Higgs boson discovery at the LHC: an informal discussion

Igor Ivanov

University of Liège, Belgium,
and
Institute of Mathematics, Novosibirsk

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Higgs mechanism

The idea of spontaneous gauge symmetry breaking applied to particle physics, and specifically, to solve the problem of massless Goldsone bosons/massive gauge bosons.

Six "official" authors of the Higgs mechanism: Brout, Englert; Higgs; Guralnik, Hagen, Kibble (1964). The boson itself first introduced by Higgs.

Search for the Higgs boson at colliders started in 70's. The SM does not predict the mass of the Higgs boson $\rightarrow$ searches began simultaneously in all mass domains, from sub-MeV and up to the highest energies available (multi-GeV).

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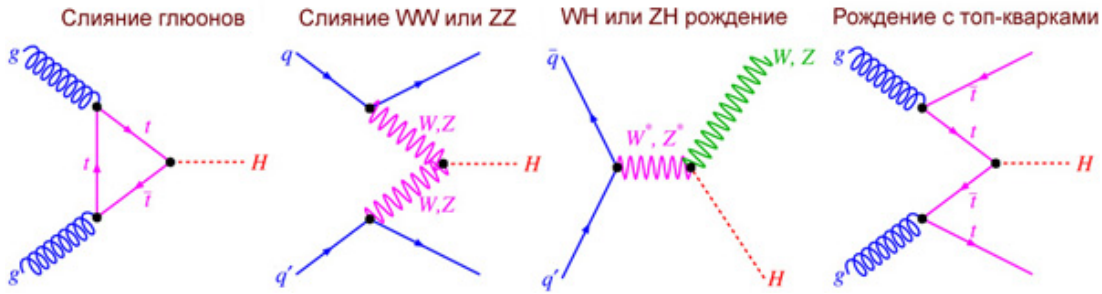
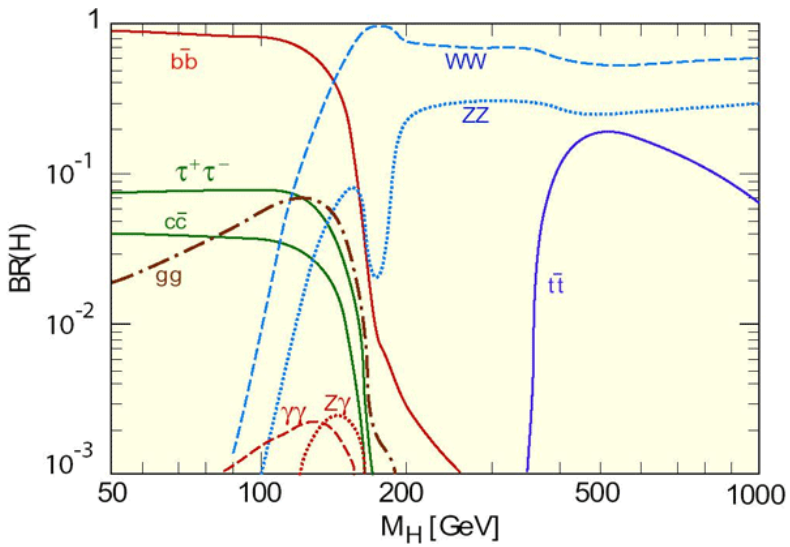
Higgs mechanism

Production and decay channels depend on its mass.
Main production channels at hadronic colliders (Tevatron and the LHC):



Main decay channels:



Higgs boson search

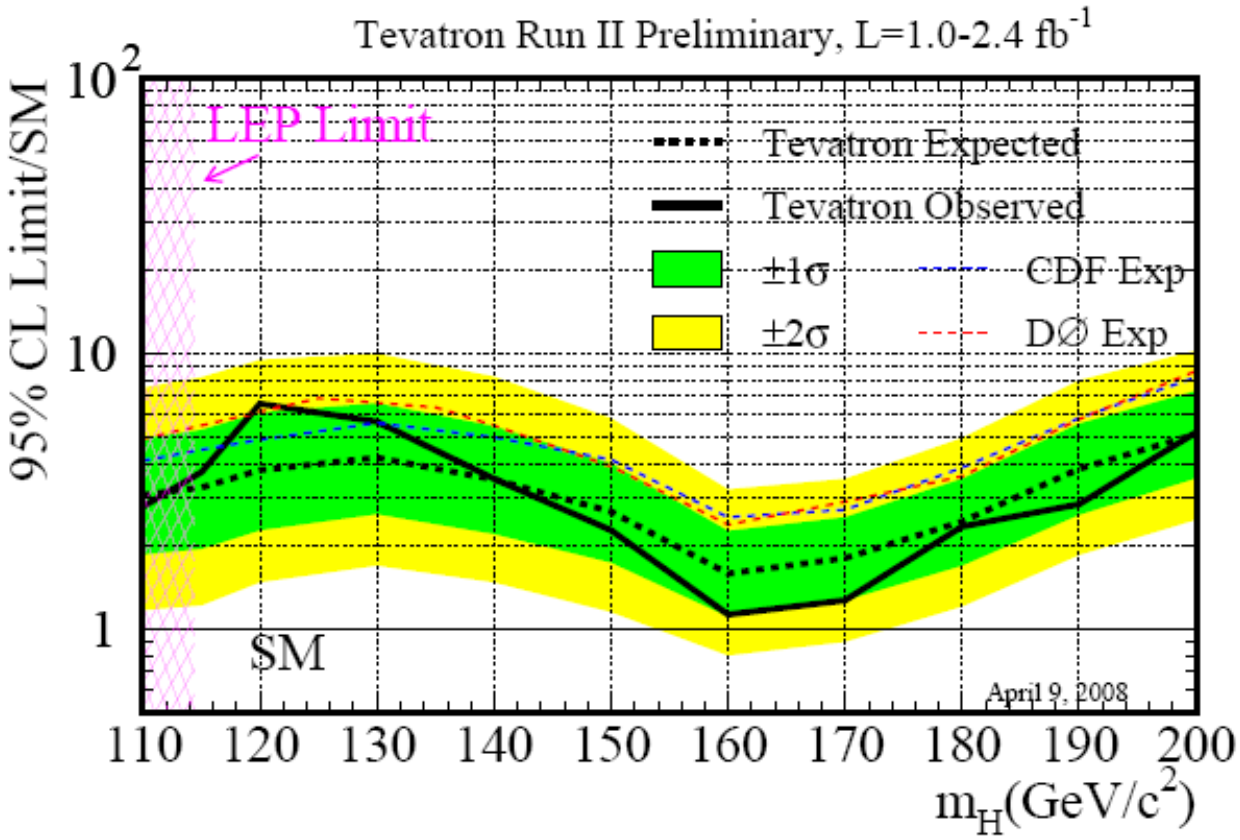
After LEP (around 2001) we know that $m_H > 114$ GeV.

Theoretical arguments require that the standard Higgs boson be lighter than ~ 500 GeV.

Indirect evaluation from the loop corrections to electroweak observables: $m_H = 91^{+31}_{-24}$ GeV.

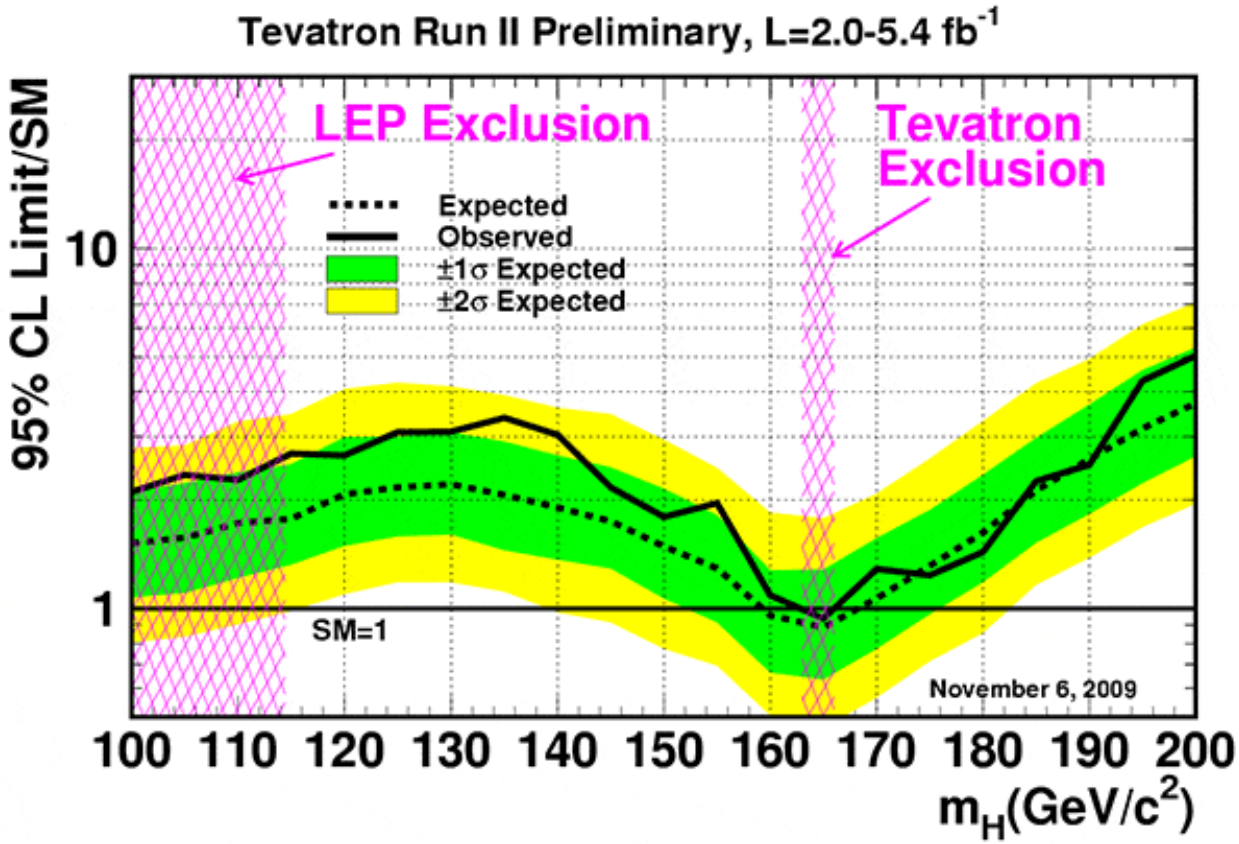
Higgs boson search at Tevatron

Tevatron has been searching for the Higgs since almost 20 years. Here are the results around 2008:



Higgs boson search at Tevatron: 2009

Here are the results around 2009:



Higgs boson search at Tevatron: 2010

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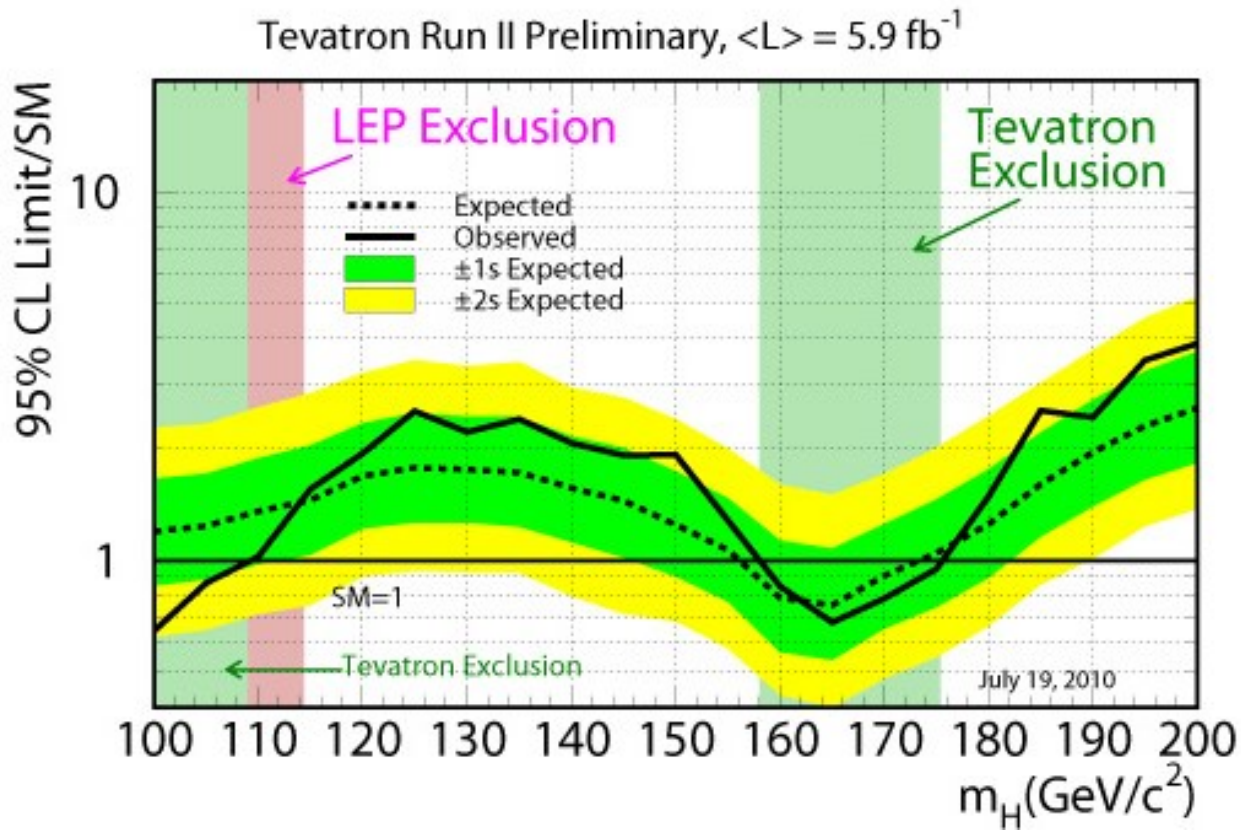
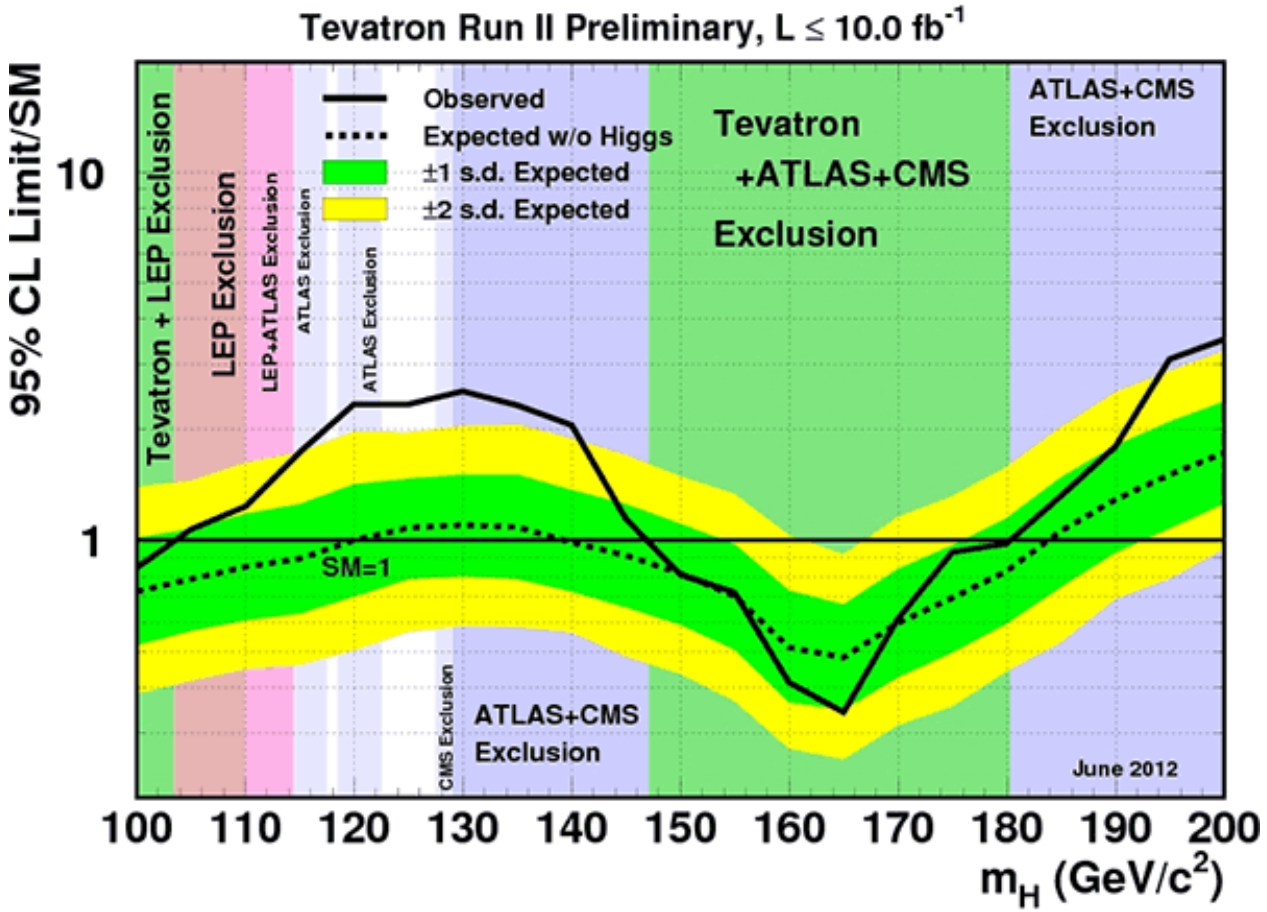


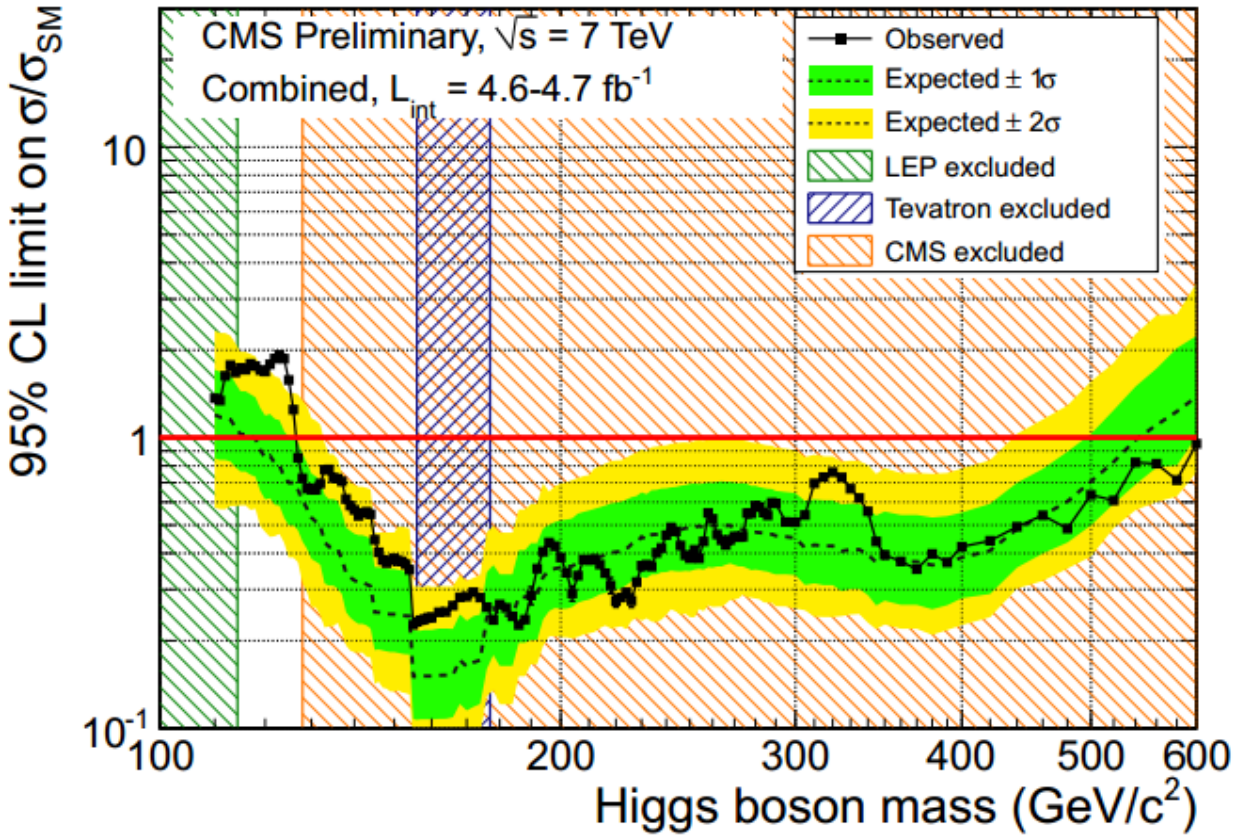
Higgs boson search at Tevatron: 2012

Tevatron was shut down in November 2011. (Almost) final results appeared 3 days ago.



Higgs boson search at the LHC: 2011

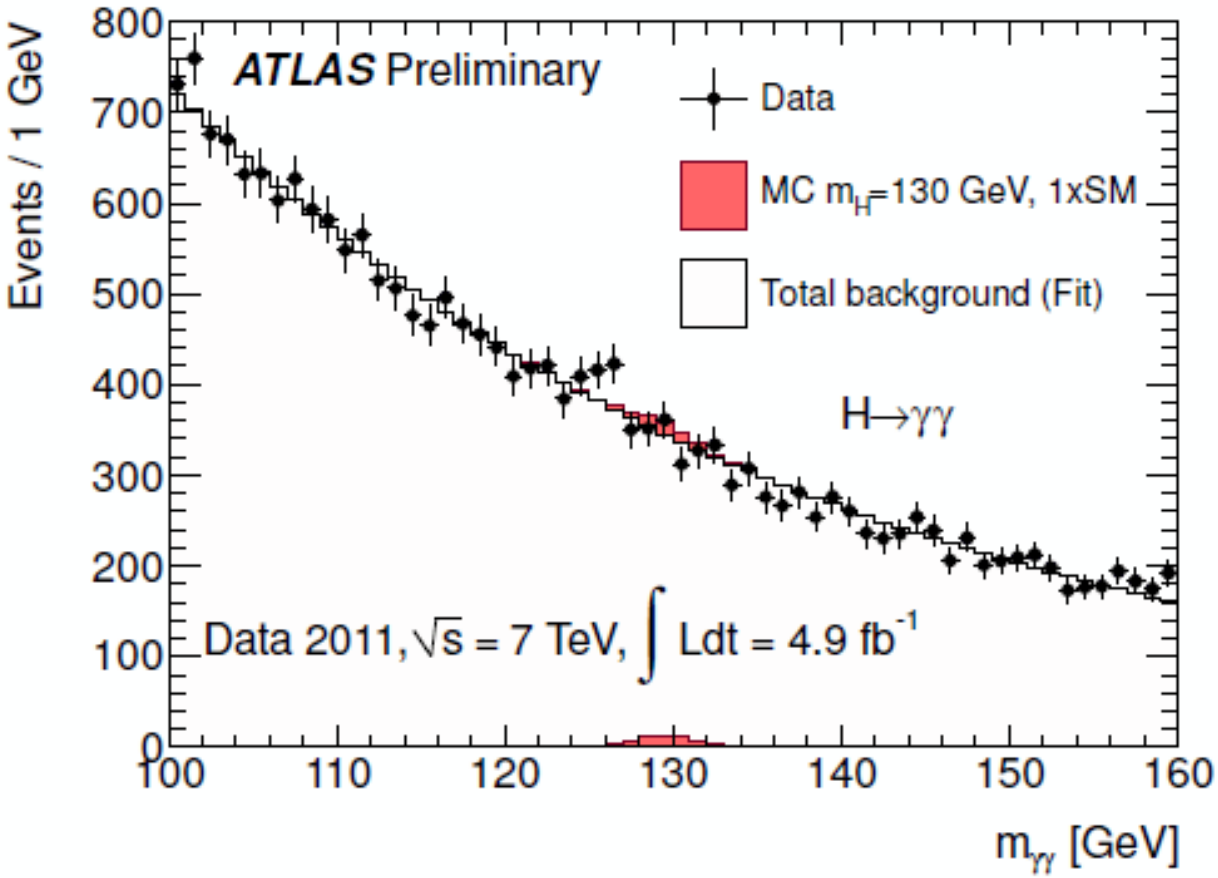
The LHC started to look for the Higgs in 2010 and quickly outperformed the Tevatron.



Almost the entire region excluded plus a signal around 125 GeV.

Higgs boson search at the LHC: 2011

Example: Higgs signal in the $\gamma\gamma$ channel:



Statistical significance of the peak

One should distinguish local statistical significance and global statistical significance.

Local SS is the usual statistical significance.

However, if the region where we search for a peak is wide and if we look anywhere in this region, then pure bkgd fluctuations with large local SS become probable ("look-elsewhere effect").

Global SS is a more "fair" measure of how unlikely it is for a pure fluctuation to appear anywhere in the considered region.

Global SS $<$ local SS, but the good thing is that it increases if the region shrinks. If there is no freedom left, global SS $=$ local SS.

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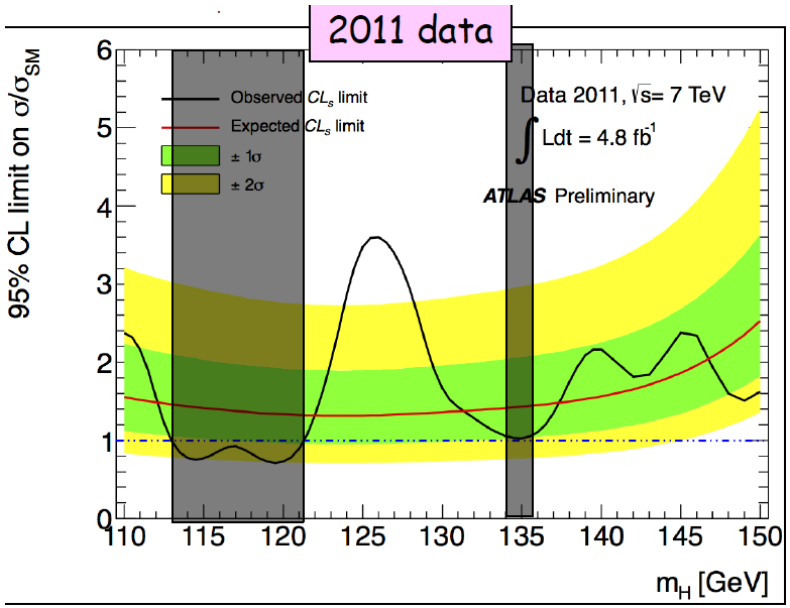
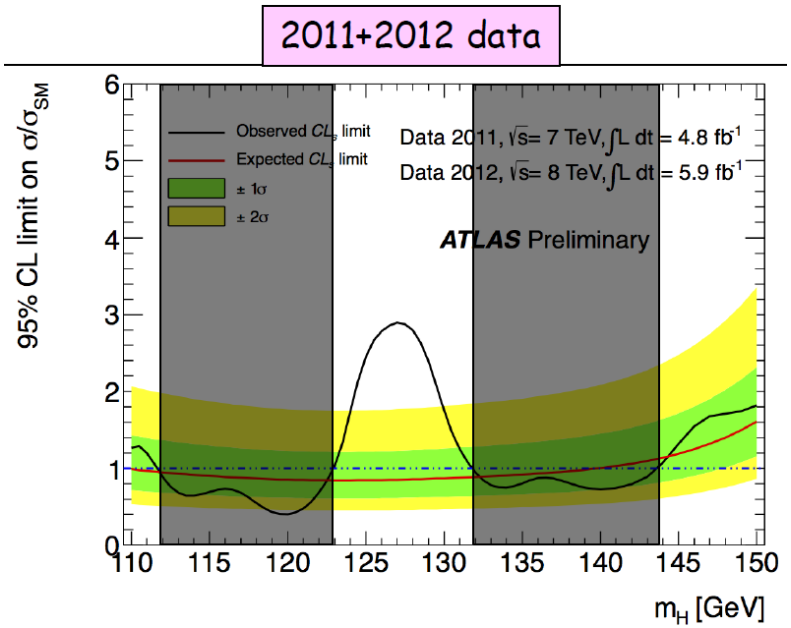
Statistical significance of the peak

See how the window left for the Higgs changes from 2011 to 2012:





Higgs boson discovery at the LHC

2011:

local SS (per experiment): 2.5–2.9σ, global SS around 1.5–2σ.

2012:

SS (CMS): 3.0σ (2011 data) and 3.8σ (2012 data) near the same mass $\rightarrow$ 4.9σ (all channels combined).

SS (ATLAS): similar picture, local SS 5.0σ.

Higgs boson discovery was announced.

Standard or non-standard Higgs?

The main question now: is this a standard or non-standard Higgs?

Check couplings to various particles!
125 GeV is the ideal region for this task because decay channels to $b\bar{b}$, WW, ZZ, $\gamma\gamma$ and $\tau\tau$ can be measured.

Standard or non-standard Higgs?

Current measurement: