SEARCHES FOR SUSY AT THE LHC

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Searches for SUSY with R-parity conservation are connected with LSP particle - the best dark matter candidate. Using the new Minimal Supersymmetric Standard Model (MSSM) parameters received from recent experimental data at the LHC (CMS) it is possible to calculate the mass spectrum, partial width and production cross sections of superpatners. In the context of MSSM model histograms of mass distributions for superpartners $\tilde{q}_R$ and $\tilde{g}$ are constructed.

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1. INTRODUCTION

The gauge hierarchy problem and other shortcomings of the Standard Model (SM) can be resolved by introducing a spectrum of new particles, that are partners of the SM particles [1, 2, 3]. These particles may be neutral, stable and weakly interacting particles that are good dark-matter candidates. The identity and properties of the fundamental particles that could be dark-matter candidates are the most important unsolved problems in particle physics and cosmology. In supersymmetry (SUSY) the R parity conservation is connected with requirement that all SUSY particles to be produced in pairs and the lightest SUSY particle (LSP) to be stable. The LSP will pass through the detector without interacting, carrying away a substantial amount of energy and creating an imbalance in the transverse momentum. If squarks are light, their production is enhanced, either through direct pair production or through production mediated by gluinos, where the latter process is favored if the gluino production cross section is large. From Fig. 1 we can see the process described above and connected with LSP production.

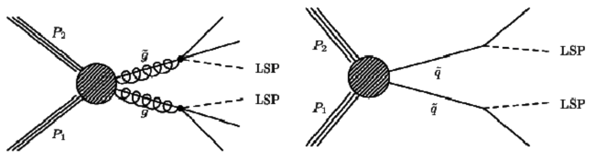


Fig.1. *Diagrams of the gluino pair production (left) and squark pair production (right)*

If confirmed experimentally, supersymmetry could also be considered evidence, because it was discovered in the context of string theory, and all consistent string theories are supersymmetric. Superstring theory posits a connection between bosons and fermions and require also the existence of several extra dimensions to the universe that have been compactified into extremely small scales, in addition to the four known spacetime dimensions. To ensure the vanishing of the conformal anomaly of the worldsheet conformal field theory we must have 10 spacetime dimensions for the superstring. We will consider the following geometry of space-time:

$$R^{3+1} \times \mathbb{C}^3/\mathbb{Z}_3 \ ,$$

where the six-dimensional additional space is orbifold. Using the correspondence between $R^{3+1} \times \mathbb{C}^3/\mathbb{Z}_3$ and $AdS_5 \times S^5$ spaces and the fact that we work on additional space, we can graphically and abstractly represent geometry of the superstring:

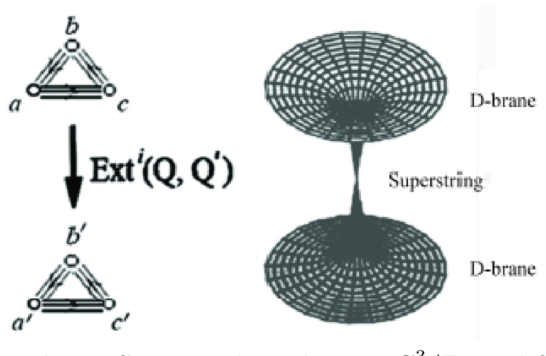
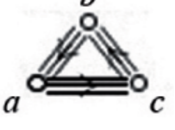


Fig.2. *Correspondence between $\mathbb{C}^3/\mathbb{Z}_3$ and S^5 geometry*

From left side of the Fig.2 we have two D-branes that are described by quivers received



after blow-up of the singularity $\mathbb{C}^3/\mathbb{Z}_3$ (numbers a, b, c and $a^{'}, b^{'}, c^{'}$ denote orbifold charges [4] char-

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acterizing McKay quivers) and open superstring is described by Ext^i groups determined by the diagram [5]. On the right part of Fig.2 we can see the Schwarzschild geometry that is connected with Friedmann universes of positive and negative spatial curvature and is the geometry of the spacelike hypersurface [6].

2. PARTICLE CONTENT AND MASS SPECTRUM OF SUPERPARTNERS

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

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

Substituting in (1) orbifold charges

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

and using the Langlands hypothesis [7], 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. The gauge invariant MSSM superpotential takes the form:

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

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.
Using the restricted parameter set in (2), received from the recent experimental data [8]

$$\begin{aligned} & \mathrm{M}_0 = 800 \text{ GeV} \ , \quad \mathrm{M}_{1/2} = 650 \text{ GeV} \ , \\ & A_0 = 0 \ , \quad \tan\beta = 10 \ , \quad \mathrm{sgn}(\mu) = +1 \end{aligned} \tag{3}$$

it is possible to calculate the mass spectrum of superpartners by application of the computer program SOFTSUSY [9]. This MSSM spectrum is shown in Table 1.

Table 1. *Mass spectrum of superpartners*

	GeV		GeV		GeV
$\tilde{u}_R$	1499			$\tilde{g}$	1498
$\tilde{u}_L$	1539	$\tilde{\nu}_e$	901	$\tilde{\chi}^0_1$	273
$\tilde{d}_R$	1495	$\tilde{e}_R$	834	$\tilde{\chi}^0_2$	516
$\tilde{d}_L$	1541	$\tilde{e}_L$	905	$\tilde{\chi}^0_3$	792
$\tilde{c}_R$	1499			$\tilde{\chi}^0_4$	805
$\tilde{c}_L$	1539	$\tilde{\nu}_\mu$	901	$\tilde{\chi}^\pm_1$	516
$\tilde{s}_R$	1495	$\tilde{\mu}_R$	834	$\tilde{\chi}^\pm_2$	805
$\tilde{s}_L$	1541	$\tilde{\mu}_L$	905		
$\tilde{t}_1$	1138			h^0	117
$\tilde{t}_2$	1411	$\tilde{\nu}_\tau$	898	A^0	1188
$\tilde{b}_1$	1389	$\tilde{\tau}_1$	825	H^0	1188
$\tilde{b}_2$	1487	$\tilde{\tau}_2$	902	$H^\pm$	1191

3. PARTIAL WIDTHS AND LSP

Using the parameter set (3) it is possible to calculate partial widths of superpartners by application of the computer program SDECAY [10]. These partial widths are shown in Tables 2, 3.

Table 2. *Partial widths of superpartners*

	channel	BR	channel	BR
$\tilde{u}_R$	$\tilde{\chi}^0_1 u$	0.997	$\tilde{\chi}^0_4 u$	0.002
$\tilde{d}_R$	$\tilde{\chi}^0_1 d$	0.997	$\tilde{\chi}^0_4 d$	0.002
$\tilde{c}_R$	$\tilde{\chi}^0_1 c$	0.997	$\tilde{\chi}^0_4 c$	0.002
$\tilde{s}_R$	$\tilde{\chi}^0_1 s$	0.997	$\tilde{\chi}^0_4 s$	0.002

Table 3. *Partial widths of superpartners*

	channel	BR	channel	BR
$\tilde{g}$	$\tilde{b}_1 b^*$	0.074	$\tilde{t}_1 t^*$	0.425
	$\tilde{b}^*_1 b$	0.074	$\tilde{t}^*_1 t$	0.425

From Fig.1 we can see that after the pp reaction each member of the produced pair initiates a decay chain that terminates with the lightest SUSY particle (LSP) and SM particles, typically including jets (one for squark and two for gluino). This fact can be proven with the help of Tables 1 and 2. From Table 1 we know that lightest SUSY particle is neutralino ($\tilde{\chi}^0_1$ = 273 GeV) and from Table 2 we can see that all SUSY particles decay through the channel $\tilde{q}_R \rightarrow q + LSP$. If the LSP only interacts weakly, as in the case of a dark-matter candidate, it escapes detection, potentially yielding significant missing transverse energy (E^{miss}_T).

4. CROSS SECTIONS

Using the parameter set (3) it is possible to calculate production cross sections of superpartners by application of the computer program PYTHIA [11]. 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
$gg \rightarrow \tilde{g}\tilde{g}$	$\sigma_{\tilde{g}\tilde{g}} = 0.139$
$qg \rightarrow \tilde{d}_R\tilde{g}$	$\sigma_{\tilde{d}_R\tilde{g}} = 0.153$
$qg \rightarrow \tilde{u}_R\tilde{g}$	$\sigma_{\tilde{u}_R\tilde{g}} = 0.341$
$qq^{'} \rightarrow \tilde{u}_R\tilde{d}_R$	$\sigma_{\tilde{u}_R\tilde{d}_R} = 0.173$

Analysis of the calculated data presented in Table 4, leads us to the conclusion that gluino production process is one of the four favored processes as was emphasized in introduction.

5. 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 [11]. This histograms are shown in Figs.3 and 4.

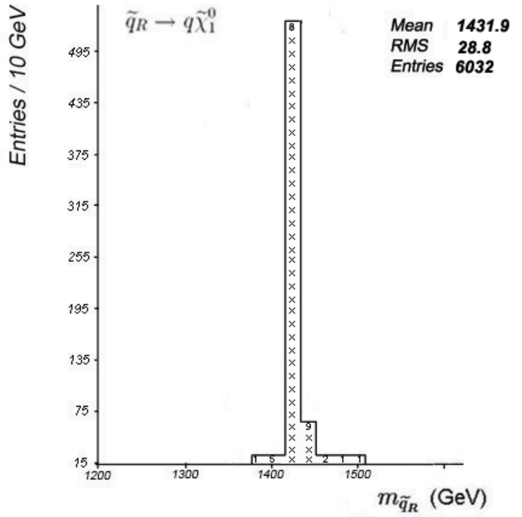

Fig.3. *Histogram of mass distribution for* $\tilde{q}_R$

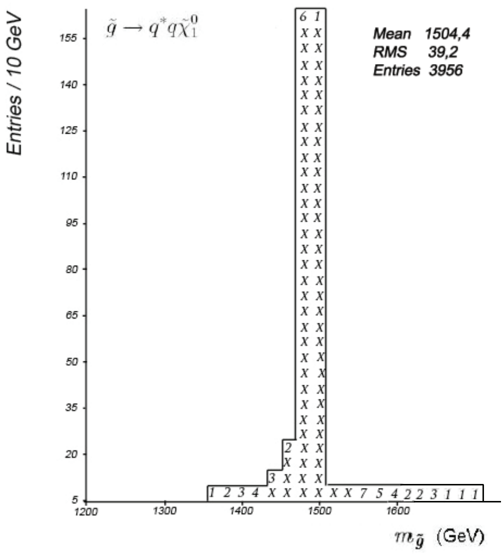

Fig.4. *Histogram of mass distribution for* $\tilde{g}$

6. CONCLUSIONS

Whereas more than 80% of the matter in the universe remains invisible deciphering the nature of this "dark matter" remains one of the most interesting questions in particle physics. The CMS collaboration recently conducted a search for the direct production of dark-matter particles (χ), with especially good sensitivity in the low-mass region. An important aspect of the search by CMS is that there is no fall in sensitivity for low masses. After event selection, 3677 events were found in the recent analysis. CMS has set limits on the production of dark matter, as shown in the Fig. 5 of the χ-cross-section versus χ mass.

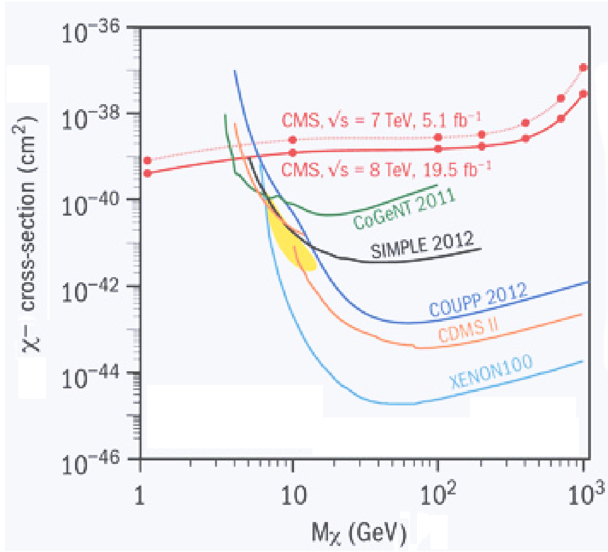

Fig.5. *χ cross-section versus χ mass*

The limits show that CMS has good sensitivity in the low-mass regions of interest. Our calculations of neutralino masses as shown in Table 1 are in agreement with the last experimental data received from the LHC (CMS).

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ПОИСКИ *SUSY* НА *LHC*

Т. В. Обиход

Поиски $SUSY$ с сохранением R-четности связаны с LSP-частицей – лучшим кандидатом темной материи. Используя новые $MSSM$ параметры, полученные из последних экспериментальных данных на $LHC(CMS)$, можно посчитать массы, ширины распадов и сечения рождения суперчастиц. В контексте $MSSM$ модели построены гистограммы распределения масс суперчастиц $\tilde{q}_R$ и $\tilde{g}$.

ПОШУКИ *SUSY* НА *LHC*

Т. В. Обiход

Пошуки $SUSY$ iз збереженням R-порності пов'язані з LSP-частинкою – кращим кандидатом темної матерії. Викормстання нових $MSSM$ параметрів, отриманих із останніх експериментальних даних на $LHC(CMS)$, дає можливість розрахувати маси, ширини розпадів і перерізи породження суперчастинок. В контексті $MSSM$ моделі побудовані гістограми розподілу мас суперчастинок $\tilde{q}_R$ і $\tilde{g}$.