Charting Higgs Self-Coupling Limits

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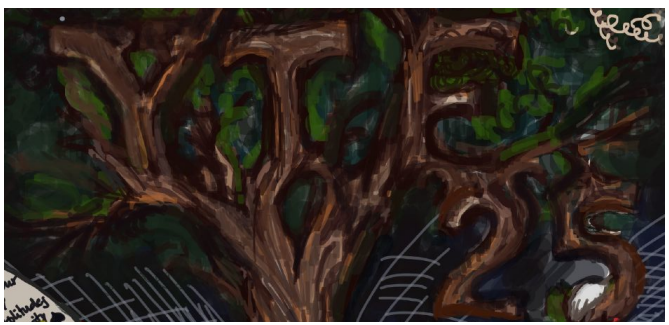

Motivation

The Higgs self-coupling is the last unconstrained parameter in the SM → promising avenue into new physics

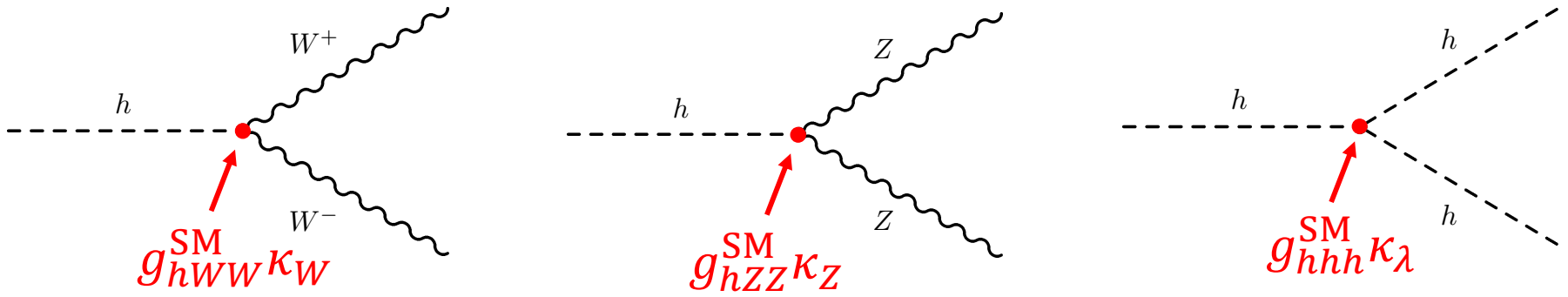

Table: Approximate 2σ bounds on κ_V and κ_λ

	Sensitivity to κ_V	Sensitivity to κ_λ	
Current	10%	$\mathcal{O}(100\%)$	[S Navas *et al.* '24]
HL-LHC	1%	$\lesssim 30\%$	[ATLAS, CMS '25]
FCC-hh	0.1%	$\lesssim 5\%$	[E Gallo *et al.* '25]

How large can the deviation in κ_λ be for a given BSM model given the tight experimental constraints on κ_V?

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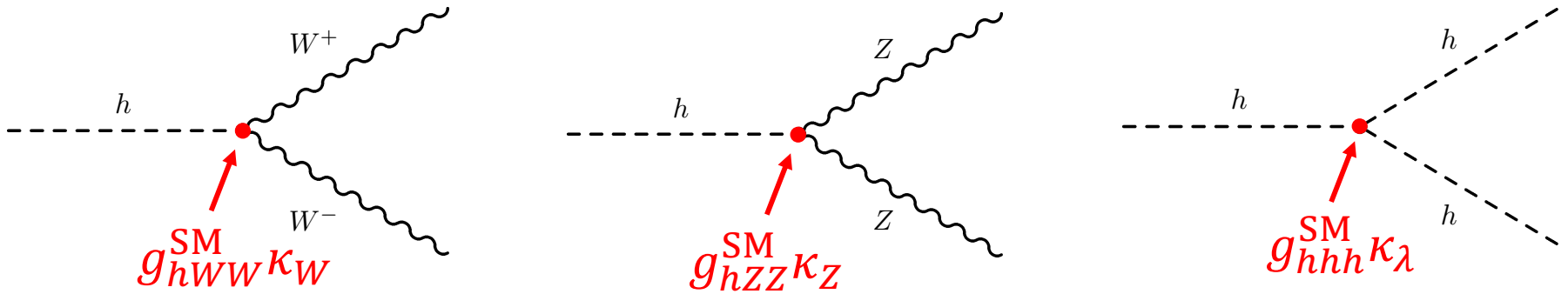

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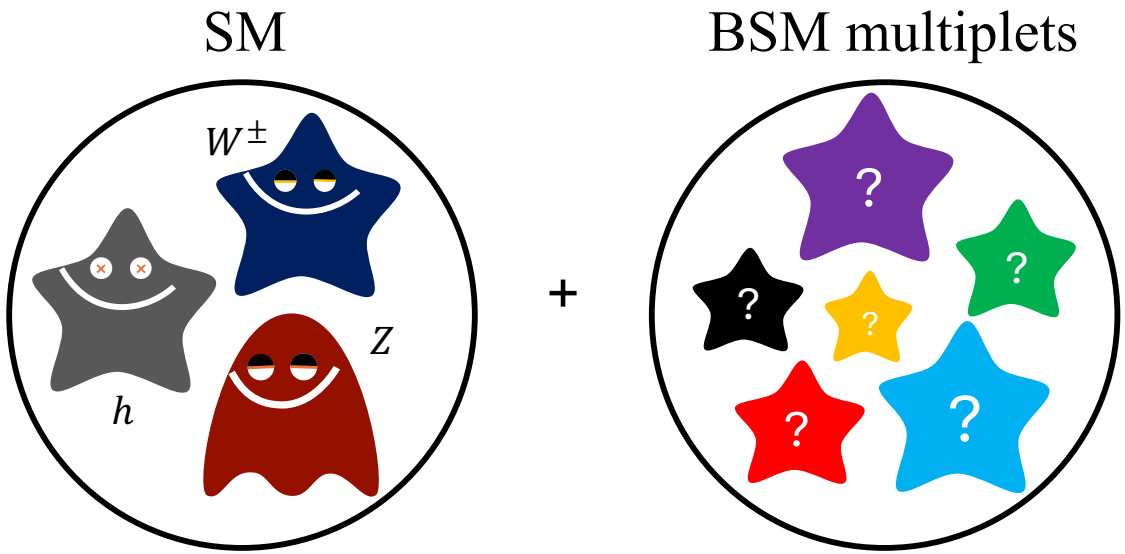
Extended Scalar Sectors



The neutral parts of the BSM electroweak multiplets mix with the SM Higgs doublet to yield the 125 GeV Higgs boson and other BSM particles.

- In the simplest case, one real scalar singlet is added to the SM

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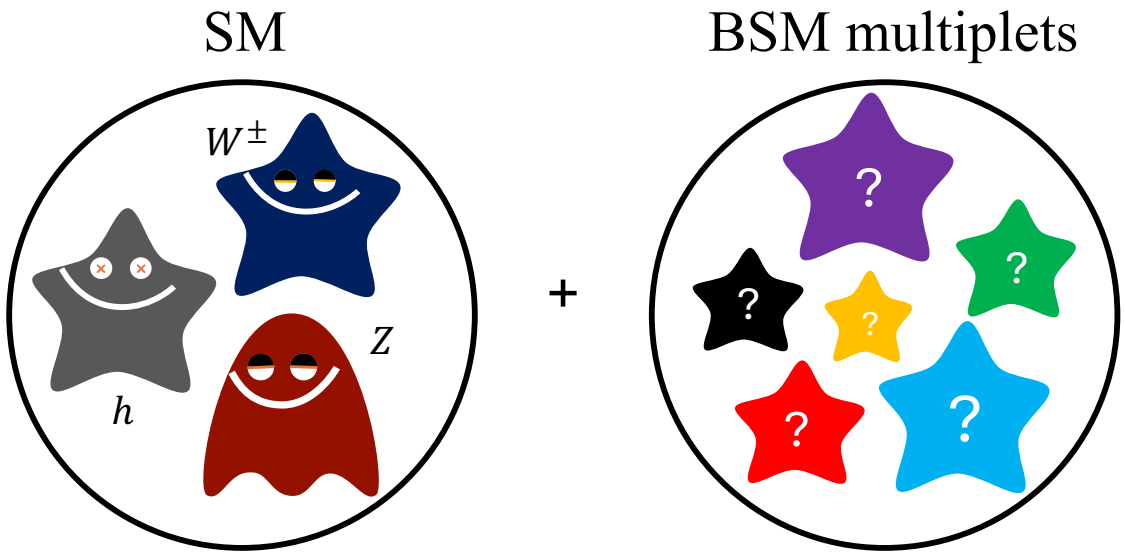

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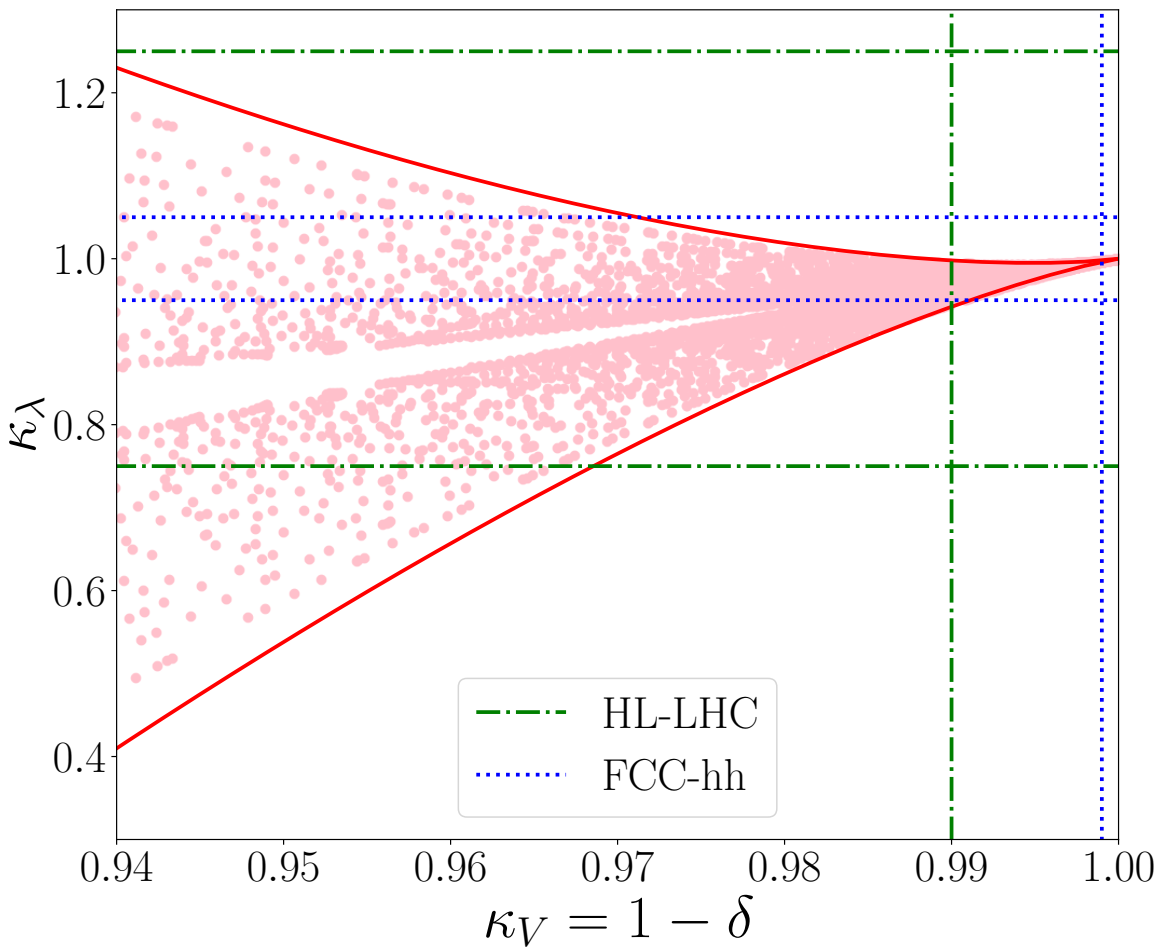
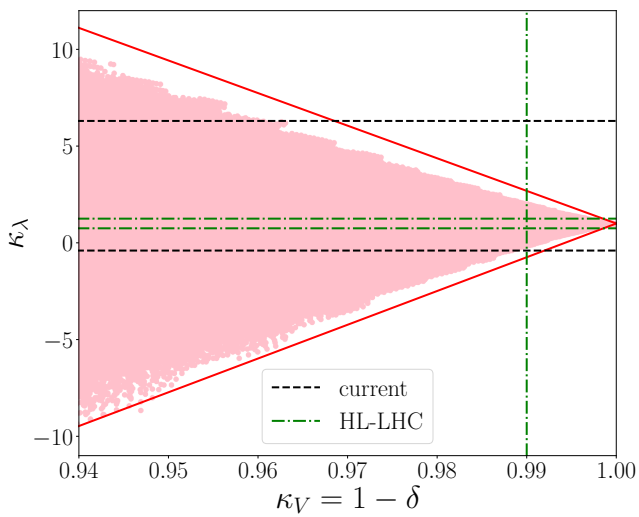
$\mathbb{Z}_2$-Symmetric Higgs + Singlet Model

$$\kappa_\lambda = 1 - 3\delta - P\frac{v\lambda_S^{\frac{1}{2}}(2\delta)^{\frac{3}{2}}}{|m_{\varphi_2}|} + \mathcal{O}(\delta^2)$$



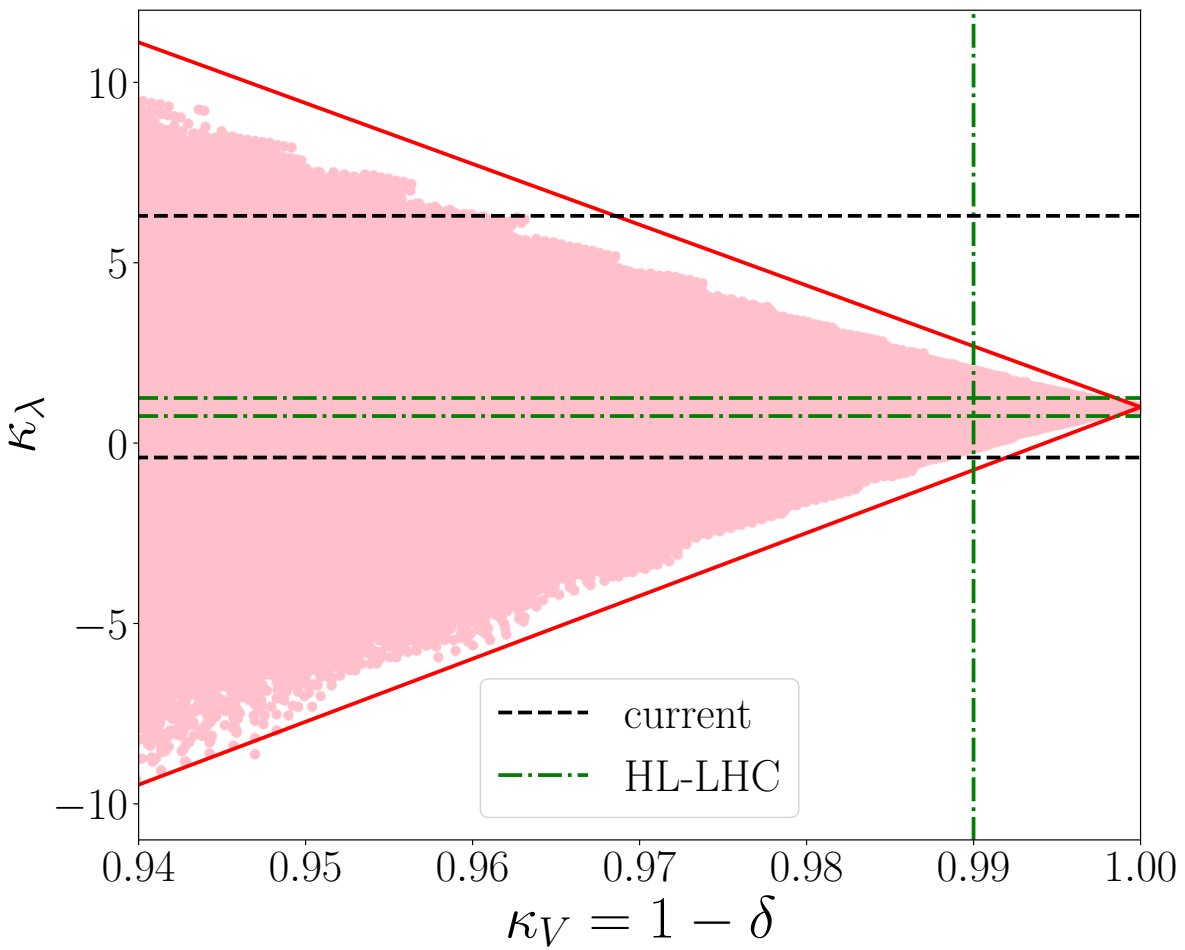
Constraints:

- Vacuum stability
- Unitarity
- Heavy singlet



Explicit $\mathbb{Z}_2$-Breaking Higgs + Singlet Model

$$\kappa_\lambda = 1 - 3\delta - \frac{\xi \lambda_S^{\frac{1}{2}} v^2 (2\delta)}{m_{\varphi_1}^2 |m_{\varphi_2}|} + \mathcal{O}\left(\delta^{\frac{3}{2}}\right)$$



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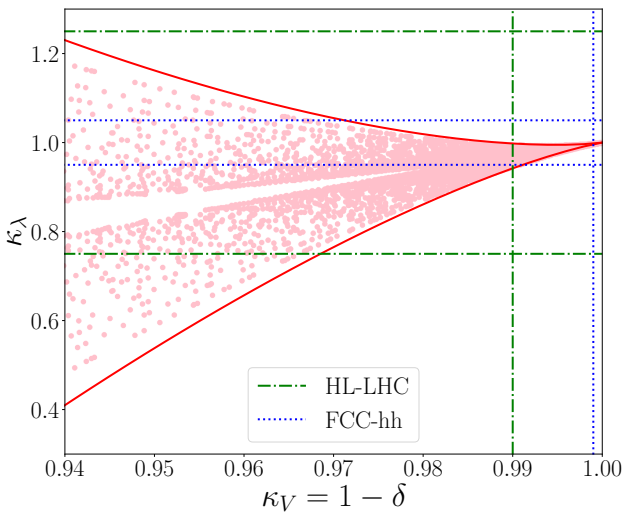
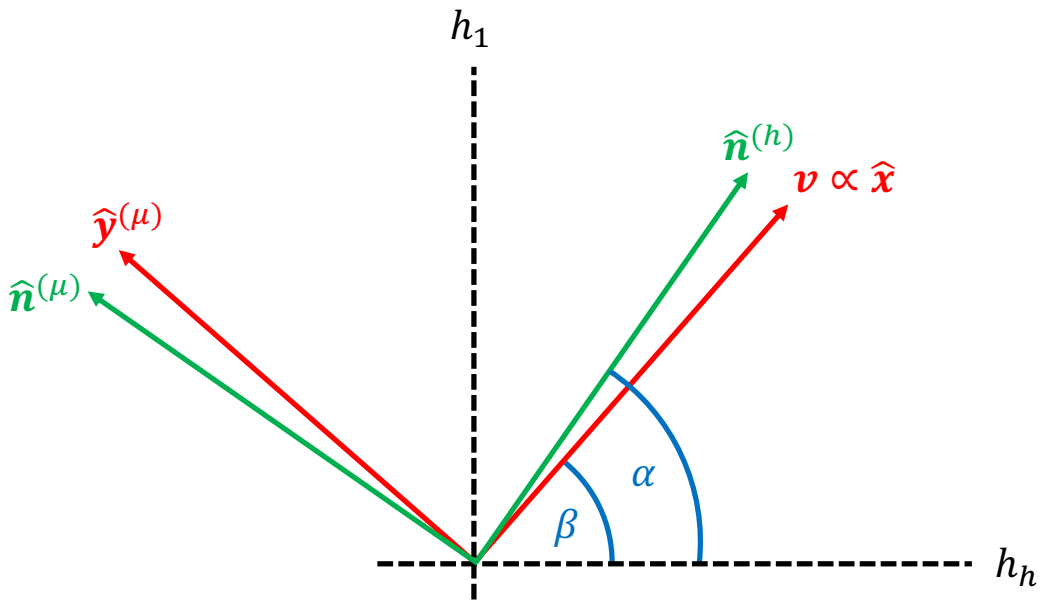


General Model

Turn on neutral part of each added multiplet.

$$\Phi = \begin{pmatrix} \vdots \\ 0 \\ \frac{1}{\sqrt{2}}(v_R + h_R) + \frac{i}{\sqrt{2}}(v_I + h_I) \\ 0 \\ \vdots \end{pmatrix} \qquad \boldsymbol{v} = \begin{pmatrix} v_h \\ v_1 \\ v_2 \\ \vdots \end{pmatrix} \qquad \boldsymbol{h} = \begin{pmatrix} h_h \\ h_1 \\ h_2 \\ \vdots \end{pmatrix}$$

We want to find expressions for κ_V, κ_λ close to the alignment limit, where $\boldsymbol{v} \underset{\sim}{\propto} \hat{\boldsymbol{n}}^{(h)}$ and α, β small.



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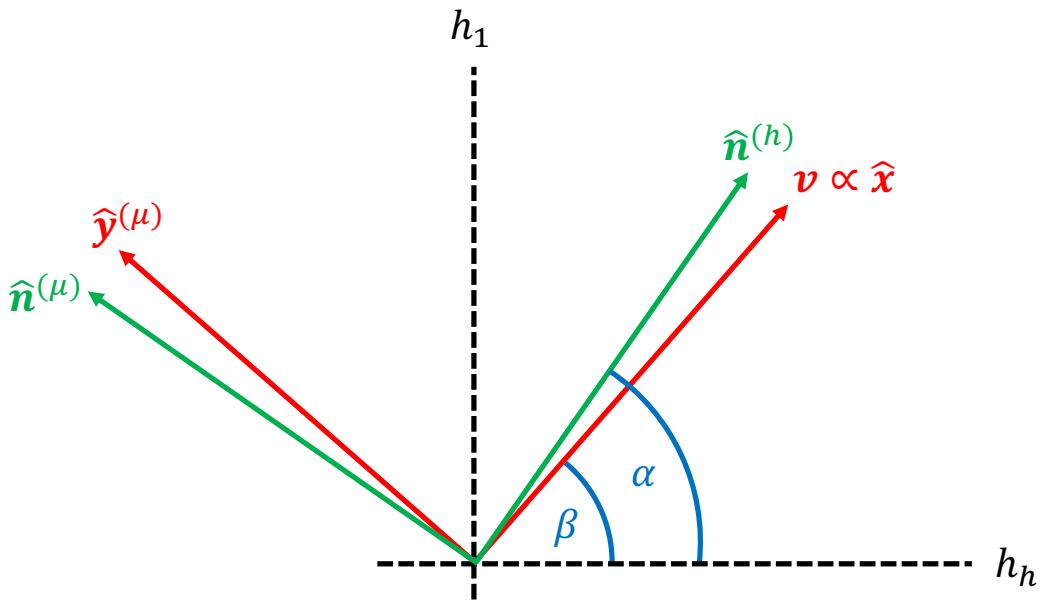

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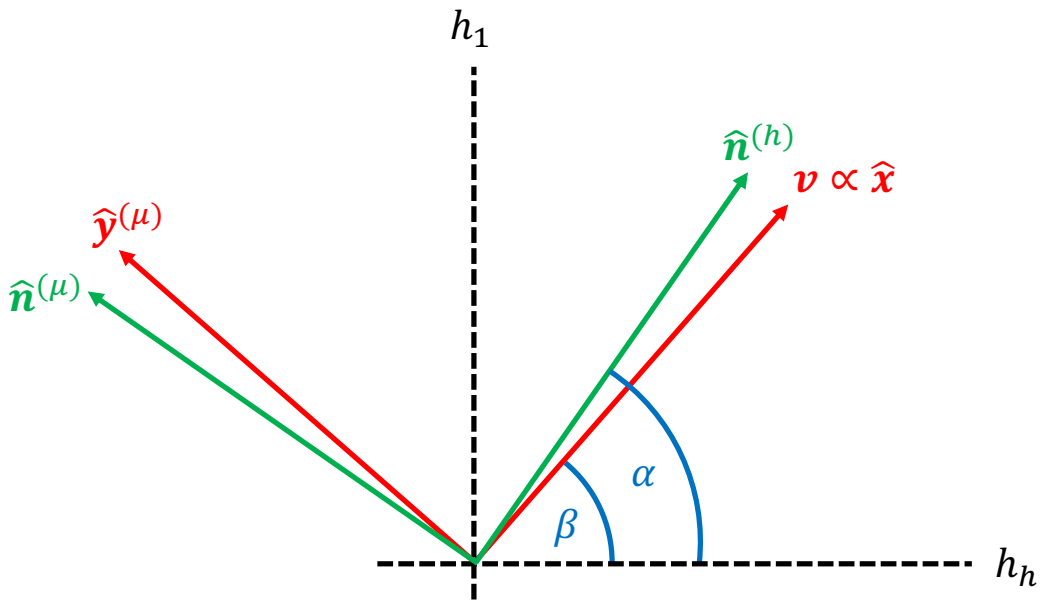

Results and Outlook

Model-independent expressions for the ρ parameter and the single-Higgs weak gauge coupling modifiers:

$$\rho = \frac{\left(m_Z^{\mathrm{BSM}}\right)^2}{\left(m_Z^{\mathrm{SM}}\right)^2} = \frac{\boldsymbol{v}\cdot\boldsymbol{P}\cdot\boldsymbol{v}}{\boldsymbol{v}\cdot\boldsymbol{C}\cdot\boldsymbol{v}} \quad \kappa_W = \frac{\boldsymbol{v}\cdot\boldsymbol{C}\cdot\hat{\boldsymbol{n}}^{(h)}}{\left(\boldsymbol{v}\cdot\boldsymbol{C}\cdot\boldsymbol{v}\right)^{\frac{1}{2}}} \quad \kappa_Z = \frac{\boldsymbol{v}\cdot\boldsymbol{P}\cdot\hat{\boldsymbol{n}}^{(h)}}{\left(\boldsymbol{v}\cdot\boldsymbol{C}\cdot\boldsymbol{v}\right)^{\frac{1}{2}}}$$

- Can we find a model-independent expression for κ_λ close to the alignment limit?
- Can our framework predict subclasses of extended scalar models in which κ_λ is significantly enhanced wrt κ_V?

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Thank you for your attention!
Any questions?