Search for SM Higgs Boson at the Tevatron

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On behalf of the CDF and D0 Collaborations

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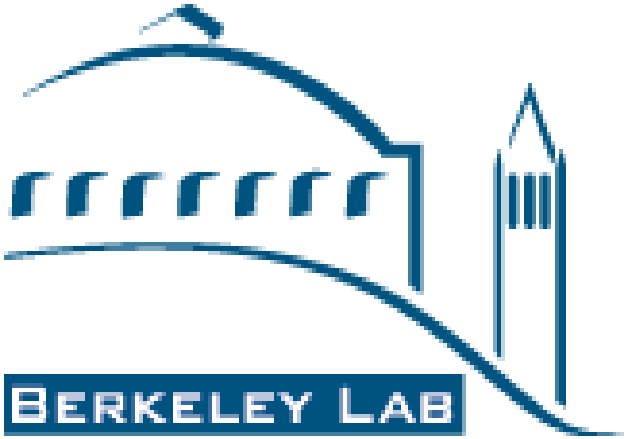


Outline

- Introduction
- SM Higgs Search Strategies and Challenges
- Recent Results
- Future Prospects
- Conclusion

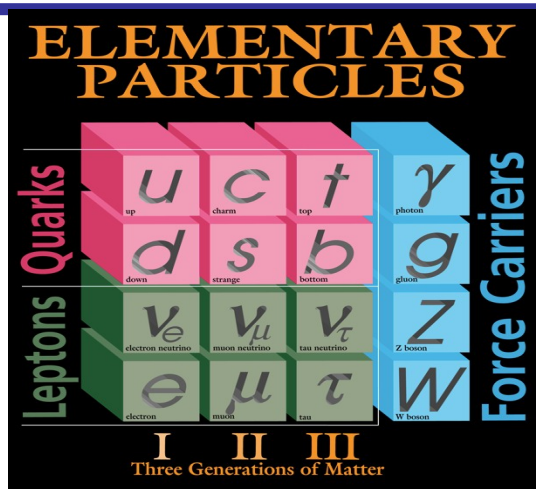
More Details:

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

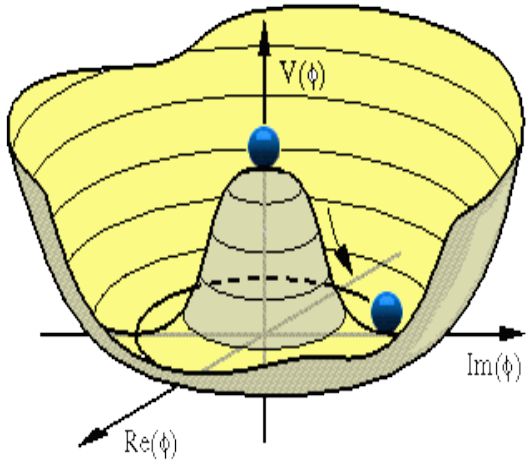
http://www-d0.fnal.gov/Run2Physics/D0Summer2011.html

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

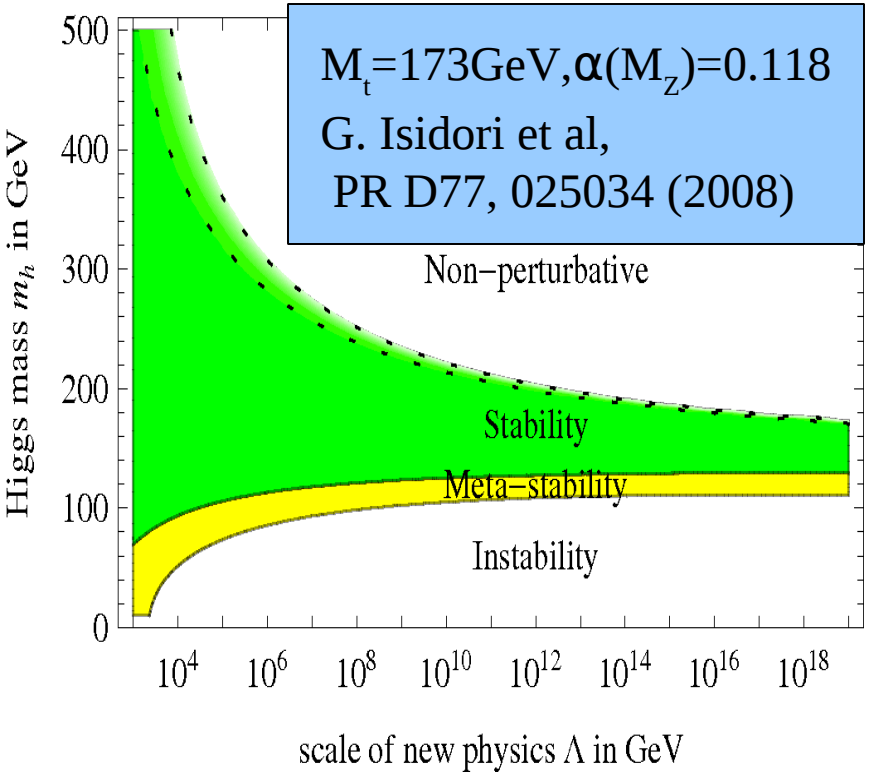
Introduction

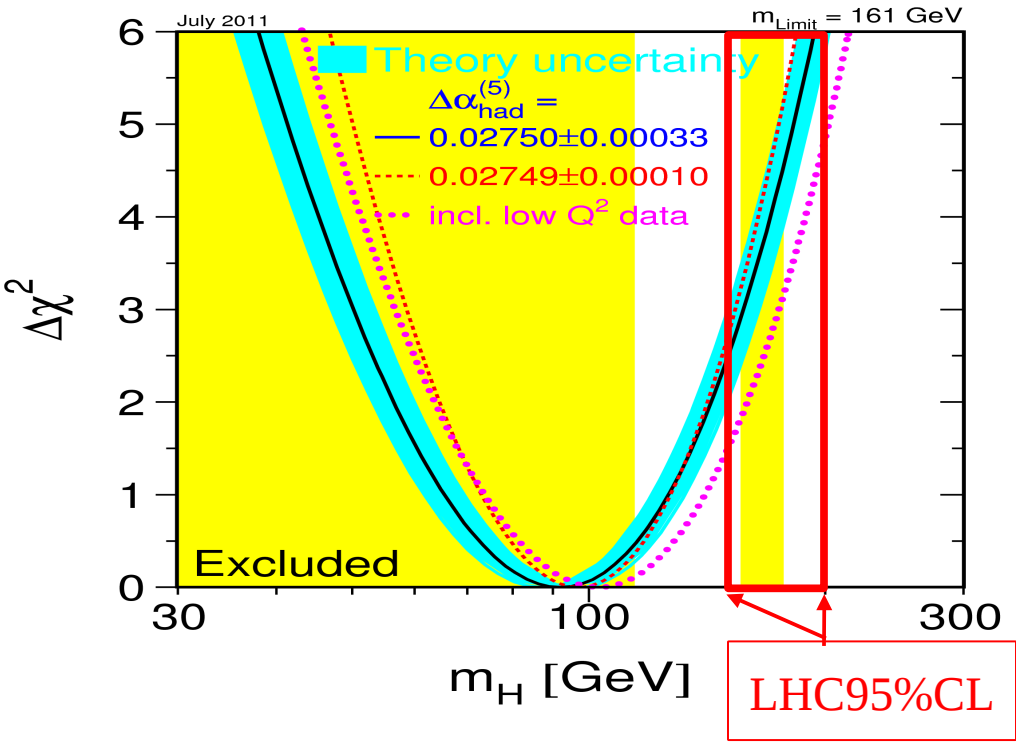


- The Higgs boson is the last unobserved particle postulated in SM to explain the origin of mass in the universe.
- **Observation of the Higgs boson or like is a longstanding key objective to probe the mechanism of electroweak symmetry breaking(EWSB).**
- **Window of opportunity:** With full dataset and improved analysis, Tevatron could add crucial information H→bb that is more difficult to detect at LHC.
- **Recent data from LHC leave significantly less room for the Higgs boson to hide.**



State of Higgs Mass

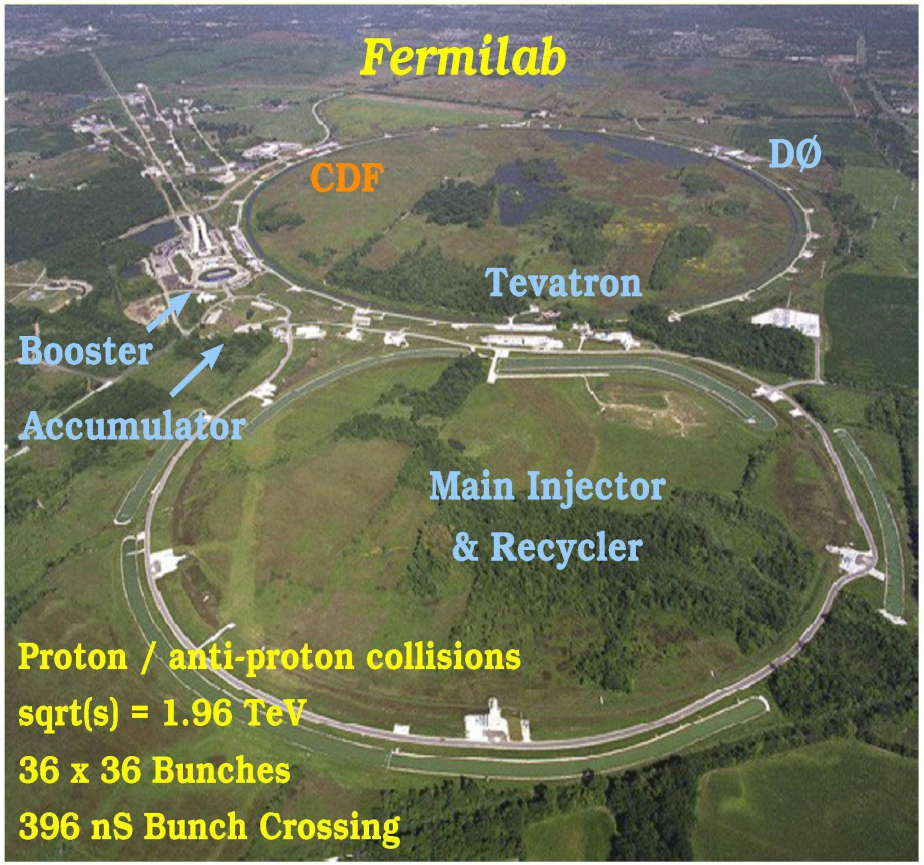


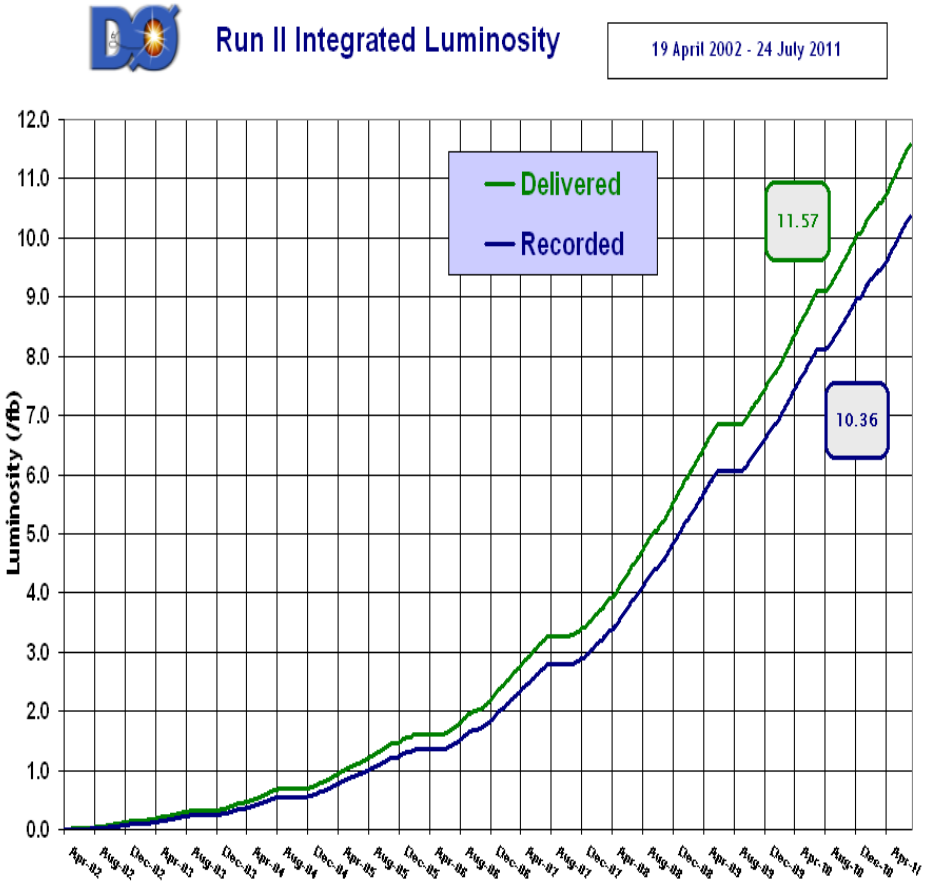


- **Theoretical Limits:** vacuum stability and perturbativity.
- **Direct from LEP+Tevatron+LHC:** M_H>114.4 & Not [150,193] GeV/c^2
- **Indirect from EW data:** M_H<161 GeV/c^2 @ 95% CL
- The low mass bound sets scale of new physics up to 10^6 GeV.

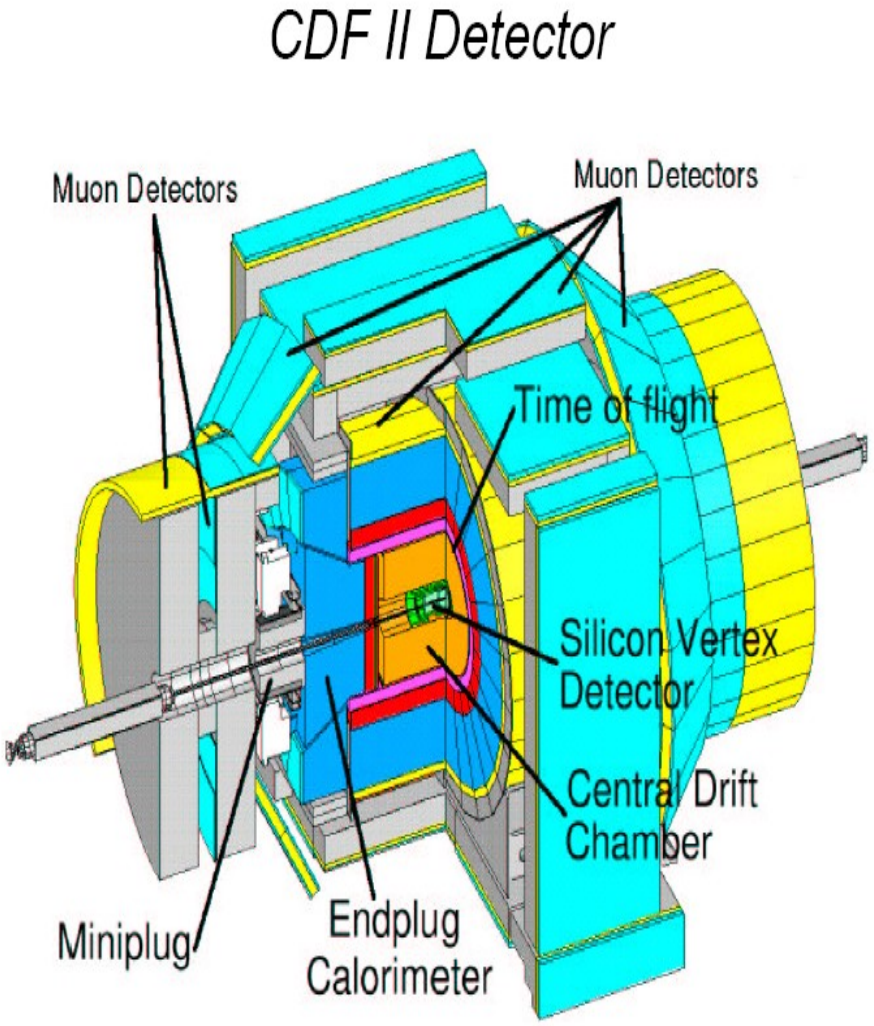
The Tevatron

- Tevatron: p-pbar collision@1.96TeV, $L_{peak}=4.3\times10^{32}\ cm^{-2}s^{-1}$
- Expect > 10 fb^{-1} analyzable data before shutdown by 9/30/2011.
- Most results presented here are based on ~8 fb^{-1}.





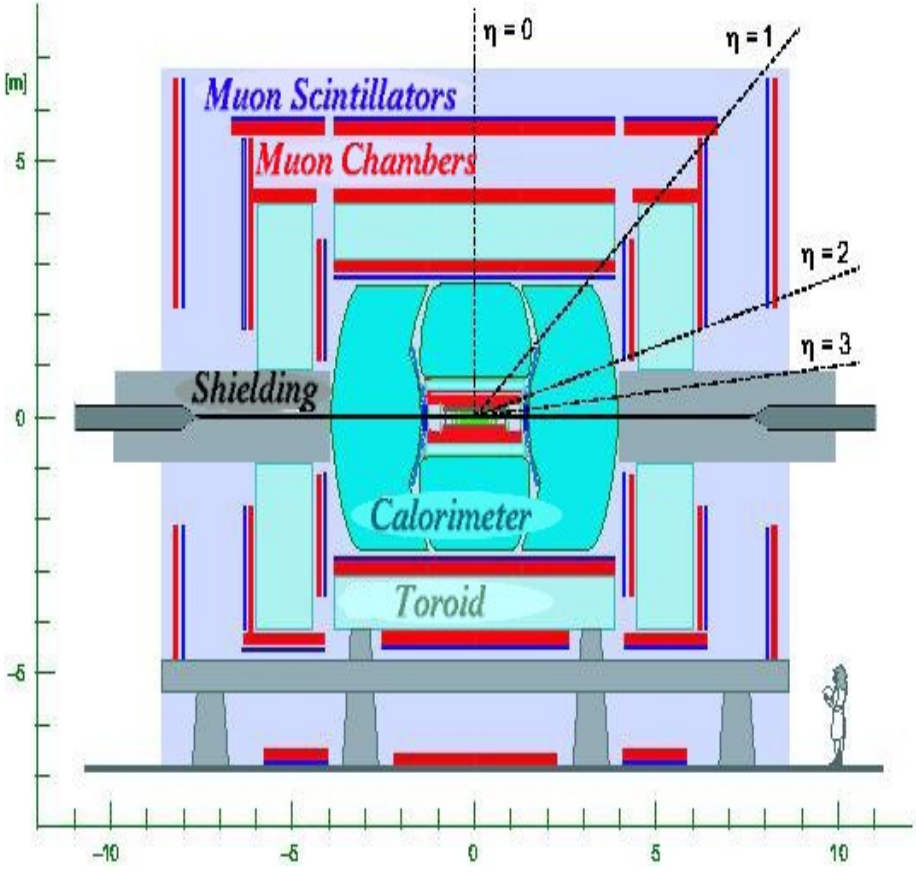
General-purpose Detectors



Excellet:

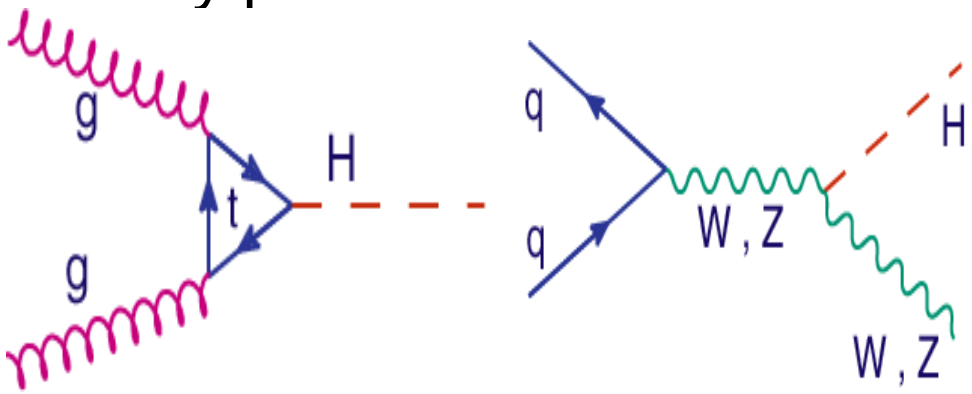
- Lepton ID
- Tracking, Vertexing
- Jets, Missing Et

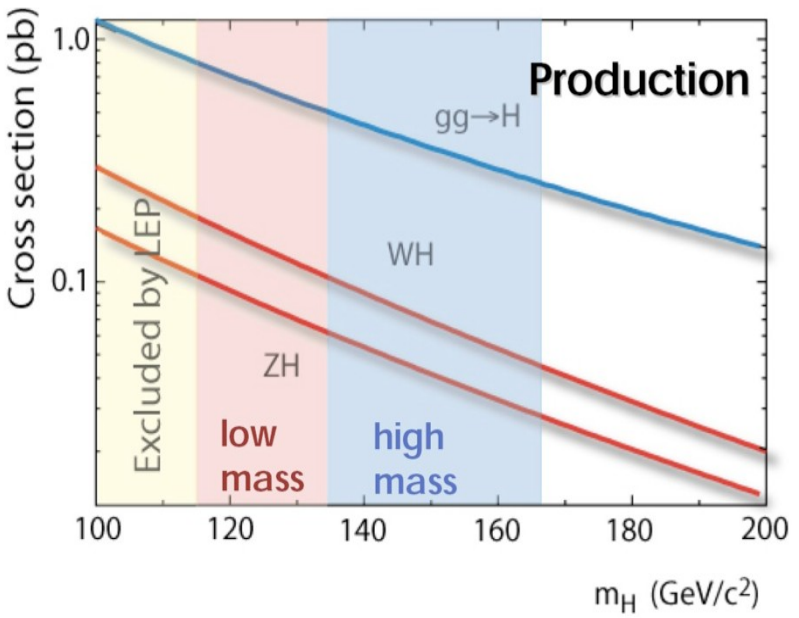
D0 Detector



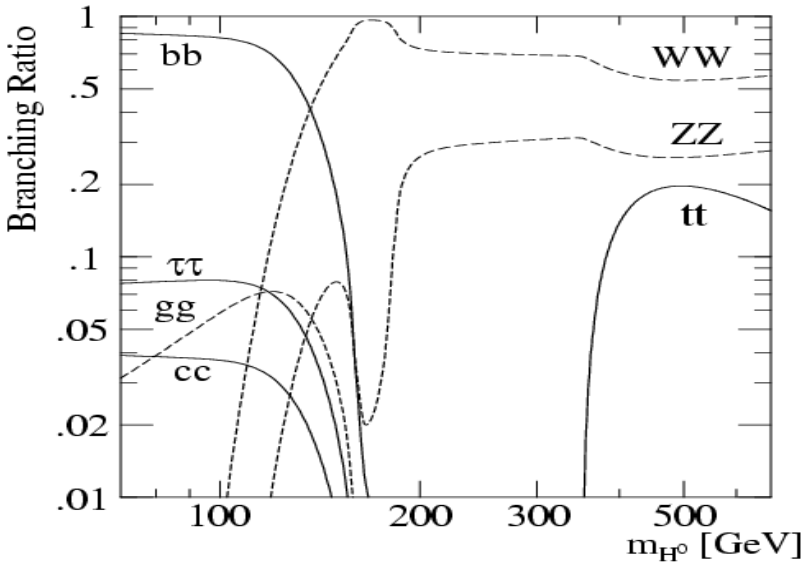
SM Higgs Production and Decay @ Tevatron

- Primary production modes are:





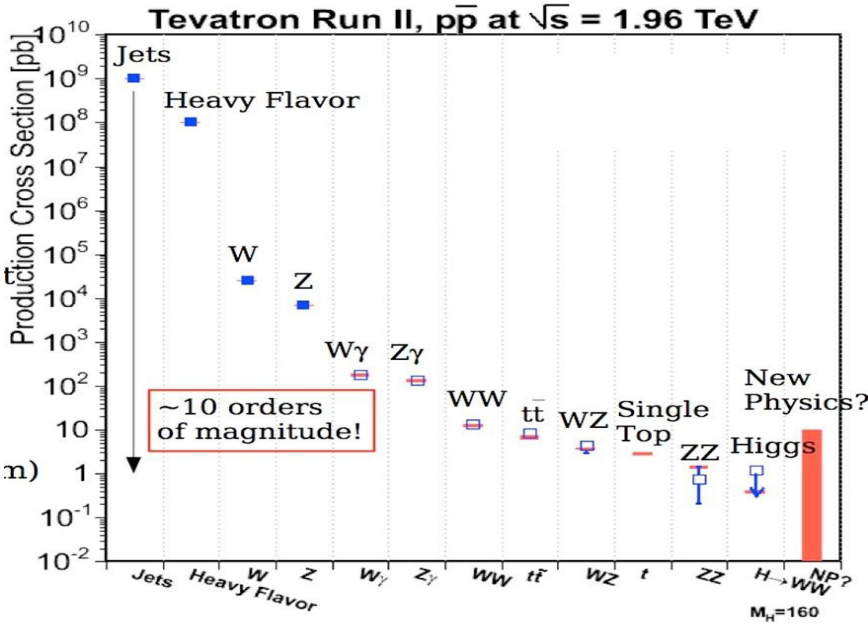
- For higher mass(M_H>135 GeV)
  - Mainly decays: H→WW, ZZ

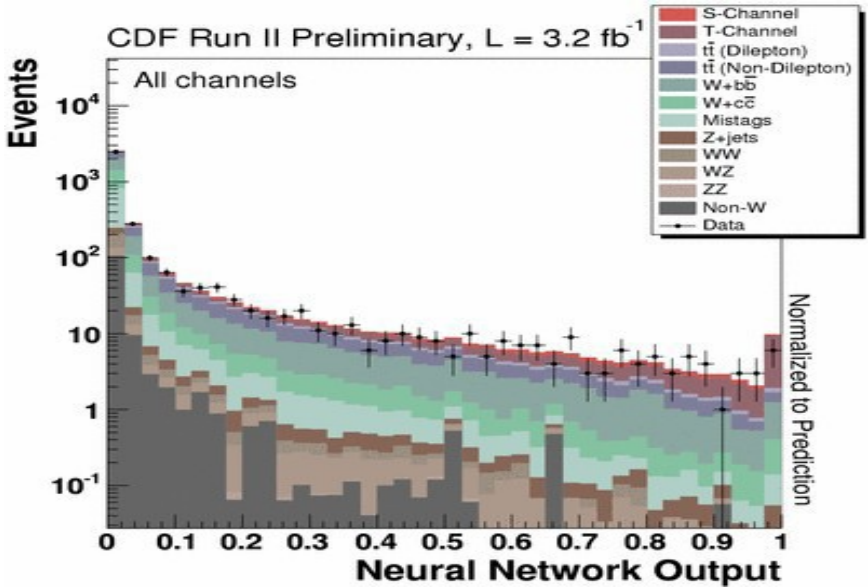


- For lower mass(M_H<135 GeV)
  - Main decay: H→bb in WH/ZH
  - Also H→γγ, ττ
  - Direct production gg→H is limited by multi-jet QCD background

The Challenges

- While Higgs events are rare, backgrounds are many orders of magnitude large.
- The challenge is how to separate small signal from huge backgrounds using advanced multivariate techniques.
- Observations of single top and diboson provide solid ground that these tools do work to separate small signal from large background.





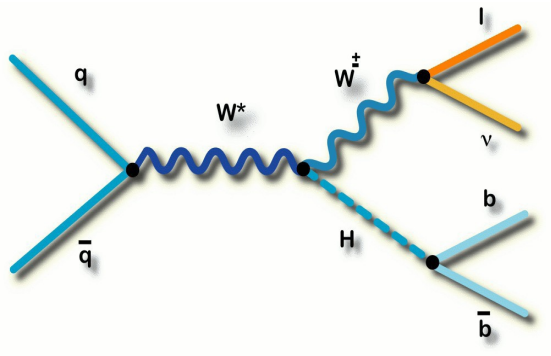
Tevatron Higgs Search Strategy

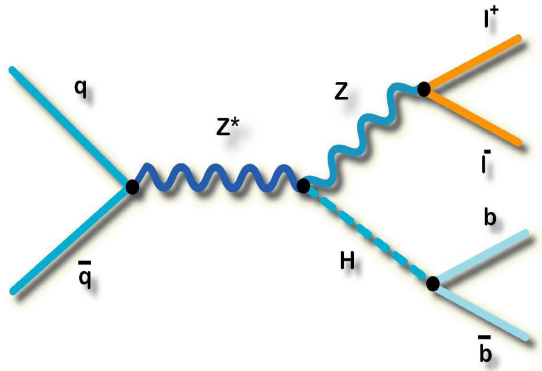
- The strategies are similar for the corresponding CDF and D0 analyses.
- **Maximize Signal Acceptances:**
  - **Utilize as much of detector as possible**
  - **Improving lepton ID and additional triggers**
- **Separate these samples into multiple analysis channels:**
  - **lepton type, btag and jet multiplicity (S/B).**
- **Carefully model all background:**
  - **Cross check using control regions in data.**
- **Use advanced MVA tools:**
  - **to isolate signal from background.**
- **Our goal is to leave no Higgs events behind, combine everything at end.**

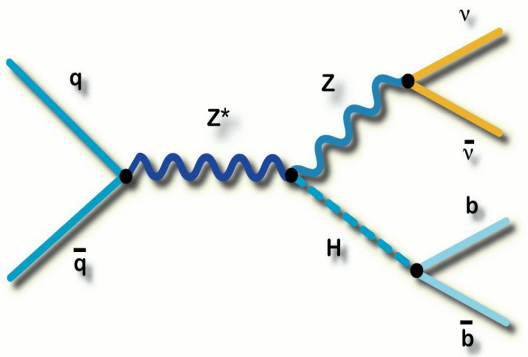
Improving S/B

- In order to improve S/B, need to utilize full kinematic event information with advanced multivariate techniques:
  - LO Matrix Elements (ME): are used to calculate event probabilities and likelihood ratios.
  - Neural network (NN): combine various kinematic variables, including ME into a final discriminant.
  - Boosted Decision Tree (BDT): an alternative to NN
- Typical Improvement is ~25% respect to use a single variable or cut-based analysis.
- However, the primary gains in recent years mainly from improved signal acceptance: more triggers, looser lepton ID, better b-tagging...

Low Mass Higgs Signitures





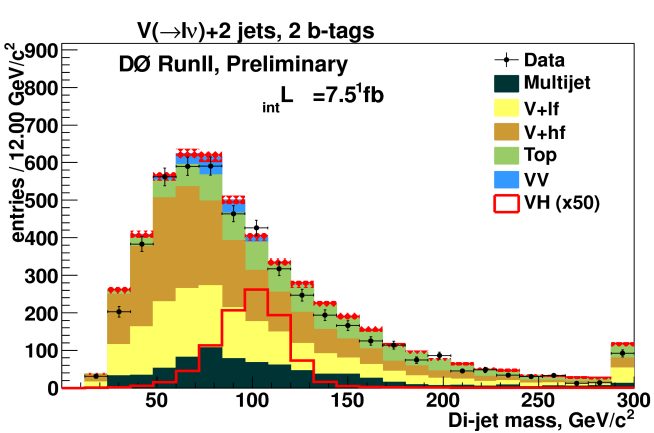


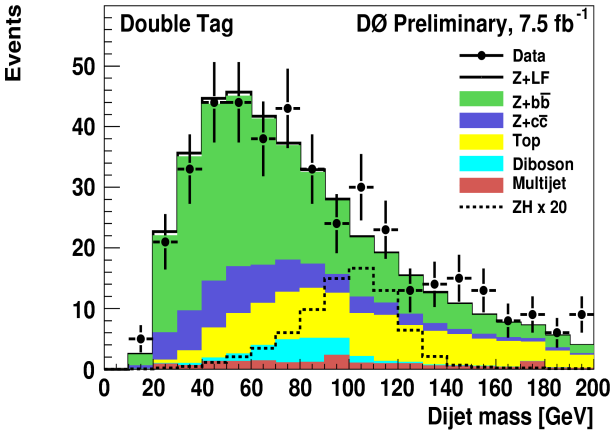
- Goal: search for dijet resonance H→bb

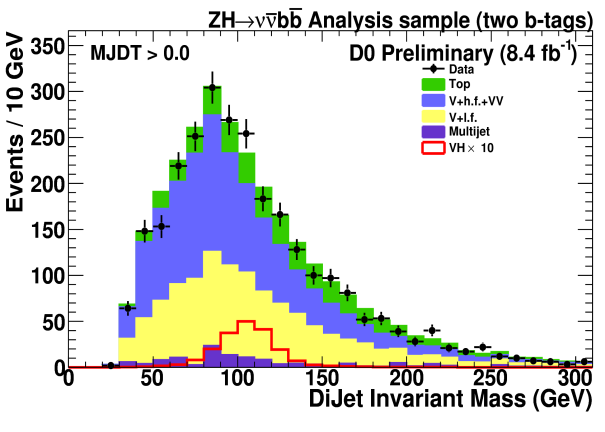
  WH→lνbb: 1 lepton + met + 2b

  ZH→llbb: 2 lepton + 2b

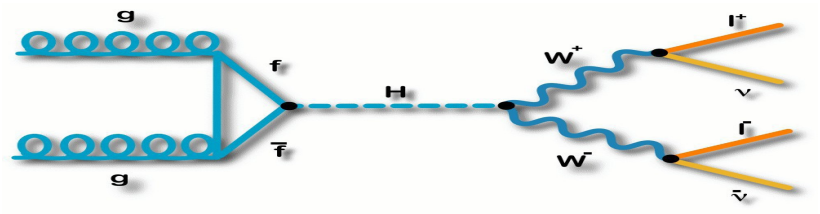
  ZH→νν̄bb, WH→(l)νbb: 0 lepton + met+2b

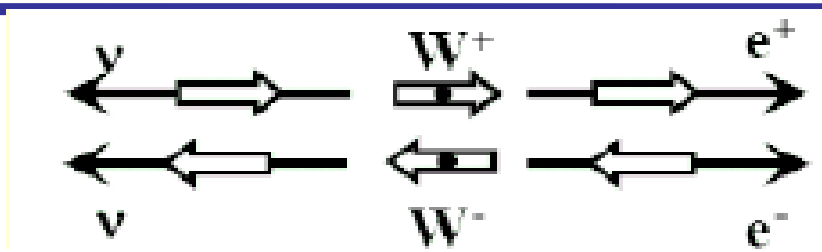




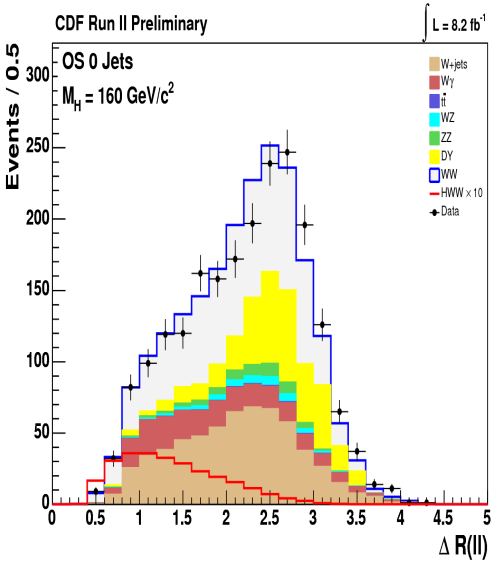


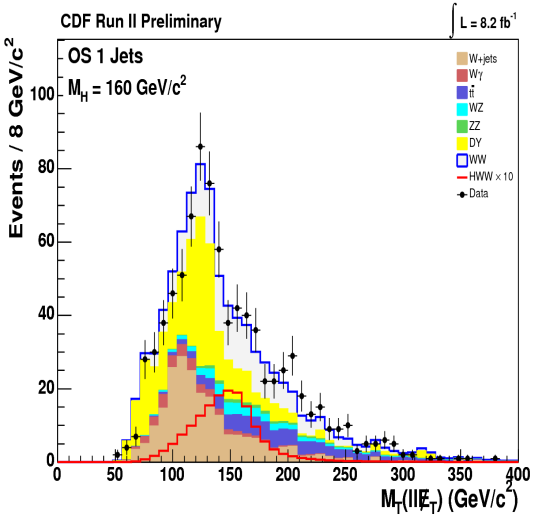
High Mass Higgs Signitures

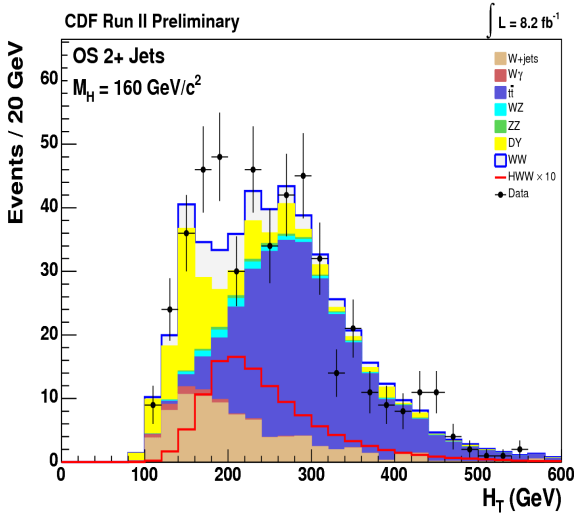




- Goal: search for H→WW, depend on how W decays:
  - H→WW→llνν: Opposite Sign Dilepton + MET + nJet (Most Sensitive)
  - H→WW→lνjj: Lepton + MET + 2Jet
  - VH→VWW: Same Sign Dilepton

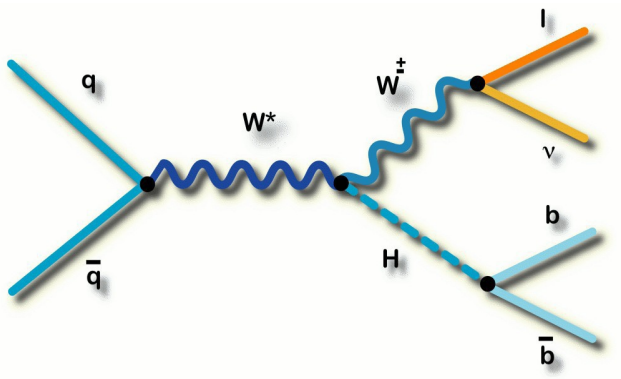


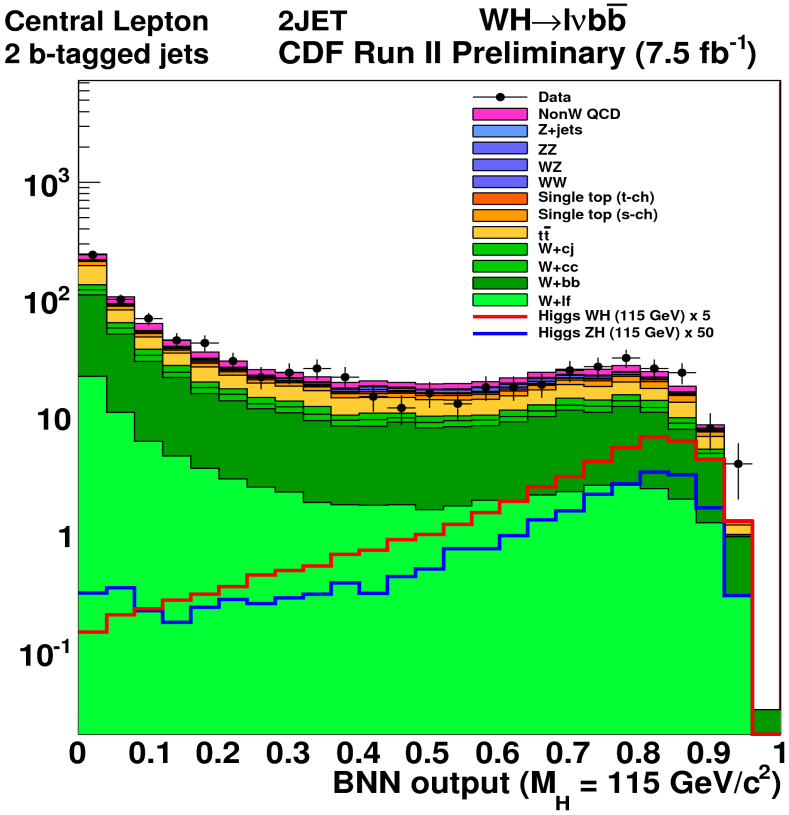


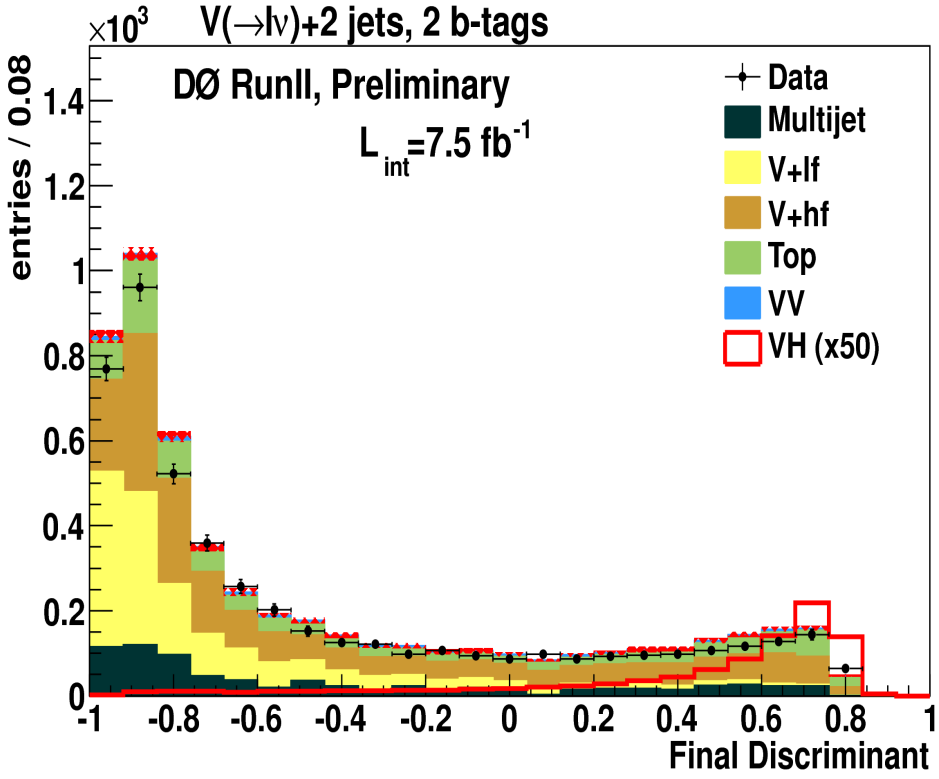


Search for WH→lνbb

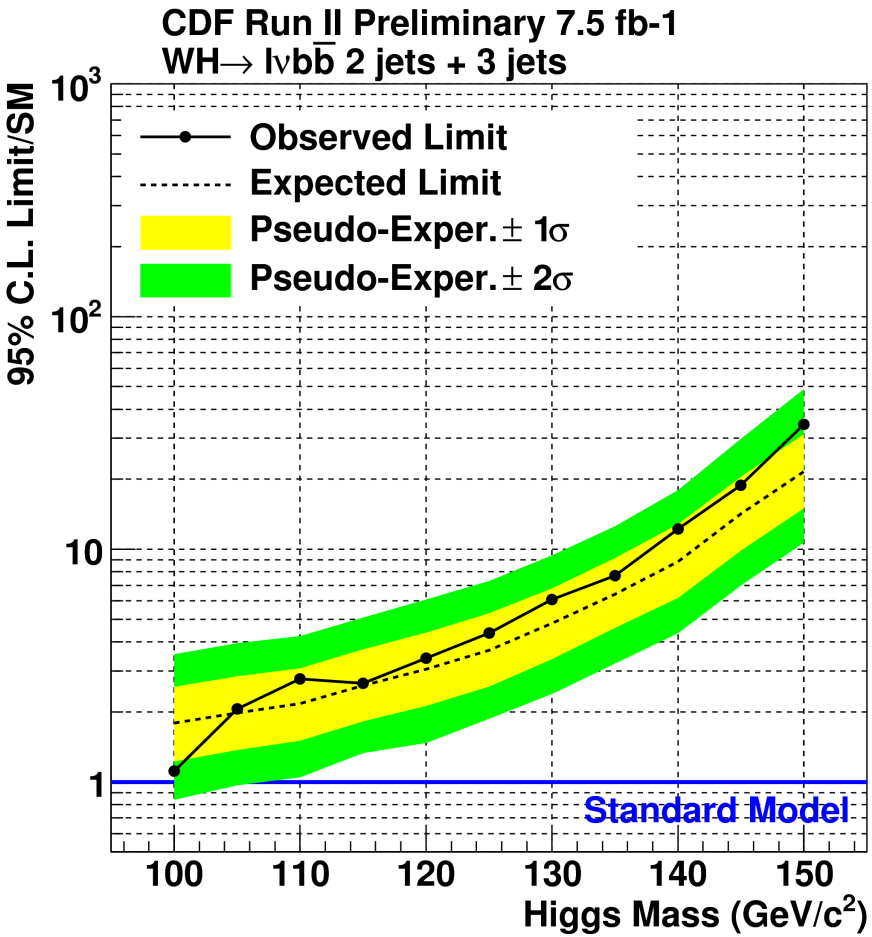
- WH→lνbb is one of most sensitive channel for low mass Higgs.
- Easy to trigger on lepton, missing Et
- Split 1 or 2 btags and MV discriminant.

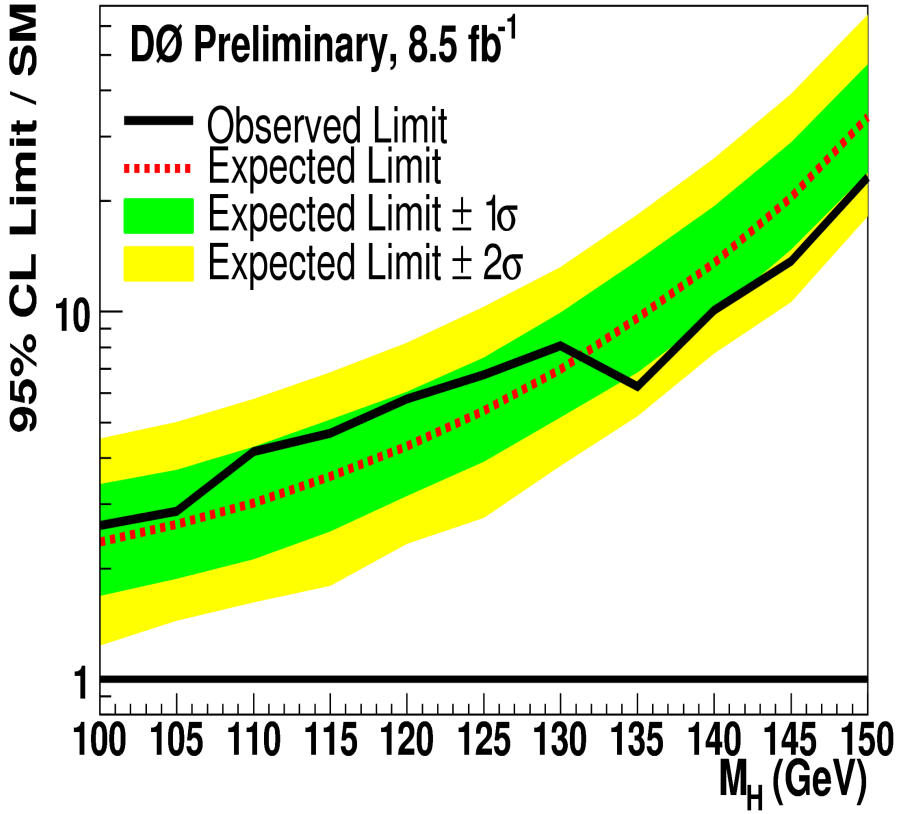






WH→lνbb Limits

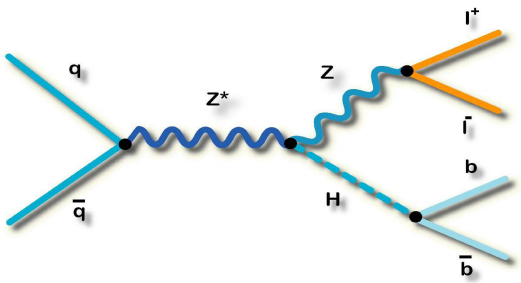


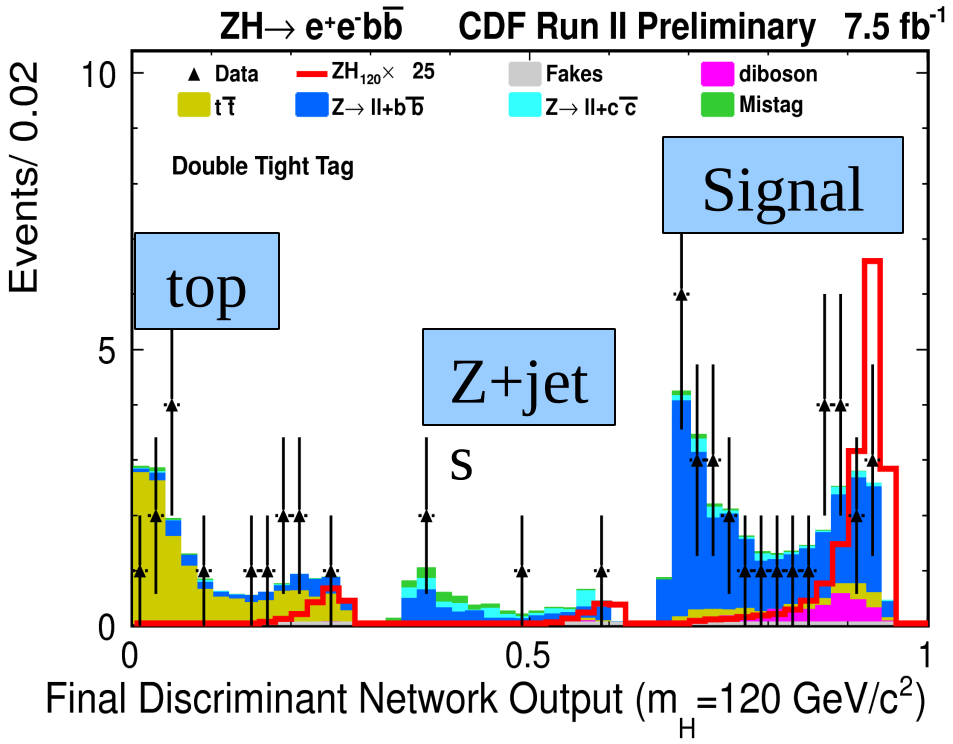


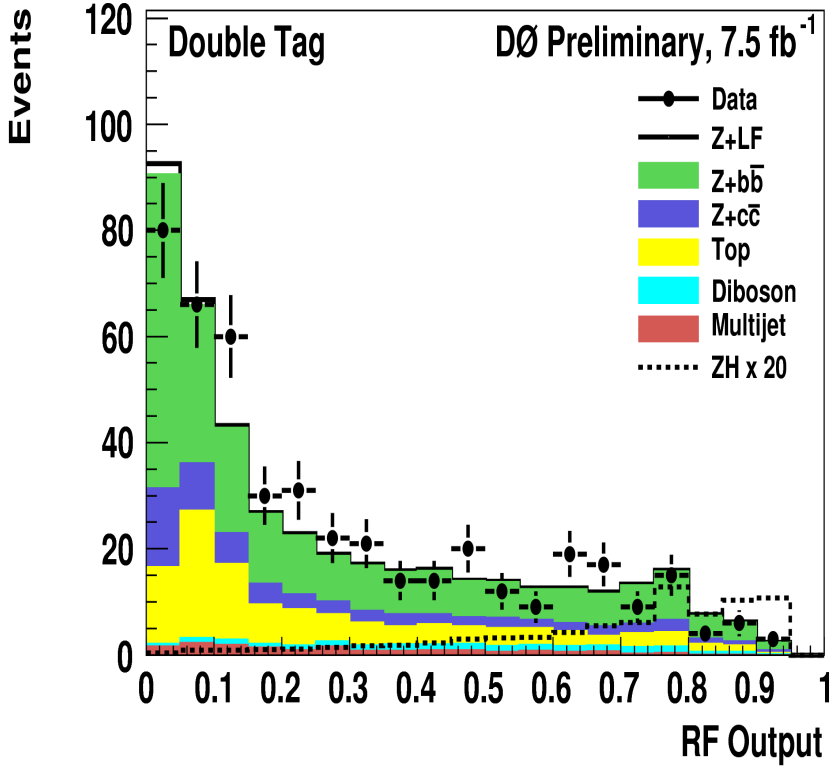
- Obs./exp. limits: 2.65/2.6(CDF) and 4.6/3.5(D0) @115 GeV
- Not competitive for a single channel, need to combine all channels and both CDF and D0.

Search for ZH→llbb

- Low event rate but clean signature
- Select two high Pt leptons (tight and loose)
- Split off 1 or 2 b-tags and MV Discriminant.



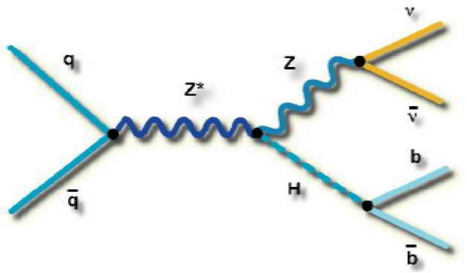


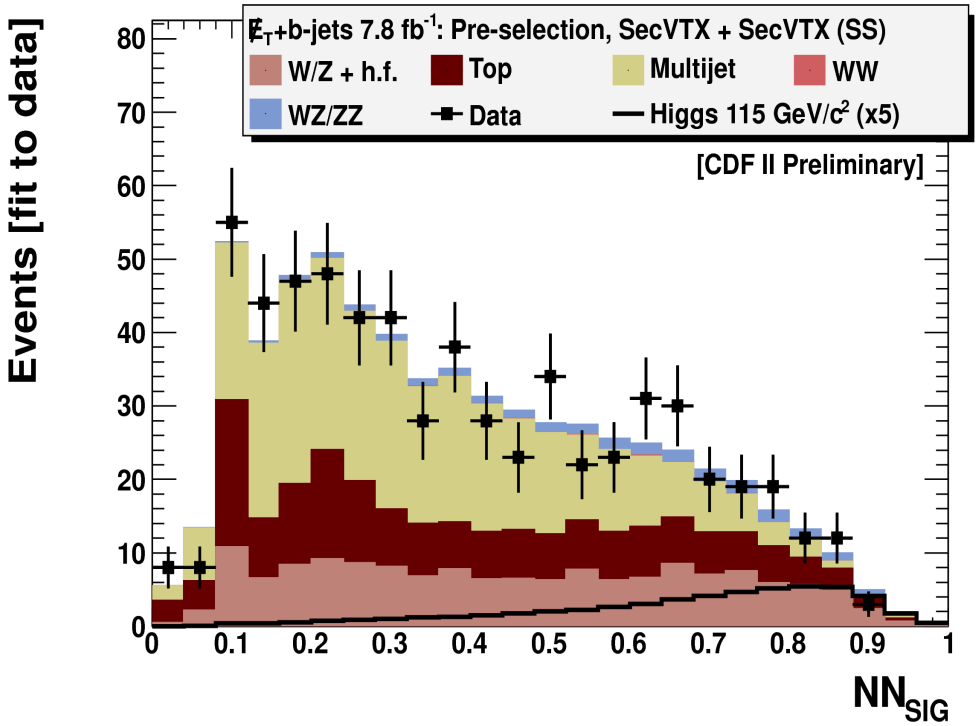


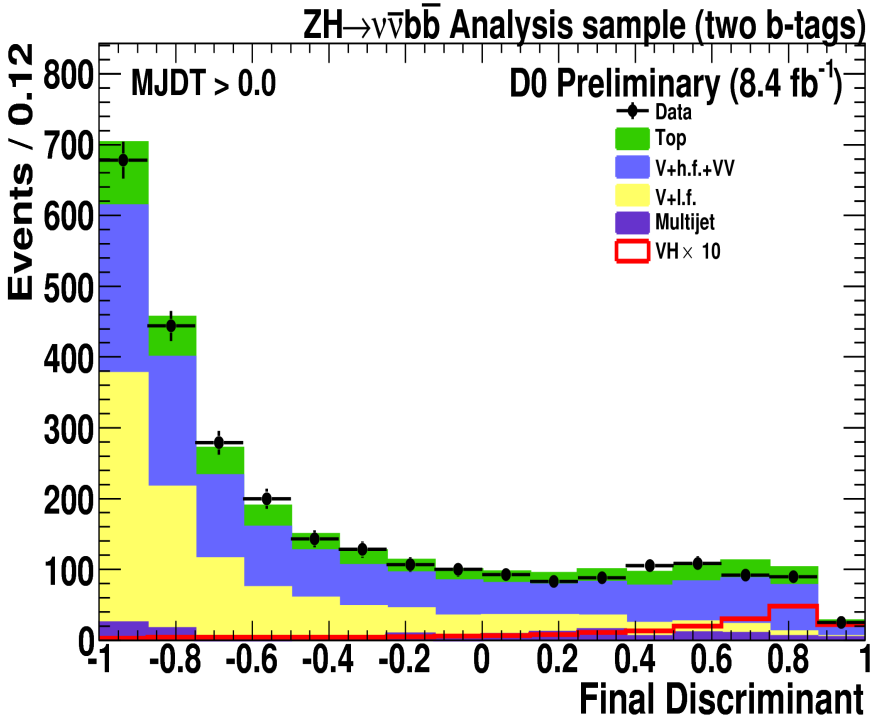
- Obs./exp. limits: 4.8/3.9(CDF) and 4.9/4.8(D0) @115 GeV

Search for ZH→vvbb, WH→(l)vbb

- Large xsec*BR, but large QCD difficulty
- Require Met>50 GeV + 2jet
- Split off 1 or 2-btags and MV discrimiant.



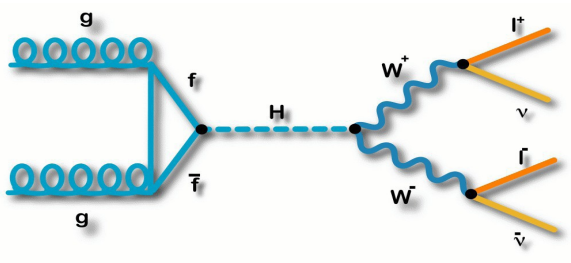


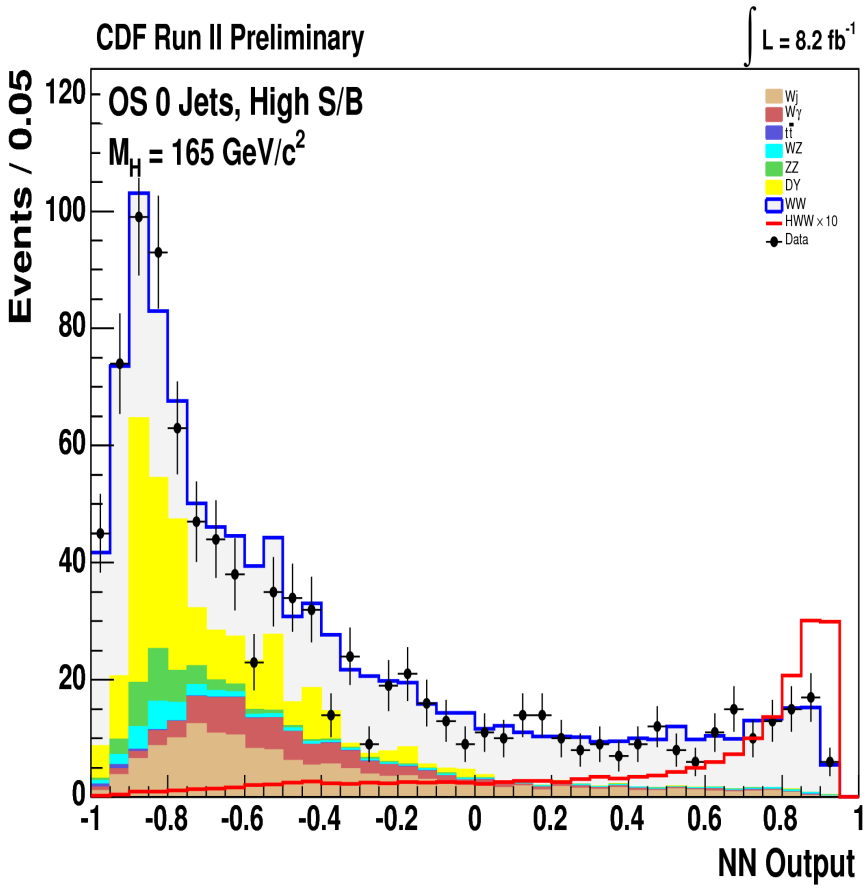


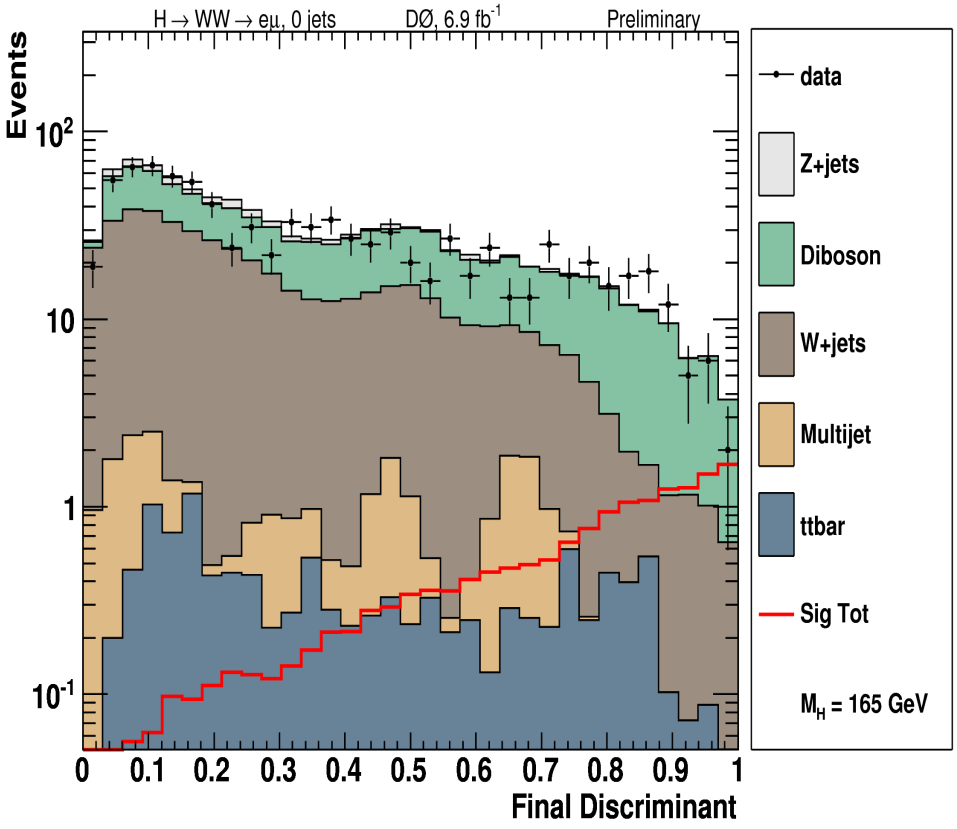
- Obs./exp. limits: 2.3/3.0(CDF) and 4.0/3.2(D0) @115 GeV

Search for H→WW→lνlν

- Selecting dilepton+met,split of n jets.
- Key: maximizing lepton acceptance
- Combining event Kinematic to a MVA



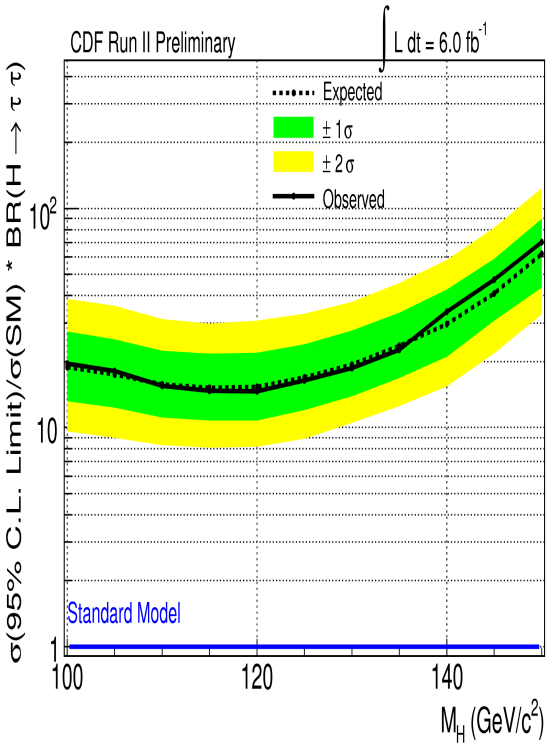




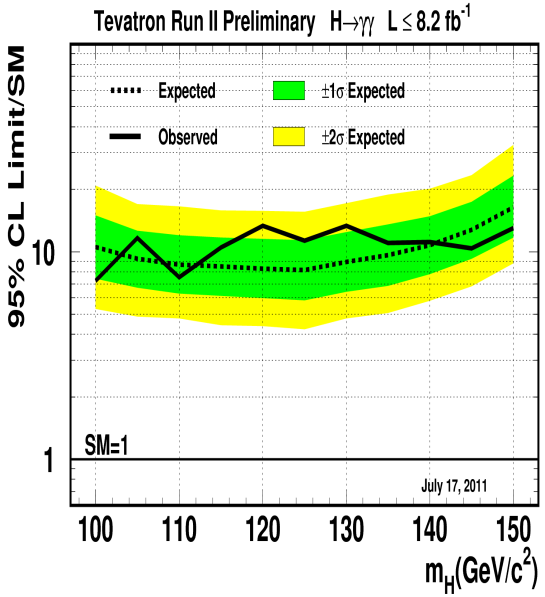
Other Searches

- Other decay chains are also being considered
- If the SM is correct, these are not as sensitive. But, every little bit helps and nature could be different

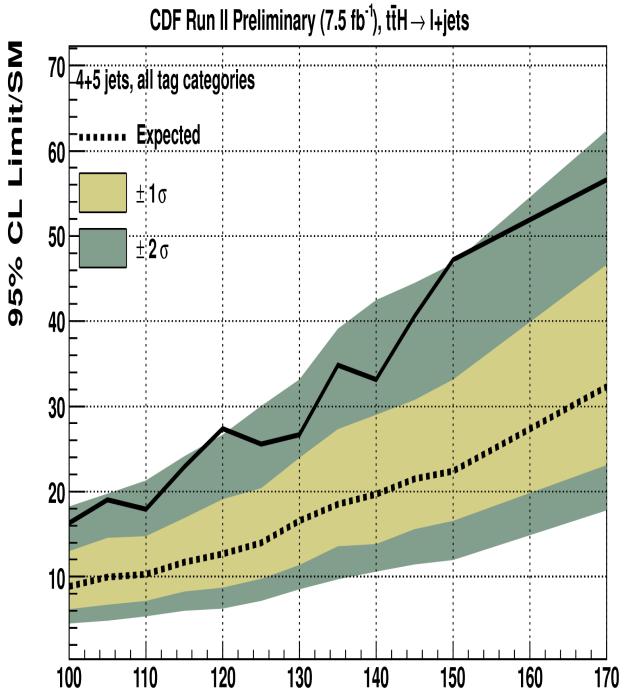
H→ττ:



H→γγ:

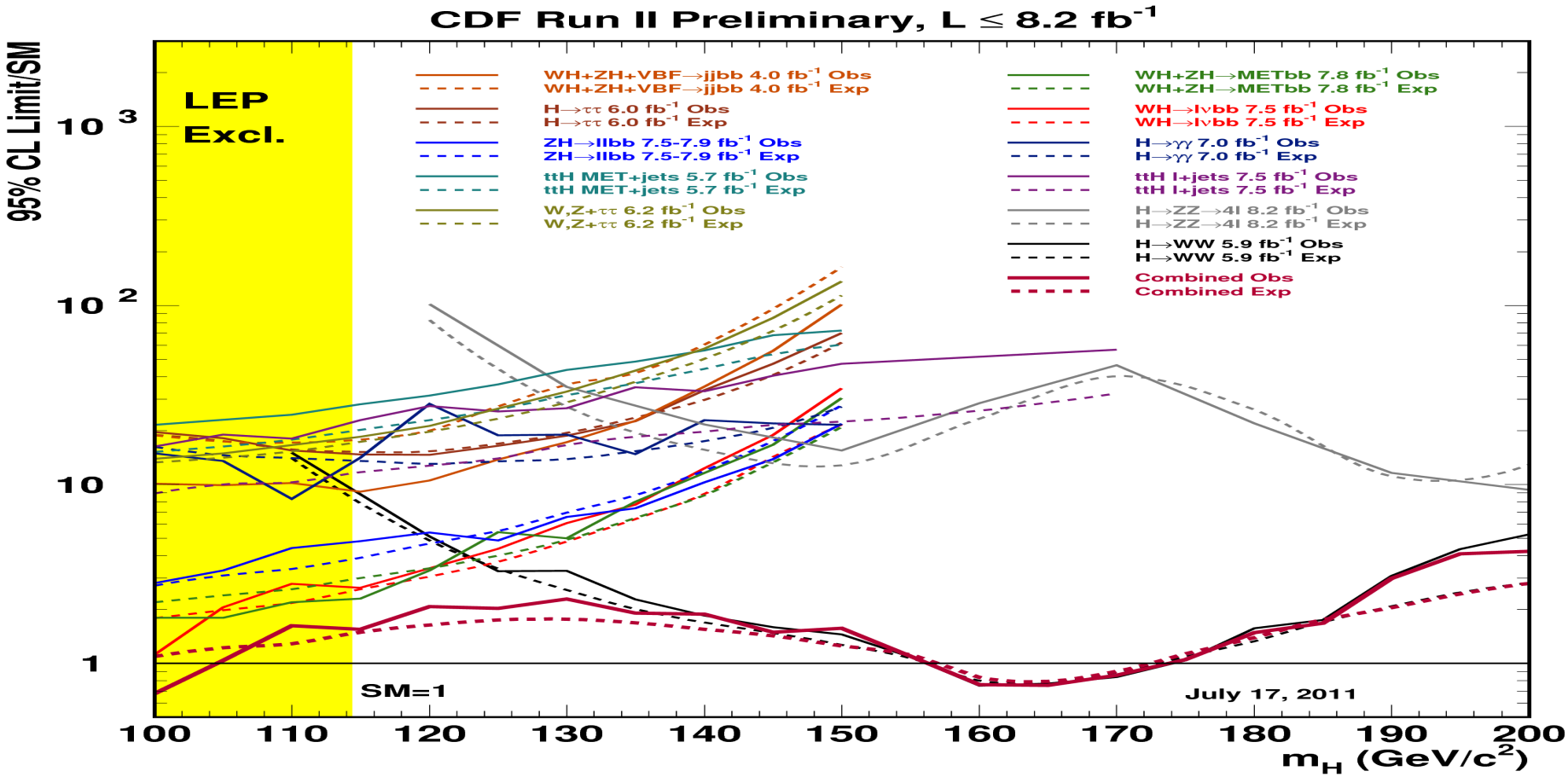


ttH(H→bb,WW):



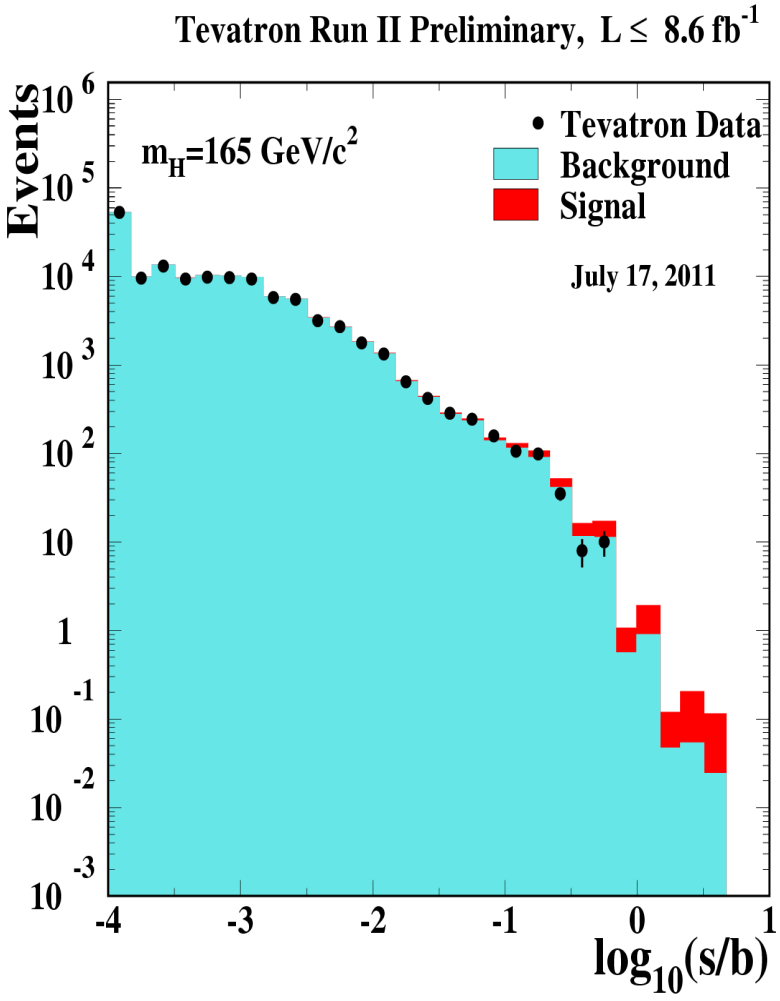
Combining Individual Channels

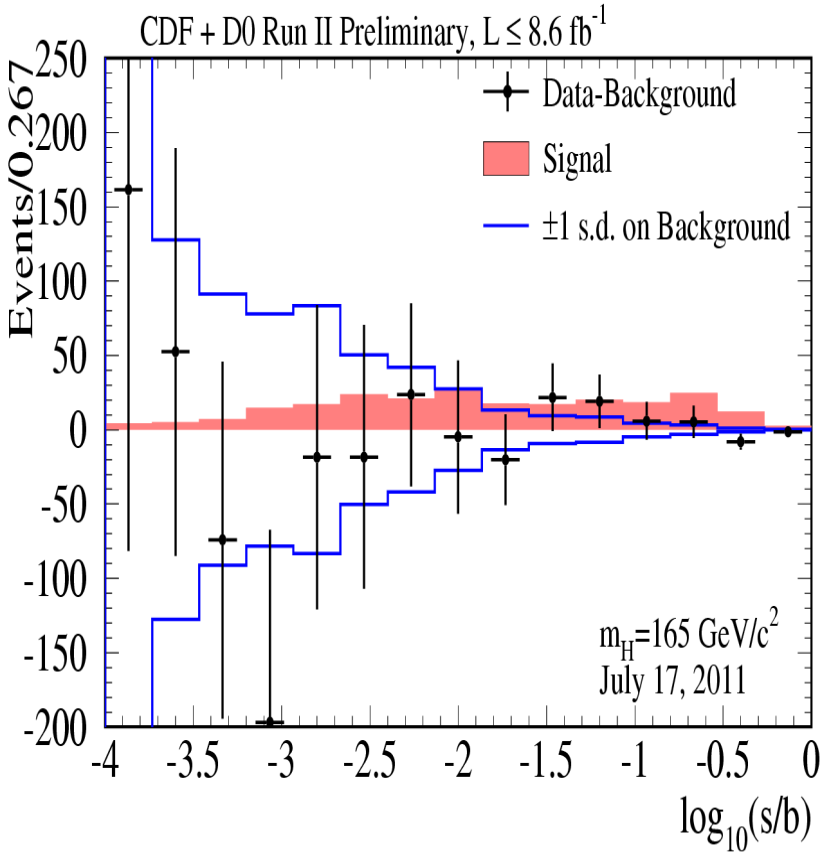
- **Many mutually exclusive final states. Both CDF & D0 see good agreement in all channels and combine statistically to improve the Higgs sensitivity.**



Combined Discriminants

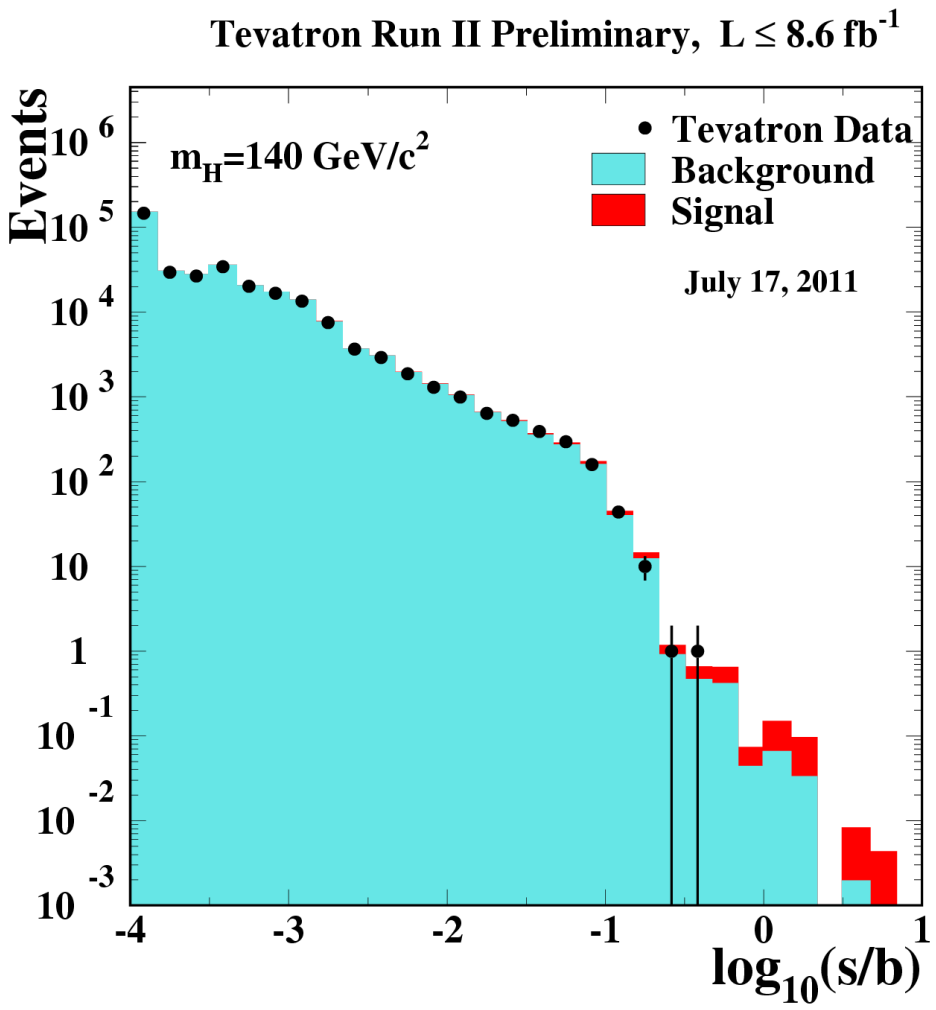
- Combining all channels based on log(S/B) for M_H=165 GeV/c^2.

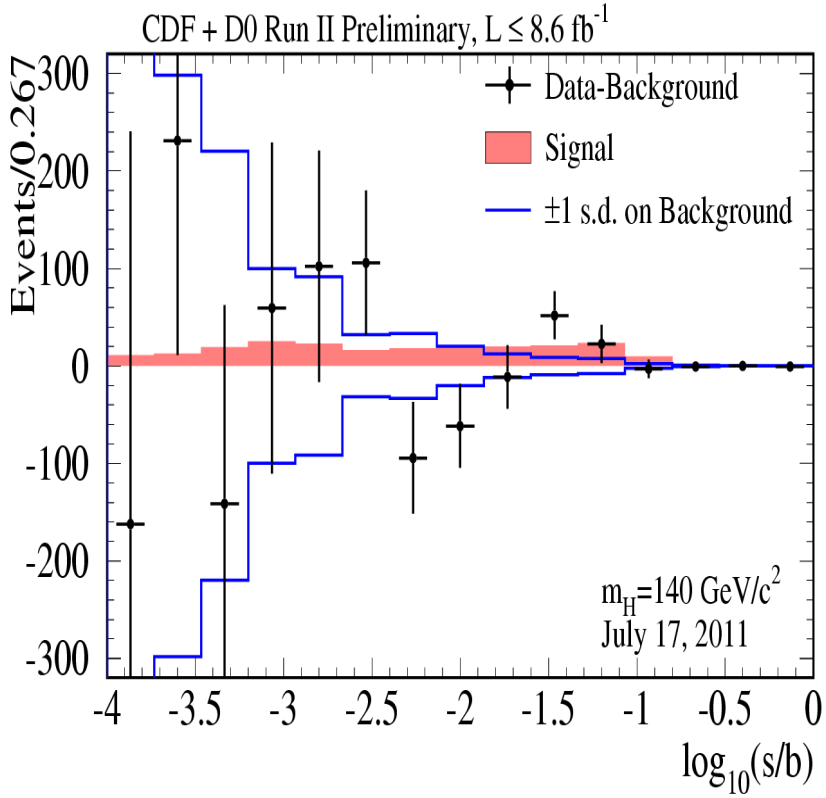




Combined Discriminants

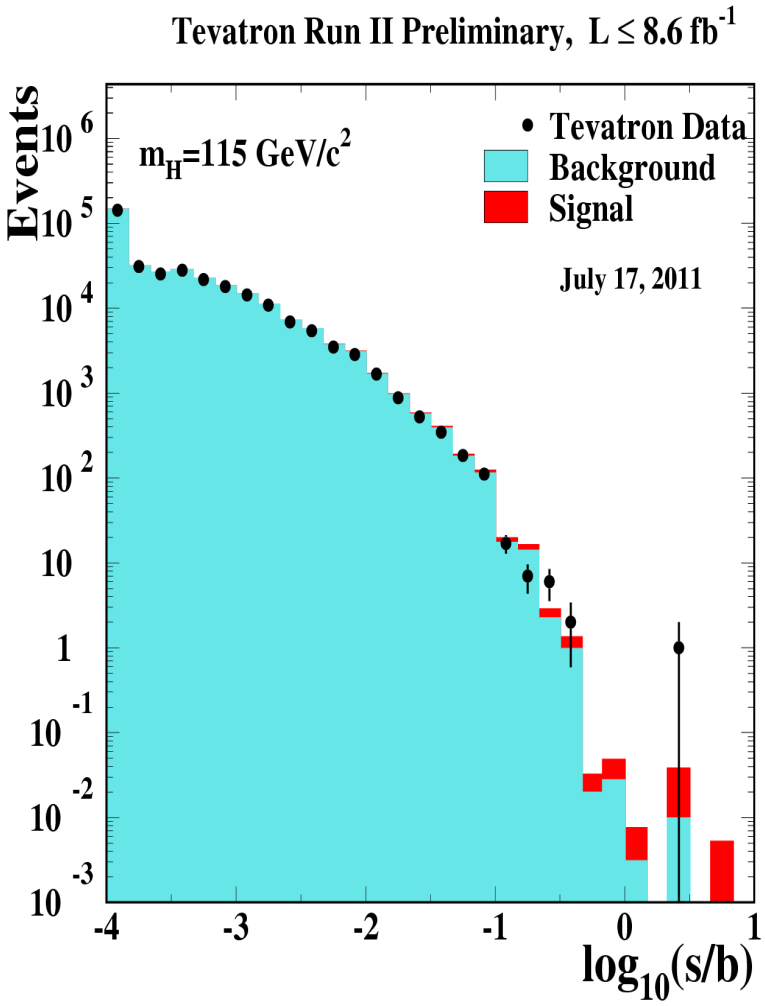
- Combining all channels based on log(S/B) for M_H=140 GeV/c².

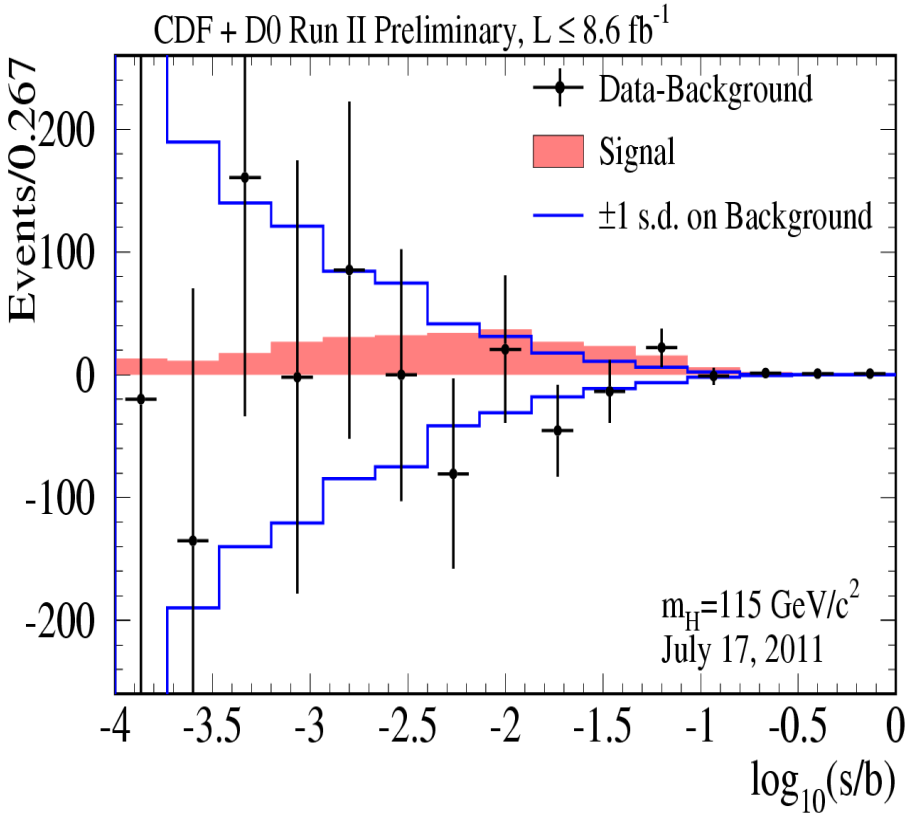




Combined Discriminants

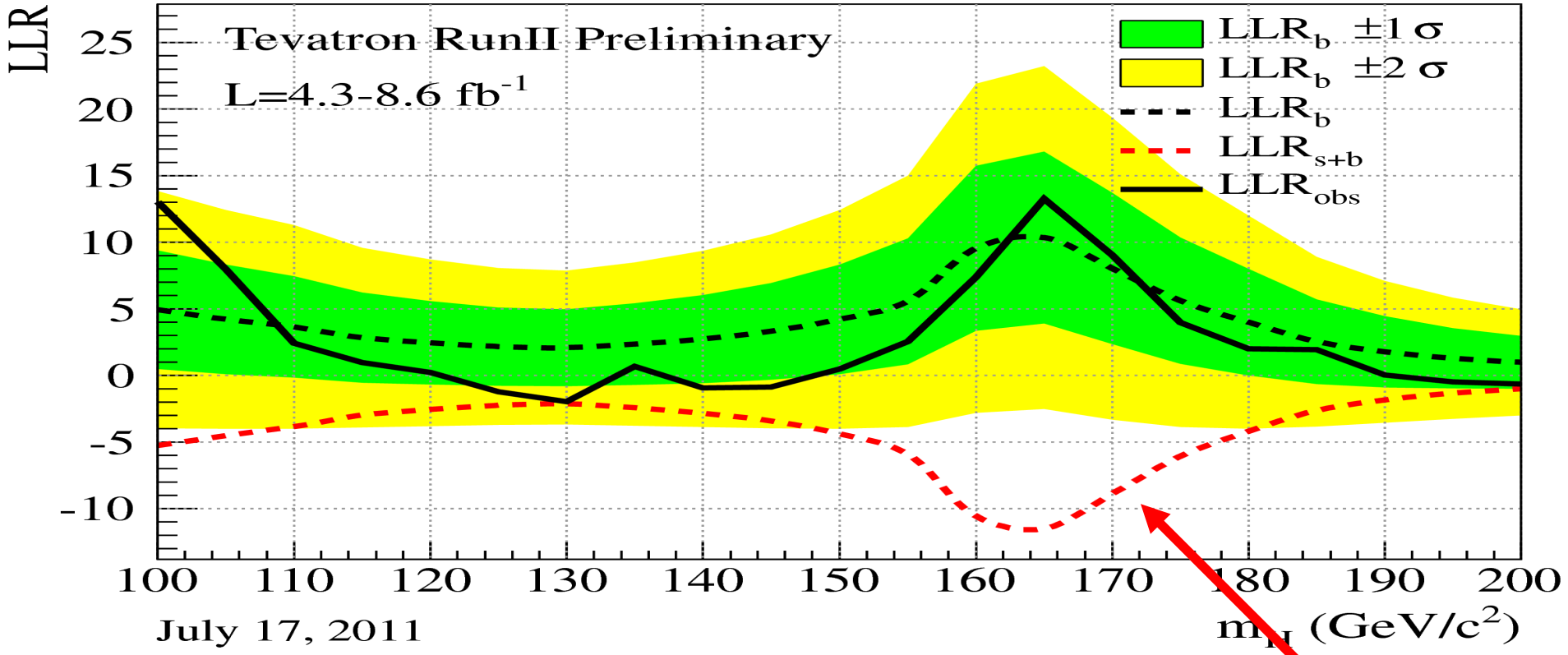
- Combining all channels based on log(S/B) for M_H=115 GeV/c².





Tevatron Sensitivity

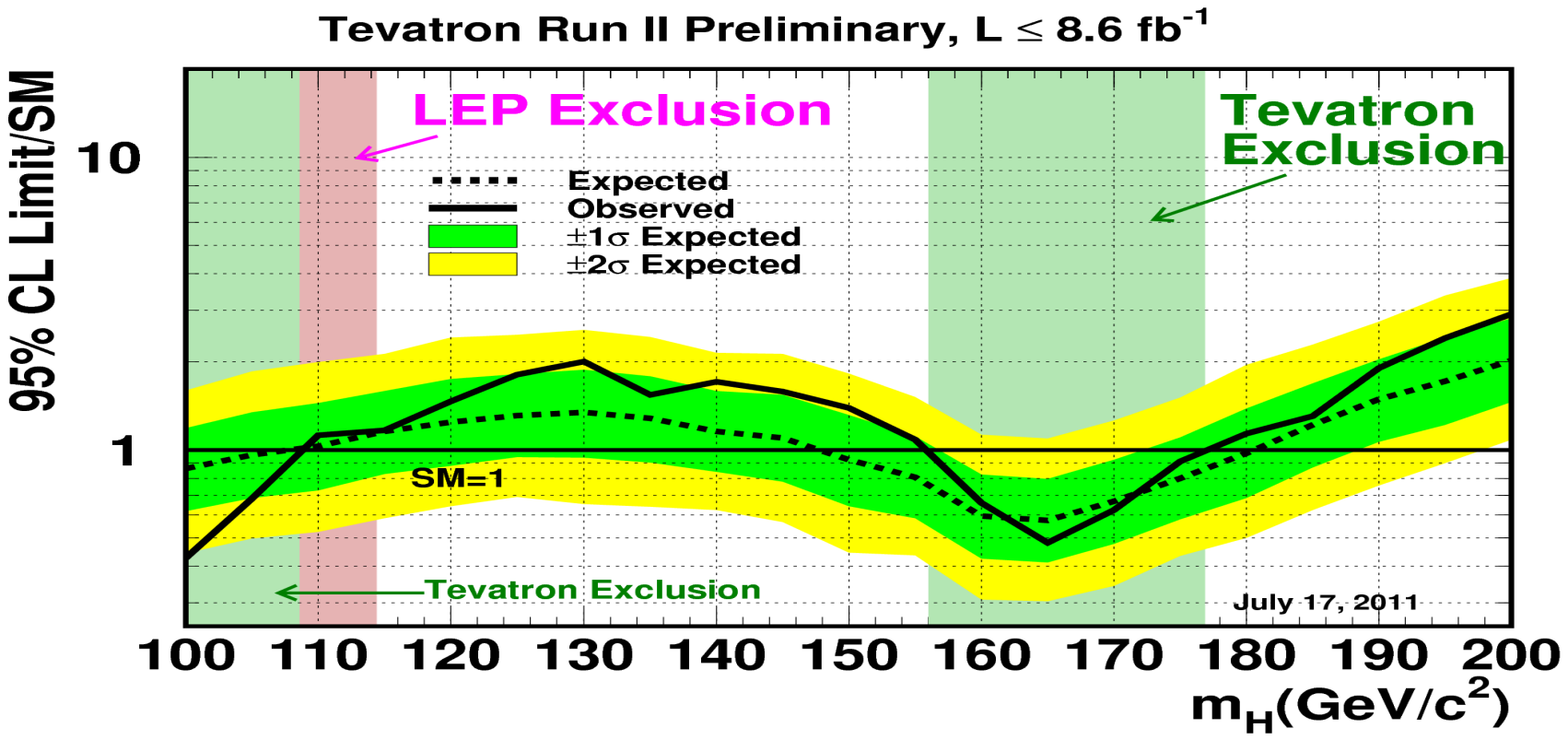
- **Log-likelihood Ratios (LLR): LLR_b, LLR_{s+b}, LLR_{obsv}**
- **Separation between LLR_b and LLR_{s+b} is the search sensitivity**



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

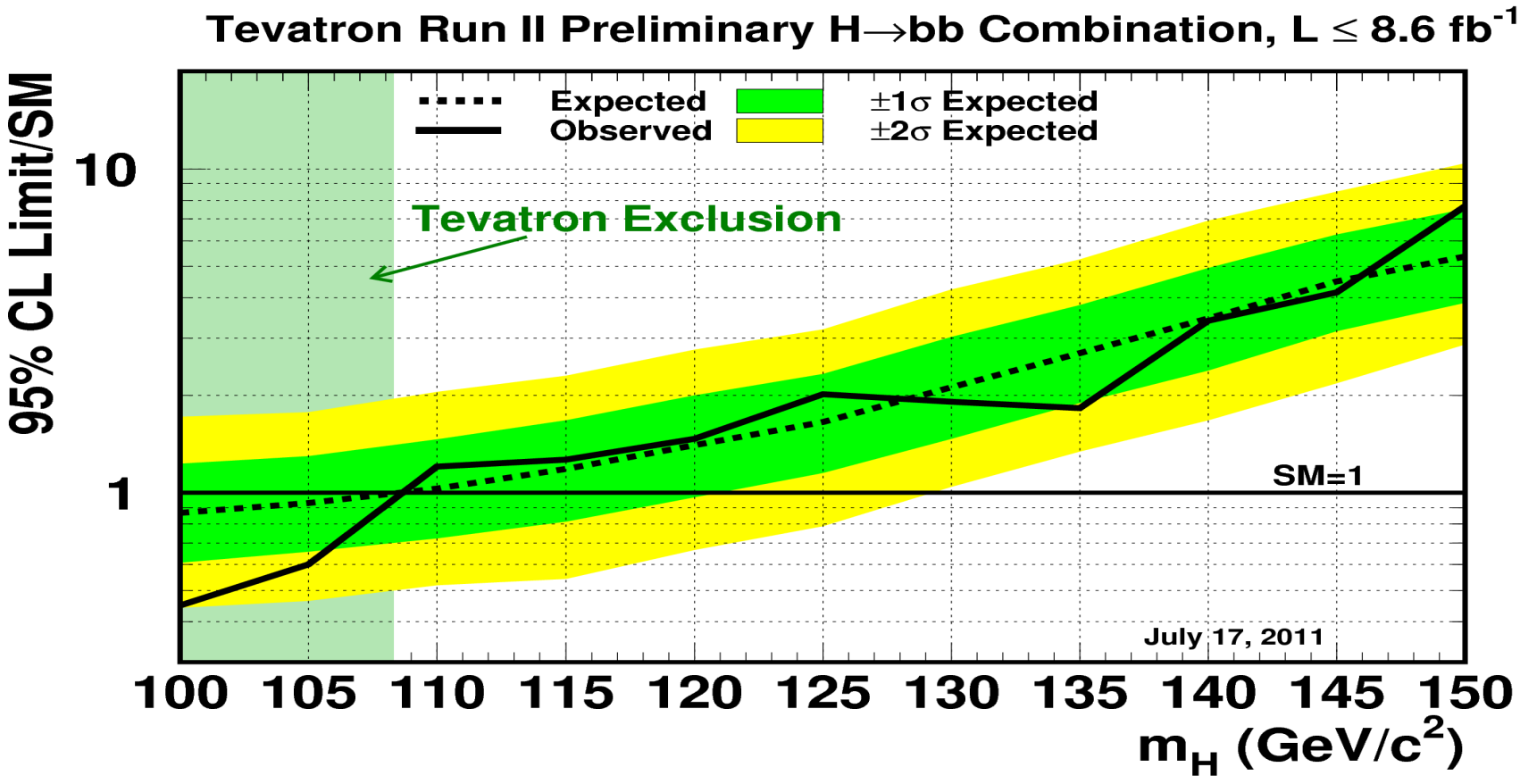
Tevatron Combination

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



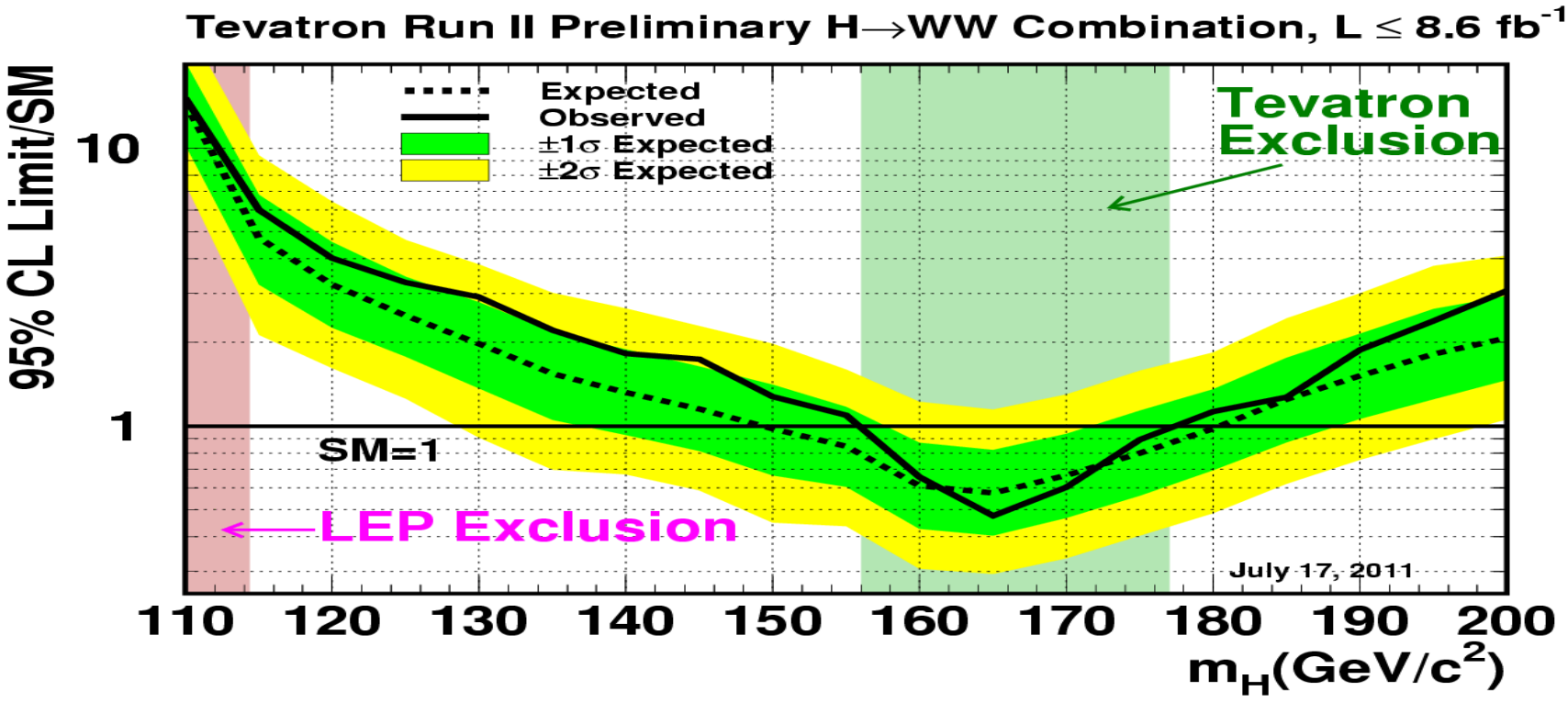
Tevatron H→bb Combination

- Combining WH/ZH, H->bb channels only.



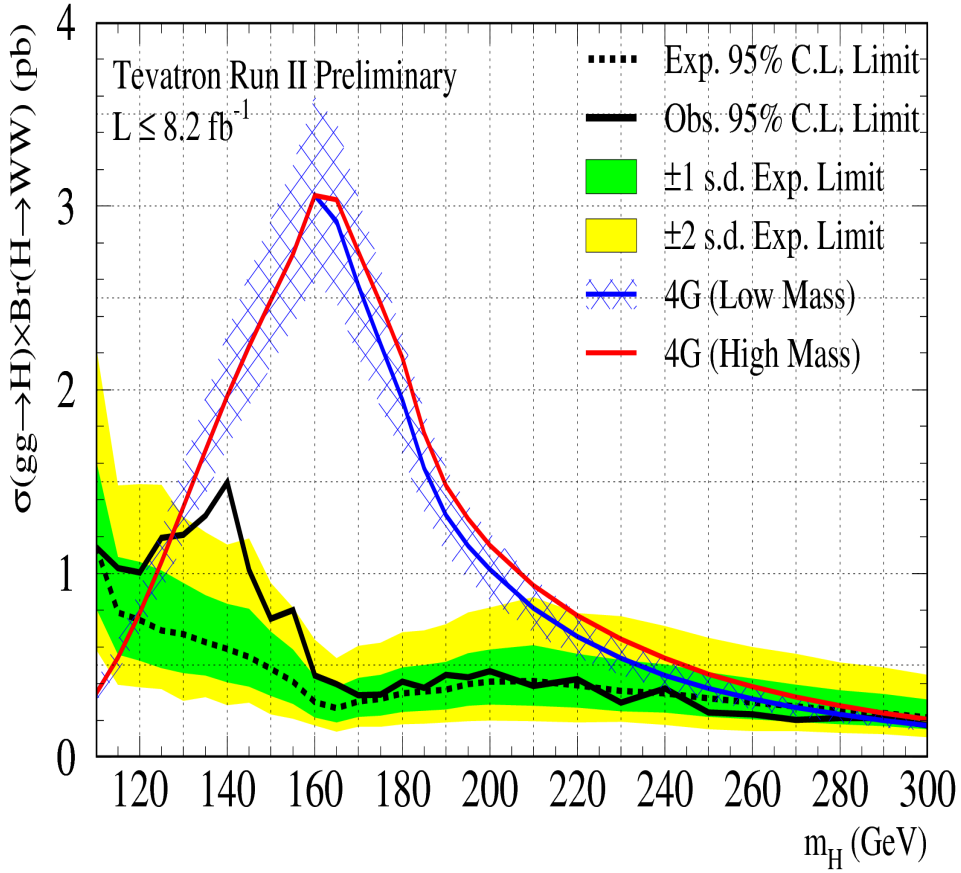
Tevtron H→WW Combination

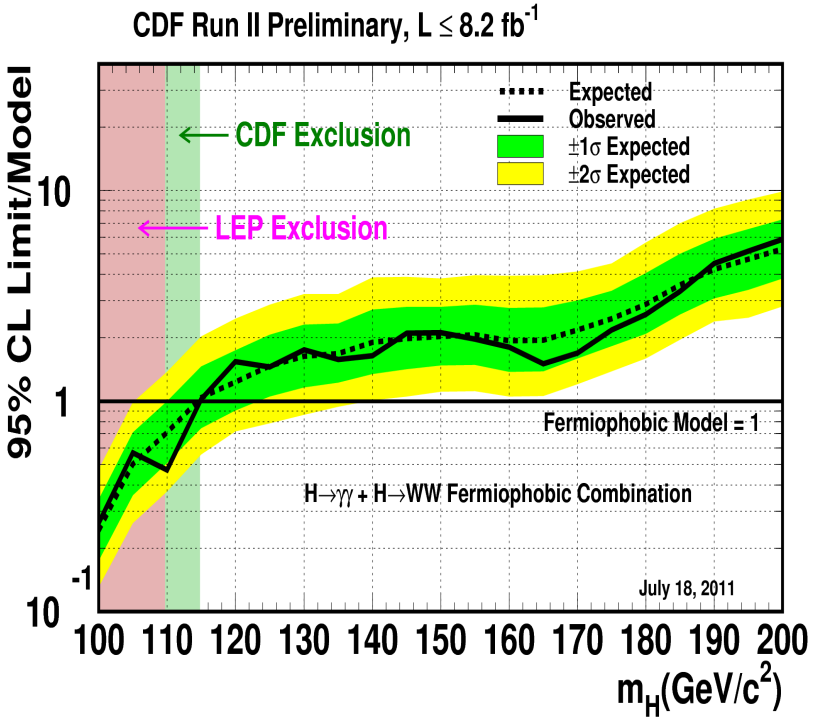
- Combining H→WW, channels only.
- Seems one sigma access in $125<M_H<150$ GeV/c^2.



Constrains on 4th Generation, Other Exotic Models

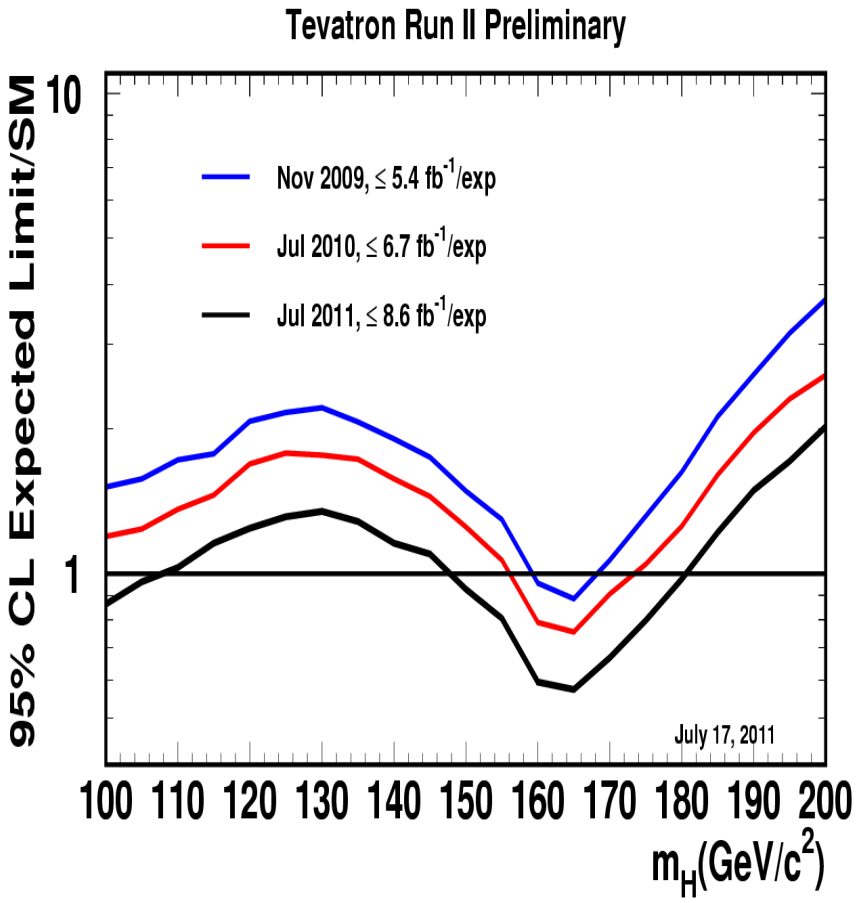
- In 4th generation model enhanced production σ(gg→H), reinterpret H→WW search, exclude 124<M_H<286 GeV@95%C.L.
- In the fermiophobic model, CDF exclude M_H>115 GeV@95%C.L.





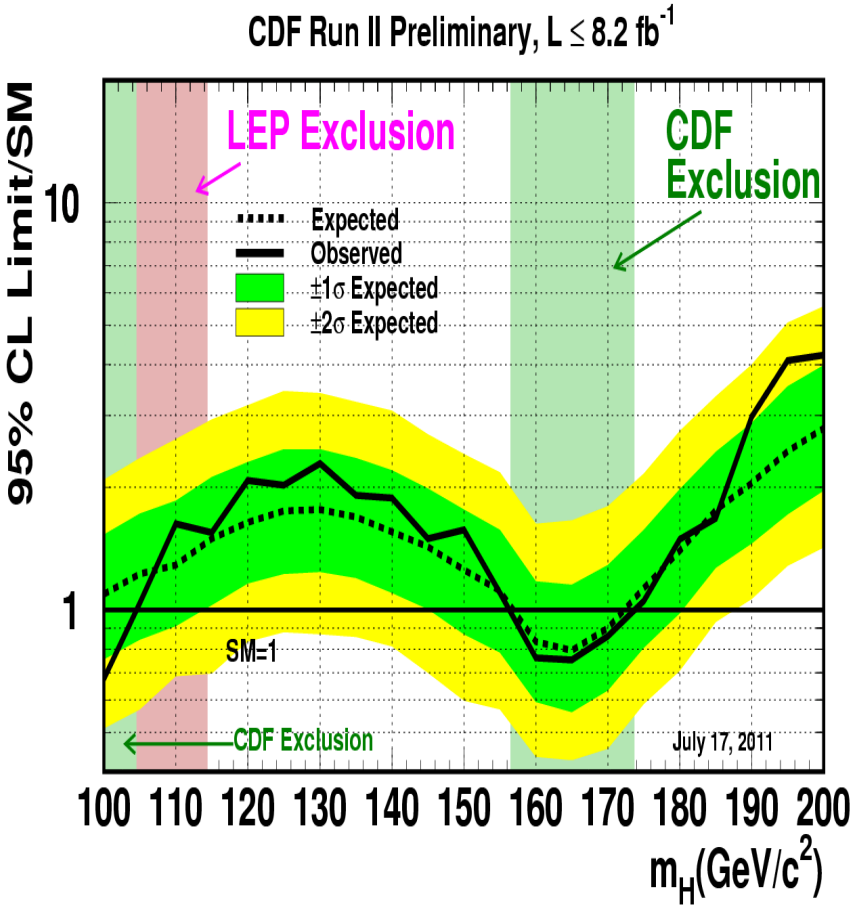
Conclusion

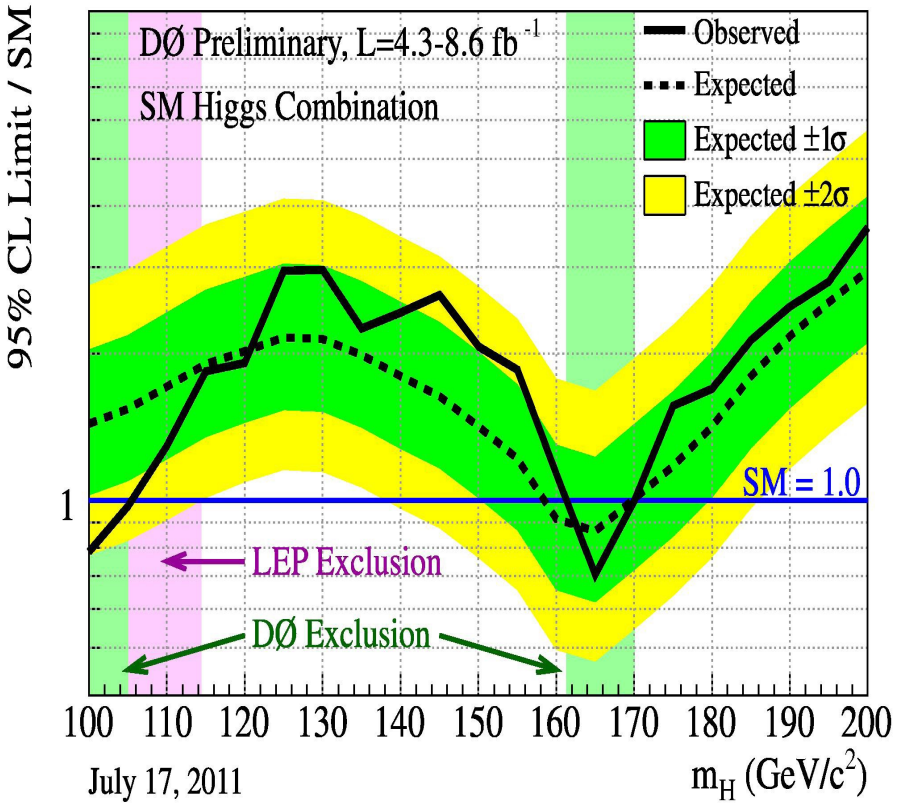
- Tevatron is doing very well.
- With 10 fb^{-1} analyzable dataset and anticipated improvement, Tevatron will remain competitive next year.
- Finding evidence for a low mass H→bb is essential to understanding EWSB.
- This is very exciting time that a discovery is just around the corner.



BackUP

CDF/D0 Limits





Search for ttH

- Looking for ttH in all jets, met+jets, lepton+jets (ttbar provides trigger, is well understood).
- Sensitive to H→bb,WW*.
- Count for tags & NN to separate ttH from ttbar.