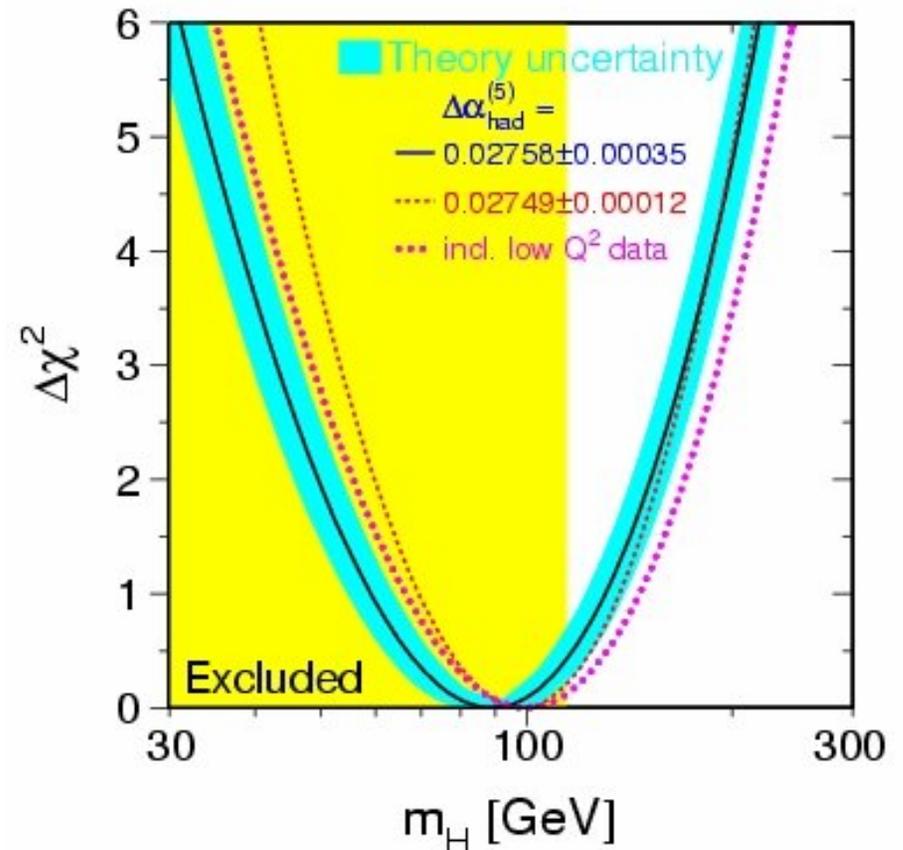


Searches for Standard Model Higgs Boson at the DØ Detector at the Tevatron

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SUSY '06

The Higgs Boson

- **Higgs:** origin of the EW symmetry breaking in SM
- **Higgs mass:** not predicted by theory, but constrained by experiment:
 - Direct searches at LEP II:
 $M_H > 114.4 \text{ GeV @ 95\% CL}$
 - EW data indirect constraint:
 $M_H < 175 \text{ GeV @ 95\% CL}$
($< 207 \text{ GeV}$ including direct LEP II limit)



Searching for SM Higgs at Tevatron

Strategy:

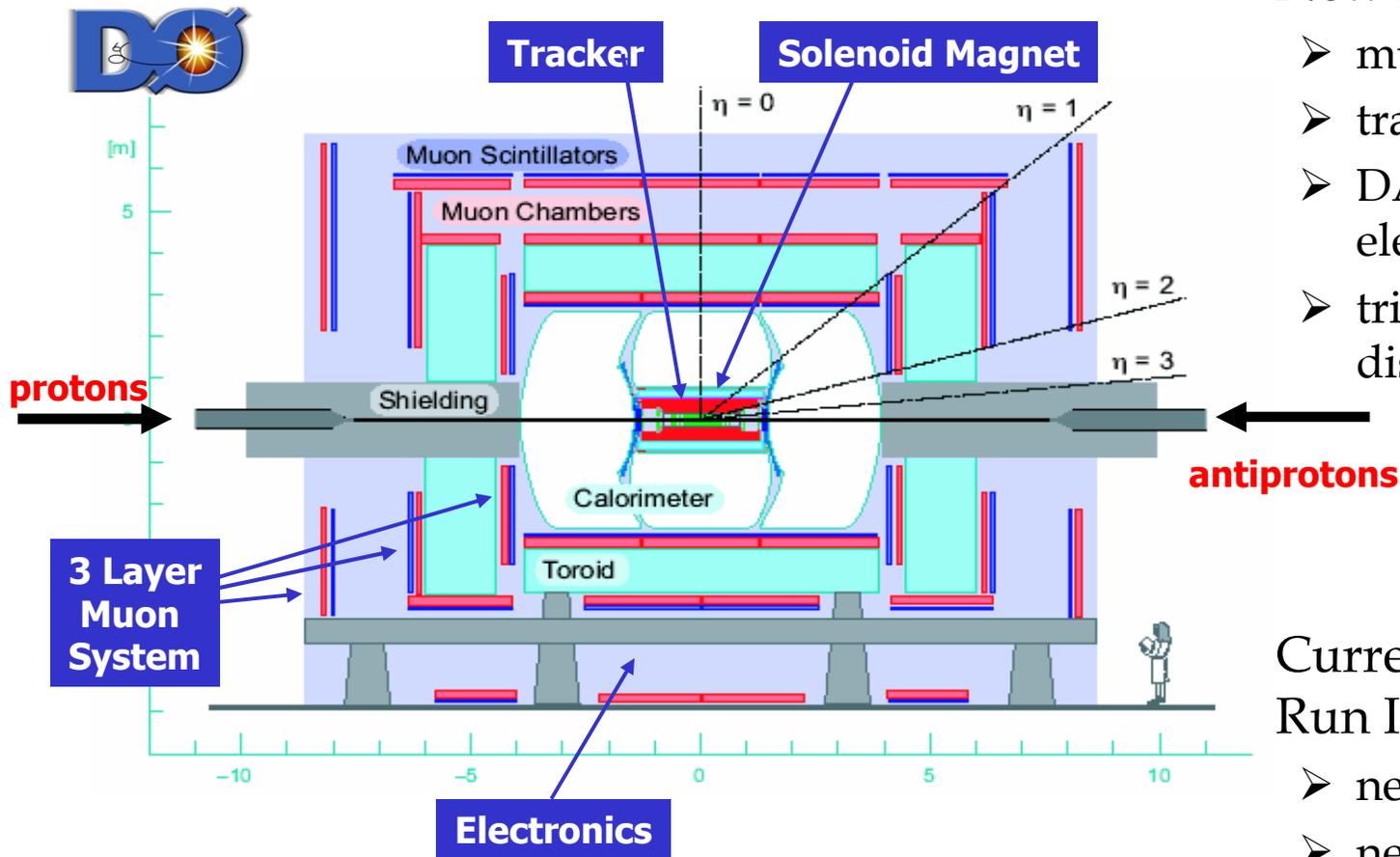
- low mass ($M_H < 135$ GeV)
 - Dominant decay: $H \rightarrow bb$
 - Direct production $gg \rightarrow H \rightarrow bb$?
Too much background...
 - Search for associated production $qq \rightarrow W/Z + H$
- high mass ($M_H > 135$ GeV)
 - Dominant decay: $H \rightarrow WW^*$
 - Look at both direct and associated production

Channels in this talk:

- Low mass region:
 - $WH \rightarrow l\nu bb$
 - $ZH \rightarrow \nu\nu bb$ (+ $WH \rightarrow l\nu bb$)
- High mass region:
 - $H \rightarrow WW^* \rightarrow l\nu l'\nu'$
 - $WH \rightarrow WW^* \rightarrow l^{\pm\nu} l'^{\pm\nu'} + X$
- For the first time, $D\emptyset$ has all principal channels covered and put together

More modes (ttH/bbH , vector boson fusion) – starting...

DØ detector: upgraded for Run II



➤ New in Run II:

- muons up to $|\eta| < 2$
- tracking in B-field
- DAQ and CAL electronics upgrades
- triggers on tracks and displaced vertices

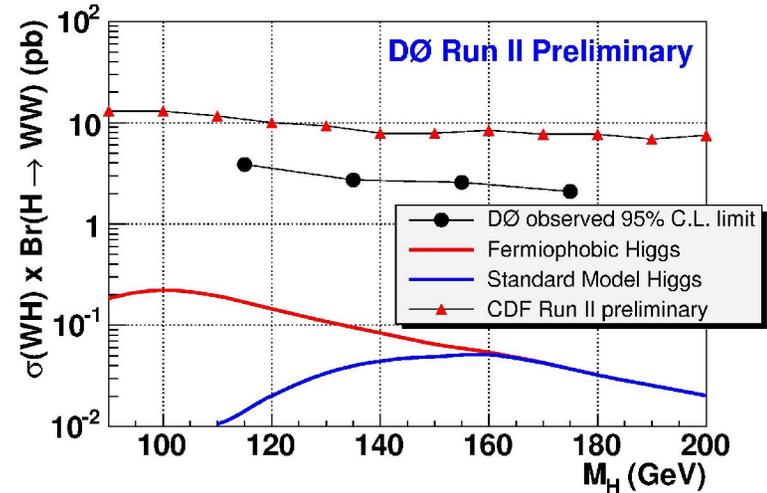
Currently upgrading to Run IIb:

- new L1 calo trigger
- new Silicon Layer 0

$WH \rightarrow WW^* \rightarrow l^\pm \nu l'^\pm \nu' + X$

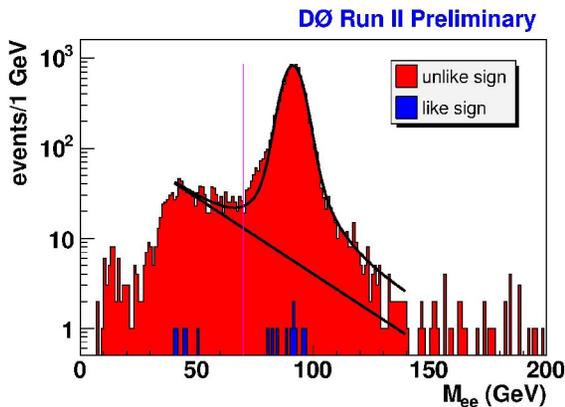
$L = 370 \text{ pb}^{-1}$

- Selection:
 - dilepton triggers
 - $p_T > 15 \text{ GeV}$
 - $|\eta| < 1.1$ (e) / 2 (μ)
 - missing $E_T > 20 \text{ GeV}$
 - same sign lepton pairs
- Backgrounds:
 - physical: WZ/ZZ
 - instrumental: charge flips, QCD (det. on data)



Results:

- at $M_H = 155 \text{ GeV}$:
 - $\epsilon_{\text{eff}} \times \text{Br} = 0.12\%$ (ee), 0.28% (e μ), 0.20% ($\mu\mu$)
- 95% CL limit : 2.1-3.9pb

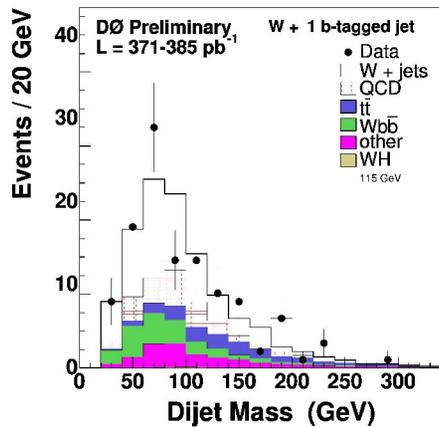
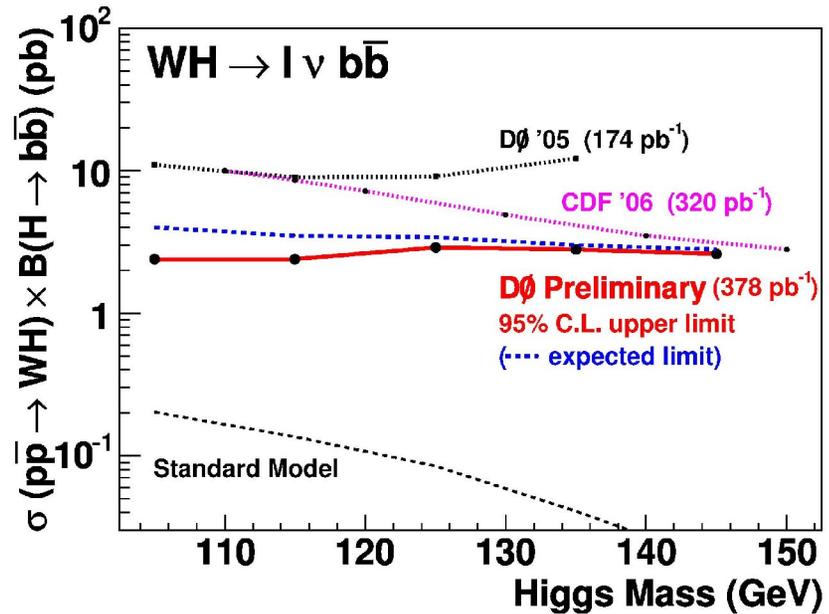


events	ee	e μ	$\mu\mu$
expected	0.7 ± 0.1	4.3 ± 0.2	3.7 ± 0.8
observed	1	3	2

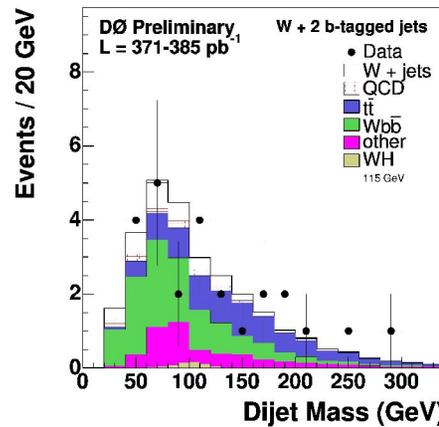
WH \rightarrow l ν bb (l=e, μ)

L = 380 pb⁻¹

- Selection:
 - lepton triggers
 - e/ μ : p_T > 20 GeV, | η | < 1.1(e) / 2(μ)
 - missing E_T > 25 GeV
 - 2 jets p_T > 20 GeV, | η | < 2.5
 - single or double b-tagging
- Backgrounds:
 - Wbb, Wjj
 - tt, VV, single top
 - instrumental (multi-jets)



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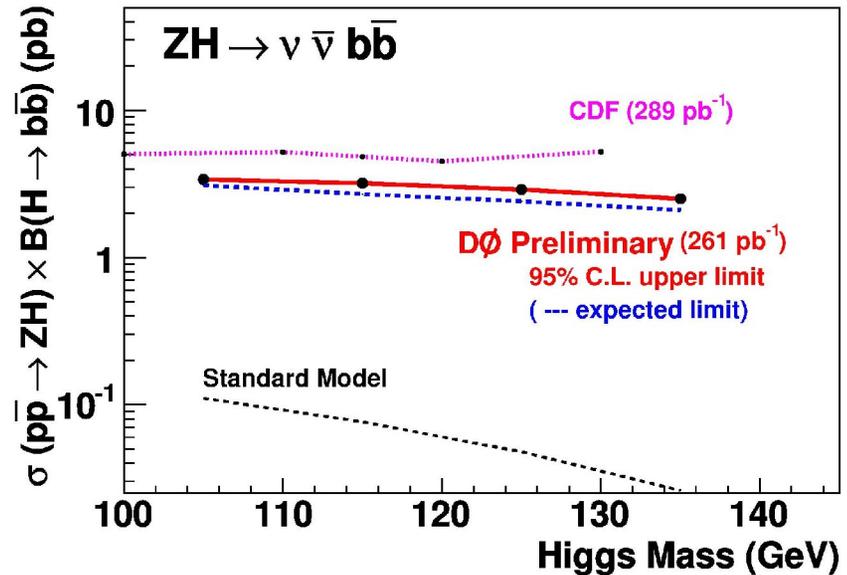
Results:

- at M_H = 115 GeV:
 - single tag: expect 45.1 events, observe 32 events
 - double tag: expect 9.3 events, observe 6 events
- 95% CL limit : 2.4–2.9 pb

ZH \rightarrow $\nu\nu$ bb (+WH \rightarrow $\ell\nu$ bb)

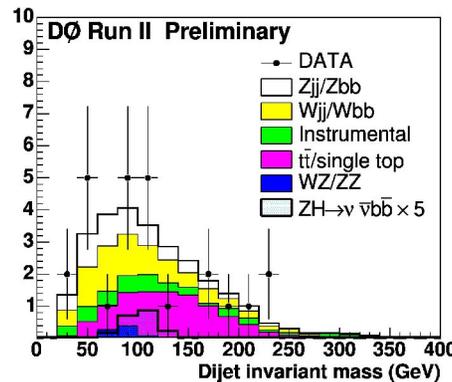
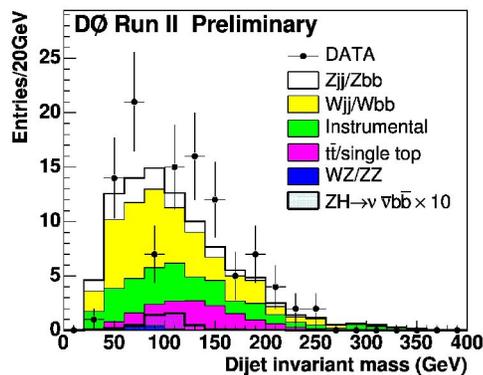
$L = 260 \text{ pb}^{-1}$

- Selection:
 - dedicated jets+missing E_T trigger
 - 2-3 jets $p_T > 20 \text{ GeV}$, $|\eta| < 2.5$
 - missing $E_T > 50 \text{ GeV}$
 - $\Delta\phi(jj) < 165^\circ$, topology
- Backgrounds:
 - W/Z + jets, tt, VV
 - instrumental (multijets)



Results:

- at $M_H = 115 \text{ GeV}$:
 - single tag: expect 34 ± 6 events, observe 33 events
 - double tag: expect 9 ± 2 events, observe 11 events
- 95% CL limit :
 - 2.5–3.4 pb (ZH \rightarrow $\nu\nu$ bb)
 - 6.3–8.3 pb (WH \rightarrow $\ell\nu$ bb)



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8

Combined SM Higgs search

➤ Channels: 14

- $WH \rightarrow (e/\mu/\tau)\nu + bb$
 - single tag (3 channels)
 - double tag (3 channels)
- $ZH \rightarrow \nu\nu$
 - single tag (1 channel)
 - double tag (1 channel)
- $H \rightarrow WW^*$
 - $ee, e\mu, \mu\mu$ (3 channels)
- $WH \rightarrow WWW^*$
 - $ee, e\mu, \mu\mu$ (3 channels)

➤ Method: CL_S (LEP)

$$CL_S = CL_{S+B} / CL_B$$

\int signal + background hypothesis \int background only hypothesis

test statistics: log-likelihood ratio

$$LLR = -2 \ln Q$$

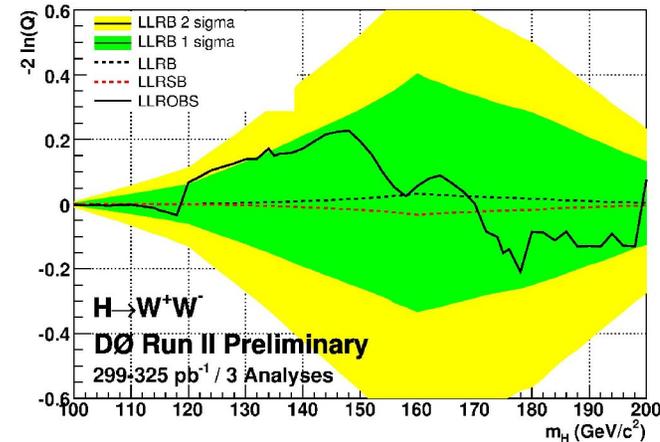
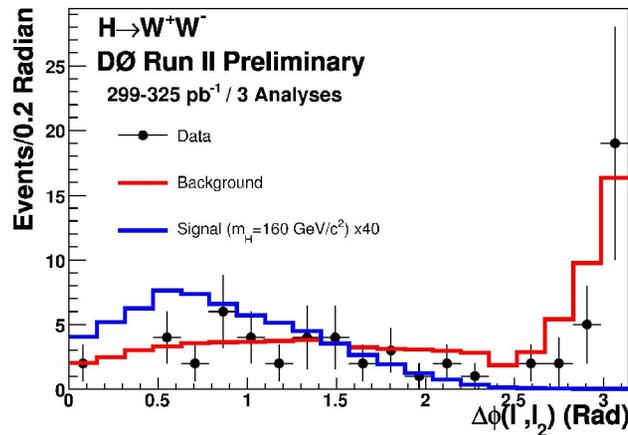
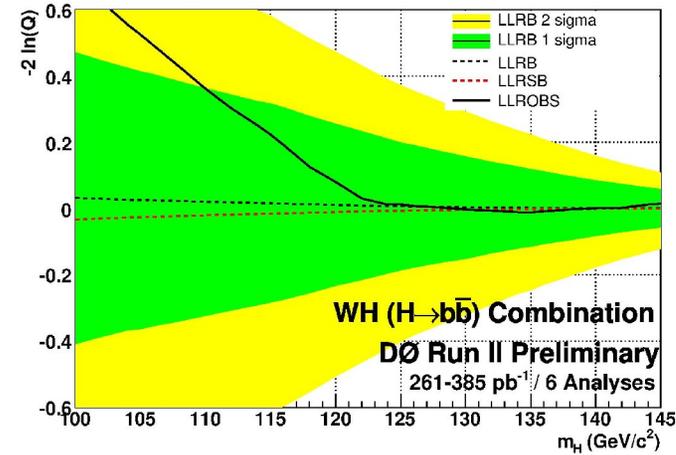
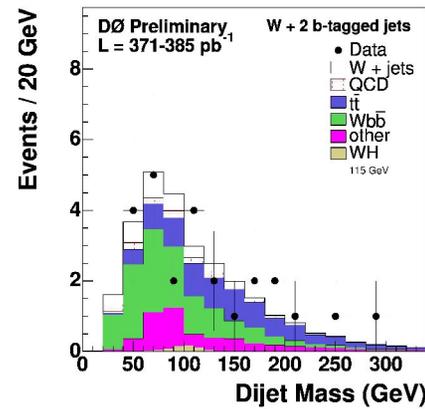
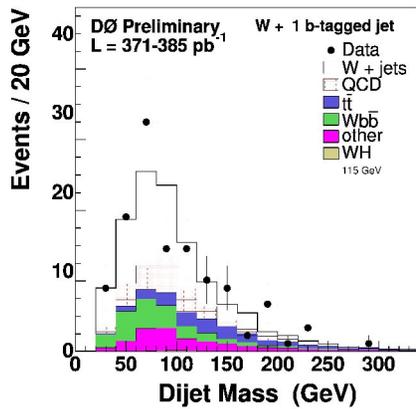
$$Q = e^{-(S+B)}(S+B)^D / e^{-B}B^D$$

S, B, D = signal, background, data

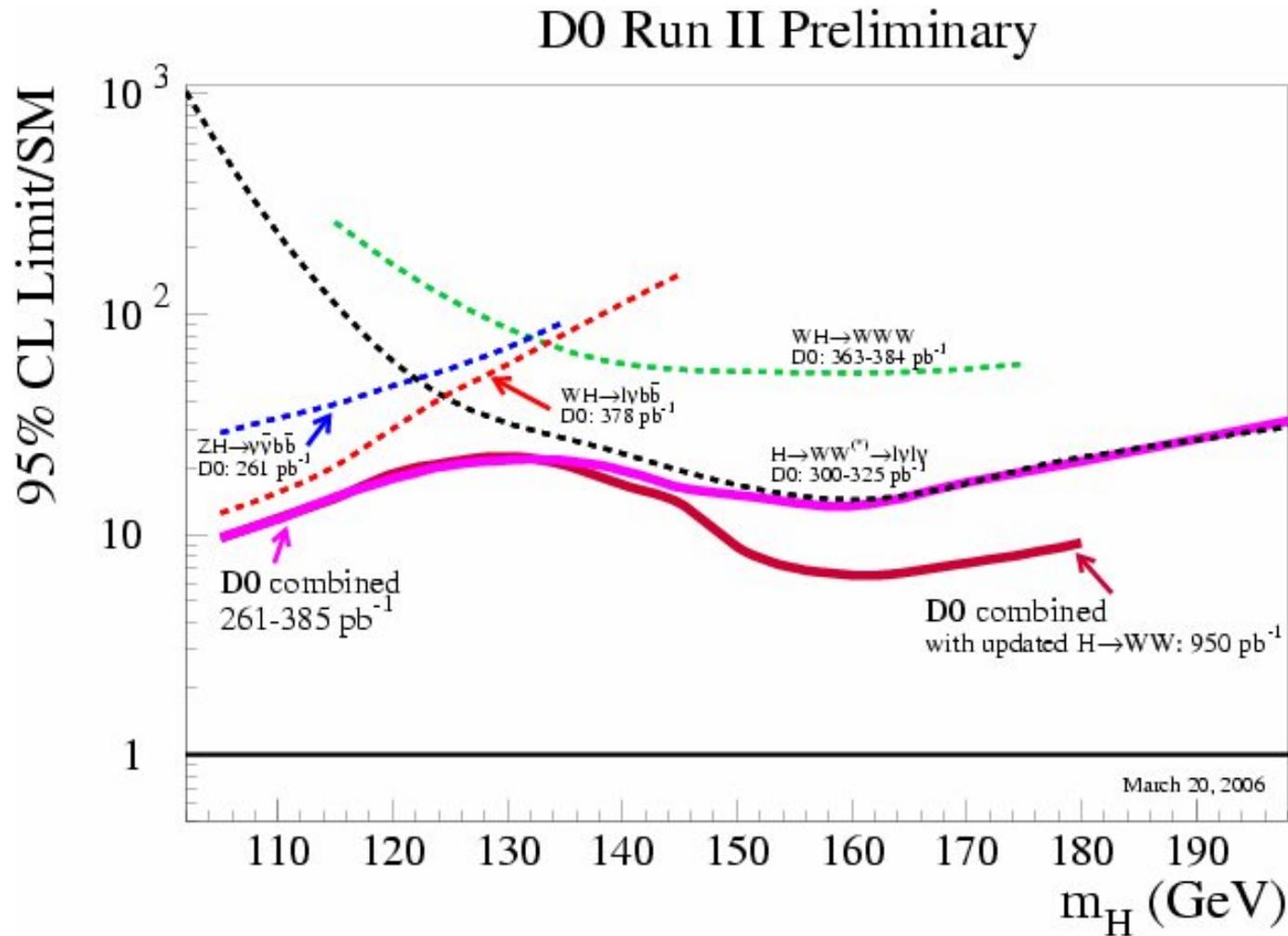
Combination: input/output

➤ Input: mass ($H \rightarrow b\bar{b}$), $\Delta\phi(l_1)$ (WW), likelihood (WW)

➤ Output: LLR \rightarrow limits



Combination: summary results



Perspectives

- There are resources we are working on:
 - add more channels ($ZH \rightarrow ll\ bb, \dots$)
 - new b-tagging algorithm
 - a neural net combining information from existing algorithms
 - improvements in jet energy resolution
 - new jet energy scale calibration, track-jets, calibration of b-jet energy scale using $Z \rightarrow bb$
 - Silicon Tracker Layer 0 upgrade ($r_1=2.7\text{cm} \rightarrow r_0=1.6\text{cm}$)
 - improved b-tagging, better pattern recognition
 - L1cal trigger upgrade
 - important for $ZH \rightarrow \nu\nu\ bb$
- We estimate that 95% CL exclusion (in combination with CDF) requires $2\ \text{fb}^{-1}$ for $M_H=115\ \text{GeV}$ and $6\ \text{fb}^{-1}$ for $M_H=115\text{--}180\ \text{GeV}$

Conclusions

- For the first time at DØ, all principal channels are covered and combined together
 - in plans: few “small channels”, combination with CDF
- Higgs searches benefit a lot from $H \rightarrow WW^*$ type of analyses
 - it also helps for the low mass region
- Combined limit looks very promising
 - LHC will have to work hard to get the low mass Higgs signal
 - If the Higgs is there, Tevatron may have evidence before 2009
- The goal is not easy, and we need some cooperation from Mother Nature, but we are optimistic