Tevatron Combination of SM Higgs Searches and Fourth Generation Limits

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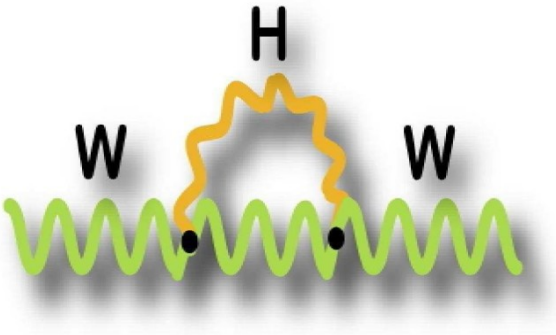
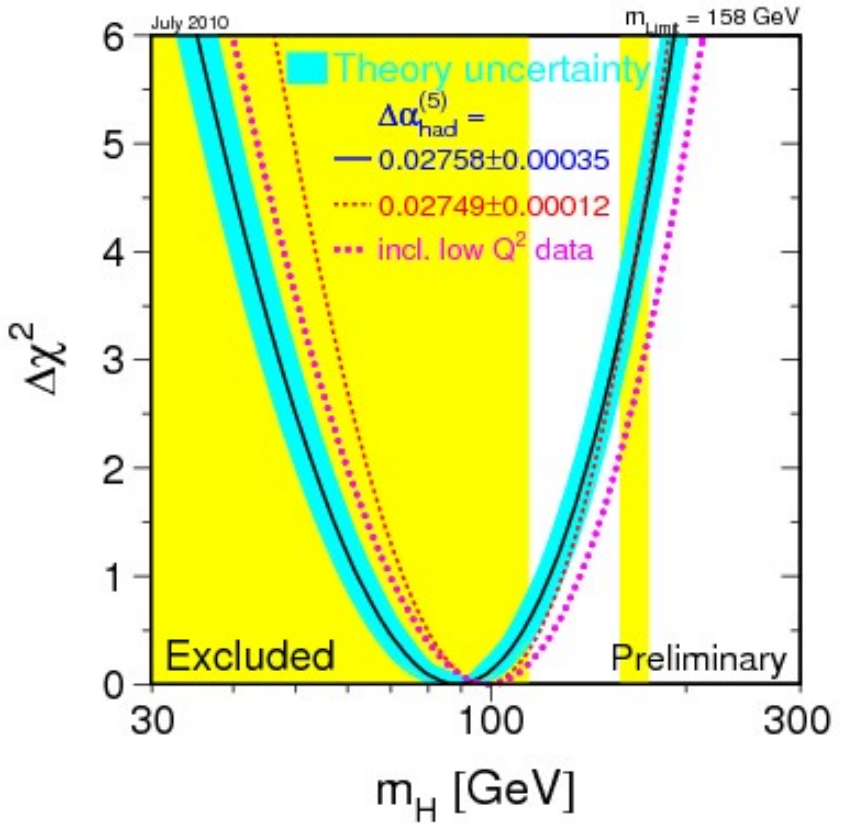
For the CDF and DØ Collaborations

19th International Conference on Supersymmetry and Unification Of Fundamental Interactions

Fits and Constraints

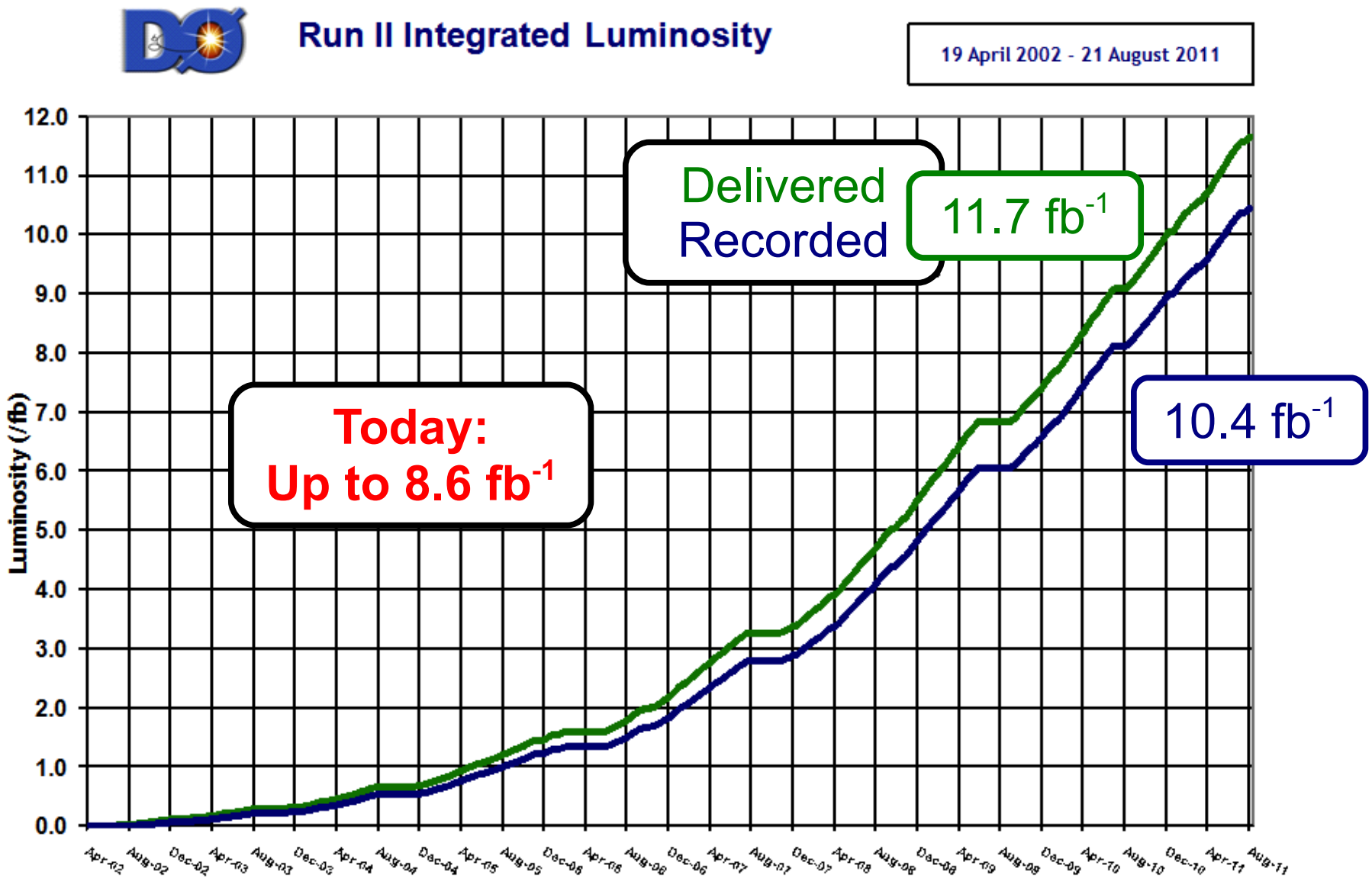
- Electroweak symmetry breaking is a cornerstone of the standard model
- Higgs mechanism provides mass for the W and Z
- A consequence of this is the Higgs boson
- Mass is not predicted





M_H < 158 GeV (indirect constraints)

M_H < 185 GeV (include LEP search)


Run II Integrated Luminosity
19 April 2002 - 21 August 2011
Delivered
Recorded
11.7 fb-1
10.4 fb-1
Today:
Up to 8.6 fb-1
Luminosity (/fb)
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
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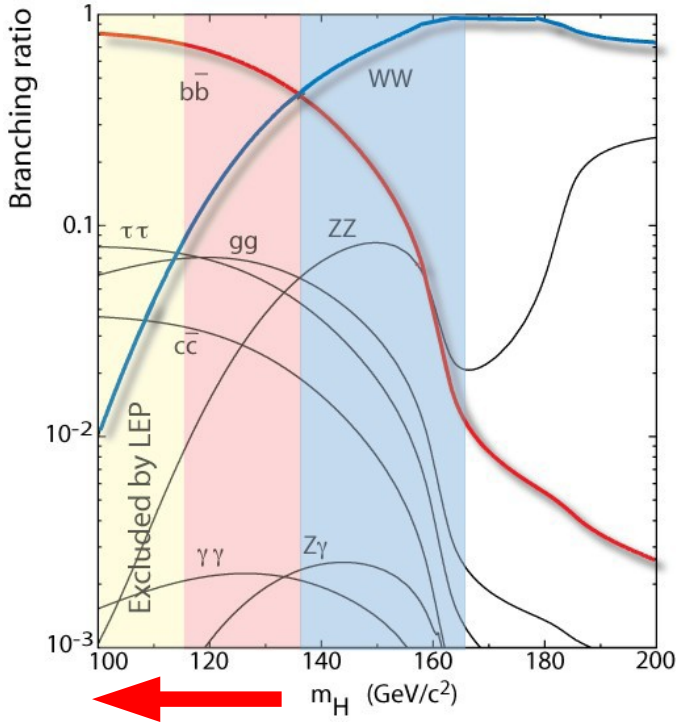
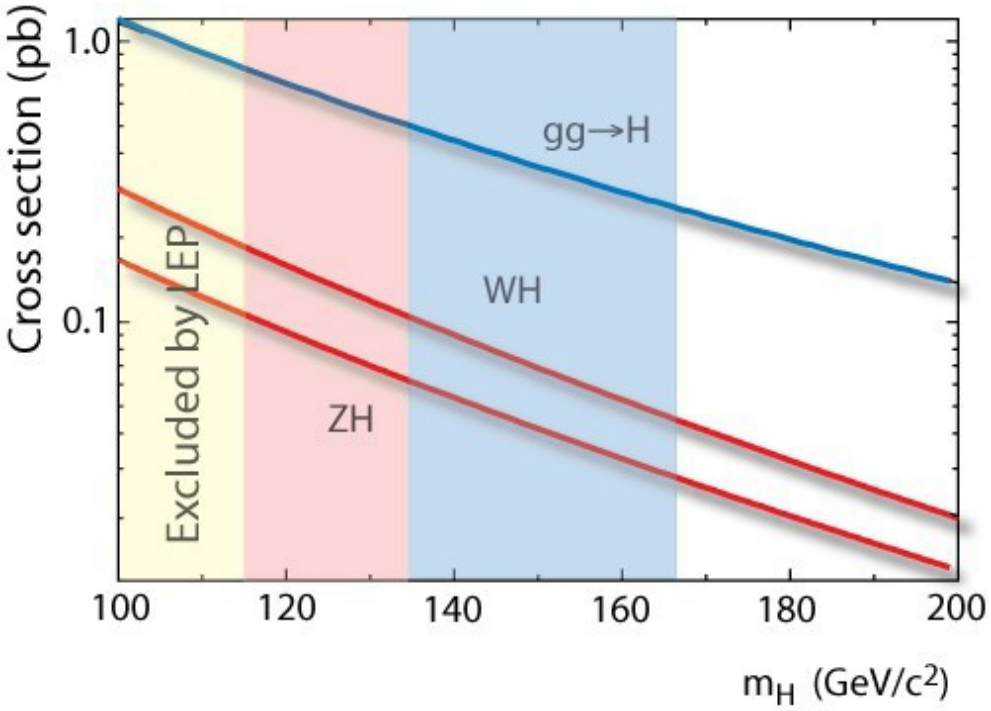
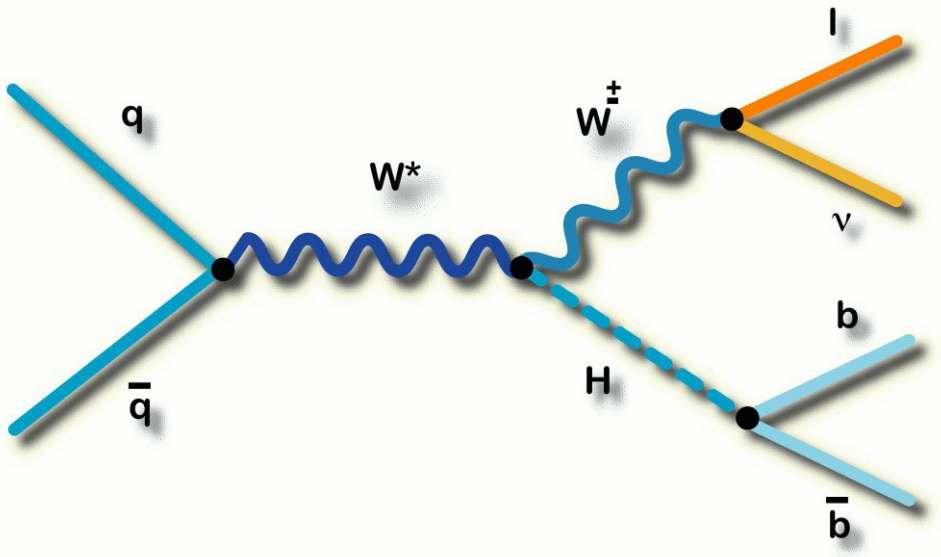
Aug-11

Higgs Production and Decay

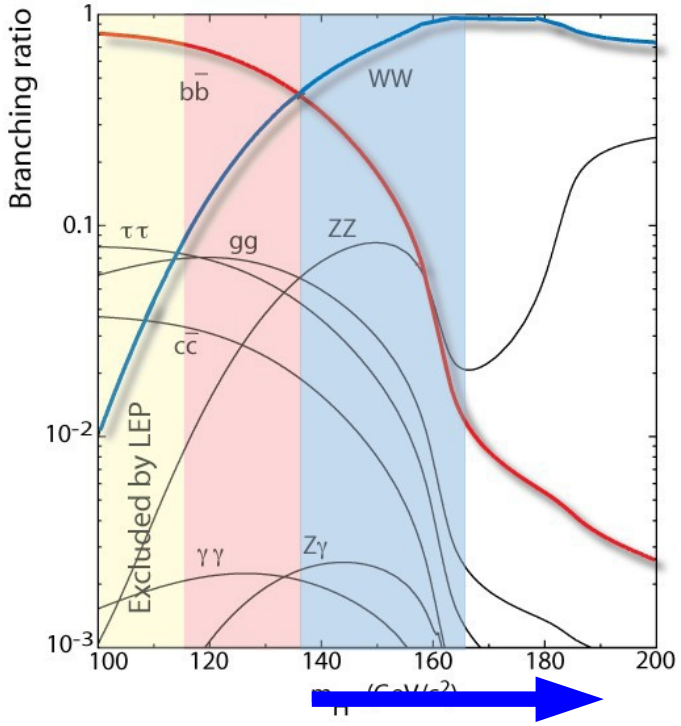


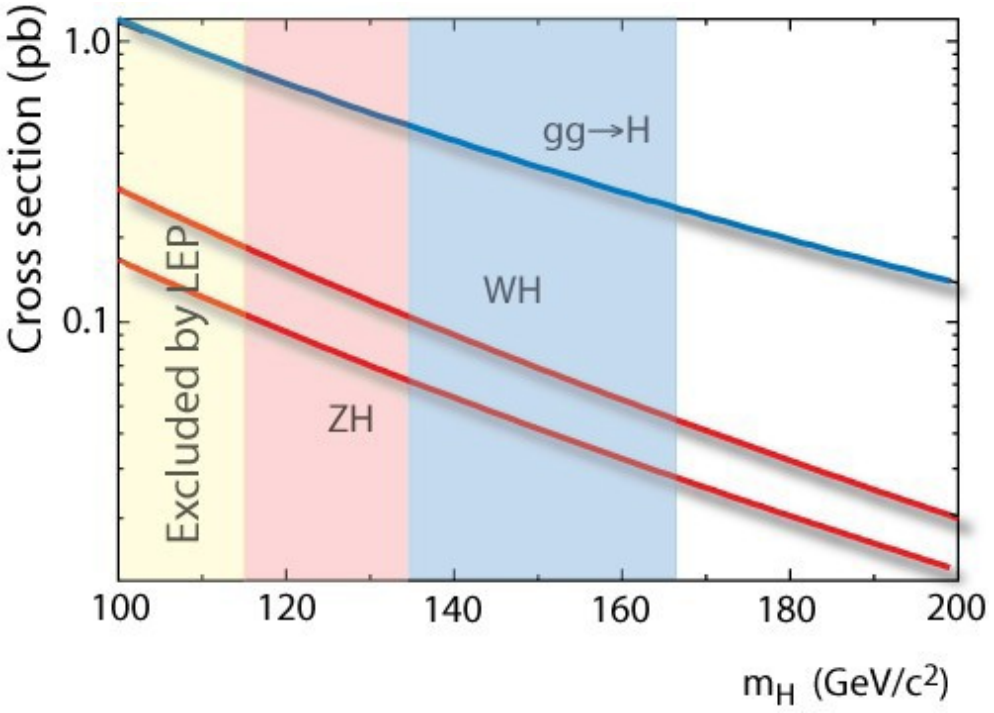


- For M_H <≈ 135 GeV, $H \rightarrow b\bar{b}$ dominates
- Control bg with leptons from associated W/Z

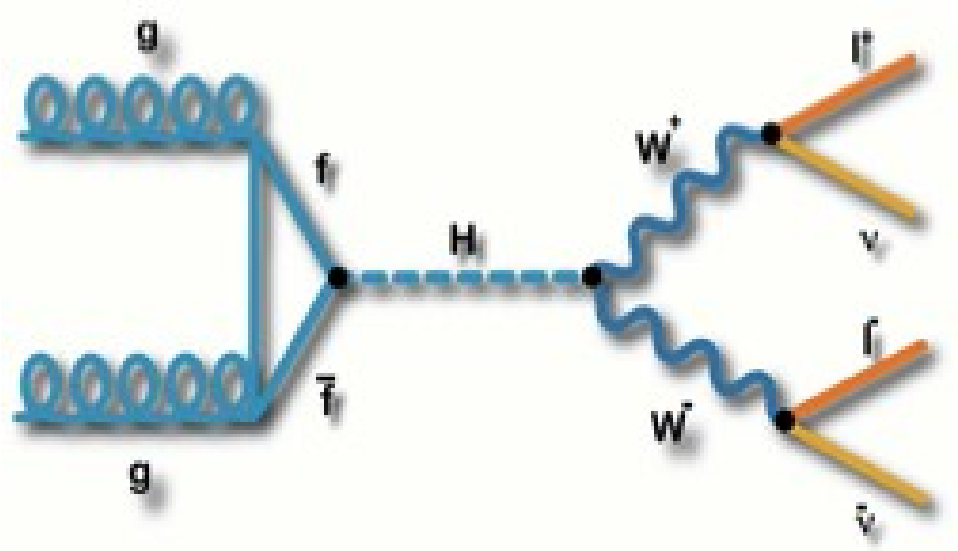


Higgs Production and Decay





- For $M_H \gtrsim 135$ GeV, $H \rightarrow WW$ dominates
- Control bg with leptons from W decays



Leave No Higgs Behind

Channel	Luminosity (fb^{-1})	m_H range (GeV/c^2)	Reference
$WH \to \ell\nu bb$ 2-jet channels 4×(TDT,LDT,ST,LDTX)	7.5	100-150	[5]
$WH \to \ell\nu b\bar{b}$ 3-jet channels 2×(TDT,LDT,ST)	5.6	100-150	[6]
$ZH \to \nu\bar{\nu}b\bar{b}$ (TDT,LDT,ST)	7.8	100-150	[7]
$ZH \to \ell^+\ell^- b\bar{b}$ 2×(TDT,LDT,ST)	7.7	100-150	[8, 9]
$H \to W^+W^-$ 2×(0 jets,1 jet)+(2 or more jets)+(low-$m_{\ell\ell}$)+(e-τ_{had})+(μ-τ_{had})	8.2	110-200	[10]
$WH \to WW^+W^-$ (same-sign leptons)+(tri-leptons)	8.2	110-200	[10]
$ZH \to ZW^+W^-$ (tri-leptons with 1 jet)+(tri-leptons with 2 or more jets)	8.2	110-200	[10]
	8.2	110-200	[11]
$H + X \to \tau^+\tau^-$ (1 jet)+(2 jets)	6.0	100-150	[12]
$WH \to \ell\nu\tau^+\tau^-/ZH \to \ell^+\ell^-\tau^+\tau^-$ (ℓ-ℓ-τ_{had})+(e-μ-τ_{had})+(ℓ-τ_{had}-τ_{had})	6.2	110-150	[13]
$WH + ZH \to jjb\bar{b}$ (GF,VBF)×(TDT,LDT)	4.0	100-150	[14]
$H \to \gamma\gamma$ (CC,CP,CC-Conv,PC-Conv)	7.0	100-150	[15]
$t\bar{t}H \to WWb\bar{b}b\bar{b}$ (lepton) (4jet,5jet)×(TTT,TTL,TLL,TDT,LDT)	6.3	100-150	[16]
$t\bar{t}H \to WWb\bar{b}b\bar{b}$ (no lepton) (low met,high met)×(2 tags,3 or more tags)	5.7	100-150	[17]

TABLE III: Luminosity, explored mass range and references for the different processes and final states ($\ell = e, \mu$) for the D0 analyses.

Channel	Luminosity (fb^{-1})	m_H range (GeV/c^2)	Reference
$WH \to \ell\nu bb$ (LST,LDT,2,3 jet)	8.5	100-150	[18]
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$ZH \to \ell^+\ell^- b\bar{b}$ (TST,TLDT,ee,$\mu\mu$,ee_{ICR},$\mu\mu_{trk}$)	8.6	100-150	[20]
$H+X \to \ell^{\pm}\tau^{\mp}_{\text{had}}jj$	4.3	105-200	[21]
$VH \to \ell^{\pm}\ell^{\pm} + X$	5.3	115-200	[22]
$H \to W^+W^- \to \ell^{\pm}\nu\ell^{\mp}\nu$ (0,1,2+ jet)	8.1	115-200	[23]
$H \to W^+W^- \to \mu\nu\tau_{\text{had}}\nu$	7.3	115-200	[24]
$H \to W^+W^- \to \ell\bar{\nu}jj$	5.4	130-200	[25]
$H \to \gamma\gamma$	8.2	100-150	[26]

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Many different channels from both CDF and DØ

For more details, see talks by X. Bu, G. Facini, S. Shalhout, R. Nayyar

TABLE III: Luminosity, explored mass range and references for the different processes and final states ($\ell = e, \mu$) for the D0 analyses.

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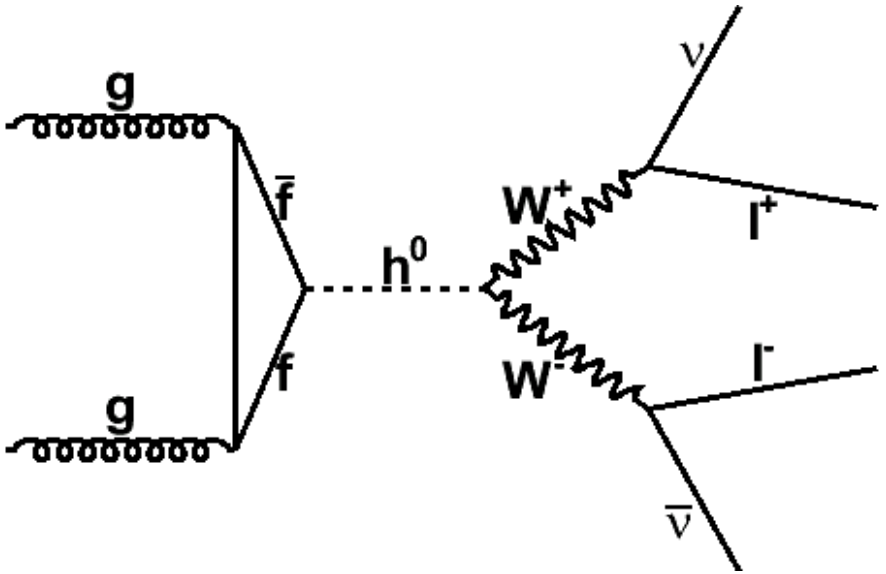
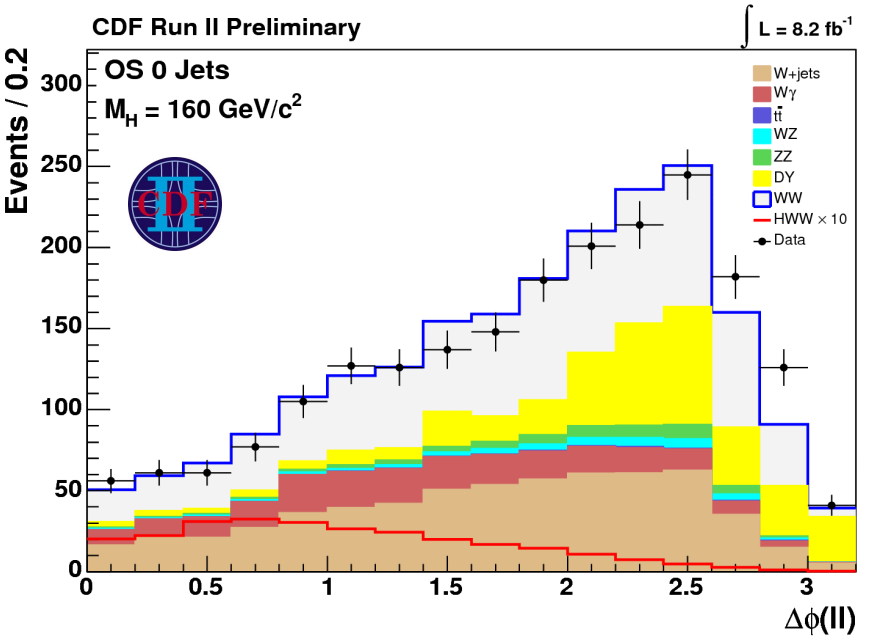
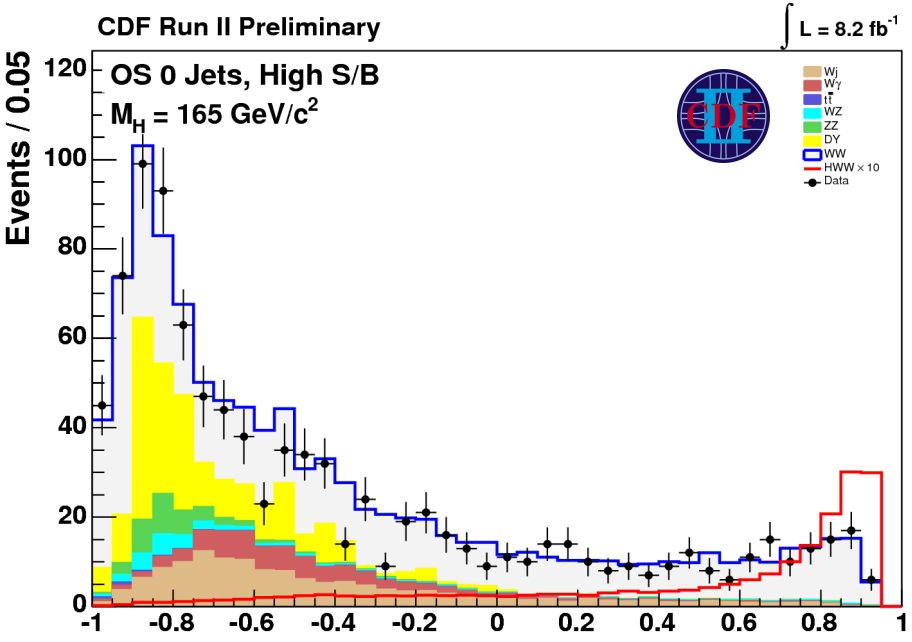
Searching for H → WW (example)



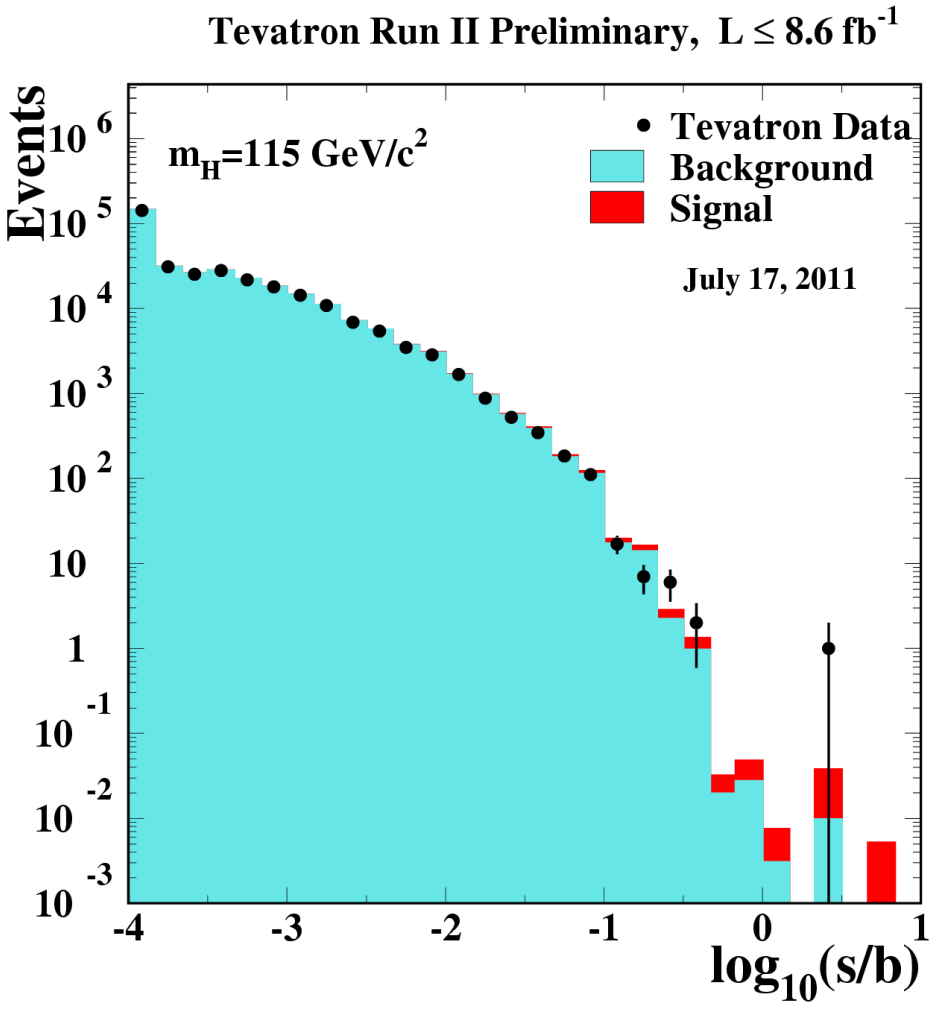


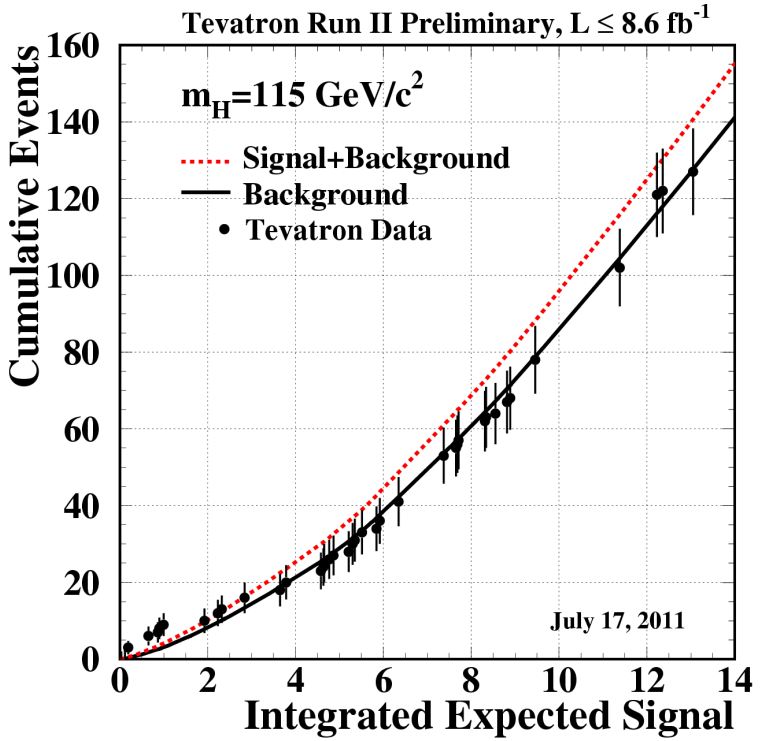


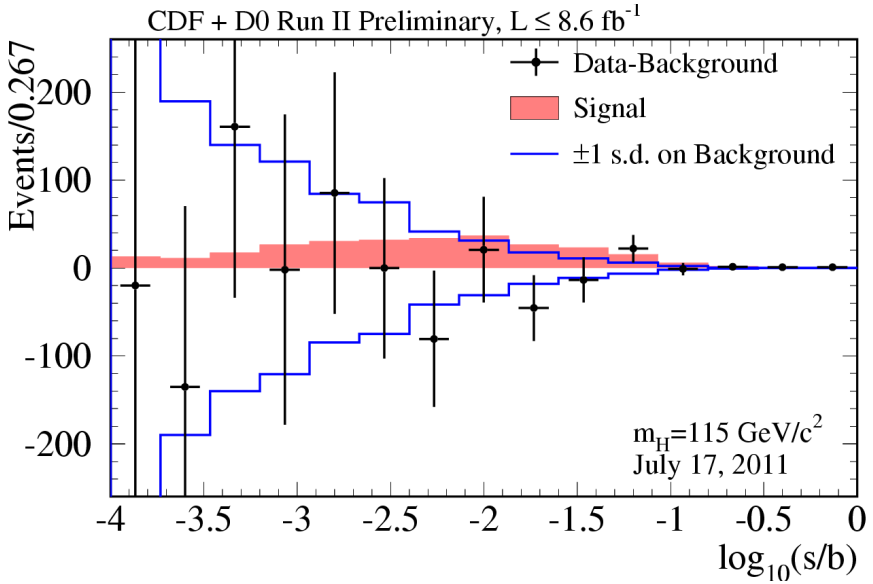
- Exploit low S/B regions without diluting more senstive subsamples
- Selection defined by final state
- Train multivariate discriminants to extract more sensitvity

Combined Discriminants

M_H: 115 GeV

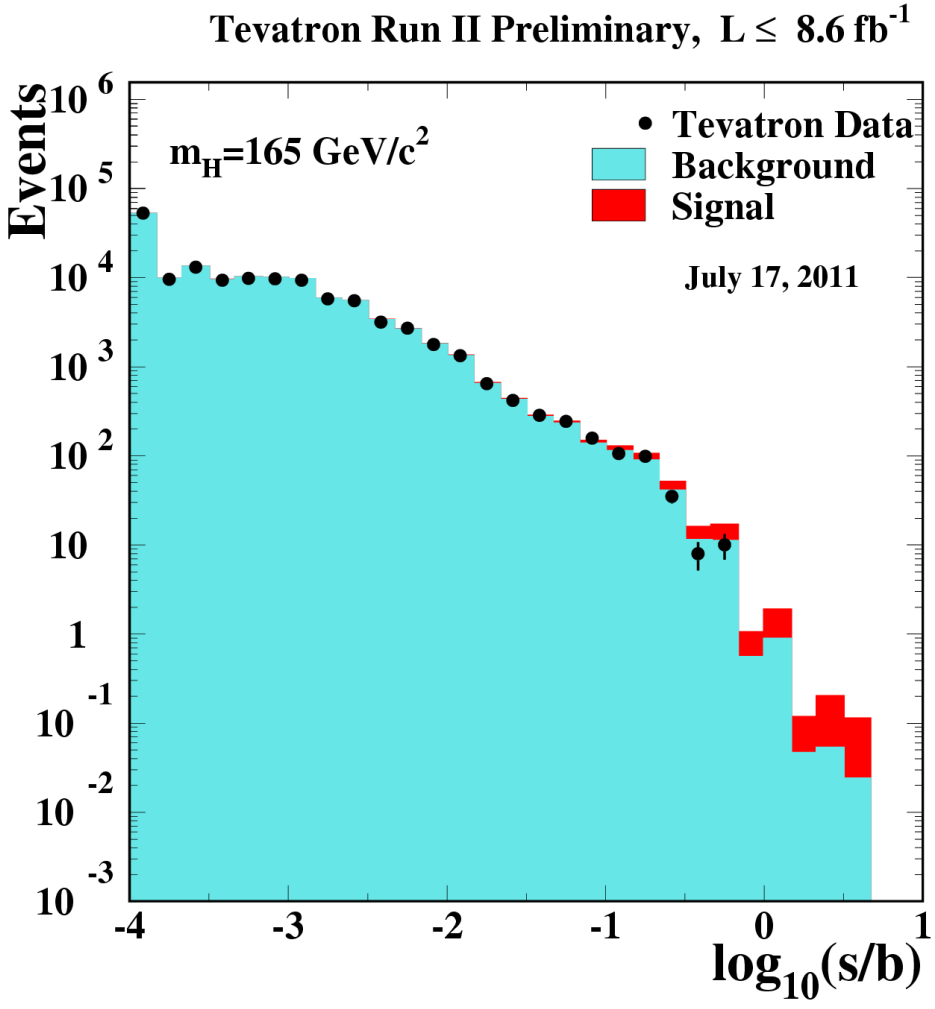


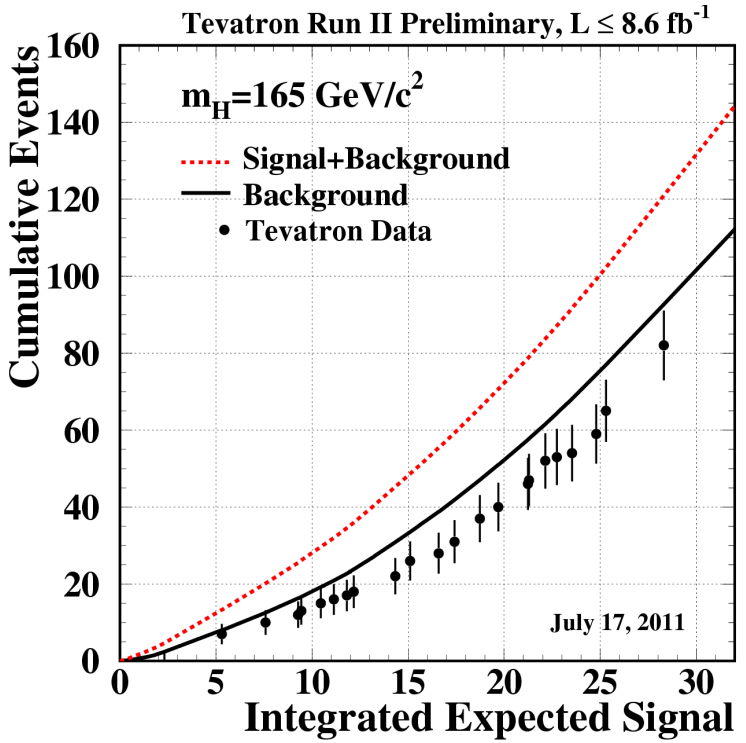


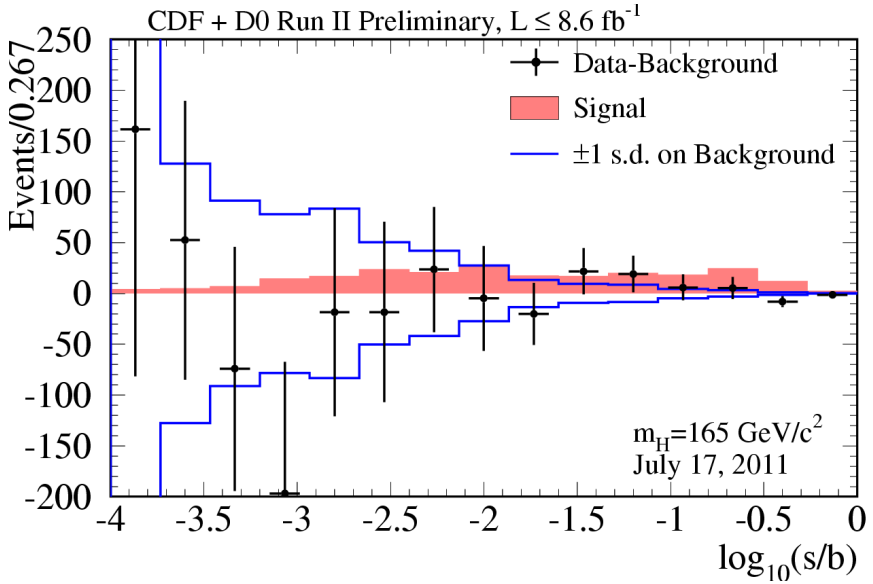


Combined Discriminants

M_H: 165 GeV

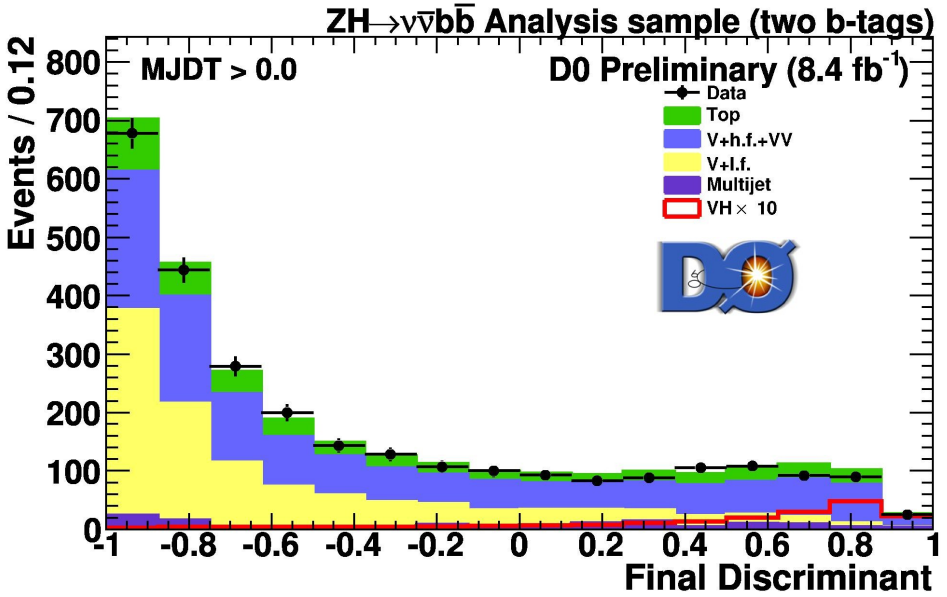






Systematic Uncertainties

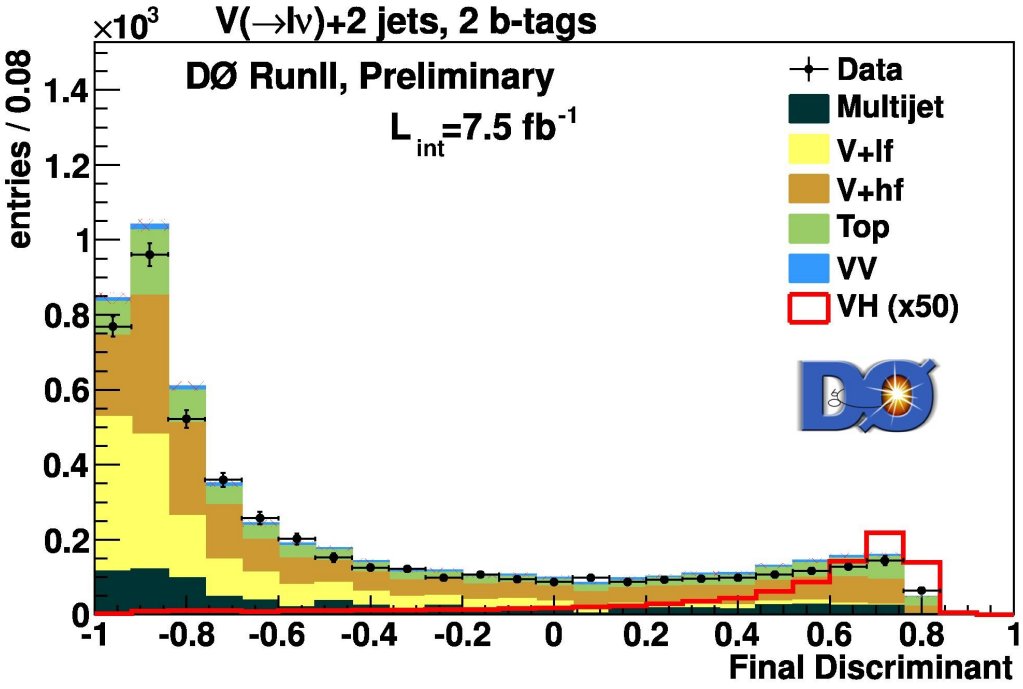
- Limits extracted using shape comparisons of final discriminant
- Important to consider
  - Normalization uncertainties
  - Shape uncertainties
- Track correlations across channel and experiment



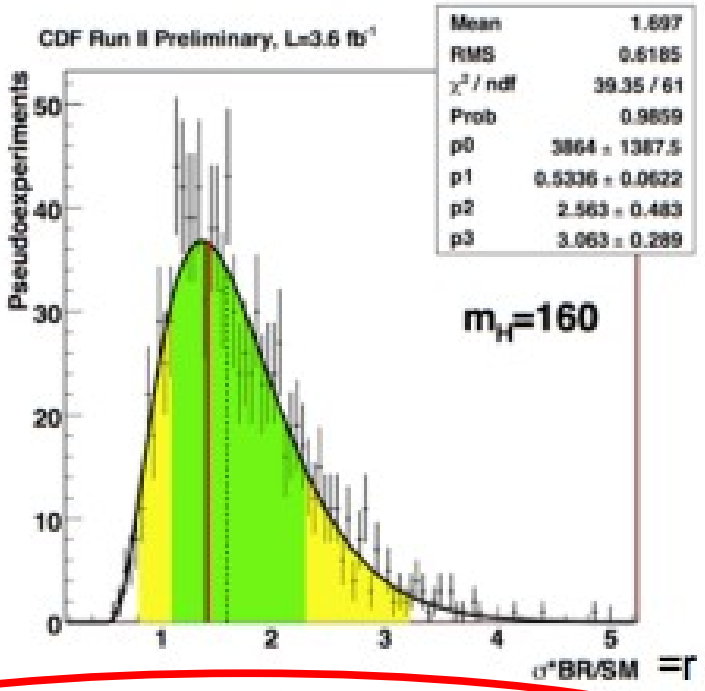
Source	Size
Trigger	2%
Jet Energy Scale	1-3%
Jet Identification	2%
Multijet Estimate	0-25%
b-tagging Efficiency	1-6%
Luminosity	6%
Cross Sections	6-20%

Getting the Results

- Use Bayesian method
- Use CLs as cross check
- Agree within 2% on average (at worst 10% depending on M_H)



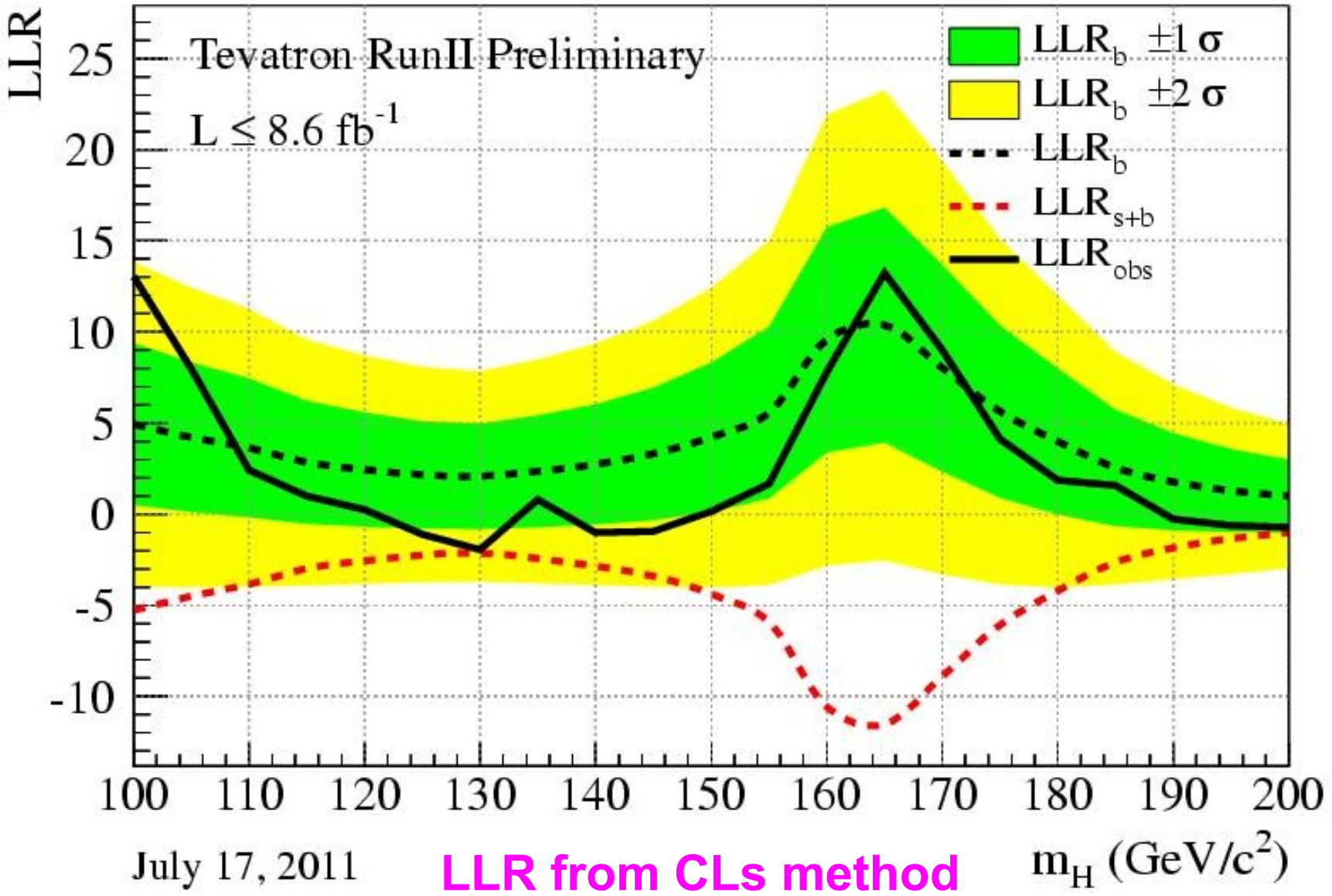
Bayesian Method



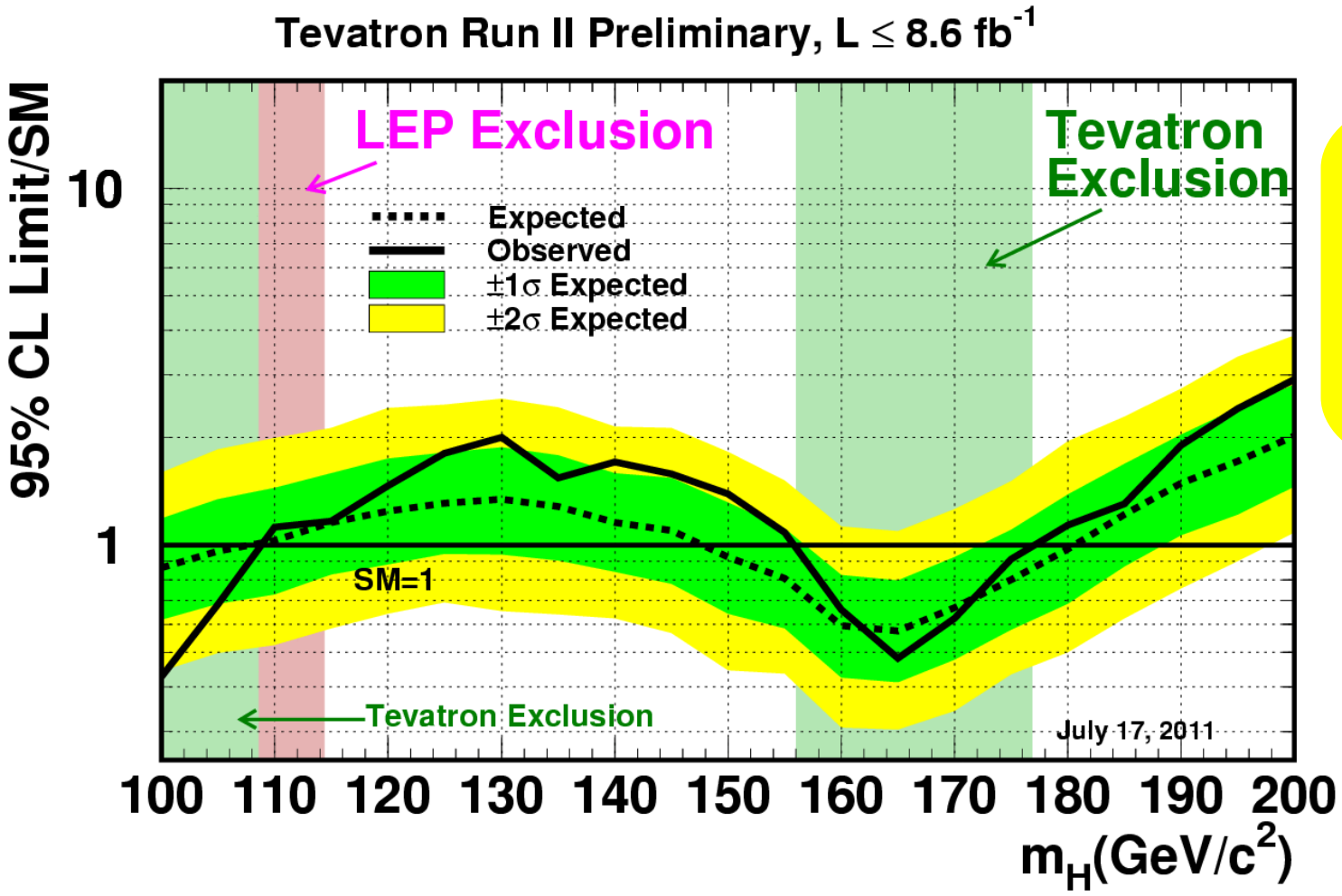
$$\prod_{i}^{bins} Poisson\left(x_i | B_i(\theta) + RS(\theta)\right)$$

$$0.95 = \frac{\int_0^{limit} dR \int L(RS, B, x, \theta)\, d\theta}{\int_0^{\infty} dR \int L(RS, B, x, \theta)\, d\theta}$$

The Log Likelihood Ratio



Limits



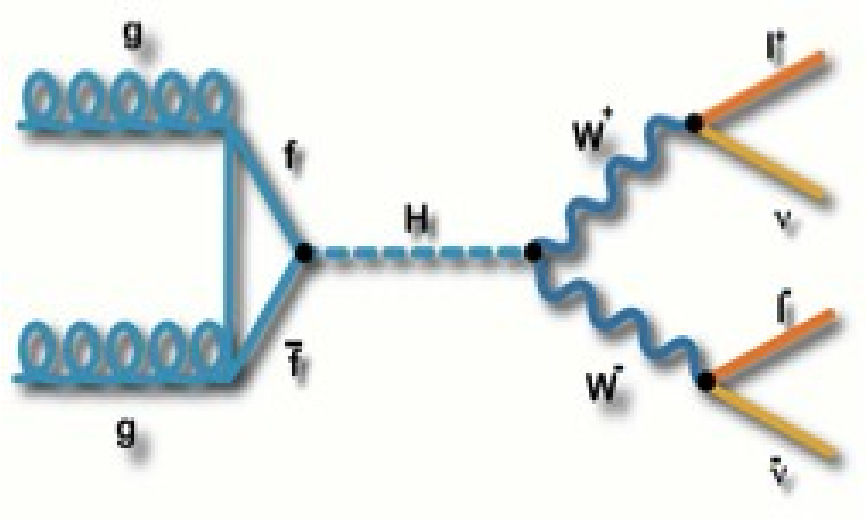
Limits at M_H =115 GeV:

Observed: 1.16×σ_{SM}

Expected: 1.17×σ_{SM}

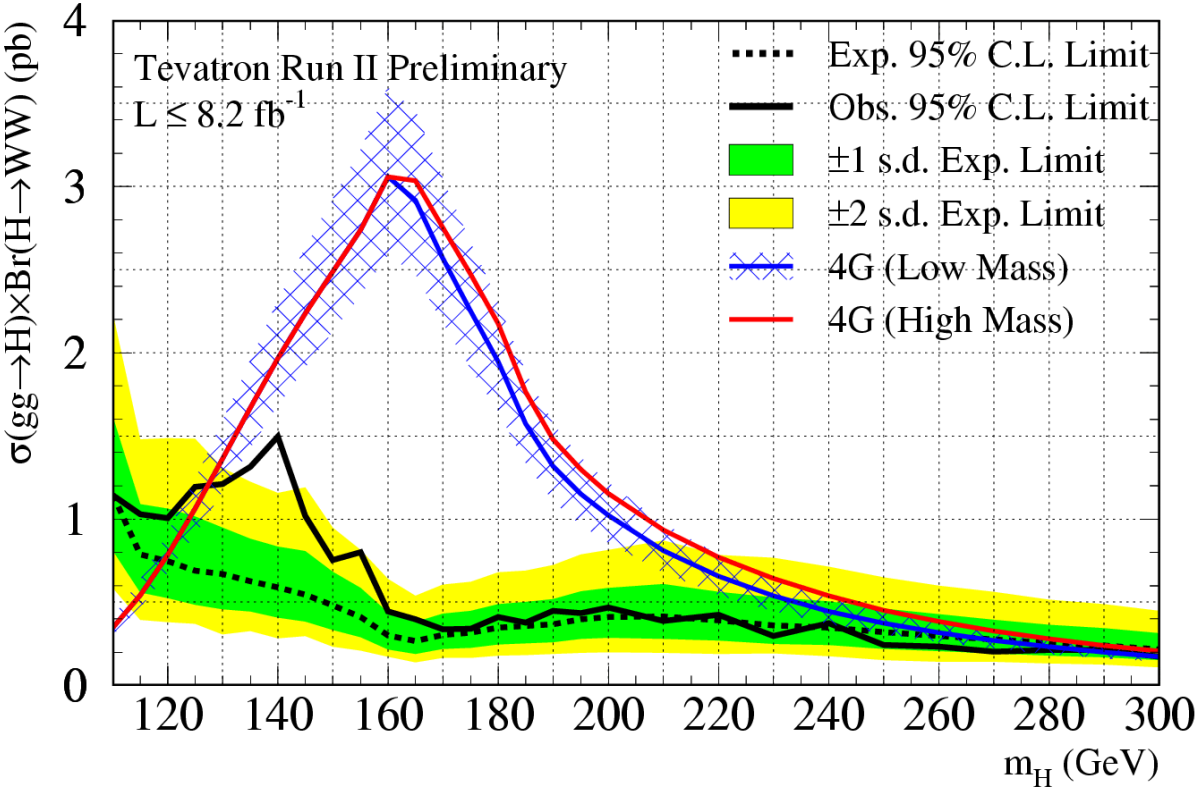
Excluded Regions:
Observed: 100-109 and 156-177 GeV
Expected: 100-108 and 148-181 GeV

Fourth Generation Models

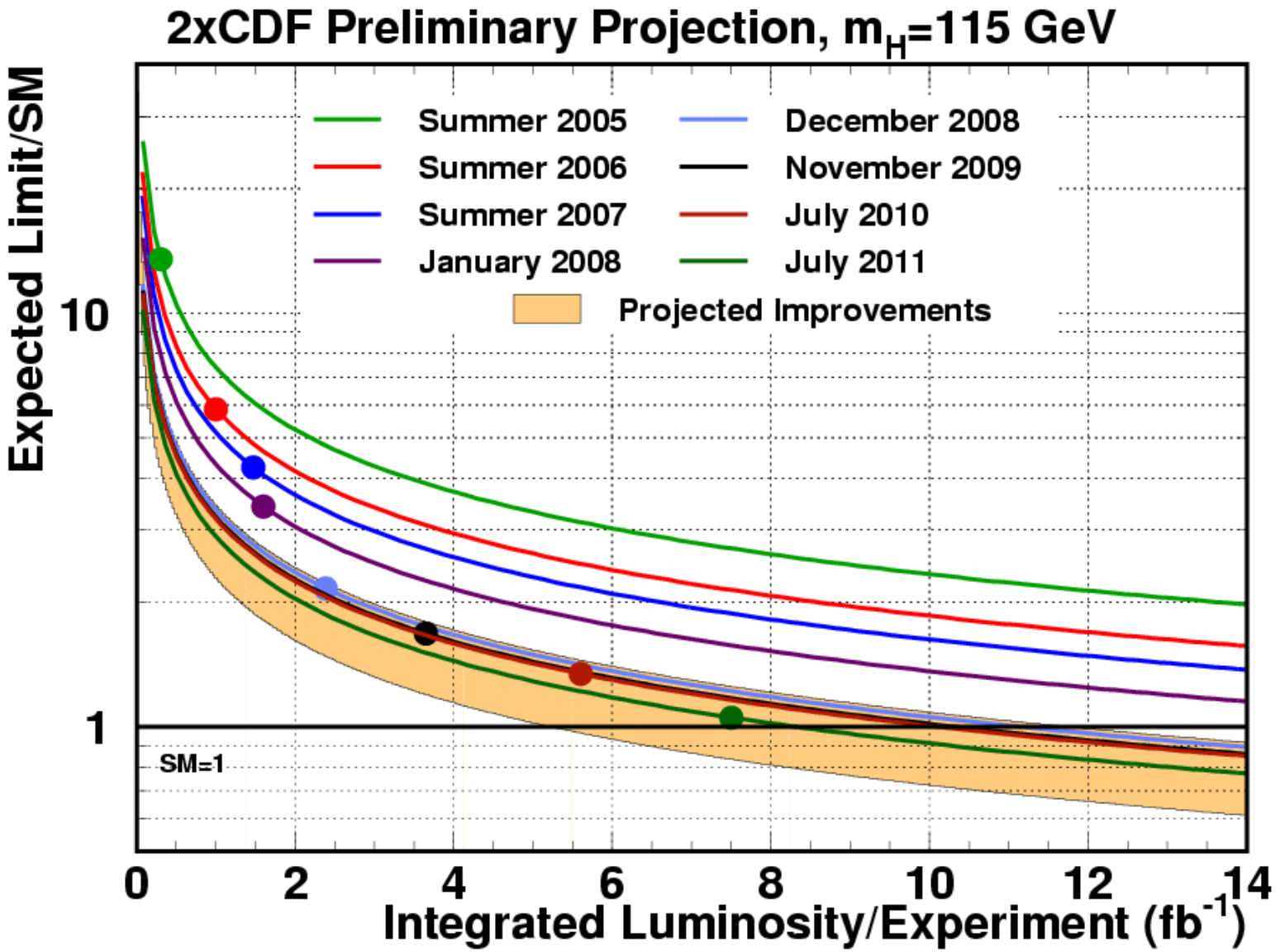


- Additional quark loops enhance $\sigma(gg \rightarrow H)$ by factor of 9
- Higgs mass up to 300 GeV allowed by indirect constraints

- Two scenarios based on mass of extra leptons
- Low mass exclusion: 124 – 286 GeV
- High mass exclusion: 124 – 300 GeV



Looking to the Future



Already recorded more than 10 fb^{-1}

Summary

- We already exclude a significant part of the M_H range allowed by electroweak fits
- Tevatron reaching sensitivity in dominant decay modes in the most interesting region
- Look forward to an exciting set of results in 2012

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

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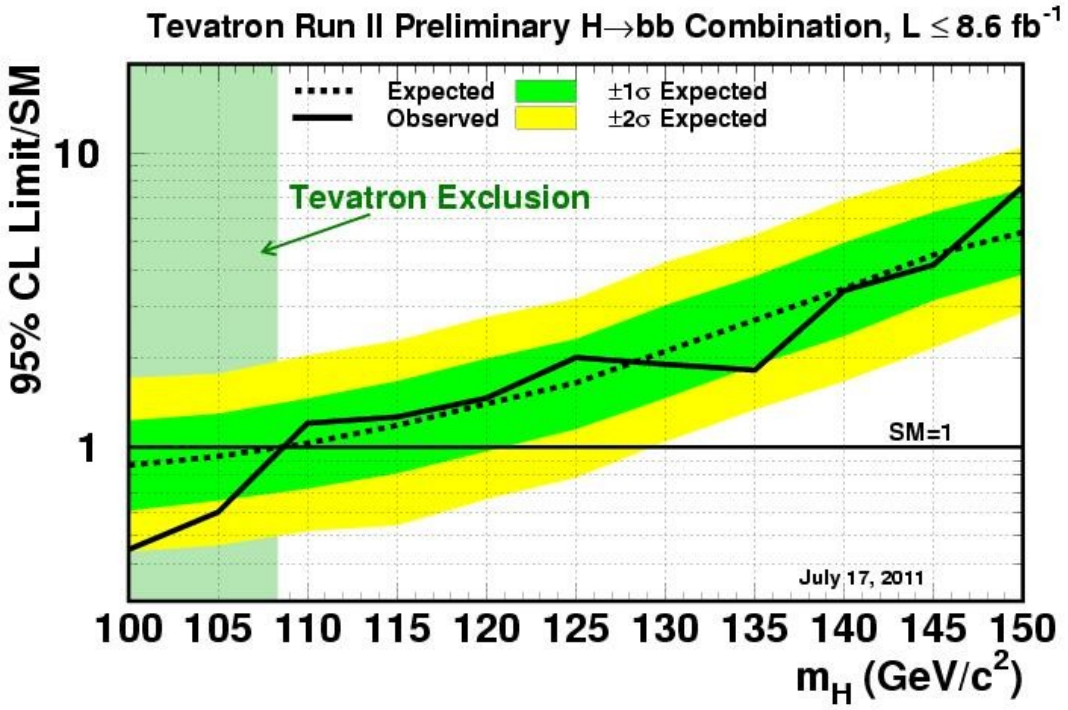
Backup Slides

Between the High and the Low

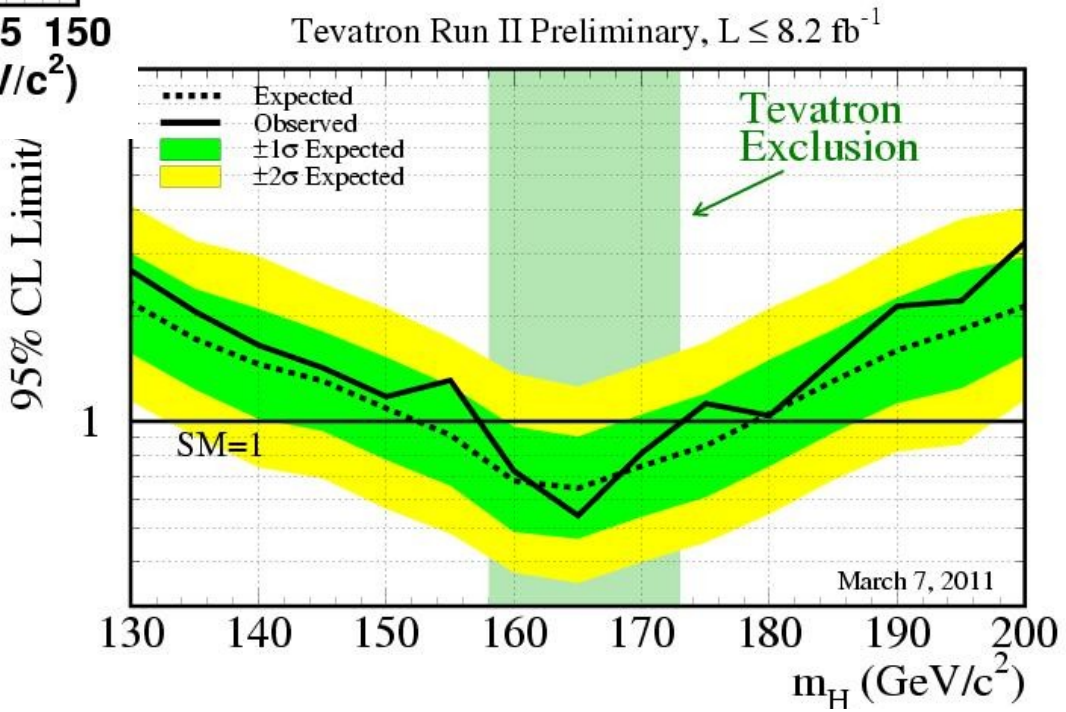


H → $b\bar{b}$ channels from EPS 2011

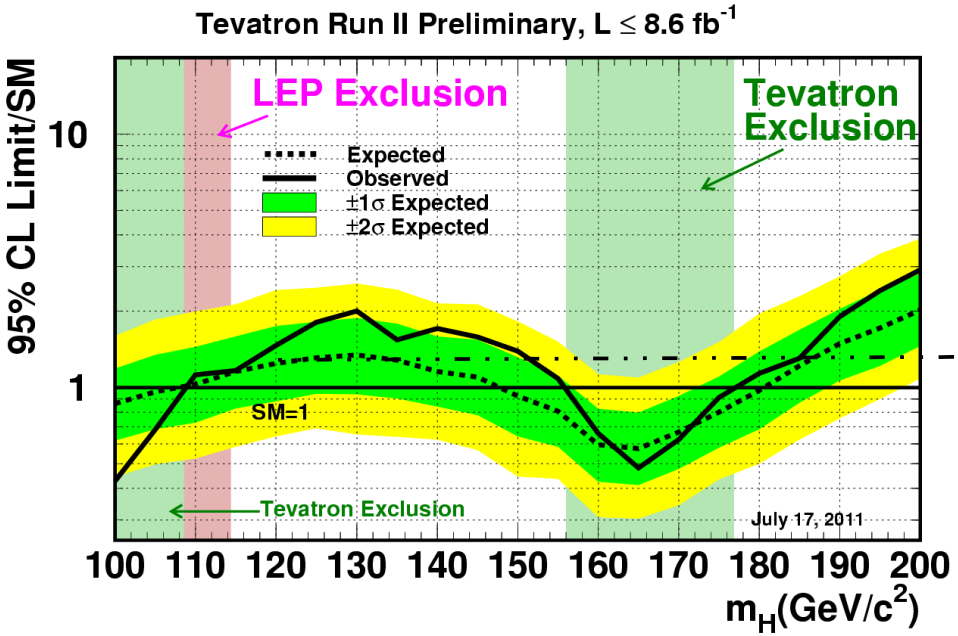
Sensitivity at M_H = 135 GeV: 2.? $\times\sigma_{SM}$

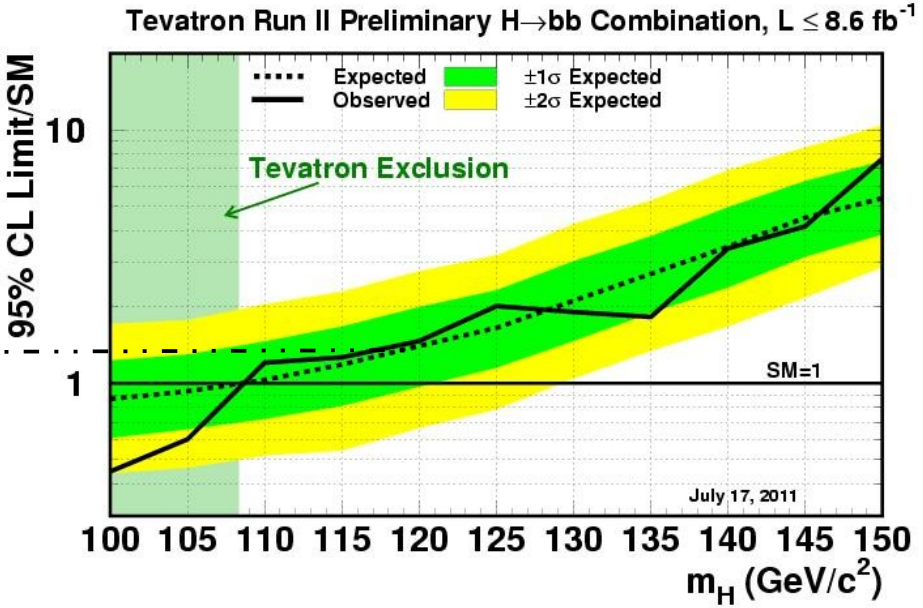
High mass channels from Moriond 2011

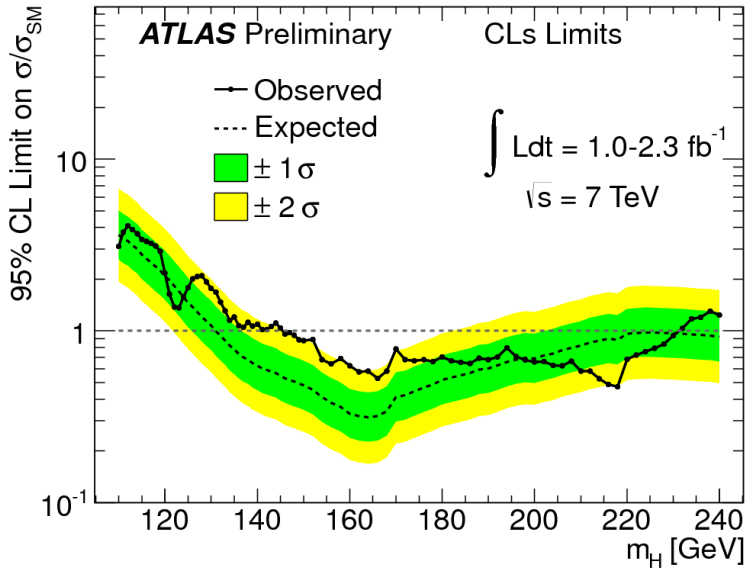
Sensitivity at M_H = 135 GeV: 2.2 $\times\sigma_{SM}$

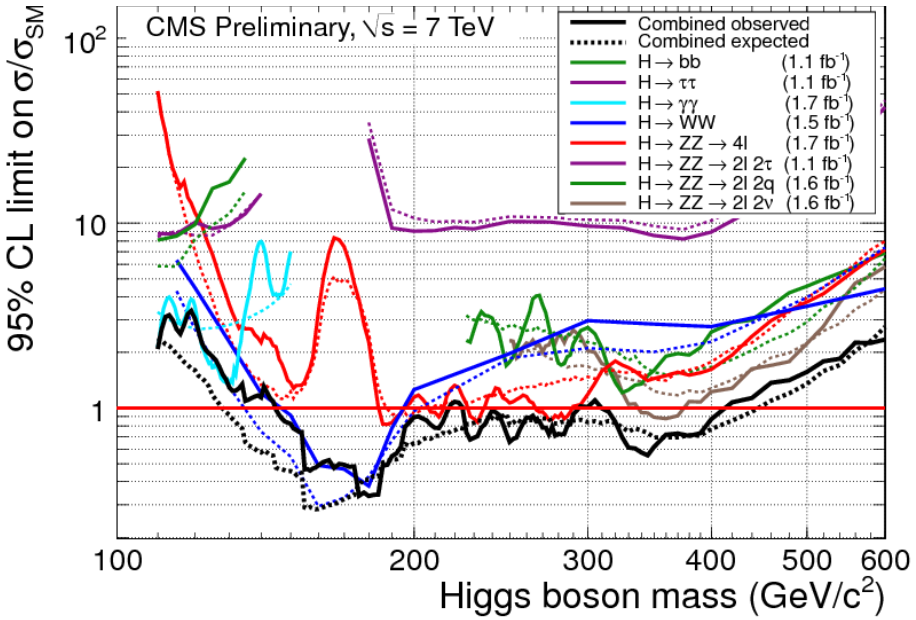


The Big Picture

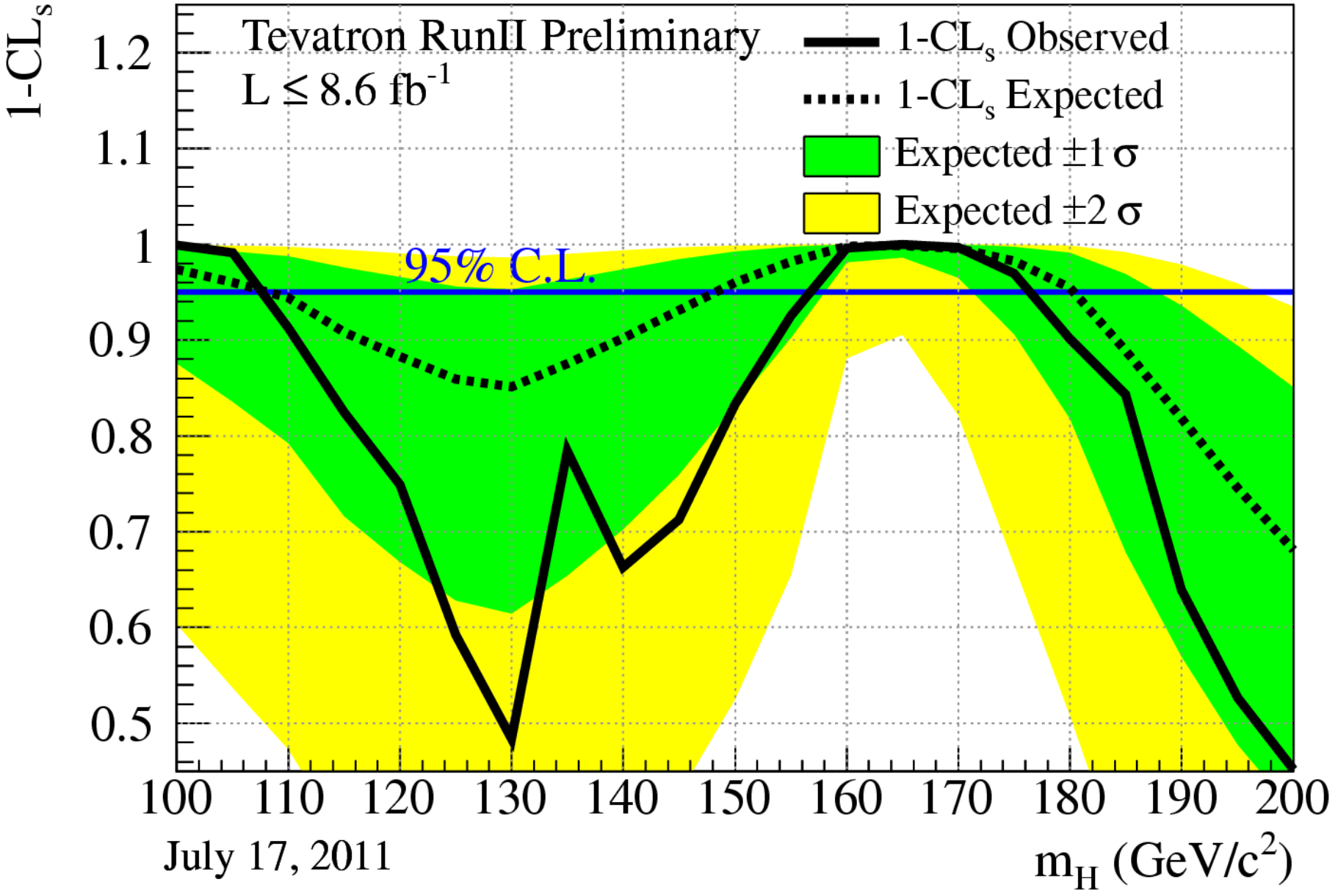




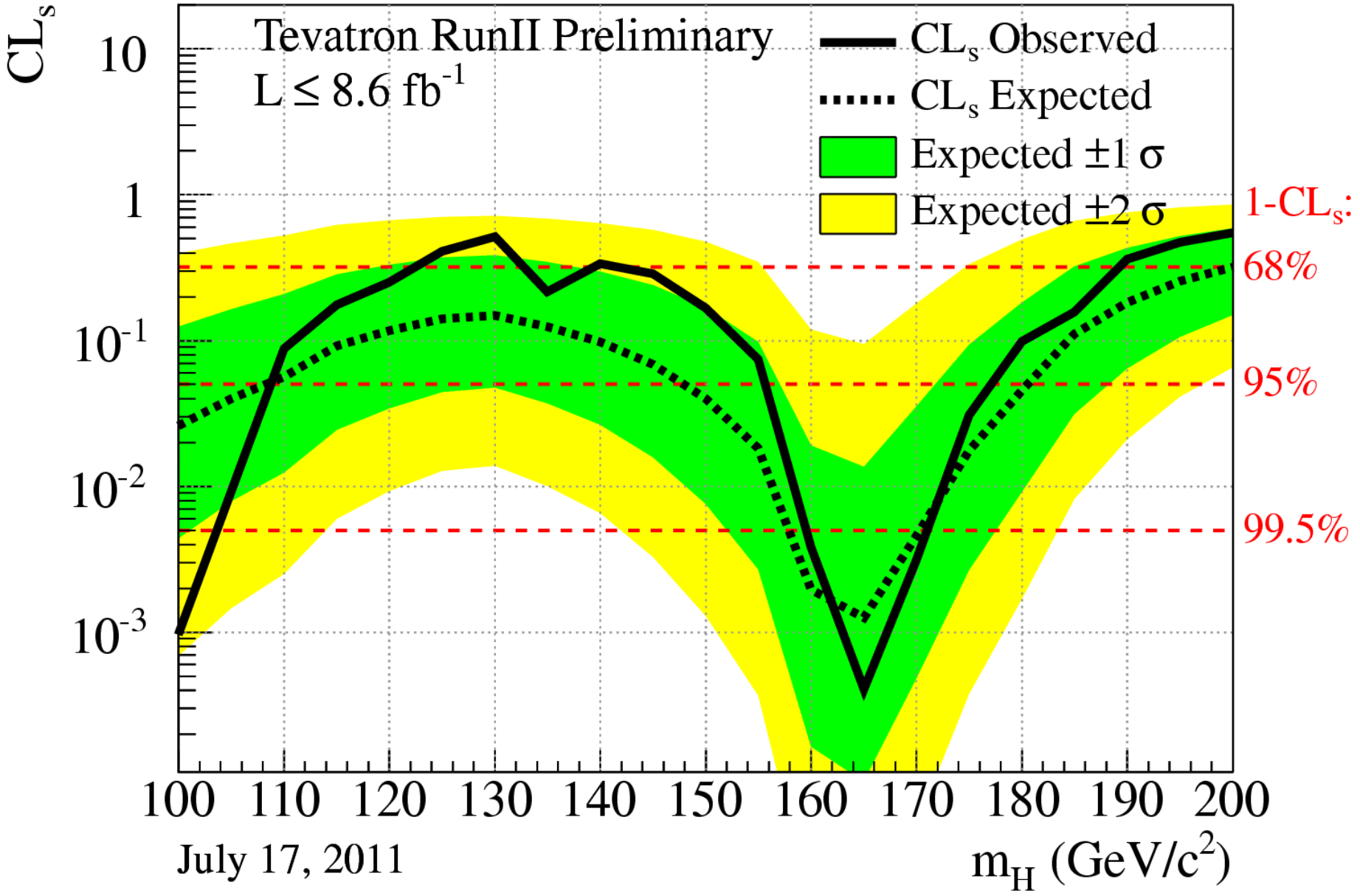




1-CLs


Tevatron RunII Preliminary
L ≤ 8.6 fb-1
1-CLs Observed
1-CLs Expected
Expected ±1 σ
Expected ±2 σ
95% C.L.
1-CLs
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
100
110
120
130
140
150
160
170
180
190
200
July 17, 2011
mH (GeV/c2)

CLs


Tevatron RunII Preliminary
L ≤ 8.6 fb-1
CLs Observed
CLs Expected
Expected ±1 σ
Expected ±2 σ
1-CLs:
68%
95%
99.5%
CLs
10
1
10-1
10-2
10-3
100 110 120 130 140 150 160 170 180 190 200
July 17, 2011
mH (GeV/c2)