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Status of the SUSY Les Houches Accord

Interfacing SUSY Spectrum Calculators, Decay Packages, and Event Generators

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Updated writeup 27'th Aug:

v2: **hep-ph/0311123** & **JHEP 0407:036**

Status

SUSY model → **Spectrum Calculator** → **Event Gen./ XS Calc.**

SUSY model

- MSSM
- SUGRA
- GMSB
- AMSB
- RPV
- CPV
- NMSSM
- ...

Spectrum Calculator

- FeynHiggs
- IsaSUSY
- (Pythia)
- SoftSUSY
- SPheno
- SuSpect
- ...

Event Gen./ XS Calc.

- CompHEP
- Grace
- Herwig
- Isajet
- Prospino
- Pythia
- Sherpa
- Susygen
- Whizard
- ...

CDM Package

- micrΩs
- DarkSUSY
- Neutdriver
- ...

Decay Package

- HDecay
- NMHDecay NEW!
- SDecay
- ...

Ellwanger+Gunion+Hugonie
hep-ph/0406215
NMSSM Higgs sector

Status

SUSY model — SLHA Input → **Spectrum Calculator** — SLHA Input + Spectrum (+ Decay table) → **Event Gen./ XS Calc.**

SUSY model
- MSSM
- SUGRA
- GMSB
- AMSB
- RPV
- CPV
- NMSSM
- ...

Spectrum Calculator
- FeynHiggs
- Isasusy
- (Pythia)
- Softsusy
- SPheno
- Suspect
- ...

Event Gen./ XS Calc.
- CompHEP
- Grace
- Herwig
- Isajet
- Prospino
- Pythia
- Sherpa
- Susygen
- Whizard
- ...

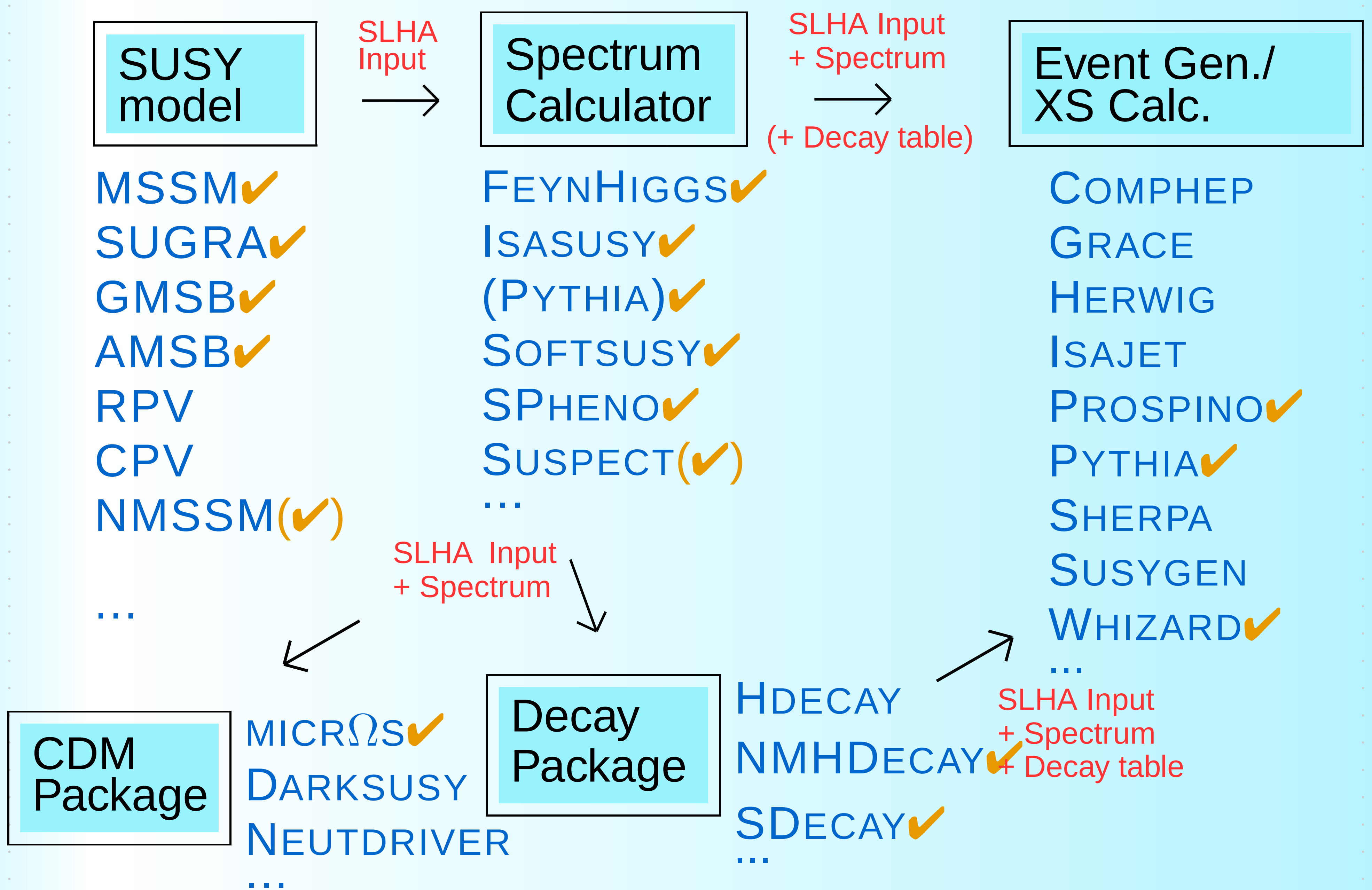
Spectrum Calculator — SLHA Input + Spectrum → **CDM Package**, **Decay Package**

CDM Package
- micrΩs
- DarkSusy
- Neutdriver
- ...

Decay Package
- HDecay
- NMHDecay
- SDecay
- ...

Decay Package — SLHA Input + Spectrum + Decay table → Event Gen./ XS Calc.

Status


SUSY model
SLHA Input
Spectrum Calculator
SLHA Input + Spectrum
(+ Decay table)
Event Gen./ XS Calc.
MSSM✔
SUGRA✔
GMSB✔
AMSB✔
RPV
CPV
NMSSM(✔)
...
FeynHiggs✔
IsaSUSY✔
(Pythia)✔
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SuSpect(✔)
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SLHA Input + Spectrum
CDM Package
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Decay Package
HDecay
NMHDecay✔
SDecay✔
...
SLHA Input + Spectrum + Decay table

Starting Point

SLHA — Considerations:

- ## Consistency

  Define parameters consistently and unambiguously $\longrightarrow$ specific conventions adopted (described in detail in writeup).

- ## Flexible/Extendable

  Structure should be general enough to *eventually* handle *any* model $\rightarrow$ files built of modular “data blocks”.

- ## Usable

  Easy to implement and to use $\rightarrow$ keep basic structure simple.

Starting Point

SLHA — Considerations:

- **Consistency**

  Define parameters consistently and unambiguously → specific conventions adopted (described in detail in writeup).

- **Flexible/Extendable**

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- **Usable**

  Easy to implement and to use → keep basic structure simple.

Conventions and Consistency

What is needed?

1. To specify experimental boundary conditions?
   (the measured “SM” couplings & masses).
2. To define the SUSY model?
   (W and the soft breaking terms, in a form suitable to spectrum calculation programs).
3. To communicate the resulting spectrum?
   (the mass and coupling spectrum at the EW scale, in a form suitable for cross section and width calculations).

$\longrightarrow$ pretty much ‘theoretician’s definitions’, you start with assumptions about the high scale physics and work out the low scale consequences.

Conventions and Consistency

1. Experimental Boundary Conditions

$\alpha_{\mathrm{em}}(m_{\mathrm{Z}})^{\overline{\mathrm{MS}}}$	$\frac{\alpha}{1-\Delta\alpha(m_{\mathrm{Z}})^{\overline{\mathrm{MS}}}}$
G_F	The Fermi constant determined from μ decay
m_{Z}	The Z boson pole mass
$\alpha_s(m_{\mathrm{Z}})^{\overline{\mathrm{MS}}}$	The 5–flavour $\overline{\mathrm{MS}}$ strong coupling at m_{Z}
$m_{\mathrm{b}}(m_{\mathrm{b}})^{\overline{\mathrm{MS}}}$	The $\overline{\mathrm{MS}}$ b quark running mass at m_{b}
m_{t}	Top pole mass
m_{τ}	Tau pole mass

Note: no SUSY corrections here!

Conventions and Consistency

2. Defining the SUSY Model

$\mathrm{sgn}(\mu)$ $\quad W_\mu = \epsilon_{ab}\left[-\mu H_1^a H_2^b\right]$, $(\epsilon_{12}=1)$

$\tan\beta(m_Z)^{\overline{\mathrm{DR}}}$ $\quad v_2/v_1$ (can also be given at $Q \neq m_Z$)

$V_3(M_{\mathrm{input}})$
$$\epsilon_{ab}\sum_{ij}\left[(T_E)_{ij}H_1^a\tilde{L}^b_{i_L}\tilde{e}^*_{j_R} + (T_D)_{ij}H_1^a\tilde{Q}^b_{i_L}\tilde{d}^*_{j_R} + (T_U)_{ij}H_2^b\tilde{Q}^a_{i_L}\tilde{u}^*_{j_R}\right] + \mathrm{h.c.},\quad A_{ij} = T_{ij}/Y_{ij}$$

$V_2(M_{\mathrm{input}})$
$$m^2_{H_j}H^*_{j\,a}H^a_j + \tilde{Q}^*_{i_L a}(m^2_{\tilde{Q}})_{ij}\tilde{Q}^a_{j_L} + \tilde{L}^*_{i_L a}(m^2_{\tilde{L}})_{ij}\tilde{L}^a_{j_L} + \tilde{q}_{i_R}(m^2_{\tilde{q}})_{ij}\tilde{q}^*_{j_R} + \tilde{e}_{i_R}(m^2_{\tilde{e}})_{ij}\tilde{e}^*_{j_R} - (m_3^2\epsilon_{ab}H_1^aH_2^b + \mathrm{h.c.})$$

- Either $(m^2_{H_1}, m^2_{H_2})$ or $\left(\mu, m_A^2 = \frac{m_3^2}{\sin\beta\cos\beta}\right)$

$\mathcal{L}_G(M_{\mathrm{input}})$
$$\frac{1}{2}\left(M_1\tilde{b}\tilde{b} + M_2\tilde{w}^A\tilde{w}^A + M_3\tilde{g}^X\tilde{g}^X\right) + \mathrm{h.c.}$$

Conventions and Consistency

3. Communicating the Spectrum: $\overline{\mathrm{DR}}$ parameters

$W(Q_i)^{\overline{\mathrm{DR}}}$	$\epsilon_{ab}\left[(Y_E)_{ij}H_1^aL_i^b\bar{E}_j + (Y_D)_{ij}H_1^aQ_i^b\bar{D}_j + (Y_U)_{ij}H_2^bQ_i^a\bar{U}_j - \mu H_1^aH_2^b\right]$
$\tan\beta(Q_i)^{\overline{\mathrm{DR}}}$	v_2/v_1
$g_j(Q_i)^{\overline{\mathrm{DR}}}$	g', g, and g_3: gauge couplings
$A_j(Q_i)^{\overline{\mathrm{DR}}}$	Soft breaking trilinear couplings
$v_j(Q_i)^{\overline{\mathrm{DR}}}$	$\sqrt{2}\langle H_j^0\rangle$, so $v^2 = (v_1^2 + v_2^2) = (246\ \mathrm{GeV})^2$
$M_j(Q_i)^{\overline{\mathrm{DR}}}$	Soft breaking gaugino masses
$m_j(Q_i)^{\overline{\mathrm{DR}}}$	Soft breaking sfermion masses
$m_A(Q_i)^{\overline{\mathrm{DR}}}$	Running A mass.

In v1 writeup / In v2 writeup (& JHEP)

Conventions and Consistency

3. Communicating the Spectrum: mixing matrices

- mixing angles avoided, matrix elements given instead.

$$T = \cancel{\begin{pmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{pmatrix}} = \begin{pmatrix} T_{11} & T_{12} \\ T_{21} & T_{22} \end{pmatrix}$$

- No consensus on best ‘scheme’ $\to$
  Effective ‘best choice’ definitions, at the discretion of each spectrum calculator.

E.g. α: Diagonalizes loop–corrected mass matrices, but not a $\overline{\mathrm{DR}}$ or $\overline{\mathrm{MS}}$ parameter. Still, not scale independent. On–shell scheme has scale fixed by renormalization conditions, and external propagators still carry some momentum, which momentum?

Some Examples...

(Examples)

```
# SUSY Les Houches Accord 1.0
# Example input file - Snowmass point 1a
Block MODSEL   # Model selection
     1     1      # SUGRA model
Block SMINPUTS # SM parameters
     5     4.25   # mb(mb)
     6   174.3    # t pole mass
Block MINPAR   # Model Parameters
     1   100.     # m0
     2   250.     # m12
     3    10.     # tanbeta
     4     1.     # sgnmu
     5  -100.     # A0
```

(Examples)

```
# SUSY Les Houches Accord 1.0
# Example spectrum file - Snowmass point 1a
Block SPINFO          # Program information
     1   SOFTSUSY     # spectrum calculator
     2   1.8.4        # version number
Block MODSEL  # Select model
     1   1  # sugra
Block MINPAR  # Input parameters
     1   1.000000000e+02  # m0
     2   2.500000000e+02  # m12
     3   1.000000000e+01  # tanb
     4   1.000000000e+00  # sign(mu)
     5  -1.000000000e+02  # A0
Block SMINPUTS # SM parameters
     1   1.279340000e+02  # 1/alpha(MZ)[MSbar]
     2   1.166370000e-05  # Gmu [GeV**-2]
     3   1.172000000e-01  # alphas(MZ)[MSbar]
     4   9.118760000e+01  # Z pole mass
     5   4.250000000e+00  # mb(mb)[MSbar]
     6   1.743000000e+02  # t pole mass
     7   1.777000000e+00  # tau pole mas
Block MASS  # Mass spectrum (pole masses)
         24    8.024639840e+01   # W
         25    1.106368320e+02   # h0
         35    4.008746040e+02   # H0
         36    4.005062720e+02   # A0
         37    4.087847760e+02   # H+
    1000001    5.537379281e+02   # sd(L)
    1000002    5.480648005e+02   # su(L)
    1000003    5.536689385e+02   # ss(L)
    1000004    5.479950083e+02   # sc(L)
    1000005    4.990864878e+02   # sb(1)
    1000006    3.866681125e+02   # st(1)
    1000011    2.005077001e+02   # se(L)
    1000012    1.844822029e+02   # snue(L)
    1000013    2.005050044e+02   # smu(L)
    1000014    1.844792730e+02   # snumu(L)
    1000015    1.339969762e+02   # stau(1)
    1000016    1.836242253e+02   # snu(tau(L))
    1000021    5.934756712e+02   # gluino
    1000022    9.701573617e+01   # neutralino(1)
    1000023    1.788864799e+02   # neutralino(2)
    1000024    1.782649096e+02   # chargino(1)
```

```
    1000025   -3.536102287e+02  # neutralino(3)
    1000035    3.733417082e+02  # neutralino(4)
    1000037    3.736128390e+02  # chargino(2)
    2000001    5.269676664e+02  # sd(R)
    2000002    5.311251030e+02  # su(R)
    2000003    5.269652151e+02  # ss(R)
    2000004    5.309795680e+02  # sc(R)
    2000005    5.257115262e+02  # sb(2)
    2000006    5.704560875e+02  # st(2)
    2000011    1.430886701e+02  # se(R)
    2000013    1.430810123e+02  # smu(R)
    2000015    2.043832731e+02  # stau(2)
Block alpha # Effective Higgs mixing angle alpha
         -1.146864127e-01   # alpha
Block hmix Q= 4.520624648e+02  # DRbar Higgs mixing
     1   3.439934743e+02   # mu
Block stopmix  # stop mixing matrix
  1  1     5.443784304e-01   # O(1,1)
  1  2     8.388397490e-01   # O(1,2)
  2  1     8.388397490e-01   # O(2,1)
  2  2    -5.443784304e-01   # O(2,2)
Block sbotmix  # sbottom mixing matrix
  1  1     9.355024721e-01   # O(1,1)
  1  2     3.533201449e-01   # O(1,2)
  2  1    -3.533201449e-01   # O(2,1)
  2  2     9.355024721e-01   # O(2,2)
Block staumix  # stau mixing matrix
  1  1     2.810947184e-01   # O(1,1)
  1  2     9.596800297e-01   # O(1,2)
  2  1     9.596800297e-01   # O(2,1)
  2  2    -2.810947184e-01   # O(2,2)
# Gaugino-higgsino mixing
Block nmix  # neutralino mixing matrix
  1  1     9.849417415e-01   # N(1,1)
  1  2    -5.795970738e-02   # N(1,2)
  1  3     1.526931274e-01   # N(1,3)
  1  4    -5.670314904e-02   # N(1,4)
  2  1     1.090115410e-01   # N(2,1)
  2  2     9.374300545e-01   # N(2,2)
  2  3    -2.852021039e-01   # N(2,3)
  2  4     1.673354023e-01   # N(2,4)
...
```

(Examples)

```
# SUSY Les Houches Accord 1.0
# Example decay file - Gluino decays
Block DCINFO     # Program information
     1    SDECAY   # Decay package
     2    1.0      # version number
#        PDG            Width
DECAY   1000021    1.01752300e+00   # gluino decays
#          BR          NDA      ID1         ID2
     4.18313300E-02    2     1000001        -1    # BR(sg -> sd(L) dbar)
     1.55587600E-02    2     2000001        -1    # BR(sg -> sd(R) dbar)
     3.91391000E-02    2     1000002        -2    # BR(sg -> su(L) ubar)
     1.74358200E-02    2     2000002        -2    # BR(sg -> su(R) ubar)
     4.18313300E-02    2     1000003        -3    # BR(sg -> ss(L) sbar)
     1.55587600E-02    2     2000003        -3    # BR(sg -> ss(R) sbar)
     3.91391000E-02    2     1000004        -4    # BR(sg -> sc(L) cbar)
     1.74358200E-02    2     2000004        -4    # BR(sg -> sc(R) cbar)
     1.13021900E-01    2     1000005        -5    # BR(sg -> sb(1) bbar)
     6.30339800E-02    2     2000005        -5    # BR(sg -> sb(2) bbar)
     9.60140900E-02    2     1000006        -6    # BR(sg -> st(1) tbar)
     0.00000000E+00    2     2000006        -6    # BR(sg -> st(2) tbar)
     4.18313300E-02    2    -1000001         1    # BR(sg -> sdbar(L) d)
     1.55587600E-02    2    -2000001         1    # BR(sg -> sdbar(R) d)
     3.91391000E-02    2    -1000002         2    # BR(sg -> subar(L) u)
     1.74358200E-02    2    -2000002         2    # BR(sg -> subar(R) u)
     4.18313300E-02    2    -1000003         3    # BR(sg -> ssbar(L) s)
     1.55587600E-02    2    -2000003         3    # BR(sg -> ssbar(R) s)
     3.91391000E-02    2    -1000004         4    # BR(sg -> scbar(L) c)
     1.74358200E-02    2    -2000004         4    # BR(sg -> scbar(R) c)
     1.13021900E-01    2    -1000005         5    # BR(sg -> sbbar(1) b)
     6.30339800E-02    2    -2000005         5    # BR(sg -> sbbar(2) b)
     9.60140900E-02    2    -1000006         6    # BR(sg -> stbar(1) t)
     0.00000000E+00    2    -2000006         6    # BR(sg -> stbar(2) t)
```

News and Updates...

News

- NMHDecay: [U. Ellwanger et al., hep-ph/0406215]
  - NMSSM Higgs sector: masses + couplings.
  - NMSSM Higgs decays.
- CPSuperH: [J. Lee et al., CPC 156(2004)283, hep-ph/0307377]
  - CPV MSSM Higgs sector: masses + mixings
  - CPV MSSM Higgs decays.
- SDecay: [M. Mühlleitner et al., hep-ph/0311167]
  - 3-body sbottom decays.
  - QCD corrections for gaugino $\to \tilde{q}q'$ and $\tilde{q} \to \tilde{q}'V$.
  - SLHA spectrum read-in. (SLHA output already there.)

News

- Sfitter: [R. Lafaye et al., hep-ph/0404282]
  - MSSM fitting.
- Fittino [P. Bechtle et al.]
  - MSSM fitting.
- SLHAlib-1.0 [T. Hahn, hep-ph/0408283]
  - F77 SLHA Read-Write libraries.

Durham Agenda

On the to-do list here...

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Conventions and Consistency:

- Conventions for CP Violation (phases and fields).
  (1st session: non-Higgs, 2nd session: Higgs.)
- Conventions for NMSSM.
  (cf. NMHDecay by Ellwanger/Gunion/Hugonie, 2nd session.)

+? (depending on interest)

- Effective parameters / Vertices (?)
  (1st session: non-Higgs, 2nd session: Higgs.)
- Conventions for decay tables.
  (e.g. treatment of on–shell propagators)
- Higher orders, cross sections, errors, ...

On the to-do list here...

+ practical implementation...

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+ practical implementation...

+ interaction with SPA...

Tentative Agenda

Session 1: 09:00 – 10:15 (SuSy + Generators)

09:00	–	now	Status report on the SLHA
now	–	10:15	SuSy Tools / SLHA / SPA Discussion

- CP Violation (non-Higgs: complex mixing, phases and fi elds).
- Effective Parameters / Vertices, Decay Tables, higher orders, XS, ...

Session 2: 10:45 – 12:30 (Higgs + Generators)

10:45	–	11:00	Informal presentation of NMHDecay.
11:00	–	12:00	Higgs Tools / SLHA Discussion.

- NMSSM.
- CP Violation (Higgs Sector).
- punch-through from session 1 + ...

12:00	–	12:30	Higgs/Generators Tools Discussion.

- Which generators for Higgs physics?
- Event data sample for physics analyses.