HiggsBounds and more

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PHYSICS AT THE TERA SCALE
Helmholtz Alliance

in collaboration with

P. Bechtle, S. Heinemeyer, G. Weiglein and K. Williams

[see arXiv:0811.4169 [hep-ph] and try it out at `www.ippp.dur.ac.uk/HiggsBounds/`]

outline :

- motivation
  - Higgs search
  - why HiggsBounds ?
- implementation
  - basic idea
  - implemented analyses
  - input
- usage and applications
  - usage
  - applications

- motivation

– Higgs search

- The **search for Higgs bosons** is a major cornerstone in the effort to unravel the **nature of electroweak symmetry breaking**.

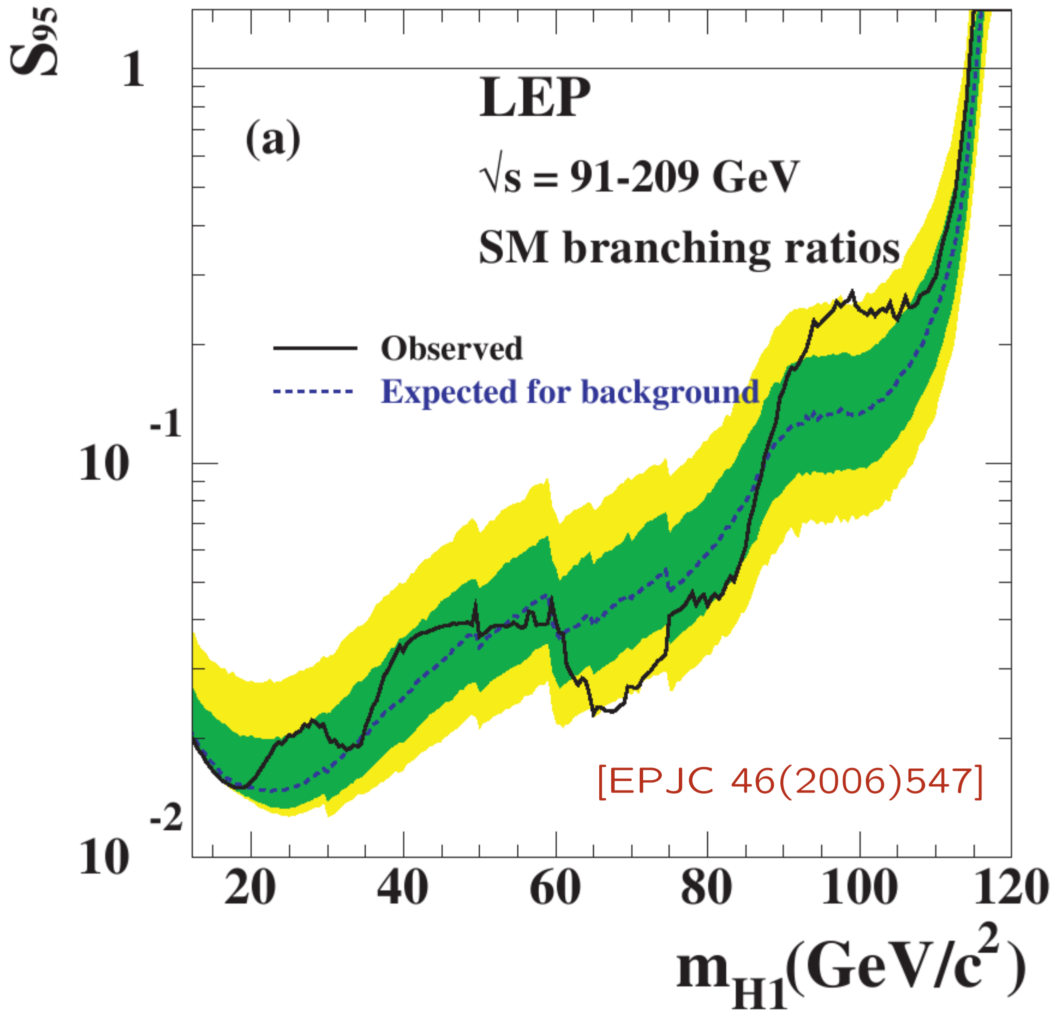
- So far: no Higgs signals.
  - LEP searched for them.
  - Tevatron is currently searching for them.

- Tevatron and LEP turn(ed) the non-observation of Higgs signals into 95% C.L. limits on rates/cross sections of ...

  a) ... individual signal topologies,
  e.g. $e^+e^- \to h_i Z \to b\bar{b}Z$, $p\bar{p} \to h_i \to W^+W^-$,

  b) ... combinations of signal topologies
  e.g. SM, MSSM combined limits.

Higgs search results: example 1: LEP SM combined limit



$$S_{95}(m_{H1}) := \frac{\sigma_{\text{max}}}{\sigma_{\text{SM}}}(m_{H1})$$

where $\sigma_{\text{max}}(m_{H1})$ is the maximal Higgs production cross section compatible with the signal + bkgd hypothesis with only 5% probability

A SM-like model with

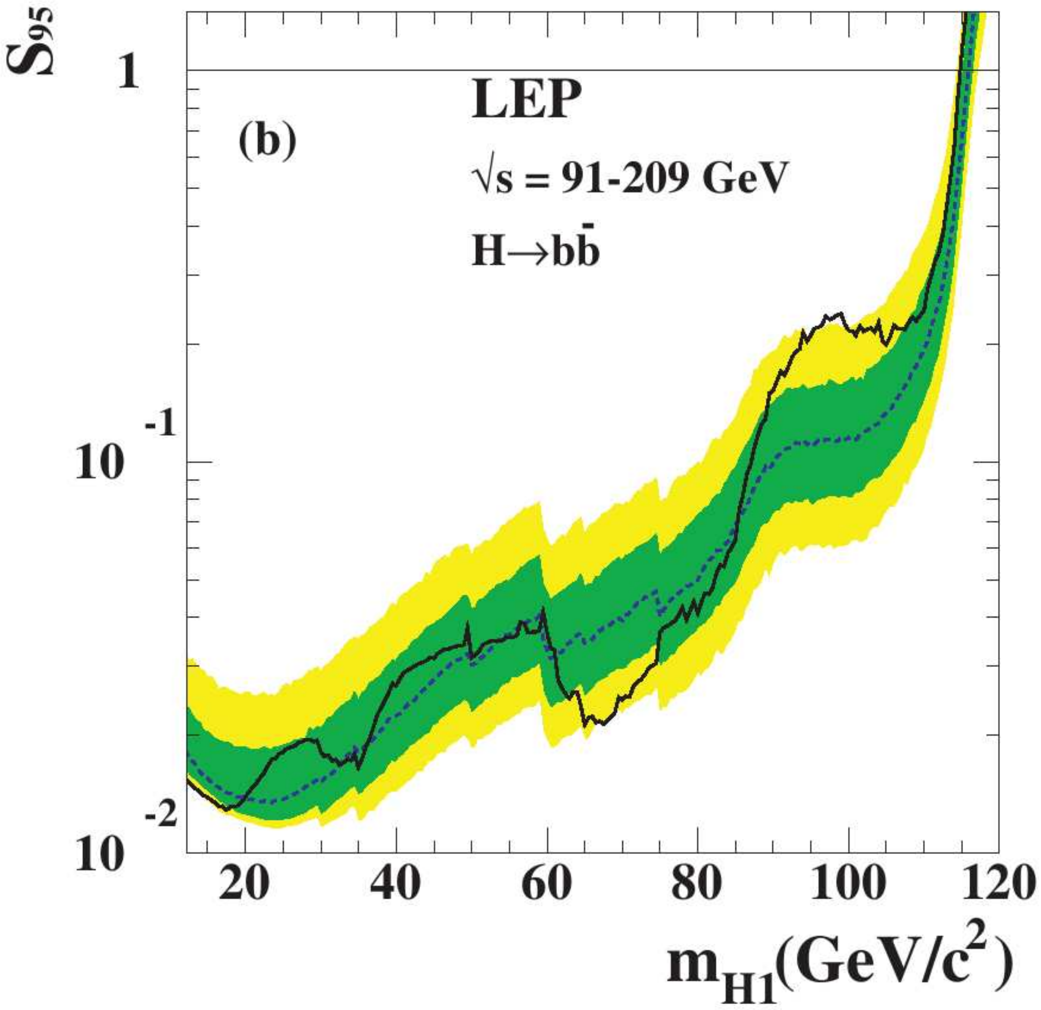
$$\sigma_{\text{model}}(m_{H1}) > \sigma_{\text{max}}(m_{H1})$$

or $\frac{\sigma_{\text{model}}(m_{H1})}{\sigma_{\text{max}}(m_{H1})} > 1$

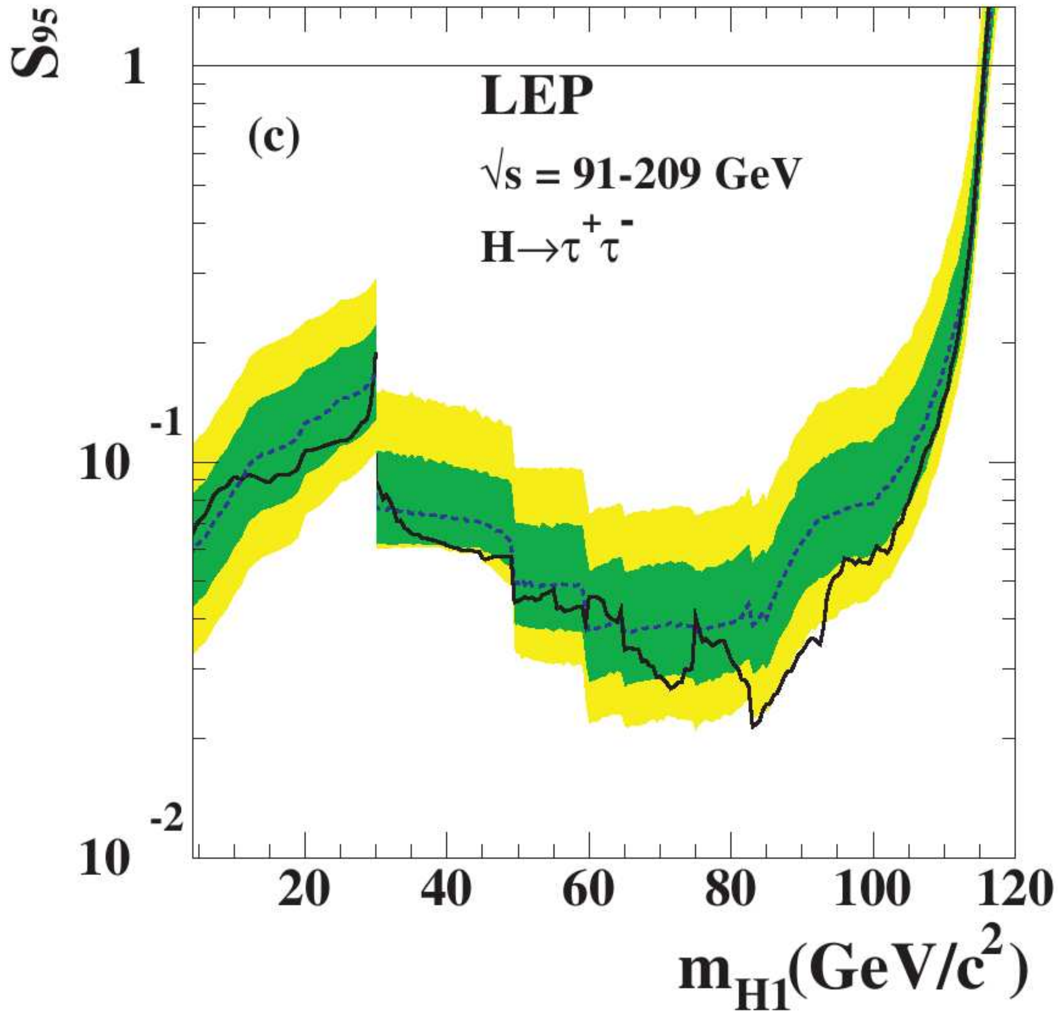
is said to be excluded at the 95% C.L.

example 2: LEP single topology limits, assuming HZ production and ...

a) ... BR($H \to b\bar{b}$)=1



b) ... BR($H \to \tau^+\tau^-$)=1

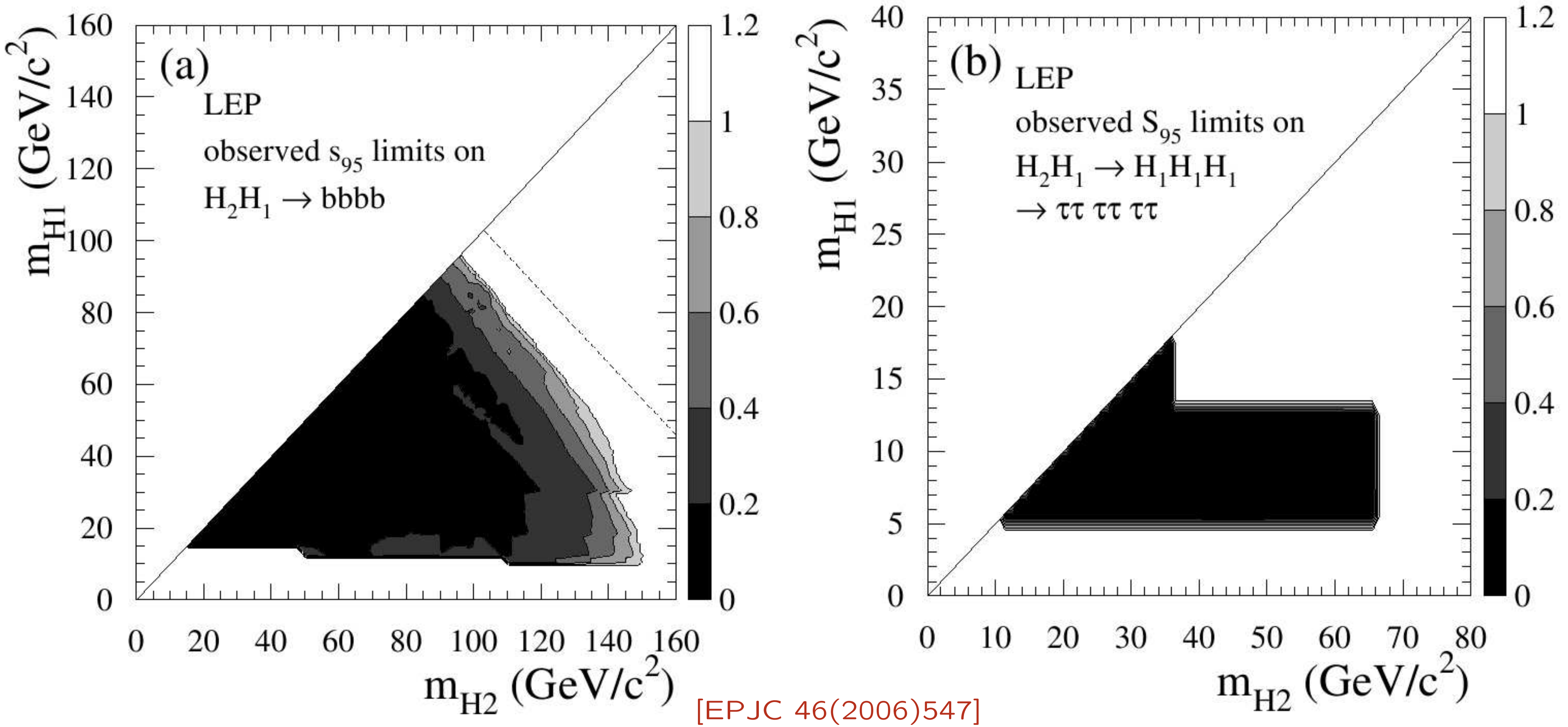


[EPJC 46(2006)547]

example 3: LEP single topology limits, assuming ...

a) ... H_2H_1 production and $\text{BR}(H_i \to b\bar{b}) = 1$

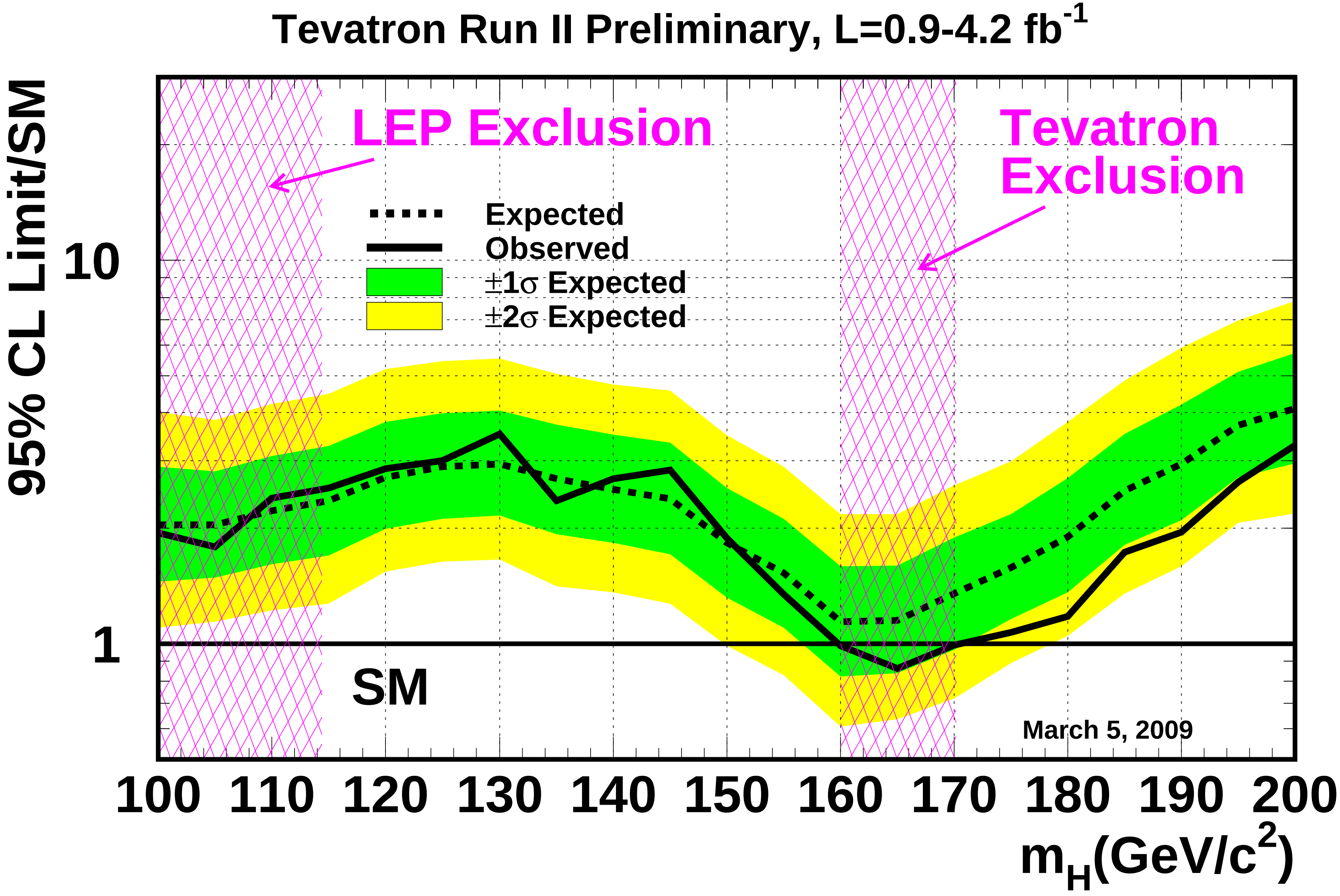
b) ... H_2H_1 production and $\text{BR}(H_i \to \tau^+\tau^-) = \text{BR}(H_2 \to H_1H_1) = 1$



[EPJC 46(2006)547]

here: $S_{95}(m_{H1}, m_{H2}) := \frac{\sigma_{\text{max}}}{\sigma_{\text{ref}}}(m_{H1}, m_{H2})$ with a reference $\sigma_{\text{ref}}(m_{H1}, m_{H2})$

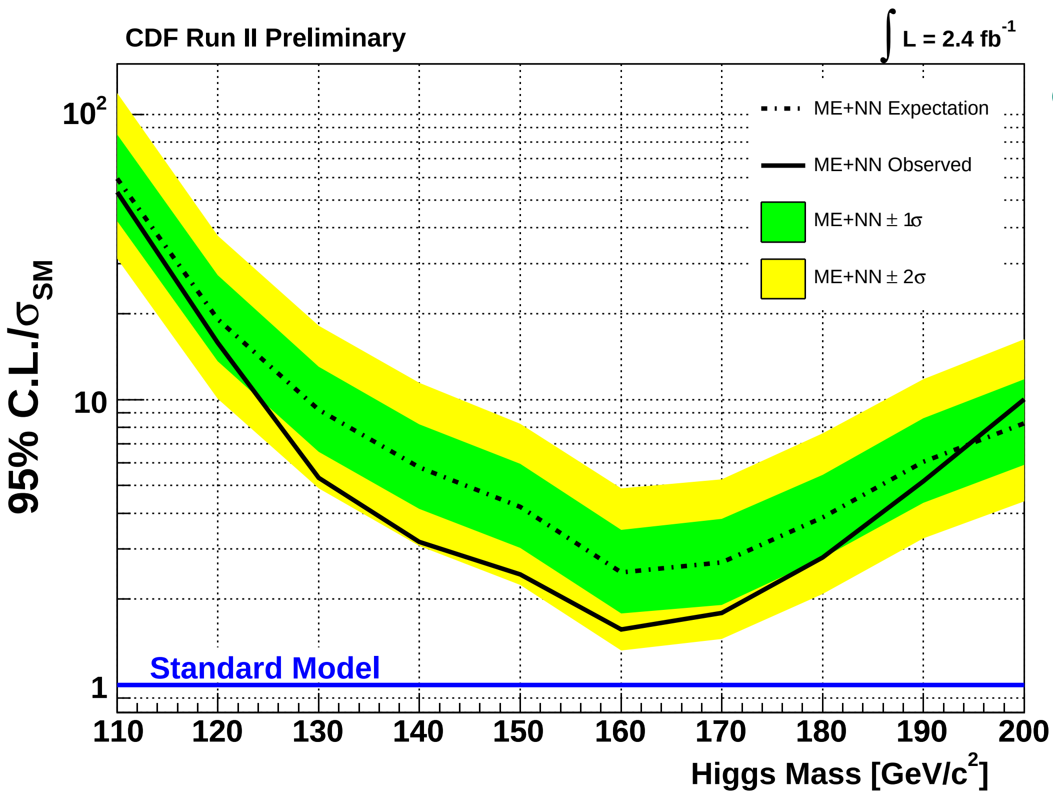
example 4: Tevatron SM combined limit [CDF note 9713, DØ note 5889]



example 5: Tevatron single topology limits

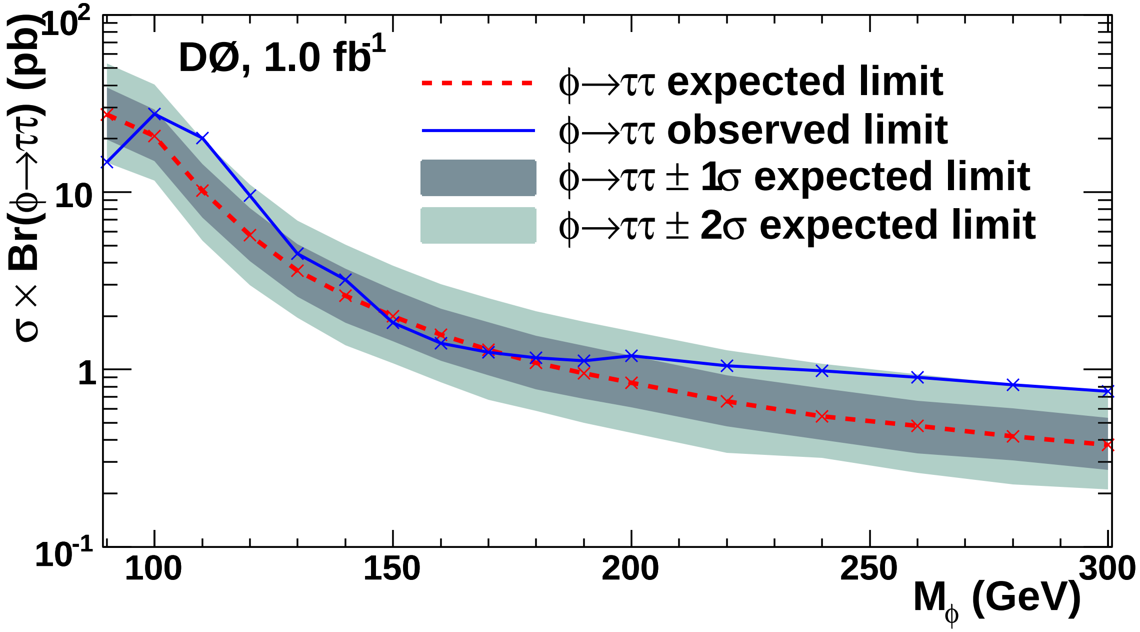
a) $p\bar{p} \rightarrow H \rightarrow WW^{\star} \rightarrow l\nu l\nu$ using 2.4 fb^{-1}
[CDF note 9236]

cross section ratio limit



b) $p\bar{p} \rightarrow H \rightarrow \tau^{+}\tau^{-}$ using 1 fb^{-1}
[DØ hep-ex/0805.2491]

absolute cross section limit



– why HiggsBounds ?

- many limits on individ./combined topologies (LEP/Tevatron) available

- normally: SM combined analyses cannot be used for BSM models

- to test such models:
  $\longrightarrow$ check predictions against individual search topologies

HiggsBounds: [Bechtle, OBr, Heinemeyer, Weiglein, Williams '08]

Test theoretical predictions of models with arbitrary Higgs sectors against exclusion bounds obtained from Higgs searches at LEP and the Tevatron.

- Easy access to all relevant Higgs exclusion limits
  including information not available in the publications.
  (e.g. expected 95% CL cross section limits for some LEP combinations)

- Applicable to models with arbitrary Higgs sectors

  HiggsBounds Input: the predictions of the model for:
  # of Higgs bosons h_i , m_{h_i}, $\Gamma_{\text{tot}}(h_i)$, $\text{BR}(h_i \to \ldots)$,
  production cross section ratios (wrt reference values)

- Combination of results from LEP and Tevatron possible

- Three ways to use HiggsBounds:
  command line, library of subroutines (Fortran 77/90), web interface

  www.ippp.dur.ac.uk/HiggsBounds

- implementation

• implementation

– basic idea

- Evaluate model prediction

$$Q_{\text{model}}(X) = \frac{[\sigma \times \text{BR}]_{\text{model}}}{[\sigma \times \text{BR}]_{\text{ref}}} \qquad \text{(reference: usually SM)}$$

  of a search topology of an analysis X,
  for given Higgs masses + deviations from the reference.

- From the experimental analysis X, read off the corresponding observed 95% C.L. limit: $Q_{\text{observed}}(X)$.

- If $\frac{Q_{\text{model}}(X)}{Q_{\text{observed}}(X)} > 1$ the model is excluded by this analysis at 95% C.L.

→ Problem : how to combine search results without losing the 95% C.L. ?

Answer: We can't do that.

Only a dedicated experimental analysis can do that.

However: we can always use the analysis of highest statistical sensitivity.

How to preserve the 95% C.L. limit:

- Obtain for each analysis X the experimental expected limit $Q_{\text{expected}}(X)$.
- Determine the analysis X_0 with the highest sensitivity for the signal, i.e. of all analyses X find the one X_0 where $\frac{Q_{\text{model}}(X)}{Q_{\text{expected}}(X)}$ is maximal.
- If for this analysis $\frac{Q_{\text{model}}(X_0)}{Q_{\text{observed}}(X_0)} > 1$ the model is excluded at 95% C.L.

– implemented analyses: LEP [HiggsBounds 1.2.0]

We include expected and observed S_{95} values for the following analyses

1. $e^+e^- \to (h_k)Z \to (b\bar{b})Z$, [EPJC 46(2006)547]
2. $e^+e^- \to (h_k)Z \to (\tau^+\tau^-)Z$, [EPJC 46(2006)547]
3. $e^+e^- \to (h_k)Z \to (\gamma\gamma)Z$, [LEP Higgs WG note 2002-02]
4. $e^+e^- \to (h_k)Z \to$ (anything)Z, [OPAL, EPJC 27(2003)311]
5. $e^+e^- \to (h_k \to h_i h_i)Z \to (b\bar{b}b\bar{b})Z$, [EPJC 46(2006)547]
6. $e^+e^- \to (h_k \to h_i h_i)Z \to (\tau^+\tau^-\tau^+\tau^-)Z$, [EPJC 46(2006)547]
7. $e^+e^- \to (h_k h_i) \to (b\bar{b}b\bar{b})$, [EPJC 46(2006)547]
8. $e^+e^- \to (h_k h_i) \to (\tau^+\tau^-\tau^+\tau^-)$, [EPJC 46(2006)547]
9. $e^+e^- \to (h_k \to h_i h_i)h_i \to (b\bar{b}b\bar{b})b\bar{b}$, [EPJC 46(2006)547]
10. $e^+e^- \to (h_k \to h_i h_i)h_i \to (\tau^+\tau^-\tau^+\tau^-)\tau^+\tau^-$, [EPJC 46(2006)547]
11. $e^+e^- \to (h_k \to h_i h_i)Z \to (b\bar{b})(\tau^+\tau^-)Z$, [LEP Higgs WG]
12. $e^+e^- \to (h_k \to b\bar{b})(h_i \to \tau^+\tau^-)$, [LEP Higgs WG]
13. $e^+e^- \to (h_k \to \tau^+\tau^-)(h_i \to b\bar{b})$, [LEP Higgs WG]

Inclusion of additional topologies is work in progress
(e.g. $e^+e^- \to h_k Z, h_k \to$ invisible; $e^+e^- \to h_k Z, h_k \to$ 2 jets, ...)

[implementation]

– implemented analyses: Tevatron [HiggsBounds 1.2.0]

single topology analyses

search topology X (analysis)	reference ($\star$=published)
$p\bar{p} \to ZH \to l^+l^-b\bar{b}$ (CDF with 4.1 [2.7]fb^{-1})	CDF note 9475 [CDF '09]*
$p\bar{p} \to ZH \to l^+l^-b\bar{b}$ (DØ with 4.2 fb^{-1})	DØ note 5876
$p\bar{p} \to WH \to l\nu b\bar{b}$ (CDF with 4.3 [2.7] fb^{-1})	CDF '09 [CDF '09]*
$p\bar{p} \to WH \to l\nu b\bar{b}$ (DØ with 5.0 [1.1] fb^{-1})	DØ note 5972 [DØ '08]*
$p\bar{p} \to WH \to W^+W^-W^\pm$ (DØ with 3.6 fb^{-1})	DØ note 5873
$p\bar{p} \to WH \to W^+W^-W^\pm$ (CDF with 2.7 fb^{-1})	CDF note 7307 v3
$p\bar{p} \to H \to W^+W^- \to l^+l'^-$ (DØ with 3.0 fb^{-1})	DØ note 5757
$p\bar{p} \to H \to W^+W^- \to l^+l'^-$ (CDF with 3.0 fb^{-1})	CDF '08*
$p\bar{p} \to H \to \gamma\gamma$ (DØ with 4.2 [2.7] fb^{-1})	DØ note 5858 [DØ '09]*
$p\bar{p} \to H \to \tau^+\tau^-$ (CDF with 1.8 fb^{-1})	CDF '09*
$p\bar{p} \to H \to \tau^+\tau^-$ (DØ with 2.2 [1.0] fb^{-1})	DØ 5740 [DØ '08]*
$p\bar{p} \to H \to \tau^+\tau^-$ (CDF & DØ with 1.8 & 2.2 fb^{-1})	CDF note 9888, DØ note 5980
$p\bar{p} \to bH, H \to \tau^+\tau^-$ (DØ with 2.7 [0.328] fb^{-1})	DØ note 5985 [DØ '09]*
$p\bar{p} \to bH, H \to b\bar{b}$ (CDF with 1.9 fb^{-1})	CDF note 9284
$p\bar{p} \to bH, H \to b\bar{b}$ (DØ with 2.6 [1.0] fb^{-1})	DØ note 5726 [DØ '08]*

– implemented analyses: Tevatron [HiggsBounds 1.2.0]

analyses combining topologies

search topology X (analysis)	reference ($\star$=publ.)
$p\bar{p} \to WH/ZH \to b\bar{b} + E_T^{\text{miss.}}$ (CDF with 3.6 [1.0] fb^{-1})	CDF note 9891 [CDF '08]*
$p\bar{p} \to WH/ZH \to b\bar{b} + E_T^{\text{miss.}}$ (DØ with 2.1 [0.93] fb^{-1})	D0 note 5586 [DØ '08]*
$p\bar{p} \to H/HW/HZ/H$ via VBF, $H \to \tau^+\tau^-$ (CDF with 2.0 fb^{-1})	CDF note 9248
$p\bar{p} \to H/HW/HZ/H$ via VBF, $H \to WW$ (CDF with 4.8 fb^{-1})	CDF note 9887
$p\bar{p} \to H/HW/HZ/H$ via VBF, $H \to WW$ (CDF with 3.0-4.2 fb^{-1})	DØ note 5871
Combined SM analysis (CDF & DØ with 0.9 – 1.9 fb^{-1})	hep-ex/0712.2383
Combined SM analysis (CDF & DØ with 1.0 – 2.4 fb^{-1})	hep-ex/0804.3423
Combined SM analysis (CDF & DØ with 3.0 fb^{-1})	hep-ex/0808.0534
Combined SM analysis (CDF with 3.0 fb^{-1})	CDF note 9674
Combined SM analysis (CDF & DØ with 0.9 – 4.2 fb^{-1}) [At the moment, used only for $m_H \geq 155$ GeV.]	hep-ex/0903.4001
Combined SM analysis (CDF with 2.0 – 4.8 fb^{-1})	CDF note 9897

Inclusion of limits in full mass range is work in progress.

Input required by HiggsBounds: input option effC ("effective couplings")

number of Higgs bosons: n_{Higgs}

masses: m_{h_k} ,

total widths: $\Gamma_{\mathrm{tot}}(h_k)$,

normalised squared effective couplings:

$$\left(\frac{g^{\mathrm{model}}_{h_k ZZ}}{g^{\mathrm{SM}}_{HZZ}}\right)^2, \quad \left(\frac{g^{\mathrm{model}}_{h_k WW}}{g^{\mathrm{SM}}_{HWW}}\right)^2, \quad \left(\frac{g^{\mathrm{model}}_{h_k \gamma\gamma}}{g^{\mathrm{SM}}_{H\gamma\gamma}}\right)^2, \quad \left(\frac{g^{\mathrm{model}}_{h_k gg}}{g^{\mathrm{SM}}_{Hgg}}\right)^2,$$

$$\left(\frac{g^{\mathrm{model}}_{h_k bb,\mathrm{eff}}}{g^{\mathrm{SM}}_{Hbb}}\right)^2, \quad \left(\frac{g^{\mathrm{model}}_{h_k \tau\tau,\mathrm{eff}}}{g^{\mathrm{SM}}_{H\tau\tau}}\right)^2, \quad \left(\frac{g^{\mathrm{model}}_{h_k h_i Z}}{g^{\mathrm{ref}}_{H'HZ}}\right)^2,$$

branching ratios: $\mathrm{BR}_{\mathrm{model}}(h_k \to h_i h_i)$,

for $k, i \in \{1, \ldots, n_{\mathrm{Higgs}}\}$.

model predictions $Q_{\text{model}}(X)$ calculated with this input: LEP examples:

$$Q_{\text{model}}\left[e^+e^- \to (h_1)Z \to (b\bar{b})Z\right] = \frac{\sigma_{\text{model}}(h_1 Z)}{\sigma_{\text{ref}}(HZ)} \text{BR}_{\text{model}}(h_1 \to b\bar{b}),$$

$$Q_{\text{model}}\left[e^+e^- \to (h_2)Z \to (h_1 h_1)Z \to (b\bar{b}b\bar{b})Z\right] = \frac{\sigma_{\text{model}}(h_2 Z)}{\sigma_{\text{ref}}(HZ)} \text{BR}_{\text{model}}(h_2 \to h_1 h_1) \text{BR}_{\text{model}}(h_1 \to b\bar{b})^2$$

with

$$\frac{\sigma_{\text{model}}(e^+e^- \to h_k Z)}{\sigma_{\text{ref}}(e^+e^- \to HZ)} = \left(\frac{g^{\text{model}}_{h_k ZZ}}{g^{\text{SM}}_{HZZ}}\right)^2, \quad \frac{\sigma_{\text{model}}(e^+e^- \to h_k h_i)}{\sigma_{\text{ref}}(e^+e^- \to H'H)} = \left(\frac{g^{\text{model}}_{h_k h_i Z}}{g^{\text{ref}}_{H'HZ}}\right)^2,$$

$$\text{BR}_{\text{model}}(h_k \to b\bar{b}) = \text{BR}_{\text{SM}}(H \to b\bar{b})(m_H) \left.\frac{\Gamma^{\text{SM}}_{\text{tot}}(m_H)}{\Gamma_{\text{tot}}(h_k)}\right|_{m_H = m_{h_k}} \left(\frac{g^{\text{model}}_{h_k bb,\text{eff}}}{g^{\text{SM}}_{Hbb}}\right)^2.$$

green: provided functions using HDECAY 3.303 [Djouadi et al.'98]

[implementation, input]

model predictions $Q_{\text{model}}(X)$ calculated with this input: Tevatron example:

model cross section for the search topology

$$X = p\bar{p} \to H \to W^+W^- \to l^+l'^-$$

normalised to the SM cross section:

$$Q_{\text{model}}(X) = \left(\frac{\sigma^{\text{model}}(X)}{\sigma^{\text{SM}}(X)}\right) = \left\{\left(\frac{\hat{\sigma}^{\text{model}}_{gg\to h_k}(\hat{s}_{\text{thr.}}, m_{h_k})}{\hat{\sigma}^{\text{SM}}_{gg\to h_k}(\hat{s}_{\text{thr.}}, m_H)} \frac{\sigma_{\text{SM}}(p\bar{p} \to gg \to H, m_H)}{\sigma_{\text{SM}}(p\bar{p} \to H, m_H)}\right.\right.$$

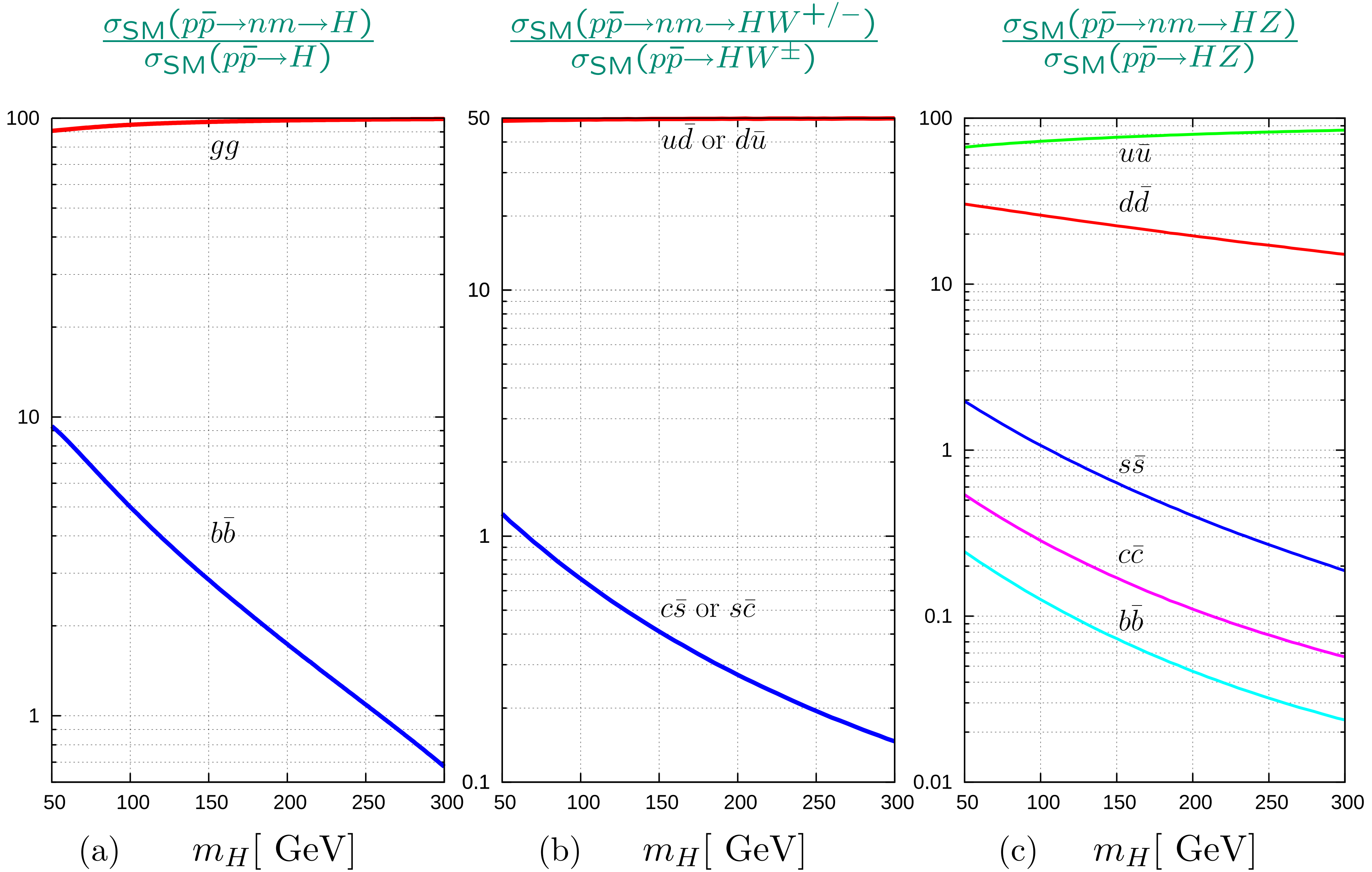
$$\left.\left. + \frac{\hat{\sigma}^{\text{model}}_{b\bar{b}\to h_k}(\hat{s}_{\text{thr.}}, m_{h_k})}{\hat{\sigma}^{\text{SM}}_{b\bar{b}\to h_k}(\hat{s}_{\text{thr.}}, m_H)} \frac{\sigma_{\text{SM}}(p\bar{p} \to b\bar{b} \to H, m_H)}{\sigma_{\text{SM}}(p\bar{p} \to H, m_H)}\right) \frac{\text{BR}^{\text{model}}_{h_k\to W^+W^-}(m_{h_k})}{\text{BR}^{\text{SM}}_{H\to W^+W^-}(m_H)}\right\}\Bigg|_{m_H = m_{h_k}}$$

with
$$\frac{\hat{\sigma}^{\text{model}}_{gg\to h_k}(\hat{s}_{\text{thr.}}, m_{h_k})}{\hat{\sigma}^{\text{SM}}_{gg\to h_k}(\hat{s}_{\text{thr.}}, m_H)} = \left(\frac{g^{\text{model}}_{h_k gg}}{g^{\text{SM}}_{Hgg}}\right)^2, \quad \frac{\hat{\sigma}^{\text{model}}_{b\bar{b}\to h_k}(\hat{s}_{\text{thr.}}, m_{h_k})}{\hat{\sigma}^{\text{SM}}_{b\bar{b}\to h_k}(\hat{s}_{\text{thr.}}, m_H)} = \left(\frac{g^{\text{model}}_{h_k b\bar{b},\text{eff}}}{g^{\text{ref}}_{Hb\bar{b}}}\right)^2,$$

$$\text{BR}^{\text{model}}_{h_k\to W^+W^-} = \text{BR}^{\text{SM}}_{H\to W^+W^-}(m_H) \frac{\Gamma^{\text{SM}}_{\text{tot}}(m_H)}{\Gamma_{\text{tot}}(h_k)}\Bigg|_{m_H = m_{h_k}} \left(\frac{g^{\text{model}}_{h_k WW}}{g^{\text{SM}}_{HWW}}\right)^2 .$$

green: provided functions

SM cross section fractions in % (using MRST 2006 NNLO PFDs)



For the SM normalisation, HiggsBounds provides also predicitons for:

– SM branching ratios using HDECAY 3.303 [Djouadi et al.'98]

and

– SM Higgs production processs using the compilation of the TEV4LHC Working Group [Aglietti et al.'06].

- usage and applications

– usage

Command-line version:

Command:

```
HiggsBounds <analyses to use> <input mode> <number of Higgses> [<fileprefix>]
```

with

```
<analyses to use>     :  LandT (LEP and Tevatron)
                      :  onlyT (only Tevatron)
                      :  onlyL (only LEP)
                      :  singH (only analyses involving one Higgs)
<input mode>          :  part (partonic CS ratios)
                      :  hadr (hadronic CS ratios)
                      :  effC (effective couplings)
<number of Higgses>   :  1 to 9 (extendable)
<fileprefix>          :  prefix for input files (optional,
                         can also be a subdirectory)
```

The command-line version works on a set of input files.
Which set depends on the selected analyses and input mode.

Sample output file (written to <prefix>HiggsBounds_Results.dat)

```
# generated with HiggsBounds on 31.10.2008 at 11:18
# settings: LandT, effC
#
# column abbreviations
#   n          : line id of input
#   Mh(i)      : Higgs boson masses
#   HBresult   : scenario allowed flag (1: allowed, 0: excluded, -1: unphysical)
#   chan       : most sensitive channel (see below). chan=0 if no channel applies
#   obsratio   : ratio [sig x BR]_model/[sig x BR]_limit (<1: allowed, >1: excluded)
#   ncomb      : number of Higgs bosons combined in most sensitive channel
#   additional : optional additional data stored in <prefix>additional.dat (e.g. tan beta)
#
# channel numbers used in this file
#           3 : (ee)->(h3)Z->(b b)Z   (LEP table 14b)
#           4 : (ee)->(h1)Z->(tau tau)Z   (LEP table 14c)
#         124 : (pp)->W(h1)->l nu (b b)   (CDF Note 9463)
#         134 : (pp)->h2->tau tau   (arXiv:0805.2491)
#         157 : (pp)->h1+... where h1 is SM-like  (arXiv:0804.3423 [hep-ex])
# (for full list of processes, see Key.dat)
#
#cols: n    Mh(1)     Mh(2)     Mh(3)    HBresult  chan    obsratio     ncomb  additional(1)
#
       1   359.121   271.963   134.929         1   134    0.212206E-03     1    0.246862
       2   75.0123   92.8677   71.9716         1     4    0.306172E-01     1    0.714964
       3   136.293   345.483   330.026         1   124    0.640713E-01     1    0.434594
       4   111.377   220.765   51.7469         1     3    0.162811         1    0.727173
       5   186.131   355.002   146.448         0   157     15.2354         1    0.230522
```

Fortran subroutine version: e.g. for effective couplings input

```
call run_HiggsBounds_effC(nH,<analyses to use>,
&    Mh,GammaTotal,
&    g2hjbb,g2hjtautau,g2hjWW,g2hjZZ,
&    g2hjgaga,g2hjgg,g2hjhiZ,
&    BR_hjhihi,
&    HBresult,chan,
&    obsratio, ncombined )
```

WWW version:

options similar to command-line version, pointwise input only

see www.ippp.dur.ac.uk/HiggsBounds/

application 1: re-evaluation of SM exclusion with improved prediction

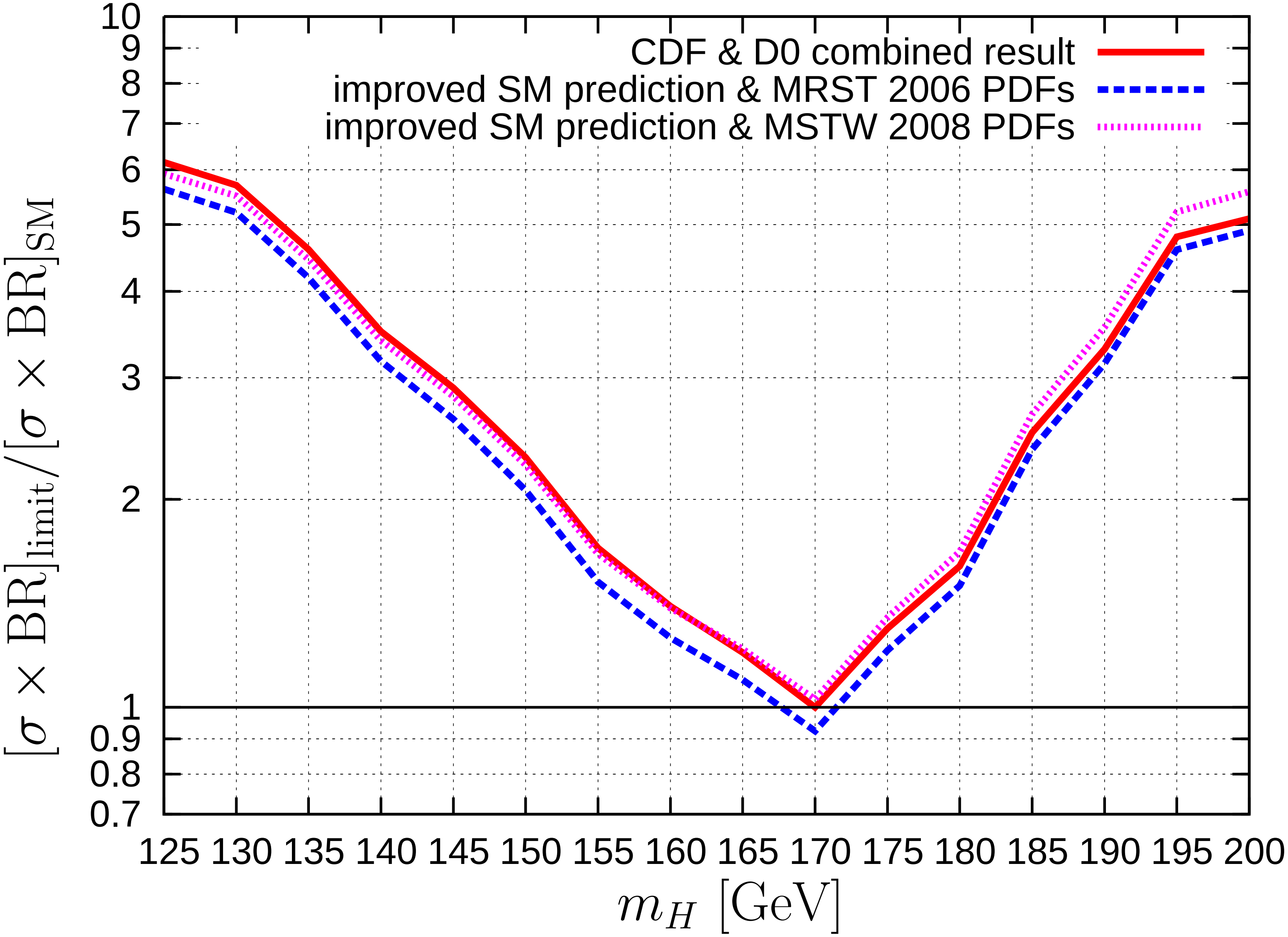
recent developments:

- Improved SM prediction for $\sigma(p\bar{p} \to gg \to H)$:
  mixed QCD-Electroweak corrections [Anastasiou, Boughezal, Petriello '08]
  $\to$ **"Our results motivate a reconsideration of the Tevatron exclusion limits."**

- Updated determination of PDFs: MSTW 2008 [Martin at al. '08]

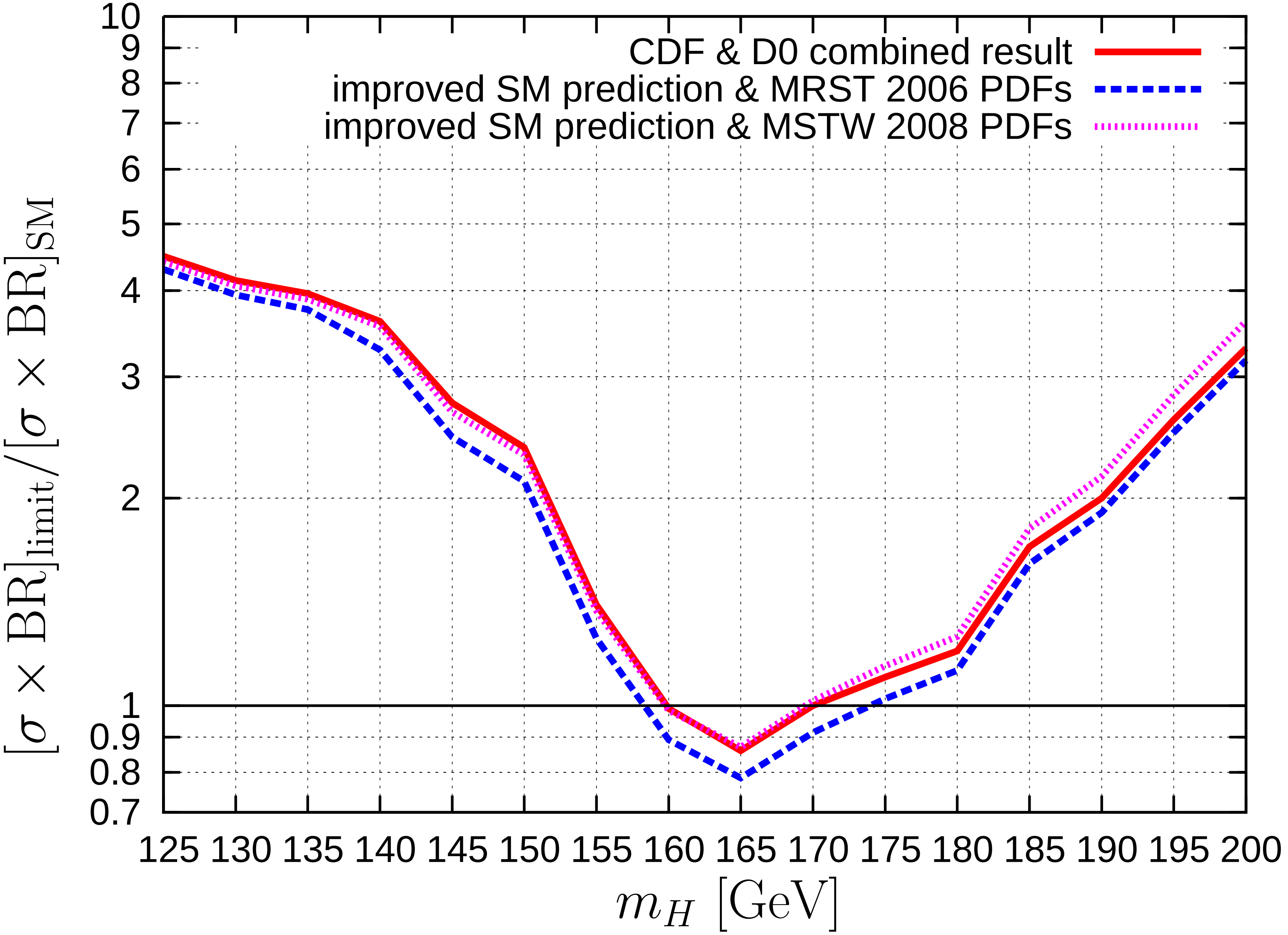
application 1: re-evaluation of SM exclusion with improved prediction

before March 2009



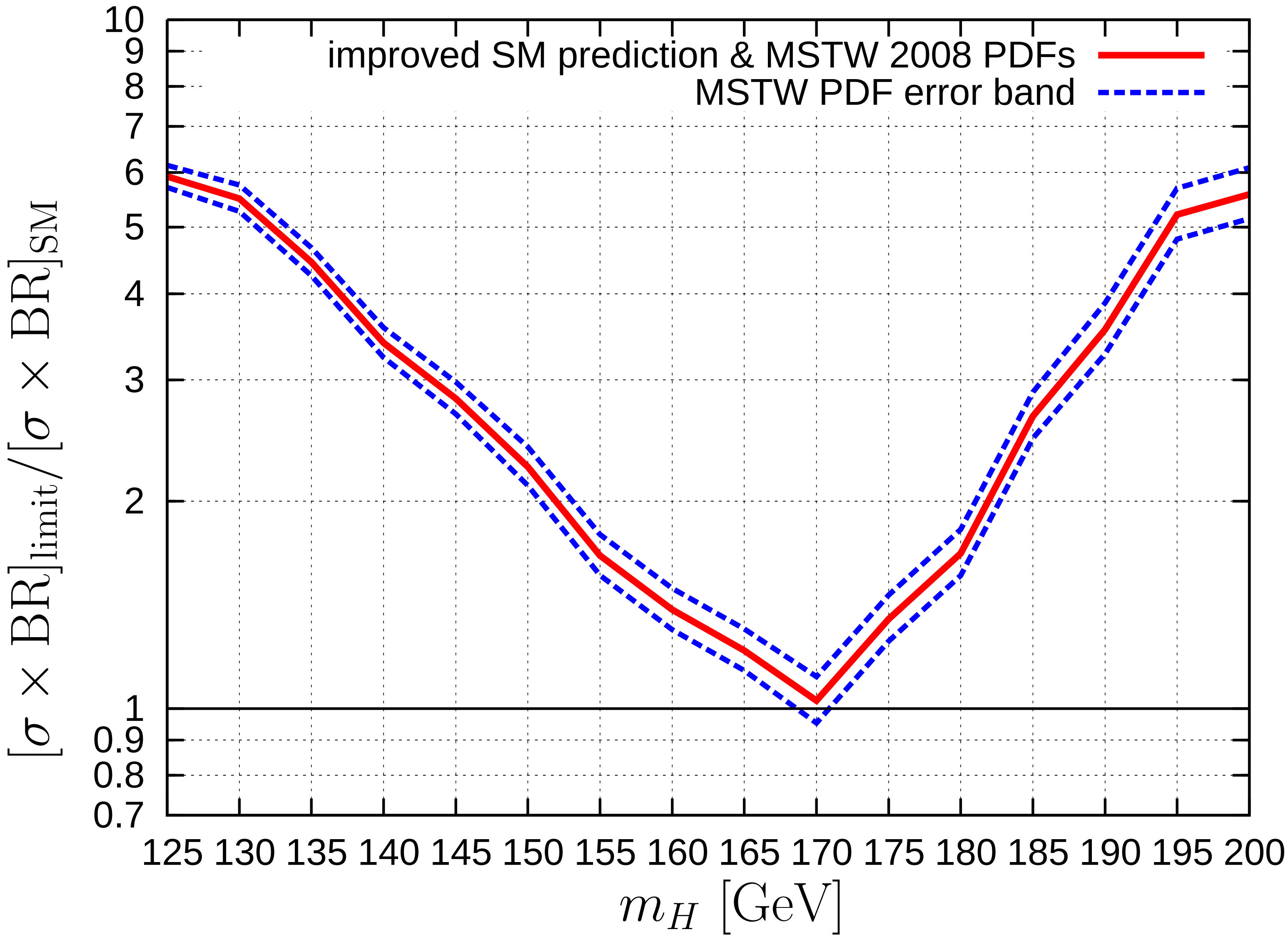
application 1: re-evaluation of SM exclusion with improved prediction

August 2009



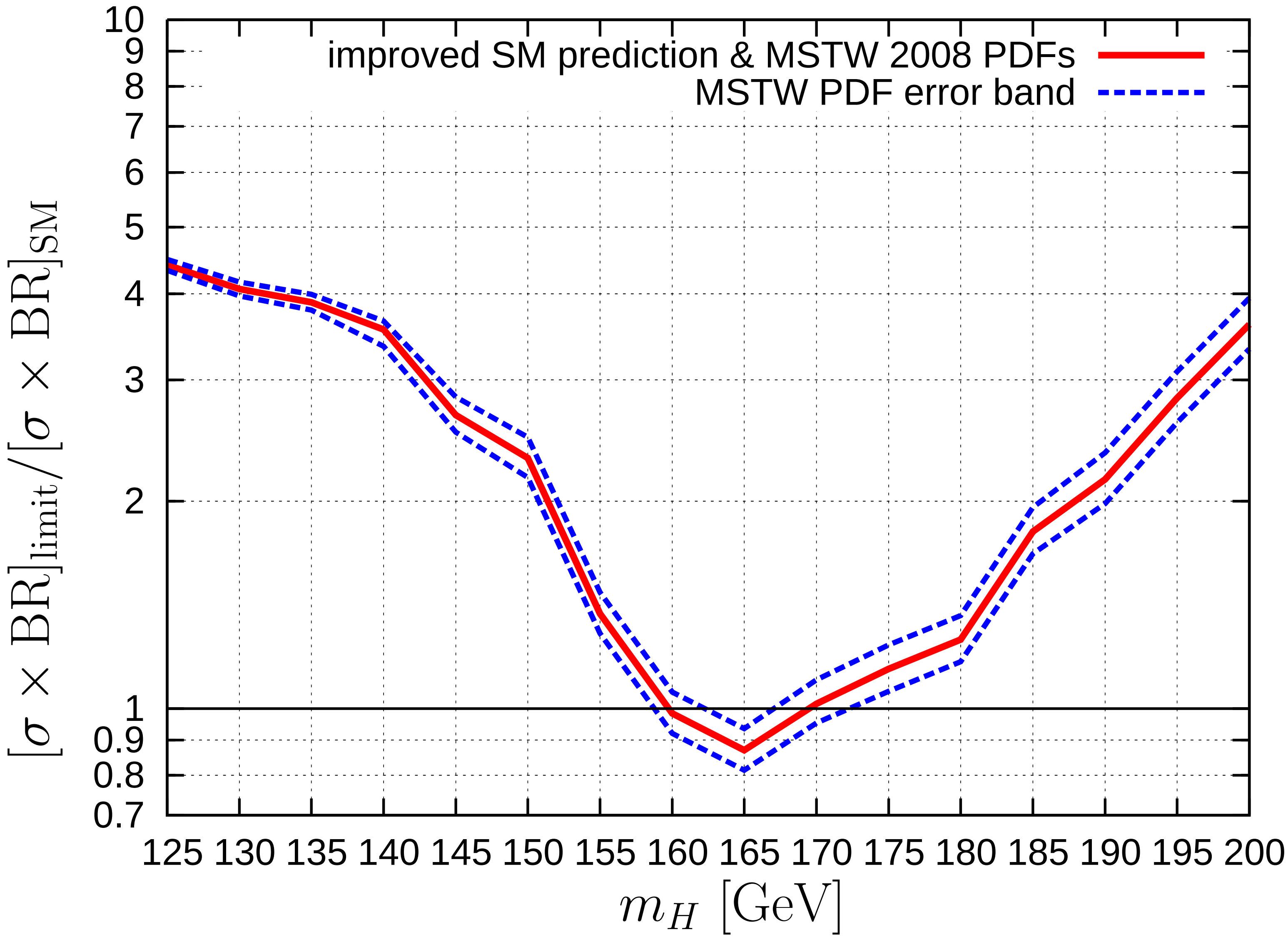
application 1: re-evaluation of SM exclusion with improved prediction

before March 2009



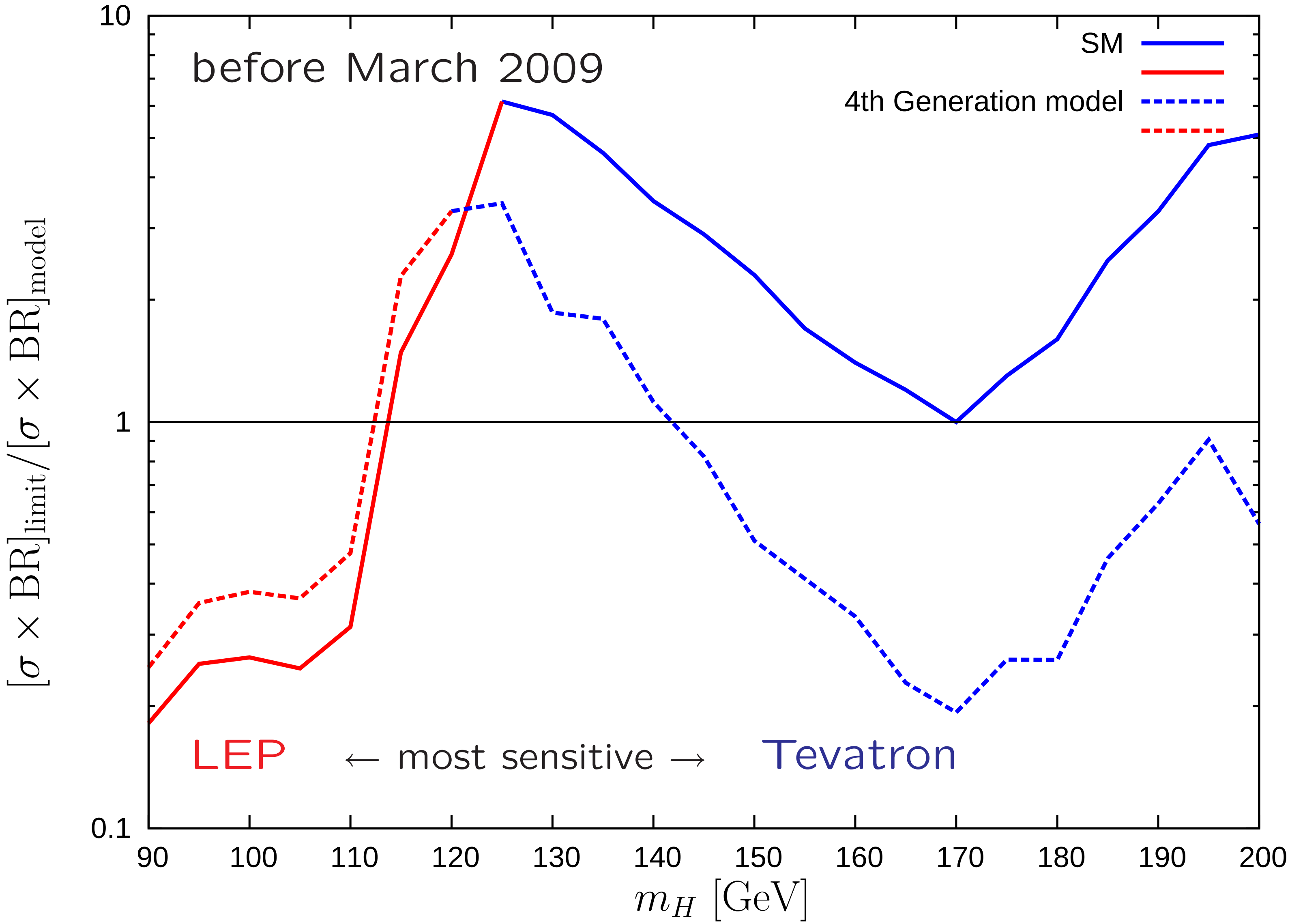
application 1: re-evaluation of SM exclusion with improved prediction

August 2009



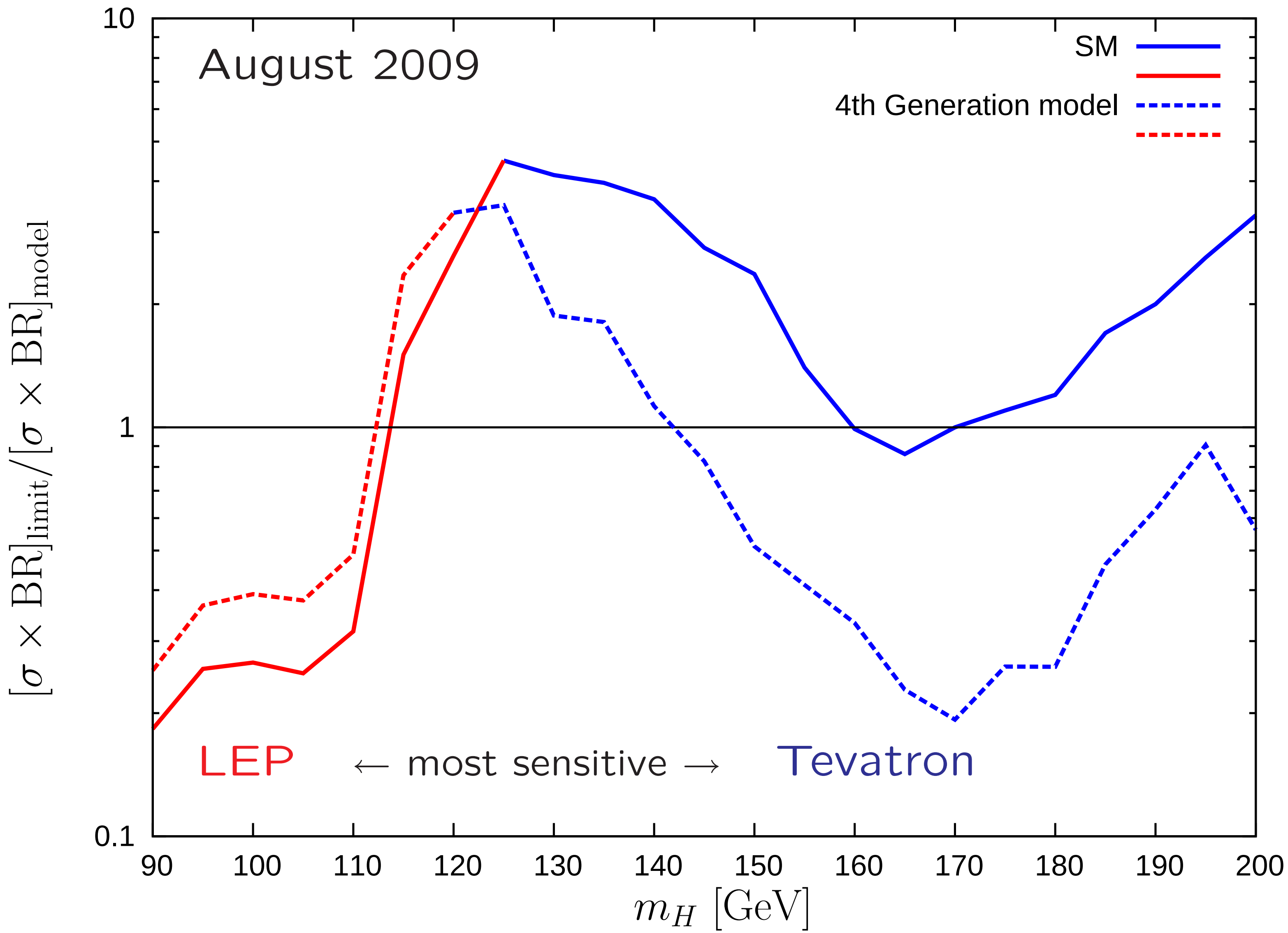
application 2: SM versus Fourth Generation Model exclusion

$$\Gamma(H \to gg)_{\text{model}} = 9 \times \Gamma(H \to gg)_{\text{SM}}$$



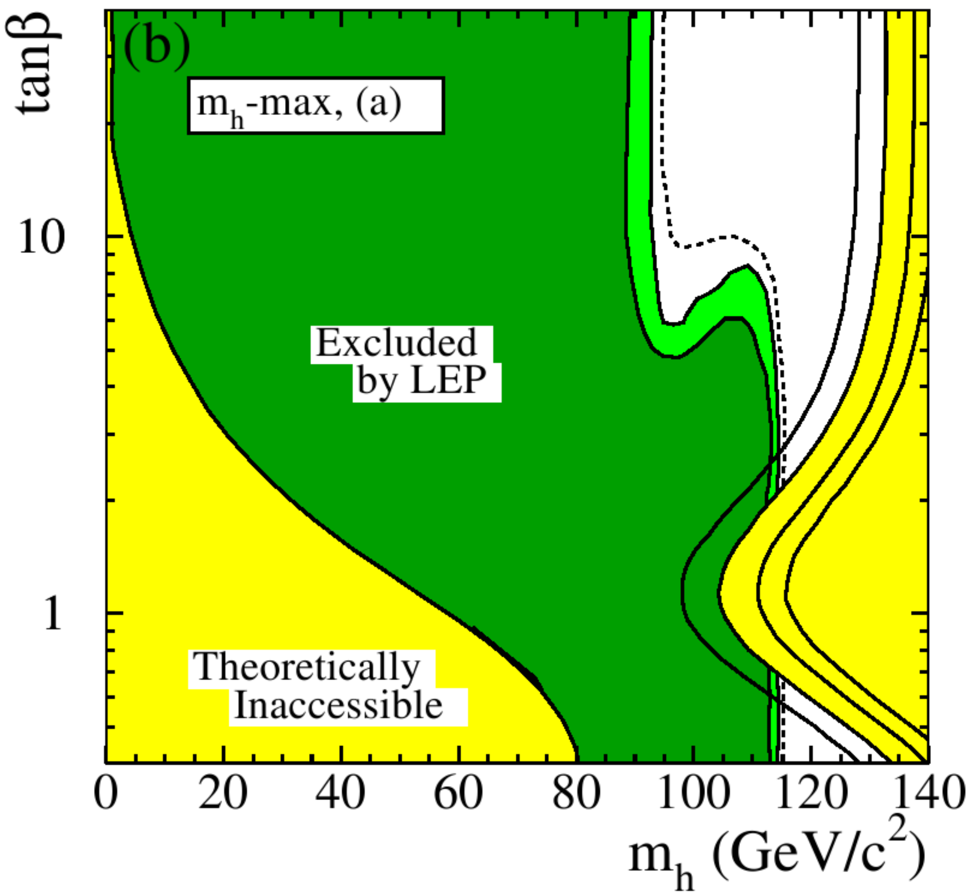
application 2: SM versus Fourth Generation Model exclusion

$$\Gamma(H \to gg)_{\text{model}} = 9 \times \Gamma(H \to gg)_{\text{SM}}$$



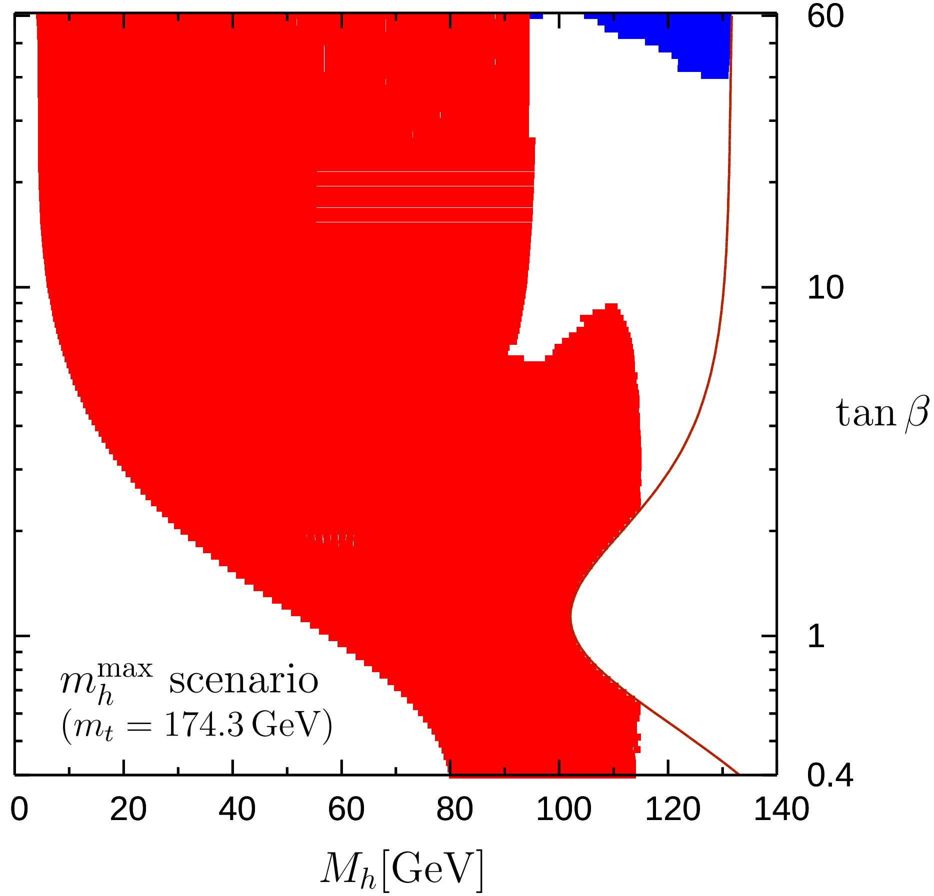
application 3: MSSM benchmark scenarios, exclusion update

a) [EPJC 46(2006)547]



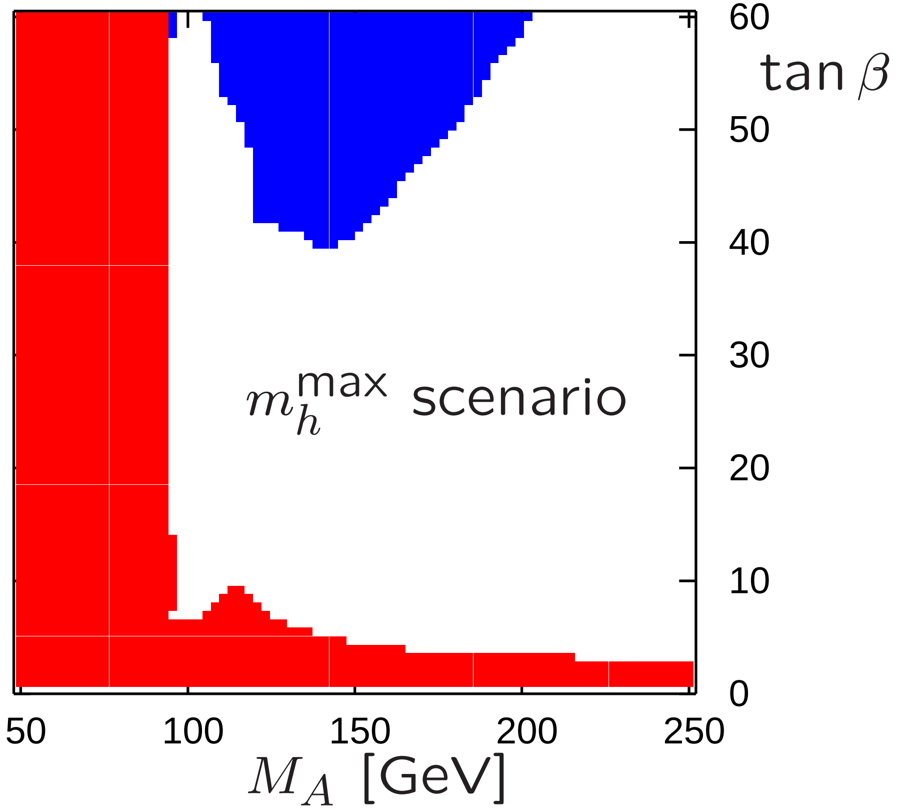
b) **HiggsBounds**

with: new m_t,
impoved m_h prediction,
Tevatron data included



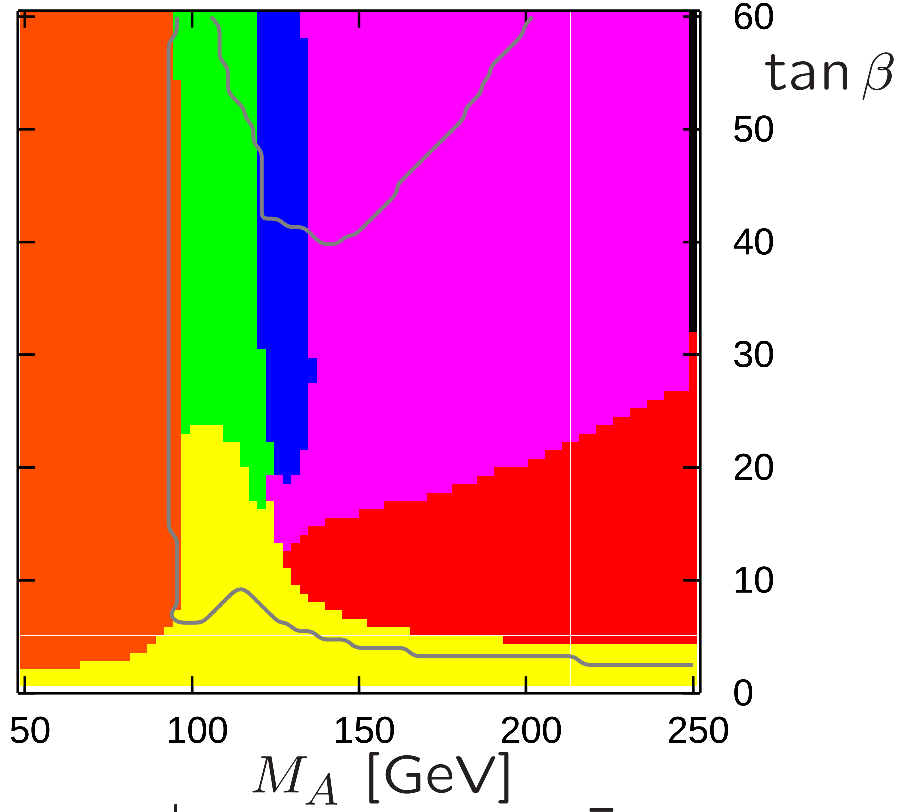
application 3: MSSM benchmark scenarios, exclusion update (before March 2009)

a) LEP and Tevatron exclusion



■ : LEP exclusion
■ : Tevatron exclusion

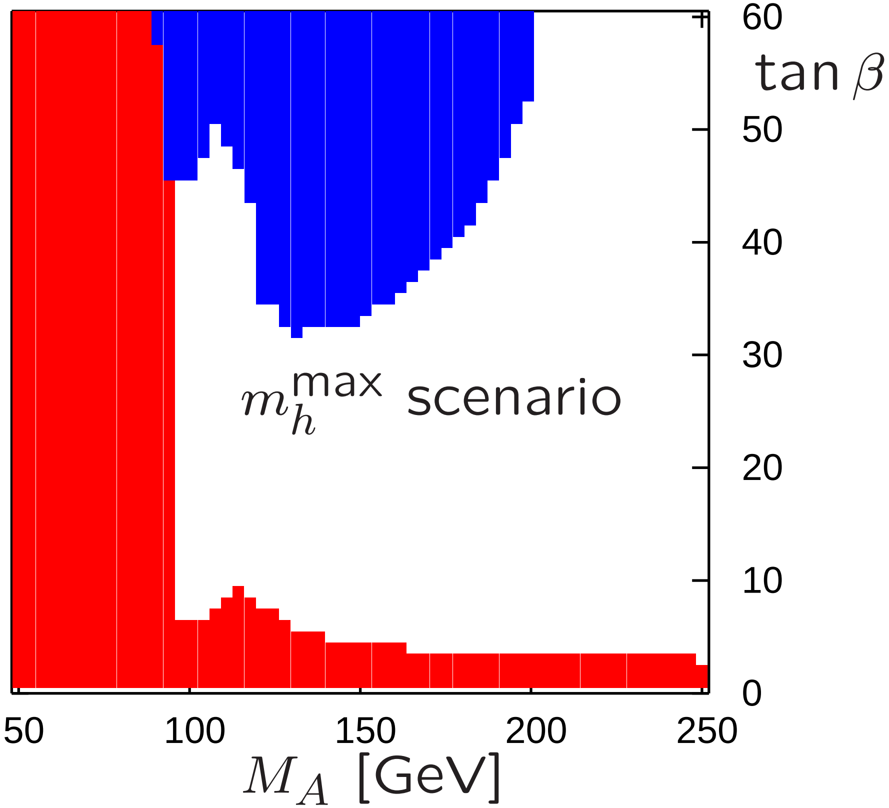
b) highest sensitivity



■ : $e^+e^- \to hZ, h \to b\bar{b}$
■ : $e^+e^- \to hA \to b\bar{b}b\bar{b}$
■ : $p\bar{p} \to hW \to b\bar{b}l\nu$ [CDF note 9463]
■ : $p\bar{p} \to h/A \to \tau^+\tau^-$ [CDF note 9071]
■ : $p\bar{p} \to h/H/A \to \tau^+\tau^-$ [CDF note 9071]
■ : $p\bar{p} \to H/A \to \tau^+\tau^-$ [CDF note 9071]
■ : $p\bar{p} \to H/A \to \tau^+\tau^-$ [DØ'08]

application 3: MSSM benchmark scenarios, exclusion update (August 2009)

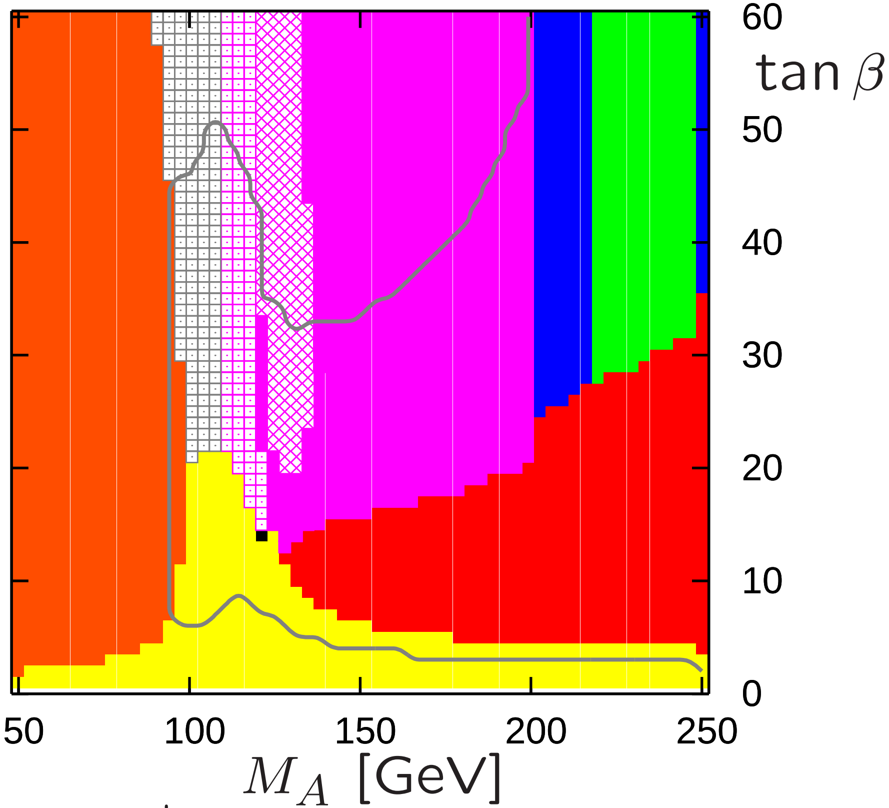
a) LEP and Tevatron exclusion



■ : LEP exclusion
■ : Tevatron exclusion

⊡ : $p\bar{p} \to b\,h/A \to b\tau^+\tau^-$ [D0 note 5985]
⊡: $p\bar{p} \to h/A \to \tau^+\tau^-$ [CDF & D0 '09]
■: $p\bar{p} \to H/A \to \tau^+\tau^-$ [CDF & D0 '09]
×: $p\bar{p} \to h/H/A \to \tau^+\tau^-$ [CDF & D0 '09]

b) highest sensitivity

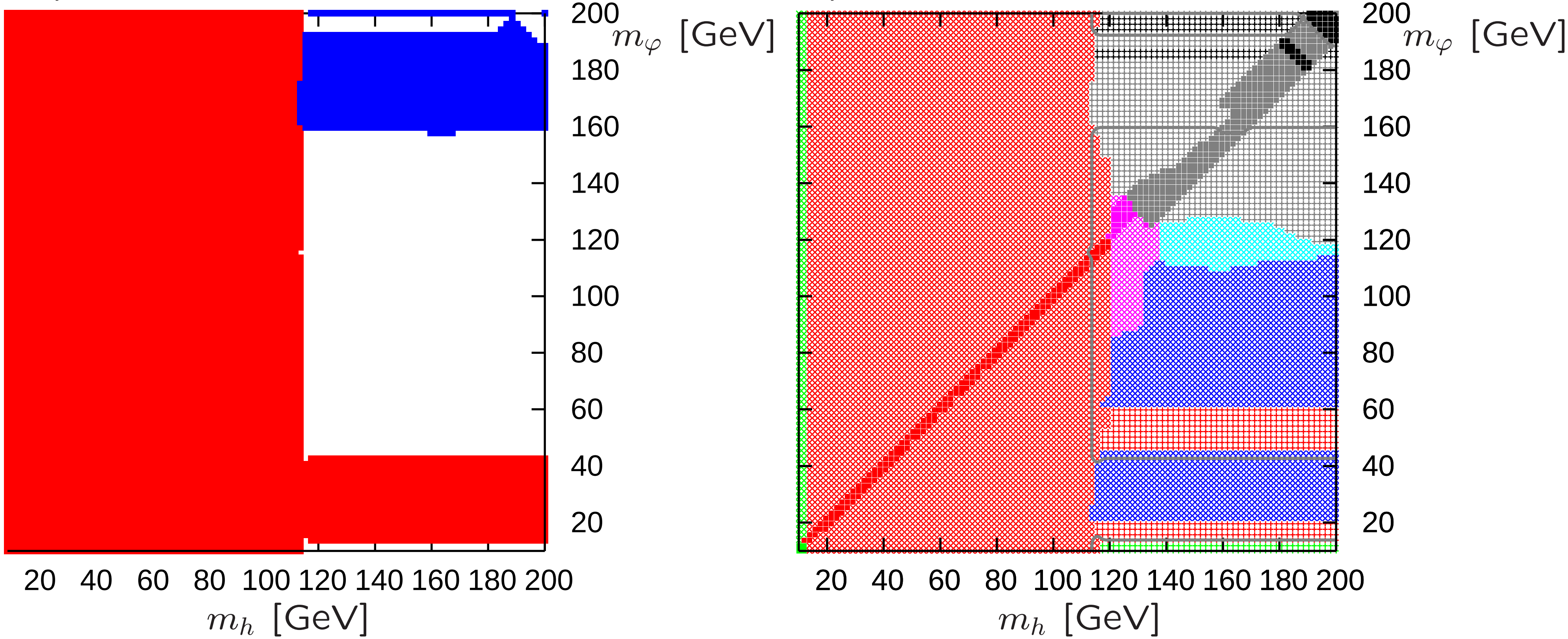


■ : $e^+e^- \to hZ, h \to b\bar{b}$ [LEP EPJC 46 ...]
■ : $e^+e^- \to hA \to b\bar{b}b\bar{b}$ [LEP EPJC 46 ...]
■: $p\bar{p} \to hW \to b\bar{b}l\nu$ [CDF '09]
■: $p\bar{p} \to HW \to b\bar{b}l\nu$ [CDF '09]
■: $p\bar{p} \to H/A \to \tau^+\tau^-$ [CDF '09]
■: $p\bar{p} \to H/A \to \tau^+\tau^-$ [D0 note 5740]

application 4: Randall-Sundrum model, excluded parameter space

parameter: $\Lambda_\varphi = 1$ TeV, $\xi = 0$, mass eigenvalues: m_h, m_φ

a) LEP and Tevatron exclusion b) highest sensitivity



■ : LEP exclusion

■ : Tevatron exclusion

×/+/■ ($\phi = h/\varphi$/both): $e^+e^- \to \phi Z, \phi \to b\bar{b}$ [EPJC 46 ...]

×/+/■: $e^+e^- \to \phi Z, \phi \to$ anything [OPAL '03]

×: $e^+e^- \to \phi Z, \phi \to$ 2 jets [LEP Higgs WG]

×/■: $p\bar{p} \to \phi W \to b\bar{b}l\nu$ [CDF note 9596]

×: $p\bar{p} \to \phi W \to 3W$ [D0 note 5873]

+/■: $p\bar{p} \to \phi \to WW \to l\nu l\nu$ [D0 note 5757]

+/■: $p\bar{p} \to \phi \to WW \to l\nu l\nu$ [CDF '08]

HiggsBounds : status and outlook

- The code is publicly available (current verison: 1.2.0).

  Please visit the web page www.ippp.dur.ac.uk/HiggsBounds/ for downloading the package or using the web interface.

- reception so far very encouraging: e.g. used in or by

  FeynHiggs, Fittino, MasterCode, 2HDMC, DarkSusy,
  S. Kraml et al., M. Carena et al.

- Current work:
  - inclusion of new Tevatron analyses (which need additional input)
  - inclusion of LEP analyses with $H \to$ invis., $H \to$ 2 jets
  - inclusion of charged Higgs analyses

- Plans:
  - providing CL_{s+b} for given m_H and $\sigma \times$ BR ($\to$ useful for model fitting)
  - inclusion of width-dependent limits

summary

- The Higgs search at Tevatron and LEP turn(ed) out many limits on cross sections of individual and combined signal topologies.

- Those limits are published as figures and tables in many individual papers which don't allow for making use of all of them in a convenient way.

- HiggsBounds offers easy access to a wealth of published limits in 3 ways: command line, subroutines, web interface.

- HiggsBounds is a model-independent tool which offers a flexible range of input formats for the necessary model predictions (including the number of neutral Higgs bosons).

The code is publicly available. Ccurrent version: 1.2.0 (as of Monday this week).

Please visit the web page `www.ippp.dur.ac.uk/HiggsBounds/` for downloading the package or using the web interface.