Standard Model Higgs Combination at the Tevatron

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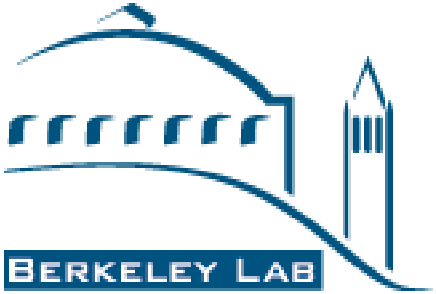
On behalf of the CDF and D0 Collaborations

HCP 2011, November 14-18, 2011, Paris, France



Outline

- **Higgs Search Analysis Overview**
  - **Searches for "High" Mass Higgs –K. Petridis**
  - **Searches for "Low" Mass Higgs –F. Sforza**
- **Combination Strategies**
- **Tevatron Results**
- **Conclusion**

More Details:

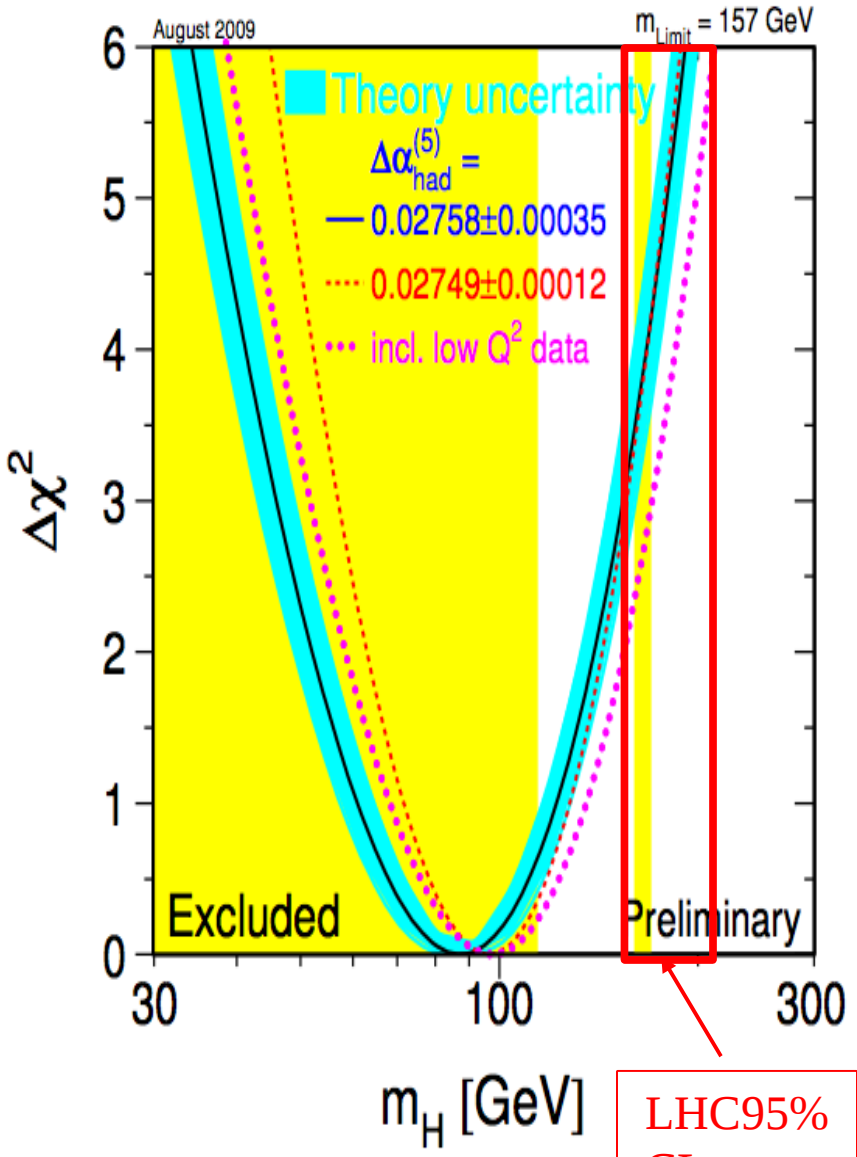
http://www-cdf.fnal.gov/physics/new/hdg/Results.html

http://www-d0.fnal.gov/Run2Physics/D0Summer2011.html

http://tevnphwg.fnal.gov/results/SM_Higgs_Summer_11

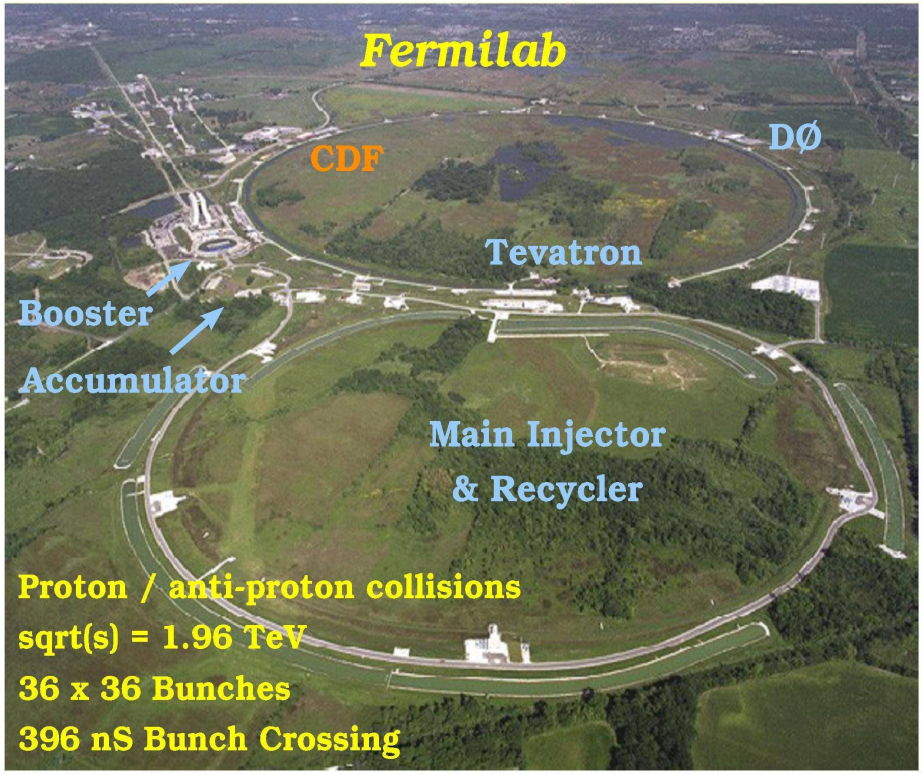
Introduction

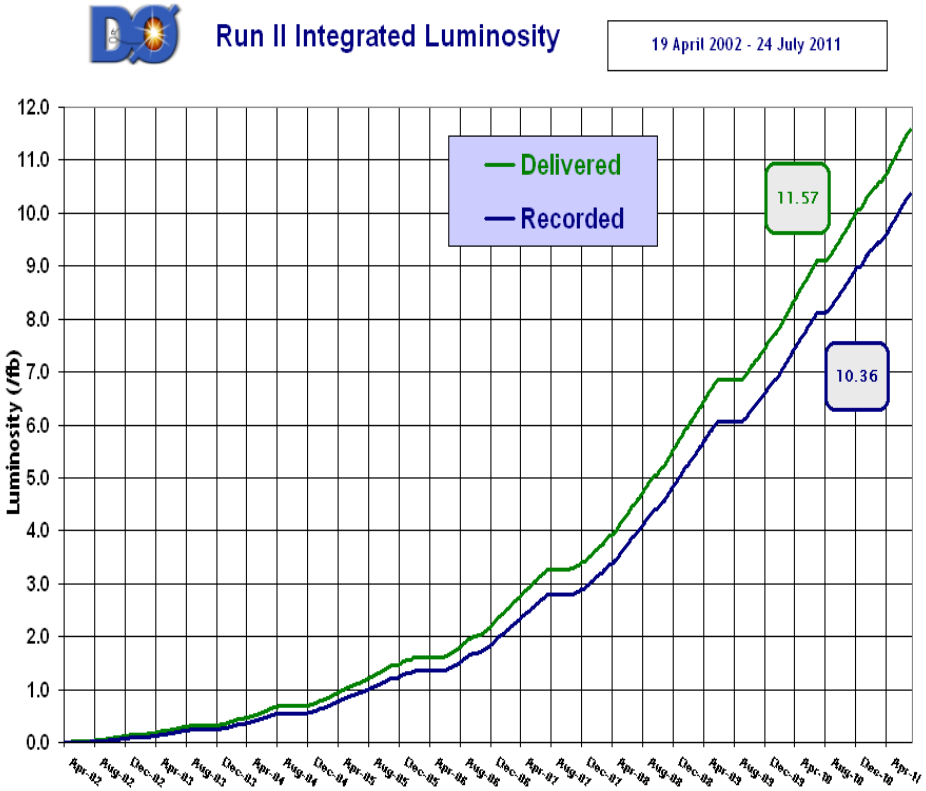
- Higgs boson is last unobserved particle postulated in SM to help explain the origin of mass.
- Higgs Mass Limits@95% CL:
  - Indirect: M_H<158 GeV
  - Direct: 114.4<M_H<146 GeV
- With full dataset & improved analyses Tevatron will be still competitive next year and will provide an unique sensitivity to H→bb in the remaining mass range.



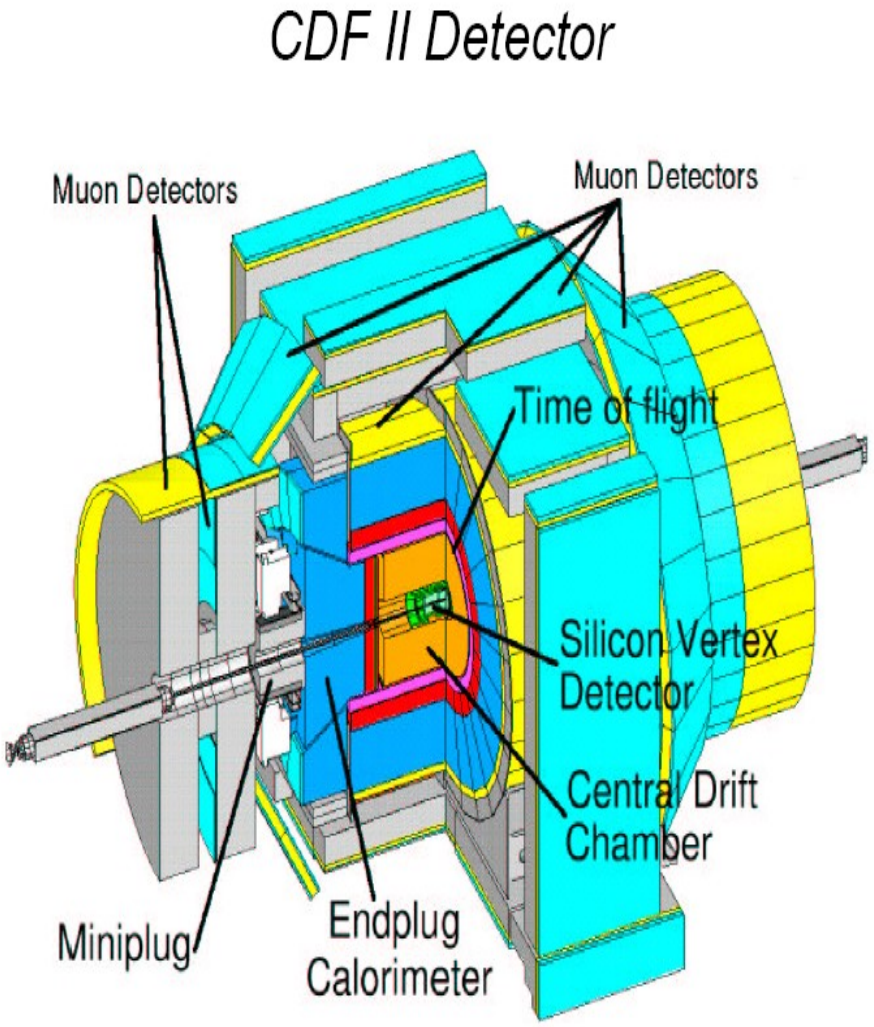
The Tevatron

- Tevatron: p-pbar collision@1.96TeV, $L_{peak}=4.3\times10^{32}\ cm^{-2}s^{-1}$
- Delivered ~12 fb^{-1} data before shutdown on 9/30/2011.
- Most results presented here are based on 8.6 fb^{-1}
- **Full dataset update will be ready for the winter conferences.**





General-purpose Detectors



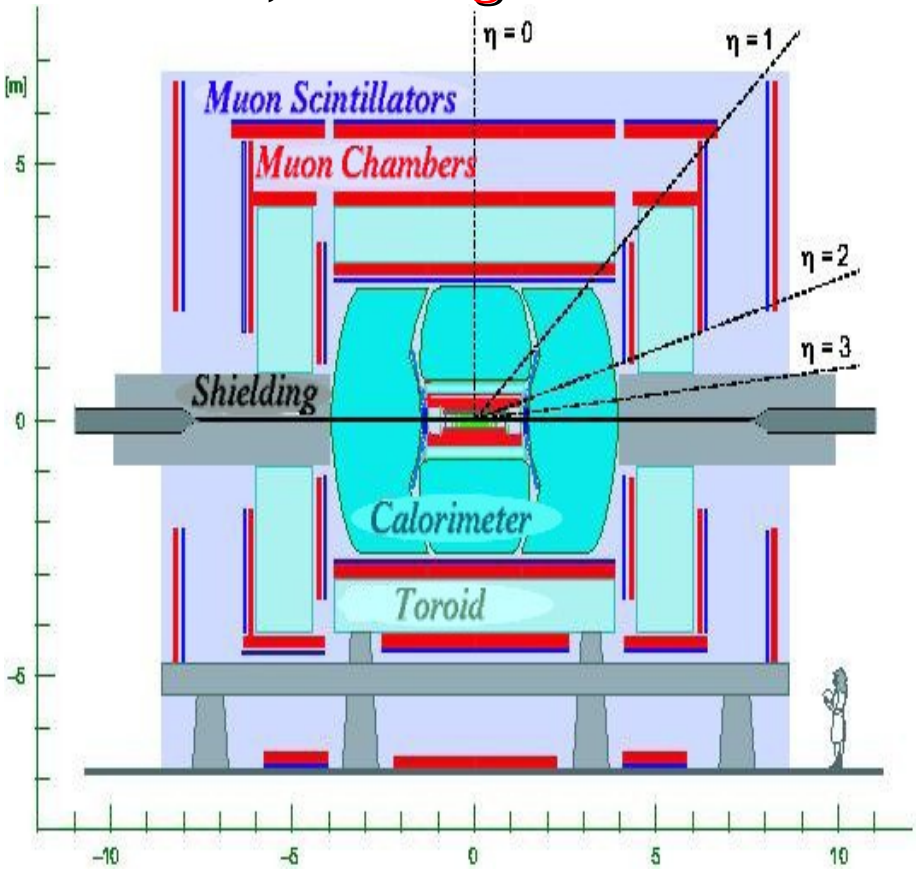
Excellent:

Lepton ID

Tracking, Vertexing

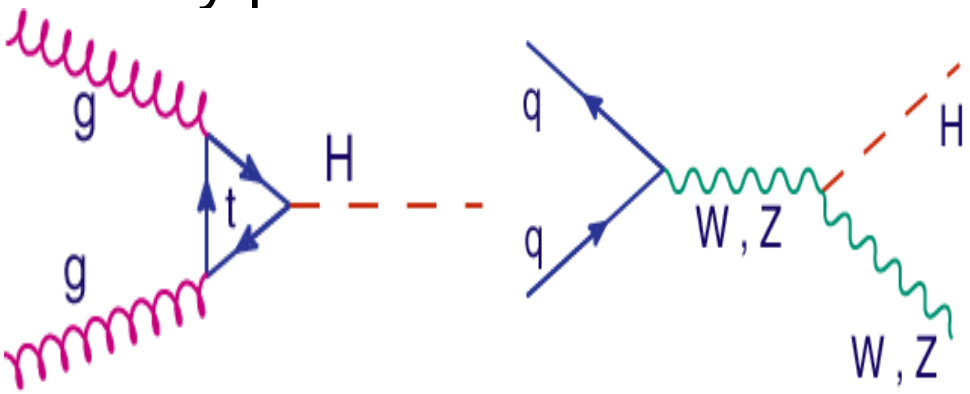
Jets, Missing Et

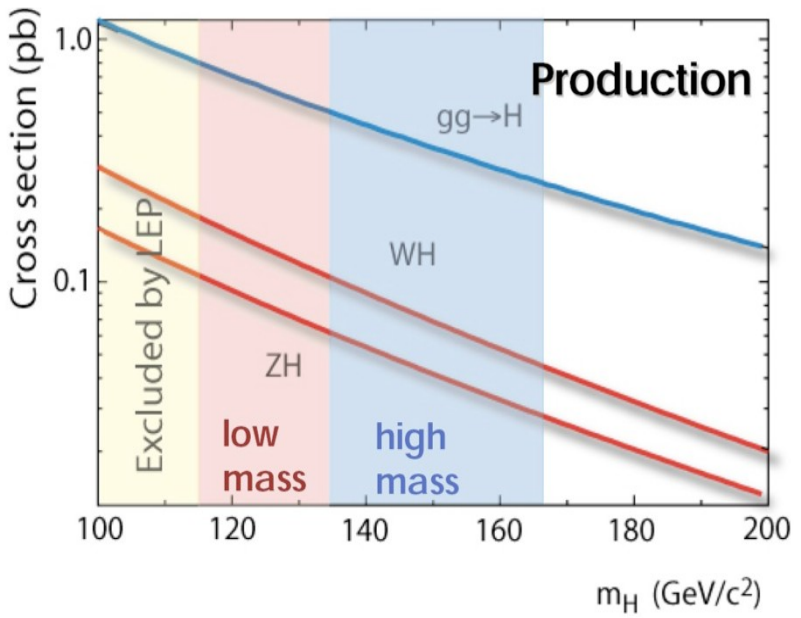
D0 Detector



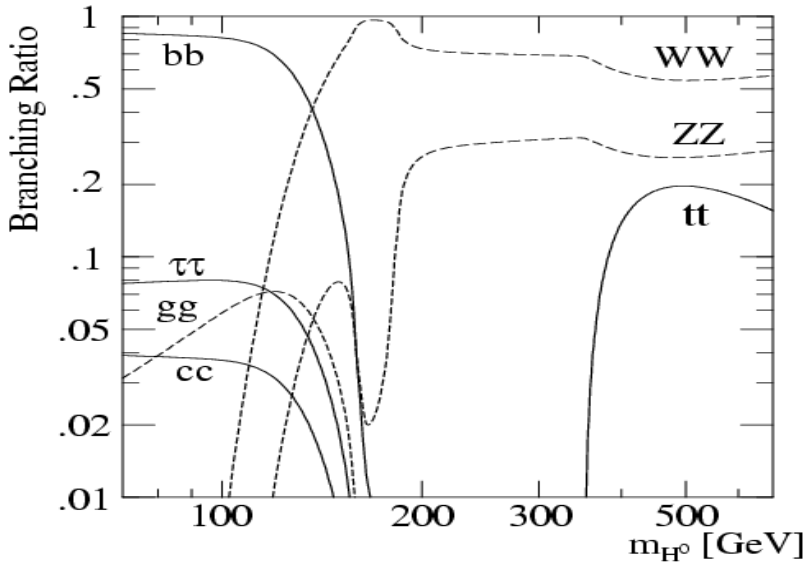
SM Higgs Production and Decay @ Tevatron

- Primary production modes are:



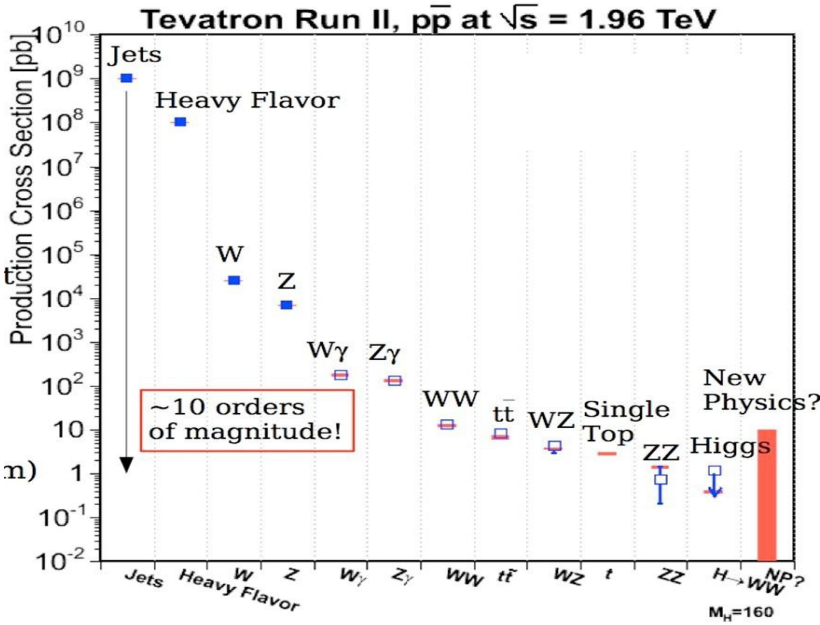


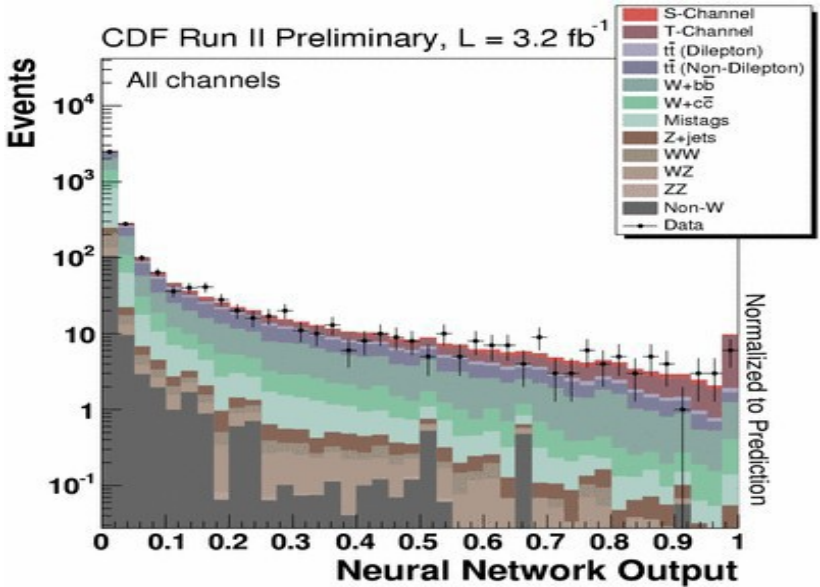
- For lower mass(M_H<135 GeV):
  - –Main decay:H→bb in WH/ZH
  - –Direct production gg→H→bb is limited by multi-jet QCD.
- For higher mass(MH>135GeV):
  - –Mainly decays: H→WW,ZZ
- Best to combine all channels.



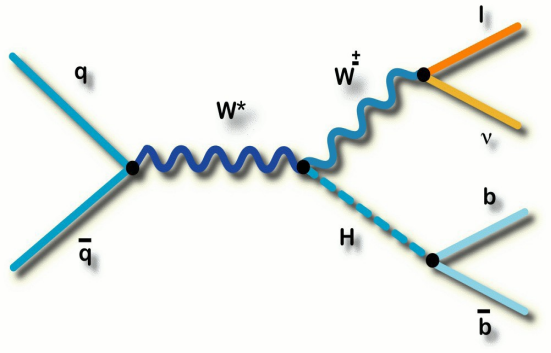
The Challenges

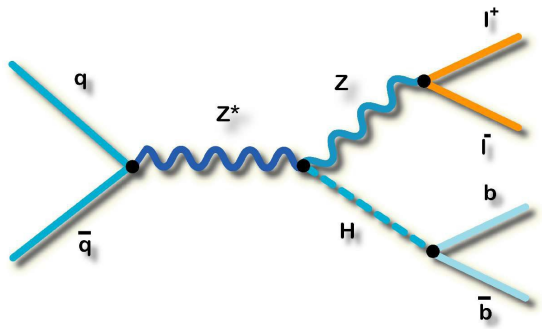
- Unfortunately, there are many backgrounds produced more copiously than the Higgs signal.
- The challenge is how to use advanced multivariate analysis tools(MVA) to separate signal from backgrounds based on full event kinematics(NN, ME, BDT).
- Observations of single top and diboson provide solid ground that these tools do improve search sensitivity by ~25% more than without.

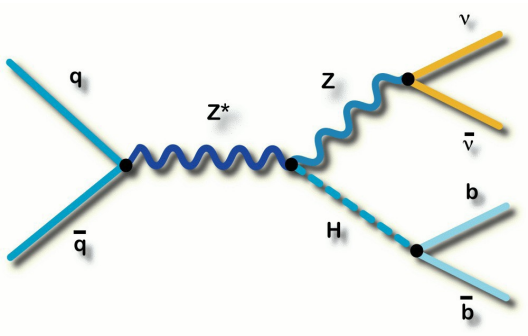




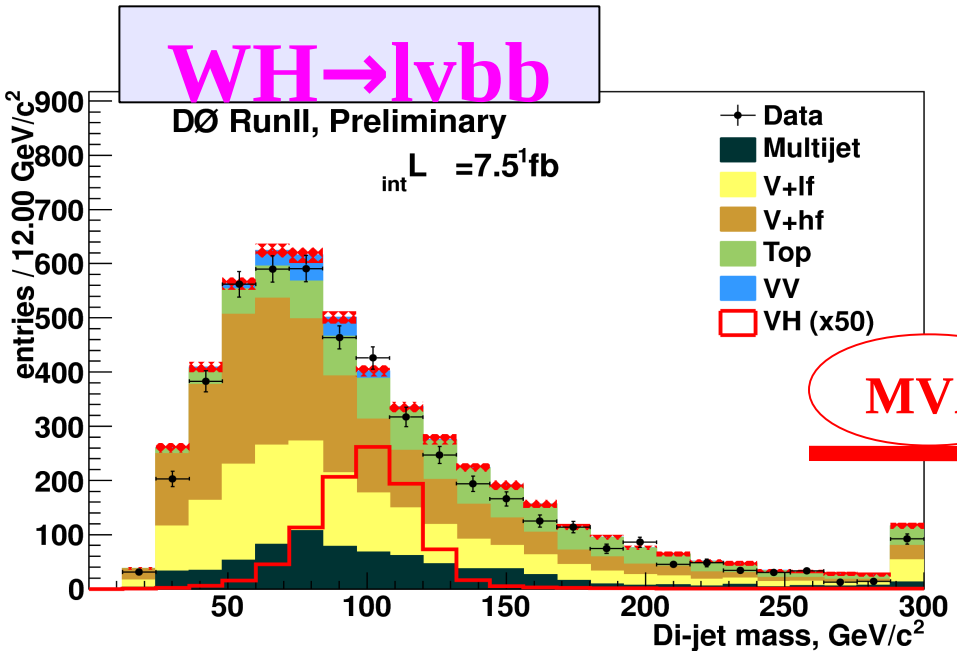
Low Mass Higgs Signatures

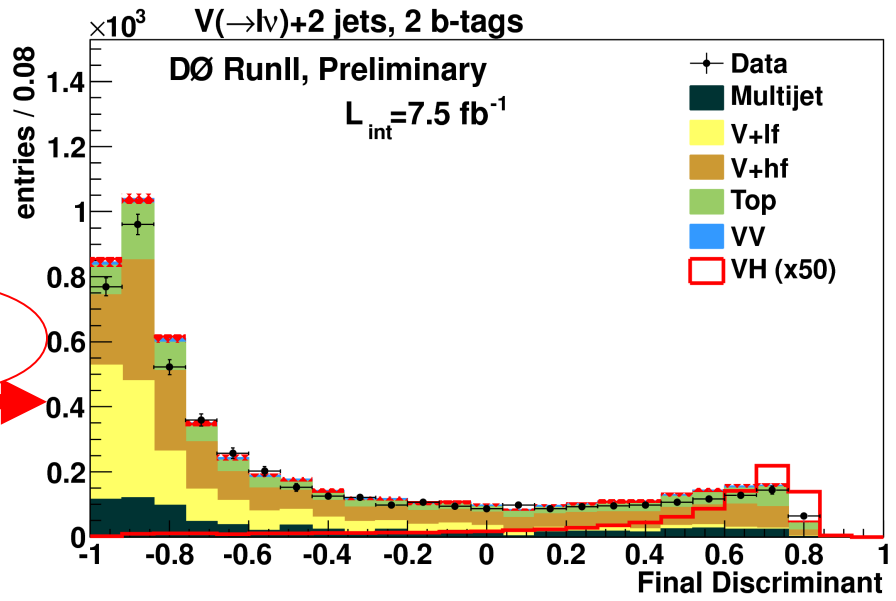




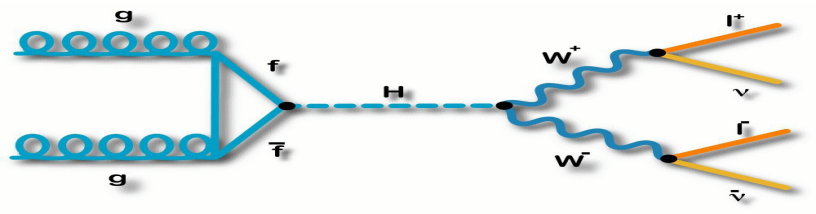


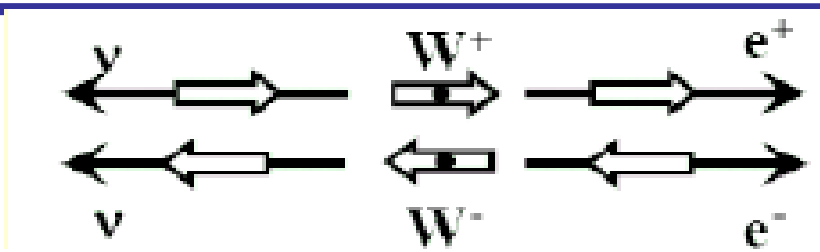
- Search for H→bb resonance in association with W, Z.
- Requiring btagging & advanced MVA to suppress W+jets & top.



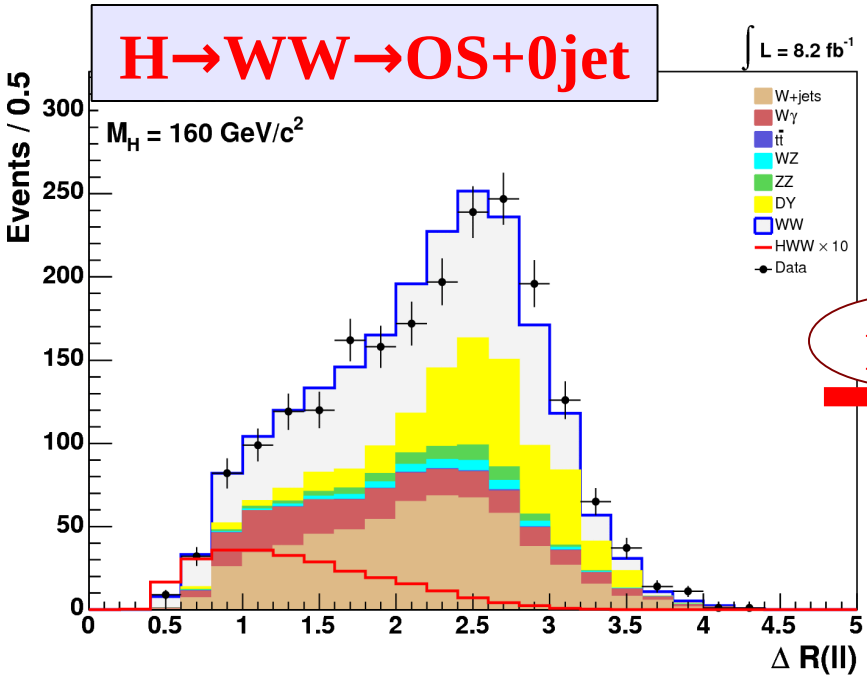


High Mass Higgs Signatures

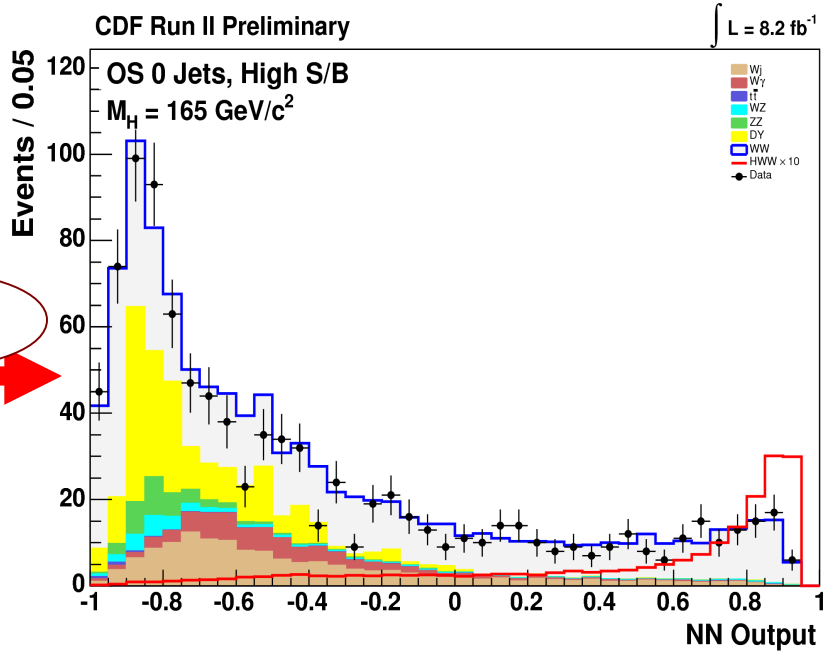




- **Search for H→WW that leads to many interesting final states.**
- **Most sensitive channel is H→WW→lluu: OS Dilepton + MET + 0,1,2 Jets.**
- **Requiring MVA to separate signal from main backgrounds(WW and top).**



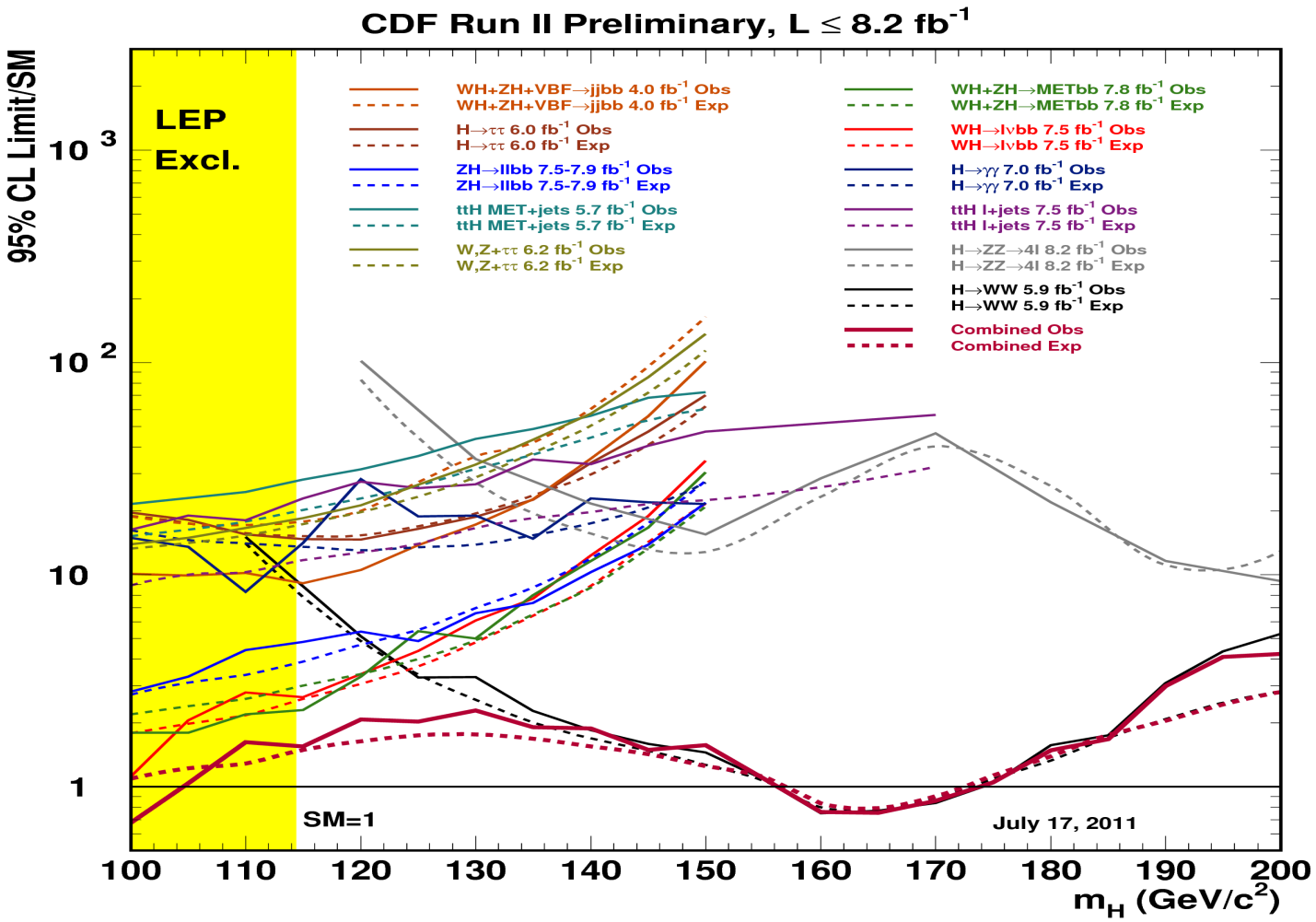
MVA



Combining Individual Channels

- **Many mutually exclusive final states that can be combined statistically to improve the Tevatron Higgs sensitivity.**

WH→lνbb
ZH→ννbb
ZH→llbb
WH/ZH→jjbb
ttH→WbWb bb
H→γγ
H→ττ
VH→(lν,ll)ττ
H→WW→lνlν
H→WW→lνjj
VH→VWW
H→ZZ



Systematic Uncertainties

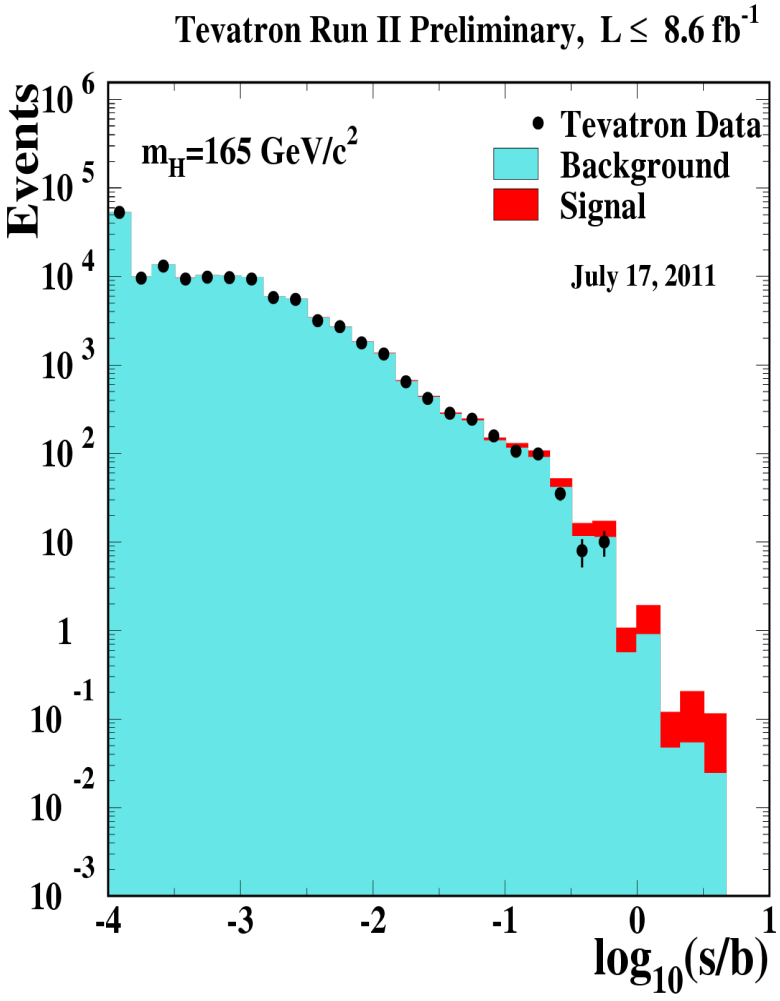
- Two types of systematic on estimated signal and background:
  - Rate systematic: only affect overall normalization
  - Shape systematic: change differential distribution, i.e. due to JES, MC modeling
- Systematic correlated between CDF and D0:
  - Integrated luminosity
  - Theoretical cross sections for signal and backgrounds
- Other Sources correlated within experiment:
  - Lepton ID
  - Btag SF, JES, FSR/ISR
  - Jet/Missing Et modeling
  - MC simulated backgrounds (W/Z+HF)
  - instrumental backgrounds(non-W, mistag)

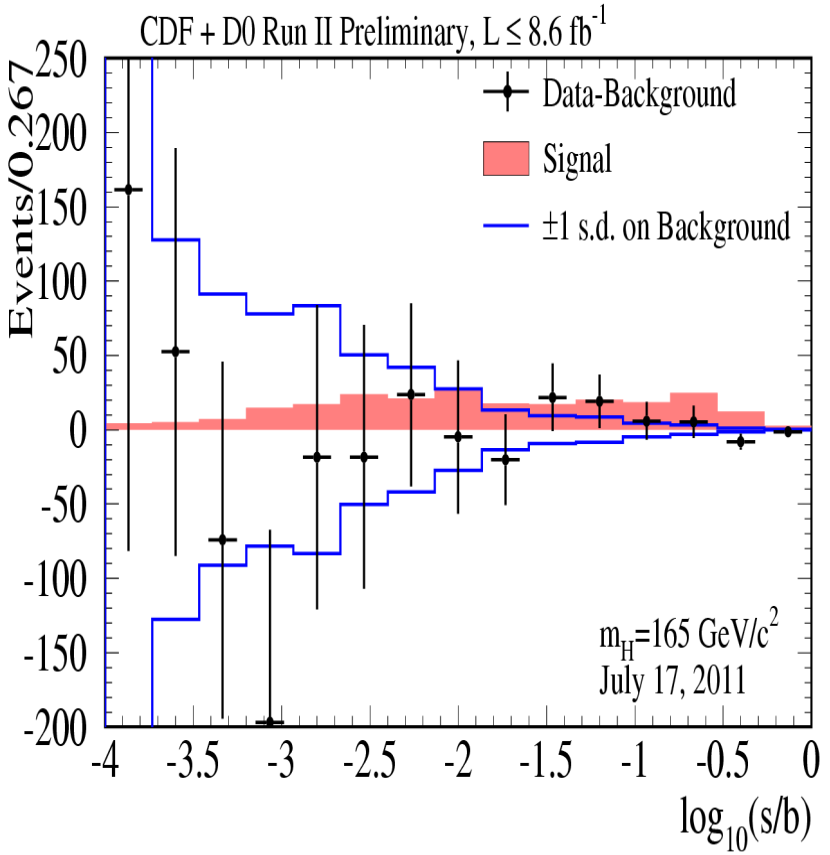
Theoretical Uncertainties

- Since we combine searches in different Higgs production/decay modes, cross section limits are given with respect to nominal SM predictions.
- This requires to incorporate latest theoretical predictions and uncertainties for signal cross section and branching ratios.
- Changes in each iteration to reflect the progresses made in theory and development of MC generators over many years, for example:
  - the new prescription of PDF by LHC Higgs cross section WG
  - BNL accord to estimate H→WW uncertainties in each jet bin.
  - the interference between H→WW& WW needs to be included next time.

Cumulative Discriminant

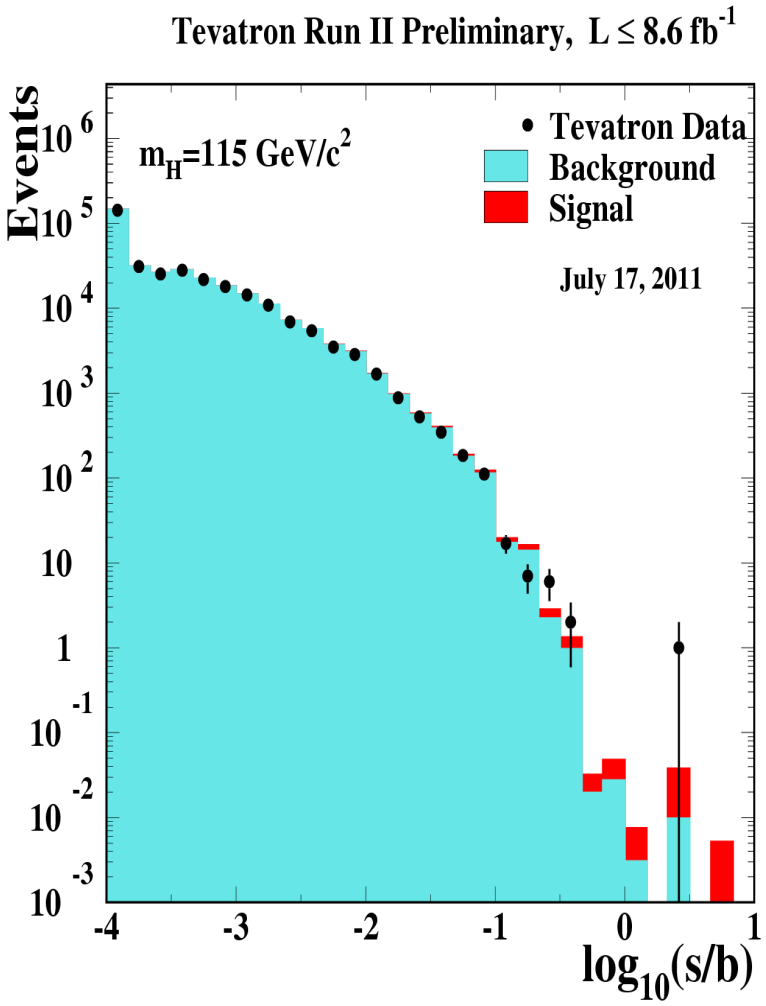
- Sum events from all channels, ordered by S/B for M_H=165 GeV.

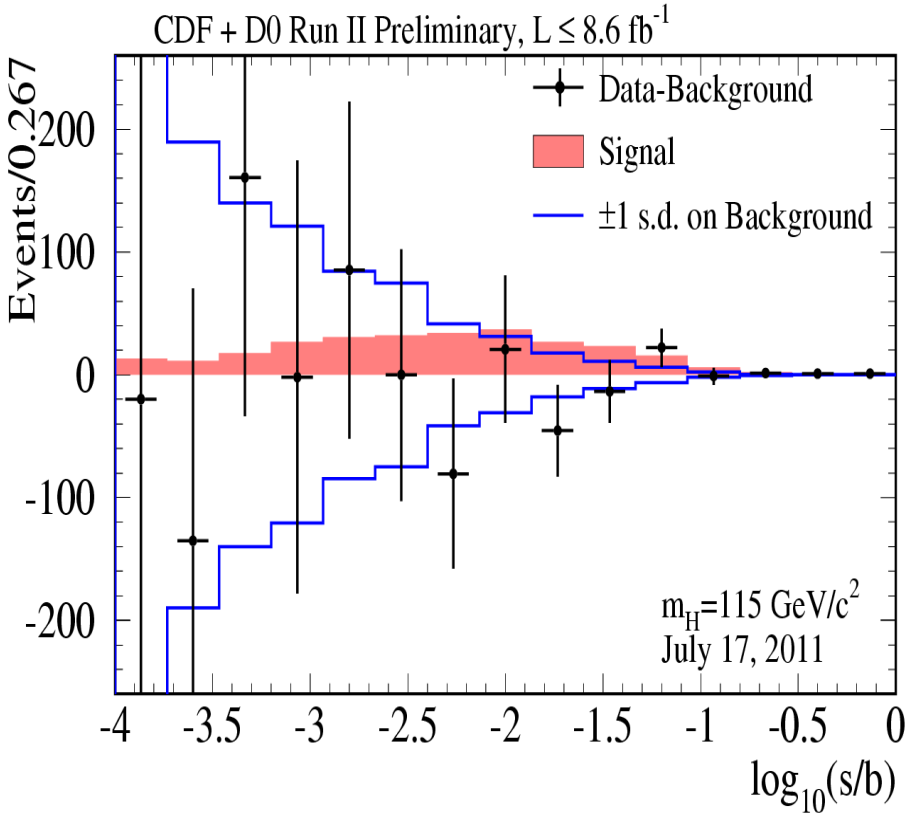




Cumulative Discriminant

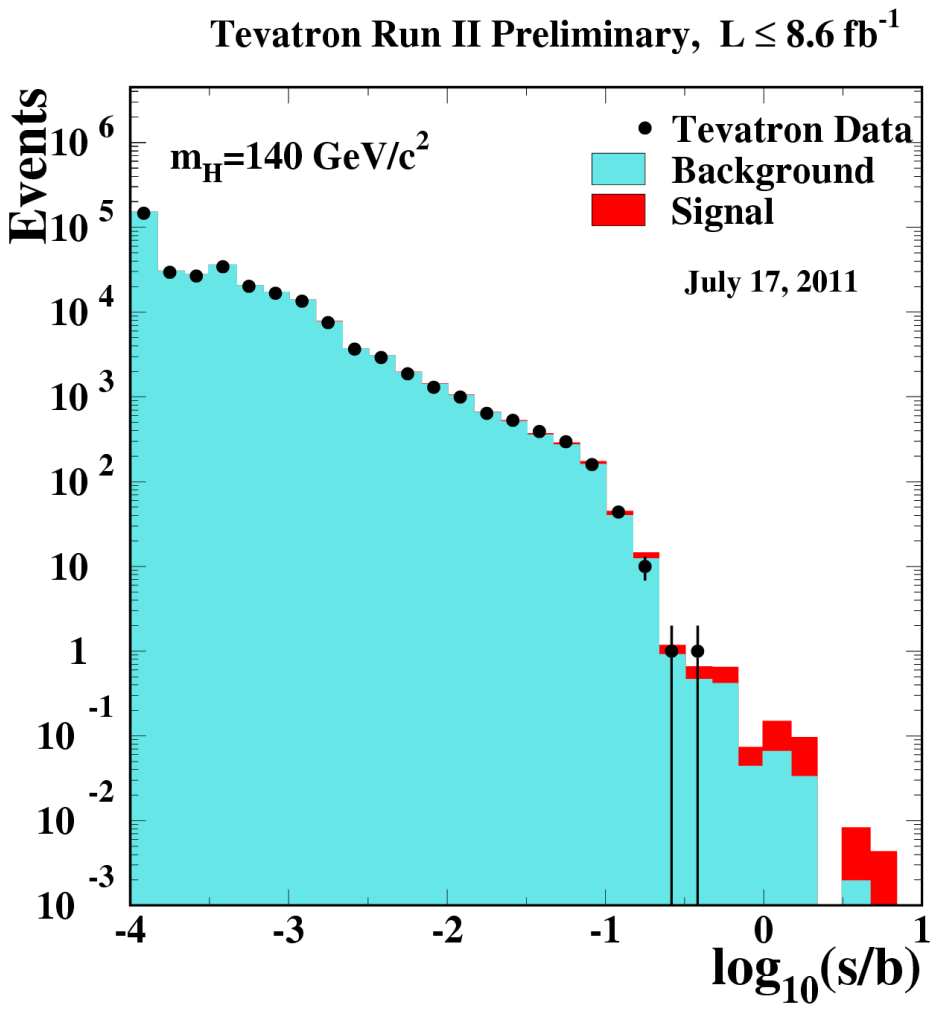
- Sum events from all channels, ordered by S/B for M_H=115 GeV.

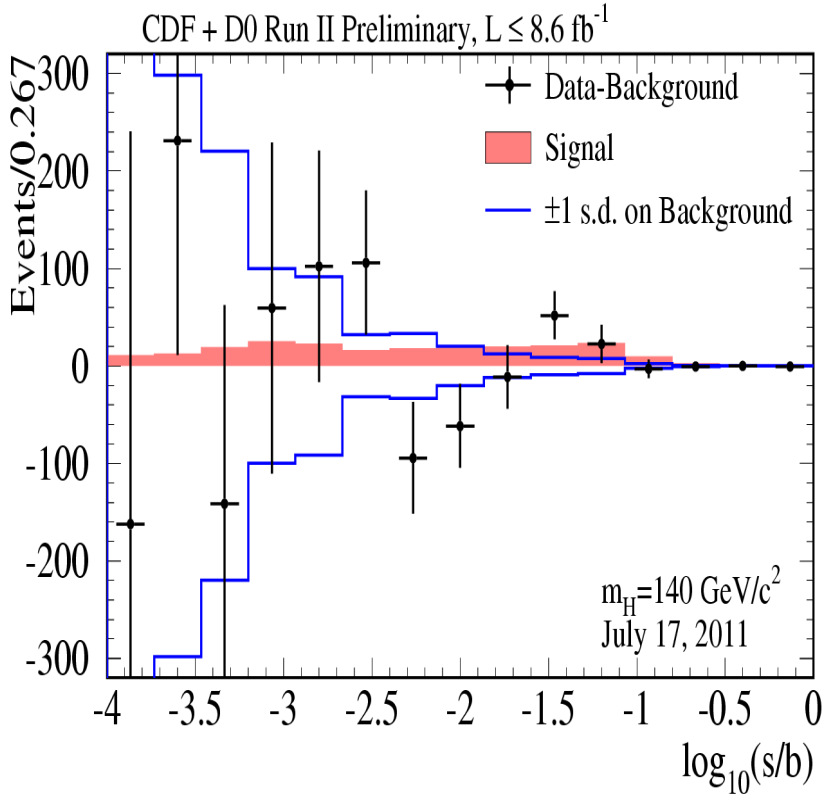




Cumulative Discriminant

- Sum events from all channels, ordered by S/B for M_H=140 GeV.



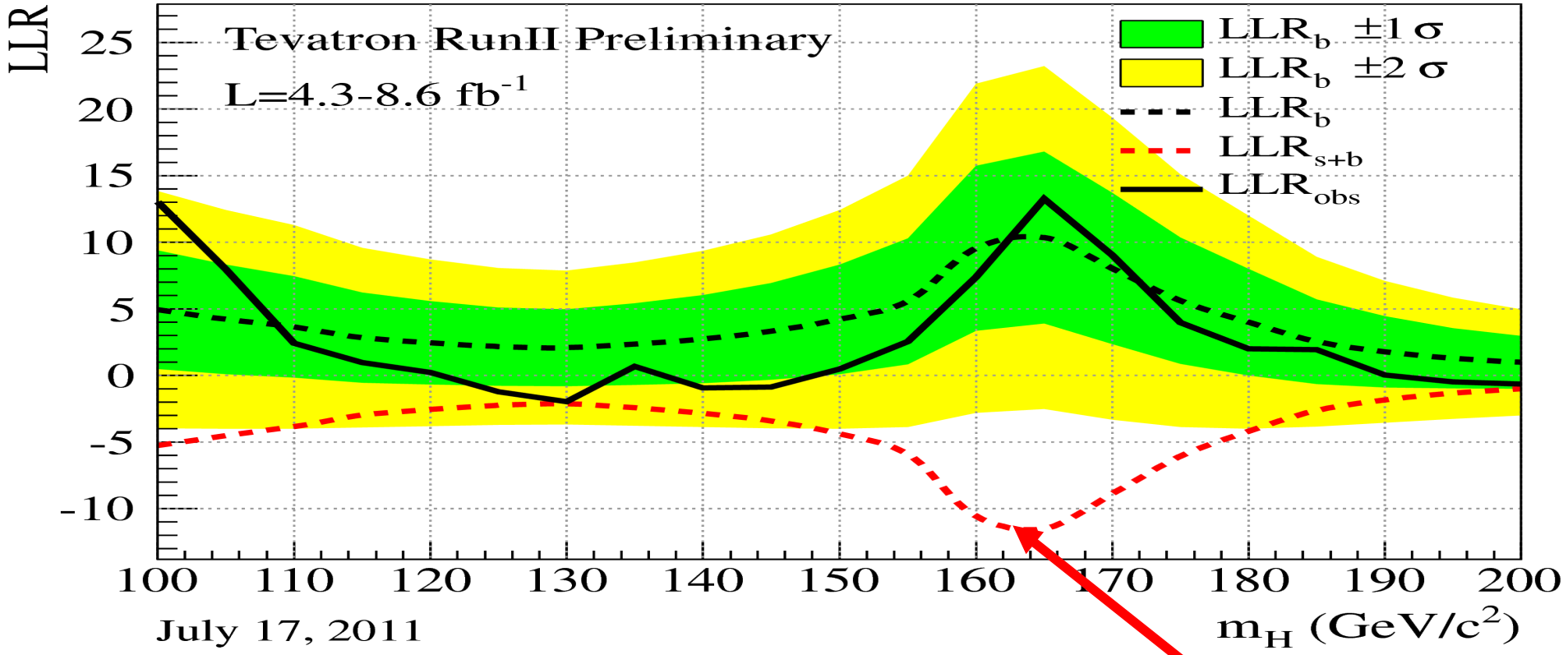


Combination Methods

- Two limit setting methods used and provide cross check.
  - Using distributions of final discriminant, not just event yields.
  - Using Poisson statistics for all bins.
  - Systematic as nuisance parameters with truncated Gaussian.
- **Bayesian Method (CDF), integrating over likelihoods:**
  - based on credibility, uses a prior
  - “How likely is the real value below limit?”
- **Modified Frequentist Method (DØ), CLs test statistics:**
  - comparing 'b-only' & 's+b' hypotheses
  - based on coverage, using pseudo-experiments
  - “How likely is the limit above the real value?”

Tevatron Sensitivity

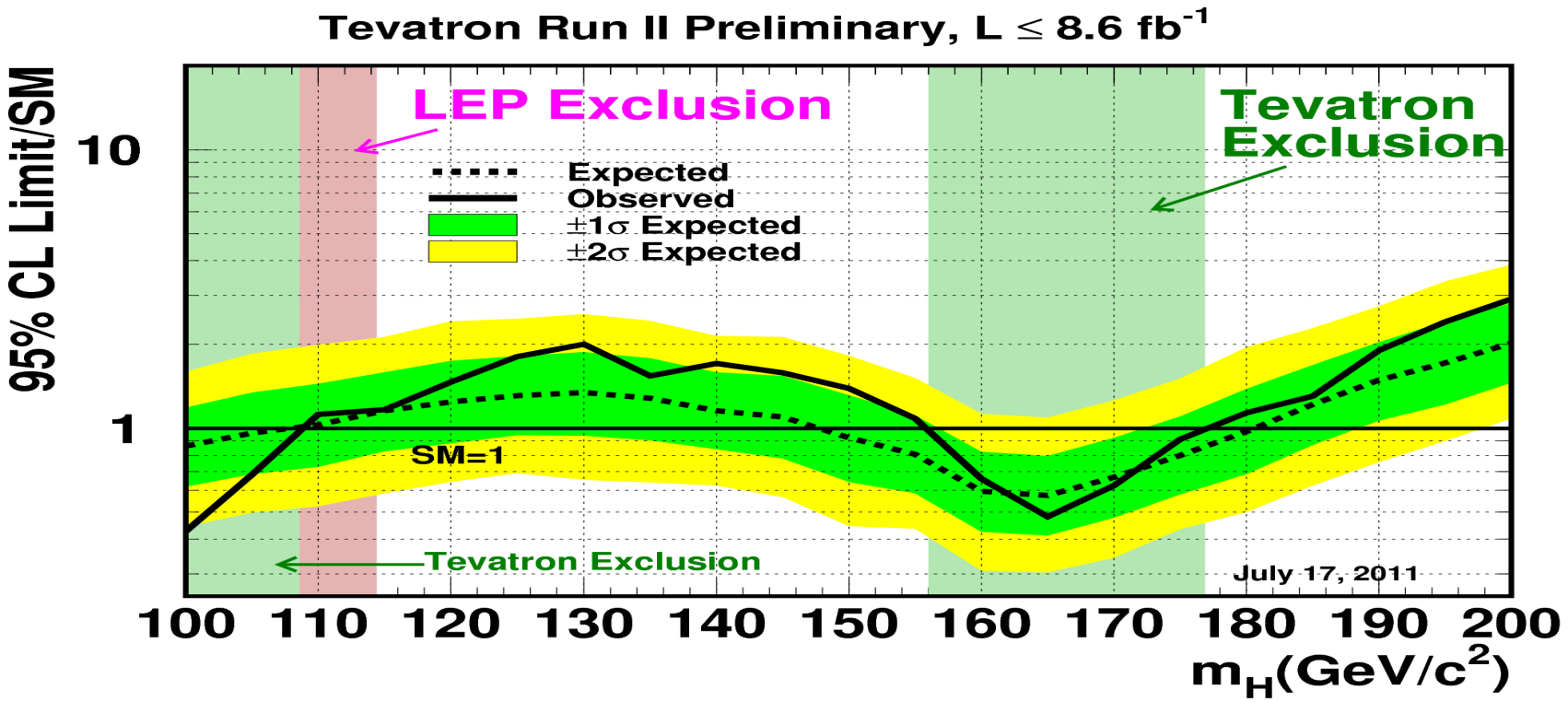
- **Log-likelihood Ratios (LLR): LLR_b, LLR_{s+b}, LLR_{obsv}**
- **Separation between LLR_b and LLR_{s+b} is the search sensitivity**



We could be seeing a ~ 3 σ excess if Higgs was at 165 GeV!

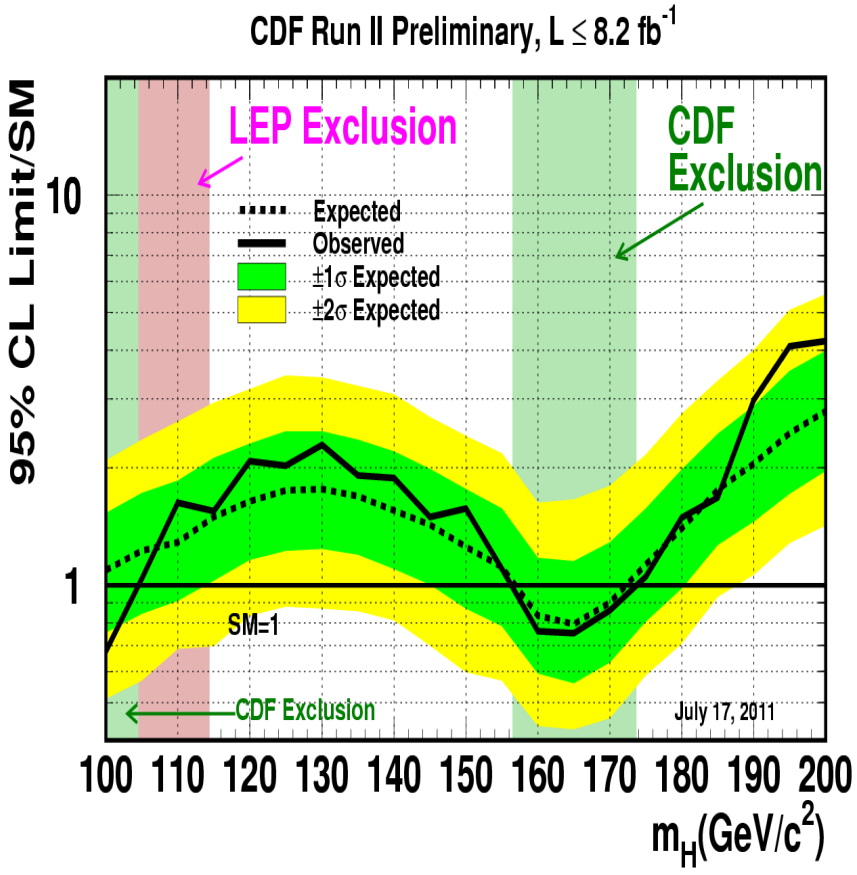
Tevatron Combination

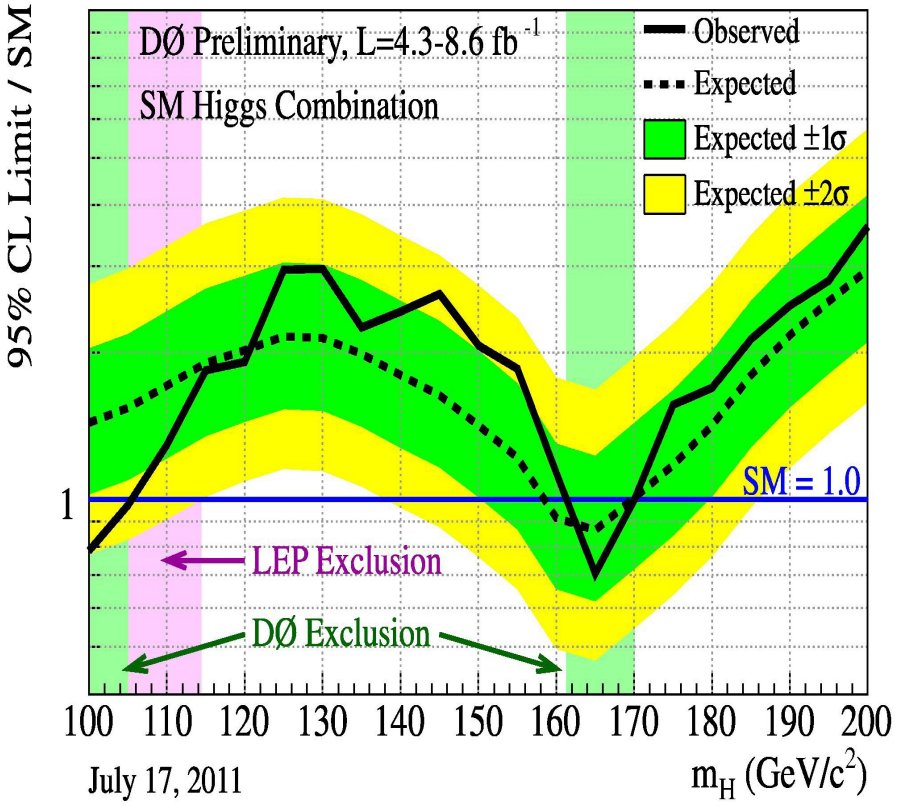
- **Observed Exclusion:** **$100<M_H<109$ & $156<M_H<177$ GeV/c^2 @95%CL.**
- **Expected Exclusion:** **$100<M_H<108$ & $148<M_H<181$ GeV/c^2@95%CL.**



CDF/D0 Limits

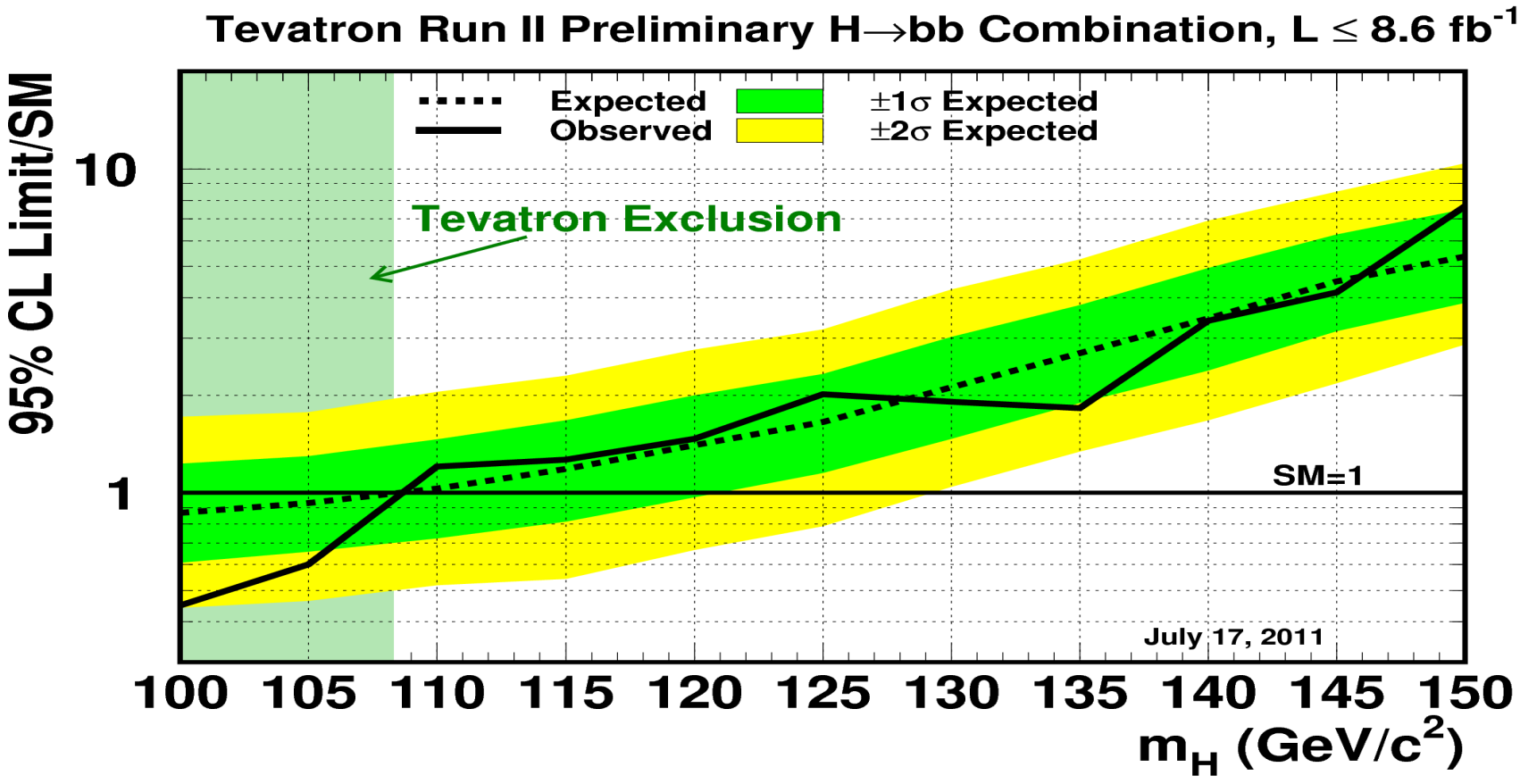
- Comparable sensitivity and Consistent results





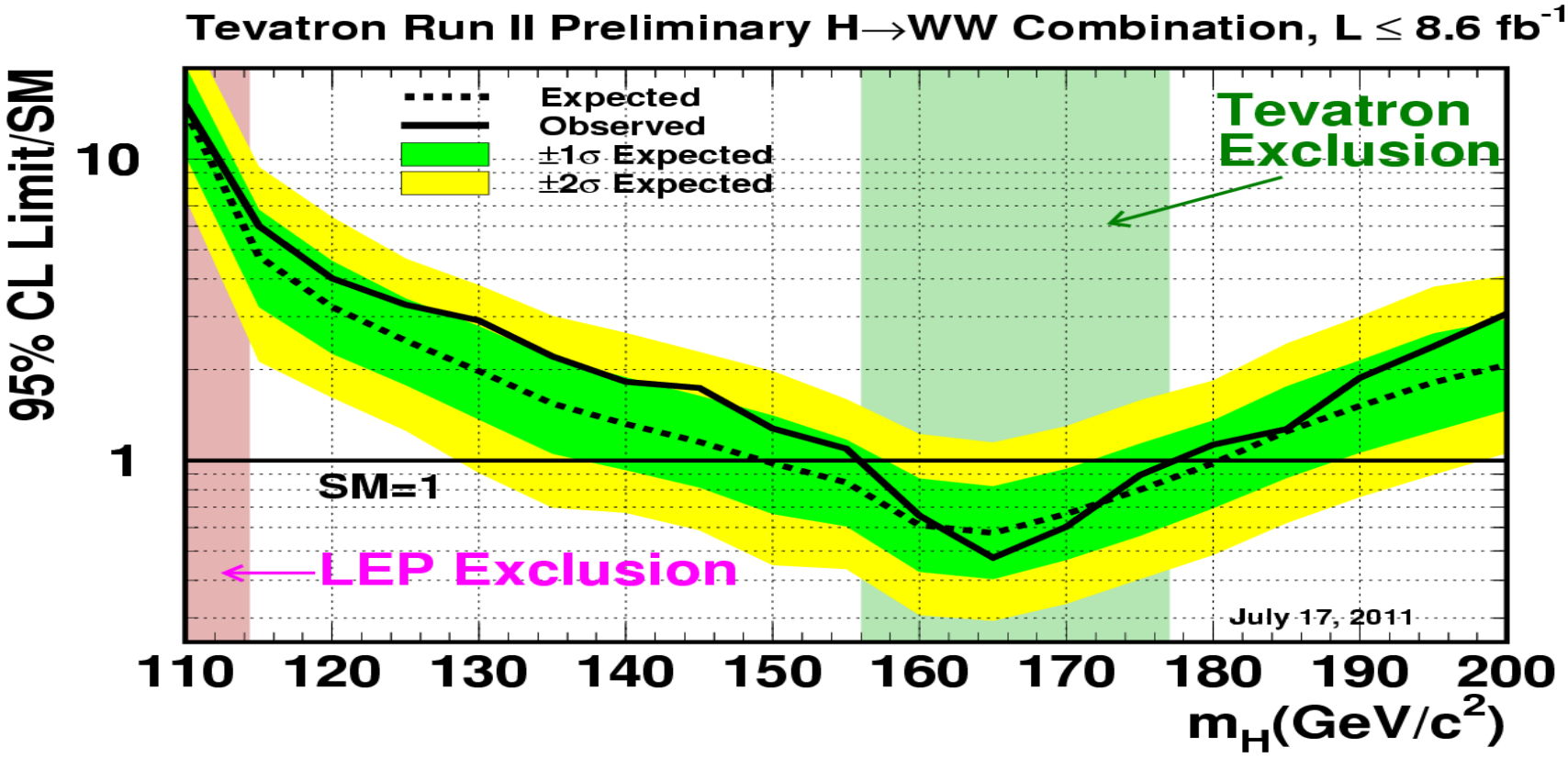
Tevatron H→bb Combination

- Combining H→bb channels only.



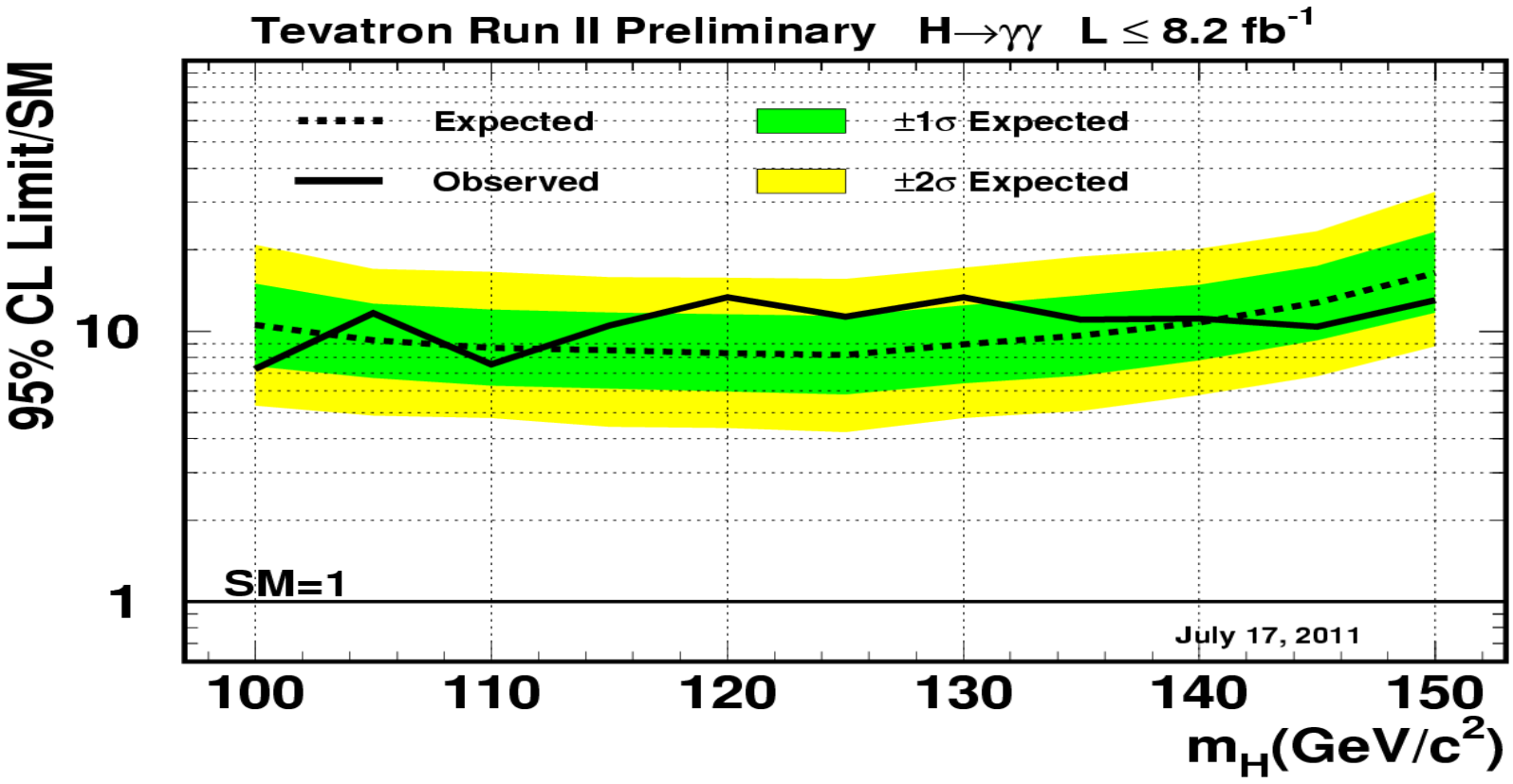
Tevatron H→WW Combination

- Combining H→WW, channels only.



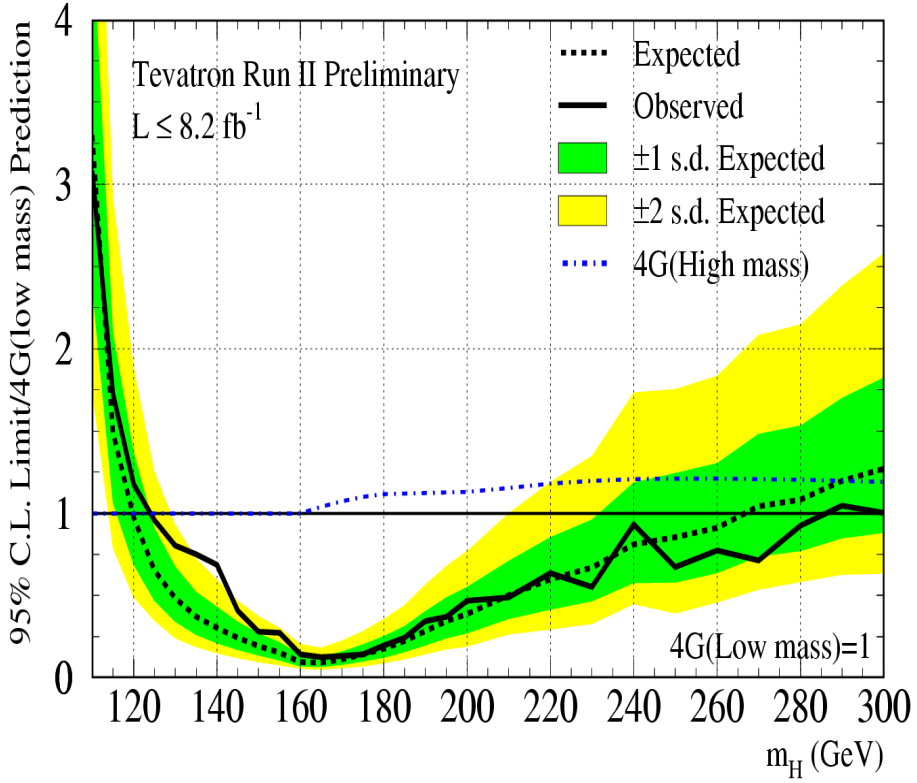
Tevatron H→γγ Combination

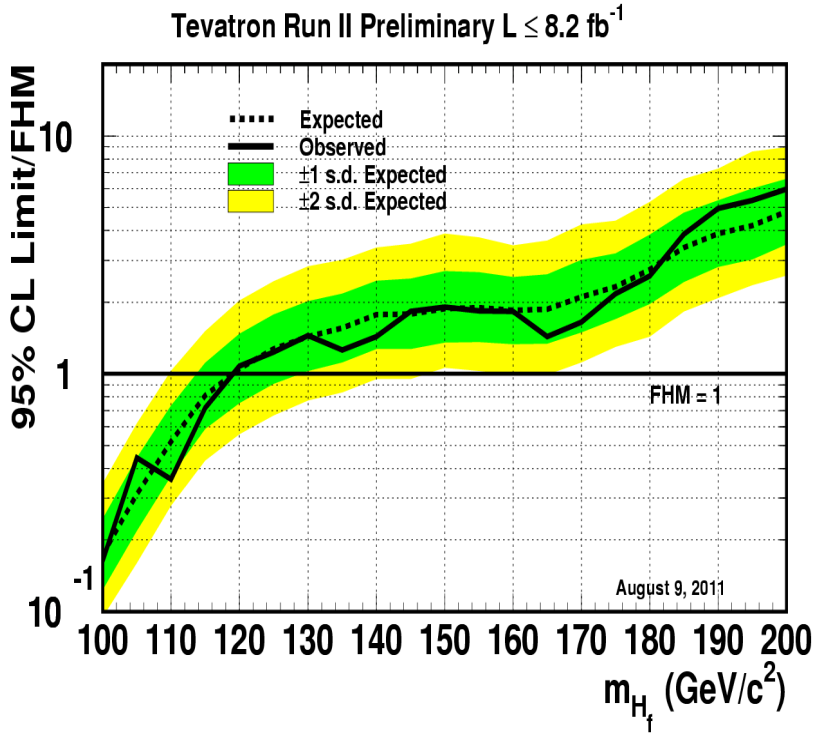
- Combining H→γγ, channels only.



Constrains on 4th Generation, Other Exotic Models

- 4th Gen model enhanced production σ(gg→H) by a factor of 9, reinterpret H→WW limit, exclude 124<M_H<286 GeV@95%C.L.
- Combining H→γγ, WW limit in fermiophobic model, exclude M_H<119 GeV@95%CL.





Conclusion

- Tevatron had a great run for last 28 years operation.
- With 10 fb^{-1} analyzable dataset and anticipated improvement, Tevatron will remain competitive to reach 95% CL exclusion sensitivity over the M_H range up to 185 GeV/c^2 next year.