Direct Searches for the SM Higgs Produced in Association with a Vector Boson at CDF

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On behalf of the CDF Collaboration

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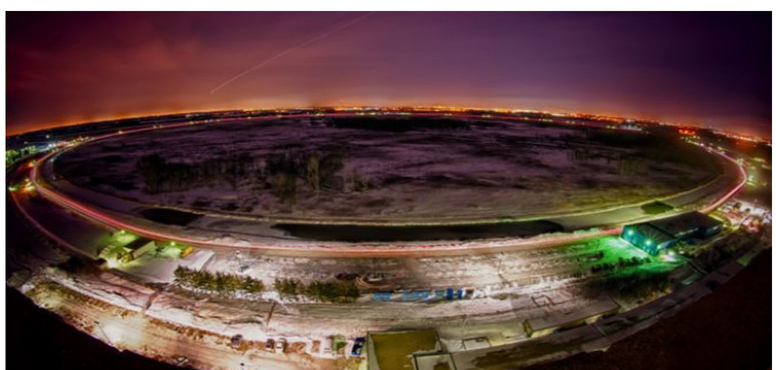


Outline

- Introduction
- Overview the Higgs Search Strategies
- Recent Improvements
- CDF $H \rightarrow bb$ Search Results with Full Dataset
- Conclusion

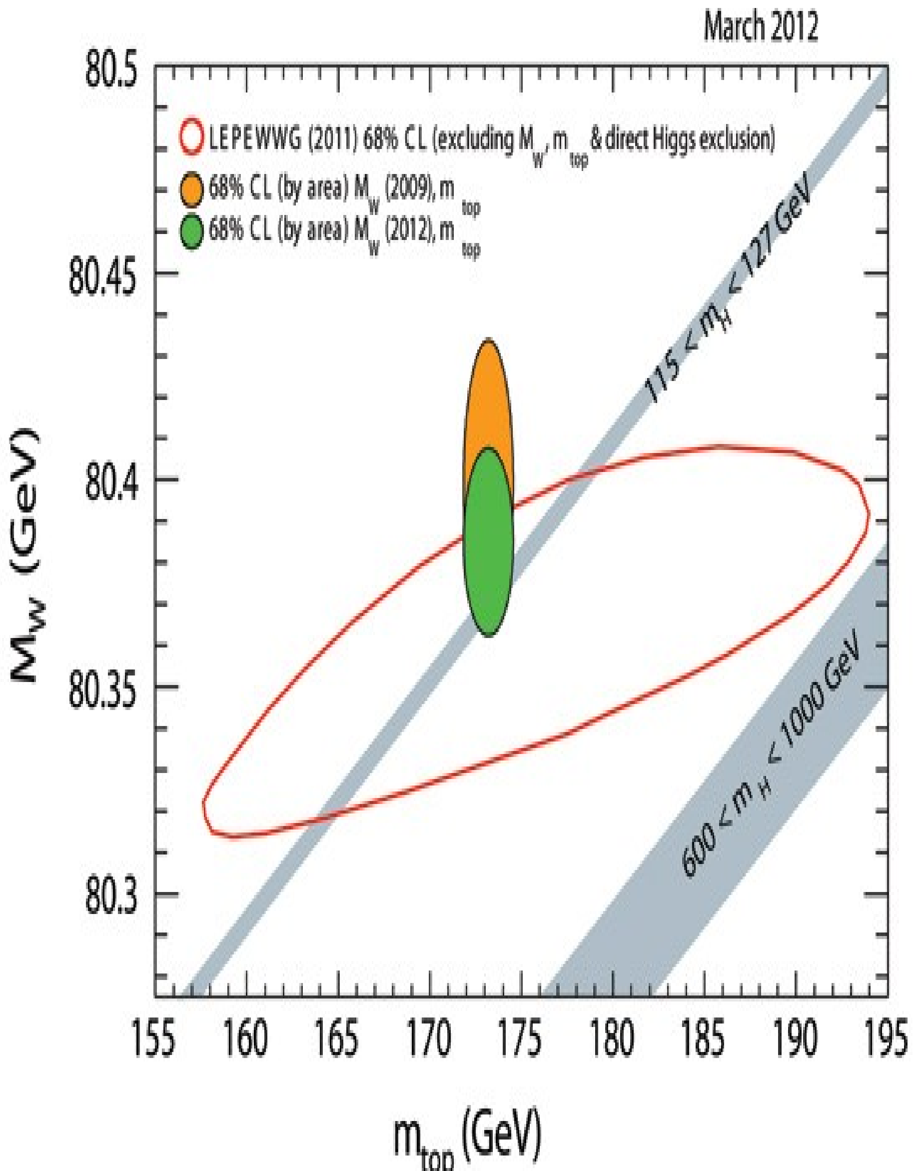
More Details:

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

CDF searches in $WH \rightarrow l\nu bb$, $ZH \rightarrow llbb$, $VH \rightarrow metbb$, and their combination with full dataset are submitted for publication.

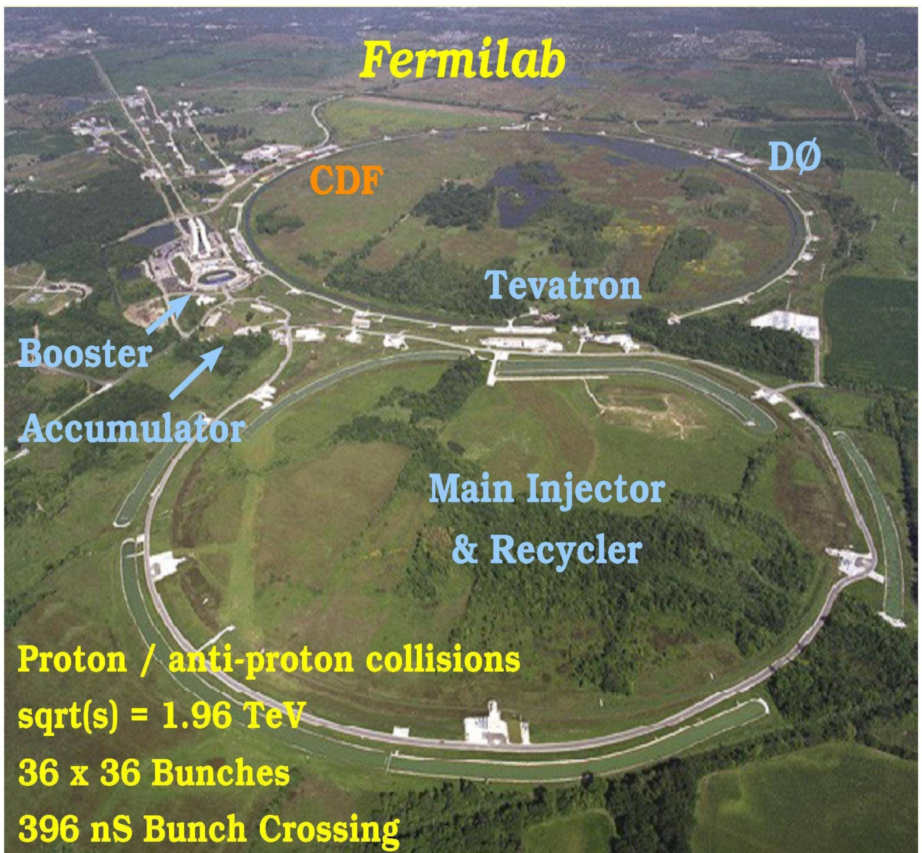
Introduction

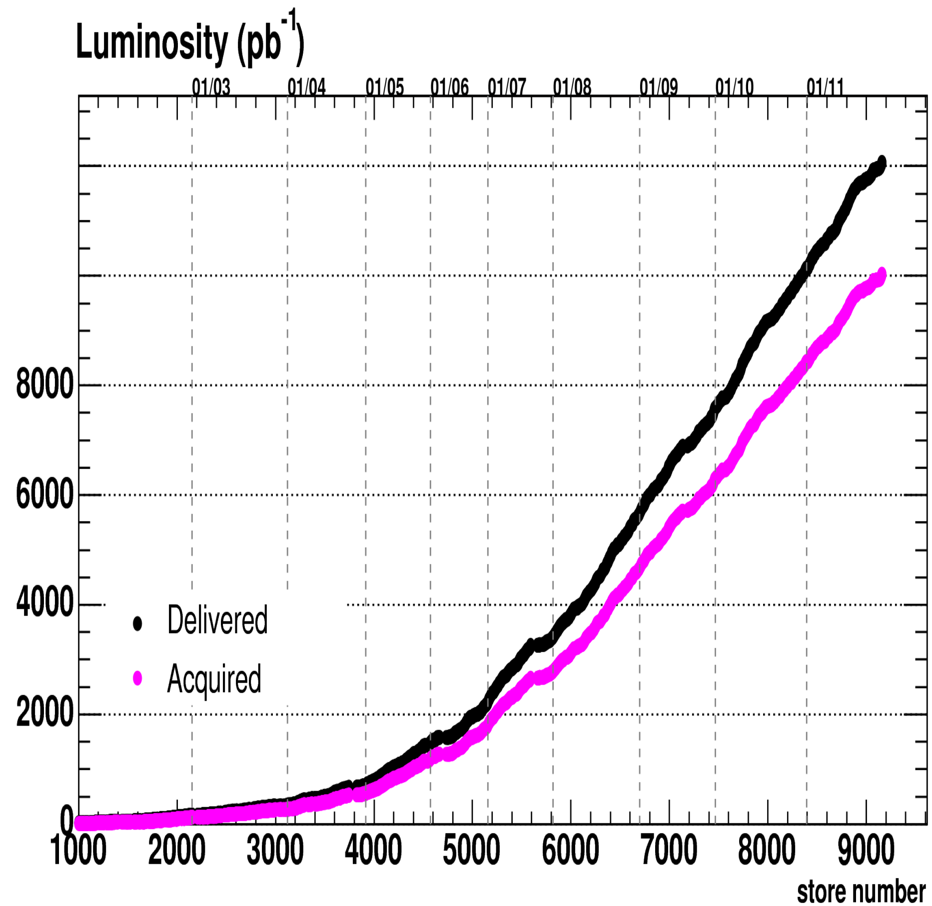
- Higgs boson is hypothesized to be the remnant of the Higgs field that responsible for electroweak symmetry breaking.
- Higgs Mass Limits@95% CL:
  - Indirect: M_H<152 GeV
  - Direct: 122.5<M_H<127 GeV
- While LHC just discovered a new Higgs-like particle, Tevatron search of H→bb decay is still important and it will provide a crucial test on the existence and nature of the Higgs boson.



The Tevatron

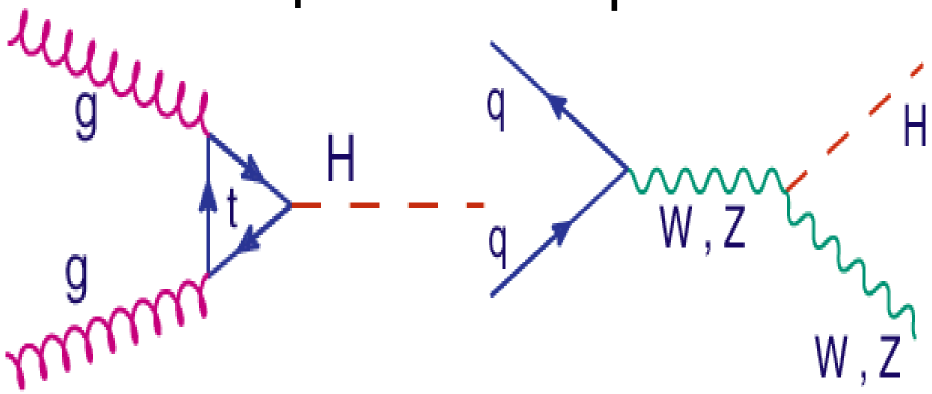
- Tevatron: p-pbar collision@1.96TeV, L_{peak}=4.3x10^{32} cm^{-2}s^{-1}
- Delivered ~12 fb^{-1} data before shutdown on 9/30/2011.
- Most results presented are based on the full dataset (~10 fb^{-1})

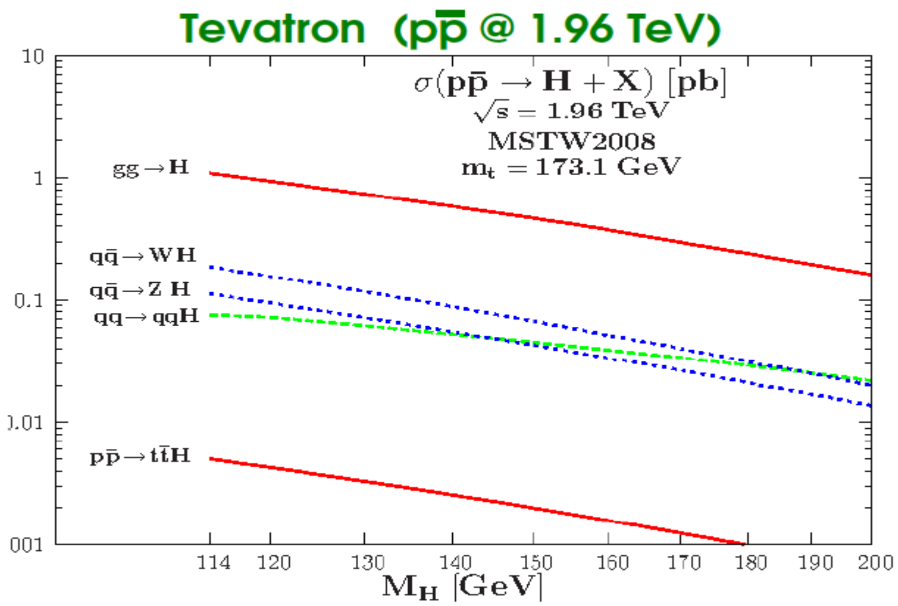




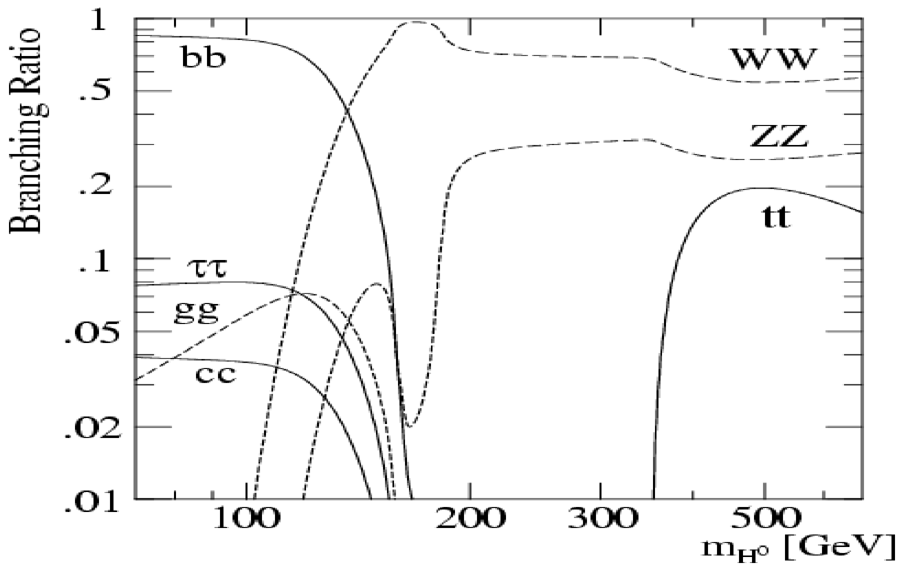
SM Higgs Production and Decay @ Tevatron

- Dominant production processes:





- 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.



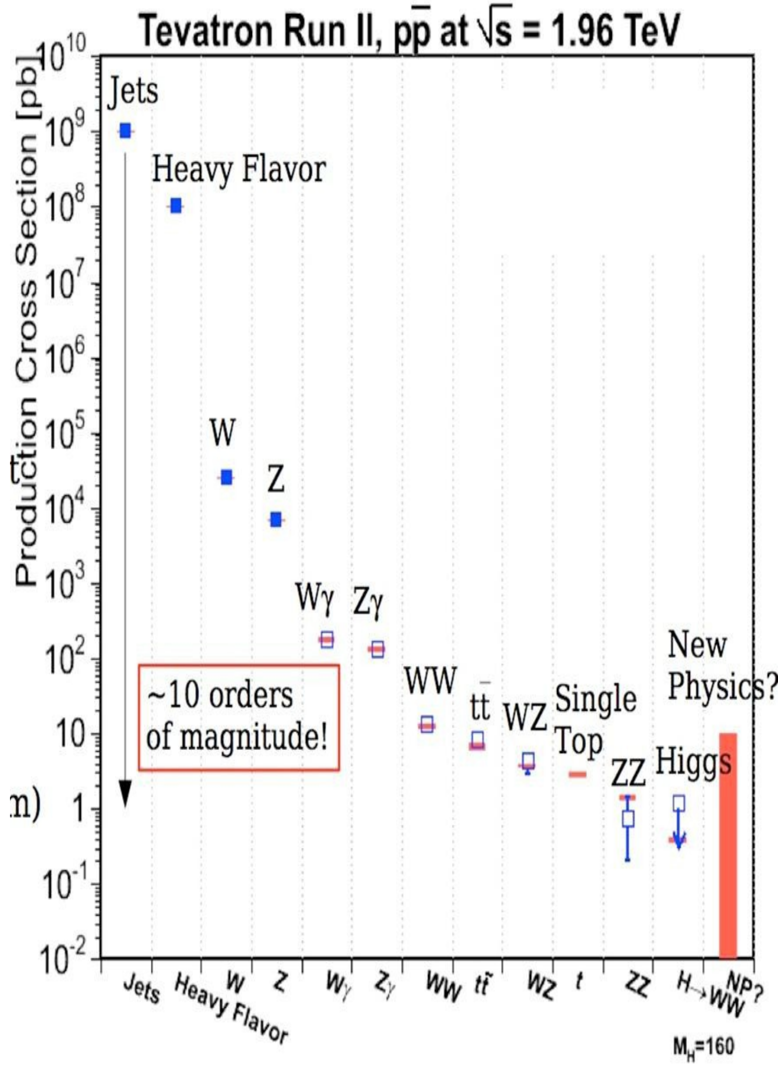
- For higher mass(MH>135GeV):

  Mainly decays: gg→H→WW,ZZ

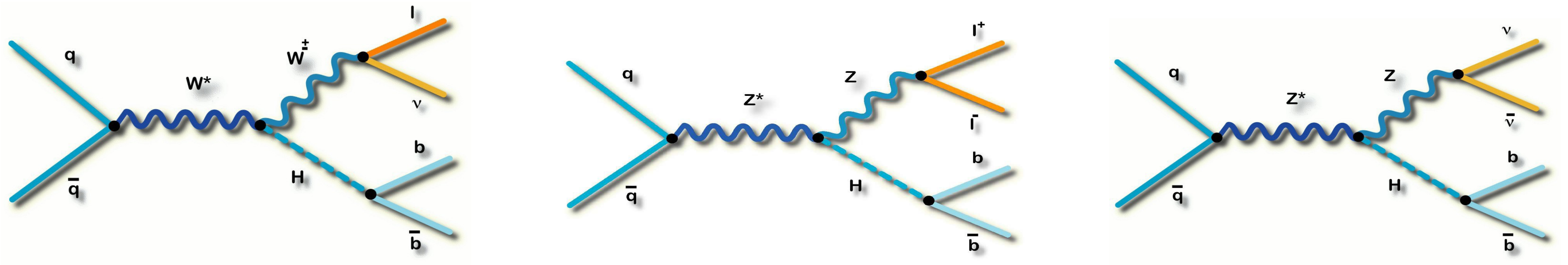
- Other decays: H→ττ,γγ, and ttH.

The Challenge

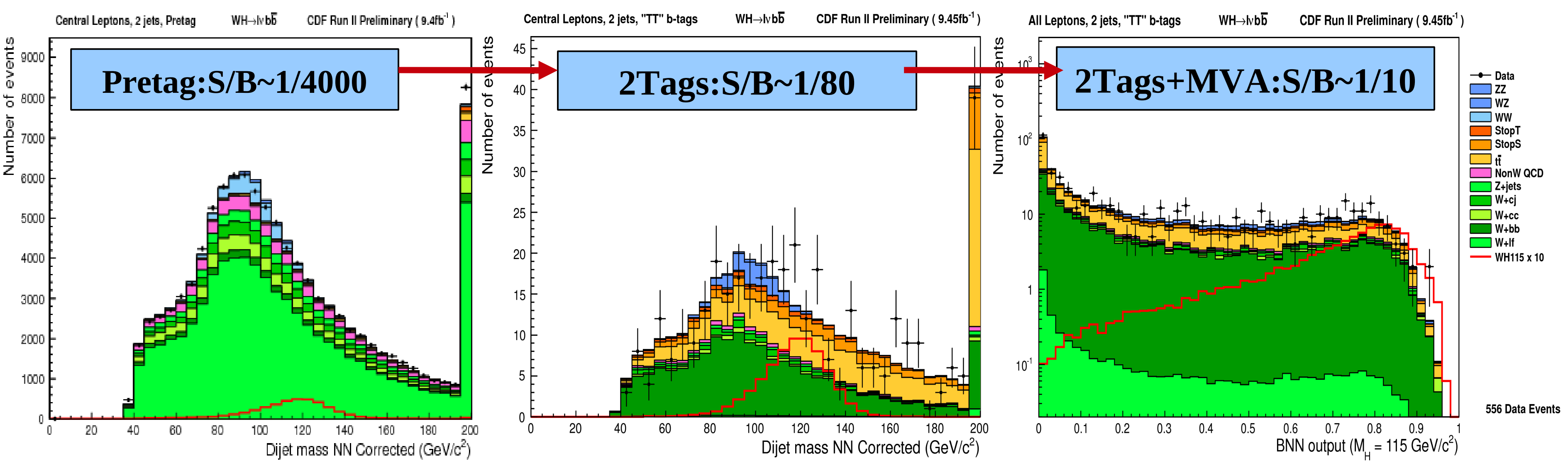
- The Challenge is that Higgs signal is so tiny compared to other SM process with the same final states.
- Search Strategy has evolved over years:
  - Maximizing signal acceptances using efficient triggers, lepton ID, and b-tagging that improves S/B to ~1/100.
  - Using multivariate analysis(MVA) to exploit kinematic differences of S and B that improves S/B to ~1/10.
- The procedures are iterated until achieving the best sensitivity



Main H→bb Signatures

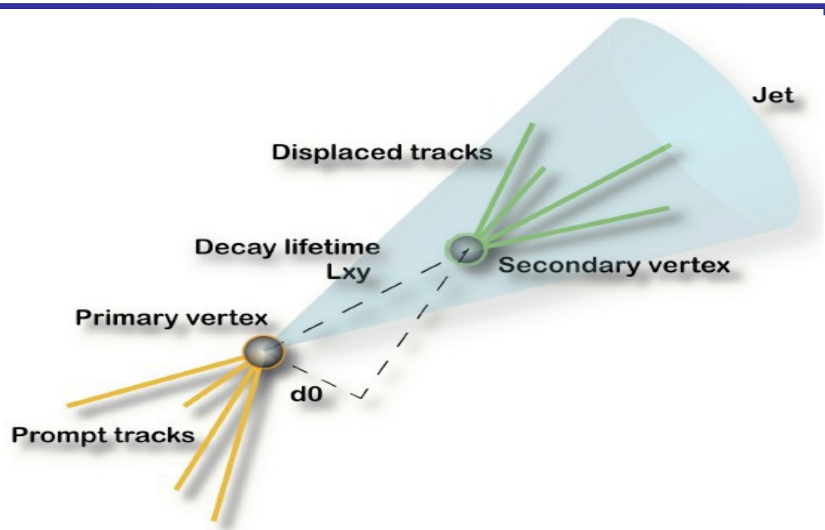


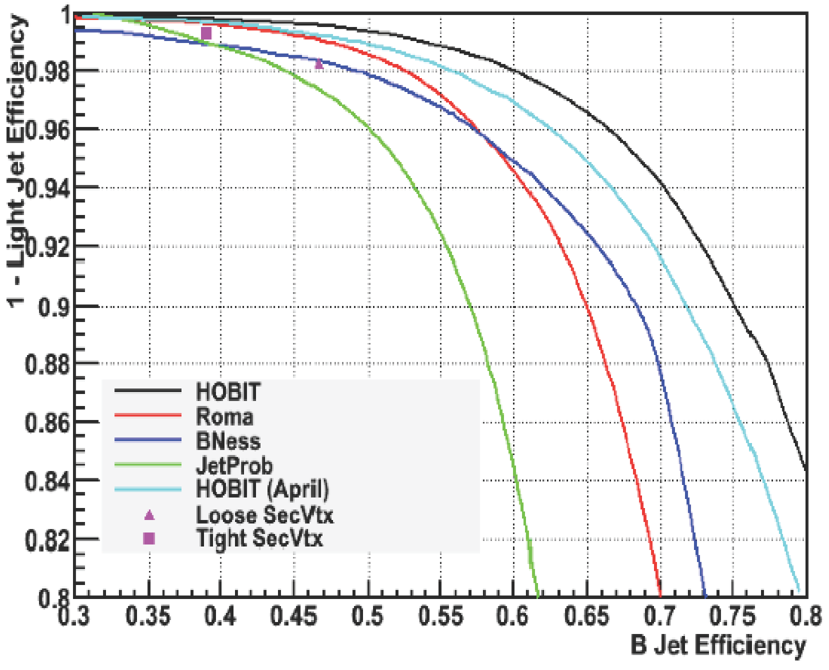
- Search for H→bb resonance in association with W or Z.
- WH→lνbb, most sensitive low-mass channel: one lepton+MET+ 2b
- Requiring b-tag and MVA improves S/B from 1/4000→1/80→1/10.



Improvement of b-tagging

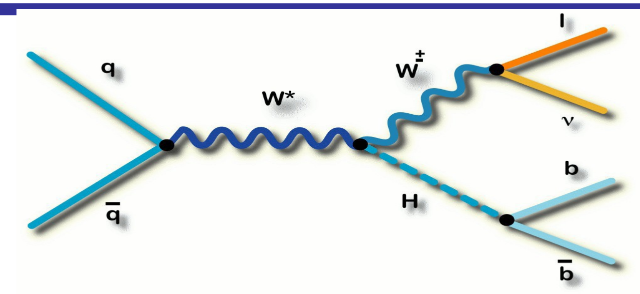
- CDF uses MVA techniques to improve b-tagging that exploits the decay of long-lived B hadron as displaced tracks/vertices. Typical eff:40-70% with mistag rate:1-5%.
- Recently CDF combined existing b-tags into a Higgs optimized b-tagger (HOBIT), which improves eff by 20% while keeping mistag rate
- Use tight and loose operating points to maximize the Higgs sensitivity.

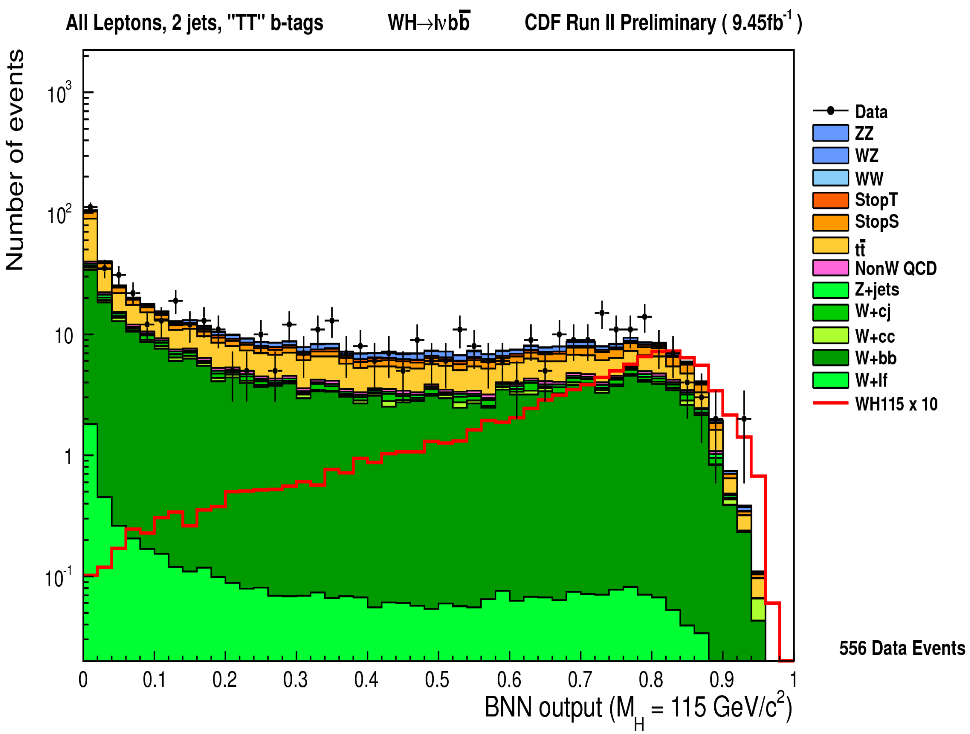


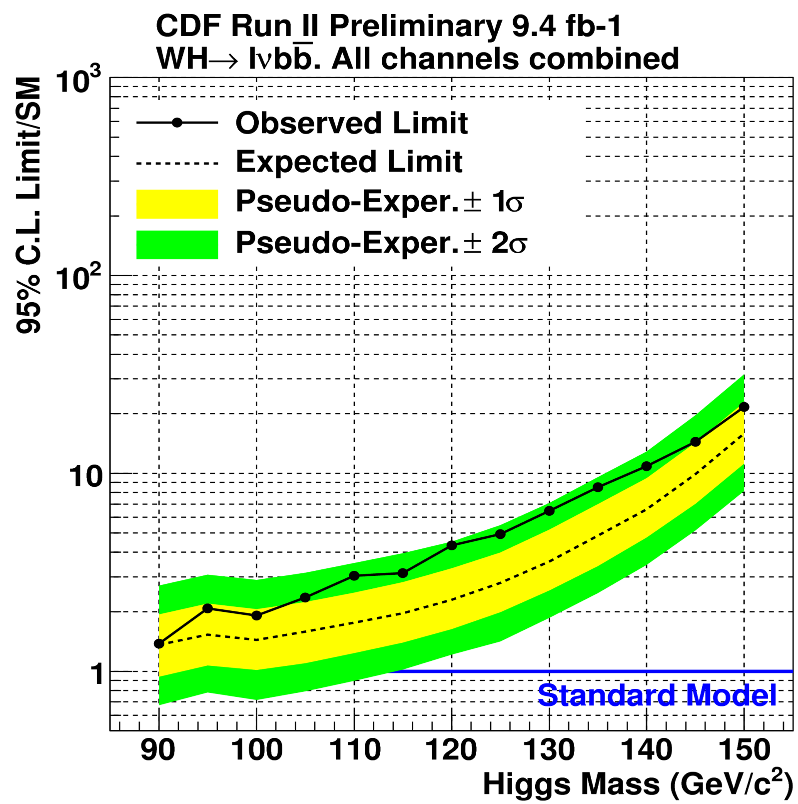


Search for WH→lvbb

- WH->lvbb is one of most sensitive channel.
- Select one lepton, missing Et, 2 and 3 jets
- Require b-tag & MVA discriminant (26-ch).



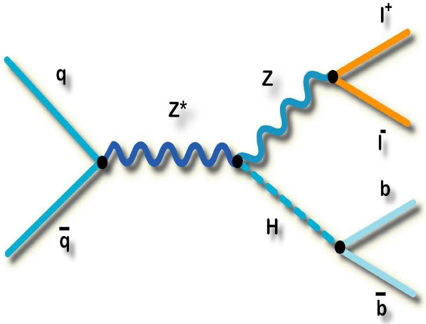


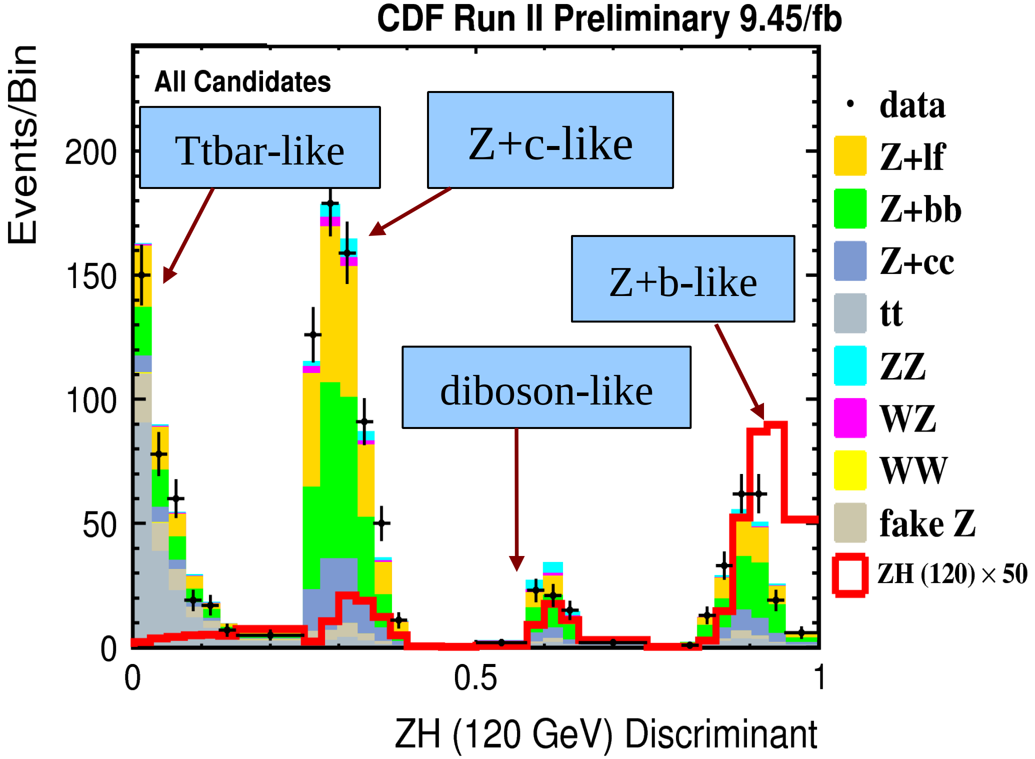


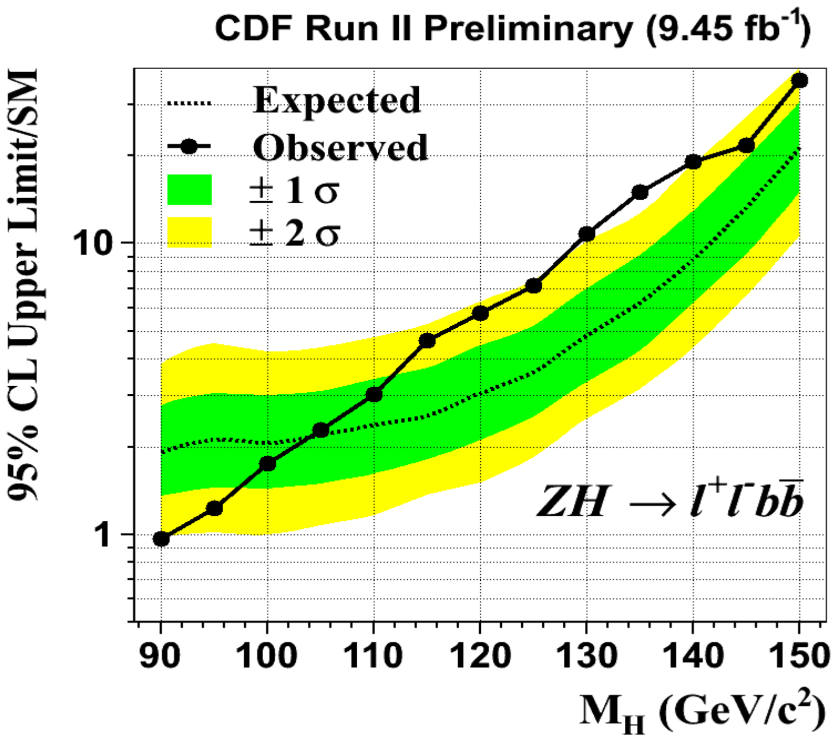
- Set 95% CL obs/exp limits: 4.9/2.8 @125 GeV

Search for ZH→llbb

- Low event rate but clean signature.
- Select two leptons for Z→ll, 2/3 jets with btag (8-ch).
- Train NNs to isolate H from top, Z+c's, diboson,Z+b's.



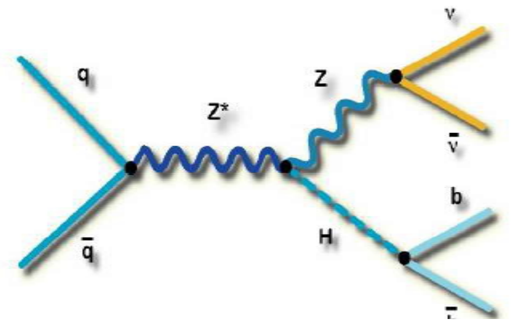


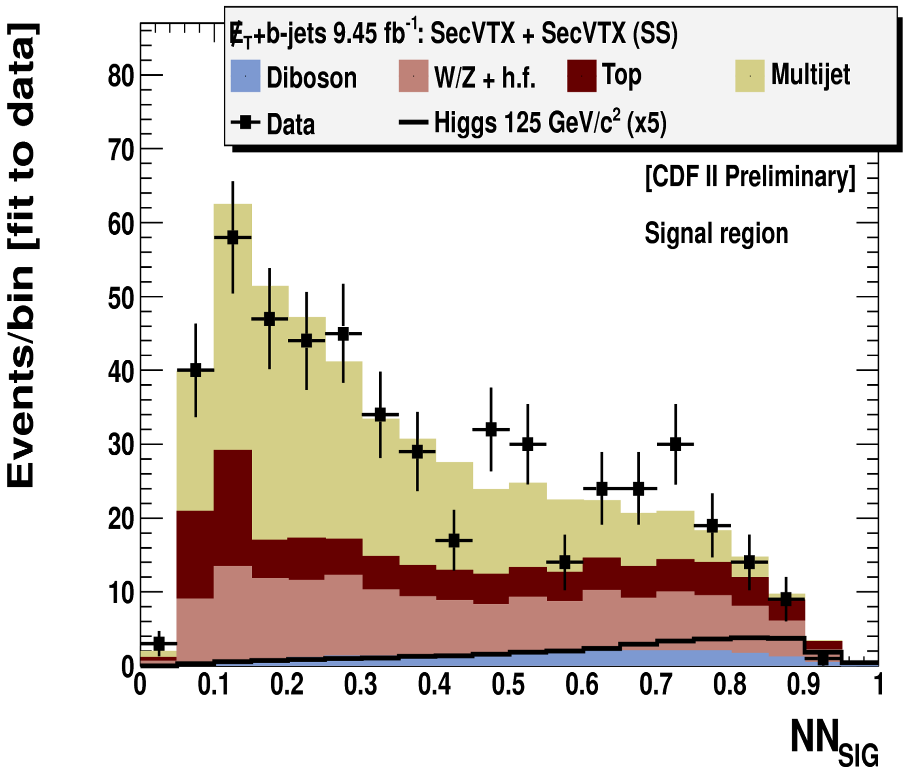


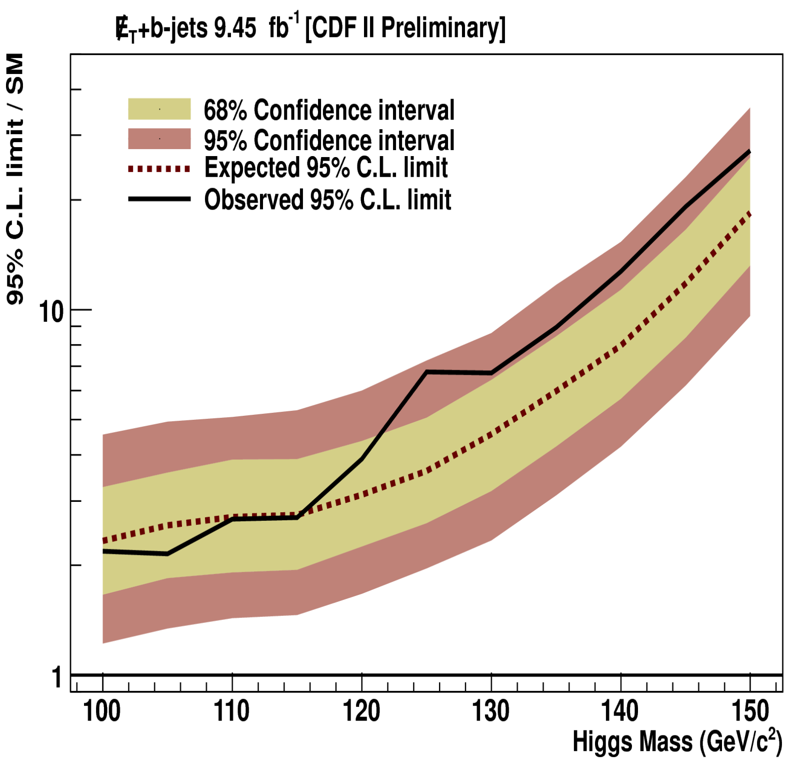
- Set 95% CL limits on obs/exp: 7.1/3.9 @ mH=125 GeV.

Search for ZH→ννbb, WH→(l)νbb

- Large event rate with large QCD MJ, very difficult
- Require met>50 GeV + 2/3 jets, b-tagging (3-ch).
- Train NN to separate Signal, bckgrnd and QCD.



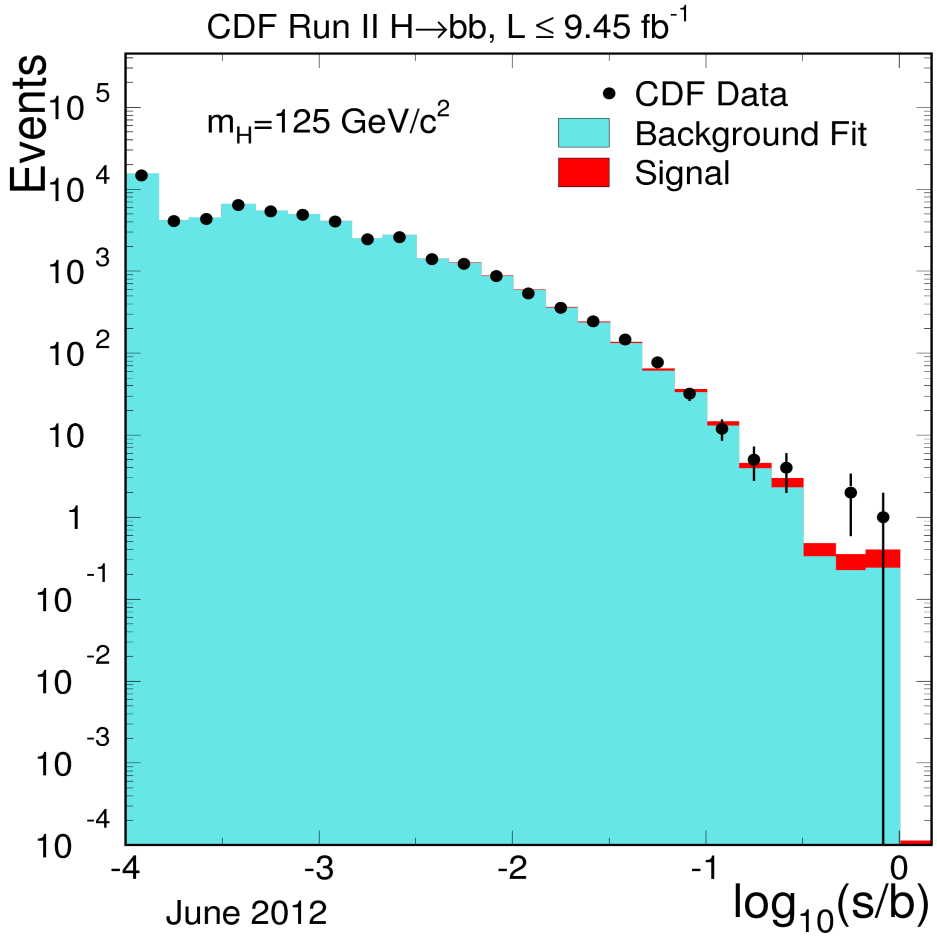


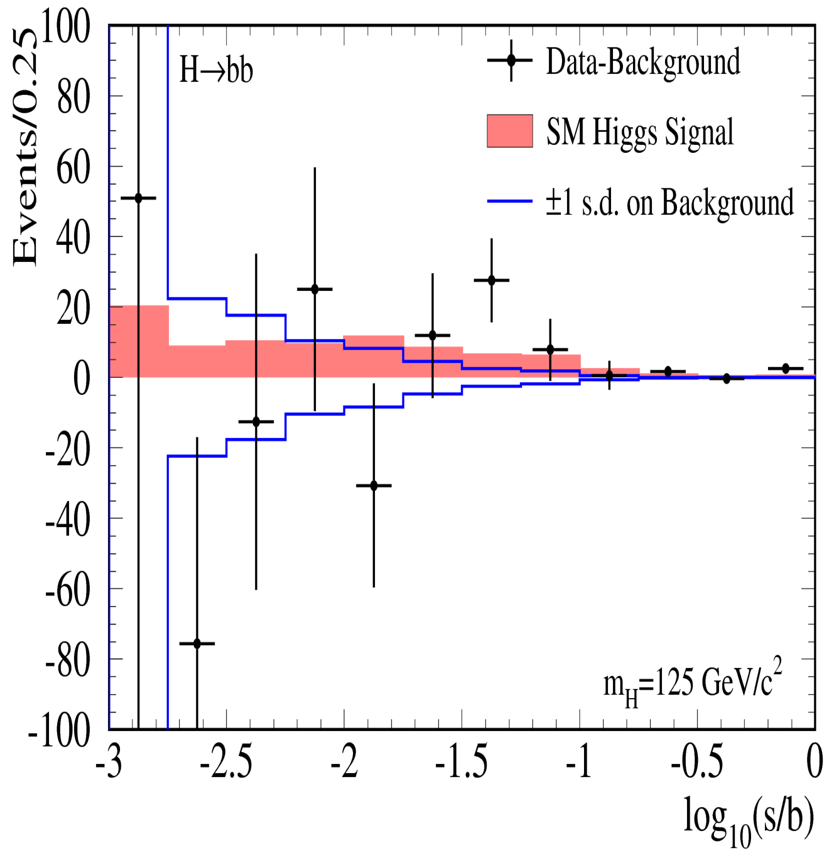


- Set 95% CL limits on Obs/exp: 6.7/3.6 @mH=125 GeV.

Cumulative Discriminant at M_H=125 GeV

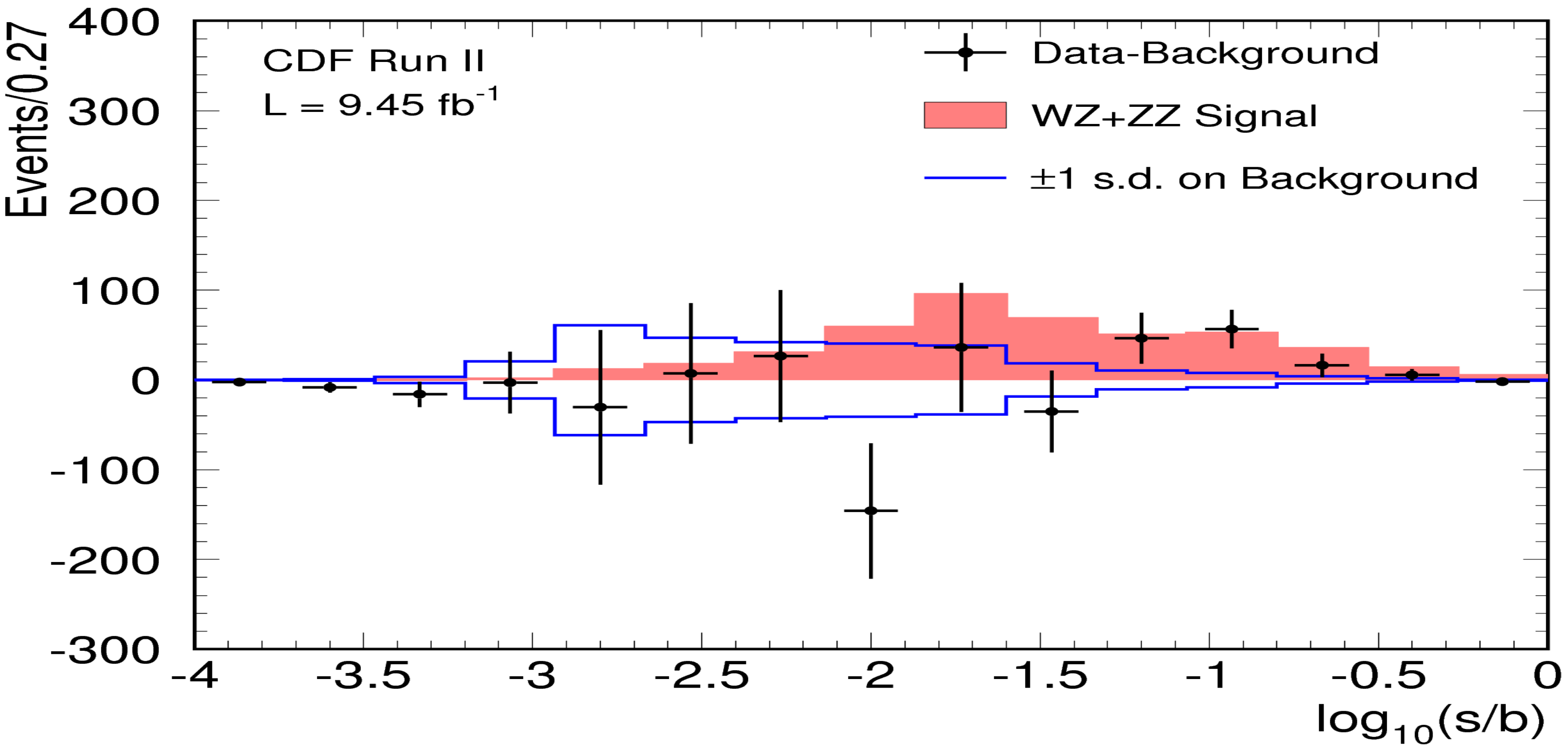
- Display events from three channels, ordered by S/B for M_H=125 GeV
- Some excesses in high S/B region seem consistent with Higgs at 125 GeV.





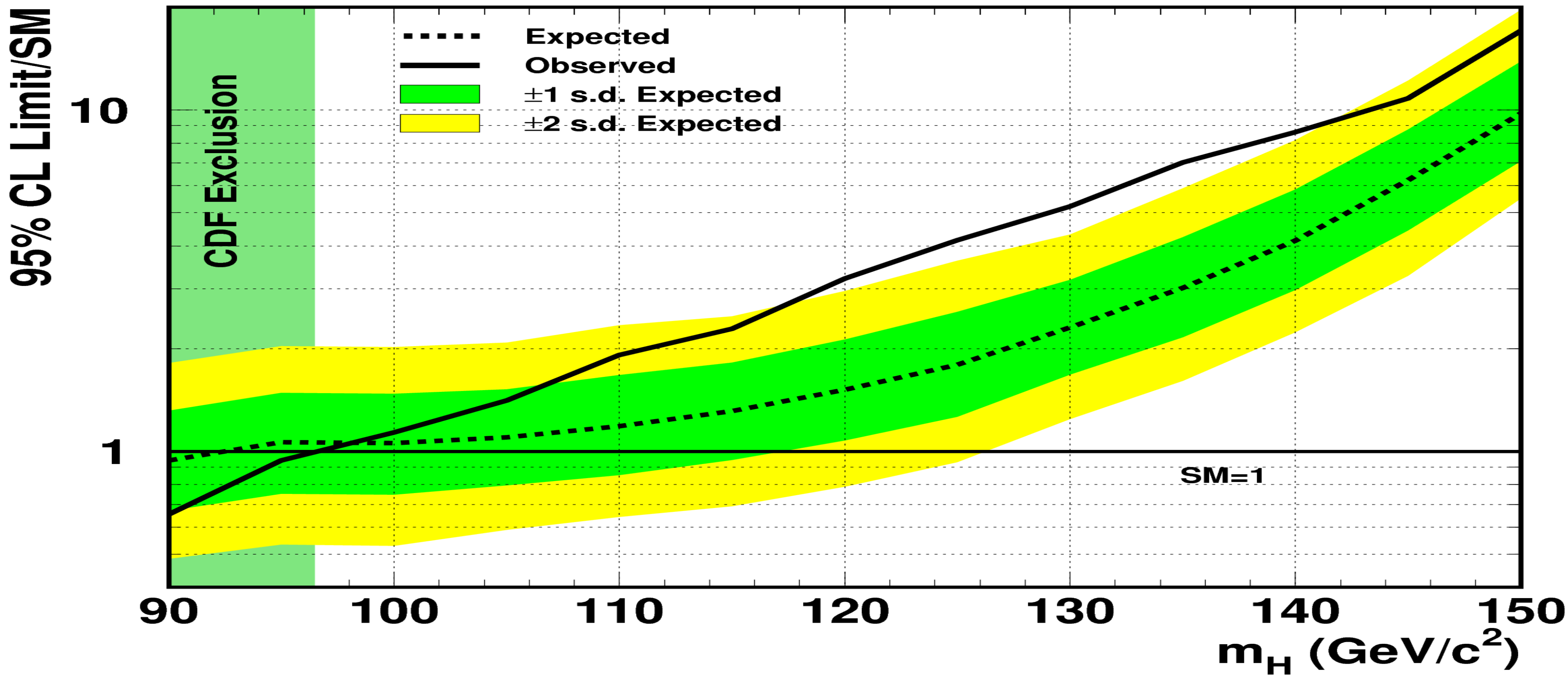
Searching for Z→bb

- To validate search strategy, we have looked for Z→bb in association with a W or Z using similar signatures: WZ/ZZ →llbb, lνbb, and ννbb.
- Measured σ_{WZ+ZZ}=(4.1+1.4-1.3)pb, compared to SM prediction of (4.4+-0.3)pb



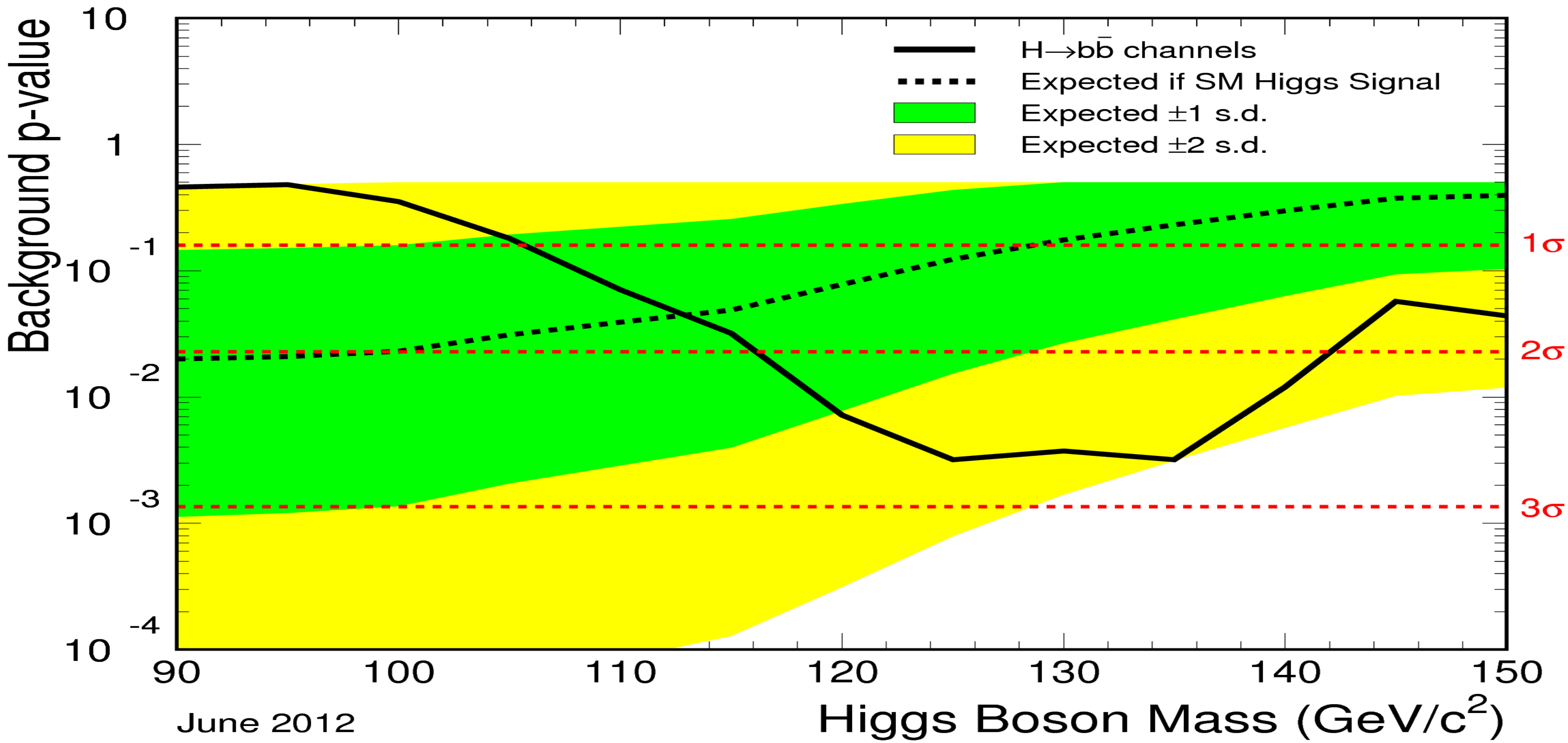
CDF H→bb Combination

- Combining H→bb in three channels to improve the Higgs sensitivity.
- Set 95% CL Obs/Exp: 4.15/1.80 @ mH=125 GeV
- There are >2σ excess of events in 115<mH<140 GeV



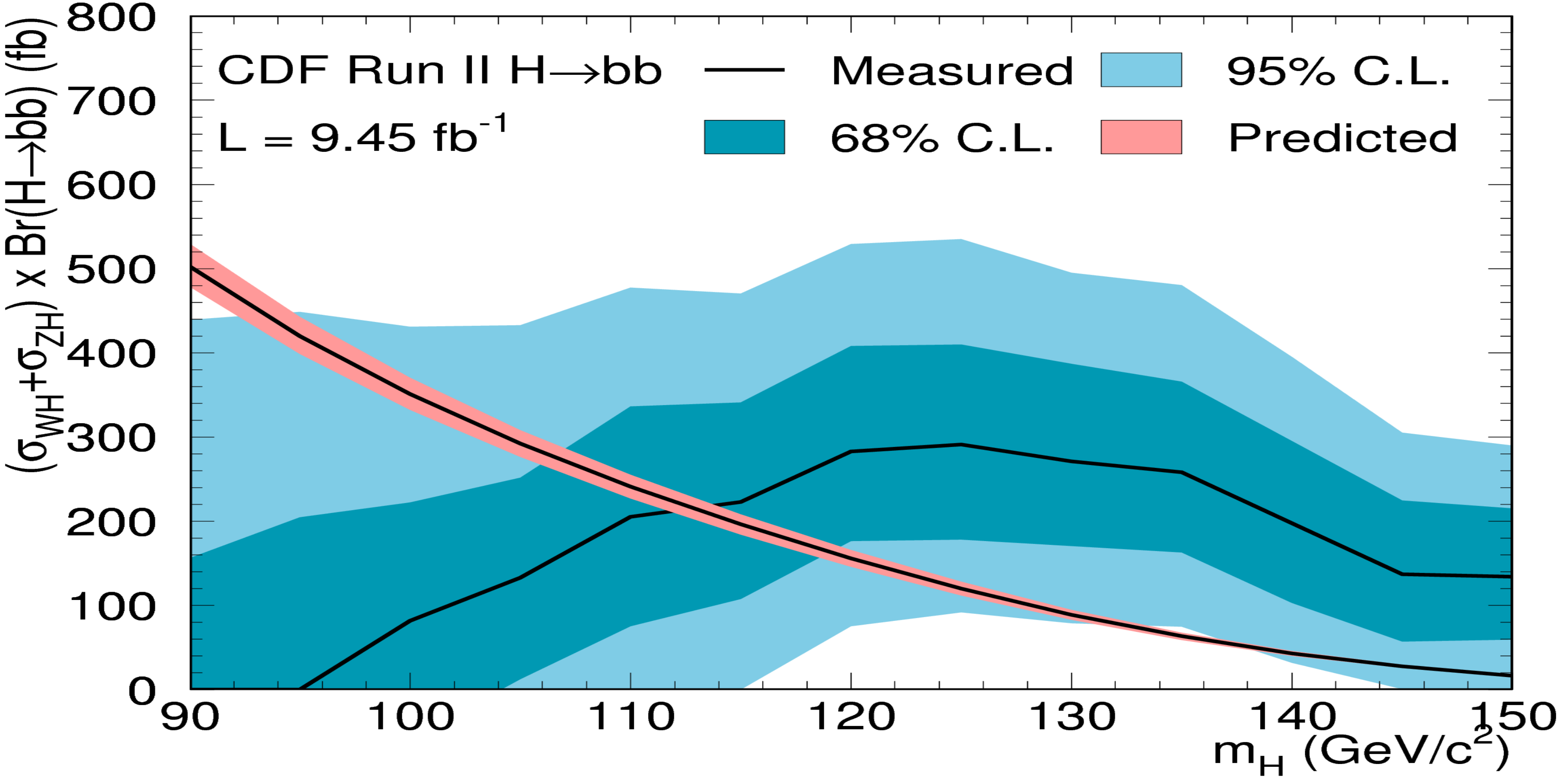
Quantifying the Excess:

- Calculating local p-value distribution for background-only hypothesis.
- Local p-value=2.7σ at 135GeV gives global p-value=2.5σ with LEE factor 2.



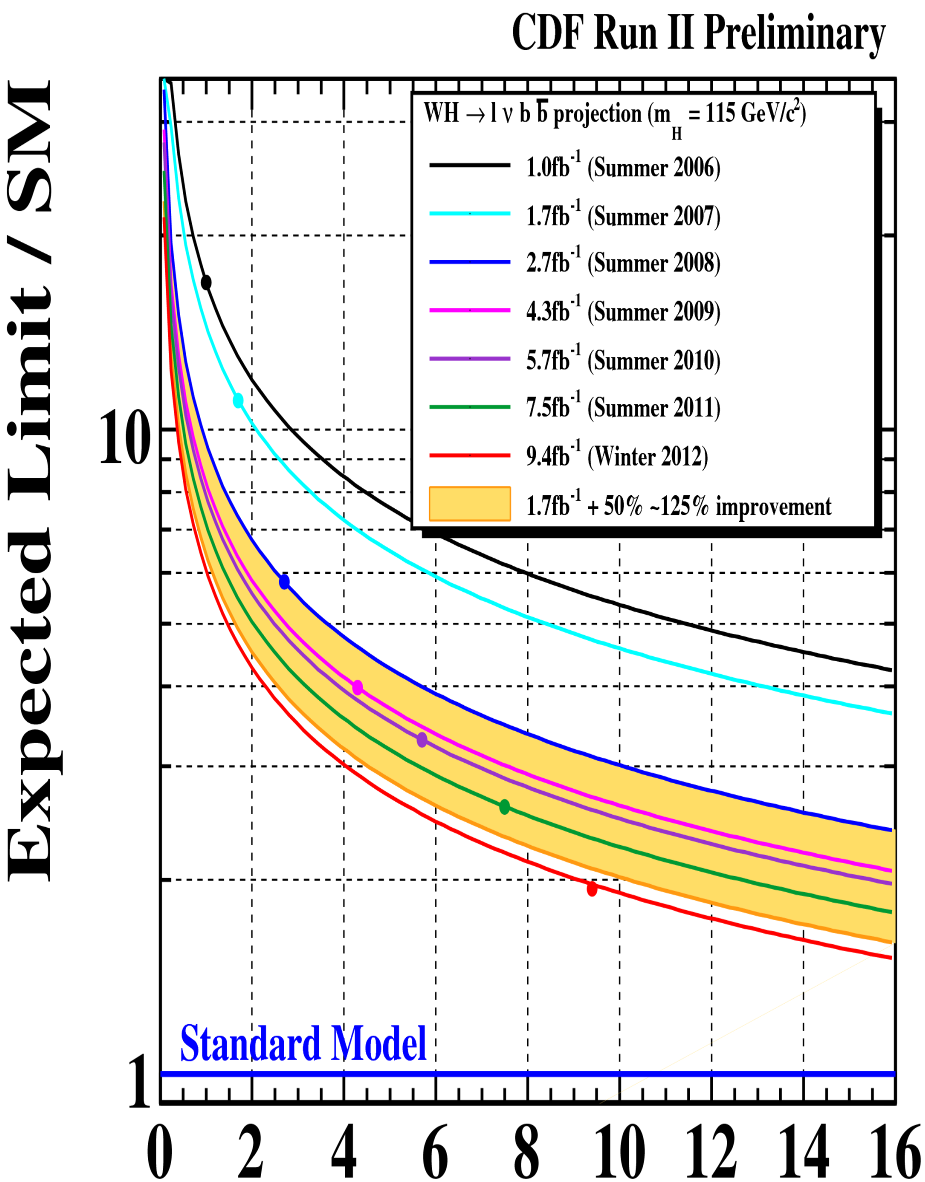
Fitted Signal Xsec*Br

- Fit to data with H→bb signal cross section times BR as a free parameter.
- Consistent with the SM Higgs expectation @ mH=125 GeV



Conclusion

- With full dataset, many years hardwork, CDF have exceeded our most optimistic sensitivity projection based on 2007 summer results.
- CDF observed small excess in $115 < m_H < 140$ GeV with a global p-value~2.5σ.
- This is exciting and looking forward to H→bb discovery at LHC.



BACKUP

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 channels:
  - Integrated luminosity (6%) , Trigger eff and Lepton Id (2-5%)
  - Btag SF (3.9-7.8%), Mistags (10-20 %)
  - JES(rate+shape), ISR/FSR + PDF + Q^2 (rate)
  - Theoretical cross sections (rate)
  - MC simulation of W/Z+HF (rate only)
- Instrumental background (no-W) is treated as independent (30%).
- Most of nuisance parameters are well constrained in the dominant background region and are not sensitive to the initial input values.
- Reweight W+HF MC to the pretag data and no effect on NN output is found.

Compatible with SM Higgs at 125 GeV

- Compared LLR after injecting Higgs(125) to bkgd-only pesudo-experiments.
- MVA is not optimized for mass, but for S/B separation, expect a broad excess.