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High energy physics and algebraic geometry

Superstring theory is applied to construction of the Minimal Supersymmetric Standard Model.

Keywords: *Superstring theory, Calabi-Yau fourfold, Superpotential, Mass spectrum of superpartners*

1. Introduction

The purpose of the present work is to derive the Minimal Supersymmetric Standard Model [1] from superstring theory [2]. It is performed by choosing superstring compactification in the form of elliptically fibred Calabi-Yau fourfold. 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. Superstring compactification

We consider superstring compactification on the Calabi-Yau fourfold F represented as the elliptic fibration

$$\begin{array}{ccc} \mathcal{E} & \longrightarrow & F \\ & & \downarrow \\ & & B \end{array} \tag{1}$$

where the base B is the Fano variety of dimension three and the fiber $\mathcal{E}$ is the elliptic curve.

Singular elliptic fibers [3] and their classification in terms of Lie groups are shown in Figure 1.

3. Matter content

The Fano variety B [4] contains two del Pezzo surfaces S and S'. The surface S intersects the surface S' transversely along complex curves $\Sigma_H^{(u)}$, $\Sigma_H^{(d)}$, $\Sigma_M^{(1)}$, $\Sigma_M^{(2)}$ shown in Table 1 and in Figure 2. The fibration (1) restricted to these curves has sections

$$1 \times 5_H, \qquad 1 \times \overline{5}_H, \qquad 3 \times 10_M, \qquad 3 \times \overline{5}_M$$

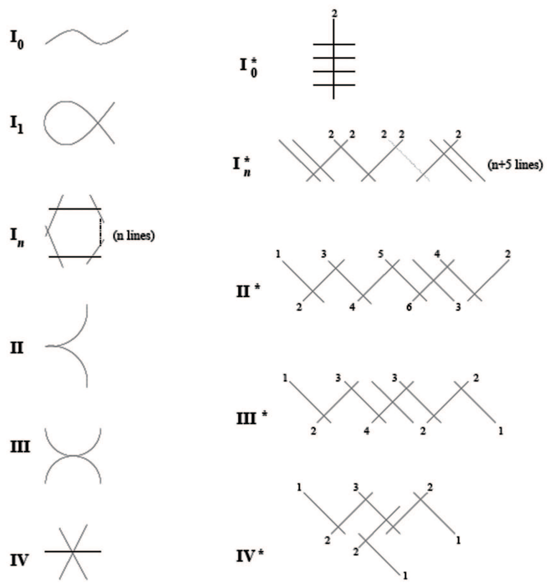
presented in Table 1 and in Figure 2. These sections determine the matter content of the MSSM.

4. Superpotential

The gauge invariant MSSM superpotential takes the form

$$W_{SU(5)} = \lambda_{ij}^d \cdot \overline{5}_H \times \overline{5}_M^{(i)} \times 10_M^{(j)} + \lambda_{ij}^u \cdot 5_H \times 10_M^{(i)} \times 10_M^{(j)} + \\ + \lambda_{ia} \cdot 5_H \times \overline{5}_M^{(i)} \times N_R^{(a)} + \mu \cdot 5_H \times \overline{5}_H \tag{2}$$

where 5_H and $\overline{5}_H$ are Higgs multiplets, $\overline{5}_M^{(i)}$ and $10_M^{(j)}$ are multiplets of quark and lepton superpartners, λ_{ij}^d, λ_{ij}^u, λ_{ia}, μ are Yukawa coupling constants.



Fiber	I_0	I_N	II	III	IV	I_0^*	I_{N-6}^*	IV^*	III^*	II^*
Singularity type	—	A_{N-1}	—	A_1	A_2	D_4	D_{N-2}	E_6	E_7	E_8

Figure 10

5. Mass spectrum of superpartners

The analysis of Yukawa coupling constants, based on observational hints and theoretical considerations, allows to restrict the

Table 1

Model	Curve	Class
$1 \times 5_H$	$\Sigma_H^{(u)}$	$H - E_1 - E_3$
$1 \times \overline{5}_H$	$\Sigma_H^{(d)}$	$H - E_2 - E_4$
$3 \times 10_M$	$\Sigma_M^{(1)}$ (pinched)	$2H - E_1 - E_5$
$3 \times \overline{5}_M$	$\Sigma_M^{(2)}$	H

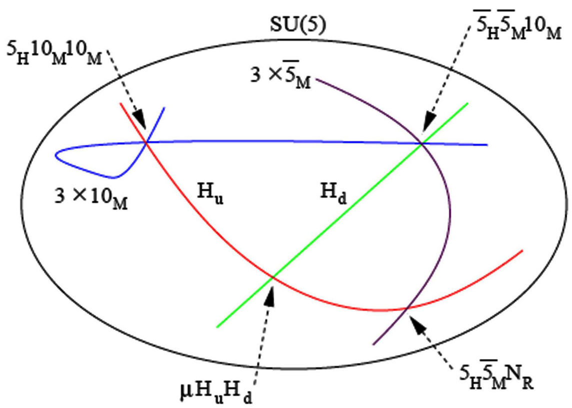


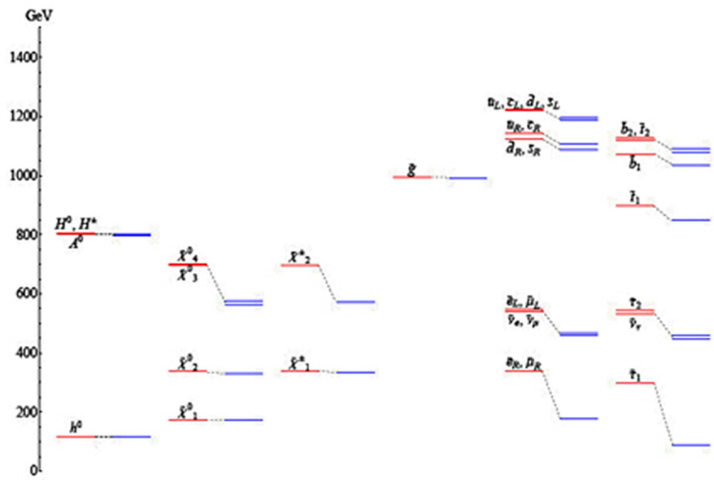
FIGURE 11

parameter space in (2) 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 [5]. This MSSM spectrum is displayed in Figure 3.

6. Comparison with experiment

Comparison of the predicted spectrum with experimental data obtained at the LEP and TEVATRON [6] (see Table 2) 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.



References

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

[3] Perevalov E., Skarke H., *Enhanced gauge symmetry in Type II and F-theory compactifications*, arXiv: hep-th/9704129.

[4] Klemm A., Lian B., Roan S-S., Yau S-T., *Calabi-Yau fourfolds for M- and F-theory compactifications*, arXiv: hep-th/9701023.

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

Table 2

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+$\not{E}_T$

FIGURE 12

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