Combination of CDF's Higgs Boson Searches with up to 10 fb^{-1} of Data

Azeddine Kasmi

Baylor University

On behalf of the CDF Collaboration

ICHEP 2012, Melbourne, Australia

July 7, 2012

The Search Strategy

- One channel is not enough
- Optimize each channel individually
- No channel left behind
- Heavy use of multivariate techniques
  - Artificial Neural Networks
  - Boosted Decision Trees
  - Support Vector Machines
- The focus of the talk is $H \rightarrow b\bar{b}$ and $H \rightarrow WW$
- Since Tevatron sensitivity is driven by $H \rightarrow b\bar{b}$ searches, it provides a complementary information to the LHC searches.
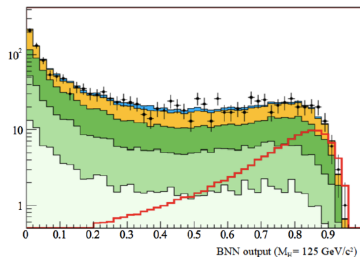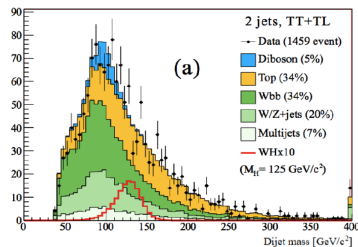
Introduction
SM Higgs Boson Searches
results
Conclusion

Higgs to b$\bar{b}$ Final States
Higgs to *WW* Final States

Higgs to b$\bar{b}$ Final State

- Single Higgs production (gluon fusion)
  - Largest cross section
  - Not feasible for *b*-quark decay: more QCD background
  - Still, use it for Higgs decays to photon or tau lepton pairs
- Associated production (WH, ZH)
  - Take advantage of the leptonic decays of the W or Z bosons
  - Charged-lepton and missing-transverse-energy-based triggers
  - Identify jets that originate from *b* quarks
- See Weiming Yao's talk

Introduction
SM Higgs Boson Searches
results
Conclusion

Higgs to b$\bar{b}$ Final States
Higgs to WW Final States
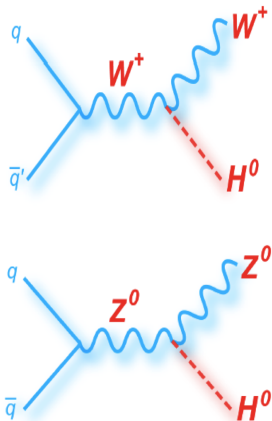
Example of NN Discriminant

- Two b-tagged jets in $WH \rightarrow l\nu bb$, most sensitive channel
- Artificial neural network as final discriminant trained for a Higgs boson mass of 125 GeV/c^2
- NN trained for each mass point tested

Introduction
SM Higgs Boson Searches
results
Conclusion

Higgs to b$\bar{b}$ Final States
Higgs to WW Final States

Higgs to *WW* Final States

- Higgs decays mostly to *W* boson pairs
- Single Higgs production (gluon fusion)

  - Most sensitive channel to the SM Higgs
  - 2 charged leptons;
    0, 1 or 2 and more jets

- See Massimo Casarsa's talk

Introduction
SM Higgs Boson Searches
results
Conclusion

Higgs to $b\bar{b}$ Final States
Higgs to WW Final States
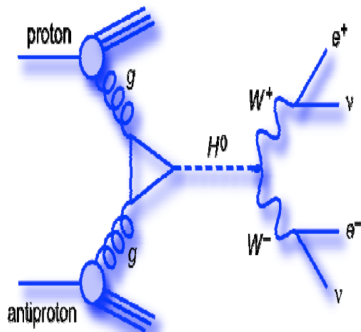
Example of NN Discriminant

- Two oppositely-charged leptons, with 0 jet
- Artificial neural network as final discriminant trained for a Higgs boson mass of 165 GeV/c^2
- NN trained for each mass point tested
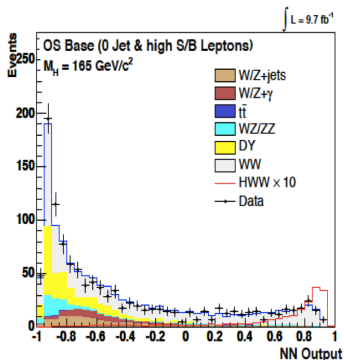
S/B Ratio Plots $m_H = 125$ GeV/c^2

- Sum final discriminants after rebinning in $\log_{10}(s/b)$
  - Sum all independent channels
  - background very well modeled
  - Data events excess in signal region
- Backgrounds subtraction from data
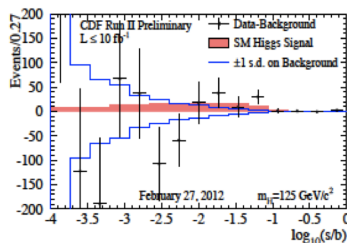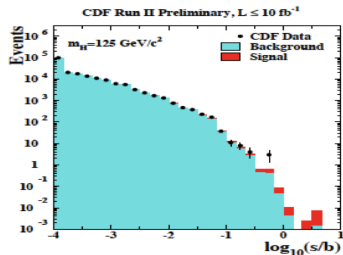
S/B Ratio Plots $m_H = 165$ Gev/c^2

- Sum final discriminants after rebinning in $\log_{10}(s/b)$
  - Sum all independent channels
  - background very well modeled
  - No data events excess in signal region
- Backgrounds subtraction from data
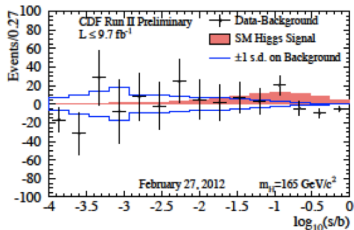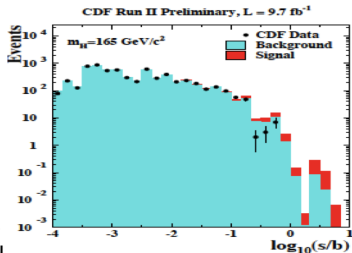
Limit Setting & Systematic Uncertainties

- Bayesian approach with Poisson statistics
- Rate and shape systematic uncertainties are introduced as nuisance parameters
- Rate: uncertainty on the total normalization
- Shape: uncertainty on bin-by-bin normalization
  - Use full discriminant shapes to extract the most information
- Correlated among various analyses
  - Charged lepton, trigger, b-tagging efficiencies
  - Luminosity, background & signal cross sections
- Uncorrelated among various analyses
  - Fake object identification (e.g.: jets faking electrons and $\displaystyle{\not}E_T$)
  - Data-driven background modeling

CDF Combination Channels

Channel	Luminosity (fb^{-1})
$H \rightarrow WW$	9.7
$ZH \rightarrow llbb$	9.45
$WH + ZH \rightarrow \not{E}_T bb$	9.45
$WH \rightarrow l\nu bb$	9.45
$H \rightarrow \tau\tau$	8.3
$ttH(\not{E}_T + jets)$	5.7
$W, Z + \tau\tau$	6.2
$H \rightarrow \gamma\gamma$	10.0
$ttH(l + jets)$	9.45
$H \rightarrow ZZ \rightarrow 4l$	9.7
$WH + ZH + VBF \rightarrow jjbb$	9.45

Secondary channels talks is covered in Elisabetta Pianori's talk

SM Higgs Boson Combined Limits
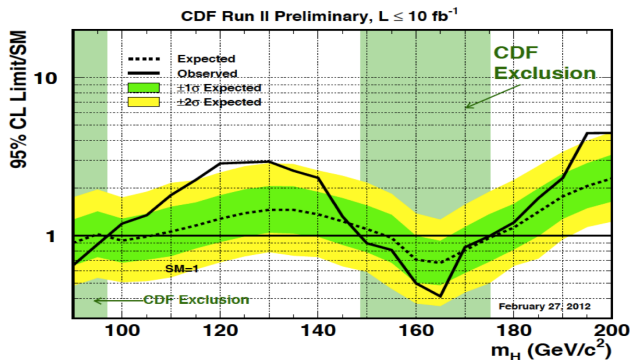
- Exclude 147–175 GeV/c^2
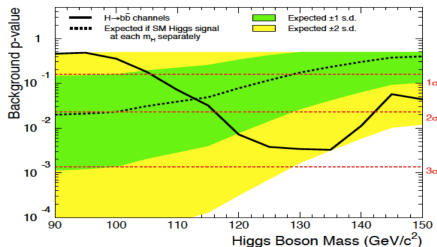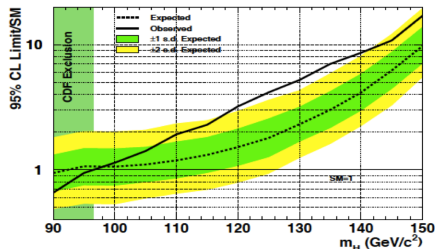- Broad excess observed. Largest excess: 120 GeV/c^2
- Global p-value = 2.1σ

SM Higgs Boson Limits Interpretation

- Broad excess observed at masses below 150 GeV/c^2

- Largest excess: 120 GeV/c^2: Global p-value = 2.1σ

- Fits to the cross sections compared to the SM expectation shows consistency within uncertainty.
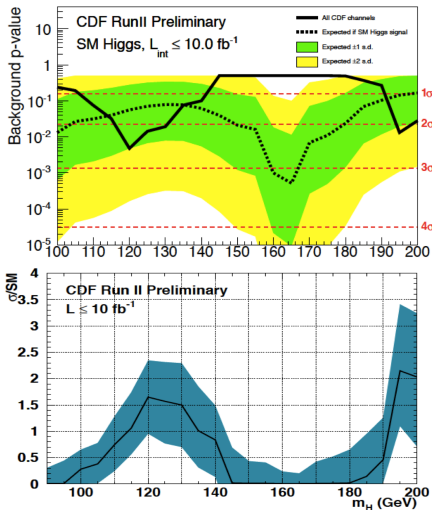
CDF Combined Search in $H \to b\bar{b}$ Decay Mode

- Exclude $m_H = 96$ GeV/c^2
- For $m_H = 125$ GeV/c^2
  - Expected: 1.80
  - Observed: 4.15
- An excess is seen in the mass range 115-150 GeV/c^2
  - Global significance of 2.5σ

Conclusion

- Search for the SM Higgs boson in many channels
- CDF has made major improvements to its SM Higgs searches
- Expected sensitivity: $1.46 \times$ SM or better < 185 GeV/c^2
- Exclude 147–175 GeV/c^2
- Associated production $H \to b\bar{b}$ channels
  - Broad excess observed.
  - Largest excess: 135 GeV/c^2: Global p-value $= 2.5\sigma$
- CDF combination
  - Broad excess observed at masses below 150 GeV/c^2
  - Largest excess: 120 GeV/c^2: Global p-value $= 2.1\sigma$
- ATLAS and CMS announced a discovery of a Higgs boson like particle. Thus, the need to understand its properties
  - CDF data will play a large role in a measurements of $\sigma(WH + ZH) \times BR(H \to b\bar{b})$

Back Up

Back up slides

Back Up

Excess at $m_H = 195$ GeV/c^2
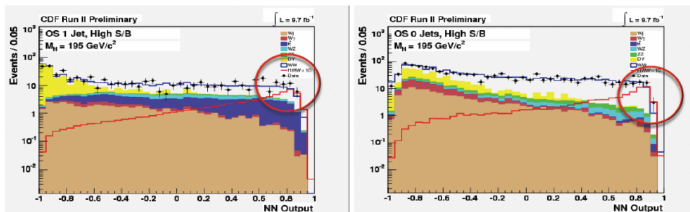
- ▸ Behavior of observed limits driven by small event excesses in the high S/B regions of opposite-sign dilepton 0 and 1 jet channels
- ▸ Nothing peculiar in the modeling of these distributions
- ▸ Of course, ATLAS and CMS have ruled out a $m_H = 195$ GeV/c^2 SM Higgs based primarily on equivalent searches in H->WW
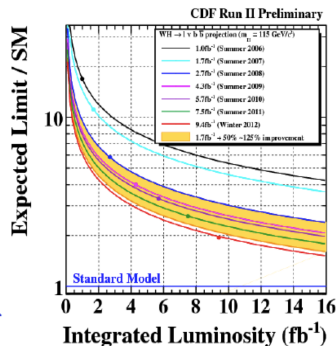
SM Higgs Boson Limits per channel
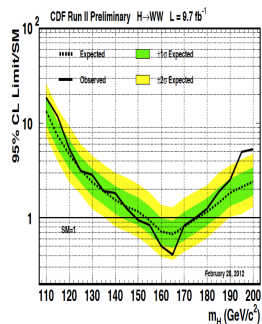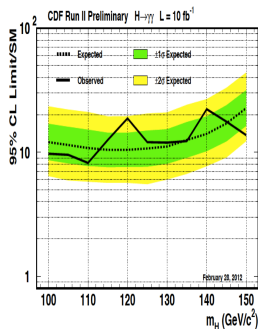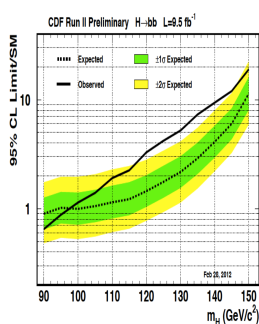
Diboson as a candle
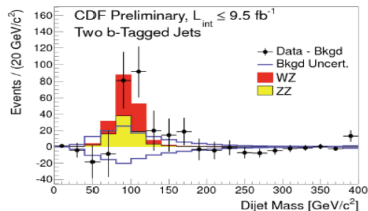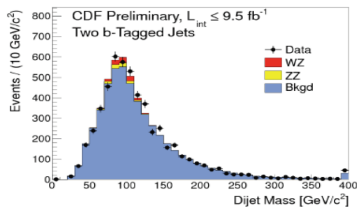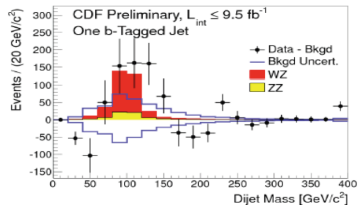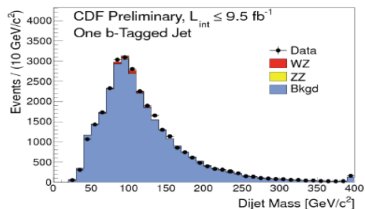
Sensitivity With Time

Many improvements

- Online Event Selection
    - Optimized trigger paths and add new triggers designed for SM Higgs searches
- Event Reconstruction
    - Employ multivariate lepton identification
- Background Rejection
    - Reject instrumental background via a support vector machine
- New $b-$jet Identification
    - New CDF neural network $b-$tagger

SM Higgs Boson Limits per Channel
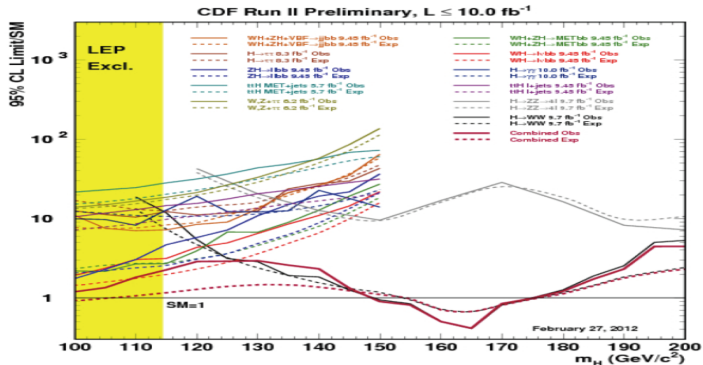
Each channel contributes. *WH* most sensitive channel for low mass Higgs searches. $H \rightarrow WW$ most sensitive channel for high mass Higgs searches.