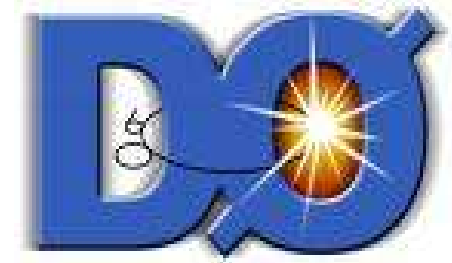


Low Mass Standard Model Higgs Boson Searches at the Tevatron

Andrew Mehta

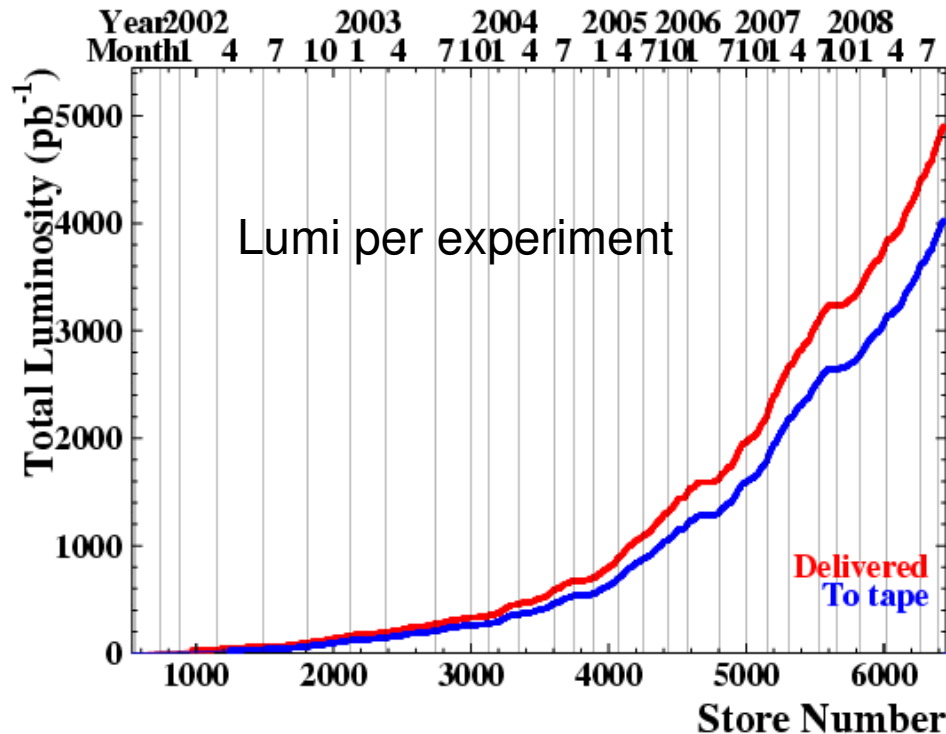


On behalf of the CDF and D0
Collaborations



Tevatron

- Tevatron is running really well:



Analyses in this talk use 0.9
- 2.7 fb⁻¹ per experiment

Expect 6-8 fb⁻¹ datasets by end of 2009 + possibly run in 2010

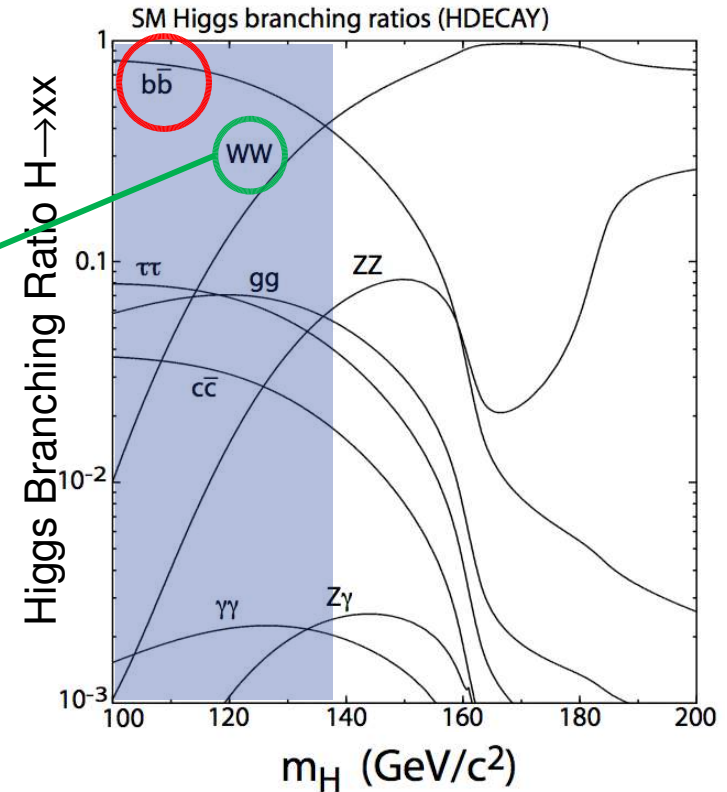
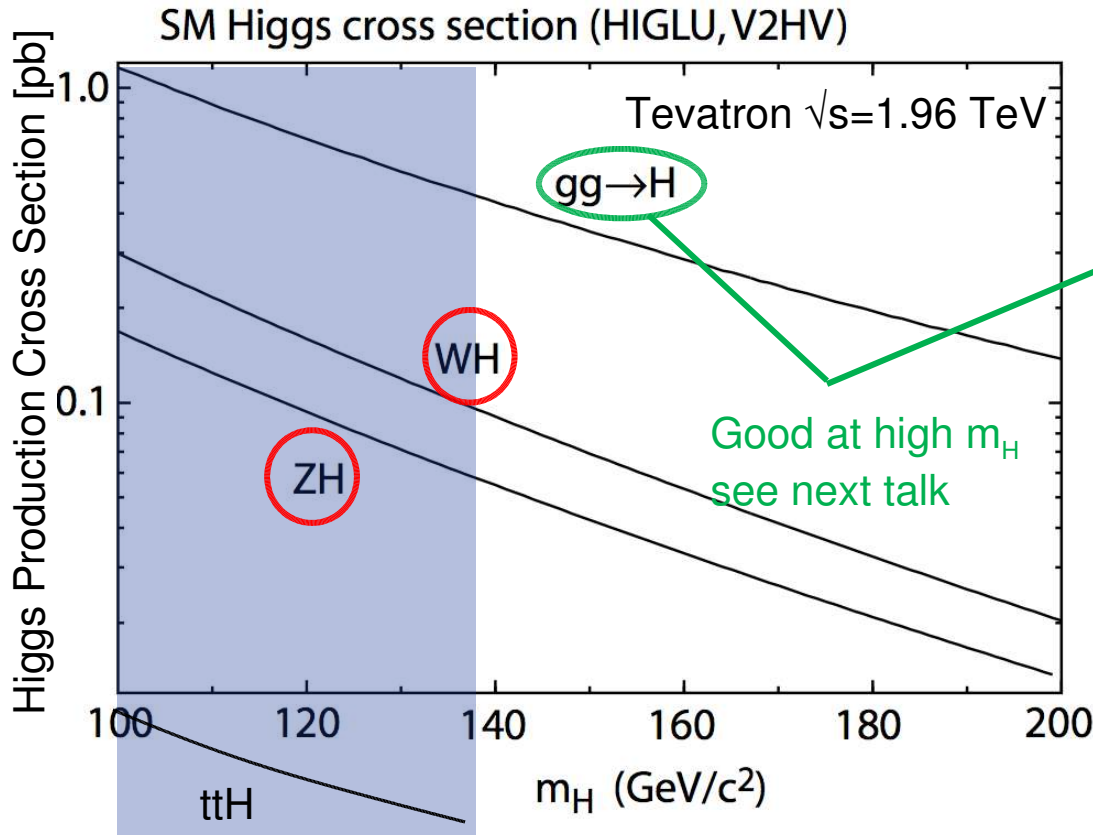
Data analysed with 2 multipurpose detectors CDF and D0:

EM +had calorimeters for e +jet id

Muon detectors

Silicon vertex detectors for b tagging

Higgs Production at the Tevatron and Decay



Main channels at low $m_H < 140$ GeV

$WH \rightarrow l\nu bb$

$ZH \rightarrow llbb, \nu\nu bb$

Additional low mass search channels:

$WH \rightarrow \tau\nu bb$

$VH \rightarrow qqbb$

$H \rightarrow \tau\tau$ (with jets)

$H \rightarrow \gamma\gamma$

$ttH \rightarrow l\nu bbbbbqq$

Dominant $gg \rightarrow H$, $H \rightarrow bb$ has massive background

The Challenge

Higgs production is very rare.
Careful analysis to separate signal from background.

5. Trigger

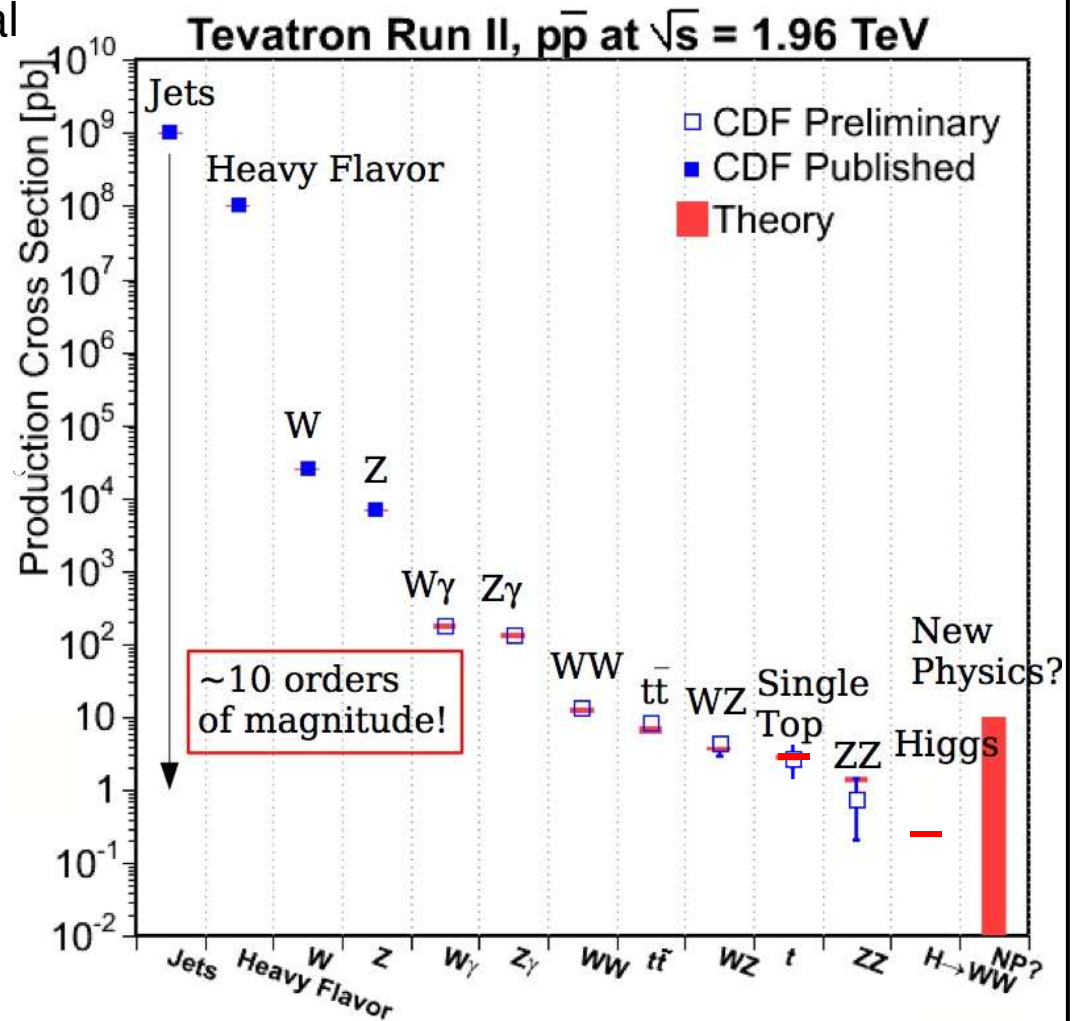
- High p_T e, μ triggers
- MET + Jets triggers
- Track + MET + Ecal τ -trigger

6. Reconstruct final state

- Leptons
- Efficient b-tagging
- Good jet resolution
- MET reconstruction

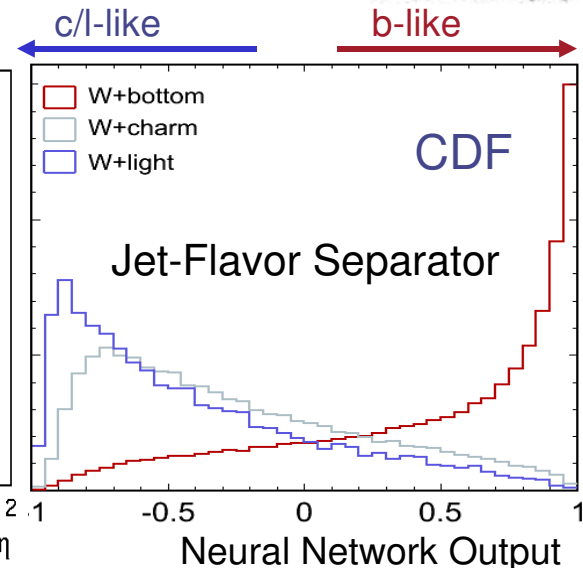
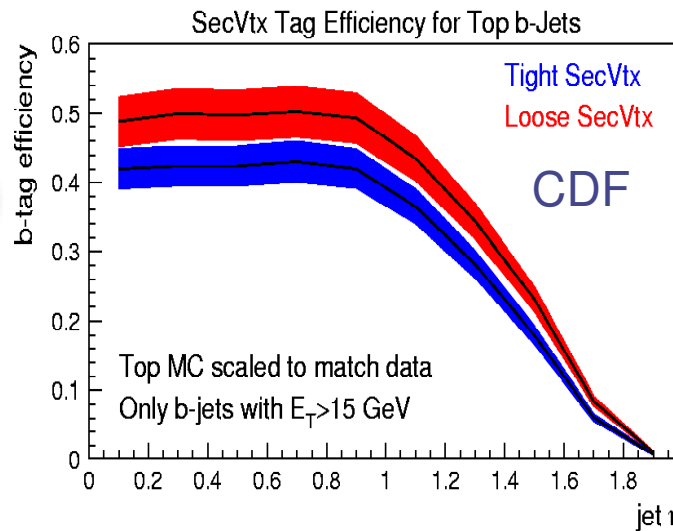
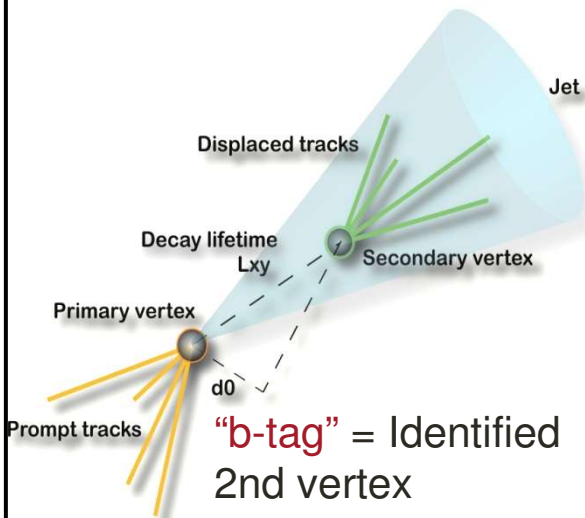
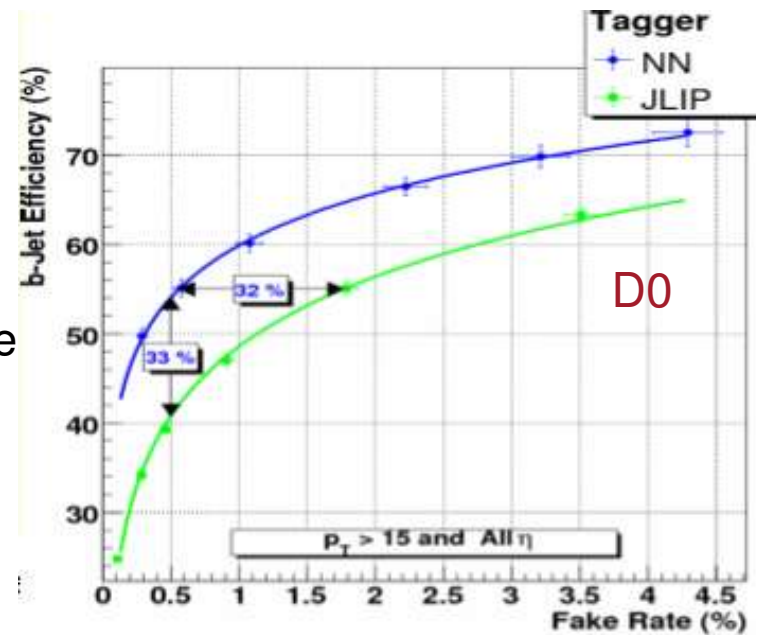
7. Separate signal and background

- Measure backgrounds
- Advanced analysis tools to separate signal from background (NN, ME, BDT)

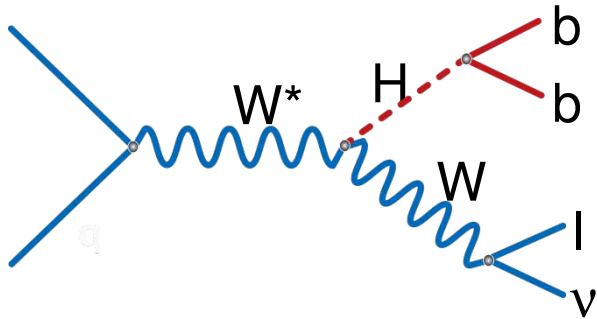


Identification of b -quarks (b -tagging)

- Most sensitive channels have $H \rightarrow bb$
- Silicon detectors used to find secondary vertices
- Efficiency $\sim 40 - 70\%$
- Fake rate (mistags) typically $0.5 - 5\%$
- D0 uses Neural Network tagger based on b -lifetime information
- CDF utilizes secondary vertex and Jet Probability algorithms + additional NN flavor separator
- Use either single tag or looser double tag



WH → l ν b b



- ◆ 1 lepton+MET+ 2 b jets final state
- ◆ About 3-4 evts / 1fb⁻¹
- ◆ Most sensitive channel at low mass

Main background W+bb



NN Inputs:

$$P_T^{j1}, P_T^{j2}, \Delta R_{jj}, \Delta\phi_{jj},$$

$$P_T^{jj}, M_{jj}, P_T^{\ell-MET}$$



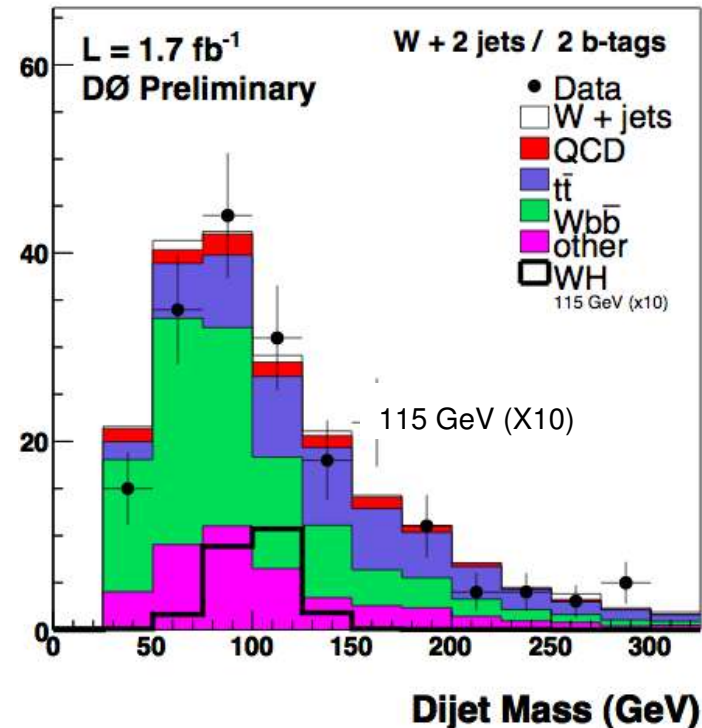
NN Inputs: -

$$M_{jj}, P_T^{imb}, P_T^{sys},$$

$$M_{\ell\nu j}^{min}, \Delta R_{\ell\nu}, E_T^{jets}$$

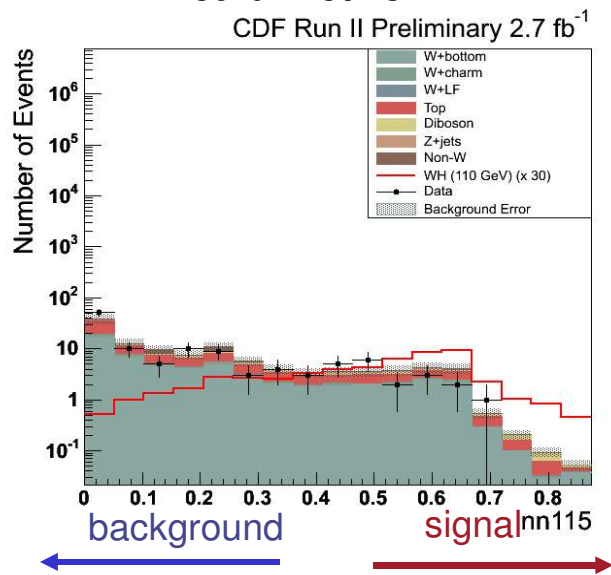
Analysis Technique

- ◆ Loose double tagging
- ◆ Lepton ID with isolated tracks/extended muons
- ◆ Include W+3 jet data
- ◆ Include fwd electrons
- ◆ NN discriminator
- ◆ ME+BDT

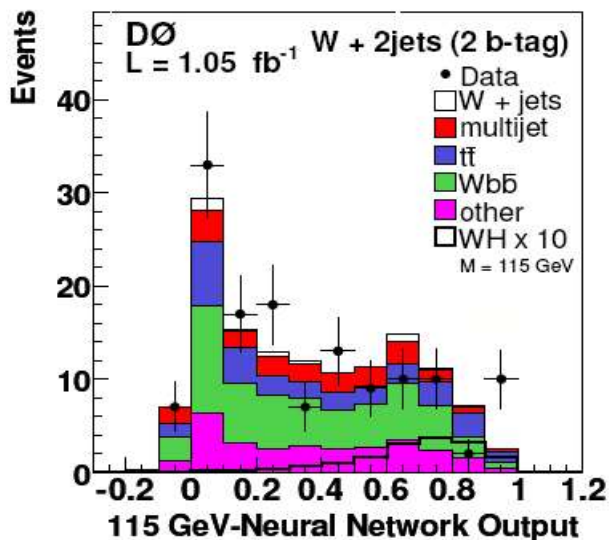
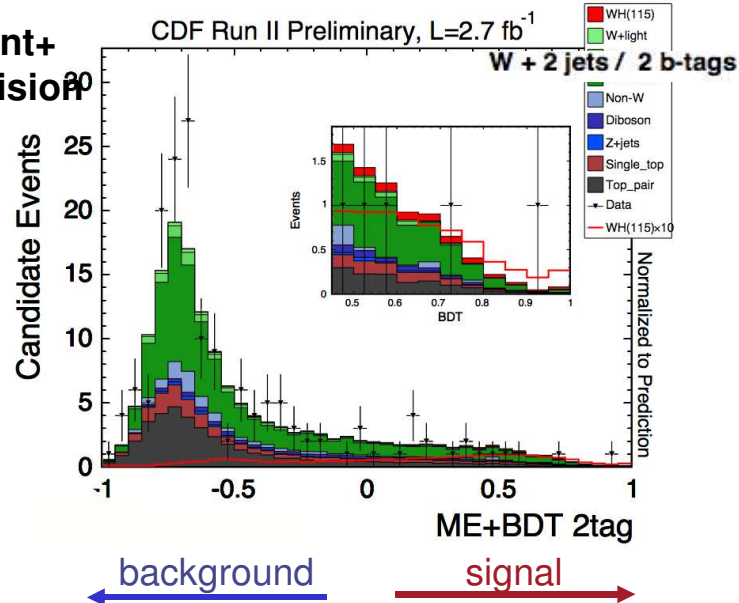


WH \rightarrow l ν b b

Neural Network



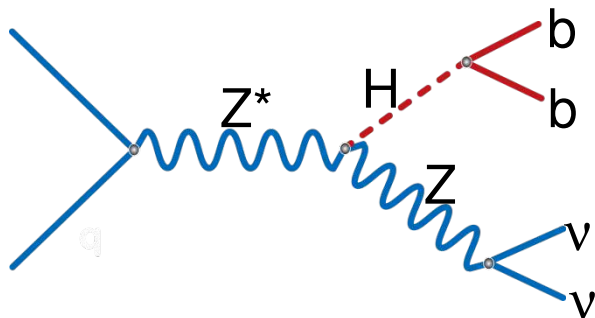
Matrix Element+ Boosted Decision Tree



Results at $m_H = 115\text{GeV}$: 95%CL Limits/SM

Analysis	Lum (fb ⁻¹)	Higgs Events	Exp. Limit	Obs. Limit
CDF NN	2.7	8.3	5.8	5.0
CDF ME+BDT	2.7	7.8	5.6	5.7
DØ NN	1.7	7.5	8.5	9.3

$ZH \rightarrow \nu \nu b b$

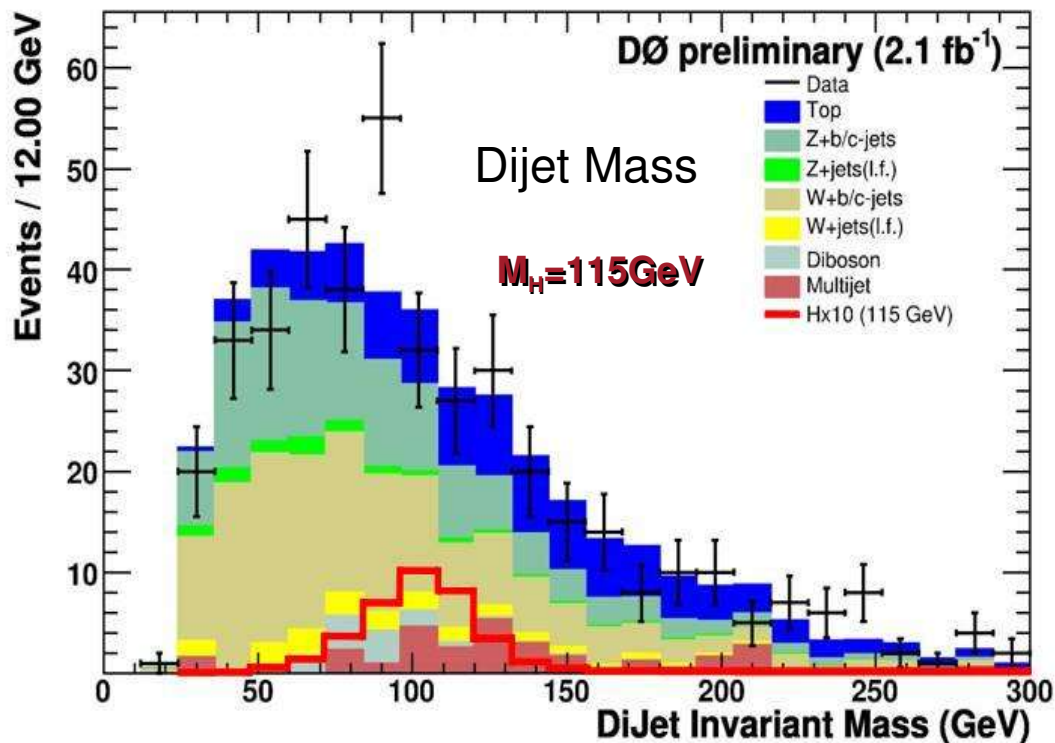


- ◆ Large MET + 2 b jets
- ◆ Also add $WH \rightarrow (l)\nu bb$ when lepton is missed
- ◆ $\sim 3-4$ evts / fb^{-1}

Main backgrounds $Z+bb$, $W+bb$, multijets

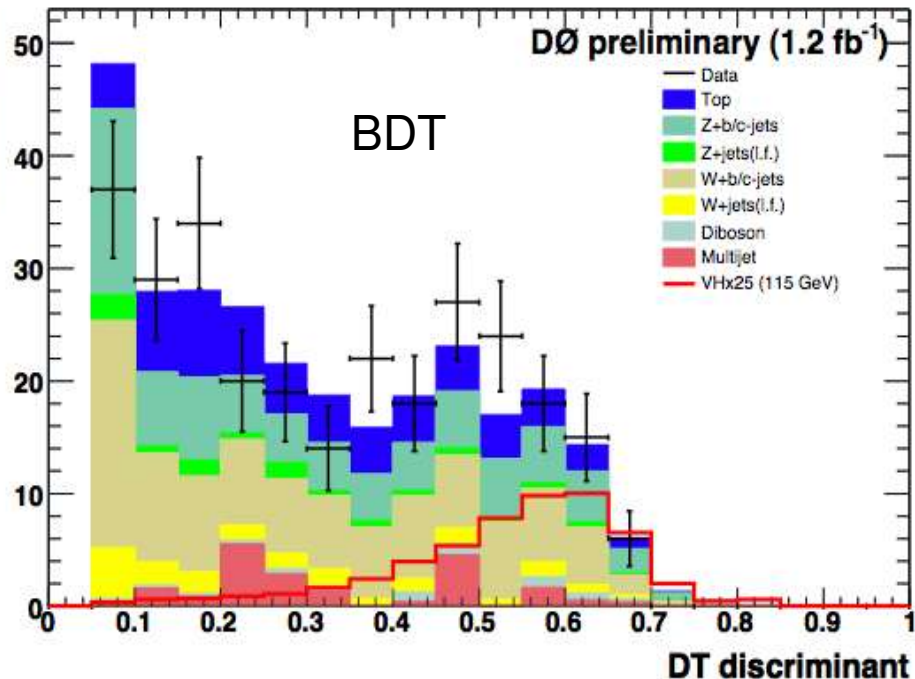
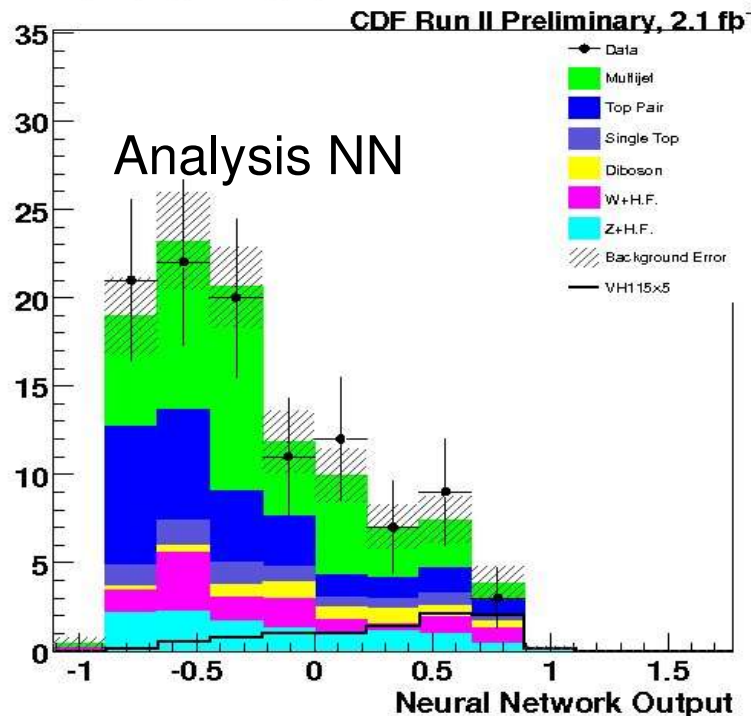
Analysis Technique

- ◆ Use data to estimate QCD
- ◆ Add 3rd jet to get acceptance for $WH \rightarrow \tau \nu bb$ (CDF) or dedicated analysis (D0)
- ◆ CDF adds tracks to jets to improve resolution (H1 alg)
- ◆ D0: BDT with 24 inputs
- ◆ CDF: Uses NNs



$ZH \rightarrow \nu\nu b b$

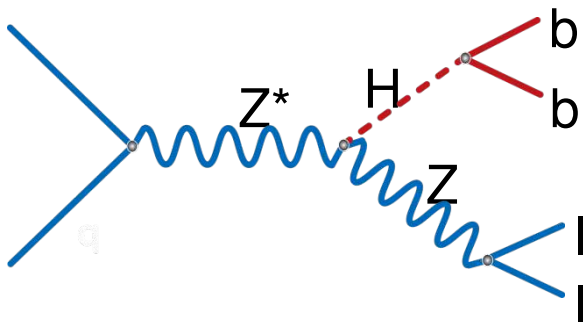
NN Output, Signal Region, ST+ST



Results at $m_H = 115\text{GeV}$: 95%CL Limits/SM

Analysis	Lum (fb ⁻¹)	Higgs Events	Exp. Limit	Obs. Limit
CDF NN	2.1	7.3	6.3	7.9
DØ BDT	2.1	3.7	8.4	7.5

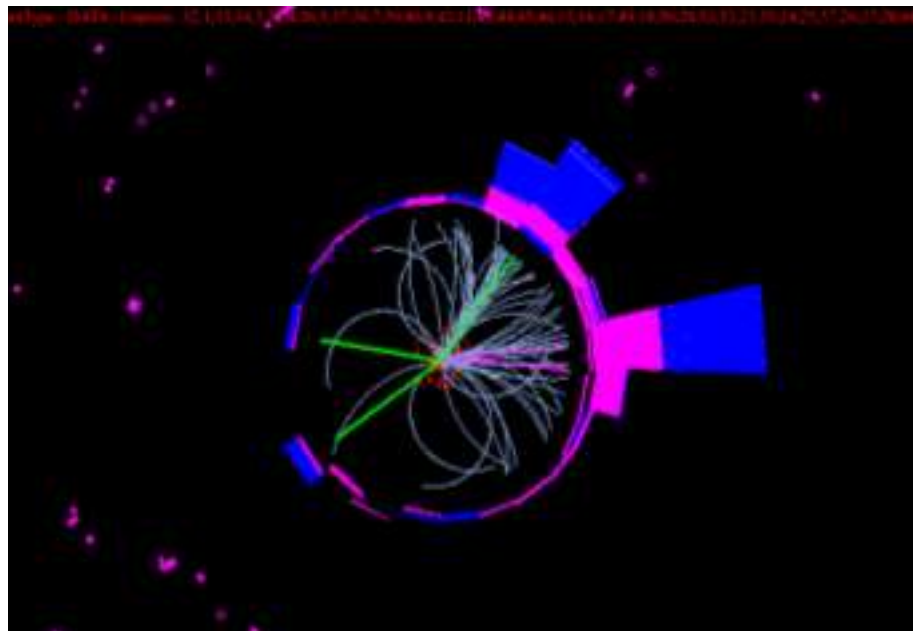
ZH \rightarrow ll bb



- ◆ 2 leptons + 2 b jets
→ Cleanest signature!

No MET, can fully reconstruct event

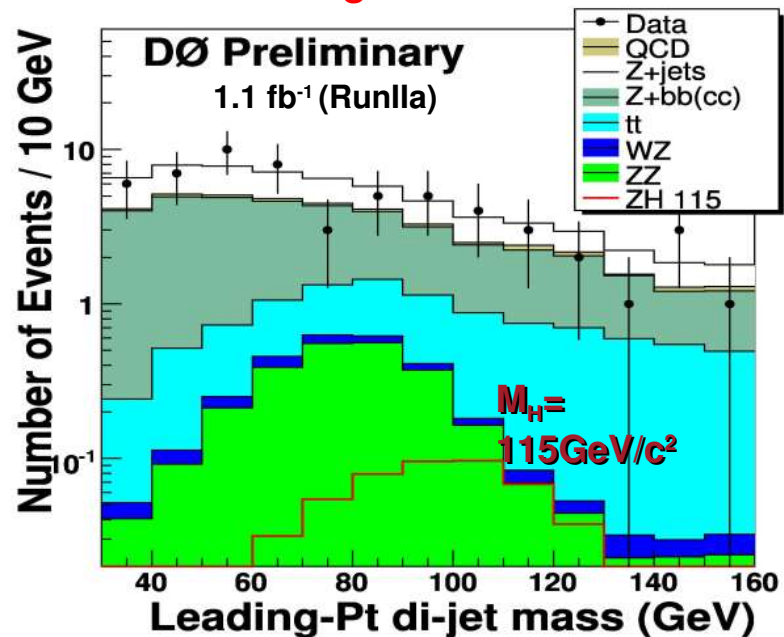
- ◆ About 1 event / 1fb^{-1}



Analysis

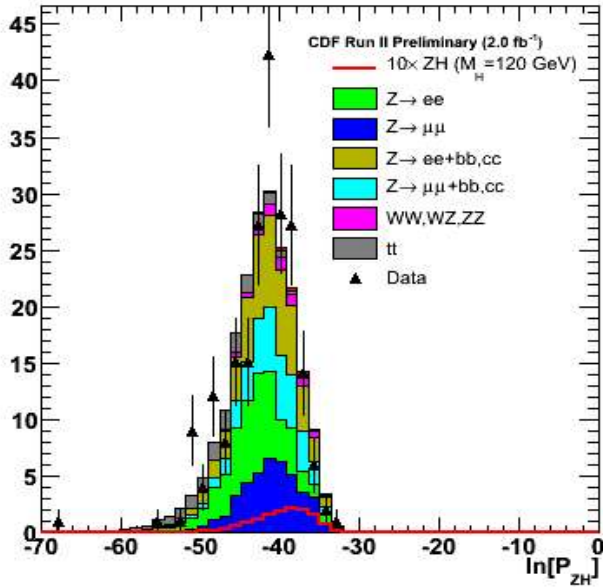
- ◆ Improved dijet mass resolution with no MET constraint
- ◆ Loose double b tagging
- ◆ CAL/track only leptons
- ◆ NN, BDT, ME techniques

Main background Z+bb



ZH → ll bb

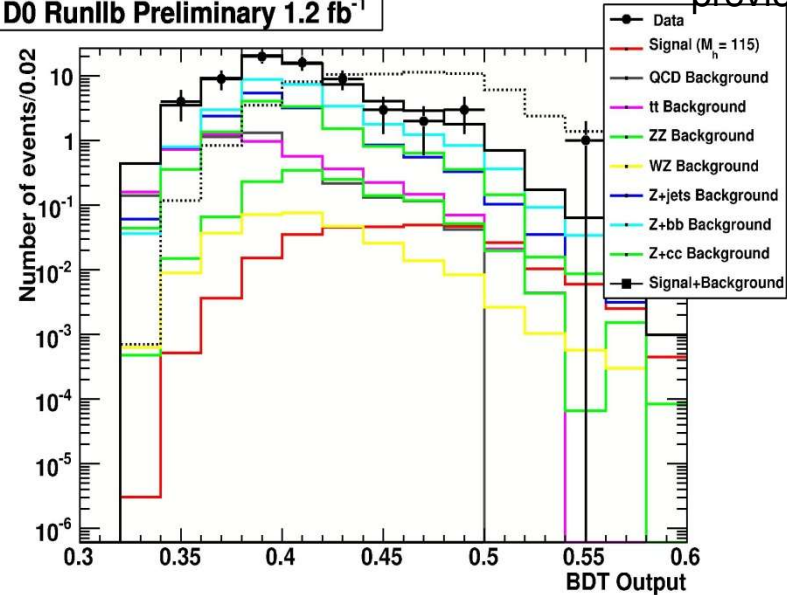
Matrix Element



Boosted decision tree

combined with previous data

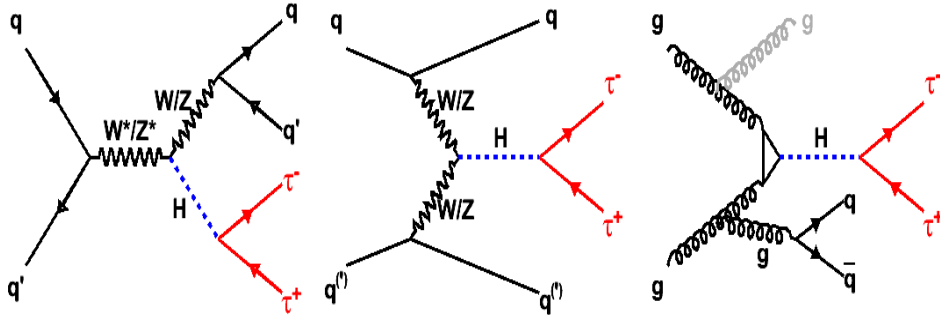
DØ RunIIb Preliminary 1.2 fb⁻¹



Results at m_H = 115 GeV: 95%CL Limits/SM

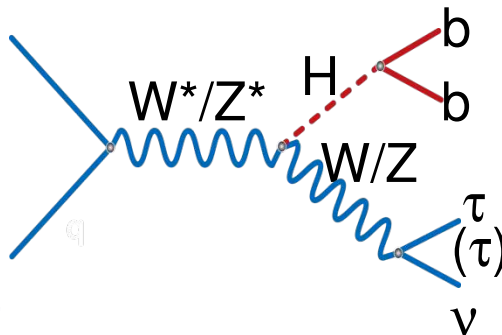
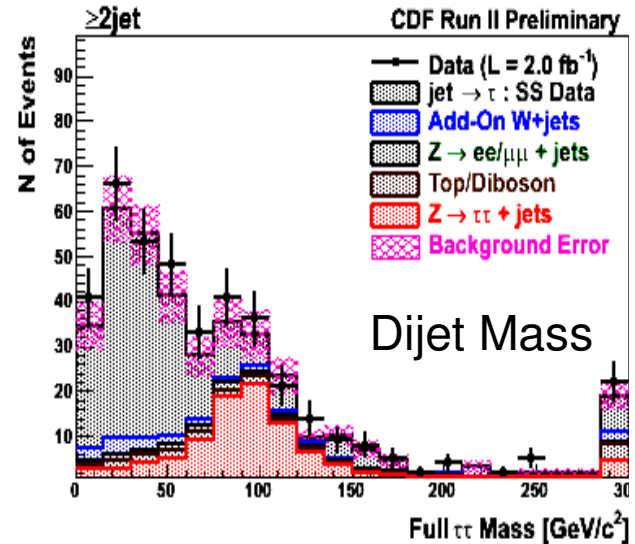
Analysis	Lum (fb ⁻¹)	Higgs Events	Exp. Limit	Obs. Limit
CDF NN	2.4	1.8	11.8	11.6
CDF ME(120)	2.0	1.4	15.2	11.8
DØ NN, BDT	2.3	2.0	12.3	11.0

Other channels sensitive at low mass



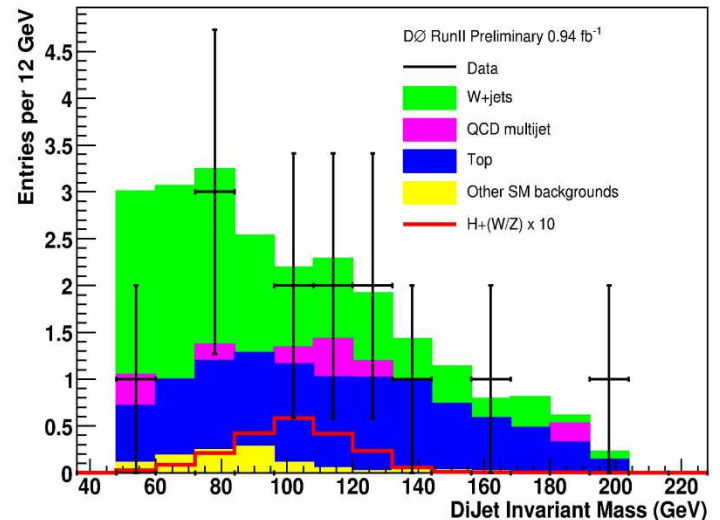
Analysis Technique

- ◆ Signature τ had+ τ lep+2 jets
- ◆ Simultaneous search in WH+ZH+VBF+ggH
- ◆ Use NN to extract signal

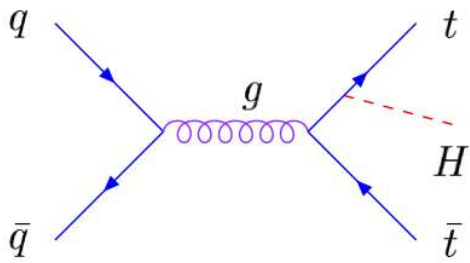


Analysis Technique

- ◆ Hadronic τ + MET + 2 b jets
- ◆ Use Dijet mass to extract signal

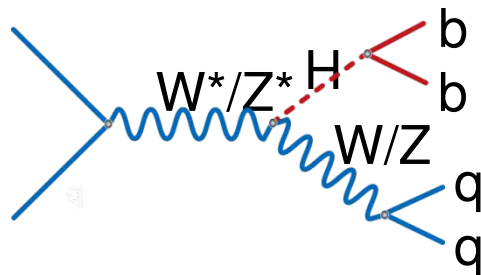


Other channels sensitive at low mass



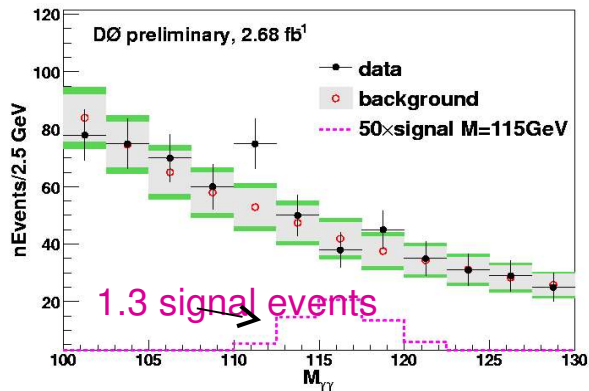
Analysis Techniques

- ◆ 1 lepton + MET + 4 or ≥ 5 jets
- ◆ Separate events into
- ◆ 1,2,3, ≥ 3 b tags
- ◆ Use scalar sum of jets (H_T) to extract signal

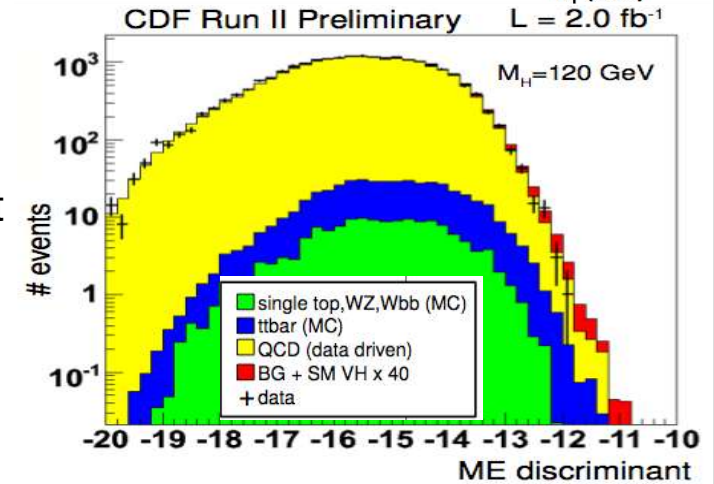
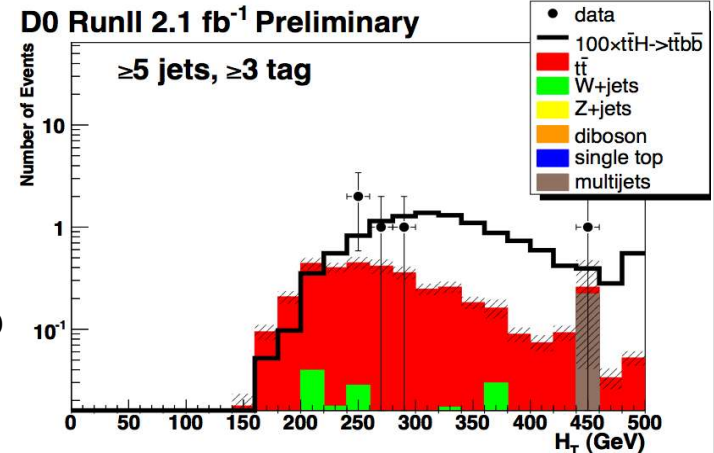


- ◆ 4 jets, ≥ 2 b jets
- ◆ Large BR of $W/Z \rightarrow qq$
- ◆ Large multijet background
- ◆ Use matrix element to extract signal

$$H \rightarrow \gamma\gamma$$



- ◆ 2 photons
- ◆ NN photon id
- ◆ Low BR $H \rightarrow \gamma\gamma$
- ◆ Background QCD $\gamma\gamma, \gamma jet$
- ◆ Use di-photon mass to extract signal



Summary of Analyses

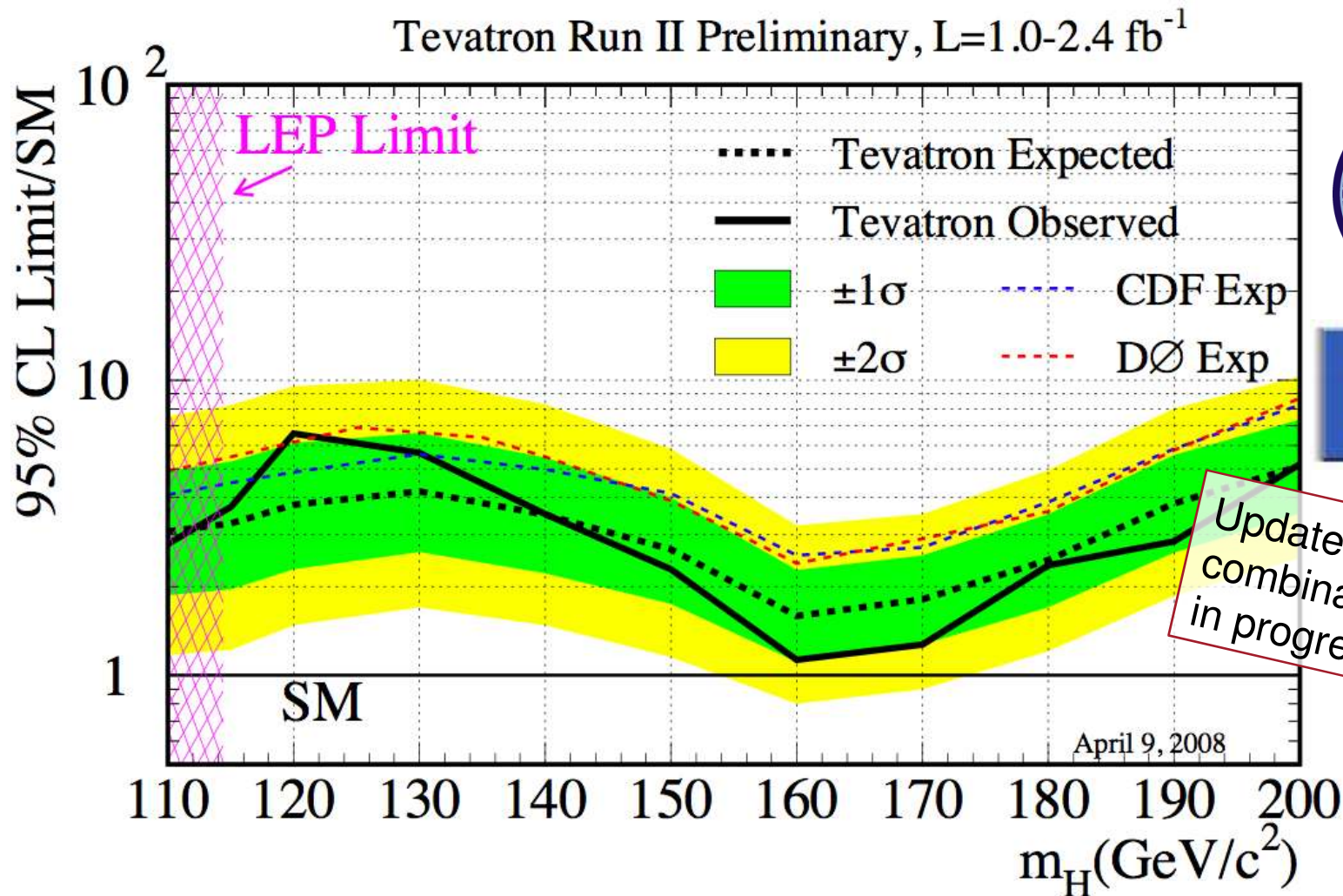
$m_H = 115 \text{ GeV}/c^2$

Channel	CDF	D0
	95% C.L. Limits $\sigma \cdot \text{BR}/\text{SM obs (exp)}$	95% C.L. Limits $\sigma \cdot \text{BR}/\text{SM obs (exp)}$
WH \rightarrow lvbb (NN)	5.0 (5.8) 2.7fb⁻¹	9.3 (8.5) 1.7fb⁻¹
WH \rightarrow lvbb (ME+BDT)	5.7 (5.6) 2.7fb⁻¹	
WH \rightarrow τ vbb (NN)	-	35.4 (42.1) 0.9fb⁻¹
VH \rightarrow qqbb (ME)	37.0 (36.6) 2.0fb⁻¹	-
ZH \rightarrow llbb (NN)	11.6 (11.8) 2.4fb⁻¹	11.0 (12.3) 2.3fb⁻¹
ZH \rightarrow llbb (ME) ($m_H=120 \text{ GeV}$)	14.2 (15.0) 2.0fb⁻¹	
ZH \rightarrow vv/WH \rightarrow (l) vbb (NN)	7.9 (6.3) 2.1fb⁻¹	7.5 (8.4) 2.1fb⁻¹
ttH \rightarrow lvbbbbqq	-	63.9 (45.3) 2.1fb⁻¹
H \rightarrow $\gamma\gamma$	-	30.8 (23.2) 2.7fb⁻¹
H \rightarrow $\tau\tau$	30.5 (24.8) 2.2fb⁻¹	-
Combined	X.X (X.X)	X.X (X.X)

Also WW contributes in the low mass region

Tevatron Combination

- Status of April 9th 2008 -



Updated Tevatron combination in progress!

Conclusions

- Higgs physics at the Tevatron is getting exciting!
- Low mass region has large backgrounds due to the dominant decay to b quarks
- Expected limit should fall below
~ 3 x SM for $m_H=115 \text{ GeV}/c^2$ in the next Tevatron combination
- Additional improvements actively in progress
 - Further extending signal acceptance for leptons and b tagging
 - Improved jet resolution
 - Extended b-tagging and flavour separators
- Expect 2-3 times current analyzed lumi (more if we run in 2010)
- Details on each analysis is available at:
 - CDF: <http://www-cdf.fnal.gov/physics/new/hdg/hdg.html>
 - D0: <http://www-d0.fnal.gov/Run2Physics/WWW/results/higgs.htm>