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Tree-level Interference in VBF production of Vh and its sensitivity on λ_{WZ}

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Abstract

Vector boson scattering is a well known probe of electroweak symmetry breaking. We propose to study another related process of two electroweak vector bosons scattering into a vector boson and a Higgs boson ($VV \to Vh, V = W, Z$). This process exhibits tree level interference and grows with energy if the Higgs couplings to electroweak bosons deviate from the SM values. Therefore, this process is particularly sensitive to the relative sign of the coupling between Higgs and the W and Z, λ_{WZ}. It is found that a high energy lepton collider is well suited to study this process through VBF.

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In the Standard Model (SM), the Higgs boson is one of the most important ingredients. The experimental discovery of the Higgs is a milestone of SM, but is insufficient to probe the underlying physics; detailed measurements of its couplings are necessary.

Measurements of the Higgs couplings to W, Z bosons are of great interest, as they are prescribed by the unitarity of the longitudinal gauge boson scattering at high energy. The most straightforward method to measure these couplings are through $h \to ZZ^*$ and $h \to WW^*$ decays. However, these measurements are only sensitive to the magnitude of the couplings, but have almost no discriminating power between positive and negative values of $\lambda_{WZ} = \frac{\kappa_W}{\kappa_Z}$ where $\kappa_{W,Z}$ are the coupling modifiers. In order to be sensitive to the sign of λ_{WZ}, interference effects should be measured as in $e^+e^- \to W^+W^-h$ [1] and in $h \to 4\ell$ [2] processes.

Here, we propose a new process utilizing the tree-level interference effects between κ_W and κ_Z with VBF at a high energy lepton collider:

$$\ell^+ \ell^- \to \nu_\ell \, \bar{\nu}_\ell \, Z \, h$$
$$\ell^+ \ell^- \to \nu_\ell \, \ell \, W \, h$$

These processes grow with the center of mass energy of the lepton collider, with CLIC [3, 4] or future muon collider [5] being a particularly good machine for the studies. The VBF hard process ($VV \to Vh$) exhibits cancellation between s and t channels. The cancellation highly depends on the value of λ_{WZ}. In the case of $W_L W_L \to Z_L h$, the total matrix element reads:

$$\mathcal{M}(W_L^+ W_L^- \to Z_L h) = \frac{g^2 \kappa_Z \cos\theta}{4m_W^2}(1 - \lambda_{WZ})s + \mathcal{O}(s^0)$$

where g is weak gauge coupling, θ is the scattering angle. We see that if the λ_{WZ} deviates from its SM value ($\lambda_{WZ} = 1$), the matrix elements will grow with the center of mass energy. Utilizing this observation, the proposed processes can be used to put constraints on λ_{WZ}, especially to discriminate between negative and positive values.

A detailed phenomenology study is performed for CLIC with both 1.5 TeV and 3.0 TeV [6]. By only counting the total event rates, we could get the luminosity needed to discriminate different λ_{WZ} values against SM one. When incorporating the differential distribution, we can further put stringent limits on λ_{WZ}. The same analysis can also be performed for muon collider at which the center mass energy will be much higher and more suitable for VBF process studies [7].

References

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