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inVisibles

NON-LINEAR to SCALAR HIGGS PORTAL DARK MATTER

Which Higgs?

An Elementary Higgs

The electroweak symmetry breaking is **linearly** realized
At the EW scale: the linear SU(2) **doublet**

$$\Phi = \frac{1}{\sqrt{2}}(v+h)\mathbf{U}\begin{pmatrix}0\\1\end{pmatrix}$$

physical Higgs — Goldstone bosons

A Composite Higgs

The electroweak symmetry breaking is **non-linearly** realized
At the EW scale: the Higgs & the Goldstone bosons are two **independent** fields

h → Higgs treated as a **singlet** → embedded in arbitrary functions $\mathcal{F}(h) = 1 + 2a\frac{h}{v} + b\frac{h^2}{v^2} + \dots$ → couplings with different # of h legs are **decorrelated**

$\mathbf{U} = e^{i\pi^a\sigma^a/v}$ → GBs described by an **adimensional** chiral matrix → expansion in derivatives $\mathbf{V}_\mu = D_\mu\mathbf{U}\mathbf{U}^\dagger$, $\partial_\mu\mathcal{F}(h)$

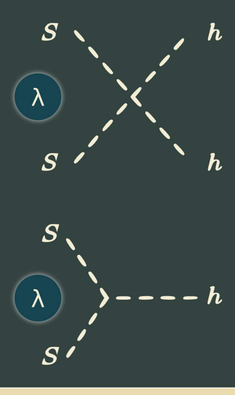
Higgs portals

Standard Higgs portals

$$\mathcal{L}_S^{\text{lin}} = \frac{1}{2}\partial_\mu S\partial^\mu S - V(S) - \lambda_{Sh}S^2\Phi^\dagger\Phi$$

Scalar Singlet DM candidate: S

The $\mathbb{Z}_2$ symmetry S → -S makes S stable

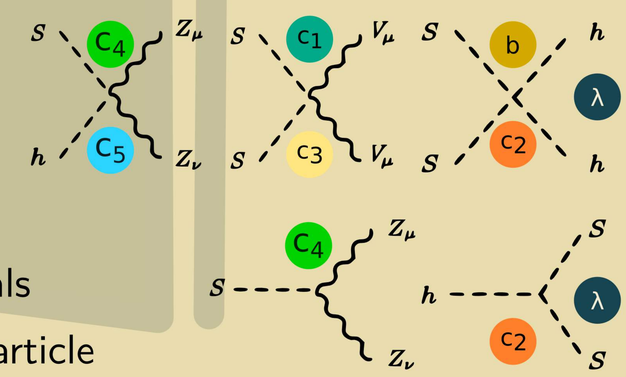


there's only **one** Higgs portal if the Higgs is an **elementary** particle

Non-linear Higgs portals

$$\mathcal{L}_S^{\text{non-lin}} = \frac{1}{2}\partial_\mu S\partial^\mu S - V(S) - \frac{\lambda_{Sh}}{2}S^2\left(2vh + bh^2\right) + \sum_i c_i\mathcal{A}_i$$

$\mathcal{A}_1 = \mathrm{Tr}(\mathbf{V}_\mu\mathbf{V}^\mu)S^2\mathcal{F}_1(h)$
$\mathcal{A}_2 = S^2\Box\mathcal{F}_2(h)$
$\mathcal{A}_3 = \mathrm{Tr}(\mathbf{T}\mathbf{V}_\mu)\mathrm{Tr}(\mathbf{T}\mathbf{V}^\mu)S^2\mathcal{F}_3(h)$
$\mathcal{A}_4 = i\mathrm{Tr}(\mathbf{T}\mathbf{V}_\mu)(\partial^\mu S^2)\mathcal{F}_4(h)$
$\mathcal{A}_5 = i\mathrm{Tr}(\mathbf{T}\mathbf{V}_\mu)S^2\partial^\mu\mathcal{F}_5(h)$

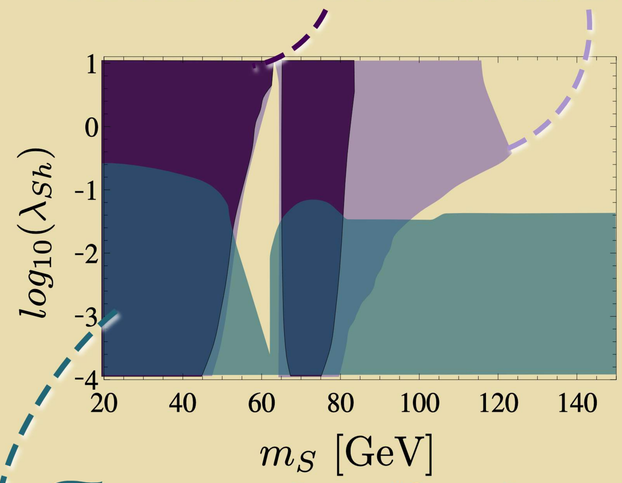


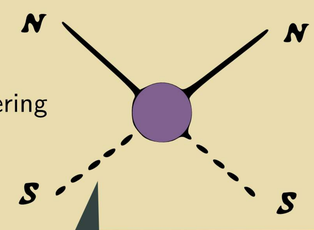
there are **many** Higgs portals if the Higgs is a **composite** particle

Impact on phenomenology

Direct detection

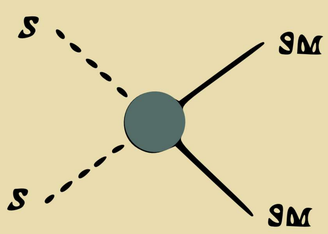
We consider the bounds on the Dark Matter-nucleon scattering cross-section from **Xenon100** and **LUX**





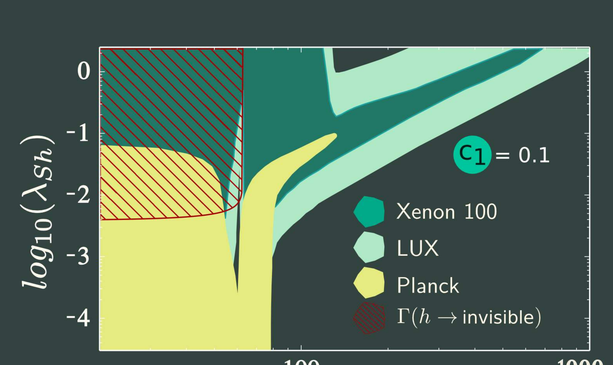
Linear case, corresponding to b=1 c_1=0 c_2=0
Colored regions are excluded by Direct detection (purple) and Relic density bounds (blue).

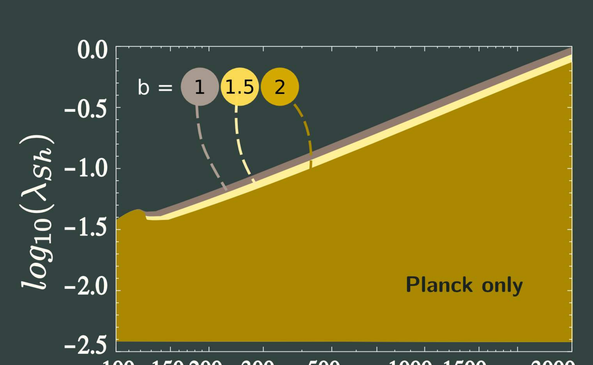
Examples of **nonlinear** scenarios. Exclusion regions for c_1=0.1 or c_2=0.1 and relic density constraints varying b=1, 1.5, 2.

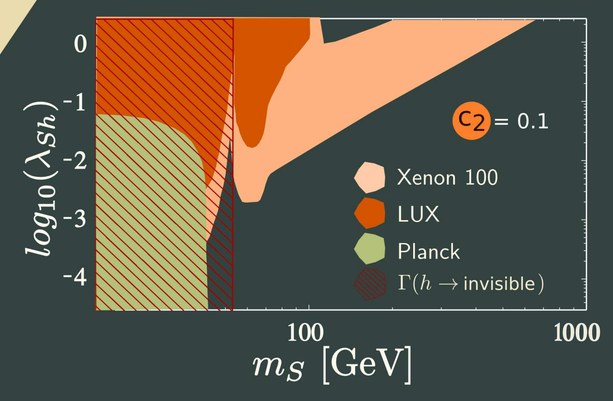


Thermal relic density

Assuming the scalar singlet S is a thermal relic of the early Universe, we require its relic density to be less or equal to the total DM density measured by **Planck**: $\Omega_S h^2 \leq \Omega_{DM} h^2 = 0.11$.





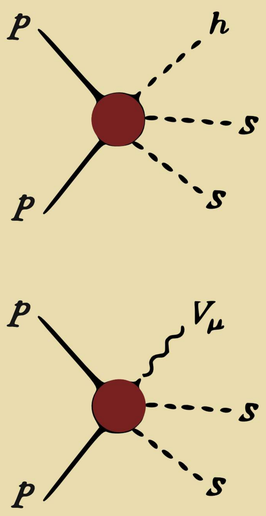


The viable parameter space is much larger in presence of non-linear Higgs portals

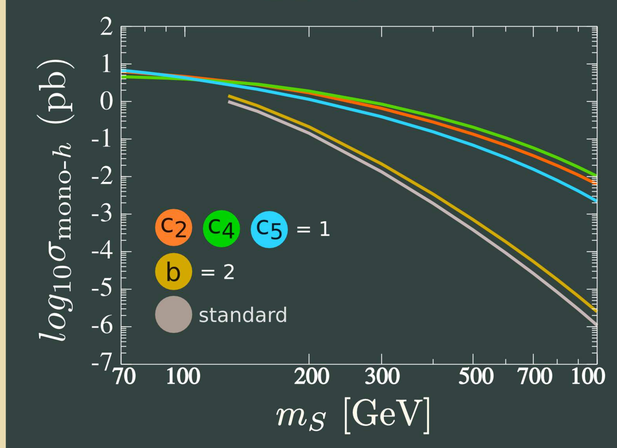
Mono-X searches @ LHC

We explore the prospects for the observation at LHC13 of mono-Higgs, mono-Z and mono-W signatures.

With a non-linear portal mono-Higgs, mono-W and mono-Z production at the LHC are significantly enhanced

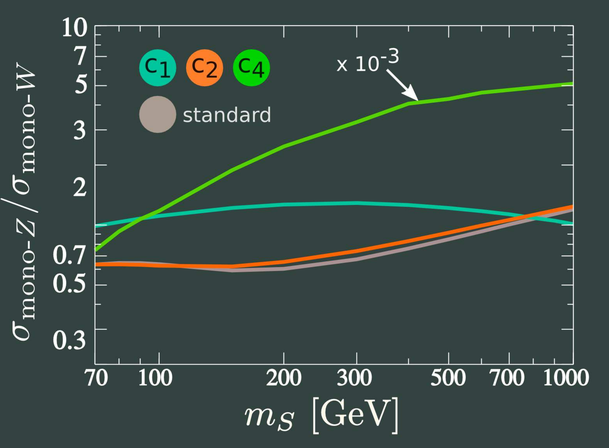


Mono-Higgs production



The cross-section is **enhanced** by up to 4 orders of magnitude thanks to direct ZSS (c_4) and ZhSS couplings (c_4,c_5) and momentum dependence in hSS (c_2)

Mono-Z/Mono-W



Any departure from the standard line is a signature of non-linearity, independently of the effective coefficients → a potential **discriminator** between standard and non-linear portal.

Brivio, Gavela, Merlo, Mimasu, No, del Rey, Sanz. hep-ph/1511.01099