SuSpect 3: status and roadmap

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SuSpect 2 & Co.

SuSpect 2

- SUSY spectrum calculator
- Authors: A.Djouadi, J-L.Kneur and G.Moultaka
- Fortran code
- MSSM spectrum, supports "mSUGRA", AMSB and GMSB (custom versions exists for heavy scalars, no-scale, right-handed sneutrinos, ...)

SuSpect 3

- SuSpect 2 has reached its limits in terms of flexibility
- C++ code, OOP design
- ROOT output option, SLHA IO support
- Flexible structure through usage of polymorphism, inheritance properties and interfaces

Standard Case: *MSSM

MSSM = SM-gauged theory with a broken SUSY and a minimal field content

- 105 parameters
- 22 parameters when:
  - SUSY breaking terms are real
  - Trilinear coupling matrices are diagonal
  - Differences between first and second generations are negligible
- 5 parameters in "mSUGRA": m_0, $m_{1/2}$, A_0, $\tan\beta$ and $\mathrm{sgn}(\mu)$

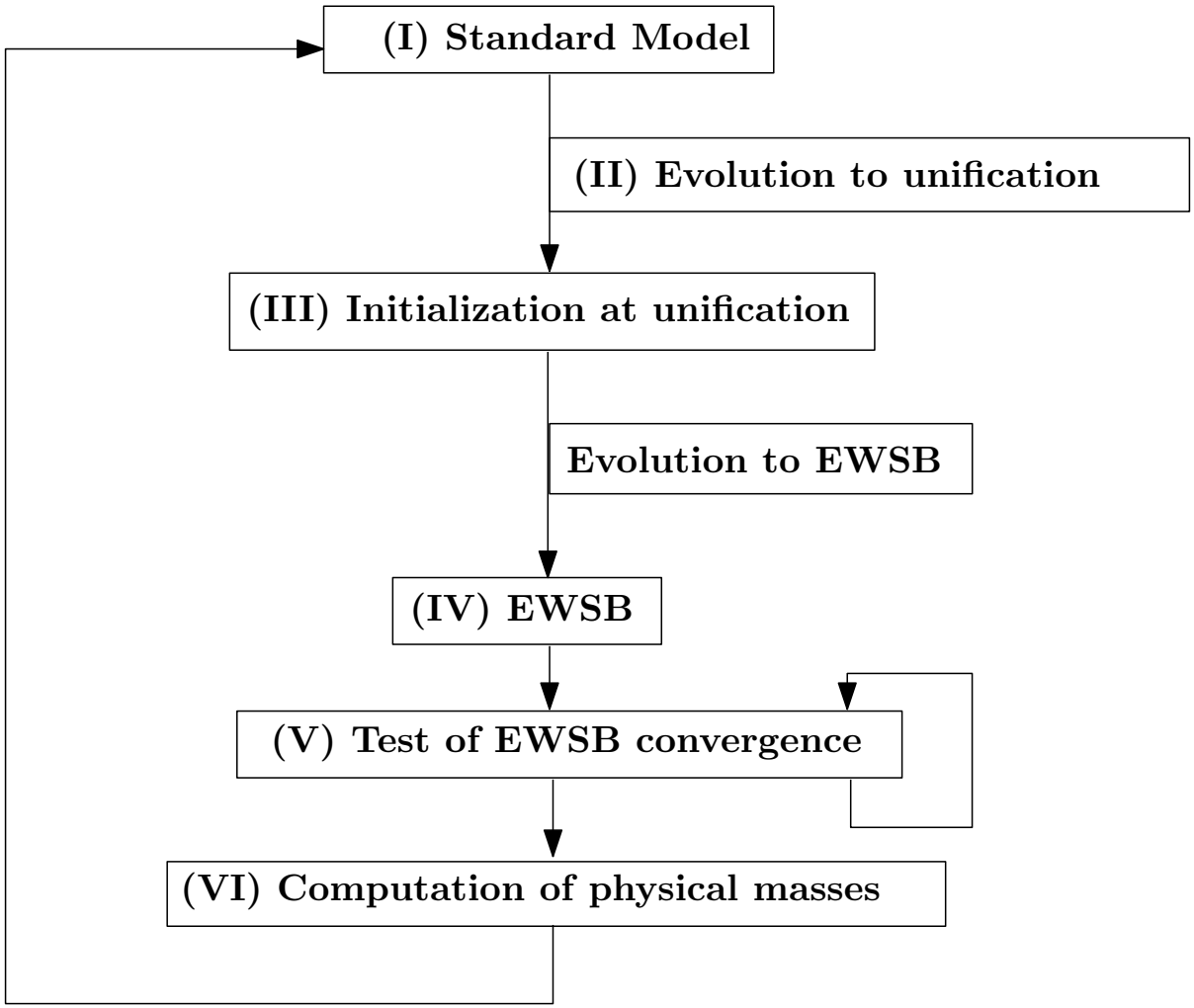
Let's review the spectrum calculation in this specific case

Ingredients

In the "mSUGRA" case:

- A way to evolve parameters through energy scales: RGEs
- Boundary conditions for these ODEs
  - MZ scale: SM inputs
  - GUT scale: assumptions on soft breaking terms, *ie* universality in "mSUGRA" case
  - EWSB scale: minimization equations for the scalar potential, tadpole contributions
- Mass matrices, radiative corrections

Typical Algorithm



Typical algorithm

Step 1: Low energy input

$\alpha(M_Z)$,$\alpha_S(M_Z)$, $M_t^{\rm pole}$, $M_\tau^{\rm pole}$,$m_b^{\overline{\rm MS}}(m_b)$, $M_Z^{\rm pole}$,etc.
Translation to $\overline{\rm DR}$

Step 2: One– or two–loop RGEs running

RGEs with choice: $g_1 = g_2 \cdot \sqrt{3/5}$
$M_{\rm GUT} \sim 2 \cdot 10^{16}$ GeV

Step 3: Choice of SUSY-breaking model

mSUGRA, GMSB, AMSB, or pMSSM. Choice of high-energy input, eg:
mSUGRA: m_0, $m_{1/2}$, A_0, sign(μ) and tan β

Step 4: EWSB

Run down all parameters to m_Z and $M_{\rm EWSB}$ scales
Calculate μ^2, $\mu B = F(m_{H_u}, m_{H_d}, \tan\beta, V_{\rm loop})$

Step 5: Testing EWSB

Check of consistent EWSB (μ convergence, no tachyons, simple CCB/UFB, etc.)

Step 6: Masses and corrections

Diagonalization of mass matrices and calculation of masses/couplings
Radiative corrections to the physical Higgs, sfermions, gauginos masses

mSUGRA implementation for end-user

2 possibilities, a standard SLHA card, or initialize SuSpect directly in memory:

```
SUSPECT::SLHA4suspect *mySLHA = new SUSPECT::SLHA4suspect();
mySLHA->setMODSEL(1,1);
mySLHA->setMINPAR(1,100);
mySLHA->setMINPAR(2,250);
mySLHA->setMINPAR(3,10);
mySLHA->setMINPAR(4,1);
mySLHA->setMINPAR(5,-100);
SUSPECT::suspect aSuspectCalculation;
aSuspectCalculation.Initialize(mySLHA);
```

It's as simple as the SLHA convention

Right now...

SuSpect 3 supports:

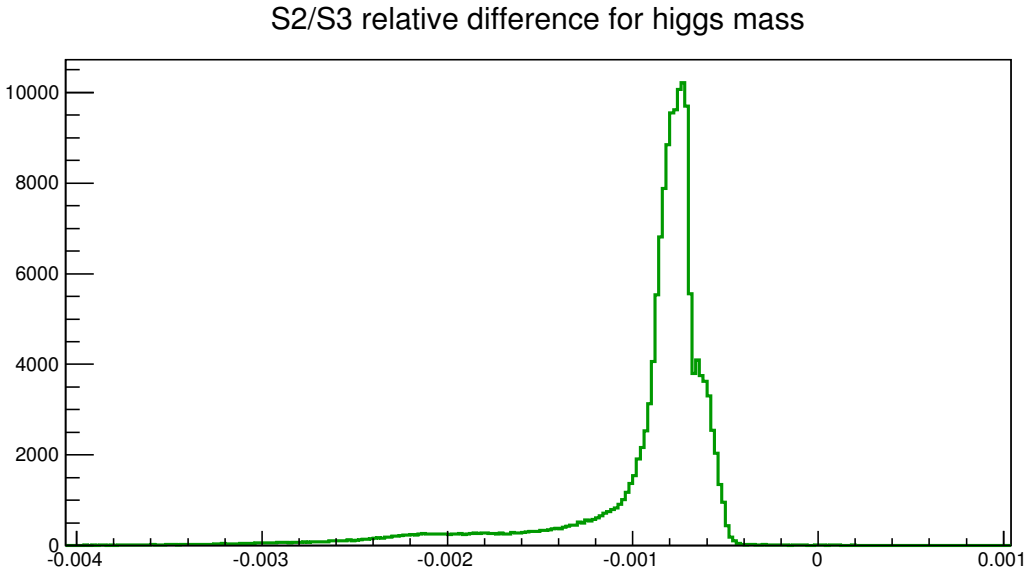
- mSUGRA (3 scales)
- AMSB (3 scales)
- GMSB (4 scales)
- Low-Scale pMSSM (2 scales) (no running to GUT, boundary conditions given at EWSB scale)
- Bottom-up pMSSM (3 scales) (Running to GUT, boundary conditions given at EWSB scale)
- High-Scale MSSM (3 scales) (Non-universal boundary conditions at GUT scale)
- Compressed-SUSY (3 scales) (example of non-universal gauginos soft-breaking terms)

SuSpect 2 and 3 used for a mutual cross-checking...

SuSpect2–SuSpect3 comparison

Example of differences for the light-higgs mass

- $\tan\beta = 20$
- $\mu > 0$
- A_0 = -1 TeV
- $m_0, m_{1/2} \in [0, 4]$ TeV



SuSpect versions compared in plenty of situations:

- All S2-supported models cross-checked
- extreme case with $\mathcal{O}(100$ TeV$)$ breaking terms checked
- relative difference typically of $\mathcal{O}(10^{-3})$

Agreement is more than reasonable

Roadmap

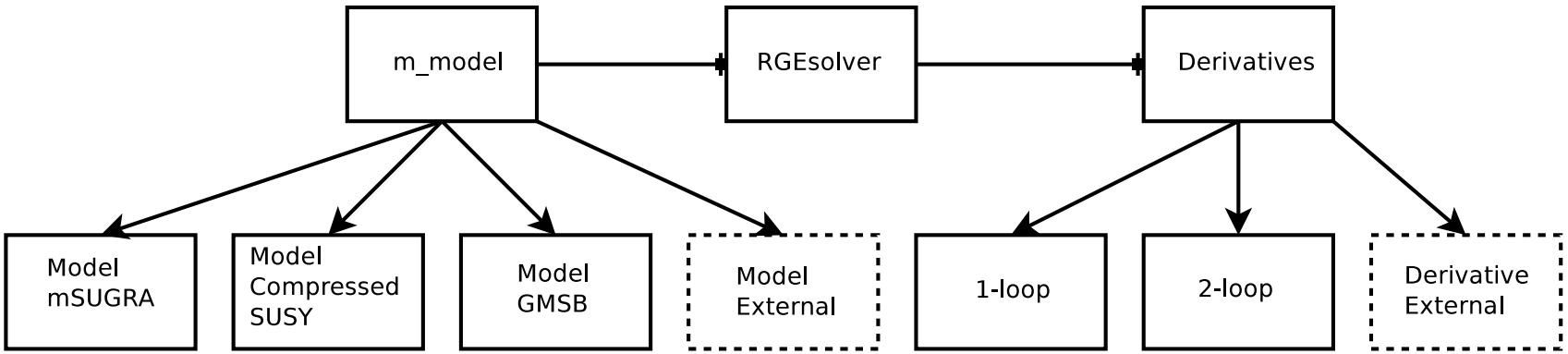
1. New RGEs
   - Full-MSSM (FV, RPV but CPC)

   Prototypes of generator with SARAH/Feynrules
2. New boundary conditions
   - true-mSUGRA
   - No-scale type
   - Yukawa unification
3. New EWSB algorithm (started)
   - No-scale

   Newton-Raphson for EWSB implemented
4. New field content
   - NMSSM (started)

   Basic draft exists

Interfaces Principle



SuSpect 3 can pick up an external definition of the following elements:

- Model (Initialization, Boundary conditions, . . .)
- RGEs (RGEs, set of variables, unification criterion)
- Particle content (eigenstates and associated RC)
- EWSB (way to know if EWSB is realized and consistent)

A more elaborated case: EWSB

Usually, one uses minimization conditions of the scalar potential to evaluate μ at EWSB scale.
But:

- very specific to MSSM
- recursive algorithm
- the equations are constrained along the "minimization" process by an *a priori* knowledge of M_Z and gauge couplings

Interfaces enable:

- customization of the scalar potential
- customization of the minimization algorithm

Newton-Raphson method implemented and being tested...

Conclusions

- S2-supported models validated and cross-checked
- Reference paper started

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How to get:

- http://www.coulomb.univ-montp2.fr/perso/jean-loic.kneur/Suspect/suspect3-alpha.tar.gz
- `tar xvzf suspect3-0.1.tar.gz`
- `./configure`
- `make`
- see `examples/*.in` for example files and `./suspect3 -h` for basic help

You have comments/questions regarding the code/plans/interfaces please contact us ☺