Standard Model Higgs searches at the Fermilab Tevatron

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For the CDF and DØ Collaborations

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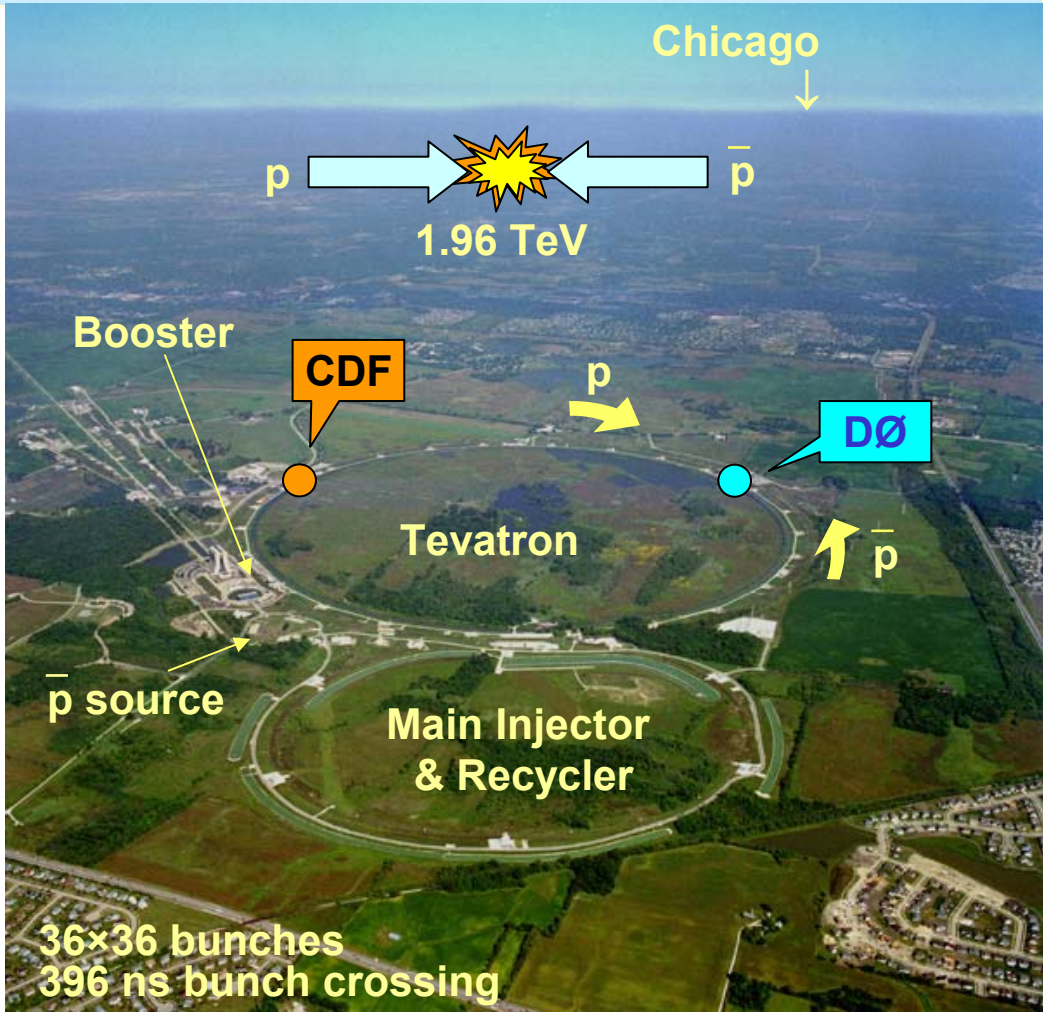
Outline

- Search overview
- Tevatron performance and extrapolations
- Search methods
- Low mass limits: associated production (WH and ZH)
- High mass limits: $H \rightarrow WW^{(*)} \rightarrow l^+l^-$ searches
- Summary and outlook



Thanks to the Fermilab accelerator team for providing collisions at increasing luminosities and to CDF and DØ physicists for their tireless efforts in collecting the collisions and understanding them.

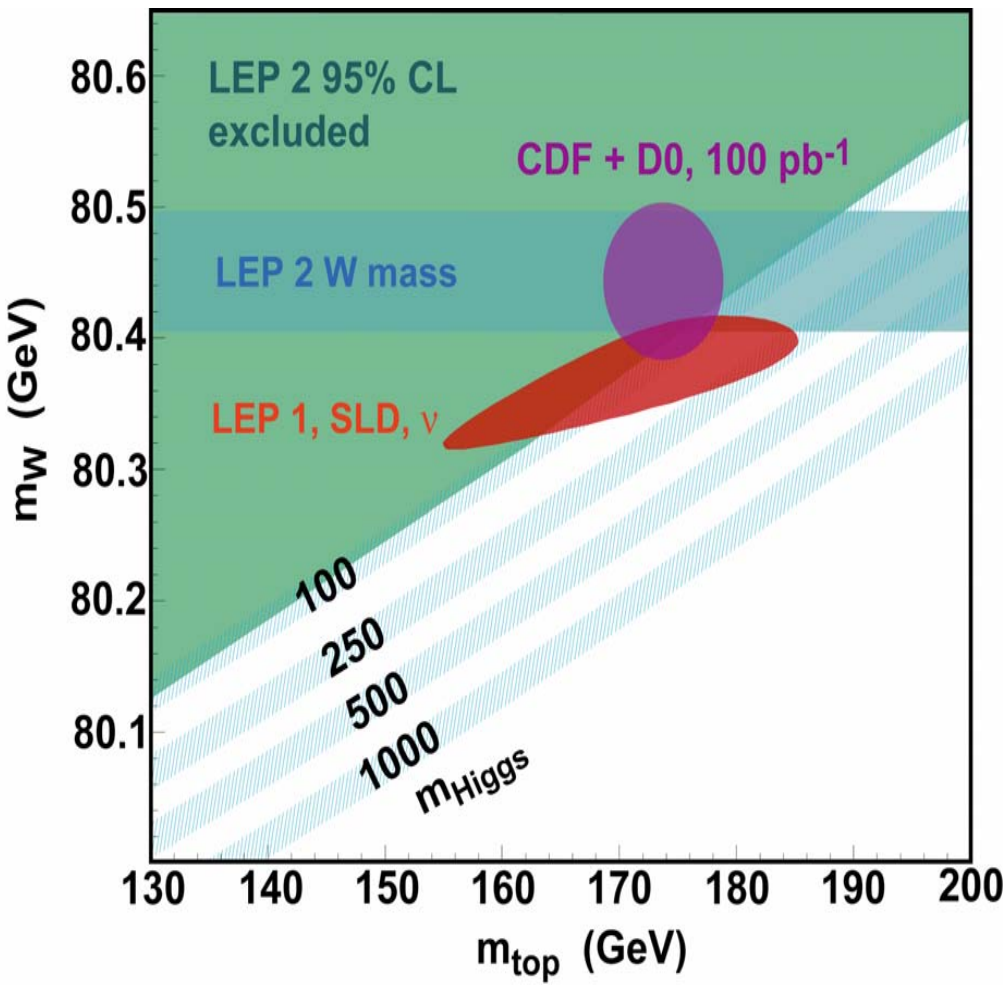
SM Higgs Search Overview

114 GeV < M_H < 251 GeV (95% CL)
(LEP Direct and M_W / M_{top} global fit)

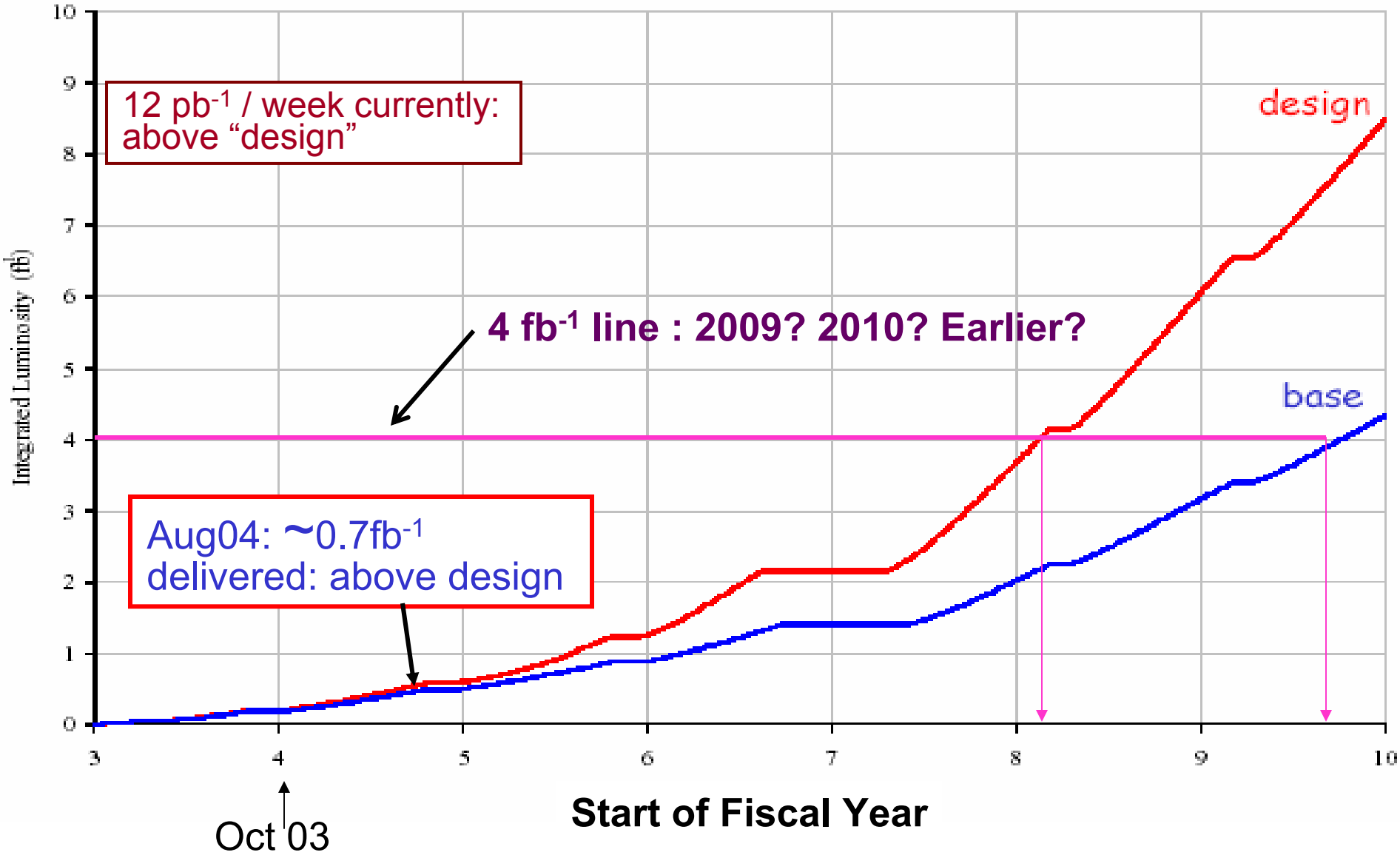
Tev Higgs Sensitivity Report (2003):

L = 4 fb^{-1} buys 50% chance of a 3σ SM Higgs signal for M_H = 120GeV (Both experiments, combined channels, smart analyses, no systematics…)

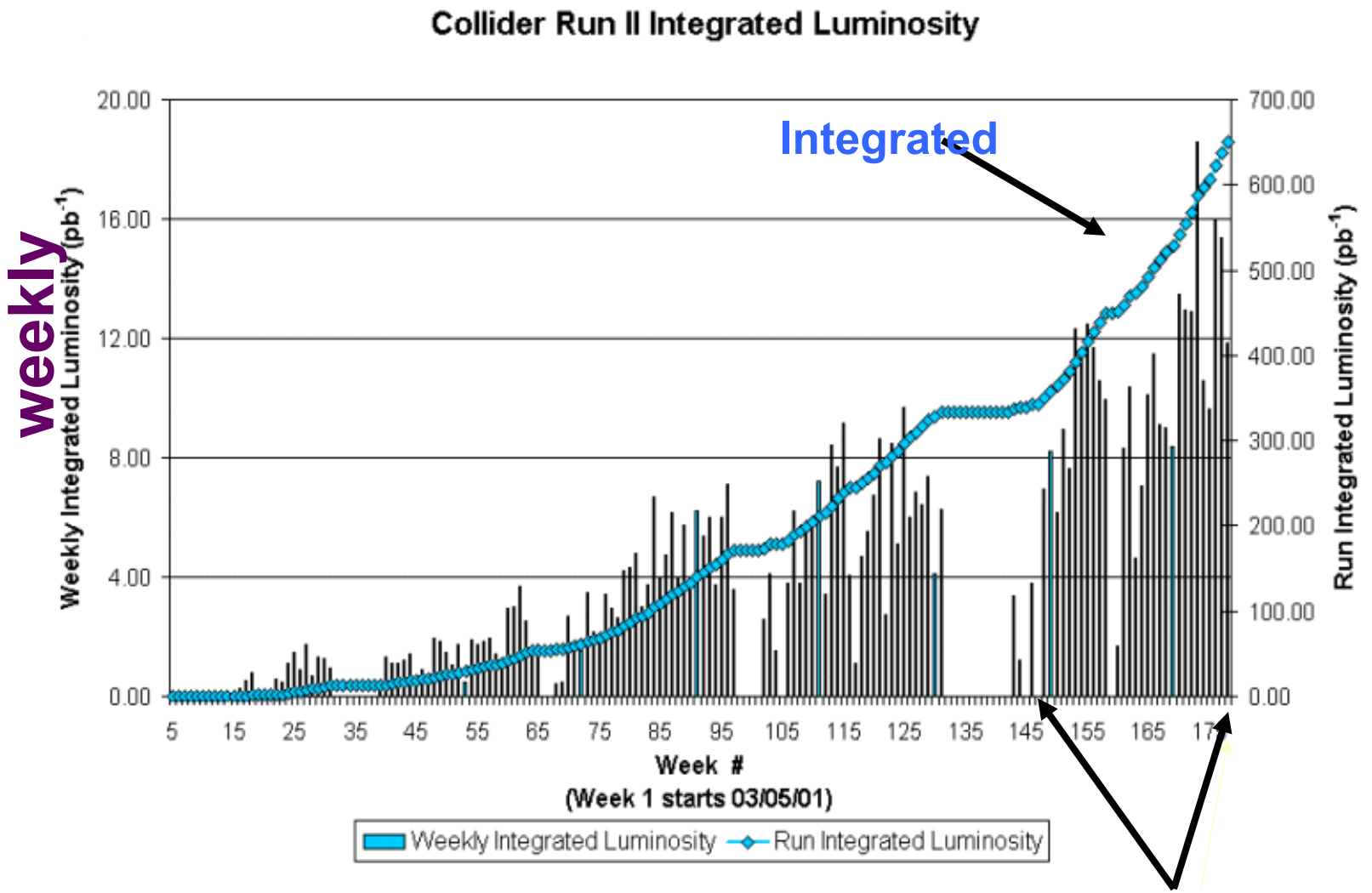
For M_H = 200GeV, relevant production cross sections down by a factor of 8.



Tevatron Integrated Luminosity (fb^{-1})

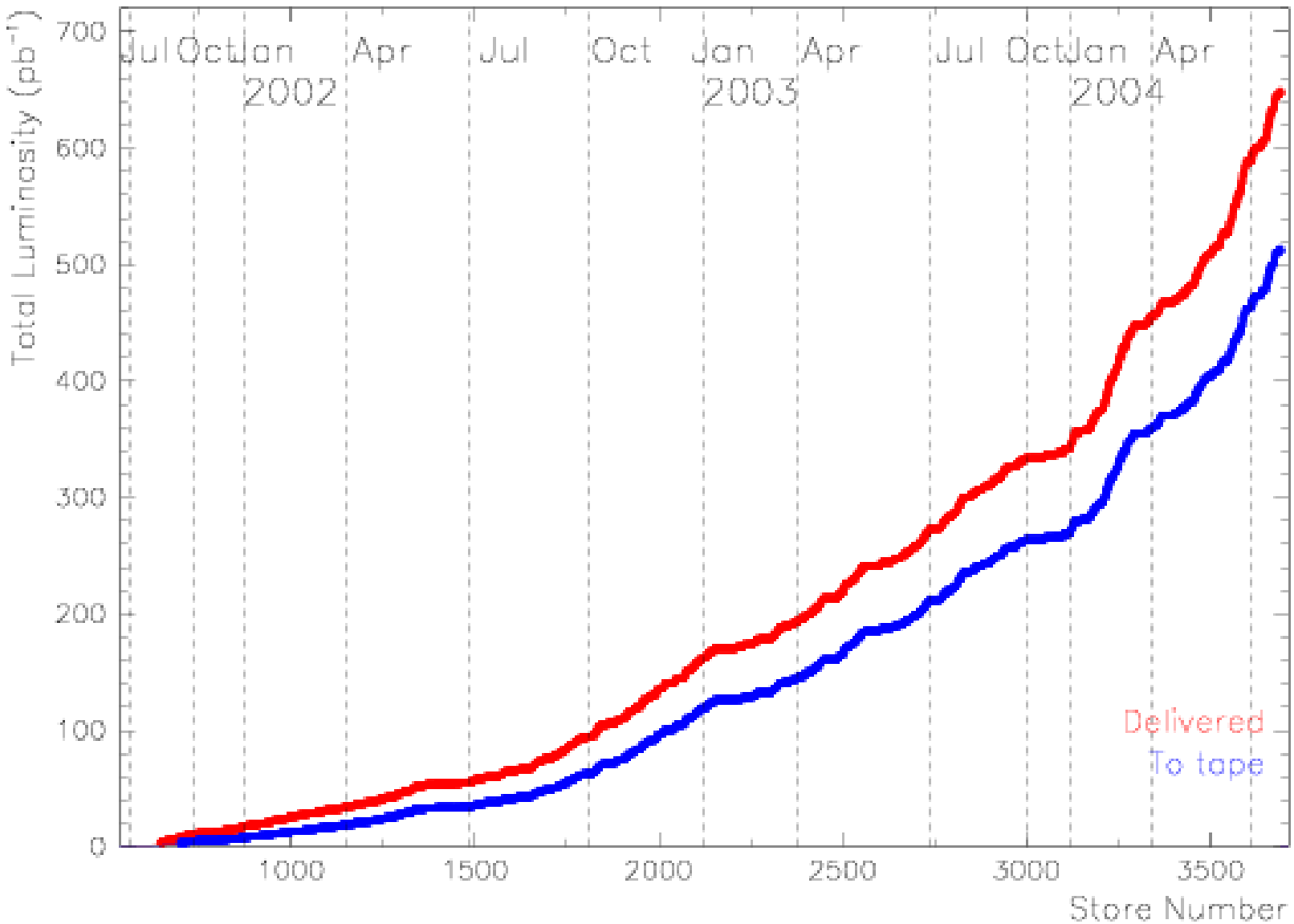


Tevatron Delivered Luminosity (pb^{-1})



Last 30 weeks

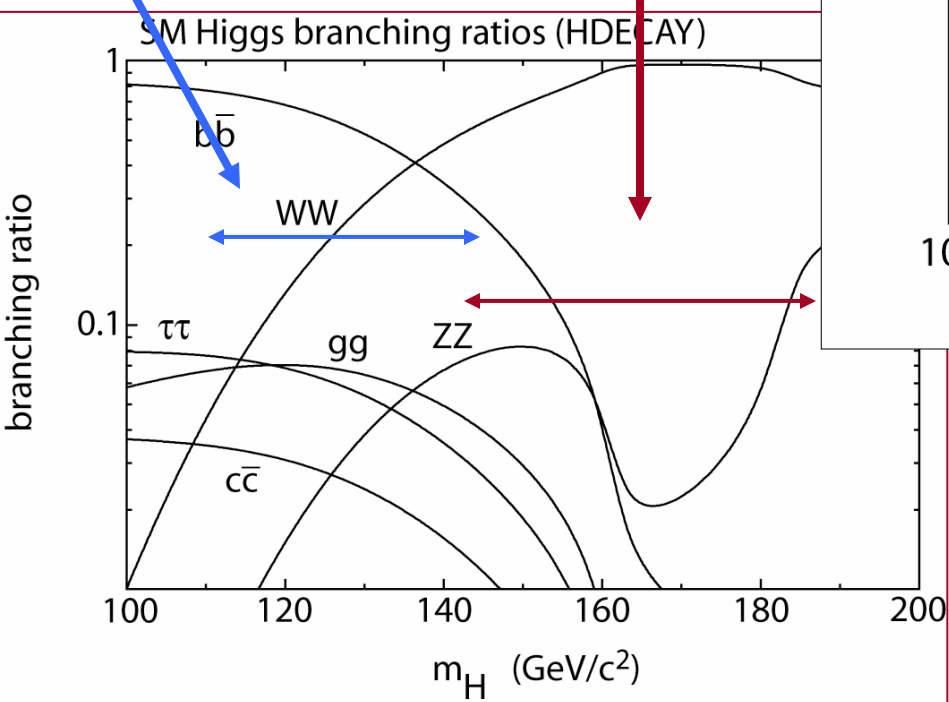
CDF Integrated Luminosity (pb^{-1}) vs Store No.

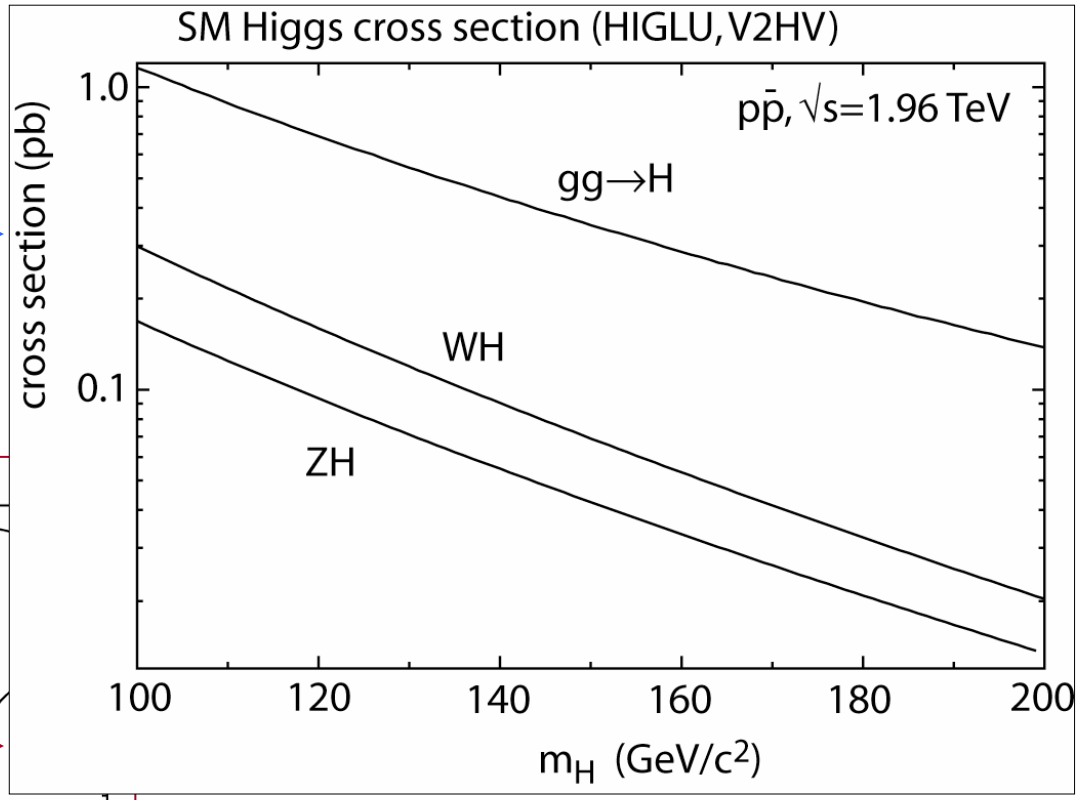


The SM Higgs production cross sections

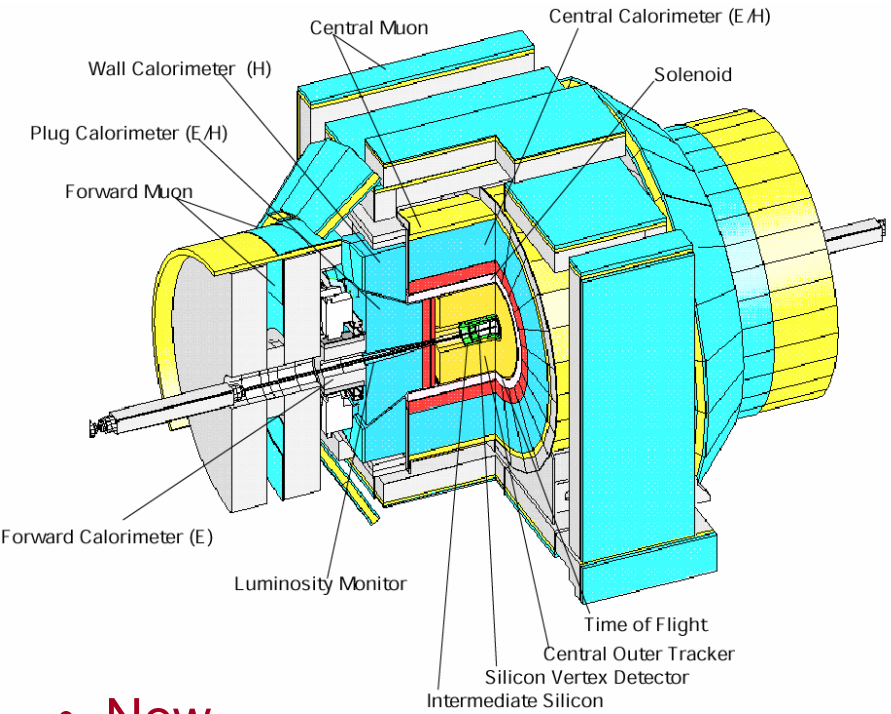
- Low M_H: Standalone Higgs ($gg \rightarrow H$) swamped: WH, ZH (associated production) better (with $H \rightarrow bb$)

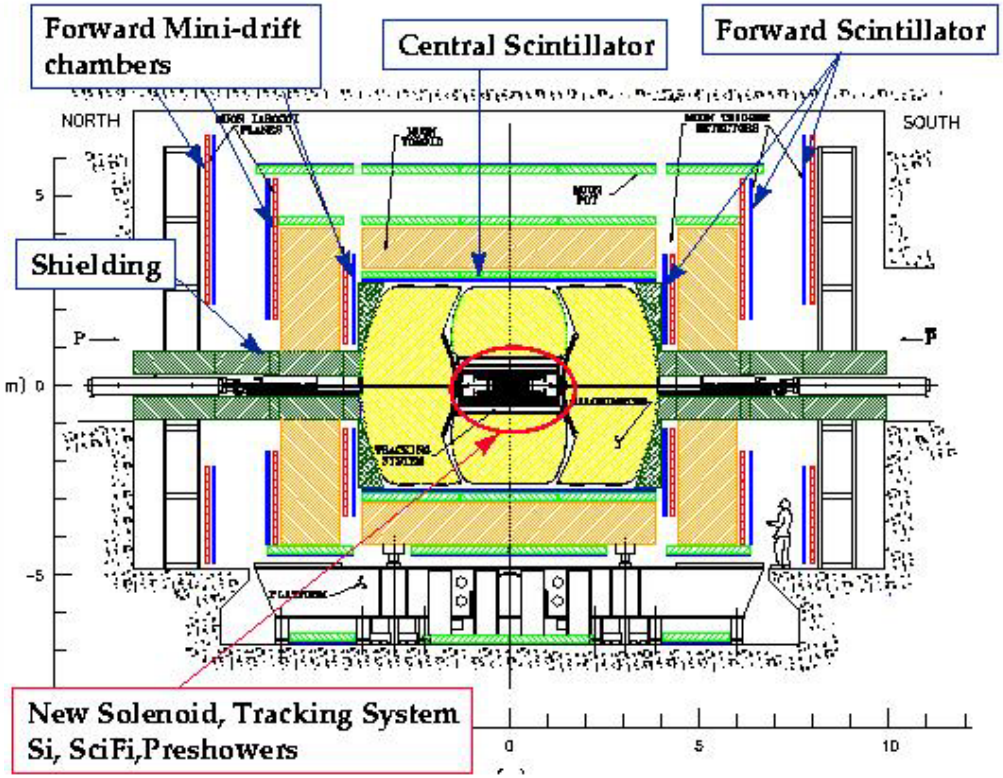
- High M_H: $H \rightarrow WW$, WW^*





The upgraded CDF and DØ Run II detectors

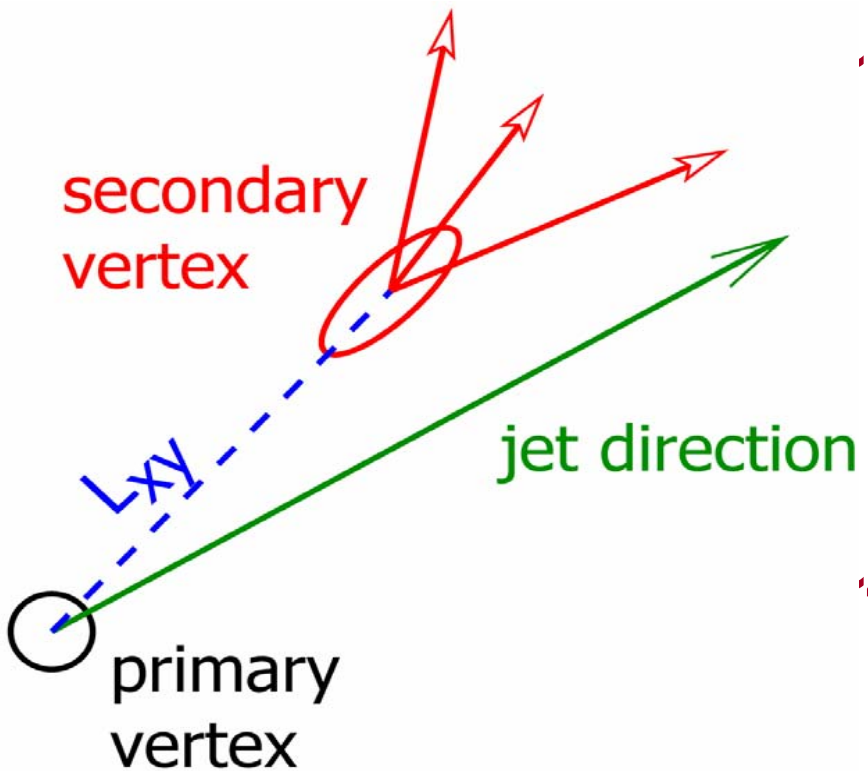




- New
  - silicon detector
  - drift chamber
  - TOF PID system
- Upgraded
  - calorimeter, muon system
  - DAQ/trigger
  - displaced-vtx trigger

- New (tracking in B-field)
  - silicon detector
  - fiber tracker
- Upgraded
  - muon system, calorimeter
  - DAQ/trigger
  - (displaced-vtx trigger soon)

b-jet tagging



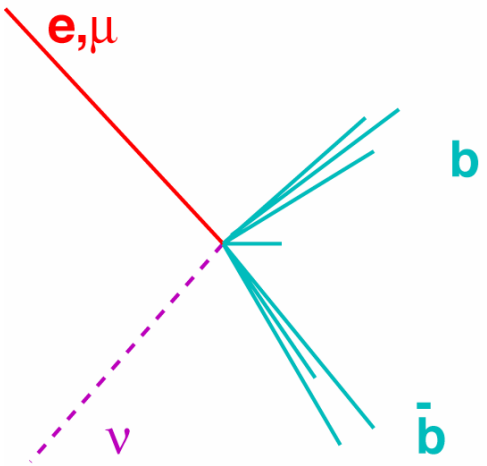
- **CDF:**
  - **50% b-tag** efficiency (top) for **~0.6%** light quark **mis-tag** rate in **$|\eta| < 2$**

D0:

- **40%** efficiency for **< 1% mis-tag** rate in **$|\eta| < 2.5$**

Low Mass Higgs Search

For m_H<135 GeV, bb decays dominate:



WH ZH

- Need good b tagging, bb mass resolution
- Understand background (amount & shapes)

Synopsis: $W(\rightarrow e\nu/\mu\nu)H(\rightarrow bb)$; Low M_H Assoc Prod

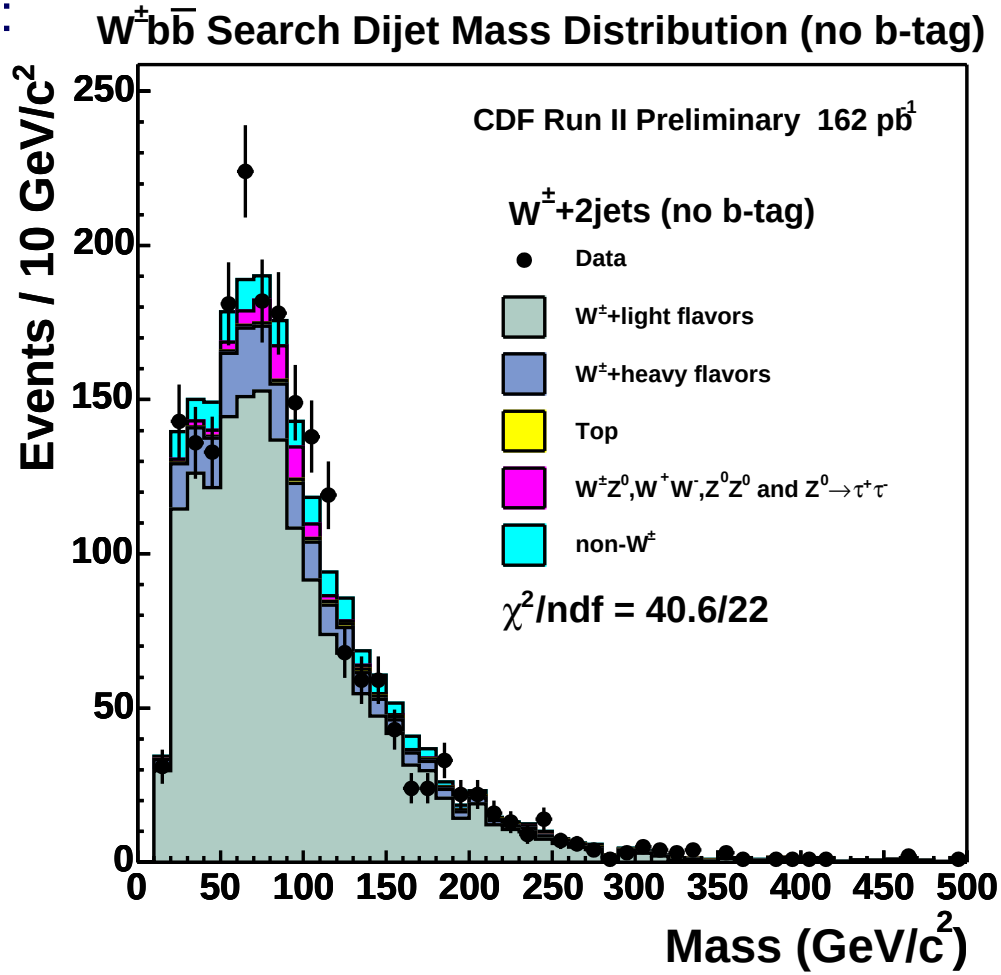
- σ.BR (WH → $l\nu bb$) ~150 fb (M_H=120GeV, l=e,μ)
- Acceptance ~ 2% (CDF)
- Background ~ 400 events per fb^{-1} (CDF)
- S/N(120GeV,1fb-1) = (150 x 2%)/sqrt(400) = 3/20
- Need: Higher luminosity
- Need: improved b-tag, bb mass resolution etc
- Need: to combine channels and experiments

$W(\rightarrow e\nu/\mu\nu)H(\rightarrow bb)$; Low M_H Assoc Prod: CDF (1)

- Look for e or μ with two jets and $\not{E}_T$:
  - Central isolated e/μ, $p_T > 20$ GeV
  - Missing $E_T > 20$ GeV
  - Two jets: $E_T > 15$ GeV, $|\eta| < 2$
  - Veto Di-lepton, extra jet, etc.

→ Observe 2072 events in data (jets are not b's yet)

- Simulations with Alpgen plus Herwig with detailed detector response



$W(\rightarrow e\nu/\mu\nu)H(\rightarrow bb)$; Low M_H Assoc Prod: CDF (2)

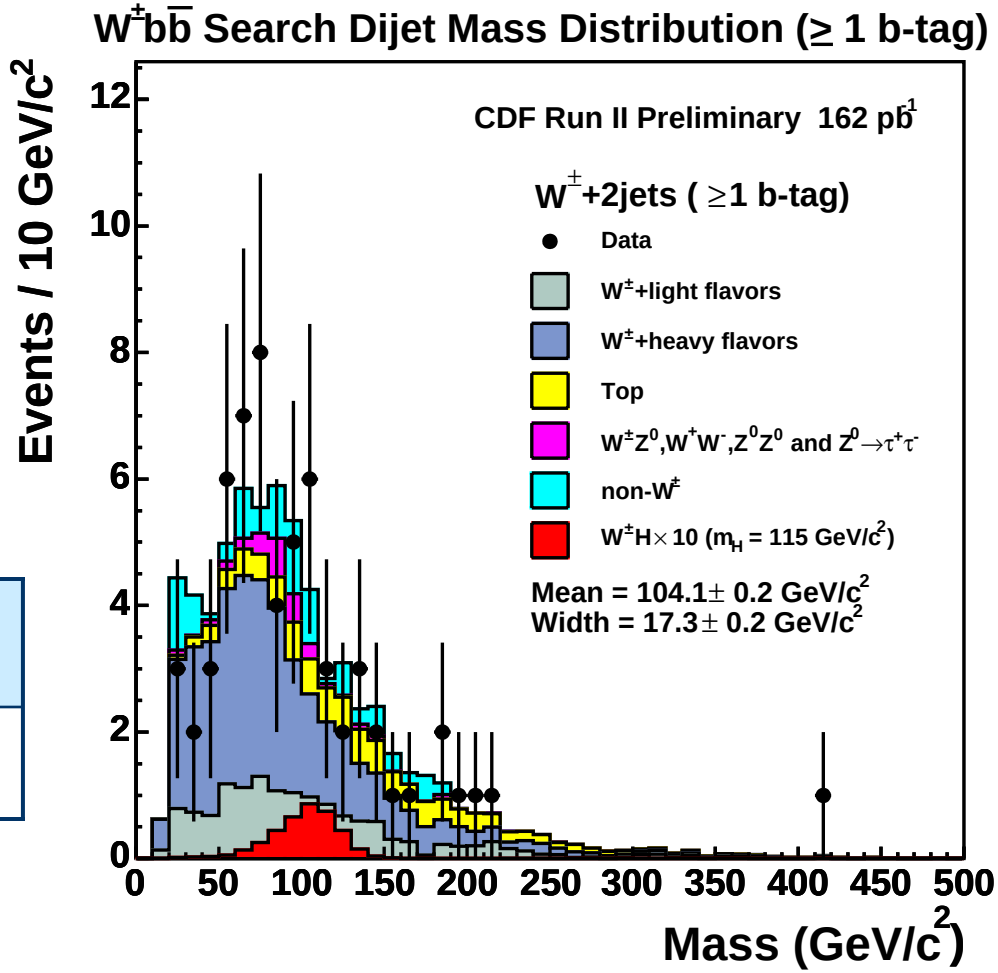
- Enrich b-content by requiring at least one b-tagged jet

→ Observe 62 events in data
→ Expect 61 ± 5 events

- Main contributions to the bkgd.

Mistags	Wc(c)	Wbb	QCD	top
14	13	12	10	9

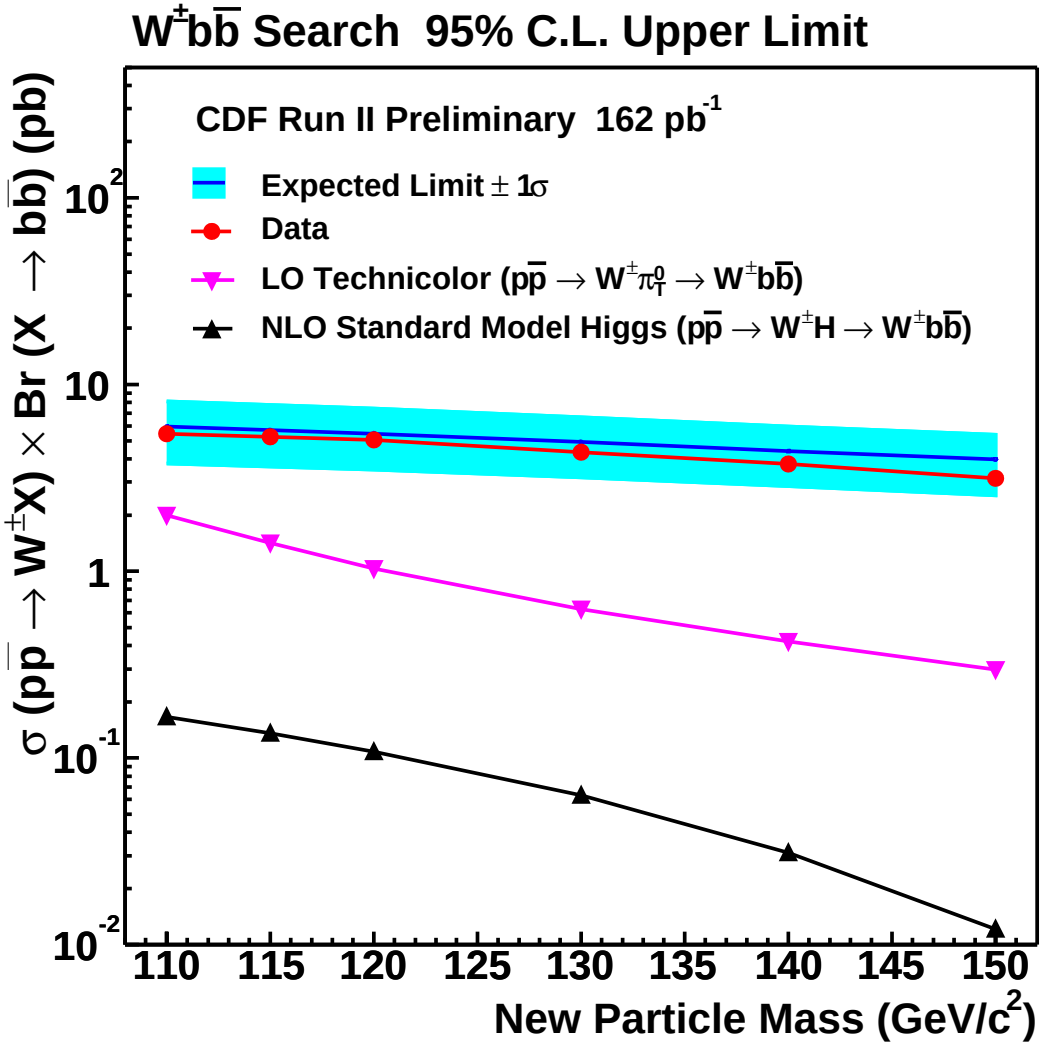
- Expect 0.3 evts from Higgs
  - Signal acceptance of ~ 1.8% for M_H = 110 – 130 GeV



$W(\rightarrow e\nu/\mu\nu)H(\rightarrow bb)$; Low M_H Assoc Prod: CDF (3)

- Limit Higgs prod cross section times branching fr. **$\sigma \times B < 5$ pb**
- Improve CDF's Run I limit **$\sigma \times B <$ 14–19 pb** for **M_H = 70–120 GeV**

Source	Uncertainty (%)
ISR / FSR	19
Secondary vertex	8.6
Lepton ID	5
Jet energy scale	3
PDF	1
Trigger	0.7
Total	**22**



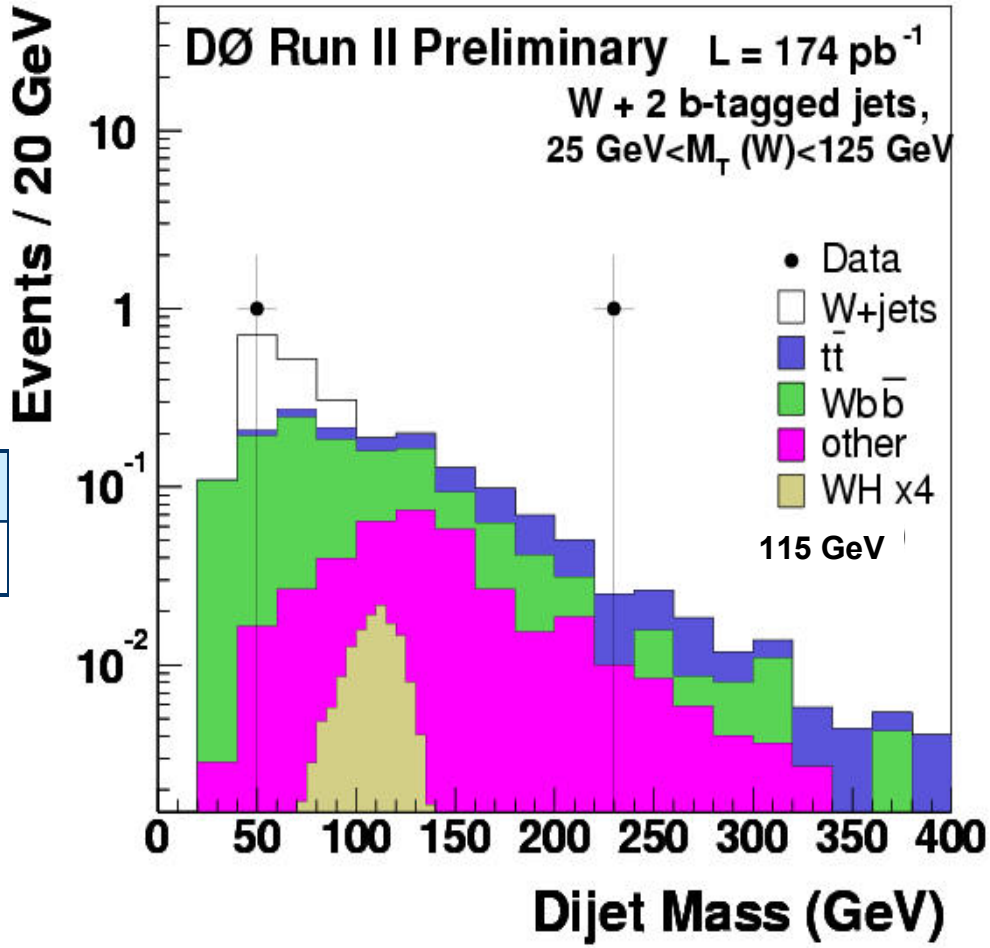
- Expect improvements due to better di-jet mass resolution

W(→eν)H(→bb); Low M_H Assoc Prod: D0

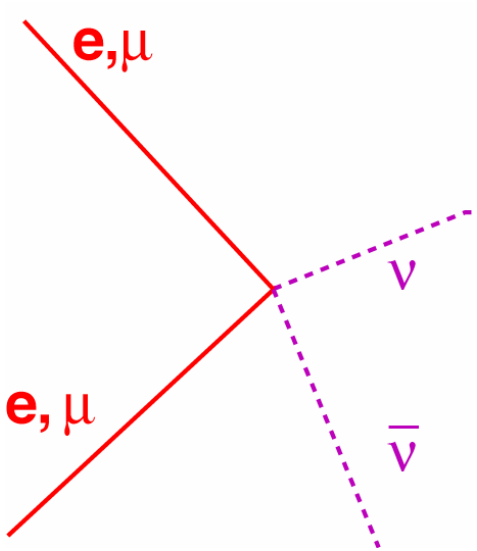
- Central isolated e, p_T > 20 GeV
- Missing E_T > 25 GeV
- ≥2 jets: E_T > 20 GeV, |h| < 2.5
- L_{int}=174 pb^{-1} of data
- B-tag jets
- Suppress top: exactly two jets
- Sample composition:

Wbb	Wc(c)	Wjj	tt+t	Others
1.4±0.4	**0.3**±0.1	**0.1**±0.03	**0.6**±0.2	**0.1**±0.03

- Observe **2 evts.**, expect **2.5±0.5**
- Set 95% CL limits
  - **σ(Wbb) < 20.3 pb**
  - **σ(WH)B(H→bb) < 12.4 pb for M_H = 115 GeV**



$H \rightarrow WW^{(*)} \rightarrow (e/\mu)(e/\mu)\nu\nu$; High M_H



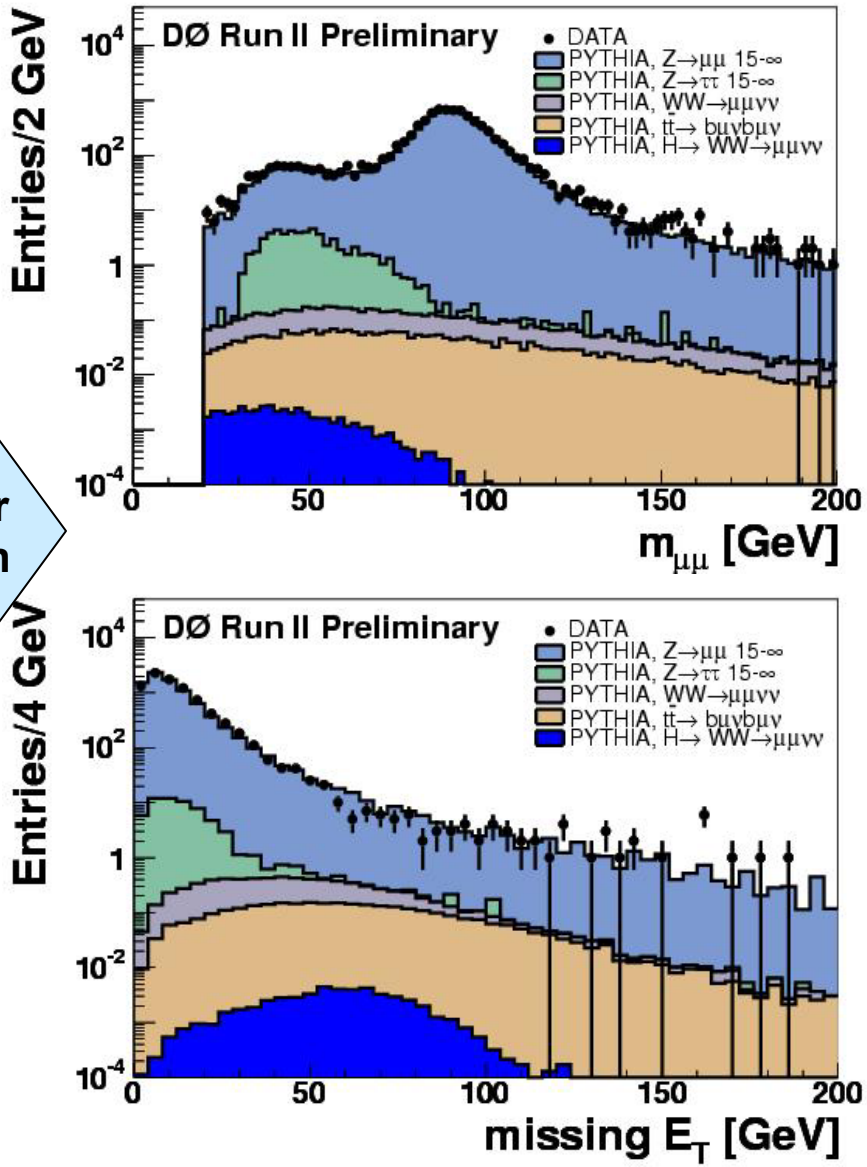
$gg \rightarrow H \rightarrow WW \rightarrow ll\nu\nu$ $\qquad$ $ZH/WH \rightarrow WWW/ZWW$

Same context as WW analysis

$H \rightarrow WW^{(*)} \rightarrow (e/\mu)(e/\mu)\nu\nu$; High M_H: D0 (1)

- Two isolated leptons with p_T > 12/8 GeV (20/10 GeV for $\mu\mu$)
- Missing E_T > 20 GeV (30GeV for $\mu\mu$)
- Veto Z resonance, Energetic jets

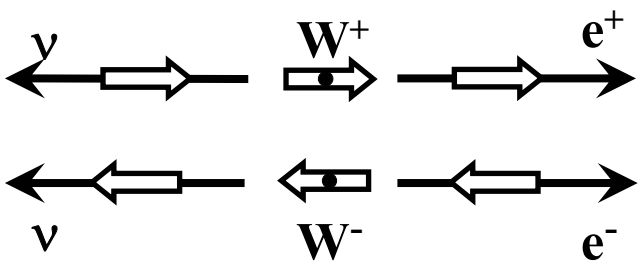
Data vs MC after evt. preselection



- Simulation: Pythia + detector
- Data Integrated luminosity
  ~ 180 (ee), 160 ($e\mu$) and 150 ($\mu\mu$) pb^{-1}

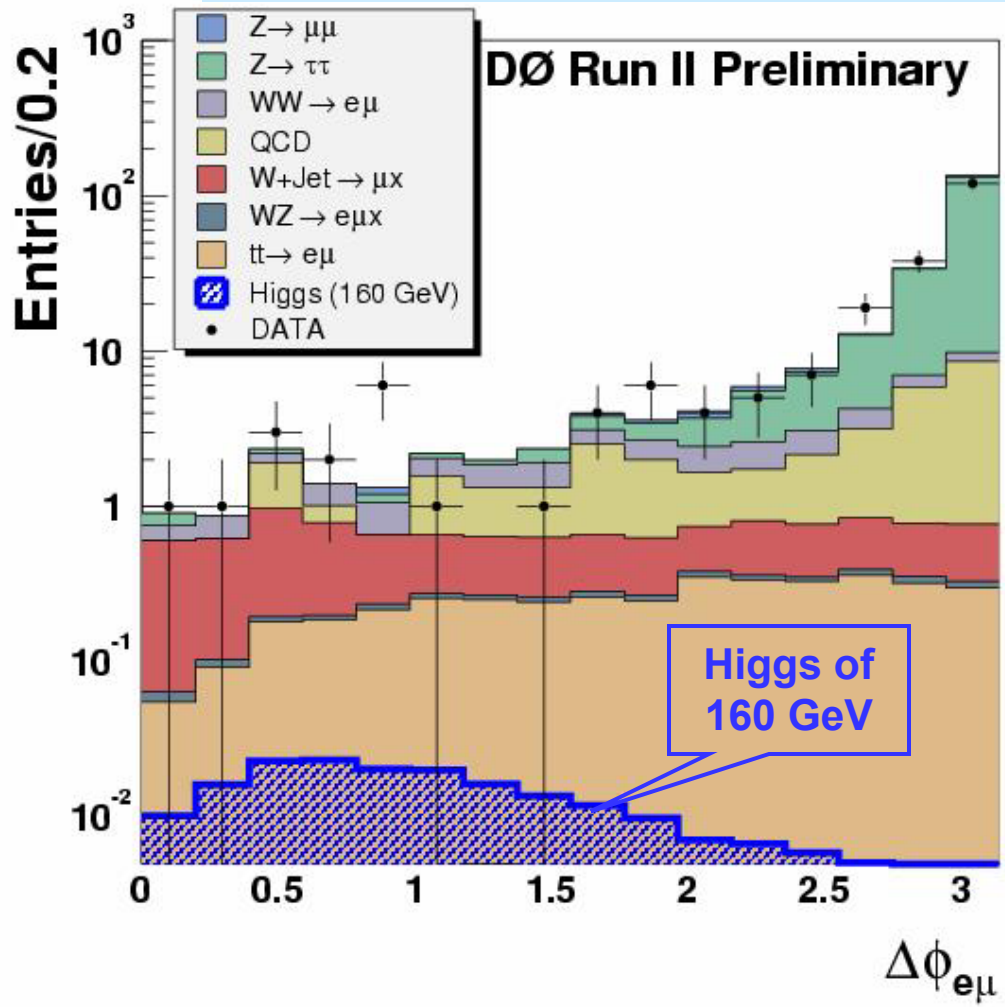
$H \rightarrow WW^{(*)} \rightarrow (e/\mu)(e/\mu)\nu\nu$; High M_H: D0 (2)

- Two neutrinos: No reconstructed Higgs mass
- Employ spin correlations (lepton-lepton angle) to suppress the background



- Leptons from Higgs tend to be collinear

Azimuthal angle between e and μ



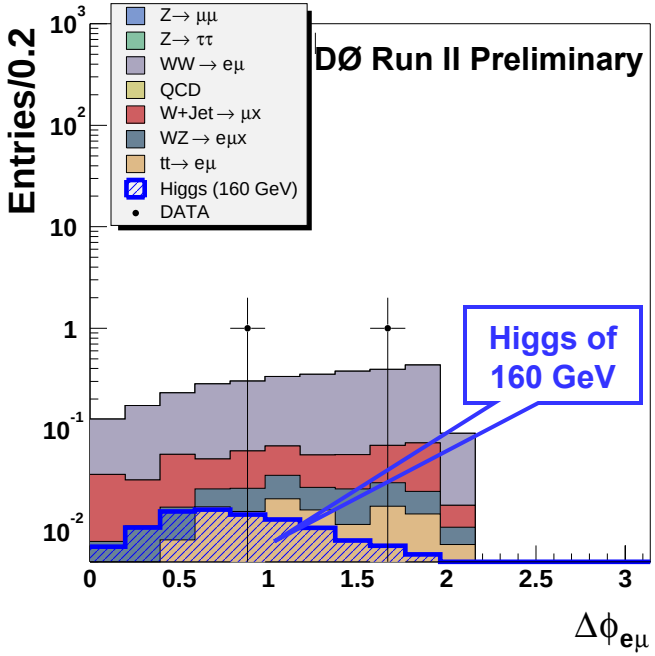
$H \rightarrow WW^{(*)} \rightarrow (e/\mu)(e/\mu)\nu\nu$; High M_H: D0 (3)

- Number of events after all cuts

	ee	eμ	μμ
Observed	**2**	**2**	**5**
Expected	**2.7**±0.4	**3.1**±0.3	**5.3**±0.6

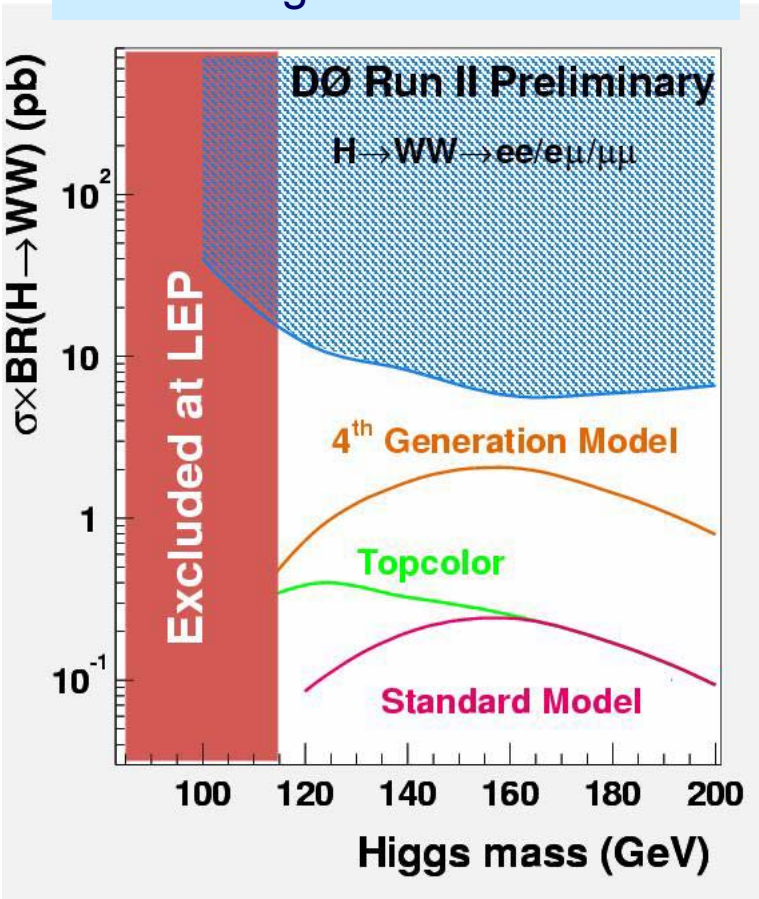
- Dominant bkgd. in eμ sample

WW	W+jets	WZ	tt
2.51±0.05	**0.34**±0.02	**0.11**±0.01	**0.13**±0.01

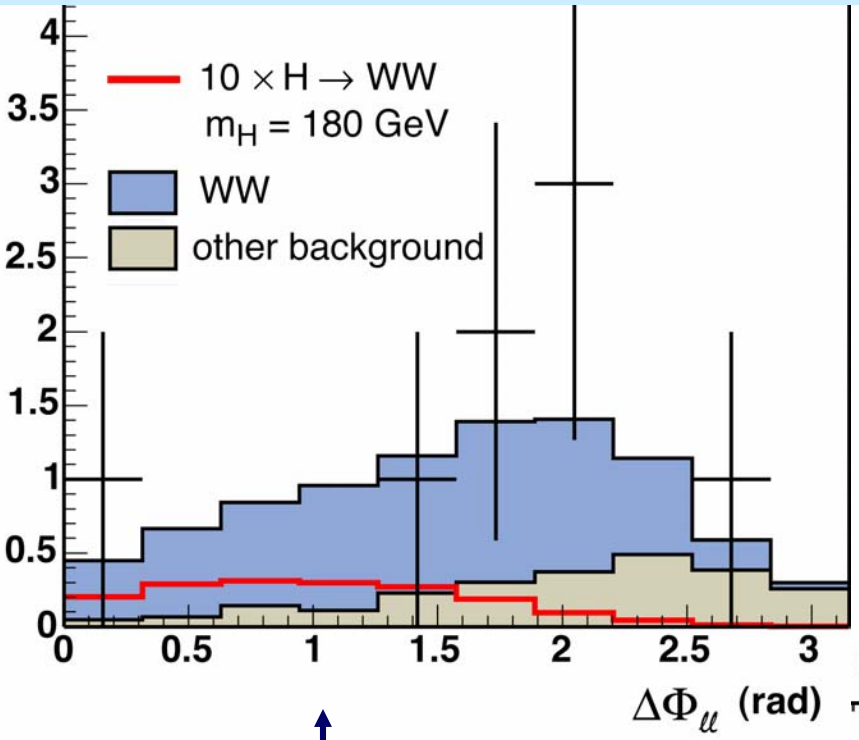


- Signal acceptance is ~ 0.02 – 0.2 depending on the Higgs mass/final state

Excluded cross section times Branching Ratio at 95% C.L.

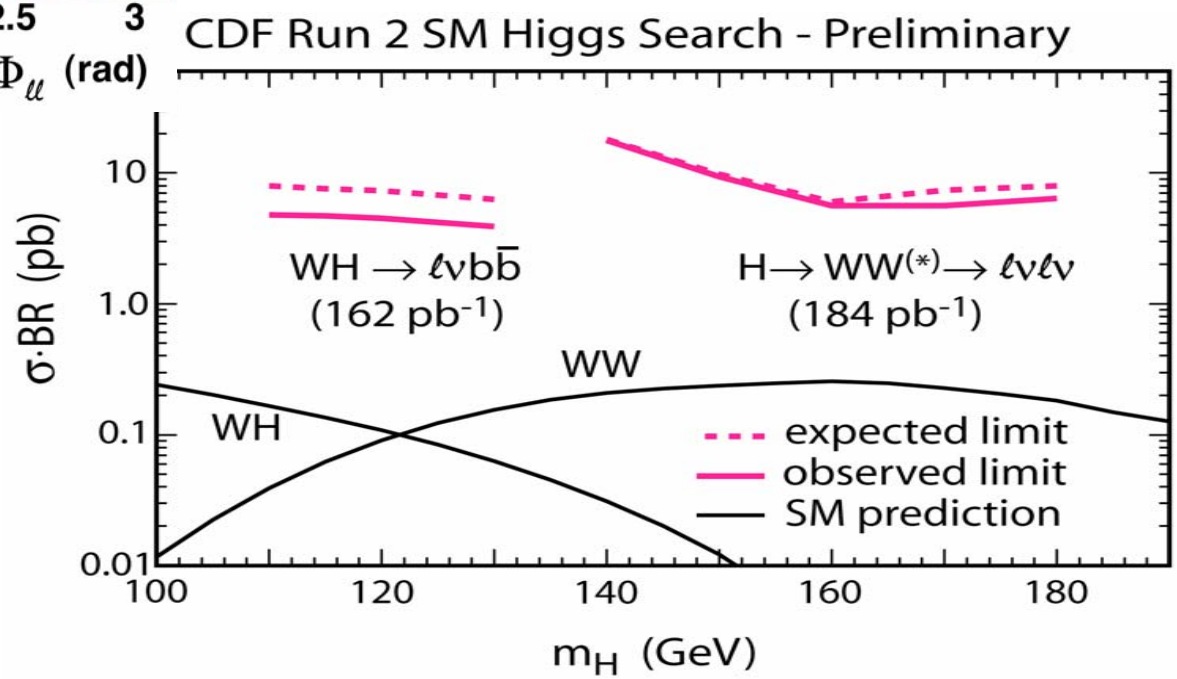


$H \rightarrow WW^{(*)} \rightarrow (e/\mu)(e/\mu)\nu\nu$; High M_H: CDF



- Use dilepton invariant mass as discriminating variable (> 60 GeV)
- 8 events seen (8.9 expected, mostly WW)

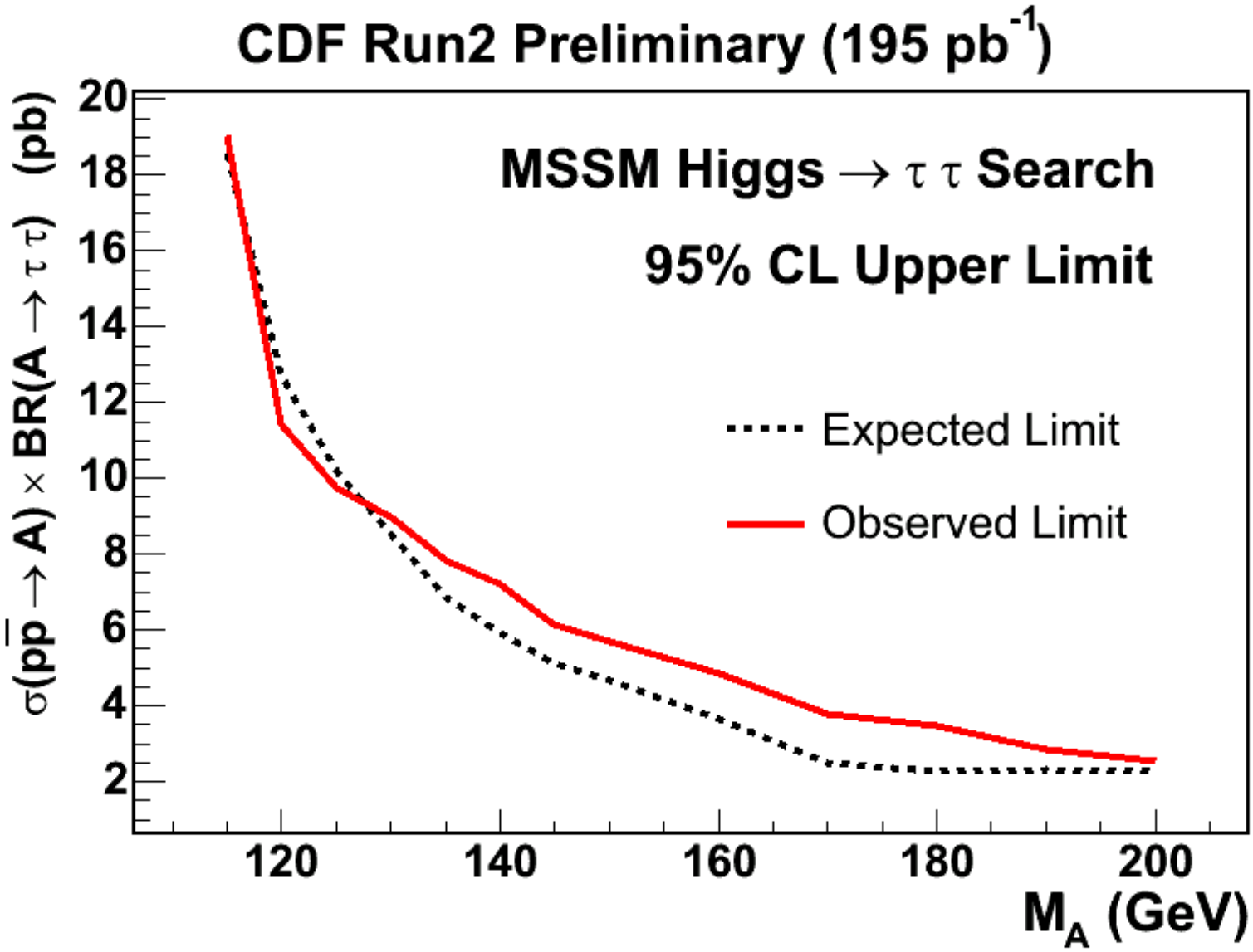
Perform likelihood fit using angular distribution



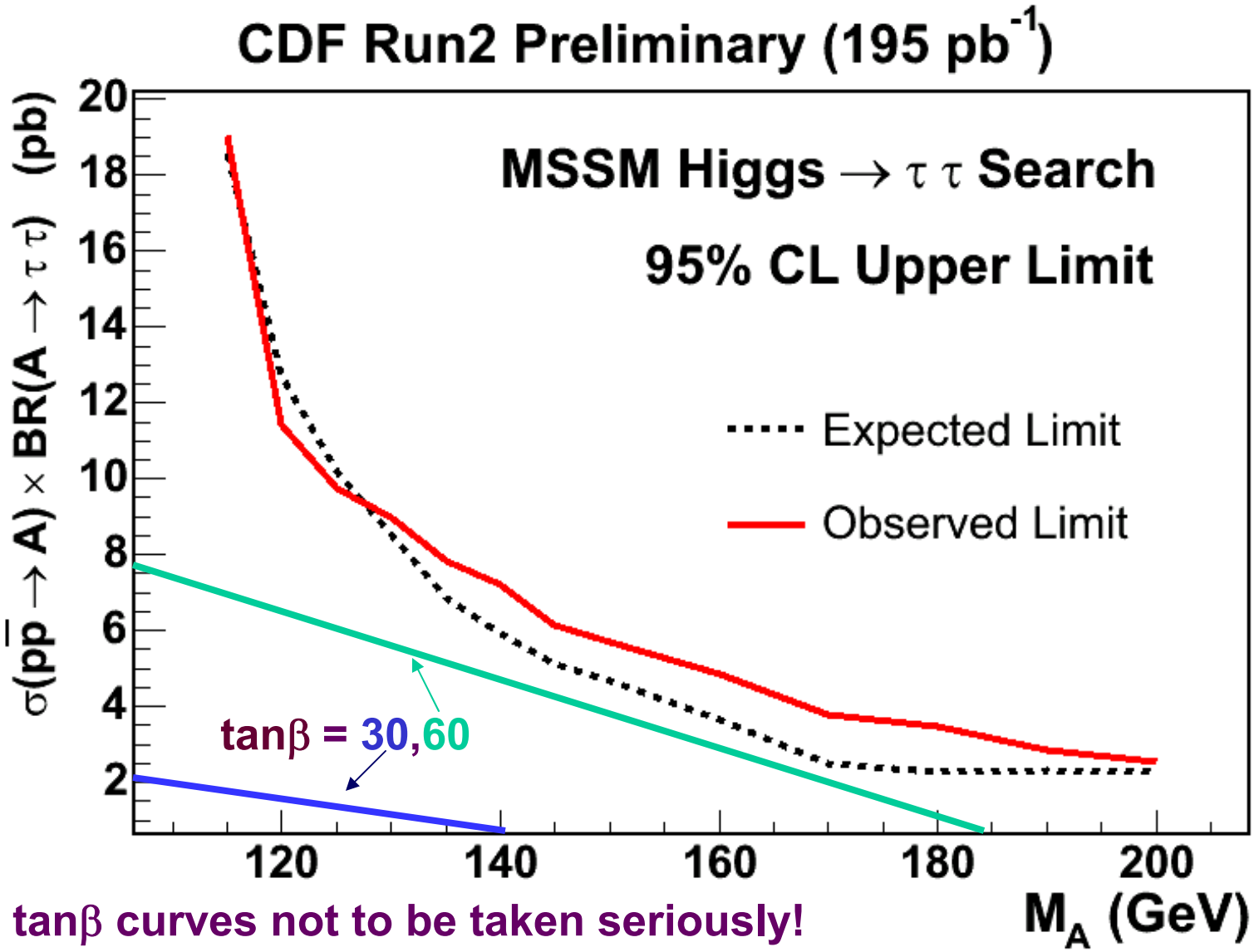
Summary & Outlook

- Low and high mass Higgs (associated production) limits from both CDF and D0 with about 0.2 fb^{-1} data.
- Tevatron needs to beat the “street estimate”. Recent record-setting performance is encouraging.
- Detector/analysis efficiency improvement is a must. Good news: as shown, B-tagging, background understanding and other tools are in place.
- Things sometimes go bump in the run!
- Maybe M_H is on the low side or we will get lucky with Susy (and Susy likes high tan(β)).

MSSM Higgs to ττ Search (CDF)



MSSM Higgs to ττ Search (CDF)



My tanβ curves not to be taken seriously!