Properties of a Higgs-like particle of mass 125 GeV

Savanna Shaw

Michigan State University

On behalf of the DØ collaboration

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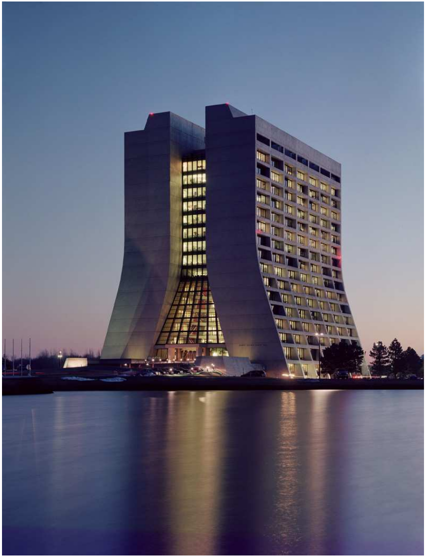
Overview

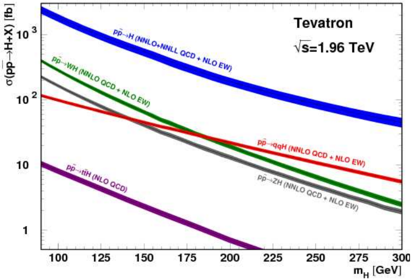
- Introduction/Motivation
  - The Higgs
  - The Tevatron
- DØ Higgs results
  - Cross Section
- Tevatron Higgs results
  - Cross Section
  - Couplings
- Higgs Spin and Parity in $VH \to Vb\bar{b}$
- Summary

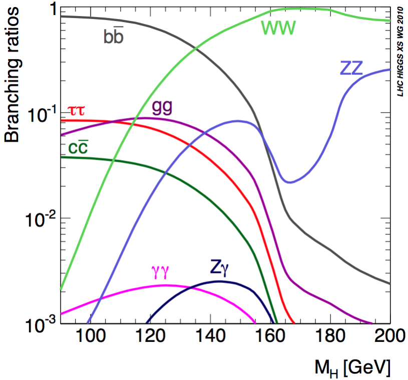


The Higgs

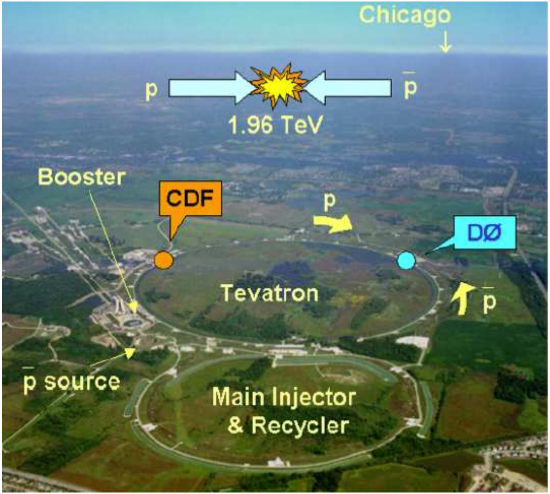
- July 2012 was an exciting time for particle physics!
- LHC experiments discovered new particle at 125 GeV in $\gamma\gamma$ and ZZ$\rightarrow 4\ell$ final states consistent with SM Higgs
- Tevatron provided 3σ evidence of particle in $b\bar{b}$ final state, also consistent with SM Higgs
- Focus now is shifting to measure this new particle's properties

- Primary search modes at LHC: $H \to ZZ$, $H \to \gamma\gamma$, $H \to WW$
- Primary search modes at the Tevatron: $VH \to Vbb$, $H \to WW$.



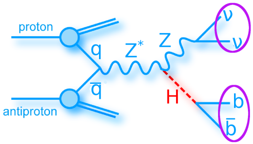


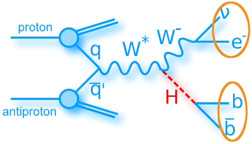
The Tevatron was a $p\bar{p}$ collider operating at $\sqrt{s}$ =1.96 TeV.

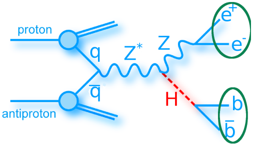


- General strategy:
  - Select events based on final state topology
  - Categorize events
  - Separate signal from background using multivariate techniques
  - Perform statistical analysis

Example: $VH \to Vbb$





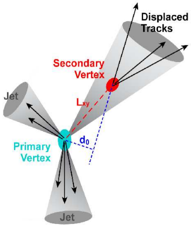


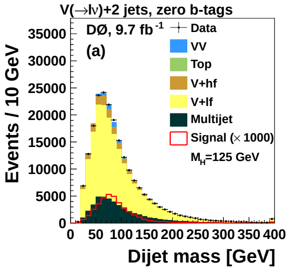
- Require large missing transverse energy and two jets
- Includes contribution from $WH \to \ell\nu bb$, where the lepton was not identified
- Dedicated MVA to reject multijet background

- Require exactly one lepton (e or μ), missing transverse energy and two or three jets
- Dedicated MVA to reject multijet background

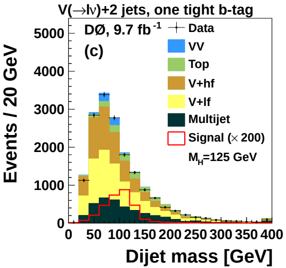
- Require two isolated charged leptons (e or μ), and at least two jets
- Able to fully reconstruct final state
- Dedicated MVA to reject $t\bar{t}$ background

- Tag events coming from decay of a B meson
  - Use secondary vertex and tracking information to build an MVA to separate out light jets from b-jets.

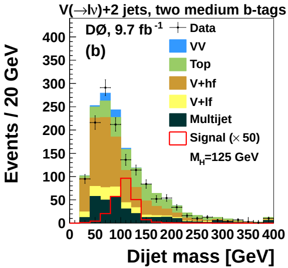




(a) 0 b-tags



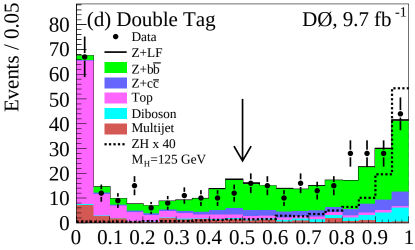
(b) 1 tight b-tags

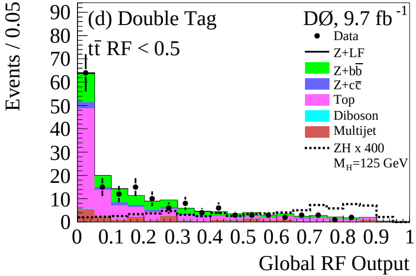


(c) 2 tight b-tags

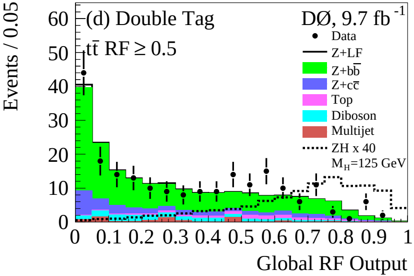
Multivariate Analysis Example: ZH$\rightarrow \ell\ell bb$

- Separate signal from specific backgrounds, or all backgrounds together.



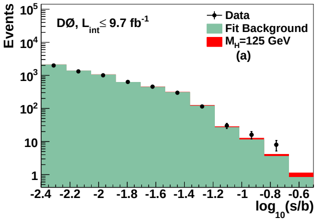


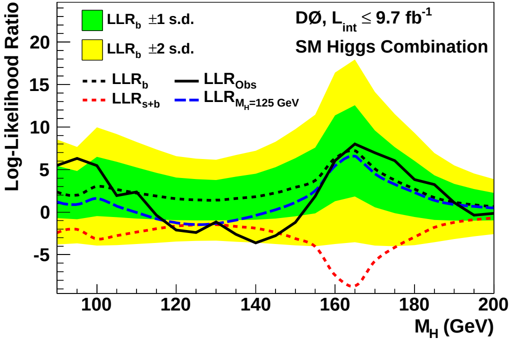
(a) $t\bar{t}$ enriched



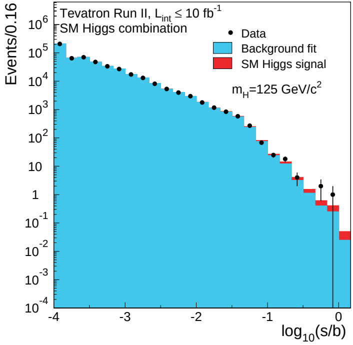
(b) $t\bar{t}$ depleted

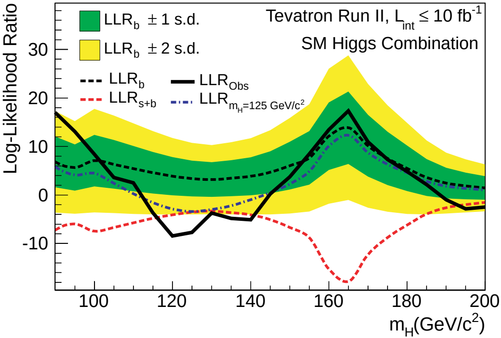
- Combine searches in $H \to bb$, $H \to WW$, $H \to \gamma\gamma$, $H \to \tau\tau$
- Observe a broad excess over background only prediction



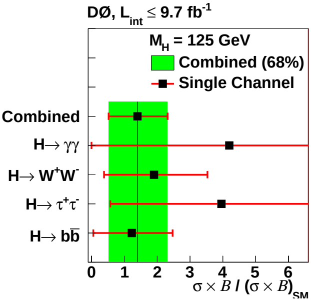


- Combine DØ and CDF Higgs searches
- Observe a broad excess over background only prediction

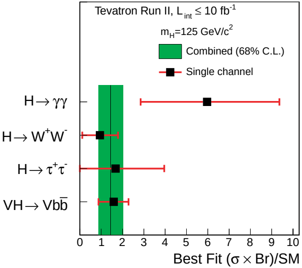




Best Fit Cross Section



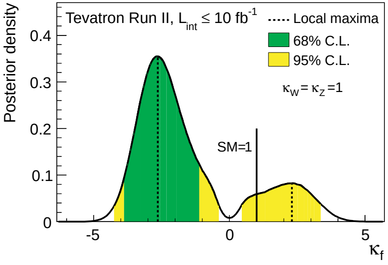
Higgs Decay Mode	$\frac{(\sigma\times BR)}{(\sigma\times BR)_{SM}}$
Combined	$1.40^{+0.92}_{-0.88}$
$H \to \gamma\gamma$	$4.20^{+4.60}_{-4.20}$
$H \to W^+W^-$	$1.90^{+1.63}_{-1.52}$
$H \to \tau^+\tau^-$	$3.96^{+4.11}_{-3.38}$
$H \to b\bar{b}$	$1.23^{+1.24}_{-1.17}$



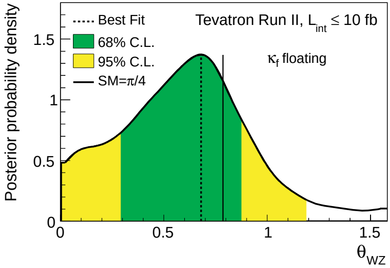
Higgs Decay Mode	$\frac{(\sigma\times BR)}{(\sigma\times BR)_{SM}}$
Combined	$1.44^{+0.59}_{-0.56}$
$H \to \gamma\gamma$	$5.97^{+3.39}_{-3.12}$
$H \to W^+W^-$	$0.94^{+0.85}_{-0.83}$
$H \to \tau^+\tau^-$	$1.68^{+2.28}_{-1.68}$
$H \to b\bar{b}$	$1.59^{+0.69}_{-0.72}$

- Introduce multiplicative scaling factors on Higgs coupling to fermions, W bosons, Z bosons, and general vector bosons: κ_f, κ_W, κ_Z, κ_V
  - Search for deviations from SM expectation of 1
- Also measure the ratio $\lambda_{WZ} = \kappa_W/\kappa_Z$
  - For custodial symmetry to hold $\lambda_{WZ} = 1$

Couplins 1-D

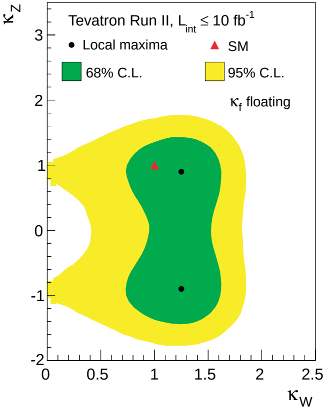


(a) κ_f

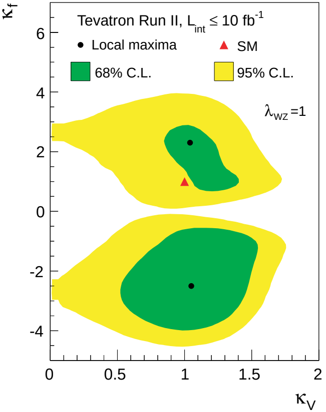


(b) $\theta_{WZ} = \tan^{-1}(1/\lambda_{WZ})$

- $\kappa_f = -2.64^{+1.59}_{-1.30}$
  - Negative sign from excess in $H \rightarrow \gamma\gamma$ ($\Gamma_{\gamma\gamma} \propto |1.28\kappa_V - 0.28\kappa_f|^2$)
- $\lambda_{WZ} = 1.24^{+2.34}_{-0.42}$



(a) κ_W vs κ_Z



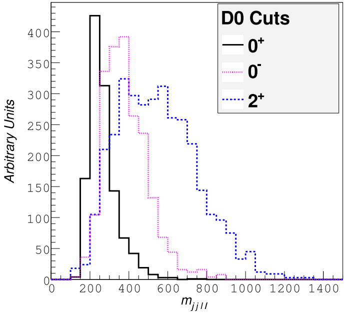
(b) κ_f vs κ_V

- $(\kappa_W, \kappa_Z) = (1.25, \pm 0.90)$
- $(\kappa_f, \kappa_V) = (1.05, \text{-}2.04)$

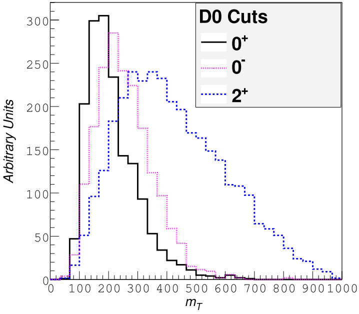
- The Standard model Higgs is predicted to have $J^P = 0^+$
- Could have non-SM scenarios with $J^P = 0^-$, 2^+.
- LHC experiments studying spin and parity in bosonic final states
- Tevatron experiments sensitive to $b\bar{b}$ final state.

Spin and Parity

- Total visible mass of the Vbb system shows good separating power between different J^P assignments
  - J. Ellis, D. S. Hwang, V. Sanz and T. You, "A Fast Track towards the 'Higgs' Spin and Parity," JHEP **1211**, 134 (2012)
  - arXiv:1208.6002 [hep-ph].

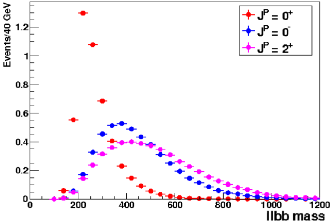


(a) ZH→ $\ell\ell bb$



(b) ZH→ $\nu\nu bb$

- Non-SM signals generated with MADGRAPH5, then interfaced with PYTHIA for showering
- Will only be considering 2^+ vs 0^+ today (work on 0^- result is ongoing)
  - 2^+ signal is generated using Randall-Sundrum graviton model
- After full reconstruction and detector simulation, we see good separation as predicted



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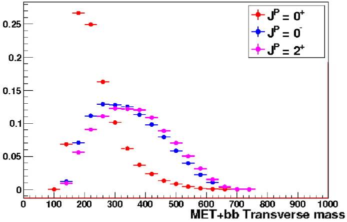
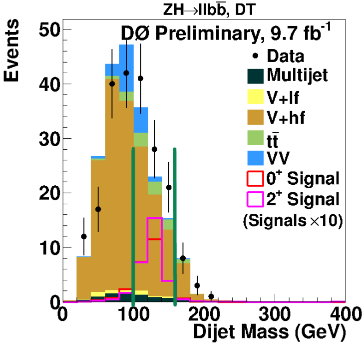


(b) ZH→ $\nu\nu bb$

- Can use the knowledge of mass to split our samples into regions of high and low signal purity
- ZH→Zbb analyses split into regions based on dijet mass, while WH→Wbb analysis split based on MVA output



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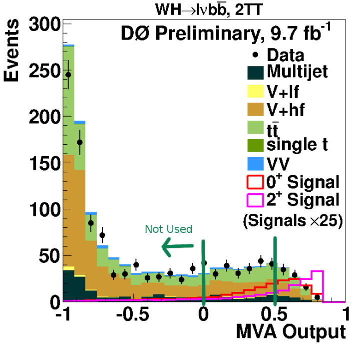
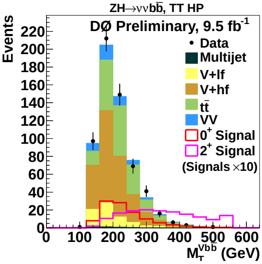
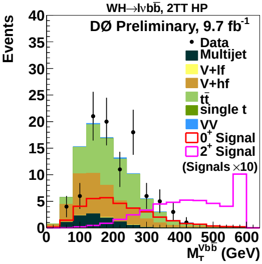


(b) WH→ $\ell\nu bb$

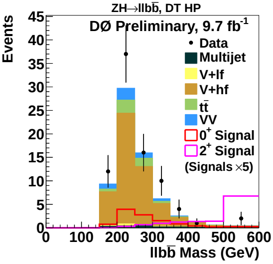
Final Variable



(a) ZH→ $\nu\nu bb$

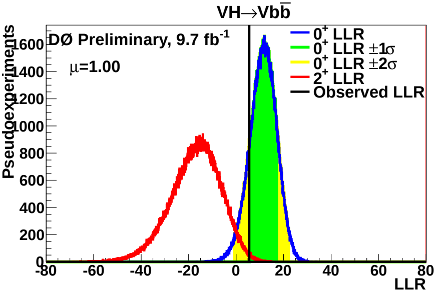


(b) WH→ $\ell\nu bb$

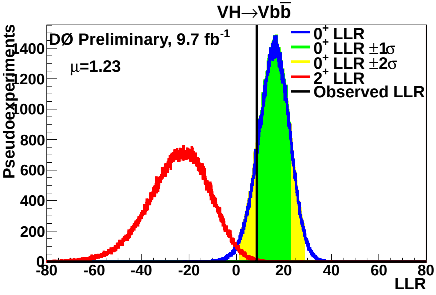


(c) ZH→ $\ell\ell bb$

- Use LLR as a test statistic: $LLR = -2\log(\frac{H_1}{H_0})$
  - $H_0 = 0^+$+background
  - $H_1 = 2^+$+background
- Do computation under two different assumptions:
  - $\sigma\times$BR $= 1.0$ SM
  - $\sigma\times$BR $= 1.23$ SM (best cross section fit value)
  - $\mu = \frac{\sigma}{\sigma_{SM}}$



(a) μ=1.00



(b) μ=1.23

- To quantify model preference, use $CL_S = \frac{CL_{H_1}}{CL_{H_0}}$
  - CL_X = P(LLR≥LLL^{observed}|X).
- Can interpret 1-CL_S as the confidence level for exclusion of 2^+ model in favour of 0^+ model.

	1-CL_S
$\mu = 1.00$, Expected	0.9995
$\mu = 1.00$, Observed	0.992
$\mu = 1.23$, Expected	0.9999
$\mu = 1.23$, Observed	0.999

Summary

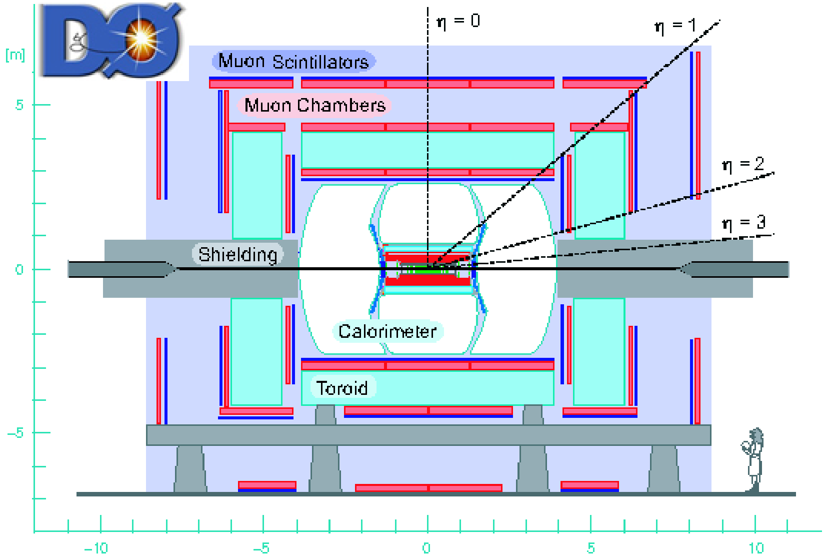
- Tevatron sees broad excess in data that is consistent with SM Higgs boson
- Tevatron primarily sensitive to H$\rightarrow b\bar{b}$, provides information complimentary to LHC H$\rightarrow$bosons
- Prefer $J^P = 0^+$ over 2^+, and reject 2^+ (with graviton like couplings) at $> 99.2\%$ confidence level in $VH \rightarrow Vb\bar{b}$
- Spin and parity studies on 0^- in $VH \rightarrow Vb\bar{b}$ coming soon!

Backup

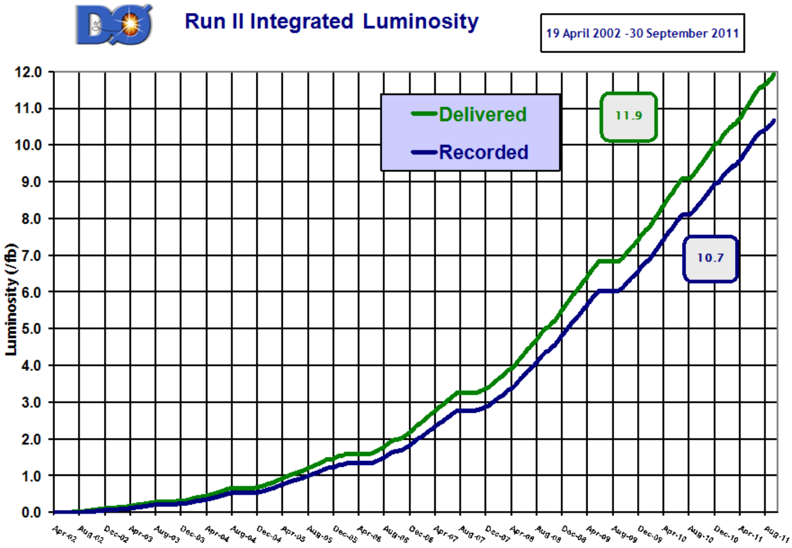
For more information:

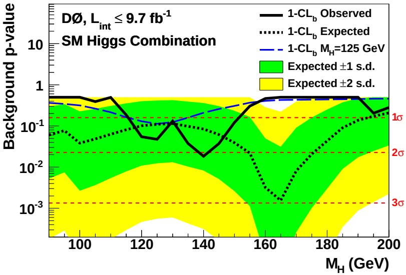
- Tevatron New Phenomena and Higgs Working Group:
  - http://tevnphwg.fnal.gov/
- DØ Higgs results:
  - http://www-d0.fnal.gov/Run2Physics/WWW/results/higgs.htm

The DØ Detector

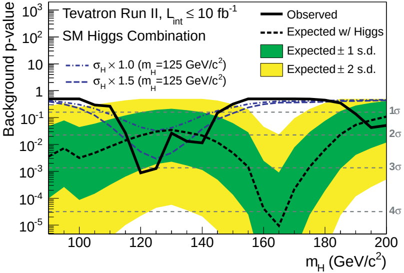


Data Collected

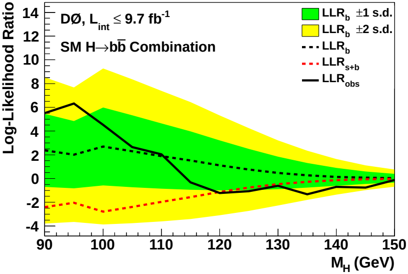




(a) D0



(b) Tevatron



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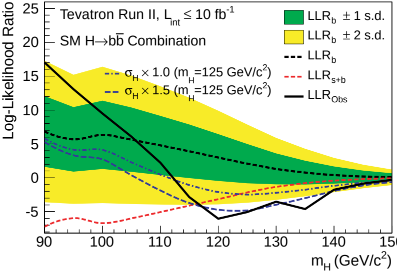
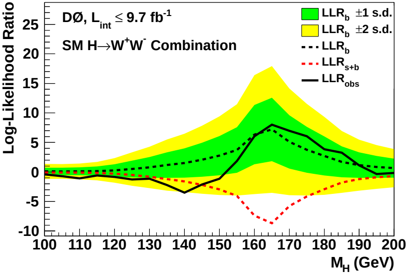


(b) Tevatron



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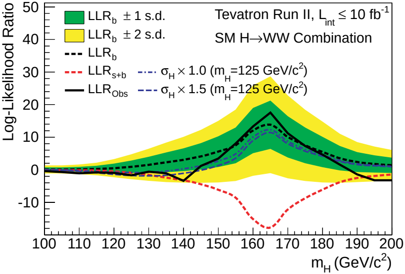
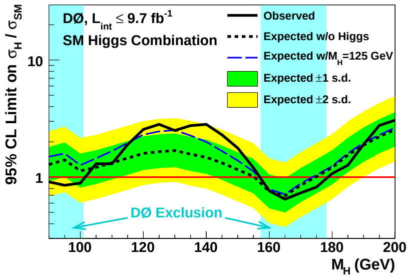
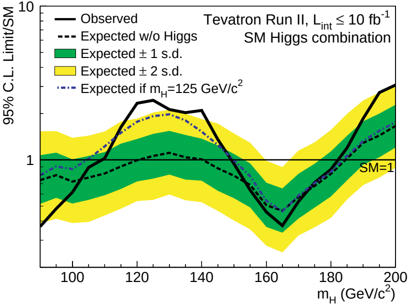


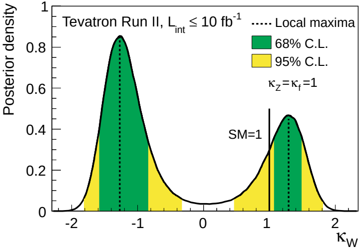
(b) Tevatron



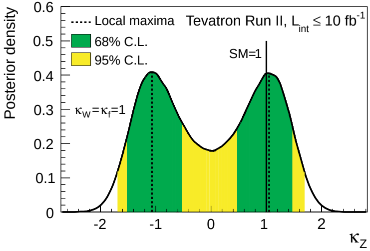
(a) D0



(b) Tevatron



(a) κ_W



(b) κ_Z