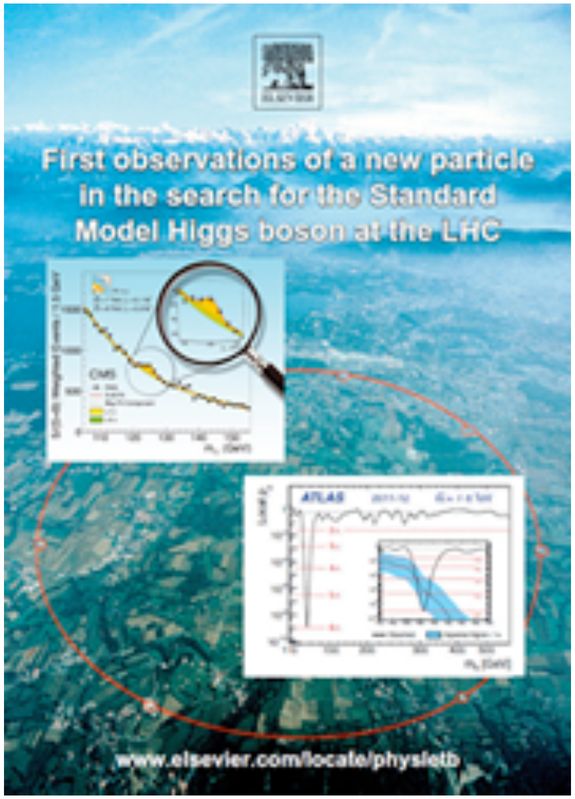
Why bother with H→ττ ?

- **Summer 2012: Historic observation of a new Higgs-like particle @ ~125 GeV**

Phys.Lett. B716 (2012) 1-29

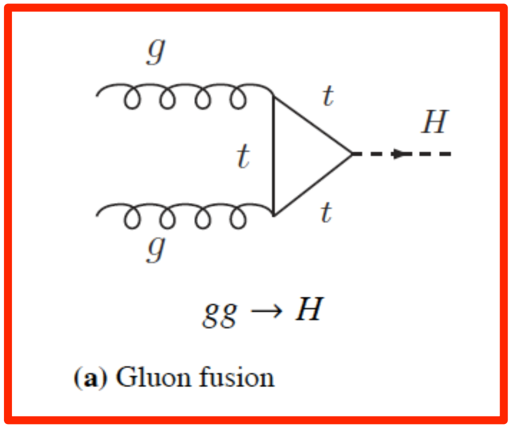


But.. What did we observe exactly?

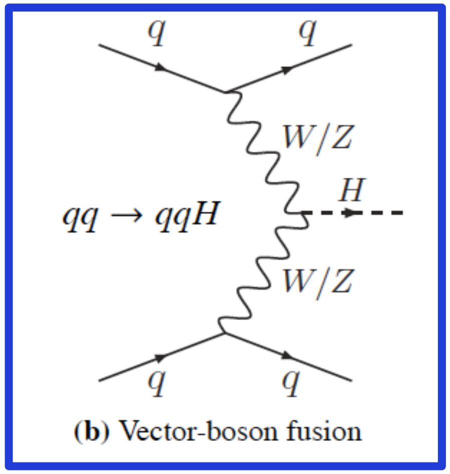
- Too early for definitive answers
- Some facts:

- Couples to Vector Bosons
  - ZZ/WW
- Couples to fermions?
  - Probably yes: ggF production and γγ decay via quark loop.
- Couples to leptons?
  - ττ search is addressing this question

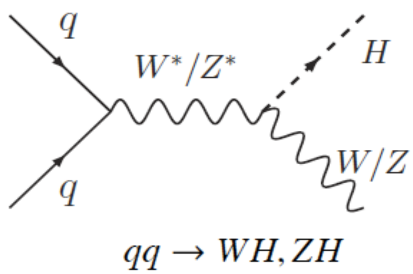
SM Higgs boson in LHC

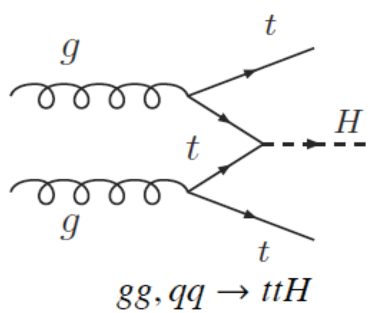


(a) Gluon fusion

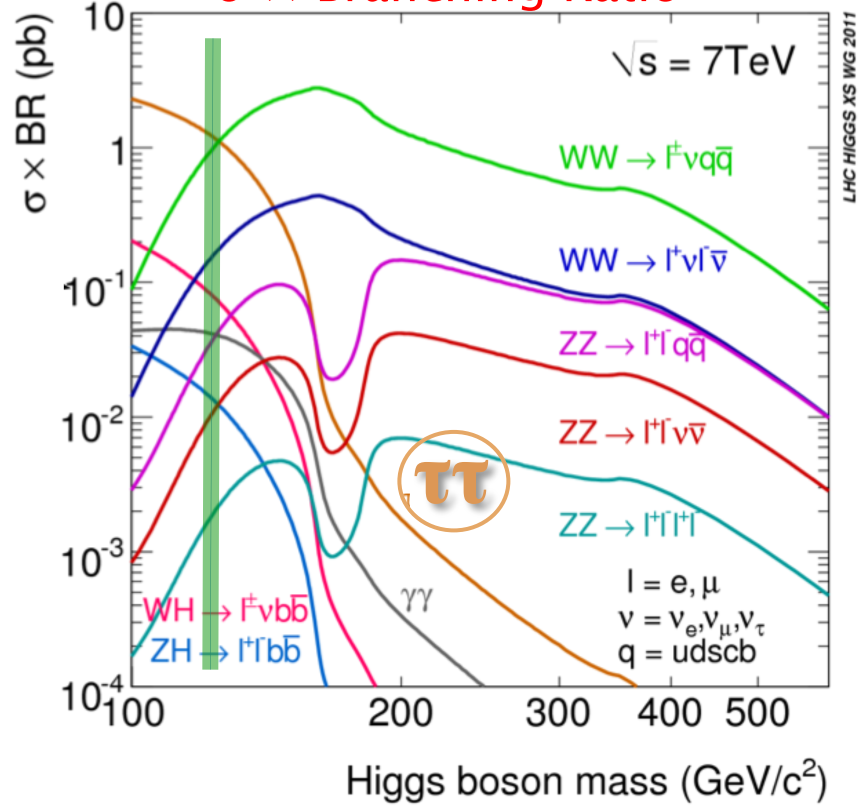


(b) Vector-boson fusion



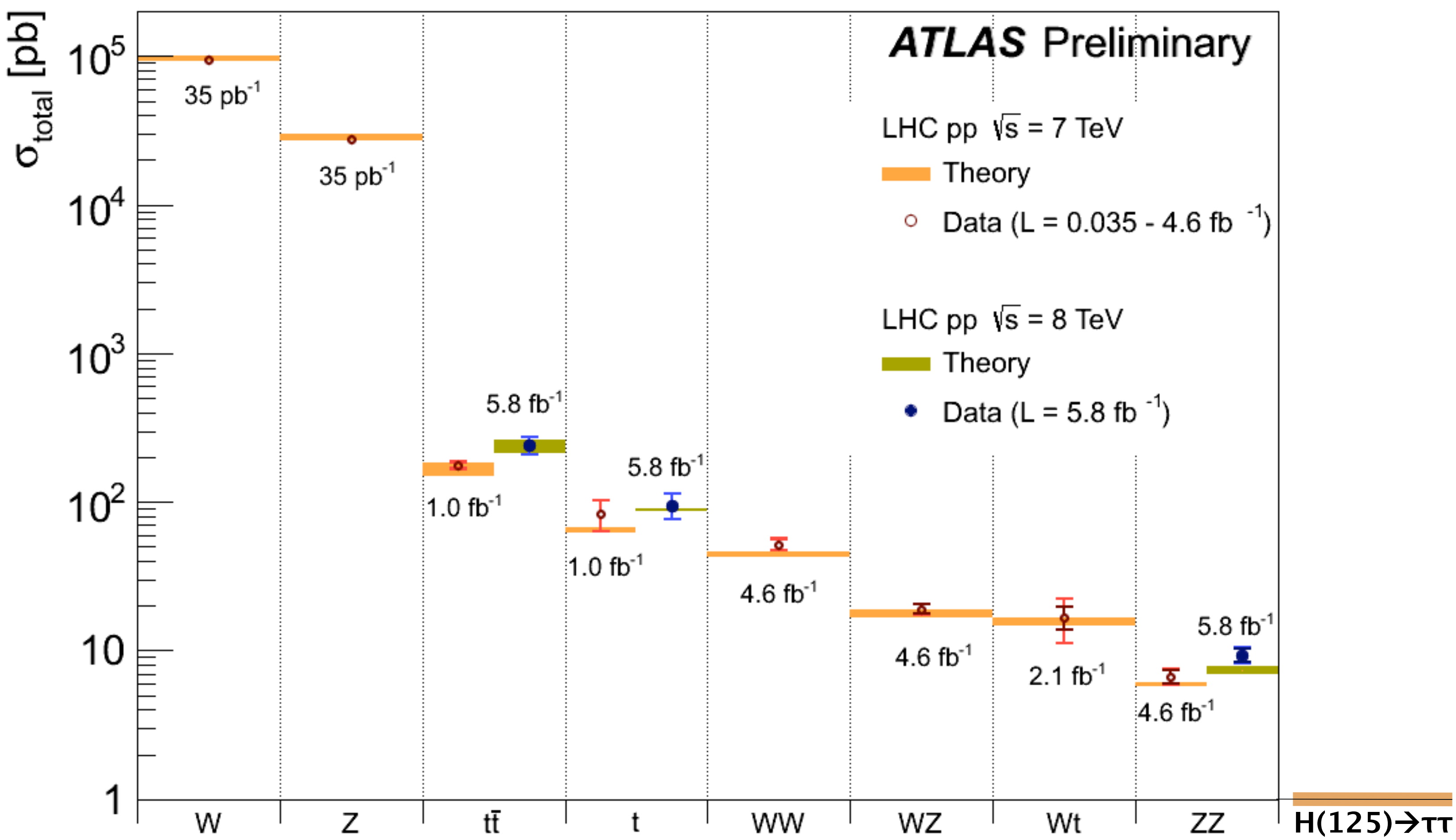


σ × Branching Ratio



- Higgs-like boson of m_H~125 GeV accessible
  - bb, **ττ**, WW*, ZZ*, γγ, Zγ, μμ
- **ττ**
  - With WW→lνqq, highest σ×BR ~ 1pb @ 7 TeV
  - Well motivated search, but very challenging

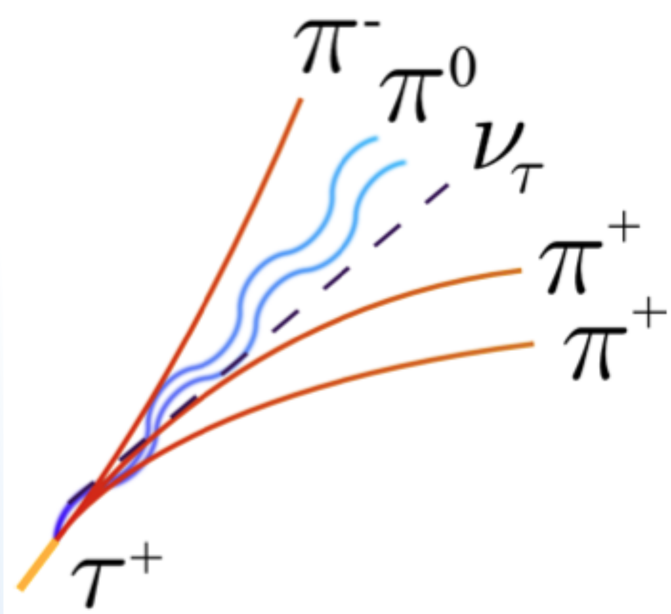
Large amount of SM backgrounds



- SM background cross-sections
  - Few to many orders of magnitude higher than expected signal cross-section

Tau lepton trivia in one slide

- Mass: 1.777 GeV/c^2
- cτ: ~87μm



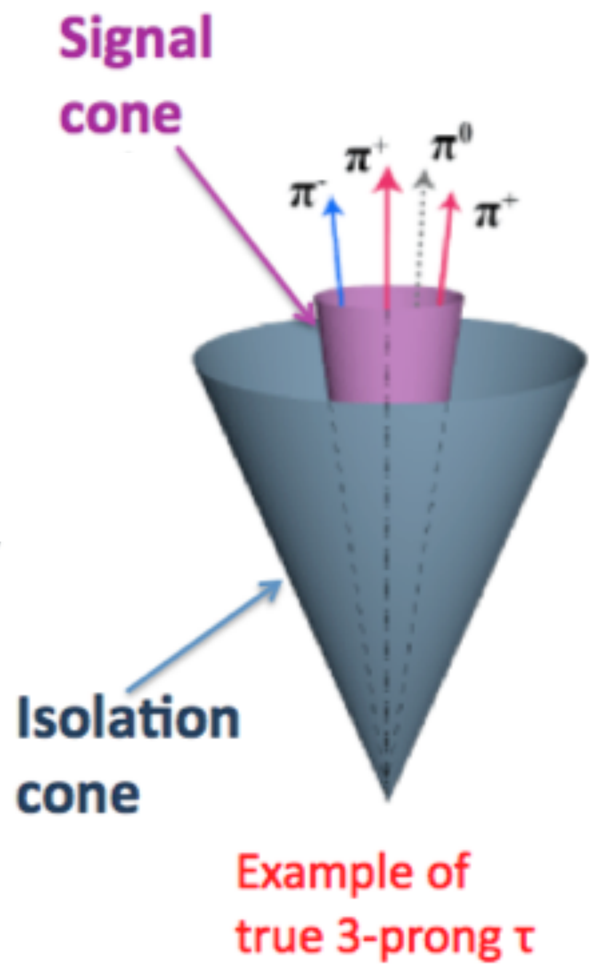
3prong hadronic tau decay

Most important decay modes

Decay Mode	Branching Fraction
Leptonic modes	**~35%**
$\tau^\pm \to e^\pm \nu_e \nu_\tau$	18%
$\tau^\pm \to \mu^\pm \nu_\mu \nu_\tau$	17%
Hadronic modes	**~65%**
1 prong (1 charged pion)	**46%**
$\tau^\pm \to \pi^\pm \nu_\tau$	11%
$\tau^\pm \to \pi^\pm 1\pi^0 \nu_\tau$	26%
$\tau^\pm \to \pi^\pm 2\pi^0 \nu_\tau$	9%
3 prong (3 charged pions)	**14%**
$\tau^\pm \to \pi^\pm \pi^\pm \pi^\mp \nu_\tau$	9%
$\tau^\pm \to \pi^\pm \pi^\pm \pi^\mp 1\pi^0 \nu_\tau$	5%

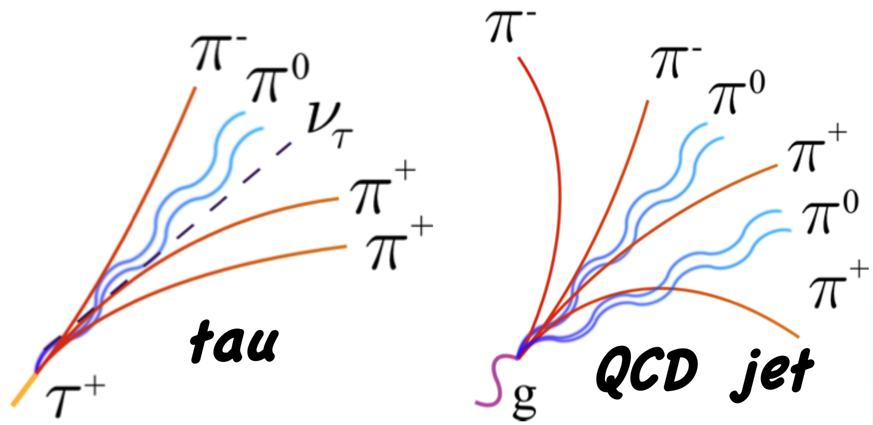
Tau Reco (τ_{had}) in ATLAS

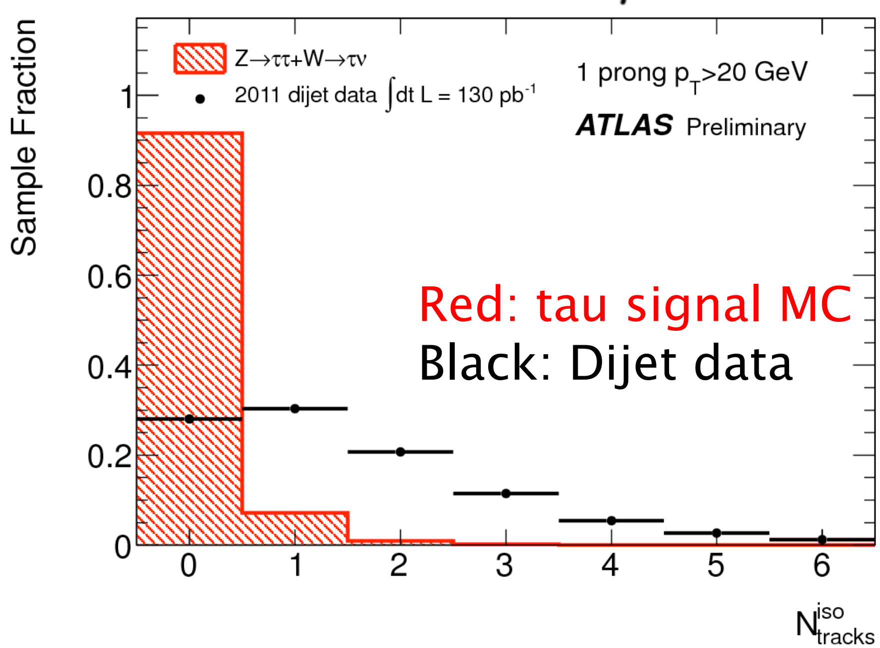
- τ_{had} appears as a narrow isolated jet
- τ_{had} seed: jet of cone $\Delta R<0.4$, $p_T>10$ GeV and $|\eta|<2.5$
- Classify τ_{had}: count number of tracks in signal cone of $\Delta R<0.2$ around the jet seed
- τ_{had} energy: Energy of calo topological clusters in $\Delta R<0.2$
- Isolation region: cone $0.2<\Delta R<0.4$



Tau Identification (TauID)

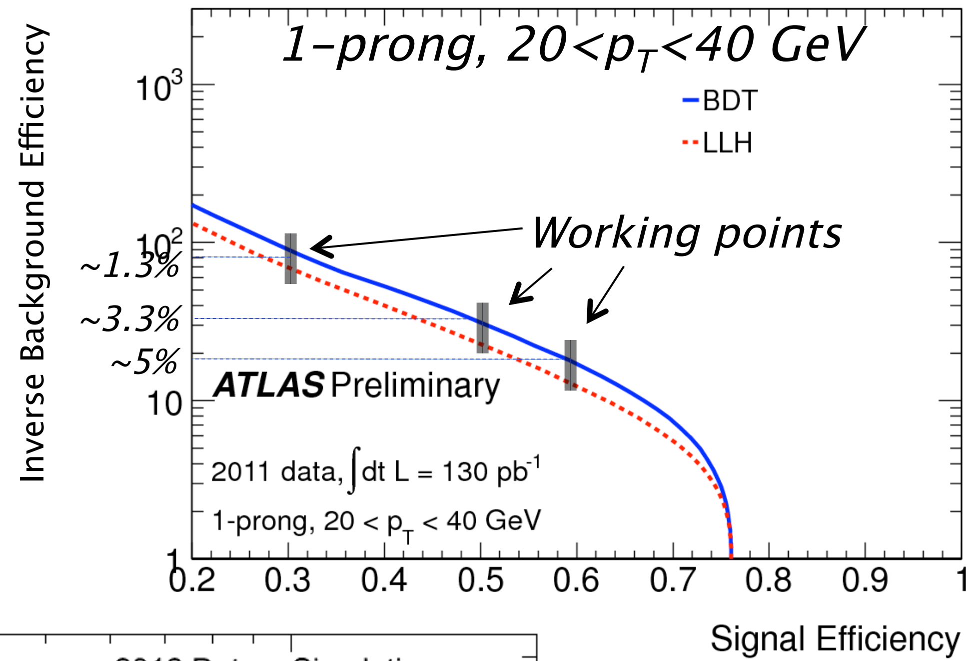
- **TauID: Distinguish τ_{had} jets from QCD jets and electrons**
- Use a number of discriminating variables based on tau properties: isolation, energy profiles, fractions of EM & Had energy, angular distances
- Combine all variables separately on 1-prong and multi-prong tau decays using MVA discriminator

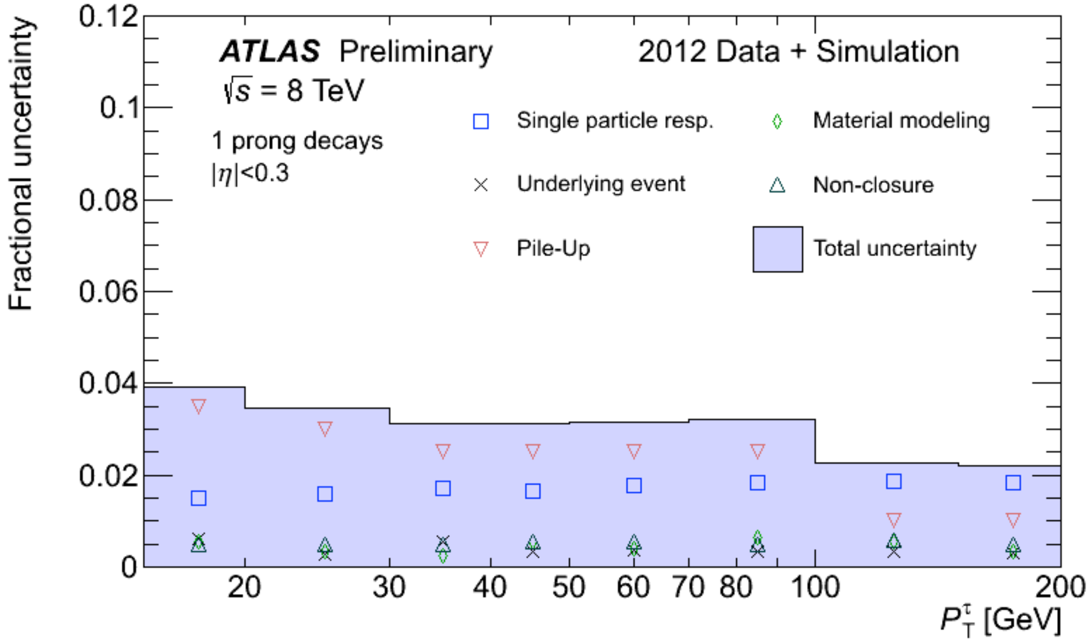




TauID efficiency, energy scale

- Every TauID available with predefined cuts, of signal efficiency:
  - Loose: ~60%
  - **Medium: ~50%**
  - Tight: ~30%
- 2012 Energy scale uncertainty: ~4%





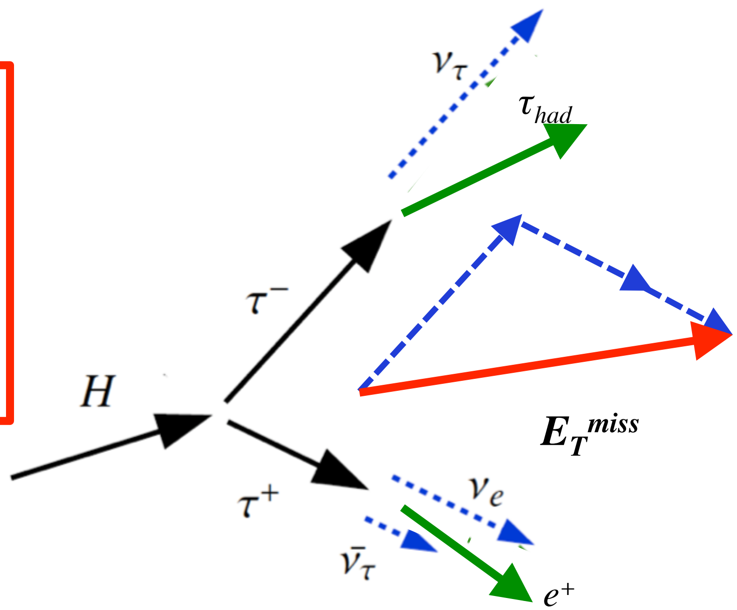
$H \to \tau^+\tau^-$

- According to the decay of τ, split the analysis in 3 channels
  - *ll 4ν* (***LepLep***)
  - *$l\tau_{had}$ 3ν* (***LepHad***)
  - *$\tau_{had}\tau_{had}$ 2ν* (***HadHad***)

, *Lep : e or μ*
Had: hadronic decay of τ

- Neutrinos result into missing energy, thus missing information

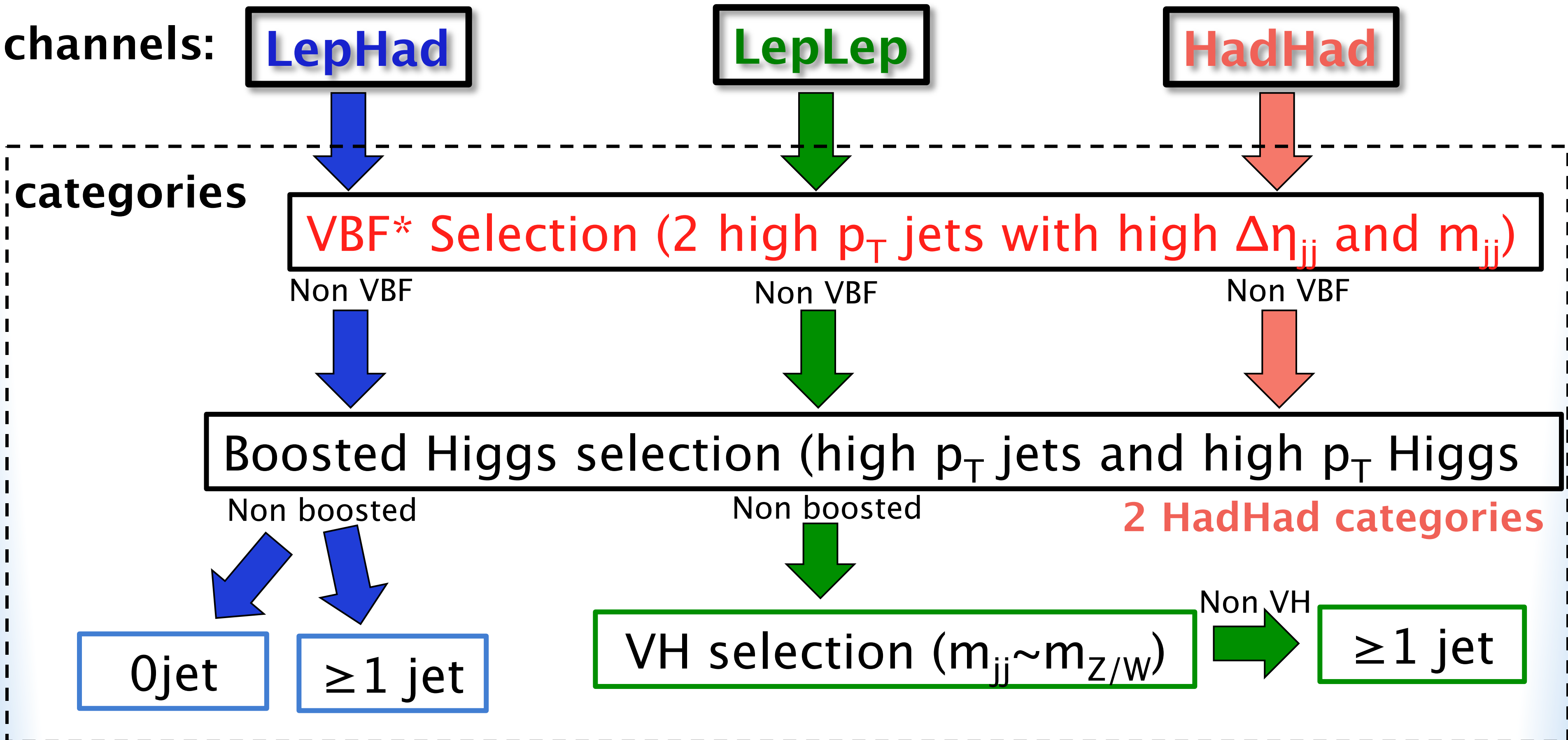
➔Main challenge: Separate signal from $Z \to \tau^+\tau^-$
- Estimate mass of di-tau: m_H
- Difficult due to the presence of neutrinos

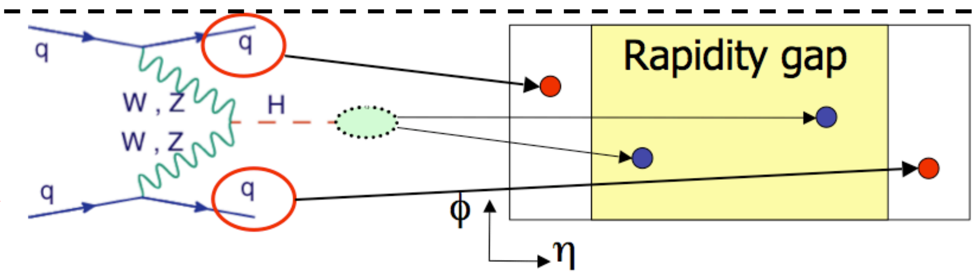


- Combine all three channels to search for H→ττ decays
- Show results with 4.6fb^{-1}(7TeV) and 13fb^{-1}(8TeV) data
  - *ATLAS-CONF-2012-160 (HCP, Kyoto November 2012)*

Analysis strategy

- Split events in several categories to enhance signal sensitivity and reduce backgrounds

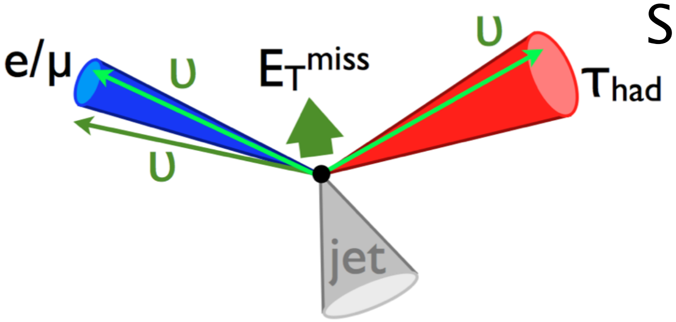




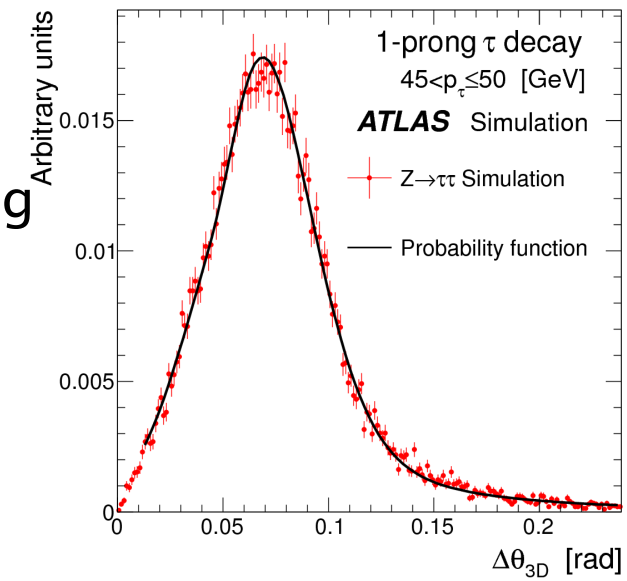
*: VBF, highest sensitivity

DiTau mass reconstruction: MMC

- **Missing Mass Calculator (MMC)** based on *NIM A 654 (2011) 481*



Solve τ, E_T^{miss} in $\Delta\varphi(\tau,\nu)$ parameter space using $\Delta\theta_{3D}(\tau,\nu)$ template from simulation as PDF



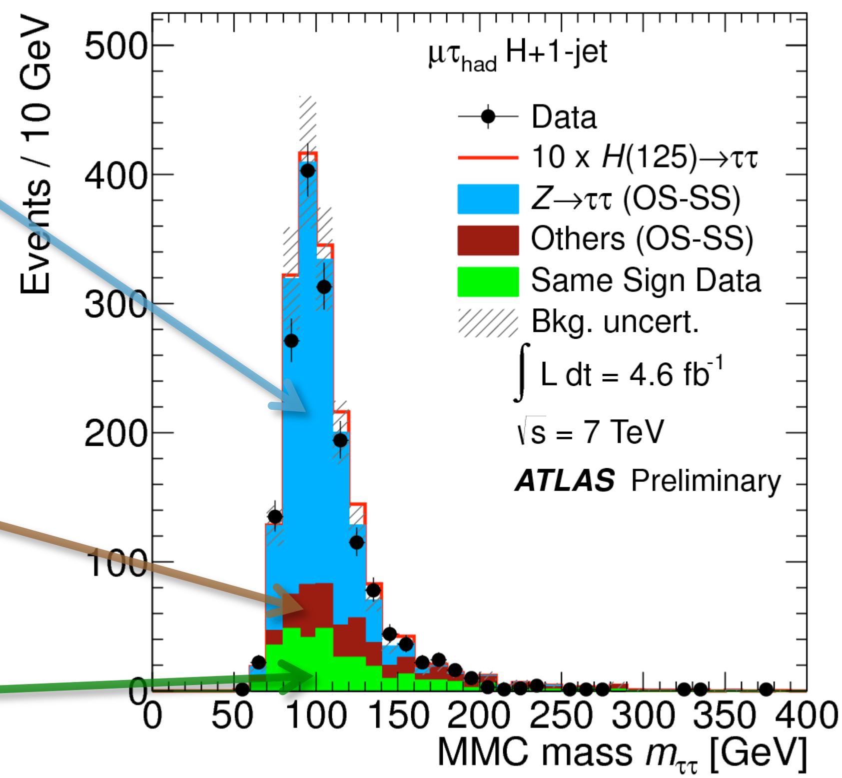
- High efficiency for ττ resonances (>97%)
  - Works for back-to-back events as well
- More precise mass description
  - Reduced tails, resolution 13-20%, correct peak position

➢ MMC mass the final discriminating variable used in all 3 channels

➢ The most powerful (and almost the only) way to enhance separation of signal against Z→ττ

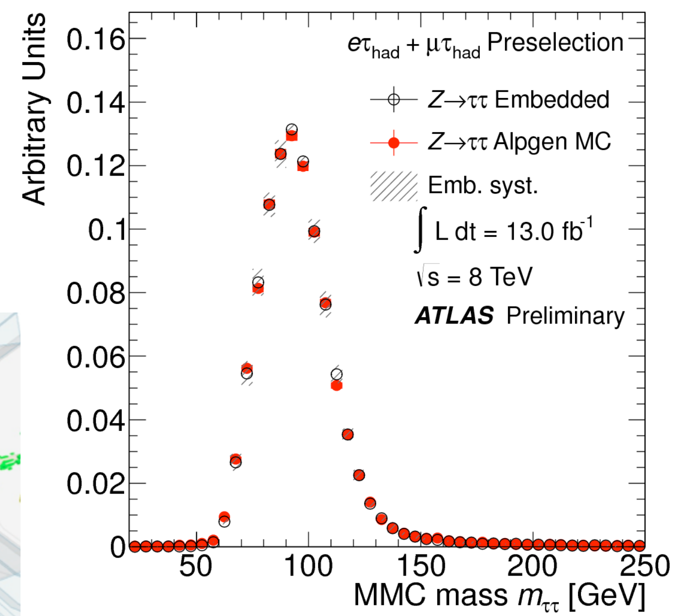
Background estimation

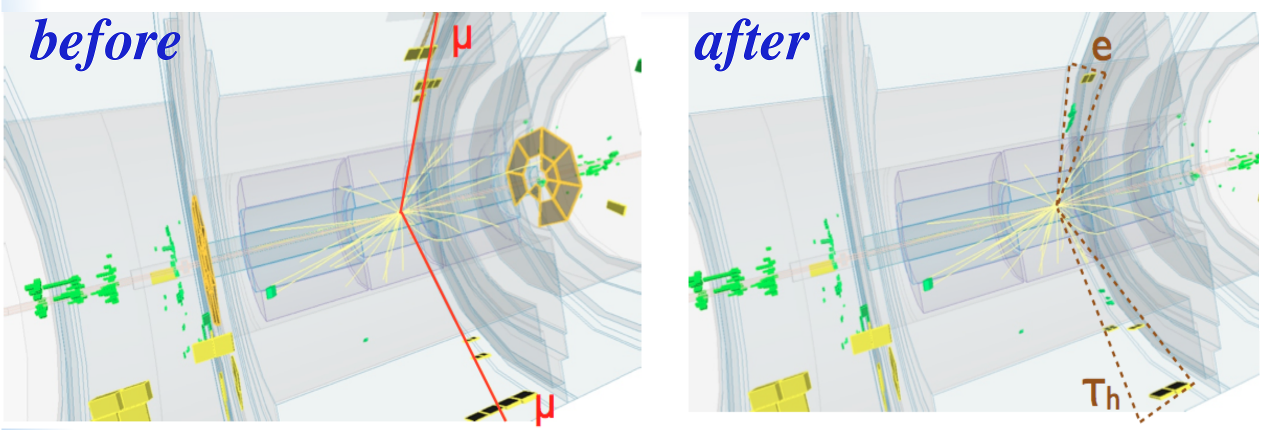
- Dominant Z→ττ
  - Almost data driven method: Embedding
  - **Same for all channels**
- Z→ll, top, Diboson
  - Shape from MC
  - Normalization from data CR
- QCD, W rich samples in fake tau's
  - Data driven methods



Background estimation: Z→ττ

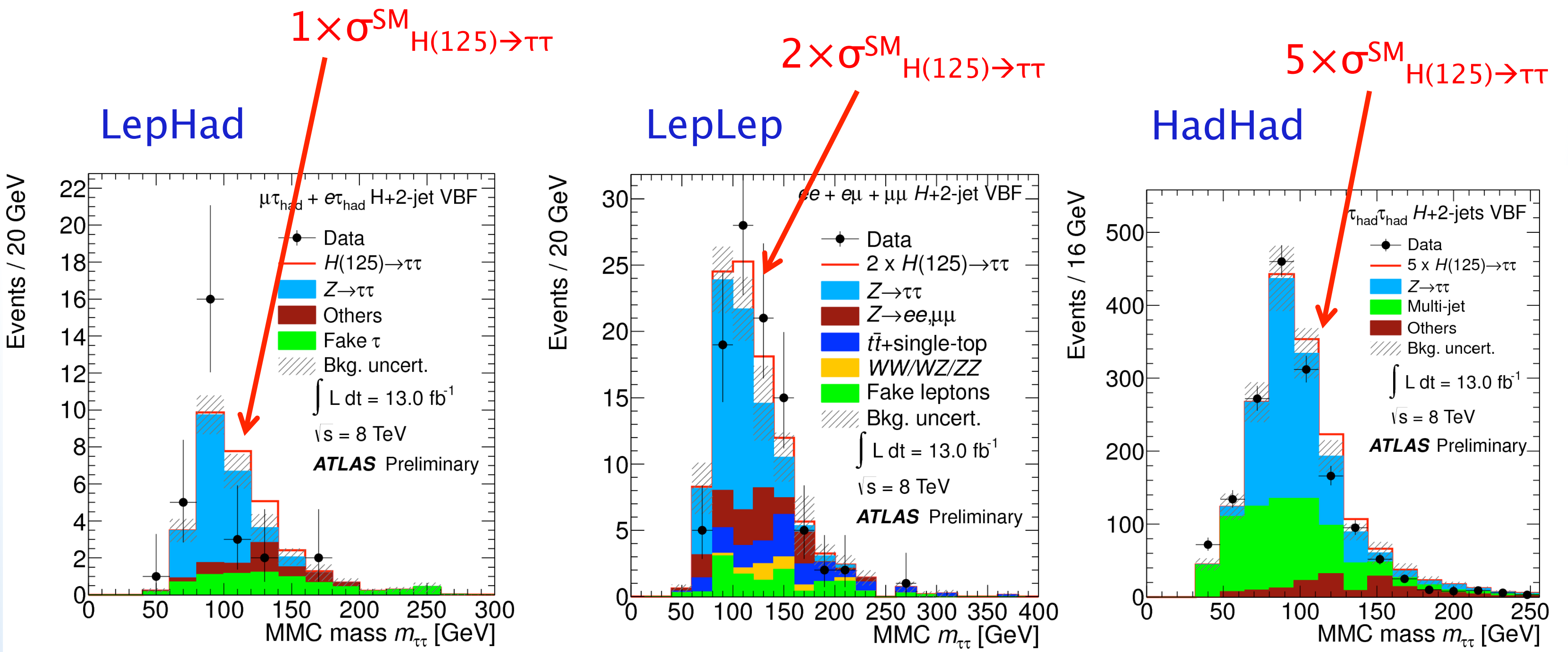
- Dominant background due to the same final state Z→ττ
- Shape estimation from Z→μμ data: "**Embedding**" technique
  - Delete muon tracks and deposited calorimeter energy from data events
  - Replace by full-simulated Z→ττ decays, generated with Tauola with identical kinematics
  - Almost a pure data-driven technique
    - Jet/MET/pile-up/UE/etc described by data
    - Only tau decays described by MC





Results: VBF category

- VBF: 1st most sensitive category
- Limited statistics but best $S/\sqrt{B}$ ratio among all categories



Systematics

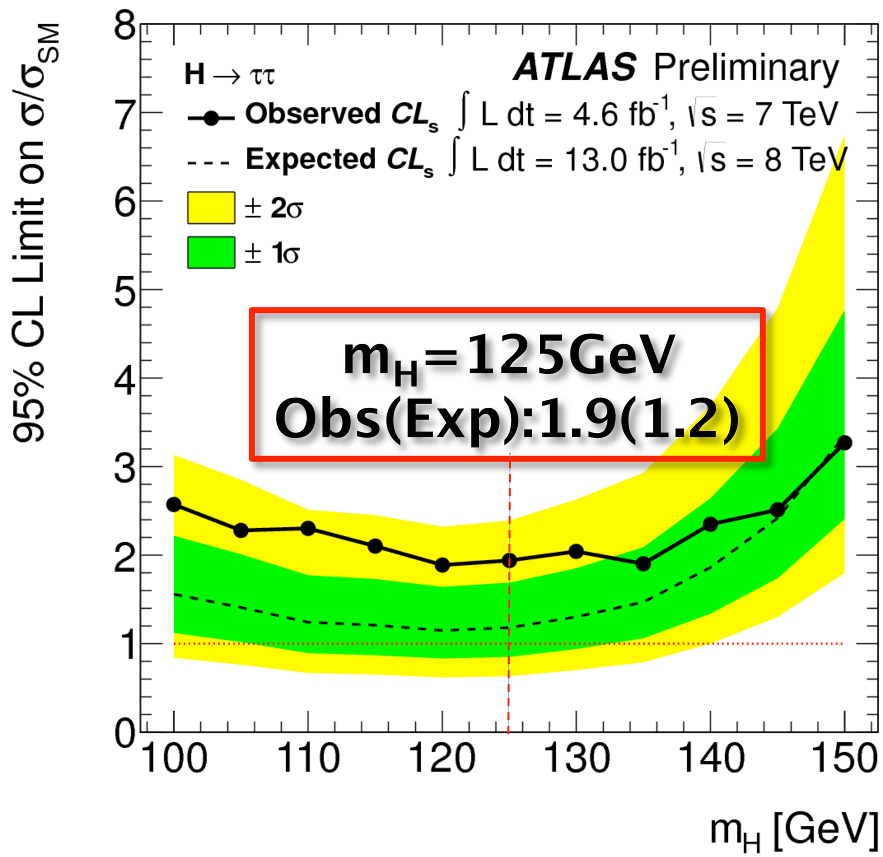
- Theory uncertainty on signal: 18 – 23%
  - QCD scale: ~1% for VBF, 8–12% for ggF
  - PDF: 8% for gluon processes, ~4% for quark processes

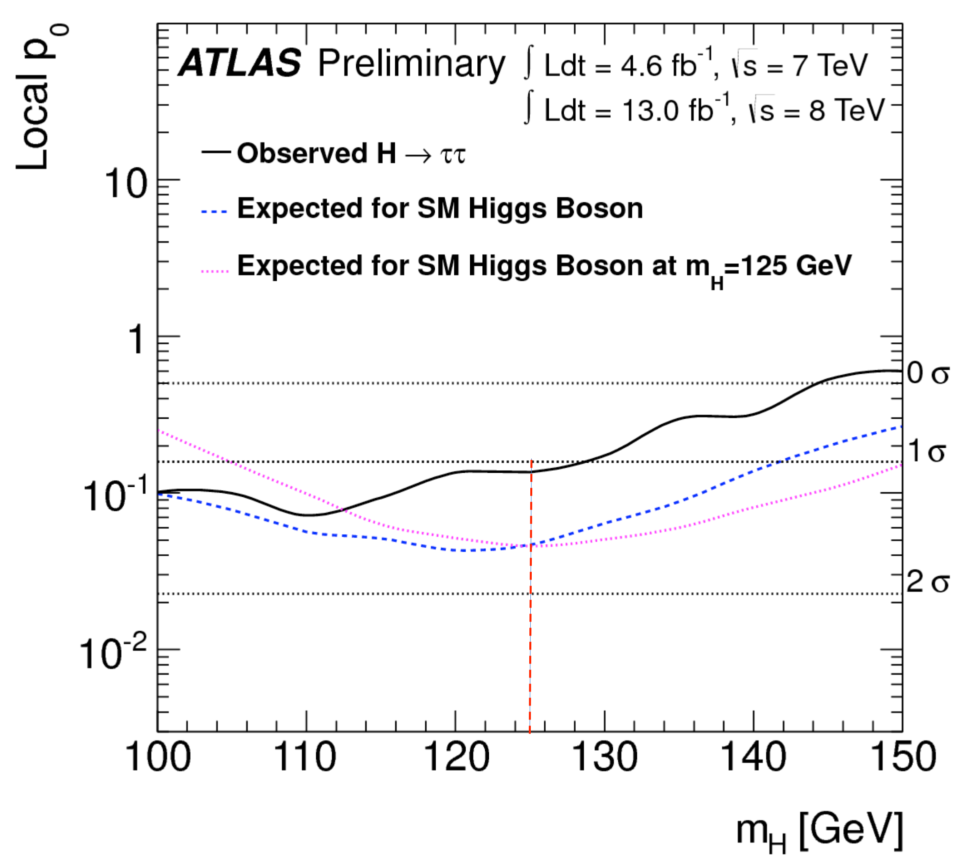
Dominant detector-related systematics:

	$Z \rightarrow \tau\tau$	*Signal*
Embedding	3%	---
JES	---	3–9%
TES	4–15%	2–9%
TauID	4–5%	
Luminosity	3.9% @ 7TeV 3.6% @ 8 TeV	

➢ Both shape and normalization variations are taken into account

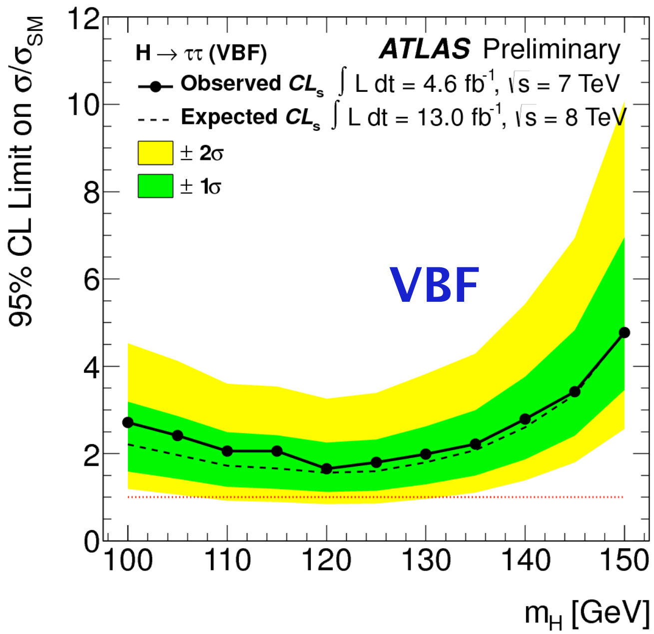
Results: combined limit and p0

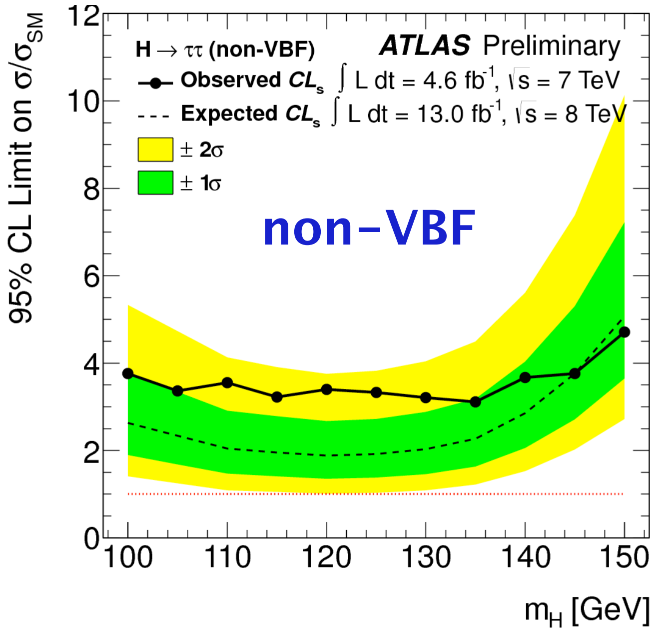


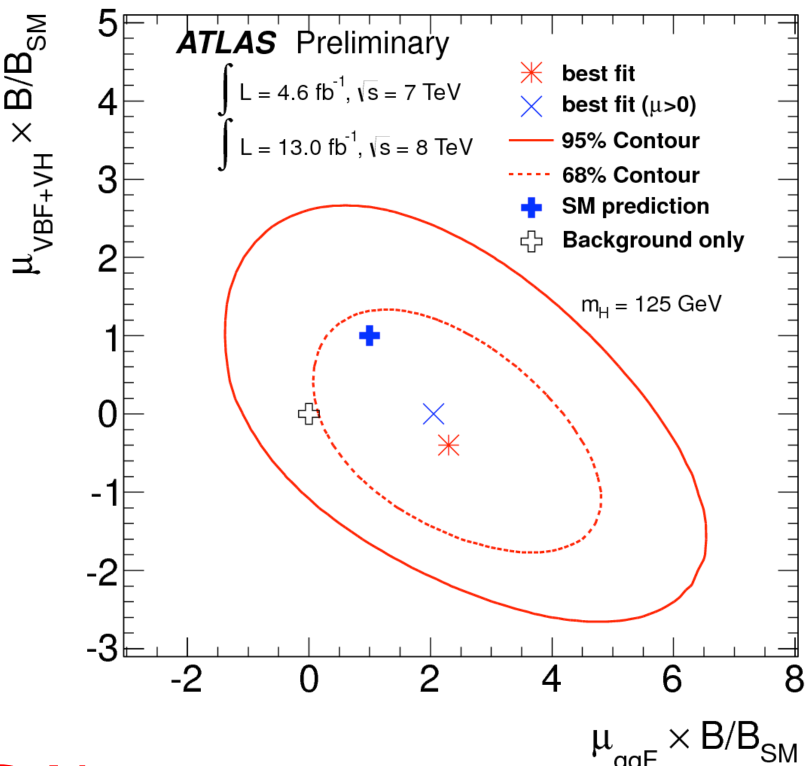


- Local p_0: probability that background fluctuation mimics signal
  - **m_H=125 GeV**
    - p_0: observed **1.1σ**, highest expected sensitivity **1.7σ**
    - Signal strength **μ= 0.7±0.7** consistent with both presence and absence of SM H→ττ signal

Result interpretation attempt





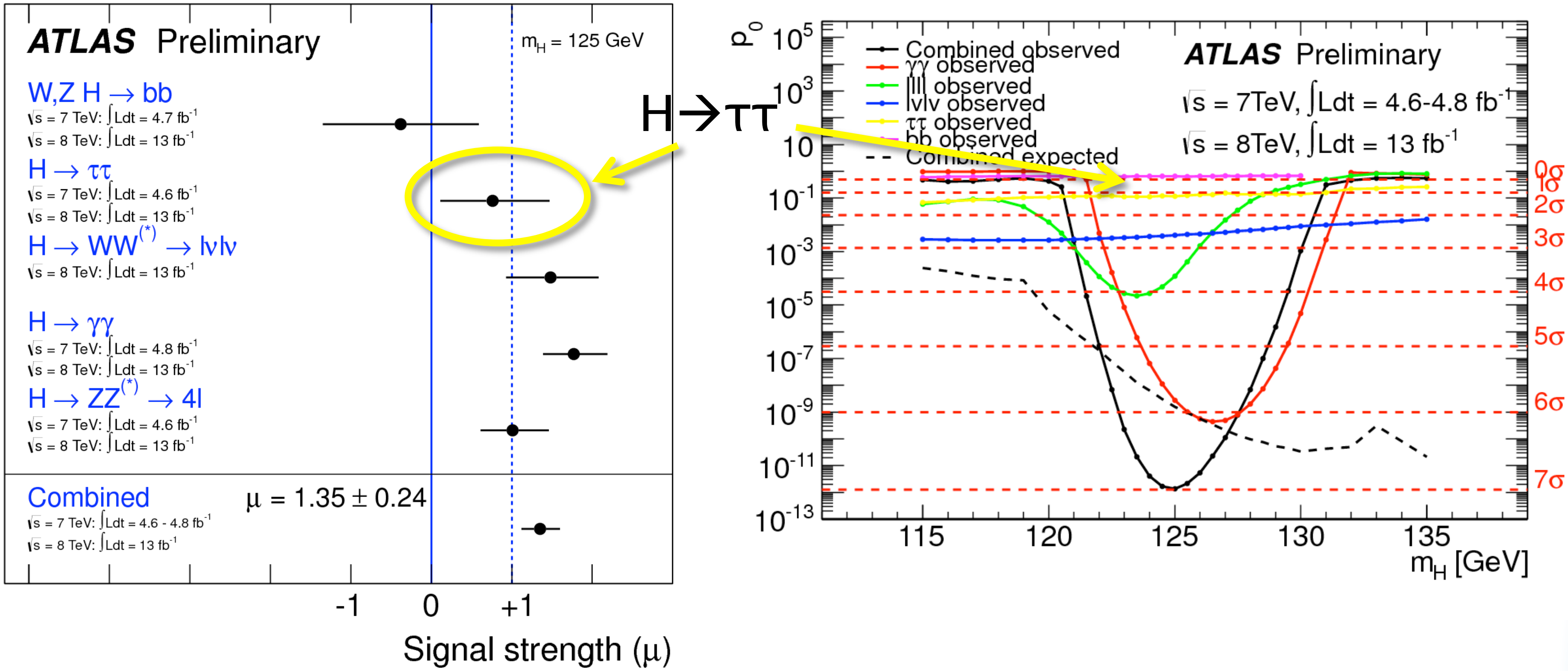


m_H=125 GeV :

- Consistent with background only hypothesis and SM Higgs signal
- Large uncertainties

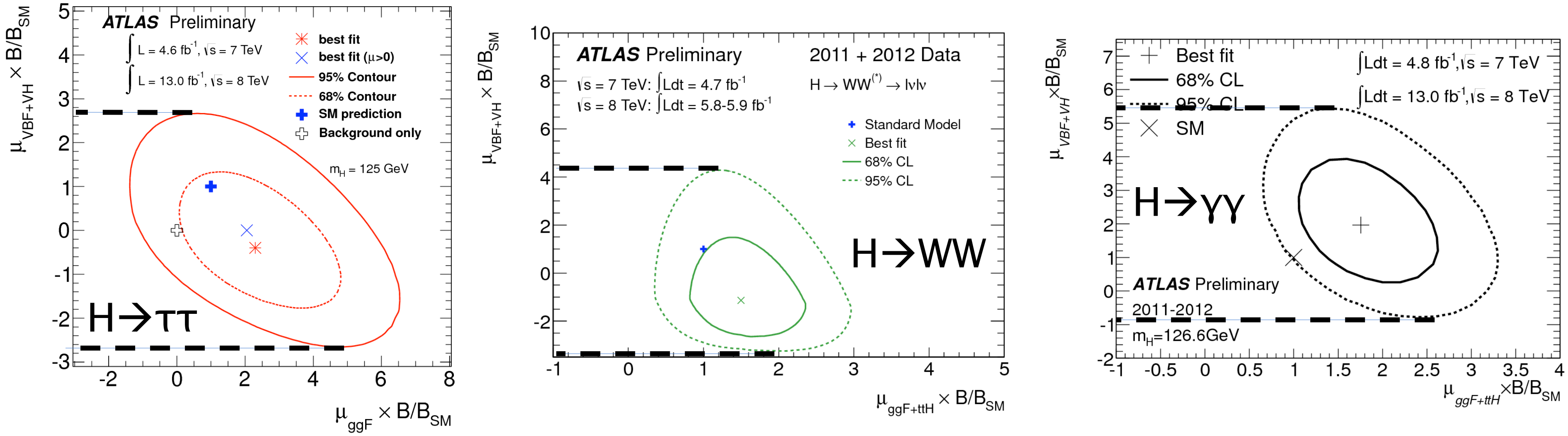
	VBF	nonVBF
Limit:	1.8(1.6)	3.3(1.9)

H→ττ in the overall picture



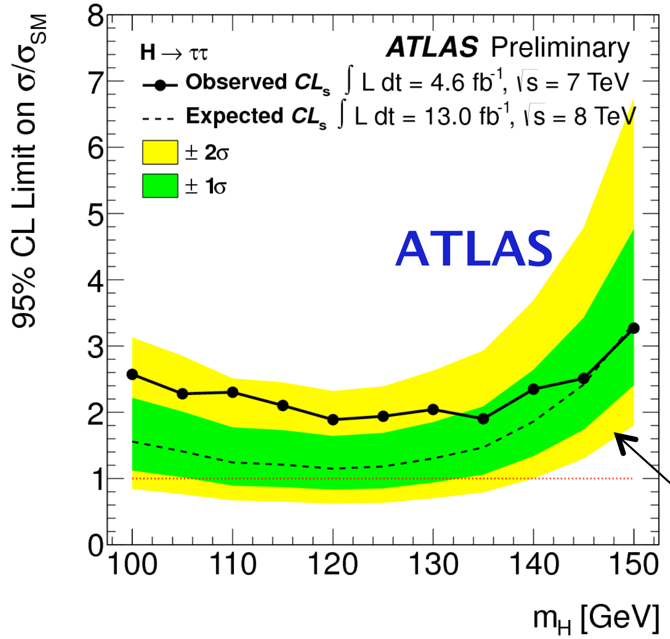
- Higgs combined excess 7σ, with H→ττ contribution of 1.1σ
- Very challenging and complicated analysis due to large amount of backgrounds, small S/√B, complexity of final state, large resolution effects
- Very important role in the SM Higgs searches, since provides direct measurement of the coupling to leptons

H→ττ uncertainty in VBF

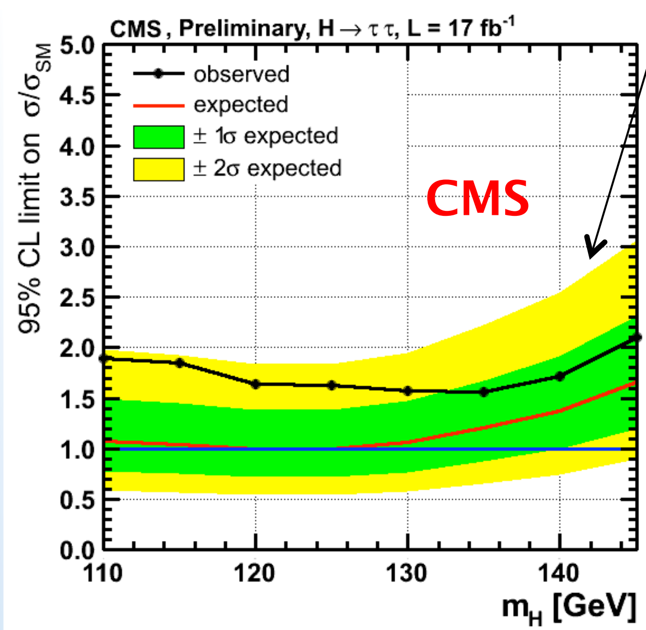


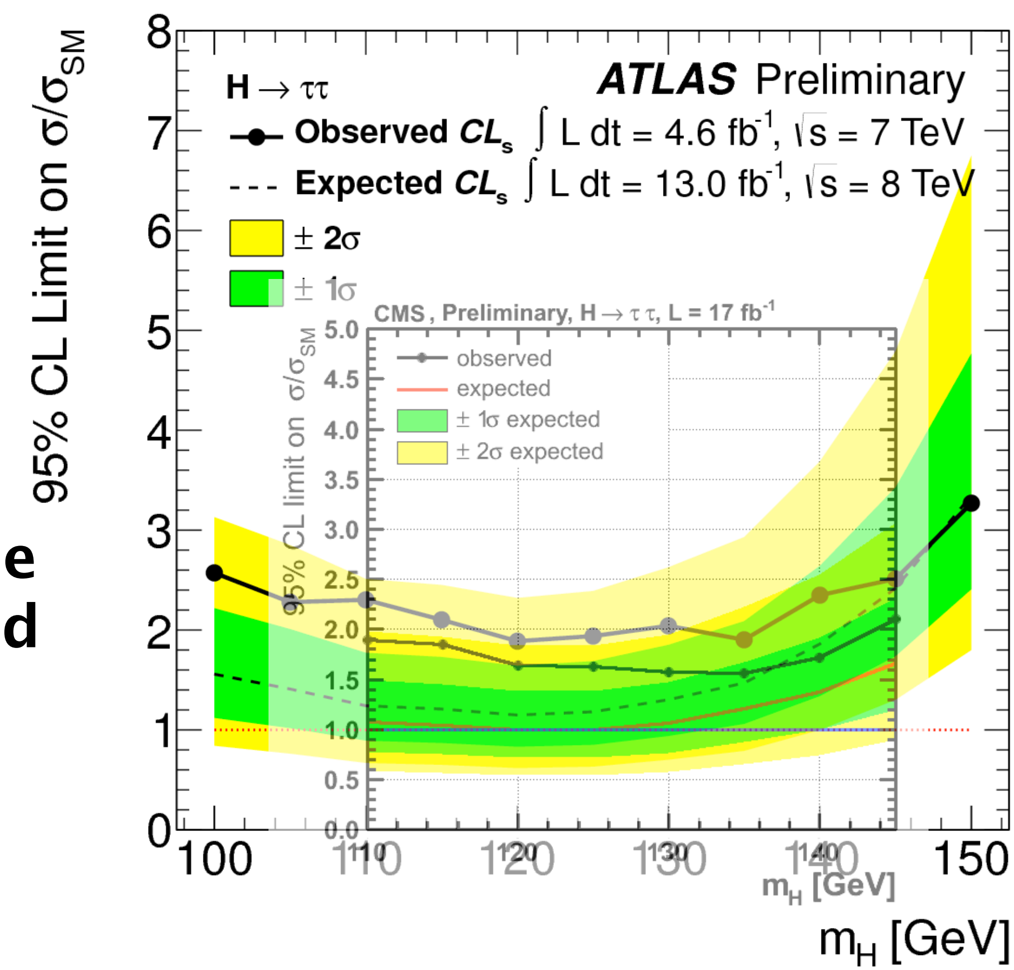
- Measure of the precision in probing VBF: projection in y-axis of 95% CL contour
  - H→ττ ~ 5.4μ
  - H→WW ~ 6.1μ
  - H→γγ ~ 6.4μ
- H→ττ has smaller uncertainty (better precision)
- Potential of contributing significantly in measuring VBF production mode of new boson

Limits H→ττ ATLAS Vs CMS



same trend



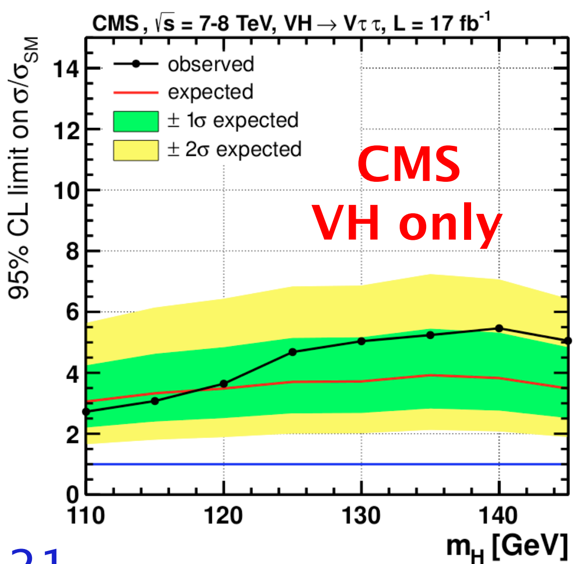


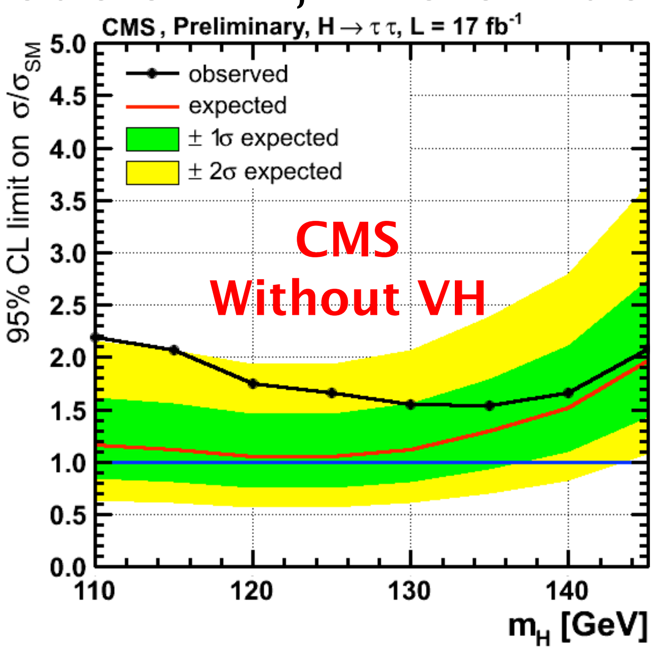
	CMS	ATLAS
	Observed (Expected) $\times\ \sigma_{SM}$	
m_H=125 GeV	1.63(1.00)	1.94(1.18)

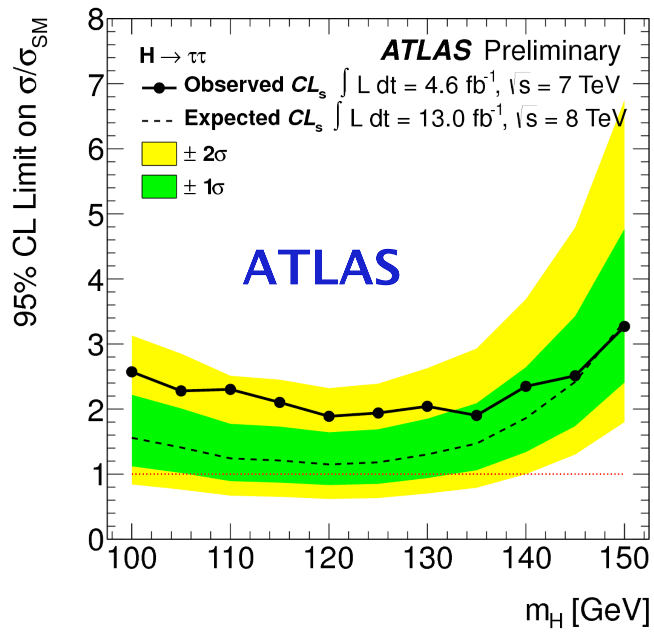
Notable differences

m_H=125 GeV	CMS	ATLAS
Local p_0 (observed)	1.8σ	1.1σ
Local p_0 (expected)	2.1σ	1.7σ
Signal strength μ	0.7 ± 0.5	0.7 ± 0.7

- CMS different event categorization low tau p_T Vs high tau p_T
  - 20% improvement with respect to CMS previous analysis
- CMS has two additional explicit analyses to probe signal in the production mode of VH, where V decays in leptons







ATLAS SM H→ττ perspective

- LHC 2 years shut-down period since a few days

H→ττ search in ATLAS

- Analyze full 2012 dataset, additional ~7fb^{-1} @ 8 TeV
- Reminder: current result with 4.6fb^{-1}(7TeV) & 13fb^{-1}(8TeV)
  - Expected sensitivity 1.7σ

- <u>Goal of new analysis to push the sensitivity as much as possible towards 3σ and provide a more conclusive statement on whether new boson couples to ττ and thus to fermions</u>

- Explore and use the enhanced discrimination power of MVA techniques
- Optimizing basic objects such as TauID, MET, jets, mass reconstruction

- Next update will include the complete 2011+2012 dataset

Conclusions

- SM $H\rightarrow\tau\tau$ in ATLAS up to now..
  - Analyzing 4.6(13) fb^{-1} @ 7(8) TeV
  - Combined limit:
    - Observed (expected): **1.9** (**1.2**)$x\sigma_{SM}$ @ $\mathbf{m_H}$**=125 GeV**
    - Excess of data driven by nonVBF, LepLep channels
  - Expected p_0 @ $\mathbf{m_H}$**=125 GeV: 1.7σ**
  - Observed p_0 @ $\mathbf{m_H}$**=125 GeV: 1.1σ**
- 7 additional fb^{-1} @ 8TeV are being analyzed
- Stay tuned for the next $H\rightarrow\tau\tau$ more sensitive update, coming soon!

VBF H→τ_{had} τ_{μ}