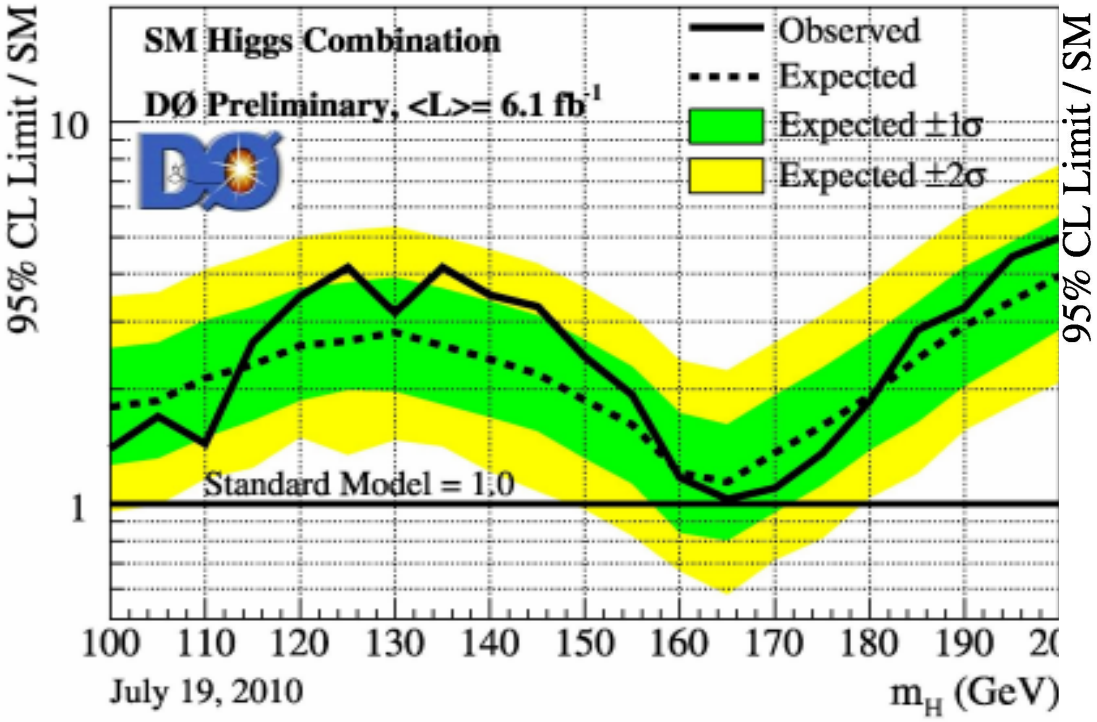
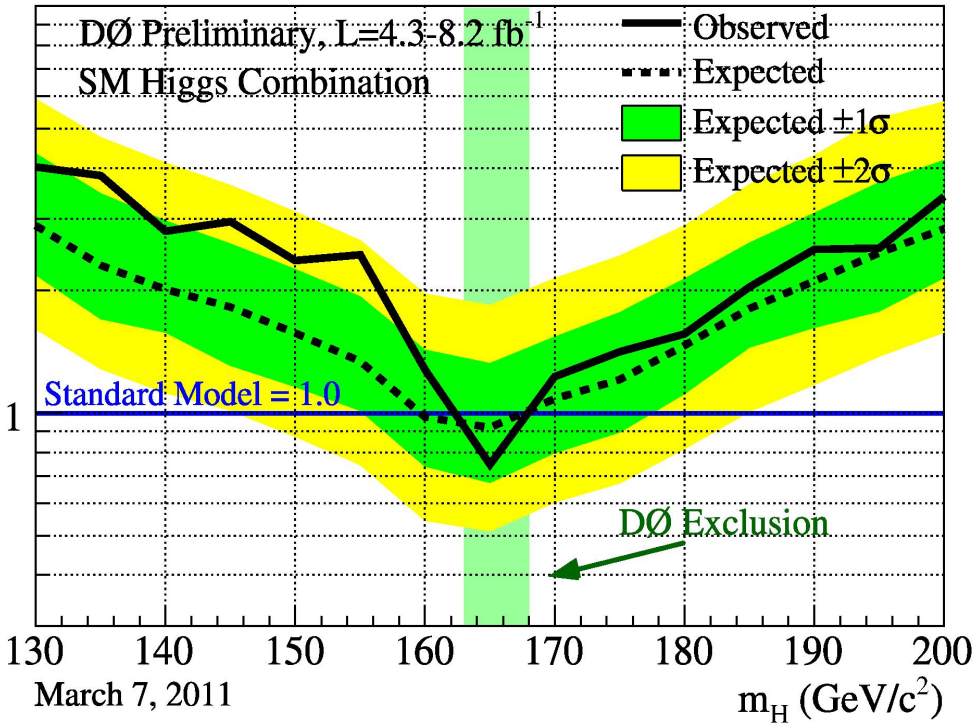
Combined upper limits on SM Higgs

Sebastien Greder,
IPHC / IN2P3-CNRS, Strasbourg
on behalf of the D0 collaboration

Introduction

Previous combination:





March 2011, single experiment exclusion:

$163 < m_H < 168$ GeV/c^2 at 95% C.L

For more details see:

http://www-d0.fnal.gov/Run2Physics/WWW/results/prelim/HIGGS/H105/

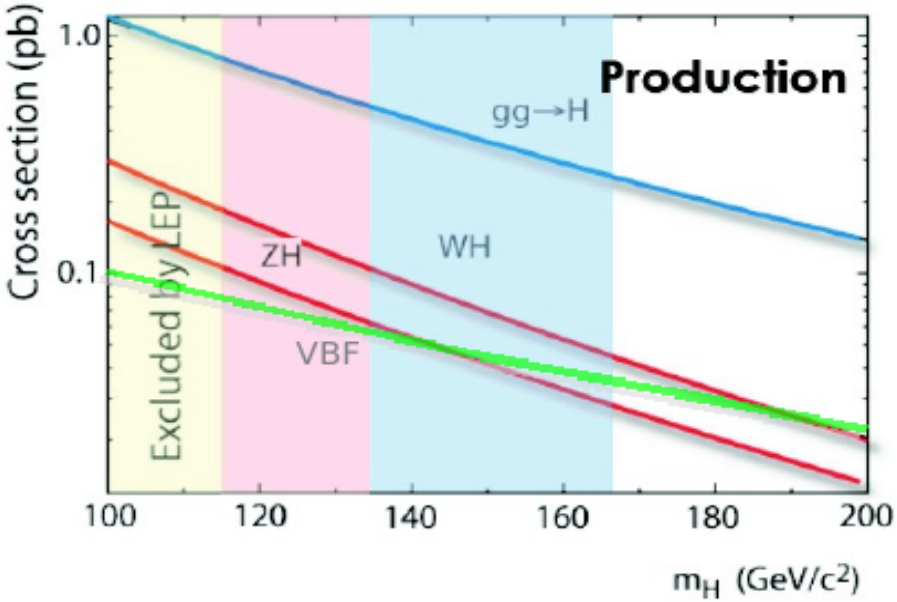
Production and decays

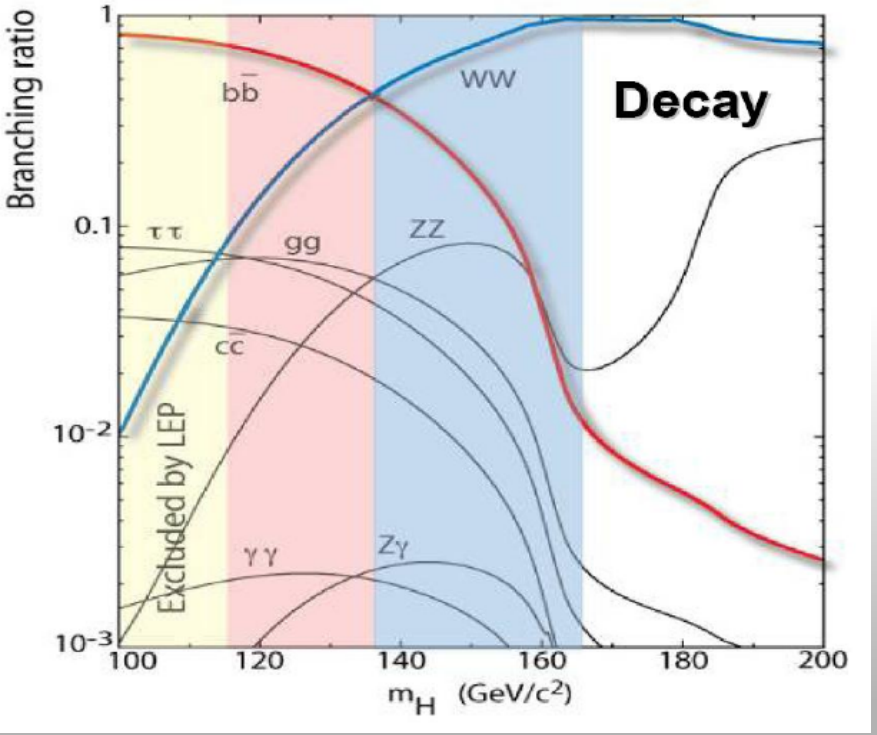
Higgs production cross sections

- ~ 0.02 - 1.3 pb
- investigate 3 productions modes

Analyzed data correspond to integrated luminosities ranging from 4.3 to 8.6 fb^{-1}

- ~7000 Higgs events





Higgs boson decay modes studied:

- H→bb (cc)
- $H\rightarrow W^+W^-$
- $H\rightarrow \tau^+\tau^-$
- H→γγ

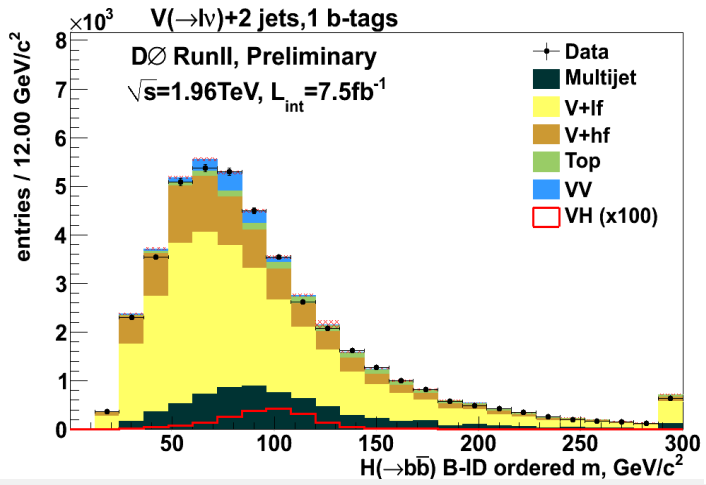
"Low" vs. "High" mass regions:

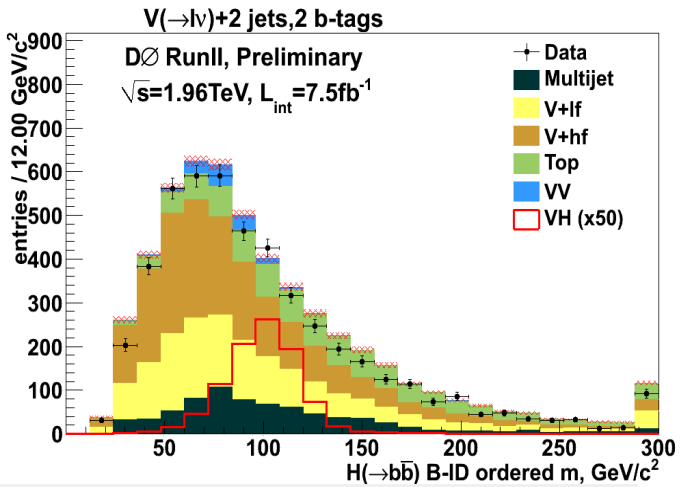
- m_H < 135 GeV : bb
- m_H > 135 GeV : WW

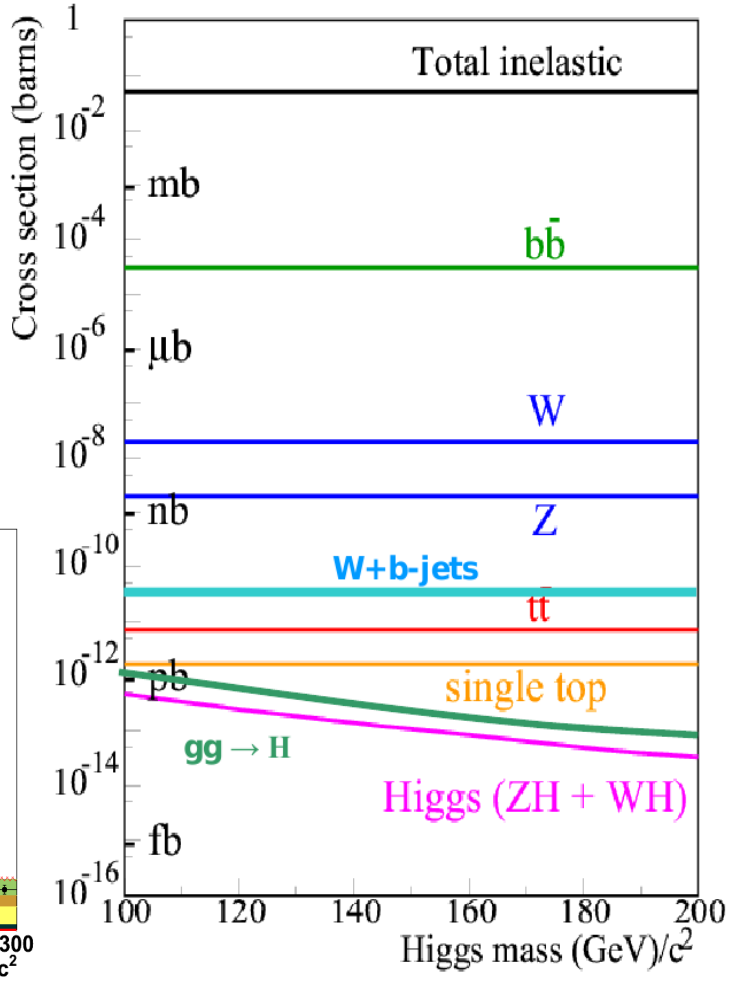
The ingredients (I)

Low-mass

- **Associated productions:** W/ZH
  - **QCD bb ~10^7 x gg→H !**
- **Main backgrounds**
  - V+bb/cc, Top
- Performant lepton & b-identification tools



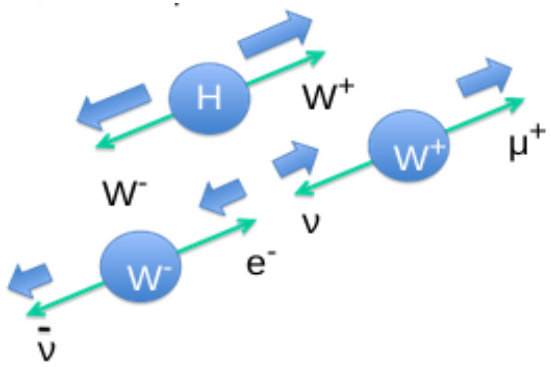




See talks from:

- **POTAMIANOS, Karolos:** *Search for the Standard Model Higgs boson in final states with b quarks at the Tevatron*
- **KASMI, Azeddine:** *Search for the Standard Model Higgs boson in final states with photons or taus at the Tevatron*

The ingredients (II)

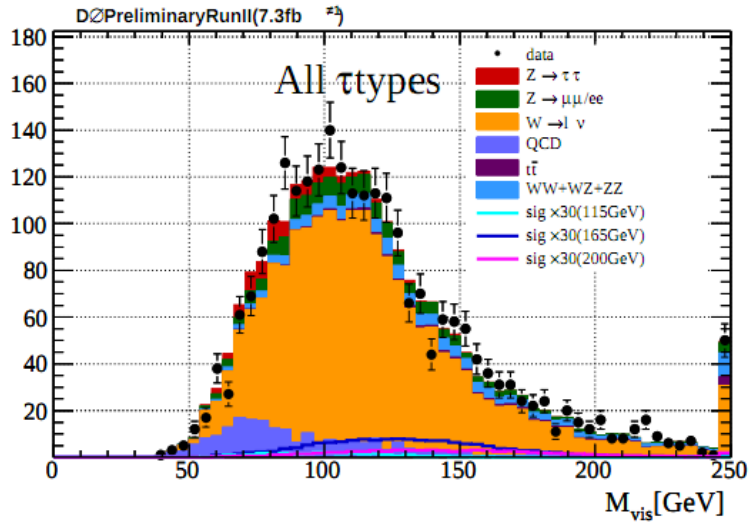


High mass

- H→WW→lνlν + 1,2 jets
- H→WW→lνqq′ *(l = e,μ)* *Phys. Rev. Lett. 106, 171802 (2011)*
- H→WW→l$\nu\tau_{had}$ν + 0, 1, 2 jets

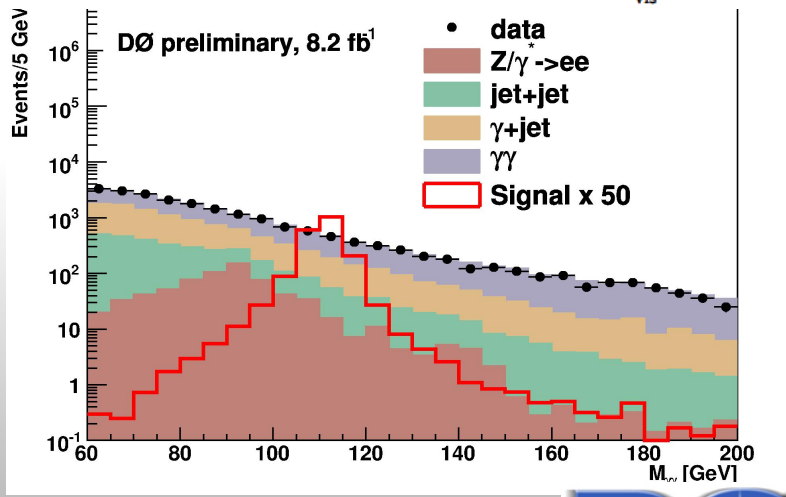
Main backgrounds

- multijet
- bosons pairs
- top pairs



To complete the picture

- VH →WWW→ll+X
- H →γγ



Boris Tuchming
Search for the Higgs boson in the W^+W^- decay at Tevatron

Antonio LIMOSANI
Other searches for a high mass Higgs boson at Tevatron

KASMI, Azeddine
Search for the Standard Model Higgs boson in final with photons or taus at Tevatron

The ingredients (III)

Improving sensitivity

- Most of analyses improve their overall sensitivity by splitting *e.g jet multiplicities, lepton flavors, 1/2 b-jet(s), ...*
  - 40 **exclusive** subsets
- Multivariate techniques *e.g Neural Networks, Decisions Trees*
- Analyses updated with > 8fb^{-1} datasets

Channel	Luminosity (fb^{-1})	Final Variable	# Sub-Channels
$WH \to \ell\nu bb$, ST/DT, 2/3 jet	8.6	DTree discriminant	24
$ZH \to \nu\bar{\nu}b\bar{b}$, ST/DT	8.6	DTree discriminant	6
$ZH \to \ell\ell b\bar{b}$, ST/DT	8.6	DTree discriminant	30
$H \to W^+W^- \to \ell^\pm\nu\ell^\mp\nu$, 0/1/2+ jet	8.1	DTree discriminant	18
$H \to W^+W^- \to \ell\nu q\bar{q}$	5.4	DTree discriminant	4
$H+X \to \mu^\pm\tau^\mp_{had}+ \leq 1j$	7.3	NN discriminant	3
$H+X \to \ell^\pm\tau^\mp_{had}jj$	4.3	DTree discriminant	2
$VH \to \ell^\pm\ell^\pm+X$	5.3	DTree discriminant	6
$H \to \gamma\gamma$	8.2	DTree discriminant	1

Limit setting

Frequentist approach: modified CL_s

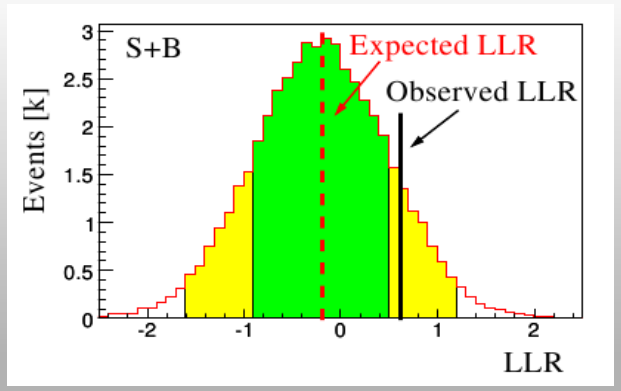
- generate ensemble of pseudo-experiments with Poisson statistics
  - **test 2 hypotheses:** background (B) and signal+background (S+B)
  - compute negative log likelihood ratio (LLR):

$L(B)$	$L(S+B)$	LLR
$\prod_i \frac{b_i^{d_i}\exp(b_i)}{d_i!}$	$\prod_i \frac{(s_i+b_i)^{d_i}\exp(s_i+b_i)}{d_i!}$	$2\cdot\sum_i s_i - d_i\cdot\log(1+s_i/b_i)$

where d_i events observed in bin i with S and B expectations s_i and b_i.

- systematics are introduced through nuisance parameters
  - constrained by data *(i.e profiling technique)*
- Confidence Levels (C.L.) are defined as the fraction of pseudo-experiments with LLR above the observed LLR
- **$CL_s = CL_{s+b}/CL_b$**

Exclude a signal cross section at **x%** C.L. with: **$CL_s = 1 - x$**



Systematics

2 types for background *and* signal

- **rate:** only affect absolute normalization, *e.g luminosity*
- **shape:** change differential distribution, *e.g due to jet energy scale corrections, MC modeling, b-tagging, ...*

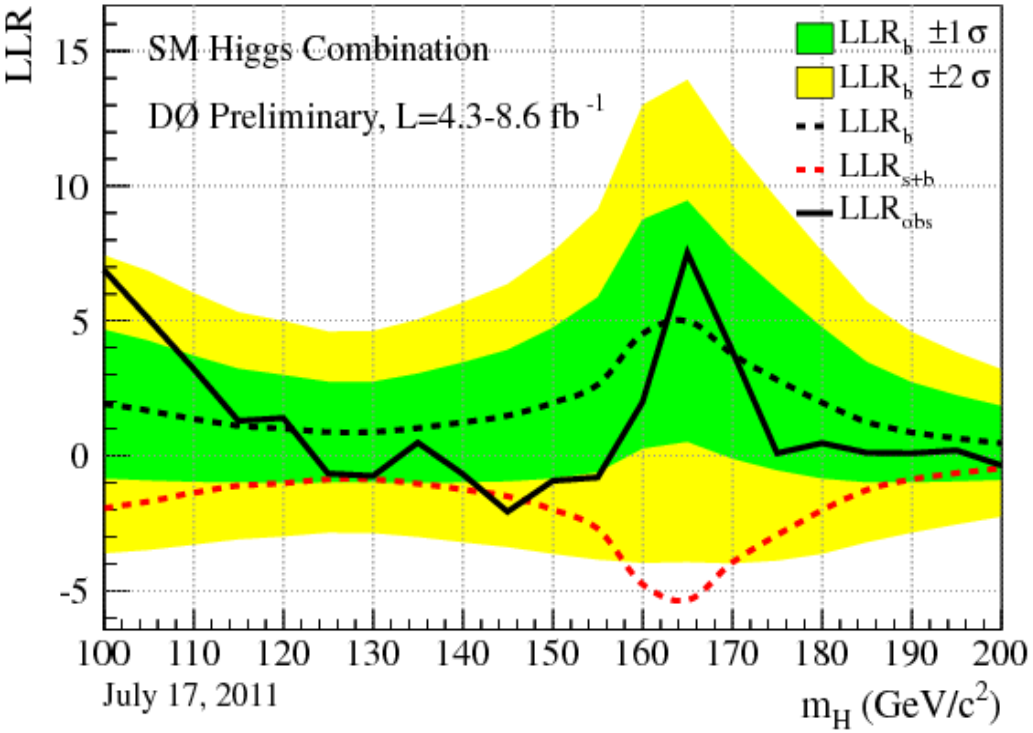
Sources

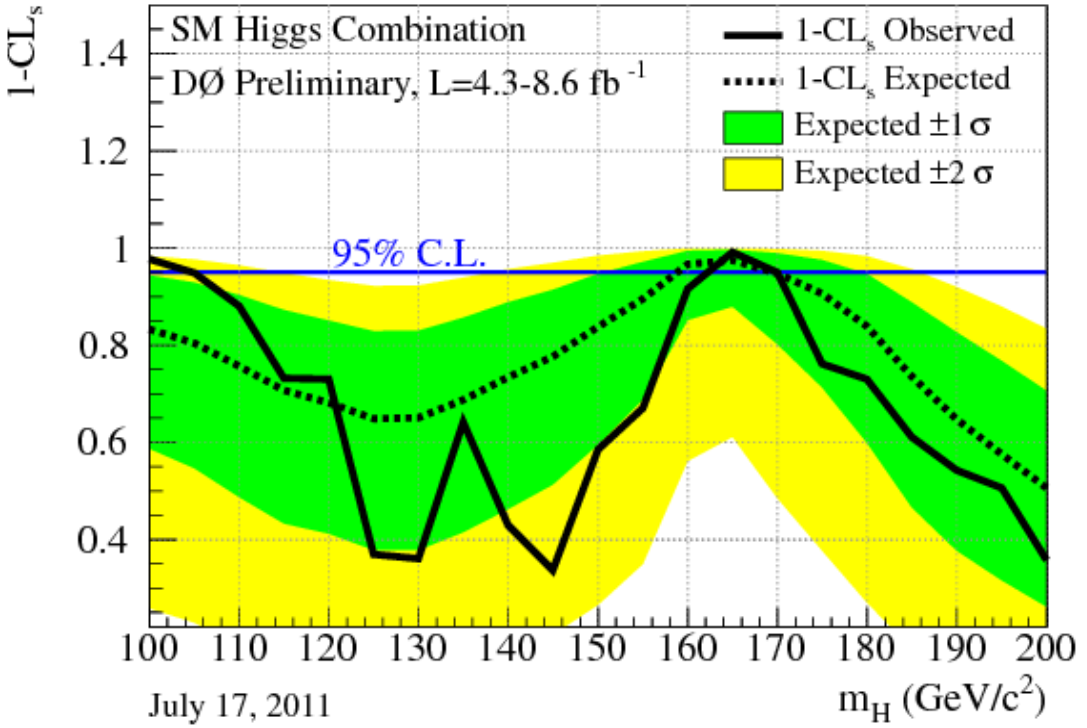
depend on the final state

● luminosity	~6%
● lepton identification	1-9%
● Jet-ID, Jet energy scale, FSR/ISR	~7%
● b-tagging	1-10%
● cross-sections	4-30%

See back-up slides for detailed low/high mass analyses examples + correlation tables

Results (I)



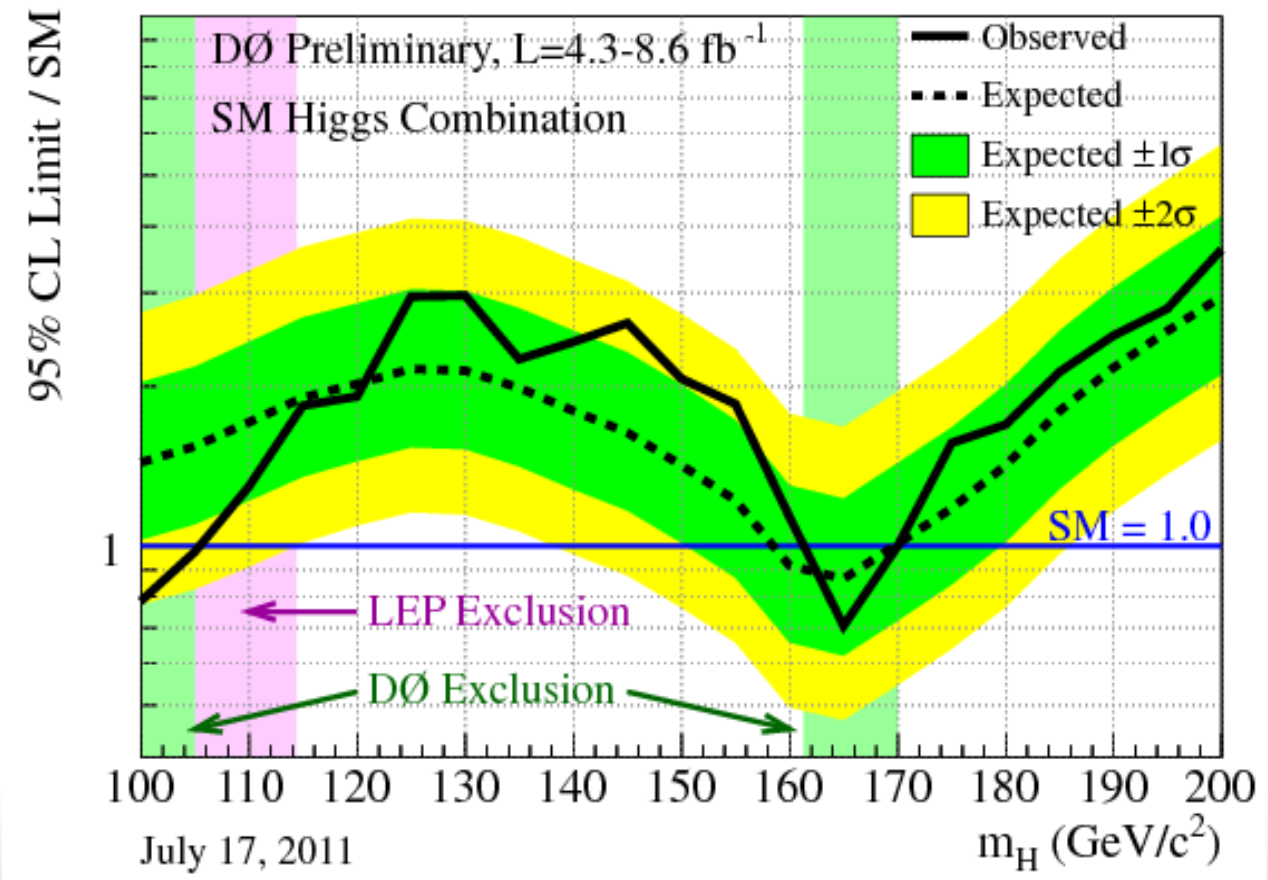


Sensitivity of Higgs search

- Separation between LLR$_b$ and LLR$_{s+b}$ translates to sensitivity of the analysis
- Maximum around ~165 GeV/c^2
- **Observation consistent with background only hypothesis**
  - **set exclusion limits at 95% CL**

Results (II)

95% C.L upper cross section limits as ratio to SM cross section



~25% improvements accross the whole mass range since last combination !

- **$162 < m_H < 170$ GeV** is excluded at 95% C.L *(expected: $159 < m_H < 169$ GeV)*
- **m_H(115 GeV): 2.05 *(1.90)* xSM, m_H(165 GeV): 0.71 *(0.87)* xSM**

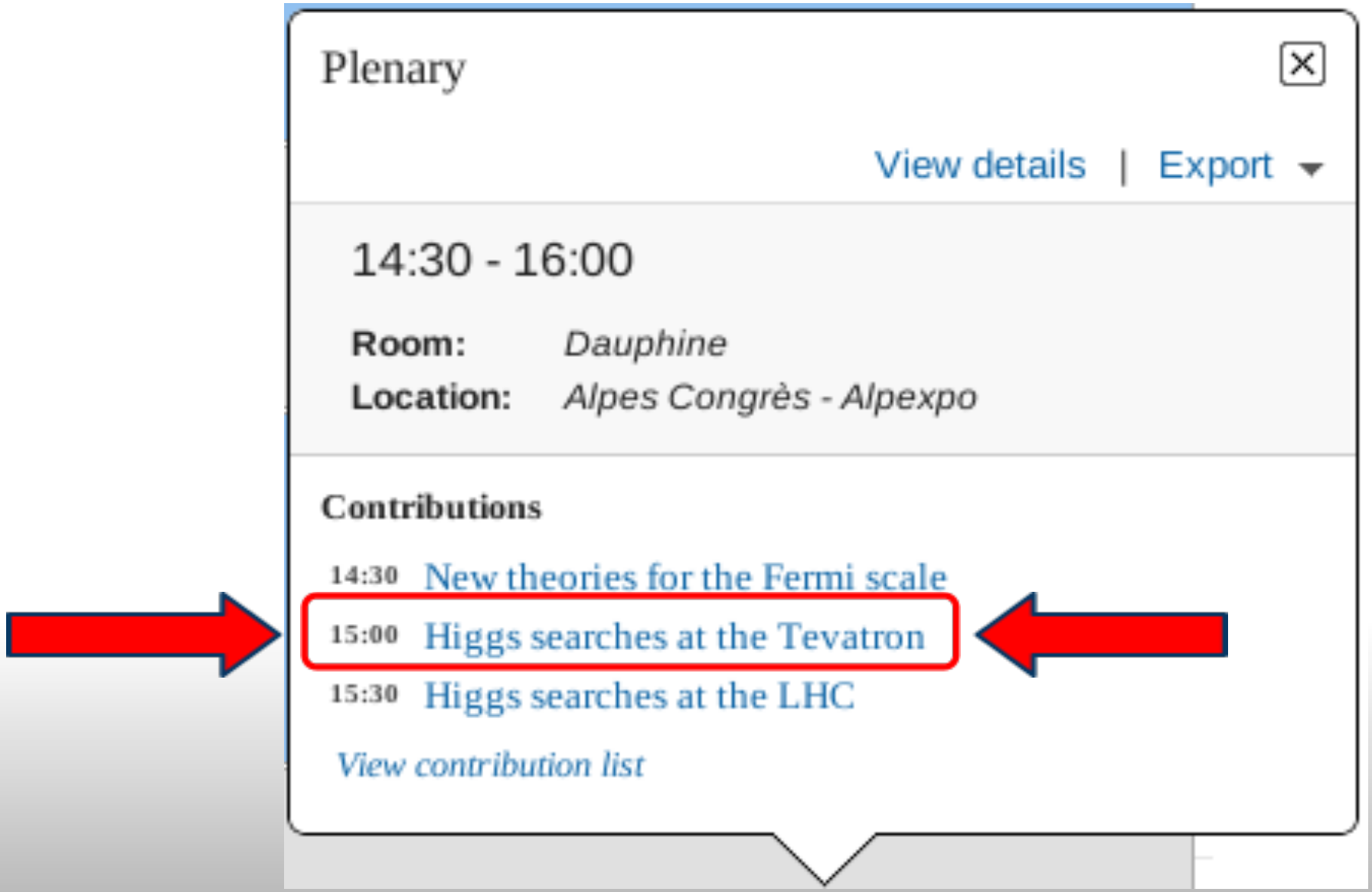
Summary

- Searches for SM Higgs boson production in pp collisions at $\sqrt{s}$ = 1.96 TeV were carried out for Higgs boson masses in the range $100 < m_H < 200$ GeV
  - no excess seen ...
  - exclude: **$162 < m_H < 170$ GeV at 95% C.L**
  - < ~2x SM *(expected)* accross whole mass range !
  - More: http://www-d0.fnal.gov/Run2Physics/WWW/results/higgs.htm

But ...

- More data to analyze *(>10fb^{-1} on tape)*
- **More analyses improvements in line**
- **Exciting times !**
- Stay tuned for future updates !

Conclusions / Outlooks



Back-up slides

Double Tag (DT) $WH \to \ell\nu b\bar{b}$ channel relative uncertainties (%)

Contribution	WZ/WW	Wbb/Wcc	Wjj/Wcj	$t\bar{t}$	single top	Multijet	WH
Luminosity	6.1	6.1	6.1	6.1	6.1	n/a	6.1
EM ID/Trigger eff. (S)	2–5	2–3	2–3	1–2	1–2	n/a	1–2
Muon Trigger eff. (S)	2–4	1–2	1–2	2–4	1–3	n/a	2–5
Muon ID/Reco eff./resol.	4.1	4.1	4.1	4.1	4.1	n/a	4.1
Jet ID/Reco eff. (S)	2–8	2–5	4–9	3–7	2–4	n/a	3–7
Jet Resolution (S)	4–7	2–7	2–7	2–9	2–4	n/a	4–6
Jet Energy Scale (S)	4–7	2–6	2–7	2–6	2–7	n/a	4–6
Vertex Conf. Jet (S)	4–10	5–12	4–10	7–10	5–10	n/a	4–6
b-tag/taggability (S)	3–7	4–6	3–10	5–10	4–10	n/a	4–9
Heavy-Flavor K-factor	n/a	20	n/a	n/a	n/a	n/a	n/a
Inst.-WH $e\nu b\bar{b}$ (S)	1–2	2–4	1–3	1–2	1–3	15	1–2
Inst.-WH $\mu\nu b\bar{b}$	n/a	2.4	2.4	n/a	n/a	20	n/a
Cross Section	6	9	9	10	10	n/a	6.1
Signal Branching Fraction							1-9
ALPGEN MLM pos/neg(S)	n/a	SH	n/a	n/a	n/a	n/a	n/a
ALPGEN Scale (S)	n/a	SH	SH	n/a	n/a	n/a	n/a
Underlying Event (S)	n/a	SH	n/a	n/a	n/a	n/a	n/a
PDF, reweighting	2	2	2	2	2	n/a	2

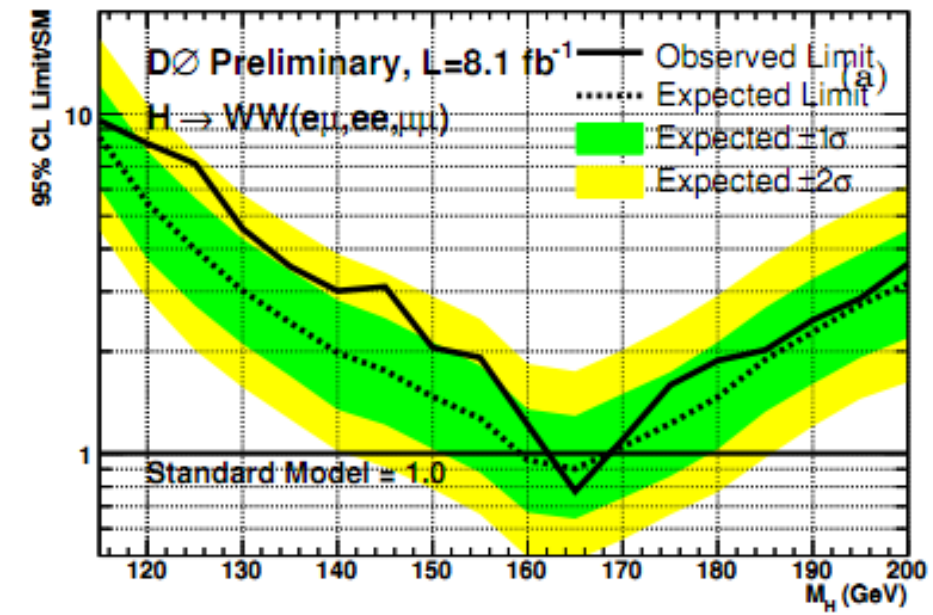
$H \to W^+W^- \to \ell^\pm\ell^\mp$ channels relative uncertainties (%)

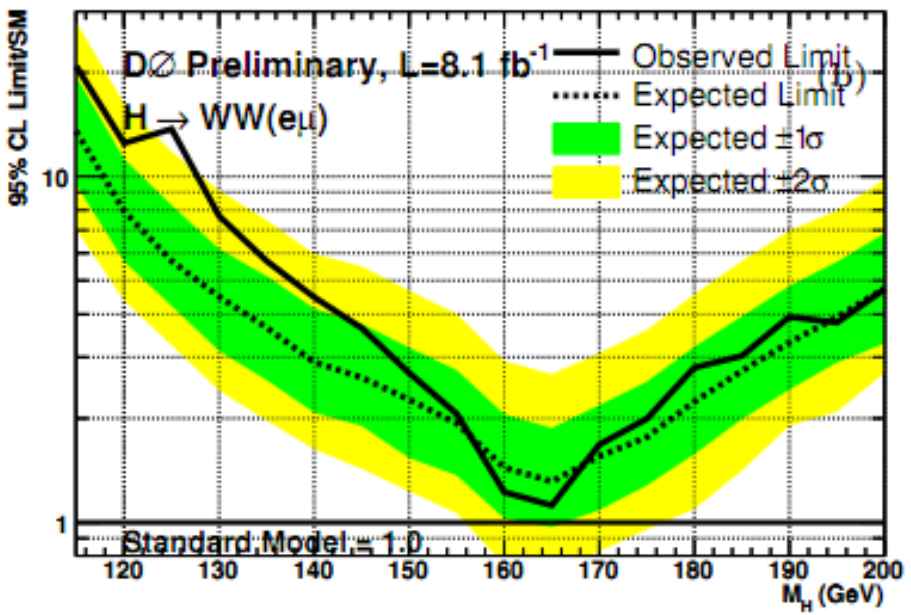
Contribution	Diboson	$Z/\gamma^* \to \ell\ell$	$W + jet/\gamma$	$t\bar{t}$	Multijet	$gg \to H$	$qq \to qqH$	VH
Luminosity/Normalization	6	6	6	6	30	6	6	6
Cross Section (Scale/PDF)	7-8	5	6	10	n/a	13-33/7.6-30	4.9	6.1
Signal Branching Fraction	N	n/a	n/a	n/a	n/a	0-7.3	0-7.3	0-7.3
PDF	2.5	2.5	2.5	2.5	n/a	8-30		
EM Identification	2.5	2.5	2.5	2.5	n/a	2.5		
Muon Identification	4	4	4	4	n/a	4		
Vertex Confirmation (s)	2-6	1-7	1-6	1-8	n/a	1-8		
Jet identification (s)	2-5	2-5	2-5	2-5	n/a	2-5		
Jet Energy Scale (s)	2-3	1-4	1-8	1-4	n/a	1-10		
Jet Energy Resolution(s)	1-4	1-4	1-12	1-3	n/a	1-12		
B-tagging	10	10	10	5	n/a	10		

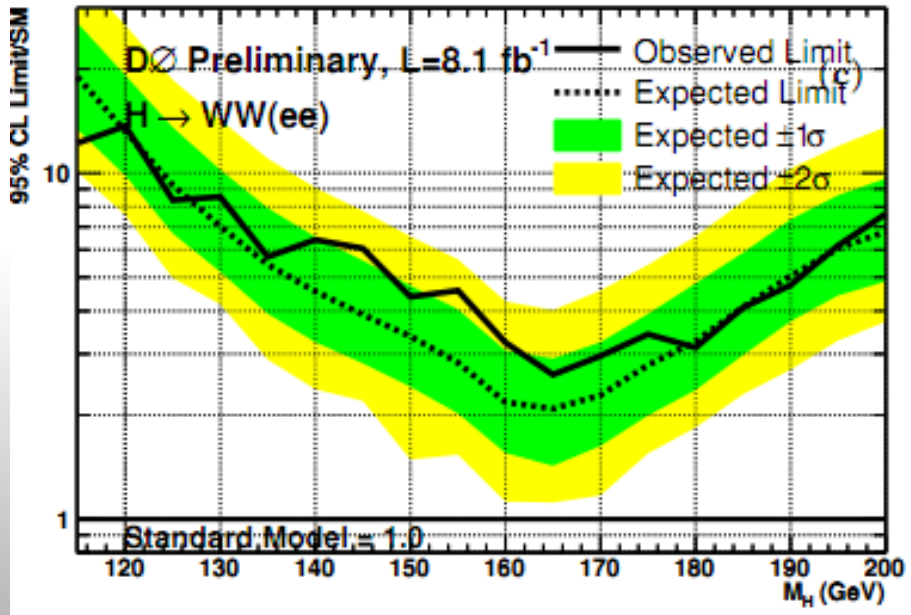
TABLE XII: The correlation matrix for the analysis channels. All uncertainties within a group are considered 100% correlated across channels. The correlated systematic uncertainty on the background cross section (σ) is itself subdivided according to the different background processes in each analysis.

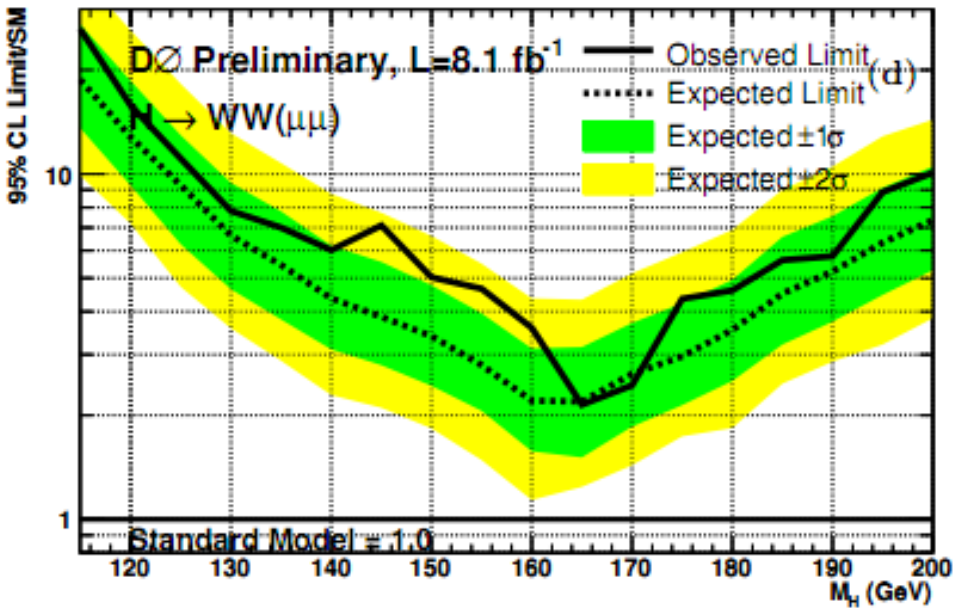
Source	$WH \to \ell\nu b\bar{b}$	$ZH \to \nu\bar{\nu}b\bar{b}$	$ZH \to \ell\ell b\bar{b}$	$H \to W^+W^- \to \ell^\pm\nu\ell^\mp\nu$
Luminosity	×	×	×	×
Normalization				
Jet Energy Scale	×	×	×	×
Jet ID	×	×	×	×
Tau Energy Scale/ID				
Electron ID/Trigger	×	×	×	×
Muon ID/Trigger	×	×	×	×
Photon ID/Trigger				
b-Jet Tagging	×	×	×	
Background σ	×	×	×	×
Background Modeling				
Multijet				
Signal σ				×
Signal modeling				×

Source	$H+X \to \mu^\pm\tau^\mp_{had} + \leq 1j$	$H+X \to \ell^\pm\tau^\mp_{had}jj$	$H \to W^+W^- \to \ell\nu jj$	$VH \to \ell^\pm\ell^\pm + X$	$H \to \gamma\gamma$
Luminosity	×	×	×		×
Normalization					
Jet Energy Scale	×	×	×	×	
Jet ID	×	×	×	×	
Tau Energy Scale/ID	×	×			
Electron ID/Trigger	×	×	×	×	
Muon ID/Trigger	×	×	×	×	
Photon ID/Trigger					×
b-Jet Tagging					
Background σ	×	×	×	×	
Background Modeling					
Multijet					
Signal σ	×	×	×	×	×
Signal modeling	×	×	×	×	×


DØ Preliminary, L=8.1 fb-1
H → WW(eμ,ee,μμ)
Observed Limit
Expected Limit
Expected ±1σ
Expected ±2σ
(a)
Standard Model = 1.0
95% CL Limit/SM
MH (GeV)


DØ Preliminary, L=8.1 fb-1
H → WW(eμ)
Observed Limit
Expected Limit
Expected ±1σ
Expected ±2σ
(b)
Standard Model = 1.0
95% CL Limit/SM
MH (GeV)

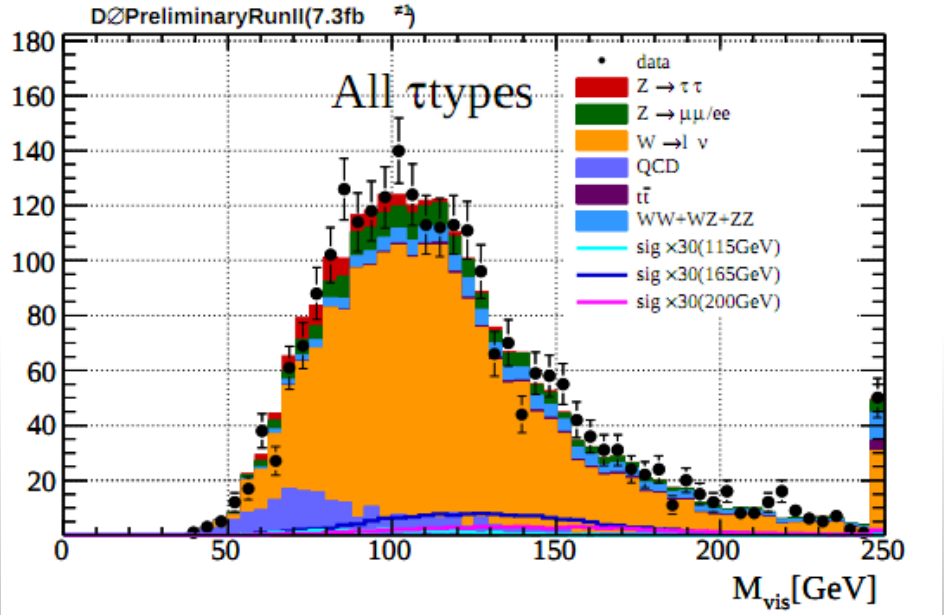

DØ Preliminary, L=8.1 fb-1
H → WW(ee)
Observed Limit
Expected Limit
Expected ±1σ
Expected ±2σ
(c)
Standard Model = 1.0
95% CL Limit/SM
MH (GeV)

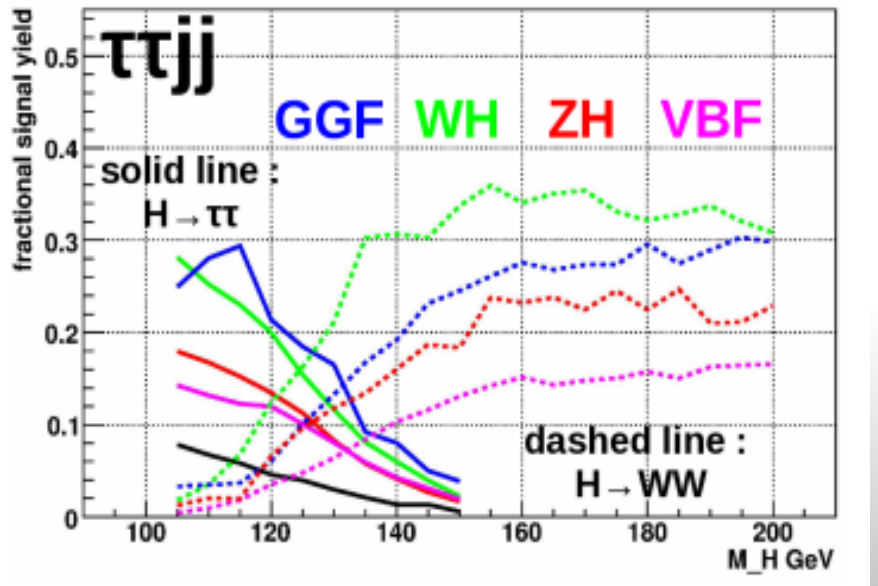

DØ Preliminary, L=8.1 fb-1
H → WW(μμ)
Observed Limit
Expected Limit
Expected ±1σ
Expected ±2σ
(d)
Standard Model = 1.0
95% CL Limit/SM
MH (GeV)

High mass final states with taus

Exclusive analysis according to the number of reconstructed jets

- ℓ + τ + 0, 1 jet (ℓ = μ only) mainly sensitive to H → WW → ℓνττν
- τℓ + τ+ ≥ 2 jets allows to benefit from ⇒ H → $\tau\ \tau$ decay at low mass ⇒ several production modes providing a flat sensitivty over the whole range mass





Tabulated limits

m_H	100	105	110	115	120	125	130	135	140	145	150	155	160	165	170	175	180	185	190	195	200
Expected:	1.43	1.54	1.71	1.90	2.02	2.15	2.14	1.98	1.79	1.63	1.42	1.22	0.92	0.87	1.01	1.18	1.42	1.79	2.17	2.55	2.95
Observed:	0.88	1.09	1.45	2.05	2.14	3.29	3.32	2.51	2.71	2.94	2.06	1.85	1.13	0.71	1.00	1.56	1.69	2.13	2.49	3.49	3.61