Seeking the Brout-Englert-Higgs Boson

New Results from Tevatron Experiments

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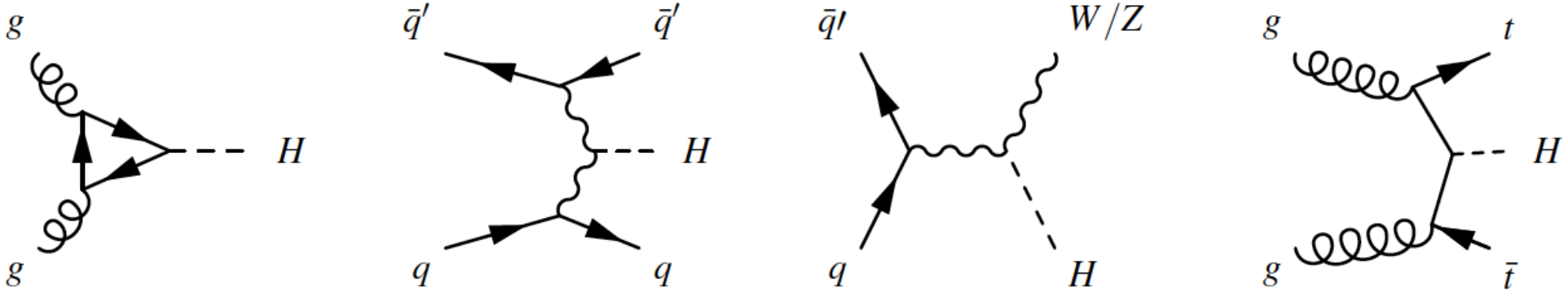
On Behalf of the CDF and DØ Collaborations

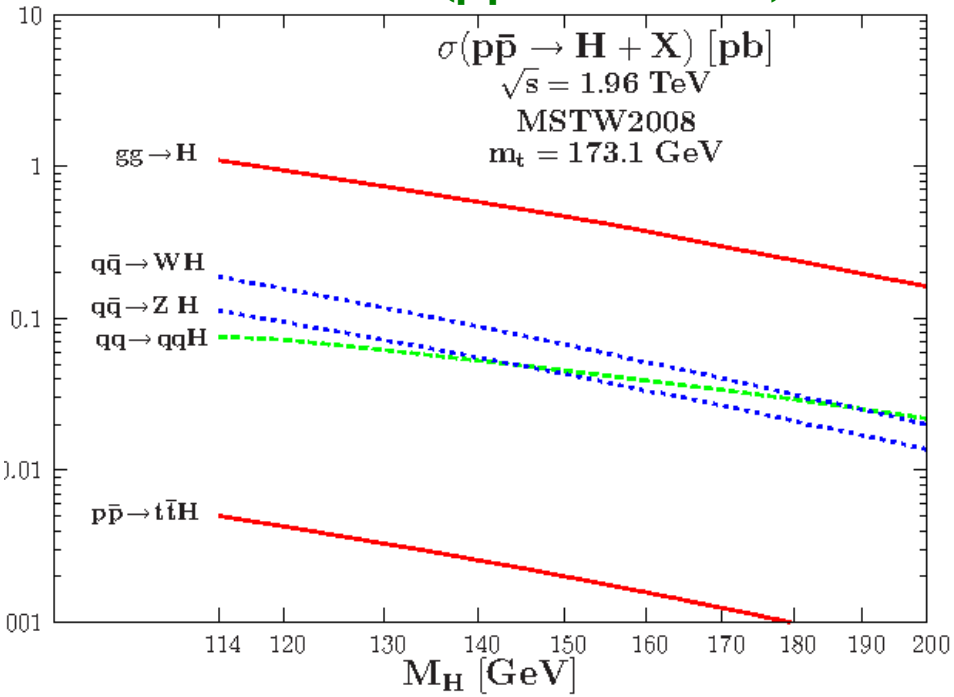
Rencontres de Moriond

7 March 2012, La Thuile, Italy

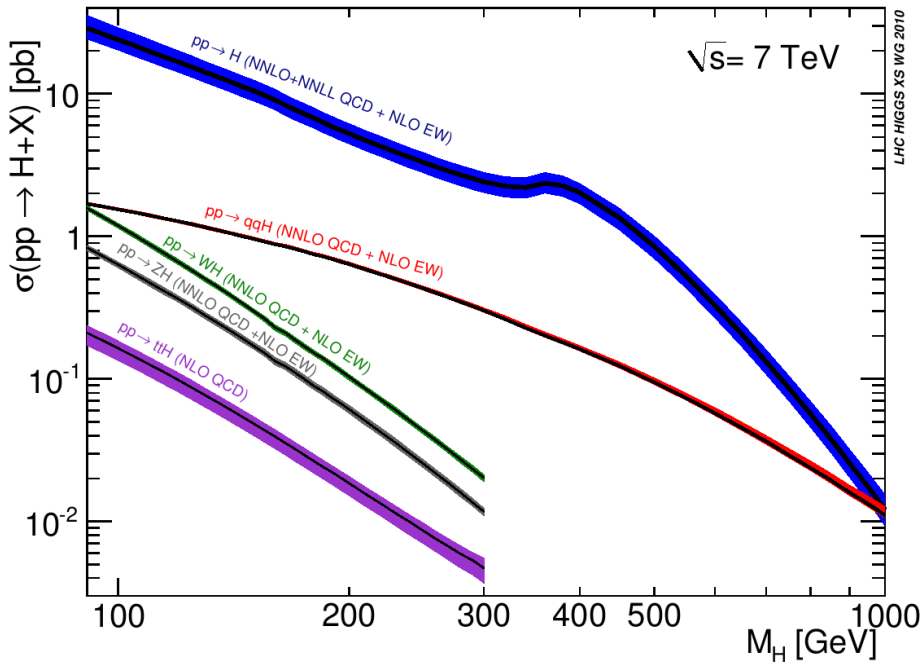
Overview of Tevatron BEH Production



Tevatron ($p\bar{p}$ @ 1.96 TeV)

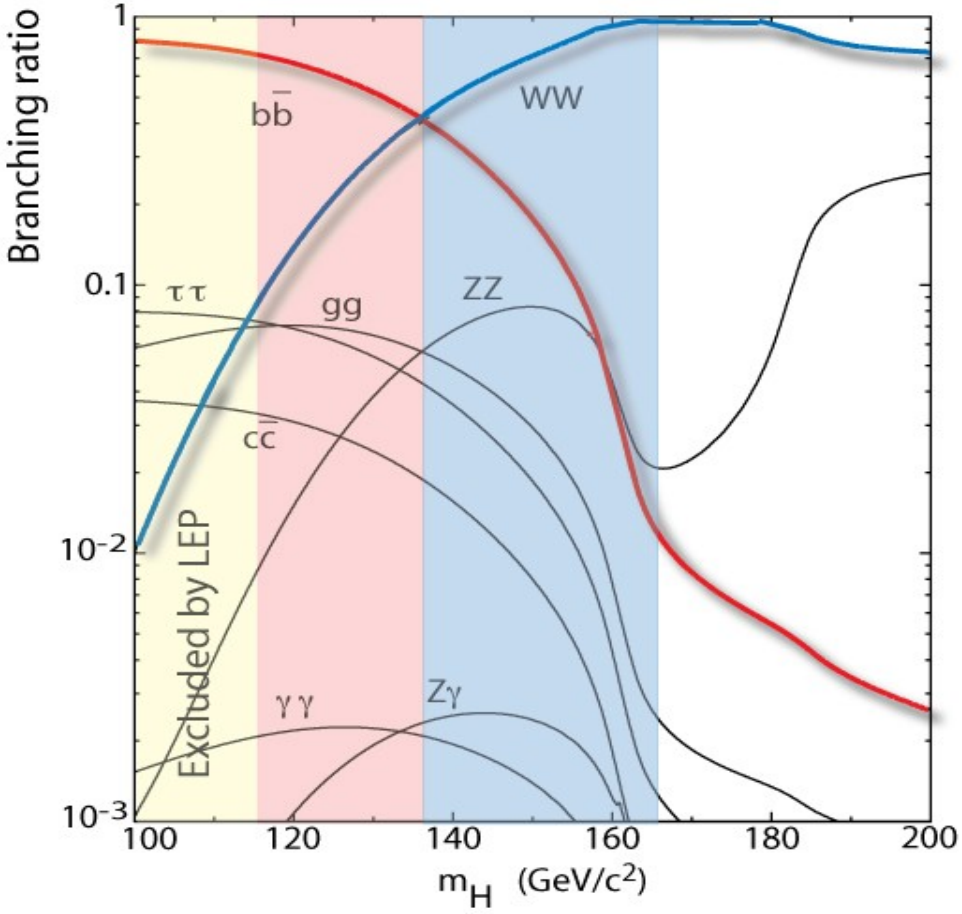


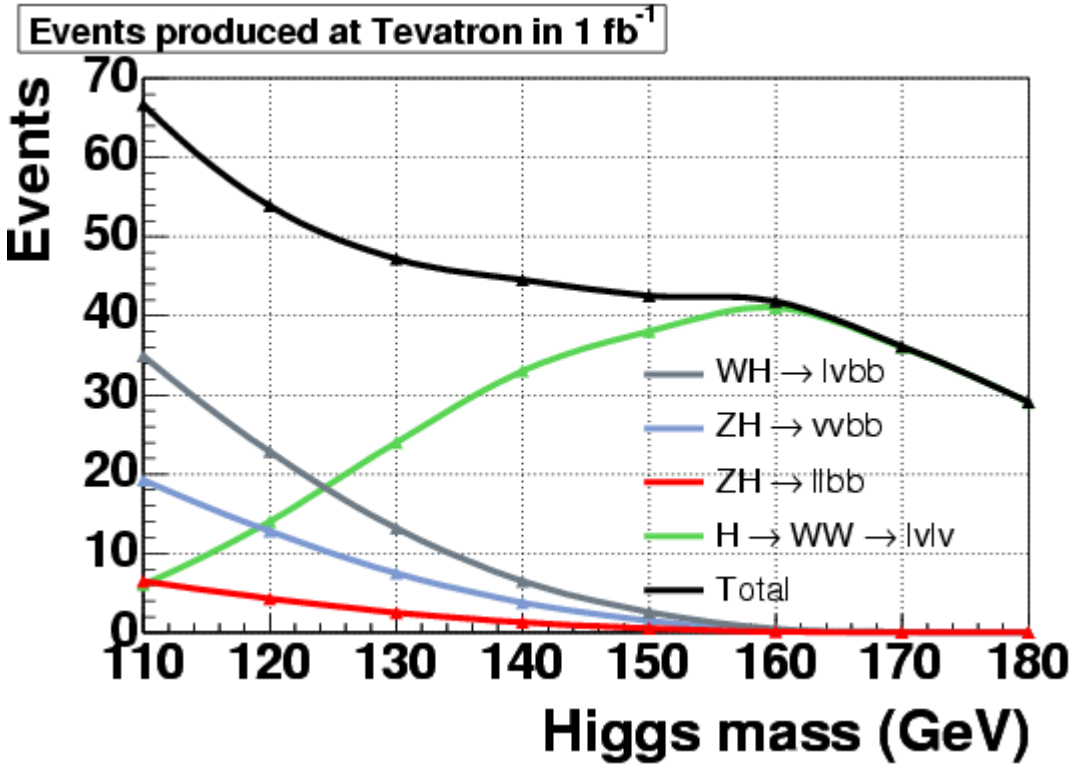
LHC (pp @ 7 TeV)



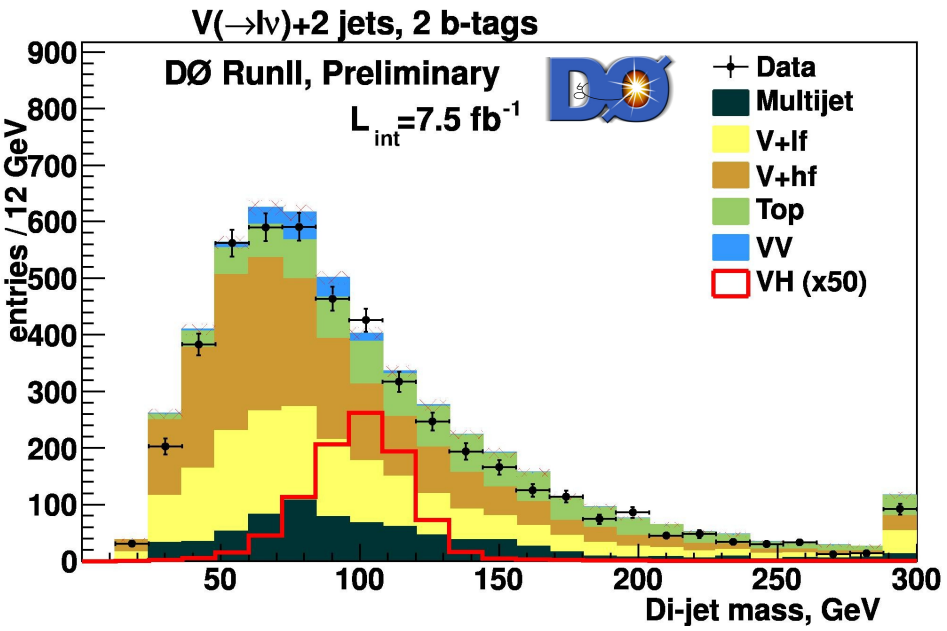
Overview of Tevatron BEH Production

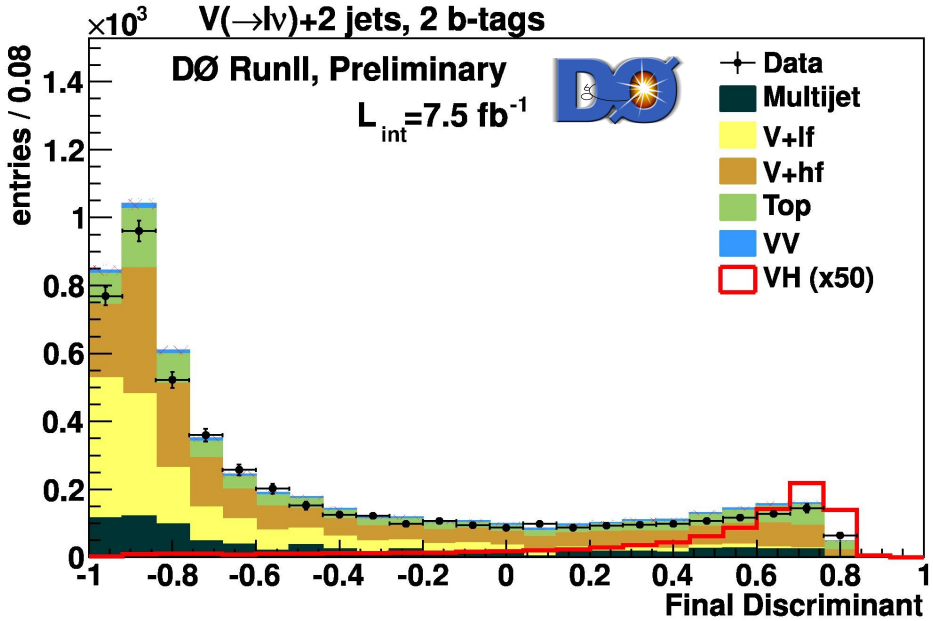
- Tevatron searches are characterized by two regions characterized by two distinct Higgs decays
  - For M_H<135 GeV, H→bb dominates
  - For M_H>135 GeV, H→WW dominates

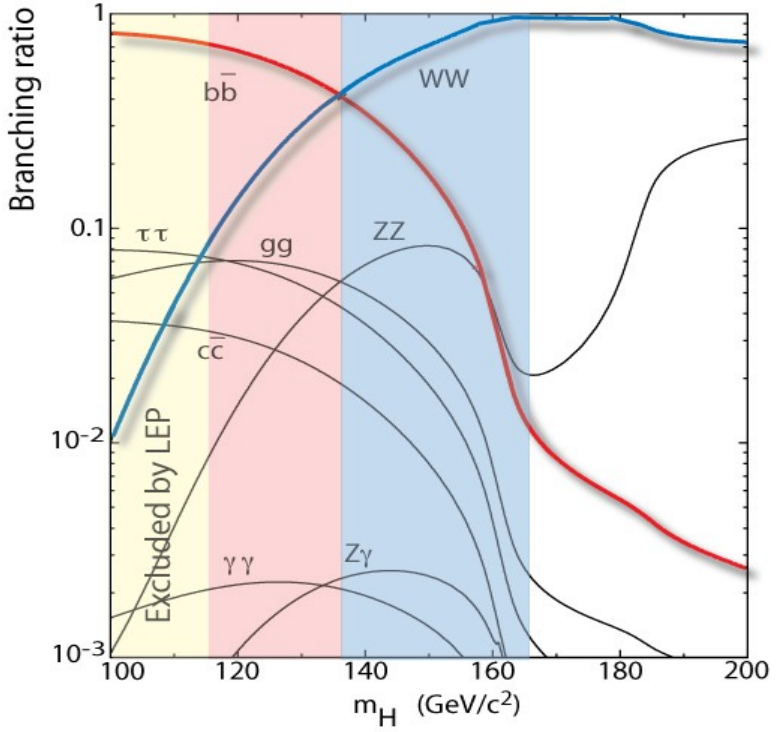


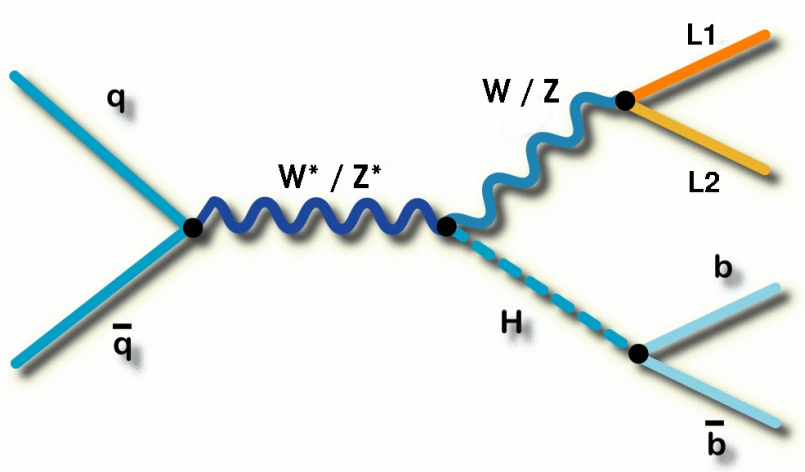


Summary of the Tevatron BEH Program









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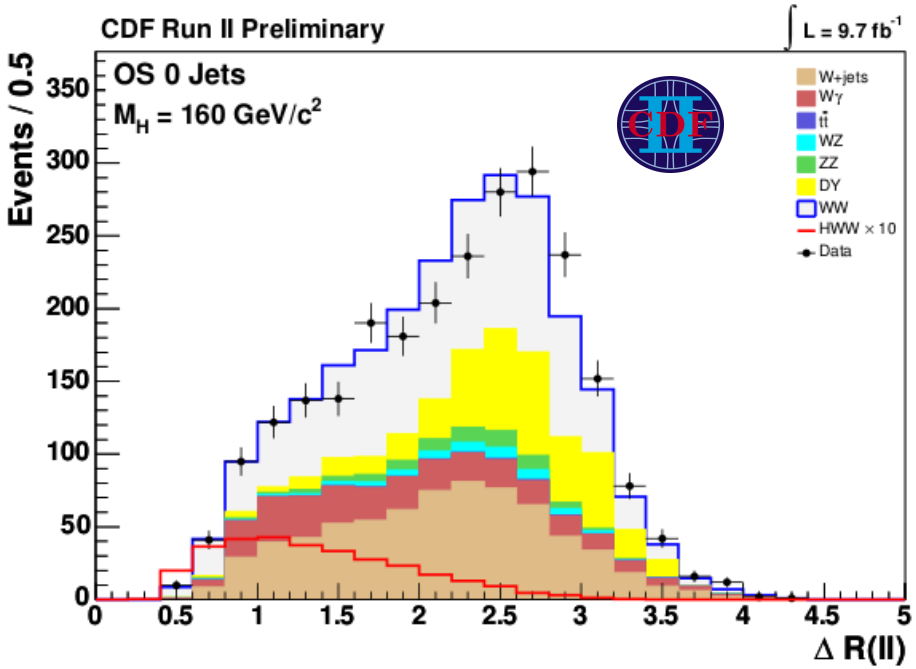
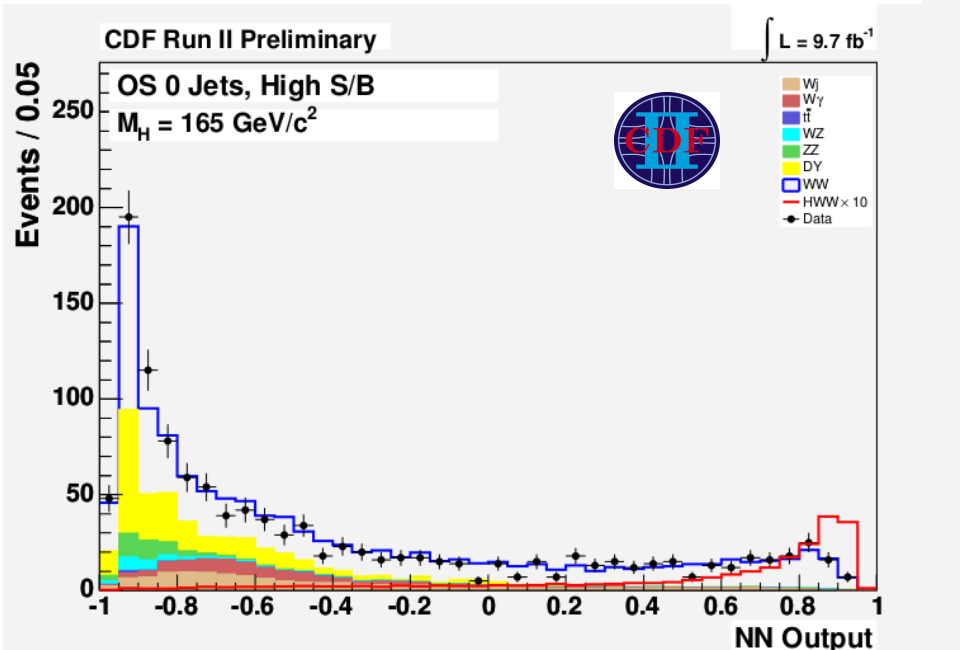
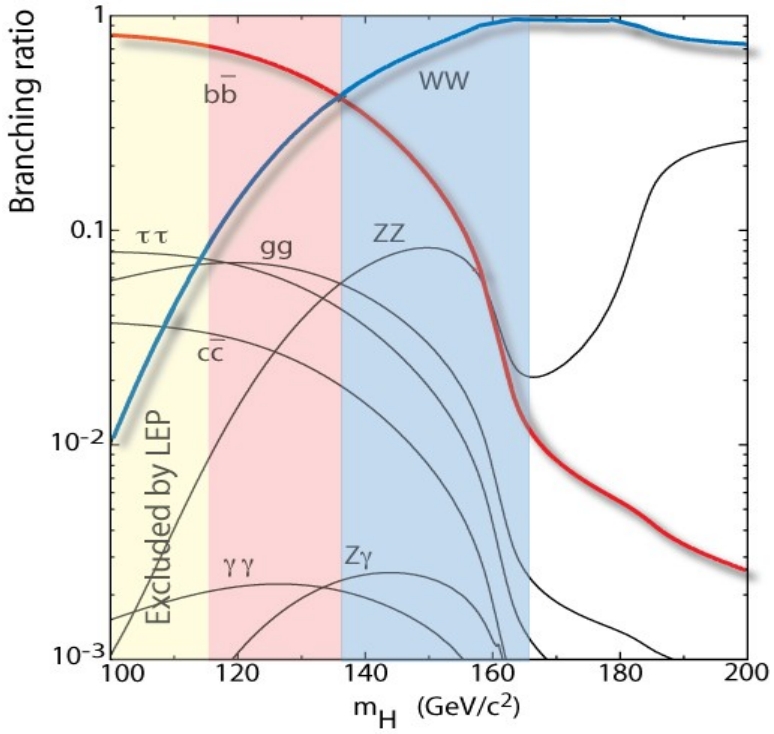
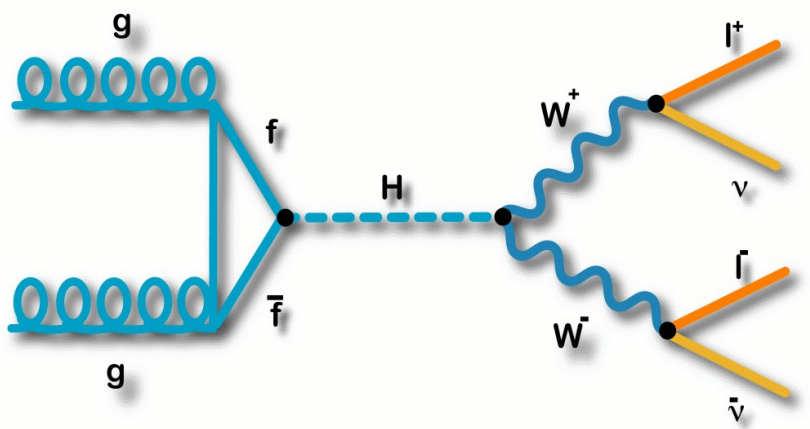




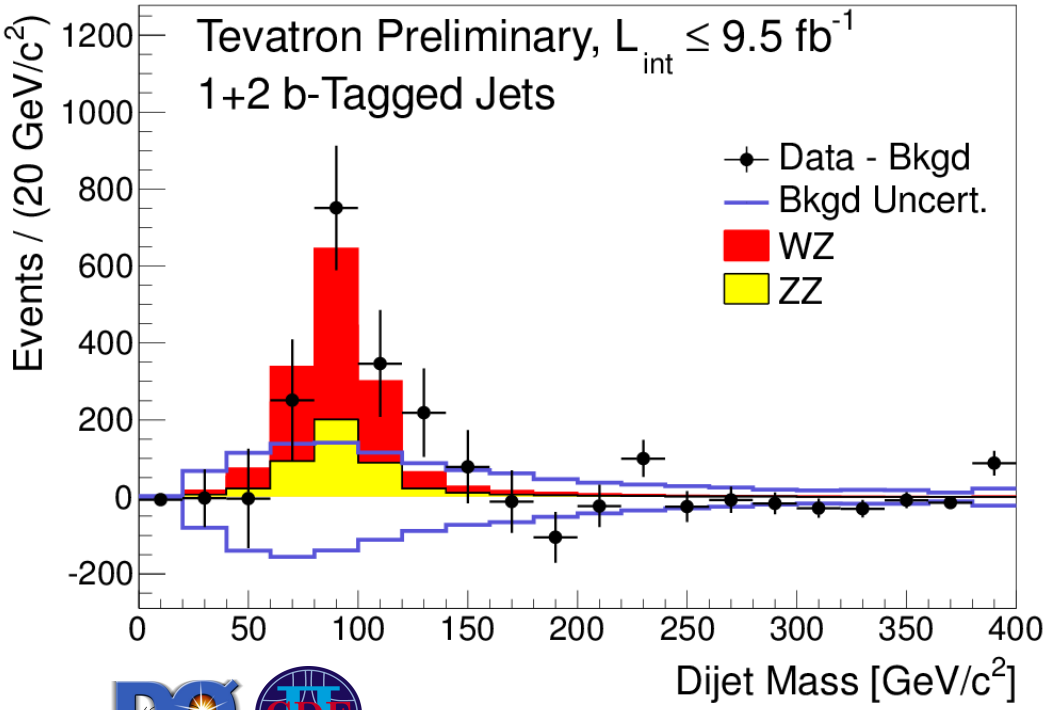




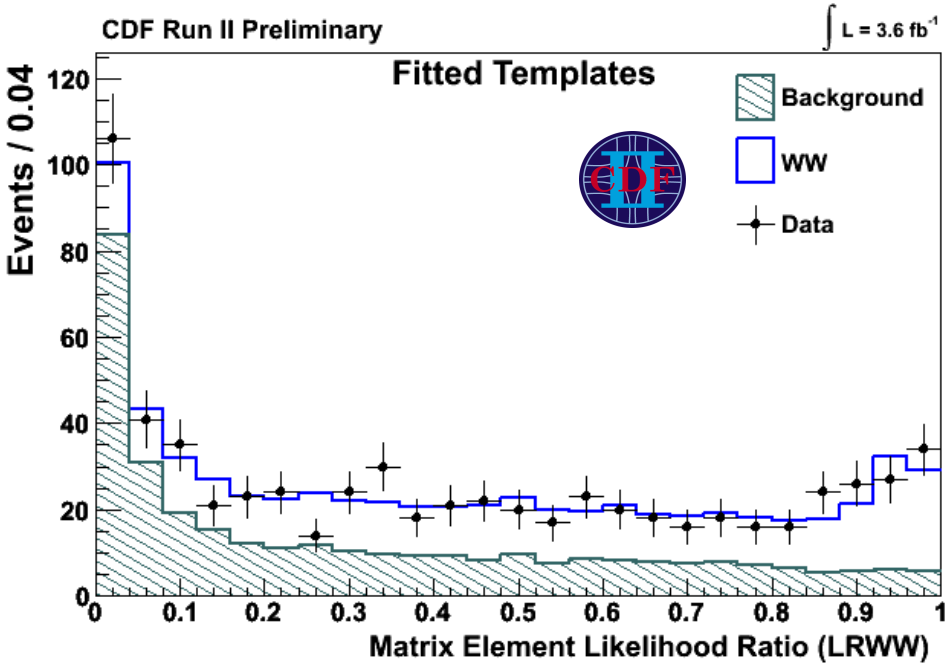
BEH Search Validation

- Tevatron experiments devote significant efforts to validate search techniques using known processes with similar signatures
  - For W/Z+H→bb searches: Study W/Z+Z→bb
  - For H→WW→lνlν searches: Study SM WW→lνlν

W/Z+Z→bb: σ_{obs} = (1.01 ± 0.21) x σ_{SM}

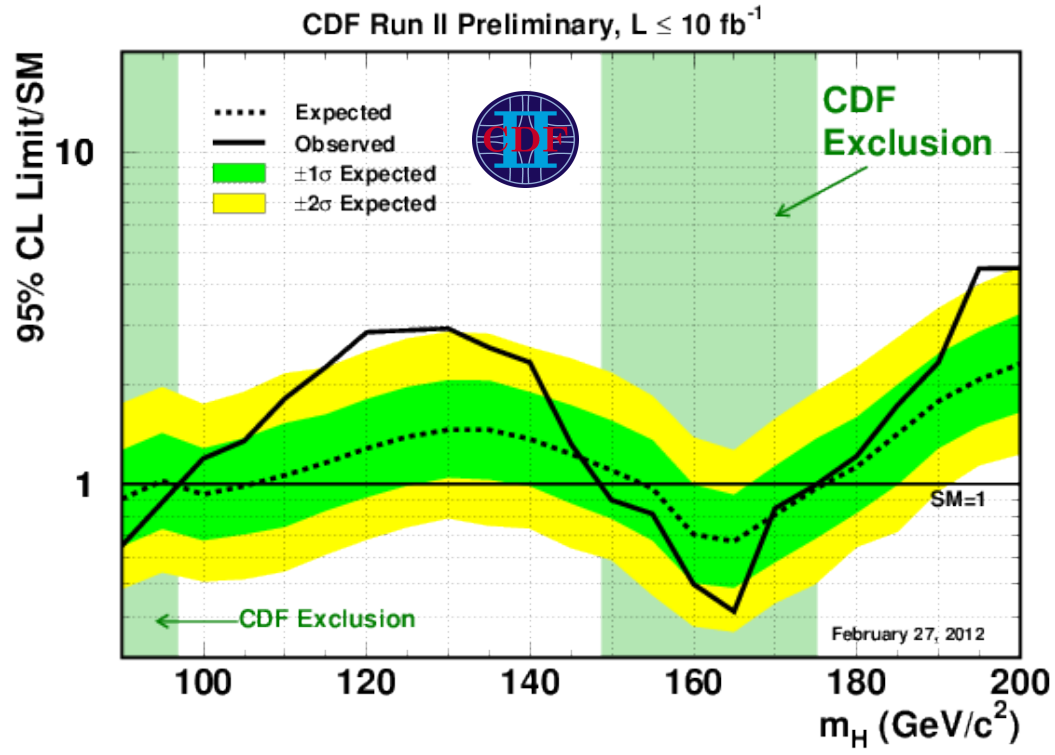


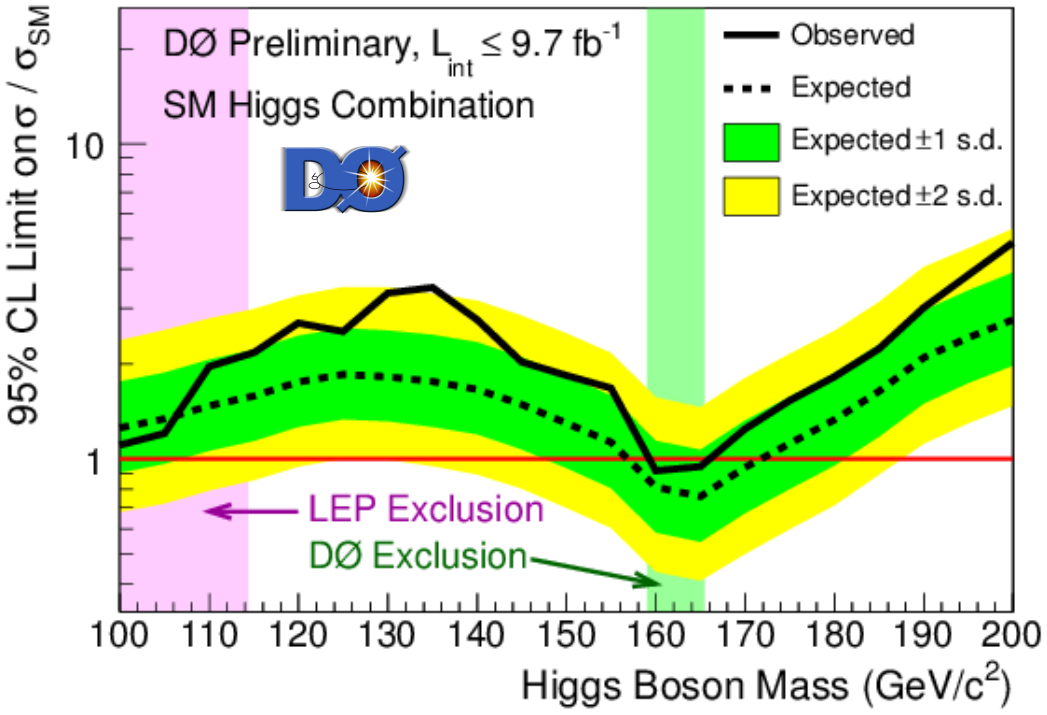
WW→lνlν: σ_{obs} = (1.07 ± 0.16) x σ_{SM}



CDF & DØ Individual Results

- Shown in the earlier talks from today
  - Similar search sensitivity over entire probed mass region
    - DØ: Exclude $159 < M_H < 166$ GeV
    - CDF: Exclude $147 < M_H < 175$ GeV





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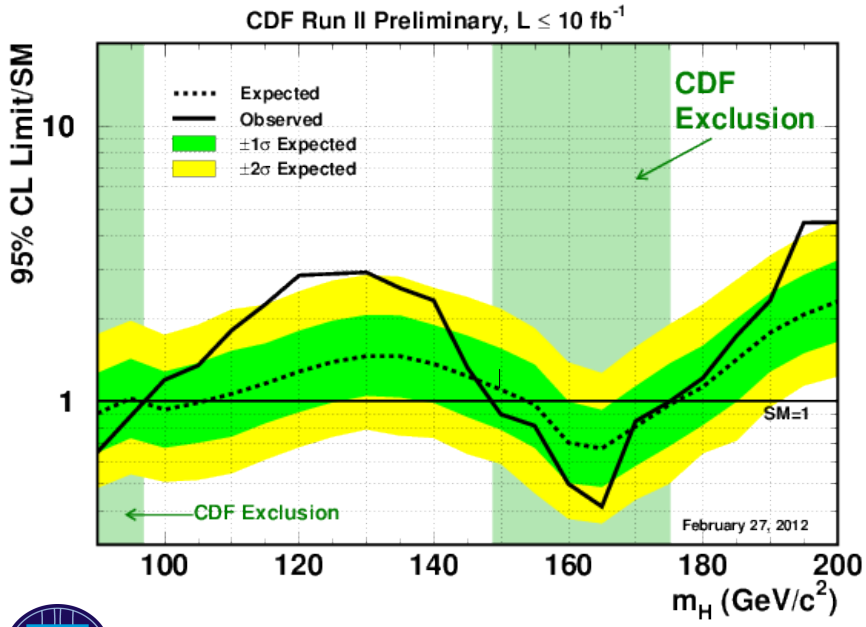
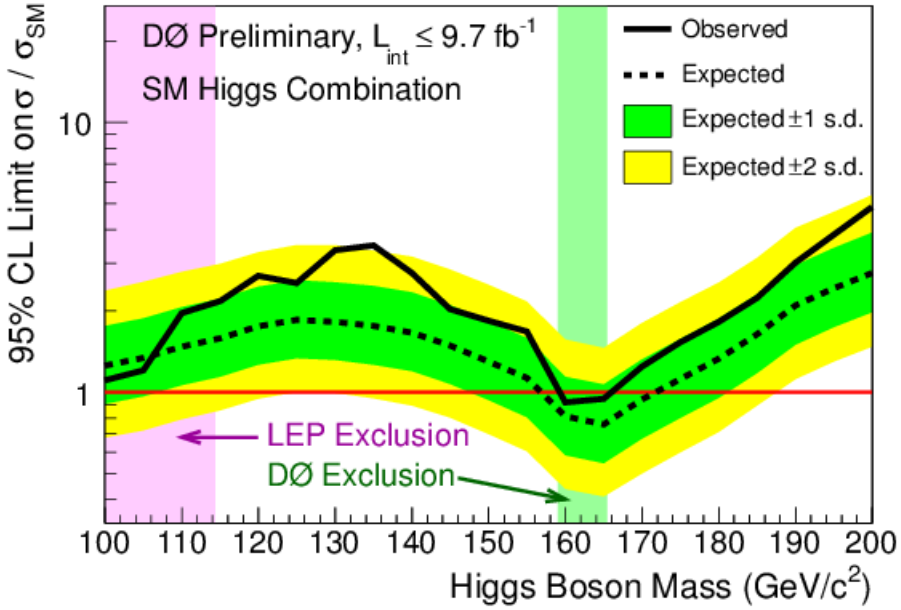
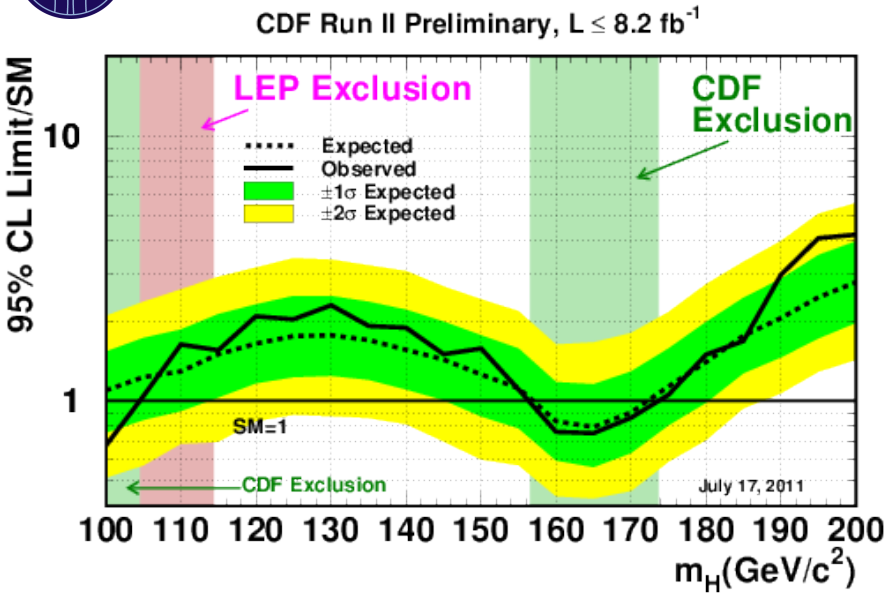
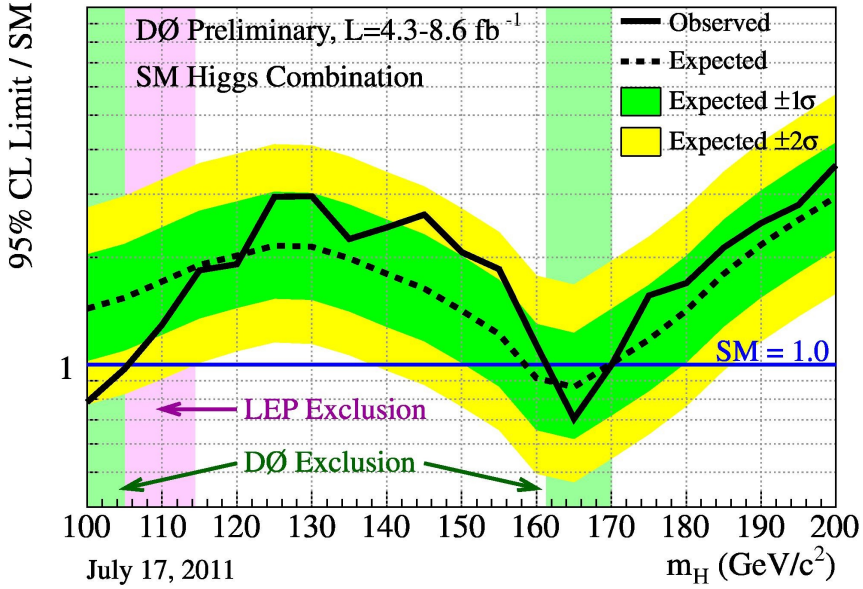




Winter 2012

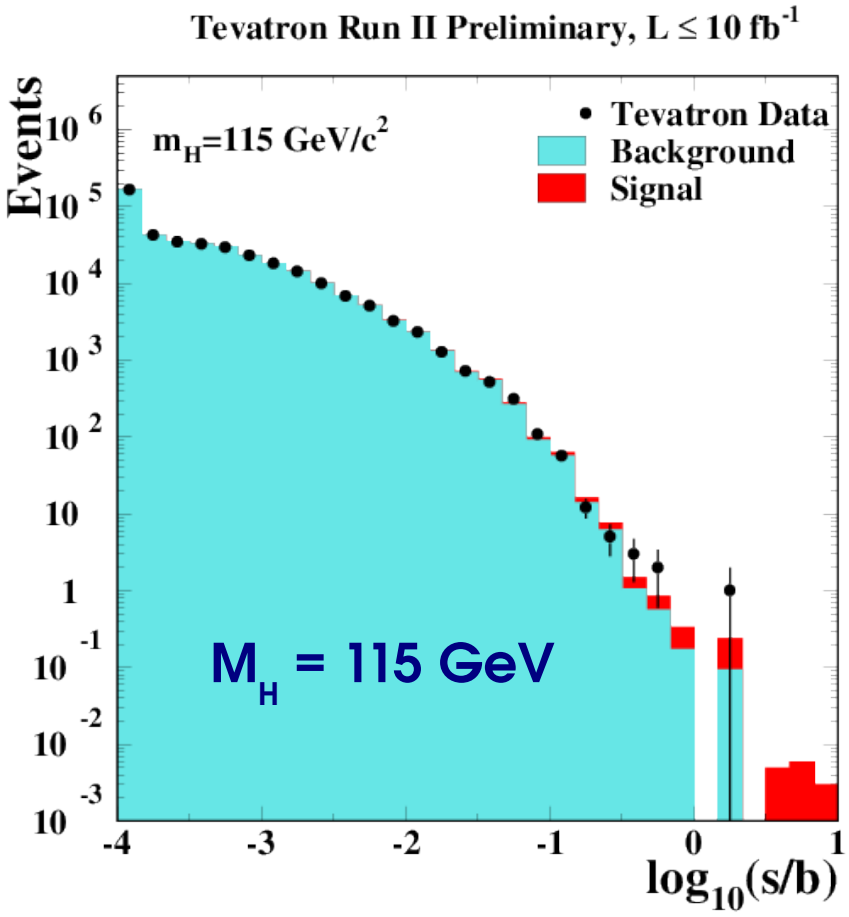
Summer 2011

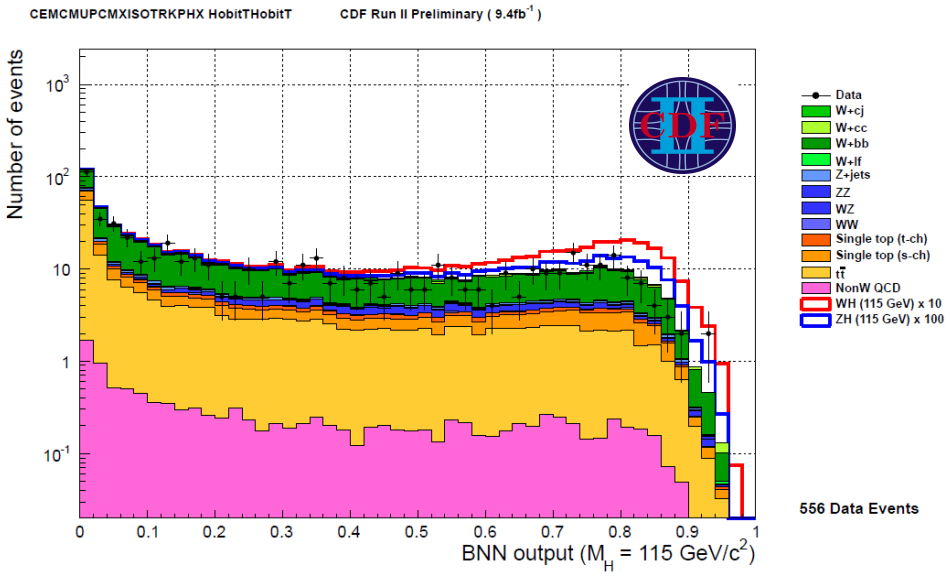


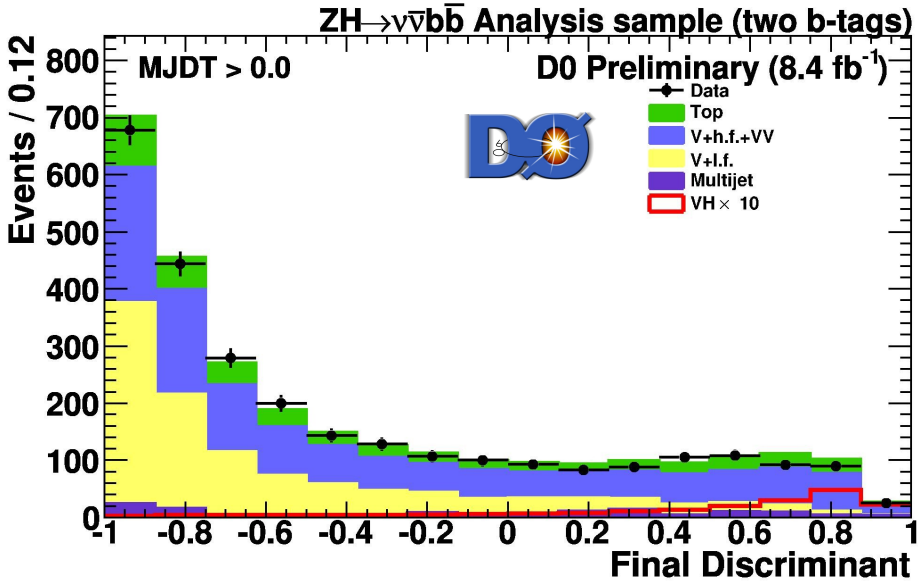


CDF & DØ Combined Distributions

- Visualizing O(100) input distributions can be simplified by reordering bins by signal and background content
  - High s/b region is where we would expect to find an excess







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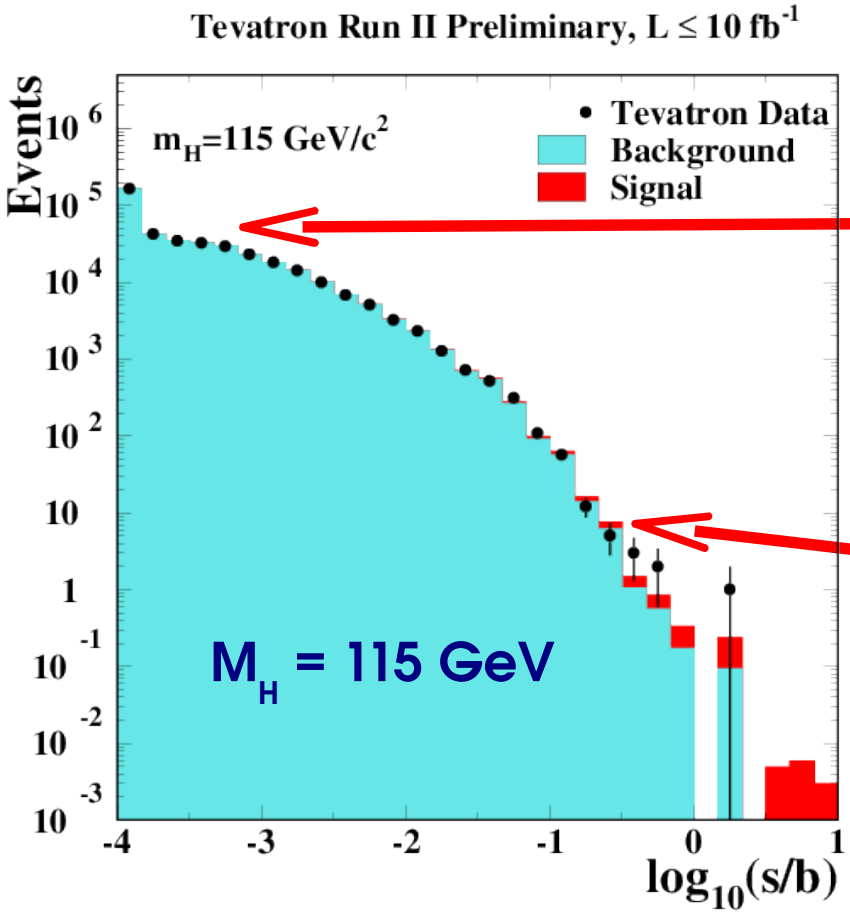

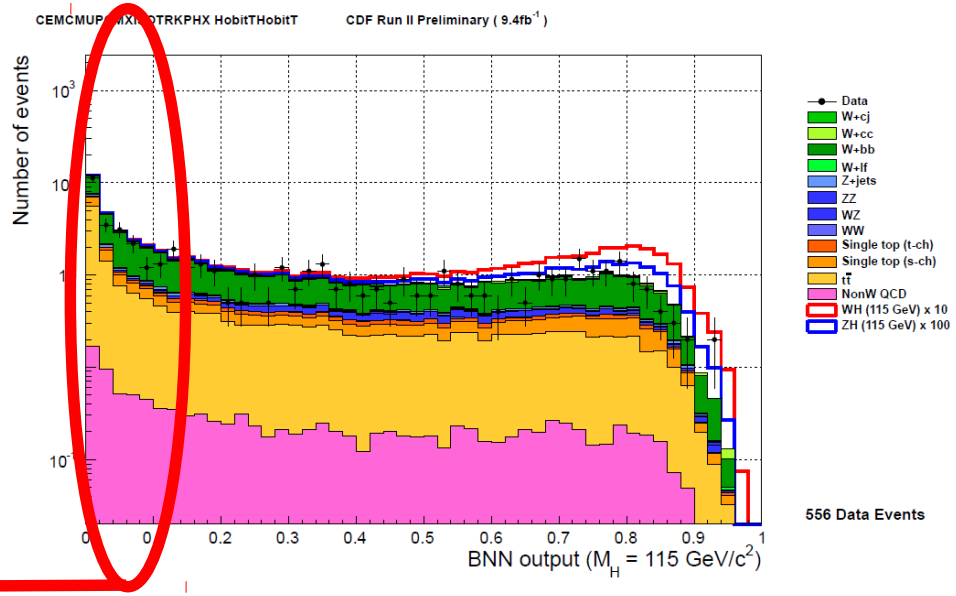

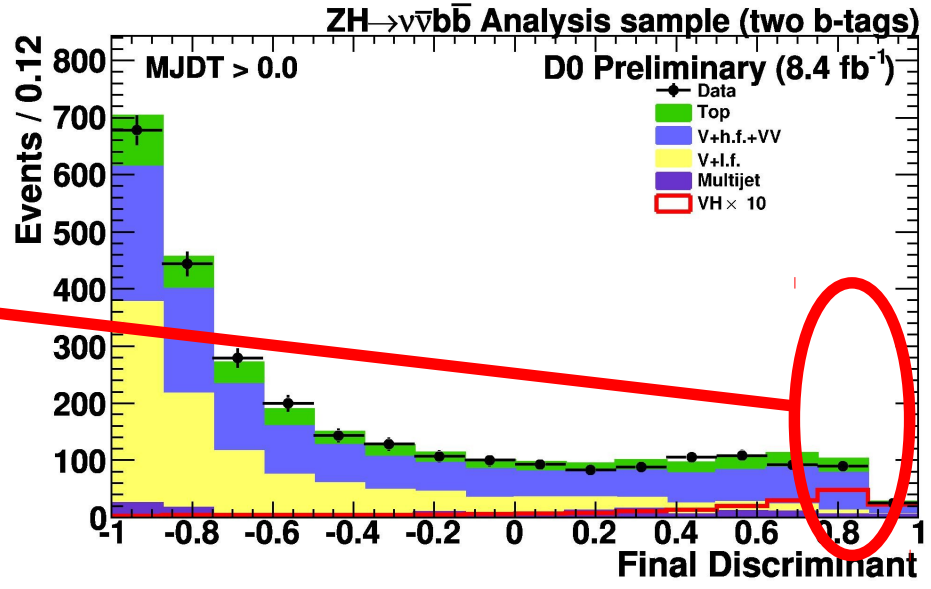

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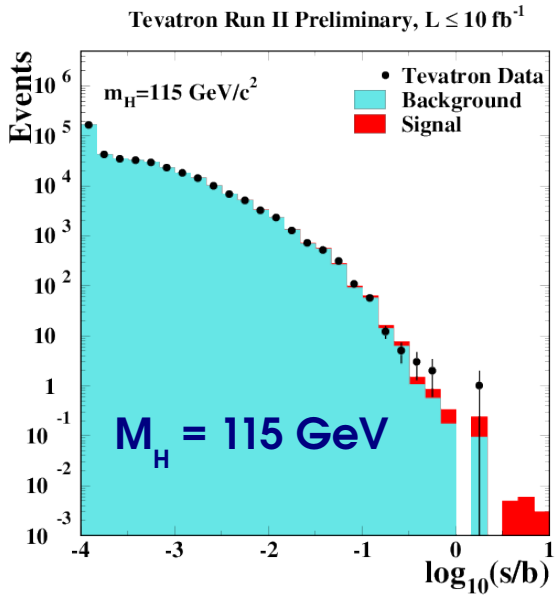
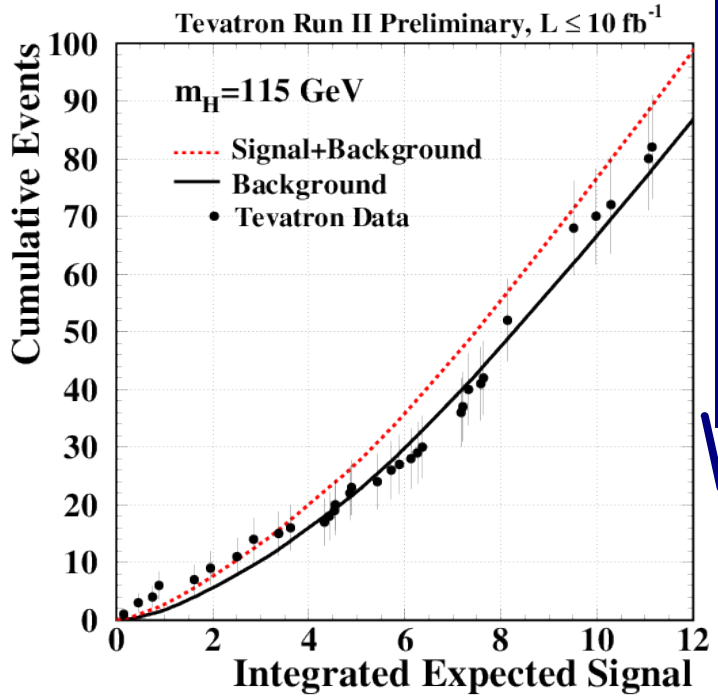
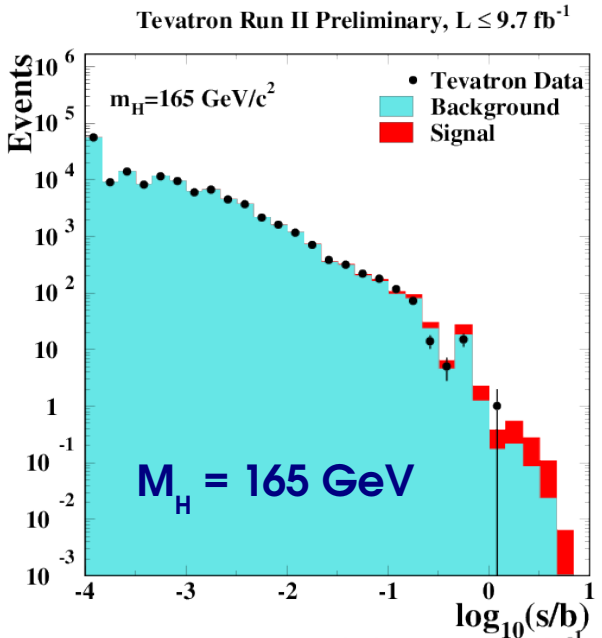
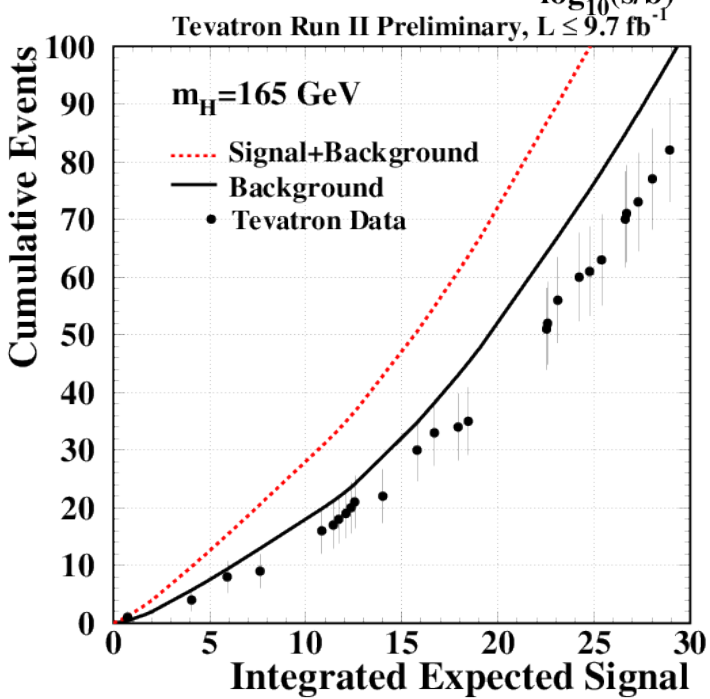




Right-to-left integral yields a means to compare data with signal and background predictions





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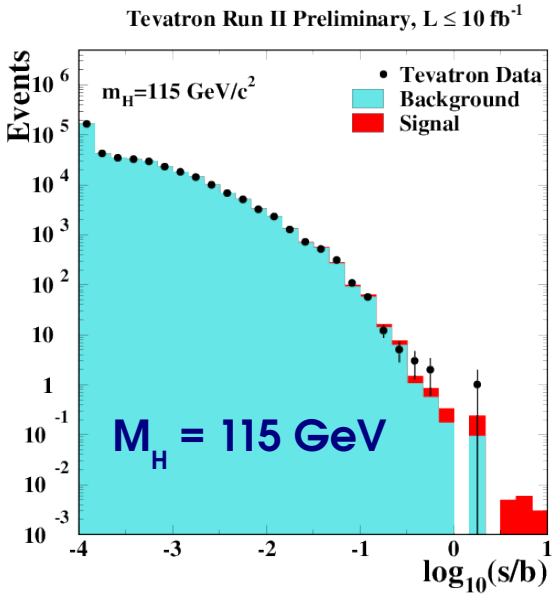
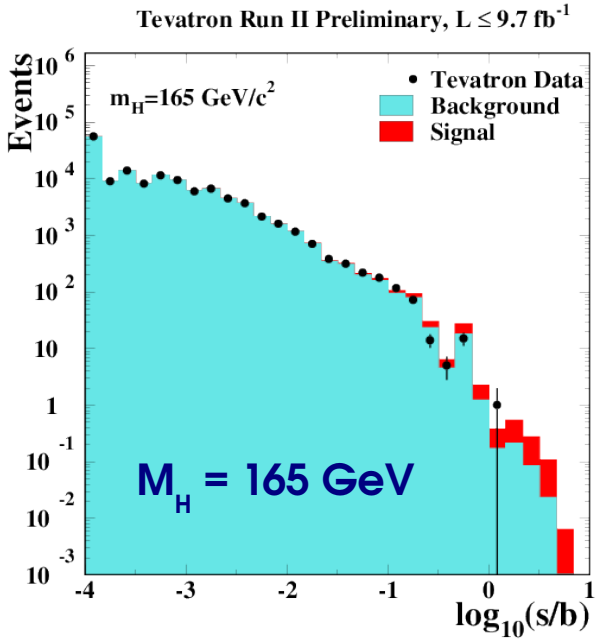
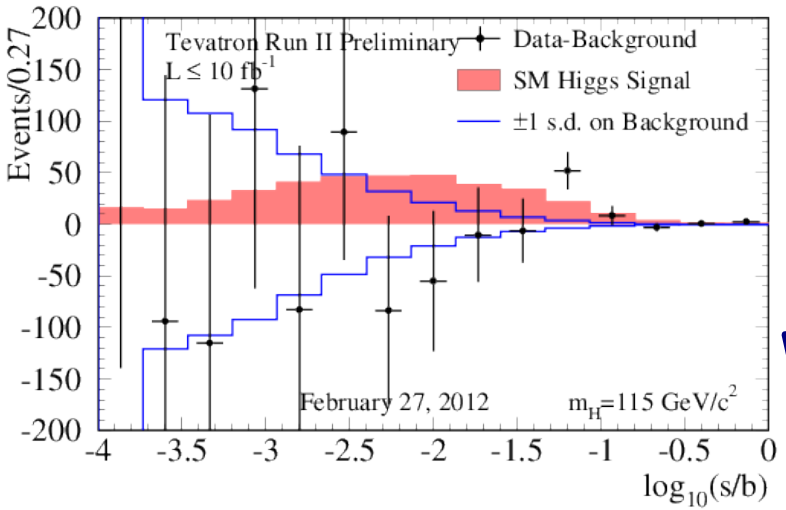
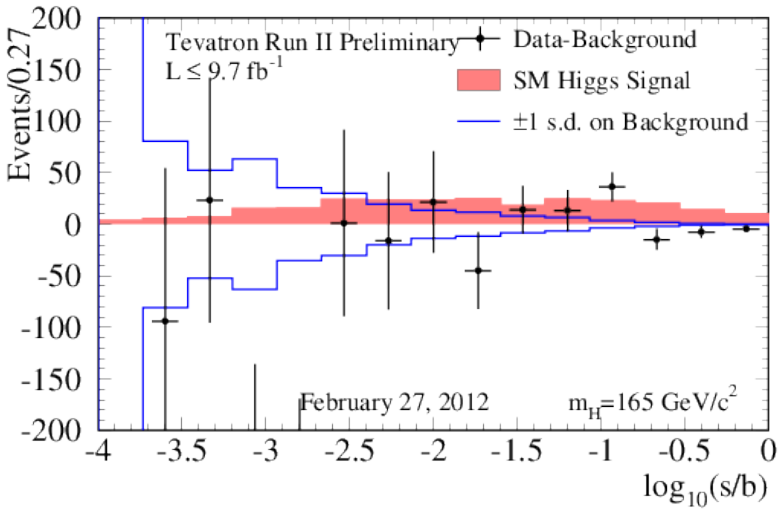


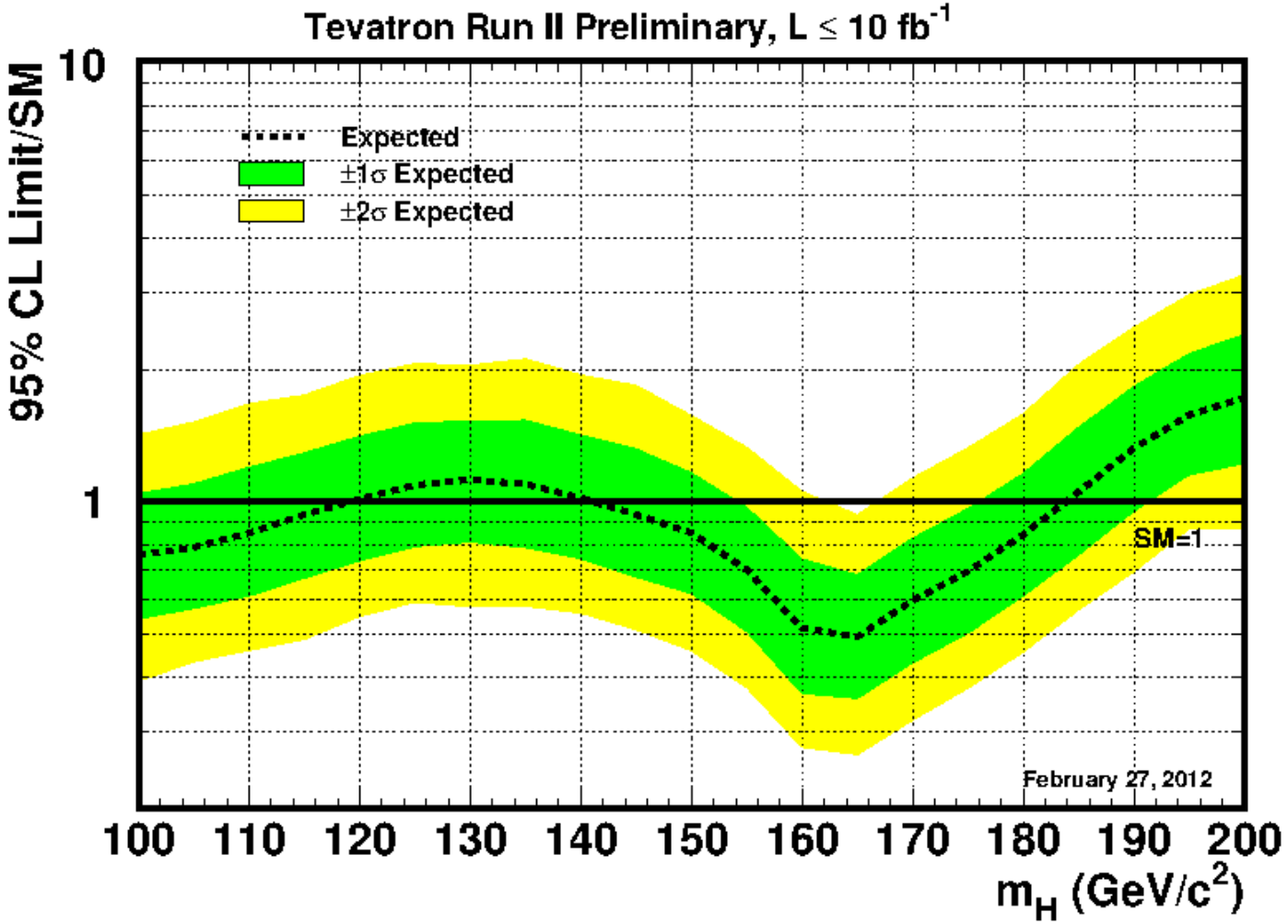


Fit to data, with background subtraction can reveal potential excesses





Upper Limits on BEH Boson Production



- 95% C.L. upper limits on SM Higgs boson production at the Tevatron
  - Expected exclusion: $100 < M_H < 120$ GeV $141 < M_H < 184$ GeV

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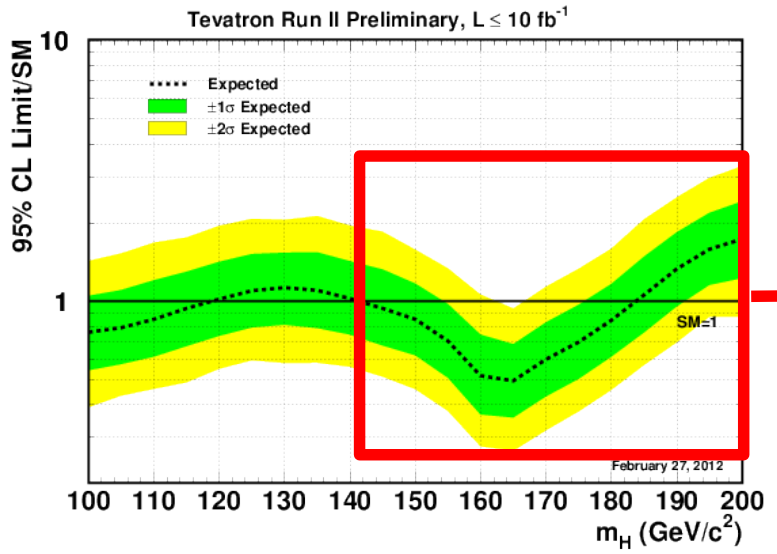
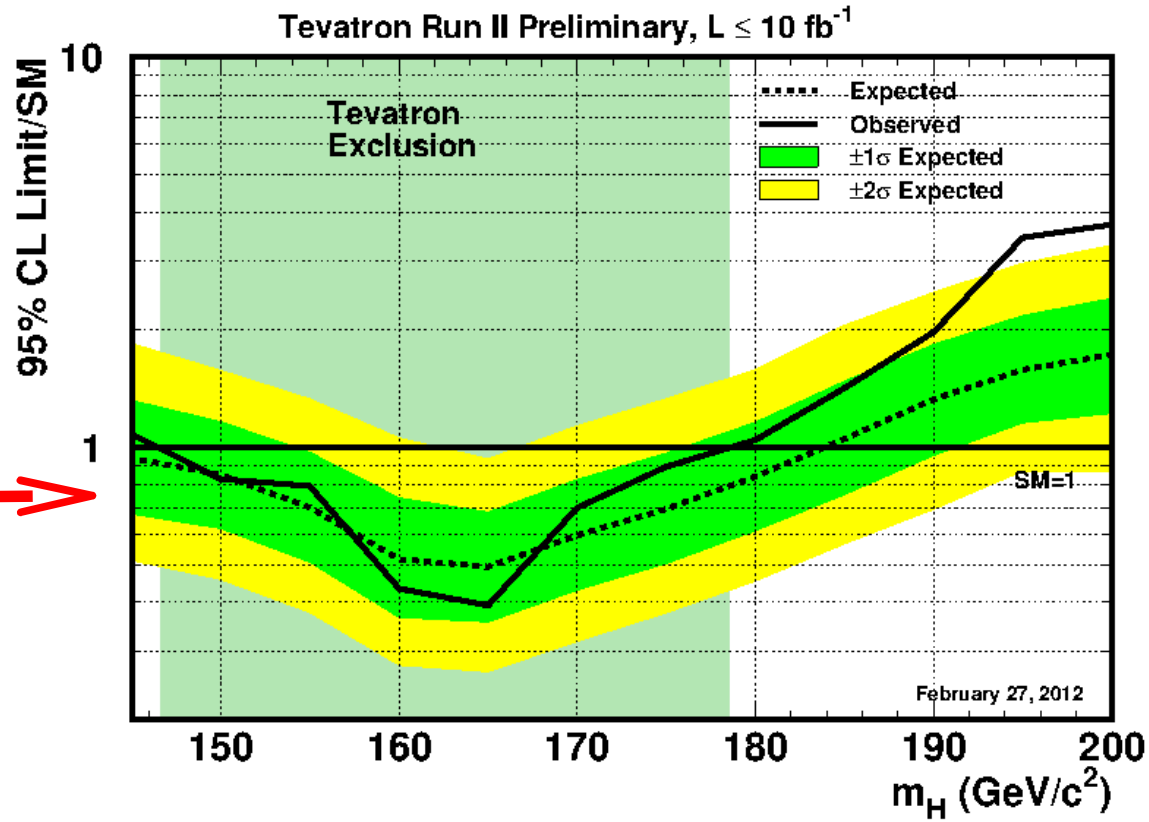
  - Expected exclusion: $100 < M_H < 120$ GeV **$141 < M_H < 184$ GeV**
  - Observed exclusion: **$147 < M_H < 179$ GeV**





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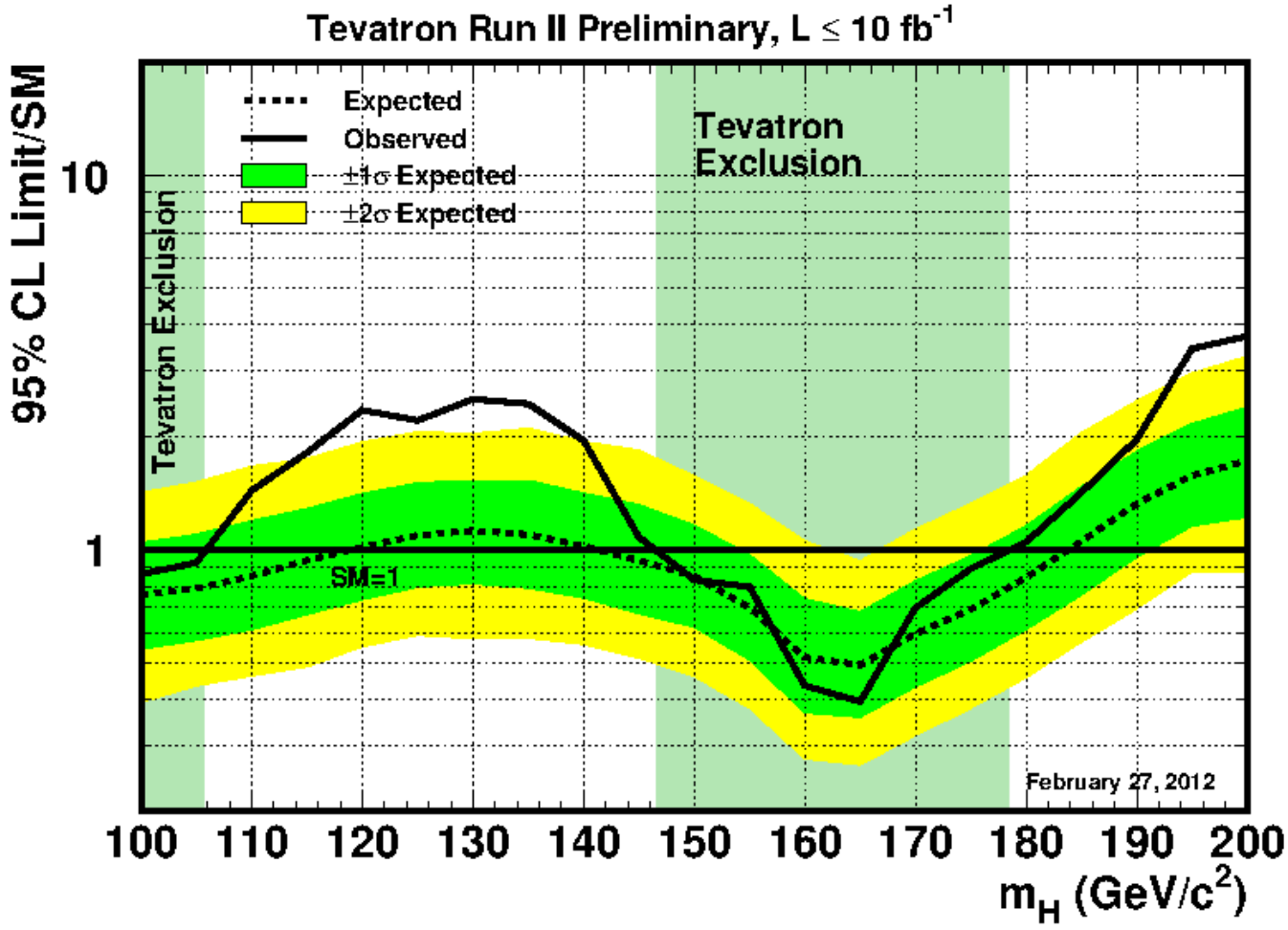
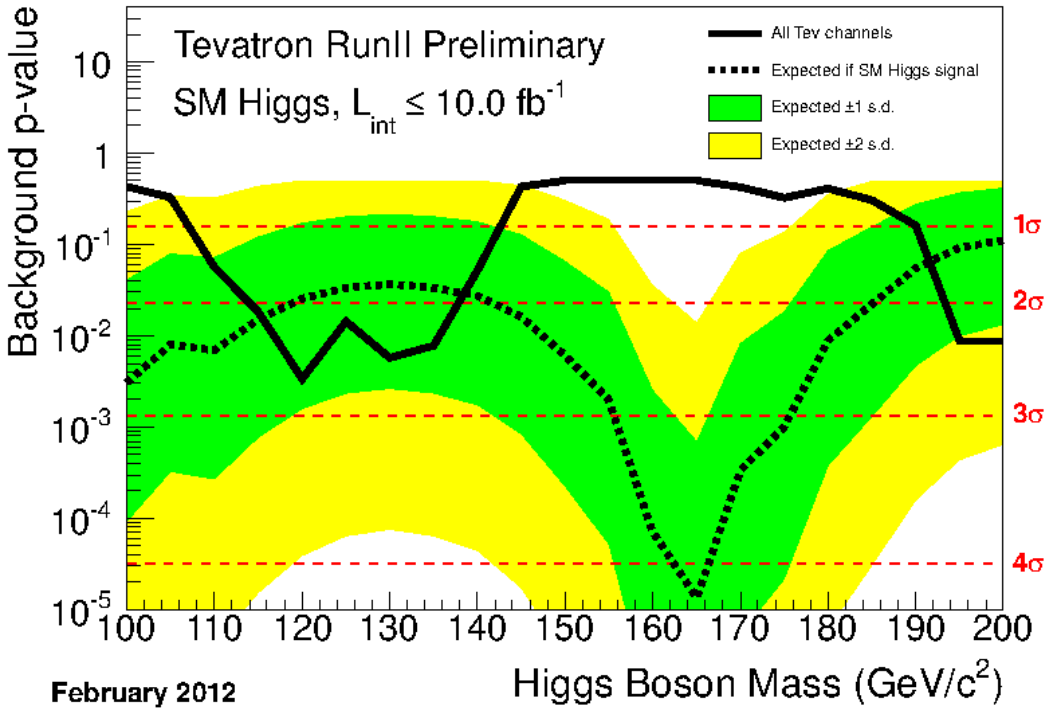
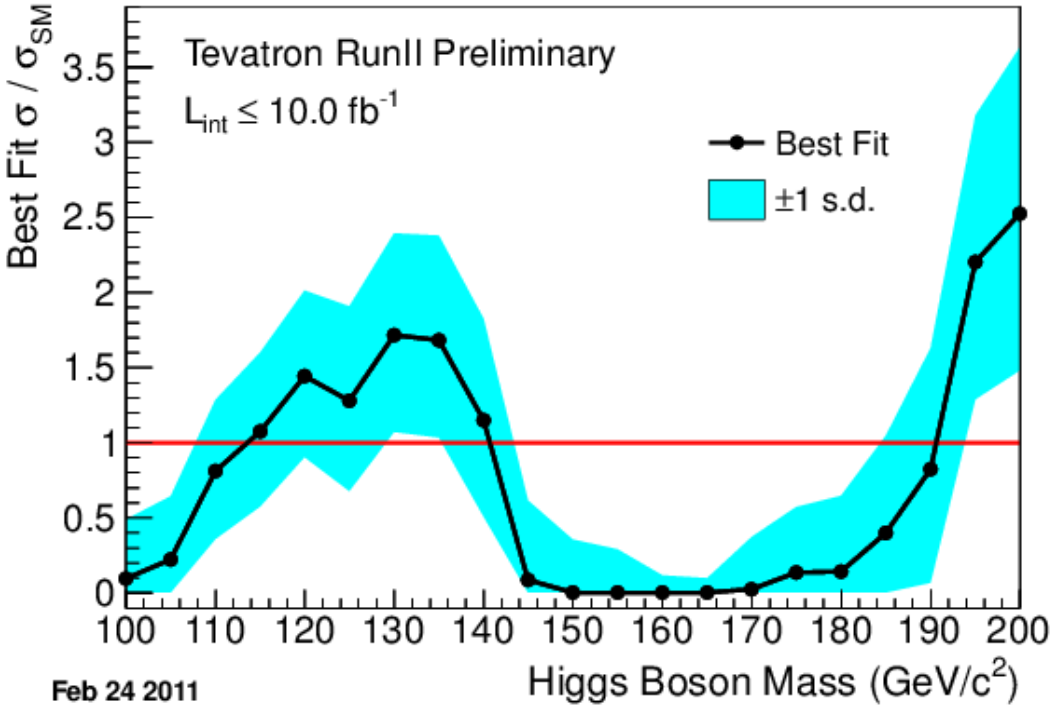


- 95% C.L. upper limits on SM Higgs boson production at the Tevatron
  - Expected exclusion: **100 < M_H < 120 GeV** 141 < M_H < 184 GeV
  - Observed exclusion: **100 < M_H < 106 GeV** 147 < M_H < 179 GeV

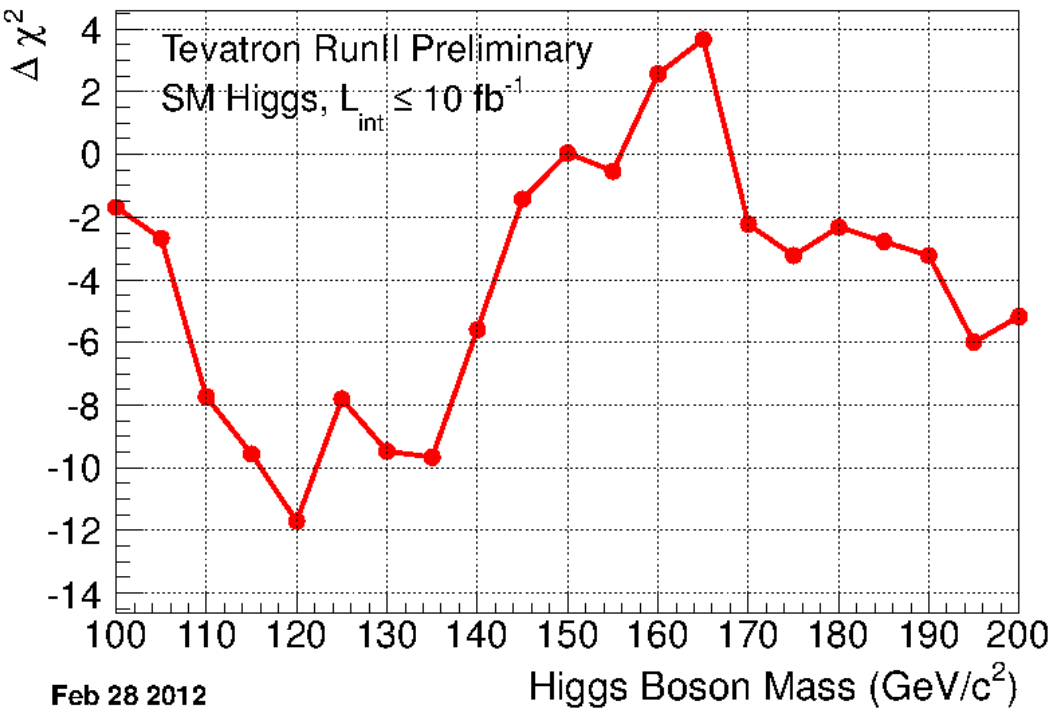
Quantifying the Excess

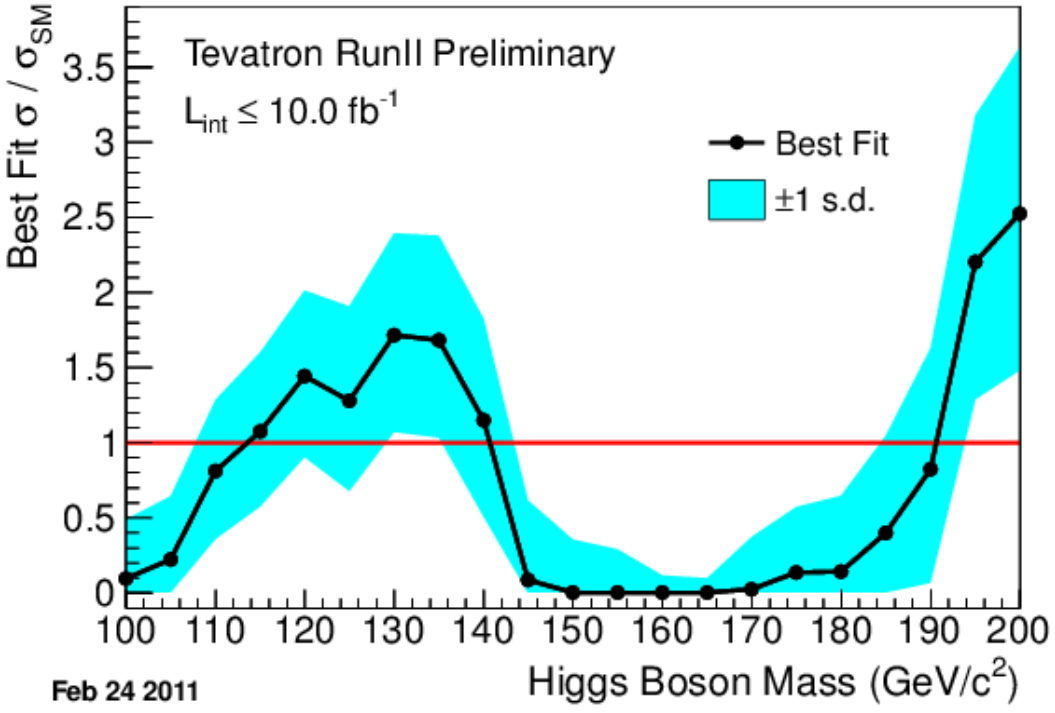




- **Two different tests of the data, comparing to S+B and B-only predictions**
  - **Left:** Local p-value distribution for background-only expectation.
    - Minimum local p-value: 2.7 standard deviations
    - Global p-value with LEE factor of 4: **2.2 standard deviations**
  - **Right:** Maximum likelihood fit to data with signal as free parameter.

Quantifying the Excess

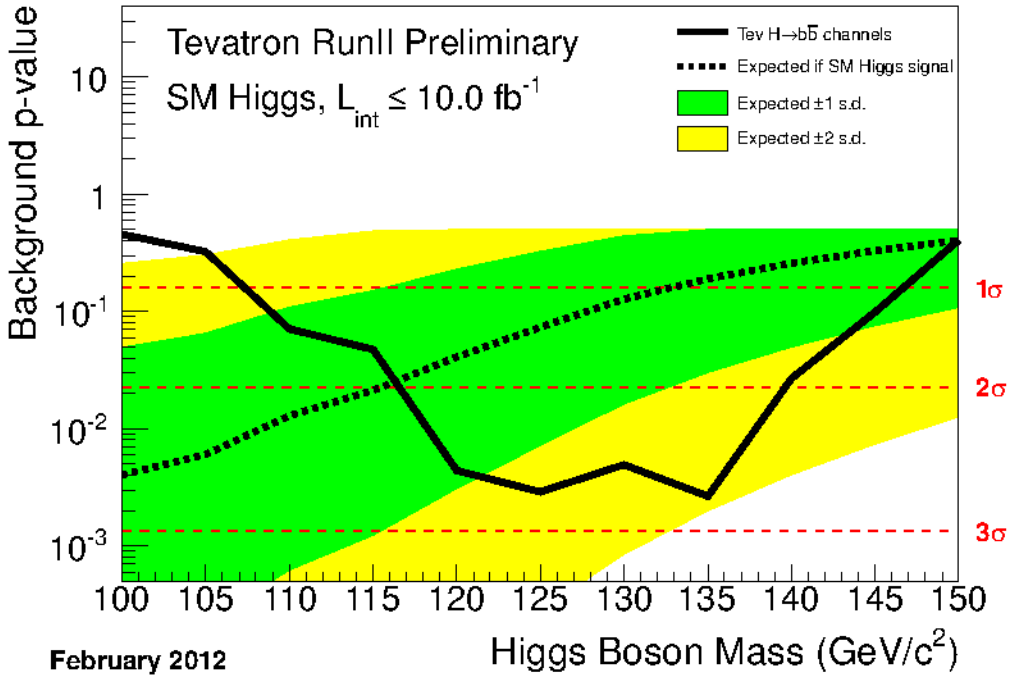


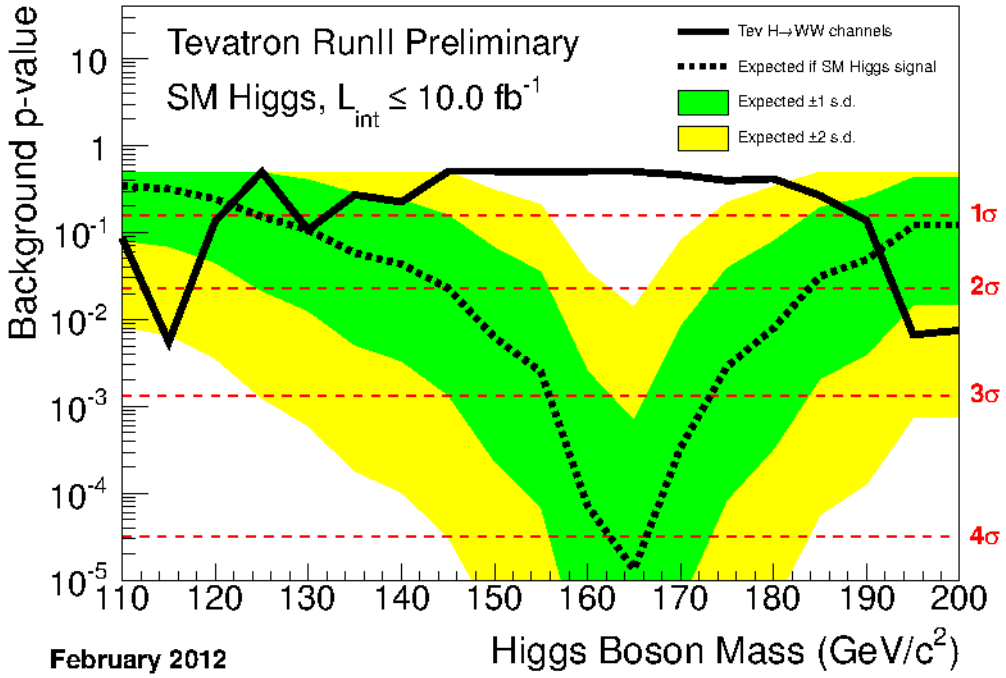


$\Delta\chi^2$ test with fixed signal prediction from SM theory agrees well with freely floating signal rate estimation

- $\Delta\chi^2$ minimum in the region $115 < M_H < 135$ GeV
- Region above M_H=150 never falls below $\Delta\chi^2 = -6$

Quantifying the Excess

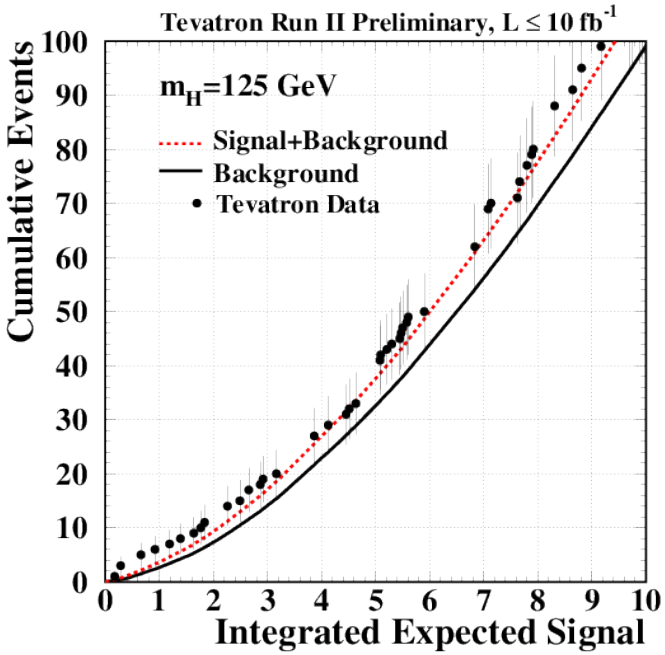


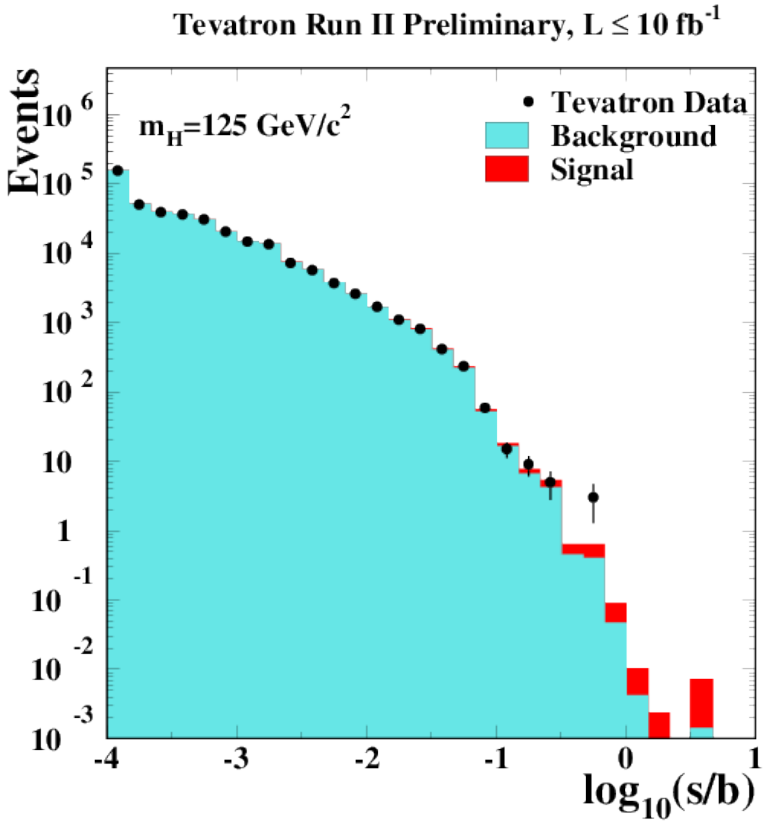


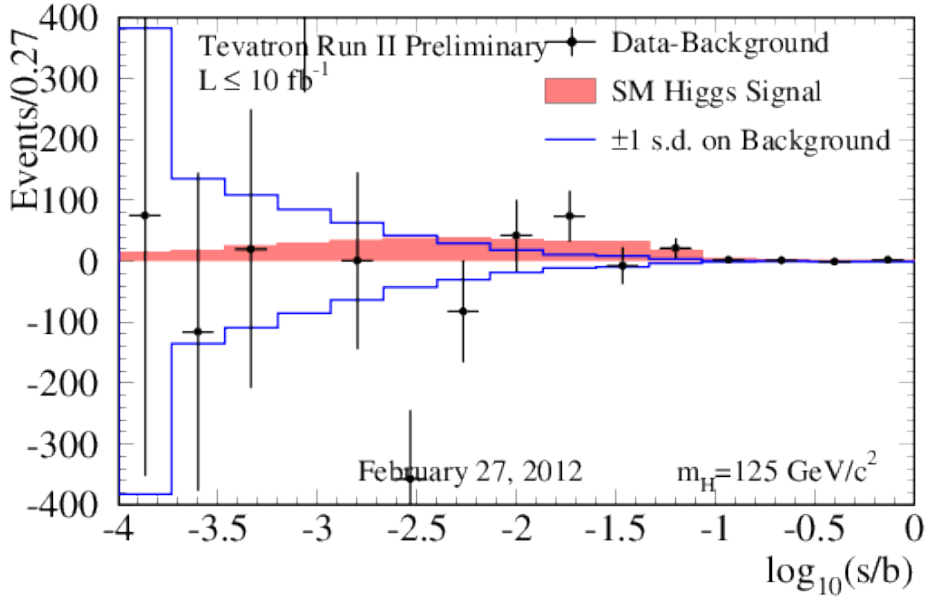
- **Considering separately the H→bb and H→WW channels**
  - Local p-value distribution for background-only expectation.
    - Minimum H→bb local p-value: 2.8 standard deviations
    - Global H→bb p-value with LEE factor of 2: **2.6 standard deviations**

Quantifying the Excess

- Revisit s/b rebinned distribution plot for M_H=125 GeV
  - Cumulative distribution seems to prefer S+B model
  - Background-subtracted plot illustrates several interesting candidate events

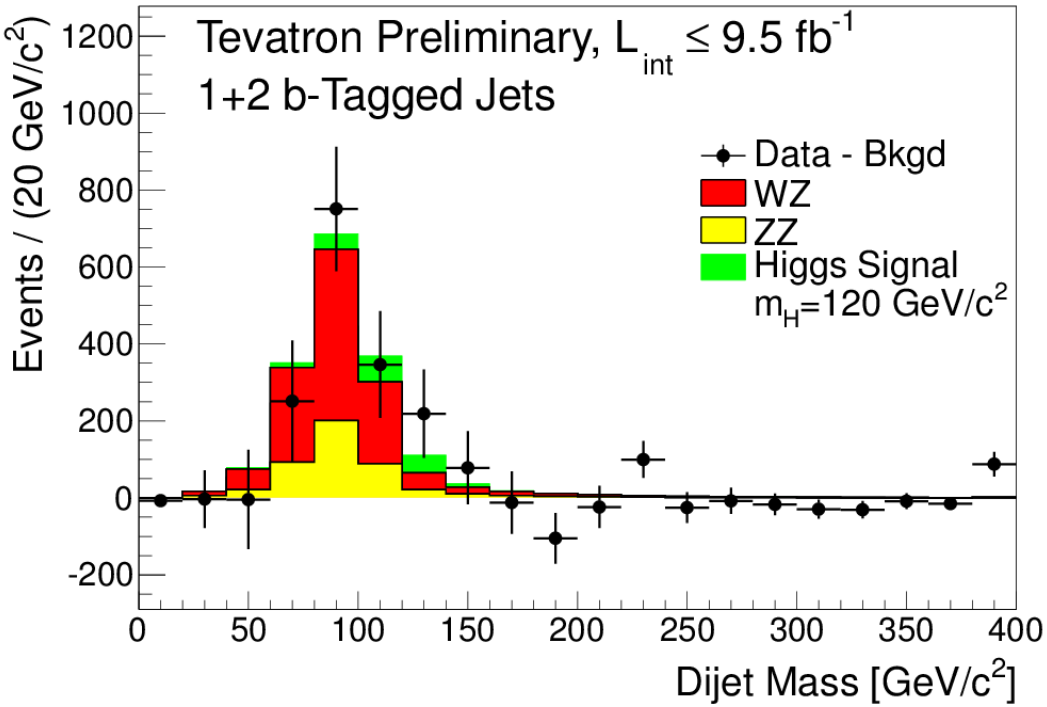


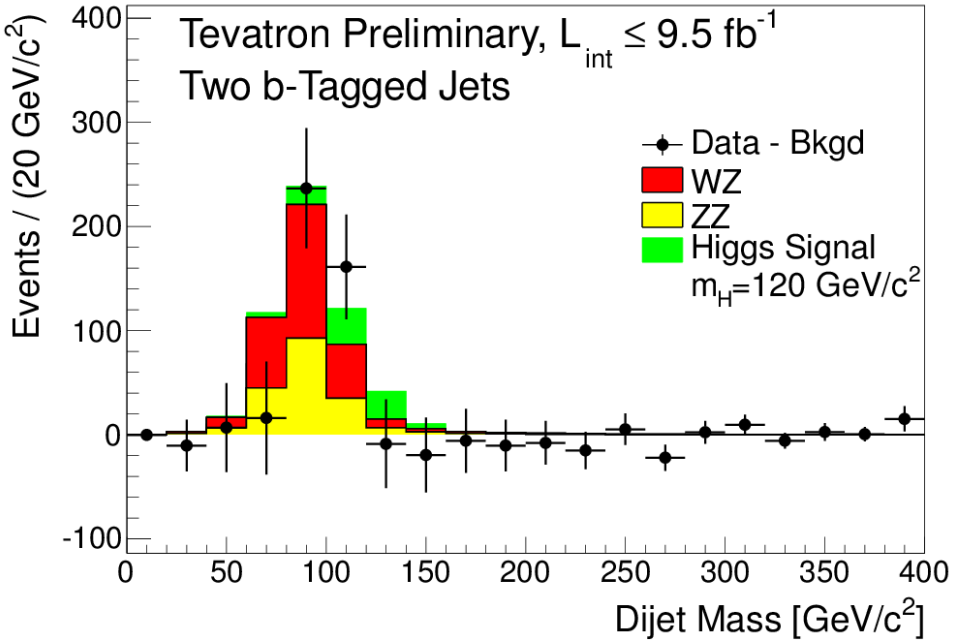


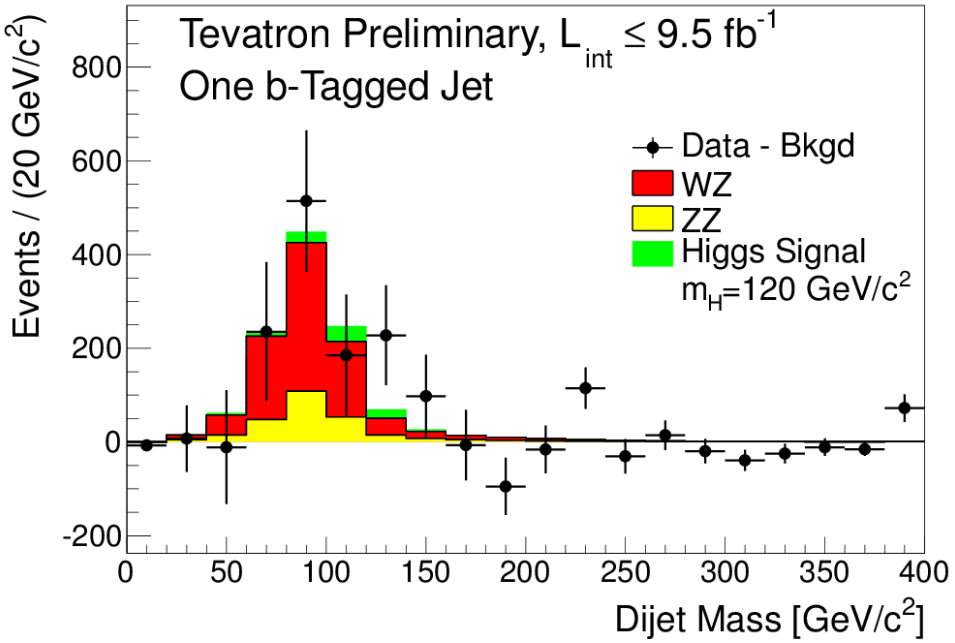


Overlaying a BEH Signal

- Simple overlay of H→bb signal prediction for the dijet invariant mass (M_H = 120 GeV)
  - Data and diboson prediction come from Tevatron low mass WZ/ZZ measurement
  - Additional signal is not incompatible







Log-Likelihood Distributions

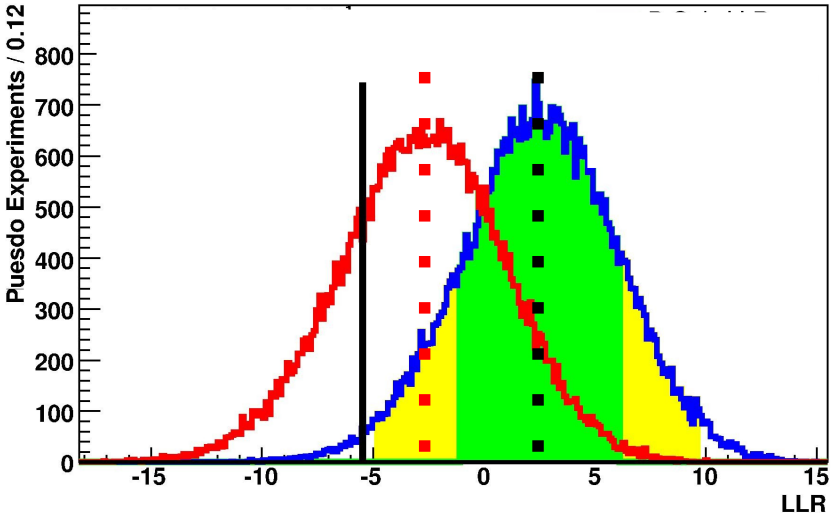
- The log-likelihood ratio helps to gauge the relative agreement of the data with the background or signal+background models

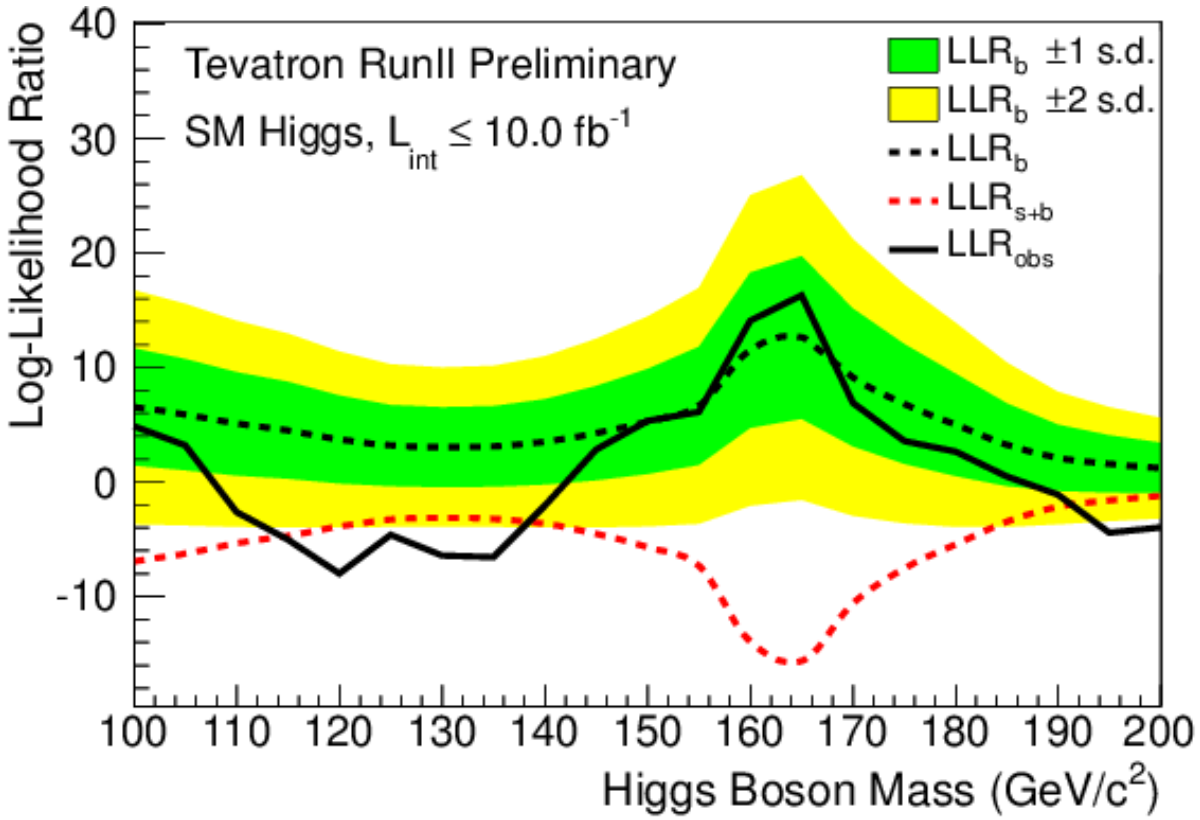
- Distributions are populated with pseudo-experiments to get an estimate of significance.

Background-Only PEs

Signal+Bkgd PEs

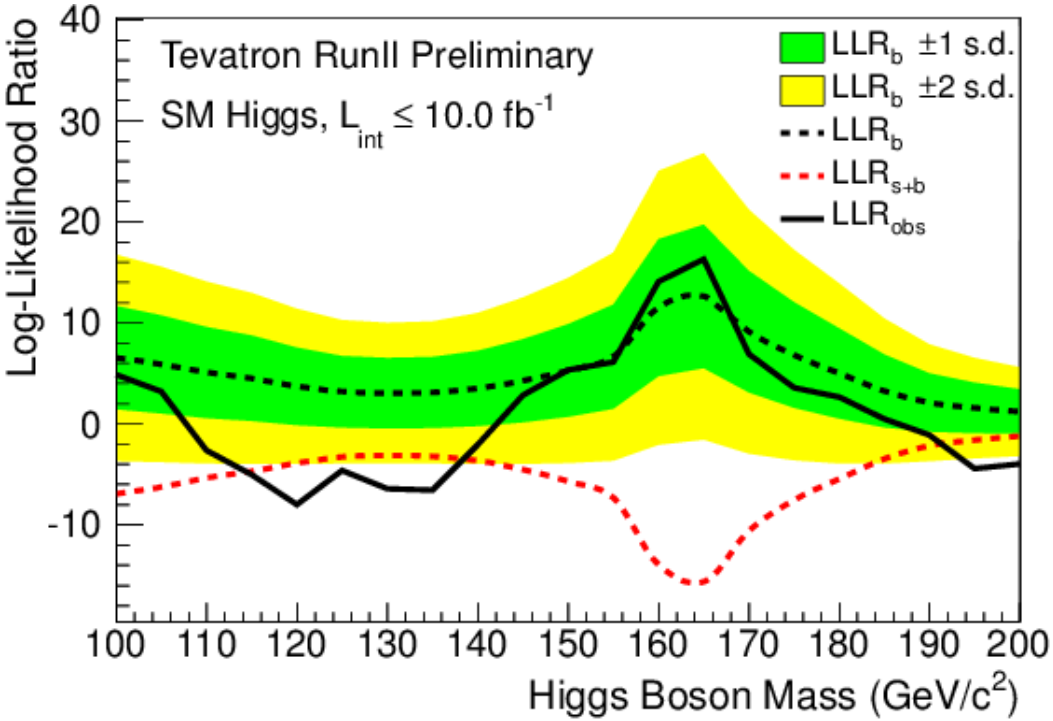
Observed LLR



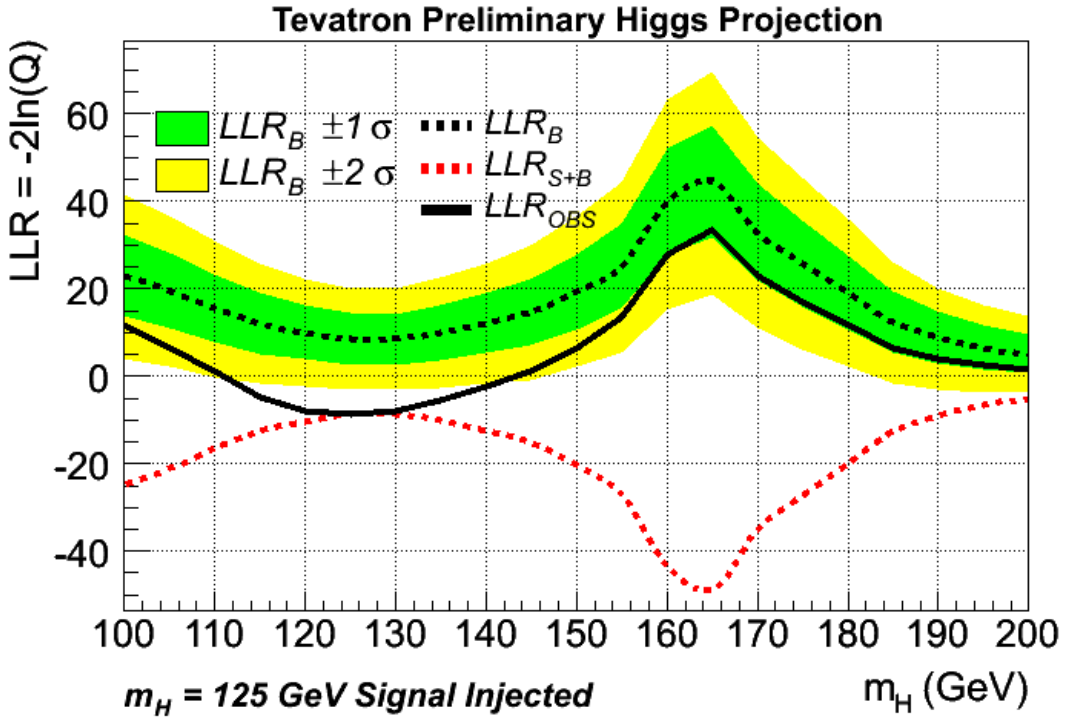


Quantifying the Excess

Real Data Analysis

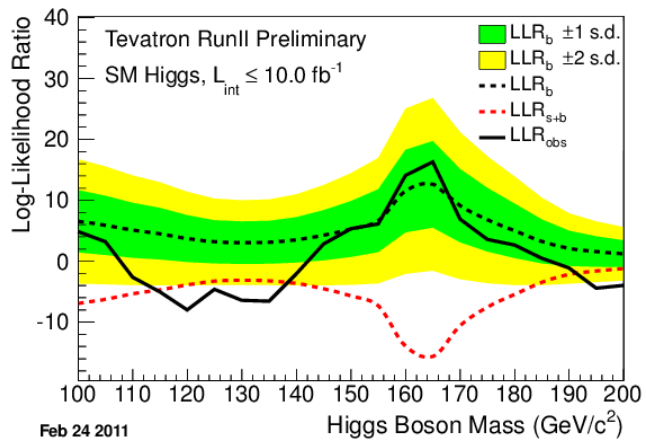


3σ Signal Injection Study

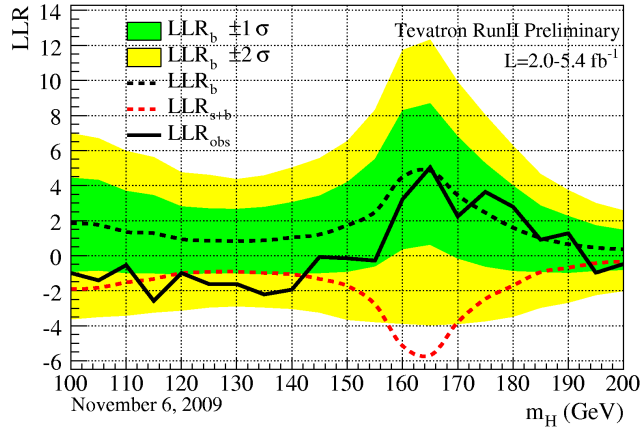


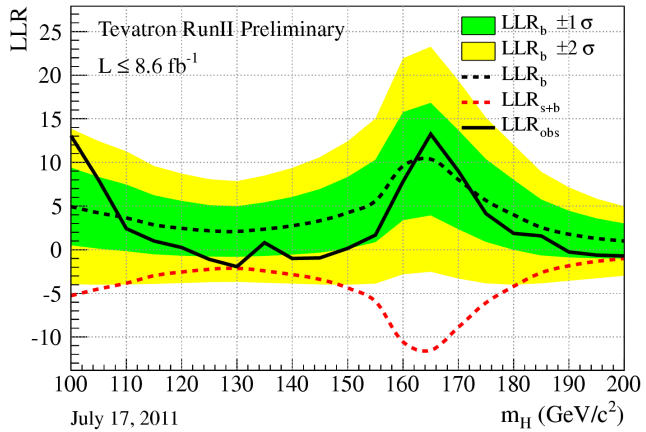
- **An obvious question:** does the global signature you observe make sense for a SM Higgs signal?
  - Consider a study performed by injecting M_H=125 GeV Higgs signal to our search, luminosity scaled so the excess is 3 s.d. above the background prediction.
  - Expect broad excess over entire mass range. +1 standard deviation at M_H=200 GeV

Log-Likelihood Distributions

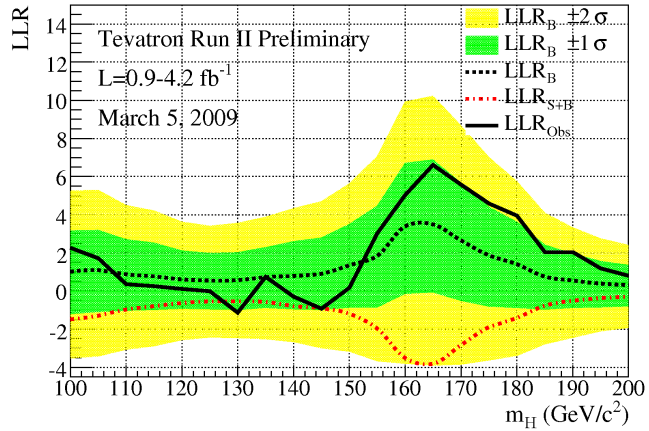


2012

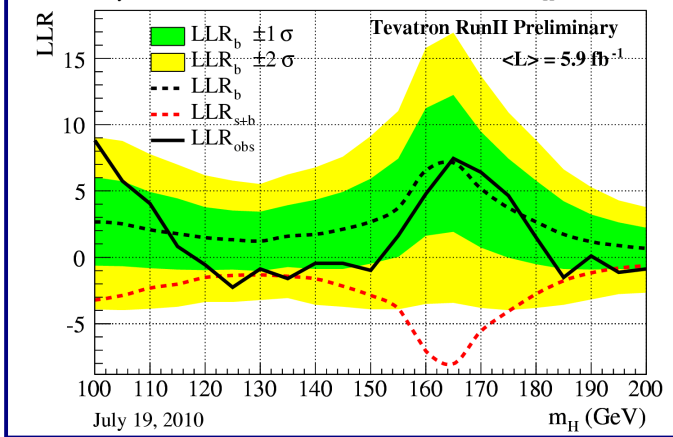




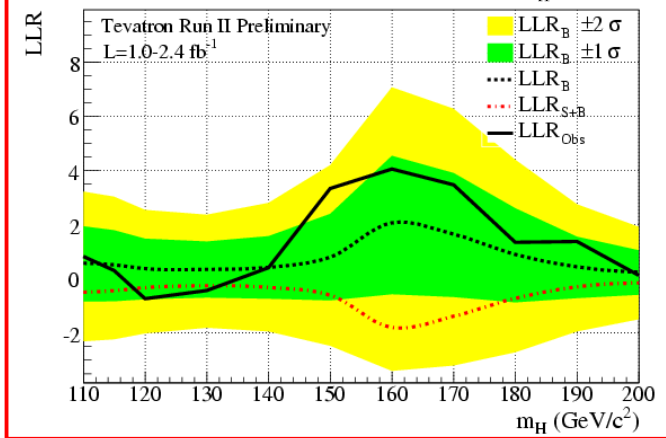
2011



2008



2010



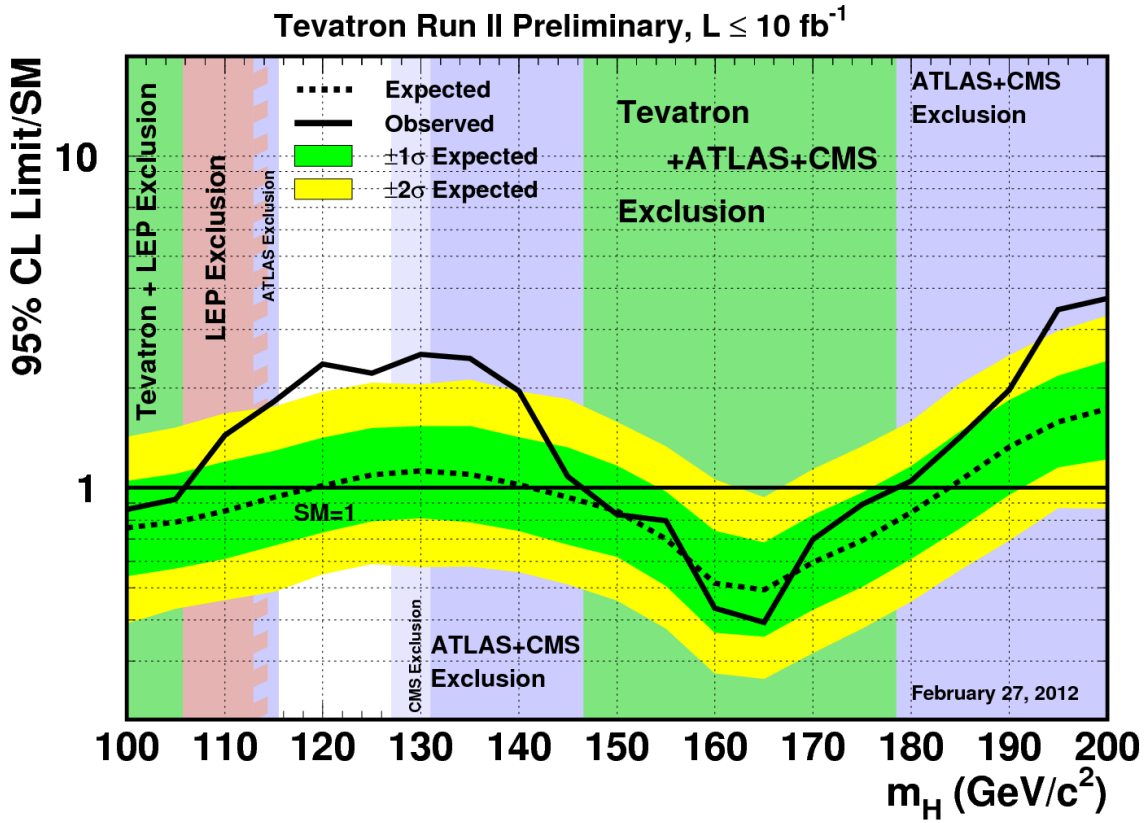
2007

Conclusions

For additional details see

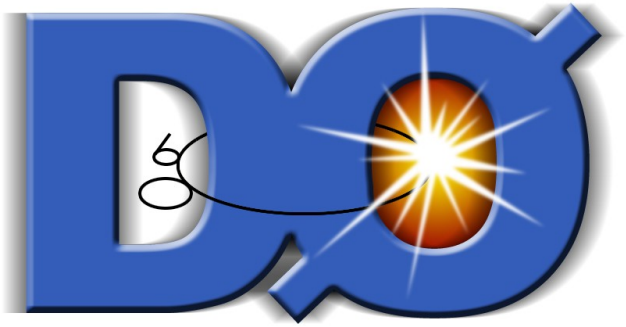
- Tevatron: http://tevnphwg.fnal.gov/results/SM_Higgs_Winter_12/
- CDF: http://www-cdf.fnal.gov/physics/new/hdg/Results.html
- D0: http://www-d0.fnal.gov/Run2Physics/WWW/results/higgs.html

- Tevatron program now analyzing full data set in most analyses
- More search improvements to come in the near future
- The data appear to be incompatible with the background, with a global p-value of **2.2 s.d. (** 2.7 local **)**
  - **H→bb only: 2.6 s.d. (** 2.8 local **)**
- Higgs mass range of **115 < M_H < 135** continues to be very interesting

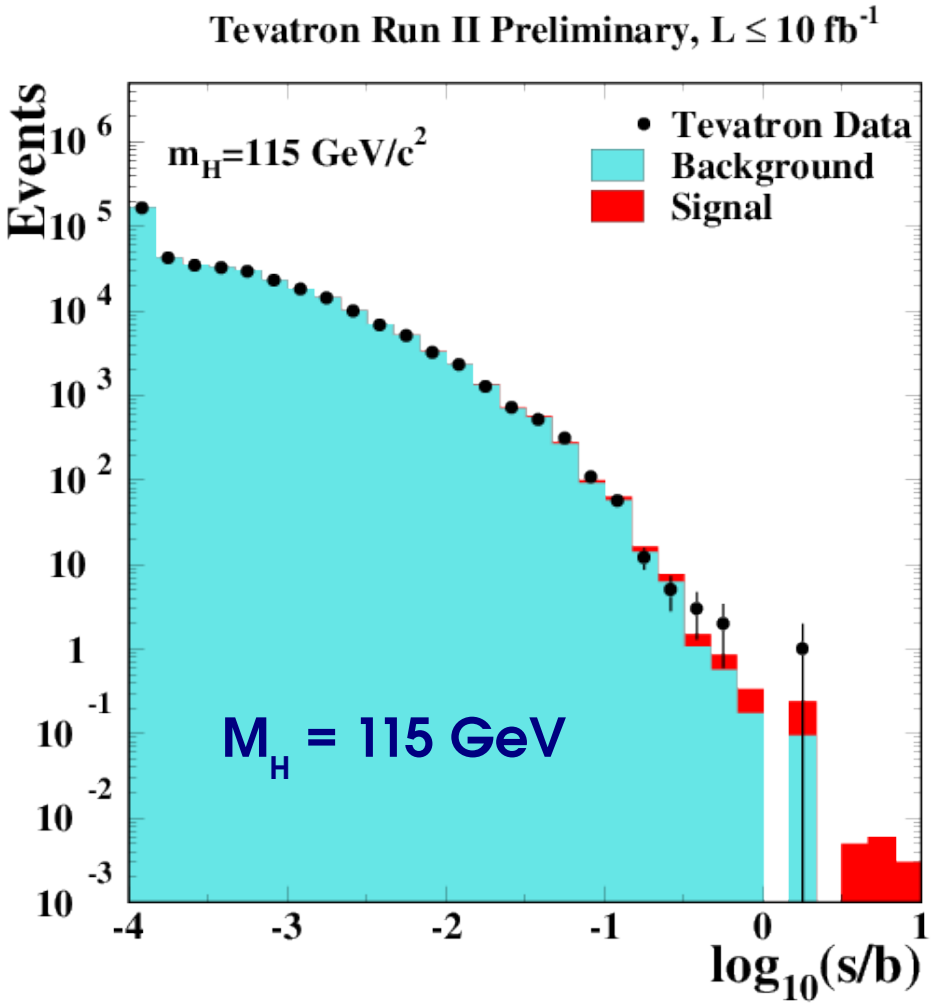


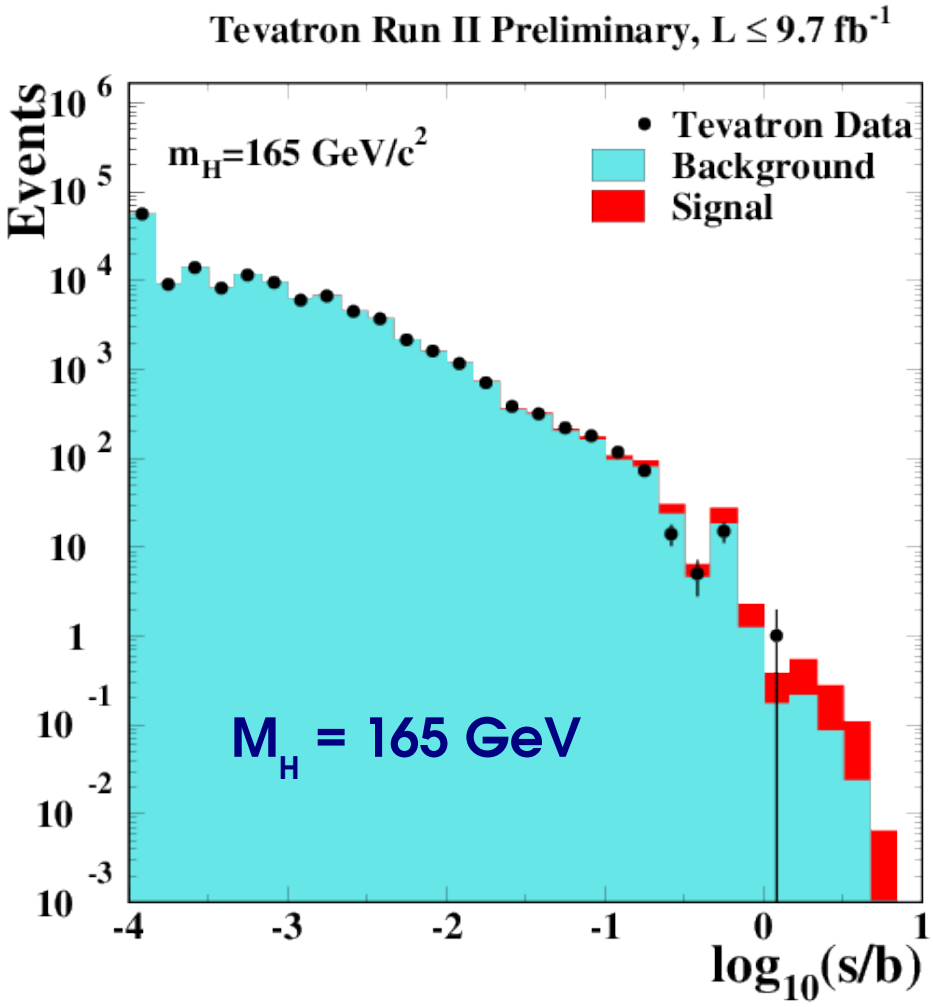
Thank you for your attention

Questions?

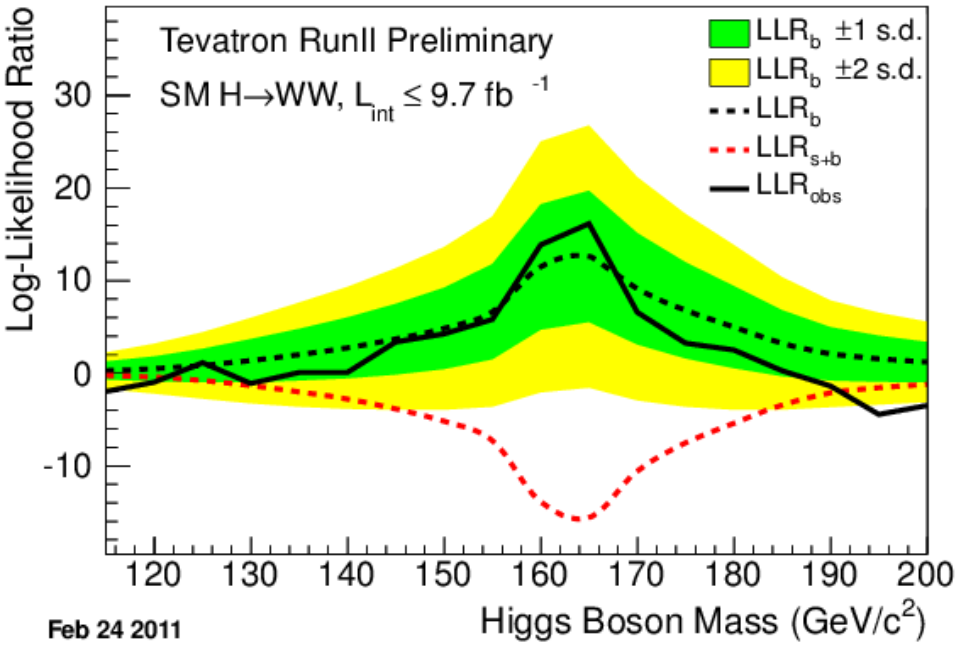


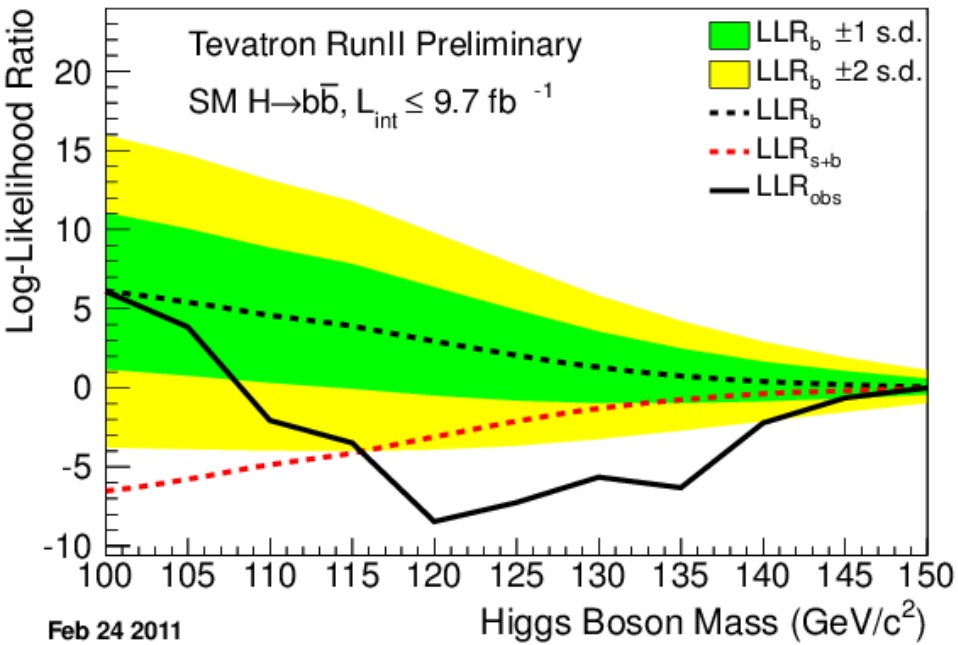
CDF & DØ Combined Distributions

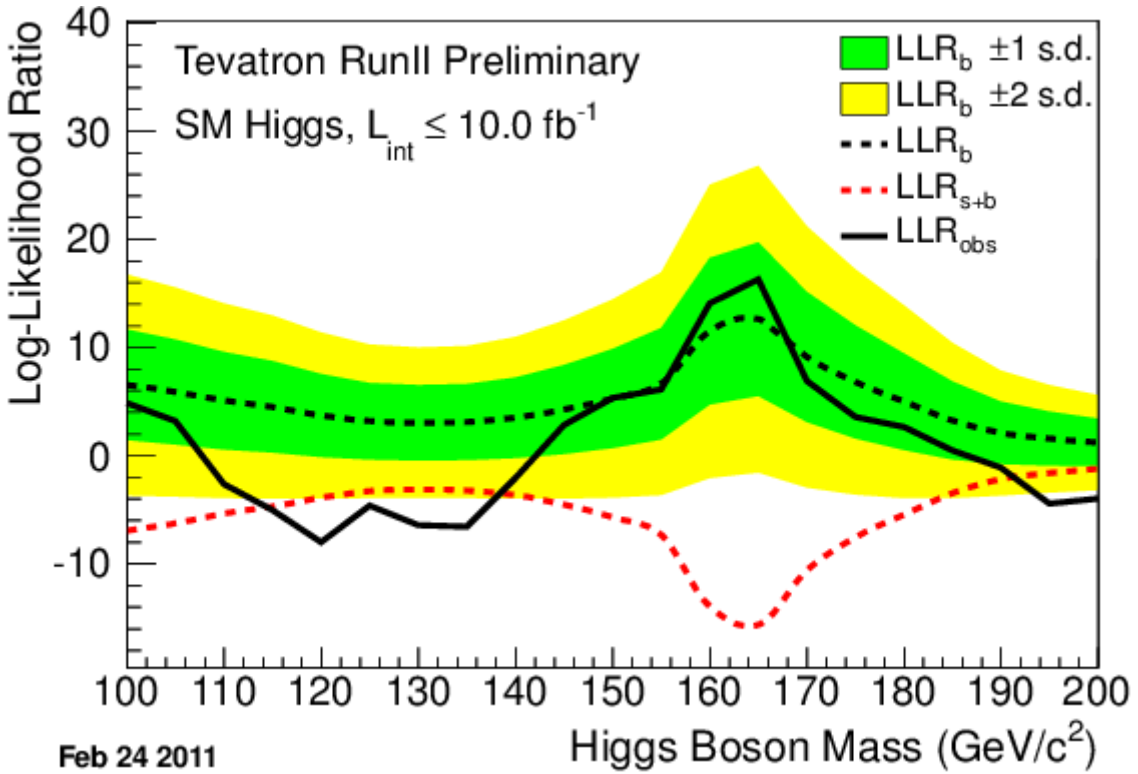




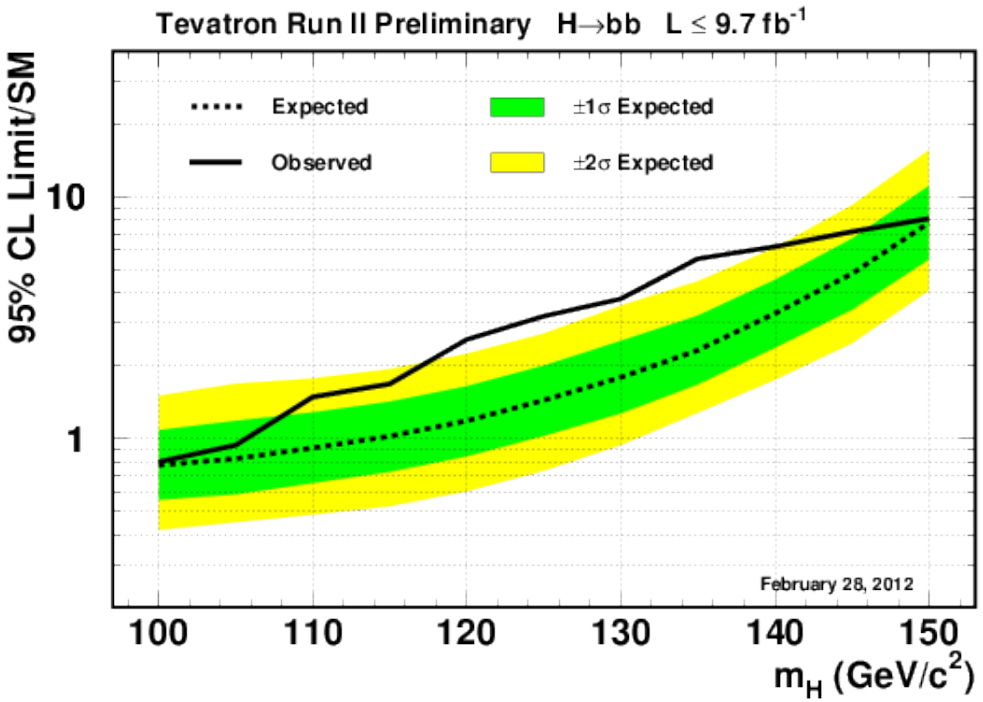
Log-Likelihood Distributions

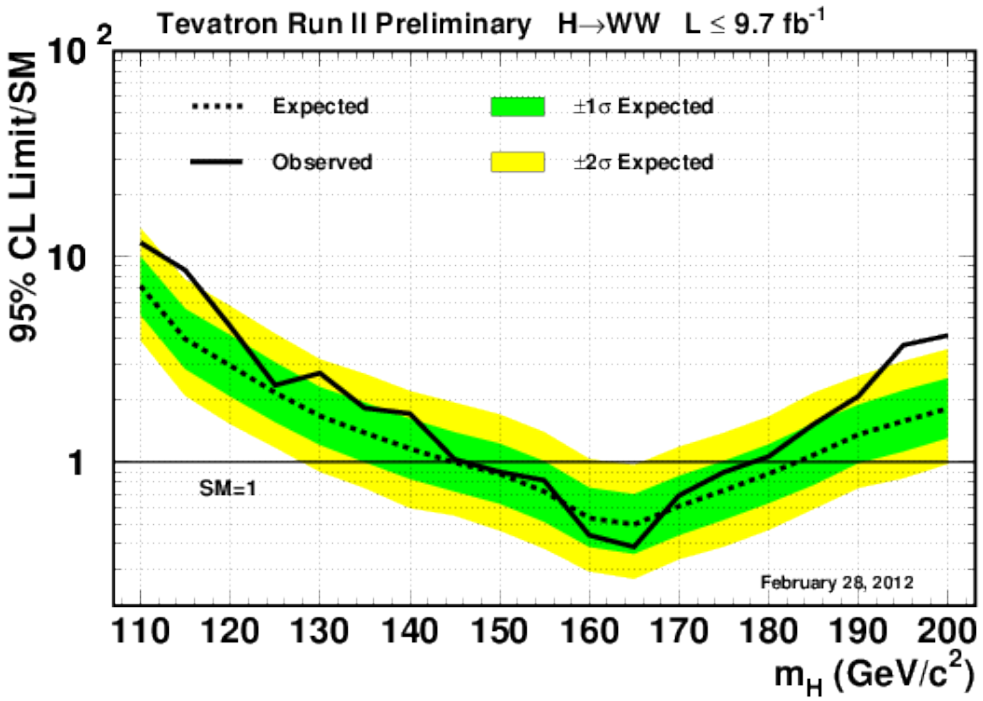




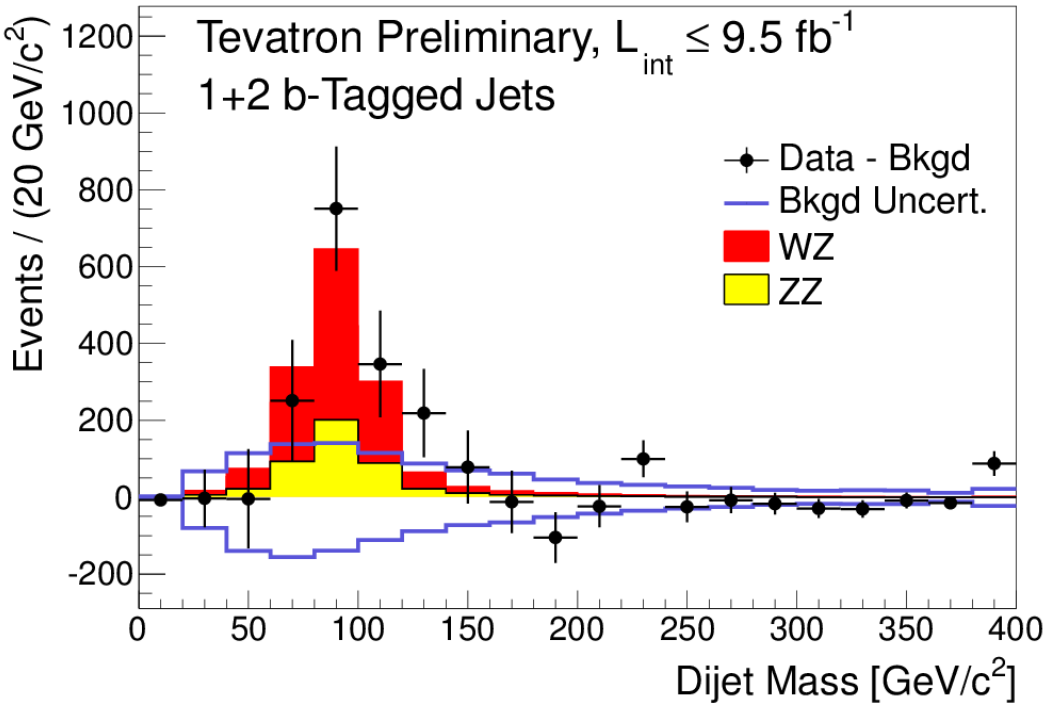


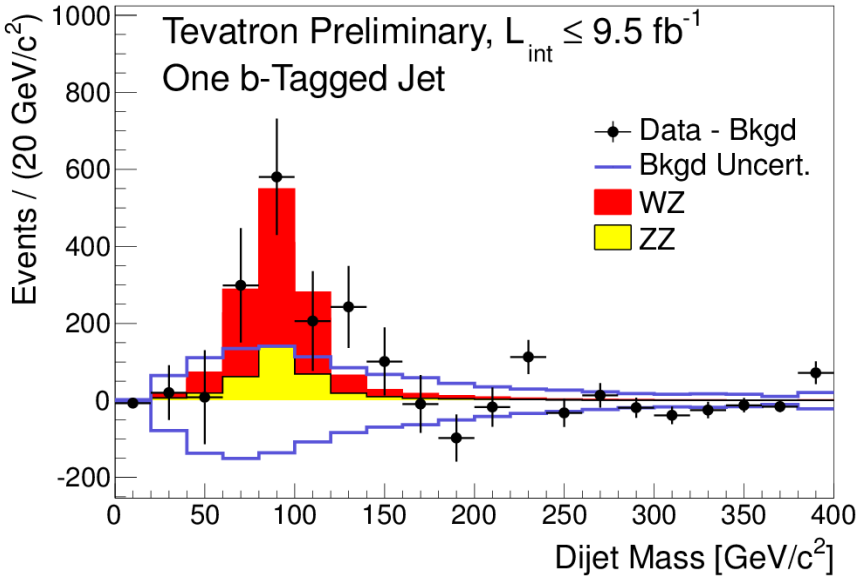
Upper Limits on BEH Boson Production

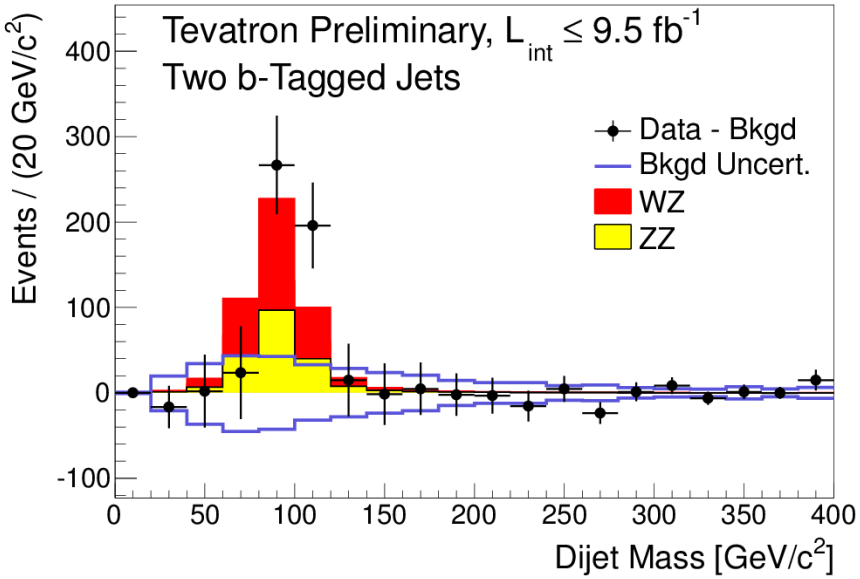




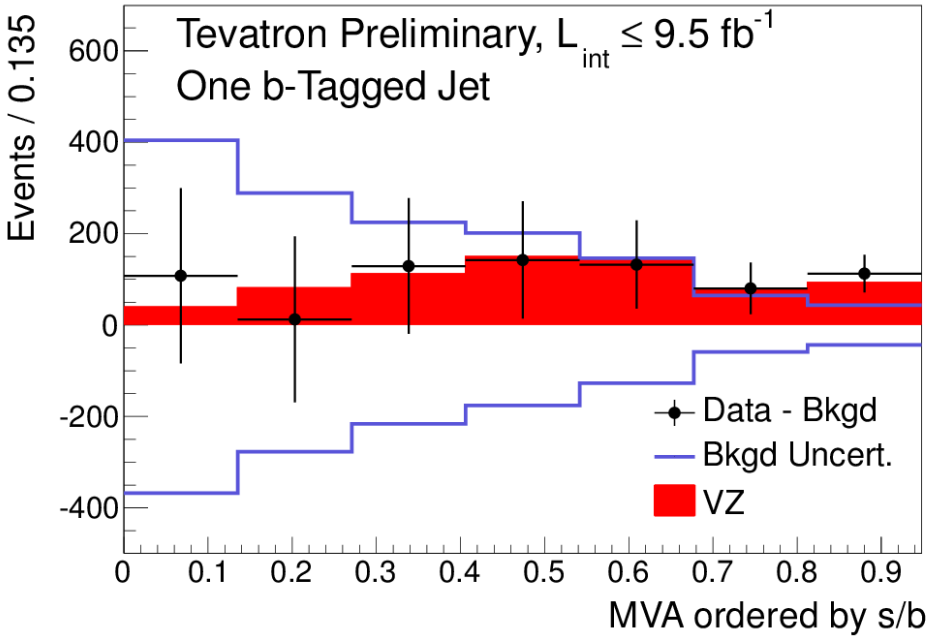
BEH Search Validation

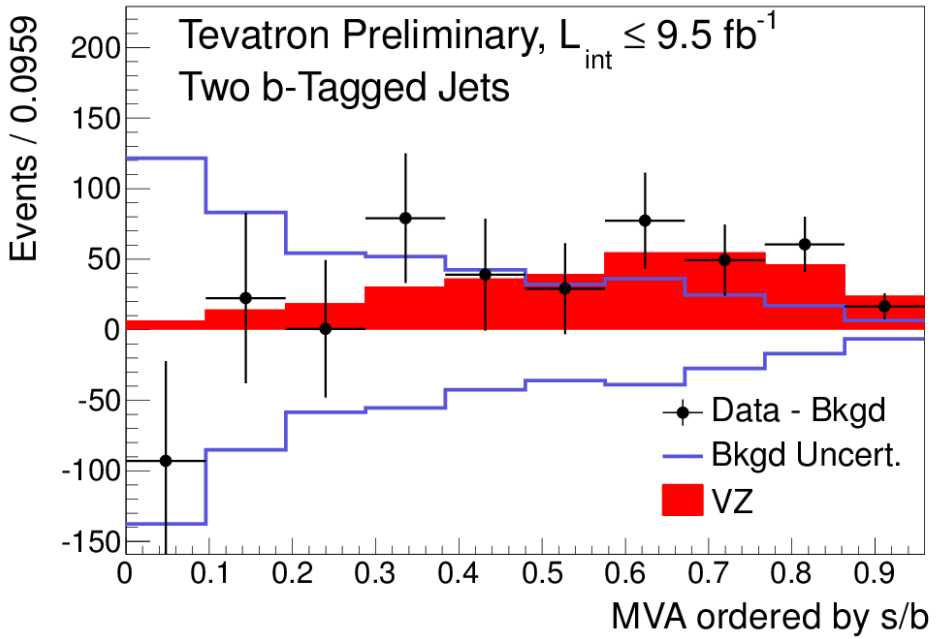


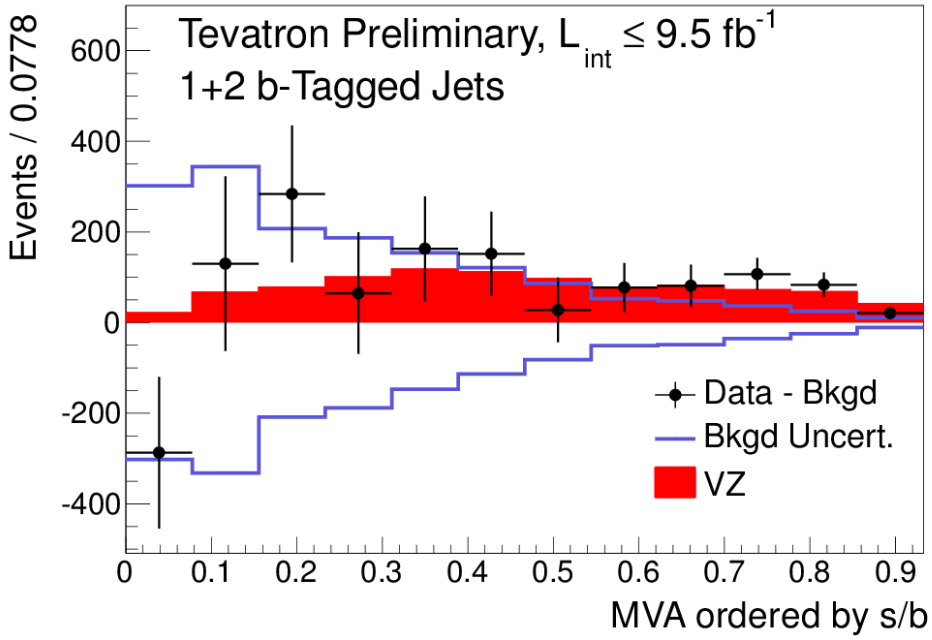




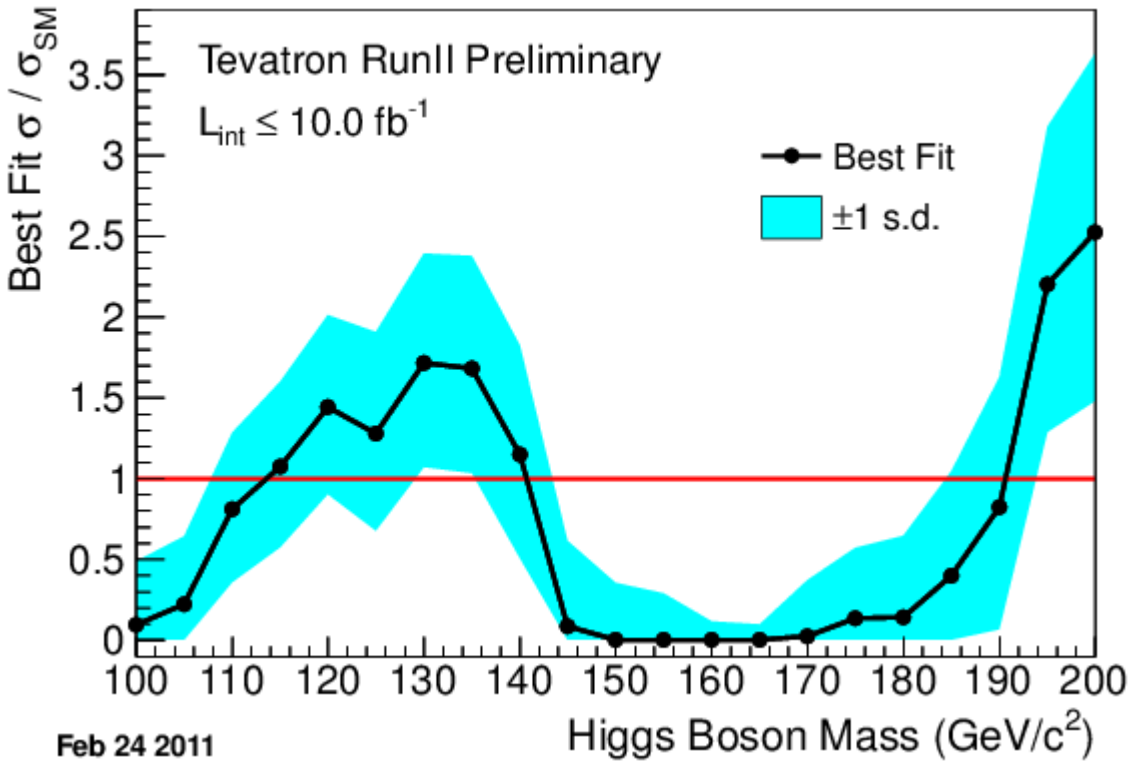
BEH Search Validation

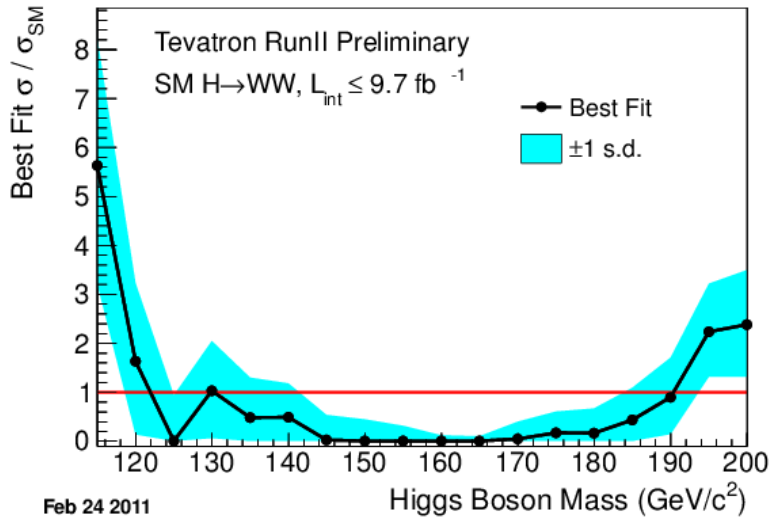


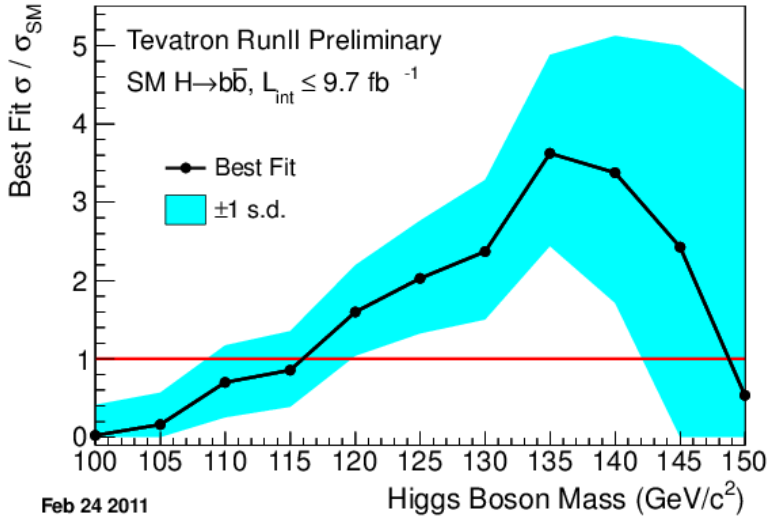




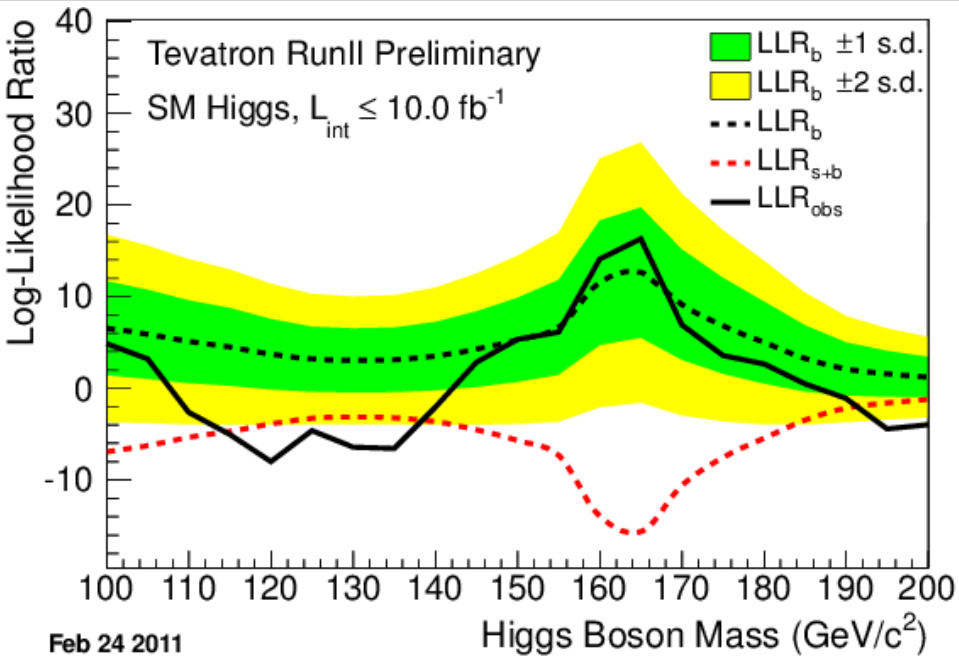
Quantifying the Excess

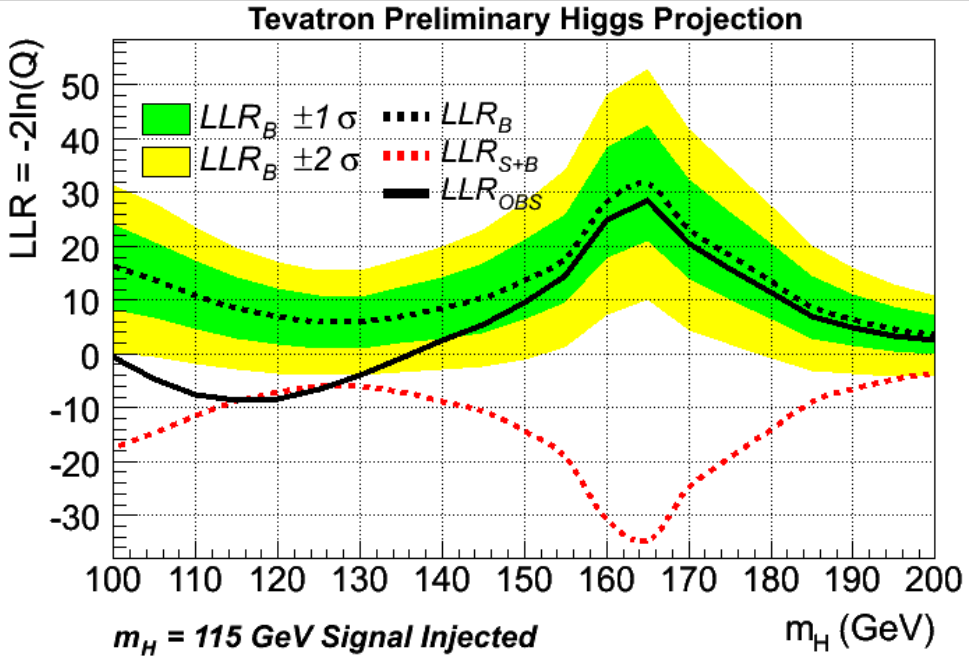


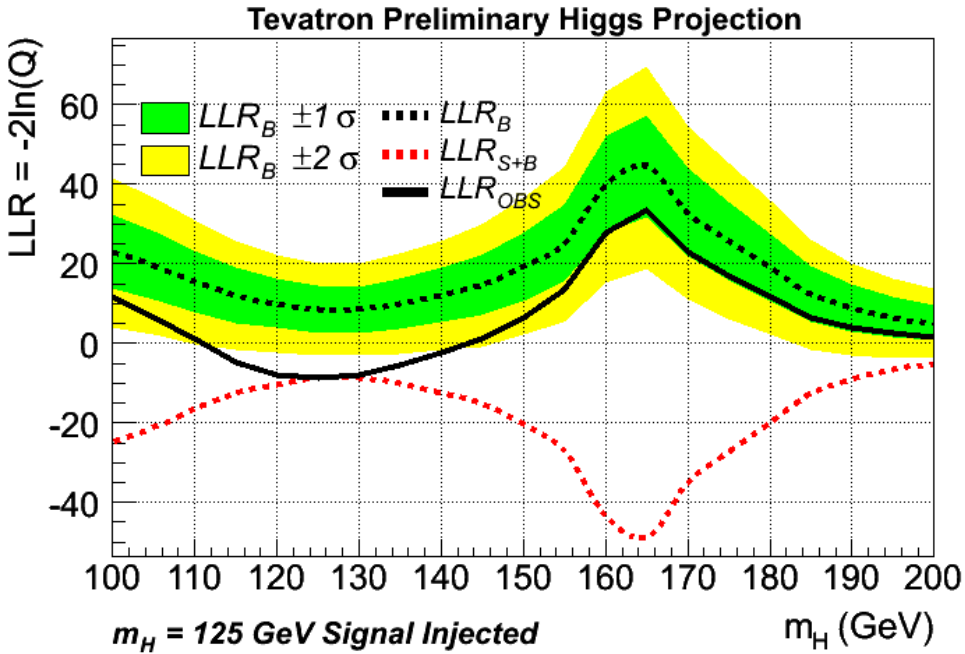


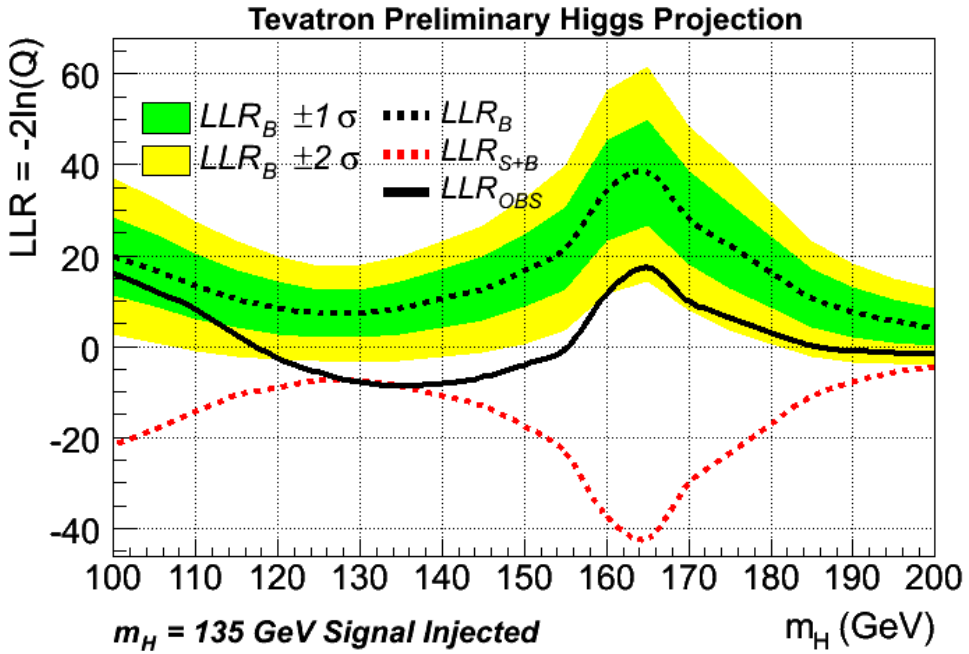


Quantifying the Excess



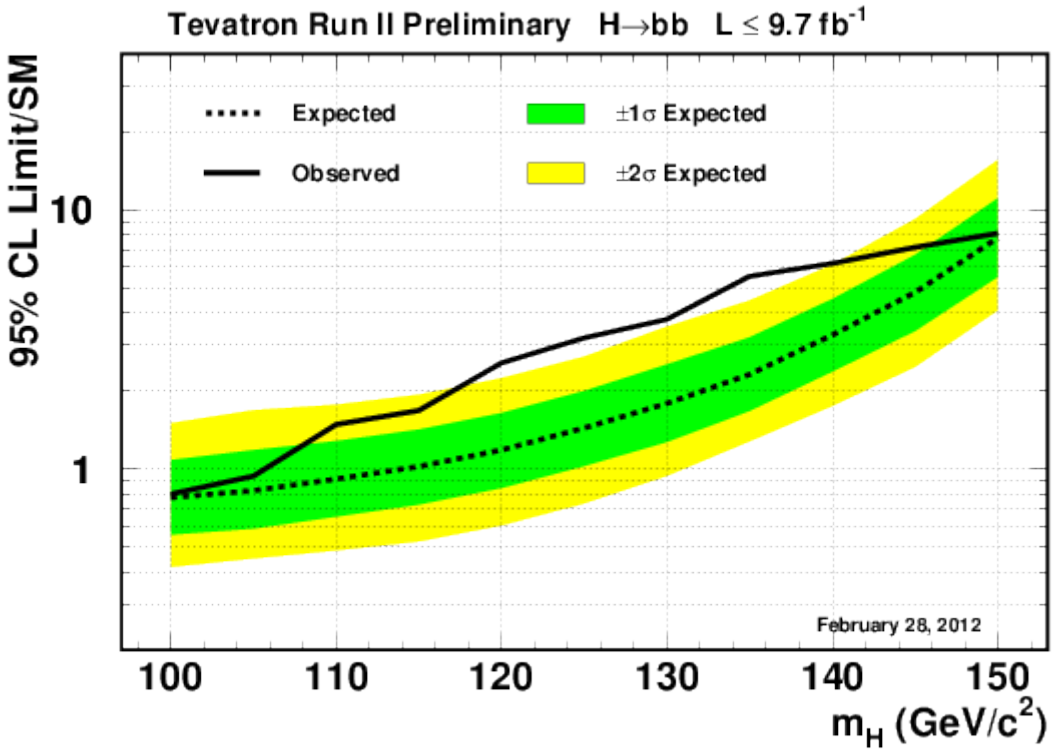




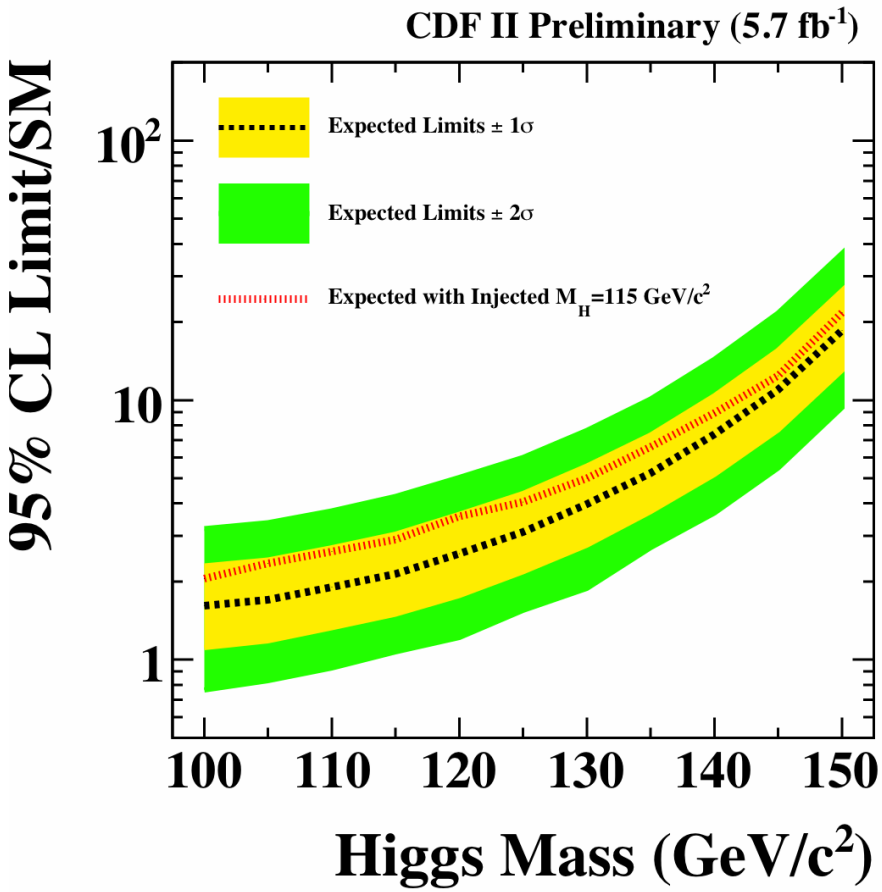


Quantifying the Excess

Real Data Analysis



Signal Injection Study



Theory Considerations for BEH Production

- General treatment
  - Consider uncertainty on Higgs branching fractions, correlated effect between H->bb and H->WW channels.
  - Associated production, vector boson fusion production uncertainties from

- Treatment for the gg→H process
  - Cross-section: NNLO with soft resummation to NNLL (& EW corrections)
    - **D. de Florian and M. Grazzini, arXiv:0901.2427 (hep-ph)**
    - **C. Anastasiou, R. Boughezal and F. Petriello, arXiv:0811.3458 (hep-ph)**
  - Use MSTW08 PDF set as recommended by PDF4LHC
  - Channels that don't split by number of jets
    - PDF+α_s: Use PDF4LHC prescription
    - Scale: Vary factorisation + renormalization uncertainty by factor of 2 together
    - PDF+α_s and scale treated as uncorrelated

Theory Considerations for BEH Production

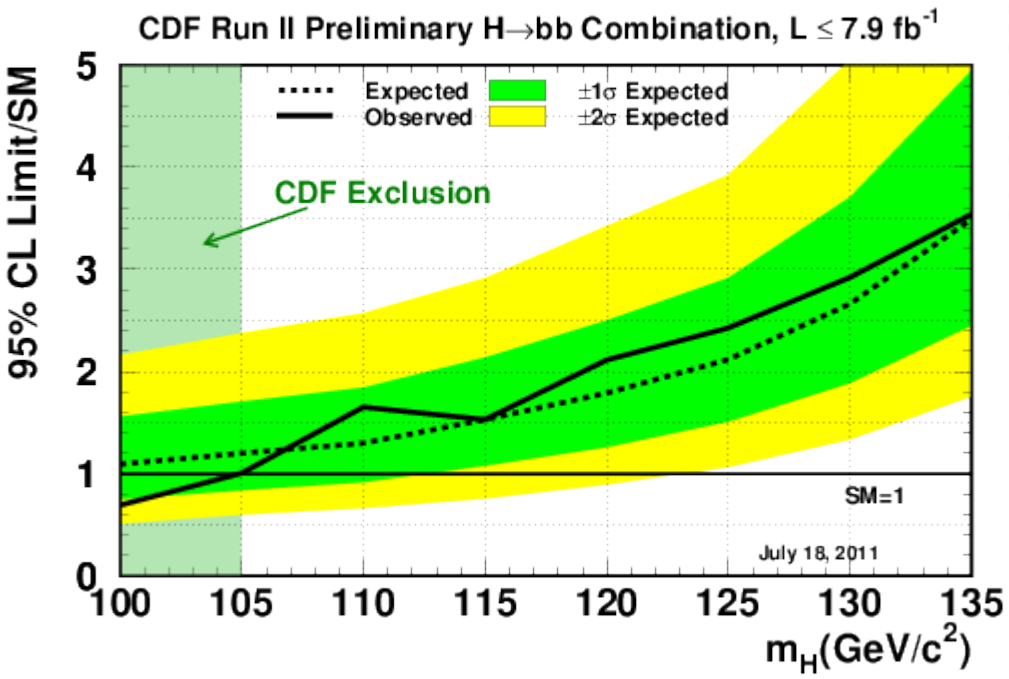
- Treatment for the gg→H process
  - Channels that split by number of jets
    - Different PDF+α_s and scale errors for each bin as before **but**
    - Treat scale uncertainty of NNLO+NNLL inclusive, NLO-1-or-more & NLO-2-or-more-jets as uncorrelated a la BNL
      - **Berger et al., arXiv:1012.4480 (hep-ph)**
      - **Stewart and Tackmann, arXiv:1107.2217 (hep-ph)**
    - From these calculate exclusive H+0jet, H+1jet, H+2jet-or-more scale uncertainties

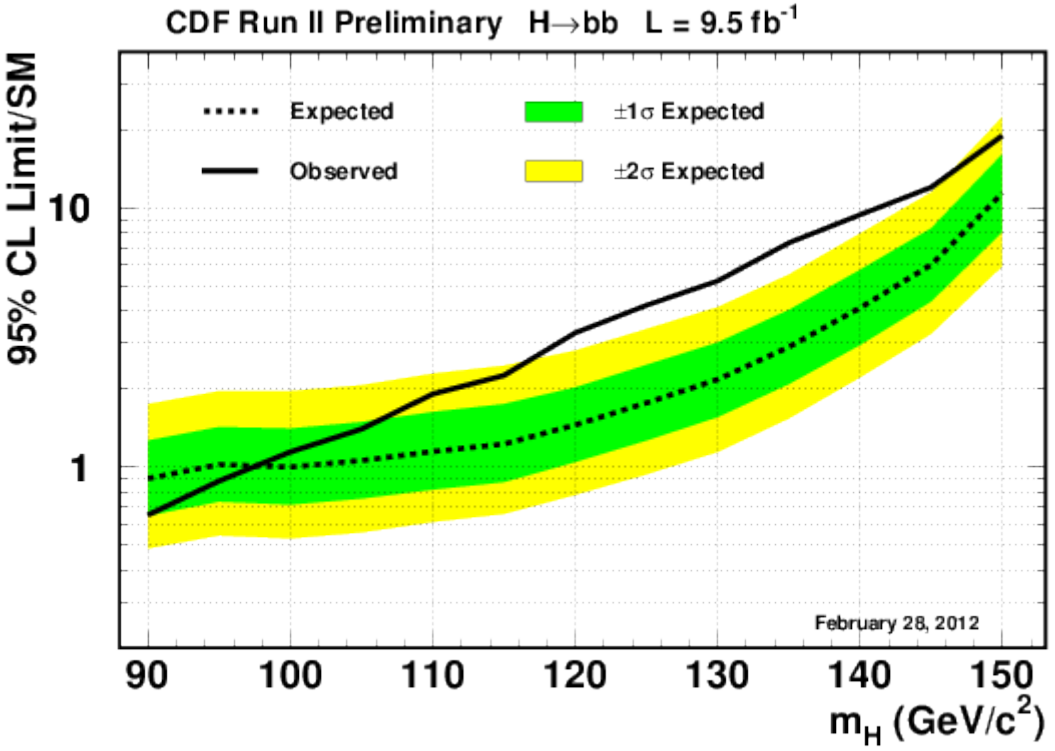
Jet bin	s0	s1	s2
0 jet	13.4%	-23.0%	0
1 jet	0	35%	-12.7%
>= 2 jets	0	0	33%

    - PDF errors from Anastasiou et al., JHEP 0908, 099 (2009) as before

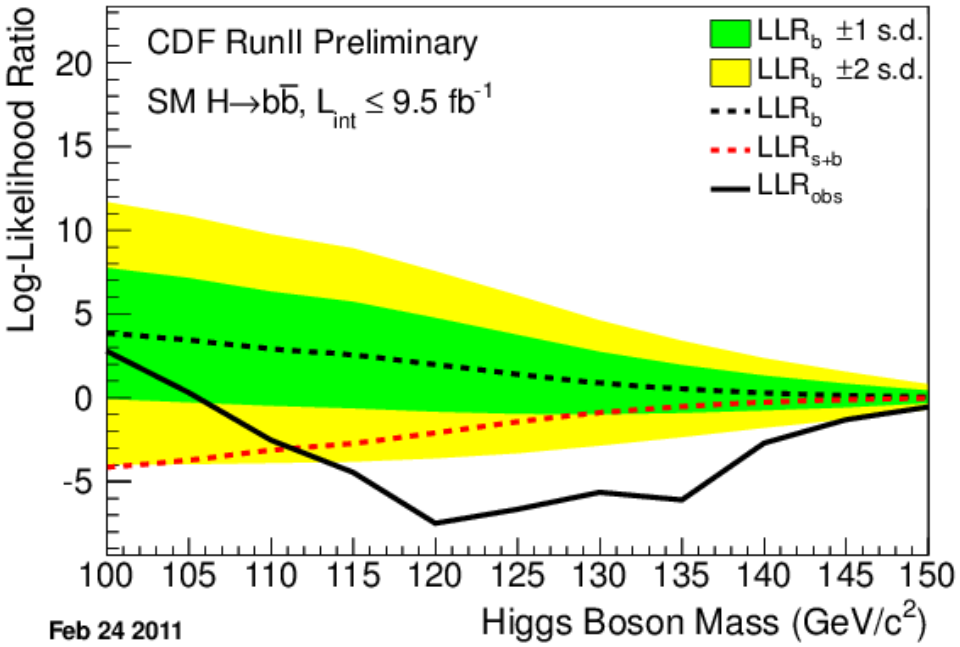
Further details on combinations: **http://tevnphwg.fnal.gov**

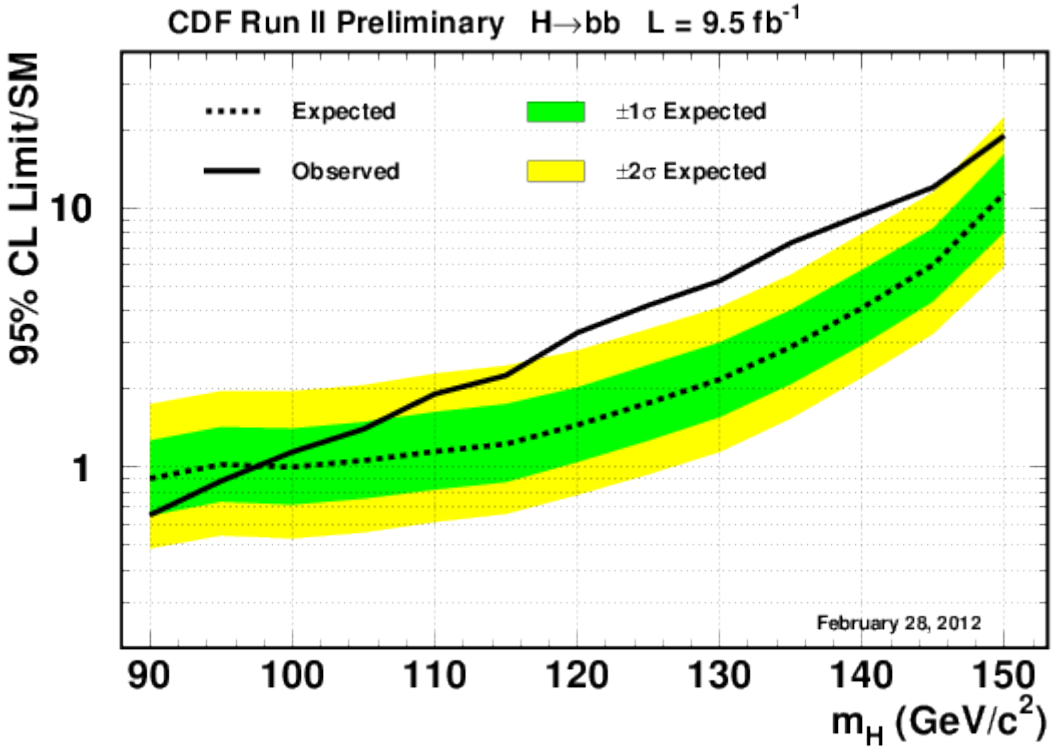
Upper Limits on H→bb Production



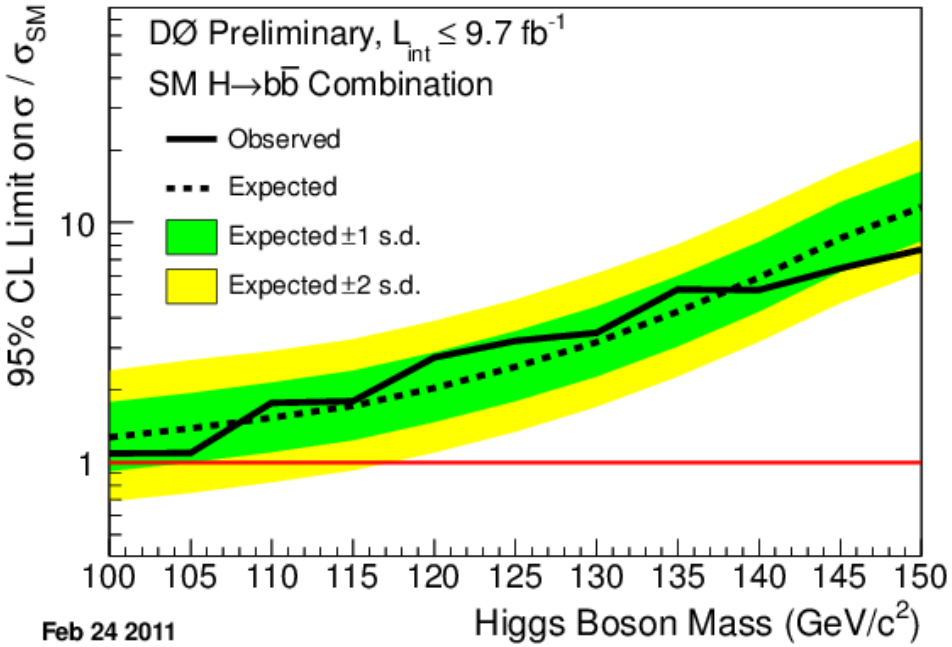


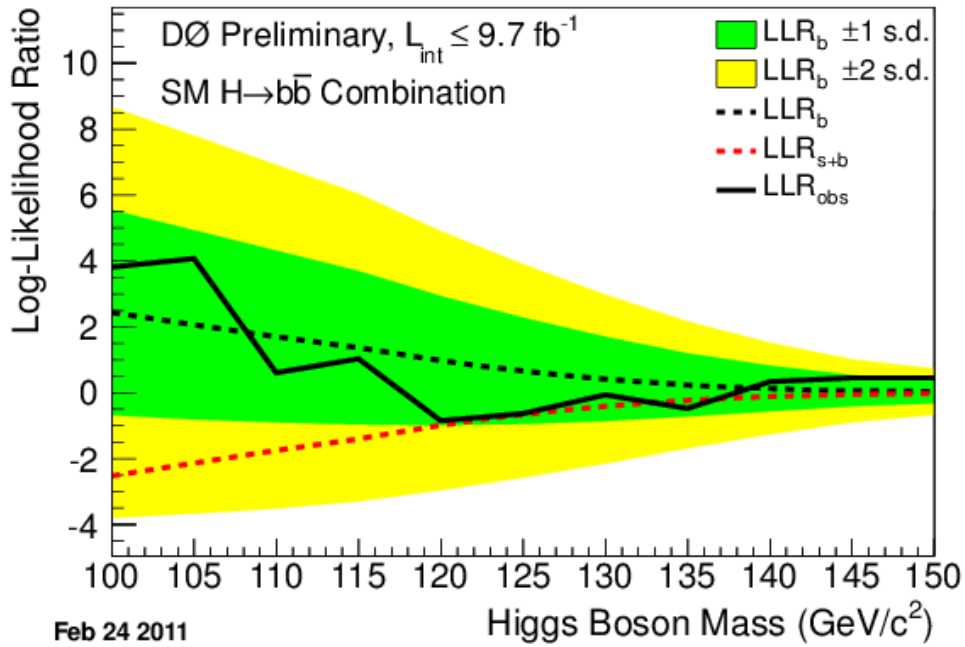
Upper Limits on H→bb Production





Upper Limits on H→bb Production





Upper Limits on H→bb Production