

Peter Skands (Fermilab)

## The SUSY Les Houches Accord and PYTHIA 6.3

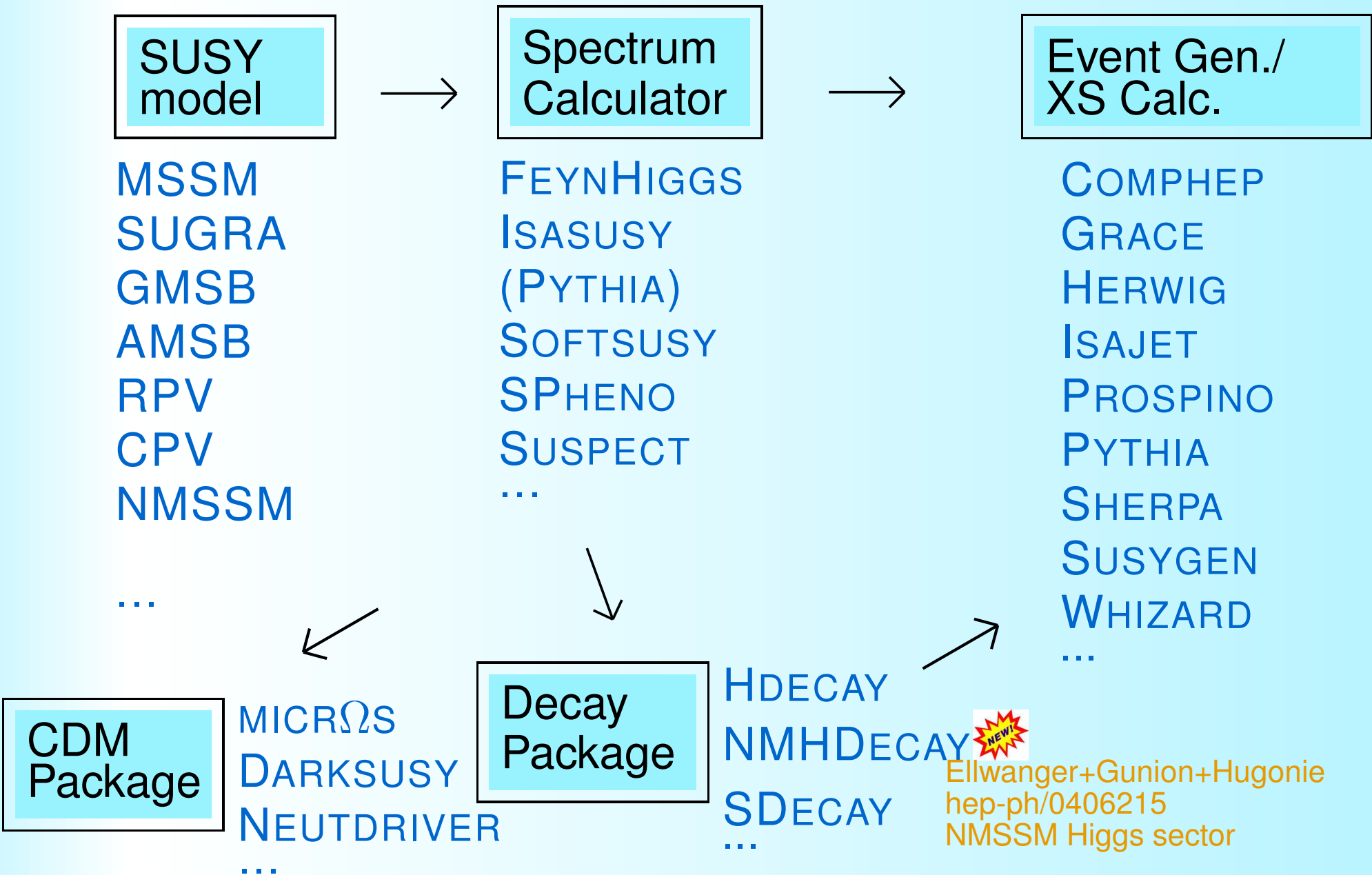
Interfacing SUSY Spectrum Calculators, Decay  
Packages, and Event Generators

P. Skands, B.C. Allanach, H. Baer, C. Balázs, G. Bélanger, F. Boudjema,  
A. Djouadi, R. Godbole, J. Guasch, S. Heinemeyer, W. Kilian, J. Kneur, S. Kraml,  
F. Moortgat, S. Moretti, M. Mühlleitner, W. Porod, A. Pukhov, P. Richardson,  
S. Schumann, P. Slavich, M. Spira, G. Weiglein

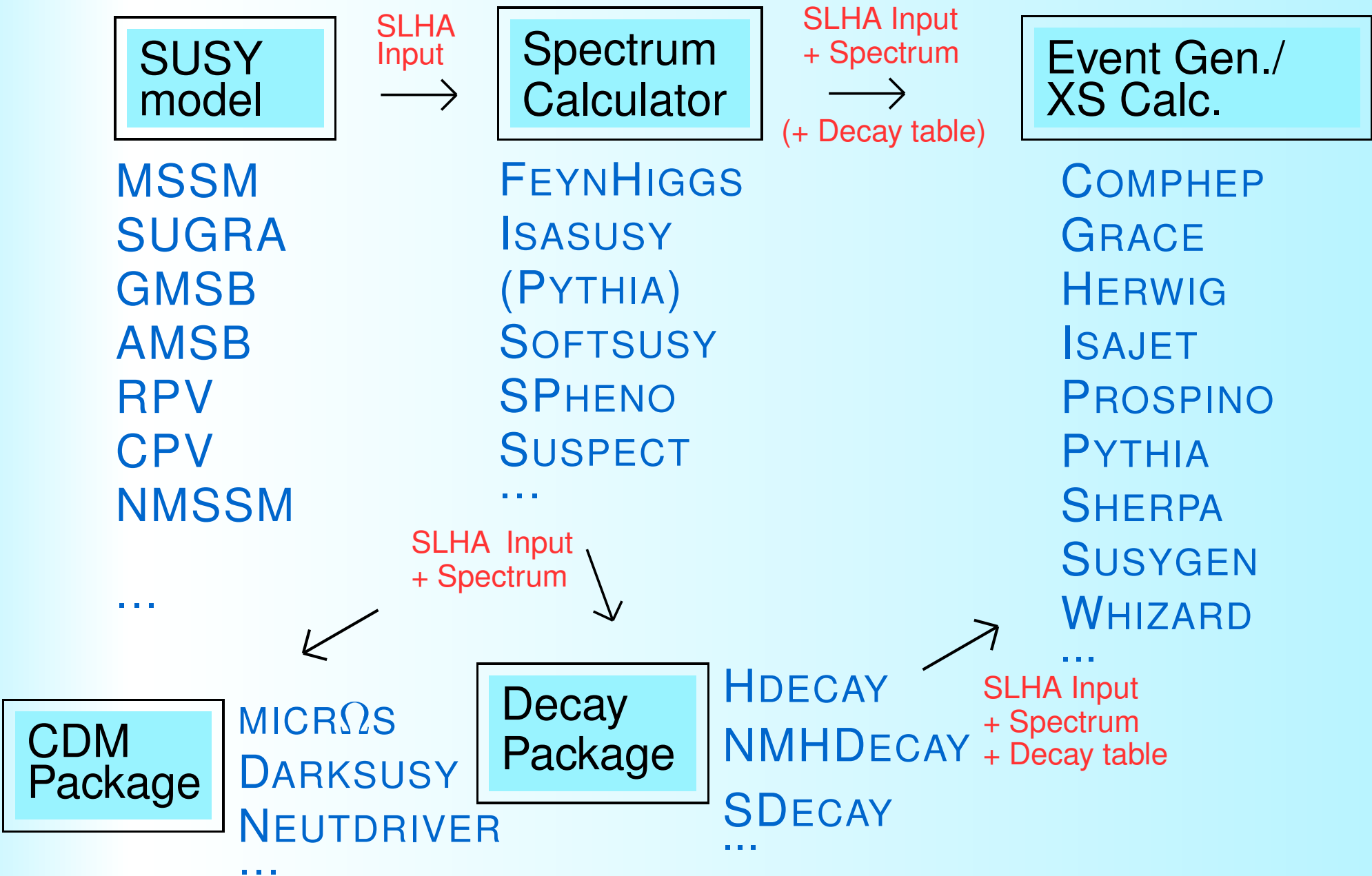
Updated writeup **27'th Aug '04**:

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

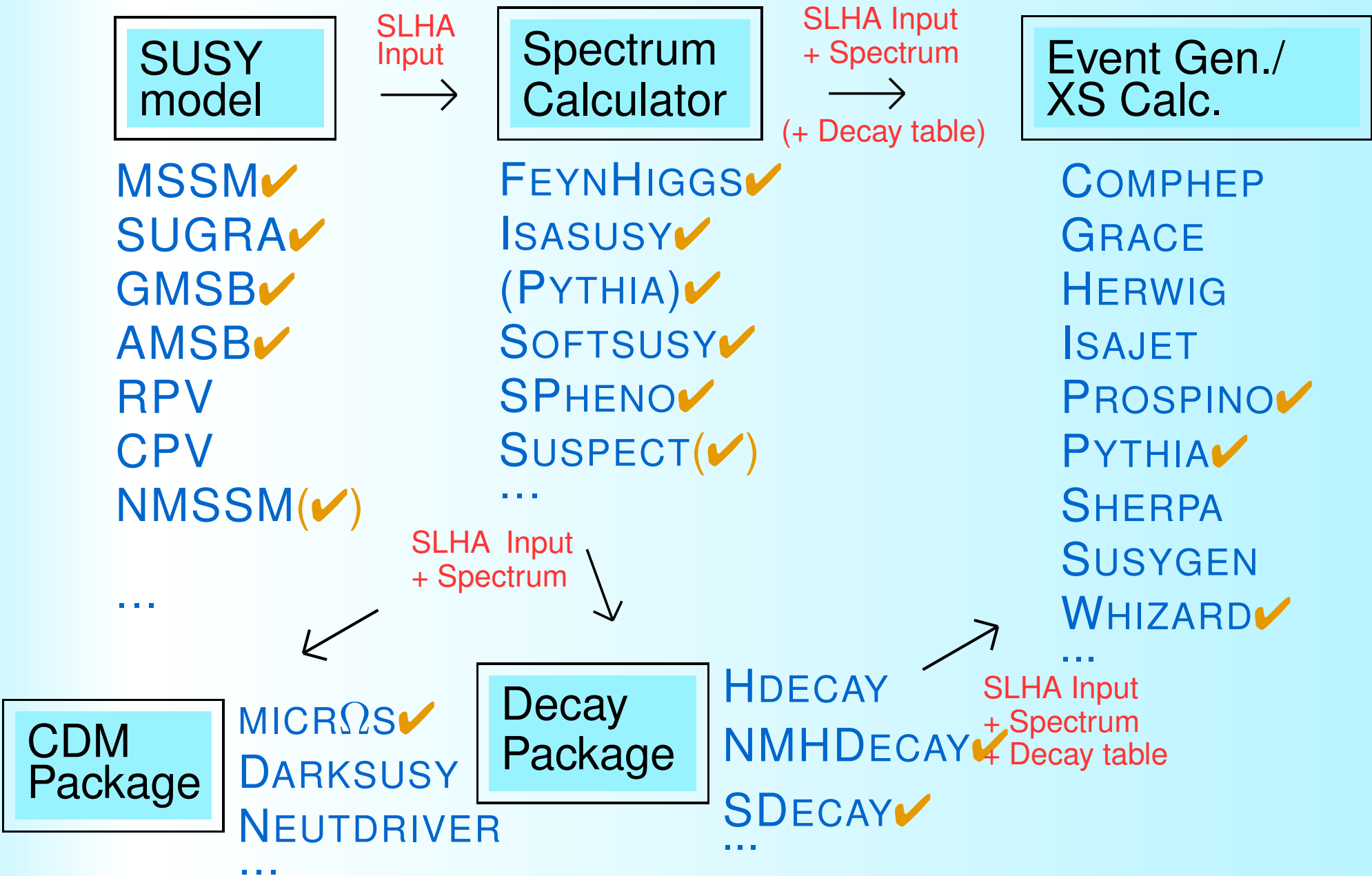
# What is the SLHA?



# What is the SLHA?



# What is the SLHA?



## SLHA — Considerations:

- **Consistency**

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

- **Flexible/Extendable**

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

- **Usable**

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

## SLHA — Considerations:

- Consistency

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

- Flexible/Extendable

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

- 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).

(→ pretty much ‘theoretician’s definitions’, you start with assumptions about the high scale physics and work out the low scale consequences.)

## 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 # m1/2
  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 mix
  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 stauxmix # 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)
  .. 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...

- NMHDecay: [U. Ellwanger et al., hep-ph/0406215]
  - NMSSM Higgs sector: masses + couplings.
  - NMSSM Higgs decays.
- SDecay: [M. Mühlleitner et al., hep-ph/0311167]
  - 3-body sbottom decays.
  - QCD corrections for gaugino  $\rightarrow \tilde{q}q'$  and  $\tilde{q} \rightarrow \tilde{q}'V$ .
  - SLHA spectrum read-in. (SLHA output already there.)
- SLHAlib-1.0 [T. Hahn, hep-ph/0408283]
  - F77 SLHA Read-Write libraries.

# Using the SLHA with PYTHIA 6.3

# Using the SLHA with PYTHIA 6.3

1. Run a spectrum calculator of your choice, and get an SLHA output file with the spectrum.

(Optional: also run a decay package, with the SLHA file as input, to add a list of decay modes and partial widths to the spectrum.)

2. In your event generation code, before initializing PYTHIA, open the SLHA file on some unit number, for instance unit 42.

```
OPEN(42, file='SPheno.spc', status='old')
```

3. Tell PYTHIA 1) to use this file and 2) where it is.

```
CALL PYGIVE('IMSS(1)=11;IMSS(21)=42')
```

4. (To also read in the decay table, add:

```
CALL PYGIVE('IMSS(22)=42') )
```

# Where to find more info:

- The SUSY Les Houches Accord:  
PS et al., JHEP 0407:036 (hep-ph/0311123)
- SLHA Latest News, codes, examples, workshops, ...:  
<http://www.thep.lu.se/~zeiler/slha/>
- The PYTHIA 6.3 Manual:  
TS, SM, PS, L. Lönnblad, hep-ph/0308153
- The PYTHIA 6.3 Update Notes (running):  
<http://www.thep.lu.se/~torbjorn/Pythia.html>,  
click on `Preview` to get to the PYTHIA 6.3 homepage
- If all else fails, [skands@fnal.gov](mailto:skands@fnal.gov)



# EXTRA MATERIAL

# Conventions and Consistency

## 1. Experimental Boundary Conditions

---

$$\alpha_{\text{em}}(m_Z)^{\overline{\text{MS}}}$$

$$\frac{\alpha}{1 - \Delta\alpha(m_Z)^{\overline{\text{MS}}}}$$

$$G_F$$

The Fermi constant determined from  $\mu$  decay

$$m_Z$$

The Z boson pole mass

$$\alpha_s(m_Z)^{\overline{\text{MS}}}$$

The 5-flavour  $\overline{\text{MS}}$  strong coupling at  $m_Z$

$$m_b(m_b)^{\overline{\text{MS}}}$$

The  $\overline{\text{MS}}$  b quark running mass at  $m_b$

$$m_t$$

Top pole mass

$$m_\tau$$

Tau pole mass

Note: **no SUSY corrections here!**

# Conventions and Consistency

## 2. Defining the SUSY Model

---

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

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

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

$$V_2(M_{\text{input}}) \quad m_{H_j}^2 H_j^* H_j^a + \tilde{Q}_{iLa}^* (m_{\tilde{Q}}^2)_{ij} \tilde{Q}_{jL}^a + \tilde{L}_{iLa}^* (m_{\tilde{L}}^2)_{ij} \tilde{L}_{jL}^a \\ + \tilde{q}_{iR} (m_{\tilde{q}}^2)_{ij} \tilde{q}_{jR}^* + \tilde{e}_{iR} (m_{\tilde{e}}^2)_{ij} \tilde{e}_{jR}^* - (m_3^2 \epsilon_{ab} H_1^a H_2^b + \text{h.c.}) \\ \circ \text{ Either } (m_{H_1}^2, m_{H_2}^2) \text{ or } (\mu, m_A^2 = \frac{m_3^2}{\sin \beta \cos \beta})$$

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

# Conventions and Consistency

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

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

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

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

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