Update on SuSpect3 development

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SuSpect3

Project initiated in March 2010 in collaboration with Djouadi, Kneur, Moultaka & Zerwas.
Goals:

- Keep precision of SuSpect Fortran
- Try to improve on flexibility/ease of use/implementation of new models by using:
  - C++
  - OOP
- Implement new options/models to test this "flexibility"

Previously. . .

green was implemented and functional, red was in implementation/test phase

Step 1: Low energy input

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

Step 2: One– or two–loop RGEs running

RGEs with choice: $g_1 = g_2 \cdot \sqrt{3/5}$
$M_{\text{GUT}} \sim 2 \cdot 10^{16}$ 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_{EWSB} scales
Calculate μ^2,
$\mu B = F(m_{H_u}, m_{H_d}, \tan\beta, V_{\text{loop}})$

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 current state

Everything is implemented and functional

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Code Overview

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main.cxx

- `SUSPECT::suspect aSuspectCalculation;`
- `aSuspectCalculation.Initialize(SLHAstructure);`
  - Read inSLHAfile and fill a SLHA object
  - Initialize the model according to MODSEL
    - `m_model = new SUSPECT::ModelmSUGRA(m_SLHAblock);`
    - `m_model = new SUSPECT::ModelpMSSM(m_SLHAblock);`
    - `m_model = new SUSPECT::ModelGMSB(m_SLHAblock);`
    - `m_model = new SUSPECT::ModelAMSB(m_SLHAblock);`
    - `...`
- `aSuspectCalculation.Execute();`
  - `m_model->Execute();`
    - `m_DRparam.Execute();`
    - `m_RGErunner.Initialize(log(m_scaleMZ),log(m_s...`
    - `m_RGErunner.Execute();`
    - `...`
    - `FinalizeMasses(m_scaleEWSB);`
- `aSuspectCalculation.Finalize(verbose,outSLHAfile);`

SLHA

The common data storage structure

The Model Structure

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ModelmSUGRA

public:

- `void Initialize();` ⇒ 3 Scales Initialization
- `void ApplyBoundaryConditions();` ⇒ Universality in mSUGRA case

Model3Scales

public:

- `virtual void Initialize();` ⇒ Preparing SLHA blocks at GUT, EWSB and MZ scales
- `virtual void Execute();` ⇒ Main loop implementation (between 3 scales)
- `virtual void ApplyBoundaryConditions();` ⇒ Dumb Boundary Conditions for security

protected:

- `double m_scaleMZ;`
- `double m_scaleEWSB;`
- `double m_scaleGUT;`

⇒ Storage of the 3 scales of interests for 3 scale scenarios (mSUGRA, pMSSM, AMSB, ...)

ModelBase

public:

- `virtual void Initialize();`
- `virtual void Execute();`
- and so on for low energy inputs, boundary conditions, rad.corr., EWSB conditions,...

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

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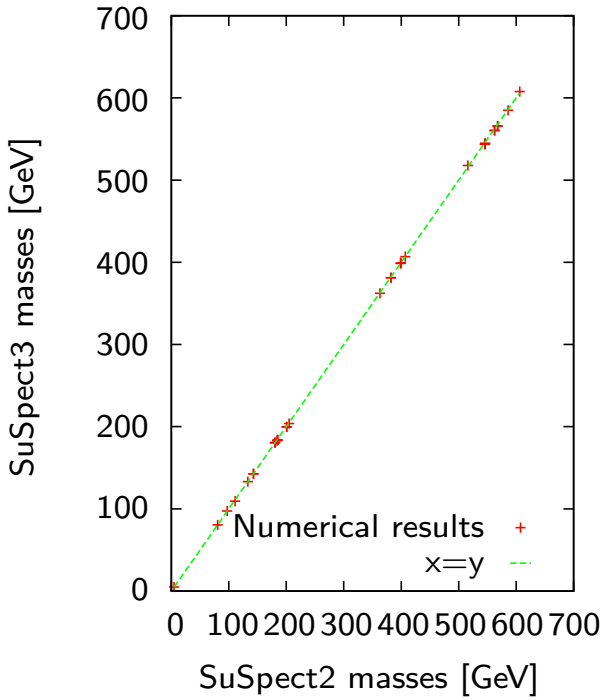
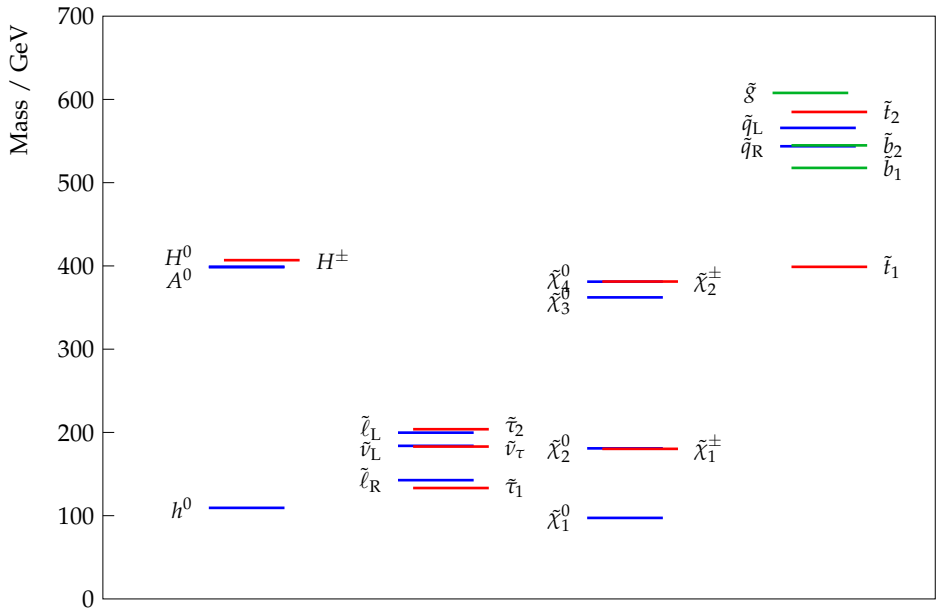


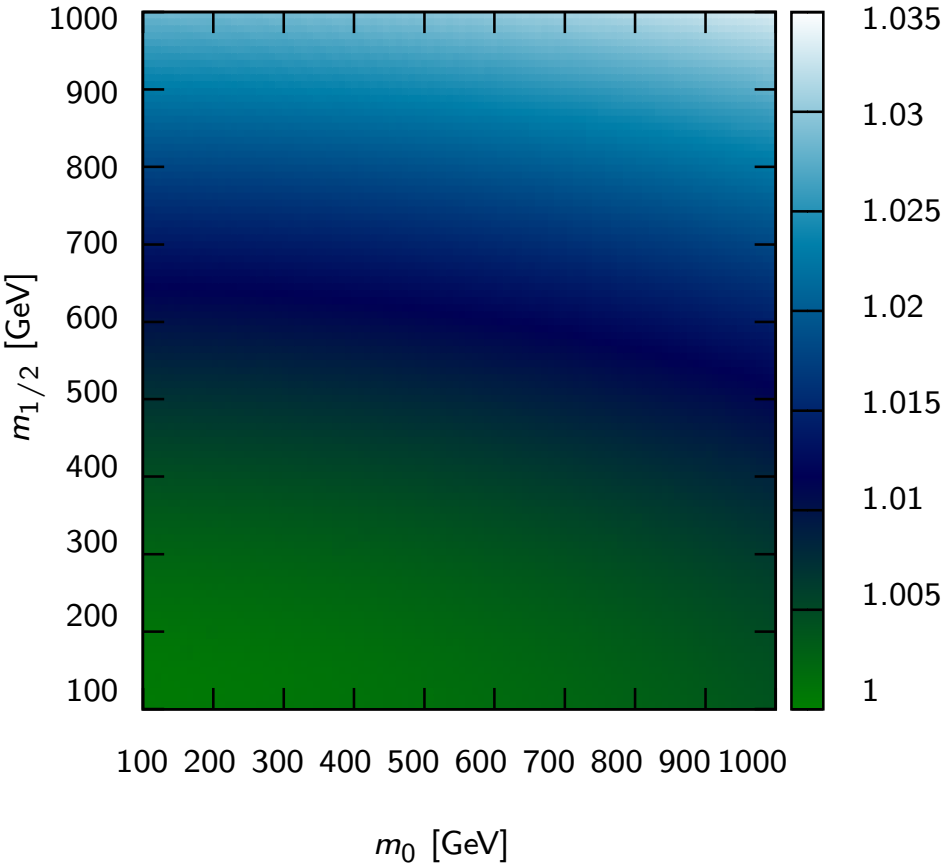


In 3 month we have managed to reach a perfect agreement between SuSpect2 and SuSpect3 for mSUGRA SPS1a.

$$\frac{\delta M}{M} \simeq 0.311\%$$

Quick scan: $m_0 = [100 : 1000]$, $m_{1/2} = [100 : 1000]$, $A_0 = -100$, $\tan\beta = 10$

- the ratio $\frac{m_h^{\text{SuSpect2}}}{m_h^{\text{SuSpect3}}}$ ranges between 1.004 and 1.034 in the scanned area.
- the ratio $\frac{m_{\tilde{q}}^{\text{SuSpect2}}}{m_{\tilde{q}}{}_h^{\text{SuSpect3}}}$ ranges between 0.999 and 1.005 at $m_0 = m_{1/2} = 1$ TeV.
- this is a pretty good agreement on a wide space of parameters



Compressed SuSy

GUT-scale conditions inspired by higher group symmetry, giving:

$$M_1 = m_{1/2}\,(1 + C_{24} + 5C_{75} + 10C_{200})$$
$$M_2 = m_{1/2}\,(1 + 3C_{24} - 3C_{75} + 2C_{200})$$
$$M_3 = m_{1/2}\,(1 - 2C_{24} - C_{75} + C_{200})$$

(See `hep-ph/0703097v1` for more)

This model can be built in three steps:

- inherits Model3Scales
- implement ModelCompressedSuSy `Initialize`
- implement ModelCompressedSuSy `BoundaryConditions`

Implementation of Compressed SuSy

BoundaryConditions

mSUGRA

```
double M1 = m12;
double M2 = m12;
double M3 = m12;

m_SLHA->setMSOFT(SLHA4suspect::M1, M1)
      ;
m_SLHA->setMSOFT(SLHA4suspect::M2, M2)
      ;
m_SLHA->setMSOFT(SLHA4suspect::M3, M3)
      ;
```

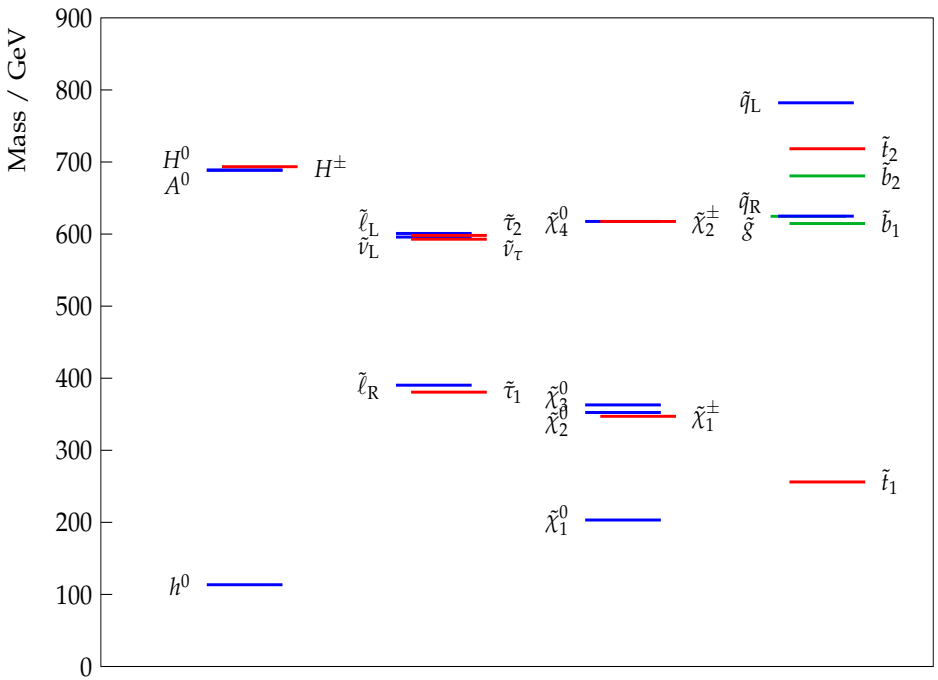
Compressed SUSY

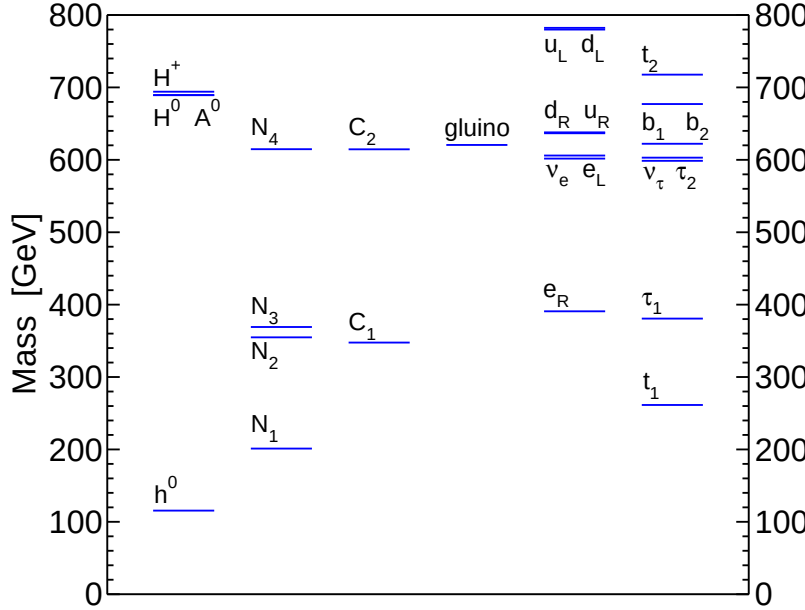
```
double C24 = m_SLHA->MINPAR(6);
double C75 = m_SLHA->MINPAR(7);
double C200 = m_SLHA->MINPAR(8);

double M1 = m12*(1+C24+5*C75+10*C200);
double M2 = m12*(1+3*C24-3*C75+2*C200)
      ;
double M3 = m12*(1-2*C24-C75+C200);

m_SLHA->setMSOFT(SLHA4suspect::M1, M1)
      ;
m_SLHA->setMSOFT(SLHA4suspect::M2, M2)
      ;
m_SLHA->setMSOFT(SLHA4suspect::M3, M3)
      ;
```

Compressed SuSy spectrum





Finally we obtain the spectrum proposed in our reference paper (hep-ph/0703097v1)

Implementation of GMSB

GMSB have different boundary conditions (easy) but it has also a new scale M_{Mess} where boundary conditions apply.

```
// first RGE run MZ -> GUT to find the
      GUT scale
m_RGErunner.Execute(log(m_scaleMZ),log
     (m_scaleGUT),m_scaleGUT,true);
// retrieve the unification scale
m_SLHA->changeScaleAllBlocks(
     m_scaleGUT,m_RGErunner.
     UnificationScale());
m_scaleGUT = m_RGErunner.
     UnificationScale();
ApplyUnificationCondition(m_scaleGUT);
ApplyBoundaryConditions();
// second RGE run from GUT to EWSB
m_RGErunner.Execute(log(m_scaleGUT),
     log(m_scaleEWSB),m_scaleEWSB,
     false);
```

```
// first RGE run MZ -> GUT to find the
      GUT scale
m_RGErunner.Execute(log(m_scaleMZ),log
     (m_scaleGUT),m_scaleGUT,true);
// retrieve the unification scale
m_SLHA->changeScaleAllBlocks(
     m_scaleGUT,m_RGErunner.
     UnificationScale());
m_scaleGUT = m_RGErunner.
     UnificationScale();
ApplyUnificationCondition(m_scaleGUT);
// GUT to Messenger scale
m_RGErunner.Execute(log(m_scaleGUT),
     log(m_scaleMessenger),
     m_scaleMessenger,false);
ApplyBoundaryConditions();
// Messenger scale to EWSB
m_RGErunner.Execute(log(
     m_scaleMessenger),log(
     m_scaleEWSB),m_scaleEWSB,false);
```

SPS 8: $\Lambda = 100$ TeV, $M_{\text{mess}} = 200$ TeV, $N_{\text{mess}} = 1$,tan $\beta = 15$

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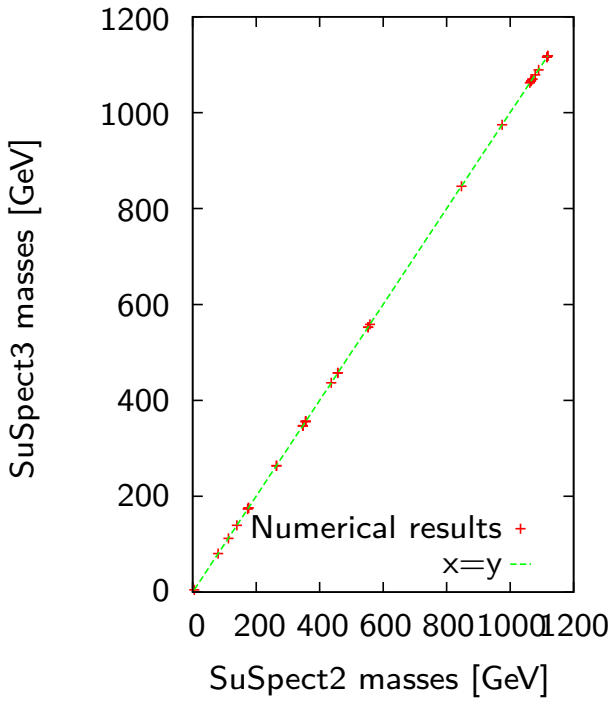

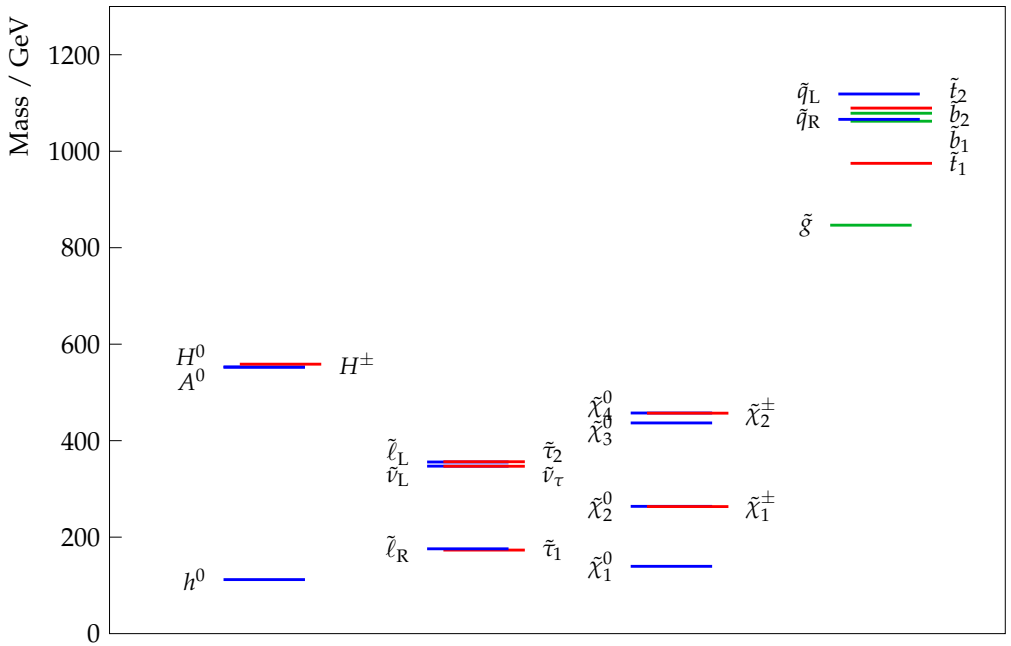

$$\frac{\delta M}{M} \simeq 0.045\% \qquad (1)$$

ROOT interface

SuSpect3 stores mass spectrum in a TTree

- Easier manipulation of huge parameter space
- Current branches are mSUGRA-specific

Lot to be done still:

- Provide a Branch setup for each model

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Ready to use:

- mSUGRA (problems persists in high tanb region)
- AMSB
- GMSB
- Low energy parameters $\delta\rho$, $(g-2)_\mu$ and BR $(b \to s\gamma)$

New features:

- ROOT interface (Ntuple)
- Compressed SuSy
- Light generations separation
- 10% faster

Still a lot to be done:

- N-scales Models (for threshold effects or intermediate SB)
- Interfacing with SUSYHIT
- Testing the External interface for the use of RGEs provided by other tools (SARAH,FEYNRULES)

Roadmap

Beginning 2012: Proceedings for "Les Houches"

Spring 2012: Alpha release