Search for Higgs Boson Production in Association with a W Boson at CDF

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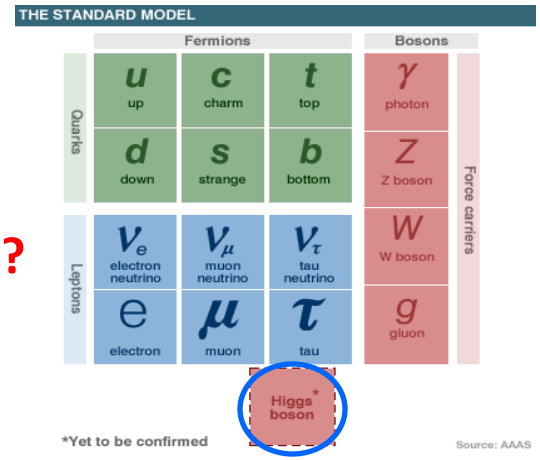
on behalf of the CDF Collaboration

Outline

- **Introduction and Motivation**
- **Tevatron and CDF**
- **Event Selection**
- **Background Estimation**
- **Multivariate Analysis Technique**
- **Results**
- **Summary**

Motivation

- The Higgs boson is the only undiscovered "elementary" particle in the Standard Model
- Its discovery will help answer the questions:
  - How do fermions/weak bosons acquire the mass?
  - How EW symmetry is broken?
- The SM can not predict the Higgs boson mass
  - Need to be determined by experiment !!



Status of SM Higgs boson Search

- Current constraint on the SM Higgs boson

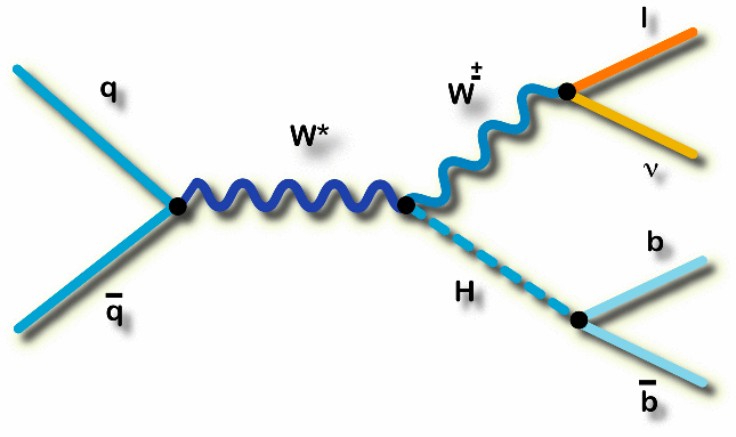
  - LEP II searches exclude: $M_H < 114.4\,GeV/c^2$
  - Tevatron searches exclude: $162 < M_H < 166\,GeV/c^2$
  - A fit to precision electroweak data:

    $M_H = 87^{+35}_{-26}\,GeV/c^2 \quad M_H < 157\,GeV/c^2$

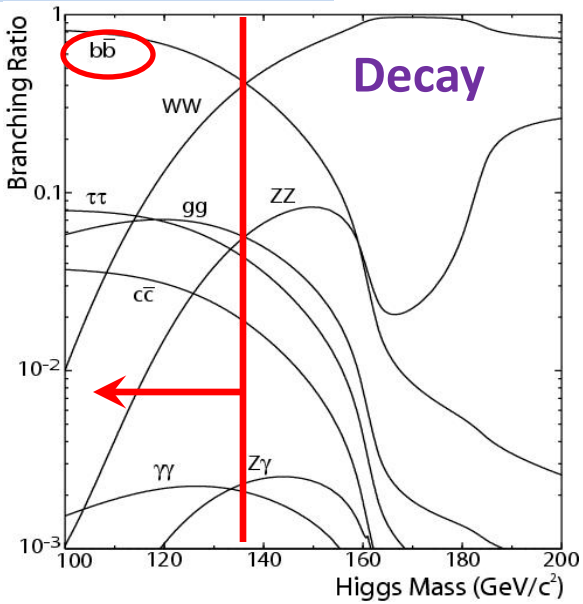
→ SM prefers light SM Higgs boson !!

- We focus on the low mass Higgs search with: $WH \to l\nu b\bar{b}$

Why the $WH \to l\nu b\bar{b}$ channel?



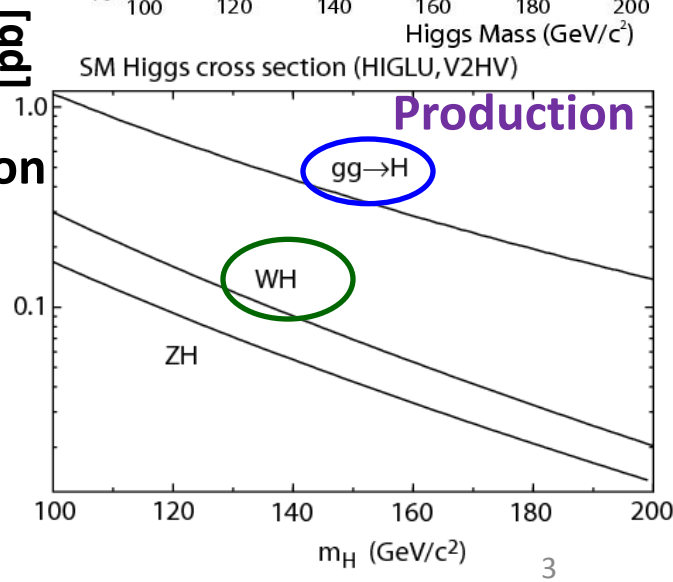
Low mass region



Focus on Low mass Higgs boson Search

$$M_H < 135 GeV/c^2$$

Dominant decay for this region is: $H \to b\bar{b}$



- $gg \to H \to b\bar{b}$: **Highest cross section @ Tevatron**
  But, huge QCD background with $p\bar{p} \to b\bar{b}$
- $q\bar{q} \to WH \to l\nu b\bar{b}$: **2nd highest cross section**
  $W \to l\nu$ **requirement: Cleaner signature**

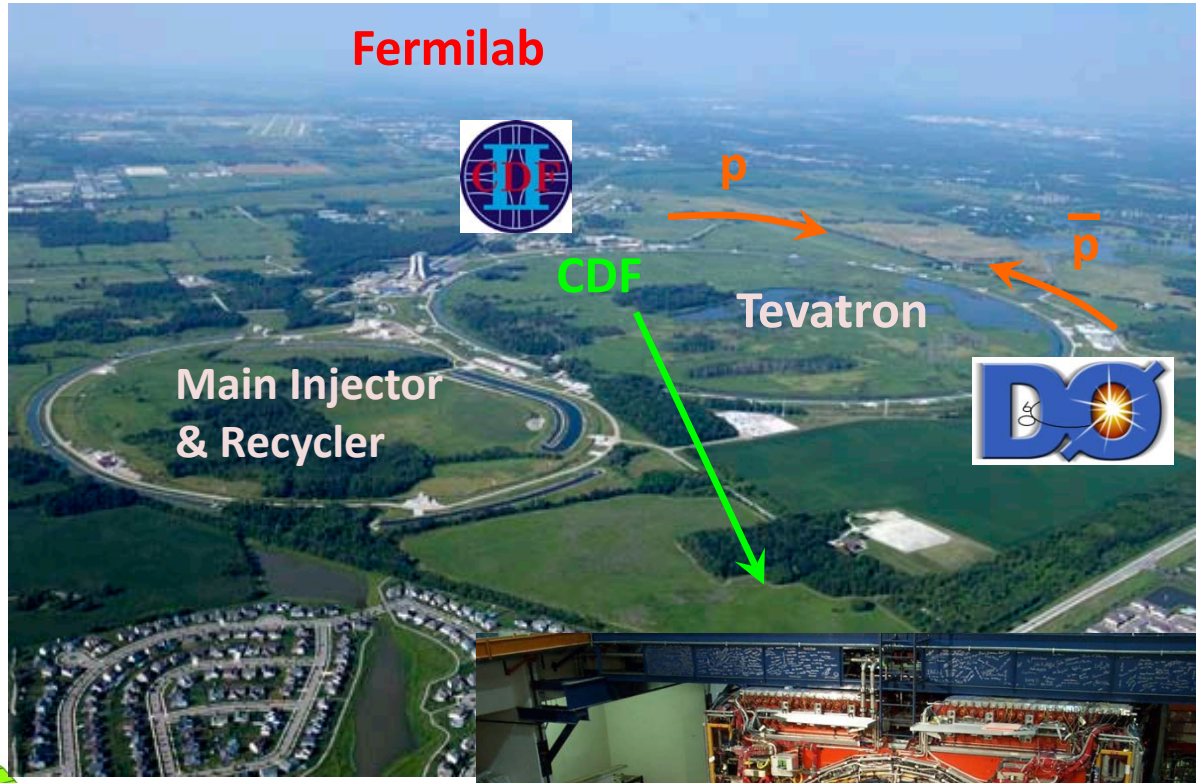
Tevatron and CDF

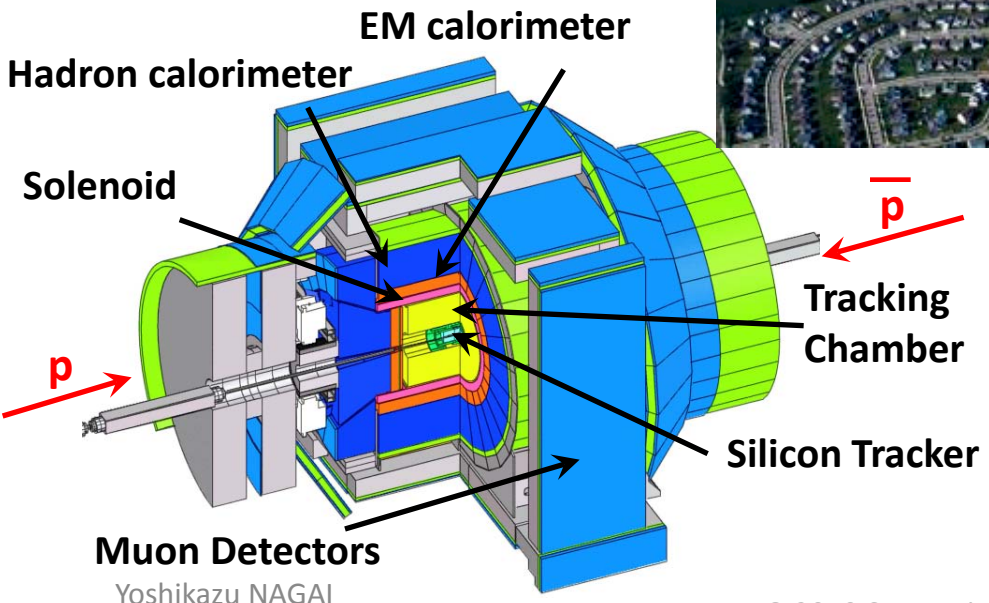
Tevatron

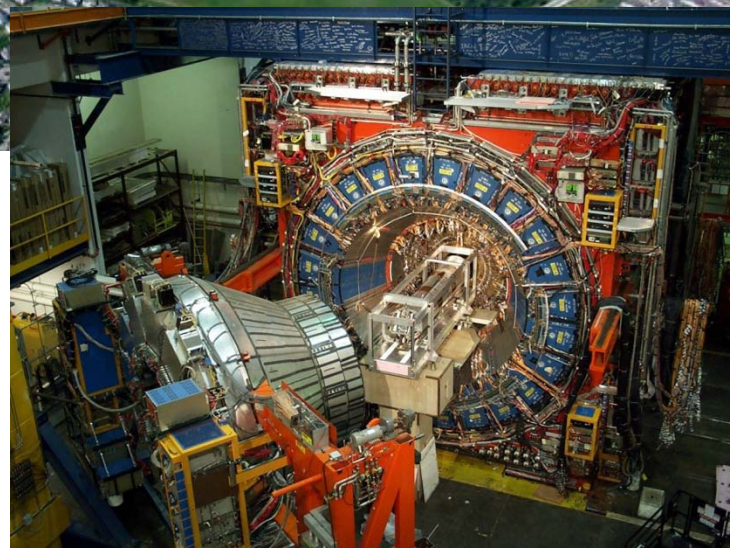
- Proton-antiproton collision at $\sqrt{S} = 1.96\text{TeV}$

CDF

- One of the general purpose detector
- Currently **> 7.0 fb^{-1}** data on tape.







Event selection

- High p_T isolated lepton (e/μ) or isolated track

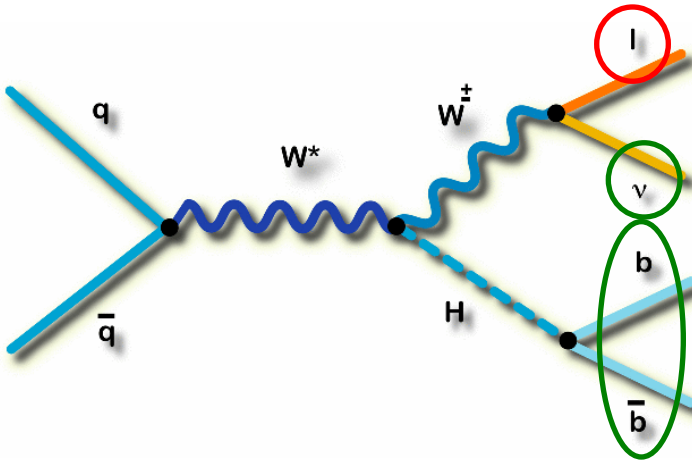
  $P_T > 20$GeV
- Large missing transverse energy

  $MET > 20$ GeV
- Two central high energy jets

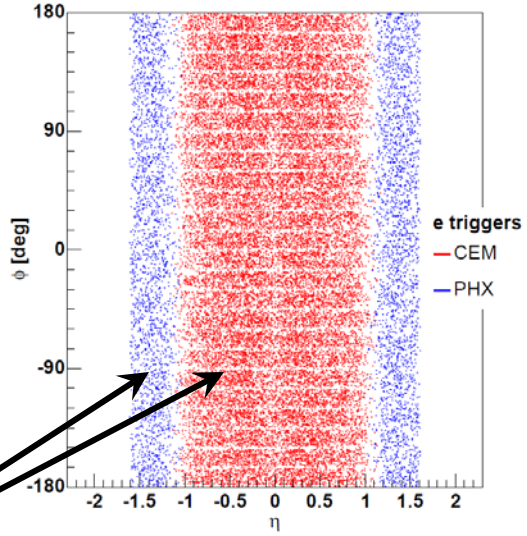
  $E_T > 20$ GeV, $|\eta| < 2.0$
- At least one *b*-tagged jet

W boson selection

W + 2 b-jets selection

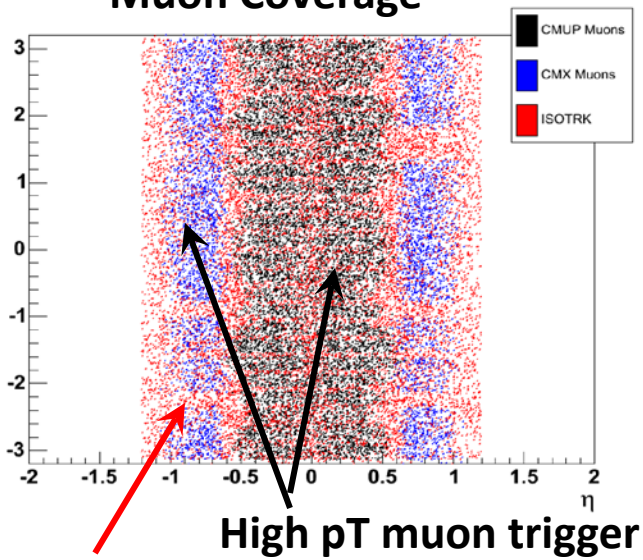


Electron Coverage



High pT electron trigger

Muon Coverage



High pT muon trigger

Isolated tracks on different triggers

b-tagging categories

Use three standard b-tagging algorithms in CDF

- Secondary Vertex b-tagging algorithm (ST)
- Jet Probability b-tagging algorithm (JP)
- Neural Network b-tagging (NN)

tight

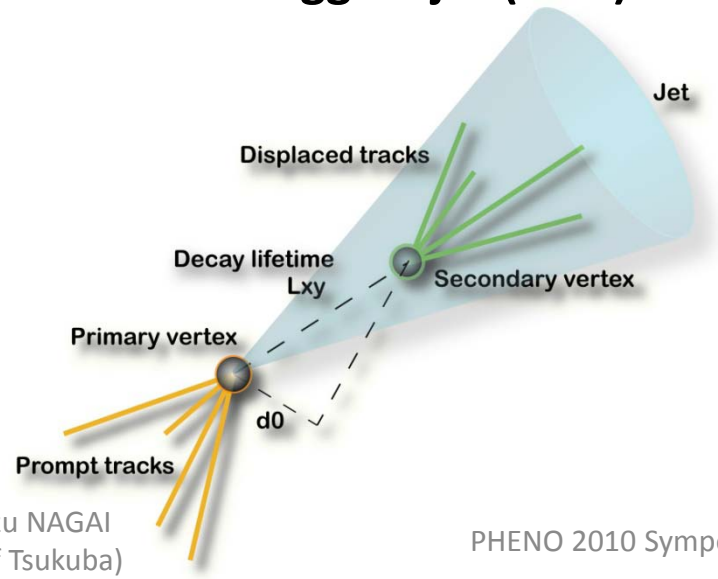
loose

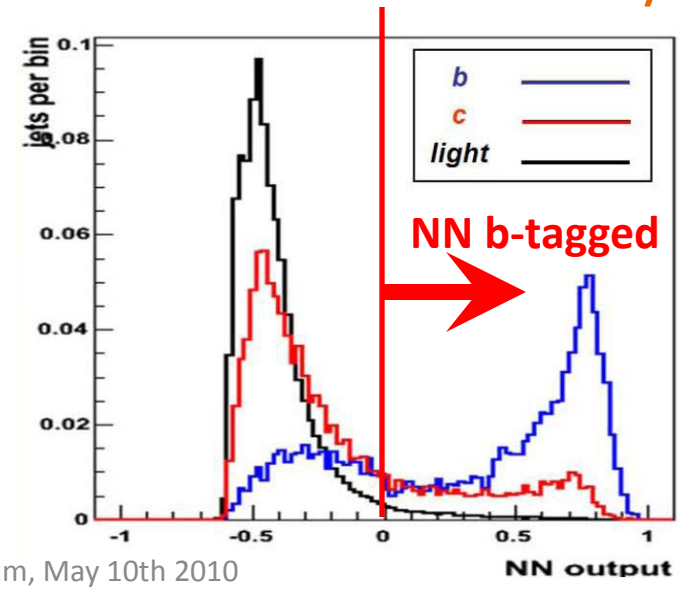
good S/B

worse S/B

Define 4 independent b-tagging categories

- Two ST-tagged jets (ST+ST)
- One ST-tagged jet + One JP-tagged jet (ST+JP)
- One ST-tagged jet + One NN-tagged jet (ST+NN)
- One ST-tagged jet (1-ST)





Background Estimation

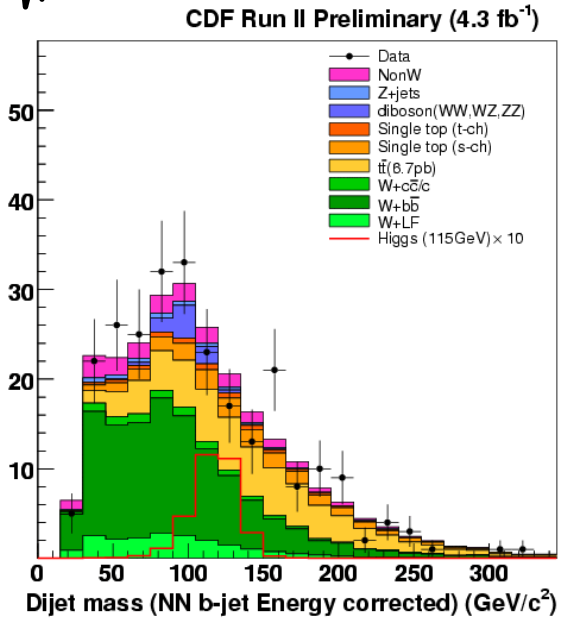
- **Mistag: falsely b-tagged W+LF jets** -> Estimated from data
- **Non-W: QCD multi-jet fake** -> Estimated from data
- **W+HF: W+bb, W+cc/c** -> Estimated from data and MC
- **MC Total: top pair, single top, diboson (WW, WZ, ZZ), Z+jets** -> Estimated from MC using theoretical cross section

Event Yield at 4.3fb^{-1}

	ST+ST	ST+JP	ST+NN	1-ST
Mistag	20.5 +/- 8.85	53.1 +/- 23.1	77.4 +/- 33.5	834.7 +/- 361.8
W+HF	116.8 +/- 32.6	115.9 +/- 29.6	61.1 +/- 23.2	1435.7 +/- 399.8
MC Total	98.1 +/- 14.4	95.1 +/- 13.9	45.4 +/- 7.73	509.3 +/- 66.0
Non-W QCD	19.2 +/- 8.5	21.8 +/- 7.9	17.7 +/- 6.8	464.9 +/- 82.4
Total background	254.6 +/- 66.7	285.8 +/- 80.3	201.6 +/- 75.3	3244.6 +/- 1055.0
Observed Events	258	261	204	3160
WH 115 GeV	3.21	2.62	1.22	6.62

Multivariate Analysis (BNN)

- **Counting experiment is hopeless due to the large backgrounds**
- **Separate signal and background using multivariate technique**



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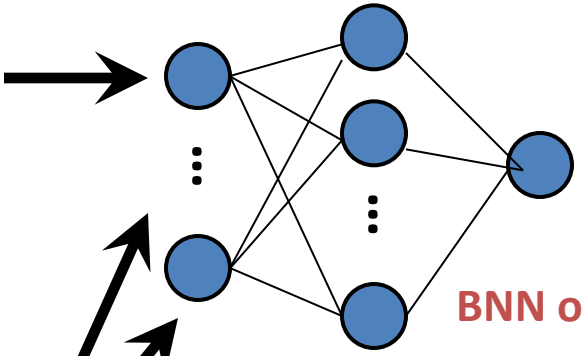
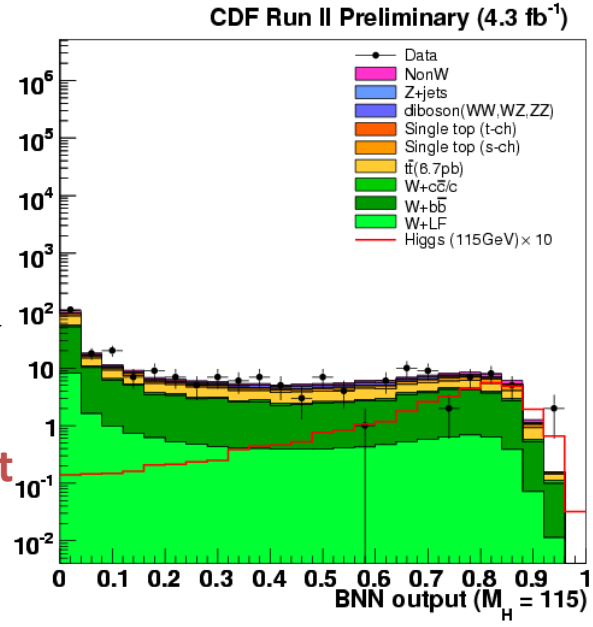
Other kinematic variables



Inputs

BNN output

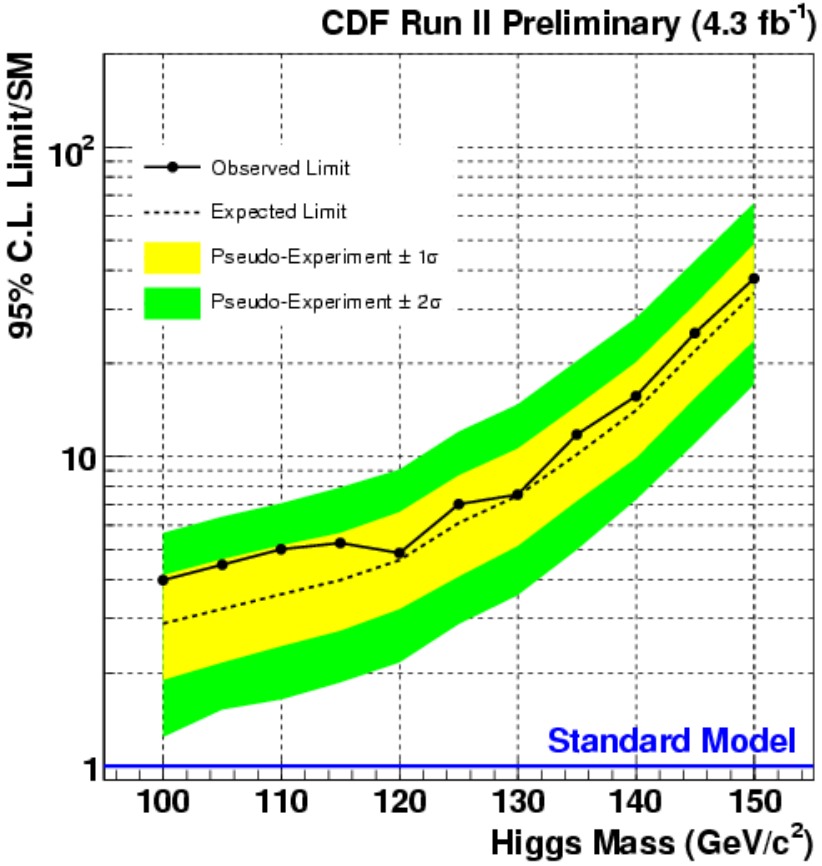


P_TImbalance, M_{lvj}, $Q_{lep}x\eta_{lep}$,

Σ(LooseJetEt), P_T(W), H_T

No significant excess observed

Result



- 4 b-tagging categories
- Bayesian Neural Network
- 4.3fb^{-1} of data

Expected upper limit

4.0 x σ(SM) (m_H = 115 GeV)

Observed upper limit

5.3 x σ(SM) (m_H = 115 GeV)

	100	105	110	115	120	125	130	135	140	145	150
Expected	2.8	3.1	3.5	4.0	4.6	6.0	7.4	10.0	14.1	21.8	33.7
Observed	4.0	4.5	5.0	5.3	4.9	7.0	7.5	11.8	15.7	25.0	37.6

Summary

- We have performed search for the SM Higgs boson using the $p\bar{p} \to W^{\pm}H \to l\nu b\bar{b}$ channel at CDF
- We employ sophisticated multivariate technique:
  Bayesian Neural Network
- We do not observed significant excesses
- We observed the 95% C.L. upper limit @ m_H = 115 GeV:
  BNN: 5.3 x σ(SM) (observed) 4.0 x σ(SM) (expected)

and for the future improvement

- We expect to increase the sensitivity with:
  - Including newer data (up to 6 fb^{-1} for summer 2010)
  - Add new triggers
  - Add 3-jet bin

} to get more signal acceptance

Stay tuned!!

Backup

Higgs signal acceptance

- Expected number of signal is calculated as follows:

$$N_{WH\to l\nu b\bar{b}} = \epsilon_{WH\to l\nu b\bar{b}} \cdot \mathcal{L} \cdot \sigma(p\bar{p} \to WH) \cdot \mathrm{Br}(H \to b\bar{b})$$

$$\epsilon_{WH\to l\nu b\bar{b}} = \epsilon_{Z0} \cdot \epsilon_{\mathrm{trig}} \cdot \epsilon_{\mathrm{leptonid}} \cdot \epsilon^{\mathrm{MC}}_{WH\to \ell\nu b\bar{b}} \cdot \left(\sum_{l=e,\mu,\tau} \mathrm{Br}(W \to l\nu) \right)$$

- Each category is exclusive

m_H = 115 GeV/c^2, 4.3/fb

1-ST Tag		
CEM	2.68	6.62
PHX	0.53	
CMUP	1.39	
CMX	0.69	
IsoTrk(MET2J)	0.95	
IsoTrk(MET45)	0.38	
ST+ST Tag		
CEM	1.25	3.21
PHX	0.26	
CMUP	0.66	
CMX	0.33	
IsoTrk(MET2J)	0.60	
IsoTrk(MET45)	0.11	

ST+JP Tag		
CEM	1.07	2.62
PHX	0.20	
CMUP	0.56	
CMX	0.26	
IsoTrk(MET2J)	0.43	
IsoTrk(MET45)	0.11	
ST+NN Tag		
CEM	0.48	1.22
PHX	0.10	
CMUP	0.26	
CMX	0.12	
IsoTrk(MET2J)	0.21	
IsoTrk(MET45)	0.05	

Total expected number of signal: 13.7 event

Systematic Uncertainties on Signal Acceptance

- Lepton identification: The difference of ID efficiency between data and MC
- Trigger efficiency: The uncertainties of trigger efficiency
- Initial/Final state radiation (ISR/FSR): The difference between higher and lower ISR/FSR MC samples
- Jet Energy Scale (JES): Estimated by JES $\pm$ 1σ shift from default value
- Parton distribution function (PDF): The difference among various PDFs (Estimated from MC)
- b-tagging: The difference of b-tagging efficiency between data and MC

- **Systematic uncertainties (Central leptons)**

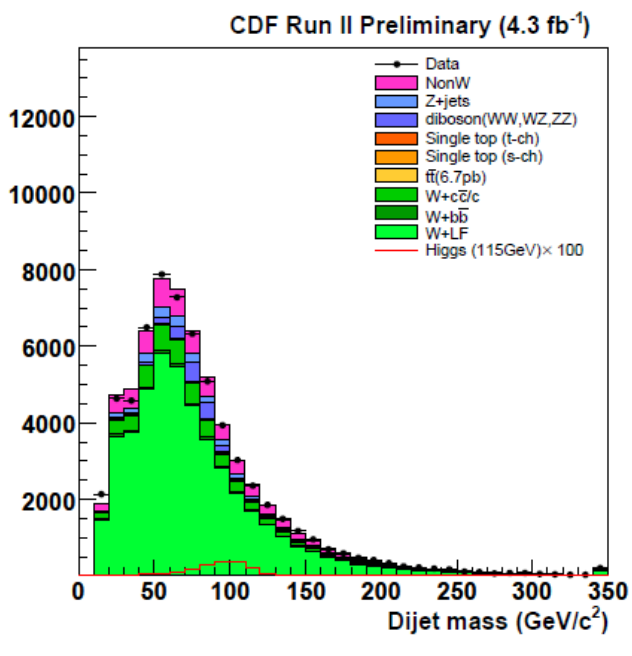
b-tagging category	Lepton ID	Trigger	ISR/FSR/PDF	JES	*b*-tagging	Total
1-ST	2%	$< 1\%$	3.0%	2.3%	4.3%	6.1%
ST+ST	2%	$< 1\%$	4.9%	2.0%	8.6%	10.3%
ST+JP	2%	$< 1\%$	4.9%	2.8%	8.1%	10.1%
ST+NN	2%	$< 1\%$	7.7%	2.2%	13.6%	15.9%

- **Luminosity uncertainty ~6%**

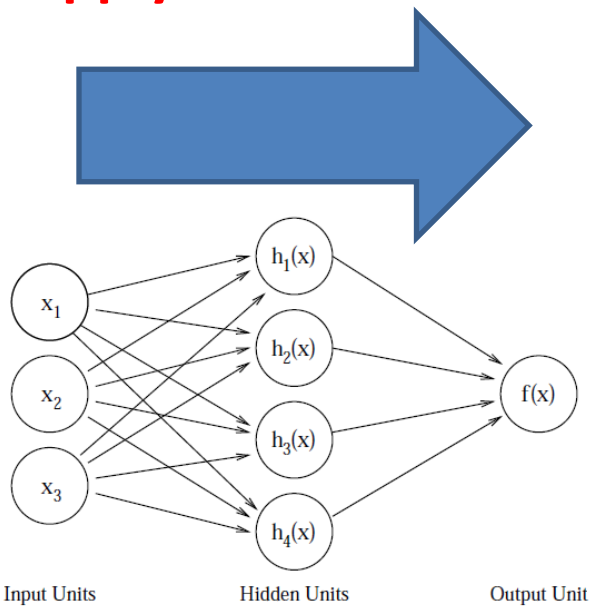
b-jet energy correction

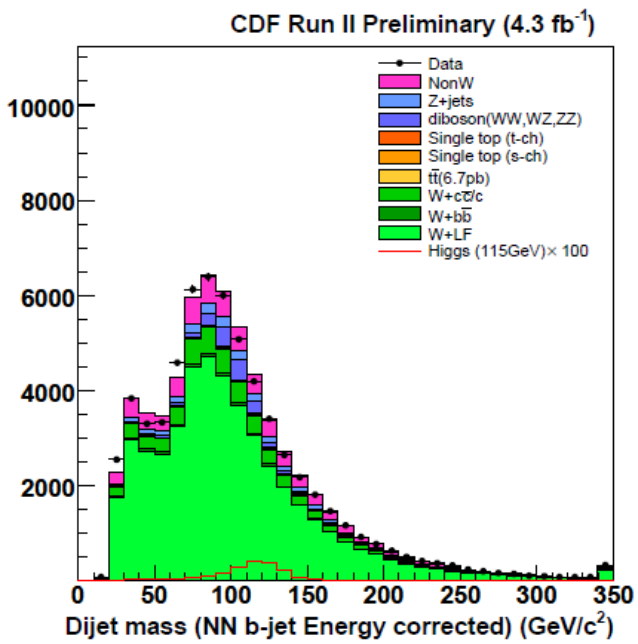
- Di-jet invariant mass is the most sensitive variable in WH->lνbb
- We develop Neural Network b-jet energy correction method

Input variables: Jet E_T and P_T, Jet M_T (= (P_T/P) x M), Jet Raw E_T, L_{XY}, $\sigma(L_{XY})$, SecVtxP_T, Track Sum P_T (P_T sum of tracks inside the jet), Track Max P_T



Apply NN correction





BNN input variables (ST+ST)