CDFにおけるWH→lνbb過程を用いたヒッグス粒子探索

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Outline

- Introduction
- Analysis
  - Event Selection
  - Background Estimation
  - Analysis Optimization
- Result and Conclusion

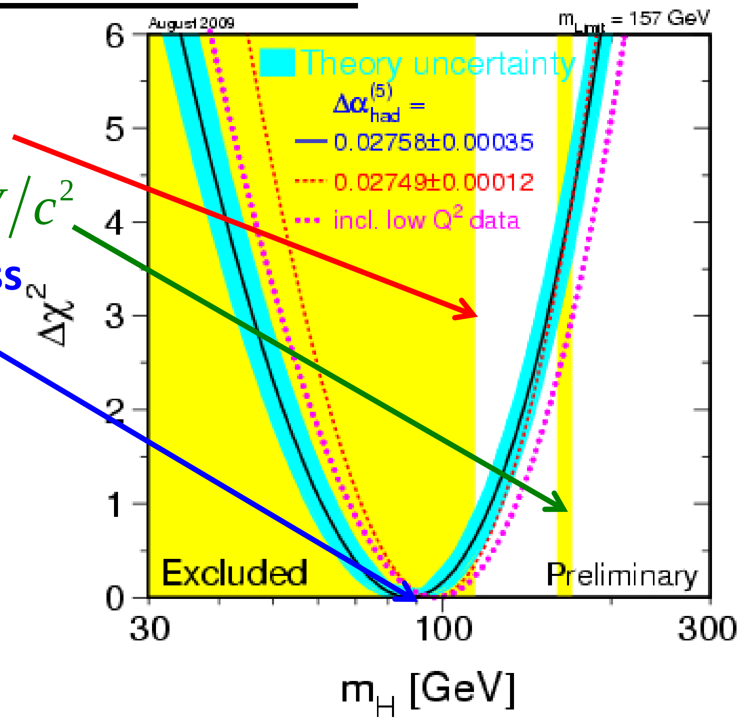
Why $WH \to l\nu b\bar{b}$ channel?

Current constraint on the SM Higgs

- LEP II direct search exclusion $M_H < 114.4\,GeV/c^2$
- Tevatron direct search exclusion $163 < M_H < 166\,GeV/c^2$
- Precision measurement of W boson and top quark mass

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

→ **Current results imply fairly light Higgs boson!!**



Low mass Higgs Search $M_H < 135\,GeV/c^2$

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

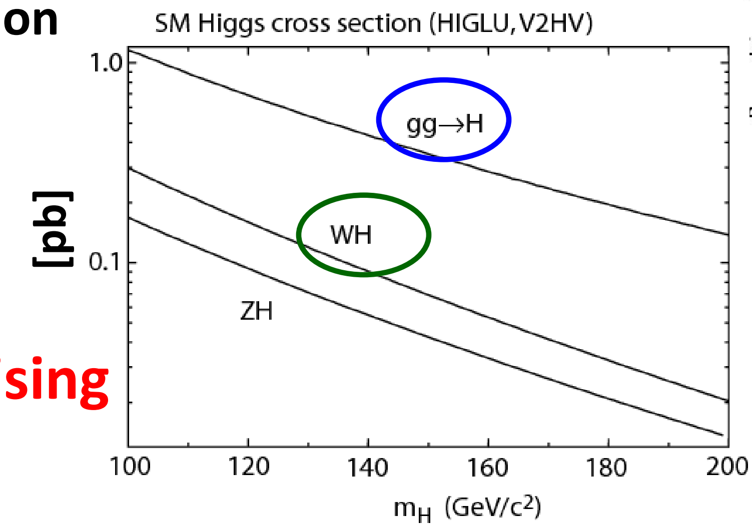
gg→H: Highest cross section

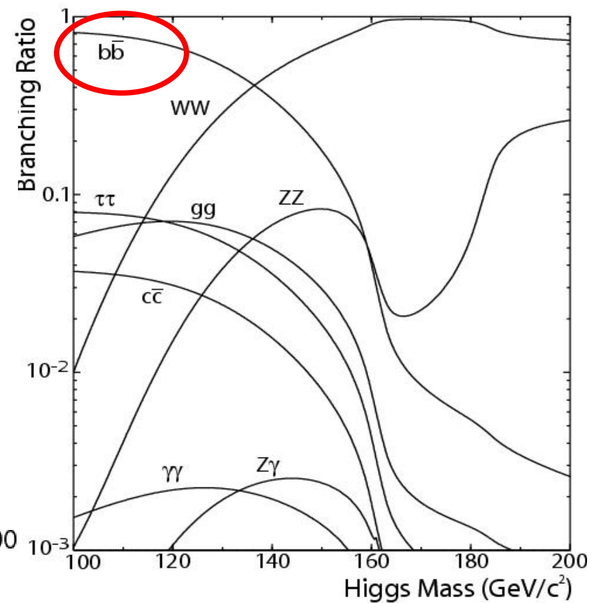
Huge QCD background

qq→WH: 2nd highest

W leptonic decay

→ one of most promising channel in low mass





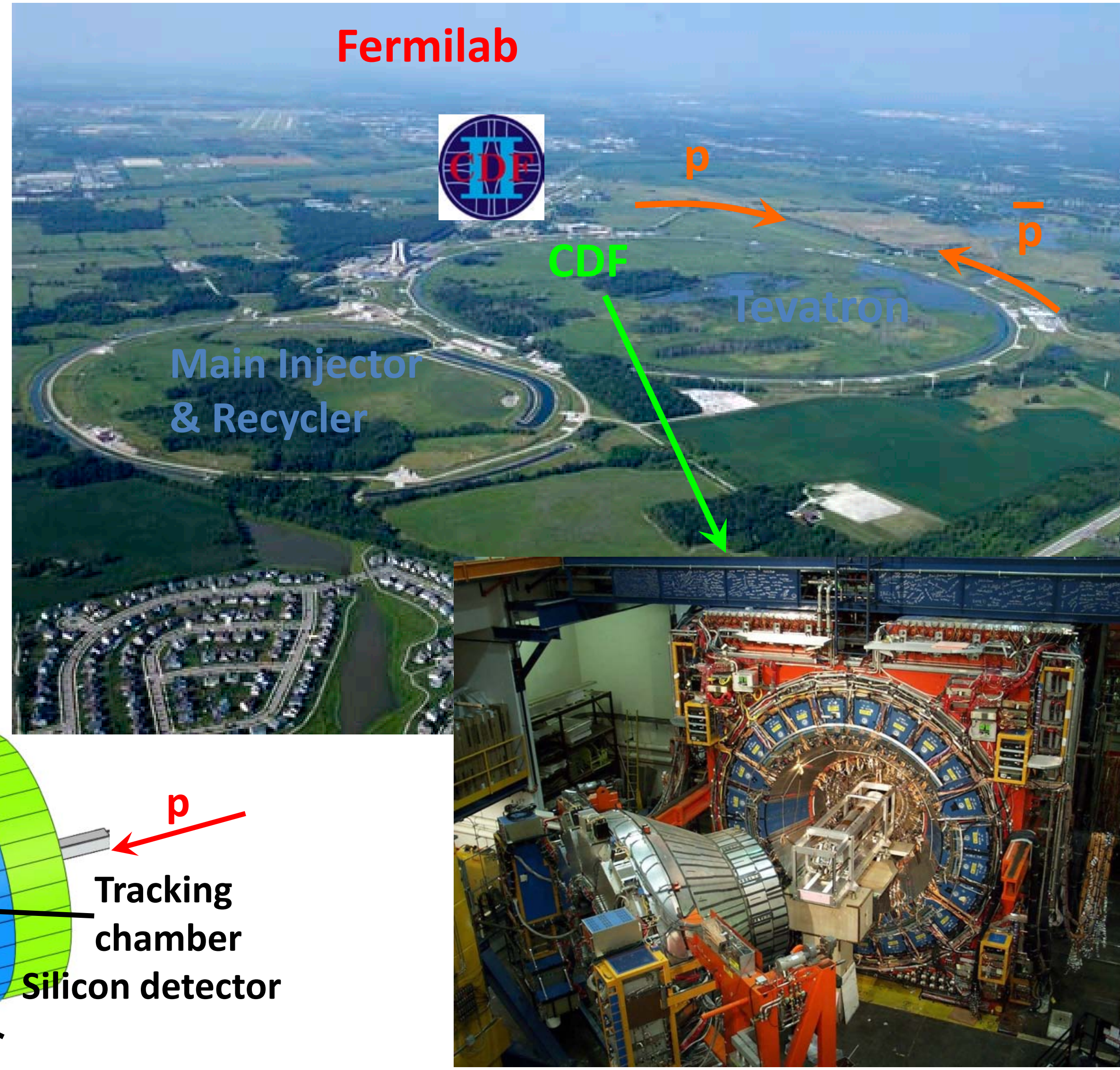
Tevatron and CDF

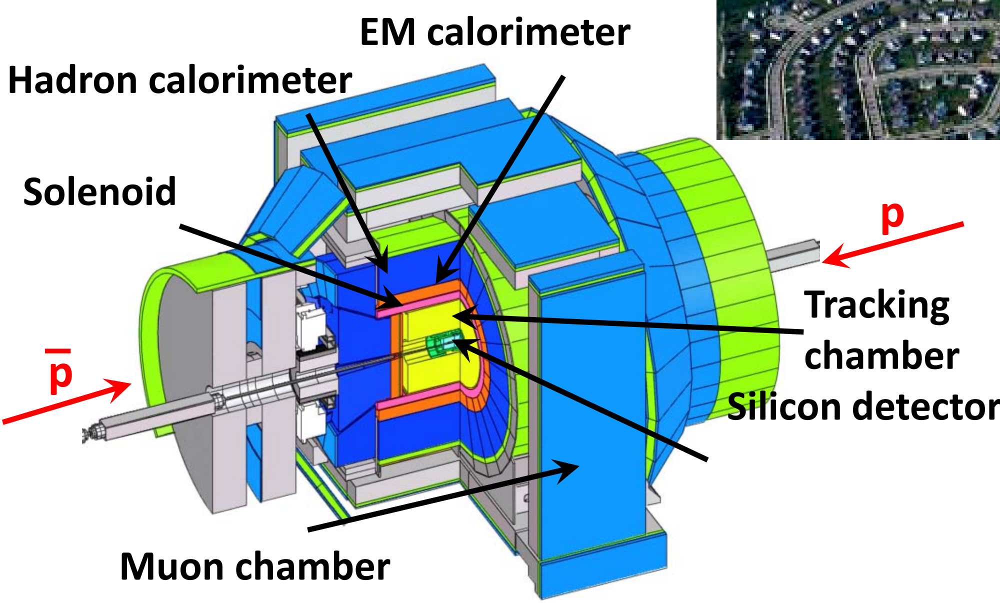
Tevatron

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

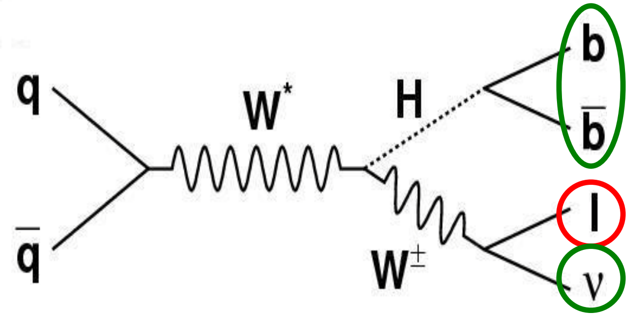
CDF

- One of the general purpose detector
- Currently **> 6.0 fb^{-1}** data on tape. For this analysis, we use **4.3 fb^{-1}** data.





Event selection



Event trigger

- Central electron/muon (CENTRAL)
- Forward electron (FORWARD)
- Missing E_T + 2jets or Missing E_T (MET)

} **3 exclusive trigger categories**

Baseline selection

- High p_T electron, muon or isolated track (P_T > 20GeV)
- Large missing E_T (*MET* > 20 GeV , > 25 GeV for FORWARD)

} ***W* boson selection**

- Exactly two high E_T jets (E_T > 20 GeV)

} ***W* + 2jets selection**

- At least one *b*-tagged jet

***b* flavor tagging**

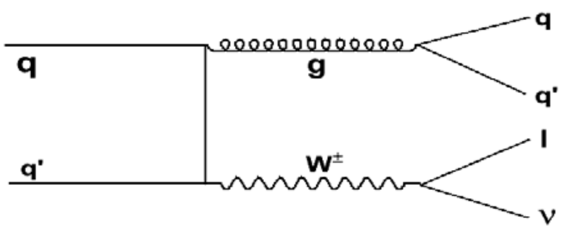
Use 3 *b* flavor tagging algorithms: SECVTX, JETPROB, and Neural Network

b-tagging is very important to improve S/B

Main background: W+jets

S/B ~1/5000 (no b-tag requirement)

S/B ~1/100 (2-SECVTX tagged jet)

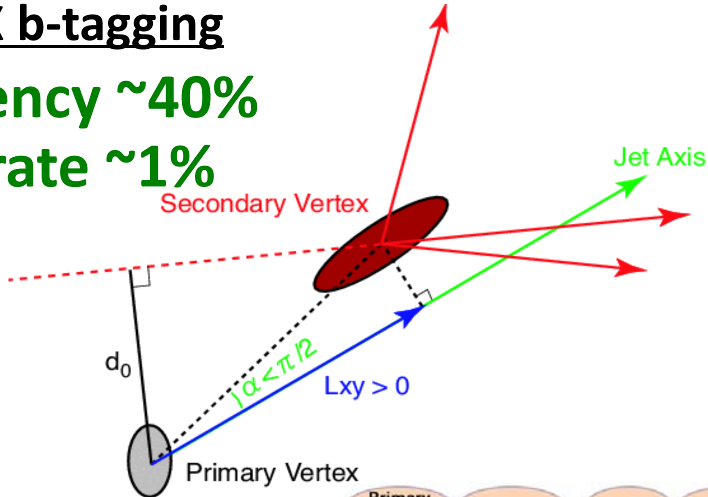


b-tagging algorithm

SECVTX b-tagging

Efficiency ~40%

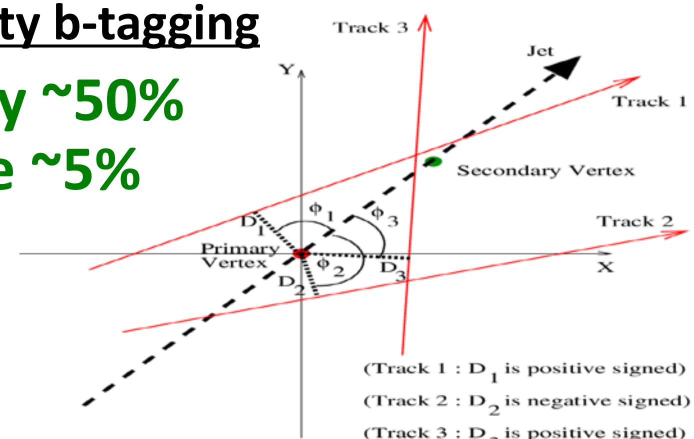
Fake rate ~1%



Jet Probability b-tagging

Efficiency ~50%

Fake rate ~5%



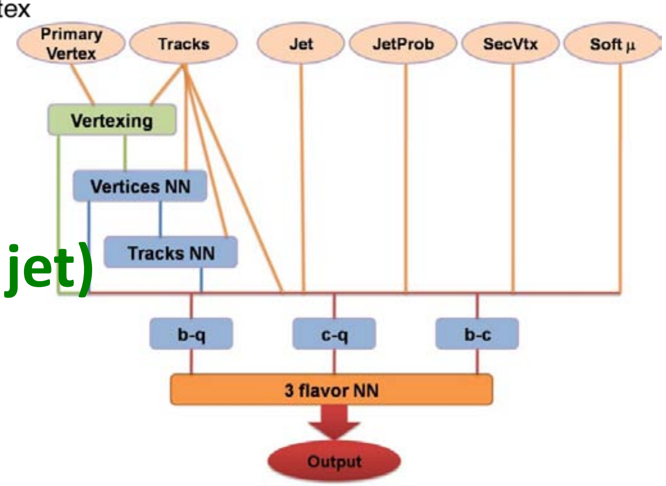
NN b-tagging

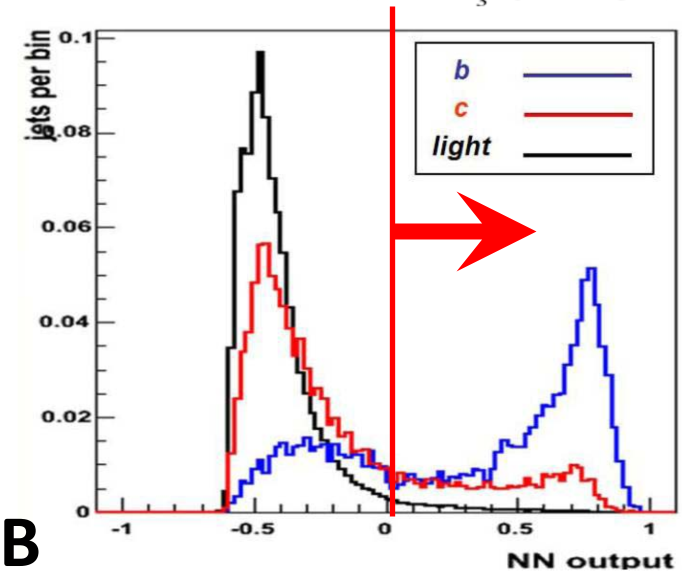
Efficiency

~ 40% (non-muon jet)

~ 75% (muon jet)

Fake rate 5-10%





- Require at least one-SECVTX tagged jet

Double SECVTX Tight tagged (ST+ST)

One SECVTX Tight + One JetProb (5%) (ST+JP)

One SECVTX Tight + One NN (ST+NN)

One SECVTX Tight tagged (1-ST)

S/B

high

low

4 exclusive *b*-tagging categories

Background Estimation

- **QCD multi-jets fake events (non-W QCD)**
- **W + light flavor events (falsely tagged jet, Mistag)**

Estimated from Data

- **W + heavy flavor events (W+bb, W+cc, W+c)**

Estimated from Data and MC

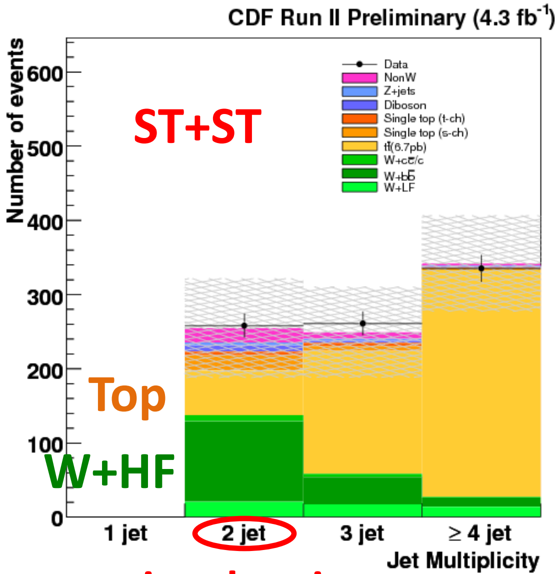
- **Top events (tt, single-top)**
- **Diboson events (WW, WZ, ZZ)**
- **Z + jets events**

Estimated from MC using theoretical cross section

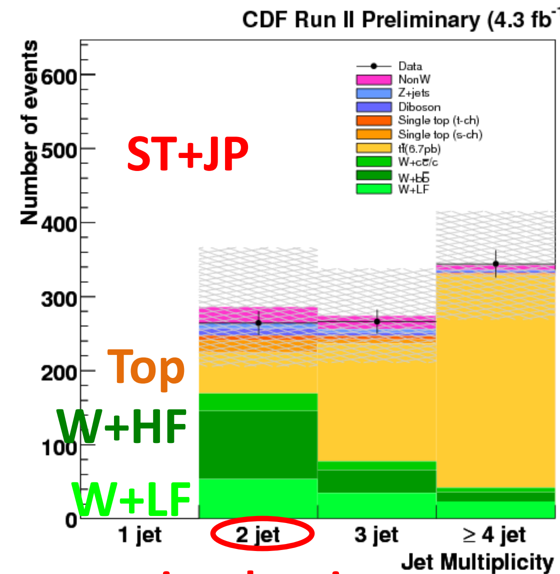
WW	12.4 +/- 0.25 pb
WZ	3.96 +/- 0.06 pb
ZZ	1.58 +/- 0.05 pb
stop-s	0.88 +/- 0.11 pb
stop-t	1.98 +/- 0.25 pb
Z + jets	787.4 +/- 50.0 pb
tt	6.7 +/- 0.9 pb

WH (H->bb, 115GeV) 0.136 pb

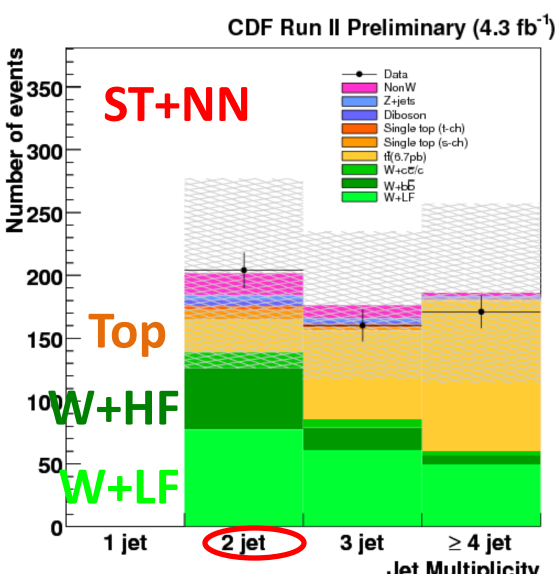
Background Estimation



signal region



signal region



signal region

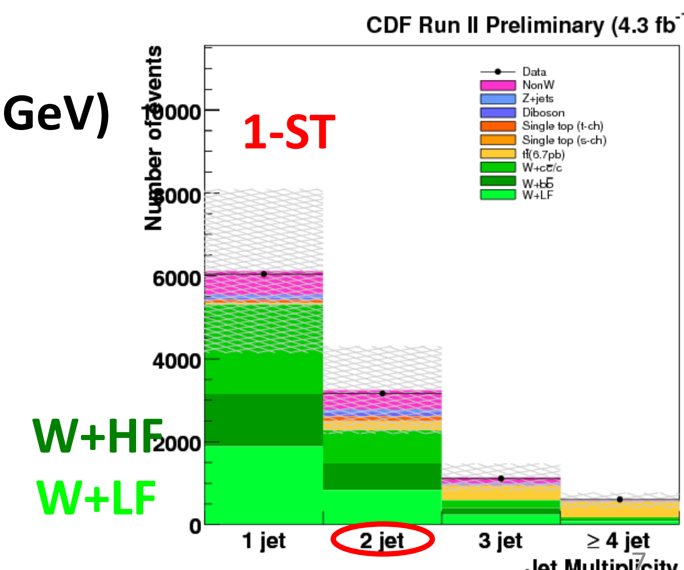
Expected signal (M_H = 115GeV)

3.21 (ST+ST)

2.62 (ST+JP)

1.22 (ST+NN)

6.62 (1-ST)



signal region

Analysis Optimization

– Neural network b-jet energy correction

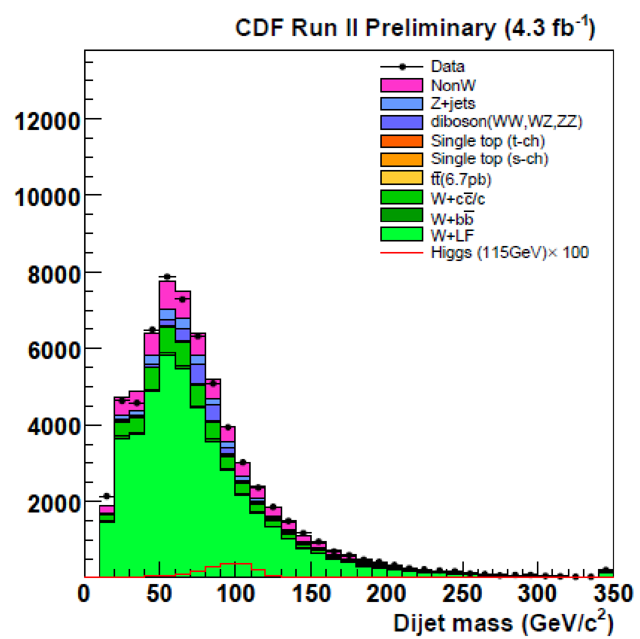
→ **Improve di-jet invariant mass resolution**

– Bayesian neural network discriminant

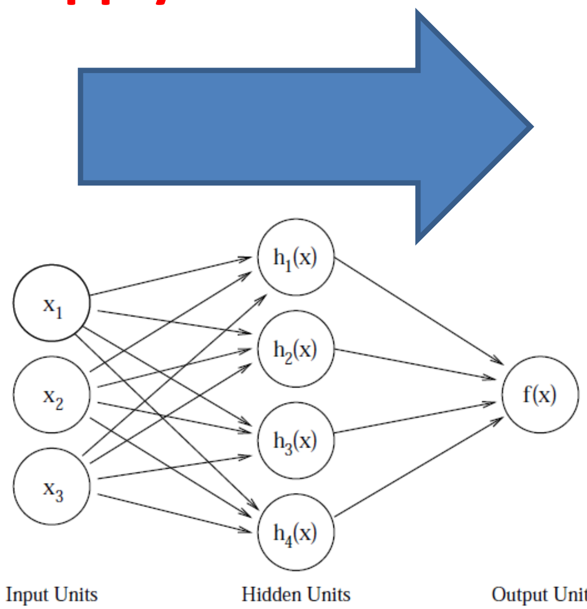
→ **Improve signal-background separation**

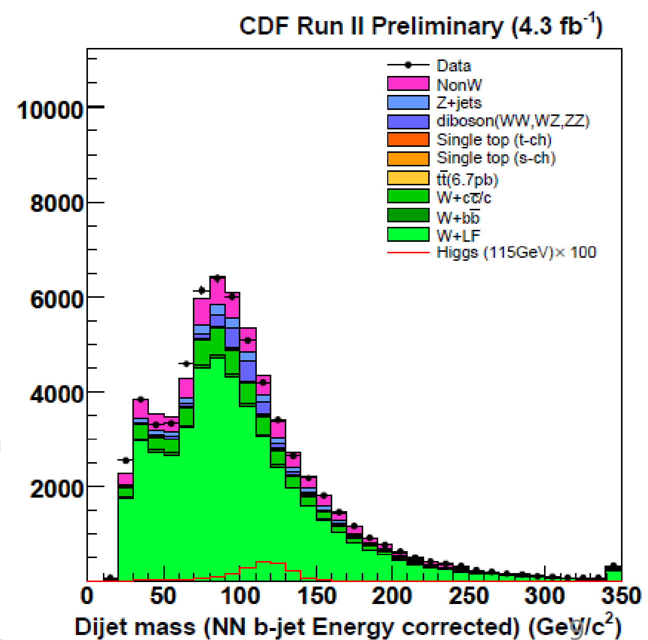
b-jet energy correction

- Di-jet invariant mass is the most sensitive variable in WH->lνbb
- We develop Neural Network b-jet energy correction method
- We use 8 input variables (Jet E_T , L_{XY} , Track p_T , etc …)



Apply NN correction





- Di-jet invariant mass resolution is improved **~4%**

Bayesian Neural Network (BNN)

- Separately train “ST+ST”, “ST+JP & ST+NN”, “1-ST”

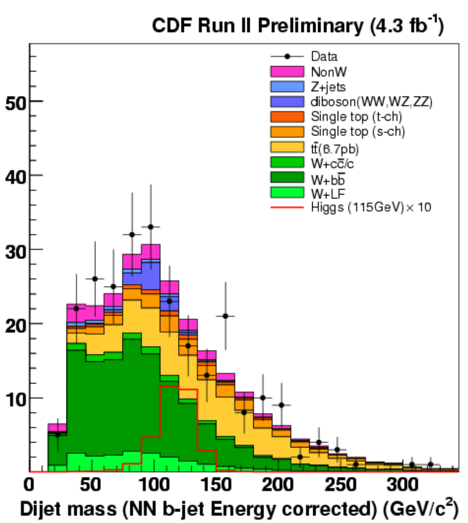
Input(ST+ST): M_{jj}, PtImbal, max($M_{l\nu j}$), $Qx\eta_{lep}$, Σ(LooseJetEt), Pt(W), Ht — 7 input

Input(ST+JP): M_{jj}, Σ(LooseJetEt), $Qx\eta_{lep}$, min($M_{l\nu j}$), Ht, Pt(W), Met — 7 input

Input(1-ST): M_{jj}, Σ(LooseJetEt), $Qx\eta_{lep}$, Pt(W), Ht, Met, PtImbal — 7 input

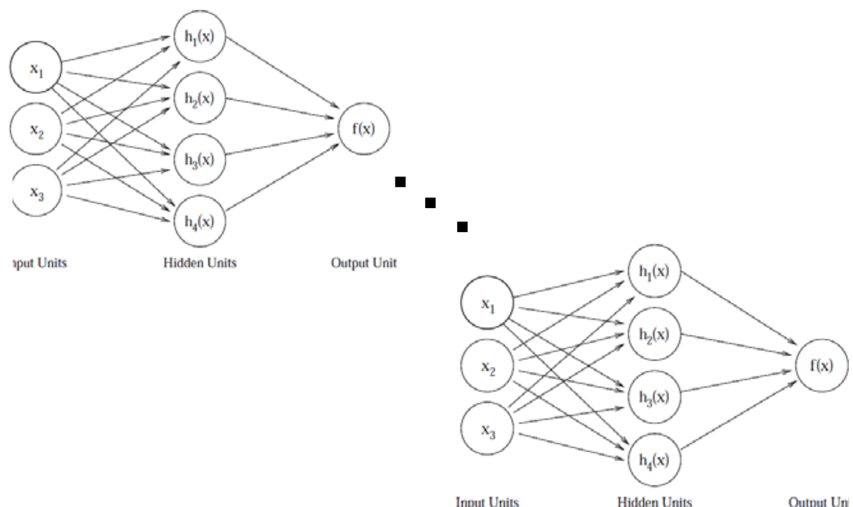
PtImbal: $p_T(j1) + p_T(j2) + p_T(l) - MET$ **Ht**: $p_T(j1) + p_T(j2) + p_T(l) + MET$

BNN inputs



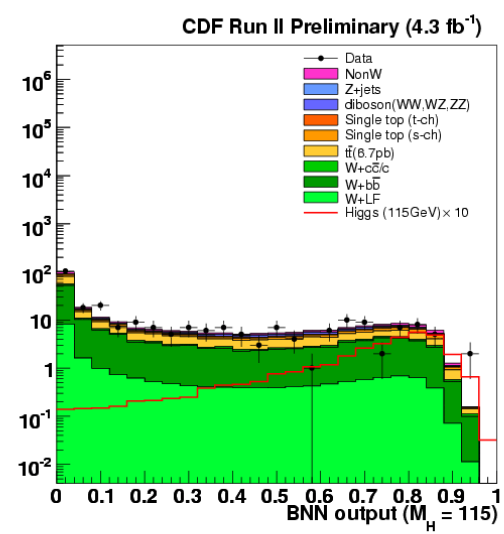
\+

Other 6 input variables

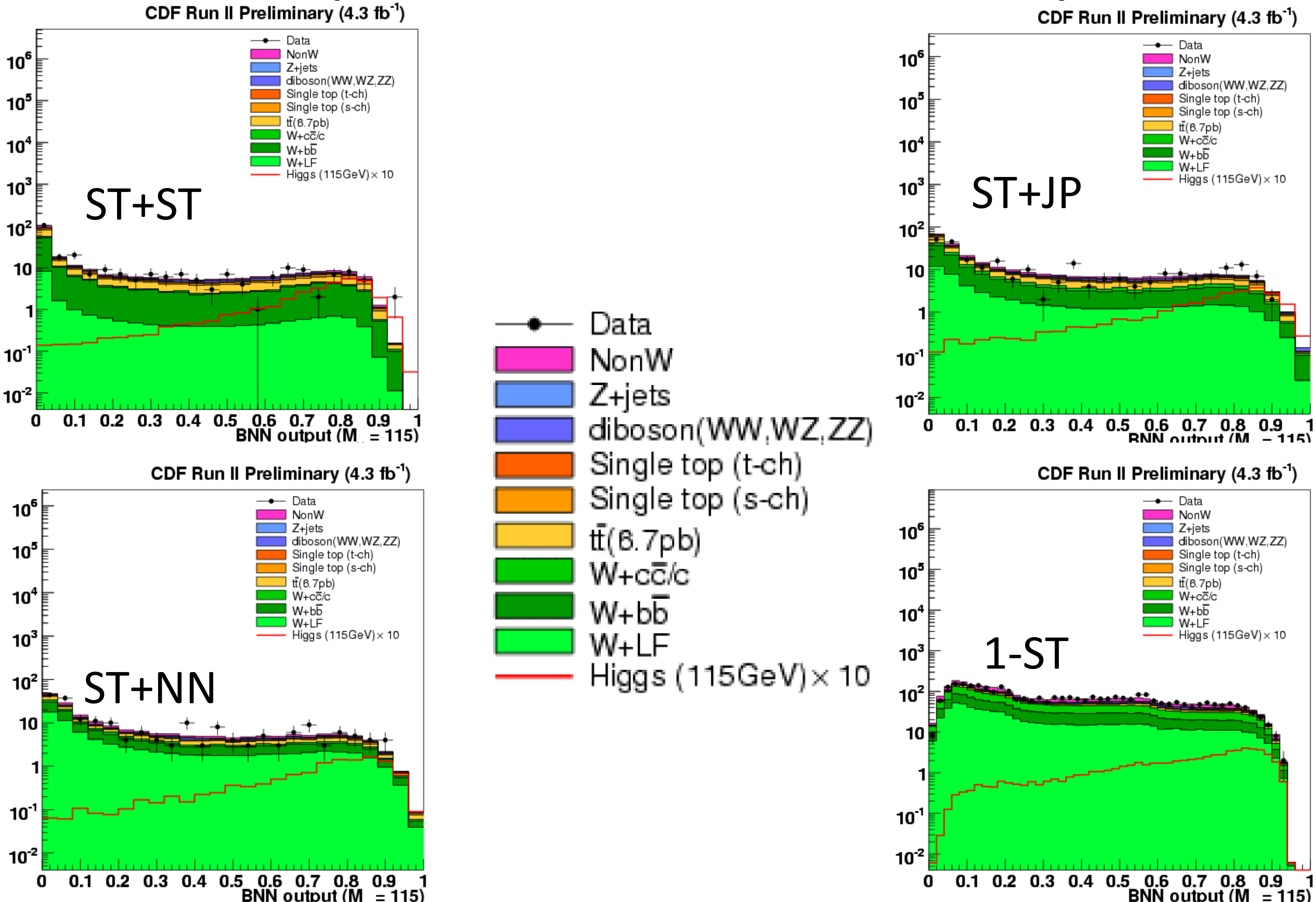


Bayesian Neural Network

BNN output



All lepton combined BNN output

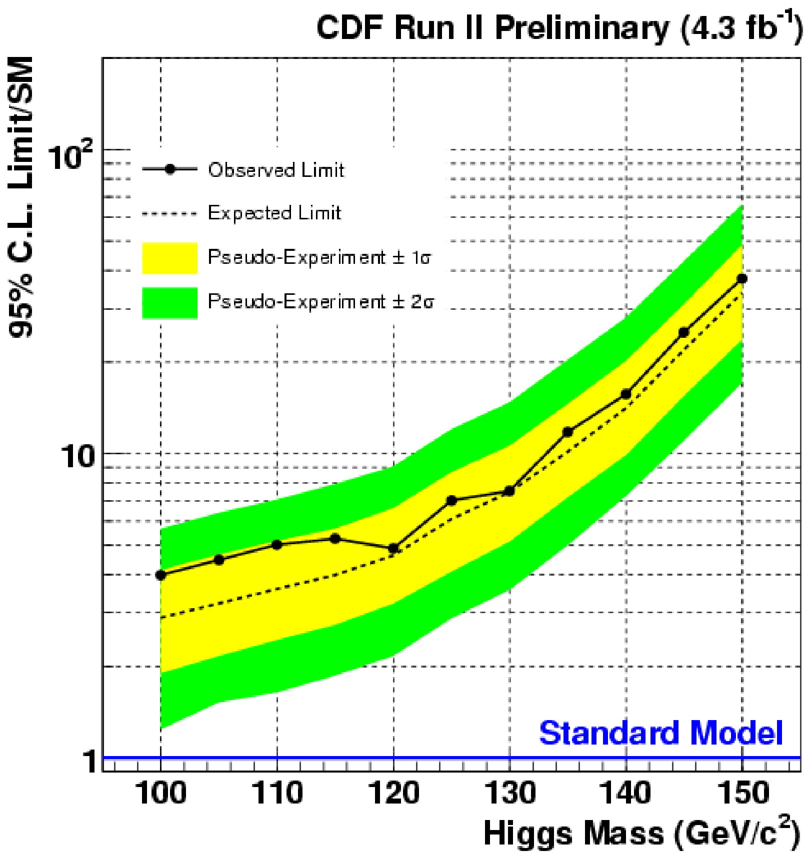


No significant excess in BNN output distribution

→ Set upper limit on Higgs boson production cross section

Final result

- We set σ(pp->WH) x Br(H->bb) upper limit using BNN output (binned likelihood)



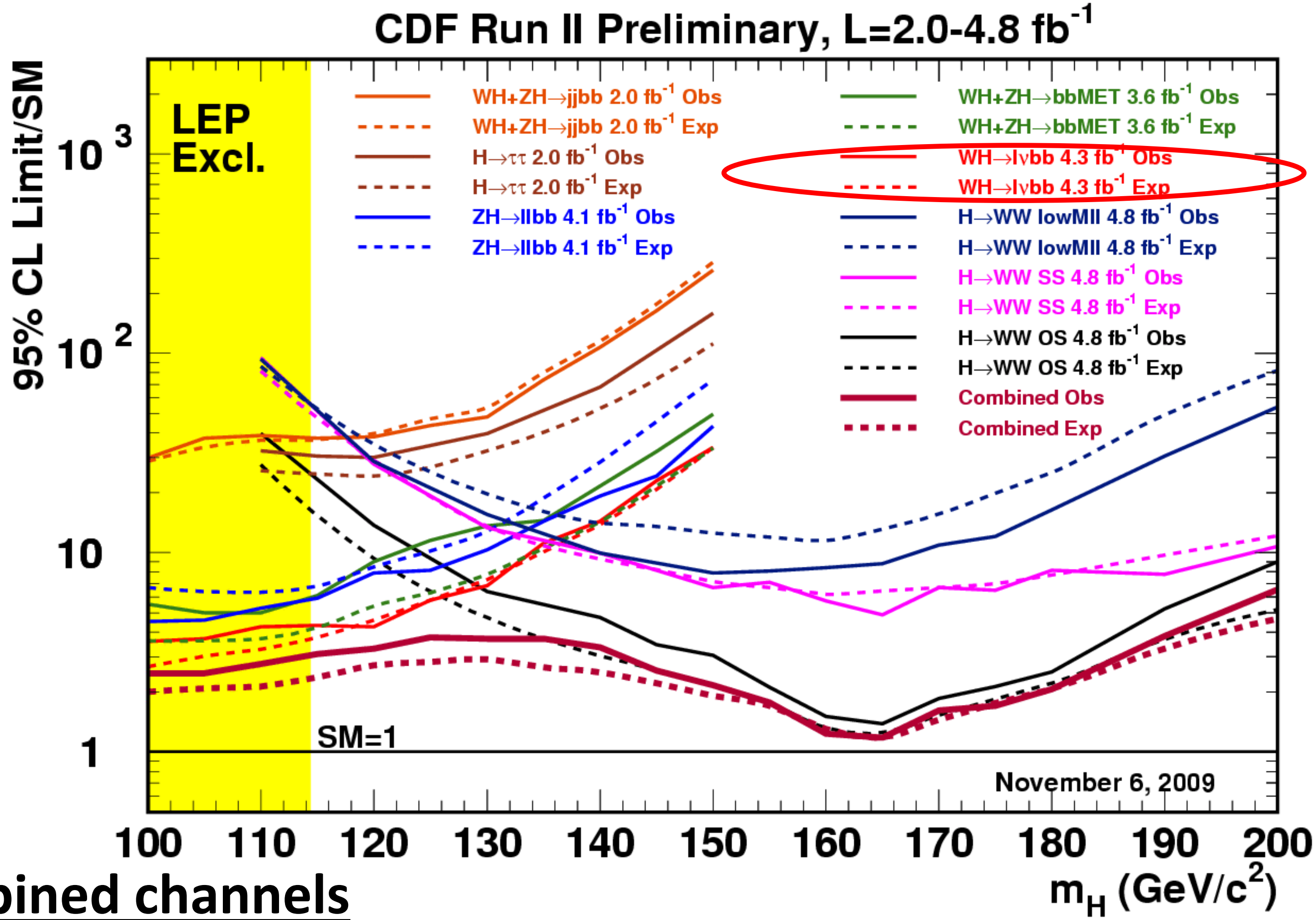
m_H (GeV/c^2)	Observed Limit	Expected Limit
100	0.96 (3.98)	0.67 (2.78)
105	0.90 (4.47)	0.63 (3.12)
110	0.83 (5.01)	0.58 (3.48)
115	0.72 (5.26)	0.54 (3.98)
120	0.53 (4.88)	0.50 (4.62)
125	0.59 (7.01)	0.50 (5.99)
130	0.47 (7.53)	0.46 (7.36)
135	0.54 (11.8)	0.45 (10.1)
140	0.49 (15.7)	0.44 (14.1)
145	0.51 (25.0)	0.44 (21.8)
150	0.46 (37.6)	0.41 (33.7)

absolute upper limit in [pb]
(normalized to SM expectation)

Observed (Expected) upper limit @ m_H = 115 GeV/c^2

5.26 (3.98) x σ(Standard Model)

CDF Combination

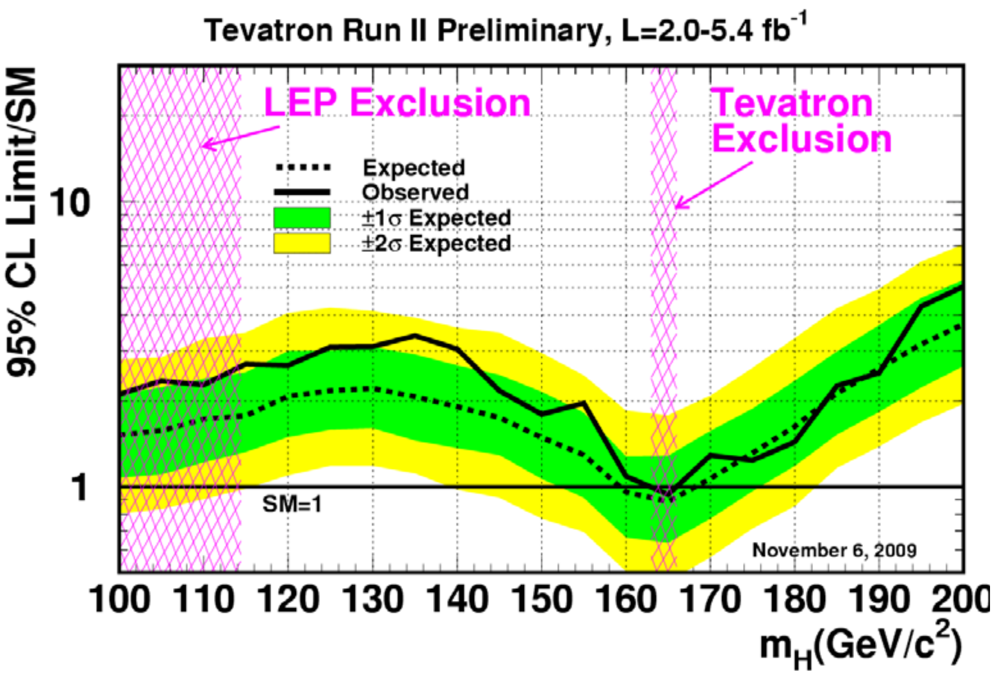


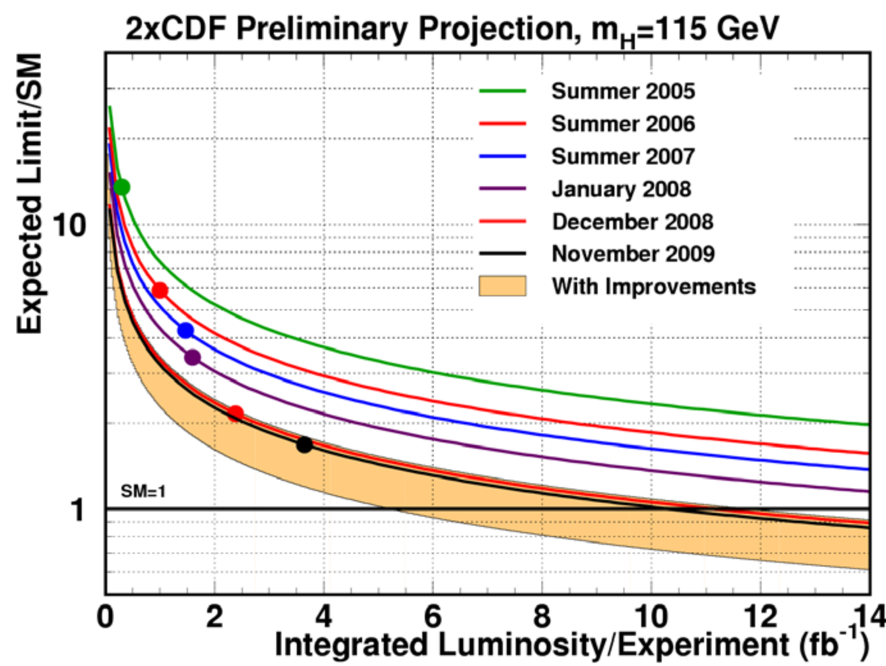
Combined channels

WH->lνbb, WH+ZH->MET+bb, ZH->llbb, H->WW->lνlν

WH+ZH->jjbb, H->ττ + 2jets

Tevatron Combination and Future





- M_H = 163 – 166 GeV/c^2 is excluded at the 95% C.L.
- Observed (expected) upper limit @ 115 GeV/c^2: 2.7 (1.8) x SM
- Observed (expected) upper limit @ 165 GeV/c^2: 0.9 (0.9) x SM
- Tevatron plan to run through 2010 -> expected > 8/fb of data
- We can reach to the SM sensitivity even at the M_H = 115 GeV/c^2

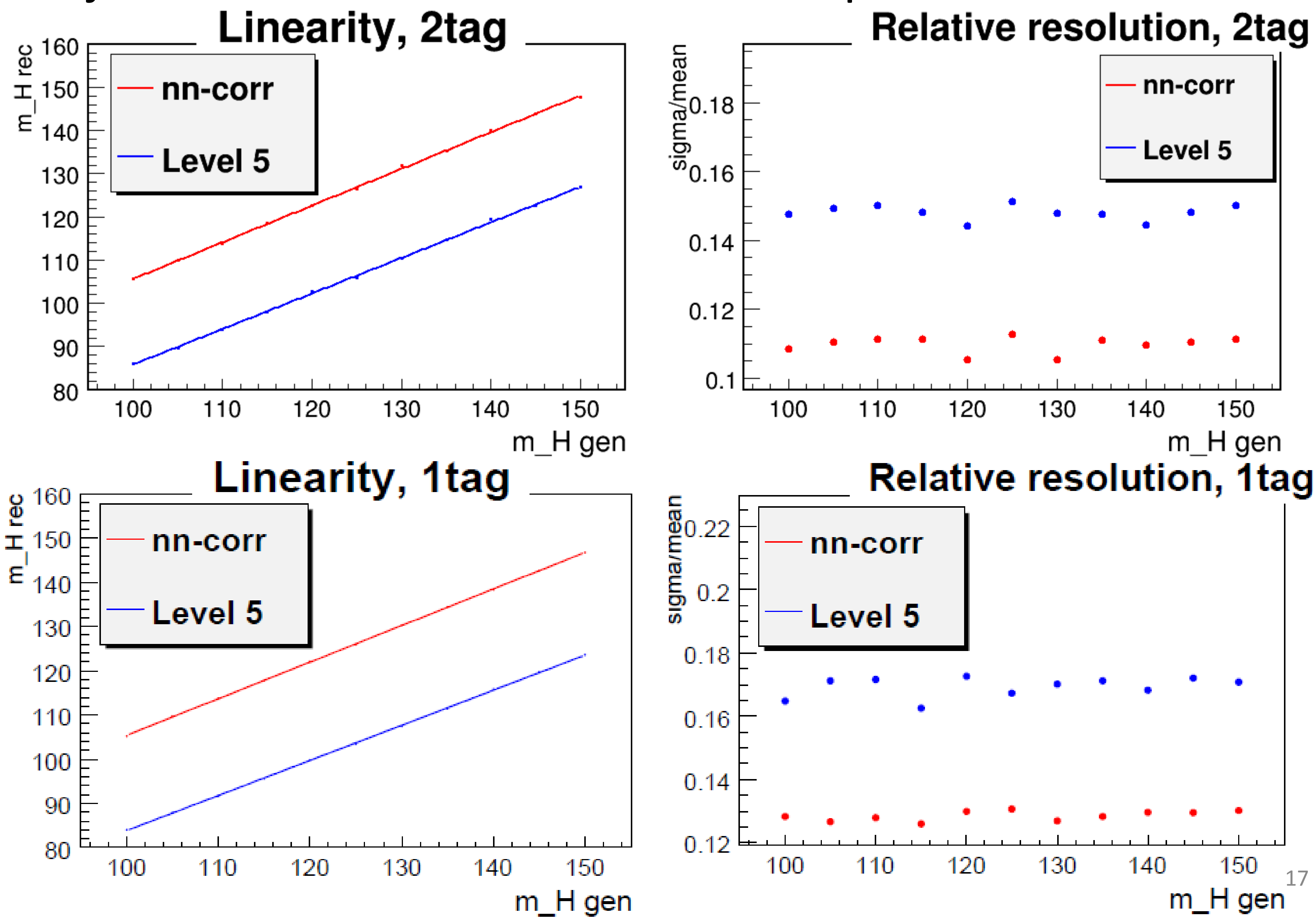
Summary

- We search for the Higgs boson in the WH->lνbb channel using 4.3/fb of data
  - ➢ Employ 3 b-tagging algorithm
  - ➢ Develop NN b-jet energy correction method
  - ➢ Develop Neural Network discriminant (BNN)
- No evidence of the Higgs boson signal
  - ➢ We set the 95% C.L. limit 3.98 – 37.6 x σ(SM) for 100 – 150 GeV
- Tevatron can reach the Standard Model sensitivity with > 8/fb of data, even at the low mass region.

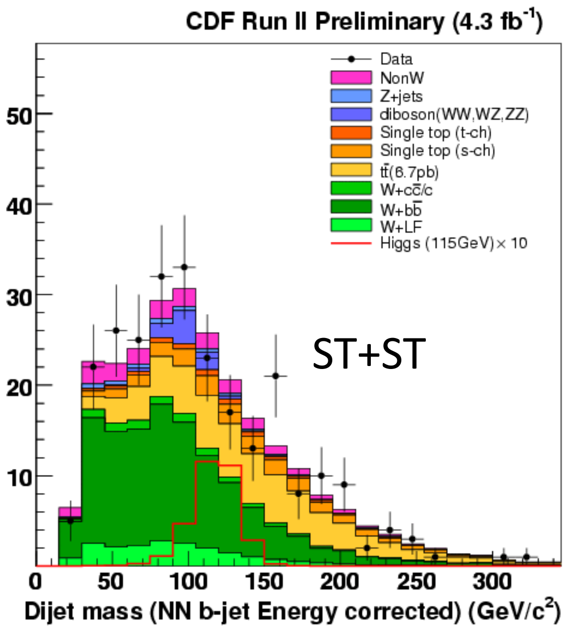
Backup

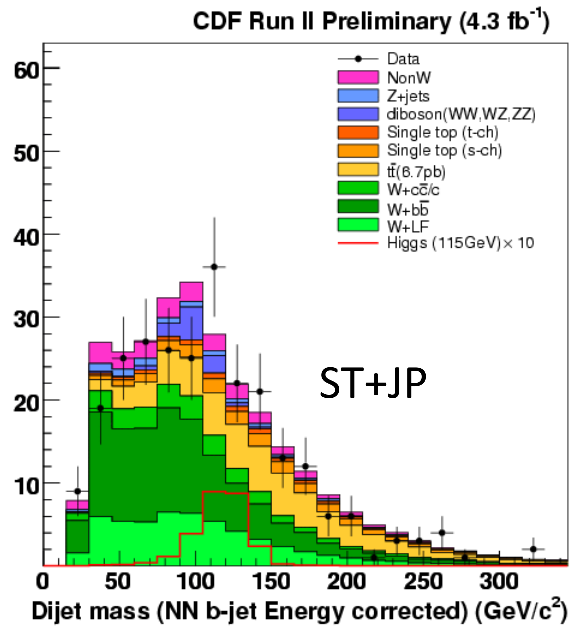
b-jet energy correction

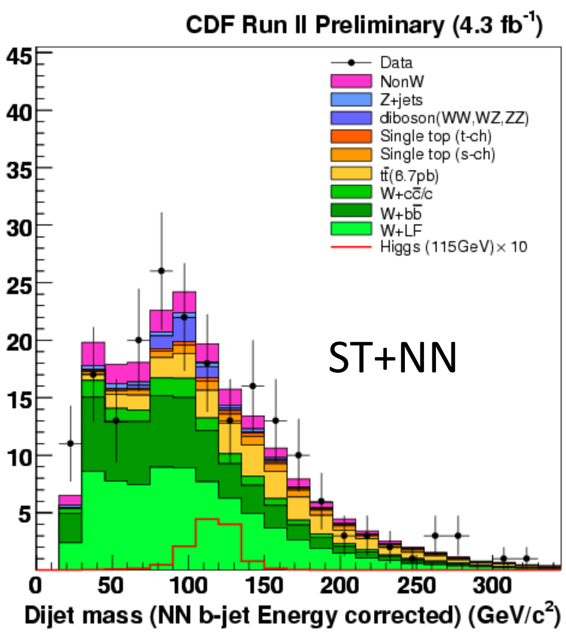
- Di-jet invariant mass resolution is improved **~4%**

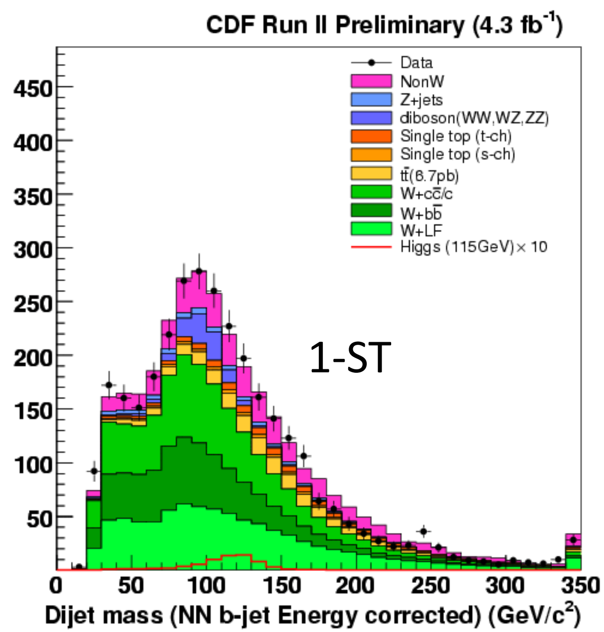


Dijet Mass Distribution with NN *b*-jet Energy Correction

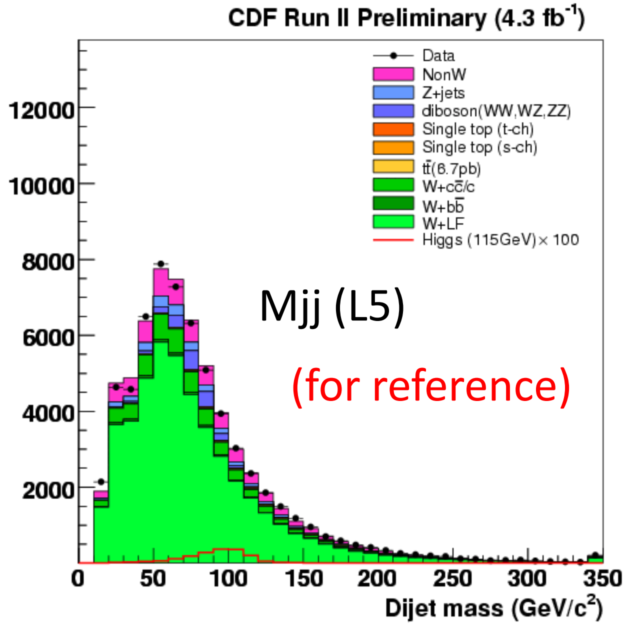


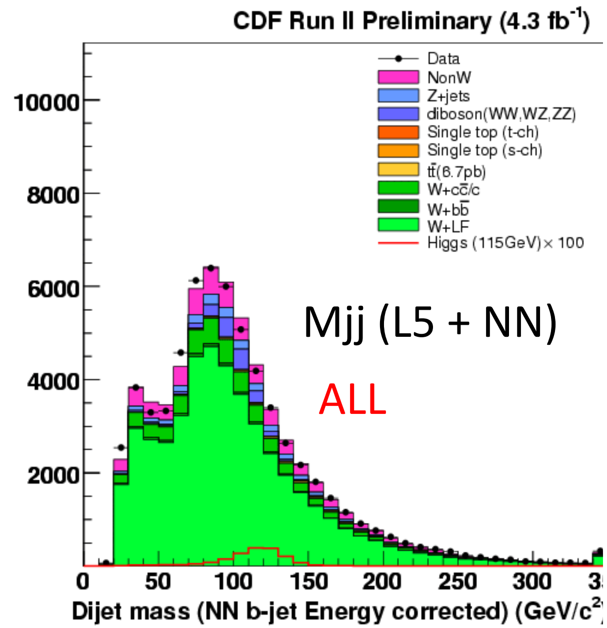


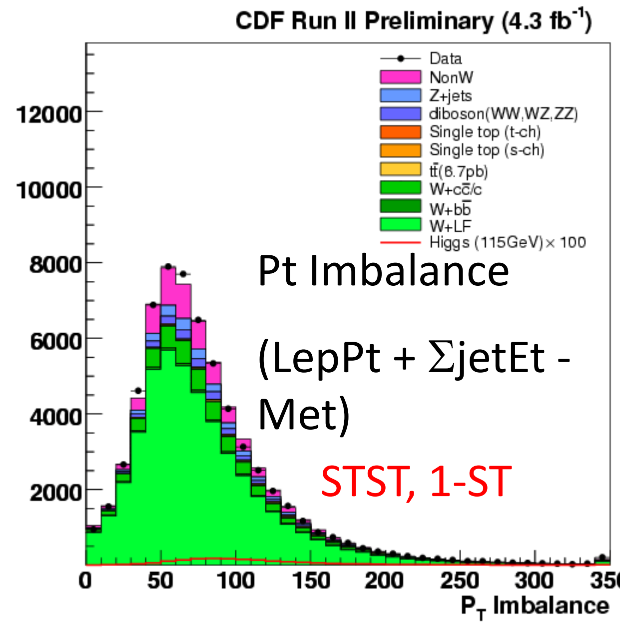


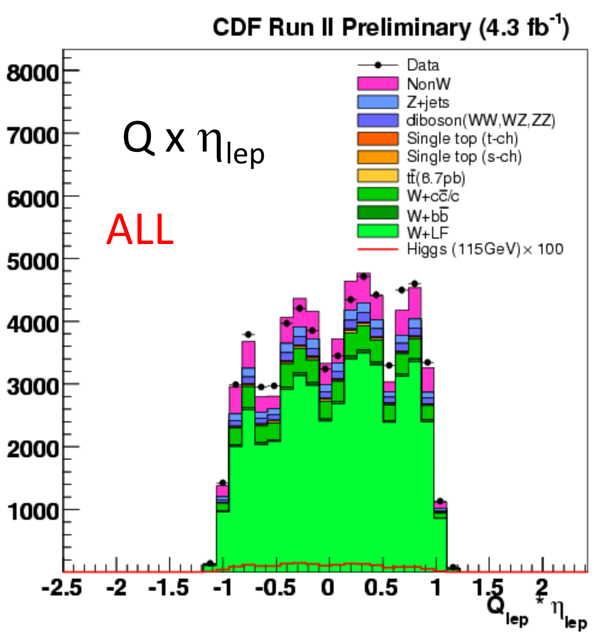


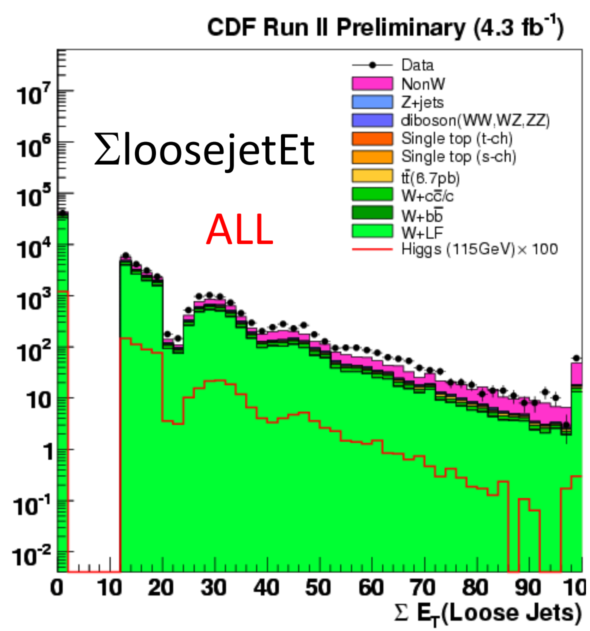
BNN input variables (Pretag)

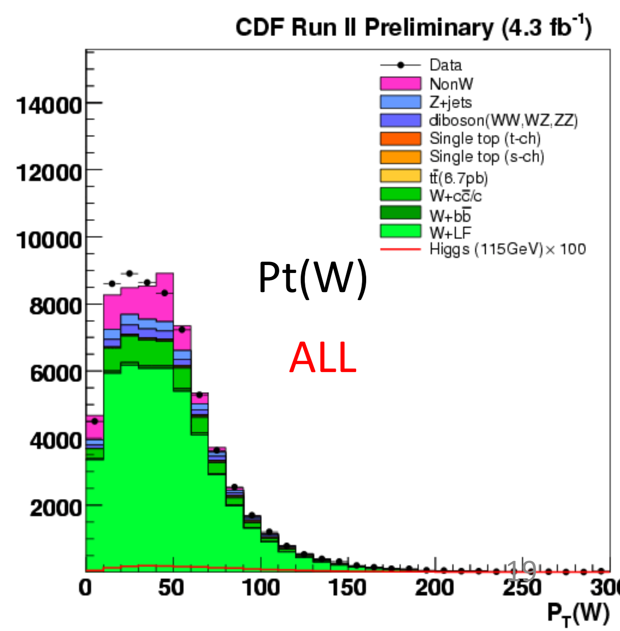




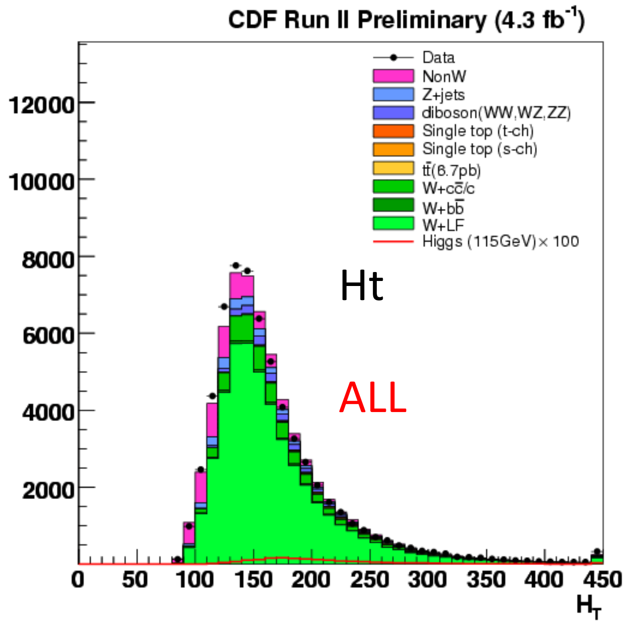


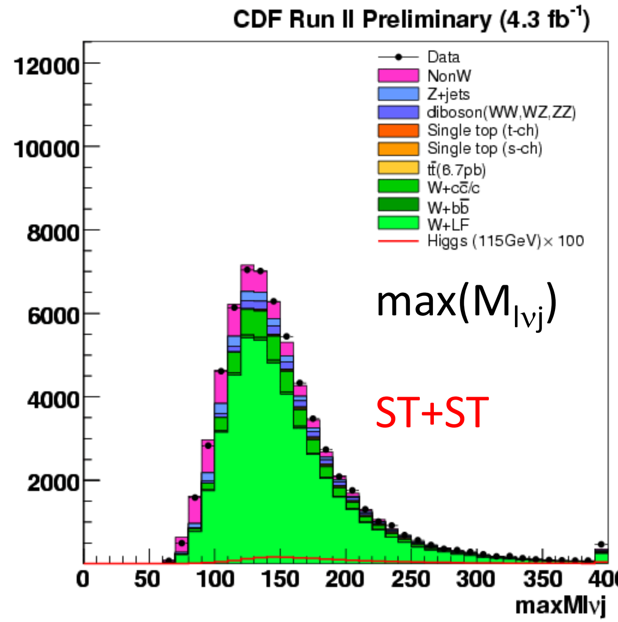


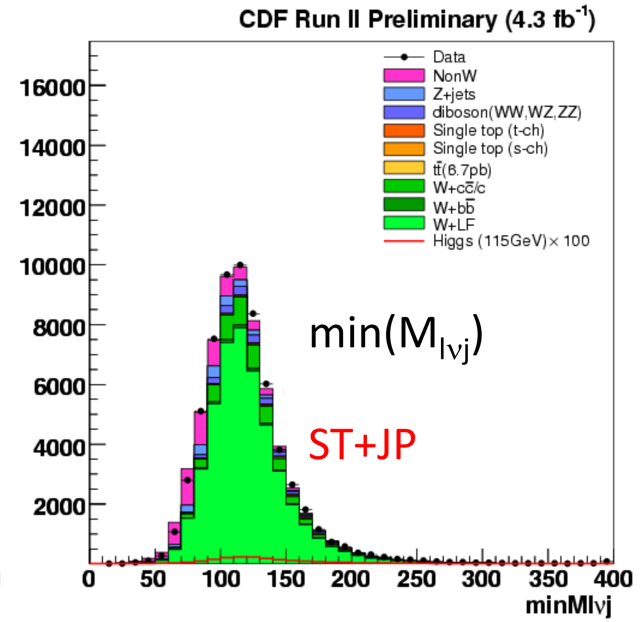


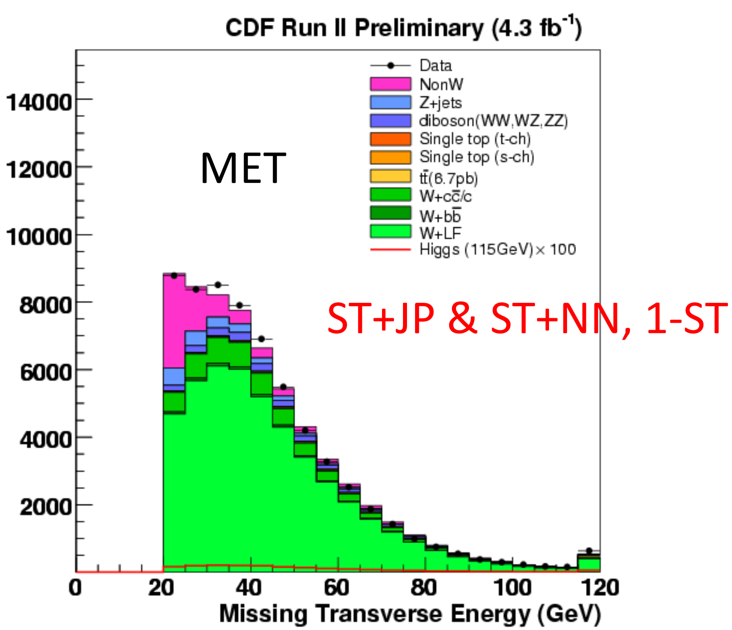


BNN input variables (Pretag)

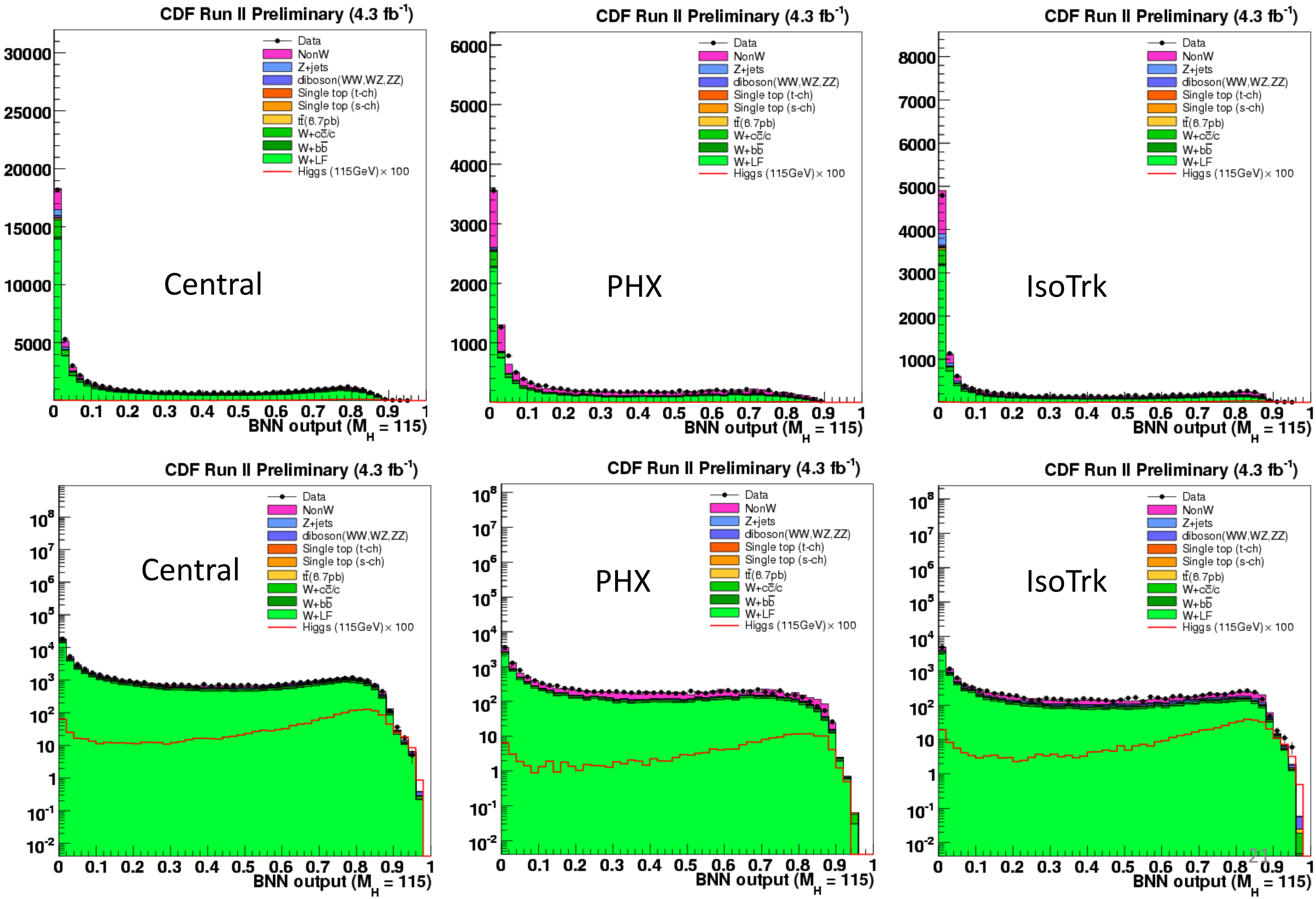






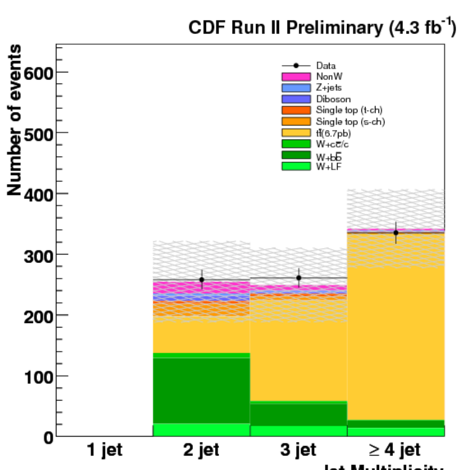


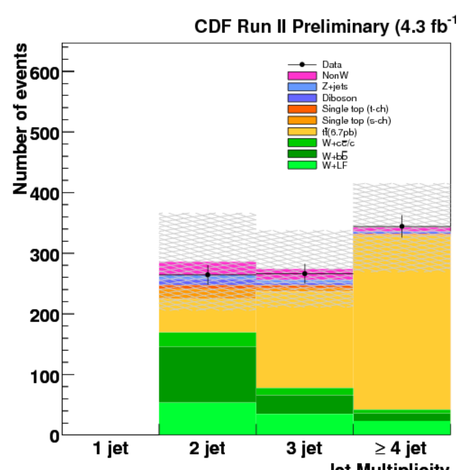
Pretag BNN outputs

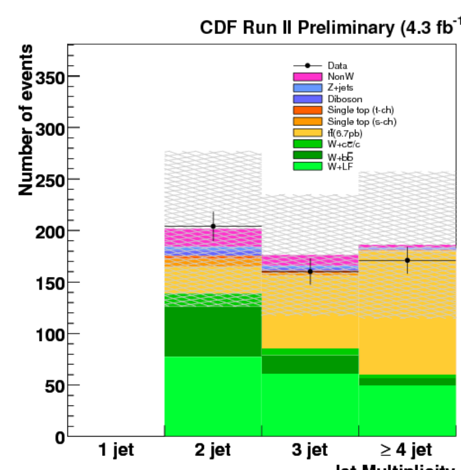


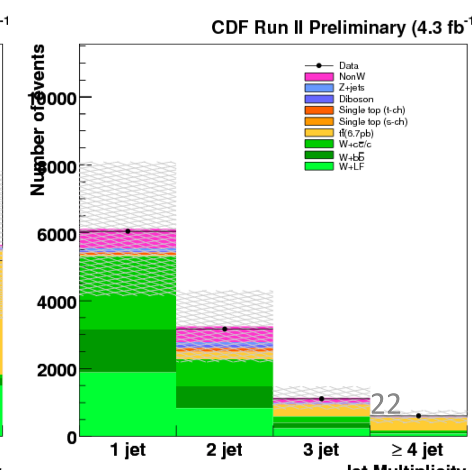
Background Estimation

Njet	2jet	2jet	2jet	2jet
Pretag Events	91437	91437	91437	91437
Mistag	20.45 ± 8.85	53.08 ± 23.13	77.43 ± 33.45	834.67 ± 361.78
$Wb\bar{b}$	108.52 ± 32.50	92.25 ± 28.66	48.62 ± 22.77	643.81 ± 196.82
$Wc\bar{c}/c$	8.27 ± 2.42	23.61 ± 7.38	12.46 ± 4.57	791.92 ± 348.03
$t\bar{t}$(6.7pb)	60.13 ± 9.15	55.17 ± 8.41	25.81 ± 4.55	195.03 ± 28.41
Single top(s-ch)	20.52 ± 3.14	17.02 ± 2.61	8.06 ± 1.42	42.16 ± 6.18
Single top(t-ch)	5.09 ± 0.79	6.12 ± 0.95	2.96 ± 0.53	97.01 ± 14.31
WW	0.41 ± 0.04	2.82 ± 0.26	1.86 ± 0.24	84.53 ± 6.61
WZ	7.62 ± 0.69	6.51 ± 0.60	3.22 ± 0.41	26.93 ± 2.09
ZZ	0.24 ± 0.02	0.25 ± 0.03	0.14 ± 0.02	0.96 ± 0.09
$Z + jets$	4.09 ± 0.57	7.16 ± 1.00	3.39 ± 0.56	62.68 ± 8.31
non-W QCD	19.24 ± 8.48	21.81 ± 7.28	17.65 ± 6.77	464.89 ± 82.36
Total background	254.58 ± 66.65	285.79 ± 80.31	201.59 ± 75.29	3244.60 ± 1054.98
WH (115 GeV)	3.21	2.62	1.22	6.62
Observed Events	258	264	204	3160









Event Selection (Baseline)

CEM,CMUP,CMX (4.3/fb)

- High p_T lepton triggered electron/muon (Pt > 20GeV)
- Large missing Et (MET > 20GeV)
- Di-lepton veto, Z veto
- QCD veto (0-tag/1-tag)
- Jets Et > 20 GeV, $|\eta| < 2.0$

PHX (4.3/fb)

- MET15_PEM20 triggered electron (Pt > 20GeV)
- Large missing Et (MET > 25GeV)
- Di-lepton veto, Z veto
- QCD veto (all events)
- Jets Et > 20 GeV, $|\eta| < 2.0$

IsoTrk (MET2J (3.9/fb), MET45 (4.2/fb))

- MET trigger fired (details shown later)
- One isolated track (Pt > 20GeV)
- Large missing Et (MET > 20GeV)
- Di-lepton veto, Z veto
- Tight lepton veto, Two track veto
- Tight jet veto (tracks not in $\Delta R < 0.4$)
- QCD veto (0-tag/1-tag)

MET2J only

- at least two jets with:

  Et > 25 GeV, $\Delta R(j1 - j2) > 1.0$

  one of two leading jets with $|\eta| < 0.9$

Lepton categories: Central, PHX, IsoTrk