A search for WH Associated Production at the DØ experiment from $p\bar{p}$ Collisions with $\sqrt{s}$ =1.96 TeV

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APS-DPF2006 AND JPS2006

October 30th 2006

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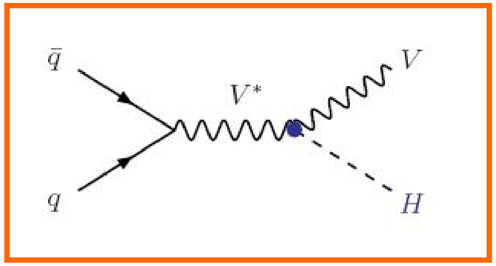
Physics Motivation

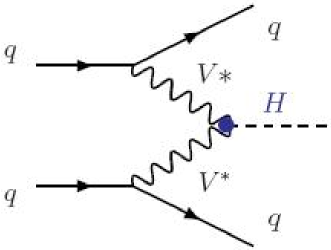
- SM has been very successful
  - Top quark (discovered in 1995)
  - Model is still incomplete
- Existence of Higgs has major consequences
  - Relation to Boson Masses via Higgs Mechanism: $M_W/M_Z = \cos\theta_W$
  - A neutral Higgs boson H^o predicted.
  - Interactions with the Higgs field can *generate* fermion masses
- SM Predicts neutral Higgs Boson which has not been verified experimentally
  - Since H^o couples strongly to W and Z the best places to search for it are at Tevatron and LHC!
  - Does *not predict* the mass of the Higgs boson
  - Does predict its couplings to other particles e.g. *coupling to fermions*
  - $H^o \rightarrow b\bar{b}$ is likely to be the decay mode for Higgs *discovery*

SM Higgs Boson – Production Mechanism

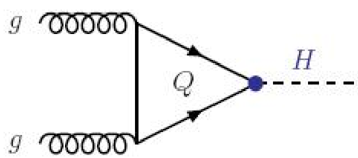
- SM Higgs couples to
  - massive W/Z Bosons
  - top/bottom quark
- Four main production channels are of interest at hadron colliders
- (W/Z) H channels have smaller QCD background
- NNLO theoretical cross-sections for WH are
  - 0.178 pb for 115 GeV Higgs
  - 0.086 pb for 140 GeV Higgs



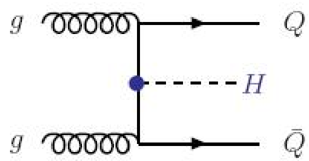
associated production with W/Z
$q\bar{q} \longrightarrow V + H$



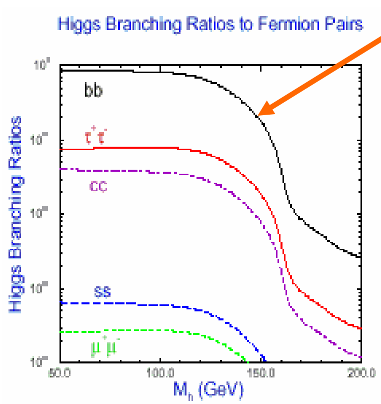
vector boson fusion
$qq \longrightarrow V^*V^* \longrightarrow qq + H$

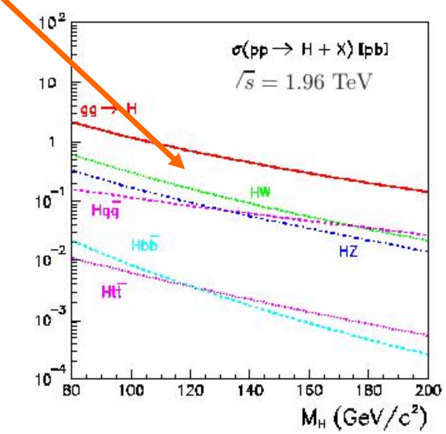


gluon – gluon fusion
$gg \longrightarrow H$

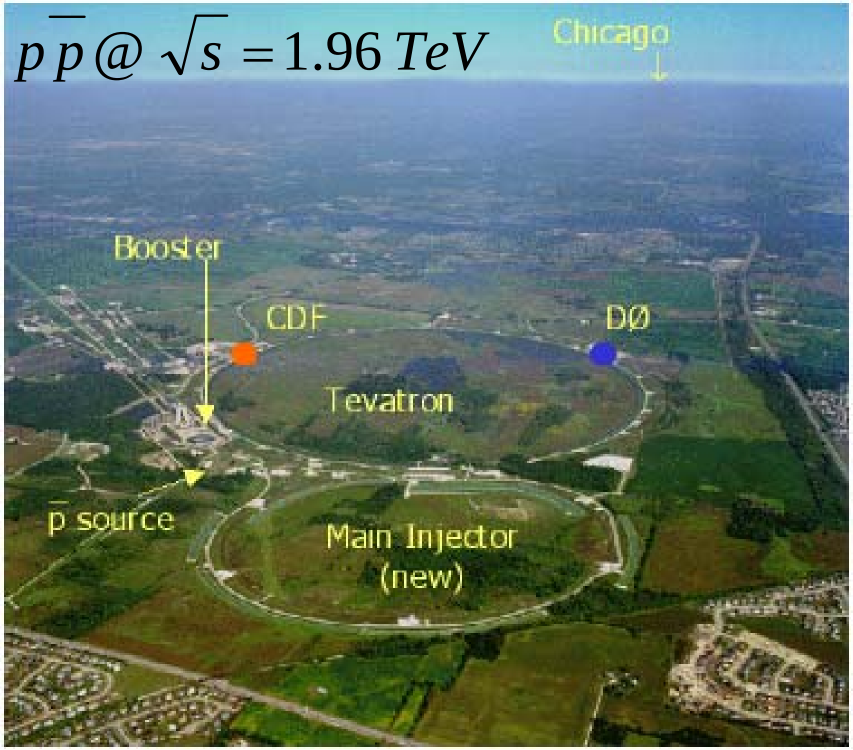


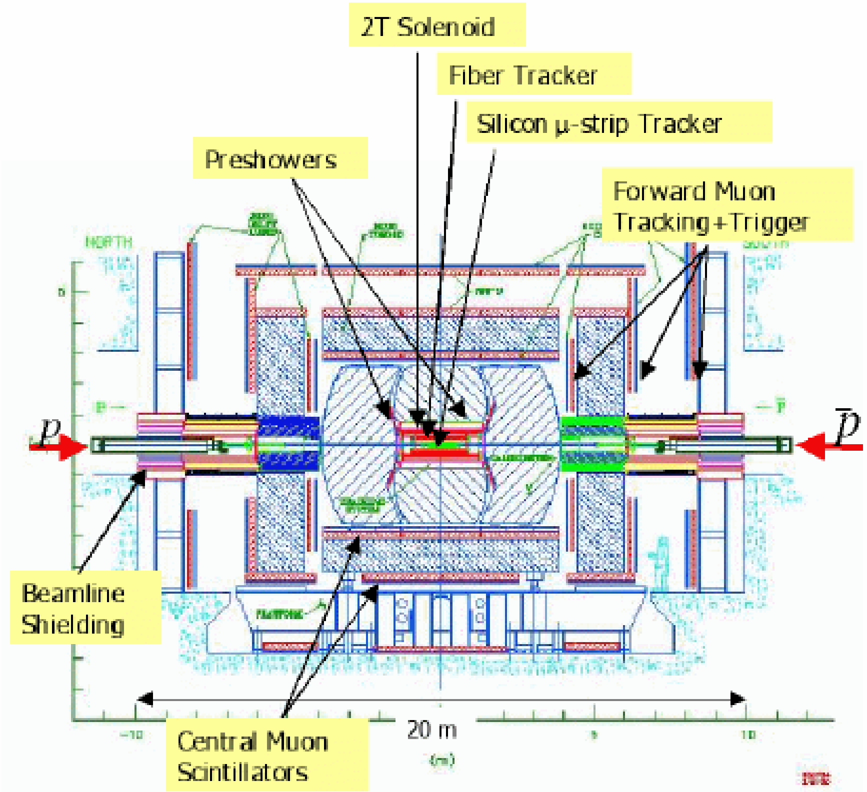
associated production with heavy quarks
$gg, q\bar{q} \longrightarrow Q\bar{Q} + H$





Experimental Apparatus





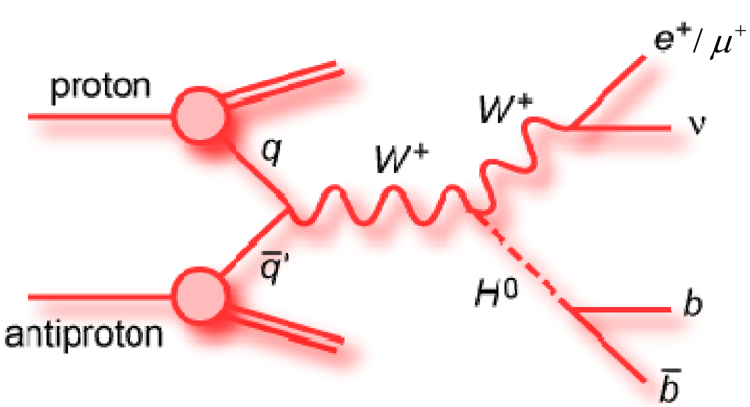
- Recorded Luminosity: 1.68fb^{-1} as of Oct 12th 2006
- RunIIA – Apr 2002 – Feb 2006
- 174pb^{-1} DØ Data - PRL for WH (evbb) in 2005
- Results shown here are for 0.37 – 0.39 fb^{-1}
- 1.0 fb^{-1} analyses are currently in progress

Upgraded DØ Detector

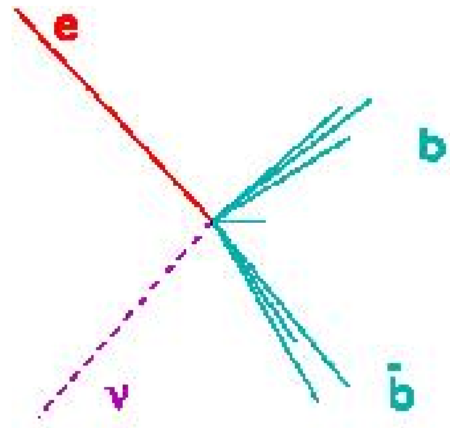
Extended Muon Spectrometer

New Tracking System

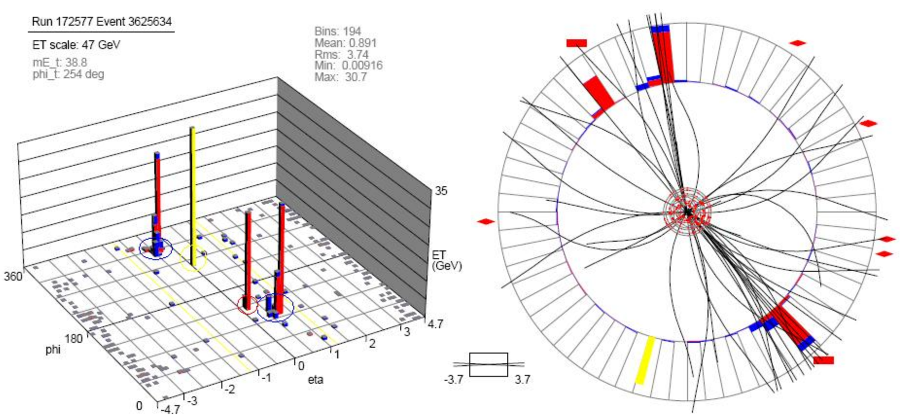
Event Signature



Physics Level



Detector Level



Event Display of a Candidate Event

- Isolated Lepton
  - electron/muon
- Large Missing Transverse Energy
  - MET or $\not{E}_T$
- Exactly two Jets (tagged as b-jets)
  - Improved Signal/Background

Data Sample and Event Selection

- **Integrated Luminosity of the Sample**

  371 pb^{-1} - electron channel

  385 pb^{-1} - muon channel

- **Isolated Lepton**

  p_T > 20 GeV/c

  Electron:
  |η| < 1.1 (for electron)
  EM Fraction in Calorimeter > 90%
  Isolation Fraction < 0.15
  Tight Shower shape, χ^2 of HMx(7) < 50
  Electron Likelihood > 0.70
  Trigger requires one EM Object

  Muon:
  |η| < 2.0
  Hits in all layers of Muon System
  equires centrally matched track
  Veto against cosmic muons
  Isolated from Jets $\Delta R(\mu, jet) > 0.5$
  Triggers require one muon object or a jet in addition to a muon

- **Neutrino ($\not{E}_T$)**

  Require $\not{E}_T$ > 25 GeV

- **Two Jets**

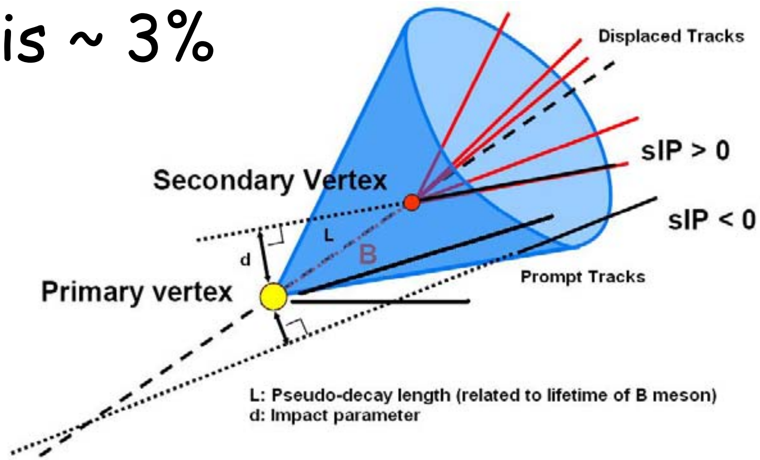
  Exactly 2 jets required (to obtain improved signal/background ratio)
  Reconstructed using 0.5 cone algorithm $\Delta R = \sqrt{\Delta\eta^2 + \Delta\varphi^2} = 0.5$
  |η| < 2.5
  p_T (jets) > 20 GeV/c

Simulated Signal/Background Samples

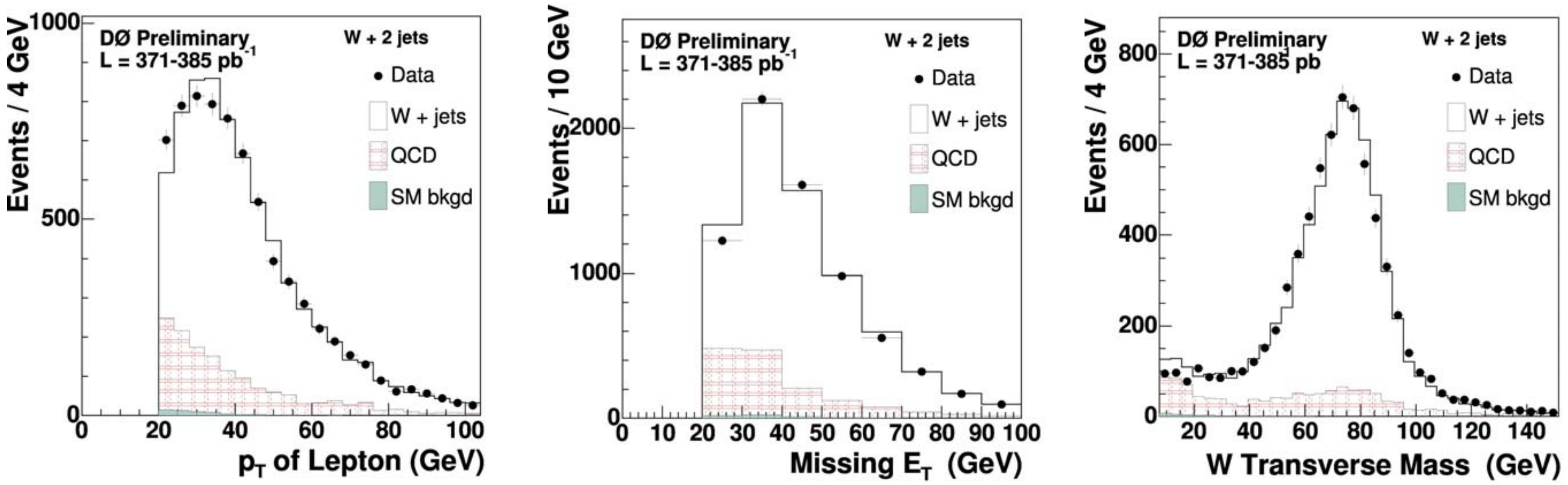
	Process	Generator	$\sigma(\times BR)[pb]$
$Wb\bar{b}$	$Wb\bar{b} \to e\nu b\bar{b}$	ALPGEN + PYTHIA	3.35
	$Wb\bar{b} \to \tau\nu b\bar{b}$	ALPGEN + PYTHIA	3.35
WH (Signal)	$HW \to b\bar{b} + e\nu$, $m_H = 105$ GeV	PYTHIA (CS compliant)	0.0222
	$m_H = 115$ GeV		0.0150
	$m_H = 125$ GeV		0.0093
	$m_H = 135$ GeV		0.0045
	$m_H = 145$ GeV		0.0022
	$HW \to b\bar{b} + \tau\nu$, $\tau \to e$, $m_H = 105$ GeV	PYTHIA (CS compliant)	0.0039
	$m_H = 115$ GeV		0.0026
	$m_H = 125$ GeV		0.0016
	$m_H = 135$ GeV		0.00078
	$m_H = 145$ GeV		0.00038
W + jets	$Wjj \to e\nu + jj$	ALPGEN + PYTHIA	287.3
	$Wjj \to \tau\nu + jj$	ALPGEN + PYTHIA	287.3
W/Z	$Zjj \to ee + jj$	ALPGEN + PYTHIA	27.2
	$\gamma^*/Z \to \tau\tau, \hat{m} \in (60, 130\,\mathrm{GeV})$	PYTHIA (CS compliant)	255.0
	$W \to \tau\nu_\tau$	PYTHIA (CS compliant)	2775
Top Pairs	$t\bar{t} \to b\bar{b} + \ell^+\ell^- + \not{E}_T$, $m_t = 175$ GeV	ALPGEN + PYTHIA	0.70
	$t\bar{t} \to b\bar{b} + 2j + \ell + \not{E}_T$, $m_t = 175$ GeV	ALPGEN + PYTHIA	2.90
Single Top	Single top s-channel ($tb \to e\nu\ b\bar{b}$)	CompHEP + PYTHIA	0.115
	single top t-channel ($tqb \to e\nu\ bqb$)	CompHEP + PYTHIA	0.258
Diboson	$WW \to l\nu jj$	PYTHIA	2.672
	$WZ \to l\nu jj$	PYTHIA	0.824
	$WZ \to lljj$	PYTHIA	0.243
	$ZZ \to lljj$	PYTHIA	0.205

Tagging b-Jets

- Tagging Jets with the using algorithm
  - Jet LIfetime Probability (JLIP)
- JLIP Probability constructed using tracks associated to jets with positive impact parameter in the transverse plane
- Define two exclusive samples
  - Double Tag (DT): 2 jets with JLIP probability < 1%
  - Single Tag (ST): 1 jet with JLIP probability < 0.1%
- Fake Rate (Negative Tag Rate) is ~ 3%
- Efficiency of Tagging
  - 33 ± 4%(ST) and 55 ± 4% (DT)



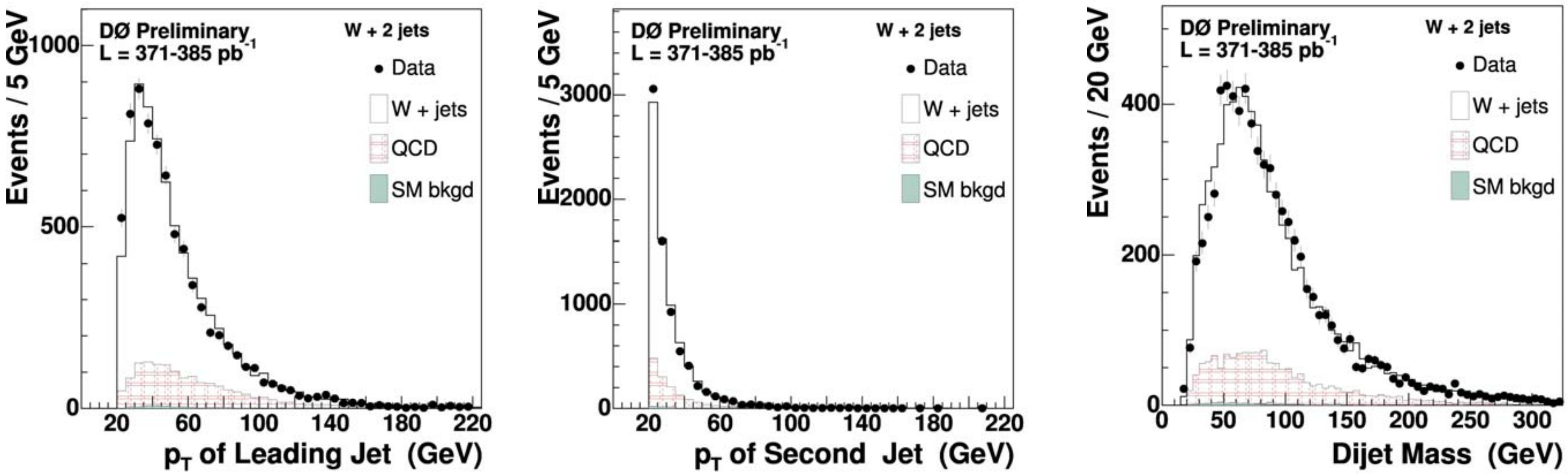
Data/Background (Before b-tagging)



W(→ ℓ ν) + ≥ 2 jets

- Before b-tagging, the dominant background is W + jets
- All backgrounds except on are normalized absolutely (i.e., to the cross-section)
- W+ jets which is normalized to data after subtracting all other backgrounds

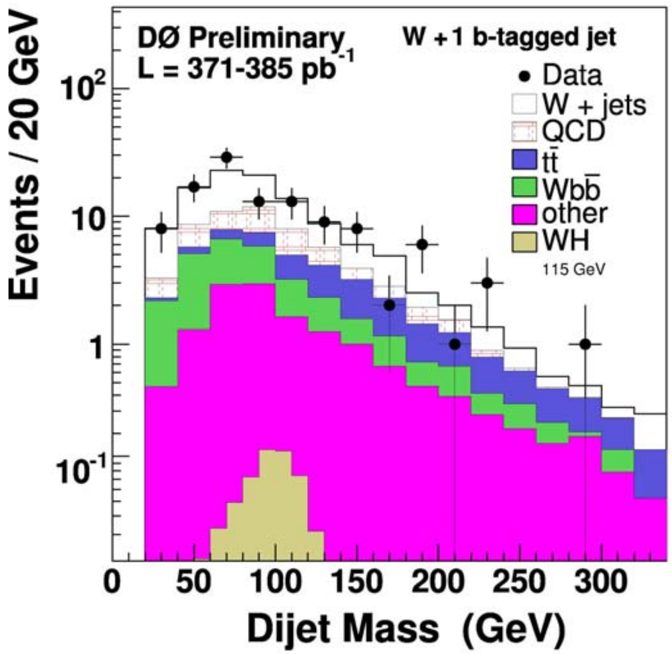
Data/Background (Observed and Expected)

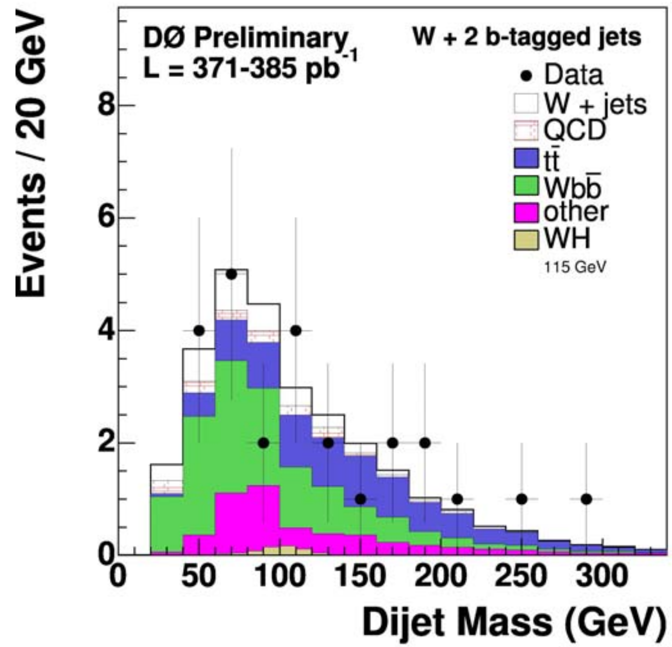


W(→ ℓ ν) + ≥ 2 jets (ℓ = e and μ)

➢ Total Expectation from Simulation	7388 ± 817
➢ Observed Number of Data Events	7388
➢ QCD (Multijet) background estimated from Data	850 ± 231

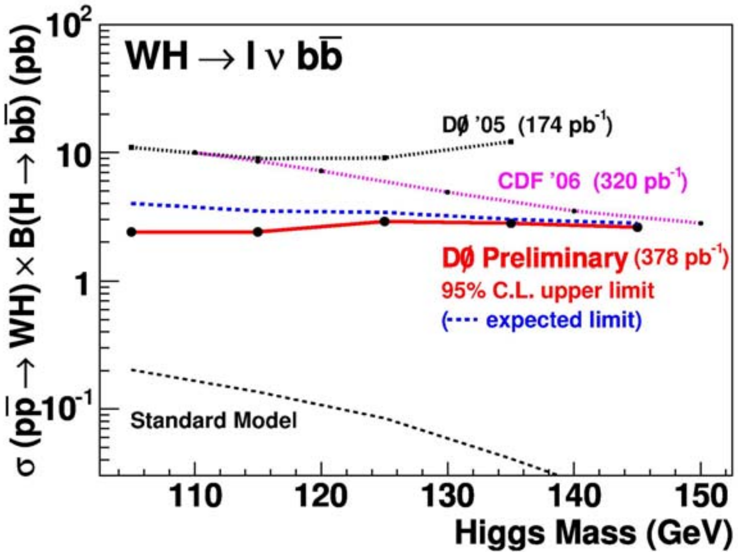
Data/Background (Single and Double Tagged)





$W(\rightarrow \ell\ \nu) + \geq 2$ jets (ℓ = e and μ)	Single Tag	Double Tag
➢ Total Expectation from Simulation	111.8 ± 17	27.9 ± 4.2
➢ Observed Number of Data Events	112	25
➢ QCD (Multijet) background	18.0 ± 6.3	1.36 ± 0.6

Cross Section Limits

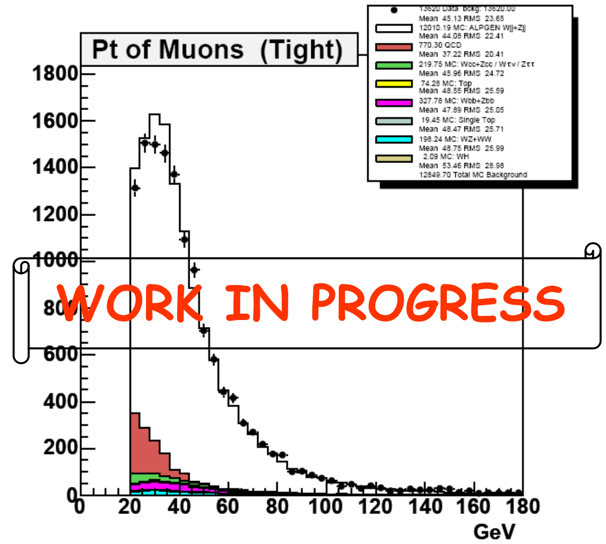


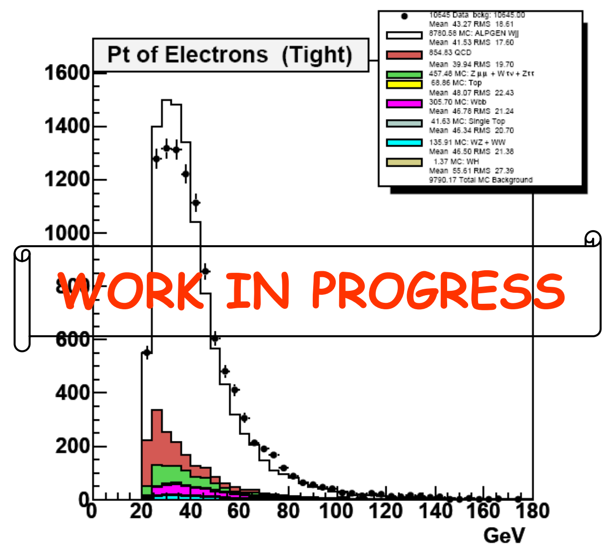
- No excess above the SM background
- Derive 95% CL Limits from Dijet mass
- Combine all four analyses to derive limits
  - Overall Expt. Systematic error 16 - 19 %
- Cross-section limits are
  - 2.4 pb (3.5 expected) for 115 GeV/c^2 Higgs boson

Higgs mass	105 GeV	115 GeV	125 GeV	135 GeV	145 GeV	
WH	0.4	0.27	0.17	0.09	0.04	Single Tag
WW, WZ, ZZ	3.3	2.5	1.1	0.4	0.15	
$Wb\bar{b}$	6.6	6.6	4.5	3.4	2.5	
$t\bar{t}$	3.9	4.3	4.4	4.5	4.5	
Single top	2.3	2.3	2.4	2.4	2.2	
QCD / W or Z +jets	19.2	30.6	23.3	19.0	16.4	
Total expectation	50.9	45.1	35.7	29.7	25.7	
Data	40	32	32	27	27	
WH	0.37	0.28	0.17	0.09	0.04	Double Tag
WZ	1.4	1.0	0.60	0.22	0.05	
$Wb\bar{b}$	4.2	3.6	3.0	2.4	2.0	
$t\bar{t}$	2.0	2.1	2.4	2.2	2.3	
Single top	0.89	0.89	0.92	0.89	2.0	
QCD / W or Z +jets	1.8	1.6	1.4	1.2	1.0	
Total expectation	10.5	9.3	8.1	6.9	6.3	
Data	7	6	7	6	6	
Combined Cross section limit (pb)	2.4	2.4	2.9	2.8	2.6	
Expected Cross section limit (pb)	4.0	3.5	3.4	3.0	2.8	

Work in Progress – 1fb^{-1} (WH) Analyses

- Analysis converging in both electron and muon channels
- Expect to have preliminary results in ~ 1 month
- Improved tagging using Neural Net b-tagging.
- Extending the analysis to include both central and end-cap calorimeters
- Combine the channels to set limits





Summary and Conclusions

- 95% C.L limits derived for $\sigma(p\bar{p} \rightarrow WH) \times B.R(H \rightarrow b\bar{b})$ between 2.4 and 2.9 pb for Higgs masses between 105 and 145 GeV
- Tevatron has delivered ~2 fb^{-1} of data as of Oct 2006
- Sensitive to low mass Higgs @ 2 fb^{-1}
- Improvements in Analysis
  - Neural Net Tagger
  - Neural Net Selection
  - TrackCalJets➔ mass resolution
  - Include End-Cap Calorimeter
- Overall sensitivity expected to improve significantly