Standard Model Higgs Searches at the Tevatron

Ken Herner

University of Michigan

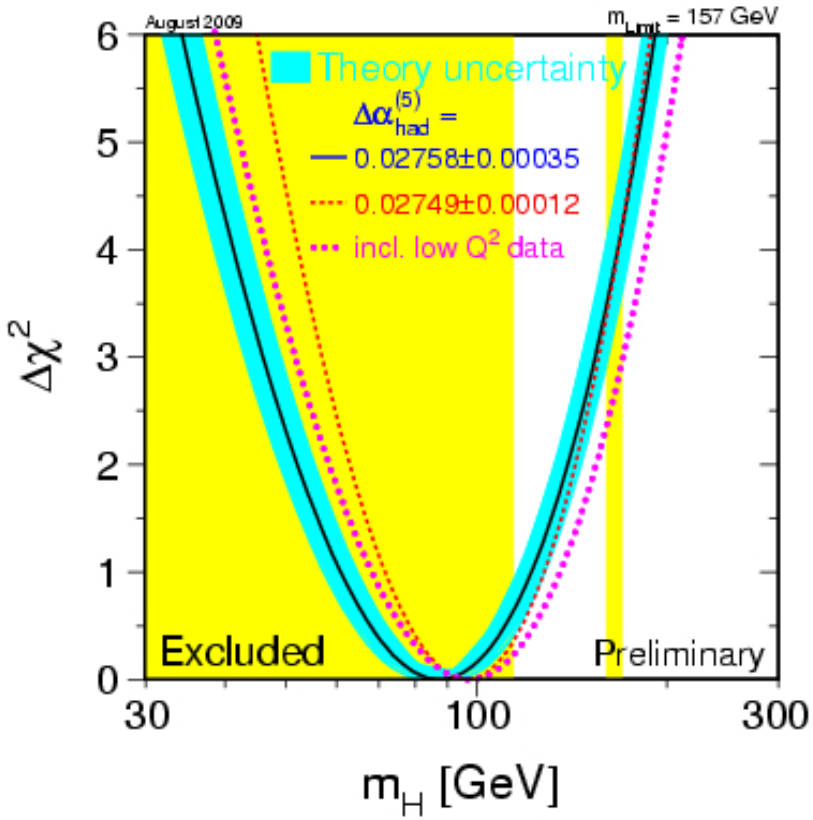
On behalf of the CDF and D0 Collaborations

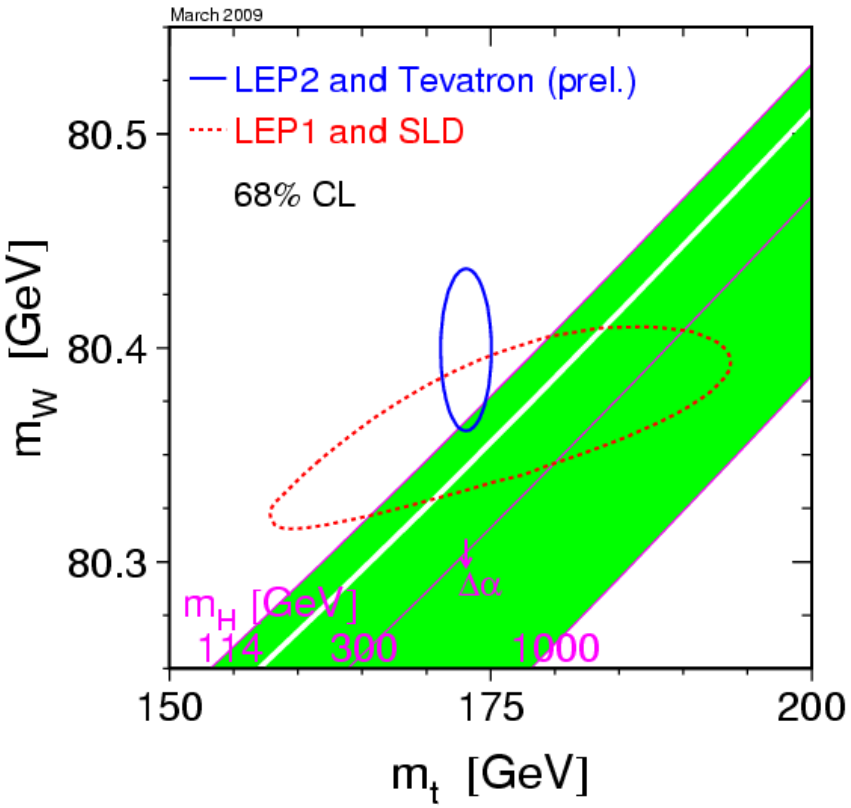
DIS 2010

Higgs Mass Constraints

Direct: M_H > 114.4 GeV (LEP) at 95% CL

Indirect via global EW fits:
M_H < 186 GeV with
LEP2 exclusion at 95% CL

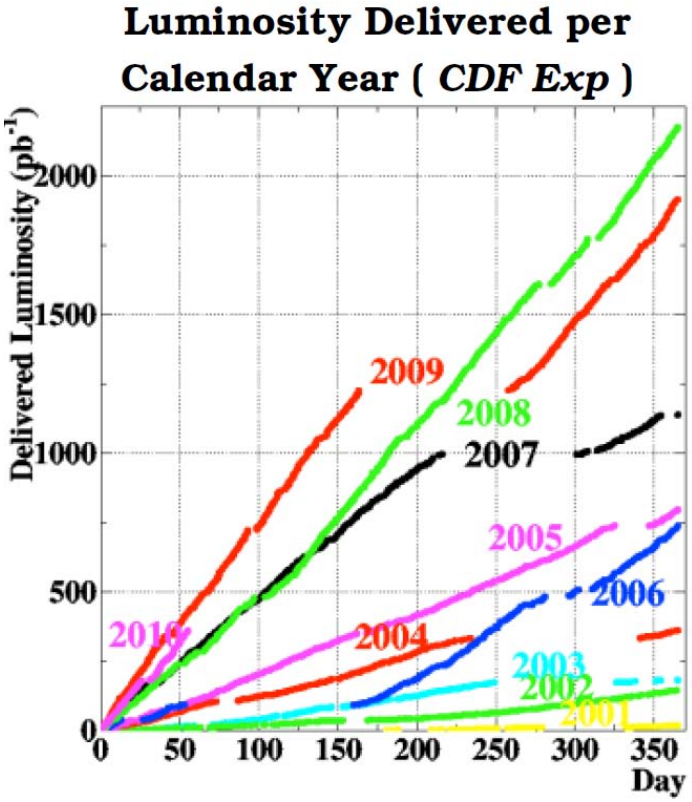




Experimental results favor a low mass Higgs

The Tevatron

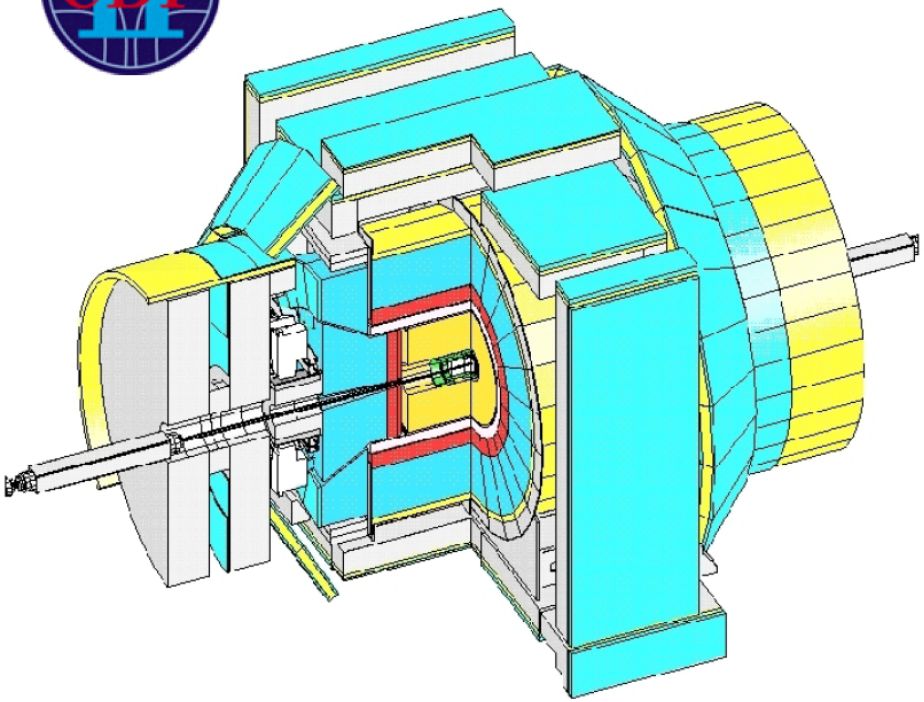
- 1.96 TeV $p\bar{p}$ accelerator
- Over 8 fb^{-1} per exp. Delivered
- Now delivering > 60 pb^{-1}/week
- Peak lumi. > 3.5 x 10^{32} cm^{-2} s^{-1}
  - Have reached 4 x 10^{32} cm^{-2} s^{-1}

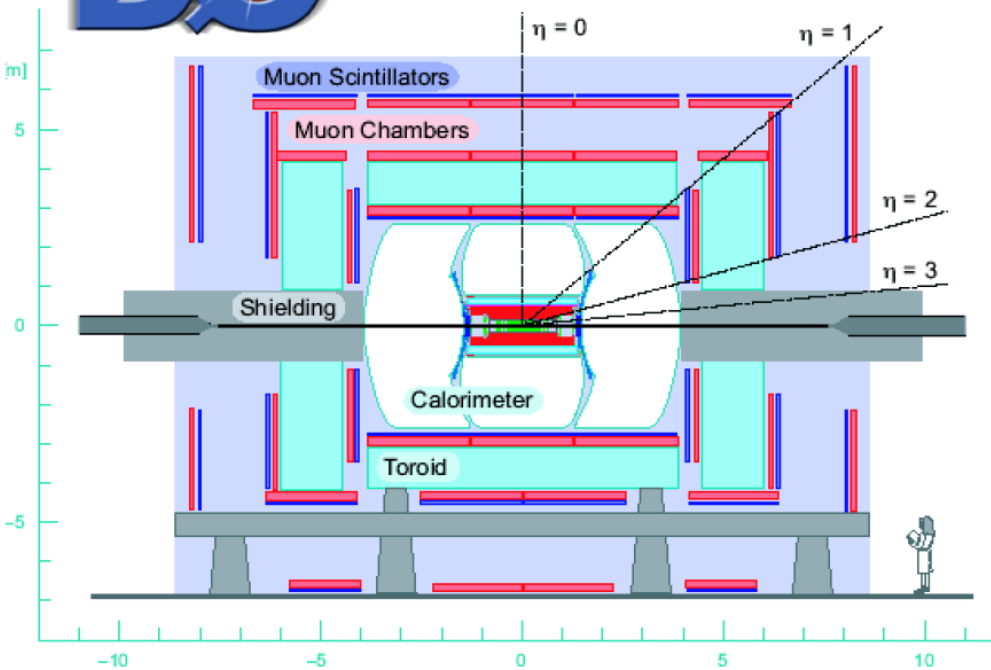


Analyses use data up to June 2009
5.4 fb^{-1} usable

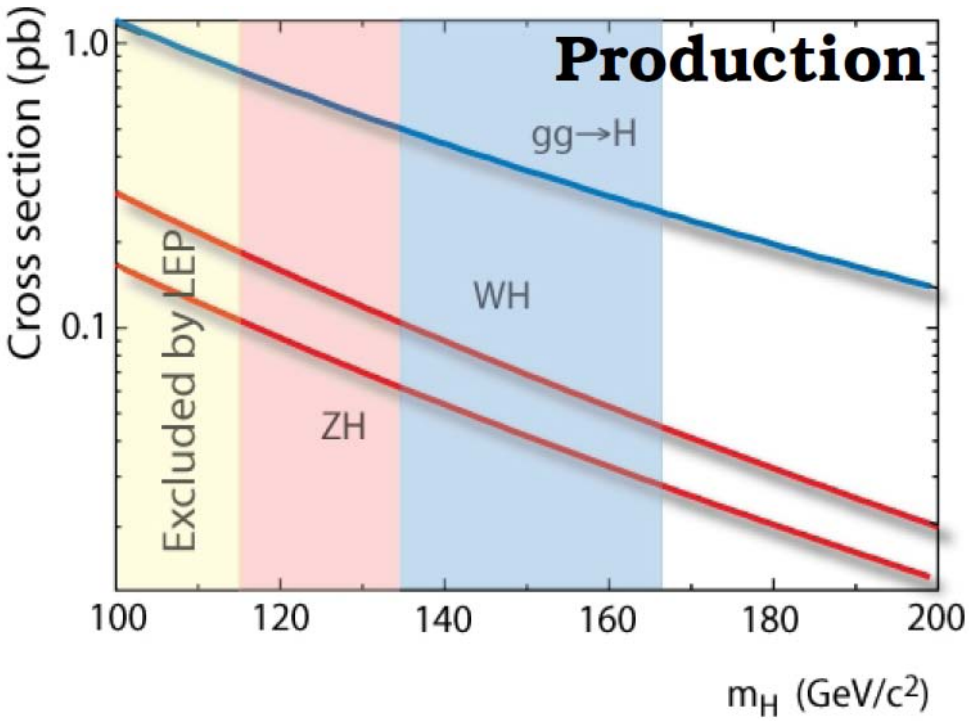
CDF and D0

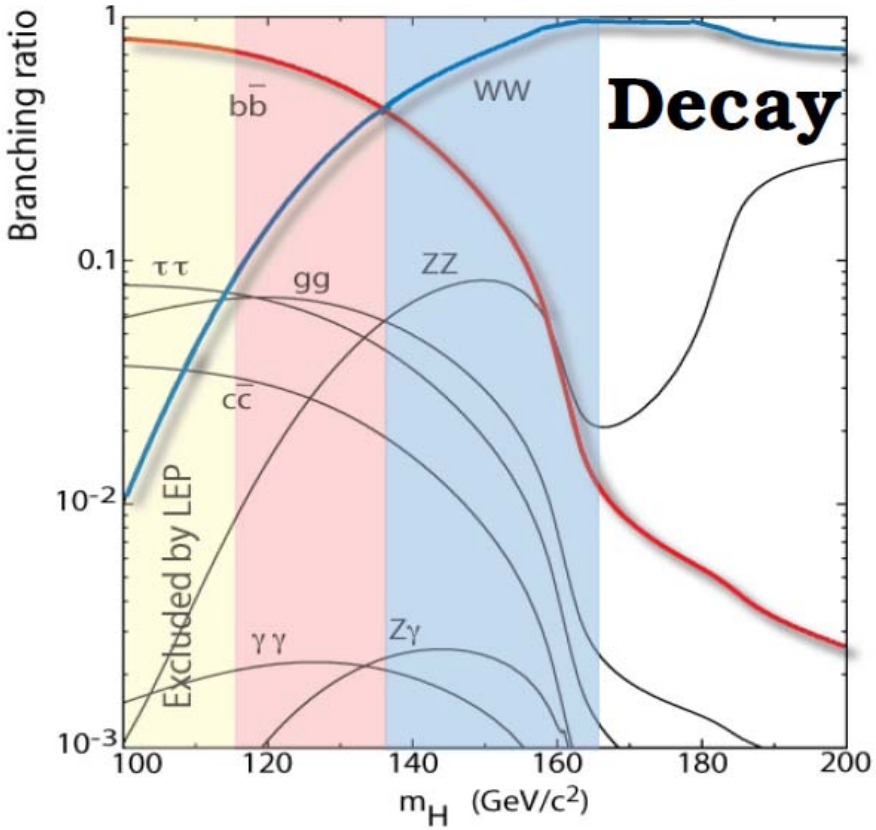
- Multipurpose detectors
- Stable, well-understood



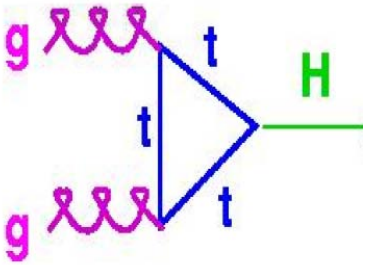


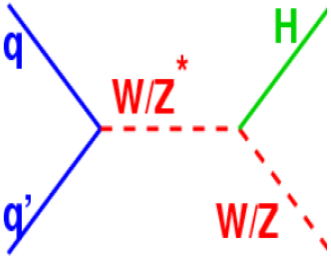
Higgs Production and Decay





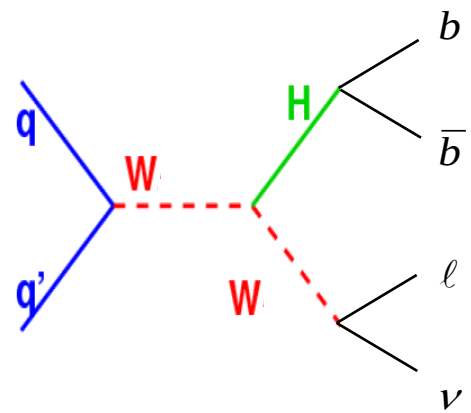
Use associated production at Tevatron for low mass Higgs

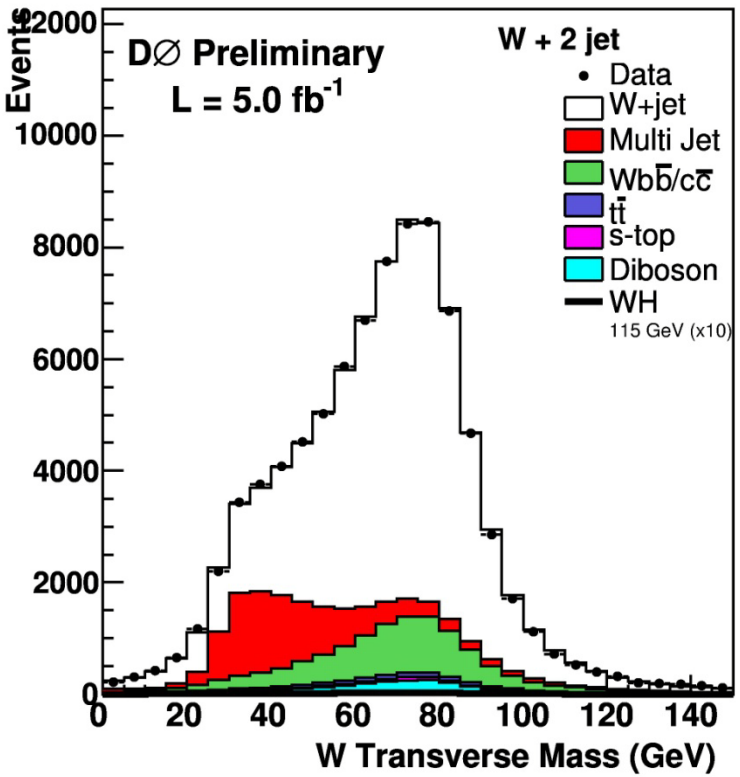


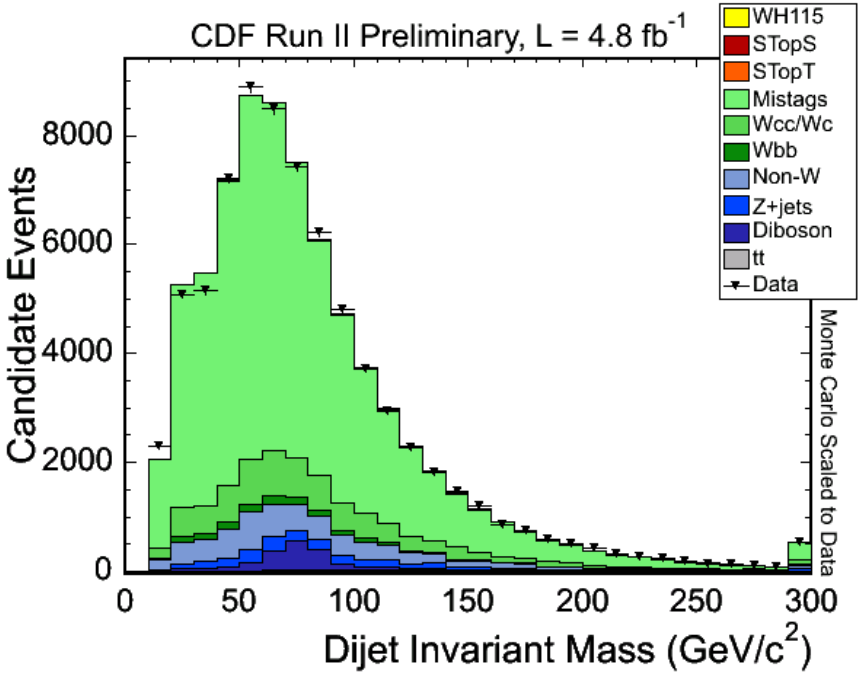


$WH \rightarrow \ell \nu b\bar{b}$ Search

- Highest cross section with accessible final state
- Signature: one isolated lepton(e,μ), missing transverse momentum (MET), and 2 jets
- Leading backgrounds: W+jets, top pair, multijet

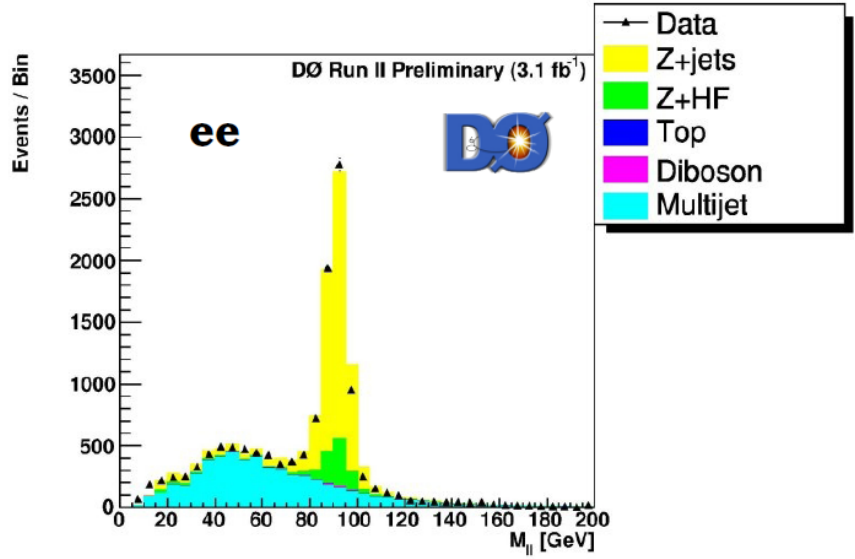


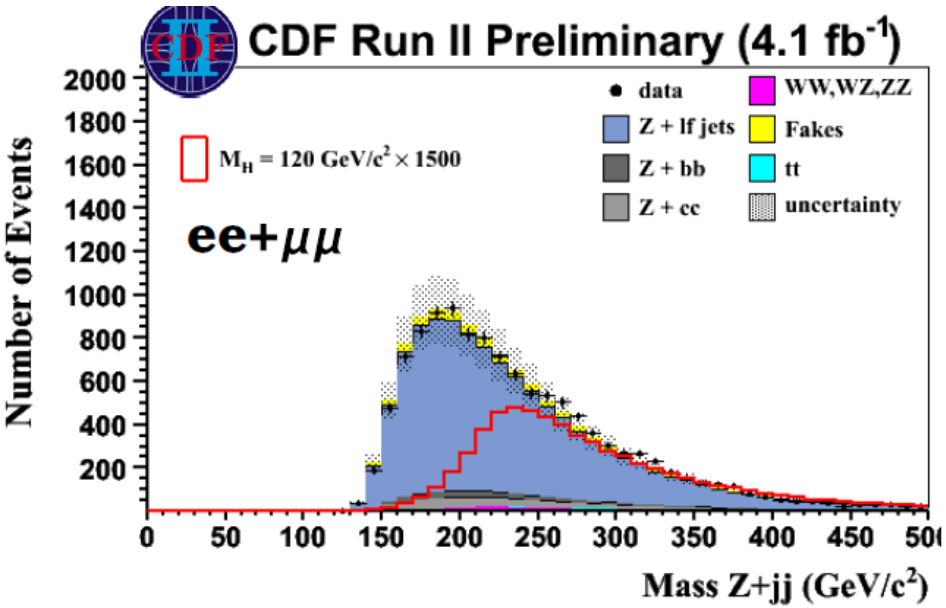


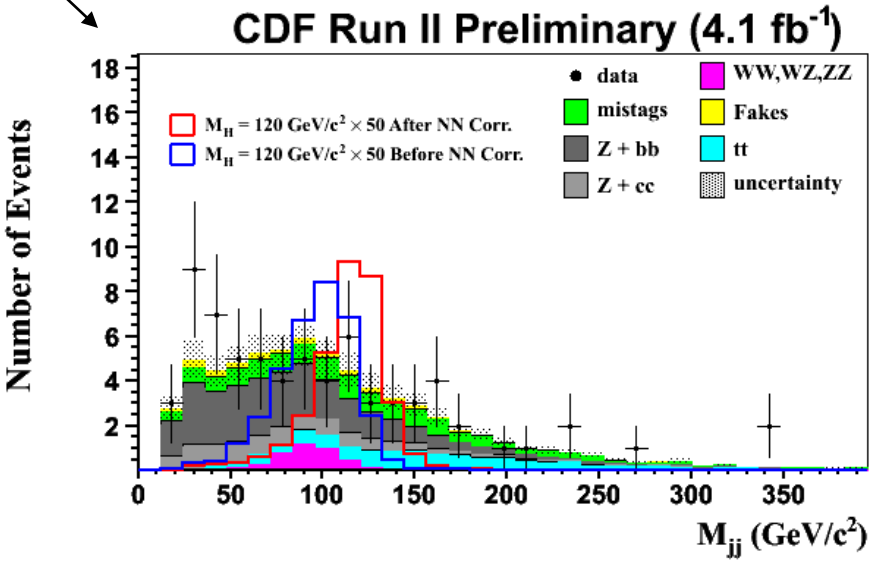


$ZH \rightarrow \ell\ell b\bar{b}$ Search

- Signature: two leptons, two jets
  - Recover missed charged leptons: l+track (CDF+D0), inter-cryostat electrons (D0)
- Leading backgrounds: Z+jet, ttbar
- Low MET, allows kinematic fitting
  - Constrain M_{ll}, M_{jj}
  - 10% improvement in sensitivity

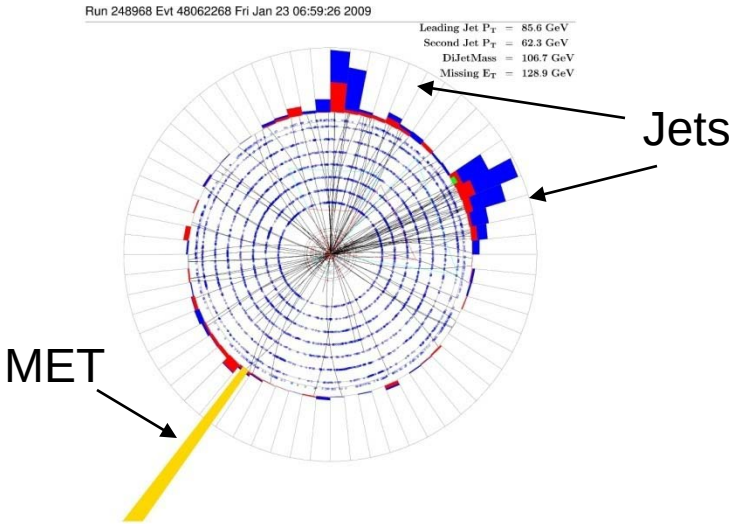


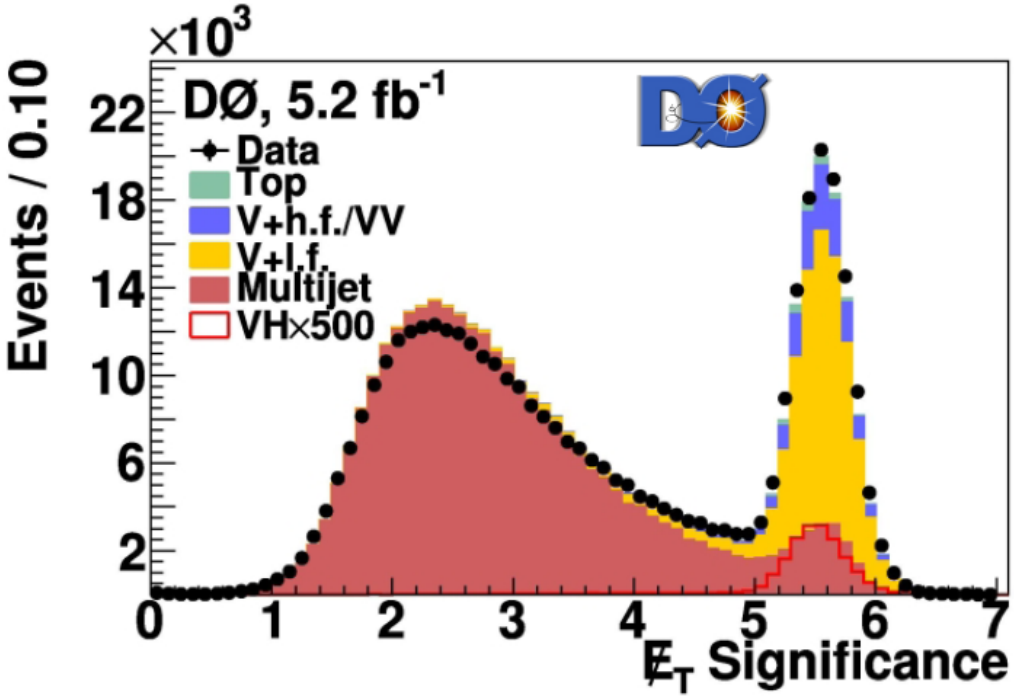


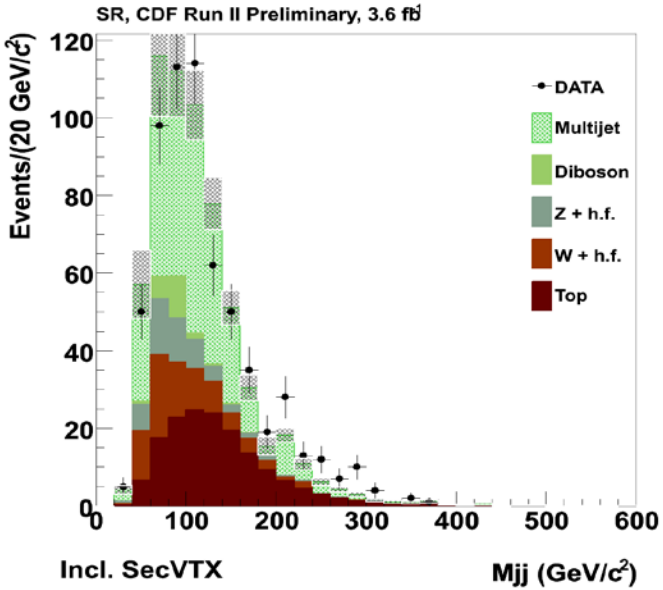


$ZH \rightarrow \nu\nu b\bar{b}$ Search

- Signature: 2 jets + MET
- Larger *Z* B.R., but large backgrounds (Z+jet, multijet)
- Techniques developed to separate multijet background



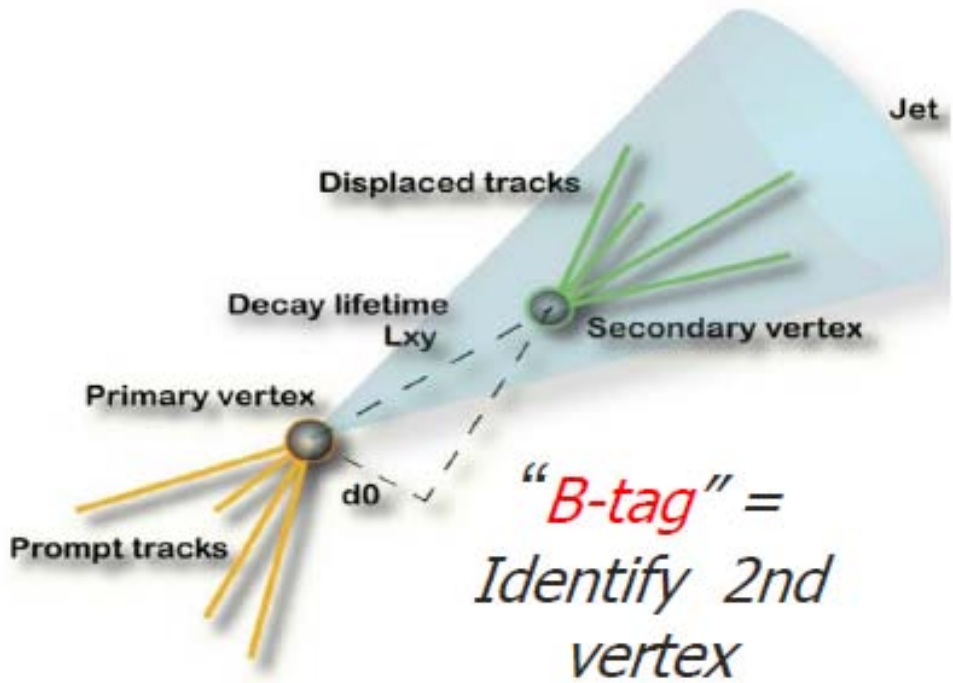


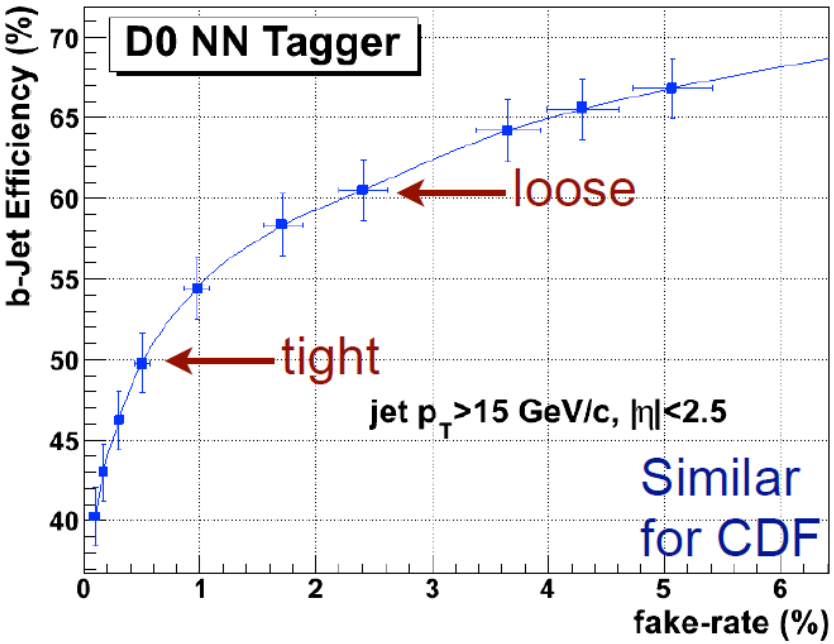


b-tagging at the Tevatron

b decays with finite lifetime, travels millimeters before decay→ displaced vertex

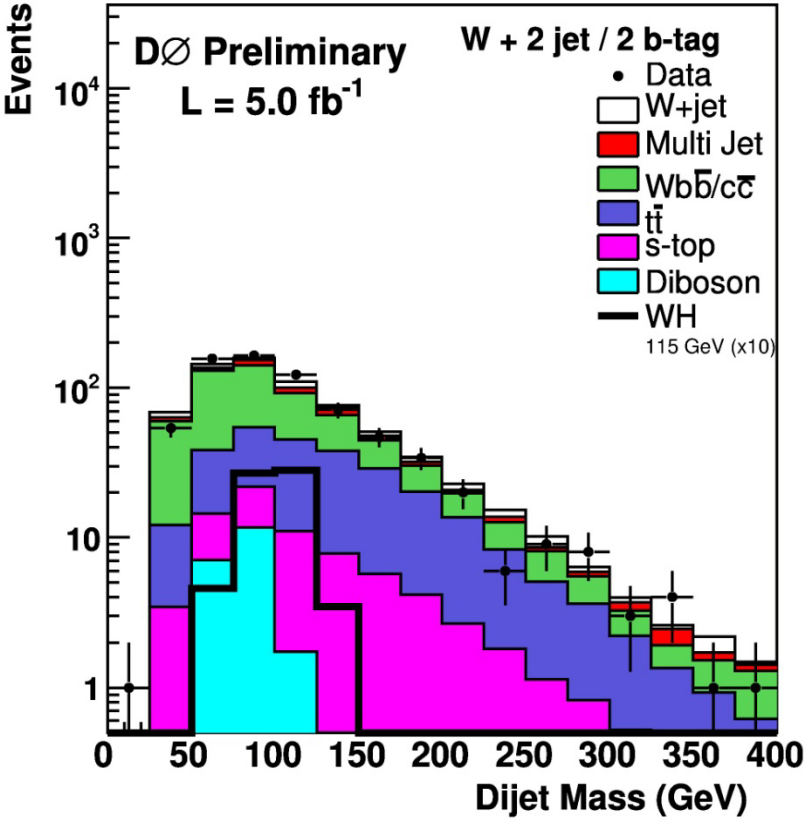
- "Taggers" with jet and track variables, impact parameter

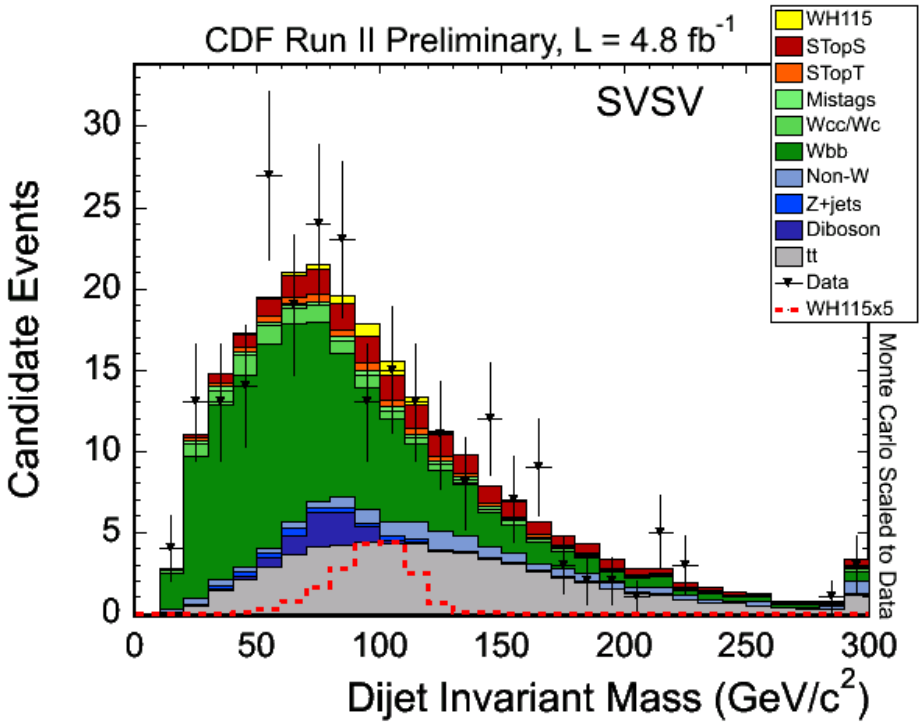




b-tagging (2)

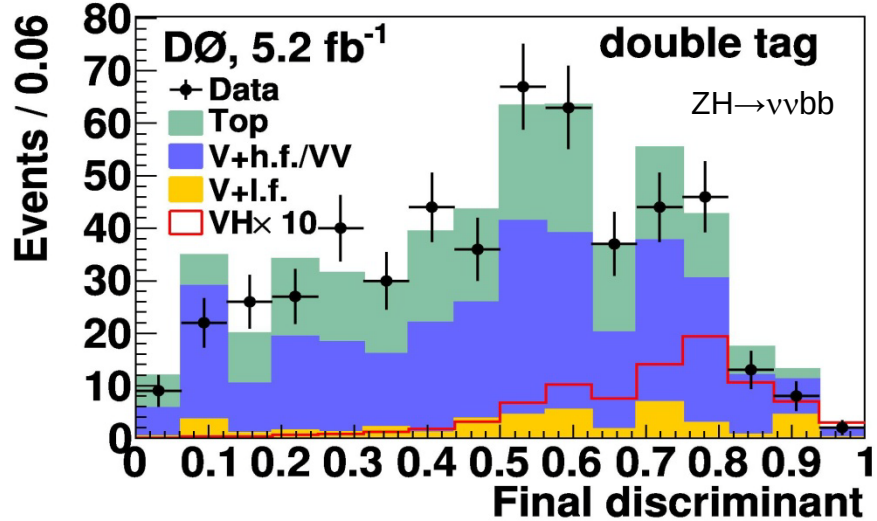
- S/B improves to ~1:100 for two-tag events
  - Also include 1-tag events
- Leading backgrounds now top pair, V+bb production

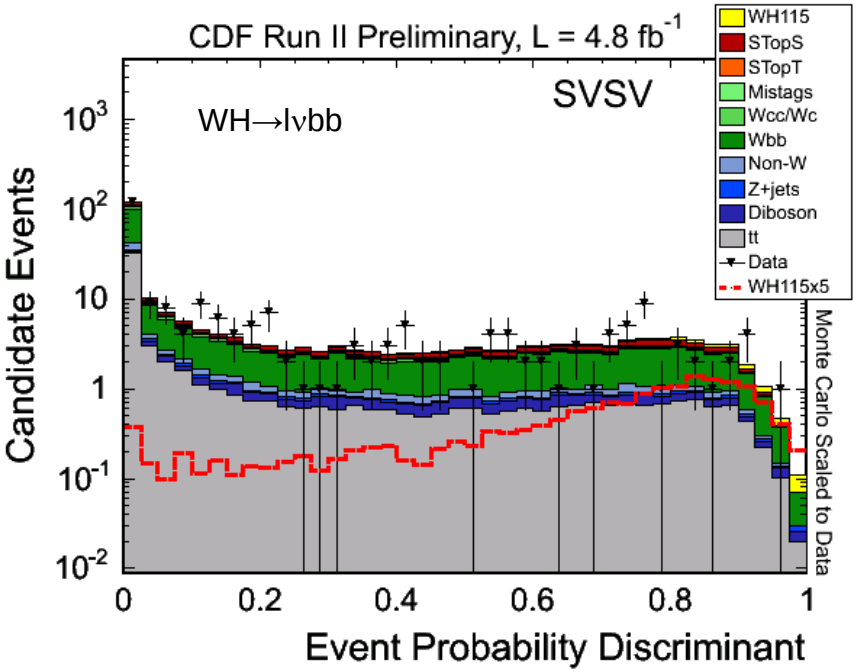


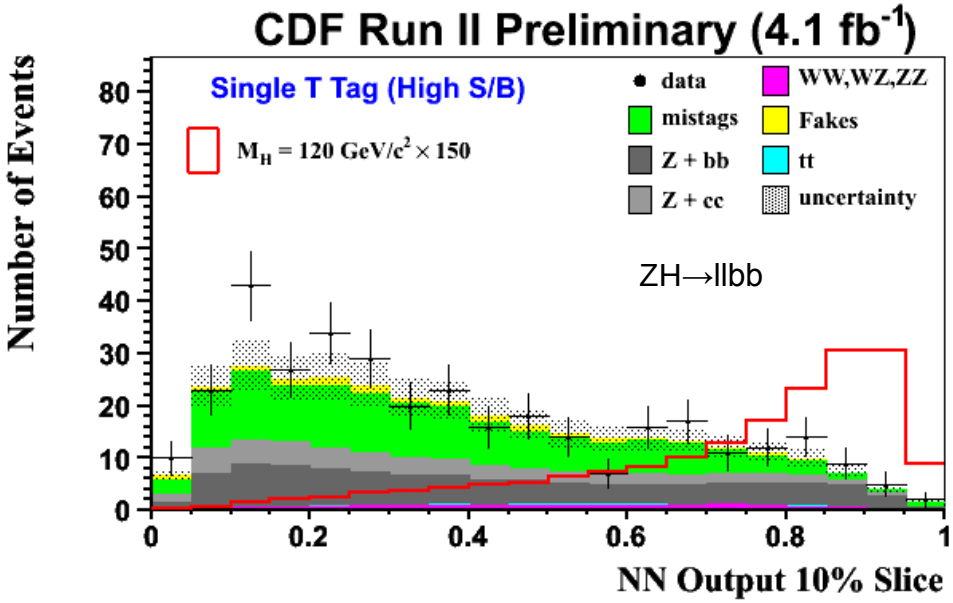


Multivariate Techniques

- Separate signal and background
  - Neural Networks, Decision Trees, Matrix Element Discriminants
  - Move bulk of background to area with low signal

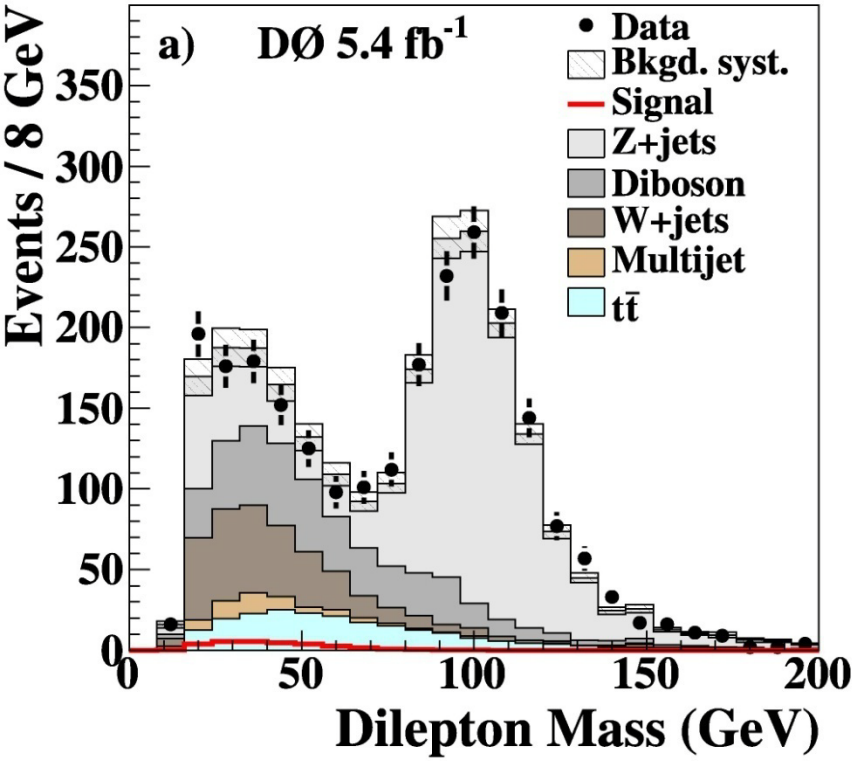


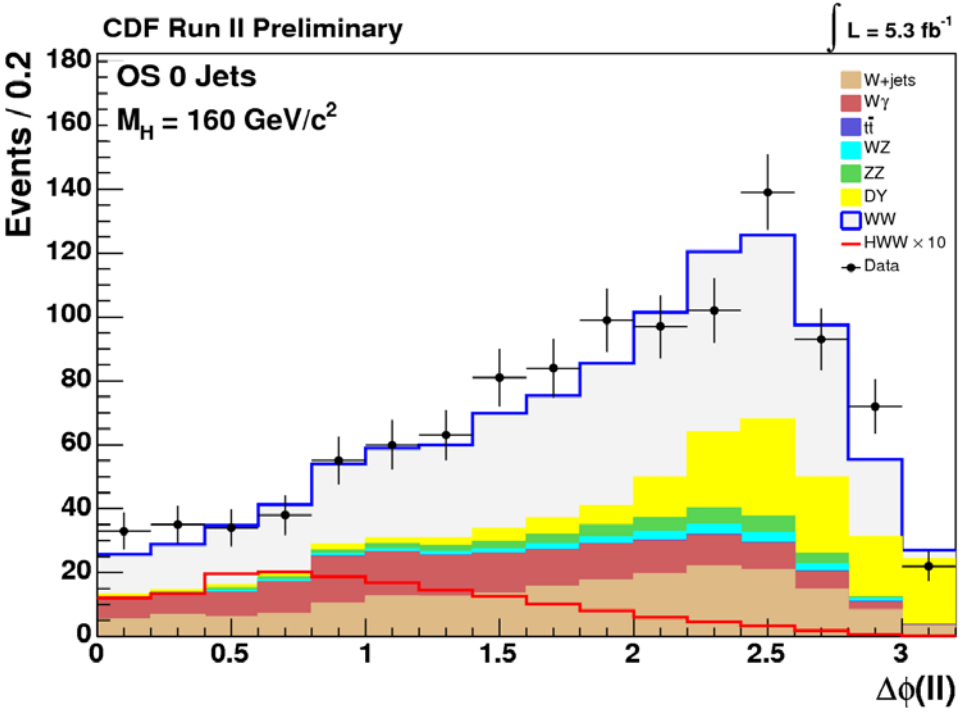




High Mass Higgs Search

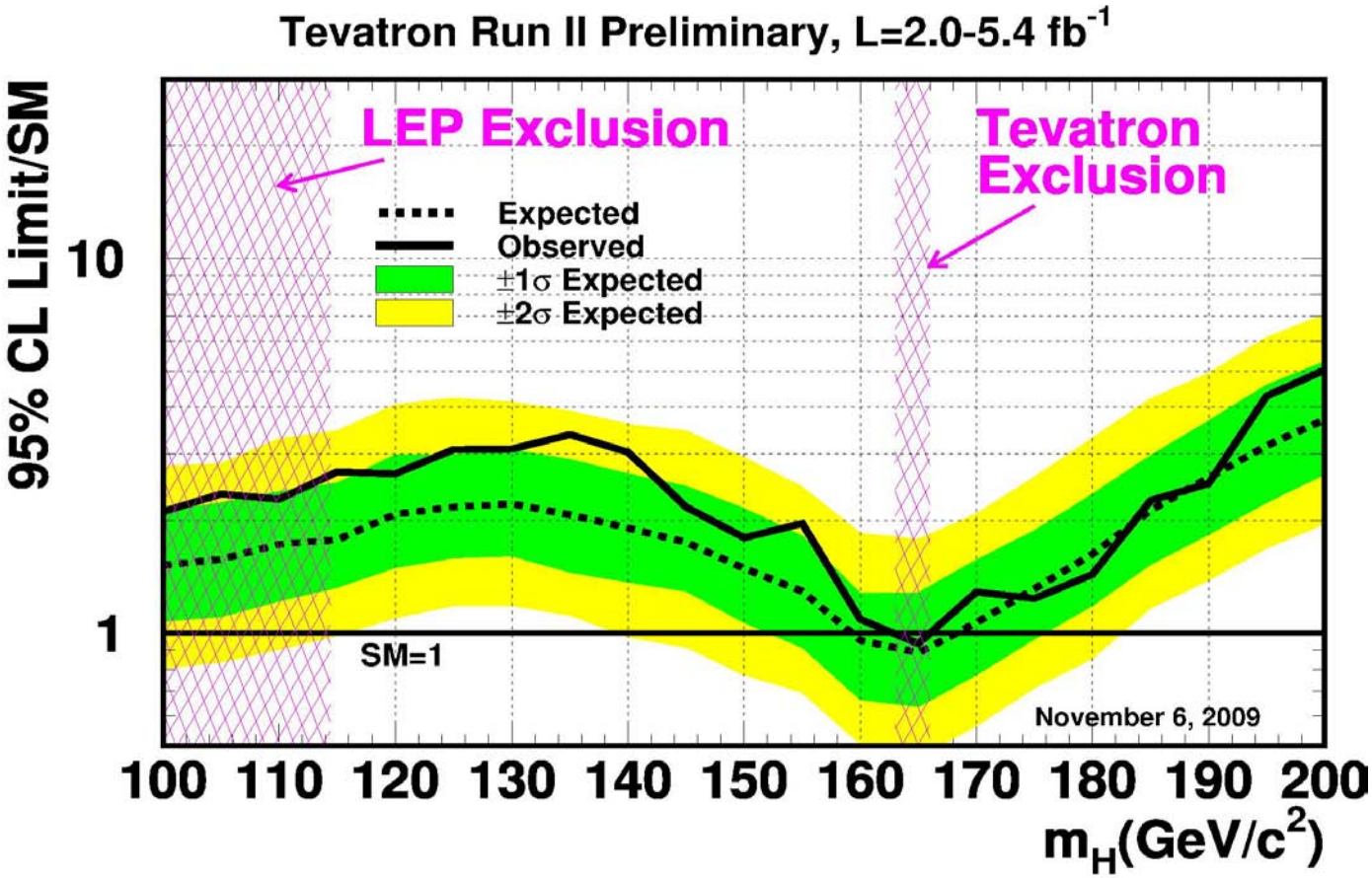
- Signature: two leptons ($\mu\mu$, *ee*, $e\mu$) + MET
  - 1 lepton+jets+MET searches ongoing
- Backgrounds: W+jets, WW/WZ production
- Exploit kinematic differences (lepton mass, spin correlation)





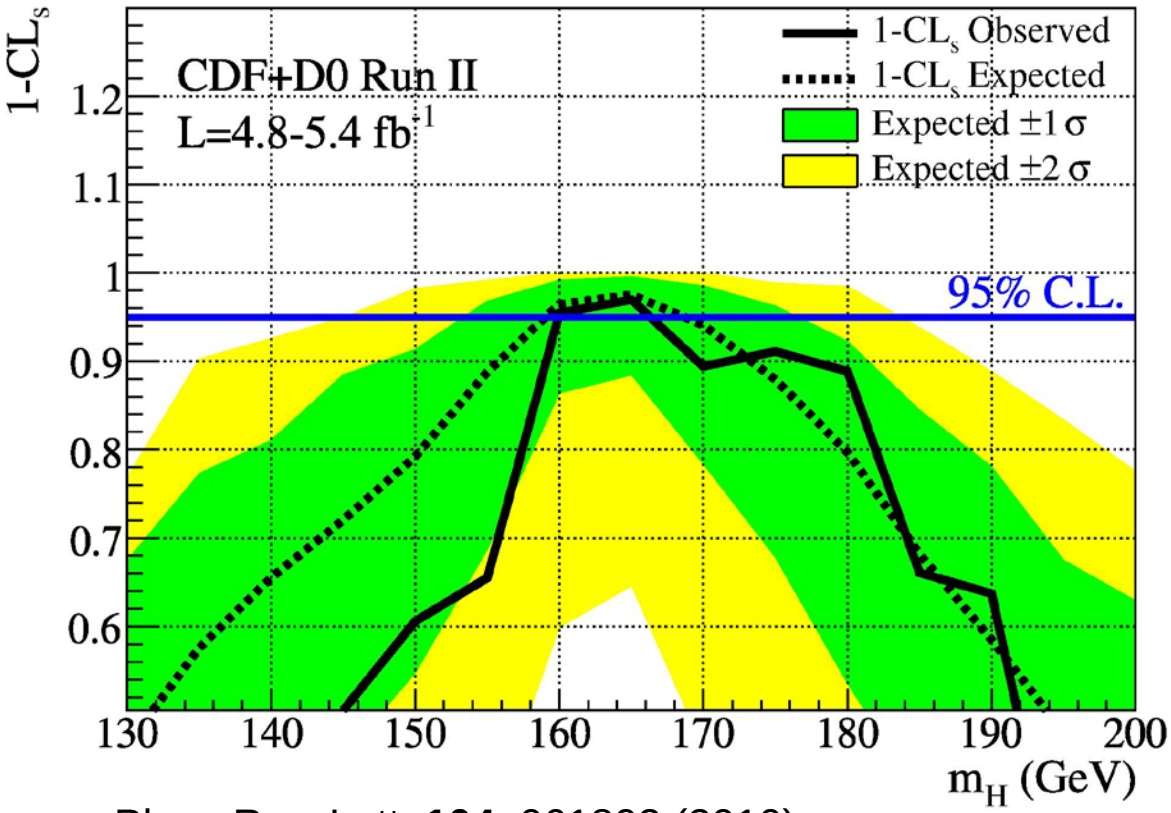
Combination

- Combine CDF+D0 in 25-30 orthogonal channels per exp.
- Bayesian, Modified Frequentist (CL_s) methods (similar results)

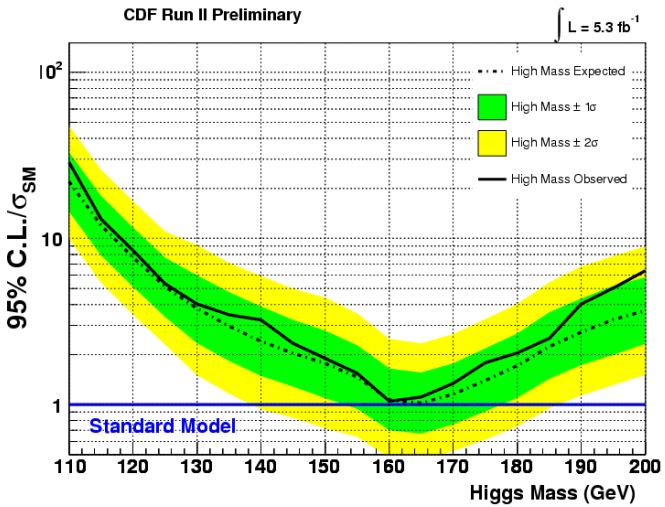


Combination (2)

- Published: WW-only combination
  - Excludes SM Higgs with mass between 162 – 166 GeV



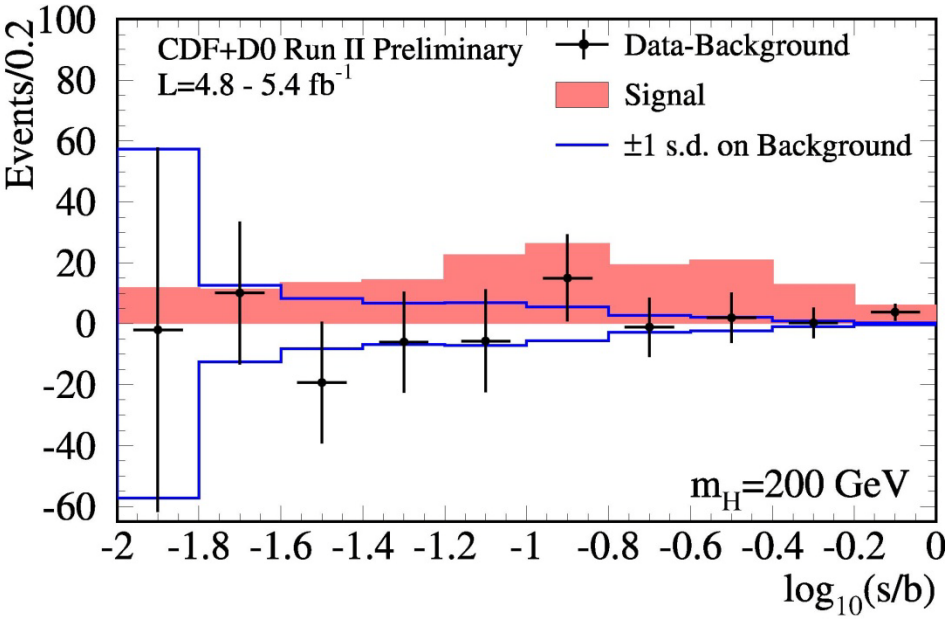
Phys. Rev. Lett. **104**, 061802 (2010)

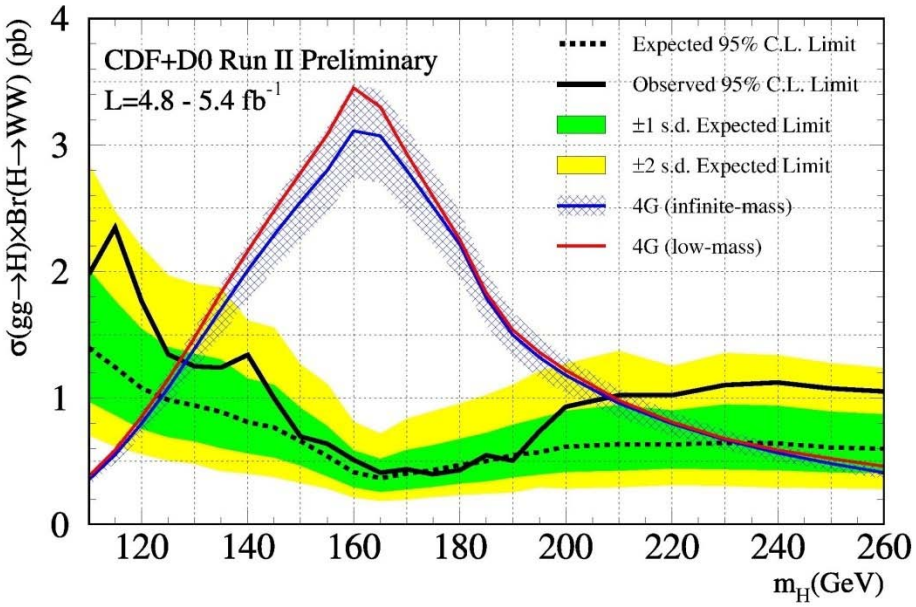


New result from CDF (5.3fb^{-1})
Includes tau channel ($W \rightarrow \tau\nu$, $\tau \rightarrow$ hadrons)
Exp. Limit 1.02 x SM, Obs. 1.11 x SM

Higgs in 4th Generation Models

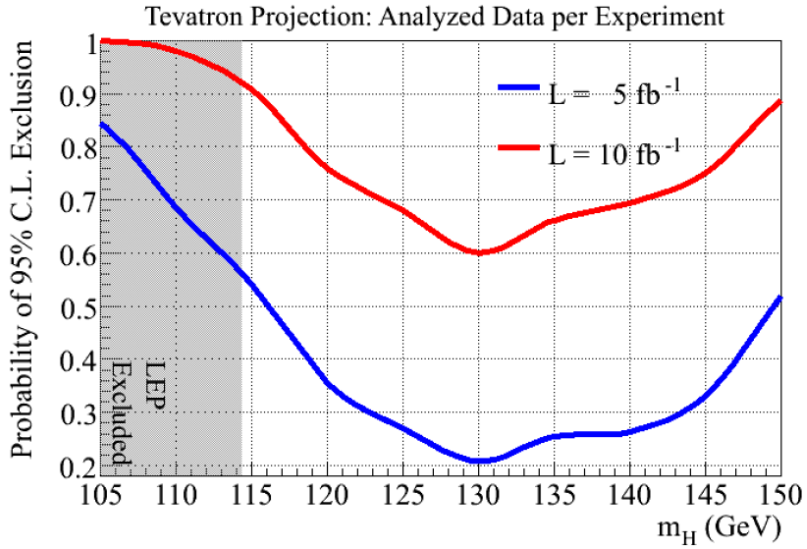
- gg→H enhanced in certain 4-generation SM extensions
  - Only consider gg→H production
- Same dataset as published H→WW results
- Exclude Higgs masses of 130 – 210 GeV in 4th gen models
  - Result largely independent of assumed 4th gen masses

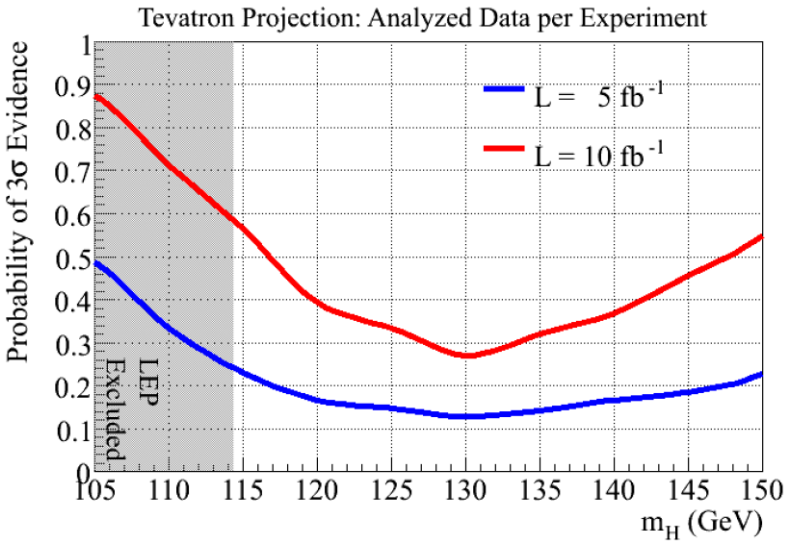




Higgs Sensitivity

- Tevatron will run through 2011: 10-12 fb^{-1} delivered per experiment
  - Translates to ~ 10 fb^{-1} available for analysis
  - Beyond 2011 under discussion
  - Expect 2.5 fb^{-1} per year from here on
  - With sensitivity improvements (e.g. lepton ID, b-jet ID, dijet mass resolution) could exclude nearly entire mass range, decent chance for 3 sigma evidence





Summary

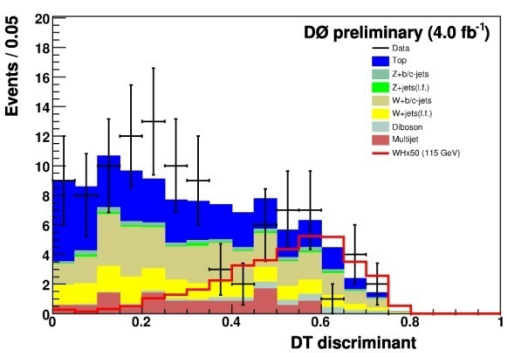
- It's a great time to be at the Tevatron
  - Accelerator performance better than ever
  - First Higgs exclusion since LEP
  - Limits approaching 2x SM over full mass range
  - It's the place to be for Higgs physics
- Working to improve sensitivity of all channels
- Tevatron will run through 2011
  - Expect double the datasets shown today
  - Good chance for exclusion, or 3σ evidence
- More exciting results coming soon

Backup

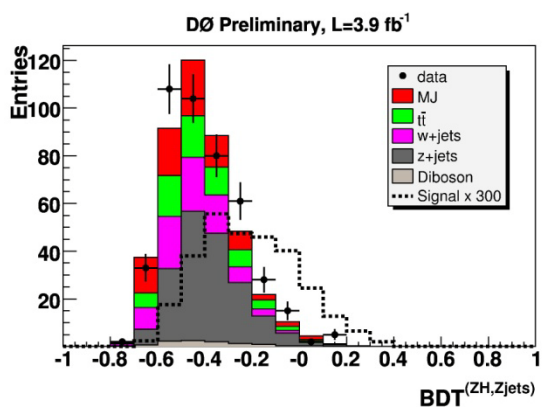
Searches in Jet and Tau Final States

- D0: WH $\rightarrow \tau\nu bb$
  - Hadronic tau, 2 jets, MET
  - Limit/σ_{SM} at 115 GeV:
    - 14.1 exp, 22.4 obs
- D0: ZH $\rightarrow \tau\tau jj$
  - Muon (from τ), τ_{had}, 2jets
  - Also includes HZ$\rightarrow\tau\tau$jj, VBF HW $\rightarrow\tau\tau$jj
  - Limitt/σ_{SM} at 115 GeV:
    - 18.8 exp, 30.3 obs

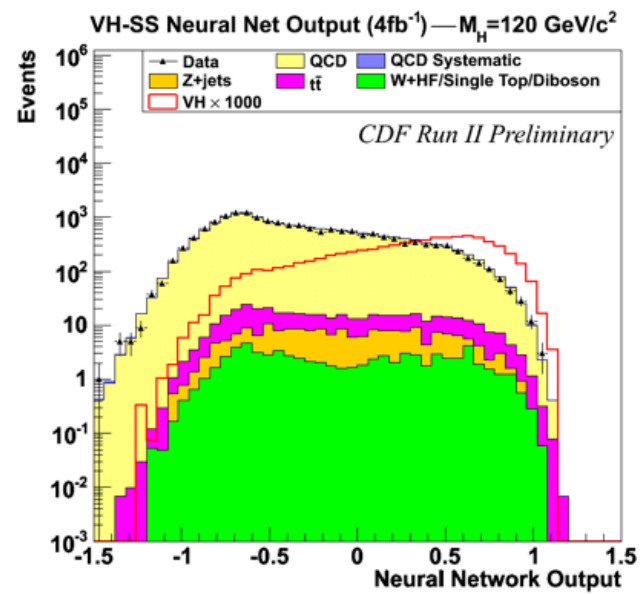
- CDF: WH$\rightarrow$qq'bb
  - Assoc. prod + VBF
- 4 jets, 2 b-tagged
- QCD background data-driven
- Limit/σ_{SM} at 120 GeV:
  - 19.9 exp, 10.1 obs



WH $\rightarrow\tau\nu bb$

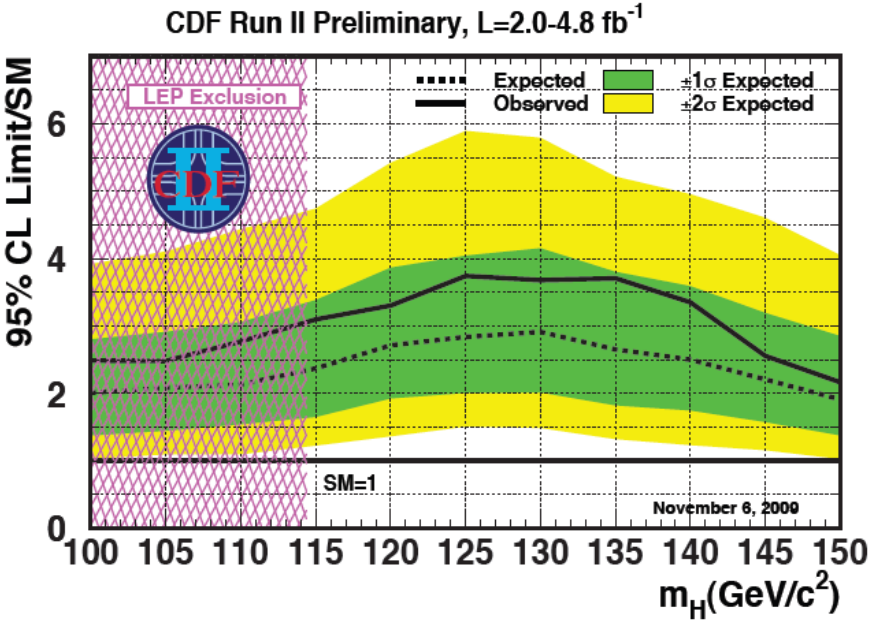


ZH $\rightarrow\tau\tau jj$

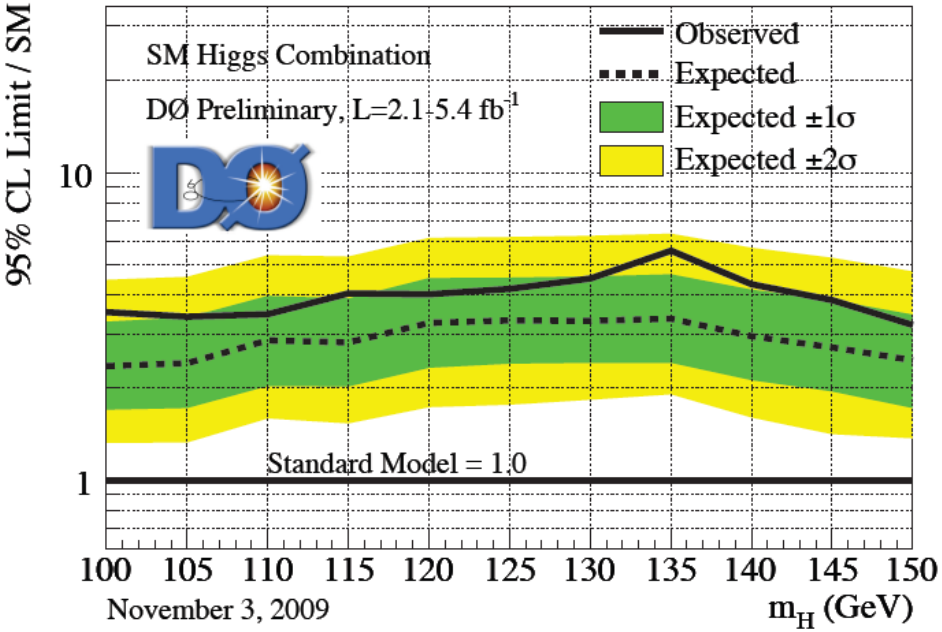


Low-mass combination

CDF only

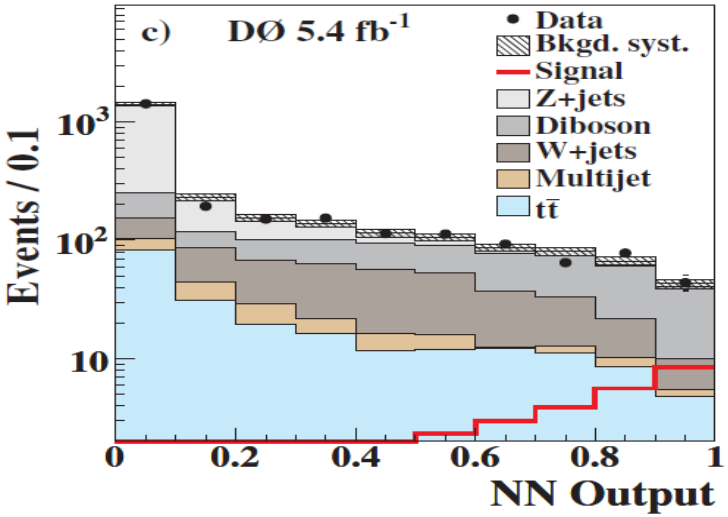


D0 only

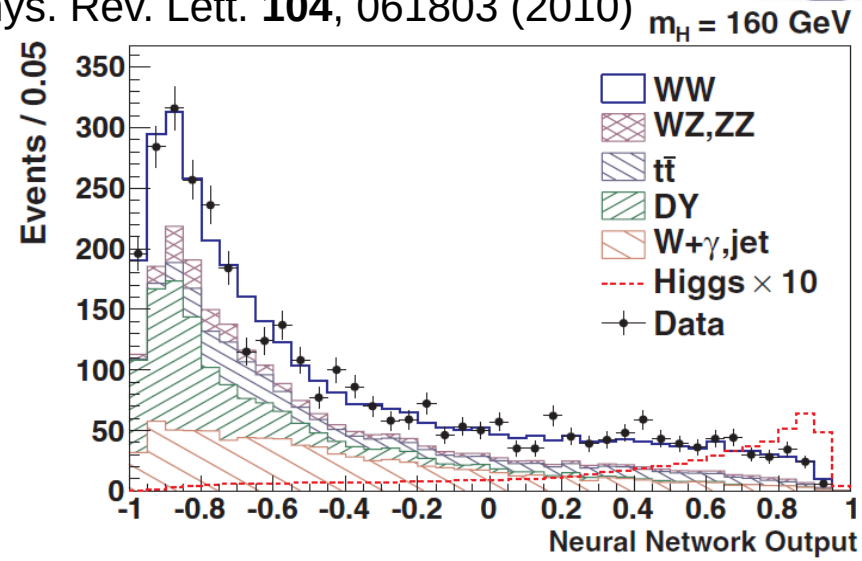


Published $H \rightarrow WW^*$ Searches

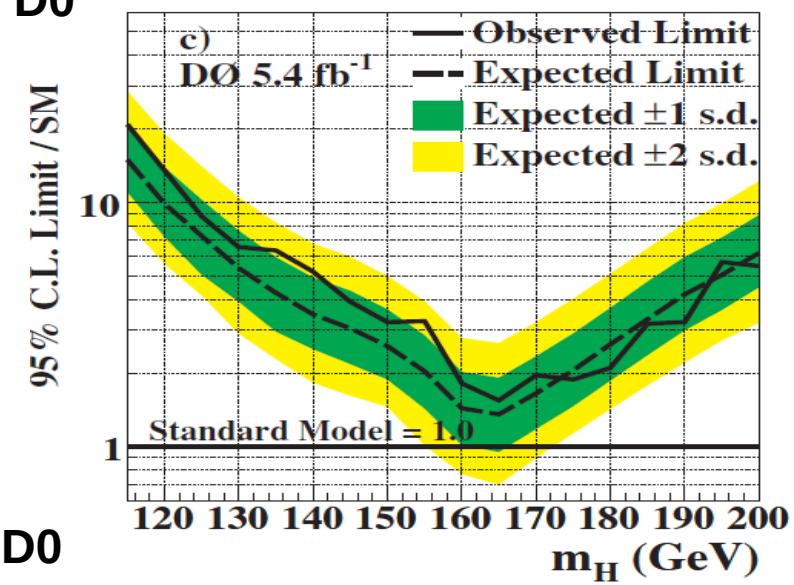
Phys. Rev. Lett. **104**, 061804 (2010)



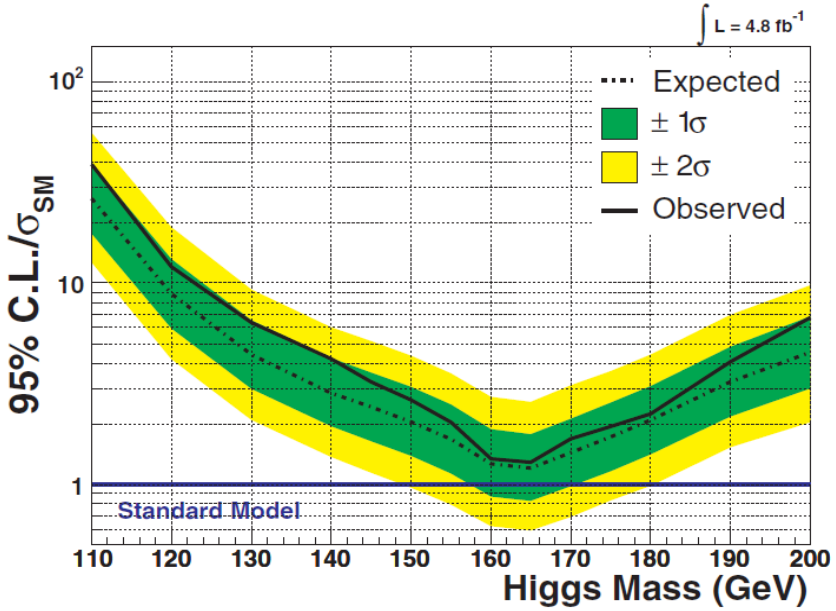
Phys. Rev. Lett. **104**, 061803 (2010)



D0

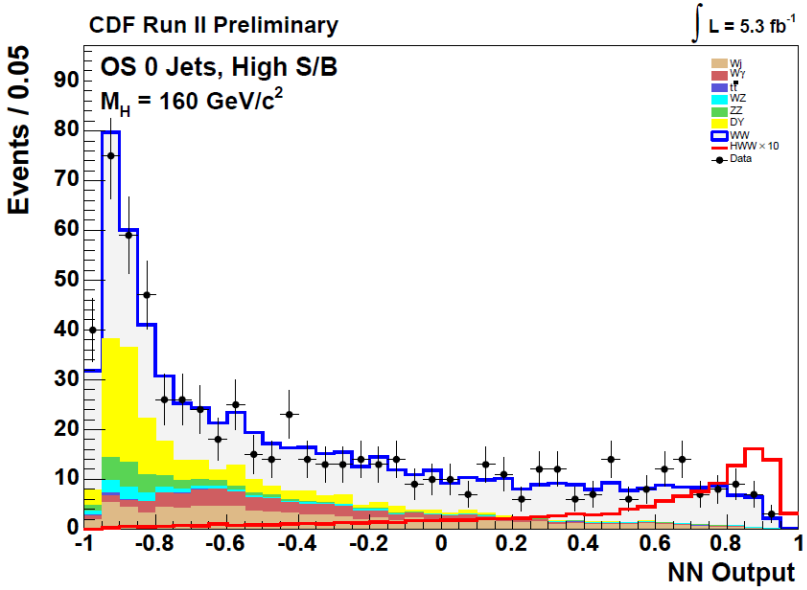


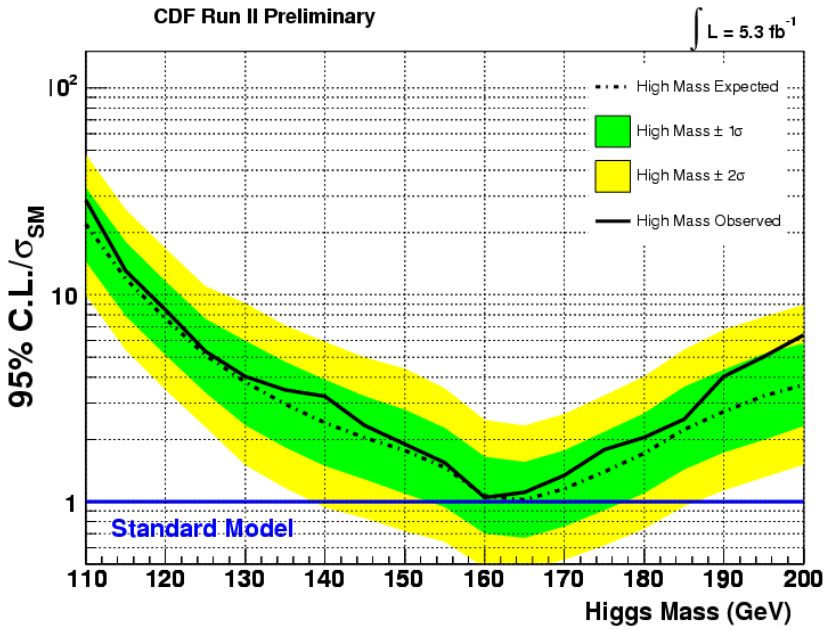
CDF



$H \rightarrow WW^*$ Search (2)

- New CDF result
  - Includes *WH→WWW (same-sign dilepton, trilepton)*
- Split into 0,1,2+ jets opp. sign, low M_{ll} OS, same sign dilepton, trilepton (with/without $M_{ll} \sim M_Z$)
  - Separate NN for each (+Matrix Element for 0-jet OS)





Low-mass limits at 115 GeV

Limit/σ_{SM}	CDF exp	CDF obs	D0 exp	D0 obs
$WH \rightarrow l\nu bb$	3.8	3.3	5.1	6.7
$ZH \rightarrow llbb$	6.8	5.9	8.0	9.1
$ZH \rightarrow \nu\nu bb$	6.1	4.2	4.6	3.7
$WH \rightarrow \tau\nu bb$	--	--	14.1	22.4
$WH \rightarrow jjbb$	19.9	10.1	--	--
$ZH \rightarrow \tau\tau jj$	--	--	18.8	30.3
Combo	1.78	2.70	1.78	2.70

Signal Modeling in H→*WW*

- We use Pythia MC for signal
  - Normalize to NNLL prediction and re-weight Higgs pT to NNLL
  - cross section and pT spectrum self consistent
- Some disagreement within theory community regarding scale variation choices (discussed with authors of our cross section sources)
- Add scale and PDF uncertainties in quadrature
  - Studied by Anastasiou and Lazopoulos , good to < 1%, essentially independent of μ
- Do not include α_s uncertainty
  - Tools now available, will do so in next iteration
  - Effect on gluon fusion cross section uncertainty: 8% -> 13%
  - Expect small effect on the final result