# The minimal linear σ model for the Goldstone Higgs

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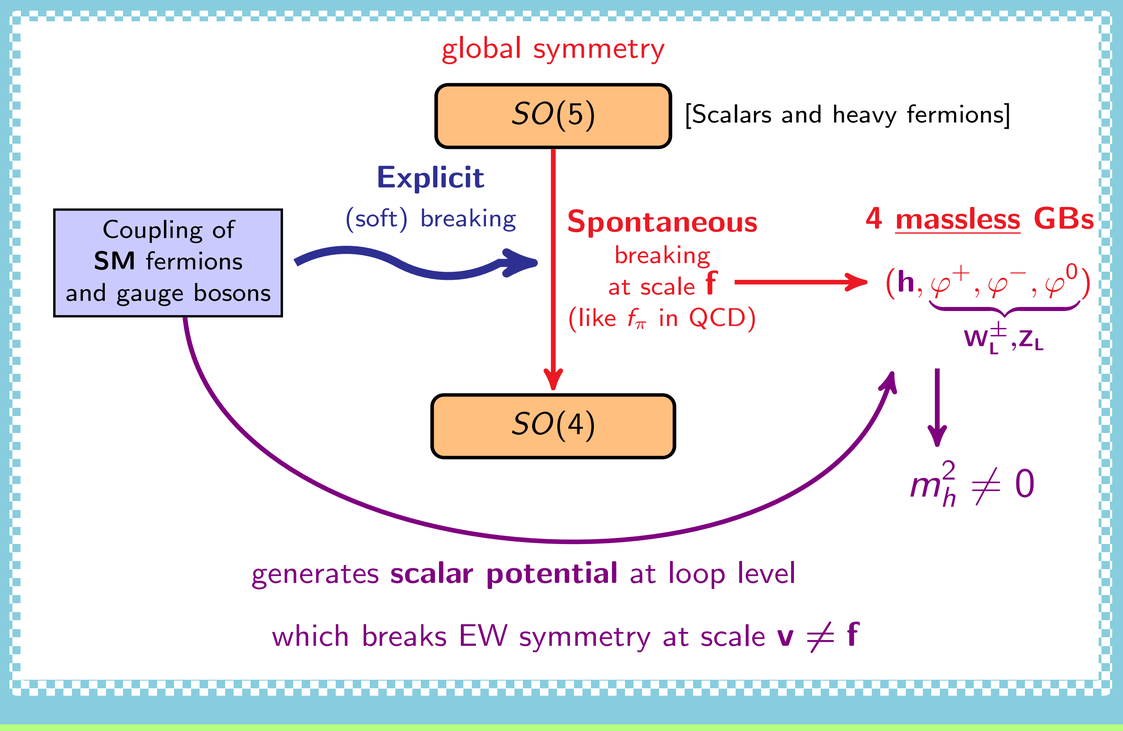
## *The question*

### Can the Higgs be a pseudo-Goldstone boson?

(like $Z_L$, $W_L^{\pm}$ = GBs)

→ hierarchy "problem"

Original idea: Georgi-Kaplan (1984) SU(5) → SO(5) (14 GBs)
SO(5) → SO(4) Agashe, Contino, Pomarol (2005)




Usually studied in non-linear (effective) models for a composite Higgs

We analyze a **linear*** (**renormalizable**) implementation instead:

Higgs **h** → { Higgs **h**; singlet **σ** }

(like linear **σ** model for QCD at low energies)

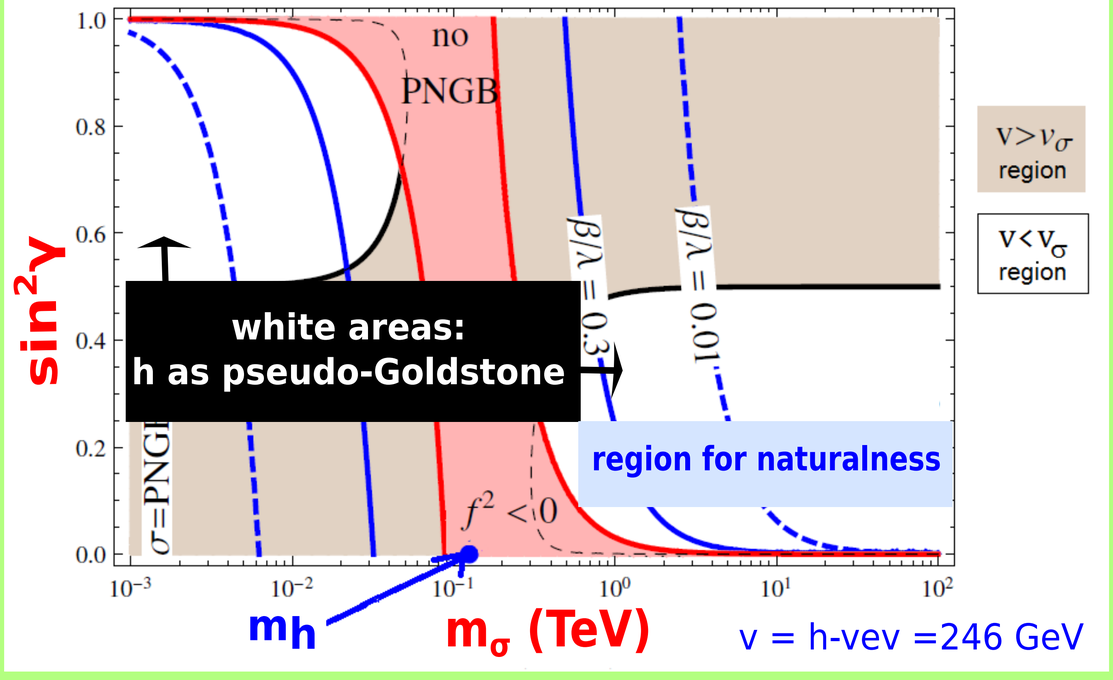
? How light could the **σ** be?

Could it be hidden in the data?

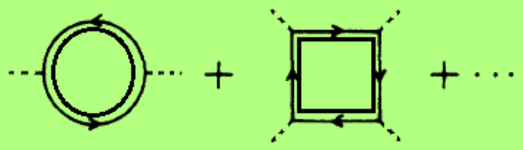
Might it help alleviate the tension in composite models†? ?

*Barbieri et al (2007)
†Panico et al (2013), Carena et al (2014)

## h and σ mix → $\sin^2\gamma$



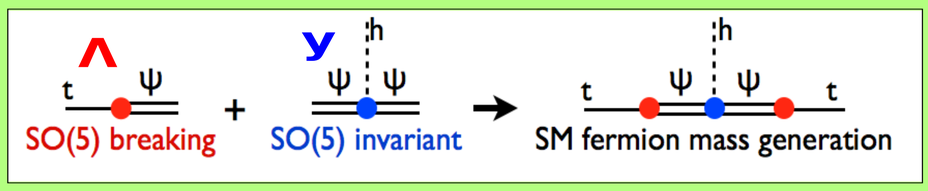

$$V(h,\sigma) = -\lambda\underbrace{(h^2+\sigma^2-f^2)^2}_{\text{spontaneous SO(5) breaking}} + \underbrace{\alpha f^3\sigma - \beta f^2 h^2}_{\text{explicit SO(5) breaking}}$$



**Coleman-Weinberg**
(2 ~~SO(5)~~ terms required as counterterms)

### Vectorial heavy fermions

two types of terms in the Lagrangian:



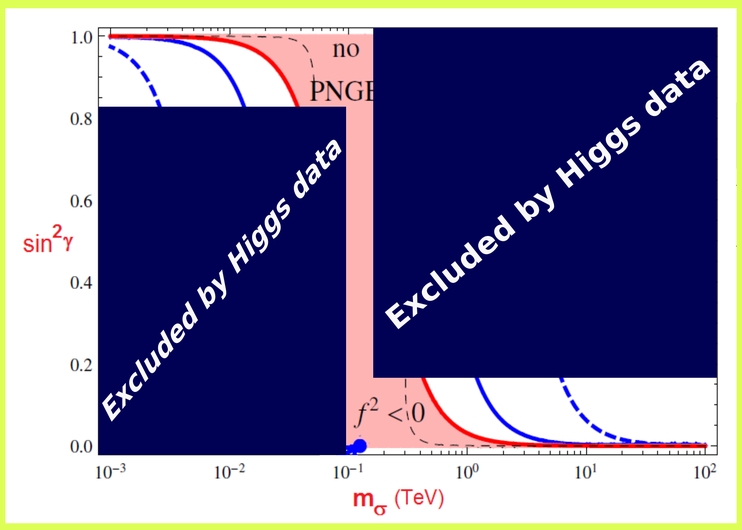

top yukawa:

$y_t \sim y\,\Lambda^2/M_\psi^2$

(à la Seesaw)

## *Phenomenology*

Modifications to the Higgs couplings → bounds on $\sin^2\gamma$

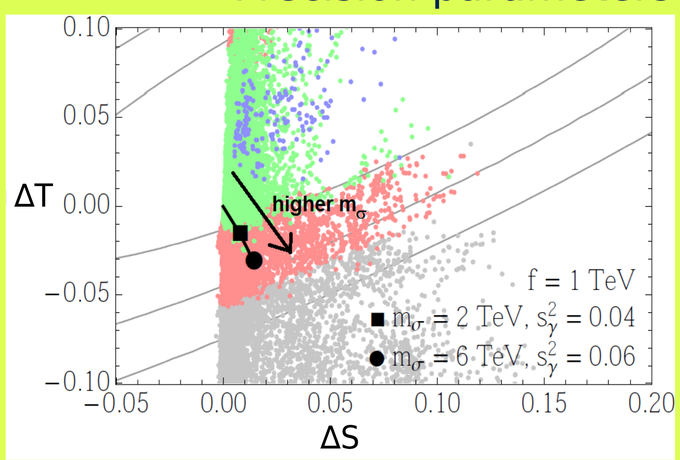



(exclusions from coupling modifiers $K_F$ and $K_V$)

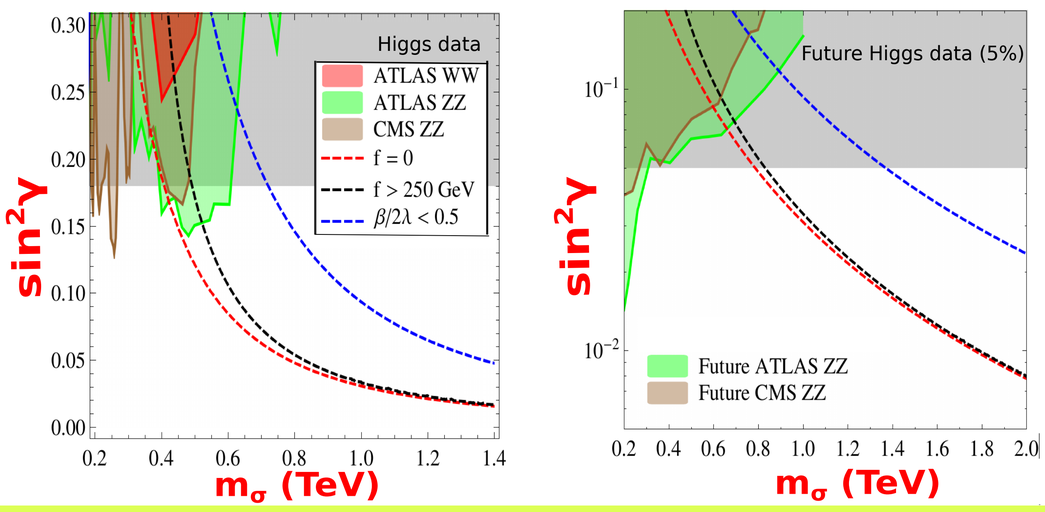
### Precision parameters

larger $m_\sigma$ can lead to more tension with data

(colored points: fermionic contribution
1σ, 2σ, 3σ regions for a global fit to (ΔS, ΔT, $\Delta g_{Zbb}$))




### σ at LHC




- white area: SM + generic singlet allowed
- natural h as pseudo-Goldstone boson:
  (to the right of dashed black curve)
  present: $m_\sigma$ >~ 500 GeV
  future: $m_\sigma$ >~ 900 GeV