# Higgs $_{SM} \rightarrow \tau^- \tau^+$ jet jet at DØ

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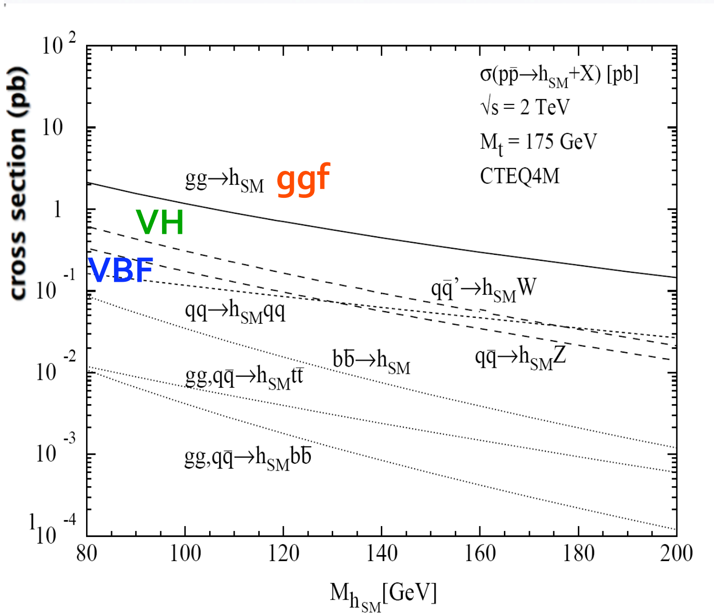
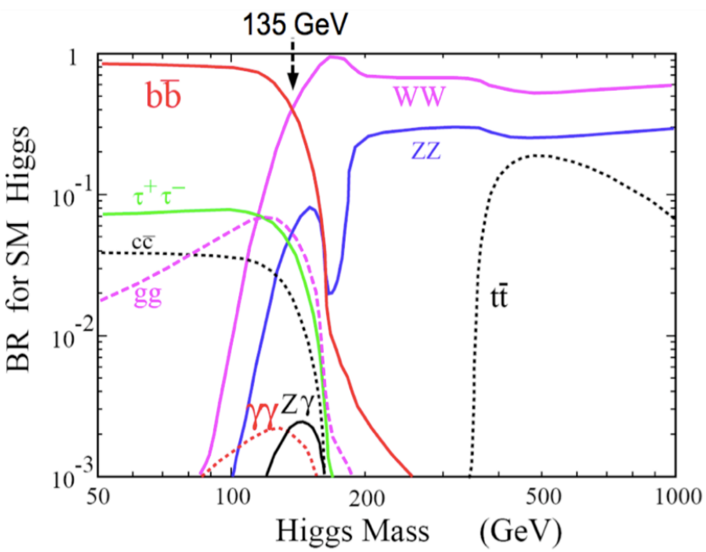
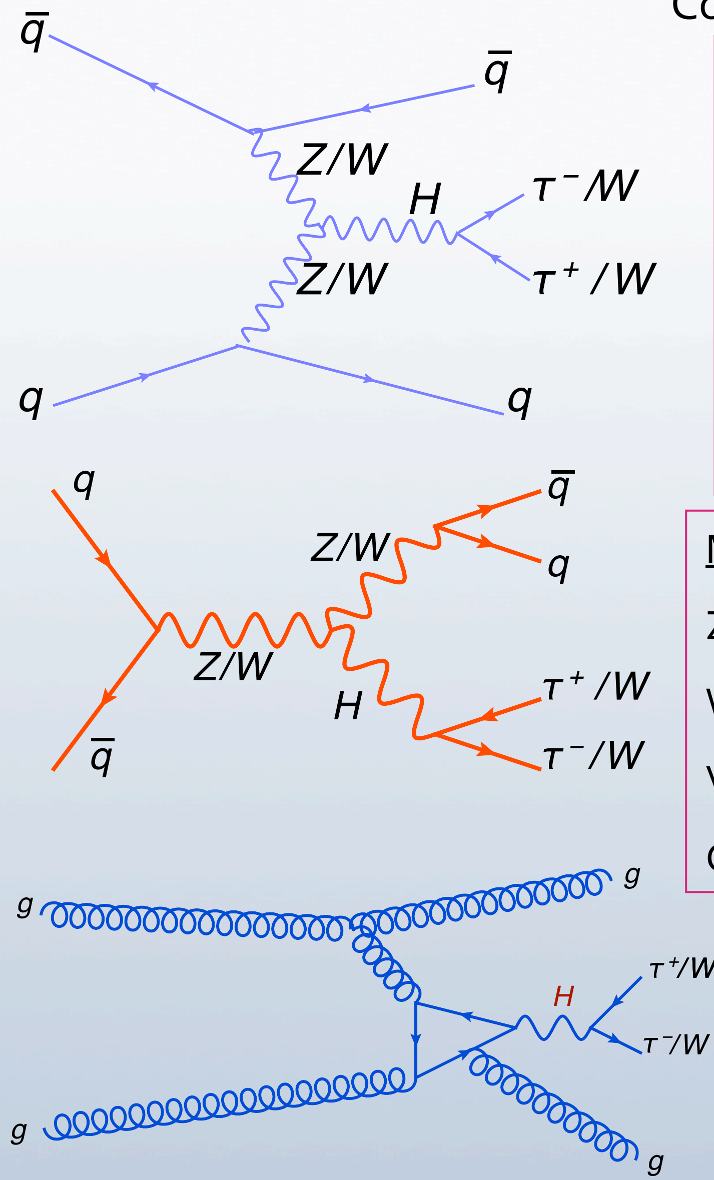
# H→ τ τ jet jet

Higgs Production and Decay Modes at the Tevatron




Sensitive to 9 Signals Covering Full Mass Range:

<u>Mainly low mass</u>

HZ: H(bb) Z($\tau\tau$)

ZH: Z(qq) H($\tau\tau$)

WH: W(qq') H($\tau\tau$)

VBF: qq' → qq'H($\tau\tau$)

GGF: gg → H($\tau\tau$) + 2 jets

<u>Mainly high mass</u>

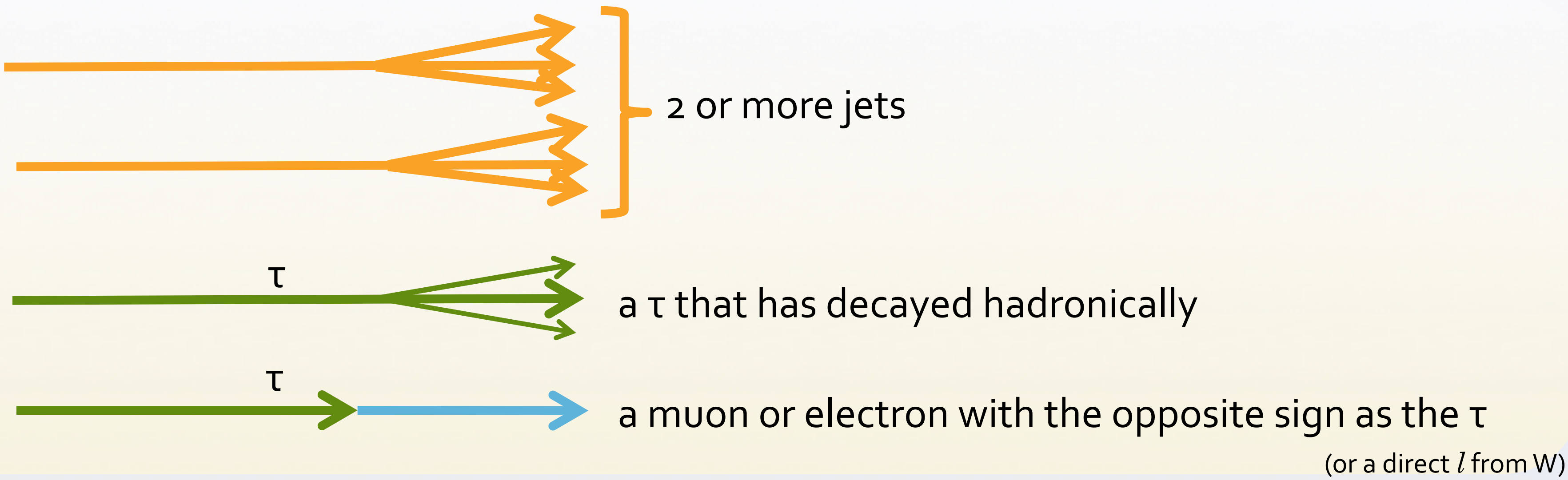
$ZH_{WW}$: Z(qq) H(WW)

$WH_{WW}$: WH(WW)

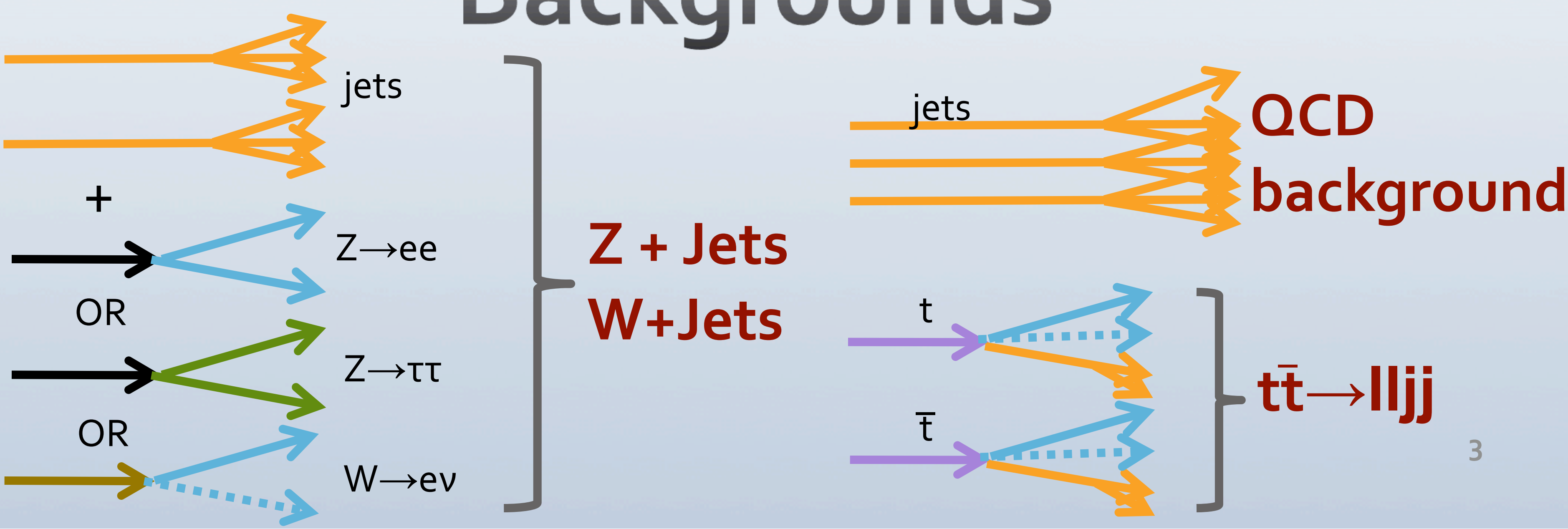
$VBF_{WW}$: qq' → qq'H(WW)

$GGF_{WW}$: gg → H(WW)+2jet

# Selecting Events



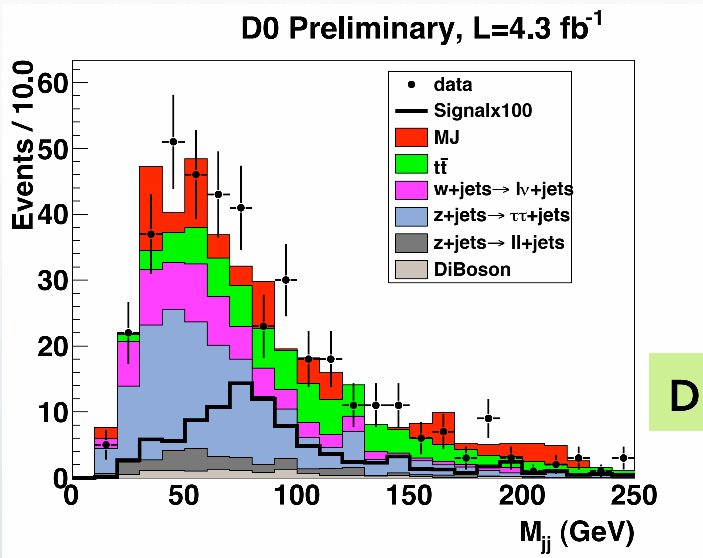

# Backgrounds

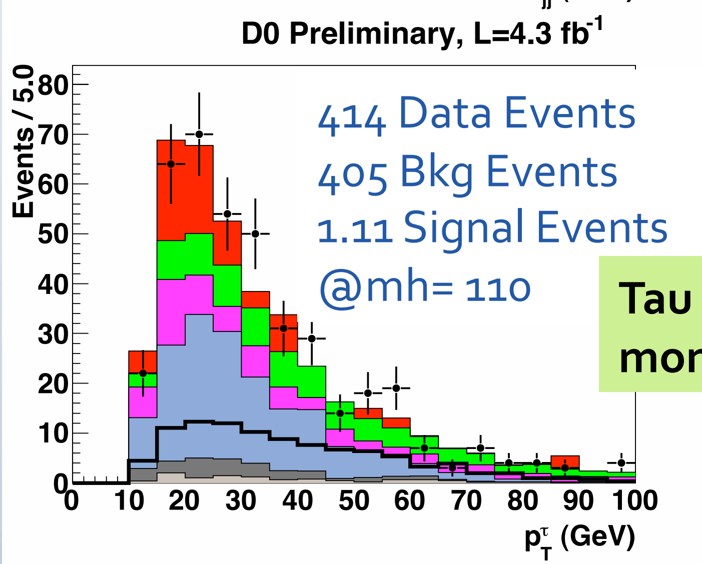


# Kinematic Variables

## 4.3 $fb^{-1}$

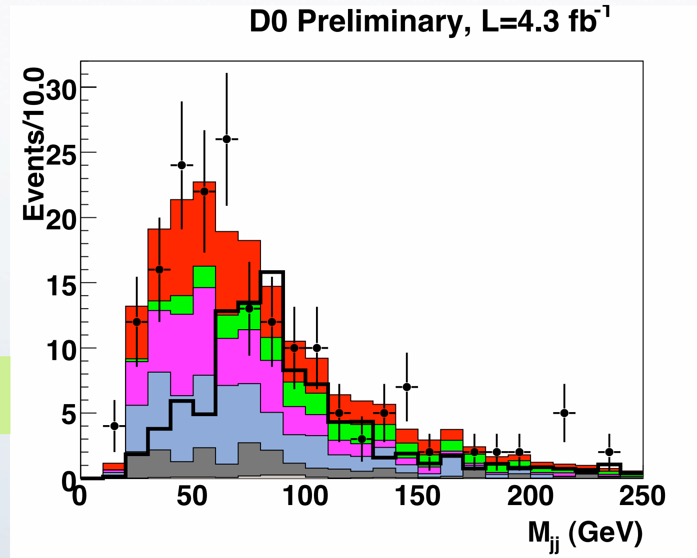
### MuTauJetJet



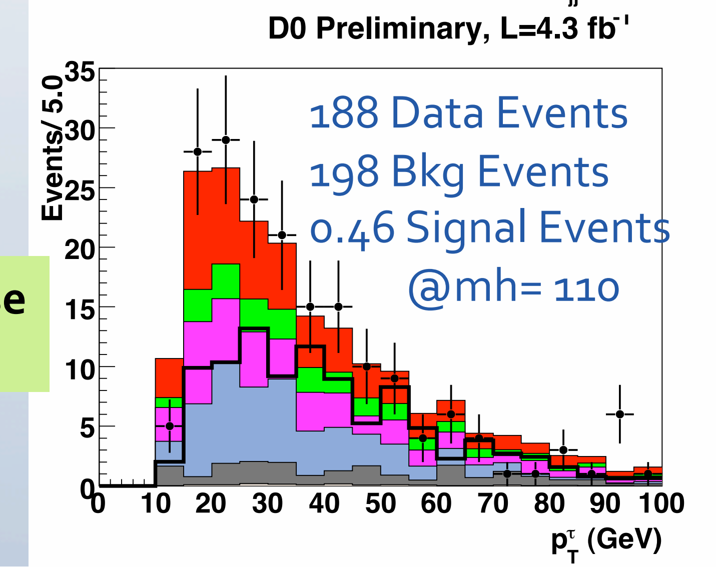




414 Data Events
405 Bkg Events
1.11 Signal Events
@mh= 110

### eTauJetJet




Di-jet Mass

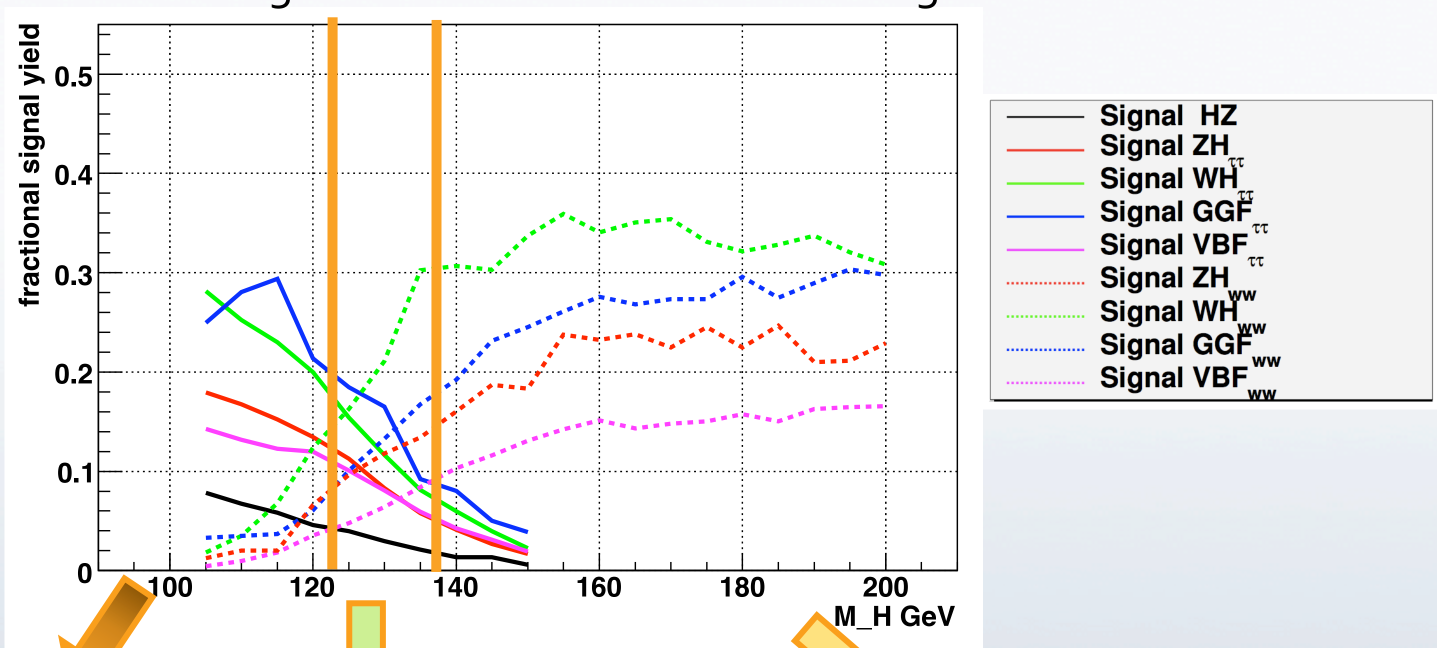



188 Data Events
198 Bkg Events
0.46 Signal Events
@mh= 110

Tau transverse momentum

# Multivariate Analysis

Three Mass Regions with Different Dominant Signals:




**BDTs: (9)**

VH MJ
GGF vs. wjets+ttbar
VBF zjets

Low Mass Combined BDT

**BDTs: (12)**

VH MJ
GGF vs. wjets+ttbar
$VH_{WW}$ zjets
$GGF_{WW}$

Intermediate Mass Combined BDT

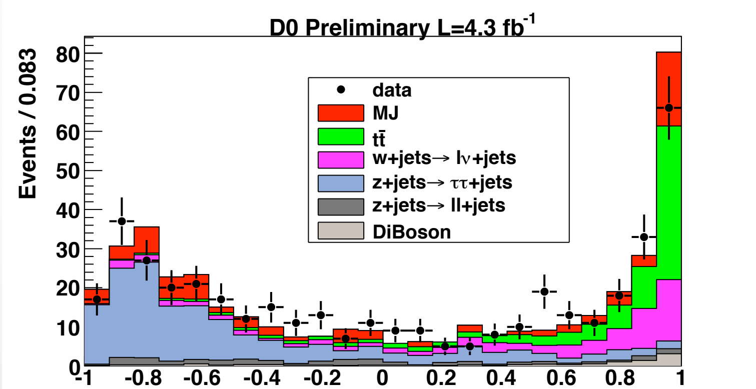
**BDTs: (9)**

$VH_{WW}$ MJ
$GGF_{WW}$ vs. wjets+ttbar
$VBF_{WW}$ zjets

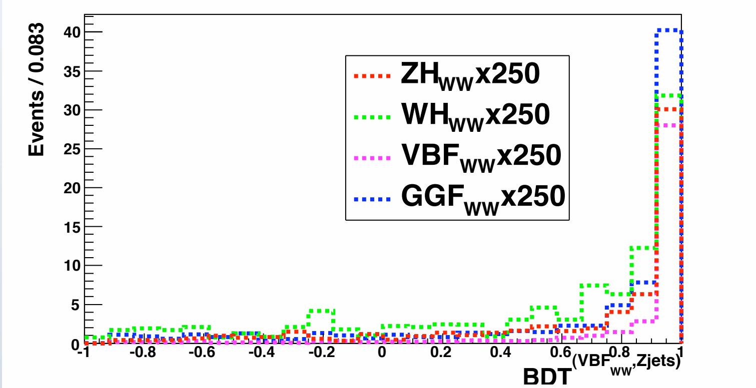
High Mass Combined BDT

=30 BDTs

# Distinguishing between signal and background: Multivariate Analysis: Boosted Decision Trees



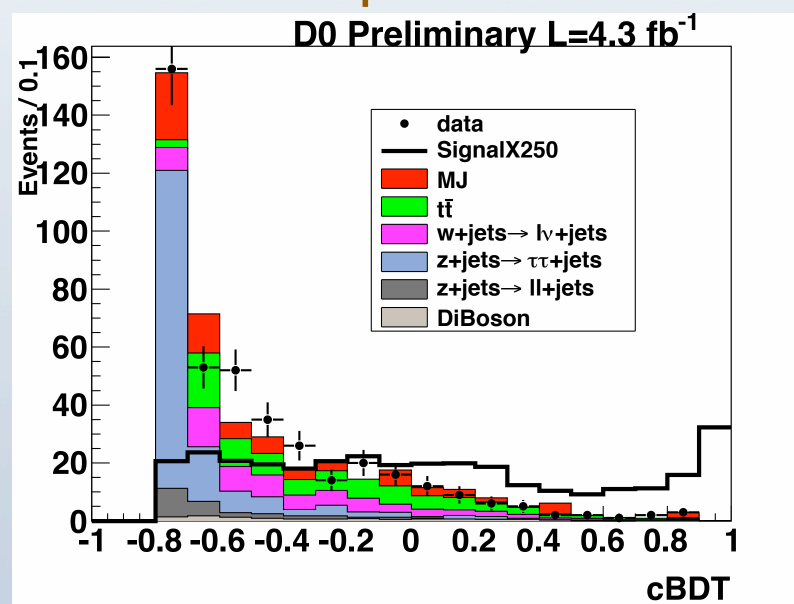

Trained VBF$_{WW}$ vs Zjets




**Result of training High Mass VBF$_{WW}$ signal against Zjets background**

Signals are pushed to + side
Zjets is pushed to – side
But other backgrounds are also at +1

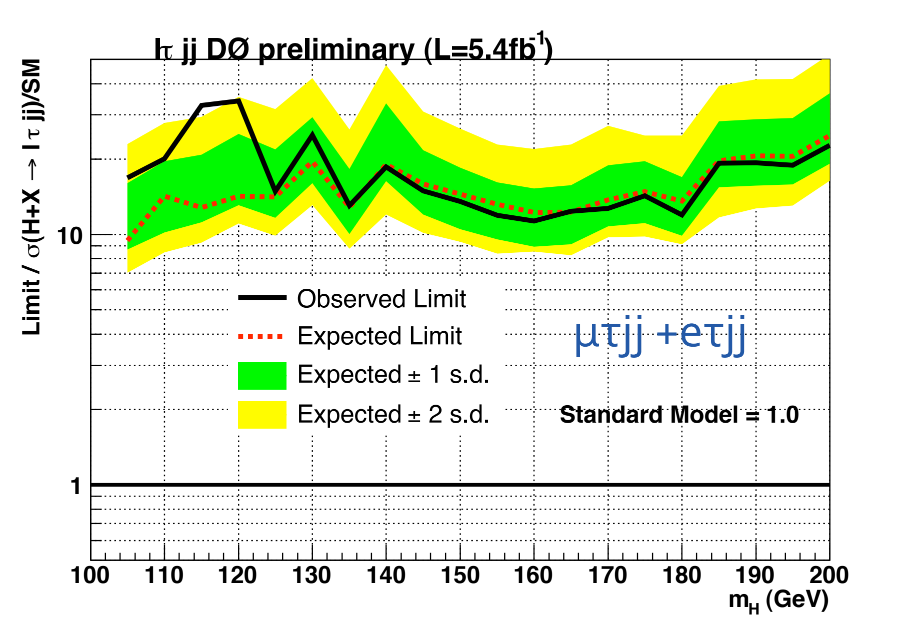
**BDT outputs are used as input to a Combined BDT**

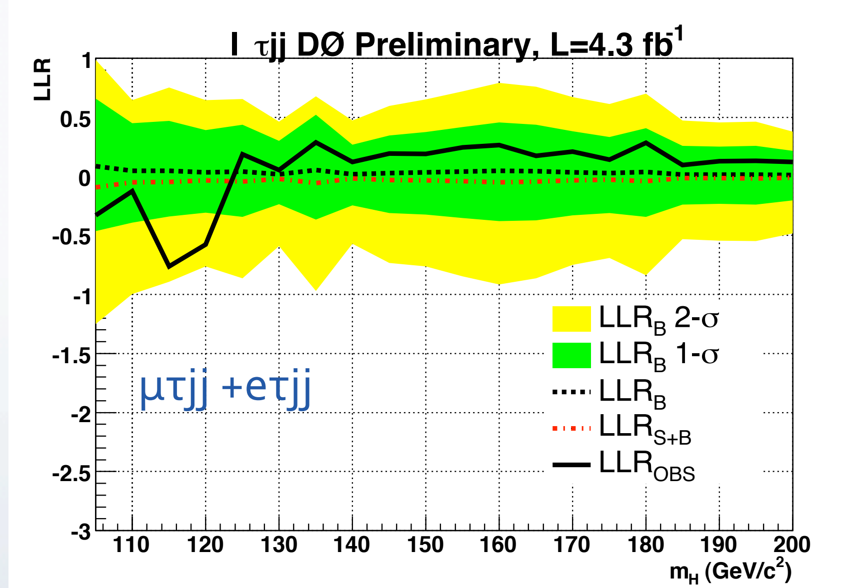



mutau high mass

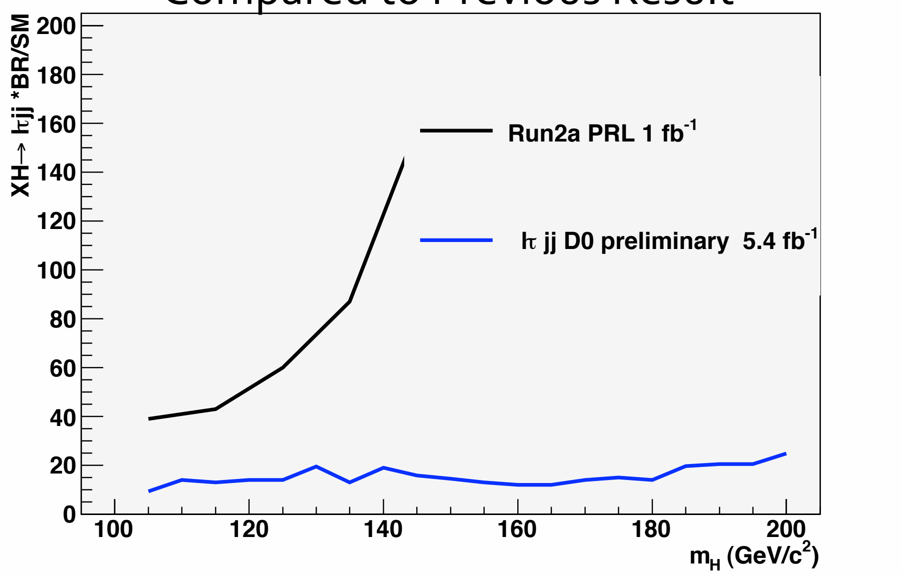
**Better Signal-Background discrimination!**

# Limit Setting




Compared to Previous Result




| $m_H$ | Expected Limit | Observed Limit |
|---|---|---|
| 115 | 12.8 | 32.8 |
| 135 | 12.9 | 13.0 |
| 165 | 12.3 | 12.4 |

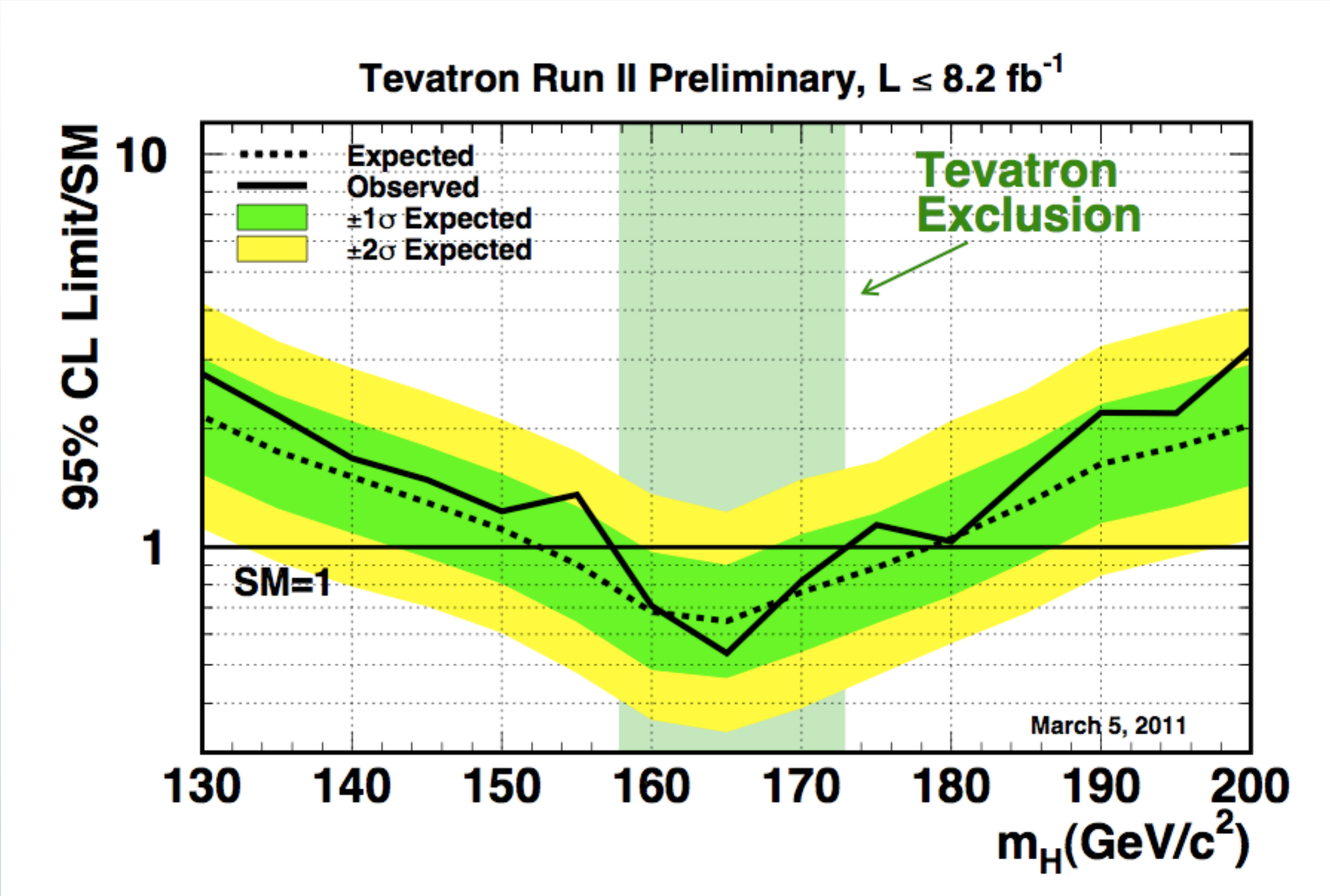
**Towards further sensitivity:**

→40% more data to be added in this channel

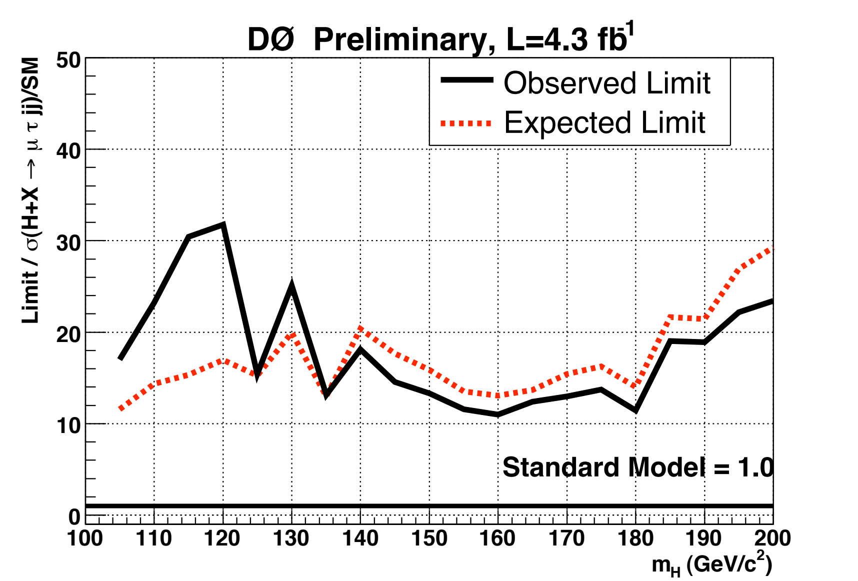
→New discriminating variables and improved multivariate analysis

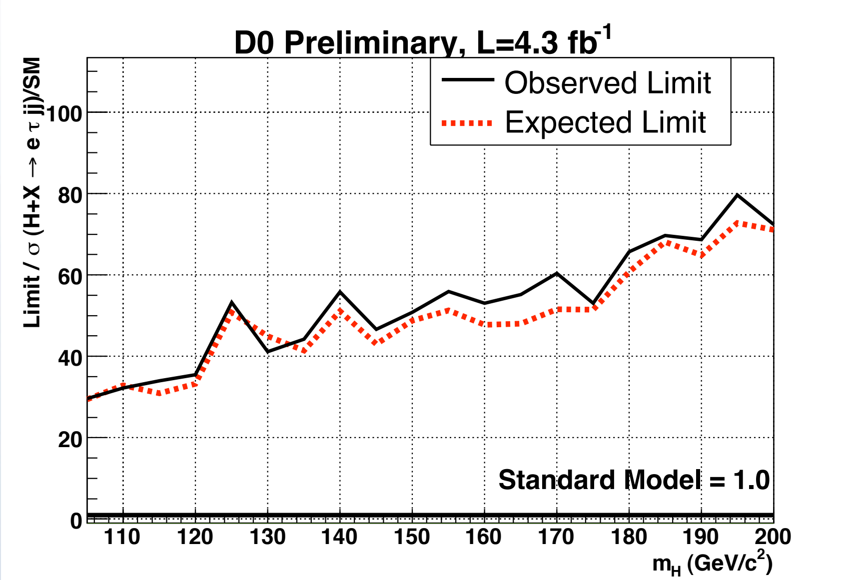
# Backup

# Tevatron Combination

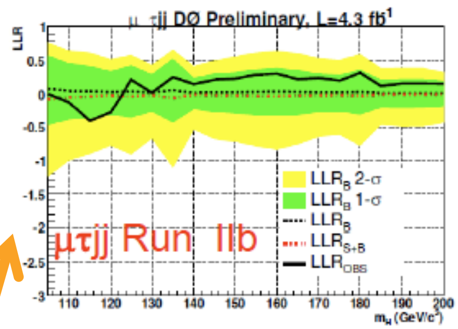


# MuTauJetJet eTauJetJet

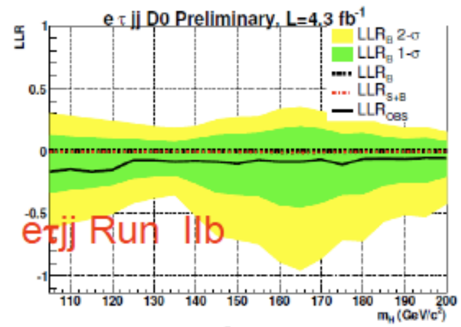


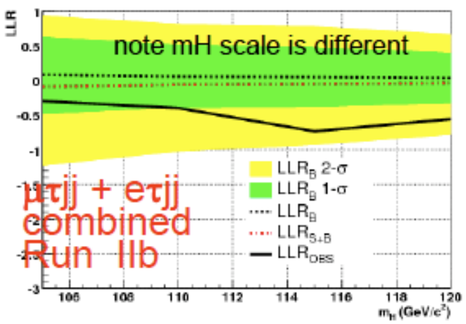
# A look at the 115 fluctuation in obs LLR

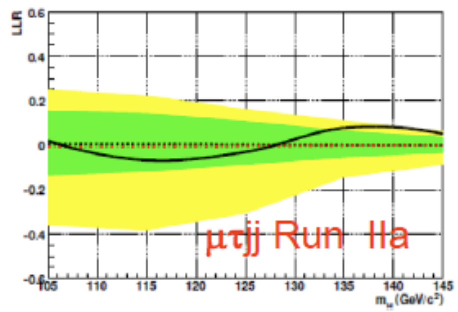



~1.0 Sigma @115

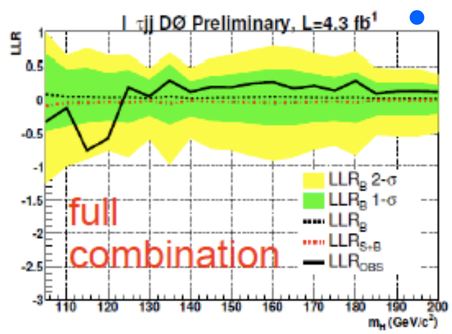



~0.5 Sigma @ 115




~0.5 Sigma @115



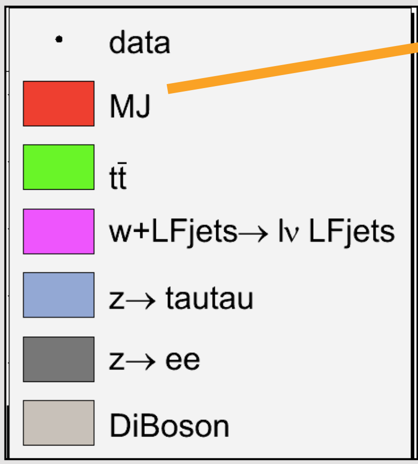

etau+mutau combination is dominated by mutau runIIb,

# monte carlo

- MC Higgs signal: pythia using CTEQ6L1 leading-order parton distribution functions (PDF). The signal cross sections are normalized to the next-to-next-to-leading order (NNLO) (or NLO for VBF).
- The SM backgrounds from tt and V +jets production are generated using alpgen with parton showering and hadronization provided by pythia. Production of electroweak VV pairs is generated with pythia. The SM backgrounds tt and V +light jets only are normalized to NLO cross sections from the mcfm program and data. The NLO cross sections for dibosons are taken from mcfm.
- Higgs and τ decays are simulated by hdecay and tauola respectively.

# QCD Background Est.

**BACKGROUNDS**



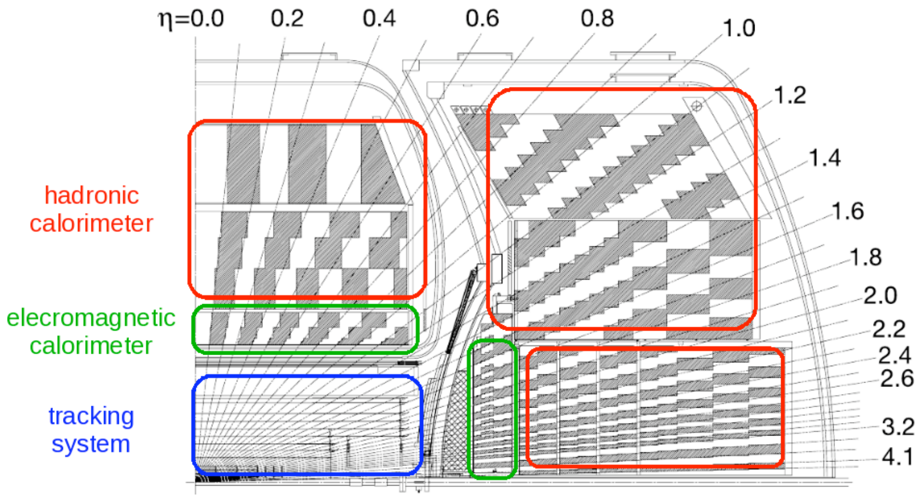

QCD is estimated using MJ enriched data samples

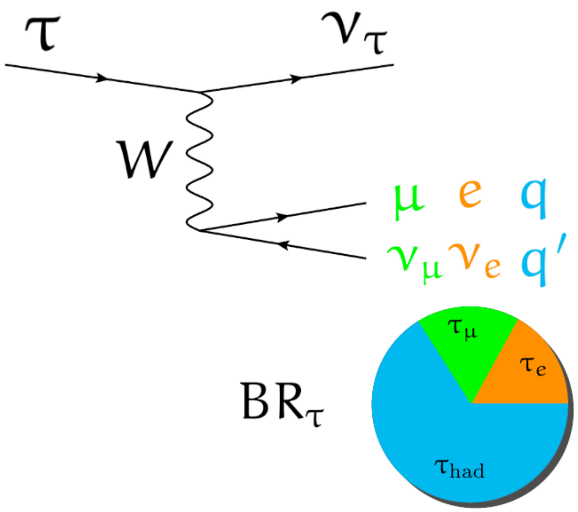
- For MuTau:
  - $0.3<NN_\tau<0.8$
  - Non-isolated Muon
  - No tau-mu OS requirement
- For eTau:
  - $0.3<NN_\tau<0.9$
  - Electron selection: TopLoose-but-not-TopTight
  - No tau-e OS requirement

Normalized using the ratio of OS/SS events in the MJ enriched sample

# The τ lepton and its reconstruction

**Physical properties :** $m_\tau = 1.78$ GeV, $c\tau_{life} = 87\ \mu m$




We will focus on **hadronic decay of τ** : $\tau_{had}$

**Reconstruction and DØ τ type definition for <u>hadronic</u> decay :**

- DØ type 1 ≡ 1 trk, HAD deposit $\sim \tau^\pm \to \pi^\pm \nu_\tau$
- DØ type 2 ≡ 1 trk, EM and HAD deposit $\sim \tau^\pm \to \rho^\pm(\to \pi^0\pi^\pm)\nu_\tau$
- DØ type 3 ≡ at least 2 trks, HAD deposit $\sim \tau^\pm \to a_1^\pm(\to \pi^\pm\pi^\mp\pi^\pm)\nu_\tau$

# BDT inputs

| variable | definition |
|---|---|
| ${p_T}^{\ell}$ | $p_T$ of the lepton candidate |
| ${p_T}^{j1}$ | $p_T$ of the leading jet candidate |
| $\not{E}_T$ | missing transverse energy |
| $M_{\tau\tau}$ | invariant mass of the ($\tau_\ell$, $\tau_{\text{had}}$) system |
| $M_{\text{jj}}$ | invariant mass of the two candidate jets |
| $\Delta R_{\text{jj}}$ | $\Delta R = \sqrt{(\Delta\phi)^2 + (\Delta\eta)^2}$ distance between the 2 leading jets |
| $M_{\text{T}}^{\ell}$ | transverse mass calculated from ${p_T}^{\ell}$ and $\not{E}_T$ |
| $M_{\text{T}}^{\tau}$ | transverse mass calculated from ${p_T}^{\tau}$ and $\not{E}_T$ |
| $H_T$ | scalar sum of the $p_T$ of all jets with $p_T > 15$ GeV and $\lvert\eta\rvert < 2.5$ |
| $S_T$ | scalar sum of the $p_T$ of $\ell, \tau$, the two jets and $\not{E}_T$ |
| $V_T$ | magnitude of the vector sum of the $p_T$ of $\ell, \tau$, the 2 jets and $\not{E}_T$ |
| $A(\not{E}_T,\not{H}_T)$ | asymmetry between $\not{E}_T$ and $\not{H}_T$, $(\not{E}_T$-$\not{H}_T)/(\not{E}_T+\not{H}_T)$. $\not{H}_T$ is $\Sigma \vec{p_T}$ for jets |
| $\min \Delta\phi(\not{E}_T, jets)$ | the smaller $\Delta\phi$ between the $\not{E}_T$ and any jet |
| $\mathcal{S}$ | the $\not{E}_T$ significance |
| $\Delta\eta(\text{jj})$ | $\lvert\Delta\eta\rvert$ between the 2 leading jets |
| $p_T^{\tau}$ | transverse momentum of the tau candidate that decays $\tau \rightarrow$ hadrons |

TABLE IV: Variables used for the BDT training.

# Preselection for tau tau jet jet

**All**

- Luminosity: 4.3 1/fb
- 1 Tau:
  - pT: 12.5, 12.5, 15.0 GeV
  - $|\eta|<2.0$
  - $NN_\tau > 0.9, 0.9, 0.95$
- Veto on additional leptons to ensure orthogonality with other analyses
- 2 Jets:
  - pT: 20.0, 15.0 GeV
  - $|\eta|<3.4$

**MuTau**

- Inclusive Trigger
- 1 isolated Muon
  - pT>15 GeV
  - $|\eta|<1.6$

**eTau**

- singleEMOR Triggers
- 1 TopTight Electron:
  - pT>15 GeV
  - $|\eta|<2.5$
- "Anti-electron" cuts:
  - Type 1τ: $1.05 < |\eta| < 1.5$
  - Type 2 τ: $NN_{el}>0.95$; 0.1<TauPhiPS<0.9
  - Type 3 τs: τemf<0.95; $1.05 < |\eta| < 1.5$

- METsig>1.0

| Yields | Data | Bkg | Signal at mh=115 |
|---|---|---|---|
| MuTau | 441 | 423 | 1.2 |
| eTau | 188 | 198 | 0.4 |

# Systematic uncertainties

| Source | type | Uncertainty (%) |
|---|---|---|
| Luminosity (DØ specific) | flat | 4.1 |
| Luminosity (Tevatron common) | flat | 4.6 |
| $\mu$ ID, track match, iso. | flat | 2.9 |
| $\mu$ trigger | flat | 8.6 |
| $\tau$ energy correction | flat | 9.8 |
| $\tau$ track efficiency | flat | 1.4 |
| $\tau$ selection by type | flat | 12, 4.2, 7 |
| $W/Z$+light flavor XS | flat | 6.0 |
| $t\bar{t}$, single top XS | flat | 10.0 |
| diboson XS | flat | 7.0 |
| $VH$ signal XS | flat | 6.2 |
| VBF signal XS | flat | 4.9 |
| GGF signal XS normalization | flat | 33 |
| GGF signal XS PDF | flat | 29 |
| GGF $p_T^H$ | shape | 1.0 |
| jet vetex confirmation | flat | 4.0 |
| Jet ID/reco eff. | shape | $\approx$ 20 |
| Jet $E$ resolution. | shape | $\approx$ 10 |
| JES | shape | $\approx$ 15 |
| jet $p_T$ | flat | 5.5 |
| PDF | shape | 2 - 6 |
| MJ normalization | flat | 5.3 |
| MJ shape | shape | 15 -20 |

μτjj

| Source | type | Uncertainty (%) |
|---|---|---|
| Luminosity (DØ specific) | flat | 4.1 |
| Luminosity (Tevatron common) | flat | 4.6 |
| $e$ ID, track match, iso. | flat | 4 |
| $e$ trigger | flat | 2 |
| $\tau$ energy correction | flat | 9.8 |
| $\tau$ track efficiency | flat | 1.4 |
| $\tau$ selection by type | flat | 12, 4.2, 7 |
| $W/Z$+light flavor XS | flat | 6.0 |
| $t\bar{t}$, single top XS | flat | 10.0 |
| diboson XS | flat | 7.0 |
| $VH$ signal XS | flat | 6.2 |
| VBF signal XS | flat | 4.9 |
| GGF signal XS normalization | flat | 33 |
| GGF signal XS PDF | flat | 29 |
| GGF $p_T^H$ | shape | 1.0 |
| jet vetex confirmation | flat | 4.0 |
| Jet ID/reco eff. | shape | $\approx$ 20 |
| Jet $E$ resolution. | shape | $\approx$ 10 |
| JES | shape | $\approx$ 15 |
| jet $p_T$ | flat | 5.5 |
| PDF | shape | 2 - 6 |
| MJ normalization | flat | 4.7 |
| MJ shape | shape | 15 - 20 |

eτjj