Combined CDF-D0 Limits on SM Higgs Production
Blessing

Weiming Yao for The TEVNPH Working Group

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OutLine of Talk

- Introduction
- Input Data, Acceptance, and Backgrounds
- Combination Procedures and systematics
- Combination Results
- Cross Checks
- Conclusion

Documented in CDF-8384 and supported by CDF-8326 and D0-5056.

Introduction

- CDF and D0 have reported direct searches for SM Higgs production in many different final states with sufficient integrated luminosity ($\approx 1 fb^{-1}$)
  - $WH \rightarrow l\nu b\bar{b}$
  - $ZH \rightarrow \nu\bar{\nu}b\bar{b}$
  - $ZH \rightarrow l^{+}l^{-}b\bar{b}$
  - $gg \rightarrow H \rightarrow W^{+}W^{-}$

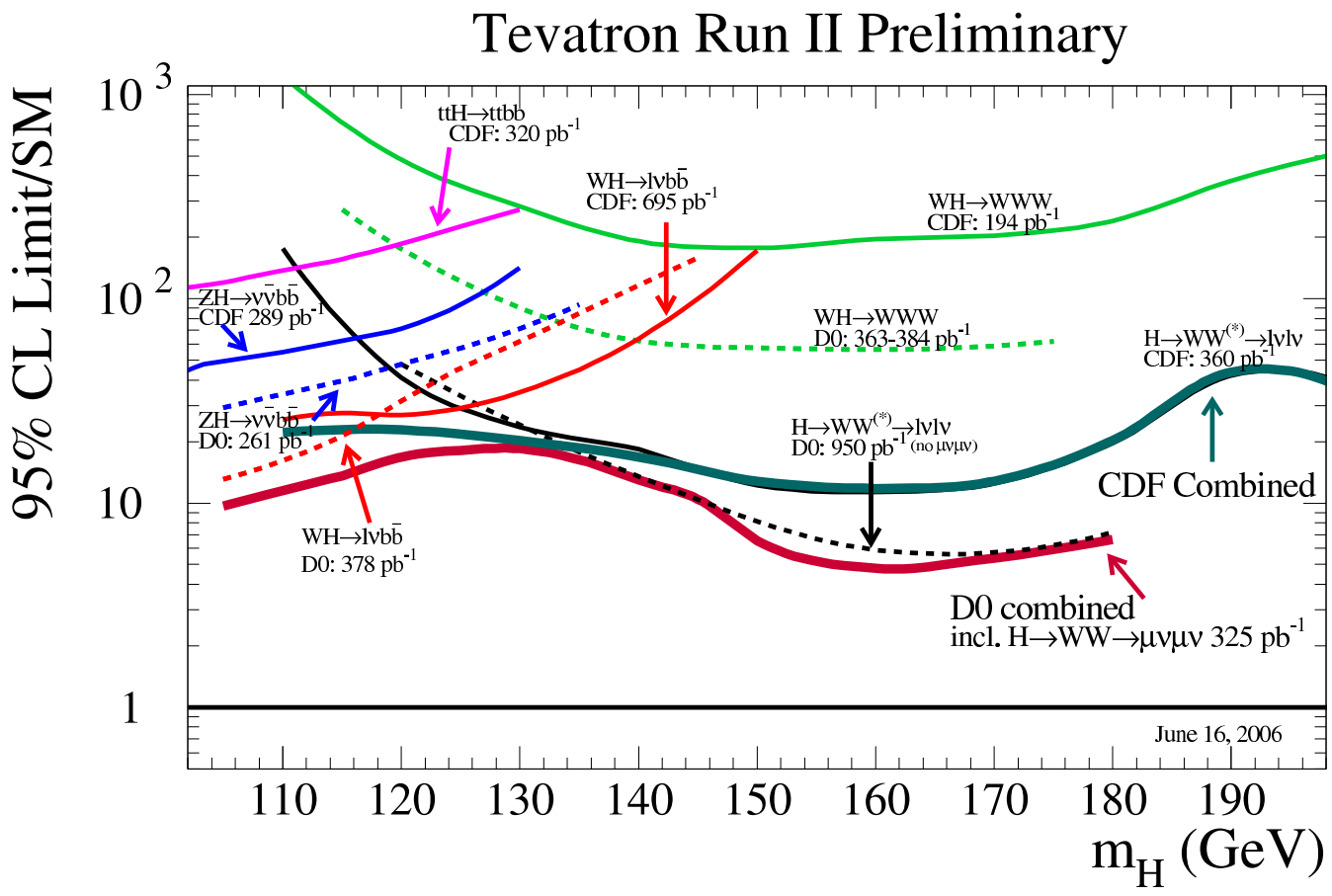
- A combined limit would significantly improve the individual limits for each experiment.

Inputs

- CDF results included:
  - $WH \rightarrow l\nu b\bar{b}$ with 1 fb^{-1} (ST, DT)
  - $ZH \rightarrow \nu\bar{\nu}b\bar{b}$ with 0.3 fb^{-1}
  - $gg \rightarrow H \rightarrow W^+W^- \rightarrow l^+l^-\nu\bar{\nu}$ with 0.4 fb^{-1}

- D0 results included:
  - $WH \rightarrow l\nu b\bar{b}$ with 0.4 fb^{-1} (e, μ, DT, ST)
  - $ZH \rightarrow \nu\bar{\nu}b\bar{b}$ with 0.3 fb^{-1} (DT, ST)
  - $H \rightarrow WW \rightarrow l^+l^-\nu\bar{\nu}$ with 1 fb^{-1} ($e^{\pm}e^{\mp}$, $e^{\pm}\mu^{\mp}$, $\mu^{\pm}\mu^{\mp}$)
  - $WH \rightarrow WWW$ with 0.4 fb^{-1} ($e^{\pm}e^{\pm}$, $e^{\pm}\mu^{\pm}$, $\mu^{\pm}\mu^{\pm}$)

Summary of Tevatron Higgs Results (SUSY06)



Source of Correlated Systematic (CDF)

Channels	$l\nu b\bar{b}ST$	$l\nu b\bar{b}DT$	$\nu\nu b\bar{b}$	W^+W^-
Acceptance				
Luminosity (%)	6.0	6.0	6.0	6.0
btag SF(%)	5.3	16.0	6.3	0.
Lepton ID (%)	2.0	2.0	2.0	3.0
JES (%)	3.0	3.0	8.0	1.0
I(F)SR+PDF(%)	4.0	10.0	2.0	5.0
Trigger (%)	0.0	0.0	0.02	0.0
Backgrounds				
HF (%)	33.0	34.0	0.	0.
Mistag (%)	22.0	15.0	16.0	0.
Top (%)	13.5	20.0	18.0	0.0
QCD (%)	17.0	20.0	-34.0	0.
Diboson (%)	16	25	18	11
Others (%)	0.	0.	0.	-(12-18)

- The positive value means correlated, the negative value means uncorrelated
- The results seems insensitive to these correlations changing from 100% to 0%

Source of Correlated Systematic (D0)

Channels	$e\nu bb$ DT(ST)	$\mu\nu bb$ DT(ST)	$\nu\nu bb$ DT(ST)	W^+W^-
Luminosity (%)	6.5	6.5	6.5	6.5
JES (%)	4	5	6	3
Jet ID (%)	6.8	6.8	7.1	0
Electron ID (%)	6.6	0	0	2.3
Muon ID (%)	0	4.9	0	7.7
b-jet Tagging (%)	8.5(5)	8.5(5)	9.6(6.7)	0
Backgrounds σ (%)	6-33	6-25	6-33	6-33

- Common Systematic between CDF and D0:
  - Luminosity: 4.5%
  - Top xsec (8%), Diboson xsec (6%), and 10% for $gg \rightarrow H$

Technique for Limit Combination

- CLs Method with Log-Likelihood Ratio (LLR) - D0

$$\chi_n = 2 \times \sum_{i=1}^{N_C} \sum_{j=1}^{Nbins} (s_{ij} - n_{ij} Log(1 + s_{ij}/b_{ij}))$$

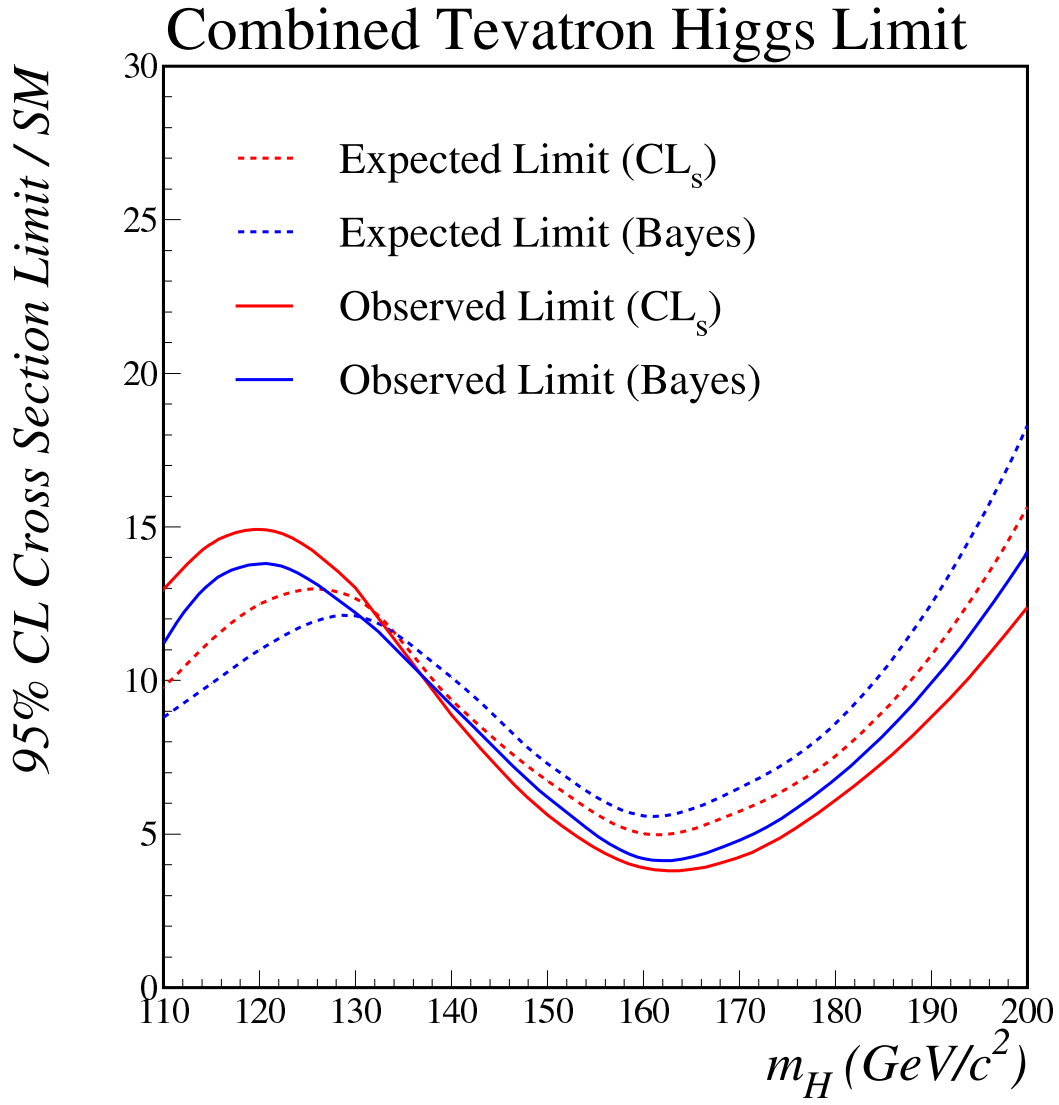
  - $CL_s = CL_{s+b}/CL_b$

- Bayesian framework - CDF
  - Use Bayesian posterior probability
  - Assume flat prior density for the number of Higgs events
  - Combined Binned Poisson Likelihood:

$$\mathcal{L}(R, \vec{s}, \vec{b}|\vec{n}) = \prod_{i=1}^{N_C} \prod_{j=1}^{Nbins} \mu_{ij}^{n_{ij}} e^{-\mu_{ij}}/n_{ij}!$$

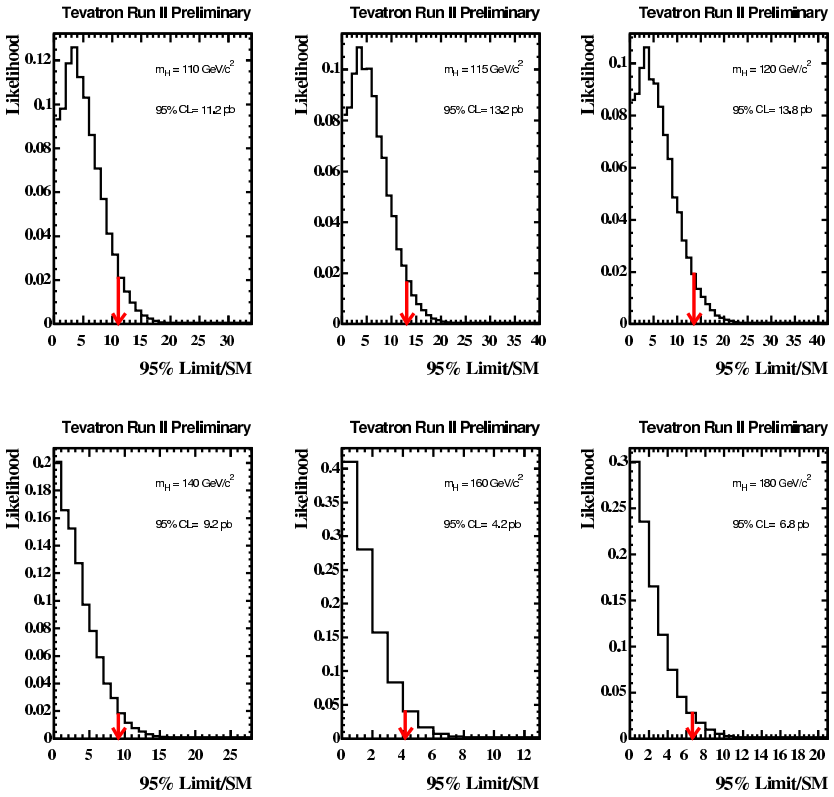
- Both methods agree within 10%

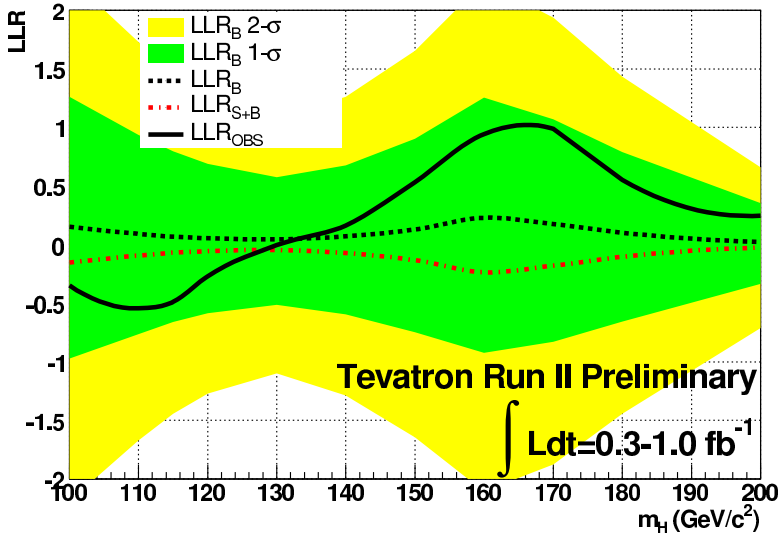
Cross Checks between Two Methods



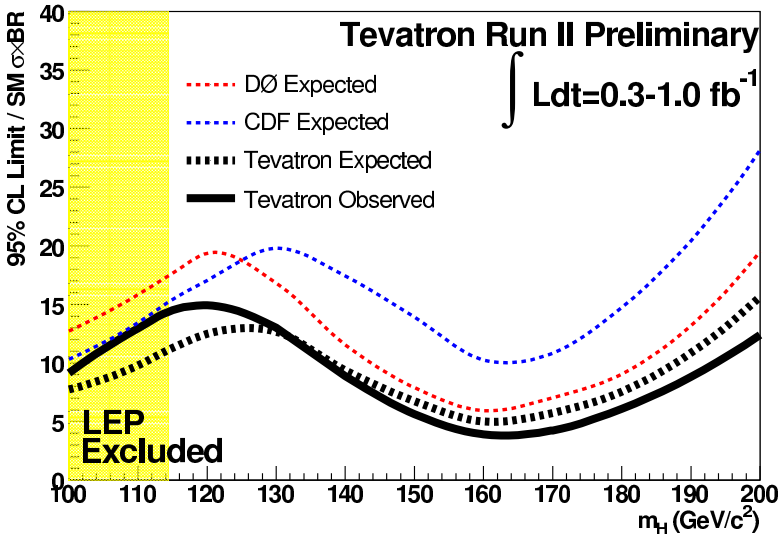
- At low mass the Bayesian procedure gives better limits while at high masses the CL_s method yeilds a better limit.

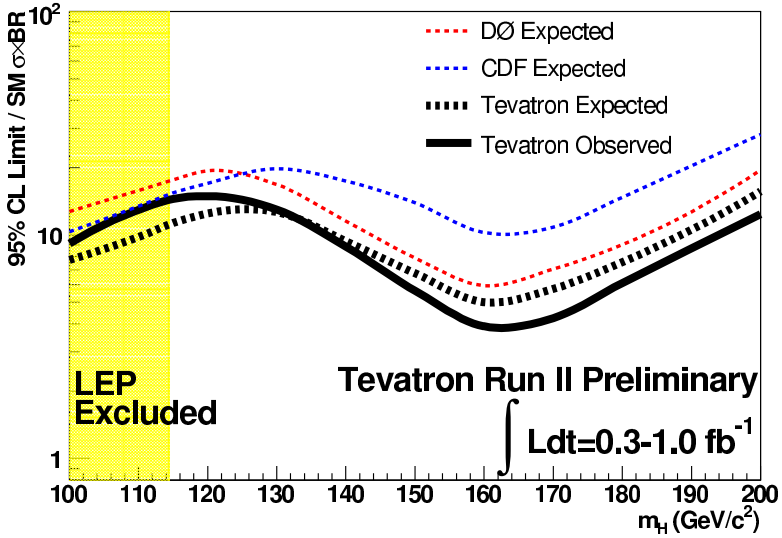
Tevatron Likelihood and Log-Likelihood Ratio (For Blessing)





Tevatron Combined Limit (For Blessing)





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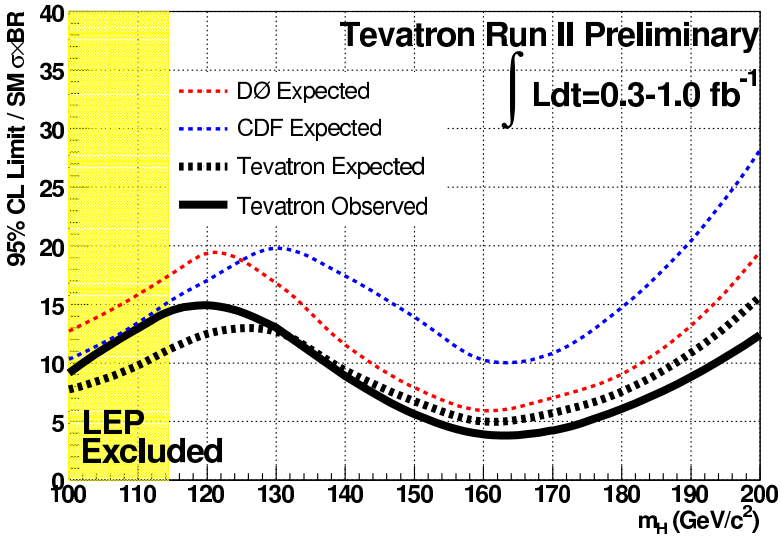

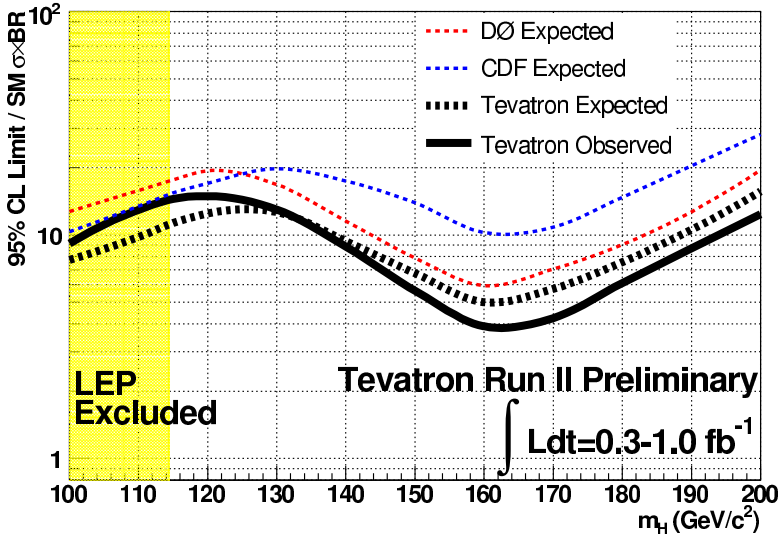

Conclusion

- We have developed two techniques to combine SM Higgs limit from CDF and D0
- The 95% CL upper limits are a factor of 14.3(3.9) higher than the standard Model cross section at $m_H = 115(160)$ GeV/c^2.
- This result significantly improves the individual limits for each experiments
- Once the method established, we should be able to include all the latest Higgs results into combination next week.
  - Updated $ZH \rightarrow \nu\bar{\nu}b\bar{b}$ from CDF
  - New $ZH \rightarrow l^+l^-b\bar{b}$ from both CDF and D0
- Hopefully, we will have the best SM Higgs limit from Tevatron for ICHEP