Imperial College London

Higgs Boson Searches at CMS

What Have We Found So Far?

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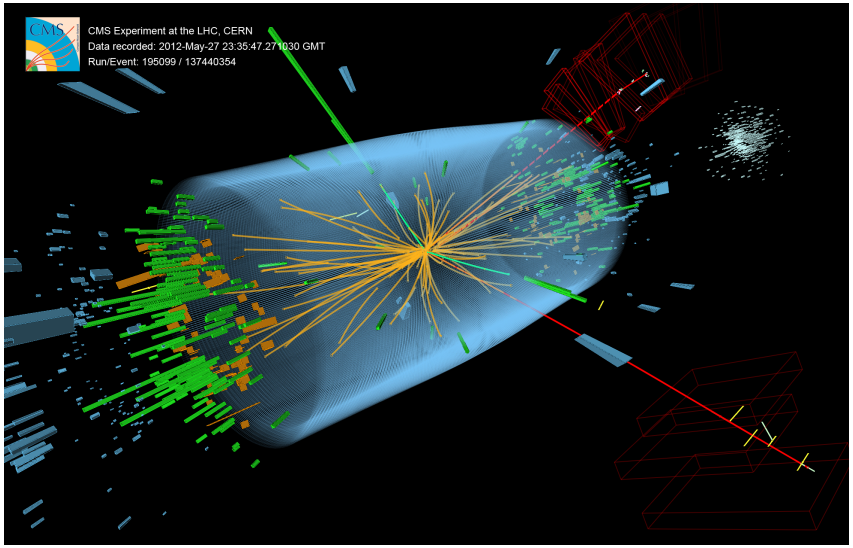
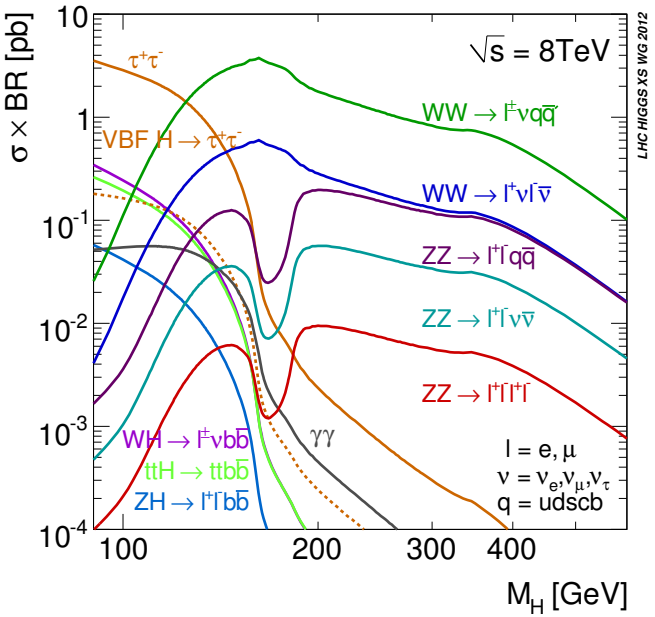
Outline

- A Higgs-like boson was discovered in 2012 at the LHC.
- How did we decide we'd discovered something?
- How do we answer the question: "Is it the Higgs?"



The Standard Model and the Higgs Boson

- Higgs boson is a consequence of the Higgs mechanism which gives mass to the weak vector bosons
- Higgs mechanism also gives rise to the fermion masses
- Standard Model couplings are well predicted



Combinations

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  - Setting exclusion limits on the SM Higgs Boson
  - Characterising excesses over the background
  - Extracting signal model parameters from the data

Setting Exclusion Limits

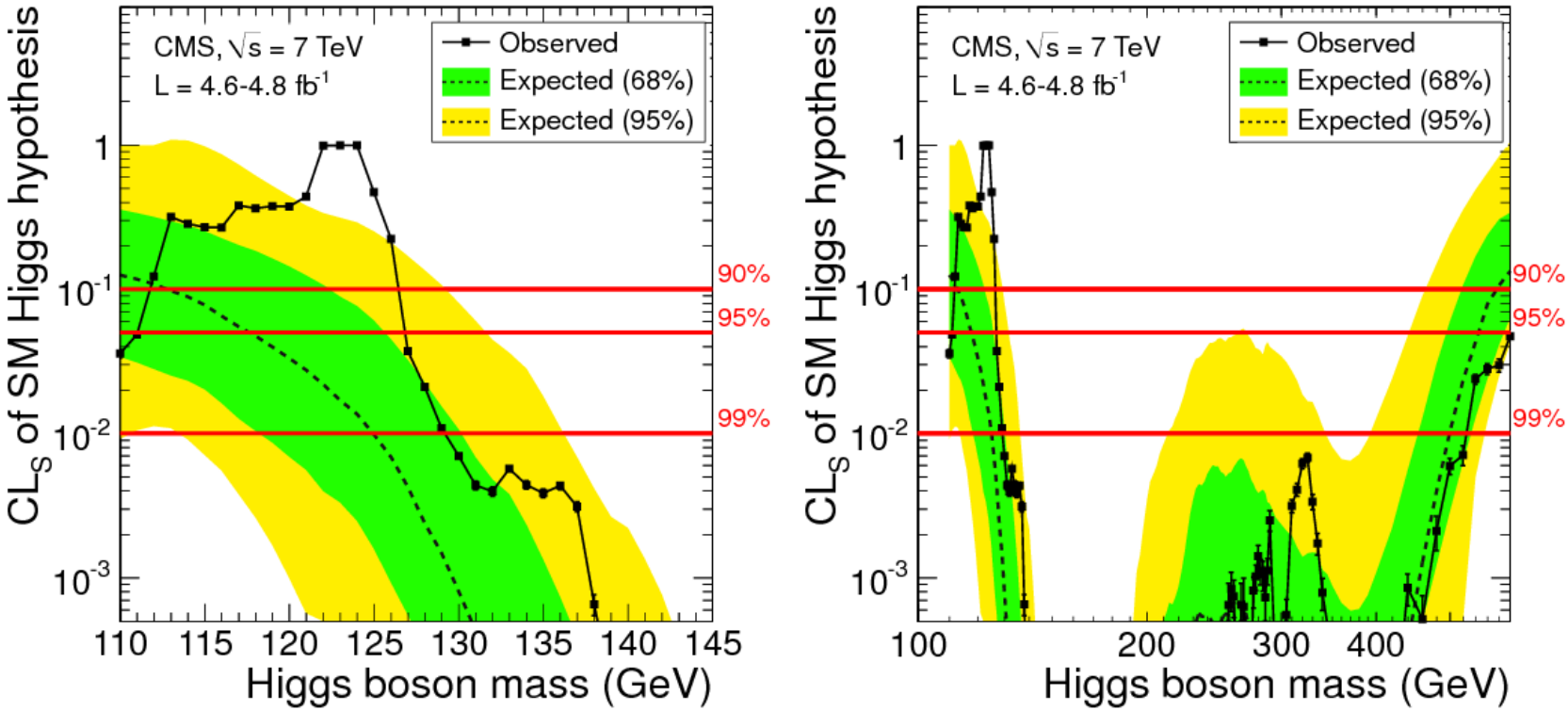
- The CL_s statistic is used, which is the number of times more likely the signal hypothesis is than the background hypothesis.
- It is defined as:

$$CL_s = \frac{P(q_\mu \geqslant q_\mu^{obs} | \mu \cdot s + b)}{P(q_\mu \geqslant q_\mu^{obs} | b)}$$

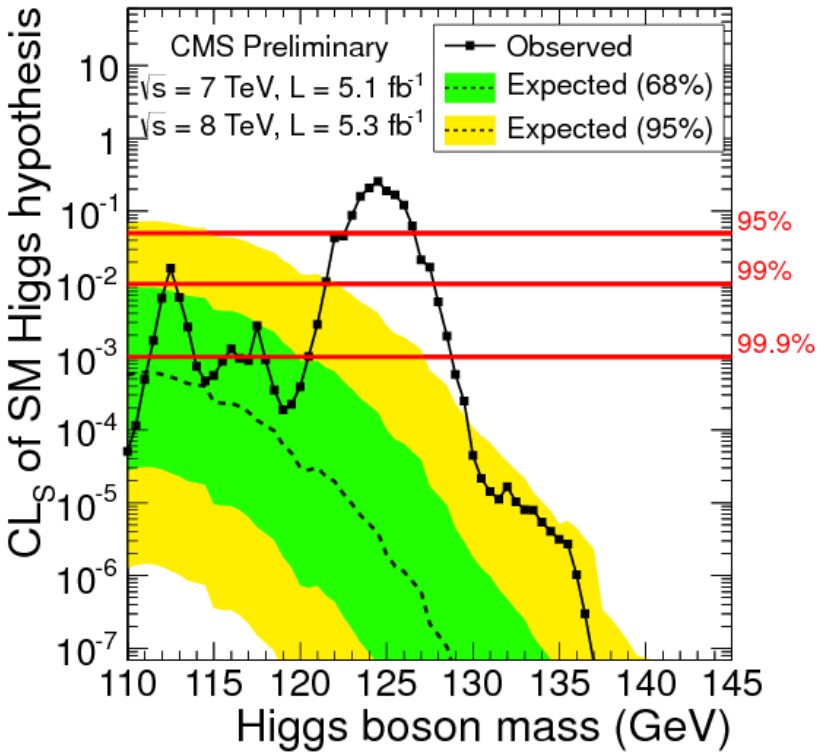
- μ is a signal strength modifier
- q_μ is a profile likelihood ratio defined as:

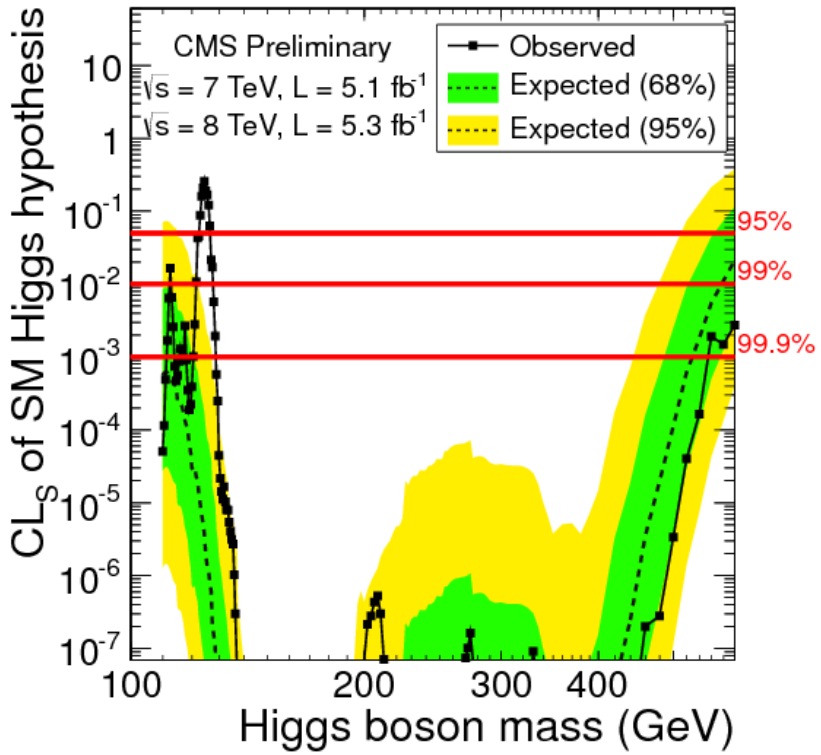
$$q_\mu = -2 \ln \frac{\mathcal{L}(obs|\mu \cdot s + b, \hat{\theta}_\mu)}{\mathcal{L}(obs|\hat{\mu} \cdot s + b, \hat{\theta})}.$$

2011 Exclusion

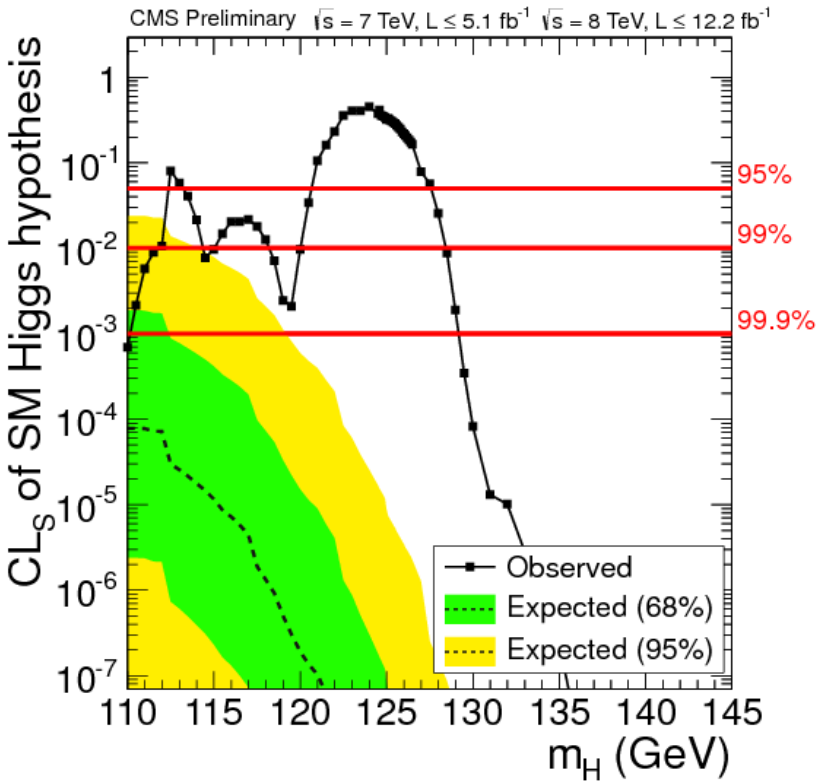


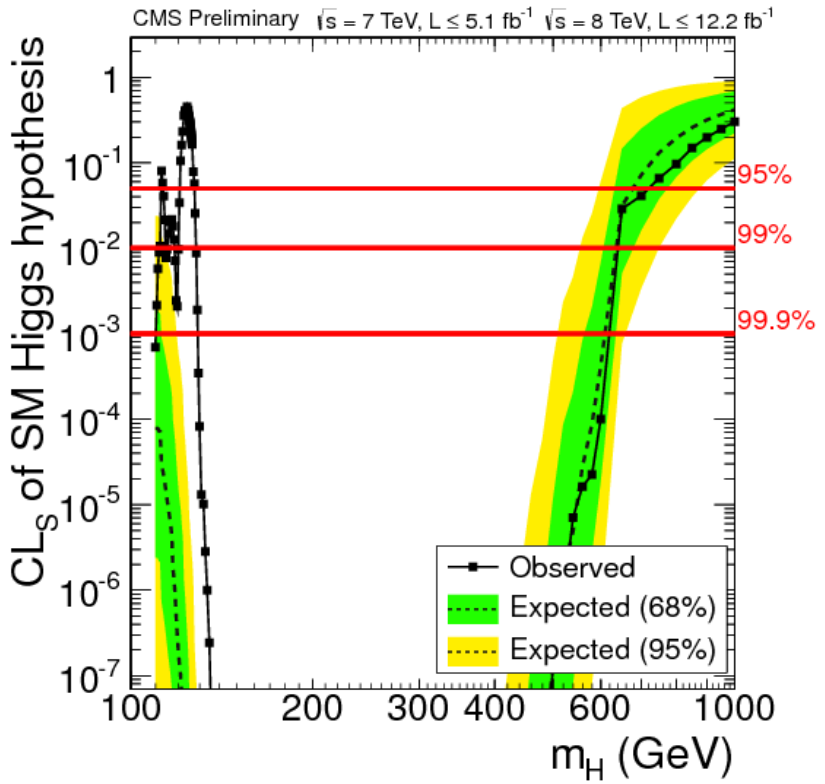
Discovery Exclusion





HCP Exclusion





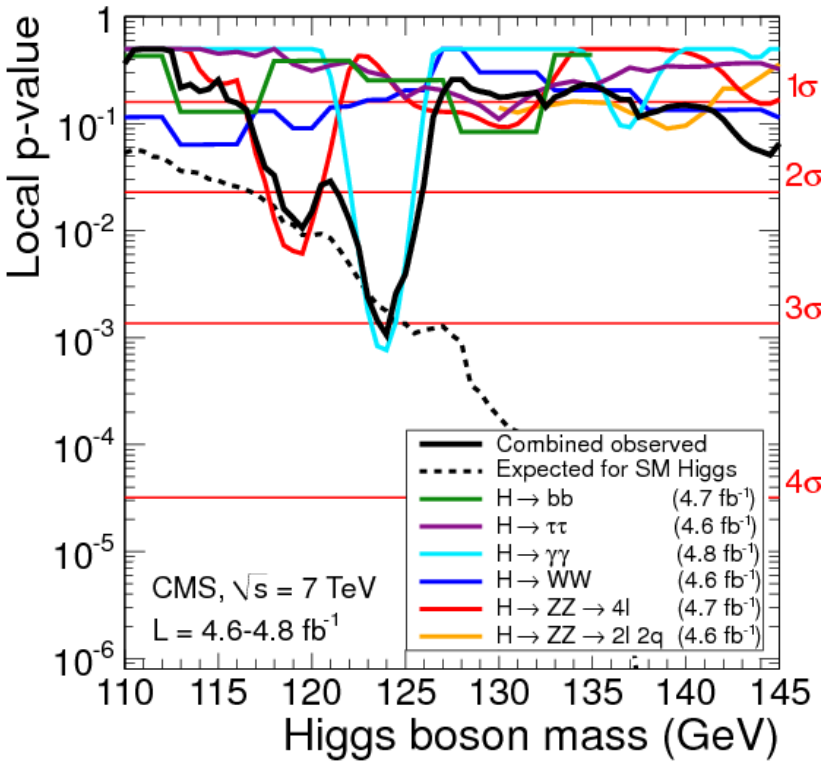
Characterising Excesses

- Higgs analyses use the p value, defined as:

$$p_0 = P(q_0 \leqslant q_0^{obs}|b),$$

- q_0 is the profile likelihood from above with μ set to zero
- i.e. the p value is the probability of observing a background fluctuation as likely or less likely than that observed in the absence of signal.
- 1-p does not tell you P(signal)!

2011 Significance



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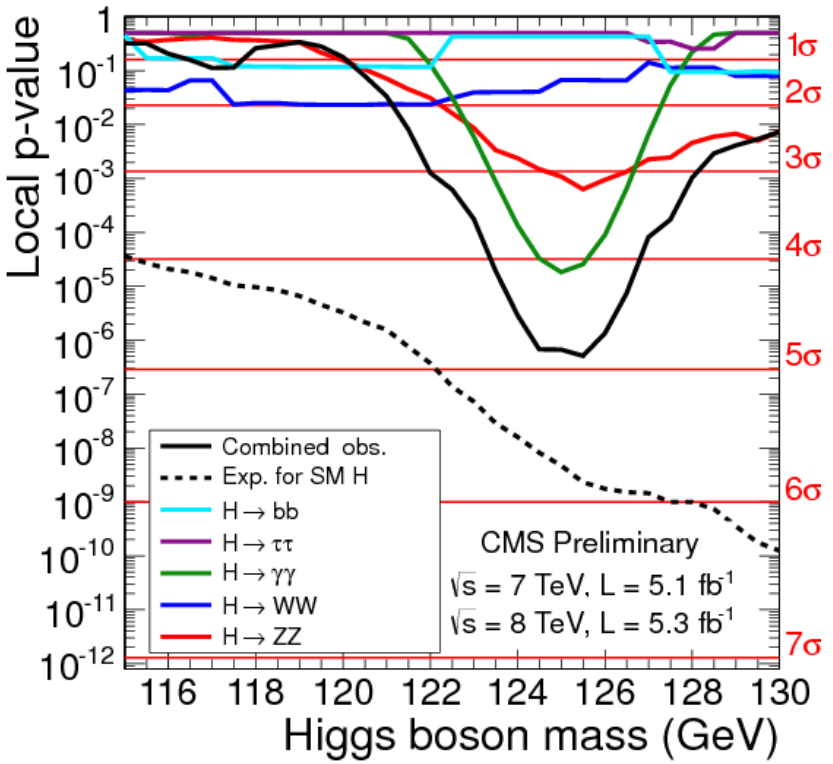
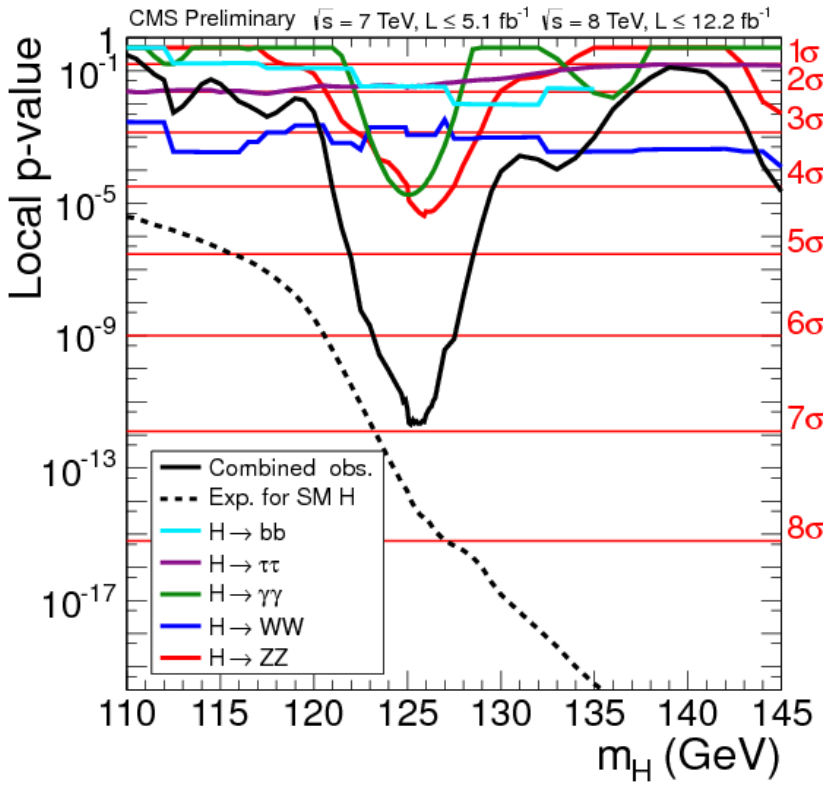


HCP Significance



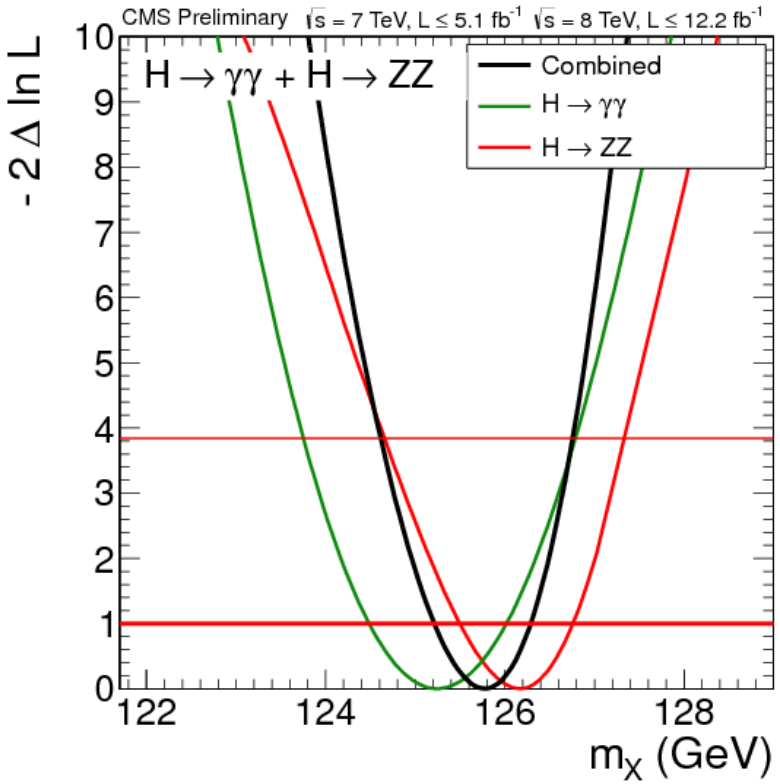
Signal Parameter Determination

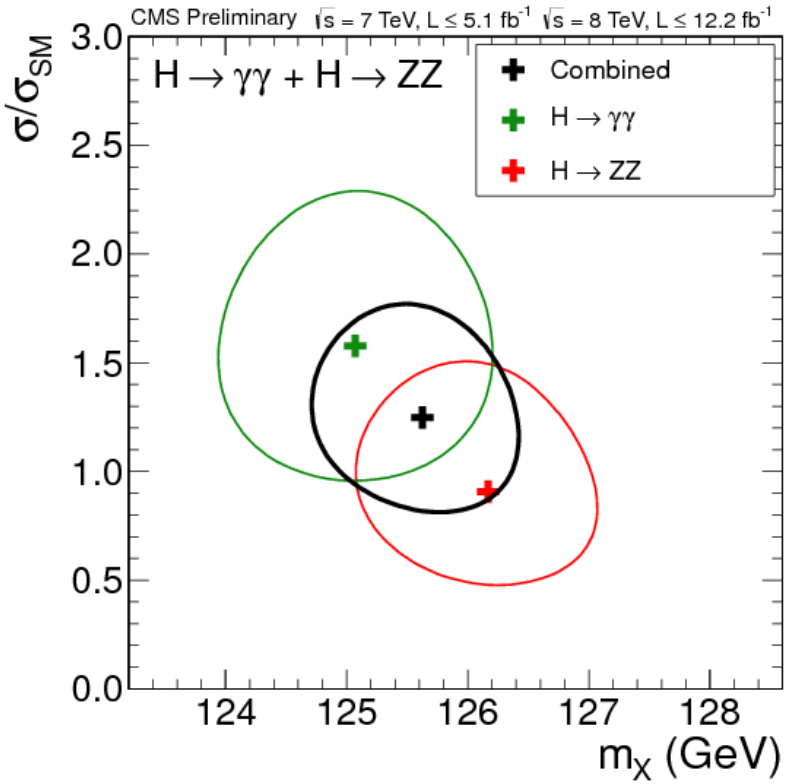
- Most channels give their results in terms of $\sigma x BR$
- We want model parameters so another, slightly different, profile likelihood ratio is used

$$q(a) = -2 \ln \frac{\mathcal{L}(obs|s(a) + b, \hat{\theta}_a)}{\mathcal{L}(obs|s(\hat{a}) + b, \hat{\theta})}$$

- a is the parameter of interest and hatted values are the values which maximise $\mathcal{L}$
- Basically a Δ log likelihood method so 1 σ etc. contours can be plotted.

Mass


CMS Preliminary √s = 7 TeV, L ≤ 5.1 fb⁻¹ √s = 8 TeV, L ≤ 12.2 fb⁻¹
H → γγ + H → ZZ
Combined
H → γγ
H → ZZ
- 2 Δ ln L
m_X (GeV)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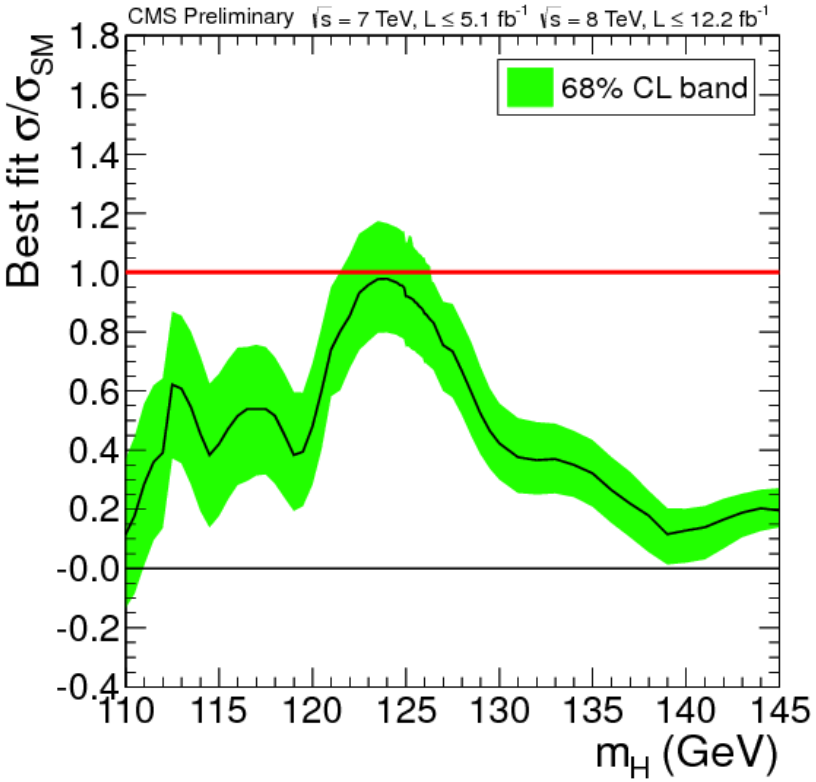
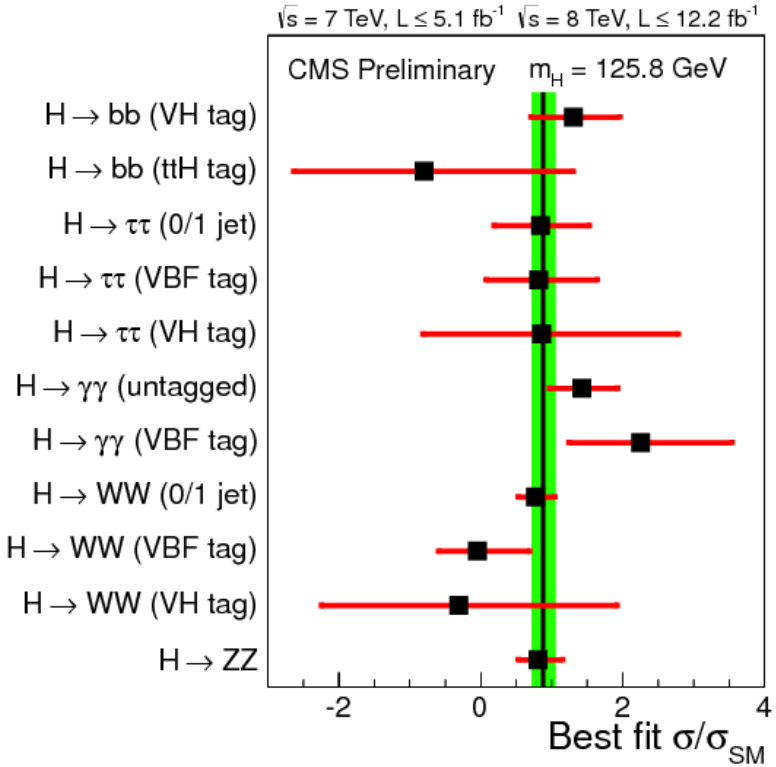
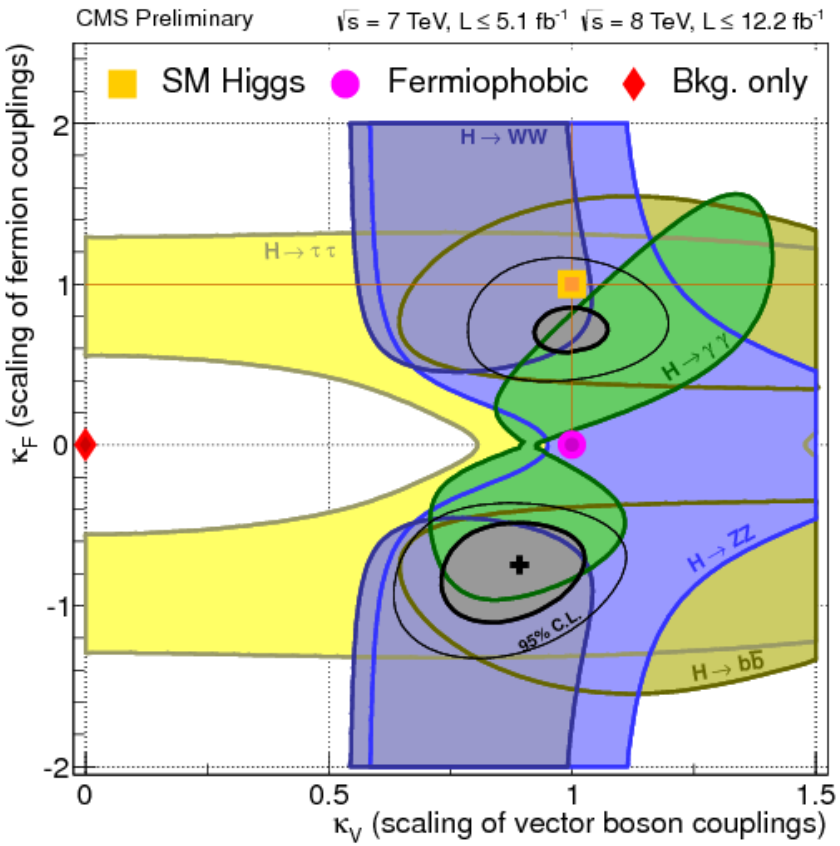
H → γγ + H → ZZ
Combined
H → γγ
H → ZZ
σ/σ_SM
m_X (GeV)

Signal Strength





Couplings


CMS Preliminary
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SM Higgs
Fermiophobic
Bkg. only
H → WW
H → ττ
H → γγ
H → ZZ
H → bb̄
95% C.L.
κF (scaling of fermion couplings)
κV (scaling of vector boson couplings)
2
1
0
-1
-2
0
0.5
1
1.5

What Next?

- Finish analysing the 2012 dataset
- Analyse parked data
- Determine spin and parity
- Better coupling determination