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Editorial

Supersymmetry beyond the NMSSM

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With the start of run II of the Large Hadron Collider (LHC) a new milestone of high energy particle physics has been reached. Run I was on the one side a great success because of the discovery of a fundamental scalar with all expected properties of the so long-expected standard model (SM) Higgs boson [1, 2]. On the other side, no clear sign of any physics beyond the SM has shown up. This has placed severe constraints on the simplest scenarios for new physics. In particular the minimal realization of supersymmetry (SUSY), the minimal supersymmetric standard model (MSSM), has lost some of its appeal since it is no longer clear that it can address the question of naturalness. In general, there are two possibilities to explain the measured mass of 125 GeV within the MSSM: either heavy SUSY masses are needed, or the stop mixing has to be very large. In the first case, a new hierarchy problem is introduced, while the second can be dangerous because of charge and colour breaking minima [3–7].

These observations together with the other null results from SUSY searches have created a much stronger interest in nonminimal SUSY models in recent years. Extensions of the MSSM not only might provide a natural explanation for the size of the Higgs mass, but also can explain other (non)observations such as neutrino masses (e.g., in seesaw models) and the missing signals for supersymmetry (e.g., due to broken R-parity). More theoretical issues of the MSSM can also be addressed, such as the μ-problem in singlet extensions and the origin of R-parity in models with gauged $B - L$.

This special issue discusses several theoretical and experimental aspects of nonminimal SUSY models. To set the scene, the first article reconsiders the beginnings of supersymmetry and reveals its secret history: "Supersymmetry: Early Roots That Did Not Grow" by C. Jarlskog points out that the fundamental concepts of SUSY were already known in the 1940s.

Our first research article is inspired by top-down approaches: "Phenomenological Hints from a Class of String Motivated Model Constructions" by H. P. Nilles connects string theoretical considerations with LHC phenomenology. Generic predictions of a specific class of string motivated models are presented.

The next two articles consider singlet extensions of the MSSM. In "Two Higgs Bosons near 125 GeV in the Complex NMSSM and the LHC Run-I Data" by S. Moretti and S. Munir the properties of the Higgs fields in the Z_3 invariant singlet extensions with complex parameters are discussed. In particular, they consider the case where two Higgs bosons have such close masses that they are not separately resolved by the LHC experiments and find that for some parameter points this can provide a better fit to the data than a single Higgs.

The authors M. Ratz and P. K. S. Vaudrevange, in "Singlet Extensions of the MSSM with Z_4^R Symmetry," consider a different discrete symmetry which allows for more parameters in the superpotential. It is shown that the potentially

dangerous linear term can be avoided in this class of models.

As mentioned, one of the best possibilities to hide SUSY at the LHC is to assume that R-parity is not conserved. In this case the limits on SUSY masses are significantly reduced. The two articles "Status of LHC searches for SUSY without R-parity" by R. Franceschini and "Searches for Prompt R-Parity-Violating Supersymmetry at the LHC" by A. Redelbach discuss the current status of SUSY searches at the LHC in the context of R-parity violation. Together these provide an excellent and up-to-date reference for this class of searches.

SUSY models which include an explanation for the neutrino masses and mixing angles also predict nonvanishing rates for lepton-flavour violating (LFV) observables like $\mu \to e\gamma$ or $\mu \to 3e$. The article "Lepton Flavor Violation beyond the MSSM" by A. Vicente discusses the constraints on different SUSY models derived by the strong experimental bounds for LFV observables.

A possible origin of R-parity in SUSY models is the presence of an Abelian $B - L$ gauge group which is broken in a specific way to retain an unbroken Z_2 subgroup. These models are always accompanied by an extended Higgs sector. The article "The Higgs Sector of the Minimal SUSY $B - L$ Model" by L. Basso discusses the Higgs properties in the minimal SUSY model with a gauged $U(1)_{B-L}$ and unbroken R-parity.

Dirac gaugino models have recently attracted much attention in the literature due to their many attractive properties over their Majorana counterparts (as in the MSSM). However when in addition an unbroken R-symmetry is imposed, such models are expected to have difficulties to explain the observed Higgs mass: since the left- and right-handed stops cannot mix, the stop radiative corrections to the Higgs are suppressed. The article "Two-Loop Correction to the Higgs Boson Mass in the MRSSM" by P. Diessner et al. discusses the minimal R-symmetric SUSY model and shows that the observed Higgs mass can be generated via large radiative corrections involving other states. It includes all of the latest corrections which have recently become available, equivalent to the precision available for the MSSM: an illustration of the rapid recent developments in beyond-the-MSSM phenomenology.

The above articles give a cross section of current thinking in this rapidly expanding area. We hope that this special issue will therefore prove to be a useful resource for those entering the field and experts alike, as we eagerly wait for the data with, we hope, the first signs of what may lie beyond the (minimal supersymmetric) standard model.

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