Search for Standard Model Higgs Bosons Produced in Association with W Bosons at CDF Using Neural Networks

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Search for Low-Mass Higgs Boson

- Current Standard Model Higgs boson constraints
  - Experimental: $m_H > 114$ GeV/c^2 (LEP HZ searches)
  - Theoretical: $m_H < 144$ GeV/c^2 (global electroweak fits)
- One favorable low-mass channel is $WH \rightarrow l\nu bb$
- Previous Tevatron results published: with 0.3 fb^{-1}
  - PRL with 0.3fb-1: Observed limits on σ x Br ranged from 7-10 pb
  - PRL/PRD with 1 fb^-1: Observed limits ranged from 1.3-3.9 pb
- Keys to the analysis:
  - Extended the btag categories: ST-ST, ST-JPB, ST+NN
  - Using an advanced multivariant techniques: NN
  - Extended the electron acceptance with the plug electron
- Updated to 1.9 fb^{-1} dataset with these improvements

Event Selection for Wbb

Running on bhel/bhmu 0d, 0h, 0i, 0j, streams: total 955 pb^{-1}

W boson

- Exactly one isolated e/μ with E_T>20 GeV
- Total missing E_T>20 (25) GeV for central (plug)

Jets

- Exactly two jets with E_T>15 GeV and |η|<2.0
- Divided events into: ST-ST, ST-JPB, and ST+NN

•Rejection of non-W events using QCD veto for the plug ele

Background Estimates

Based on “Method 2” W+jets background studies

W+heavy flavor (Wbb, Wcc)
- use ALPGEN HF fraction
- scale to observed W+jets
- HF calibration in jet data
- rescaling same as top group

W+light flavor (mistag jets)
- mistag rate from jet data
- asymmetry factor 1.37±0.13
- Gen6 correction 1.05±0.03

Non-W QCD multijet
- fake leptons and/or fake MET
- sideband extrapolation
- MET vs Iso method

Electroweak backgrounds
- single-top production
- WW/WZ boson production
- Z decays to τ pairs

Neural Network Tagging Variables

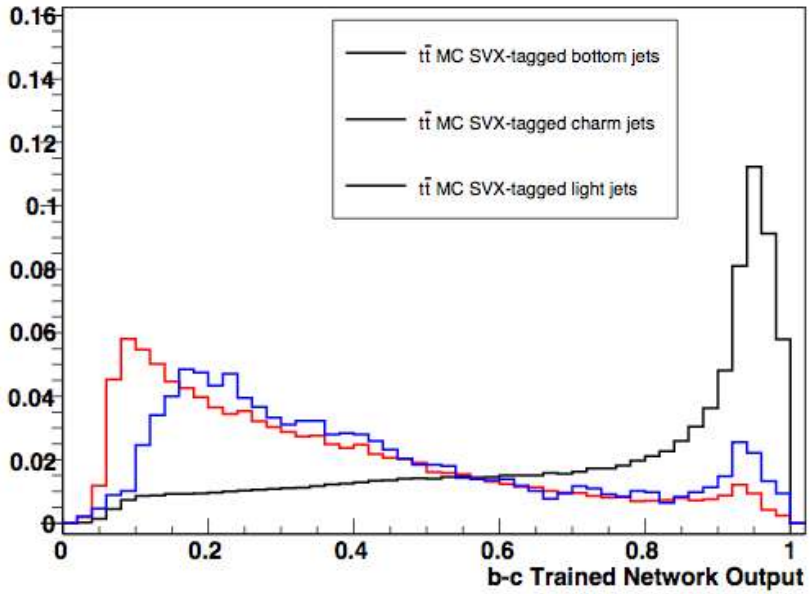
Even in SECVTX-tagged W+jets sample, significant contribution from Wc and Wcc processes, mistagged light-flavor jets

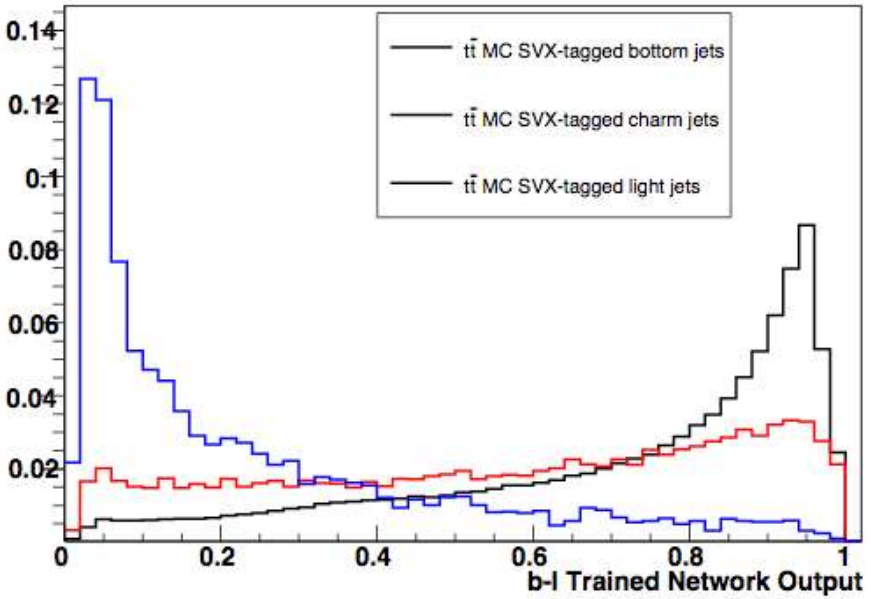
SECVTX variable	SECVTX-independent variable
Number of tracks in fitted vertex	Number of good tracks
Vertex fit χ^2	Jet Probability (JetProb)
Transverse decay length (L_{xy})	Reconstructed mass of pass 1 tracks
L_{xy} significance ($L_{xy}/\sigma_{L_{xy}}$)	Reconstructed mass of pass 2 tracks
Pseudo-$c\tau$ ($L_{xy} \times M_{\rm vtx}/p_T^{\rm vtx}$)	Number of pass 1 tracks
Vertex Mass ($\sqrt{(\sum \lvert p_{\rm vtx}\rvert)^2 - (\sum p_{\rm vtx})^2}$)	Number of pass 2 tracks
$p_T^{\rm vtx}/(\sum_{\rm good\ tracks} p_T)$	$\sum_{\rm Pass1\ track} p_T/p_T^{jet}$
Vertex pass number (pass 1 or 2)	$\sum_{\rm Pass2\ track} p_T/p_T^{jet}$

Train two different 14-input networks on MC jet samples:

- to separate b-quark jets and light-quark jets
- to separate b-quark jets and c-quark jets

Performance of NN b-tag filter





Cuts at 0.242, 0.182 give 90% b-tagging efficiency

Compare results in lepton-selected b-tagged jets (HF-enriched)

NN filter b-jet efficiency scale factor: 0.97±0.02
NN filter rejection factor: 0.65±0.05 (uds), 0.50 ±0.05 (c)

Background Rate Uncertainties

Dominant uncertainties for our different background types

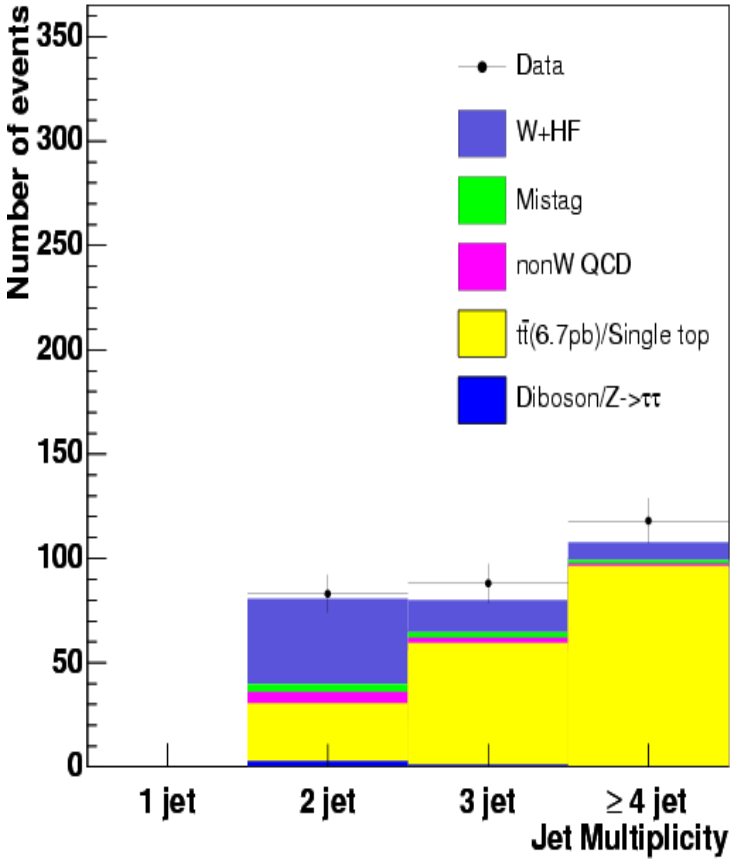
W+heavy flavor (Wbb, Wcc)
- HF calibration from jet data
- carries 35% rel. uncert.

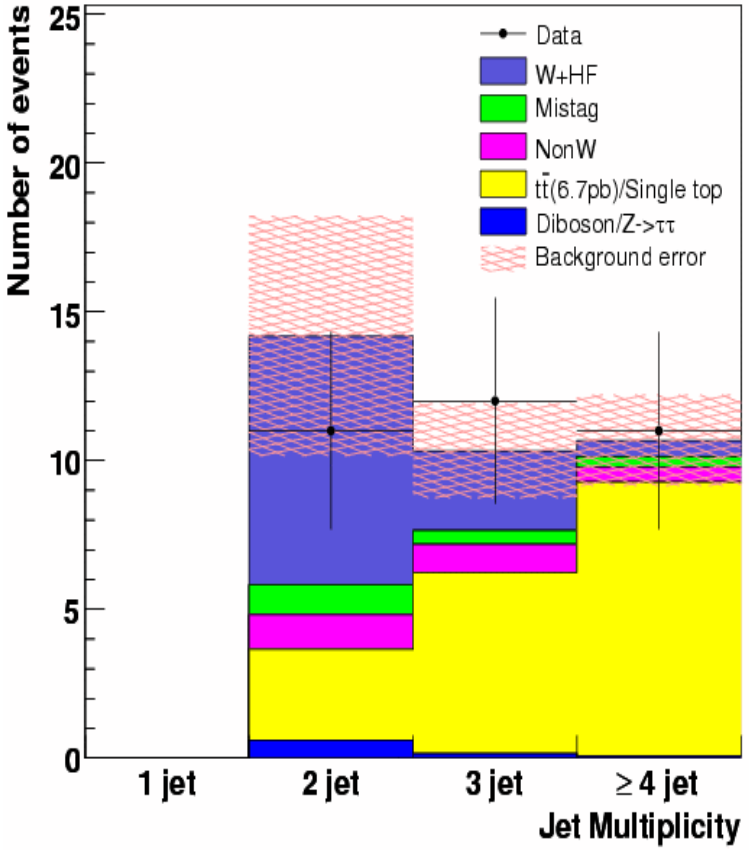
W+light flavor (mistag jets)
- asymmetry factor 1.37±0.13
- NN filter rejection similar

Non-W QCD multijet
- checks in different sidebands
- assign 17% rel. uncert.

Electroweak backgrounds
- b-tagging efficiency SF
- cross section calculations

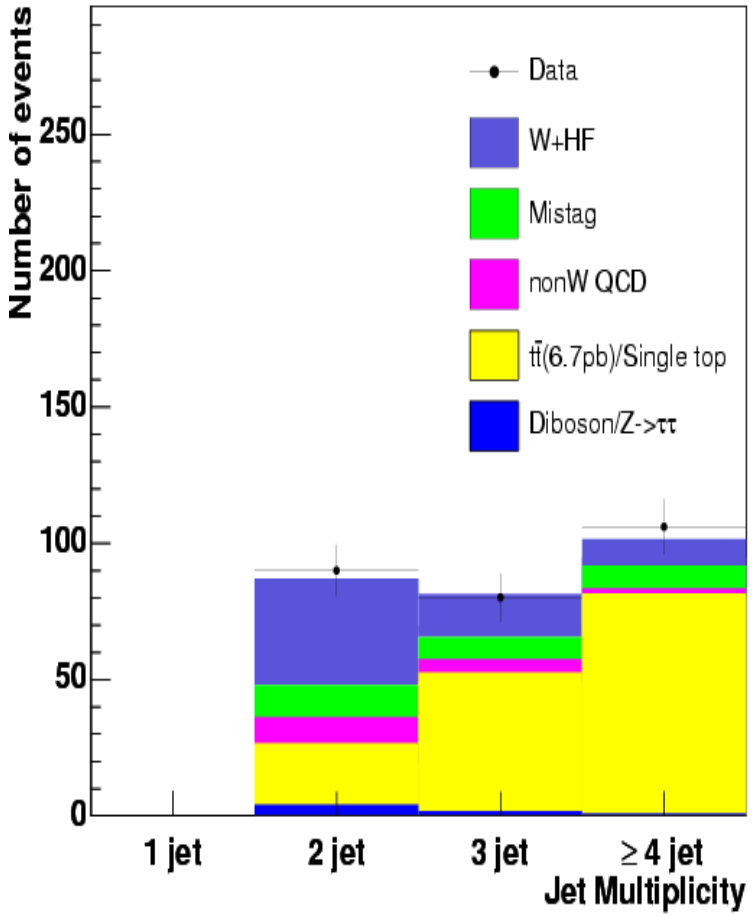
Njet of ST-ST Double Tags

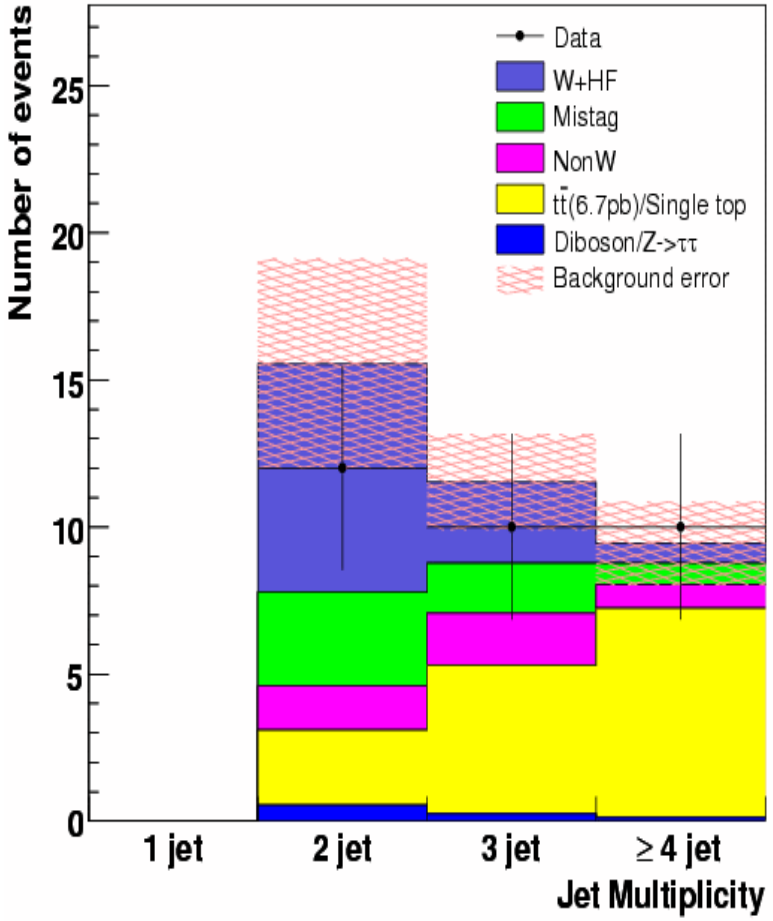




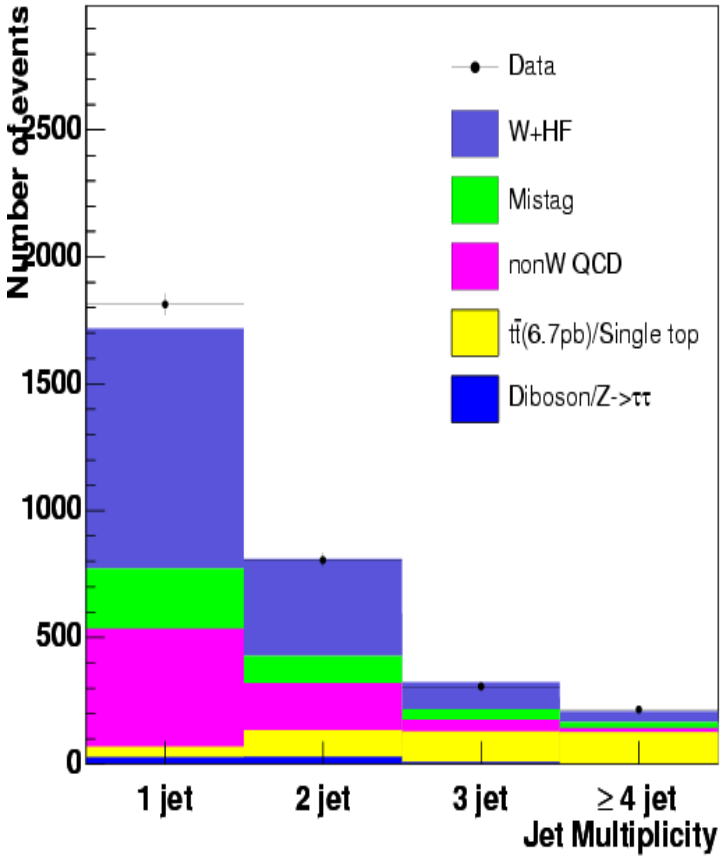
Left: for the central and right: for the plug

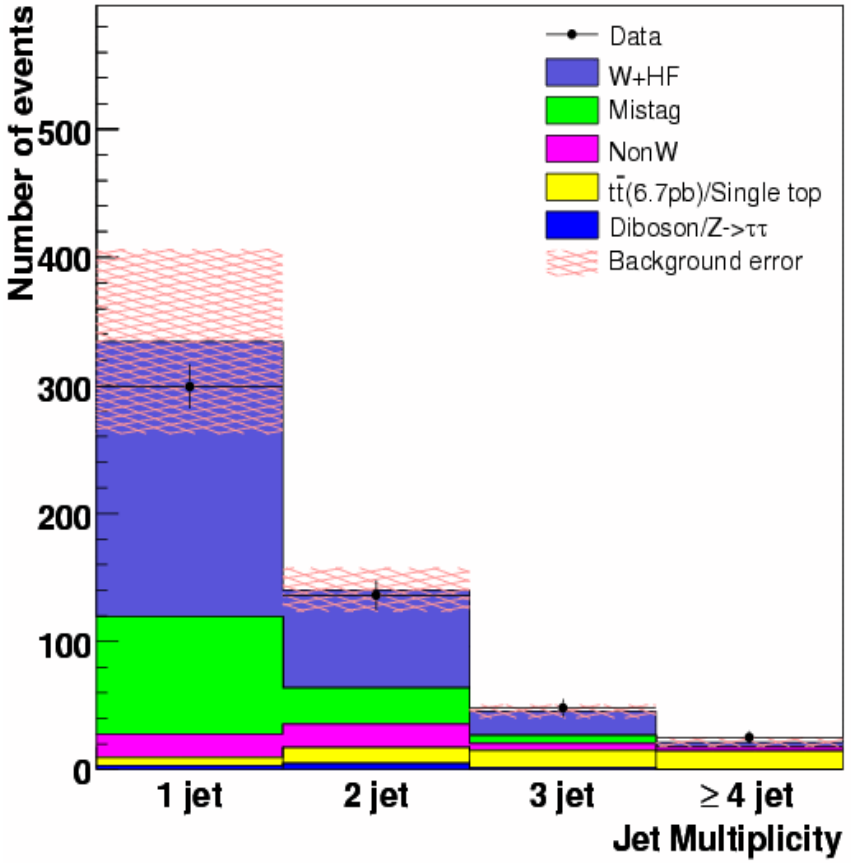
Njet of ST-JPB Double Tags



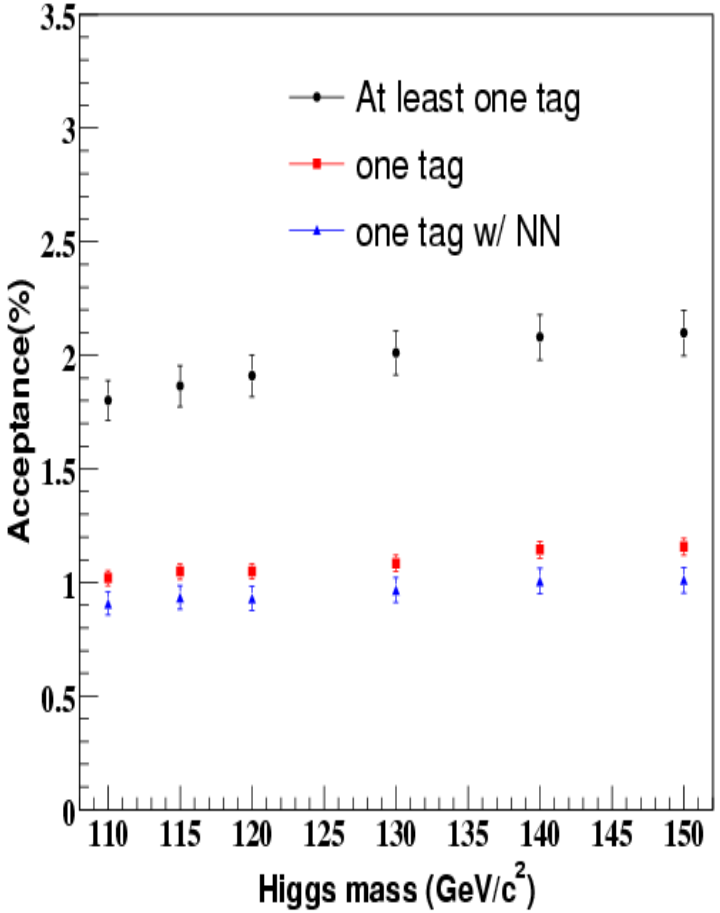


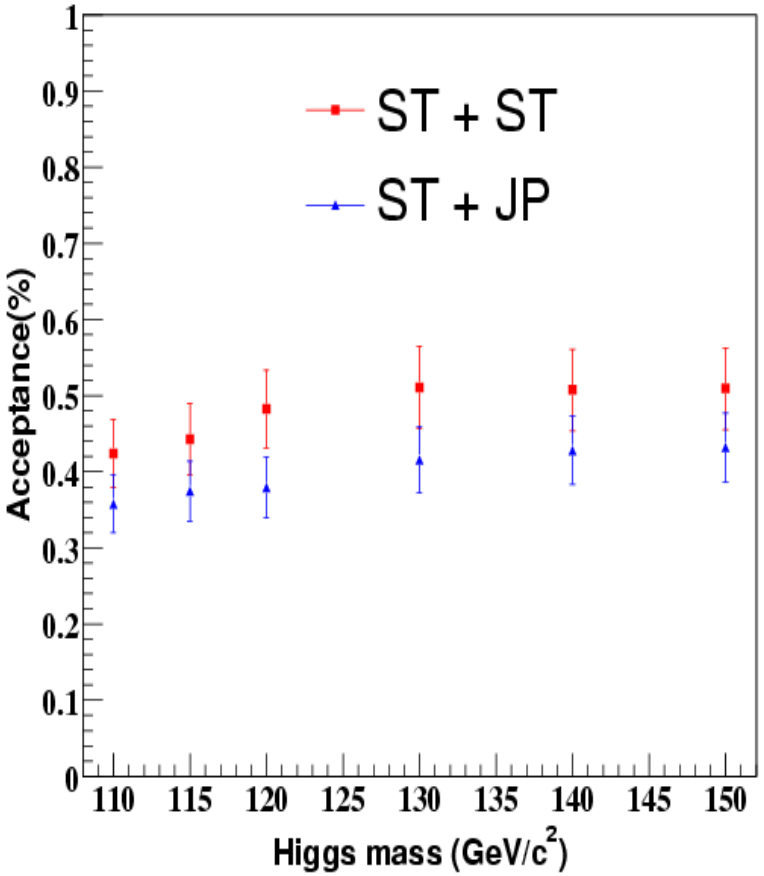
Njet of ST+NN


Number of events
2500
2000
1500
1000
500
0
Data
W+HF
Mistag
nonW QCD
tt̄(6.7pb)/Single top
Diboson/Z->ττ
1 jet
2 jet
3 jet
≥ 4 jet
Jet Multiplicity

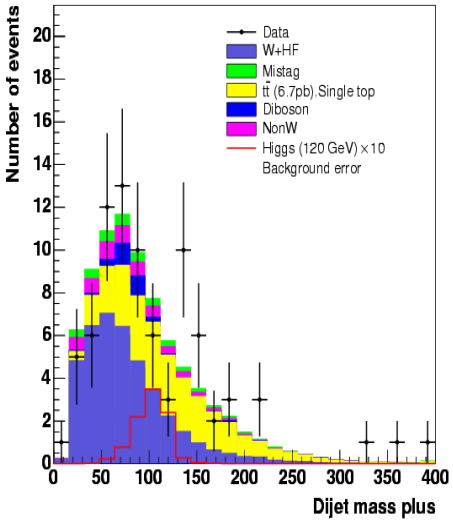

Number of events
500
400
300
200
100
0
Data
W+HF
Mistag
NonW
tt̄(6.7pb)/Single top
Diboson/Z->ττ
Background error
1 jet
2 jet
3 jet
≥ 4 jet
Jet Multiplicity

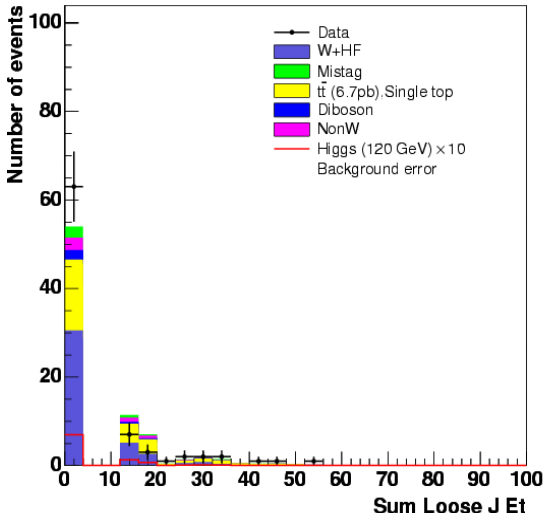
Acceptance of WH

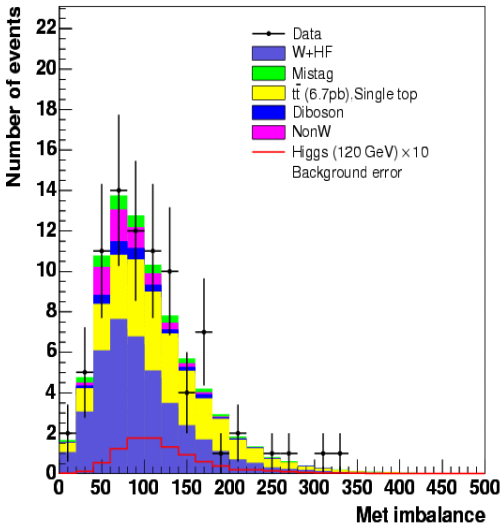


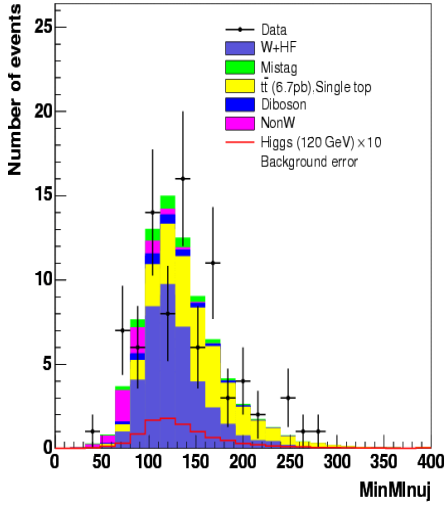


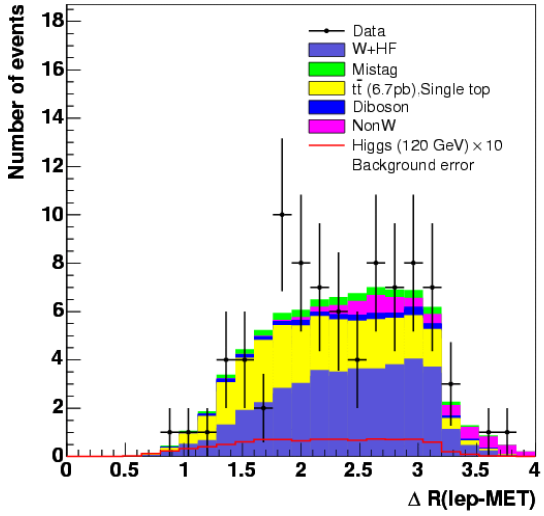
NN Inputs for Double Tags in Central

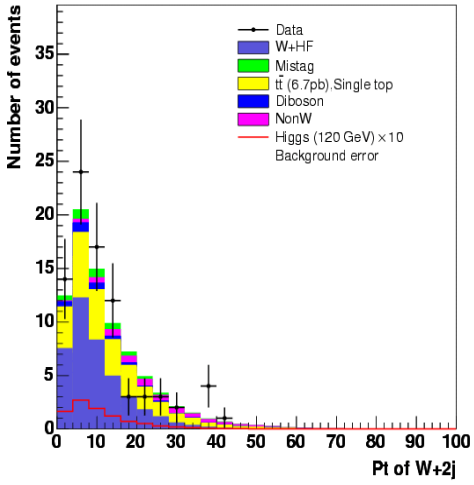




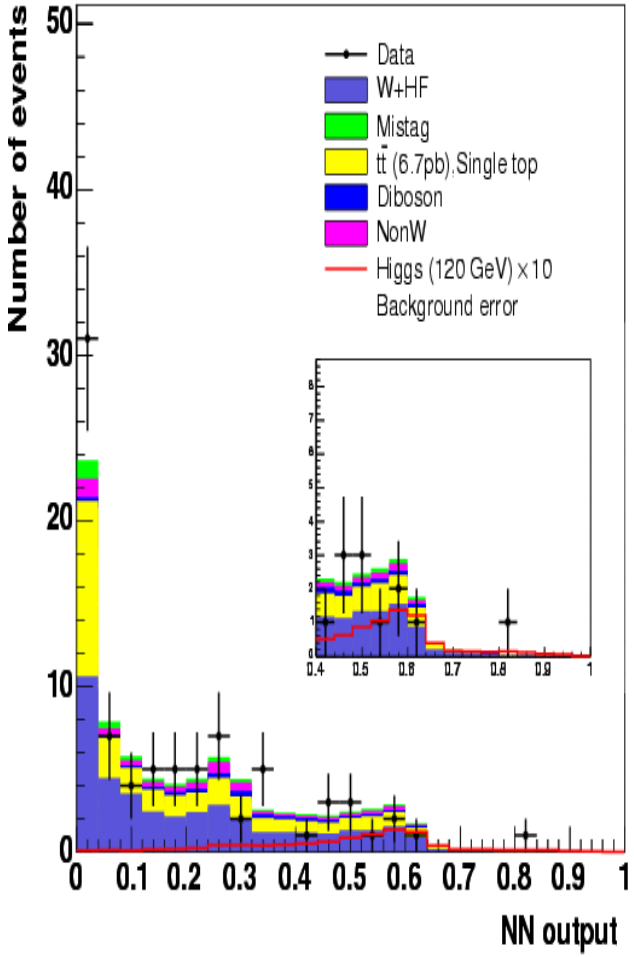




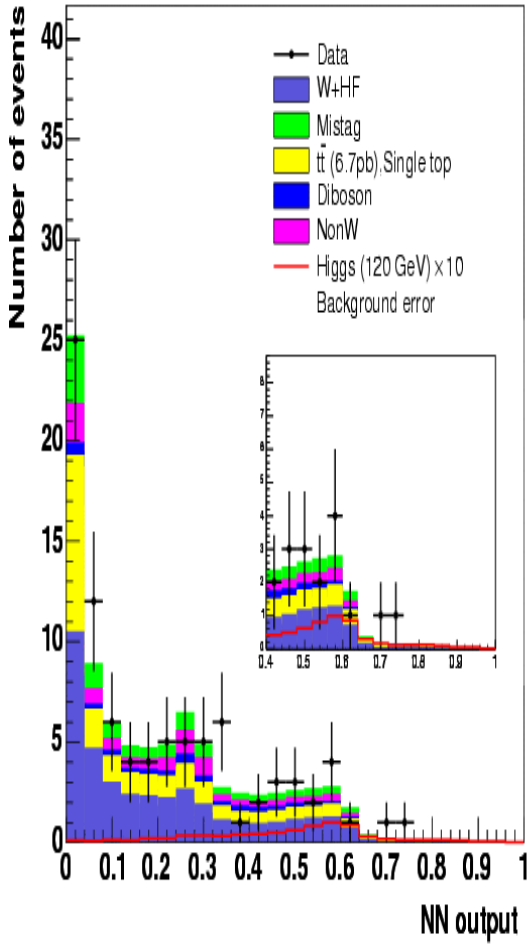




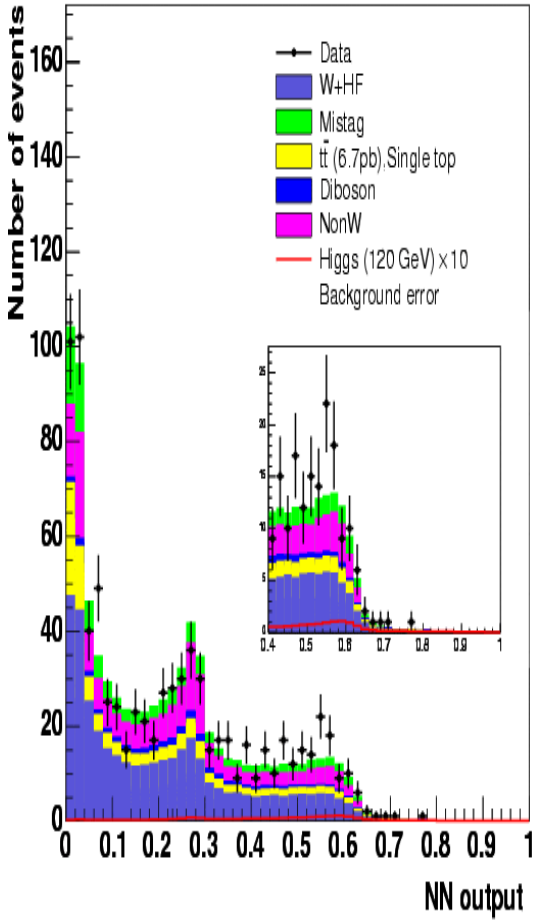
Nnoutputs of Central Leptons



ST-ST

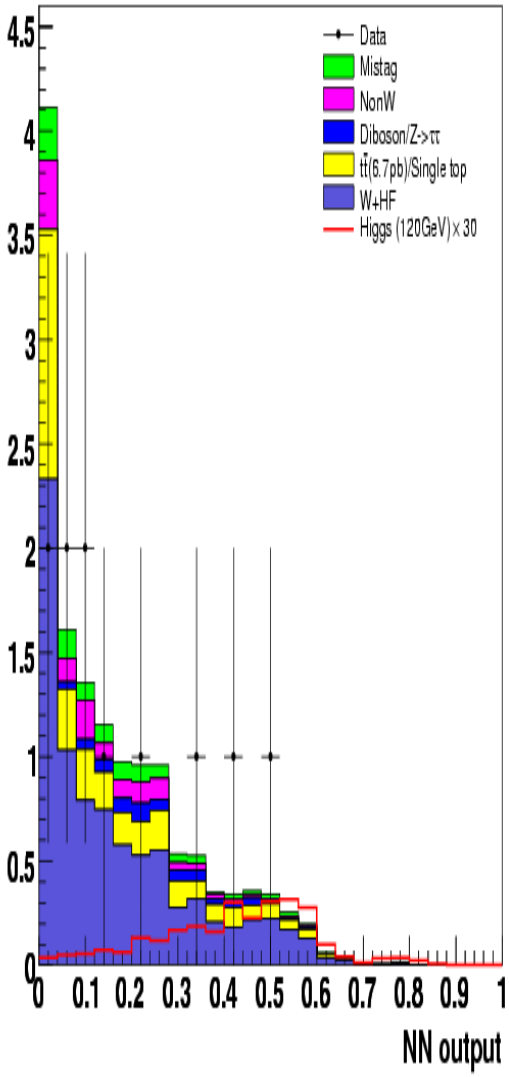


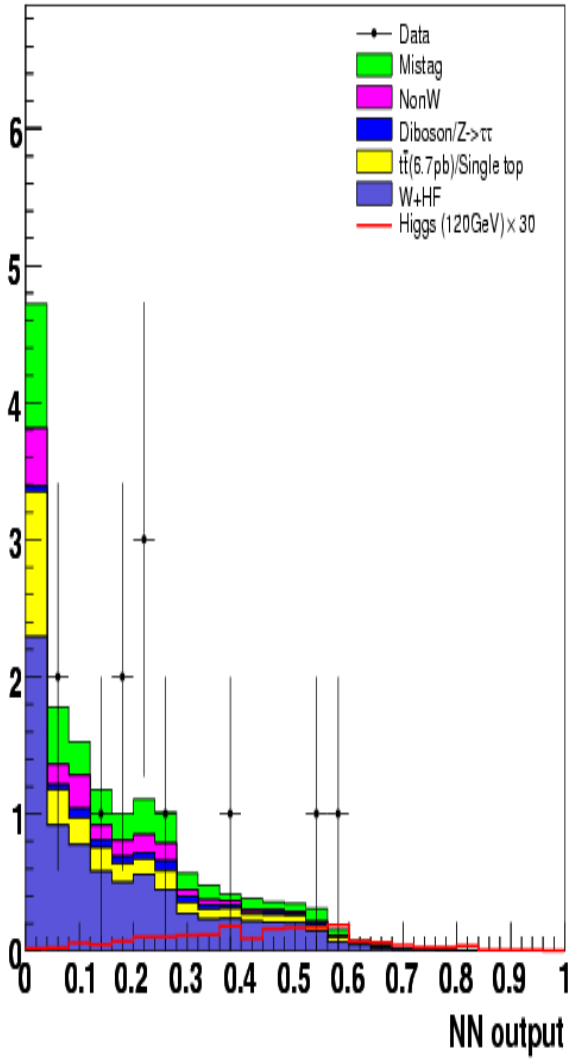
ST-JPB

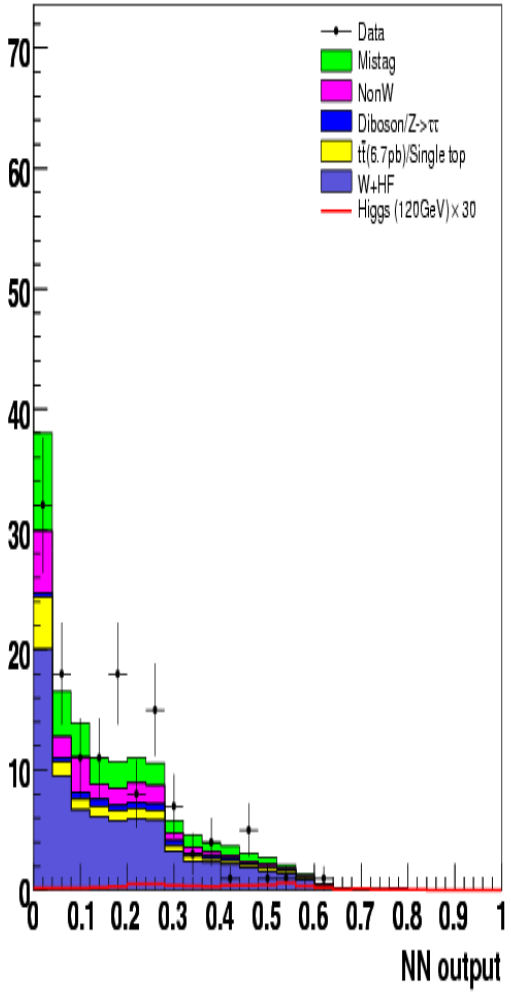


ST+NN

Nnoutputs of Plug electrons







Procedure to Calculate Exclusions

Designed to set a limit on the number of signal events: $s = \mu - b$

Fit restricted mass window (1.3σ)

for likely Higgs signal, given

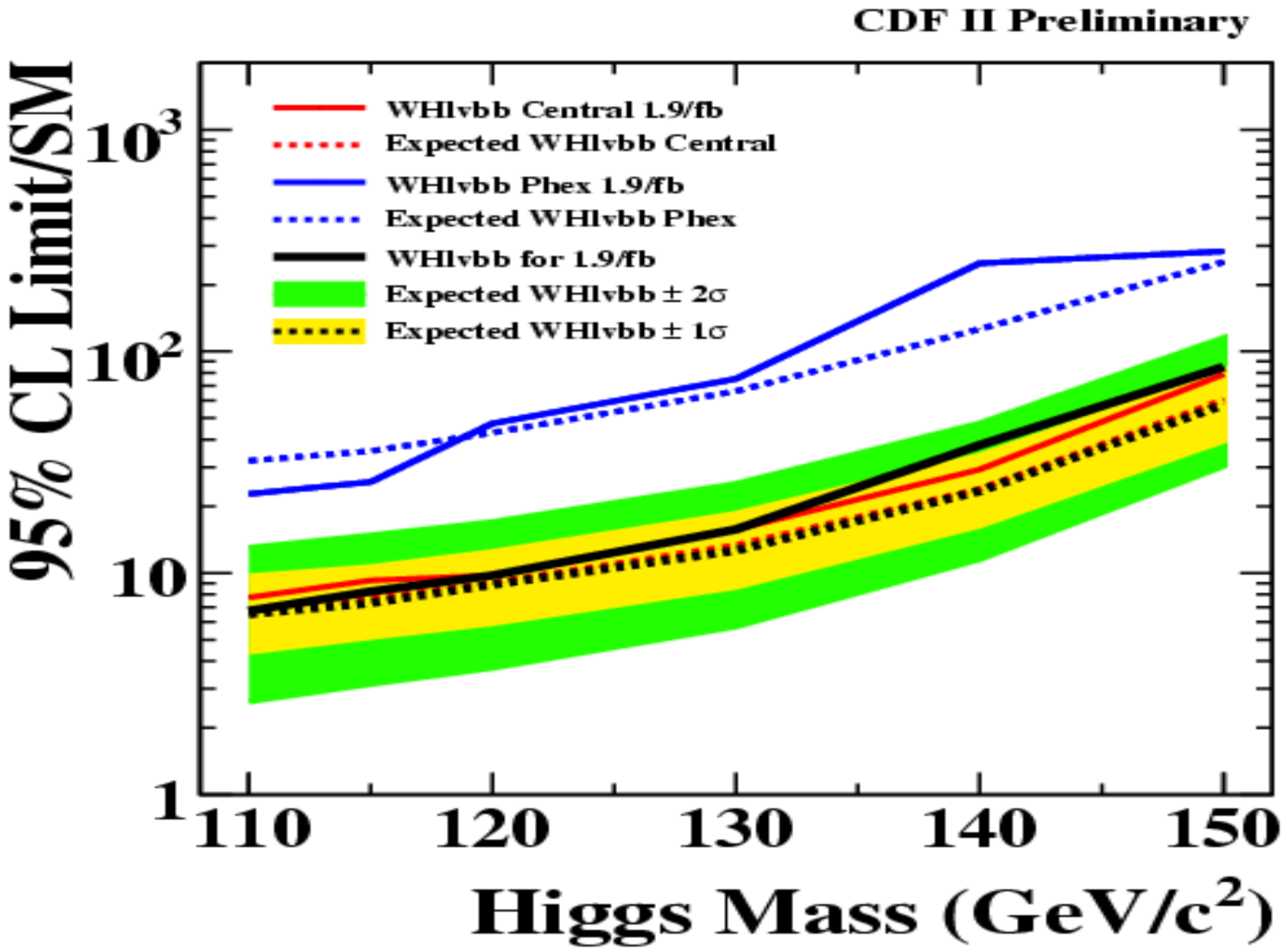
number of observed events *n*

$$L = \prod_{i=1}^{N_{\text{bin}}} P_i(n_i, \mu_i) = \prod_{i=1}^{N_{\text{bin}}} \frac{\mu_i^{n_i} e^{-\mu_i}}{n_i!}$$

Combine likelihoods for events with single NN tag, double tag

Re-interpret *s* as a σ x Br, given acceptance and efficiencies

WH Exclusion Summary Plot



Summary and Future Work on WH

- WH search with 1.9 fb^{-1} excludes σ x Br 1.2 to 0.9 pb
- Known Issues: too many plots (Central vs Plug, and 3 btags) and the acceptance needs to fix with SF bug (~10%).
- Observed exclusion improved by approximately a factor of 3 over previous result for mH=115 GeV/c^2
  - Larger dataset (2 times larger)
  - Separating single- and double-tagged events
  - Modest improvement from NN b-tagging and kinematic filter
- Current work toward publication:
  - A first draft of PRD is close to release to GP
  - There will be another PRD with 2.7 fb^-1 and focus on isolated track.
  - A prd with 2.7 fb^-1 with ME+DBT and combination of two as a PRL.