WG3: Outlook and Plans

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Rui Santos, Davide Zuliani

LHC Higgs WG Meeting

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WG3 Overview

5 Subgroups:

- MSSM
- NMSSM
- bbH
- Exotic decays
- Extended scalar

WG3 convenors			
ATLAS	Tatjana Lenz	Bonn	05/2024
CMS	Alexis Kalogeropoulos	Princeton	10/2023
LHCb	Davide Zuliani	Padova	03/2025
Theory	Samuel Homiller	Cornell	06/2024
	Rui Santos	Lisbon	12/2024

Talks - 11 parallel 3 plenary 1 lightning talks

Just arrived: Daniela Kock is the new ATLAS MSSM subgroup convenor.
Stefano Manzoni is the new ATLAS bbH subgroup convenor.

WG3 subgroups	Subgroup mailing list	Mail to conveners	ATLAS	CMS	LHCb	Theory	
bbH/bH		Mail		Andrea Cardini, Oviedo (03/2025)		Christian Biello, MPI Munich (03/2025)	Alessandro Gavardi, University of Turin (11/2025)
Extended Higgs Sector	Mailing List	Mail	Lidija Zivkovic, Belgrade Inst. Phys. (2019), Nikos Rompotis Liverpool (01/2021)	Alexandra Carvalho, PKU (01/2024), Khawla Jaffel USTC (03/2024)		Tania Robens, Zagreb (02/2021)	Thomas Biekötter, IFT Madrid (03/2025)
MSSM		Mail		Alexei Raspereza, DESY (02/2025)		Emanuele Bagnaschi, CERN (06/2020)	Michael Spira, PSI (04/2012)
NMSSM		Mail	Nikos Rompotis, Liverpool	Daniel Winterbottom, Imperial (07/2021)		Margarete Mühlleitner, KIT	Nausheen Shah, Wayne State (11/2019)
Exotic Higgs Decays		Mail	Verena Martinez, U Mass (01/2021)	Fengwangdong Zhang, UC Davis (01/2024)	Qundong Han, Padova (08/2025)	Daniel Stolarski, Carleton (06/2025)	Andrea Thamm, U Mass (10/2023)

MSSM

- Future update of the MSSM benchmarks (for those benchmarks that requires it) but this will take some time, and first the 13.6 TeV cross sections for the old benchmarks have to be computed.

- Finish the full NLO SUSY-QCD calculation for gg -> H (A already done).

- Updates of SUSY-decays of the Higgs bosons on the calculation side.

- Finally, there will be work on the extension of the grids for tbH+- production - meaning that old codes have to be set to run again (the 4FS code is running) and the corresponding interface between the 4FS and 5FS (scale choice of the 5FS).

NMSSM

- Recent ATLAS/CMS results on searches interesting for NMSSM interpretation
  ATLAS: $tta/tWa, a \to b\bar{b}$, $a \to b\bar{b}$ in $(4b), (6b)$, $X \to SH, H \to \gamma\gamma, S \to b\bar{b}$, $H \to aa \to (4\tau)$
  CMS: $X \to YH, Y \to \gamma\gamma, H \to b\bar{b}$; $Y \to WW \to 4q, H \to b\bar{b}$; $H \to aa \to 4\gamma, 4e$

- Benchmark points and planes (maximally allowed cross section times branching ratio):
  Tool chain for intelligent scans in complex parameter space: first results
  SUSY decays now included in NMSSMCALC

- New precision results (Higgs mass higher-order calculations for heavy sparticle spectrum, trilinear Higgs self-coupling in NMSSM w/ inverse seesaw mechanism, W mass prediction}

- New effects in EDM calculation included

Future:
- Provide further di-Higgs benchmarks in close collaboration w/ experimentalists
- Work out related constraints in NMSSM parameter space
- Progress in precision calculations and impact on collider phenomenology

M. Mühlleitner talk (Wednesday WG3 plenary)
M. Gabelmann (Thursday WG4 parallel)

bbH

- Comparison of two Monte Carlo generators (MiNNLOPS and Geneva) at NNLO+PS in 5FS.

- Simulations for light-quark Yukawa bounds in Higgs production.

- Role of yt^2 (and yb^2) in the bbH signal relevant for HH searches. (C. Biello, WG3 Lightning session)

- Outlook - continue to focus on the Monte Carlo comparison of 5FS, on flavour-scheme matching and on the fiducial studies of 4FS for HH background modelling.

Modelling $b\bar{b}H$ production for the LHC at 13.6 TeV

Christian Biello,[a] Alessandro Gavardi,[b] Rebecca von Kuk,[b] Matthew A. Lim,[c,d] Stefano Manzoni,[e] Elena Mazzeo,[e] Javier Mazzitelli,[f] Aparna Sankar,[a,g] Michael Spira,[f] Frank J. Tackmann,[b] Marius Wiesemann,[a] Giulia Zanderighi,[a,g] Marco Zaro[h]

C. Biello, WG3 plenary

bbH contribution to Report 5

Exotic Decays

SciPost Physics Community Reports Submission

Rare few-body decays of the Standard Model Higgs boson

David d'Enterria[1,⋆] and Van Dung Le[2,†]

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2 Ho Chi Minh University, Vietnam
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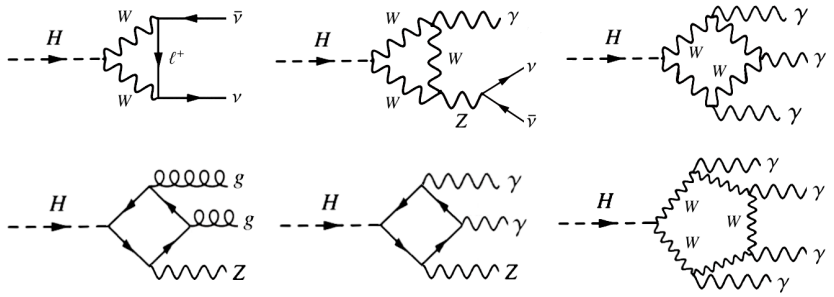


Figure 2: Representative diagrams of rare 2-, 3-, and 4-body decays of the H boson into photons and/or neutrinos, and into Z bosons plus gluons or photons.

Table 1: Rare Higgs decays to two neutrinos, a photon plus two neutrinos, three or four photons, and a Z boson plus two γ's or two gluons. For each decay, we provide the theoretical branching fraction computed with MG5_aMC. No current (or extrapolated, future) experimental limits exist.

Decay		Theoretical branching fraction	Experimental limit current	HL-LH(
$H \to$	$\nu+\overline{\nu}$	7.2 $\times 10^{-36}$ (this work)	–	–
	$\gamma+\nu+\overline{\nu}$	(3.4–3.7) $\times 10^{-4}$ (this work), [37]	–	–
	$\gamma+\gamma+\gamma$	1.0 $\times 10^{-40}$ (this work)	–	–
	$\gamma+\gamma+\gamma+\gamma$	5.4 $\times 10^{-12}$ (this work)	–	–
	$Z+\gamma+\gamma$	(2.0–2.4) $\times 10^{-9}$ (this work), [38,39]	–	–
	$Z+g+g$	(3.6–6.3) $\times 10^{-7}$ (this work), [38,39]	–	–

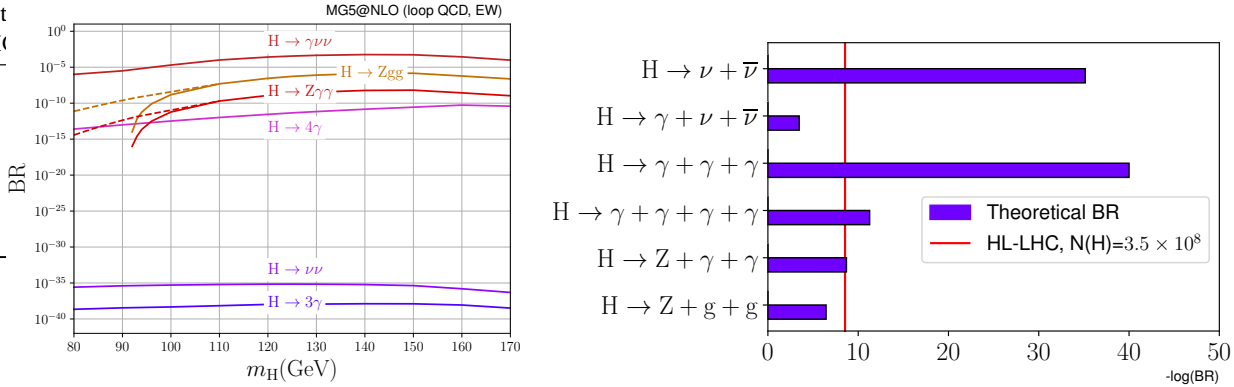


Figure 3: Theoretical branching fractions of the Higgs boson into rare two-, three-, or four- gauge bosons and/or neutrinos shown as a function of the Higgs boson mass (left) and as blue bars in negative log scale (right). In the left panel, the dashed lines for $m_H < m_Z$ show the $H \to Z^*gg$, $Z^*\gamma\gamma$ decays with offshell Z bosons. In the right panel, the red vertical line indicates the minimum $\mathcal{B}$ value reachable at the HL-LHC given just by the total number of H bosons expected to be produced.

Extended scalar sectors

- Updates for recommended cross sections:

  - Neutral Higgs bosons: Since last year 13.6 TeV cross sections available for SM-like Higgs bosons http://twiki.cern.ch/twiki/pub/LHCPhysics/LHCHWG/Higgs_XSBR_YR4_update.xlsx. Thanks to WG1!

  - Update from this year: new recommendations for ttH, thanks to Henning Bahl who generated the cross sections for HiggsTools.

  - Charged Higgs bosons 13.6 TeV cross sections for single-$H^{\pm}$ production work in progress → extended mass range and newer PDFs. Main contact persons: Emanuele Bagnaschi and Michael Spira (MSSM subgroup theory) see Emanuele's talk from last year for details [Indico].

  - GM model : VBF production cross sections for H_5^0 , $H_5^{\pm}$ and $H_5^{\pm\pm}$ only available for 13 TeV [LHCHXSWG-2015-001] Logan, Zaro. ATLAS and CMS will soon request VBF cross sections at 13.6 TeV. Suggestion by Marco Zaro: generate new cross sections using MadGraph5_aMC@NLO arXiv:1512.01243 Degrande, Hartling, Logan, Peterson, Zaro.

  - New results: [LHCWG note]: Charged Higgs Pairs at the LHC: A NLO Analysis, Ahmed, Biermann, Ita, Rusetski, Spira, Yedelkina

M. Spira, WG3 parallel

L. Biermann, Lightning talks

Extended scalar sectors

- Lots of new results from the experimental groups with a variety of signatures, many more results incoming!

- Contribute to benchmarks in upcoming report!

- Regular subgroup activities have facilitated cross-talk between Th/Exp on LHC searches, connections to DM, details of interference effects, etc.

- Join forces with dark matter group regarding extended scalar sector models with DM candidates

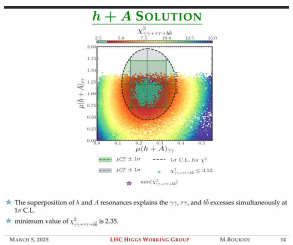
- Join forces with WG2 for the CP-violating benchmarks.

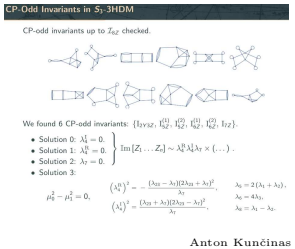
WG2+WG3 topical meeting: CPV

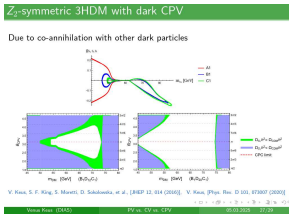
Series of meetings on **CP violation in extended Higgs sectors**

Last meeting on March 5 2025 with three contributions [Indico]

Superposition of CP-Even and CP-Odd Higgs Resonances: Explaining the 95 GeV Excesses within a 2HDM, Mohammed Boukidi
Complex S3-symmetric 3HDM, Anton Kunčinas
Distinguishing P-violation and C-violation in CP-violating extended Higgs sectors, Venus Keus







Anton Kunčinas

Report 5

- We have two submitted contributions: rare decays (LHCHWG-2025-006) and bbH (LHCHWG-2025-011) plus one from in circulation (LHCHWG-2025-014).

- Various contributions planned for Report 5 - contact WG3 convenors if you plan to contribute!

See you all next year!