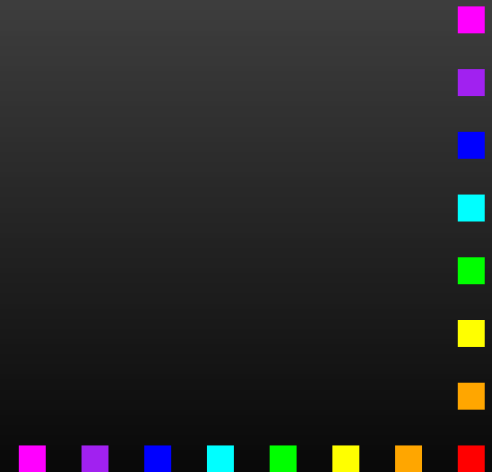# Thoughts on the SUSY Les Houches Accord

T. Hahn

SLHA Mission

Provide 'connectivity' to SUSY calculators of all sorts.

Basic interfacing scheme:

$$\boxed{\text{SUSY Scenario}} \rightarrow \boxed{\text{Spectrum Calculator}} \rightarrow \boxed{\text{Decay Package}} \rightarrow \boxed{\text{Event Generator}}$$

SLHA provides pure **Transport Layer only.**

No 'tampering' with physics (e.g. running masses to different scale). The latter is dealt with in the 'sister project' **SPA** (SUSY Parameter Analysis, **http://spa.desy.de**).

Format Structure

- **ASCII text input/output.**

- **Comments encouraged for readability.**

- **Data organized in blocks.**

- **PDG codes for particles.**

- **Robust, i.e. whitespace, case, order of blocks irrelevant.**

- **Private blocks allowed, e.g. to store data specific to a particular code.**

- **Many digits given, so as not to lose precision due to 'technical' reasons.**

```
BLOCK MODSEL
    1     1
BLOCK MINPAR
    1    0.100000000E+03   # m0
    2    0.250000000E+03   # m12
    3    0.100000000E+02   # tanb
    4    0.100000000E+01   # sgn(mu)
    5   -0.100000000E+03   # A
BLOCK SMINPUTS
    4    0.911870000E+02   # MZ
    5    0.425000000E+01   # mb(mb)
    6    0.175000000E+03   # t
...
```
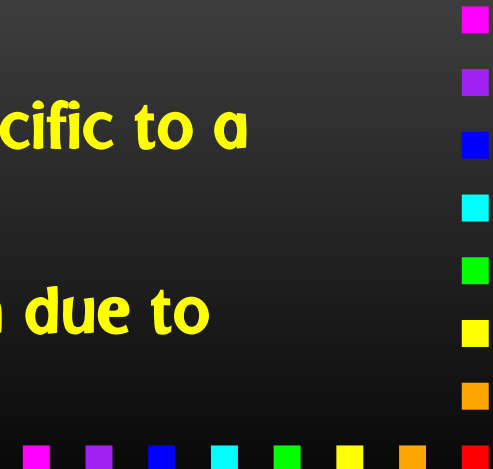
Example SLHA File

```
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             # Standard Model inputs
    1    1.279340000e+02   # alpha^(-1) SM MSbar(MZ)
    2    1.166370000e-05   # G_Fermi
    3    1.172000000e-01   # alpha_s(MZ) SM MSbar
    4    9.118760000e+01   # MZ(pole)
    5    4.250000000e+00   # mb(mb) SM MSbar
    6    1.743000000e+02   # mtop(pole)
    7    1.777000000e+00   # mtau(pole)
Block SPINFO               # Program information
    1    SOFTSUSY          # spectrum calculator
    2    1.8               # version number
Block MASS  # Mass spectrum
#PDG code       mass            particle
         6    1.743000000e+02  # top
        25    1.096471686e+02  # h0
        35    3.905646065e+02  # H0
        36    3.849267509e+02  # A0
        37    3.963987424e+02  # H+
   1000001    5.537379281e+02  # ~d_L
   1000002    5.480648005e+02  # ~u_L
   1000003    5.536689385e+02  # ~s_L
   1000004    5.479950083e+02  # ~c_L
   1000005    4.990864878e+02  # ~b_1
   1000006    3.866681125e+02  # ~t_1
   1000011    2.005077001e+02  # ~e_L
   1000012    1.844822029e+02  # ~snue_L
...
```

```
Block alpha # Higgs mixing parameters
      -1.146864127e-01  # alpha
Block hmix Q= 4.520624648e+02   # Higgs mixing parameters
    1    3.439934743e+02  # mu
Block stopmix  # stop mixing matrix
    1  1    5.443784304e-01  # O_{11}
    1  2    8.388397490e-01  # O_{12}
    2  1    8.388397490e-01  # O_{21}
    2  2   -5.443784304e-01  # O_{22}
Block sbotmix  # sbottom mixing matrix
    1  1    9.355024721e-01  # O_{11}
    1  2    3.533201449e-01  # O_{12}
    2  1   -3.533201449e-01  # O_{21}
    2  2    9.355024721e-01  # O_{22}
Block staumix  # stau mixing matrix
    1  1    2.810947184e-01  # O_{11}
    1  2    9.596800297e-01  # O_{12}
    2  1    9.596800297e-01  # O_{21}
    2  2   -2.810947184e-01  # O_{22}
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}
    3  1   -6.143190096e-02  # N_{3,1}
    3  2    9.173963120e-02  # N_{3,2}
    3  3    6.949466769e-01  # N_{3,3}
    3  4    7.105343608e-01  # N_{3,4}
...
```
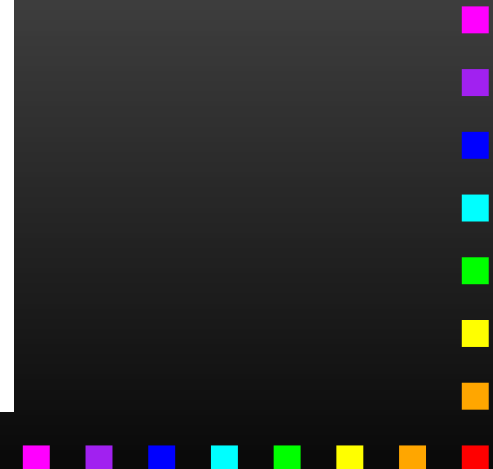
Editing Tools

Vim syntax highlighting for SUSY Les Houches Accord (SLHA)

In my diploma thesis I'm working with supersymmetry spectrum calculation programs (primarily SPheno) which use the SUSY Les Houches Accord (SLHA), defined in arXiv:hep-ph/0311123 and arXiv:0801.0045 [hep-ph], for data input and output. To ease editing input files and reading output files with my favourite text editor Vim I wrote a corresponding syntax file for the Accord. It is really helpful for preventing spelling errors of block names (which are partially cryptic) and for navigating and extracting numerical data.

To enable syntax highlighting in Vim for SLHA download the two files slha.vim and scripts.vim. Copy the slha.vim into ~/.vim/syntax/ and copy scripts.vim into ~/.vim/ or if you have already a scripts.vim file append the content of my file to it. Without further ado Vim should now highlight SLHA files. Here is the compulsory screenshot:

Codes using the SLHA

Spectrum Calculators:

- CPsuperH, FeynHiggs, ISASUSY, NMSSMTools, Pythia, SoftSusy, SPheno, SuSpect.

Decay Packages:

- CPsuperH, FCHDecay, FeynHiggs, HDecay, NMSSMTools, SDecay, SPheno, SuperIso, SusyBSG.

Relic Density Programs:

- DarkSusy, ISAReD, MicrOmegas, NeutDriver, SuperIso Relic.

Event Generators / XS Calculators:

- CalcHEP, CompHEP, Freitas' programs for ILC NLO slepton production, GRACE SUSY, Herwig (ISAwig), ISAJet, Madgraph (SUSY-Madgraph), Pythia, Sherpa, SusyGen, Prospino, Whizard, Spira's programs for SM/MSSM Higgs at LHC.

SLHA History

## SLHA 1   hep-ph/0311123 [JHEP 07 (2004) 036]

SUSY Les Houches Accord: Interfacing SUSY Spectrum Calculators, Decay Packages, and Event Generators

P. Skands[1], B.C. Allanach[2], H. Baer[3], C. Balázs[3,4], G. Bélanger[2], F. Boudjema[2], A. Djouadi[5,6], R. Godbole[7], J. Guasch[8], S. Heinemeyer[6,9], W. Kilian[10], J-L. Kneur[5], S. Kraml[6], F. Moortgat[11], S. Moretti[12], M. Mühlleitner[8], W. Porod[13], A. Pukhov[14], P. Richardson[6,15], S. Schumann[16], P. Slavich[17], M. Spira[8], G. Weiglein[15]

SLHA 2   0801.0045 [CPC 180 (2009) 8]

SUSY Les Houches Accord 2

B.C. Allanach[1], C. Balázs[2], G. Bélanger[3], M. Bernhardt[4], F. Boudjema[3], D. Choudhury[5], K. Desch[4], U. Ellwanger[6], P. Gambino[7], R. Godbole[8], T. Goto[9], J. Guasch[10], M. Guchait[11], T. Hahn[12], S. Heinemeyer[13], C. Hugonie[14], T. Hurth[15,16], S. Kraml[15,17], S. Kreiss[18], J. Lykken[19], F. Moortgat[20], S. Moretti[6,21], S. Peñaranda[22], T. Plehn[18], W. Porod[23], A. Pukhov[24], P. Richardson[15,25], M. Schumacher[26], L. Silvestrini[27], P. Skands[15,19], P. Slavich[3,15], M. Spira[28], G. Weiglein[25], P. Wienemann[4]
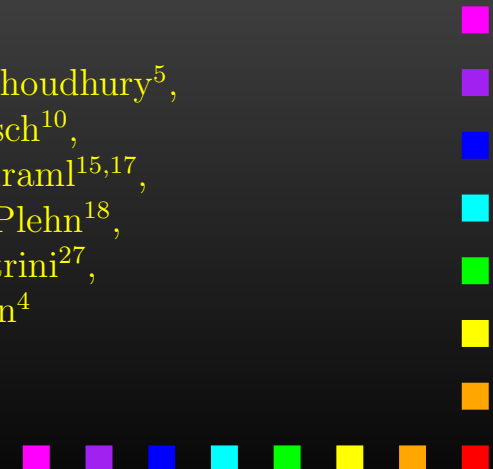
SLHA 1 (2003)

- SLHA 1 designed for 'minimal' SUSY models (mSUGRA, mGMSB, mAMSB with $\mathcal{O}(5)$ inputs).

- First-ever collaborative effort to interface SUSY codes – suffice it to say that the 'compromise' finally encoded in SLHA 1 was difficult enough to come up with.

- Inputs: `MINPAR` (necessary), `EXTPAR` (optional), `SMINPUTS`.

- Third-generation parameters only.

- No imaginary parts: e.g. one neutralino mass had to be taken negative, to compensate for imaginary row in mixing matrix.

- Remarkably successful (given the amount of discussion), adopted by most major codes within $\sim$ 1 year.

SLHA 2 (2006/07)

- Extension of SLHA 1 for **non-minimal models.**

- Concept of Accord widely accepted by now. Discussions with a lot less 'heat'.

- **Upward compatibility:** SLHA 2 code reads SLHA 1 files (e.g. should be able to handle 'negative' neutralino mass).

- Many of the **shortcomings of SLHA 1 fixed,** e.g. 1st and 2nd gen included, imaginary parts.

- Many **extensions of 'vanilla' SUSY:** CPV, RPV, LFV, NMFV, Neutrinos, NMSSM, but **only one at a time.**

- Number of blocks in SLHA 1: 23. Number of blocks in SLHA 2: 81.

Extensions

- **Peter Skands' semi-official QNUMBERS block for defining PDG-like codes for new particles (used by Pythia).**

```
BLOCK QNUMBERS 1234567 # new_guy
        1 0  # 3 times electric charge
        2 2  # number of spin states (2S+1)
        3 1  # colour rep (1: singlet, 3: triplet, 8: octet)
        4 0  # Particle/Antiparticle distinction (0=own anti)
BLOCK MASS  # Mass Spectrum
   1234567  3.417200E+02  # new_guy
DECAY   1234567    1.000000E+00 # new_guy width
   1.0000E-00 2        22        22 # Br(new_guy -> gamma gamma)
```
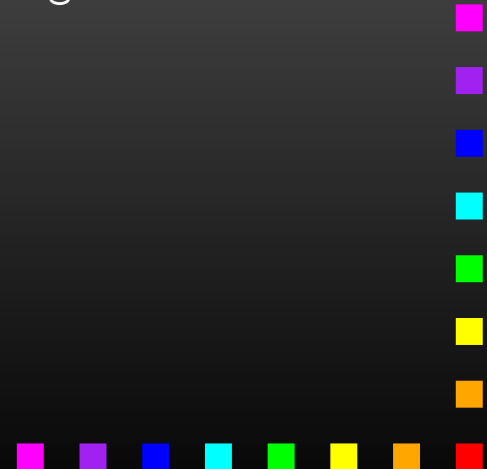
Notes / Guiding Principles

There is a lot of 'fine print' achieved through community discussion which makes the SLHA **flexible and usable:**

- The **Block structure** makes the Accord **extendable** – e.g. for the FLHA.

- The SLHA **prefers certain inputs over others,** e.g. matrix elements are preferred over a mixing angle.

- The SLHA write-up is very **specific on the exact definition** of all quantities for consistency.

- Parameters should not appear more than once in the accord, so as **not to risk ambiguities.**

- Encodes theorist's model: start from assumptions at the high scale and work out the low-scale consequences.

SLHA I/O

- Reading/writing SLHA files **not entirely straightforward.**

- Even if you don't need all fields, you **must be able to transport them.** Your program may after all be in the middle of an evaluation chain.

- Many private solutions, mainly due to historic reasons (no libraries available at the time). Robustness not clear.

- Two **public libraries** available:
    - SLHAio (C++),
    - SLHALib (Fortran).
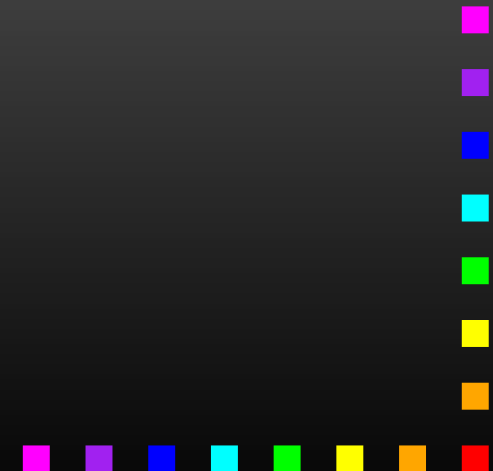
SLHAio

- **C++ code for SLHA I/O** by Sven Kreiss,
  http://svenkreiss.com/SLHAio.

- Bindings: C++, C, Fortran, Python, …

- Claims to be used so far in SFitter and SUSYHit(?).
  (Present S'Hit code does not contain SLHAio.)

- Source code currently available only through SFitter SVN.

- Able to **read/write arbitrary entries** (not just doubles).
  Can possibly transfer original comments of input file to
  output file.

- Coverage of SLHA 2 not clear.
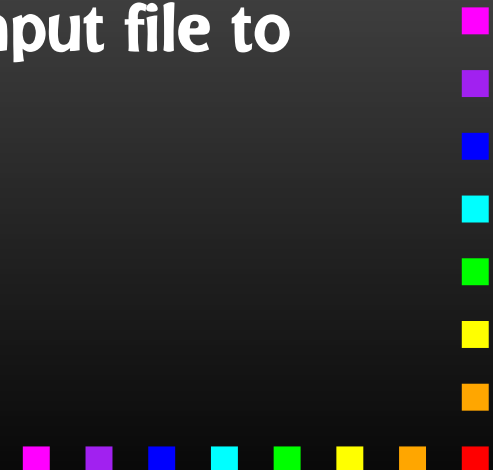
SLHALib

- **By-product of FeynHiggs. Used by the ISA∗ codes, FCHDecay, DarkSUSY, older versions of SFitter, …**
  Available at http://feynarts.de/slha.

- **Implemented as native Fortran 77 Library with C/C++ interface (used e.g. in FH's Mathematica interface).**

- **All data transferred in one double complex array.**

- **This array is indexed by preprocessor macros, e.g. `MinPar_TB` instead of `slhadata(20)`.**
  Decay information (non-static) accessed by subroutines.

- **Implements the full SLHA 2.**

Update planned to transport/access(?) private blocks.
(Current: Mathematica code SLHA2.m generates macros.)

Some Technical Brainstorming

- **Binary transfer format.** Text format was believed to be an obstacle to performance in the beginning. Critics probably assuaged (topic didn't come up recently). Workaround: use one of public libraries and pass internal data structure from one routine to next.

- **Client-Server architecture** (my pet peeve). Example: FeynHiggs loads in 'server mode' and listen(2)s on agreed port. Client (e.g. XS calculator) connect(2)s and exchanges information via SLHA.
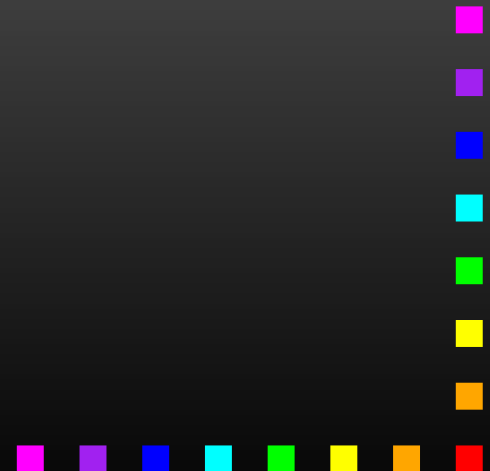
Summary

- **SLHA** defines a **common exchange format for SUSY parameters.**

- **Text-based format,** allows for 'human intervention' (reading, editing).

- **Widely used,** implemented in most **SUSY** codes.

- Peter Skands is the main coordinator of the **SLHA** and keeps all information at his Web site at http://home.fnal.gov/∼skands/slha/.

- **The mere fact that interchange standards like the SLHA are devised shows that computational science plays a much bigger rôle these days than e.g. at LEP.**