Unveiling BSM Physics: Multi-scalar coupling modifiers

[C. Englert, **WN**, D. Sutherland '23 (2307.14809)]

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The κ-Framework

- Ratios with respect to SM couplings:

$$\boxed{\kappa_i = \frac{g_i}{g_i^{SM}}}$$

[LHC Higgs Cross-Section WG '13]

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$$\mathcal{L} = m_W^2 \left(W_\mu^+ W^{-\mu} + \frac{1}{2c_W^2} Z_\mu Z^\mu \right) \left[1 + \kappa_V \frac{2h}{v} + \kappa_{2V} \frac{h^2}{v^2} \right] - \frac{m_h^2}{2v} \kappa_\lambda h^3$$

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Precision (2σ)	$\delta\kappa_V$	$\delta\kappa_{2V}$	$\delta\kappa_\lambda$
HL-LHC	2.5%	40%	100%

[ATLAS '23, CMS '22]

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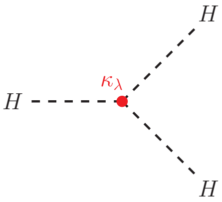
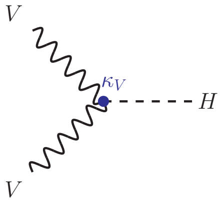
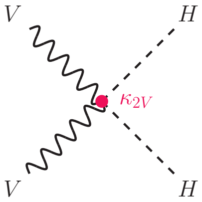
$$\kappa_\lambda = \frac{g_{HHH}}{g_{HHH}^{SM}}$$

$$\kappa_V = \frac{g_{HVV}}{g_{HVV}^{SM}}$$

$$\kappa_{2V} = \frac{g_{HHVV}}{g_{HHVV}^{SM}}$$



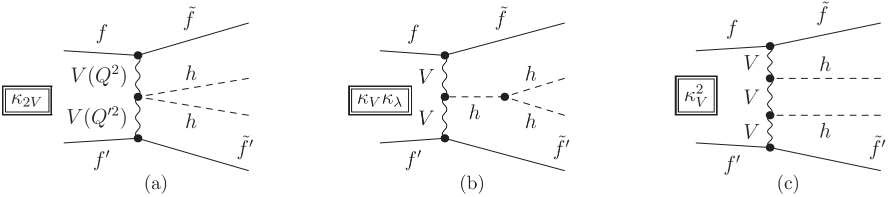




Collider Constraints on κs

- κs can be cornered through WBF Higgs pair production processes in hadron and lepton colliders.

[Figy et al '03, Figy et al '08, Dreyer et al '18, Maltoni et al '18, ATLAS, CMS]



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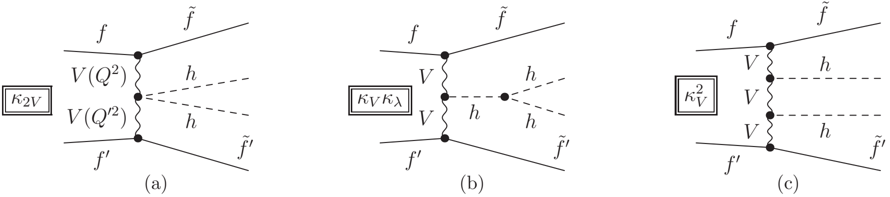

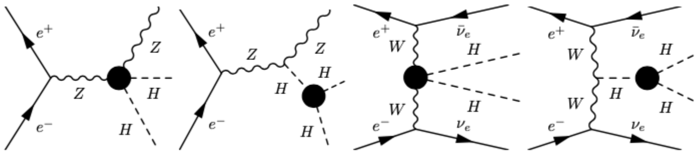

[Maltoni et al '18]

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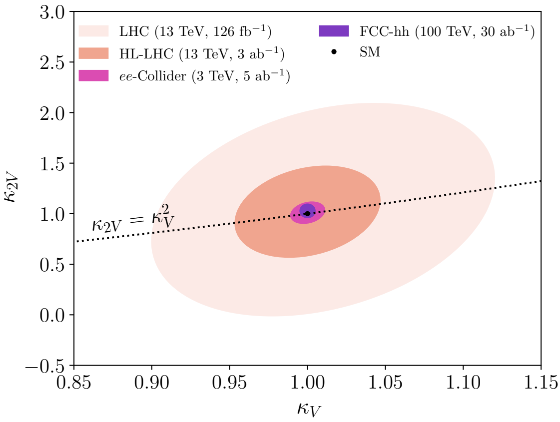

- κ_V limits from Single Higgs data. [ATLAS Collaboration '22]

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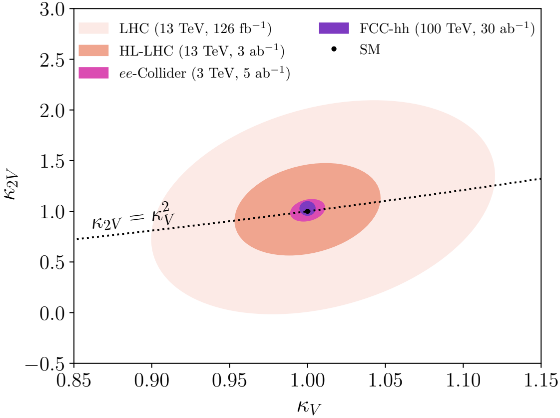

This serves as a motivation to check what signals the myriad of BSM models have on the κ parameter space!

Scalar Extensions: Tree Level

$$\mathcal{L} \supset \sum_i \frac{1}{2}(\partial h_i)^2 - V(v,h) + \frac{1}{4}g^2 W^+ W^- \left[C_{ij} v_i v_j + 2 C_{ij} v_i h_j + C_{ij} h_i h_j\right].$$

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κ_λ is enhanced close to the Alignment and Decoupling Limit:

$$\kappa_\lambda \approx 1 - 2 \sum \epsilon_a^2 \left(\frac{m_a^2}{m_h^2} - \frac{1}{4}\right) .$$

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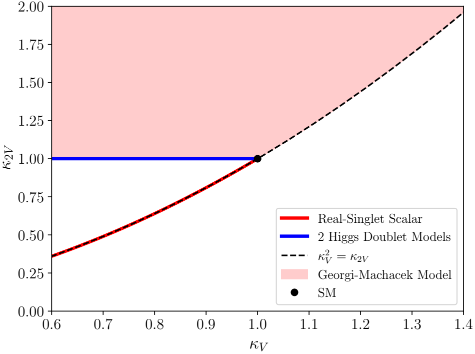

Scalar Extensions: Loop Level

$$\mathcal{L} = |\mathcal{D}\Phi_A|^2 - m_\varphi^2 |\Phi_A|^2 - 2\lambda |\Phi_A|^2 \left(\Phi^\dagger \Phi - \frac{v^2}{2} \right) \, .$$

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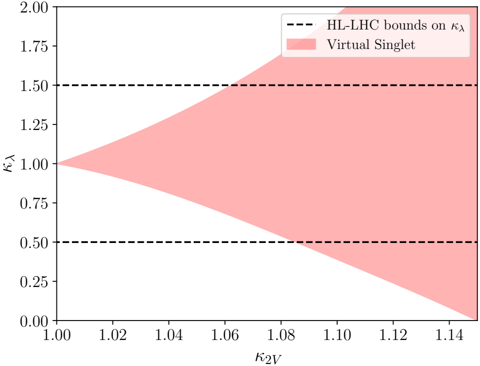

Composite Higgs Models

[Agashe et al '04, Contino et al '07]

- MCHM

$$\kappa_V = \sqrt{1-\xi}$$
$$\kappa_{2V} = 1 - 2\xi$$

$$\kappa_\lambda = \sqrt{1-\xi} \quad \text{(MCHM4)}$$
$$\kappa_\lambda = \frac{1-2\xi}{\sqrt{1-\xi}} \quad \text{(MCHM5)}$$

($\xi = \frac{v^2}{f^2}$, $\xi \to -\xi$,
sin $\to$ sinh for hyperbolic)

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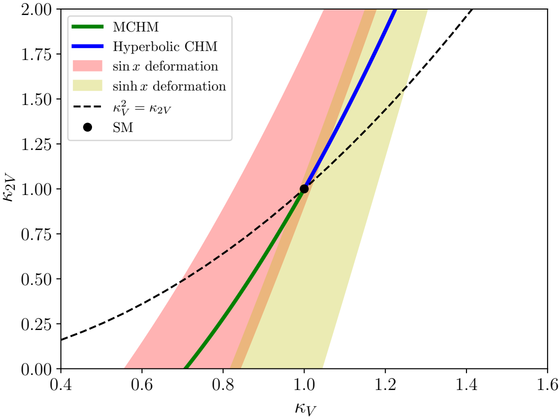

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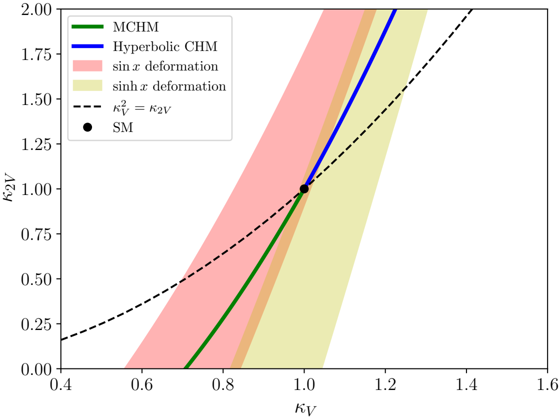

- All custodial G/H models with compact G have $1-\kappa_V^2, \kappa_V^2 - \kappa_{2V} \geq 0$.

[Alonso, West '21]

Composite Higgs-Dilaton Mixing

$$\mathcal{L} = \frac{g_W^2 f^2}{4} W^+ W^- \left(\frac{\chi}{\langle \chi \rangle} \right)^2 \sin^2 \left(\frac{h}{f} \right) - \left(\frac{\chi}{\langle \chi \rangle} \right)^4 V_{\text{MCHM}} \left(\frac{h}{f} \right) .$$

[Brugisser et al '22, Goldberger et al '07]

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$$\kappa_V \approx \kappa_V^{\text{MCHM}} c_\phi - s_\phi \sqrt{\zeta}$$
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$$\kappa_\lambda \approx \kappa_\lambda^{\text{MCHM}} c_\phi^3 - 4 c_\phi^2 s_\phi \sqrt{\zeta}$$

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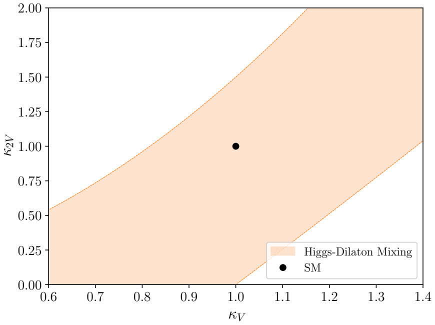
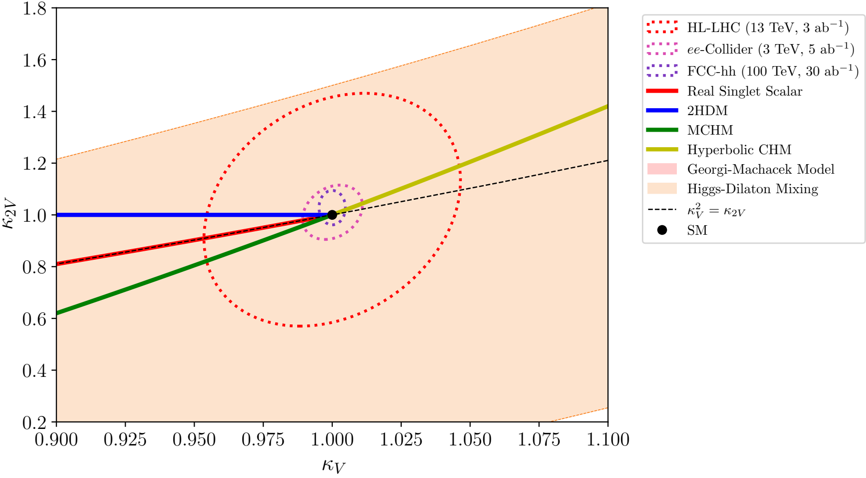


Results



1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
κ_{2V}
0.900
0.925
0.950
0.975
1.000
1.025
1.050
1.075
1.100
κ_V
HL-LHC (13 TeV, 3 ab^{-1})
ee-Collider (3 TeV, 5 ab^{-1})
FCC-hh (100 TeV, 30 ab^{-1})
Real Singlet Scalar
2HDM
MCHM
Hyperbolic CHM
Georgi-Machacek Model
Higgs-Dilaton Mixing
$\kappa_V^2 = \kappa_{2V}$
SM

Thank You

Questions?