Particle spectrum prediction in non-minimal supersymmetric models

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Motivation of non-minimal SUSY models

	CMSSM	non-minimal SUSY	CE_6SSM
solves μ problem of the MSSM	✗	✓	✓ [hep-ph/0510419]
avoid m_h fine tuning	✗	✓	✓ [hep-ph/1302.5291]
connection to specific gravity models	✗	✓	✓ [hep-ph/0510419]
complete repres. of simple GUT gauge group	✗	✓	✓ [hep-ph/0510419]
new particles and phenomena	✓	✓	✓ [hep-ph/1302.5291]
explanation of $(g-3)_\mu^{\text{exp.}}$	✗	✓	✗

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Definition of the CE_6SSM

Q_i, $\bar{U}_i$, $\bar{D}_i$, L_i, $\bar{E}_i$, $\bar{N}_i$	MSSM fields	$\mathbf{27}_i$
S_i	G_{SM} singlet	
H_{1i}, H_{2i}	higgs-like doublets	
X_i, $\overline{X}_i$	exotic colored matter	
H', $\overline{H'}$	higgs-like doublets	$\in \mathbf{27}', \overline{\mathbf{27}}'$
V_Y, V_W^i, V_g^a, V_N	gauge bosons, gauginos	$\in \mathbf{78}$

Superpotential:

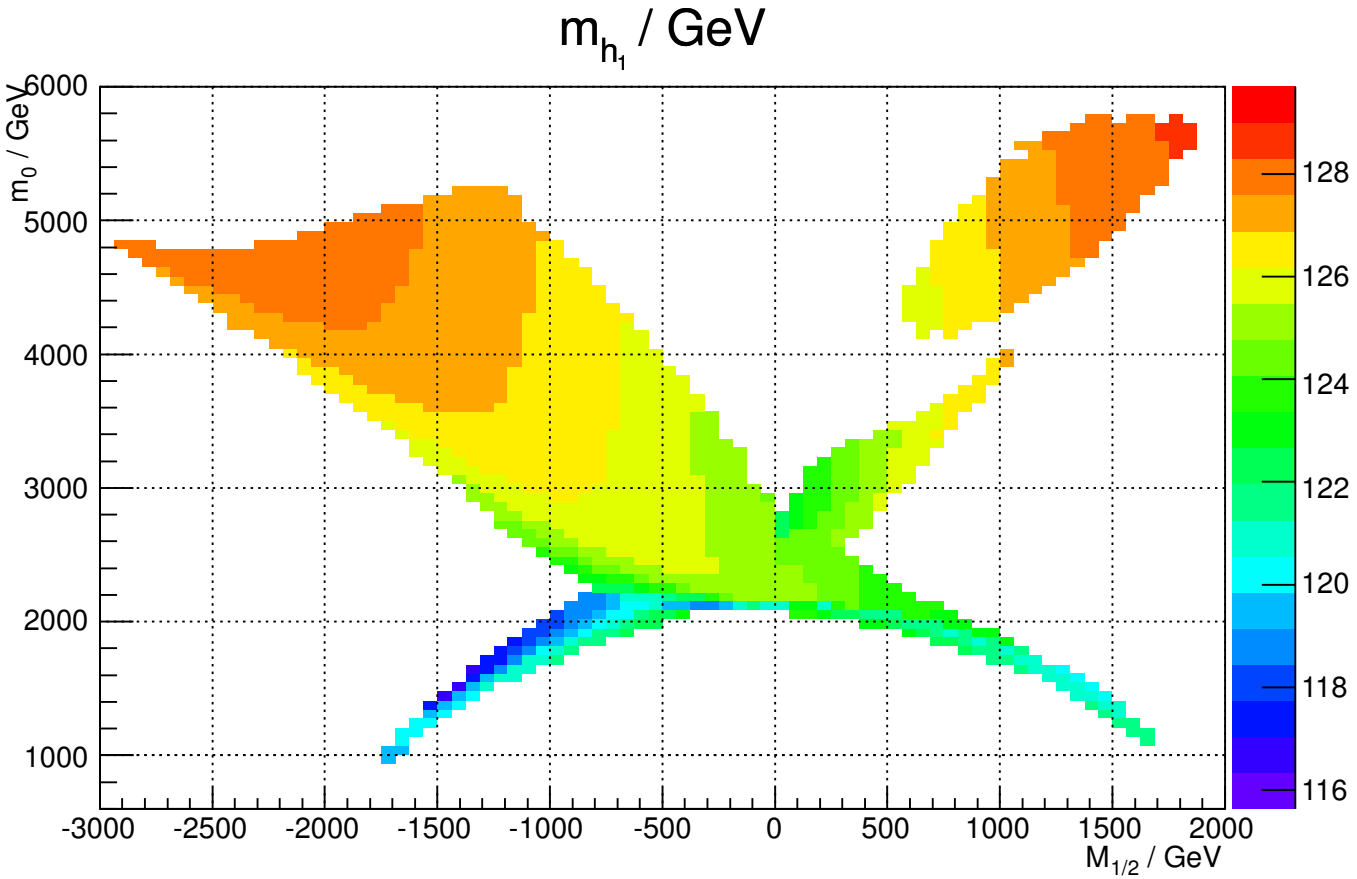
$$\mathcal{W}_{E_6SSM} \approx -y_e(H_{13}L_3)\bar{E}_3 - y_d(H_{13}Q_3)\bar{D}_3 - y_u(Q_3H_{23})\bar{U}_3 + \lambda_i S_3(H_{1i}H_{2i}) + \kappa_i S_3(X_i\overline{X}_i) + \mu'(H'\overline{H'})$$

GUT constraints: $m_i(M_X) = m_0, M_i(M_X) = M_{1/2}, A_i(M_X) = A$

Input parameters: $\lambda_i(M_X), \kappa_i(M_X), v, \tan\beta, s; m_{H'}, m_{\bar{H}'}, \mu', B\mu'$

Parameter space study of the CE_6SSM – Higgs mass

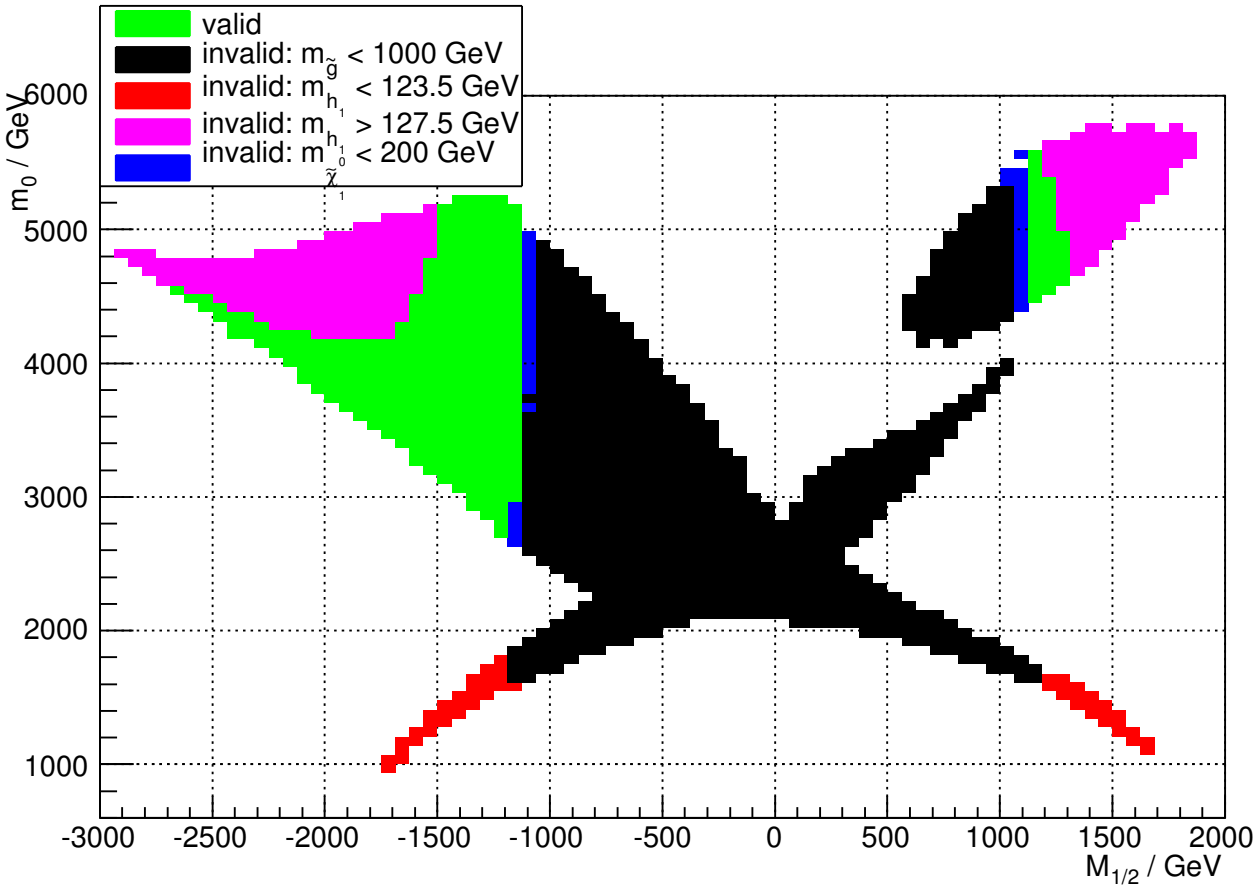
[hep-ph/12091470]



$\tan\beta = 2\ldots45,\ \lambda_3 = 0\ldots3,\ s = 10\,\text{TeV},\ \lambda_{1,2,3} = \kappa_{1,2,3},$
$\mu' = m_{H'} = m_{\bar{H}'} = 10\,\text{TeV},\ B\mu' = 0$

Parameter space study of the CE_6SSM – LHC limits

[hep-ph/12091470]



$\tan\beta = 2\ldots45,\ \lambda_3 = 0\ldots3,\ s = 10\,\text{TeV},\ \lambda_{1,2,3} = \kappa_{1,2,3},$
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A new spectrum generator – FlexibleSUSY

Problem:

- CE_6SSM spec. gen. can not be generated with SARAH
- large variety of non-minimal SUSY models
  $\Rightarrow$ spectrum generators needed that
  - are flexible (modular, object-oriented, are easy to understand)
  - work in parameter regions where convergence is hard

Our approach:

SARAH $\longrightarrow$ SoftSusy + lattice

Goals:

- modular C++ classes to help the user modifying the generated code
- SoftSusy-like classes
- extra RGE solving methods
  - standard two-scale running method
  - lattice method + variants (Jae-hyeon Park)

A new spectrum generator – Code example

```
Needs["SARAH`"];
Start["MSSM"];
MakeFlexibleSUSY[];
```

```
typedef Two_scale T; // or lattice
MSSM<T> mssm;
MSSM_parameter_point pp;

std::vector<Constraint<T>*> constraints = {
  new MSSM_mz_constraint<T>(&mssm, pp),
  new MSSM_msusy_constraint<T>(&mssm, pp),
  new MSSM_sugra_constraint<T>(&mssm, pp)
};

RGFlow<T> solver;
solver.add_model(&mssm, constraints);
solver.solve();
```

VEV beta functions

For a complete SUSY spectrum generator β_{v_i} is needed at one- and two-loop level, but missing in [Martin-Vaughn hep-ph/9311340].

Current status:

Model	$\beta_{v_i}^{(1L)}$	$\beta_{v_i}^{(2L)}$
MSSM	✓ [Chankowski Nucl.Phys. B423]	(✓)[1] [hep-ph/0210324]
E_6SSM	✓ [hep-ph/12091470]	✗
$\forall$ SUSY model	?	✗

We currently calculate: β_{v_i} in a general spontaneously broken gauge theory at one- and two-loop order

[1] $O(g_i^2 g_j^2)$ terms unknown in $\beta_v^{(2L)}$

Conclusions

- Non-minimal SUSY models are attractive extensions of the Standard Model
- Large variety of non-minimal SUSY models

$\Rightarrow$ flexible / highly configurable spectrum generators are needed

- FlexibleSUSY will provide a C++ spectrum generator that is
  - usable in parameter regions the two-scale algorithm does not converge
  - modular, object-oriented
  - easy to understand
  - easy to change and extend
- Need to calculate $\beta_{v_i}^{(2L)}$ in general SUSY models