SModelS v1.0: a short user guide

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Abstract

SModelS is an automatised tool for interpreting simplified-model results from the LHC.
Version 1.0 of the code is now publicly available. This document provides a quick user guide
for installing and running SModelS v1.0.

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1 Introduction

SModelS [1] is an automatic tool for interpreting simplified-model results from the LHC. It is based on a general procedure to decompose Beyond the Standard Model (BSM) collider signatures presenting a Z_2 symmetry into Simplified Model Spectrum (SMS) topologies. Our method provides a way to cast BSM predictions for the LHC in a model independent framework, which can be directly confronted with the relevant experimental constraints. Our concrete implementation currently focusses on supersymmetry (SUSY) searches with missing transverse energy, for which a large variety of SMS results from ATLAS and CMS are available. The main ingredients of SModelS are

- the decomposition of the BSM spectrum into SMS topologies,

- the database of experimental SMS results,

- the interface between decomposition and results database.

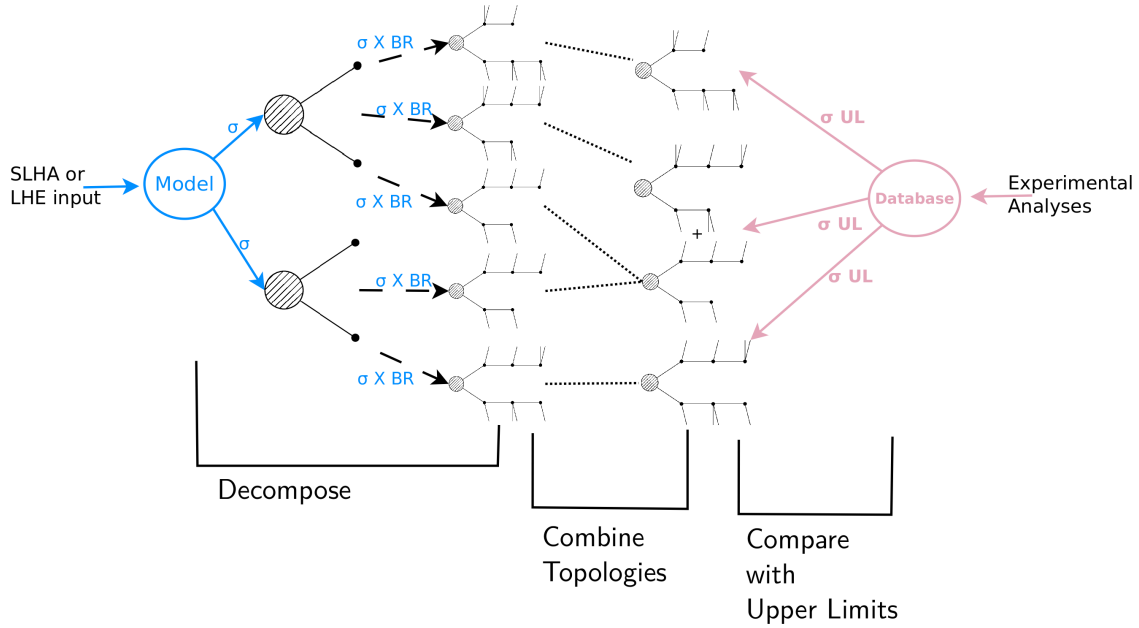The working principle is illustrated schematically in Fig. 1.

Figure 1: Schematic view of the working principle of `SModelS`.

Version 1.0 of SModelS is now publicly available. This document provides a short user guide for the installation and for running SModelS v1.0. More details can be found in the primary physics publication [1] and in the documentation provided with the code (an html manual, which is also available online at [2]). In case of troubles using SModelS v1.0, we ask the user to kindly contact the authors at smodels-users@lists.oeaw.ac.at.

2 Download and Installation

SModelS is a Python [3] library that requires Python version 2.6 or later (but not version 3). Internally, SModelS v1.0 uses Pythia 6.4.27 [4], NLL-fast versions 1.2 and 2.1 [5] (see also [6–12]) and a modified version of PySLHA [13]. It has been tested on Ubuntu 14.X, Scientific Linux 6, Scientific Linux CERN 6, as well as on Mac Os X 10.9 and 10.10.

The SModelS v1.0 package can be downloaded from [2]. Unpacking the tar ball with

```
tar -zxfv smodles-v1.0.tgz
```

creates a directory `smodels-v1.0` where the code (subdirectory `smodels`) and the results database (subdirectory `smodels-database`) are located.

For installation, SModelS makes use of Python's setuptools. On most machines (apart from SL6/SLC6)

```
python setup.py install
```

inside the `smodels-v1.0` directory should install the entire project, resolving automatically the external Python dependencies and compiling the internal Pythia 6 and NLL-fast versions using `gfortran`. Note that depending on the path specified in `setup.py` you may need to do the installation as superuser.

More details on the installation procedure, external dependencies and in particular instructions for installation on SL6 and SLC6 can be found in the INSTALL file in `smodels-v1.0`.

3 Citation

When you use results obtained with SModelS v1.0 in a publication, please cite this document as well as the original SModelS paper [1], Pythia 6.4 [4], NLL-fast [6–12] and PySLHA [13]. For convenience, these citations are provided in bibtex format in the SModelS v1.0 distribution.

4 Using SModelS

4.1 Basic input

SModelS v1.0 can be used with two forms of inputs

- SLHA (SUSY Les Houches Accord) [14] files containing masses, branching ratios and cross-sections, or

- LHE (Les Houches Event) [15] files containing parton-level events.

The SLHA format is usually more compact and best suited for supersymmetric models. On the other hand, a LHE file can always be generated for any BSM model (through the use of your

favorite Monte Carlo generator).[2] In this case, however, the precision of the results is limited to the MC statistics used to generate the file.

In the case of **SLHA input**, the production cross sections for the BSM states also have to be included as SLHA blocks, according to the SLHA cross-section format [16]. For the MSSM and some of its extensions, the cross sections can be conveniently calculated and added to the SLHA input file by means of the internal SModelS' `xseccomputer` described in the tools section of the html manual.

In the case of **LHE input**, the total production cross-section as well as the center-of-mass energy should be listed in the <init></init> block, according to the standard LHE format. Moreover, all the Z_2-even BSM particles (*e.g.*, additional Higgs states) should be set as stable, since in SModelS v1.0 they are effectively considered as final states.

Besides information about the masses and branching ratios ($\mathscr{B}$), the user must also **define** which of the particles are Z_2-**odd states** and which are Z_2-even. This is done in the `particles.py` file, where some default values (for SM and MSSM particles) are already loaded. Finally, if the user wants to check the SLHA input file for possible issues using SModelS' SLHAchecker, it is also necessary to define the BSM particle quantum numbers in `particles.py`.

4.2 runSModelS.py

For the first-time user, SModelS ships with a command-line tool, `runSModelS.py`, which covers several different applications of the SModelS functionalities. These functionalities include detailed checks of input SLHA or LHE files, running the SMS decomposition, evaluating the theory predictions for the input model and comparing them to the experimental limits available in the database, determining the most important missing topologies and printing a summary text file.

The usage is

```
runSModelS.py -f INPUTFILE [-p PARAMETERFILE] [-o OUTPUTFILE]
```

Some comments are in order.

- The INPUTFILE can be an SLHA or LHE file as explained in Section 4.1.

- The PARAMETERFILE controls the basic options and parameters used by `runSModelS.py`. An example including all available parameters together with a short description, is provided as `parameters.ini`. If no parameter file is specified, the default parameters stored in `etc/parameters_default.ini` are used. Note that the input type (SLHA or LHE) needs to be properly specified in the parameter file.

- If no OUTPUTFILE is specified, the file output will be printed to `summary.txt`.

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[2]SModelS v1.0 can easily be used for non-SUSY models as long as they present a Z_2-type symmetry. However, it is the responsibility of the user to make sure that the SMS results in the database actually apply to the model under consideration. In this context, see also the caveats in [1].

4.3 Default output

The results of `runSModelS.py` are printed to the screen and to the output (summary) file. The level of detail is controlled via the parameters file. The screen output comprises

- a full list of the topologies generated by the decomposition procedure (if `printDecomp = True`),

- a list of all the analyses considered (if `printAnalyses = True`),

- a list of all the theory predictions obtained and the corresponding upper limits from the experiments (if `printResults = True`),

- possible warnings or error messages.

The file output contains status flags for the input file and the decomposition indicating possible problems, followed by the name of the input file, basic information on the run parameters and the version of the database used. This looks as follows:

```
Input status: 1
Decomposition output status: 1 #decomposition was successful
#Input File: inputFiles/slha/gluino_squarks.slha
#maxcond = 0.2
#minmassgap = 5.
#sigmacut = 0.03
#Database version: GrenobleNov2014 (27/11/2014)
```

The main part of the output file is then the list of analyses which constrain the input model. For each analysis, its ID, Tx name,[3] centre-of-mass energy and the amount of condition violation are given, followed by the predicted signal cross section and the 95% CL experimental upper limit on it. The last entry in the line is the ratio r of the signal cross-section and the upper limit, $r = \sigma(\text{predicted})/\sigma(\text{excluded})$, where σ effectively means $\sigma \times \mathscr{B}$ or the weight of the topology. A value of $r \geq 1$ means that the input model is likely excluded by the corresponding analysis. Concretely, this looks like this:

```
#Analysis  Tx_Name  Sqrts  Cond. Violation  Theory_Value(fb)  Exp_limit(fb)  r

 CMS-PAS-SUS-13-019        T2  8.00E+00  0.0  1.773E+00  3.762E+00  4.714E-01
#[[['jet']],[['jet']]]
----------------------------------------------------------------------------
    CMS-SUS-13-012         T2  8.00E+00  0.0  1.773E+00  6.099E+00  2.907E-01
#[[['jet']],[['jet']]]
----------------------------------------------------------------------------
 ATLAS-SUSY-2013-12     TChiWZ  8.00E+00  0.0  1.847E+01  3.301E+02  5.595E-02
#[[['W']],[['Z']]]
----------------------------------------------------------------------------
```

In this example, the topologies tested by the analysis are shown in bracket notation just below the analysis entry, here *e.g.* `[[['jet']],[['jet']]]`. This can be turned off by setting `addConstraintInfo = False` in the parameter file. Finally, the last line of this block reports the maximum value of r:

```
The highest r value is 4.71E-01
```

---

[3] The **Tx** names are explained in the SMS dictionary on http://smodels.hephy.at/wiki/SmsDictionary.

The detailed breakdown can be switched off by setting `expandedSummary=False`; in this case only the most constraining analysis (the one with the maximum *r* value) is printed.

Finally, if `findMissingTopos = True`, a list of the missing topologies (in bracket notation) and their cross sections at the given $\sqrt{s}$ is also included. This list is ordered from high to low cross sections; per default only the 10 leading ones are printed. Concretely this looks, *e.g.*, like this:

```
Missing topologies with the highest cross-sections (up to 10):
Sqrts (TeV)   Weight (fb)        Element description
8.00E+00   1.567E+01    #                [[[jet],[W]],[[jet,jet],[W]]]
8.00E+00   1.395E+01    #        [[[jet],[jet,jet],[W]],[[jet,jet],[W]]]
```

For more details, including an explanation of the bracket notation, we refer the user to the html manual.

4.4   Using SModelS v1.0 as Python library

Although `runSModelS.py` provides the main SModelS features with a command line interface, users familiar with Python and the SModelS language may prefer to write their own main program, using SModelS v1.0 as a Python library. A simple example code for this purpose is provided as `Example.py` in the SModelS v1.0 distribution.

5   List of analyses included in the SModelS v1.0 release

The SModelS v1.0 database comprises a large number of SMS results from ATLAS and CMS SUSY searches at $\sqrt{s} = 8$ TeV. Most of them are for full luminosity. (The 7 TeV results will be included in a later release together with more 8 TeV results). Concretely, in the default run mode, the following results are considered:

ID	short description	L [fb^{-1}]	Ref.	Tx names
ATLAS-SUSY-2013-02	0 leptons + 2-6 jets + Etmiss	20.3	[17]	T1, T2
ATLAS-SUSY-2013-04	0 leptons + >=7-10 jets + Etmiss	20.3	[18]	T1tttt, T1ttttoff
ATLAS-SUSY-2013-05	0 leptons + 2 b-jets + Etmiss	20.1	[19]	T2bb
ATLAS-SUSY-2013-11	2 leptons (e,mu) + Etmiss	20.3	[20]	TChiWZ, TChiSlepSlep
ATLAS-SUSY-2013-12	3 leptons (e,mu,tau) + Etmiss	20.3	[21]	TChiWH, TChiWZ,TChiV
ATLAS-SUSY-2013-14	2 taus + Etmiss	20.3	[22]	TStauStau
ATLAS-SUSY-2013-15	1 lepton + 4(1 b-)jets + Etmiss	20.3	[23]	T2tt, T2bbWW
ATLAS-SUSY-2013-19	2 leptons + (b)jets + Etmiss	20.3	[24]	T6bbWW, T2tt, T2bbWW
ATLAS-CONF-2012-105	2 same-sign leptons + >=4 jets + Etmiss	5.7	[25]	T1tttt
ATLAS-CONF-2012-166	1 lepton + 4(1 b-)jets + Etmiss	13.0	[26]	T2tt
ATLAS-CONF-2013-024	0 lepton + 6 (2 b-)jets + Etmiss	20.5	[27]	T2tt
ATLAS-CONF-2013-047	0 leptons + 2-6 jets + Etmiss	20.3	[28]	T1, T2
ATLAS-CONF-2013-053		20.1	[29]	T2bb
ATLAS-CONF-2013-061	0-1 leptons + >=3 b-jets + Etmiss	20.1	[30]	T1bbbb, T1tttt
ATLAS-CONF-2013-065	2 leptons + (b)jets + Etmiss	20.3	[31]	T2tt

ID	short description	L [fb^{-1}]	Ref.	Tx names
CMS-SUS-12-024		19.4	[32]	T1bbbb, T1ttttoff, T1tttt, T5tttt
CMS-SUS-12-028		11.7	[33]	T1, T1tttt, T1bbbb, T2, T2tt
CMS-SUS-13-002		19.5	[34]	T1tttt
CMS-SUS-13-006		19.5	[35]	TChiWZ, TSlepSlep, TChiChipmSlepStau, TChiC
CMS-SUS-13-007		19.3	[36]	
CMS-SUS-13-011		19.5	[37]	T6bbWW, T2tt
CMS-SUS-13-012		19.5	[38]	T1, T1tttt, T1ttttoff, T2
CMS-SUS-13-013		19.5	[39]	T1tttt, T1ttttoff
CMS-PAS-SUS-13-008		19.5	[40]	T6ttWW, T1tttt
CMS-PAS-SUS-13-016		19.7	[41]	T1tttt, T1ttttoff
CMS-PAS-SUS-13-018		19.4	[42]	T2bb
CMS-PAS-SUS-13-019		19.5	[43]	T1, T1tttt, T1ttttoff, T1bbbb, T2, T2tt, T2bb
CMS-PAS-SUS-14-011		19.3	[44]	T1bbbb, T1tttt, T1ttttoff, T2tt

List of superseded by analyses:

ID	short description	L [fb^{-1}]	Ref.	Tx names
ATLAS-CONF-2013-007	2 same-sign leptons + 0-3 b-jets + Etmiss	20.7	[45]	T1tttt
ATLAS-CONF-2013-035	3 leptons + Etmiss	20.7	[46]	TChiWZ, TChiWZoff
ATLAS-CONF-2013-037	1 lepton + 4(1 b-)jets + Etmiss	20.7	[47]	T2tt, T6bbWW
ATLAS-CONF-2013-048	2 leptons (+ jets) + Etmiss	20.3	[48]	T6bbWW
ATLAS-CONF-2013-049	2 leptons + Etmiss	20.3	[49]	TSlepSlep
CMS-PAS-SUS-12-022		9.2	[50]	TChiWZ, TSlepSlep, TC
CMS-PAS-SUS-12-026		9.2	[51]	T1tttt
CMS-PAS-SUS-13-004		19.3	[52]	T1tttt, T1ttttoff, T1bbbb,

The database contains moreover the entries of several preliminary results (ATLAS CONF notes or CMS PAS) which were superseded by a publication. These results are not listed here, and are not used when running `runSModelS.py`. They can, however, be activated by

```
smsAnalysisFactory.load(useSuperseded=True)
```

when using SModelS v1.0 as a Python library. For more details, see "How to load the database" in the Examples section of the html manual.

Last but not least we note that for topologies with more than one step in the decay chain, *e.g.* charginos decaying through intermediate leptons, or stops decaying into bottom plus chargino followed by the chargino decay into the lightest neutralino, we need several (more than one) mass planes in order to interpolate between them. *Whenever only one mass plane is provided, the result is not useful for our purpose and thus not included in the database.*

6   Conclusions

We presented the first public release of SModelS, an automatic tool for interpreting simplified-model results from the LHC in generic models possessing a Z_2 symmetry. SModelS v1.0 consists of a SMS decomposition procedure, a database of SMS cross section upper limits from ATLAS

and CMS, and an interface between these two components to confront the theoretical predictions of BSM models with the experimental results. The database of v1.0 comprises results from ?? ATLAS and ?? CMS SUSY searches at 8 TeV, based on missing-energy signatures. In this document, we provided the basic instructions for installing and running SModelS v1.0 and understanding its output. More detailed explanations are given in the html manual which comes as part of the SModelS v1.0 distribution.

We hope that SModelS v1.0 will be a useful tool for the High-Energy Physics community and contribute to the legacy of the LHC results. Here note that SModelS v1.0 can be used not only to test whether a particular scenario is excluded by the recent LHC results — it can also be conveniently used to classify untested regions, missing topologies and new signatures that might be interesting to look for.

This said, the release of SModelS v1.0 is but the beginning of the story. Several extensions and improvements are already in development. One such extension will be a more extensive database of experimental results, ideally comprising also non-SUSY searches. This, however, depends also on the co-operation of the ATLAS and CMS search groups in making the relevant information available. Another extension will be the inclusion of efficiency maps. This will be a major upgrade of the code. Further plans include ways to determine the most sensitive analysis and ways to combine results from different analyses, extensions to asymmetric branches (if suitable experimental results become available for this), sub-branches (to treat, *e.g.*, Higgs decays) and signatures without missing energy.

Acknowledgements

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