Recasting Higgs Data

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Implications of the 125 GeV Higgs Boson
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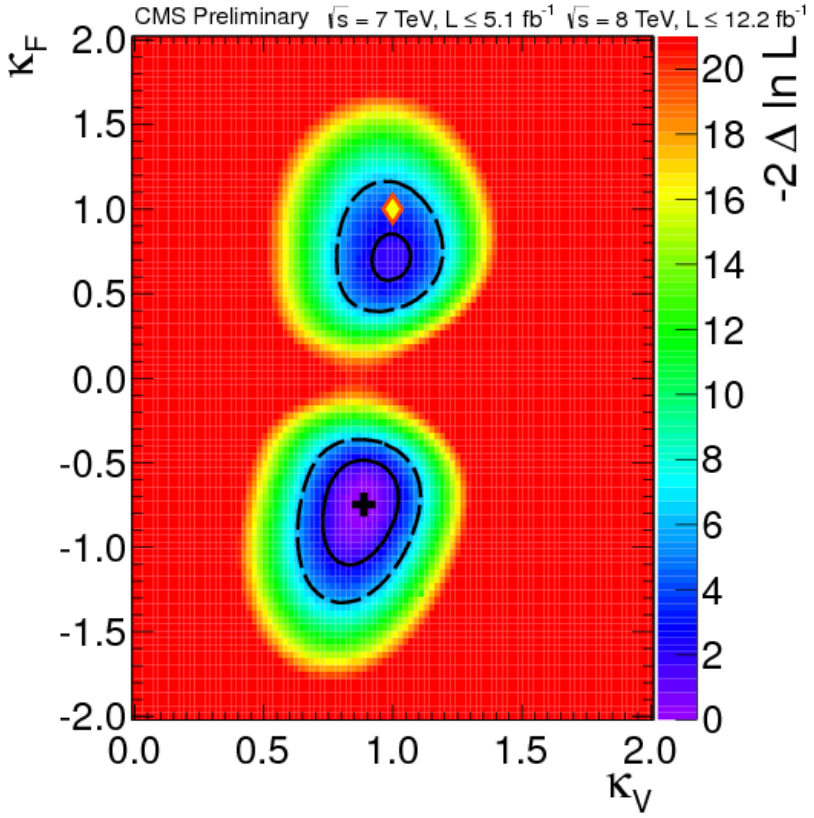
Why should we do fits?

- experimental collaborations are already testing the coupling structure of the new particle
- scaling factors κ parametrize deviations from the SM Higgs couplings (follows the interim recommendations from the LHC Higgs XS WG)



but:

- we want to combine the information from ATLAS, CMS and Tevatron
- we want to study the implications on various BSM models, use different parametrizations

→ fits from theorists are necessary to fully exploit the LHC Higgs results

Starting a fit

$$\chi^2 = \sum_k \frac{(\mu_k - \mu_k^{\rm exp})^2}{\Delta\mu_k^2}$$

- most simple fit: χ^2
- $\mu_k^{\rm exp} = (N_{\rm observed} - N_{\rm background})\,/N_{\rm SM}$
- but what exactly should we take from the experimental papers?

One example: ATLAS H→γγ

What do we have in the conf note? [ATLAS-CONF-2013-012]

Abstract

Measurements of the mass and couplings of the Higgs-like boson in the two photon decay channel with the ATLAS detector at the LHC are presented. The proton-proton collision datasets used correspond to integrated luminosities of 4.8 fb^{-1} collected at $\sqrt{s} = 7$ TeV and 20.7 fb^{-1} collected at $\sqrt{s} = 8$ TeV. The updated measurements benefit from an increased data sample and an improved analysis. The measured value of the mass of the Higgs-like boson is $126.8 \pm 0.2(\text{stat}) \pm 0.7(\text{syst})$ GeV and the fitted number of signal events is found to be $1.65 \pm 0.24(\text{stat})^{+0.25}_{-0.18}(\text{syst})$ times the value predicted by the Standard Model. Measurements of the signal strengths in different production processes and a fiducial cross section for the observed particle are also presented.

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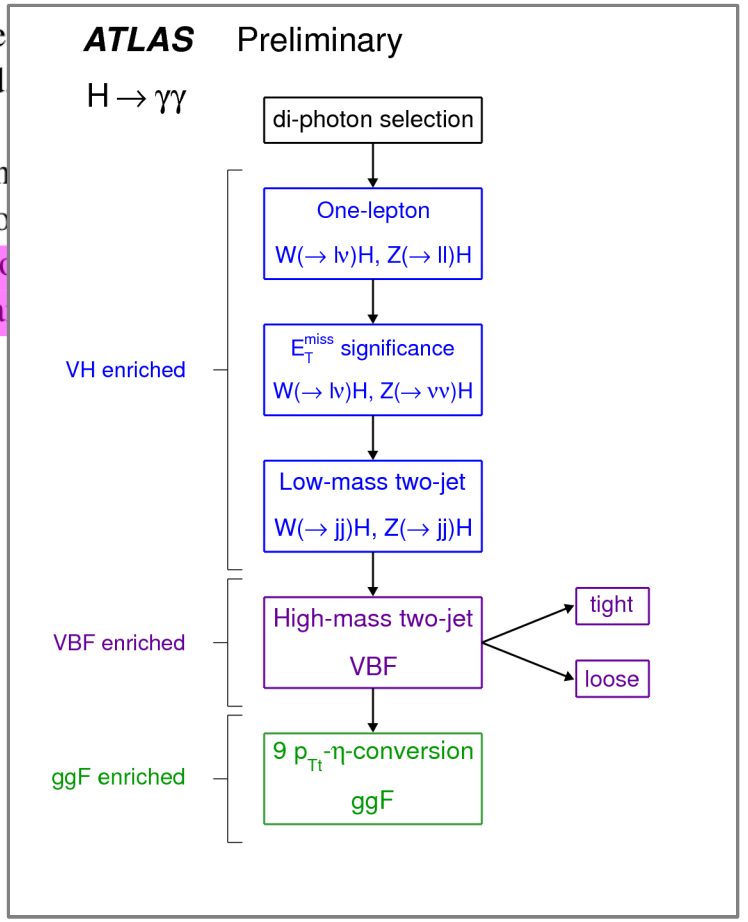
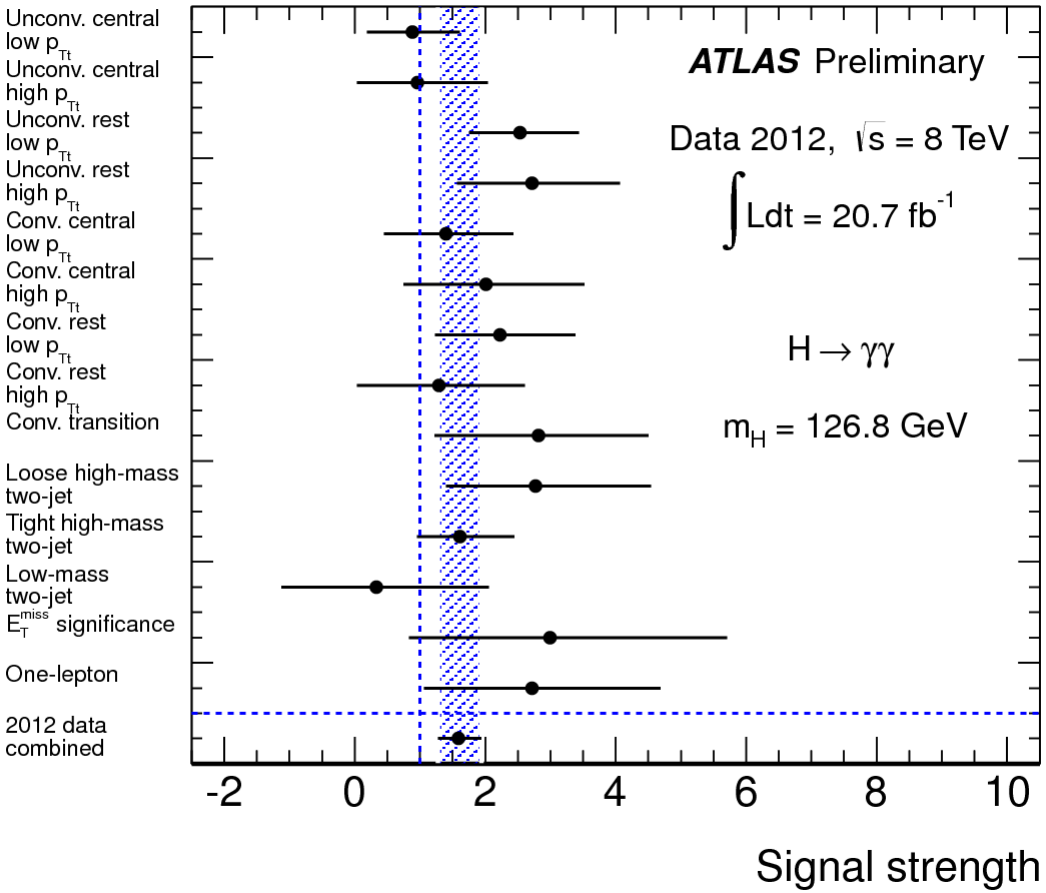


...but this is the combination of several sub-categories with different sensitivity to the various production mechanism

and New Physics modifies both production and decay of the Higgs!

One example: ATLAS H→γγ

Ok, so let's have a look at the 14 sub-categories! [ATLAS-CONF-2013-012]



$\sqrt{s}$	8 TeV						
Category	N_D	N_S	$gg \to H$ [%]	VBF [%]	WH [%]	ZH [%]	ttH [%]
Unconv. central, low p_{Tt}	10900	51.8	93.7	4.0	1.4	0.8	0.2
Unconv. central, high p_{Tt}	553	7.9	79.3	12.6	4.1	2.5	1.4
Unconv. rest, low p_{Tt}	41236	107.9	93.2	4.0	1.6	1.0	0.1
Unconv. rest, high p_{Tt}	2558	16.0	78.1	13.3	4.7	2.8	1.1
Conv. central, low p_{Tt}	7109	33.1	93.6	4.0	1.3	0.9	0.2
Conv. central, high p_{Tt}	363	5.1	78.9	12.6	4.3	2.7	1.5
Conv. rest, low p_{Tt}	38156	97.8	93.2	4.1	1.6	1.0	0.1
Conv. rest, high p_{Tt}	2360	14.4	77.7	13.0	5.2	3.0	1.1
Conv. transition	14864	40.1	90.7	5.5	2.2	1.3	0.2
Loose high-mass two-jet	276	5.3	45.0	54.1	0.5	0.3	0.1
Tight high-mass two-jet	136	8.1	23.8	76.0	0.1	0.1	0.0
Low-mass two-jet	210	3.3	48.1	3.0	29.7	17.2	1.9
E_T^{miss} significance	49	1.3	4.1	0.5	35.7	47.6	12.1
One-lepton	123	2.9	2.2	0.6	63.2	15.4	18.6
All categories (inclusive)	118893	395.0	88.0	7.3	2.7	1.5	0.5

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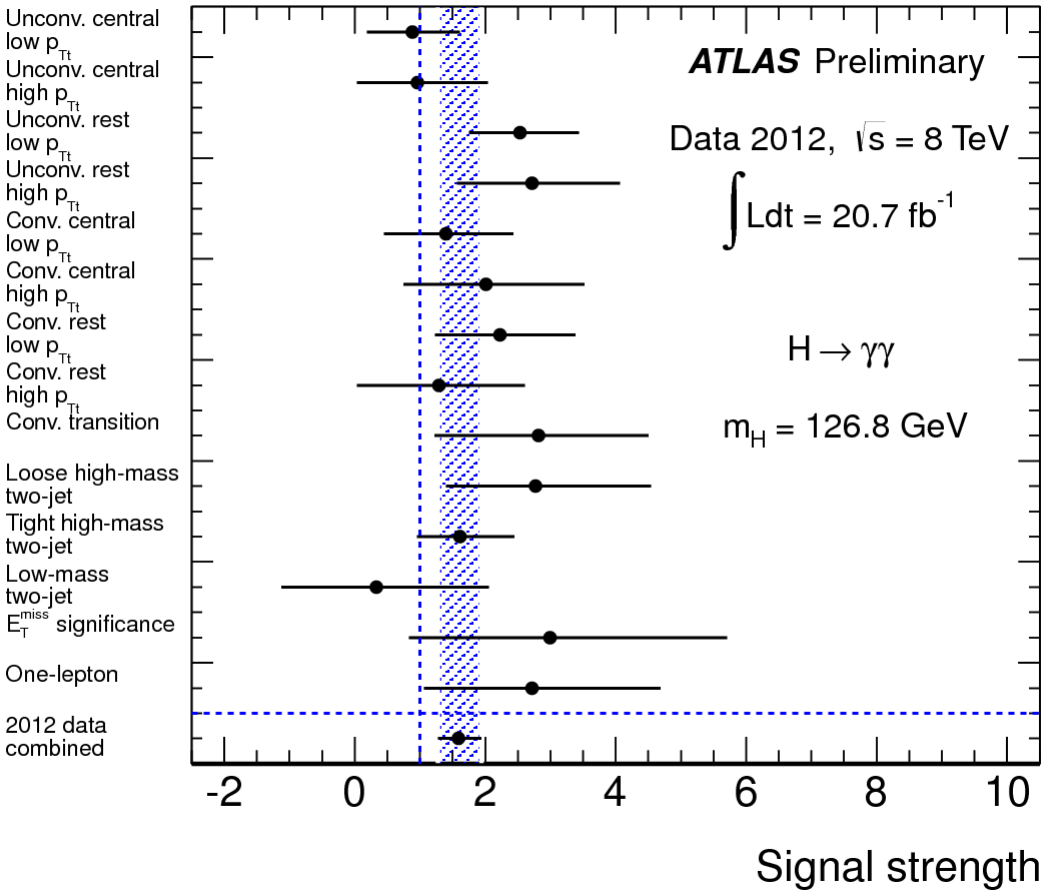

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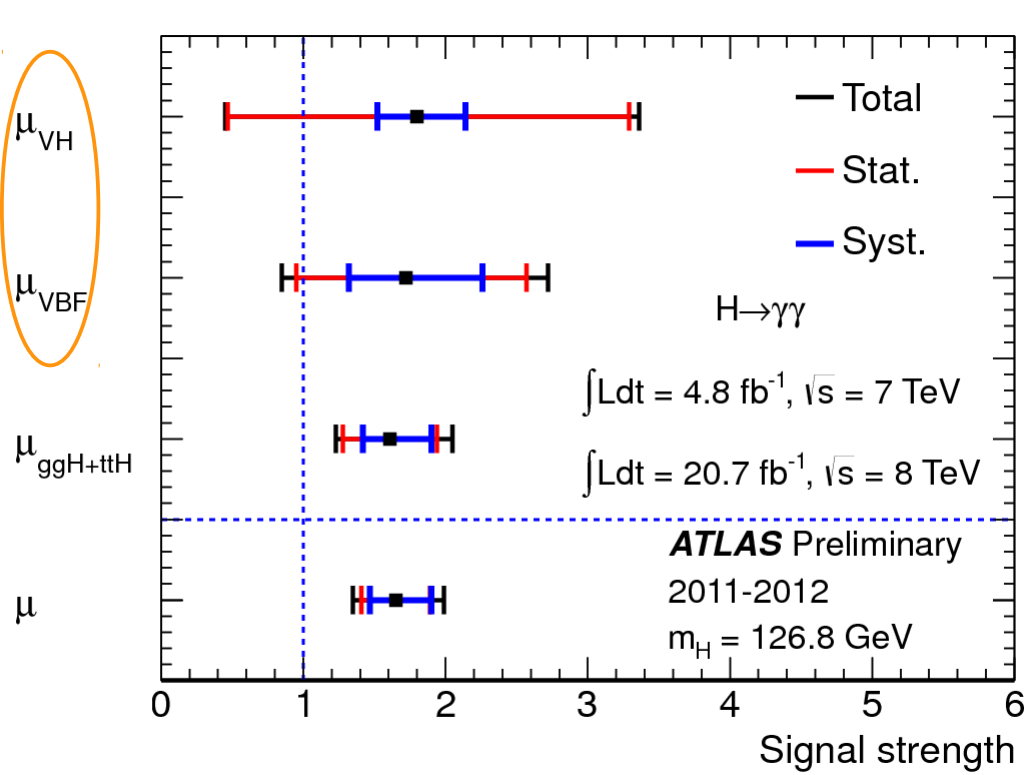
…but what about the correlations between sub-channels? (not given by the experiments)

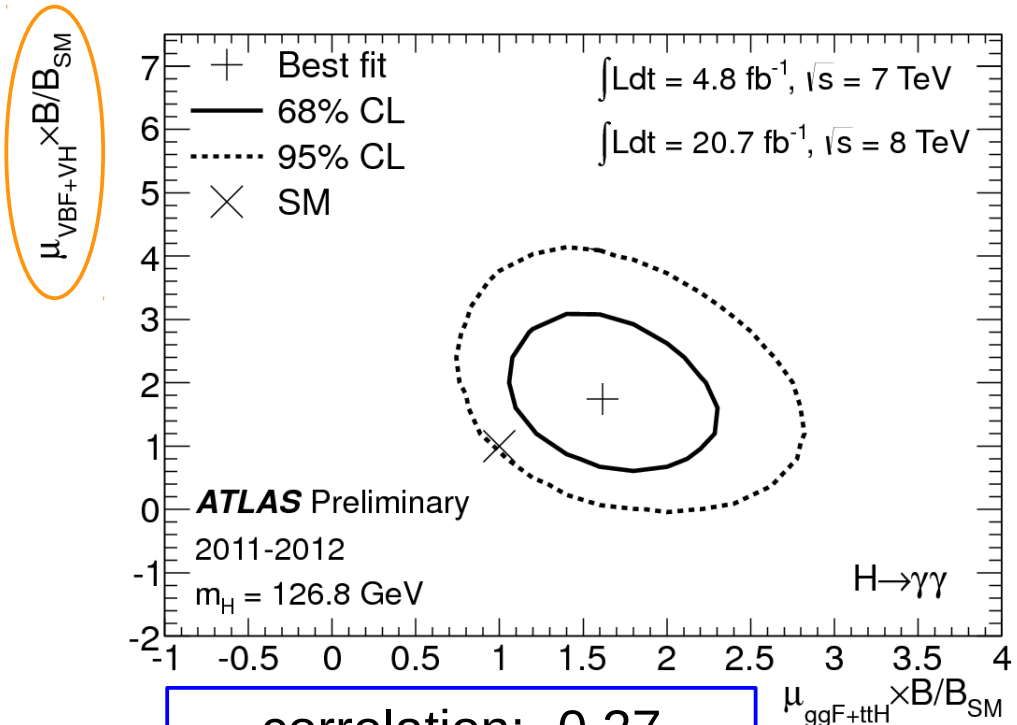
can we safely neglect them? probably not...

One example: ATLAS H→γγ

Hmm... is there anything else in this conf note? [ATLAS-CONF-2013-012]

In a second step, signal strength parameters for different Higgs boson production modes are introduced to characterise their contributions to the observed excess. To further enhance the sensitivity, the

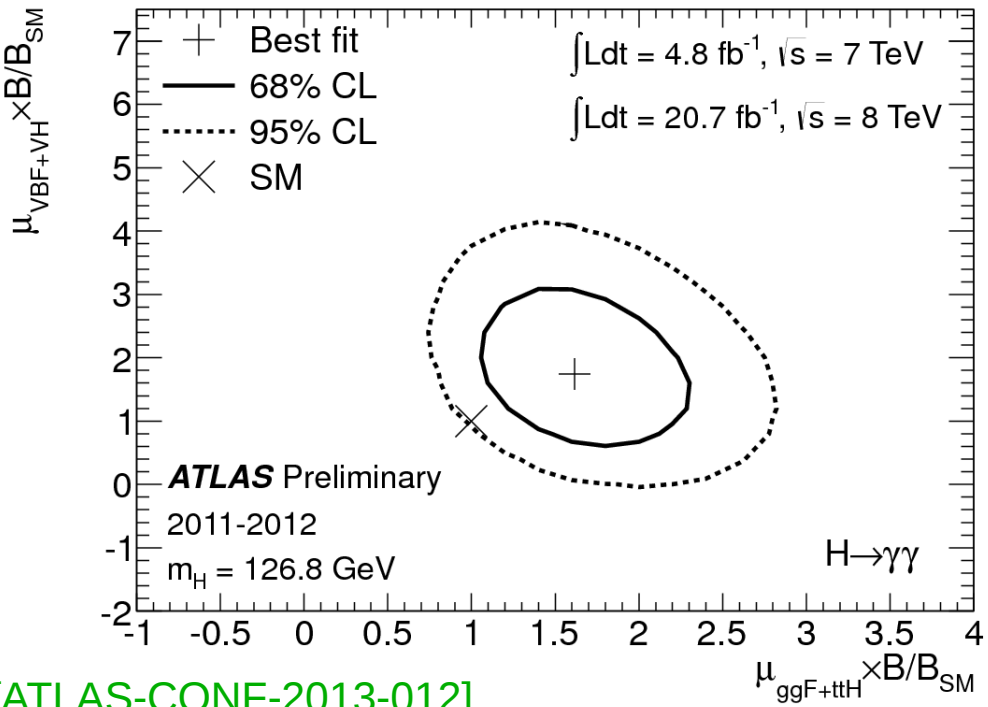




correlation: -0.27
(-0.50 in CMS H → γγ)

One example: ATLAS H→γγ

I want to use this one!



[ATLAS-CONF-2013-012]

But we only have contours...

simplest option: fit Gaussian measurements from one contour

is it a good approximation? maybe...

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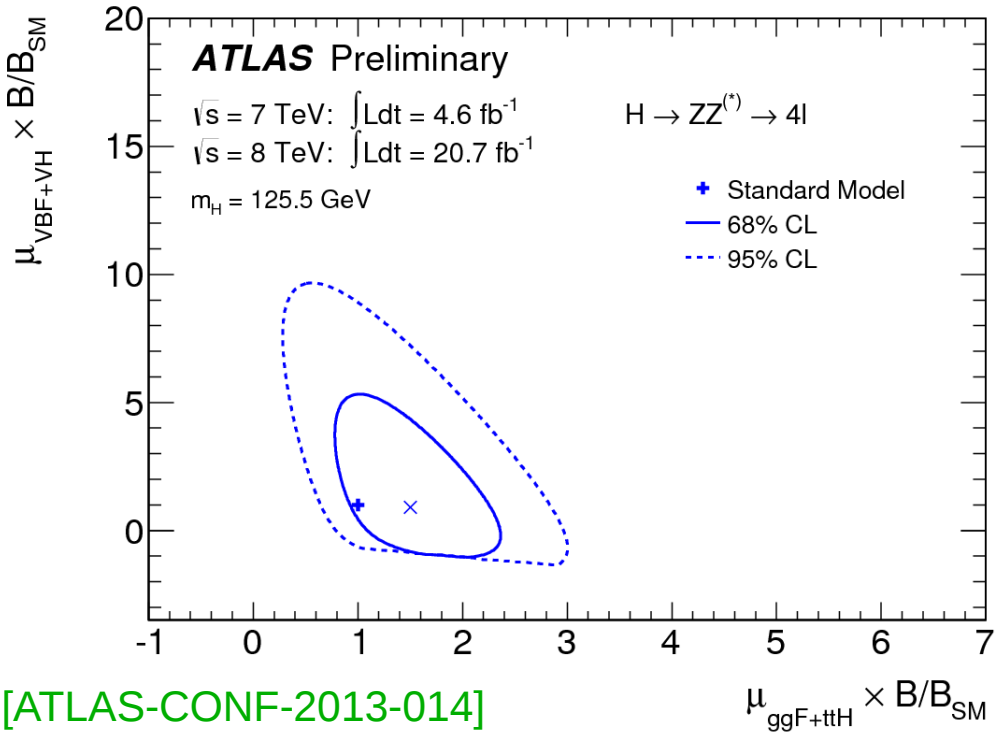


[ATLAS-CONF-2013-014]

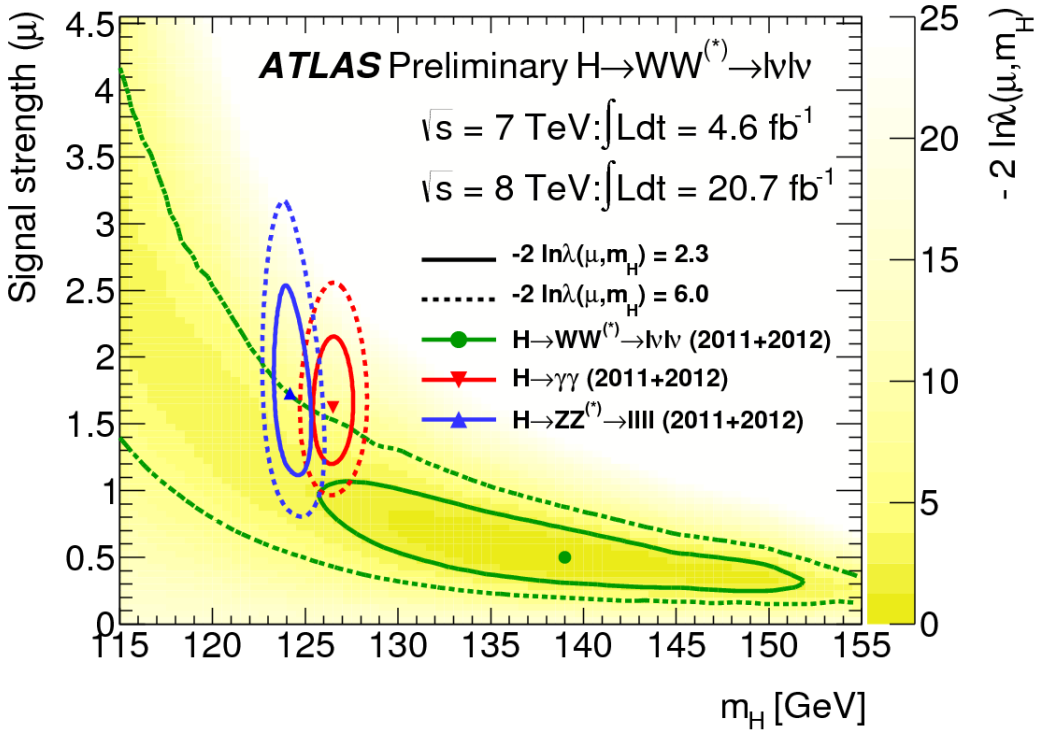
But we only have contours...

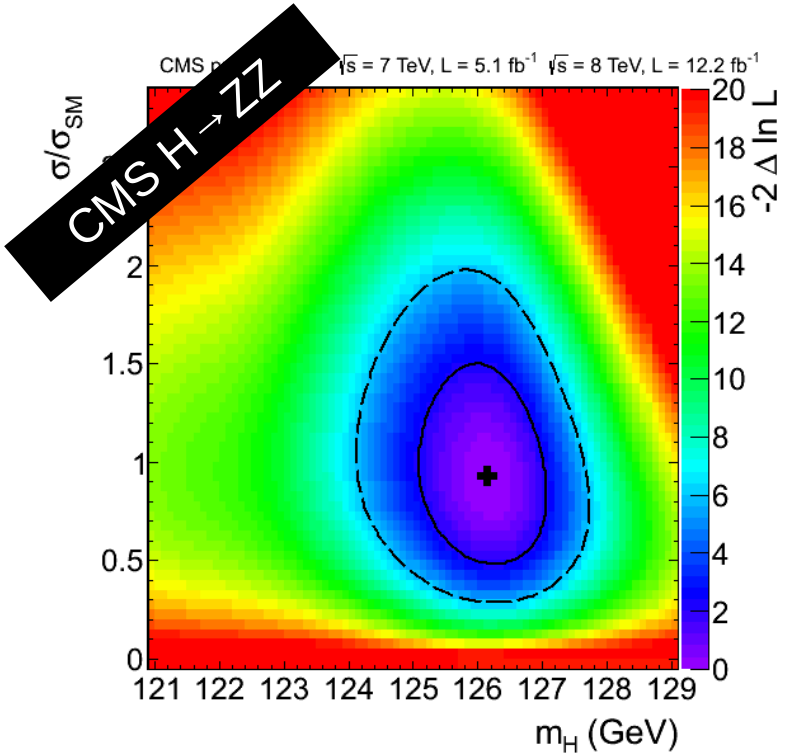
simplest option: fit Gaussian measurements from one contour

is it a good approximation?
maybe...
or maybe not

The Higgs mass

- we would like to treat the Higgs mass as a nuisance parameter in our fit
- a priori important for the two high resolution channels ($H \to ZZ$ and $H \to \gamma\gamma$)





- we would like to combine this information with the previous one...

My conclusion

- ($\mu_{ggF+ttH}$, μ_{VBF+VH}) plots are very useful and should be generalized
  The 2D likelihood in addition to the 68% and 95% CL contours would be valuable in order to get rid of the Gaussian approximation

- However...
  - not suitable to test custodial symmetry
  - not appropriate once ttH measurements become precise
  - it is for a fixed Higgs mass

- note: also e.g. VH→bb results could be presented in the plane (μ_{WH}, μ_{ZH})

- Our theorist dream would be to have the full likelihood in the 6D plane (m_H , μ_{ggF} , μ_{ttH} , μ_{VBF} , μ_{WH} , μ_{ZH}) for each channel

What We Need to do a Good Job

- **What we need: Information on**
  - ◇ Signal strengths separately for 7 and 8 TeV.
    [For Nov12 data updates of 7 TeV analyses, but not publically available.]
  - ◇ Separately for the individual subchannels.
  - ◇ Separately for the various Higgs boson masses;
    ideally in form of "blue band" signal strength plots as function of the mass.
  - ◇ State clearly for each subchannel the composition of the production mechanisms, which has been used by the experiments.
  - ◇ Correlations among the channels: in terms of a simple correlation matrix on the signal strengths.
    Theory-Exp cross talk on basis of signal strengths with clear errors and correlations
    ($\rightarrow$ *e.g.* EWPD)
  - ◇ Include theory errors in the correlations - would be good

$\mathcal{F}$urther

More specific requests:

- $\diamond$ WW subchannel compositions 0, 1, 2 jets (gg and VBF breakup) from ATLAS
- $\diamond$ ATLAS $\gamma\gamma$ broken up in many pieces $\rightsquigarrow$ correlations high priority
- $\diamond$ CMS: $\tau\tau$ sub-channels as function of mass as blue band plots.
- $\diamond$ Mutually exclusive signal strength classes for dijet tagged $\gamma\gamma$ events and for "everything else"

- **What we do $\mathcal{N}$ot want:**
  - $\diamond$ Complicated, hard to use multidimensional likelihood given in a complex form.
  - $\diamond$ Too exclusive subchannels.
  - $\diamond$ Multidimensional μ fits with only one best fit point in the 2-dimensional space.

- **Helful for us:**
  - $\diamond$ Boil down information into simple form with maximum transparency
  - $\diamond$ $E.g.$ plot with μ as function of mass (not 2-dim contours of μ versus mass).