Analysis of the R-symmetric supersymmetric models including quantum corrections

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Abstract

In this thesis the Minimal R-symmetric Supersymmetric Standard Model (MRSSM) is analyzed at the quantum level. The MRSSM presents a viable alternative to the most commonly considered supersymmetric extensions of the Standard Model like the MSSM or the NMSSM. It is based on the assumption that the $U(1)_R$ symmetry of the $\mathcal{N} = 1$ SUSY algebra is left unbroken at the weak scale. This assumption leads to a model with a distinct phenomenology, containing an extended Higgs sector, Dirac gauginos and color octet scalars.

The thesis consists of two parts. First one treats about the electroweak sector of the model. Among others, it identifies the parameter region allowed by the electroweak precision observables. Since the MRSSM contains an $SU(2)_L$-triplet with a non-zero vacuum expectation value the emphasis is put on the calculation of the W boson mass. To that end, a full one-loop calculation of m_W augmented with the leading two-loop SM result is presented. This allows to identify the region of parameter space consistent with the measured value of m_W. The region is then checked against the measurement of the Higgs boson mass (where it is assumed that the lightest MRSSM Higgs state is SM-like). For this, the full one-loop and leading two-loop corrections to the Higgs boson mass in the MRSSM are calculated. Devised benchmark points, consistent with both of these observables, are shown to fulfill also a number of additional experimental constraints like properties of the Higgs boson(s), b-physics observables and vacuum stability. Correlating all of these observables allows to put bounds on the parameters of the model.

Second part of the thesis treats about the strongly interacting scalar sector. First, NLO QCD corrections to the production of scalar gluon (sgluon) pair at the LHC are calculated. The calculation of the virtual part and details of the zero-momentum subtraction scheme are given. Large emphasis is put on the treatment of the infrared/collinear divergences which are dealt with using the two-cut phase space slicing method. Their cancelation between real and virtual contributions is also explicitly checked. A set of K-factors for a selected sgluon masses at 13 and 14 TeV LHC is presented. This calculation is applied to constrain the sgluon mass using 2015 data set from Run 2 of the LHC. To that end, a same-sign lepton search by ATLAS is recasted for the case of the production of the sgluon pair decaying to $t\bar{t}$ pairs. The analysis is reproduced with the help of shower Monte Carlo softwares and the program performing a fast detector response simulation. Before applying this analysis to the sgluon pair production,

it is validated on the selection of background processes showing reasonable agreement with the ATLAS one. Its application to the sgluon signal gives (to my knowledge) first limits on the sgluon mass from the 13 TeV data. The analysis shows that already using 3.2/fb of integrated luminosity the exclusion limits from Run 2 are competitive with the 8 TeV ones.