UNIVERSIDAD DE ANTIOQUIA
Facultad de Ciencias Exactas y Naturales

UNIVERSITÄT BONN

Effective models for two-component scalar dark matter with Z_{2n} symmetries

Simón González Gómez[1,2] Diego Restrepo Quintero[2] Amalia Betancur Rodríguez[3]

May 10, 2026

[1]Universität Bonn, [2]Universidad de Antioquia, [3]Universidad EIA

EFTs in a nutshell

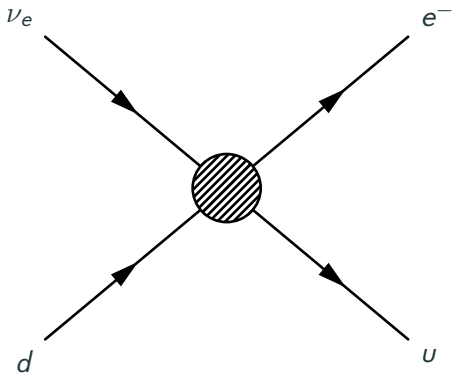
$$\mathcal{L} = \frac{1}{2}(\partial_\mu \phi)(\partial^\mu \phi) - \frac{1}{2}m^2\phi - \frac{\lambda}{4!}\phi^4$$

EFTs in a nutshell

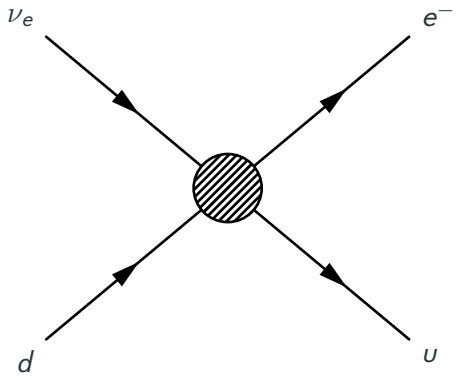
$$\mathcal{L} = \frac{1}{2}(\partial_\mu \phi)(\partial^\mu \phi) - \frac{1}{2}m^2\phi - \frac{\lambda}{4!}\phi^4$$

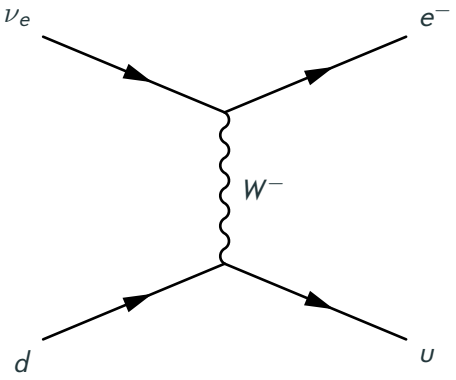
$$\mathcal{L} = \mathcal{L}_{\text{renorm}} + \sum_i \frac{C_i}{\Lambda^{n-4}}\mathcal{O}_i$$

Fermi theory: a prototype

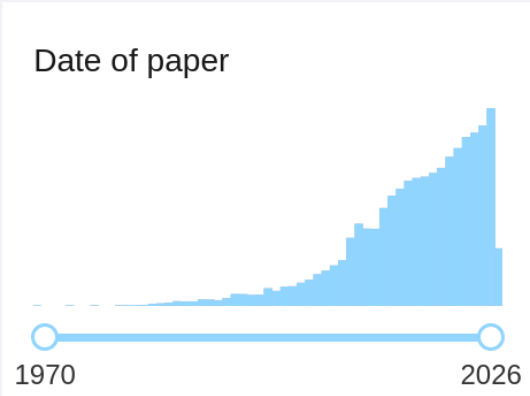


Fermi theory: a prototype

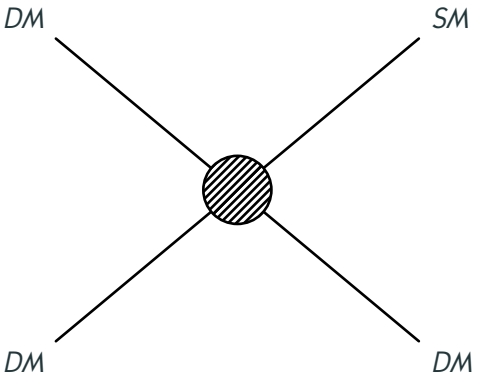




Why for DM



Why for DM



It takes two to tango

Multi-component DM

It takes two to tango

Multi-component DM

Why not?

New interactions

Complex ϕ_A and real ϕ_B with Z_{2n}:

$$\mathcal{V}_1 = \mu_A^2|\phi_A|^2 + \frac{1}{2}\mu_B^2\phi_B^2 + \lambda_{4AB}|\phi_A|^2\phi_B^2 + \lambda_{SA}|H|^2|\phi_A|^2 + \frac{1}{2}\lambda_{SB}|H|^2\phi_B^2$$

Complex ϕ_A and real ϕ_B with Z_{2n}:

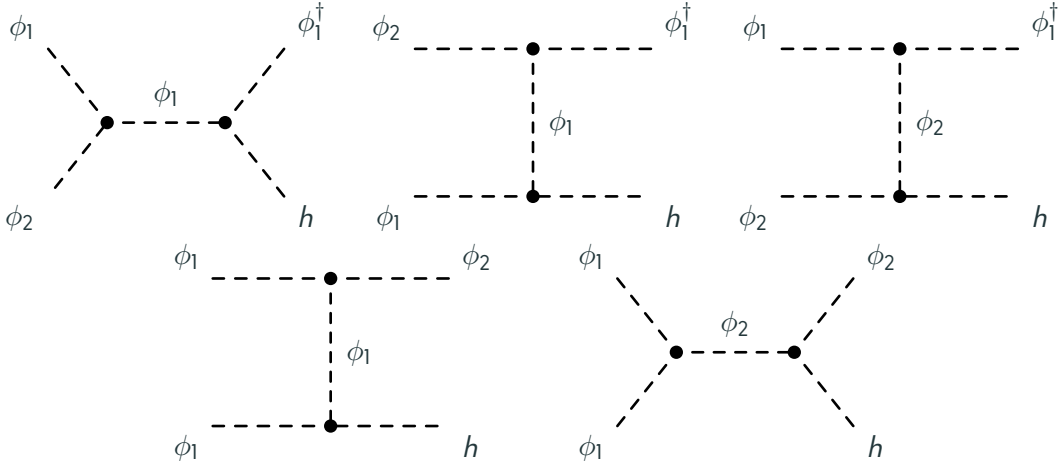
$$\mathcal{V}_1 = \mu_A^2|\phi_A|^2 + \frac{1}{2}\mu_B^2\phi_B^2 + \lambda_{4AB}|\phi_A|^2\phi_B^2 + \lambda_{SA}|H|^2|\phi_A|^2 + \frac{1}{2}\lambda_{SB}|H|^2\phi_B^2$$

For Z_4:

$$\mathcal{V}_2 = \frac{1}{2}\left[\mu_{S1}\phi_1^2\phi_2 + \lambda_{51}\phi_1^4\right] + \text{h.c.}$$

[3]

Semi-annihilations



An EFT extension

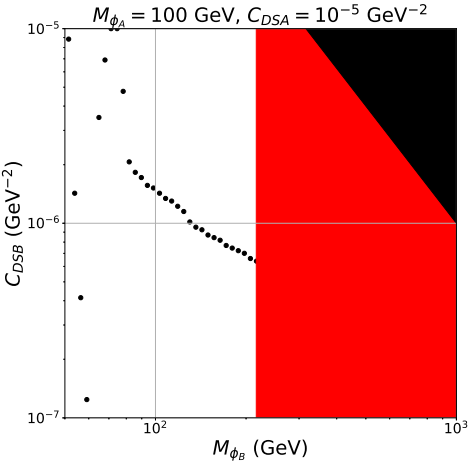
$$\mathcal{V}_1^{\text{Eff}}(\phi_A, \phi_B) = C_{6AB1}|\phi_A|^4\phi_B^2 + C_{6AB2}|\phi_A|^2\phi_B^4 + C_{S4A}|H|^4|\phi_A|^2 + C_{S2A}|H|^2|\phi_A|^4 + C_{S4B}|H|^4\phi_B^2 + C_{S2B}|H|^2\phi_B^4 + C_{6SAB}|H|^2|\phi_A|^2\phi_B^2$$

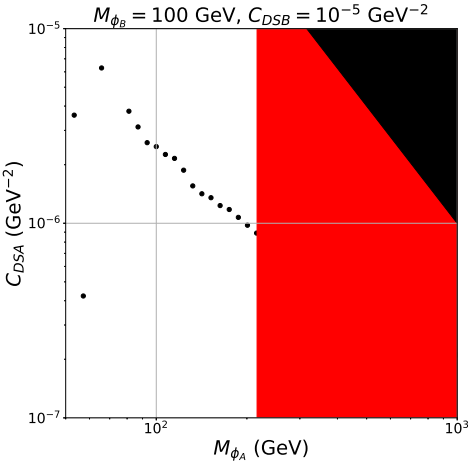
An EFT extension

$$\mathcal{V}_1^{\text{Eff}}(\phi_A, \phi_B) = C_{6AB1}|\phi_A|^4\phi_B^2 + C_{6AB2}|\phi_A|^2\phi_B^4 + C_{S4A}|H|^4|\phi_A|^2 + C_{S2A}|H|^2|\phi_A|^4 + C_{S4B}|H|^4\phi_B^2 + C_{S2B}|H|^2\phi_B^4 + C_{6SAB}|H|^2|\phi_A|^2\phi_B^2$$

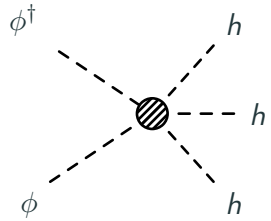
$$\mathcal{V}_D^{\text{Eff}}(\phi_A, \phi_B) = C_{DSA1}\left(H^\dagger\partial^\mu H\right)\left(\phi_A^\dagger\partial_\mu\phi_A\right) + C_{DSA2}\left(\partial^\mu H\right)^\dagger H\left(\partial_\mu\phi_A\right)^\dagger\phi_A + C_{DSB}\left(H^\dagger\partial^\mu H\right)\left(\phi_B\partial_\mu\phi_B\right) + C_{DAB}\left(\phi_A^\dagger\partial_\mu\phi_A\right)\left(\phi_B\partial_\mu\phi_B\right)$$

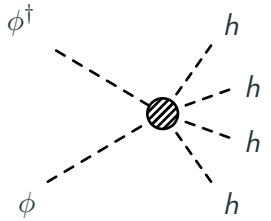
Exploring the parameter space

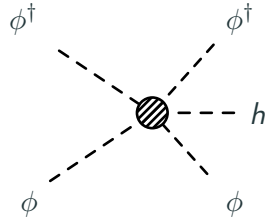


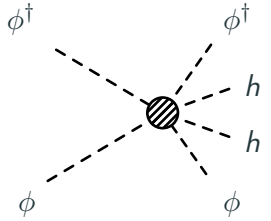


Interactions of many



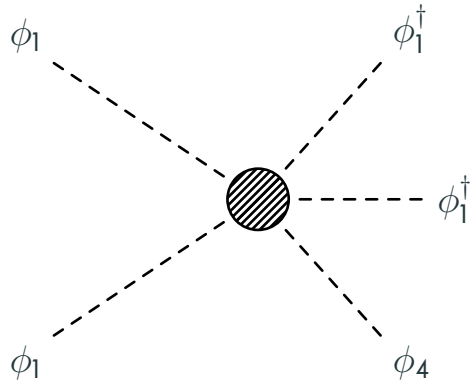






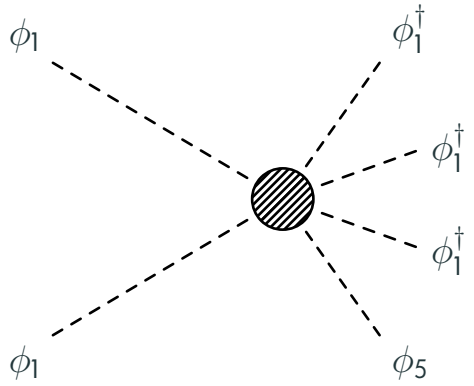
$$\mathcal{V}^{Z_8}_{\text{Eff}\,2}\left(\phi_1, \phi_4\right) = C_{E_8}\phi^4_{1/3}\phi_4 + \text{h.c.}$$

$$\mathcal{V}_{\text{Eff}\,2}^{Z_8}(\phi_1, \phi_4) = C_{E_8}\phi_{1/3}^4\phi_4 + \text{h.c.}$$



$$\mathcal{V}_{\text{Eff}\,2}^{Z_{10}}\left(\phi_1, \phi_5\right) = C_{E_{10}} \phi_{1/3}^5 \phi_5 + \text{h.c.}$$

$$\mathcal{V}_{\text{Eff}\,2}^{Z_{10}}(\phi_1, \phi_5) = C_{E_{10}} \phi_{1/3}^5 \phi_5 + \text{h.c.}$$

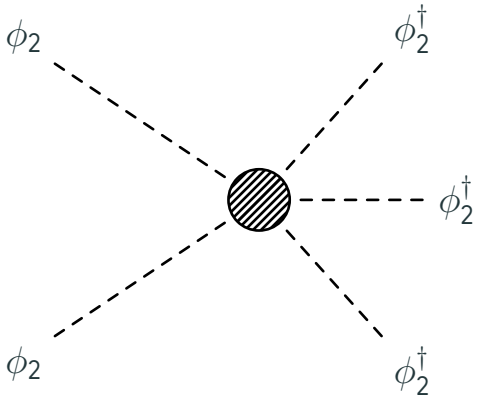


Z_{10} again

$$\mathcal{V}_{\text{Eff}\,2}^{Z_{10}}(\phi_2, \phi_5) = C'_{E_{10}} \phi_2^5 + \text{h.c.}$$

Z_{10} again

$$\mathcal{V}_{\text{Eff}\,2}^{Z_{10}}(\phi_2, \phi_5) = C'_{E_{10}} \phi_2^5 + \text{h.c.}$$



EFT + DM = interesting possibilities!

Acknowledgments

This work was part of the Joven Investigador program from the Vicerrectoría de Investigación of Universidad de Antioquia, project number 2022-54209_EXPLORANDO LAS FRONTERAS DEL MODELO ESTÁNDAR: NEUTRINOS Y MATERIA OSCURA. CENTRO DE COSTOS: 21430004, ELEMENTO PEP: CV03220102. Cto Minciencias. 2021-1080.

References

[1] Luis Álvarez-Gaumé and Miguel Á. Vázquez-Mozo. **"Lectures on Field Theory and the Standard Model: A Symmetry-Oriented Approach".** In: 2022 European School of High-Energy Physics. June 2023. arXiv: 2306.08097 [hep-th].

[2] Juan Carlos Criado et al. **"A complete effective field theory for dark matter".** In: JHEP 07 (2021), p. 081. DOI: 10.1007/JHEP07(2021)081. arXiv: 2104.14443 [hep-ph].

[3] Carlos E. Yaguna and Óscar Zapata. **"Two-component scalar dark matter in Z_{2n} scenarios".** In: JHEP 10 (2021), p. 185. DOI: 10.1007/JHEP10(2021)185. arXiv: 2106.11889 [hep-ph].

BU: Cut-Off energy of the EFT

For an effective operator of dimension D its coupling c:

$$c = \frac{1}{\Lambda^{D-4}} \Rightarrow \Lambda = c^{-1/(D-4)}$$

With E the typical energy scale of a DM process we say that the EFT breaks down at $E \sim \Lambda$. For effective operators that involve one field we take the typical energy of a DM process as $E \sim M_{DM}$:

$$M_{DM} < c^{-1/(D-4)}$$

For effective operator involving both DM fields we take the sum of the masses instead:

$$\sum M_{DM} < c^{-1/(D-4)}$$

BU: Charges under Z_{2n}

In principle for Z_8 we can have $A = 1, 2, 3$:

- $A = 2$ is analogous to $Z_4(12)$.
- $A = 1, 3$ allow the same operators up to dim 6 so we only show $Z_8(14)$ and drop the (14).

For Z_{10} it is possible to have $A = 1, 2, 3, 4$:

- $A = 1, 3$ allow the same operators up to dim 6 so we only show $Z_{10}(15)$ and drop the (15).
- $A = 2, 4$ allow for a ϕ_2^5 term.