

# Higgs Review for PDG

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## HIGGS BOSONS: THEORY AND SEARCHES

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**Introduction**

**The Standard Model Higgs Boson**

**Higgs Bosons in the MSSM**

**Charged Higgs Bosons**

**Other Model Extensions**

**Other Searches for Higgs Bosons Beyond the SM**

**Outlook**

Previous review by P. Igo-Kemenes, 10/2005

# Higgs Review for PDG

## Introduction

### The Standard Model Higgs Boson

Searches for the SM Higgs Boson at LEP

Indirect Constraints on the SM Higgs Boson

Searches for the SM Higgs Boson at the Tevatron

Prospects for SM Higgs Boson Searches at the LHC

### Higgs Bosons in the MSSM

Radiative Corrections to MSSM Higgs Masses and Couplings

Decay Properties of MSSM Higgs Bosons

Searches for Neutral Higgs Bosons (CPC Scenario)

Searches for Neutral MSSM Higgs Bosons at Hadron Colliders

Effects of CP Violation on the MSSM Higgs Spectrum

Searches for Neutral Higgs Bosons in CPV Scenarios

Indirect Constraints from Electroweak and B-physics

Observables and Dark Matter Searches

### Charged Higgs Bosons

Doubly-Charged Higgs Bosons

### Other Model Extensions

### Other Searches for Higgs Bosons Beyond the SM

Outlook

# Higgs Bosons in the MSSM

## Searches for Neutral MSSM Higgs Bosons at Hadron Colliders

2007 review

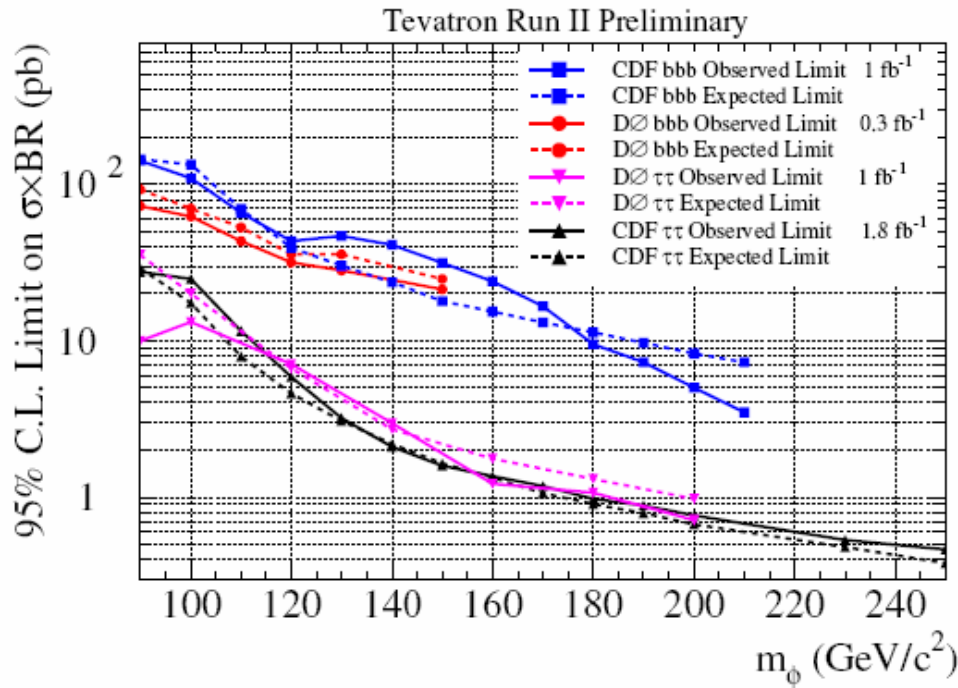
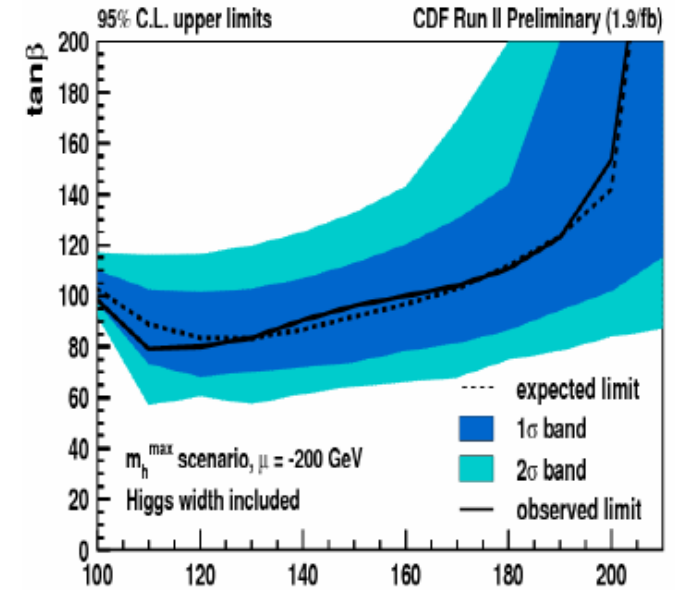
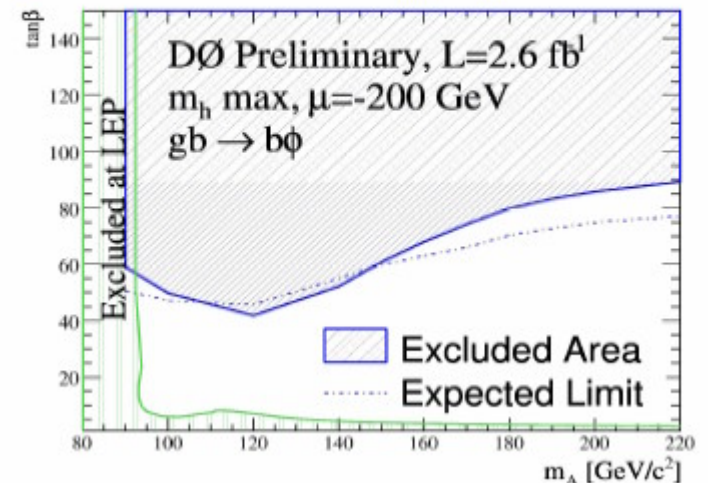


Figure 8: The 95% C.L. limits on the production cross section times the relevant decay branching ratios for the Tevatron searches for  $\phi \rightarrow b\bar{b}$  and  $\phi \rightarrow \tau^+\tau^-$ . The observed limits are indicated with solid lines, and the expected limits are indicated with dashed lines. The limits are to be compared with the sum of signal predictions for Higgs boson with similar masses.

Now



Results start to exclude interesting region  $\tan(\beta) \sim 40 \sim M_{\text{top}}/M_b$



# Higgs Bosons in the MSSM

## Searches for Neutral MSSM Higgs Bosons at Hadron Colliders

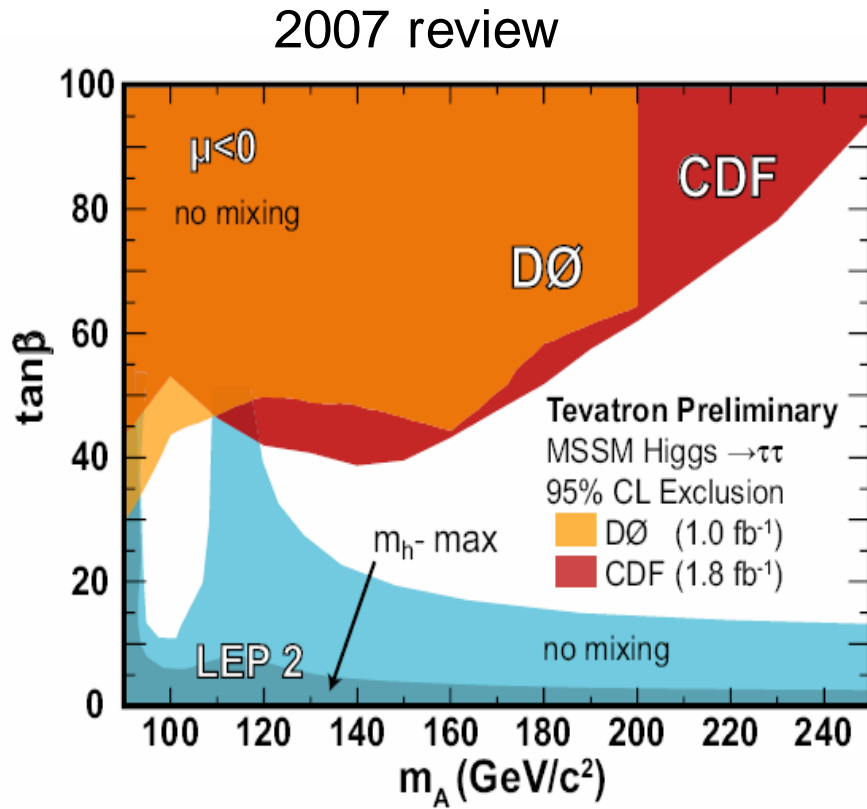
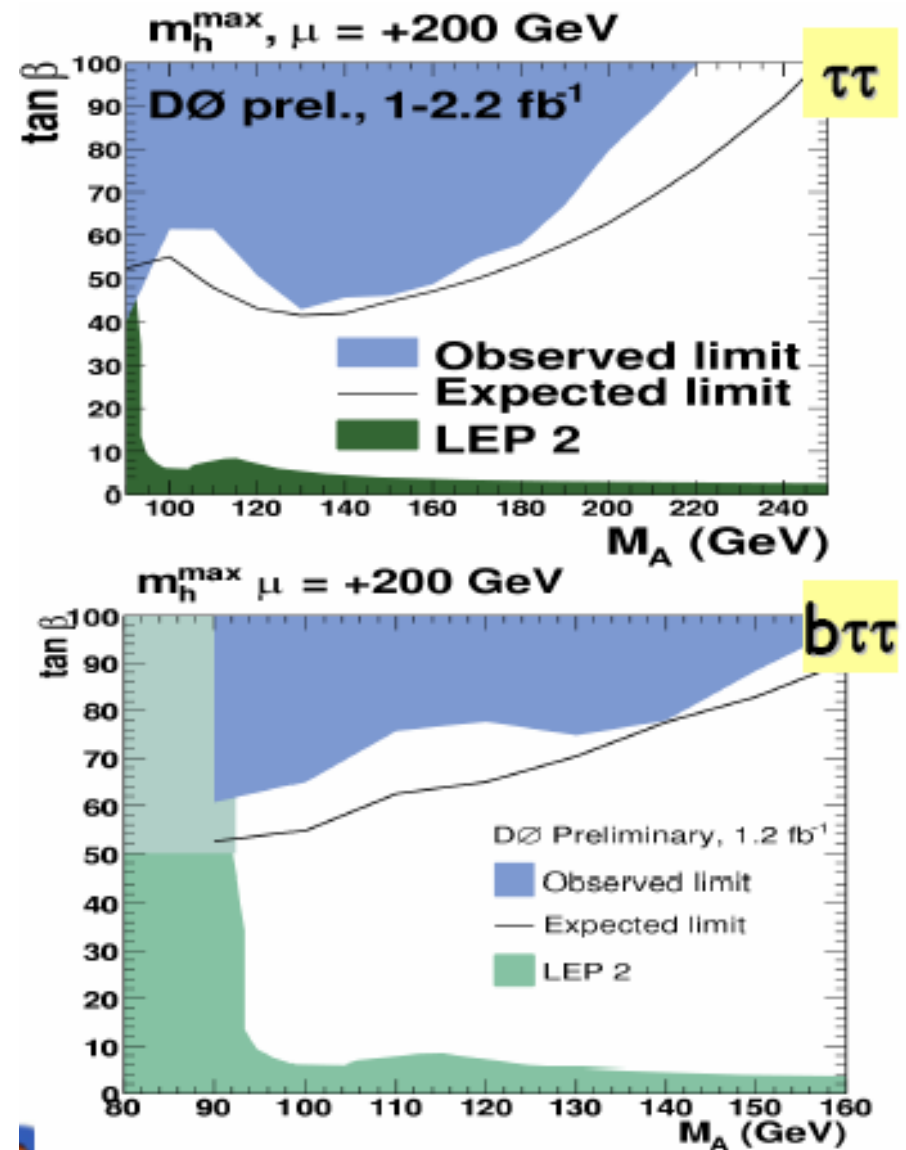


Figure 9: The 95% C.L. MSSM exclusion contours obtained by CDF and DØ in the  $H \rightarrow \tau^+\tau^-$  searches in the *no-mixing* benchmark scenario with  $\mu = -200$  GeV, projected onto the  $(m_A, \tan\beta)$  plane [118,119]. The Tevatron lim-

Now

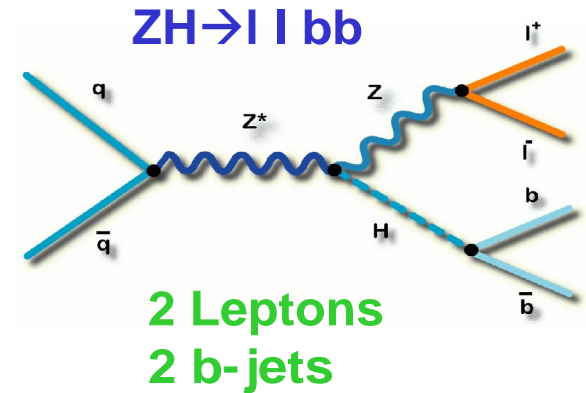
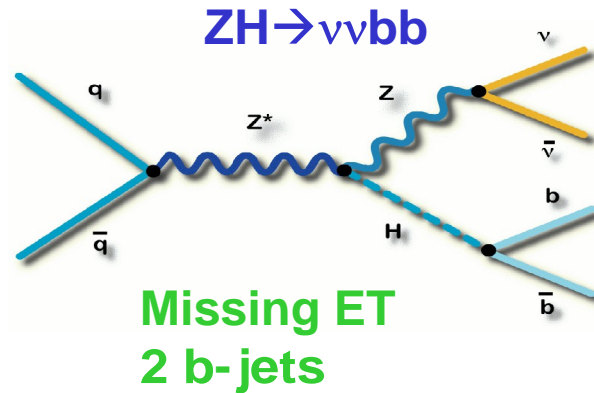
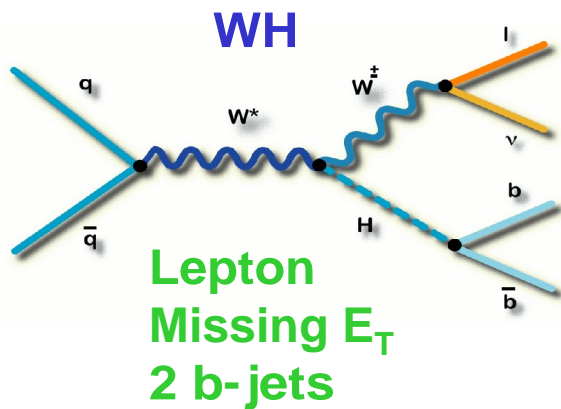


# The Standard Model Higgs Boson

Searches for the SM Higgs Boson at the Tevatron

Prospects for SM Higgs Boson Searches at the LHC ??

Publications on single channels are now being published with significant Luminosity, and it will continue  $\rightarrow 8 \text{ fb}^{-1}$ . They were described in a terse way in 2007 review



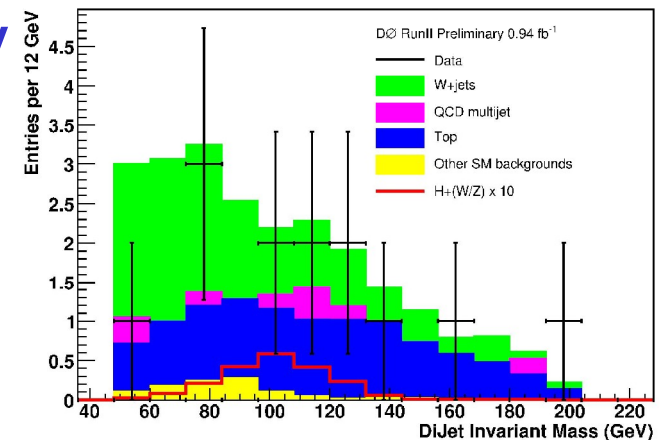
	CDF	DØ
Prel:	2.7 $\text{fb}^{-1}$	1.7 $\text{fb}^{-1}$
Pub:	1.0 $\text{fb}^{-1}$	1.1 $\text{fb}^{-1}$

	CDF	DØ
Prel:	2.7 $\text{fb}^{-1}$	2.1 $\text{fb}^{-1}$
Pub:	1.0 $\text{fb}^{-1}$	0.4 $\text{fb}^{-1}$

	CDF	DØ
Prel:	1.0 $\text{fb}^{-1}$	1.1 $\text{fb}^{-1}$
Pub:	1.0 $\text{fb}^{-1}$	0.4 $\text{fb}^{-1}$

# New SM Higgs Searches not in the review

- CDF and DØ are performing searches in every viable mode
  - CDF/DØ:  $WH \rightarrow WWW$ : same sign leptons
    - Adds sensitivity at high and middle masses
    - Also Fermiophobic Higgs search
  - CDF:  $VH \rightarrow qqbb$ : 4 Jet mode.
  - CDF:  $H \rightarrow \tau\tau$  with 2jets
    - Simultaneous search for Higgs in VH, VBF and  $gg \rightarrow H$  production modes
    - Interesting benchmark for LHC
  - DØ:  $H \rightarrow \gamma\gamma$ 
    - Also model independent and fermiophobic search
  - DØ:  $WH \rightarrow \tau\nu bb$ , new mode
    - Dedicated search with hadronic  $\tau$  decays
  - DØ:  $ttH$ , new mode



Analysis: Limits at 160 and 115GeV	Exp. Limit	obs. Limit
CDF $WH \rightarrow WWW$	33	31
DØ $WH \rightarrow WWW$	20	26
CDF $VH \rightarrow qqbb$	37	37
CDF $H \rightarrow \tau\tau$	25	31
DØ $WH \rightarrow \tau\nu bb$	42	35
DØ $H \rightarrow \gamma\gamma$	23	31
DØ $ttH$	45	64

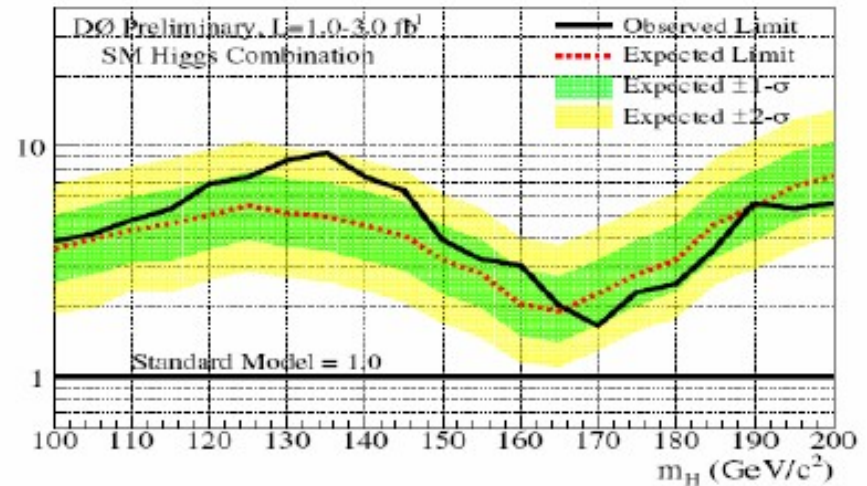
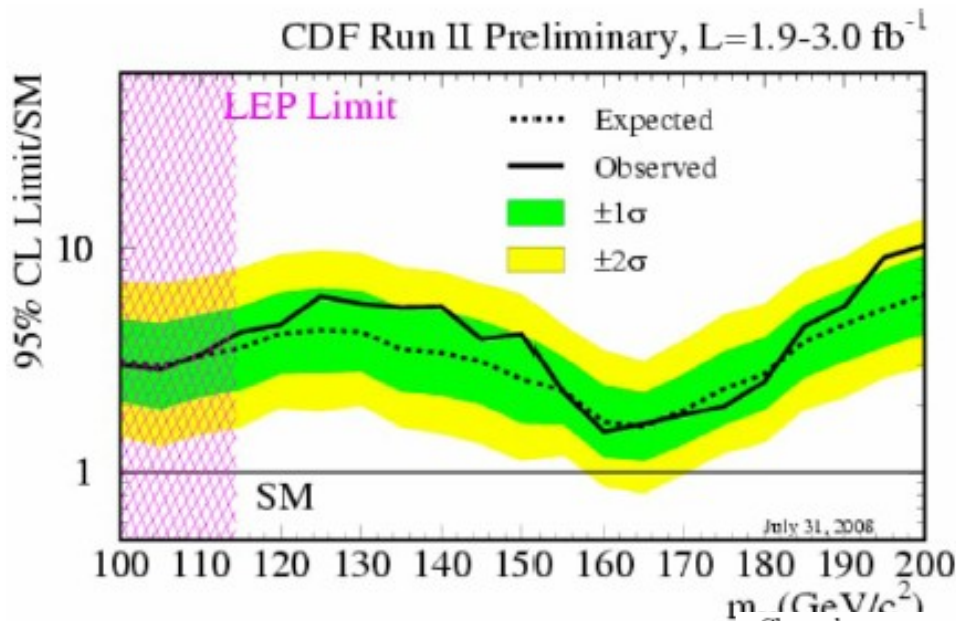




# Combinations per experiment



Each experiment is becoming sensitive at high mass, at low mass still some way to go



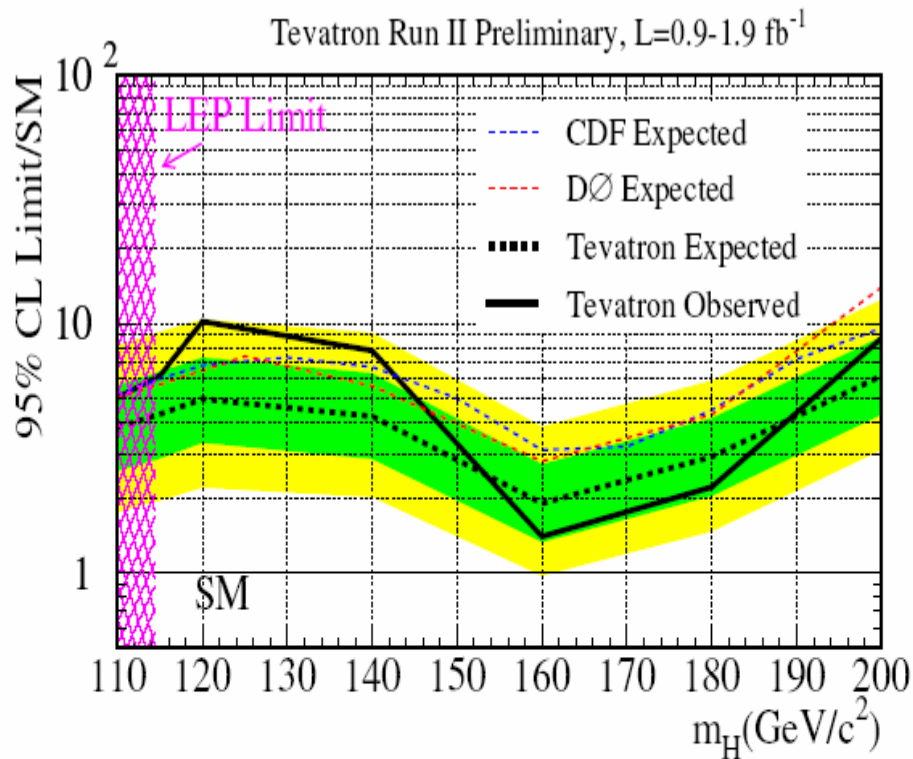
Channel	Data Epoch	Luminosity (fb <sup>-1</sup> )	Final Variable
$WH \rightarrow c\bar{b}b$ , ST/DT, W + 2 jet	Run IIa	1.1	NN discriminant
$WH \rightarrow c\bar{b}b$ , ST/DT, W + 3 jet	Run IIa	1.1	Dijet Mass
$WH \rightarrow c\bar{b}b$ , ST/DT, W + 2 jet	Run IIb	0.6	NN discriminant
$WH \rightarrow \mu\nu\bar{b}b$ , ST/DT, W + 2 jet	Run IIa	1.1	NN discriminant
$WH \rightarrow \mu\nu\bar{b}b$ , ST/DT, W + 3 jet	Run IIa	1.1	Dijet Mass
$WH \rightarrow \mu\nu\bar{b}b$ , ST/DT, W + 2 jet	Run IIb	0.6	NN discriminant
$WH \rightarrow f\nu\bar{b}b$ , DT	Run IIa	0.9	DTree discriminant
$WH \rightarrow f\nu\bar{b}b$ , DT	Run IIb	1.2	DTree discriminant
$ZH \rightarrow \nu\bar{\nu}b\bar{b}$ , DT	Run IIa	0.9	DTree discriminant
$ZH \rightarrow \nu\bar{\nu}b\bar{b}$ , DT	Run IIb	1.2	DTree discriminant
$ZH \rightarrow e^+e^-b\bar{b}$ , ST/DT	Run IIa	1.1	NN discriminant
$ZH \rightarrow \mu^+\mu^-b\bar{b}$ , ST/DT	Run IIa	1.1	NN discriminant
$ZH \rightarrow e^+e^-b\bar{b}$ , ST/DT	Run IIb	1.2	NN discriminant
$ZH \rightarrow \mu^+\mu^-b\bar{b}$ , ST/DT	Run IIb	1.2	DTree discriminant
$WH \rightarrow WW^+W^- (\mu^\pm\mu^\pm)$	Run IIa	1.1	2-D Likelihood
$WH \rightarrow WW^+W^- (e^\pm\mu^\pm)$	Run IIa	1.1	2-D Likelihood
$WH \rightarrow WW^+W^- (e^\pm e^\pm)$	Run IIa	1.1	2-D Likelihood
$H \rightarrow W^+W^- (\mu^+\mu^-)$	Run IIa+Run IIb	3.0	NN discriminant
$H \rightarrow W^+W^- (e^\pm\mu^\mp)$	Run IIa+Run IIb	3.0	NN discriminant
$H \rightarrow W^+W^- (e^+e^-)$	Run IIa+Run IIb	3.0	NN discriminant
$H \rightarrow \gamma\gamma$	Run IIa+Run IIb	2.7	Di-photon Invariant Mass



# Tevatron Combination



2007 review



April 2008

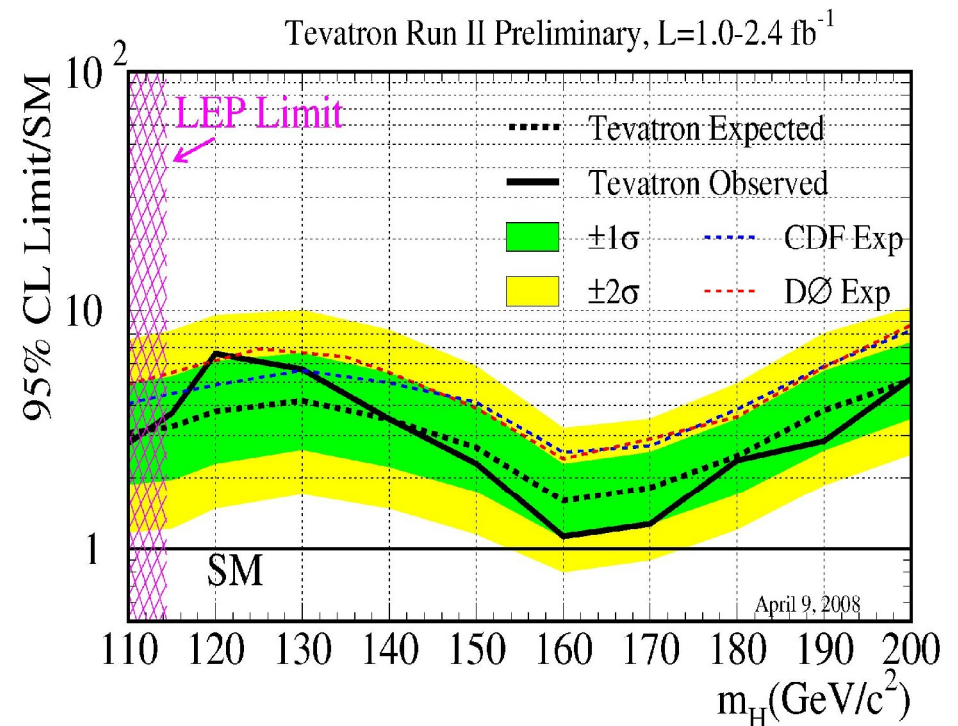


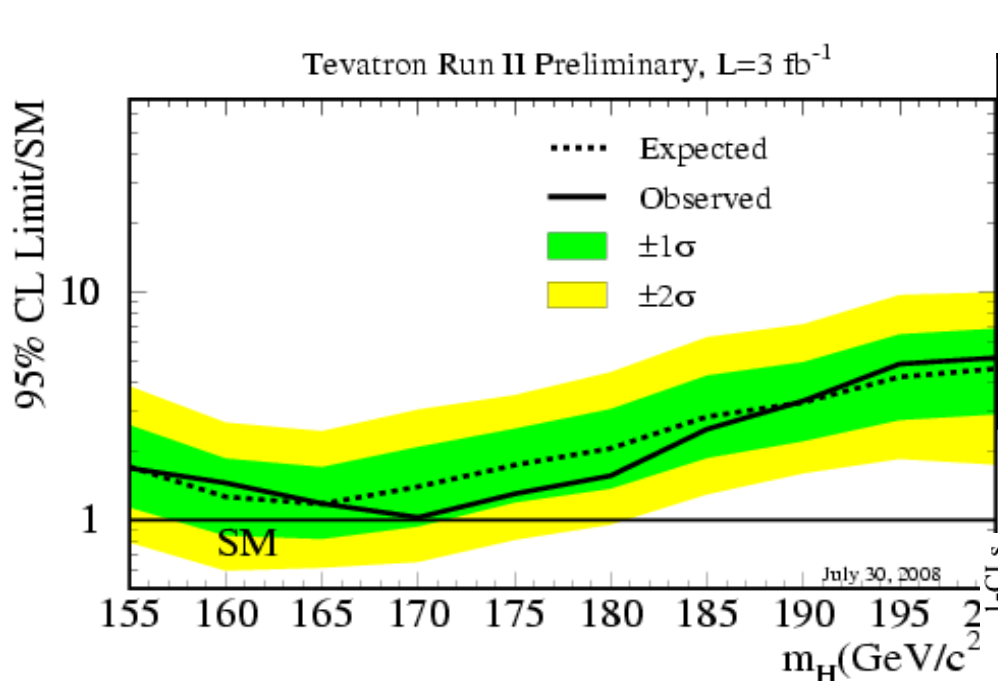
Figure 6: Upper bound on the SM Higgs boson cross section obtained by combining CDF and DØ search results, as a function of the mass of the Higgs boson sought. The limits are shown as a multiple of the SM cross section. The ratios of different production and decay modes are assumed to be as predicted by the SM. The

July 2008,  
next page...





# SM Higgs Combination at High Mass



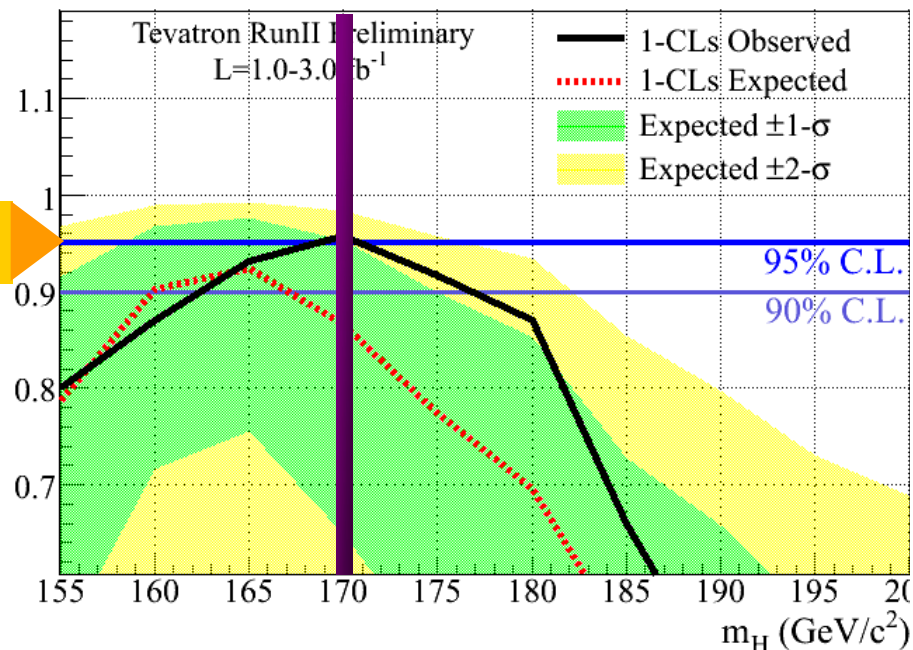
95%CL Limits/SM

M Higgs(GeV)	160	165	170	175
Method 1: Exp	1.3	1.2	1.4	1.7
Method 1: Obs	1.4	1.2	1.0	1.3
Method 2: Exp	1.2	1.1	1.3	1.7
Method 2: Obs	1.3	1.1	0.95	1.2

**SM Higgs Excluded:  $m_H = 170 \text{ GeV} @ 95\% \text{CL}$**

Expect large exclusion, or evidence, with full Tevatron data set and improvements

→ variation of exclusion on a 6 months time scale, evidence on a yearly time-scale?



# Conclusions for Higgs review

**Significant update was done for the 2007-2008 version (beyond new experimental results, theory section was also updated (little Higgs, Extra D...), relation to cosmology,)**

**Tevatron data are being taken at high rate, and CDF and D0 have a major fraction of their analysis effort now on Higgs → many new results coming in regularly, with combinations updated in a timely fashion by the TeV-NP-Higgs working group.**

**(SUSY Higgs combination being prepared for Moriond 08)**

**2009-2010 version will still be strongly focused on Tevatron results, with hopefully some very first Higgs results from LHC (limits at that stage)**

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