SFOLD - a program package for calculating two-body sfermion decays at full one-loop level in the MSSM

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Abstract

SFOLD (Sfermion Full One Loop Decays) is a Fortran program package for calculating all sfermion two-body decay widths and the corresponding branching ratios at full one-loop level within the MSSM. The package adopts the SUSY Parameter Analysis convention and supports the SUSY Les Houches Accord input and output format. With the SFOLD package we found non-negligible electroweak corrections in bosonic decays of \( \tilde{b}, \tilde{t} \) and \( \tilde{\tau} \).

Keywords: Supersymmetry; Loop calculations; MSSM sfermion decays

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Operating system: Linux
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Number of processors used:
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External routines/libraries: SLHALib 2.2
Subprograms used: LoopTools 2.6
Nature of problem:
If the MSSM is realized in nature, LHC will produce supersymmetric particles copiously. The best environment for a precise determination of the model parameters would be a high energy $e^+e^-$ linear collider. Experimental accuracies are expected at the per-cent down to the per-mill level. These must be matched from the theoretical side. Therefore loop calculations are mandatory.
Solution method:
This program package calculates all sfermion two-body decay widths and the corresponding branching ratios at full one-loop level within the MSSM. The renormalization is done in the DR scheme following the SUSY Parameter Analysis convention. The program supports the SUSY Les Houches Accord input and output format.
Restrictions:

Unusual features:

Additional comments:

Running time:

1. Introduction

Supersymmetry (SUSY) is widely regarded as the most appealing extension of the Standard Model (SM). Among supersymmetric theories, the Minimal Supersymmetric Standard Model (MSSM) is the most extensively studied. If the MSSM is realized in nature, LHC will produce supersymmetric particles copiously. The best environment for a precise determination of the model parameters would be a high energy $e^+e^-$ linear collider. Experimental accuracies are expected at the per-cent down to the per-mill level [1, 2, 3]. These must be matched from the theoretical side. Therefore loop calculations are mandatory.

There are a few program packages available for the automatic computation of amplitudes at full one-loop level in the MSSM: FeynArts/FormCalc [4], SloopS [5, 6] and GRACE/SUSY-loop [7]. SloopS and GRACE/SUSY-loop also perform renormalization at one-loop level. However, so far there
is no publicly available code for the two-body sfermion decays at full one-loop level within the MSSM. Therefore, we have developed the Fortran code SFOLD \cite{8} (and HFOLD \cite{9,10}). Like HFOLD, it adopts the renormalization prescription of the SUSY Parameter Analysis project (SPA) \cite{11} and supports the SUSY Les Houches Accord (SLHA) input and output format \cite{12}. The package SFOLD (Sfermion Full One-Loop Decays) computes all two-body decay widths and the corresponding branching ratios of all sfermions at full one-loop level.

Full one-loop radiative corrections to decays of sfermions into charginos and neutralinos are discussed in \cite{13} for all sfermion flavours and generations. Yukawa corrections to sbottom decay into lighter stop and charged Higgs boson are given in \cite{14}. SUSY-QCD corrections to top and bottom squark decays into all Higgs bosons are calculated in \cite{15}. SUSY-QCD corrections to stop and sbottom decays into weak bosons can be found in \cite{16}. Finally, SUSY-QCD corrections to squark decays to gluinos are given in \cite{17}. Up to now, the electroweak corrections to sfermion decays into Higgs and gauge bosons have not been fully addressed. It turns out that also these corrections cannot be neglected in a significant part of the parameter space.

2. MSSM sfermion sector at tree-level

2.1. Masses and mixing angles

The mass matrix in the gauge eigenstates basis ($\tilde{f}_L, \tilde{f}_R$) is of the form \cite{18}

$$ M^2_{\tilde{f}} = \begin{pmatrix} m^2_{\tilde{f}_L} & a_f m_f \\ a_f m_f & m^2_{\tilde{f}_R} \end{pmatrix} $$

(1)

where

$$ m^2_{\tilde{f}_L} = M^2_{\tilde{Q},\tilde{L}} + (f^3_R - e_f s^2_W) \cos 2\beta M^2_Z + m^2_f $$

(2)

$$ m^2_{\tilde{f}_R} = M^2_{\tilde{U},\tilde{D},\tilde{E}} + e_f s^2_W \cos 2\beta m^2_Z + m^2_f $$

(3)

$$ a_f = A_f - \mu^* (\tan \beta)^{-2 f^3_L} $$

(4)

The mass eigenstates are obtained by diagonalizing $M^2_{\tilde{f}}$ with a unitary matrix

$$ R^f = (\cos \theta_f, \sin \theta_f; -\sin \theta_f, \cos \theta_f) $$

$$ \text{diag}(m^2_{\tilde{f}_1}, m^2_{\tilde{f}_2}) = R^f M^2_{\tilde{f}} (R^f)^\dagger $$

(5)
leading to the following sfermion masses and the mixing angle

\[
m^2_{\tilde{f}_{1,2}} = \frac{1}{2} \left( m^2_{\tilde{f}_L} + m^2_{\tilde{f}_R} \mp \sqrt{(m^2_{\tilde{f}_L} - m^2_{\tilde{f}_R})^2 + 4|a_f|^2m^2_f} \right)
\]

\[
\cos \theta_{\tilde{f}} = \frac{-a_f m_f}{\sqrt{(m^2_{\tilde{f}_L} - m^2_{\tilde{f}_1})^2 + |a_f|^2m^2_f}}
\]

In the case of stop, sbottom and stau the left and right states are generally mixed. In contrast, sfermions from first and second generation have negligible Yukawa couplings. Therefore, \( \tilde{f}_1 = \tilde{f}_L, \tilde{f}_2 = \tilde{f}_R \) if \( (M^2_{\tilde{f}})_{11} < (M^2_{\tilde{f}})_{22} \) and \( \tilde{f}_1 = \tilde{f}_R, \tilde{f}_2 = \tilde{f}_L \) if \( (M^2_{\tilde{f}})_{11} > (M^2_{\tilde{f}})_{22} \).

2.2. Decay patterns

There are four possibilities of Feynman graphs for a two-body decay of a scalar: the decay into two scalars, into two fermions, into scalar and a vector particle and into two vector particles. The fourth possibility is not realized in the decay of a sfermion in the MSSM. The following sfermion decays are calculated (the first generation is shown, \( i, j, c = 1, 2; n = 1, \ldots, 4 \)):

| \( \tilde{\nu}_e \rightarrow \nu_e \tilde{\chi}^0_n \) | \( \tilde{e}_i \rightarrow e \tilde{\chi}^0_n \) | \( \tilde{u}_i \rightarrow u \tilde{\chi}^0_n \) | \( \tilde{d}_i \rightarrow d \tilde{\chi}^0_n \) |
| --- | --- | --- | --- |
| \( \tilde{\nu}_e \rightarrow e \tilde{\chi}^+ \) | \( \tilde{e}_i \rightarrow \nu_e \tilde{\chi}^- \) | \( \tilde{u}_i \rightarrow \tilde{\nu} \tilde{\chi}^- \) | \( \tilde{d}_i \rightarrow \tilde{u} \tilde{\chi}^- \) |
| \( \tilde{\nu}_e \rightarrow H^+ \tilde{e}_j \) | \( \tilde{e}_i \rightarrow H^- \tilde{\nu}_e \) | \( \tilde{u}_i \rightarrow H^+ \tilde{u}_j \) | \( \tilde{d}_i \rightarrow H^+ \tilde{d}_j \) |
| \( \tilde{\nu}_e \rightarrow W^+ \tilde{e}_j \) | \( \tilde{e}_i \rightarrow h^0 \tilde{e}_j \) | \( \tilde{u}_i \rightarrow h^0 \tilde{u}_j \) | \( \tilde{d}_i \rightarrow h^0 \tilde{d}_j \) |
| \( \tilde{e}_i \rightarrow H^0 \tilde{e}_j \) | \( \tilde{u}_i \rightarrow H^0 \tilde{u}_j \) | \( \tilde{d}_i \rightarrow H^0 \tilde{d}_j \) |
| \( \tilde{e}_i \rightarrow A^0 \tilde{e}_j \) | \( \tilde{u}_i \rightarrow A^0 \tilde{u}_j \) | \( \tilde{d}_i \rightarrow A^0 \tilde{d}_j \) |
| \( \tilde{e}_i \rightarrow \tilde{e}_j Z \) | \( \tilde{u}_i \rightarrow \tilde{\nu}_j Z \) | \( \tilde{d}_i \rightarrow \tilde{u}_j Z \) |
| \( \tilde{e}_i \rightarrow \tilde{e}_j W^- \) | \( \tilde{u}_i \rightarrow \tilde{d}_j W^+ \) | \( \tilde{d}_i \rightarrow \tilde{u}_j W^- \) |

If the squark decay into a gluino is kinematically allowed it will dominate due to the QCD interaction. The third generation \( \tilde{f}_2 \) can decay into \( \tilde{f}_1 \) and a neutral boson if there is sufficiently large mass splitting. For stops and sbottoms with large mass differences, decays into charged boson and a sfermion are possible.

3. Calculation at full one-loop level

The calculation of the decay widths is done in the same way as in the HFOLD program. We work in the DR (dimensional reduction) renormaliza-
tion scheme and in the general linear $R_\xi$ gauge for the $W^\pm$ and $Z^0$-boson. We wrote a Mathematica program that generated the whole Fortran code using the packages FeynArts (FA) and FormCalc (FC). In FA all particle couplings in the MSSM are implemented. We kept the divergent parts of the counterterms to examine the UV finiteness of the renormalized amplitudes. The IR divergence is removed by using soft bremsstrahlung or by adding a corresponding 1 to 3 process (hard bremsstrahlung) for which we calculated all formulae analytically. The IR finiteness can be checked by varying the photon (gluon) mass $\lambda$. Finally, we implemented several switchers that are described in sections 5.5, 5.6.

4. Input parameters

At the program start, SFOLD reads the file in SLHA format, where the Yukawa couplings, the gauge couplings $g_1, g_2, g_3$, gaugino masses, the soft breaking terms, the VEV, $m_A, \tan \beta, \mu$ are taken as input parameters at the scale $Q$. These parameters may be further changed. In that case, SFOLD recalculates on-shell masses of Susy particles and does not take them from the input file.

5. Program manual

5.1. Requirements

- Fortran 77 (g77, ifort, gfortran)
- C compiler (e.g. gcc)
- LoopTools-2.6 [19]
- SLHALib-2.2 [20]

5.2. About version 1.0

- The CKM matrix is set diagonal
- Real SUSY input parameters
- One-loop corrections to Higgs masses
- Absence of three-particle sfermion decays
5.3. Installation

1. Download the file `sfold.tar.gz` at
   [http://www.hephy.at/tools](http://www.hephy.at/tools)
2. Unpack the archive by
   ```bash
tar -xvzf sfold.tar.gz
```
3. Go to the sfold folder and create symbolic links named LoopTools and SLHALib by
   ```bash
   ln -s ../path../LoopTools-m.n LoopTools
   ln -s ../path../SLHALib-m.n SLHALib
   ```
4. Then run
   ```bash
   ./configure
   make
   ```
5. That will generate an executable called `sfold`. To run SFOLD type
   ```bash
   ./sfold
   ```

5.4. Further notes

- To use an older version of LoopTools you have to
  - change the ‘call ltini’ to ‘call ffini’ in decay.F file
  - include `A00`, `A00C` in `looptools.h` file
- LoopTools and SLHALib are installed correctly if folders `ix86-linux/bin` and `ix86-linux/include` were created. (The name `ix86-linux` varies according to the system.) We further expect that the following files are present in the mentioned folders: `looptools.h`, `libooptools.a`, `SLHA.h`, `libSLHA.a`.

5.5. The input file `sfold.in`

1. **name of input file (SLHA format)**
2. **type = 1, 2, 3, 4,**
   - `1 = sneutrino`, `2 = slepton`, `3 = sup type`, `4 = sdown type`
3. **generation = 1, 2, 3**
4. sfermion index = 1,2

5. bremsstrahlung = 0,1,2
   0 = off, 1 = hard, 2 = soft

6. resummation of bottom yukawa coupling = 0,1
   0 = off, 1 = on

7. esoftmax
   cut on the soft photon (gluon) energy if soft strahlung is used

8. name of output file

5.6. The file sfold.F

Further parameters, switchers and options are:

- \texttt{delta\_in} divergent part of loop integrals
- \texttt{lambda\_in} photon (gluon) mass
- \texttt{Qscale} scale at which \( \overline{\text{DR}} \) parameters are defined
- \texttt{xiW, xiZ} gauge parameters \( \xi_W, \xi_Z \)
- \texttt{localchangesOn} If set to 0, on-shell masses are taken from SLHA input file. If set to 1, on-shell masses are calculated through self energies. (Must be set to 1, if some of the input parameters described in section 4 are changed.) Masses can be seen in \texttt{masses.out} file.
- \texttt{osextmassesOn} If set to 0, \( \overline{\text{DR}} \) masses in kinematics. If set to 1, on-shell masses in kinematics.
- \texttt{osloopmassesOn} If set to 0, \( \overline{\text{DR}} \) masses in vertex corrections. If set to 1, on-shell susy masses in vertex corrections. (This is to avoid a trap when a process is not kinematically allowed with respect to \( \overline{\text{DR}} \) masses.)
- \texttt{SMPRINTON} If defined, prints the SM parameters.
- \texttt{MSSMPRINTON} If defined, prints the MSSM parameters.
- \texttt{NO\_SQUARK\_MIXING} If defined, squark mixing is switched off.

If any changes are done to \texttt{sfold.F} file, it is necessary to run \texttt{make} first.
5.7. Working in Mathematica

To work with SFOLD in Mathematica, the SPheno package (version 3.1.0) is required additionally. To establish a link:

1. Compile the sfold with Mmakefile by
   \texttt{make -f Mmakefile} \hspace{1cm} \text{(or make -f Mmakefile-mac)}
2. Open the \texttt{sfold.nb} file
3. Go to the terminal and type
   \texttt{./Msfold -linkcreate &}
4. Copy the output, return to \texttt{sfold.nb} file and install link by
   \texttt{link=Install[LinkConnect["...output..."]]}\hspace{1cm}
5. Evaluate the cell. (It may be further necessary to go to the terminal and press Enter.) Continue working in the nb file.

It is further necessary to:

1. Specify the path to the SPheno executable
   \texttt{SPhenoPath = ".\...path.../SPheno"}
2. Setting the Directory to sfold directory
   \texttt{SetDirectory["...path.../sfold"]}

We provided the user with six examples. The first one calculates the partial widths of a sfermion at a specified mSugra point, the second one at a specified MSSM point, the third one as a function of the mSugra parameter, the fourth one as a function of the GMSB parameter, the fifth one as a function of the AMSB parameter and the sixth one as a function of the MSSM parameter.

The input parameters are the same parameters as in \texttt{sfold.in} and \texttt{sfold.F} file except for the names of the SLHA input and output file which are set to be \texttt{SPheno.spc, sfold.out}, respectively.

The following functions and auxiliary lists are implemented:
| Function                  | Description                                                                 |
|---------------------------|-----------------------------------------------------------------------------|
| MakeSphenoSPCmsugra[]     | create the file SPheno.spc. At first, LesHouches.in file is created and then |
| msugraPara                | SPheno is called. s_string is the path to the SPheno executable, l_list is   |
|                          | the list of the corresponding model parameters.                            |
| s_string                  |                              | msugraPara                     |
| gmsbPara                  | Decay[] calculates the partial widths of the specified sfermion.            |
|                          | The rows correspond to decay modes, the first column is the tree level result, |
|                          | the second is SUSY-QCD and the third one is the full result.               |
|                          | Decay[] is the list of the corresponding model parameters (see msugraPara,  |
|                          | gmsbPara, amsbPara above).                                                 |
| amsbPara                  | GetDM[] returns the particular decay mode of the specified particle.        |
|                          | GetDM[] is the list of the appropriate decay mode index.                     |
|                          |                               |                               |
|                          | MakeSphenoSPCGmsb[]            | MakeSphenoSPCGmsb[]            |
| mgsbPara                  | MakeSphenoSPCGmsb[s_string, l_list]                                       |
|                          | MakeSphenoSPCamsb[]            | MakeSphenoSPCamsb[s_string, l_list] |
| amsbPara                  | MakeSphenoSPCmssm[]            | MakeSphenoSPCmssm[s_string, l_list] |
| mssmPara                  | MakeSphenoSPCmssm[s_string, l_list]                                       |
|                          | MakeSphenoSPCmsugra[s_string, l_list]                                      |
|                          | MakeSphenoSPCGmsb[s_string, l_list]                                        |
|                          | MakeSphenoSPCamsb[s_string, l_list]                                        |
|                          | MakeSphenoSPCmssm[s_string, l_list]                                        |

6. Electroweak corrections in bosonic decays

We give a few examples using the Sfold package. First, we focus on the $\tilde{b}_2$ decay. Figure 1 shows the partial widths as a function of the mSugra parameter $m_0$. Other parameters are: $m_{\tilde{b}_2} = am_0^2 + bm_0 + c$, $\tan \beta = 3$, $\text{sign}(\mu) = 1$, $A_0 = 0$, where $a, b, c$ are chosen such that the whole parabola lies just above the excluded region in Figure 2 of reference [23]. The parabola
goes through the points [40, 330], [450, 300] and [740, 120]. For Figure 2 we took \( \tan \beta = 10 \) and \( A_0 = -300 \). Here the dominant decay is the decay into \( \tilde{t}_1 \) and \( W^- \) if \( m_0 \lesssim 200 \).

| \( \Gamma \) [GeV] | 100 | 200 | 300 | 400 |
|-----------------|-----|-----|-----|-----|
| 0.5             |     |     |     |     |
| 0.4             |     |     |     |     |
| 0.3             |     |     |     |     |
| 0.2             |     |     |     |     |
| 0.1             |     |     |     |     |
| 0.0             |     |     |     |     |
| \( m_0 \) [GeV] | 100 | 200 | 300 | 400 |
| 0.5             |     |     |     |     |
| 0.4             |     |     |     |     |
| 0.3             |     |     |     |     |
| 0.2             |     |     |     |     |
| 0.1             |     |     |     |     |
| 0.0             |     |     |     |     |

Figure 1: \( \tilde{b}_2 \) decays, \( \tan \beta = 3, A_0 = 0 \); red: \( t\tilde{\chi}^0_1 \), green: \( t\tilde{\chi}^0_2 \), blue: \( b\tilde{\chi}^0_1 \), gold: \( t\tilde{\chi}^0_2 \), violet: \( t\tilde{\chi}^0_3 \), cyan: \( t\tilde{\chi}^0_4 \), orange: \( b\tilde{g} \), purple: \( t_1 W^- \). The solid lines correspond to the full one-loop result, dashed line to the SUSY-QCD result, dotted line to the tree level result.

It is clearly seen that the electroweak corrections can reach about 20%. They cannot be neglected also in \( \tilde{\tau}_2 \rightarrow h_0 \tilde{\tau}_1 \) as follows from Figure 3. Here the \( \tilde{\tau}_2 \) partial widths are functions of the MSSM parameter \( \mu \). Other MSSM parameters are: \( M_1 = 100, M_2 = 200, M_3 = 600, A_u = A_d = 0, A_e = -400, A_c = A_s = 0, A_\mu = -400, A_l = -600, A_b = -900, A_\tau = -400, m_{\tilde{A}_0} = 140 \), \( \tan \beta = 10, M_{\tilde{L}} = 250, M_{\tilde{E}} = 100, M_{\tilde{Q}} = M_{\tilde{U}} = M_{\tilde{D}} = 500 \).

7. Comparison of SFOLD with SPheno 3.0beta and SUSY-HIT 1.3

In the following tables we compare the third generation sfermion partial decay widths with SPheno 3.0beta and SUSY-HIT 1.3 at the SPS1a’ point. In SUSY-HIT, the QCD corrections to the decays \( \tilde{q} \rightarrow \tilde{\chi}^\pm + q' \), \( \tilde{q} \rightarrow \tilde{q} + H^\pm \) and \( \tilde{q} \rightarrow \tilde{g} + q \) are implemented.
Figure 2: \( \tilde{b}_2 \) decays, \( \tan \beta = 10, A_0 = -300 \); red: \( t \tilde{\chi}^-_1 \), green: \( t \tilde{\chi}^-_2 \), blue: \( b \tilde{\chi}^0_1 \), gold: \( t \tilde{\chi}^0_2 \), violet: \( t \tilde{\chi}^0_3 \), cyan: \( t \tilde{\chi}^0_4 \), orange: \( b \tilde{g} \), purple: \( \tilde{t}_1 W^- \). The solid lines correspond to the full one-loop result, dashed line to the SUSY-QCD result, dotted line to the tree level result.

Figure 3: \( \tilde{\tau}_2 \) decays; red: \( \nu_\tau \tilde{\chi}^-_1 \), green: \( \nu_\tau \tilde{\chi}^-_2 \), blue: \( \tau \tilde{\chi}^0_1 \), gold: \( \tau \tilde{\chi}^0_2 \), violet: \( \tau \tilde{\chi}^0_3 \), cyan: \( \tau \tilde{\chi}^0_4 \), orange: \( h_0 \tilde{\tau}_1 \), purple: \( \tilde{\tau}_1 Z \). The solid lines correspond to the full one-loop result, dashed line to the SUSY-QCD result, dotted to the tree level result.
| $\tilde{\nu}_\tau$ | BR-tree | SF-tree | SF-sqcd | SF-full | SPheno | SUSY-HIT |
|-----------------|---------|--------|--------|--------|--------|---------|
| $\nu_\tau \chi_1^0$ | 1.00 | 0.1166 | 0.1166 | 0.1124 | 0.1166 | 0.1099 |

Table 1: Comparison of the partial decay widths of $\tilde{\nu}_\tau$

| $\tilde{\tau}_1$ | BR-tree | SF-tree | SF-sqcd | SF-full | SPheno | SUSY-HIT |
|-----------------|---------|--------|--------|--------|--------|---------|
| $\tau \chi_1^0$ | 1.00 | 0.0166 | 0.0166 | 0.0161 | 0.0166 | 0.0123 |

Table 2: Comparison of the partial decay widths of $\tilde{\tau}_1$

| $\tilde{\tau}_2$ | BR-tree | SF-tree | SF-sqcd | SF-full | SPheno | SUSY-HIT |
|-----------------|---------|--------|--------|--------|--------|---------|
| $\nu_\tau \chi_1^-$ | 0.08 | 0.0148 | 0.0148 | 0.0151 | 0.0147 | 0.0089 |
| $\tau \chi_1^0$ | 0.87 | 0.1548 | 0.1548 | 0.1481 | 0.1548 | 0.1513 |
| $\tau \chi_2^0$ | 0.04 | 0.0080 | 0.0080 | 0.0080 | 0.0080 | 0.0044 |

Table 3: Comparison of the partial decay widths of $\tilde{\tau}_2$

| $\tilde{t}_1$ | BR-tree | SF-tree | SF-sqcd | SF-full | SPheno | SUSY-HIT |
|------------|---------|--------|--------|--------|--------|---------|
| $t \chi_1^0$ | 0.23 | 0.3023 | 0.3004 | 0.2901 | 0.3023 | 0.3139 |
| $t \chi_2^0$ | 0.05 | 0.0640 | 0.0674 | 0.0656 | 0.0640 | 0.0755 |
| $b \chi_1^0$ | 0.72 | 0.9628 | 0.9747 | 0.9771 | 0.9771 | 0.1034 |

Table 4: Comparison of the partial decay widths of $\tilde{t}_1$

| $\tilde{t}_2$ | BR-tree | SF-tree | SF-sqcd | SF-full | SPheno | SUSY-HIT |
|------------|---------|--------|--------|--------|--------|---------|
| $t \chi_1^+$ | 0.04 | 0.2518 | 0.2573 | 0.2235 | 0.2518 | 0.2664 |
| $t \chi_2^+$ | 0.10 | 0.6740 | 0.6197 | 0.6326 | 0.6740 | 0.6453 |
| $t \chi_3^+$ | 0.01 | 0.0732 | 0.0721 | 0.0733 | 0.0732 | 0.0886 |
| $t \chi_4^+$ | 0.04 | 0.2694 | 0.2818 | 0.2675 | 0.2694 | 0.3321 |
| $b \chi_1^+$ | 0.26 | 1.7753 | 1.5696 | 1.6988 | 1.7485 | 1.6461 |
| $b \chi_2^+$ | 0.15 | 1.0140 | 1.0280 | 0.9674 | 1.0223 | 1.0752 |
| $h^0 \tilde{t}_1$ | 0.05 | 0.3538 | 0.3729 | 0.2965 | 0.3528 | 0.4049 |
| $\tilde{t}_1 Z$ | 0.36 | 2.4851 | 2.5018 | 2.3873 | 2.4851 | 2.2822 |

Table 5: Comparison of the partial decay widths of $\tilde{t}_2$
| $\tilde{b}_1$ | BR-tree | SF-tree | SF-sqcd | SF-full | SPheno | SUSY-HIT |
|---|---|---|---|---|---|---|
| $t \chi_1^-$ | 0.36 | 1.6161 | 1.5735 | 1.6665 | 1.6078 | 1.6682 |
| $b \chi_1^0$ | 0.04 | 0.1621 | 0.1550 | 0.1319 | 0.1621 | 0.1610 |
| $b \chi_2^0$ | 0.29 | 1.2901 | 1.2086 | 1.3346 | 1.2901 | 1.2810 |
| $b \chi_3^0$ | 0.00 | 0.0104 | 0.0103 | 0.0111 | 0.0104 | 0.0112 |
| $b \chi_4^0$ | 0.00 | 0.0167 | 0.0158 | 0.0185 | 0.0167 | 0.0186 |
| $\tilde{t}_1 W^-$ | 0.31 | 1.4224 | 1.4755 | 1.4366 | 1.4224 | 1.3836 |

Table 6: Comparison of the partial decay widths of $\tilde{b}_1$

| $\tilde{b}_2$ | BR-tree | SF-tree | SF-sqcd | SF-full | SPheno | SUSY-HIT |
|---|---|---|---|---|---|---|
| $t \chi_1^-$ | 0.16 | 0.1774 | 0.1822 | 0.1038 | 0.1750 | 0.1885 |
| $b \chi_1^0$ | 0.21 | 0.2368 | 0.2179 | 0.2222 | 0.2368 | 0.2272 |
| $b \chi_2^0$ | 0.12 | 0.1350 | 0.1336 | 0.8063 | 0.1350 | 0.1397 |
| $b \chi_3^0$ | 0.03 | 0.0292 | 0.0290 | 0.0302 | 0.0292 | 0.0305 |
| $b \chi_4^0$ | 0.04 | 0.0397 | 0.0395 | 0.0366 | 0.0397 | 0.0414 |
| $\tilde{t}_1 W^-$ | 0.45 | 0.5143 | 0.5630 | 0.3404 | 0.5143 | 0.4209 |

Table 7: Comparison of the partial decay widths of $\tilde{b}_2$

The screen output when running SFOLD is as follows:

```
----- ----- ---- - ----
/ ___| ___/ _ \ | | | _ \
| (___ | |___ | | | | |
\_ _ \| |___ | | | |
___) | | | | | | |
|_____| | \__/_| |____|____| 1.0
```

Scalar Full One Loop Decays by H. Hlucha, H. Eberl, W. Frisch

====================================================================
FF 2.0, a package to evaluate one-loop integrals written by G. J. van Oldenborgh, NIKHEF-H, Amsterdam
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for the algorithms used see preprint NIKHEF-H 89/17,
'New Algorithms for One-loop Integrals', by G.J. van Oldenborgh and J.A.M. Vermaseren, published in Zeitschrift fuer Physik C46(1990)425.

ffxdb0: IR divergent B0', using cutoff 1.00000000000000
ffxc0i: infra-red divergent threepoint function, working with a cutoff 1.00000000000000

Qscale = 0.100E+004
lambda = 0.100E+001
delta = 0.000E+000
xiW = 0.100E+001
xiZ = 0.100E+001

DRbar parameters are read from SLHA input file SPheno-test.spc
Masses are taken from SLHA input file.
On-shell masses in kinematics.
On-shell susy masses in vertex corrections.
Hard photon (gluon) bremsstrahlung.
BRs are written to SLHA output file outputs.slha

====================================================================

tree
\bar{b}_2 \rightarrow t \chi_{1^-} : 0.177440E+000 / BR : 0.16
\bar{b}_2 \rightarrow b \chi_{10} : 0.236841E+000 / BR : 0.21
\bar{b}_2 \rightarrow b \chi_{20} : 0.135022E+000 / BR : 0.12
\bar{b}_2 \rightarrow b \chi_{30} : 0.292376E-001 / BR : 0.03
\bar{b}_2 \rightarrow b \chi_{40} : 0.397420E-001 / BR : 0.04
\bar{b}_2 \rightarrow \tilde{t}_1 W^- : 0.514351E+000 / BR : 0.45

Total width = 0.113263E+001
====================================================================

sqcd
\bar{b}_2 \rightarrow t \chi_{1^-} : 0.182192E+000 / BR : 0.16
\bar{b}_2 \rightarrow b \chi_{10} : 0.217873E+000 / BR : 0.19
\bar{b}_2 \rightarrow b \chi_{20} : 0.133641E+000 / BR : 0.11
\bar{b}_2 \rightarrow b \chi_{30} : 0.289576E-001 / BR : 0.02
\[ \bar{b}_2 \rightarrow b \ \chi_{40} : 0.395272E-001 / \text{BR} : 0.03 \]
\[ \bar{b}_2 \rightarrow \bar{t}_1 \ W^- : 0.562988E+000 / \text{BR} : 0.48 \]

Total width = 0.116518E+001

\[ \bar{b}_2 \rightarrow t \ \chi_{1-} : 0.103772E+000 / \text{BR} : 0.13 \]
\[ \bar{b}_2 \rightarrow b \ \chi_{10} : 0.222152E+000 / \text{BR} : 0.27 \]
\[ \bar{b}_2 \rightarrow b \ \chi_{20} : 0.806297E-001 / \text{BR} : 0.10 \]
\[ \bar{b}_2 \rightarrow b \ \chi_{30} : 0.301927E-001 / \text{BR} : 0.04 \]
\[ \bar{b}_2 \rightarrow b \ \chi_{40} : 0.365692E-001 / \text{BR} : 0.04 \]
\[ \bar{b}_2 \rightarrow \bar{t}_1 \ W^- : 0.340364E+000 / \text{BR} : 0.42 \]

Total width = 0.813681E+000

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