Higgs Sensitivity Update @ DØ

Gregorio Bernardi

for the DØ Higgs group

Status in the different channels

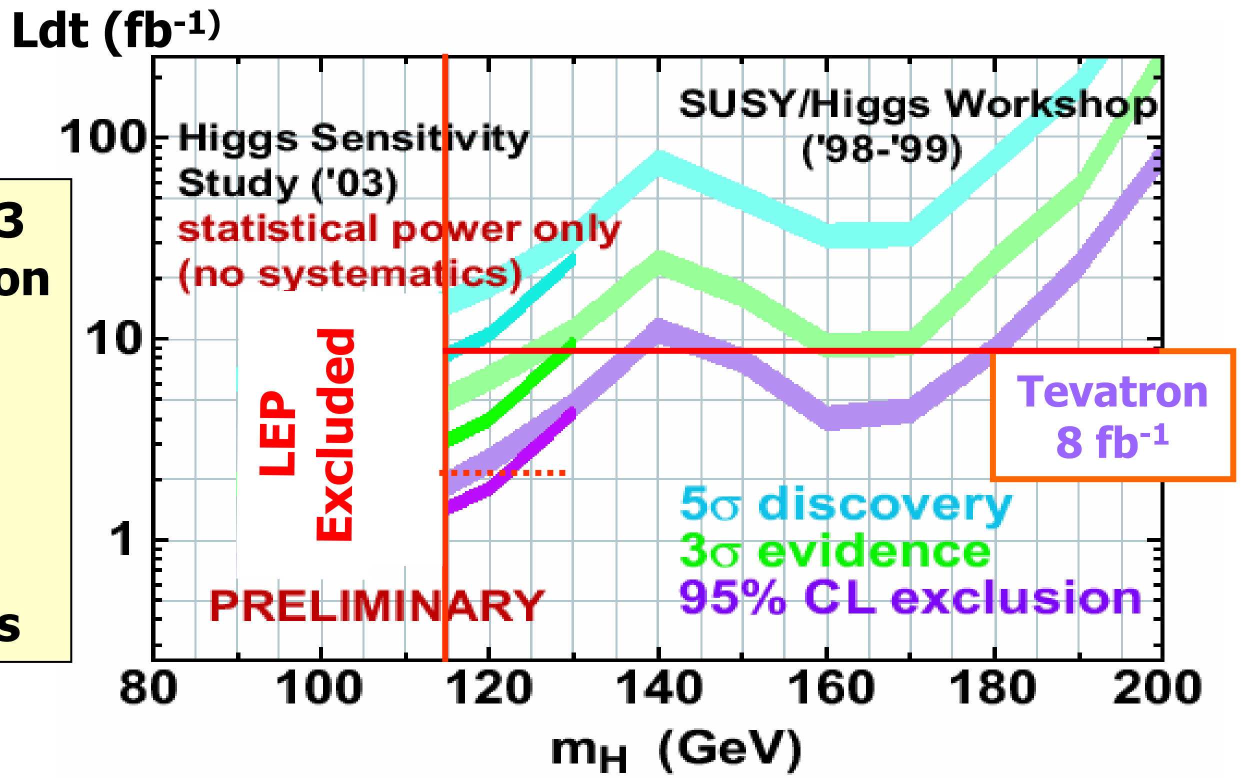
improvement prospects (2 steps)

SM Higgs Search: Outlook

Prospects updated in 2003 in the low Higgs mass region

W(Z) H→ lν(νν,ll) $b\bar{b}$

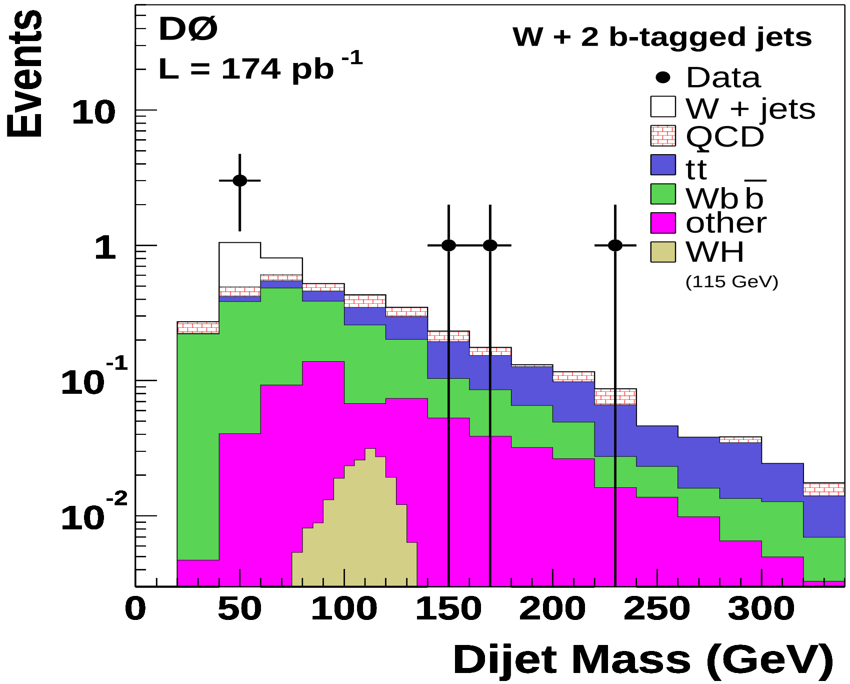
→ better detector understanding
→ optimization of analysis

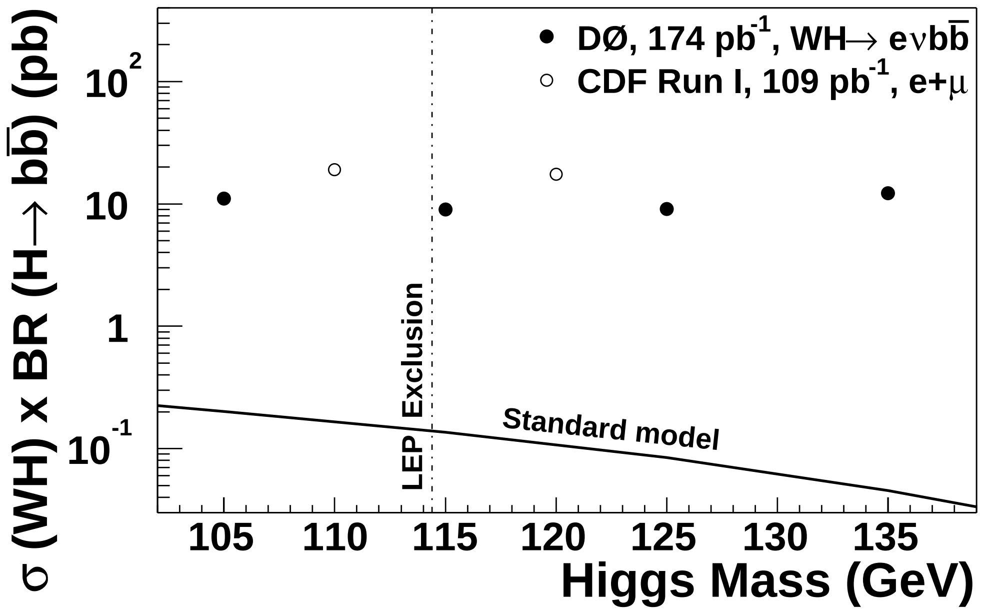


Sensitivity in the mass region above LEP limit (114 GeV) starts at ~2 fb^{-1}
With 8 fb^{-1}: exclusion 115-135 GeV & 145-180 GeV,
5 - 3 sigma discovery/evidence @ 115 – 130 GeV

Meanwhile
- → understanding detectors better, optimizing analysis techniques
- → measuring SM backgrounds (Zb, WW, Wbb)
- → Placing first Higgs limits which can be compared to the prospects

First Run II Higgs Search - WH(e)





For 115 GeV Higgs, mass window cut:

0 data, 0.05 exp Higgs, 1.07 bckgd

➔95% CL limit on WH of 9.0 - 12.2 pb for m_Higgs of 105-135 GeV

Published Run II limit better than Run I ➔ detector improvements

But ...

The difference is so huge with SM expectation

"you'll never make it"

(factor 50 in sensitivity, factor 2500 in luminosity, i.e. 450 fb^{-1} would be needed !)

Comparison of WH published Results with Sensitivity Prospective Study

	DØ Analysis (PRL '05) 174 pb^{-1} $WH \to e\nu bb$	Prospective Study ('03) normalized to 174 pb^{-1} and to $WH \to bbe\nu$	Ratio $\frac{\text{Prospective}}{\text{DØ Analysis}}$
Dijet mass window	[85,135]	[100,136]	R=0.72
Dijet mass resolution	14 +/- 1 %	10 %	R=0.71
Signal events (S)	0.049	0.145	R=3.0
Background evts (B)	1. 07	1.76	R=1.6
$S/\sqrt{B}$	0.045	0.11	R=2.4
S/B	0.046	0.082	R=1.8

We are missing a factor 2.4 in sensitivity for this WH(e) channel.

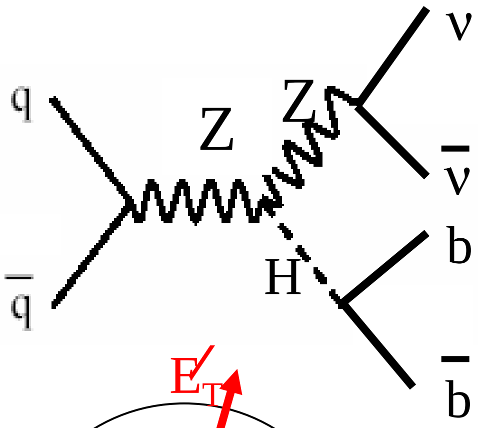
The following factors are not included:

3 (leptons) * 2 (experiments) * 2.5 (channels) * 1.8 (NN-selec) * 12 (lumi → 2fb^{-1}) = 324 = 18^2

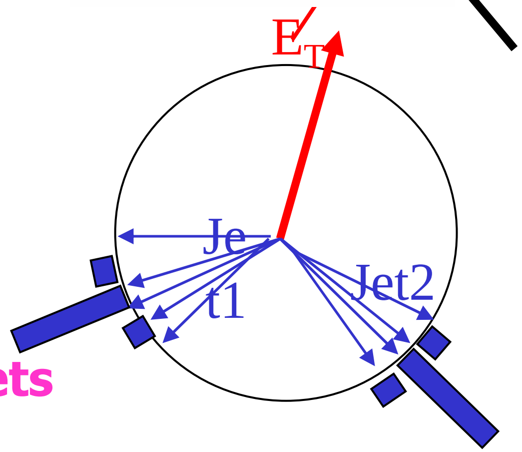
→factor of 18 is not included in WH sensitivity

→Combining both factor 2.4*18 =43 → consistent with 50

ZH→ννbb searches

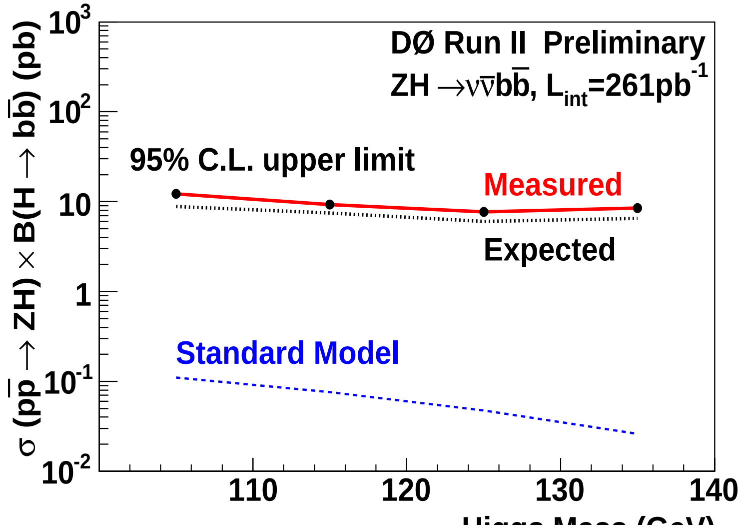


- Missing E_T from Z→νν and 2 b jets from H→bb
  - Large missing E_T > 25 GeV
  - 2 acoplanar b-jets with E_T > 20 GeV, $|\eta| < 2.5$



- Backgrounds
  - "physics"
    - W+jets, Z+jets, top, ZZ and WZ
  - "instrumental"
    - QCD multijet events and mismeasured jets
      - Huge x-section/small acceptance

- Strategy
  - Trigger on events with large missing H_T
  - Estimate "instrumental" bckgd from data
  - Search for an excess in di-b-jet mass distribution



ZH→ννbb Comparison with Prospective Study

All numbers @261pb^{-1}	D0 analysis 261pb^{-1} ZH→nnbb	SHWG (no NN)	Ratio SHWG/ D0 anal	Ratio HSS-nn/ D0 anal
#data	3	-	-	-
#signal (ZH+WH)	0.065+0.017	0.57+0.43	8.8(12)	8.5(12)
#physics bkg	1.8	12	6.6	2.3
#instrumental bkg	0.37	12	32	7.3
#total bkg	2.2	24	11	3.1
S/B	0.037	0.041	4	4
S/√B	0.055	0.20	3.6	7 (NN)

Mass window (GeV)	80-130	85-130	0.9	0.72
Mass resolution	16%	10%	0.6	0.6
Taggability (2 jets)	60%	100%	1.7	1.7
B-tagging (2 b jets)	16%	40%	2.5	1.6
Trigger	70%	100%	1.4	1.1
Effi. W/o trig, b-tag	20%	30%	1.5	2.5
			8.9	7.5

Need to improve signal acceptance!!

Need progress on
- B-tagging
- Trigger
- Selection optimization
- mass reconstruction

$H \rightarrow WW$ Selection Criteria

- Preselection cuts
  - Trigger, Object ID, oppositely charged leptons
  - p_T>15 (10) GeV for leading (trailing) lepton
- $\not{E}_T$>20 GeV
  - Suppresses dominant Z/γ^* bkg
- Scaled $\not{E}_T$>15 GeV
  - Remove bkg due to large contributions from mismeasured jet energy
- Invariant mass cut
  - m_{ee}< min(80 GeV, M_H/2)
  - 20 GeV < $m_{\mu\mu}$< M_H/2
    - Remove J/Ψ, Y, Z/γ^*
- Sum of p_T of the leptons and $\not{E}_T$, and the transverse invariant mass cuts
  - Rejects W+jets/γ and WW events, and further reduces Z/γ^*
- Scalar sum of the transverse energies of the jets, H_T<100 GeV
  - p_T>20 GeV, $|\eta|$<2.5
  - Suppresses bkg from tt production
- Azimuthal opening angle between the two leptons $\Delta\varphi_{ll}$< 2.0
  - Remove remaining Z boson and multijet bkg which exhibit back-to-back topology
  - **Not the case for Higgs decays because of spin correlations**

Comparison of H→ WW with Sensitivity Report

	Current Analysis	HWG report	Same cuts as in HWG now
L = 1 (fb-1)	H(160) --> WW --> ee		
Signal events (S)	0.635	0.325	0.24
Background evts (B)	16.8 (10.4 WW)	1.1 (1.0 WW)	2.5 (1.6 WW)
$S/\sqrt{B}$	0.16	0.31	0.15
L = 1 (fb-1)	H(160) --> WW --> emu		
Signal events (S)	1.17	0.65	0.42
Background evts (B)	22.3 (16.3 WW)	2.2 (2.0 WW)	3.8 (2.7 WW)
$S/\sqrt{B}$	0.24	0.44	0.215

S/B ratio is worse compared to HWG report

We are missing factor of 2 in sensitivity

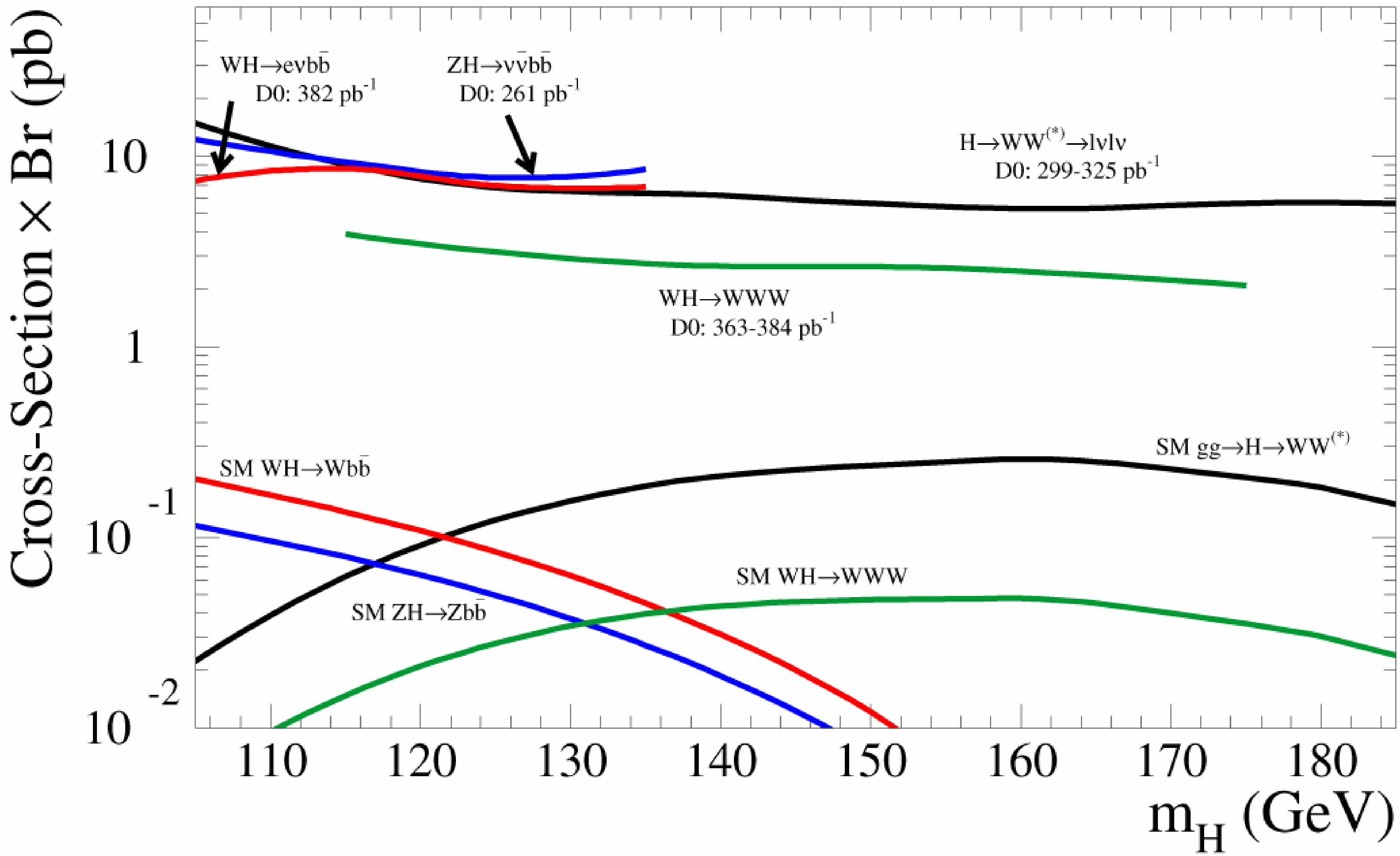
Using same cuts (no likelihood) as in Tevatron Higgs Working group study now:

1. Smaller selection efficiency to H→ WW → ll
(HWG report assumes higher em-id efficiency and improved muon resolution);

2. Larger WW background and tt background contribution;

3. Only W +jet background was considered in HWG (no W+γ background)

DØ SM Higgs Summary



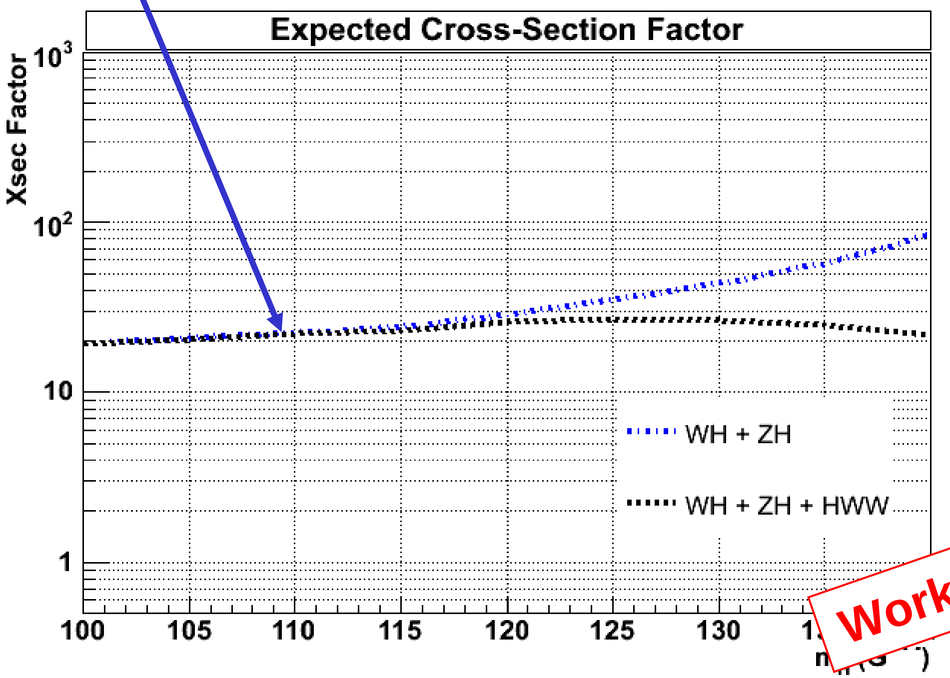
Ratio between Limit and SM expectation

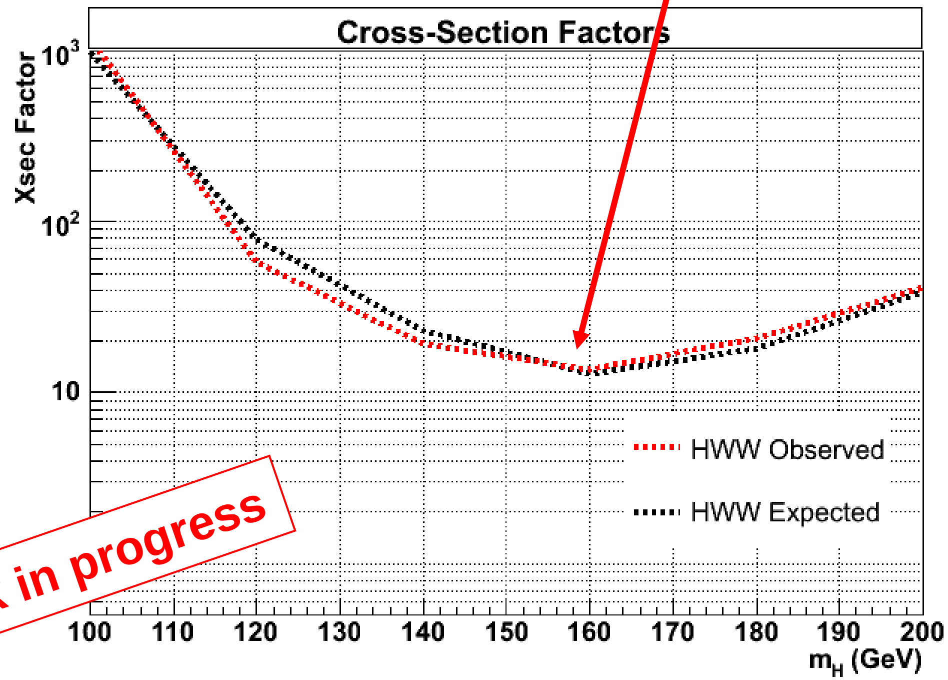
For WW* this “x-section factor” is about 13 at 160 GeV

For WH+ZH combined: x-section factor is about 20-25

➔ and “helped” by WW above 120 GeV

The “kink” at around 140 GeV goes away

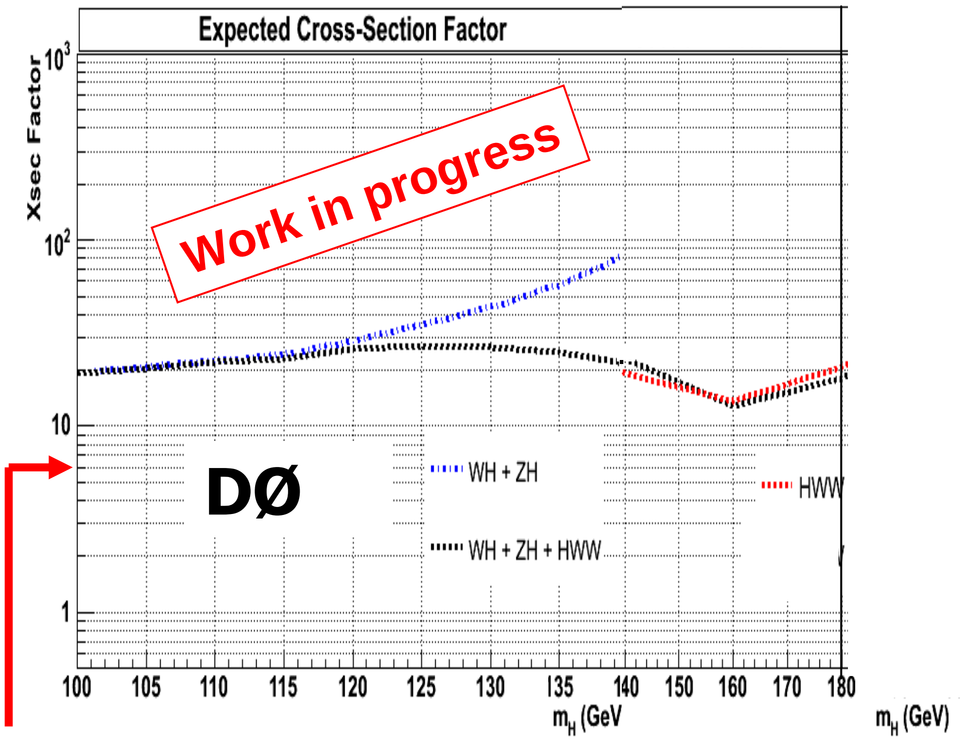


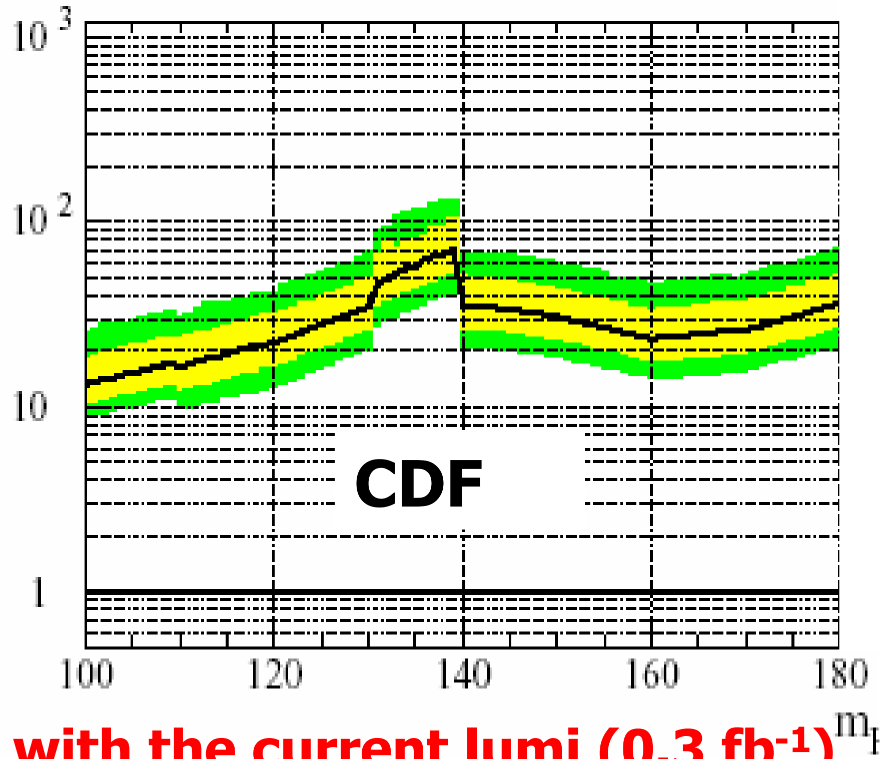


Work in progress

Comparison with CDF (shown at P5)

We are similar at low mass (115-130 GeV), better at High mass, and we have no 140 GeV kink, but…





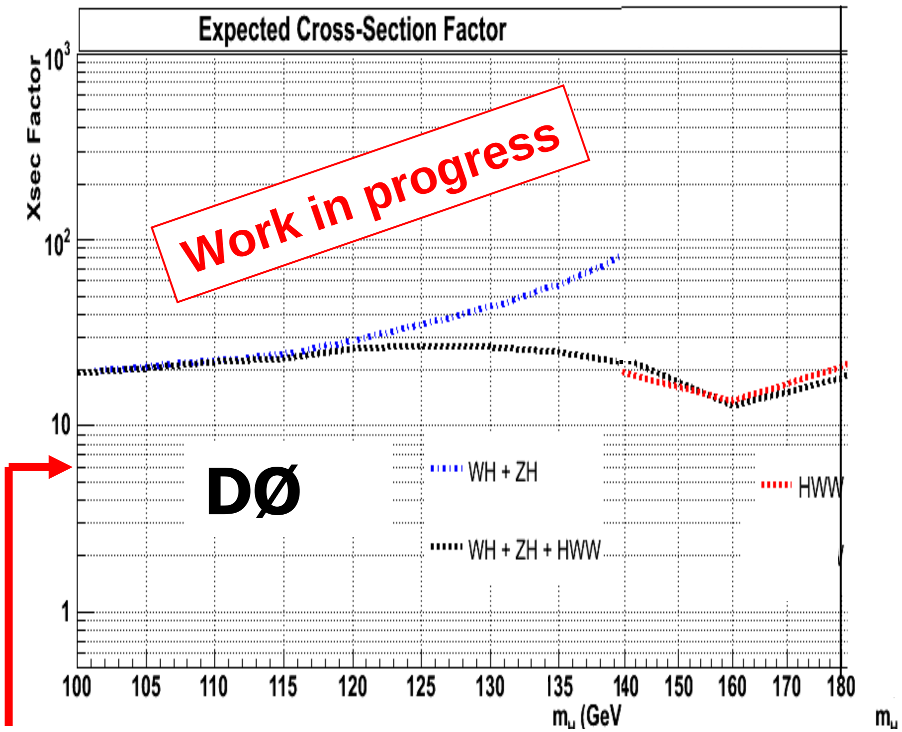
we should be around 6, not around 20 with the current lumi (0.3 fb^{-1})

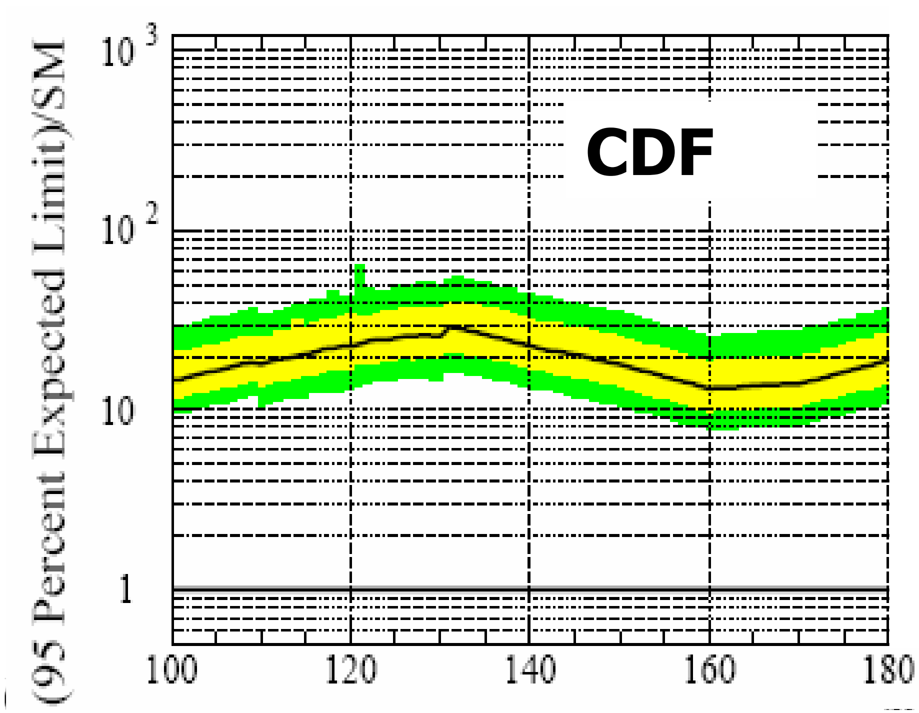
Where can we gain ?

Comparison with CDF (shown today)

We are similar everywhere !

➔ Progressing together, needed for final combination !





we should be around 6, not around 20 with the current lumi (0.3 fb^{-1})

Where can we gain ?

How to Reach "Expected" Sensitivity

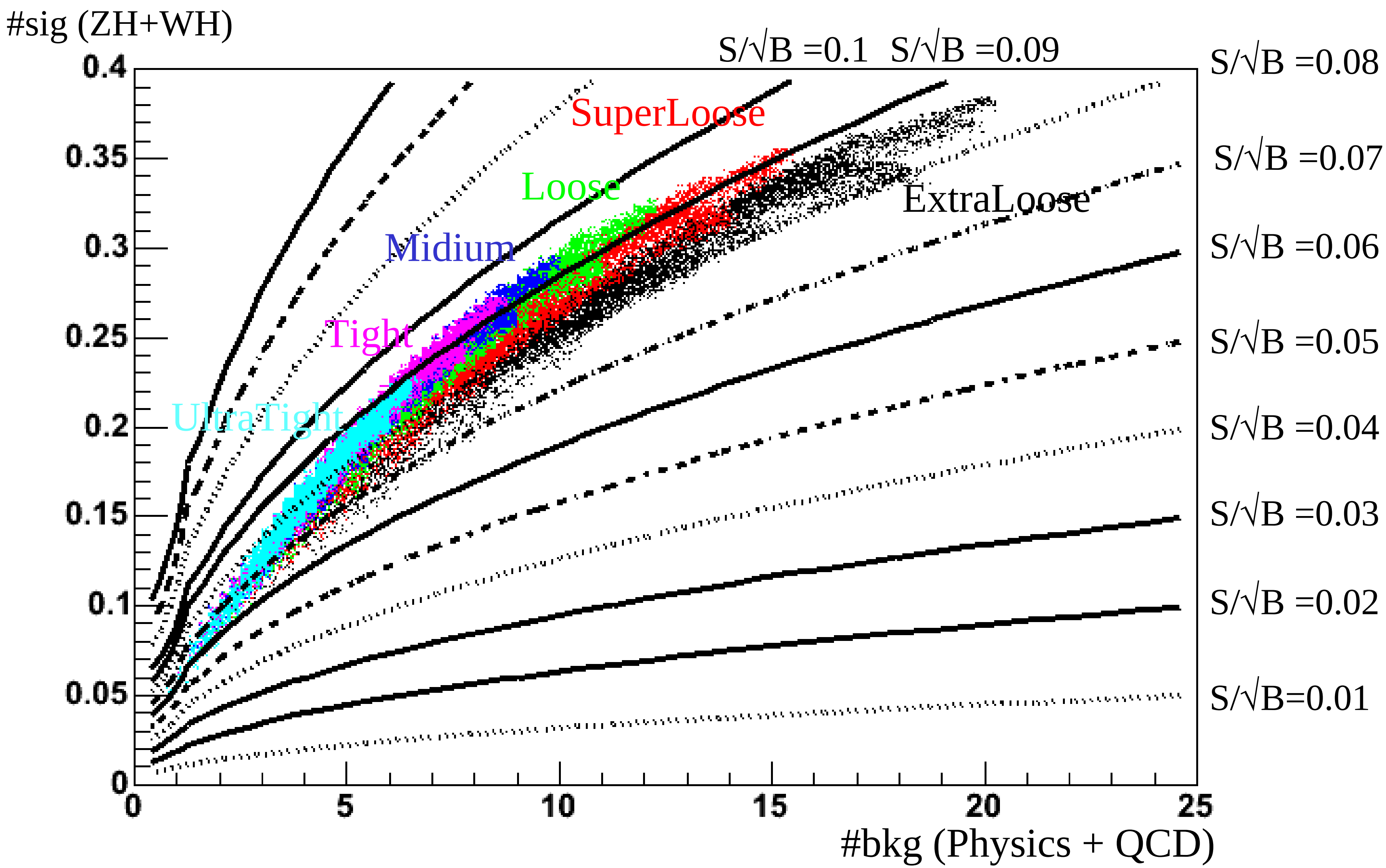
Two steps improvement to be ready by next P5 (2006)

Step1: End of 2005 → Publications on 300-400 pb^{-1}

WH/ZH: Optimize b-tagging (Looser)
Combine single and double tag
WH(e): Include Phi-cracks
WH(μ): Combine single-μ and μ+jets trigger
ZH : Optimize Selection
WW : ...first optimization done/submitted !

B-tagging: signal vs. bkg (M_H=115GeV)

M_H=115GeV, ExtraLoose jlip for 2nd leading jet, Mass window is 1.5 sigma



Combine Single Tag / Double Tag (WH, e and mu)

Example from work in progress:

115 GeV mass window. e-DT: S=0.11 B=2.60 s/sqrt(b)= 0.068

e-ST: S=0.25 B=39.3 s/sqrt(b)= 0.039

115 GeV mass window. μ-DT: S=0.082 B=1.80 s/sqrt(b)= 0.062

μ-ST: S=0.147 B=32.2 s/sqrt(b)= 0.026

S/sqrt(B) is 40-50% in single tag compared to double tag.

Equivalent to 20% more lumi than Double tag alone.

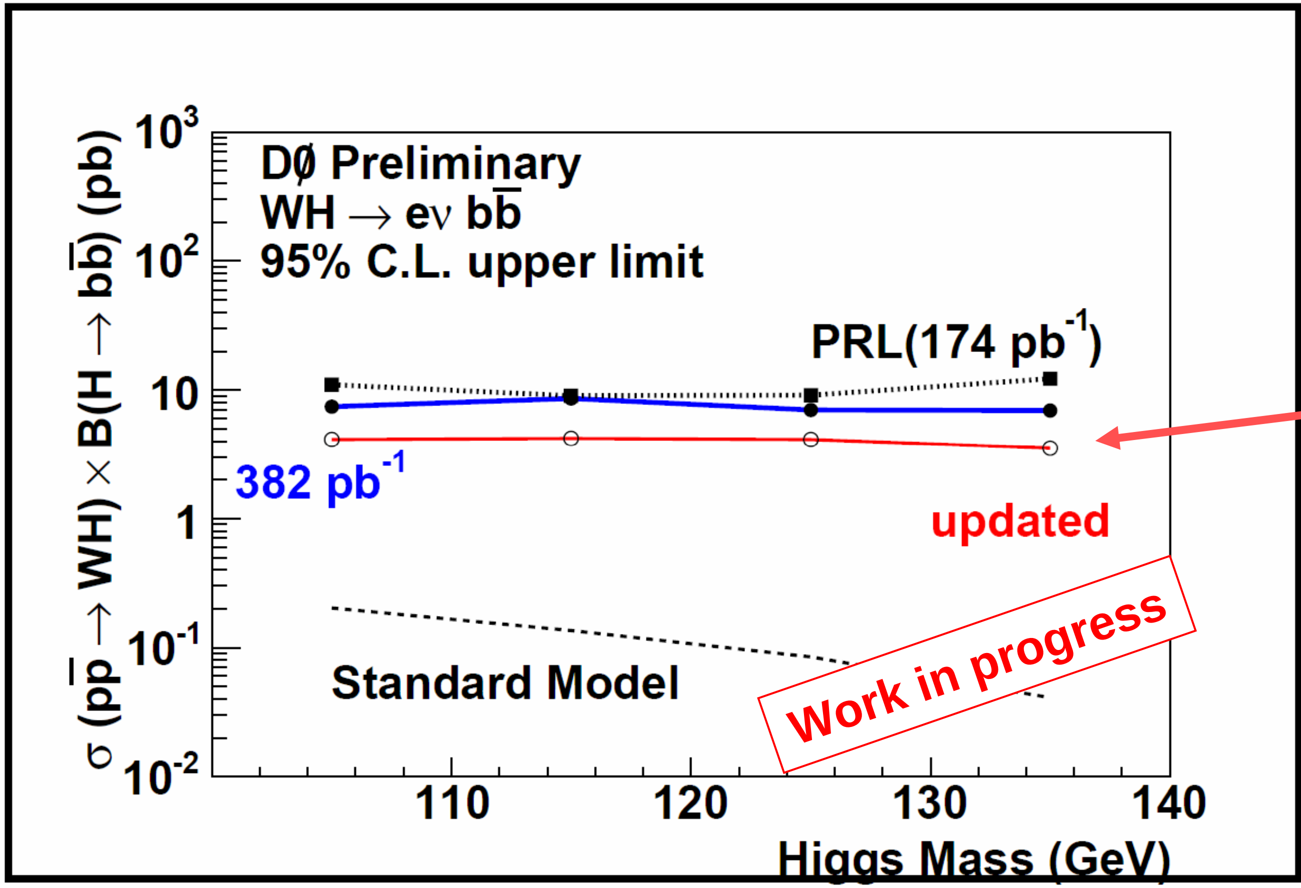
ZH→ννbb : How limits are improved?

Work in progress

	MET+bb (105GeV)	MET+bb (115GeV)	MET+bb (125GeV)	MET+bb (135GeV)
#ZH(nnbb) Acceptance (preliminary)	0.23 0.80 ± 0.21% (0.28%)	0.19 0.96 ± 0.25% (0.33%)	0.14 1.1 ± 0.29% (0.35%)	0.078 1.1 ± 0.29% (0.34%)
#WH(lnbb) #ZH+WH Acceptance	0.14 0.37 1.28 ± 0.33%	0.11 0.30 1.51 ± 0.39 %	0.09 0.23 1.84 ± 0.48%	0.057 0.14 1.99 ± 0.52 %
Total Backgd	9.8 ± 3.2	10.3 ± 3.4	10.8 ± 3.6	10.8 ± 3.6
		(expected)		
ZH Estimate Prel (260pb^{-1})	(6.6) pb (8.8) pb	(5.9) pb (7.5) pb	(5.2) pb (6.0) pb	(5.2) pb (6.5) pb
ZH Est.+WH	(4.0) pb	(3.7) pb	(3.0) pb	(2.8) pb

Factor 2 since preliminary! (equiv to 4 times more lumi) using looser selection, tagging and misidentified WH

WH (e) : How limits are improved?



B-tagging optimized

Phi cracks included

Here also a factor 2 has been gained compared to the preliminary results. (Muon channel has similar sensitivity)

Since the average WH/ZH missing sensitivity was a factor 3, these improvements reduce it to about 1.5

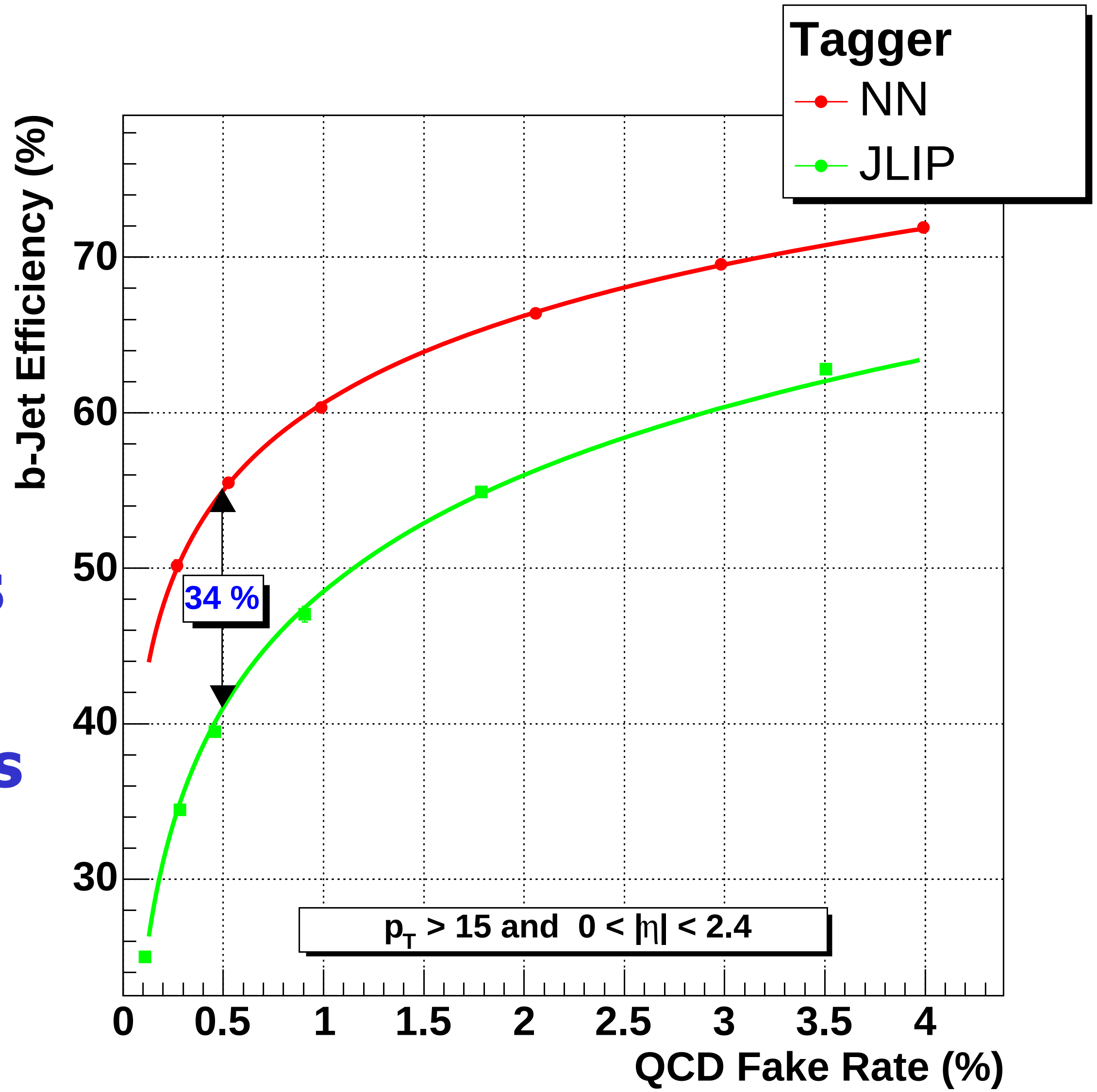
How to Reach "Expected" Sensitivity

Several points,

2 Examples:

Use Neural Net b-tagging in all Higgs analyses

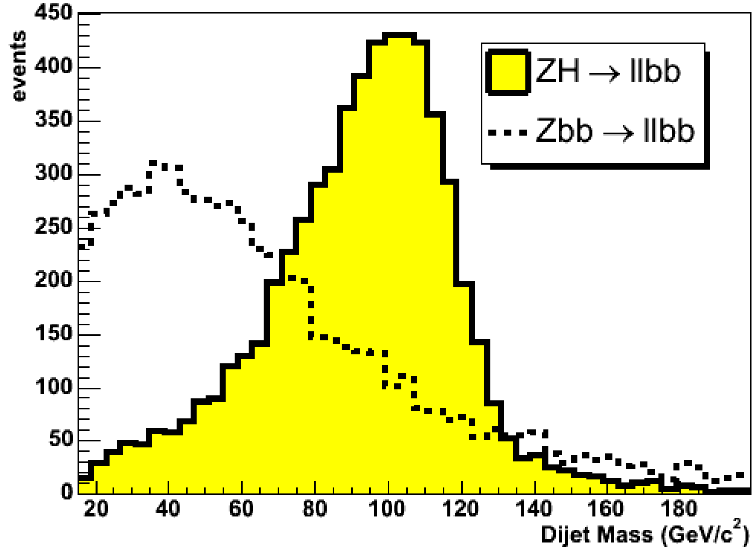
the NN tagger combines the 3 b-tagging algorithms used in DØ



Use Neural Net Event Selection

No Neural Net selection yet. Working group being formed, using single top expertise

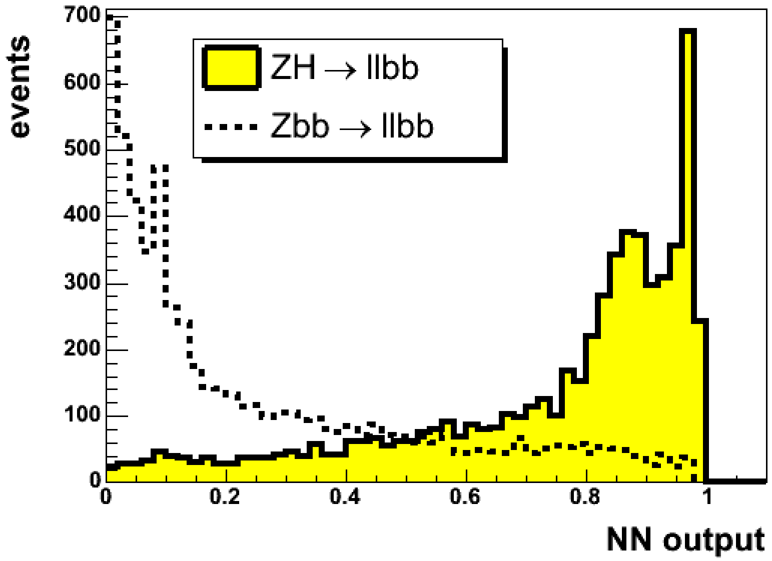
In D0 we have gained factor 2 in (S/√B) in single top NN analysis



Example of CDF Run II Neural Net:

- **NN analysis done for ZH→llbb**

➔ Improves S/√B by factor 1.5



Factor 1.8 used for 2003-HSWG is in reach, assumed that we will have it by summer.

How to Reach "Expected" Sensitivity: Step 2

For summer 2006, with 1 fb^{-1} data, we expect:

- WH/ZH → include WH→WWW and Z→ l^+l^- channel ! (*1.3)
- WH/ZH: use Neural Net Tagger (*1.34*1.34)
- WH/ZH: use Neural Net Selection (*1.8)
- WH/ZH: use TrackCalJets→ mass resolution (*1.3)
- WH(e): include End-Cap calorimeter
- WH(μ): improve QCD rejection → loosen b-tag (*1.2)
- WH : include W→ τ ν (*1.4)

Total for WH/ZH: $1.34^2 * 1.3 * 1.2 = 2.8$ →another gain of sqrt(2.8)=1.7 in sensitivity (compare to the missing 1.5)

→we can reach the expected sensitivity by summer 06

Summary and Remarks

After the first round of analyses, both experiments are devoting more efforts to sensitivity optimization:

- **Combination (channels, but also 1-2 tags)**
- **Include all channels (taus, WWW)**
- **Neural Net selections**
- **b-tagging (neural-net, combination etc..)**
- **Mass reconstruction (track cal jet)**

Our studies show, that, barring surprise D0 (and CDF?) could reach the expected sensitivity by summer 2006 (1fb^{-1})

If we are lucky, we could already say something on 115 GeV Higgs at the end of next year, else wait for 2007… but we do need to work coherently/critically.

In the mean time, we will probably be able to progress beyond the expected sensitivity.