Search for Higgs Bosons Produced in Association with W Bosons at CDF

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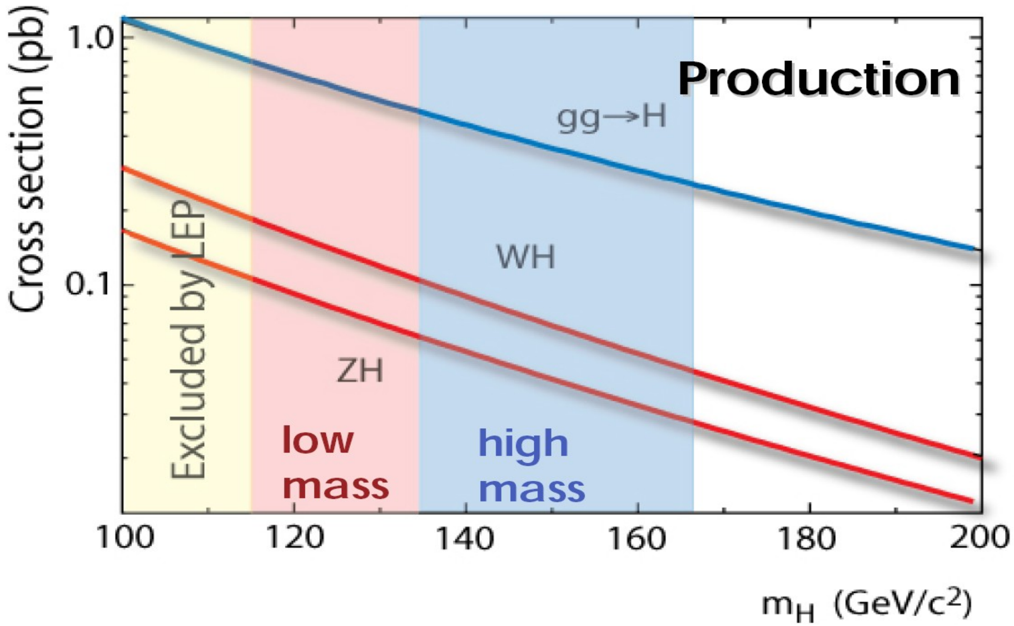
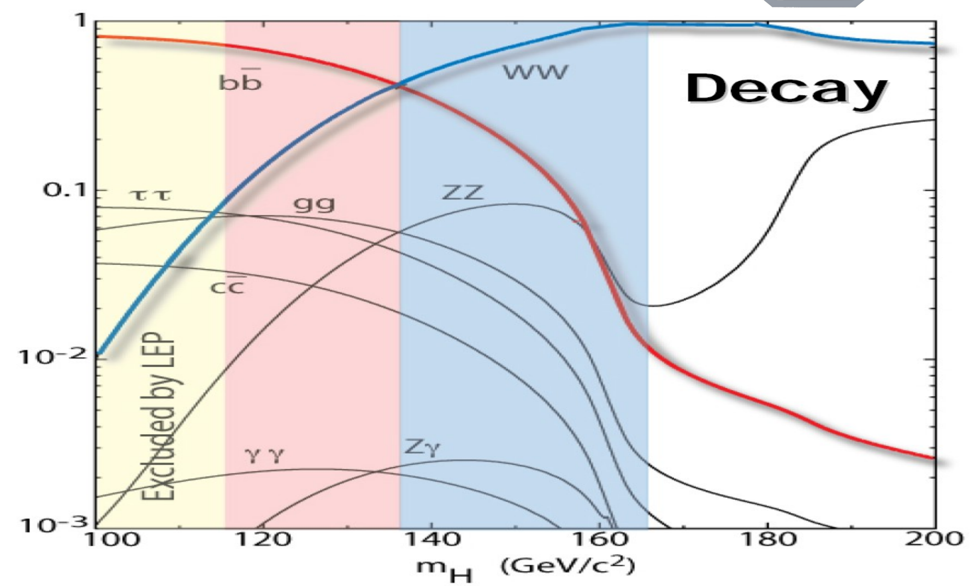
on behalf of the CDF Collaboration

SM: Higgs Production/ Decay

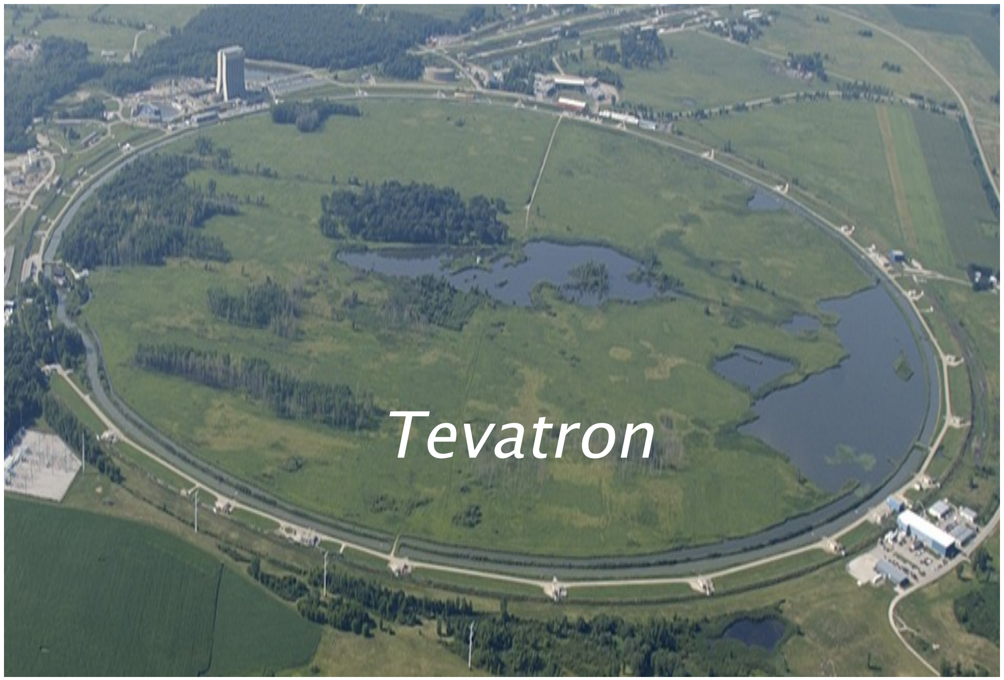


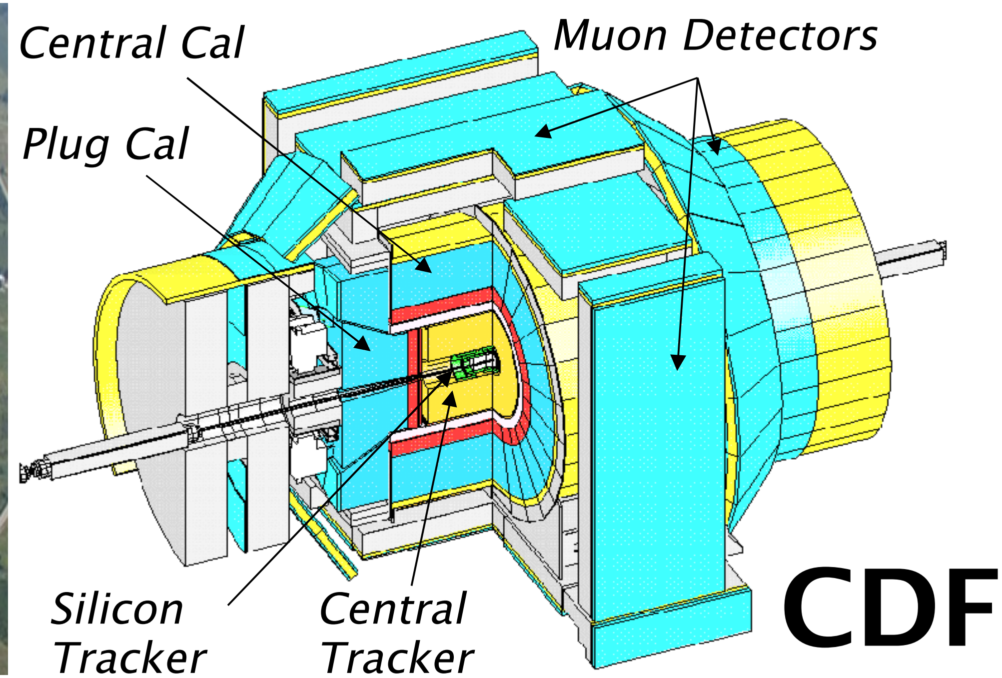


- Higgs is source of Electroweak Symmetry Breaking in SM
- Higgs mass is
  - M > 115 GeV/c^2 (direct)
  - M < 160 GeV/c^2 (Electroweak fit)

- Current Direct searches look for ggH, WH, ZH (small σ < 1 pb)
- In the low mass range (M_H < 135 GeV/c^2) Decay to bb dominates
- We will focus on WH to lνbb

Tevatron + CDF



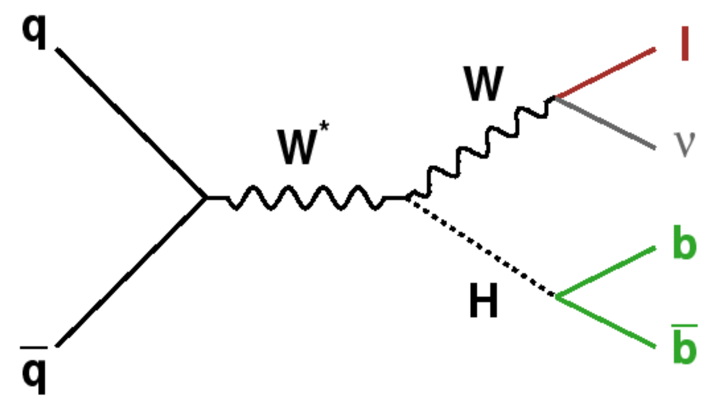


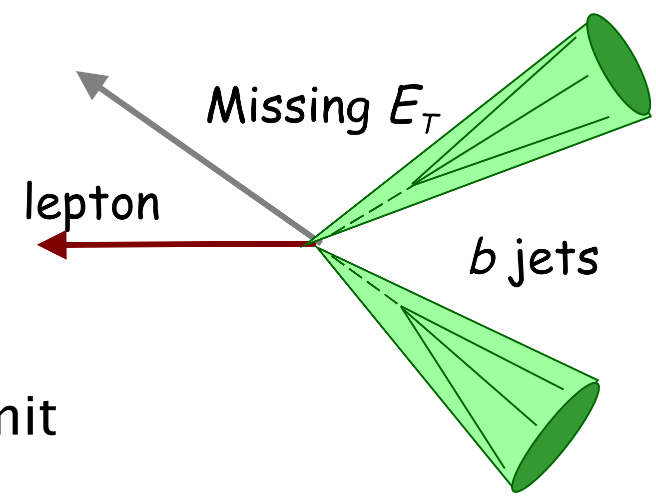
- Collides protons and antiprotons
- **1.96 TeV** center of mass energy
- Record lumi: 3.13 x 10^{32} $/cm^2/s$
- Integrated lumi: > 3 fb^{-1}

- CDF experiment: 600+ scientists
- Multipurpose detector Records Tevatron Collisions

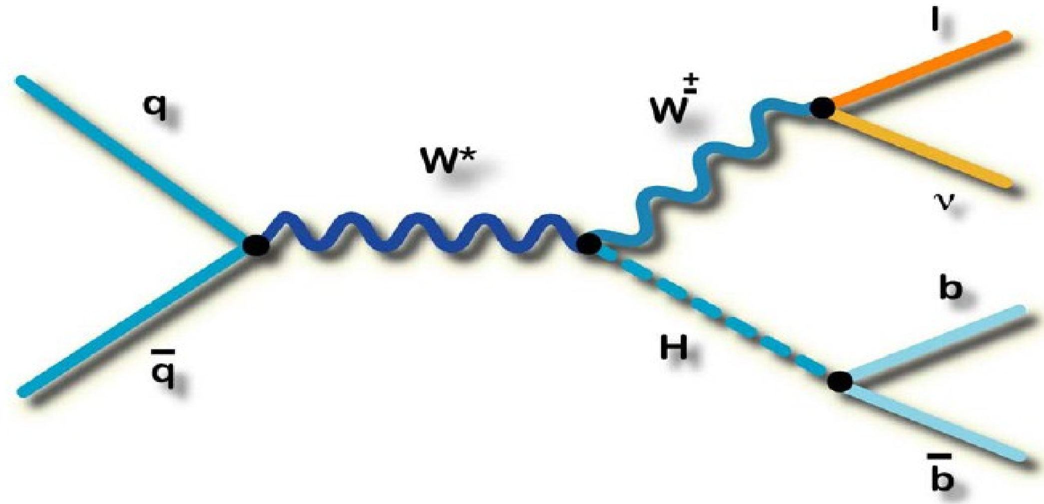
Analysis Strategy

- Select events with WH topology
  - W to (e,μ)+ν
  - H to bb (two b-quark jets)
- Estimate backgrounds
  - W+jets (including W+bb)
  - Top production (single and pair)
  - QCD (events with fake leptons)
- Devise discriminant: maximize sensitivity
- Likelihood fit to search for an excess
- If no excess observed, set a 95% confidence limit





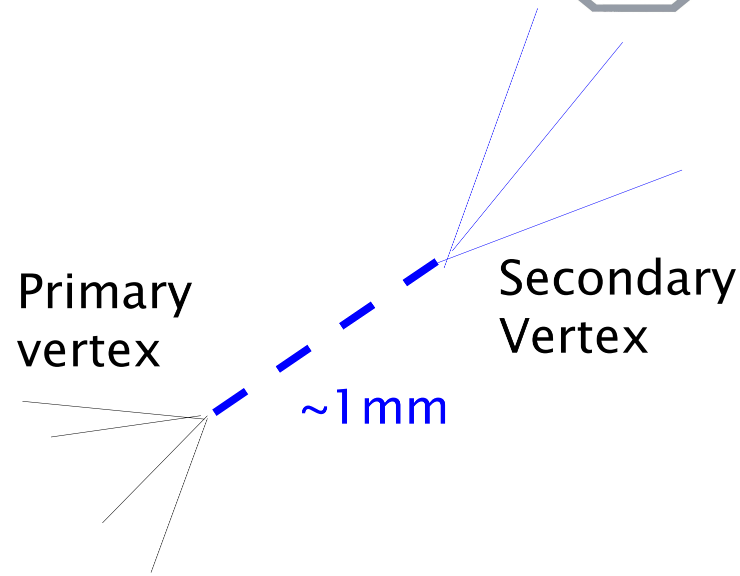
WH Signature and Selection

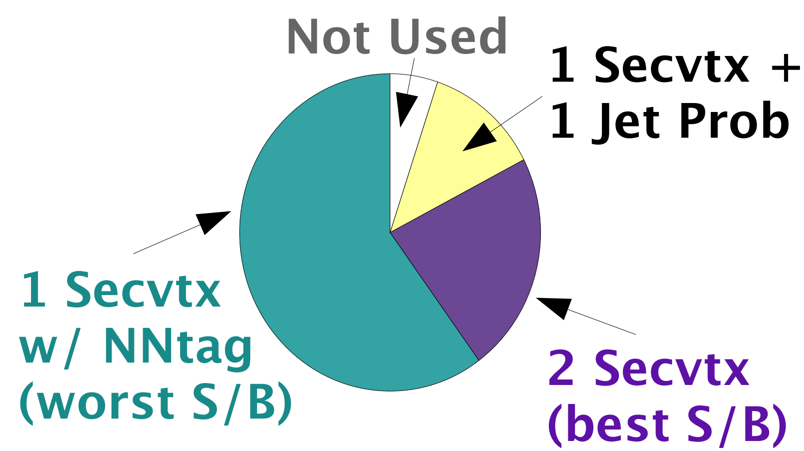


- Trigger Electron or Muon
  - Pt > 20 GeV
  - Central leptons $|\eta| < 1.1$
  - Forward (plug) electrons $1.1 < |\eta| < 2.0$ Adds 10% relative to central
- Neutrino
  - Missing Transverse Energy (MET) > 20 GeV
- Forward Electrons: QCD veto to reject fakes
  - Angular cuts, MET > 25 GeV
- Two Jets
  - $E_T > 20$ GeV
  - $|\eta| < 2.0$

B-tagging

- B hadrons have a long lifetime, look for jets with secondary vertices (b-tagging)
- Use three tagging algorithms to maximize acceptance
  - Secondary Vertex tagging (**secvtx**) iterates through combinations of tracks looking for 2nd vertex
  - Jet Probability tagging (**jet prob**) compares track impact parameter to primary vertex resolution
  - Neural Network flavor separator (**NNtag**) applied to secvtx tags
    - Increases purity of tags
- Separate search in each tag category





Background Estimate

W+jets: Estimate tagged amount from observed number of pretag events

W+light flavor: from pretag using false tag rate

W+heavy: from pretag using a b-tag rate

EWK+Top: estimated using theory x-sec and MC acceptance

Non-w: Estimated from MET and isolation sidebands

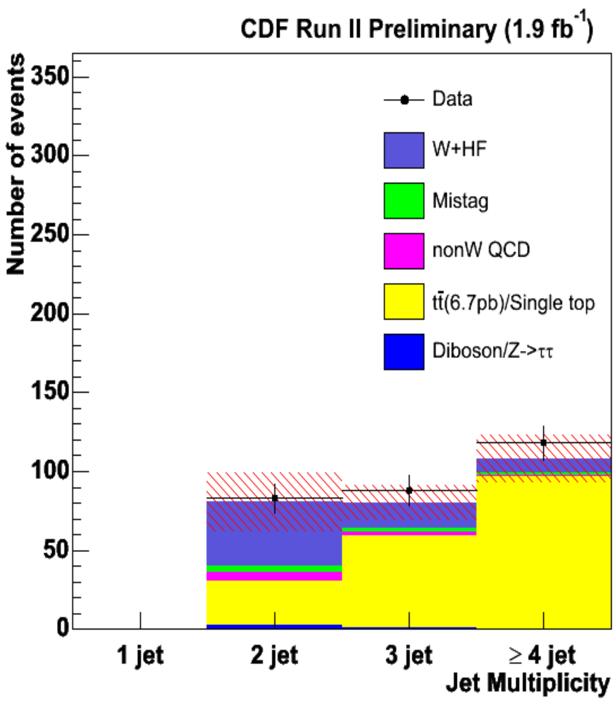
L(int) = 1.9 fb^{-1}

Njet	2jet	3jet	>=4jet
Pretag Events	32242	5496	1494
Mistag	3.88±0.35	2.41±0.24	1.62± 0.14
Wbb	37.93±16.92	14.05±5.49	7.39± 2.93
$Wc\bar{c}$	2.88±1.25	1.52±0.61	1.15± 0.47
$t\bar{t}$(6.7pb)	19.05±2.92	54.67±8.38	94.93± 14.56
Single top(s-ch)	6.90±1.00	2.28±0.33	0.61± 0.088
Single top(t-ch)	1.60±0.23	1.43±0.21	0.50± 0.07
WW	0.17±0.02	0.15±0.02	0.16± 0.02
WZ	2.41±0.26	0.68±0.07	0.16± 0.02
ZZ	0.06±0.01	0.06±0.01	0.02±0.001
$Z->\tau\tau$	0.25±0.04	0.19±0.03	0.06±0.01
nonW QCD	5.50±1.00	2.56±0.48	1.02± 0.22
Total Bkg	80.62±18.75	79.99±10.92	107.63± 15.15
WH signal (120 GeV)	0.94±0.11	Control region	Control region
Observed Events	83	88	118

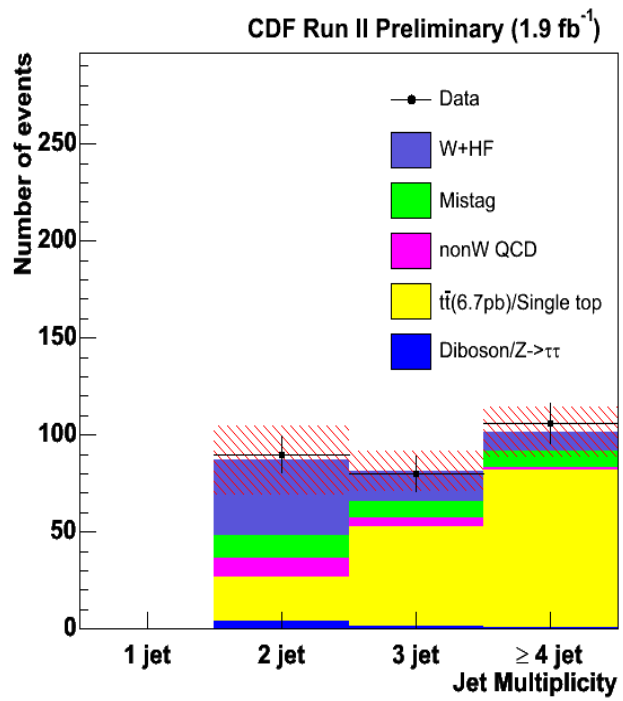
We use only 2-jet events
Other jet bins provide cross check

2 tight Secvtx tagged events

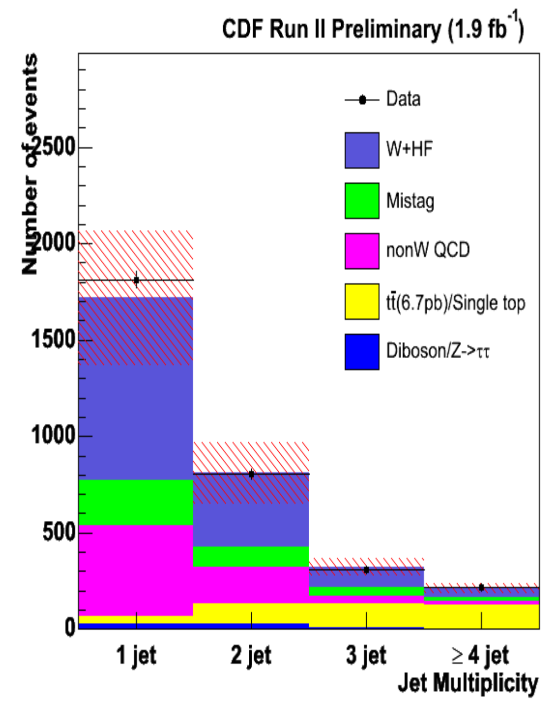
Background Estimate (2)



2 Secvtx Tags (Best S/B)



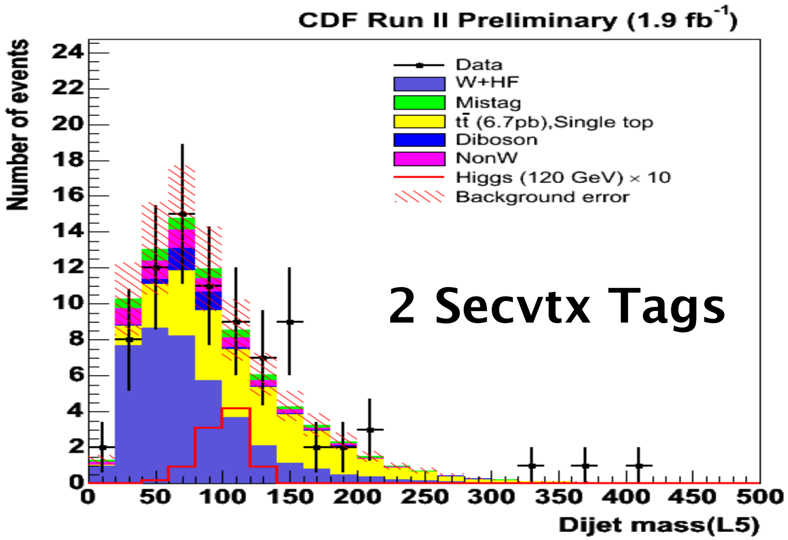
1 Secvtx +1 JetProb Tag

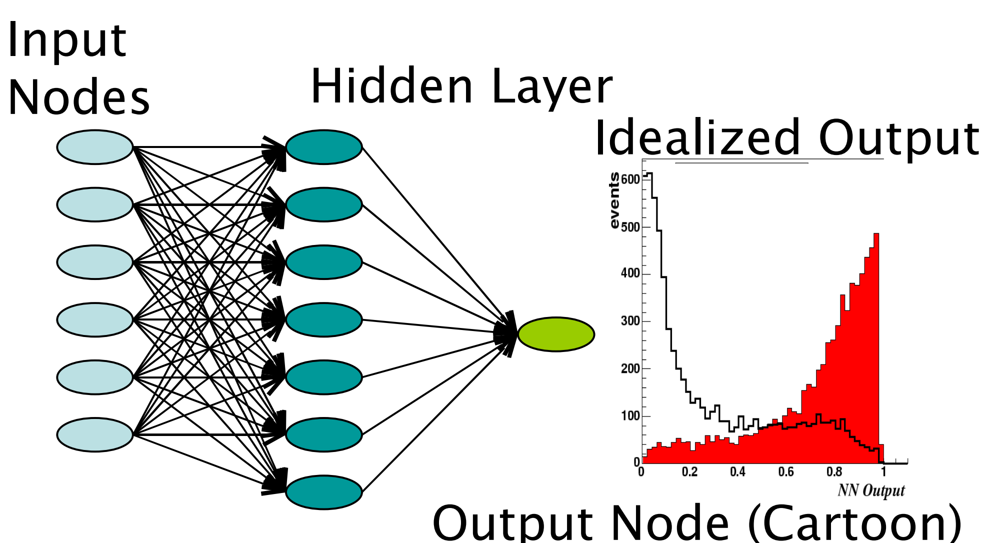


1 Secvtx w/ NN tag (Worst S/B)

- Observed data agrees with expectation
- Backgrounds can float within uncertainties in search

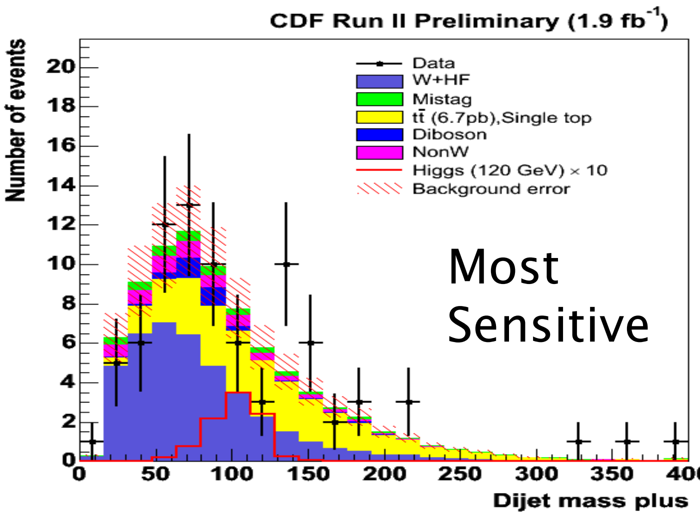
Separating Signal from Background

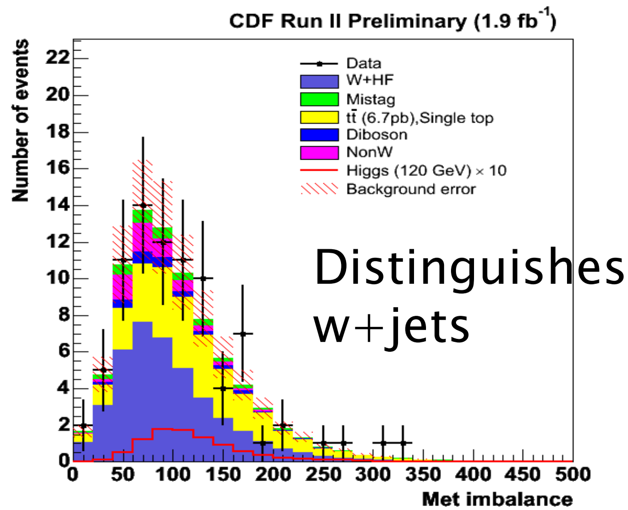


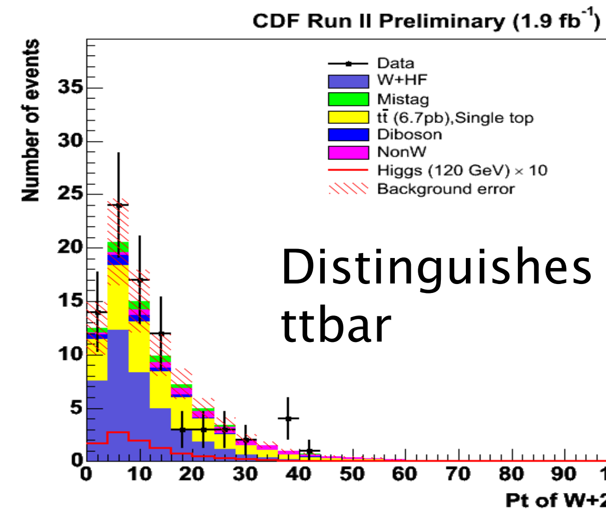


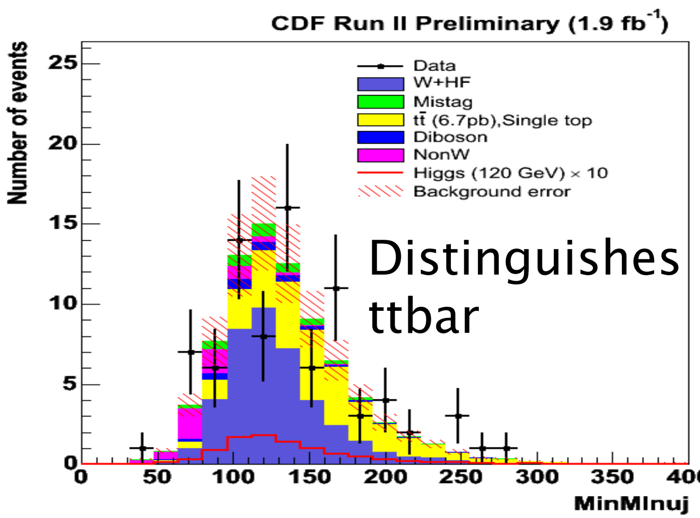
- Backgrounds are overwhelming even in purest tag category (double secvtx) and most sensitive shape (dijet mass)
- We combine 6 variables with an artificial **Neural Network (NN)** to optimize our sensitivity
- The NN is iteratively trained to distinguish WH events from W+jets and top background
  - Exploits correlations between kinematic variables
- 10% improvement in sensitivity over fitting dijet mass

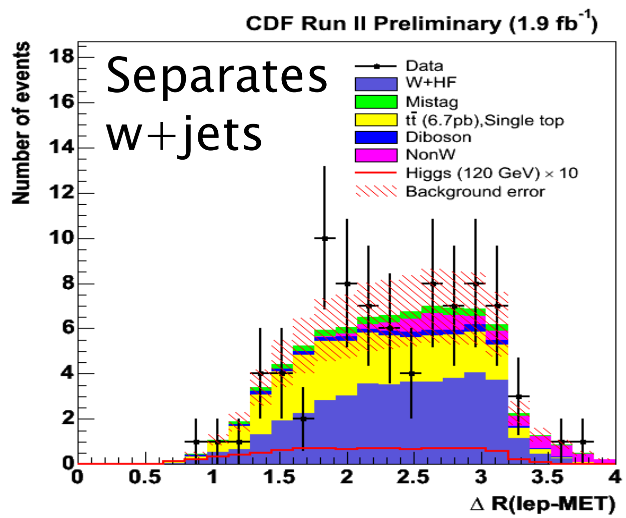
6 NN input variables

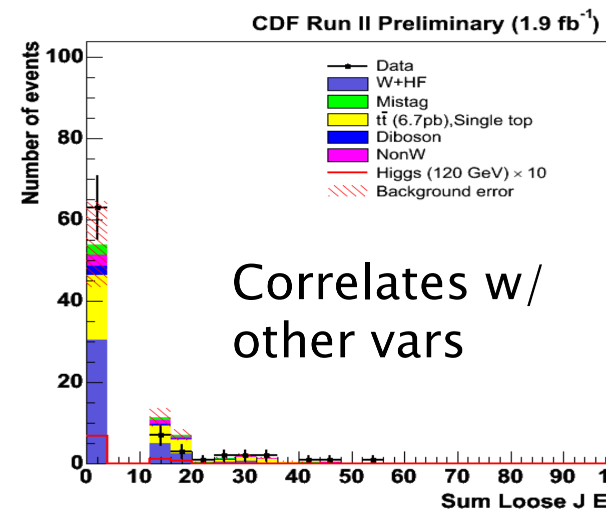






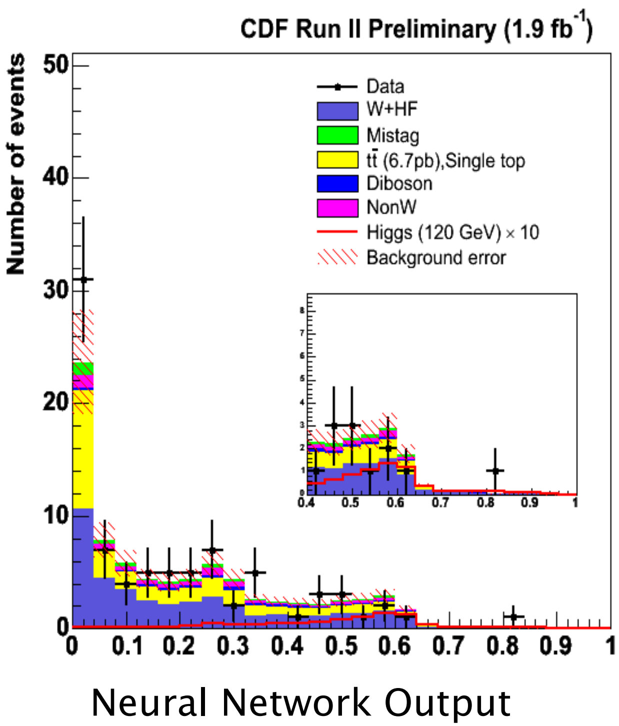




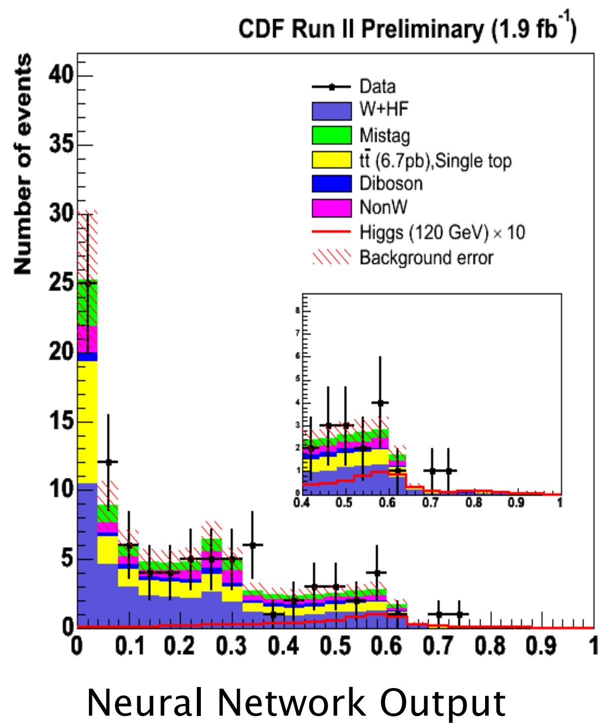


Neural Network Output

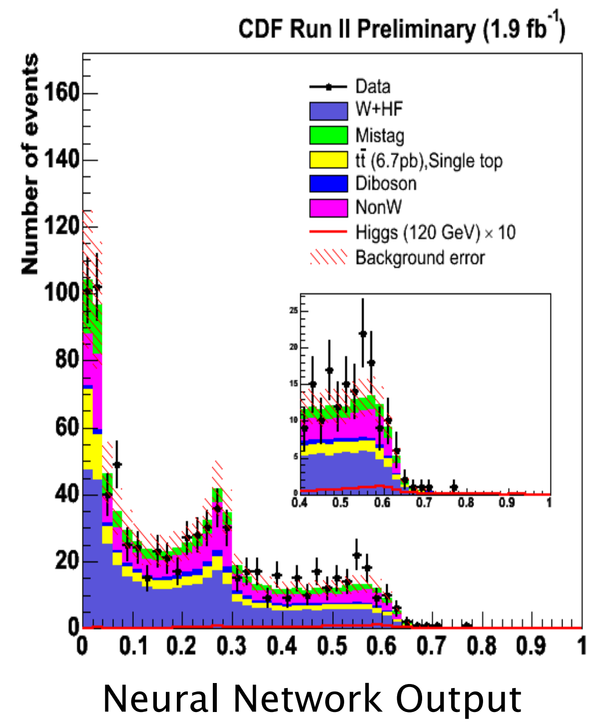
2 Secvtx



1 Secvtx + 1 JP



1 Secvtx w/ NN

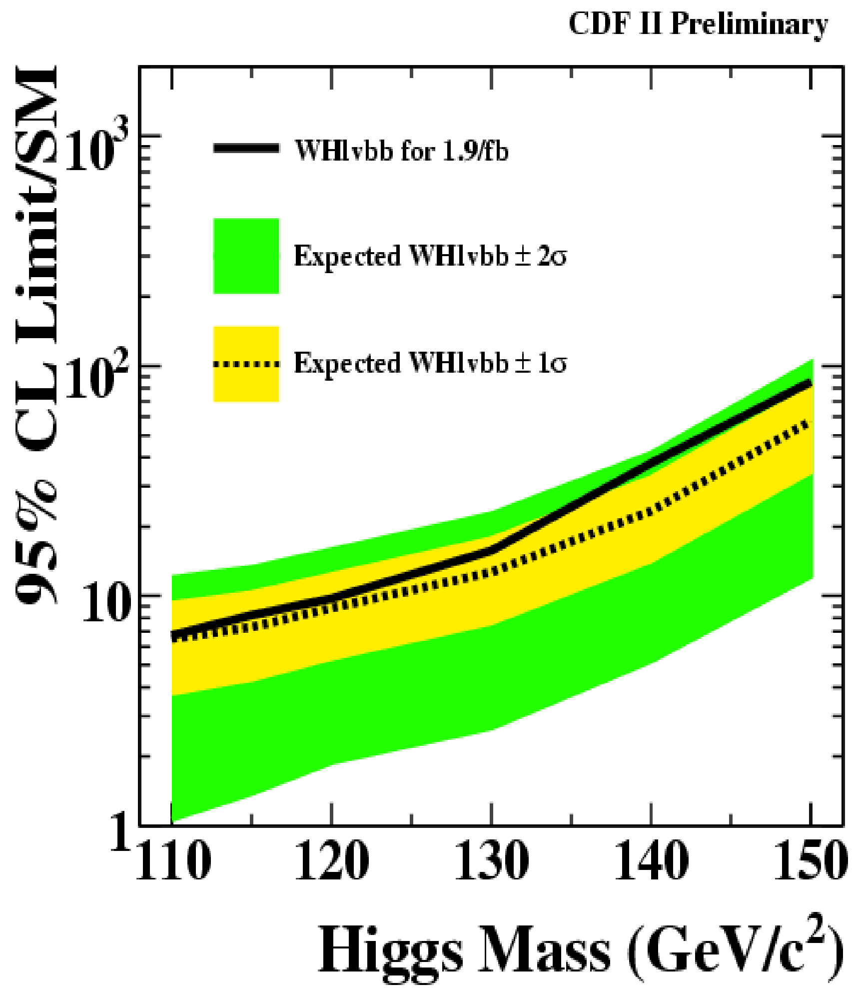


- NN improves expected sensitivity by 10% over dijet mass
- Fit NN output, find no evidence for signal, so set 95% CL

Expected and Observed Limits

- Expected and observed limits agree quite well
- Observed limit is 8.2 (expect 7.3) at M_H = 115 GeV/c^2
  - **Most sensitive low mass Higgs search**
- Improves 1fb^{-1} result by factor of 2.2
  - Lum. Factor: 1.4
  - Additional 60% from btagging, NN discrim, forward ele's

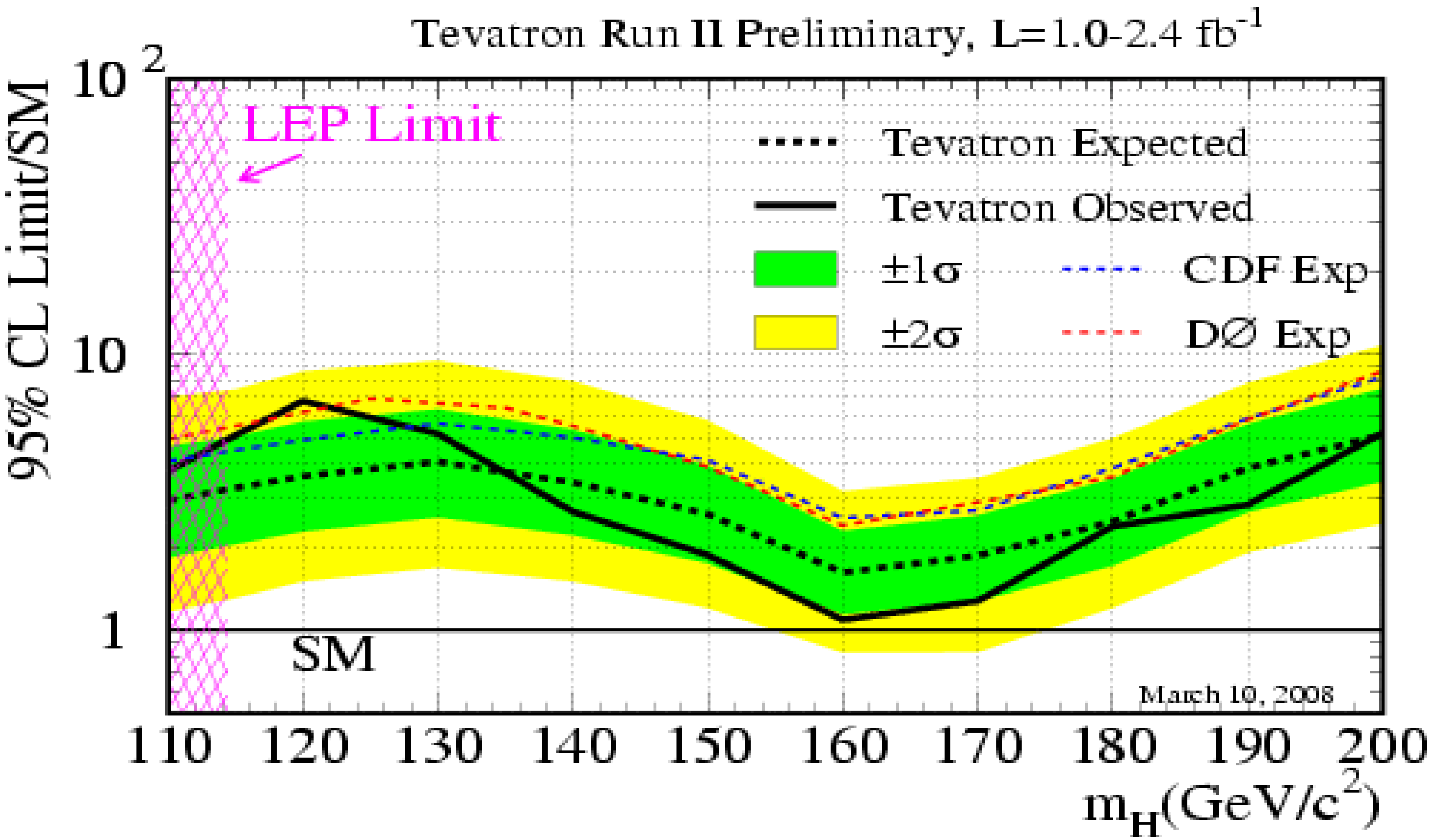
L(int) = 1.9 fb^{-1}



Summary

- WH to $l\nu bb$ is currently the most sensitive low-mass Higgs search
- Updated Result for Winter Conferences (Jan 2008) w/1.9 fb^{-1}
  - Added more data (and leptons, taggers)
  - Improved analysis techniques (Neural Networks)
- We are continuing to pursue improvements
  - Matrix Element Discriminant
  - MET+Jet triggered events
  - Adding more data
- Ultimately, our hope for SM Higgs sensitivity lies in a combined search. The success of the search at the Tevatron depends on each channel pursuing every improvement!

Backup: Tevatron Combination



Limit at M =115
Expect 3.3
Observe 3.7

Limit at M = 160
Expect 1.6
Observe 1.1

Backup: CDF combination