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EUROPEAN COOPERATION
IN SCIENCE & TECHNOLOGY

SHORT TERM SCIENTIFIC MISSION (STSM) SCIENTIFIC REPORT

This report is submitted for approval by the STSM applicant to the STSM coordinator

Action number: CA15108
STSM title: MicrOMEGAs studies in Unified Theories with Reduced Couplings
STSM start and end date: 20/01/2019 to 10/02/2019
Grantee name: Patellis Grigorios

PURPOSE OF THE STSM:

The purpose of this STSM was to familiarize with the MicrOMEGAs software and to understand the physics behind the code by collaborating with the host, Prof. Cedric Delaunay and with the members of the group that developed it, namely Prof. Genevieve Belanger. Furthermore, it was in the scope of the STSM to use the code in anumber of models our research group has been working on.

In particular, the plan was to work with the members of Laboratoire d'Anecy-le-Vieux de Physique Theorique (LAPTh) in order to learn the MicrOMEGAs software and use it on four models, namely the reduced Minimal Supersymmetric Standard Model (MSSM), the N=1 supersymmetric SU(5) Finite Unified Theory (FUT), the minimal N=1 supersymmetric SU(5) model and the N=1 supersymmetric SU(3)xSU(3)xSU(3) FUT.

This is a continuation of previous work with my supervisor, Prof. George Zoupanos (N.T.U.Athens, visiting professor in LAPTh), Prof. Nicholas Tracas (N.T.U.Athens), Prof. Myriam Mondragon (U.N.A.Mexico) and Prof. Sven Heinemeyer (Instituto de Fisica Teorica UAM-CSIC) on the reduction of the large number of free parameters in the abovementioned models.

DESCRIPTION OF WORK CARRIED OUT DURING THE STSMS

One of the problems in the Standard Model (SM) - and especially in the MSSM - is the large number of free parameters (over 100 in the SUSY version). This motivated the technique of "reduction of couplings", which can be achieved through the search for renormalization group invariant (RGI) relations between gauge and Yukawa couplings that hold below the Planck scale. A early but successful attempt was a reduced version of the N=1 supersymmetric SU(5) Grand Unified Theory (GUT), known best as "minimal N=1 SU(5).

Under this perspective, there is also great promise in N=1 supersymmetric FUTs. In this case, finiteness allows RGI relations that are preserved down to unification scale. This makes these models very predictive. Arguably the best examples of such FUTs are the N=1 Finite SU(5) model and the N=1 SU(3)xSU(3)xSU(3) "trinification" model.

Although the traditional way to achieve reduction of couplings is a unified theory, recent work demonstrated the existence of a RGI relation in the context of MSSM. In particular, the top and bottom Yukawa couplings are related to the colour gauge coupling. Furthermore, the search for RGI relations was extended to the soft

Funded by the Horizon 2020 Framework Programme
of the European Union

supersymmetry breaking sector. As a result, yet another such relation was discovered, namely one between soft scalar masses and the gaugino mass, the so-called "sum rule". Expressing the above massless and massive parameters in terms of the colour gauge coupling and the gaugino mass gives a reduced version of the MSSM. Thus, this reduced system can serve as boundary conditions of the RGEs of the MSSM at the unification scale, where the gauge couplings are assumed to meet. The RGEs are run down to supersymmetry scale (which initially is taken to be the geometrical average of the stop masses), and then down to the electroweak scale.

All the cases described above predict the light Higgs mass, the scale where supersymmetry breaking takes place and the supersymmetric spectrum, using 2-loop RGEs for the gauge and Yukawa couplings and 1-loop for the soft breaking parameters and the Higgs corrections. Since R-parity is preserved, the lightest sypersymmetric particle (LSP), which in our case is the lightest neutralino, is stable. Thus, it can be considered as a cold Dark Matter (CDM) candidate (a weakly interacting massive particle –a WIMP- in particular). Since the supersymmetric spectrum of all our model is rather heavy, the experimental constraint that is very important concerns the relic density.

During this STSM, we worked on using the MicrOMEGAs code to calculate the relic density in each of these models. In particular, the first week was dedicated to familiarization with MicrOMEGAs. In the following weeks, collaboration members of the group was crucial in order to implement the four models in the code and above all to understand how the parameter space of each specific model affects the relic density.

DESCRIPTION OF THE MAIN RESULTS OBTAINED

The two SU(5) models were implemented first in the MicrOMEGAs code. In the finite SU(5) case, in particular, there is a slice of the parameter space that can accommodate a relic density within experimental limits, although it severely restricts the bottom quark mass. This was a pleasant surprise, since past versions of the model had given negative results.

In the case of a version of the MSSM there is a part of the parameter space that allows for acceptable values of the relic density, while the bottom, top and lightest Higgs masses are also within experimental bounds.

Finally, in a version of SU(3)xSU(3)xSU(3) that was examined, the results were not favourable. However, a newest version of the model shows promise concerning CDM.

FUTURE COLLABORATIONS (if applicable)

To conclude, I had a very productive and pleasant collaboration with the members of LAPTh. The help of G. Belanger, in particular, had a huge impact on the completion of the project. The daily meetings with the hosts were of great help as well. Thus, future collaboration is more than probable, especially since there are variations of our research group's models still to be examined, mostly versions of the reduced MSSM and the N=1 SU(3)xSU(3)xSU(3), that include contributions from extra dimensions. Finally, it is worth noting that LAPTh provided an excellent working environment with access to all facilities.