Grant report on Higgs Effective Field Theory for the LHC

Congreso IPARCOS 2023
Universidad Complutense de Madrid

From our statute “Regulation of UCM Centers and Structures”

37.2.i (departments), 61.1.h (institutes)
Among the institutional duties are
(...) conocer las actividades y proyectos de investigación de los miembros del mismo.

Grant report on Higgs effective field theory for the LHC

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Juan J. Sanz Cillero

\+ Felipe J. Llanes Estrada (research team)

Grant number ID2019-108655GB- I00 MICINN
2020-2023 (Completed)

Students and collaborators

Directly worked on the HEFT 4 LHC research line:

Carlos Quezada Calonge (ongoing PhD student)

Alexandre Salas Bernárdez (doctorate 2023)

Javier Martínez Martín (ongoing PhD student)

Worked with us on other research lines

Eva Lope Oter (doctorate 2023)

Adrián Casado Turrión (doctorate 2023)

Clara Álvarez Luna (doctorate 2023)

Juan J. Gálvez Viruet (ongoing PhD student)

Msc students:

Adriana Bariego, Pablo Navarro

Students and collaborators

Here some external collaborations last year

Raquel Gómez Ambrosio (INFN Turín) and Rafael Delgado (UPM)

Sally Dawson (Stony Brook) and Duarte Fontes (Brookhaven)

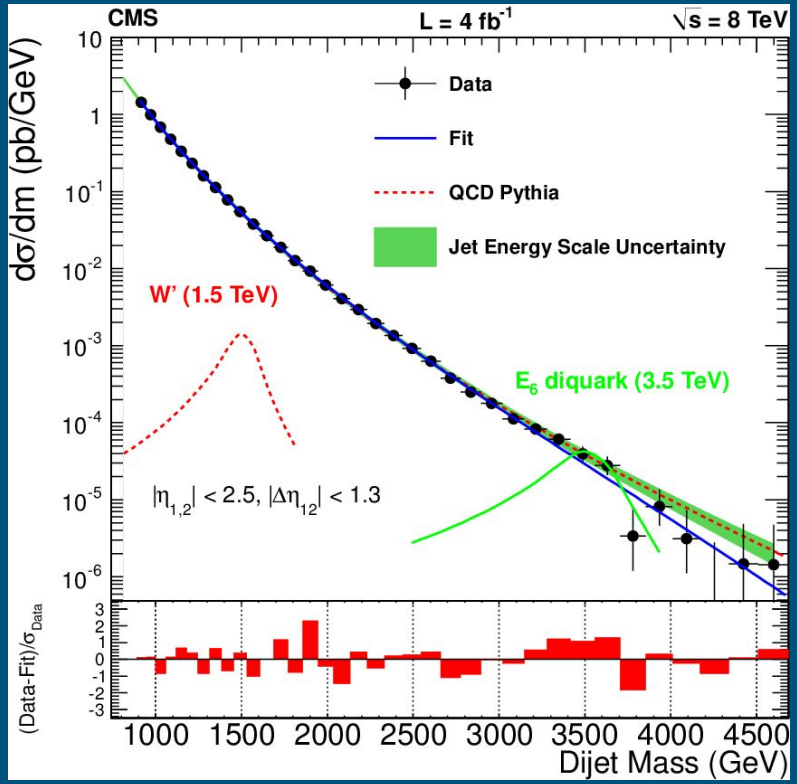
Reinhard Alkofer (Graz)

Toni Pich (UV) and Ignasi Rosell (Cardenal Herrera)

Álvaro de la Cruz Dombriz (USAL)

Víctor González Sebastián (Wayne State) and Noe Demazure (ENS Lyon)

No new particles?



New physics? 600 GeV

GAP

H (125.9 GeV, PDG 2013)

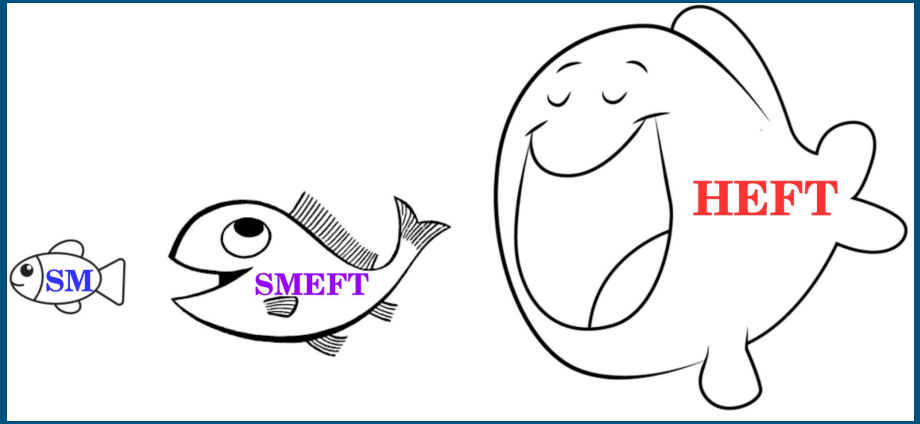
W (80.4 GeV), Z (91.2 GeV)

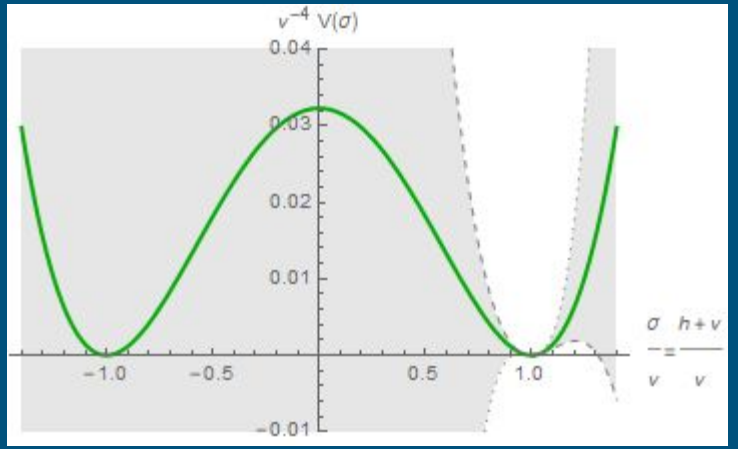
Let's look for new forces!

All you always wanted to know about…

The right effective theory to modify the

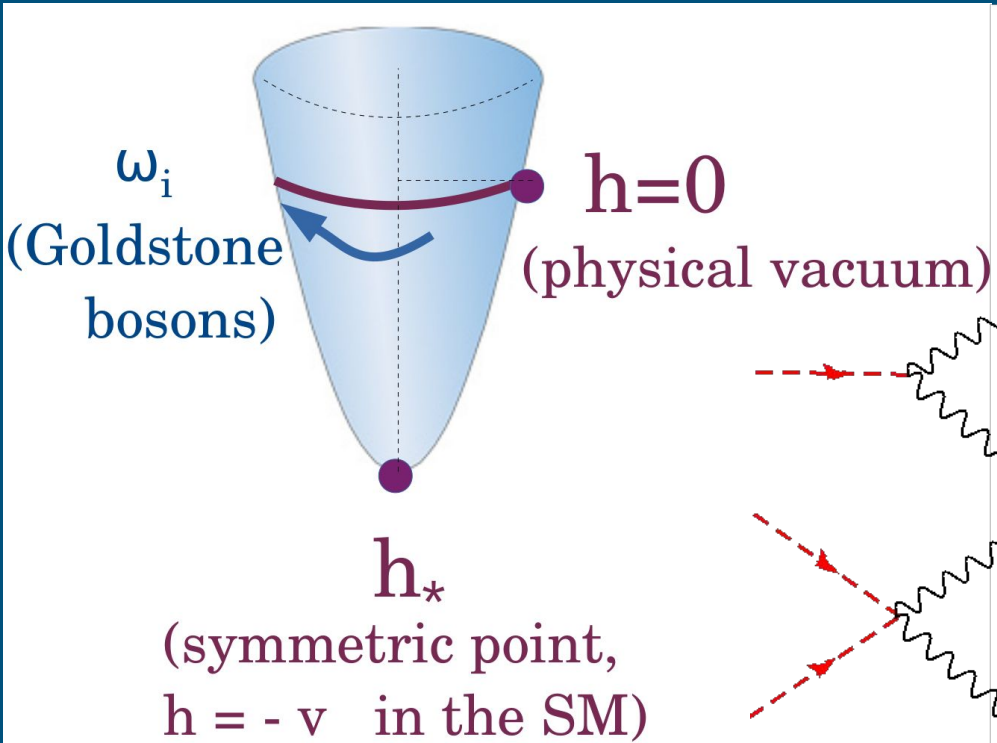
Standard Model, SMEFT vs. HEFT

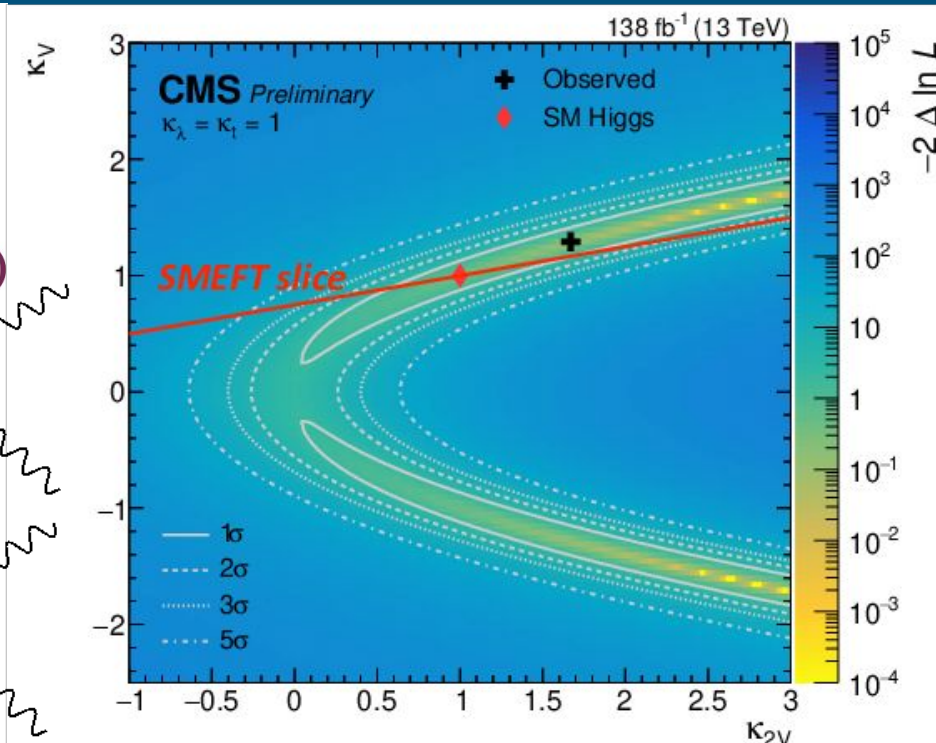




Knowledge on the Higgs potential

SMEFT vs. HEFT





SMEFT vs. HEFT

$$
\begin{aligned}
|H|^2 &= \frac{(v+h)^2}{2}\,, \\
(\partial|H|^2)^2 &= (v+h)^2\,(\partial h)^2 \;=\; 2|H|^2\,(\partial h)^2\,.
\end{aligned}
$$

$$
\mathcal{L}_{\rm SMEFT} \;=\; \underbrace{|\partial H|^2}_{=\mathcal{L}_{SM}} \;+\; \underbrace{\frac{1}{2}\left[\left(\frac{1}{v}(F^{-1})'[\sqrt{2|H|^2/v^2}]\right)^2 \;-\; 1\right]\frac{(\partial|H|^2)^2}{2|H|^2}}_{=\Delta\mathcal{L}_{BSM}}\,.
$$

All you always wanted to know about...
Top loops in WW scattering

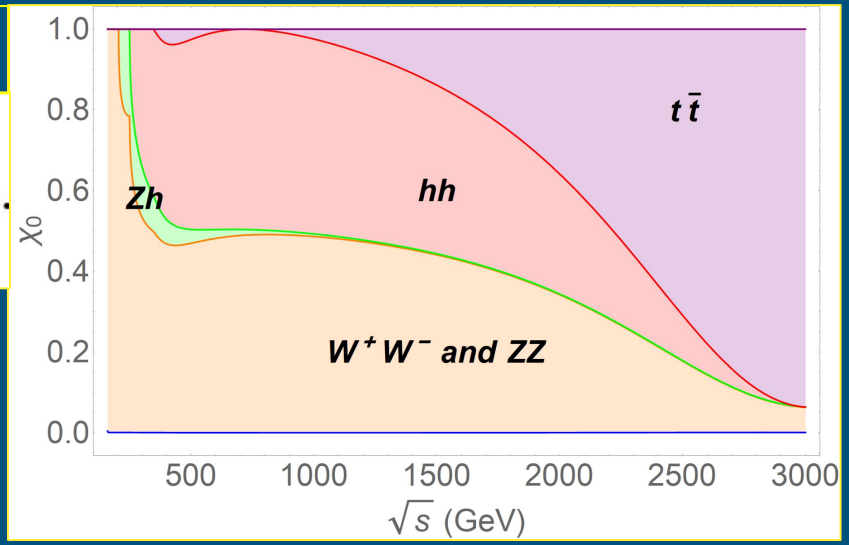
-Boson contributions proportional to $\mathcal{O}(s^2/v^4)$

-Fermion contributions proportional to $\mathcal{O}(M_{\rm Fer}^2 s/v^4)$

HEFT ⟹ new interactions

Relevance of fermions vs bosons quantified by

$$R_J = \frac{\mathrm{Fer}_J}{\mathrm{Bos}_J + \mathrm{Fer}_J}$$



Example HEFT coefficients yielding large fermion contributions: a=1.008, b=1.035, c1=1.100, d3=0.900

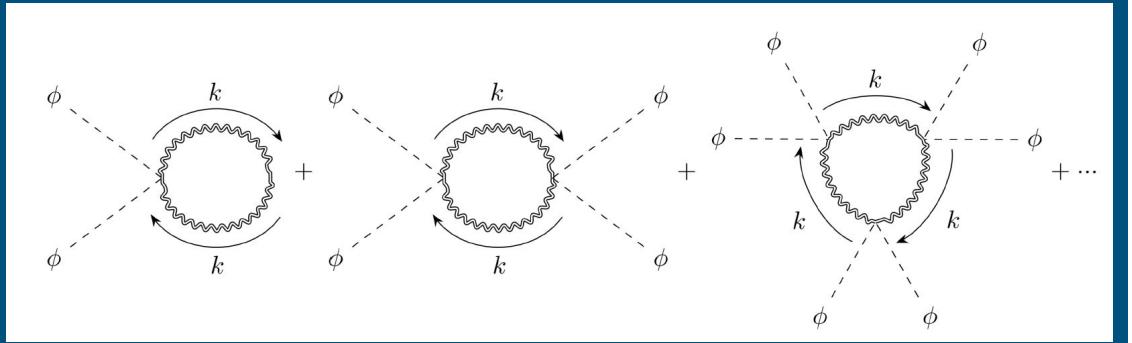
All you always wanted to know about…
Coleman-Weinberg mechanism applied to gravity

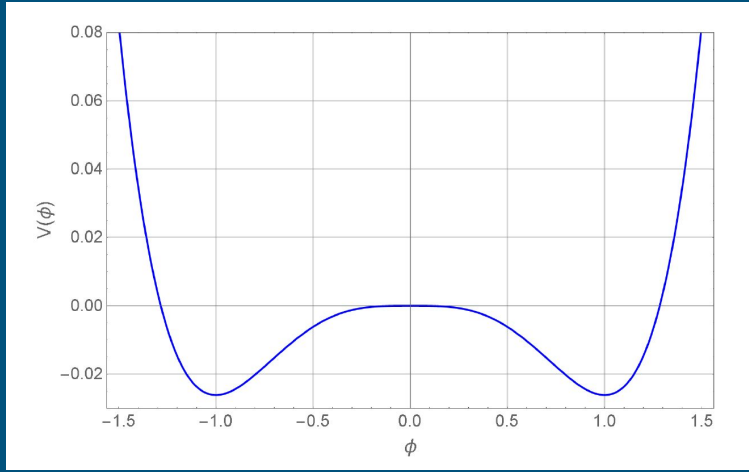
$$\sqrt{|\det g|}\,\mathcal{L} = \sqrt{|\det g|}\left[\frac{1}{2}(\partial_\mu\phi_1)^2 + \frac{1}{2}(\partial_\mu\phi_2)^2 - V_0(\phi_1,\phi_2) + \frac{R^2}{6f_0^2} + \frac{\frac{1}{3}R^2 - R_{\mu\nu}^2}{f_2^2} - \frac{1}{2}R(\xi_1\phi_1^2 + \xi_2\phi_2^2)\right]$$

$$V_0(\phi_1,\phi_2) = \frac{1}{4!}\left(\lambda_{11}\phi_1^4 + \lambda_{22}\phi_2^4 + 2\lambda_{12}\phi_1^2\phi_2^2\right)$$

$\langle\phi\rangle \to M_{Pl}^2$

Renormalization magic: scaleless L + quantization scale





Zero-point energy of graviton field affects the scalar

2023 Publications

5 Physical Review D

1 Annals of Physics (NY)

1 Journal of High Energy Physics

1 Few Body Systems

1 Nuclear Physics A

1 Communications in Theoretical Physics

Total: 10 refereed papers

\+ 4 published proceedings, + 4 preprints under refereeing (pipeline for 2024)

Ongoing work

Multiquark states (FLE + Clara Peset+students): Hartree-Fock up to 6t 6t̲

Constrain EFT parameters involving tops?

Juan J. Sanz Cillero continues (with Sally Dawson and Duarte Fontes) pursuing 2DHM (an extra Higgs doublet)
+ matching BSM high-energy theories to a low energy EFT.

We are always interested in any sort of new resonances and unitarization.

New MICINN grant: ~ level of funding 20 k€/year

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