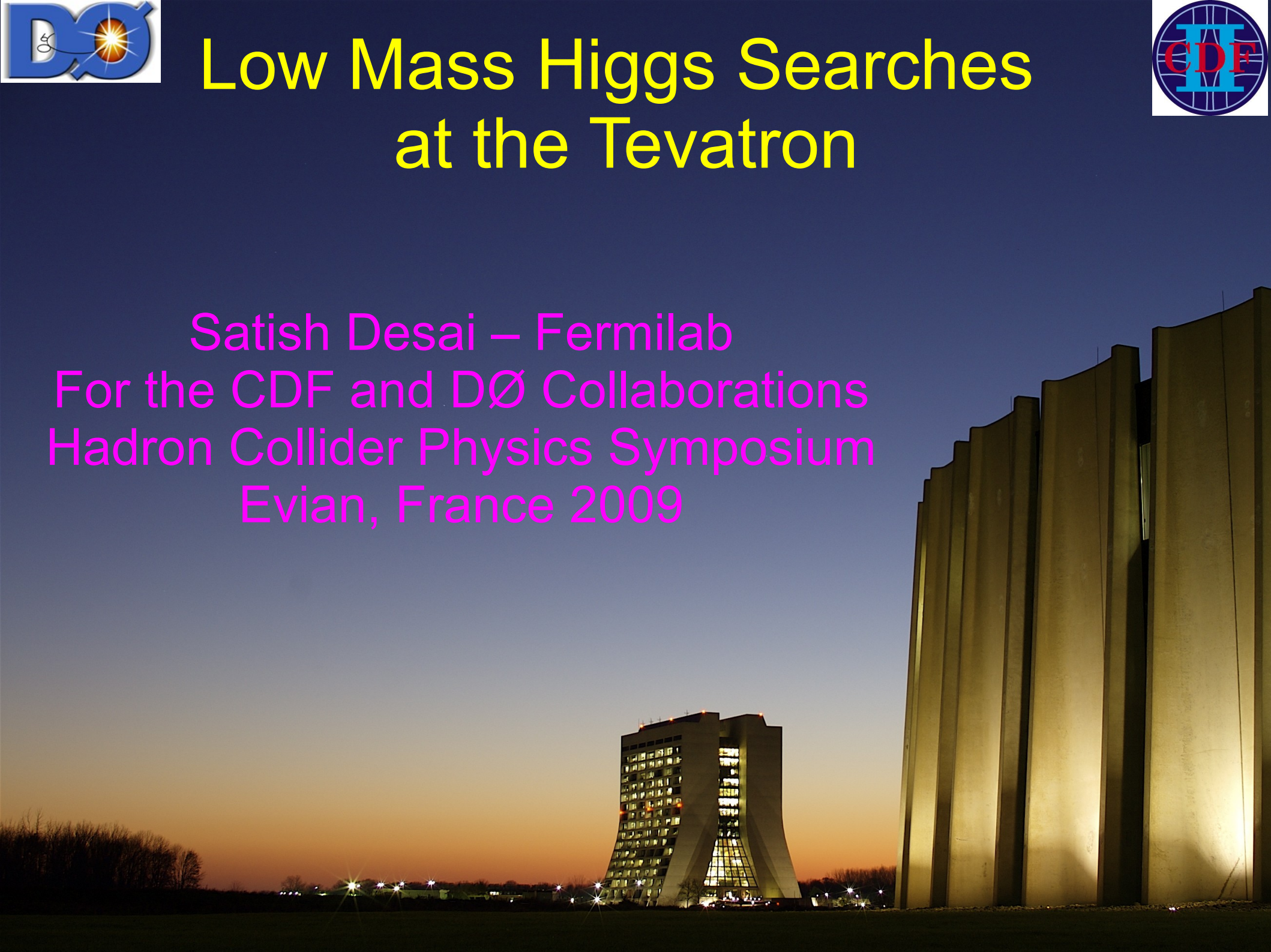
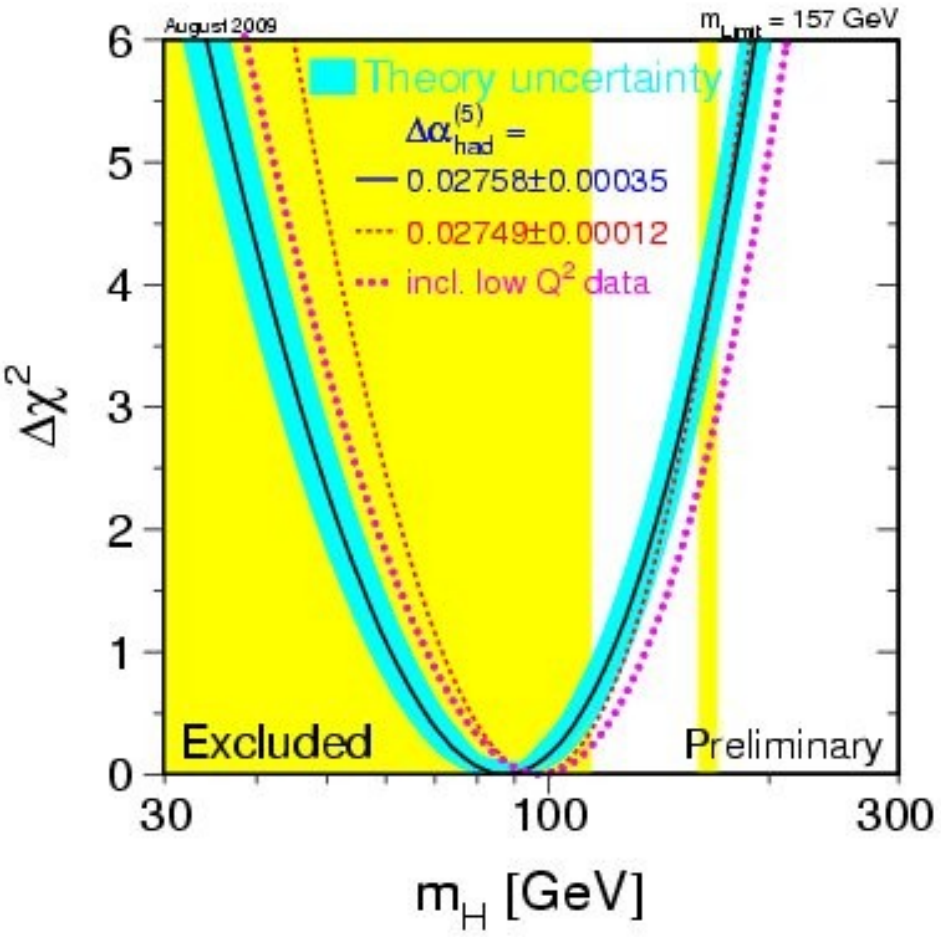
Low Mass Higgs Searches at the Tevatron

Satish Desai – Fermilab
For the CDF and DØ Collaborations
Hadron Collider Physics Symposium
Evian, France 2009



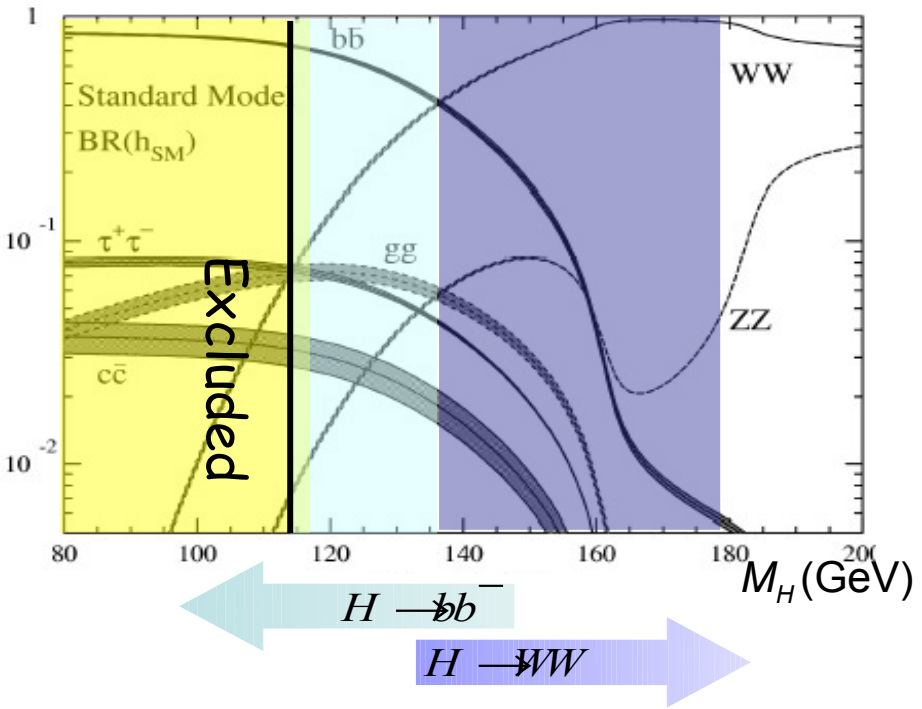
The Recent Past

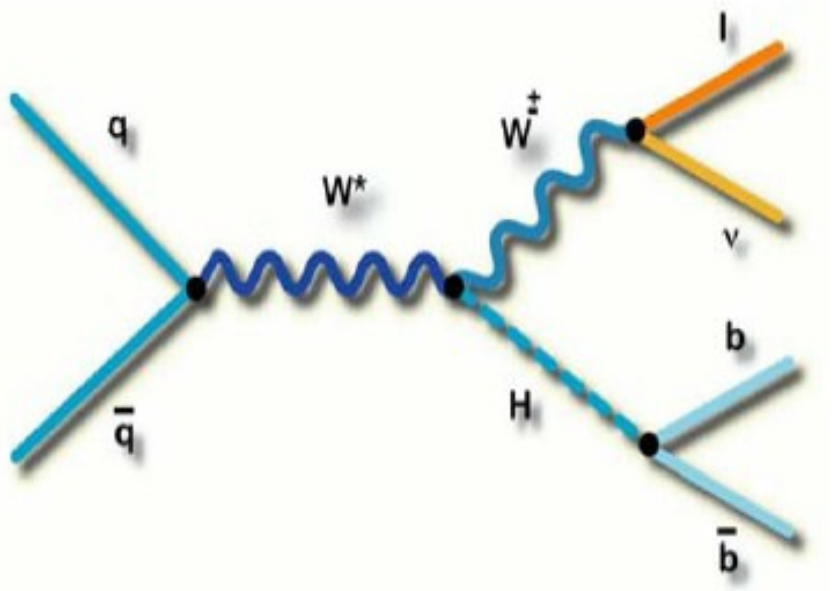


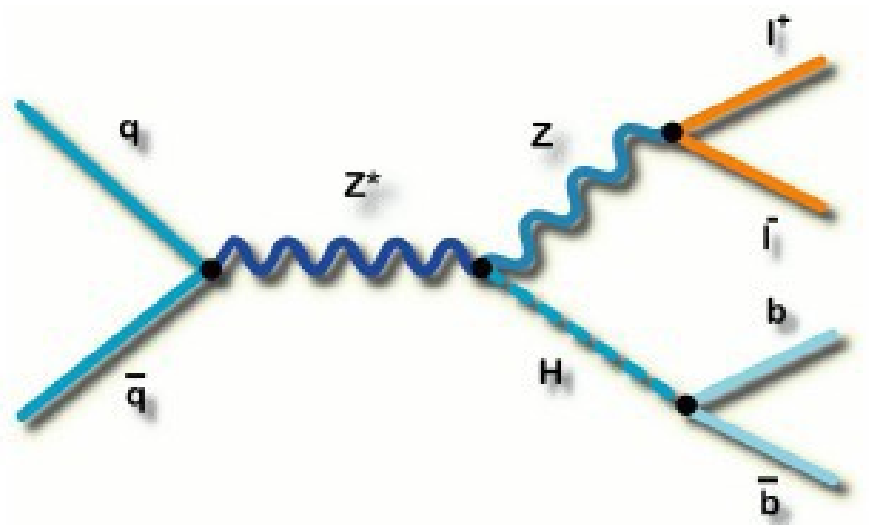
- Indirect constraints:
  - M_H < 157 GeV
  - M_H < 186 GeV including direct searches
- Direct Searches:
  - LEP: M_H > 114 GeV
  - Tevatron excludes around 160 GeV

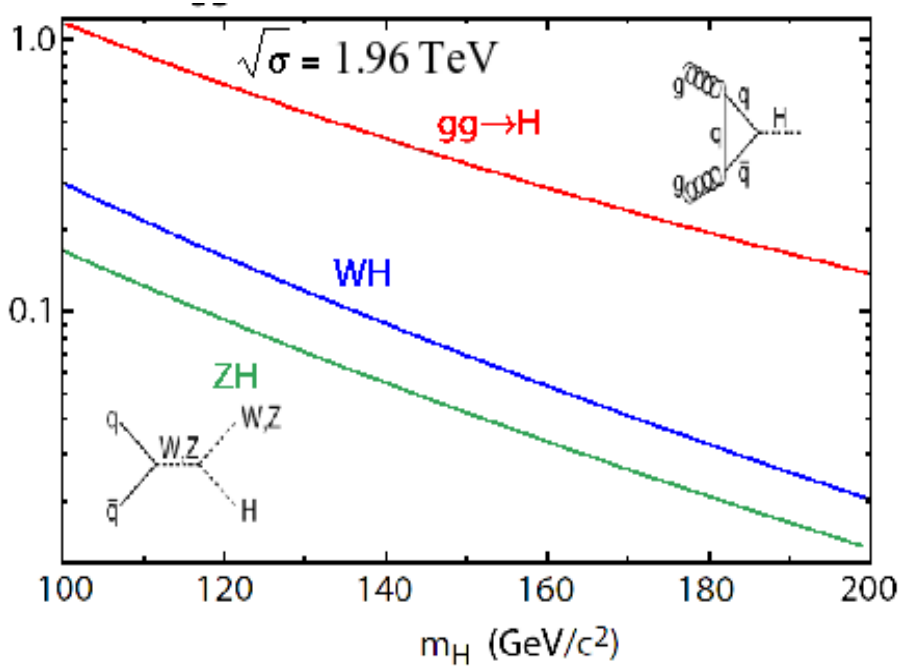
- Light Higgs is favored
- Within reach of the Tevatron experiments

Production and Decay

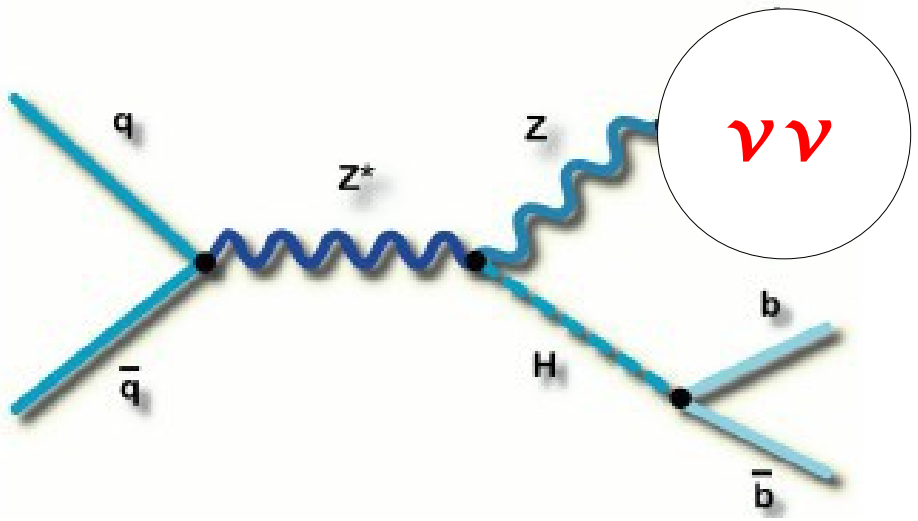


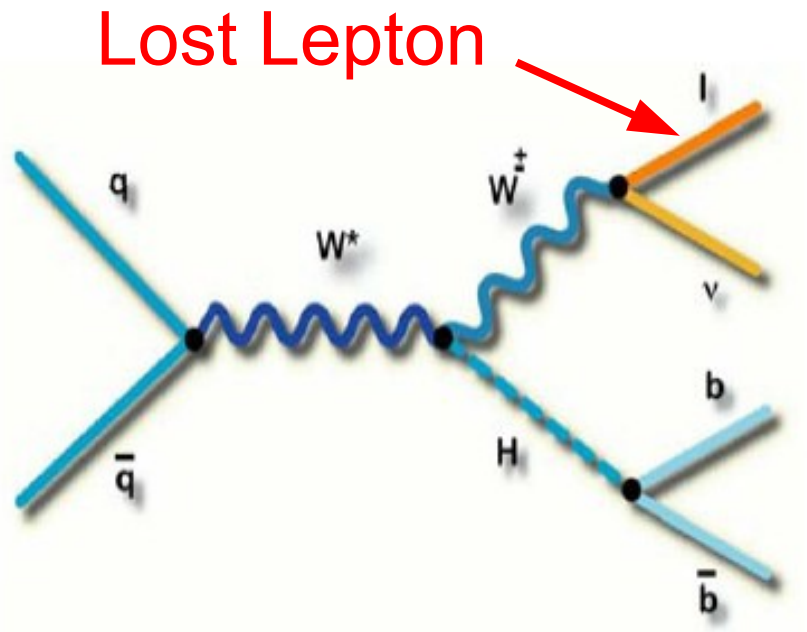






W/ZH $\rightarrow \not{E}_T$+bb (1)

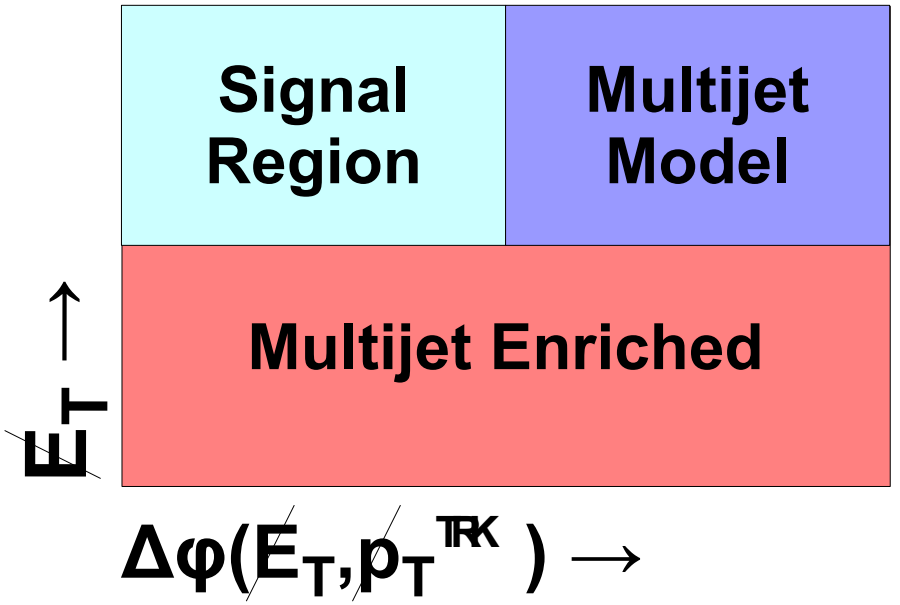


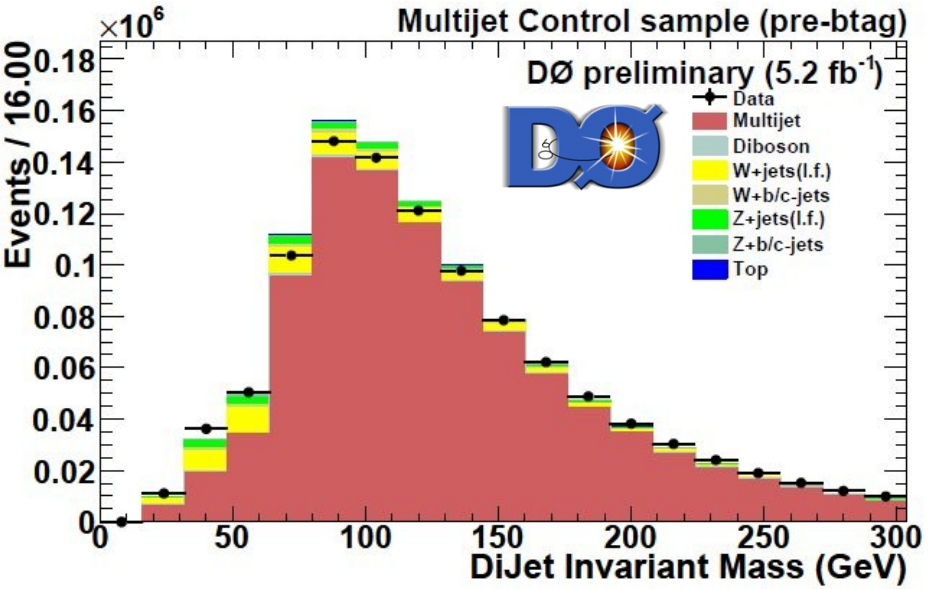


- Contributions from
  - ZH$\rightarrow \nu\nu$bb
  - WH with missing lepton
- Experimentally challenging, but big payoff
- Two analyses: DØ and CDF
- Large multijet background drives analysis design
- Several control samples to estimate backgrounds and validate predictions

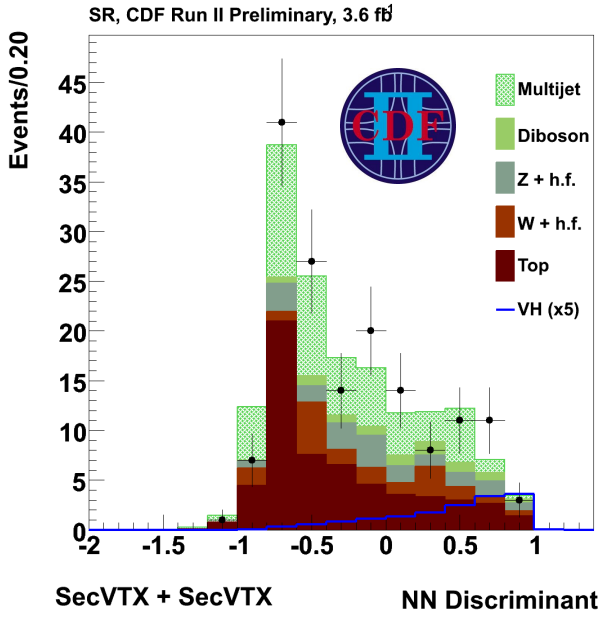
W/ZH $\rightarrow \not\!\!E_T$+bb (2)

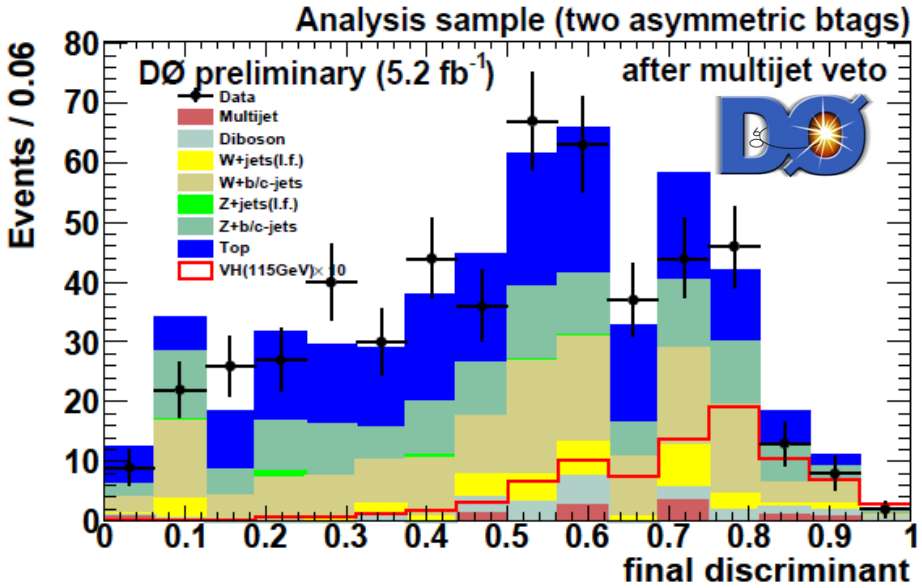
- Analysis Selection
  - Lepton veto
  - Large $\not\!\!E_T$
  - $\not\!\!E_T$ Significance
  - $\Delta\varphi(\not\!\!E_T, \not\!\!p_T^{TRK}) < \pi/2$
  - Jets well separated from $\not\!\!E_T$
- At least one b-tag
  - Jet probability and secondary vertex taggers from CDF
  - Neural net tagger from DØ





W/ZH $\rightarrow \not\!\!E_T$+bb (3)





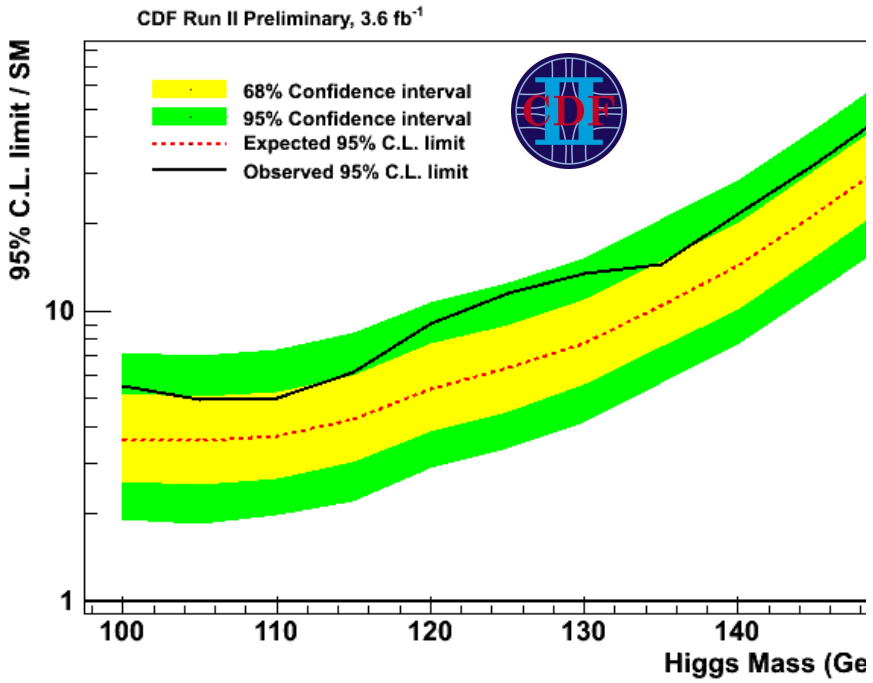
- Multijet backgrounds rejected by cuts on dedicated discriminants

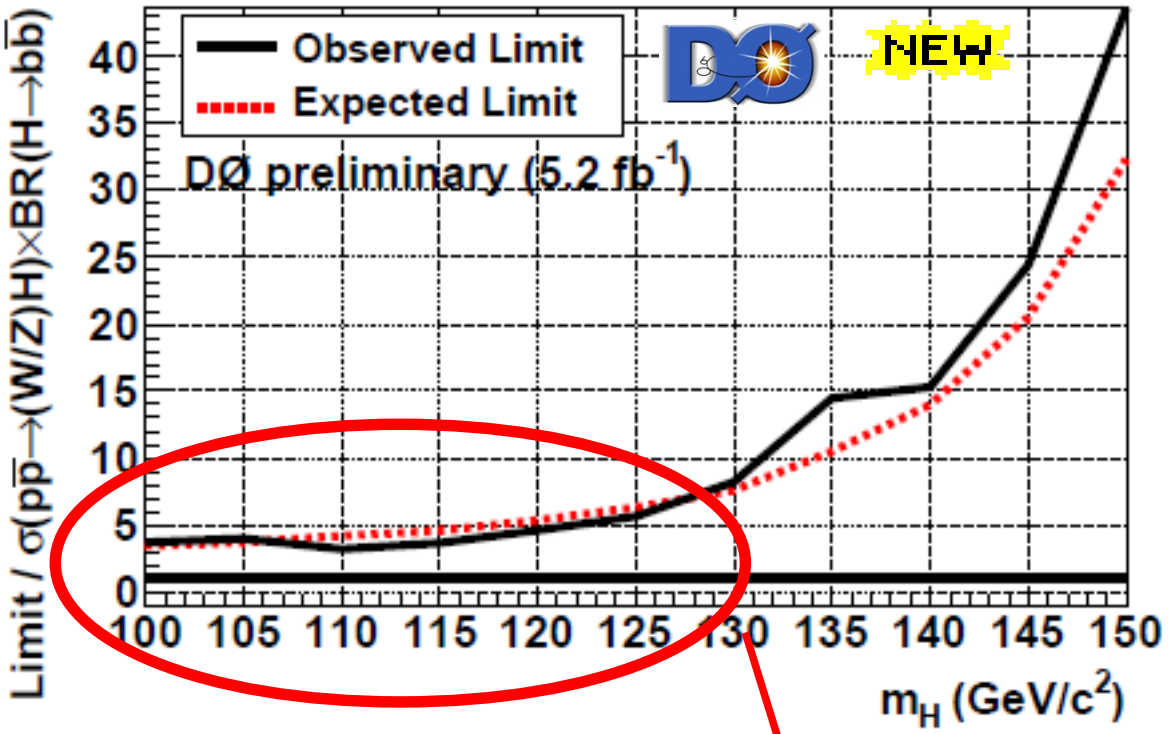
	Yield
Data	514
Background	542
Signal	7.6

DØ: Two Jets and two tags

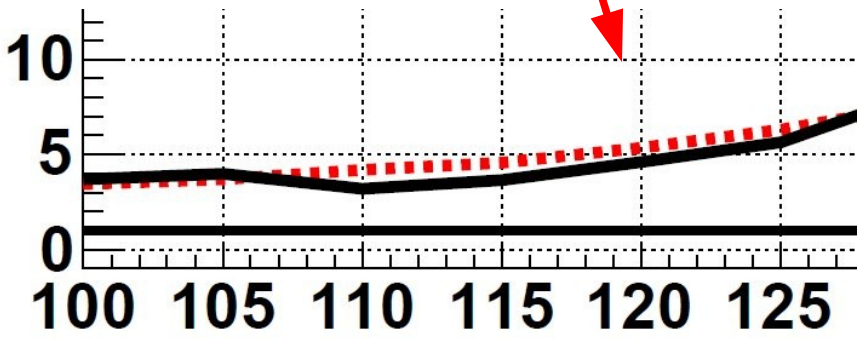
- Train final discriminants against W/Z+jets, tt, diboson
  - CDF: NN
  - DØ: decision tree
- Limits extracted from shapes

W/ZH $\rightarrow \not\!\!E_T$+bb (4)

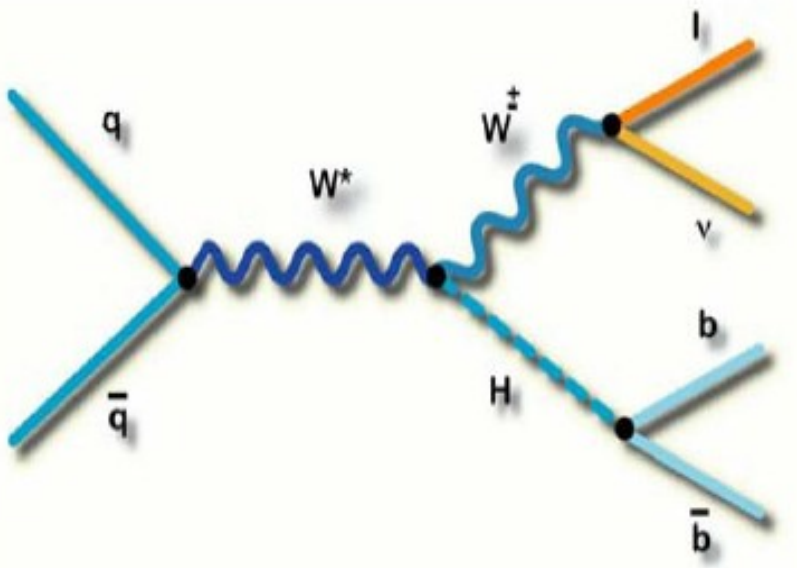




- Observed/Expected Limits at M_H=115 GeV
  - CDF: 6.1/4.2 × SM (3.6 fb^{-1})
  - DØ: 3.7/4.6 × SM (5.4 fb^{-1})



WH $\rightarrow l\nu bb$ (1)



- Highest cross section at low masses
- Two analyses
  - DØ e/$\mu\nu$bb neural nets
  - CDF e/$\mu\nu$bb: matrix elements

NEW

- Common selection
  - One high p_T e or μ
  - Large $\not\!\!E_T$
  - Two or three high energy jets
  - One or two b-tags

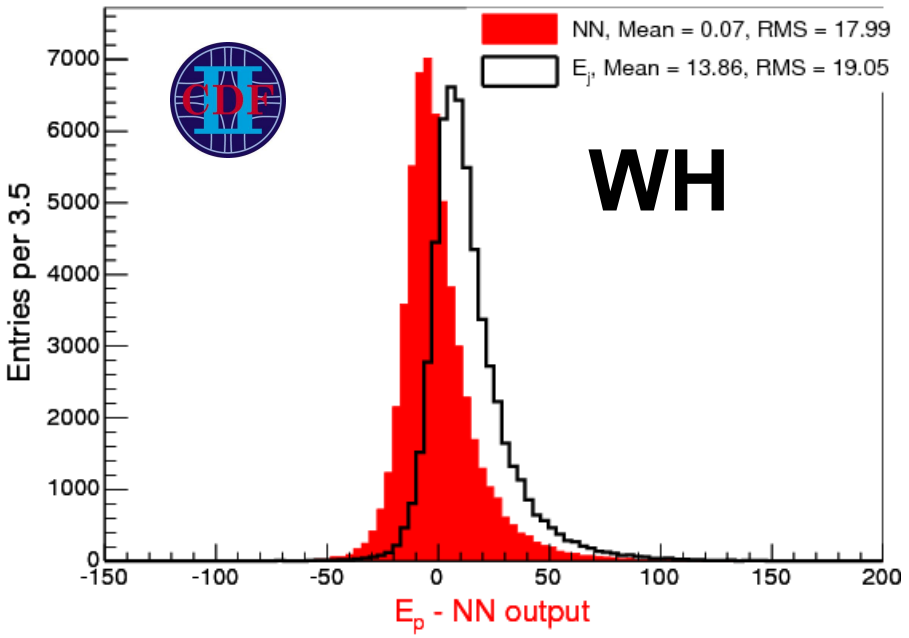
3 jet sample used in combination with 2 jet NN result

Track only leptons from CDF expand acceptance

WH $\rightarrow l\nu bb$ (2)

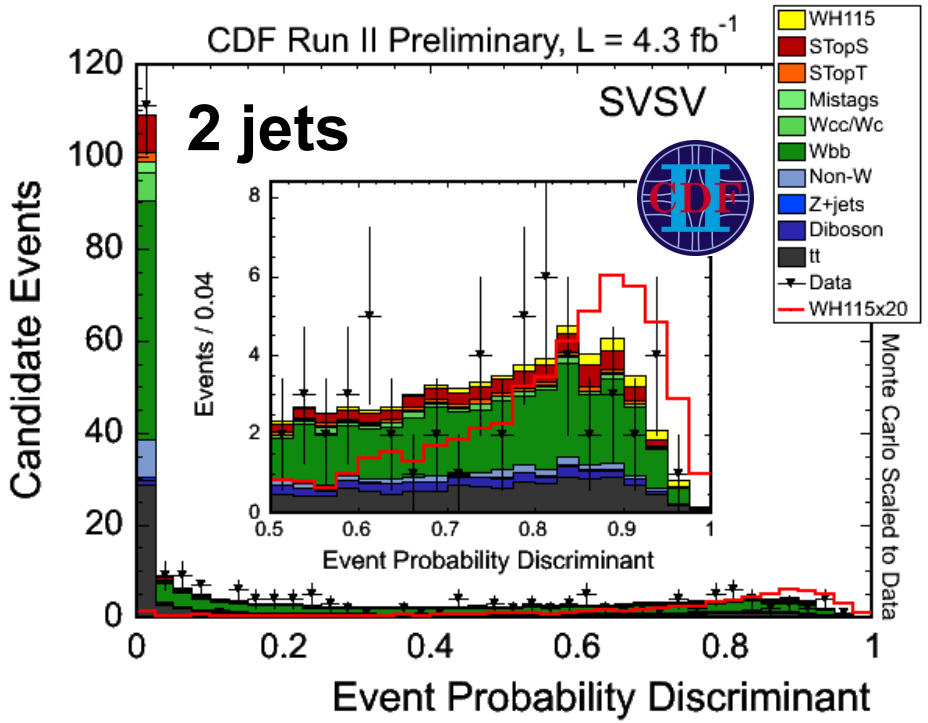
$$EDM = \frac{P_{WH}}{P_{WH} + P_{Wbb} + P_{tt} + \ldots}$$

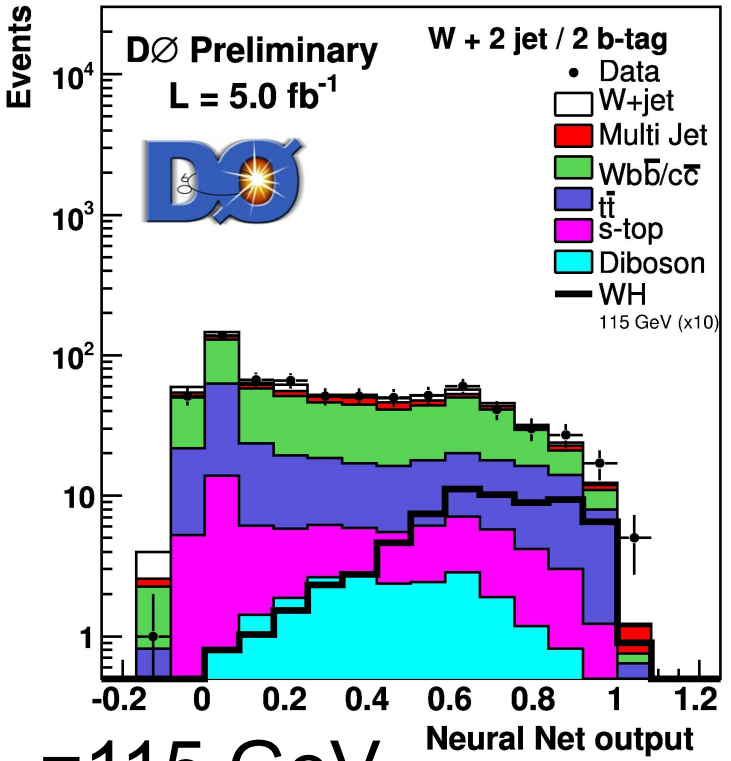
ME probabilites weighted by b-tagging efficiency



- Correct jet energies using neural nets
- Process specific corrections used when evaluating individual matrix elements
- Observe 5% improvement in jet energy resolution

WH →lνbb (3)





- Observed/Expected Limits at M_H=115 GeV

NEW CDF ME (full): 6.6/4.1 × SM (4.3 fb $^{-1}$)

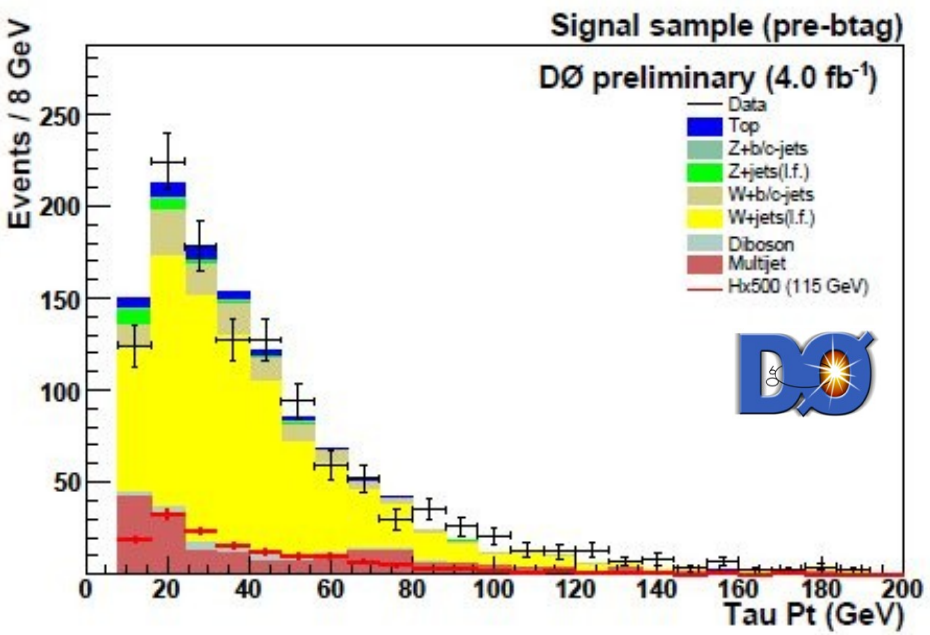
NEW CDF ME (3 jets): 11/18 × SM (4.3 fb $^{-1}$)

- CDF NN (2 jets): 5.3/4.0 × SM (4.3 fb $^{-1}$)
- DØ NN: 6.9/5.1 × SM (5.0 fb $^{-1}$)

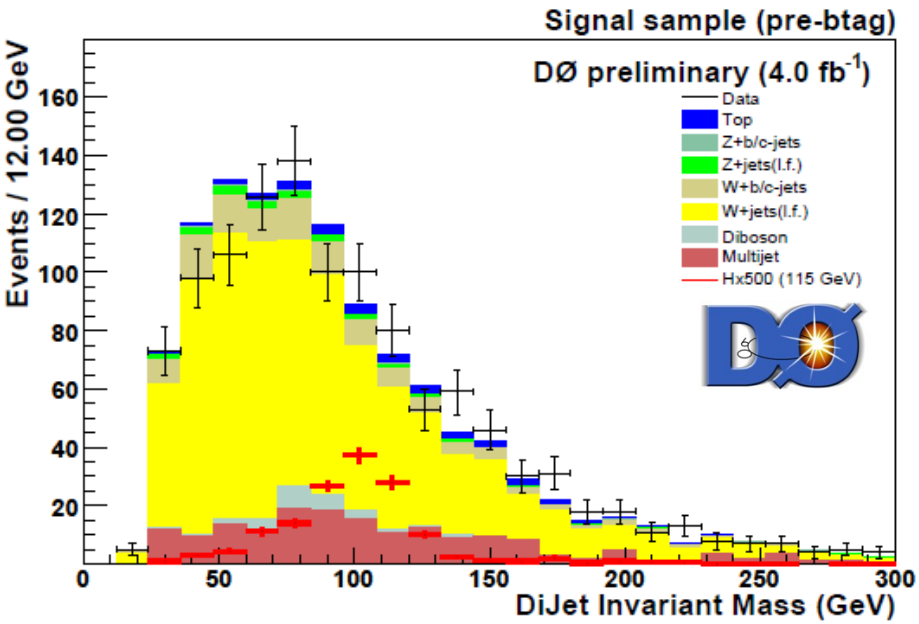
Used for Combination

WH $\rightarrow \tau \nu bb$ (1)

- Require one prong hadronic τ with $|\eta| < 2.0$
- Missing $\not\!\!E_T > 15$ GeV
- Two jets with $p_T > 20$ GeV, $|\eta| < 2.5$
- One tight or two loose b-tags

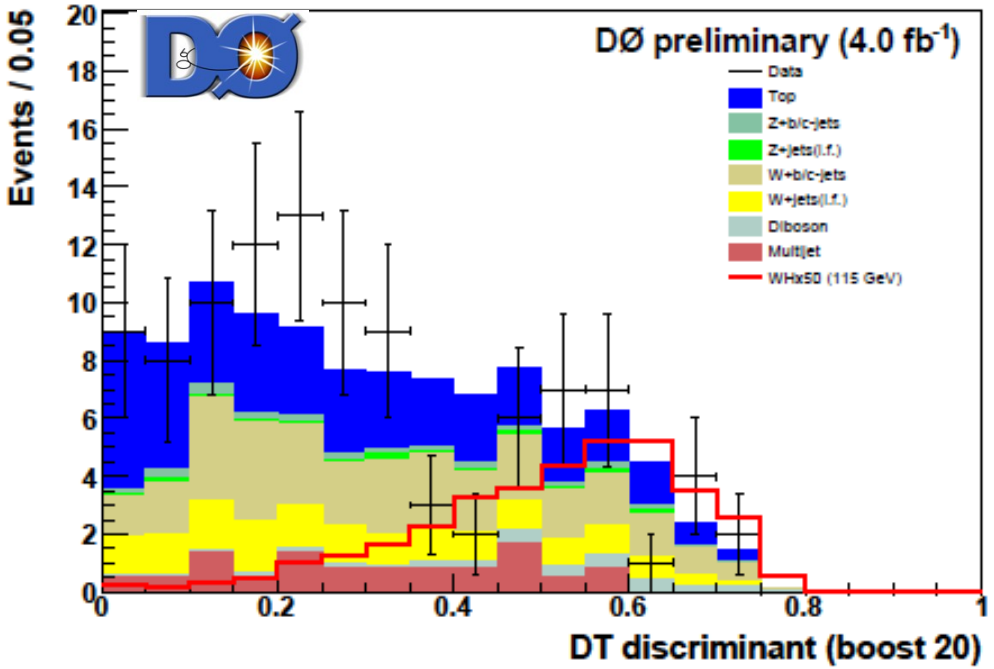


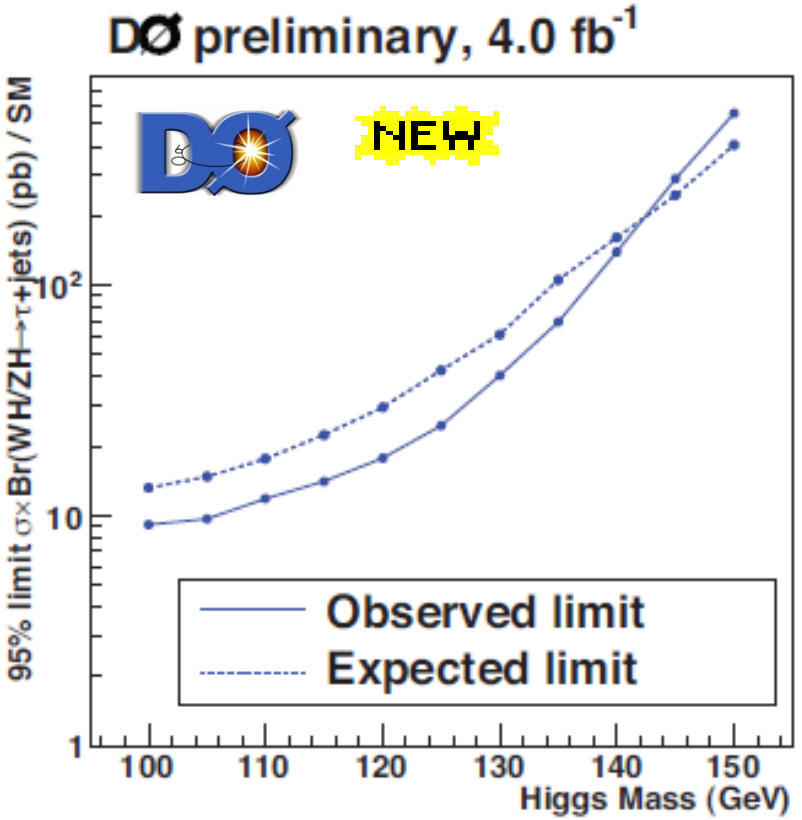
NEW



WH $\rightarrow \tau\nu bb$ (2)

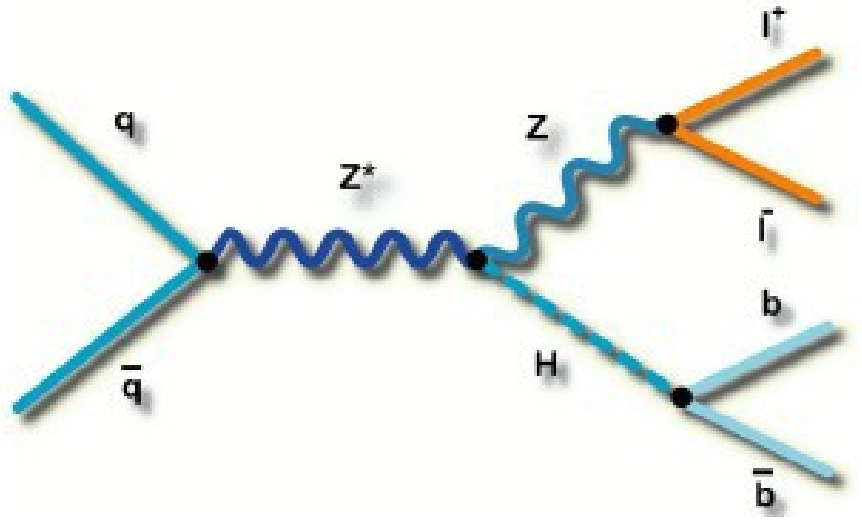
- Boosted Decision Trees used to further extract signal
- Obs/Exp Limit: 14/22 × SM (4.0 fb^{-1}, M_H = 115 GeV)
- Not yet included in combination

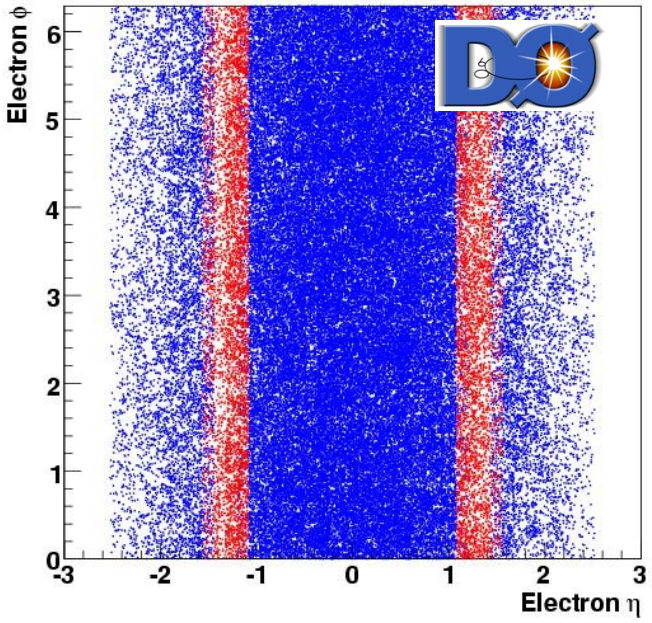




ZH →ee/$\mu\mu$+bb (1)

- Low signal, low background
- Fully measured final state can be exploited to improve jet energies
- Two analyses (CDF and DØ)

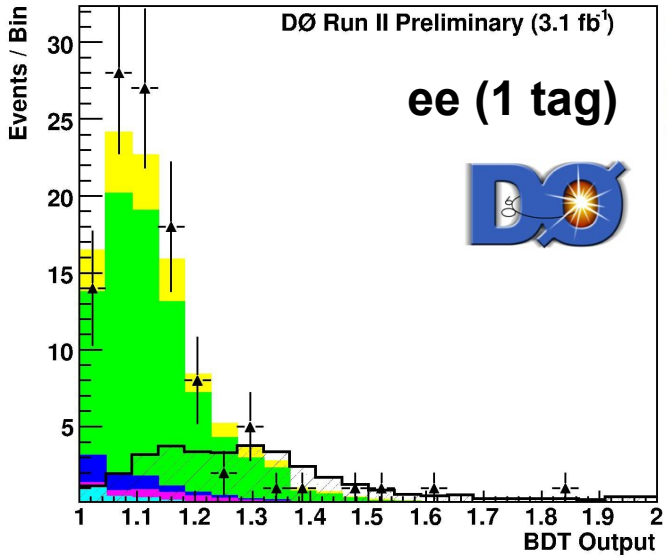


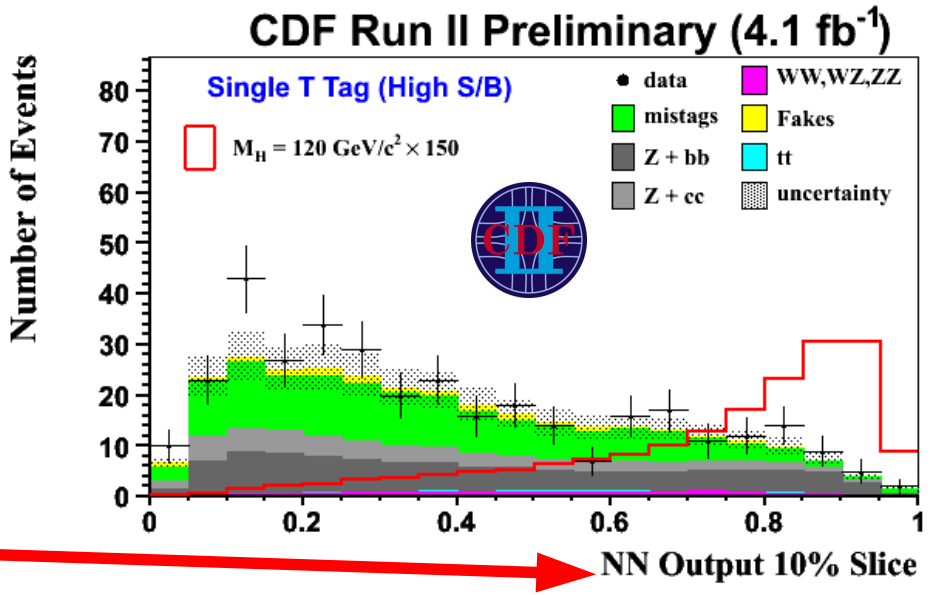


- High p_T isolated ee or $\mu\mu$ pair
- Expanded lepton selection to recover acceptance gaps
- Dilepton mass requirement
- At least two jets
- At least one b-tag

ZH →ee/$\mu\mu$+bb (2)

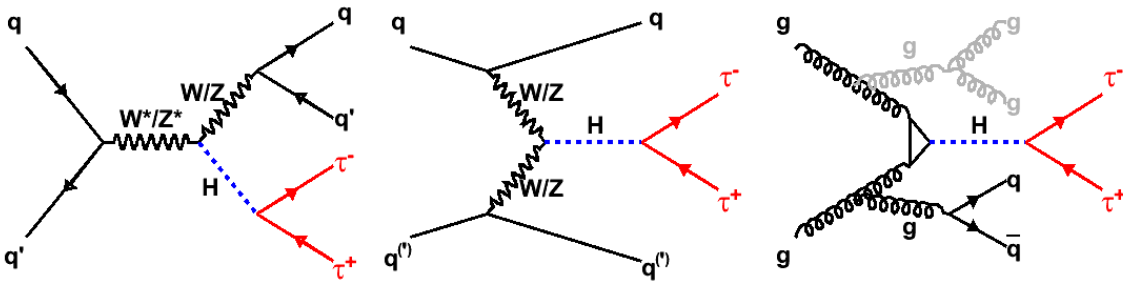
- CDF uses a 2D NN trained against tt and Z+jets
- DØ uses boosted decision trees
- Observed/Expected limits at M_H=115 GeV
  - DØ: 9.1/8.0 × SM (4.2 fb^{-1})
  - CDF: 5.9/6.8 × SM (4.1 fb^{-1})



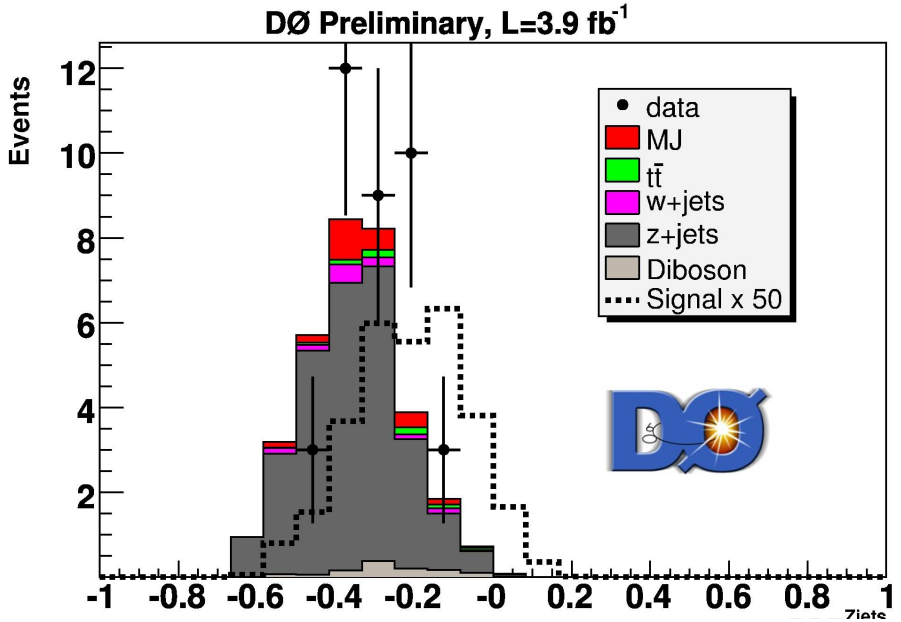


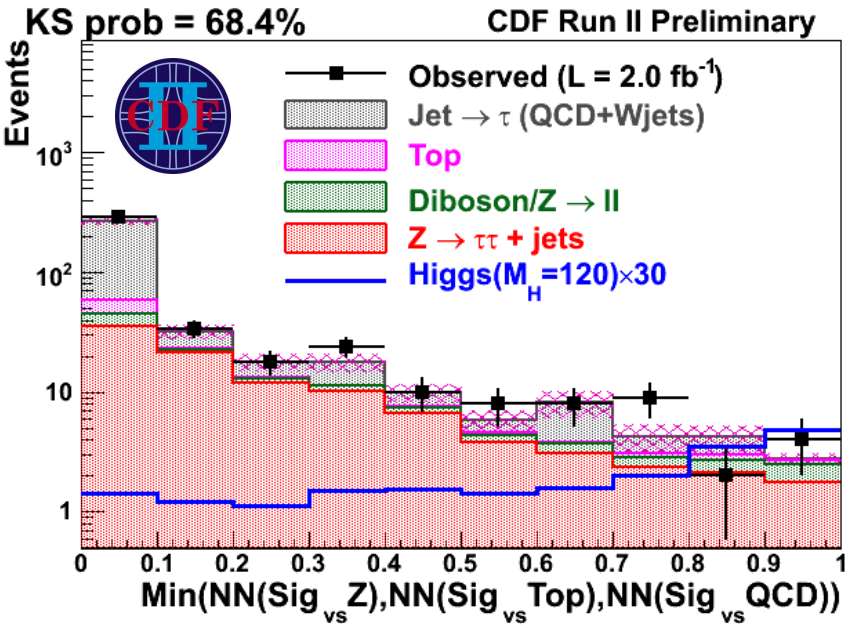
Cut on NN against tt

Search in $\tau\tau$jj Channel



- Multiple topologies complicates analysis
- Two analyses (CDF and DØ)
  - Select $\mu\tau_h$ (CDF also $e\tau_h$)
  - Two jets
- Exp/Obs Limits at M_H=115 GeV
  - DØ 16/27 × SM (4.9 fb^{-1})
  - CDF 25/26 × SM (2.0 fb^{-1})





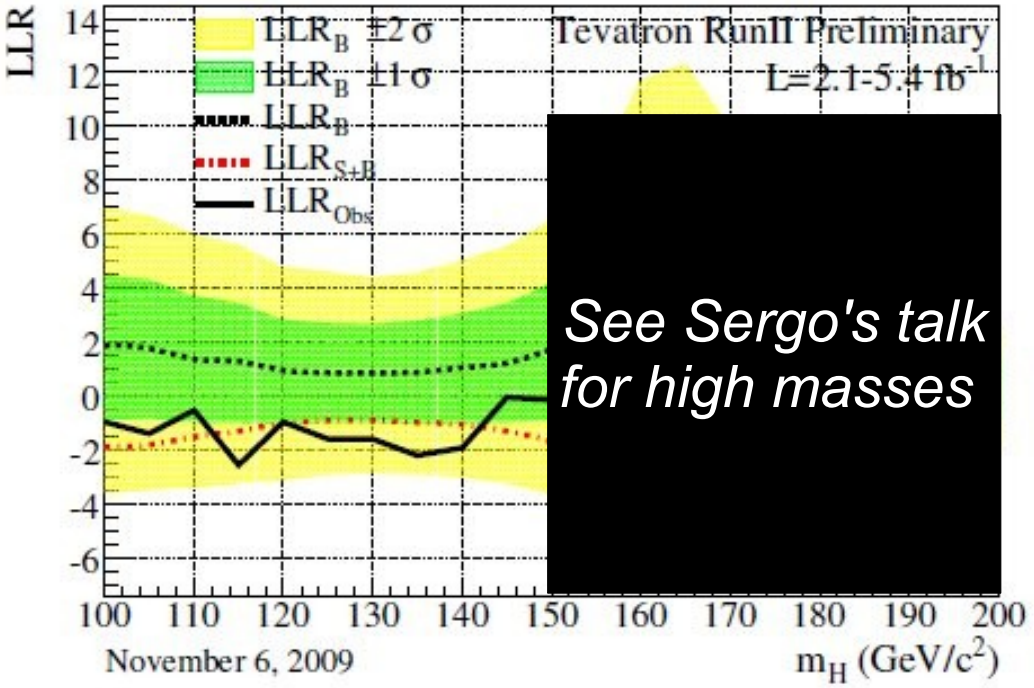
Summary of Inputs

Channel	Luminosity (fb^{-1})
$WH \to \ell\nu bb$ 2-jet channels 3×(TDT,LDT,ST,LDTX)	4.3
$WH \to \ell\nu b\bar{b}$ 3-jet channels 2×(TDT,LDT,ST) NEW	4.3
$ZH \to \nu\bar{\nu}b\bar{b}$ (TDT,LDT,ST)	3.6
$ZH \to \ell^+\ell^- b\bar{b}$ (low,high s/b)×(TDT,LDT,ST)	4.1
$H \to W^+W^-$ (low,high s/b)×(0,1 jets)+(2+ jets)+Low-$m_{\ell\ell}$	4.8
$WH \to WW^+W^- \to \ell^\pm\nu\ell^\pm\nu$	4.8
$H + X \to \tau^+\tau^- + 2$ jets	2.0
$WH + ZH \to jjbb$	2.0

Channel	Luminosity (fb^{-1})
$WH \to \ell\nu bb$ 2×(ST,DT)	5.0
$VH \to \tau\tau b\bar{b}/q\bar{q}\tau\tau$	4.9
$ZH \to \nu\bar{\nu}b\bar{b}$ (ST,DT) NEW	5.2
$ZH \to \ell^+\ell^- b\bar{b}$ 2×(ST,DT)	4.2
$WH \to WW^+W^- \to \ell^\pm\nu\ell^\pm\nu$	3.6
$H \to W^+W^- \to \ell^\pm\nu\ell^\mp\nu$	5.4
$H \to \gamma\gamma$	4.2
$t\bar{t}H \to t\bar{t}b\bar{b}$ 2×(ST,DT,TT)	2.1

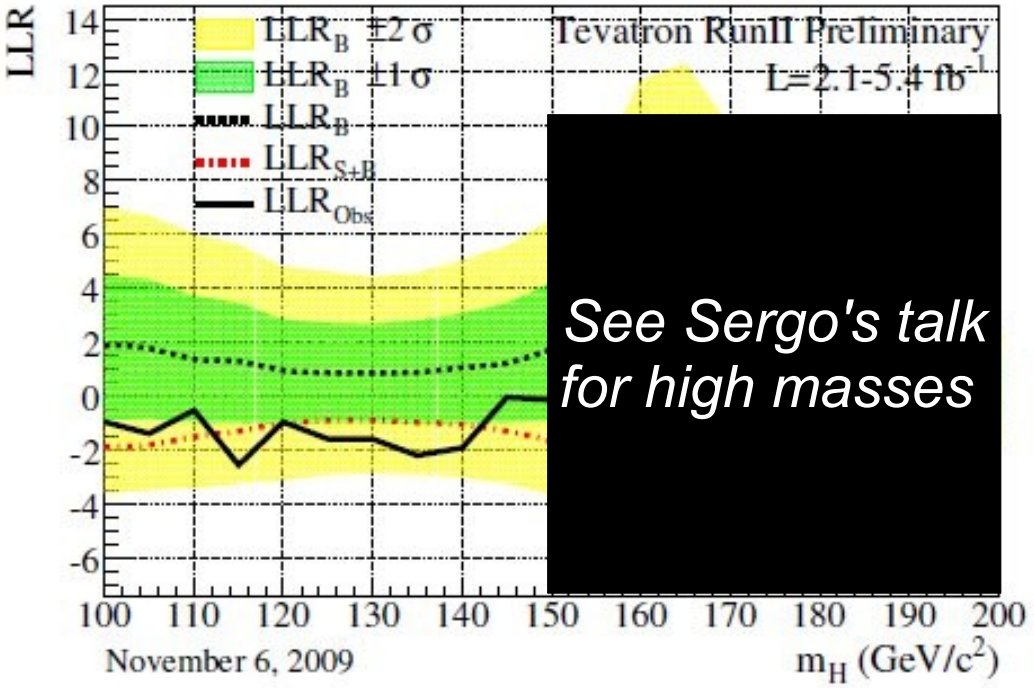
Presented Today

Putting It All Together



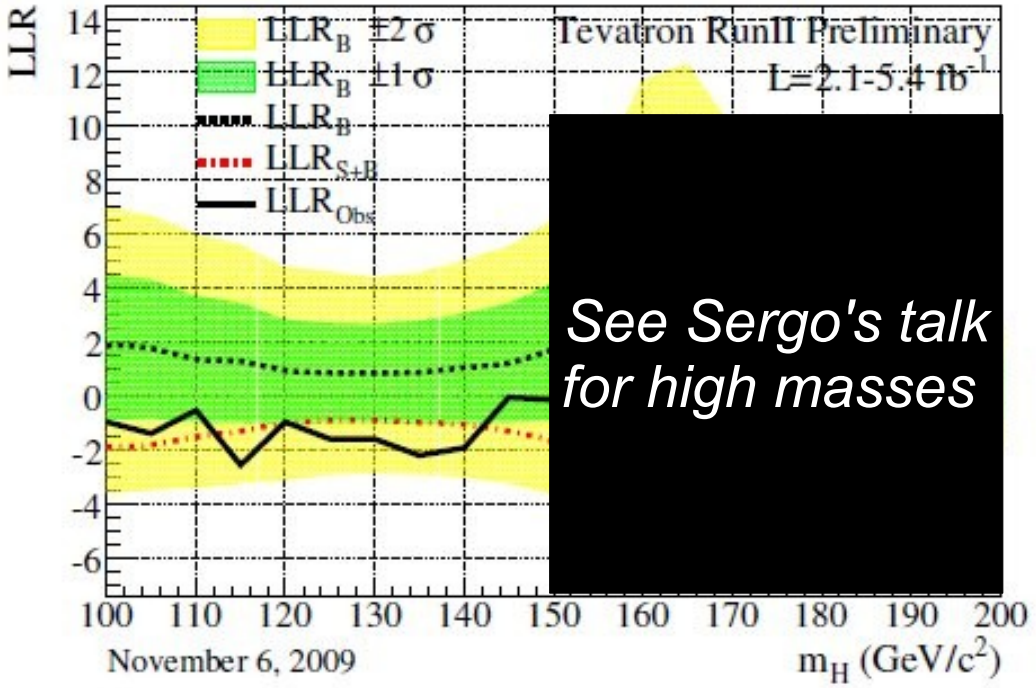
- Use both Bayesian (CDF) and CLs methods (DØ) as cross checks

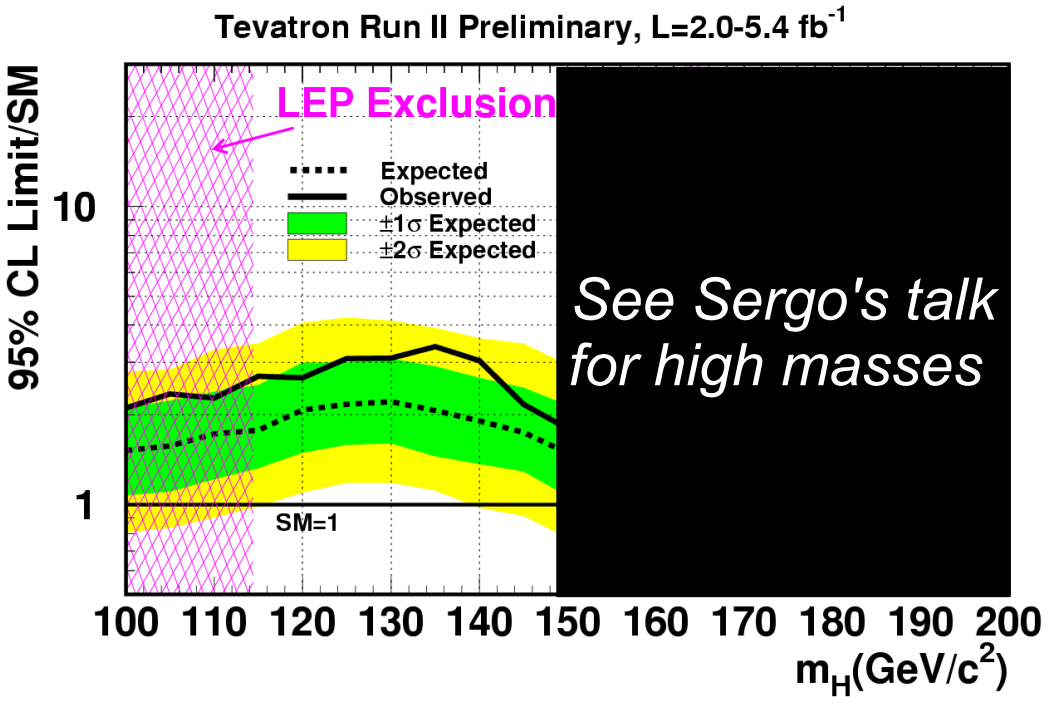
Putting It All Together



- Use both Bayesian (CDF) and CLs methods (DØ) as cross checks
- ~ 1σ sensitivity at low masses

Putting It All Together





- Use both Bayesian (CDF) and CLs methods (DØ) as cross checks
- ~ 1σ sensitivity at low masses

Limit/SM

	Exp	Obs
Bayesian	**1.78**	**2.70**
CLs	**1.77**	**2.81**

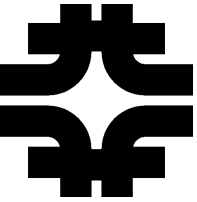
M_H = 115 GeV

A Promising Future

- Observed (expected) limit at low M_H=115 GeV is at 2.70 (1.78) times the Standard Model
- Full Run II dataset will be more than a factor of two larger than presented here
- We are also getting smarter
  - Improvements to b-tagging
  - Mass resolution
  - Extending acceptance
- The Higgs is running out of places to hide

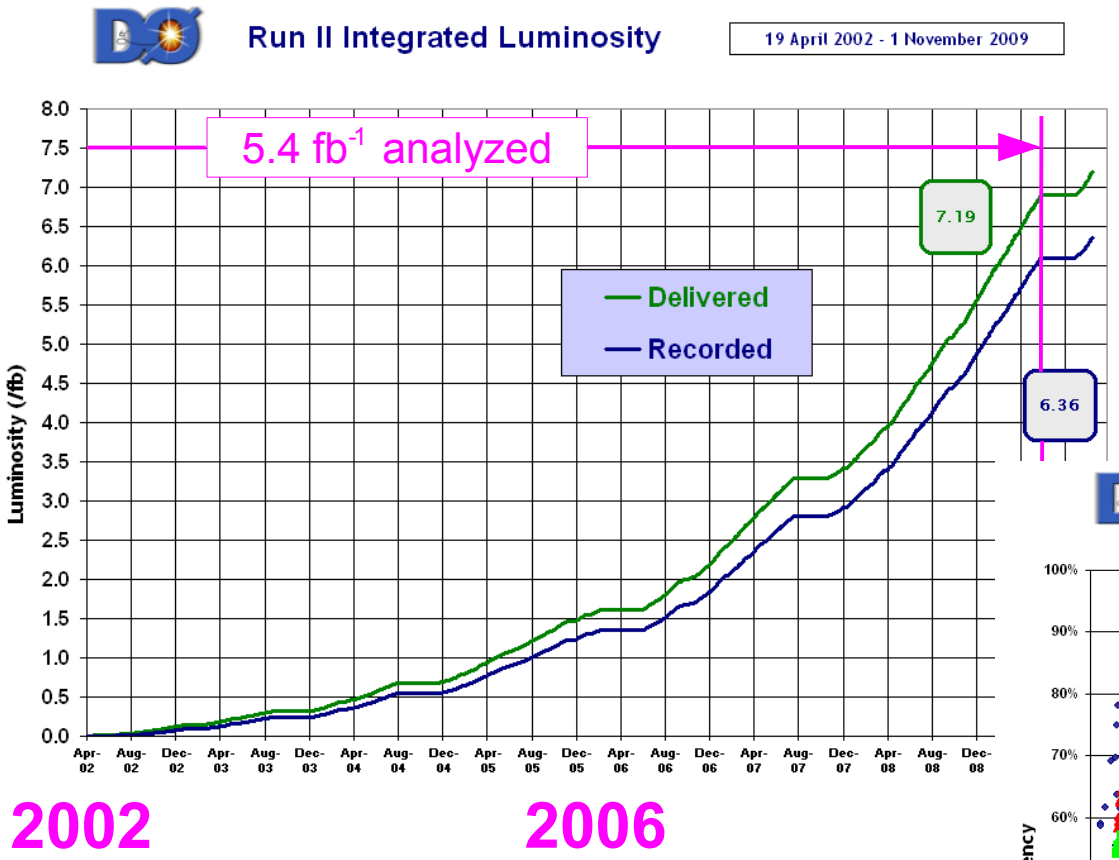
http://www-d0.fnal.gov/Run2Physics/WWW/results/higgs.htm

http://www-cdf.fnal.gov/physics/new/hdg/hdg.html

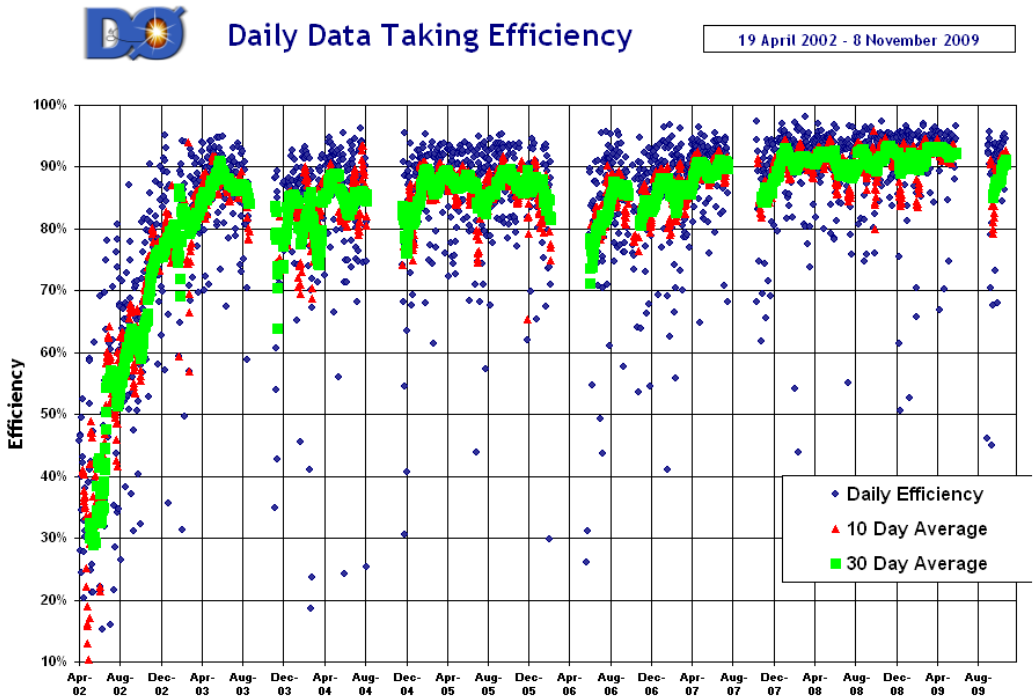


Backup Slides

Tevatron Performance



2002 2006



2002 2006 2009

Matrix Elements

- Interpret differential cross sections as probability distributions
- Convolute with experimental resolutions

$$EDM = \frac{P_S}{P_S + P_B}$$

Weight by probability to tag jets

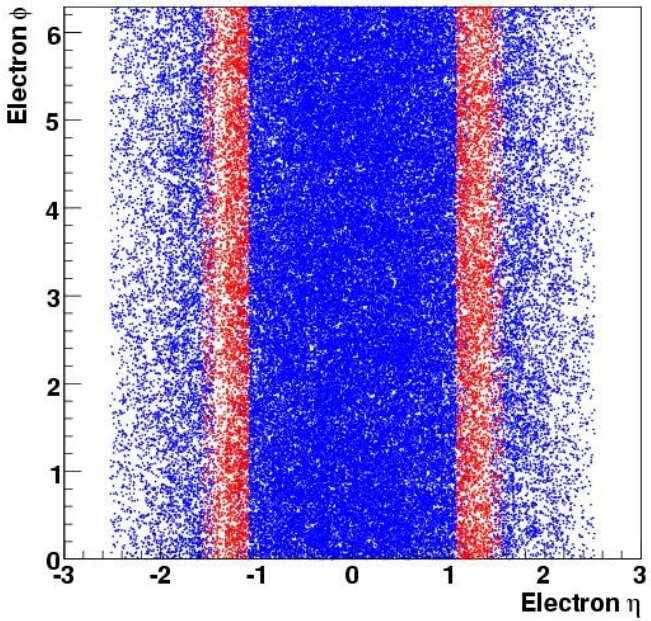
Diffrential cross section from MADGRAPH

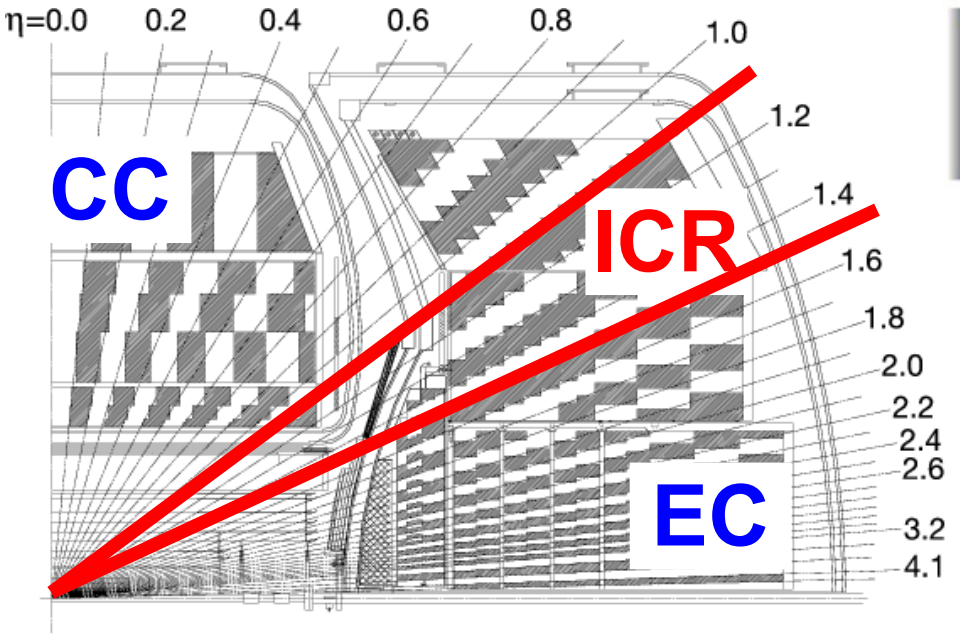
$$P(x) = \frac{b}{\sigma} \int W(x, y) f(y) f(y) \frac{d\sigma(y)}{dy} dy$$

Transfer functions connect observables x to hard scatter kinematics y

Parton Distributions

Expanded Lepton ID

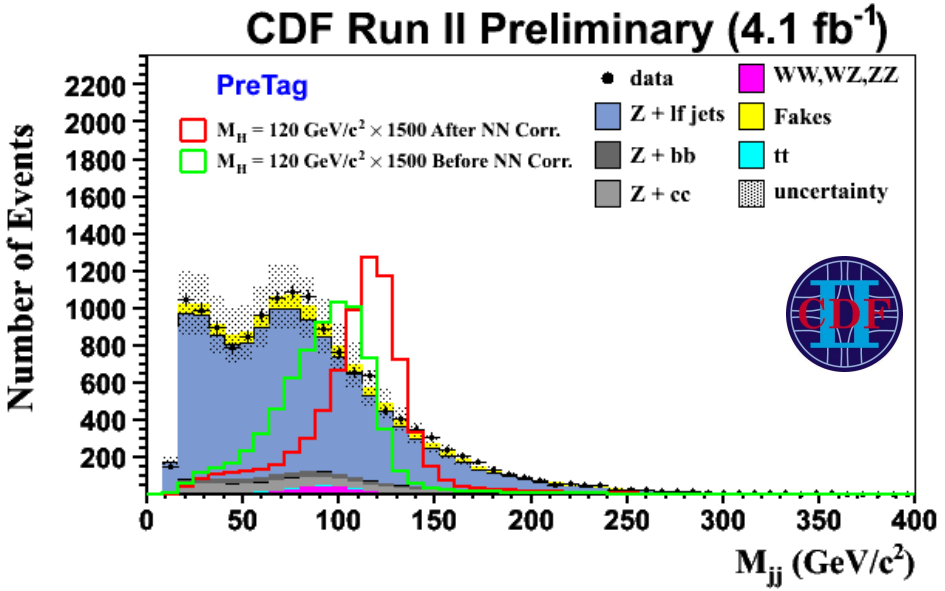




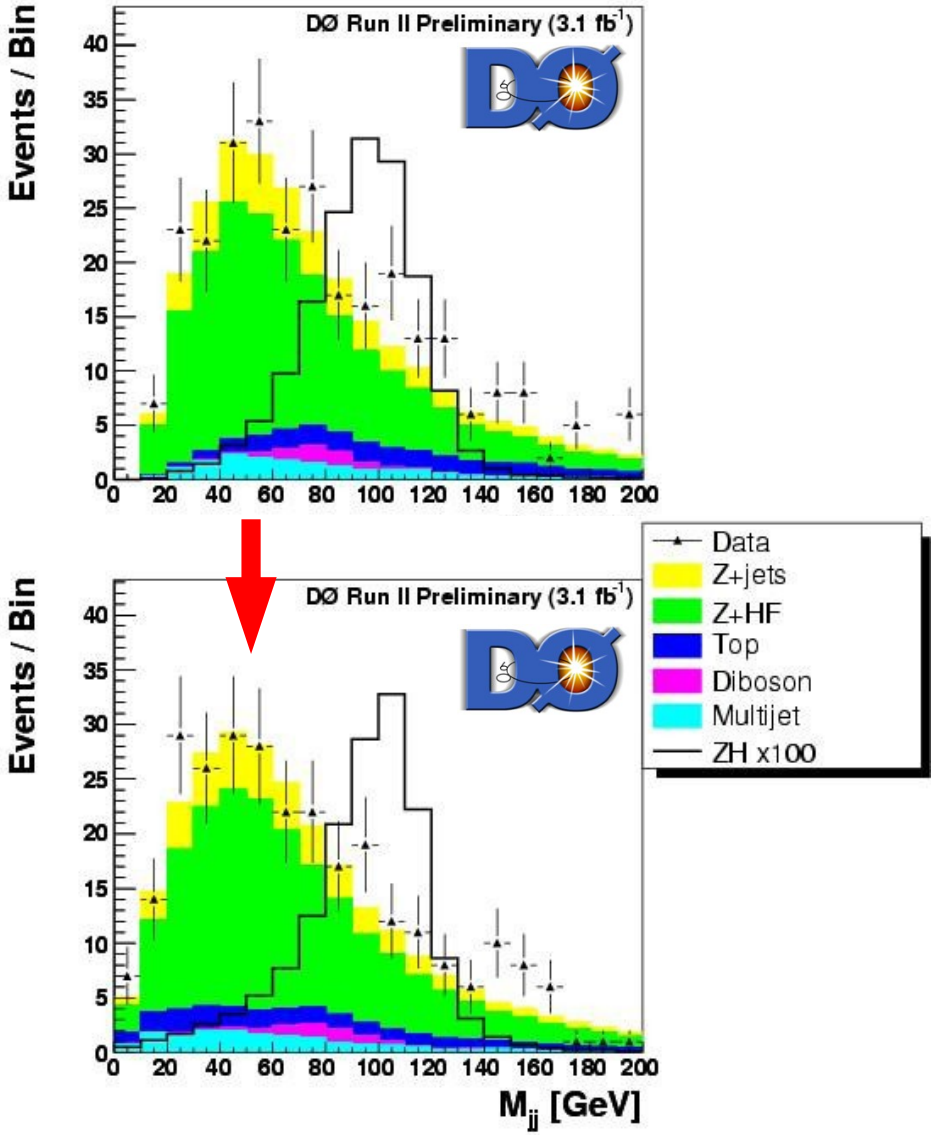
- Lepton selection expanded to cover gaps in acceptance
  - CDF has been doing this for some time
  - Use τ-based selection to find electrons in calorimeter gap
  - Use isolated tracks for gaps in muon coverage

ZH →ee/$\mu\mu$+bb

- Improving mass resolution
  - CDF: neural net based on correlations of $\not\!\!E_T$ and jets
  - DØ : kinematic fit based on lepton, jet uncertainties

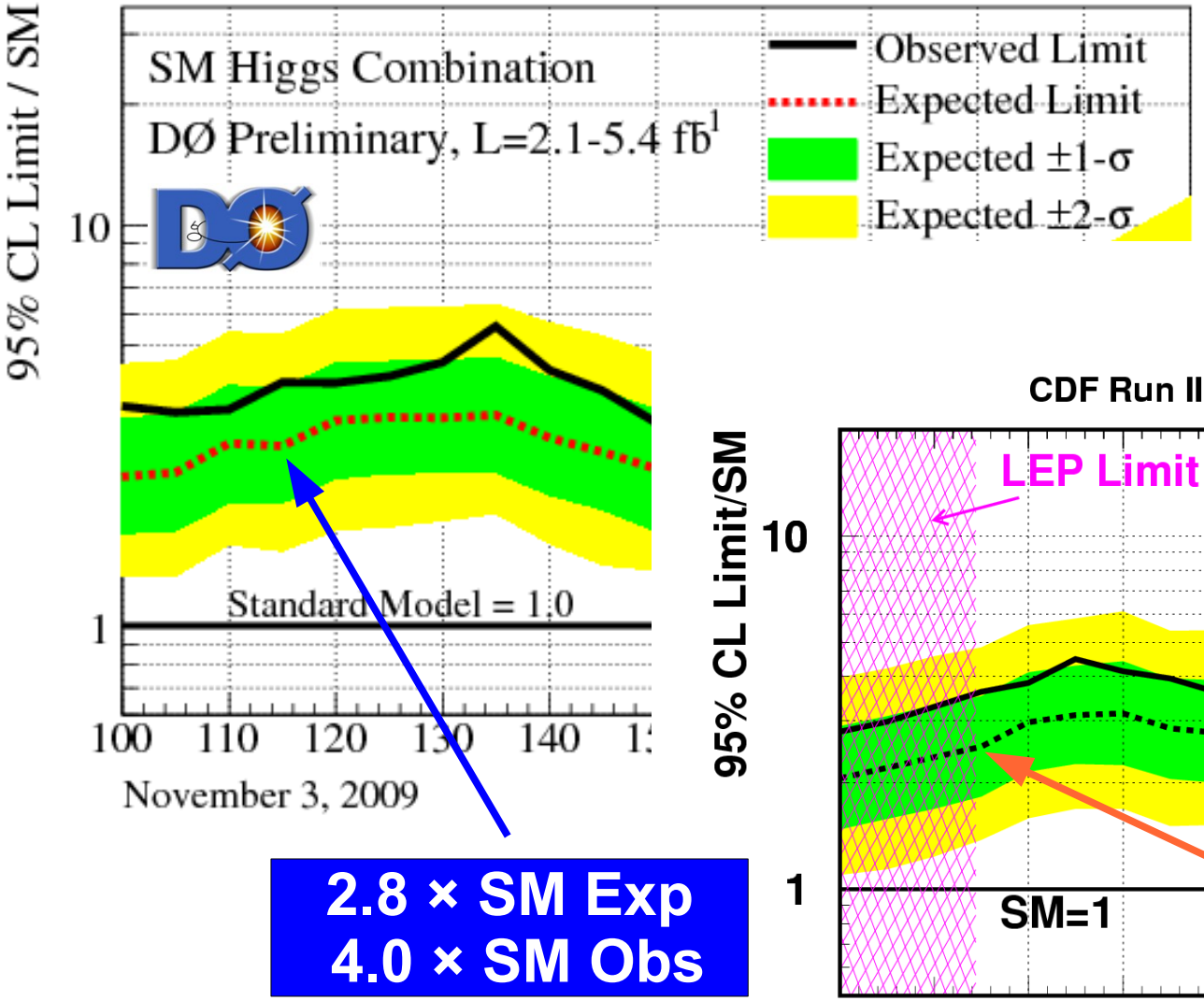


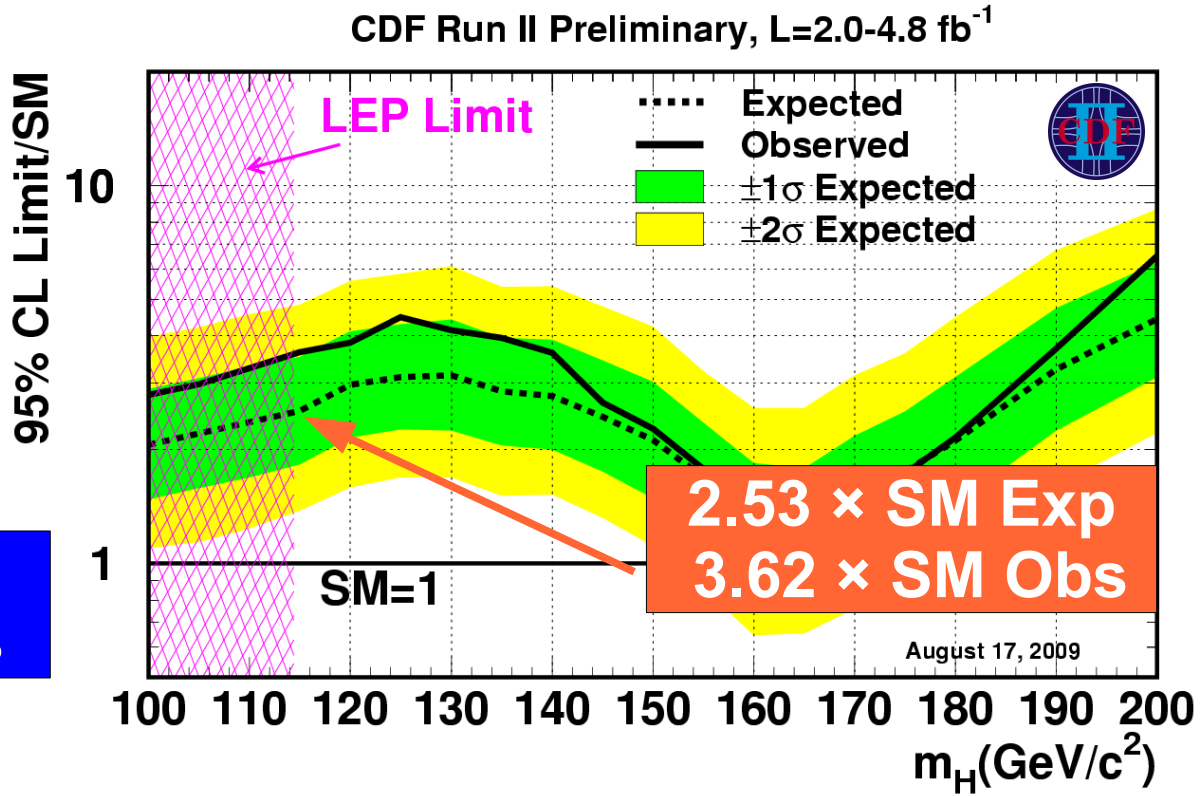
σ_M/M improves by 33%



σ_M/M improves by 15%

Individual Limits





Moriond '09 Limits