

# CDF and D0 Higgs results with the full Tevatron dataset

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on behalf of the CDF and D0 collaborations

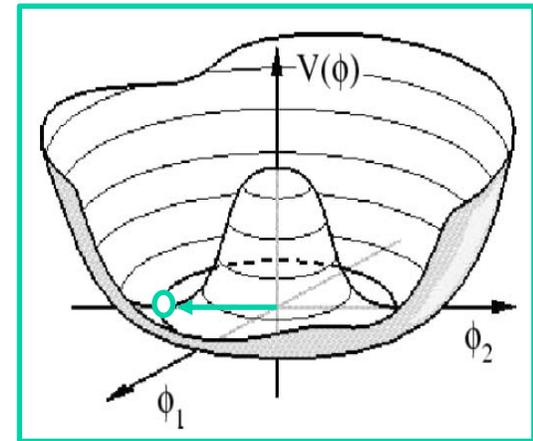
July 2<sup>nd</sup>, 2012

Tevatron Higgs Seminar

# Higgs in Standard Model

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- The standard model mechanism for electroweak symmetry breaking was first proposed forty-eight years ago
- Theory still awaits validation through the discovery of predicted Higgs boson
- This is likely to be the week when either evidence for the Higgs boson is reported or it is excluded over the entire mass range consistent within the standard model



# Today's Presentations

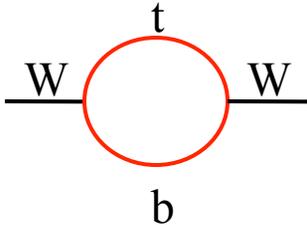
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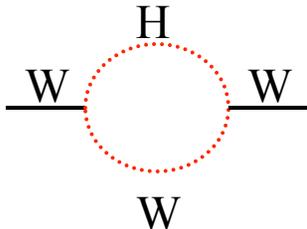
- On Wednesday, the LHC experiments are expected to present their first Higgs search results based on  $\sim 5 \text{ fb}^{-1}$  of additional data collected at  $\sqrt{s} = 8 \text{ TeV}$
- Tevatron presented first results based on full datasets this past spring
- Since then additional analysis improvements, made to the D0 searches in particular, have been implemented leading to an increase in the combined sensitivity of Tevatron searches
- Today's talks :
  - Part I - Overview of Higgs search channels and review of CDF results
  - Part II – Updates to D0 search results and Tevatron combination

# Indirect SM Higgs Mass Constraints

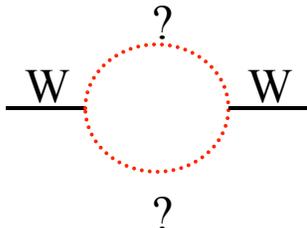
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- SM Higgs boson mass is a free parameter of the theory
- Constrained indirectly through precision measurements
- In particular, self-energy corrections to the W mass depend on the mass of the top quark and Higgs boson

$$\Delta M_W \propto M_{\text{top}}^2$$


$$\Delta M_W \propto \ln M_H$$


New Physics



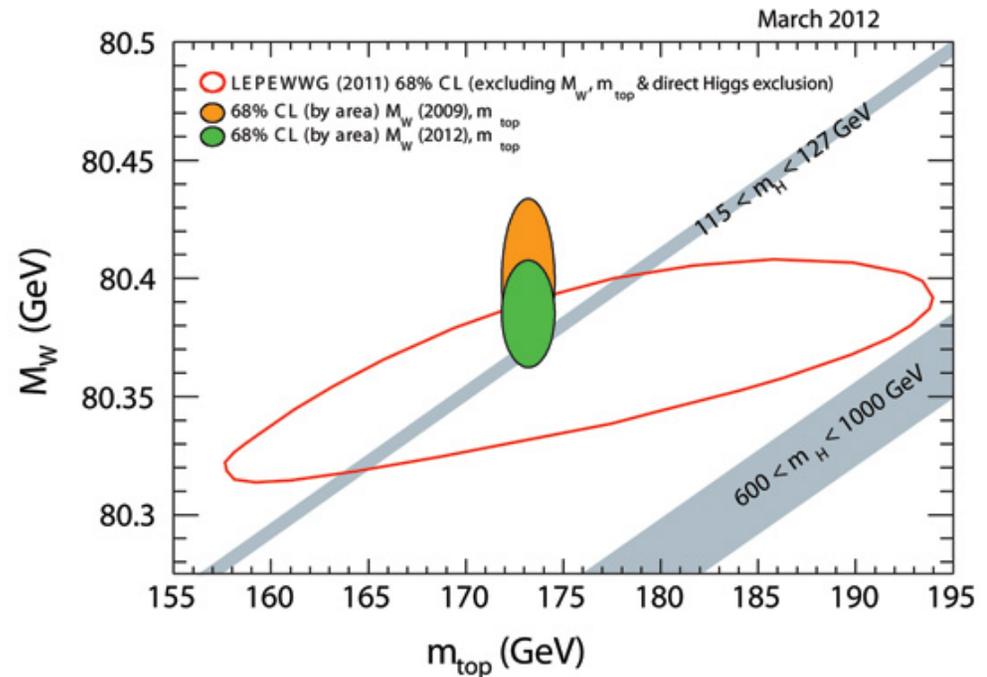
# Indirect SM Higgs Mass Constraints

- Recently updated top quark and W boson mass measurements from the Tevatron

$$m_W = 80385 \pm 15 \text{ MeV}$$

$$m_t = 173.2 \pm 0.9 \text{ GeV}$$

- If Higgs boson is found, next question to be answered is its compatibility with the standard model



$$m_H < 152 \text{ GeV at 95\% C.L.}$$

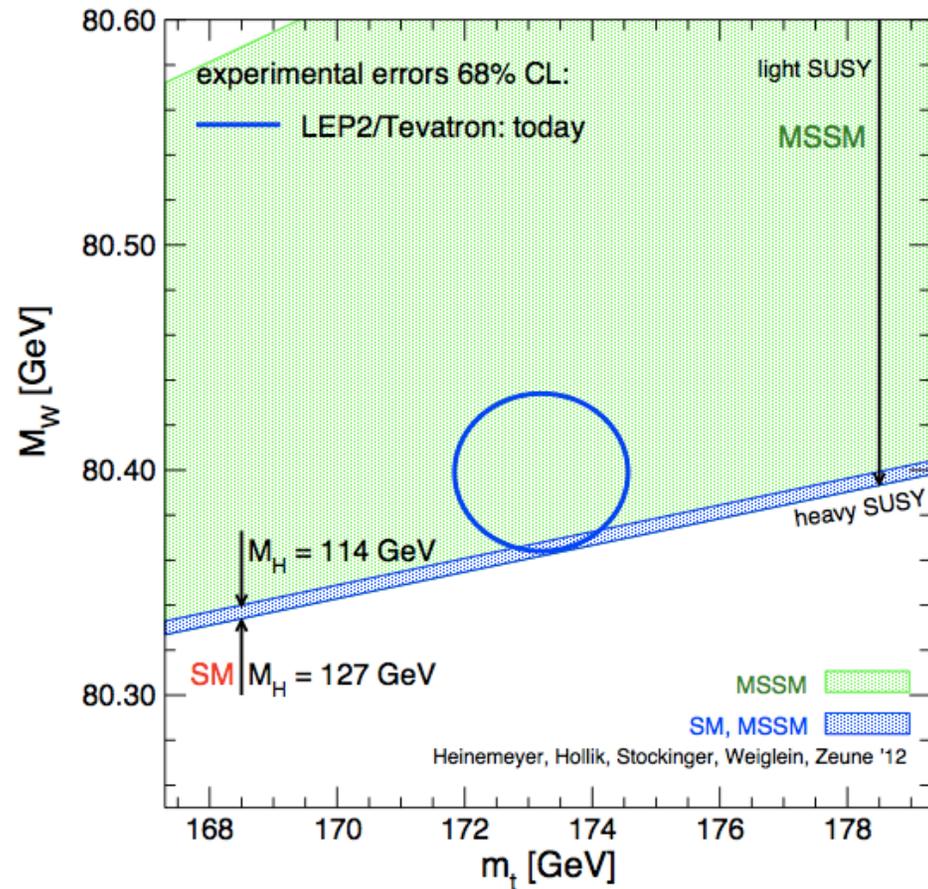
# Indirect SM Higgs Mass Constraints

- Recently updated top quark and W boson mass measurements from the Tevatron

$$m_W = 80385 \pm 15 \text{ MeV}$$

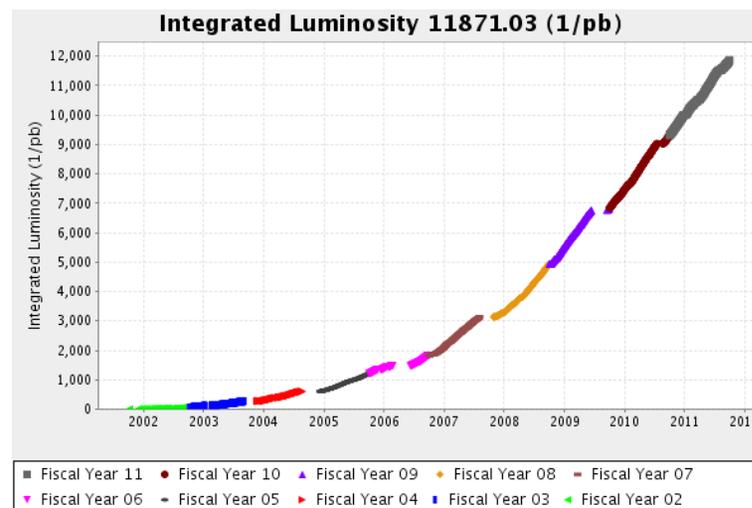
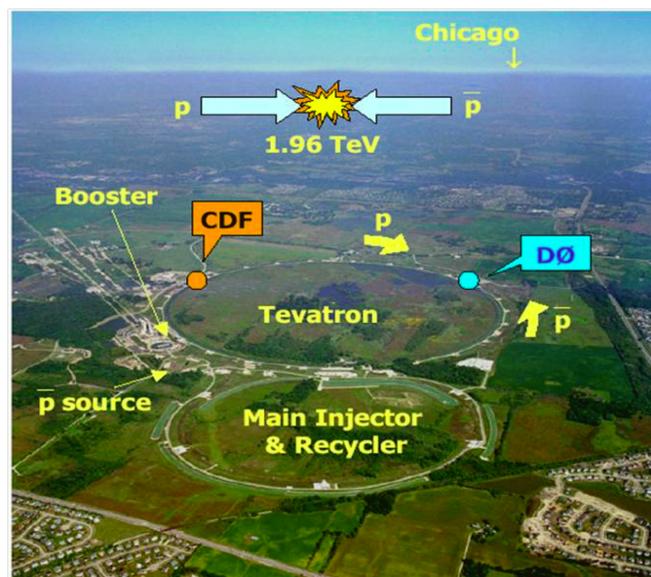
$$m_t = 173.2 \pm 1.0 \text{ GeV}$$

- If Higgs boson is found, next question to be answered is its compatibility with the standard model

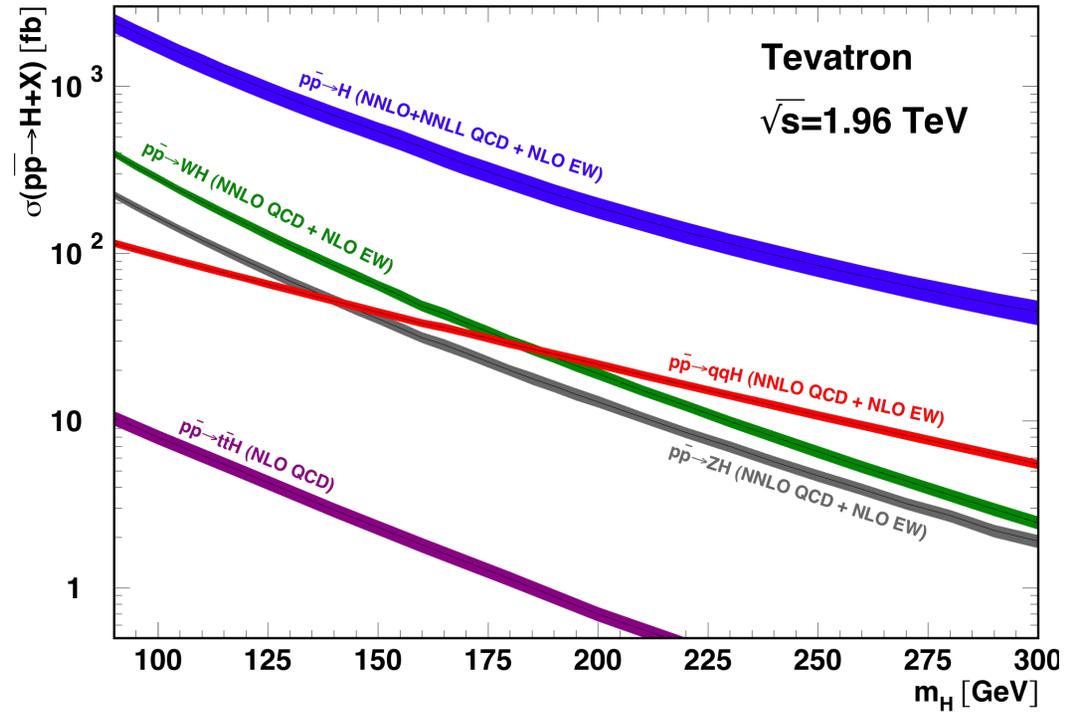
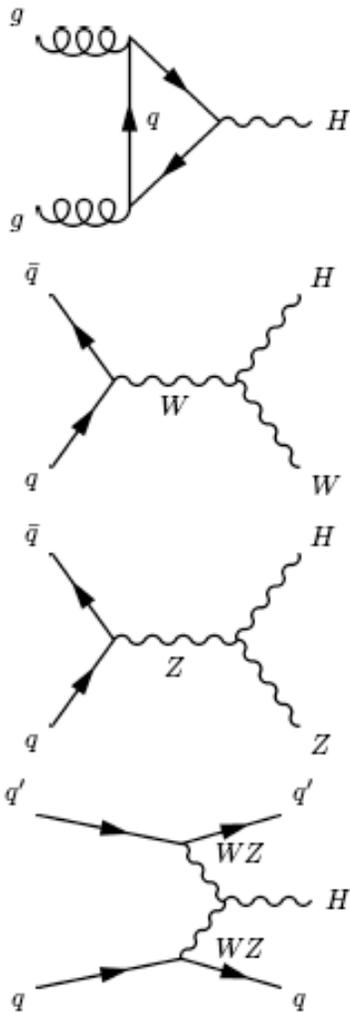


# Tevatron

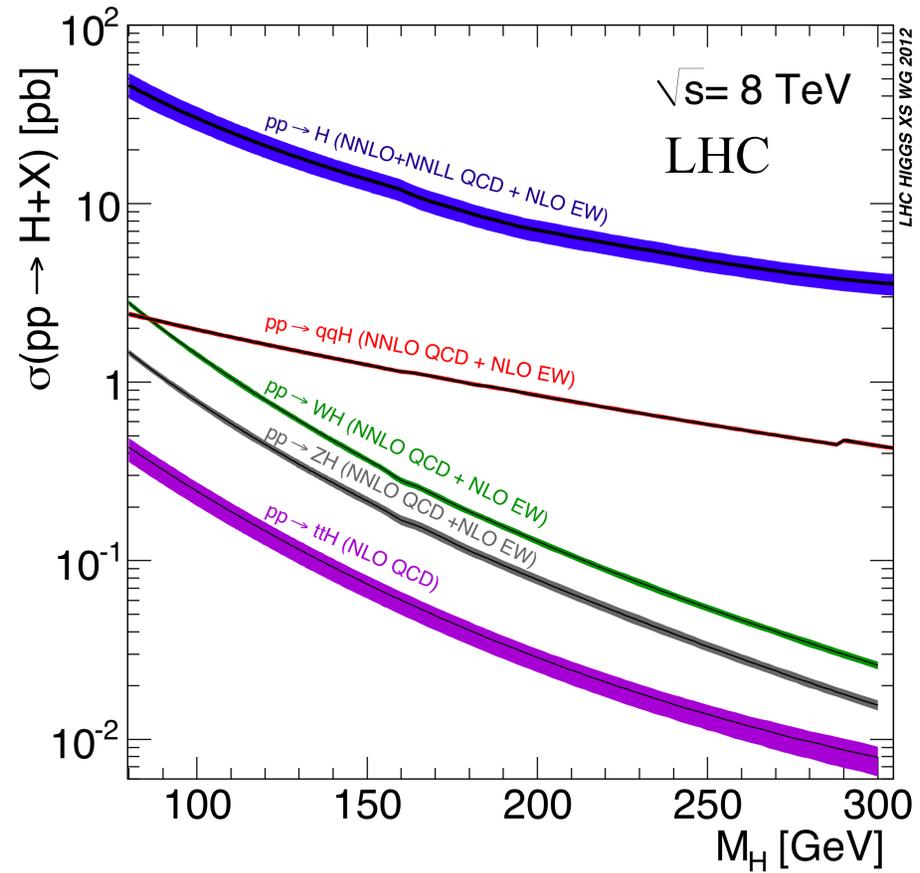
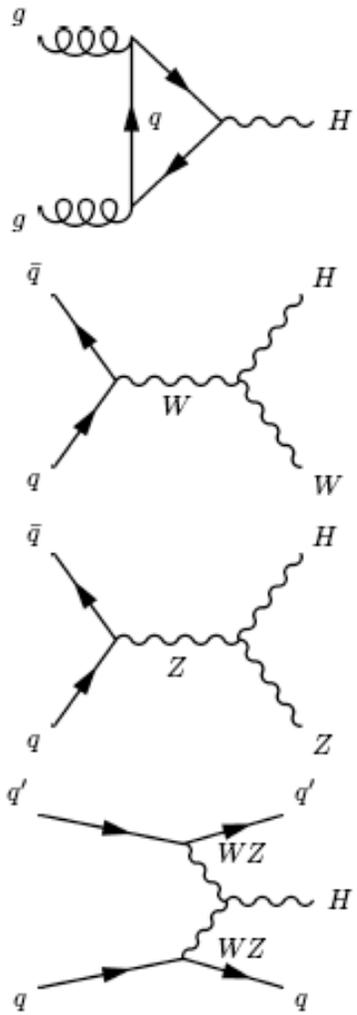
- Run II : 2001-2011
- Over  $12 \text{ fb}^{-1}$  delivered and  $10 \text{ fb}^{-1}$  recorded with the CDF and D0 detectors
- Initial luminosity record of  $4.31 \times 10^{32} \text{ cm}^{-2}\text{s}^{-1}$
- Thanks once again to all the people who contributed to the production of these datasets



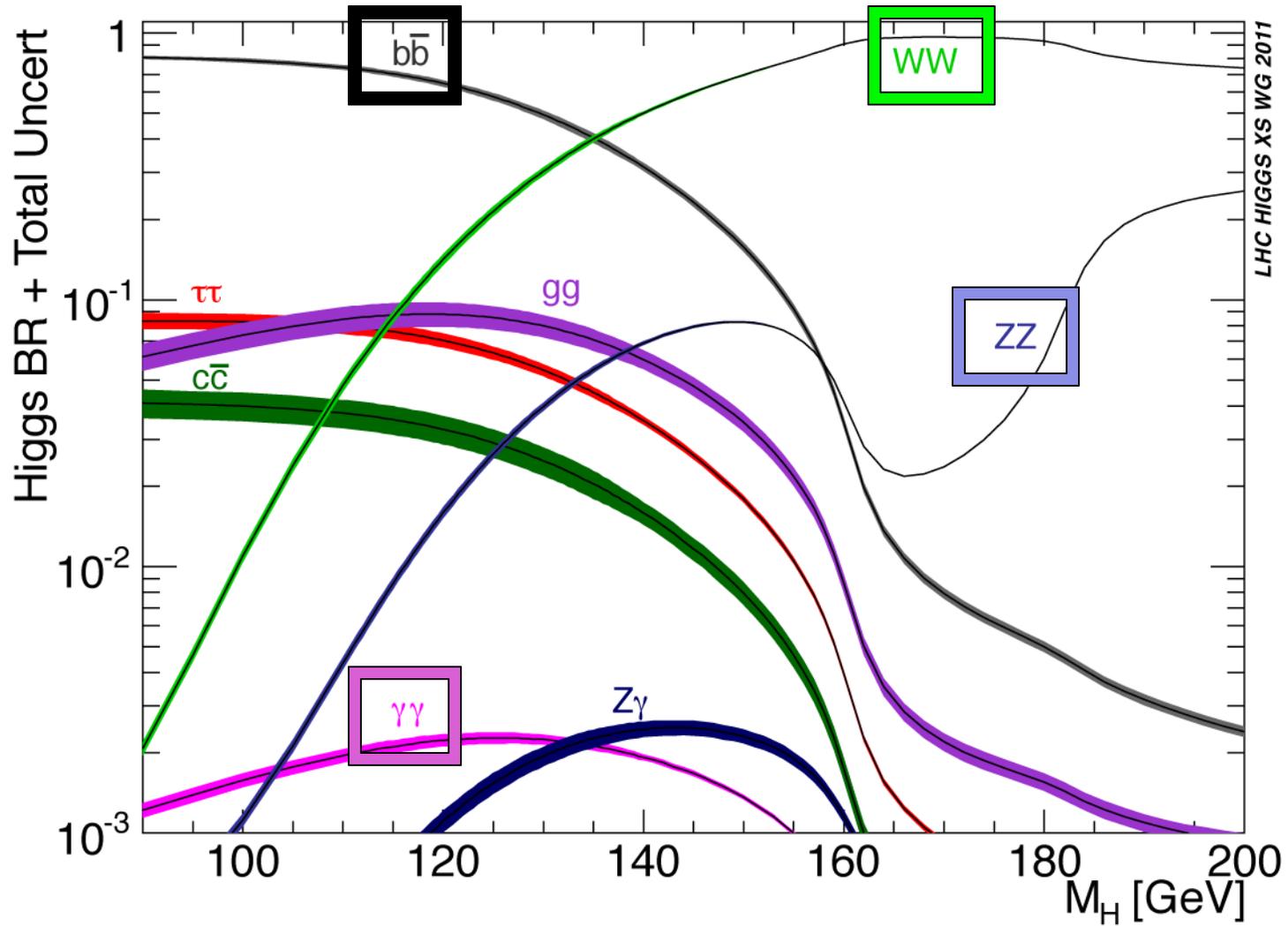
# SM Higgs Production



# SM Higgs Production

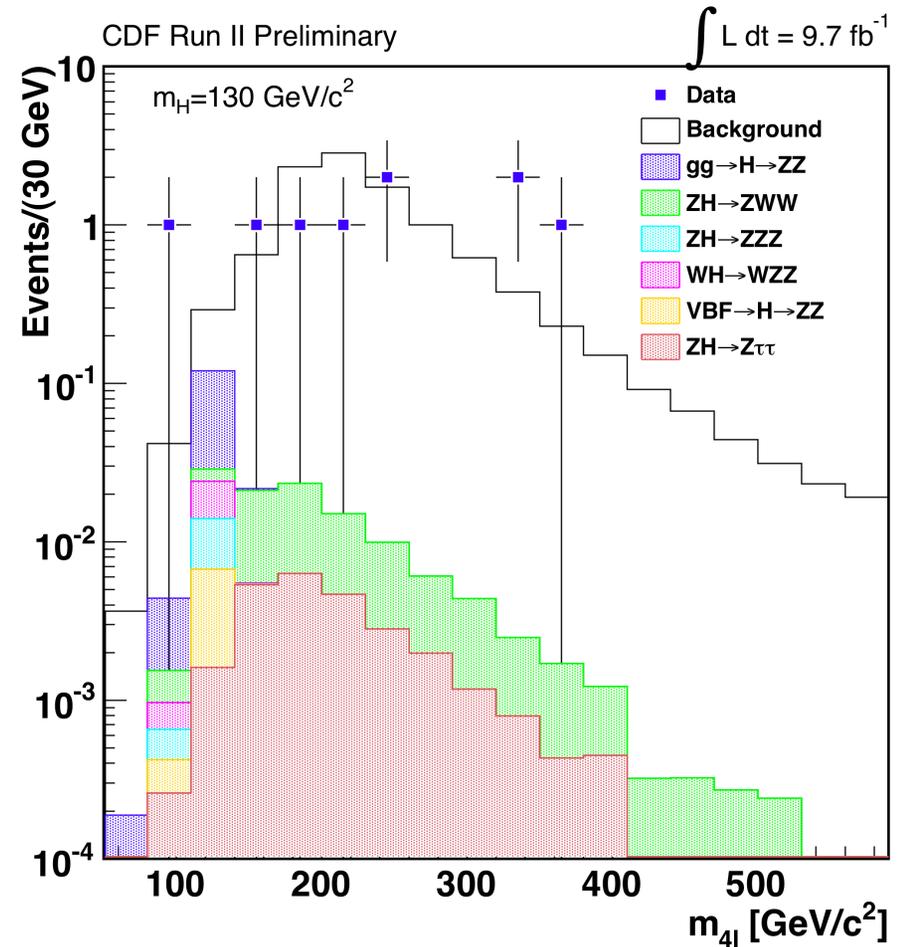


# SM Higgs Decay

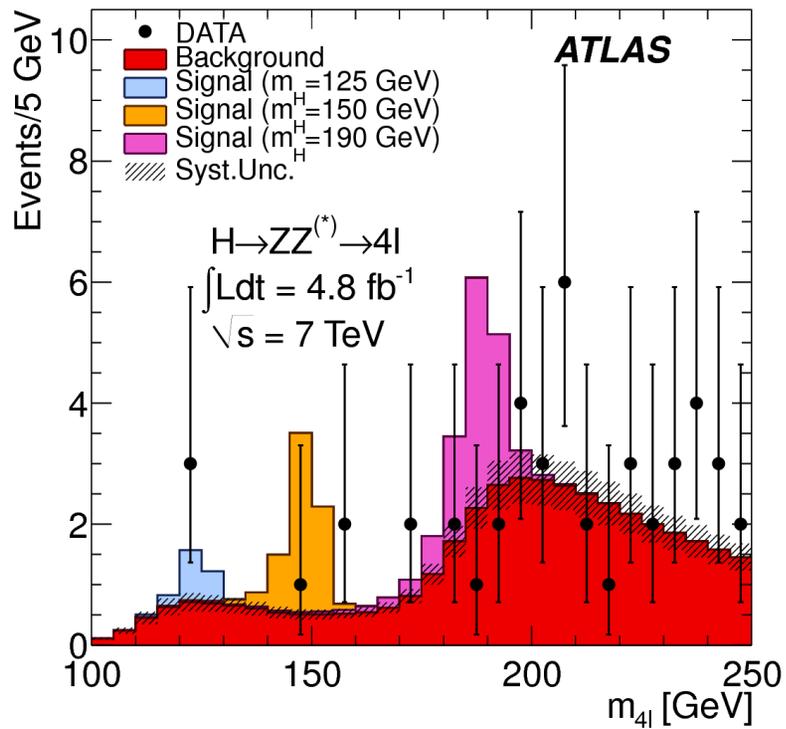


# H $\rightarrow$ ZZ $\rightarrow$ 4 leptons

- Small expected signal rates
- Low SM backgrounds
- Narrow Higgs boson mass resonance easy to separate from non-resonant background contributions



# H → ZZ → 4 leptons

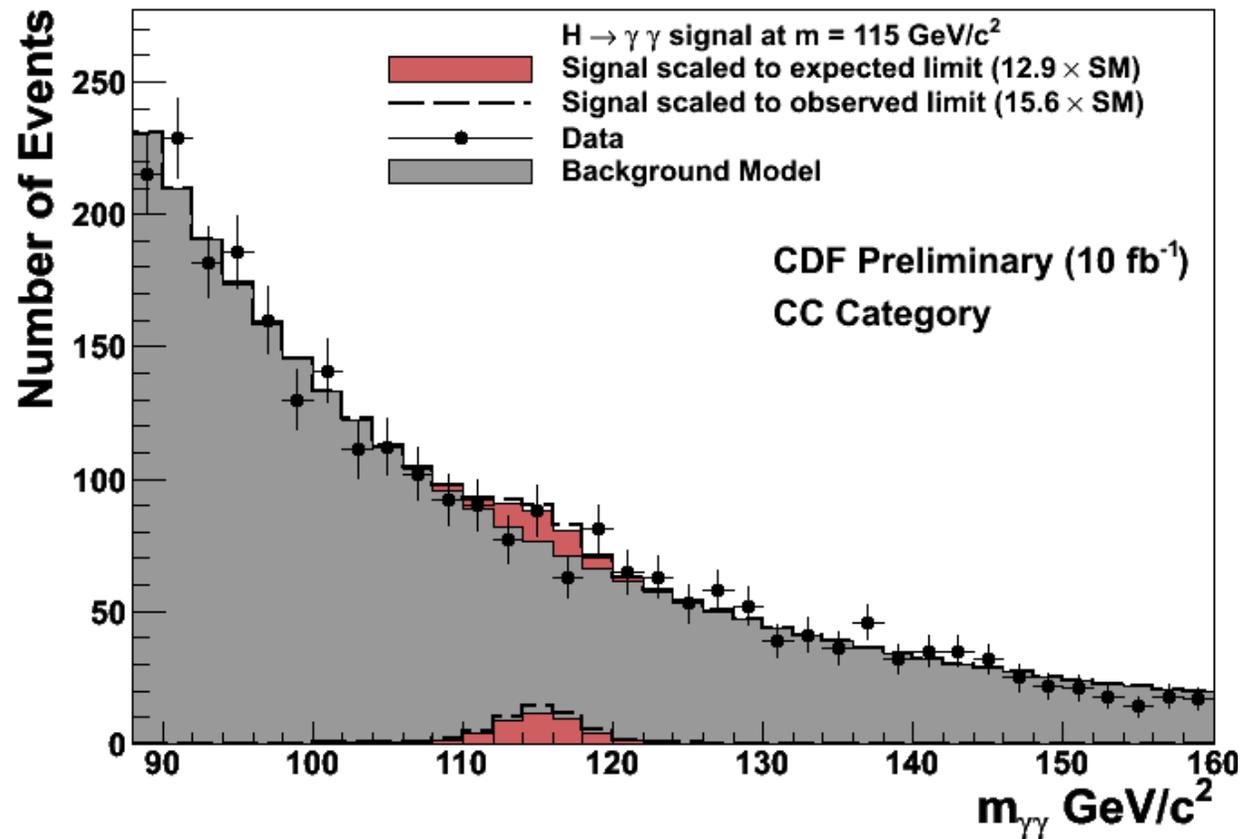


Sqrt(s)	2 TeV	7 TeV	8 TeV
Luminosity	10 fb-1	5 fb-1	5 fb-1
Signal Events	2.1	16	20
Detector	CDF	ATLAS	ATLAS
Signal Yield	0.2	2.7	?
Sensitivity	18xSM	1.5xSM	?

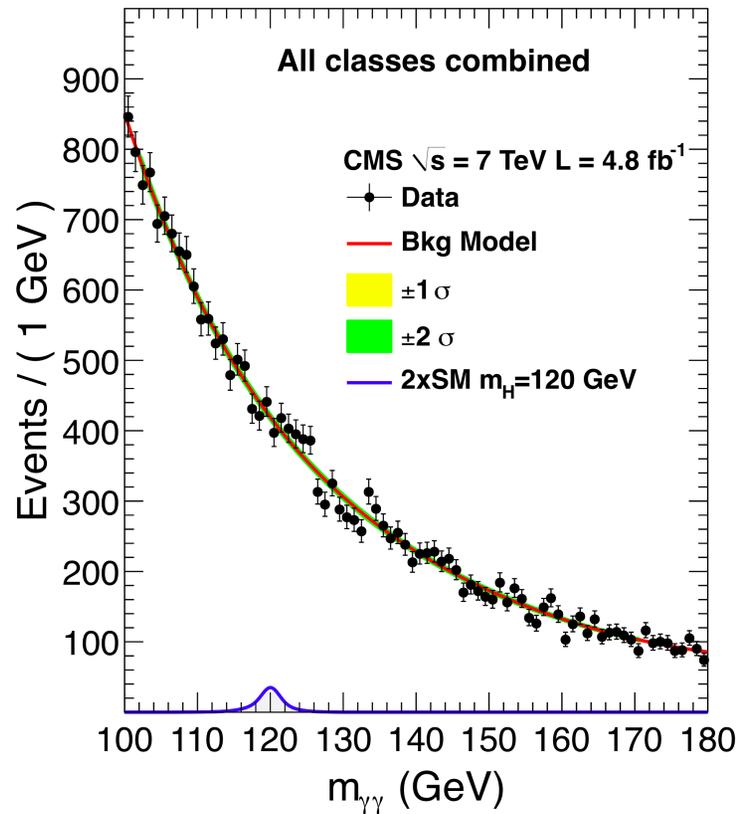
$m_H = 130 \text{ GeV}$

# $H \rightarrow \gamma\gamma$

- Slightly larger expected signal rates
- Larger non-resonant SM backgrounds
- Signal appears as narrow mass resonance on top of falling background spectrum



# H → γγ

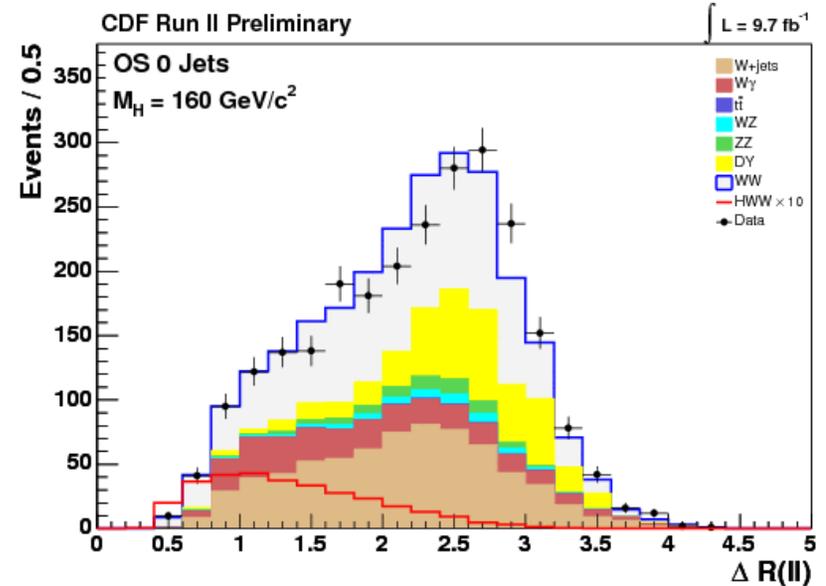
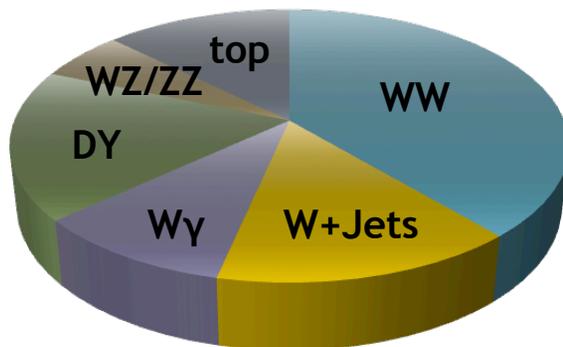
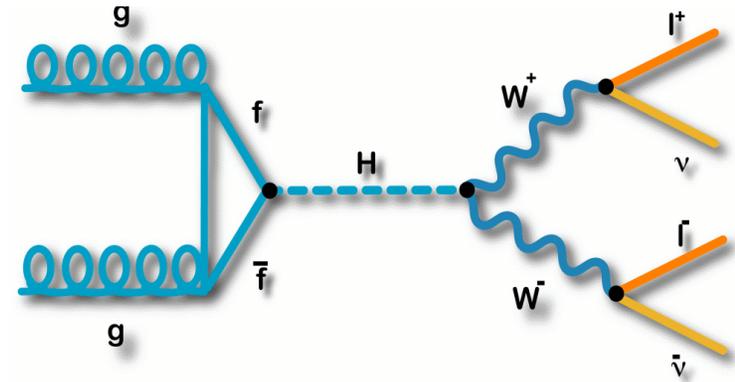


Sqrt(s)	2 TeV	7 TeV	8 TeV
Luminosity	10 fb-1	5 fb-1	5 fb-1
Signal Events	28	200	255
Detector	CDF	CMS	CMS
Signal Yield	7	75	?
Sensitivity	11xSM	1.4xSM	?

$m_H = 125 \text{ GeV}$

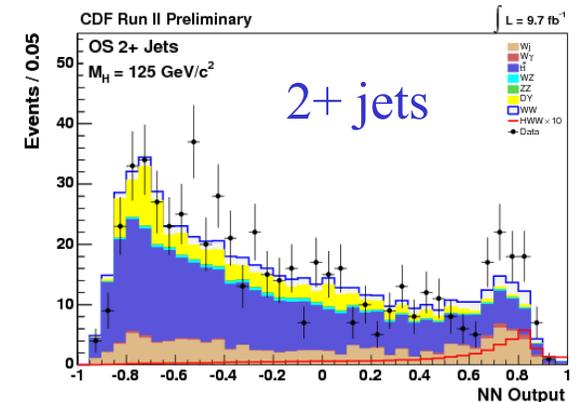
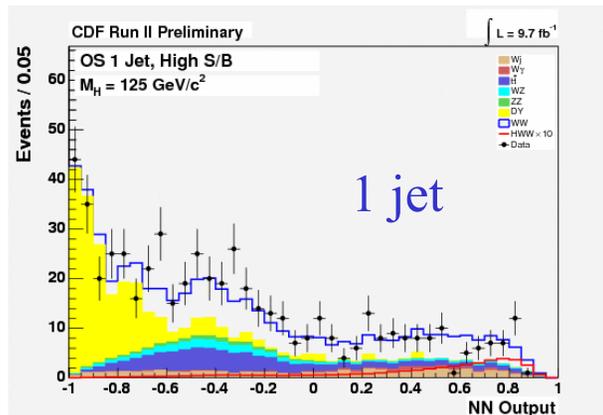
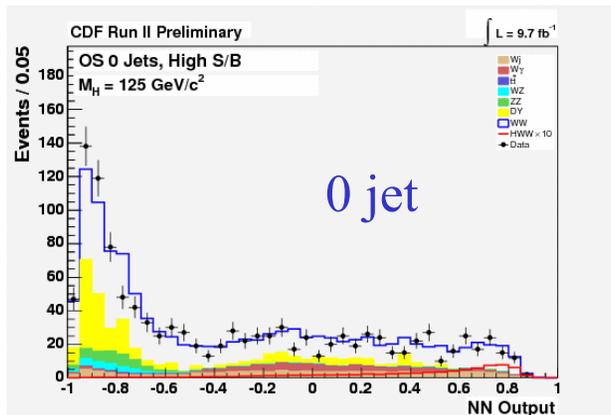
# $H \rightarrow WW \rightarrow l\nu l\nu$

- Basic event selection is two reconstructed leptons and missing  $E_T$
- Presence of two neutrinos in final state prevents complete Higgs mass reconstruction
- Separate potential signal from large backgrounds using kinematic event information



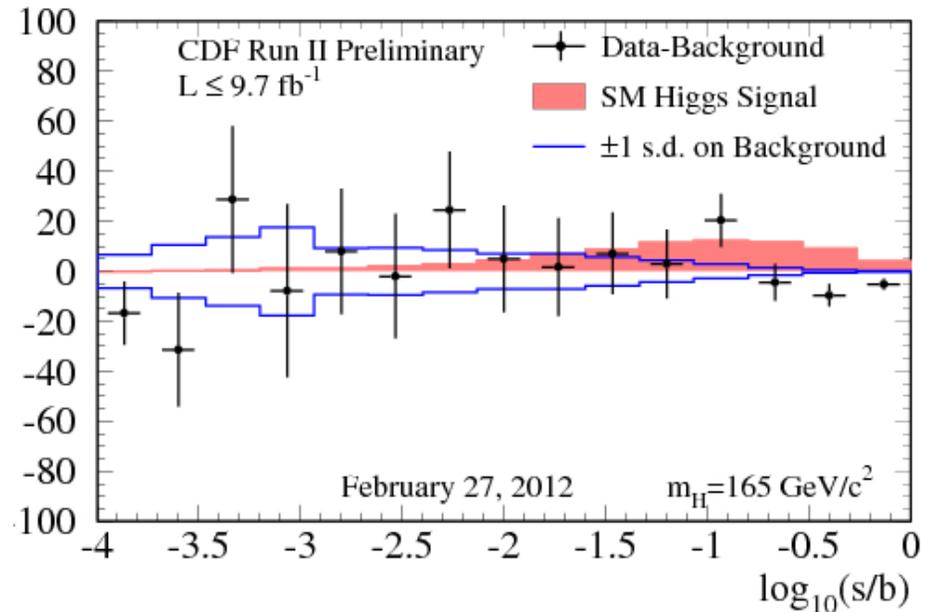
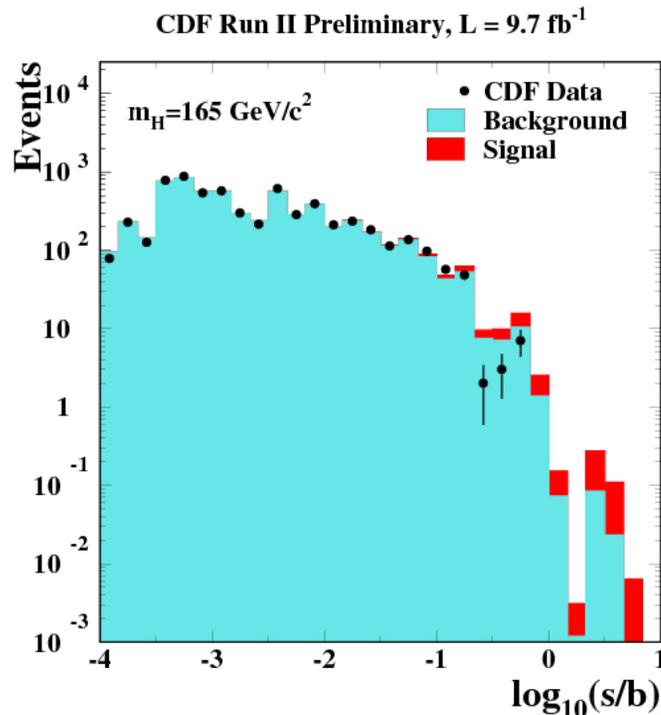
# $H \rightarrow WW \rightarrow l\nu l\nu$

- Multi-variate techniques are used to exploit as much kinematic event information as possible
- Data are separated into multiple search samples to isolate contributions from specific signal and background processes



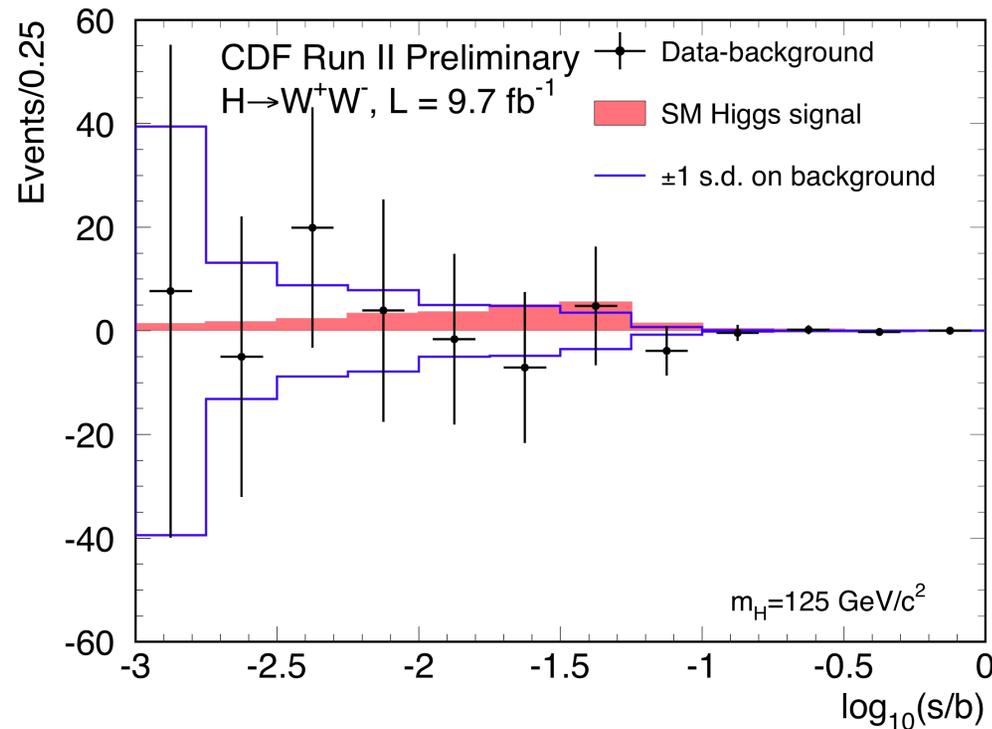
# $H \rightarrow WW \rightarrow l\nu l\nu$

- Results from thirteen independent search samples are combined to obtain the best possible sensitivity
- No significant, observed excesses in data above predicted SM background contributions

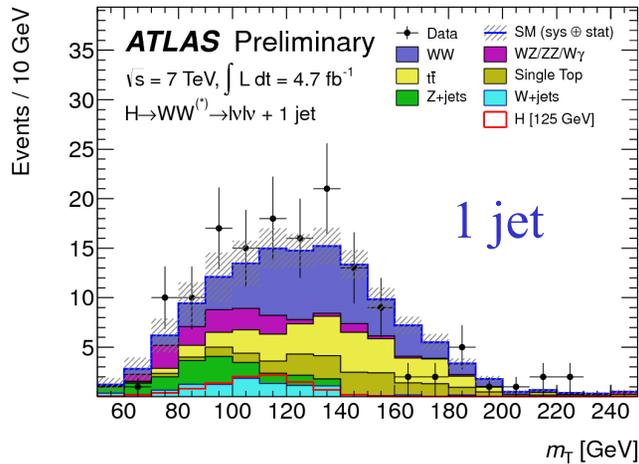
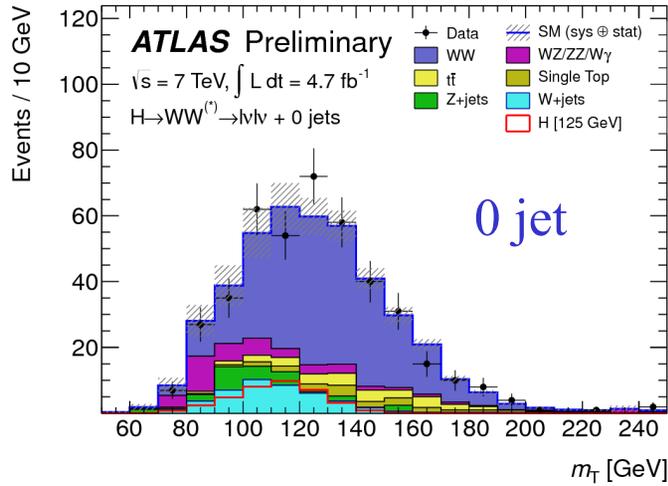


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# H → WW → lνlν

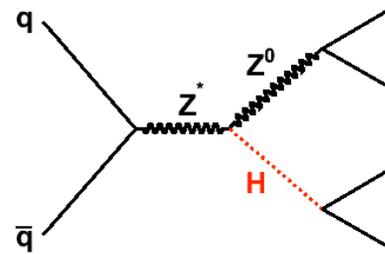


Sqrt(s)	2 TeV	7 TeV	8 TeV
Luminosity	10 fb-1	5 fb-1	5 fb-1
Signal Events	170	1215	1550
Detector	CDF	ATLAS	ATLAS
High S/B Signal Yield	7	32	?
Sensitivity	3.1xSM	1.2xSM	?

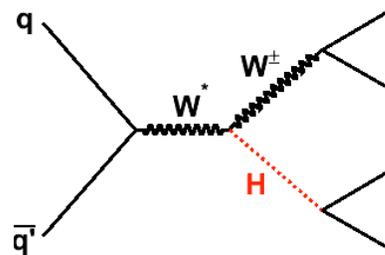
$m_H = 125 \text{ GeV}$

# H → bb

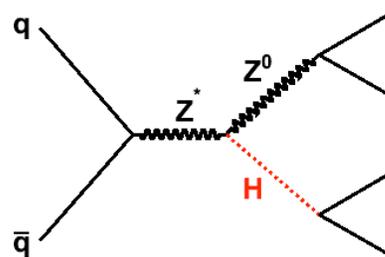
- Tevatron searches in this decay mode are still the world's most sensitive
- Basic event selection is 0, 1, or 2 leptons and/or missing  $E_T$  plus two high  $E_T$  jets
- Challenge is separating the small number of potential signal events from the much larger SM background contributions



$ZH \rightarrow \nu\bar{\nu}bb$



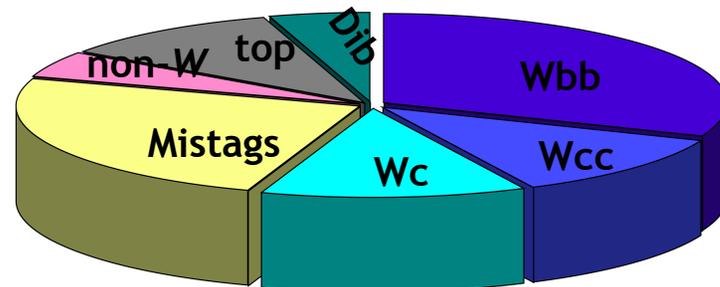
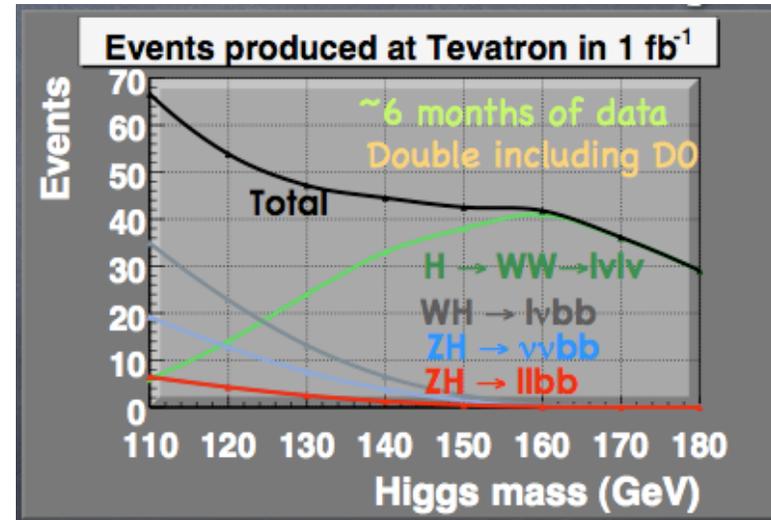
$WH \rightarrow l\bar{l}bb$



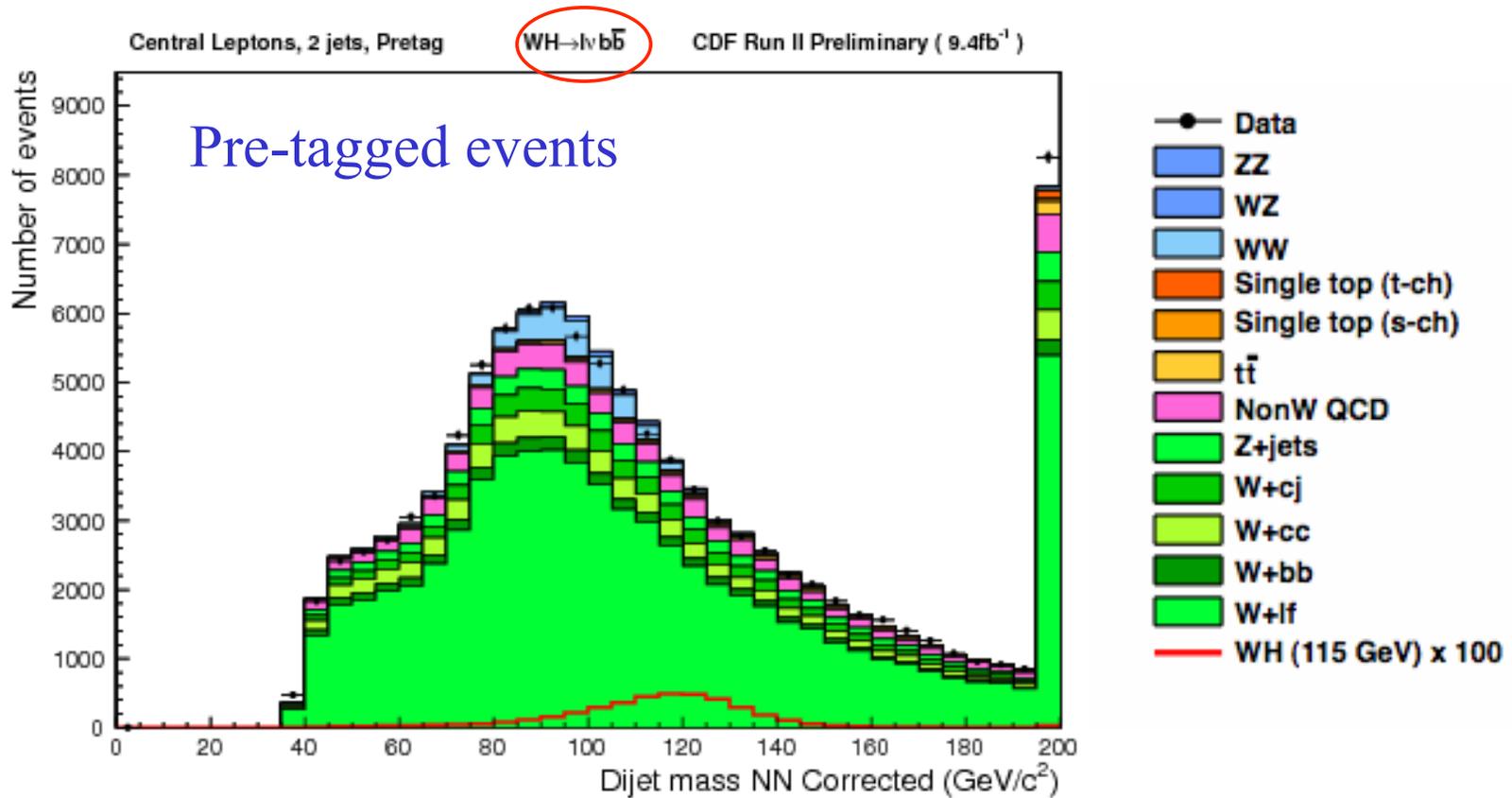
$ZH \rightarrow l\bar{l}bb$

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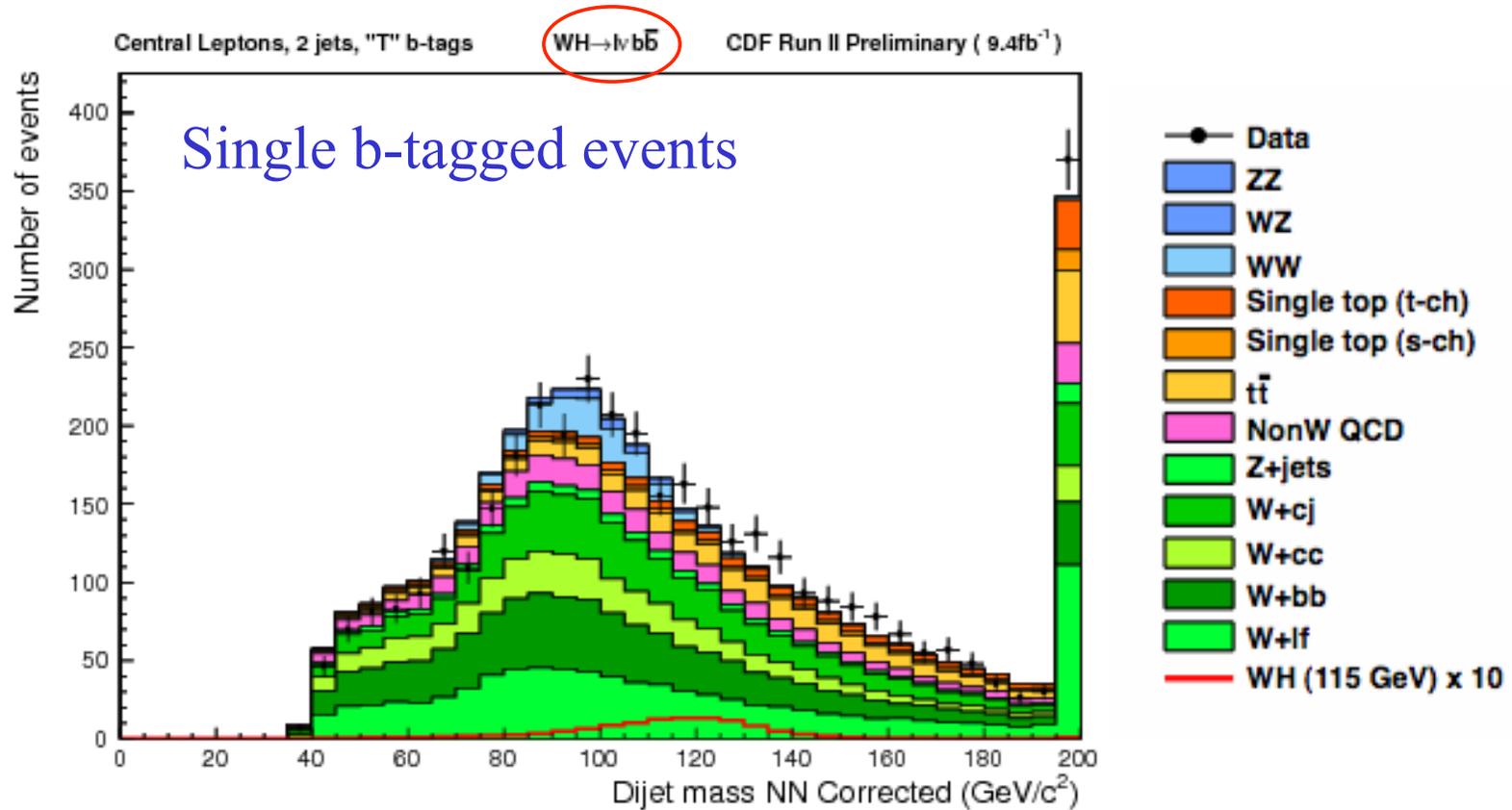


Focus on Increasing lepton reconstruction and selection efficiencies

Improving the efficiency for tagging bottom quark jets

Optimizing dijet mass resolution

# H → bb

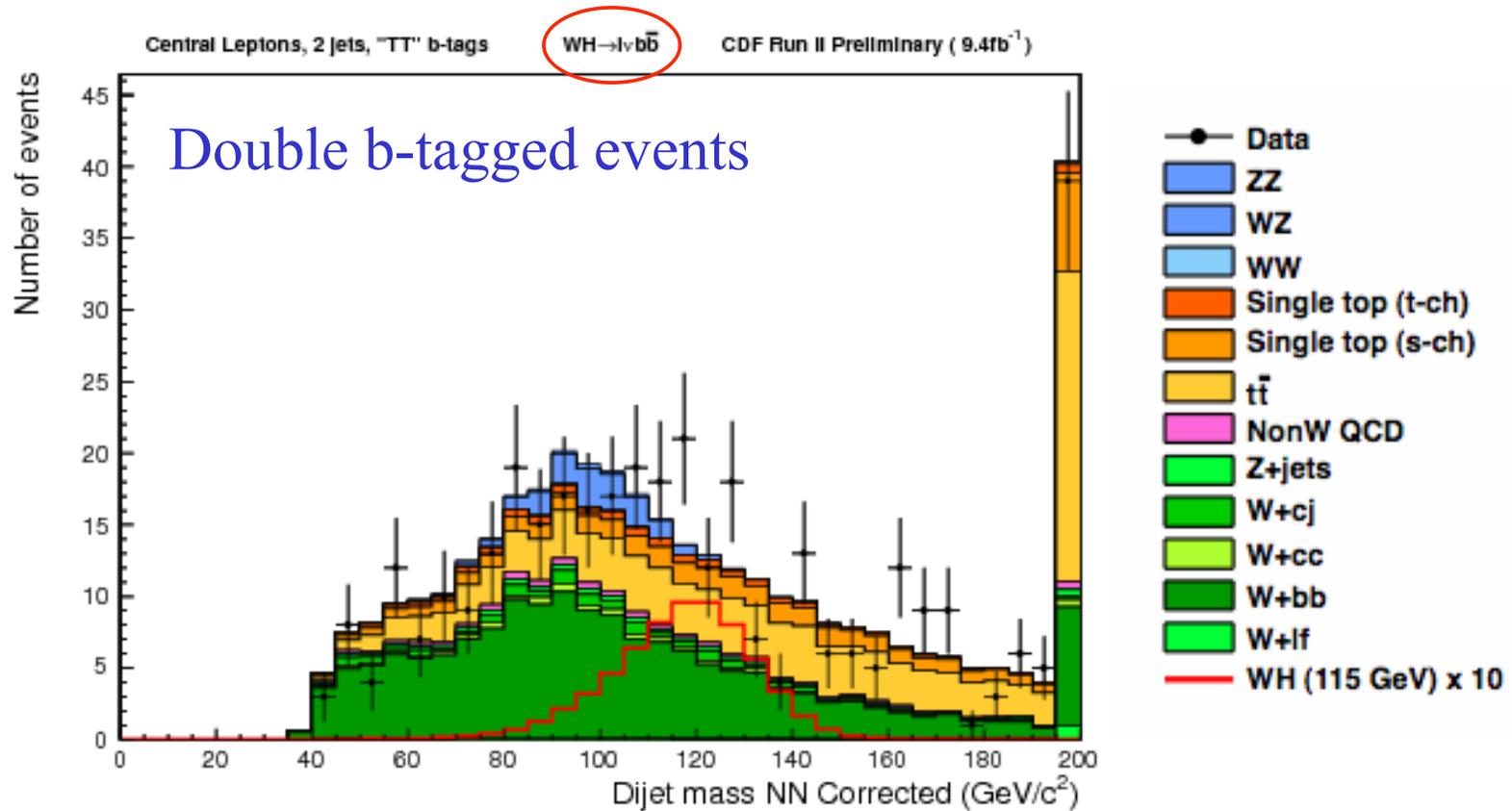


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# H → bb



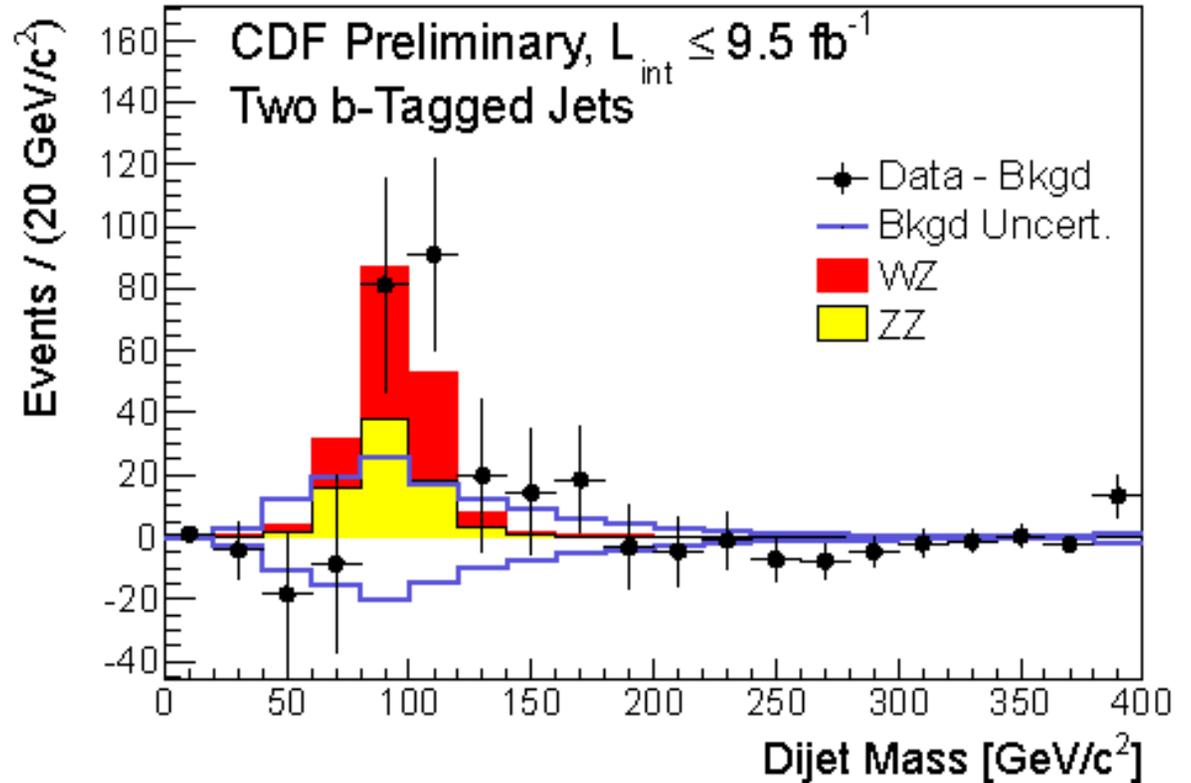
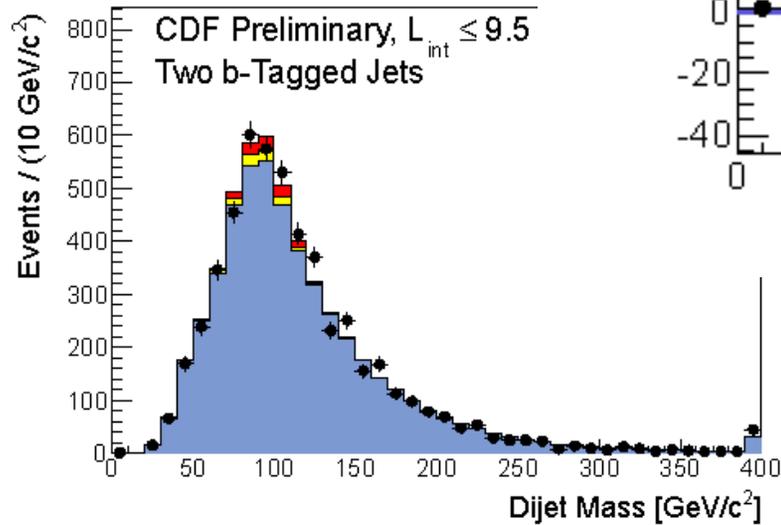
Focus on Increasing lepton reconstruction and selection efficiencies

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# Validation of $H \rightarrow bb$

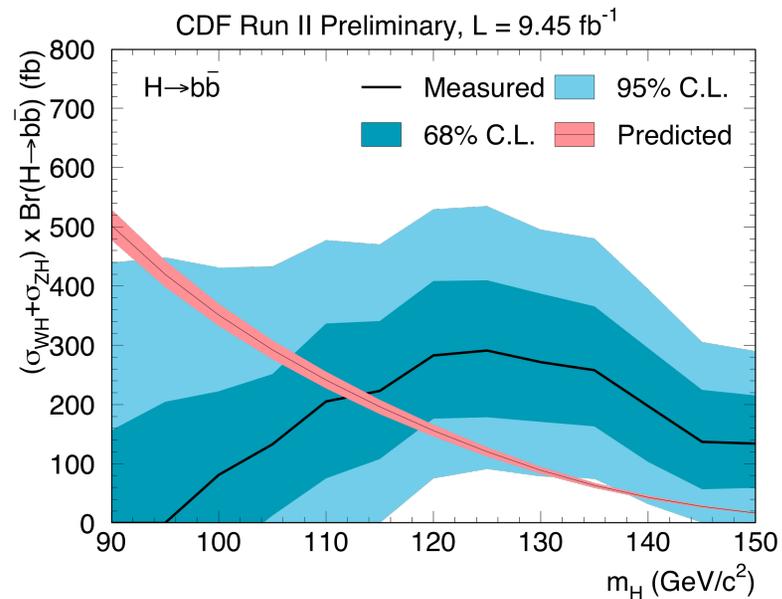
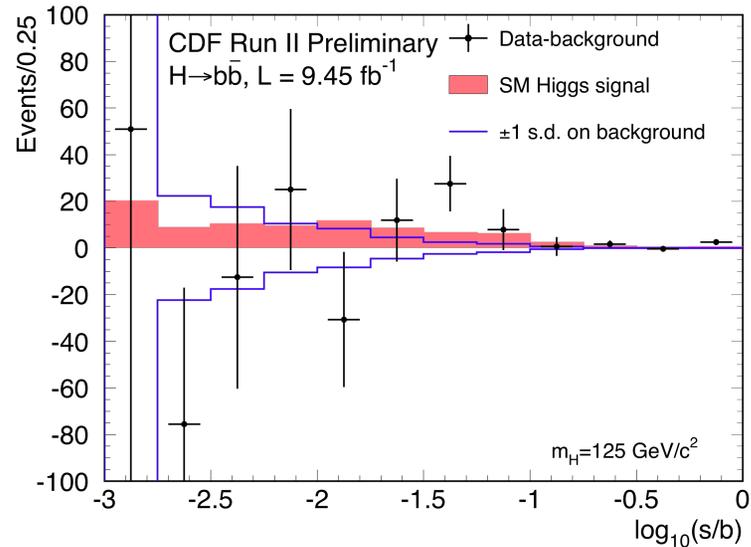
- Background model validation
- Measure  $WZ/ZZ$  with  $Z \rightarrow bb$



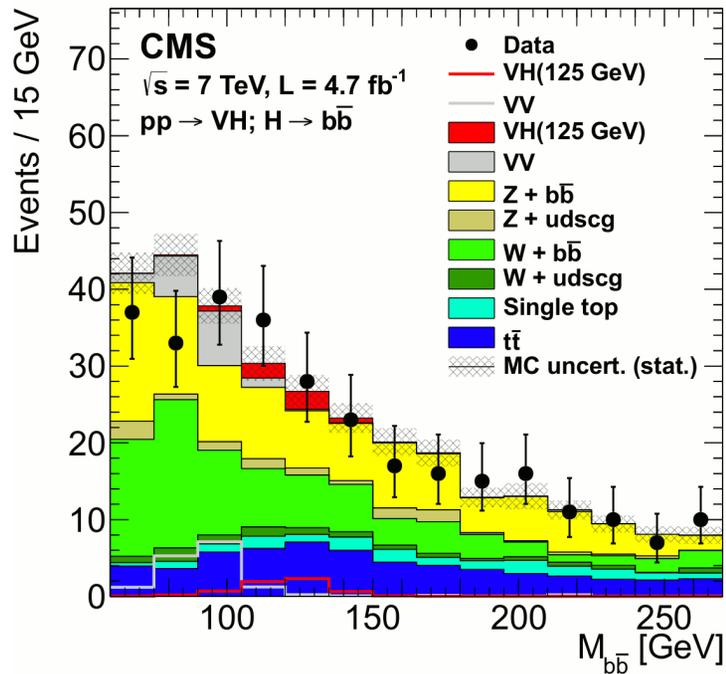


# H → bb

- Data excess above the predicted SM background contributions in the highest S/B discriminant bins
- Fitted Higgs cross section is about 2x SM expectation at  $m_H = 125 \text{ GeV}$  (and also consistent with SM at  $\sim 1.5\sigma$ )
- Maximum local p-value associated with excess is  $2.7\sigma$  corresponding to global p-value of  $2.5\sigma$



# H → bb

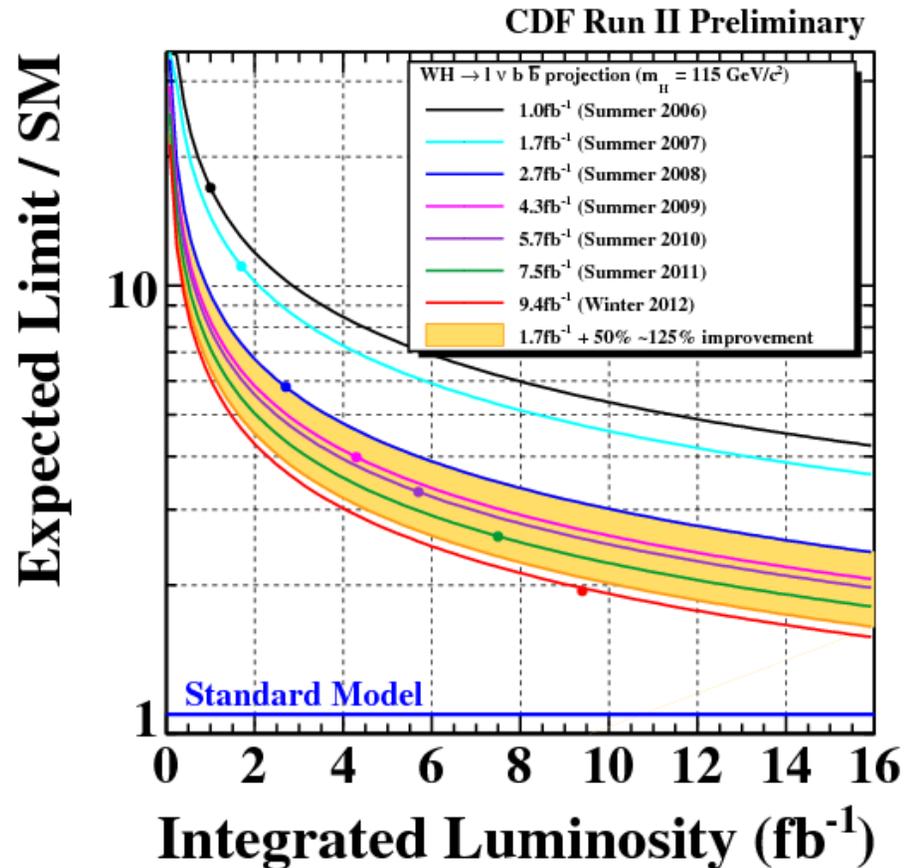


Sqrt(s)	2 TeV	7 TeV	8 TeV
Luminosity	10 fb-1	5 fb-1	5 fb-1
Signal Events	315	670	820
Detector	CDF	CMS	CMS
High S/B Signal Yield	13.7	5	?
Sensitivity	1.7xSM	4.3xSM	?

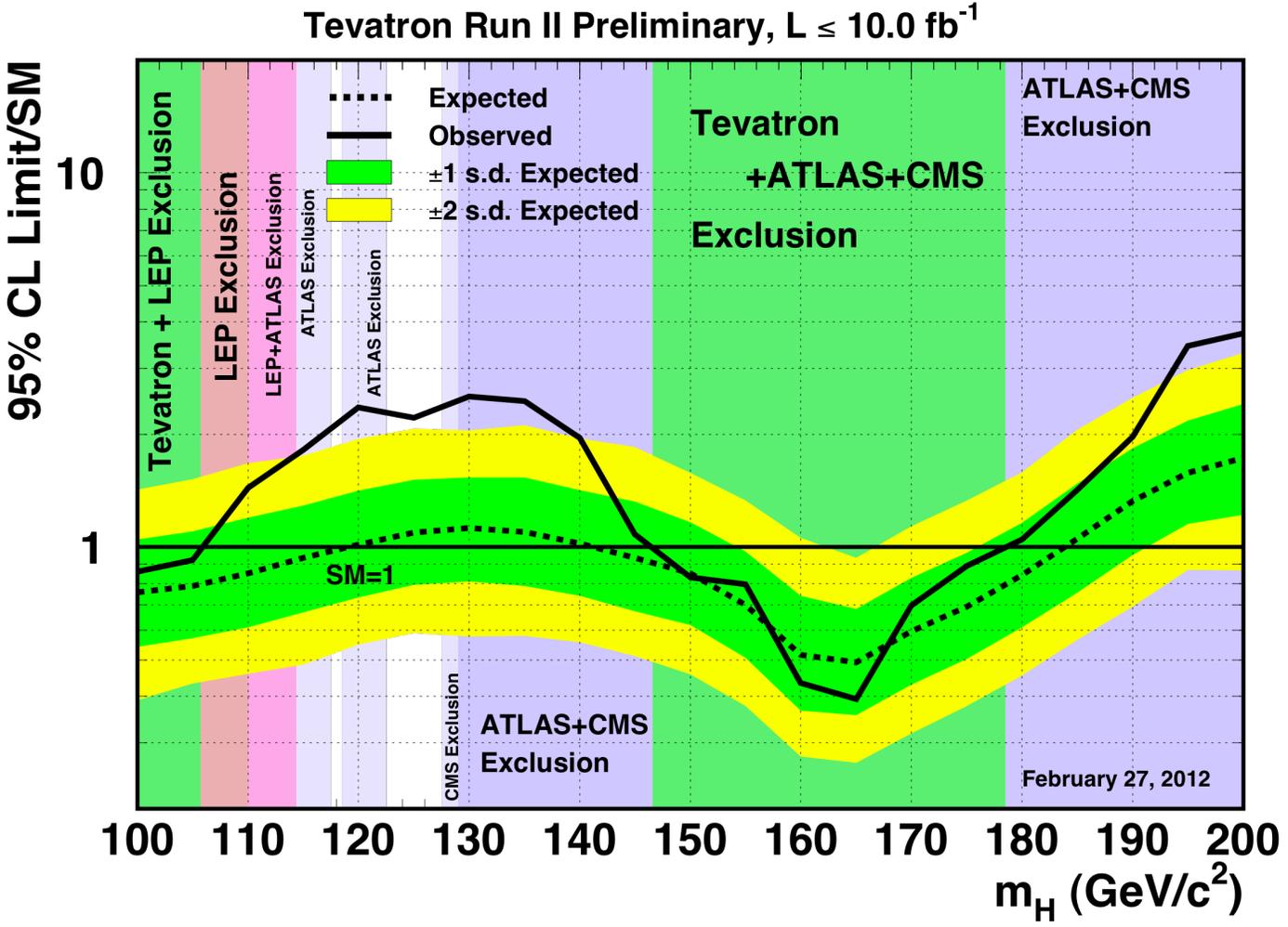
$$m_H = 125 \text{ GeV}$$

# Summarizing CDF searches

- CDF Higgs searches have exceeded our most optimistic sensitivity projections from five years ago
- Work still in progress to incorporate neural network bottom quark tagging in  $ZH \rightarrow \nu b b$  search
- If a Higgs boson is found, goal moving forward will be best possible measurement of  $\sigma(\text{WH}+\text{ZH}) \times \text{Br}(\text{H} \rightarrow \text{bb})$



# Current Landscape

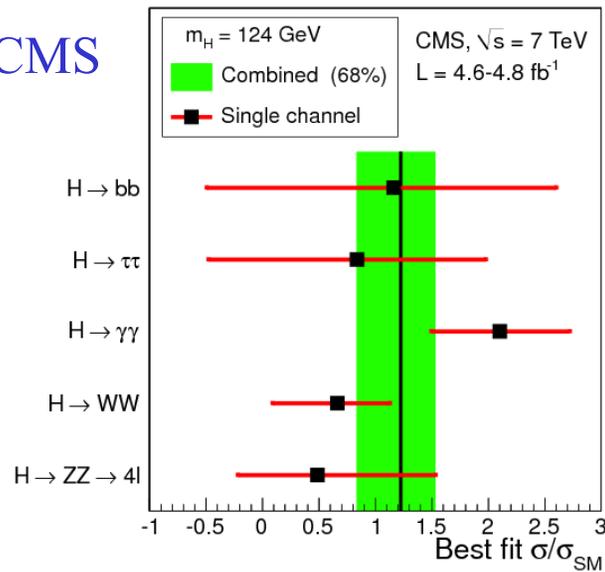


Spring 2012  
Results

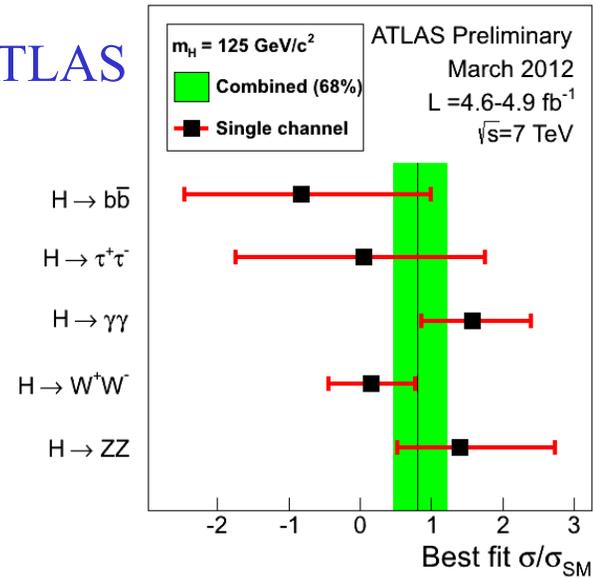
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Spring 2012  
Results

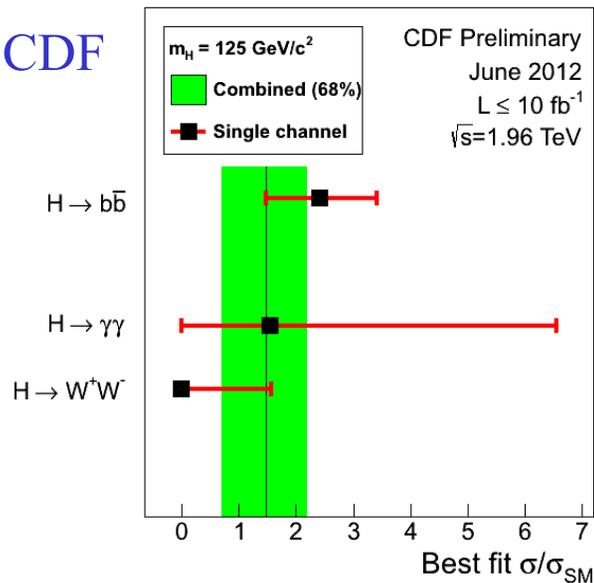
CMS



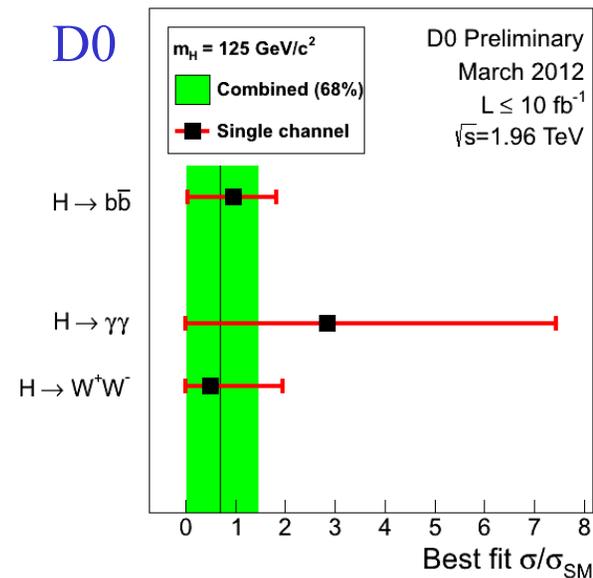
ATLAS



CDF



D0



# Current Landscape

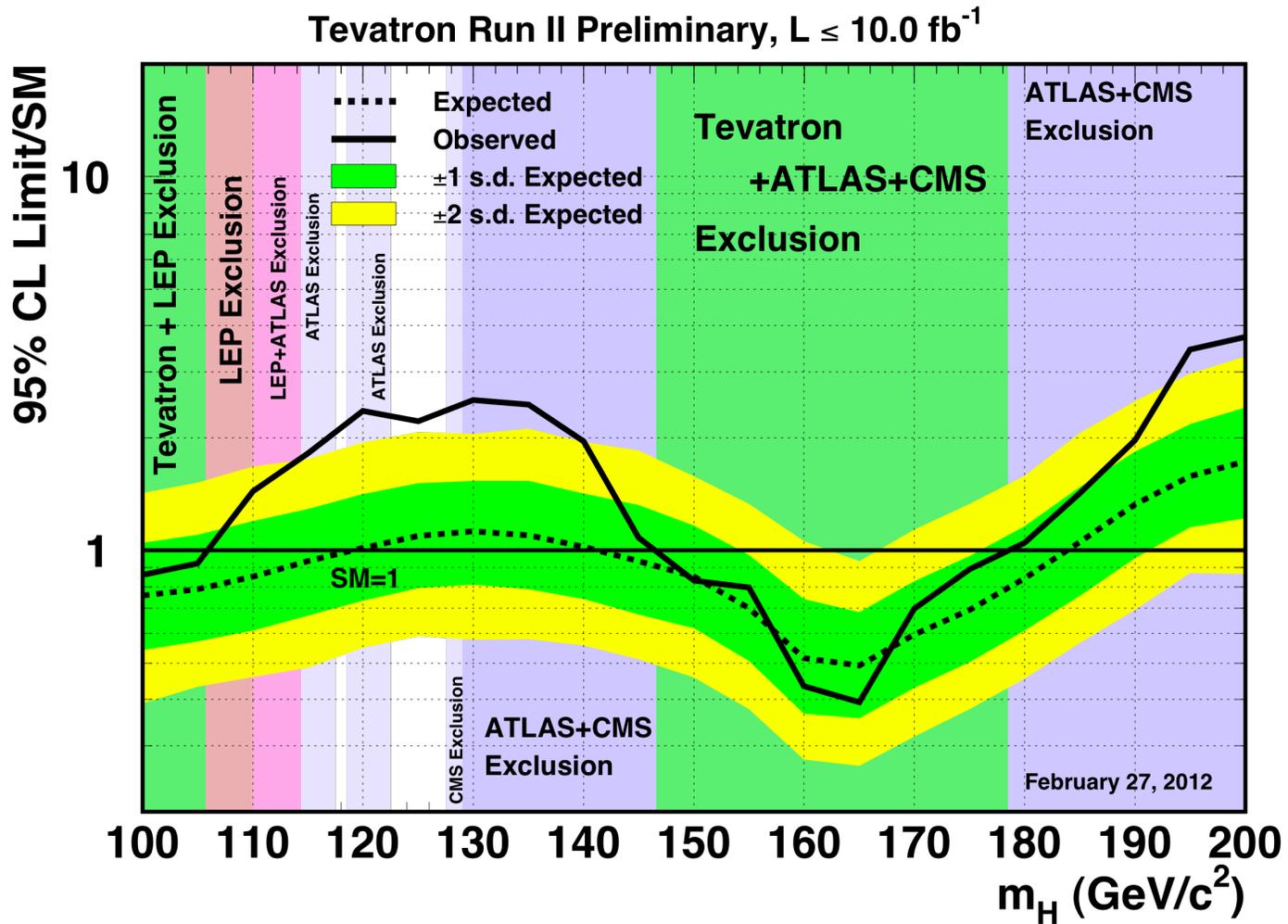
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SM Higgs Searches		
Experiment	Local P-value	Global P-value
CDF+D0	2.8 $\sigma$	2.2 $\sigma$
ATLAS	2.9 $\sigma$	1.6 $\sigma$
CMS	3.1 $\sigma$	2.1 $\sigma$

Spring 2012  
Results

Single Channel Searches			
Experiment	Channel	Local P-value	Global P-value
CDF	H->bb	2.7 $\sigma$	2.5 $\sigma$
ATLAS	H-> $\gamma\gamma$	2.8 $\sigma$	1.5 $\sigma$
CMS	H-> $\gamma\gamma$	3.1 $\sigma$	1.8 $\sigma$

# Summer 2012



And now to new results ...