SEARCHES FOR SUPERPARTICLES AT THE LHC BY APPLICATION OF COMPUTER SIMULATION

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The analys of recent experimental data received from LHC (CMS) restricts the range of MSSM parameters to the new five parameters. Using computer programs SOFTSUSY, SDECAY and PYTHIA the mass spectrum, partial width and production cross sections of superpatners are calculated. In the context of Minimal Supersymmetric Standard Model histograms of mass distributions for superpartners $\tilde{q}_R$ and $\tilde{g}$ are constructed.

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1. INTRODUCTION

The searches for new physics at the LHC motivated the necessary tools for building Grand Unification Theory (GUT) models in F-theory [1]. It is known that Minimal Supersymmetric Standard Model (MSSM) [2] through its connection to string theory improves the Standard Model (SM). There are several problems of SM, connected with our experimental knowledge and with some theoretical aspects:

1) there is the neutrino mass problem - the SM predicts neutrinos having zero mass, whereas we have experimental evidence for massive neutrinos;

2) SM field theory which include gravity ends up being non-renormalizable without predictions below the Planck scale;

3) SM has 19 free parameters to be determined experimentally;

4) the hierarchy problem;

5) the unification problem.

These problems can be decided with the help of MSSM model. In this model each particle, for example fermion, has its superpartner - boson with appropriate masses and couplings. MSSM includes new symmetry called R-parity. This gives us some usefull phenomenological results:

- the lightest sparticle, LSP must be stable and than it would be an excellent candidate for dark matter;
- the LSP interacts very weakly with matter;
- supersymmetric particles are produced in pairs;
- all supersymmetric particles are unstable and decay.

2. CATEGORY OF D-BRANES

To construct the MSSM model from superstring theory we must use the notion of derived category [3]. We will give the short review of the theory of category.

A category $\mathcal{L}$ consists of the following data:

1) A class Ob $\mathcal{L}$ of objects $A, B, C, \cdots$;

2) A family of disjoint sets of morphisms $\mathrm{Hom}(A, B)$ one for each ordered pair A, B of objects;

3) A family of maps

$$\mathrm{Hom}(A, B) \times \mathrm{Hom}(B, C) \rightarrow \mathrm{Hom}(A, C) \ ,$$

one for each ordered triplet A, B, C of objects.

These data obey the axioms:

a) If $f \ : A \rightarrow B$, $g \ : B \rightarrow C$, $h \ : C \rightarrow D$, then composition of morphisms is associative, that is, $h(gf) = (hg)f$;

b) To each object B there exists a morphism $1_B \ : \ B \rightarrow B$ such that $1_B f = f$, $g 1_B = g$ for $f \ : A \rightarrow B$ and $g \ : B \rightarrow C$.

There are several aspects that are necessary for construction the category of D-branes [3]:

- D-brane is associated to the locally-free sheaf;
- An open string from one D-brane (sheaf E) to another D-brane (sheaf F) is given by an element of the group $\mathrm{Ext}^q(E, F)$;
- the category of D-branes is the derived category of coherent sheaves $D(X)$;
- If X and Y are mirror Calabi-Yau threefolds then the category $D(X)$ is equivalent to the triangulated category $\mathrm{Tr}\mathcal{F}(Y)$;
- D-branes on the orbifold $\mathbb{C}/G$ and open strings between them are described by the derived category of McKay quiver representations.

We consider the derived category of distinguished triangles over the abelian category of McKay quivers [**?**]. Objects of this category are distinguished triangles

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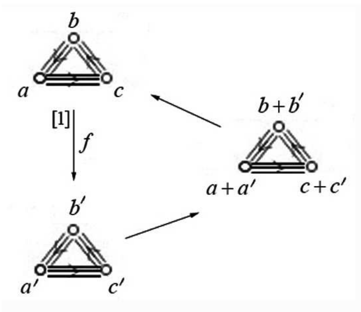

Fig.1. *Triangles*

(numbers a, b, c and a', b', c' denote orbifold charges [4] characterizing McKay quivers); morphisms of this category are morphisms of distinguished triangles.

3. PARTICLE CONTENT

The moduli space of an open superstring [5] has the form

$$\begin{aligned} \mathrm{Ext}^0(Q,Q') &= \mathbb{C}^{\,aa'+bb'+cc'}\ , \\ \mathrm{Ext}^1(Q,Q') &= \mathbb{C}^{\,3ab'+3bc'+3ca'}\ . \end{aligned} \qquad (1)$$

Substituting in (1) orbifold charges

$$a = b = c = a' = b' = c' = 4$$

(Fig. 1) and using the Langlands hypothesis [6], we obtain the realization of (1) in terms of $SU(5)$ multiplets

$$3 \times (24 + 5_H + \overline{5}_H + 5_M + \overline{5}_M + 10_M + \overline{10}_M)\ .$$

This result determines the particle content of the MSSM.

4. SUPERPOTENTIAL

The gauge invariant MSSM superpotential takes the form

$$\begin{aligned} W_{SU(5)} = \lambda^d_{ij} \cdot \overline{5}_H \times \overline{5}^{(i)}_M \times 10^{(j)}_M + \\ +\lambda^u_{ij} \cdot 5_H \times 10^{(i)}_M \times 10^{(j)}_M + \mu \cdot 5_H \times \overline{5}_H\ , \end{aligned} \qquad (2)$$

where 5_H and $\overline{5}_H$ are Higgs multiplets, $\overline{5}^{(i)}_M$ and $10^{(j)}_M$ are multiplets of quark and lepton superpartners, λ^d_{ij}, λ^u_{ij} are Yukawa coupling constants and μ is the Higgs mixing parameter.

5. MASS SPECTRUM

The analysis of Yukawa coupling constants, based on observational hints and theoretical considerations, allows to restrict the parameter space in (2) to five free parameters [7]:

$$\begin{aligned} \mathrm{M}_0 = 450 \text{ GeV}\ , \quad \mathrm{M}_{1/2} = 425 \text{ GeV}\ , \\ A_0 = 0\ , \quad \tan\beta = 10\ , \quad \mathrm{sgn}(\mu) = +1\ . \end{aligned} \qquad (3)$$

Using this restricted parameter set it is possible to calculate the mass spectrum of superpartners by application of the computer program SOFTSUSY [8]. This MSSM spectrum is shown in Table 1.

Table 1. *Mass spectrum of superpartners*

	GeV		GeV		GeV
$\tilde{u}_R$	974			$\tilde{g}$	1006
$\tilde{u}_L$	1000	$\tilde{\nu}_e$	525	$\tilde{\chi}^0_1$	174
$\tilde{d}_R$	972	$\tilde{e}_R$	477	$\tilde{\chi}^0_2$	327
$\tilde{d}_L$	1003	$\tilde{e}_L$	531	$\tilde{\chi}^0_3$	546
$\tilde{c}_R$	974			$\tilde{\chi}^0_4$	562
$\tilde{c}_L$	1000	$\tilde{\nu}_\mu$	525	$\tilde{\chi}^\pm_1$	327
$\tilde{s}_R$	972	$\tilde{\mu}_R$	477	$\tilde{\chi}^\pm_2$	562
$\tilde{s}_L$	1003	$\tilde{\mu}_L$	531		
$\tilde{t}_1$	741			h^0	114
$\tilde{t}_2$	947	$\tilde{\nu}_\tau$	523	A^0	749
$\tilde{b}_1$	910	$\tilde{\tau}_1$	471	H^0	749
$\tilde{b}_2$	968	$\tilde{\tau}_2$	531	$H^\pm$	753

6. PARTIAL WIDTHS

Using the parameter set (3) it is possible to calculate partial widths of superpartners by application of the computer program SDECAY [9]. These partial widths are shown in Tables 2, 3.

Table 2. *Partial widths of superpartners*

	channel	BR	channel	BR
$\tilde{u}_R$	$\tilde{\chi}^0_1 u$	0.993	$\tilde{\chi}^0_4 u$	0.004
	$\tilde{\chi}^0_2 u$	0.002		
$\tilde{d}_R$	$\tilde{\chi}^0_1 d$	0.993	$\tilde{\chi}^0_4 d$	0.004
	$\tilde{\chi}^0_2 d$	0.002		
$\tilde{c}_R$	$\tilde{\chi}^0_1 c$	0.993	$\tilde{\chi}^0_4 c$	0.004
	$\tilde{\chi}^0_2 c$	0.002		
$\tilde{s}_R$	$\tilde{\chi}^0_1 s$	0.993	$\tilde{\chi}^0_4 s$	0.004
	$\tilde{\chi}^0_2 s$	0.002		

Table 3. *Partial widths of superpartners*

	channel	BR	channel	BR
$\tilde{g}$	$\tilde{d}_R d^*$	0.017	$\tilde{b}_1 b^*$	0.119
	$\tilde{d}^*_R d$	0.017	$\tilde{b}^*_1 b$	0.119
	$\tilde{u}_R u^*$	0.015	$\tilde{b}_2 b^*$	0.021
	$\tilde{u}^*_R u$	0.015	$\tilde{b}^*_2 b$	0.021
	$\tilde{s}_R s^*$	0.017	$\tilde{t}_1 t^*$	0.294
	$\tilde{s}^*_R s$	0.017	$\tilde{t}^*_1 t$	0.294
	$\tilde{c}_R c^*$	0.015		
	$\tilde{c}^*_R c$	0.015		

7. CROSS SECTIONS

Using the parameter set (3) it is possible to calculate production cross sections of superpartners by application of the computer program PYTHIA [10]. These cross sections at center-of-mass energy $\sqrt{s} = 14$ TeV are shown in Table 4.

Table 4. Cross sections of superpartners

channel	cross section, pb
$gg \rightarrow \tilde{g}\tilde{g}$	$\sigma_{\tilde{g}\tilde{g}} = 0.323$
$qg \rightarrow \tilde{d}_R\tilde{g}$	$\sigma_{\tilde{d}_R\tilde{g}} = 0.260$
$qg \rightarrow \tilde{u}_R\tilde{g}$	$\sigma_{\tilde{u}_R\tilde{g}} = 0.489$
$qq^{'} \rightarrow \tilde{u}_R\tilde{d}_R$	$\sigma_{\tilde{u}_R\tilde{d}_R} = 0.132$

8. RECONSTRUCTION OF MASSES

To construct histograms describing mass distributions for superpartners $\tilde{q}_R$ and $\tilde{g}$ we choose the set of parameters (3). Using this parameter set it is possible to construct histograms of mass distributions for superpartners by application of the computer program PYTHIA [10]. This histograms are shown in Fig. 2 and Fig. 3.

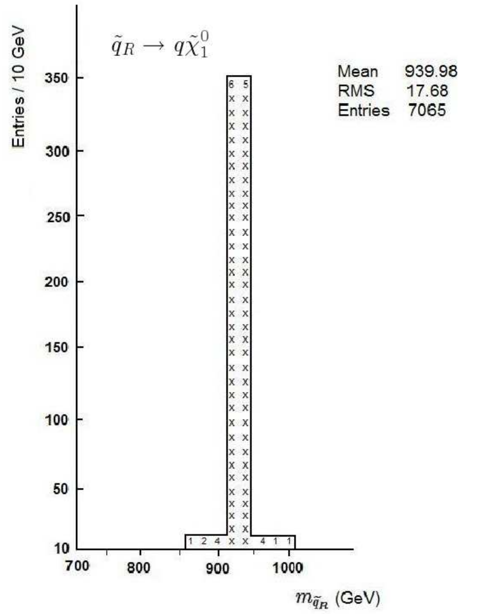

Fig.2. *Histogram of mass distribution for* $\tilde{q}_R$

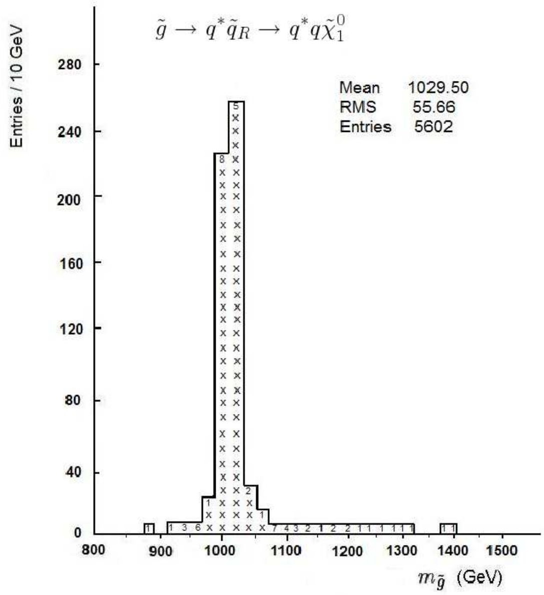

Fig.3. *Histogram of mass distribution for* $\tilde{g}$

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ПОИСКИ СУПЕРЧАСТИЦ НА LHC ПУТЕМ ПРИМЕНЕНИЯ КОМПЬЮТЕРНОГО СИМУЛИРОВАНИЯ

Т.В. Обиход, Ю.М. Малюта

Анализ последних экспериментальных данных, полученных на LHC, ограничил пространство MSSM параметров до новых пяти параметров. Путем применения компьютерных программ SOFTSUSY, SDECAY и PYTHIA посчитаны массы, ширины распадов и сечения рождения суперчастиц. В контексте минимальной суперсимметричной стандартной модели построены гистограммы распределения масс суперчастиц $\tilde{q}_R$ и $\tilde{g}$.

ПОШУКИ СУПЕРЧАСТИНОК НА LHC ШЛЯХОМ ЗАСТОСУВАННЯ КОМП'ЮТЕРНОГО СИМУЛЮВАННЯ

Т.В. Обіход, Ю.М. Малюта

Аналіз останніх експериментальних даних, отриманих на LHC, обмежив простір MSSM параметрів до нових п'яти параметрів. Шляхом застосування комп'ютерних програм SOFTSUSY, SDECAY і PYTHIA розраховано маси, ширини розпадів і перерізи народження суперчастинок. У контексті мінімальної суперсиметричної стандартної моделі побудовані гістограми розподілу мас суперчастинок $\tilde{q}_R$ и $\tilde{g}$.