Top Quark and BSM Interactions at the HL-LHC and HE-LHC

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Letter of Interest for Snowmass 2021

Abstract

In the context of the Snowmass process, we propose to study possible top quark spin correlation effects in Dark Matter (DM) production in association with a pair of top quarks or a single top quark at the HL-LHC and HE-LHC in the context of EFT and Simplified Models. The main goal is to study in detail angular correlations and distributions of the top quark which may allows us to explore and establish constraints on the DM and Standard Model (SM) interactions at the HL-LHC and HE-LHC.

One of the main goals of the high energy physics program at theoretical and experimental level is the study of the top quark. The study of top quark properties and dynamics provides a very unique and interesting window to the SM itself and to the study of physics BSM. Due to its large mass, which is at the EWSB scale, it plays a very important role in the study of the mechanism of EWSB and also in searching for signals of new physics connected to EWSB, which may be found through precision studies of top quark observables. The top quark has a very short lifetime, smaller than its hadronization time, which means that it decays before it hadronizes or flips its spin. This provides a very interesting testing ground for perturbative QCD. In addition, information about spin correlation and polarization coming from the top-pair and single top production processes are conserved during their decay and can be studied in angular distributions of top decay products. This provides an interesting way of searching for deviations from SM expectations [1, 2].

A very interesting and important challenge not only in particle physics but also in cosmology is the search for DM particles. Although we have only observed gravitational effects of DM and we do not know for sure if DM particles interact strongly enough with ordinary matter to be produced at a collider, they are at the center of the LHC and future colliders explorations because of their observational potentiality. DM particles must be invisible to any particle detector and would emerge as missing transverse momentum. Any deviations in the missing transverse momentum may be measured and could be used to constrain DM models. If DM particles couple to heavy quarks, such as the top quark, then very interesting and challenging production channels at the LHC and future colliders can be studied, such as top quark pair production and single top quark production in association with missing transverse momentum [3, 4, 5, 6].

The HL-LHC and HE-LHC will allow us to study the top quark properties such as its mass, couplings and its importance in the determination of the stability of the SM. The analysis of the data collected

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will permit to increase and improve the reach and sensitivity of searches for SM and BSM top quark physics and to research in detail the interaction between the top quark and DM, this represents the important challenge of improving theoretical calculations and predictions in order to understand the regions of the parameter space observed experimentally and also those regions unexplored yet. We will explore the physics at the electroweak energy scale by performing a systematic analysis in the search of deviations from the SM predictions in the interaction between the top quark and DM by studying different observables sensitive to new physics, such as spin-spin correlating observables which could be observed and measured at present [7] and future colliders.

References

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