Prospects of measuring low mass Higgs properties

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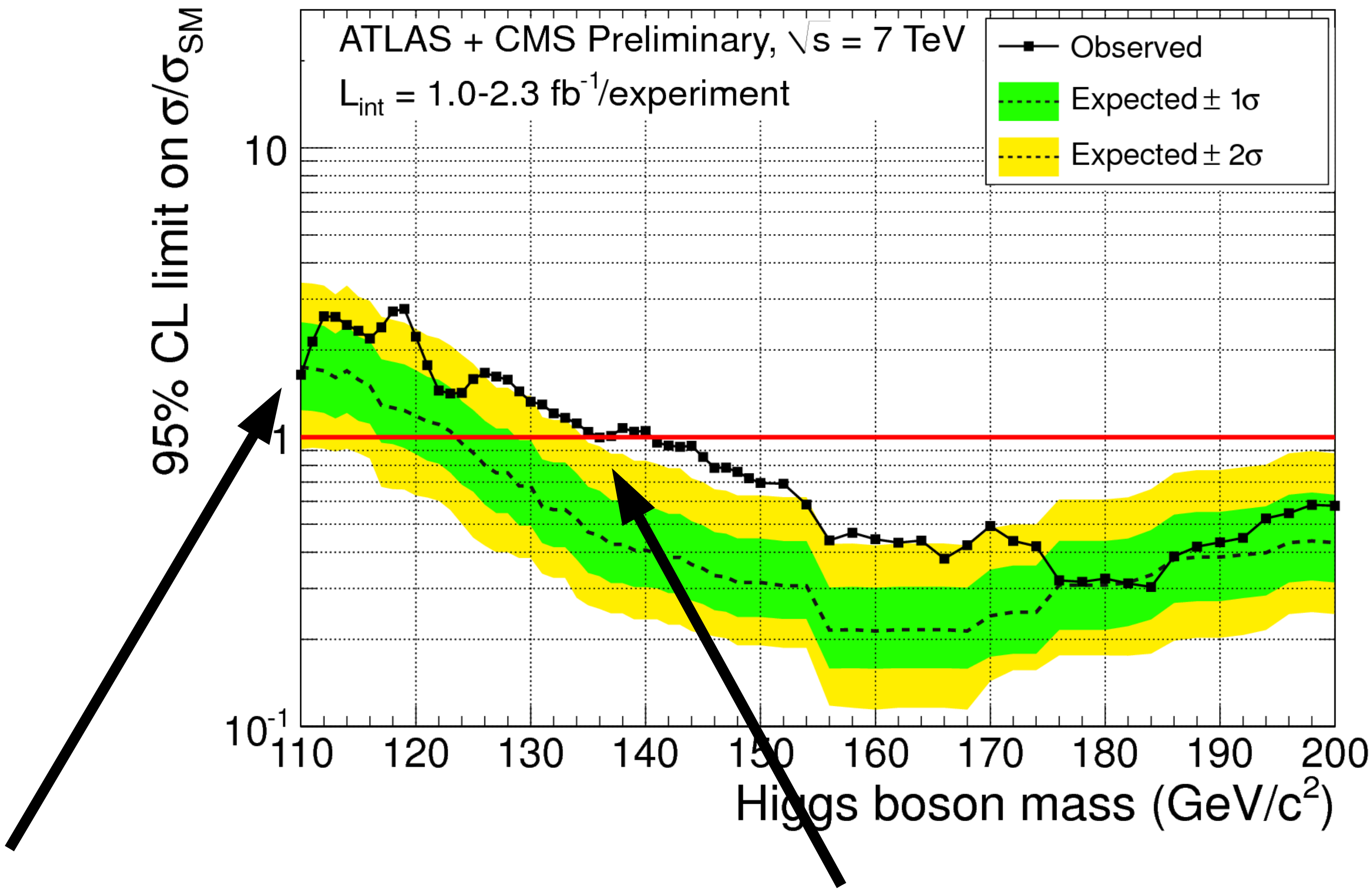
Assumptions

- **Nothing of the following is relevant, if a signal is seen that is clearly incompatible with SM Higgs predictions → lucky situation!**
- **Otherwise use assumption for now: something was seen in m_H<160 GeV**
- **Will not cover "no Higgs" scenarios**
- **Will also assume that this "something" is at least somehow related to the SM Higgs boson → why : next slides**
- **All following numbers are guesses!**

Content

- For the moment concentrate on $\sigma \bullet$BR for possible channels as observable for the coupling strength of the Higgs in production and decay
- Once a sufficient number of $\sigma \bullet$BR measurements are available, coupling parameters can be estimated – not sure this will happen already in 2012

Low mass Higgs properties for 10-20 fb^{-1}



If something is seen for m_H<114GeV:
Obviously not SM because of LEP and Tevatron

If something is seen for m_H>~140GeV:
Obviously not SM because of LHC and Tevatron

Guessing for 10-20 fb^{-1}

Assume factor 10 in luminosity, ~ factor 3-4 in sensitivity
- Can be better because of improved analysis, tighter cuts, ...
- Can be worse because of systematics, high pileup, ...
- Worse for couplings: should also treat ggH, VBF, … independent

Guesses of measurement precisions for a SM Higgs:

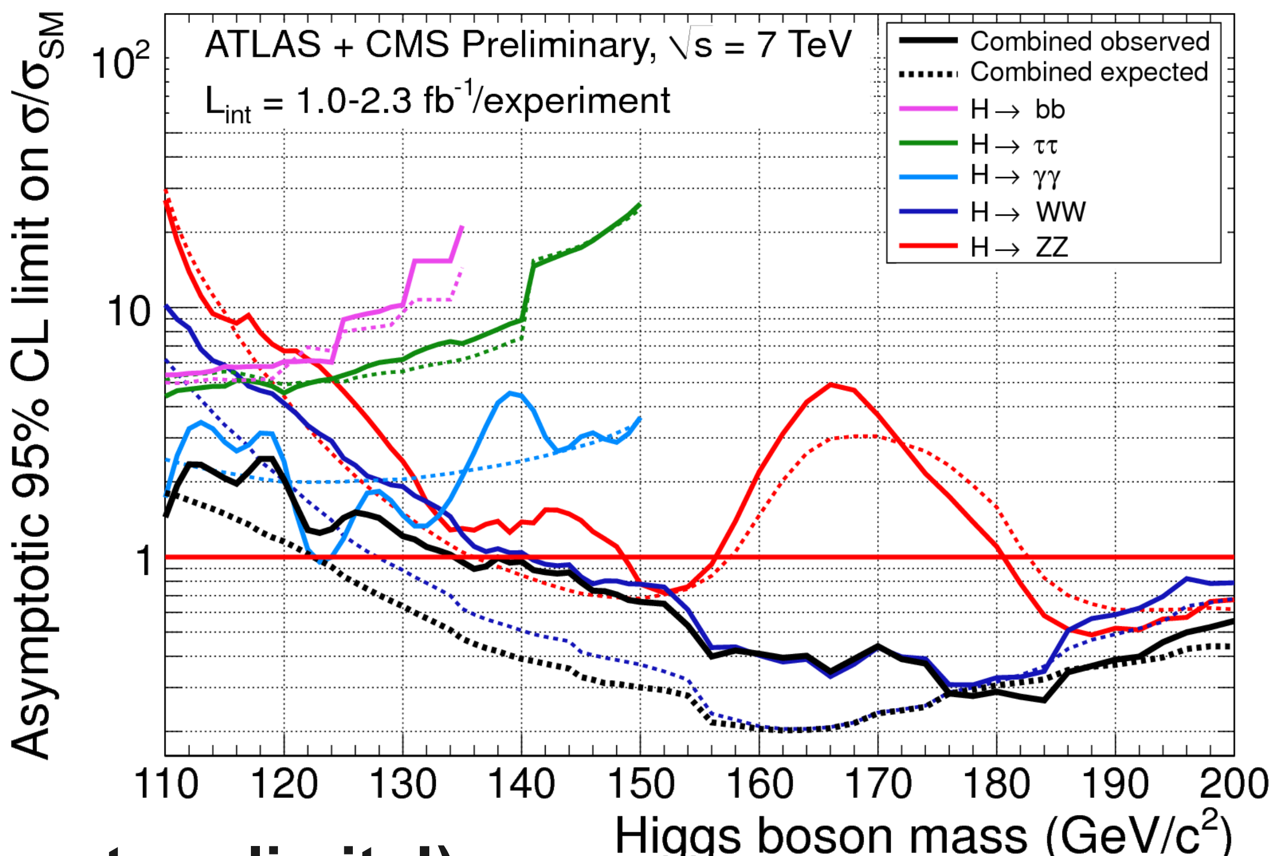
m_H ~ 120 GeV

$gg \to H \to \gamma\gamma$	: O(25%)
$gg \to H \to WW$	: O(50%)
$gg \to H \to ZZ$	: O(100%)
gg/VBF $H \to \tau\tau$	: O(75%)

m_H ~ 135 GeV

$gg \to H \to \gamma\gamma$	: O(25%)
$gg \to H \to WW$	: O(15%)
$gg \to H \to ZZ$	: O(20%)
gg/VBF $H \to \tau\tau$	: O(75%)

(ignoring $H \to bb$ for now: Tevatron limits!)



Problems with low stats in 10-20 fb^{-1}

Not every surplus we measure has to come from a Higgs
- How to count 1 and 2σ measurements? 1σ=O(100%), 2σ=O(50%)
- No model! If we don't use them: strong bias of all results!
- No model! If we use them: high risk of including fluctuations!

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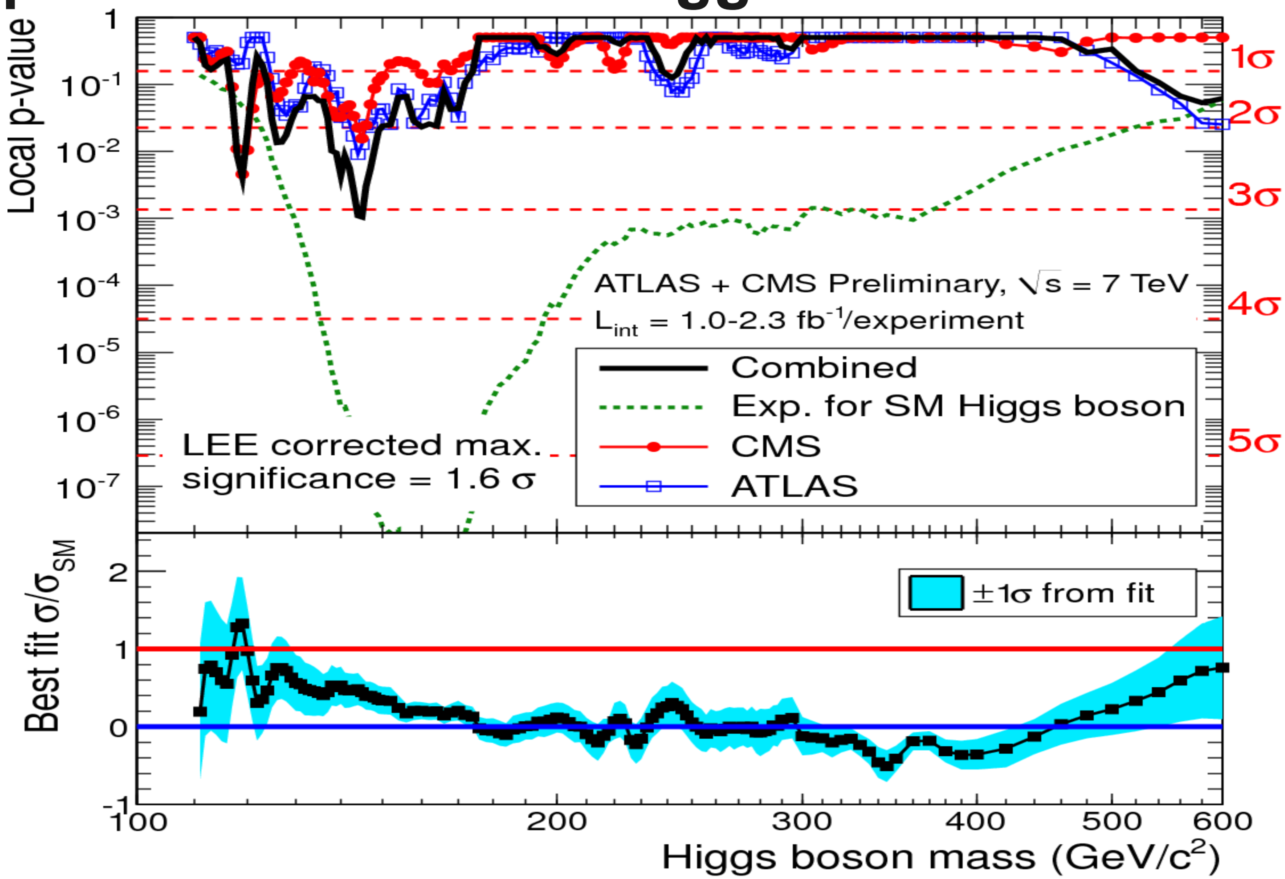
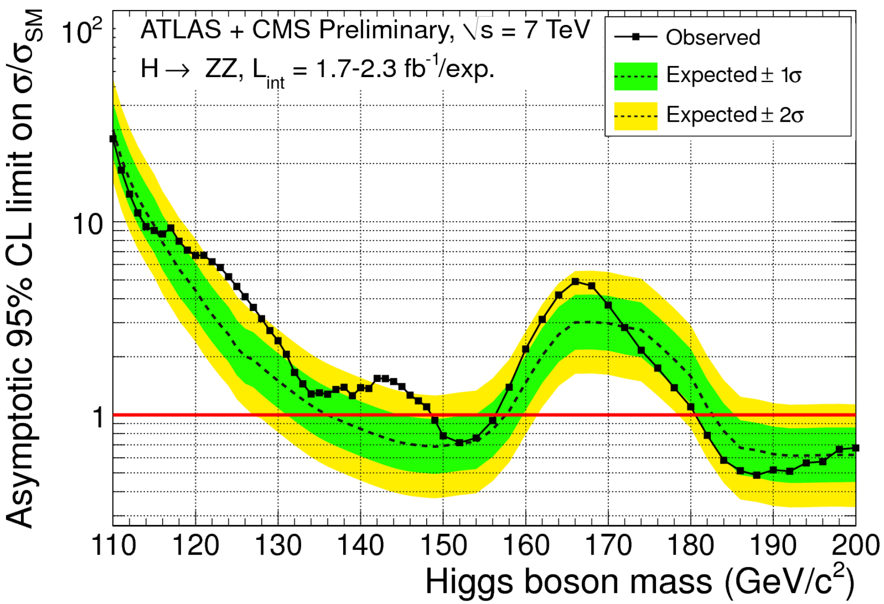
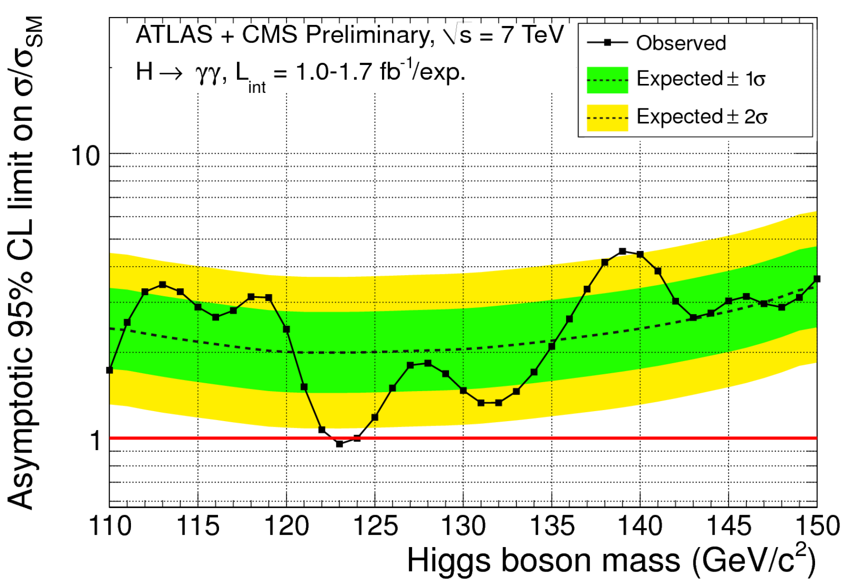


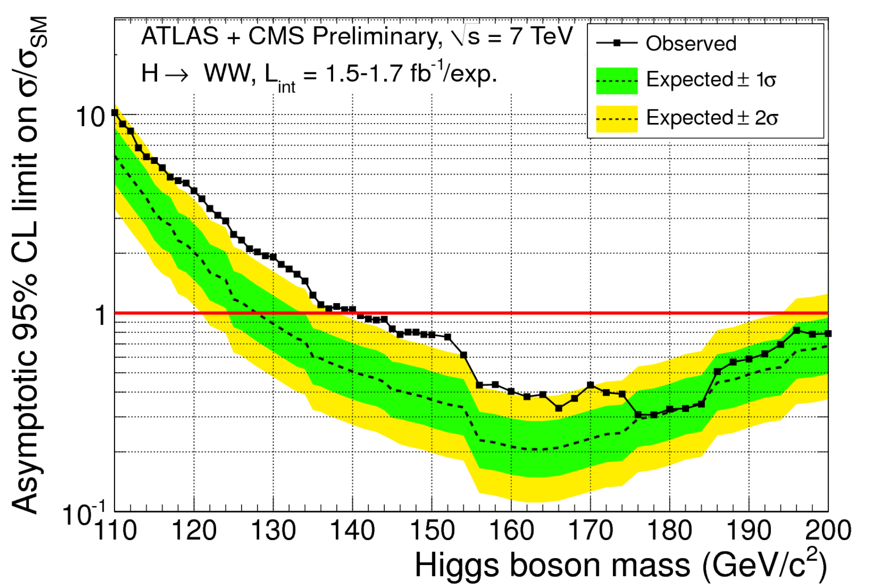
Problems with low stats in 10-20 fb^{-1}

Example: Combing $H\to\gamma\gamma$, $H\to ZZ$ and $H\to WW$ today at m_H~140GeV

- **All 3 channels have some up fluctuation**
- **Could combine this to several O(50%) or better measurements, suggesting that we already have some understanding of the particle**
- **BUT REMEMBER: with the look elsewhere effect this is only 1.6σ! Extremely high probability of just a fluctuation**







Possible measurement range

Not every surplus we measure has to come from a Higgs

- Assume we need at least <50% precision to use any signal
- In cases like $H \rightarrow \gamma\gamma$ still very problematic!

→ Maximum allowed increase in xsec in order to keep the limits

→ Maximum allowed decrease in xsec in order to keep it measurable

m_H ~ 120 GeV

$gg \rightarrow H \rightarrow \gamma\gamma$	: O(25%)	: max. up:	SM*2, max down: SM/2
$gg \rightarrow H \rightarrow WW$	: O(50%)	: max. up:	SM*2, max down: SM/1
$gg \rightarrow H \rightarrow ZZ$	: O(100%)	: max. up:	SM*8
gg/VBF $H \rightarrow \tau\tau$	: O(75%)	: max. up:	SM*5

m_H ~ 135 GeV

$gg \rightarrow H \rightarrow \gamma\gamma$	: O(25%)	: max. up:	SM*2, max down: SM/2
$gg \rightarrow H \rightarrow WW$	: O(15%)	: max. up:	SM*1, max down: SM/3
$gg \rightarrow H \rightarrow ZZ$	: O(20%)	: max. up:	SM*1.5, max down: SM/2.5
gg/VBF $H \rightarrow \tau\tau$	: O(75%)	: max. up:	SM*5

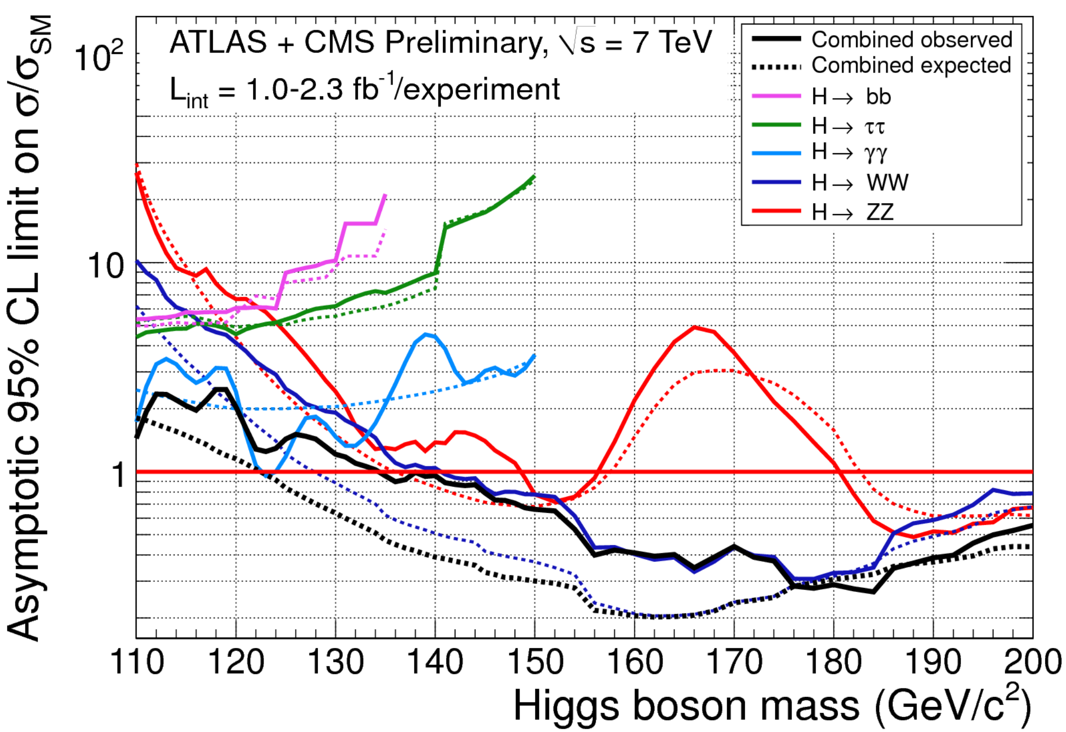
Conclusion???

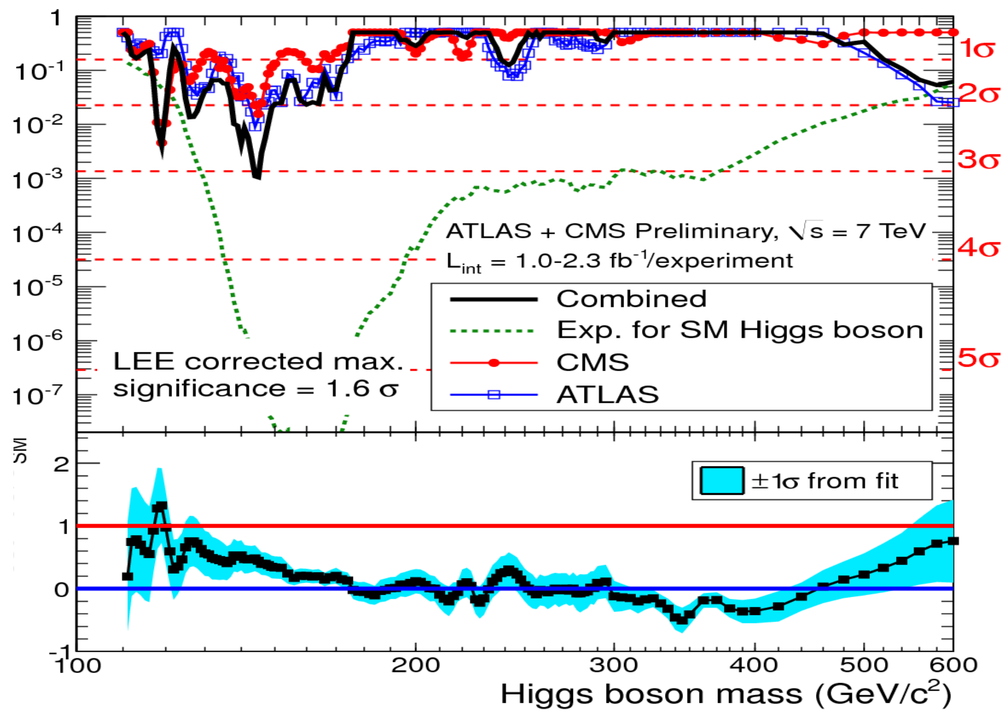
In most cases, cross sections outside a factor ~2-3 of the SM are either

- **already excluded by the existing measurements or would directly indicate the non SM nature of the particle**
- **or will lead to a too small signal which is easily confused with a fluctuation**

➔ **What to do and prepare for?**

➔ **Rather narrow range for couplings: xsec ~ $g_X^2 * g_Y^2 / \Gamma$**





Options???

Could imagine two extreme analysis options for couplings:

- **Assume the SM and look for deviations**
  - **Nice: one knows what to expect, so its easier to include/exclude 1 or 2σ signals**
  - **But essential the same information as the current SM Higgs exclusion plots**

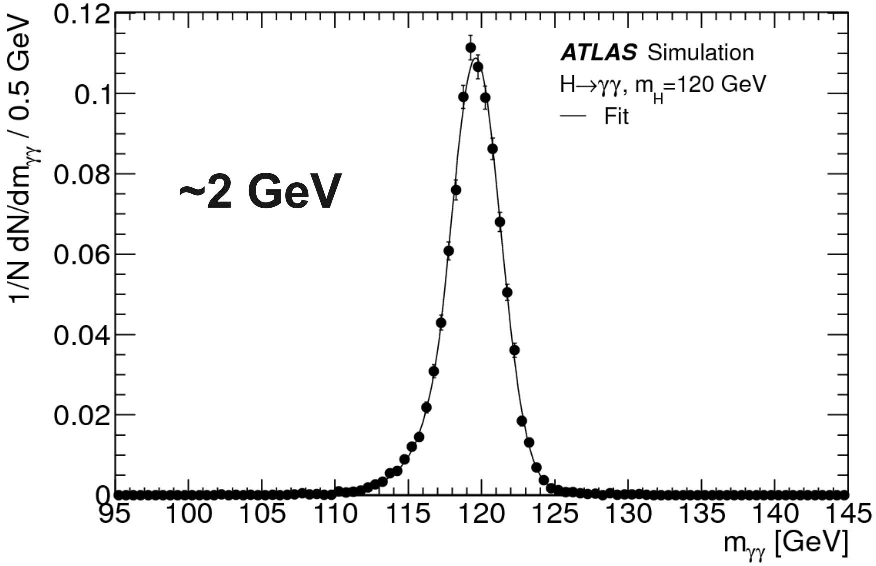
- **Don't assume the SM and evaluate each channel independently**
  - **Nice: could give couplings without SM bias**
  - **But: difficult to distinguish noise from signal without introducing a bias just by including everything**
  - **Difficult with the expected luminosity of next year**

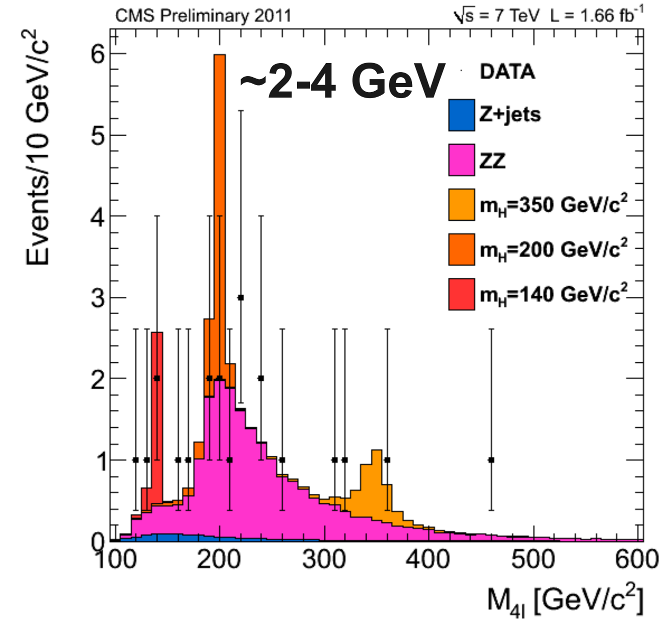
- **Can we do something in between?**
- **Gain additional information on exclusions without assuming completely independent and unknown σ•BR, e.g. define very few effective SM motivated pseudo-observables?**
- **Can something more be extracted by combining with LEP precision data and Tevatron m_W and m_{top} measurements?**

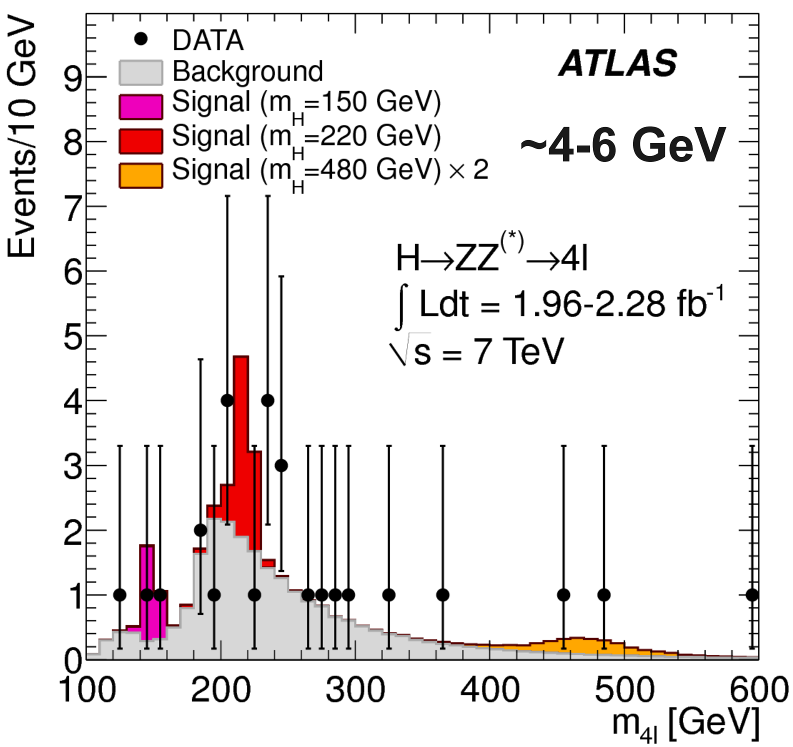
Other low mass Higgs properties

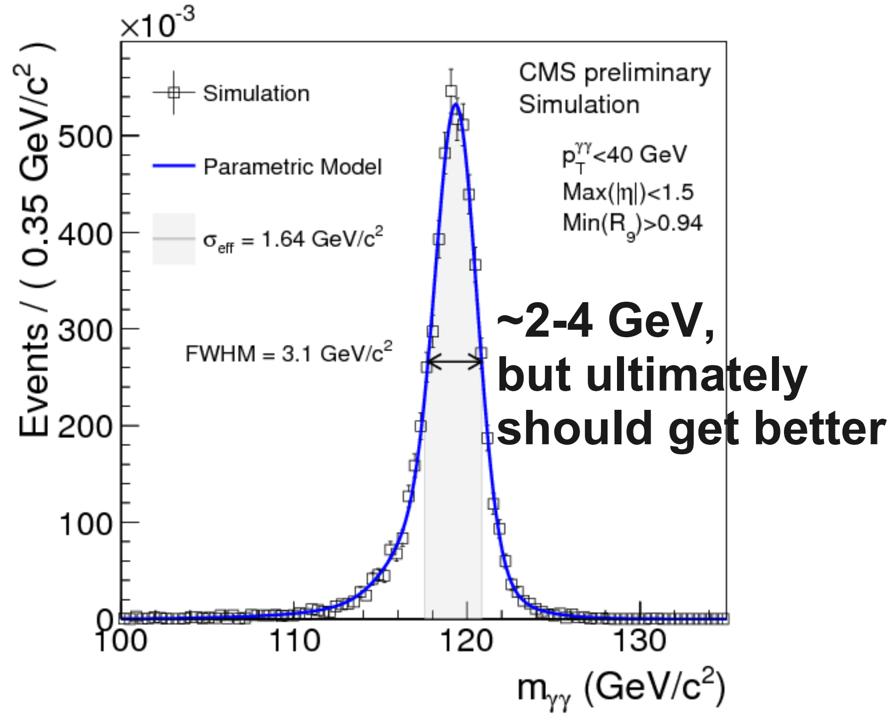
- **Mass and mass resolution**
- **Counting the number of Higgs resonances**
- **Spin and CP**

Higgs resolution with $\gamma\gamma$ and ZZ

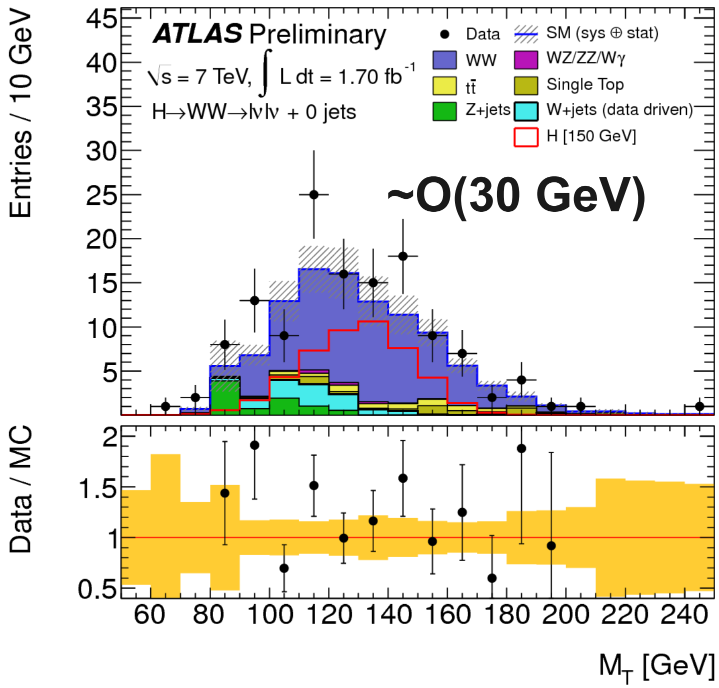


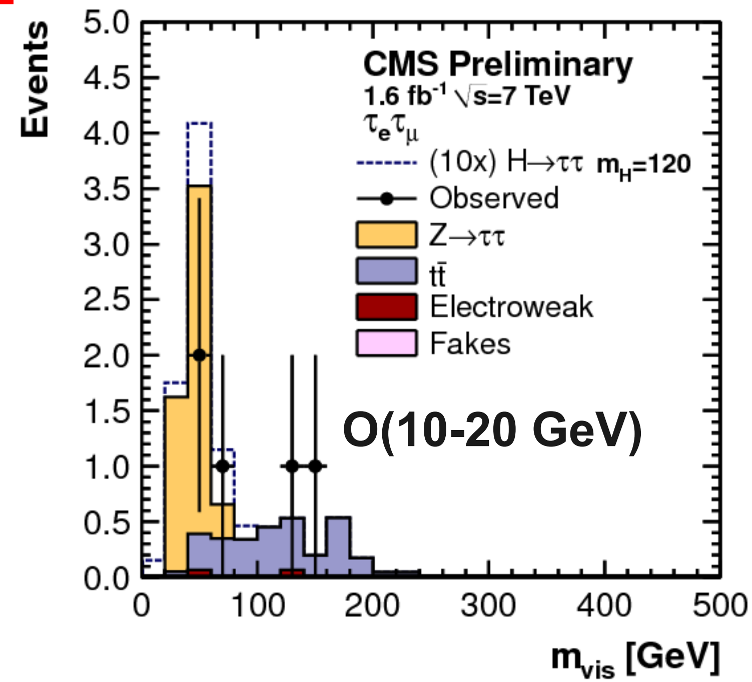


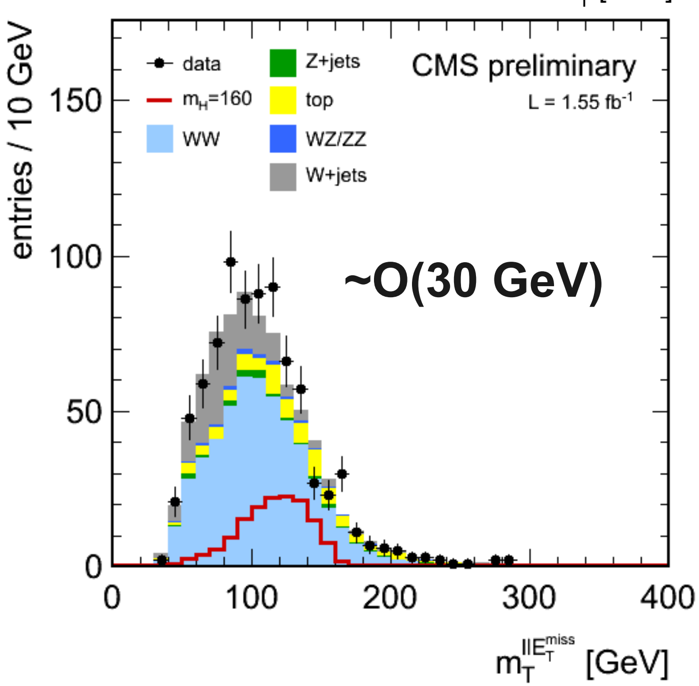


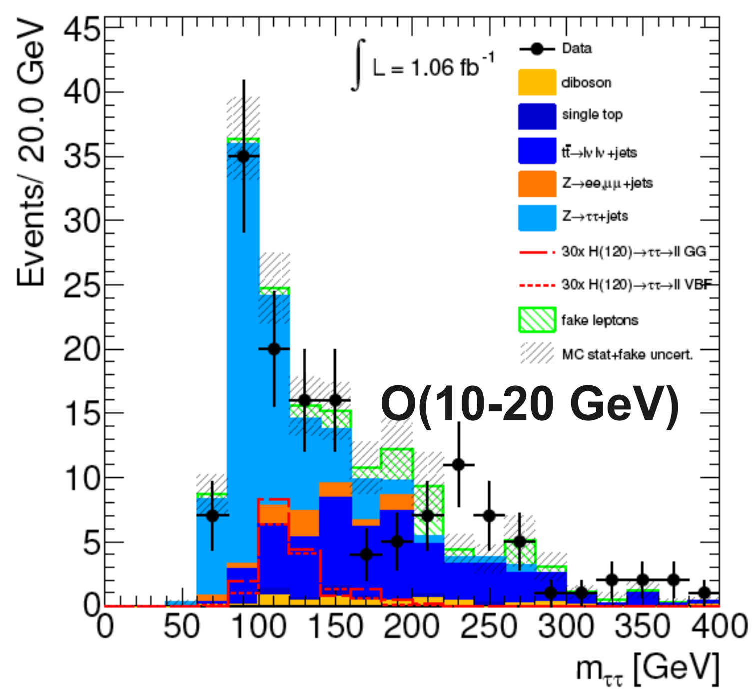


Higgs resolution with $\tau\tau$ and WW









Higgs mass

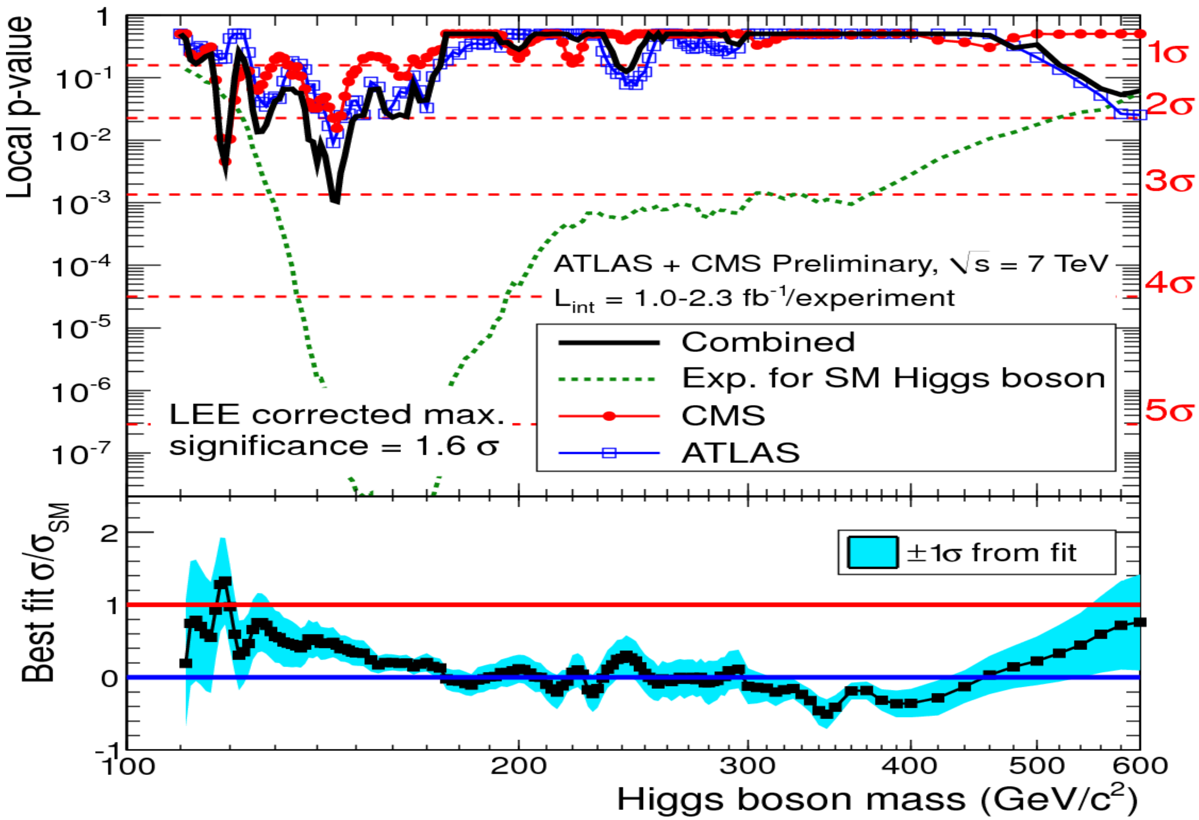
- If either $\gamma\gamma$ or ZZ→4l final state is found : no problem, mass can be well measured (and some limit given on width)
- If both are not found → assume something observed in bb, $\tau\tau$ or WW
  - bb : unlikely, as Tevatron has seen nothing so far and the channel is currently (1-2fb^{-1}) still far away from SM limit. If observed, it will have large uncertainties also on the mass. ~O(10GeV)?
  - $\tau\tau$: in the low mass range sits on top of the Z tail with small signal. Next year will make this even more difficult because of high pileup. ~O(10GeV)?
  - WW : no peak, only wide transverse mass peak O(30GeV). However, high statistics expected, so could get ~O(10GeV) on the peak (or better), if one assumes exactly one narrow resonance

- **What could be done for more precise predictions?**
  - Should be possible to inject a (SM) Higgs signal in the existing combination fits and then extract some idea of mass peak position resolution

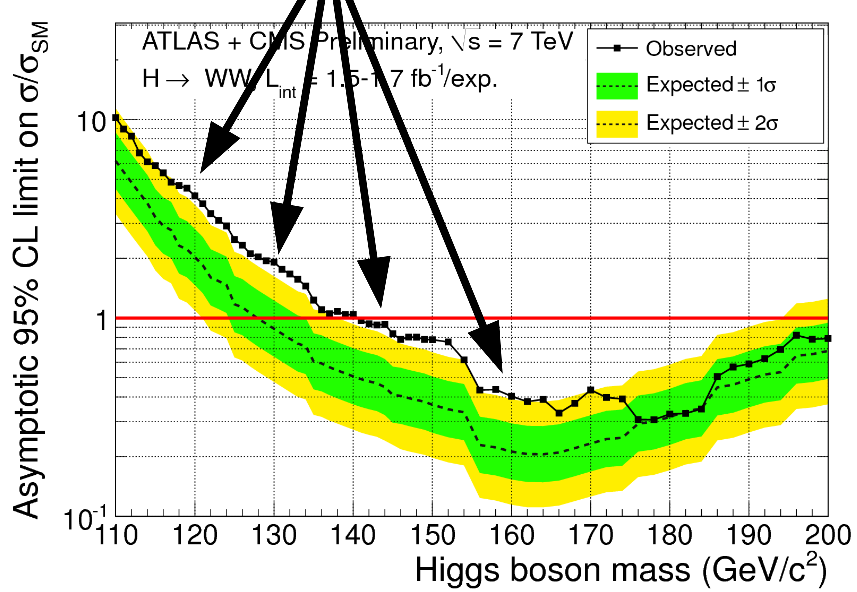
Counting Higgs resonances

So far we assume only one Higgs. If we have several resonances

- In either $\gamma\gamma$ or ZZ→4l final state : signal would most likely get too small to be visible because of shared W/Z VEV
- In $\tau\tau$ or WW : no separation power. Could interpret either as one signal or systematically underestimated background
- Same applies to a very wide Higgs resonance



Very unlikely anybody would be happy to accept a claim that this is caused by several Higgs Bosons with masses between 120 and 160GeV



Spin and CP

Classical channels for spin/CP studies

- Obvious : indication for spin 0 from $\gamma\gamma$ or WW observation

Otherwise difficult

- ZZ→4l : needs a lot of statistics which will not be available
- VBF H→$\tau\tau$ or WW : could just be possible with a large Higgs signal and jet angular correlations that are maximally different from the SM
- ttH : xsec most likely too small and further reduced by jet combinatorics