Higgs Review for PDG-2012

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on behalf of GB, Marcela Carena, Tom Junk
CERN 10/07/2010

HIGGS BOSONS: THEORY AND SEARCHES

Updated May 10, 2012

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Introduction
The Standard Model Higgs Boson
Higgs Bosons in the MSSM
Charged Higgs Bosons
Other Model Extensions
Other Searches for Higgs Bosons Beyond the SM
Outlook

Previous reviews: 2006 / P. Igo-Kemenes
2008 & 2010 / GB / MC / TJ

Evolution of content of the Higgs review

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covering more experimental and theoretical areas

➔ The theory part was rewritten in 2008 in an effort to include the main theoretical ideas in the field by then, and their impact on the experimental searches.

Example:	in 2006	2008	2010	2012
SM Higgs at Tevatron	< 0.5 page	7 pages	7 pages	5 pages
SM Higgs at LHC		1 page	2 pages	9 pages
SUSY Higgs theory	< 1 page	4 pages	7 pages	9 pages
SUSY Higgs Searches	< 2 pages	4 pages	9 pages	9 pages
Model extensions	1.5 pages	4 pages	8 pages	10 pages

2008/2010, Tevatron ramped up in new domains, many channels unexplored at LEP while previous results were still relevant.

2012: LEP summarized, Tevatron reduced, now LHC has taken over but the review stopped at Moriond 2012 (2011 LHC data),

Then came the 4th of July!

Higgs Review

2008

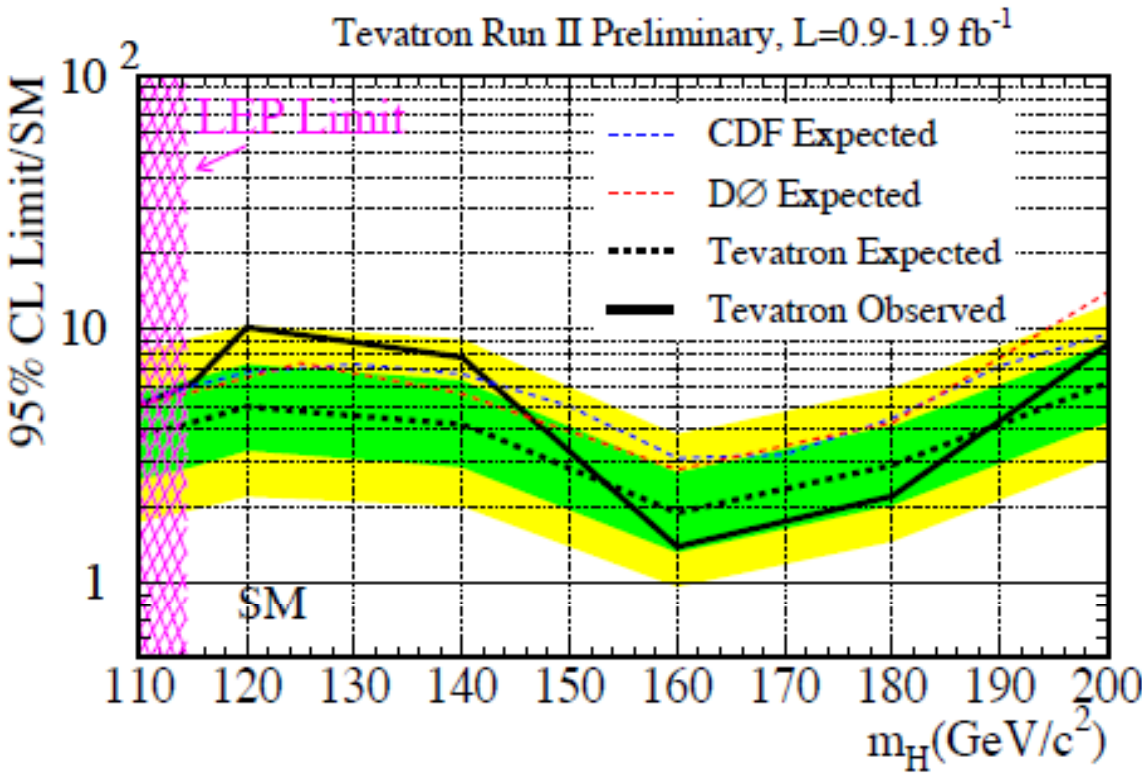
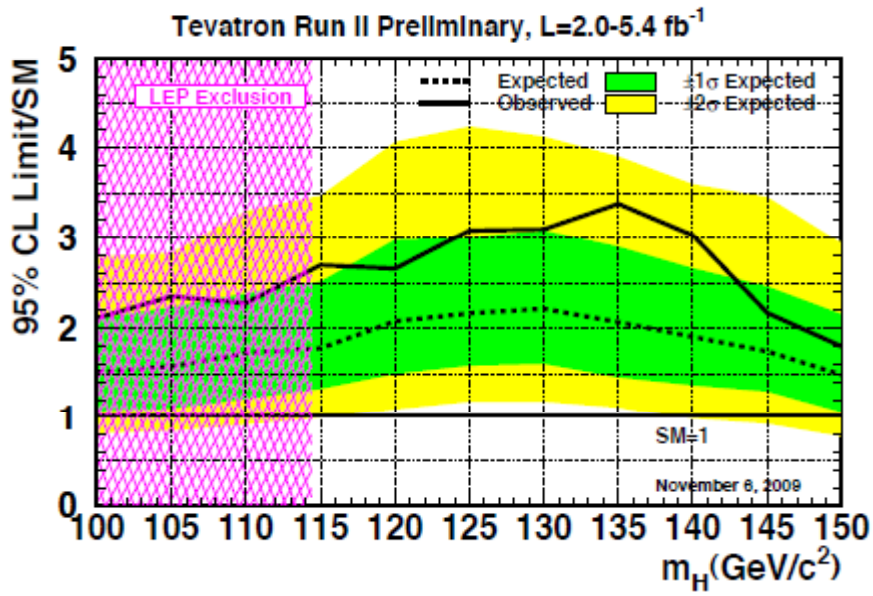
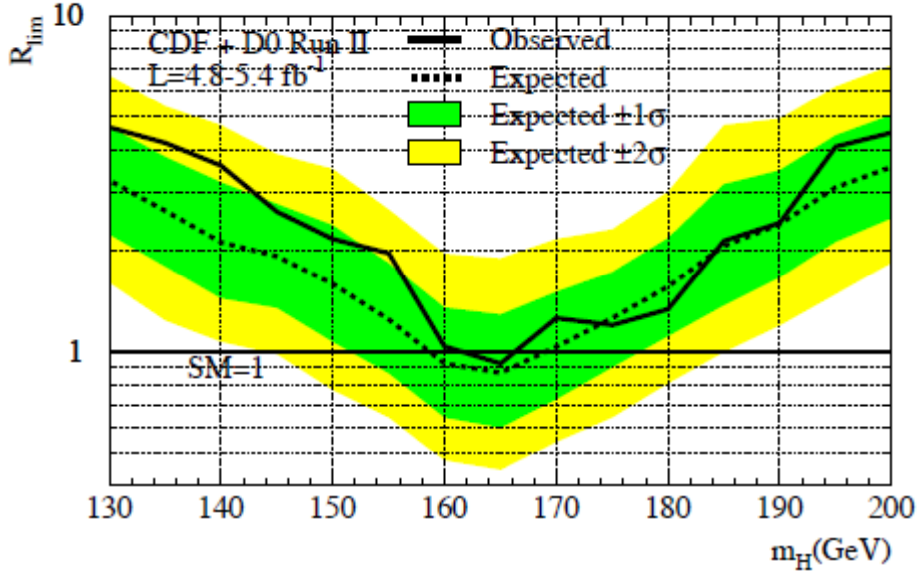


Figure 6: Upper bound on the SM Higgs boson cross section obtained by combining CDF and DØ search results, as a function of the mass of the Higgs boson sought. The limits are shown as a multiple of the SM cross section. The ratios of different production and decay modes are assumed to be as predicted by the SM. The

2010





Higgs Review 2012 – a Preview
(Concluding Slide from the 2010 PDG review)

Theory: inclusion of new computational developments (SM in particular) and BSM ideas will be done

Electroweak fit including direct limits?

Will include all results up to HCP 2011 (November '11) or Moriond 2012 (March 2012)

Tevatron ~ 10 fb^{-1} (doubling of the statistics)
LHC ~ 1 fb^{-1}

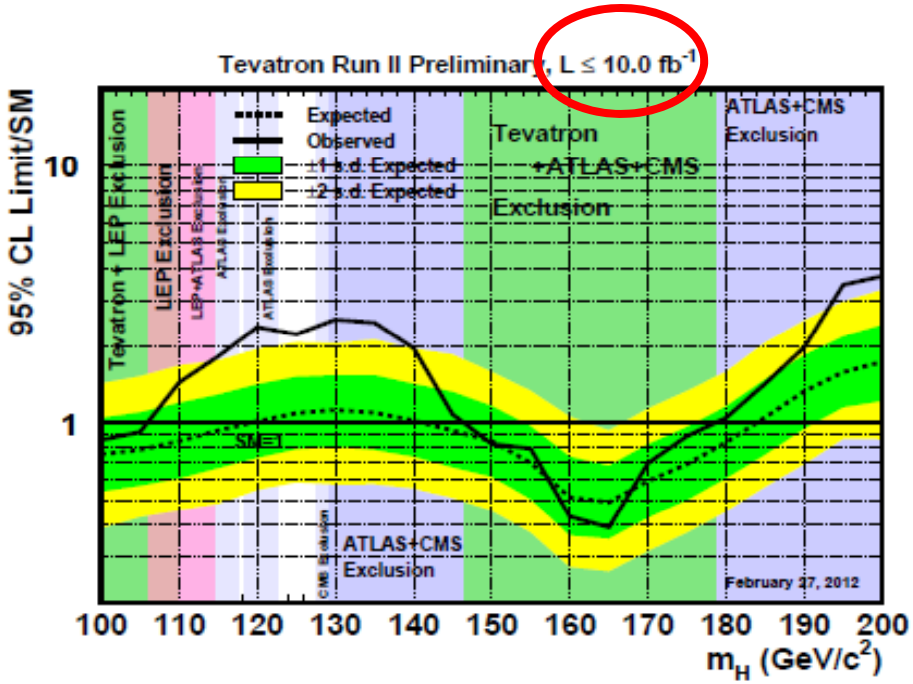
Competition at high mass, but already excluded

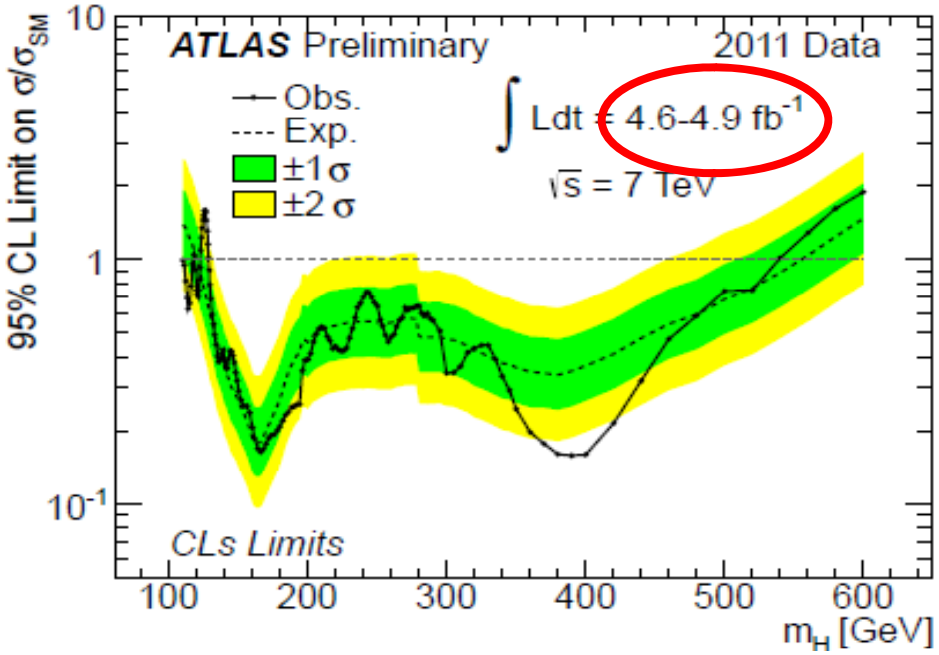
Complementarity at low mass and in some Susy channels

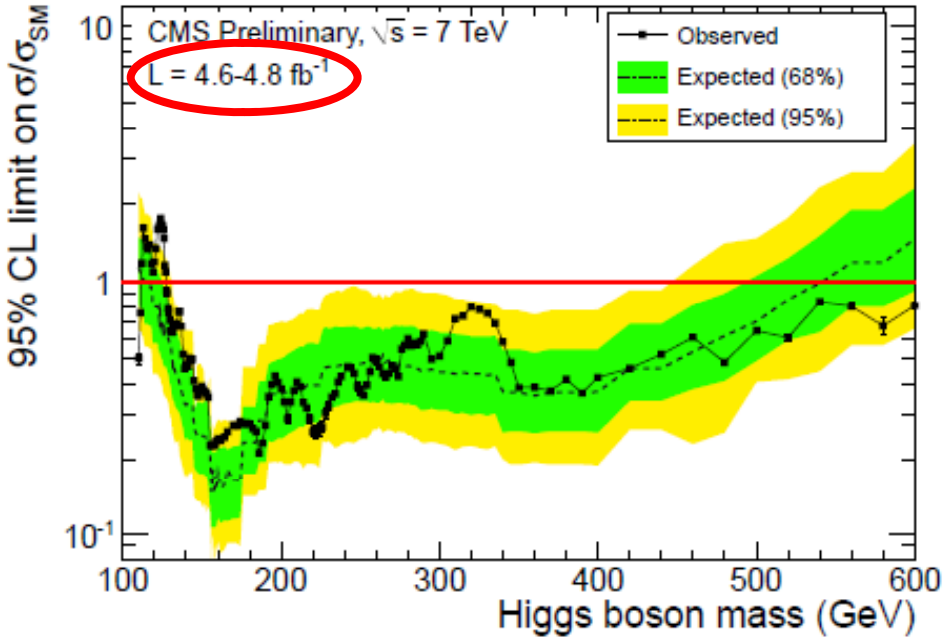
LHC – Tevatron combinations?

Or something more fun?

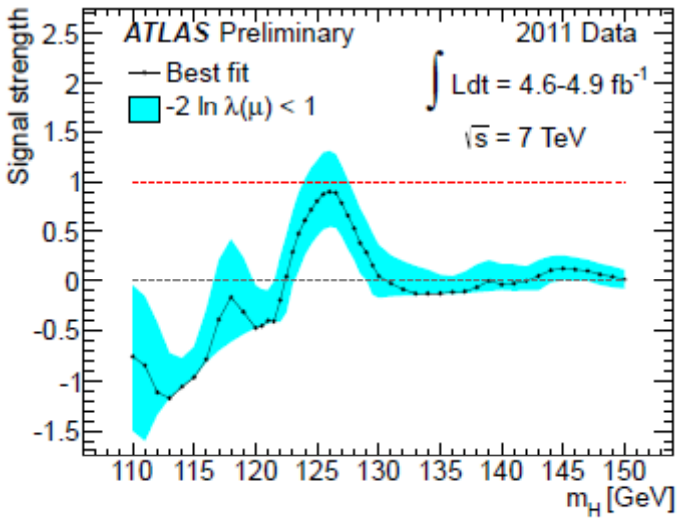
Plots in Higgs Review for PDG-2012

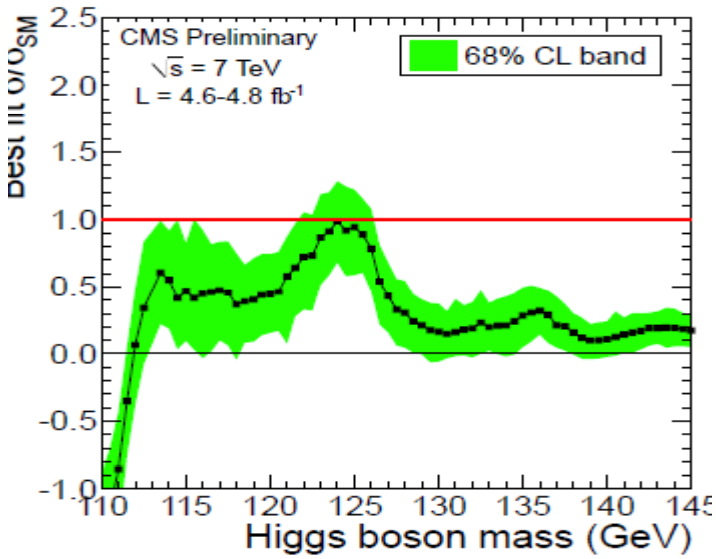


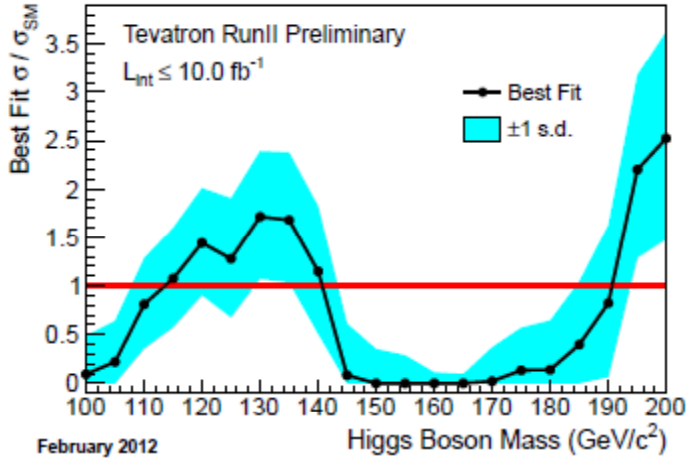




Plots in Higgs Review for PDG-2012







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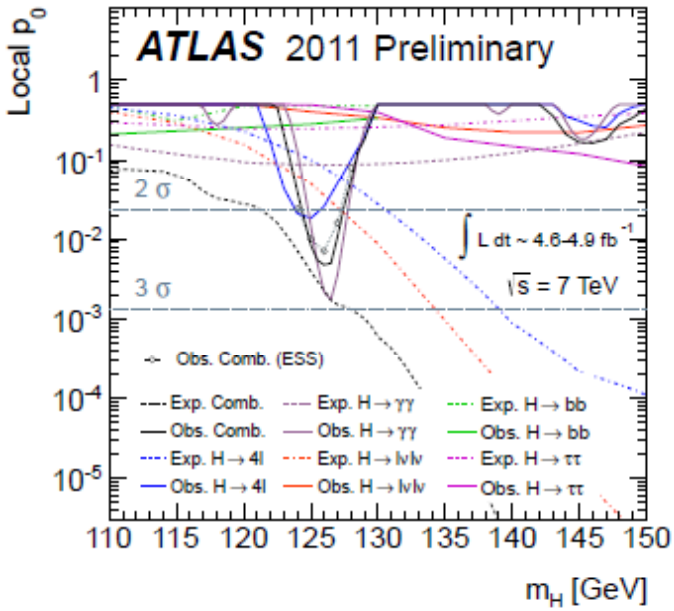
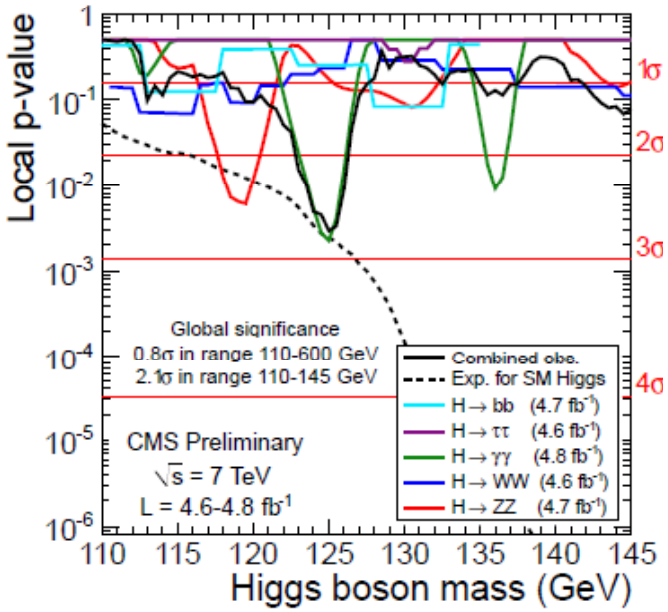




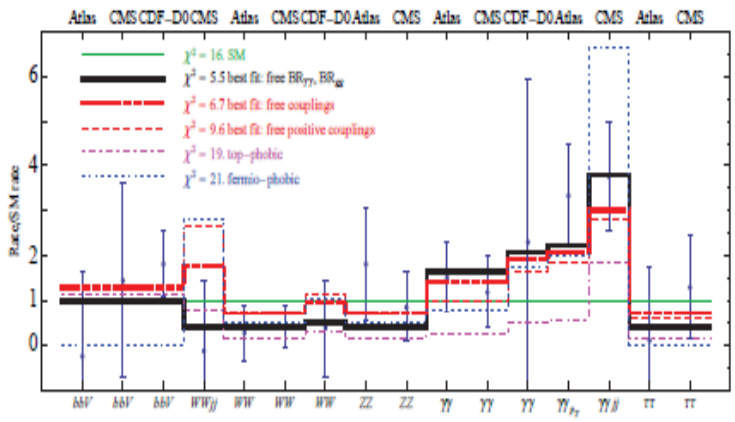


Figure 14: Summary of the cross section times branching ratio measurements from ATLAS, CMS, and the Tevatron. The values are quoted

Table in Higgs Review for PDG-2012

Table 1: Observed and expected limits at the 95% C.L. normalized to the SM predictions for the main search channels at the Tevatron and the LHC, evaluated for $m_H = 125$ GeV

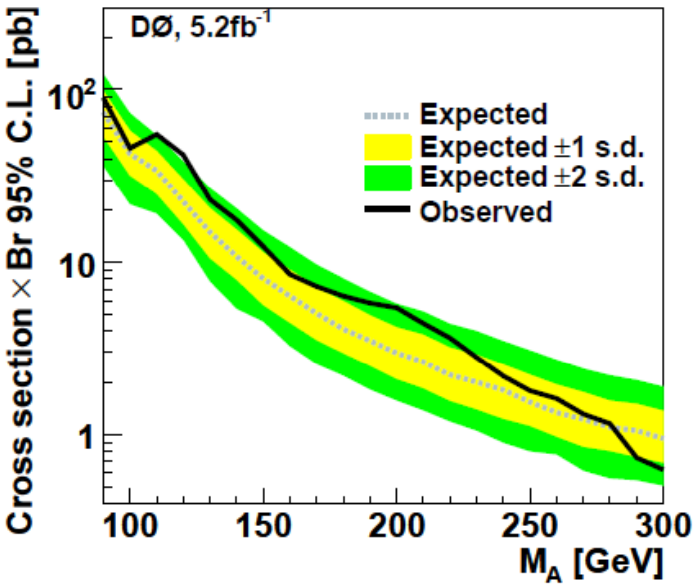
Channel	Obs	Exp	Lumi [fb^{-1}]	Ref.
Tevatron				
$H \to W^+W^-$	2.4	2.2	9.7	[6]
$H \to b\bar{b}$	3.2	1.4	9.7	[6]
Combined	2.2	1.1	10.0	[6]
ATLAS				
$H \to \gamma\gamma$ (MVA)	3.5	1.6	4.9	[132]
$H \to W^+W^- \to \ell^+\nu\ell^-\bar{\nu}$	1.4	1.2	4.7	[121]
$H \to ZZ \to \ell^+\ell^-\ell^+\ell^-$	4.2	2.4	4.8	[125]
Combined	1.5	0.8	4.9	[8]
CMS				
$H \to \gamma\gamma$ (MVA)	2.9	1.2	4.8	[134]
$H \to W^+W^- \to \ell^+\nu\ell^-\bar{\nu}$	1.5	1.1	4.6	[122]
$H \to ZZ \to \ell^+\ell^-\ell^+\ell^-$	2.5	1.6	4.7	[126]
Combined	1.6	0.7	4.8	[10]

2.2 sigma with LEE

1.3 sigma with LEE

2.1 sigma with LEE

Plots in Higgs Review for PDG-2012
Susy Higgs



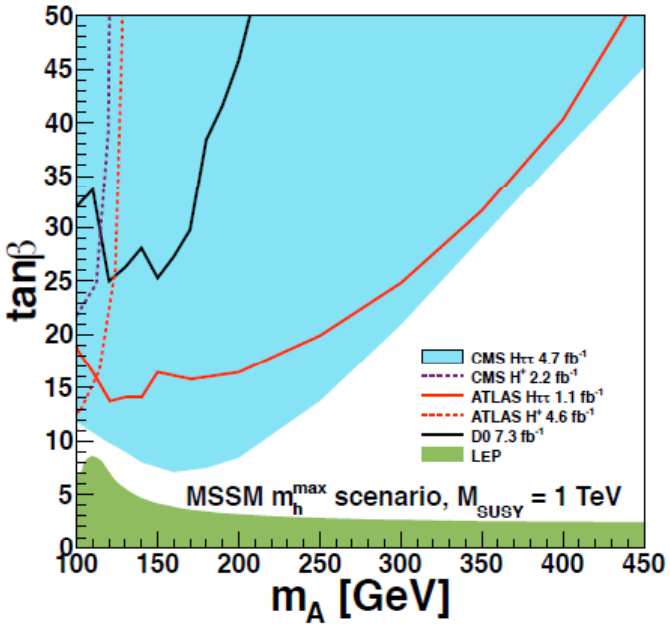
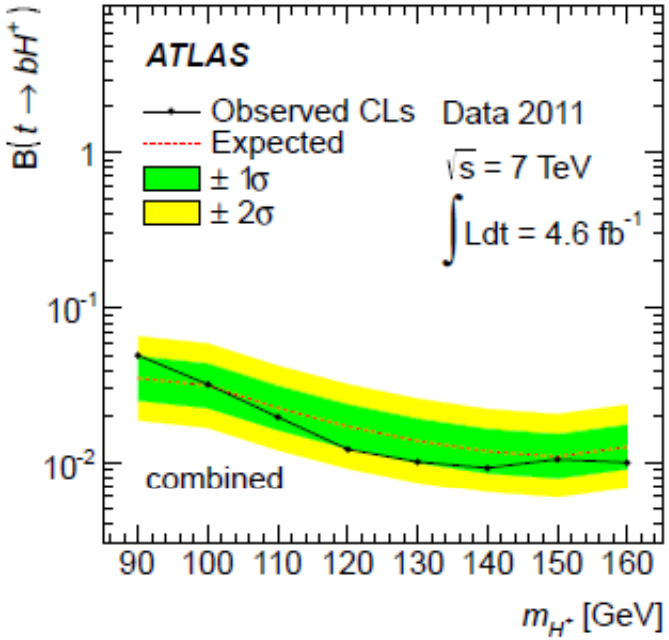


Figure 15: The 95% C.L. limits on $\sigma(p\bar{p} \to b\phi) \times \mathrm{BR}(\phi \to b\bar{b})$ from CDF and DØ. The ob-



We thought we were done, but 4th of July….

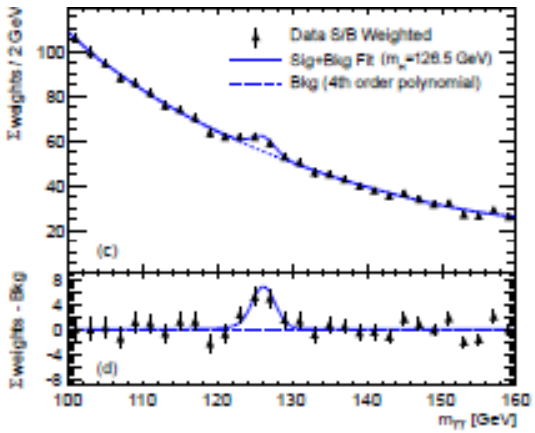


FIG. 11: Invariant mass of the diphoton events in the ATLAS experiment. The results are presented with and without event weighting by expected signal to background.

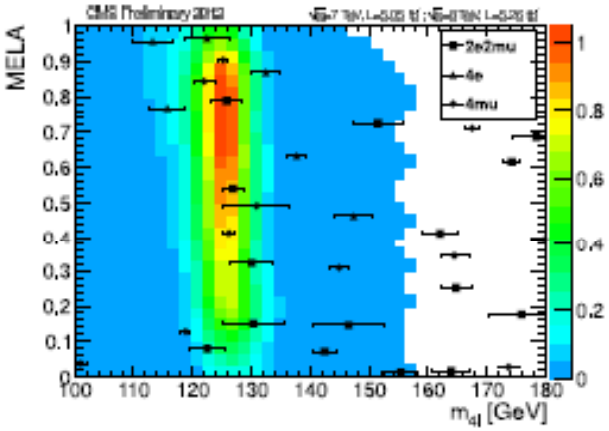
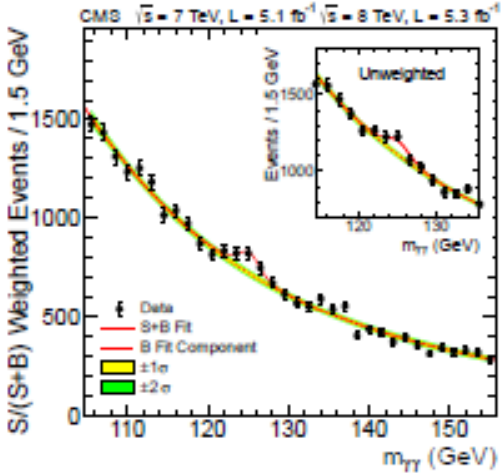


FIG. 9: A two dimensional plot of four lepton invariant invariant mass vs. matrix element likelihood from the CMS experiment. Data is shown with event by event mass uncertainties while the expectation of a 125 GeV SM Higgs boson is superimposed as a temperature plot.



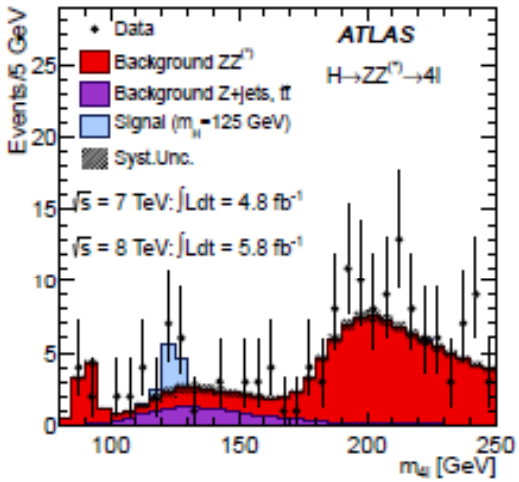


FIG. 10: The four lepton invariant mass invariant mass distribution from the ATLAS experiment. The data is displayed as point and the background expectation as a histogram. Several example SM Higgs signal are included for different hypothet-

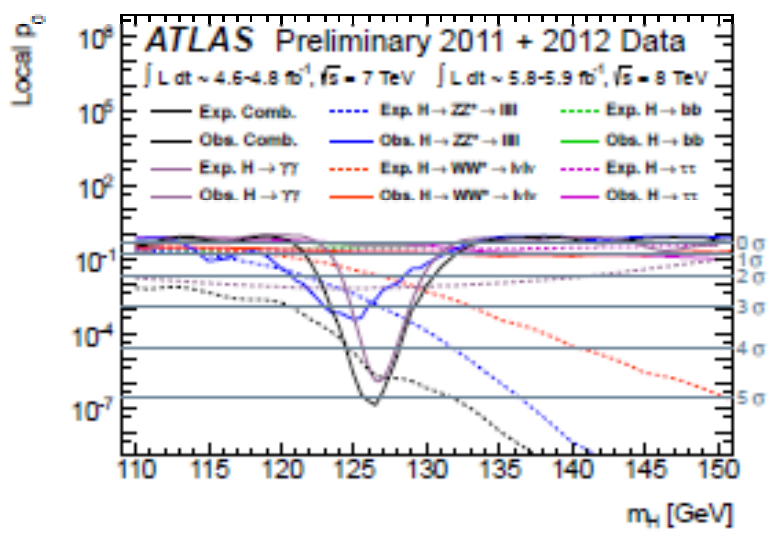
Addendum to Higgs Review for PDG-2012

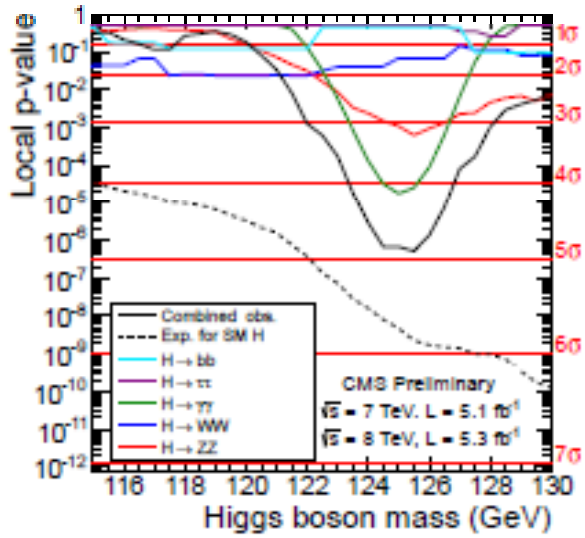
Addendum to "Higgs Bosons: Theory and Searches" (2012)

G. Bernardi (CNRS/IN2P3, LPNHE/U. of Paris VI & VII), M. Carena (Fermi National Accelerator Laboratory and the University of Chicago), and T. Junk (Fermi National Accelerator Laboratory).

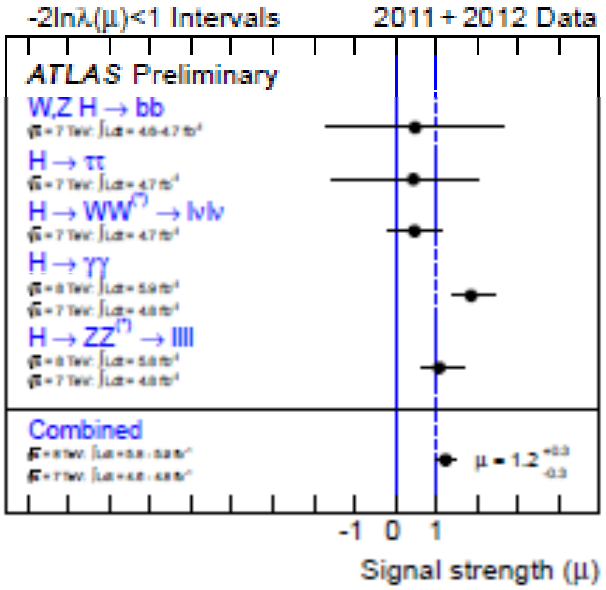
Updated July 12, 2012 After iterations with PDG referees + ATLAS/CMS spokes and PC

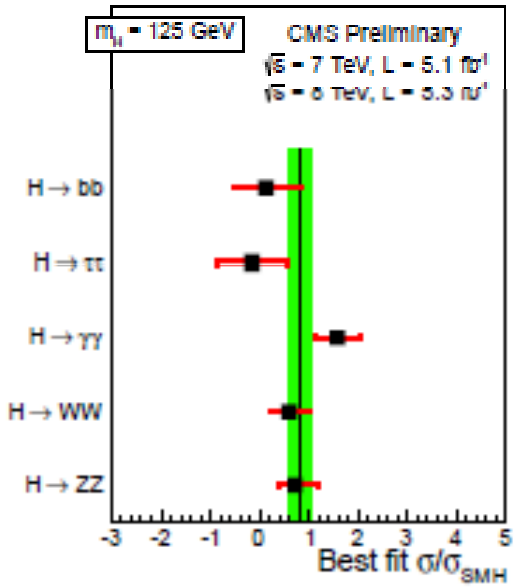
On July 4, 2012, the ATLAS and CMS collaborations simultaneously announced observation of a new particle produced in pp collision data at high energies [1–4]. The data samples used correspond to between 4.6 and 5.1 fb^{-1} of collision data collected at $\sqrt{s} = 7$ TeV in 2011, and between 5.3 and 5.9 fb^{-1} of collisions collected at $\sqrt{s} = 8$ TeV in 2012. The observed decay modes indicate that the new particle is a boson. The evidence is strong that the new particle decays to $\gamma\gamma$ and ZZ with rates consistent with those predicted for the Standard Model (SM) Higgs boson. There are indications that the new particle might also decay to W^+W^-, and decays to $b\bar{b}$ and $\tau^+\tau^-$ are being sought as well.

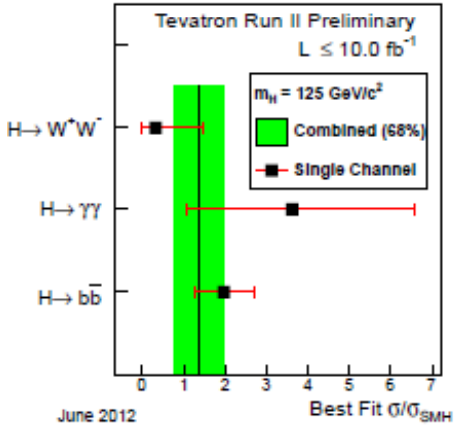




Addendum to Higgs Review for PDG-2012







In summary, a new particle has been observed at the LHC. Within the experimental uncertainties, it has characteristics consistent with those expected from the Higgs boson predicted by the Standard Model, with a mass near 125 GeV. Tevatron data also are consistent with the production and decay of a SM-like Higgs boson at this mass. However, the present experimental uncertainties still allow for a wide variety of new physics alternatives.

Higgs Review 2014, How to call it?

⟨Personal image of the Higgs section in the next edition (K.Hikasa)⟩

Higgs Bosons (S055) Listings

H^0 **or** $X^0(126000)$ **(New Section) — Naming should be discussed**

The properties of this particle are consistent with being the Higgs boson predicted in the Standard Model.

Spin: 0, 2 or higher (spin 1 is excluded by $\gamma\gamma$)

Mass: 126.±

Decay Modes:

$\gamma\gamma$ seen

ZZ seen

...

$\sigma{\cdot}B$ relative to $(\sigma{\cdot}B)_{\mathrm{SM}}$

...

STANDARD MODEL H^0 **(Higgs Boson) MASS LIMITS**

(Existing and new search results: exclusions – stays for a while)

New name while waiting sufficient confirmation, but we may be not that far, so name should be similar to H^0 : H(125) or H(126) or H(12x) since mass may oscillate between 125 and 126 for quite some time?

Higgs Review 2014 – a Preview

Theory: inclusion of new models which could explain the boson beyond the SM (and corresponding searches)

Experimental:
will include all final results from LHC 8 TeV (30-40 fb^{-1}) run and from Tevatron ~ 10 fb^{-1}

Properties, Quantum numbers,

Closer to know how compatible it is with SM

LHC – Tevatron combinations?

Or something more fun?