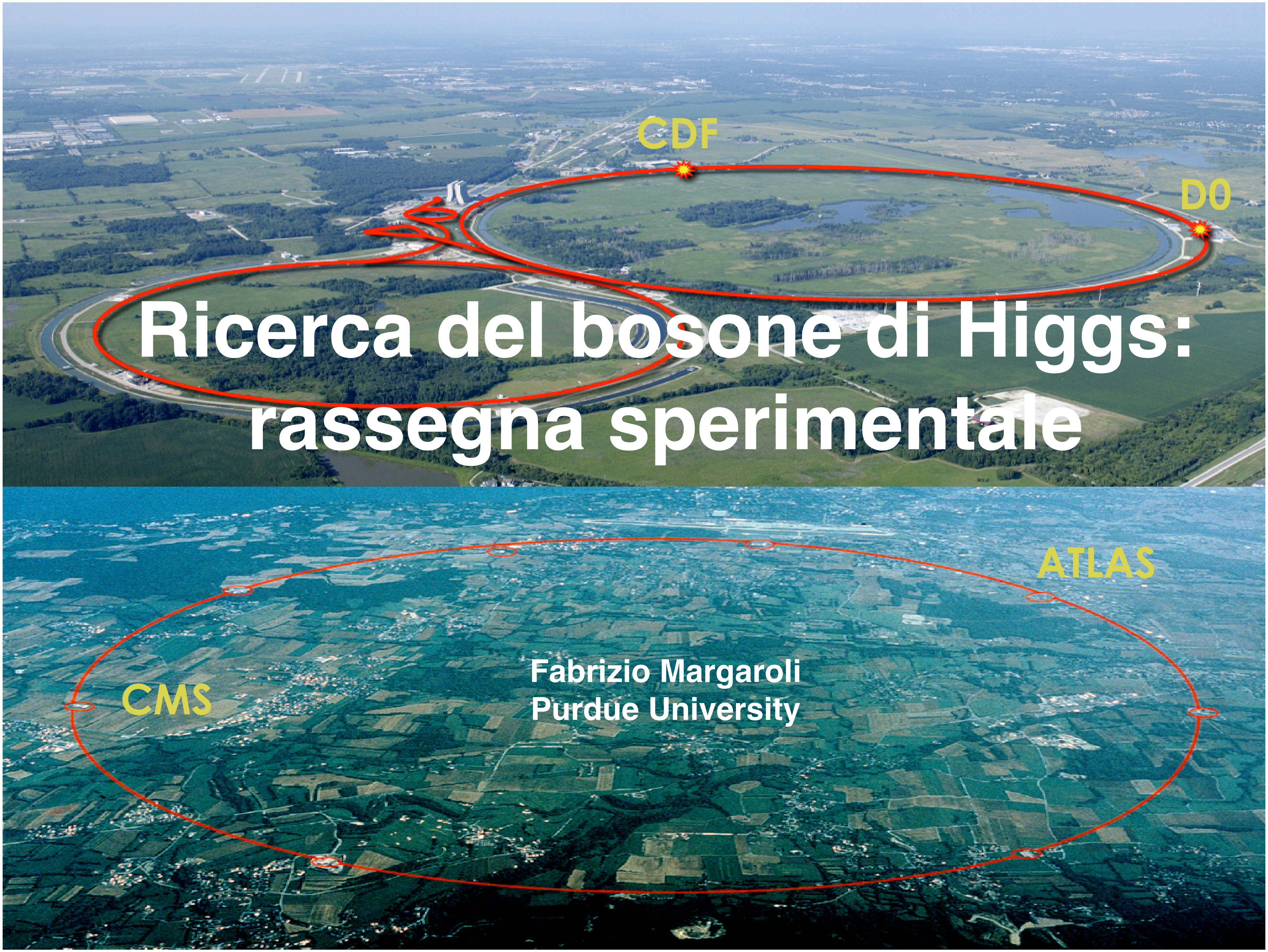
Ricerca del bosone di Higgs: rassegna sperimentale



Fabrizio Margaroli
Purdue University

Higgs: where to look?

Top quark mass was found in agreement with predictions from fits to EWK parameters

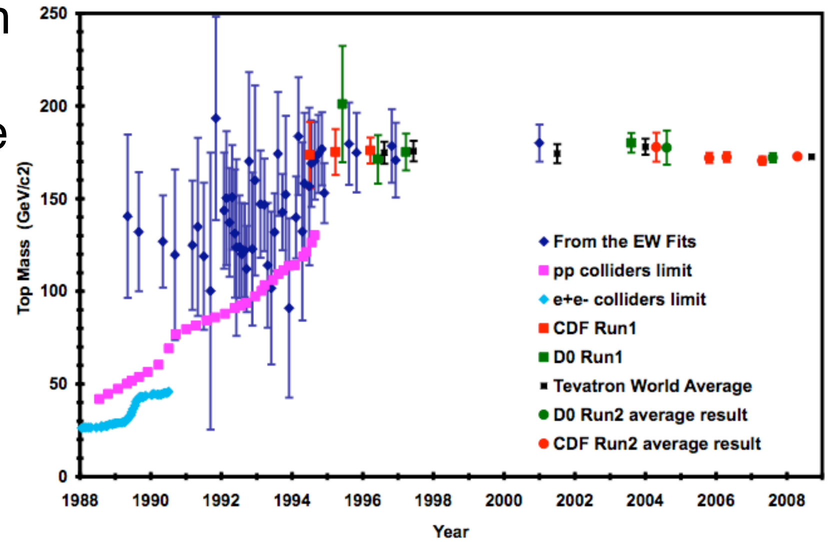
Now use m_{top}, m_W and more to point us to the Higgs!

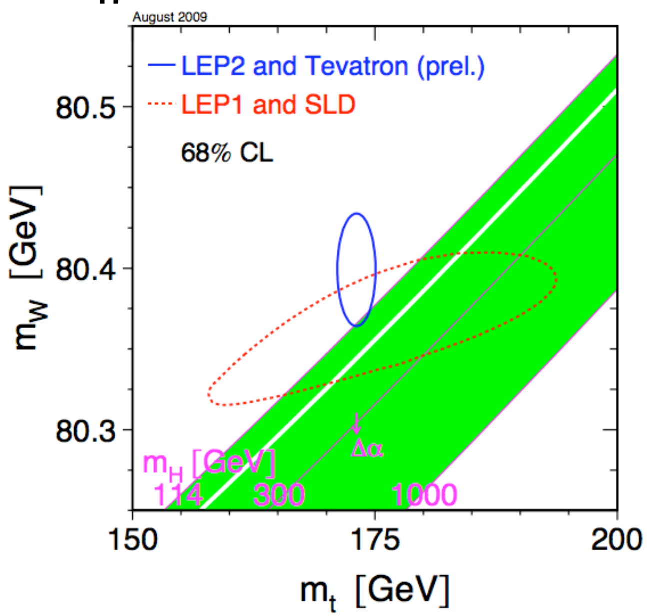
m_{top} = 173.1 ± 1.3 GeV

m_W = 80.399 ± 0.023 GeV

which give the following predictions

- **$m_H = 87^{+35}_{-26}$ GeV** @ 68 % CL or
- **m_H < 157 GeV** @ 95 % CL

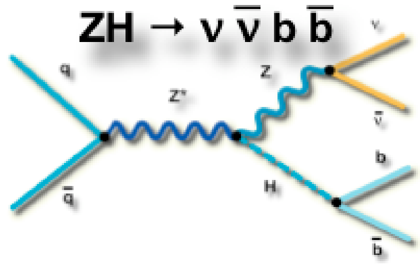


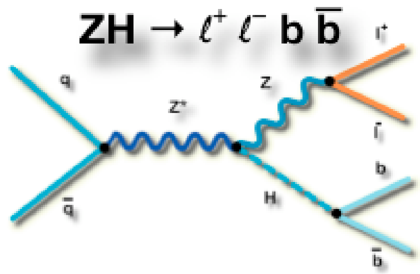


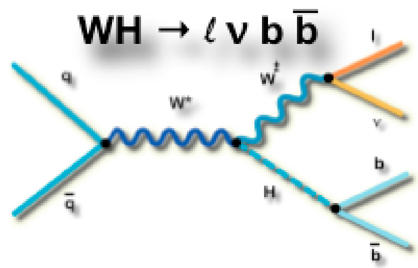
LEP directly searched the existence of the Higgs boson and found: **m_H > 114.4 GeV** @ 95% CL

Once adding LEP exclusion to EWK fits, the constraint becomes **114.4<m_H<186 GeV** @ 95% CL

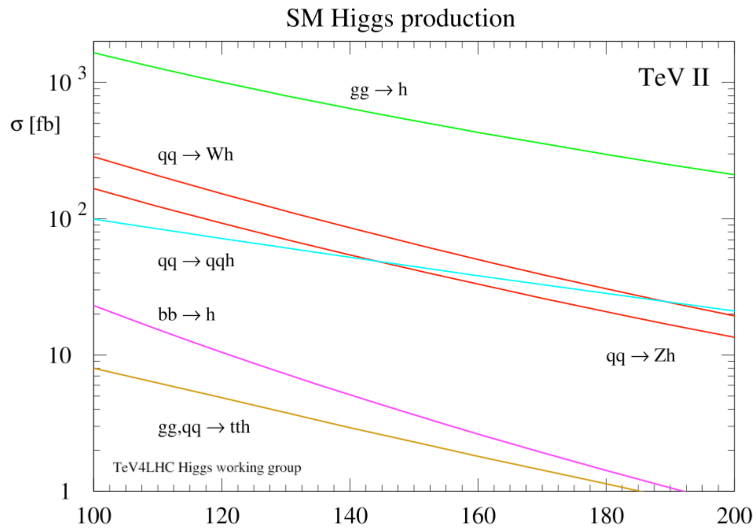
And how to look: the Tevatron

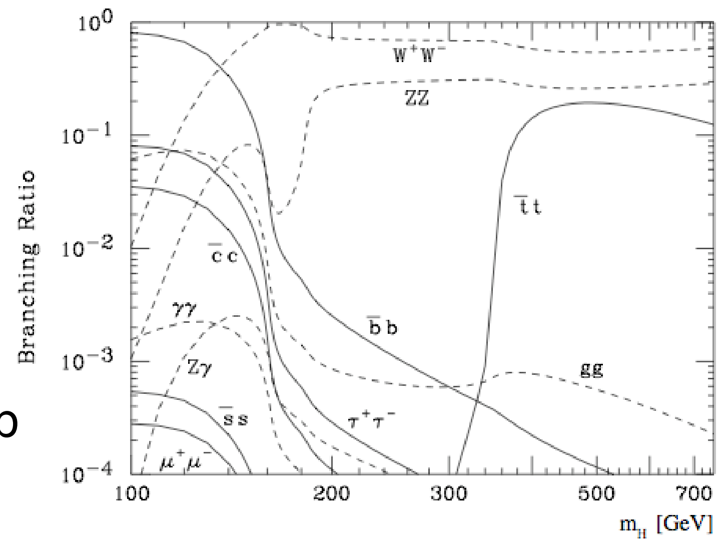




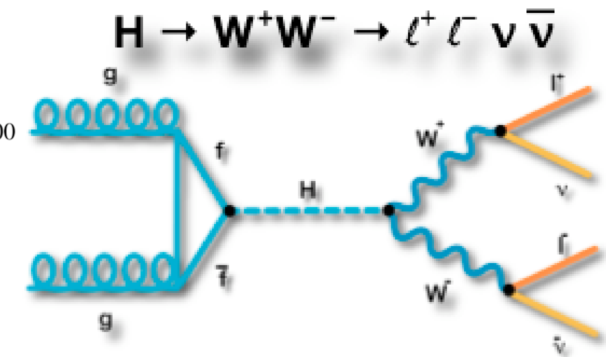


- σ(VH)xBR(H→bb)~0.1pb low cross section but extra W/Z decays help to reduce bck

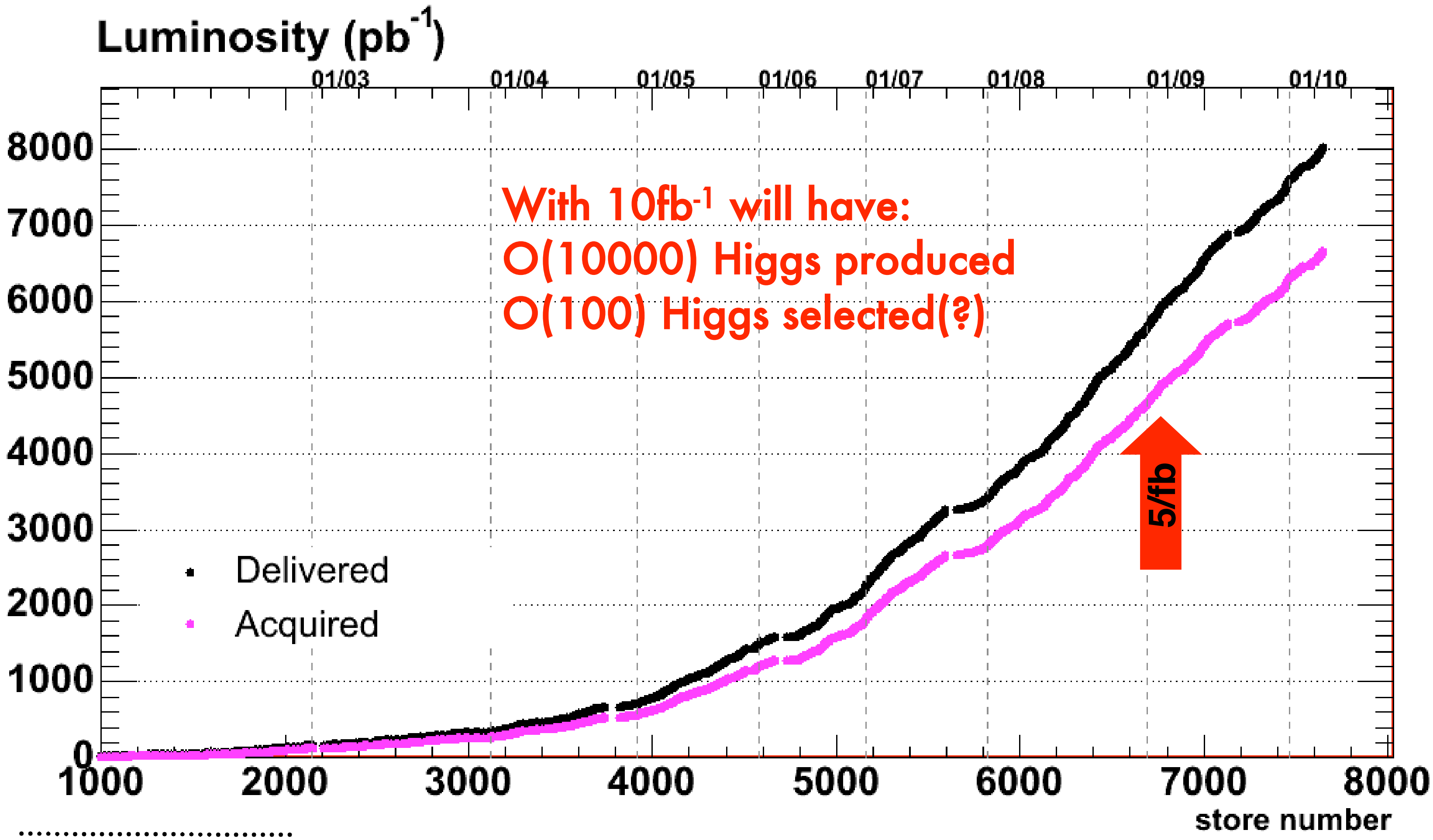




- σ(H)xBR(H→WW) largest cross section, largest BR, clean leptons and MET

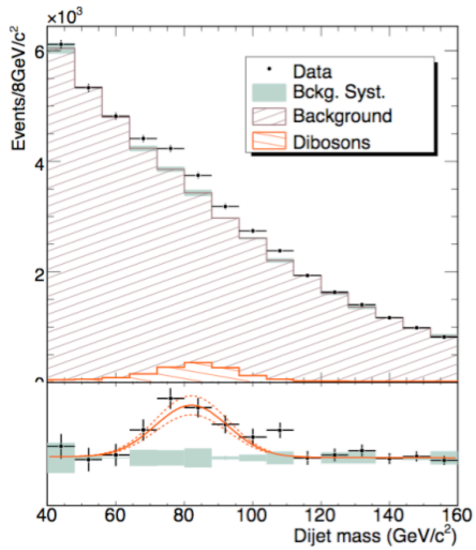


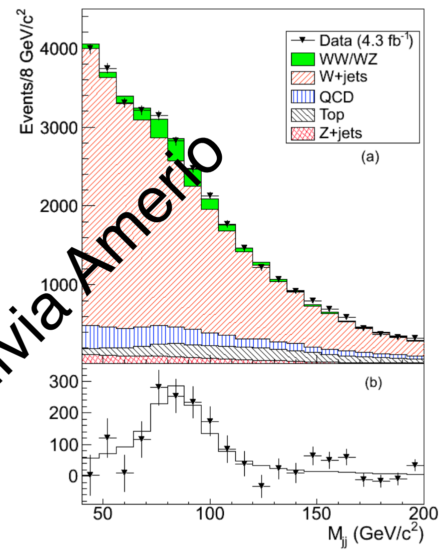
On the other side of the atlantic



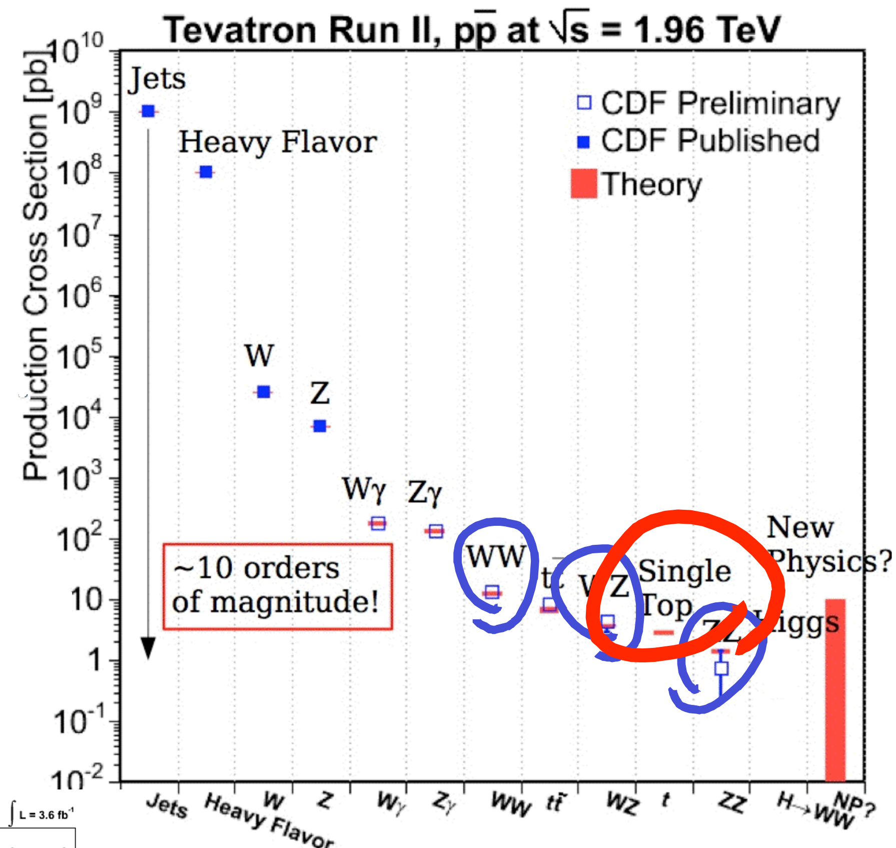
Delivered > 8.0 fb^{-1}
Acquired almost 7 fb^{-1} (slightly less w/ silicon)
Up to 5fb^{-1} analyzed

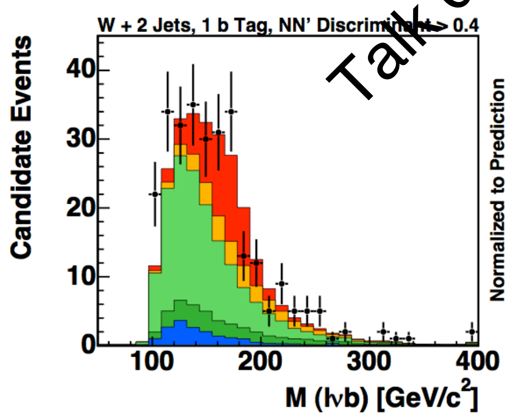
Understanding backgrounds

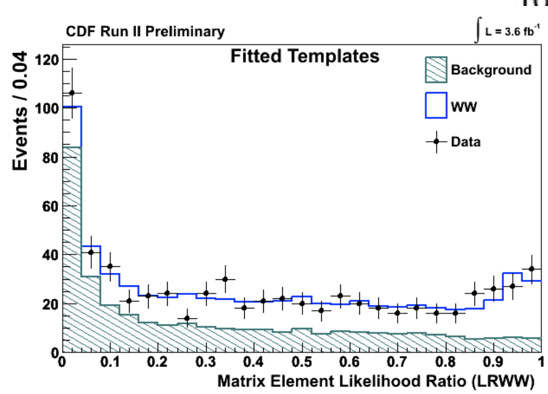




Talk di Silvia Amerio







- All backgrounds quite to very well-understood
- And a lot of physics done with them

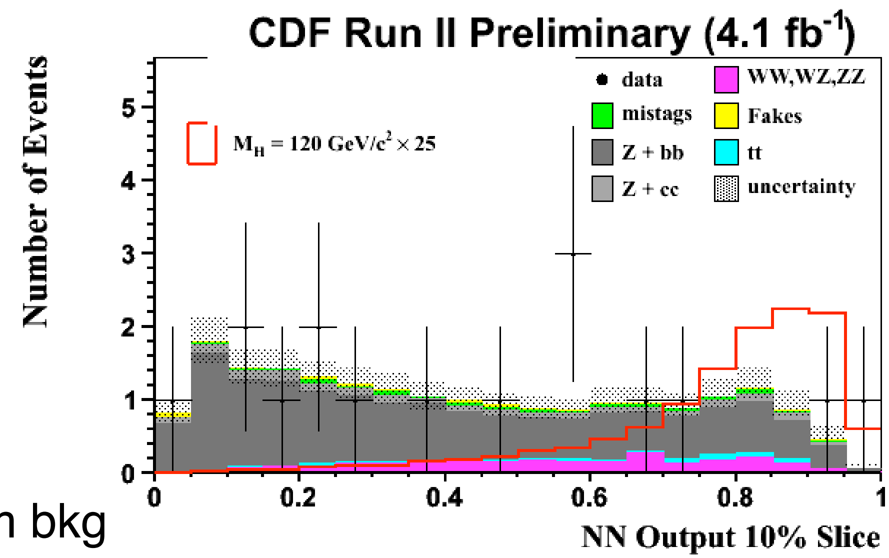
2 charged leptons $ZH \to \ell^+\ell^- b\bar{b},\ \ell = e,\mu$

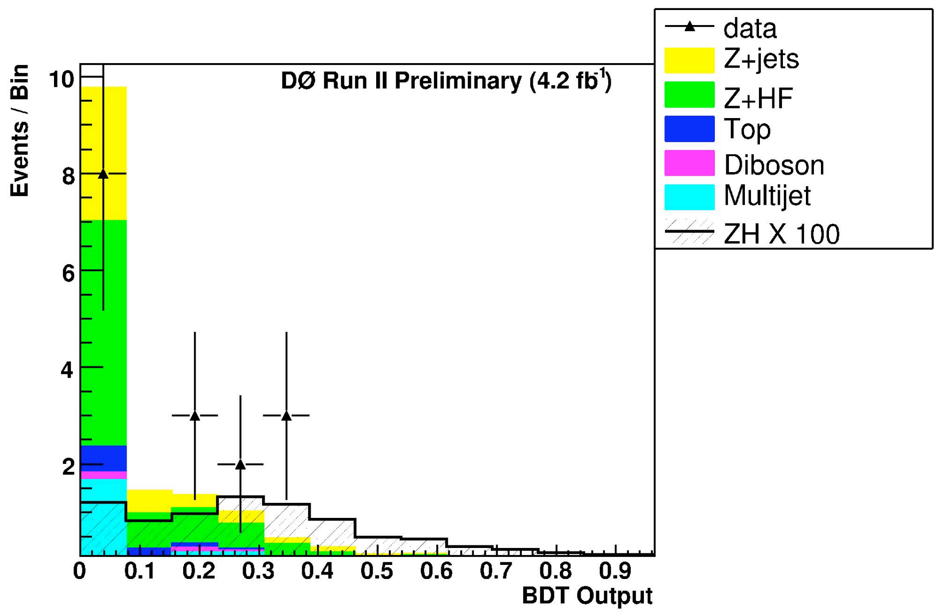
Small acceptance but clean signature

- 2 high P_T (b-)jets, 2 high P_T leptons

Fully reconstructed final state

- Dominant backgrounds:
  - Z+jets (irreducible Z+bb), top, dibosons
- CDF: Likelihood scan of 2D NN
  - HZ vs Z+jets - HZ vs ttbar
- D0: boosted decision tree to isolate ZH from bkg





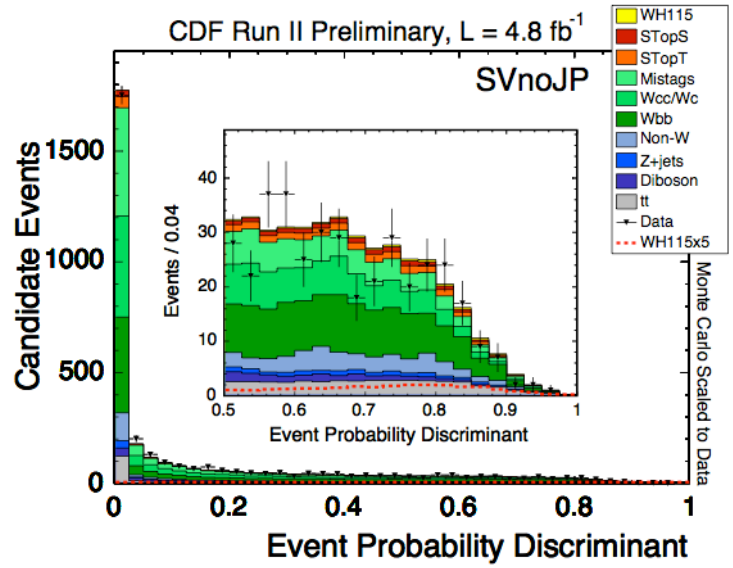
Limit quoted as NxSM cross section

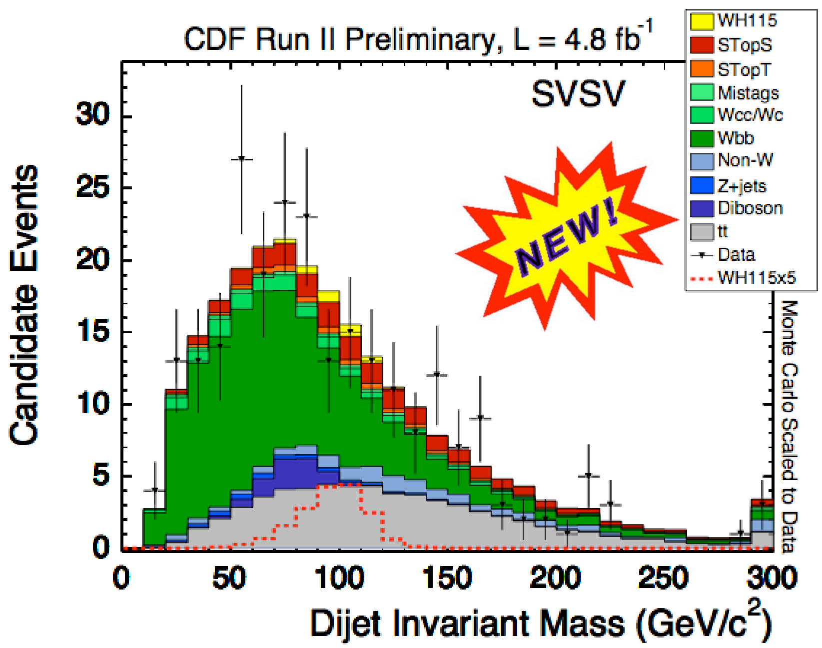
Exp	Lum (fb^{-1})	Higgs Events (@115)	Exp. Limit	Obs. Limit
CDF	4.1	2.9	6.8	5.9
DØ	4.2	3.1	8.0	9.1

1 charged lepton $WH \to \ell\nu b\bar{b},\ \ell = e,\mu$

"Large" σ *x* Br, clean signature

- High P_T leptons, MET and 2 high P_T jets
- Dominant backgrounds:
  - W+bb, top, dibosons, QCD multi-jet
- CDF: exploit knowledge of LO Matrix element
- D0: use neural networks to classify S and Bs



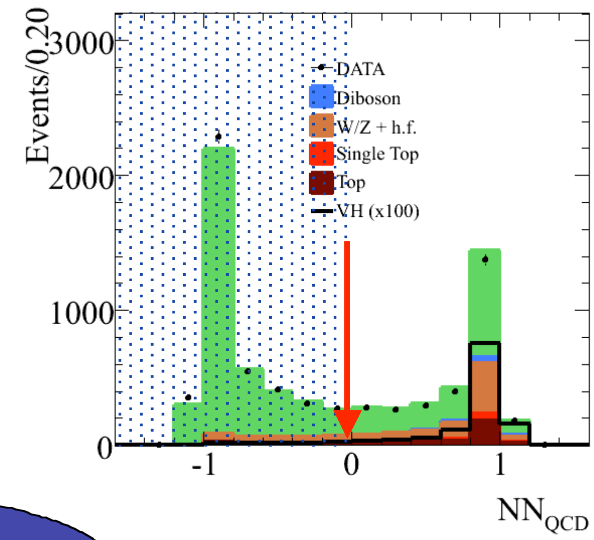


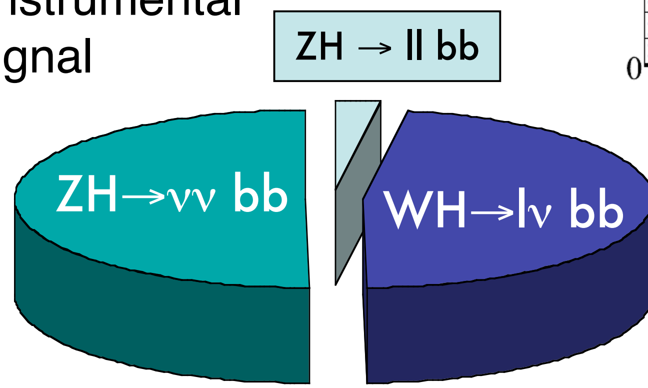
Exp.	Lum (fb^{-1})	Higgs Events (@115)	Exp. Limit	Obs. Limit
CDF	4.8	18.6	3.8	3.3
DØ	5.0	19.3	5.1	6.9

Same techniques used for single top observation

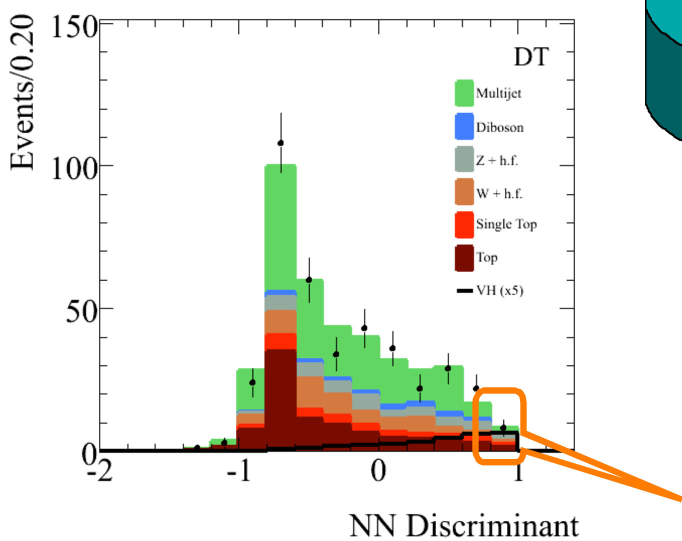
No charged leptons $VH \rightarrow \not{E}_T b\bar{b}$

- Large signal acceptance:
  - Large MET and 2 or 3 high P_T jets
- Dominant backgrounds:
  - QCD with fake MET due to calo resolution
  - W/Z+jets, top, dibosons
- Two step approach: eliminate instrumental backgrounds,then isolate the signal





D0:PRL104:071801,2010
CDF: preliminary

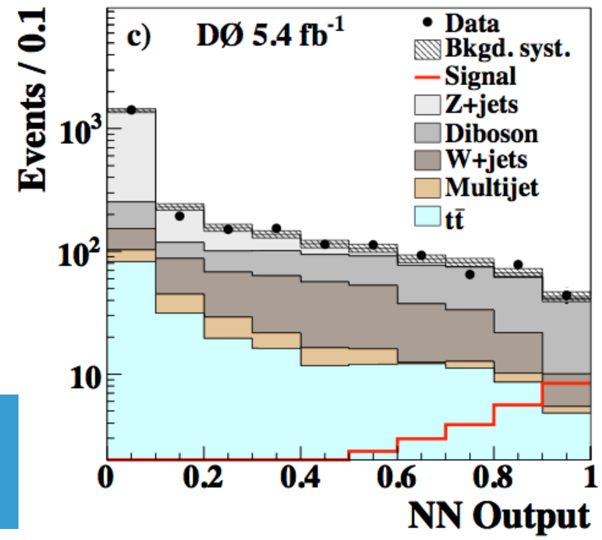


Exp.	Lum (fb^{-1})	H evts (@115)	Exp. Limit	Obs. Limit
CDF	3.6	12.4	4.2	6.1
DØ	5.2	16.4	4.6	3.7

Same techniques used for single top observation

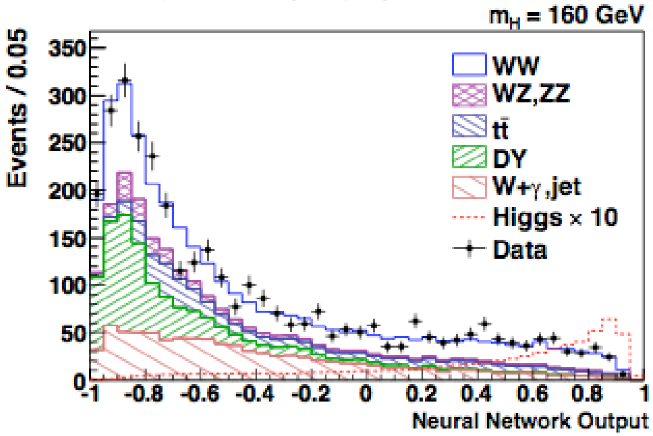
High mass Higgs

- Large signal acceptance:
  - Large MET and 2 high P_T leptons
  - Events with extra jets sensitive to VH and VBF
  - CDF add sensitivity to WH->WWW including same-sign leptons
- Dominant backgrounds:
  - WW production (physics)
  - Everything else (instrumental)
- Use ME and NN to isolate signal
- Different splitting in high/low S/B regions at CDF and D0 leads to similar results



CDF: PRL104:061803 (2010)
D0: PRL104:061804 (2010)
TeV: PRL104:061802 (2010)

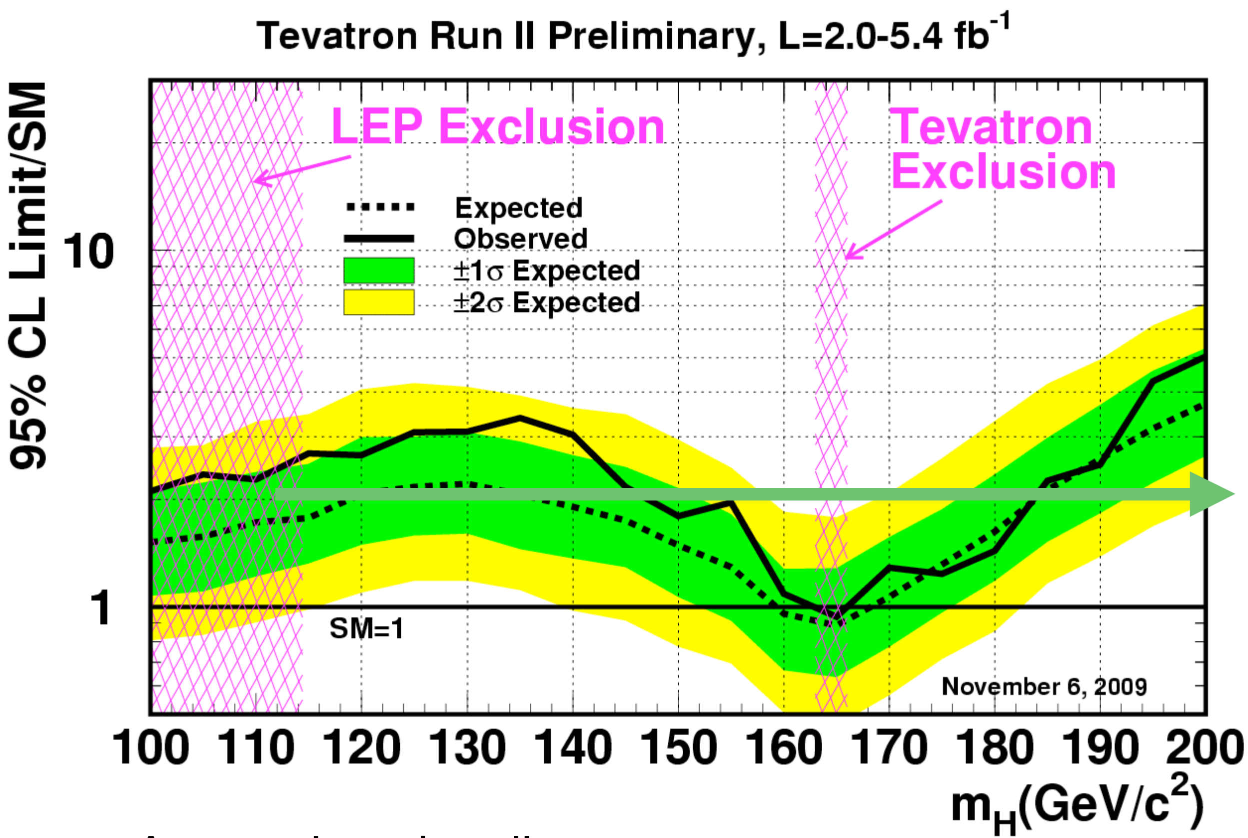
Exp.	Lum (fb-1)	H evts (@165)	Exp. Limit	Obs. Limit
CDF	4.8	29	1.20	1.29
DØ	5.4	43	1.36	1.55
TeVatron	**10.2**	**72**	**0.87**	**0.93**



Tevatron excluded MH hypo for 162<Mh<166GeV
First direct exclusion since LEP

NEW!

The current word from the Tevatron



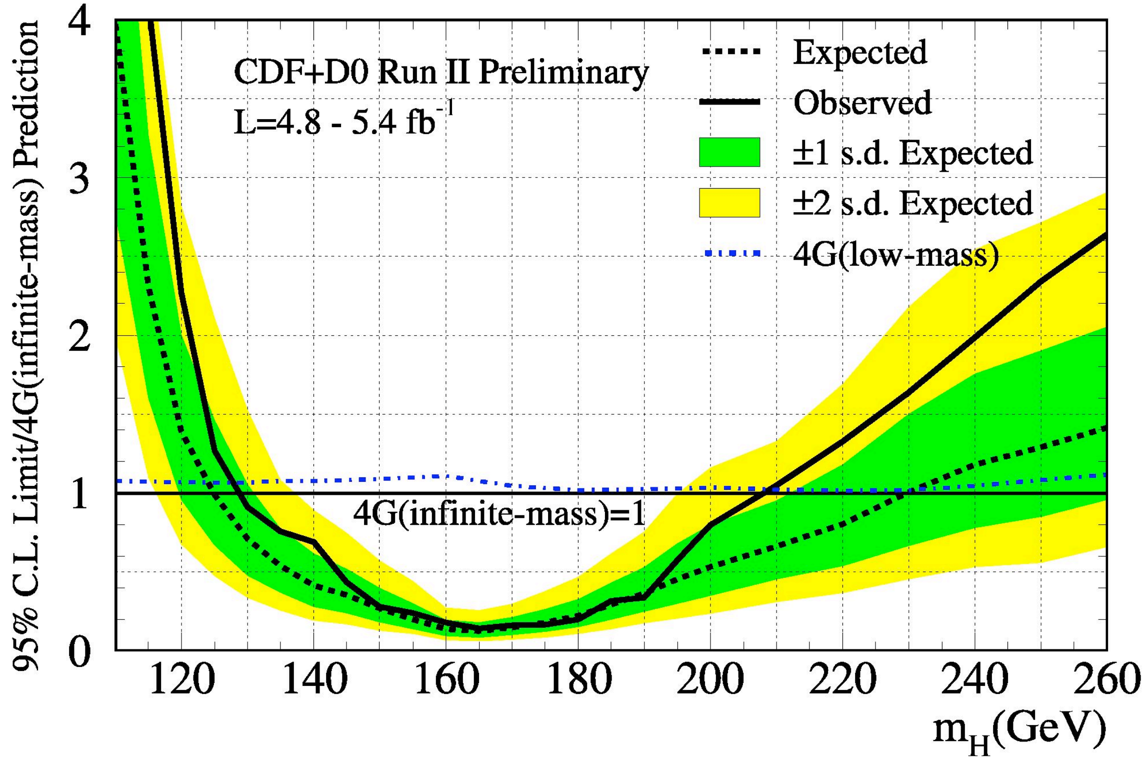
Expect below 2 times the SM expectation everywhere

As mentioned earlier..

- No single analysis at low mass sensitive to Higgs
- BUT! Combination of many channels provides a large improvement with respect to to single best analysis
- Combination of 2 experiments provides extra ~40% improvement

Higgs in presence of a 4th gen

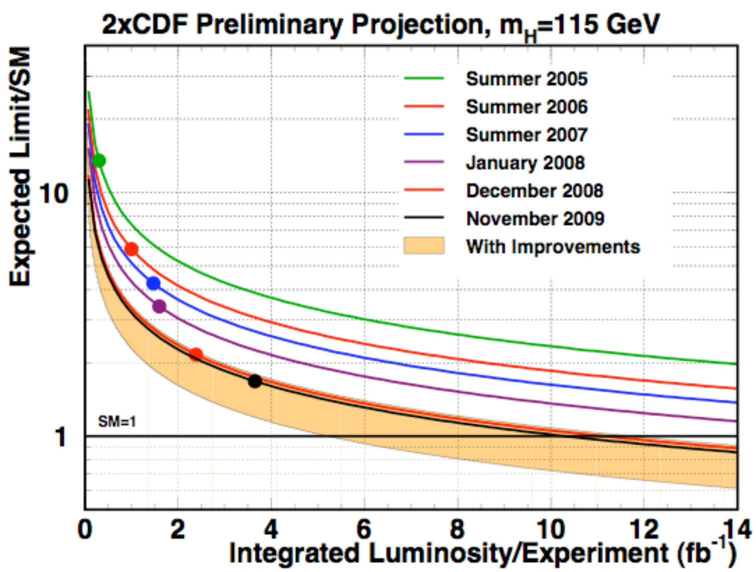
- *EWK (SM) allows a 4th gen, with quark masses favored range 300-500GeV*
- Direct presence explorable at Tevatron and with LHC first data
- Indirect consequences for the Higgs:
  - gg→H enhanced by a factor of about 9 ~independent on q' masses
  - EWK constraints on Higgs mass no longer valid → higher Higgs mass



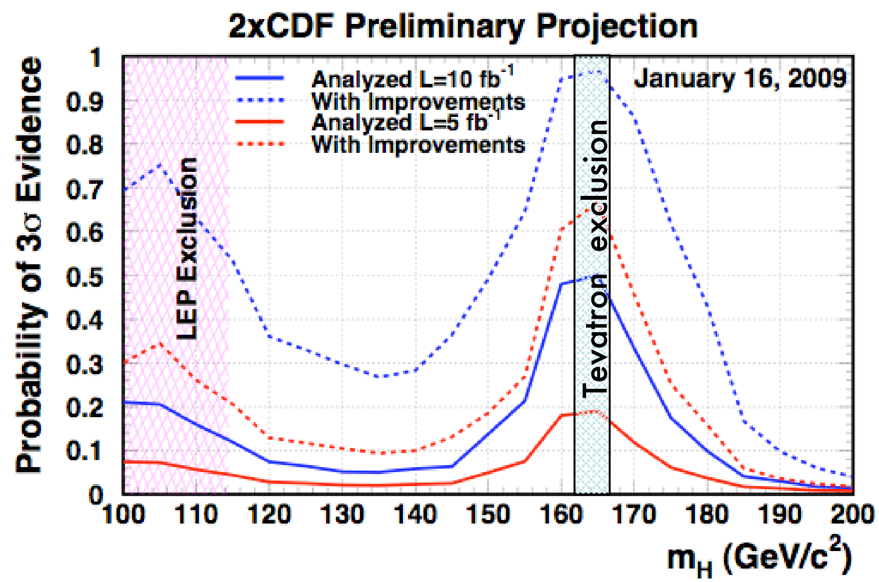
- *Tevatron excludes a SM-like Higgs boson with 4th gen with 130<mH<210 GeV*

Tevatron future at low mass

Low mass extrapolation



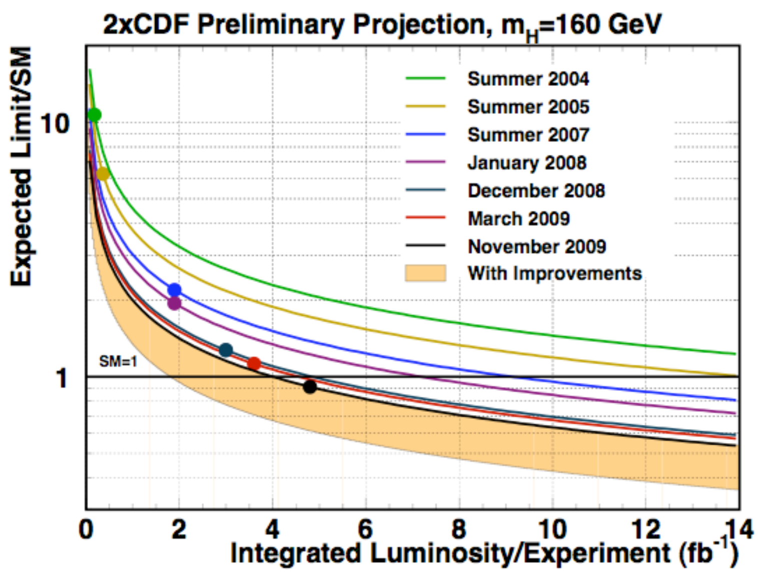
A priori probability of 3σ excess



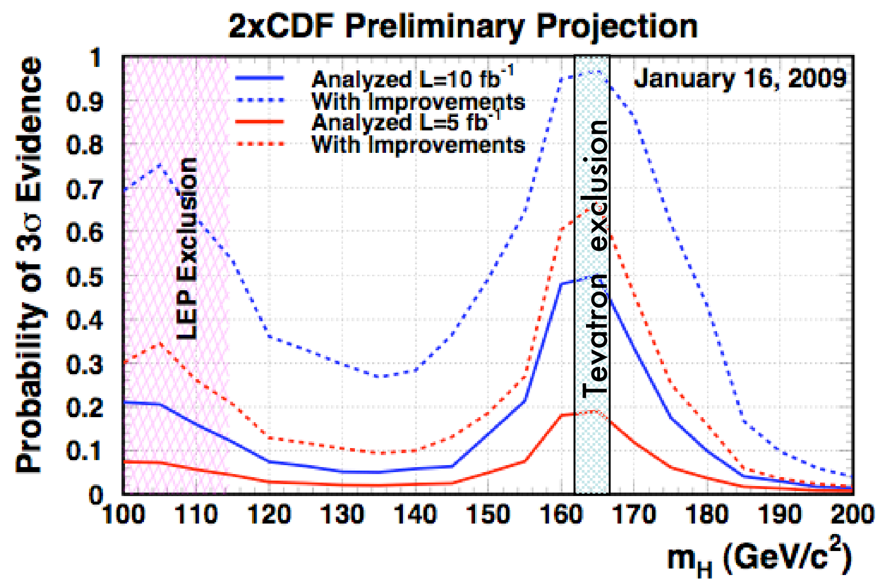
- Experiments are continuously improving analysis technique:
  - Summer 07 projection expect a improvements between 1.5 to 2.25 to existing sensitivity
  - increased indeed by a factor of >1.5 last year: equivalent of using more than double luminosity
  - More/new ideas currently being tested to increase further sensitivity

Tevatron future at high mass

Low mass extrapolation



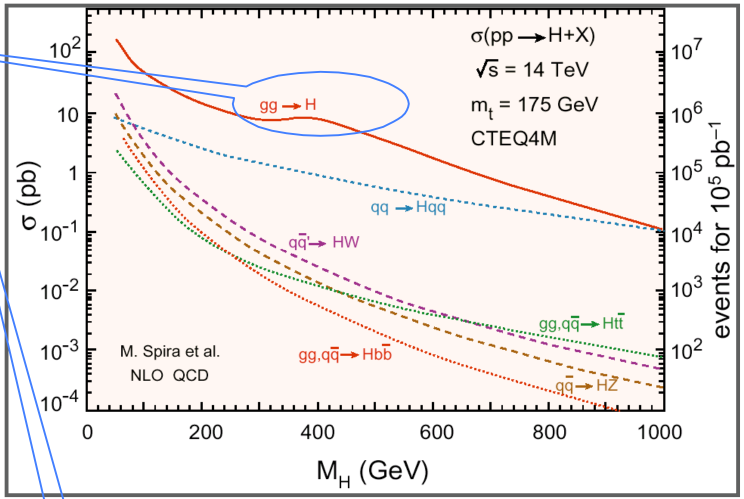
A priori probability of 3σ excess

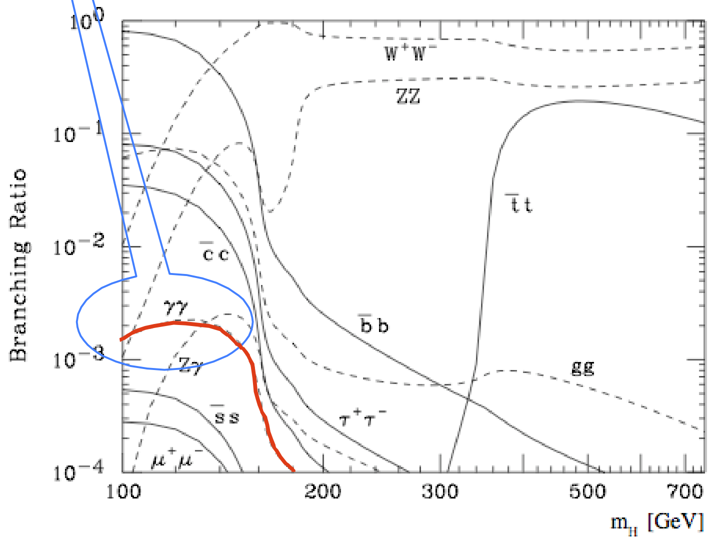


- Experiments are continuously improving analysis technique:
  - Summer 07 projection expect a improvements between 1.5 to 2.25 to existing sensitivity
  - increased indeed by a factor of >1.5 last year: equivalent of using more than double luminosity
  - More/new ideas currently being tested to increase further sensitivity

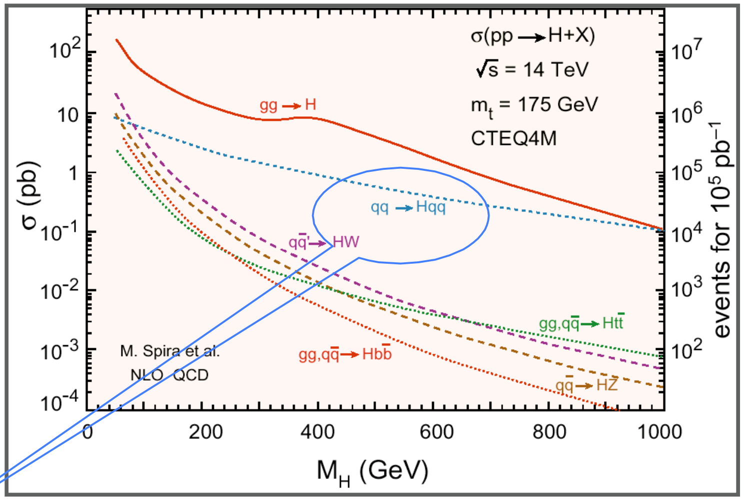
How to look at the LHC (low mass)

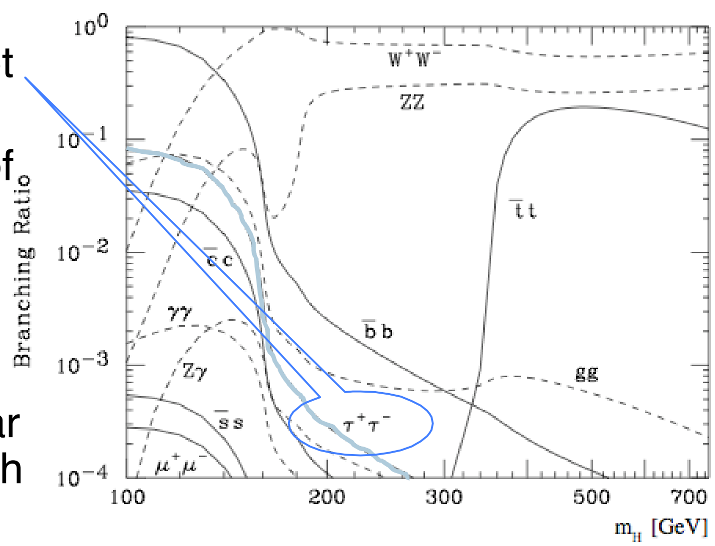
- Largest $\sigma(H)$, very low BR, high resolution on gammas
- Will need understanding of jets faking photon





How to look at the LHC (low mass)

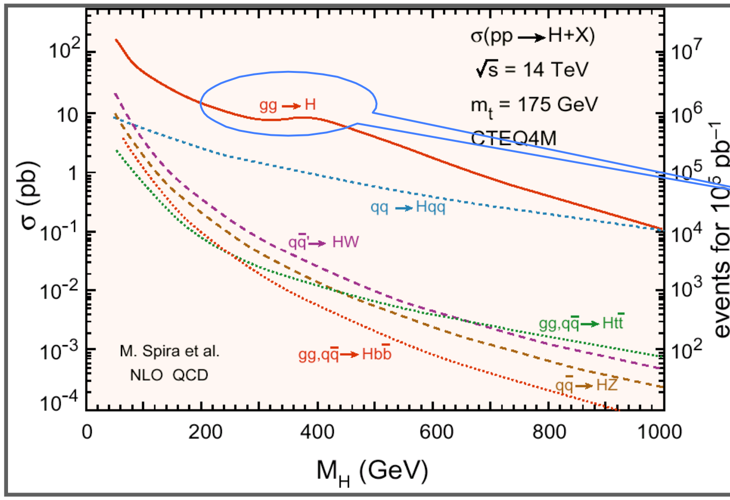


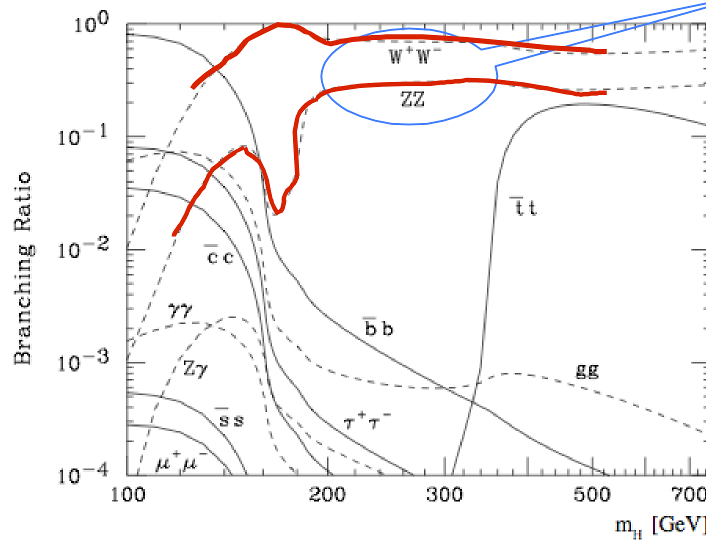


- Second largest σ(H), reasonable BR, forward jet tagging
- Will need understanging of forward jets (difficult)
- But HW/HZ and ttH possible too, once H->bbar appears as a single jet with substructure

Buttersworth/Davison/Rubin/Salam 0802.2470

How to look at the LHC (high mass)



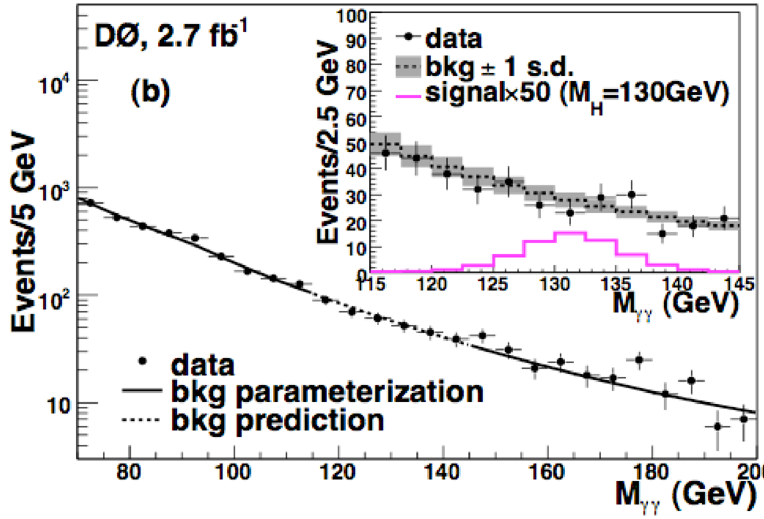


σ(H)xBR(H→WW) largest cross section, largest BR, clean leptons and MET

σ(H)xBR(H→ZZ) offers the advantage of fully reconstructed events

Higgs in $\gamma\gamma$

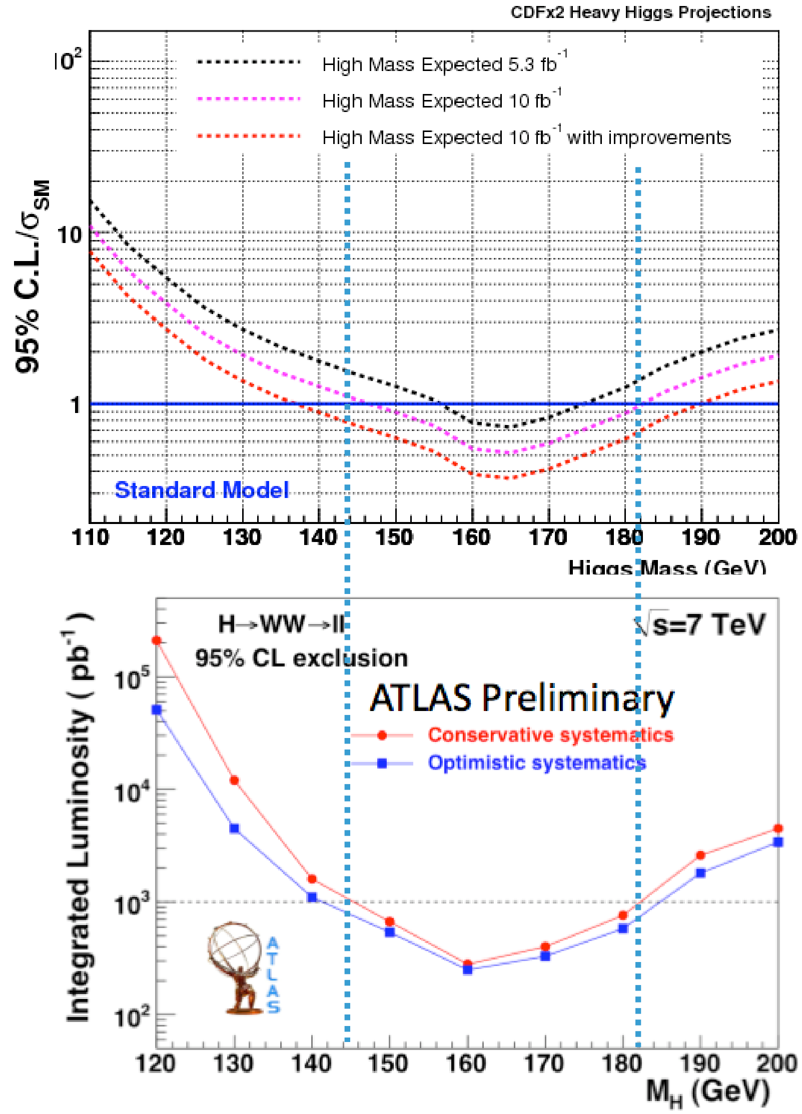
- BR($H \to \gamma\gamma$)~0.2% @ 120GeV
- All production modes: gg→H/HW(Z)/VBF
- Expect about 2 events in 5.3fb^{-1}
- CDF sensitivity 20xSM (preliminary) NEW!
- D0 same sensitivity with half the data
  – PRL102:231801 (2009.)
- need O(1000)fb^{-1} to see a SM Higgs



- Background largely irreducible, ways to improve exclusion is by
  – improving detector → CMS has 3 times better EM calorimeter resolution
  – Changing collider :)
    - LHC (7 TeV) ~10xσ_{TeV} and ~similar S/B ratio → need ~O(10) fb^{-1} to reach exclusion, and many more to observe it.
    - LHC(@14TeV) ~100xσ_{TeV} exclude with a few fb^{-1}, observe with O(10)fb^{-1}
- *Extrapolation from CDF/D0 results matches ~well with ATLAS/CMS studies* of observation with 30fb^{-1} @14TeV

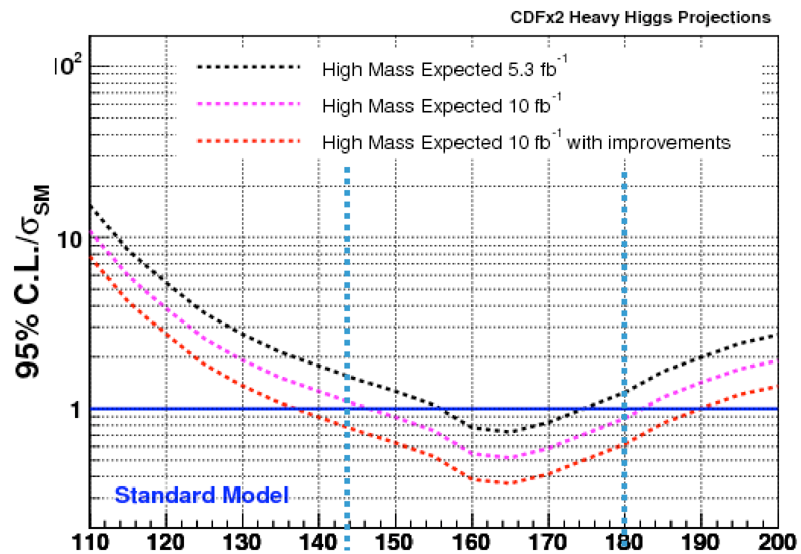
The near future

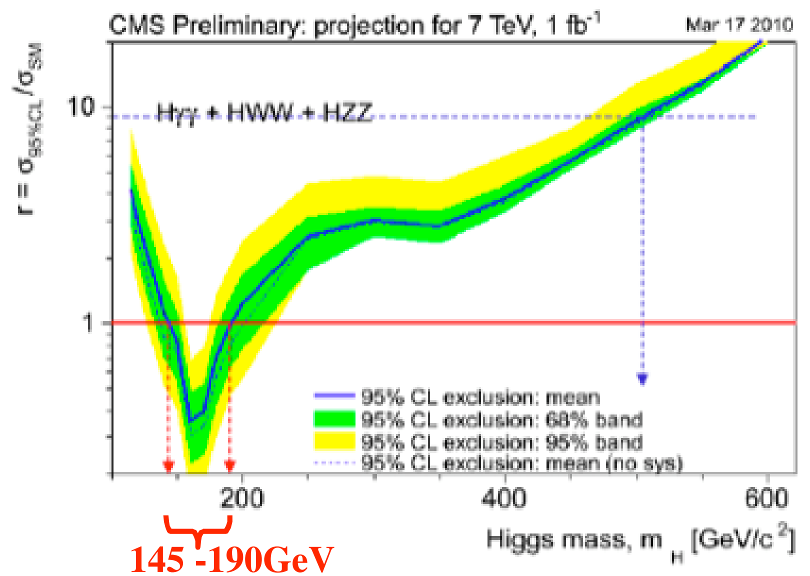
- Region 145-185 will likely be excluded in 2011 by Tevatron
- LHC will initially probe region already excluded by Tevatron
- ATLAS/CMS exclusion extrapolation with $1fb^{-1}$ @7TeV nearly identical to Tevatron (2xCDF) projection of current Higgs exclusion at $10fb^{-1}$
- Tevatron expect to improve implementing ideas currently tested



The near future

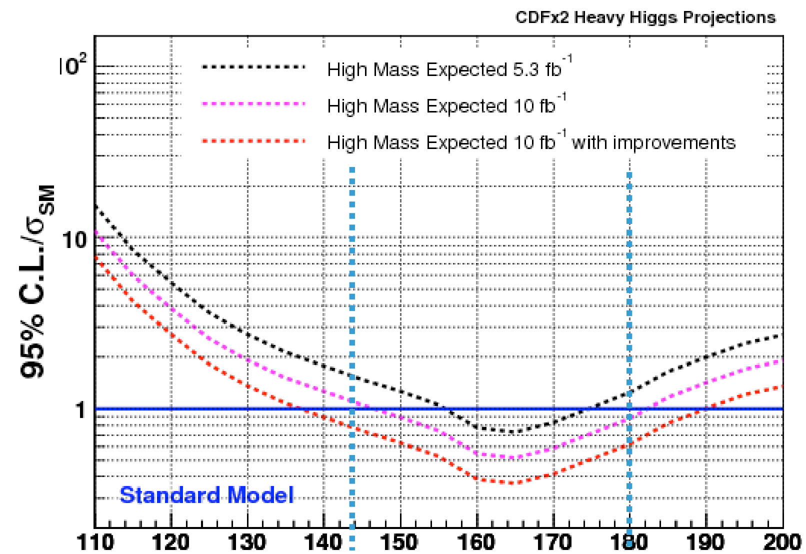
- Region 145-185 will likely be excluded in 2011 by Tevatron
- LHC will initially probe region already excluded by Tevatron
- ATLAS/CMS exclusion extrapolation with 1fb^{-1} @7TeV nearly identical to Tevatron (2xCDF) projection of current Higgs exclusion at 10fb^{-1}
- Tevatron expect to improve implementing ideas currently tested

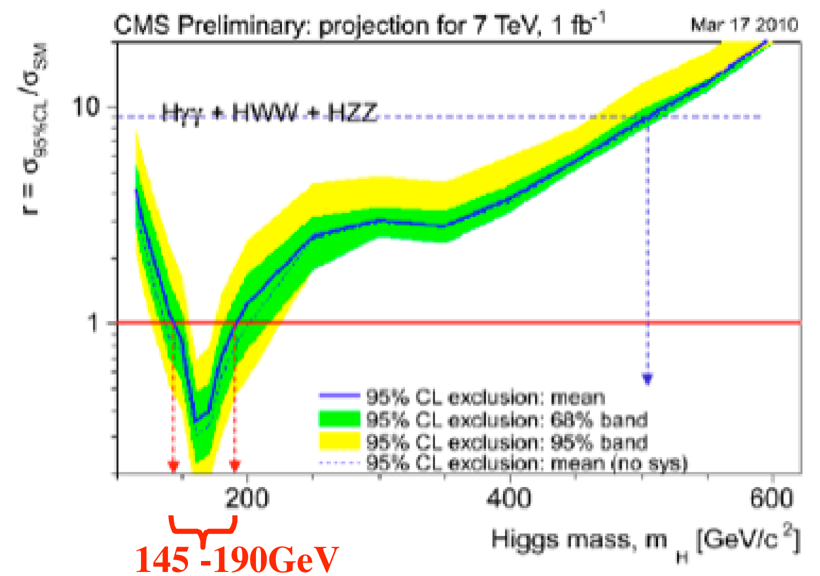




The near future

- Region 145-185 will likely be excluded in 2011 by Tevatron
- LHC will initially probe region already excluded by Tevatron
- ATLAS/CMS exclusion extrapolation with 1fb^{-1} @7TeV nearly identical to Tevatron (2xCDF) projection of current Higgs exclusion at 10fb^{-1}
- Tevatron expect to improve implementing ideas currently tested
- LHC can benefit of 40% by combining CMS and ATLAS results

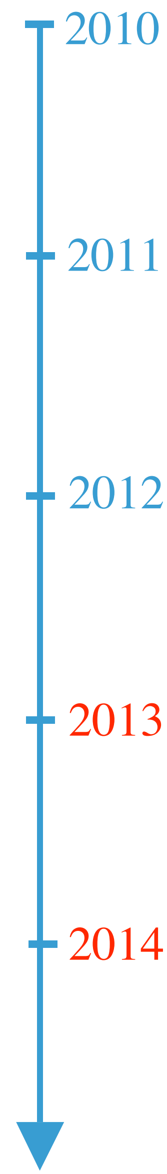




Conclusions

- Tevatron is still the main place for a SM Higgs boson search for the next 2/3 years. With ~10fb^{-1} of data collected by the Tevatron by end of 2011:
  - Expect to exclude roughly everything in the SM-favored range, but a narrow window around 130GeV
  - Expect to have a 3σ evidence (with a bit of luck) of a SM Higgs boson in high mass range
  - ATLAS/CMS comparable sensitivity- but only at high mass with 1fb^{-1}@7TeV

- LHC will catch up shortly thereafter and provide access to a much larger Higgs mass range. Assuming 14TeV in 2013, and O(100)fb^{-1}
  - Ultimately, the LHC will have access to all production and decay modes
  - If neutral Higgs discovered, mass, and some couplings can be determined with accuracy to test If it's SM (width also if Mh<200GeV)
  - Be aware of look-alikes (Z',SUSY h^0, etc), study quantum number



Back up

The needed improvements

- Low mass improvements
  - NN b-tagger for CDF
  - Adding data from orthogonal triggers
  - Including lower S/B regions

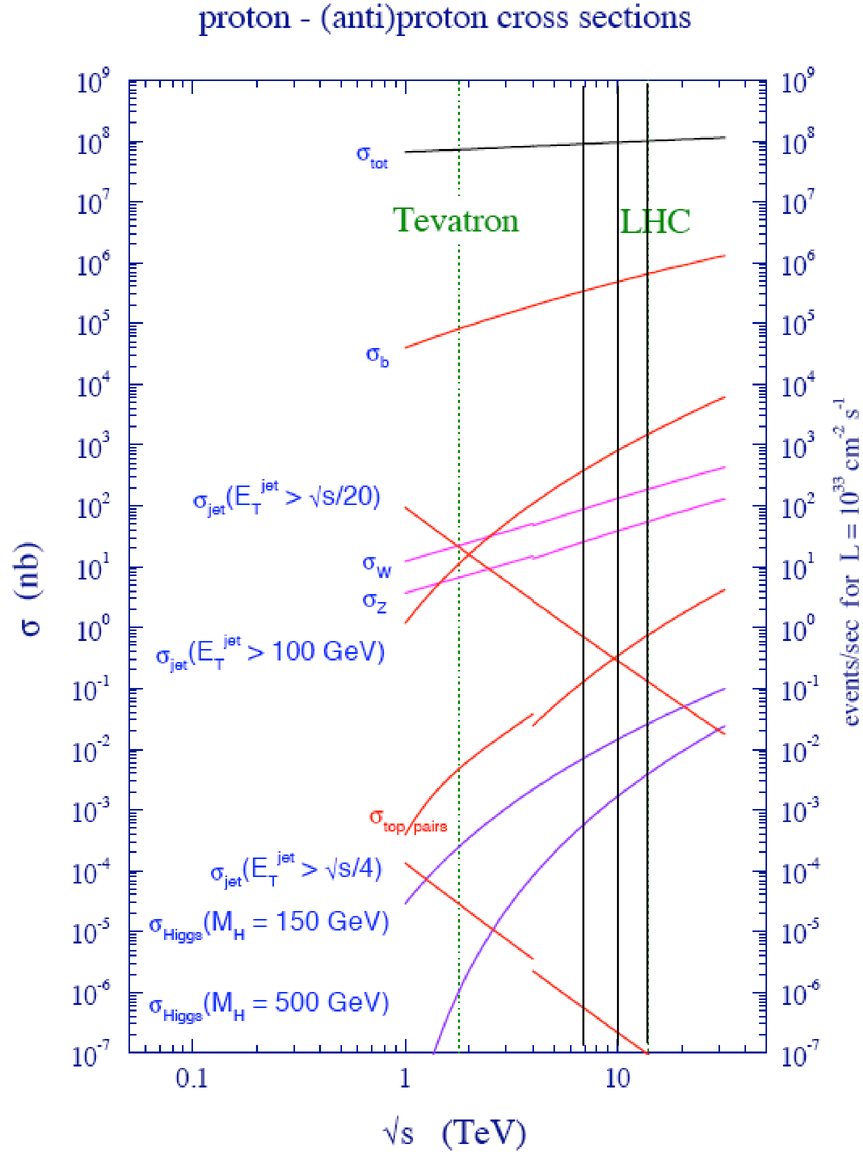
- High mass improvements:
  - Included tau/e and tau/mu with hadronic taus
  - Allow close in R-space, non-isolated leptons
    - Increase acceptance, different (and lower) backgrounds
  - Computing more ME for the other backgrounds
  - Looser ele/mu definitions
  - More triggers
  - More channels: H - >WW->lnujj, H->ZZ

Production cross-sections vs √s

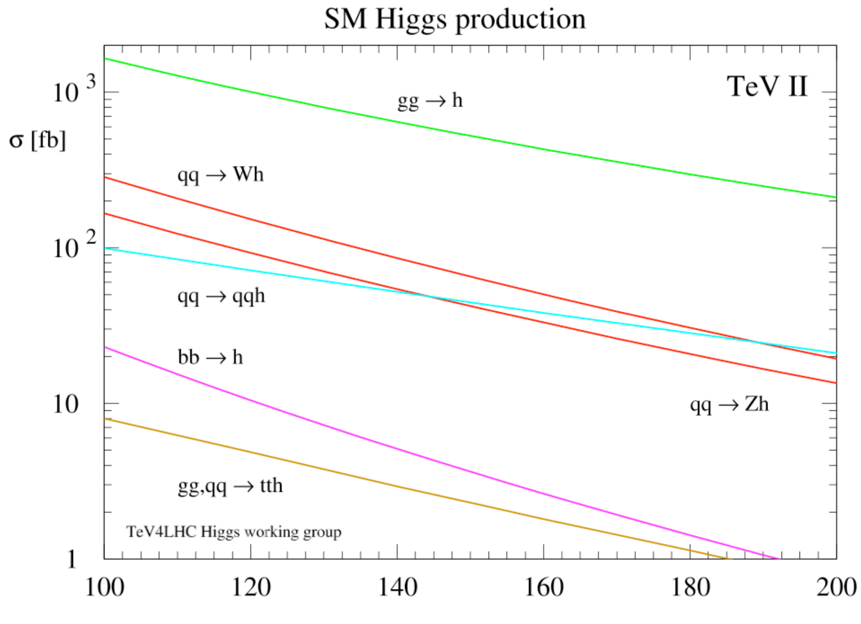
•Higgs production cross section goes down with decreasing E(cdm)

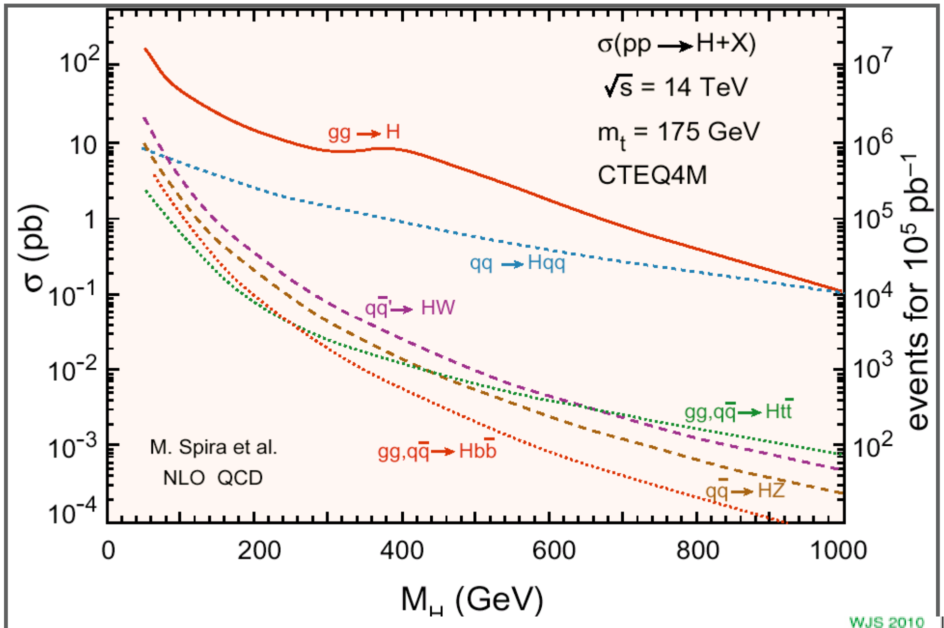
•CMS expects at 7TeV the need to increase luminosity by ~7 times wrt to the 14TeV studies

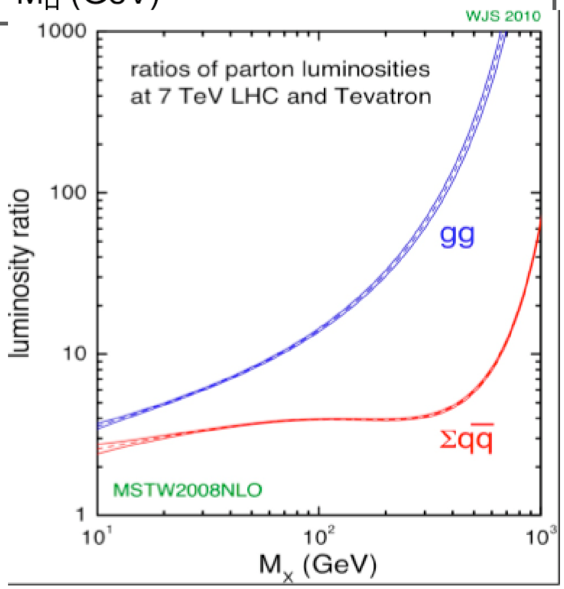
•A recent pheno paper confirms that arxiv:1003.3875 Berger et al.



Higgs @ Tevatron/LHC





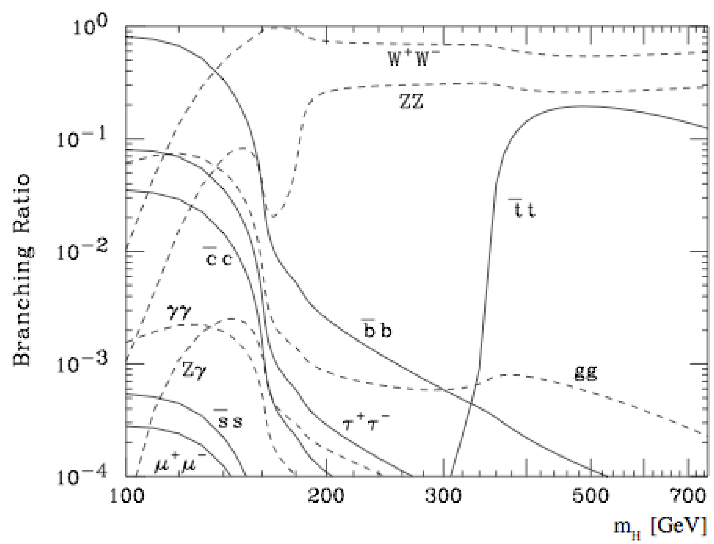


σ(LHC)/σ(Tevatron)
~70 (gg→H)
~60 (qq→qqH)
~10 (qq→WH/ZH)
~100 (gg→ttH)
for m_H<200 GeV

Higgs couplings

- gg->H QCD cross sections known to NLO for arbitrary top mass, NNLO in the large top-mass limit
  - NLO~2XLO
  - NNLO~1.5xNLO

$$g_{HVV} = \frac{2 m_V^2}{v} \qquad g_{Hff} = \frac{m_f}{v}$$



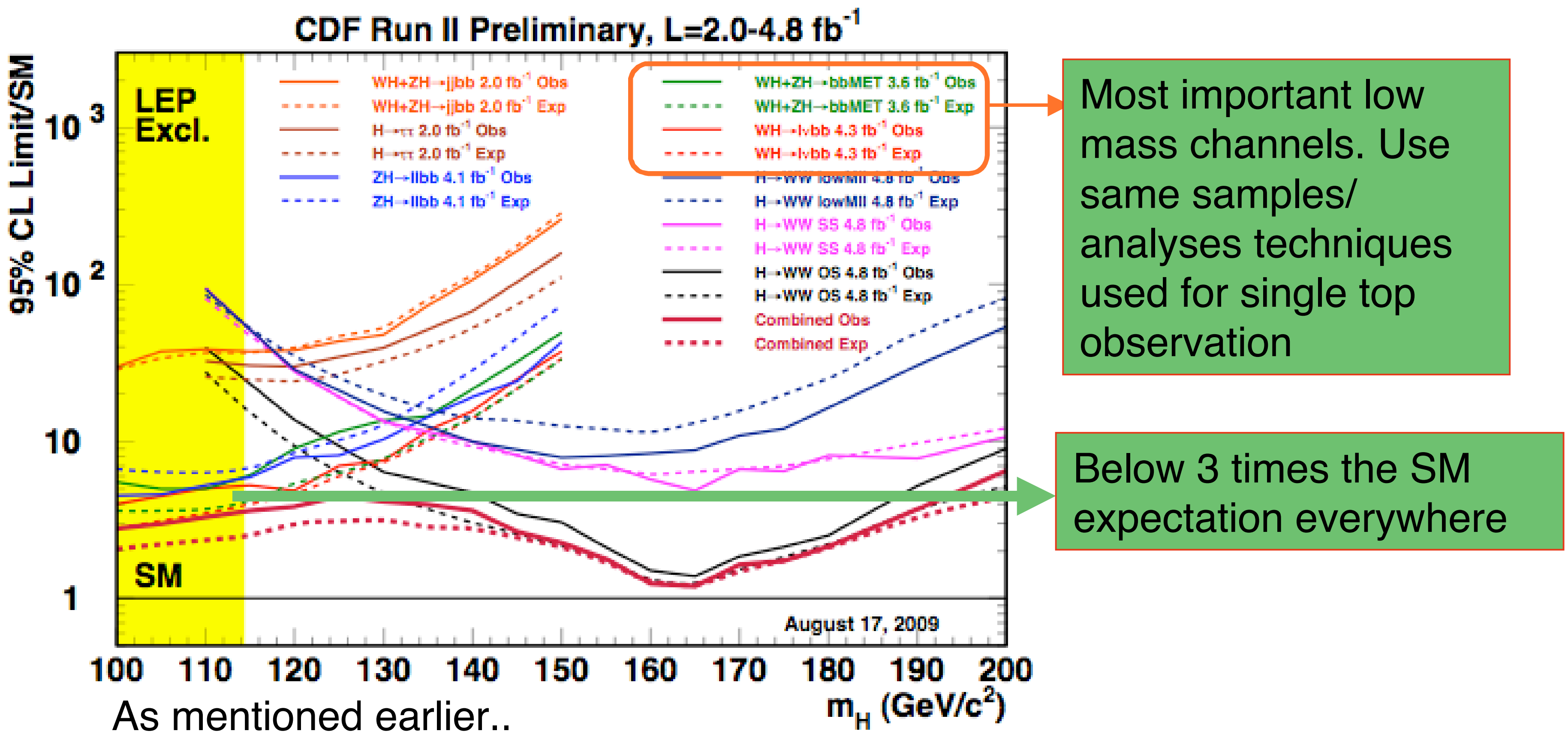
For more on Higgs searches..

…visit the experiments public webpage of preliminary Higgs results:

www-cdf.fnal.gov/physics/new/hdg/hdg.html#prelim

www-d0.fnal.gov/Run2Physics/WWW/results/higgs.htm

Case example: CDF combination



As mentioned earlier..

- No single analysis at low mass sensitive to Higgs
- BUT! Combination of many channels provides a large improvement with respect to to single best analysis