If the Higgs mass is ... or "What might be known by 2016"

Michael Dittmar (ETH-Zürich/CMS)
DESY Seminar (Hamburg / Zeuthen) 9/10.2.2010

- Introduction: Higgs boson (the missing link of the SM)
- The Higgs mass, the "5+1" scenarios
- Phases of Higgs searches at the LHC
  yesterdays simulations, todays "indirect" Higgs limits and
  tomorrows (the year 2016) knowledge: the "5+1" Higgs masses.
- Summary: The discovery of a Higgs like particle
  "Nightmare" or "Happy End"?

Introduction: LHC and the Higgs Boson some "google" hit results

"LHC" = 6.8 Million hits; "LHC Higgs" = 3.2 Million hits;

"LHC Higgs Scenario" = 270 000 hits;

"What if the Higgs boson isn't found" = 26800 hits

"LHC Higgs Nightmare Scenario" = 1270 hits;

"What if the Higgs mass is" = 142000 hits ! (7.2.2010)
"first google hit ("seems to work well!"):

Deutsches Elektronen-Synchroton DESY - If the Higgs mass is ?
Michael Dittmar (ETH Zürich) Seminar Room 3, 15:00.
physikseminar.desy.de/zeuthen/seminars_in_2010/feb_10_2010/

Introduction (0)

from the "Universe Today" (17 Sepember 2009)
http://www.universetoday.com/tag/higgs-boson/

"The higgs boson is thought to be a very heavy particle, and so it takes a lot of energy in the collider to create particles this massive. When the LHC starts running, it will collide protons at higher and higher energies, searching for the higgs boson. **If it is found, it will confirm a theorized class of particles predicted by the theory of supersymmetry..."**

(Question I: Not really true, but who informed the "Universe Today people"?)

... **"And even if the higgs boson isn't found, it will help disprove the theory. Either way, physicists win."**

(Question II: Did "Universe Today people" wanted to say: "physics wins"?)

Introduction: some quotes (I)

From Scientific American, July 2008 (In anticipation of the start-up, CERN convened a panel of five Nobel Prize winning physicists to give their thoughts on the project.)

"The LHC was built first and foremost to seek out a subatomic particle called the Higgs boson , which solves the conundrum of why the photon has no mass, whereas its counterparts (W and Z), do.

- David Gross:
  "We are all enormously excited that the LHC is about to turn on"
  "Discovering the Higgs would close a three-decade-long chapter in the history of physics";

  "(I) expect that the LHC (will) reveal supersymmetry"; and

  "...even more interesting than the Higgs would be the discovery of particles responsible for dark matter as well as an explanation of why the universe has a preponderance of matter over antimatter , either of which would break new ground in fundamental physics."

Introduction: some quotes (II)

From Scientific American, July 2008 (In anticipation of the start-up, CERN panel of five Nobel Prize..)

- Martinus Veltman made a "speculative scenario" in which
  "Higgs exists but fails to show up at the LHC." If that happens, he predicted, "it will probably be the end of particle physics."

- Gross said that such a result, going against the standard model, would itself be "enormously exciting."
  "My nightmare is we find the Higgs and nothing else," he said. "I have a lot of confidence that we won't, but that is a nightmare."

  "What worried him was finding the Higgs and nothing else, because then it would be impossible to persuade world governments to fund future machines such as the proposed International Linear Collider , which took a hit in December when Congress yanked 2008 funding for the U.S. share of R&D on the project."

Introduction: some quotes (III)

Physicists Nightmare Scenario: The Higgs and Nothing Else
"Some would rather see nothing new at all." Science Vol 315 23 March 2007

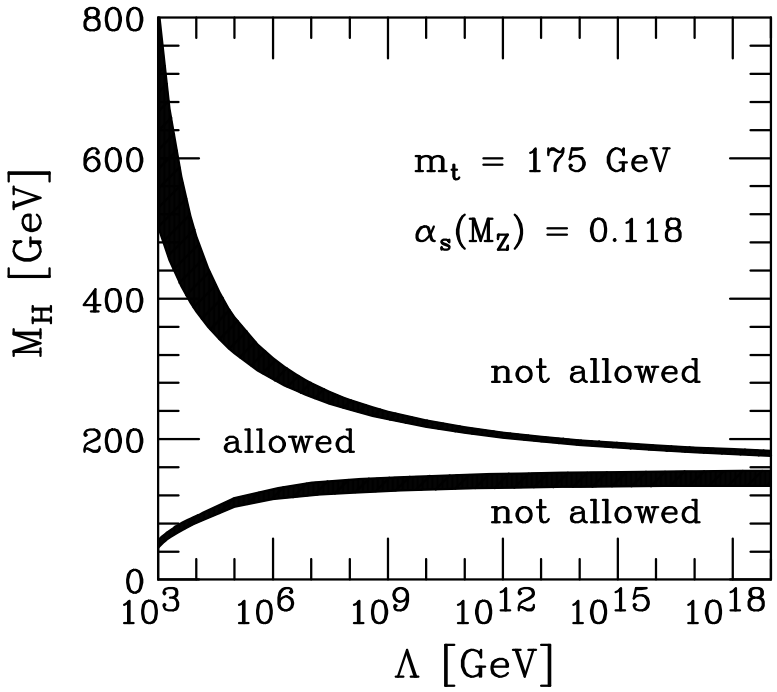
If it has the right mass, the Higgs and nothing else **"would be the real five-star disaster, because that would mean there wouldn't need to be any new physics."**

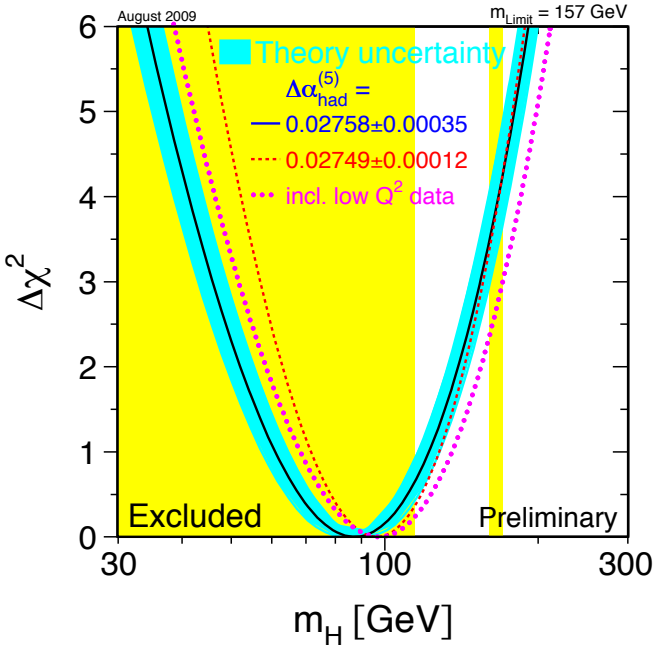
—Jonathan Ellis, CERN

Which Higgs mass stands for the "nightmare scenario"?

The SM Higgs mass or the nothing else "nightmare scenario?"

- If SM and nothing else $\rightarrow M_H \approx 150 - 180$ GeV or "the SM could be an effective theory up to very high scales!"
- Direct searches from LEP II: $M_H > 114$ GeV
  Jan 2010 Tevatron exclusion claims: 162-166 GeV (more later)
- from electroweak parameters ("bad fit" more later): $M_H < 157$ GeV
  (for more precise numbers stay tuned for the latest changes)!

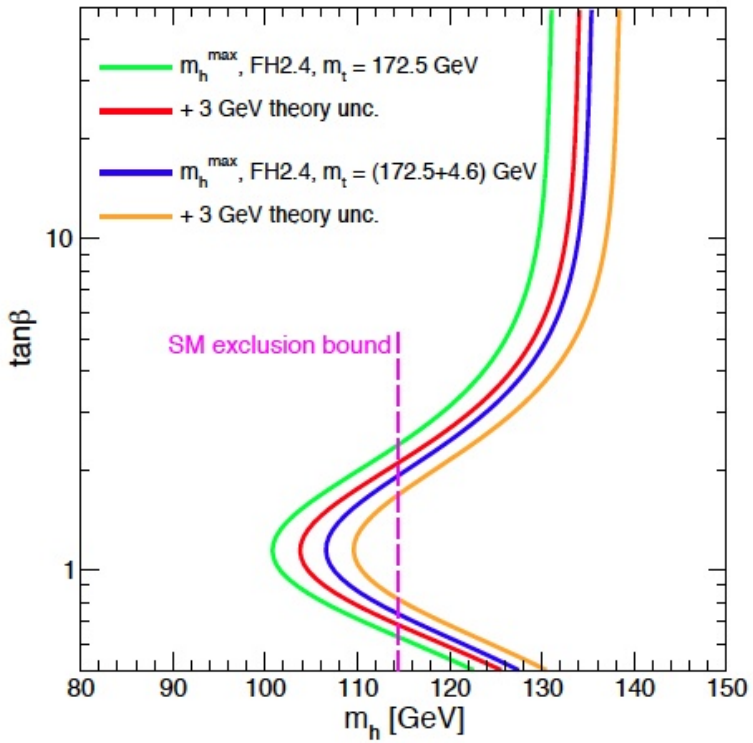


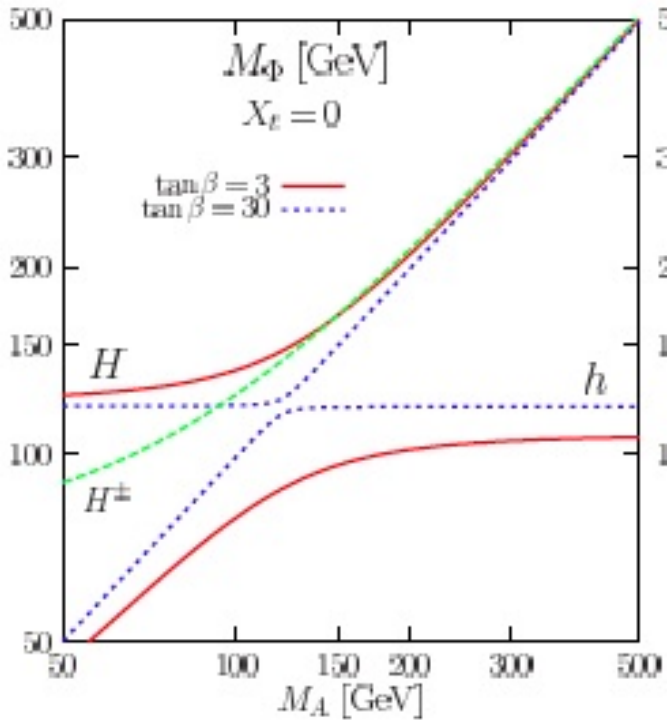


source: T. Hambye and K. Riesselmann, PRD 55, 7255 (1997) and
http://lepewwg.web.cern.ch/LEPEWWG/plots/summer2009/s09_blueband.eps

Supersymmetry and the lightest Higgs boson?

Within the MSSM: 5 Higgs bosons h,A,H and $H^{\pm}$
mass of the lightest Higgs $M_h \leq$ 130-135? GeV
for "large" M_A: SM(Higgs) and SUSY(h) roughly identical!
if $M_h \geq 125$ GeV $\rightarrow \tan\beta \geq 5$





source: S. Heinemeyer http://www.ifca.unican.es/ heinemey/uni/plots/

For Supersymmetry with "extended Higgs sector" ..
the mass of the "SM like Higgs" can be a couple(?) of GeV higher!
see for example NSSM, Ellwanger http://arxiv.org/pdf/0809.0779v1

The Higgs mass, the "5+1" scenarios
Do you have a preferred scenario? (Why?)

With or without the discovery of other "new physics"

1. M_H = 125 GeV: the "(N)MSSM SUSY" scenario;

2. M_H = 145 GeV: a "yes/no" "SM/NSSM SUSY" like" scenario;

3. M_H = 168 GeV: (N)MSSM SUSY excluded
   an effective SM forever ("is this really a nightmare scenario"?)

4. M_H = 250 GeV: a just beyond the SM (end of SUSY!) scenario;

5. M_H = 450 GeV: the beyond SM (end of SUSY!) scenario;

6. The "Higgs" can not be observed as a detectable LHC "resonance";
   and the real nightmare scenario!

Higgs searches the LHC:1984-1997 (Phase I)

- Lausanne Workshop (1984) and La Thuile Workshop (1986/87)
  "CERN's long term future after LEP": A 16 TeV pp collider with up to 100 fb^{-1}/year!
  "Almost" equivalent to the SSC 40 TeV pp project (10 fb^{-1}/year)
  Higgs search ($M_H \geq 200$ GeV), Supersymmetry etc

- The physics potential at the LHC:
  Workshops: from Aachen (1990) to Evian (1992)
  (the "why" and the "how" preparations ...)
  Higgs search becomes the "reason" to construct the LHC
  (possibility to discover the Higgs from 100 GeV-1000 GeV)

- CMS Letter of Intent (1 October 1992)
  "The LHC has been designed to collide protons at a centre-of-mass energy of $\sqrt{s} = 15.4$ *TeV every 15 nsec at a luminosity of* $1.7 \times 10^{34} cm^{-2} s^{-1}$
  .. It is expected that over the first one or two years of running the maximum luminosity will progressively increase from 10^{32} *to* $10^{34} cm^{-2} s^{-1}$*."*

- 1992-1996: Out of the ashes of the SSC
  CERN becomes "pregnant" with the LHC and its experiments!

Higgs search at the LHC : Phase I

Understanding the "needs": Early simulations (before 1995) (1)

- Define a theoretical motivated LHC "purpose and goal":
  Find or exclude the Higgs (the missing link of the SM) if $M_{Higgs} \geq 100$ GeV

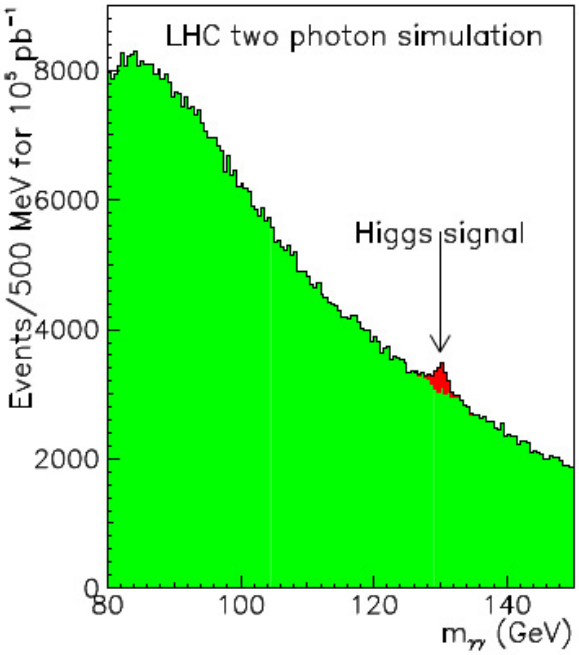
- Understand the LHC energy needs, luminosity and detector requirements.
  Simulating the Higgs search in $H \rightarrow \gamma\gamma$ and $H \rightarrow ZZ^* \rightarrow \ell\ell\ell\ell$
  extraordinary requirements for γ energy resolution!

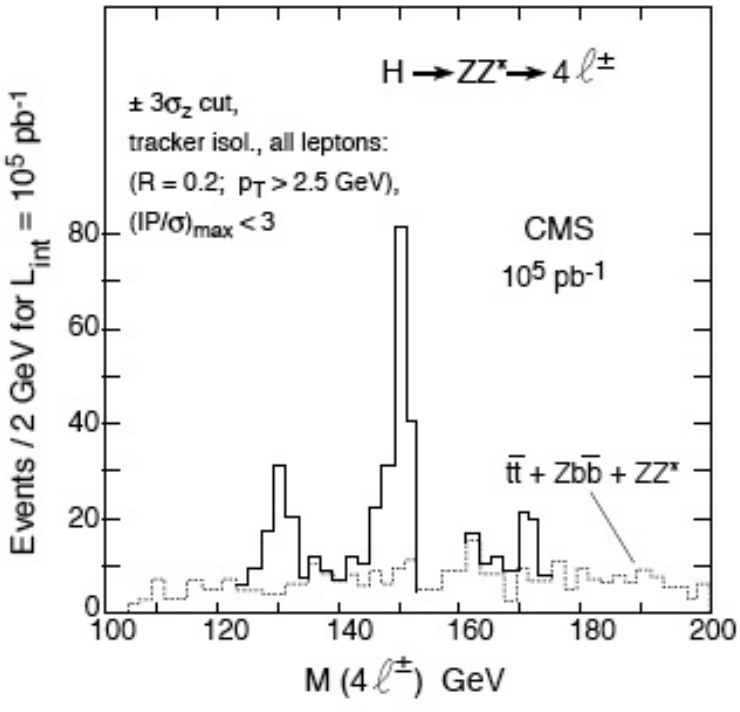
- Most important SM Higgs result(s): It can be done!
  Extras: many other discoveries/measurements can be performed at the LHC, especially if the "missing transverse" energy can be measured!
  Many other Higgs decay channels, supersymmetry (MSSM),
  additional vector bosons, Z' W' etc

For 1995 state of the art Higgs review see: Higgs Boson Discovery and Properties, Snowmass 1996 report J. Gunion et al, http://xxx.lanl.gov/abs/hep-ph/9703330

Higgs search at the LHC : Phase I

Understanding the "needs": Early simulations (before 1995) (2)

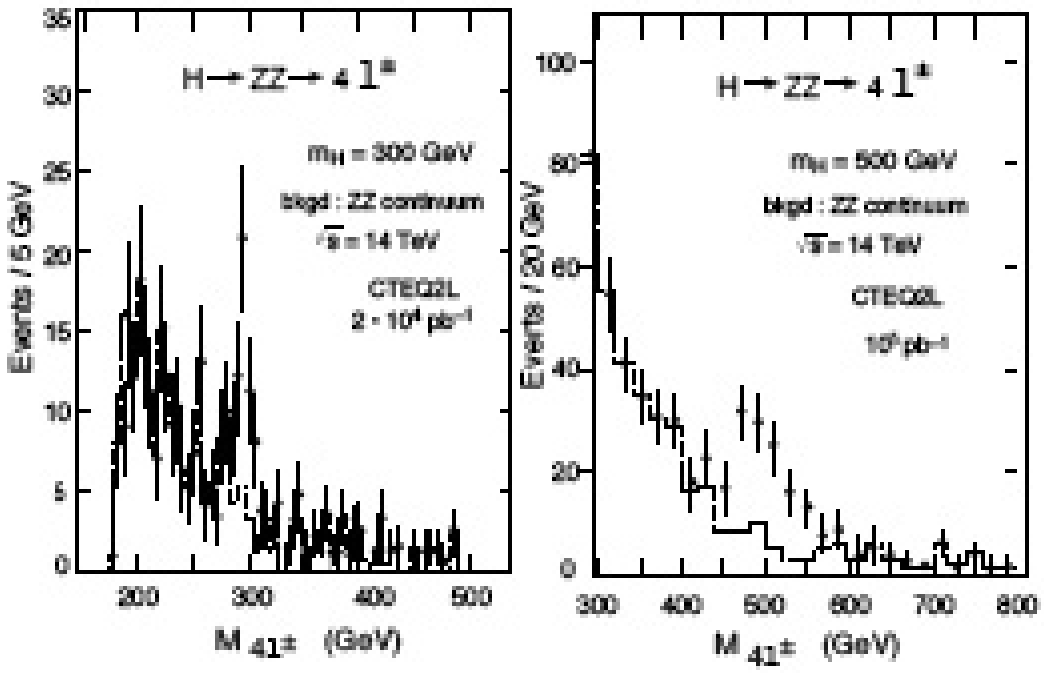




High luminosity low mass Higgs signals with 100 fb^{-1} (CMS around 1995)

Higgs search at the LHC : Phase I

Understanding the "needs": Early simulations (before 1995) (3)



$H \to ZZ \to \ell\ell\ell\ell$ M_H = 300 GeV and 500 GeV
Luminosity = 20 fb^{-1} and 100 fb^{-1}
(CMS around 1995)

Higgs search at the 14 TeV LHC: Phase I

Closing the "last LHC gap" ... M_H = 155-180 GeV (1997) (4)

Establishing a signature with $\mathbf{H \to WW \to \ell\nu\ell\nu}$:

- oppositely charged leptons with small opening angle
  (Spin correlations and V-A interaction);
- signal events are more central
  (gluon fusion production versus $q\bar{q} \to$ WW continuum production);
- signal events with no or little jet activity
  (Jet veto against huge $t\bar{t}$ background);
- lepton p_t spectra close to $M_W/2$
  (low transverse momentum of W near threshhold).

"Surprising" Result: former difficult mass region will give the first LHC Higgs results!

see M. D. and H. Dreiner, Phys. Rev. D 55, 167 - 172 (1997) and CMS note 1997/083

Higgs search at the 14 TeV LHC: Phase II

Towards the LHC start (1997-2007) (1)

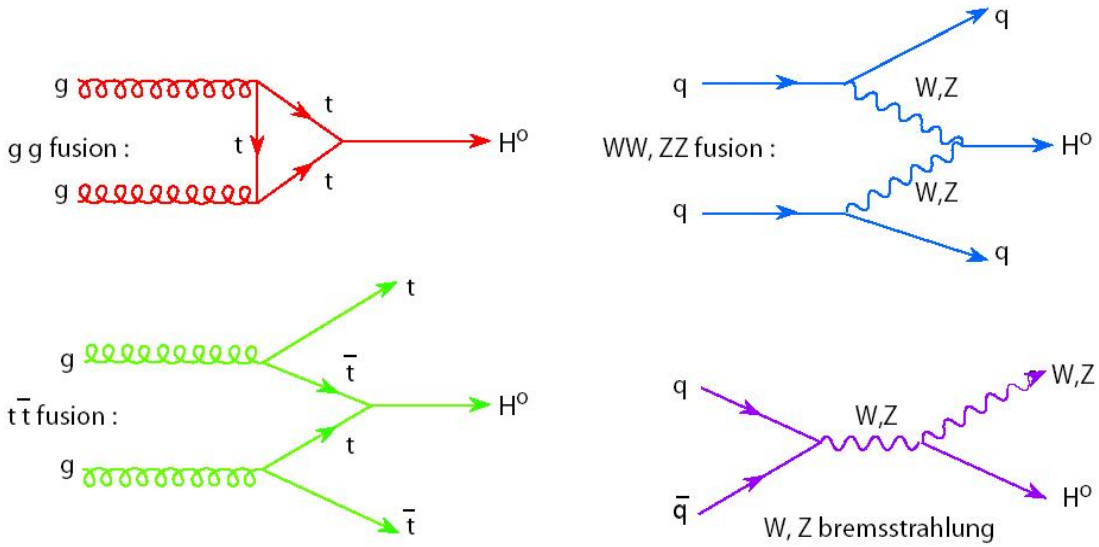
- LHC Conceptual Design Report (CERN/AC/95-05) and E. Keil DPF-DPB Workshop Snowmass 1996
  "$\sqrt{s} = 14$ *TeV, collisions every 25 nsec and* $L = 10^{34} cm^{-2} s^{-1}$
  .. *Injection tests foreseen October 2003, commissioning second half 2005*"

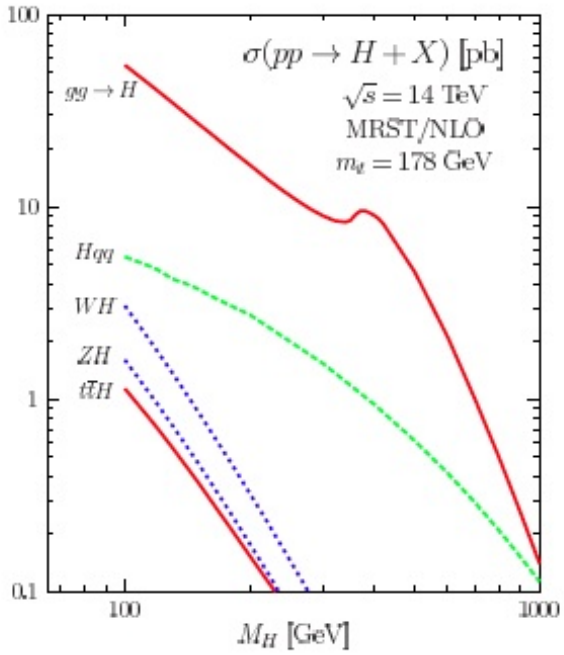
- Revised schedule: L. Evans, EPJ C 34 s11-15 (2004).
  Ring will be closed by end 2006 with first beam injected in spring 2007 and first physics run in second half of 2007.
  Important milestone in April 2006 when a beam will be injected at Point 8 and transported around the first octant to Point 7.

- Particle collider is on schedule... just, Nature 449, 761 (17.10.2007)
  CERN's new machine still aiming for 2008 debut.
  "The next three months are going to be pretty critical" says Evans.
  "If something unforeseen comes up between now and then, it will slip. There's no doubt."

Higgs search at the 14 TeV LHC: Phase II

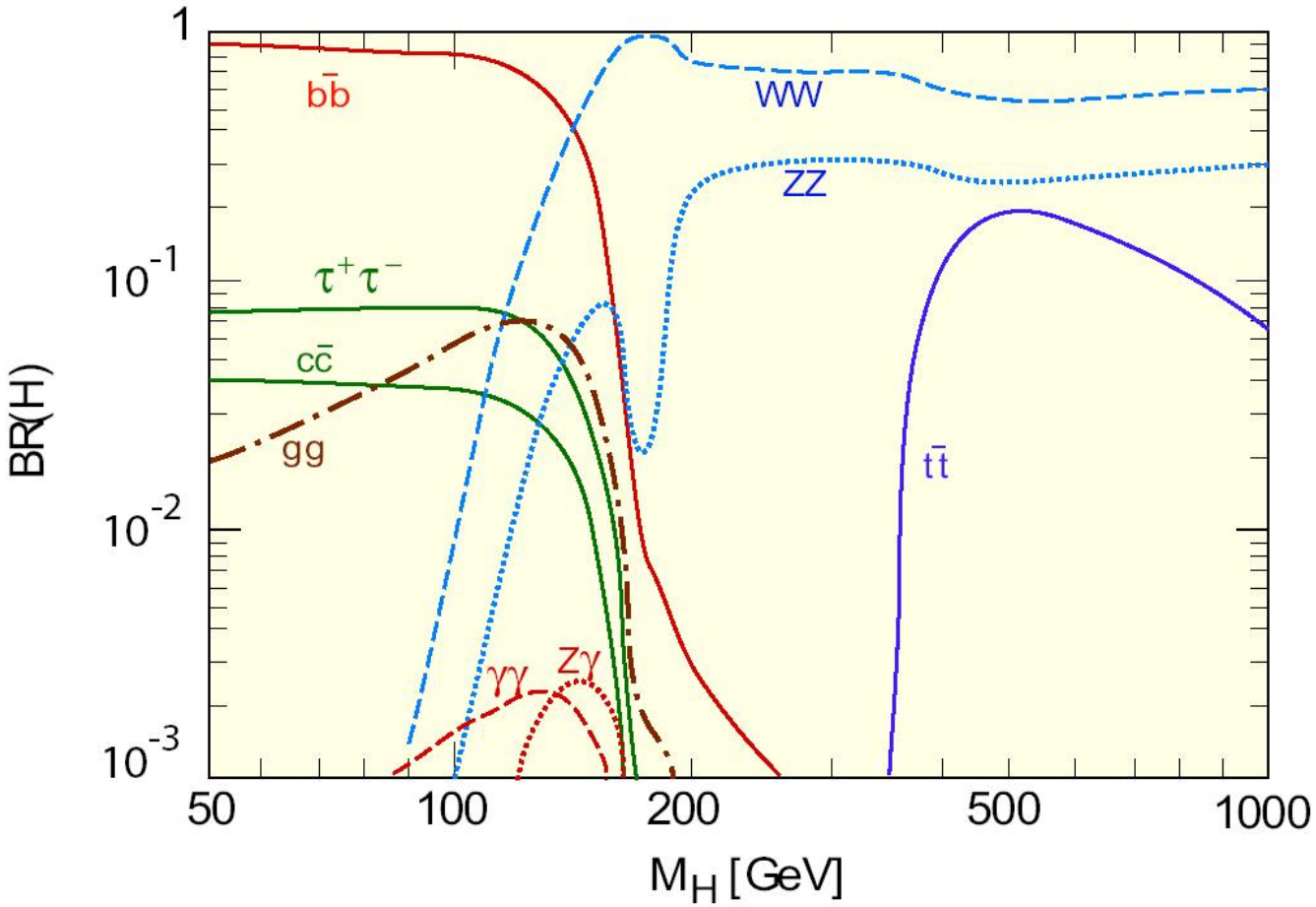
Higgs Cross section and BR's well known (1996-2006)(2a)





Higgs search at the 14 TeV LHC: Phase II

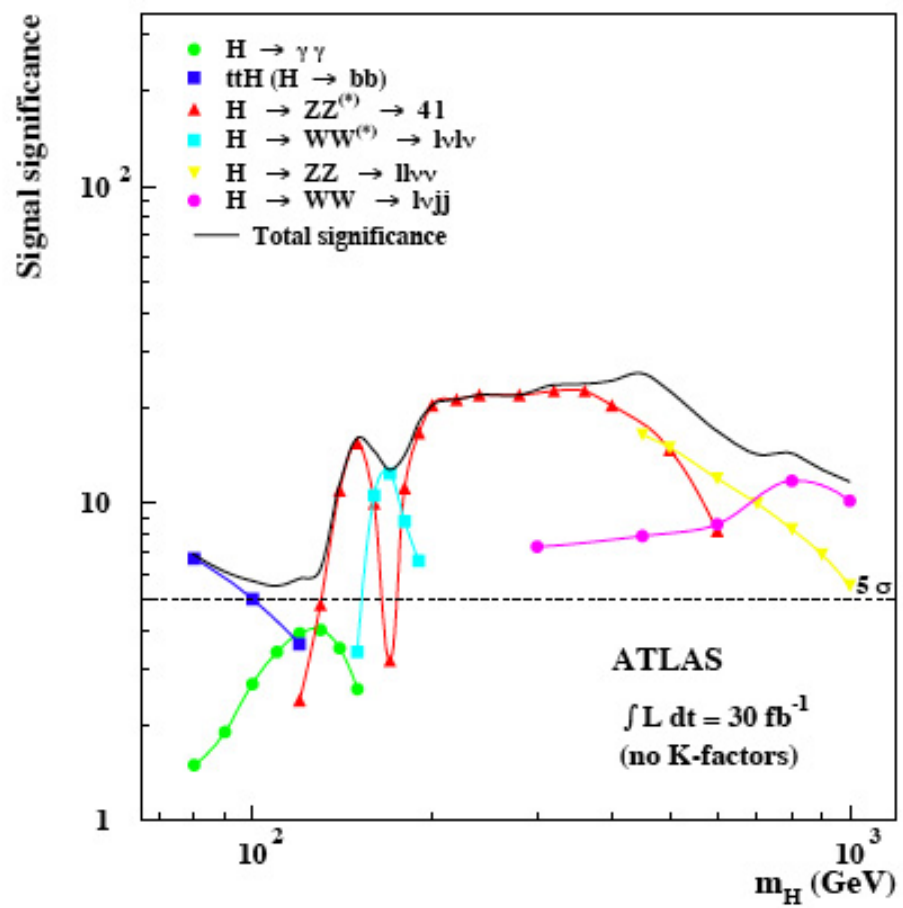
Higgs Cross section and BR's well known (1996-2006)(2b)



Higgs search at the 14 TeV LHC: Phase II

The 14 TeV ultimate potential (1996-2006)(3)

1999 The ATLAS Physics TDR (similar for CMS):
Higgs observable with many decays (dominated by the "best" channel!)



Higgs search at the 14 TeV LHC: Phase II

The ultimate and the real potential (1996-2006)(4)

- Higgs cross section known at NNLO, often as a function of cut variables (Monte Carlos at or approaching NLO accuracies)

- Knowledge of background cross sections far less advanced!

- Higgs studies now "performed" with full (perfect!) detector simulations
  Background MC's are not perfect and often too little statistics $\rightarrow$ developing methods to "data driven" background estimates.

- Signal cross sections are "small" $\rightarrow$ statistics dominate most channels!
  For L = 30 fb^{-1}: statistical plus systematic errors at best $\pm$ 10%!
  (to get smaller errors "some advanced" studies use ultimate 2 $\times$ 300 fb^{-1})
  - 300 GeV Mass: $H \rightarrow ZZ \rightarrow 4\ell^{\pm}$ (30 fb^{-1}):
    at best $\approx 100 \pm 12$(stat.) signal events
  - 165 GeV Mass: $H \rightarrow WW \rightarrow \ell\nu\ell\nu$ (30 fb^{-1}):
    at best $\approx 1500 \pm 50$(stat.) $\pm$ 150-200 (syst.) signal events
  - larger errors for other masses and channels!

numbers (rounded) from the CMS physics TDR 2006

Higgs search at the 14 TeV LHC: Phase III

Announcing the birth date a few times (2007)

- R. Bailey (25.1.2007): "LHC startup plans for 2007 and 2008":
  - *November 2007: Full machine checkout followed by beam commissioning run with 450 GeV protons for the last weeks of 2007*
  - *April 2008: Machine hand over for beam operations*
  - *followed by (July(?) to December 2008): Three phase machine operations with 14 TeV pp collisions: assuming 40 efficient physics days the luminosity might add up to 1 fb^{-1} at the end of 2008!*
  - *But, a detailed planning for 2008 will only be possible after the "450 GeV run"!*

- Revised LHC schedule (October 2007): a "three months delay"
  First beams in July 2008 with perhaps 0.05-0.1 fb^{-1} at 14 TeV and at the end of 2008!

Higgs search at the 14 TeV LHC: Phase III

Announcing birth complications (2008)

- January 2008: "Aymar declares important dates for 2008"
  (1) Open day April and (2) LHC inauguration party 21.10.08

- Some time later: Robert Aymar (CERN Bulletin) 31.3.08:
  10 TeV instead of 14 TeV physics!
  "During the commissioning of Sector 4-5 earlier this year, three dipoles quenched below 9.5kA, despite having previously been tested to the nominal LHC operating current of 12kA. It seems that some re-training of some of the magnets will be necessary, which will take a few more weeks. After agreement with all the experiments and having informed the Council at the March session, it was decided to push for collisions at an energy of 10 TeV this year, as quickly as possible, with full commissioning to 14 TeV to follow over the winter shutdown."

- **10.9.2008: World media document the "glorious" LHC birth**

- **19.9.08: "The incident": "Restart some time in summer 2009!**
  MayoClinic.com: *"A premature birth gives a baby less time to develop and mature in the womb. The result is an increased risk of various medical and developmental problems, including trouble breathing and bleeding in the brain. If you go into labor too early, your doctor may try to delay your baby's birth. Even if premature birth is inevitable, a few extra days in the womb can promote significant development. Although the rate of premature birth seems to be on the rise, there's good news. A healthy lifestyle can go a long way toward preventing preterm labor and premature birth."*

Higgs search at the 14 TeV LHC: Phase IV

leaving the hospital in fall 2009

- February 2009: "New DG" Rolf Heuer announces LHC running will restart in fall 2009 and continues over the Winter 2009/2010

- Expect up to 200 pb^{-1} at 10 TeV during the 2009/2010 run

- After some new magnet worries during spring 2009 ....
  7 TeV center of mass energy considered to be safe!

- beam start circulating again (20 November 2009!) followed quickly by: first collisions at 900 GeV (November 23) and 2.36 TeV (November 30) center of mass energy.

- All four LHC experiments report their first successful data taking results (18 December 2009)

The LHC has really started in 2009!

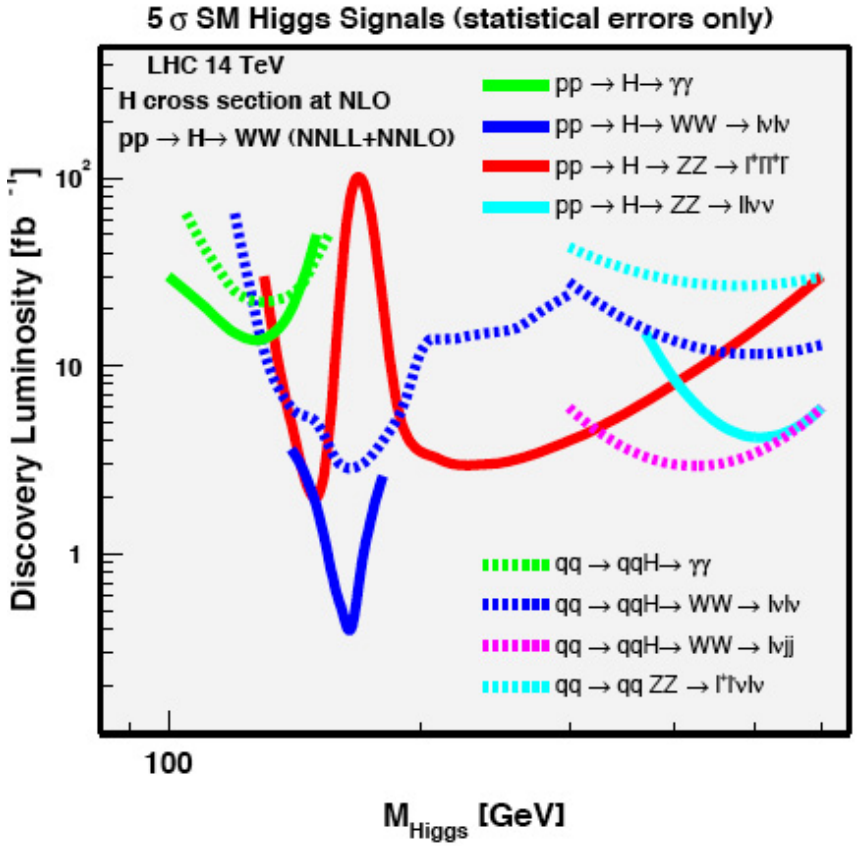
even though the "Wikipedia (1.2.2010)" statement is not 100% correct:

"The Large Hadron Collider (LHC) at CERN, which became fully operational on November 20, 2009"

Higgs search at the 14 TeV LHC: Phase V

starting the real thing: discovery luminosities at 14 TeV

If ATLAS/CMS (and the LHC) reach design parameters:
Minimal 5 sigma Higgs discovery luminosity for 100-600 GeV
possible with gluon-gluon fusion and WW(ZZ) boson fusion channels!



plot based on "optimistic (and realistic) results from ATLAS and CMS"

Higgs search at the 14 TeV LHC: Phase V

Guessing the next 5 LHC years (one needs a scenario!)

optimistic, pessimistic, wishful thinking or realistic?

My guess (ETH phenomenology workshop, January 2009) was too optimistic:
2009 running: $\sqrt{s} \leq 10$ TeV with $L \leq 0.01 - 0.1$ fb^{-1} and
14 TeV operation during 2010-2012 with L $\leq$ 1 fb^{-1}; 5 fb^{-1} and 10 fb^{-1}

The January/February 2010 "crystal ball guesswork"

M. Lamont (Chamonix workshop): Maximum safe energy $\sqrt{s} = 7$ TeV maximum possible luminosity 0.2 fb^{-1} in 2010 and 0.8 fb^{-1} in 2011 followed by long repair shutdown ($\geq$ 1 year?)

after repair .. 14 TeV between 2013-2015 ("unclear"!)

My six year "on tape" lumi scenario (February 2010)
2010: $\sqrt{s} \approx 7$ TeV with $L \leq 0.01 - 0.1$ fb^{-1}
2011: $\sqrt{s} \approx 7$ TeV with $L \leq 0.5$ fb^{-1}
2012: shutdown and repair
2013-2015: $\sqrt{s} \approx 13$ TeV with $L \leq$ 1; 10; 20 fb^{-1}/year
Feb. 2016 with ("total 14 TeV equivalent luminosity"): $\approx$ 30 fb^{-1}!

For your own crystal ball: start with "official numbers" and multiply by guessed "performance" number (≤ 1!)

Higgs search at the 14 TeV LHC: Phase V

Higgs search at $\sqrt{s}$= 7 TeV (2010-2011)

The "bad" news: "We know already"

- Being competitive with Tevatron results/limits from 5 fb^{-1} at $\sqrt{s} = 2$ TeV!
  "Search experiments" at $\sqrt{s}$= 7 TeV require at least 1 fb^{-1}!
  (and perfectly prepared and working CMS/ATLAS detectors!)

- **Nothing new about the Higgs up to some time in 2013!**

The "good" news:

even at $\sqrt{s} = 7$ TeV and with 0.01 - 0.05 fb^{-1}
W and Z production can be studied in detail (experimental and theoretical)!

- **at least a realistic preparation for the Higgs search!**

Higgs search at 14 TeV LHC: Phase V
The years 2013-2015

Higgs searches during the first real 14 LHC year(s):
If well prepared and $\leq$ 2, 10, 20 fb^{-1} "luminosities" /year allow to:

2013 "find" perhaps a 5 sigma signal with a mass from 160-170 GeV!
Perhaps some exclusion limits ($H \rightarrow ZZ^*$) from 150-350 GeV.
with 0.2-0.5 fb^{-1} at 14 TeV perhaps hints or limits for M_H =160-170 GeV

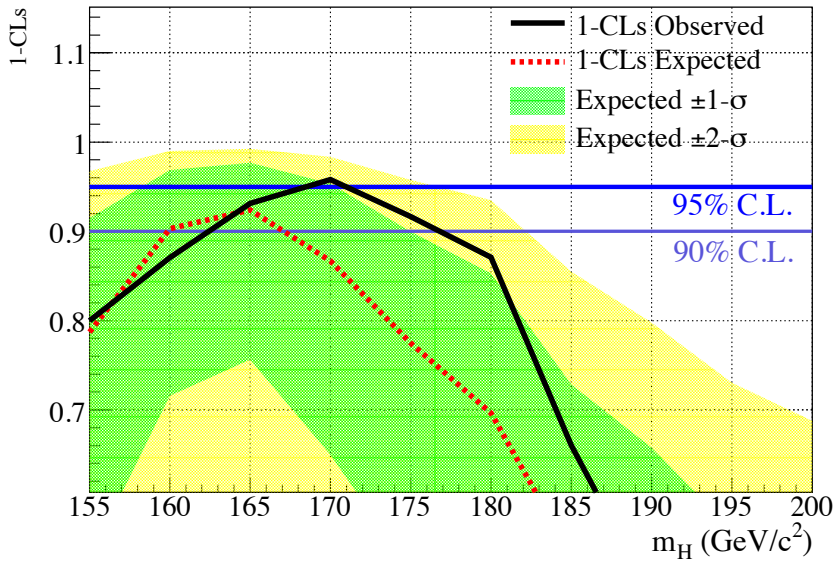
2014 with 10 fb^{-1} 5 sigma signals possible from 130-600 GeV

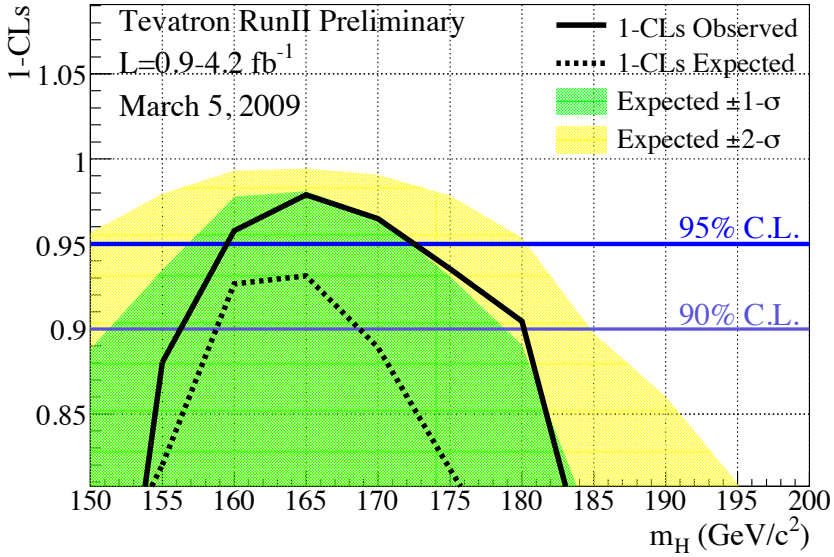
2015 with 10+20 fb^{-1} 5 sigma Higgs signal over entire mass range
and with the gluon-gluon and vector boson fusion channels.
including 5 sigma $H \rightarrow \gamma\gamma$ signal possible M_H=100-130GeV

the "5+1" Higgs mass scenarios

todays "direct" Higgs limits (I)

- Direct SM Higgs search from LEP II: $M_H > 114$ GeV
- The "outdated" Tevatron 95% c.l. limits(?) from "D0+CDF" ...
  Summer 2008: "exclude $M_H = 170$ GeV (CDF+D0 with ≤ 3 fb^{-1})
  Winter 2009: "exclude $M_H = 160 - 170$ GeV (CDF+D0 with ≤ 4.2 fb^{-1})



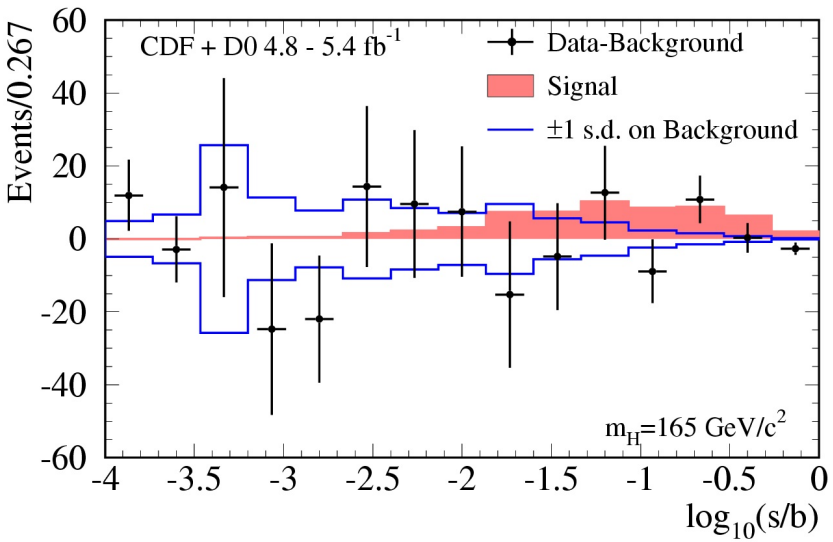


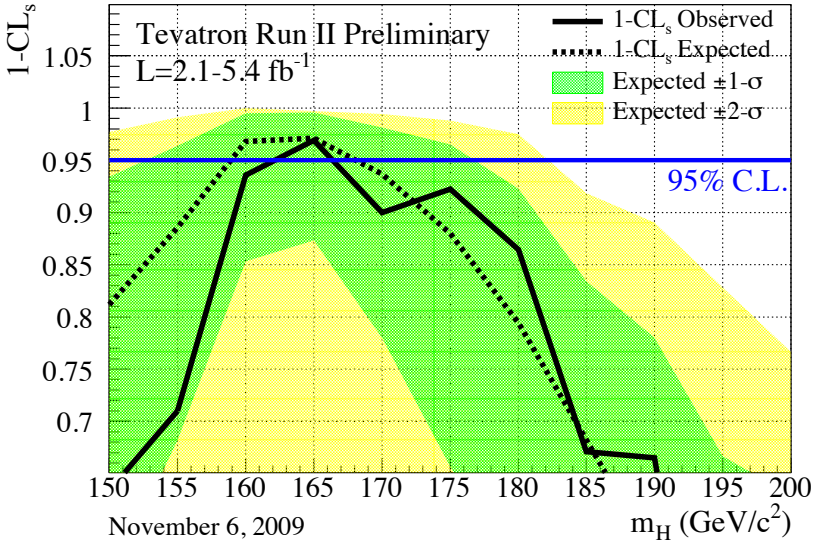
source: Tevatron Higgs Working Group http://tevnphwg.fnal.gov/

the "5+1" Higgs mass scenarios

todays "direct" Higgs limits (II)

- Latest Tevatron direct SM Higgs search (Winter 2010):
  "exclude only": 162-166 GeV with CDF+D0 with $\leq$ 4.8 + 5.4 fb^{-1}
  but ...
  still true: with a 1 sigma Higgs cross section reduction
  (or a 1 sigma background increase)
  → and gone is the Tevatron "2 sigma exclusion"!



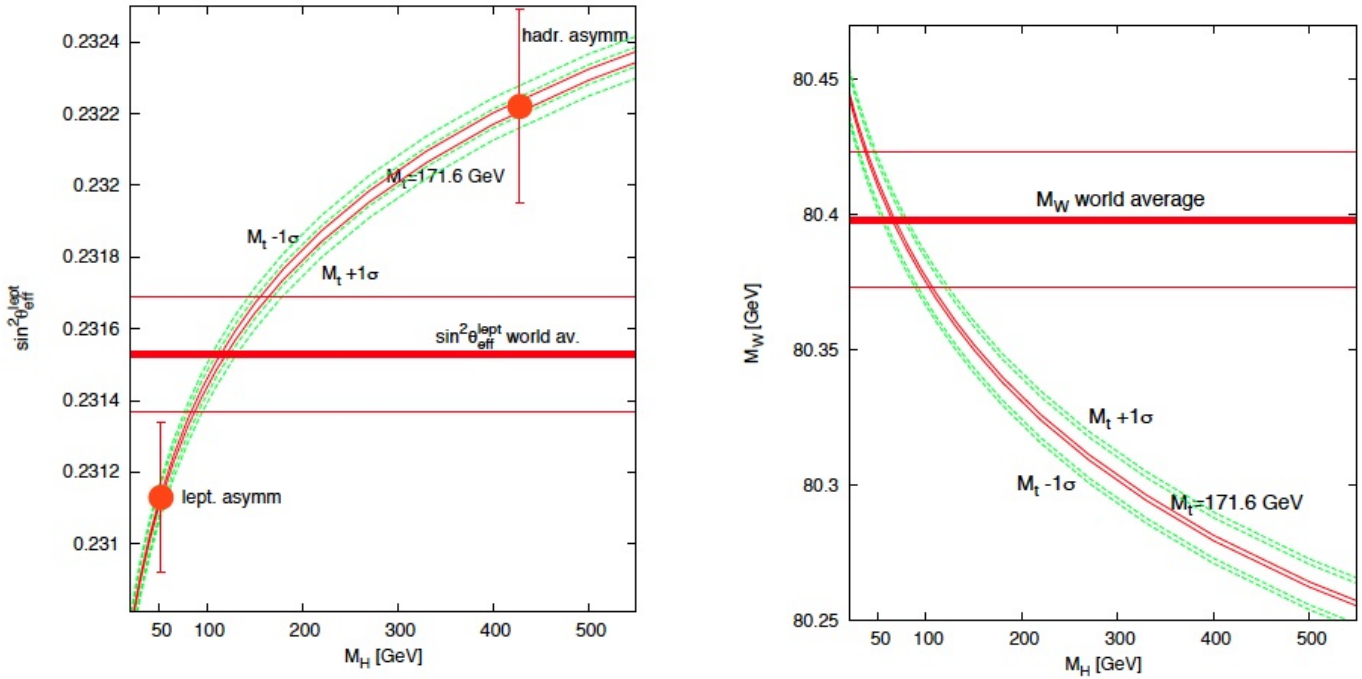


source: Tevatron Higgs Working Group http://tevnphwg.fnal.gov/

the "5+1" Higgs mass scenarios

comments about todays "indirect" Higgs limits

M(H) should be smaller than 157 (including direct H limits $\leq$ 186) GeV but:
(1) inconsistent $sin^2\theta_W$ measurements since at least 15 years!
(2) PDG $M_W = 80.399 \pm 0.025$ GeV from "inconsistent" measurements!
M_W(LEP) = 80.376 $\pm$ 0.033 GeV and (Tevatron) = 80.432 $\pm$ 0.039 GeV
plus CDF measures: M_W(electrons) = 80.493 $\pm$ 0.048 GeV
and M_W(muons) = 80.349 $\pm$ 0.054 GeV

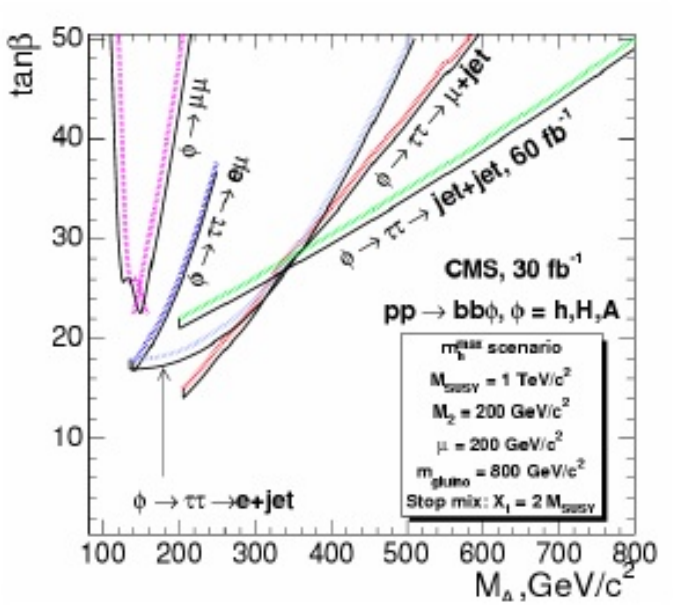


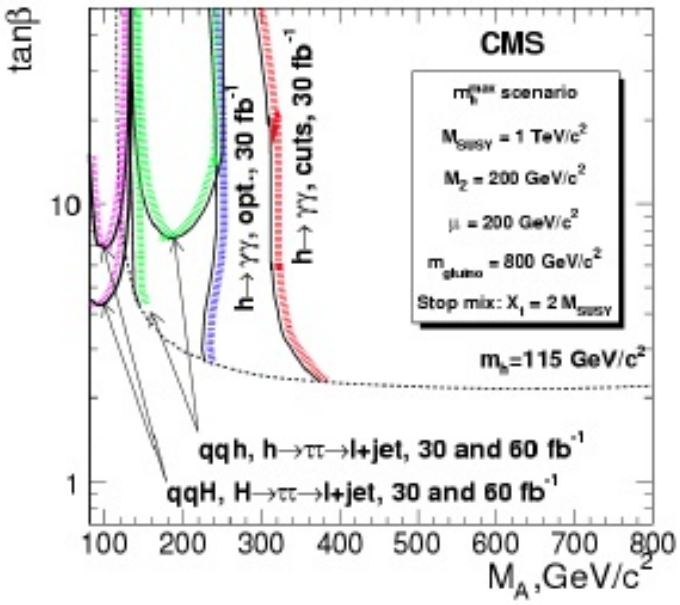
plots from P. Gambino (thanks!), the top mass was 171.6 GeV
(current 173.1 GeV corresponds roughly to $M_t + 1\sigma$!)
for M_W see CDF coll. Aug. 2007 http://xxx.lanl.gov/pdf/0708.3642v1

the "5+1" Higgs mass scenarios

Observation of additional SUSY Higgs bosons?

The 14 TeV and "30 fb^{-1} LHC plus fully functioning CMS/ATLAS
for tan $\beta \geq 20$ and $M_A \leq 250$ GeV: signals for H, A $\rightarrow \tau\tau$ possible
for smaller M_A signals more and more model dependent!





source: CMS physics TDR 2006

the "5+1" Higgs mass scenarios

What are the implications of a Higgs discovery?(I)

Some possible questions:

- Constraints from other discoveries (e.g. squarks, gluinos, new heavy vector bosons, new quarks etc?)
- Mass dependent luminosity requirement for the SM like Higgs boson?
- Do "measured" cross sections agree with SM like expectations?

the "5+1" Higgs mass scenarios

What are the implications of a Higgs discovery?(II)

M_h = 125 GeV ($h \to \gamma\gamma$) scenario
the (N)MSSM SUPERSYMMETRY yes answer:

- **With the observation of squarks and gluinos ($M_x \leq 1-2$ TeV) and/or at least one "additional" Higgs boson (A, H, $H^{\pm}$) $\to$ MSSM becomes "the new SM" (even without a M_h signal)**

- **Without additional SUSY like signals (particles are too heavy!) 5 σ signal $h \to \gamma\gamma$ observable "during 2015" $\to$ MSSM will be considered true! (like today!?) M_A probably larger than 200 GeV and $5 \leq \tan\beta \leq 20$.**

- **The (ugly) MSSM scenario: no direct SUSY signals and $\sigma(h \to \gamma\gamma)$ too small! Possible for $M_A \leq 200$ GeV and $5 \leq \tan\beta \leq 20$ $\to$ many exclusion limits, some statistical background fluctuations and perhaps a "3-4 sigma" $M_{\gamma\gamma}$ excess at 125 GeV.**

the "5+1" Higgs mass scenarios

What are the implications of a Higgs discovery?(III)

M_h = 145 GeV ($h \to WW^*/ZZ^*$) scenario
a "yes/no" SM/NMSSM answer:

- **Without the observation of squarks and gluinos ($M_x \leq 1-2$ TeV) and/or at least one "additional" Higgs boson (A, H, $H^{\pm}$)**
  $\to$ MSSM excluded! (NMSSM not yet!)
  4-5 σ signals (vector boson and gluon-gluon fusion signature!) from $h \to WW^*$ and $h \to ZZ^*$ likely "during 2014/2015"
  $\to$ SM will be accepted as "ultimate" effective theory

- **The (ugly) scenario: no signals at all?**
  Possible NMSSM parameter space can certainly be found!
  $\to$ many exclusion limits, some statistical background fluctuations and some "2-3 sigma" excess at 145 GeV.

the "5+1" Higgs mass scenarios

What are the implications of a Higgs discovery?(IV+V)

M_h = 250 GeV ($h \to ZZ$): The end of Supersymmetry!

- Without the observation of new quarks, vector bosons etc..
  need to "stress" electro weak fit and electro weak measurements
  like already with todays inconsistent $sin^2\theta_W$ results!
  Higgs signal will exclude Supersymmetry
  5 σ signals (vector boson and gluon-gluon fusion signature!)
  from $h \to ZZ$ likely "during 2014/2015"
  $\to$ SM will be accepted as "ultimate" effective theory

M_h = 450 GeV ($h \to ZZ$): terra incognita
(or "Here be dragons")

- Without the observation of new quarks, vector bosons etc..
  need to include "free parameters" into the electro weak fit
  many 5 σ signals (vector boson and gluon-gluon fusion signature!)
  from $h \to ZZ/WW$ likely "during 2014/2015"
  $\to$ SM plus something unknown (some quark/lepton decoupling?)

the "5+1" Higgs mass scenarios

What are the implications of a Higgs discovery?(VIa)

M_h = 168 GeV ($H \to WW \to \ell\nu\ell\nu$): the SM "forever" answer:

- **Without the observation of other new particles:**

  5 σ signal $pp \to H \to WW \to \ell\nu\ell\nu$ observable "during 2013"

  5 σ signal $pp \to Hqq$ and $H \to WW \to \ell\nu\ell\nu$ observable "during 2014"

  $\to$ MSSM and NMSSM excluded
  current Tevatron exclusion limits kind of "wrong"
  Perhaps the SM will be "accepted" as an effective "final" theory!?

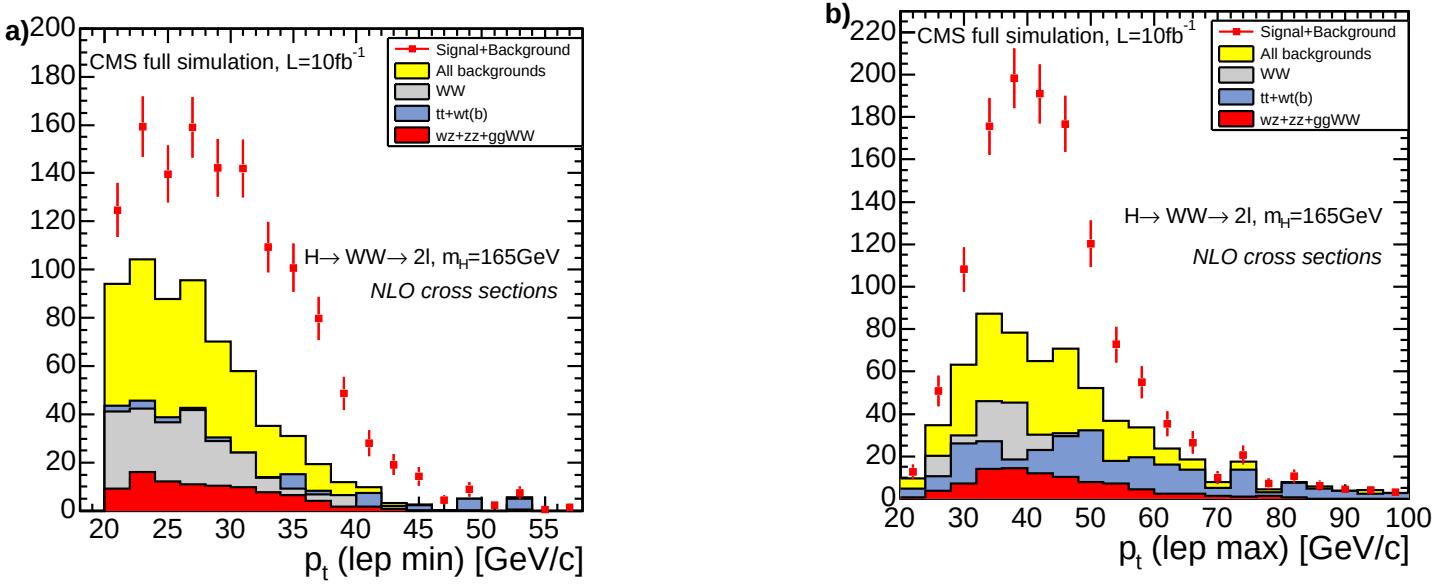
Summary: "Happy end" or "Nightmare"? (I)

- LHC has finally "started" in late 2009 (with some pain);
- next two year running at $\sqrt{s} \leq 7$ TeV and L≤ 1 fb^{-1}
  followed by a one year "repair" shutdown!
- Without a miracle .. new physics results
  (not only) about the "Higgs boson" impossible before summer 2013!
- If "particle physics needs a discovery at the LHC"
  0.5-1 fb^{-1} at 14 TeV enough for SM Higgs with $M_H = 168$ GeV!
- To be compared with M. Veltman's "night mare scenario":
  "Higgs exists but fails to show up at the LHC."
- To be compared with the "real nightmare scenario"
  The LHC fails to achieve design parameters by 2015!

160-170 GeV Higgs
"happy end" or a "nightmare"?

Lets assume $M_H = 168$ GeV .. what would this mean?

Already with L $\approx$ 1 fb^{-1}:
It "tastes" and "smells" like a SM Higgs
with a mass near 165 GeV!



source: CMS Note 2006/047, attention plots for 10 fb^{-1}

Summary: "Happy end" or "Nightmare"? (II)

What would one learn from a $M_H = 168$ GeV signal?

1. The MSSM ($M_h \leq$140 GeV) would be excluded!
   Other SUSY Higgs bosons do not decay to WW!

2. SM might remain a valid approximation up to very large scales ...

A nightmare scenario for some

but a "happy end" for others!

If no $M_H \to WW \to \ell\nu\ell\nu$ signal will appear:

"Alternating" 2-3 sigma fluctuations and many Higgs limits
will be reported during the years 2013-2015 ...

of course .. unexpected discoveries and events like "Black Holes",
Unicorns or Yetis would change everything!

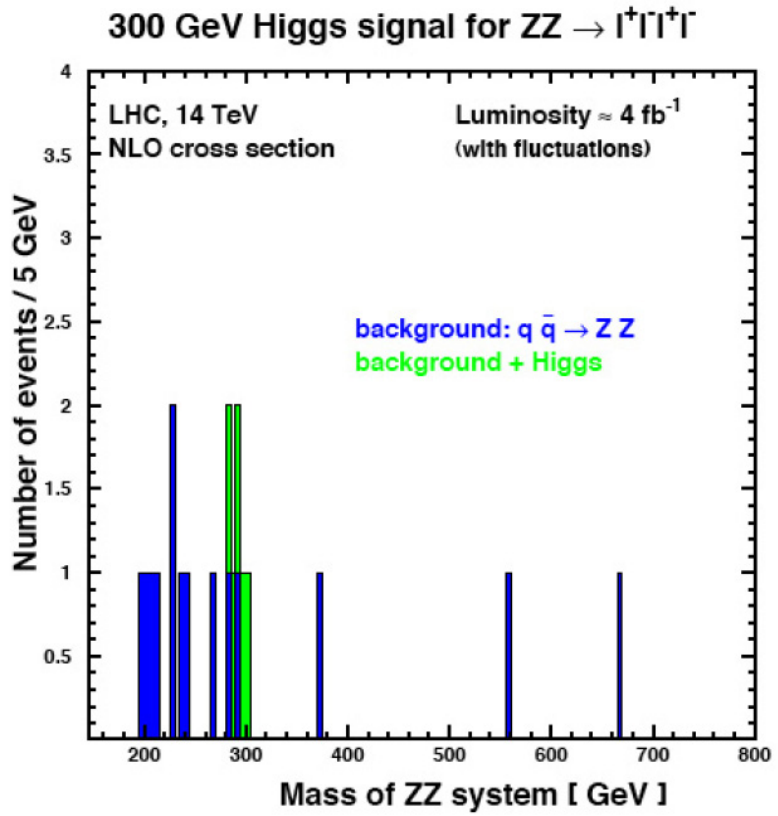
Some spare slides:

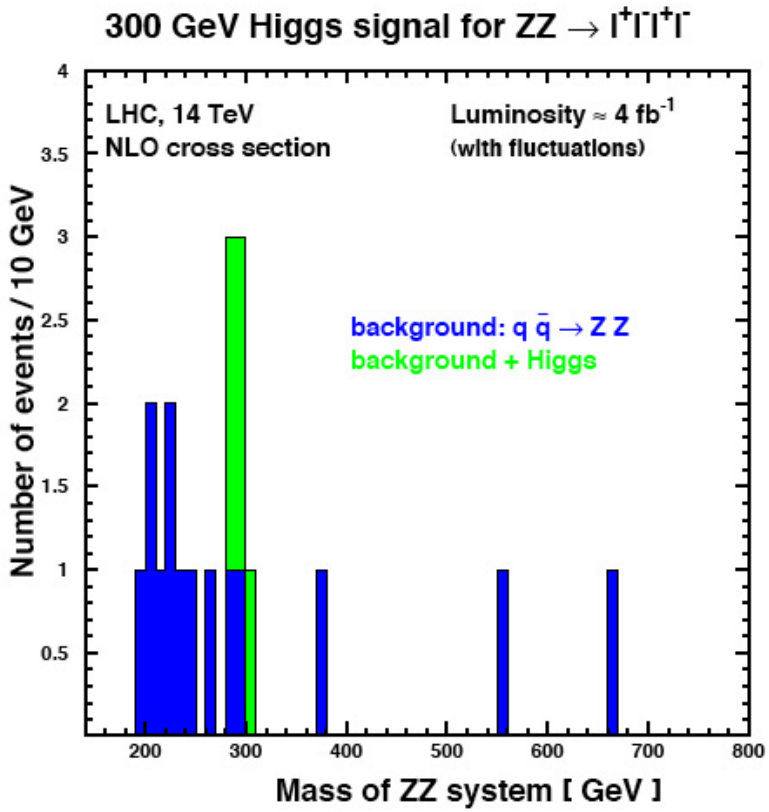
Searches within realistic LHC boundaries (2013-2015)

an optimistic and not (yet) unrealistic 14 TeV scenario:

$\leq$ 1 fb^{-1} in 2013: some Higgs sensitivity near 160-170 GeV mass

with 5-10 fb^{-1} 2014-2015:
A possible 4-5 sigma signal $H \rightarrow ZZ$ 4 lepton (possible from 200-350 GeV)





Attention: Identical events but plots with 5 GeV and 10 GeV binning!

Experience from the Tevatron Run I and II
A help for realistic guessing?

Tevatron Run I (1986-1996) and Run II (2001-2010(?))

1986/7 Engineering Run a: 0.05 pb^{-1}

1988/9 Engineering Run b: 9.2 pb^{-1}

1992-96 Run Ia + Ib: delivered 154.7 pb^{-1}, collected by CDF/D0 $\approx$ 100 pb^{-1}

2001/2 Run II(0): delivered/recorded: about 0.02 fb^{-1}

2002-5 Run IIa: delivered 1.4 fb^{-1} recorded about 1 fb^{-1}

2006/7 Run IIb: delivered about 1.4 fb^{-1}/year. CDF/D0 recorded about 70%.

2008-10 Almost 2 fb^{-1}/year recorded by CDF..

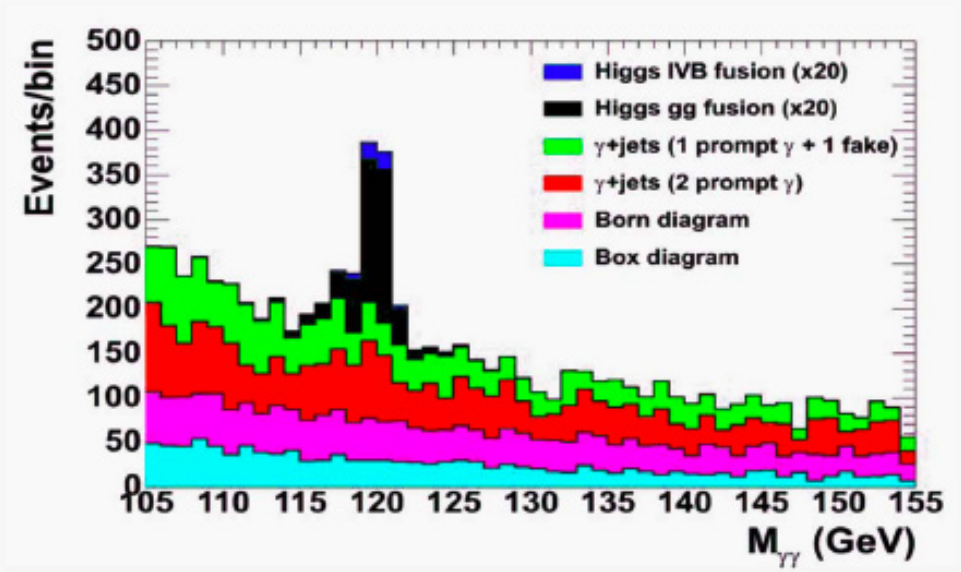
$\rightarrow$ startup (few years) luminosity was "always"
a factor of $\approx$ 10 below the defined goals!
$\rightarrow$ after "warm up" luminosity was "always"
a factor of $\approx$ 3 below the defined goals!

Higgs search at the LHC: Phase III

Realism about the LHC performance (2007-2009)

Period of fantasies (1), depression (2) and wishful thinking(3)?

(1) Lets assume the Higgs cross section is much much larger (factor 20!!!), background probably for ≈ 1 fb^{-1}??



source: www.hep.caltech.edu

(2) no Higgs physics can be done for the next year(s) or

(3) "no matter what, discoveries just around the corner..."

Consequently: "our(?) most urgent experimental problem": "Need to think now about who will give the discovery talk!"

Tevatron run II performance 2001-2010