Models/EFTs Subgroup Update

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for the Off-shell Interpretations Task Force

https://twiki.cern.ch/twiki/bin/view/LHCPhysics/HiggsOffshellTaskForce

HXSWG Offshell Interpretations 4th Joint Meeting

CERN

September 23, 2020

Guidelines

► discuss and make recommendations on which models/AnomCoupls/EFTs should be investigated with what priority in the context of off-shell $gg \rightarrow H \rightarrow VV$ analyses

► carefully consider and compare theoretical assumptions/choices made

► explore to what degree compatibility/translatability between ATLAS and CMS results is feasible

See also presentations at previous meetings:

► Offshell & Interference Meeting (25 November 2019) [link]

► HXSWG Offshell Interpretations 1st Joint Meeting (10 March 2020) [link]

► HXSWG Offshell Interpretations 2nd Joint Meeting (16 April 2020) [link]

Discussion Points

- ▶ EFT effects in $gg \ (\to H) \to ZZ$ (see below)
- ▶ Relation between the Higgs and Warsaw bases (see below)
- ▶ What types of BSM benchmark models should be analysed? Light degrees of freedom up to what scale? In particular to uncover limitations of EFT fits. Are common models sufficient (MSSM, 2HDM, SM+scalar)? What toy models (composite inspired, ...)?
- ▶ Interplay with other channels due to shared couplings, e.g. top production. How to disentangle coefficients? Independent subsets? Proper treatment? Best use of limited number of degrees of freedom in fits. How to expand? Take into account (better) bounds on relevant Wilson coefficients obtained in other channels.
- ▶ Can off-shell data resolve on-shell parameter degeneracy?
- ▶ Statistics/data analysis methods available to include BSM effects in backgrounds (relative to Higgs production) when determining bounds on Wilson coefficients/model parameters?
- ▶ and others, see TWiki page [link]

Road Map

1. Immediate issues:
   - discuss and converge to a "minimal" list of couplings/operators that deserve priority at this stage
   - clarify basis issues and make recommendations
   - take into account bounds on relevant Wilson coefficients obtained in other channels

2. Medium-term issues:
   - what types of BSM benchmark models should be analysed? Light degrees of freedom up to what scale? In particular to uncover limitations of EFT fits.
   - interplay with other channels due to shared couplings, e.g. top production. How to disentangle operators? Proper general treatment? Independent subsets?
   - take into account $VBF \to H \to VV$ (VBF/VH)

3. Long-term issues:
   - take into account SMEFT effects in background amplitudes
   - take into account NLO effects in EFT studies
   - study specific BSM extended with higher-dimensional operators
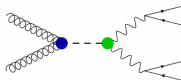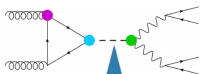
SMEFT analysis of $gg \to H \to VV \to$ leptons

Extension of the SM by dimension-6 operators Q_i composed of SM fields, which are invariant under the SM gauge symmetries (C_i: Wilson coefficients):

$$\mathcal{L}_{\mathrm{SMEFT}} = \mathcal{L}_{\mathrm{SM}} + \sum_i C_i Q_i$$
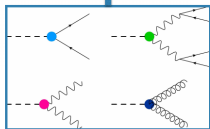
detailed Higgs basis definition $\to$ Adam's contribution at previous meeting
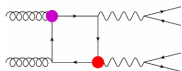
The background

The signal

The Higgs width

graphs by Eleni Vryonidou

What can $gg \to ZZ$ including off-shell tell us about the SMEFT?

$\to$ Ennio's slides at previous meeting

Models/EFTs: contributions to task force write-up

- Alex Azatov, Christophe Grojean, Ennio Salvioni with Jorge de Blas: *Effect of relaxing coupling universality in the fit to on-shell data (prelim.)* → next two slides
- Eleni Vryonidou: *EFT effects in the off-shell region (prelim.)*
- Adam Falkowski: *Summary of the Higgs basis parametrization of the SMEFT*
- Ennio Salvioni: *tbc*
- Tania Robens: *tbc*

Flat direction in on-shell Higgs measurements

$$\sigma(XX \to h)\,\mathrm{BR}(h \to YY) \;\propto\; g_{hXX}^2 \frac{g_{hYY}^2}{\Gamma_h}$$

$$g_{hii} = \kappa_{\mathrm{univ}}\, g_{hii}^{\mathrm{SM}}$$
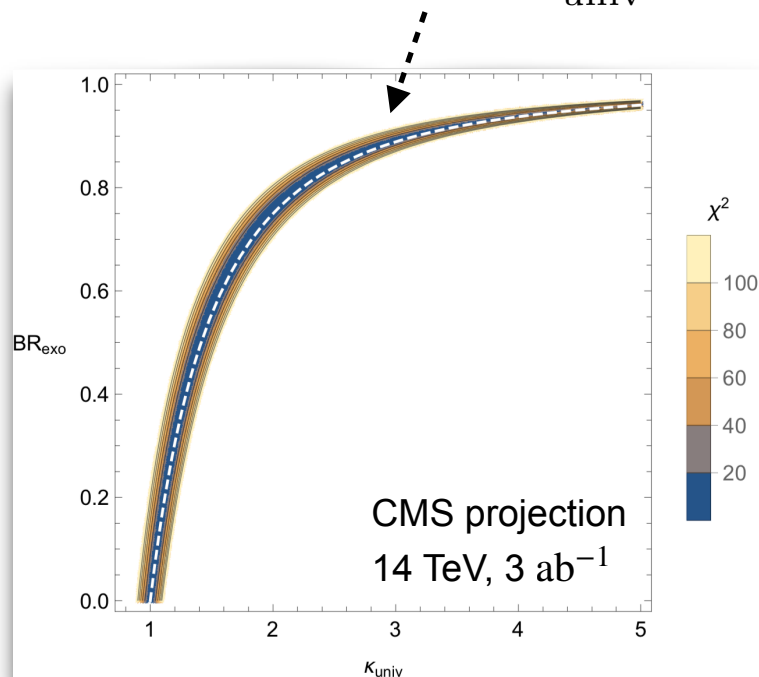
$$\Gamma_h = \kappa_{\mathrm{univ}}^4 \Gamma_h^{\mathrm{SM}}$$

➡ all on-shell rates unchanged

$$\Gamma_h = \kappa_{\mathrm{univ}}^2 \Gamma_h^{\mathrm{SM}} + \Gamma_h^{\mathrm{exo}} \quad \to \quad \mathrm{BR}_{\mathrm{exo}} = \frac{\kappa_{\mathrm{univ}}^2 - 1}{\kappa_{\mathrm{univ}}^2}$$

untagged BR gives most leeway,
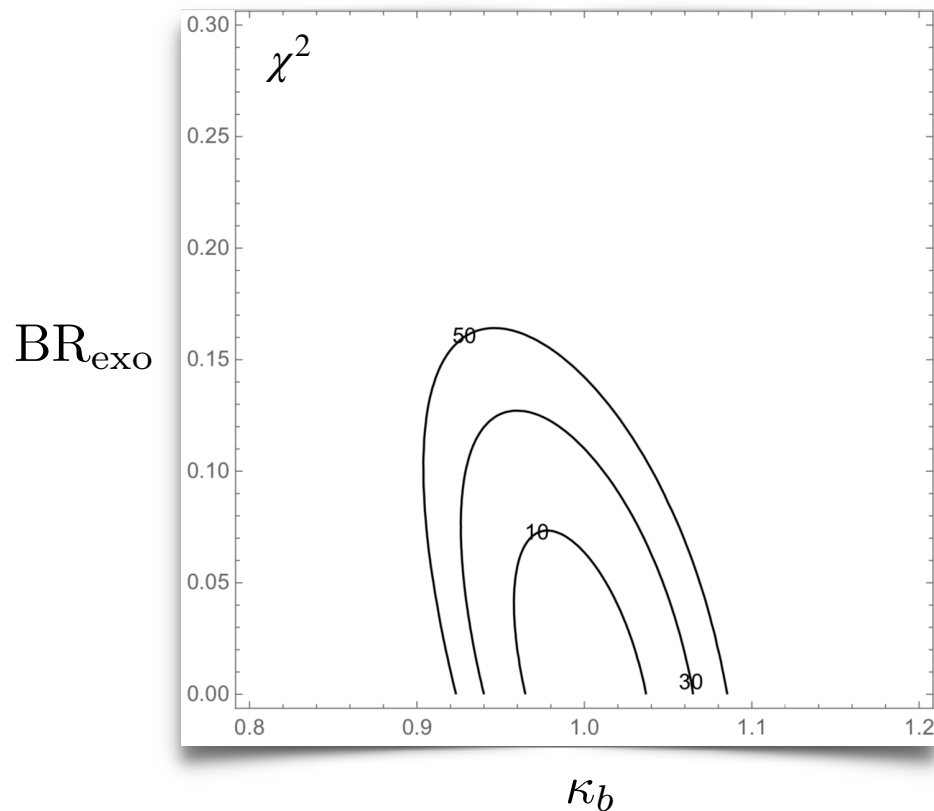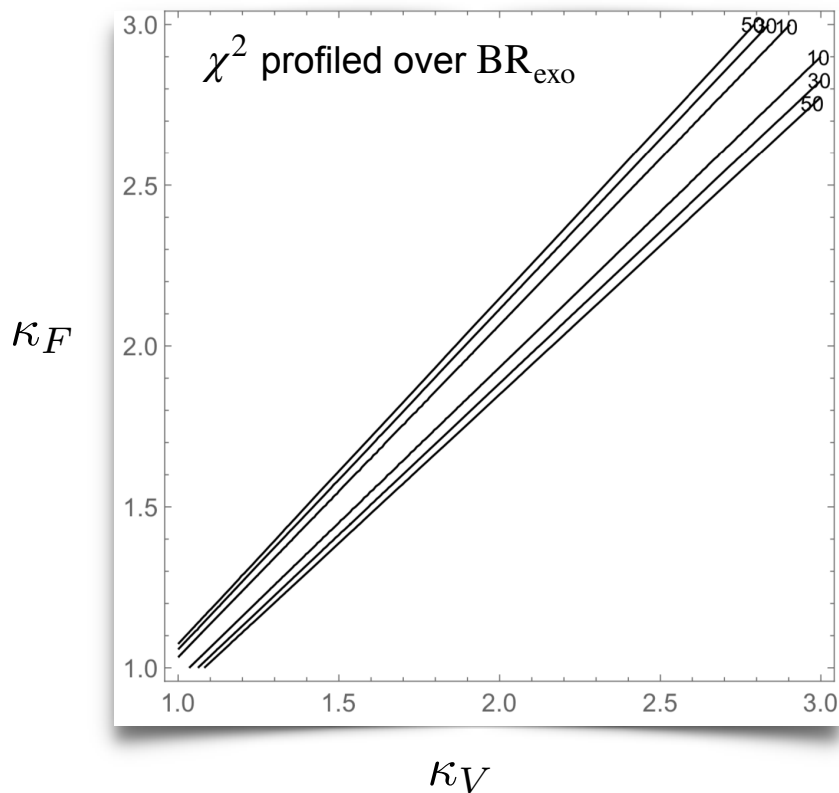*invisible* BR already strongly constrained

$$\mathrm{BR}(\mathrm{Higgs} \to \mathrm{invisible}) < 13\% \;\; (95\%\ \mathrm{CL})$$

[ATLAS-CONF-2020-008]

CMS projection
14 TeV, 3 ab^{-1}

thanks to Jorge de Blas for providing the likelihood from [1905.03764]

Relaxing coupling universality?

χ^2 profiled over $\mathrm{BR}_{\mathrm{exo}}$

κ_F

κ_V

χ^2

$\mathrm{BR}_{\mathrm{exo}}$

κ_b

Flat direction is lifted very rapidly when we depart

from universal rescaling of Higgs couplings

Preliminary - in progress