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SuSpect3

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Abstract
We present here an overview of the SuSpect3 project, ultimately aimed to be a major upgrade of the present SuSpect2 code for calculation of spectra in various supersymmetric models.

1 INTRODUCTION

The public Fortran code **SuSpect** [79] calculates the supersymmetric and Higgs particle spectrum in the Minimal Supersymmetric Standard Model (MSSM). In its present version (latest 2.41), it can deal with specific supersymmetry-breaking models with universal boundary conditions at high scales, such as the gravity (mSUGRA), anomaly (AMSB) or gauge (GMSB) mediated supersymmetry breaking models, as well as non-universal MSSM (restricted however to R–parity and CP conservation). Input and Output can be driven from the standard SLHA format files [15]. The algorithm includes the main mandatory ingredients such as the renormalization group evolution (RGE) of parameters between low and high energy scales, the consistent implementation of radiative electroweak symmetry breaking, and the calculation of the physical masses of the Higgs bosons and supersymmetric particles including the full one-loop and dominant two-loop radiative corrections. In addition a control of important theoretical and experimental features is available, such as the absence of non-physical minima, the amount of fine-tuning in the electroweak symmetry breaking condition, or the agreement with some precision observables. Although SuSpect2 is still considered essentially up-to-date and will continue to be maintained in the future, a major upgrade is timely for several reasons.

Given the experimental prospects for supersymmetry, the available tools for the interpretation of the data to come at the LHC should allow high flexibility in implementing new models and/or new theoretical improvements and variants of the existing ones. It is obviously necessary to keep up with the state of the art regarding any eventual new and more precise theoretical calculation that can affect the predictions. It is also desirable to be able to encode in the same tool a large variety of supersymmetric models, non-minimal extensions, more general flavor structure in the (s)quark and (s)lepton sectors, R-parity violation, CP-violating phases, new energy thresholds related to low or high scale extended gauge groups, modified GUT or universality conditions, etc. The task becomes less formidable than it may seem if one recognizes properly the generic features of the various extensions. An object oriented programming approach is particularly suitable in this context. SuSpect3, which we describe below, is the first step in this project. It is a C++ version of the latest SuSpect2 version, fully rewritten with an object-oriented architecture but containing the same algorithms as SuSpect2 (though details of the implementation have changed). In the following the structure and the implementation will be described first. Then a comparison between SuSpect2 and SuSpect3 for an mSUGRA benchmark point as well as a scan will be described.

2 STRUCTURE AND IMPLEMENTATION

C++ was chosen for the implementation of SuSpect3. The use of this language is widespread in the experimental high energy physics community, where ATLAS and CMS rely on it for a major part of their software, as well as in the theoretical community, where the event generators PYTHIA8 [117] and Herwig++ [138] have moved from FORTRAN to this language.

In writing SuSpect3 care was taken not to resort to a line-by-line technical conversion of SuSpect2 as this would have been a change of syntax with no added benefit. The rewrite limits the inheritance structure to essentially three layers. Additionally the possibility of using other codes for parts of the calculations usually performed by SuSpect2 is also foreseen. An example is the use of the renormalization group equations provided by tools such as SARAH [139] or Feynrules [140].

As a first test of the flexibility and the robustness of the new implementation, the first and second generation of sfermions were separated. In SuSpect2 these were hard-coded to be equal. The change took less than a day (testing included), giving a first indication of the robustness of the new structure.

The internal communication between different objects is assured by an implementation of the SLHA structure in memory. The SLHA object contains all SLHA1 standard blocks as well as supplementary blocks used internally.

The top object `suspect` has three methods: Initialize, Execute and Finalize. For the initialization polymorphism is used: one can either use the default settings of SuSpect (SPS1a), read an SLHA file by passing the name of the file as argument or create and initialize an SLHA object in memory and pass it as argument to the object `suspect`. After the calculation, the output is given either on screen or written to a file.

The requested model is configured in the `suspect` object: the MSSM (defined at either a high scale or at the EWSB scale), mSUGRA, AMSB, mGMSB and CompressedSUSY have been implemented so far. In these objects only the initialization of the model as well as the definition of the boundary conditions have to be implemented. The next layer consists of `Model4Scales`, `Model3Scales` or `Model2Scales`. These classes implement the logic of the sequence of the calculation of the spectrum. The separation is driven by the number of scales involved in the definition of the model. All `Model2/3/4Scales` are objects which inherite from a common baseclass `ModelBase`. This class holds the data members common to all classes: an RGE solver, determination of the $\overline{\mathrm{DR}}$ parameters, the calculators of the particle masses, the implementation of electroweak symmetry breaking (`EWSBBase`) etc. As an example: the object `ModelmSUGRA` (created in the object `suspect`) inherits from `Model3Scales` as its parameters are defined at the GUT scale, RGE-evolved to the EWSB scale and corrections to the Standard Model particles are calculated at the scale of the Z boson mass. `ModelAMSB` is derived from `Model3Scales`. As GMSB has an additional intermediate scale, it is derived from the `Model4Scales`, whereas `ModelLowScaleMSSM` is derived from `Model2Scales`.

The RGE evolution from one scale to another is steered by the object `Model2/3/4Scales`. The `RgeEvolution` object can be called multiple times in a calculation. The object fetches the information in the SLHA object, solves the RGE equations and writes the final result back into the SLHA object.

Each particle to be calculated is implemented as an object which can be configured to include radiative corrections or not. All particle objects inherite from a common baseclass. The calculation of the particle masses from the parameters is steered by the object `ModelBase`. The result of the calculations is stored in the SLHA object.

If the environment variable ROOTSYS is defined, ROOT will be linked automatically. If the variable is not defined, the compilation will be performed without in a transparent way. The ROOT output file contains a tree suspect3 with the content of the SLHA blocks.

3 Results

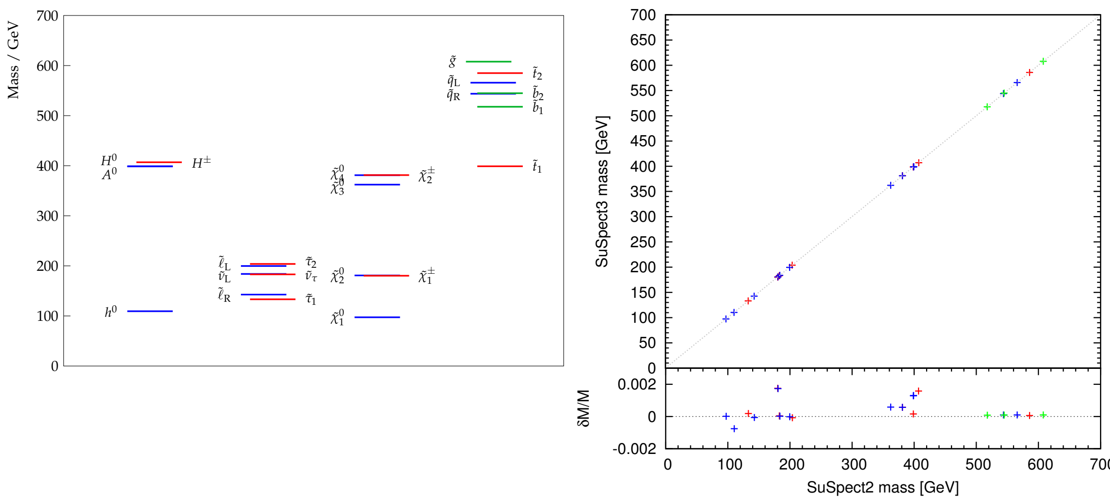

Figure 1: On the left, the SPS1a spectrum is shown as computed by SuSpect3. On the right, the comparison of the masses calculated by SuSpect2 and SuSpect3 is shown.

As a benchmark point the well known mSUGRA point SPS1a [141] has been used to compare SuSpect3 and SuSpect2. SPS1a has the GUT scale boundary conditions: $A_0 = -100$ GeV, $\tan\beta = 10$, $m_0 = 100$ GeV and $m_{1/2} = 250$ GeV. The Higgs mass parameter μ was chosen to be positive. The electroweak symmetry breaking scale (EWSB) is set to 1 TeV as suggested in Ref. [142]. At each step of the algorithm, comparisons were performed to make sure that all details agree. As an example, the spectrum predicted by SuSpect3 as well as the comparison of the mass of the particles with respect to SuSpect2 are shown in Figure 1. The two predictions are in good agreement at the per mil level.

As a further illustration a scan was performed in mSUGRA. Three parameters ($A_0 = -100$ GeV, $\tan\beta = 10$, $\mu > 0$) were fixed. The common scalar and sfermion masses were scanned from 100 GeV to 1 TeV in steps of 9 GeV. In Figure 2 the relative deviation of SuSpect2 and SuSpect3 is shown. As an illustration the mass of the lightest Higgs boson and the mass of the lightest stop quark are used. The first is sensitive to the radiative corrections and the second is sensitive to the mixing effects. Thus both are good sensitive indicators whether all ingredients of the calculation agree. With the exception of 3 points each for the stop and the Higgs mass the agreement is at the per mil level for the 10201 points analyzed. For the stop quark mass the RMS of the relative difference is one tenth of a per mil.

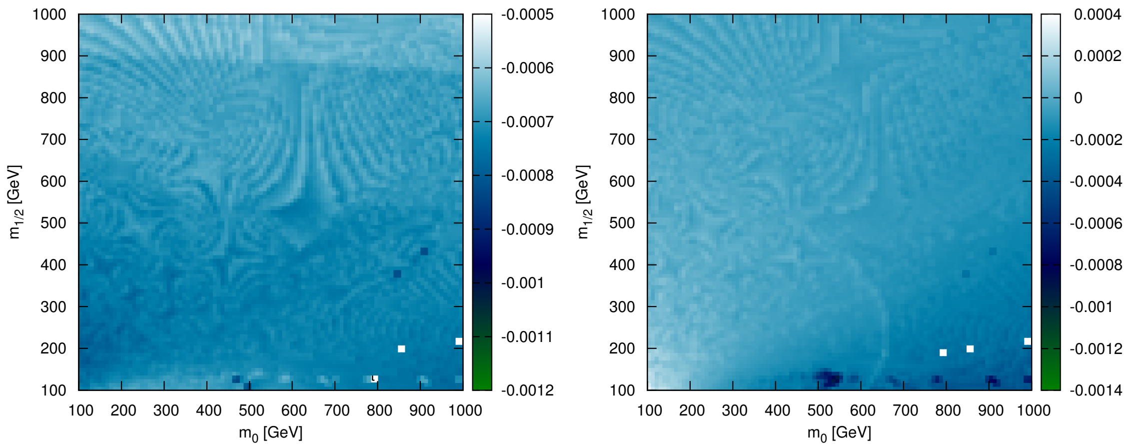

Figure 2: The two plots show relative differences between SuSpect2 and SuSpect3 with respect to SuSpect3. The left one is for M_h, and the right one for $M_{\tilde{t}_1}$. Scan on m_0 and $m_{1/2}$ has been performed for mSUGRA with $A_0 = -100$, $\tan\beta = 10$ and $\mu > 0$.

4 OUTLOOK

The rewriting of SuSpect3 in C++ with added features and a more flexible design to accomodate the use of calculations by other tools is on its way. All models currently implemented in SuSpect2 have been implemented in SuSpect3. All major options allowed by SuSpect2 have also been implemented in SuSpect3. The first comparisons for SPS1a show very good agreement. In the next months SuSpect3 will be tested intensely before making it available to a selected public for tests and later on releasing it publicly as an addition to SuSpect2.

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