Christoph Englert

Extracting κ_λ and κ_{2V} from all angles

SM@LHC `22

14/04/22

Fingerprinting the lack of new physics

coupling/scale separated BSM physics

Effective Field Theory

$$\mathcal{L} = \mathcal{L}_{\rm SM} + \sum_i \frac{c_i}{\Lambda^2}\mathcal{O}_i + \dots$$

[Grzadkowski, Iskrzynski, Misiak, Rosiek `10] ...

- benchmarking as part of WGR 4
- limitations known and tackled
- limits on ad-hoc EFT deformations

HXSWG benchmarks e.g. [CMS `18]

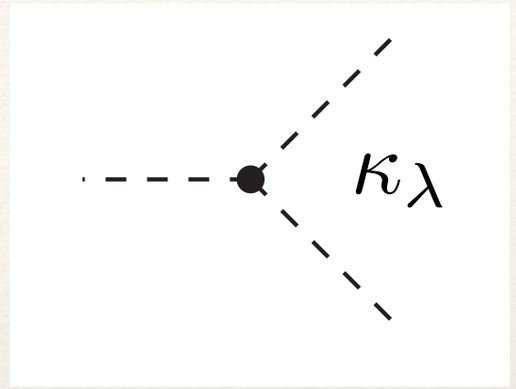
concrete models

- extended SMEFT
- (ℂ) Higgs portals
- 2HDMs
- simplified models
- compositeness….

Trilinear and Quartic Couplings: SM expectation

trilinear couplings directly sensitive to the Higgs potential

$$\mathcal{L}_{\rm SM} \supset |D_\mu \Phi|^2 - V(\Phi)$$



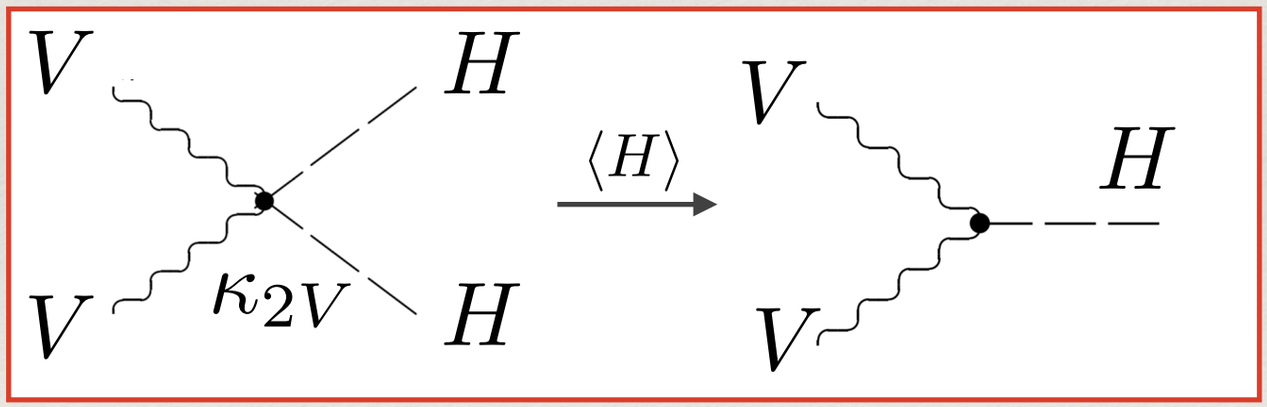
quartic Higgs-V couplings are gauge couplings

deviations correlated with single Higgs data for concrete scenarios

significant progress for generic approaches beyond classical limit

[Buchalla et al.` 18]

...



SM	$g_v^2/2$	$g_v m_v$
vs singlet mix.	$\cos^2\eta$	$\cos\eta$
vs MCHM5	$1-2v^2/f^2$	$\sqrt{1-v^2/f^2}$

κ_λ, κ_{2V} fingerprint (elements of) EWSB mechanism

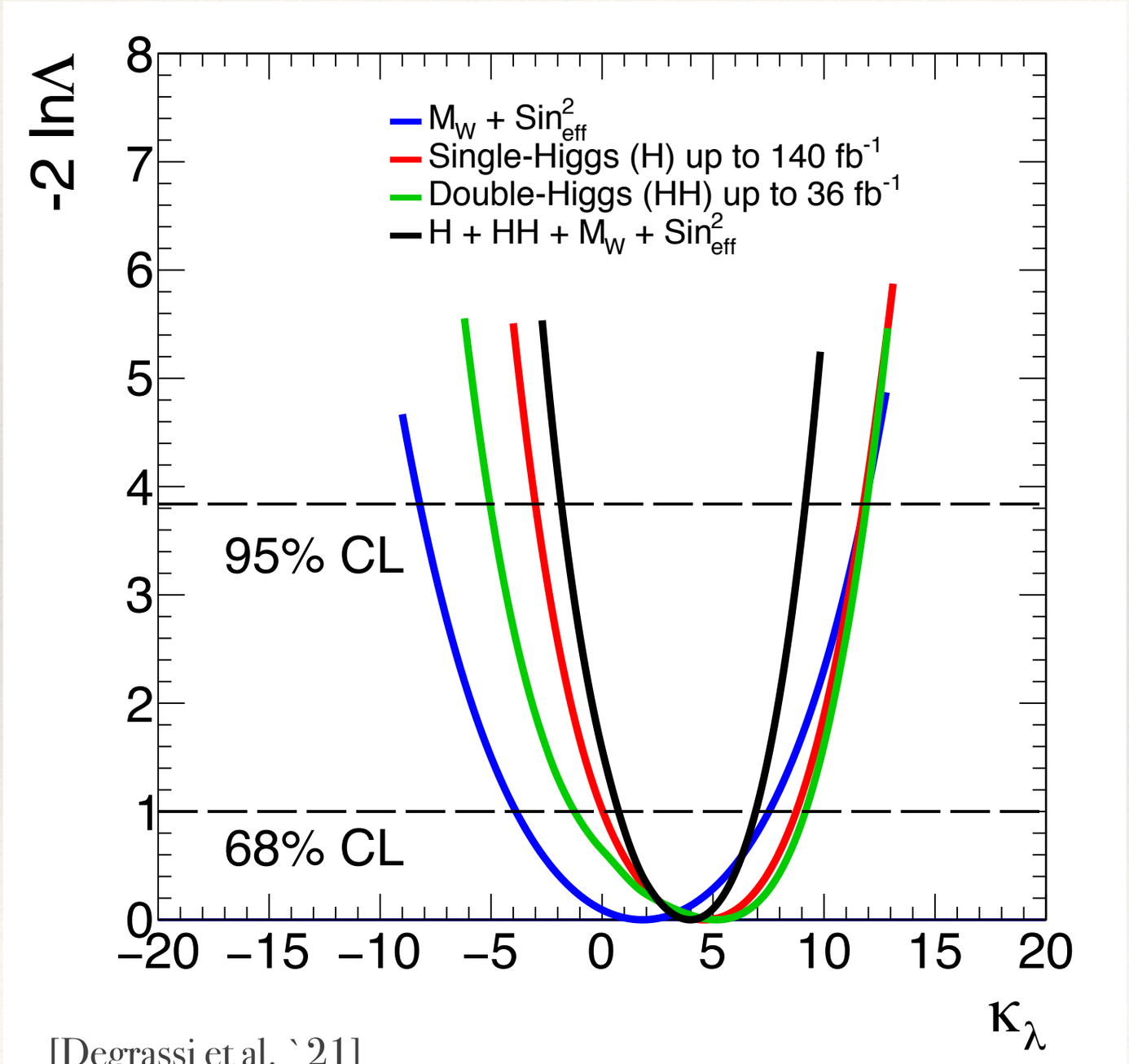
extensions to quartic Higgs couplings

[Borowka et al. `18]
[Bizón et al. `18]
[Liu et al. `18]

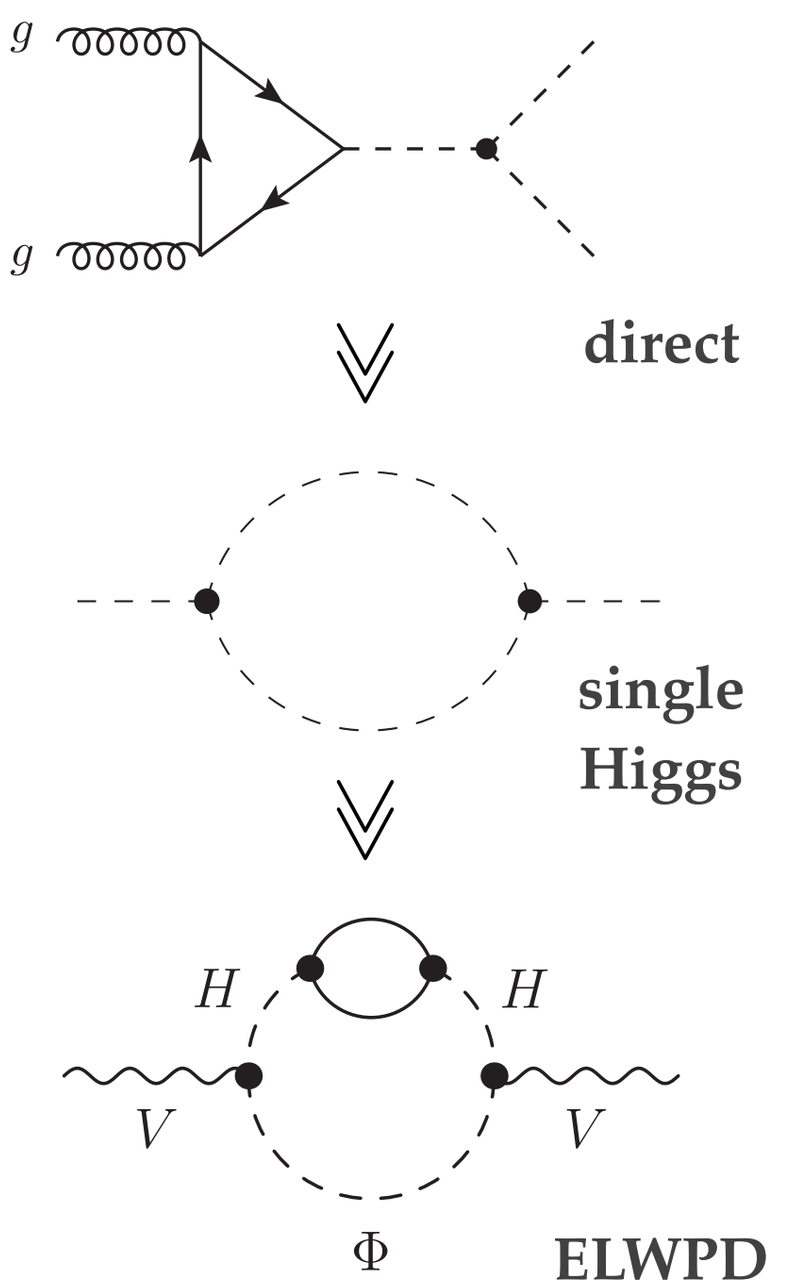
κ_λ : indirect vs direct sensitivity

- κ_λ enters (with theoretical assumptions) in loop corrections to Higgs and EW precision measurements

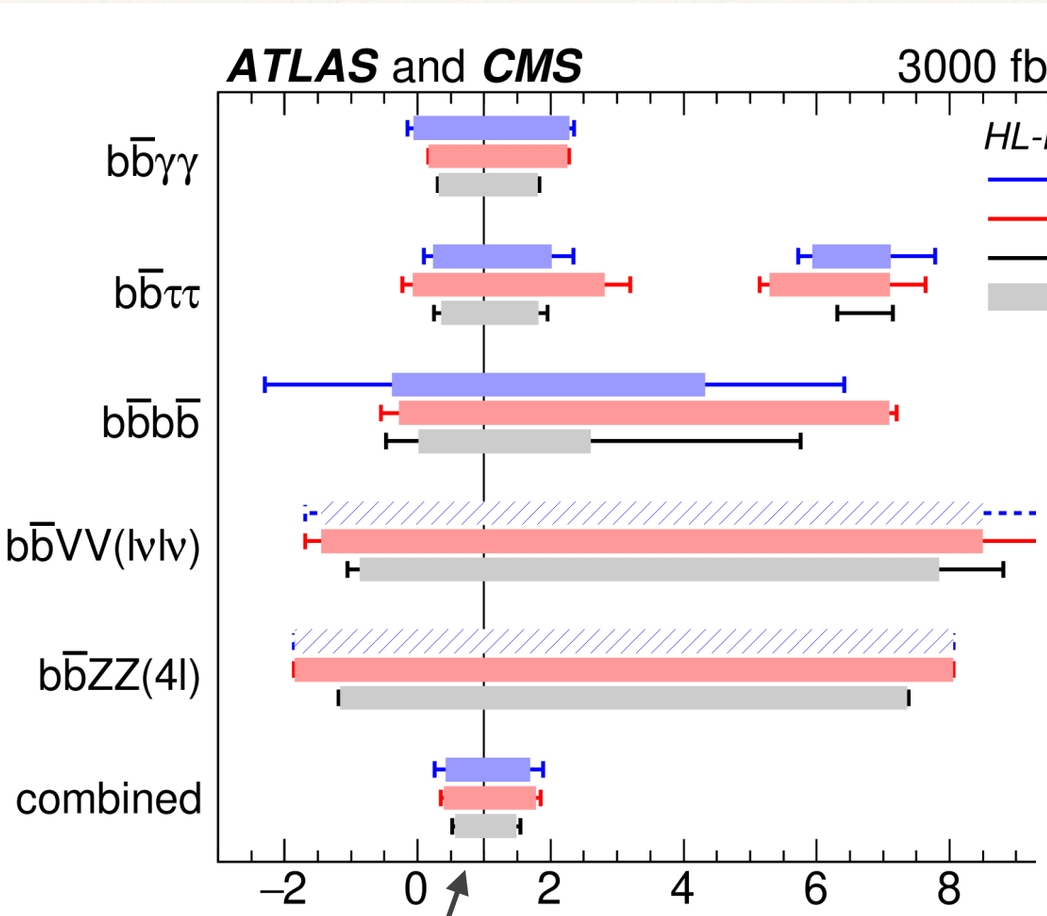
[McCullough `13]
[Kribs et al. `17]
[Maltoni et al. `17]
[Degrassi et al. `16, `21]



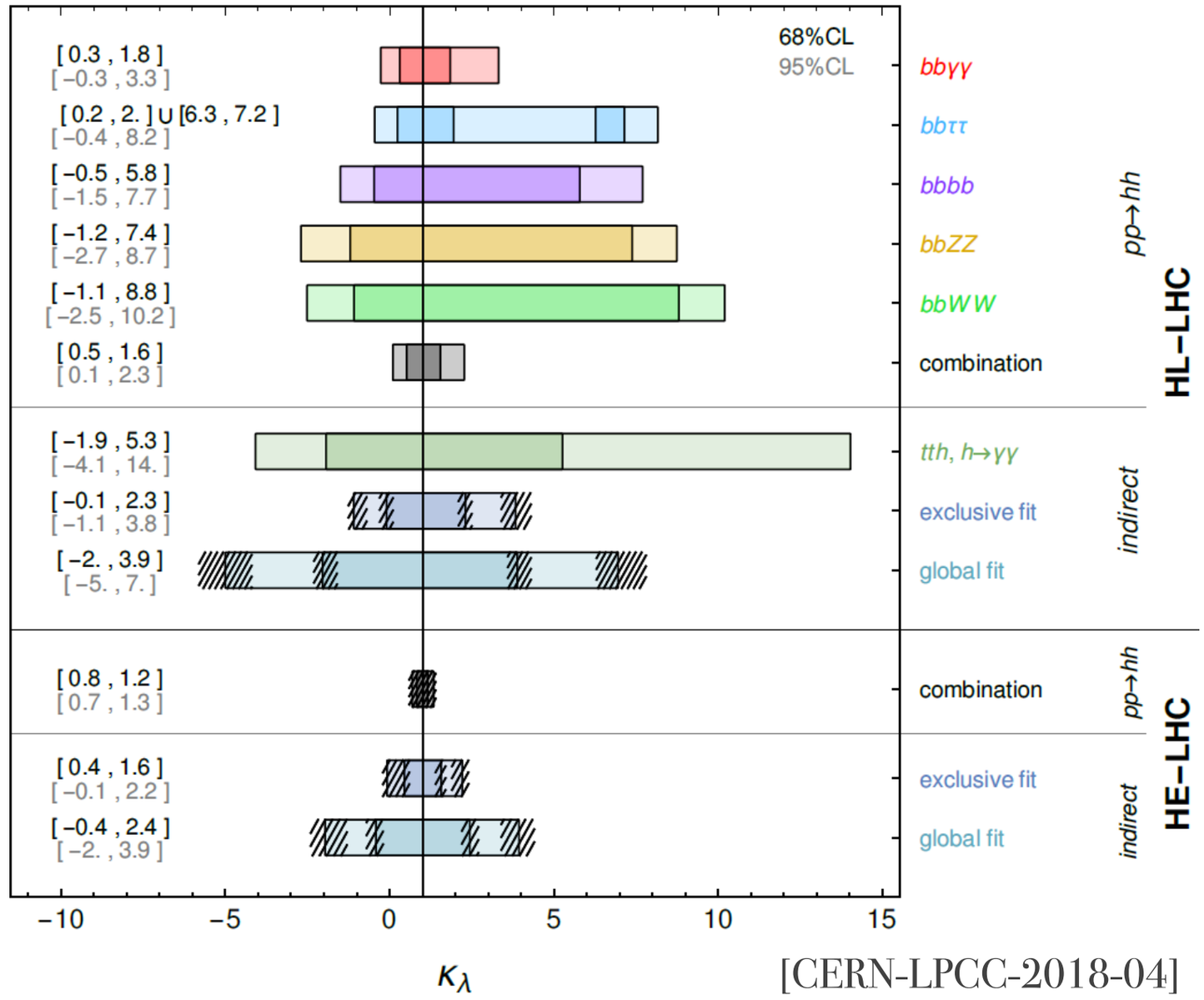
[Degrassi et al. `21]



κ_λ : looking into the future



sensitivity of 50% in direct sensitivity seems attainable



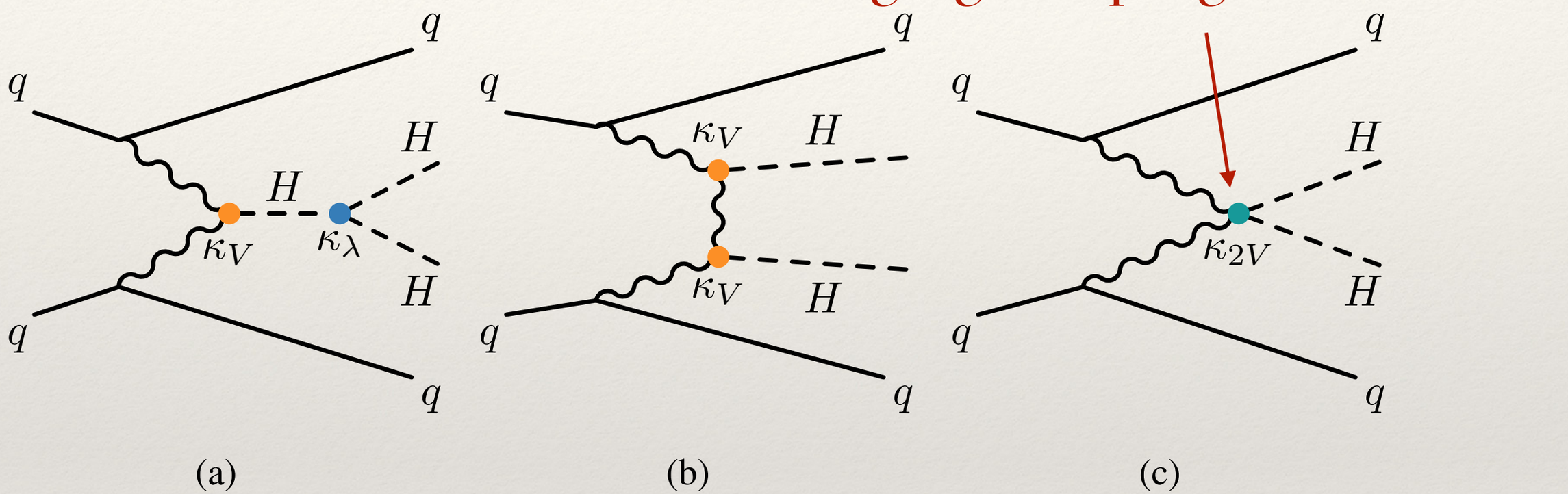
[CERN-LPCC-2018-04]

Theoretical consistency

- significant work devoted to constraining VVhh interactions

e.g. [ATLAS 2001.05178]

gauge coupling ~ $V^{3,4}$, HV^2



- κ_V sensitive in the electroweak fit, suppressed κ_{2V} impact
- nature preserves probability ⇒ is the constraint relevant, or do we just map something obvious (unitarity) onto something opaque (κ_{2V}) ?

Theoretical consistency

- longitudinal gauge boson polarisations scale ~ E(W), growth of amplitude ~$E^2(W) \implies \kappa_{2V} \neq 1$: loss of unitarity at a critical scale Λ

maximum energy correlates with critical $\kappa_{2V}=1+c_{2V,}$ analysis needs to perform better than that

has to be larger than maximum energy probed in analysis

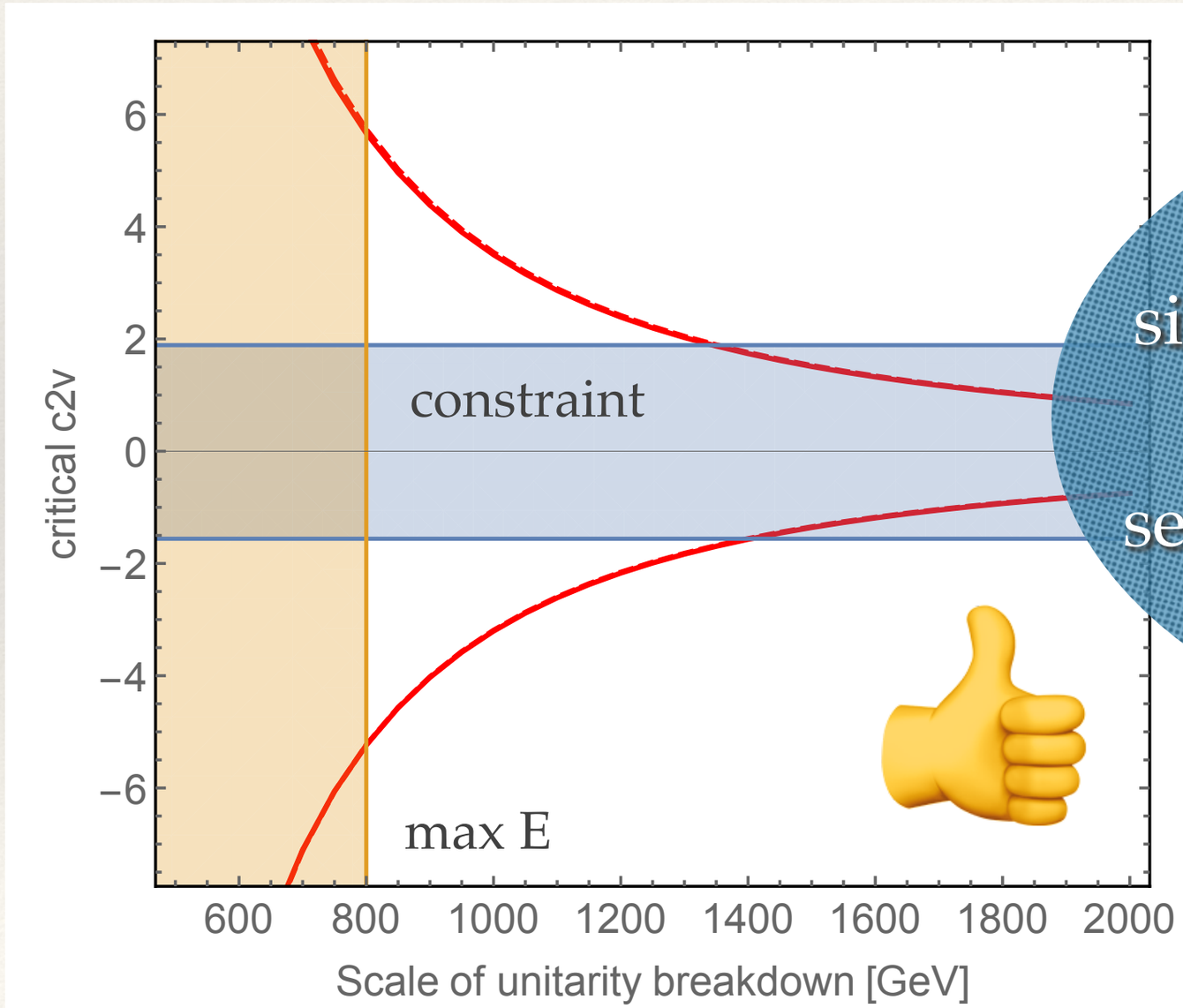
- checking this for [ATLAS 2001.05178]

$$\kappa_{2V} < -0.76 \text{ and } \kappa_{2V} > 2.90 \qquad \max E \sim 800 \text{ GeV}$$

Theoretical consistency

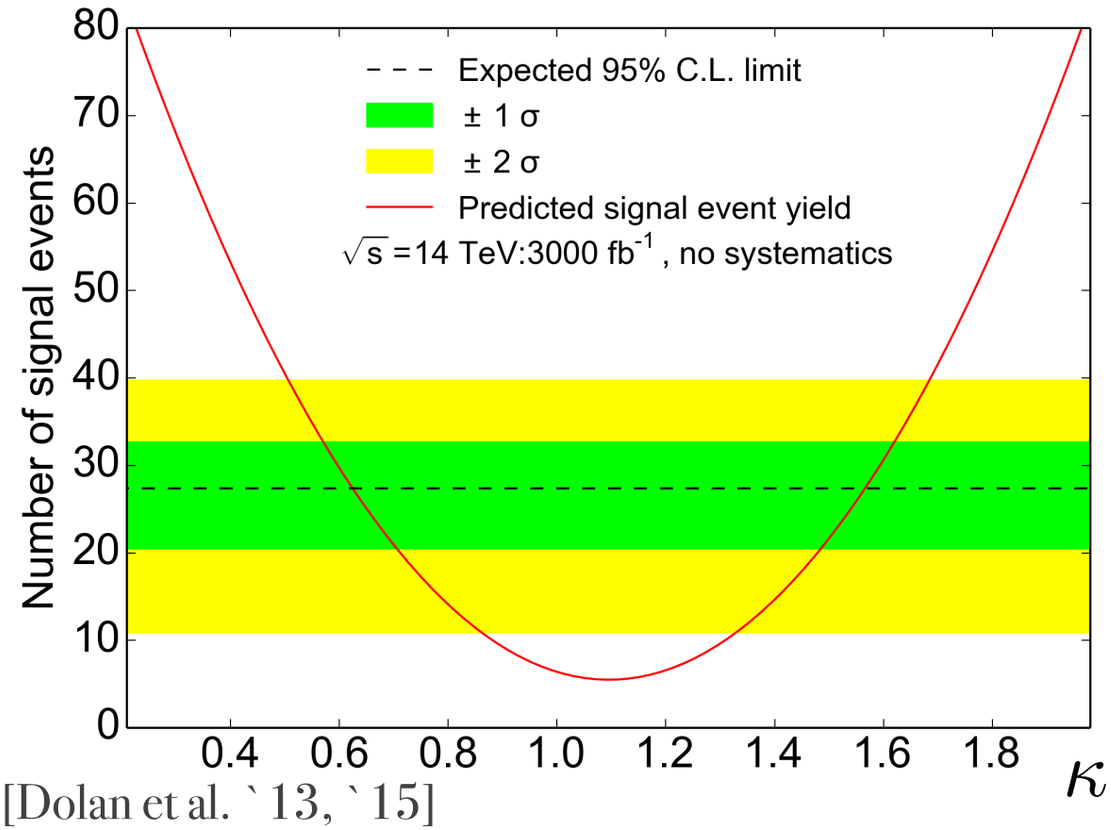
- checking this for 2001.05178:

$\kappa_{2V} < -0.76$ and $\kappa_{2V} > 2.90$ $\qquad$ $\max E \sim 800$ GeV

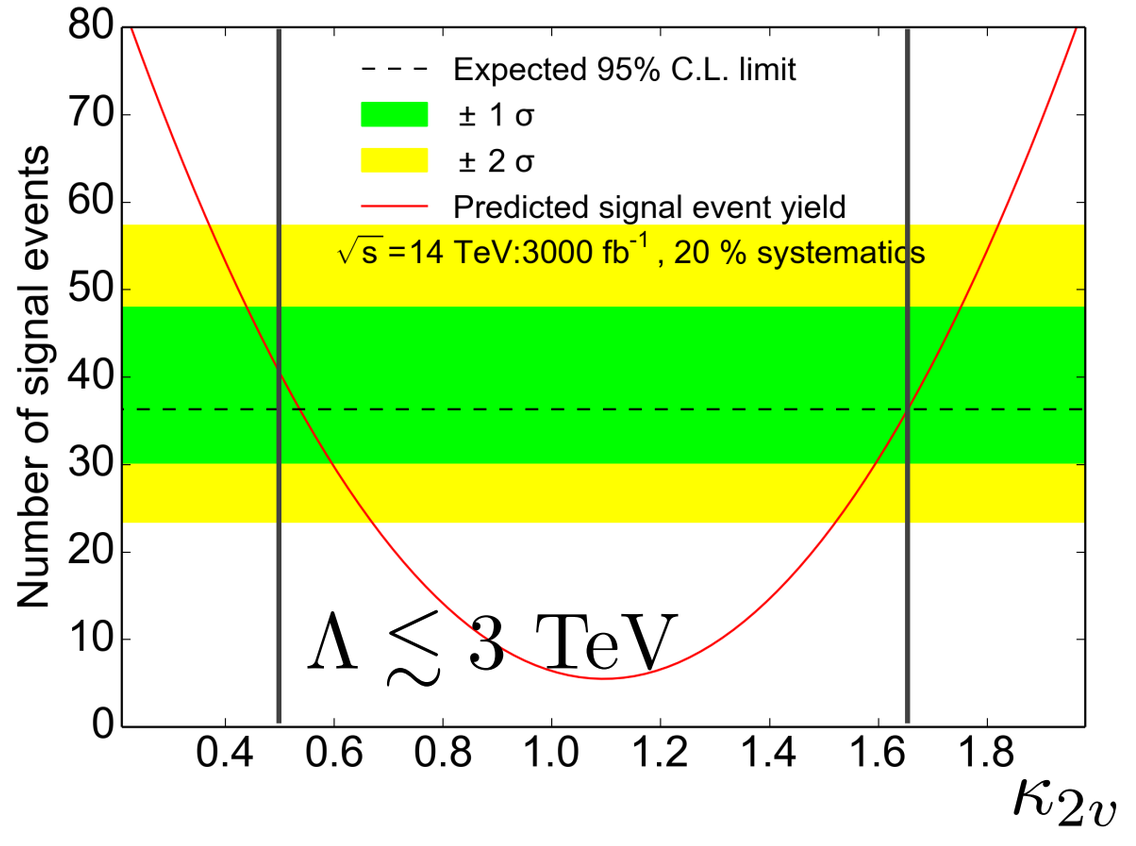


Phenomenological situation qualitatively similar to run-1 κ Higgs framework: sensitivity to low to theoretically critical deviations.

Weak boson fusion: Looking to the future



[Dolan et al. `13, `15]



- interplay with gluon fusion in finite top mass critical to evaluate sensitivity yield

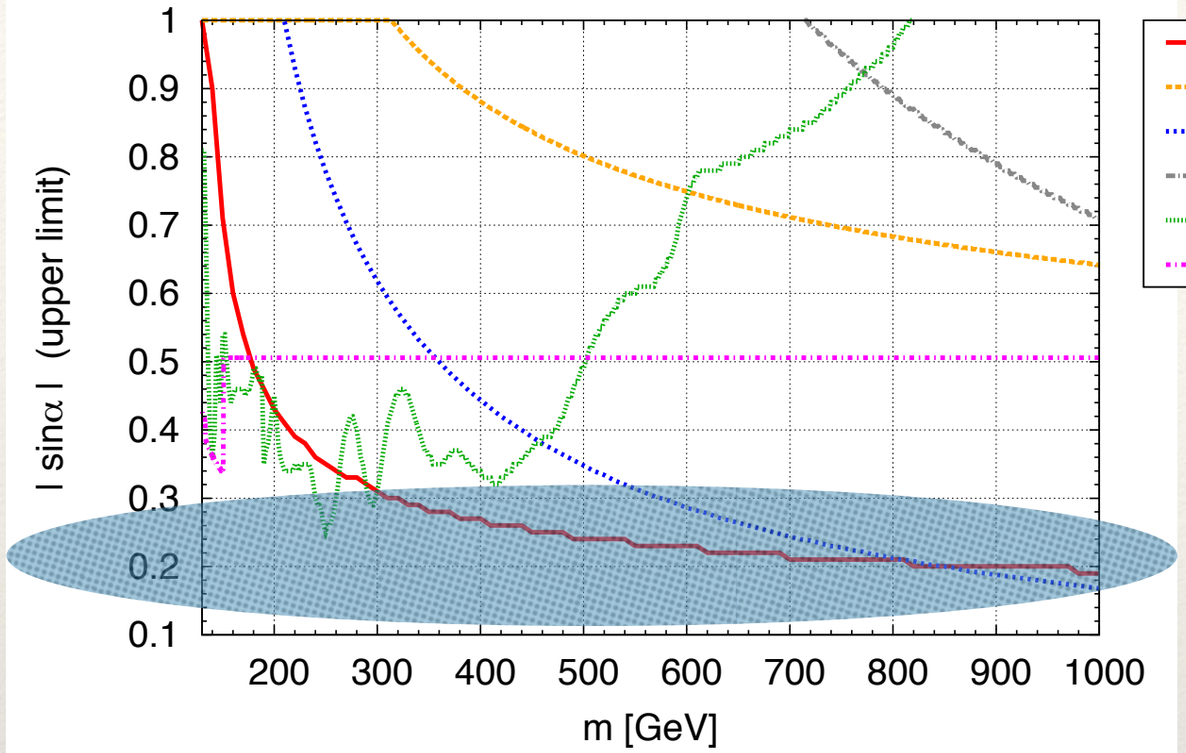
see also
[Bishra, Contino, Rojo `17]
[Arganda, Garcia-Garcia, Herrero`18]
[Killian et al. `21]

- potential improvements through traditional techniques (jet vetos, etc.) and machine learning

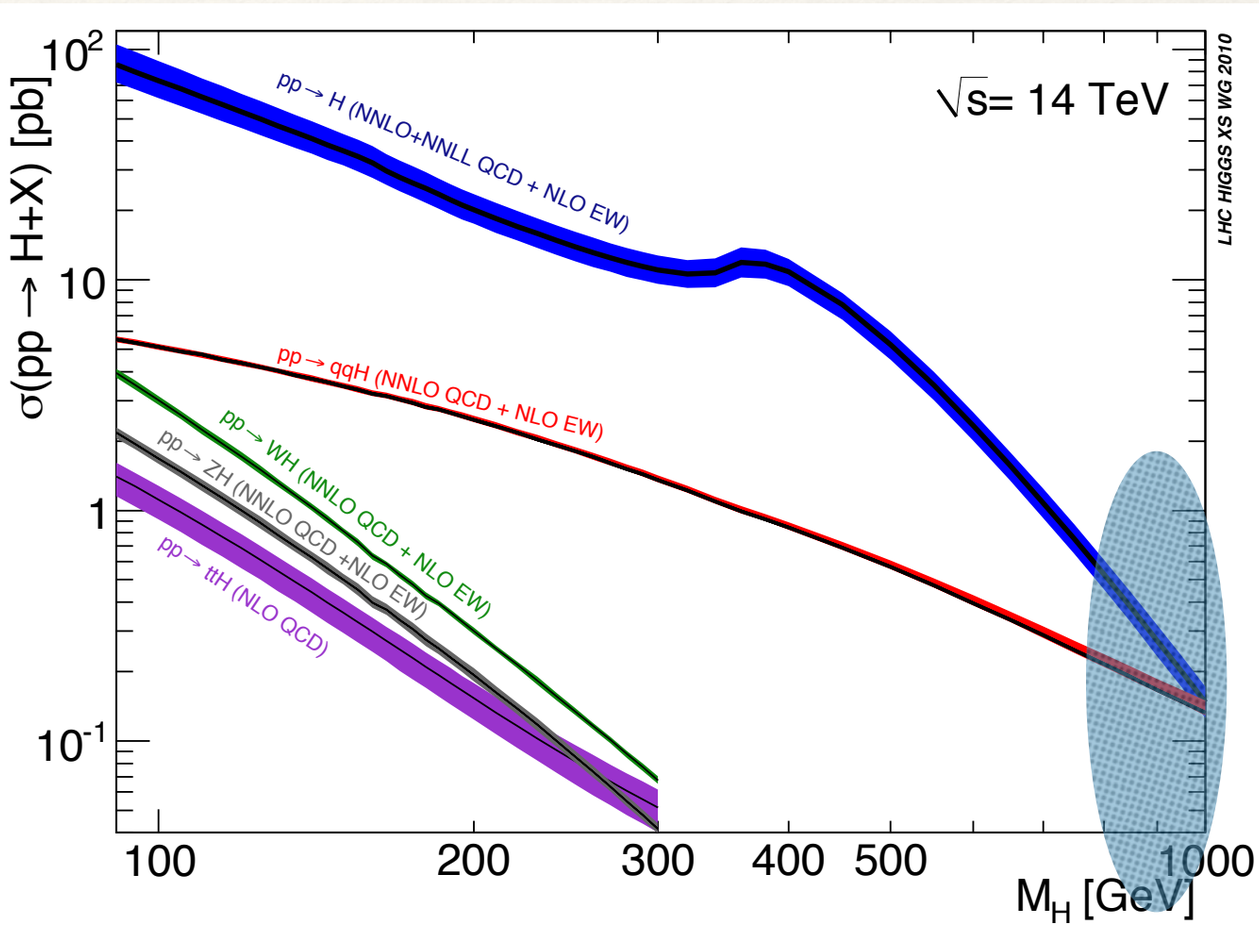
[Killian et al. `21]
[Diaz et al. `22]

κ_{2V} informing concrete scenarios?

[Robens, Stefaniak `15].....

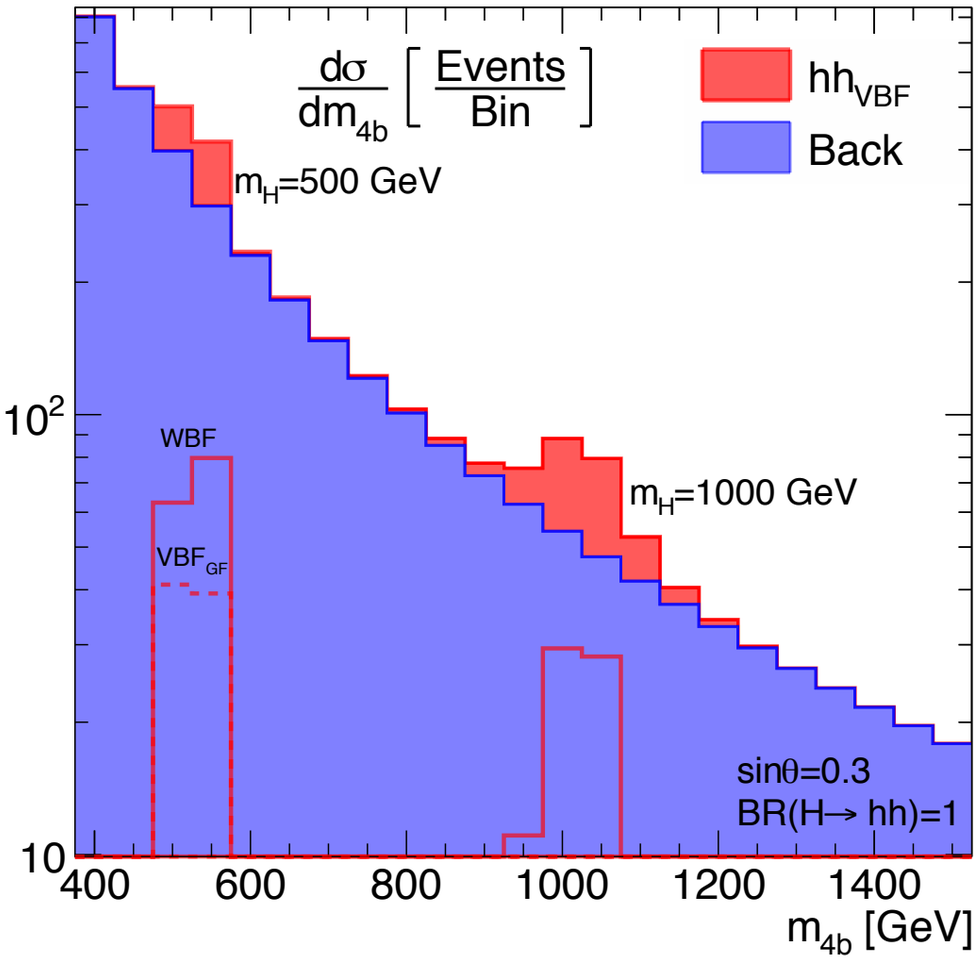


- SM-likeness of 125 GeV selects alignment limit, κ_λ and κ_{2V} suppressed
- heavy exotics and allignment **WBF plays an essential role!**

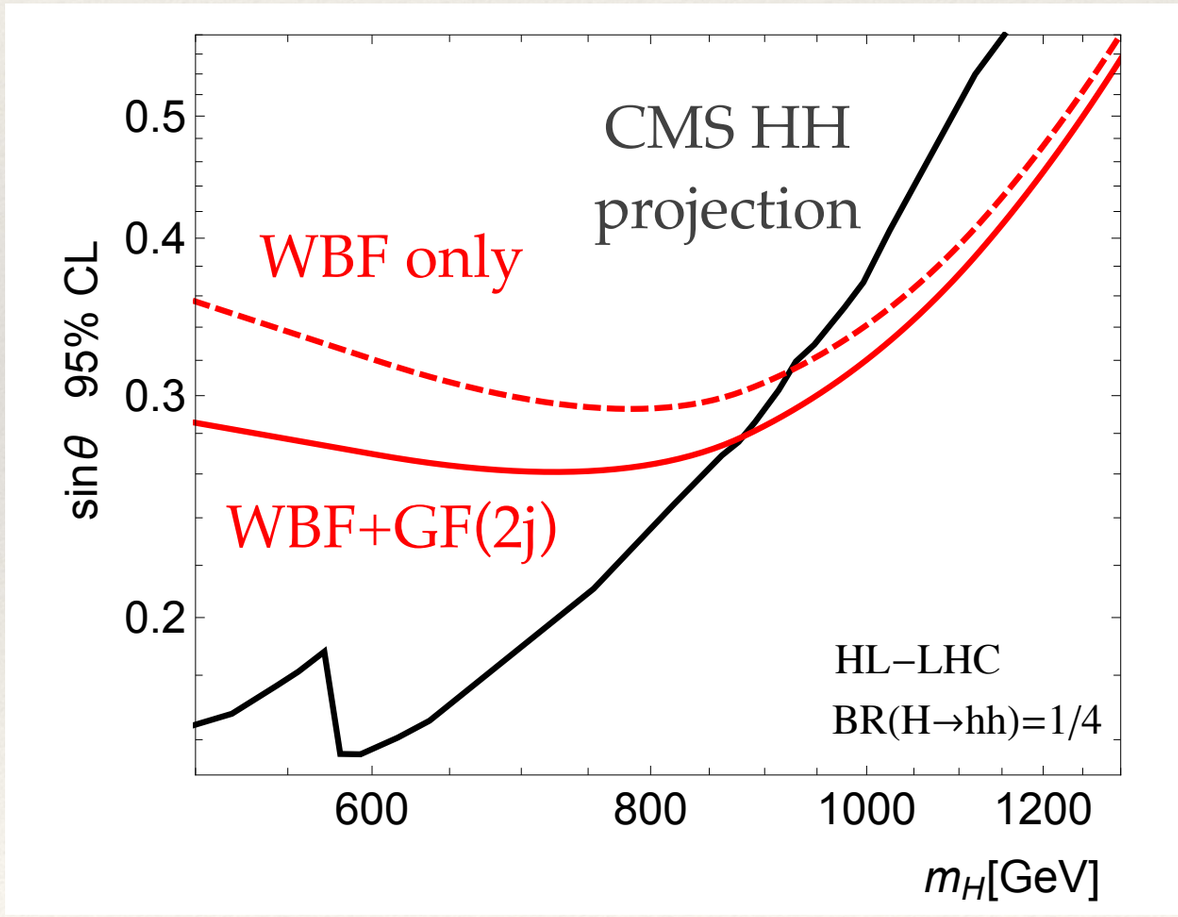


…good coverage of searches for SM-like Higgs and SM HH channels…

Proof-of-principle analyses

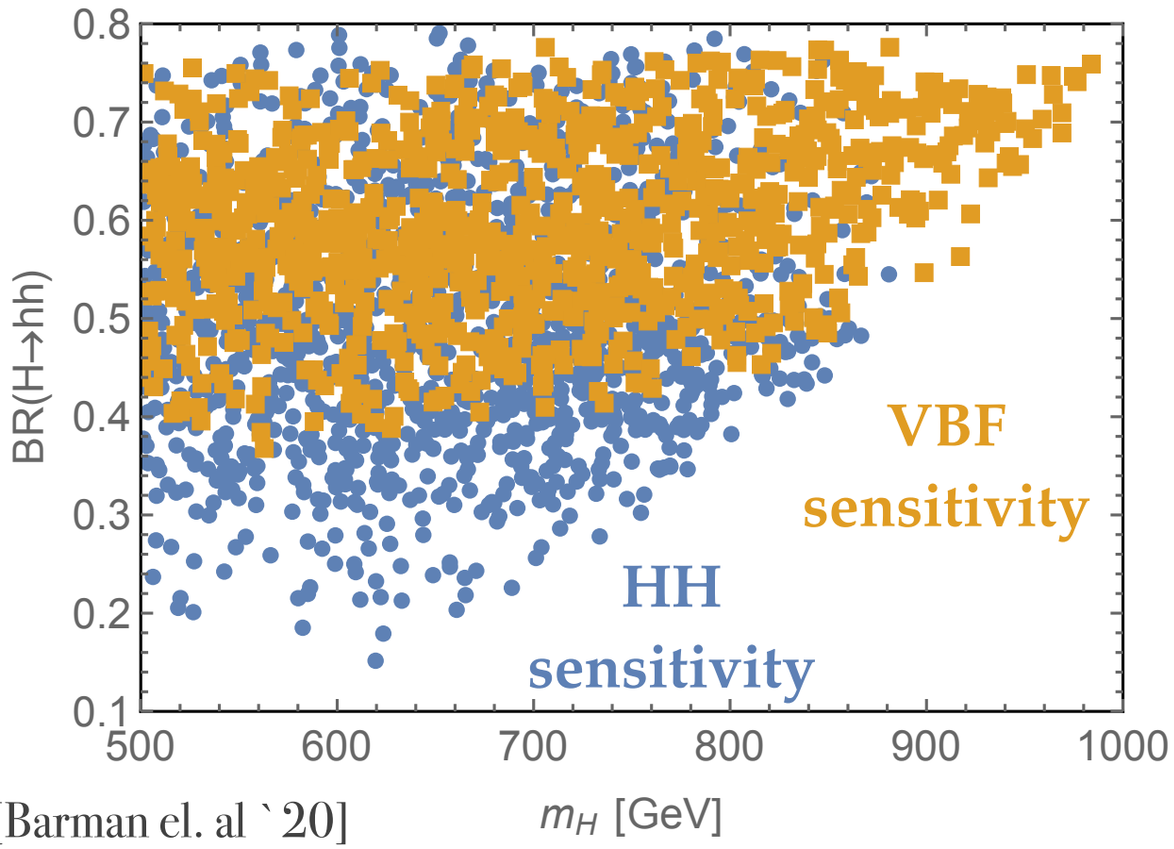


- scan over singlet parameter space, taking into account constraints from electroweak precision data, etc.

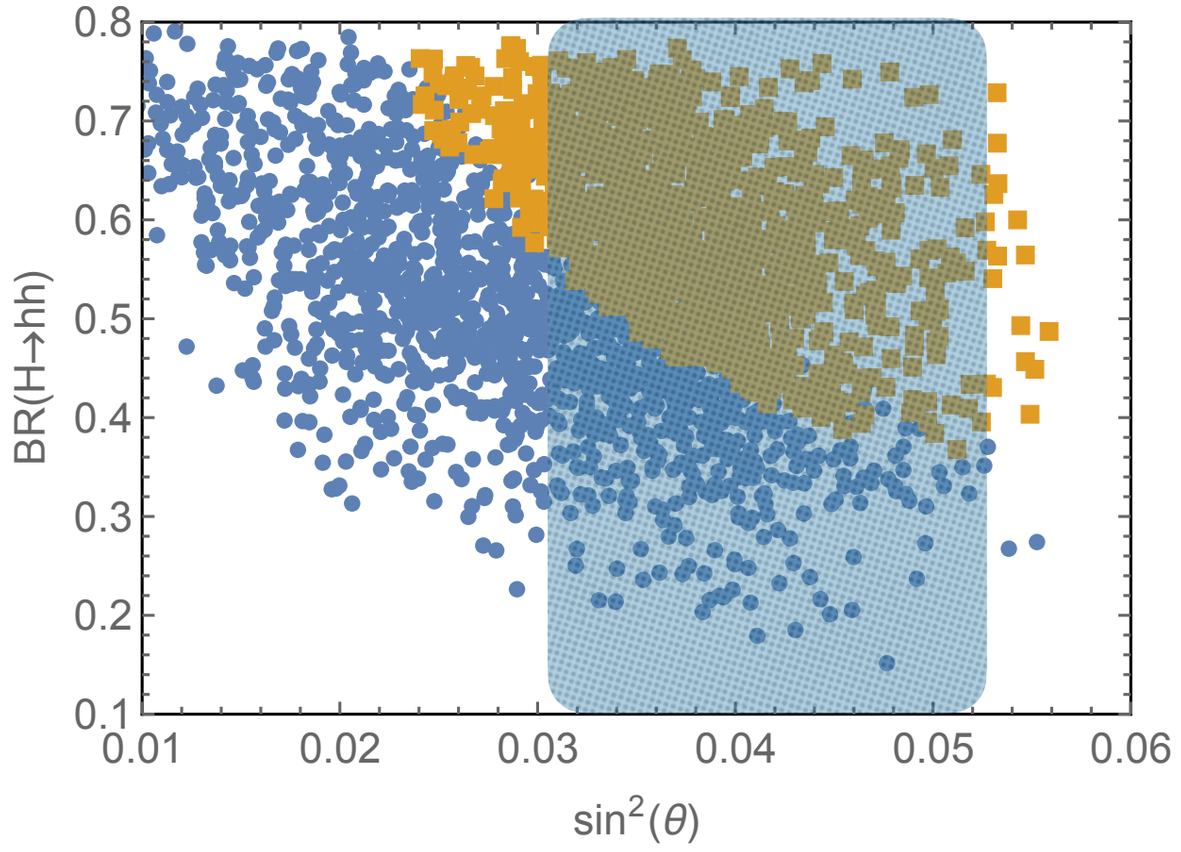


- Searches for concrete exotics can provide superior sensitivity for current constraints

Proof-of-principle analysis



[Barman el. al `20]



- WBF has significant overlap with "ordinary" HH searches: adds global sensitivity/exclusion potential
- **more relevant: WBF only sensitive channel for the heavy Higgs partner mass region, when 125 GeV is consistent with the SM**

Summary

- Sensitivity to κ_λ and κ_{2V} provide important tools to analyse the mechanism of electroweak symmetry breaking

- Large progress in obtaining sensitivity from a range of observables

- indirect searches based ad-hoc assumptions, difficult to motivate but good progress in EFT precision calculation to partially address these

- improve direct sensitivity: more data, less background, etc.