

*Sally Dawson, Christoph Englert, Maxime Gouzevitch,
Roberto Salerno, Magdalena Slawinska*

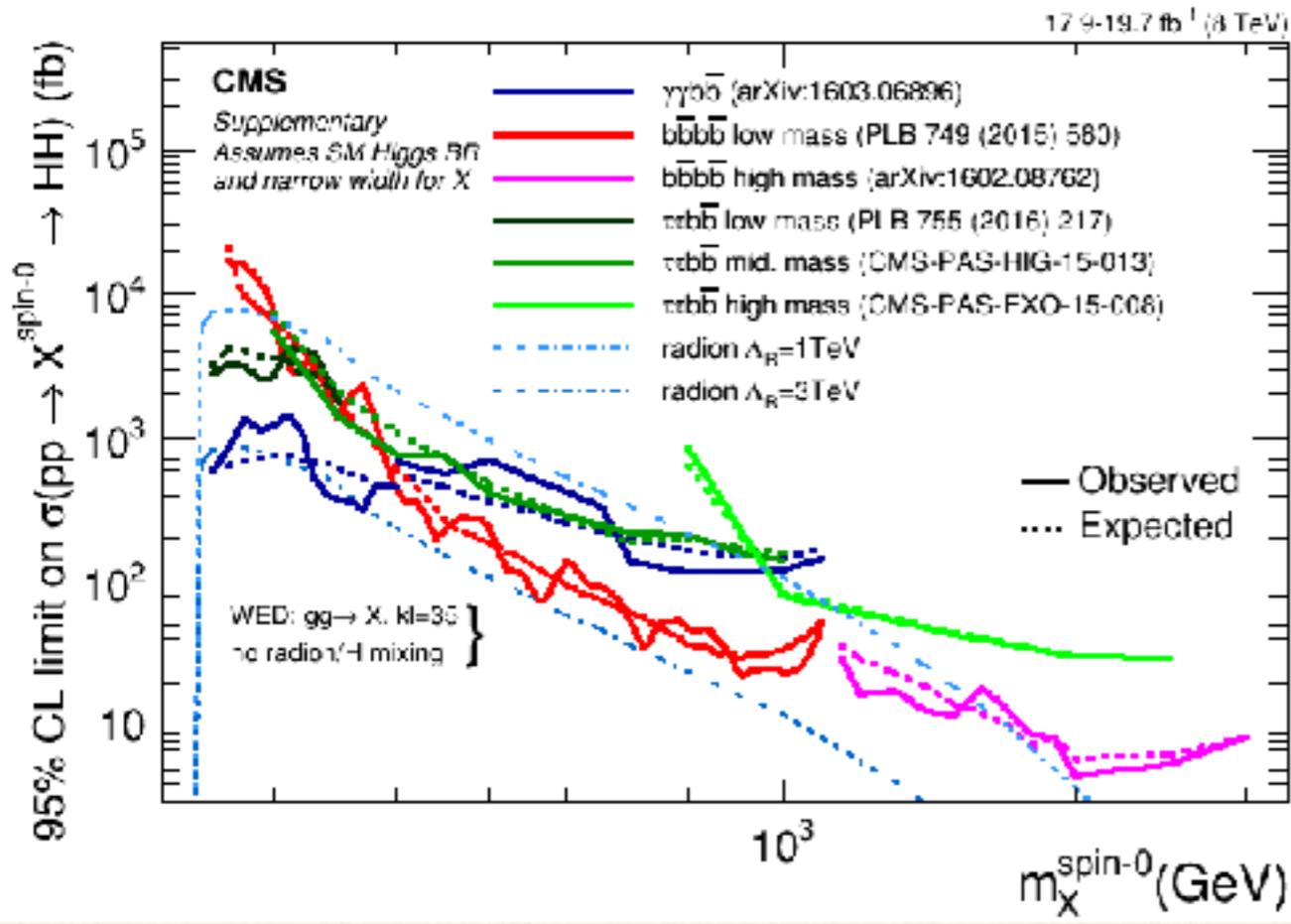
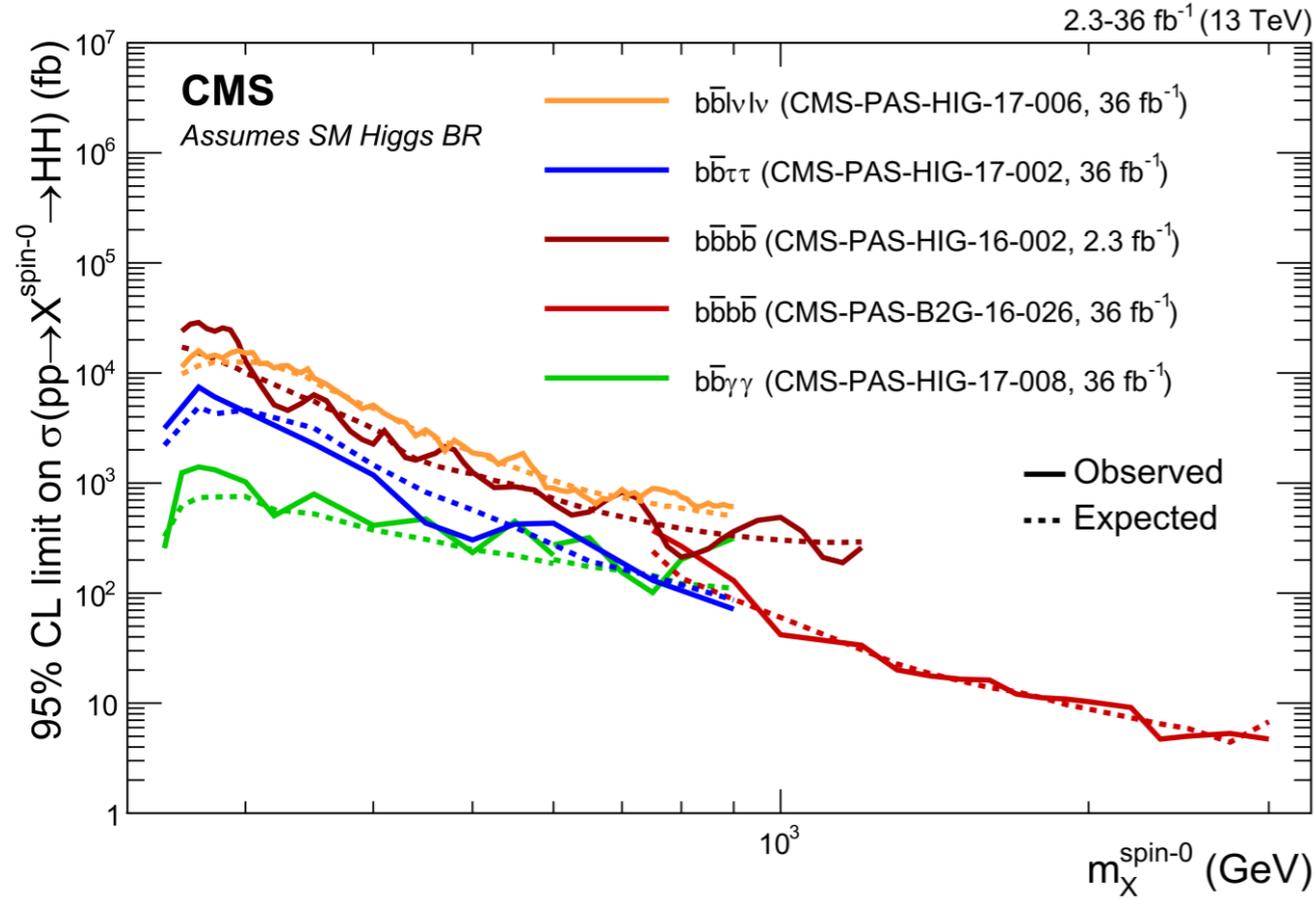
on behalf of the HH xGroup

BSM physics and hh measurements at Run-2

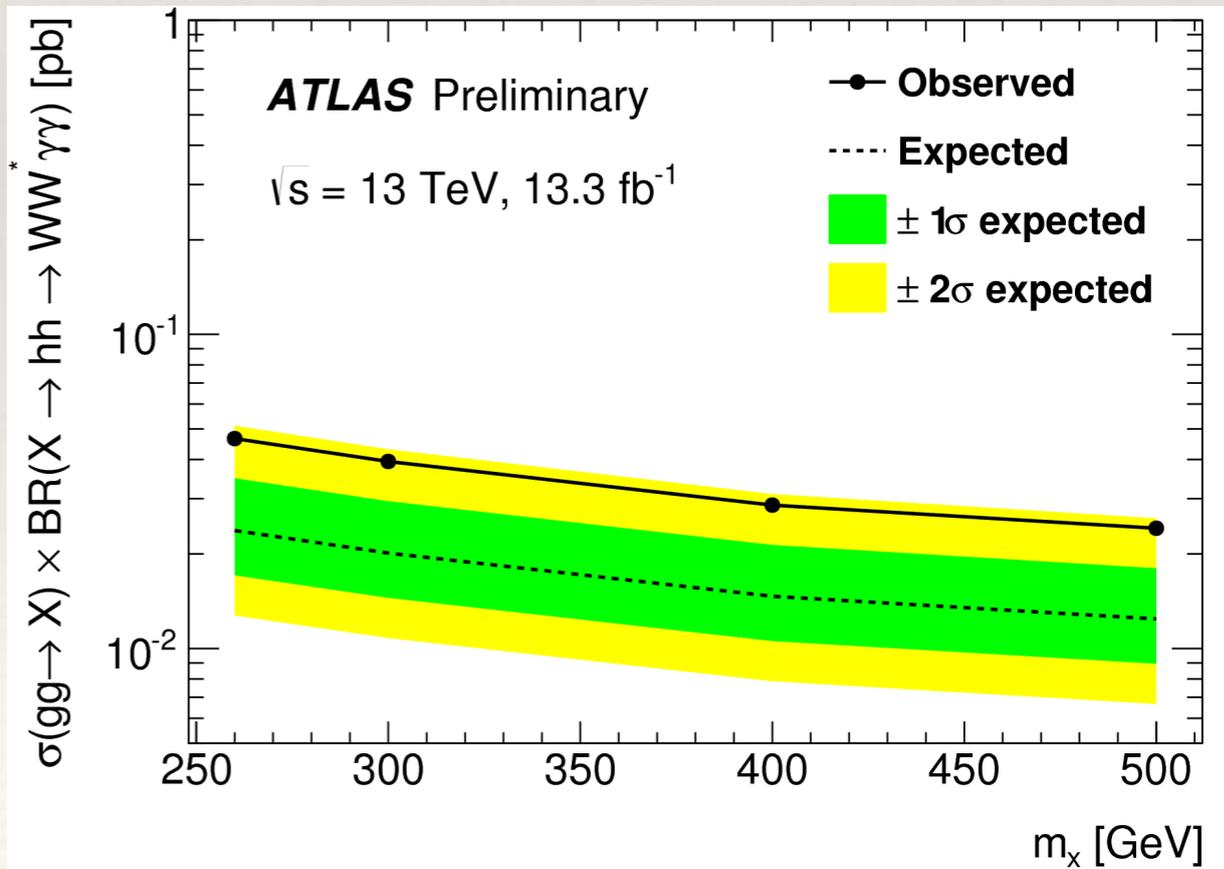
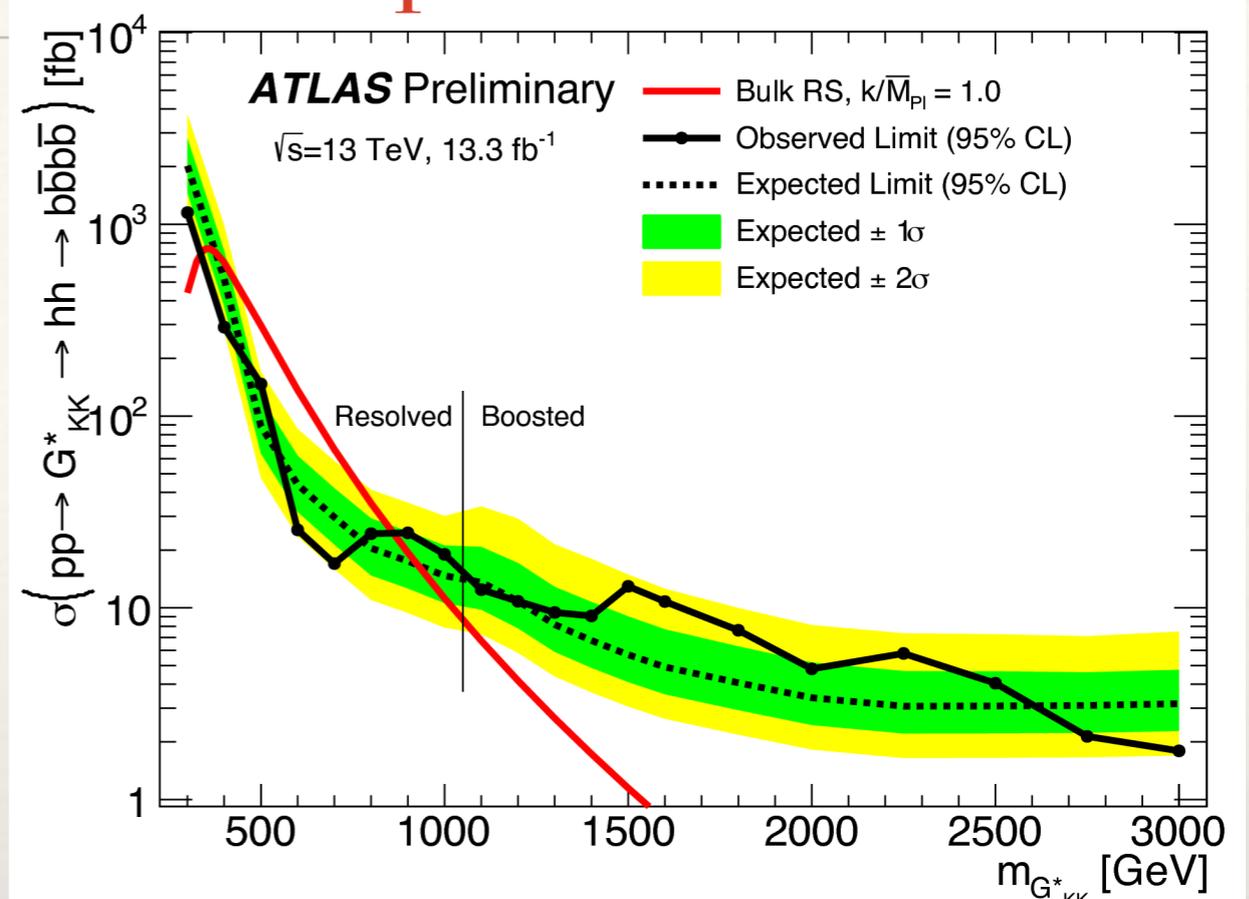
*General Assembly Meeting of LHC Higgs
Cross Section Working Group*

13.07.2017

→ see also Cécile's talk



Experimental searches



→ see also Cécile's talk

σ/σ_{SM} 95% CL (exp)

	ATLAS	CMS
bbbb	<29 (38)	<342 (308)
bbWW		<79 (89)
bb $\tau\tau$		<28 (25)
bb $\gamma\gamma$	<117 (161)	<19 (17)
WW $\gamma\gamma$	<747 (386)	

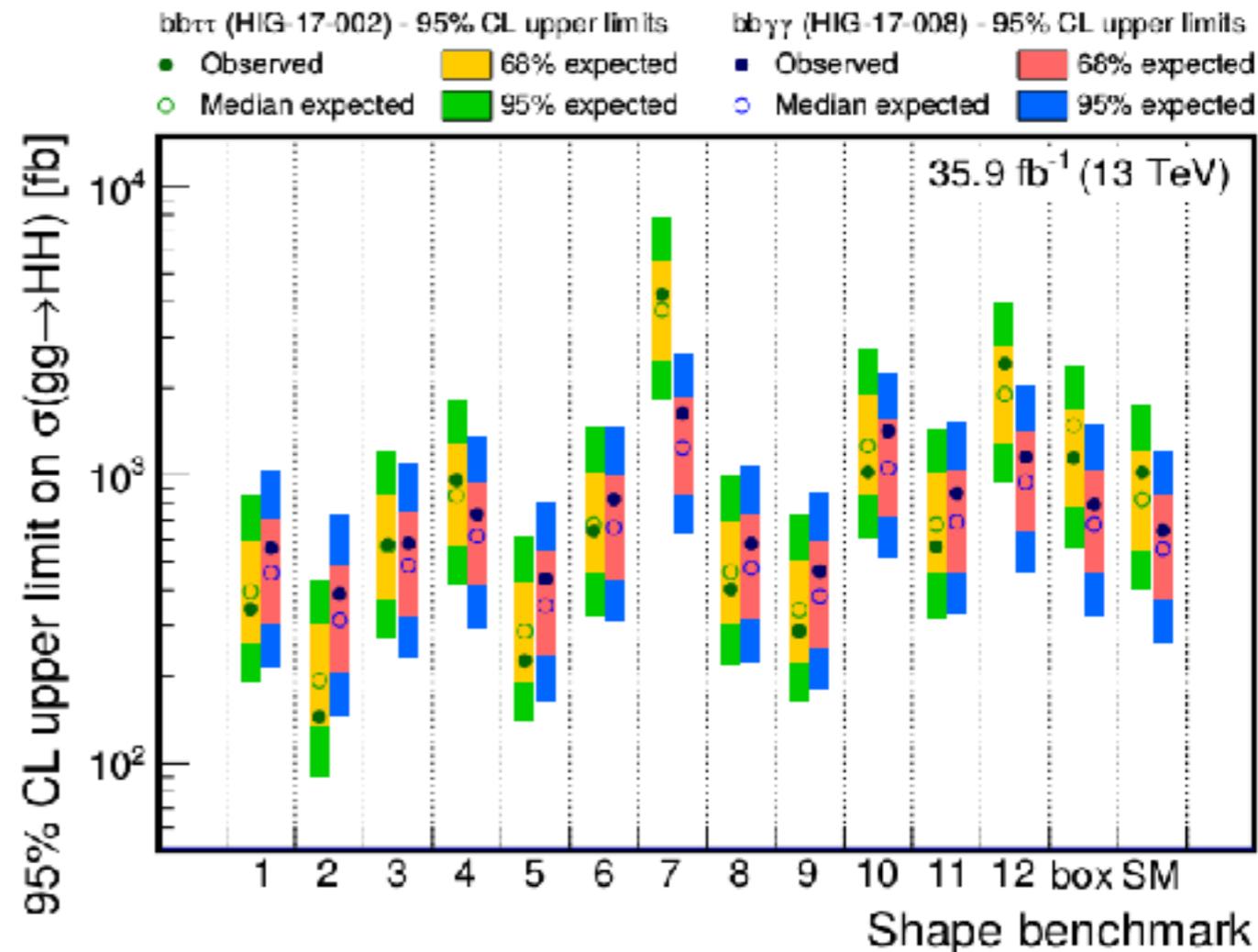
Run2 **3 fb⁻¹** **13 fb⁻¹** **36 fb⁻¹**

[P. Meridiani, EPS `17]

→ focus of Run-2 physics is BSM

Experimental searches

Benchmark	κ_λ	κ_t	c_2	c_g	c_{2g}
1	7.5	1.0	-1.0	0.0	0.0
2	1.0	1.0	0.5	-0.8	0.6
3	1.0	1.0	-1.5	0.0	-0.8
4	-3.5	1.5	-3.0	0.0	0.0
5	1.0	1.0	0.0	0.8	-1.0
6	2.4	1.0	0.0	0.2	-0.2
7	5.0	1.0	0.0	0.2	-0.2
8	15.0	1.0	0.0	-1.0	1.0
9	1.0	1.0	1.0	-0.6	0.6
10	10.0	1.5	-1.0	0.0	0.0
11	2.4	1.0	0.0	1.0	-1.0
12	15.0	1.0	1.0	0.0	0.0
SM	1.0	1.0	0.0	0.0	0.0



see also [Carvalho et al. LHCXSWG-LHCHSWG-2016-001]

- YR4: first steps towards hh BSM benchmarking
 - **scope:**
 - BSM benchmarks directly related to other (e.g. single Higgs) measurements
 - phenomenologically transparent and signature-driven

non-resonant:
SMEFT

resonant:
2HDM
SM \oplus Singlet

non-resonant: SMEFT

- new physics out of reach: EFT description valid
- communication of results consolidated by **WG2** in YR4

isomorphic to [Carvalho et al. LHCXSWG-LHCHXSWG-2016-001]

$$L = L_{SM} + \left(c_g \frac{h}{v} + c_{gg} \frac{h^2}{2v^2} \right) \frac{g_s^2}{4} G_{\mu\nu}^A G^{A,\mu\nu} - \frac{h}{v} \sum_f \sum_i m_{f_i} [\delta y_f]_i \bar{f}_i f_i \\ - \frac{h^2}{2v^2} \sum_f \sum_i m_{f_i} [y_f^{(2)}]_i \bar{f}_i f_i + \delta\lambda_3 h^3 + \text{CP odd operators}$$

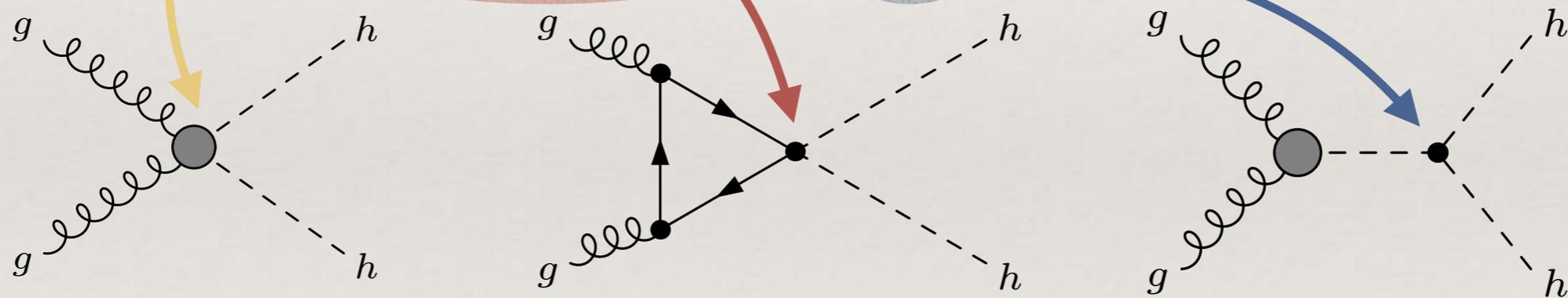
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- NLO QCD corrections insensitive to EFT deformations in the $m_t \rightarrow \infty$ limit

[Gröber, Mühlleitner, Spira, Streicher `15]

[Gröber, Mühlleitner, Spira `17]

- signature-driven benchmarks available in YR4 (see also CMS)

resonant:
2HDM
SM \oplus Singlet

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- minimalist approach to new resonances in the Higgs sector

mass

states $h = \cos \alpha \phi_0 + \sin \alpha s$

$H = -\sin \alpha \phi_0 + \cos \alpha s$



$$\begin{aligned} \Gamma(h \rightarrow X_{SM} X_{SM}) &= \cos^2 \alpha \Gamma(h \rightarrow X_{SM} X_{SM})_{SM} \\ \Gamma(H \rightarrow X_{SM} X_{SM}) &= \sin^2 \alpha \Gamma(H \rightarrow X_{SM} X_{SM})_{SM} \\ \Gamma_H &= \sin^2 \alpha \Gamma_{H,SM}(M_H) + \Gamma(H \rightarrow hh) \\ \Gamma_h &= \cos^2 \alpha \Gamma_{h,SM}(m_h), \end{aligned}$$



$\max \text{BR}(hh) \sim 0.3$

e.g. [Robens, Stefaniak `16]

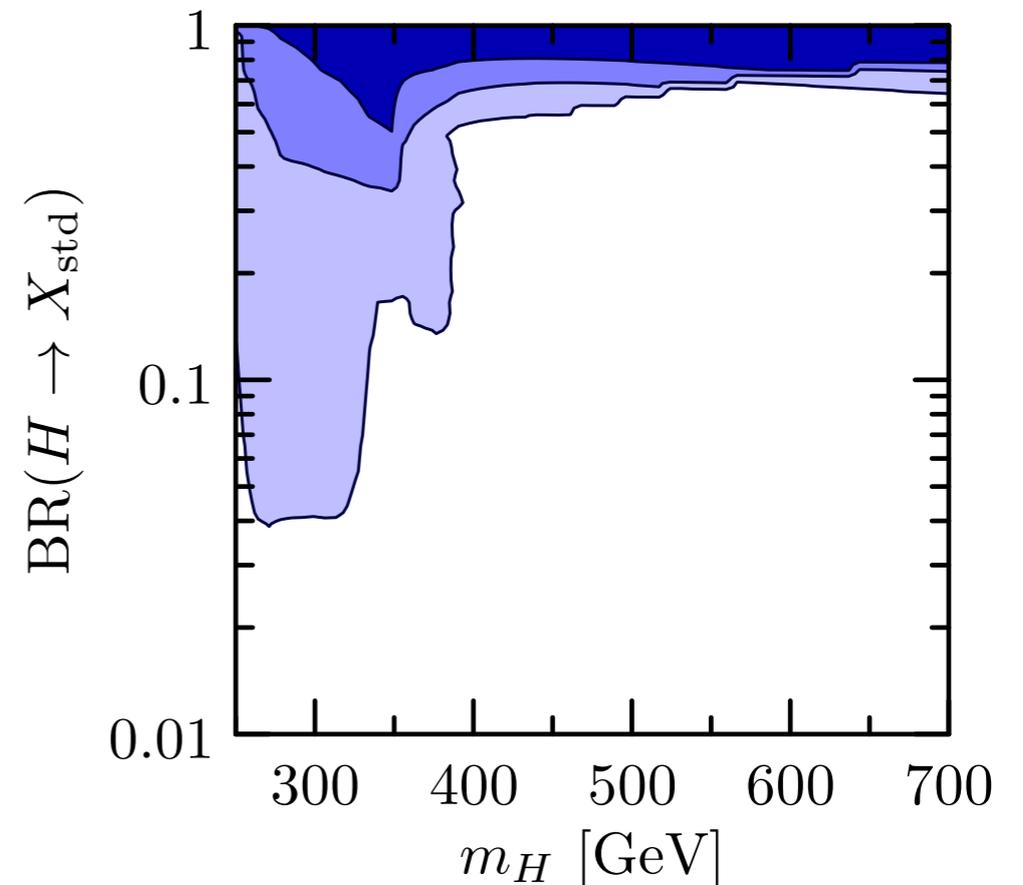
2HDM

[Hespel, Lopez-Val, Vryonidou `14]

	$\tan \beta$	α	m_{H^0}	m_{A^0}	m_{H^\pm}	m_{12}^2
B1	1.75	-0.5881	300	441	442	38300
B2	1.50	-0.6792	700	701	670	180000
B7	10.00	0.1015	500	500	500	24746

- scan over 2HDM type 2 II

[Baglio, Eberhardt, Nierste, Wiebusch `14]



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$\Gamma(h \rightarrow X_{SM} X_{SM}) = \cos^2 \alpha \Gamma(h \rightarrow X_{SM} X_{SM})_{SM}$

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Single Higgs pheno is the driving force of discoveries
hh provides additional information

$\max BR(hh) \sim 0.3$

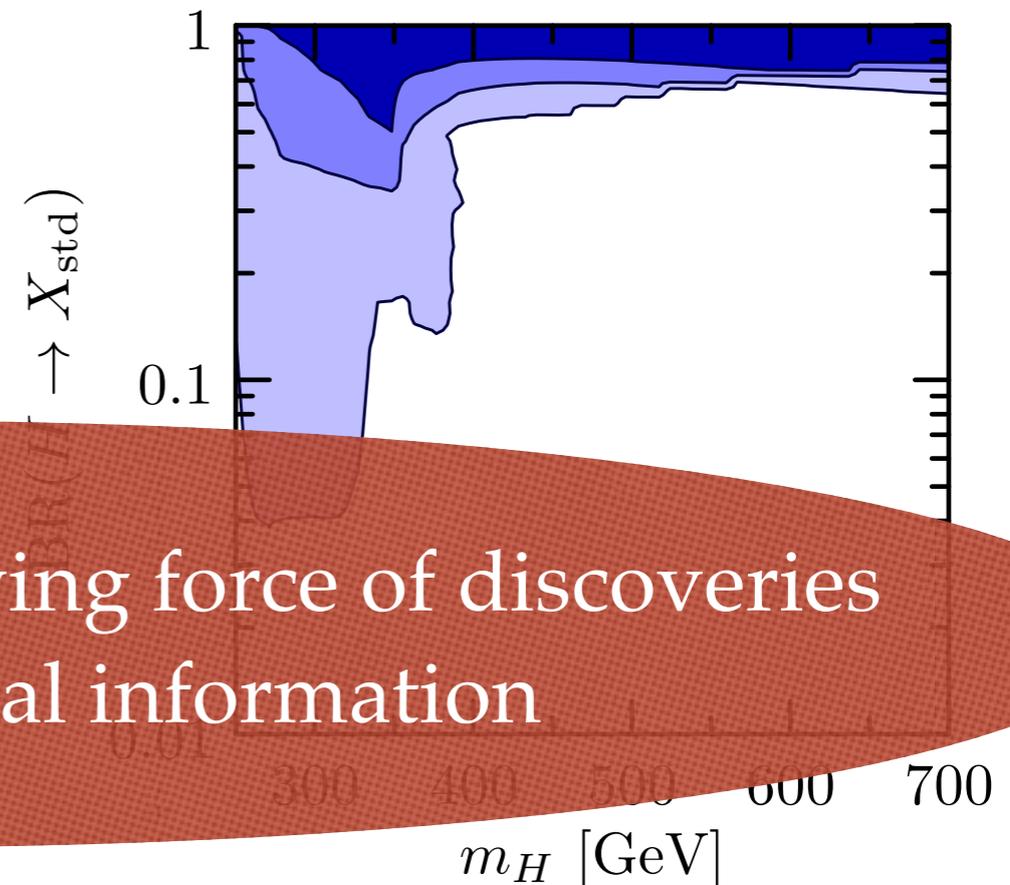
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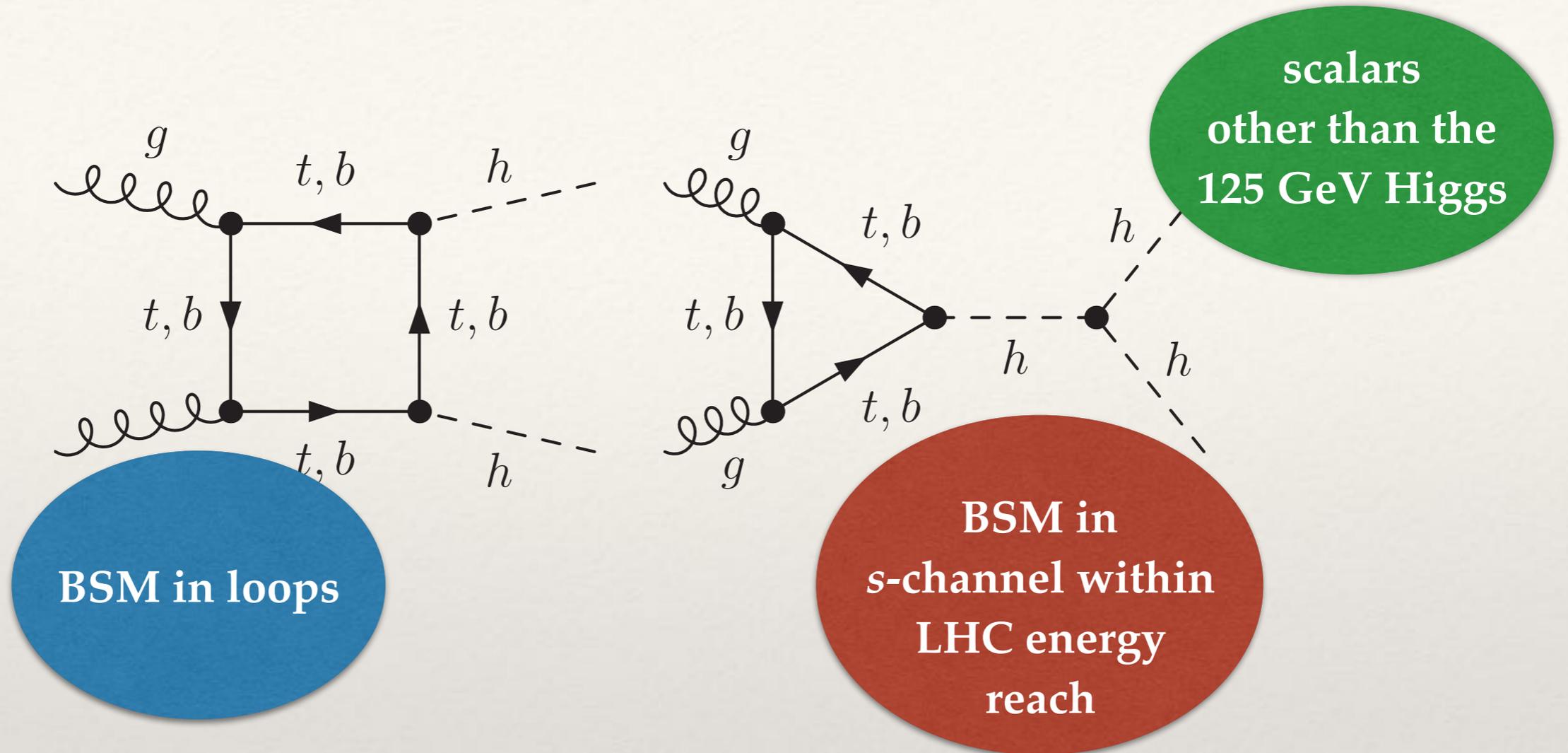
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going beyond minimal benchmarks

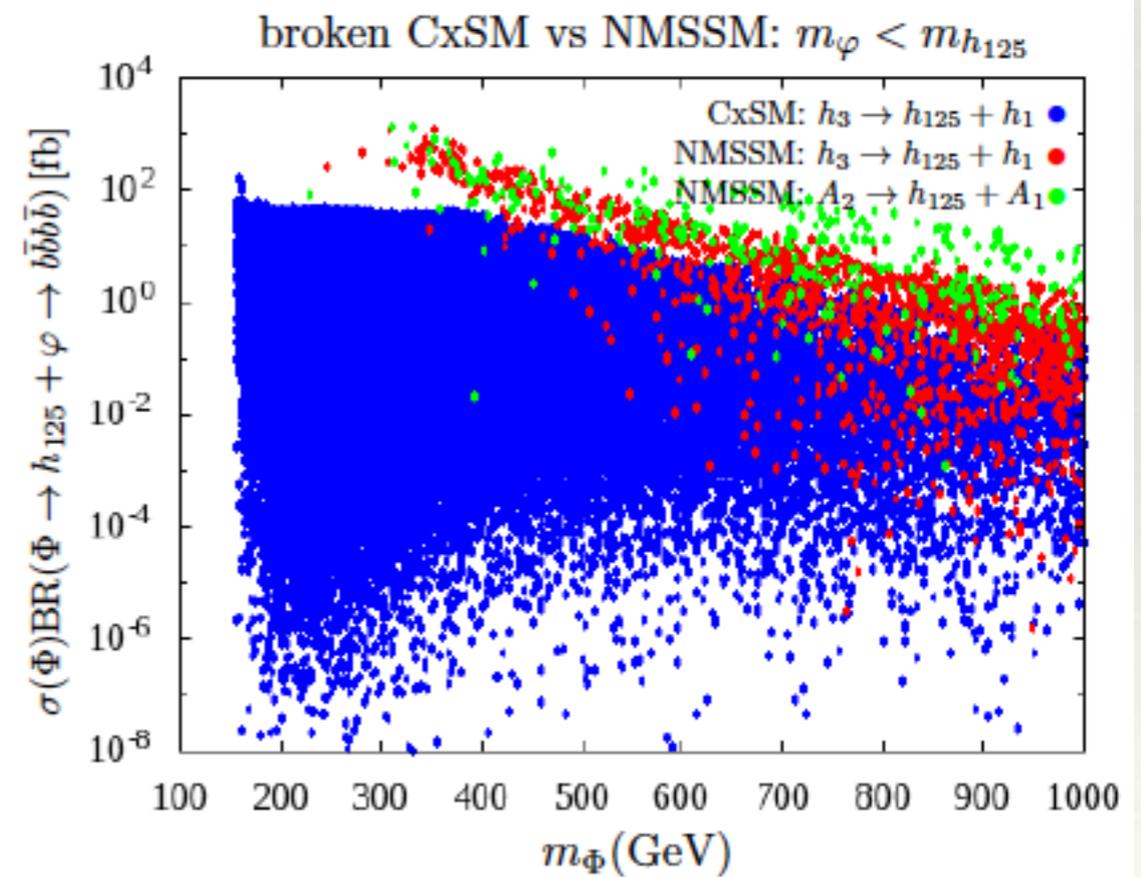
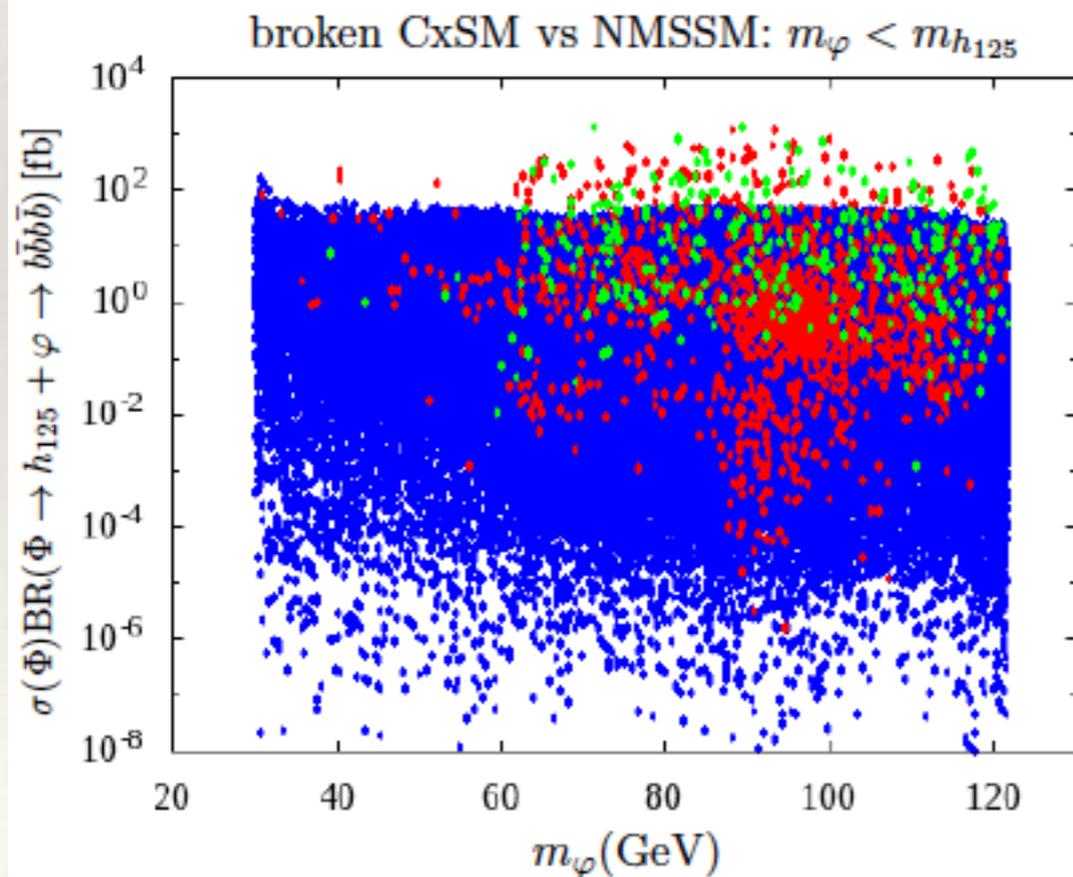


- Is there any scope for model-independence?
- What is the information gain of improving hh measurements?

→ joint effort with WG3

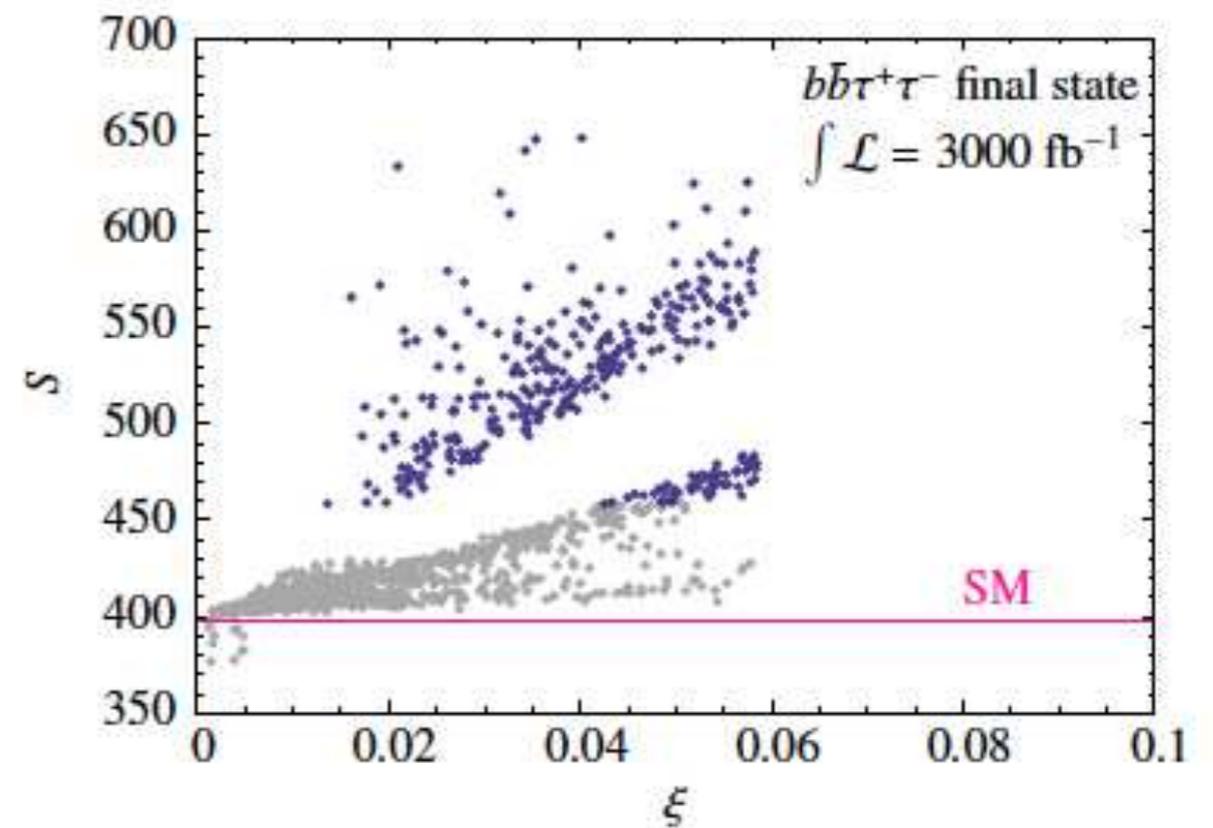
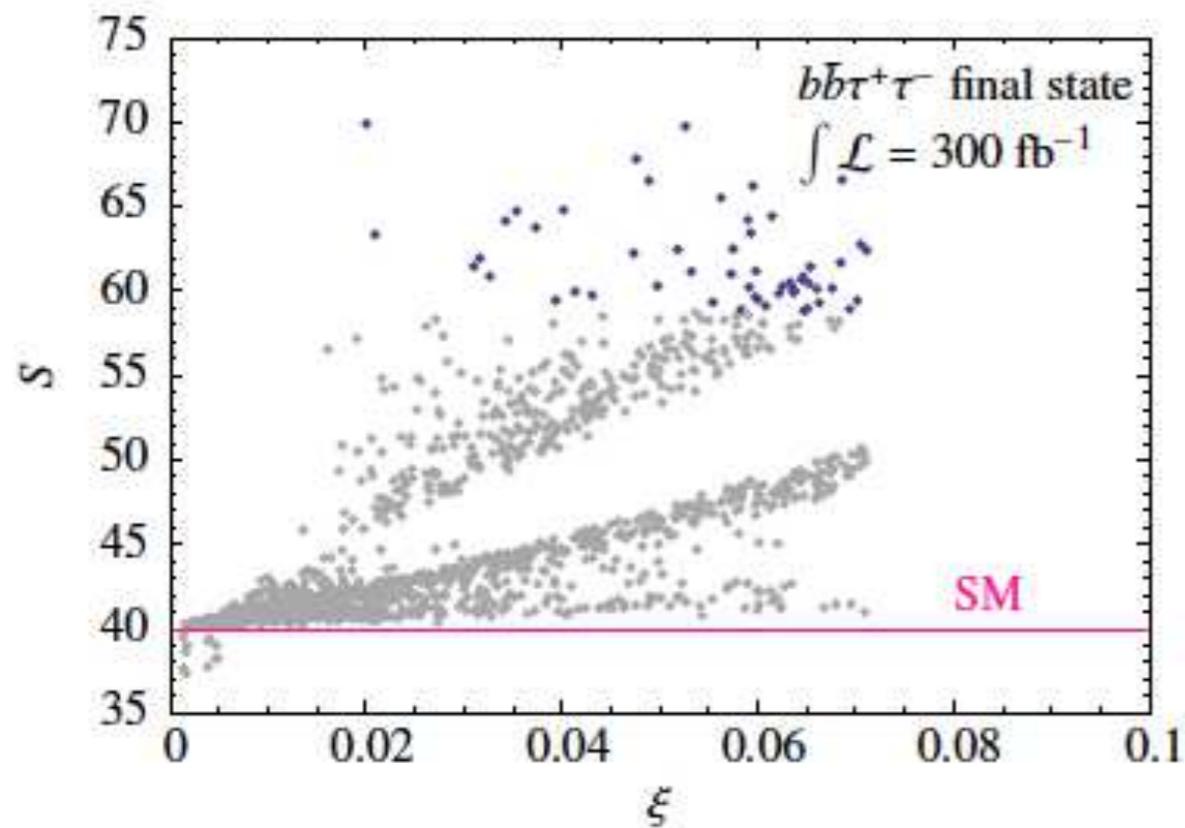
- Assumptions:

- * Only subset of Higgs bosons common in CxSM and NMSSM has been found
- * *No* non-SM final state signature discovered so far
- * *No* observation of final state signatures unique to the model
- * *No* information on CP properties of Higgs bosons so far



- **Assumption:** no new physics before Higgs pair production is accessible \rightsquigarrow Higgs coupling deviations $<$ projected sensitivities for 300 fb^{-1} and 3000 fb^{-1}

[Gröber, Mühlleitner, Spira`16]



- motivation of benchmarks depends on expected sensitivity
 \rightarrow **experimental input crucially required**

➤ signature-driven categorisation of hh phenomenology

➤ resonant & Higgs-sector related (singlet+2HDM)

➤ non-resonant via EFT approach

tools &
benchmarks
available

➤ further benchmarking necessary to highlight genuine information gain from di-Higgs analyses

➤ maximise BSM cross section in light of developing single Higgs results

➤ complementarity to single Higgs measurements

underway