Search for H→WW and WH→WWW* at DØ

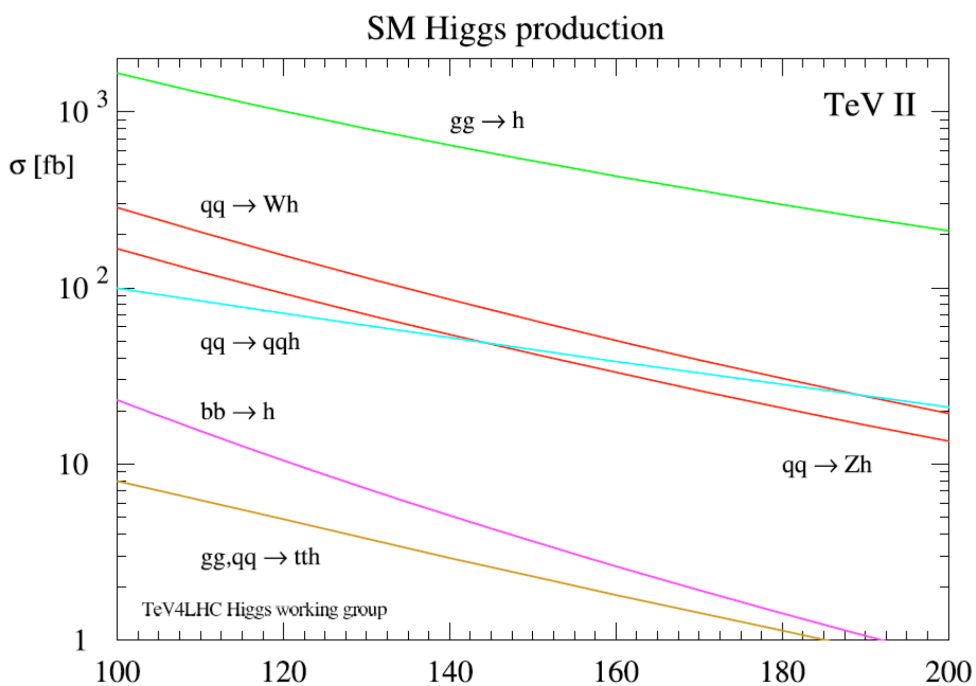
DPF 2009, Wayne State University


Michael Kirby

Northwestern University

on behalf of the DØ Collaboration

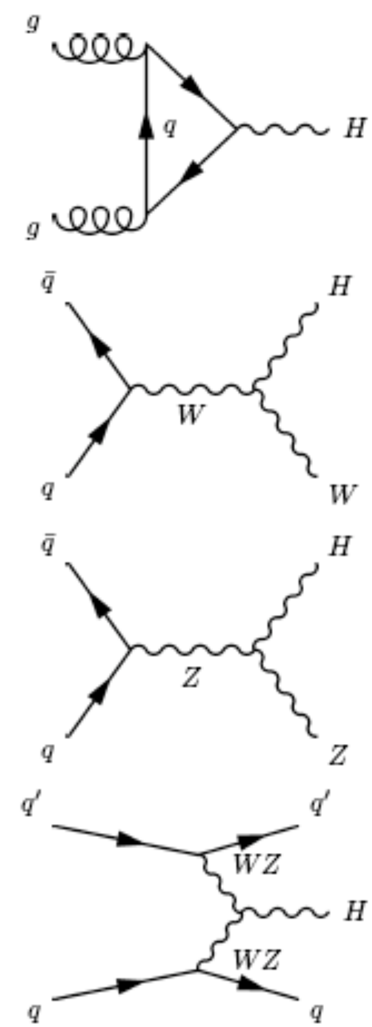
Higgs Production at the Tevatron



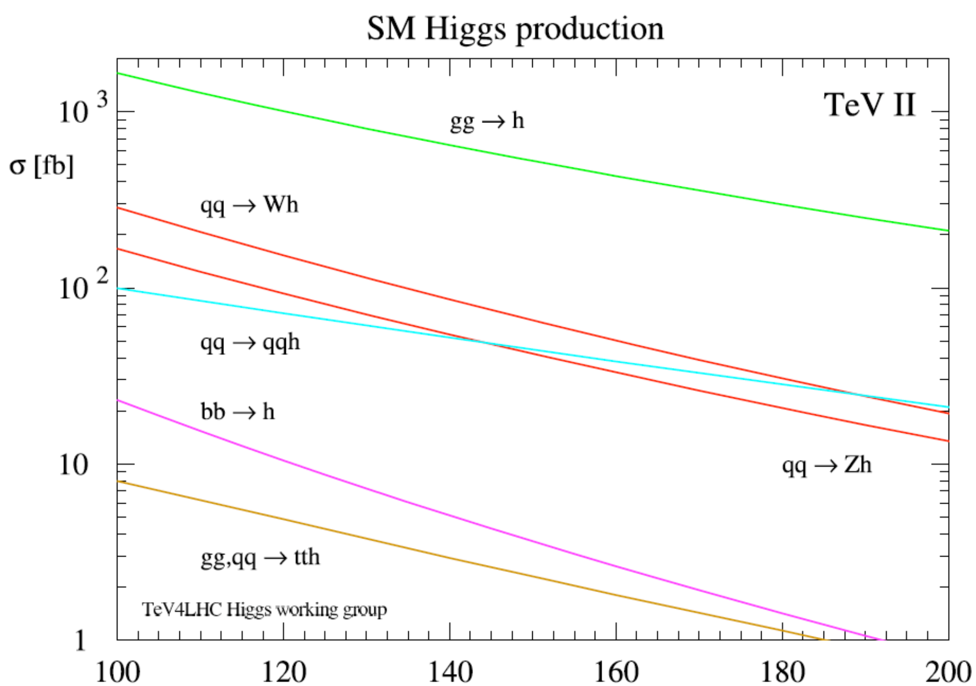
Gluon fusion dominates

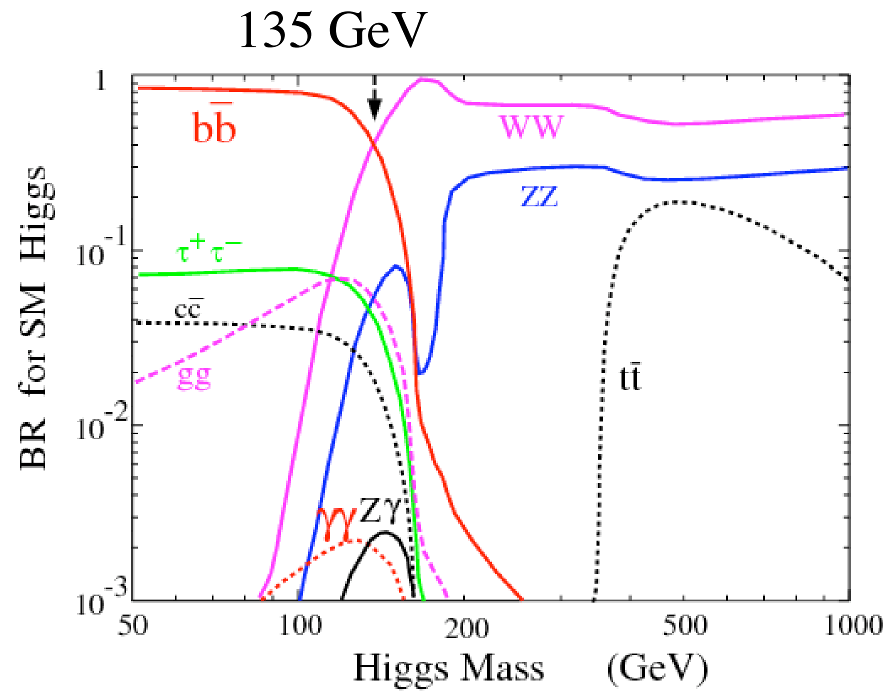
Associated production (WH,ZH)

Vector Boson fusion



Higgs Production at the Tevatron





Gluon fusion dominates

Associated production (WH,ZH)

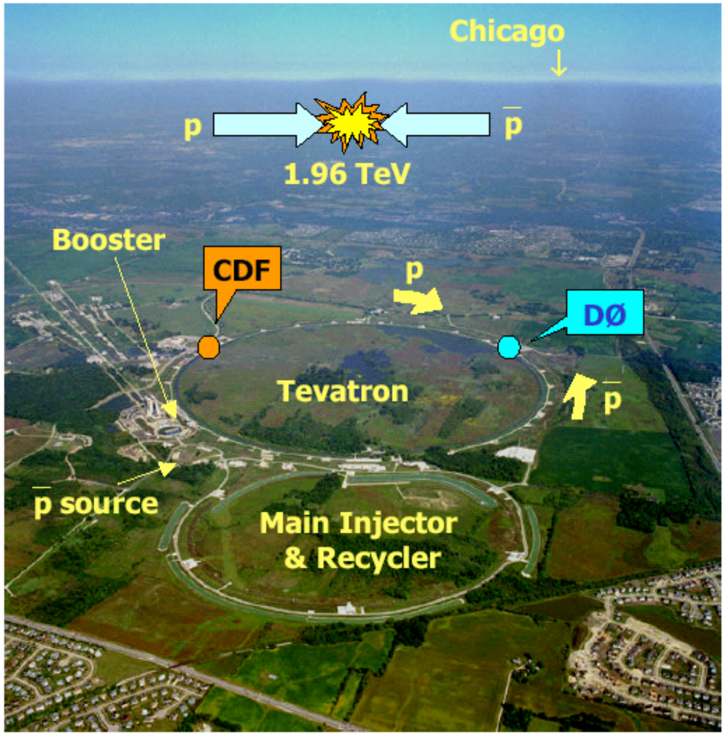
Vector Boson fusion

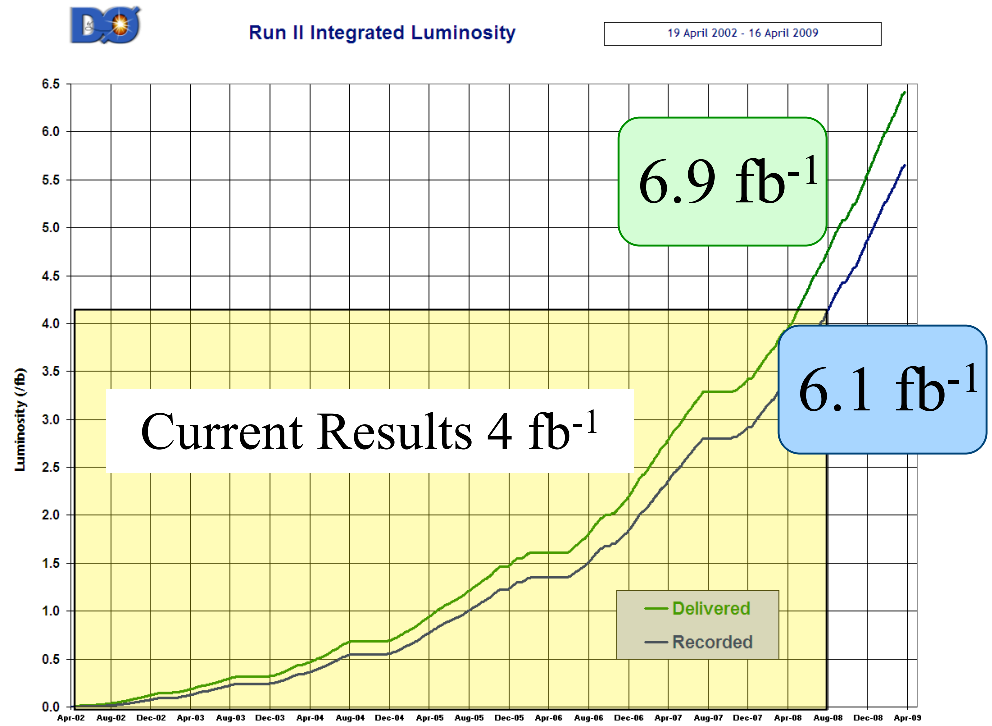
Dominant Higgs Decays

For m_H<135, H→bb

For m_H >135, H->WW

Tevatron & DØ Dataset





Apr 2002 Dec 2008

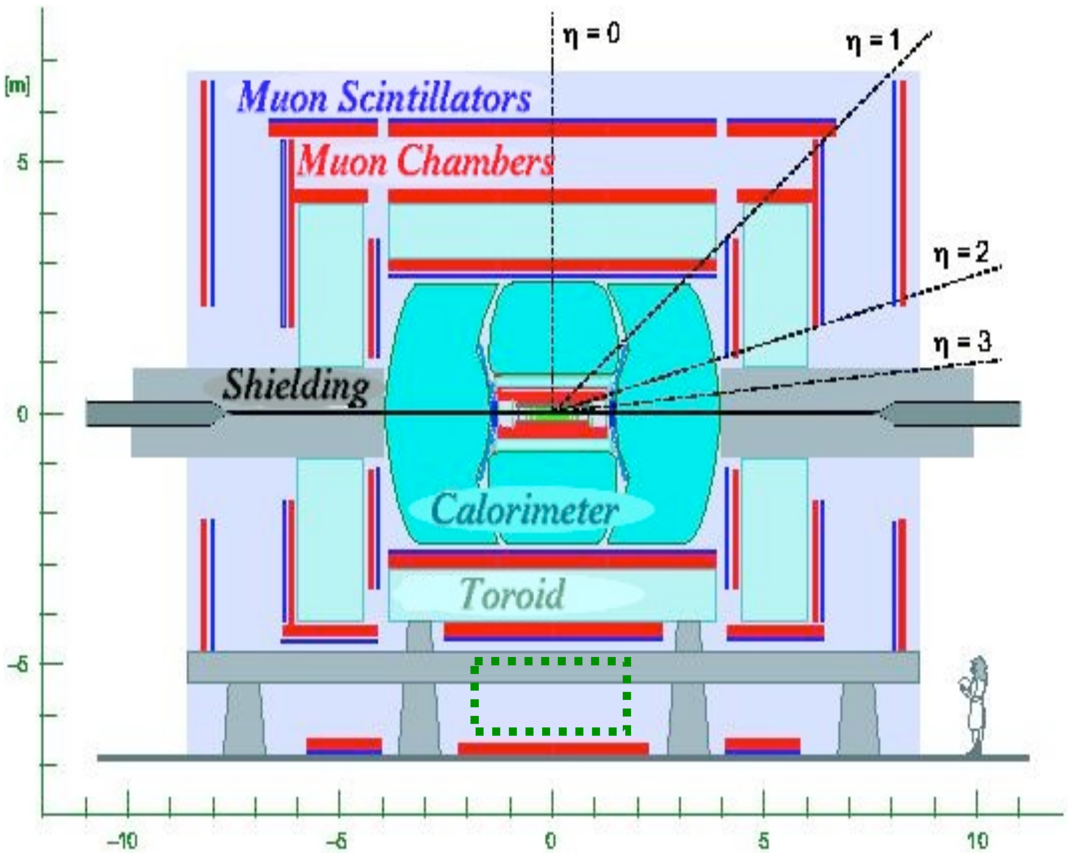
Tevatron delivering ~70 pb^{-1} per week

Thanks to Fermilab Accelerator Division!

Data taking efficiency > 90 %

Expect to continue to collect data through 2011

DØ Detector



detector coverage |η|

muons ~ 2

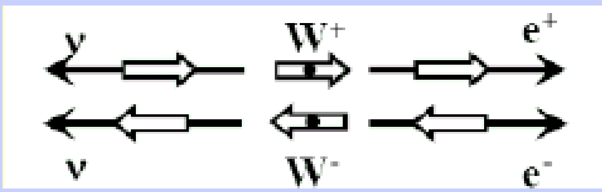
tracking ~ 2.5

EM/Jet ~ 4

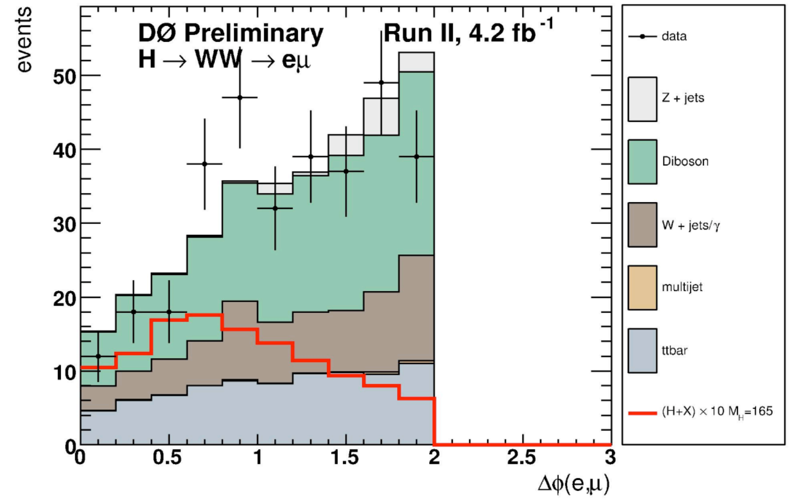
- **Spectrometer : Fiber and Silicon Trackers in 2 T Solenoid**
- **Energy Flow : Fine segmentation liquid Ar Calorimeter and Preshower**
- **Muons : 3 layer system & absorber in 1.8 T Toroidal field**
- **Hermetic : Excellent coverage of Tracking, Calorimeter and Muon Systems**

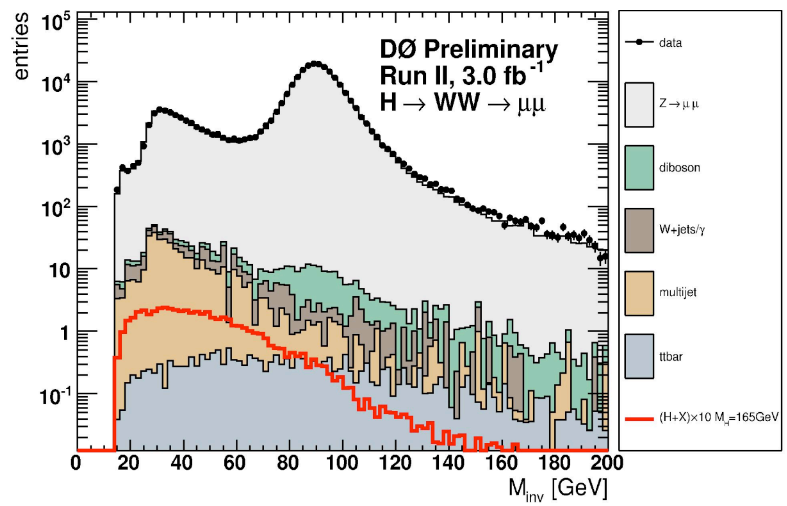
H→WW→*lνlν* Signature

- Decay Kinematics
  - WW pair from Spin-0 Higgs boson



  - charged leptons tend to point in same direction
  - *ll* Opening Angle
  - Broad invariant mass spectrum

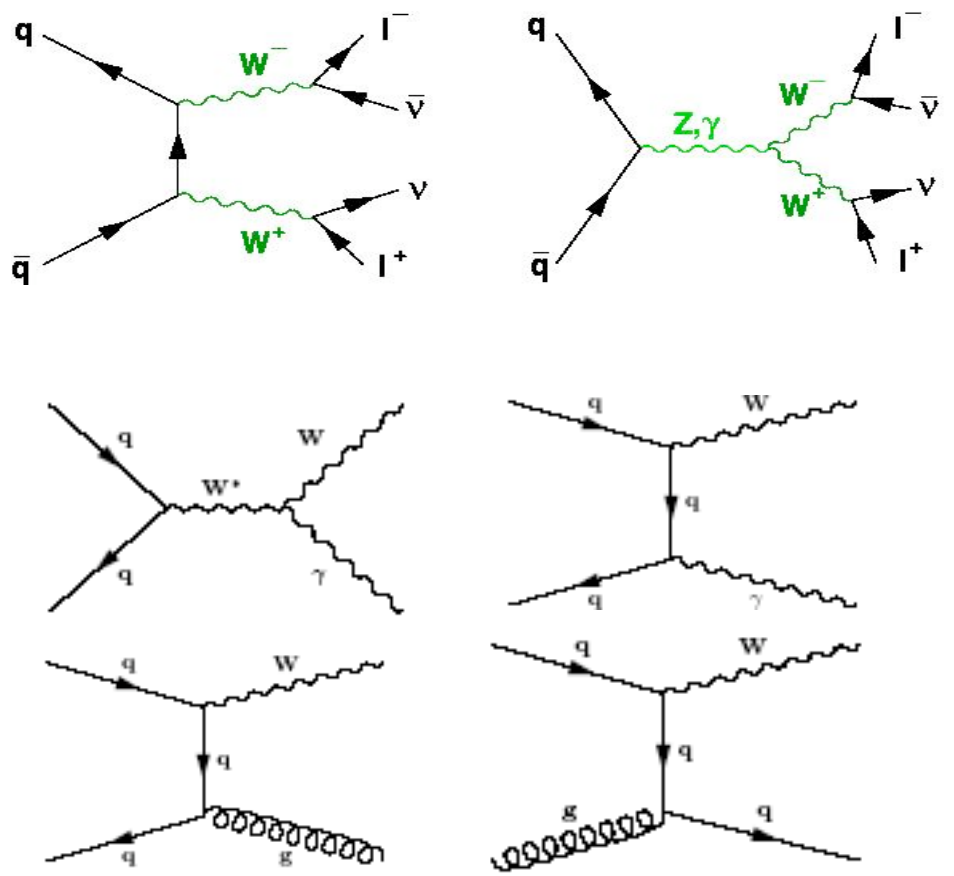




$H \rightarrow WW \rightarrow l\nu l\nu$ Backgrounds

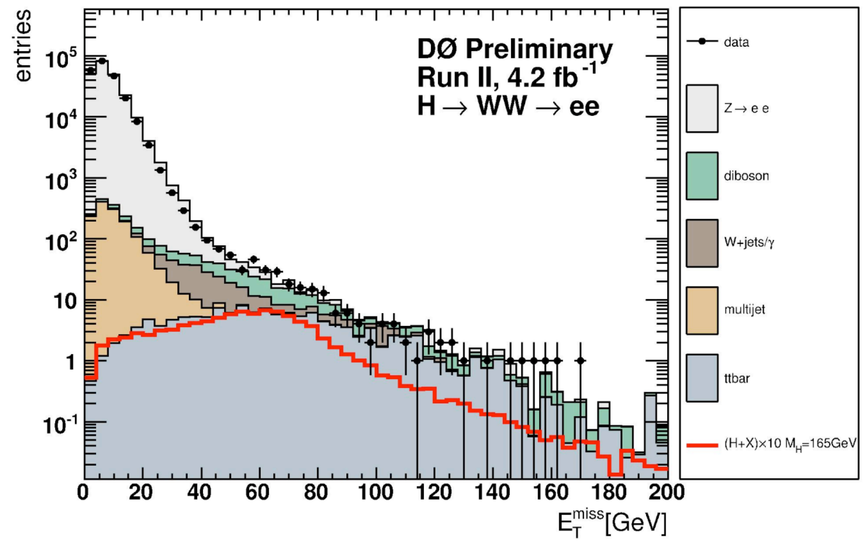
- WW/WZ
- W+Jets/γ
- Drell-Yan
- $t\bar{t}$, single top
- Multijet from like-sign sample

All cross sections have been measured at the Tevatron



$H \rightarrow WW \rightarrow l\nu l\nu$ Selection

- Trigger on high P_T lepton
- $P_T^{\mu} > 10$ GeV
- $P_T^{e} > 15$ GeV
- Isolation cuts
- Opp Charge leptons
- $M_{ll} > 15$ GeV



Final state	$e\mu$	ee	$\mu\mu$
$\not{E}_T$ (GeV)	> 20	> 20	
$\not{E}_T^{scaled}$	> 6	> 6	
$M_t^{min}(l,E_T)$ (GeV)	> 20	> 30	
$p_T^{\mu\mu}$ (GeV) for $n_{jet} = 0$ $\not{E}_T$ (GeV) for $n_{jet} = 1$			>20 >20
$\Delta\phi(l,l)$	< 2.0	< 2.0	< 2.5

m_H(165 GeV) ~ 23 Signal events in final selection

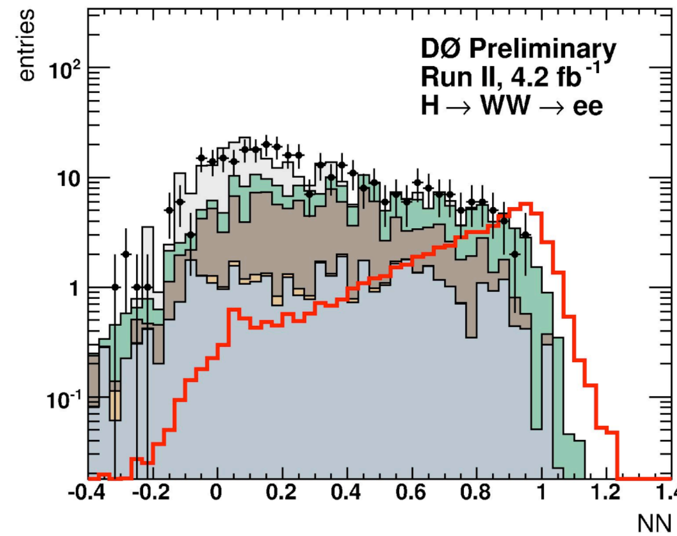
Total Background ~ 5000 events

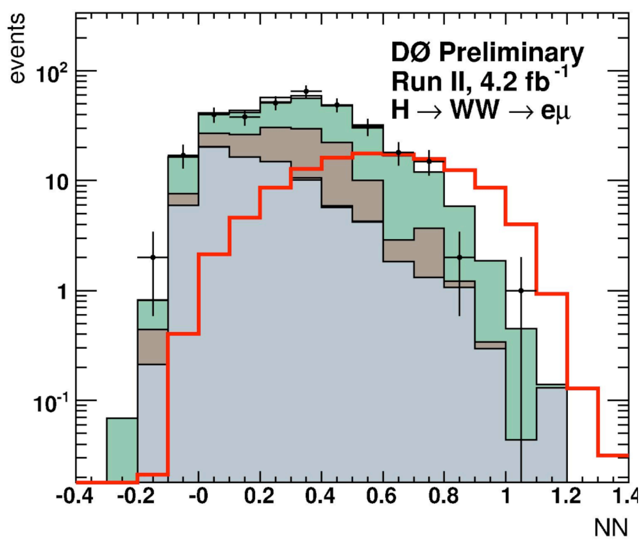
$H \rightarrow WW \rightarrow l\nu l\nu$ Neural Net

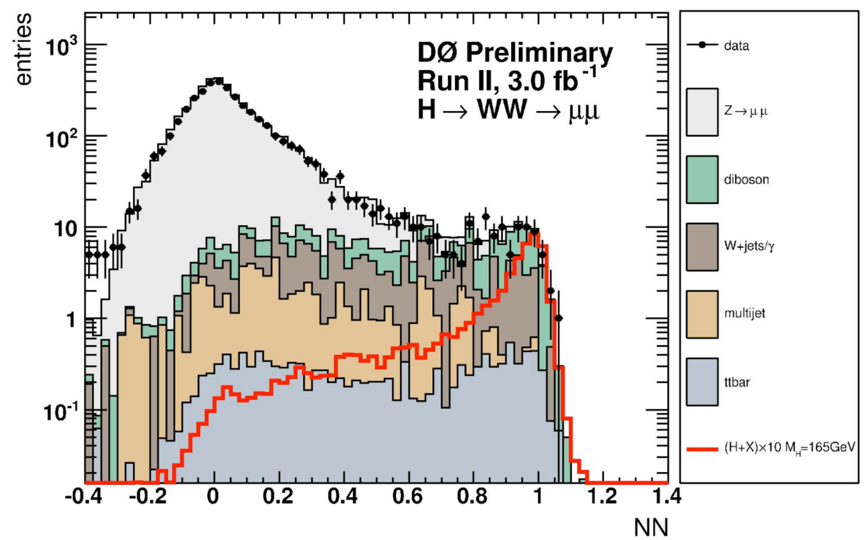
NN trained for each Higgs mass in 5 GeV steps, for each channel

Output of NN distribution used to set limits

Object Variables	Event Var	Topo Var
P_T^{l1} & P_T^{l2}	$M_{inv}(l,l)$	$\Delta\phi(l,l)$
$\sum$ lepton P_T	$M_t^{min}(l,\not{E}_T)$	$\Delta\Theta(l,l)$
$\sum$ jet P_T (H_T)	$\not{E}_T$	$\Delta\phi(E_T,l_1)$
Lepton Quality	$\not{E}_t^{scalar}$	$\Delta\phi(E_T,l_2)$







H→WW Neural Net Output

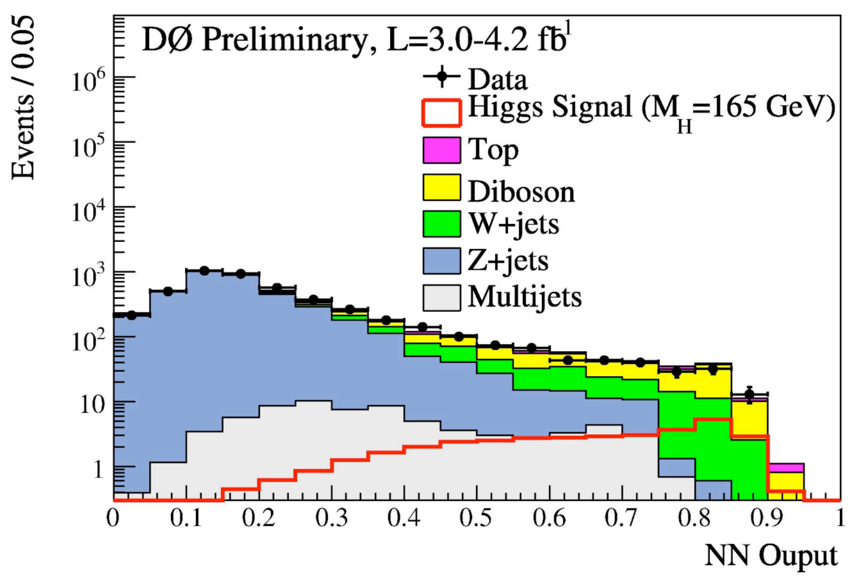
NN trained for each Higgs mass in 5 GeV steps, for each channel

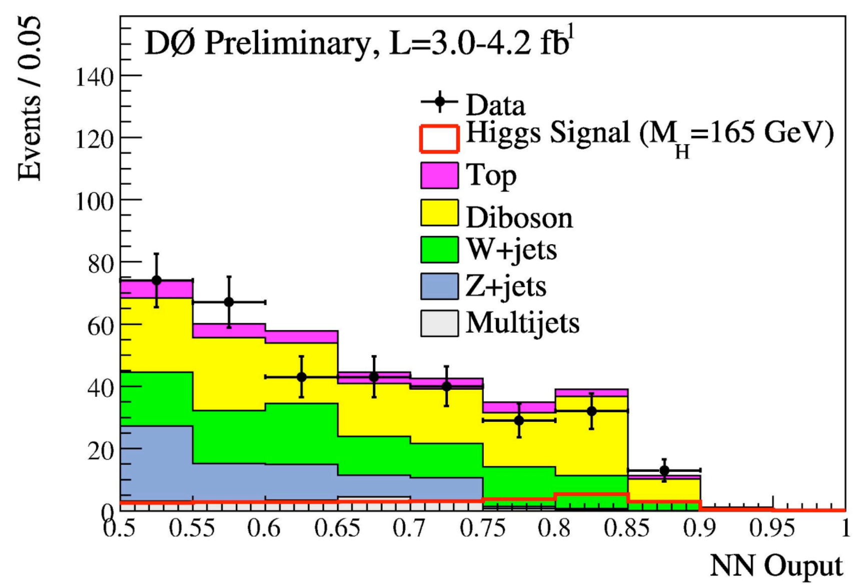
Output of NN distribution used to set limits

Object Variables	Event Var	Topo Var
P_T^{l1} & P_T^{l2}	$M_{inv}(l,l)$	$\Delta\phi(l,l)$
$\sum$ lepton P_T	$M_t^{min}(1,\not{E}_T)$	$\Delta\phi(\not{E}_T,l_1)$
$\sum$ jet P_T (H_T)	$\not{E}_T$	$\Delta\phi(\not{E}_T,l_2)$
Lepton Quality	$\not{E}_t^{scalar}$	

Limits calculated using modified frequentist (CLs) and a LLR test statistic

Backgrounds fitted to minimize systematics



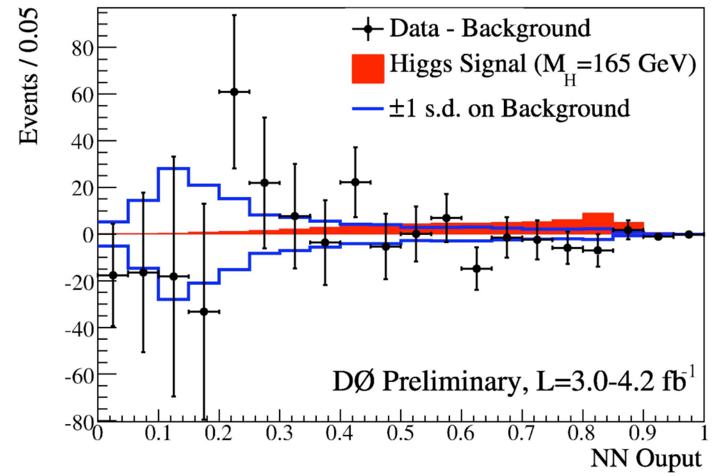


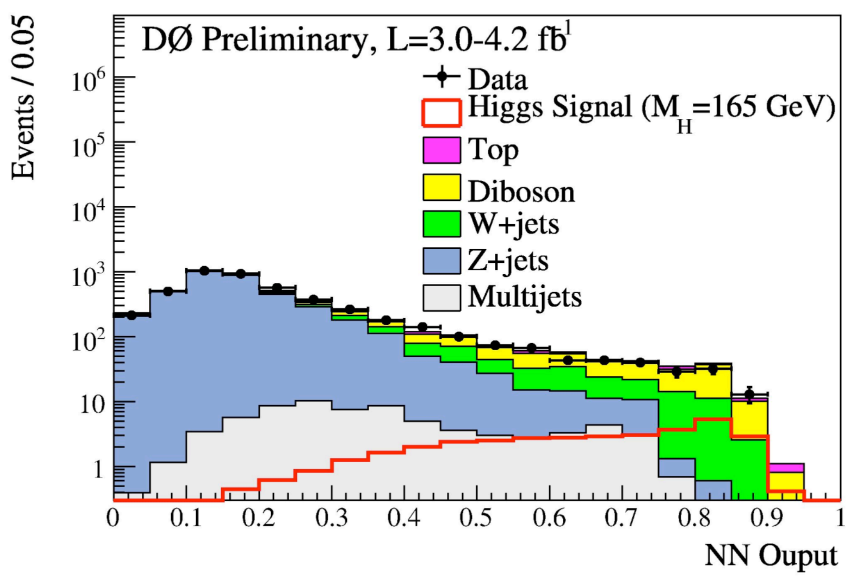
H→WW Neural Net Output

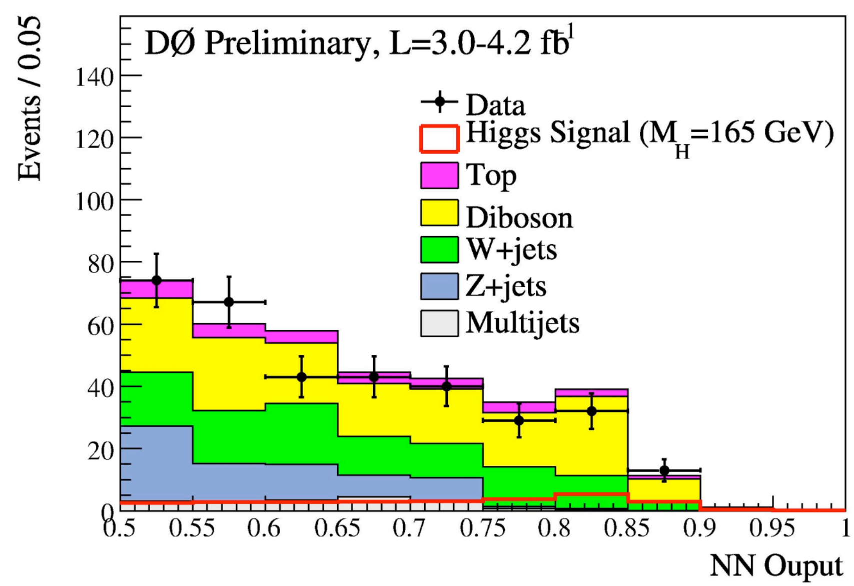
NN trained for each Higgs mass in 5 GeV steps, for each channel

Output of NN distribution used to set limits

Object Variables	Event Var	Topo Var
P_T^{l1} & P_T^{l2}	$M_{inv}(l,l)$	$\Delta\phi(l,l)$
Σ lepton P_T	$M_t^{min}(l,\not\!\!E_T)$	$\Delta\phi(\not\!\!E_T,l_1)$
Σ jet P_T (H_T)	$\not\!\!E_T$	$\Delta\phi(\not\!\!E_T,l_2)$
Lepton Quality	$\not\!\!E_t^{scalar}$	

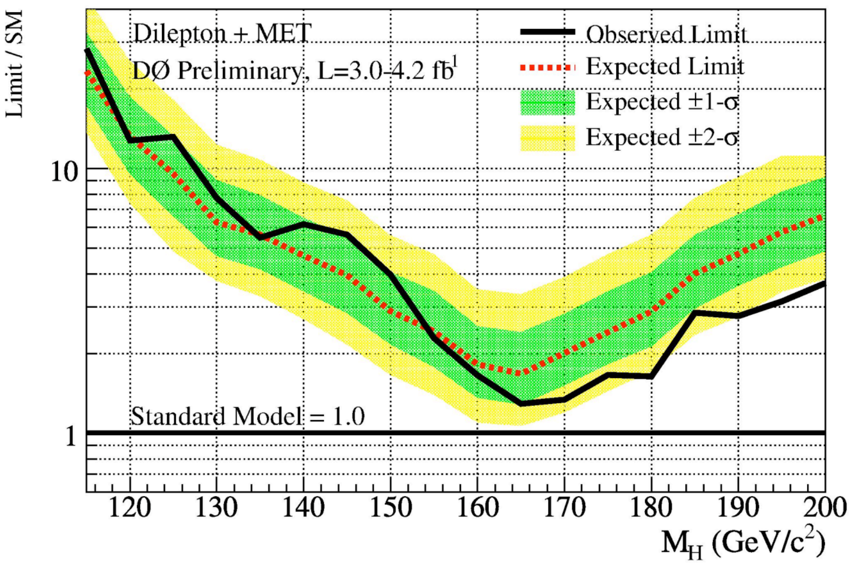


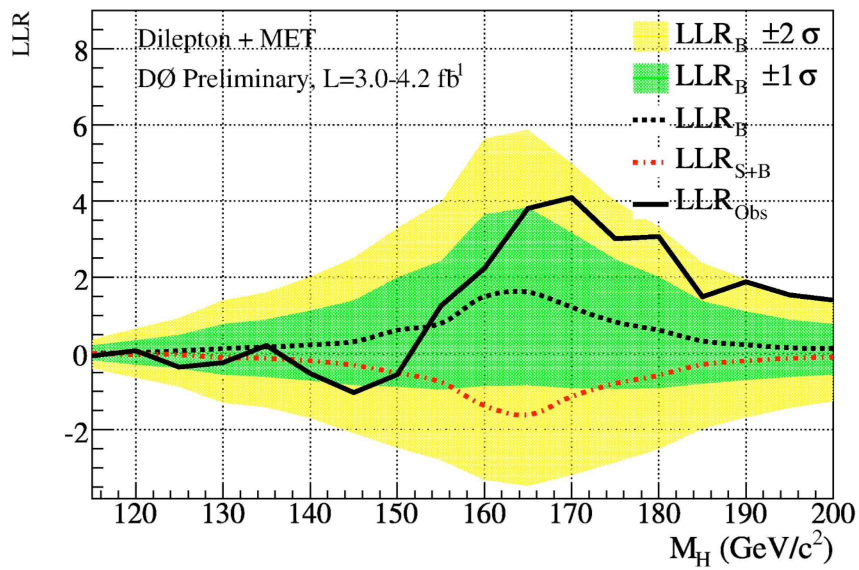




H→WW→$l\nu l\nu$ Limits

Combined *ee*, *eμ*, *μμ* sample





σ x BR(H→WW*) Exp 1.7 times SM

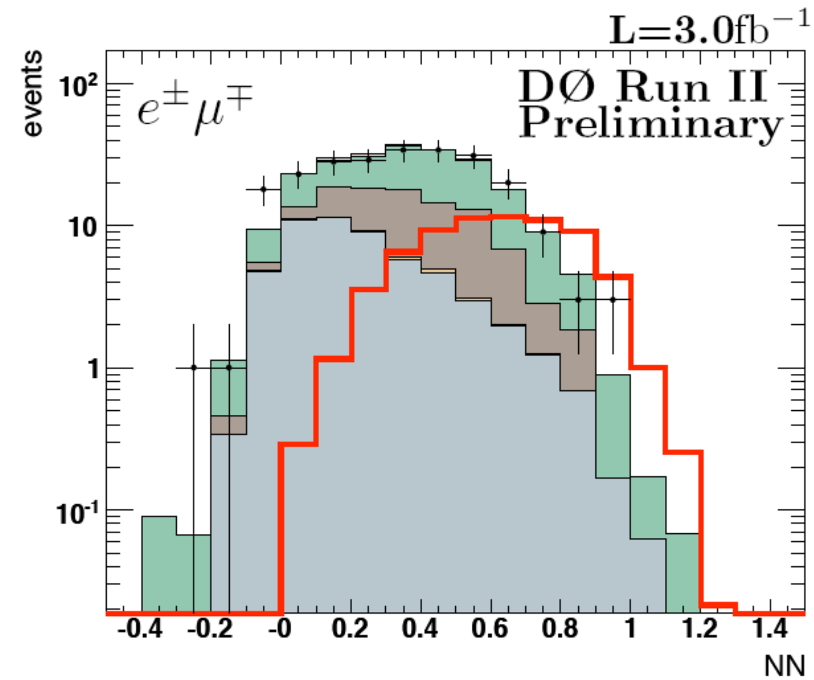
for m_H=165 GeV, Obs 1.3 times SM

$H \rightarrow WW \rightarrow l\nu l\nu$ Systematics

Shape systematics - modify the output of discriminant

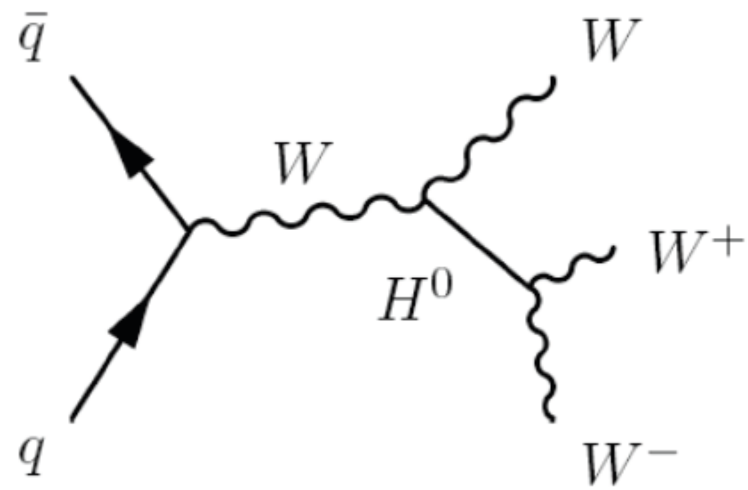
Flat systematics - efficiencies, normalizations, etc

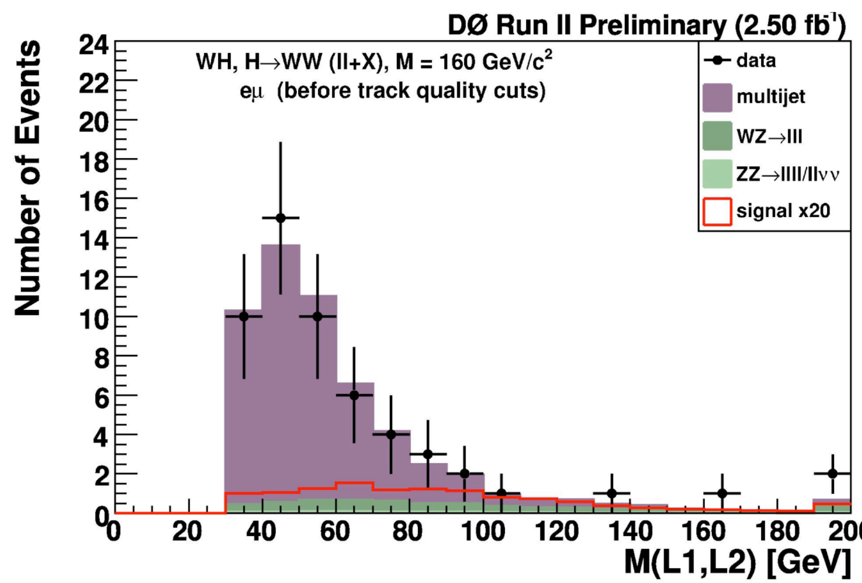
Syst(%)	Signal	∑Bkg
JES	0.3	1.1
Jet ID	6.0	0.0
PV Rew	0.9	0.6
Z-p_T Rew	4.6	0.
WW NLO	6.8	3.0
σ	5	4
Multijet	0	2
PDF	4	4
Lepton ID	5.7	5.7



WH→W(WW*)→$l^{\pm}\nu l^{\pm}\nu+X$

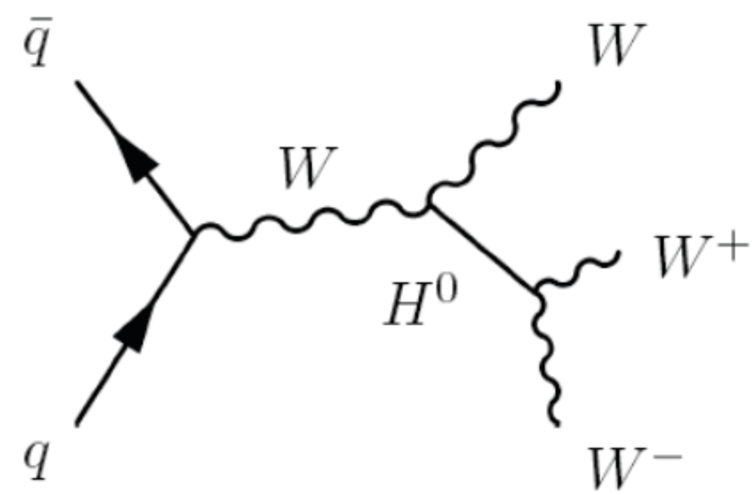
- For M_H > 135, H→WW dominate decay
- Important for intermediate mass ranges
- Look for like charged, high p_T leptons
  - easily triggered
  - small physics backgrounds
  - WZ, ZZ and $t\bar{t}$+V
  - charge flip and multijet



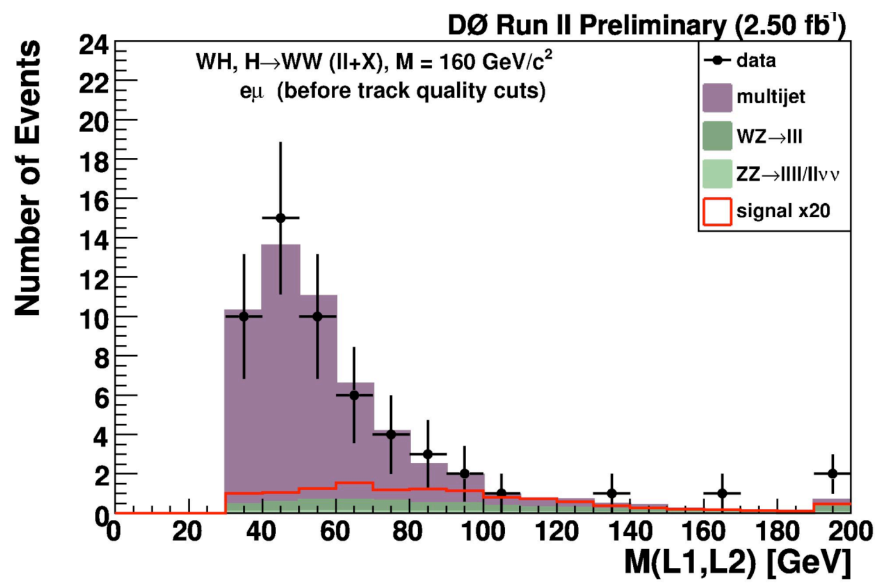


WH→$l^{\pm}\nu l^{\pm}\nu$+X Selection

- P_T^{μ} > 15 GeV
- P_T^{e} > 15 GeV
- Isolation cuts
- Like Charge leptons
- M_{ll}>30 GeV

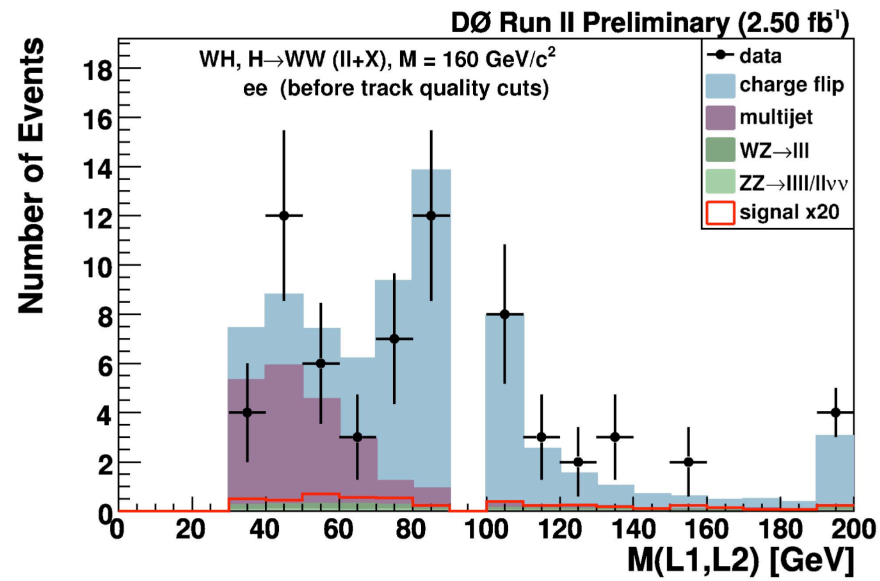


- P_T^{μ} < 200 GeV
- $\Delta(\text{vtx}, l)$ < 1 cm
- dca < 0.02 cm
- χ^2/NDF < 4 track fit
- require Silicon Det hits & Fiber tracker hits

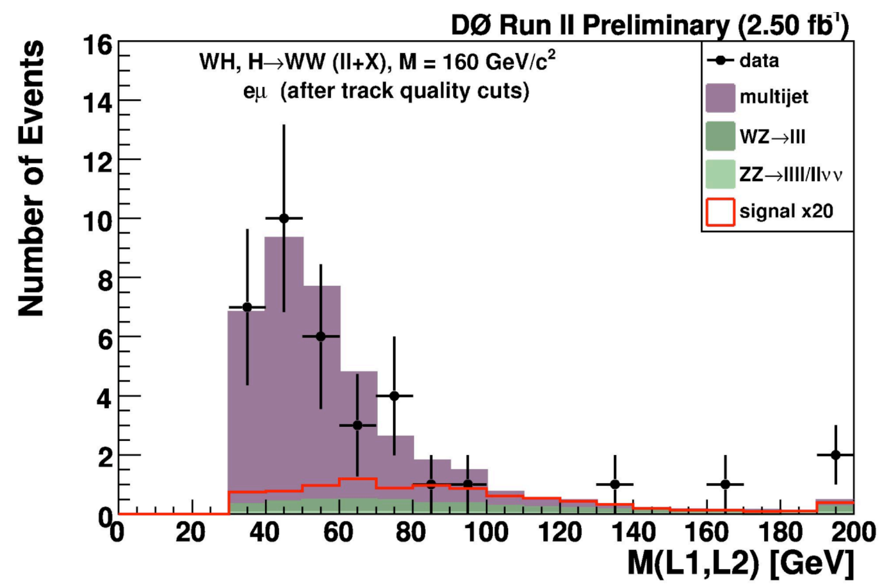


WH→$l^{\pm}\nu l^{\pm}\nu+X$ Backgrounds

- Physics backgrounds
  - *ZZ→llll*
  - *WZ→lνll*
- Estimated using MC
- 5-10% depending on channel

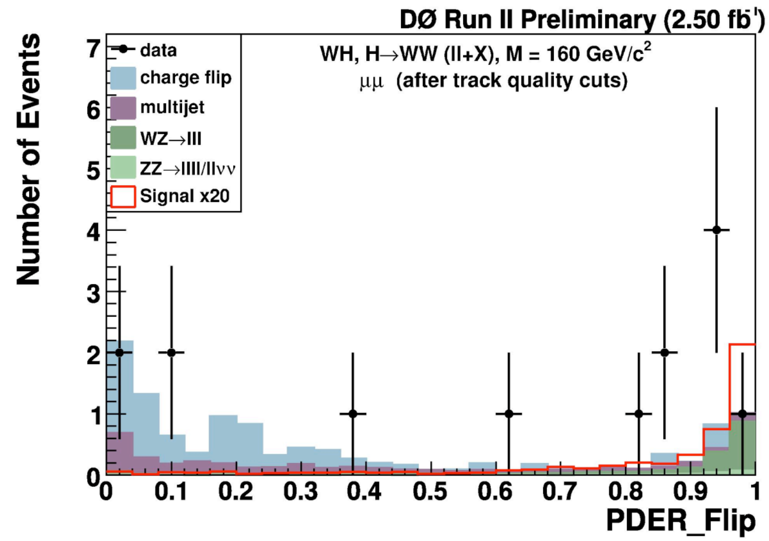


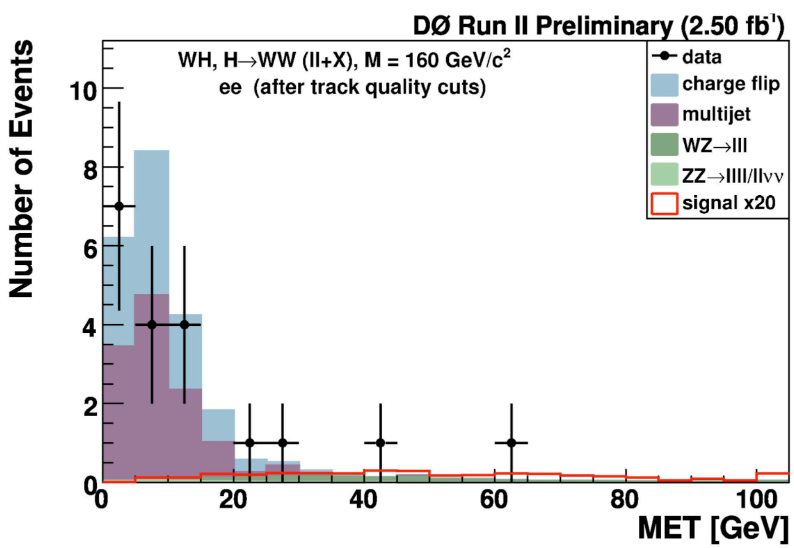
- Charge flip background
  - ee - like-sign in Z mass
  - μμ - use track vs muon system charge measurements
- Multijet background
  - measure from data
  - loose/tight sample estimate

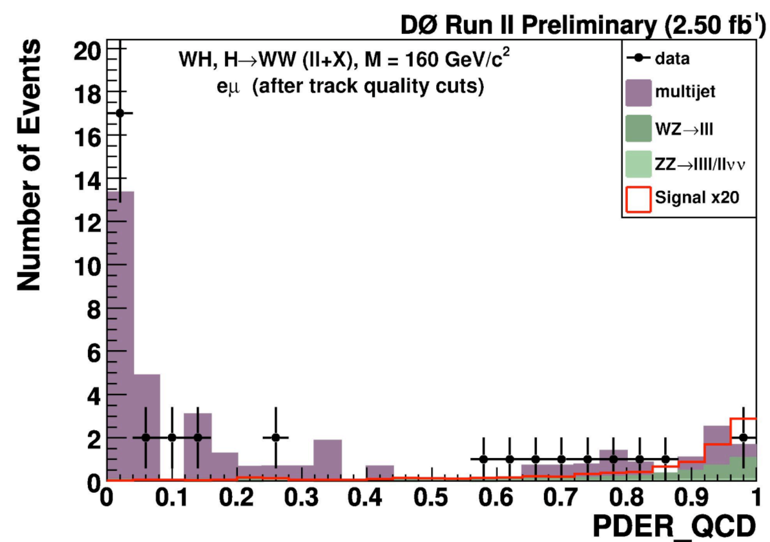


Multivariate Discriminant

- μμ-Δφ(μ,μ), Met⊥μ
- eμ-Met, Δφ(*l*,*l*), Met⊥μ, min p_T
- ee -Met

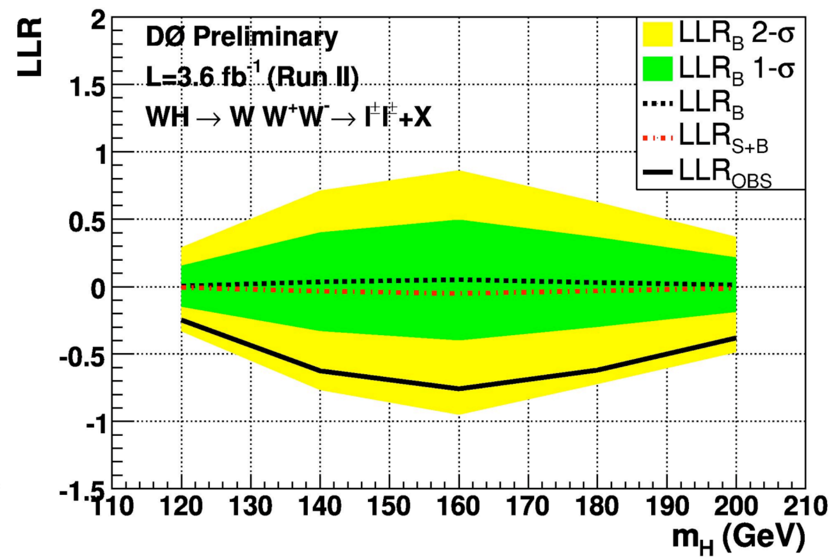


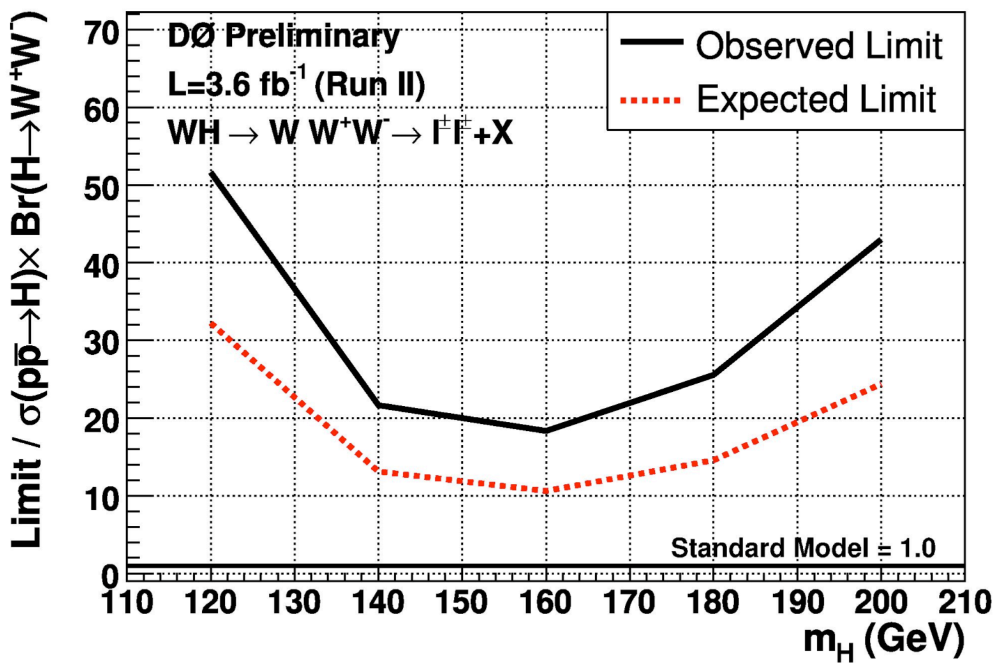




WH→$l^{\pm}\nu l^{\pm}\nu+X$ Results

- Same Modified Frequentist Calc
- @140 GeV, 95% CL →22 x SM σ

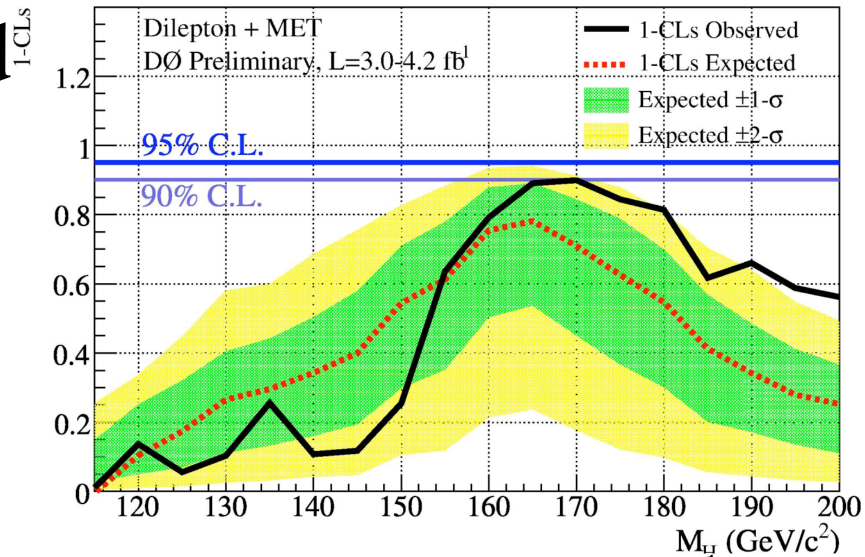


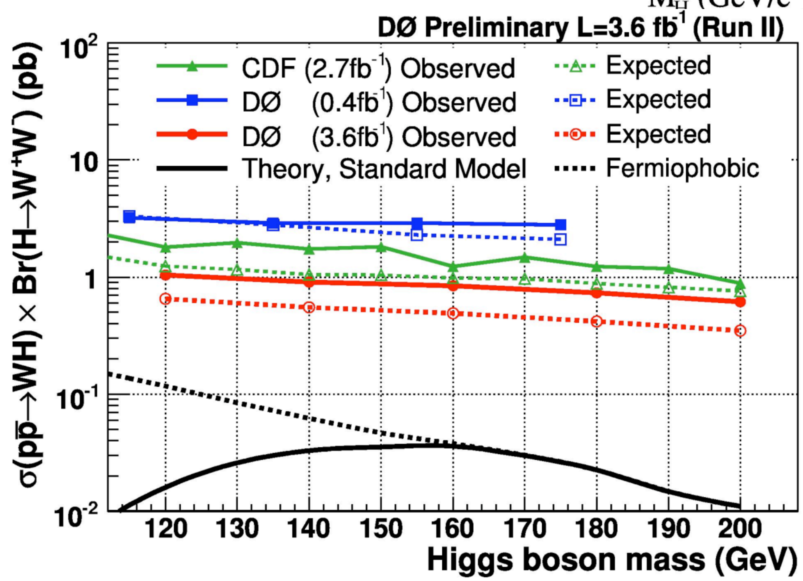


May also be sensitive to low mass Fermiophobic Higgs (M_H > 100 GeV)

DØ High Mass Higgs Search

- The search continues, and sensitivity continues to improve faster than luminosity scaling
- Rapid data analysis and incorporation of improved predictions
- First 95% exclusions from DØ are close at hand…





DØ High Mass Higgs Search

Tevatron sensitivity at m_H = 165 GeV