High Energy Physics and Triangulated Categories

Yu.M. Malyuta, T.V. Obikhod

Institute for Nuclear Research
National Academy of Sciences of Ukraine
03068 Kiev, Ukraine
e-mail: obikhod@kinr.kiev.ua

Abstract

Superstring theory is applied to construction of the Minimal Supersymmetric Standard Model. The mass spectrum of superpartners is predicted. Comparison of this spectrum with experimental data at the LEP and TEVATRON is analyzed.

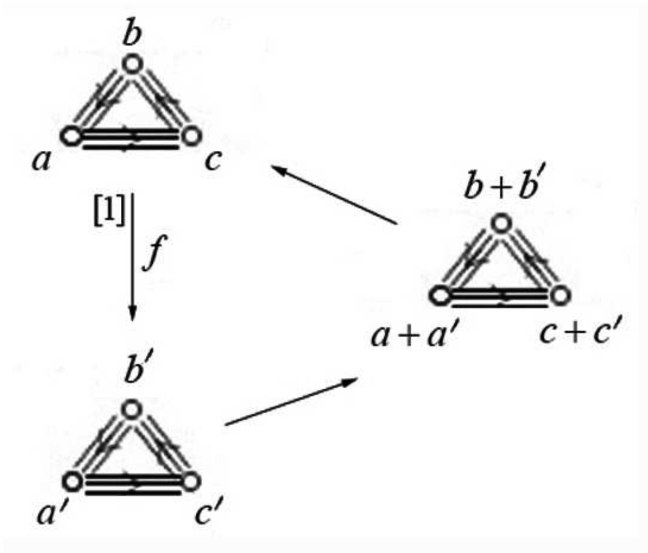
1 Introduction

The purpose of the present work is to derive the Minimal Supersymmetric Standard Model [1] from superstring theory [2]. This aim is achieved by using the notion of triangulated category. Such approach allows to determine the gauge group, matter content, superpotential and mass spectrum of superpartners.

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

2 Triangulated category

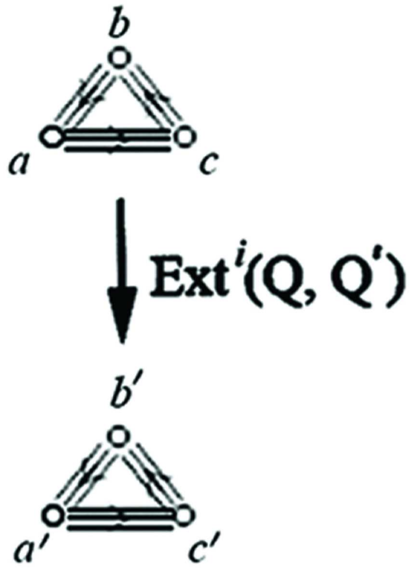
We consider the triangulated category of distinguished triangles over the abelian category of McKay quivers [3]. Objects of this category are distinguished triangles



(1)

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

From (1) we infer the following construction



interpreted as two D-branes (described by quivers), between which the superstring (described by Ext^i groups) is stretched.

3 Matter content

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

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

$$\mathrm{Ext}^1(Q, Q') = \mathbb{C}^{\,3ab'+3bc'+3ca'} \quad . \qquad (2)$$

Substituting in (2) orbifold charges

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

and using the Langlands hypothesis [6], we obtain the realization of (2) 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 matter content of the MSSM.

4 Superpotential

The gauge invariant MSSM superpotential takes the form

$$W_{SU(5)} = \lambda^d_{ij} \cdot \overline{5}_H \times \overline{5}^{(i)}_M \times 10^{(j)}_M + \lambda^u_{ij} \cdot 5_H \times 10^{(i)}_M \times 10^{(j)}_M + \mu \cdot 5_H \times \overline{5}_H \ , \qquad (3)$$

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, $\lambda^d_{ij},\ \lambda^u_{ij},\ \mu$ are Yukawa coupling constants.

5 Mass spectrum of superpartners

The analysis of Yukawa coupling constants, based on observational hints and theoretical considerations, allows to restrict the parameter space in (3) to five free parameters. Using this restricted parameter set it is possible to calculate the mass spectrum of superpartners by application of the computer program SOFTSUSY [7]. This MSSM spectrum is displayed in Figure 1.

6 Comparison with experiment

Comparison of the predicted spectrum with experimental data obtained at the LEP and TEVATRON [8] (see Table 1) shows, that the calculated masses exceed the lower limits on masses reached at colliders.

New searches for superpartners and measurements of their masses should be realized at the LHC.

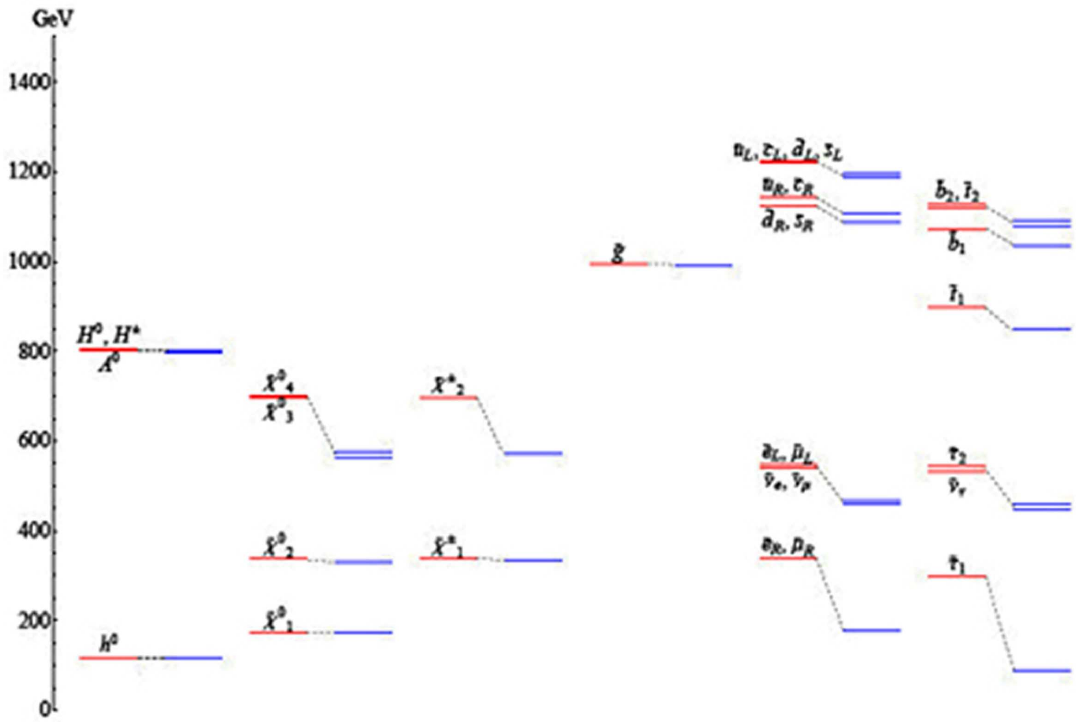


Fig. 1

Table 1

particle		Condition	Lower limit (GeV/c^2)	Source
$\widetilde{\chi}_1^{\pm}$	gaugino	$M_{\widetilde{\nu}} > 200$ GeV/c^2	103	LEP 2
		$M_{\widetilde{\nu}} > M_{\widetilde{\chi}^{\pm}}$	85	LEP 2
		any $M_{\widetilde{\nu}}$	45	Z width
	Higgsino	$M_2 < 1$ TeV/c^2	99	LEP 2
	GMSB		150	DØ isolated photons
	RPV	$LL\overline{E}$ worst case	87	LEP 2
		$LQ\overline{D}$ $m_0 > 500$ GeV/c^2	88	LEP 2
$\widetilde{\chi}_1^0$	indirect	any $\tan\beta$, $M_{\widetilde{\nu}} > 500$ GeV/c^2	39	LEP 2
		any $\tan\beta$, any m_0	36	LEP 2
		any $\tan\beta$, any m_0, SUGRA Higgs	59	LEP 2 combined
	GMSB		93	LEP 2 combined
	RPV	$LL\overline{E}$ worst case	23	LEP 2
$\widetilde{e}_R$	$e\widetilde{\chi}_1^0$	$\Delta M > 10$ GeV/c^2	99	LEP 2 combined
$\widetilde{\mu}_R$	$\mu\widetilde{\chi}_1^0$	$\Delta M > 10$ GeV/c^2	95	LEP 2 combined
$\widetilde{\tau}_R$	$\tau\widetilde{\chi}_1^0$	$M_{\widetilde{\chi}_1^0} < 20$ GeV/c^2	80	LEP 2 combined
$\widetilde{\nu}$			43	Z width
$\widetilde{\mu}_R$, $\widetilde{\tau}_R$		stable	86	LEP 2 combined
$\widetilde{t}_1$	$c\widetilde{\chi}_1^0$	any θ_{mix}, $\Delta M > 10$ GeV/c^2	95	LEP 2 combined
		any θ_{mix}, $M_{\widetilde{\chi}_1^0} \sim \frac{1}{2} M_{\widetilde{t}}$	115	CDF
		any θ_{mix} and any ΔM	59	ALEPH
	$b\ell\widetilde{\nu}$	any θ_{mix}, $\Delta M > 7$ GeV/c^2	96	LEP 2 combined
$\widetilde{g}$	any $M_{\widetilde{q}}$		195	CDF jets+$\not{E}_T$
$\widetilde{q}$	$M_{\widetilde{q}} = M_{\widetilde{g}}$		300	CDF jets+$\not{E}_T$

References

[1] B.C. Allanach et al., *Mass spectrum in R-parity violating minimal supergravity and benchmark points*, arXiv: hep-ph/0609263.

[2] C. Vafa et al., *Stringy reflections on LHC*, http://www.claymath.org/workshops/lhc/.

[3] P.S. Aspinwall, *D-branes on Calabi-Yau manifolds*, arXiv: hep-th/0403166.

[4] M.R. Douglas, B. Fiol and C. Römelsberger, *The spectrum of BPS branes on a noncompact Calabi-Yau*, arXiv: hep-th/0003263.

[5] S. Katz, T. Pantev and E. Sharpe, *D-branes, orbifolds, and Ext groups*, arXiv: hep-th/0212218.

[6] M.S. Narasimhan, K. Okamoto, *An analogue of the Borel-Weil-Bott theorem for hermitian symmetric pairs of non-compact type*, Ann. Math. **91**, 3 (1970) 486.

[7] B.C. Allanach, *SOFTSUSY2.0: a program for calculating supersymmetric spectra*, arXiv: hep-ph/0104145.

[8] M. Schmitt, *Supersymmetry, Part II (Experiment)*, Phys. Lett. **B592** (2004) 1014.