Exploring polarized vector bosons to measure the Higgs boson properties in diboson channels

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Abstract

We propose to exploit longitudinally polarized vector bosons (V_LV_L, $V = W, Z$) to measure the Higgs boson couplings at high-energy scale, complementing to the on-shell Higgs measurements. The V_LV_L final states in the high mass tail also provides a sensitive probe for new physics that could modify Higgs couplings.

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I. PROPOSAL

The precise measurement of the Higgs boson couplings to other Standard Model (SM) particles is one of the main motivations for the planned high-luminosity upgrade of the LHC (HL-LHC). These measurements are key to understand the nature of the electroweak symmetry breaking; at the same time they offer a window into heavy dynamics Beyond the Standard Model (BSM). With run-2 LHC data, the measured Higgs boson production cross sections receive about equal size of statistical and systematic uncertainties [1]. The measurements of Higgs couplings, at low energy scale, will soon be limited by systematic uncertainties. On the other hand, high-energy probes [2, 3] are based on the observation that leading-order higher-dimensional operators within an Effective Field Theory (EFT) formalism can produce energy-growing corrections in some specific processes. By measuring such processes at high enough energy, new physics effects can become large enough to overcome systematic uncertainties.

These high-energy processes probe off-shell Higgs couplings, and usually involve longitudinally polarized vector bosons in the final states, rather than decay products from an on-shell Higgs resonance. That is the so-called "Higgs without Higgs" as proposed in [3]. For instance, the process $pp \to jt + V_L V_L'$ could probe the top Yukawa coupling κ_t, and the process $pp \to W_L^+ W_L^-, Z_L Z_L$ and $pp \to jj + V_L V_L'$ could probe the coupling of Higgs boson to gluons, κ_g, and the coupling of the Higgs boson to the vector bosons, κ_V, respectively.

We propose to exploit longitudinally polarized vector bosons $V_L V_L (V = W, Z)$ to probe κ_g and κ_t, and also the vector boson scattering (VBS) process, $V_L V_L jj$, to probe κ_V. Only fully leptonic decays of vector bosons, $WW \to \ell\nu\ell\nu$ and $ZZ \to 4\ell$, will be considered to reduce the background processes. Machine learning techniques will be utilized to separate the longitudinally polarized vector bosons from transversely polarized vector bosons. It is shown in [3] that the expected sensitivities to Higgs boson couplings from these high-energy processes could be comparable to the ones obtained from on-shell Higgs measurements. We propose to combine both on-shell and off-shell measurements to improve the Higgs coupling measurements further. New phenomena appearing at energy scales higher than those accessible by the experiment will be constrained, within the picture of the EFT, simultaneously by the on shell Higgs kinematic distributions probing κ_V and κ_t. This complementarity from both the on-shell and off shell region of the Higgs is expected to further improve the sensitivity on EFT coupling parameters when measured simultaneously by canceling out the systematics that are (anti) correlated between the two processes.

This novel technique is expected to narrow down the corner of the phase-spaces where new physics might exist.

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[1] ATLAS Collaboration, (2020), ATLAS-CONF-2020-027.

[2] R. Franceschini, G. Panico, A. Pomarol, F. Riva, and A. Wulzer, JHEP **02**, 111 (2018), arXiv:1712.01310 [hep-ph].

[3] B. Henning, D. Lombardo, M. Riembau, and F. Riva, Phys. Rev. Lett. **123**, 181801 (2019),

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