Search for the Higgs Boson in $H \longrightarrow WW^* \longrightarrow l^+\nu l^-\nu$ at DØ

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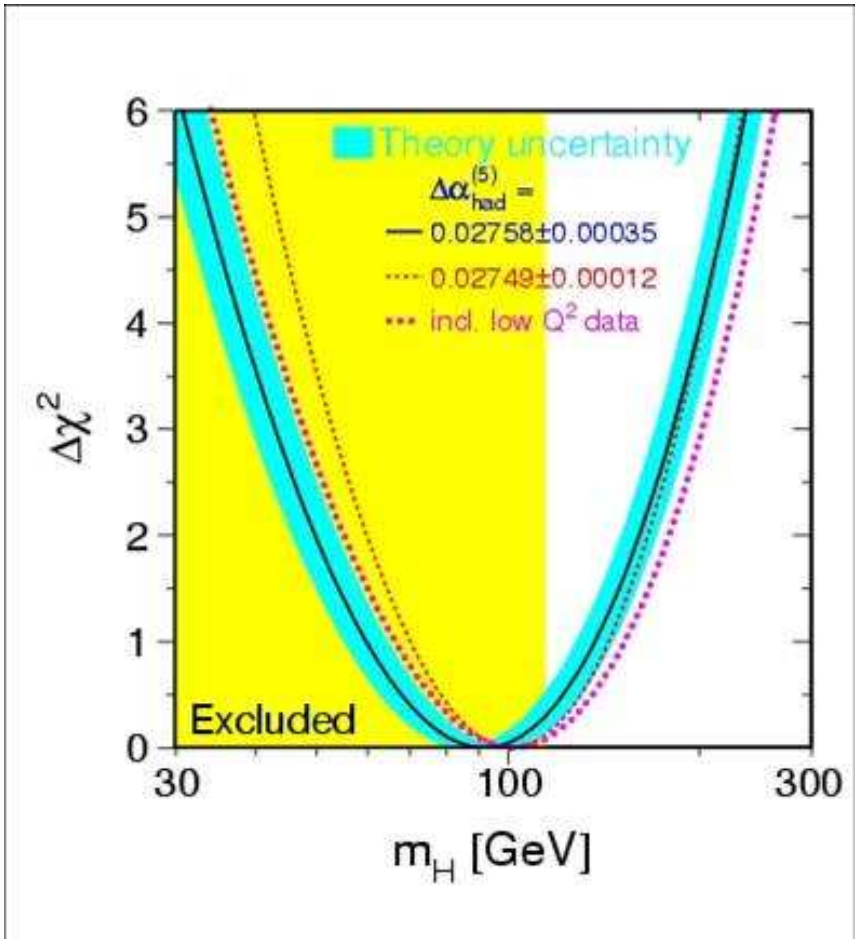
Outline

* **Motivation**
* **Method**
* **Results**
* **Summary**

Where is the Higgs

$\Delta\chi^2$ of the EW observables global fit .VS. SM Higgs mass m_H

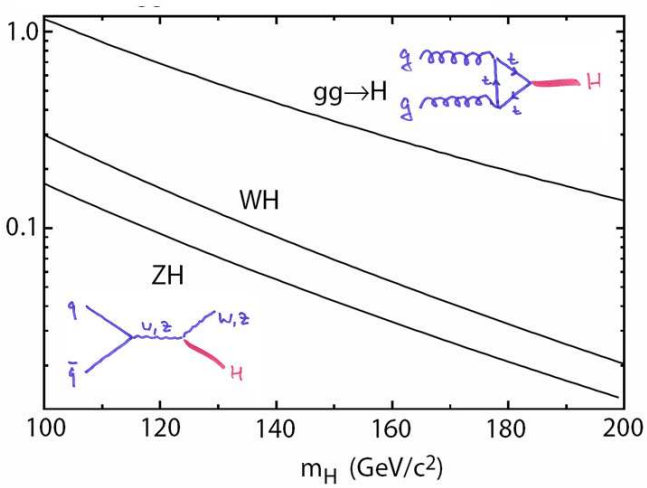


* Higgs is the only Standard Model (SM) particle not discovered yet;
* Mass not predicted, but constrained by (in)direct searches;
* $m_H > 114.4$ GeV at 95% CL placed by LEP2 direct search;
* $m_H < 166$ GeV at 95% CL placed by global fit to ElectroWeak (EW) observables, with preferred mass $m_H = 85 + 39 - 28$ GeV at 68% CL;
* Tevatron currently is the unique place for the direct Higgs search.

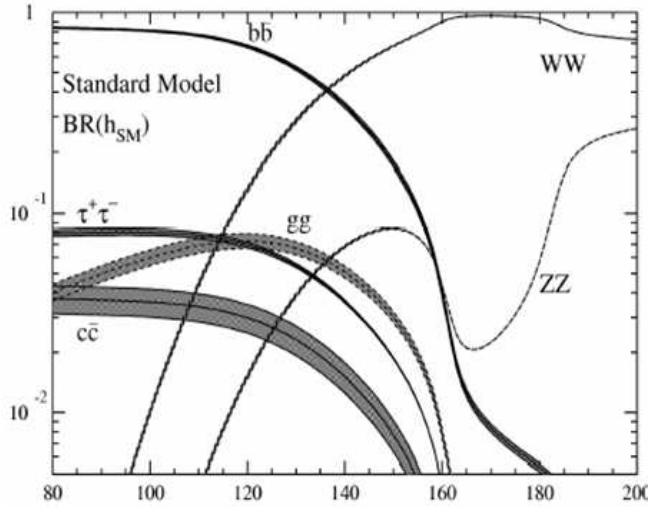
Higgs Searches at Tevatron

* Tevatron is a $p\bar{p}$ collider, with $\sqrt{s} = 1.96$ TeV;
* Main production mechanism: gluon fusion: $gg \rightarrow H$ (0.8 - 0.2 pb); and W/Z associated production: WH and ZH (0.2 - 0.03 pb);
* Higgs Decays:
  - $m_H < 135$ GeV, predominantly to $b\bar{b}$, due to the overwhelmed QCD BKGD, the $gg \rightarrow H \rightarrow b\bar{b}$ is not favored, the more promising processes are the W/Z associated production which trigged by high p_T leptons from W/Z;
  - $m_H > 135$ GeV, to WW^* becomes dominant, especially the leptonic decays of the W-pair provide the most clean signal;
* the $H \rightarrow WW^* \rightarrow l\nu l'\nu$ ($l = e, \mu$, including those from τ decay) is the most favorite channel for the exploring of the "heavy" SM Higgs.

Production

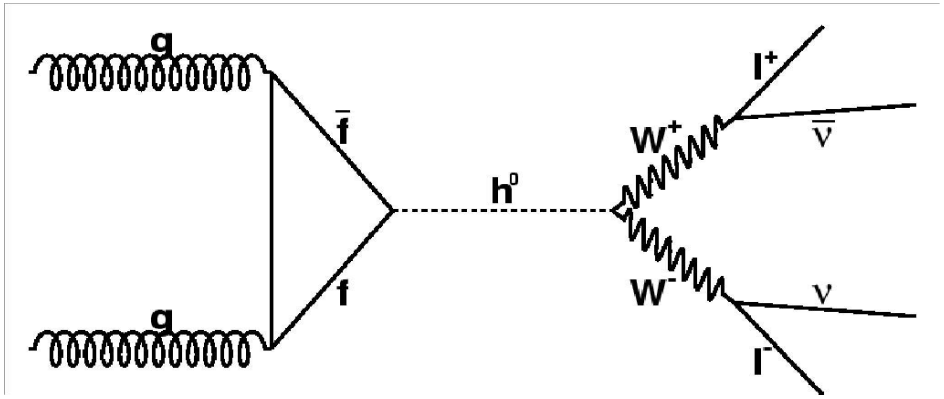


Higgs Decay



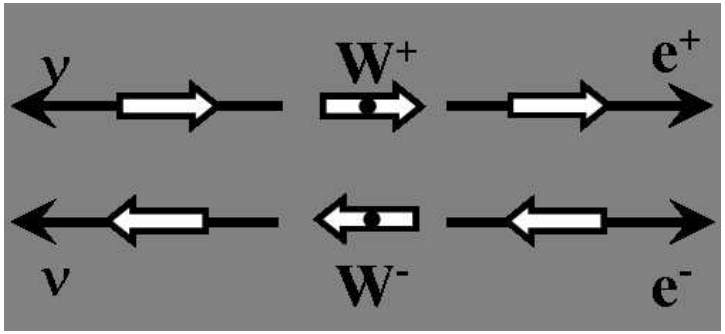
the Signal Feature

Signal Feynman diagram



also for the simple extension of SM. *e.g.* the 4th generation

angular correlation between Ws (therefore between leptons) since they come from spin 0 Higgs;

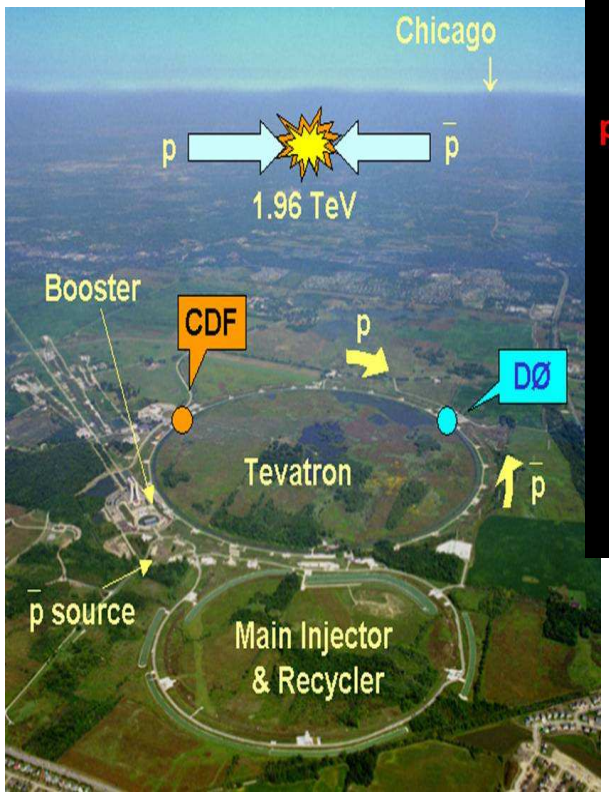


Signature:

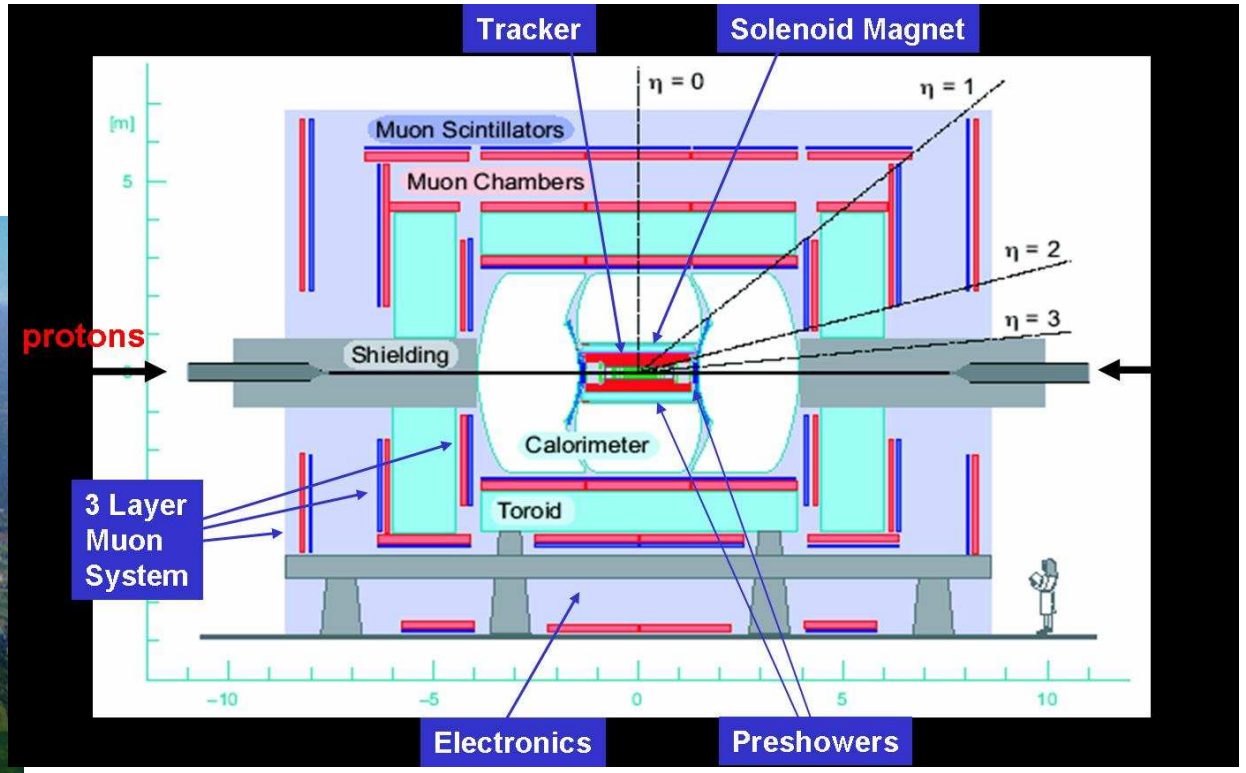
* two isolated High p_{T} leptons, with the preference of pointing to the same direction;
* large missing transverse moment ($\not\!\!E_{\mathrm{T}}$).

Apparatus

Tevatron at Fermilab



DØ Detector



Pseudorapidity (η) Coverage:

Calorimeter: $|\eta| < 1.1$ by central part,

$|\eta| < 4.2$ by two end parts

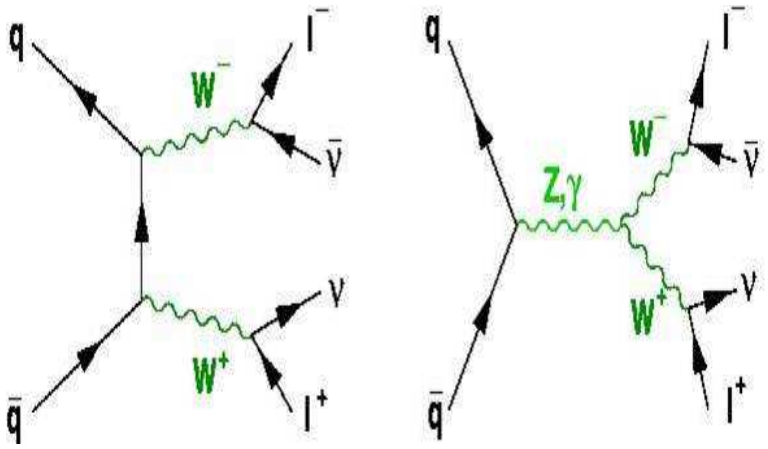
Muon: $|\eta| < 2$

Tracker: $|\eta| < 3$

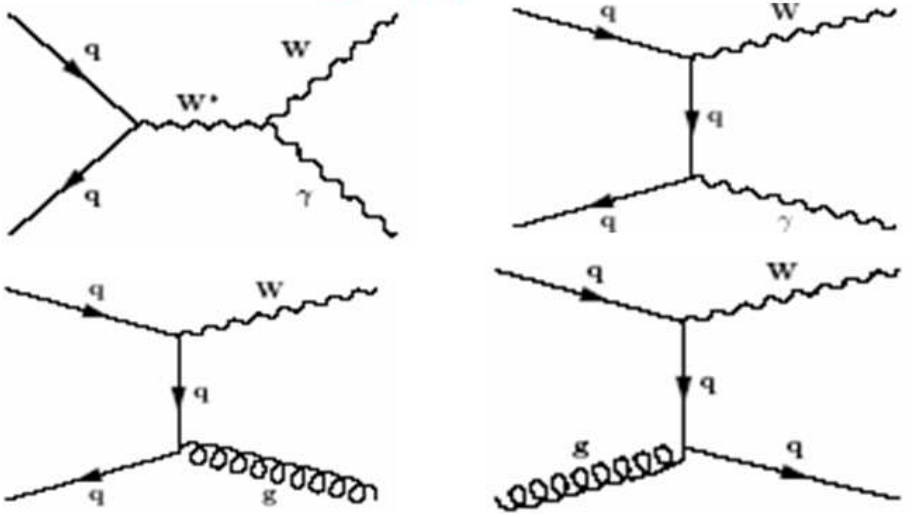
Dataset

* Data was collected at DØ between April 2002 and February 2006, corresponding to $\mathcal{L} \sim 1 fb^{-1}$
* Three separated analyses were performed using different skimmed dataset, aimed at the three different final states of WW^* leptonic decay;
  - $H \rightarrow WW^* \rightarrow e^+\nu e^-\nu$, corresponding $\mathcal{L} \sim 950 pb^{-1}$
  - $H \rightarrow WW^* \rightarrow \mu^+\nu\mu^-\nu$, corresponding $\mathcal{L} \sim 930 pb^{-1}$
  - $H \rightarrow WW^* \rightarrow e^\pm\nu\mu^\mp\nu$, corresponding $\mathcal{L} \sim 950 pb^{-1}$
* Marjor Background

WW production



W + jet/γ production:

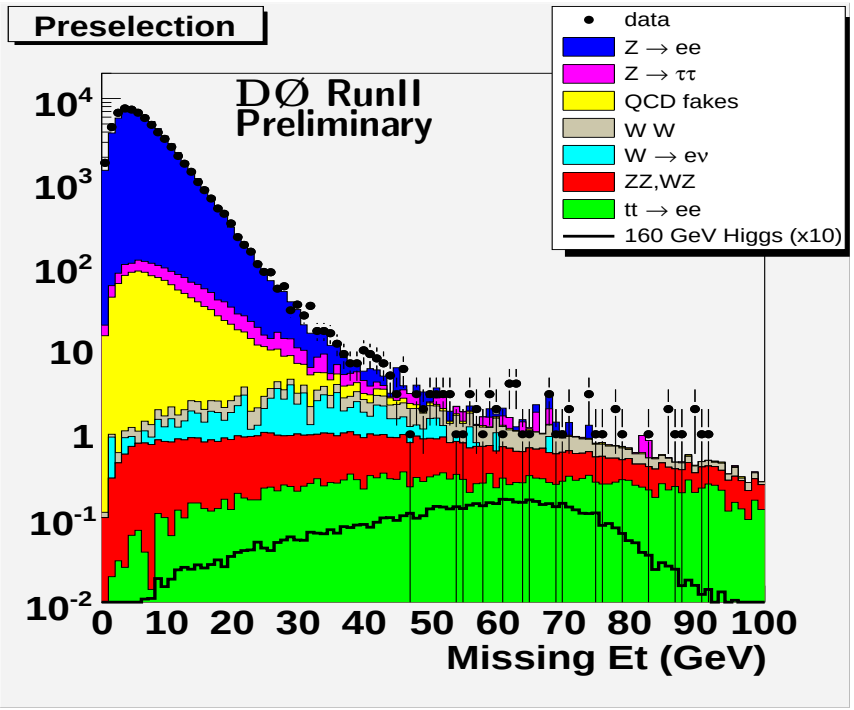


* Signal ($m_H = 120, 140, 160, 180, 200$ GeV) and most SM BKGD processes (WW, W+jets/γ, WZ, ZZ, Drell-Yan, $t\bar{t}$) generated with Pythia, QCD BKGD estimated from data.

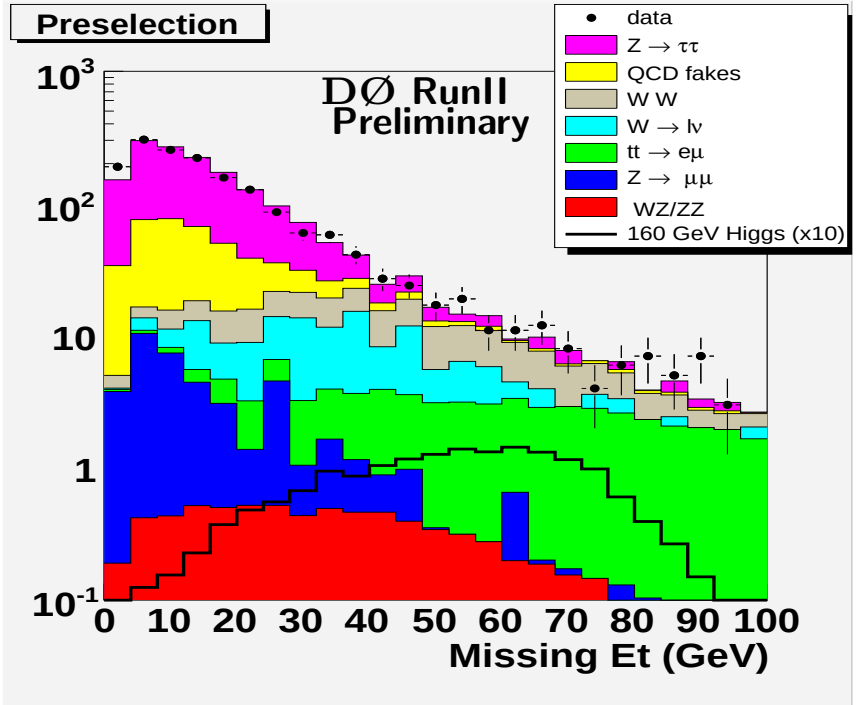
Event Selection (I)

1. **Preselection: online trigger, lepton ID, two high p_{T} leptons with opposite charges;**

$\not\!\!E_{\mathrm{T}}$ **for** $e^+\nu e^-\nu$ **Channel**



$\not\!\!E_{\mathrm{T}}$ **for** $e^{\pm}\nu\mu^{\mp}\nu$ **Channel**



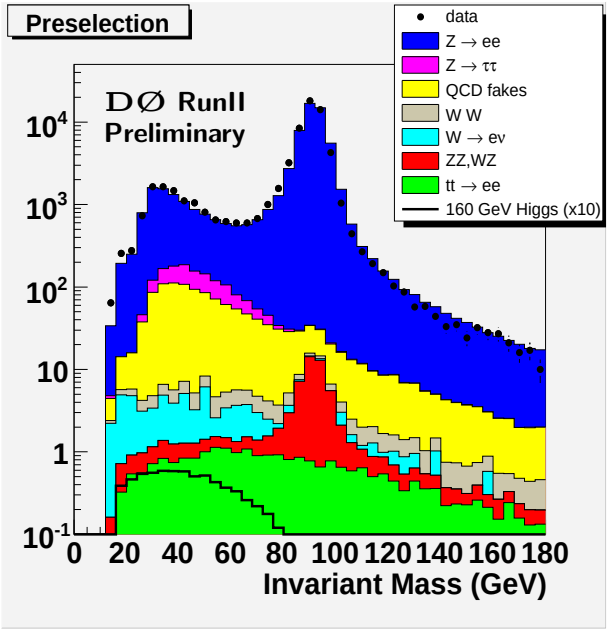
2. **Cut on missing transverse energy $\not\!\!E_{\mathrm{T}}$ to remove the QCD and Drell-Yan events;**

3. **Cut on the significance of missing transverse energy;**

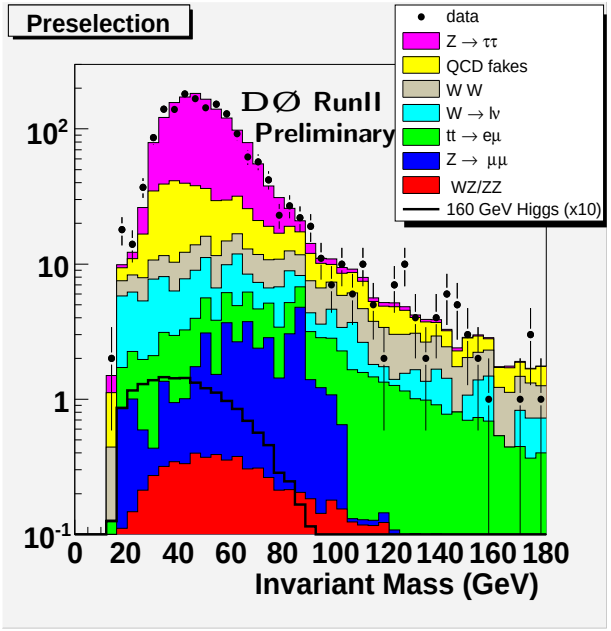
Event Selection (II)

Invariant Mass of di-lepton

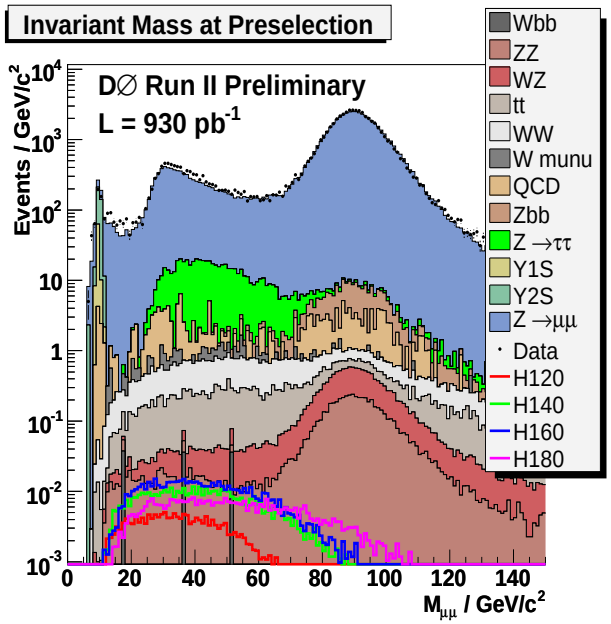
$e^+\nu e^-\nu$ Channel



$e^{\pm}\nu\mu^{\mp}\nu$ Channel



$\mu^+\nu\mu^-\nu$ Channel

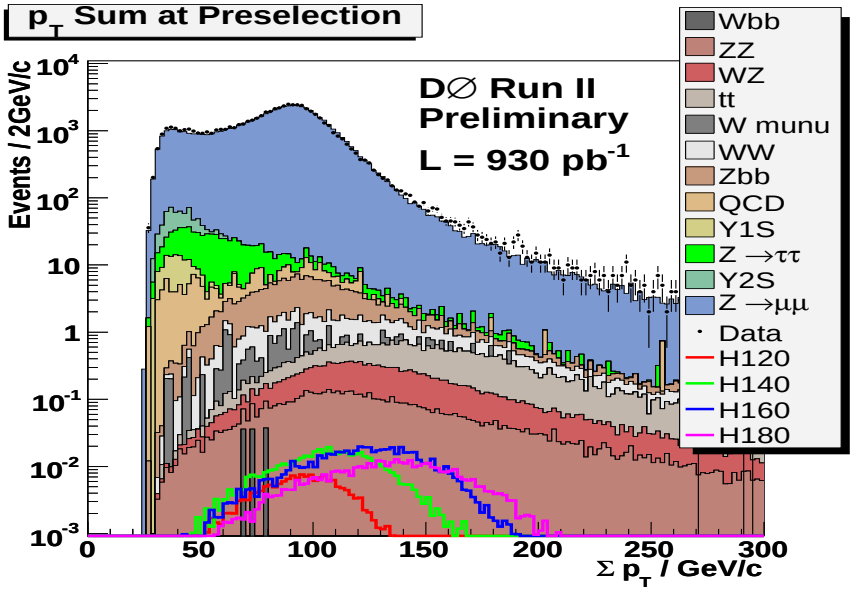


4. Cut on the di-lepton invariant mass to remove the BKGD with Z;

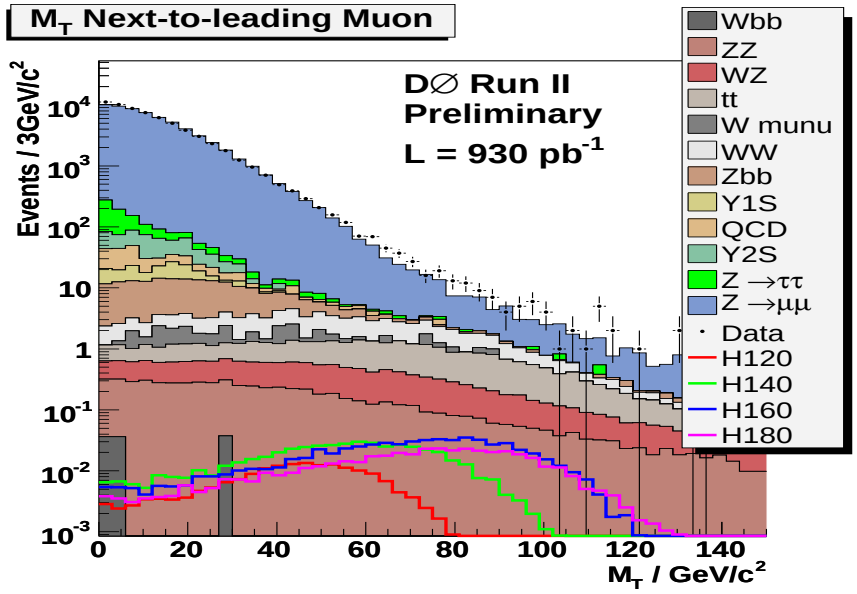
Event Selection (III)

5. Cut on the sum of the leptons transverse momentum and missing transverse energy ($p_{\mathrm{T}}^{l} + p_{\mathrm{T}}^{l'} + \not\!\!E_{\mathrm{T}}$);
6. Cut on the min. transverse mass between each lepton and missing transverse energy (Min. $m_{\mathrm{T}}(p_{\mathrm{T}}^{l}, \not\!\!E_{\mathrm{T}})$);

$p_{\mathrm{T}}^{\mu^+} + p_{\mathrm{T}}^{\mu^-} + \not\!\!E_{\mathrm{T}}$



m_{T} of the next-to-leading μ

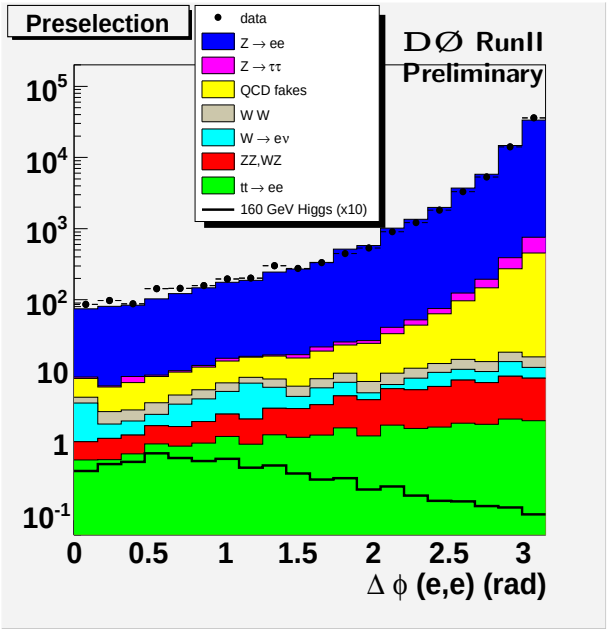


7. Cut on the Scalar sum of jets transverse energy to remove $\mathrm{t\bar{t}}$ events;

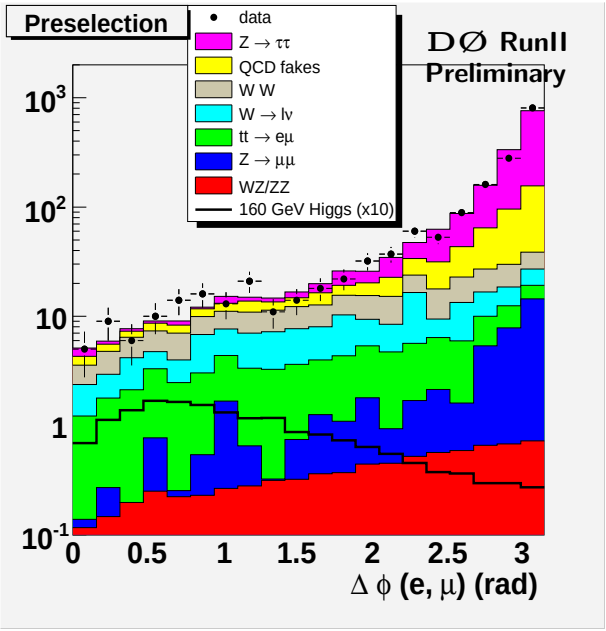
Event Selection (IV)

$\Delta\phi(l, l')$ after preselection

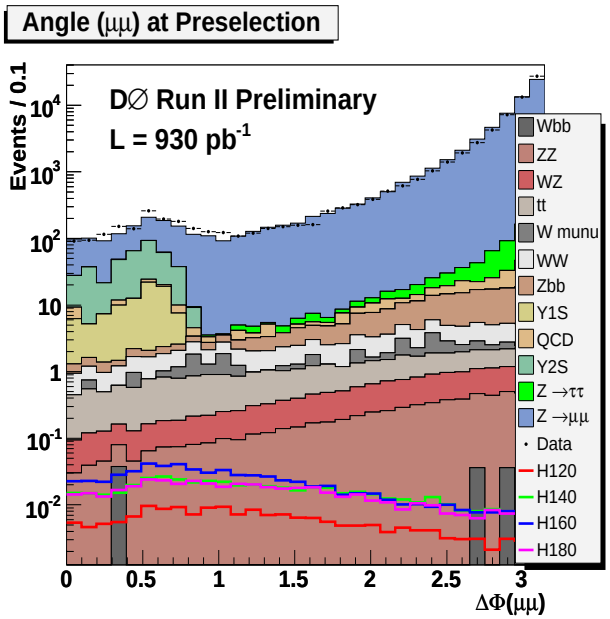
$e^+\nu e^-\nu$ Channel



$e^\pm\nu\mu^\mp\nu$ Channel

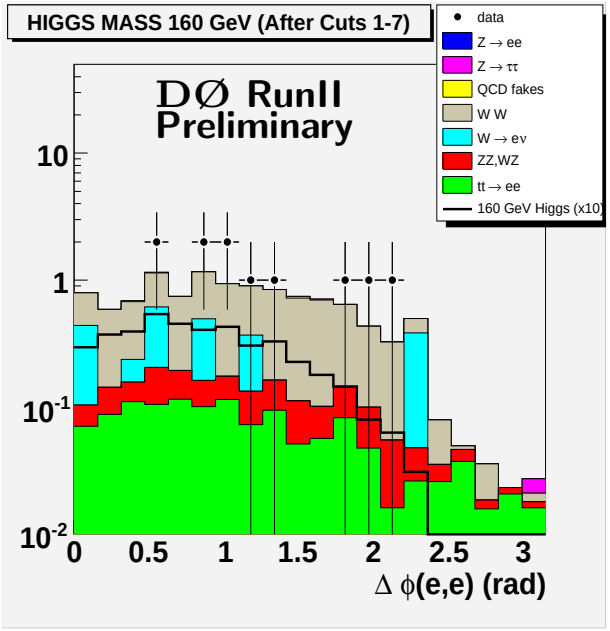


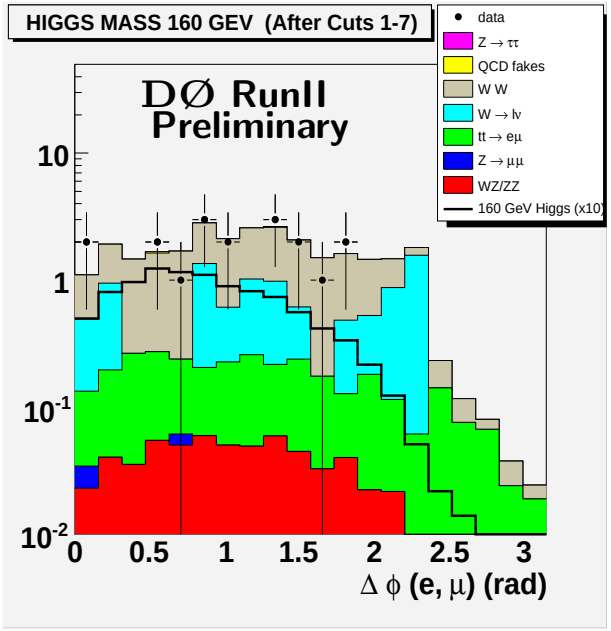
$\mu^+\nu\mu^-\nu$ Channel

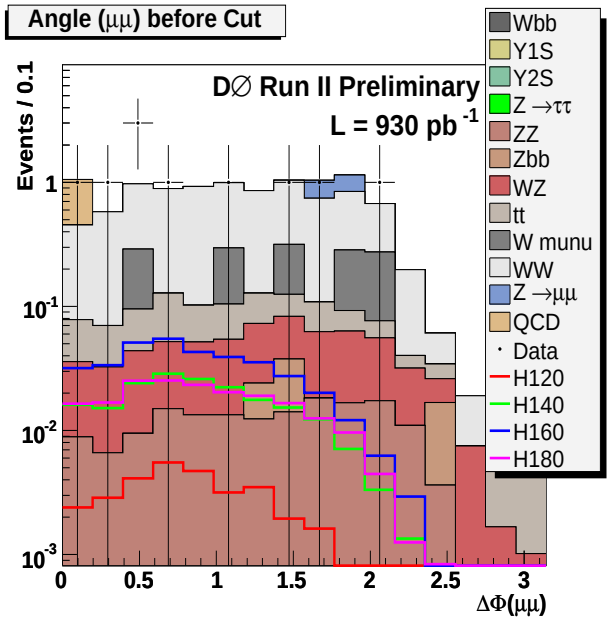


Event Selection (V)

$\Delta\phi(l, l')$ before final $\Delta\phi$ cut







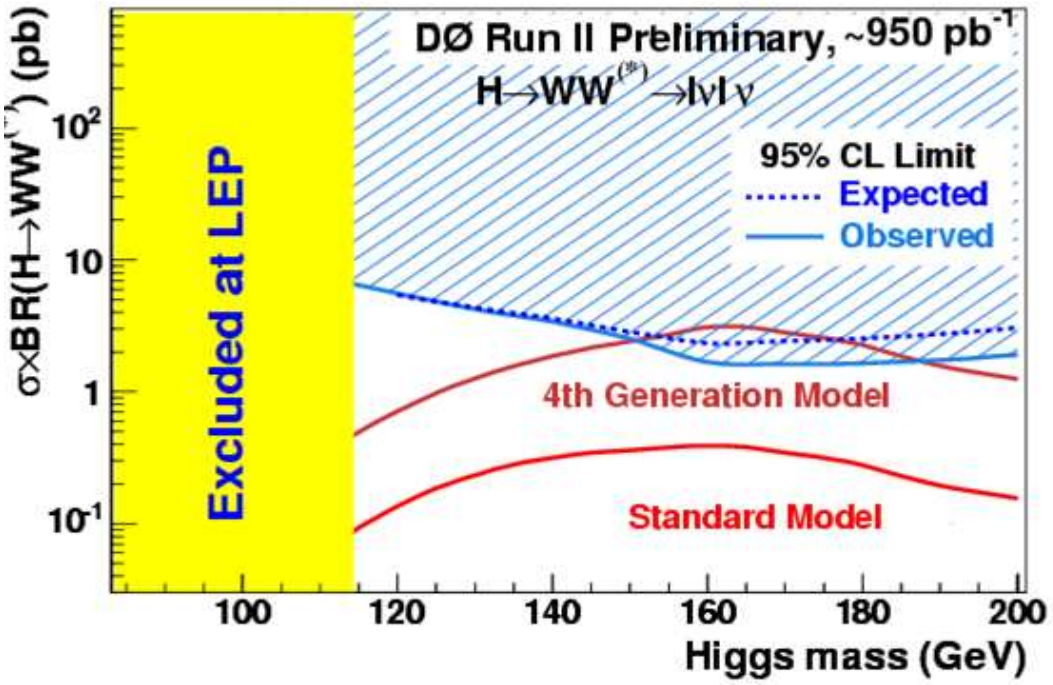
8. **Cut on the di-lepton opening angle ($\Delta\phi(l, l')$).**

   $\Delta\phi(l, l')$ will also be used as the final discriminant variable to combine with other DØ search channels to evaluate the Higgs mass limit.

Results

Observed/Expected number of candidate events for $m_{\mathrm{H}} = 160$ GeV ($L \sim 950$ pb^{-1})

	Data	All BKGD	WW	W+jet/γ	Z/γ^*	$\tau^-\tau^+$	WZ/ZZ	QCD	$H \to WW^*$
e^-e^+	10	10.3±0.6	7.0±0.2	1.4±0.6	0.0±0.0	1.1±0.1	0.8±0.1	0.06±0.02	0.415
$e^\pm\mu^\mp$	18	24.4±1.5	16.4±0.1	5.3±1.5	0.02±0.01	2.1±0.1	0.6±0.1	0.1±0.05	0.97
$\mu^-\mu^+$	9	9.8±0.8	6.6±0.1	1.0±0.4	0.6±0.4	0.5±0.1	0.5±0.1	0.6±0.6	0.35



* Observed data is well consistent with expected SM BKGD;
* The results from these three analyses are combined to evaluate the Higgs production Xsection (σ) $\times$ Branching ratio BR($H \to WW^*$) limits using the MCLIMIT method;
* Shadow region has been excluded at 95% CL;
* not sensitive enough to exclude SM Higgs, a factor of 4 away;
* m_{H} between 150 to 185 GeV has been excluded for the 4th generation model.

Summary

* Searches for the Higgs boson via $H \rightarrow WW^* \rightarrow l^+\nu l^-\nu$ have been performed in $\mathrm{p\bar{p}}$ collisions at $\sqrt{s} = 1.96$ TeV, with DØ detector at Tevatron;
* Three channels with different WW^* leptonic decay modes were studied using data collected from April 2002 to February 2006, corresponding to the $\mathcal{L}$ of the order of 1 fb^{-1};
* The number of observed events is consistent with what is expected from the SM background;
* Limits on the Higgs production cross section times the branching ratio $\sigma \times \mathrm{BR}(H \rightarrow WW^*)$ have been set, Higgs mass between 150 to 185 GeV has been excluded for the 4th generation model;
* DØ is continuously accumulating data, analysis sensitivity is keeping optimization, more exciting results are expected.