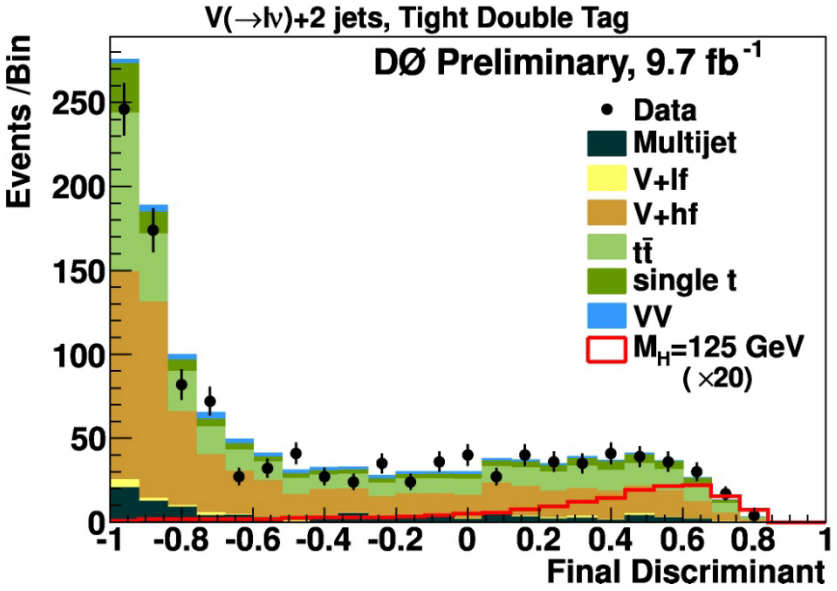
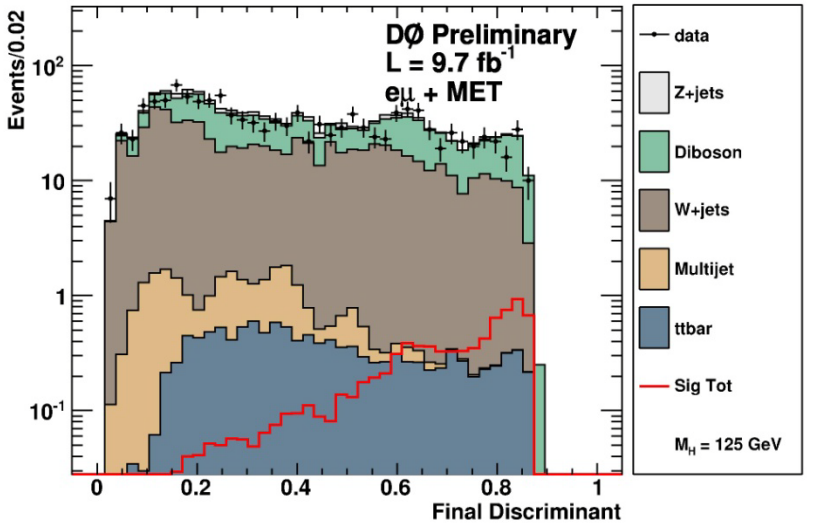
Combination of D0 Searches for the SM Higgs Boson

Ken Herner
University of Michigan
on behalf of the D0 collaboration
7 July 2012

Recap of D0 Higgs Analyses

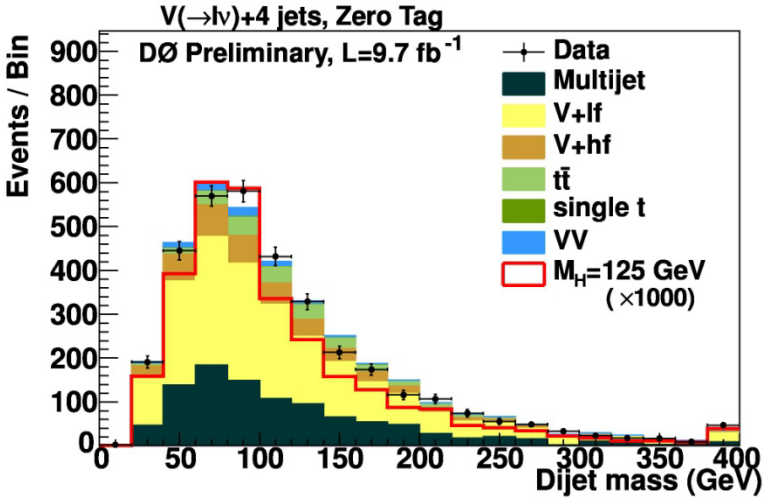
- Analyses divided into "Low-mass" and "High-mass"
- Low-mass: associated production $VH \rightarrow Vb\bar{b}$
  - See S. Desai's talk
- High-mass: H→WW decays
  - See A. Patwa's talk
- Also contributions in secondary (tau, $\gamma\gamma$) channels
  - See P. Grannis' talk
- All in all, 12 analyses with over 50 orthogonal sub-channels

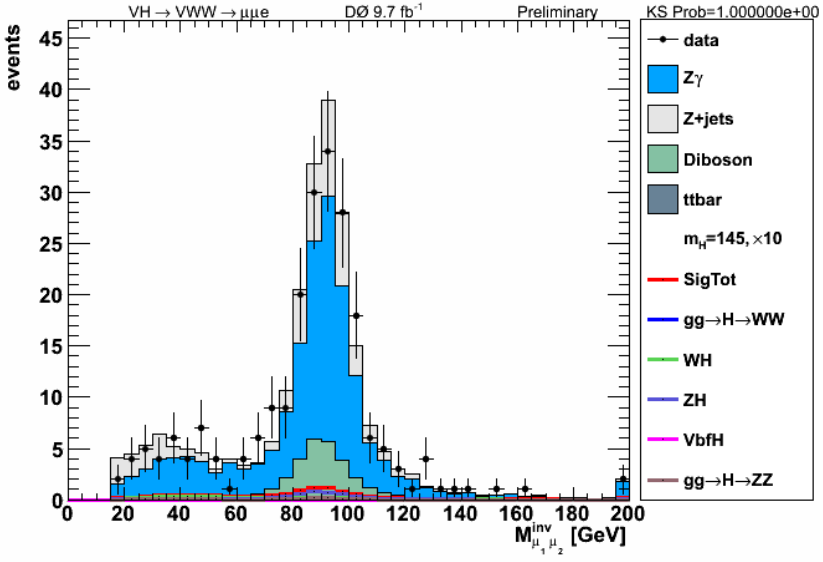


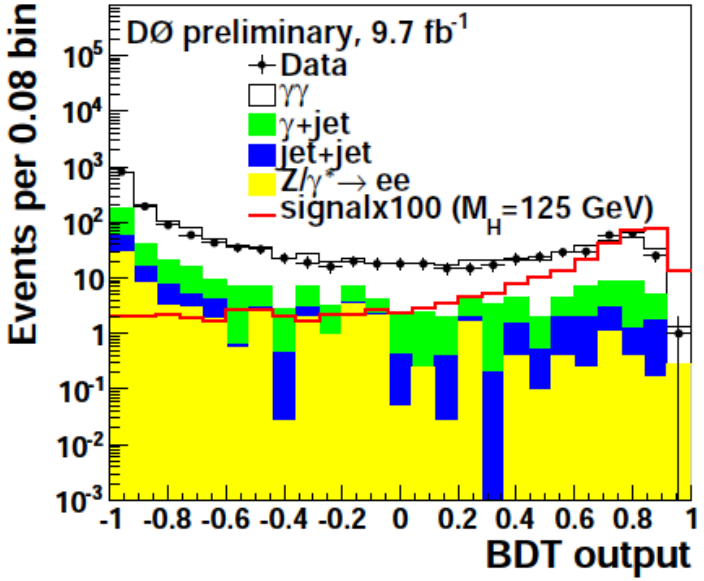


New for Summer 2012

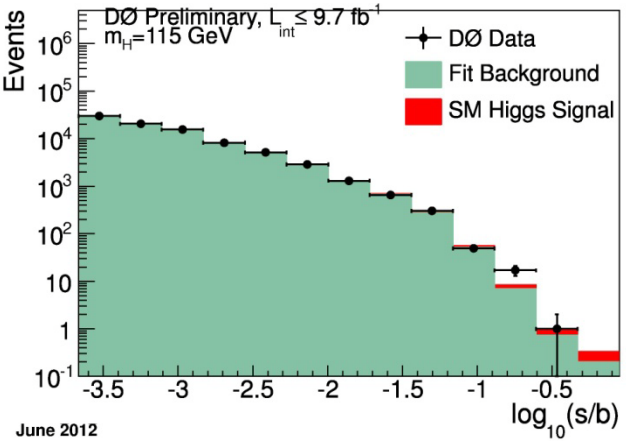
- Updates to most analyses (a few also added data)
- New channel: VH→VWW→lvjjjj
- Update to VH→VWW→lvlvlv
- Changes to γγ
  - split into γ-dominated/jet dominated

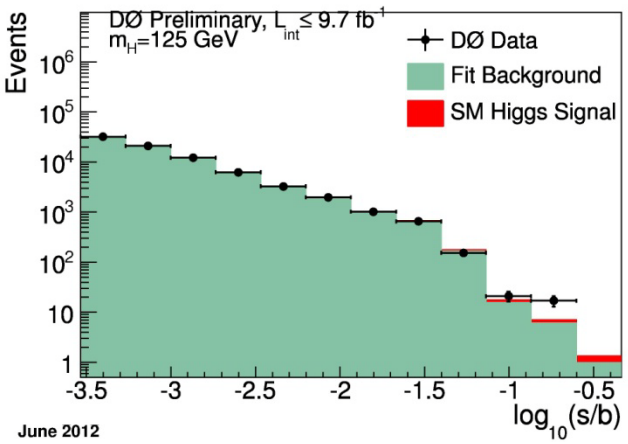


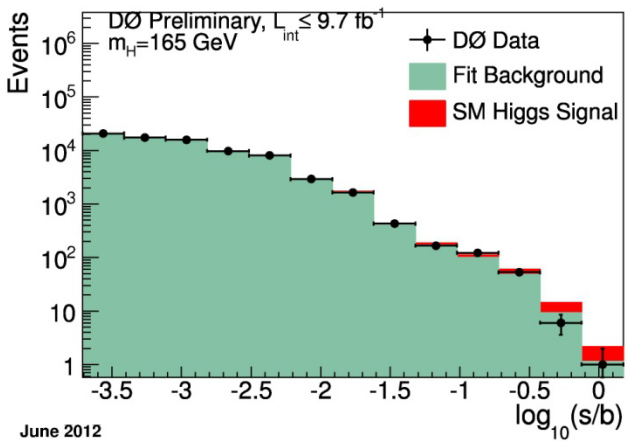


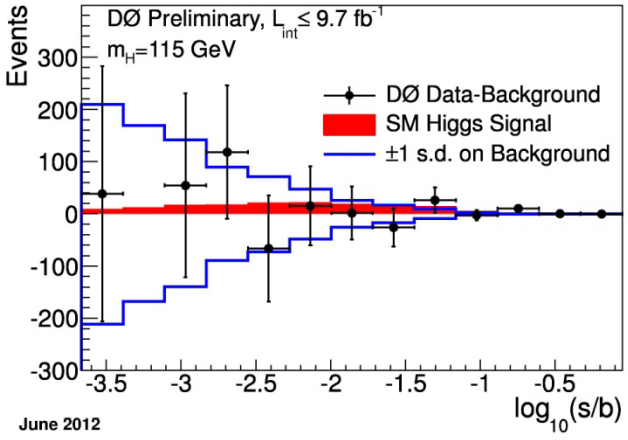


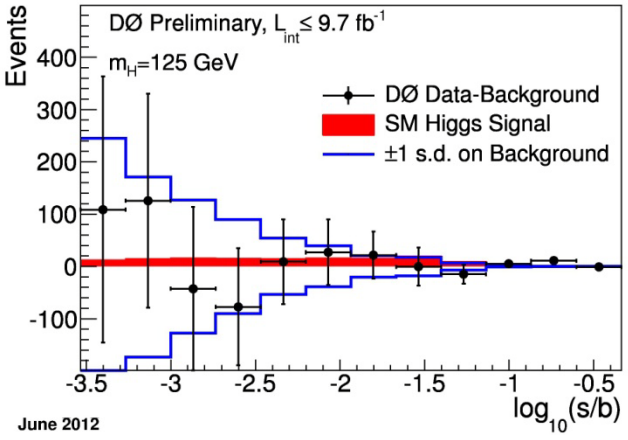
Combining Analyses

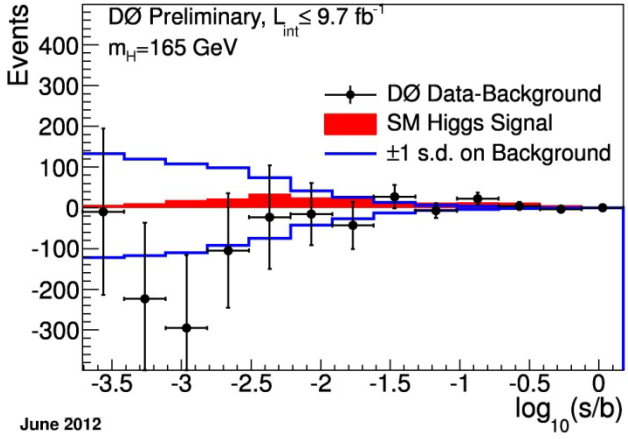












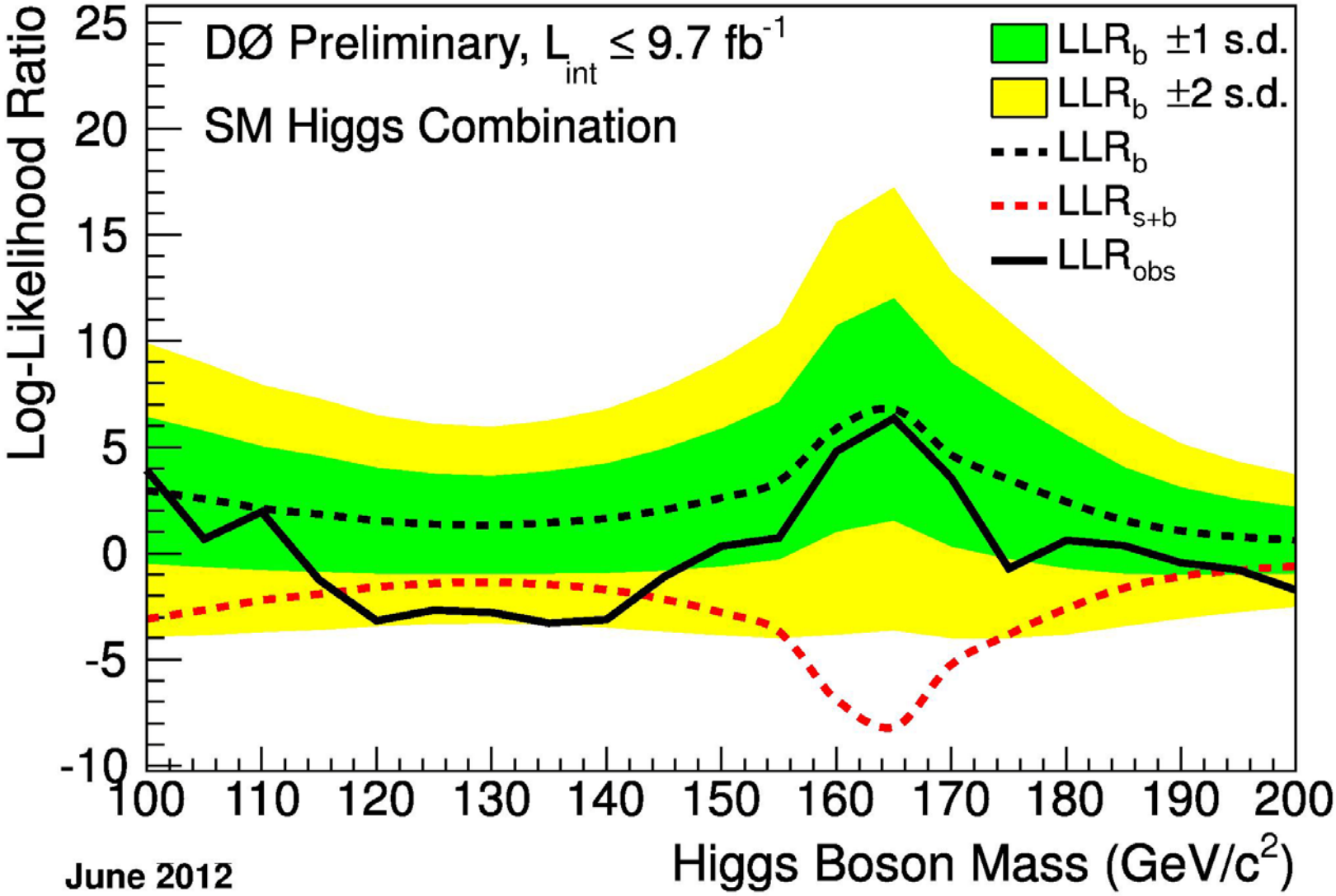
Ordering rule: combine bins by S/B

Systematics (blue) shown are after being constrained by data

(note pseudoexperiments are thrown before this step)

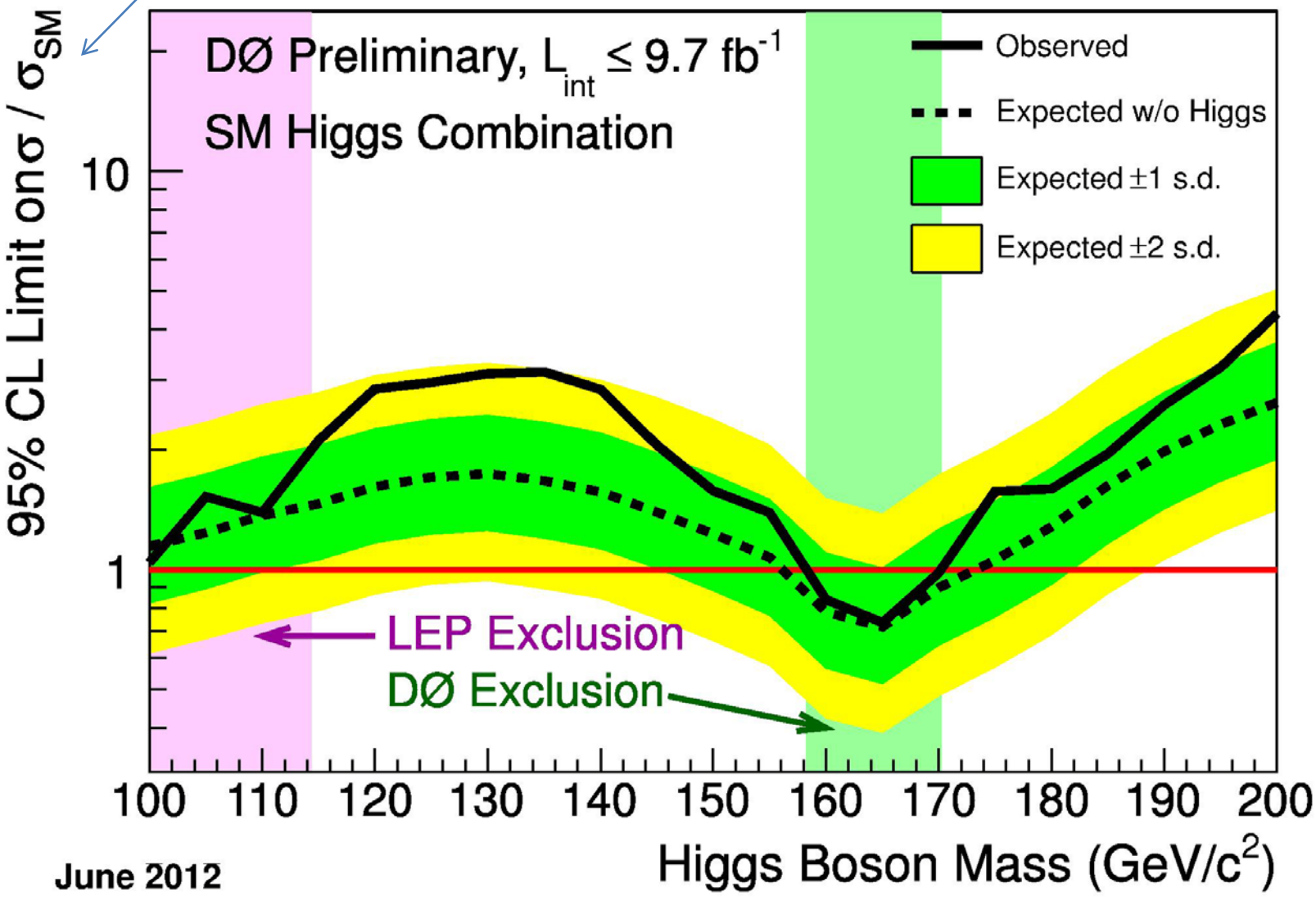
Summer 2012 D0 Combination

- D0: Modified frequentist (CL_s) technique, negative LLR as test statistic (LLR = -2 log (L_{S+B}/L_B))



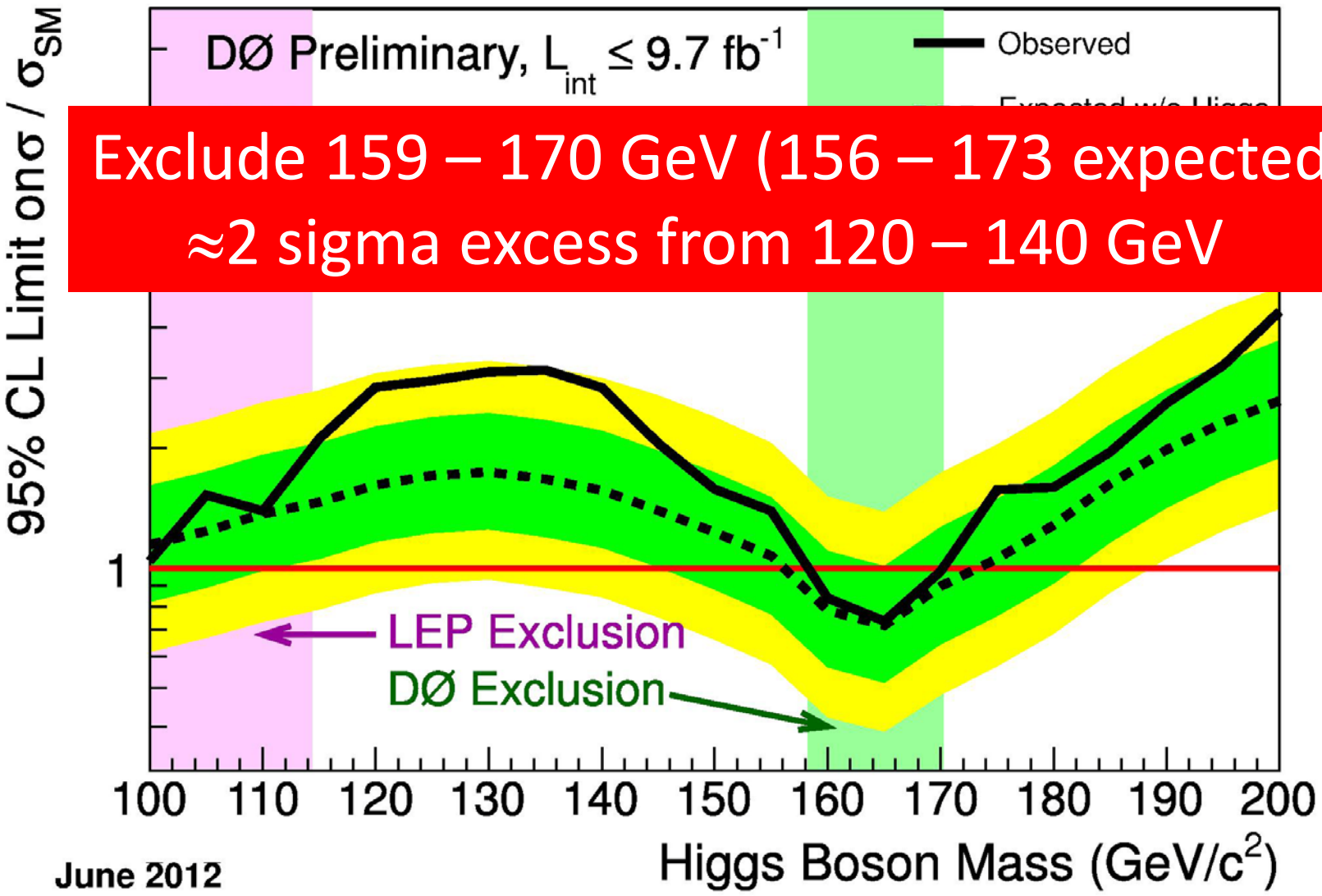
Summer 2012 D0 Combination

Limit cast as Ratio to SM xsec



Summer 2012 D0 Combination

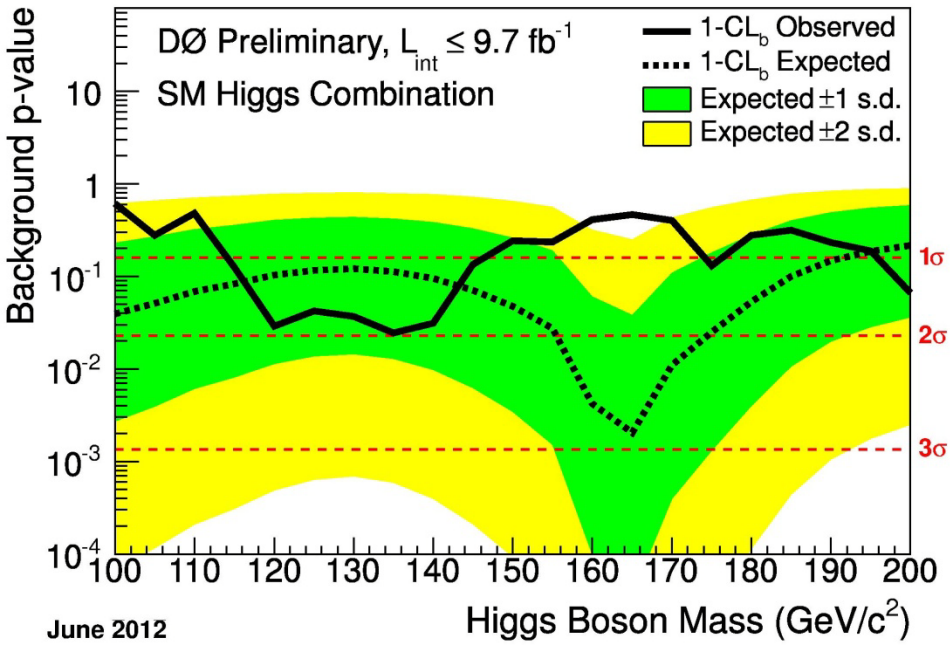
Limit cast as Ratio to SM xsec

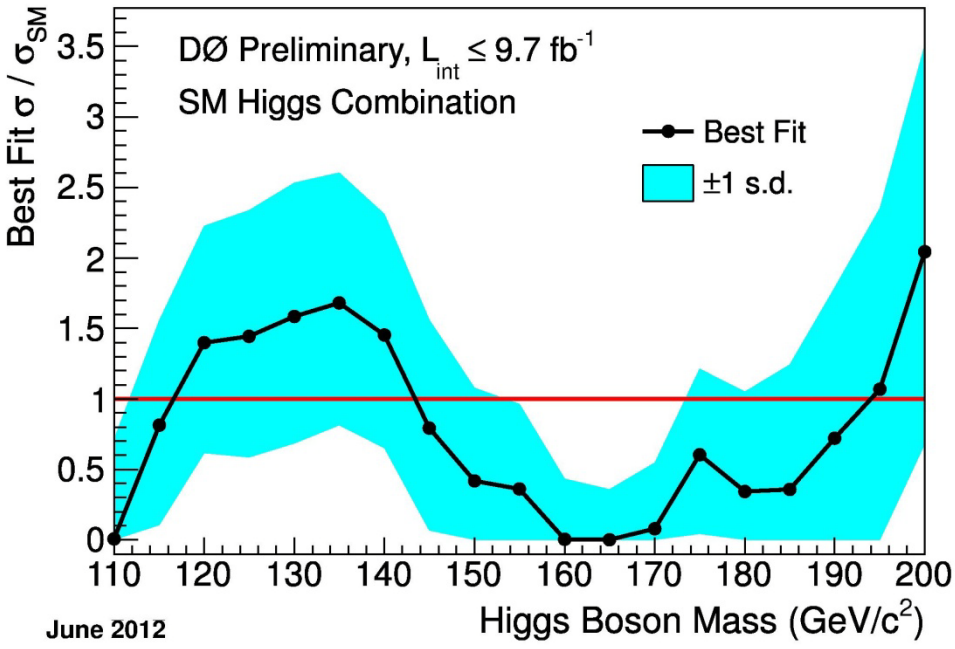


Exclude 159 – 170 GeV (156 – 173 expected)

≈2 sigma excess from 120 – 140 GeV

Quantifying Excesses

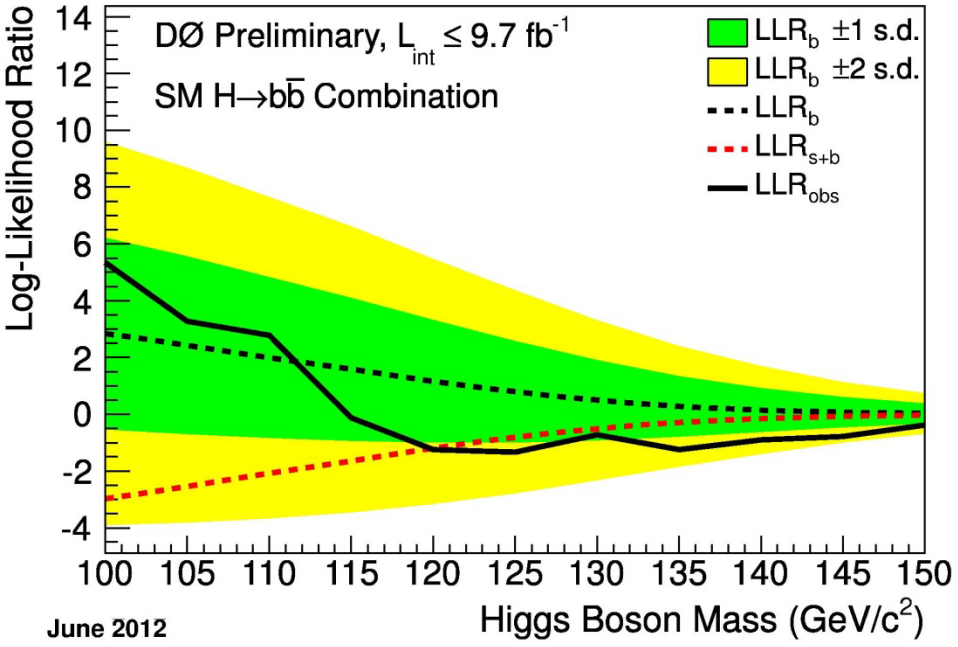




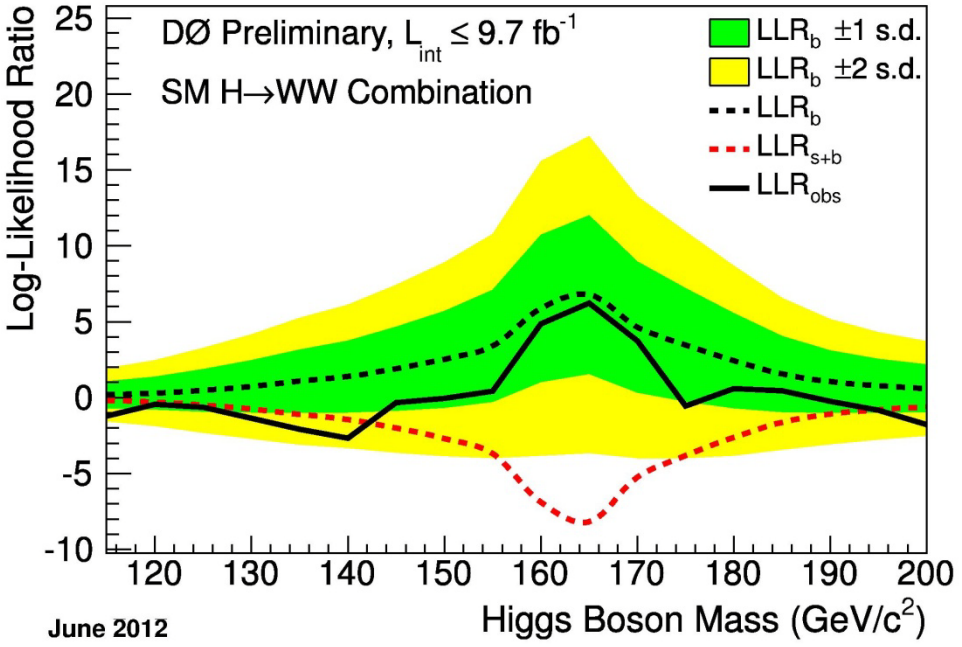
- Maximum at 135 GeV, followed by 120 GeV
- Right: best fit signal cross section to data

Examining Sub-Combinations

- Consider channels with H→WW/bb decay only



VH→Vbb

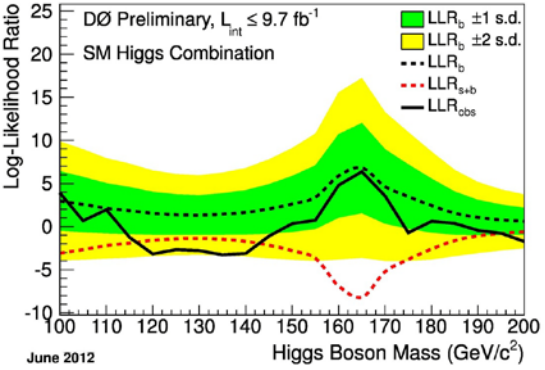


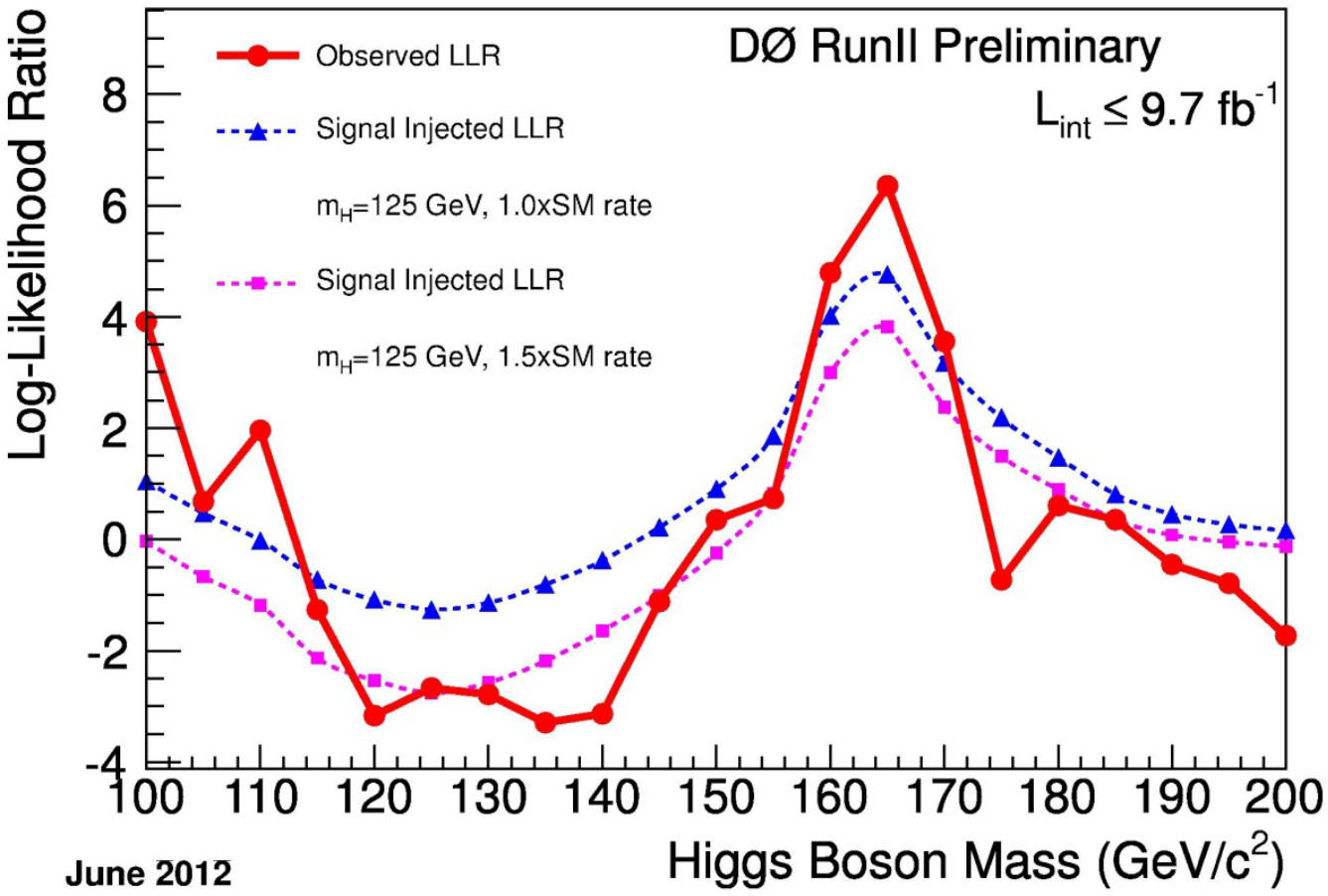
H→WW

Contributions from both sub-combinations

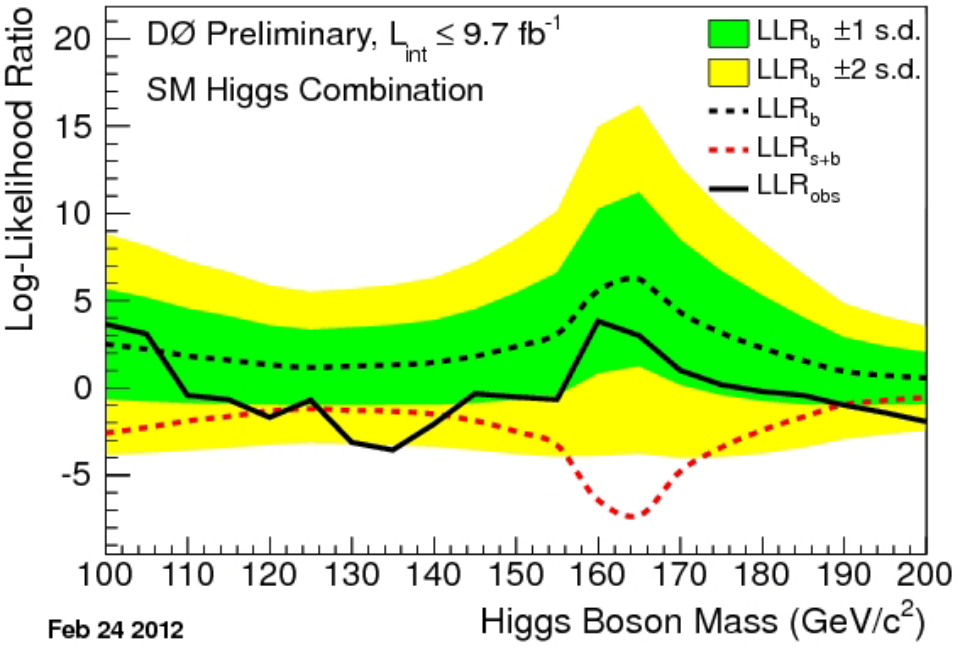
Signal Injection

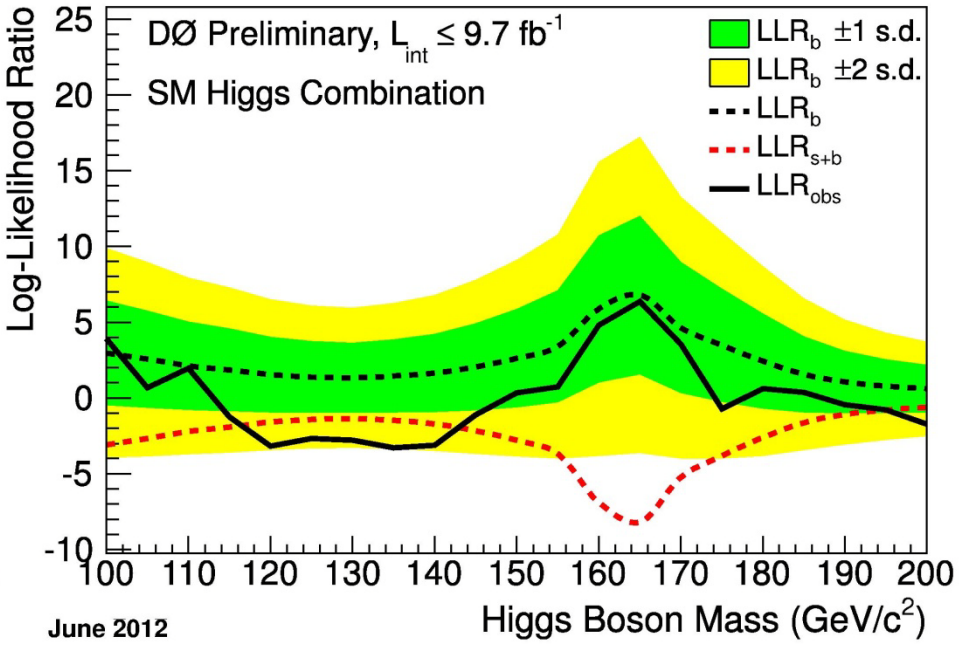
- Replace data with sum of backgrounds and signal
  - What would these "data" look like in LLR?
  - Also inject at best-fit cross section rate





Combination Evolution



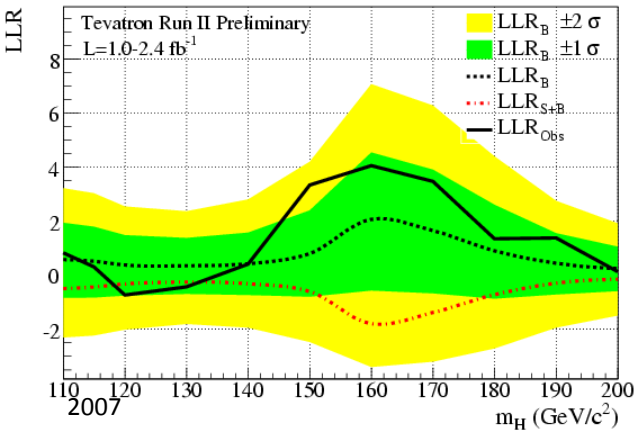


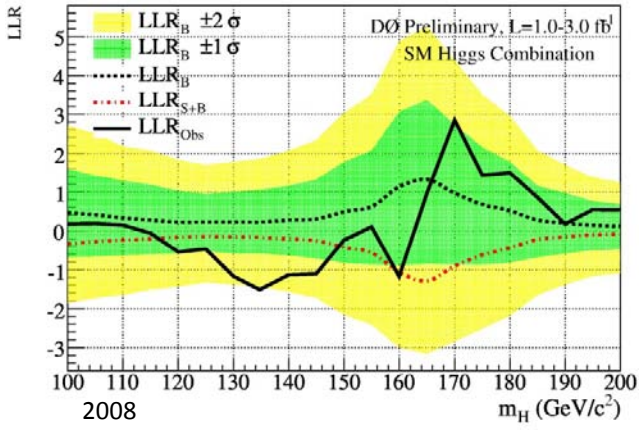
Winter 2012

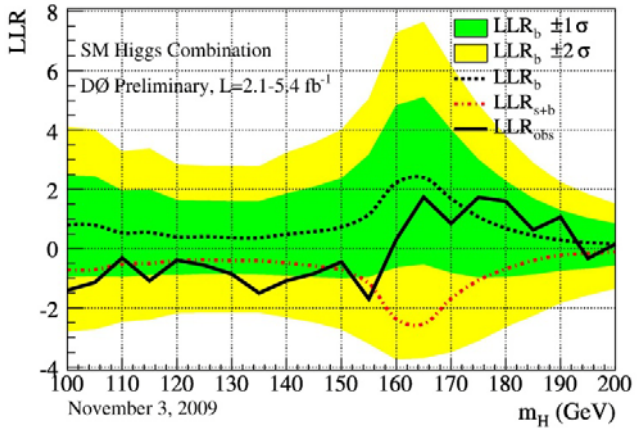
Summer 2012

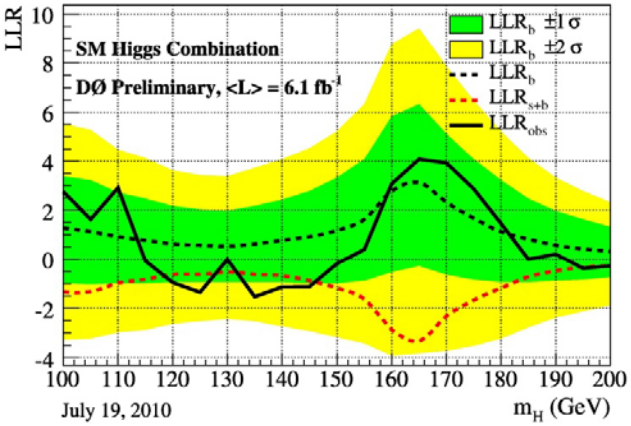
What has changed?
Improved MVA techniques
Some channels added data
A few new channels
Improved background modeling/rejection
Please see other talks

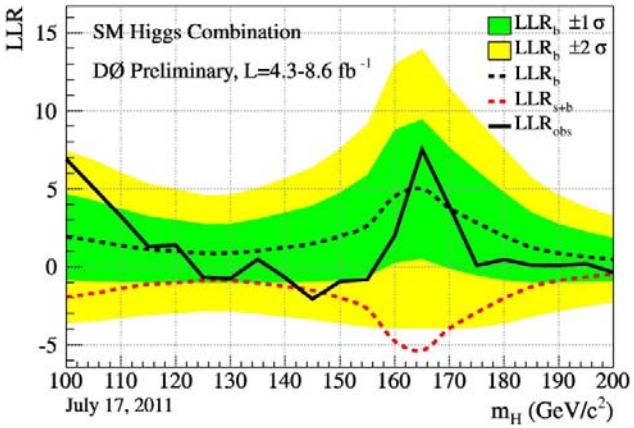
Combination Evolution

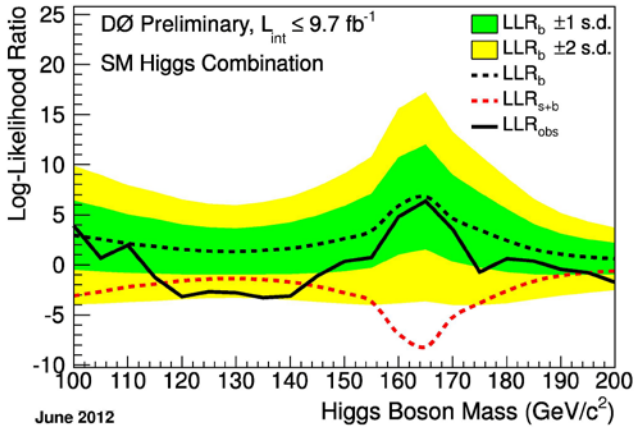








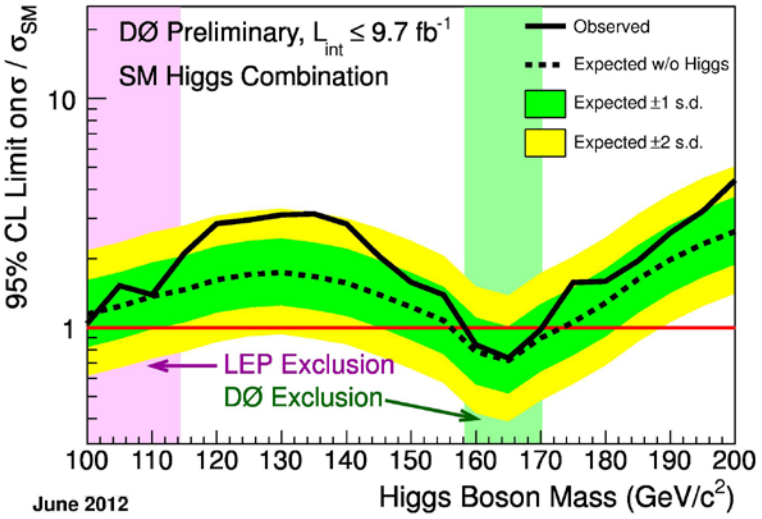


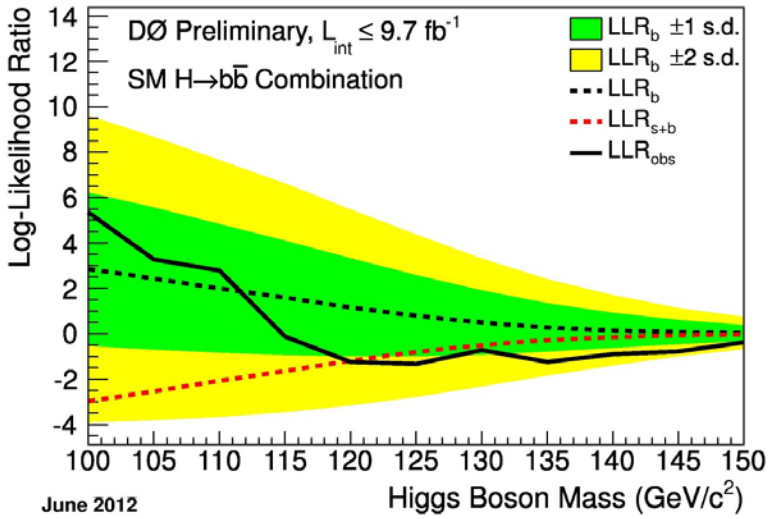


- Have consistently seen low-mass excess since 2007

Summary

- D0 has updated the Higgs combination with some additional channels and numerous improvements to existing channels
- 8% improvement in expected limits wrt Winter 2012
- Exclude 159-170 GeV at 95% CL
- Interesting excess consistent with 115 – 140 GeV SM Higgs
  - Best fit cross section 1.5 x SM
- Moving quickly to finalize results
- Further reading: [arXiv:1207.0422]





Backup

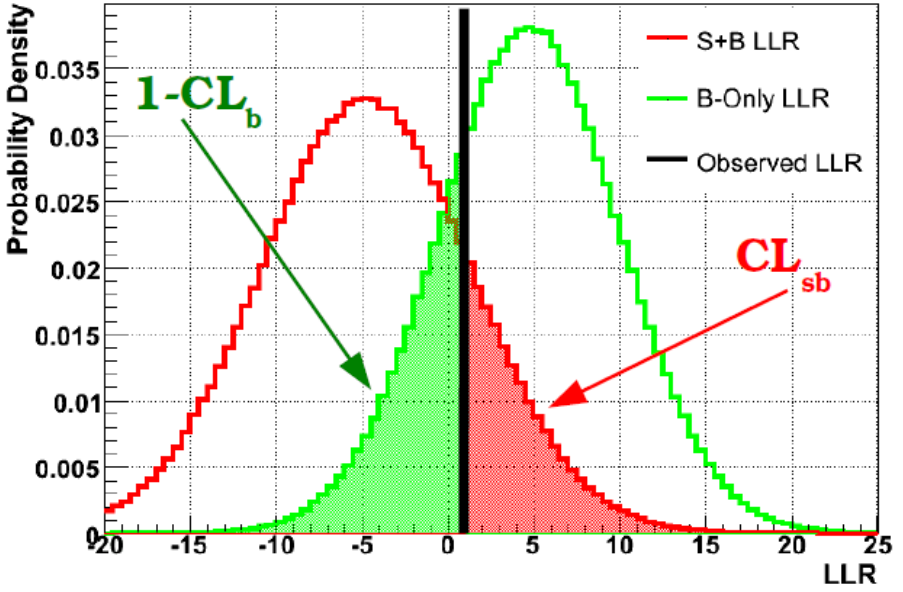
Inside the Limit Black Box

- N.B. I will focus on the D0 method here
- Key value is log-likelihood ratio (LLR)

$$LLR(\vec{s},\vec{b},\vec{d}) = -2\mathrm{Log}(Q) \qquad Q(\vec{s},\vec{b},\vec{d}) = \prod_{i=0}^{N_c}\prod_{j=0}^{N_{bins}} \frac{(s+b)_{ij}^{d_{ij}} e^{-(s+b)_{ij}}}{d_{ij}!} \Big/ \frac{b_{ij}^{d_{ij}} e^{-b_{ij}}}{d_{ij}!}$$

- S+B and B-only LLR populated by pseudoexperiments
- Define CLs:

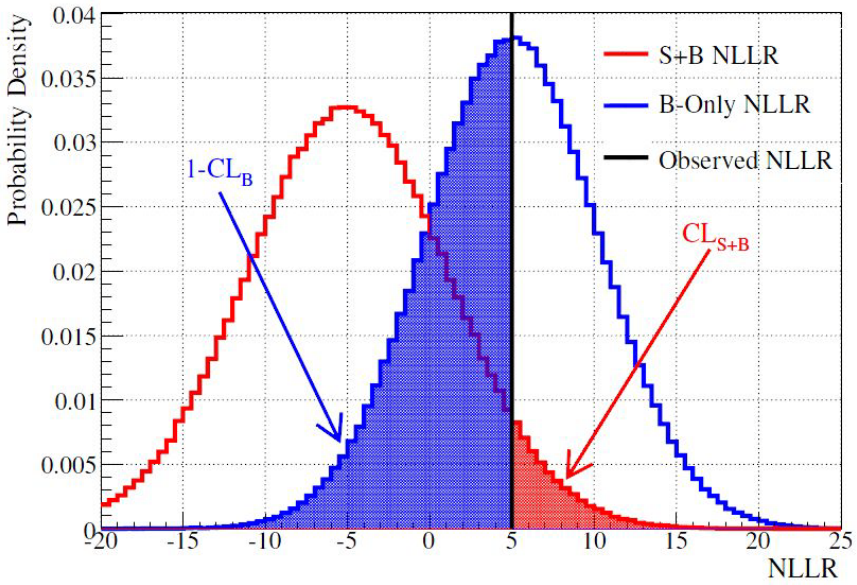
$$CL_S = \frac{CL_{S+B}}{CL_B}$$



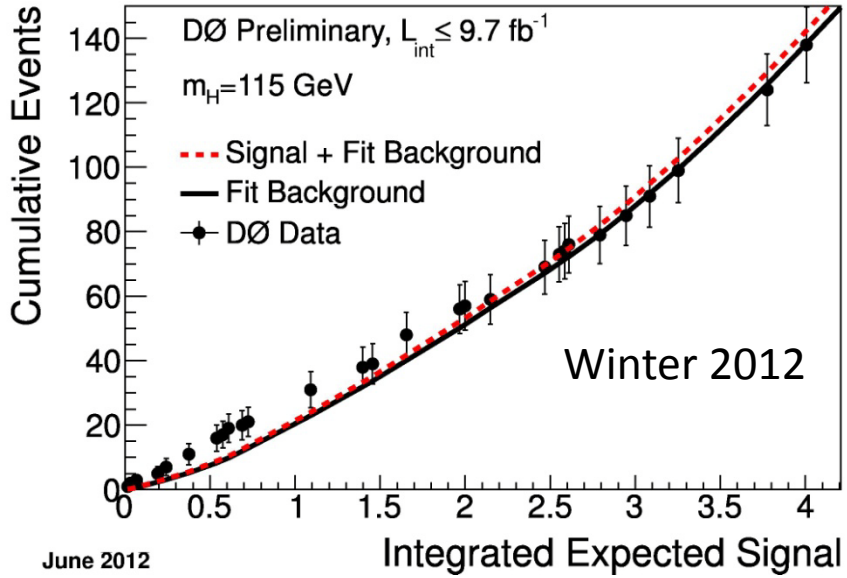
Finding the Limit

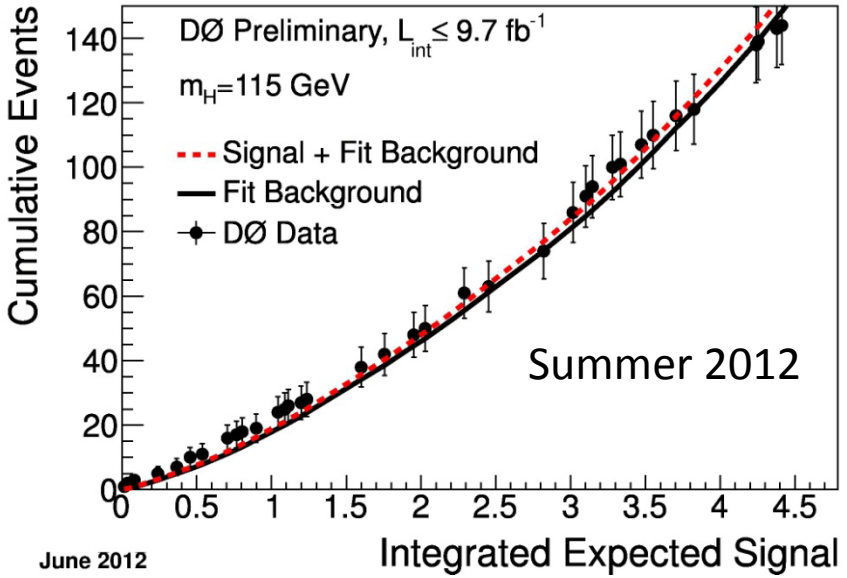
- Systematic variations allowed to float to maximize likelihood for each hypothesis separately for each pseudoexperiment
  - Redefine LLR as difference in fit to data of the two hypotheses (“Profiling”)
  - Reduces overall impact of systematics
- Finding the limit
  - Scale up signal cross section: LLR_{sb} and LLR_b will separate
  - Repeat entire procedure
  - Scale until $CL_{sb}/CL_b = 0.05$

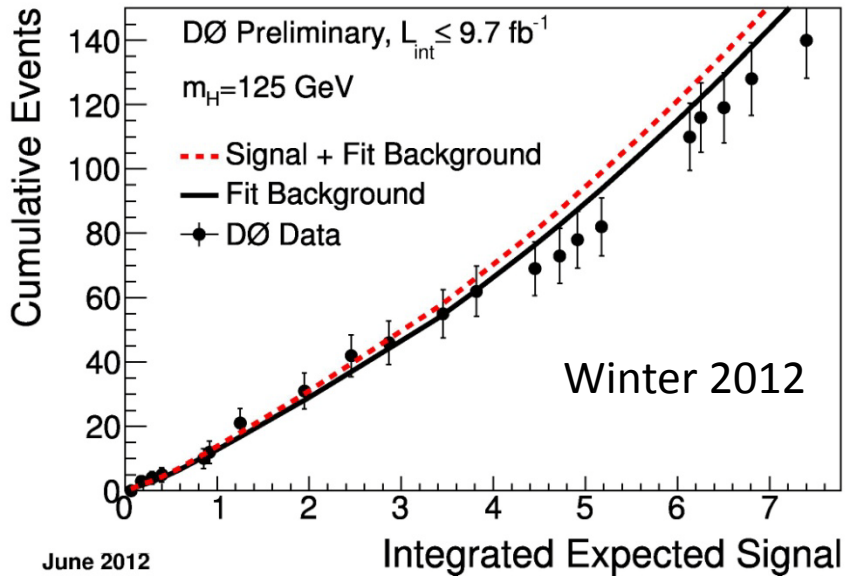
$$Q = \frac{L(x|\theta_{R1}, \hat{\theta}_S)}{L(x|\theta_{R0}, \hat{\hat{\theta}}_S)}$$

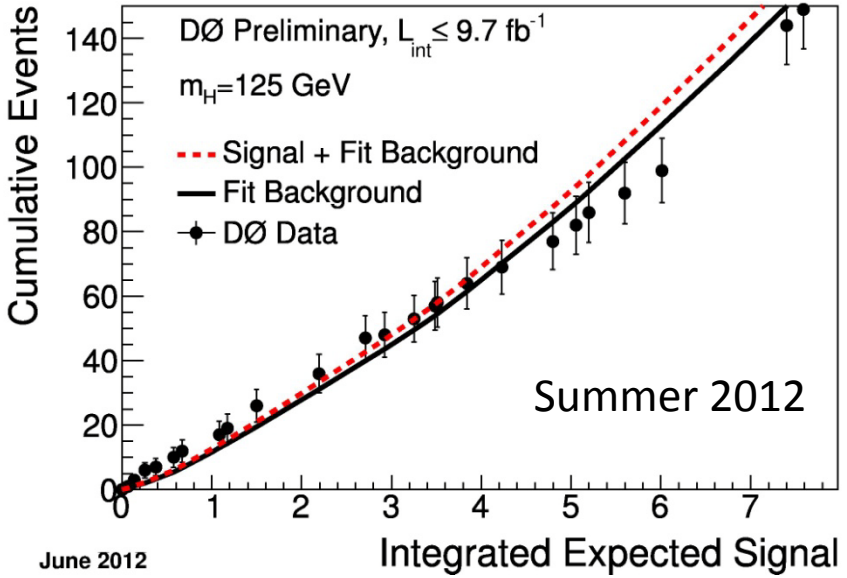


Changes from the previous result

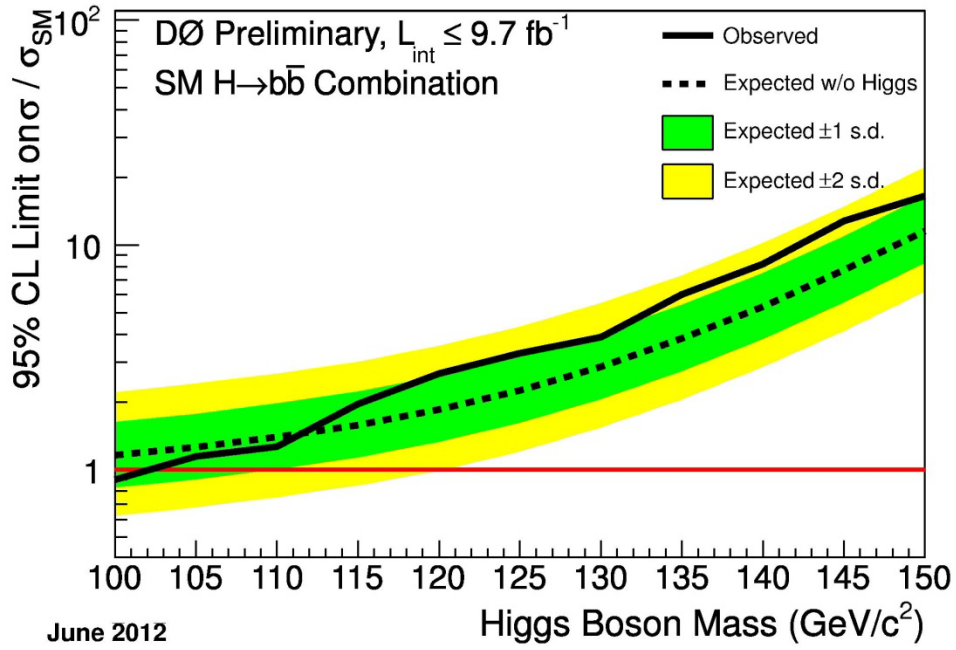


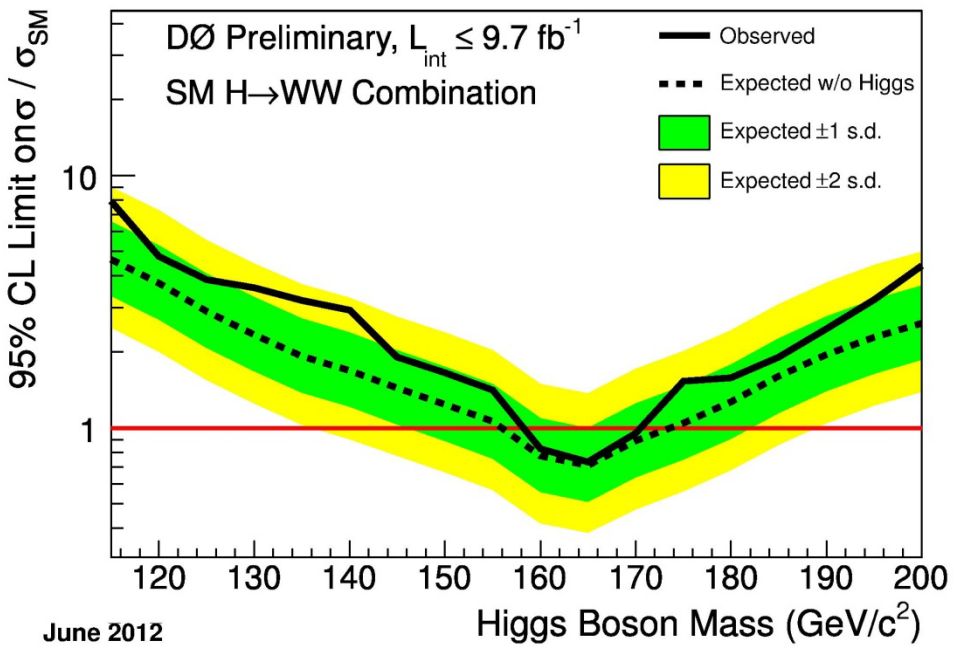






Sub-combination Limits

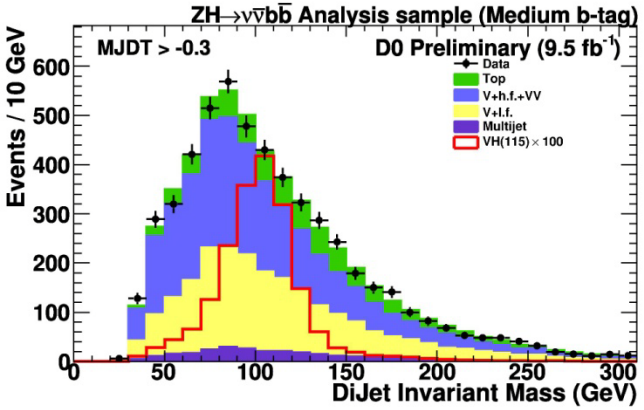




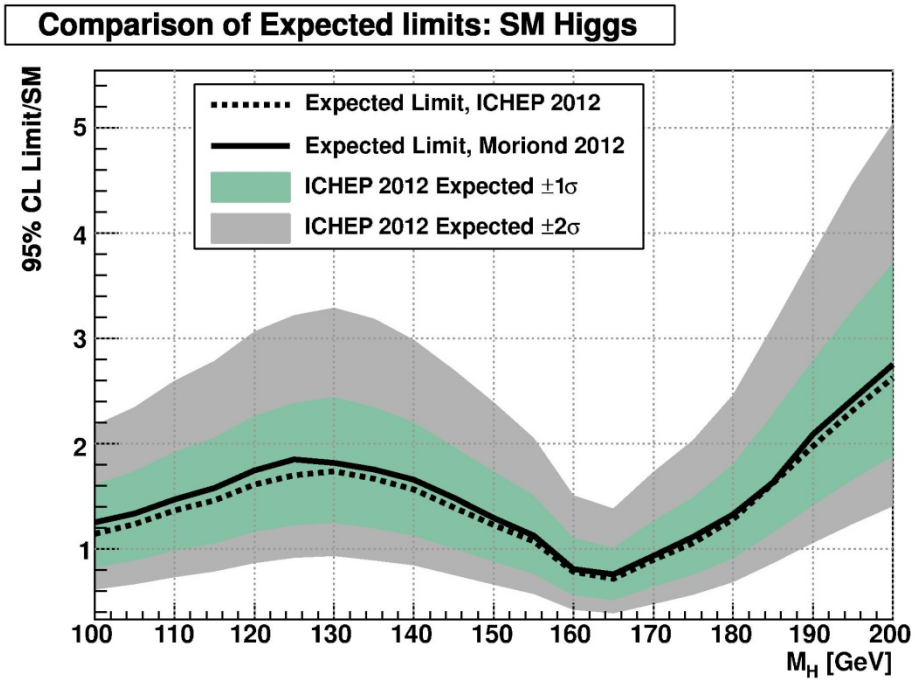
M_H(GeV)	100	105	110	115	120	125	130	135	140	145	150
bb Exp	1.16	1.26	1.40	1.58	1.85	2.25	2.87	3.82	5.31	7.72	11.53
bb Obs	0.90	1.14	1.26	1.96	2.67	3.30	3.89	6.01	8.23	12.81	16.52
WW Exp.	--	--	--	5.81	4.37	3.20	2.57	2.09	1.81	1.54	1.31
WW Obs.	--	--	--	10.59	5.87	4.59	3,18	3.42	2.76	1.89	1.63

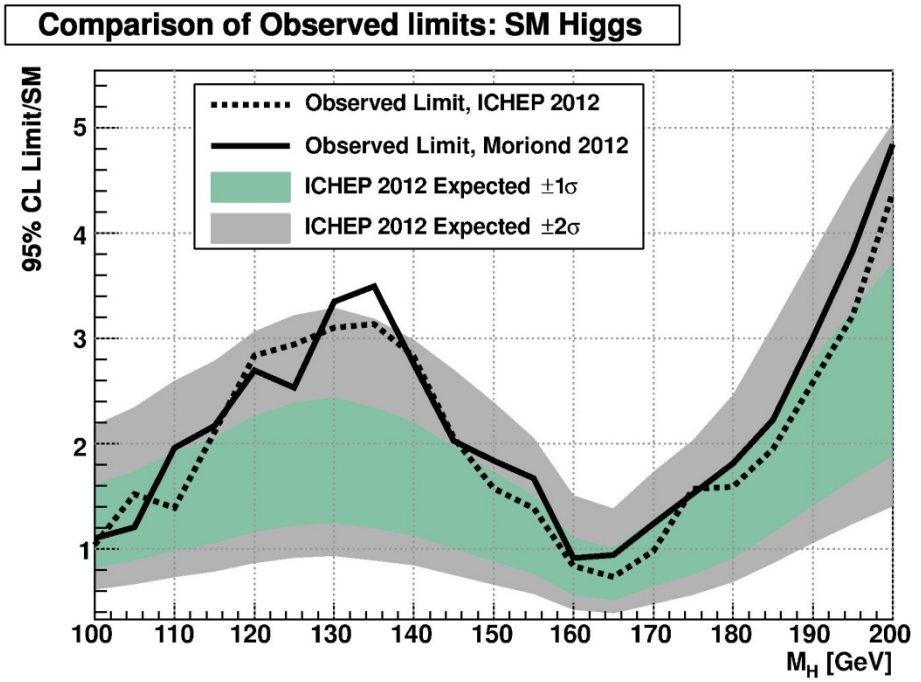
Look Elsewhere Effect

- Estimate based on experimental resolution (dominated by dijet mass resolution)
  - For Low-mass channels, estimate LEE of 2 (supported by pseudoexperiments in dijet mass)
  - For high-mass, estimate LEE of 2 for full range (poor mass resolution due to $\not\!\!E_T$)
- LEE of 2 for bb combination, 4 for full combination
- Max. local significance reduced to 1.3 after LEE correction



Combination Evolution





About 8% improvement in sensitivity

Changes reasonable within updates to analyses