Search for Low Mass SM Higgs at the Tevatron

Les Rencontres de Physique de la Vallée d'Aoste, La Thuile

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Michiel Sanders

LPNHE Paris

For the DØ and CDF Collaborations

Outline

- Introduction
- Tevatron
- Higgs at low mass: WH & ZH searches
- Tevatron combination
- Conclusion & Outlook

Introduction

- Standard model: very successful !

- Higgs mechanism to break electroweak symmetry

  $\Rightarrow$ Massive EW bosons

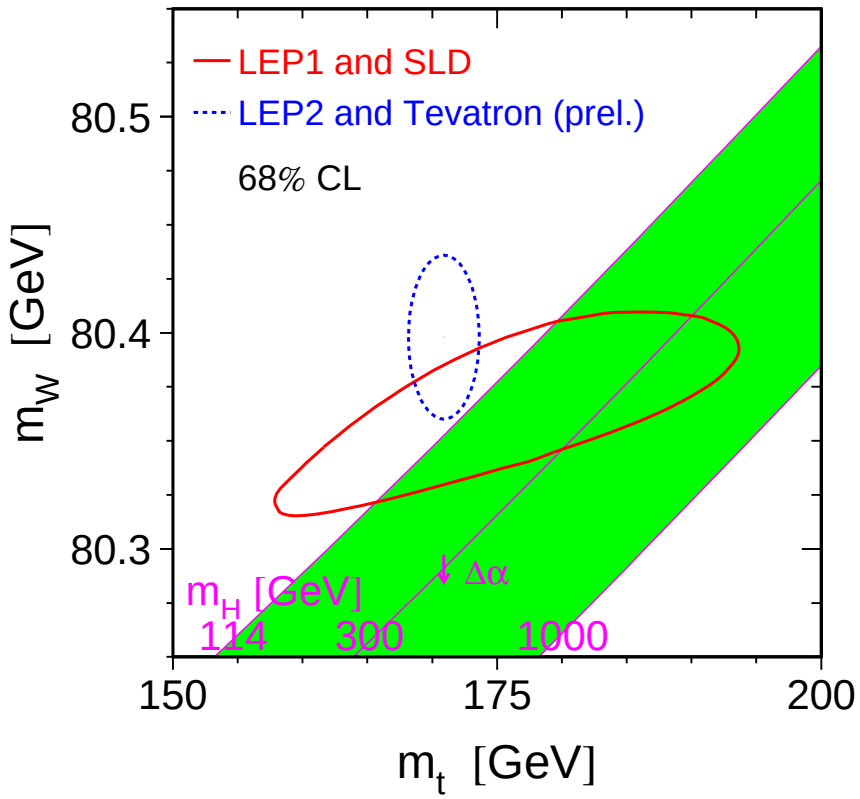
  $\Rightarrow$ Massive quarks and leptons

  $\Rightarrow$ Higgs boson

- Where is the Higgs ?

What Do We Know?

Precision EW measurements at Tevatron, LEP and SLD



$m_{\mathrm{H}} = 76^{+33}_{-24}$ GeV

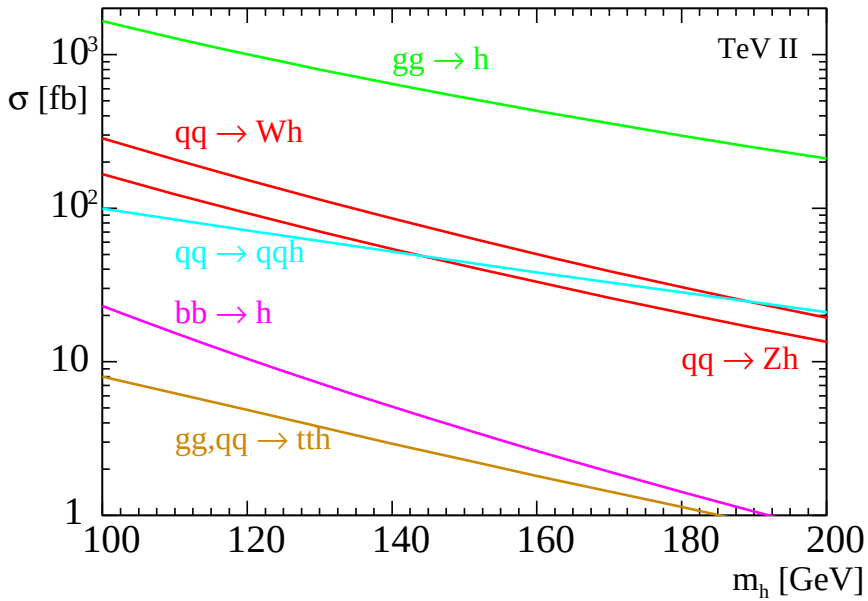
$m_{\mathrm{H}} < 144$ GeV at 95% CL

LEP2 direct search: $m_{\mathrm{H}} > 114$ GeV ($m_{\mathrm{H}} < 182$ GeV)

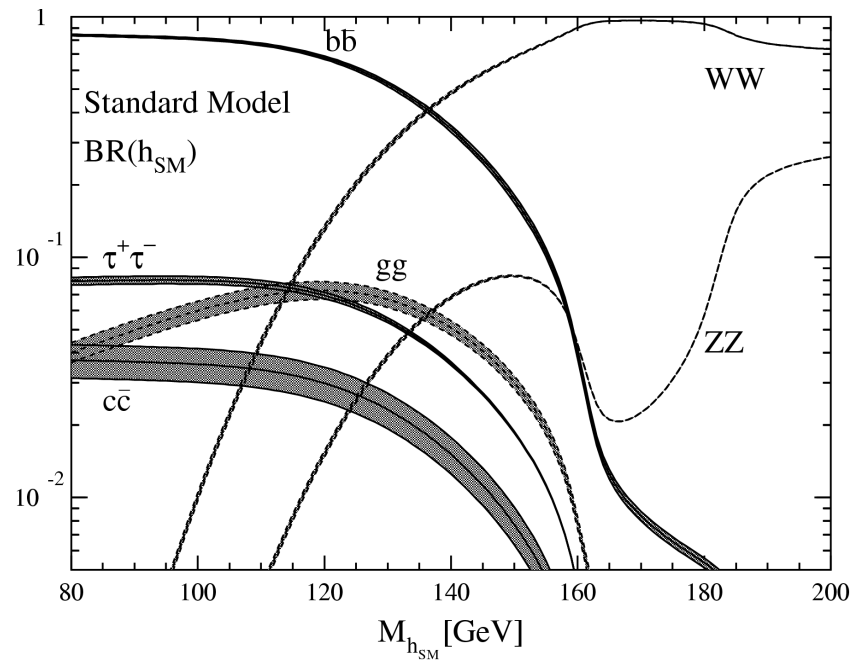
$\Rightarrow$ Within reach of the Tevatron!

Higgs @ Tevatron

Production



Decay

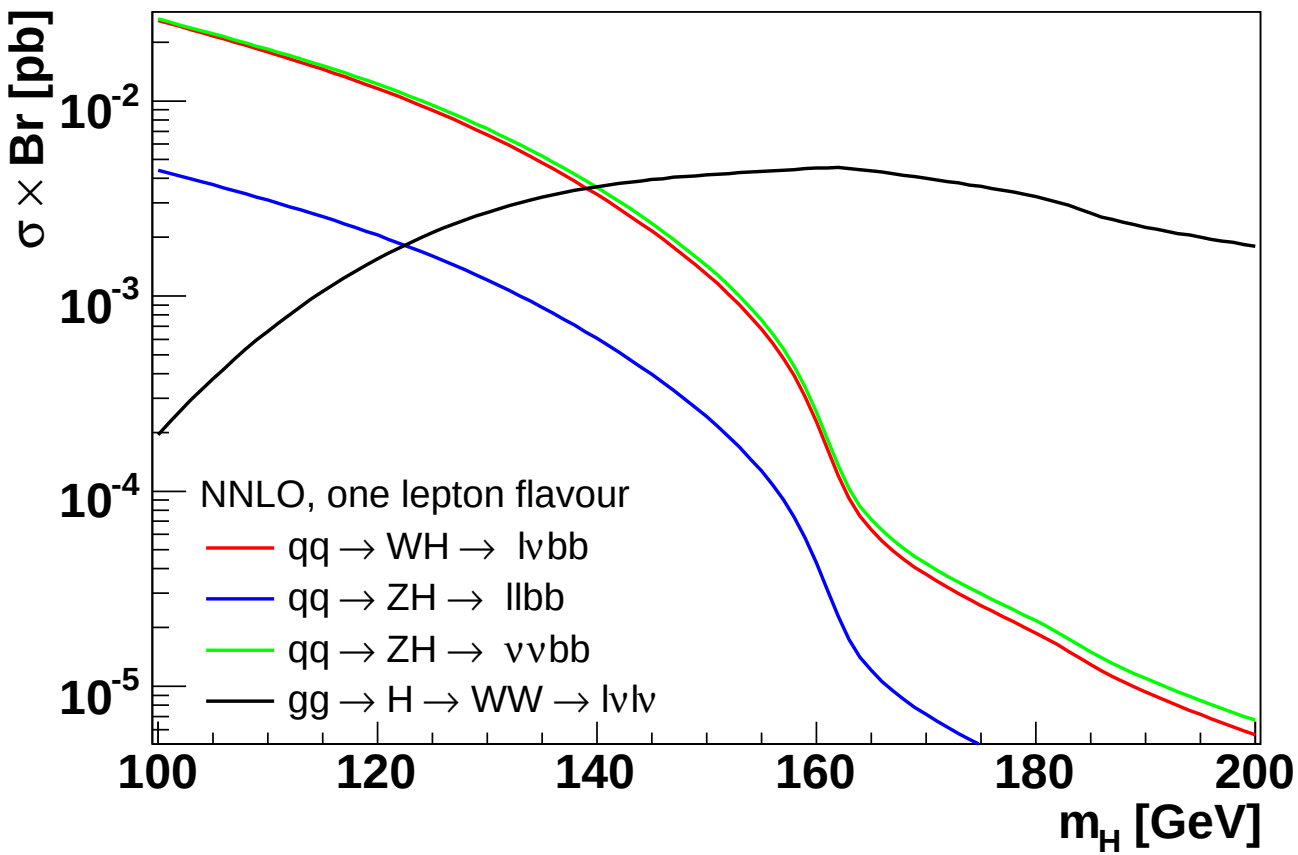


- Gluon fusion
- Associated production

- $b\bar{b}$ at low m_{H}
- WW at high m_{H}

Higgs @ Tevatron

$\sigma \times$Br for experimentally most accessible final states

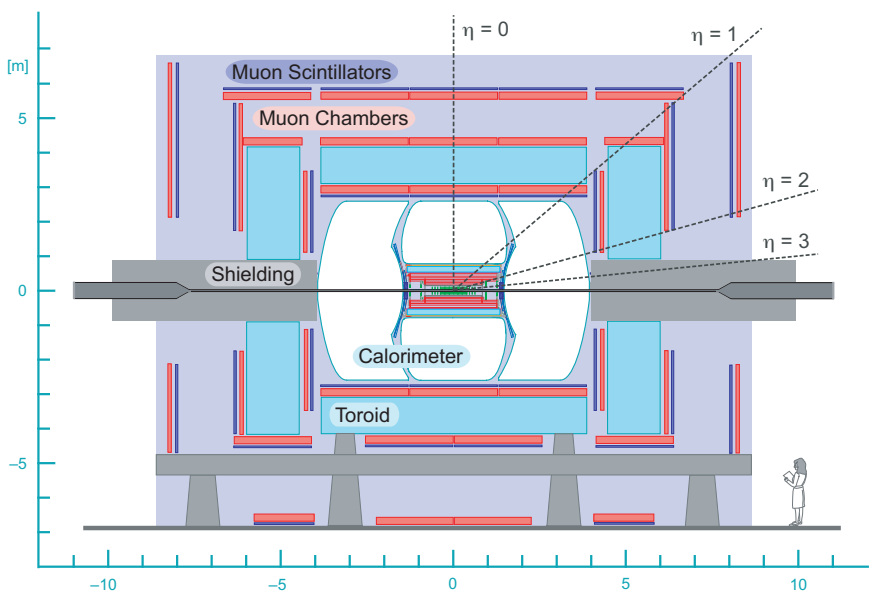


This talk: low mass Higgs $\Rightarrow$ WH and ZH

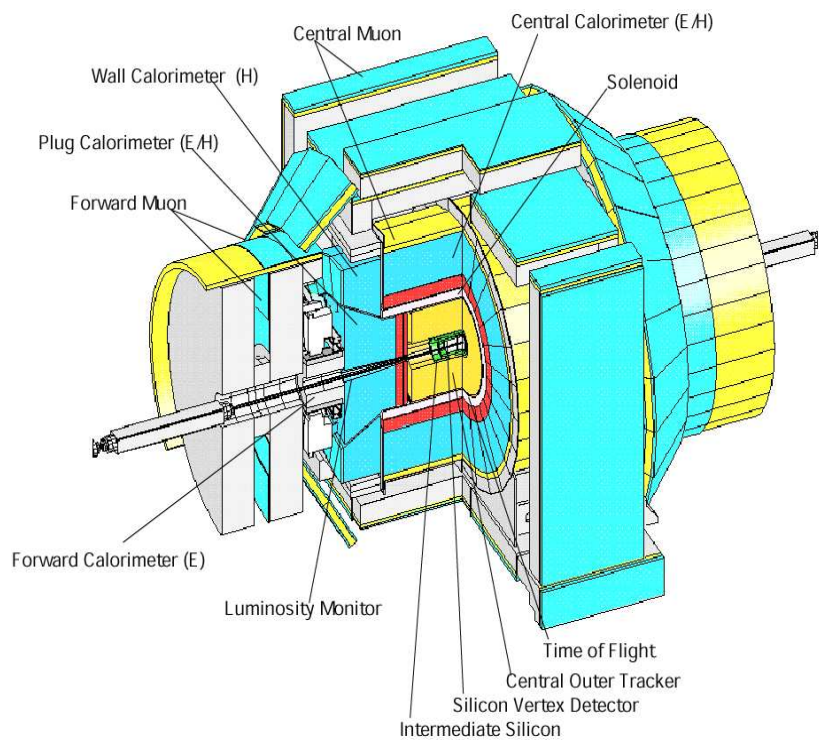
Tevatron

- $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV
- Up to now: $\int \mathcal{L} dt \simeq 3.7$ fb^{-1} delivered / experiment
- Results shown in this talk: up to 1.9 fb^{-1}

DØ



CDF



Higgs at Low Mass: WH & ZH Searches

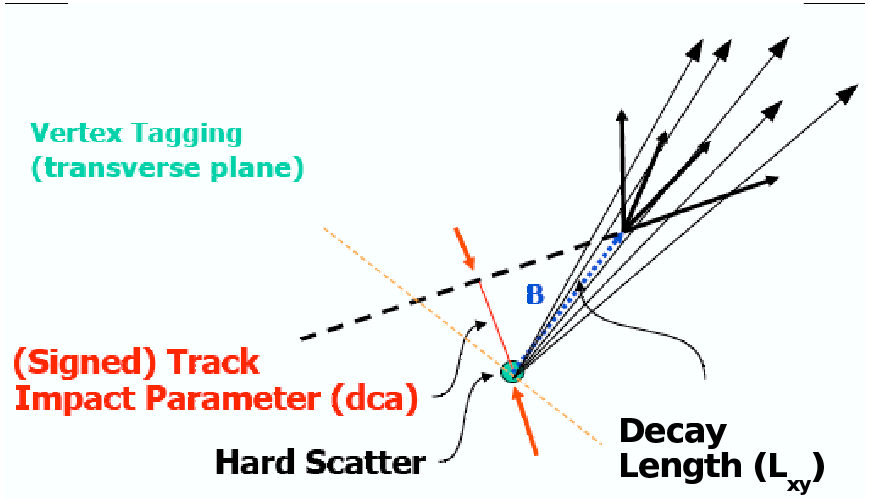
- Decays of W and Z: high p_{T} leptons and/or $\not{E}_{\mathrm{T}}$
- $\mathrm{H} \rightarrow \mathrm{b}\bar{\mathrm{b}}$: at least two jets
- Background sources:
  - $*$ W/Z with additional jets (including $\mathrm{Wb}\bar{\mathrm{b}}$, $\mathrm{Zb}\bar{\mathrm{b}}$)
  - $*$ $\mathrm{t}\bar{\mathrm{t}}$, single top
  - $*$ Multi-jet production with mis-ID of lepton or $\not{E}_{\mathrm{T}}$
  - $*$ Di-boson (WW, WZ, ZZ)

$\Rightarrow$ Need to precisely model these !

- $*$ Multi-jet directly from data
- $*$ Others from simulation (ALPGEN, PYTHIA, HERWIG)

b-Tagging

Exploit b-lifetime:



– Combine lifetime variables in, e.g. a neural network:

  * Vertex mass, decay length, impact parameters, . . .

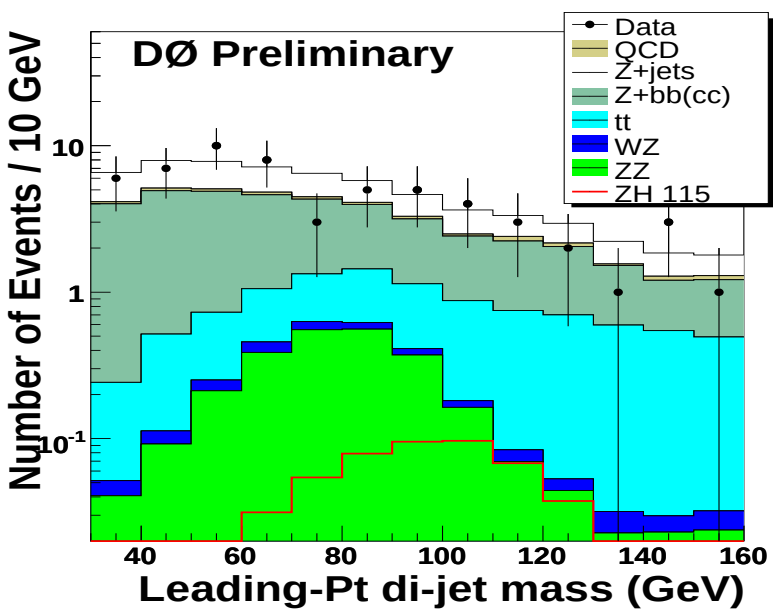
⇒ High b-tagging efficiency:

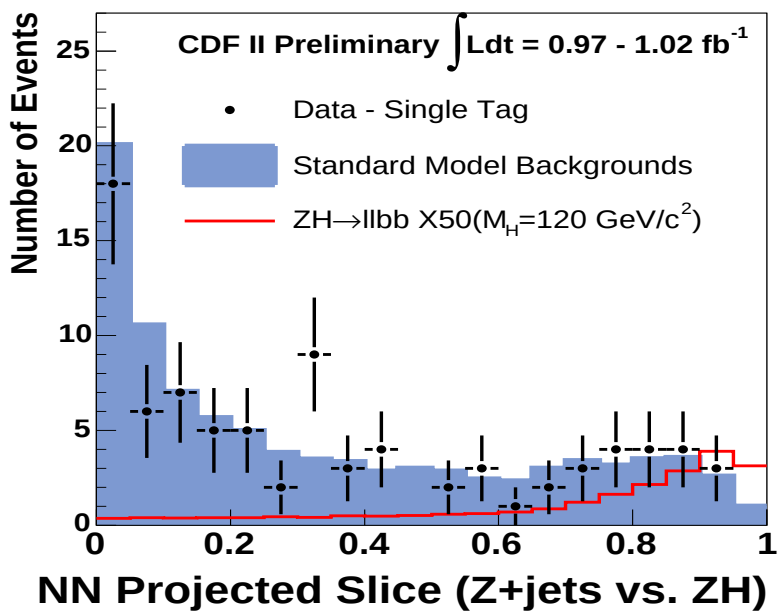
  * "Tight": 50% at 0.5% fake rate (DØ neural net tagger)
  * "Loose": 74% at 5.0% fake rate (DØ neural net tagger)

– Typical analysis: two "Loose" tags or one "Tight" tag

Two Charged Leptons: ZH $\rightarrow \ell\ell b\bar{b}$

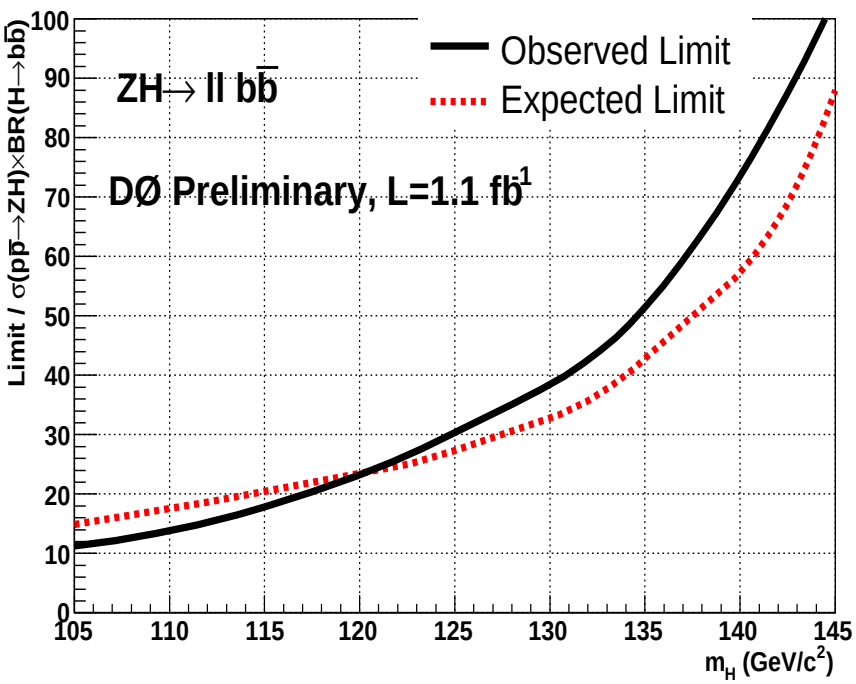
- Clean signature: two isolated leptons, $m_{\text{inv}} \simeq m_Z$; no $\not\!\!E_T$
- $\int \mathcal{L} dt \simeq 1$ fb^{-1} both CDF and DØ (summer 2007)
- CDF: improved jet energy measurement using $\not\!\!E_T$
- DØ: lower p_T thresholds for larger acceptance
- Neural networks to improve sensitivity

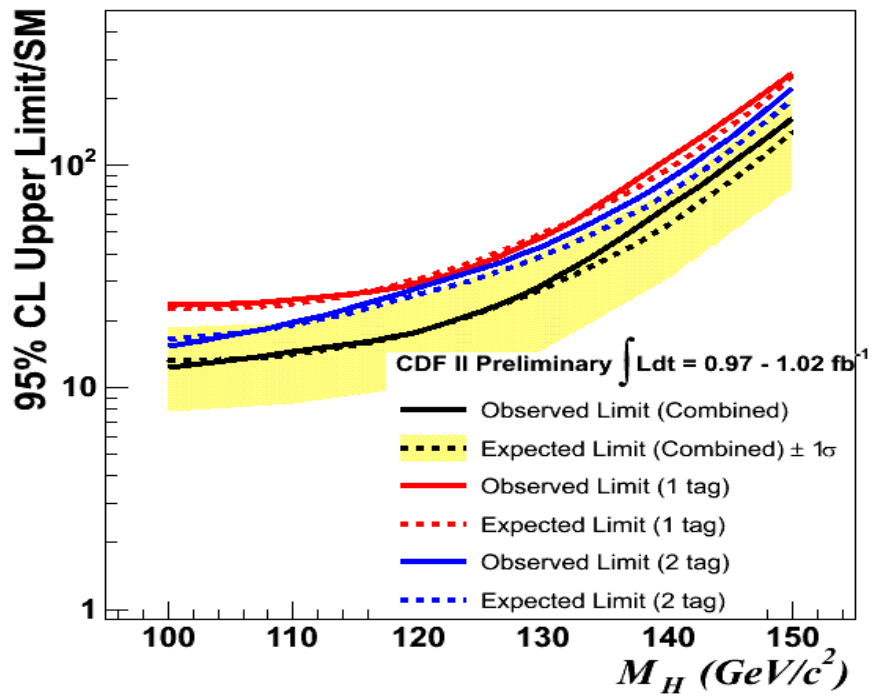




$ZH \rightarrow \ell\ell b\bar{b}$ Results

- No excess, data agree with background model
- Use neural network output to derive limits



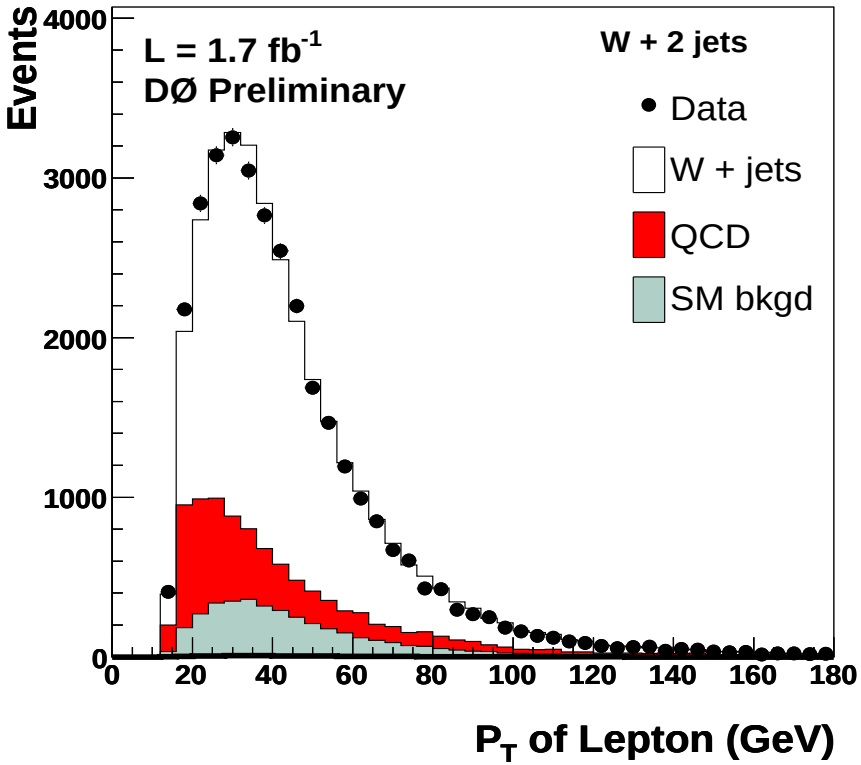


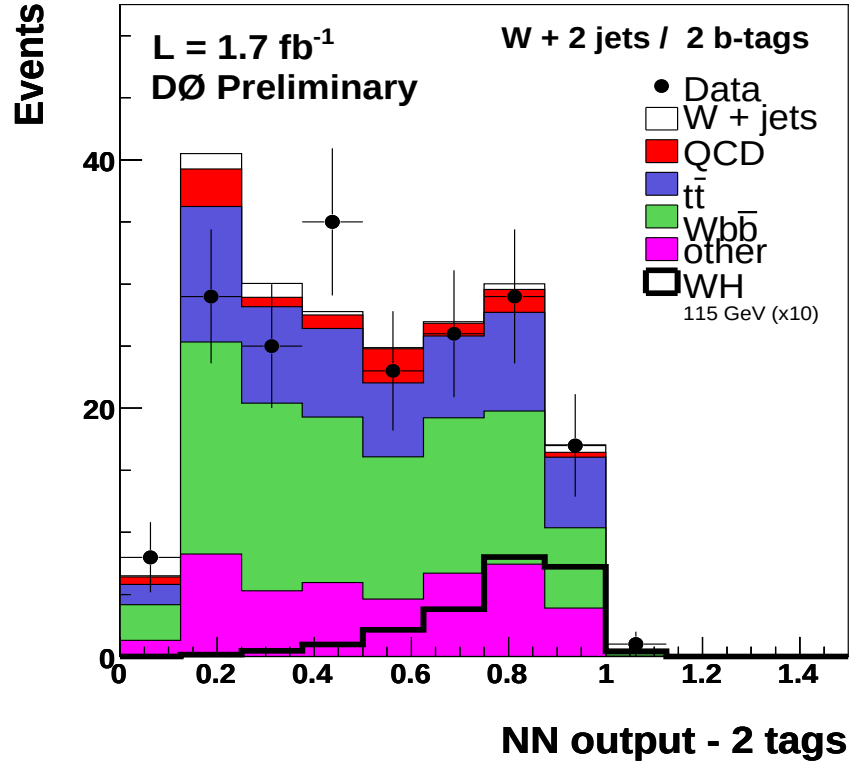
DØ at $m_{\mathrm{H}} = 115$ GeV limit/SM 18 (20 expected)

CDF at $m_{\mathrm{H}} = 115$ GeV limit/SM 16 (16 expected)

One Charged Lepton: WH $\rightarrow \ell\nu b\bar{b}$ (DØ)

$\int \mathcal{L} dt \simeq 1.7$ fb^{-1} (summer 2007)





Before b-tag: 9.9 WH

33.5k background events

Double b-tag: 2.3 WH

204.1 background events

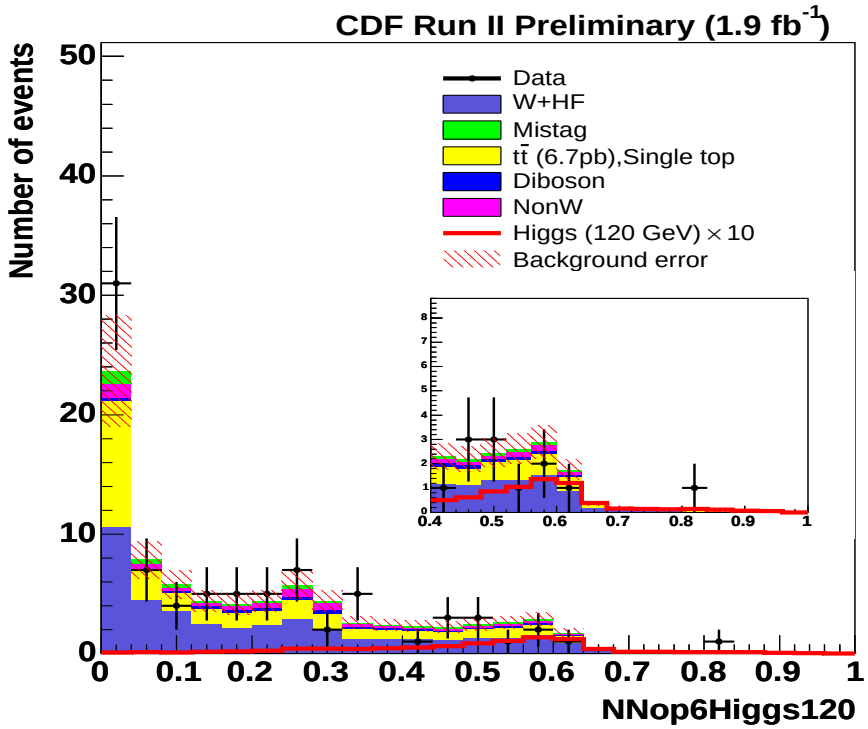
Near future:

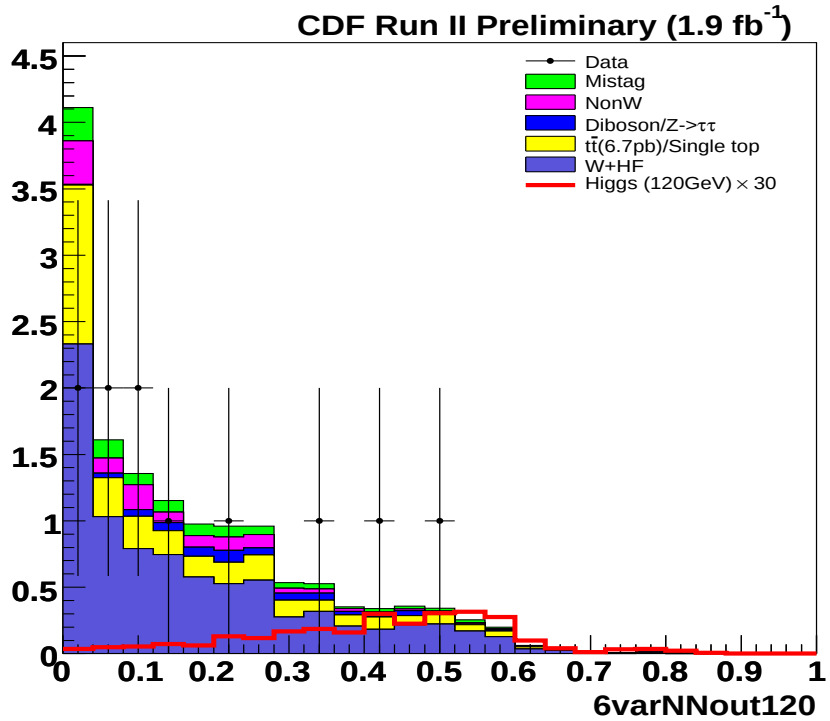
Forward electrons, 3 jet channel, improved neural network

One Charged Lepton: WH $\rightarrow \ell\nu b\bar{b}$ (CDF)

– $\int \mathcal{L}dt \simeq 1.9$ fb^{-1} (winter 2008):

  * Two double b-tag, one single b-tag categories
  * Forward electrons included





Central e + μ 0.94 WH

80.62 background events

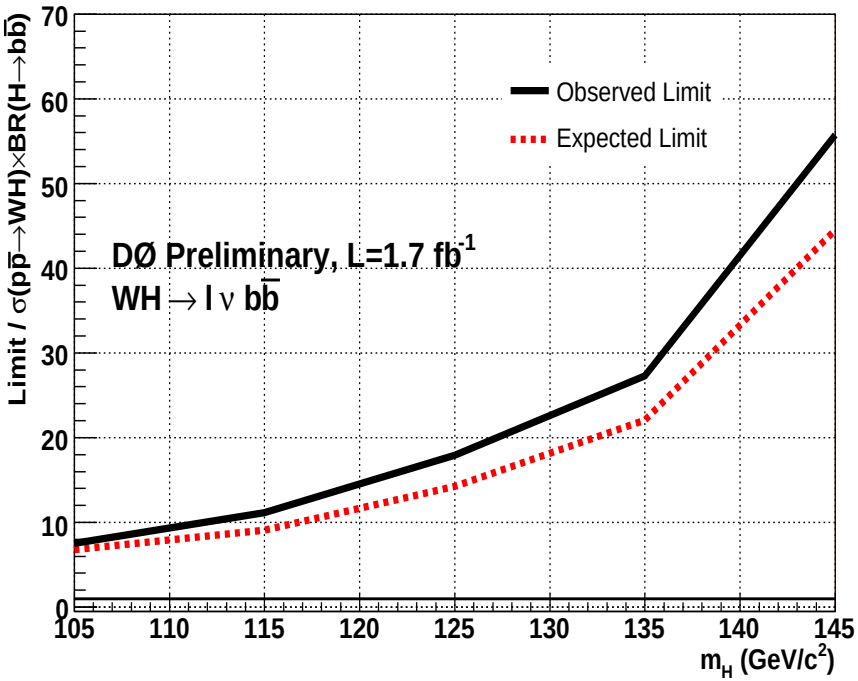
Forward e 0.09 WH

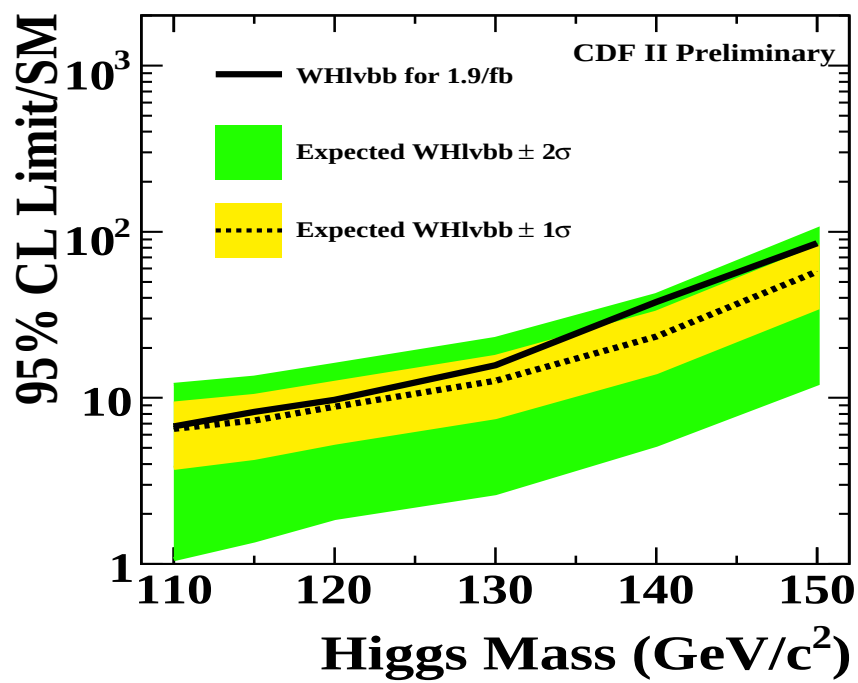
14.18 background events

WH $\rightarrow \ell\nu b\bar{b}$ Results

– No excess, data agree with background model

– Use neural network output to derive limits



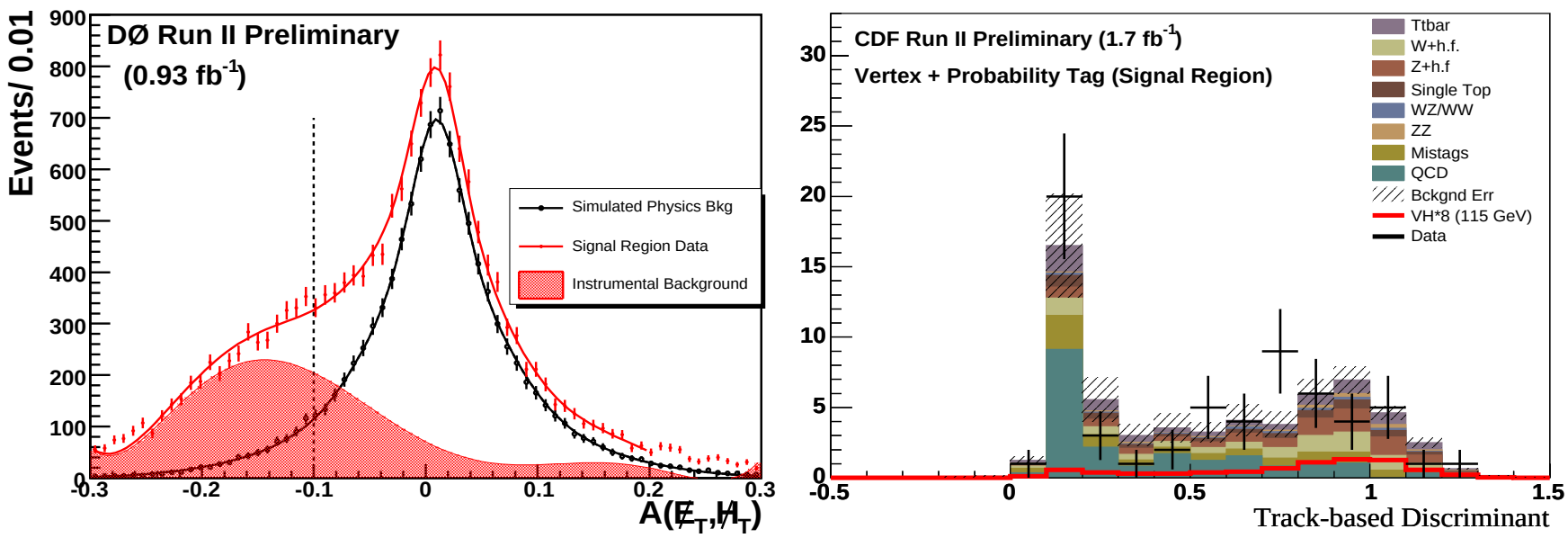


DØ at $m_{\mathrm{H}} = 115$ GeV
limit/SM 11.1 (9.1 expected)

CDF at $m_{\mathrm{H}} = 115$ GeV
limit/SM 8.2 (7.3 expected)

No Charged Lepton: ZH $\longrightarrow \nu\nu b\bar{b}$

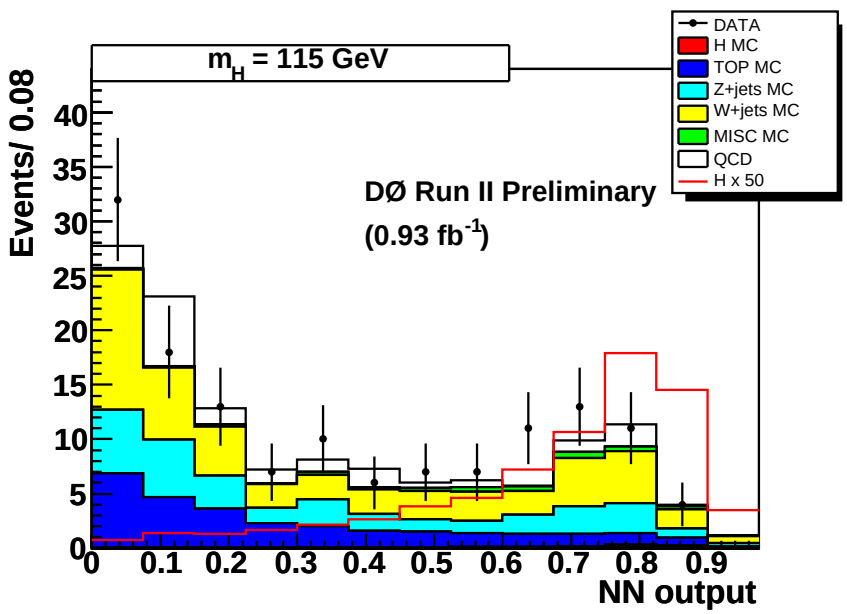
- $\int \mathcal{L} dt \simeq 0.9$ fb^{-1} (DØ fall 2007), 1.7 fb^{-1} (CDF winter 2008)
- Signature: two jets and large $\not\!\!E_T$
- Significant instrumental background from mismeasured $\not\!\!E_T$
  - Direction $\not\!\!E_T \neq$ direction jet
  - Use calorimeter-based $\not\!\!E_T$ and tracks

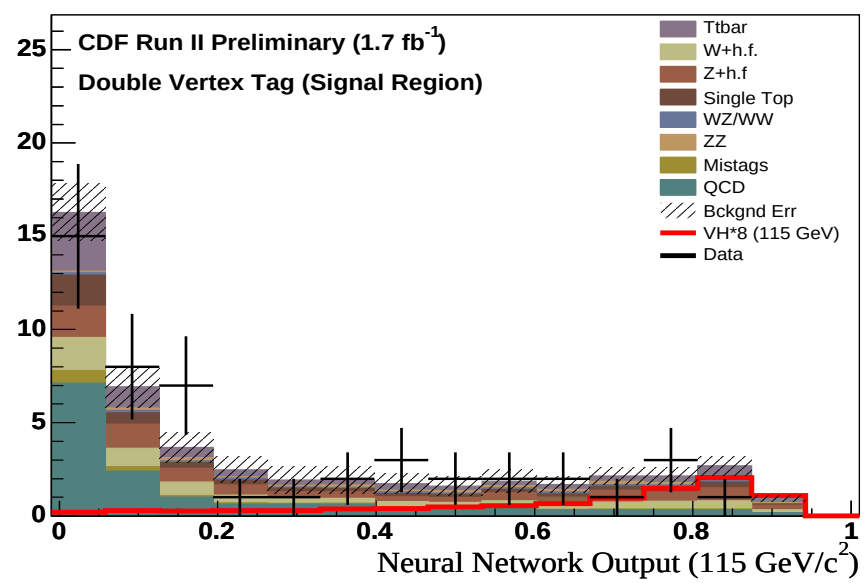


No Charged Lepton: ZH $\longrightarrow \nu\nu b\bar{b}$

– Neural networks to improve sensitivity

  * Combine jet, $\not{E}_T$ kinematics
  * More discriminating than m_{jj}





ZH $\rightarrow \nu\nu b\bar{b}$ Results

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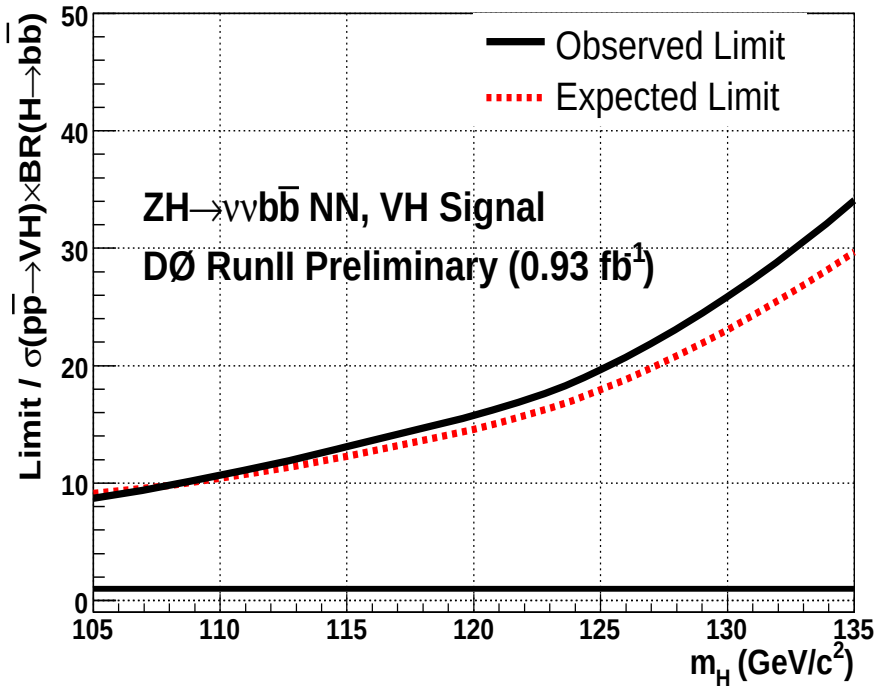
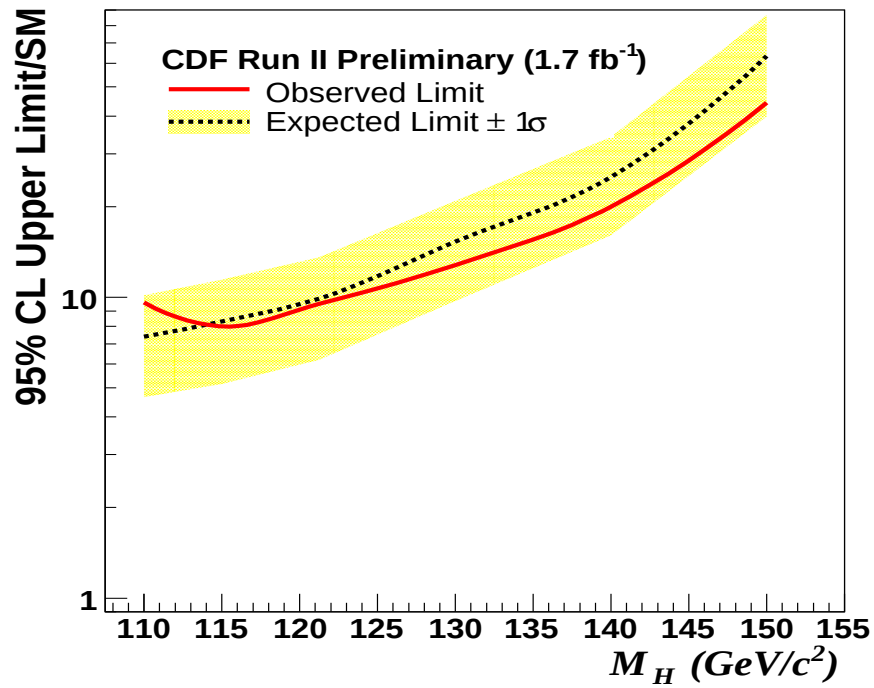


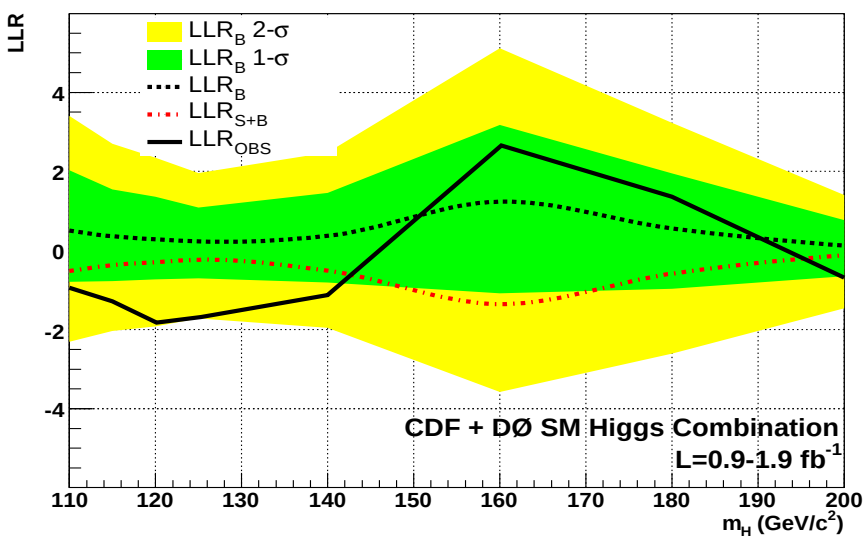


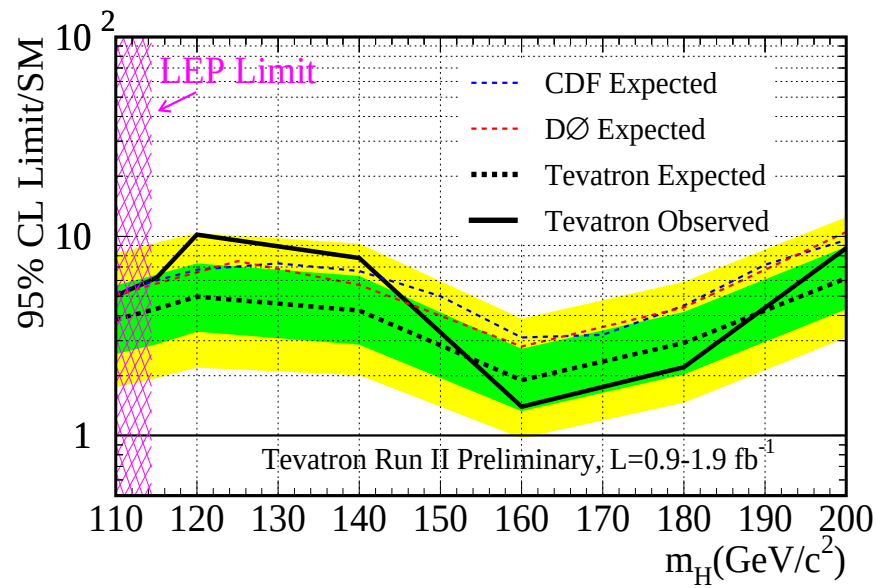
DØ at $m_{\mathrm{H}} = 115$ GeV
limit/SM 13 (12 expected)

CDF at $m_{\mathrm{H}} = 115$ GeV
limit/SM 8.3 (8.0 expected)

Tevatron Combination

- Looking for SM Higgs $\rightarrow$ assume SM branching ratios $\rightarrow$ combine search channels (arXiv:0712.2383 [hep-ex])
- Latest CDF WH and $\not{E}_T b\bar{b}$ results not (yet) included
- "Modified frequentist" or "Bayesian" approaches
  - $*$ Agreement to within 10%





At $m_H = 115$ GeV limit/SM 6.2 (4.3 expected)

Conclusion & Outlook

- Higgs not found yet . . .
- Improvement in sensitivity $\sim \int \mathcal{L} \mathrm{d}t$
- Many small steps to follow:
  - $\int \mathcal{L} \mathrm{d}t = 7$ to 9 fb^{-1} by 2010
  - Improvements to b-tagging, jet energy, mass resolution
  - Improved multivariate techniques
  - Increased efficiency for leptons
- Exclusion or observation possible soon !