Search for the SM Higgs Boson in Dilepton + $\not{E}_T$ final state

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Brief Outline of the talk:
* Introduction
* Analysis Selection
* Multivariate Methods
* Results

Young Scientist Forum
ElectroWeak Session
Rencontres de Moriond
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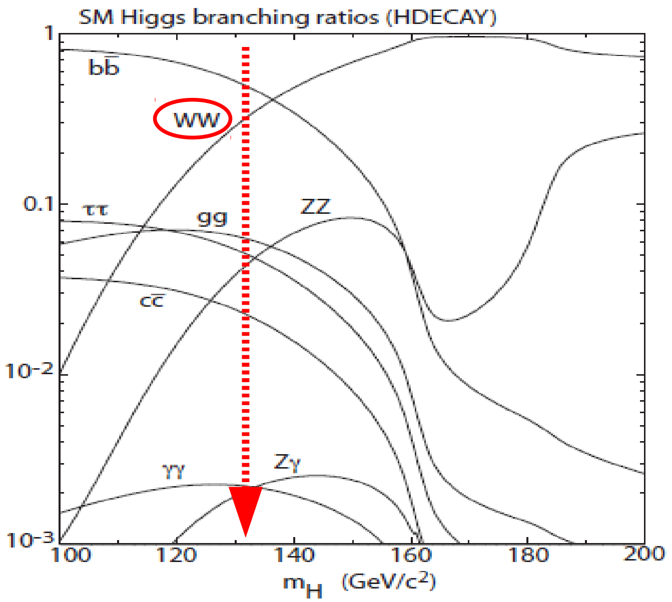
Introduction

- **Higgs Boson**, massive scalar particle predicted by SM *yet to be observed !*

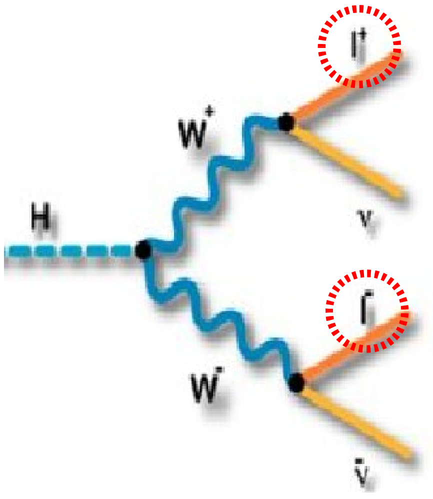
- The analysis considers all SM Higgs production modes:
  - Gluon fusion $gg \rightarrow H$ (σ = 0.2 – 1.0 pb)
  - Associated production Z/WH (σ = 0.01 – 0.3 pb)
  - Vector boson fusion $qq \rightarrow H$ (σ = 0.01 – 0.1 pb)

- Above 130 GeV Higgs mass, the dominant decay mode is $H \rightarrow WW^*$

- Three dilepton final states considered (eμ/ee/μμ)
  - ***Combined dilepton channel has the highest sensitivity to the Higgs Boson at m_H=165 GeV***

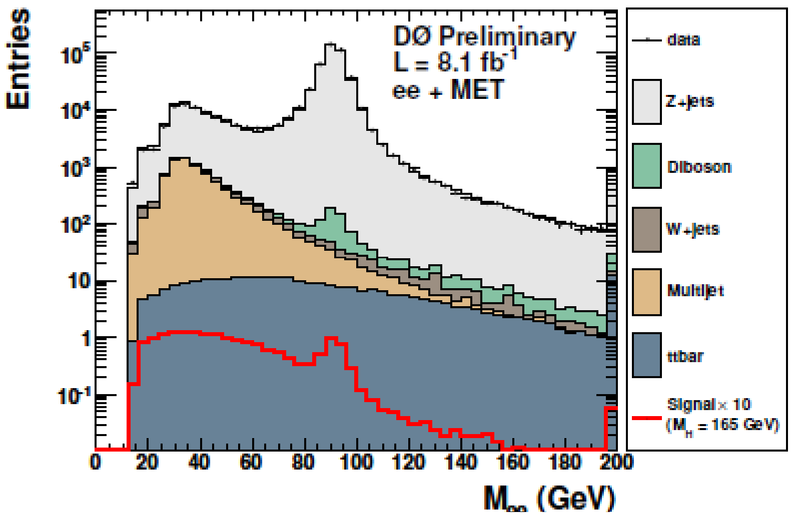


Background to this search signal:
- $Z/\gamma^* \rightarrow ll$ (instrumental $\not{E}_T$)
- multijet (jets faking as lepton)
- W+jets (one real lepton)
- $t\bar{t}$ (real leptons and real jets)
- SM Diboson production (WW/WZ/ZZ)



Clean signal signature:
- Two high p_T leptons
- Oppositely charged
- High missing E_T

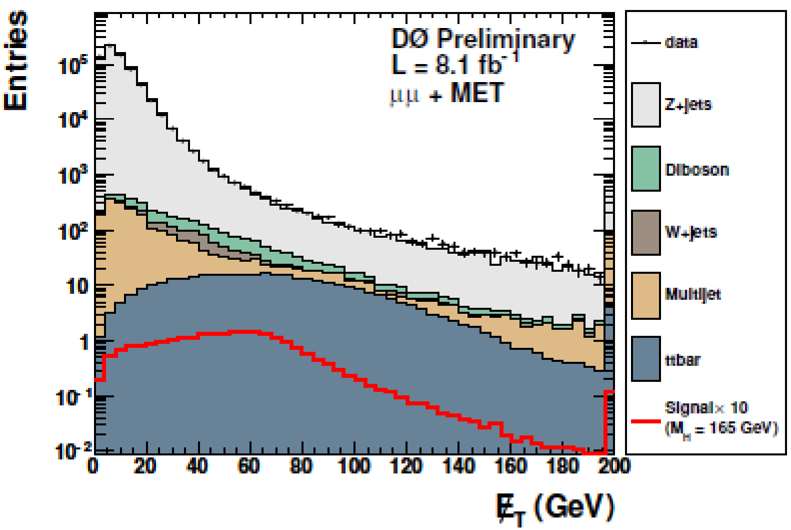
PreSelection

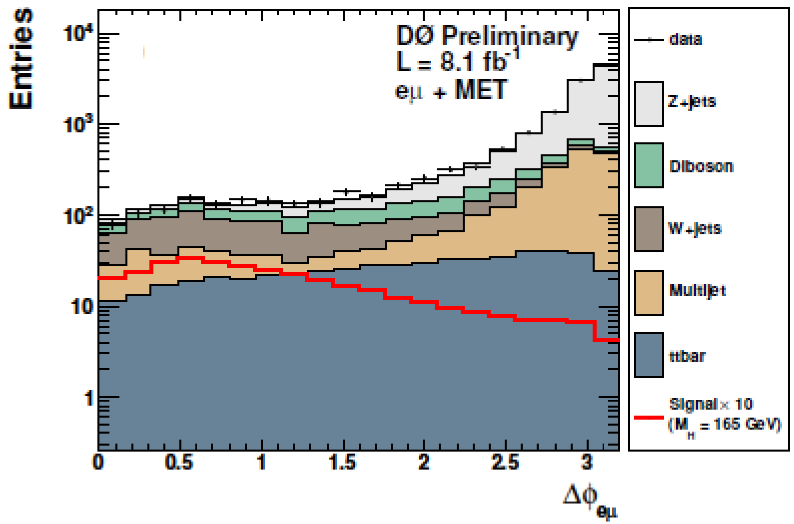


- The analysis uses 8.1 fb^{-1} of data.
- Select events with:
  - two high p_T leptons
  - within the detector acceptance
- Split the analysis into three jet multiplicity bins (0, 1, >1).
- 9 exclusive selection channels (three dilepton final state and three jet bins)
- At preselection (all dilepton channels combined)

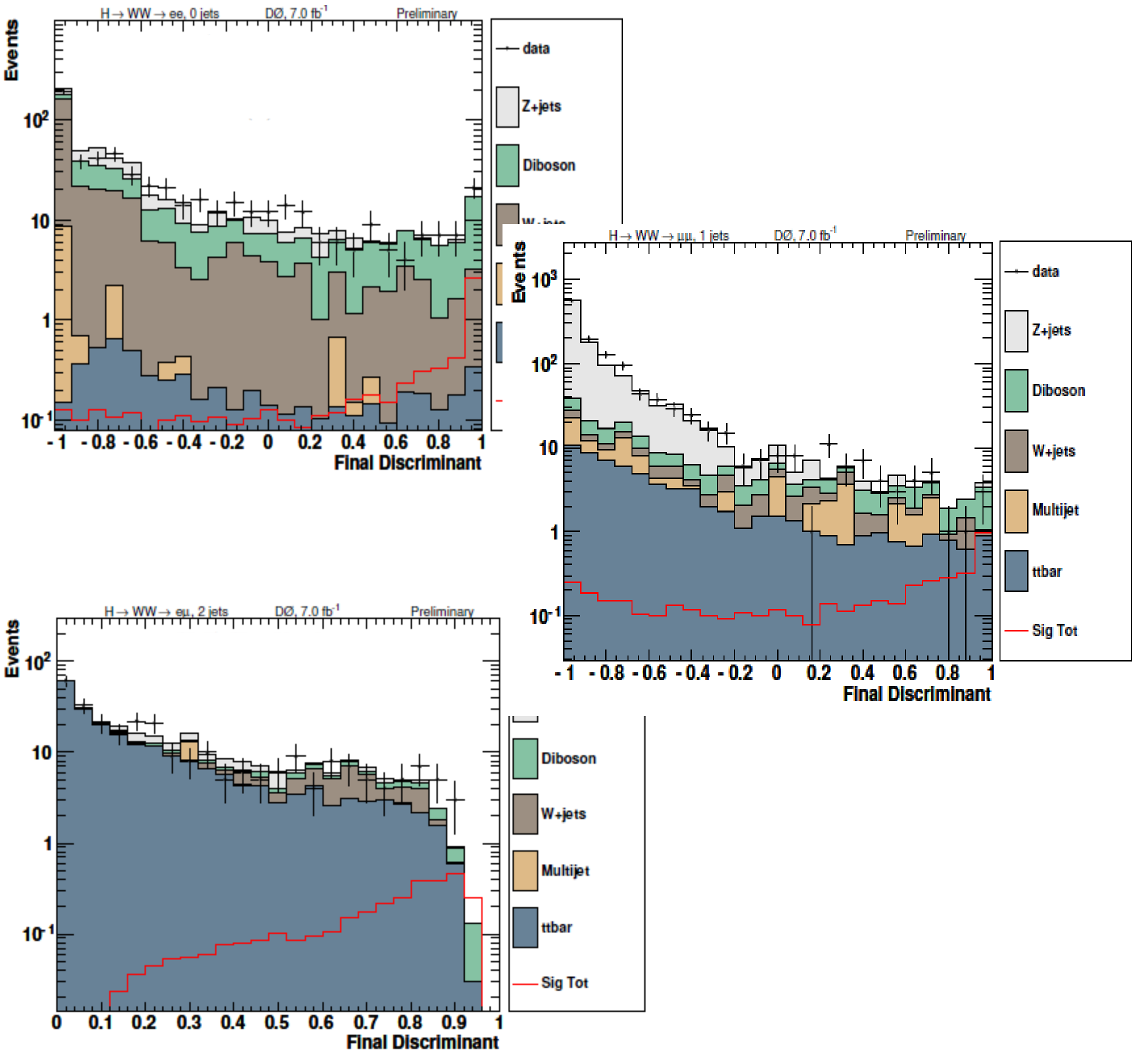
Exp. Bkgd	1218279
Obs. Data	1213141
Exp. Sig (**165 GeV**)	70

S/B ≈1/10^5





Multivariate Techniques



- Since at pre-selection S/B is very low, multivariate techniques (DTs) are used to separate the signal from backgrounds.

- ee/μμ channels use DTs twice
  - ➢ to reject the Z/γ^* background
  - ➢ Separate signal from other bkgds.

- The DT's are trained for each jet bin and for each higgs mass point.

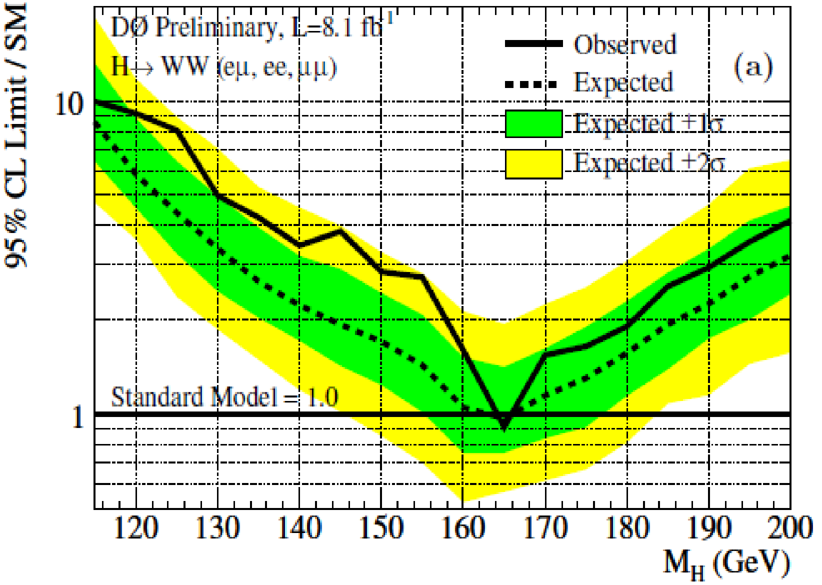
- The signal as well as the background composition changes with jet bin.
  - 0-Jet : Diboson vs. $gg \rightarrow H$
  - 2-Jet : $t\bar{t}$ vs. Z/WH

- Different discriminating input variables used in each jet bin to enhance the signal seperaton (Eg. b-tagging in the 2 jet bin against $t\bar{t}$).

- The output of the Final Discriminant (FD) is used to search for a signal or to place limits on the Higgs boson σ_{incl} $(p\bar{p} \rightarrow H+X)$.

Results

- No significant excess is observed hence exclusion limits are set at 95 % C.L .
- With the increased senstivity, we are able to exclude 165 GeV at 95 % C.L, exp(obs) limit is 0.97(0.91).
- Good sensitivity at low mass as well. At 115 GeV, exp(obs) limit is 8.55(9.95).
- **Major improvments in the expected senstitivity since summer 2010 update.**
- **The channel plays a dominant role in the SM high mass Higgs combination!**



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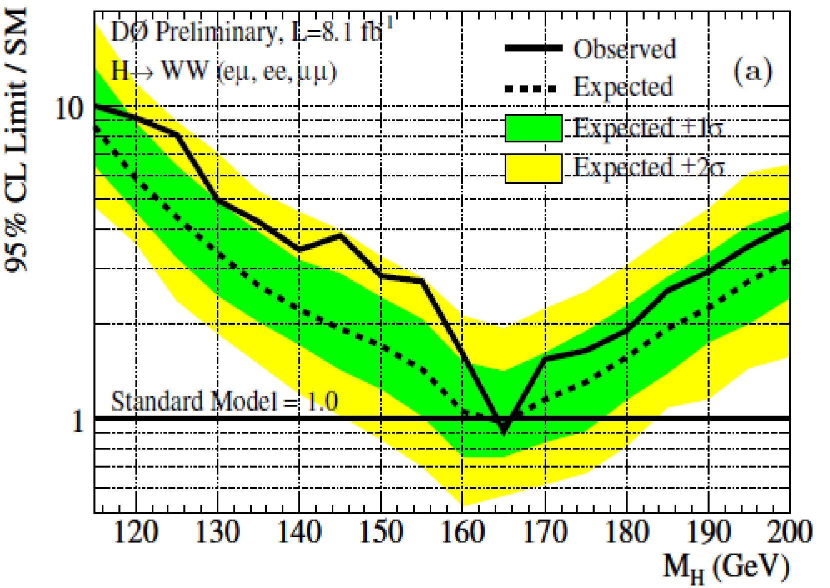

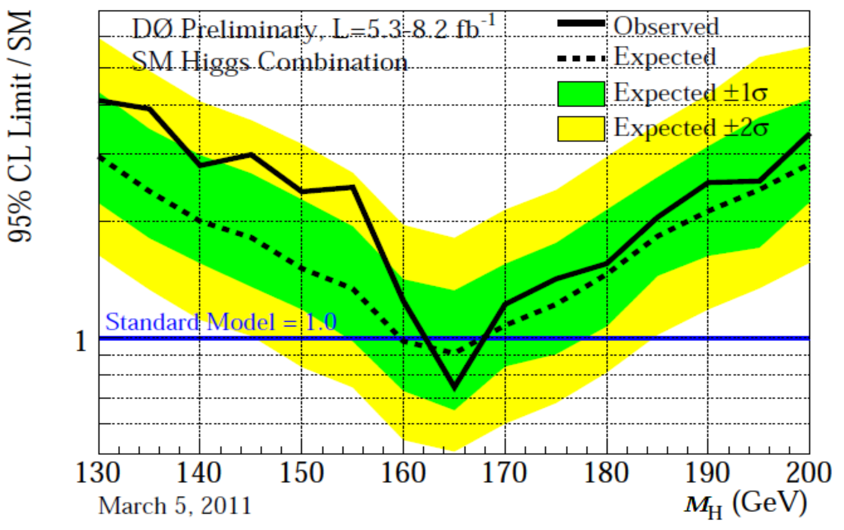

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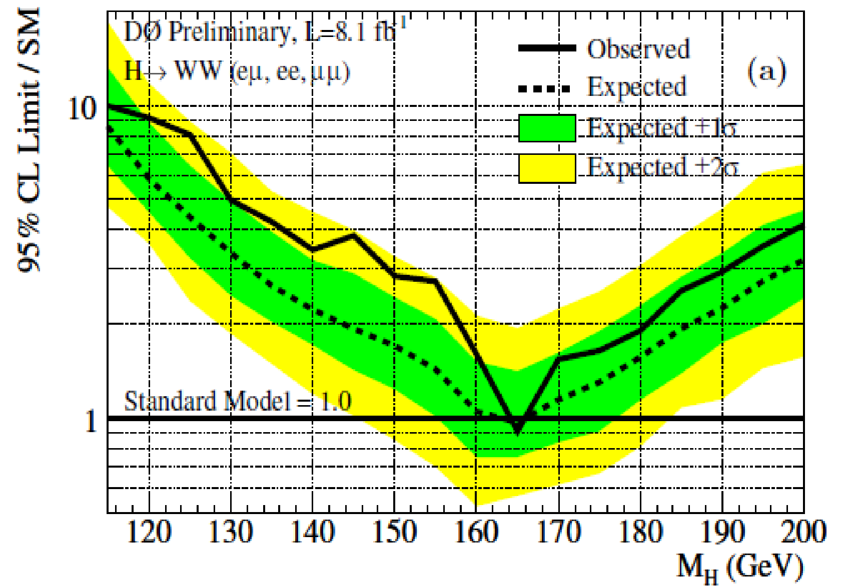
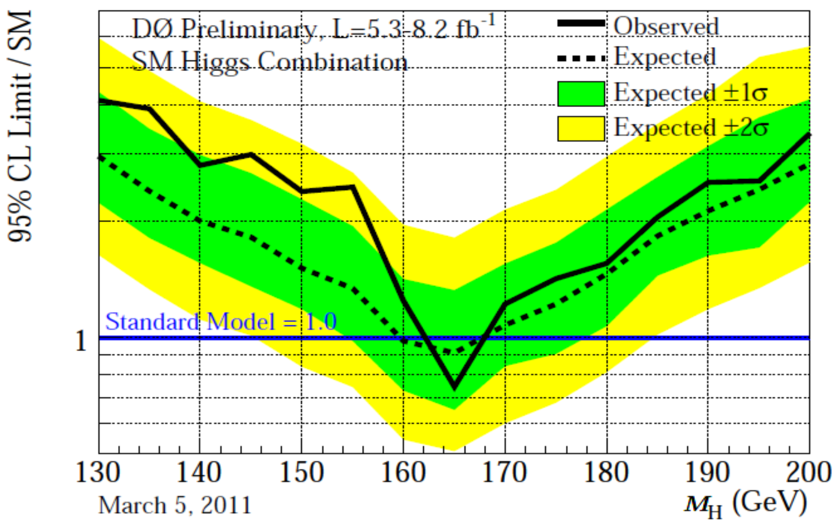
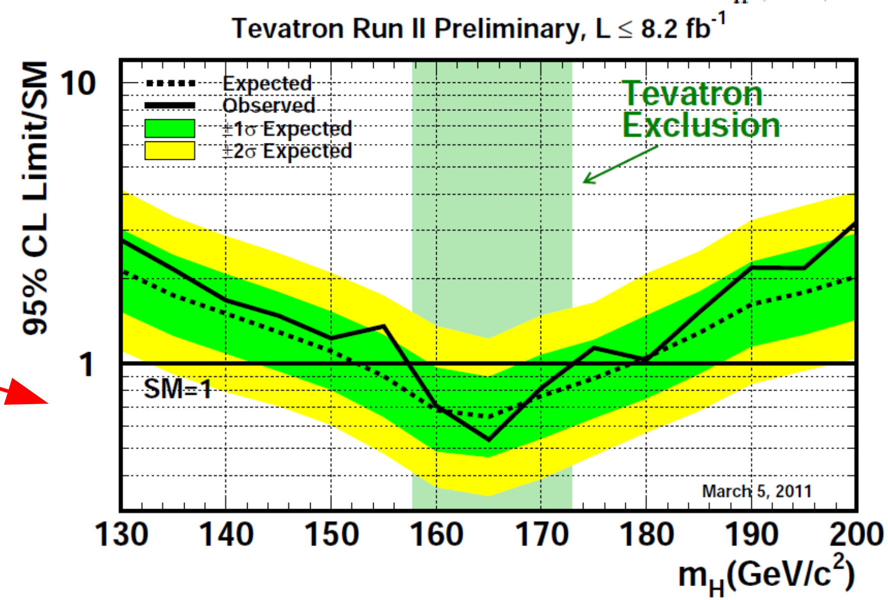


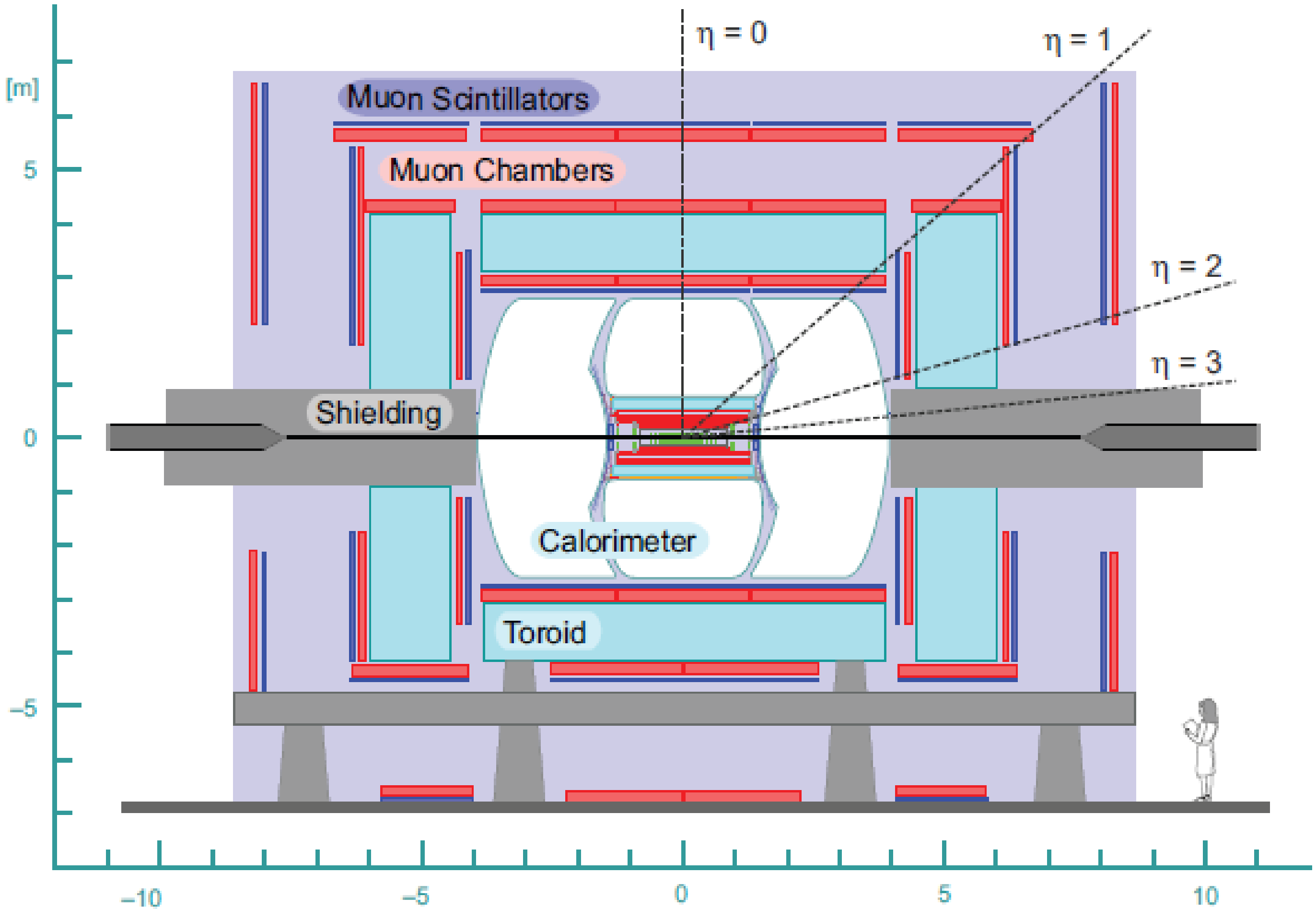




Backup Slides

For More Information

DØ Detector



Tracking :
Silicon Microstrip tracker
Central Fibre trackers
in a 2T mag. field

Calorimeter :
Hermetic coverage with
A Central &
2 End Cap calorimeters

Muon System:
Outermost system
Scintillators &
Wire chambers
in 1.8 T mag.field

Event Selection Details

*** ee channel**

- two opposite charged electrons, required to originate from same vertex.
- leading electron with p_T >15 GeV and trailing electron with p_T > 10 GeV
- M_{ee} >15 GeV
- jets with pT > 20 GeV

Final Selection : Train a BDT against the Z/γ* background and place a cut on this discriminant.

*** eμ channel**

- two leptons (oppositely charged) required to originate from the same vertex.
- electron p_T >15 GeV
- muon p_T > 10 GeV
- ΔR (e,μ) >0.3
- jets with pT > 20 GeV

Final Selection : a cut is applied on the min. M_t > 20 GeV

*** μμ channel**

- oppositely charged dimuons originating from the same vertex.
- leading muon with p_T >15 GeV and trailing muon with p_T > 10 GeV
- ΔR (μ,jet) >0.1
- calorimeter isolation < 10 GeV
- jets with pT > 20 GeV

Final Selection : Train a BDT against the Z/γ* background and place a cut on this discriminant.

BackGround Rejection

- To reduce the massive Z/γ* background, di-electron and dimuon channel train a multivariate discriminant.

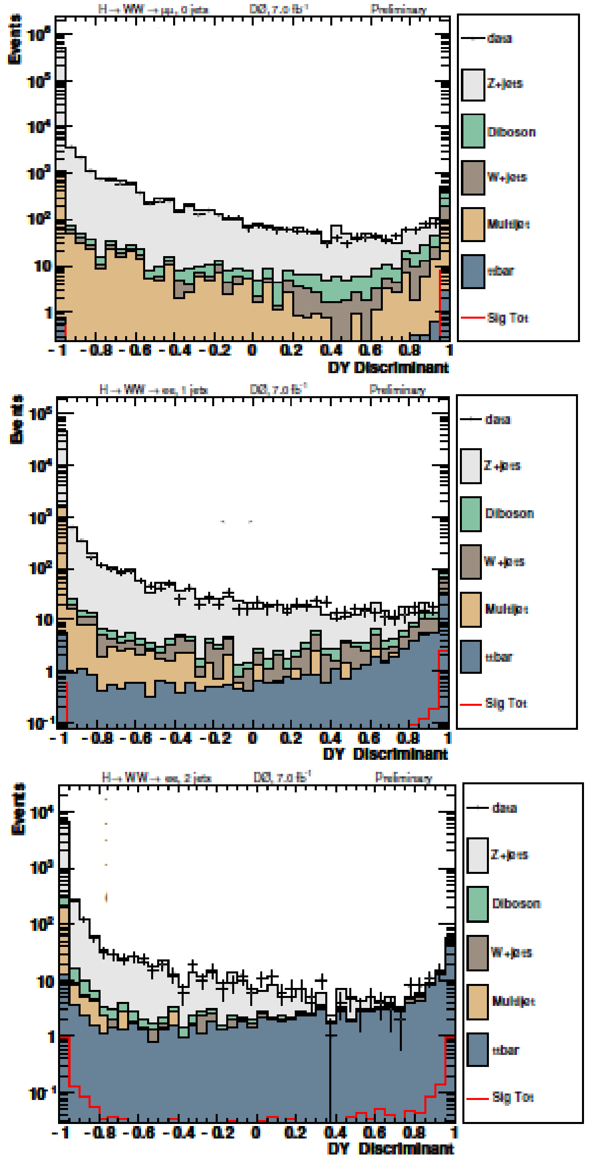
- This discriminant is trained against Z/γ* background only, for each jet bin and for each Higgs mass point.

- Different discriminating input variables are used to seperate the signal. (P_t , $\not{E}t$, $\Delta\varphi_{l1l2}$ ..)

- A cut is applied on this discriminant. The choice of the cut depends on the jet bin and m_H

- The electron-muon channel does not use a mutlivariate discriminant and rather place a requirement on M_t^{min} to reject the Z/γ* as well as the multijet background.

$$M_T = \sqrt{2 \cdot p_{\mathrm{T}}^{\ell} \cdot \not{E}_T \cdot (1 - \cos\Delta\phi(\ell, \not{E}_T))}$$



Event Yield's ..(1)

At Pre-Selection

TABLE I: Expected and observed number of events in each jet multiplicity at preselection in the $e\mu$, ee and $e\mu$ final states. The signal assumes a Higgs boson mass of 165 GeV.

	Data	Total Background	Signal	$Z \to ee$	$Z \to \mu\mu$	$Z \to \tau\tau$	$t\bar{t}$	W+jets	Diboson	Multi-jet
$e\mu$:										
0 jets	8505	8565.6	16.9	219.2	666.9	5292.6	17.5	613.6	604.6	1151.2
1 jet	1396	1421.7	8.2	30.6	93.9	660.0	140.3	126.7	93.3	276.7
$\geq$ 2 jets	512	509.5	3.9	5.1	19.6	119.0	284.9	34.4	16.2	30.4
ee:										
0 jets	447698	444084.1	8.4	433776.7	-	3820.1	11.2	658.7	448.2	5369.2
1 jet	59806	60218.6	5.2	57115.0	-	645.2	88.8	184.5	201.9	1983.4
$\geq$ 2 jets	9352	9385.3	3.6	8622.1	-	111.1	189.0	22.1	154.6	286.5
$\mu\mu$:										
0 jets	592539	598085.0	11.3	-	590715.5	4995.3	9.5	296.9	597.6	1470.2
1 jet	79759	81791.7	6.9	-	80333.2	696.4	95.6	59.2	260.8	346.6
$\geq$ 2 jets	13574	14219.1	5.8	-	13521.4	117.8	258.3	11.4	222.2	87.9

Event Yield's ..(2)

At Final-Selection

TABLE II: Expected and observed number of events in each jet multiplicity after the final selection in the $e\mu$,ee, and $\mu\mu$ final states. The signal assumes a Higgs boson mass of 165 GeV.

	Data	Total Background	Signal	$Z \to ee$	$Z \to \mu\mu$	$Z \to \tau\tau$	$t\bar{t}$	W+jets	Diboson	Multi-jet
$e\mu$:										
0 jets	1074	1163.5 ± 145.4	16.0	16.9	74.7	89.9	14.1	462.8	473.2	31.9
1 jet	392	373.7 ± 58.7	7.2	3.6	15.9	75.0	109.6	86.0	67.9	15.7
≥ 2 jets	280	285.7 ± 41.4	3.2	1.1	3.9	21.8	220.6	24.2	10.2	3.9
ee:										
0 jets	676	715.8 ± 89.9	7.2	108.5	-	9.1	6.1	376.8	205.3	10.0
1 jet	836	831.9 ± 144.5	4.2	477.6	-	83.5	75.4	125.0	56.9	14.2
≥ 2 jets	477	442.6 ± 73.9	2.4	201.7	-	42.9	160.8	13.9	17.1	6.2
$\mu\mu$:										
0 jets	612	689.7 ± 60.7	9.3	-	201.8	2.7	3.8	136.6	240.6	104.2
1 jet	1420	1313.2 ± 173.3	5.5	-	969.1	109.8	76.4	38.0	74.4	45.6
≥ 2 jets	888	890.8 ± 135.4	3.7	-	579.6	46.8	209.4	7.2	28.2	19.5

DT Details

BDT Settings

- 200 trees;
- number of variables used per node splitting = 8;
- maximal-depth of the tree = 9;
- minimum events per final leaf = 50;
- UseYesNoLeaf flag is set as false;
- UseRandomisedTrees flag is set as true;
- SeparationType is set to GiniIndex;
- NoPruning.

List of Inputs to DT against Z/γ*:

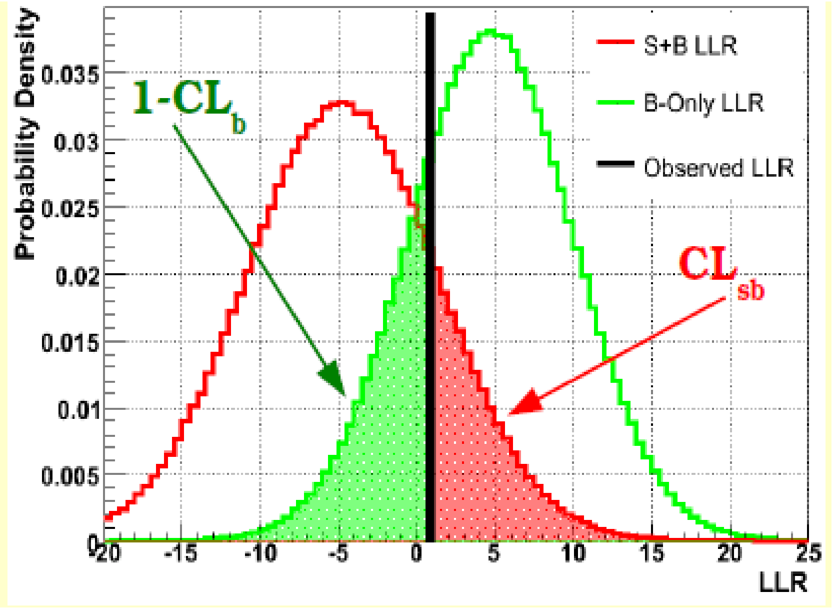
- leading lepton pT
-trailing lepton pT
- invariant dilepton Mass
-$\Delta\Phi(l,l)$
-$\not{E}_T$
-M_t^{min}
- $\Delta\Phi(l,\not{E}_T)_{max/min}$
- leading and trailing jet pT
- $\Delta\eta(j1,j2)$
- invariant mass of the dijet system
- $\Delta\Phi(jet,\not{E}_T)_{max/min}$

Final discriminant – All above and :

- likelihood of the electrons
- quality of the muon
- Number of hits in the first layer of the tracker
- track isolation of Muons.

Limit Setting

Test the background-only (B) and the signal + background (S+B) hypoteses using a Profile Likely Ratio test, as implemented in COLLIE (COnfidence Level LImit Evaluator).
Take into account the following systematic uncertainties:
- theoretical cross sections
- lepton momentum calibration
- jet reconstruction efficiency and JES
- modeling of the pT of H, WW, Z
- modeling of the multijet background



Generate two ensembles of pseudo-experiments for the two hypotesis, and using their probability distributions, compute the log-Likelihood-Ratio (LLR):

$$LLR = -2\ln \frac{\frac{e^{-(s+b)}(s+b)^d}{d!}}{\frac{e^{-b}b^d}{d!}}$$

Given the H0(null) and H1(test) hypothesis, we define:

CL_b = fraction of H0 pseudo experiments less signal like than data

Cl_{s+b} = fraction of H1 psuedo-experiments less signal like than data

$$CL_s = \frac{CL_{s+b}}{CL_b}$$