Top-quark electroweak interactions at high energy

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Modified interactions in the electroweak sector may lead to scattering amplitudes that grow with energy compared to their Standard Model (SM) counterparts. We present a detailed study of all $2 \to 2$ *scattering amplitudes involving at least one top quark and a pair of EW bosons. We analyse the high energy behaviour of the amplitudes using the Standard Model Effective Field Theory (SMEFT) to parametrise the departures from the SM. We also discuss the embeddings of the scattering amplitudes into physical collider processes, presenting the parametric SMEFT sensitivity to relevant top quark operators and paying special attention to the extent to which the high energy behaviour of the* $2 \to 2$ *amplitude is retained in the actual processes accessible at colliders.*

Introduction

One of the most fascinating aspects of spontaneously broken, non-Abelian gauge-Yukawa theories, such as the Standard Model (SM), is how the high-energy behaviour of scattering amplitudes seems to magically arise from a set of intricate cancellations between contributions that would otherwise display unacceptable energy growth. A natural strategy to observe new physics is to look for deviations from the precise structure of the SM predictions that may lead to the aforementioned anomalous energy growths in the amplitudes. Such non-unitary behaviour in top quark scattering processes could be observed at high energy collider experiments and would indicate a limited range of validity of the SM description, implying the presence of new physics at higher scales. Our study aims to provide an overview of the potential to probe high energy top-quark scattering processes at colliders.

SMEFT: a framework to parametrise new physics

The Standard Model Effective Field Theory (SMEFT) is an appropriate framework to study effects of heavy states in the low energy regime. It describes deviations from SM interactions and the associated energy growth of scattering amplitudes with a minimal set of high-scale assumptions. This picture is rooted in a gauge invariant description of modified interactions through higher dimensional operators that preserve the underlying symmetries of the SM, and offers an additional advantage of being mappable to a large class of theories Beyond the SM (BSM) [1, 2]. The higher dimensional operators lead to modified SM vertices as well as the appearance of new Lorentz structures, both of which can introduce energy growth in scattering processes. Many LHC searches for deviations from SM interactions are therefore framed in the context of the SMEFT.

The building blocks: $2 \to 2$ scatterings

With the general framework for modified interactions in the EW sector in hand, we proceed to analyse the scattering amplitudes of a generic $2 \to 2$ process $fB \to f'B'$, where f,f' = b,t and B,B' = h,W,(Z/γ) and at least one of the 2 fermions is a top quark. We identify and compute the helicity amplitudes for 10 such scatterings.

	Single-top	Two-top ($t\bar{t}$)
w/o Higgs	$bW \to t\,(Z/\gamma)$	$tW \to tW$ $t\,(Z/\gamma) \to t\,(Z/\gamma)$
w/ Higgs	$bW \to th$	$t\,(Z/\gamma) \to th$ $th \to th$

Table 1: The ten $2 \to 2$ scattering amplitudes whose high-energy behaviour we study in this paper.

Embedding in collider processes

Figure 1 schematically shows how such scattering amplitudes, a single-top one in this case, provide the building blocks for EW collider processes in order to study the high-energy behaviour of the EW top sector.

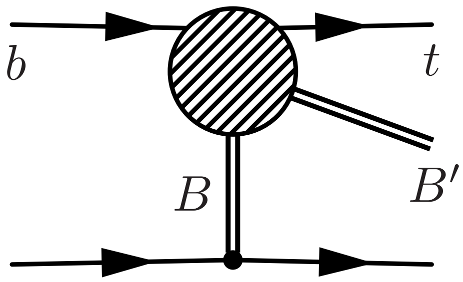

Figure 1: Schematic Feynman diagram for the embedding of an EW top scattering amplitude into a physical, single-top process at a hadron collider. Here f and f' must be a b- and t-quark respectively, while B and B' can be several combinations of Z, γ, W and h.

To perform our study we consider the High-Luminosity LHC phase as well as a future hadron collider at 27 TeV centre of mass energy and a high energy e^+e^- collider operating at 380 GeV, 1.5 TeV and 3 TeV. All cross section computations are performed with MadGraph5_aMC@NLO [3, 4].

References

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