The Higgs Portal

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Outline :

- Higgs key to the hidden sector
- Higgs portal DM
- Higgs potential stability and inflation

The Higgs key to the hidden sector

Motivation :

✓ E_8 X E_8 strings

observable hidden

✓ dark matter

✓ …

Special role of the Higgs :

Silveira, Zee '85
Veltman, Yndurain '89
...

$|H|^2$ = the only gauge and Lorentz-inv. dim-2 operator

$$L = a\,|H|^2\,S^2 + b\,|H|^2\,S$$

(S = "hidden" scalar)

b=0 (S has hidden charge):

$$L = a\,|H|^2\,S^2$$

"S" is stable and couples weakly to SM --> DARK MATTER (?)

Vector Higgs portal:

OL, Lee, Mambrini '11

$$L = a\,|H|^2\; V_\mu V^\mu \;+\; b\,(\,\bar{H} i D_\mu H\, V^\mu + \text{h.c.})$$

(V_μ = "hidden" vector)

b=0 (V^μ <--> $-V^\mu$ symmetry):

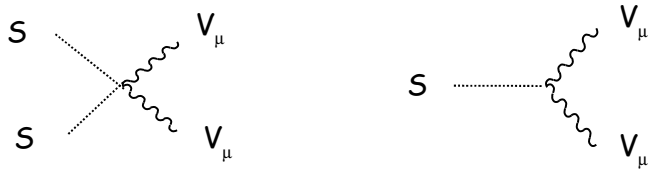
$$L = a\,|H|^2\; V_\mu V^\mu$$

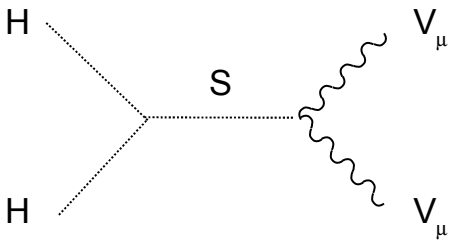
V^μ = DM (?)

Higgs mechanism in the hidden sector :

$$L = -1/4\ F_{\mu\nu} F^{\mu\nu} + D_\mu S^* D^\mu S - V(S) + \lambda/4\ H^*H\ S^*S$$

$$S \longrightarrow VEV$$





$H^*H\ V_\mu V^\mu$ vertex

(automatic Z_2 parity)

OL, Lee, Mambrini '11

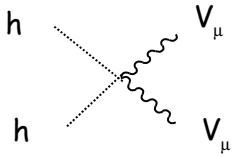
Unitarity:

$$L = \tfrac{1}{4}\lambda |H|^2 V_\mu V^\mu + \tfrac{1}{2} m^2 V_\mu V^\mu$$

Physical mass :

$$m^2_V = m^2 + \tfrac{1}{2}\lambda v^2$$

Cutoff :

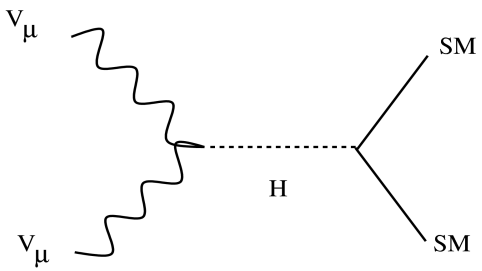


$+ \quad \ldots \quad \sim E^2$

$$E \sim m^2_V / m \qquad (\cdot \sqrt{16\pi/\lambda}\ )$$

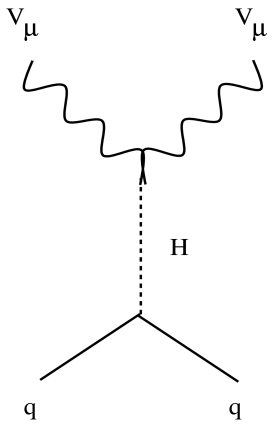
Higgs Portal DM

annihilation



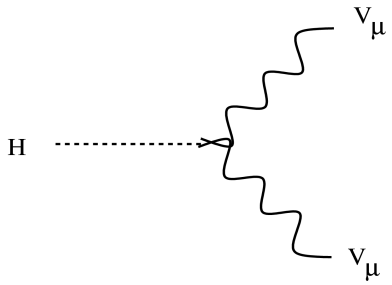
$< \sigma v >$

DM-nucleon scattering



σ^{SI}_{S-P}

invisible Higgs decay



Γ_H^{inv}

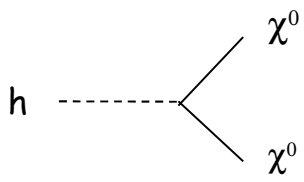
LHC constraint on h -> invisible :

Giardino et al. '12
Espinosa et al. '12

$$Br_{inv} < 30\text{-}40\ \%$$

E.g. SUSY :

Dreiner, Kim, OL '12



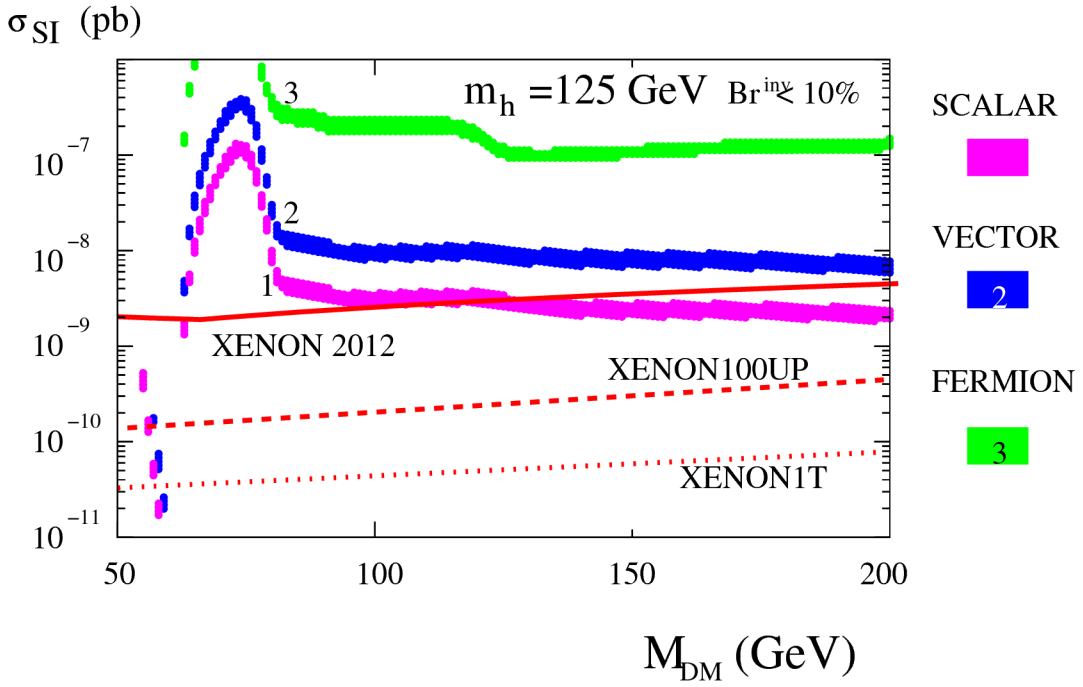
$\mu < 170$ GeV

$M_1 < 70$ GeV

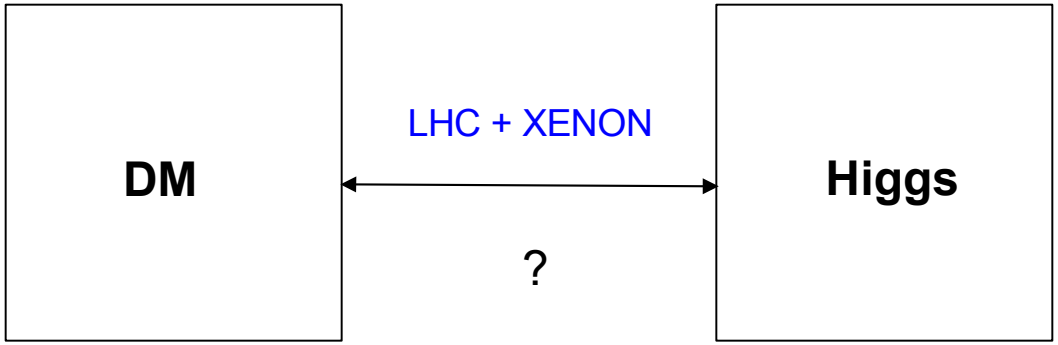
⇨ *strongly disfavored*

Prediction :

Djouadi, OL , Mambrini , Quevillon '11



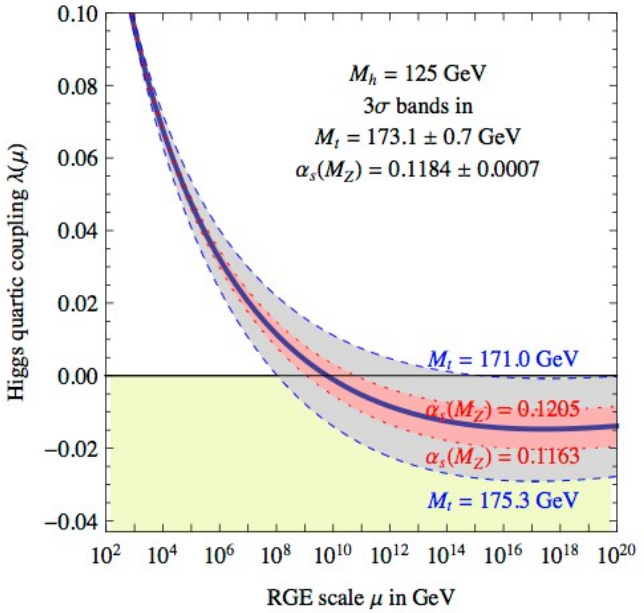
DM direct detection with $\sigma \sim 10^{-8} - 10^{-9}$ pb


DM
LHC + XENON
?
Higgs

Higgs potential stability and inflation

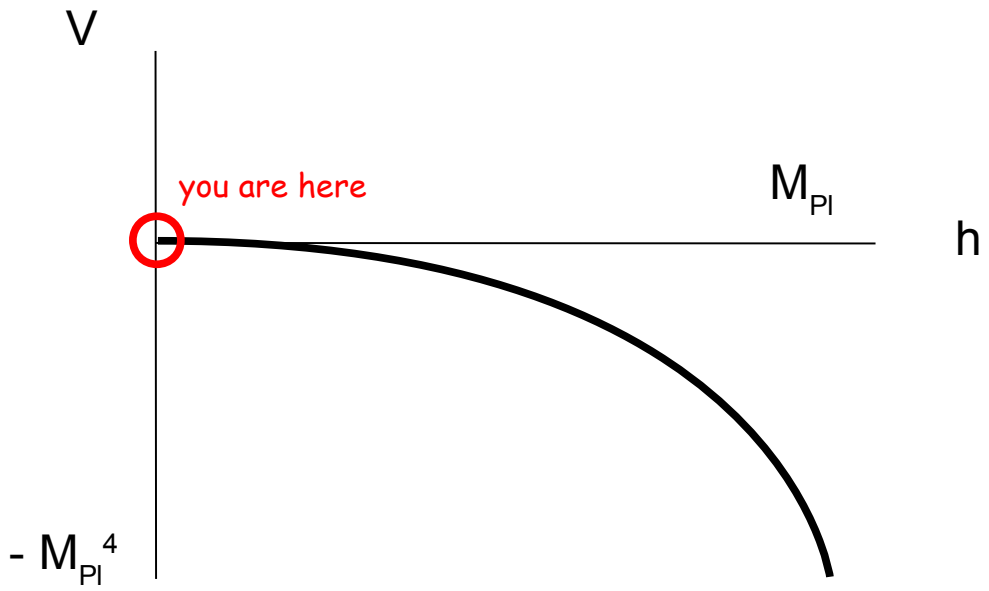
Degrassi et al.'12

SM stability bound: $m_h >$ 126 GeV at 98% CL



(not settled: Alekhin et al.'12
Bezrukov et al.'12)

$h >> \Lambda \sim 10^{10}\,\text{GeV}$ ⇨ $V \sim \frac{1}{4}\,\lambda(h)\,h^4$, $\lambda(h) < 0$



$\Lambda = 10^{-8}\,M_{Pl}$, barrier $= 10^{-32}\;M_{Pl}^4$

OL, Westphal ' 12

Problems :

- how did the Universe end up at h ~ 0 ?

- why did it stay there during inflation ?

Possible solution :

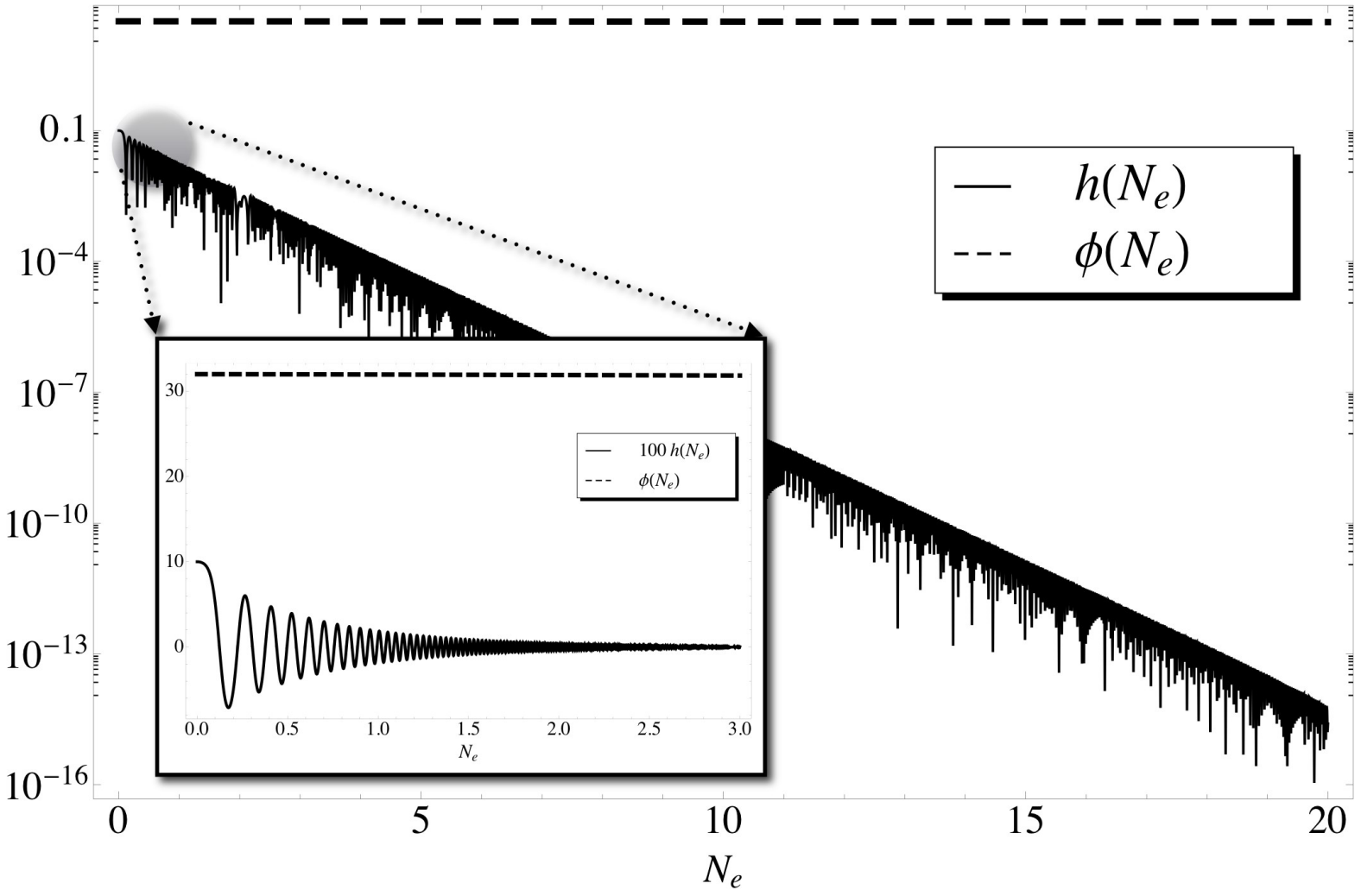
Higgs-inflaton coupling $\Delta V = \frac{1}{2} \xi h^2 \phi^2$ (simplest choice)

$\Delta V + V_{Higgs} > 0$ ⇨ $\phi_0 \sim 20\, M_{Pl}$, $\xi \sim 10^{-6}$

Large effective mass term ⇨ $h(t) \sim h(0) \exp(-3/2\, Ht)$

Higgs field is driven to zero during inflation !

Higgs/inflaton evolution (in M_{Pl}):



Another option:

stabilize the EW vacuum

$$\Delta L = \tfrac{1}{4}\,\lambda_{hs}|H|^2 S^2 + \tfrac{1}{2}\,m^2 S^2 + \tfrac{1}{4}\,\lambda_s S^4$$

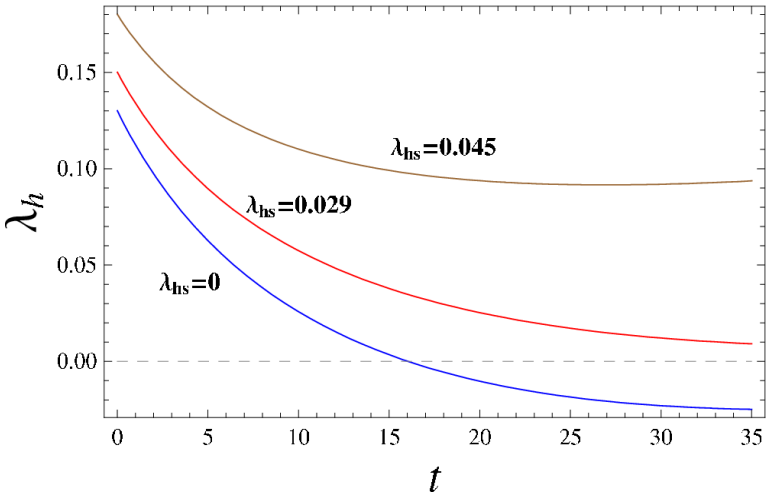
Low energy states :

$$\begin{cases} H_1 = H\cos\theta + S\sin\theta \\ H_2 = H\sin\theta - S\cos\theta \end{cases}$$

If $\langle S\rangle \gg 246$ GeV ,

$$\begin{cases} \theta \to 0 \qquad \text{(SM—like Higgs)} \\ m_h^2 = 2v^2\,[\,\lambda_h - \lambda_{hs}^2/(4\lambda_s)\,] \end{cases}$$

OL '12
Elias-Miro et al.'12



$\lambda_s = 0.01$
$t = \ln(\mu/m_t)$

Conclusion

- Higgs sector is special
- vector/scalar Higgs-portal DM
- Higgs-inflaton coupling
- vacuum stabilization by a singlet