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SDECAY - A Fortran Code for the Decays of Supersymmetric Particles in the MSSM

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The code can be obtained at the url:
http://people.web.psi.ch/muehlleitner/SDECAY

Outline

- $\mathcal{I}$ntroduction
- $\mathcal{I}$mplementation of the MSSM
- $\mathcal{I}$mplemented SUSY particle decays
- $\mathcal{P}$rogram structure
- $\mathcal{E}$xample for input and output
- $\mathcal{S}$ummary and outlook

Introduction

- SUSY $\mathcal{P}$article $\mathcal{P}$roperties:

  accuracy of a few % at the LHC
  and below 1% at future e^+e^- colliders

$\Rightarrow$ Programs needed for the calculation of the

SUSY particle spectrum
SUSY particle production cross sections
SUSY particle decay widths and BR's

with high precision, also including H.O. effects

- $\mathcal{E}$xistence of various tools desirable:
  - check of the programs
  - different implementations/approximations
    $\rightsquigarrow$ rough understanding of theor. errors

- $\mathcal{O}$n the market:

Spectrum of SUSY particles:

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

Production cxn's and BR's:

ISASUSY **(S)HERWIG** Corcella,...
SPYTHIA Sjostrand,...;Mrenna,... **SUSYGEN** Katsavenas
PROSPINO Beenakker et al. **SPHENO**
MICROMEGAS Bélanger et al. ...

SDECAY

Calculation of 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) First and Second Sfermion Generations are Universal at low energy

- Mass spectrum and soft SUSY breaking parameters:
  - link to RGE program `SuSpect` Djouadi,Kneur,Moultaka
    easy to link to any other RGE code
  - New: via SUSY Les Houches Accord input file Skands et al.

- SDECAY: ♢ Evaluation of SUSY particle couplings
  ♢ Calculation of decay widths and BR's

Implemented SUSY particle decays

(i) Tree level 2-body decays

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

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

$\mathcal{O}$ption: QCD coupling constant and b, t Yukawa couplings at the scale of decaying SUSY particle or any other scale (only standard QCD corrections).

(ii) The QCD corrected 2-body decays

$\mathcal{O}$ne-loop QCD corrections to

$\tilde{q}$	$\to$	$\tilde{\chi} q$	and	$\tilde{\chi} \to \tilde{q} q$	Kraml et al. Djouadi,Hollik,Junger
$\tilde{q}$	$\to$	$\tilde{q} \Phi$			Arhrib et al. Bartl et al.
$\tilde{q}$	$\to$	$\tilde{q} V$			Bartl et al.
$\tilde{q}$	$\to$	$\tilde{g} q$	and	$\tilde{g} \to \tilde{q} q$	Beenakker et al.

⋆ Corrections included in the $\overline{\text{DR}}$ scheme

⋆ Bulk of EW corrs.: running gauge and third generation Yukawa couplings taken at the EWSB scale

(iii) Loop induced decays

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

$\tilde{\chi}_2^0$	$\to$	$\tilde{\chi}_1^0 \gamma$	Haber,Wyler Ambrosanio,Mele Baer,Krupovnickas
$\tilde{g}$	$\to$	$\tilde{\chi}_1^0 g$	Ma,Wong Barbieri et al. Baer,Tata,Woodside
$\tilde{t}_1$	$\to$	$\tilde{\chi}_1^0 c$	Hikasa,Kobayashi

(iv) Multibody decay modes

If 2-body decays are closed $\rightsquigarrow$ 3-body decays

* gauginos: $\tilde{\chi} \to \tilde{\chi} f \bar{f}$, $\tilde{\chi} \to \tilde{g} q \bar{q}$ — Bartl,Majerotto,Porod; Baer et al.; Djouadi,Mambrini,MM

* gluino: $\tilde{g} \to \tilde{\chi} q \bar{q}$

$\tilde{g} \to \tilde{t}_1 \bar{b} W^-$ — Porod

$\tilde{g} \to \tilde{t}_1 \bar{b} H^-$ — Datta,Djouadi,Guchait,Mambrini

* stops: $\tilde{t} \to b W^+ \tilde{\chi}_1^0$, $\tilde{t} \to b H^+ \tilde{\chi}_1^0$ — Porod,Wohrmann; Datta,Guchait,Jeong; Djouadi,Guchait,Mambrini

$\tilde{t} \to b l^+ \tilde{\nu}_l$, $b \tilde{l}^+ \nu_l$

$\tilde{t} \to \tilde{b} f \bar{f}'$

$\tilde{t}_2 \to \tilde{t}_1 f \bar{f}$

* sbottoms: $\tilde{b} \to t l^- \tilde{\nu}_l^*$, $t \tilde{l}^- \bar{\nu}_l$ — Djouadi,Mambrini

$\tilde{b} \to \tilde{t} f \bar{f}'$

$\tilde{b}_2 \to \tilde{b}_1 f \bar{f}$

In 3-body decays:

- rad. corrected third generation Yukawa couplings
- mixing between sfermions taken into account
- masses of final state fermions included
- no total decay widths in propagators of virtual particles

If stop 3-body decays are closed $\rightsquigarrow$ $\tilde{t}_1$ 4-body decays

$\tilde{t}_1 \to b \tilde{\chi}_1^0 f \bar{f}'$ — Boehm,Djouadi,Mambrini

(v) Top quark decays

Included in SDECAY:

$$t \to bW^+$$
$$t \to bH^+ \quad \text{and} \quad \tilde{t}_1\tilde{\chi}_1^0$$

Structure of SDECAY

Files: `SuSpect` files or `SD_leshouches.in` ($\rightsquigarrow$ parameter setting)

SDECAY files:

(i) `sdecay.in`:
- ◇ options: QCD corrections, multibody and/or loop decays, GMSB decays, top decays
- ◇ scale and # of loops for the running couplings
- ◇ option: read in input file in the SLHA

(ii) sdecay.f:
- ◇ couplings of SUSY and Higgs particles evaluated
- ◇ decay branching ratios and total widths calculated

(iii) `sdecay.out`:
- ◇ masses of SUSY and Higgs particles
- ◇ mixing matrices
- ◇ gauge and third generation Yukawa couplings at EWSB or chosen scale
- ◇ soft SUSY breaking param. at EWSB
- ◇ branching ratios and total widths

2 possible formats: simple transparent form or SLHA

$\mathcal{N}$ew: subroutines and functions denoted by prefix SD_

Example for input and output file

SPS1a: $m_0 = 100$ GeV, $m_{1/2} = 250$ GeV, $A_0 = -100$ GeV, $\tan\beta = 10$, $\mu > 0$

The input file:

```
                SDECAY INPUT FILE
                -----------------
* Input parameters: given by SuSpect (1) or an 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.)
  DR_bar scheme (1) and MS_bar scheme (0).
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
```

Summary and outlook

♣ SDECAY calculates

- ◇ 2-body decays of all SUSY particles + QCD corrections to the processes involving strongly interacting particles
- ◇ loop induced decays of neutralinos, gluino, $\tilde{t}_1$
- ◇ 3-body decays of neutralinos, charginos, gluino, stops, sbottoms
- ◇ 4-body decays of $\tilde{t}_1$
- ◇ top quark decays

♣ New:

- ◇ finalization of QCD corrections to 2-body decays
- ◇ inclusion of bottom squark 3-body decays
- ◇ option: read in input file in the SUSY Les Houches accord
- ◇ subroutines and functions denoted by prefix `SD_`

♣ Outlook:

- ◇ include QCD corrections to top quark
- ◇ spin correlations
- ◇ implementation of some important EW rad. corrections.

⋮

http://people.web.psi.ch/muehlleitner/SDECAY

```
#
#                                =====================
#                                | THE SDECAY OUTPUT |
#                                =====================
#
#
#               ---------------------------------------------------
#               |  SUSY Les Houches Accord - MSSM Spectrum + Decays |
#               |                                                   |
#               |                      SDECAY 1.1                   |
#               |                                                   |
#               |  Authors: M.Muhlleitner, A.Djouadi and Y.Mambrini |
#               |  Ref.:    hep-ph/0311167                          |
#               |                                                   |
#               |  In case of problems please send an email to      |
#               |           margarete.muehlleitner@psich            |
#               |           djouadi@lpm.univ-montp2.fr              |
#               |           mambrini@delta.ft.uam.es                |
#               |                                                   |
#               |  If not stated otherwise all DRbar couplings and  |
#               |  soft SUSY breaking masses are given at the scale |
#               |  Q=  0.46374599E+03                               |
#               |                                                   |
#               ---------------------------------------------------
#
#
BLOCK DCINFO  # Decay Program information
     1   SDECAY       # decay calculator
     2   1.1          # version number
#
BLOCK SPINFO  # Spectrum calculator information
     1   SuSpect      # spectrum calculator
     2   2.3          # 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]
         3     1.17200000E-01   # alpha_S(M_Z)^MSbar
         4     9.11870000E+01   # M_Z pole mass
         5     4.25000000E+00   # mb(mb)^MSbar
         6     1.78000000E+02   # mt pole mass
         7     1.77700000E+00   # mtau pole mass
#
BLOCK MASS  # Mass Spectrum
# PDG code           mass       particle
        24     8.05242299E+01   # W+
        25     1.12096757E+02   # h
        35     4.06461015E+02   # H
        36     4.06119958E+02   # A
        37     4.14275400E+02   # H+
         5     4.87884274E+00   # b-quark pole mass calculated from mb(mb)_Msbar
   1000001     5.73065871E+02   # ~d_L
   2000001     5.46427885E+02   # ~d_R
   1000002     5.67624937E+02   # ~u_L
   2000002     5.47354466E+02   # ~u_R
   1000003     5.73065871E+02   # ~s_L
   2000003     5.46427885E+02   # ~s_R
   1000004     5.67624937E+02   # ~c_L
   2000004     5.47354466E+02   # ~c_R
   1000005     5.17365564E+02   # ~b_1
   2000005     5.47189785E+02   # ~b_2
   1000006     3.96402171E+02   # ~t_1
   2000006     5.86605785E+02   # ~t_2
   1000011     2.04342680E+02   # ~e_L
   2000011     1.45552503E+02   # ~e_R
   1000012     1.88743509E+02   # ~nu_eL
   1000013     2.04342680E+02   # ~mu_L
   2000013     1.45552503E+02   # ~mu_R
   1000014     1.88743509E+02   # ~nu_muL
   1000015     1.36017749E+02   # ~tau_1
   2000015     2.08433459E+02   # ~tau_2
   1000016     1.87856168E+02   # ~nu_tauL
   1000021     6.06917407E+02   # ~g
   1000022     9.73858252E+01   # ~chi_10
   1000023     1.81569768E+02   # ~chi_20
   1000025    -3.70511612E+02   # ~chi_30
   1000035     3.88598381E+02   # ~chi_40
```

```
   1000024     1.81025728E+02   # ~chi_1+
   1000037     3.88864824E+02   # ~chi_2+
#
BLOCK NMIX  # Neutralino Mixing Matrix
  1  1     9.86741624E-01   # N_11
  1  2    -5.29651707E-02   # N_12
  1  3     1.44339796E-01   # N_13
  1  4    -5.19777092E-02   # N_14
  2  1     9.82323496E-02   # N_21
  2  2     9.45644736E-01   # N_22
  2  3    -2.69126586E-01   # N_23
  2  4     1.53874361E-01   # N_24
  3  1     5.96137014E-02   # N_31
  3  2    -8.86534307E-02   # N_32
  3  3    -6.95821436E-01   # N_33
  3  4    -7.10224827E-01   # N_34
  4  1     1.14619284E-01   # N_41
  4  2    -3.08368761E-01   # N_42
  4  3    -6.50053408E-01   # N_43
  4  4     6.84982988E-01   # N_44
#
BLOCK UMIX  # Chargino Mixing Matrix U
  1  1    -9.19474141E-01   # U_11
  1  2     3.93150485E-01   # U_12
  2  1     3.93150485E-01   # U_21
  2  2     9.19474141E-01   # U_22
#
BLOCK VMIX  # Chargino Mixing Matrix V
  1  1    -9.74152159E-01   # V_11
  1  2     2.25892831E-01   # V_12
  2  1     2.25892831E-01   # V_21
  2  2     9.74152159E-01   # V_22
#
BLOCK STOPMIX  # Stop Mixing Matrix
  1  1     5.37960772E-01   # cos(theta_t)
  1  2     8.42969874E-01   # sin(theta_t)
  2  1    -8.42969874E-01   # -sin(theta_t)
  2  2     5.37960772E-01   # cos(theta_t)
#
BLOCK SBOTMIX  # Sbottom Mixing Matrix
  1  1     9.28724239E-01   # cos(theta_b)
  1  2     3.70771206E-01   # sin(theta_b)
  2  1    -3.70771206E-01   # -sin(theta_b)
  2  2     9.28724239E-01   # cos(theta_b)
```

```
#
BLOCK STAUMIX  # Stau Mixing Matrix
  1  1     2.84542686E-01   # cos(theta_tau)
  1  2     9.58663372E-01   # sin(theta_tau)
  2  1    -9.58663372E-01   # -sin(theta_tau)
  2  2     2.84542686E-01   # cos(theta_tau)
#
BLOCK ALPHA  # Higgs mixing
          -1.13466462E-01   # Mixing angle in the neutral Higgs boson sector
#
BLOCK HMIX Q=  4.63745990E+02  # DRbar Higgs Parameters
     1     3.64713788E+02   # mu(Q)
     2     9.73388470E+00   # tanbeta(Q)
     3     1.72370355E+02   # v(Q)
#
BLOCK GAUGE Q=  4.63745990E+02  # The gauge couplings
     1     3.60880368E-01   # gprime(Q) DRbar
     2     6.46457261E-01   # g(Q) DRbar
     3     1.09622209E+00   # g3(Q) DRbar
#
BLOCK Au Q=  4.63745990E+02  # The trilinear couplings
  1  1    -6.85815984E+02   # A_u(Q) DRbar
  2  2    -6.85815984E+02   # A_c(Q) DRbar
  3  3    -4.86697847E+02   # A_t(Q) DRbar
#
BLOCK Ad Q=  4.63745990E+02  # The trilinear couplings
  1  1    -8.65450847E+02   # A_d(Q) DRbar
  2  2    -8.65450847E+02   # A_s(Q) DRbar
  3  3    -7.94730392E+02   # A_b(Q) DRbar
#
BLOCK Ae Q=  4.63745990E+02  # The trilinear couplings
  1  1    -2.58050920E+02   # A_e(Q) DRbar
  2  2    -2.58050920E+02   # A_mu(Q) DRbar
  3  3    -2.56292593E+02   # A_tau(Q) DRbar
#
BLOCK Yu Q=  4.63745990E+02  # The Yukawa couplings
  3  3     9.11111063E-01   # y_t(Q) DRbar
#
BLOCK Yd Q=  4.63745990E+02  # The Yukawa couplings
  3  3     1.39418450E-01   # y_b(Q) DRbar
#
BLOCK Ye Q=  4.63745990E+02  # The Yukawa couplings
  3  3     1.01034578E-01   # y_tau(Q) DRbar
#
```

```
BLOCK MSOFT Q=  4.63745990E+02  # The soft SUSY breaking masses at the scale Q
         1     1.01440905E+02   # M_1
         2     1.91654639E+02   # M_2
         3     5.87089396E+02   # M_3
        31     1.99111696E+02   # M_eL
        32     1.99111696E+02   # M_muL
        33     1.98270762E+02   # M_tauL
        34     1.38833134E+02   # M_eR
        35     1.38833134E+02   # M_muR
        36     1.36404891E+02   # M_tauR
        41     5.51260032E+02   # M_q1L
        42     5.51260032E+02   # M_q2L
        43     4.98460404E+02   # M_q3L
        44     5.29290641E+02   # M_uR
        45     5.29290641E+02   # M_cR
        46     4.15648573E+02   # M_tR
        47     5.26537254E+02   # M_dR
        48     5.26537254E+02   # M_sR
        49     5.23236685E+02   # M_bR
#
#
#
#                               ================
#                               |The decay table|
#                               ================
# - The QCD corrections to the decays gluino -> squark  + quark
#                                     squark -> gaugino + quark_prime
#                                     squark -> squark_prime + Higgs
#                                     squark -> gluino  + quark
#   are included.
# - The multi-body decays for the inos, stops and sbottoms are included.
# - The loop induced decays for the gluino, neutralinos and stops
#   are included.
# - The SUSY decays of the top quark are included.
#
#         PDG            Width
DECAY         6     1.61167082E+00   # top decays
#          BR         NDA      ID1       ID2
     1.00000000E+00    2           5        24   # BR(t ->  b    W+)
DECAY   1000021     4.32757403E+00   # gluino decays
#          BR         NDA      ID1       ID2
     1.73005634E-02    2     1000001        -1   # BR(~g -> ~d_L  db)
     1.73005634E-02    2    -1000001         1   # BR(~g -> ~d_L* d )
     5.27753102E-02    2     2000001        -1   # BR(~g -> ~d_R  db)
```

```
     5.27753102E-02    2    -2000001          1   # BR(~g -> ~d_R* d )
     2.30944599E-02    2     1000002         -2   # BR(~g -> ~u_L  ub)
     2.30944599E-02    2    -1000002          2   # BR(~g -> ~u_L* u )
     5.12531172E-02    2     2000002         -2   # BR(~g -> ~u_R  ub)
     5.12531172E-02    2    -2000002          2   # BR(~g -> ~u_R* u )
     1.73005634E-02    2     1000003         -3   # BR(~g -> ~s_L  sb)
     1.73005634E-02    2    -1000003          3   # BR(~g -> ~s_L* s )
     5.27753102E-02    2     2000003         -3   # BR(~g -> ~s_R  sb)
     5.27753102E-02    2    -2000003          3   # BR(~g -> ~s_R* s )
     2.30944599E-02    2     1000004         -4   # BR(~g -> ~c_L  cb)
     2.30944599E-02    2    -1000004          4   # BR(~g -> ~c_L* c )
     5.12531172E-02    2     2000004         -4   # BR(~g -> ~c_R  cb)
     5.12531172E-02    2    -2000004          4   # BR(~g -> ~c_R* c )
     1.03760662E-01    2     1000005         -5   # BR(~g -> ~b_1  bb)
     1.03760662E-01    2    -1000005          5   # BR(~g -> ~b_1* b )
     5.34217303E-02    2     2000005         -5   # BR(~g -> ~b_2  bb)
     5.34217303E-02    2    -2000005          5   # BR(~g -> ~b_2* b )
     5.39707063E-02    2     1000006         -6   # BR(~g -> ~t_1  tb)
     5.39707063E-02    2    -1000006          6   # BR(~g -> ~t_1* t )
DECAY   1000006     1.91858088E+00   # stop1 decays
#          BR         NDA      ID1       ID2
     2.05903431E-01    2     1000022         6   # BR(~t_1 -> ~chi_10 t )
     1.11235566E-01    2     1000023         6   # BR(~t_1 -> ~chi_20 t )
     6.80902026E-01    2     1000024         5   # BR(~t_1 -> ~chi_1+ b )
     1.95897689E-03    2     1000037         5   # BR(~t_1 -> ~chi_2+ b )
DECAY   2000006     7.05678460E+00   # stop2 decays
#          BR         NDA      ID1       ID2
     3.02571838E-02    2     1000022         6   # BR(~t_2 -> ~chi_10 t )
     9.32177296E-02    2     1000023         6   # BR(~t_2 -> ~chi_20 t )
     3.68800911E-02    2     1000025         6   # BR(~t_2 -> ~chi_30 t )
     1.72850027E-01    2     1000035         6   # BR(~t_2 -> ~chi_40 t )
     2.35750346E-01    2     1000024         5   # BR(~t_2 -> ~chi_1+ b )
     1.89404011E-01    2     1000037         5   # BR(~t_2 -> ~chi_2+ b )
     4.73659551E-02    2     1000006        25   # BR(~t_2 -> ~t_1    h )
     1.94274657E-01    2     1000006        23   # BR(~t_2 -> ~t_1    Z )
DECAY   1000005     3.77411689E+00   # sbottom1 decays
#          BR         NDA      ID1       ID2
     4.51299934E-02    2     1000022         5   # BR(~b_1 -> ~chi_10 b )
     3.43078525E-01    2     1000023         5   # BR(~b_1 -> ~chi_20 b )
     4.70274664E-03    2     1000025         5   # BR(~b_1 -> ~chi_30 b )
     9.07088864E-03    2     1000035         5   # BR(~b_1 -> ~chi_40 b )
     4.44706838E-01    2    -1000024         6   # BR(~b_1 -> ~chi_1- t )
     1.53311009E-01    2     1000006       -24   # BR(~b_1 -> ~t_1    W-)
DECAY   2000005     8.74521097E-01   # sbottom2 decays
```

```
#          BR         NDA      ID1       ID2
     2.55669334E-01    2     1000022         5   # BR(~b_2 -> ~chi_10 b )
     1.54003985E-01    2     1000023         5   # BR(~b_2 -> ~chi_20 b )
     4.72207714E-02    2     1000025         5   # BR(~b_2 -> ~chi_30 b )
     6.78427036E-02    2     1000035         5   # BR(~b_2 -> ~chi_40 b )
     2.06622028E-01    2    -1000024         6   # BR(~b_2 -> ~chi_1- t )
     2.68641178E-01    2     1000006       -24   # BR(~b_2 -> ~t_1    W-)
DECAY   1000002     5.53038229E+00   # sup_L decays
#          BR         NDA      ID1       ID2
     6.71207198E-03    2     1000022         2   # BR(~u_L -> ~chi_10 u)
     3.17966714E-01    2     1000023         2   # BR(~u_L -> ~chi_20 u)
     9.06183232E-04    2     1000025         2   # BR(~u_L -> ~chi_30 u)
     1.07833398E-02    2     1000035         2   # BR(~u_L -> ~chi_40 u)
     6.50304270E-01    2     1000024         1   # BR(~u_L -> ~chi_1+ d)
     1.33274204E-02    2     1000037         1   # BR(~u_L -> ~chi_2+ d)
DECAY   2000002     1.14737960E+00   # sup_R decays
#          BR         NDA      ID1       ID2
     9.86425831E-01    2     1000022         2   # BR(~u_R -> ~chi_10 u)
     8.40714332E-03    2     1000023         2   # BR(~u_R -> ~chi_20 u)
     1.24559048E-03    2     1000025         2   # BR(~u_R -> ~chi_30 u)
     3.92143535E-03    2     1000035         2   # BR(~u_R -> ~chi_40 u)
#         PDG            Width
DECAY   1000001     5.33590323E+00   # sdown_L decays
#          BR         NDA      ID1       ID2
     2.30217899E-02    2     1000022         1   # BR(~d_L -> ~chi_10 d)
     3.08763146E-01    2     1000023         1   # BR(~d_L -> ~chi_20 d)
     1.60689188E-03    2     1000025         1   # BR(~d_L -> ~chi_30 d)
     1.53241872E-02    2     1000035         1   # BR(~d_L -> ~chi_40 d)
     6.07795842E-01    2    -1000024         2   # BR(~d_L -> ~chi_1- u)
     4.34881428E-02    2    -1000037         2   # BR(~d_L -> ~chi_2- u)
DECAY   2000001     2.86349161E-01   # sdown_R decays
#          BR         NDA      ID1       ID2
     9.86460410E-01    2     1000022         1   # BR(~d_R -> ~chi_10 d)
     8.40257241E-03    2     1000023         1   # BR(~d_R -> ~chi_20 d)
     1.23932457E-03    2     1000025         1   # BR(~d_R -> ~chi_30 d)
     3.89769334E-03    2     1000035         1   # BR(~d_R -> ~chi_40 d)
DECAY   1000004     5.53038229E+00   # scharm_L decays
#          BR         NDA      ID1       ID2
     6.71207198E-03    2     1000022         4   # BR(~c_L -> ~chi_10 c)
     3.17966714E-01    2     1000023         4   # BR(~c_L -> ~chi_20 c)
     9.06183232E-04    2     1000025         4   # BR(~c_L -> ~chi_30 c)
     1.07833398E-02    2     1000035         4   # BR(~c_L -> ~chi_40 c)
     6.50304270E-01    2     1000024         3   # BR(~c_L -> ~chi_1+ s)
     1.33274204E-02    2     1000037         3   # BR(~c_L -> ~chi_2+ s)
```

```
DECAY   2000004     1.14737960E+00   # scharm_R decays
#          BR         NDA      ID1       ID2
     9.86425831E-01    2     1000022         4   # BR(~c_R -> ~chi_10 c)
     8.40714332E-03    2     1000023         4   # BR(~c_R -> ~chi_20 c)
     1.24559048E-03    2     1000025         4   # BR(~c_R -> ~chi_30 c)
     3.92143535E-03    2     1000035         4   # BR(~c_R -> ~chi_40 c)
DECAY   1000003     5.33590323E+00   # sstrange_L decays
#          BR         NDA      ID1       ID2
     2.30217899E-02    2     1000022         3   # BR(~s_L -> ~chi_10 s)
     3.08763146E-01    2     1000023         3   # BR(~s_L -> ~chi_20 s)
     1.60689188E-03    2     1000025         3   # BR(~s_L -> ~chi_30 s)
     1.53241872E-02    2     1000035         3   # BR(~s_L -> ~chi_40 s)
     6.07795842E-01    2    -1000024         4   # BR(~s_L -> ~chi_1- c)
     4.34881428E-02    2    -1000037         4   # BR(~s_L -> ~chi_2- c)
DECAY   2000003     2.86349161E-01   # sstrange_R decays
#          BR         NDA      ID1       ID2
     9.86460410E-01    2     1000022         3   # BR(~s_R -> ~chi_10 s)
     8.40257241E-03    2     1000023         3   # BR(~s_R -> ~chi_20 s)
     1.23932457E-03    2     1000025         3   # BR(~s_R -> ~chi_30 s)
     3.89769334E-03    2     1000035         3   # BR(~s_R -> ~chi_40 s)
DECAY   1000011     2.29953421E-01   # selectron_L decays
#          BR         NDA      ID1       ID2
     5.46960622E-01    2     1000022        11   # BR(~e_L -> ~chi_10 e-)
     1.63793313E-01    2     1000023        11   # BR(~e_L -> ~chi_20 e-)
     2.89246065E-01    2    -1000024        12   # BR(~e_L -> ~chi_1- nu_e)
DECAY   2000011     2.24037122E-01   # selectron_R decays
#          BR         NDA      ID1       ID2
     1.00000000E+00    2     1000022        11   # BR(~e_R -> ~chi_10 e-)
DECAY   1000013     2.29953421E-01   # smuon_L decays
#          BR         NDA      ID1       ID2
     5.46960622E-01    2     1000022        13   # BR(~mu_L -> ~chi_10 mu-)
     1.63793313E-01    2     1000023        13   # BR(~mu_L -> ~chi_20 mu-)
     2.89246065E-01    2    -1000024        14   # BR(~mu_L -> ~chi_1- nu_mu)
DECAY   2000013     2.24037122E-01   # smuon_R decays
#          BR         NDA      ID1       ID2
     1.00000000E+00    2     1000022        13   # BR(~mu_R -> ~chi_10 mu-)
DECAY   1000015     1.55053029E-01   # stau_1 decays
#          BR         NDA      ID1       ID2
     1.00000000E+00    2     1000022        15   # BR(~tau_1 -> ~chi_10  tau-)
DECAY   2000015     2.88679364E-01   # stau_2 decays
#          BR         NDA      ID1       ID2
     5.75354452E-01    2     1000022        15   # BR(~tau_2 -> ~chi_10  tau-)
     1.54142869E-01    2     1000023        15   # BR(~tau_2 -> ~chi_20  tau-)
     2.70502678E-01    2    -1000024        16   # BR(~tau_2 -> ~chi_1-  nu_tau)
```

```
DECAY   1000012     1.67037869E-01   # snu_eL decays
#          BR         NDA      ID1       ID2
     9.22061618E-01    2     1000022        12   # BR(~nu_eL -> ~chi_10 nu_e)
     2.07274682E-02    2     1000023        12   # BR(~nu_eL -> ~chi_20 nu_e)
     5.72109140E-02    2     1000024        11   # BR(~nu_eL -> ~chi_1+ e-)
DECAY   1000014     1.67037869E-01   # snu_muL decays
#          BR         NDA      ID1       ID2
     9.22061618E-01    2     1000022        14   # BR(~nu_muL -> ~chi_10 nu_mu)
     2.07274682E-02    2     1000023        14   # BR(~nu_muL -> ~chi_20 nu_mu)
     5.72109140E-02    2     1000024        13   # BR(~nu_muL -> ~chi_1+ mu-)
DECAY   1000016     1.62007307E-01   # snu_tauL decays
#          BR         NDA      ID1       ID2
     9.39732924E-01    2     1000022        16   # BR(~nu_tauL -> ~chi_10 nu_tau)
     1.65651389E-02    2     1000023        16   # BR(~nu_tauL -> ~chi_20 nu_tau)
     4.37019368E-02    2     1000024        15   # BR(~nu_tauL -> ~chi_1+ tau-)
DECAY   1000024     1.53796275E-02   # chargino1+ decays
#          BR         NDA      ID1       ID2
     9.53192841E-01    2    -1000015        16   # BR(~chi_1+ -> ~tau_1+  nu_tau)
     4.68071586E-02    2     1000022        24   # BR(~chi_1+ -> ~chi_10  W+)
DECAY   1000037     2.61582270E+00   # chargino2+ decays
#          BR         NDA      ID1       ID2
     1.84261241E-02    2     1000012       -11   # BR(~chi_2+ -> ~nu_eL   e+  )
     1.84261241E-02    2     1000014       -13   # BR(~chi_2+ -> ~nu_muL  mu+ )
     2.57515434E-02    2     1000016       -15   # BR(~chi_2+ -> ~nu_tau1 tau+)
     5.00499204E-02    2    -1000011        12   # BR(~chi_2+ -> ~e_L+    nu_e)
     5.00499204E-02    2    -1000013        14   # BR(~chi_2+ -> ~mu_L+   nu_mu)
     3.19211970E-04    2    -1000015        16   # BR(~chi_2+ -> ~tau_1+  nu_tau)
     5.47893377E-02    2    -2000015        16   # BR(~chi_2+ -> ~tau_2+  nu_tau)
     2.46698047E-01    2     1000024        23   # BR(~chi_2+ -> ~chi_1+  Z )
     6.66568099E-02    2     1000022        24   # BR(~chi_2+ -> ~chi_10  W+)
     2.89102170E-01    2     1000023        24   # BR(~chi_2+ -> ~chi_20  W+)
     1.79730791E-01    2     1000024        25   # BR(~chi_2+ -> ~chi_1+  h )
DECAY   1000022     0.00000000E+00   # neutralino1 decays
DECAY   1000023     2.00200848E-02   # neutralino2 decays
#          BR         NDA      ID1       ID2
     2.89608206E-02    2     2000011       -11   # BR(~chi_20 -> ~e_R-     e+)
     2.89608206E-02    2    -2000011        11   # BR(~chi_20 -> ~e_R+     e-)
     2.89608206E-02    2     2000013       -13   # BR(~chi_20 -> ~mu_R-    mu+)
     2.89608206E-02    2    -2000013        13   # BR(~chi_20 -> ~mu_R+    mu-)
     4.42078359E-01    2     1000015       -15   # BR(~chi_20 -> ~tau_1-   tau+)
     4.42078359E-01    2    -1000015        15   # BR(~chi_20 -> ~tau_1+   tau-)
DECAY   1000025     2.04483683E+00   # neutralino3 decays
#          BR         NDA      ID1       ID2
     1.09706964E-01    2     1000022        23   # BR(~chi_30 -> ~chi_10   Z )
```

```
     2.19860108E-01    2     1000023        23   # BR(~chi_30 -> ~chi_20   Z )
     2.93958830E-01    2     1000024       -24   # BR(~chi_30 -> ~chi_1+   W-)
     2.93958830E-01    2    -1000024        24   # BR(~chi_30 -> ~chi_1-   W+)
     2.09845606E-02    2     1000022        25   # BR(~chi_30 -> ~chi_10   h )
     1.28212320E-02    2     1000023        25   # BR(~chi_30 -> ~chi_20   h )
     5.59139678E-04    2     1000011       -11   # BR(~chi_30 -> ~e_L-     e+)
     5.59139678E-04    2    -1000011        11   # BR(~chi_30 -> ~e_L+     e-)
     1.19316139E-03    2     2000011       -11   # BR(~chi_30 -> ~e_R-     e+)
     1.19316139E-03    2    -2000011        11   # BR(~chi_30 -> ~e_R+     e-)
     5.59139678E-04    2     1000013       -13   # BR(~chi_30 -> ~mu_L-    mu+)
     5.59139678E-04    2    -1000013        13   # BR(~chi_30 -> ~mu_L+    mu-)
     1.19316139E-03    2     2000013       -13   # BR(~chi_30 -> ~mu_R-    mu+)
     1.19316139E-03    2    -2000013        13   # BR(~chi_30 -> ~mu_R+    mu-)
     5.01860413E-03    2     1000015       -15   # BR(~chi_30 -> ~tau_1-   tau+)
     5.01860413E-03    2    -1000015        15   # BR(~chi_30 -> ~tau_1+   tau-)
     6.60045064E-03    2     2000015       -15   # BR(~chi_30 -> ~tau_2-   tau+)
     6.60045064E-03    2    -2000015        15   # BR(~chi_30 -> ~tau_2+   tau-)
     3.07028721E-03    2     1000012       -12   # BR(~chi_30 -> ~nu_eL    nu_eb)
     3.07028721E-03    2    -1000012        12   # BR(~chi_30 -> ~nu_eL*   nu_e )
     3.07028721E-03    2     1000014       -14   # BR(~chi_30 -> ~nu_muL   nu_mub)
     3.07028721E-03    2    -1000014        14   # BR(~chi_30 -> ~nu_muL*  nu_mu )
     3.09050648E-03    2     1000016       -16   # BR(~chi_30 -> ~nu_tau1  nu_taub
     3.09050648E-03    2    -1000016        16   # BR(~chi_30 -> ~nu_tau1* nu_tau
DECAY   1000035     2.74259689E+00   # neutralino4 decays
#          BR         NDA      ID1       ID2
     2.10743407E-02    2     1000022        23   # BR(~chi_40 -> ~chi_10   Z )
     1.94243517E-02    2     1000023        23   # BR(~chi_40 -> ~chi_20   Z )
     2.58869096E-01    2     1000024       -24   # BR(~chi_40 -> ~chi_1+   W-)
     2.58869096E-01    2    -1000024        24   # BR(~chi_40 -> ~chi_1-   W+)
     6.78872309E-02    2     1000022        25   # BR(~chi_40 -> ~chi_10   h )
     1.43065331E-01    2     1000023        25   # BR(~chi_40 -> ~chi_20   h )
     9.20646508E-03    2     1000011       -11   # BR(~chi_40 -> ~e_L-     e+)
     9.20646508E-03    2    -1000011        11   # BR(~chi_40 -> ~e_L+     e-)
     3.56460594E-03    2     2000011       -11   # BR(~chi_40 -> ~e_R-     e+)
     3.56460594E-03    2    -2000011        11   # BR(~chi_40 -> ~e_R+     e-)
     9.20646508E-03    2     1000013       -13   # BR(~chi_40 -> ~mu_L-    mu+)
     9.20646508E-03    2    -1000013        13   # BR(~chi_40 -> ~mu_L+    mu-)
     3.56460594E-03    2     2000013       -13   # BR(~chi_40 -> ~mu_R-    mu+)
     3.56460594E-03    2    -2000013        13   # BR(~chi_40 -> ~mu_R+    mu-)
     2.54565420E-03    2     1000015       -15   # BR(~chi_40 -> ~tau_1-   tau+)
     2.54565420E-03    2    -1000015        15   # BR(~chi_40 -> ~tau_1+   tau-)
     1.56613828E-02    2     2000015       -15   # BR(~chi_40 -> ~tau_2-   tau+)
     1.56613828E-02    2    -2000015        15   # BR(~chi_40 -> ~tau_2+   tau-)
     2.38392711E-02    2     1000012       -12   # BR(~chi_40 -> ~nu_eL    nu_eb)
```

```
2.38392711E-02    2    -1000012        12   # BR(~chi_40 -> ~nu_eL*   nu_e )
2.38392711E-02    2     1000014       -14   # BR(~chi_40 -> ~nu_muL   nu_mub)
2.38392711E-02    2    -1000014        14   # BR(~chi_40 -> ~nu_muL*  nu_mu )
2.39775559E-02    2     1000016       -16   # BR(~chi_40 -> ~nu_tau1  nu_taub
2.39775559E-02    2    -1000016        16   # BR(~chi_40 -> ~nu_tau1* nu_tau
```

```
                          ====================
                          | THE SDECAY OUTPUT |
                          ====================


SDECAY 1.1
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Ref. hep-ph/0311167
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If not stated otherwise all couplings and masses
are given at the scale of the electroweak symmetry
breaking Q=  463.74599


 Notation:
 ---------
 bosons: gm = gamma, gl = gluon, G = Gravitino

 fermions: up   = up,          ub   = up_bar,      dn = down,     db = down_bar,
           ch   = charm,       cb   = charm_bar,   st = strange,  sb = strange_bar,
           bt   = bottom,      bb   = bottom_bar,  tp = top,      tb = top_bar,
           e+   = positron,    e-   = electron,    mu+= muon_+,   mu-= muon_-
           tau+ = tau_+,       tau- = tau_-
           nue  = neutrino_electron, num = neutrino_muon,
           nueb = neutrino_el_bar,   numb = neutrino_muon_bar,
           nut  = neutrino_tau,      nutb = neutrino_tau_bar

 sfermions: supl/r   = sup_L/R,        subl/r   = sup_L/R_bar,
            sdnl/r   = sdown_L/R_bar,  sdbl/r   = sdown_L/R_bar,
            schl/r   = scharm_L/R,     scbl/r   = scharm_L/R_bar,
            sstl/r   = sstrange_L/R,   ssbl/r   = sstrange_L/R_bar,
            stop1/2  = stop_1/2,       stop1/2b = stop_1/2_bar,
            sbot1/2  = sbottom_1/2,    sbot1/2b = sbottom_1/2_bar,
            sel+/-   = selectronL+/-,  ser+/-   = selectronR+/-,
            smul+/-  = smuonL+/-,      smur+/-  = smuonR+/-,
            stau1+/- = stau_1+/-,      stau2+/- = stau_2+/-,
            snuel = sneutrino_el_L,    snuml  = sneutrino_muon_L,
            snut1 = sneutrino_tau_1,   snuelb = sneutrino_el_L_bar
```

```
           snumlb= sneutrino_mu_L_bar, snut1b = sneutrino_tau_1_bar

gauginos: chi0_1/2/3/4 = neutralino1/2/3/4, chi+_1/2 = chargino_1/2_+


Decay Program information
-------------------------
SDECAY      decay calculator
1.1         version number

Spectrum calculator information
-------------------------------
SuSpect     spectrum calculator
2.3         version number

Model selection
---------------
mSUGRA model (cMSSM)

Input parameters
----------------
  0.10000000E+03   m0
  0.25000000E+03   m_1/2
  0.10000000E+02   tan(beta)
  0.10000000E+01   sign(mu)
 -0.10000000E+03   A0

Standard Model inputs
---------------------
  0.12793400E+03   alpha_emˆ-1(M_Z)ˆMSbar
  0.11663900E-04   G_F [GeVˆ-2]
  0.11720000E+00   alpha_S(M_Z)ˆMSbar
  0.91187000E+02   M_Z pole mass
  0.42500000E+01   mb(mb)ˆMSbar
  0.17800000E+03   mt pole mass
  0.17770000E+01   mtau pole mass

The W+ and b-quark mass
-----------------------
  0.80524230E+02   W+
  0.48788427E+01   b-quark pole mass calculated from mb(mb)_Msbar

Higgs and SUSY particle mass spectrum
-------------------------------------
```

```
   h             H             A             H+
112.096757  406.461015  406.119958  414.2754

  chi+_1      chi+_2
181.025728  388.864824

  chi0_1      chi0_2      chi0_3      chi0_4
97.3858252  181.569768 -370.511612  388.598381

  gluino
606.917407

  supl         supr       sdnl        sdnr
567.624937  547.354466  573.065871  546.427885

  schl         schr       sstl        sstr
567.624937  547.354466  573.065871  546.427885

  stop1        stop2      sbot1       sbot2
396.402171  586.605785  517.365564  547.189785

  sel          ser        smul        smur
204.34268  145.552503  204.34268  145.552503

  stau1        stau2
136.017749  208.433459

  snuel        snuml      snut1
188.743509  188.743509  187.856168


Mass matrices and mixing angles
-------------------------------
Q =  463.74599

 alpha(h,H)
-0.113466462

 theta_t      theta_b    theta_tau
1.00278019  0.379839276  1.28226697

N(i,j) Neutralino mixing matrix
i=1        0.986742E+00      -0.529652E-01       0.144340E+00      -0.519777E-01
i=2        0.982323E-01       0.945645E+00      -0.269127E+00       0.153874E+00
```

```
i=3        0.596137E-01      -0.886534E-01      -0.695821E+00      -0.710225E+00
i=4        0.114619E+00      -0.308369E+00      -0.650053E+00       0.684983E+00

U(i,j) Chargino mixing matrix U
i=1       -0.919474E+00       0.393150E+00
i=2        0.393150E+00       0.919474E+00

V(i,j) Chargino mixing matrix V
i=1       -0.974152E+00       0.225893E+00
i=2        0.225893E+00       0.974152E+00


DRbar Higgs parameters at the scale Q
-------------------------------------
Q =  463.74599
mu(Q)      =  364.713788
tanbeta(Q) =  9.7338847
v(Q)       =  172.370355


The gauge couplings at the scale Q
----------------------------------
Q =  463.74599
gprime DRbar =  0.360880368
g DRbar      =  0.646457261

Q =  463.74599
alpha_s DRbar   =  0.0956284765


The trilinear couplings AU, AD, AE at the scale Q
-------------------------------------------------
Q =  463.74599

1,1 A_u   DRbar = -685.815984
1,1 A_d   DRbar = -865.450847
1,1 A_e   DRbar = -258.05092
2,2 A_c   DRbar = -685.815984
2,2 A_s   DRbar = -865.450847
2,2 A_mu  DRbar = -258.05092
3,3 A_t   DRbar = -486.697847
3,3 A_b   DRbar = -794.730392
3,3 A_tau DRbar = -256.292593
```

```
 The Yukawa couplings at the scale Q
 ----------------------------------
 Q =  463.74599

 y_tau DRbar =  0.101034578
 y_t DRbar   =  0.911111063
 y_b DRbar   =  0.13941845

 MSOFT Q=  4.63745990E+02   The soft SUSY breaking masses at the scale Q
 ------------------------------------------------------------------------
   0.10144091E+03   M_1
   0.19165464E+03   M_2
   0.58708940E+03   M_3
   0.19911170E+03   M_eL
   0.19911170E+03   M_muL
   0.19827076E+03   M_tauL
   0.13883313E+03   M_eR
   0.13883313E+03   M_muR
   0.13640489E+03   M_tauR
   0.55126003E+03   M_q1L
   0.55126003E+03   M_q2L
   0.49846040E+03   M_q3L
   0.52929064E+03   M_uR
   0.52929064E+03   M_cR
   0.41564857E+03   M_tR
   0.52653725E+03   M_dR
   0.52653725E+03   M_sR
   0.52323669E+03   M_bR


==================
| The decay table |
==================

 The QCD corrections to the decays gluino -> squark  + quark
                                   squark -> gaugino + quark_prime
                                   squark -> squark_prime + Higgs
                                   squark -> gluino  + quark

 The multi-body decays for the inos, stops and sbottoms are included.

 The loop induced decays for the gluino, neutralinos and stops
 are included.
```

The SUSY decays of the top quark are included.

Decaying particle + total width
Parent --> Daughters Width Branching Ratio

TOP DECAYS 1.61167082
---
top --> bottom W+ 0.161167082E+01 0.100000000E+01