Standard Model Higgs Searches and Perspectives at the Tevatron

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on behalf of the CDF and DØ collaborations

1) Introduction

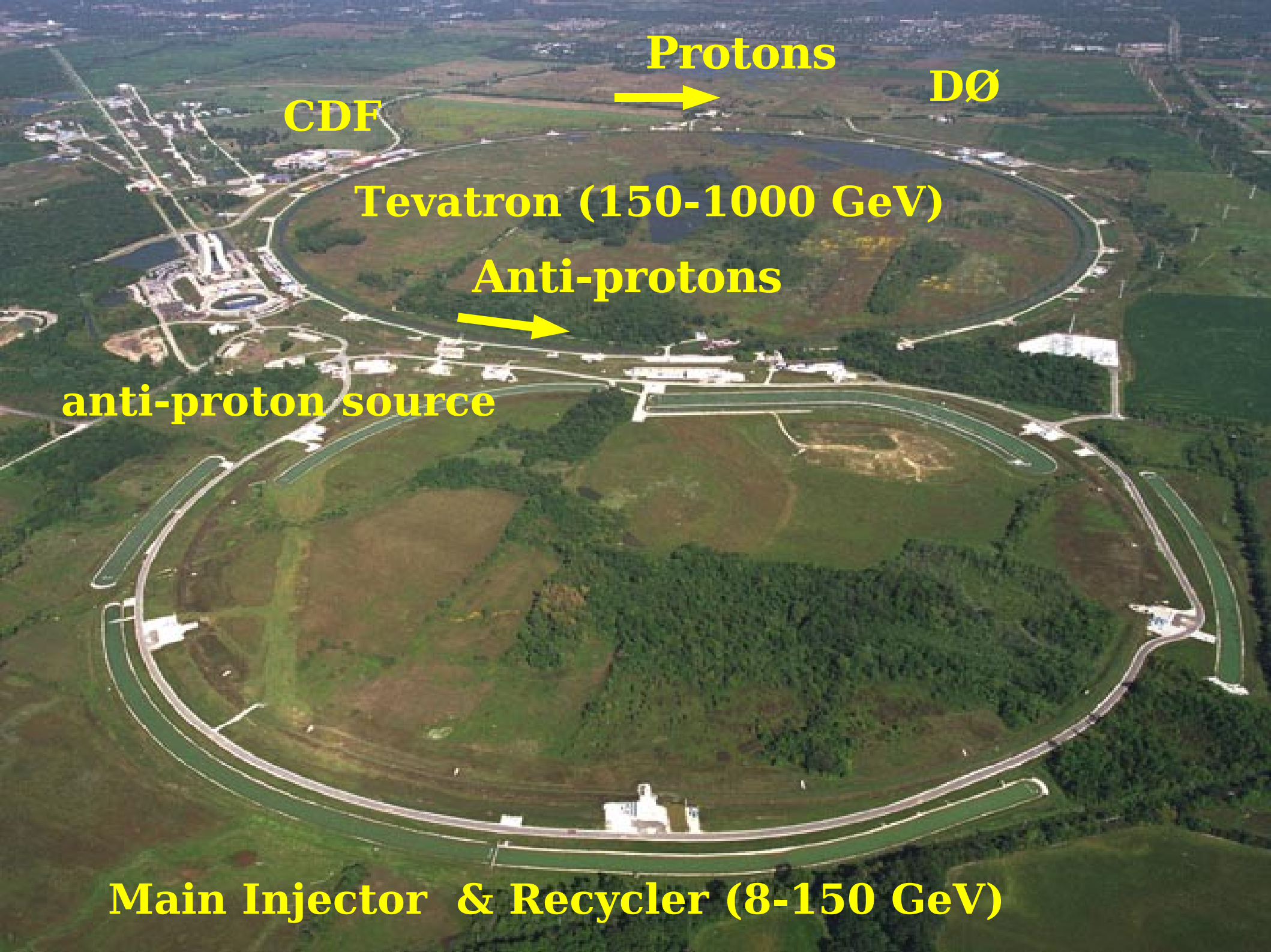
2) Higgs → bb (lower mass)

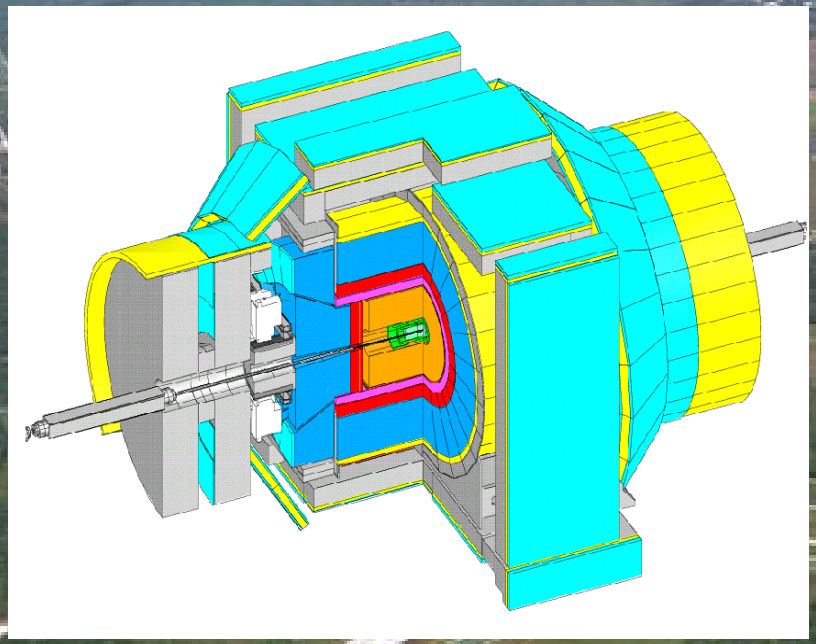
2.1) WH → lνbb
2.2) ZH → ννbb

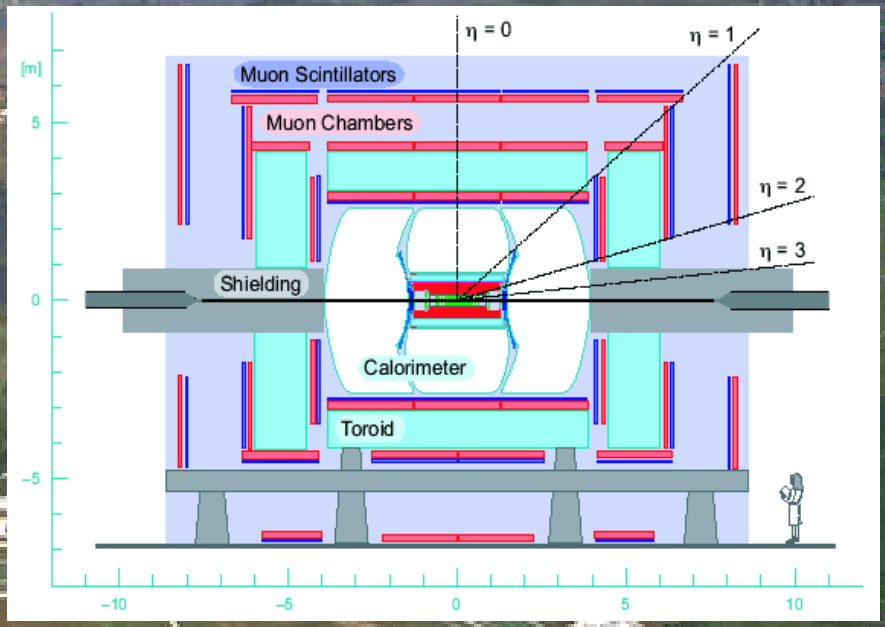
3) Higgs → WW (higher mass)

3.1) H → WW
3.2) WH → WWW

4) Perspectives


Protons
DØ
CDF
Tevatron (150-1000 GeV)
Anti-protons
anti-proton source
Main Injector & Recycler (8-150 GeV)





The Standard Model (SM) Higgs Boson:

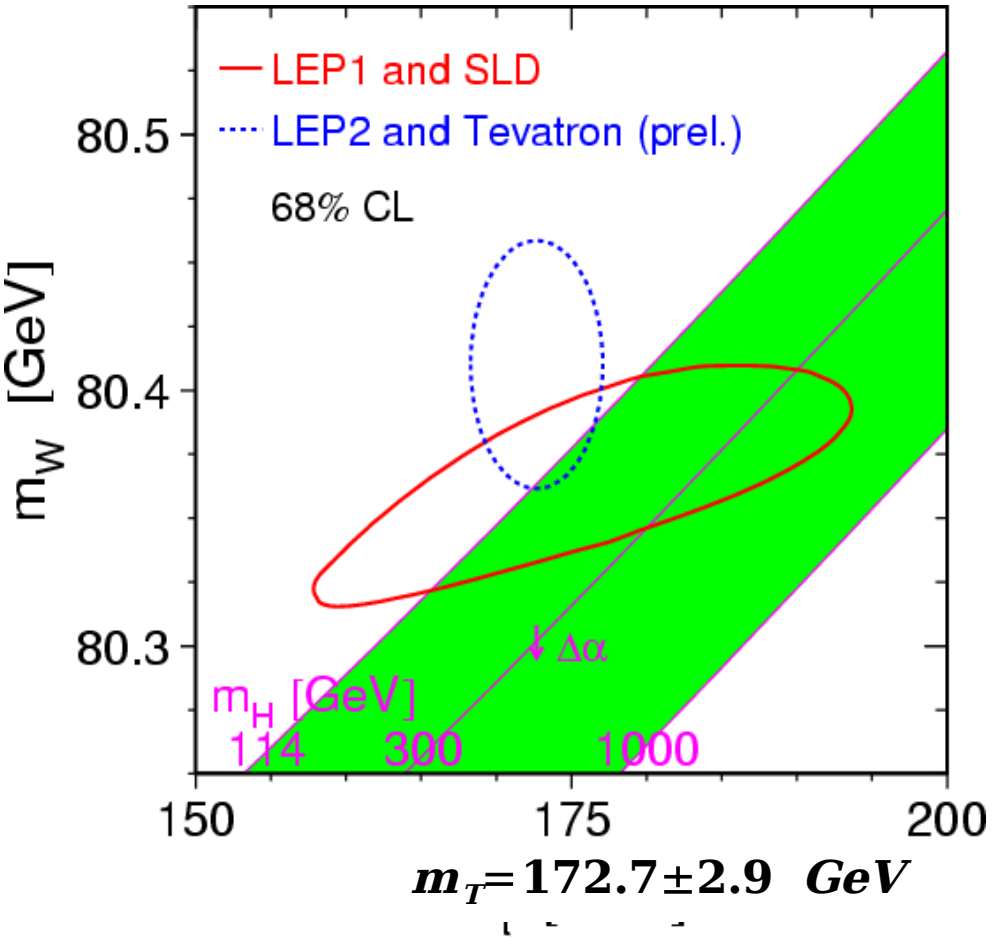
- **is responsible for electroweak (EW) symmetry breaking in SM**
- **is a scalar with the Higgs mass as the only free parameter**

CDF and DØ constrain SM Higgs boson mass:

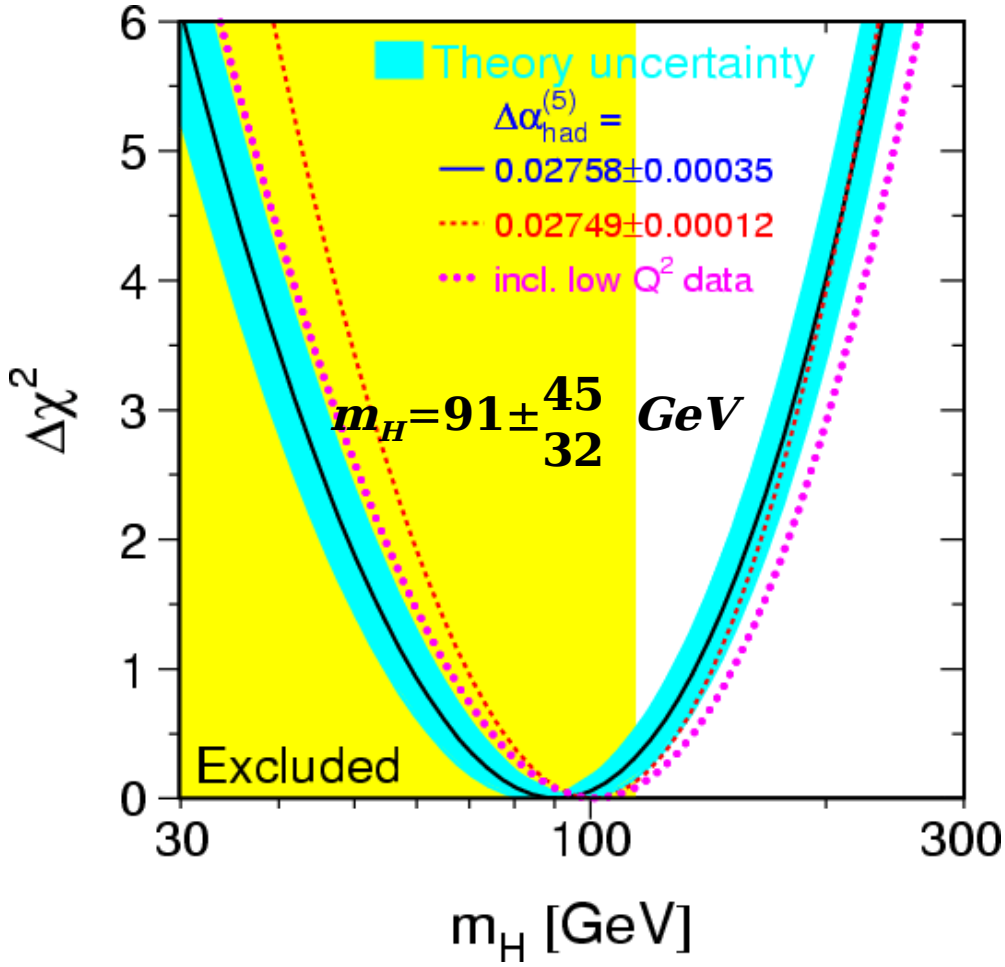
- **indirectly: Top and W mass measurements (→ E. Barberis)**
- **directly: Search for Higgs boson production (this talk)**

LEP: $m_H > 114.4$ *GeV* (95% *CL*)

Stalking the Higgs Boson

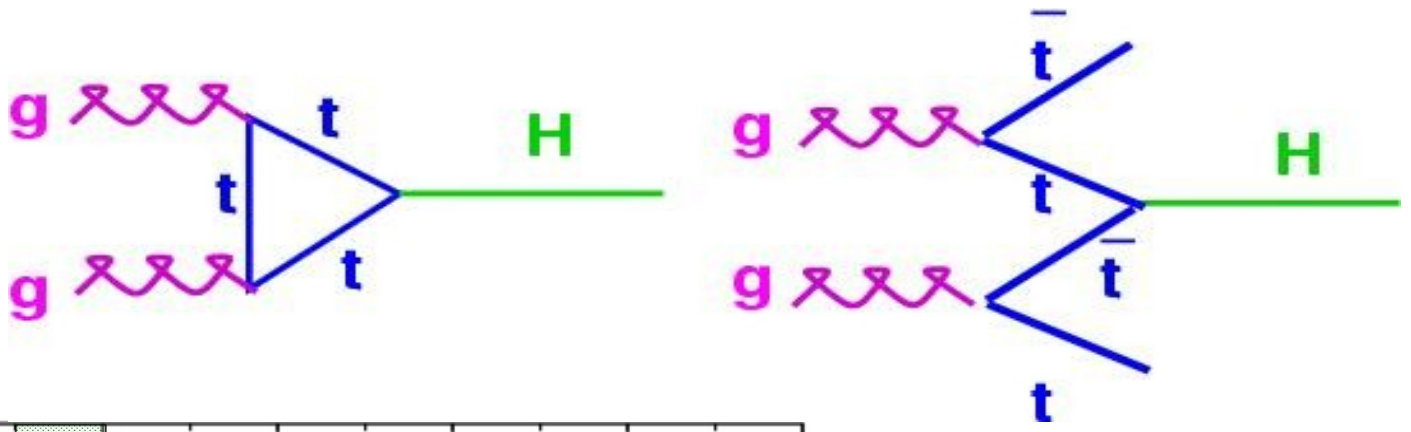


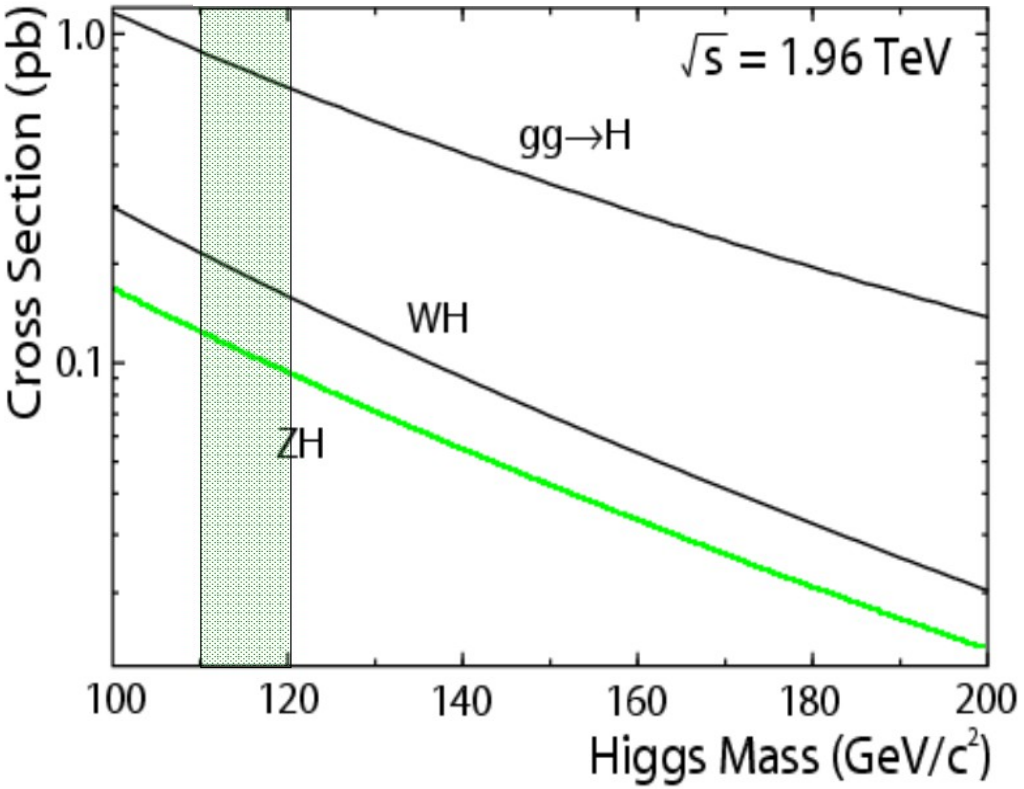
$m_T = 172.7 \pm 2.9$ *GeV*

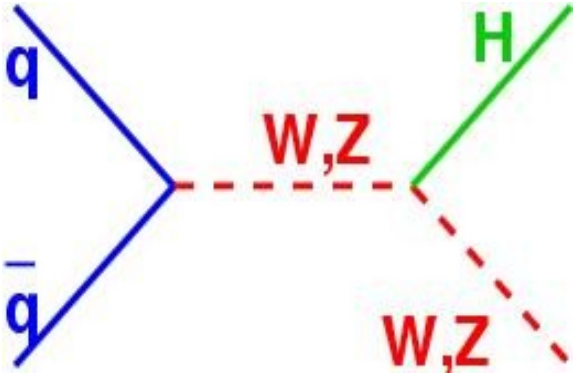


A light Higgs Boson might be in our reach..

$m_H < 186$ *GeV* (95% *CL*)

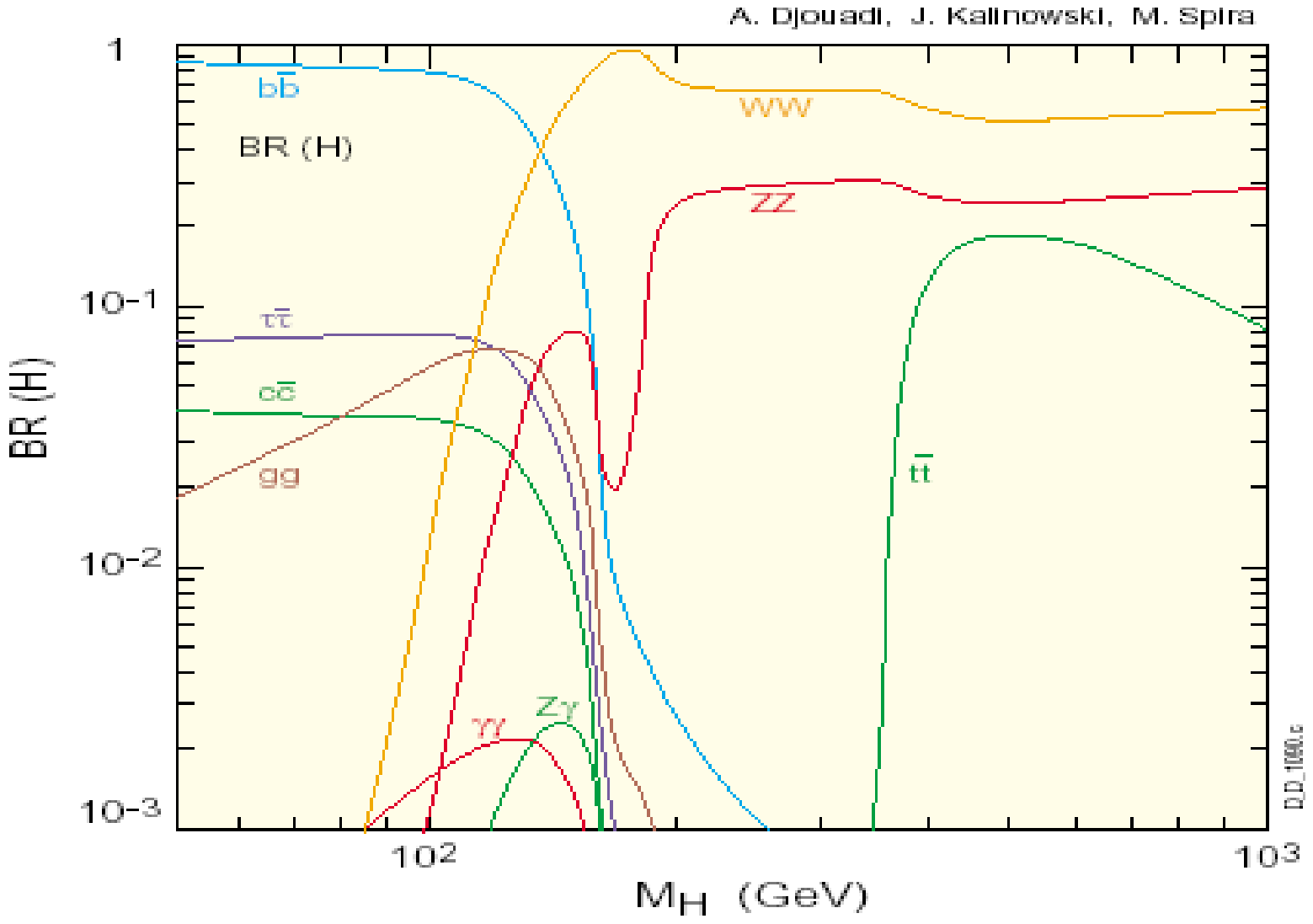






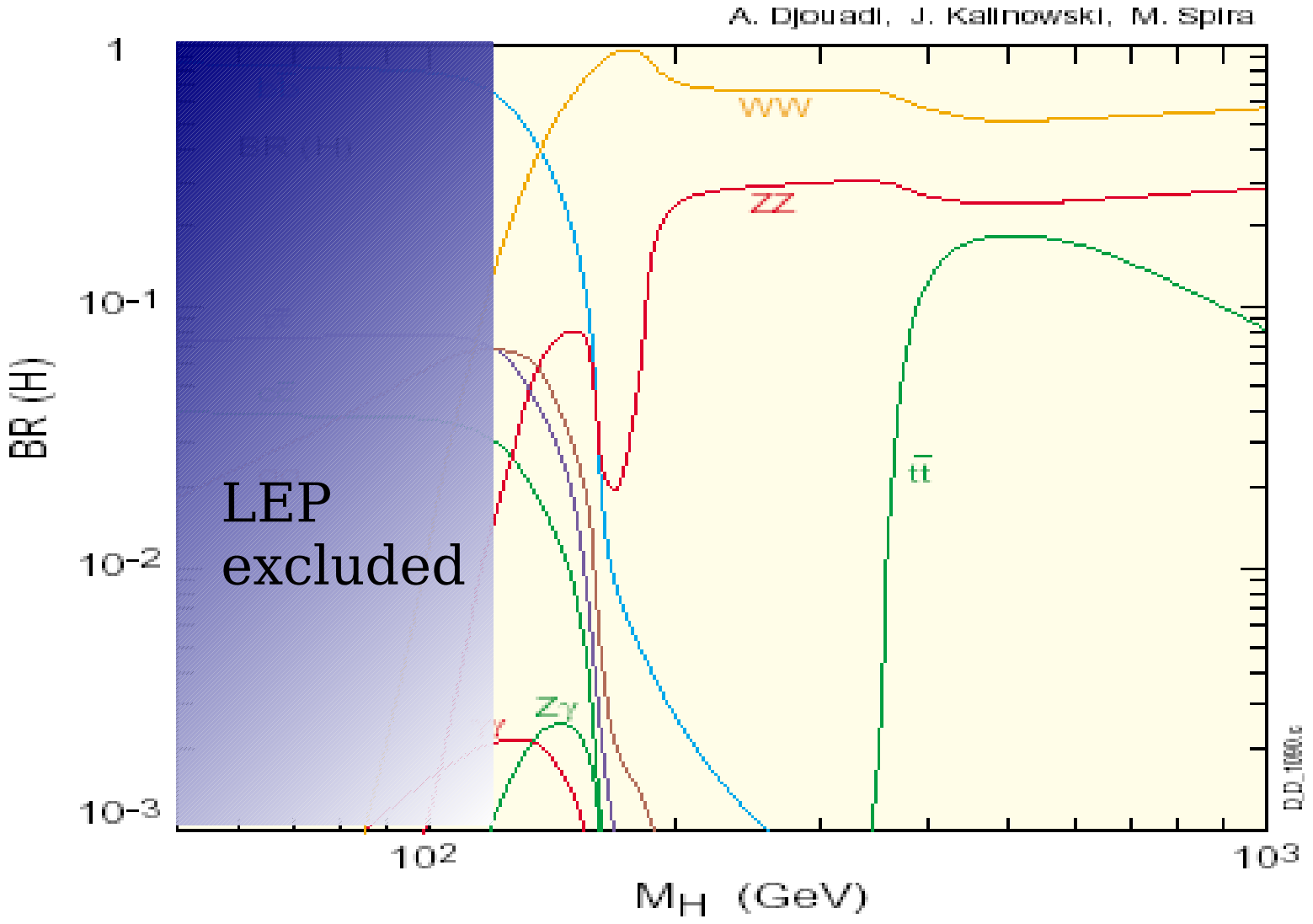
~one in 10^{12} $p\bar{p}$ events will be a Higgs boson

Branching Fractions:

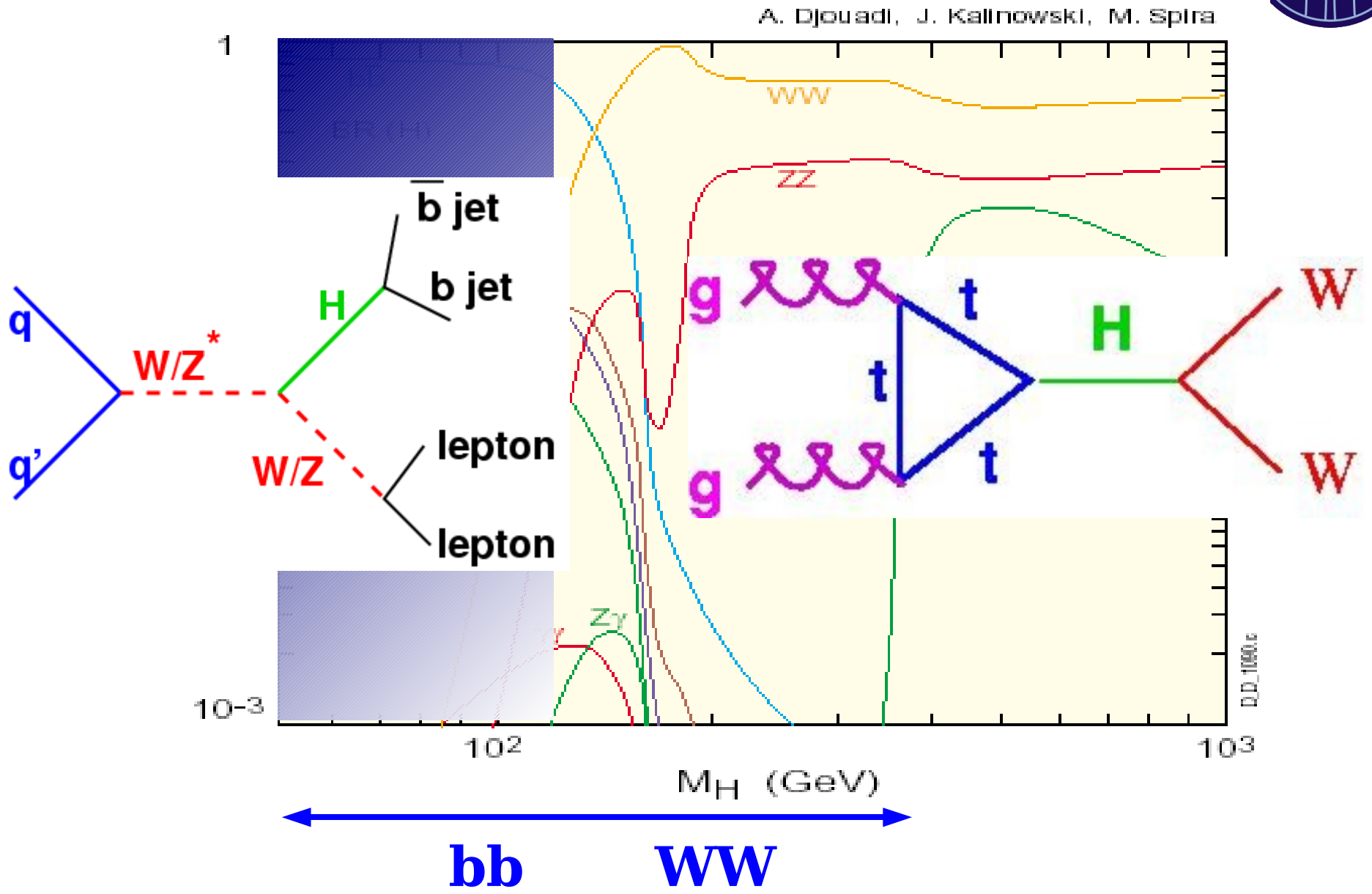


bb **WW**

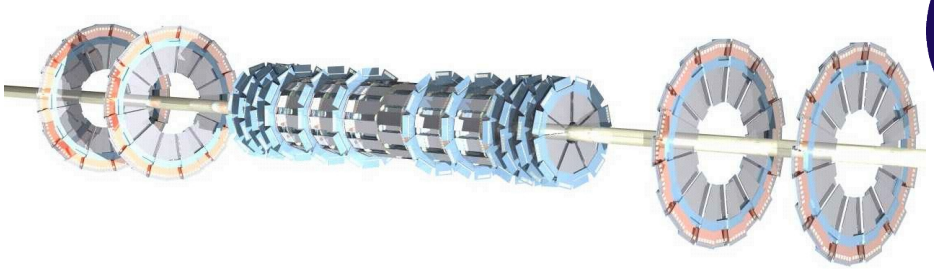
Branching Fractions:



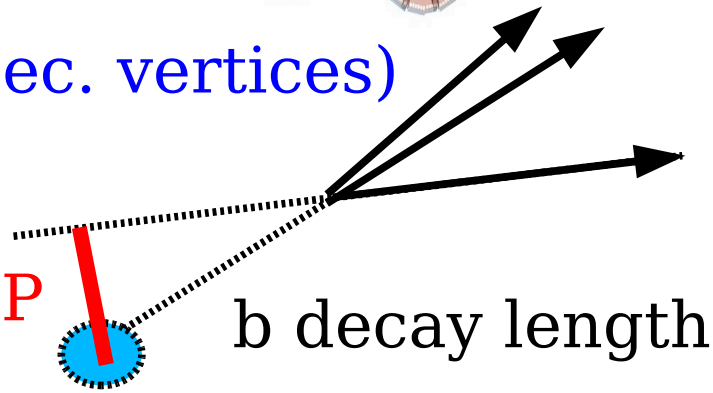
Branching Fractions:



Tools:



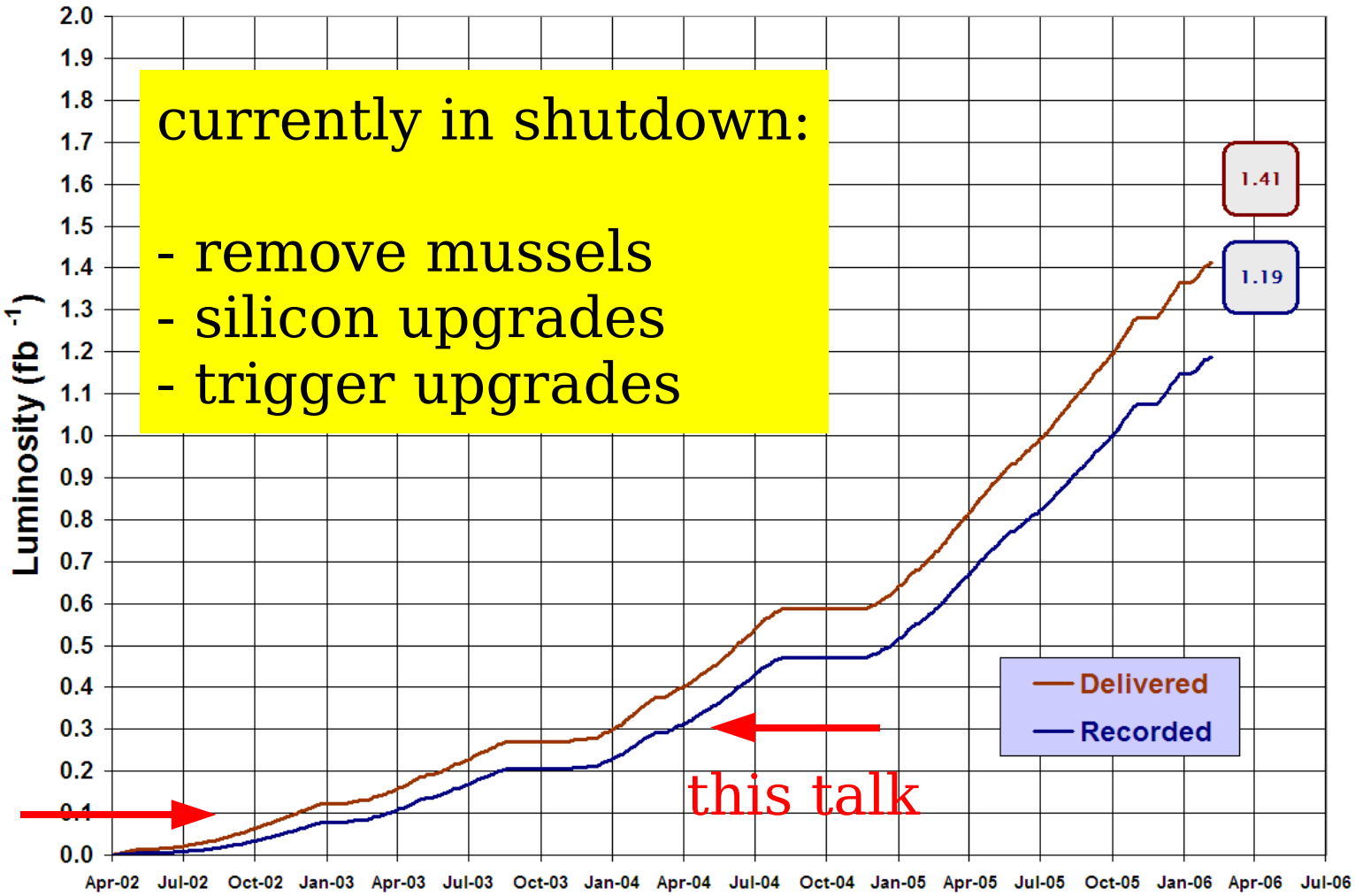
- Jet reconstruction
- B tagging (impact parameters, sec. vertices)
- Electron identification
- Muon identification
- Missing transverse energy



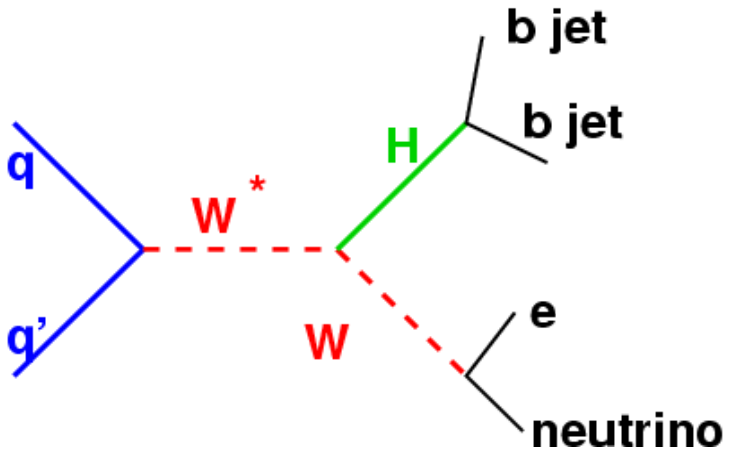
require excellent detector performance

Backgrounds:

- Electroweak background (W, Z, WW, WZ, top)
  kinematic distributions using Monte Carlo
  normalised with (N)NLO calculations
- QCD and instrumental background taken from
  data using control samples


Run II Integrated Luminosity
19 April 2002 - 22 February 2006
currently in shutdown:
- remove mussels
- silicon upgrades
- trigger upgrades
Luminosity (fb -1)
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
Apr-02 Jul-02 Oct-02 Jan-03 Apr-03 Jul-03 Oct-03 Jan-04 Apr-04 Jul-04 Oct-04 Jan-05 Apr-05 Jul-05 Oct-05 Jan-06 Apr-06 Jul-06
1.41
1.19
Delivered
Recorded
Run I
this talk

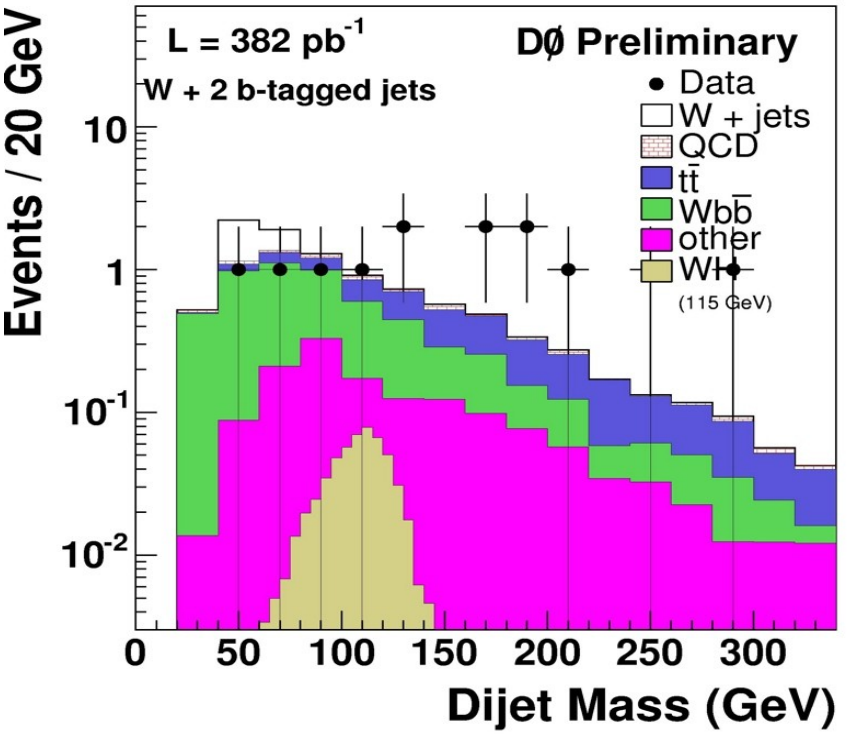
2.1) WH→eνbb



- Selection
  - two tagged b-jets
  - isolated electron with E_T > 20 GeV
  - E_T^{miss} > 25 GeV

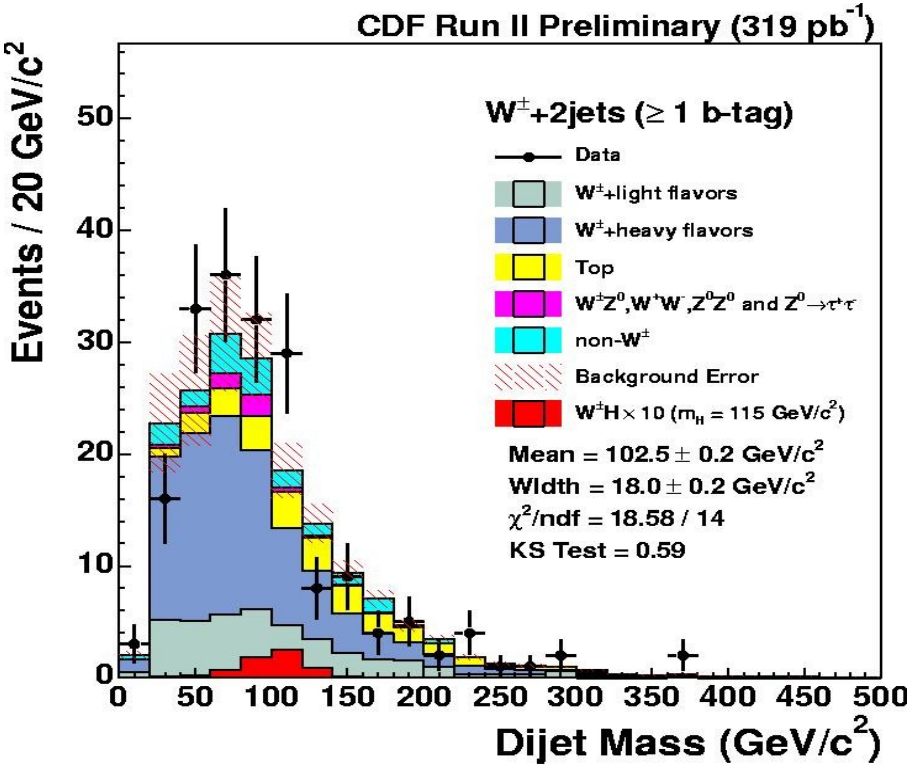
M_H=115 GeV, 85<M_{jj}<135 GeV

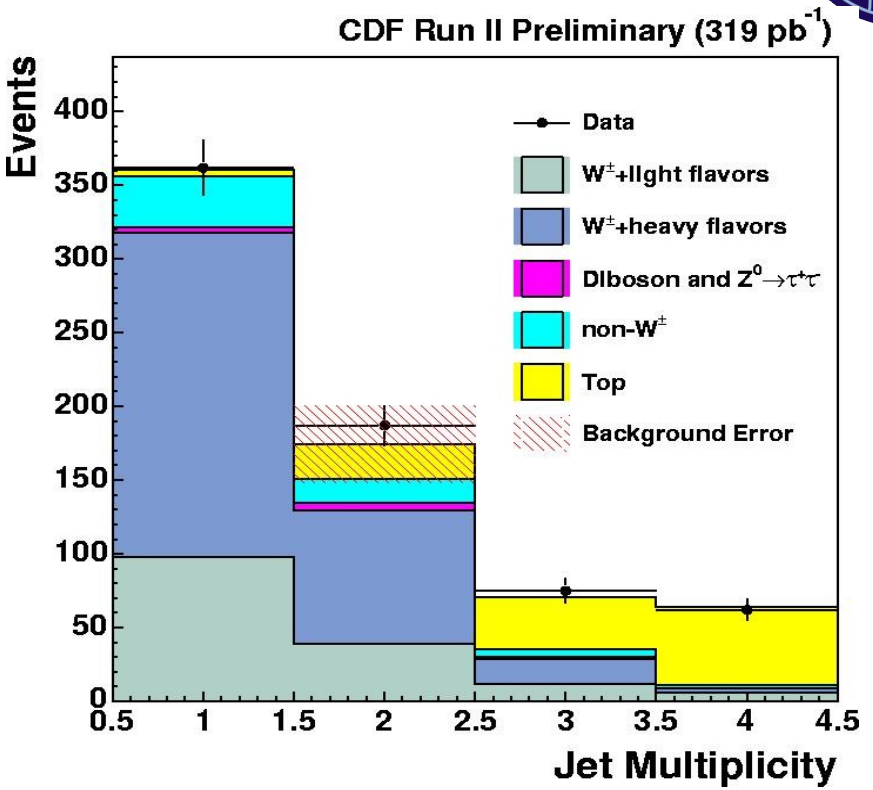
- 4 events observed
- 2.37 ± 0.59 predicted
- σ_{95}=8.6 pb



WH→lνbb

- muon and electron channel combined:
  - 1 or 2 tagged b-jets
  - electron or muon with p_T > 20 GeV
  - E_T^{miss} > 20 GeV

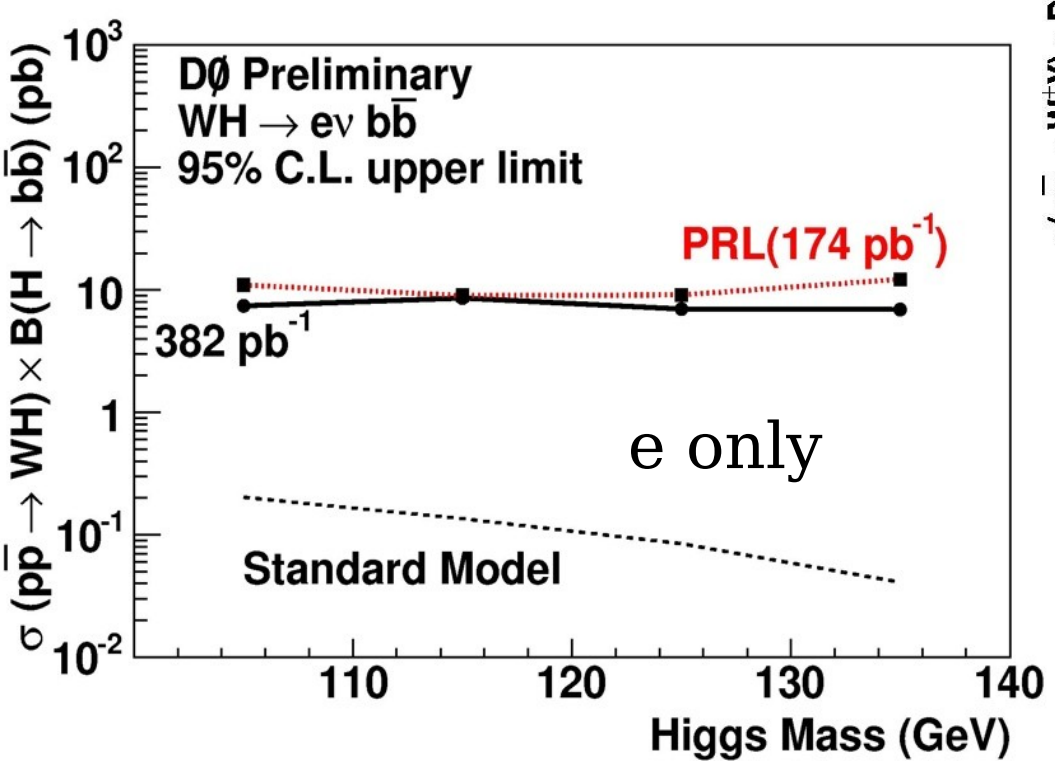


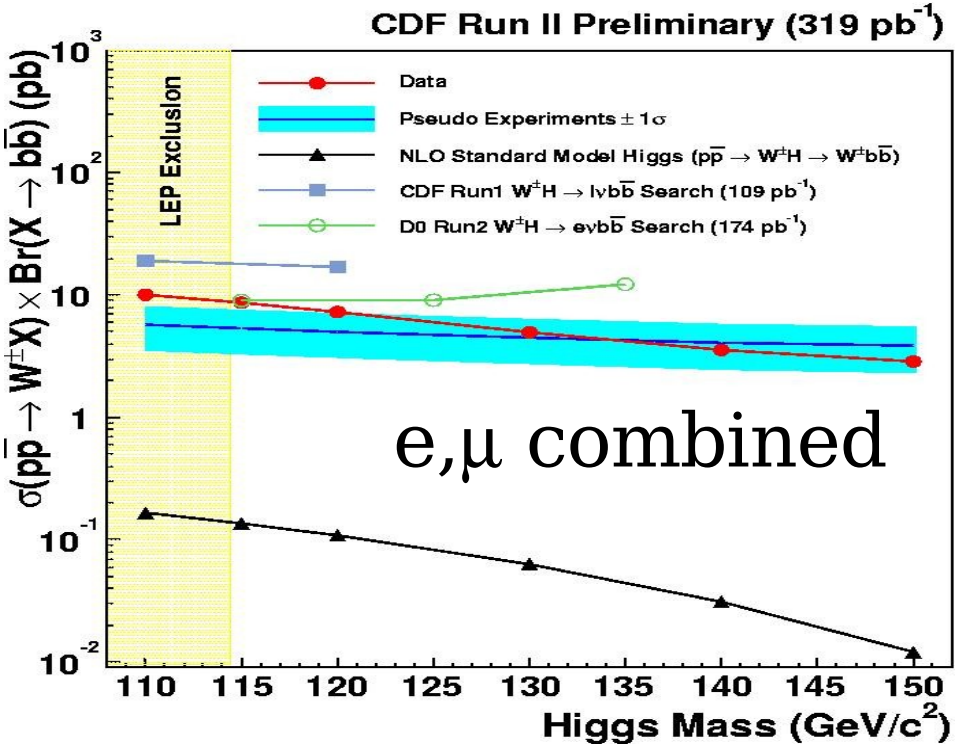


- main backgrounds:

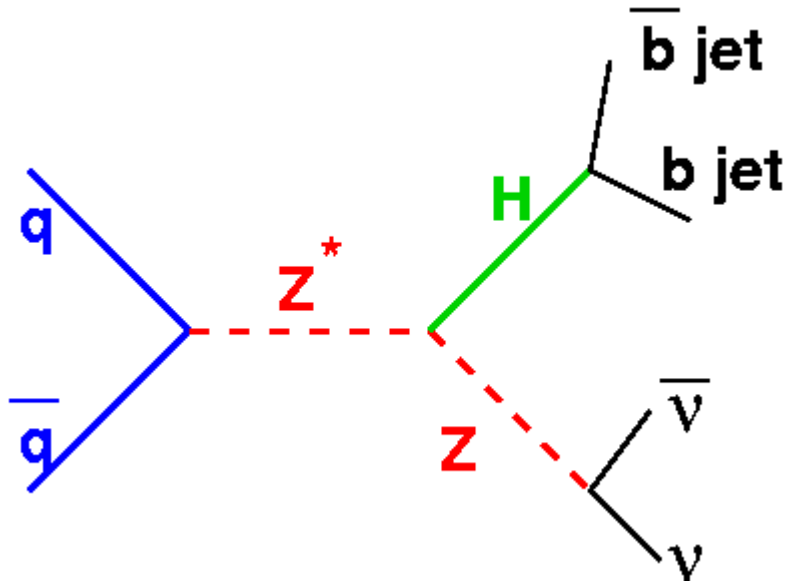
  W+heavy flavour jets
  top pairs
  di-bosons (WZ, WW etc.)

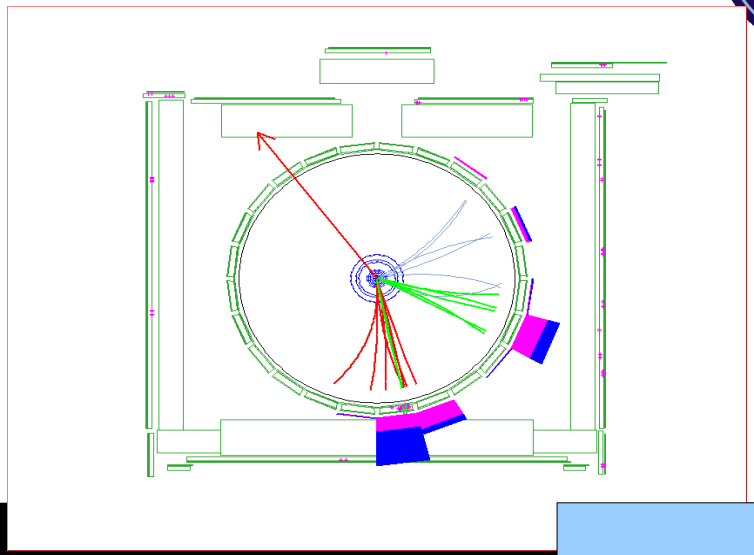
Cross-section Limits

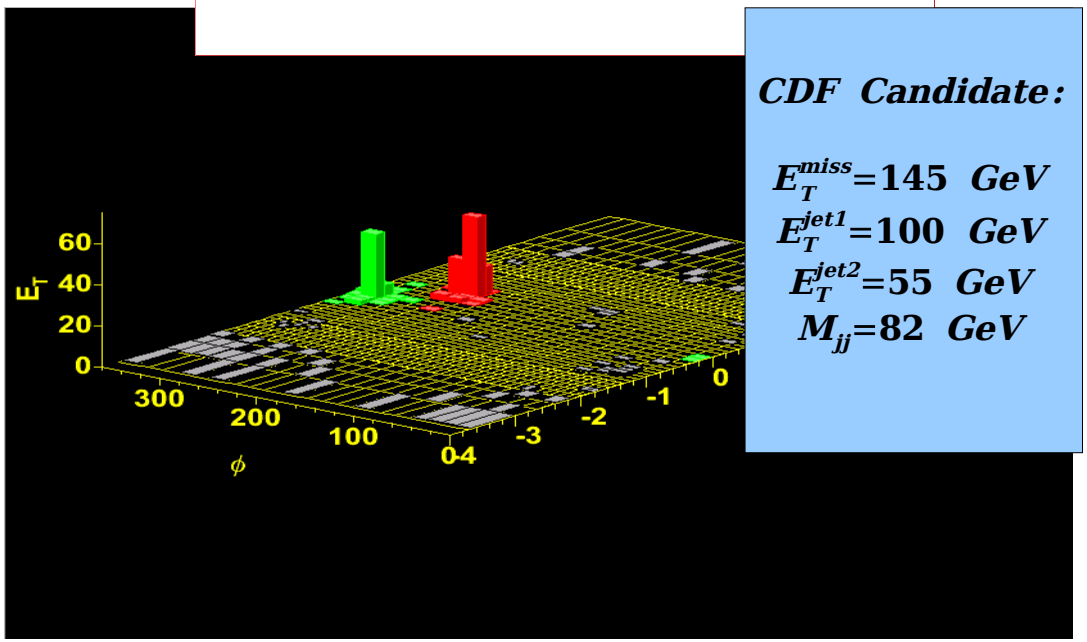




2.2) ZH→ννbb







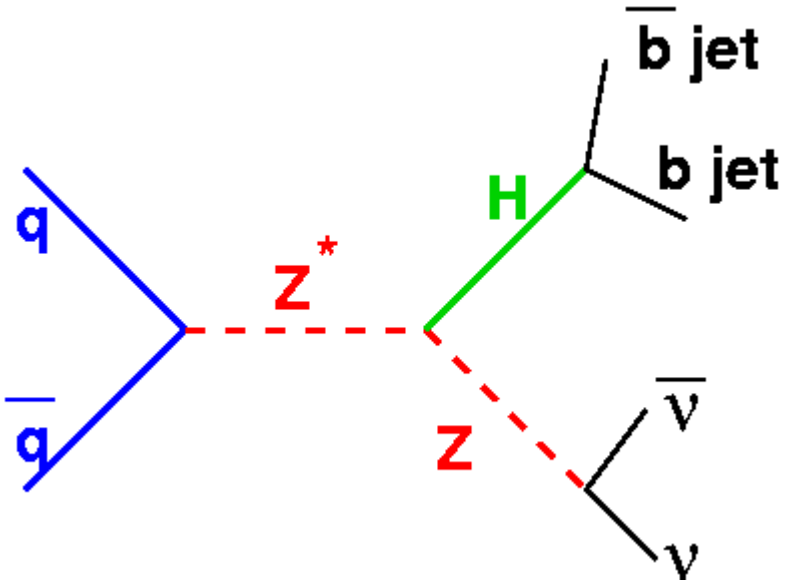
CDF Candidate:

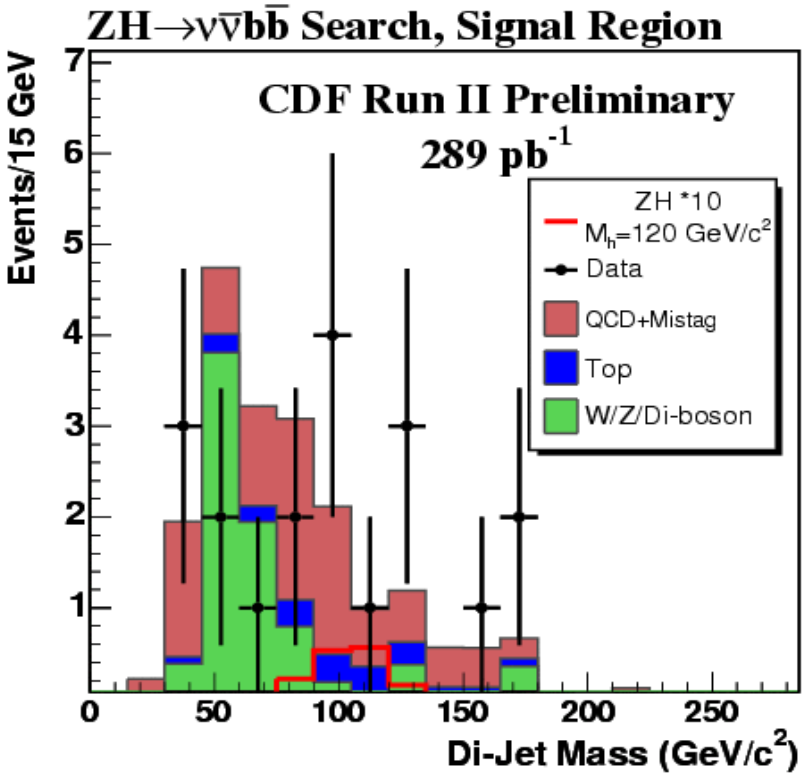
E_T^{miss}=145 *GeV*
E_T^{jet1}=100 *GeV*
E_T^{jet2}=55 *GeV*
M_{jj}=82 *GeV*

Selection:

- ≥ 1 tagged b-jets (secondary vertex)
- two jets with E_T > 40/20 GeV
- E_T^{miss} > 70 GeV

ZH→νν̄bb̄





Backgrounds :

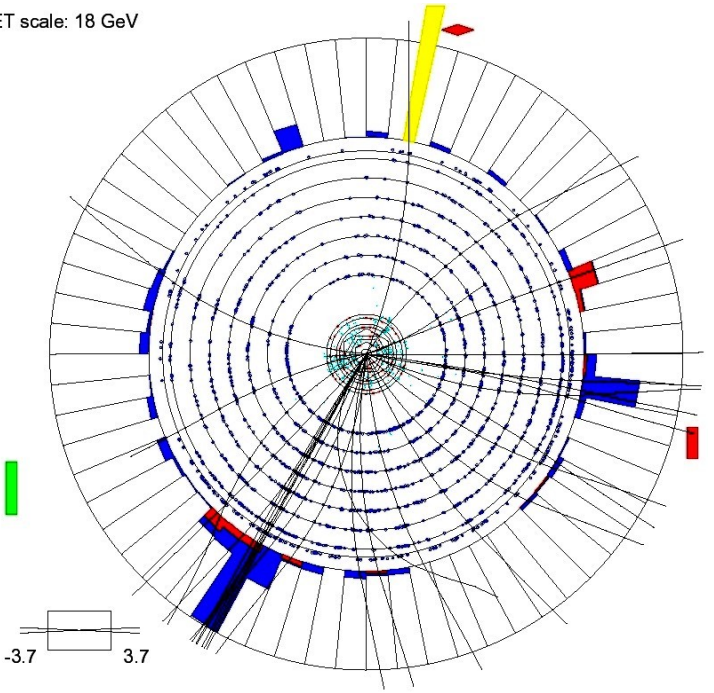
- W+heavy flavour jets
- Z +heavy flavour jets
- di-bosons
- misidentified b jets
- top pairs

M_H=120 GeV, 80<M_{jj}<120 GeV

- 6 events observed
- 4.36 ± 1.02 predicted
- σ_{95}=4.5 pb

ZH→ννbb

L=261 pb^{-1}

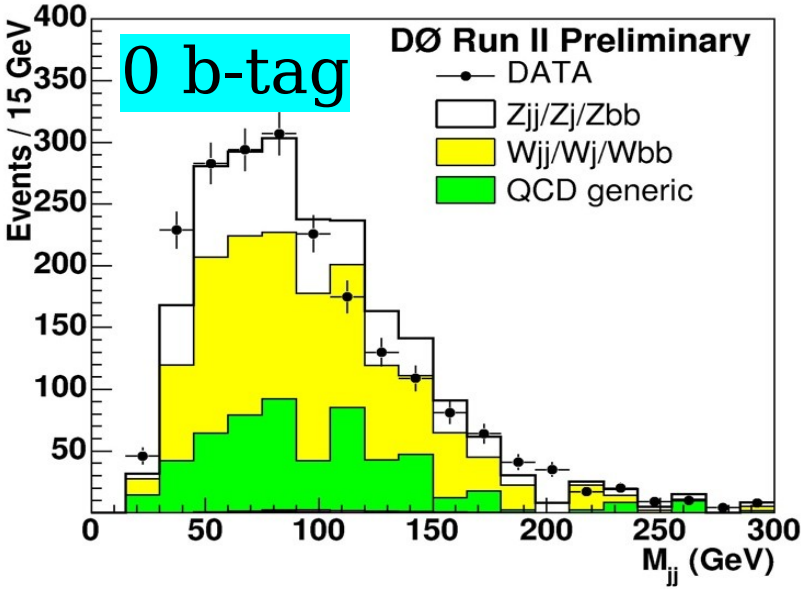


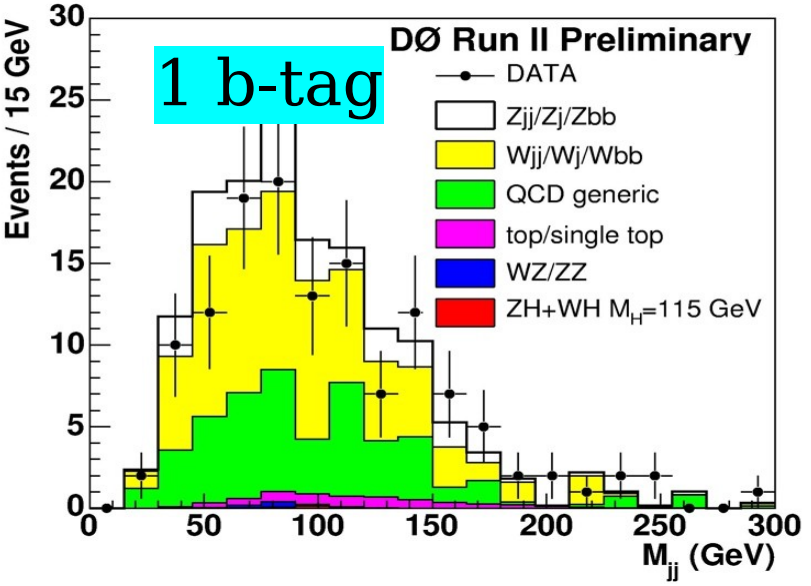
Selection:

- two <u>acoplanar</u> b-jets with E_T > 40/20 GeV
- E_T^{miss} > 70 GeV
- Sum of scalar jet E_T<200 GeV

b-tagging efficiency 43%
mistag rate 0.5%

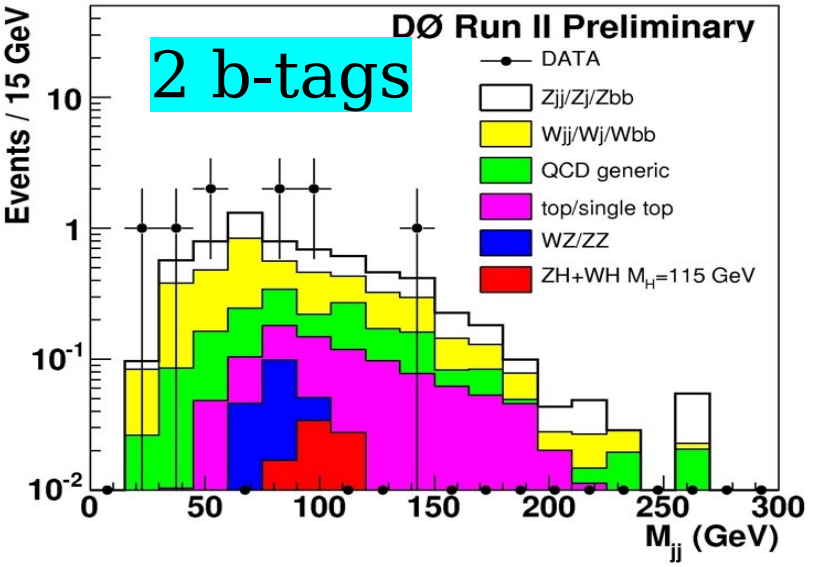
ZH→ννbb



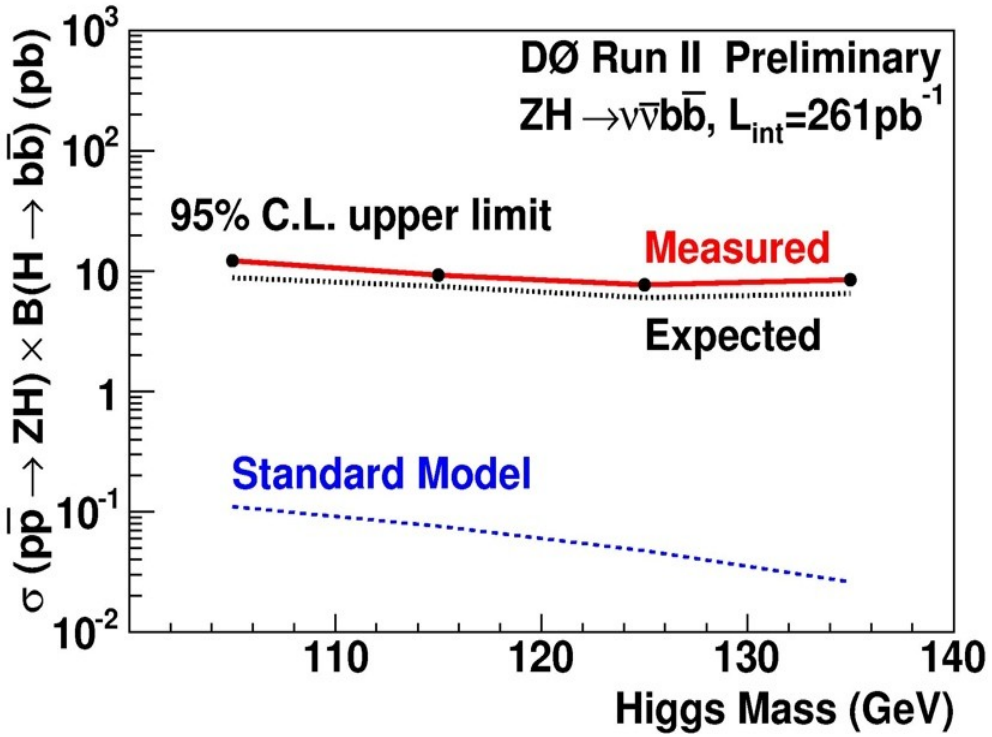


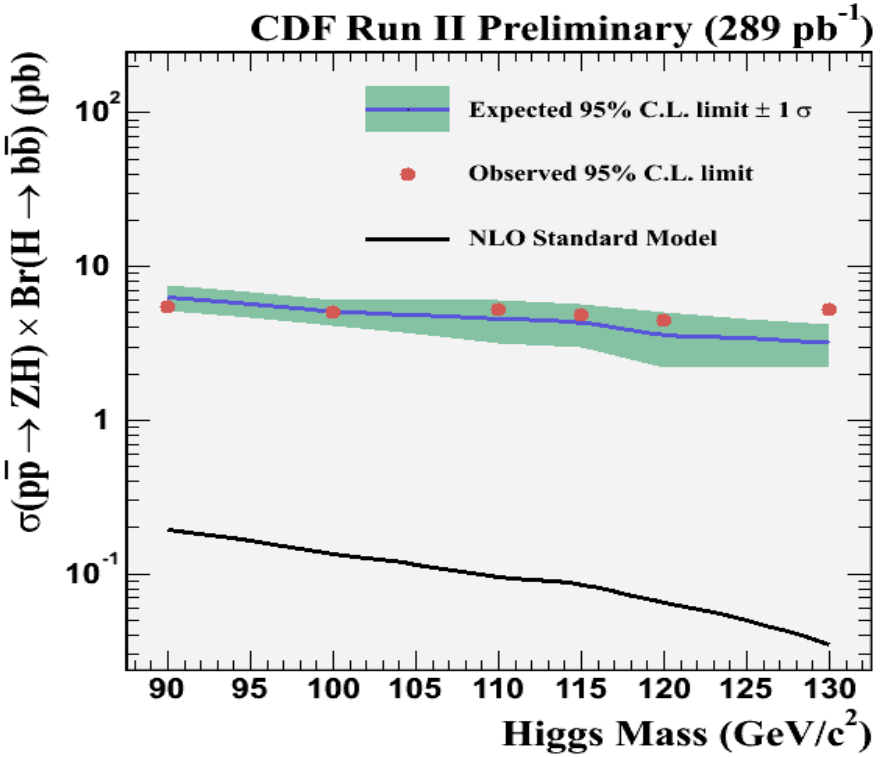
M_H=115 GeV, 80<M_{jj}<130 GeV

- 3 events observed
- 2.2 ± 0.7 predicted
- σ_{95}=9.3 pb

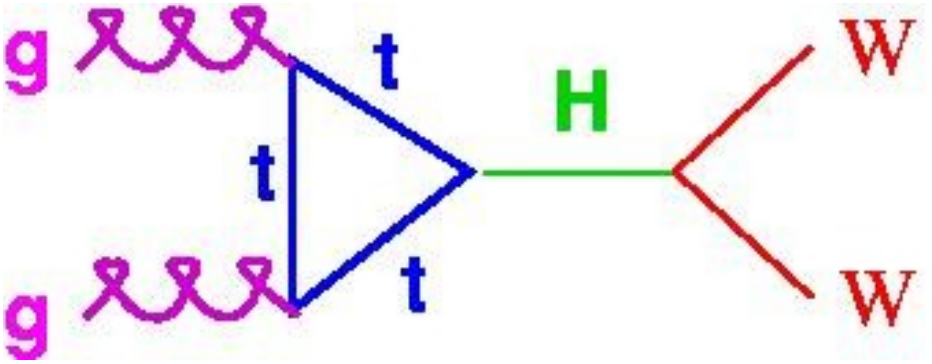


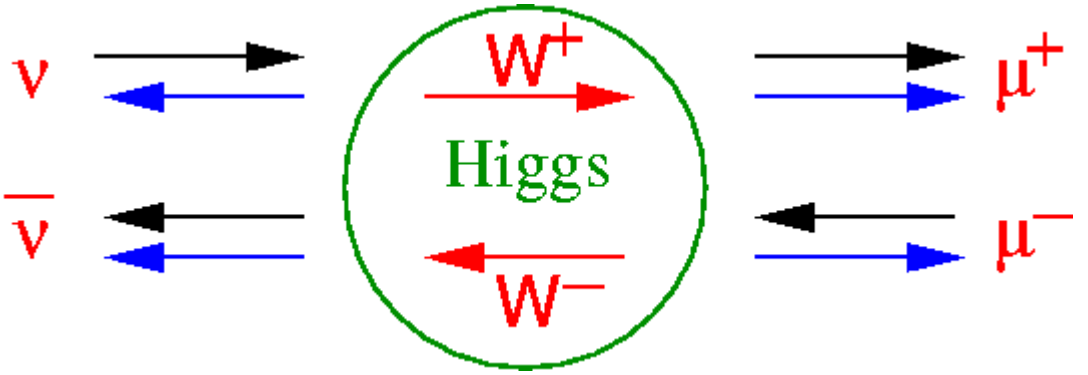
Limits still far away from SM
..a long way to go





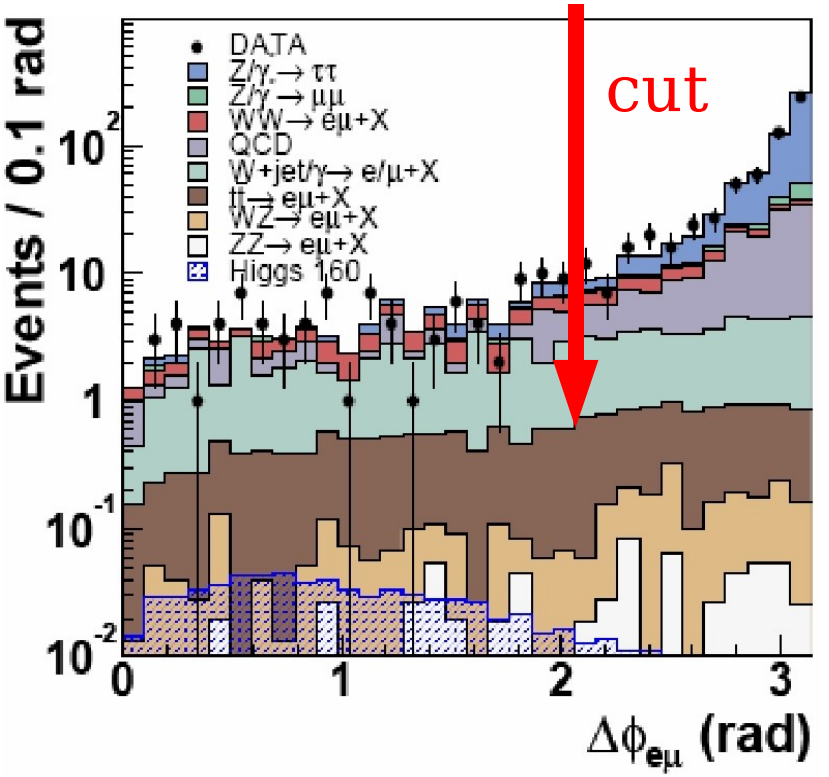
3.1) H→ WW→ eνeν, μνμν, eνμν

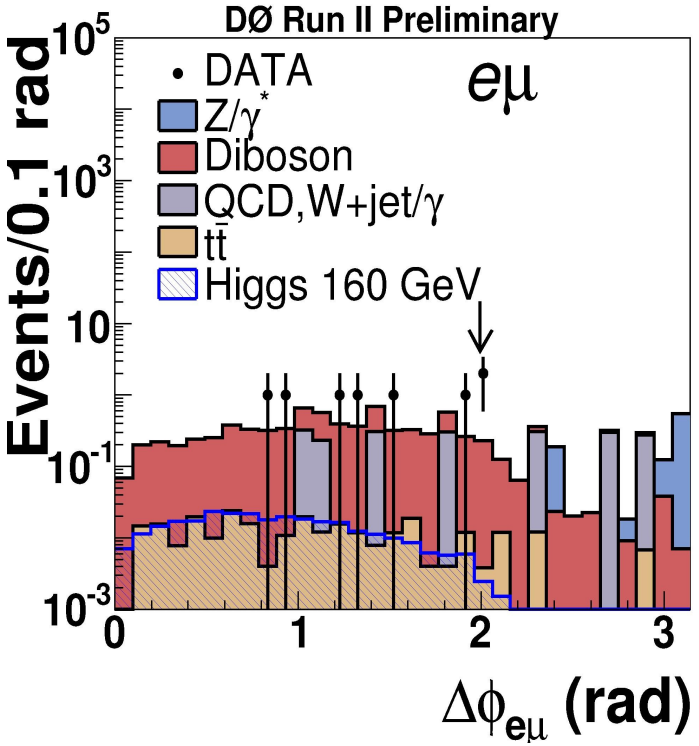


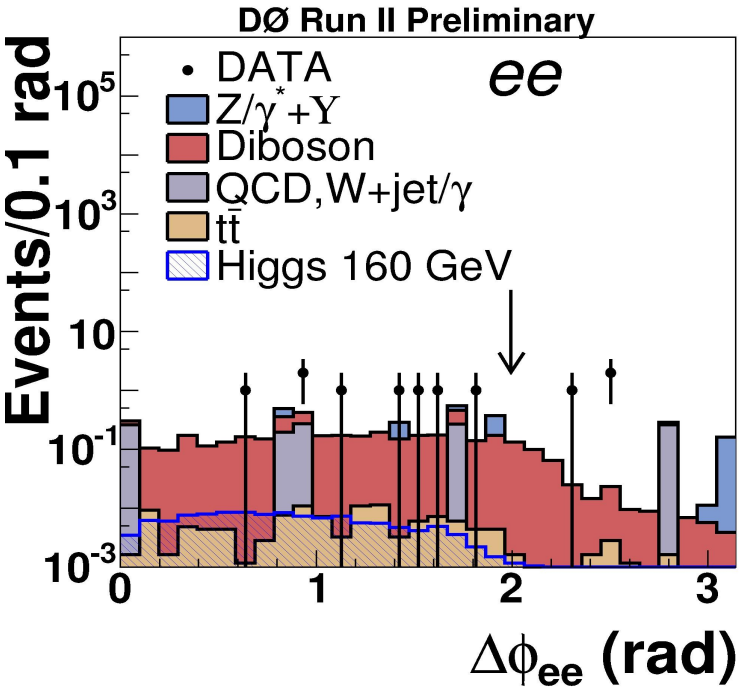


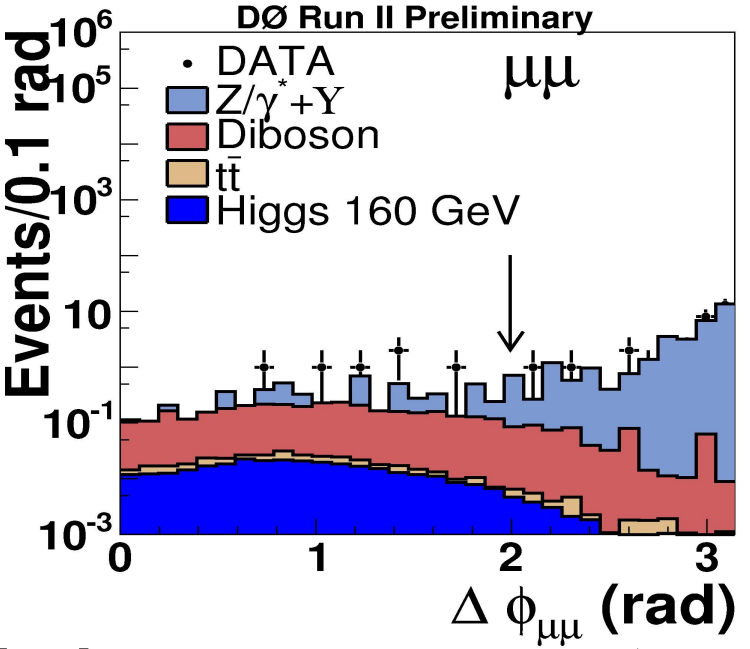
Selection:

- two leptons with p_T > 15/10 GeV
- E_T^{miss} > 20 GeV
- $\Delta\phi_{ll} < 2$





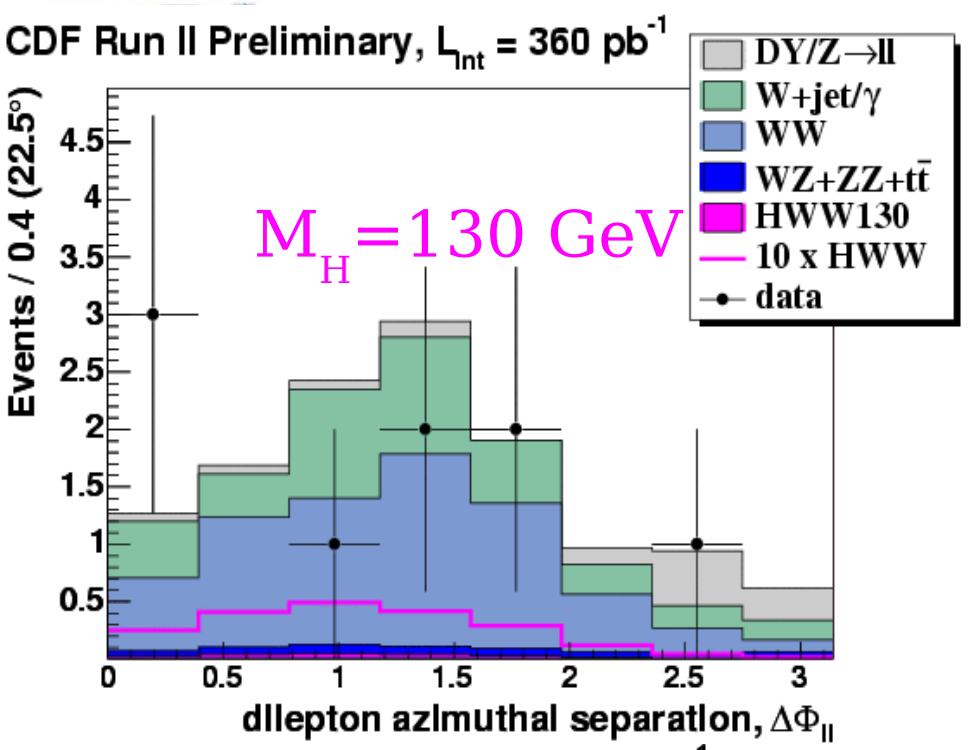


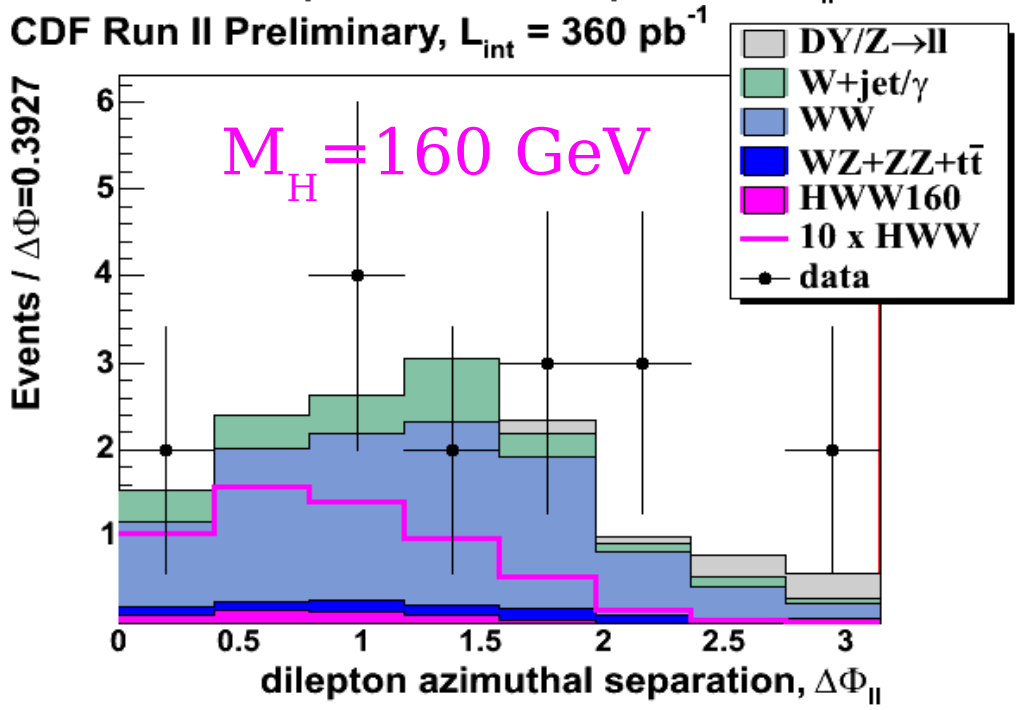


M_H=120 GeV

- 21 events observed
- 30.1 ± 2.3 (stat) predicted
- BG syst. uncertainty 8-14%
- σ_{95}(obs)=5.6 pb
- σ_{95}(exp)=9.5 pb

published in PRL 96, 011801 (2006)

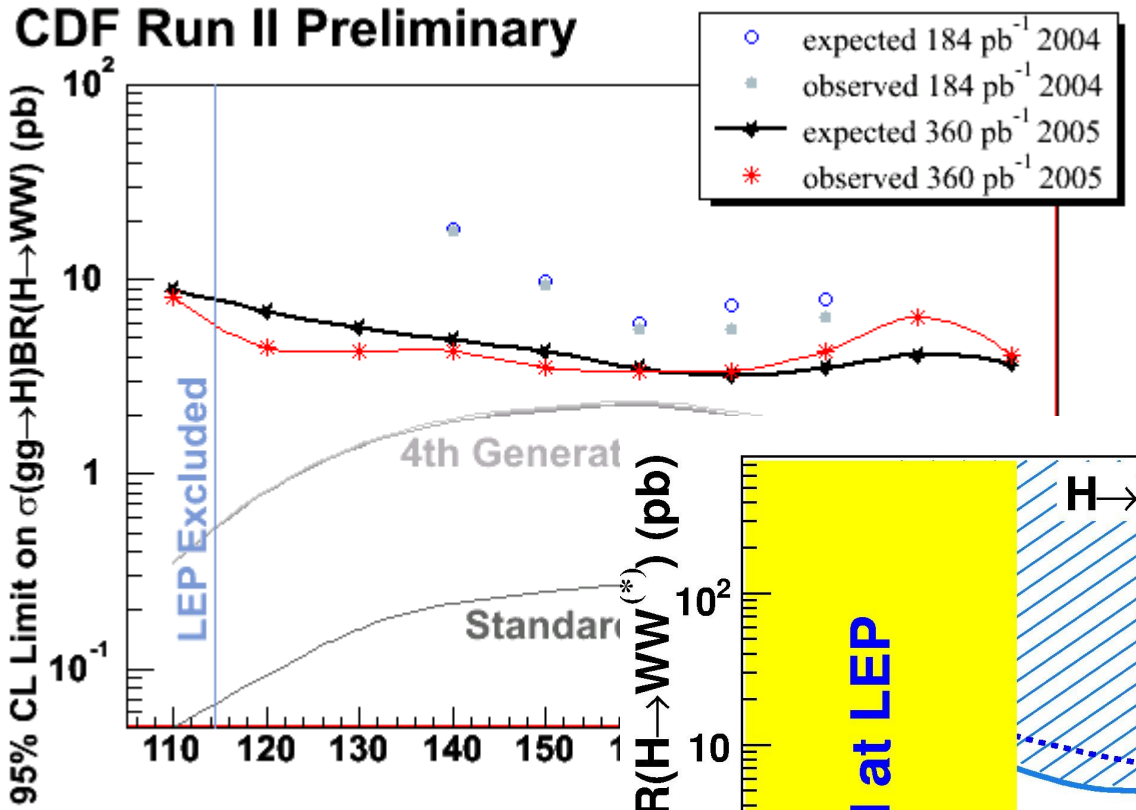


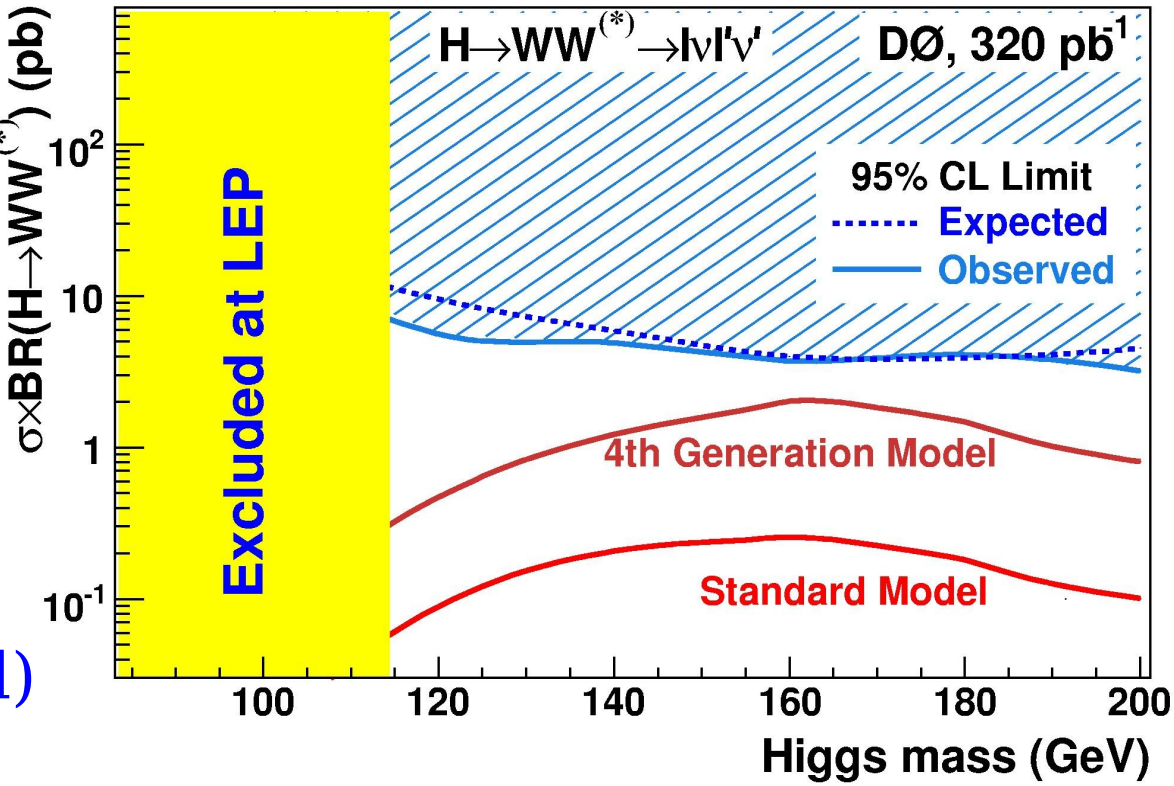


Selection:

- two leptons with p_T>20/10 GeV
- $E_T^{miss} > M_H/4$
- $16 < M_{ll} < M_H/2$-5 GeV

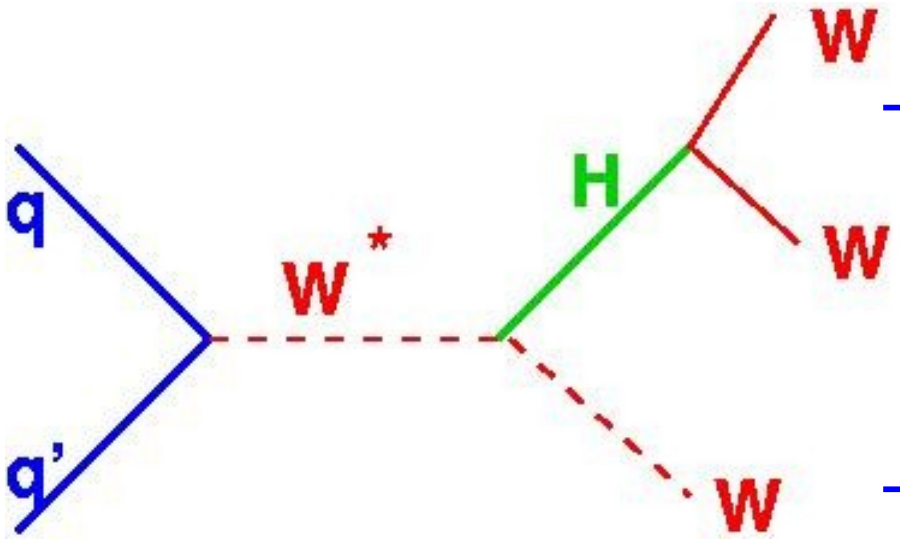
$\Delta\phi_{ll}$ distribution fitted to extract 95% CL limit





DØ also uses shape information for limit setting (LEP CL_s method)

3.2) $WH \rightarrow WWW^* \rightarrow l\nu l'\nu qq$



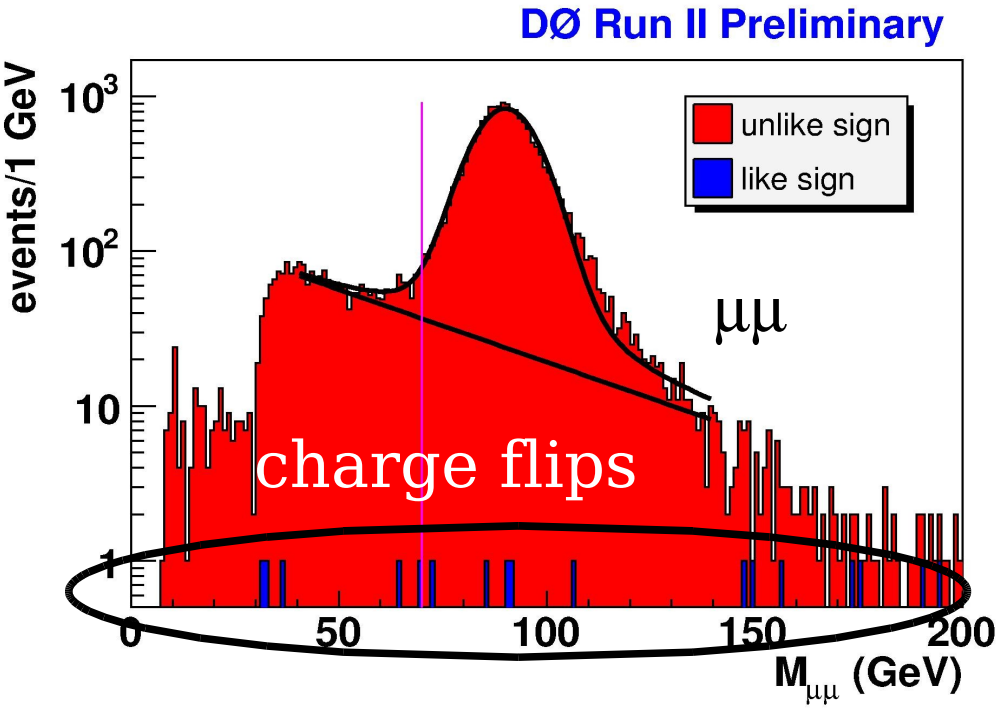
→like-sign leptons

L=363-384 pb^{-1}

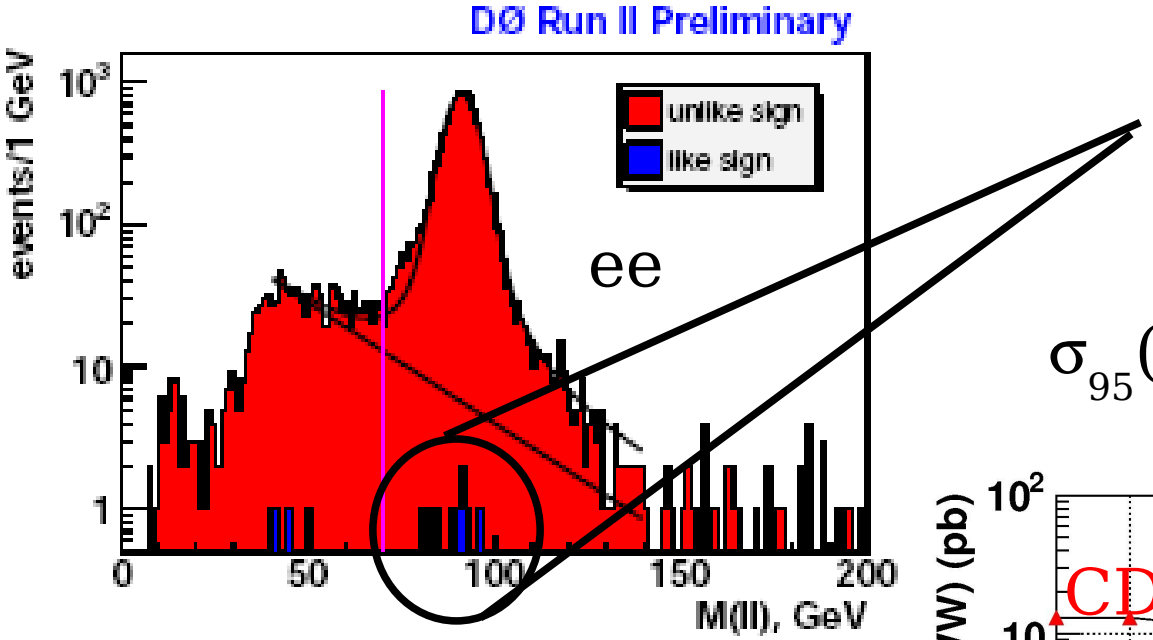
→hadrons

Selection:

- two isolated leptons (ee, μμ, eμ)
- both leptons have $p_T > 15$ GeV
- $E_T^{miss} > 20$ GeV

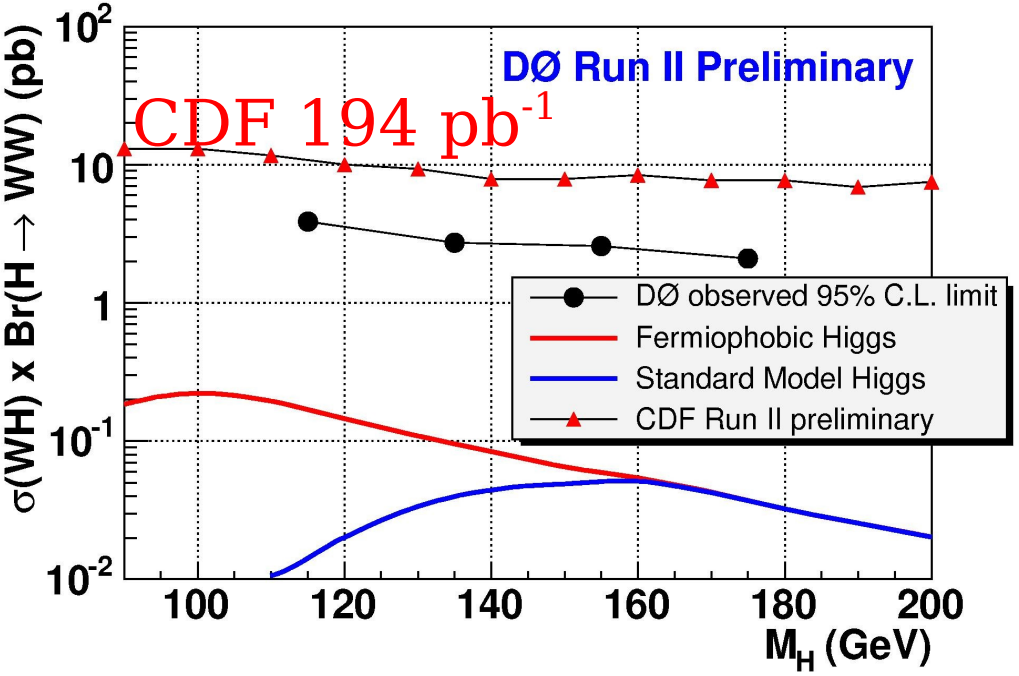


WH→WWW*

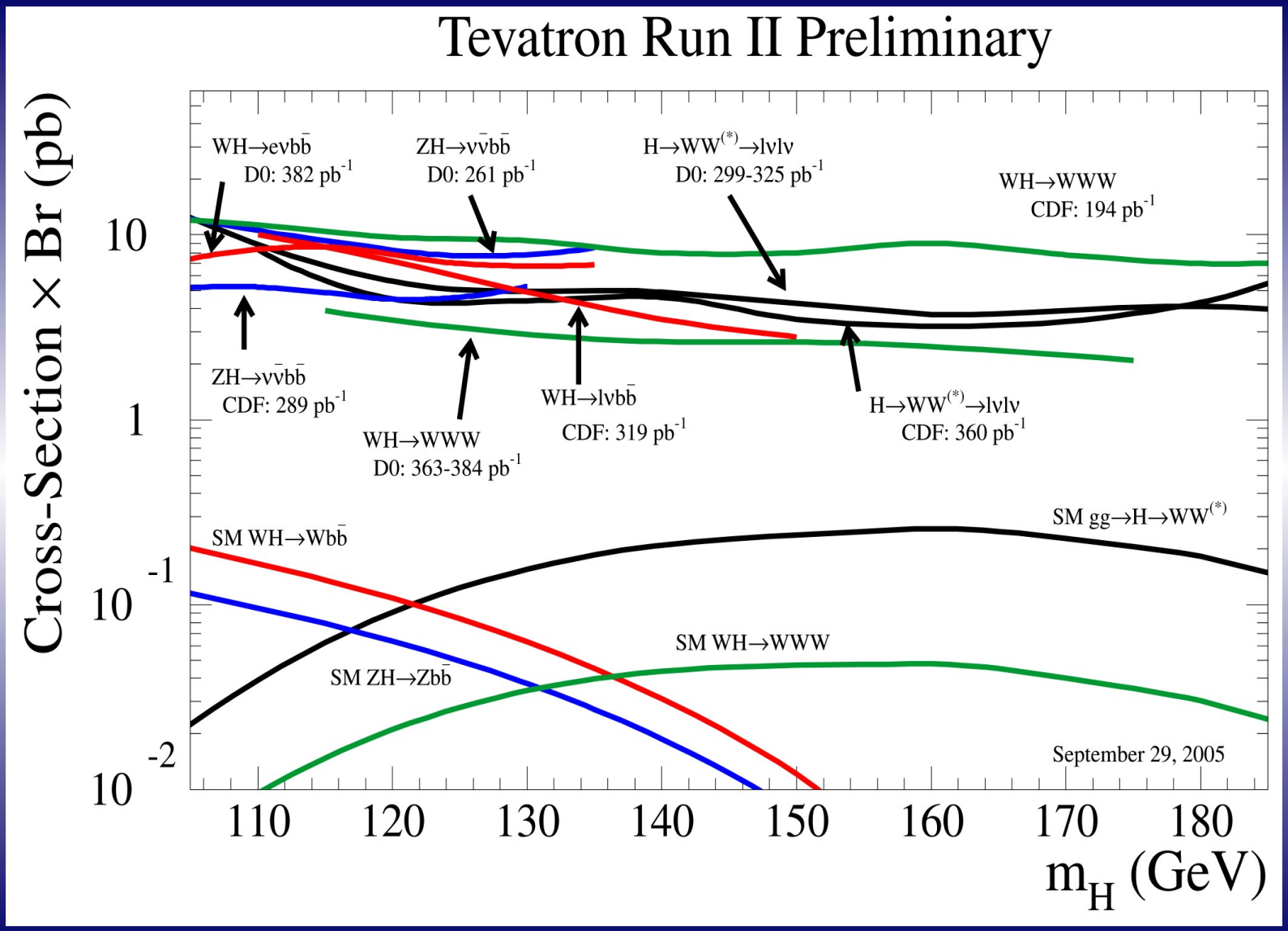


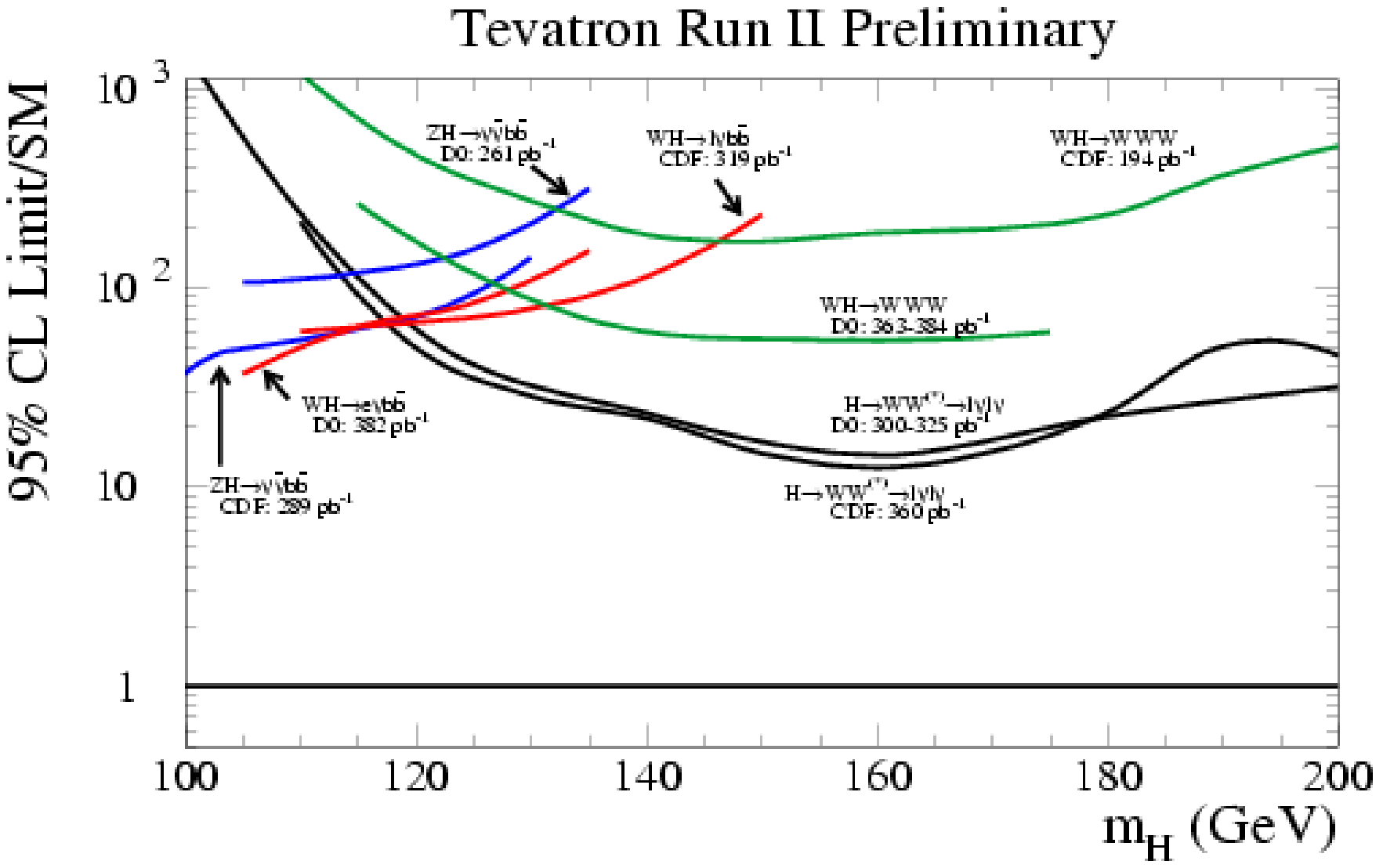
mainly di-boson (WZ)

$\sigma_{95}(M_H=115\ \text{GeV})=3.88$ pb



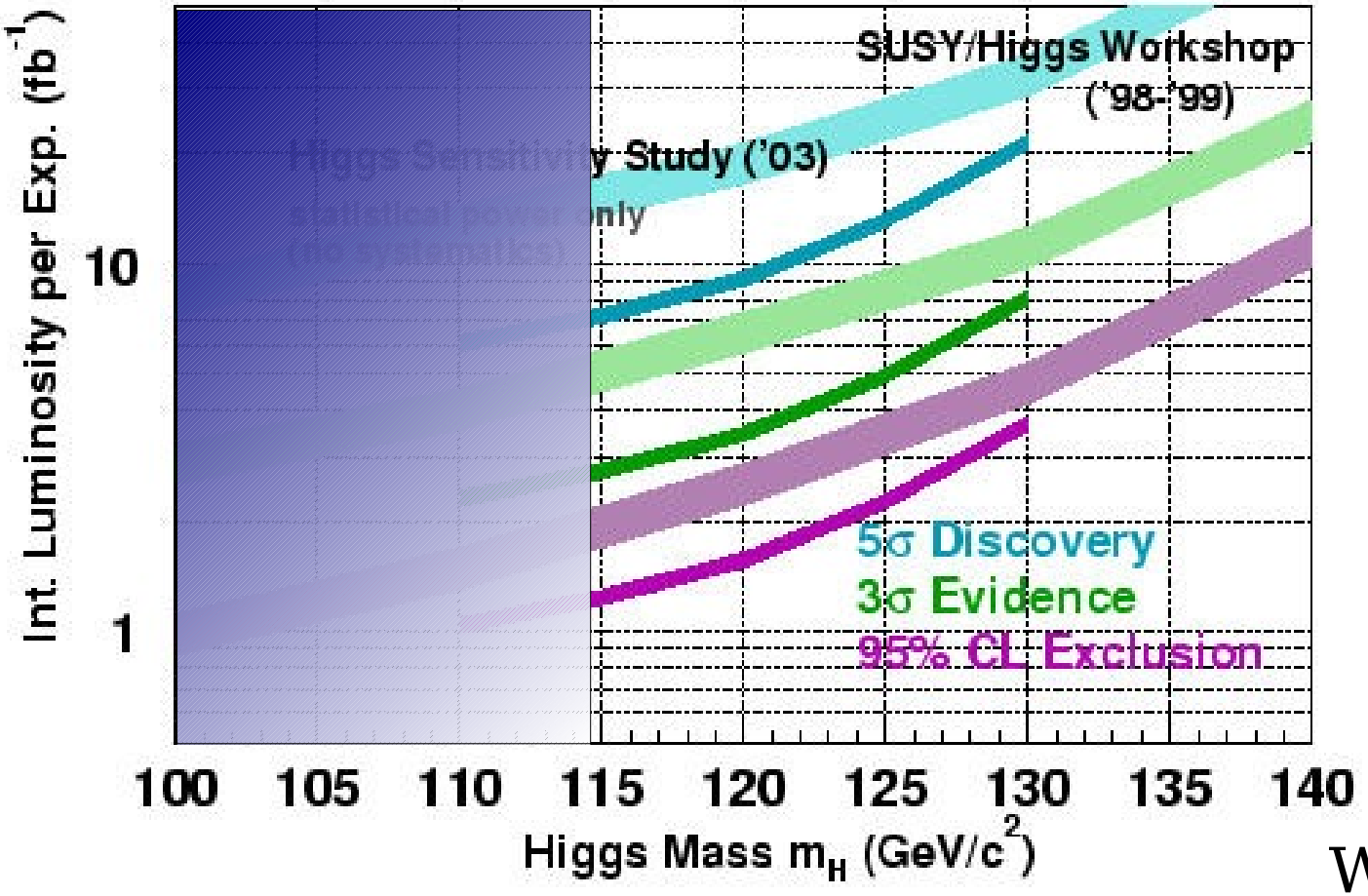
	obs	expected
ee	1	0.70 ± 0.08
eμ	3	4.32 ± 0.23
μμ	2	3.72 ± 0.75


Tevatron Run II Preliminary
Cross-Section × Br (pb)
10
1
10^-1
10^-2
WH→eνbb̄
D0: 382 pb^-1
ZH→νν̄bb̄
D0: 261 pb^-1
H→WW(*)→lνlν
D0: 299-325 pb^-1
WH→WWW
CDF: 194 pb^-1
ZH→νν̄bb̄
CDF: 289 pb^-1
WH→WWW
D0: 363-384 pb^-1
WH→lνbb̄
CDF: 319 pb^-1
H→WW(*)→lνlν
CDF: 360 pb^-1
SM WH→Wbb̄
SM gg→H→WW(*)
SM WH→WWW
SM ZH→Zbb̄
September 29, 2005
110
120
130
140
150
160
170
180
m_H (GeV)


Tevatron Run II Preliminary
95% CL Limit/SM
10 3
10 2
10
1
ZH→νν̄bb̄
D0: 261 pb-1
WH→lνbb̄
CDF: 319 pb-1
WH→WWW
CDF: 194 pb-1
WH→WWW
D0: 363-384 pb-1
WH→eνbb̄
D0: 382 pb-1
H→WW(*)→lνlν
D0: 300-325 pb-1
ZH→νν̄bb̄
CDF: 289 pb-1
H→WW(*)→lνlν
CDF: 360 pb-1
100
120
140
160
180
200
mH (GeV)

4) Perspectives

only statistical uncertainties



WH→evbb

Current sensitivities are ~1.5 lower

	DØ (382 pb-1)	Study '03
S/√B	0.08	0.20

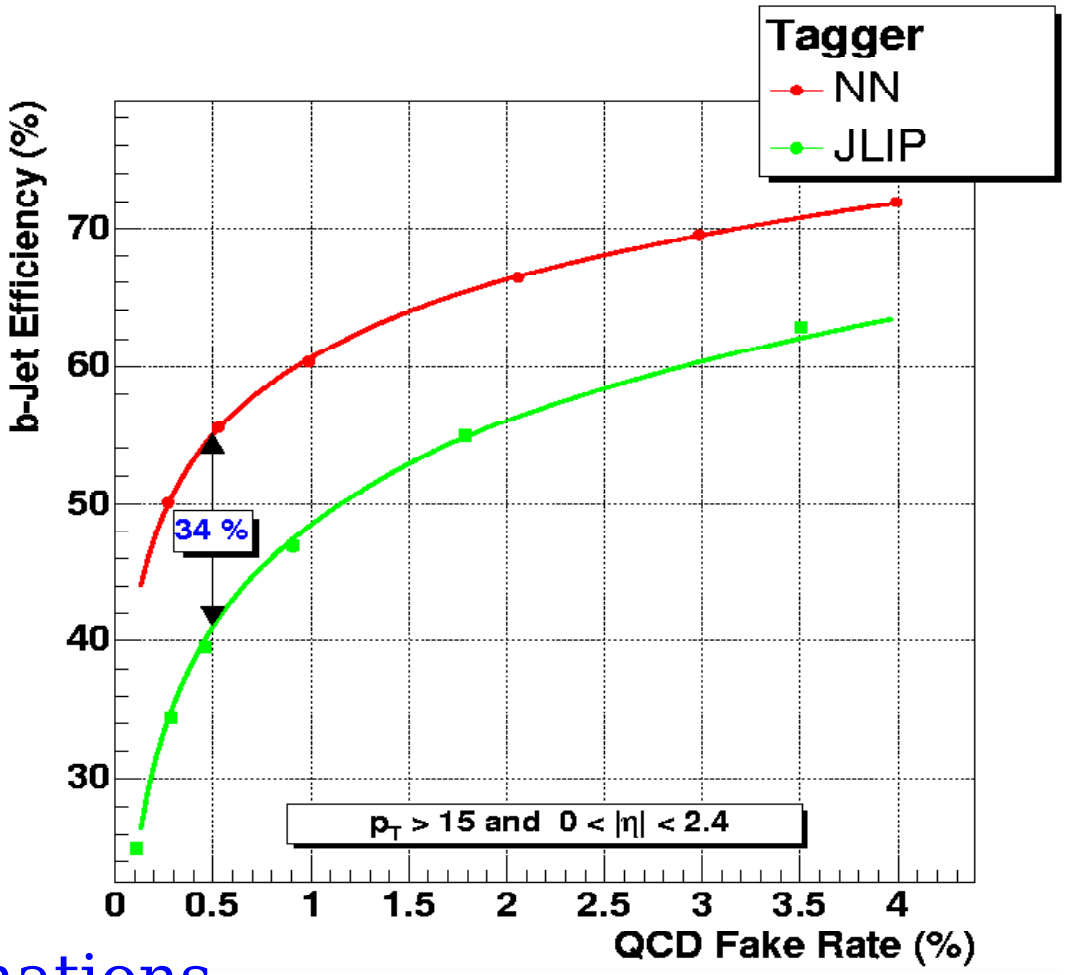
A Long List of Improvements

- Neural Net B tagging

- Di-jet mass resolution

  typically 14% → 10%
  in Higgs mass window

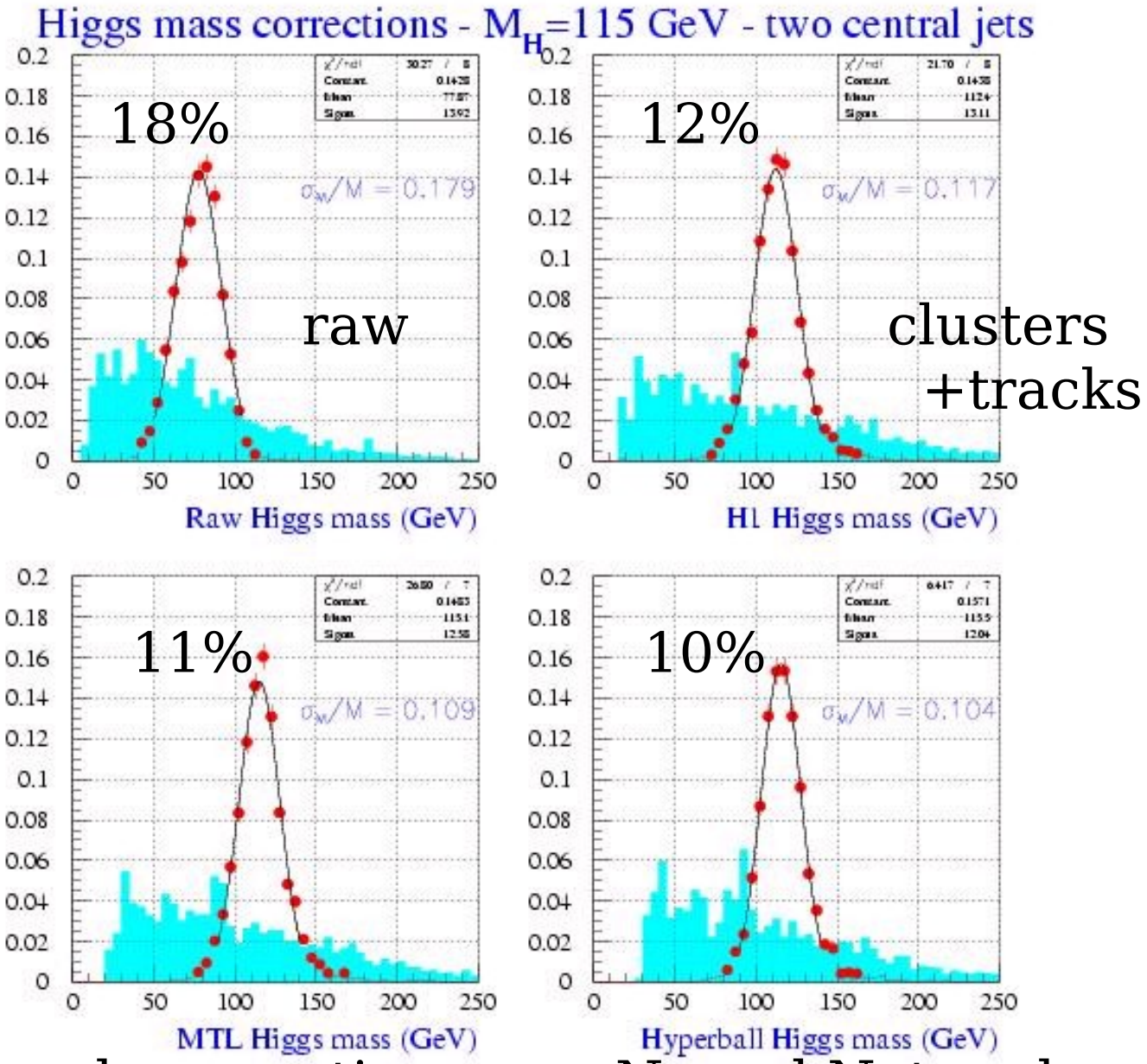
- More channels, e.g.
  - WH → WWW
  - ZH → llbb
  - WH → τ(→hadrons)νbb



- Channel/Experiment Combinations

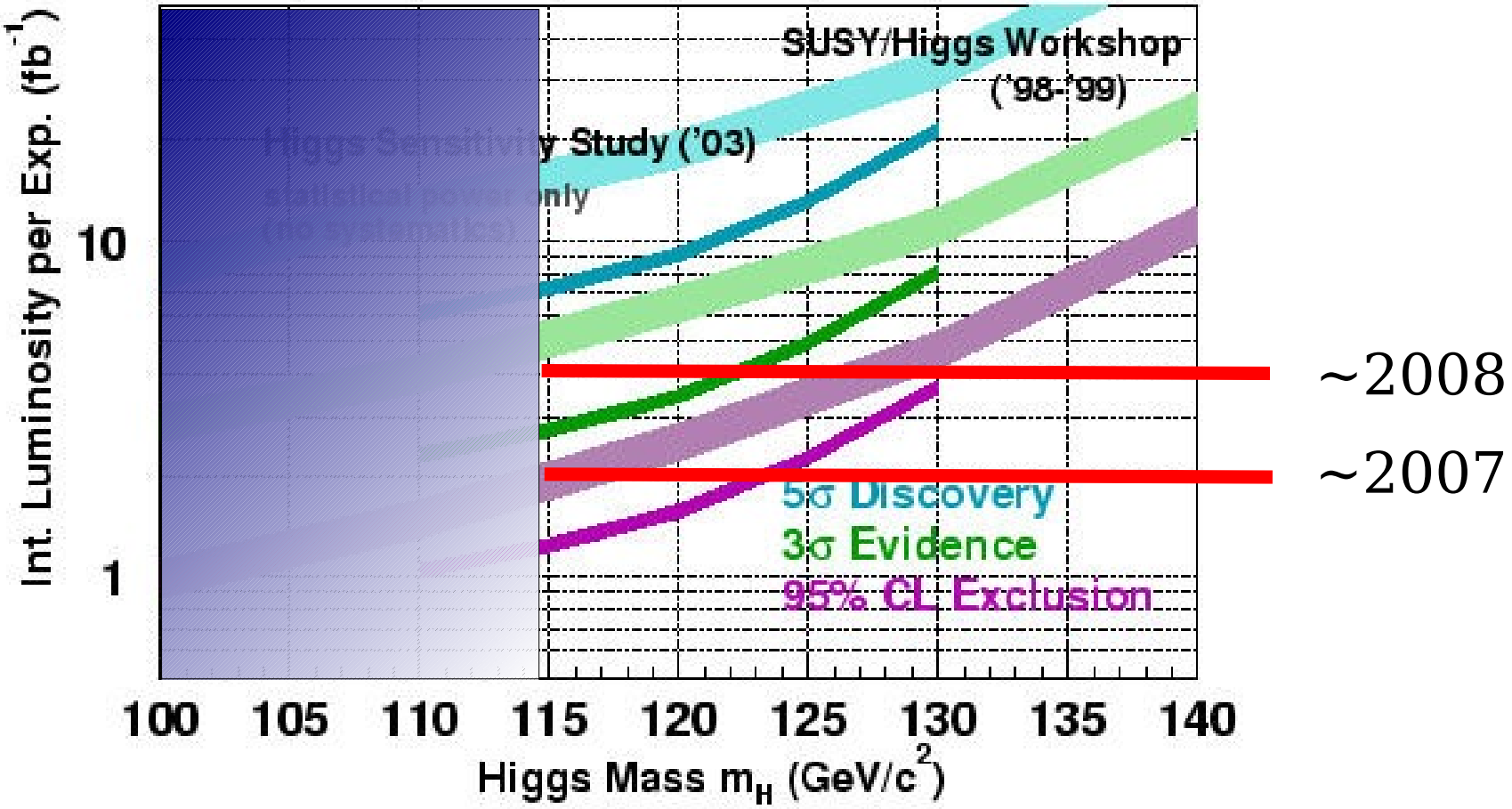
- More data, better techniques

Higgs Sensitivity Study '03



Higgs Sensitivity Study (2003)

only statistical uncertainties



Summary

- Both experiments have studied a wide variety of search channels for the SM Higgs in the 300 pb^{-1} data sets.

- cross-section limits currently about one order of magnitude above SM.

- More work needed to reach expected sensitivity but there is a clear road map and we will be able to reach the targets.

- A whole new set of results will be released in spring 2006.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