Executive Summary of the MITP Scientific Program

"Flavour and Electroweak Symmetry Breaking"

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The hierarchy problem and the origin of flavor are two major unsolved mysteries of fundamental physics connected to deep questions such as the origin of mass, the stability of the electroweak scale, the matter-antimatter asymmetry, the origin of fermion generations, and the reason for the hierarchies observed in the fermion sector. One cannot say to really understand the SM until we understand these puzzles (both rooted in Higgs Yukawa interactions). Higgs and flavor physics provide unique opportunities to probe the structure of electroweak interactions at the quantum level, thereby offering sensitive probes of physics beyond the SM. Flavor and Higgs physics are foremost in the assessment of results within the Standard Model and search for physics beyond. Analyzing their interplay is fundamental in order to formulate a coherent framework in our ambitious quest for the ultimate laws of physics. The goal of the Institute has been to interpret the results coming from a wide range of experiments, in particular LHC and new B factories, and to formulate a coherent framework to account for them.

One of the main topics was the tentative hint of a 750 GeV di-photon resonance seen by both ATLAS and CMS in the first 13 TeV LHC data. Martin Bauer gave an introduction, discussing the physics implications of the excess in the di-photon channel and the absence of events for any other final state at this mass scale in both the 8 TeV and 13 TeV data set, in an effective field theory (EFT) framework. Based on this EFT analysis, gluon fusion was identified as the preferred production channel, with a b bar b initial state emerging as more tuned option. Other production mechanisms, in particular photon fusion was found to be in strong tension with the zero results from 8 TeV data. The talk then focused on weaknesses and strengths of the most obvious UV completions, and it was established, that both the decay loop and the production loop (in the case of gluon fusion) require new, heavy physics in order to be in agreement with data. In particular, large couplings to the top quark can explain the gluon fusion production cross section, but tree-level decays into top pairs would rule out the observed (loop-suppressed) signal in the di-photon channel. This fact calls for a more complex New Physics sector, including new particles mediating production and decay of the new resonance. It was further pointed out, that the large excess disfavors supersymmetric models, due to the relatively small scalar loop function expected from quark superpartners, compared to new fermionic quark partners, which lead to an eight times larger contribution to the gluon-fusion loop for the same couplings and masses. Bhaskar Dutta discussed possible ways to distinguish the production process of a possible resonance from associated production with jets in the final state. In particular, the different N_j distributions and shapes of the leading jet p_T for gg, $\gamma\gamma$ and WW induced production was stressed. Jonathan Rosner presented a specific embedding in a well-motivated UV theory based on a grand unified group E_6. In this model, the tentative resonance would be part of the 27-plet, that also includes the SM Higgs boson and vector-like fermions appear naturally from the mullets including the SM quarks and leptons.

Another focus of the scientific program has been the various tensions with the SM predictions in the present flavor physics data on $b \to s$ transitions, the so-called flavor anomalies. Nazila Mahmoudi discussed the tensions in the angular observables of the exclusive decay of B meson into a kaon and a lepton pair. She presented the details of a global fits to the present data and showed that the significance of the deviation from the SM prediction does heavily depend on the assumptions on power corrections in the various analyses. She presented strategies and a number of observables to clear up the source of these anomalies. Roman Zwicky presented details of the calculation of the form factors within the light-cone sum rule approach which enter the analysis of the LHCb anomalies. In particular, he derived correlations in this framework which correspond to the well-known form factor relations in the large energy limit. Finally, Svjetlana Fajfer discussed signs in the data for lepton non-universality and in several ratios of $B \to K$ or $B \to D$ meson decays and reviewed the theoretical SM predictions.

Dark matter has been approached by Felix Yu, Michael Baker and Oleg Lebedev. Felix Yu presented a general classification of simplified models that lead to dark matter coannihilation processes of the form DM + X → SM1 + SM2, where X is a coannihilation partner for the DM particle and SM1, SM2 are Standard Model fields. Michael Baker proposed a new alternative to the Weakly Interacting Massive Particle (WIMP) paradigm for dark matter. Rather than being determined by thermal freeze-out, the dark matter abundance in this scenario is set by dark matter decay, which is allowed for a limited amount of time just before the electroweak phase transition. Oleg Lebedev considered the possibility that the dark SU(N) sector couples to the visible sector through the Higgs portal.

Finally, Mikhail Shifman discussed dynamically emergent flavor in a confining theory with unbroken chiral symmetry and Ayan Paul presented the new HEPfit code for the combination of indirect and direct constraints on High Energy Physics Models.