Higgs decays into sfermions at 1 loop

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Outline

1. Overview of the Calculation
   - Diagrammatics
   - Renormalization Scheme
2. SPA numerical analysis
   - SPA & Tools
   - Results

Decays of Higgs bosons into sfermions

All decay channels

- Decays of Higgs bosons $h^0, H^0, A^0, H^\pm$ into all possible sfermions including crossed channels

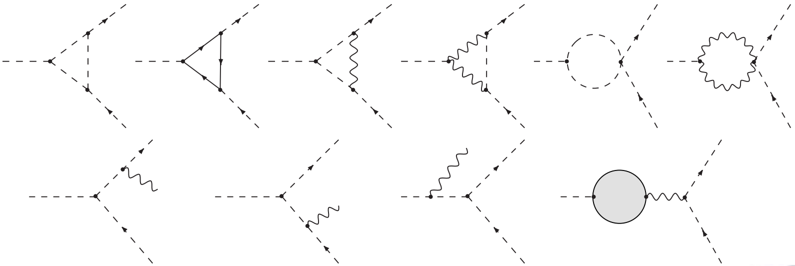
$$h^0, H^0, A^0 \longrightarrow \tilde{f}_i \tilde{f}_j \qquad H^\pm \longrightarrow \tilde{f}_i \tilde{f}_j^{,}$$

$$\tilde{f}_i \longrightarrow (h^0, H^0, A^0)\, \tilde{f}_j \qquad \tilde{f}_i \longrightarrow H^\pm \tilde{f}_j^{,}$$

Decays of Higgs bosons into sfermions
Diagrams and contributions

- Everything at one-loop incl. full QCD & EW corrections and gluon/photon radiation

Vertex diagrams

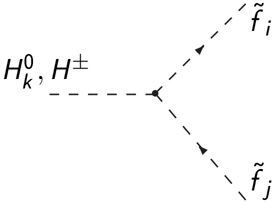


Bremsstrahlung diagrams & Higgs-Vector mixing

Renormalization Scheme

On-shell scheme and its problems

- Tree level



for A^0 the tree-level coupling is

$$G^{\tilde{f}}_{12} = \frac{i}{\sqrt{2}} h_f \left(A_f \begin{Bmatrix} \cos\beta \\ \sin\beta \end{Bmatrix} + \mu \begin{Bmatrix} \sin\beta \\ \cos\beta \end{Bmatrix} \right)$$

- On-shell renormalization
  - Couterterms δh_f, δA_f, $\delta\mu$, $\delta\tan\beta$
  - For large $\tan\beta$ $\longrightarrow$ δm_f, δA_f numerically large for bottom-type squarks

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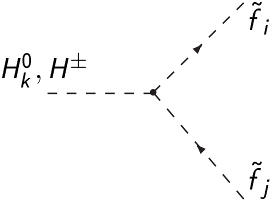

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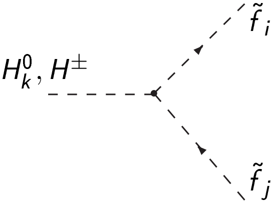

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Renormalization Scheme

Improvements - A_f & m_f running

- The counterterm δA_f fixed via the sfermion mixing matrix
- Large δA_f for large values of $\tan\beta$

$$\delta A_f = \delta\left(m_f \mu \begin{Bmatrix} \cot\beta \\ \tan\beta \end{Bmatrix}\right) - \delta m_f + \frac{1}{2}\left(\delta m^2_{\tilde{f}_1} - \delta m^2_{\tilde{f}_2}\right) \sin 2\theta_{\tilde{f}}$$

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- Use of A_f & m_f running necessary

$$A_f^{\overline{\mathrm{DR}}} + \delta^{\overline{\mathrm{DR}}} A_f = A_f^{OS} + \delta^{OS} A_f$$

$\rightarrow$ change the renormalization of the sfermion mixing angle

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SPA Project
Numerical analysis

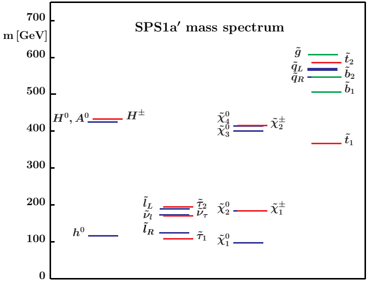
SPA CONVENTION

- The masses of the SUSY particles and Higgs bosons are defined as pole masses.
- All SUSY Lagrangian parameters, mass parameters and couplings, including $\tan\beta$, are given in the $\overline{\mathrm{DR}}$ scheme and defined at the scale $\tilde{M} = 1$ TeV.
- Gaugino/higgsino and scalar mass matrices, rotation matrices and the corresponding angles are defined in the $\overline{\mathrm{DR}}$ scheme at $\tilde{M}$, except for the Higgs system in which the mixing matrix is defined in the on-shell scheme, the momentum scale chosen as the light Higgs mass.
- The Standard Model input parameters of the gauge sector are chosen as G_F, α, M_Z and $\alpha_s^{\overline{\mathrm{MS}}}(M_Z)$. All lepton masses are defined on-shell. The t quark mass is defined on-shell; the b, c quark masses are introduced in $\overline{\mathrm{MS}}$ at the scale of the masses themselves while taken at a renormalization scale of 2 GeV for the light u, d, s quarks.

SPA Project
Numerical analysis

SPS1a' benchmark point

g'	0.36354	M_1	103.01
g	0.64804	M_2	192.84
g_s	1.08412	M_3	571.44
Y_τ	0.09958	A_τ	-249.8
Y_t	0.88176	A_t	-487.7
Y_b	0.13143	A_b	-766.9
μ	362.35	$\tan\beta$	10.0
$M^2_{L_1}$	$3.7821 \cdot 10^4$	$M^2_{L_3}$	$3.7513 \cdot 10^4$
$M^2_{E_1}$	$1.8399 \cdot 10^4$	$M^2_{E_3}$	$1.7773 \cdot 10^4$
$M^2_{Q_1}$	$28.177 \cdot 10^4$	$M^2_{Q_3}$	$23.416 \cdot 10^4$
$M^2_{U_1}$	$26.198 \cdot 10^4$	$M^2_{U_3}$	$16.734 \cdot 10^4$
$M^2_{D_1}$	$25.972 \cdot 10^4$	$M^2_{D_3}$	$25.682 \cdot 10^4$
$M^2_{H_1}$	$3.2864 \cdot 10^4$	$M^2_{H_2}$	$-11.804 \cdot 10^4$



SPA numerical analysis

DRbar2OS & SPheno

Tools used in numerical evaluation - SPheno & DRbar2OS

- In MSSM beyond tree-level - parameters interdependent
- Parameter plot implies varying a parameter $\rightarrow$ more parameters are actually varied
- Calculation in on-shell scheme (with A_f and m_f running) - transformation from SPA necessary
- SPA parameters varied and transformed for each single parameter point
- SPheno - transforms SPA to pure $\overline{\mathrm{DR}}$ parameter set
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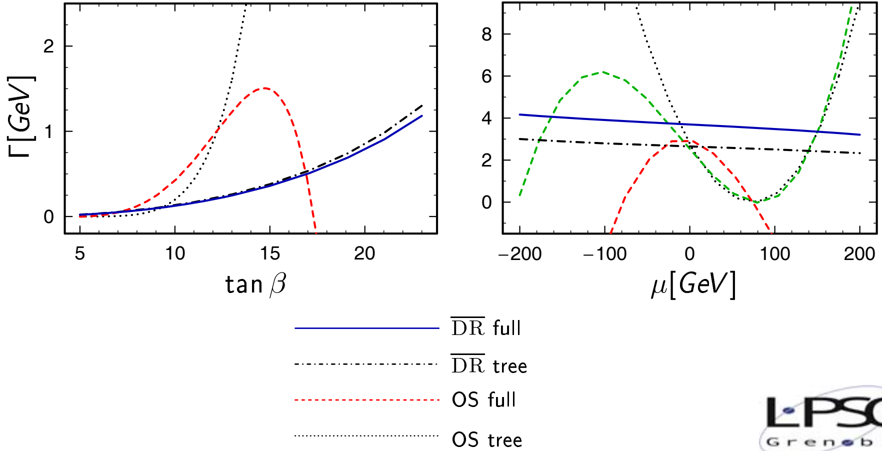
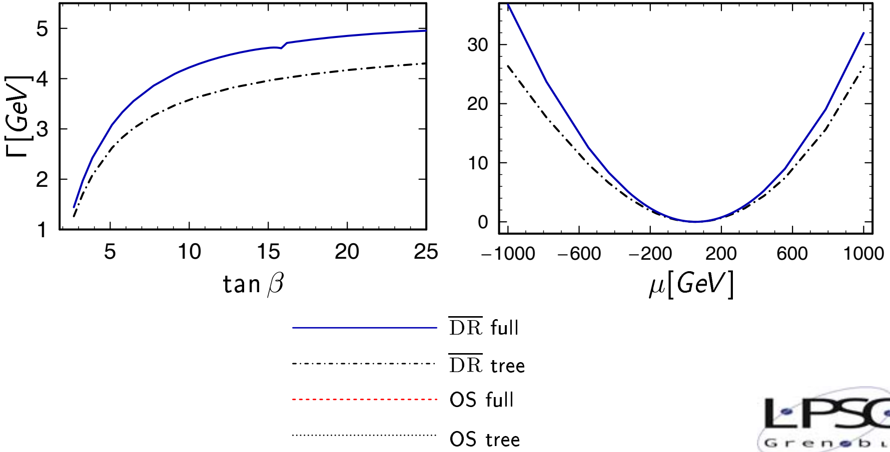
SPS1a' parameter shift - $m_{D_3} \rightarrow 150\ GeV \quad m_{A^0} \rightarrow 1000\ GeV$



$A^0 \longrightarrow \tilde{t}_1 \tilde{t}_2$

SPS1a' parameter shift - $m_{U_3} \rightarrow 150\ GeV$ $m_{A^0} \rightarrow 1000\ GeV$



$H^+ \longrightarrow \tilde{t}_1 \tilde{b}_2$

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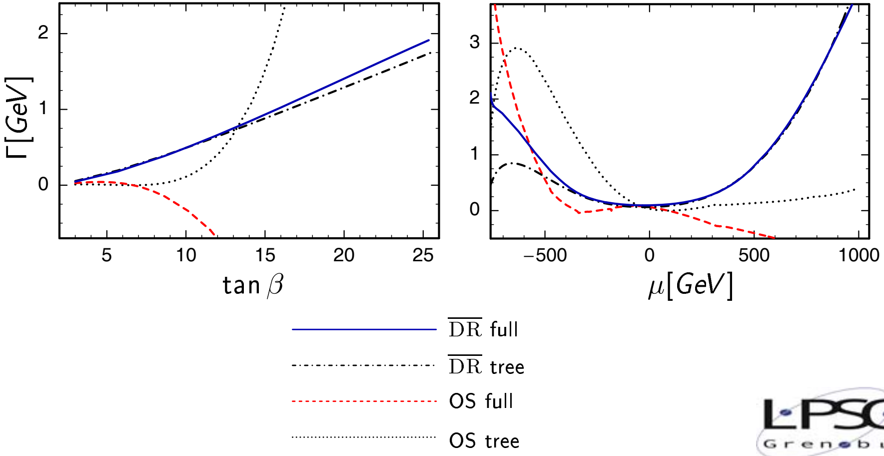

Summary

- All Higgs decays into sfermions (or crossed-channels) calculated to one-loop
- Pure on-shell scheme not appropriate - A_f, m_f taken running
- SPA analysis for decays possible for on-shell renormalization scheme using `SPheno` & `DRbar2OS`

- Outlook
  - Inclusion of the result in a package calculating all Higgs decay-channels to one-loop