Search for the Higgs boson decaying to W pair with the D0 experiment at the Tevatron

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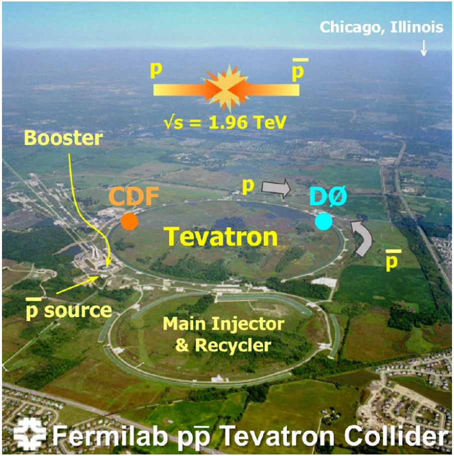
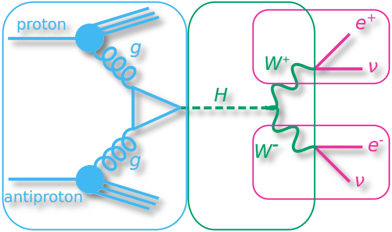
Outline

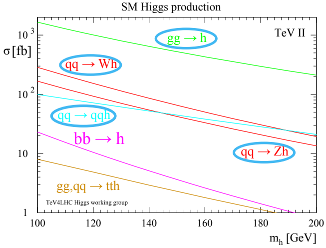


Many thanks to the Tevatron

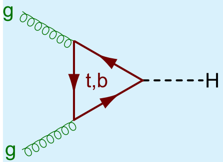
- 11.9 fb^{-1} of $p\bar{p}$ collisions delivered (April 2002 - September 2011).
- Using the full 9.7 fb^{-1} of good quality data recorded by DØ.

Higgs boson production

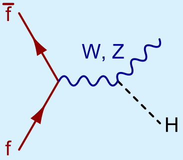




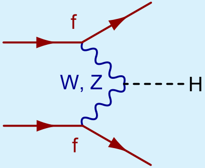
Production modes



gluon-gluon fusion
(a.k.a. *ggH*)

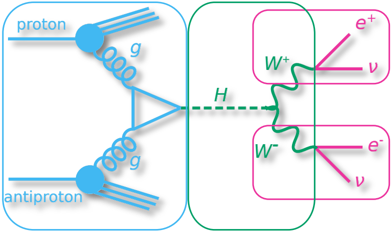


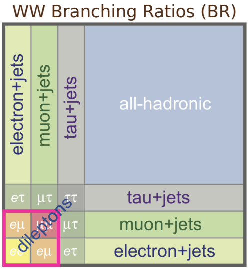
associated production
(a.k.a Higgsstrahlung, *VH*)



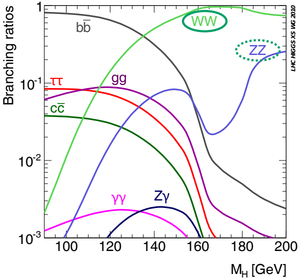
vector boson fusion
(a.k.a. VBF, *qqH*)

Overview of $H \to W^+W^- \to \ell^+\nu\ell^-\bar{\nu}$ analysis





- Most sensitive channel above $m_H = 135$ GeV.
- Clear experimental signature:
  - two opposite sign leptons (e^+e^-, $e^\pm\mu^\mp$ or $\mu^+\mu^-$).
  - missing transverse energy ($\not\!\!E_T$) from the neutrinos.
  - $BR(WW \to ee, \mu\mu, e\mu) \sim 6.4\,\%$, $BR(WW \to ee) \sim 1.6\,\%$

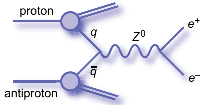


Physics backgrounds

They all contain two "true" electrons. These backgrounds are estimated from simulation.

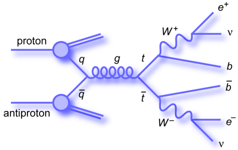
Z/γ^*+jets (Drell-Yan)

- Huge production cross-section ($p\bar{p}$ collider).
- Back to back electrons, no true $\not{E}_T$.



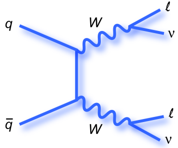
$t\bar{t}$

- Electrons coming from a W boson pair, like for the signal.
- Presence of an additional pair of b-jets.



Diboson (WW, WZ, ZZ)

- Exact same final state as the signal.
- However the signal is a spin-0 resonance.

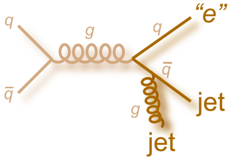


Instrumental backgrounds

These backgrounds are due to jets or photons being identified as electrons.

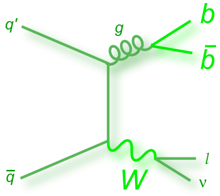
Multijet

- No true $\not{E}_T$(no neutrino) in the final state.
- Two bad quality electrons.
- Completely estimated from data.

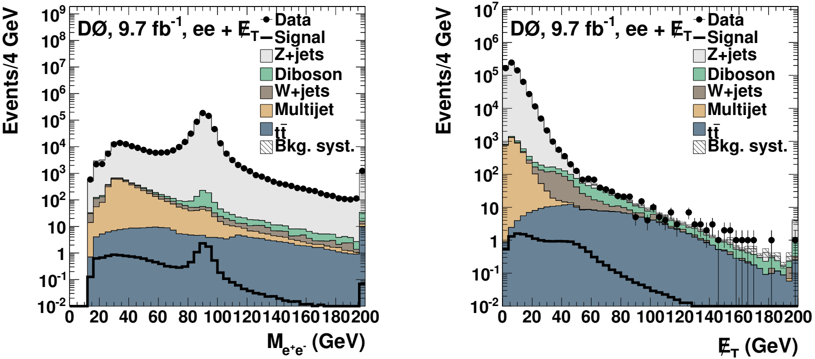


W+jets

- Similar topology as the signal (true $\not{E}_T$).
- One of the two electrons has bad quality.
- Estimated from simulation, corrected from data.

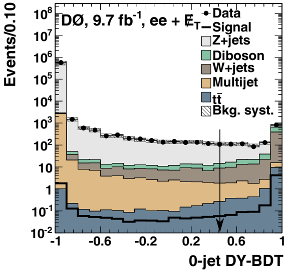


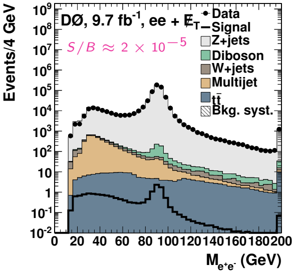
Preselection



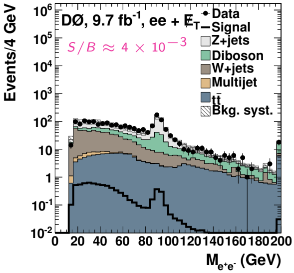
Z/γ^* rejection

- Use a Boosted Decision Tree (BDT) to reject the Z/γ^* (Drell-Yan) background.
- Want both efficient background rejection and as little signal loss as possible.
- Input variables:
    - Event kinematics and topology (M_{ee}, $\Delta\phi(ee)$, ...).
    - $\not{E}_T$-related ($\not{E}_T$, $\Delta\phi(\not{E}_T, e)$, ...).



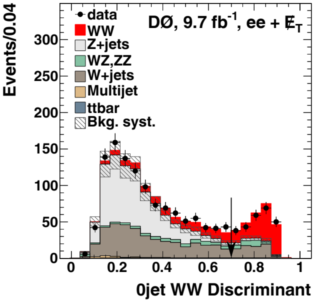


after cutting on the DY-BDT: ⟶



Classifying events

Events are divided into 5 categories, depending on jet multiplicity and "*WW*-likeness" (depending on a *WW* BDT output).

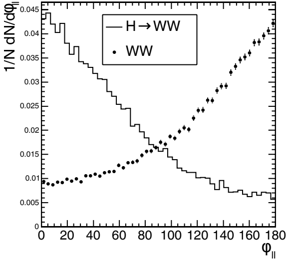


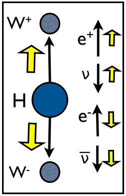
Event categories

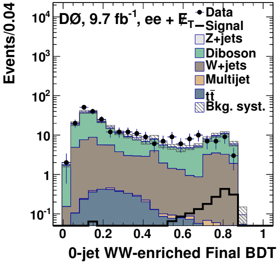
0 jet		1 jet		$\geq$ 2 jets
WW-depleted	*WW*-enriched	*WW*-depleted	*WW*-enriched	

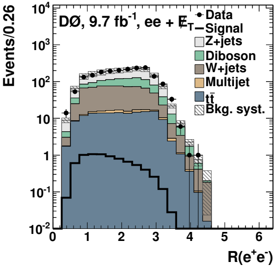
Final discriminant

- We use a final BDT to discriminate the signal against the remaining backgrounds.
- Additional information:
  - electron quality (against W+jets),
  - b-tagging information (against $t\bar{t}$),
  - angular variables (against diboson: the Higgs is a spin-0 resonance).

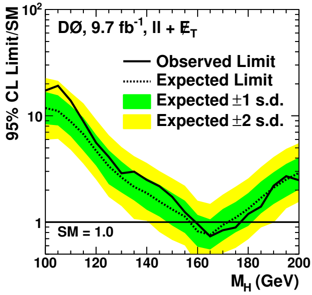


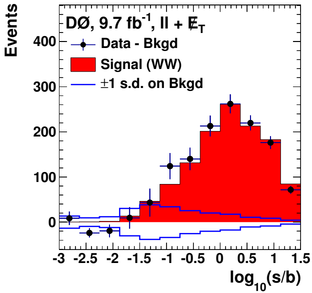






SM Higgs boson and *WW* cross sections





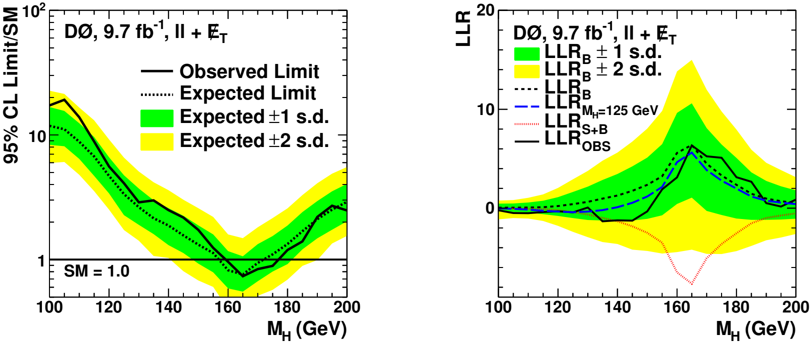
Upper limits on SM Higgs boson cross section

- No signal is observed.
- Observed (expected) exclusion: $159 < m_H < 176$ GeV ($156 < m_H < 172$ GeV).

Non-resonant *WW* cross-section measurement

- We obtain a cross section of $\sigma_{p\bar{p}\to WW} = 11.4 \pm 0.4\,(\text{stat.}) \pm 0.6\,(\text{syst.})$ pb.
- Theoretical cross-section: $\sigma_{p\bar{p}\to WW} = 11.34 \pm 0.7$ pb.

Summary



Final $H \to WW \to \ell\nu\ell\nu$ results from DØ

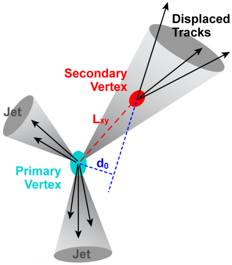
- Observed (expected) exclusion: $159 < m_H < 176$ GeV ($156 < m_H < 172$ GeV).
- Analysis included in the DØ and Tevatron Higgs combinations.
- Results compatible with the observation of a new boson at the LHC.
- $H \to WW \to \ell\nu\ell\nu$ paper accepted by Phys. Rev. D [1301.1243 [hep-ex]]

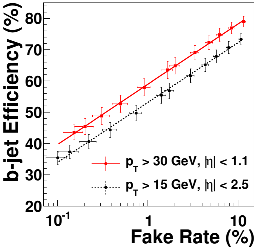
Additional material

4. *b*-ID
5. LLR
6. Systematic uncertainties
7. Non-SM Higgs boson searches in $H \rightarrow WW \rightarrow \ell\nu\ell\nu$

b-jet identification at DØ

- B hadrons travel in the detector before they decay.
- Information used in b-tagging:
  - Secondary vertex,
  - Impact parameters of tracks,
- DØ: Multivariate discriminant.



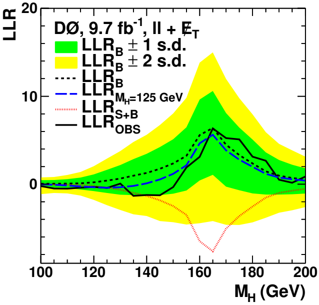


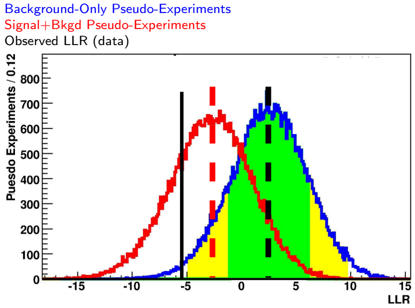
Log-likelihood distributions

- The log-likelihood ratio helps to gauge the relative agreement of the data with the background or signal+background models (resp. H_0 and H_1):

$$\mathrm{LLR} = -2\ln\left(\frac{P(\mathrm{data}|H_1)}{P(\mathrm{data}|H_0)}\right)$$

- Systematic uncertainties (signal and background normalizations (cross sections), modeling effects, etc.) are taken into account as nuisance parameters in the fit.
- Distributions are populated with pseudo-experiments to get an estimate of significance.





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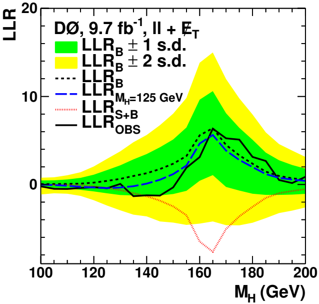
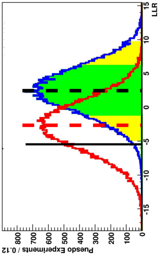




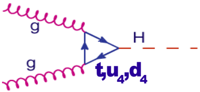
Systematic uncertainties

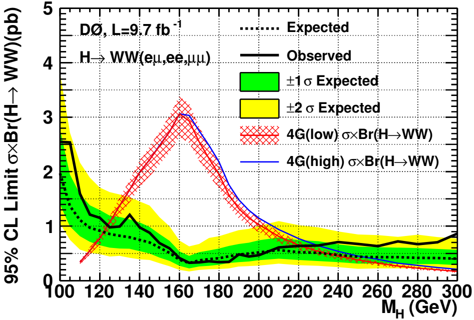
Table: Summary of systematic uncertainties (in %) for source categories. The jet, b-tagging and PDF related uncertainties are quoted for all the backgrounds combined.

Source	Uncertainty (%)
Overall normalization	4.0
W+jets normalization	6.0–50.0
Diboson cross section	6.0
$t\bar{t}$ cross section	7.0
Multijet normalization	30.0
Z+jets jet-bin normalization	2.0–15.0
$gg \rightarrow H$ cross section	7.6–35.0
VH cross section	6.0
qqH cross section	5.0
Jet energy scale	1.0–4.0
Jet resolution	1.0–3.0
Jet primary vertex association	1.0–2.0
b-tagging discriminant	1.0–2.0
PDF (background)	2.5

Models with a fourth generation of fermions

- A fourth generation of fermions would much enhance the $gg \to H$ production cross-section.
- Enhancement by a factor 7 to 9.
- Analysis redone with $gg \to H$ signals only and extending the mass range to $100 < m_H < 300$ GeV.





Fermiophobic Higgs model

- Unchanged couplings to bosons compared to the SM, zero couplings to fermions.
- Only associated production VH and VBF remain possible.
- The branching ratio $H \to$ bosons is enhanced compared to the SM.
- Analysis redone with VH and VBF signals only and adequate cross-sections and BRs.