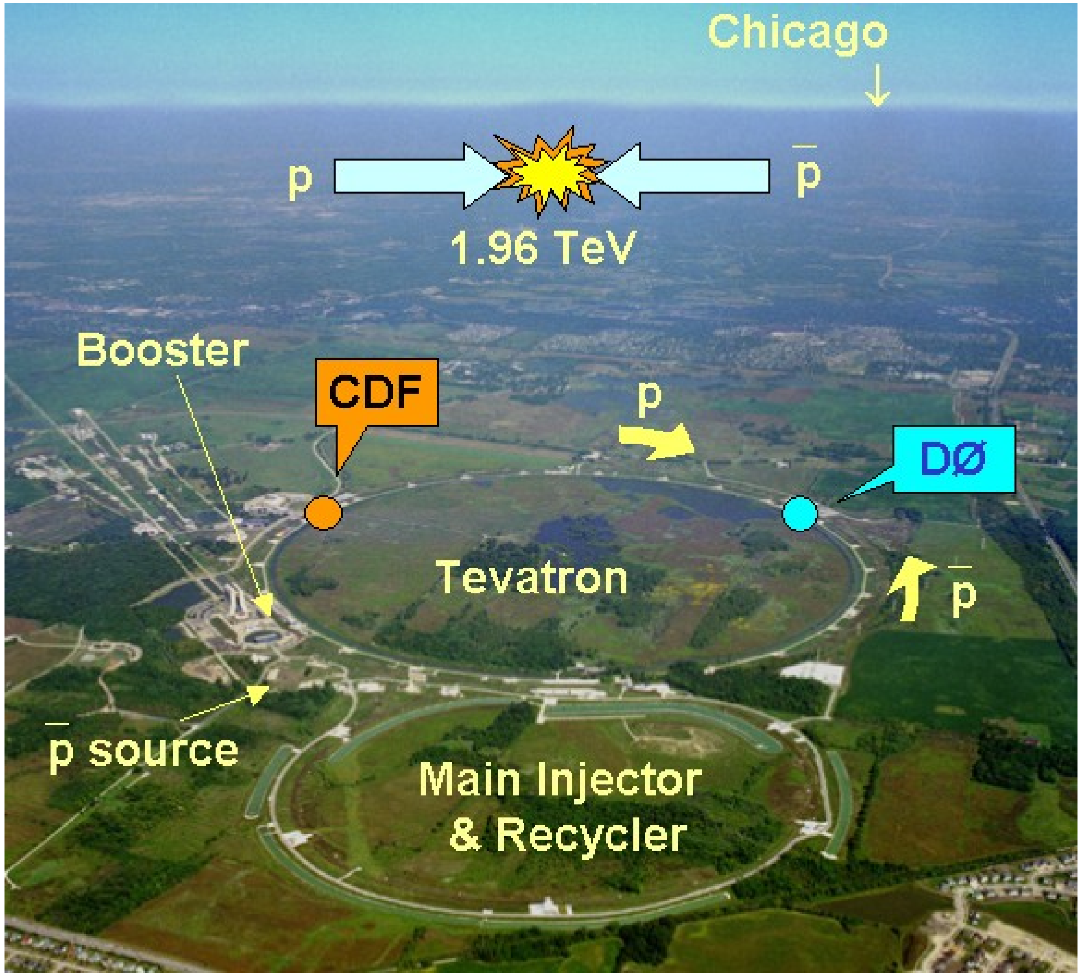
Results on Higgs Searches @ DØ

Wine and Cheese, May 5th 2006,

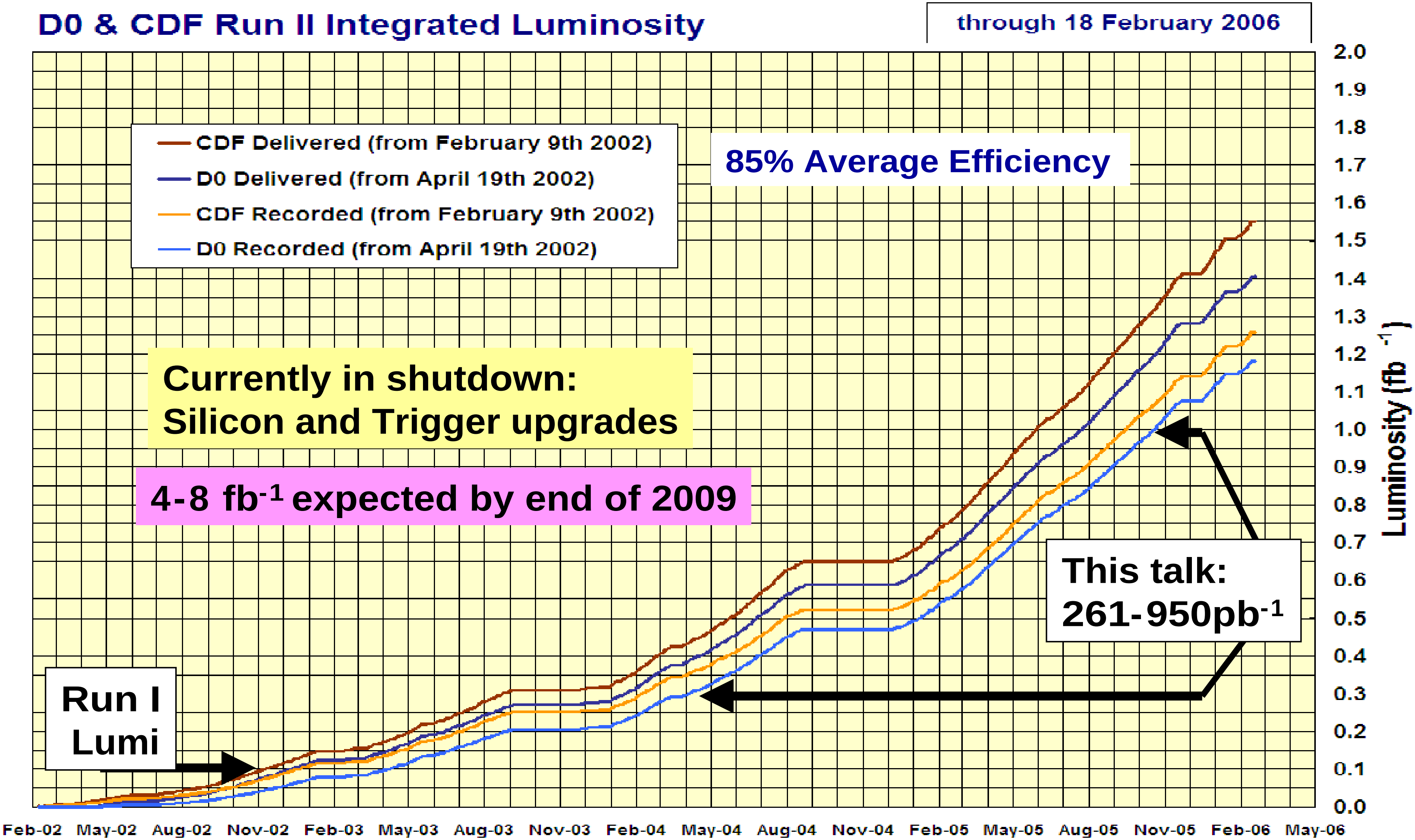
Gregorio Bernardi, LPNHE-Paris

for the DØ Collaboration

- **Luminosity/DØ**
- **Introduction to Higgs**
- **SM Higgs Searches**
- **Sensitivity Prospects**
- **MSSM Higgs Searches**
- **Conclusions**
- **(Only 2006 results shown)**



Tevatron Performance

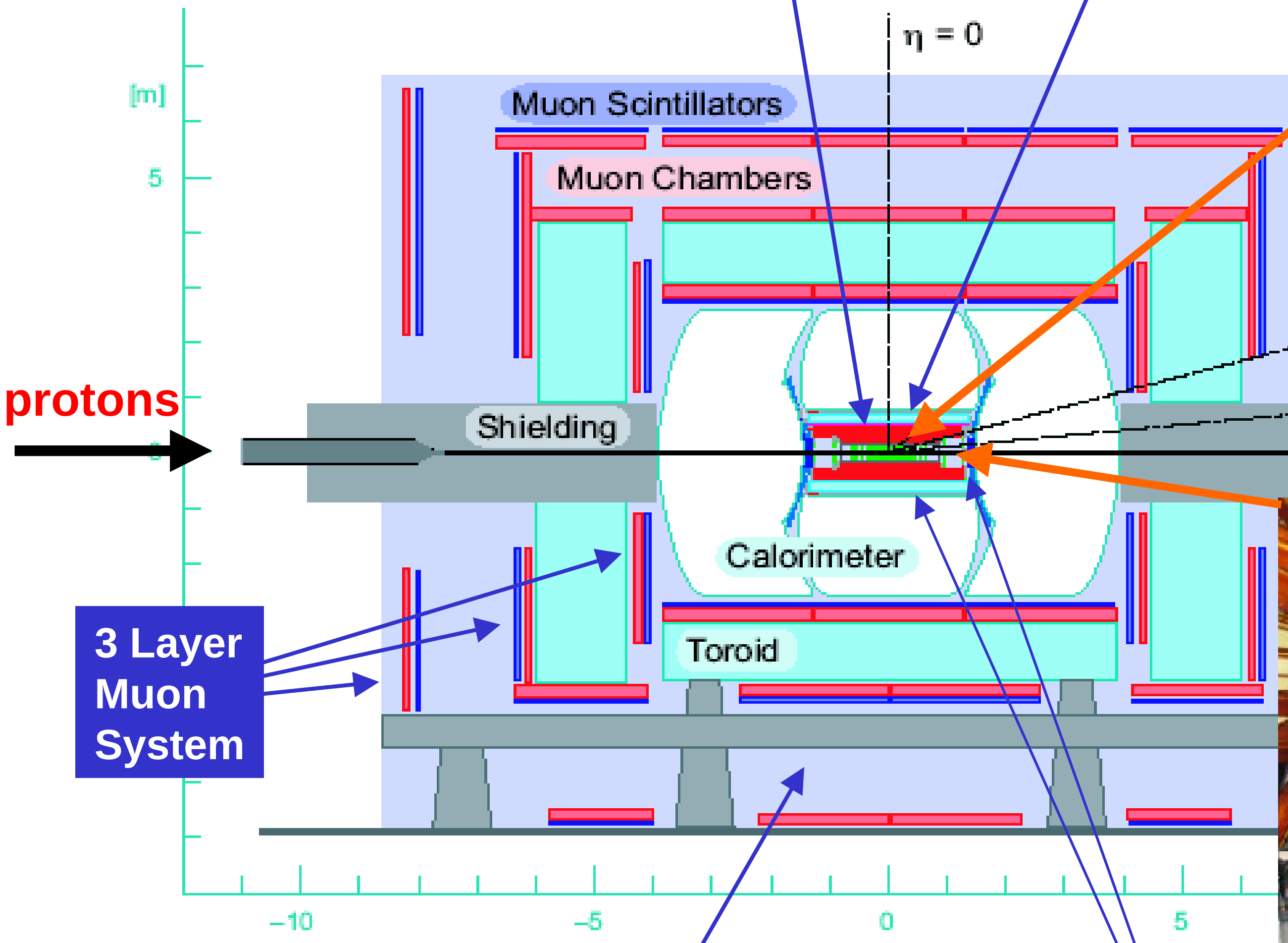


The Upgraded DØ detector in Run II

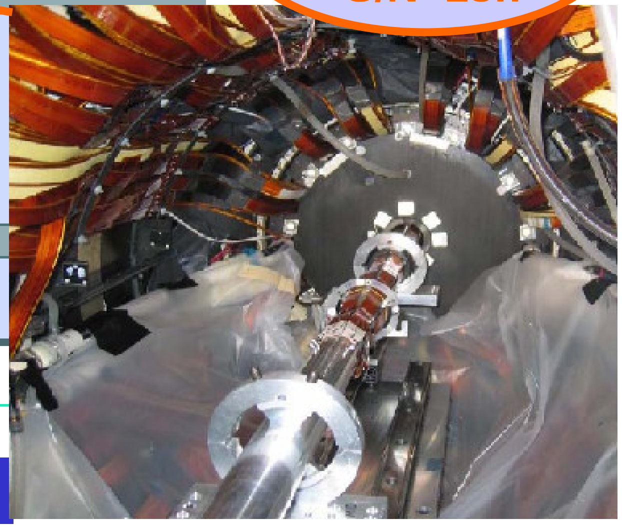
Upgraded @ Run IIa
Muon system, CAL Electronics
DAQ, (track) trigger system
Displaced-vtx trigger

New @ Run IIa (tracking in B-field)
Silicon detector
Fiber tracker, preshowers

@ Run IIb:
- L1 CAL
- LØ for SMT



Layer 0 now inserted and fully readout



Excellent noise performance S/N=18!!

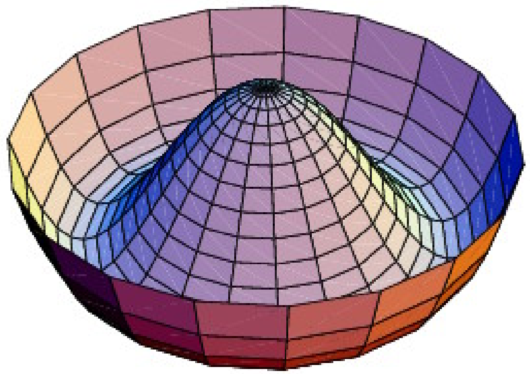
Goal: Test the Hypothesis of Spontaneous Symmetry Breaking

$SU(2)_L \times U(1)_Y$ is very well tested in collider experiments

But it is not a symmetry of our vacuum   otherwise
quarks, leptons, and gauge bosons would all be massless

➔ $$L_{EM} = (\partial_\mu - ieA_\mu)\phi^*(\partial_\mu + ieA_\mu)\phi - [\mu^2\phi^*\phi - \lambda(\phi^*\phi)^2] - \frac{1}{4}F_{\mu\nu}F_{\mu\nu}$$

Simplest model   one complex doublet of scalar fields in a ϕ^4 potential resulting in a non-zero VEV
W and Z get three of the four d.o.f,
one left over → fundamental scalar H_{SM}

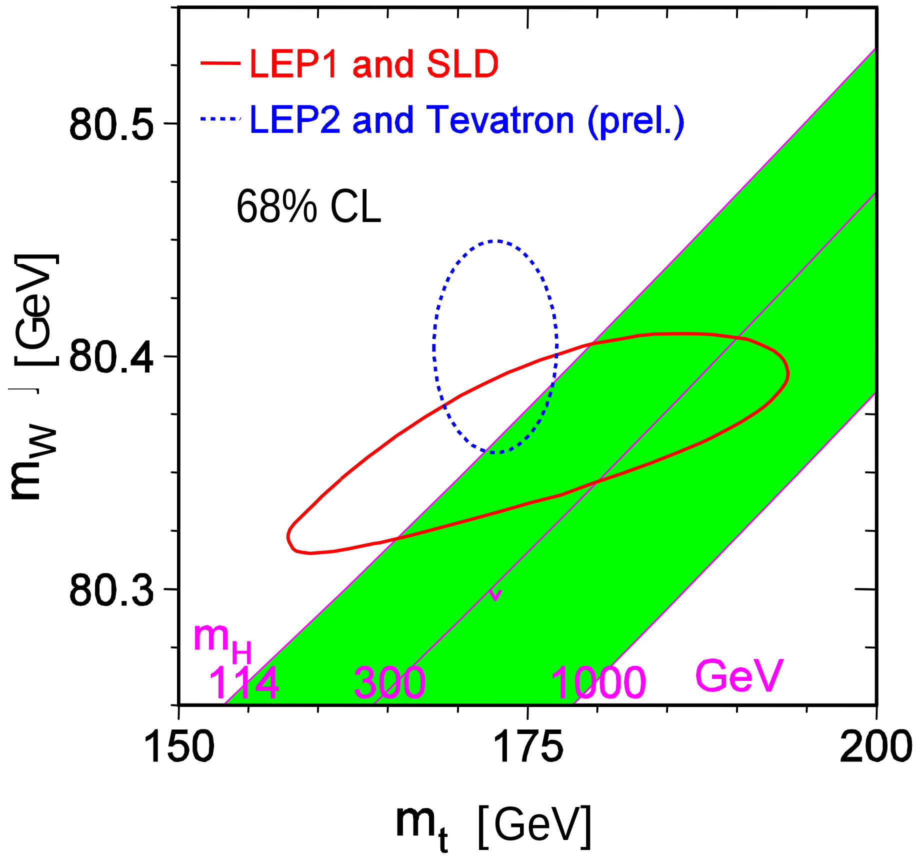


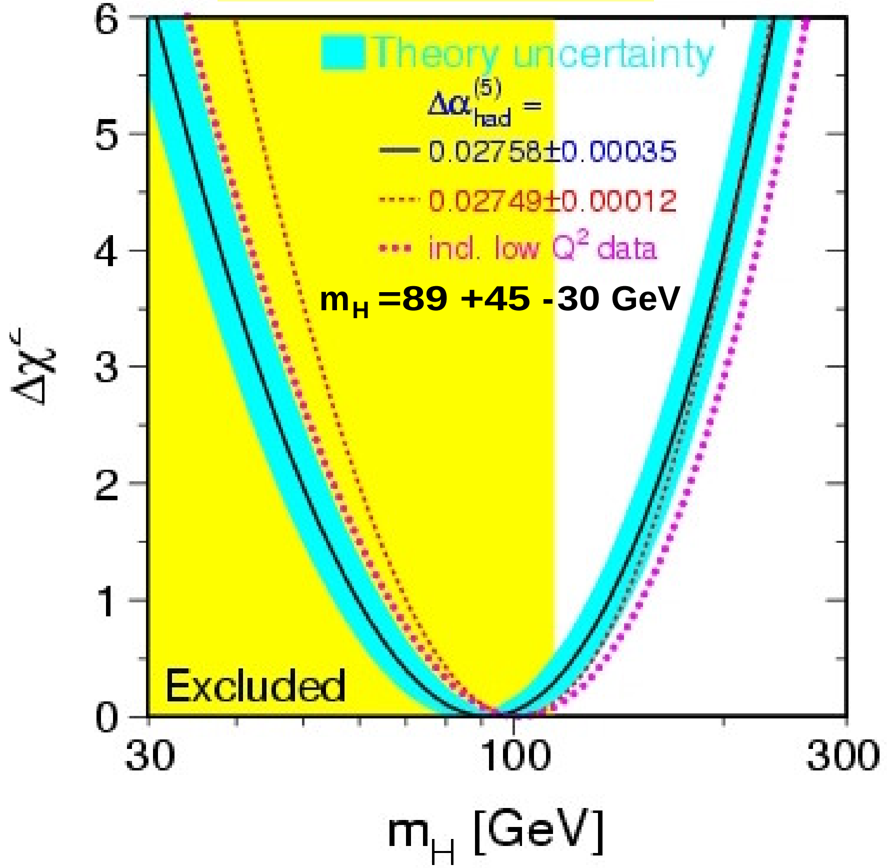
Not the only possibility
- SUSY Higgs (described later)
- General 2HDM
- Higgs Triplets
- Little Higgs
- Technicolor (new results coming soon)

Experimental constraints on Higgs

m_H constrained in the Standard Model

LEPEWWG 18/03/06





Direct search at LEP2:

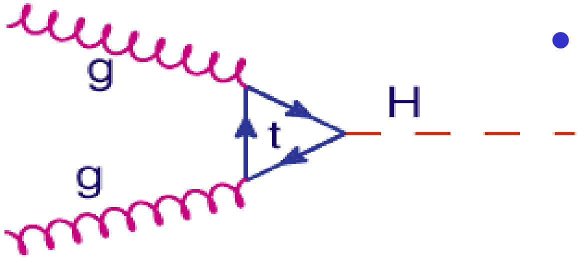
m_H>114.4 GeV @95%CL

m_H<175 GeV @95%CL

m_H< 207 GeV if direct search included

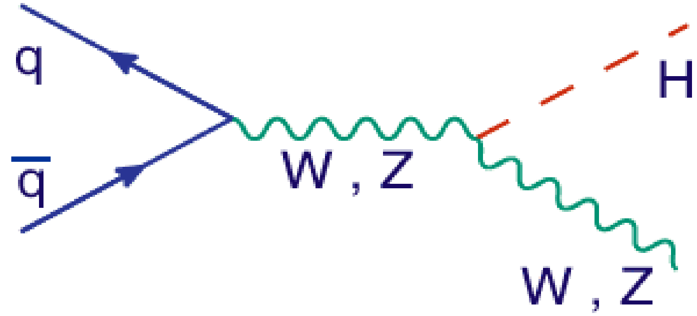
➔ a light Higgs is favored (also true from other theoretical arguments)

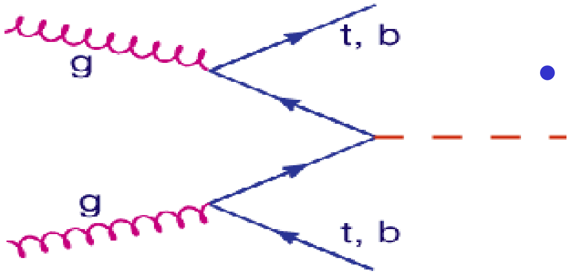
SM Higgs boson production



- gg fusion
  - Dominates at hadron machines
  - Usefulness depends on the Higgs decay channel

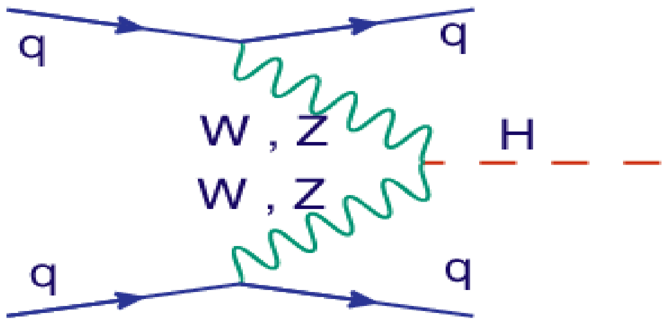
- WH, ZH associated production
  - Important at hadron colliders since can trigger on 0/1/2 high-p_T leptons and MET





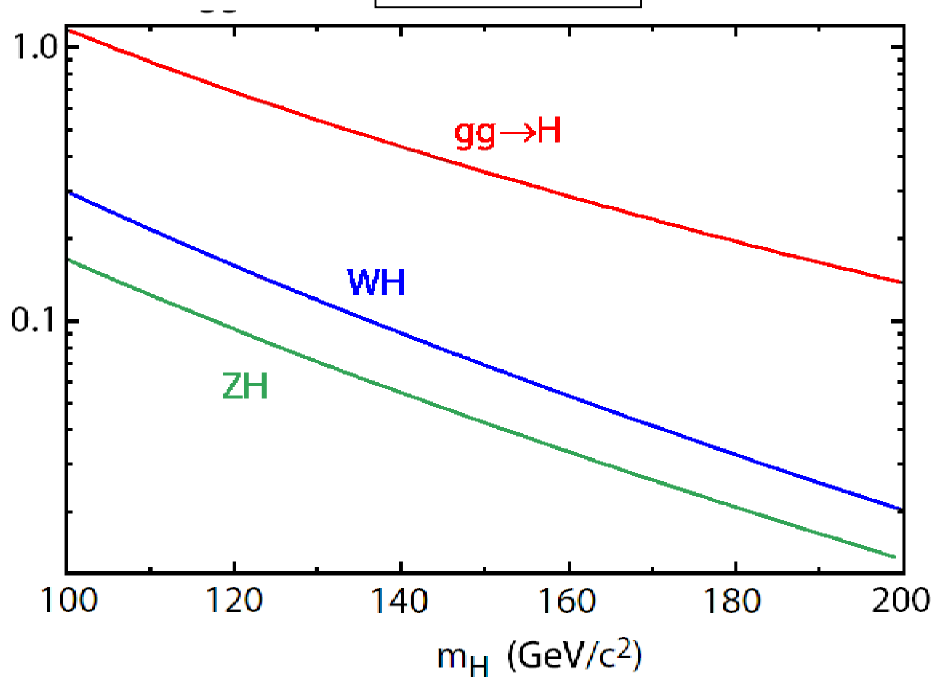
- ttH and bbH associated production
  - High-p_T lepton, top reconstruction, b-tag
  - Low rate at the Tevatron

- Vector Boson Fusion
  - Two high-p_T forward jets help to "tag" event
  - Important at LHC, being studied at DØ

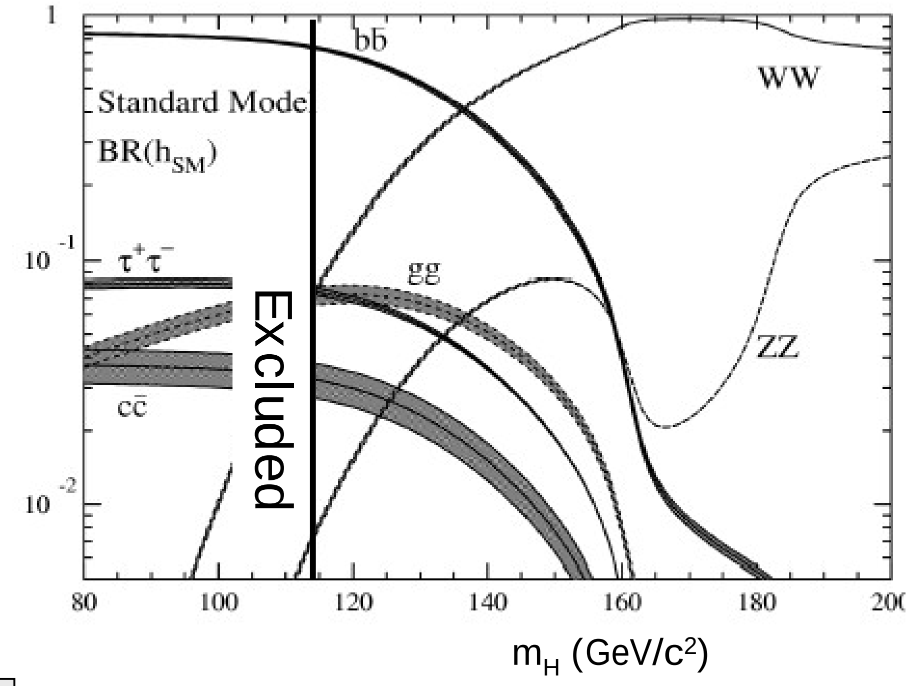


SM Higgs Production and Decays

Production



Decays



Production cross section (m_H 115-180)
→ in the 0.8-0.2 pb range for gg → H
→ in the 0.2-0.03 pb range for WH associated vector boson production

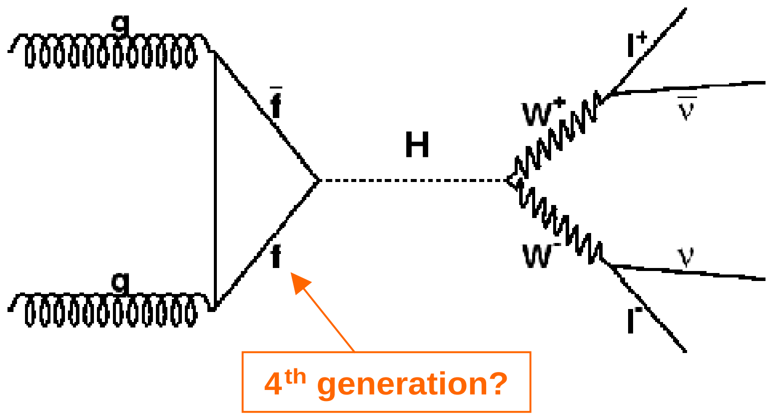
Dominant Decays
→ $b\bar{b}$ for M_H < 135 GeV
→ WW^* for M_H > 135 GeV

Search strategy:

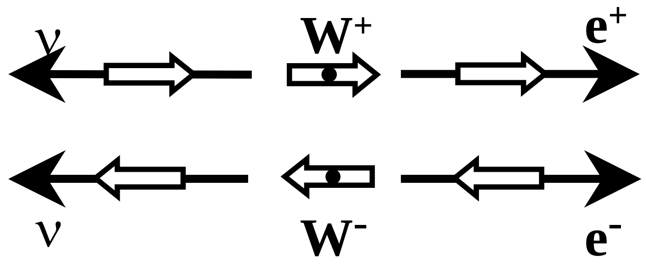
M_H <135 GeV: associated production WH and ZH with H→bb decay
Backgrounds: top, Wbb, Zbb... complement it with WWW^* and WW^*

M_H >135 GeV: gg →H production with decay to WW^*
Backgrounds: WW, DY, WZ, ZZ, tt, tW, ττ

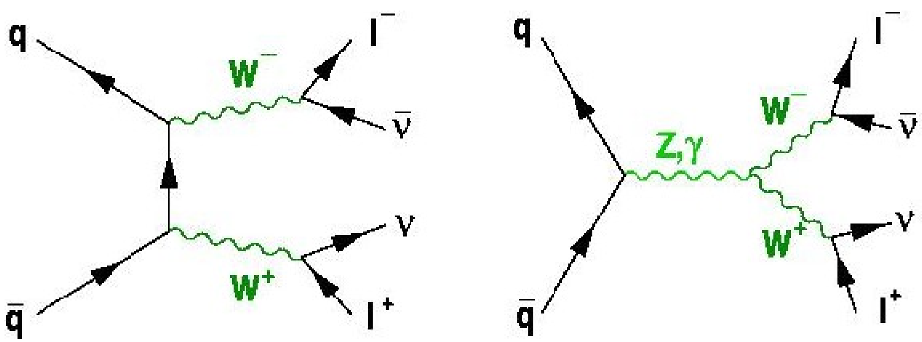
SM "Heavy" Higgs: H → WW* → lνlν



Search strategy:
→ 2 high P_t leptons and missing E_t
→ WW comes from spin 0 Higgs:
leptons prefer to point in the same direction

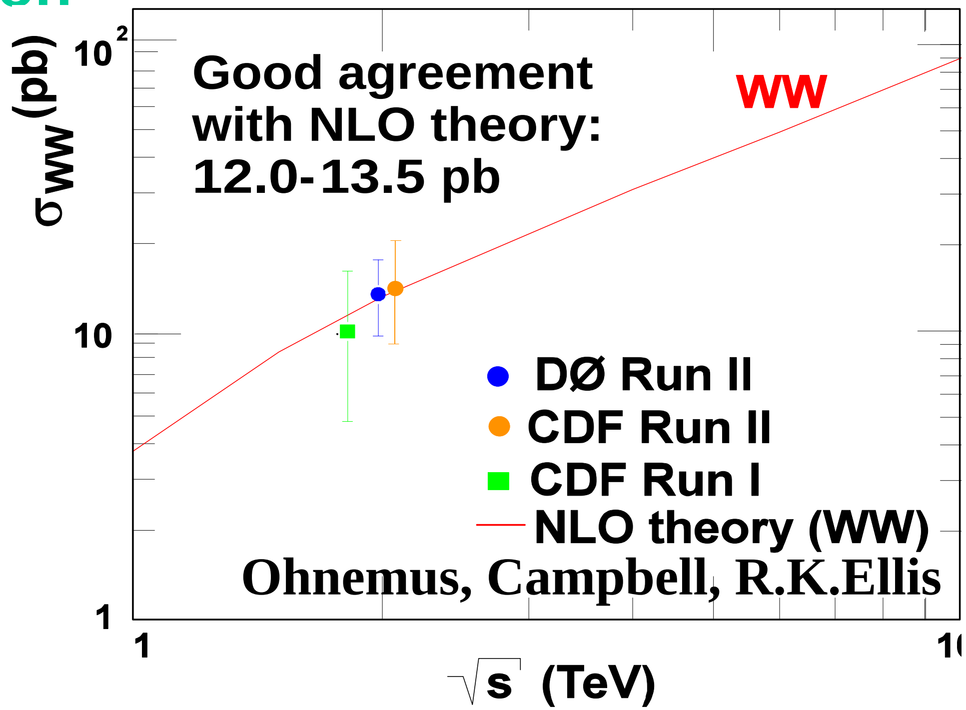


Main Background: WW Production



Now measured at the Tevatron by both experiments

DØ: PRL/ hep-ex/0410062



Search for H → WW* ($325\ pb^{-1}$)

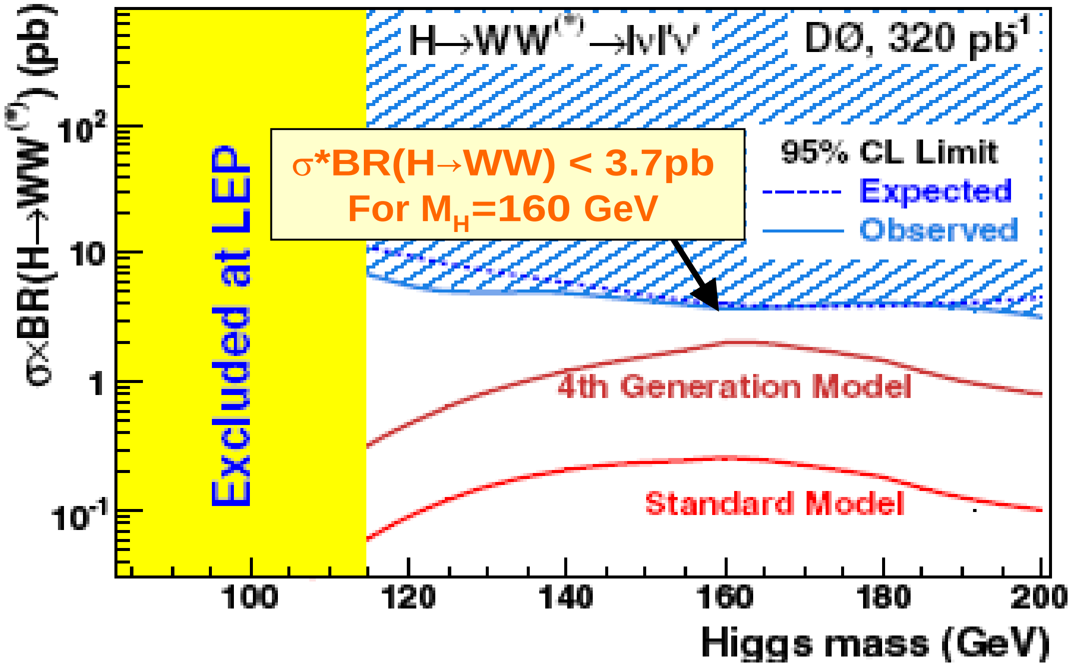
Search in 3 channels: $H \to WW^* \to ll\nu\nu$

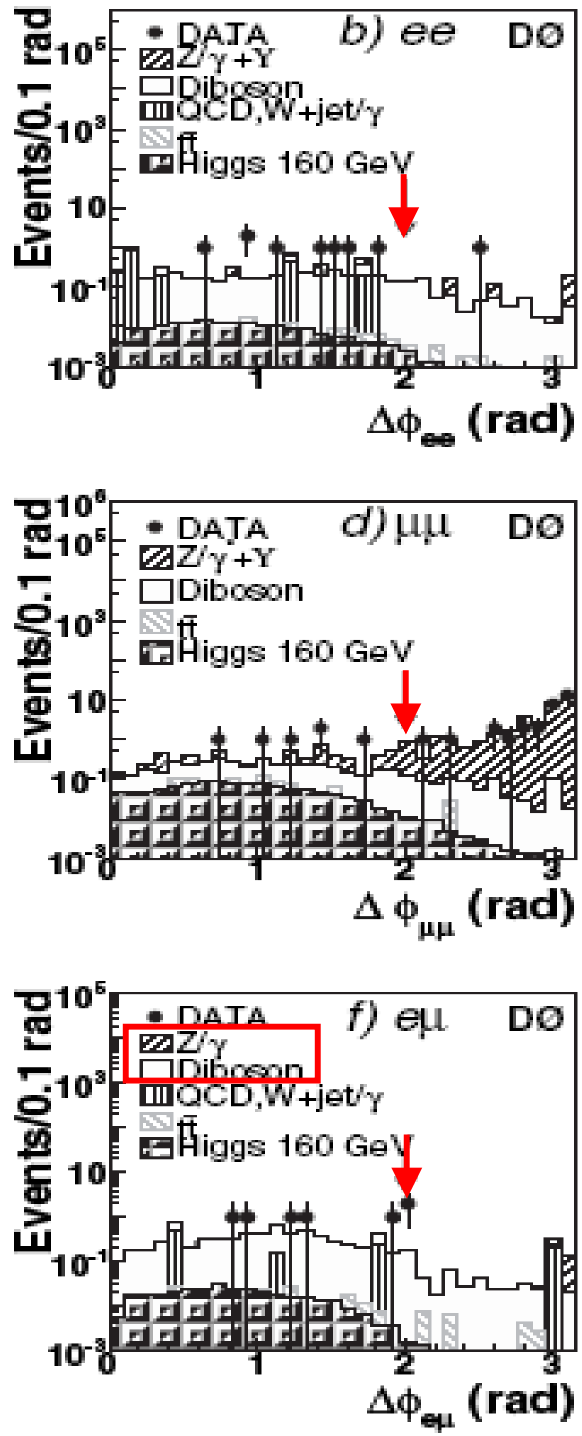
with ll= ee,$\mu\mu$,eμ → single high p_T lepton or dilepton triggers: integrated luminosity 325 pb^{-1}

Data Selection: 2 isolated leptons at $|\eta| < 3.0$ (e) /2.0(μ) with opposite charges and p_T > 20 and 15 GeV; $\not{E}_T$>20 GeV,

Higgs→ light invariant dilepton mass (<M_H/2) , Sum of p_T consistent with m_H, Minimum M_T ($\not{E}_T$, l) , $\Delta\phi$ < 2 rad

Observed:19 evts; Bkgnd:19.2 ± 1.8
Signal: 0.68 ± 0. 04 (m_H=160 GeV)





Search for H→WW* ee/ eμ channels, 950 pb^{-1}

Full data sets (L=950pb^{-1})

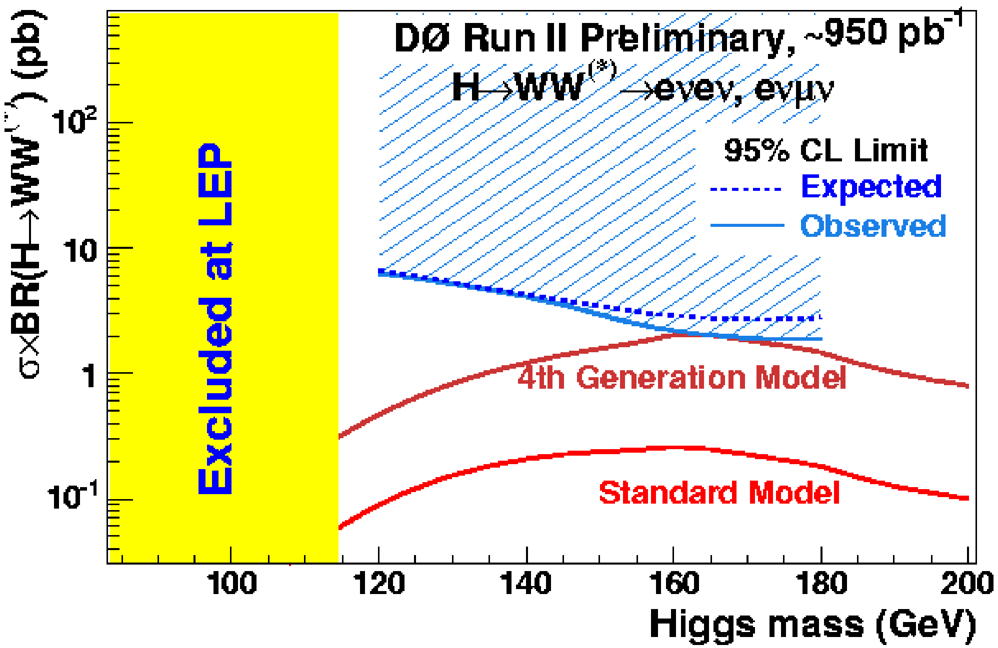
- ee and eμ channel only, $\not{E}_T$ > 20 GeV
- pT(1st)>15 GeV, pT(2nd)> 10GeV
- Veto on Z/g*→ll, and on energetic jets as before

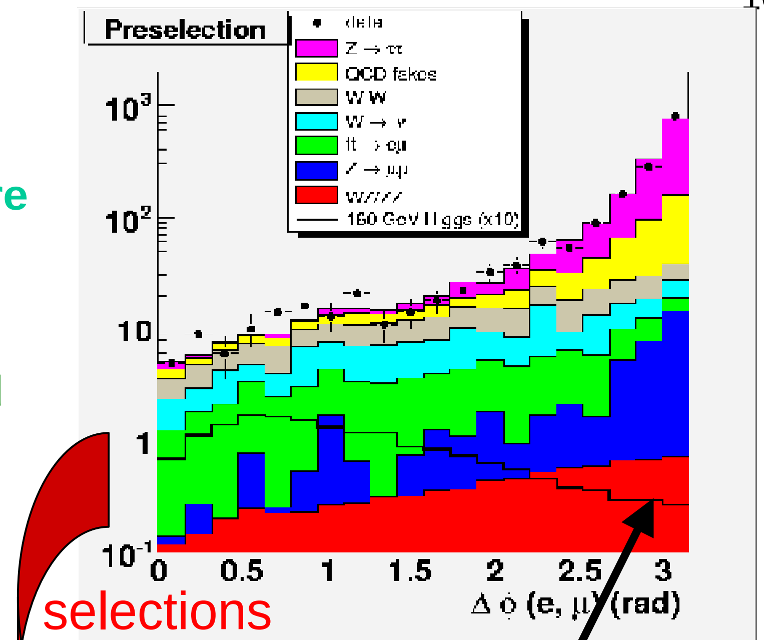
example: M_H = 160 GeV:

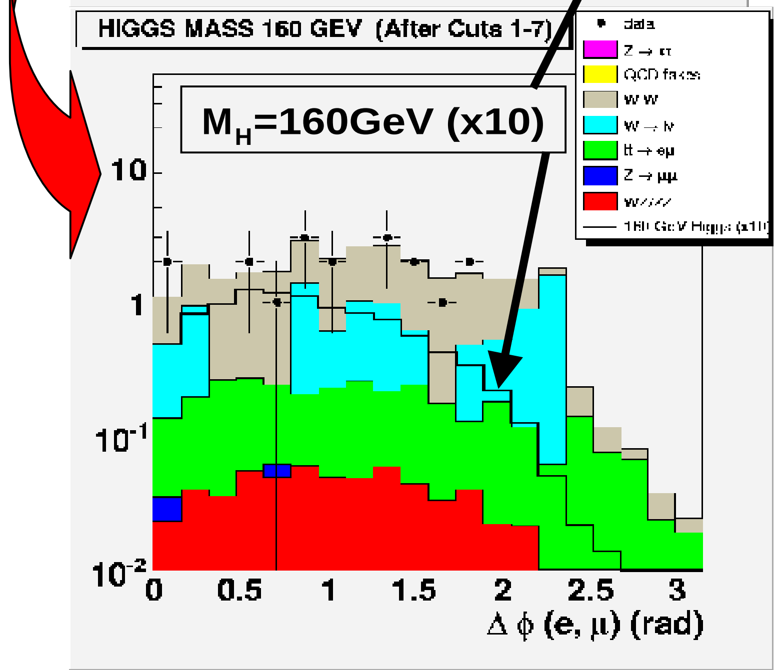
- Expected signal: 1.4 +/- 0.14 events
- 28 events observed, 34.7+/ 5.5 (stat) predicted
- Bkg systematic uncertainty: 15%

95% C.L. limits using CLs method

- 4th Generation Model starts to be excluded







WH→WWW* →lνl'νX (l, l' = e, μ)

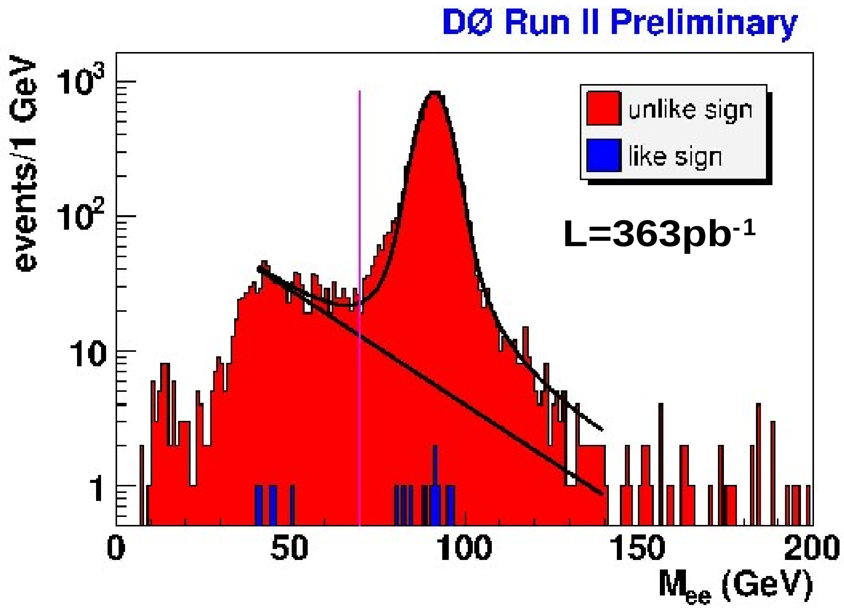
Event Selection

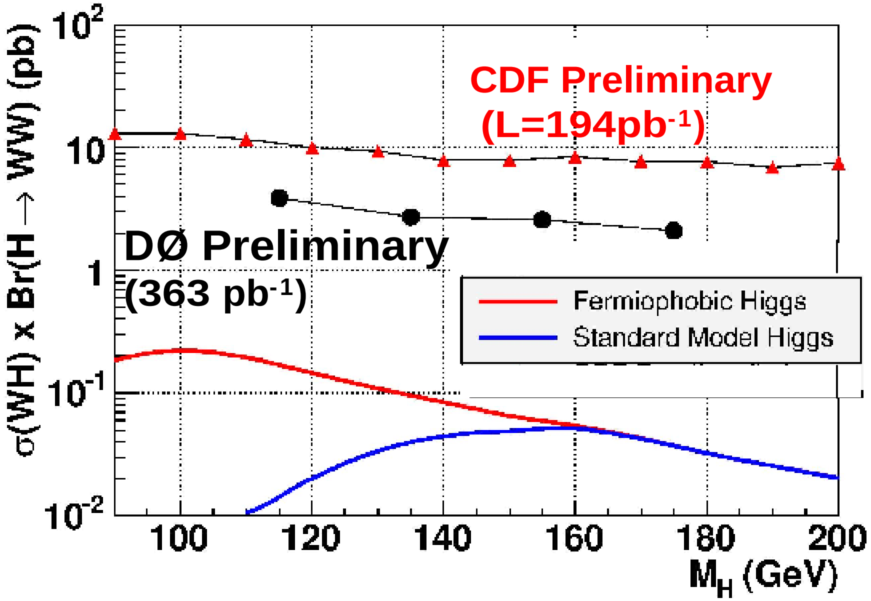
- Same charge di-lepton from W's
  (one from H→WW, the other from prompt W)
  →Suppress SM backgrounds
- p_T (lepton)> 15 GeV, |η| < 1.1/2.0
- $\not\!E_T$ > 20 GeV

Main backgrounds

- WZ production → obtained from MC
- Charge flip from Z/γ* →ll, WW, and tt→llX → derived from data
- QCD multijet, W+jets → data

	observed	expected	ε % (MH=155GeV)
ee	1	0.70 ± 0.08	0.12 ± .006
eμ	3	4.32 ± 0.23	0.28 ± 0.02
μμ	2	3.72 ± 0.75	0.20 ± 0.02





Higgs Search Strategies: Low Mass

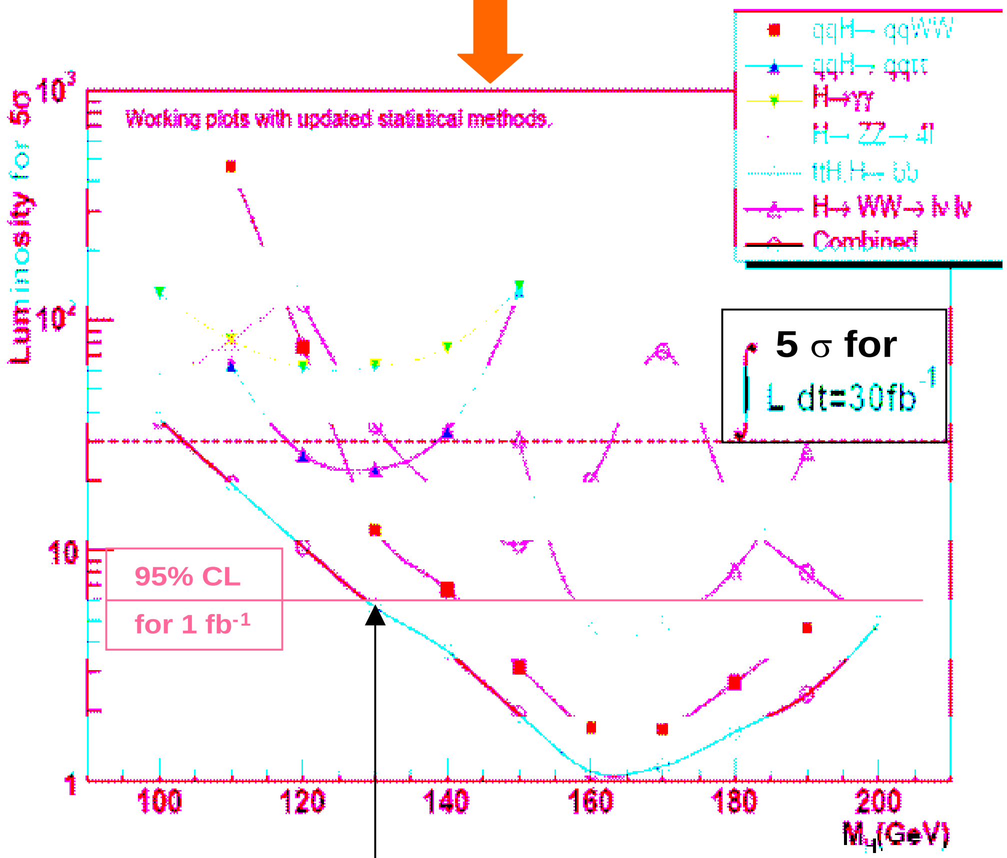
M_H < 135 GeV: H → bb

Higgs produced in gluon fusion has too large QCD/bb background

ATLAS update
(working plot)

Search for (W/Z)H production where W/Z decay leptonically

- qq′ → W* → WH → ℓνbb
  - Bkgd: Wbb, WZ, tt, single top
- qq → Z* → ZH → $\ell^+\ell^-$bb
  - Bkgd: Zbb, ZZ, WW, tt
- qq → Z* → ZH → ννbb
  - Bkgd: QCD, Zbb, ZZ, tt



Identify leptons (e/μ) and missing transverse energy from neutrinos

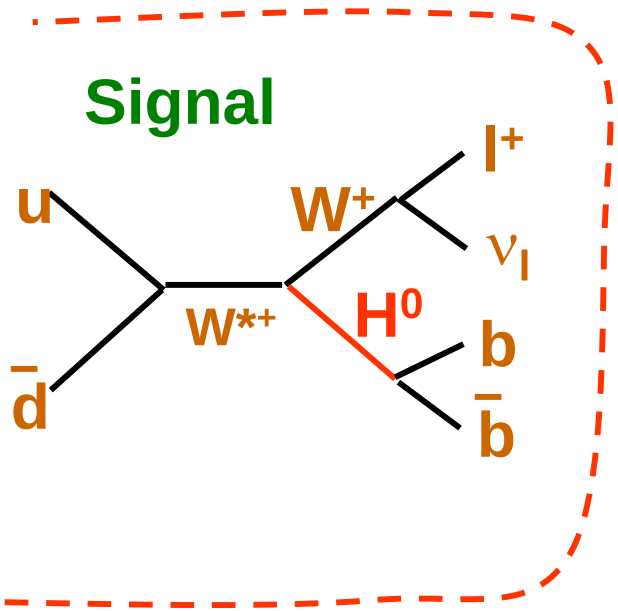
Tag b-jets

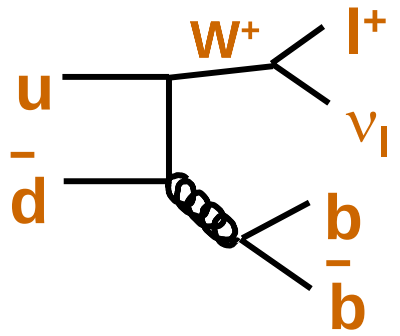
Disentangle H → bb peak in di-b-jet mass spectrum

ALSO DIFFICULT AT LHC !!!!! →

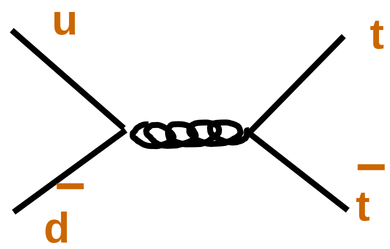
At 95% CL with 1 fb^{-1}, exclude only above 130 GeV, with 3 fb^{-1} → 115 GeV 15 fb^{-1} needed for discovery @ 115 G.

SM Higgs Searches @ Tevatron: WH→lνbb

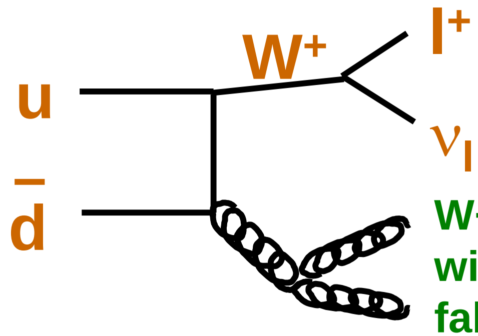




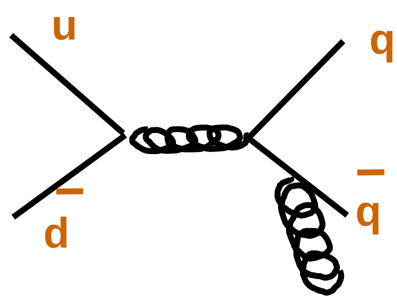
Large background (also Wc$\bar{c}$)



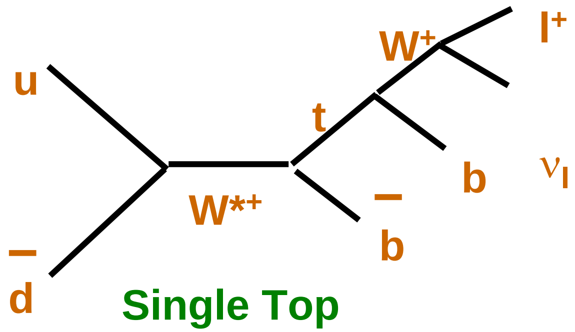
ttbar : Jets+leptons from W decay



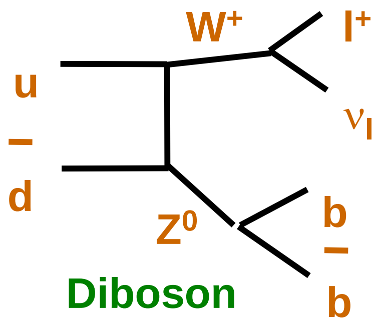
W+2 light jet with one/two false b-tag



Non-W from QCD



Single Top



Diboson

and Non-W from EW ,
e.g. all Zbb processes
In which one lepton is lost

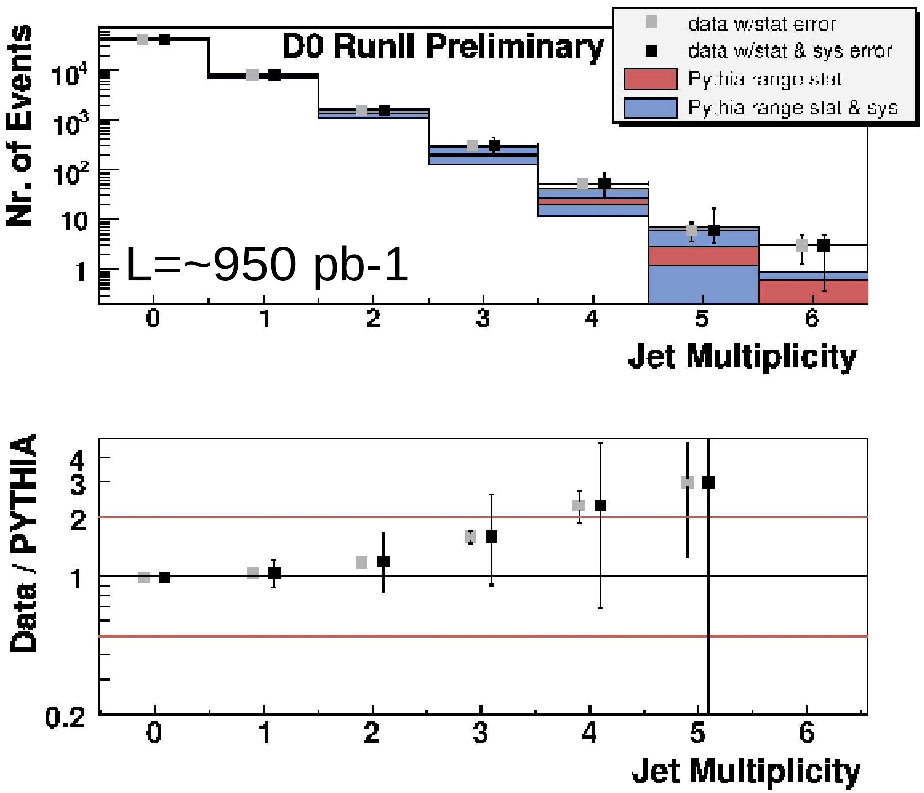
Search for WH,ZH ➔ Z/ γ^* → ee + jets

Comparison of jet multiplicities and distributions in data and MC:

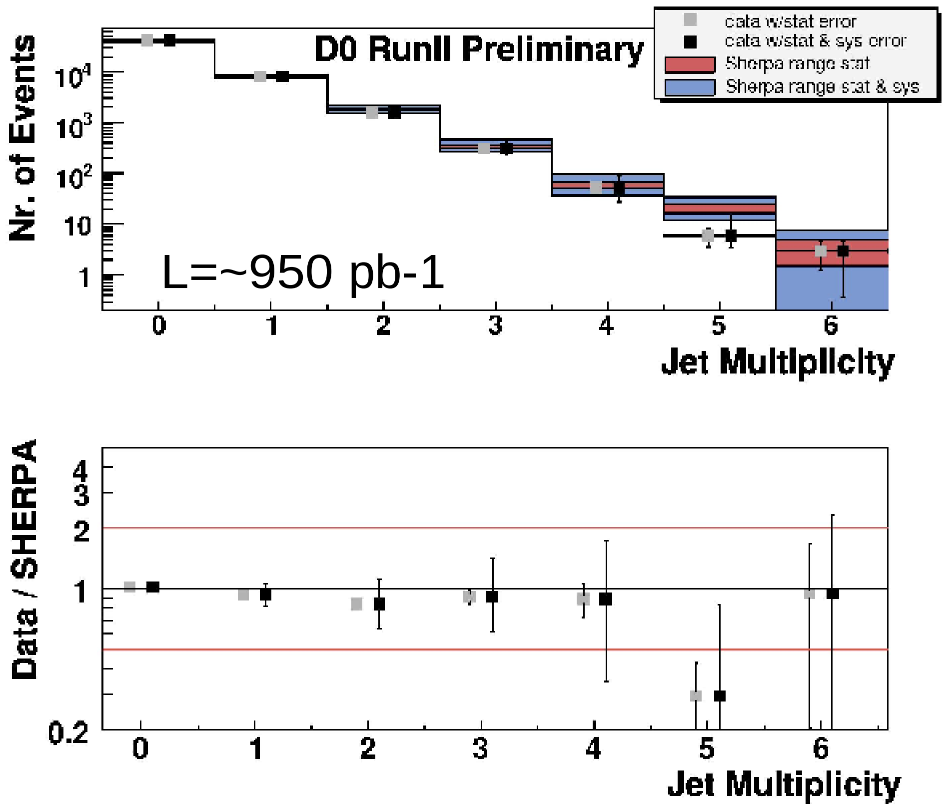
- Pythia 6.319 vs. Sherpa 1.0.6
- Sherpa : Matrix Element + Parton showers, using CKKW algorithm

- Event selection includes:
  - Electron $p_T > 25$ GeV, $\eta<2.5/1.1$
  - 70 GeV < M_{ee} < 120 GeV

Pythia gives bad description of high multiplicity



Sherpa agrees well with data for all jet multiplicities



Search for WH ➔ W+ jets Production

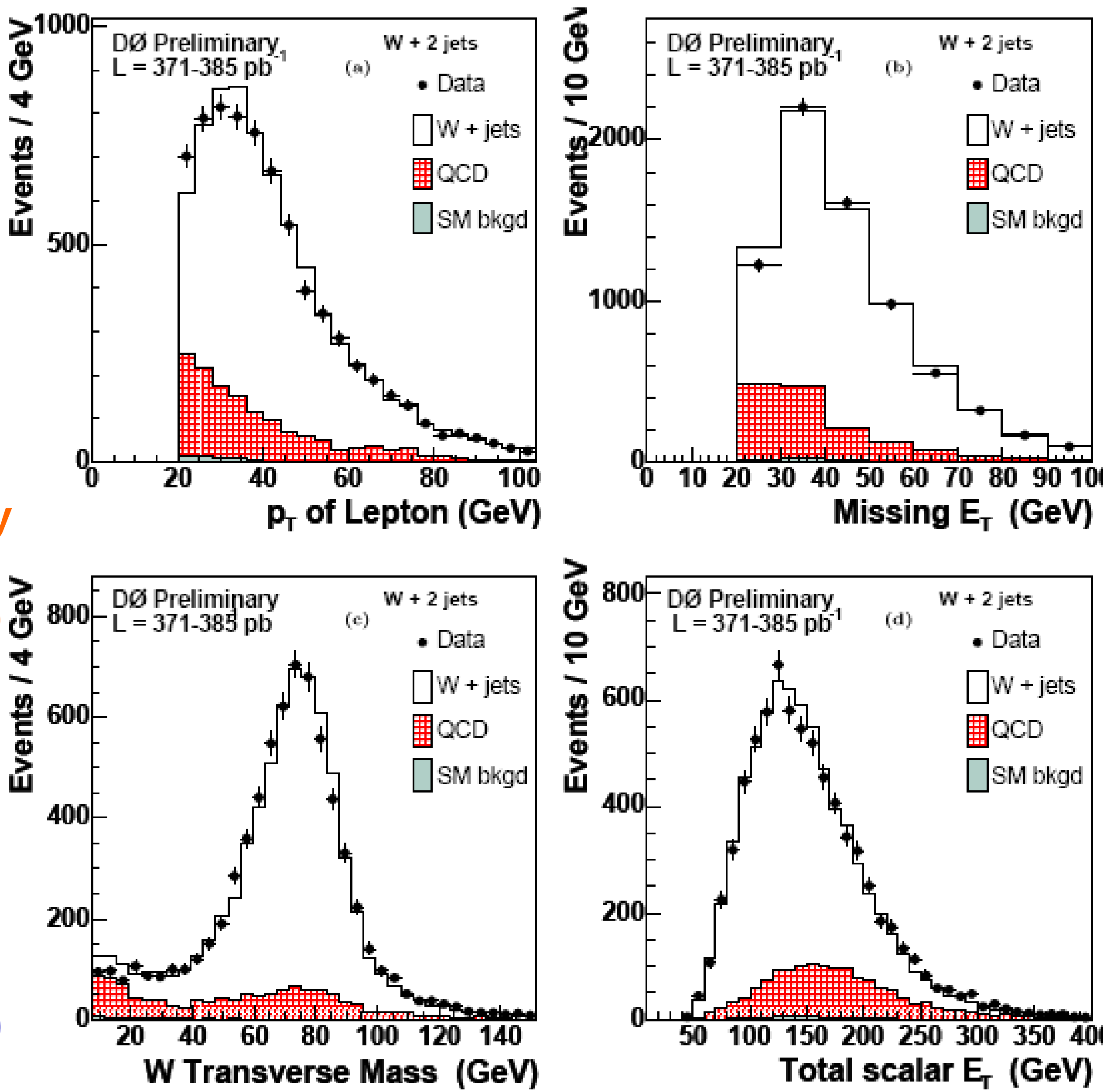
W+ 2 jets selection

371/385 pb^{-1} for e/mu channels

e/muon: p_T > 20 GeV, $|\eta|$<1.1/2.0
Missing E_T > 25 GeV
2 Jets: p_T > 20 GeV, $|\eta|$<2.5

All backgrounds absolutely normalized, except for ALPGEN+Pythia(W+2jets) normalized to data (but within 10% of MCFM NLO calculation), and non-W from QCD, derived from data

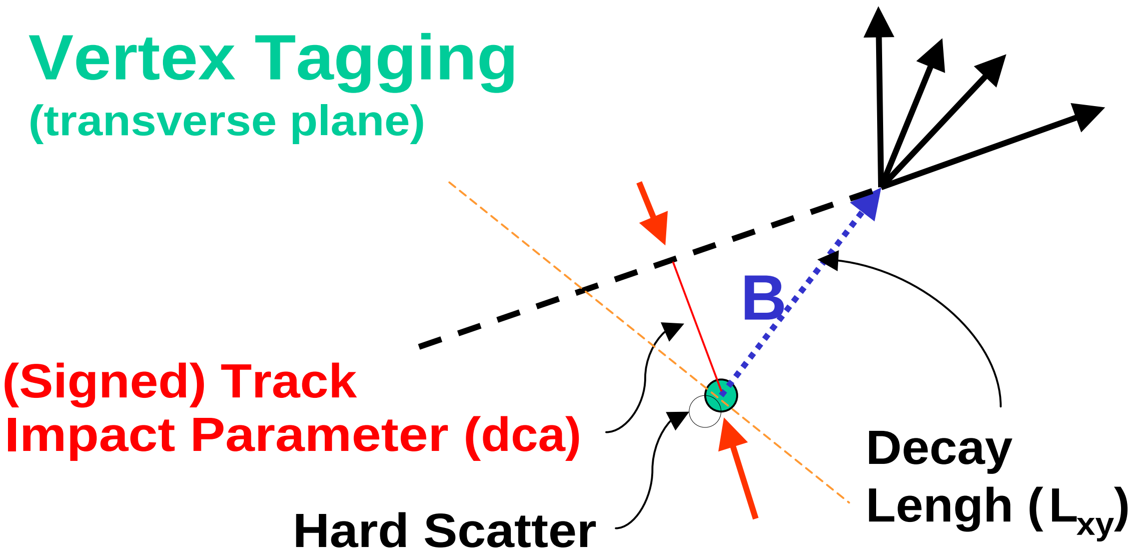
➔2540 selected events
(2580 ± 630 expected)



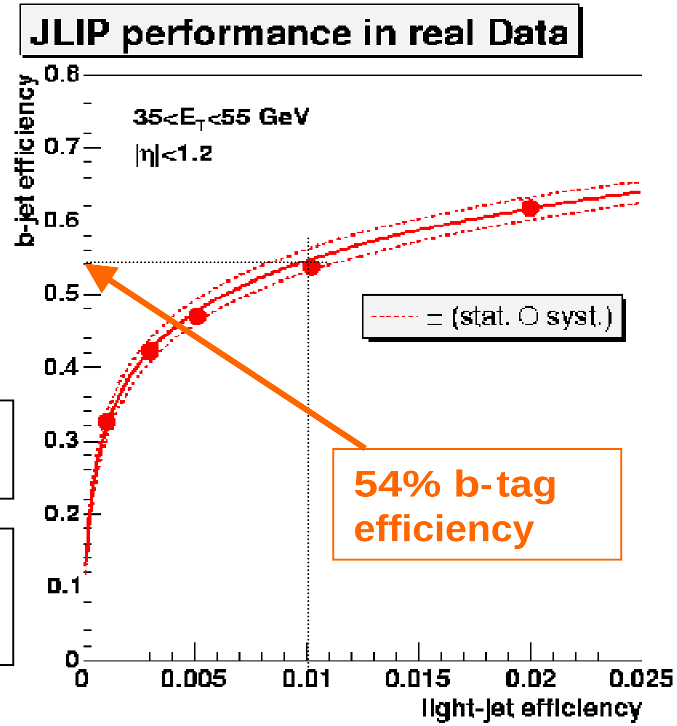
Tagging b-quarks (B-hadrons)

Vertex Tagging

(transverse plane)



- Top, Higgs have b-quark jets → contains a B hadron
  - Travels some distance from the vertex before decaying
  - -With charm cascade decay, about 4.2 charged tracks



Several mature algorithms used:

3 main categories:

- Soft-lepton tagging
- Impact Parameter based
- Secondary Vertex reconstruction

Impact Parameter Resolution

Decay Length Resolutin

Now analyzing separately one b-tag (allowing low mistag) and two b-tag events (allowing larger mistag) to optimize sensitivity

Search for W$b\bar{b}$/ WH Production

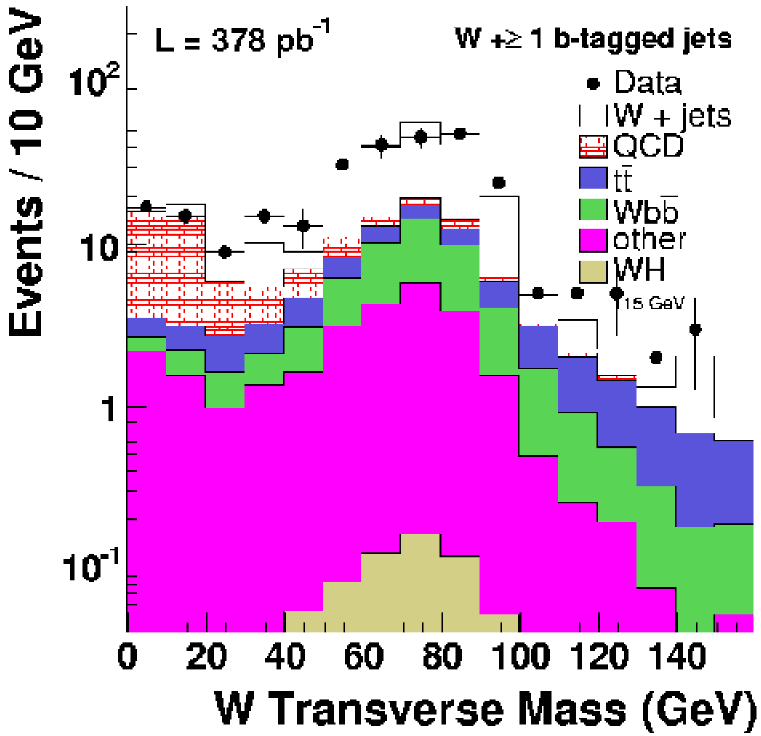
370/385 pb^{-1} sample e/mu+$\not{E}_T$+2 jets

e/muon: p_T > 20 GeV, |η|<1.1/2.0
Missing E_T > 25 GeV
2 Jets: p_T > 20 GeV, |η|<2.5

Wbb dominant backgd for WH, W peak now also visible in W+2b-tag events . Good description by ALPGEN+PYTHIA showering, and full detector simulation. Normalized to NLO x-section (MCFM for Wbb)

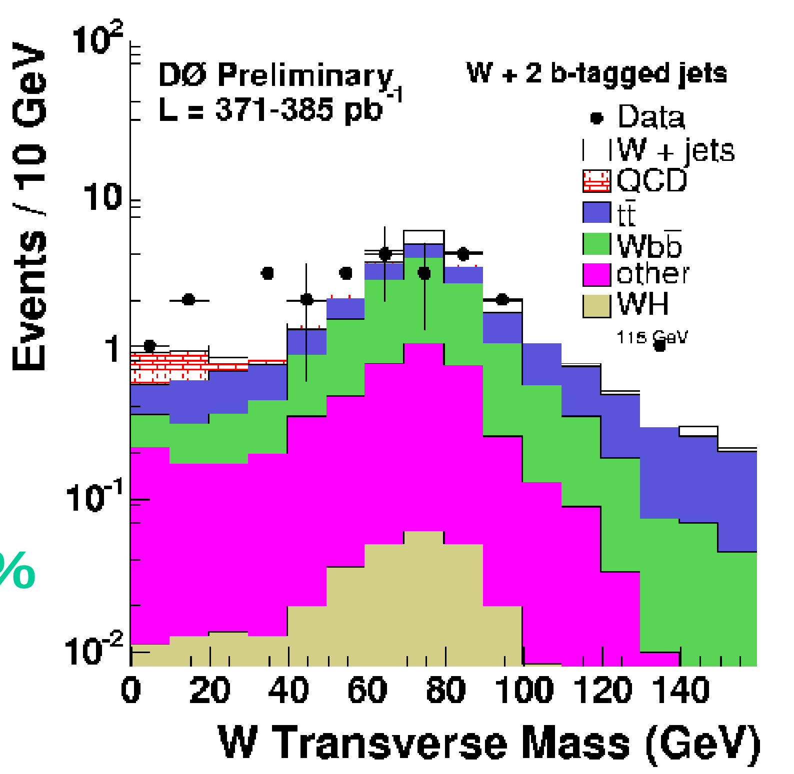
Apply b-tagging ➔

≥1 tag: 112 evts (111.8 ± 17 exp.) **≥2 tag: 25 evts (27.9 ± 4.2 exp.)**



Data well described by MC

Total syst. error ~15 %



WH→lνbb

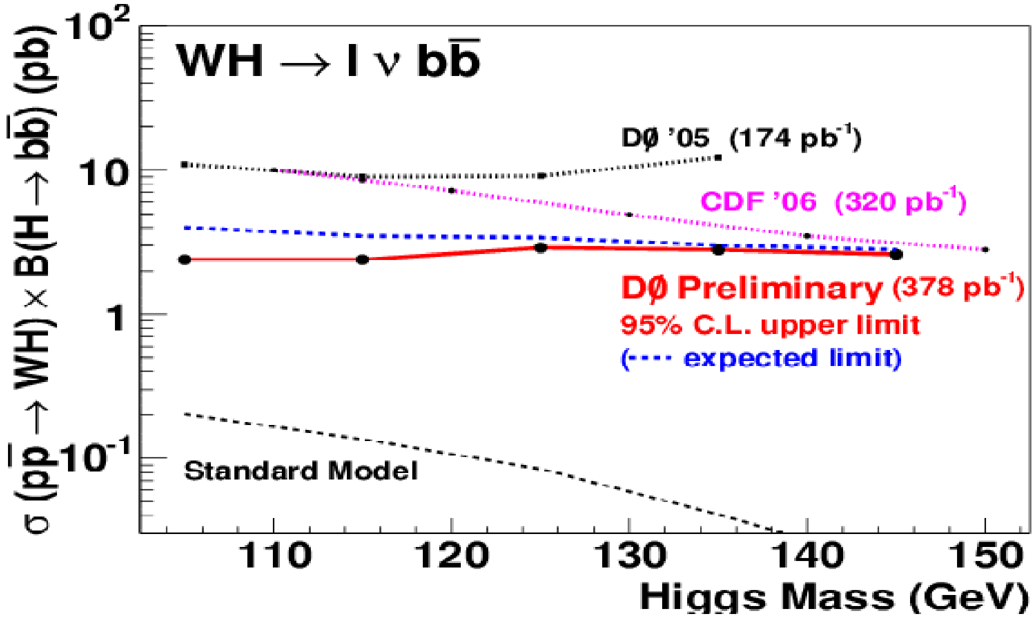
Limit from combined channels: e, μ, ST, DT

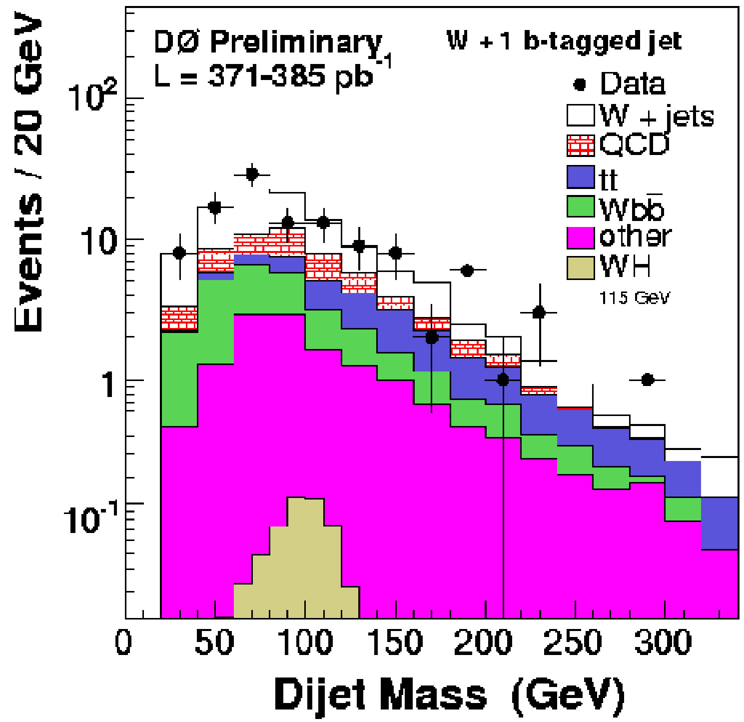
look in window: m_H = 115 GeV, 75<m_{jj}<125 GeV:

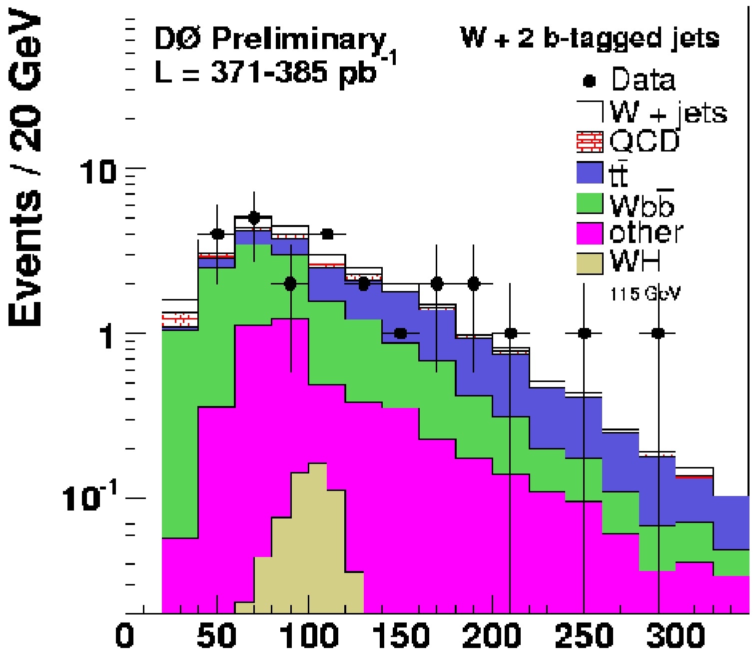
32 ST events observed, 0.3 Higgs events expected

6 DT events observed, 0.3 Higgs events expected

Limit at 115 GeV: 2.4 pb, (12 times higher than SM)



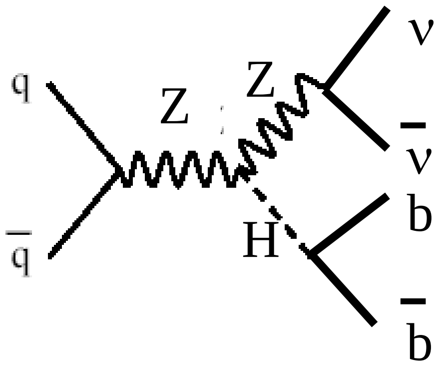




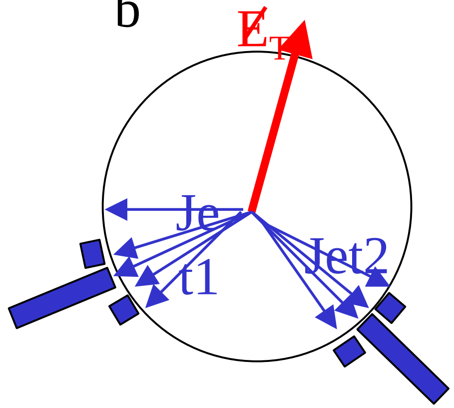
This new result is 4 times better than our previous WH published result on 174 pb^{-1}, i.e. 16 times in equivalent lumi, while luminosity used is only the double!

- Include new muon analysis
- Re-optimized electron analysis (looser selection)
- Separate exclusive single b-tag and double b-tag analysis, with optimized tagging efficiency

ZH→ννbb (WH→ℓνbb) searches

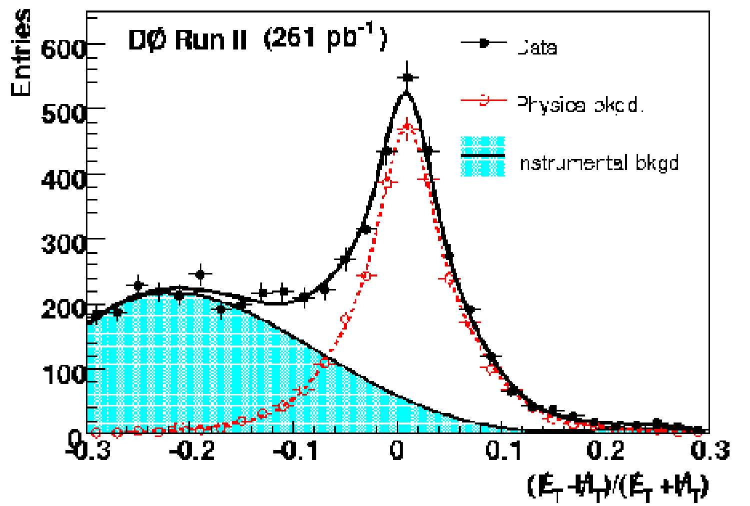


- Missing E_T from Z→νν and 2 b jets from H→bb
  - Large missing E_T > 50GeV
  - 2 acoplanar b-jets with $E_T > 20$ GeV, $|\eta| < 2.5$
- Backgrounds
  - "physics"
    - W+jets, Z+jets, top, ZZ and WZ
  - "instrumental"
    - QCD multijet events with mismeasured jets
      - Large cross section & small acceptance

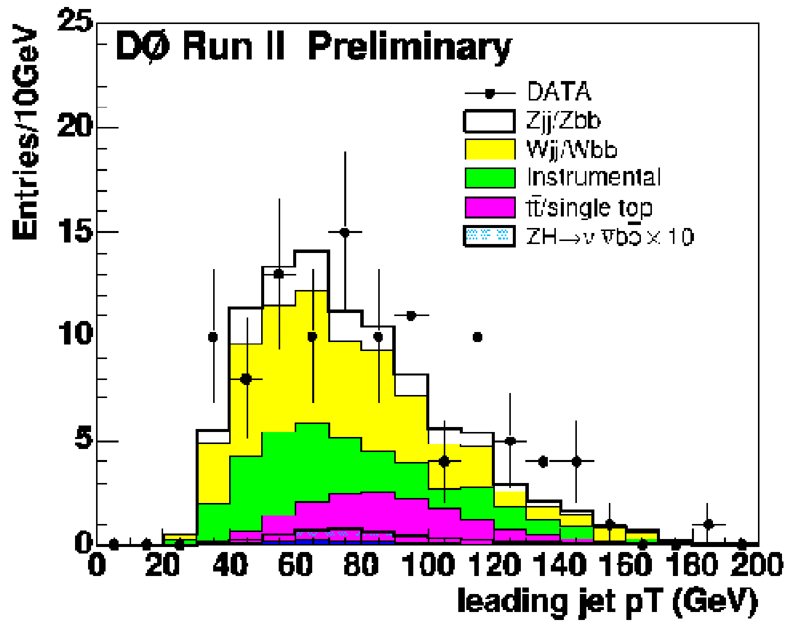


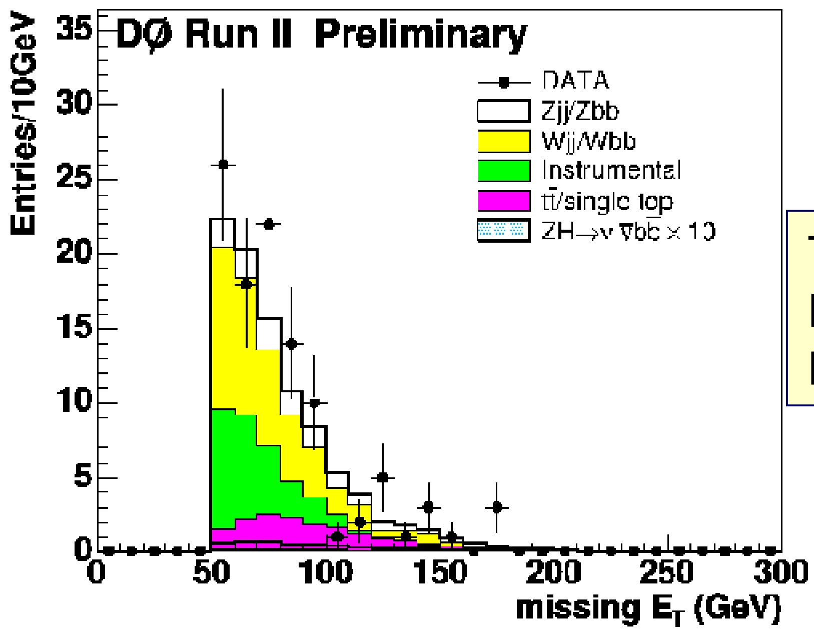
- Strategy
  - Trigger on events with large missing H_T (vector sum of jets' E_T)
  - Estimate "instrumental" background from data, physics bkd from simulation
  - Search for an event excess in di-jet mass distribution

- Reduce "instrumental" background
  - Jet acoplanarity $\Delta\phi$(dijet) < 165°
  - define missing energy/momentum variables
    - $\not{E}_T$ calculated using calorimeter cells
    - $\not{H}_T = -|\Sigma p_T(\text{jet})|$ ... jets
  - And select on their asymmetry
    - $\text{Asym}(\not{E}_T, \not{H}_T) = (\not{E}_T - \not{H}_T)/(\not{E}_T + \not{H}_T)$

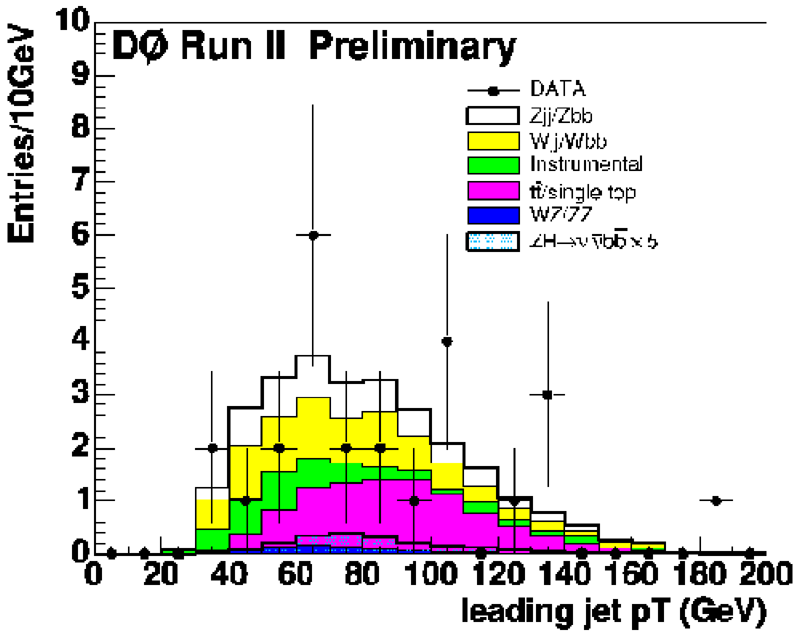


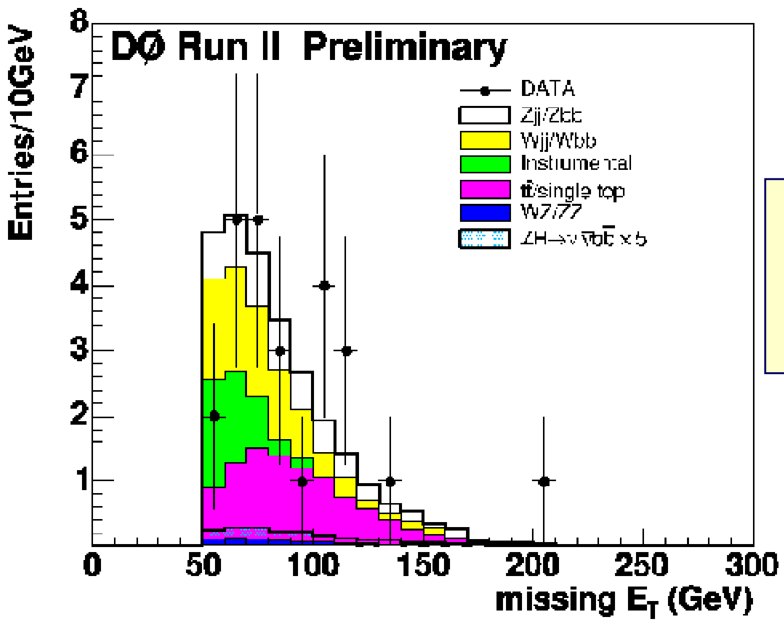
ZH: single and double b-tag events





Total ST:
Data: 106
Expect: 94.5





Total DT:
Data: 25
Expect: 27.0

ZH →ννbb / Dijet mass

Improved event selection includes:

- Two acoplanar jets with:
- $E_T > 20$ GeV
- $E_T^{miss} > 50$ GeV
- Sum of scalar jet $E_T < 240$ GeV

$m_H = 115$ GeV, $75 < m_{jj} < 125$ GeV:

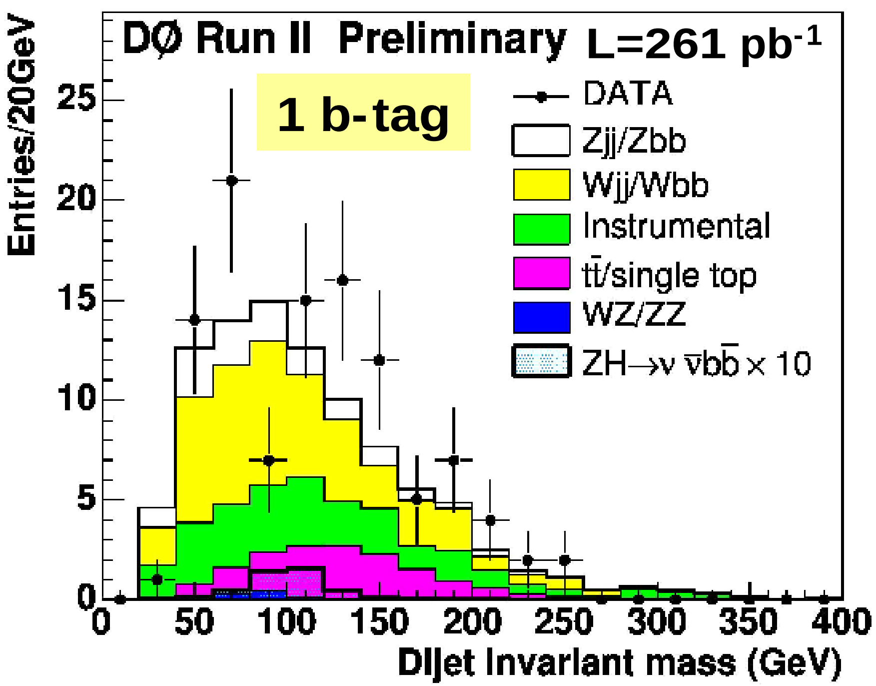
- 11 events observed
- 9.4 +/- 1.8 predicted
- $s_{95} = 4.3$ pb

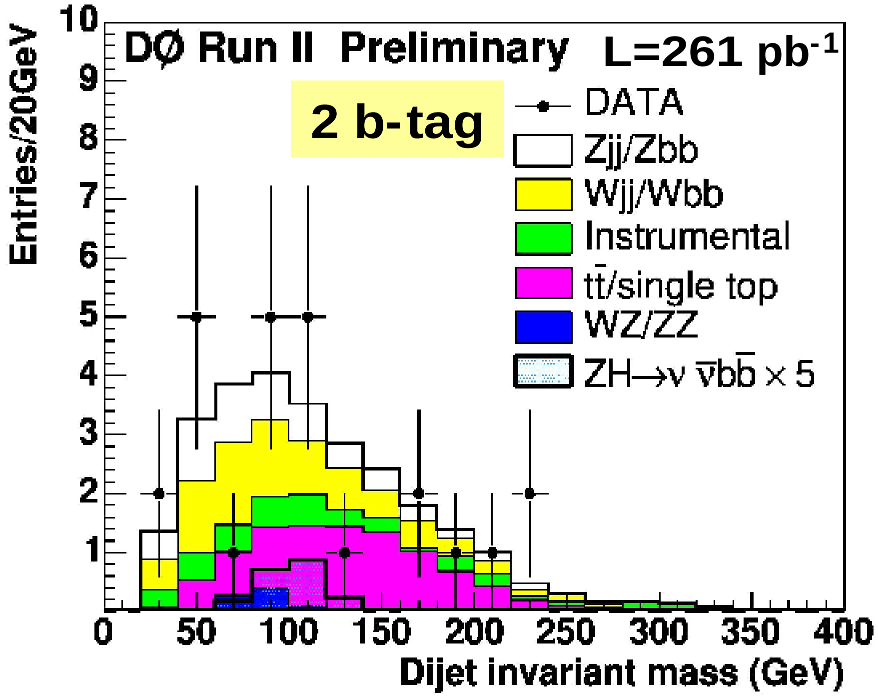
Bkgd. composition (%)	
Wjj/Wbb	30
Zjj/Zbb	20
Instrumental	15
Top	32
WZ/ZZ	3

Separate analysis for single and double b-tagged events, like in WH.

- Increased statistics

Same analysis used for WH → lνbb with missed lepton→ improves the combined WH limit





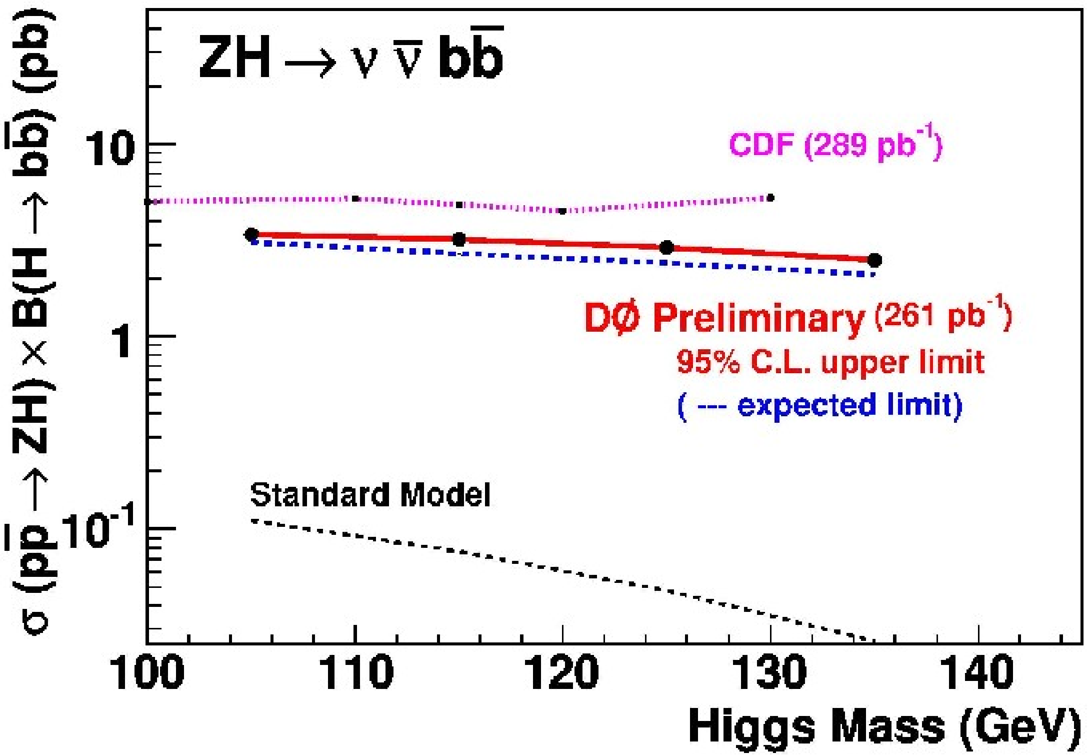
ZH→ννbb (WH) / Systematics & Results

TABLE V: Expected and observed 95% C.L. limits for the combined (double b-tagged and exclusive single b-tagged analysis) $ZH \to \nu\bar{\nu}b\bar{b}$ and $WH \to l^{\pm}\nu b\bar{b}$ final state in fully simulated Higgs mass points.

Channel	105 GeV	115 GeV	125 GeV	135 GeV
ZH Combined Expected (pb)	3.1	2.7	2.4	2.1
ZH Combined Observed (pb)	3.4	3.2	2.9	2.5
WH Combined Expected (pb)	7.6	6.3	6.0	5.0
WH Combined Observed (pb)	8.3	7.5	7.4	6.3

Systematic uncertainty, DT (%)

Source	Sig	bkgd
Trigger efficiency	6	6
Jet ID	7	6
JES	7	8
Jet energy resolution	5	2
b-tagging	14	12
Instrumental bkgd.	-	9
Bkgd Cross Section	-	5
Total for DT	**19**	**19**
Total for ST	**14**	**18**



Combined Higgs boson Search

14 independent channels have been combined, taking into account correlated & uncorr. systematics

- WH (e) ST, DT
- WH (μ) ST,DT
- WH ($\not{l}$) ST DT
- ZH ($\nu\nu$) ST,DT
- WWW (ee,eμ,$\mu\mu$)
- WW (ee,eμ,$\mu\mu$)

Source	$WH \to e\nu b\bar{b}$	$WH \to \mu\nu b\bar{b}$	$WH \to \not{l}\nu b\bar{b}$	$ZH \to \nu\nu b\bar{b}$	$WH \to WW^+W^-$	$H \to W^+W^-$
Luminosity	x	x	x	x	x	x
Jet Energy Scale	x	x	x	x		x
Jet ID	x	x	x	x		
Electron ID	x				x	x
Muon ID		x			x	x
b-Jet Tagging	x	x	x	x		
Background σ	x	x	x	x	x	x

(a few more channels to come)

We have used the CLs (LEP) Method

the CL_S confidence interval is a normalization of CL_{S+B}

CL_{S+B} = signal + bkgd hypothesis, CL_B = bkgd only hypothesis

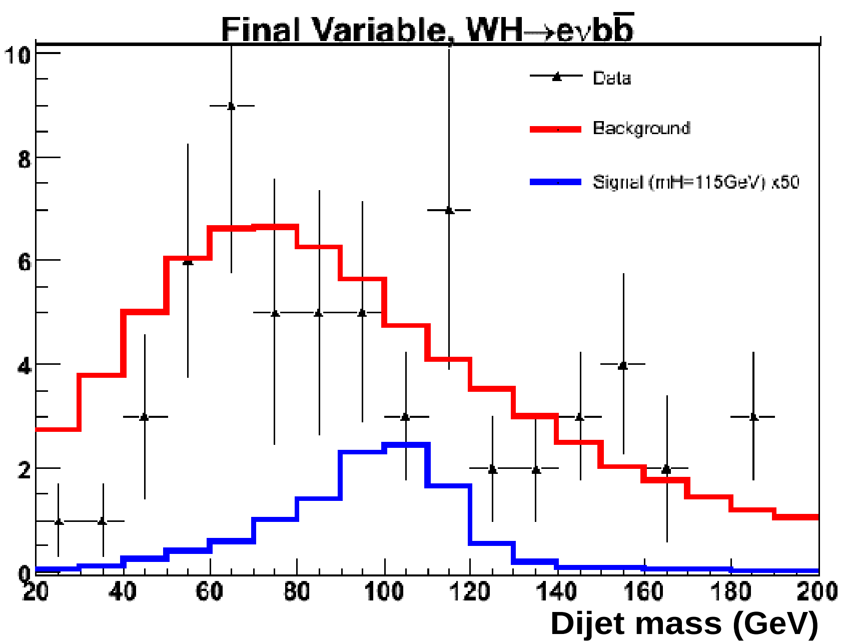
$CL_S = CL_{S+B}/CL_B$: CL_{S+B} & CL_B are defined using a "test statistic"

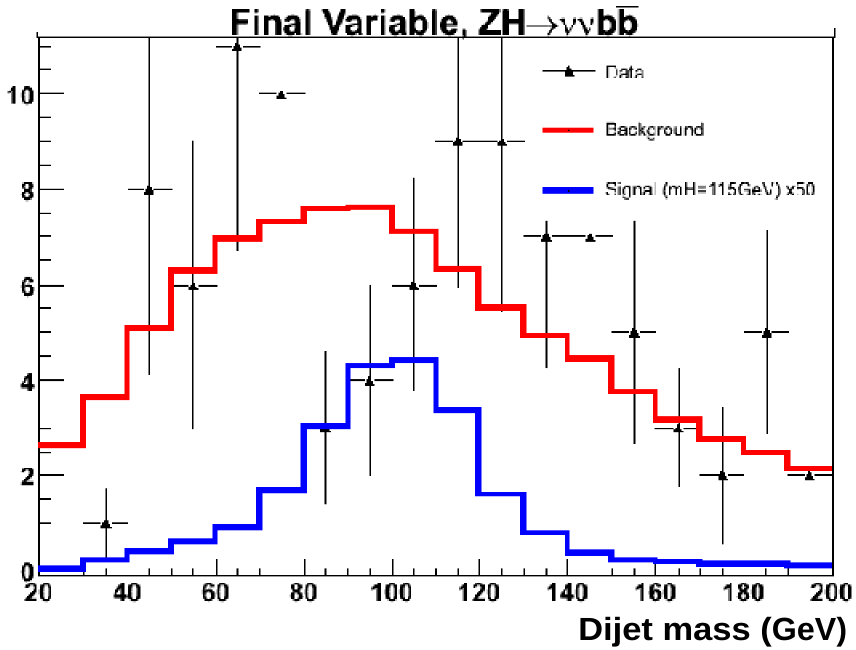
Test statistic used is the Log-Likelihood Ratio (LLR=-2 ln Q)

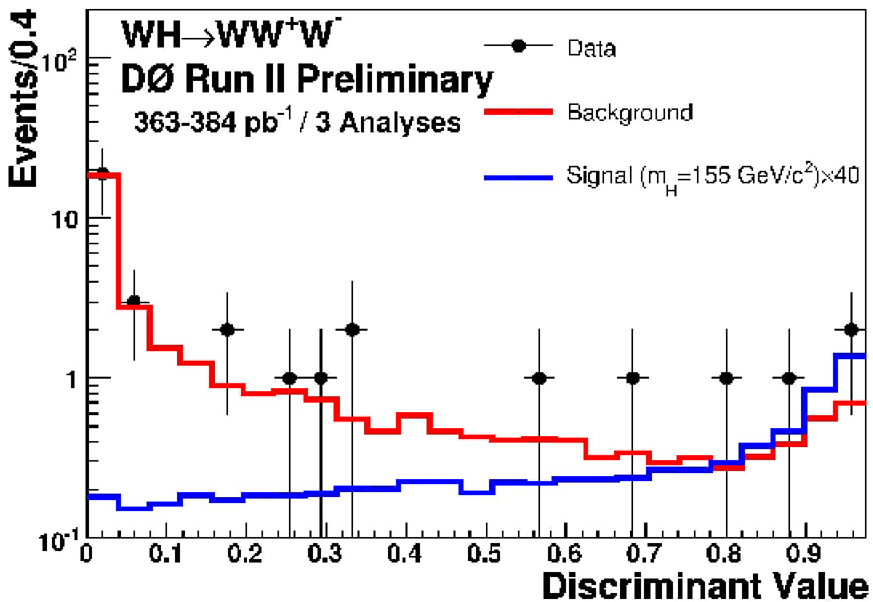
generated via Poisson statistics ($Q=e^{-(s+b)}(s+b)^d/e^{-b}b^d$) s,b,d=sig.,bkd,data)

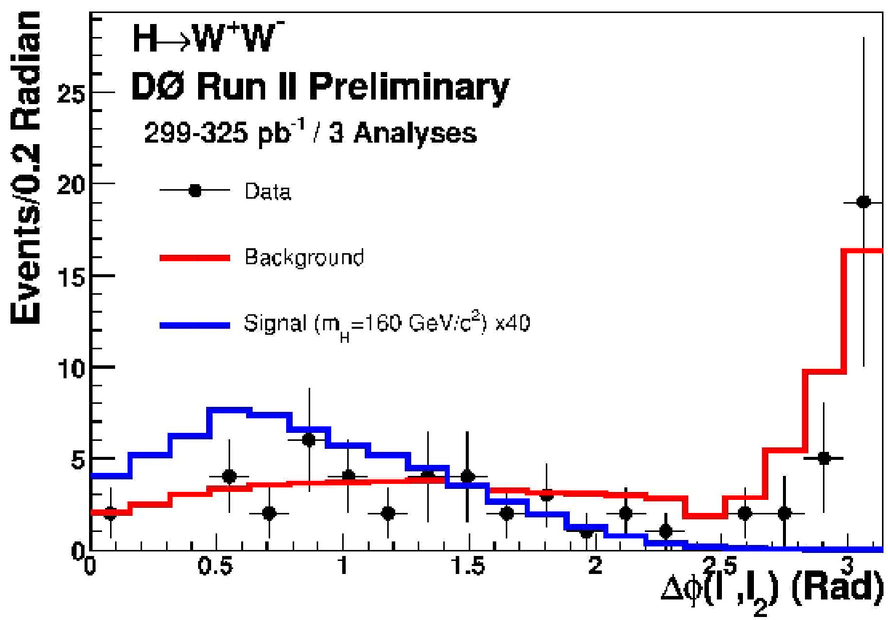
Tevatron Higgs combination effort started with CDF

Example of Input distributions







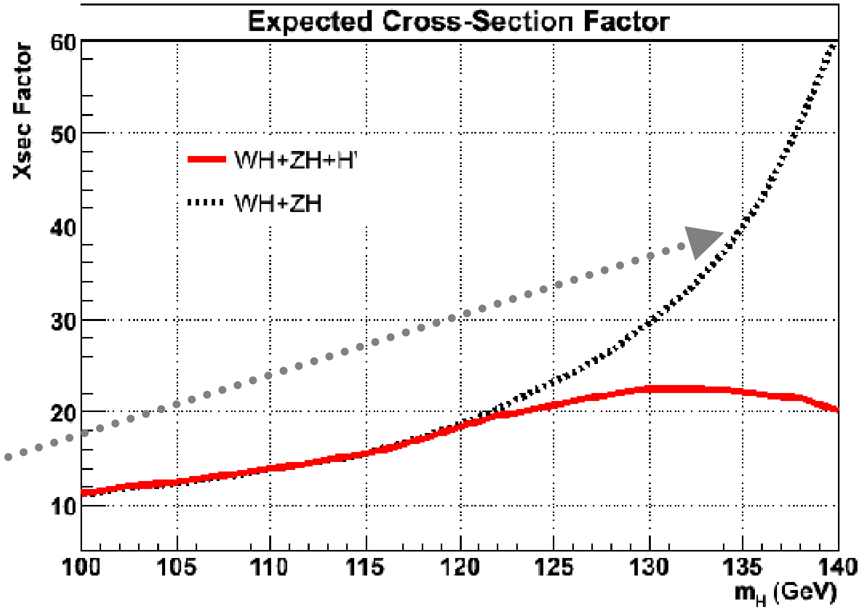


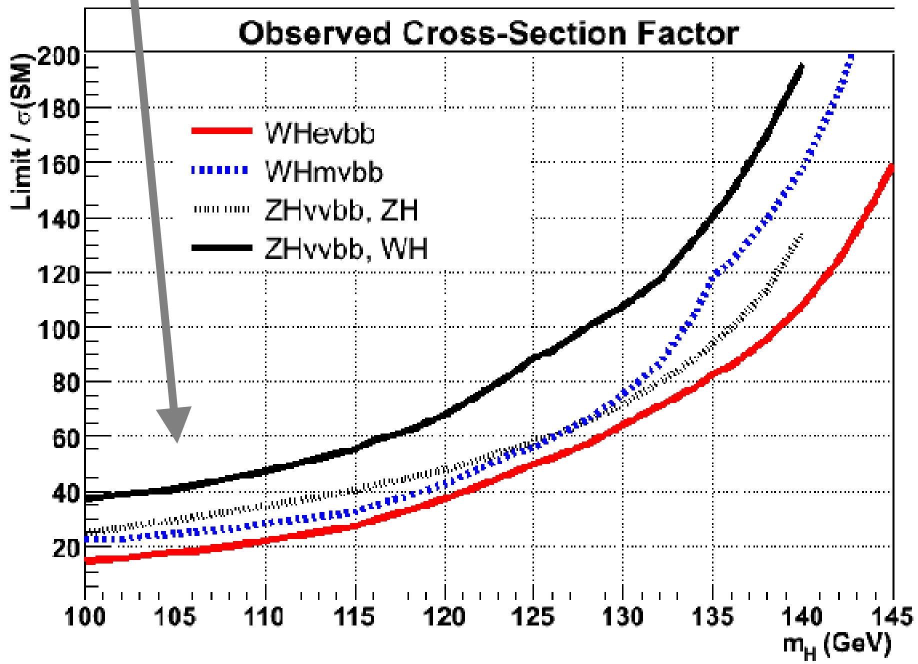
x-sections, Ratios and Combinations at low Higgs mass

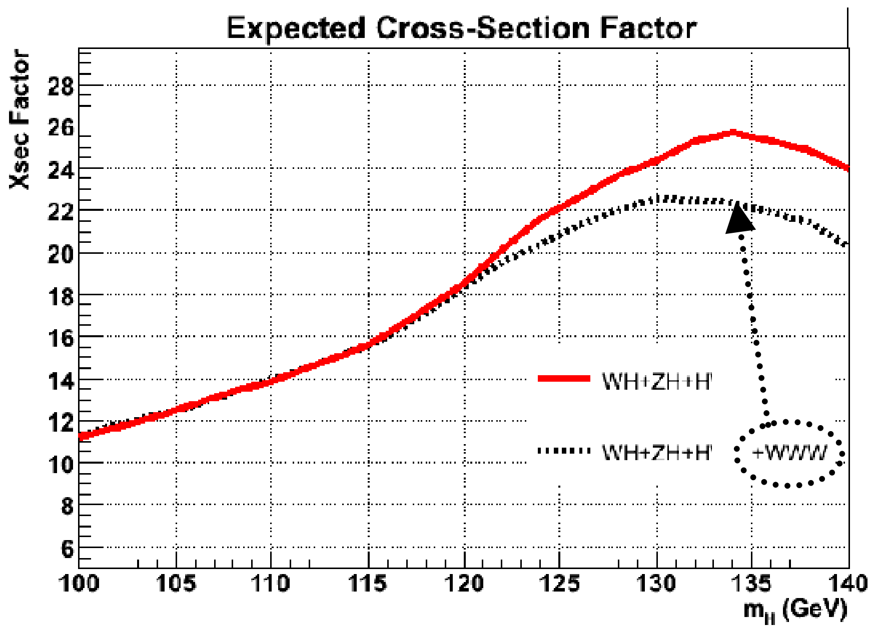
Now presenting the ratio of the 95% CL x-section limit to the SM higgs x-section.

If this "x-section-factor"= 1 ➔ SM Higgs excluded at 95% CL. There is still some way to go…

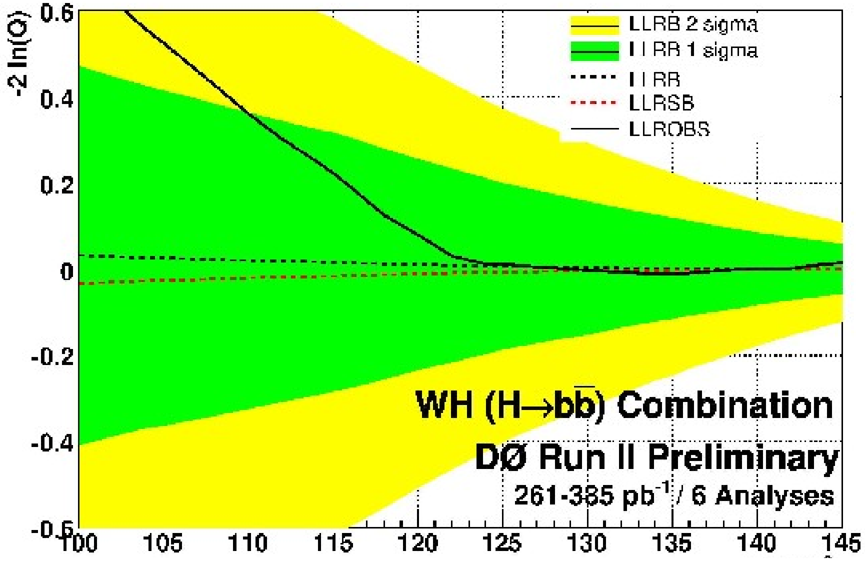
Compare 4 Channels before combining them

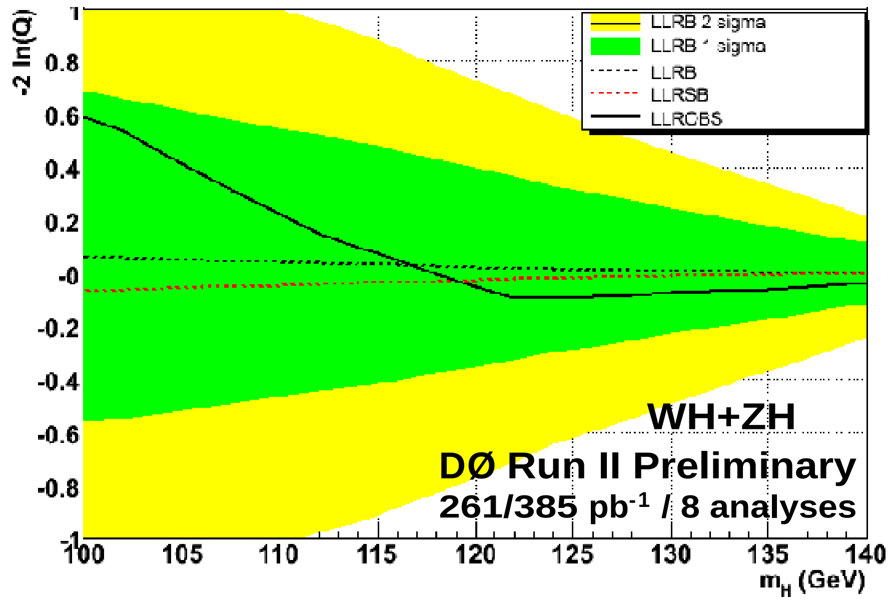


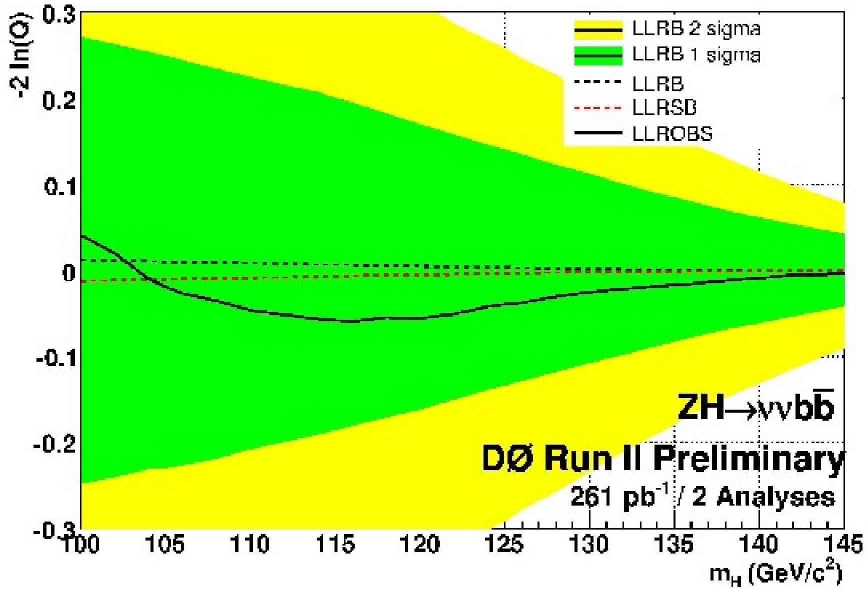


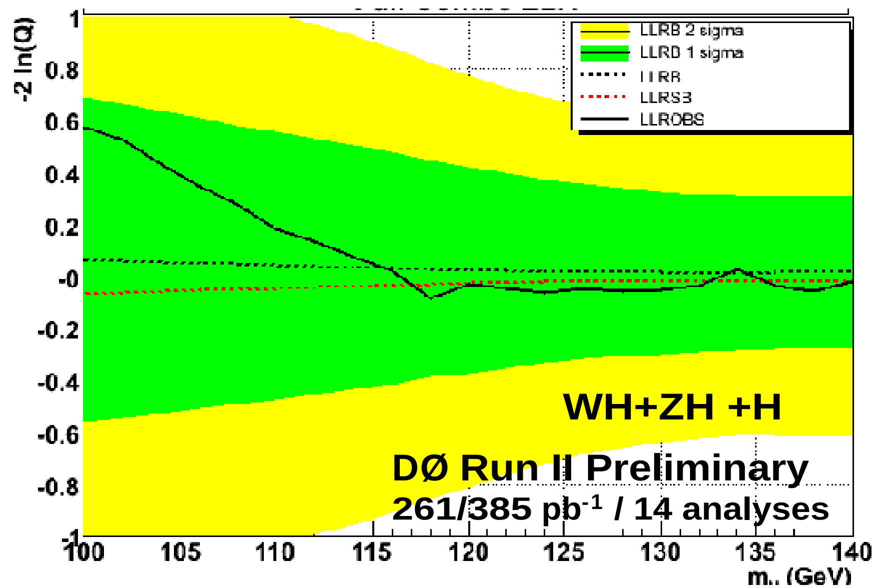


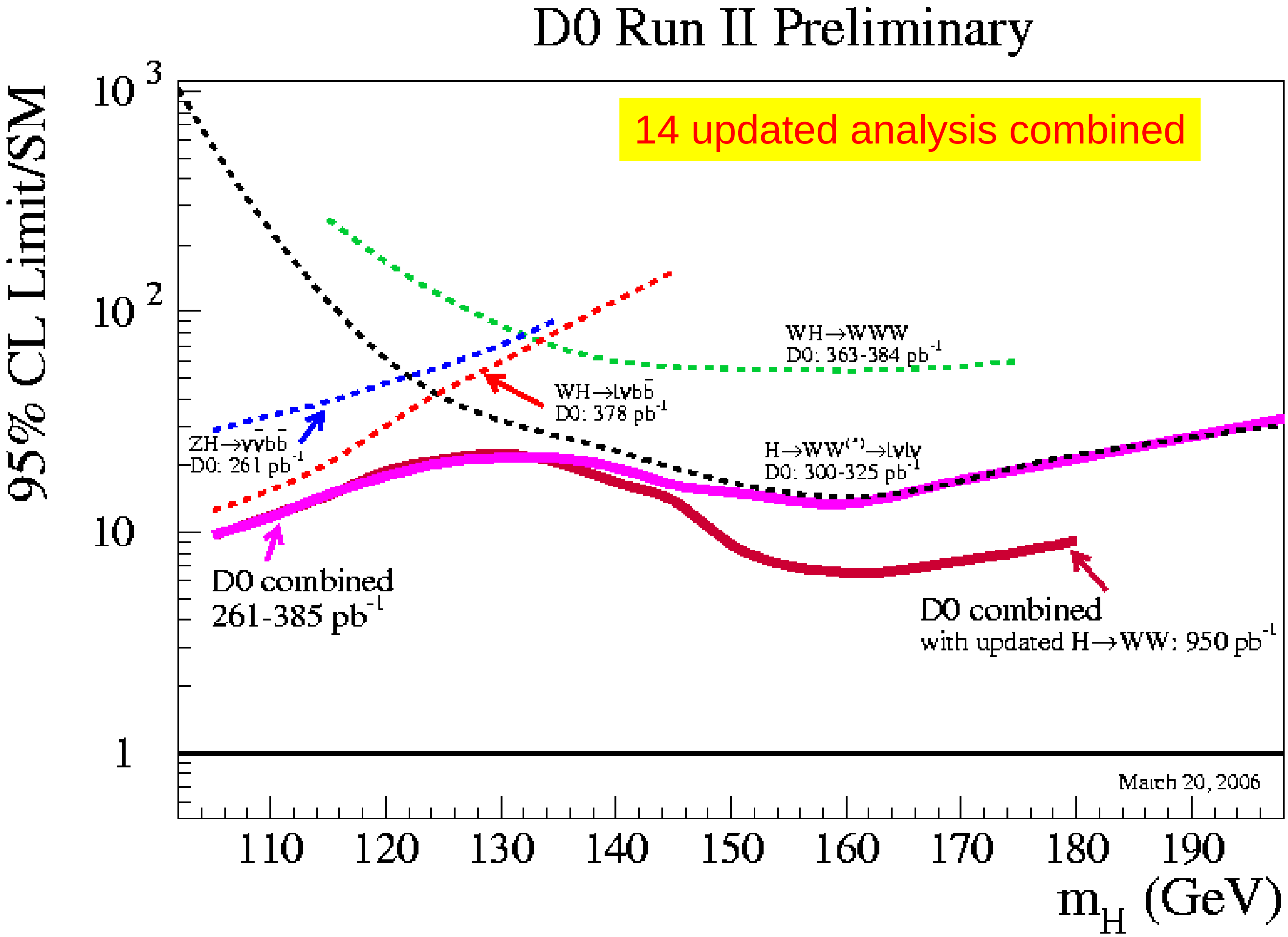
Another View: LLR Plots

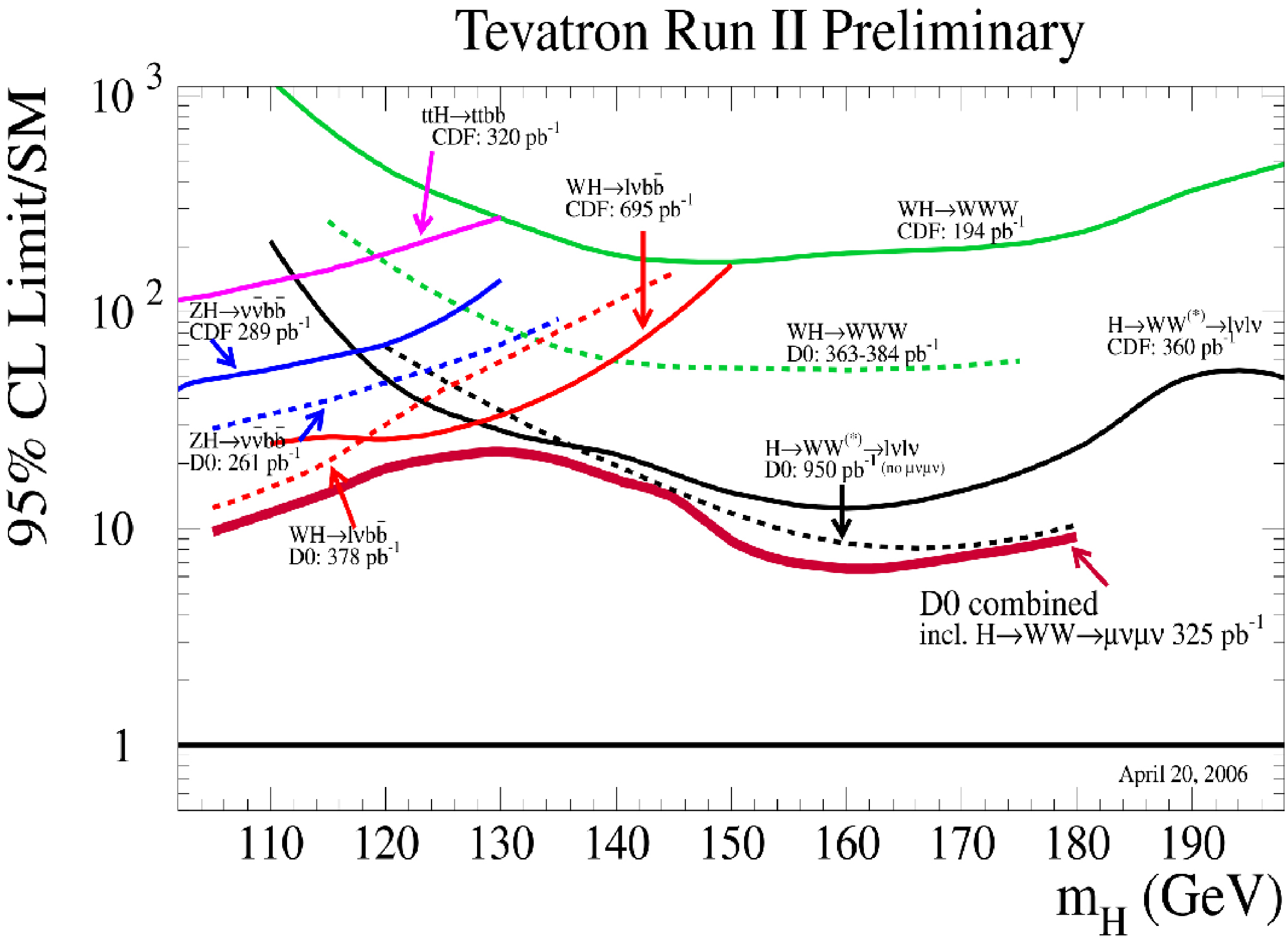




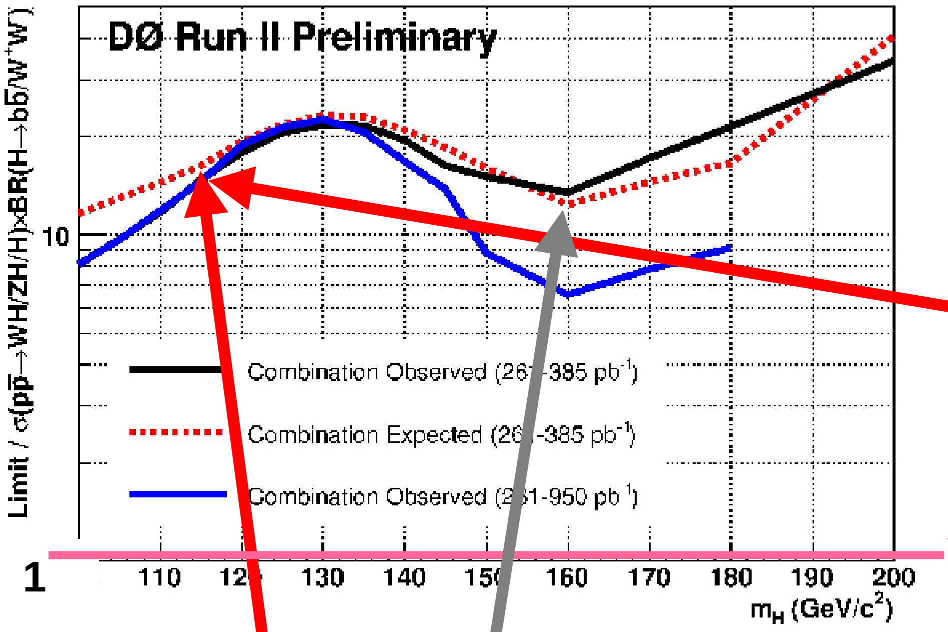





D0 Run II Preliminary
14 updated analysis combined
95% CL Limit/SM
WH→WWW
D0: 363-384 pb-1
WH→lνbb̄
D0: 378 pb-1
ZH→ννbb̄
D0: 261 pb-1
H→WW(*)→lνlν
D0: 300-325 pb-1
D0 combined
261-385 pb-1
D0 combined
with updated H→WW: 950 pb-1
March 20, 2006
110
120
130
140
150
160
170
180
190
mH (GeV)



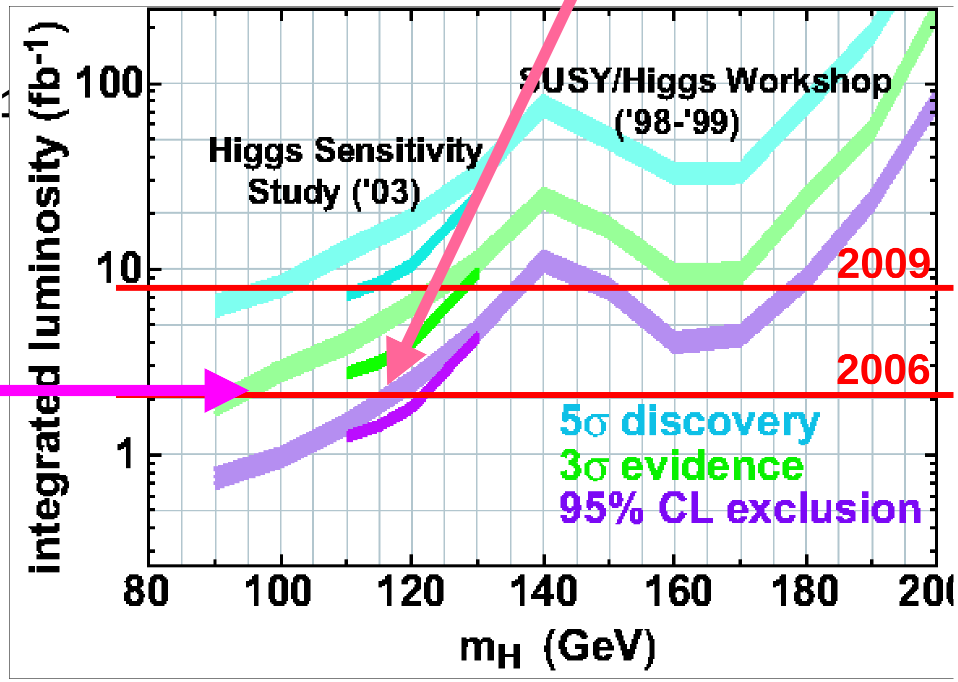
Tevatron Run II Preliminary
95% CL Limit/SM
10^3
10^2
10
1
ttH→ttbb
CDF: 320 pb-1
WH→lνbb̄
CDF: 695 pb-1
WH→WWW
CDF: 194 pb-1
ZH→ννbb̄
CDF 289 pb-1
WH→WWW
D0: 363-384 pb-1
H→WW(*)→lνlν
CDF: 360 pb-1
ZH→ννbb̄
D0: 261 pb-1
H→WW(*)→lνlν
D0: 950 pb-1 (no μνμν)
WH→lνbb̄
D0: 378 pb-1
D0 combined
incl. H→WW→μνμν 325 pb-1
April 20, 2006
110
120
130
140
150
160
170
180
190
mH (GeV)



How do we go from here to here, i.e. here??

Factor of 15 (12) is for ~330 pb^{-1}

i.e. 2 sigma evidence or 95%CL exclusion at 115 GeV with 2 fb^{-1}



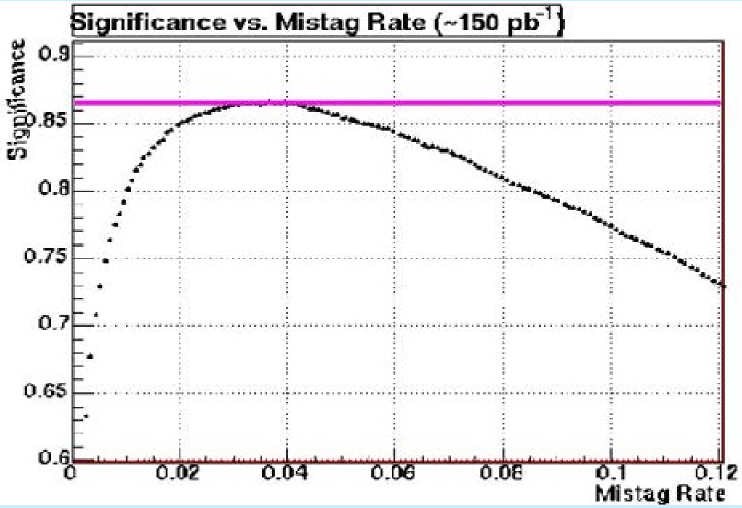
Add channels: Z(→$l^+ l^-$) bb

(b-tagging working point optimization)

Optimize mistag rate vs. b-tag effic. to obtain best significance S/√B

- Standard operating point is at **0.5%** for mistag rate, This corresponds to **> 10^{-4}** reduction in Z+jj rates, while **Z+bb/Z+jj is ~ 1/50**
- After b-tagging the bkgd. to ZH is dominated by Zbb production
- Optimize against Z+jj background

Optimal is ~ 4% mistag rate for DT



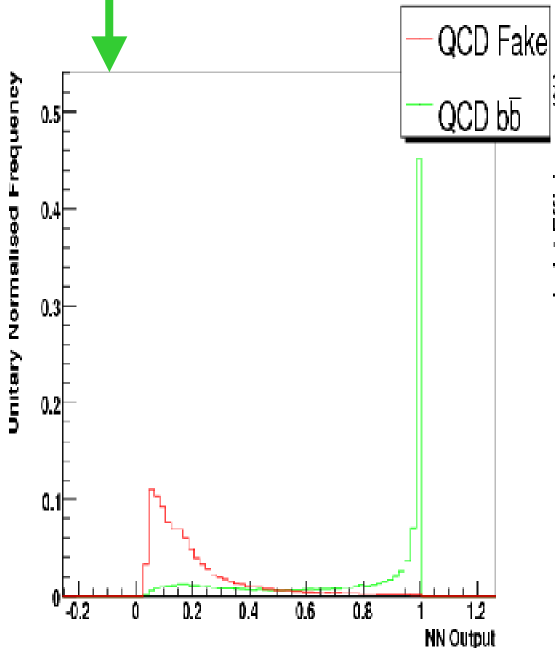
Gain a factor of 1.6 in efficiency !

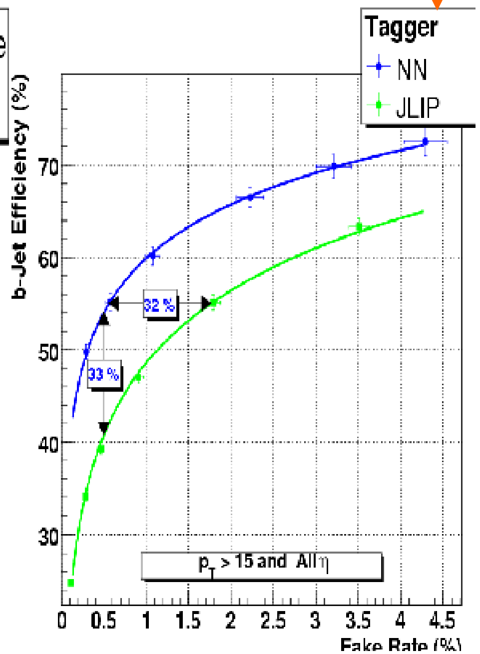
Preliminary results soon available

b-tagging Neural Net

New b-tagging tool at DØ

- Combines various variables from the track based b-tagging tools in a Neural Network, trained on Monte Carlo
- Performance measured on data
- Substantial improvement in performance over constituent input b-taggers
- Increase of 33% in efficiency for a fixed fake rate of 0.5 %

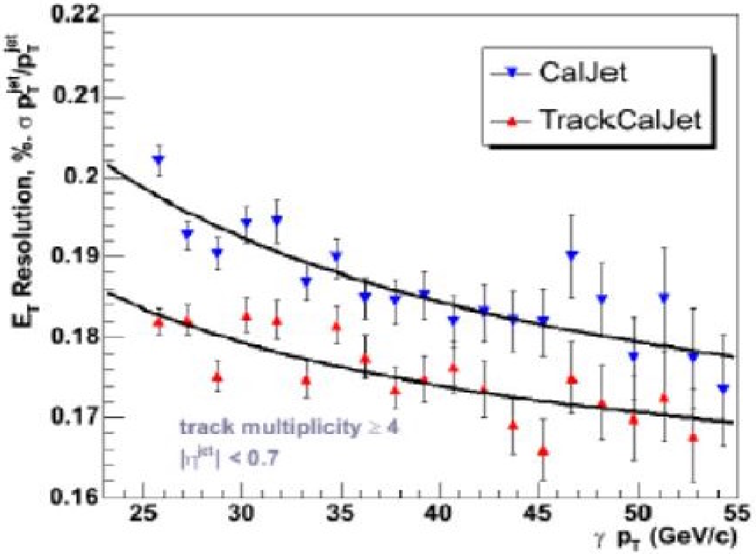




Reconstruction and Upgrade

- Jet energy resolution (track-jet algorithm)
  - Subtract expected energy deposition in cal
  - Add the track momentum
  - Add the energy of out-of-cone tracks

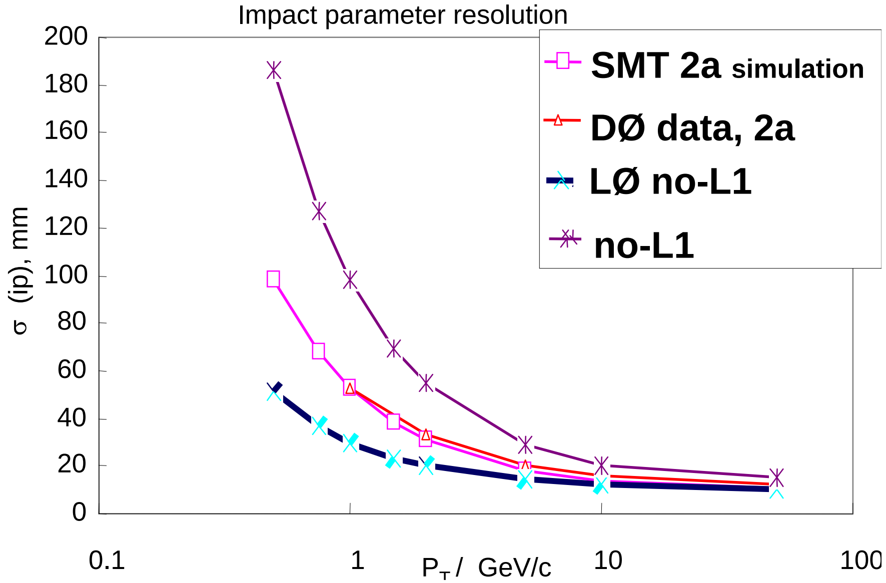
Improve the jet energy resolution by ~10% →



- Use improved calorimeter calibration
  Z→ bb to calibrate b-jet response
- L1-cal Trigger (Upgrade)
  - Important for difficult channels → efficiency improvement (ZH→ννbb, hbb)
- Addition of SMT Layer 0 (Upgrade)
  - r@L1 = 2.7 cm → r@L0 = 1.6 cm
  - better impact parameter resolution
  - More redundancy in pattern
  - Recognition for higher luminosity → reduce fake track
  - Keep functionality in case of degradation of Layer 1 due to radiation damage

➔ better b-tag performance (15%)

➔ improvement of Higgs sensitivity



Sensitivity Prospects

Will 6X more lumi take our x-section factor of 15 to 1?? **No**, but with analyses improvements under work and CDF → YES!!!!!!!

Ingredient	Equiv Lumi gain (@115)	Xsec Factor m_H=115 GeV	Xsec Factor m_H= 160 GeV
Today with 330 fb^{-1}	-	15	12
Lumi = 2.0 fb-1	6.00	6.1	4.9
NN b-Tagger	2.50	3.9	
NN Analyses	3.00	2.2	2.8 (smaller gain)
Track Cal Jets	1.40	1.9	
Increased Acceptance	1.20	1.7	2.5
New channels	1.20	1.5	2.2
Reduced Systematics	1.20	1.4	
Combine with CDF	2.00	1.0	1.5

→At 115 GeV ok with 2 fb^{-1}

→At 160 GeV needs 4.5 fb^{-1} (2 fb^{-1} x1.5^2)

→ 95% CL exclusion for m_H= 115-180 GeV with 6 fb^{-1}

SM Higgs Summary

First time with almost complete result (lacks a couple of "small" channels and combination with CDF, in the pipeline)

- Full impact of systematics uncertainties is included
- Analyses have been steadily improving due to optimization, already close to the Prospective reports

Combined limit looks very promising

- High mass region benefits a lot from $H \rightarrow WW^*$ type analyses (H and WH production), but low mass as well, as low as 120 GeV.

Our outlook for the future looks bright

- LHC experiments will have to work hard to get the signal, if the Higgs is light (<130 GeV). Barring accidents, the Tevatron will have evidence before 2009, if it's there.

Agreed, there is still a tough road in front of us, and even if m_H is light we could be unlucky, in some SUSY cases....

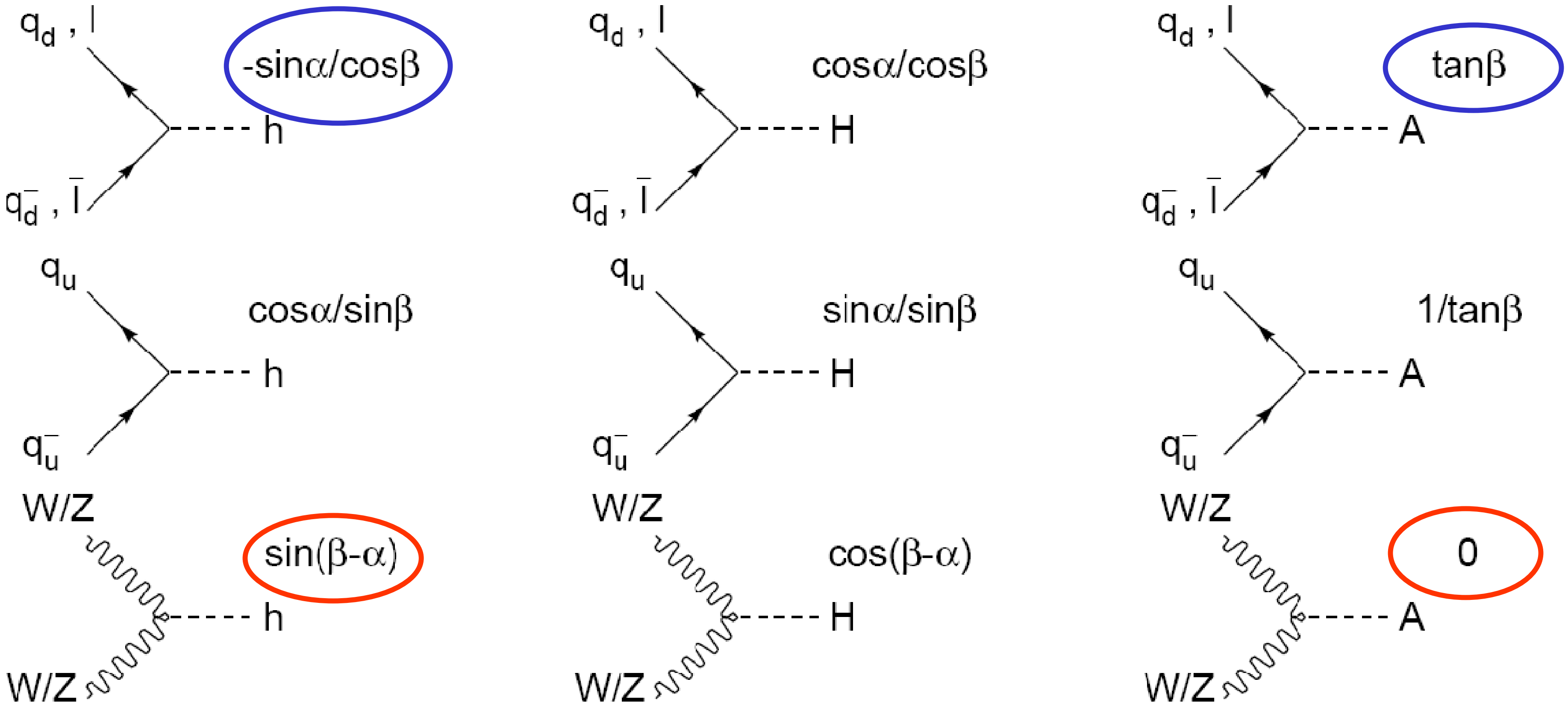
Higgs Bosons in the MSSM

- Two Complex Higgs Doublets needed to avoid anomalies
- Eight Degrees of Freedom minus $W^{+,-}$, Z^0 longitudinal polarization states→five scalars predicted: h, H, A, H^+, H^-
- CP-conserving models: h, H are CP-even, A is CP-odd
- At tree-level, two independent Parameters:
  - m_A
  - $\tan\beta$ = ratio of VEV's
  - M_{SUSY} (parameterizes squark, gaugino masses)
  - X_t (related to the trilinear coupling A_t) → stop mixing)
  - M_2 (gaugino mass term)
  - μ (Higgs mass parameter)
  - m_{gluino}(comes in via loops)

These 5 parameters intervene via radiative corrections, we study 2x2 scenarios →
(cf M. Carena et al., hep-ph/051123)

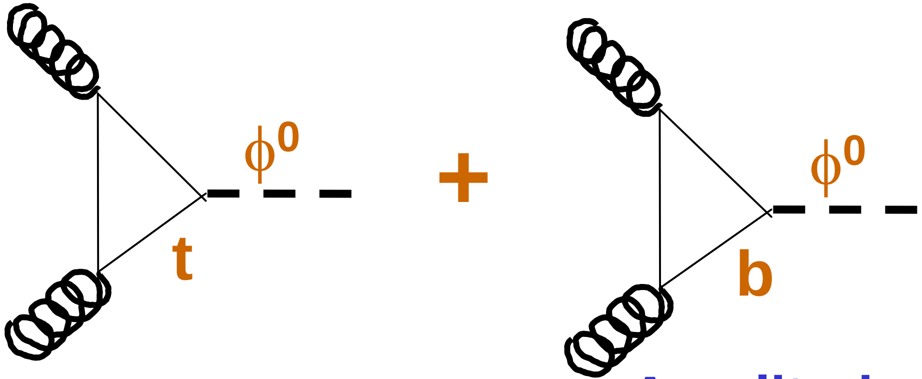
	m_h-max	no-mixing
M_{SUSY}	1 TeV	2 TeV
X_t	2 TeV	0
M_2	200 GeV	200 GeV
μ	±200 GeV	±200 GeV
m_g	800 GeV	1600 GeV

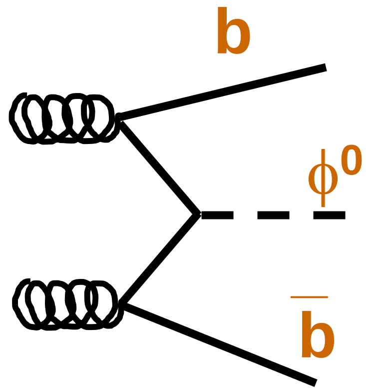
Couplings of MSSM Higgs Relative to SM



W and Z couplings to H, h are suppressed relative to SM (but the sum of squares of h^0, H^0 couplings are the SM coupling). Yukawa couplings can be enhanced for tanβ >1

MSSM Higgs Production Mechanisms





Amplitude $\propto$ 1/tanβ
suppressed!

Amplitude $\propto$ tanβ
enhanced!

Amplitude $\propto$ tanβ
enhanced!

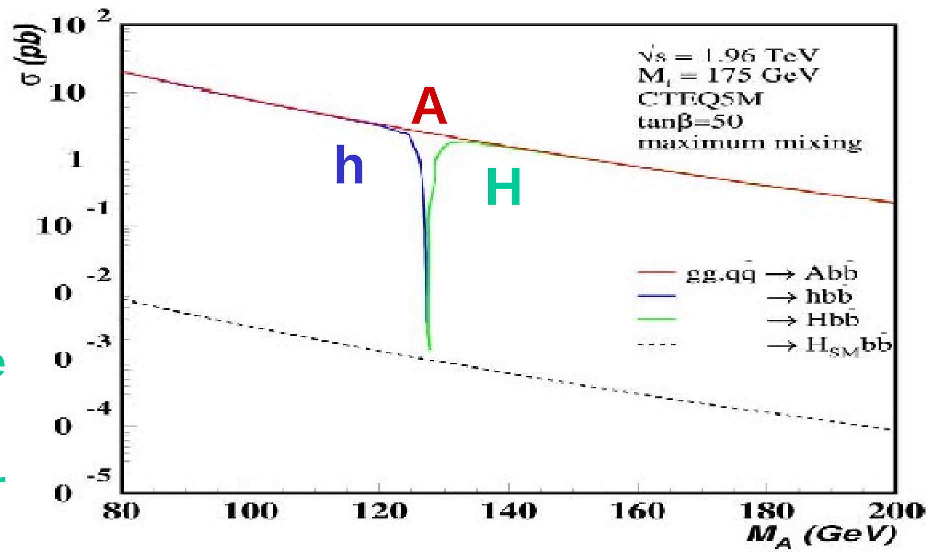
at high tanβ, σ(h,A+X) $\propto$ $\tan^2\beta$

Interesting feature of many MSSM scenarios: $[m_h, m_H] \approx m_A$ at high tanβ

$Br(A^0 \to bb)$ ~ 90% and $Br(A^0 \to \tau^+\tau^-)$ ~ 10% almost independent of tanβ (some gg too).

Our two benchmark scenarios:

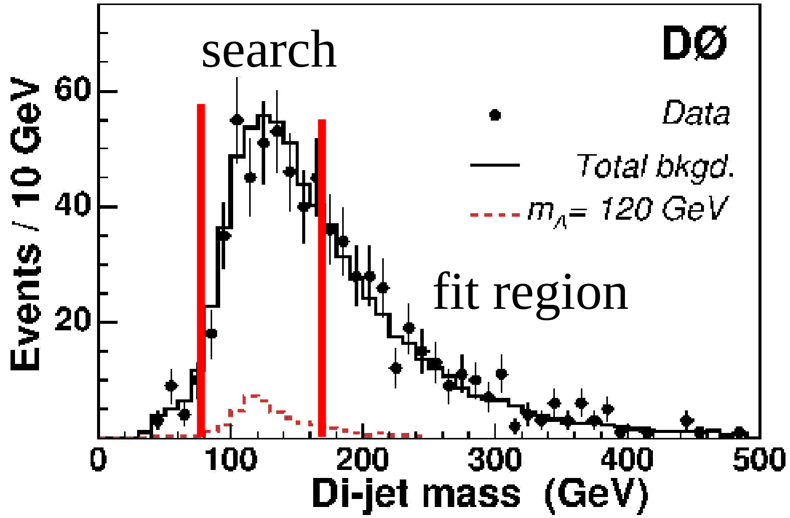
- **m_h-max:** Higgs boson mass m_h close to the maximum possible value for a given tanβ
- **no-mixing:** vanishing mixing in stop sector → small mass for h.



hb(b) Published Result (reminder)

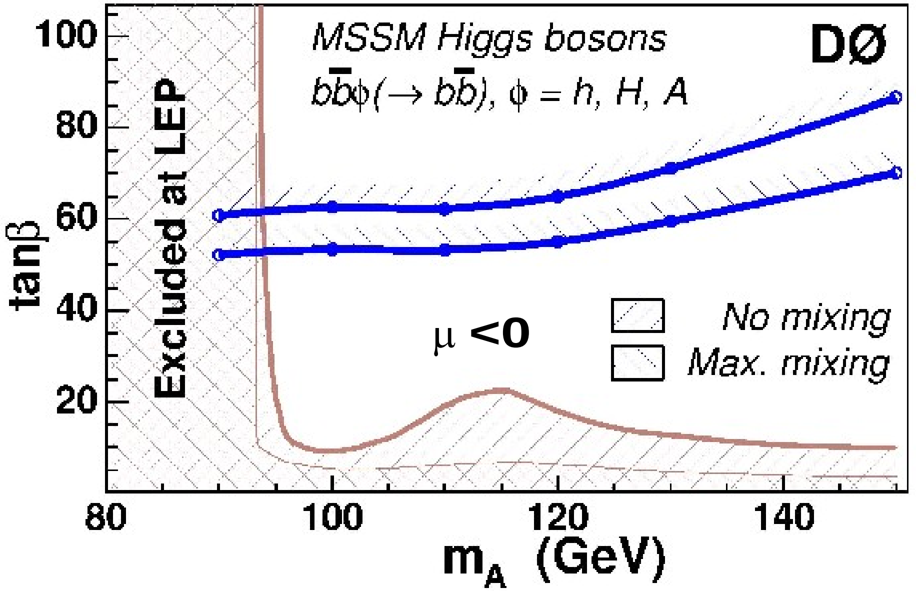
- **L=260pb^{-1}**
- **At least 3 b-tagged jets**
  - **pT cuts optimized**
  - **b-tag rate estimated from data (~2%)**
    - **2 b-tagged sample × b-tag rate**
  - **Z(bb,cc)+jets, tt estimated from MC**

at least 3 b-tagged jets



- **No Excess found**
  - **95% C.L. from fit of dijet mass**

- **Results reinterpreted in modified scenarios and combined to our new h→tautau result, see below**



$gg \to h,A \to \tau^+\tau^-$ Channel

- Large production cross-section
- Tau leptons are distinct from QCD background
- b(b) $\tau^+\tau^-$ channel is possible too – we're working on it.
- Useful $\tau^+\tau^-$ decay modes → one hadronically decaying τ and e-mu channel (low BR, but low bckgd)
- Final state: opposite sign tau pair and missing transverse energy

- Signal would stand out as enhancement from background in the visible mass, M_{vis} = sqrt ($p_{\tau,1}+p_{\tau,2}+\not{p}_t$)
- Standard Model backgrounds
  - Z: irreducible background
  - $Z/\gamma^* \to ee/\mu\mu$, multi-jet, $W \to l\nu$+jet (rejected with M_W<20 GeV) Di-boson (WW,WZ,ZZ)

Mode	Fra (%)	Comments
$\tau_e\tau_e$	3	Large DY bg
$\tau_\mu\tau_\mu$	3	Large DY bg
$\tau_e\tau_\mu$	6	Small QCD bg
$\tau_e\tau_h$	23	Large BR, medium bg
$\tau_\mu\tau_h$	23	Large BR, medium bg
$\tau_h\tau_h$	41	Large QCD bg

Data/Background:

- Data Sample, L = 325 pb^{-1}, recorded by single Electron/Muon Trigger
- Standard Model background is simulated using Pythia 6.2
- multi-jet background determination from data: $e+\tau_h$: like sign events, $\mu+\tau_h$: inverted lepton isolation criteria

Tau Identification

Tau = narrow isolated jet with low track and π^0 multiplicity

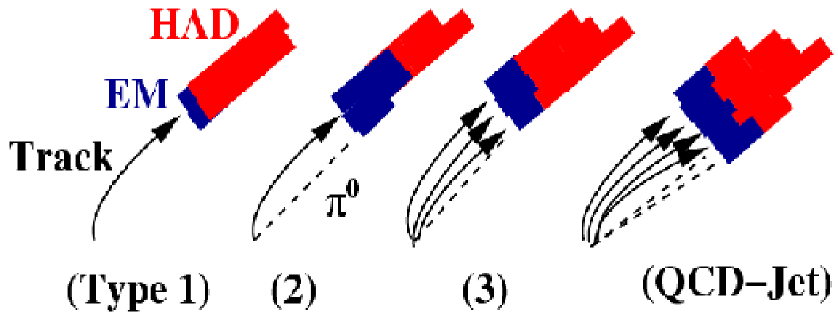
- Tau candidates are divided into 3 types:
  - Type 1: one track, calorimeter cluster without EM subcluster
  - Type 2: one track, calorimeter cluster with EM subclusters
  - Type 3: 2 or 3 tracks consistent with tau mass, calorimeter cluster

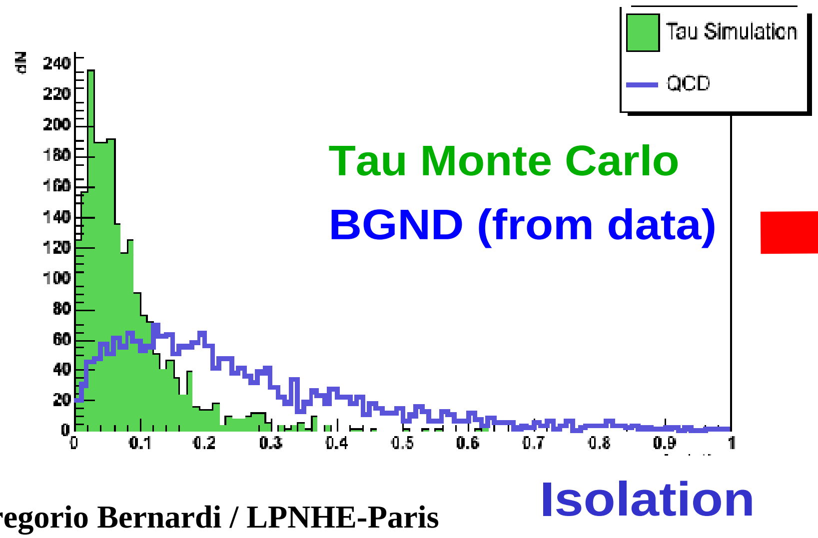
Tau identification is based on Neural Network

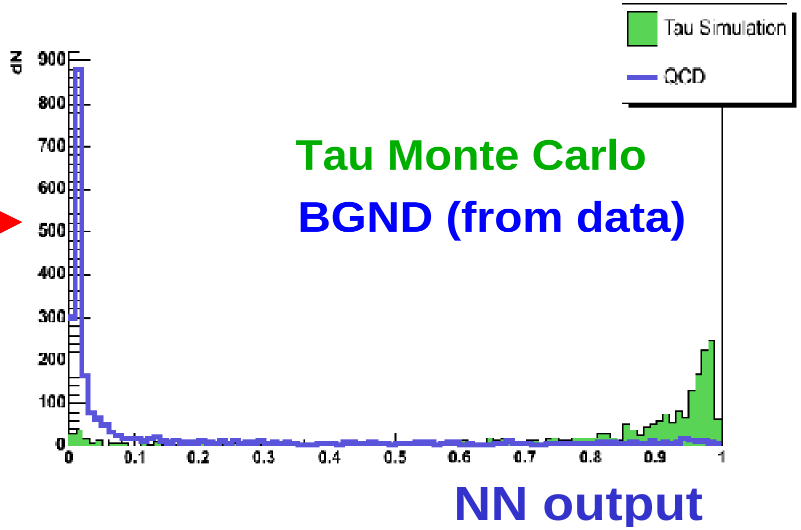
Non-linear correlations between variables are taken into account

Discriminating variables: Profile, Isolation,

Used for cross section measurement $Z \rightarrow \tau\tau$ (PRD 71, 072004 (2005))







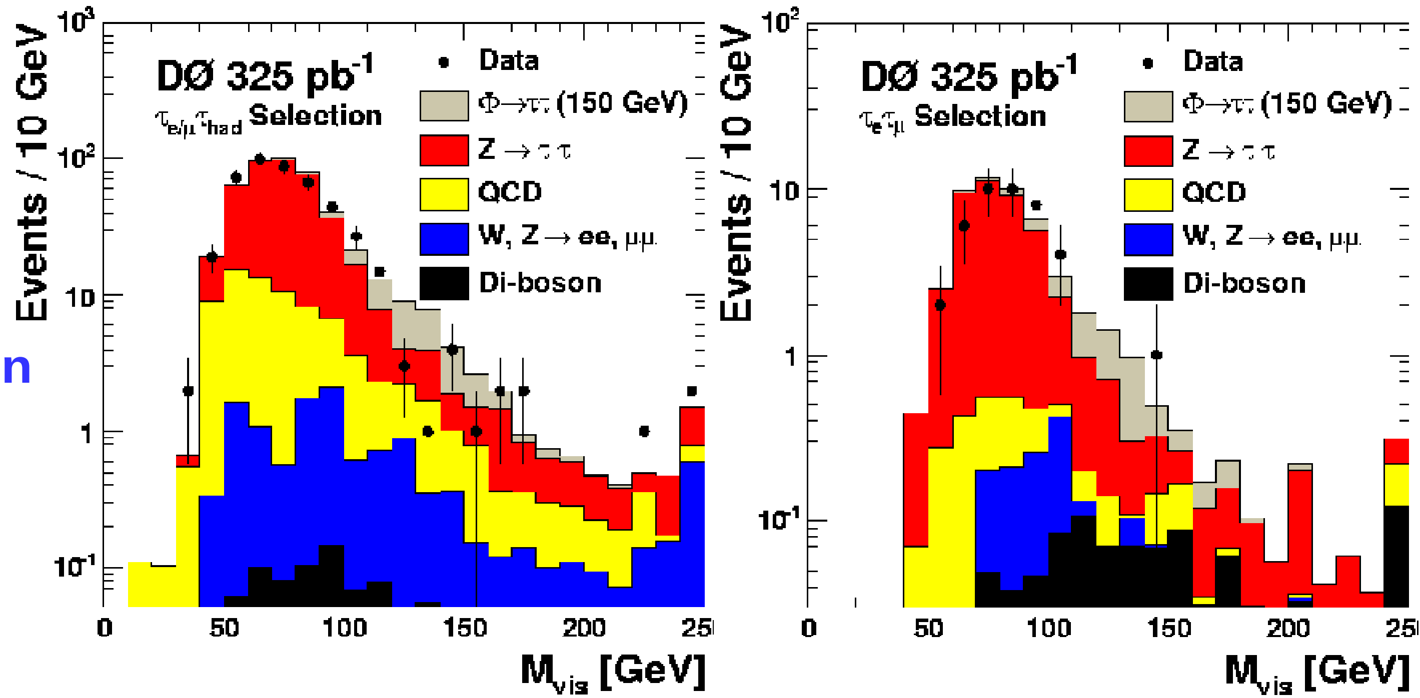
Combined Results: e+ τ_h , μ+ τ_h , e+ μ

Observed data events and expected bckgnd events at the end of the selection: (statistical and systematic uncertainties are added in quadrature)

	Data	Sum BGND	QCD	$Z\to\tau\tau$	$Z\to \mu\mu/ee$	W	Di-Boson	tt(bar)
$e+\tau_h$	484	427.3 ± 55.3	199.5 ± 26.0	202.7 ± 26.3	10.2 ± 1.4	14.0 ± 1.9	0.54 ± 0.09	0.35 ± 0.05
$\mu+\tau_h$	575	576.3 ± 61.5	62.2 ± 6.6	491.7 ± 52.6	4.6 ± 1.1	13.5±1.6	3.05 ± 0.33	1.22 ± 0.14
$e+\mu$	42	43.5 ± 5.3	2.1 ± 0.4	39.1 ± 5.0	0.63 ± 0.12	0.30 ± 0.20	0.99 ± 0.14	0.06 ± 0.02

Major systematic uncertainties:

- normalization of multi-jet backgrnd
- muon-identification
- tau energy scale
- Jet-Energy-Scale



Gregorio Bernardi / LPNHE-Paris

Combined Results: Cross Section Limit

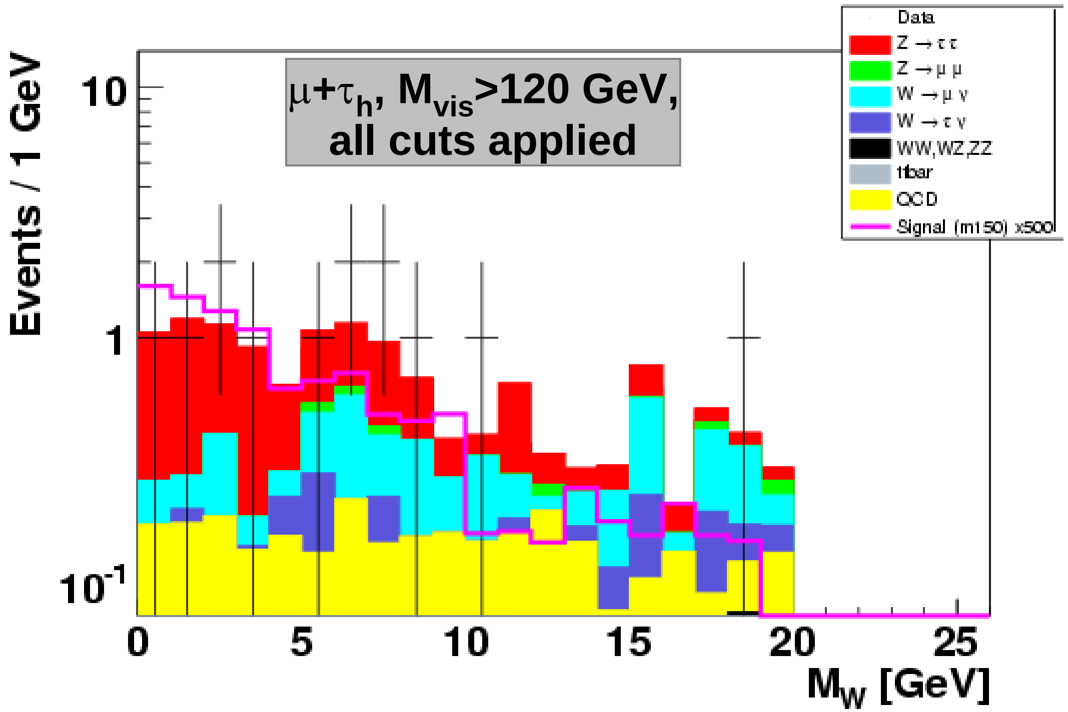
- Calculate limit at 95% CL
  - Use full M_{vis} distribution
  - Split event sample into 13 subsamples according to different signal-to-background ratios, e. g.

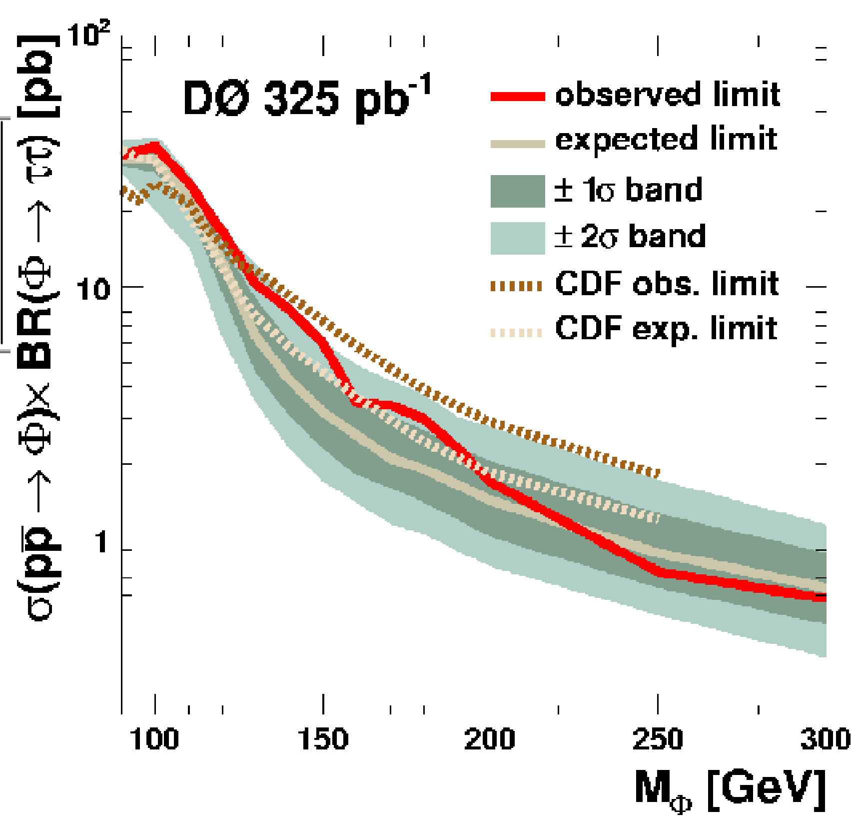
(1) $M_W <$ 6 GeV

(2) 6 GeV $< M_W <$ 20 GeV

times 3 different tau-types

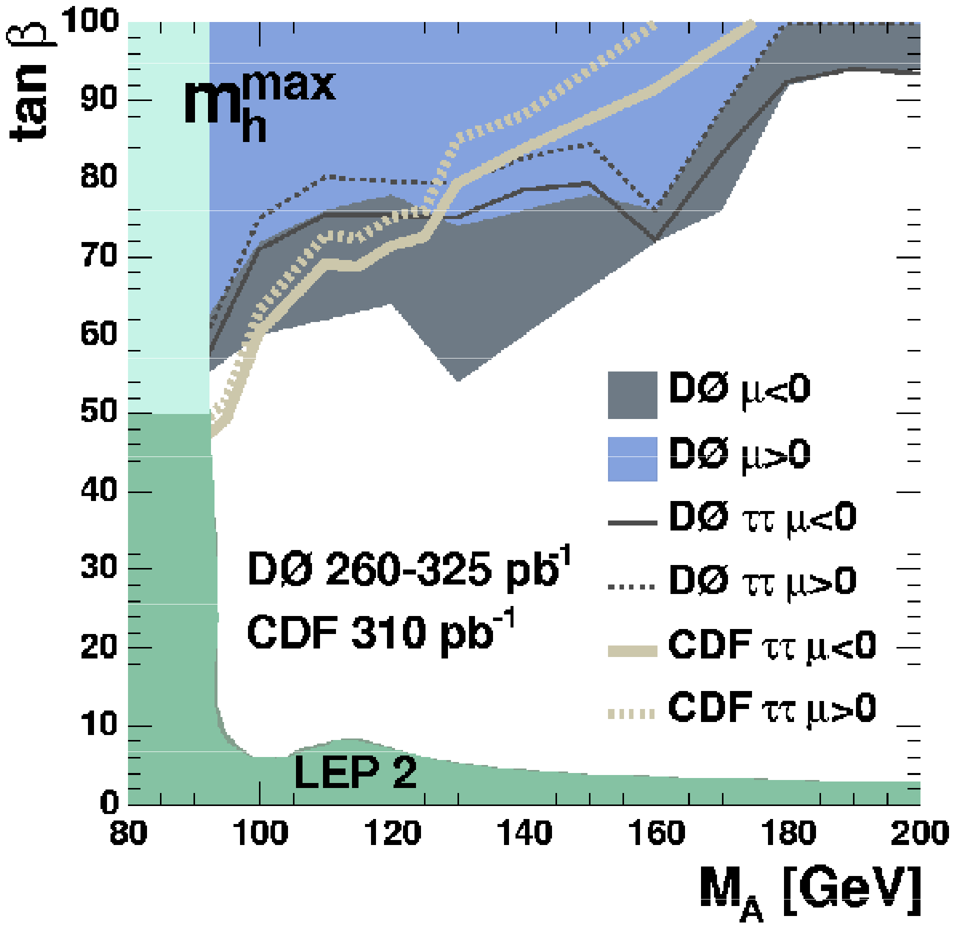
Submitted: hep-ex/0605009

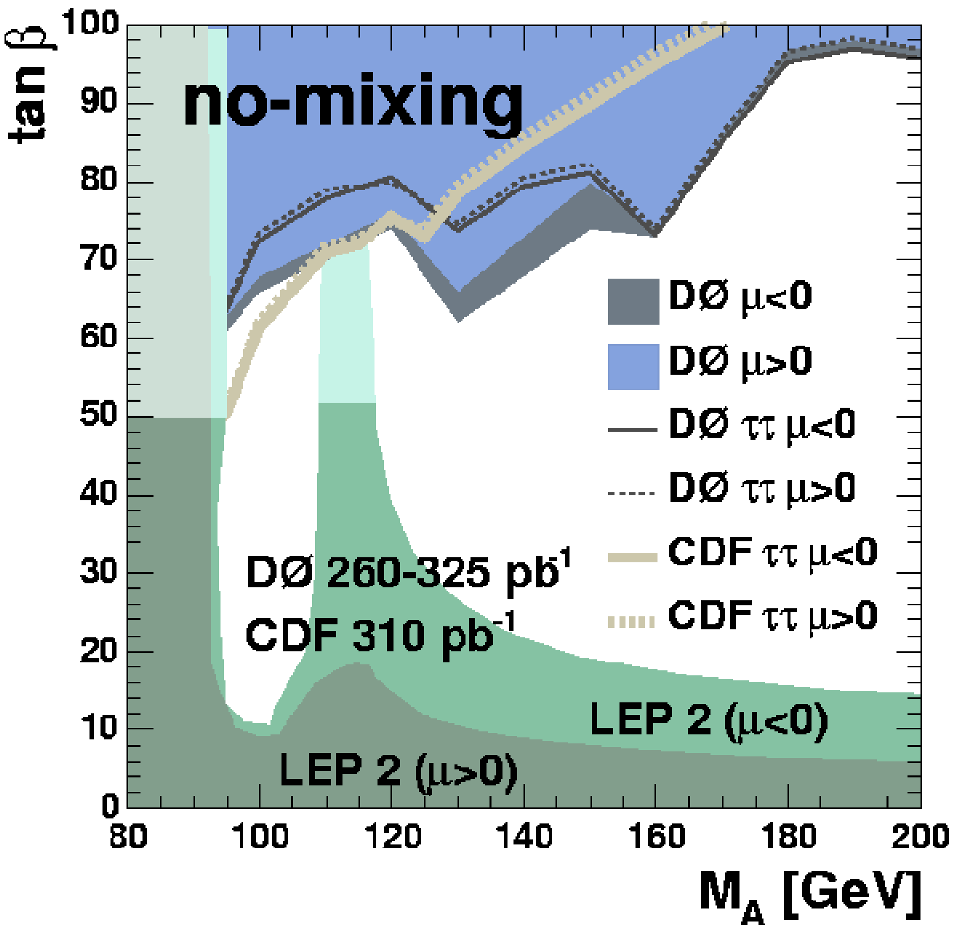




Combined Results with hb(b): m_A-tanβ plane

DØ results of bbh are included, L = 260 pb^{-1}, PRL 95, 151801 (2005), after reinterpretation in these 4 scenarios (small modification)





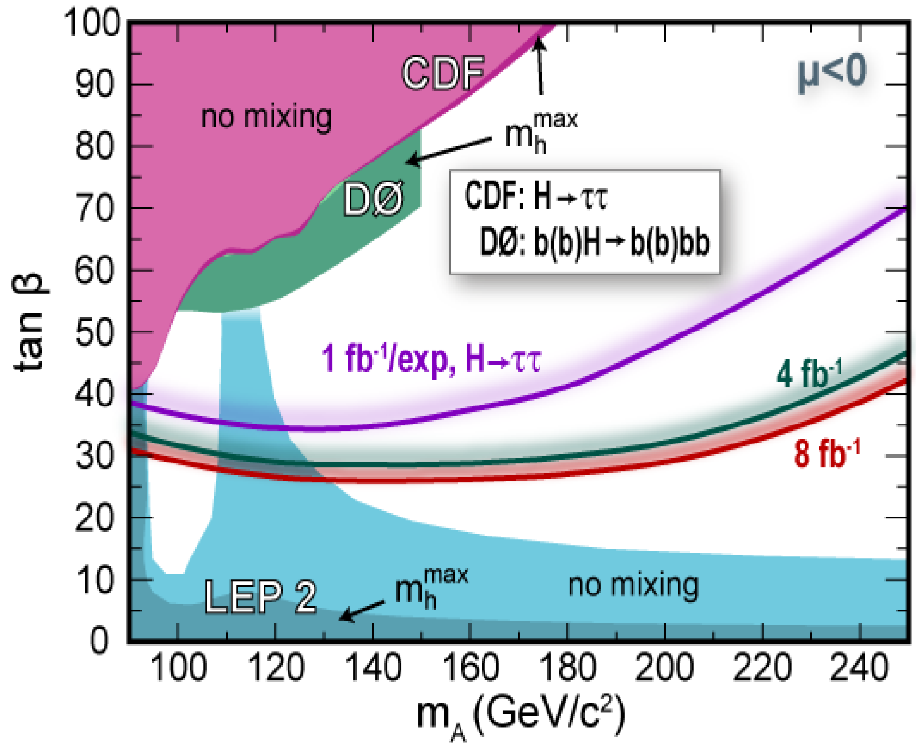
Feynhiggs 2.3 (Thanks to S. Heinemeyer et. al.)

MSSM Higgs Summary and Outlook

After the published bbh search, another search for MSSM Neutral Higgs Bosons in $\tau\tau$ final states has been performed using 325 pb^{-1} data taken by DØ in Run II
No indication for a signal has been found
Upper limits were derived at 95% CL

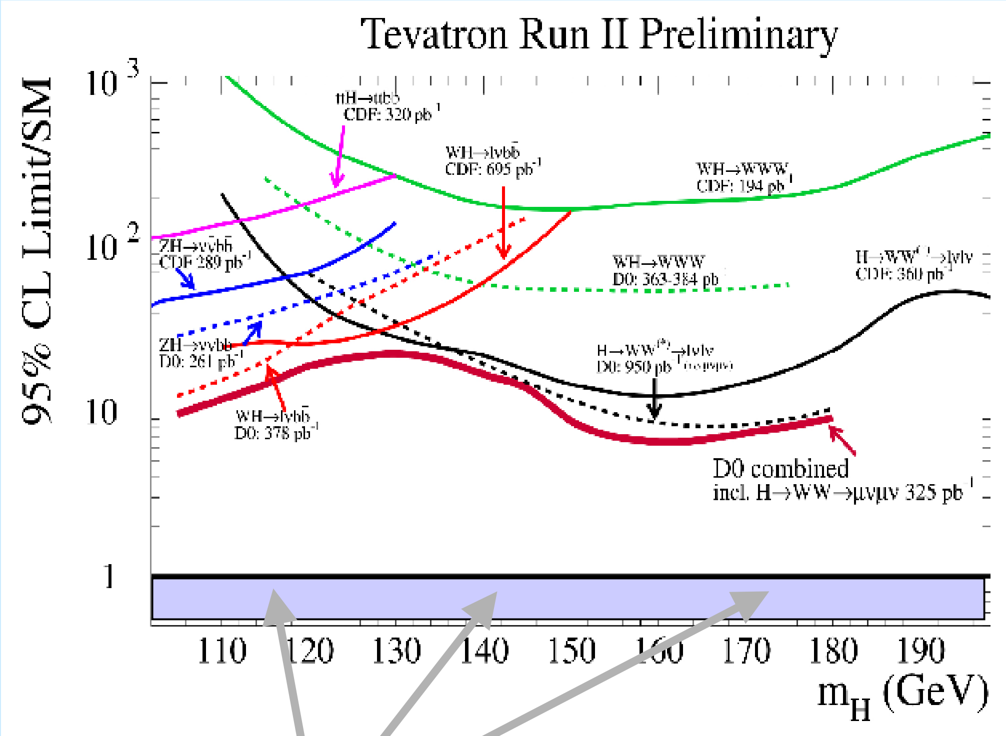
$\tau\tau$ results are comparable in sensitivity with those of CDF

- Combination with hb(b)→bbb(b) has been performed → most sensitive to date.
- Update with 1.2 fb^{-1} in progress
- With some sensitivity progress MSSM Higgs could be, by 2009, well constrained in some of these models up to 180 GeV, since, for instance, LEP exclude them up to 15-20 in tan β in the no-mixing scenario



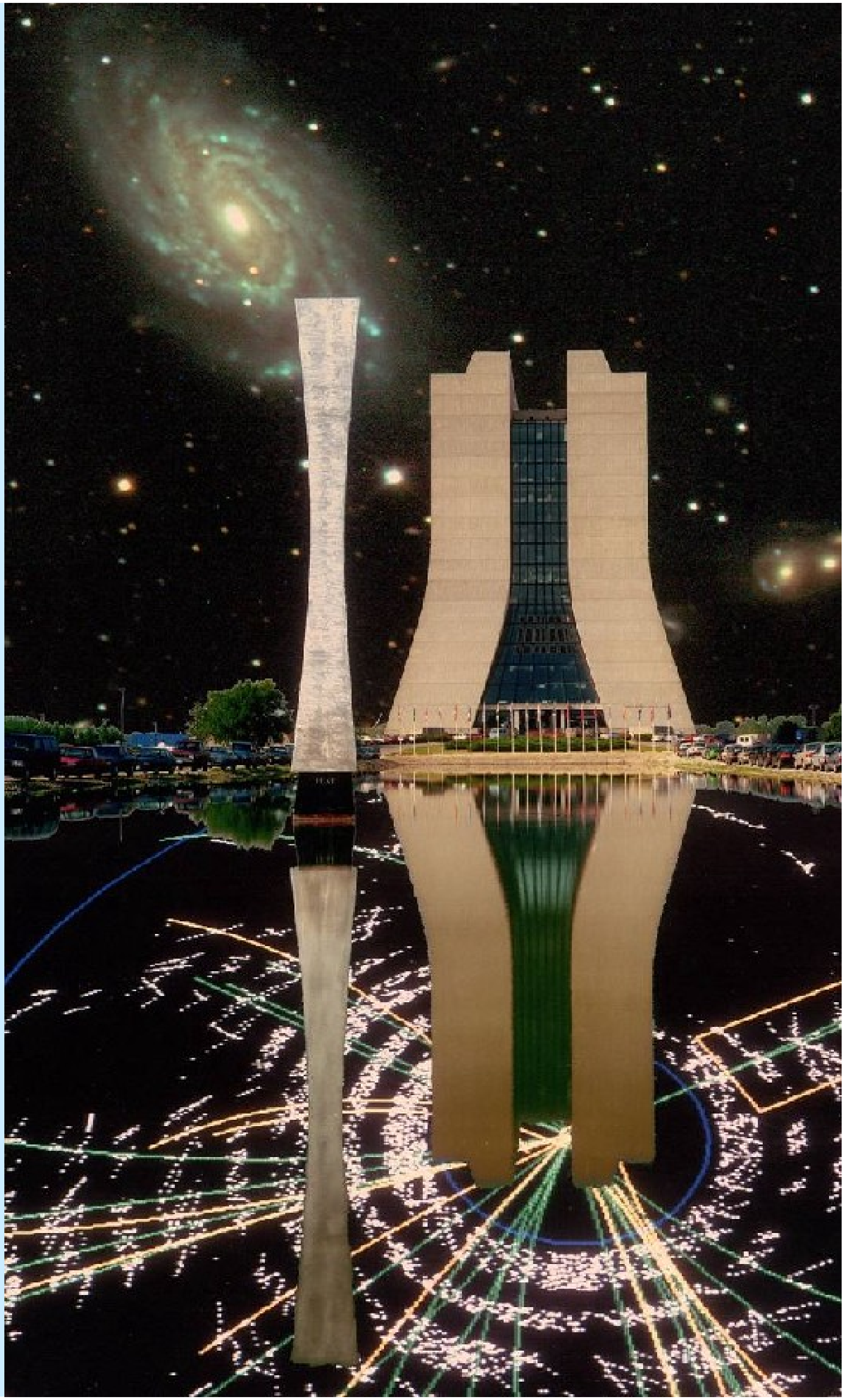
Conclusions

Will we soon understand better what's going on in the Universe?



around here if we get somewhere the answer is YES!

So let's carry on !!!

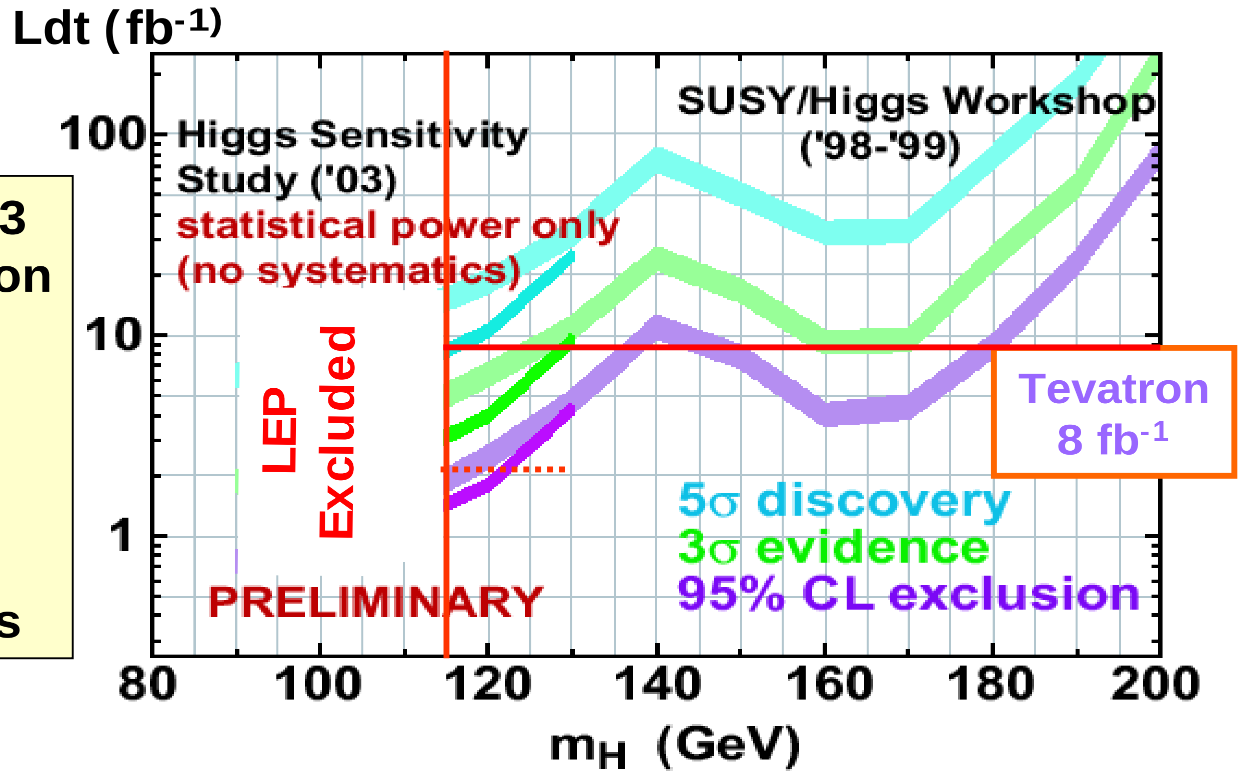


Tevatron SM Higgs Search: Outlook

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

→ optimizing analysis techniques, understanding detectors better
→ measuring SM backgrounds (ttbar, Zbb, Wbb, WW, soon single top)
→ Placing first Combined Higgs limits and compare to the prospects

Higgs Production and Decay at High $\tan\beta$

- **Interesting feature of many MSSM scenarios:**
  $[m_h, m_H] \approx m_A$ at high $\tan\beta$ (most benchmark scenarios)

- **At leading order, $\Gamma(A^0 \to bb)$ and $\Gamma(A^0 \to \tau^+\tau^-)$ are both proportional to $\tan^2\beta$.**

- **Decays to W, Z are not enhanced**
  and so Br. falls with increasing $\tan\beta$ (even at high m_A)

- **$Br(A^0 \to bb) \sim 90\%$ and $Br(A^0 \to \tau^+\tau^-) \sim 10\%$ almost independent of $\tan\beta$ (some gg too).**

- **Our two benchmark scenarios**
  - **m_h-max:** Higgs boson mass m_h close to the maximum possible value for a given $\tan\beta$
  - **no-mixing:** vanishing mixing in stop sector → small mass for h