Search for the SM Higgs in $\tau_e \tau_h\, jj$ Final States

Ian Howley on behalf of the DØ Collaboration

New Perspectives 2012

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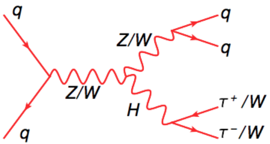
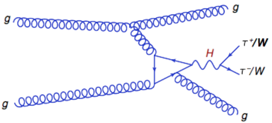
HIGGS SIGNALS

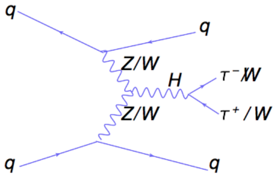
- $H \to \ell\tau jj$ is sensitive to 3 production channels, that give 1 e/μ, 1 hadronic τ, 2 jets, and missing energy. (referred to as *etau* and *mutau*)
- We combined our final limits with a separate search of $\mu\tau$ with 0 jets



Associated Production



Gluon-Gluon Fusion (GGF)

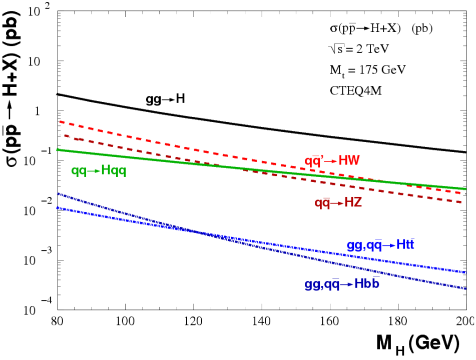


Vector-Boson Fusion (VBF)

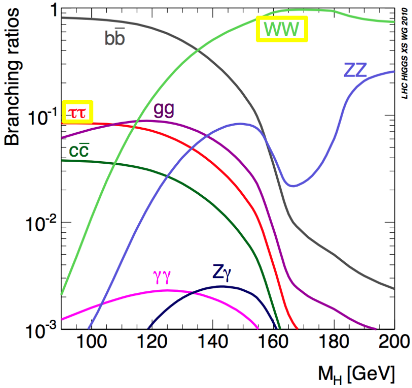
Our final state is sensitive to both $H \to \tau\tau$ and $H \to WW$.

Higgs Signals II

- At $\sqrt{s} = 2$TeV GGF has the largest cross section $\sim$1fb^{-1}



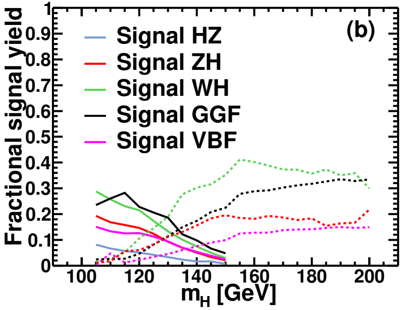
- At $m_H = 135$ GeV $H \to WW$ becomes the dominant decay.



Higgs Signals III

- There are 9 physical processes, in two large mass ranges
- It is important to know the dominant process in the low and high mass ranges
- The large number of channels increases the sensitivity, but complicate the separation of signals from background

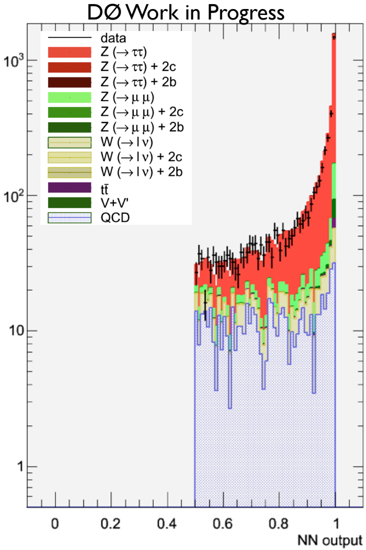
Name	Decay
low mass	
HZ	$H(bb) + Z(\tau\tau)$
ZH	$Z(qq) + H(\tau\tau)$
WH	$W(qq\prime) + H(\tau\tau)$
VBF	$qq\prime \to qq\prime + H(\tau\tau)$
GGF	$gg \to H(\tau\tau) + 2jets$
high mass	
ZH_{WW}	$Z(qq) + H(WW)$
WH_{WW}	$W + H(WW)$
VBF_{WW}	$qq\prime \to qq\prime + H(WW)$
GGF_{WW}	$gg \to H(WW) + 2jets$



HADRONIC τ DECAYS

- Hadronic τ decays are reconstructed as narrow jets $dR = \sqrt{(\Delta\phi)^2 + (\Delta\eta)^2} = 0.4$
- It is useful to classify the main hadronic decays based on their detector signature
- We employ a neural network (NN_τ) to distinguish τ's from fakes

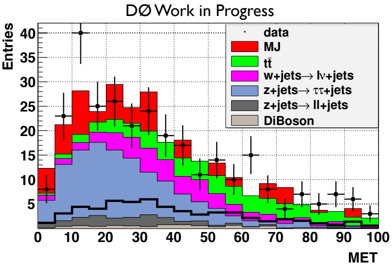
τ type	Physical Process	BR
1	$\tau^\pm \to \pi^\pm \nu_\tau$	10.9%
2	$\tau^\pm \to \rho^\pm(\to \pi^0\pi^\pm)\nu_\tau$	36.5%
	$\tau^\pm \to (\geq 2\pi^0)\pi^\pm\nu_\tau$	
3	$\tau^\pm \to a_1^\pm(\to \pi^\pm\pi^\mp\pi^\pm)\nu_\tau$	13.9%



BACKGROUND

- There are 5 backgrounds considered:
  - $Z \rightarrow ee/\mu\mu$ and $Z \rightarrow \tau\tau$ (irreducible)
    - $Z \rightarrow ee$ dominant in the $e\tau$ channel
  - W+jets is the primary background for the $\mu\tau0$ channel
  - $t\bar{t}$ contributes $\sim 15\%$
  - Di-boson contribution is quite small
  - Multi-jet (MJ) arise from QCD heavy flavor events, where jets fake either the τ or the electron
    - It is instrumentally induced and hard to simulate, and thus estimated from data

- We use standard definitions of p_T η, and other variables to ensure we use good quality electrons, muons, taus, jets and missing energy



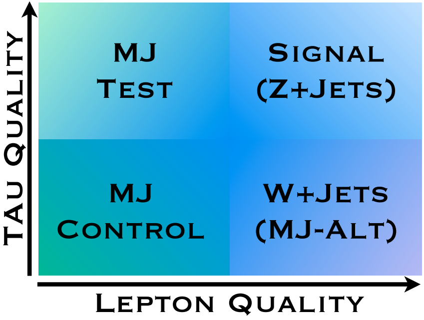
MJ Definition

- We define a set of multi-jet enriched events 'MJ Control' by reversing the τ and lepton quality
- Subtract all other SM backgrounds to acquire the MJ shape ($\mathcal{M}$)
- The number of MJ events in the signal sample, $\mathcal{N}_{\mathrm{OS}}^{\mathrm{MJ}}$, are scaled by the ratio ρ_i

$$\mathcal{N}_{\mathrm{OS}}^{\mathrm{MJ}} = \rho_i(\mathcal{N}_{\mathrm{SS}}^{\mathrm{DATA}} - \mathcal{N}_{\mathrm{SS}}^{\mathrm{SM}})$$

$$\rho_i = \frac{\mathcal{M}_{\mathrm{OS}}}{\mathcal{M}_{\mathrm{SS}}} \quad i = 1, 2, 3\,(\tau\!-\!type)$$

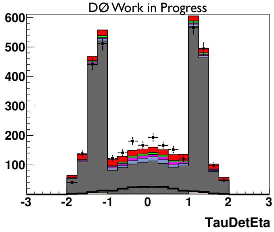
- MJ systematics are estimated from the 'MJ Test' sample



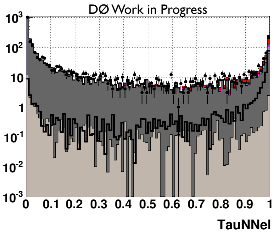
$Z \rightarrow ee$ Supression

- The $e\tau$ channel is overwhelmed by $Z \rightarrow ee$ background
- We employ a series of cuts to reduce the background contribution
- We remove events in the following regions:

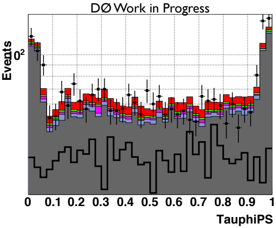
Type 1: $1.5 < |\eta_d^\tau| < 1.05$



Type 2: TauNNel < 0.95

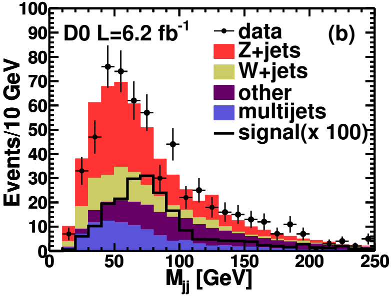


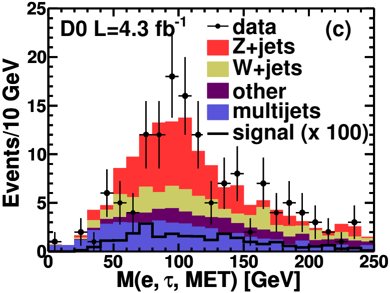
Type 2: $0.9 < |\phi_{PS}| < 0.1$



Data and MC Agreement

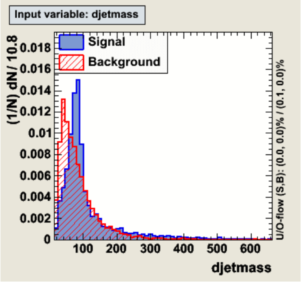
- The background contributions to each channel are different.
- It is very important to check the MC modeling before moving to a multivariate analysis

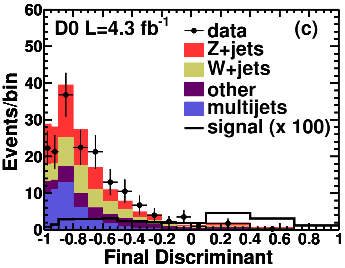




Multivariate Analysis

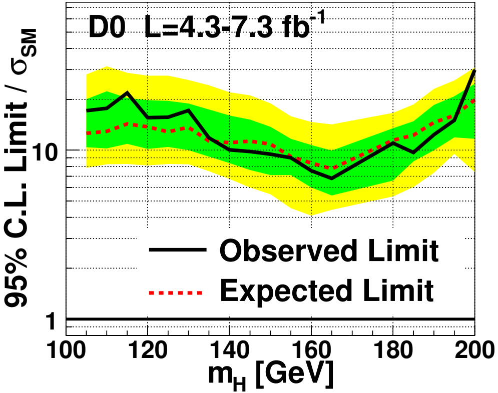
- A simple cut based approach is inadequate to observe a possible excess of events
- Instead we utilize a Boosted Decision Tree (BDT) that uses shape differences and correlations of many variables to differentiate signal-like from background-like
- 17 variables well modeled variables are input to a BDT
- Unequal binning of the final discriminant is used to ensure a continuous background distribution





Limits

- The $e\tau$ (4.3fb^{-1}) channel is combined with the $\mu\tau$ 2jet (7.2fb^{-1}) and $\mu\tau$ 0jet (7.3fb^{-1}) channels to produce our final limit
- We have relatively flat sensitivity across the full mass region, and set upper limits on SM Higgs cross section of $\sim$ 10 times the SM



CONCLUSIONS

- $H \rightarrow \tau\tau$ involves several production modes, and has a pervasive $Z+$ jets background
- Our recent publication (arXiv:1203.4443v1 [hep-ex]) uses up to 7.3fb^{-1} of data, and was included in the Moriond 2012 Tevatron combination result (FERMILAB-CONF-12-065-E)
- This is the first publication to included the $e\tau$ channel at DØ
- Significant improvements to the limits are expected for ICHEP 2012

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Thank you