Incontri di Fisica delle Alte Energie

Napoli – 11-13 Aprile 2007

Ricerca del bosone di Higgs (Standard Model) a CDF e D0

Silvia Amerio

Universita' di Padova e INFN

Outline

SM constraints and higgs production

CDF/D0 detectors and triggers

Latest results in SM higgs searches

- ✔ $H \rightarrow WW$
- ✔ $ZH \rightarrow llbb$
- ✔ $ZH \rightarrow \nu\nu bb$
- ✔ $WH \rightarrow l\nu bb$

1 fb^{-1}

2007 Tevatron combination plot

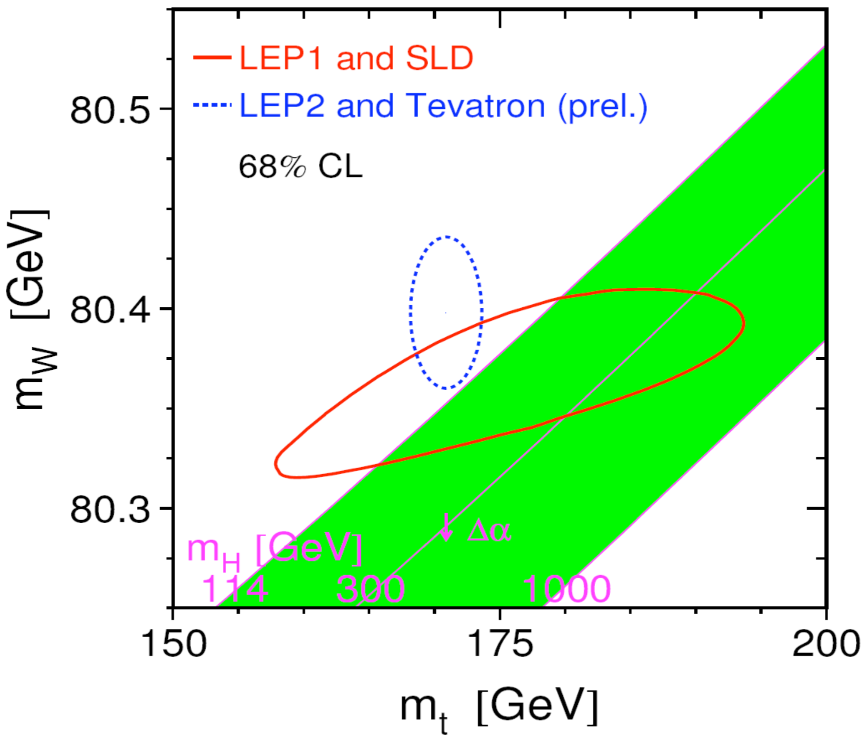
Working hard to increase higgs sensitivity!

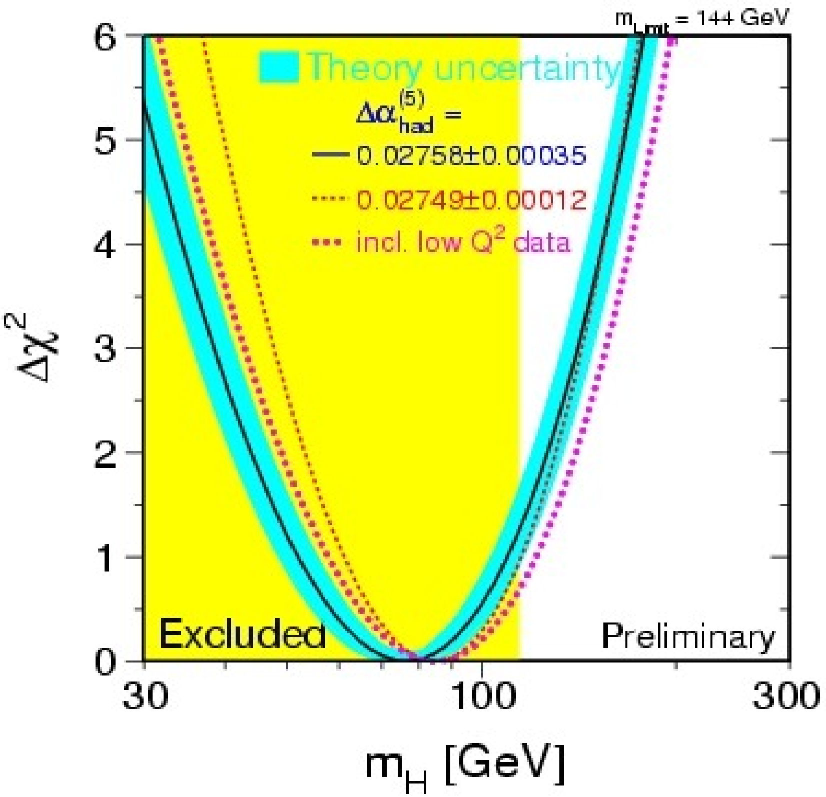
SM Constraints on Higgs

- Direct searches at LEP have excluded the Higgs up to 114.4 GeV
- New Tevatron direct measurements $\mathbf{M_{TOP} = 170.9 \pm 1.8}$ **GeV** and

$\mathbf{M_w = 80.398 \pm 0.025}$ **GeV** constrain

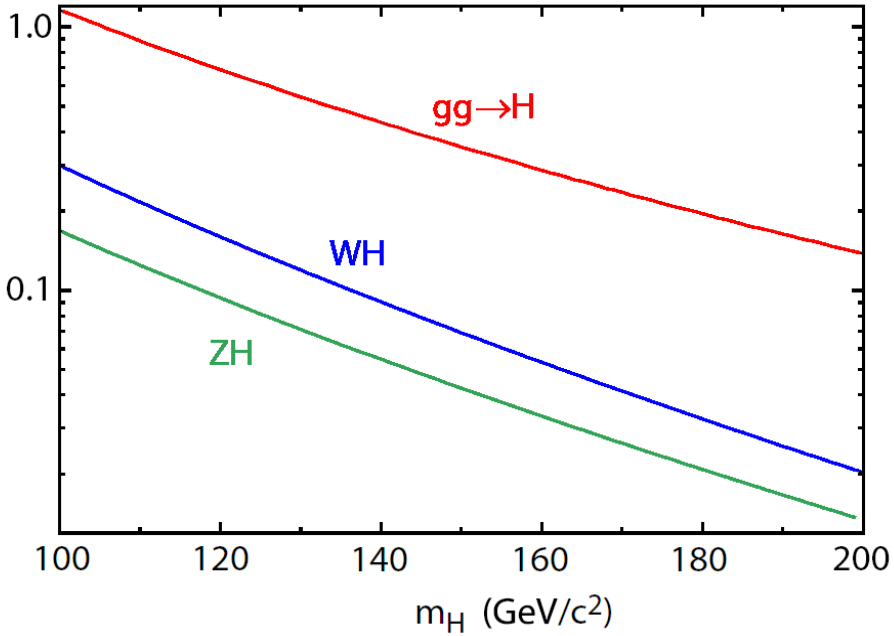
- ➢ $M_H = 76 + 33 - 24$ GeV
- ➢ $M_H < 144$ GeV @ 95% CL





Higgs Production at Tevatron

S = √1.96 TeV

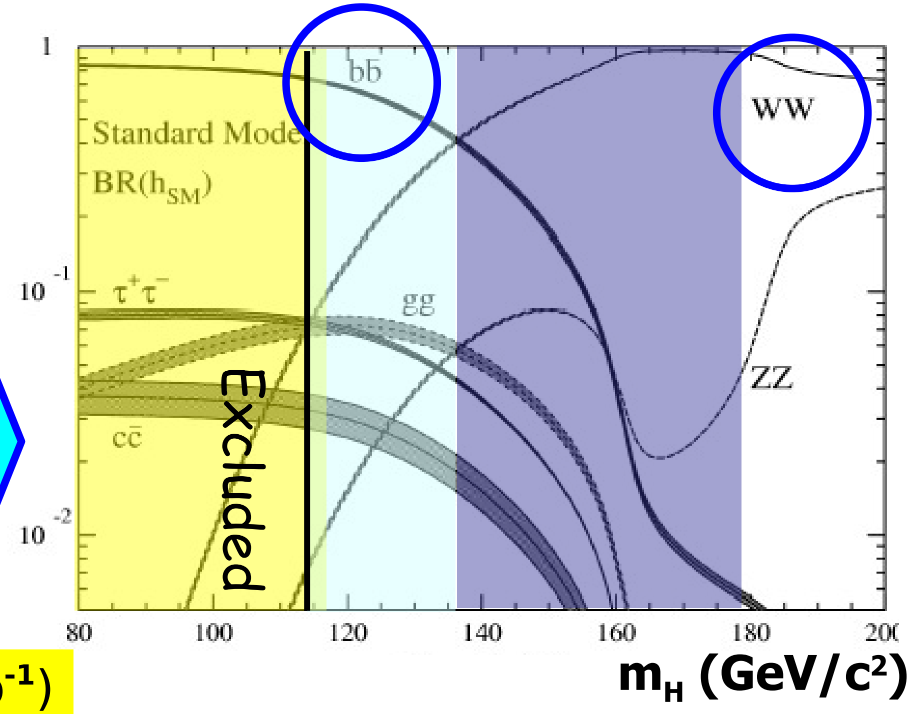


Production

- gg→H (0.2 – 1 pb)
- WH – ZH (0.03 – 0.5 pb)

Dominant decay modes

- MH < 135 GeV : H → bb
- MH > 135 GeV : H → WW

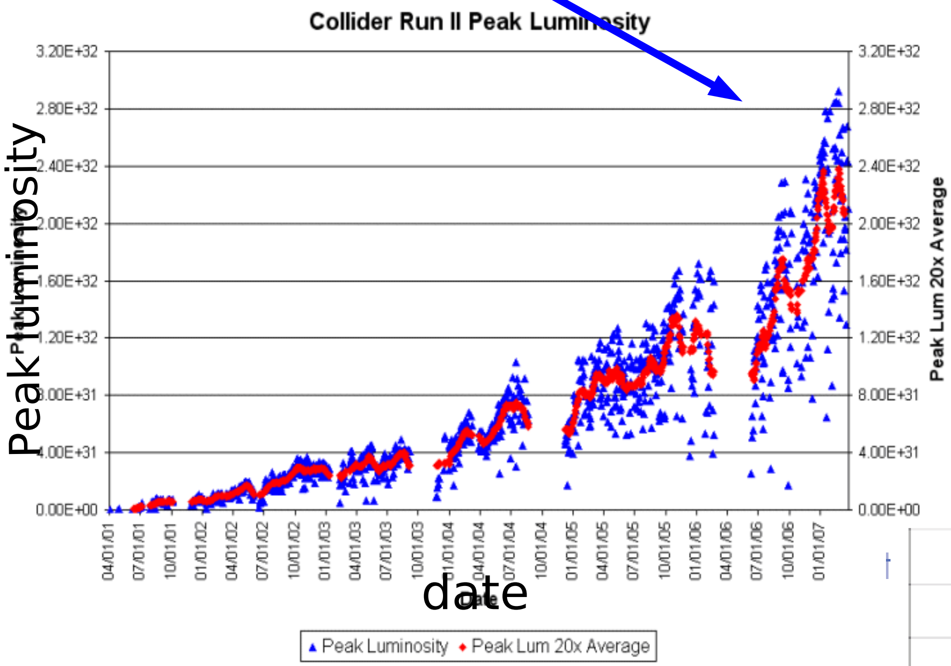


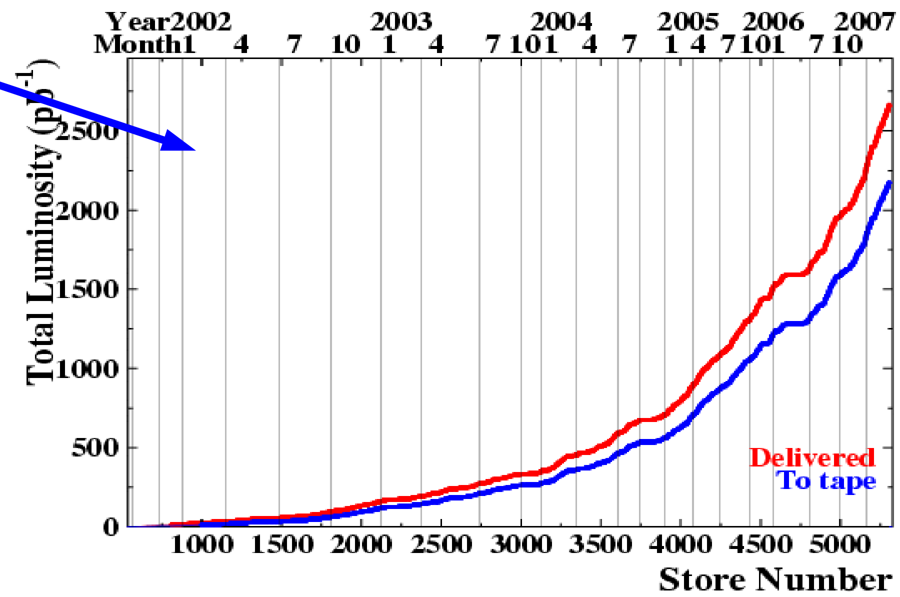
Number of events expected at CDF (**1fb^{-1}**)
- H→ WW : **20** (Mh = 160)
- ZH → llbb : **5**
- ZH → ννbb : **15**
- WH → lνbb : **30**

} Mh = 115 GeV

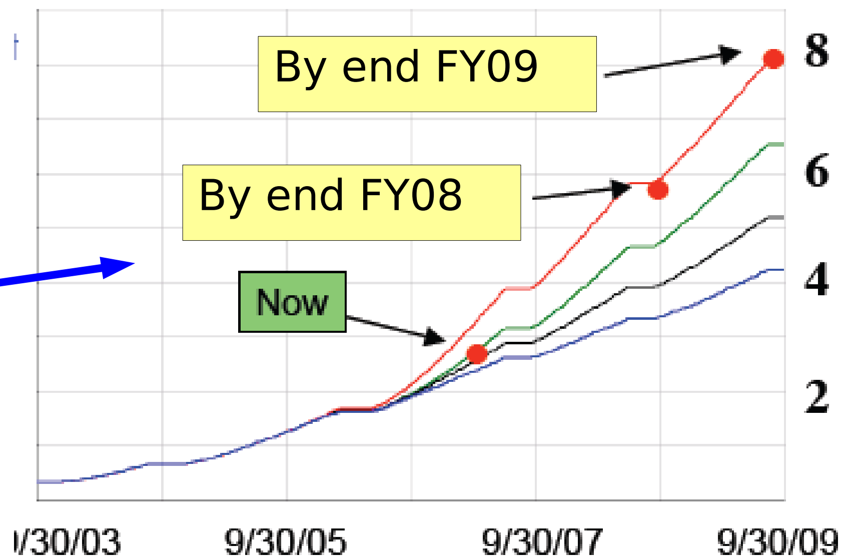
Tevatron performance

Tevatron is performing very well!
Increasing peak instantaneous luminosity (**$2.9 \cdot 10^{32}$ cm^{-2} s^{-1}**)
2.1 fb^{-1} on tape

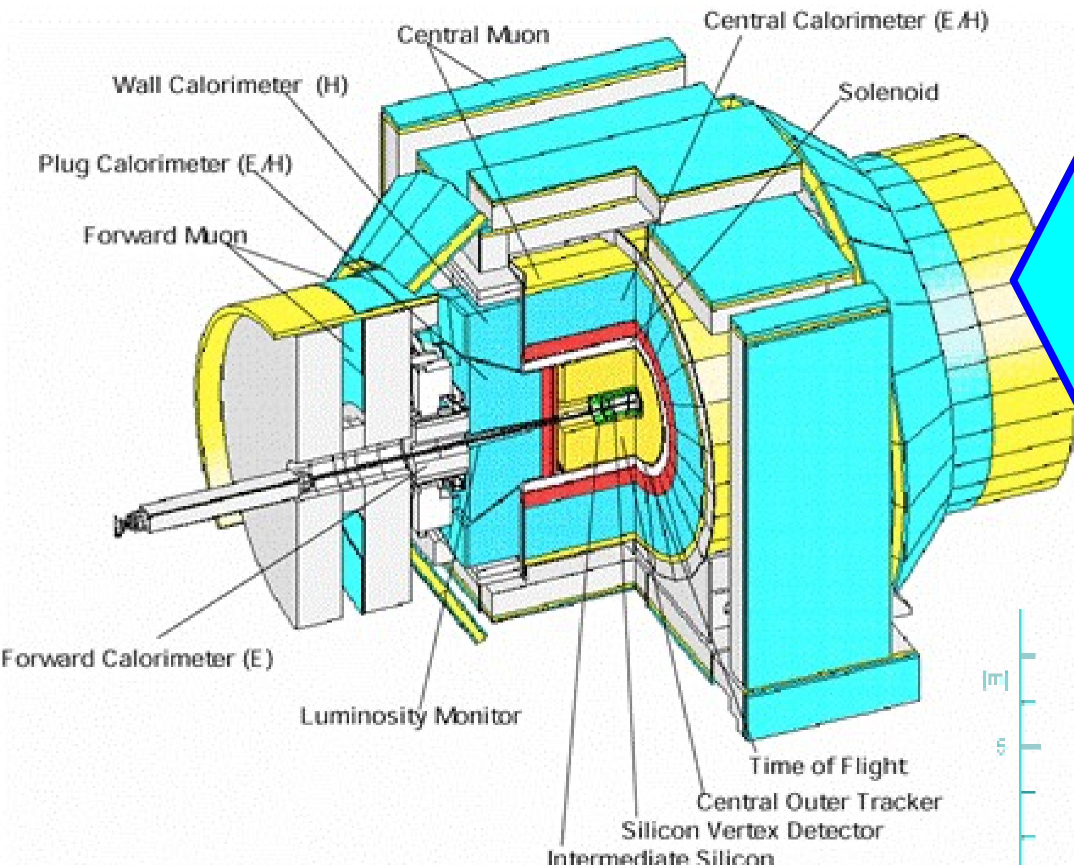




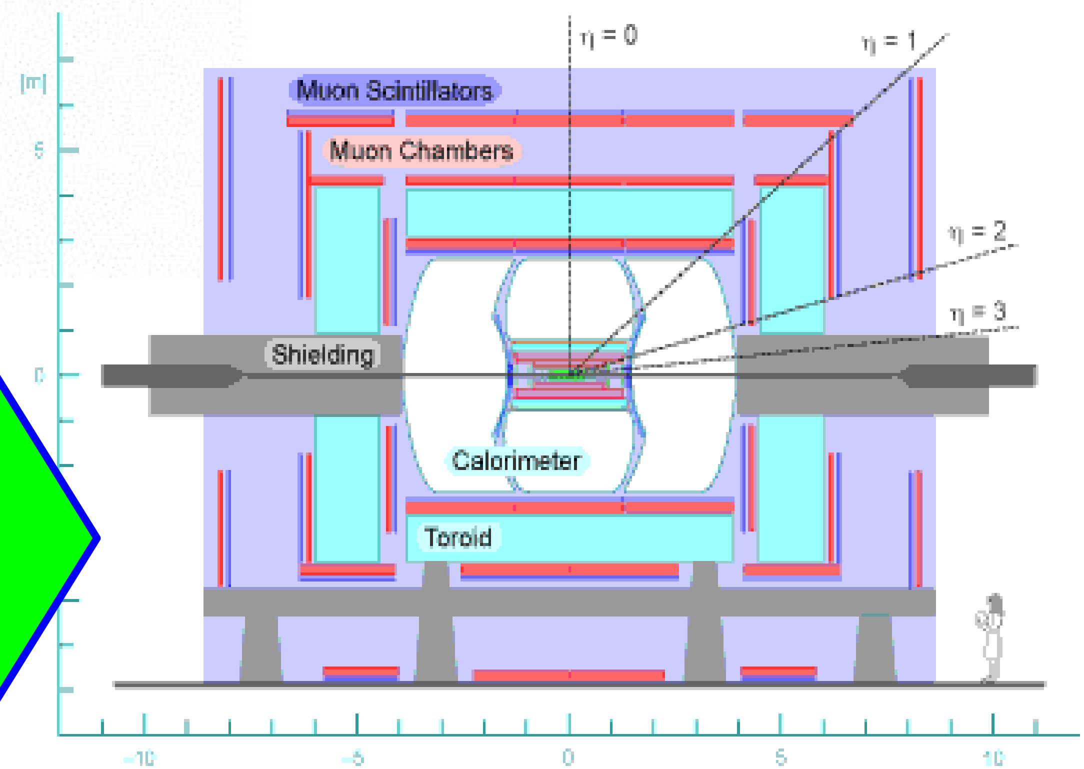
Doubled dataset in each of the last 3 years



CDF and D0 detectors



- **Tracking system**
  - Silicon microstrip [|η| < 2]
  - Drift chamber [|η| < 1]) within 1.4T magnetic field
- Lead-scintillator em and iron-scintillator had **calorimeters** up to |η| < 3.6
- **Muon system**: drift tube chambers and scintillators (|η| < 2)



- **Tracking system**
  - Silicon microstrip [|η| < 3]
  - central fiber tracker [|η| < 2.5]) within 2T magnet
- Liquid argon and uranium **calorimeter** (|η| < 4.2)
- **Muon system** (|η| < 2): muon chambers and scintillators before and after 1.8 T magnet

Triggers

Both experiments: 3 level trigger system

- L1 $\rightarrow$ calorimetric energy in towers, raw tracks and muons
- L2 $\rightarrow$ jets, electron, photons, Missing transverse energy, tracks and muons
- L3 $\rightarrow$ fully reconstructed event

For Higgs analysis:

HighPT central lepton (ZH $\rightarrow$ llbb, WH $\rightarrow$ lνbb, H $\rightarrow$ WW)

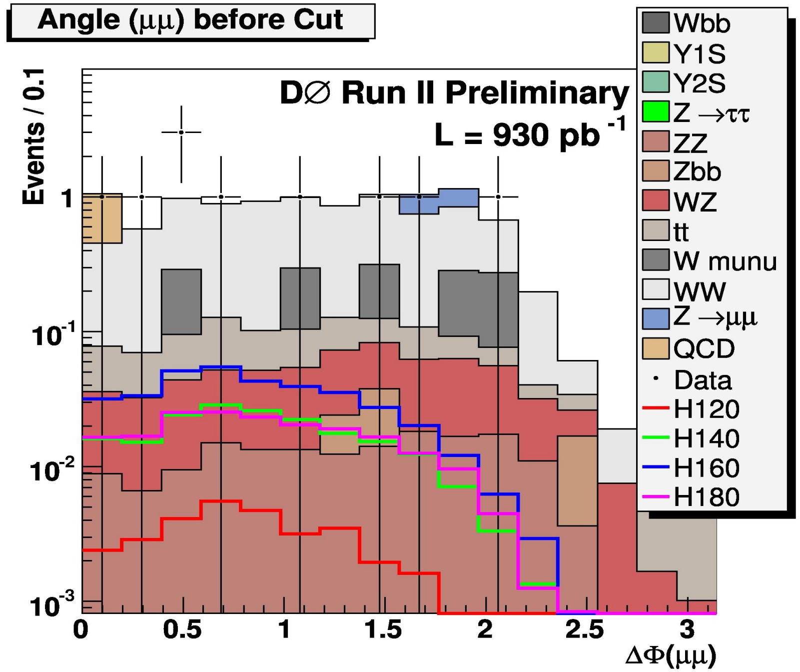
Missing Et + 2 jets (ZH $\rightarrow$ $\nu\nu$bb)

Single / dilepton trigger (H $\rightarrow$ WW, ZH $\rightarrow$ llbb)

electron/muon + jet (WH $\rightarrow$ lνbb)

Missing Et + jet (ZH $\rightarrow$ $\nu\nu$bb)

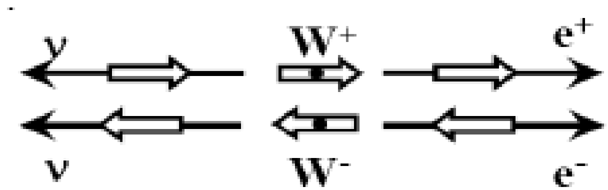
H→WW

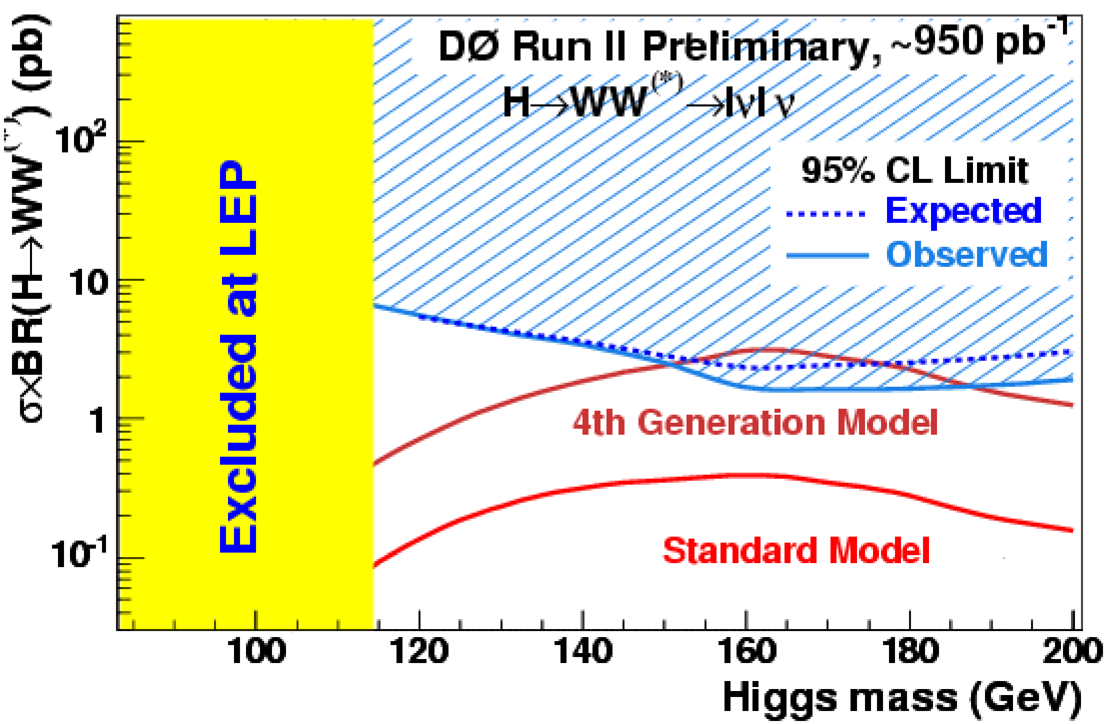


Cut based analysis

- 2 high Pt opposite sign **leptons**
- **Met** > 20 GeV to remove DY
- **Ht** < 70 GeV to remove top
- Exploit spin correlation to remove

WW (**Δφ(ll)** < 2)





Mh = 160 GeV

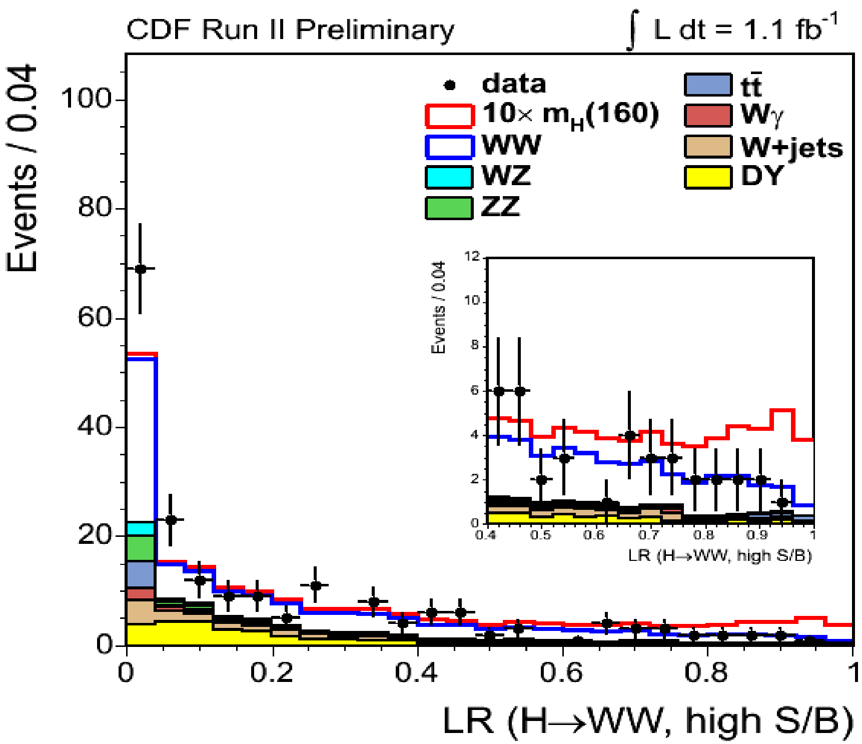
σ/σ_{SM} ~ 5 (Exp)

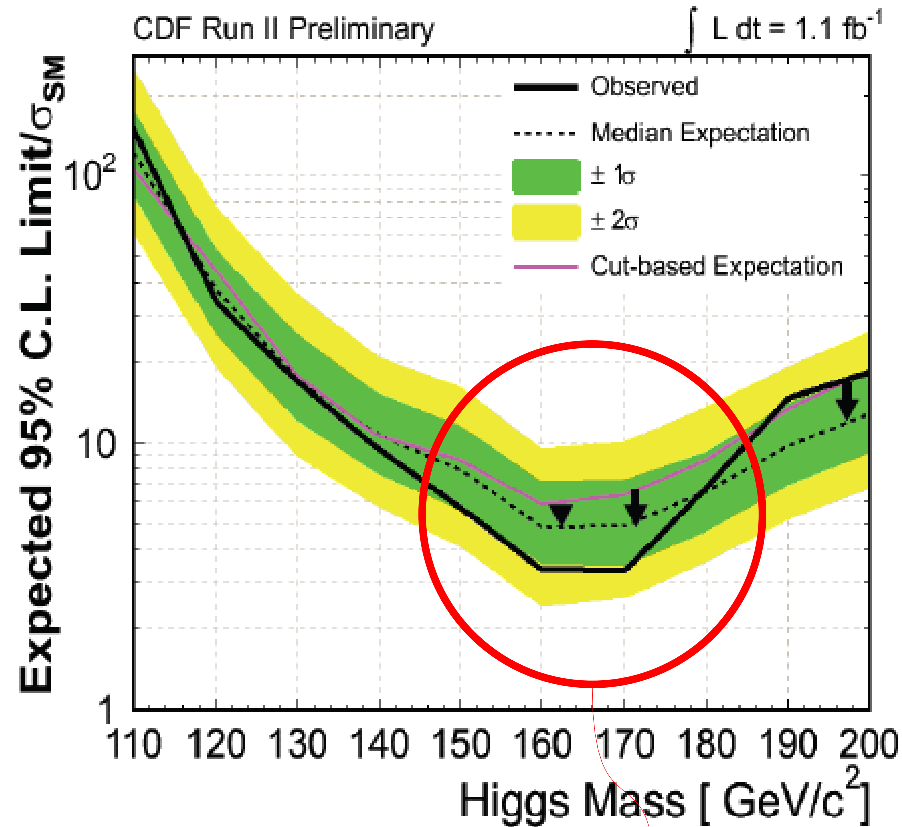
σ/σ_{SM} ~ 4 (Obs)

H→WW

Matrix element method to calculate event probability and build a likelihood ratio discriminator

$$LR = \frac{P_{Higgs}(M_H)}{P_{Higgs}(M_H) + \sum_i f_{\mathrm{bkg,i}} P_{\mathrm{bkg,i}}}$$





Mh = 160 GeV

σ/σ_{SM} ~ 5 (Exp)

σ/σ_{SM} ~ 3.5 (Obs)

Increased sensitivity wrt standard cut based analysis

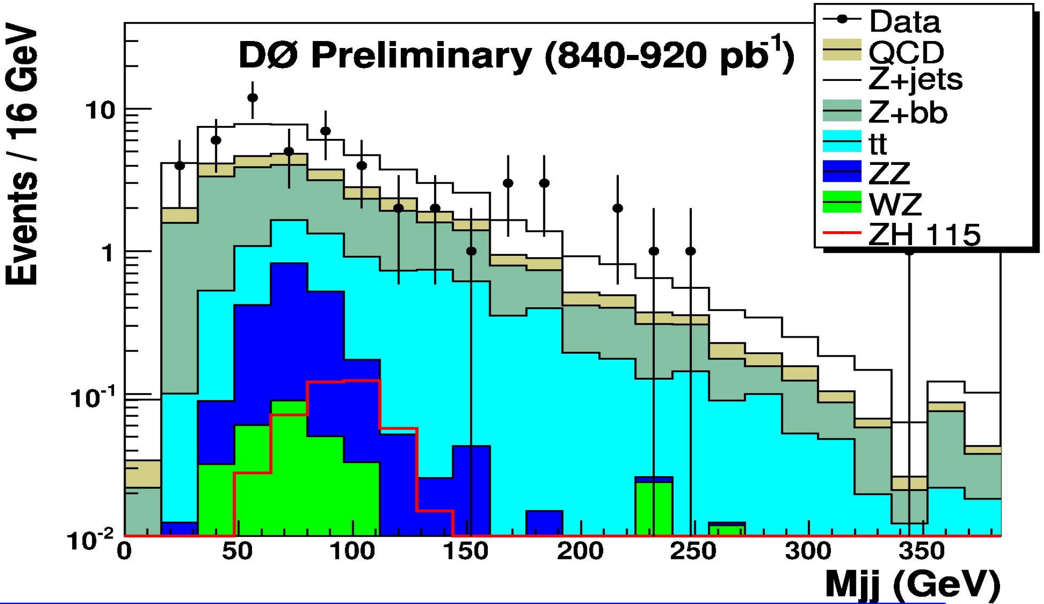
ZH→llbb

LEPTONS

• 2 leptons with invariant mass in Z mass range, opposite charge

JETS

• 2 high Pt Jets



BTAGGING

• CDF: 2 loose b-tagged jets (or 1 tight) → B-tagging algorithm searching for displaced tracks

• D0: at least 2 b-tagged jets → NN based b-tagging algorithm

CDF: 2D NN to further discriminate between ZH and tt/Z+jets bgnds

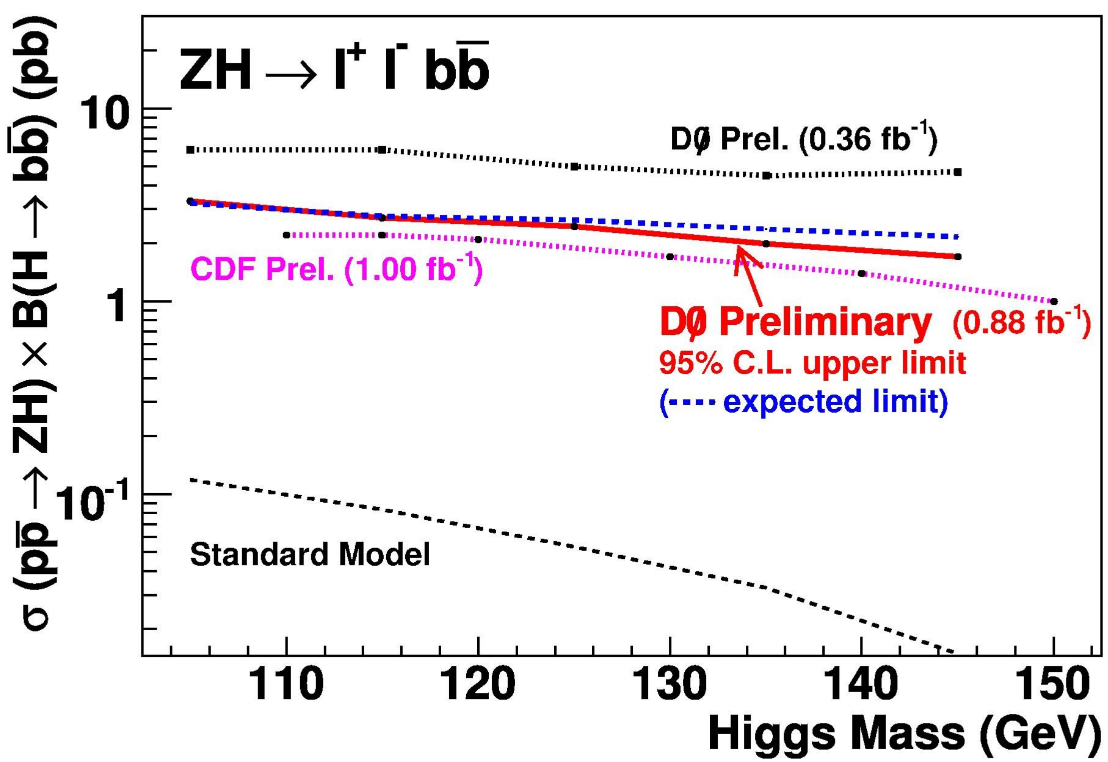
ZH→llbb

CDF: cross section limits derived from 2D NN distribution

Mh = 115 GeV

σ/σ_{SM} ~ 23 (Exp)
σ/σ_{SM} ~ 27 (Obs)

D0:cross section limits derived from dijet invariant mass distribution



Mh = 115 GeV

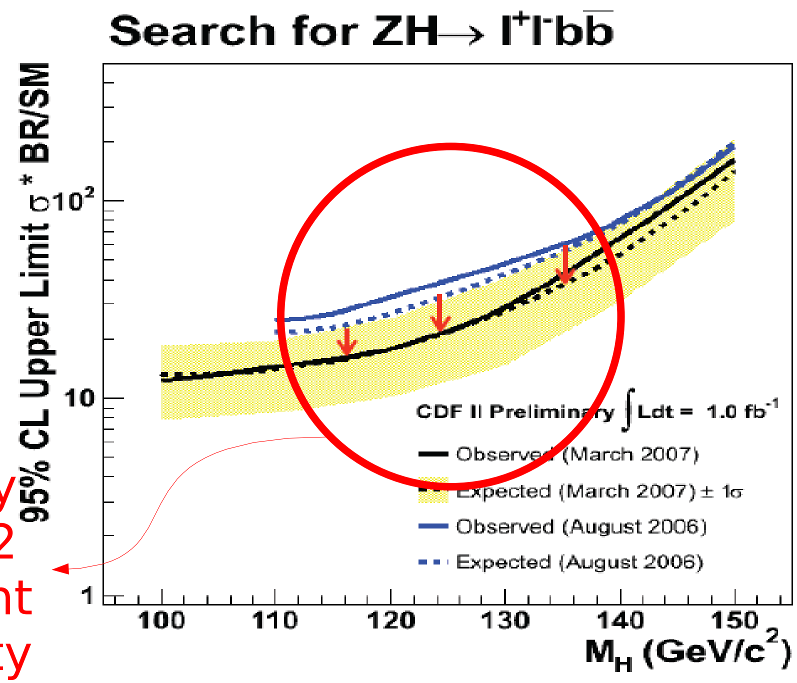
σ/σ_{SM} ~ 34 (Exp)
σ/σ_{SM} ~ 33 (Obs)

ZH→llbb

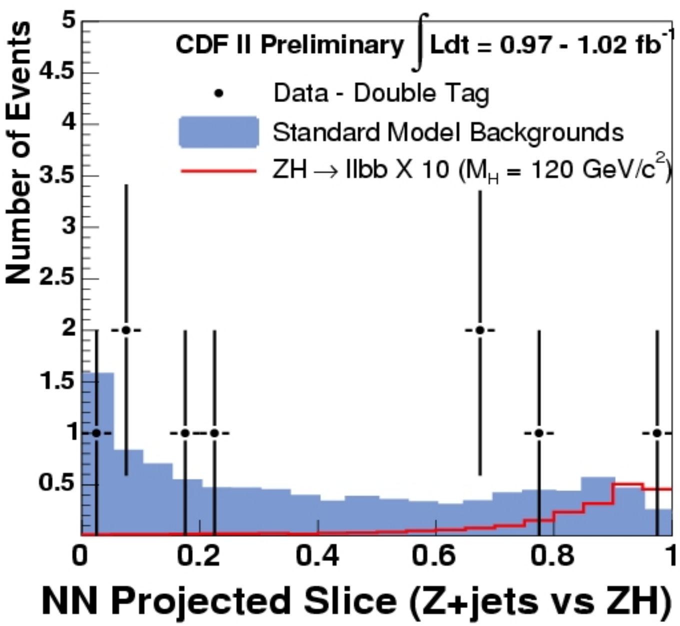
New results on the same dataset

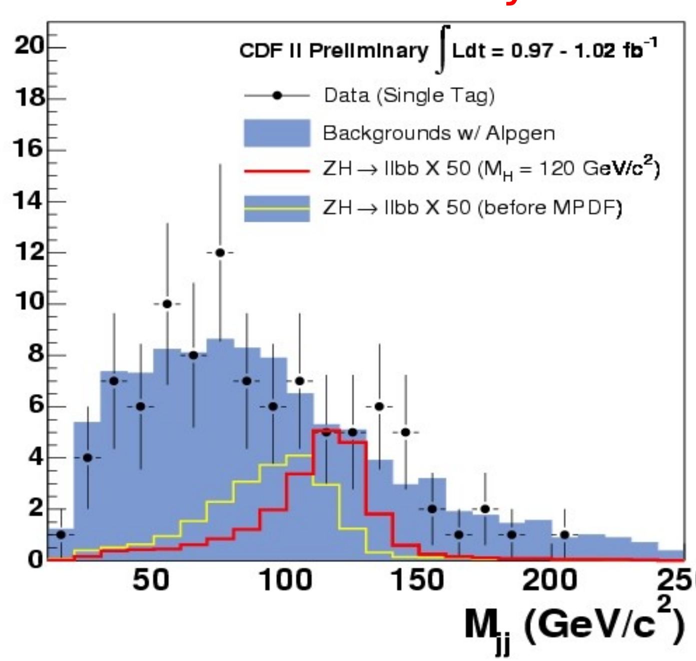
Changes wrt older analysis:

- Use a <u>Missing Transverse Energy Projection Dijet Fitter</u> to correct jet energies for the missing energy in the event
- Split one and two b-tagged events



Improvement by a factor 2 improvement in luminosity





Mh = 115 GeV

σ/σ_{SM} ~ 16 (Exp)

σ/σ_{SM} ~ 16 (Obs)

ZH→ννbb

Search channel sensitive also to WH→(l)νbb

Selection:

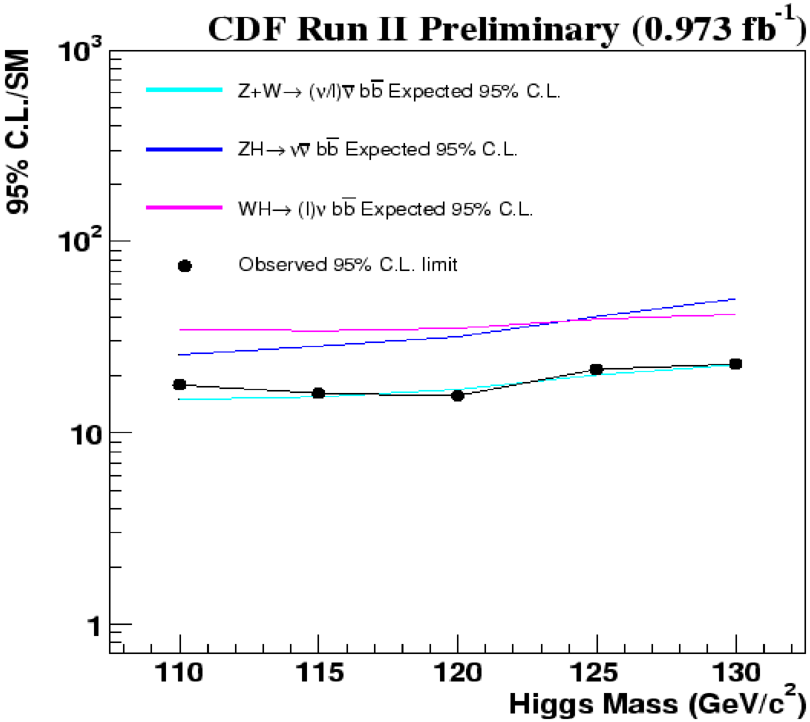
At least 2 high transverse energy jets

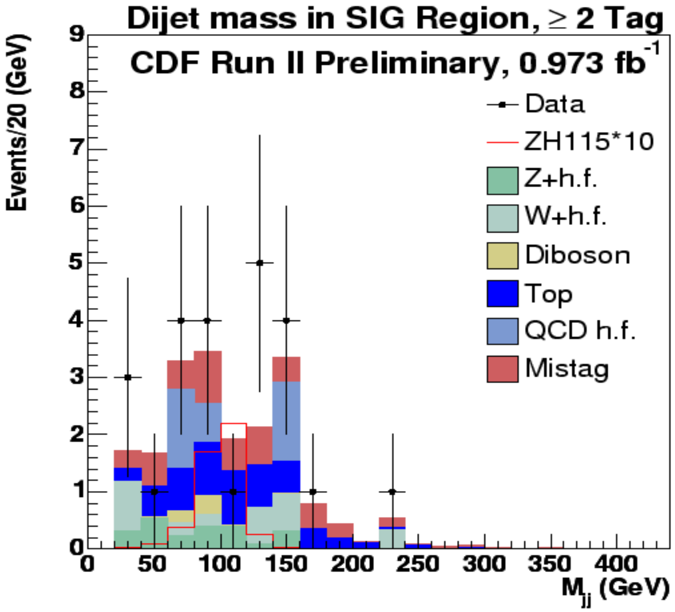
Large missing energy (> 75 GeV)

1^{st} jet Et > 60 GeV

Phi(1st jet, MET) > 0.8

1 / 2 or more b-tags (treated separately)





Limits obtained on the dijet invariant mass

Mh = 115 GeV

σ/σ_{SM} ~ 18 (Exp)

σ/σ_{SM} ~ 18 (Obs)

WH→lνbb

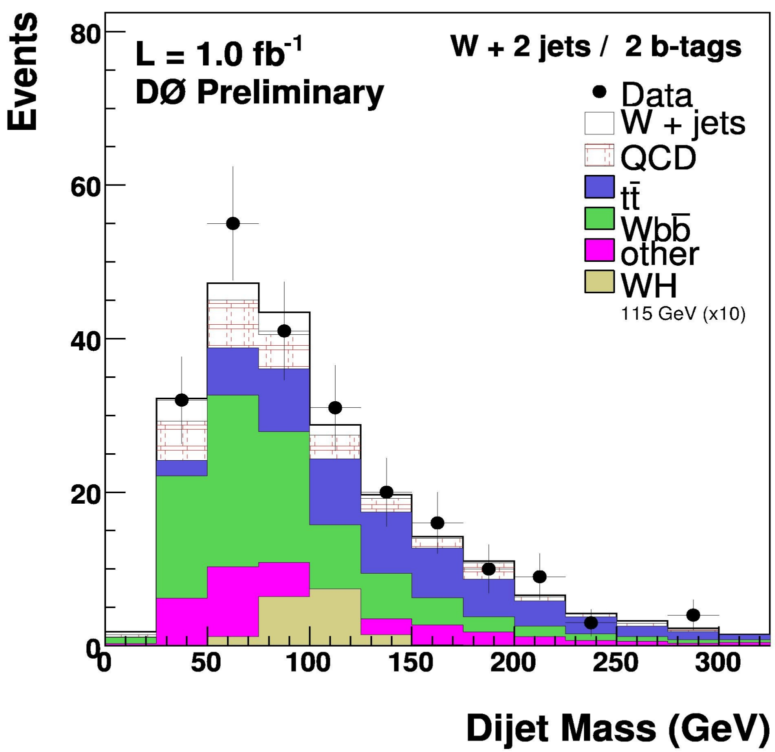
D0

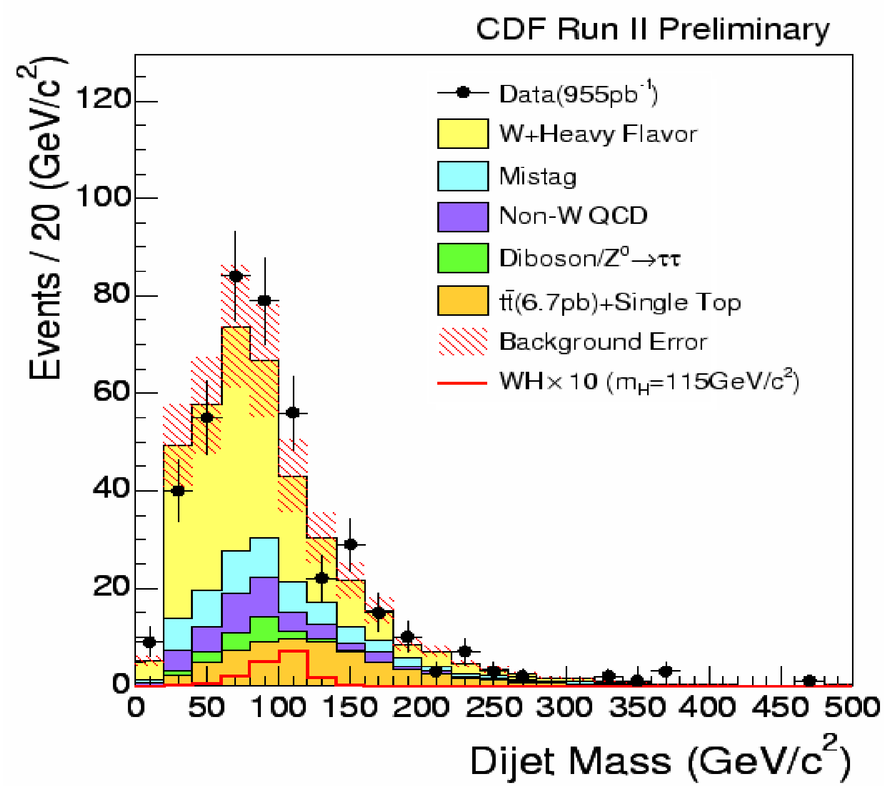
- Use full muon acceptance (50% more signal)
- 2 loose b-tags / 1 tight b-tag

To reduce mistagging of c and light jets

CDF

- 1 b-tagged jet passing **NN b tagging** selection
- 2 b-tagged jets



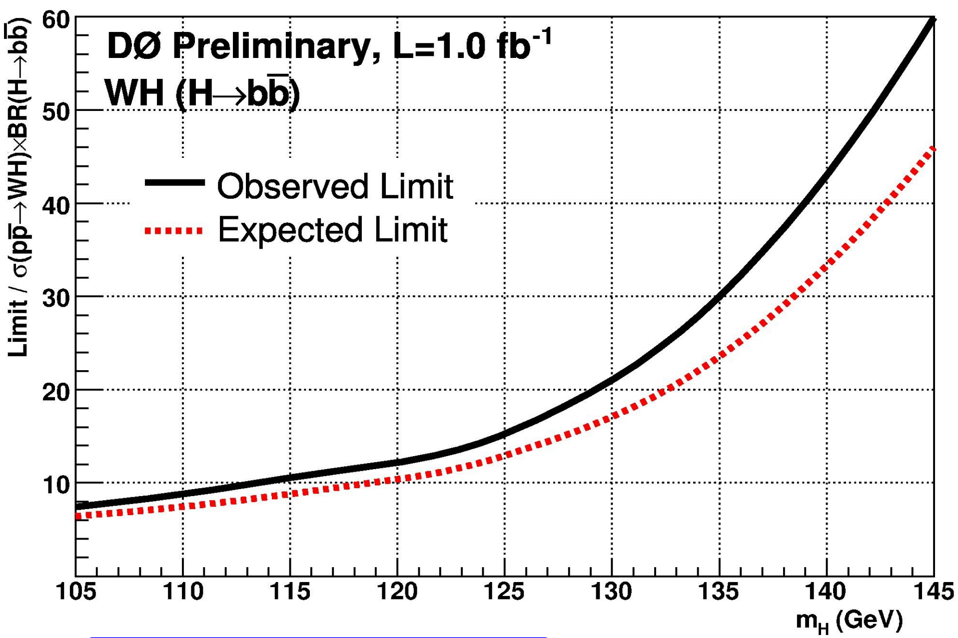


WH→lνbb

D0

limit from fit on dijet mass

(2 loose b-tags / 1 tight tag)



Mh = 115 GeV

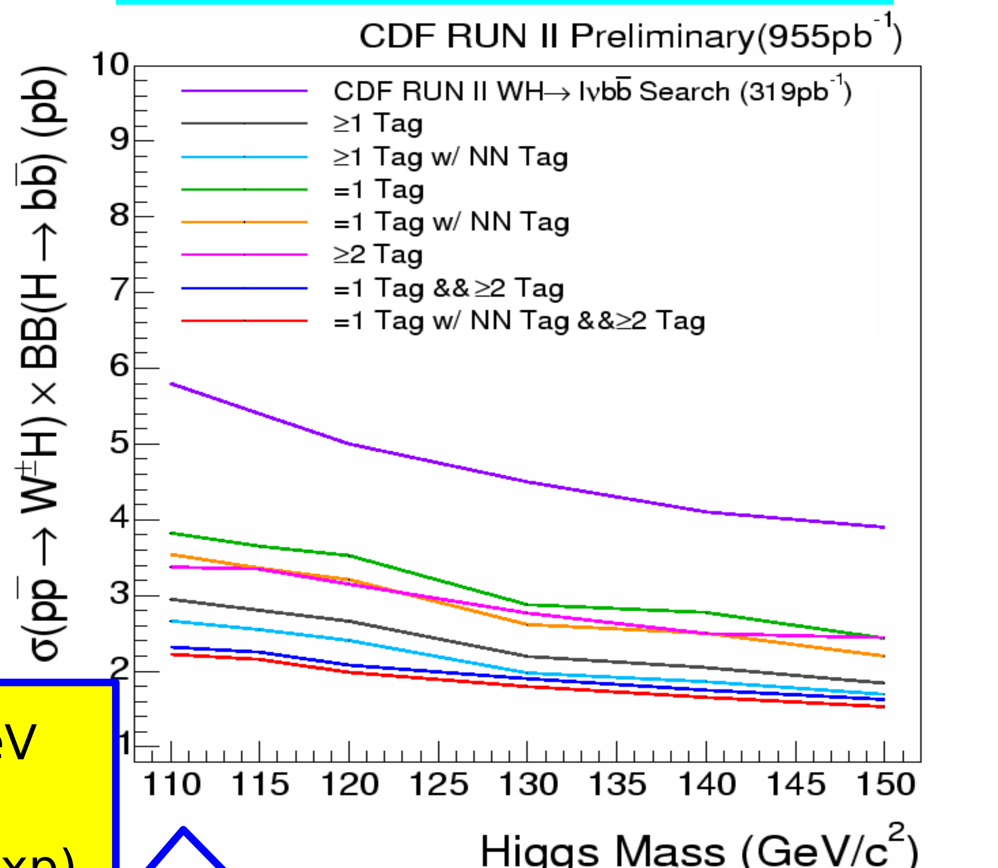
σ/σ_{SM} ~ 9 (Exp)

σ/σ_{SM} ~ 10 (Obs)

CDF

limit from fit on dijet mass

(1 / 2 tags separately)



Mh = 115 GeV

σ/σ_{SM} ~ 17 (Exp)

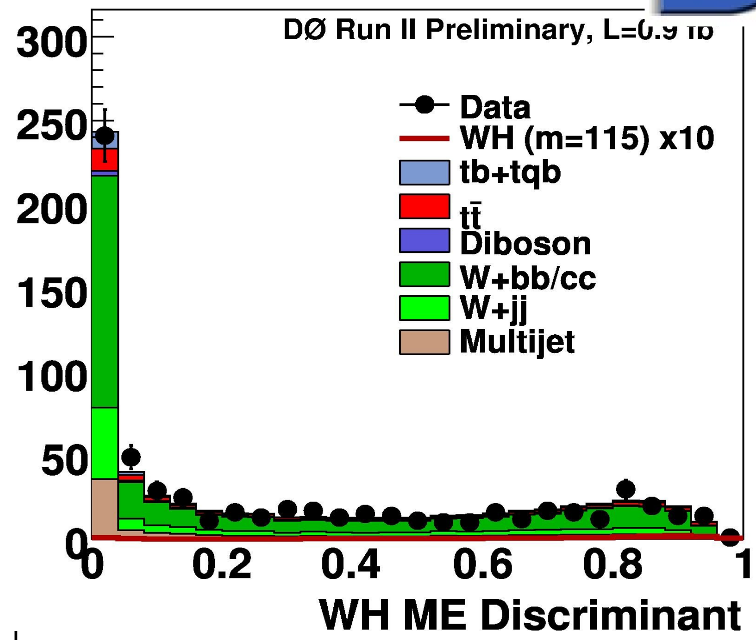
σ/σ_{SM} ~ 26 (Obs)

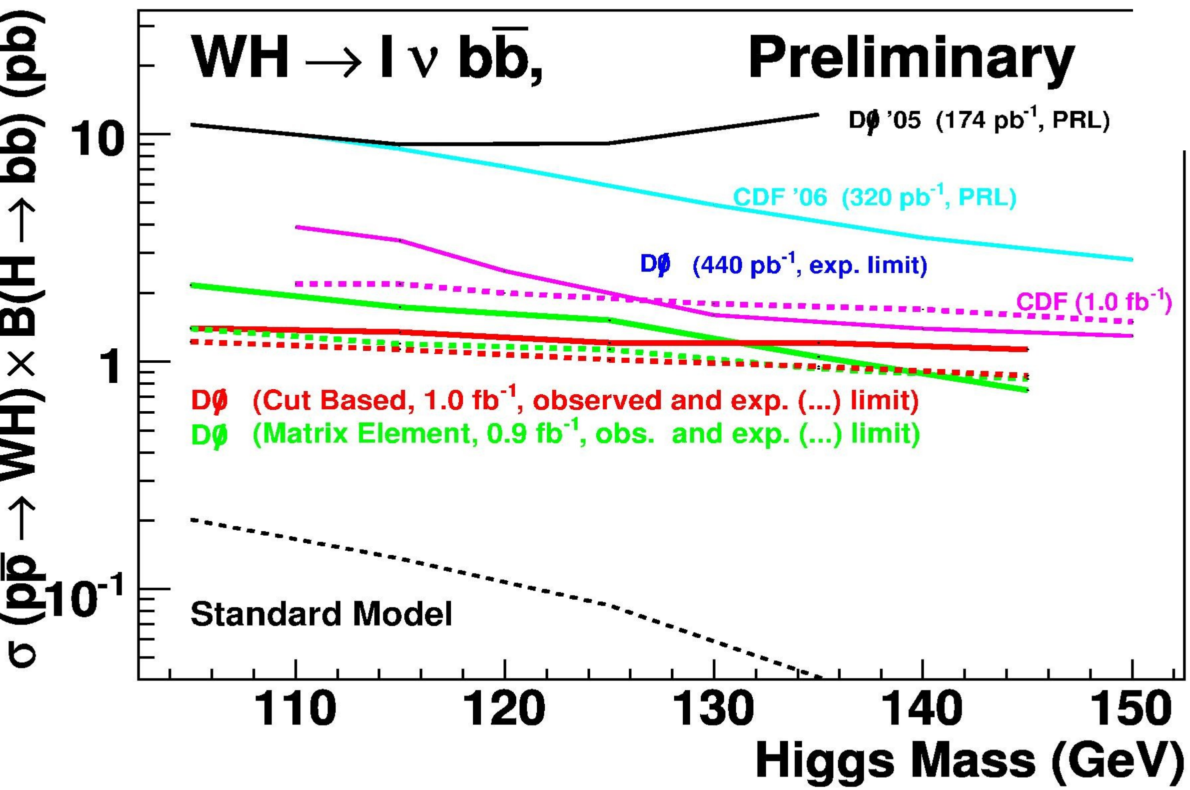
WH→lνbb

Matrix element technique

- 1 OR 2 jets NN b-tagged
- ME discriminant:

$$\text{Discriminant} = \frac{P_{WH}}{P_{WH} + \sum_i c_i P_{background\,i}}$$





Mh = 115 GeV

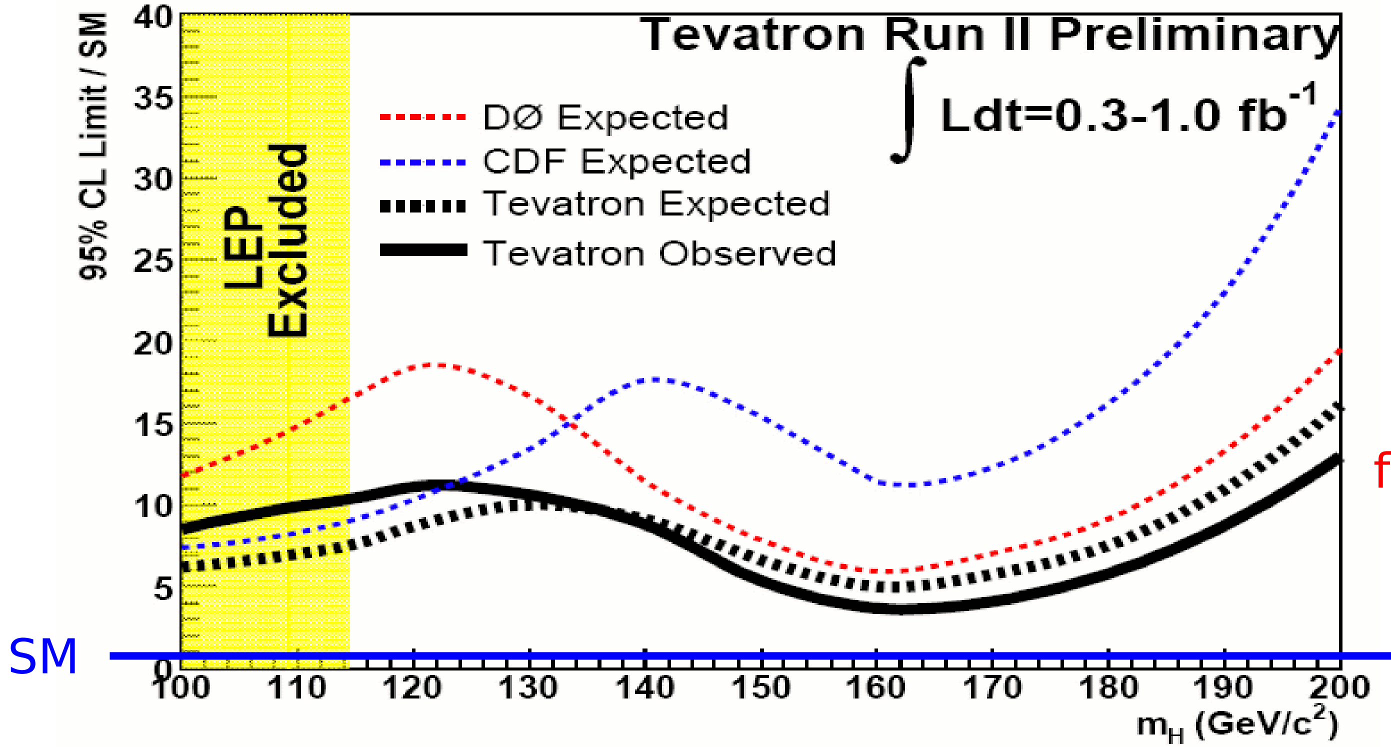
σ/σ_{SM} ~ 9 (Exp)

σ/σ_{SM} ~ 13 (Obs)

Not yet using full muon acceptance

Expect 30% better limit

Conclusions



Not included:
New CDF ZH -> llbb
New CDF H-> WW
New D0 WH -> lνbb

σ/σ_{SM} < 10

for Mh = 100 -200 GeV

Find or exclude Higgs at Tevatron is very challenging but possible.

We need

- Luminosity -> Good Tevatron performance -> 8fb^{-1} by 2009
- Increasing signal acceptance
  - Improved analysis techniques
  - Upgrades

CDF upgrades

Needed to deal with triggers too hot at high luminosity
Will become fundamental to increase signal acceptance

L2 cluster finder upgrade

Switch to Cone based jet clustering.

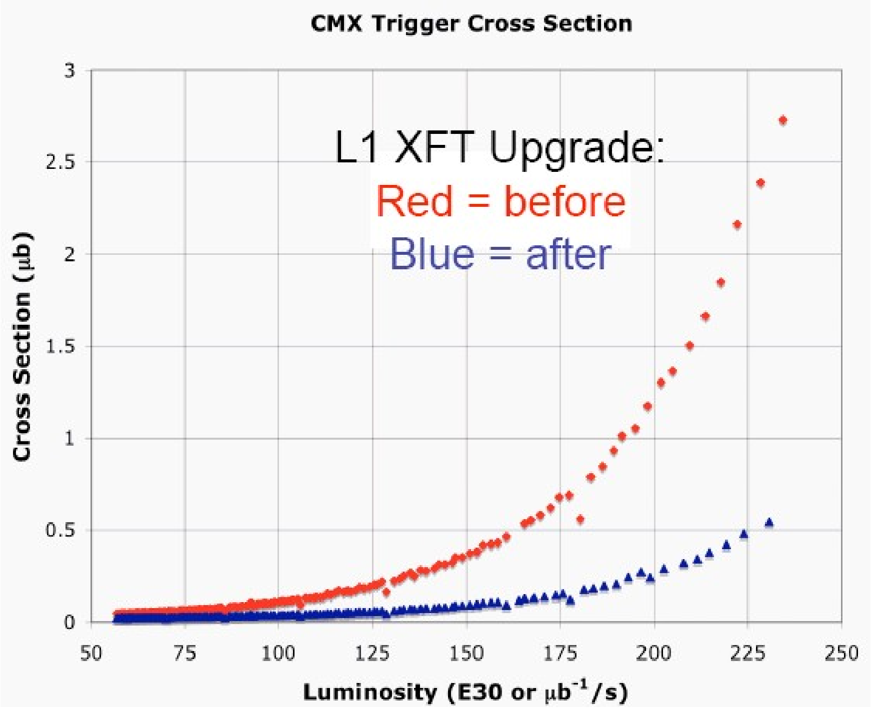
At L2: Met calculated with better resolution, dijet mass, $\Delta\varphi$ between jets and jets-Met, better jet-track matching for b-jets

Extremely Fast Tracker upgrade

Tracking algorithm upgrade

At L1 $\rightarrow$ ~ 7 fake tracks rejection factor

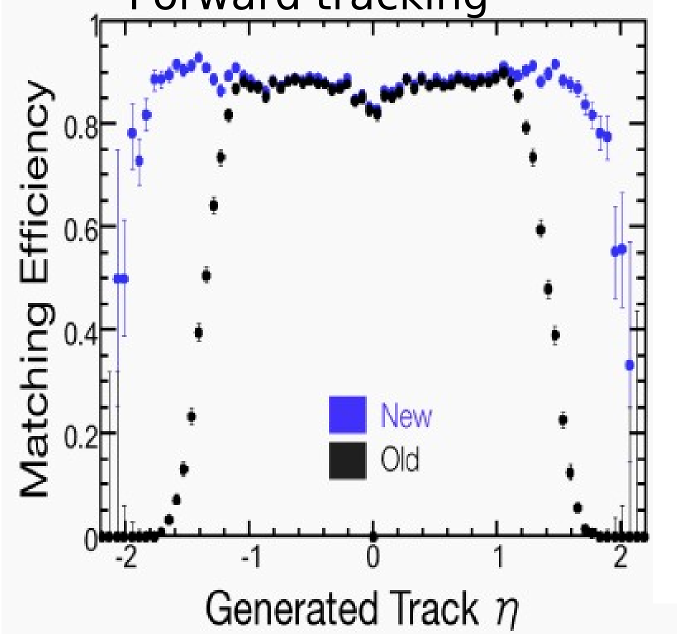
At L2 $\rightarrow$ Full 3D reconstruction of tracks



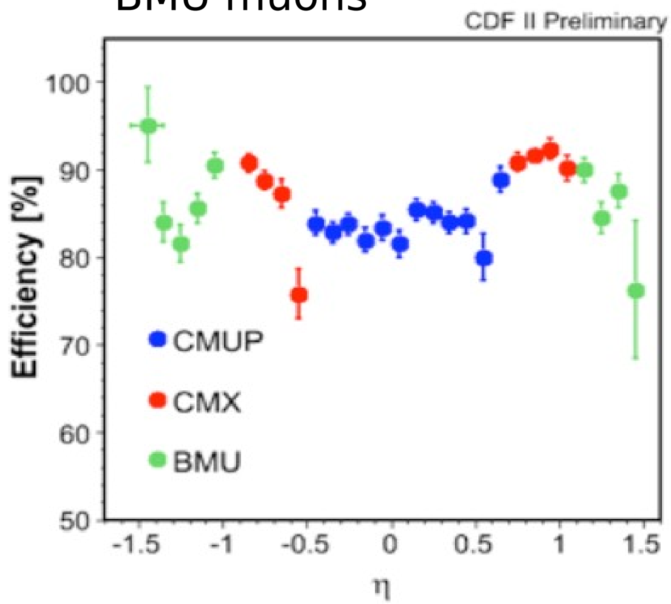
Improvements under study

Increasing lepton acceptance

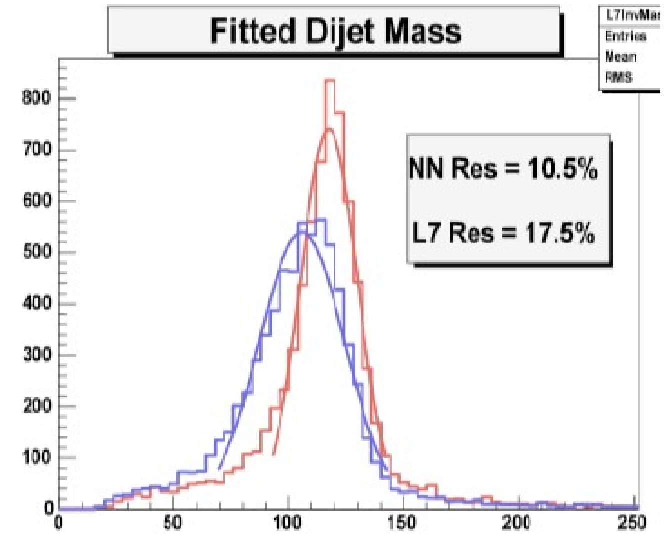
Forward tracking



BMU muons

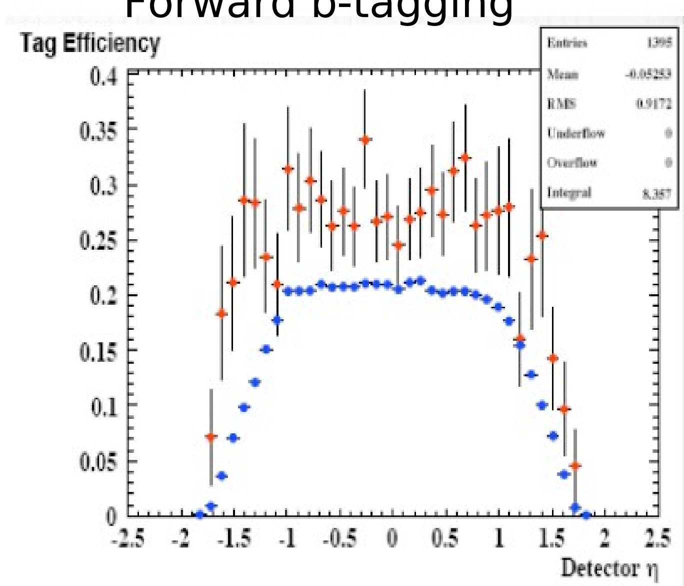


Better jet energy resolution

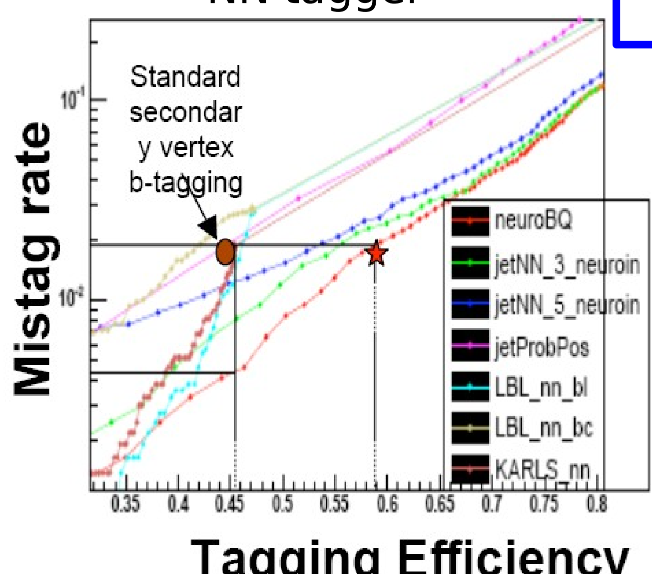


B-tagging

Forward b-tagging

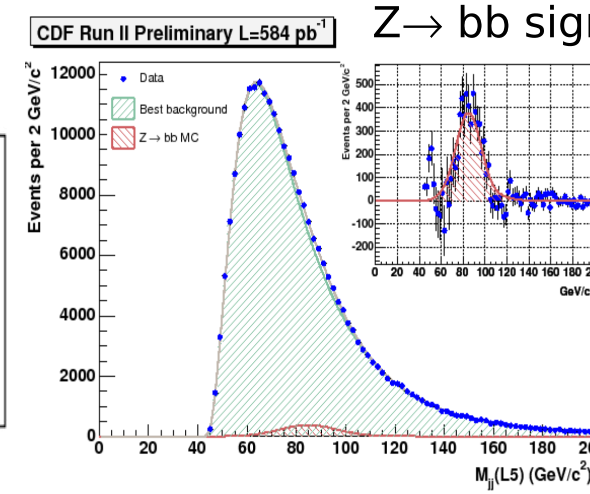


NN tagger



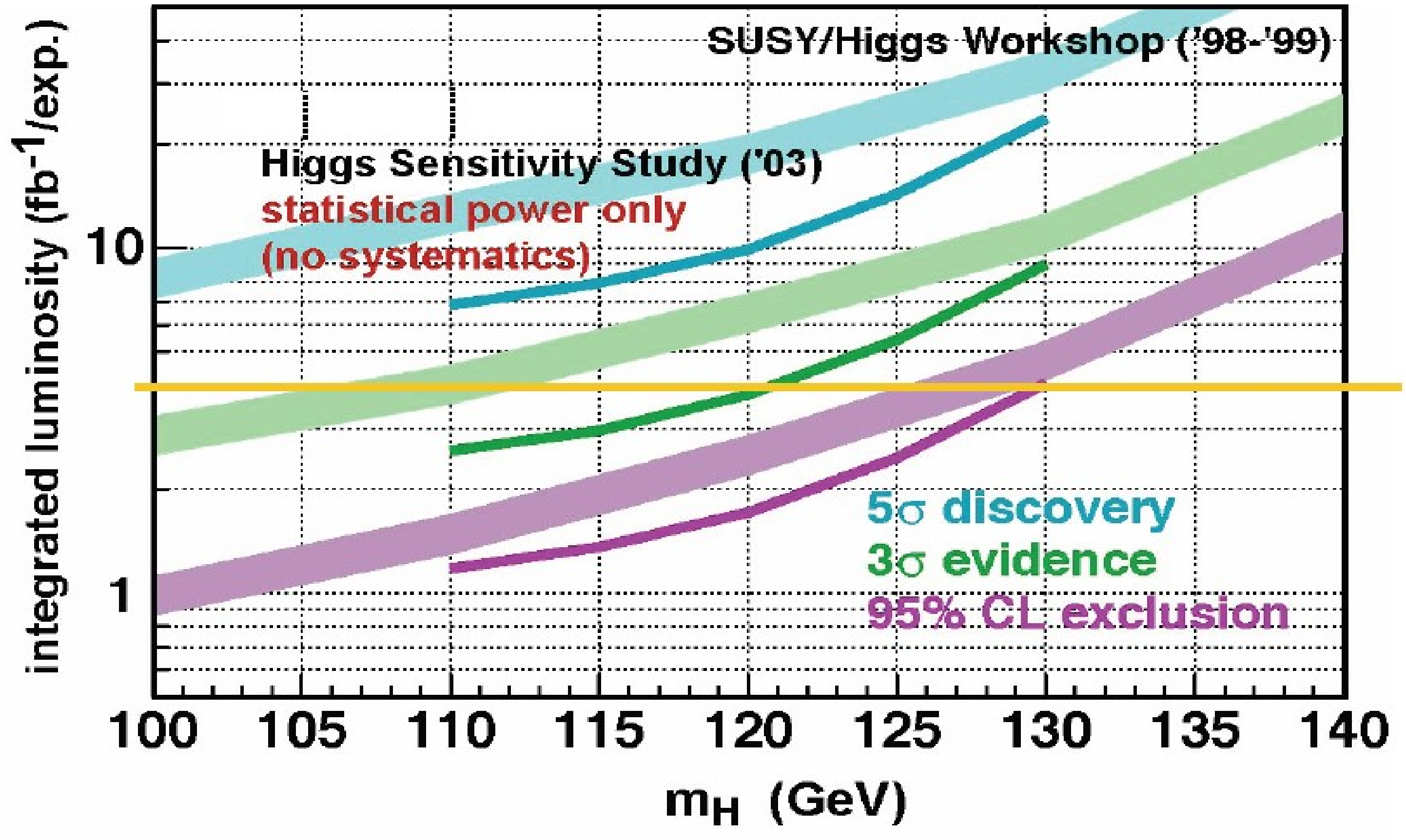
Also studying a L2 b-tagging algorithm

Z→ bb signal



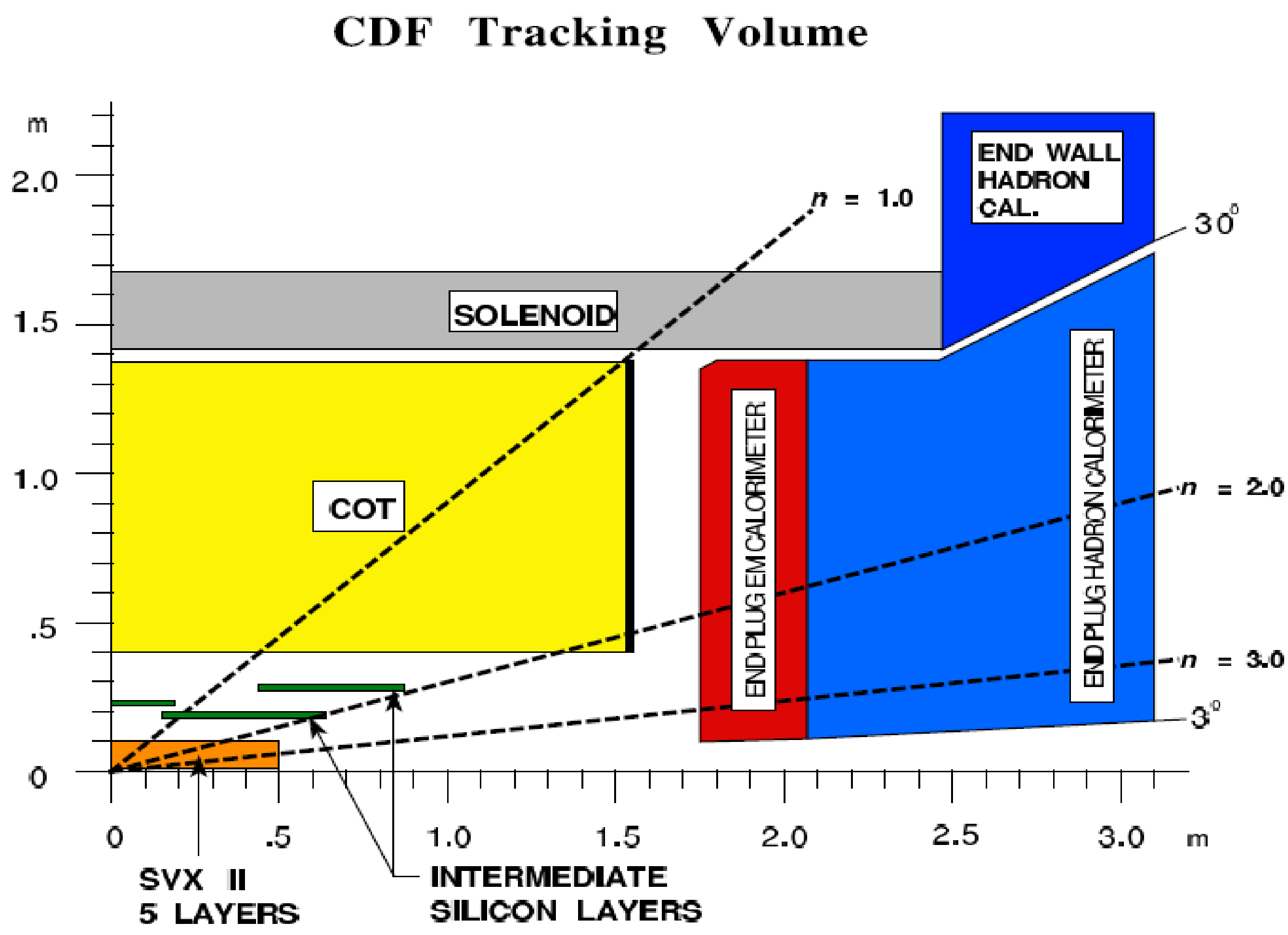
...more than just $1/\sqrt{Lum}$ increase!

Backup slides



Higgs sensitivity studies need to be updated to take into account all the work in progress...

CDF detector

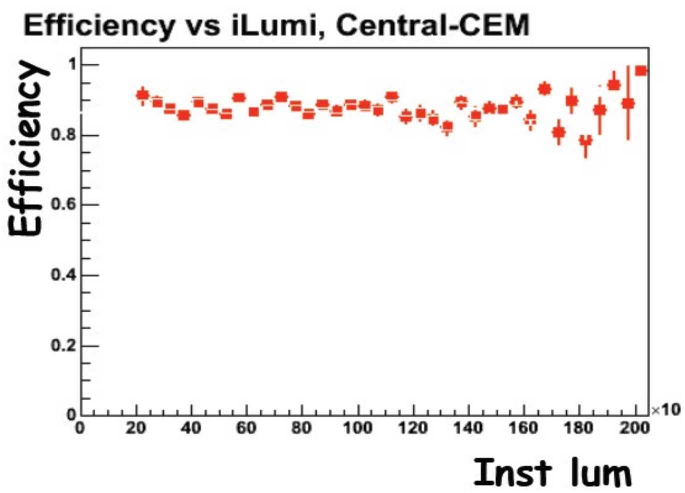


Trigger Accept rates

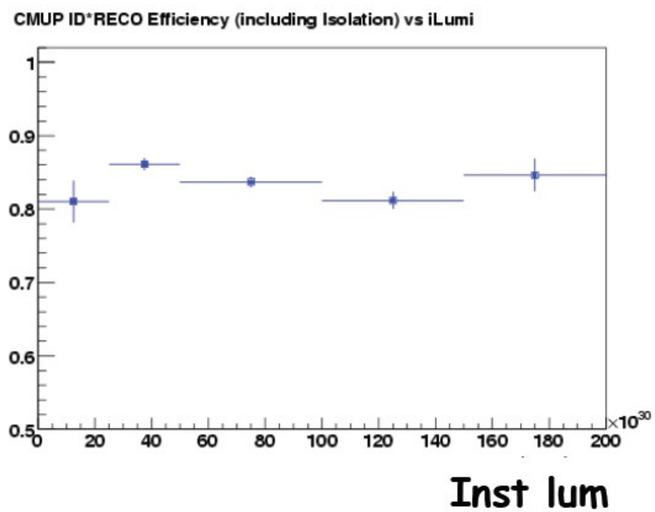
	L1	L2	L3
CDF	30 kHz	1 kHz	100 Hz
D0	1.6 kHz	850-900 Hz	55 Hz

Physics at high luminosity

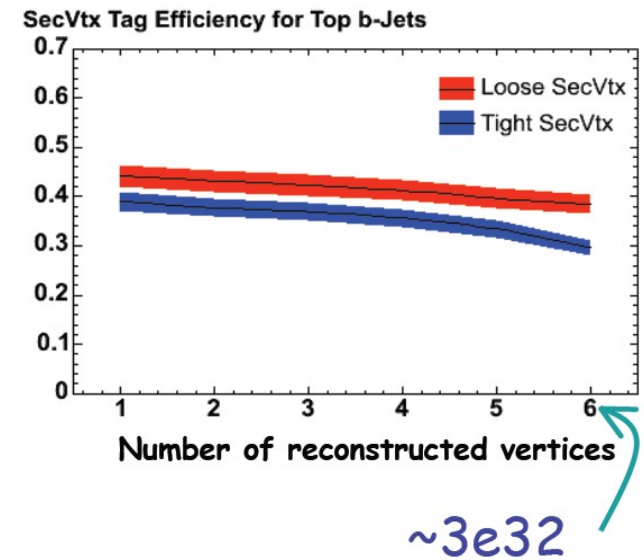
Electron ID efficiency



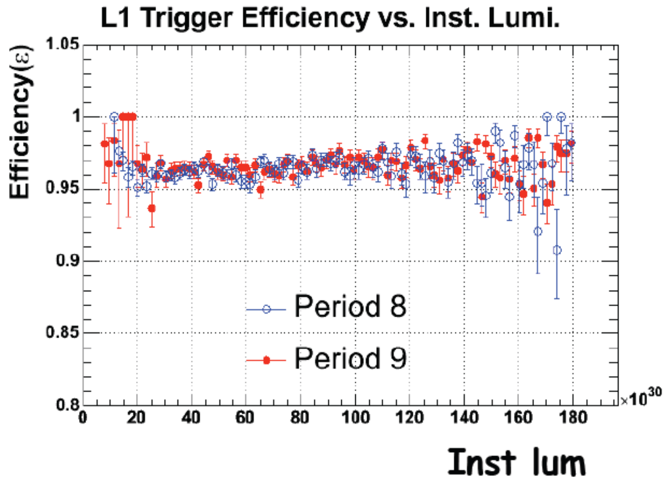
Muon ID efficiency



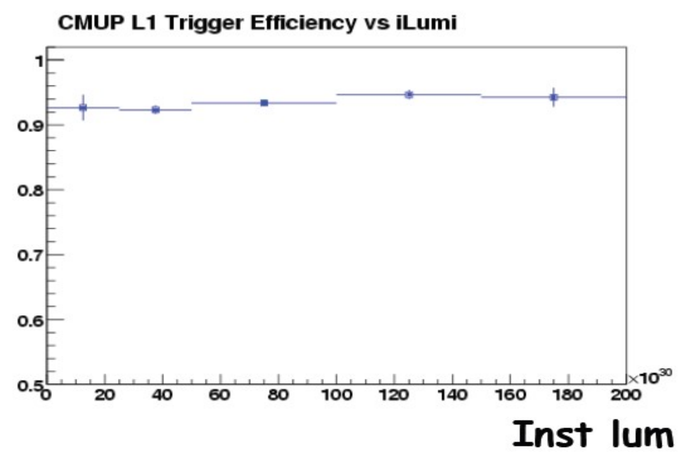
B-tagging efficiency



Electron L1 trigger efficiency



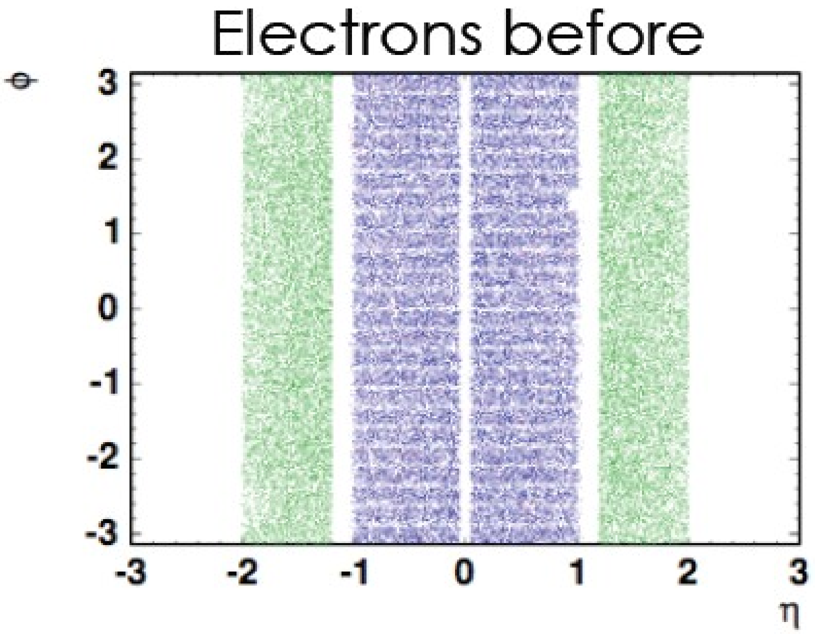
Muon L1 trigger efficiency

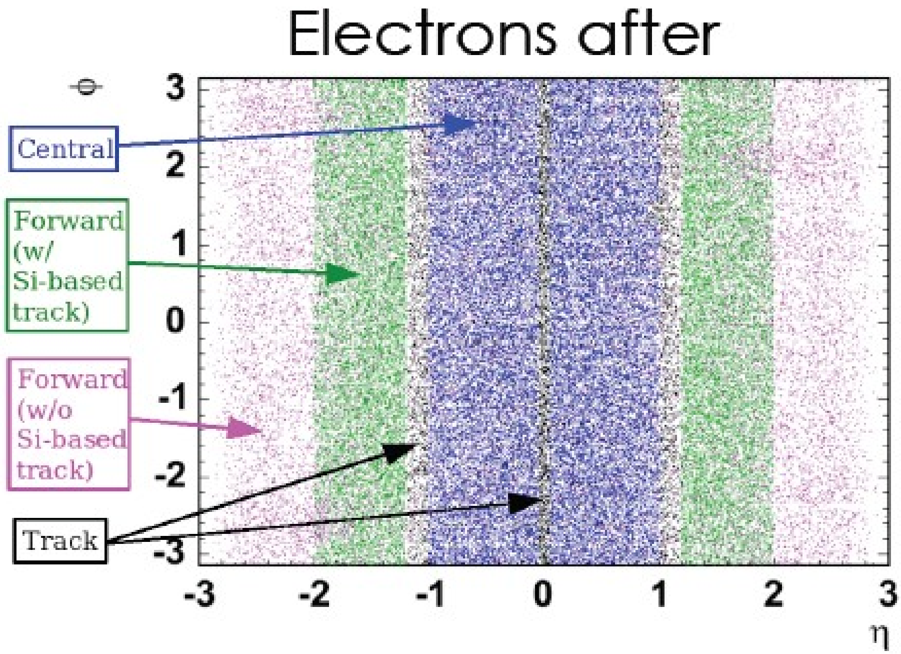


Physics at
high lumonosity
under control

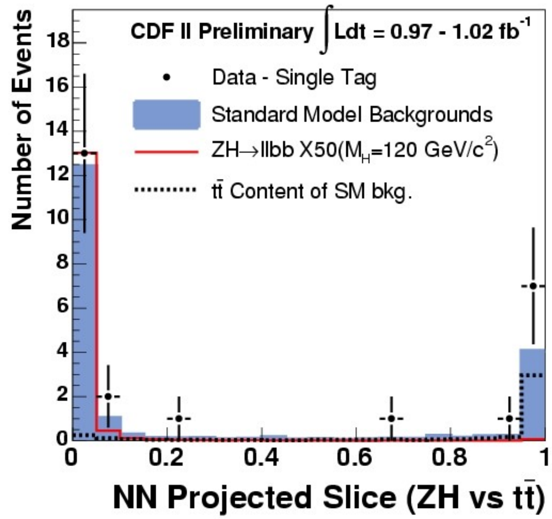
Increasing lepton acceptance

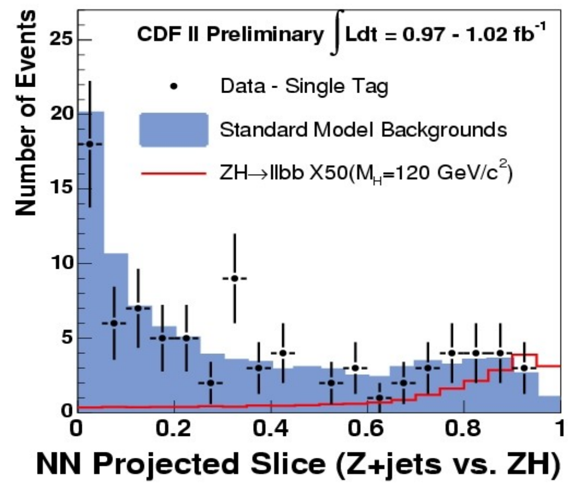
New lepton categories
H→WW uses many of these lepton categories: signal yeld from2.5 to 4 exp evts

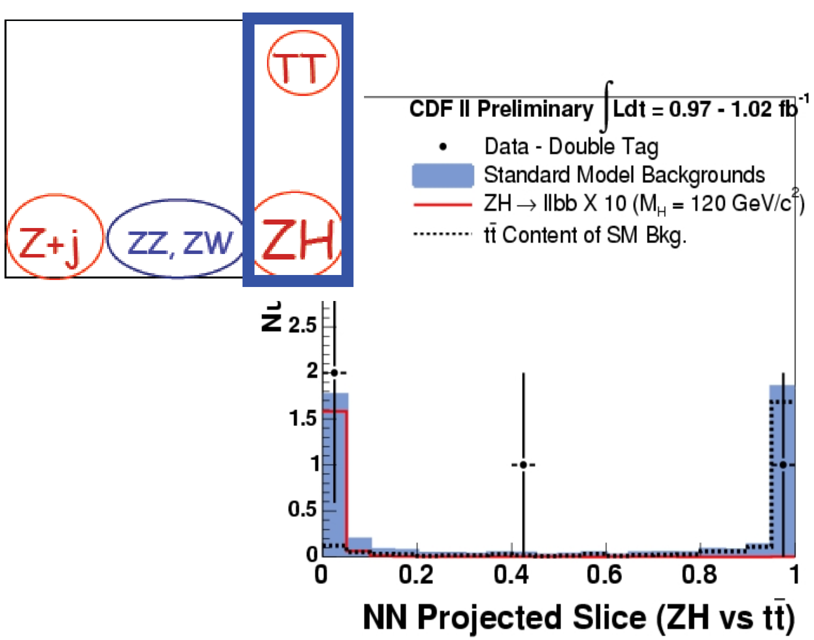


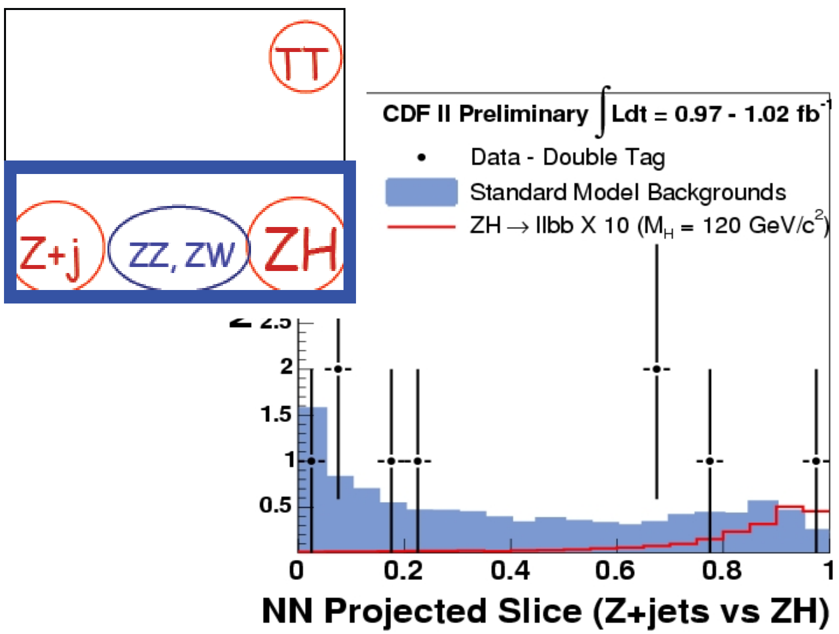


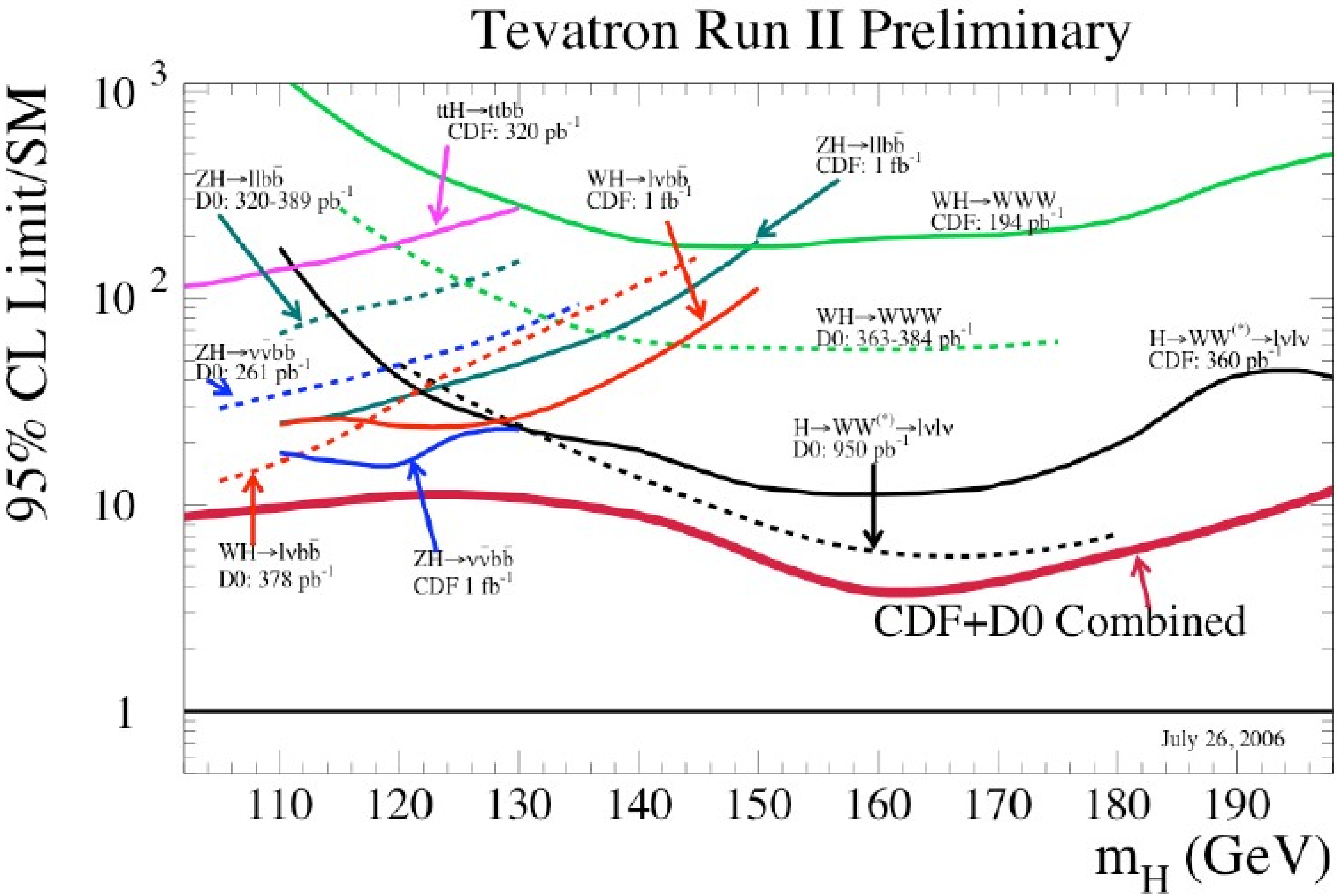
ZH→llbb


CDF II Preliminary ∫Ldt = 0.97 - 1.02 fb⁻¹
Data - Single Tag
Standard Model Backgrounds
ZH→llbb X50(M_H=120 GeV/c²)
tt̄ Content of SM bkg.
Number of Events
NN Projected Slice (ZH vs tt̄)


CDF II Preliminary ∫Ldt = 0.97 - 1.02 fb⁻¹
Data - Single Tag
Standard Model Backgrounds
ZH→llbb X50(M_H=120 GeV/c²)
Number of Events
NN Projected Slice (Z+jets vs. ZH)


TT
Z+j
ZZ, ZW
ZH
CDF II Preliminary ∫Ldt = 0.97 - 1.02 fb⁻¹
Data - Double Tag
Standard Model Backgrounds
ZH → llbb X 10 (M_H = 120 GeV/c²)
tt̄ Content of SM Bkg.
NN Projected Slice (ZH vs tt̄)


TT
Z+j
ZZ, ZW
ZH
CDF II Preliminary ∫Ldt = 0.97 - 1.02 fb⁻¹
Data - Double Tag
Standard Model Backgrounds
ZH → llbb X 10 (M_H = 120 GeV/c²)
NN Projected Slice (Z+jets vs ZH)


Tevatron Run II Preliminary
95% CL Limit/SM
10^3
10^2
10
1
ttH→ttbb
CDF: 320 pb⁻¹
ZH→llbb̄
D0: 320-389 pb⁻¹
WH→lνbb̄
CDF: 1 fb⁻¹
ZH→llbb̄
CDF: 1 fb⁻¹
WH→WWW
CDF: 194 pb⁻¹
WH→WWW
D0: 363-384 pb⁻¹
ZH→ννbb̄
D0: 261 pb⁻¹
H→WW(*)→lνlν
CDF: 360 pb⁻¹
H→WW(*)→lνlν
D0: 950 pb⁻¹
WH→lνbb̄
D0: 378 pb⁻¹
ZH→ννbb̄
CDF 1 fb⁻¹
CDF+D0 Combined
July 26, 2006
110
120
130
140
150
160
170
180
190
m_H (GeV)

Analysis	CDF limit ($1fb^{-1}$) factor above SM observed (expected)	D0 limit ($1fb^{-1}$) factor above SM observed (expected)
ZH → νν bb @ 115 Technique: M_{jj}	16 (15)	40 (34)*
WH → lν bb @ 115 Technique: M_{jj} Technique: ME	26 (17)	★ 10 (9) ★ 13 (10)
ZH → llbb @ 115 Technique: NN2D	★ 16 (16)	33 (34)
H → WW → lνlν @ 160 Technique: ΔΦ (l,l) Technique: ME	9 (6) ★ 3.5 (5)	4 (5)

B.Kilminster – Moriond 07