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The TeV scale: a threshold to new physics?

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After the discovery of the Higgs boson, the SM of particle physics is theoretically complete but phenomenologically limited and it also leaves many questions unanswered. The most important open questions are the naturalness of the electroweak scale, the nature of dark matter, the origin of matter in the universe and the structure of flavor. Eagerly awaited to comply with the naturalness arguments, the LHC has revealed no unambiguous signs of new physics so far. This situation raises the question whether the TeV scale is indeed a threshold to new physics. This question was debated and scrutinized in many different ways during the scientific program. If no definitive conclusion can be reached, there is certainly no evidence yet that Hinchlife's rule applies. The diversity of the models presented and discussed by the participants is a motivation to continue the exploration of the TeV threshold.

The format of the workshop has been chosen to enhance interactions among participants, to foster discussions by raising topics during in-depth technical presentations followed by public and private debates. We deliberately limited the numbers of talks to one per day. For these talks, we also gave priority to young scientists without permanent jobs and we encouraged black-board presentations. The format and the spirit of the workshop were overwhelmingly appreciated by the participants. It resulted in in-depth discussions on a variety of active topics. Discussions during lunch and dinner time took place in smaller groups. The atmosphere was very informal with a schedule organized at a late time, taking into account the participants' suggestions. This played a great role in making the younger researchers immediately comfortable and triggered many informal discussions. The scientific program has run over 4 weeks with a total of 20 talks. The workshop was heavily oversubscribed with more than 130 applications of a very high level. Participants were chosen based on their proven expertise on the field, keeping an eye on assuring balance among various aspects. A total number of 57physicists joined (including 6 locals and 2 Ph.D. students), of which 23/34 European/out-of-European origin, 49/8 men/women.

A few models of TeV scale new physics were discussed. In addition, several new developments were presented and elaborated. One main concern was the hierarchy problem. Variations of the well-established minimal models (supersymmetry and compositeness) were discussed. In particular some explicit UV realizations of composite Higgs models were presented which rely on six dimensional constructions and establish a connection to little Higgs and twin Higgs models. Fermion compositeness scenarios

utilizing non-linearly realized supersymmetry were introduced and it was shown that they can soften the usual constraints on contact interactions and predict specific patterns of interactions exhibiting a stiff growth with energy. It was also shown that non-minimal SUSY models can still be realized at or even below the TeV scale. That reveals that the strong constraints on super-partners which are often quoted do not always apply. Furthermore, it was pointed out that the LHC, while generally thought of as discovery machine, could also indirectly reveal new physics via precision measurements of standard model processes such as Drell-Yan. In the meantime, the exploration of the Higgs sector will remain a high priority on the experimental side and require a strong involvement of the theory community. Recent alternative solutions to the hierarchy problem are the so called relaxion and clockwork models. As of today there are no phenomenologically fully realistic models. Ongoing activities on the model building side were presented by the world experts on these topics.

Two of the strongest data-driven motivations for new physics are dark matter and baryogenesis. Here some models were introduced that go beyond the usual paradigms,. New ways of probing dark matter and dark sectors experimentally were highlighted. While solid quantum field theory arguments strongly motivate the TeV scale as new physics threshold, experimental data do not point to any definite scale as of today. Therefore, the search for new physics has to continue on all frontiers, including very weakly coupled states at lower scales like axions or dark photons. New methods for probing such light states were elaborated. In particular, the new method of using isotope shift spectroscopy to constrain new interactions benefitted from the presence of local experts in atomic physics who added a refreshing and stimulating interdisciplinary aspect to the workshop.

After the consolidated results of the LHC at 13 TeV with more than 30/fb, the timing of the scientific program was very appropriate. The flavor anomalies reported by LHCb were extensively discussed. But the absence so far of clear evidence of new physics at the TeV raised many questions. Thus, a scientific program like this one with ample time for informal discussions is the perfect avenue to ponder on the current situation and foster new unconventional and creative ideas. The program was extremely successful in motivating people with very different strengths and expertise to discuss and collaborate on the challenges posed by the LHC results. Many of the most pressing and sometimes controversial questions were addressed – without the usual (negative) constrains (time, closed experimental collaborations, presence of non-specialized audience). A very positive and constructive atmosphere has characterized all the meetings.