Phenomenology of super-symmetric model inspired by inflation

Wolfgang G. Hollik, Cheng Li, Gudrid Moortgat-pick, Steven Paasch

Motivations

- Embedding inflation in collider phenomenology
- Distinguishing inflation-inspired SUSY models from SUSY models without inflation

NMSSM and Inflation

- Superpotential with non-minimal coupling

$$\mathcal{W}_{\text{Higgs}} \to \mathcal{W}_{\text{Higgs}} + \tfrac{3}{2}\, m_{3/2}\, \chi\, \hat{H}_u \cdot \hat{H}_d \qquad \mu_{\text{inf}} = \frac{3}{2} m_{3/2} \chi$$

- Higgs potential

$$\begin{aligned} V_{\text{Higgs}} = &\left(m_{H_d}^2 + (\mu_{\text{inf}} + \lambda S)^2\right) |H_d|^2 + \left(m_{H_u}^2 + (\mu_{\text{inf}} + \lambda S)^2\right) |H_u|^2 \\ &+ \left(\kappa S^2 + \lambda H_u \cdot H_d\right)^2 + \frac{g_2^2}{2} |H_d^\dagger H_u|^2 + \frac{g_1^2 + g_2^2}{8} \left(|H_d|^2 - |H_u|^2\right)^2 \\ &+ m_S^2 S^2 + 2\lambda A_\lambda S H_u \cdot H_d + \frac{2}{3} \kappa A_\kappa S^3 \,. \end{aligned}$$

$$\begin{aligned} -\mathcal{L}_{\text{soft}} = &\left[A_\lambda\, \lambda\, S\, H_u \cdot H_d + \frac{1}{3} A_\kappa\, \kappa\, S^3 + B_\mu\, \mu\, H_u \cdot H_d + \text{h. c.}\right] \\ &+ m_{H_d}^2\, |H_d|^2 + m_{H_u}^2\, |H_u|^2 + m_s^2\, |S|^2 \,. \end{aligned}$$

NMSSM benchmark point

- Fixed input parameters

$M_1 = 239$ GeV	$M_2 = 500$ GeV	$M_3 = 2500$ GeV	$A_{f_3} = 1200$ GeV
$m_{\tilde{f}_L, \tilde{f}_R} = 2000$ GeV	$M_A = 2000$ GeV	$\tan\beta = 12$	

- Random Scan interval
  - κ {0, 0.1}
  - λ {0, 0.1}
  - $|\mu_{\text{eff}}|$ {100, 1000} GeV
  - A_κ {-300, 300} GeV

NMSSM benchmark point

- Input parameters of benchmark point

$\kappa = 0.01846$	$\lambda = 0.04215$
$\mu_{\text{eff}} = -212.3$ GeV	$A_\kappa = 268.6$ GeV

- Benchmark mass spectrum:

$m_{h_1} = 96.99$ GeV	$m_{h_2} = 125.3$ GeV	$m_{H_3} = 1962$ GeV
$m_a = 273.7$ GeV	$m_A = 1962$ GeV	$m_{H^\pm} = 1964$ GeV
$m_{\tilde{\chi}_1^0} = 190.4$ GeV	$m_{\tilde{\chi}_2^0} = 194.2$ GeV	$m_{\tilde{\chi}_3^0} = 226.1$ GeV
$m_{\tilde{\chi}_4^0} = 255.1$ GeV	$m_{\tilde{\chi}_5^0} = 538.3$ GeV	
$m_{\tilde{\chi}_1^\pm} = 214.5$ GeV	$m_{\tilde{\chi}_2^\pm} = 538.3$ GeV	

Experimental Check

- HiggsBounds
  - Higgs production
    - LEP bounds
    - Tevatron bounds
    - LHC bounds
- CheckMATE
  - Neutralino & chargino production:
    - HL_LHC bounds
- HiggsSignal:

$$\chi^2 = 77.30283230$$

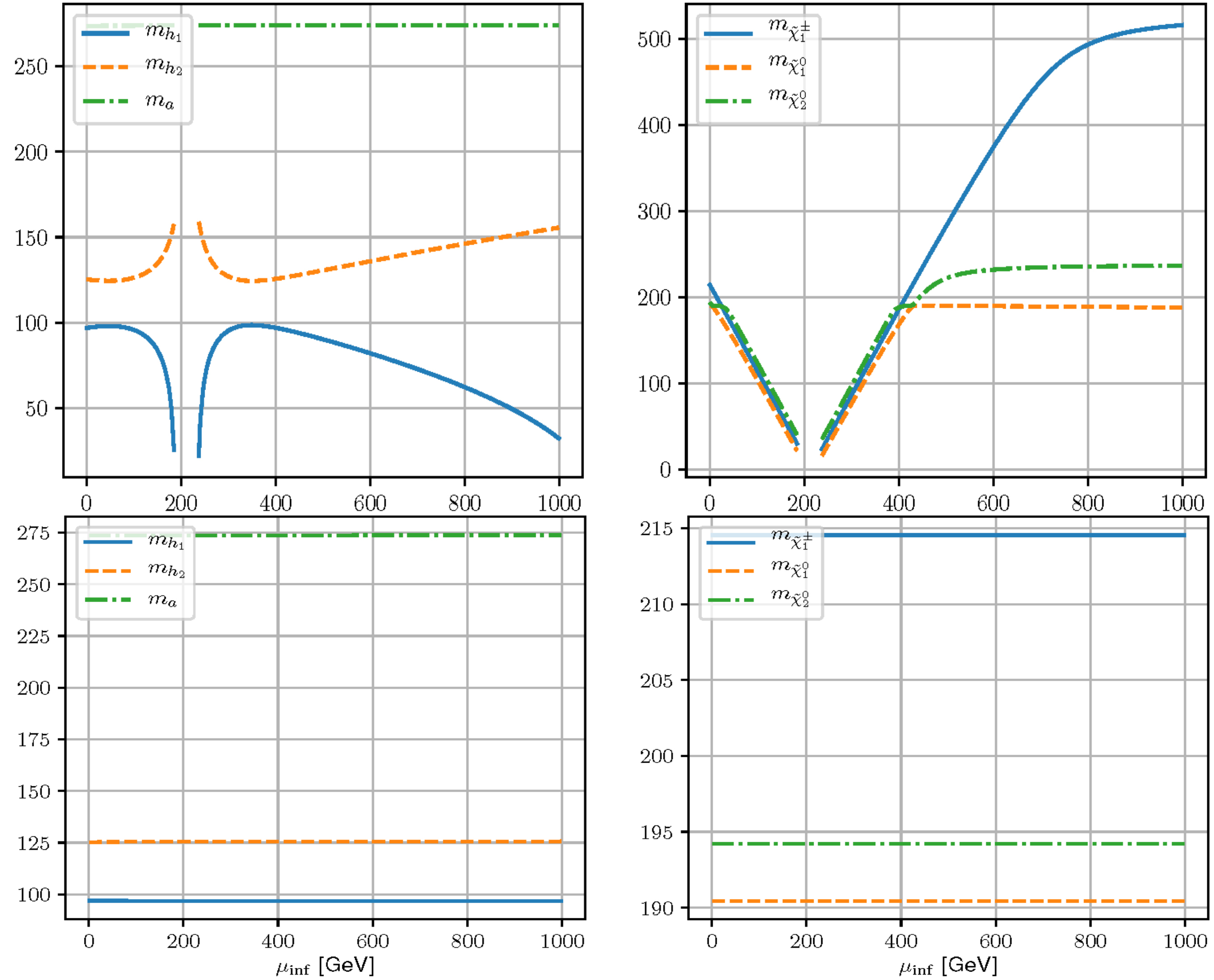
- Dark Matter relic density:

$$\Omega h^2 = 0.109070098$$

μNMSSM Scan

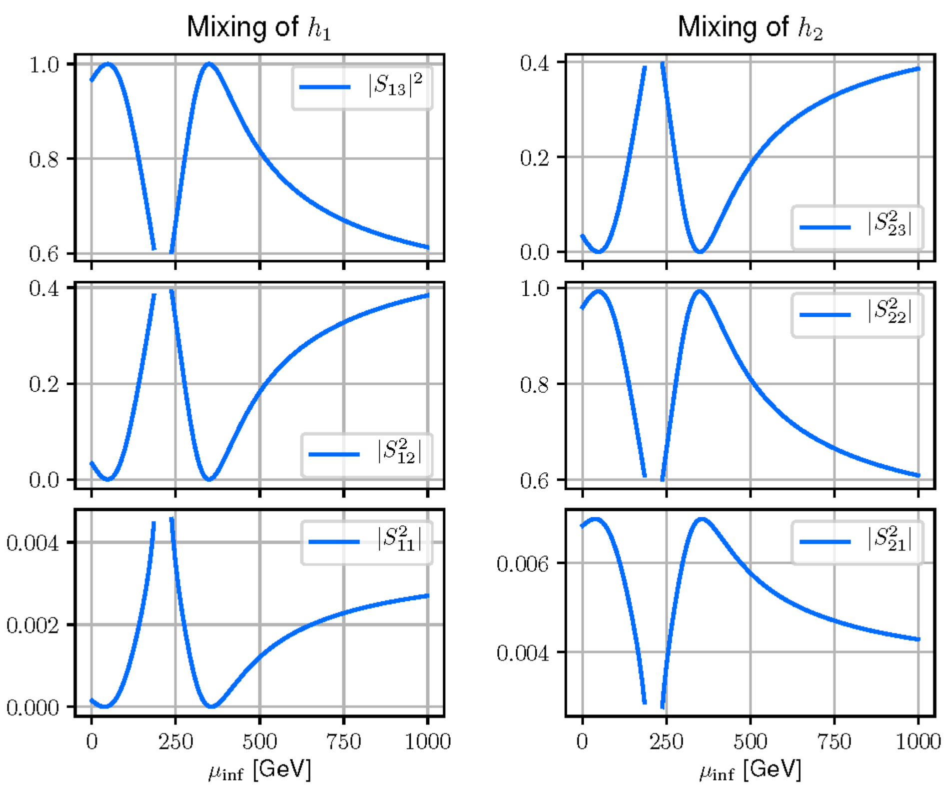
- “Direct” μ_{inf} scan
  - Vary μ_{inf} directly
- “Pure” μ_{inf} scan
  - Vary μ_{inf} with fixing combinations:

$$\mu_{\text{inf}} + \mu_{\text{eff}}, \qquad \frac{\kappa}{\lambda}\mu_{\text{eff}}$$

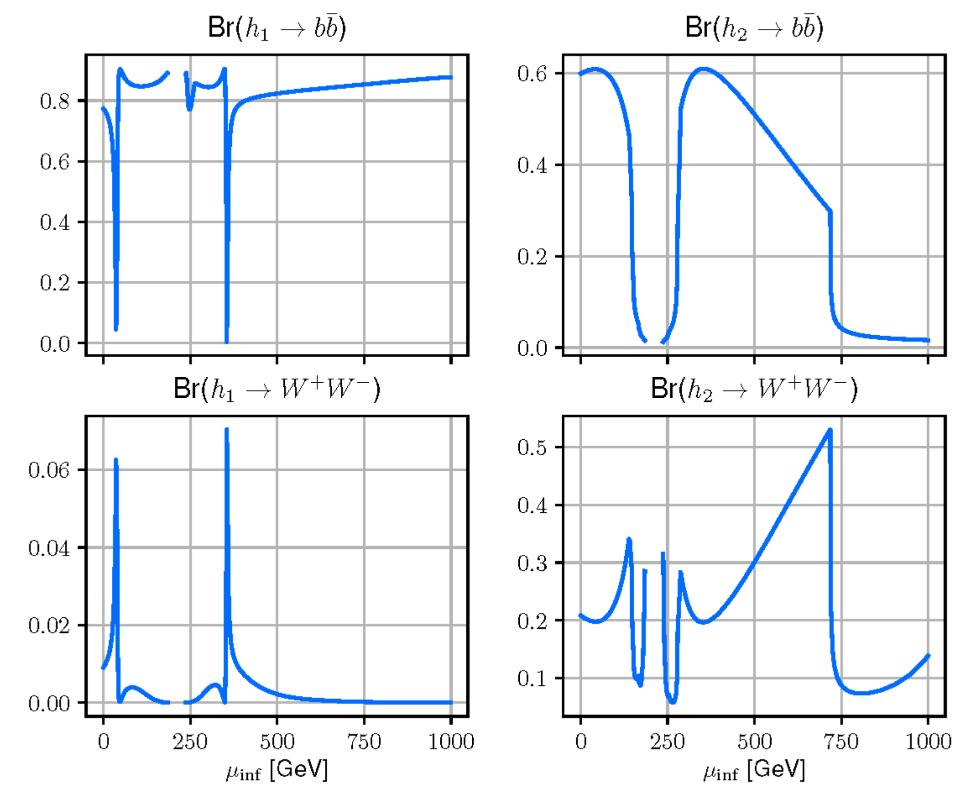


"Direct" μ_{inf} effects

- Mixings

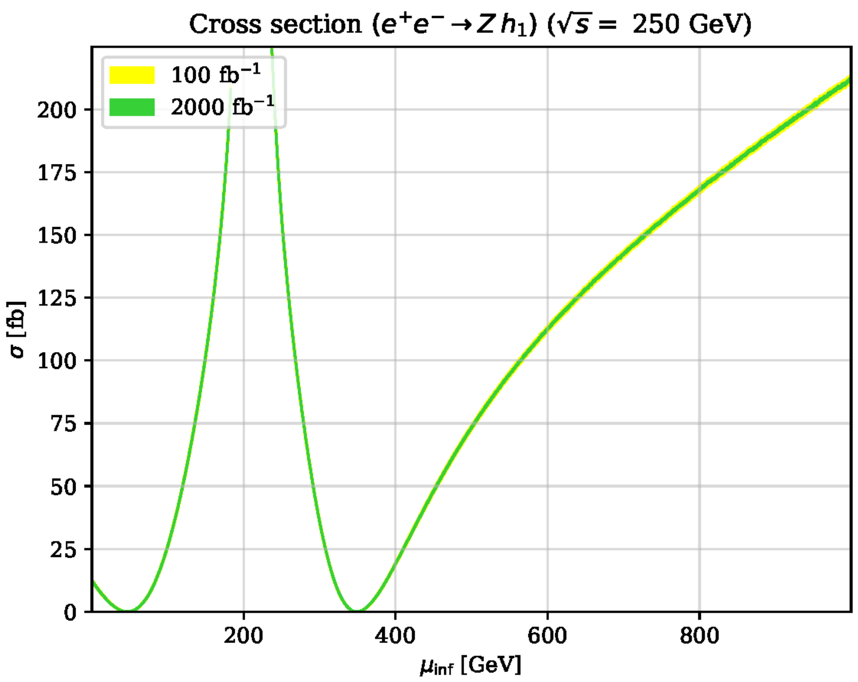


- Branching ratios

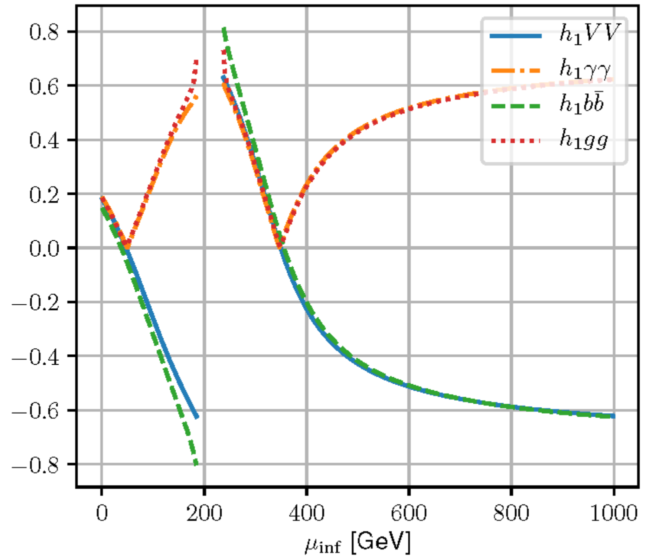


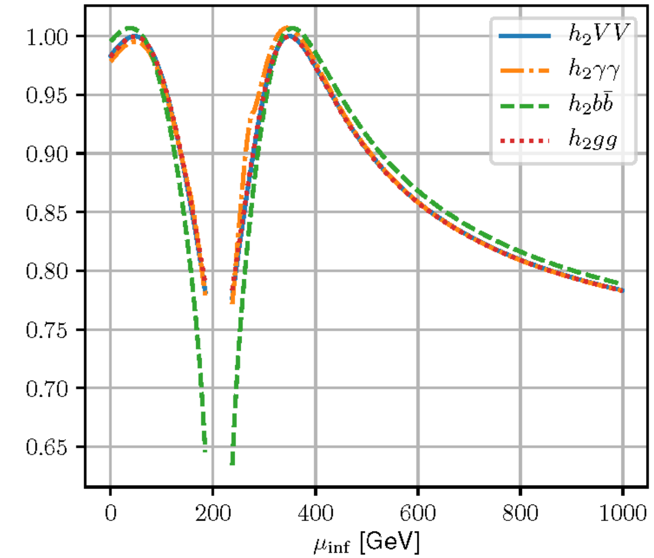
"Direct" μ_{inf} effects

- Cross-section



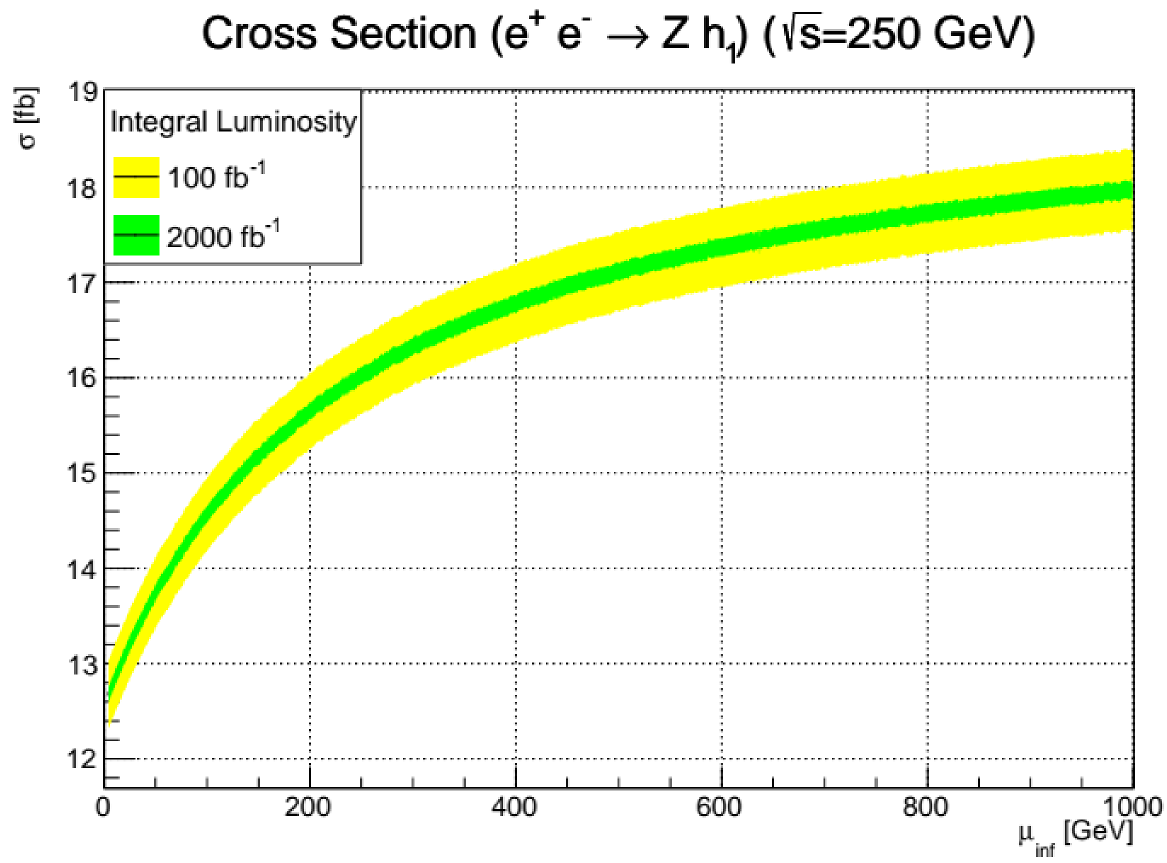
- Reduced couplings





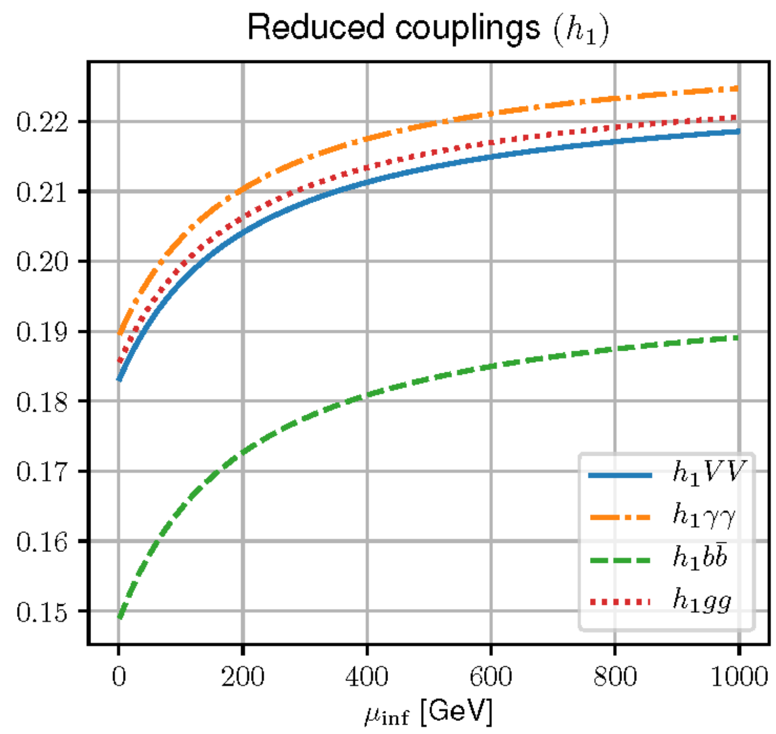
"Pure" μ_{inf} effects

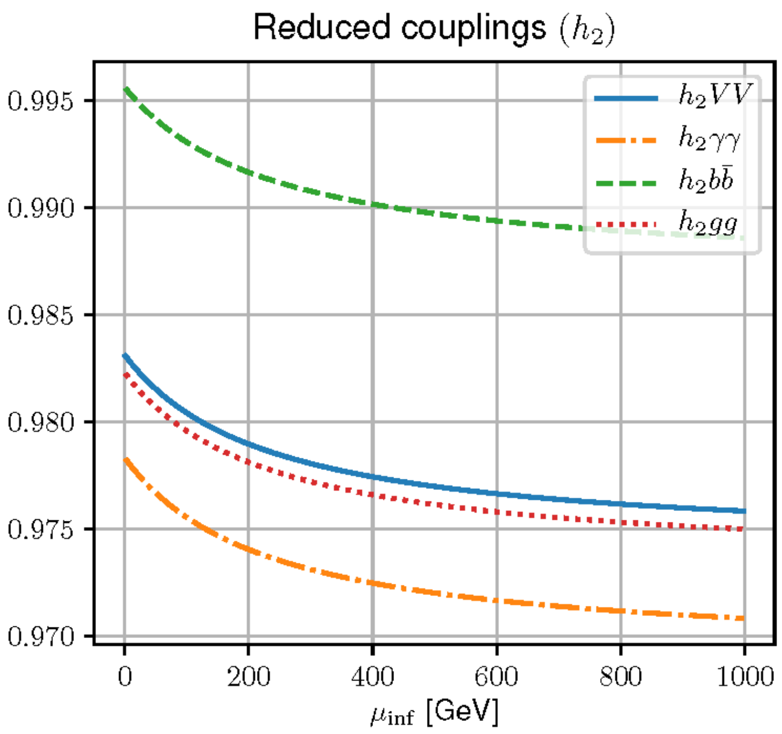
- Cross section



"Pure" μ_{inf} effects

- Reduced couplings
  - For h_2, deviations are ~1%.
  - For h_1, there are ~10% deviations





Conclusions

- We discussed phenomenological effect from μ_{inf}
- We found some experimental distinction between μNMSSM and normal NMSSM
- We studied reduced couplings and prodcution cross section of the 97 GeV light singlet-like Higgs state at ILC

Outlook

- One can study the μ_{inf} effect for heavy Higgs states

Backup

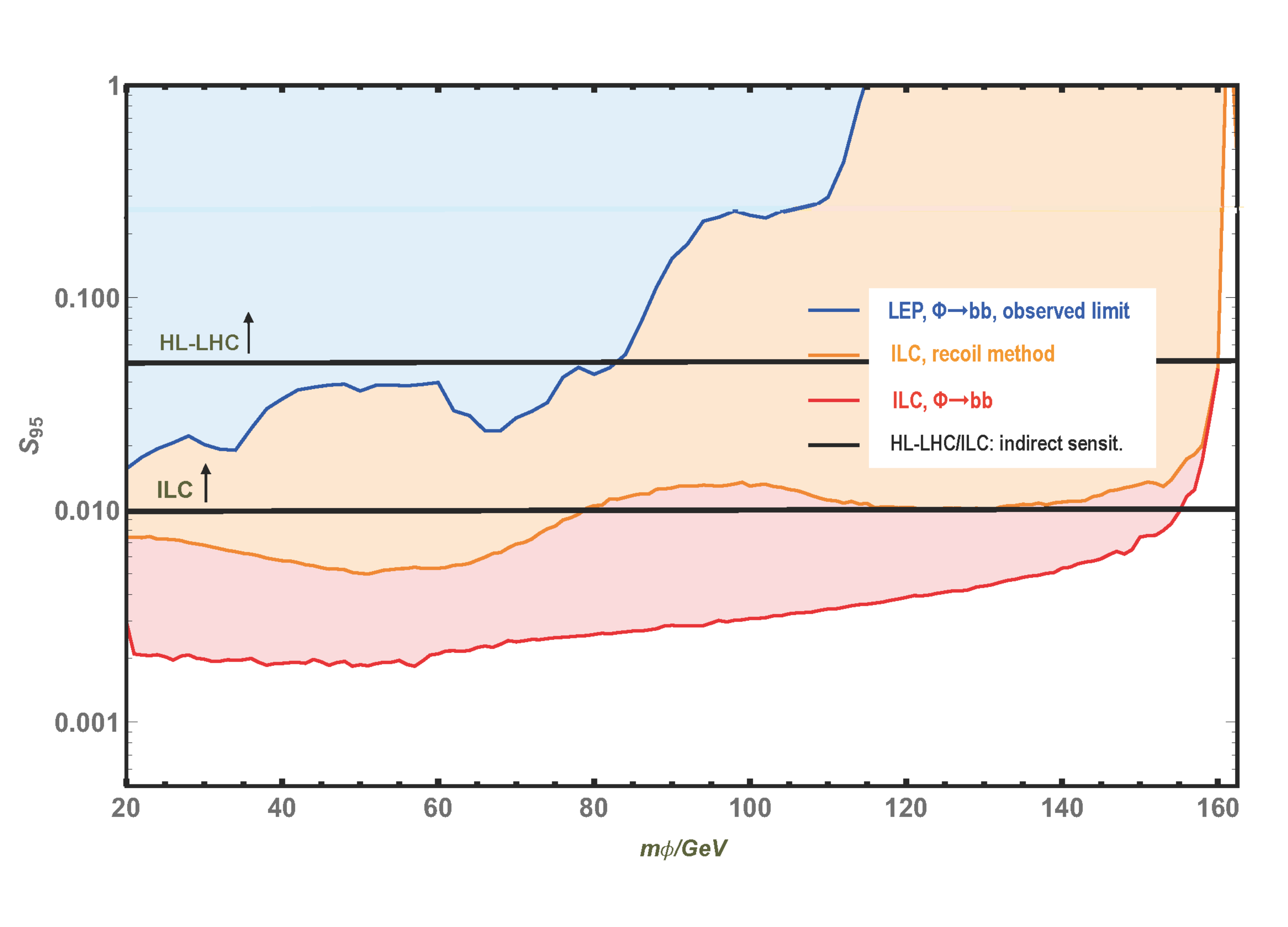
- Other NMSSM points

  $(\tan\beta=12,\quad M_A=800)$

κ=0.0298	λ=0.0726	μ_{eff}= -126.32	A_κ=15.06	M_1=341.998	M_2=253.065	A_{f3}=2000
M_{h1}=95.7	M_{h2}=124.6	M_a=48.87	$M_{\chi1+}$=121.9	$M_{\chi10}$=105.6	$M_{\chi20}$=112.0	$M_{\chi30}$=143.3

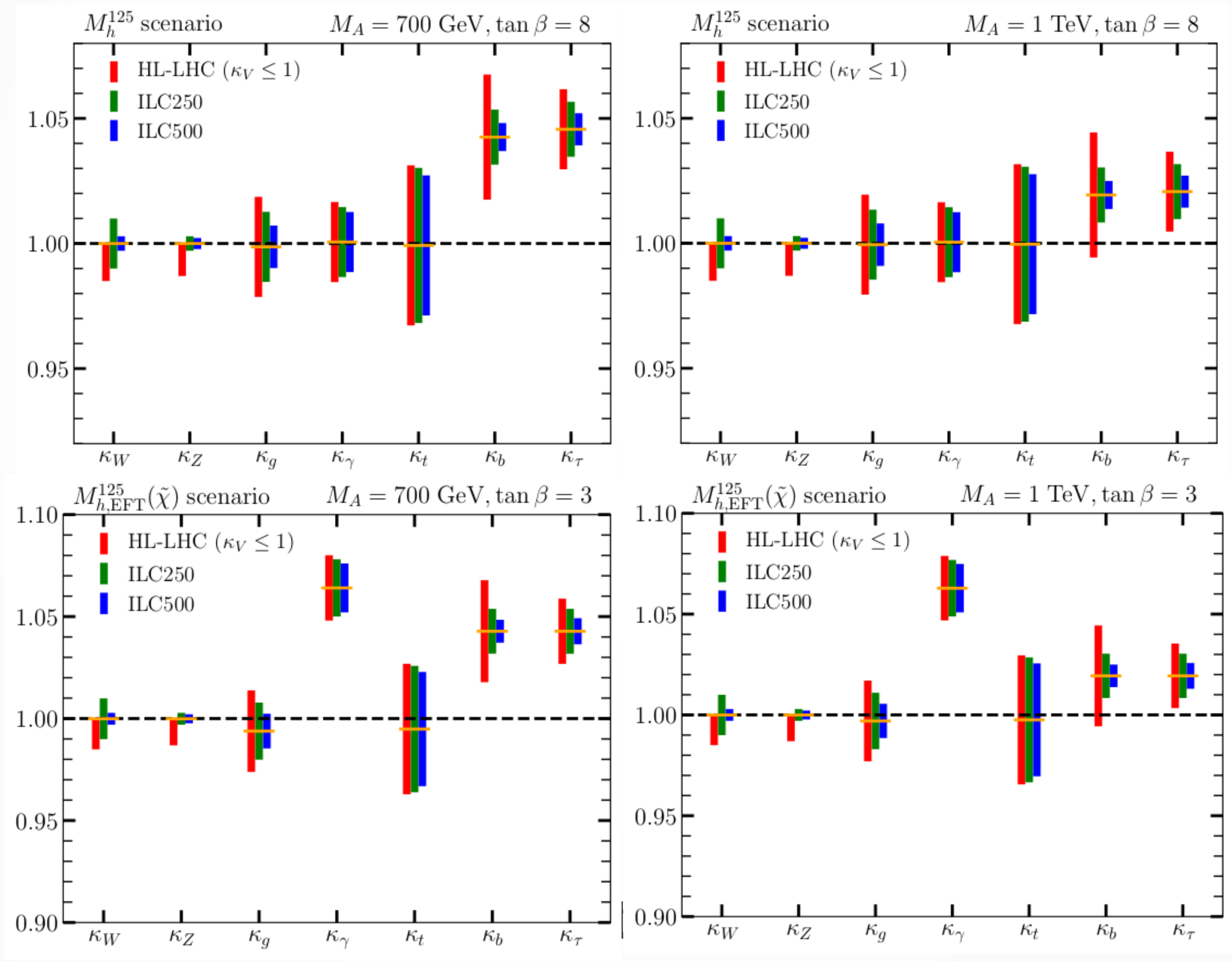
κ=0.0045	λ=0.0148	μ_{eff}= 247.51	A_κ=-130.65	M_1=286.04	M_2=193.51	A_{f3}=2500
M_{h1}=112.0	M_{h2}=125.3	M_a=172.3	$M_{\chi1+}$=170.68	$M_{\chi10}$=154.5	$M_{\chi20}$=166.8	$M_{\chi30}$=260.1

Backup



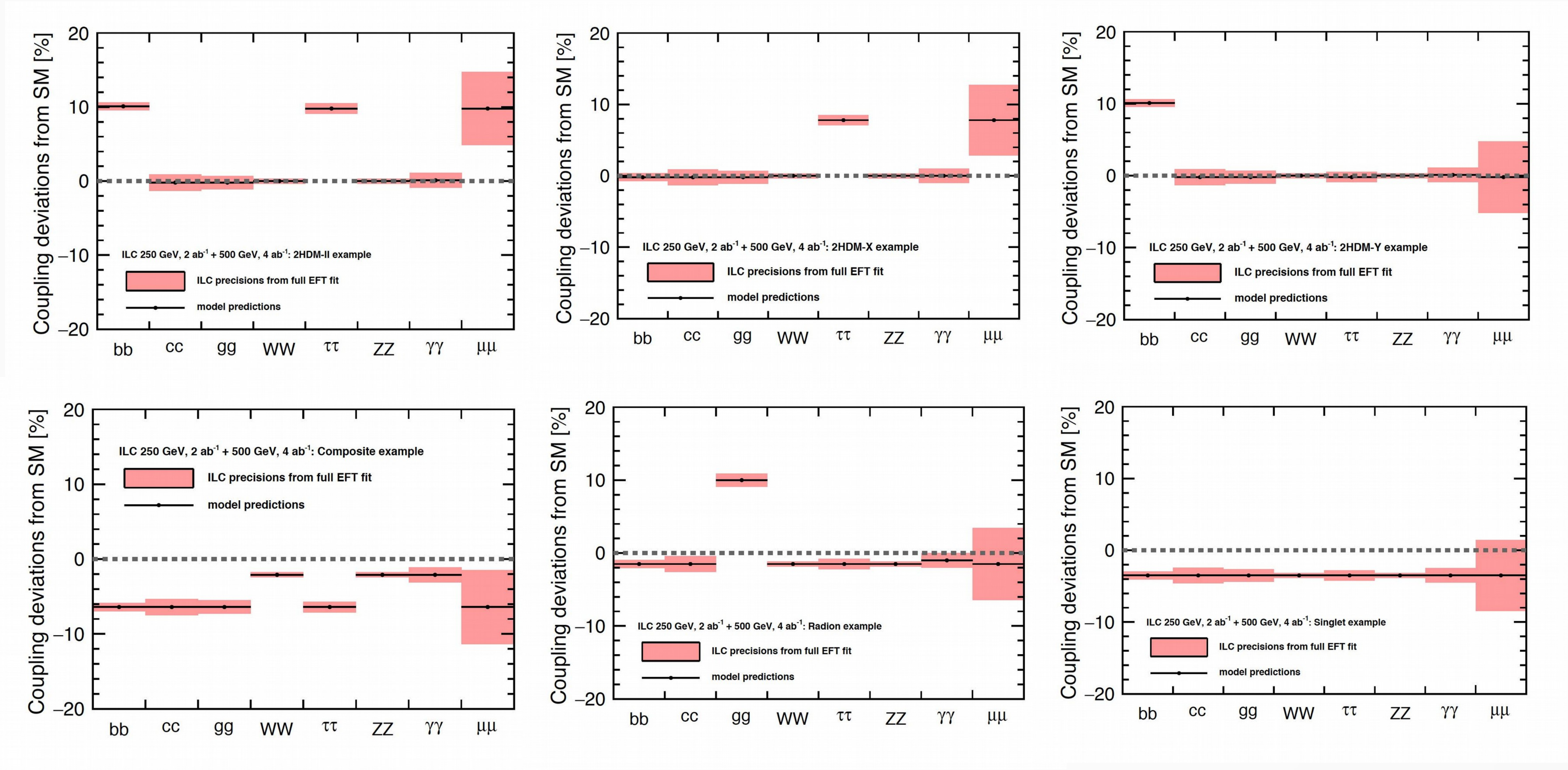
1
0.100
0.010
0.001
S_{95}
HL-LHC
ILC
LEP, Φ→bb, observed limit
ILC, recoil method
ILC, Φ→bb
HL-LHC/ILC: indirect sensit.
20
40
60
80
100
120
140
160
mϕ/GeV

Backup



M_h^{125} scenario
$M_A = 700$ GeV, $\tan\beta = 8$
$M_A = 1$ TeV, $\tan\beta = 8$
$M_{h,\mathrm{EFT}}^{125}(\tilde{\chi})$ scenario
$M_A = 700$ GeV, $\tan\beta = 3$
$M_A = 1$ TeV, $\tan\beta = 3$
HL-LHC ($\kappa_V \leq 1$)
ILC250
ILC500
κ_W κ_Z κ_g κ_γ κ_t κ_b κ_τ
0.90 0.95 1.00 1.05 1.10

Backup



Coupling deviations from SM [%]
20
10
0
−10
−20
bb
cc
gg
WW
ττ
ZZ
γγ
μμ
ILC 250 GeV, 2 ab⁻¹ + 500 GeV, 4 ab⁻¹: 2HDM-II example
ILC 250 GeV, 2 ab⁻¹ + 500 GeV, 4 ab⁻¹: 2HDM-X example
ILC 250 GeV, 2 ab⁻¹ + 500 GeV, 4 ab⁻¹: 2HDM-Y example
ILC 250 GeV, 2 ab⁻¹ + 500 GeV, 4 ab⁻¹: Composite example
ILC 250 GeV, 2 ab⁻¹ + 500 GeV, 4 ab⁻¹: Radion example
ILC 250 GeV, 2 ab⁻¹ + 500 GeV, 4 ab⁻¹: Singlet example
ILC precisions from full EFT fit
model predictions