STRINGY APPROACH TO THE MINIMAL SUPERSYMMETRIC STANDARD MODEL

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Superstring theory is applied to construct the Minimal Supersymmetric Standard Model. The mass spectrum, partial widths and production cross sections of superpartners are calculated. This approach gives concrete predictions for superpartner searches at the LHC.

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1. INTRODUCTION

The purpose of the present work is to construct the Minimal Supersymmetric Standard Model [1] from superstring theory [2]. This aim is achieved by using the notion of derived category [3]. Such approach allows to determine the mass spectrum, partial widths and production cross sections of superpartners.

These predictions are important from experimental point of view as they are connected with searches for new physics at the LHC.

2. DERIVED CATEGORY

Derived categories are the mathematical foundation of superstring theory. We consider the derived category of distinguished triangles over the abelian category of McKay quivers [3]. Objects of this category are distinguished triangles and open superstrings are described by $\text{Ext}^i(Q, Q')$ groups determined by the diagram [3] :

3. PARTICLE CONTENT

It was shown in [5] that the moduli space of the open superstring has the form

$$
\text{Ext}^0(Q, Q') = \mathbb{C}^{aa' + bb' + cc'},
$$

$$
\text{Ext}^1(Q, Q') = \mathbb{C}^{3ab' + 3bc' + 3ca'}.
$$

Substituting in (1) orbifold charges

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

(numbers $a, b, c$ and $a', b', c'$ denote orbifold charges [4] characterizing McKay quivers); morphisms of this category are morphisms of distinguished triangles. In this approach D-branes are described by quivers $Q$ :

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

$$3 \times (24 + 5H + 5H + 5M + 5M + 10M + \overline{10}M) \, .$$

This result determines the particle content of the MSSM.

4. SUPERPOWENTIAL

The gauge invariant MSSM superpotential takes the form

$$W_{SU(5)} = \lambda^q_i \cdot \bar{\chi}^q_i \times \bar{\chi}^{(q)}_i \times 10^{(q)}_M + \lambda^e_i \cdot 5H \times \bar{\chi}^{(e)}_i \times 10^{(e)}_M + \mu \cdot 5H \times \bar{\chi}_H \, ,$$

where $5H$ and $\bar{\chi}_H$ are Higgs multiplets, $\bar{\chi}^{(q)}_i$ and $10^{(q)}_M$ are multiplets of quark and lepton superpartners, $\lambda^q_i$, $\lambda^e_i$ are Yukawa coupling constants and $\mu$ 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]:

$$M_0 = 0.01 \text{ GeV} \, , \quad M_{1/2} = 600 \text{ GeV} \, ,$$

$$A_0 = 0 \, , \quad \tan \beta = 35 \, , \quad \text{sgn}(\mu) = +1 \, .$$

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

<table>
<thead>
<tr>
<th>GeV</th>
<th>GeV</th>
<th>GeV</th>
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<tbody>
<tr>
<td>$\tilde{u}_R$</td>
<td>1187</td>
<td>$\tilde{g}$</td>
</tr>
<tr>
<td>$\tilde{u}_L$</td>
<td>1232</td>
<td>$\tilde{v}_\nu$</td>
</tr>
<tr>
<td>$\tilde{d}_R$</td>
<td>1182</td>
<td>$\tilde{e}_R$</td>
</tr>
<tr>
<td>$\tilde{d}_L$</td>
<td>1235</td>
<td>$\tilde{e}_L$</td>
</tr>
<tr>
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<td>1187</td>
<td>$\tilde{\chi}^c_1$</td>
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<tr>
<td>$\tilde{e}_L$</td>
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<td>$\tilde{\nu}_\nu$</td>
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<tr>
<td>$\tilde{s}_R$</td>
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<td>$\tilde{\mu}_R$</td>
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<tr>
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<td>1235</td>
<td>$\tilde{\mu}_L$</td>
</tr>
<tr>
<td>$t_1$</td>
<td>958</td>
<td>$\tilde{t}_1$</td>
</tr>
<tr>
<td>$t_2$</td>
<td>1155</td>
<td>$\tilde{t}_2$</td>
</tr>
<tr>
<td>$b_1$</td>
<td>1095</td>
<td>$\tilde{b}_1$</td>
</tr>
<tr>
<td>$b_2$</td>
<td>1148</td>
<td>$\tilde{b}_2$</td>
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</tbody>
</table>

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, 4, 5.
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 6.

<table>
<thead>
<tr>
<th>Table 6. Cross sections of superpartners</th>
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<tbody>
<tr>
<td>channel</td>
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<tr>
<td>$gg \rightarrow \tilde{g}\tilde{g}$</td>
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<tr>
<td>$gu \rightarrow \tilde{g}u$</td>
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<tr>
<td>$du \rightarrow \tilde{d}u$</td>
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<tr>
<td>$\pi u \rightarrow \tilde{\chi}_1^\pm \tilde{\chi}_1^0$</td>
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<tr>
<td>$\tilde{d}u \rightarrow \tilde{\chi}_1^+ \tilde{\chi}_1^0$</td>
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</table>

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<thead>
<tr>
<th>Table 7. Lower limits on masses reached at colliders</th>
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<tbody>
<tr>
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8. COMPARISON WITH EXPERIMENTS

Comparison of the predicted MSSM spectrum with experimental data obtained at the LEP and TEVATRON [11] (see Table 7) shows, that the calculated masses exceed the lower limits on masses reached at colliders. New searches for superpartners will be made at the LHC.

References