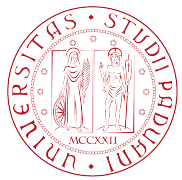
CP-odd Sigma Decomposition

Ignacio Miguel Hierro Rodríguez

Università degli Studi di Padova
Dipartimento di Fisica e Astronomia "Galileo Galilei"
INFN Sezione di Padova

work in collaboration with L.Merlo and S.Rigolin

Invisibles Workshop '15



Composite Higgs

Hierarchy Problem

m_H^2 is sensitive to quantum corrections in the presence of NP.

Possible solution: Composite Higgs

- Higgs scalar as a pNGB of a global breaking $\mathcal{G} \to \mathcal{H}$.
- pNGB nature protects m_H^2.
- $\mathcal{G}$ broken by strong dynamics at $\Lambda_s > f \gg v$.

Low-energy chiral Lagrangian

- Dynamical Higgs $\Longrightarrow$ low-energy effects described by chiral EFT.
- CP violating $\mathcal{L}_{low}$ in terms of SM GB's and arbitrary $\mathcal{F}_i(h)$.

$$\mathcal{L}_{low,CPV} = S_{BB*}\mathcal{F}_{BB*}(h) + S_{WW*}\mathcal{F}_{WW*}(h) + \sum_i c_i S_i \mathcal{F}_i(h)$$

Some operators

$$S_{BB*} = -\frac{1}{4}\epsilon^{\mu\nu\rho\sigma} B_{\mu\nu} B_{\rho\sigma}$$

$$S_{WW*} = -\frac{1}{2}\epsilon^{\mu\nu\rho\sigma} \mathrm{Tr}\left(W_{\mu\nu} W_{\rho\sigma}\right)$$

$$S_1 = 2gg'\epsilon^{\mu\nu\rho\sigma} B_{\mu\nu} \mathrm{Tr}\left(T W_{\rho\sigma}\right)$$

$$S_2 = 2ig'\epsilon^{\mu\nu\rho\sigma} B_{\mu\nu} \mathrm{Tr}\left(T V_{\rho}\right) \partial_\sigma\left(h/v\right)$$

$$S_3 = 2ig\epsilon^{\mu\nu\rho\sigma} \mathrm{Tr}\left(W_{\mu\nu} V_{\rho}\right) \partial_\sigma\left(h/v\right)$$

Building blocks

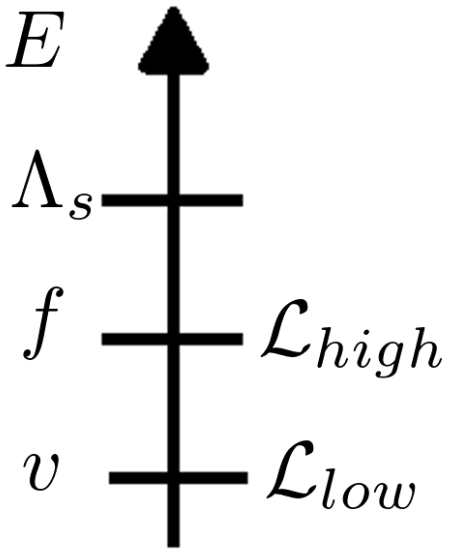
$$U(x) = e^{i\sigma_a \pi^a(x)/v}$$

$$T = U\sigma_3 U^\dagger$$

$$V_\mu = \left(D_\mu U\right) U^\dagger$$

Objective

- Write most general $\mathcal{L}_{high}$ for an arbitrary $\mathcal{G}/\mathcal{H}$.
- Study its projection to $\mathcal{L}_{low}$ in different CH models.



$$\xi = \frac{v^2}{f^2} \ll 1$$

High-energy chiral Lagrangian

- pNGB parametrized by $\Sigma(x) = e^{i\Xi(x)/f}$.
- CP violating $\mathcal{L}_{high}$ (gauging only G_{SM})

$$\mathcal{L}_{high,CPV} = \tilde{c}_{WW*}\tilde{\mathcal{B}}_{WW*} + \tilde{c}_{B\Sigma}\tilde{\mathcal{B}}_{B\Sigma} + \tilde{c}_{W\Sigma}\tilde{\mathcal{B}}_{W\Sigma} + \tilde{c}_1\tilde{\mathcal{B}}_1 + \tilde{c}_2\tilde{\mathcal{B}}_2$$

Independent basis

$$\tilde{\mathcal{B}}_{WW*} = g^2\epsilon^{\mu\nu\rho\sigma}\mathrm{Tr}\left(\tilde{W}_{\mu\nu}\tilde{W}_{\rho\sigma}\right)$$

$$\tilde{\mathcal{B}}_{B\Sigma} = g'^2\epsilon^{\mu\nu\rho\sigma}\mathrm{Tr}\left(\Sigma\tilde{B}_{\mu\nu}\Sigma^{-1}\tilde{B}_{\rho\sigma}\right)$$

$$\tilde{\mathcal{B}}_{W\Sigma} = g^2\epsilon^{\mu\nu\rho\sigma}\mathrm{Tr}\left(\Sigma\tilde{W}_{\mu\nu}\Sigma^{-1}\tilde{W}_{\rho\sigma}\right)$$

$$\tilde{\mathcal{B}}_1 = gg'\epsilon^{\mu\nu\rho\sigma}\mathrm{Tr}\left(\Sigma\tilde{B}_{\mu\nu}\Sigma^{-1}\tilde{W}_{\rho\sigma}\right)$$

$$\tilde{\mathcal{B}}_2 = \epsilon^{\mu\nu\rho\sigma}\mathrm{Tr}\left(\tilde{V}_\mu\tilde{V}_\nu\tilde{V}_\rho\tilde{V}_\sigma\right)$$

Building blocks

$$\tilde{V}_\mu = (D_\mu\Sigma)\,\Sigma^\dagger$$

$$\tilde{\mathcal{B}}_{\mu\nu}, \Sigma\tilde{\mathcal{B}}_{\mu\nu}\Sigma^{-1}$$

$$\tilde{W}_{\mu\nu}, \Sigma\tilde{W}_{\mu\nu}\Sigma^{-1}$$

Projections

- Example of decomposition to $\mathcal{L}_{low}$ in two particular models.

$c_i\mathcal{F}_i(h)$	$SU(5)/SO(5)$ $SO(5)/SO(4)$
$\mathcal{F}_{BB*}(h)$	$8g'^2\tilde{c}_{B\Sigma}\cos^2\left(\frac{\varphi}{2f}\right)$
$\mathcal{F}_{WW*}(h)$	$g^2\left(\tilde{c}_{WW*}+8\tilde{c}_{W\Sigma}\cos^2\left(\frac{\varphi}{2f}\right)\right)$
$c_1\mathcal{F}_1(h)$	$\frac{\tilde{c}_1}{2}\sin^2\left(\frac{\varphi}{2f}\right)$

Summary

- Lagrangian for generic CH models involving gauge bosons and pNGBs.
- Study low-energy effects through an EFT approach.
- Comparison among predictions of different models.

Thank you!

¡Muchas gracias!