Tevatron combination and BEH properties

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On behalf of the CDF and D0 Collaborations

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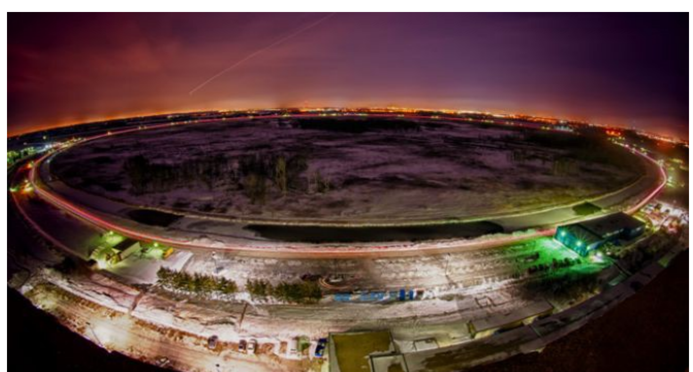
La Thuile, Italy



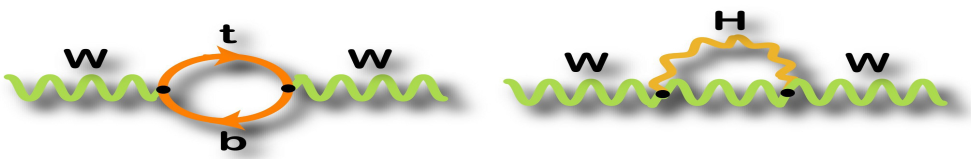
Outline

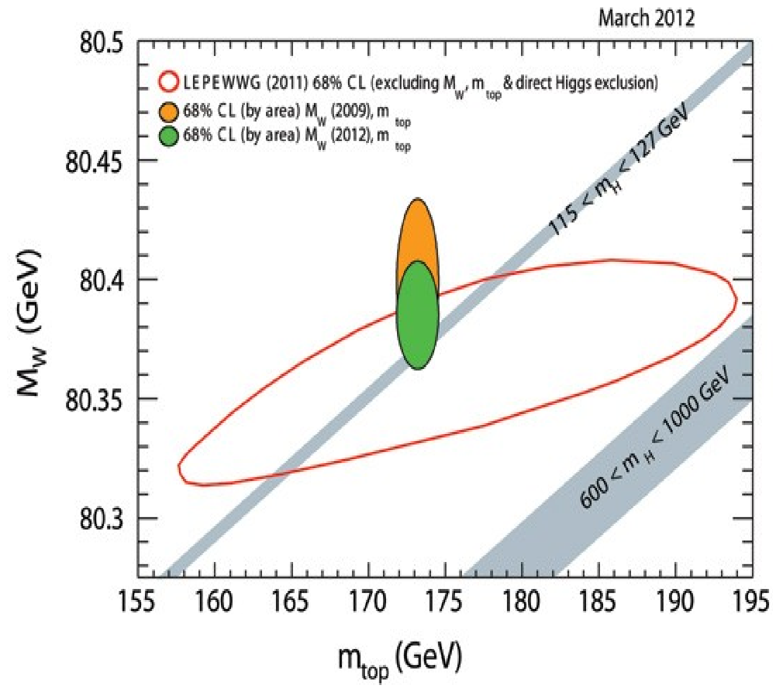
- Introduction
- Overview the BEH search strategies at Tevatron
- What's new since HCP
- Tevatron combination results with full dataset
- Studies of the BEH coupling
- Conclusion

- More Details:
- http://www-cdf.fnal.gov/Physics/S12CDFResults.html
- http://www-d0.fnal.gov/Rn2Physics/D0Summer2012.html
- http://tevnphwg.fnal.gov/results/SM_Higgs_Sumer_12/

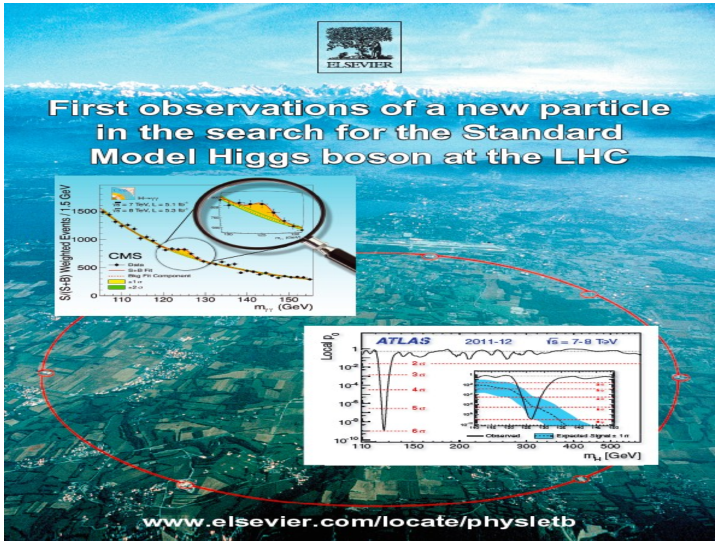
Introduction

- The BEH boson is hypothesized to be the remnant of a scalar field (H), responsible for the electroweak symmetry breaking.
- M_H is unknown,but indirect constrained by the global fit: M_H<152GeV@95%CL.





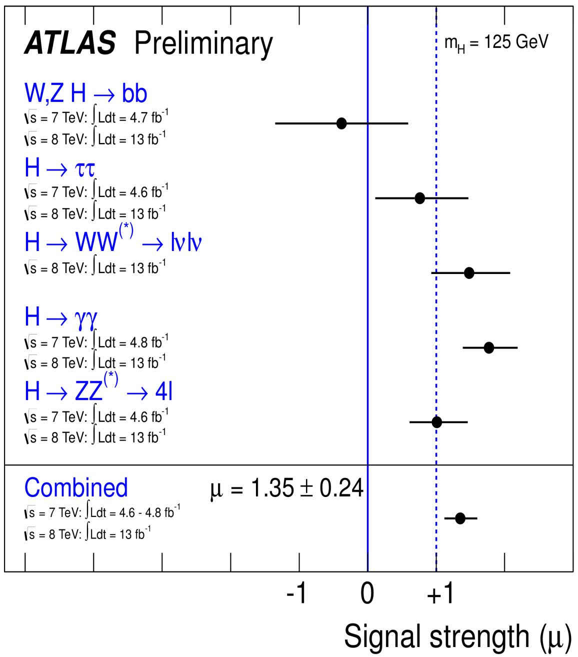
- Direct searches prior to the discovery
  - LEP, M_H>114.4 GeV
  - Tevatron: exclude 147<M_H<179 GeV
  - LHC:122<M_H<127 GeV.

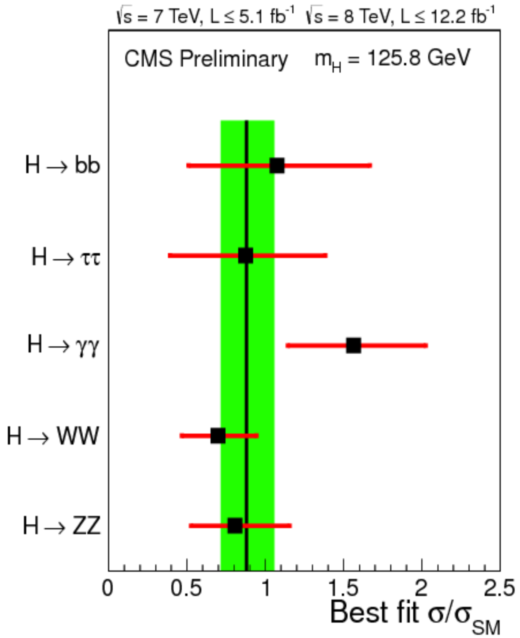


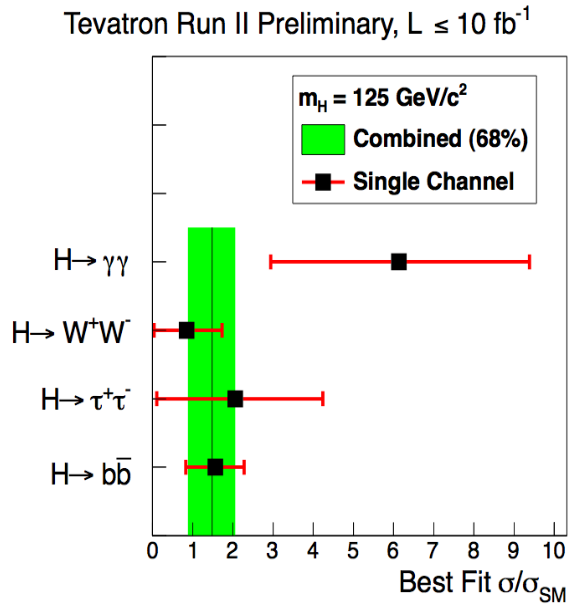
- Consistent with the LHC observation of a BEH-like particle at 125 GeV.

What is it ?

- In SM, bosons and fermions expected to gain mass through H coupling.
- Both ATLAS and CMS report strong signal for H decays to γγ, WW, ZZ, which probe the coupling to bosons. But no evidence for coupling to fermions yet.
- Tevatron reported an excess of H→bb in association with a vector boson production, providing first evidence for H coupling to ferminos (b-quarks).

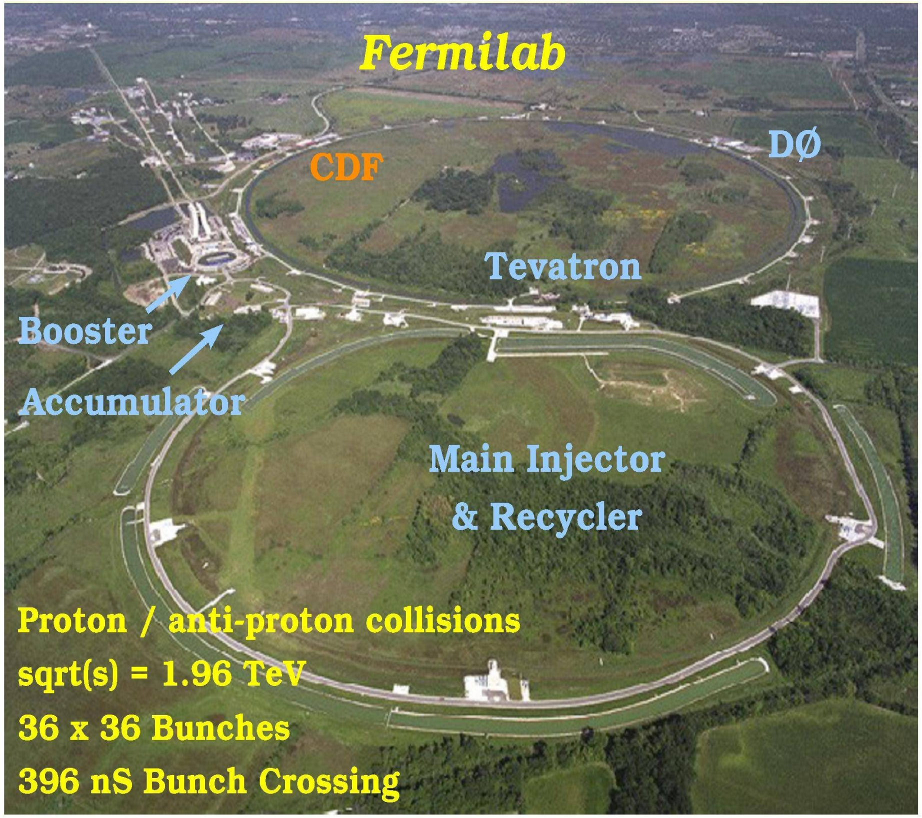


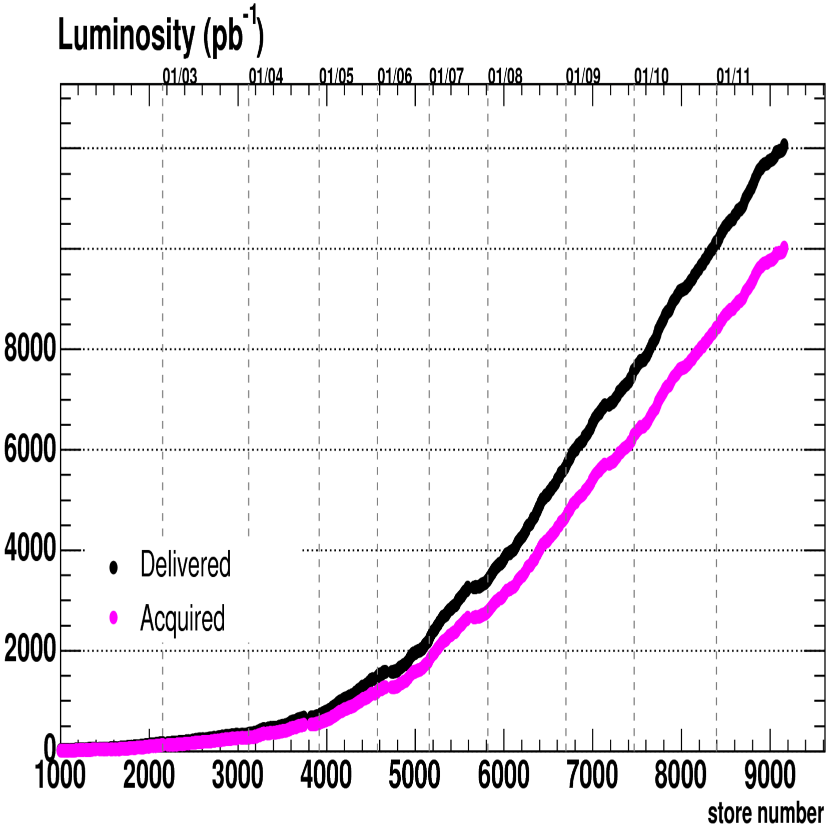




The Tevatron

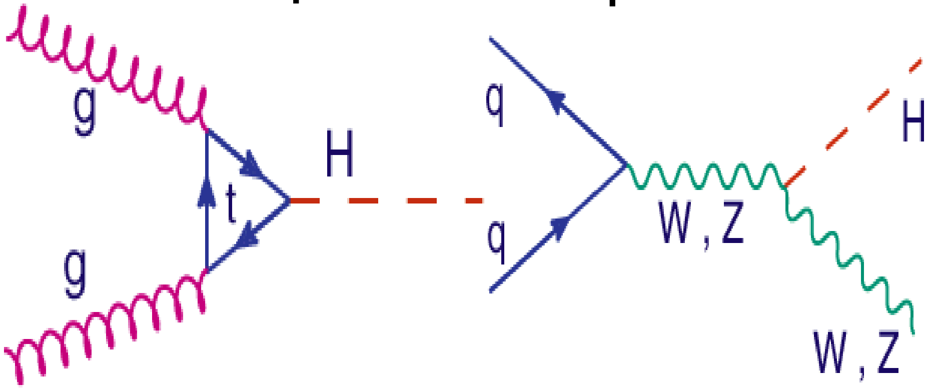
- Tevatron: p-pbar collision@1.96TeV, L_{peak}=4.3x10^{32} cm^{-2}s^{-1}
- Delivered ~12 fb^{-1} data before shutdown on 9/30/2011.
- Most results presented are based on the full dataset (~10 fb^{-1})

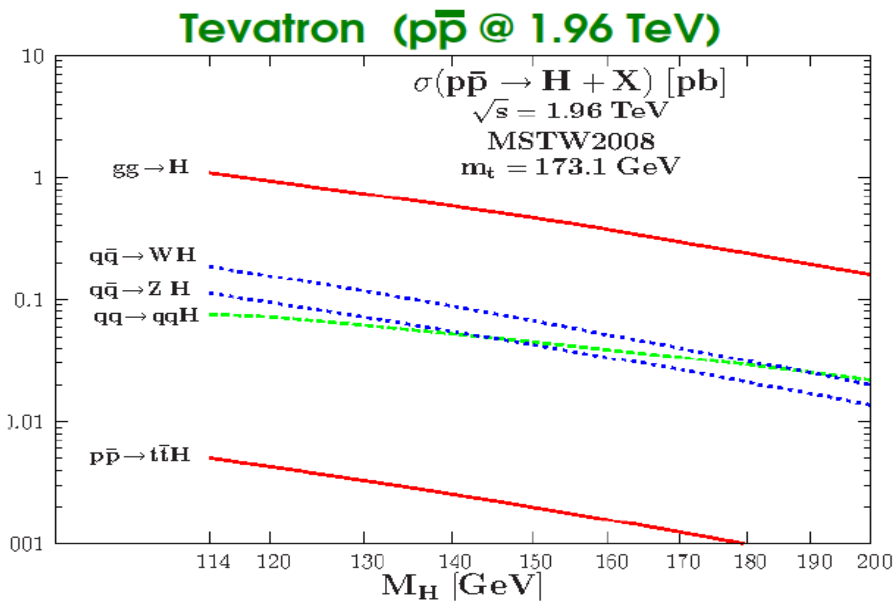




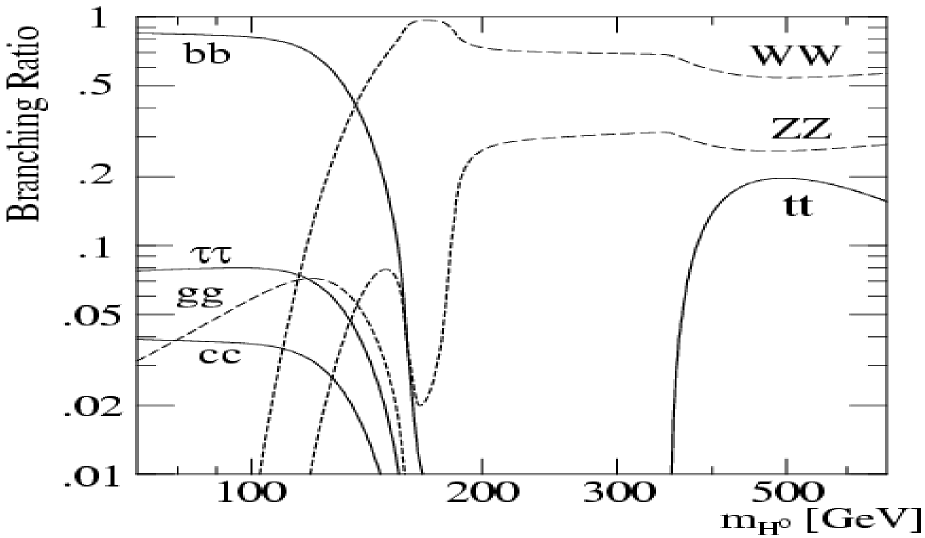
SM BEH Boson Production and Decay @ Tevatron

- 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.



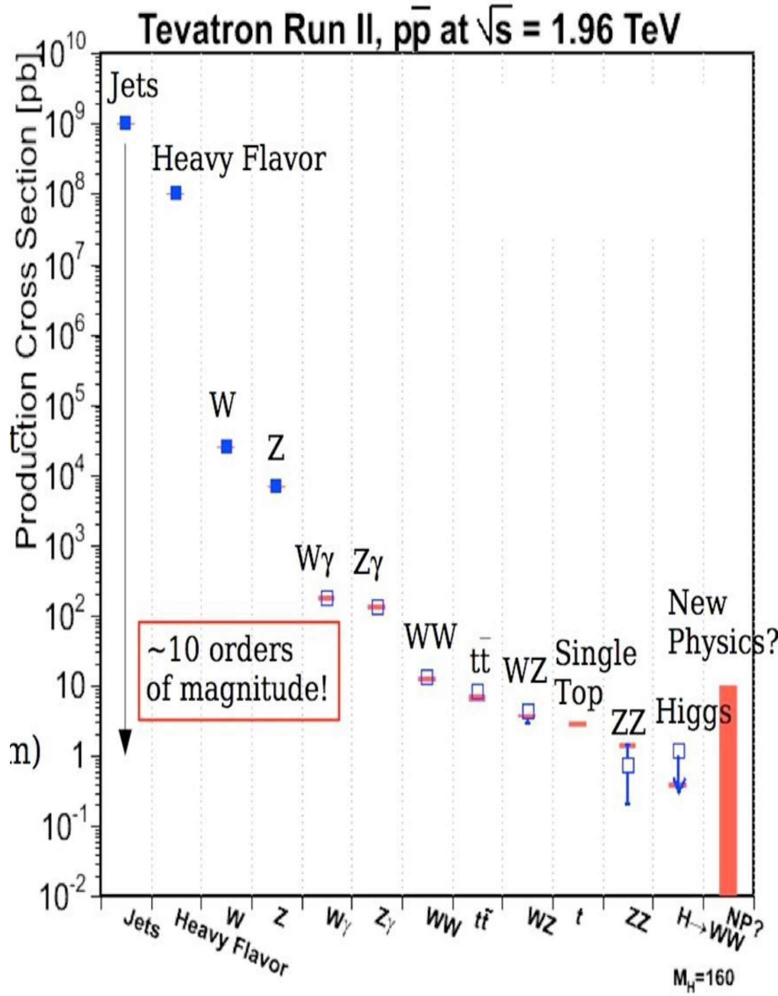
- For higher mass(MH>135GeV):

  Mainly decays: gg→H→WW,ZZ

- Other decays: H→ττ,γγ, and ttH.

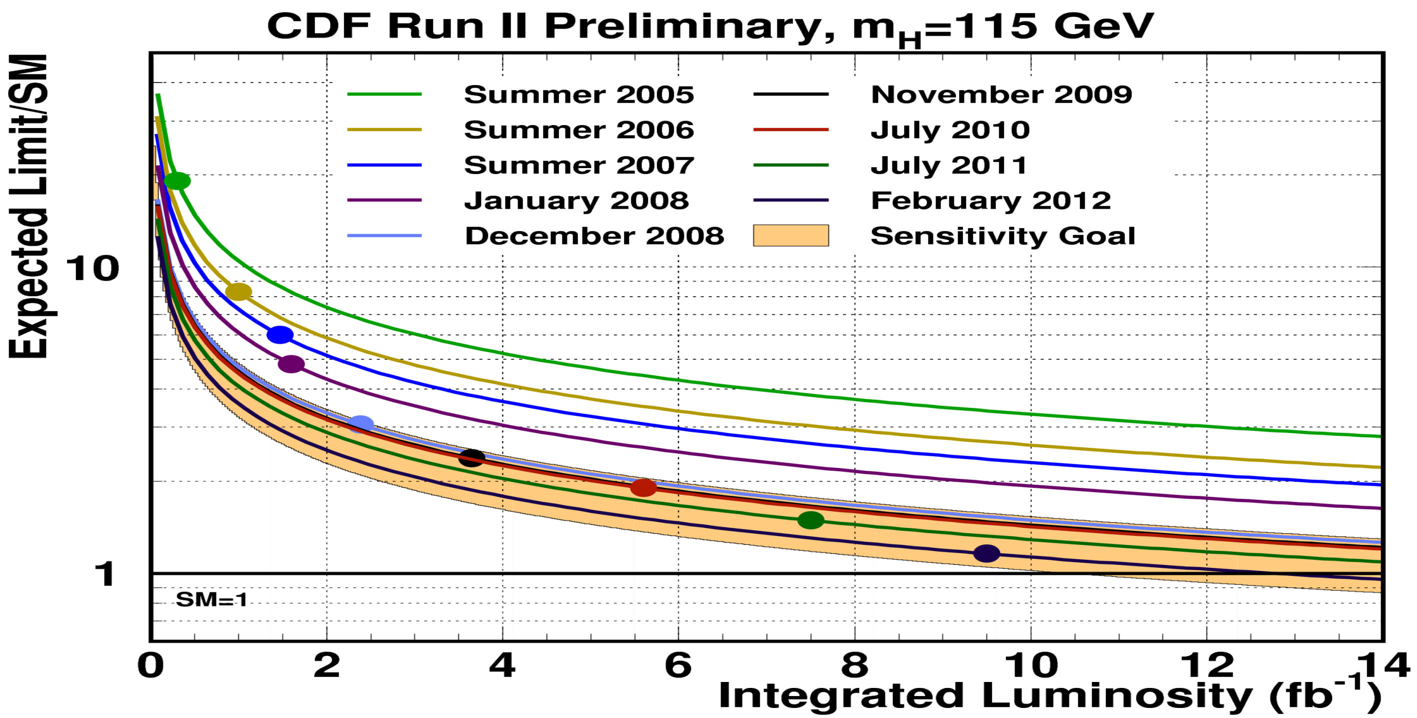
The Challenge

- The challenge for BEH boson search at Tevatron is that the 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 the best sensitivity is achieved.

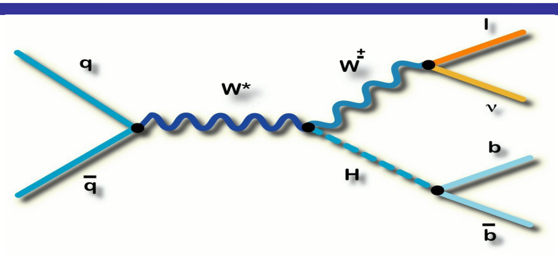


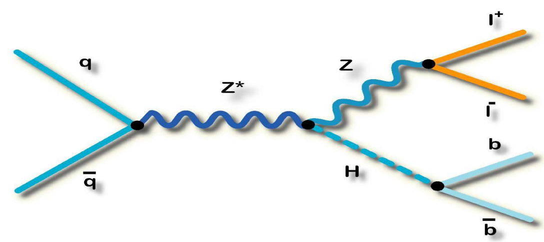
Sensitivity Improvement

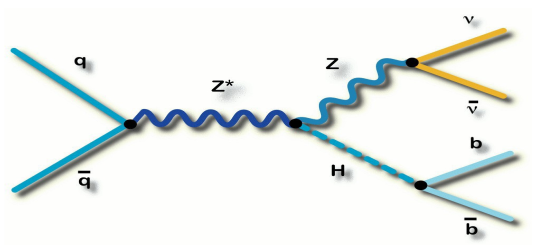
- In the past, we constantly introduced and improved analysis techniques that boost sensitivity beyond expectation from increased luminosity.
- Orange band corresponds to our conservative and aggressive sensitivity projection based on 2007 summer results.



Search for H→bb

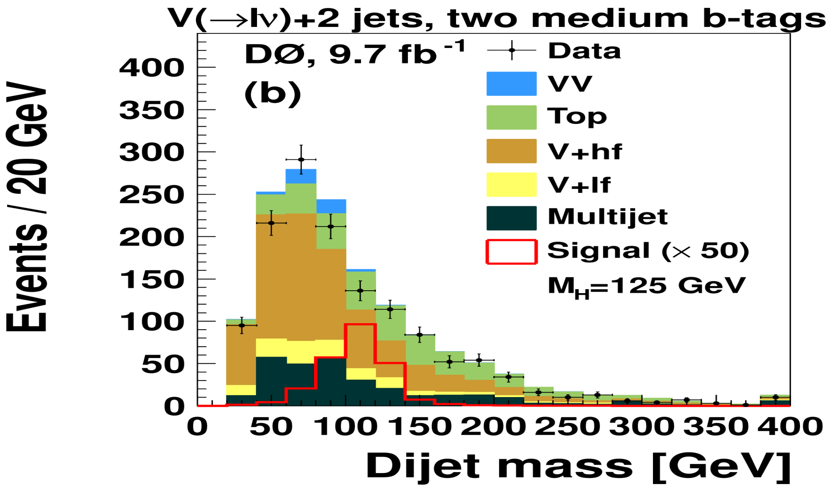


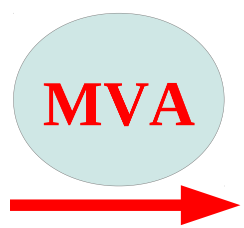


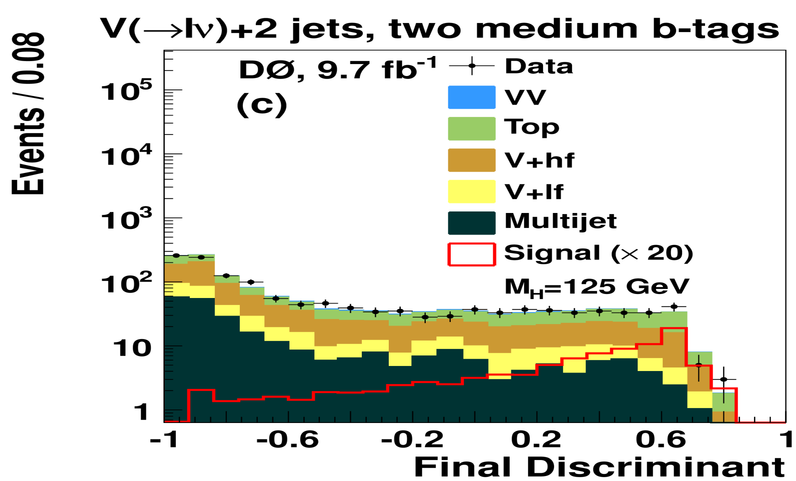


- Search for H→bb resonance in association with W or Z in three main channels.
- Most sensitivity channels is WH→lνbb: one lepton + MET+bb
- Requiring b-tagging and use advanced multivariate analysis (MVA) to further suppress the background with gain of 25% in sensitivity.

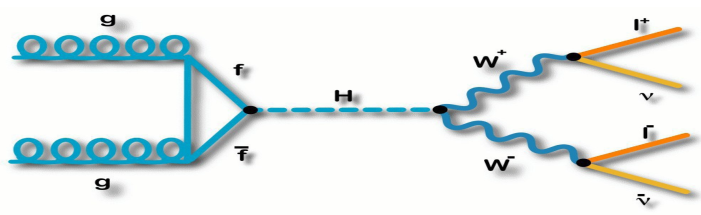
WH→lνbb

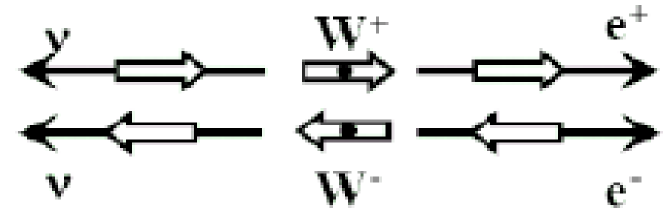






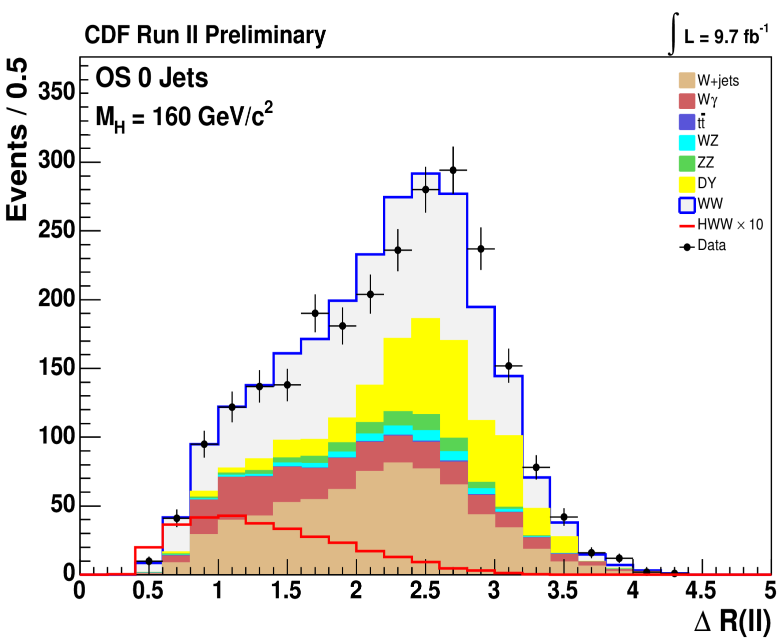
High Mass Signatures



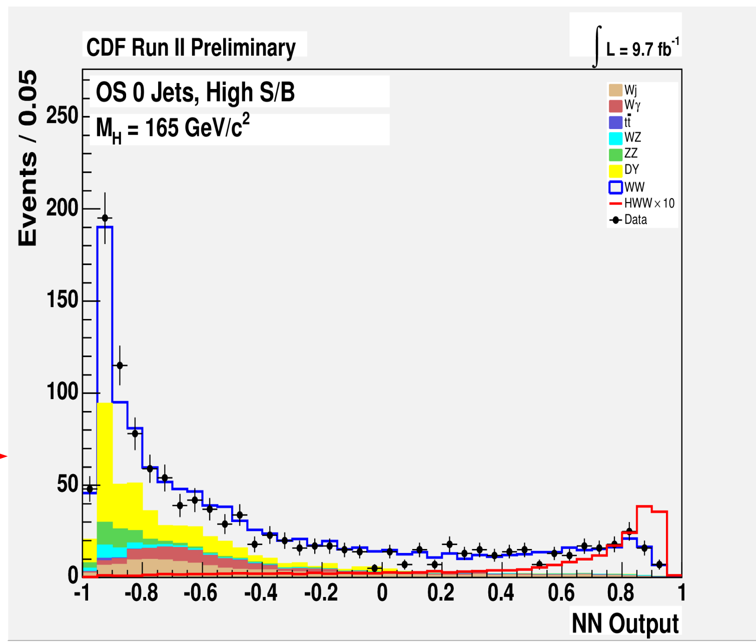


- Search for H→WW that leads to many interesting final states.
- Most sensitive channel is H→WW→lvlv: OS dilepton+met+0,1,2jets
- Requiring MVA to separate signal from main backgrounds (WW, ttbar)

H→WW→lvlv

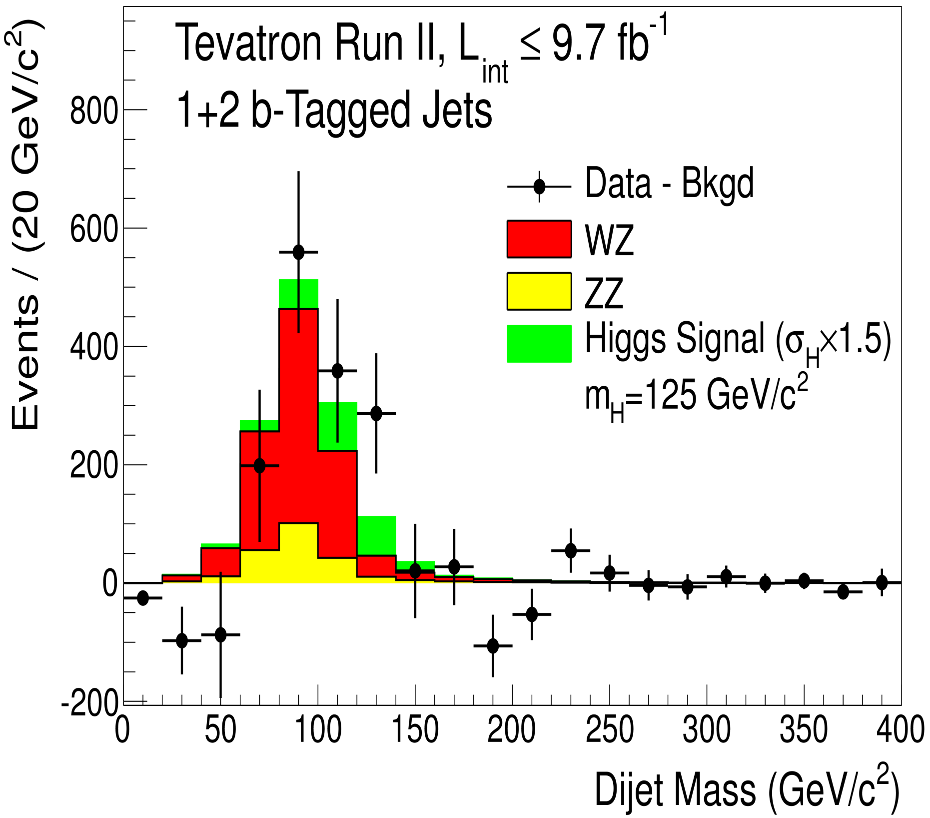


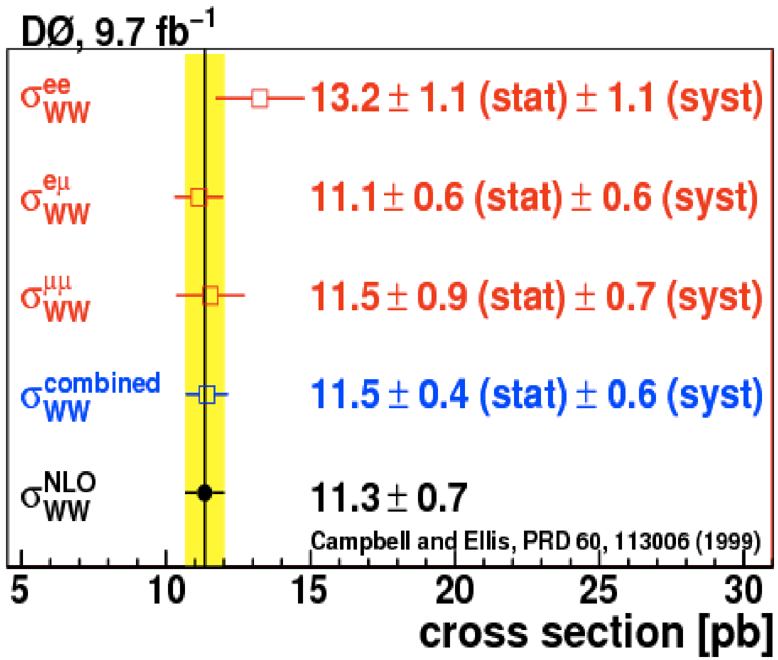
MVA



Validation of Search Strategies

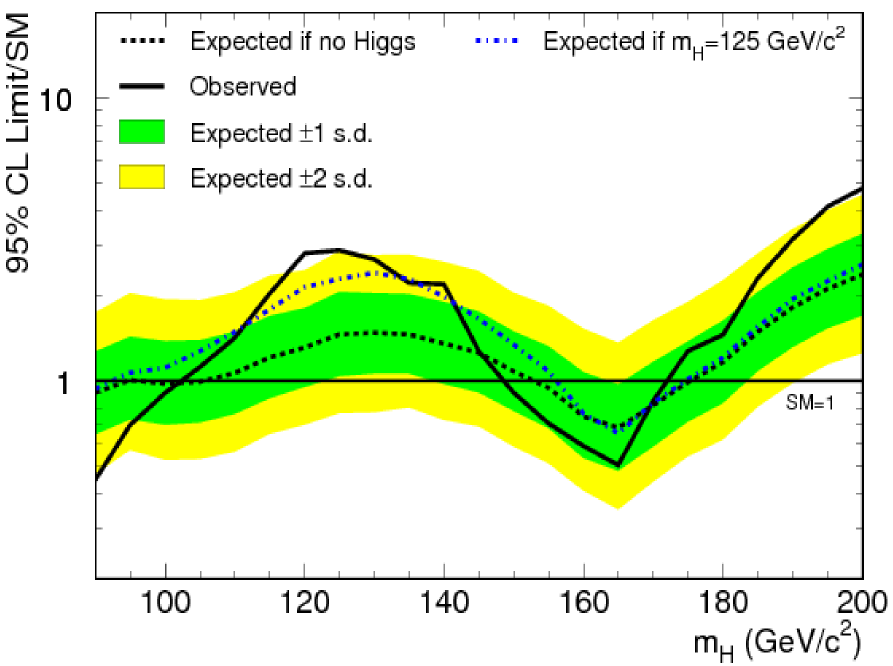
- Looking for known SM processes with same signatures and analysis tools.
  - For H→bb: look for Z→bb in WZ/ZZ→lvbb, llbb, and vvbb with measured σ_{WW+WZ}=(3.0+-0.9) pb, in good agreement with SM prediction of 4.4±0.3 pb.
  - For H→W+W-: look for SM WW production in WW→lvlv decay.

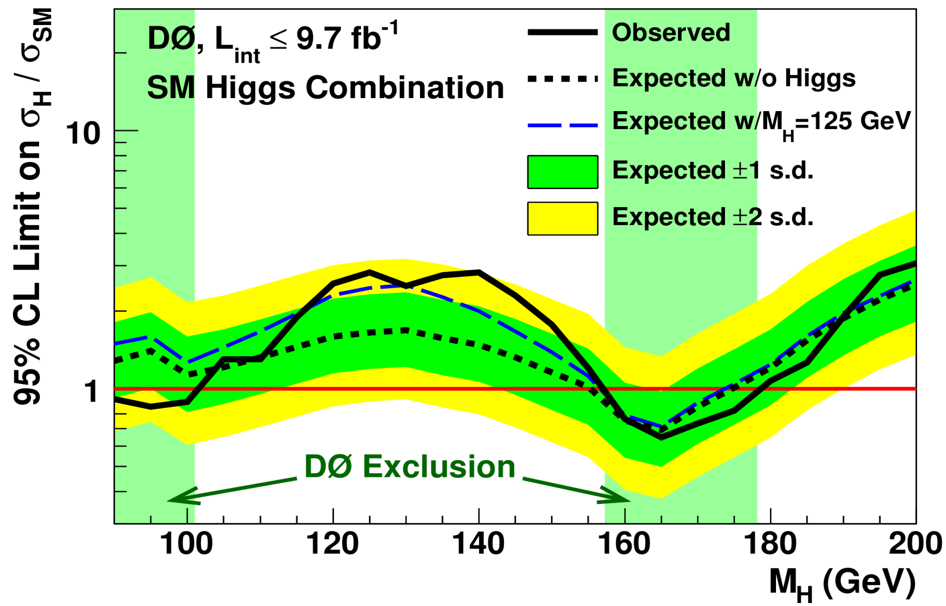




What's new since HCP

- There are no major changes in the analyses since HCP2012.
- Both collaboration have done many checks and are finalizing the publication of all analyses.
- Both collaborations have similar sensitivities, comparable results.
- The final Tevatron paper is under review by the collaborations and will be ready soon for the publication.





Combined Limits on SM BEH Boson Production

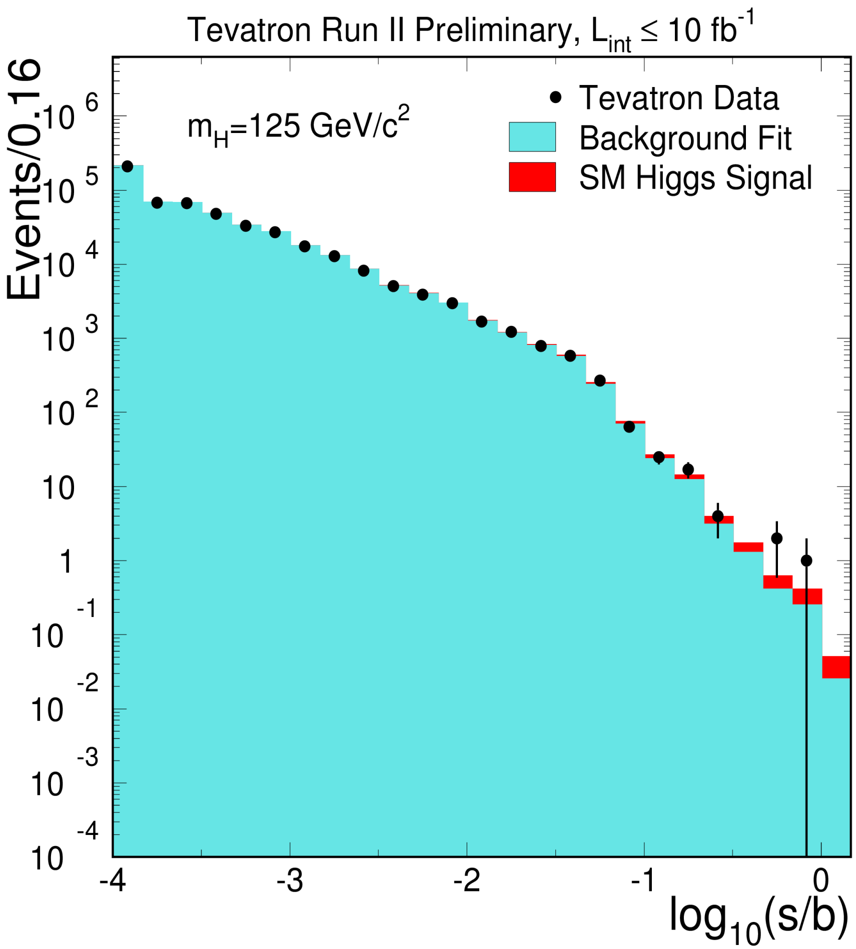
- Since combing searches in many different production/decays, cross section limits are given with respect to nominal SM predictions.
- This requires to incorporate latest theoretical predictions and careful treatment of systematic, correlations cross channels & experiments.
  - Luminosity (6%), trigger and lepton ID(2-5%)
  - B-tagging (3.9-7.8%) and mistag (10-20%)
  - Jet energy scale (JES) shape and rate
  - Theoretical uncertainties (PDF, Q2, ISR/FSR)
  - W/Z + jets modeling
- Interpreting data using Bayesian or Cls statistical tools to set limits or measure the production cross section.
- Most systematic parameters are constrained by the data in the background dominated region.

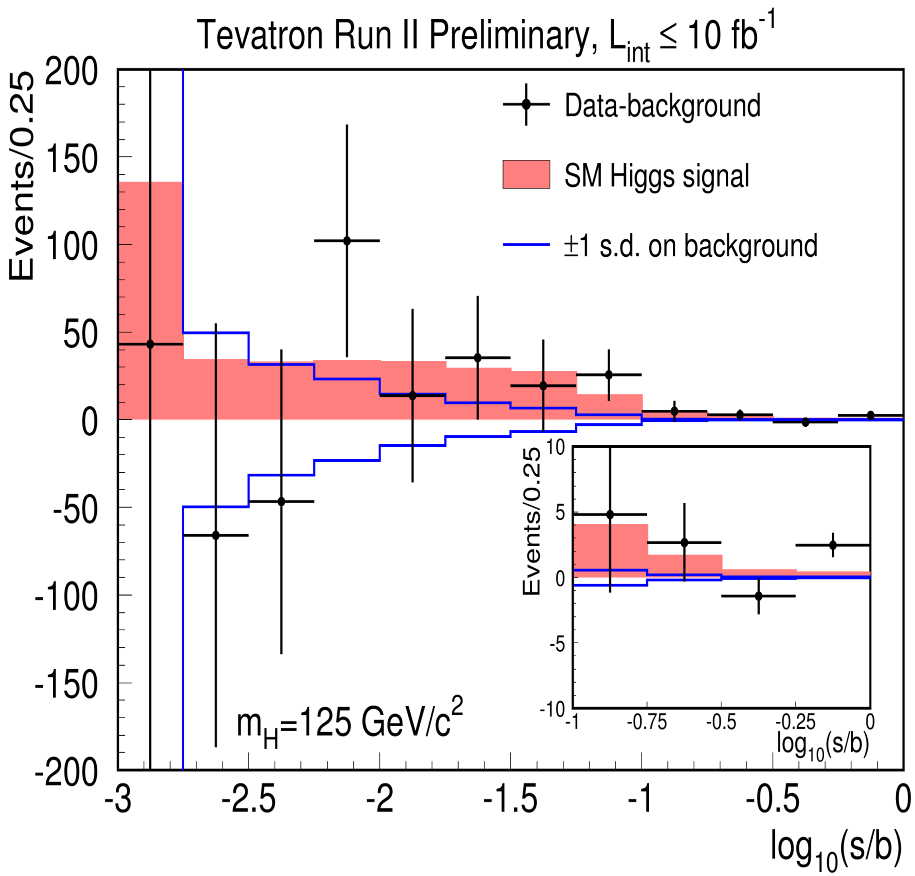
List of Input Channels

DØ	Luminosity (fb^{-1})	M_H (GeV)	Reference
$WH \to \ell\nu bb$	9.7	90–150	Phys. Rev. Lett. 109, 121804 (2012); Sub to PRD arXiv:1301.6122
$ZH \to \ell\ell b\bar{b}$	9.7	90–150	Phys. Rev. Lett. 109, 121803 (2012)
$ZH \to \nu\bar{\nu}b\bar{b}$	9.5	100–150	Phys. Lett. B 716, 285 (2012)
$H \to W^+W^- \to \ell^+\nu\ell^-\bar{\nu}$	9.7	100–200	Acc to PRD arXiv:1301.1243
$H + X \to WW \to \mu^\pm\tau_h^\mp + \leq 1\text{jet}$	7.3	155–200	Phys. Lett. B 714, 237 (2012)
$H \to W^+W^- \to \ell\nu q'\bar{q}$	9.7	100–200	Sub to PRD arXiv:1301.6122
$VH \to ee\mu/\mu\mu e{+}X$	9.7	100–200	Sub to PRD arXiv:1302.5723
$VH \to e^\pm\mu^\pm{+}X$	9.7	100–200	Sub to PRD arXiv:1302.5723
$VH \to \ell\nu q'\bar{q}q'\bar{q}$	9.7	100–200	Sub to PRD arXiv:1301.6122
$VH \to \tau_h\tau_h\mu + X$	8.6	100–150	Sub to PRD arXiv:1302.5723
$H + X \to \ell\tau_h jj$	9.7	105–150	Acc. by PRD arXiv:1211.6993
$H \to \gamma\gamma$	9.7	100–150	Submitted to PRD, arXiv:1301.5358
CDF			
$WH \to \ell\nu bb$	9.45	90–150	Phys. Rev. Lett. 109, 111804 (2012)
$ZH \to \ell\ell b\bar{b}$	9.45	90–150	Phys. Rev. Lett. 109, 111803 (2012)
$ZH \to \nu\bar{\nu}b\bar{b}$	9.45	90–150	Phys. Rev. Lett. 109, 111805 (2012); Acc. by PRD arXiv: 1301.4440
$H \to W^+W^- \to \ell^+\nu\ell^-\bar{\nu}$	9.7	110–200	FERMILAB-PUB-13-029-E, For submission to PRD
$H \to WW \to e\tau_h\mu\tau_h$	9.7	130–200	FERMILAB-PUB-13-029-E, For submission to PRD
$VH \to ee\mu/\mu\mu e{+}X$	9.7	110–200	FERMILAB-PUB-13-029-E, For submission to PRD
$H \to ZZ \to llll$	9.7	120–200	Phys. Rev. D 86 (2012) 072012
$H \to \tau\tau$	6.0	100–150	Phys. Rev. Lett. 108, 181804 (2012)
$VH \to jjb\bar{b}$	9.45	100–150	JHEP 1302 (2013) 004
$H \to \gamma\gamma$	10.0	100–150	Phys. Lett. B 717, 173 (2012)
$t\bar{t}H \to WWb\bar{b}b\bar{b}$	9.45	100–150	Phys. Rev. Lett. 109 (2012) 181802

Visualizing Data at M_H=125 GeV

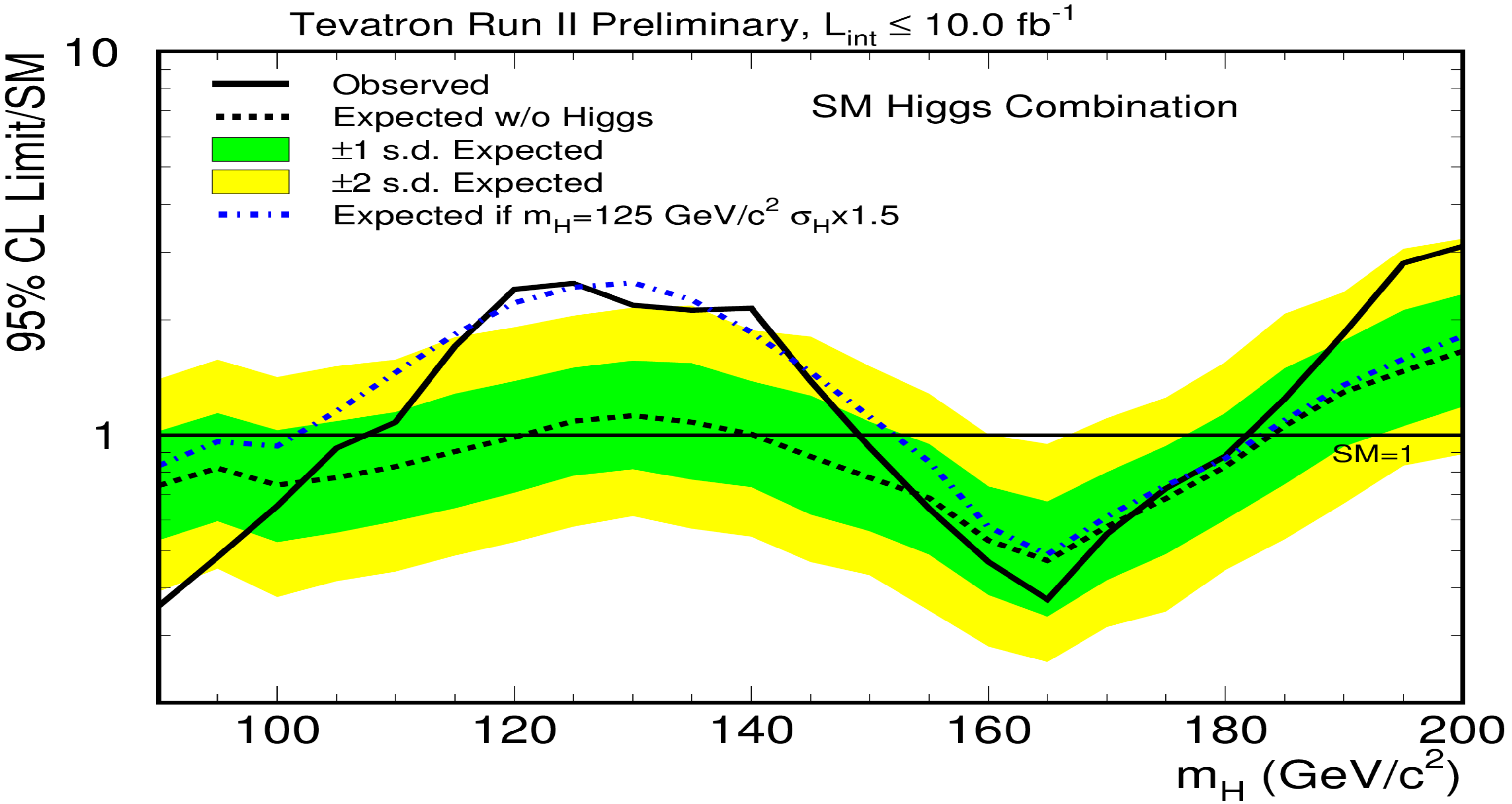
- Display cumulative discriminant from >100 channels, ordered by S/B.
- Expect to find an excess in high score region if there is a signal.



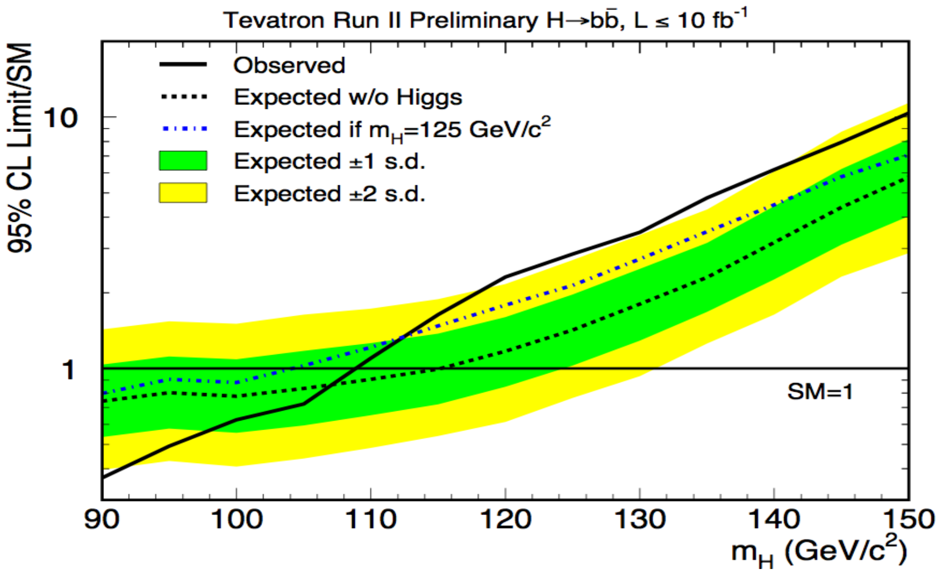


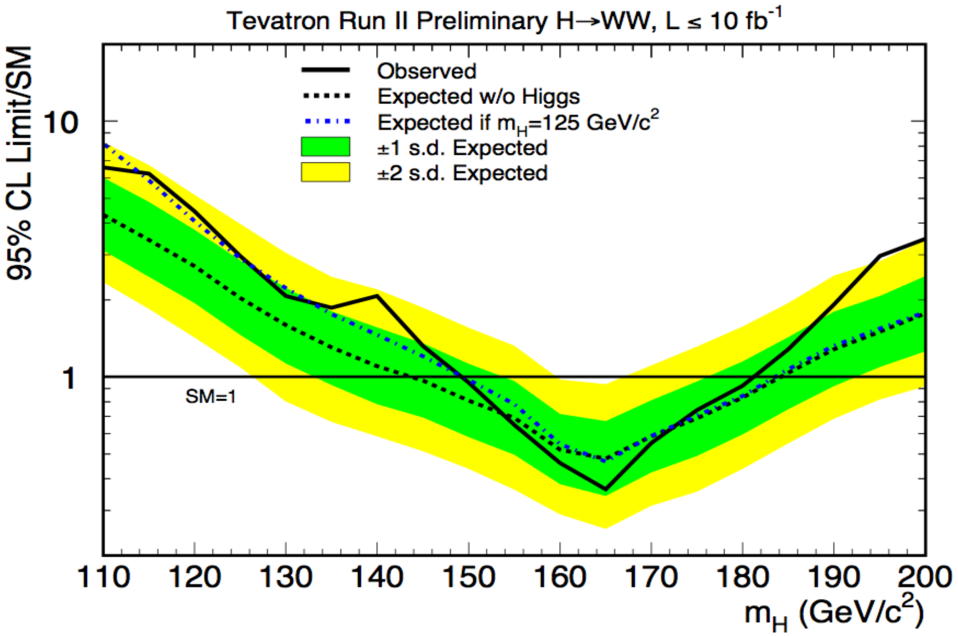
Tevatron Combination

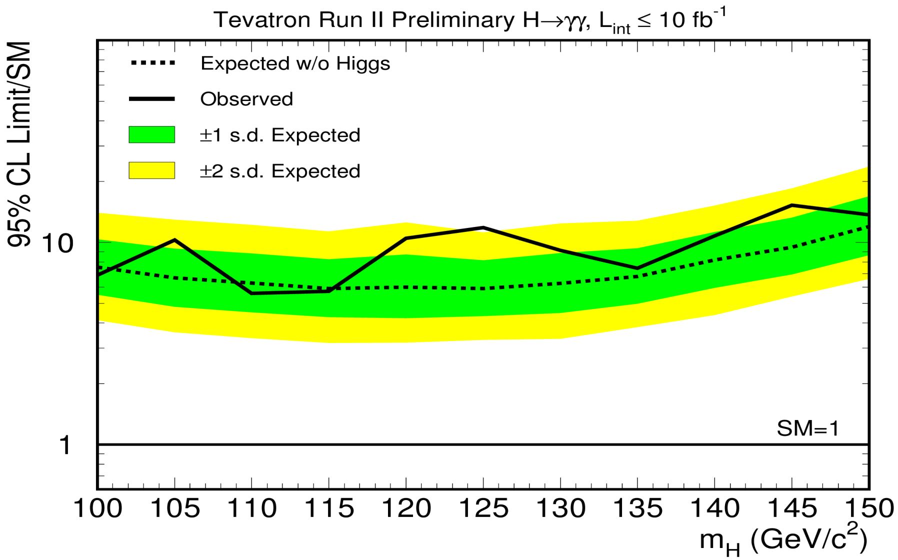
- Exclusion regions at 95% CL:
  - high mass: 149-182 with expectation of 140-184 GeV/c2
  - low mass: 90-107 with expectation of 90-121 GeV/c2.
- Broad excess(>2σ) observed between 115-140 GeV/c2.

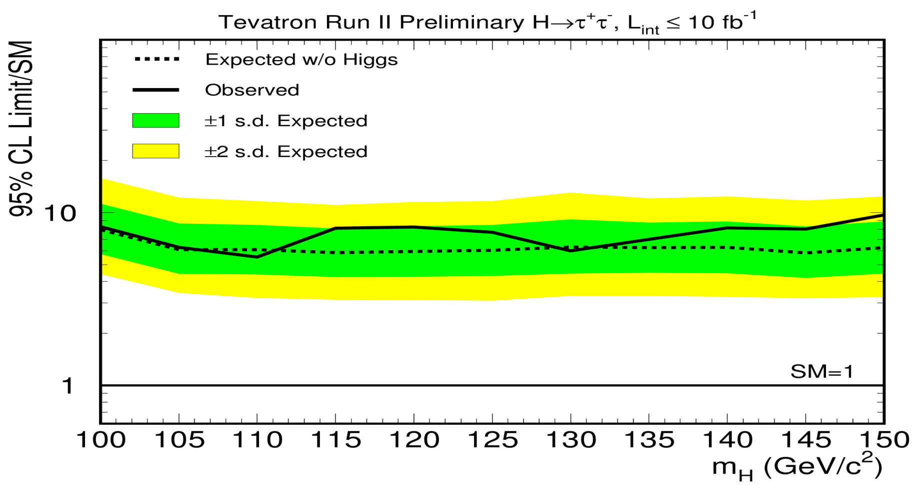


Tevatron Combination by Channel



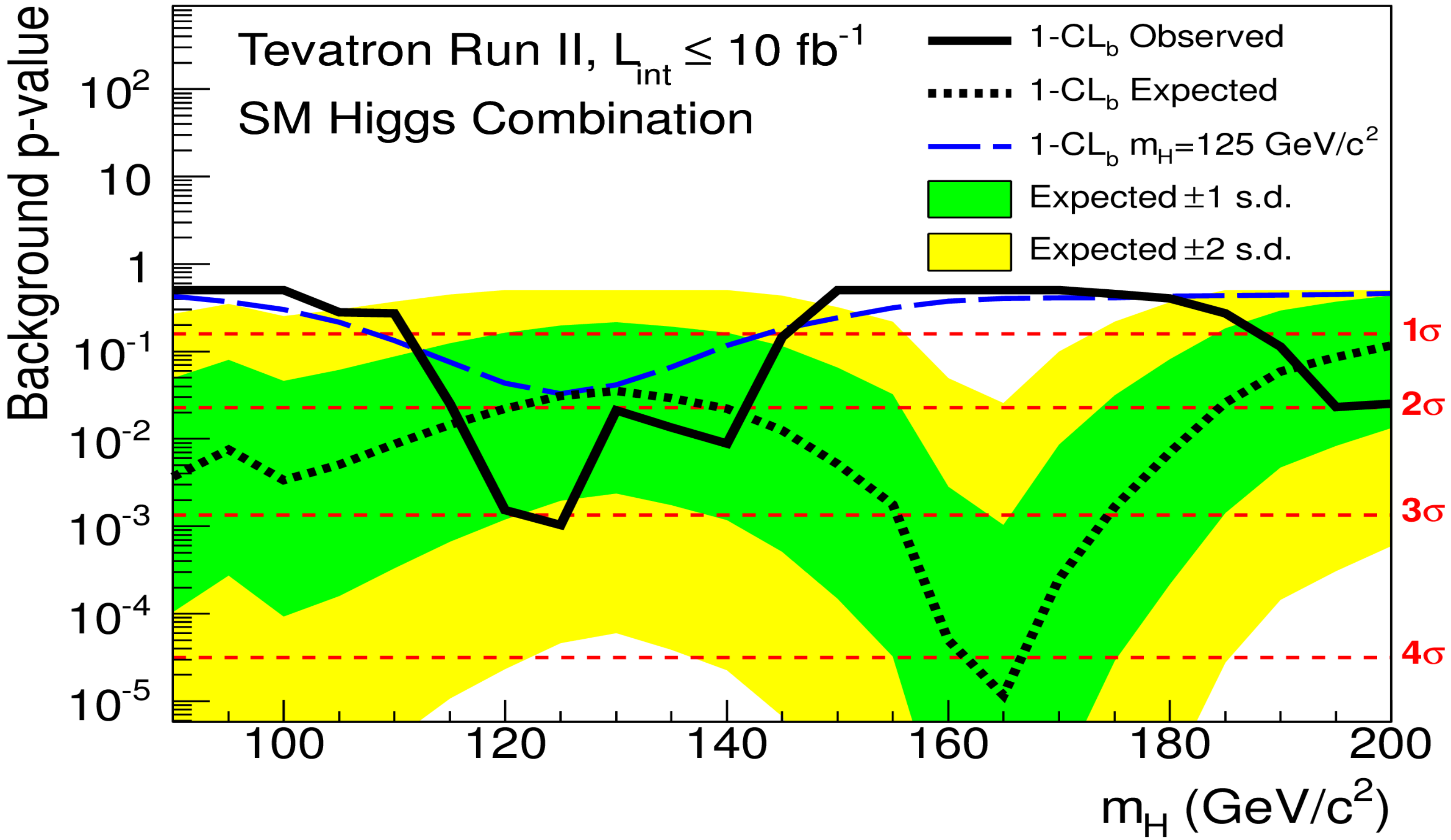






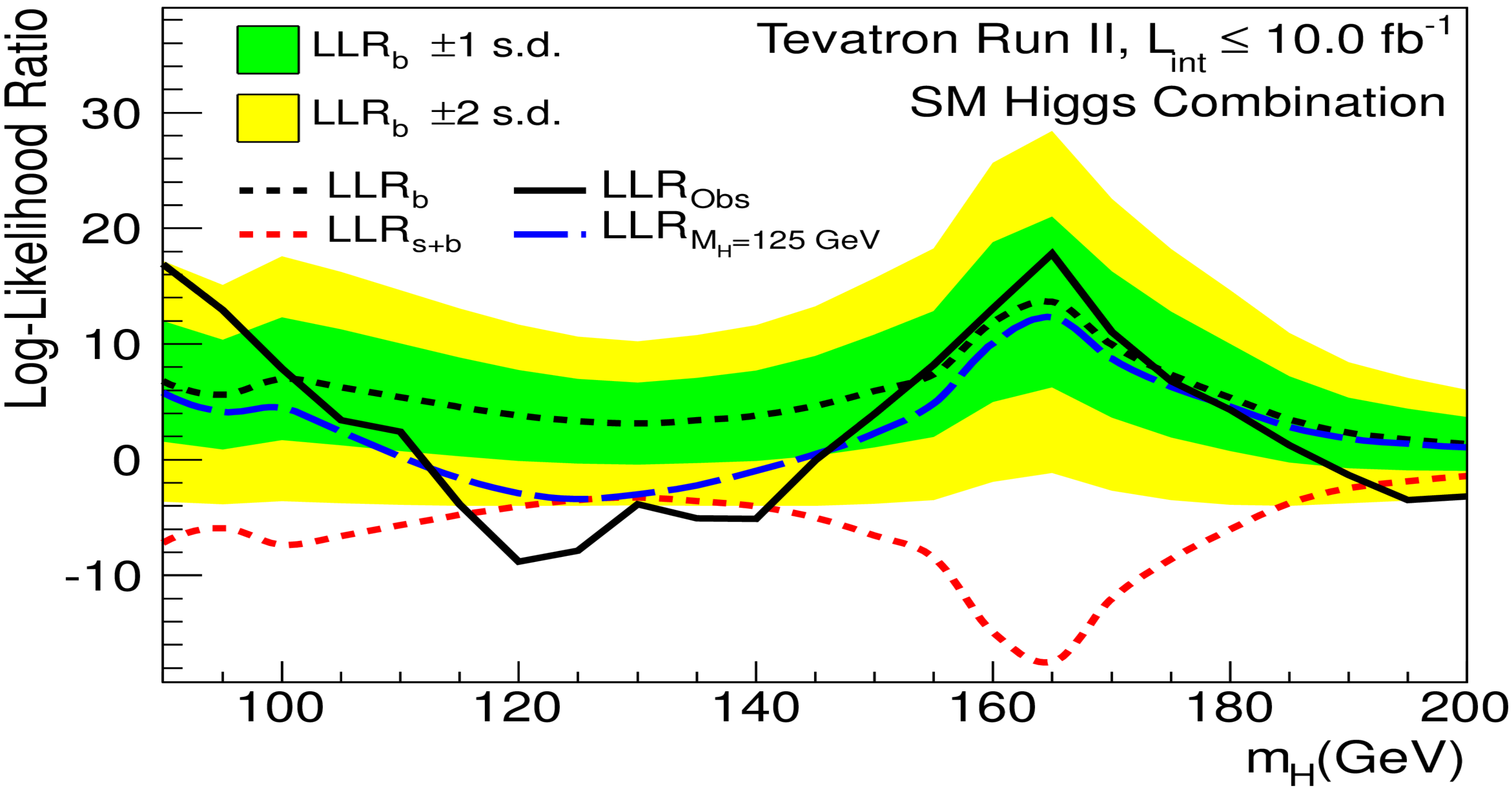
Quantifying the Excess

- Calculating local p-value distribution for background-only hypothesis.
- The minimum p-value is found to be 3.1σ at m_H =125GeV.



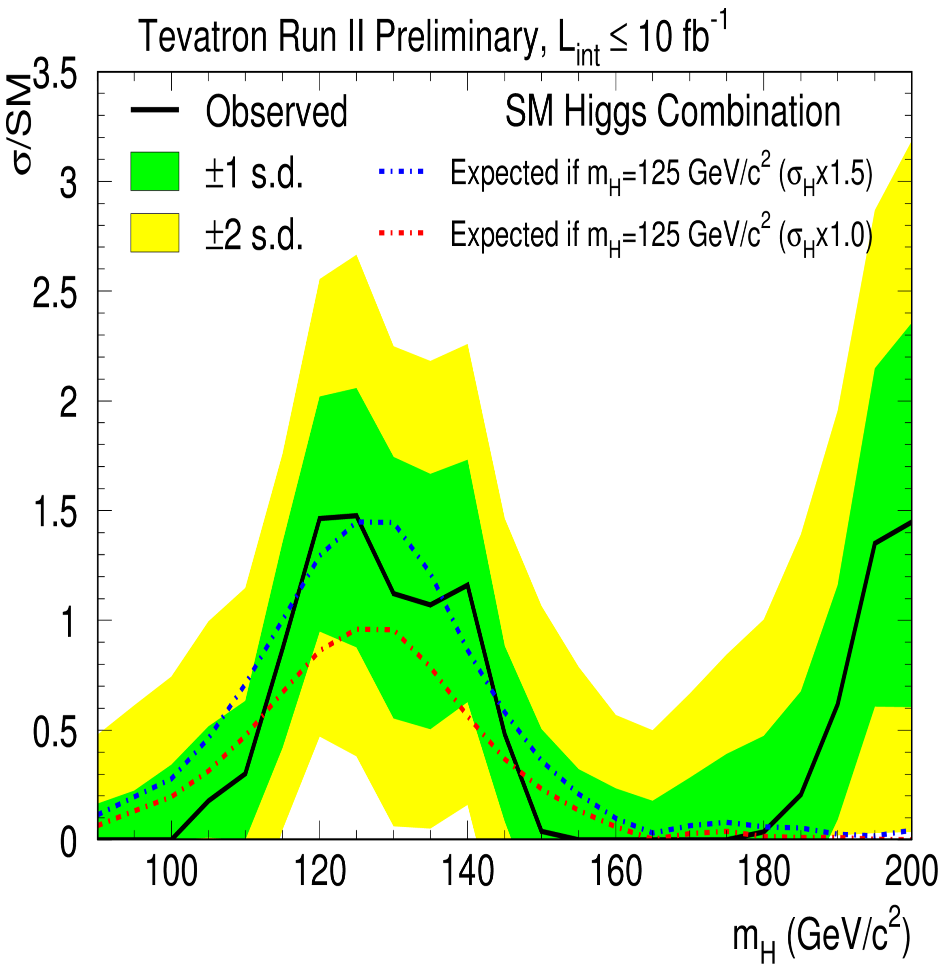
Compatible with SM BEH at 125 GeV

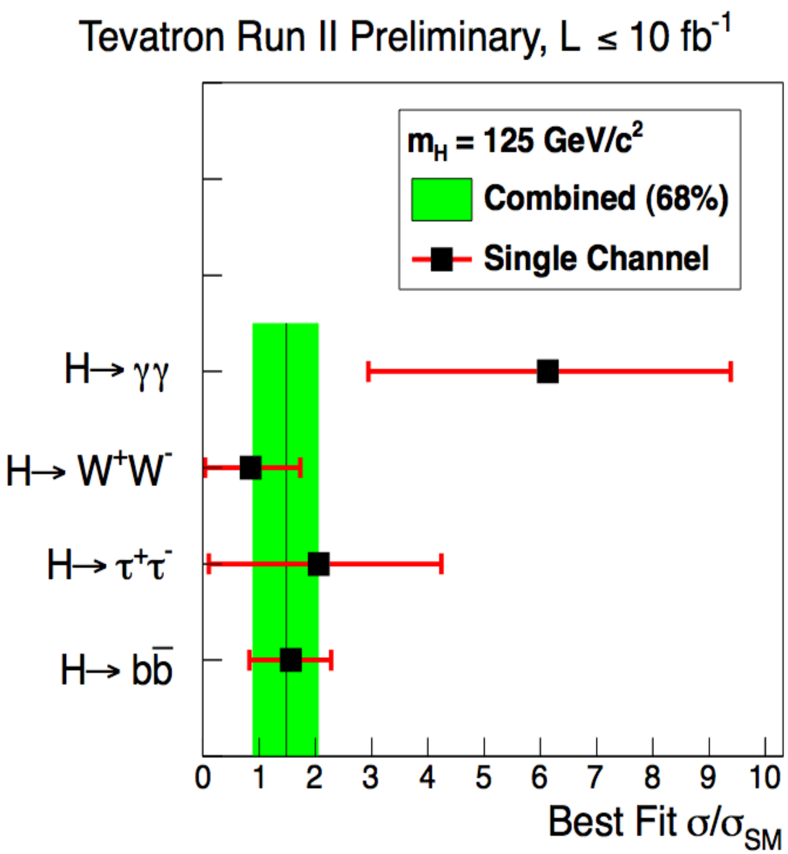
- Compared LLR by injecting a H signal of 125 to background-only pesudo-experiments, which is broad due to MVA is not optimized for mass, but for S/B.
- The shape including a 125 GeV Higgs is consistent with observed in the data.



Tevatron Cross Section Fits

- Fit to signal strength (1.4±0.6)xSM @125 GeV, consistent with SM prediction.
- Fit separately to H→γγ, WW, ττ, and bb, consistent across channels.





Studies of BEH Boson Properties

•Studies of the coupling will help to understand what the new particle is and they can be parameterized through coupling factors respect to SM:

- K_f is for Hff fermion coupling,
- K_W, K_Z, K_V for HWW, HZZ, HVV boson coupling ($\lambda_{WZ}=K_W/K_Z$).

•Most searches at the Tevatron are sensitive to the product of fermion and boson couplings , for example:

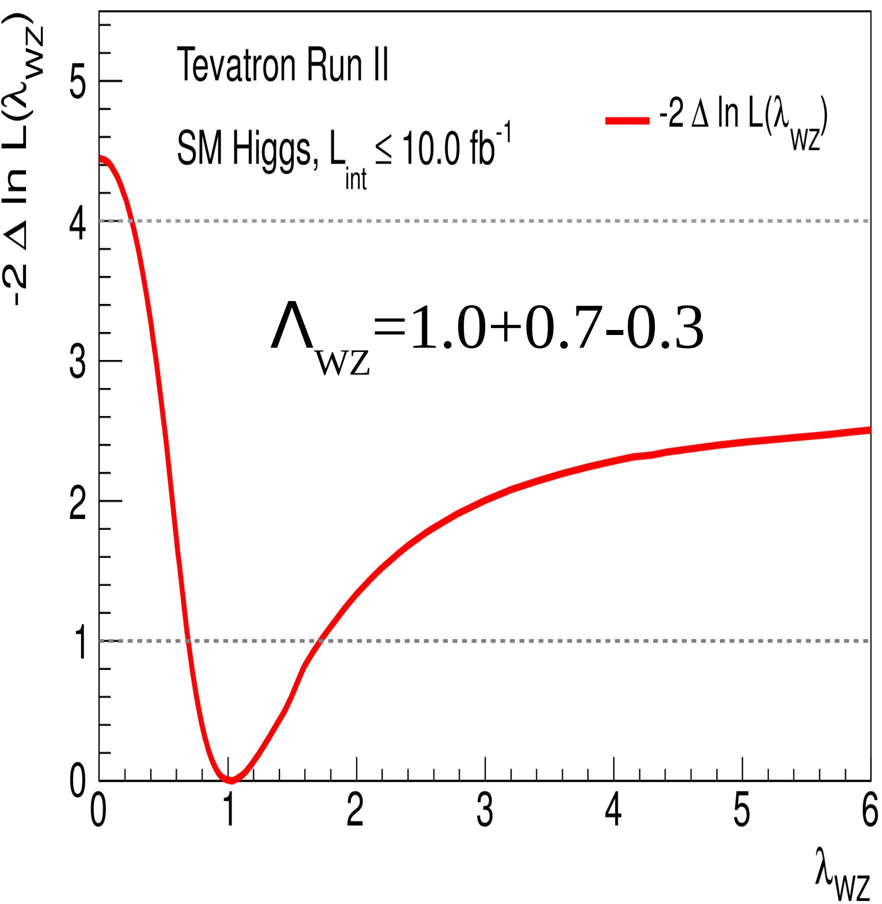
- $\sigma(gg\rightarrow H)*B(H\rightarrow VV) = (\sigma*B)_{SM}*(0.95K_f^2+0.05K_fK_V)*K_V^2$.
- $\sigma(VH)*B(H\rightarrow bb) = (\sigma*B)_{SM}*K_V^2*K_f^2$.

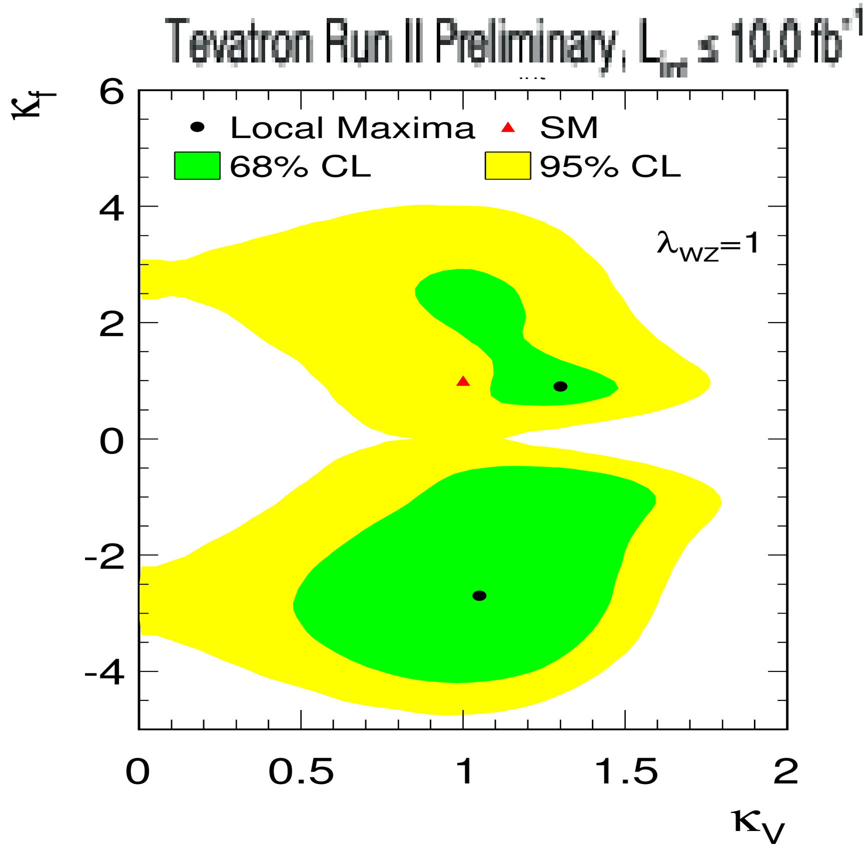
•We follow the procedures of LHC Higgs cross section WG (arXiv:1209.0040).

• Assuming uniform prior for all K's.

Constraining BEH Boson Coupling

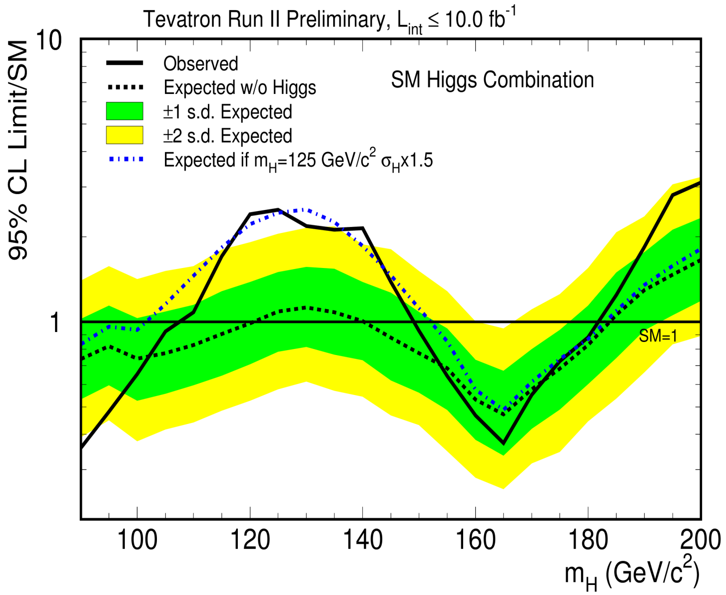
- Constraining the custodial symmetry: $\lambda_{WZ}=K_W/K_Z$ by assuming $K_f=1$
- Constraining K_f and K_V simultaneously by assuming $\lambda_{WZ} = 1$.
- Results are consistent with SM predictions.

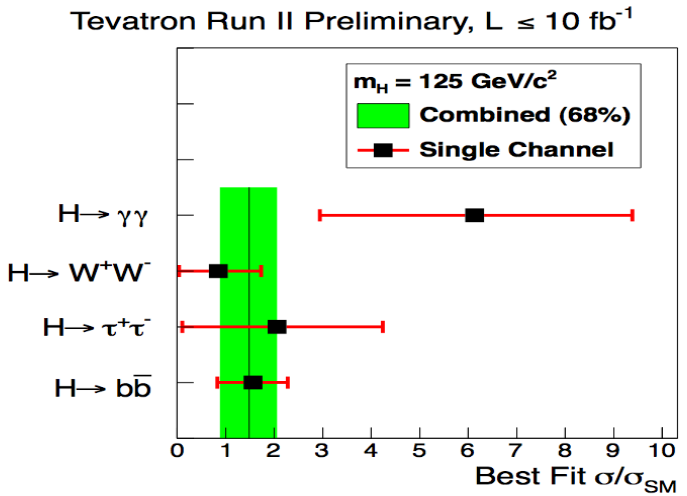




Conclusion

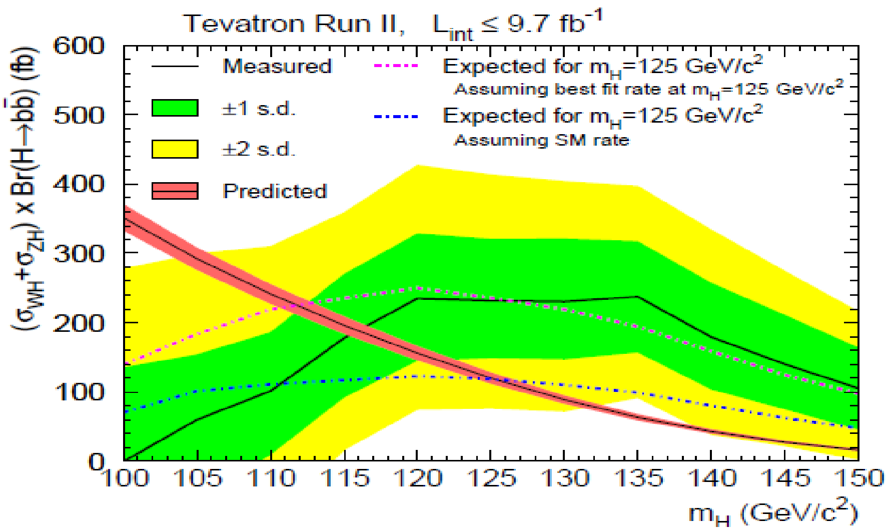
- Latest Tevatron results are presented based on full Run II dataset.
- Tevatron has achieved SM sensitivity over its expected accessible mass region(90-190 GeV).
- Observed a broad excess in $115<M_H<140$ GeV relative to background-only hypothesis with a local p-value of 3.1σ consistent with LHC discovery.
- Studies of Higgs boson coupling at Tevatron are consistent with SM prediction and provide complementary information to LHC.

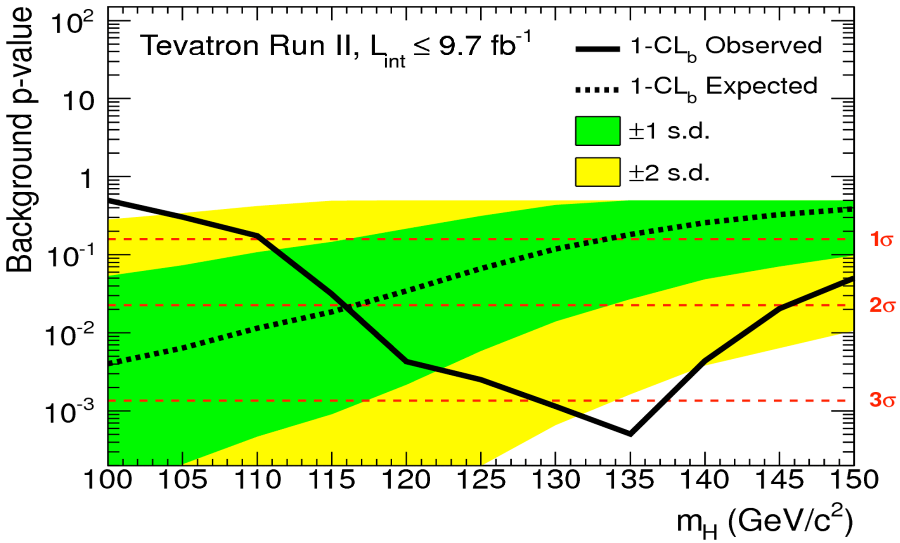




BACKUP

Tevatron H→bb Results, PRL 109,071804(2012)





- Last Summer:
  - σ_{VH}=0.23+-0.09pb (SM:0.12+-0.01pb)@125
  - Local max p-value=3.3σ @135GeV(global p-value=3.1σ) and p-value=2.8σ @125 GeV
- HCP:
  - σ_{VH}=0.19+-0.09 pb, consistent with the summer results.
  - We find no significant issues with the previous metbb analysis and stay firmly behind last summer published results.