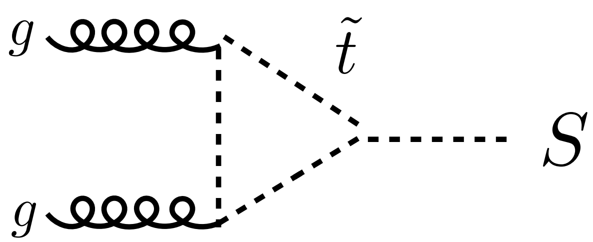
# Why is S(750) a case for strong dynamics over SUSY?

# Why is S(750) a case for strong dynamics over SUSY?

SUSY

- New scalar particles




$$\propto \frac{\alpha_s}{196\pi} g^2_{S\tilde{t}} \frac{f_0(\tau)}{M_S}$$

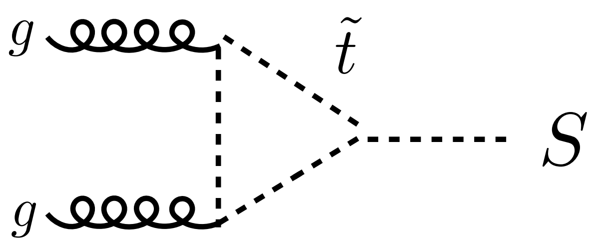
- Weak couplings

$$g_{S\tilde{t}} \approx 0.1 - 1$$

## Why is S(750) a case for strong dynamics over SUSY?

### SUSY

- New scalar particles



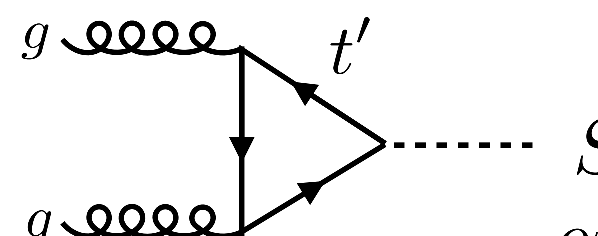

$$\propto \frac{\alpha_s}{196\pi} g^2_{S\tilde{t}} \frac{f_0(\tau)}{M_S}$$

- Weak couplings

$$g_{S\tilde{t}} \approx 0.1 - 1$$

### Strong dynamics

- New sermonic particles




$$\propto \frac{\alpha_s}{12\pi} g^2_{St'} \frac{f_{1/2}(\tau)}{M_S}$$

- Strong couplings

$$g_{St'} \approx 1 - 4\pi$$

Thats the reason, why supersymmetric models are hard to construct.

The “leading candidate” is the sgoldstino, which is not expected to be part of the low energy spectrum.

$$-\frac{1}{2\mathcal{F}}\int d^2\theta X\left(m_1 W^{\alpha}W_{\alpha}+m_2 W^{\alpha\, a_2}W_{\alpha}^{a_2}+m_3 W^{\alpha\, a_3}W_{\alpha}^{a_3}\right)+h.c..$$

$$\Gamma_{gg}=\left(\frac{m_3}{2\mathcal{F}}\right)^2\frac{m_\sigma^3}{\pi},\qquad \Gamma_{\gamma\gamma}=\frac{1}{2}\left(\frac{m_{\sigma\gamma\gamma}}{4\mathcal{F}}\right)^2\frac{m_\sigma^3}{\pi},$$

$$\Gamma_{ZZ}\simeq\frac{1}{2}\left(\frac{m_{\sigma ZZ}}{4\mathcal{F}}\right)^2\frac{m_\sigma^3}{\pi},\qquad \Gamma_{WW}\simeq\left(\frac{m_2}{4\mathcal{F}}\right)^2\frac{m_\sigma^3}{\pi},\qquad \Gamma_{Z\gamma}\simeq\left(\frac{m_{\sigma Z\gamma}}{4\mathcal{F}}\right)^2\frac{m_\sigma^3}{\pi}.$$

Sizable couplings (=many Messengers) and low SUSY breaking scale.

There is no shortage of papers involving strong dynamics.
I will concentrate on extra dimensional constructions.

- Graviton (Adrians talk)
- Radion
- The Localizer field

# The Radion

Coupling of the Ricci scalar to the Higgs (on or off the IR brane)

$$S=\int_0^L d^5x\,\sqrt{g}\left[\left(\frac{M_5^3}{2}+\xi H^\dagger H\right)R_5+|D_M H|^2-V(H)\right]+S_{brane}\,,$$

yields at 4D with $\Omega(\phi_0)=1-\dfrac{\phi_0}{\Lambda_\phi}$ $\Lambda_\phi=\sqrt{6}M_{\rm Pl}e^{-kr_c}$

$$\mathcal{L}_{\rm eff}=\frac{1}{2}(\partial_\mu\phi_0)^2-\frac{1}{2}m_{\phi_0}^2\phi_0^2-6\xi\Omega\Box\Omega H^\dagger H+|D_\mu H|^2-\Omega^4 V(H),$$

# The Radion

The nice part is most transparent in the SM -> IR limit

$$\mathcal{L}_{\rm int}^{\phi_0\text{-SM}} = \frac{\phi_0}{\Lambda_\phi} T^\mu_\mu,$$

$$T^\mu_\mu = -(1-6\xi)\left[\partial_\mu h_0 \partial^\mu h_0 + m_V^2 V_{a\,\mu} V^{a\,\mu}\left(1+\frac{h_0}{v_0}\right)^2 - m_i \bar{\psi}_i \psi_i \left(1+\frac{h_0}{v_0}\right) - \lambda(v_0+h_0)^4\right]$$
$$-(1-3\xi) m_{h_0}^2 (v_0+h_0)^2 + b_3 \frac{\alpha_s}{8\pi} \mathrm{Tr}[G_{\mu\nu}G^{\mu\nu}] + (b_2+b_Y)\frac{\alpha}{8\pi} F_{\mu\nu}F^{\mu\nu}, \qquad (2.7)$$

All couplings vanish in the conformal limit:

$$\xi = 1/6,\ m_h = 0$$

# The Radion

The not so nice part is, that the ratio of beta functions times coupling strengths is too small. Bulk gauge fields are needed.

And even then, there is a problem:

$$m_1^g = \frac{2.45}{\sqrt{6}} \frac{k}{M_{\rm Pl}} \Lambda_\phi$$

but

$$\mathcal{L}_{\rm int}^{\phi_0\text{-SM}} = \frac{\phi_0}{\Lambda_\phi} T^\mu_\mu,$$

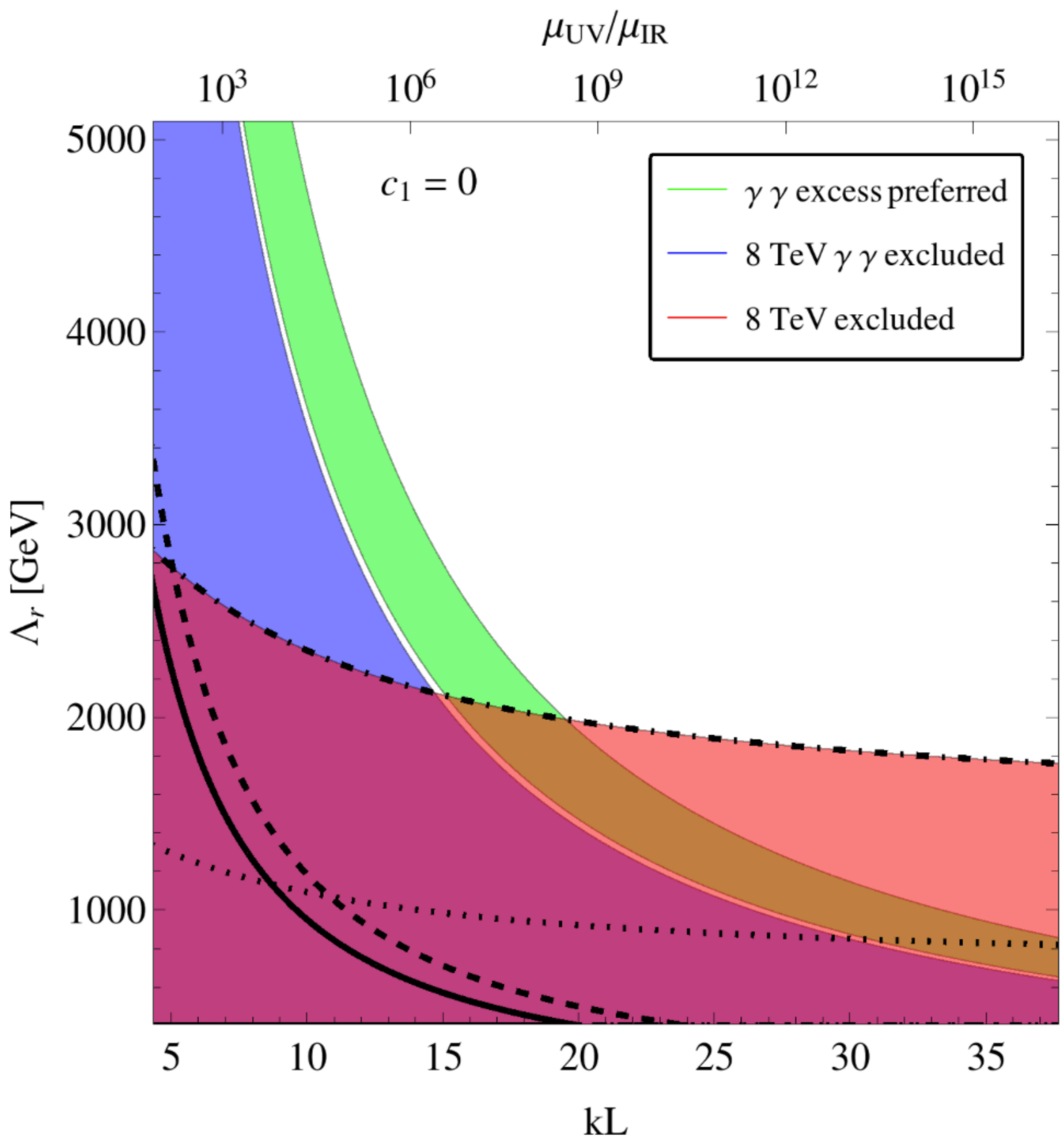
Thus either

$$\frac{k}{M_{\rm Pl}} > 1$$

or

$$\frac{\Lambda_\phi}{M_{\rm Pl}} > \frac{\rm TeV}{M_{\rm Pl}}$$

# The Radion




[arxiv:1512.05618]

Radion and Sgoldstino explanations are similar. In both cases, the breaking of the spacetime symmetry has happen at low scales.

# The Localizer

There is another fundamental scalar in extra dimensional models

$$\int d^4x \int d\phi\, e^{-4\sigma(\phi)} \sum_f \left(\bar{f} i \Gamma_A D^A f - \mathrm{sgn}(\phi) \bar{f} \mathbf{M}_f f\right)$$

This function should be the profile of an odd field!

We used

$$\int d^4x \int_{-\pi}^{\pi} d\phi\, r\, e^{-4\sigma(\phi)} \left[\frac{g^{MN}}{2} (\partial_M S)(\partial_N S) - \frac{\mu^2}{2} S^2 - \sum_f \left(\mathrm{sgn}(\phi)\, \bar{f}\, \boldsymbol{M}_f f + S\, \bar{f}\, \boldsymbol{G}_f f\right)\right],$$

# The Localizer

Using

$$S(x,\phi) = \frac{e^{\sigma(\phi)}}{\sqrt{r}} \sum_n S_n(x)\, \chi_n^S(t)\,,$$

Boundary conditions

$$\chi_n^S(1) = \xi\, \chi_n^{S\prime}(1)$$
$$\chi_n^S(\epsilon) = 0$$

Yields

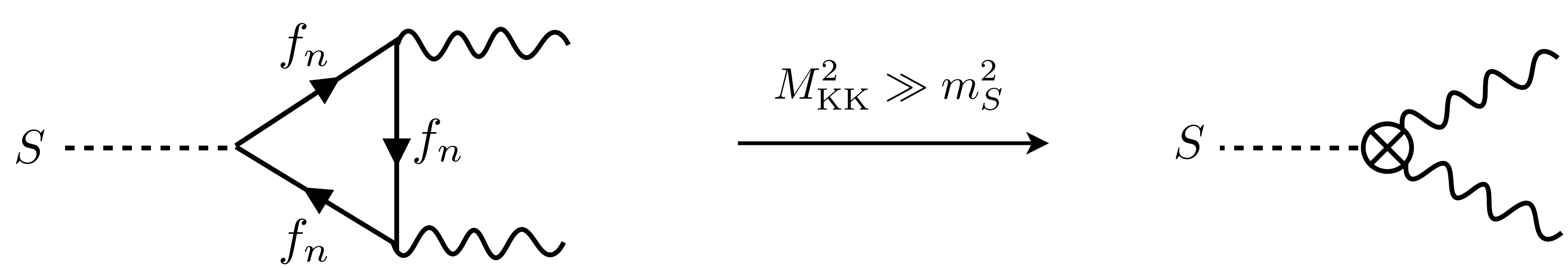
$$x_1^2 \approx \frac{4(1+\beta)\,[1-\xi(1+\beta)]}{1-\xi(3+\beta)}\,.$$

# The Localizer

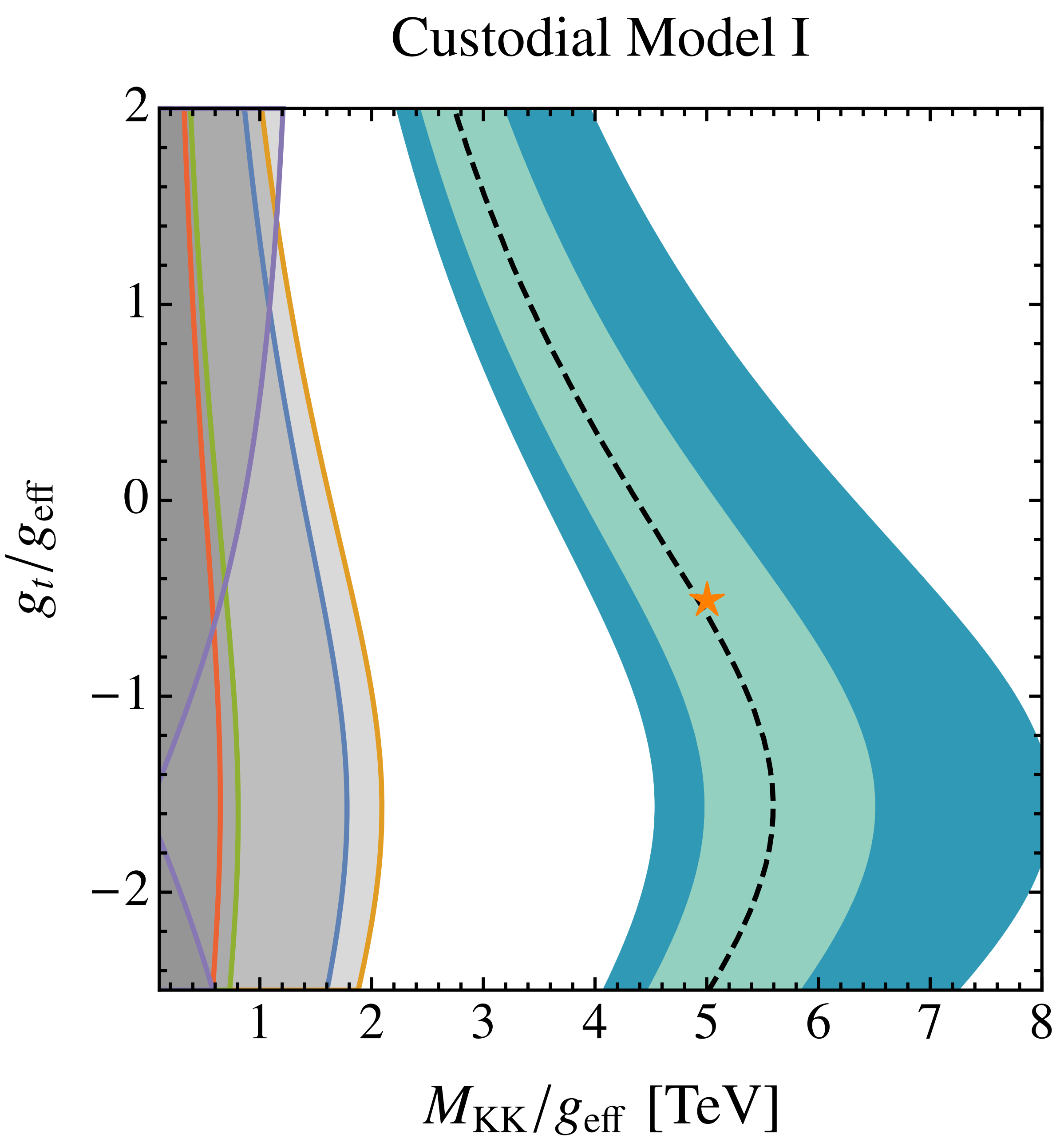
The most general Lagrangian

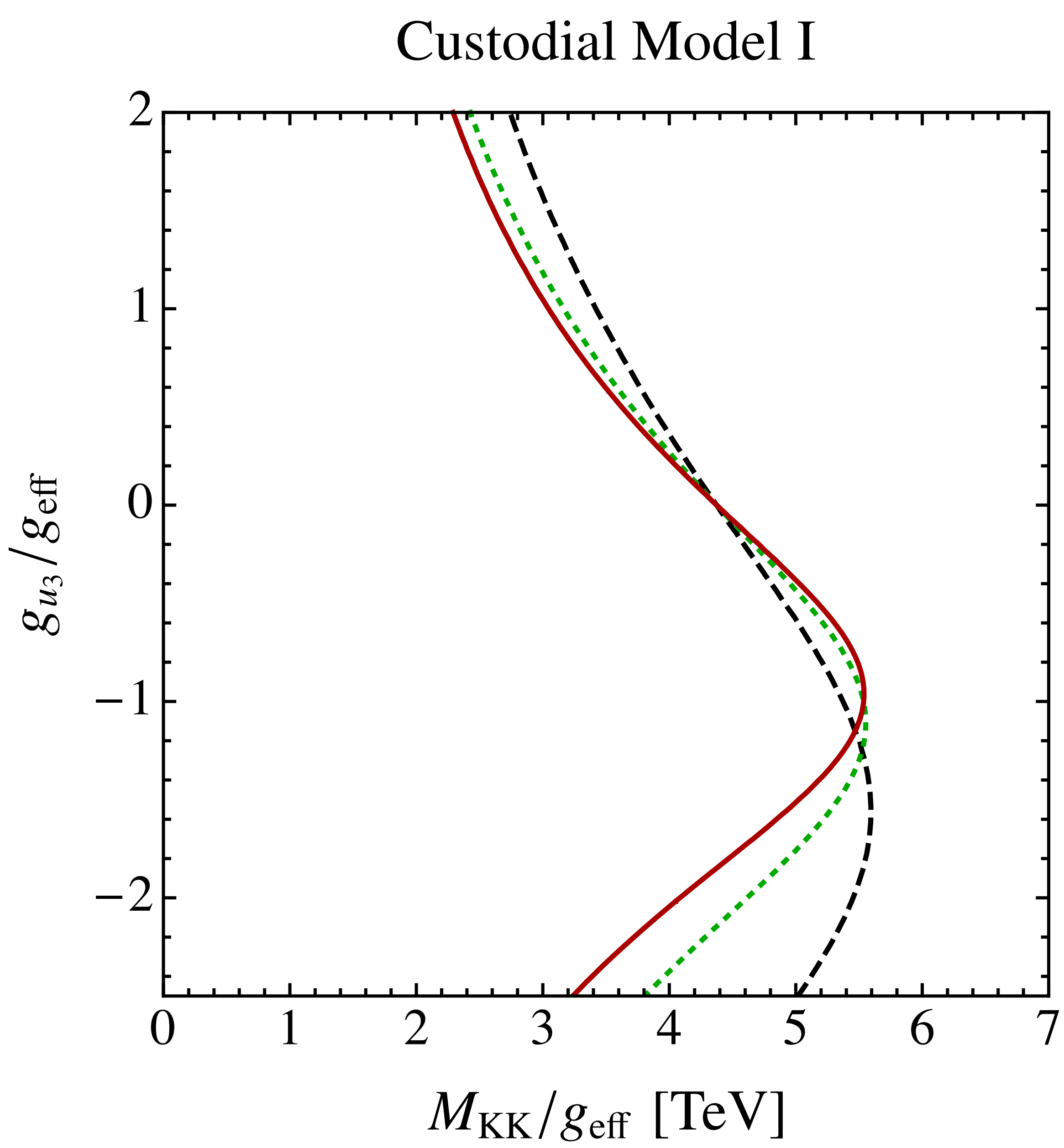
$$\mathcal{L}_{\rm eff} = c_{gg}\,\frac{\alpha_s}{4\pi}\,S\,G^a_{\mu\nu}G^{\mu\nu,a} + c_{WW}\,\frac{\alpha}{4\pi s_w^2}\,S\,W^a_{\mu\nu}W^{\mu\nu,a} + c_{BB}\,\frac{\alpha}{4\pi c_w^2}\,S\,B_{\mu\nu}B^{\mu\nu}$$
$$+ \left( S\,\bar{Q}_L\,\boldsymbol{C}_u\,\tilde{\Phi}\,u_R + S\,\bar{Q}_L\,\boldsymbol{C}_d\,\Phi\,d_R + S\,\bar{L}_L\,\boldsymbol{C}_e\,\Phi\,e_R + \text{h.c.} \right),$$

We integrate out the bulk fermions in 5D Language
(using the full 5D propagator)

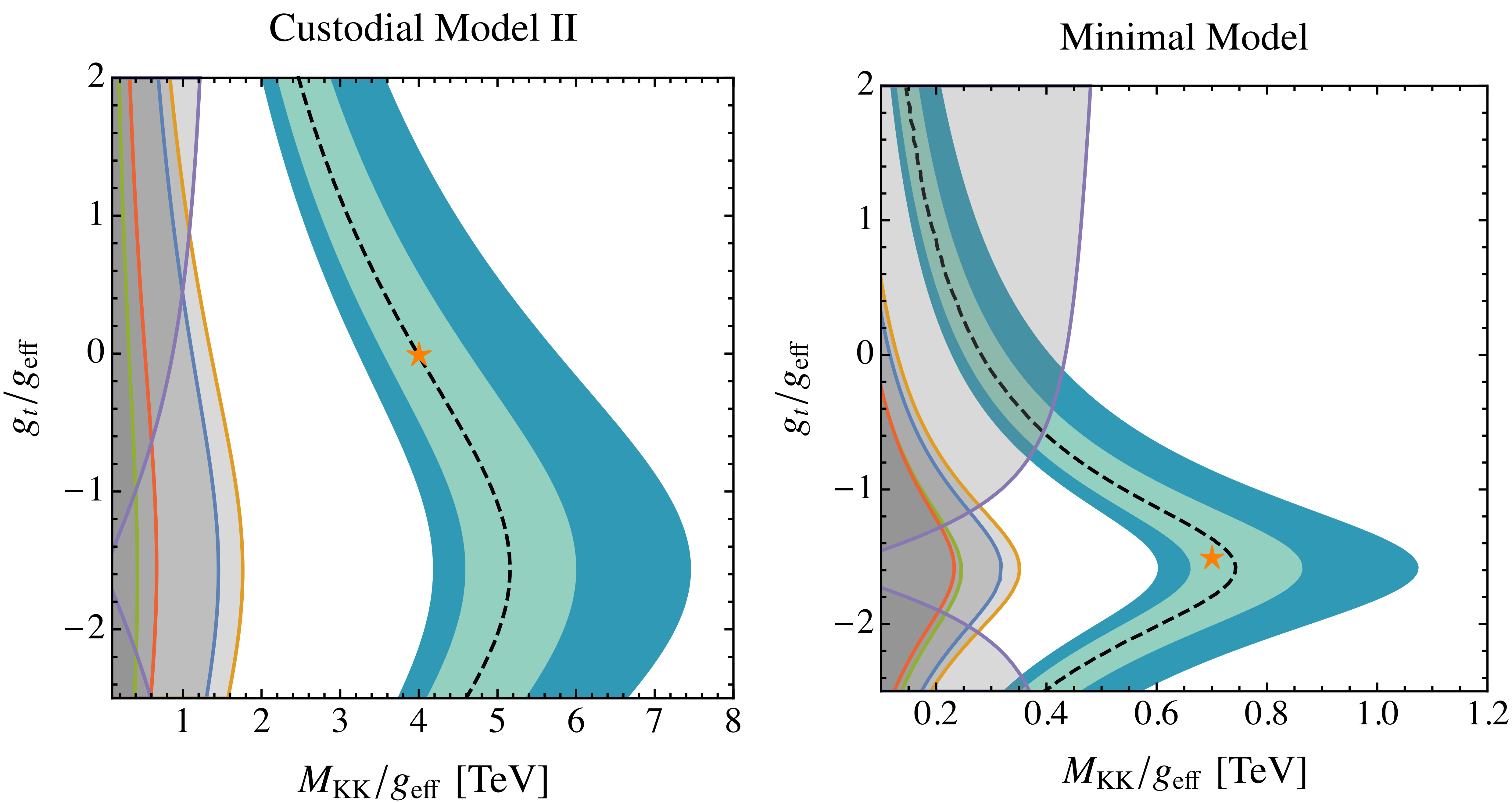


# The Localizer



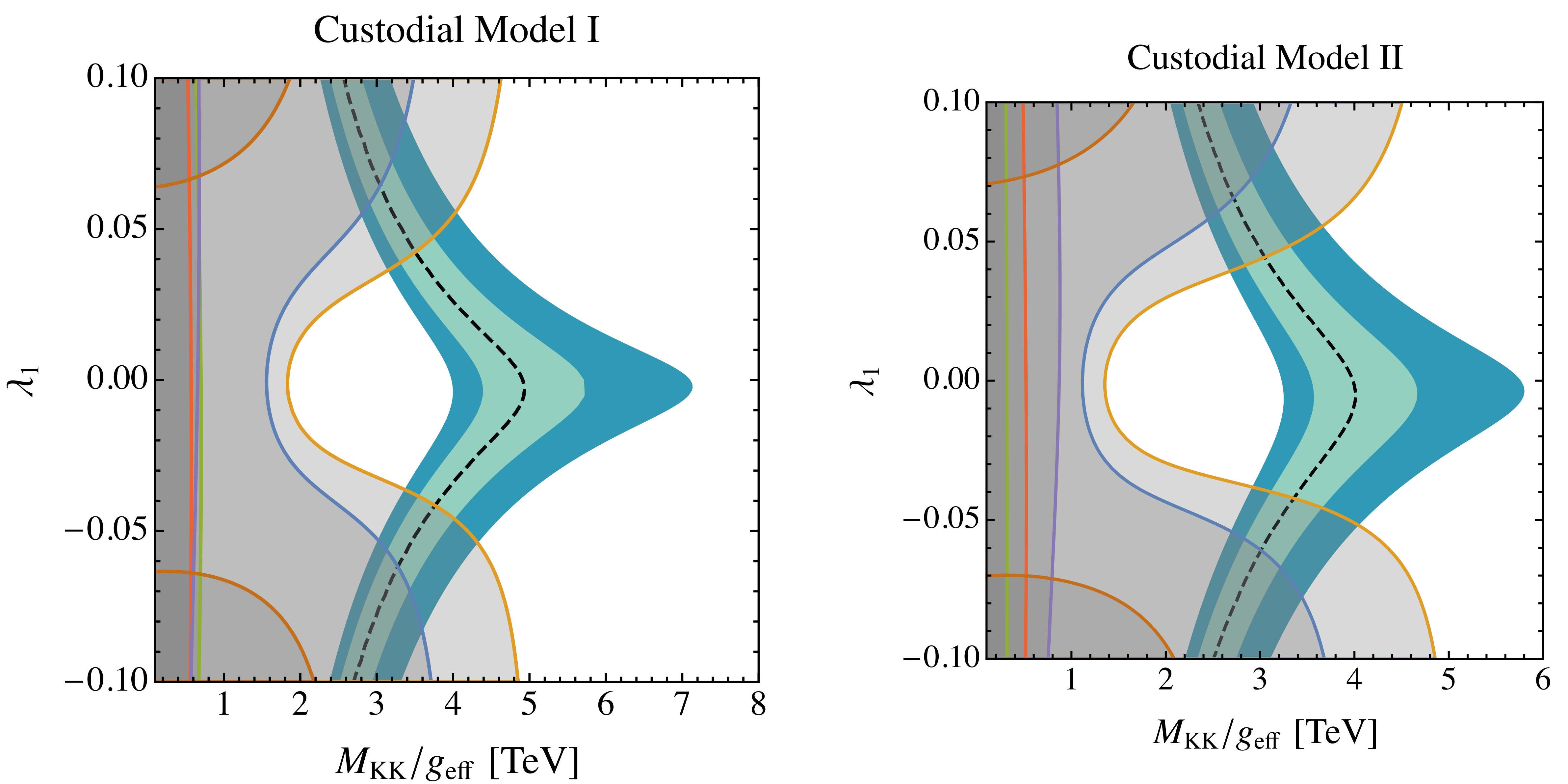
# The Localizer



# The Localizer

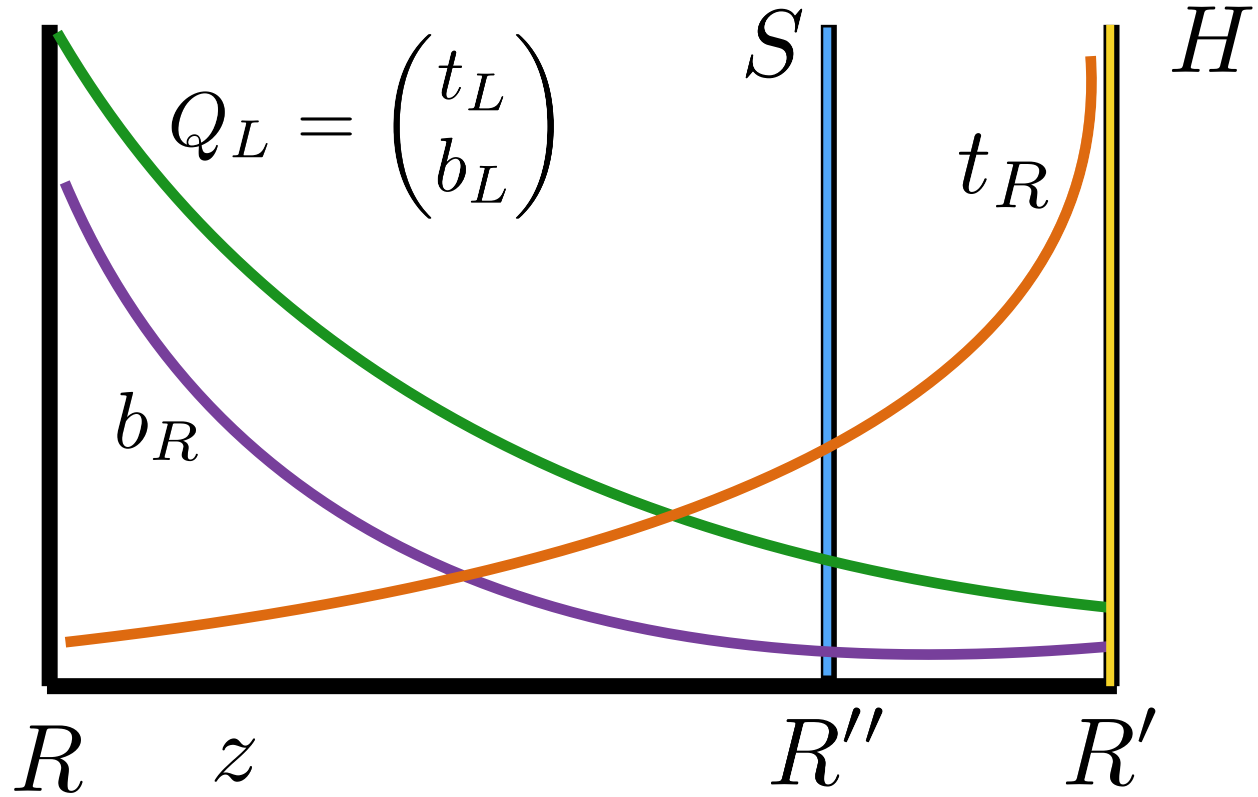
## Opening up the Higgs portal

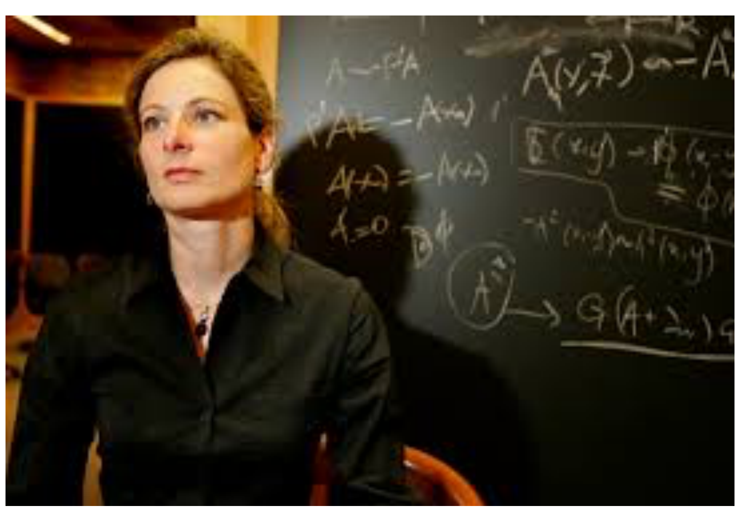
$$\delta\mathcal{L}_{\text{eff}} = -\lambda_1\, m_S\, S\, |\Phi|^2 - \frac{\lambda_2}{2}\, S^2\, |\Phi|^2 \ni -\frac{\lambda_1}{2}\, m_S\, S\, (v+h)^2 - \frac{\lambda_2}{4}\, S^2\, (v+h)^2 \,.$$



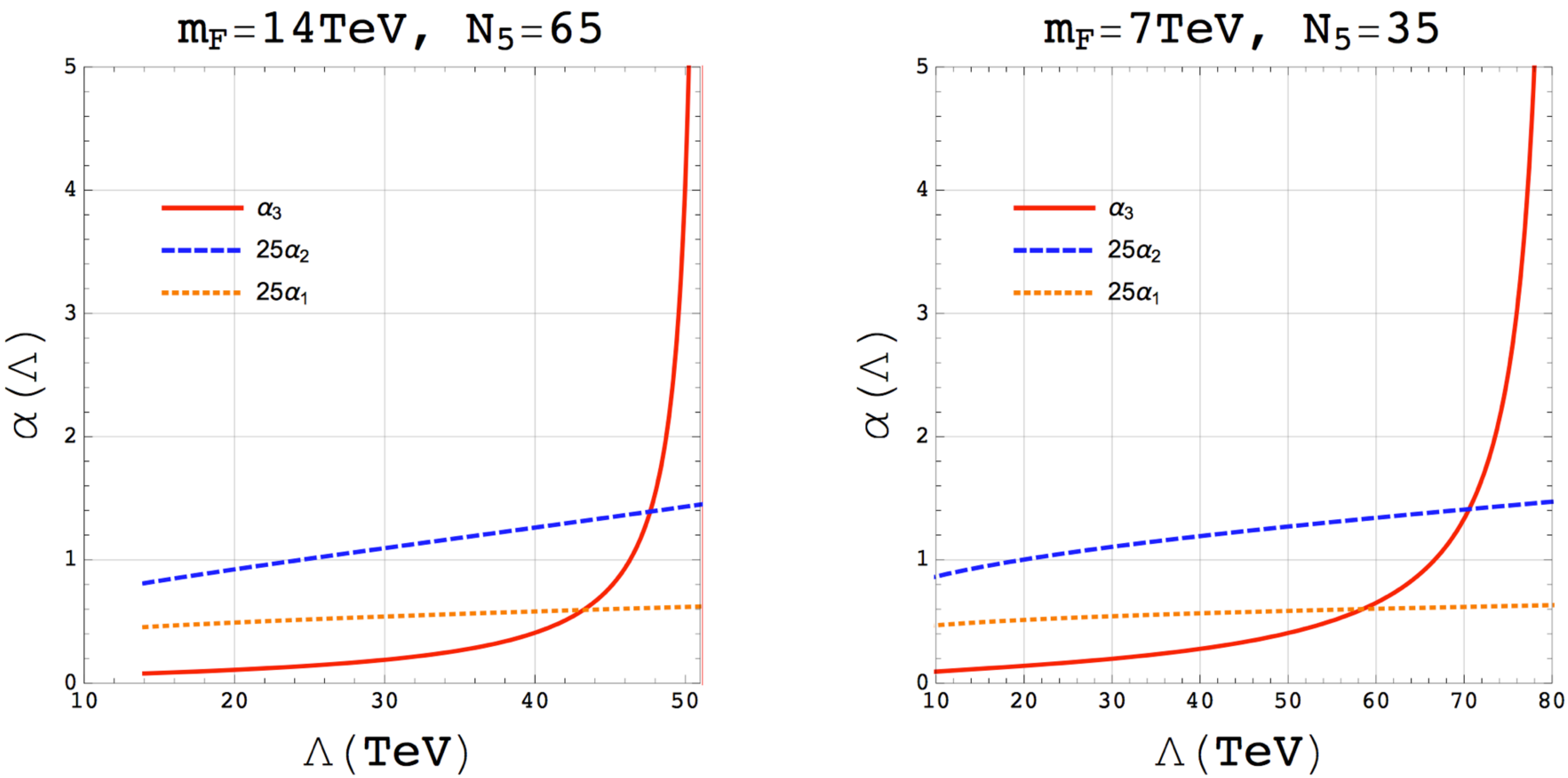
# The Localizer

The IR' brane



# Backup Sgoldstino




[arxiv:1603.05251]