Goldstino Couplings in MSSM

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[with I. Antoniadis, E. Dudas, D. Ghilencea]

Scales in standard ~~SUSY~~

$M_{Planck}\,,\ M_{mes}$ → **Scale of physics that communicates the breaking.**

$\sqrt{f}$ → **SUSY breaking scale.**

$\frac{f}{M_{Planck}}\,,\ \frac{\alpha}{4\pi}\frac{f}{M_{mes}}$ → **Mediated breaking scale.**

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What are the effects on MSSM of the ~~SUSY~~ physics?

Low scale ~~SUSY~~ ($f \ll M_{Planck}$)

Gravitino nearly massless (f/M_{Planck})

Interactions of its longitudinal component (goldstino) dominate over Planck suppressed interactions of the transverse components.

Goldstino couplings to matter.

Nonlinear SUSY

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Supersymmetry realized on a single fermion (goldstino)

$$\delta_\eta G_\alpha = f\eta_\alpha - \frac{i}{f}(G\sigma^\mu\bar{\eta} - \eta\sigma^\mu\bar{G})\partial_\mu G_\alpha \quad \Rightarrow \quad (\delta_\eta\delta_{\eta'} - \delta_{\eta'}\delta_\eta)G_\alpha = -2i(\eta\sigma^\mu\bar{\eta}' - \eta'\sigma^\mu\bar{\eta})\partial_\mu G_\alpha$$

Akulov, Volkov '73

Various languages have been developed for goldstino couplings:

"Geometric" approach,	Goldstino superfield,	Constrained Superfield
Akulov, Volkov '73	Ivanov, Kapustnikov '78	Rocek '78
Clark, Love '96	Samuel, Wess '83	
	Brignole, Feruglio, Zwirner '97	
	Antoniadis, Tuckmantel '04	

Here we use a formalism very similar to the Constrained Superfield.

Komargodski, Seiberg '09

Goldstino Couplings to Matter

Take chiral superfield ➡ $X_{nl} = \phi + \sqrt{2}\,\theta\,\psi + \theta\theta F$

Impose constraint ➡ $X_{nl}^2 = 0 \longrightarrow \phi = \frac{\psi\psi}{2F}$

- **The constraint is independent from the UV completion.**

Komargodski, Seiberg '09

- $\int d^4\theta\, X_{nl}^\dagger X_{nl} + \left(\int d^2\theta\, f\, X_{nl} + h.c.\right)$ **reproduces the Akulov - Volkov Lagrangian.**

MSSM + X_{nl}

Minimal coupling of X_{nl} to MSSM:

$$\begin{aligned}\mathcal{L} &= \int d^4\theta \left[X_{nl}^\dagger X_{nl} + \left(1 - \frac{m_i^2}{f^2} X_{nl}^\dagger X_{nl}\right) \Phi_i^\dagger e^{V_i} \Phi_i \right] \\ &+ \int d^2\theta \left[f X_{nl} + W(\Phi_i) + \frac{B_{ij}}{2f} X_{nl} \Phi_i \Phi_j + \frac{A_{ijk}}{6f} X_{nl} \Phi_i \Phi_j \Phi_k + \frac{1}{4}\left(1 + \frac{2m_\lambda}{f} X_{nl}\right) \mathrm{Tr}[W^\alpha W_\alpha] \right] + h.c.\end{aligned}$$

- **The goldstino couplings are set by the soft terms. No arbitrary scales or coefficients.**

- **Non Goldstino couplings are necessarily included.**

Nonlinear MSSM: Higgs sector

$$V = \tilde{m}_1^2\,|h_1|^2 + \tilde{m}_2^2\,|h_2|^2 + (B\,h_1 \cdot h_2 + h.c.) + \frac{g_1^2 + g_2^2}{8}\left(|h_1|^2 - |h_2|^2\right)^2 + \frac{g_2^2}{2}|h_1^\dagger h_2|^2$$

MSSM

$$+ \quad f^2 + \frac{1}{f^2}\left|m_1^2|h_1|^2 + m_2^2|h_2|^2 + B\,h_1 \cdot h_2\right|^2 + \mathcal{O}(f^{-3})$$

nonlinear

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$$m_h^2 = \left[m_Z^2 + \mathcal{O}(tan^{-2}\beta)\right] + \frac{v^2}{2f^2}\left[(2\mu^2+m_Z^2)^2 + \mathcal{O}(tan^{-2}\beta)\right] + O(f^{-3})$$

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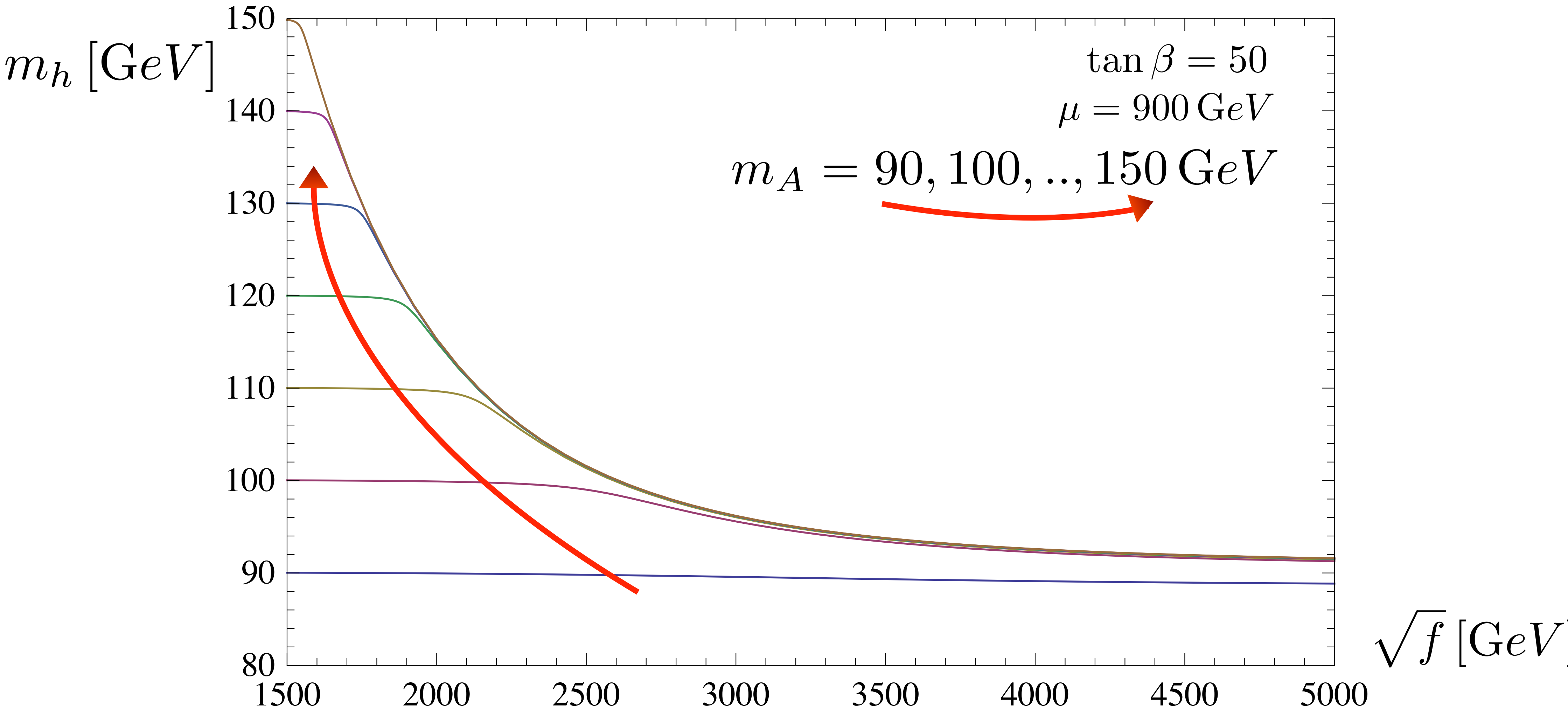
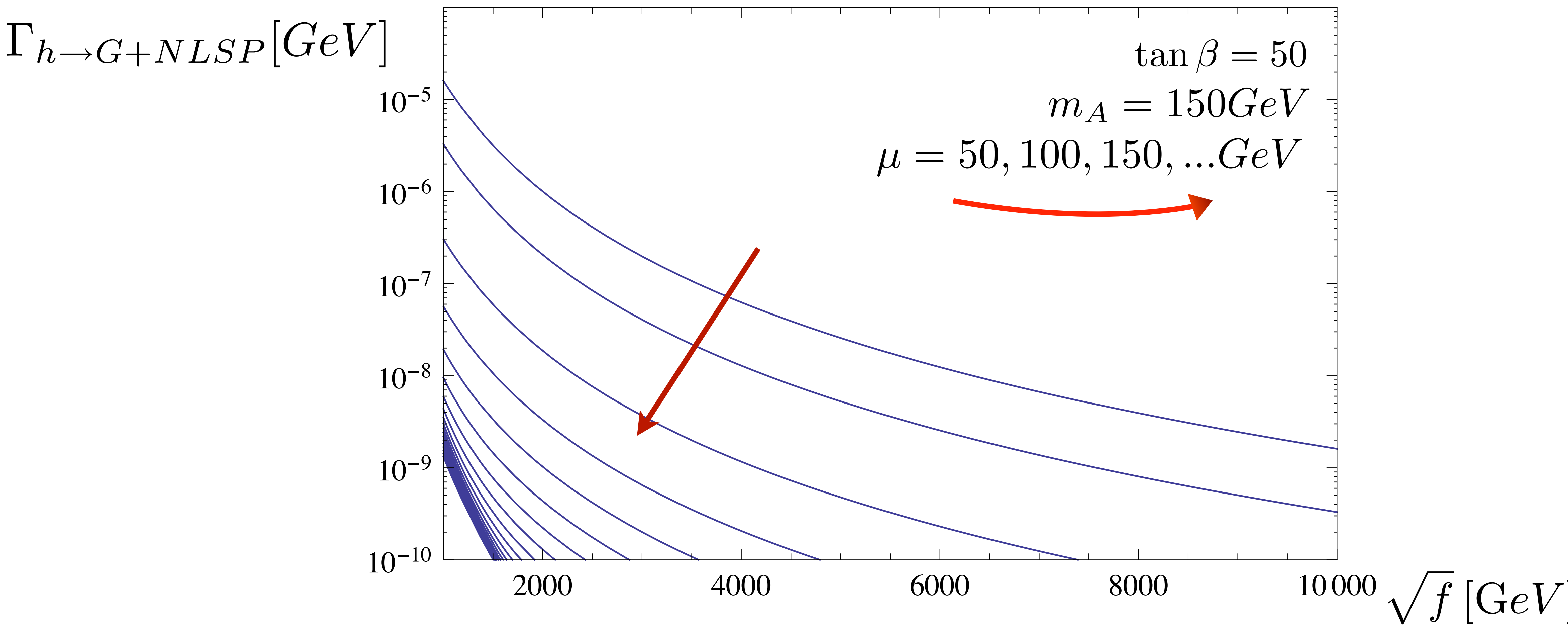


Nonlinear MSSM: New couplings

Invisible Higgs decay: $h \rightarrow G + NLSP$



Compare to SM Higgs (at 115 GeV) h → γ γ : 10^{-6} GeV

Dimopoulos, Thomas, Wells '96
Djouadi, Drees '97

Also invisible decay $Z \rightarrow G + NLSP$ **et c.**