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Editorial

Top and flavour physics in the LHC era

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Abstract We have entered a new era, where experiments are probing the top sector both directly and indirectly with an unprecedented accuracy. In the standard model, the top couplings lead to a severe fine tuning problem as well as dominating the amount of flavour violation. Thus, it is expected that in natural extensions of the standard model (SM) the top sector will include new states and consequently, both flavour conserving as well as flavour violating related observables might show deviation from SM predictions. This special issue aims to cover various aspects of top and flavour physics that are commonly considered as orthogonal. However, since very often flavour physics and top physics phenomena arise from the same fundamental sources, it is worth studying them in conjunction. Thus, this review attempts to study in reasonable depth the state of the art in experimental and theoretical research on top and flavour physics.

The top quark is special among the standard model (SM) particles. It is the most massive point like particle known to us and has the largest coupling to the Higgs field (for the first time we now have some preliminary indications that the Higgs particle may actually exist and its mass is around 125 GeV). This fact implies that the most severe fine tuning is due to the top quark. For instance, using cutoff regularization for simplicity, we find that with a cutoff of ∼10 TeV the quadratic contributions to the Higgs mass squared from the top are already hundred times bigger than its mass. This fact by itself implies that in natural extensions of the SM the top sector is generically larger and containing more degrees of freedom. These new fields are expected to induce deviations from the SM predictions in observables that probe the top sector.

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Naively, the fine tuning problem has nothing to do with flavour physics. However, if one is to take a hint from the SM structure, then within the SM the most dominant contributions to flavour violation actually arise due to the top couplings. This is a manifestation of one of the great mysteries of the SM in the form of the hierarchies among the fermion masses and mixings. Thus, generically we expect that an extended top sector would also lead to new contributions to flavour changing processes. In fact even the most minimal extension of the standard model flavour sector that goes under the name, minimal flavour violation (MFV), tends to lead to observable deformation of the subtle manner in which CP violation (CPV) proceeds within the SM.

The strength of flavour physics as a probe of physics beyond the standard model rests precisely on the fact that the breaking of the SM global flavour symmetries and the violation of the CP symmetry arise in a highly non-trivial way within the SM. It requires, for instance, the existence of three generations, the weak interaction, and misalignment (in flavour space) between the up and down Yukawa matrices must all be present at the same time or CPV will be switched off. Since, generically, in SM extensions no such condition holds then studying flavour and CP violation in a precise way may be a very efficient way to probe new physics or to constrain it. Two more points are in place:

1. Since flavour and CP violation in SM extensions need not be related to the weak interaction, the extended top sector might potentially lead to deviations from the SM predictions only in the up sector. Two heuristic examples for such a scenario are supersymmetric models where the dominant new contributions are due to gluino loop mediated by stops coupling or Kaluza–Klein (KK) gluon exchange in warped extra dimensions where the top is a composite state. In both cases flavour violation actually is associated with an extended top sector but also new

states related to the strong force, which unlike the weak force do not mix up and down quark states;

2. It is therefore extraordinarily exciting that in the last few years we have witnessed a revolution in the field of charm physics where for the first time precision information regarding D–$\bar{D}$ mixing and CP violation have become accessible to us due to the outstanding performance of the B-factories as well as the LHCb experiment.

Another aspect of top and flavour physics which is covered by this volume deals with the interplay of the high p_T and luminosity frontiers. One of the issues, which is unfortunately less appreciated by our communities, is the fact that seemingly flavour diagonal information encodes potentially invaluable flavour information. Technically, one can distinguish between two types of flavour diagonal information: The first kind is usually denoted as flavour blind or flavour universal information where the relevant parameters do not lead to breaking of the SM global flavour group (say $\mathcal{G}_{\rm SM} = U(3)_Q \times U(3)_U \times U(3)_D$ for the quark sector with Q denotes weak doublet and U, D up and down singlet, respectively). The second is related to data that by themselves distinguish between the three generations and while not being related to flavour conversion phenomena lead to breaking of the flavour group to a subgroup of it.

Measurements related to the first kind may be revolutionary (say the discovery of the axion or the gluino) but are typically not directly related to the flavour sector of the SM. However, measurement of the second kind could be revolutionary and may lead to a cascade of discoveries, since they may shed light on other puzzles of the SM, such as the celebrated flavour puzzle or at least on the way flavour information is mediated into the new physics flavour sector. Observables of the second kind could be the spectrum of the squarks and/or sleptons. For instance, discovering that the supersymmetric matter sector is anarchical would be sensational since "smuon–selectron" or "sup–sdown" non-degeneracy would reinforce that some mechanism of flavour alignment has to be at work. Similarly a discovery of a Z' or KK gluon with different couplings among the three generations would hint for the same class of microscopic dynamics, but clearly in a very different context. The last example for flavour diagonal information is the Tevatron $t\bar{t}$ forward–backward asymmetry. This charge asymmetry is a particularly interesting phenomenon since in order to generate such an asymmetry one needs to deform not only the top sector but also the $u\bar{u}$ (or $d\bar{d}$) couplings. However, if we are to interpret this anomaly as related to non-SM physics, due to constraint from dijets the couplings of whatever new physics to the light quarks and the tops cannot be universal, hence contains some amount of unblind flavour physics.

To summarize, even though at present, beside the preliminary hints for a 125 GeV Higgs, there is no solid evidence for new physics, significant progress has been made in understanding our world at the sub electroweak scale that if correctly interpreted would lead to a better understanding of our microscopic world. It is the aim of this review to make a small step in this direction in this special era, where a significant experimental progress is simultaneously made in several frontiers of particle physics.

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