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# Decays of SUSY Particles: new developments of SDECAY

MMM,Djouadi,Mambrini, hep-ph/0311167,Comput.Phys.Commun.168(2005)46

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## Introduction

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- **SUSY particle properties:** precision of a few % at the LHC and  $\lesssim 1\%$  at future  $e^+e^-$  colliders

⇒ Need programs for the calculation of the

- SUSY particle spectrum
- SUSY particle production cross sections
- SUSY particle total widths and branching ratios

with high precision, also including higher order effects

- **Existence of several programs wanted:**

- test of the programs
- estimate of the theoretical errors

- **On the market:**

SUSY particle spectrum:

ISASUSY Baer et al.      SOFTSUSY Allanach  
SuSpect Djouadi et al.      SPHENO Porod ...

Production cxns and BR's:

ISASUSY Baer,...      (S)HERWIG Corcella,...  
SPYTHIA Sjostrand,...;Mrenna,...      SUSYGEN Ghodbane ...  
PROSPINO Beenakker et al.      MICROMEGAS Bélanger et al.  
GRACE GRACE Coll.      . . .

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# SDECAY

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## Calculation of the SUSY particle decays in the MSSM

- **Implementation of the MSSM**

- minimal gauge group,  $SU(3)_C \times SU(2)_L \times U(1)_Y$
- minimal particle content
- minimal set of couplings imposed by R-parity
- minimal set of soft SUSY breaking parameters

(i) soft SUSY breaking parameters are real

(ii) matrices for sfermion masses and trilinear couplings are diagonal

(iii) sfermions of the first and second generation are universal at low energy

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- **Mass spectrum and soft SUSY breaking parameters**

- interface with the RGE program SuSpect [Djouadi,Kneur,Moultaka](#) via [SUSY Les Houches Accord](#)
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- **SDECAY:** ◇ evaluation of the SUSY particle couplings

◇ calculation of the particle decay widths and BRs

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## SUSY Particle Decays

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### • 2-body decays at LO

* sfermions	$\tilde{f} \rightarrow \tilde{\chi} f$	$\tilde{\chi} : \text{gaugino}$	* charginos/ neutralino	$\tilde{\chi} \rightarrow \tilde{\chi} V$ $\tilde{\chi} \rightarrow \tilde{\chi} \Phi$
	$\tilde{f} \rightarrow \tilde{f} V$	$V : W, Z$		$\tilde{\chi} \rightarrow \tilde{f} f$
	$\tilde{f} \rightarrow \tilde{f} \Phi$	$\Phi : h, H, A, H^\pm$		
* squarks	$\tilde{q} \rightarrow \tilde{g} q$		* gluino	$\tilde{g} \rightarrow \tilde{q} q$
* GMSB model	$\tilde{\chi}_1^0 \rightarrow \tilde{G} \gamma, \tilde{G} Z, \tilde{G} \Phi$	Giudice, Rattazzi		
	$\tilde{\tau}_1 \rightarrow \tilde{G} \tau$			

Running parameters at the EWSB scale for the Yukawa couplings of the third generation, for the soft SUSY breaking parameters and the sfermion mixing angles of the third generation.

Option: QCD coupling and  $b, t$  Yukawa couplings at the scale of the decaying SUSY particle or at any other scale (only the standard QCD corrections).

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## SUSY Particle Decays

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- 2-body decays including the QCD corrections

QCD corrections at one loop

$$\tilde{q} \rightarrow \tilde{\chi}q \quad \text{et} \quad \tilde{\chi} \rightarrow \tilde{q}q$$

Kraml et al.  
Djouadi, Hollik, Junger

$$\tilde{q} \rightarrow \tilde{q}\Phi$$

Arhrib et al.  
Bartl et al.

$$\tilde{q} \rightarrow \tilde{q}V$$

Bartl et al.

$$\tilde{q} \rightarrow \tilde{g}q \quad \text{et} \quad \tilde{g} \rightarrow \tilde{q}q$$

Beenakker et al.

- \* Corrections included in the  $\overline{\text{DR}}$  renormalisation scheme
- \* The dominant EW corrections: running gauge and Yukawa couplings at the EWSB scale

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## • Loop decays

If the 2-body decays are closed  $\rightsquigarrow$  loop decays

$$\tilde{\chi}_2^0 \rightarrow \tilde{\chi}_1^0 \gamma$$

Haber, Wyler  
Ambrosanio, Mele  
Baer, Krupovnickas

$$\tilde{g} \rightarrow \tilde{\chi}_1^0 g$$

Ma, Wong  
Barbieri et al.  
Baer, Tata, Woodside

$$\tilde{t}_1 \rightarrow \tilde{\chi}_1^0 c$$

Hikasa, Kobayashi





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## Top and Higgs Decays

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- Top decays:

$$t \rightarrow bW^+$$

$$t \rightarrow bH^+ \quad \text{et} \quad \tilde{t}_1 \tilde{\chi}_1^0$$

- Higgs decays:

### Interface with HDECAY

HDECAY [Djouadi, Kalinowski, Spira](#):

Calculation of SM and MSSM Higgs boson branching ratios and total widths.

Interface via SUSY Les Houches Accord - practically finished.

SUSPECT - HDECAY - SDECAY will be linked.

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## Structure of SDECAY

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SuSpect files or `SD_leshouches.in` ( $\rightsquigarrow$  parameter specifications) and the

### SDECAY files:

- (i) `sdecay.in`:
  - ◇ options: QCD corrections, 3, 4-body and/or loop decays, GMSB decays, top decays
  - ◇ scale at which the running couplings are calculated

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- (ii) `sdecay.f`:
  - ◇ evaluation of the SUSY and Higgs couplings
  - ◇ calculation of the branching ratios and total widths
  
- (iii) `sdecay.out`:
  - ◇ parameters used
  - ◇ warning in case a necessary parameter is missing in the input file
  - ◇ option to choose a default value in case a parameter is missing in the input file
  - ◇ branching ratios and total widths

2 possible formats: a format easy to read or à la SLHA

SDECAY INPUT FILE

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\* Input parameters: SuSpect2-SLHA format (1) or any SLHA format (0):  
1

\* Choice of the output, SLHA format (1) or simple (0):  
1

\* Include (1) or not (0) the QCD corrections to the 2-body decay widths:  
1

\* Include (1) or not (0) the multi-body decays for inos, stops and sbottoms:  
1

\* Include (1) or not (0) the loop induced decays for the gluino,  
the neutralinos and stop1:  
1

\* Include (1) or not (0) the SUSY decays of the top quark:  
1

\* Include (1) or not (0) the possible decays of the NLSP in GMSB models:  
(ichoice(1) has to be set 11 in suspect2.in.)  
0

\* Scheme in which the running alphas and quark masses are calculated:  
(If QCD corrections are included, the DR\_bar scheme has to be used.)  
1 (DR\_bar scheme) and 0 (MS\_bar scheme).  
1

\* Scale at which the scale dependent couplings are calculated:  
1: EWSB scale, 2: mass of the decaying sparticle, 3: user choice  
1

\* Scale of the couplings if chosen by the user (in GeV):  
100.D0

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## Example output

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```
#          =====
#          | THE SDECAY OUTPUT |
#          =====
BLOCK DCINFO # Decay Program information
  1  SDECAY      # decay calculator
  2  1.1a        # version number
BLOCK SPINFO # Spectrum calculator information
  1  SuSpect     # RGE+Spectrum calculator
  2  2.33        # version number
BLOCK MODSEL # Model selection
  1  1  mSUGRA model (cMSSM)
BLOCK MINPAR # Input parameters
  1  1.00000000E+02 # m0
  2  2.50000000E+02 # m_1/2
  3  1.00000000E+01 # tan(beta)
  4  1.00000000E+00 # sign(mu)
  5  -1.00000000E+02 # A0
BLOCK SMINPUTS # Standard Model inputs
  1  1.27934000E+02 # alpha_em^-1(M_Z)^MSbar
  2  1.16639000E-05 # G_F [GeV^-2]
```

...

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## Example output

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```
#          PDG          Width
DECAY  1000021      4.32775578E+00  # gluino decays
#          BR           NDA      ID1      ID2
      1.72998517E-02      2       1000001      -1  # BR(~g -> ~d_L db)
      1.72998517E-02      2      -1000001       1  # BR(~g -> ~d_L* d )
      5.27731375E-02      2       2000001      -1  # BR(~g -> ~d_R db)
      5.27731375E-02      2      -2000001       1  # BR(~g -> ~d_R* d )
      2.30935092E-02      2       1000002      -2  # BR(~g -> ~u_L ub)

...
#          PDG          Width
DECAY  1000006      1.91843734E+00  # stop1 decays
#          BR           NDA      ID1      ID2
      2.05890056E-01      2       1000022       6  # BR(~t_1 -> ~chi_10 t )
      1.11215798E-01      2       1000023       6  # BR(~t_1 -> ~chi_20 t )

...
#          PDG          Width
DECAY  2000006      7.05754500E+00  # stop2 decays
#          BR           NDA      ID1      ID2
      3.02585416E-02      2       1000022       6  # BR(~t_2 -> ~chi_10 t )

...
```



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## Summary and future

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**SDECAY** calculates all SUSY particle decays:

- 2-body at LO and including the QCD corrections
- 2-body loop decays
- 3-body decays
- 4-body decay
- & top decays

**present/future:**

- Interface with HDECAY practically finished
- Include the total widths in the propagators of the virtual particles  $\rightsquigarrow$   
smooth transition between 2- and 3-body decays
- include QCD corrections to the top decays
- include some important EW corrections
- ⋮

<http://lappweb.in2p3.fr/~muehlleitner/SDECAY/>