Search for the Higgs boson in the dilepton channel

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Outline

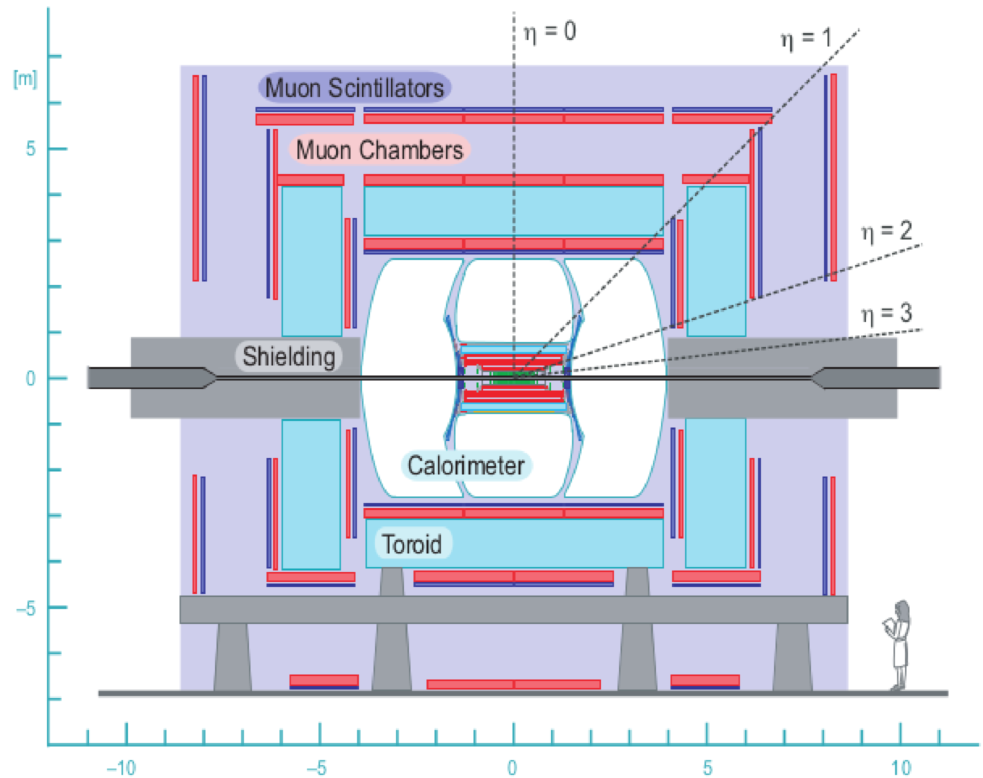
- Introduction
- Analysis Strategy
- Recent results
- WW Cross section measurements
- Conclusion

The D0 detector

The DØ detector is one of the two experiments at the Fermilab's TeVatron, located near Chicago, IL, USA.

Run II dataset

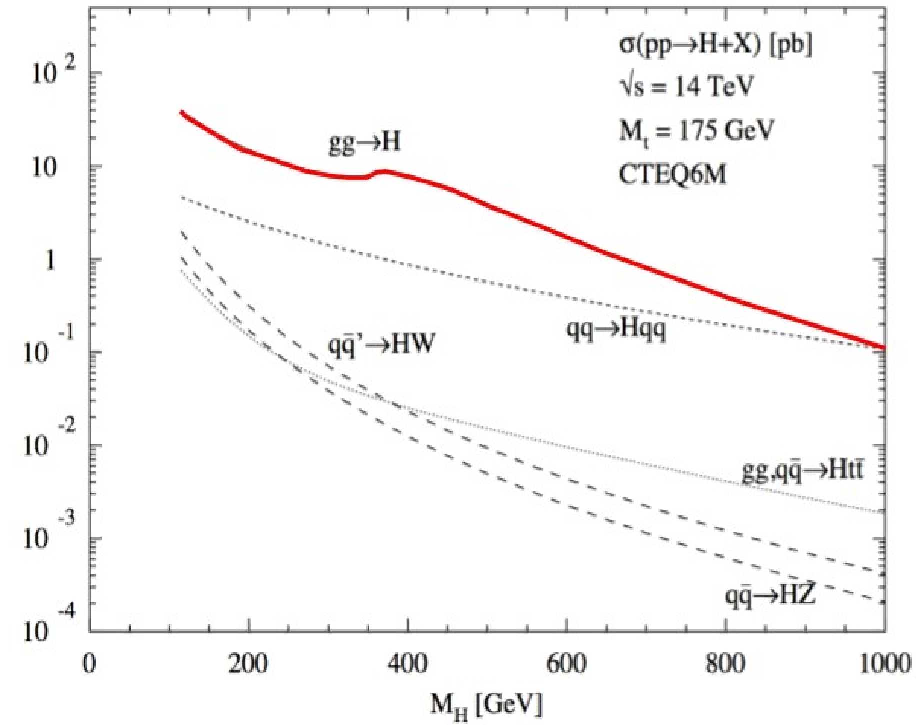
- $p\bar{p}$ collisions
- $\sqrt{s} = 1.96$ TeV
- Start: April 2002
- End: September 2011
- Run II full dataset for this analysis: 9.7 fb^{-1}



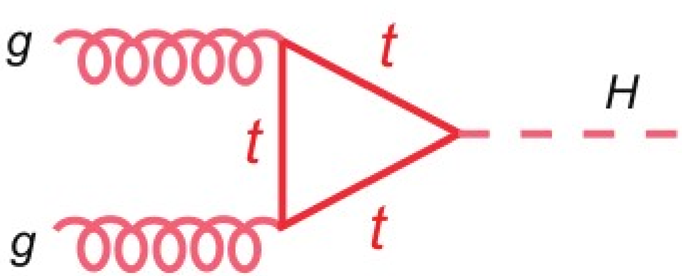
Higgs Production and Xsection

Sources of signal :

- Gluon fusion
- Associated production via HiggsStrahlung (VH)
- Vector boson fusion (VBF)

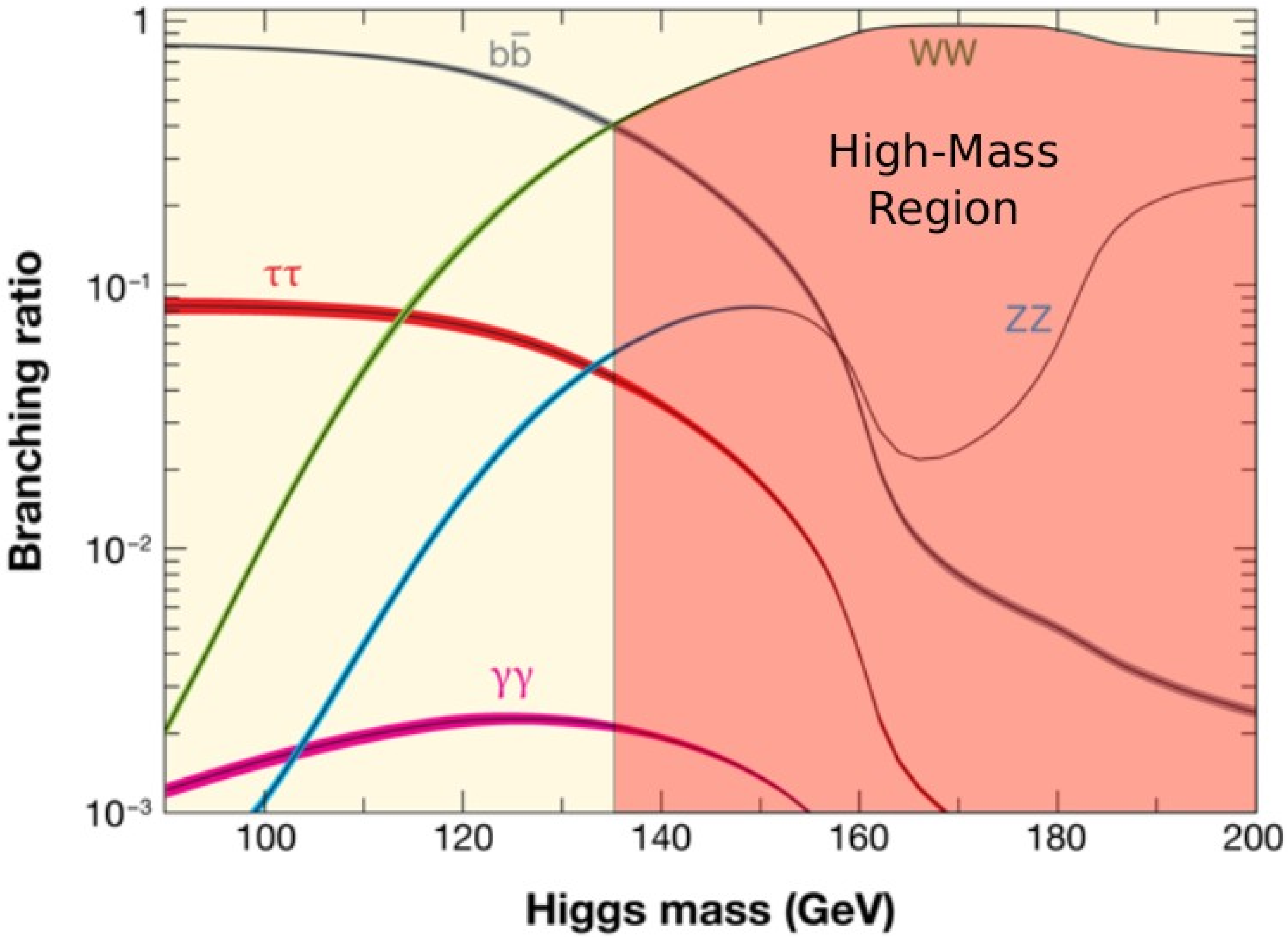


→ The most important Higgs production process is the gluon fusion process.



Higgs Boson Decays

At high mass, the $H \rightarrow WW$ channel is the most sensitive one for the search of the Higgs boson at DØ.



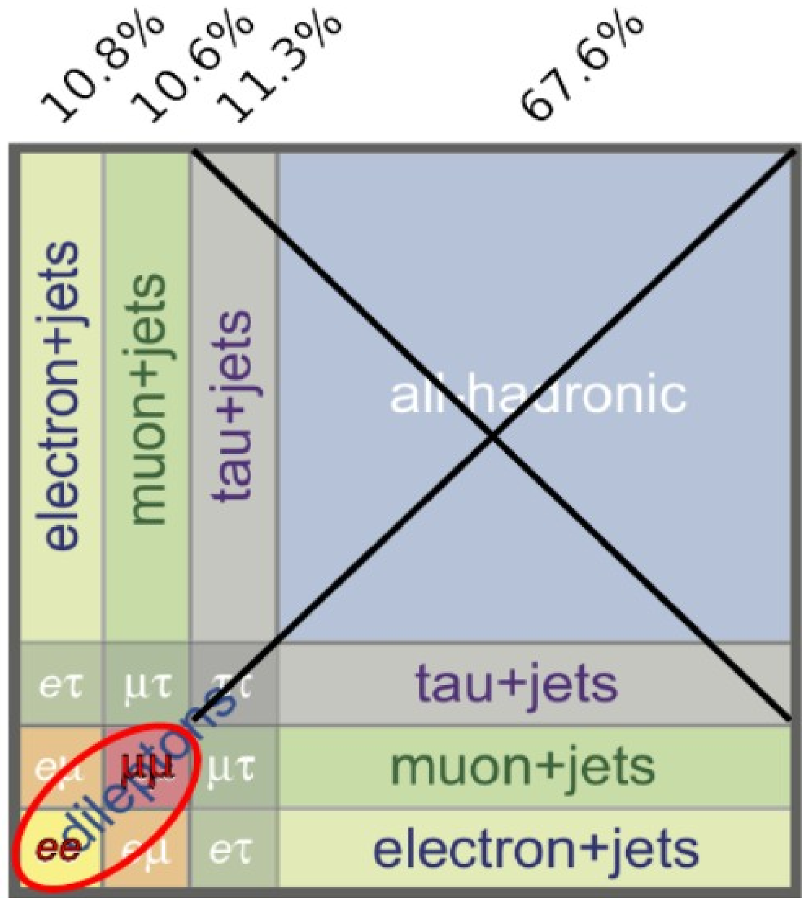
W Boson Decays

The $H \to WW \to l\nu l\nu$ has the highest sensitivity for the high-mass region and has an impact for the lower masses as well.

Final states available :

- **All hadronic**: not doable at the TeVatron/LHC.
- **Semi-Leptonic**: high signal - high background
- **All Leptonic**: low signal - low background.

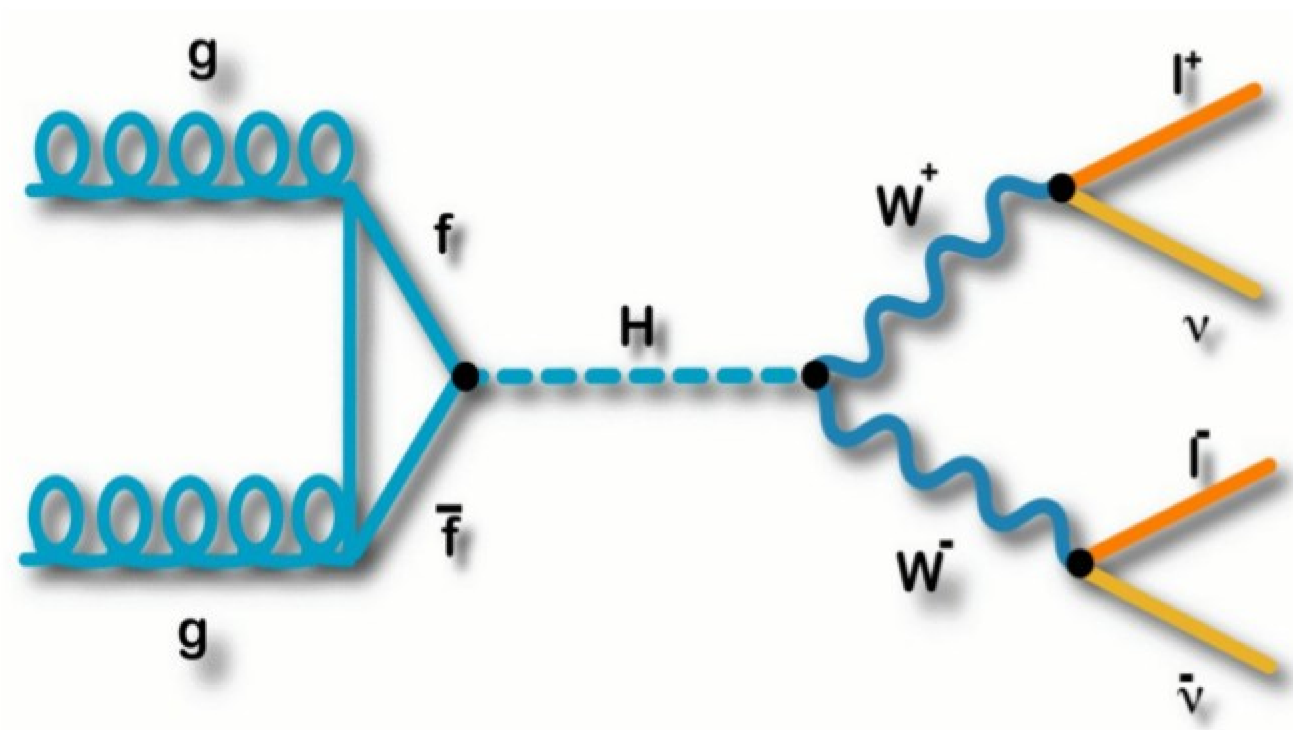
→ Higgs part of my PhD is dedicated to μμ channel .



Signal Topology

Signal Signature

- Two opposite sign leptons (e^+e^-, $e^+\mu^-$ and $\mu^+\mu^-$).
- High p_T leptons.
- Close $\Delta R(l^+l^-)$ due to the Higgs spin 0.
- Presence of Missing Transverse Energy ($\not{E}_T$).



Strategy of Search

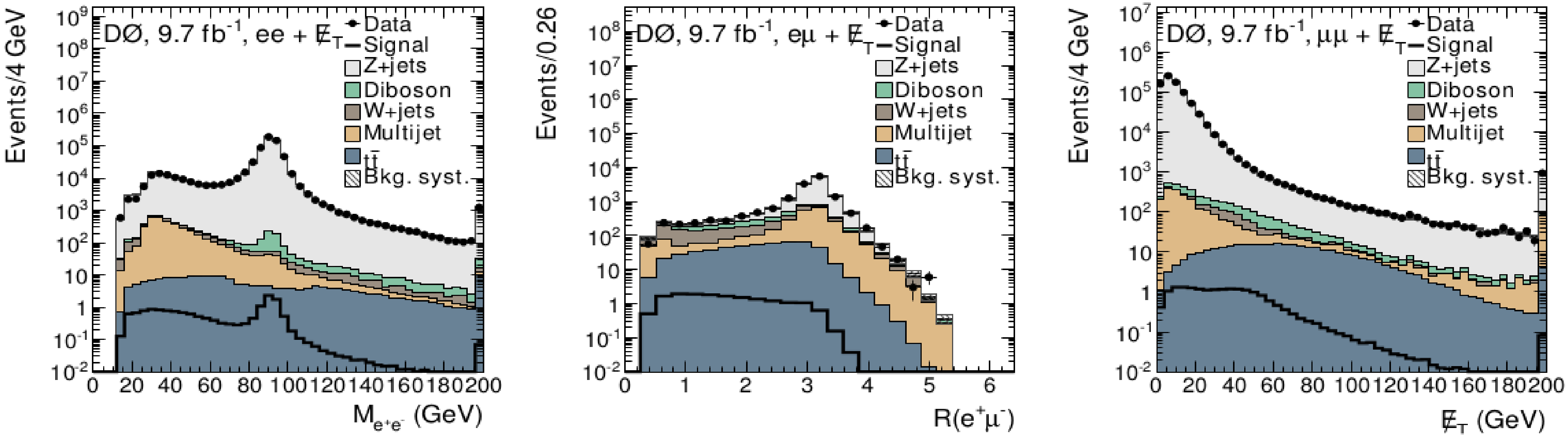
Common steps for the 3 analyses.

1. Preselection
2. Trigger Correction (for mumu channel)
3. Reweighting to correct the MC simulation
4. Signal discrimination : BDTs for rejecting backgrounds.
5. Derive final results

Preselection Plots

Technique

- Preselection of two opposite sign high p_T leptons.
- Data/MC Normalization in the Z peak mass window.



	Data	Total background			Signal
ee:	659570	664460	$\pm$	13290	16.1
$e\mu$:	14936	15142	$\pm$	303	16.6
$\mu\mu$:	811549	818269	$\pm$	16370	18.7

Reweightings

→ During the analysis steps, we need to correct our MC simulations in order to match the data distributions.

- REWEIGHTINGS COMMON TO THREE CHANNELS [SIMULATION]:
  Instantaneous luminosity and primary vertex position.

- SAMPLE SPECIFIC REWEIGHTINGS [PHYSICS]:
  WW p_T, H p_T, WW ϕ_{ll}, p_T^Z and p_T^W.

One of my first task for the μμ analysis !

- TRIGGER CORRECTION [DETECTOR] (for $\mu\mu$ only):
  η_{det},φ,$njets$ and p_T distributions.

- INCLUSIVE JETS REWEIGHTINGS [DETECTOR]:
  for $e\mu$ and ee : electron-ID variable.
  for $\mu\mu$: η_{det}

- JET MULTIPLICITY DEPENDENT $Z + jets$ REWEIGHTINGS [PHYSICS]:
  for ee and $\mu\mu$: $\Delta R(j_1 j_2)$, p_T^Z and jet η.

- W+JETS/γ [PHYSICS] (FOR $e\mu$ AND ee):
  normalization and shape correction are applied.

Trigger Correction

- The aim is to maximize the acceptance in the analysis so no explicit trigger is required.
- No simulation of the inclusive trigger (INCL) is available. Need to compute dedicated modeling.

How to determine correction?

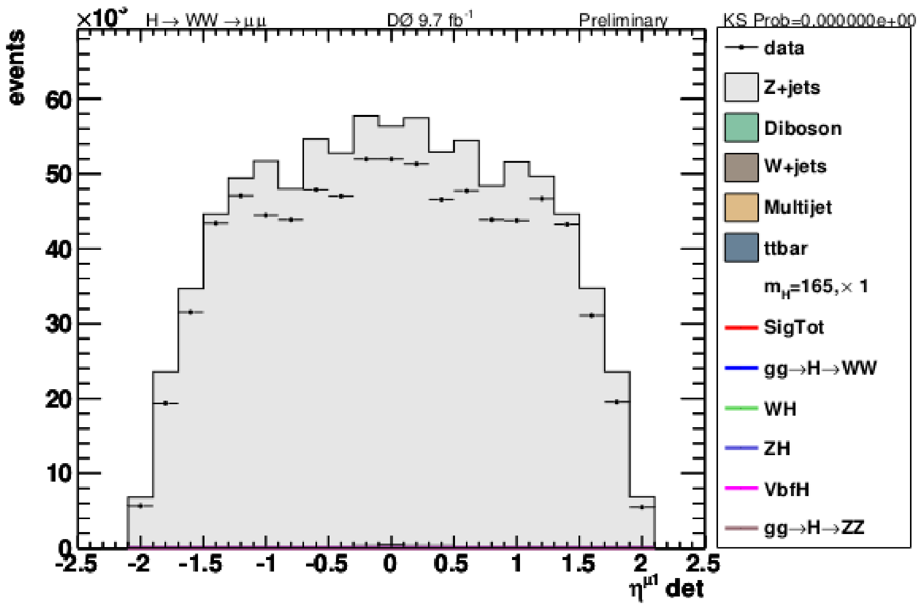
1. « Single Muon » trigger (SMOR) efficiency is measured in data and is included in MC (efficiency = 80%).

2. I derived from data the difference of shape and normalization between INCL trigger and SMOR trigger (correction = 15%).
Variables : η_{det}, φ, njets and p_T distributions.

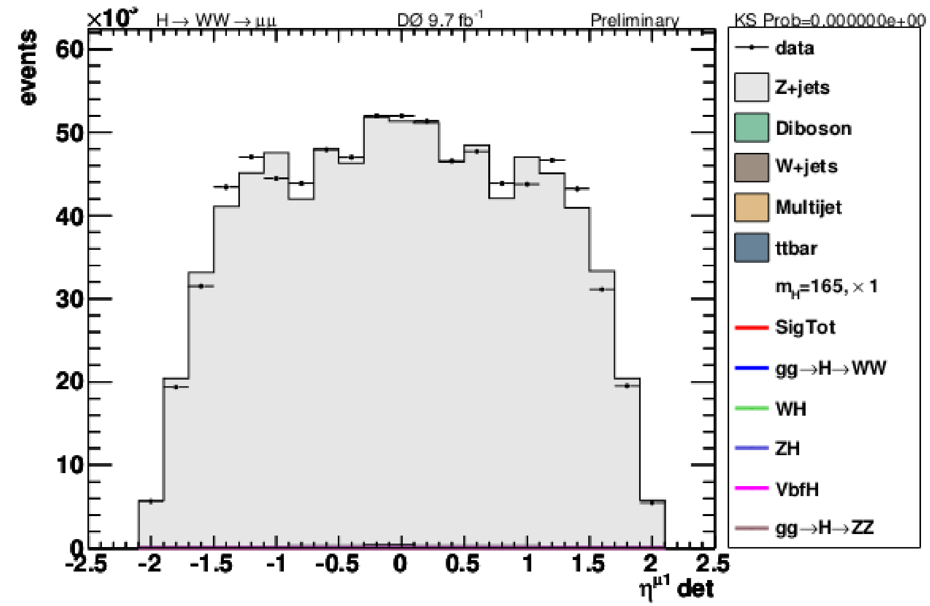
3. I finally correct for the residual pT dependence due to the trigger turn-on. Derived by comparing the SMOR data to SMOR MC.

4. Overall inclusive trigger efficiency = 92 %.

Trigger Correction



η_{det1} before Trigger Correction



η_{det1} after Trigger Correction

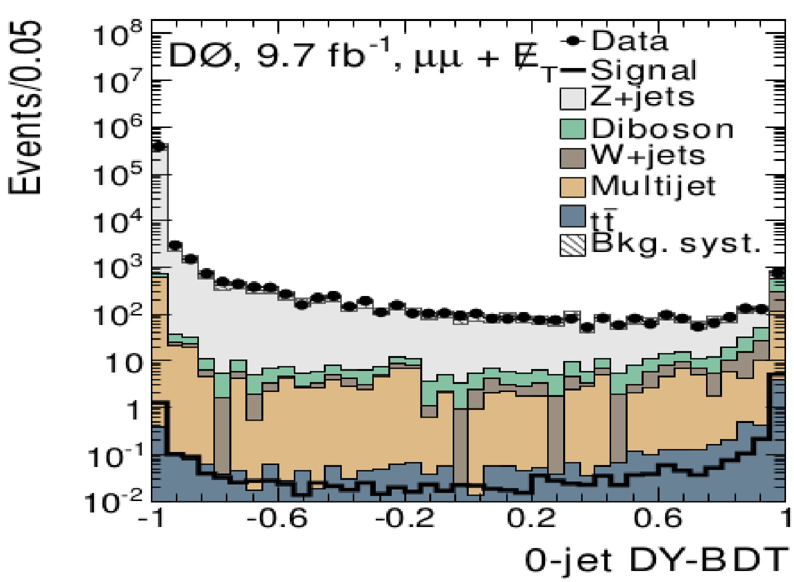
BDTs : 1. Reject DY background

First Step

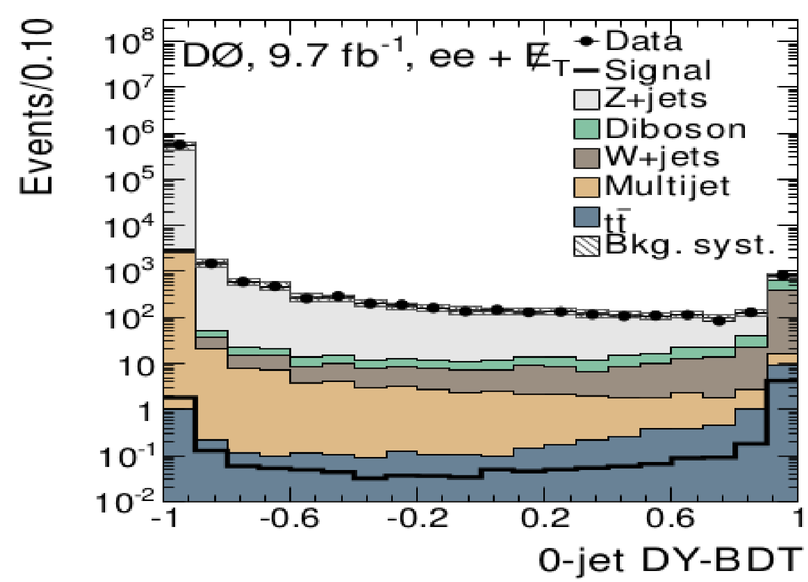
1. A first BDT is trained to reject most of the Drell-Yan (Z/γ^* process) background in ee and $\mu\mu$ channel.
   We used the combination of the most discriminating variables like $\Delta\phi(l^+l^-)$, $\not{E}_T$.

   $\rightarrow$ It is performed separately for all sub-channels (0, 1 and ≥ 2 jets), for all the Higgs mass range.

2. How to choose the DY-BDT cut ? $\rightarrow$ Get a balanced mixture of the different backgrounds, after selection.



DY-BDT for $\mu\mu$, $m_H = 125$ GeV



DY-BDT for ee, $m_H = 125$ GeV

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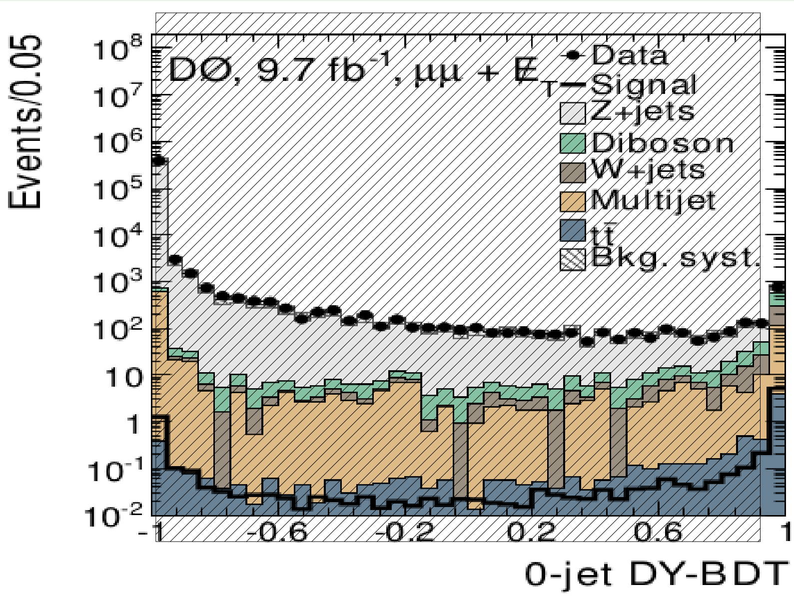
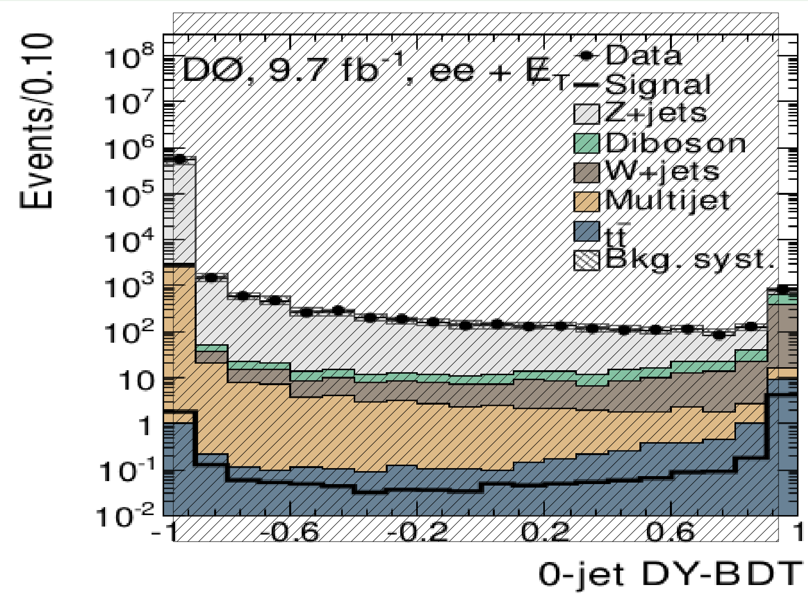


DY-BDT for $\mu\mu$, m_H = 125 GeV



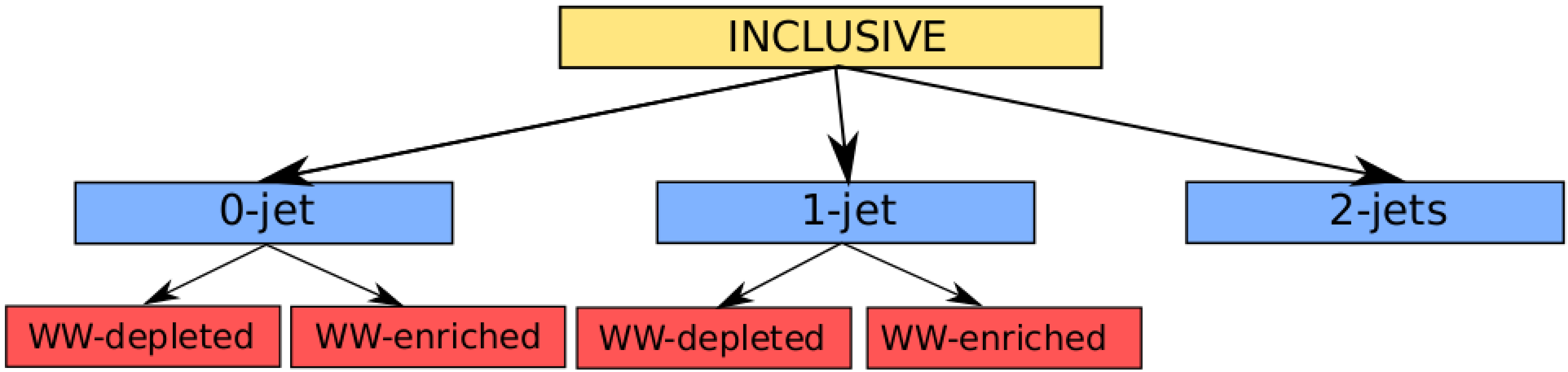
DY-BDT for ee, m_H = 125 GeV

BDTs : 2. Split

Second Step

After the DY-BDT cut, split the 0-jet and 1-jet channel in **WW background enriched/depleted** samples according to :

- dedicated WW-BDT for ee and $\mu\mu$ channels (0-jet and 1-jet).
- lepton quality for $e\mu$ channel (0-jet).

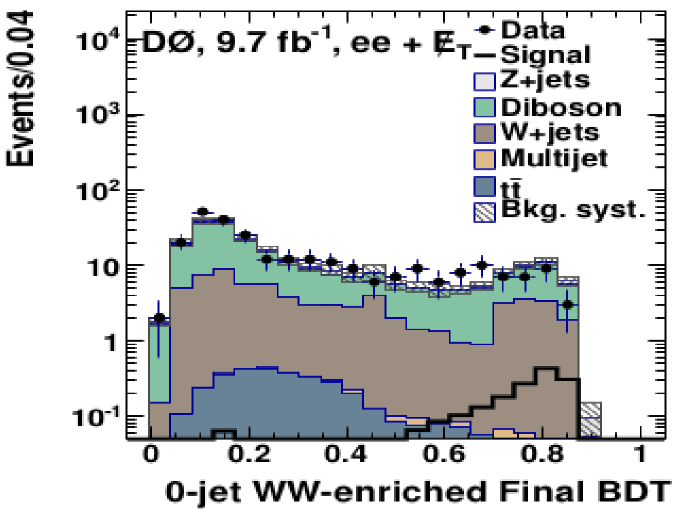


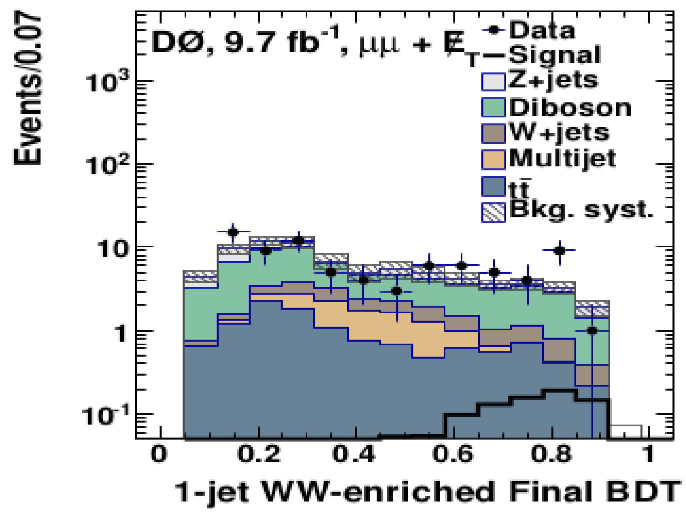
Third Step

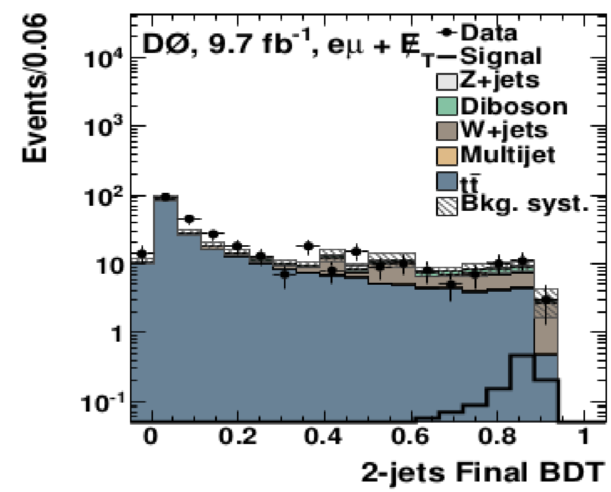
A final FD-BDT is trained to reject all remaining backgrounds
It is performed separately for all sub-channels (0-, 1- and $\geq$ 2-jets) depending on **WW background enriched/depleted** and **lepton quality** regions = 4-5 sub-channels.

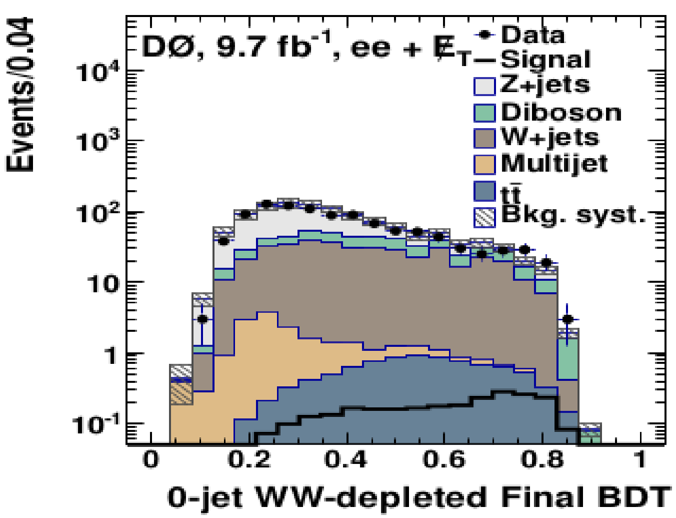
BDTs : 3. Reject other backgrounds

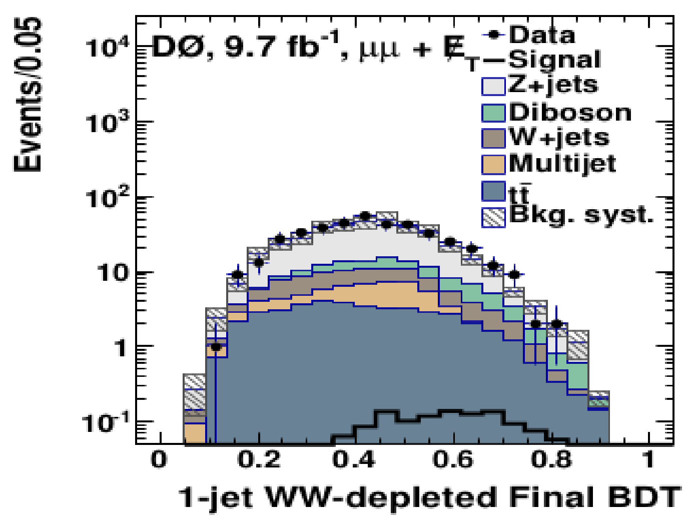
- *ee* and $\mu\mu$ (0-1-jet channels) : Use the **WW discriminant** to separate *WW* background from the others.
- $e\mu$ (0-jet channel) : Use the **lepton quality** variable in LowLikelihood and HighLikelihood regions.











Systematics

1. FLAT: Which only affects normalization of both signals and backgrounds (e.g. cross section uncertainty).
2. SHAPE: Wich affect the shape of distributions, for both signals and backgrounds (e.g. Jet Energy Scale).

Source	Uncertainty (%)
Overall normalization	4.0
W+jets normalization	10.0 - 30.0
Diboson cross section	6.0
t cross section	7.0
Multijet normalization	30.0
Z+jets jet-bin normalization	2.0-15.0
$gg \rightarrow H$ cross section (PDF)	7.6 - 13.8 - 29.7
VH cross section	6.0
qqH cross section	5.0
Jet energy scale	4.0
Jet resolution	0.5
Jet primary vertex association	2.0
b-tagging discriminant	<2.0
$gg \rightarrow H$ cross section (scale)	20.0 - 40.0 - 8 inc + cov. matrix

WW Xsection measurements

The WW cross-section measurement is a way to validate our analysis techniques used in the Higgs search. The signal is now : $p\bar{p} \rightarrow WW$.

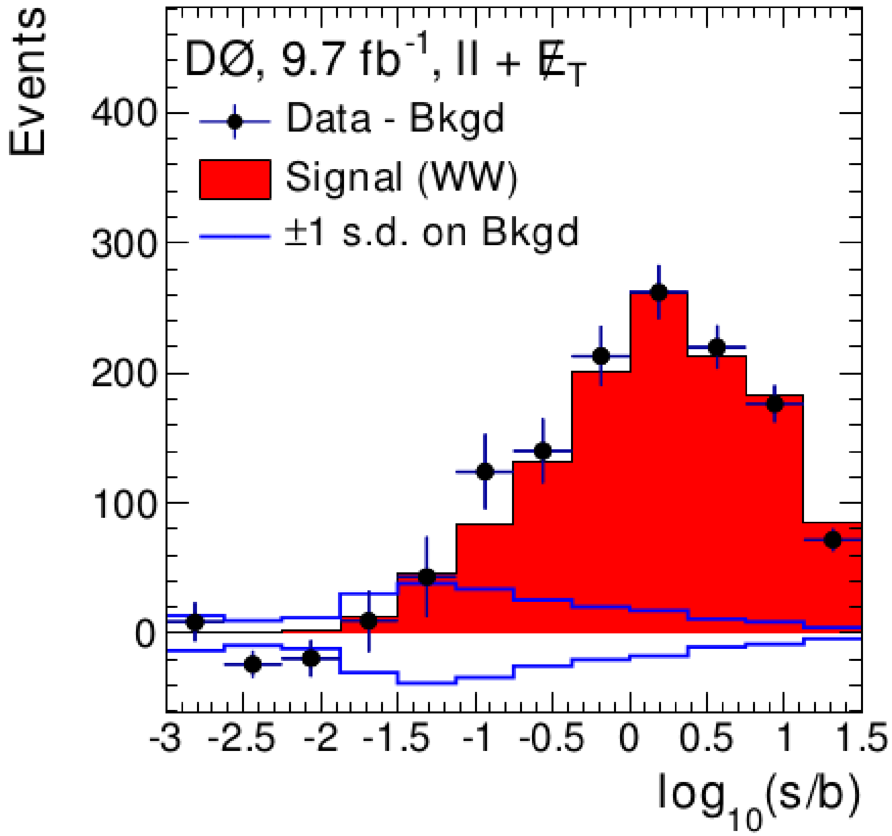
The same treatment is made from the preselection criteria up to the multi-variate techniques. Only some points are different from our regular Higgs search.

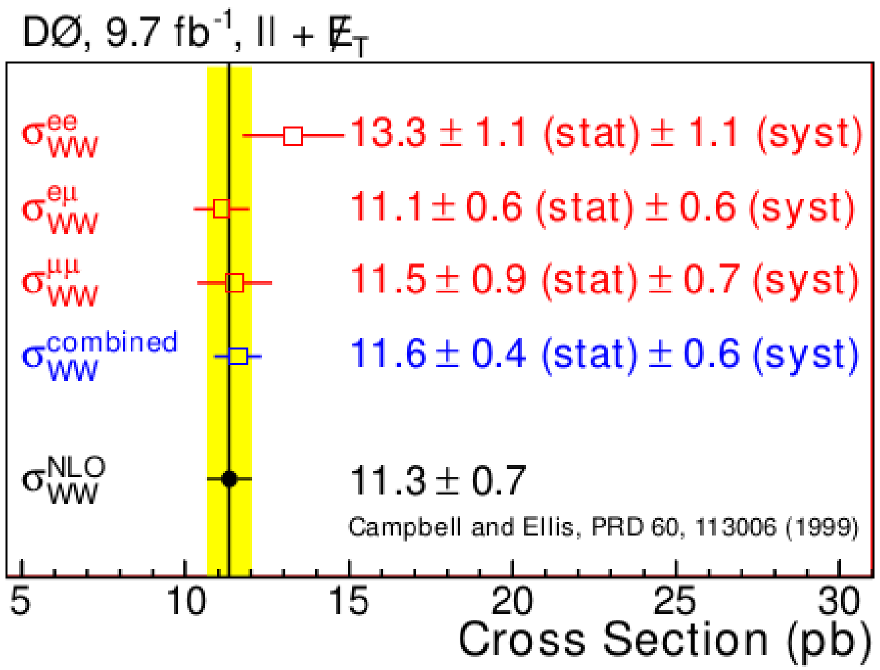
Measurement strategy

1. The DY-BDT is the same used as the Higgs search analysis (Topology difference between SM di-boson production and SM H $\rightarrow$ WW is the dilepton angular distribution).
2. All channels do not use the $\geq$2-jets channel due to the extremely low WW contribution.
3. The FD-BDT is re-trained using only WW as signal.

WW Xsection measurements

The background-subtracted data distribution for the final discriminant for the **final WW cross section measurement** and the **summary of cross-section measurements**.

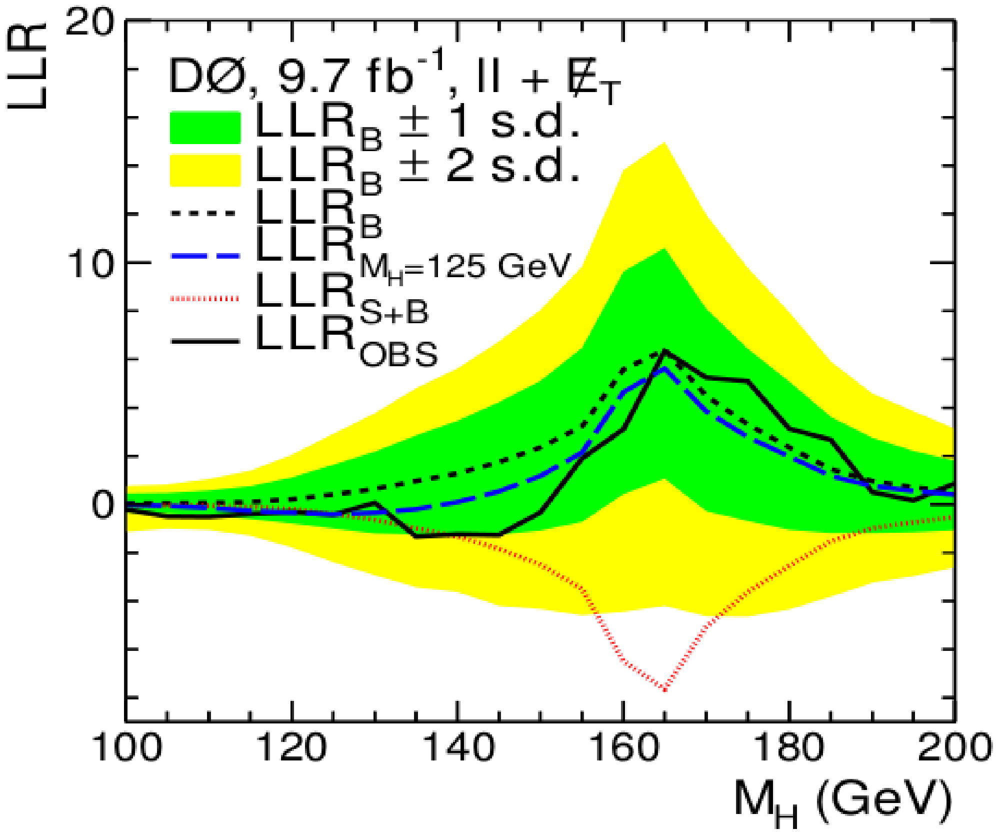


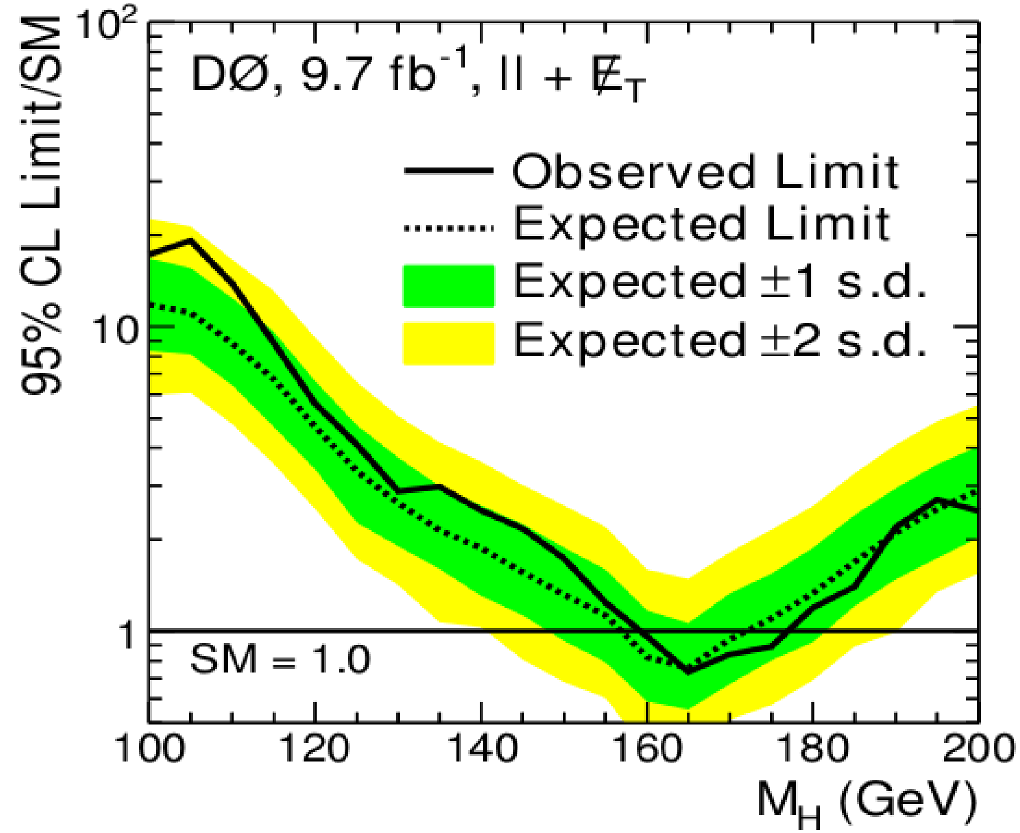


Result

The measured value of $\mathbf{11.6 \pm 0.7}$ **pb** is in good agreement with the SM prediction of $\mathbf{11.3 \pm 0.7}$ **pb**.

H->WW Combination Limits





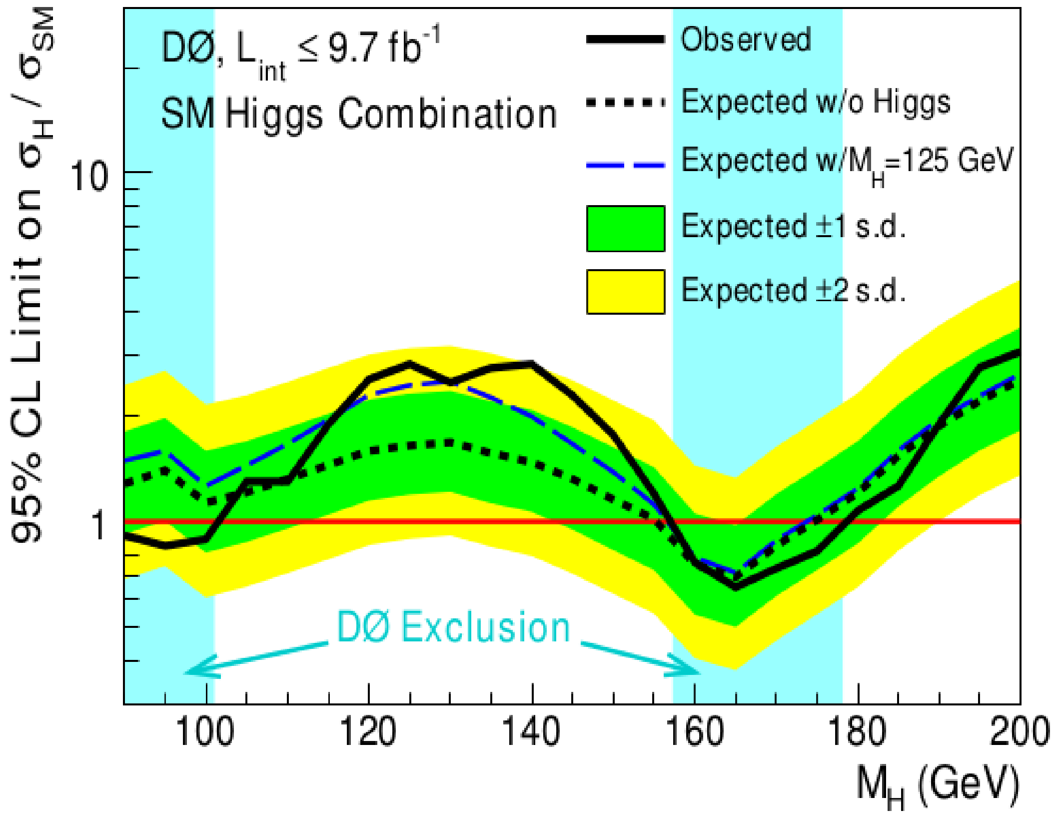
Result

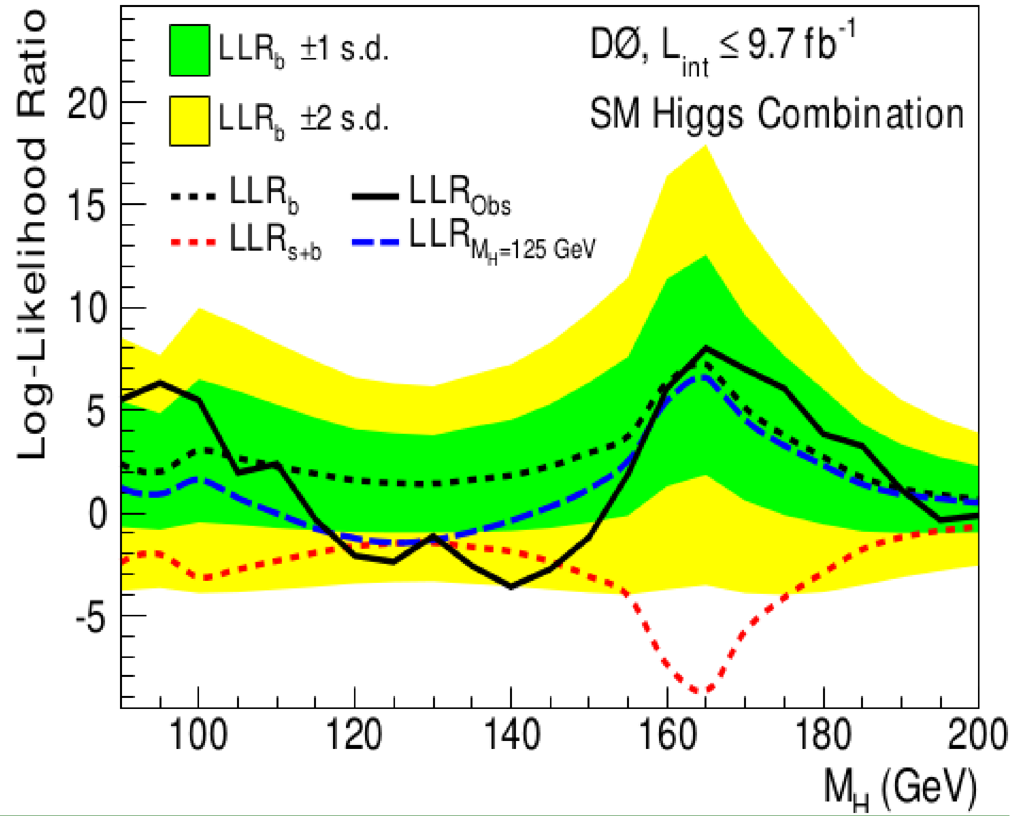
We exclude at 95% C.L. $159 < m_H < 176$ GeV (expected exclusion sensitivity is $156 < m_H < 172$ GeV).

$\rightarrow$ For $m_H = 125$ GeV, we exclude **4.1** $\times \sigma_H^{SM}$ (expected sensitivity is 3.4).

Slight excess in $110 < m_H < 150$ GeV (compatible with a SM Higgs boson of 125 GeV).

D0 Combination Limits





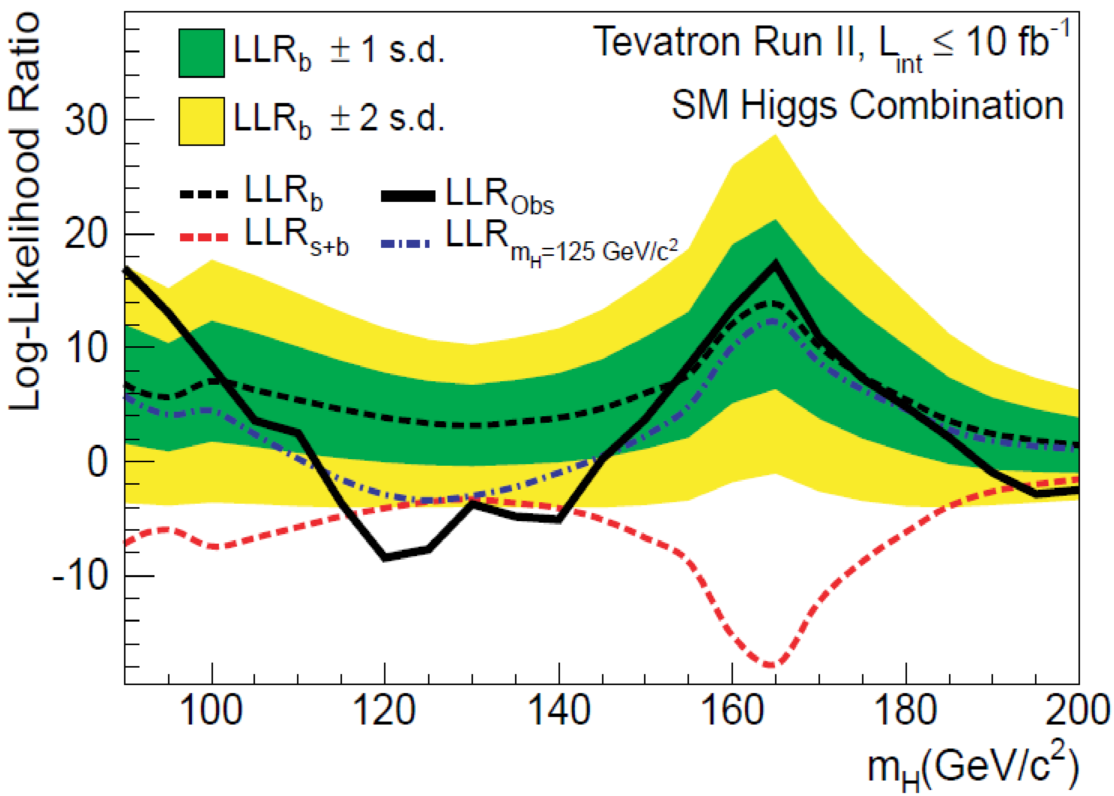
Result

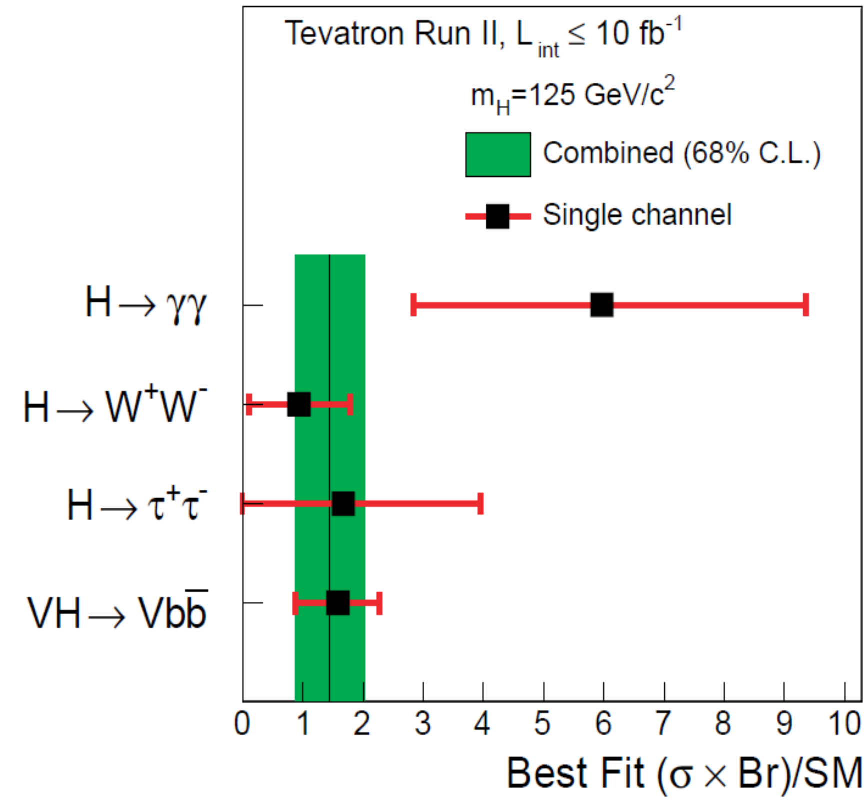
D0 excludes at 95 % C.L. 157<m_H<178 GeV (expected exclusion is 155<m_H<175 GeV).

→ For m_H=125 GeV, D0 excludes 2.86 x σ^{SM} (expected sensitivity is 1.68).
Slight excess in 120<m_H<145 GeV (compatible with a 125 SM Higgs).

Accepted by PRD, hep-ex/1303.0823

TeVatron Combination Limits





Result

TeVatron excludes at 95 % C.L. $149<m_H<182$ GeV (expected exclusion is $140<m_H<184$ GeV).

- Best fit overall signal strength : R = 1.4 +- 0.6 for m_H=125 GeV.

- Best fit H->WW signal strength : R = 0.9 +- 0.8 for m_H=125 GeV.

Submitted to PRD, hep-ex/1303.6346

Summary

With the H-> WW channel, we contribute to the final answer that the TeVatron gives for the search of a SM Higgs boson.

Higgs Search

With only the H->WW channel, we are able to exclude at 95 % C.L. The region 159<mH<176 GeV.

About the Higgs boson at 125 GeV found by ATLAS and CMS :
- H->WW channel has a non-negligible sensitivity for mH=125 GeV and we have a slight excess.

- The combined D0 result shows a slight excess (< 2 s.d.) compatible with a 125 GeV Higgs boson.

- Combined TeVatron results shows 3.0 s.d. Excess for m_H=125 GeV.

After the Higgs ?

I finished to work on the Higgs since the end of 2012.

Started to work on the Top Quark Asymmetry in the dilepton channel with Slava Sharyy and Boris Tuchming.