The Higgs Portal and Cosmology

Oleg Lebedev

University of Helsinki

Plan :

- Key to the hidden sector
- Higgs portal and Dark Matter
- Higgs portal and inflation

The Higgs key to the hidden sector

Motivation :

✓ E_8 X E_8 strings

observable hidden

✓ dark matter

✓ ...

Lowest order operators ("Higgs Portal") :

$$\bar{H}H\,S^2 \quad + \quad \ldots$$

$$\bar{H}H\,V_\mu\,V^\mu \quad + \quad \ldots$$

$$\bar{H}H\,\bar{\chi}\,\chi\,/\,\Lambda \quad + \ldots$$

"Portal" due to Patt,Wilczek'06 (earlier : Silveira,Zee'85; Shabinger,Wells'05;...)

The Higgs portal and Dark Matter

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):

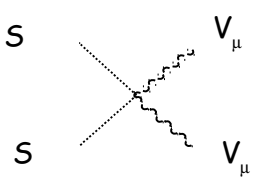
$$L = a\,|H|^2\; V_\mu V^\mu$$

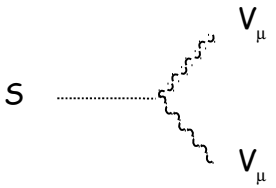
V^μ = DM (?)

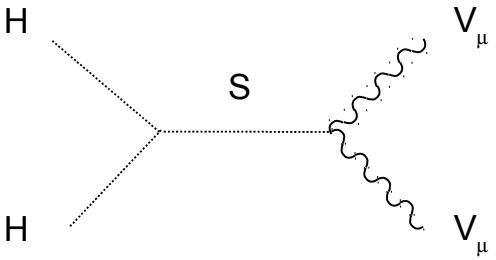
Higgs mechanism in the hidden sector :

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

$$S \longrightarrow \text{VEV}$$





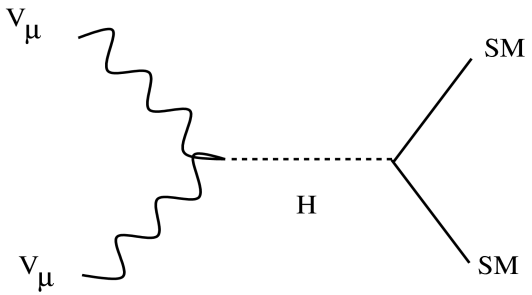


$\Rightarrow$ $H^*H\, V_\mu V^\mu$ vertex

(Z_2 parity)

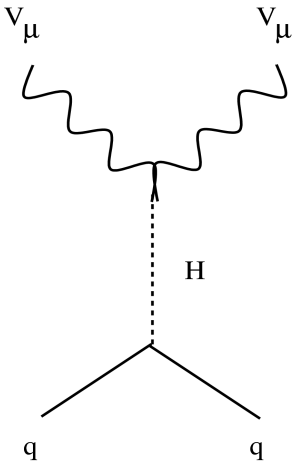
Important processes :

annihilation



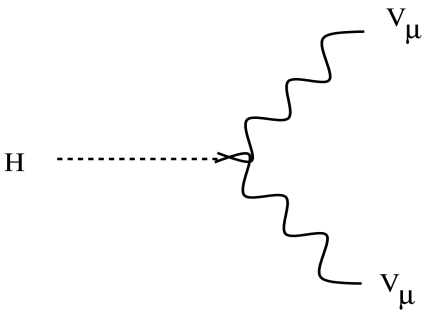
$< \sigma v >$

DM-nucleon scattering



σ^{SI}_{S-P}

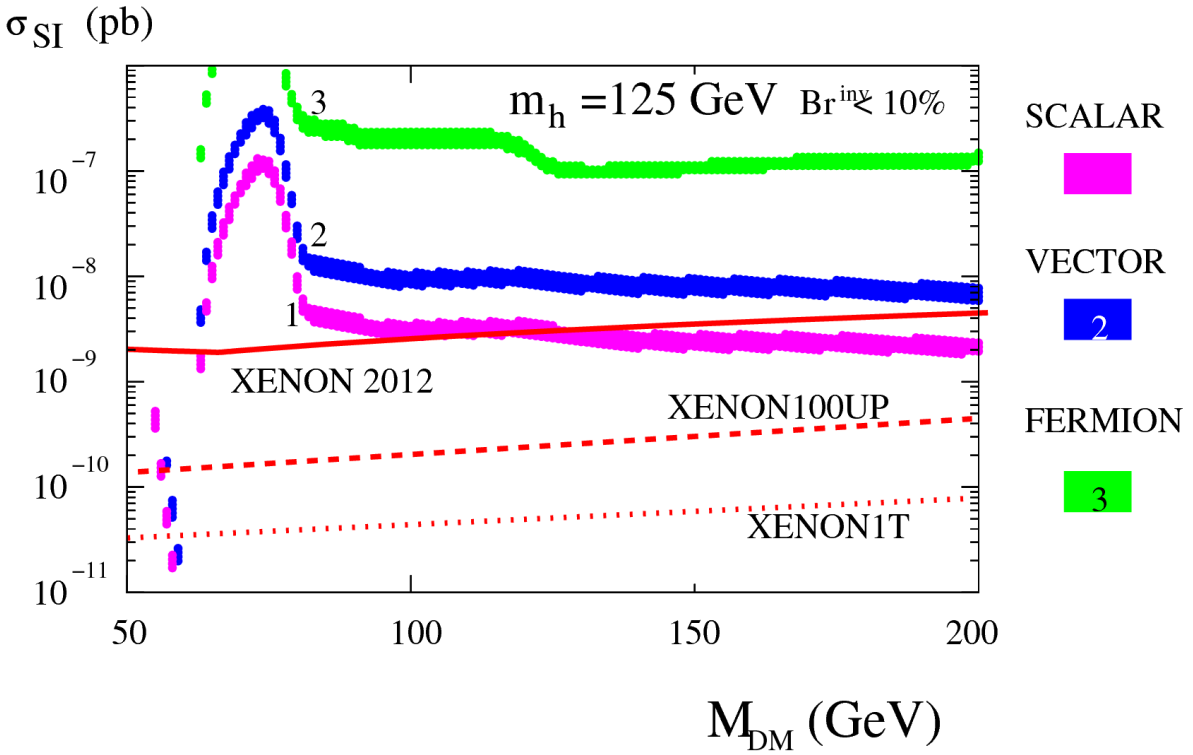
invisible Higgs decay



Γ_H^{inv}

Prediction :

Djouadi, OL , Mambrini , Quevillon '11



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

Scalar vs Vector DM :

annihilation **:**	$g^2_{vector} = 3\, g^2_{scalar}$	(3 species)
direct detection **:**	same	(Higgs exchange)
Higgs decay **:**	$\Gamma_{vector} \sim m_h^4 / m_V^4 \;\; \Gamma_{scalar}$	(Goldstone production)

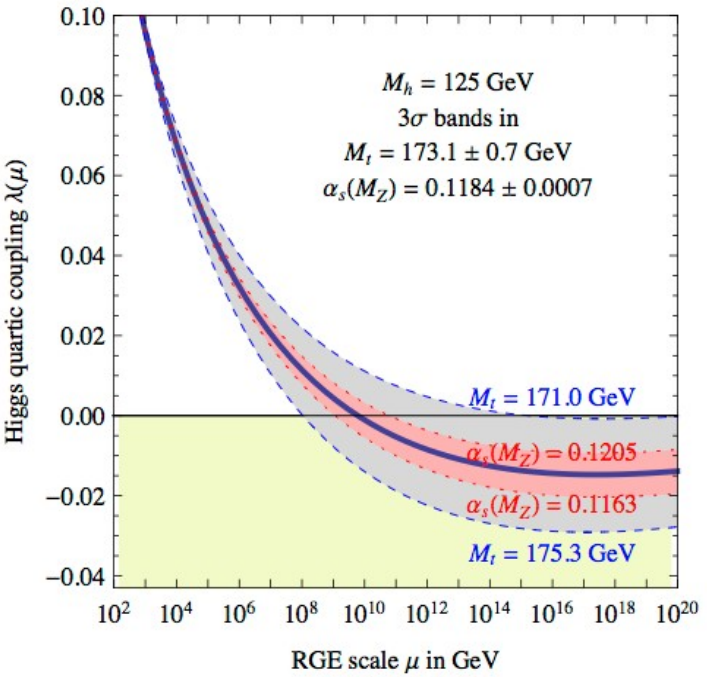
Fermionic DM :

disfavored :	velocity suppressed annihilation	(CP symmetry)

The Higgs portal and inflation

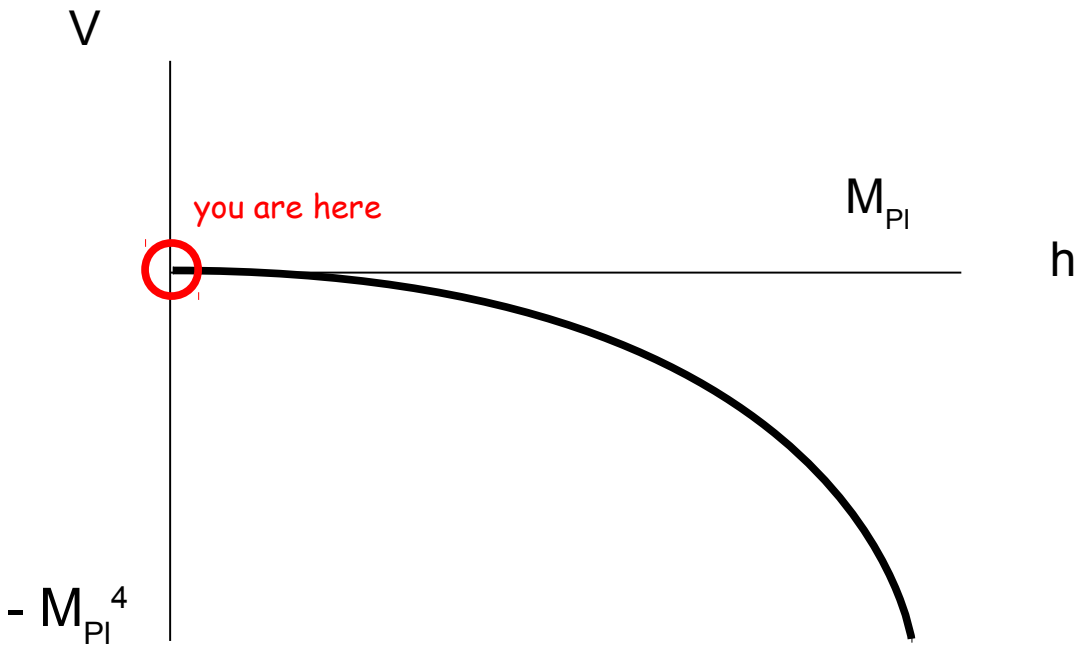
Degrassi et al.'12

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



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

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



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

Problems :

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

- why did it stay there during inflation ?

Possible solution :

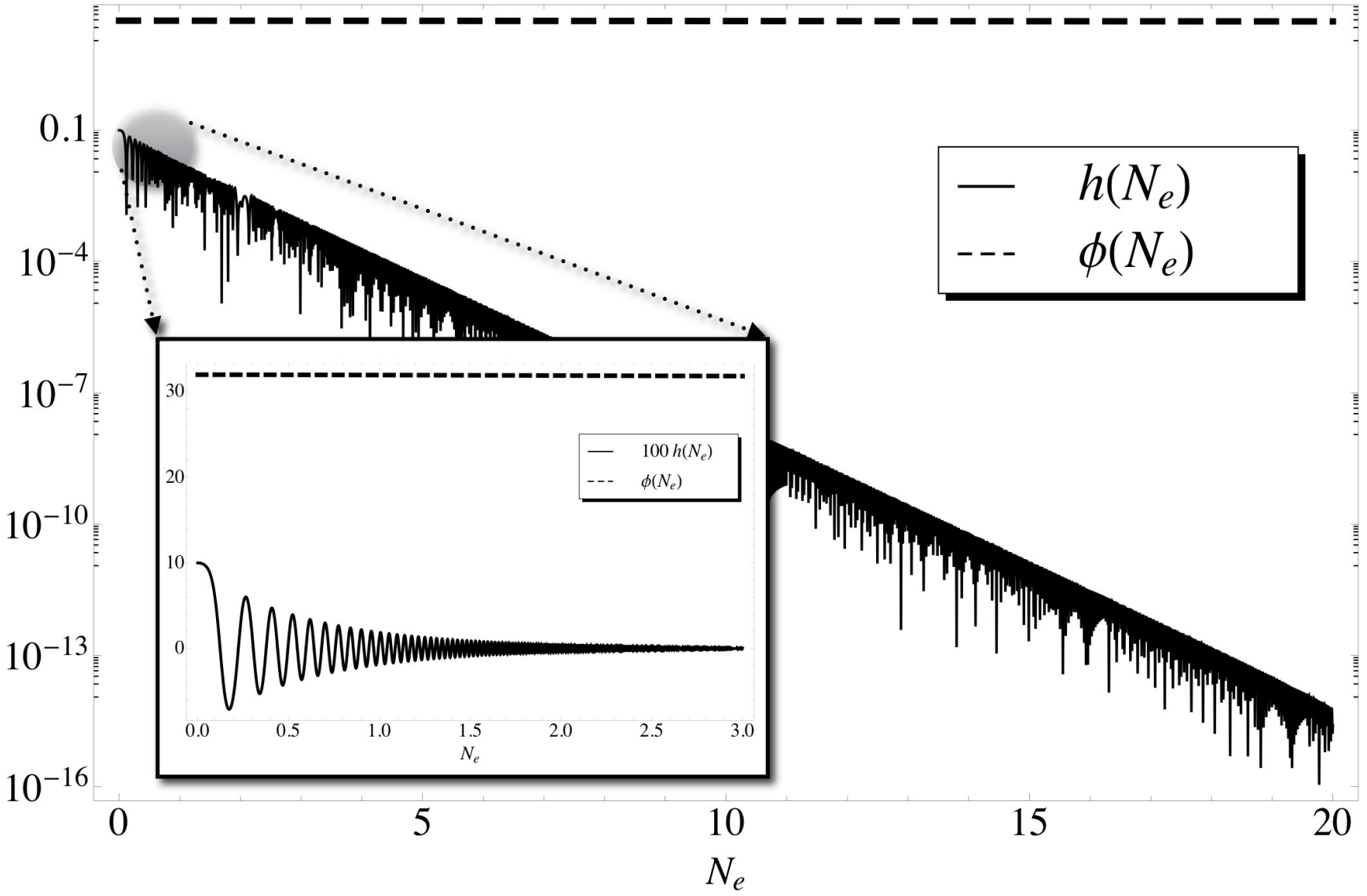
Higgs-inflaton coupling $\boxed{\Delta V = \tfrac{1}{2}\, \xi\, h^2 \phi^2}$ (simplest choice)

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

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

Higgs field is driven to zero during inflation !

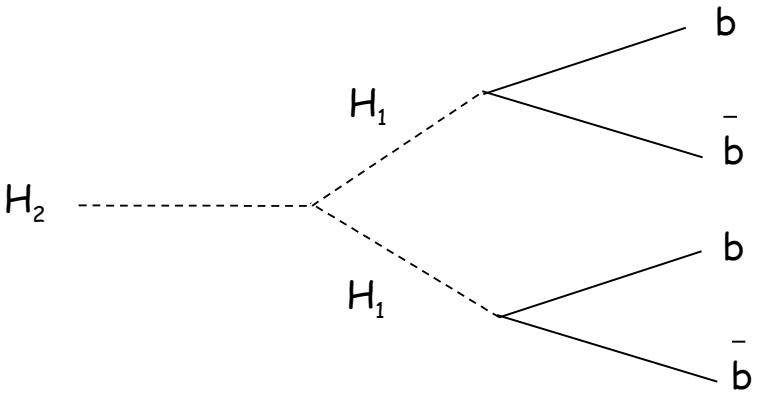
Higgs/inflaton evolution (in M_{Pl}):



⇨ Higgs-portal coupling favored by cosmology

Possible low-energy signatures :

- 2 Higgs-like states
- suppressed couplings
- cascades



Higgs potential reconstruction :

Englert et al. '11

m_1 , m_2 , θ , $H_2 \longrightarrow H_1 H_1$ ⇨ 4 parameters of the scalar potential

Conclusion

- Higgs sector is special
- Higgs portal coupling favored by cosmology
- LHC / DM detection are crucial