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BR subgroup

New (=old) contacts:

ATLAS: Daniela Rebuzzi

CMS: Ivica Puljak

Theory: Ansgar Denner
Sven Heinemeyer
Alexander Mück

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BR subgroup

Achievements in the past:

Predictions for SM BRs:

- for all relevant decay channels
- in tabulated form (for a wide range of Higgs masses)
- including error estimates
  (PUs and THUs, based on existing tools)
- information on partial widths available
  (for error correlations)

Predictions for BSM BRs:

- for MSSM benchmark scenarios
- including heavy-to-light Higgs decays

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Plans and questions for the future:

General issue:

- update of predictions with updated set of input parameters?
- presentation: tables $\Leftrightarrow$ uncertainty due to Higgs mass

BR specific issues:

- updated predictions with new HDecay version (reduced THUs)
- rare decays
  - Which decays are experimentally relevant? (SM and BSM)
  - Experimental input on Dalitz decay?

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BSM BR issues:

- MSSM
  - BRs for decays into SUSY particles
    (experimentally needed?)
  - uncertainties for MSSM benchmark scenarios?
- other models
  - e.g. benchmark models for 2HDM
  - general issue:

    How to organize interplay
    with other (BSM) groups?

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Talk at the last HXSWG meeting

CERN, June 12, 2014

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Updates of Higgs Branching Ratios

Alexander Mück

RWTH Aachen University

for the BR subgroup

A. Denner, S. Heinemeyer, I. Puljak, D. Rebuzzi, M. Spira, . . .

Meeting of the LHC Higgs Cross Section Working Group

CERN, June 12, 2014

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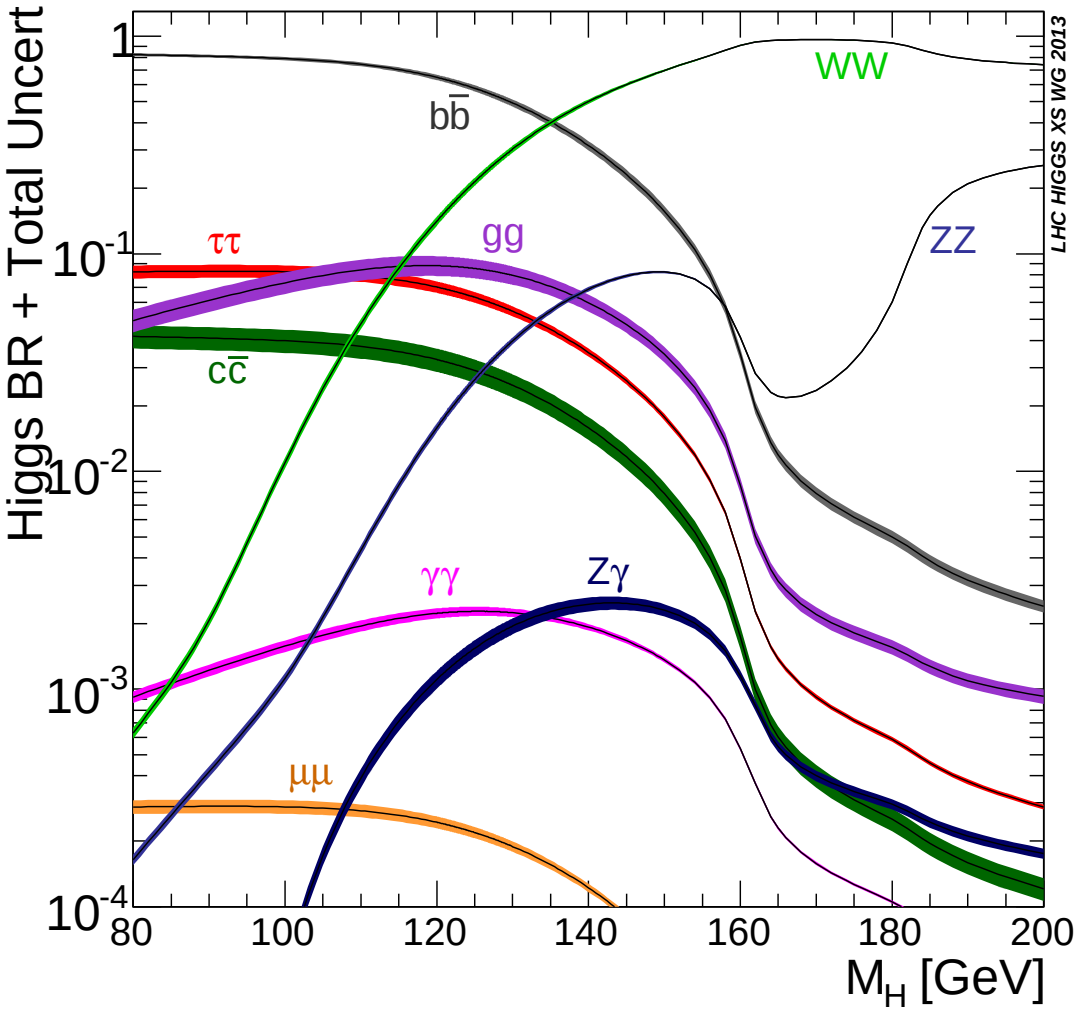
Outline

- Standard Model Branching Ratios
  - within the HXSWG (no changes since YR3)
  - additional activities on BR predictions
  - Dalitz decays: $H \to e^+e^-\gamma$
- BSM Branching Ratios
  - MSSM (new benchmarks)
  - 2HDM (tool comparison)
  - eHDECAY ($\to$ talk by M. Ghezzi)

SM BRs

Branching ratios including error estimates:



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SM partial widths

- errors on partial widths induced by parametric and theory uncertainties (YR3):

Channel	M_H [GeV]	Γ [MeV]	$\Delta\alpha_s$	Δm_b	Δm_c	Δm_t	THU
$H \to bb$	122	2.30	$^{-2.3\%}_{+2.3\%}$	$^{+3.2\%}_{-3.2\%}$	$^{+0.0\%}_{-0.0\%}$	$^{+0.0\%}_{-0.0\%}$	$^{+2.0\%}_{-2.0\%}$
	126	2.36	$^{-2.3\%}_{+2.3\%}$	$^{+3.3\%}_{-3.2\%}$	$^{+0.0\%}_{-0.0\%}$	$^{+0.0\%}_{-0.0\%}$	$^{+2.0\%}_{-2.0\%}$
	130	2.42	$^{-2.4\%}_{+2.3\%}$	$^{+3.2\%}_{-3.2\%}$	$^{+0.0\%}_{-0.0\%}$	$^{+0.0\%}_{-0.0\%}$	$^{+2.0\%}_{-2.0\%}$
$H \to \tau^+\tau^-$	122	$2.51 \cdot 10^{-1}$	$^{+0.0\%}_{+0.0\%}$	$^{+0.0\%}_{-0.0\%}$	$^{+0.0\%}_{-0.0\%}$	$^{+0.0\%}_{-0.1\%}$	$^{+2.0\%}_{-2.0\%}$
	126	$2.59 \cdot 10^{-1}$	$^{+0.0\%}_{+0.0\%}$	$^{+0.0\%}_{-0.0\%}$	$^{+0.0\%}_{-0.0\%}$	$^{+0.1\%}_{-0.1\%}$	$^{+2.0\%}_{-2.0\%}$
	130	$2.67 \cdot 10^{-1}$	$^{+0.0\%}_{+0.0\%}$	$^{+0.0\%}_{-0.0\%}$	$^{+0.0\%}_{-0.0\%}$	$^{+0.1\%}_{-0.1\%}$	$^{+2.0\%}_{-2.0\%}$

⋮

- starting point to include error correlations for BRs
- theory uncertainties based on existing tools

  (HDECAY, PROPHECY4F)
- next release of HDECAY $\to$ reduced THU errors
- conservative assumptions for parametric uncertainties

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BR calculations

Almeida, Lee, Pokorski, Wells [arXiv:1311.6721]

- recalculation of partial width for $m_H = 125.7$ GeV
- using predictions from the literature
- parametric dependence in terms of Taylor coefficients

$$\Gamma_{H\to X} = \Gamma_X^{(\mathrm{ref})} \left(1 + \sum_i a_{\tau_i,X}\,\overline{\delta\tau_i}\right) \quad \text{with} \quad \overline{\delta\tau_i} = \frac{\tau_i - \tau_{i,ref}}{\tau_{i,ref}}$$

	$\Gamma_X^{(\mathrm{Ref})}$/GeV	$a_{m_t,X}$	$a_{m_H,X}$	$a_{\alpha(M_Z),X}$	$a_{\alpha_S(M_Z),X}$	$a_{m_b,X}$	$a_{M_Z,X}$	$a_{m_c,X}$	$a_{m_\tau,X}$	$a_{G_F,X}$
total	3.96×10^{-3}	-3.48×10^{-2}	4.53	8.77×10^{-1}	-1.35	1.4	-3.49	9.05×10^{-2}	1.3×10^{-1}	8.43×10^{-1}
gg	3.57×10^{-4}	-1.62×10^{-1}	2.89	0.	2.49	-7.1×10^{-2}	3.77×10^{-1}	0.	0.	1.
$\gamma\gamma$	1.08×10^{-5}	-2.73×10^{-2}	4.32	2.56	1.8×10^{-2}	9.01×10^{-3}	-1.85	0.	0.	7.24×10^{-1}
$b\bar{b}$	2.17×10^{-3}	8.11×10^{-3}	8.09×10^{-1}	3.76×10^{-2}	-2.46	2.57	-4.75×10^{-1}	0.	0.	9.53×10^{-1}
$c\bar{c}$	9.99×10^{-5}	-4.55×10^{-2}	7.99×10^{-1}	1.02×10^{-2}	-9.17	0.	-1.41	3.59	0.	9.7×10^{-1}
$\tau^+\tau^-$	2.58×10^{-4}	4.74×10^{-2}	9.95×10^{-1}	-2.09×10^{-2}	-2.15×10^{-3}	0.	-1.61×10^{-2}	0.	2.01	1.02
WW^*	9.43×10^{-4}	-1.13×10^{-1}	1.37×10^{1}	3.66	9.04×10^{-3}	0.	-1.21×10^{1}	0.	0.	2.49×10^{-1}
ZZ^*	1.17×10^{-4}	2.28×10^{-2}	1.53×10^{1}	-7.37×10^{-1}	-1.82×10^{-3}	0.	-1.12×10^{1}	0.	0.	2.53
$Z\gamma$	6.88×10^{-6}	-1.54×10^{-2}	1.11×10^{1}	8.46×10^{-1}	0.	-9.76×10^{-3}	-4.82	0.	0.	2.62
$\mu^+\mu^-$	8.93×10^{-7}	4.84×10^{-2}	9.92×10^{-1}	-4.31×10^{-2}	-2.2×10^{-3}	0.	-1.62×10^{-2}	0.	0.	1.02

different way to give complete information
m_H treated as input parameter

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BR calculations

Almeida, Lee, Pokorski, Wells [arXiv:1311.6721]

- BRs and their ratios derived from partial width
  (as in HXSWG)
- assumptions on parametric errors differ
  (0.7% for α_s; 0.7% for m_b ($\overline{\rm MS}$ mass))
  (more optimistic estimates than HXSWG $\rightarrow$ also next slide)
- theory uncertainty from scale variation only
- pole or $\overline{\rm MS}$ masses can be used as input for m_b and m_c
  (HXSWG uses $\overline{\rm MS}$ masses internally, pole mass input only as bookkeeping device to minimize correlation with α_s)
- complete comparison with HXSWG results not done yet

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Input Parameters

Lepage, Mackenzie, Peskin [arXiv:1404.0319]

- How well can the Higgs BRs be predicted in the future?
- Limitation due to parametric errors?
- use lattice gauge theory to improve α_s, m_b, and m_c
  (e.g. using current-current correlators)
  (stated errors already now quite small)
- optimistic projection for lattice improvements:

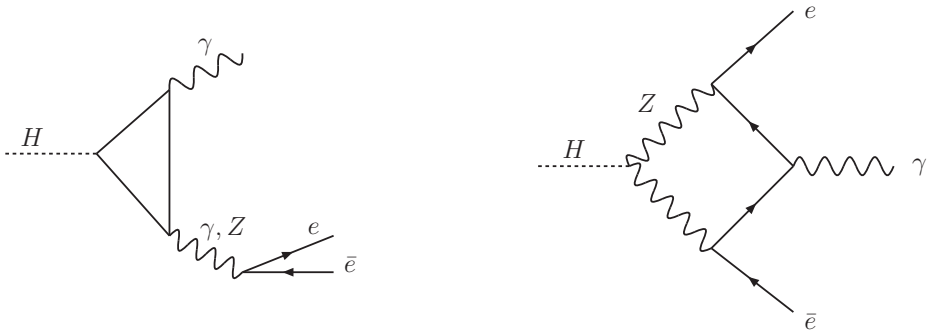
	$\delta m_b(10)$	$\delta\alpha_s(m_Z)$	$\delta m_c(3)$	δ_b	δ_c	δ_g
current errors [10]	0.70	0.63	0.61	0.77	0.89	0.78
+ PT	0.69	0.40	0.34	0.74	0.57	0.49
+ LS	0.30	0.53	0.53	0.38	0.74	0.65
+ LS^2	0.14	0.35	0.53	0.20	0.65	0.43
+ PT + LS	0.28	0.17	0.21	0.30	0.27	0.21
+ PT + LS^2	0.12	0.14	0.20	0.13	0.24	0.17
+ PT + LS^2 + ST	0.09	0.08	0.20	0.10	0.22	0.09
ILC goal				0.30	0.70	0.60

(errors in %)

time-scale: 10-15 years

Dalitz Decay

- $H \to e^+e^-\gamma$ not Yukawa suppressed at 1-loop



- $H \to e^+e^-\gamma$ to be defined by suitable cuts

Abbasabadi, Bowser-Chao, Dicus, Repko [hep-ph/9611209]
Chen, Qiao, Zhu [arXiv:1211.6058]
Dicus, Repko [arXiv:1302.2159]
Passarino [arXiv:1308.0422]

- use invariant masses $m_{e^+e^-}$, $m_{e^\pm\gamma}$ as identification cuts

Dicus, Repko [arXiv:1302.2159]
Passarino [arXiv:1308.0422]

- use proper definition of pseudo-observable $H \to Z\gamma$

Passarino [arXiv:1308.0422]

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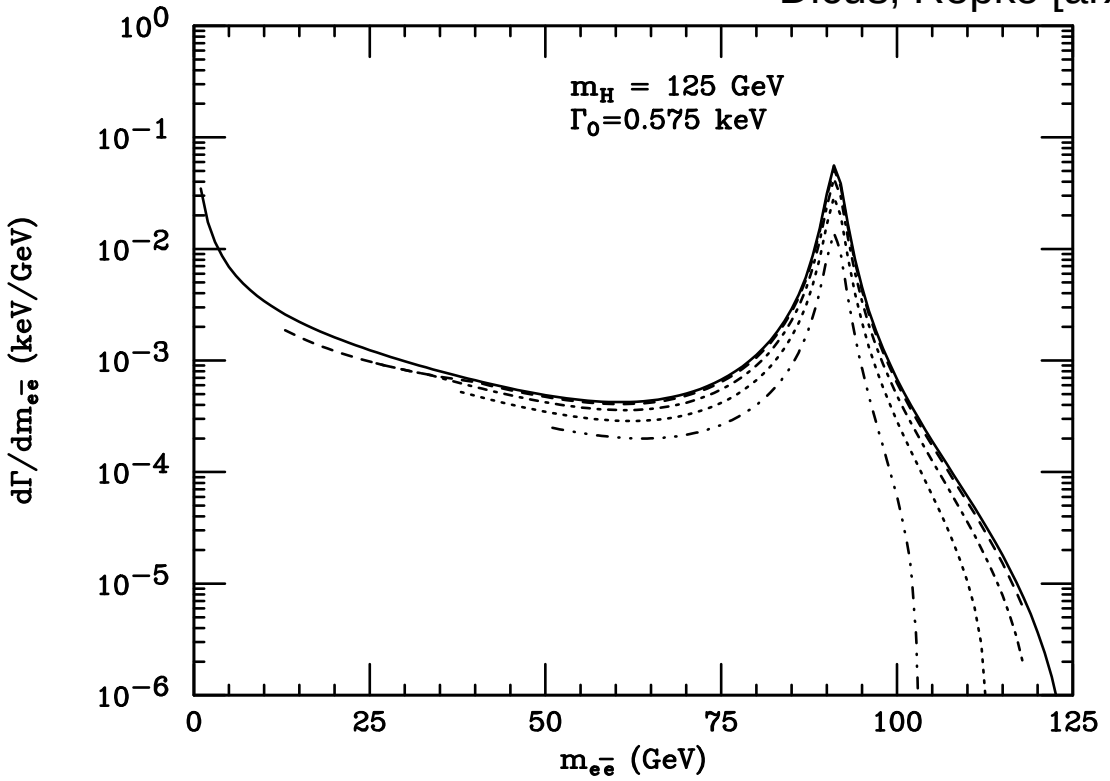
Dality Decay

- exemplary m_{ee} distributions for different sets of cuts

Dicus, Repko [arXiv:1302.2159]



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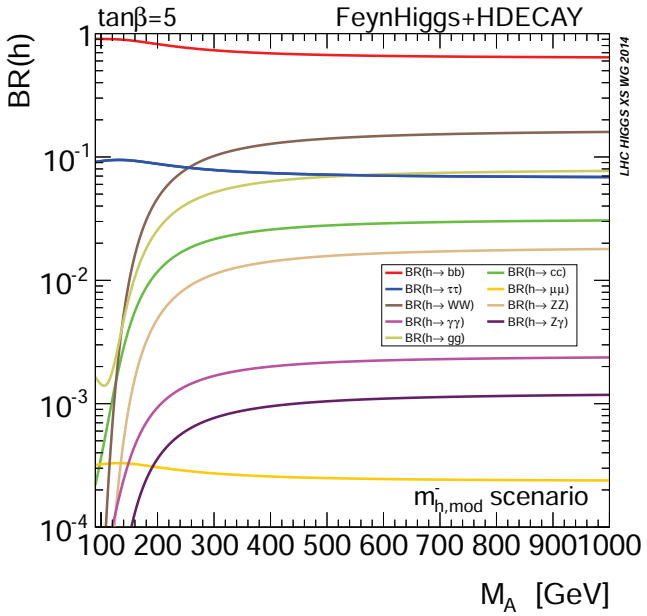
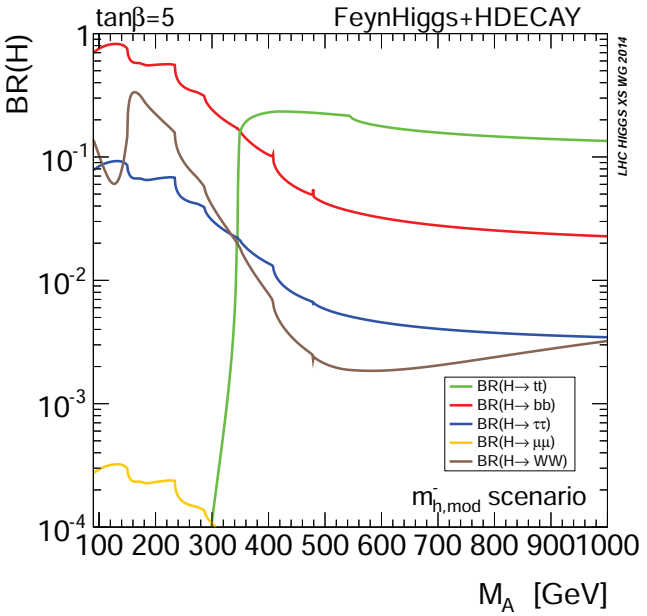
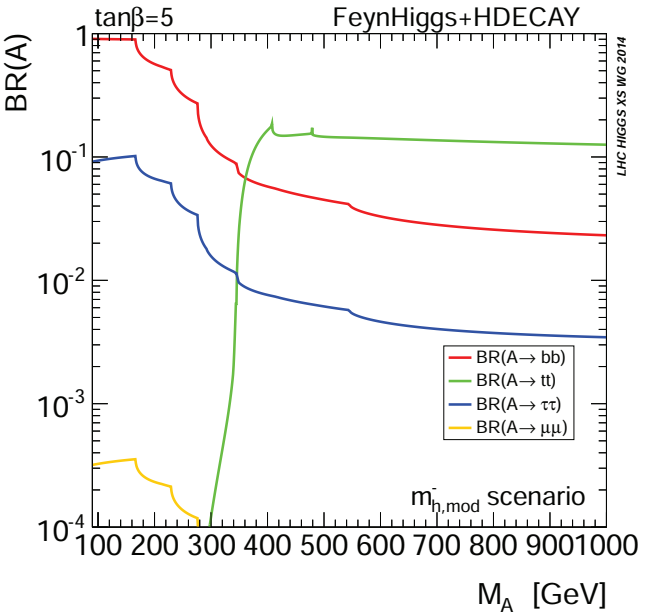
MSSM benchmarks







- results for new benchmark scenarios are available
  https://twiki.cern.ch/twiki/bin/view/LHCPhysics/CrossSectionsFigures#MSSM_BR_plots
- also for charged Higgs
- using predictions by FeynHiggs and HDECAY

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MSSM benchmarks

- Total work flow:
  1. Input parameters to FeynHiggs (native format or SLHA)
  2. FeynHiggs $\Rightarrow$ Higgs masses, couplings, decay widths/BRs
     Output via SLHA file (total width and BRs)
  3. SLHA file is stored and fed to HDECAY
  4. HDECAY $\Rightarrow$ decay widths
     Output via SLHA file (total width and BRs)
  5. "Script" reads both SLHA files, extracts total width and branching ratios $\Rightarrow$ calculation of partial widths
  6. "Script" calculates total width (using best predictions)
  7. "Script" calculates BRs
- for neutral and charged Higgs bosons
- not fully automated, but works reasonably well

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2HDM

Harlander, Mühlleitner, Rathsman, Spira, Stål [arXiv:1312.5571]

- tools for production and decay in the 2HDM
- available codes for BRs: 2HDMC and HDECAY

  2HDMC: Eriksson, Rathsman, Stål [arXiv:0902.0851]
  HDECAY: Djouadi, Kalinowski, Spira [hep-ph/9704448]
  Djouadi, Mühlleitner, Spira [hep-ph/0609292]

- good agreement for investigated reference scenarios

  (generically at the 1% level)

- general strategy:
  - use (generic) SM QCD corrections
  - do not use SM EW corrections (not generic)

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Conclusions

- no big news from BRs
- recent activities in the SM
  - recalculation of SM BRs [arXiv:1311.6721]
  - quest for precise input [arXiv:1404.0319]
  - Dalitz decay calculations [arXiv:1211.6058, 1302.2159, 1308.0422]
- recent BSM activities
  - MSSM benchmarks [HXSWG page]
  - 2HDM tool comparison [arXiv:1312.5571]
  - eHDECAY [arXiv:1312.5571]