Probing anomalous HVV couplings using Higgs production in electron-proton collisions

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Objectives

We probe anomalous HZZ coupling through single Higgs boson production at the Large Hadron-electron collider with 60 GeV (7 TeV) of electron (proton) energy. The sensitivity of CP-even and CP-odd anomalous couplings are assessed through azimuthal angle difference between scattered electron and forward jets along with cross section as a function of luminosity. A comparative studies for HWW anomalous couplings are also performed.

Introduction

Discovery of 125 GeV Higgs boson (H) at ATLAS and CMS experiments completes particle spectrum of Standard Model (SM). Experimental results for Higgs couplings to other SM particles are in good agreement with SM predictions. Despite of this success, SM has several shortcomings which suggest to look for signals beyond SM. Symmetry breaking mechanism of scalar potential in the SM predicts couplings of H with electroweak gauge bosons $W^{\pm}$ and Z. We may find deviations in these couplings if there exists new physics beyond the standard model. Using Effective Field Theory (EFT) approach, a model independent framework, we can parametrize deviations from the SM. In this work we consider the effect of dimension-six operators which lead to modification in the HVV coupling.

Formalism

e^-p collider is more advantageous with respect to e^+e^- and pp colliders because it provides (1) a clean environment with suppressed background (2) sufficiently large cross section for Higgs production. In an ep collider, HVV coupling can be probed through: (1) neutral current process, $e^-p \to e^-Hj$ and (2) charged current process, $e^-p \to \nu_e Hj$,

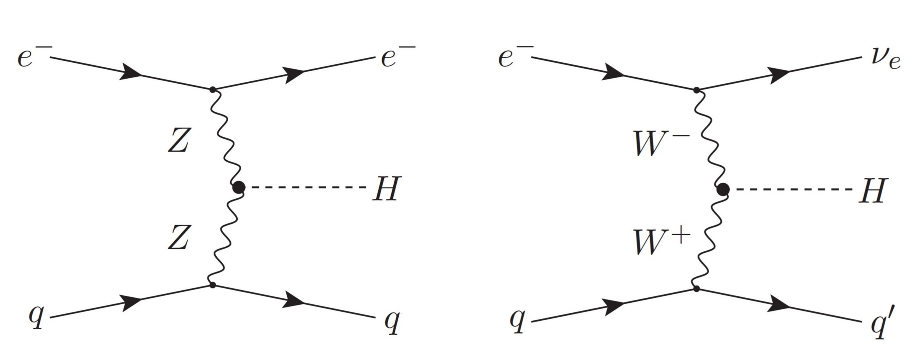

Figure 1. Neutral (left) and charge (right) current process at e^-p collider

Effective Lagrangian for HVV coupling in broken phase, obtained from dimension six operators is,

$$\mathcal{L}_{HVV} = -g\left[\frac{\lambda_{1e}^V}{2m_V}V^{\mu\nu}V^{\dagger}_{\mu\nu}H + \frac{\lambda_{2e}^V}{m_V}(V^{\nu}\partial^{\mu}V^{\dagger}_{\mu\nu}H + \mathrm{h.c}) + \frac{\lambda_{o}^V}{2m_V}V^{\mu\nu}\tilde{V}^{\dagger}_{\mu\nu}H\right] \quad (1)$$

Where $V = W^{\pm}, Z$. λ_{1e}^V and λ_{2e}^V are CP-even and λ_o^V is CP-odd couplings of HVV vertex.

Form of effective vertex is

$$\Gamma_{HVV} = g m_V\left[\left\{1+\frac{\lambda_{1e}^V}{m_V^2}p_2\cdot p_3 + \frac{\lambda_{2e}^V}{m_V^2}(p_2^2+p_3^2)\right\}\eta^{\mu_2\mu_3} - \frac{\lambda_{1e}^V}{m_V^2}p_2^{\mu_3}p_3^{\mu_2} - \frac{\lambda_{2e}^V}{m_V^2}(p_2^{\mu_2}p_2^{\mu_3} + p_3^{\mu_2}p_3^{\mu_3}) - \mathrm{i}\frac{\lambda_o^V}{m_V^2}\epsilon^{\mu_2\mu_3\mu\nu}p_{2\mu}p_{3\nu}\right] \quad (2)$$

Momenta and indices correspond to vector bosons appearing in same order in index of vertex Γ.

Analysis and results

Observable: $\Delta\phi$

$\Delta\phi$ is difference of azimuthal angles between two final state particles. It has been found useful in distinguishing CP-even coupling with CP-odd coupling in charged current process [1]

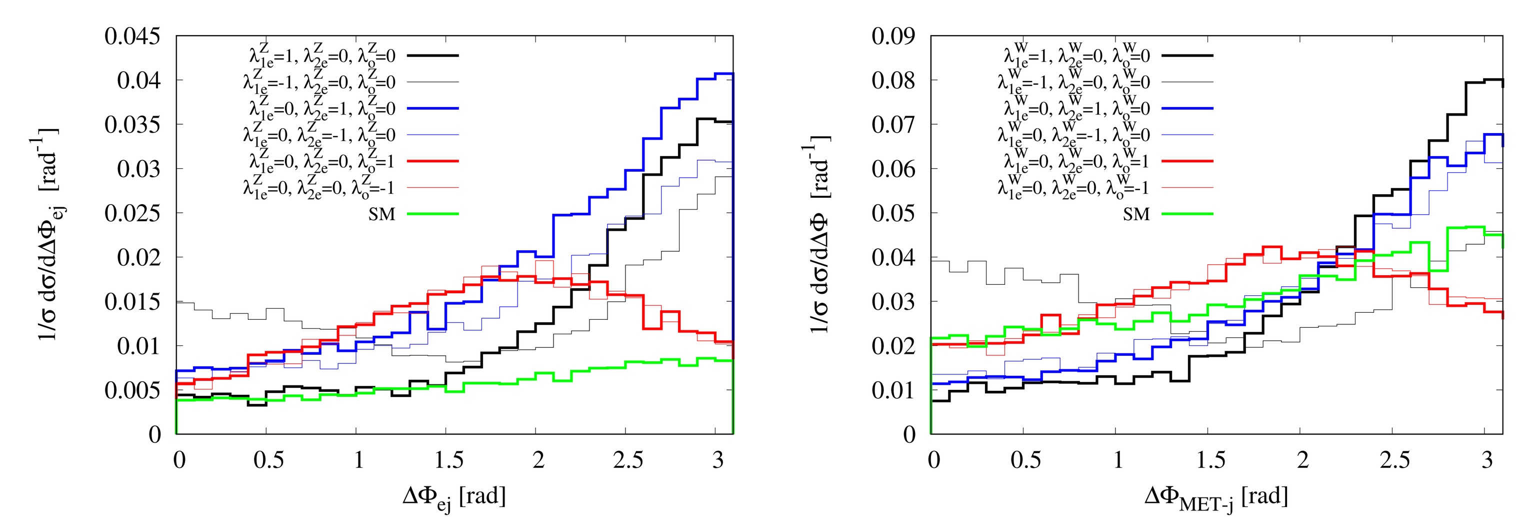

Figure 2. $\Delta\phi$ distribution for e^- and jet of neutral current process (left) and missing energy and jet of charged current process (right).

Breakground and cuts

Contribution to the backgrounds for neutral current process come from $e^-p \to e^-b\bar{b}j, e^-jjj, e^-cjj, e^-ccj, e^-ccc$

Applied cuts are

(i) 120 GeV $< M(b,\bar{b}) <$ 130 GeV

(ii) $p_T(e^-) >$ 20 GeV, $p_T(j) >$ 30 GeV, $p_T(b) >$ 20 GeV

(iii) $-2 < \eta(e^-) < 1$, $-5 < \eta(j) < -2$, $-3 < \eta(b) < 0.5$

Contribution to the backgrounds for charge current process come from $e^-p \to \nu_e b\bar{b}j, \nu_e jjj, \nu_e cjj, \nu_e ccj, \nu_e ccc$

Applied cuts are 120 GeV $< M(b,\bar{b}) <$ 130 GeV, $E_T >$ 30 GeV, $P_T(j) >$ 20 GeV and $P_T(b) >$ 10 GeV

Results

In order to estimate constraints on new couplings, we used χ^2 analysis (assuming standard model hypothesis) for $\Delta\phi$ distribution by dividing it into two equal half bins. Based on this analysis, we present results in Fig. 3, for the integrated luminosity required to measure limit on new couplings.

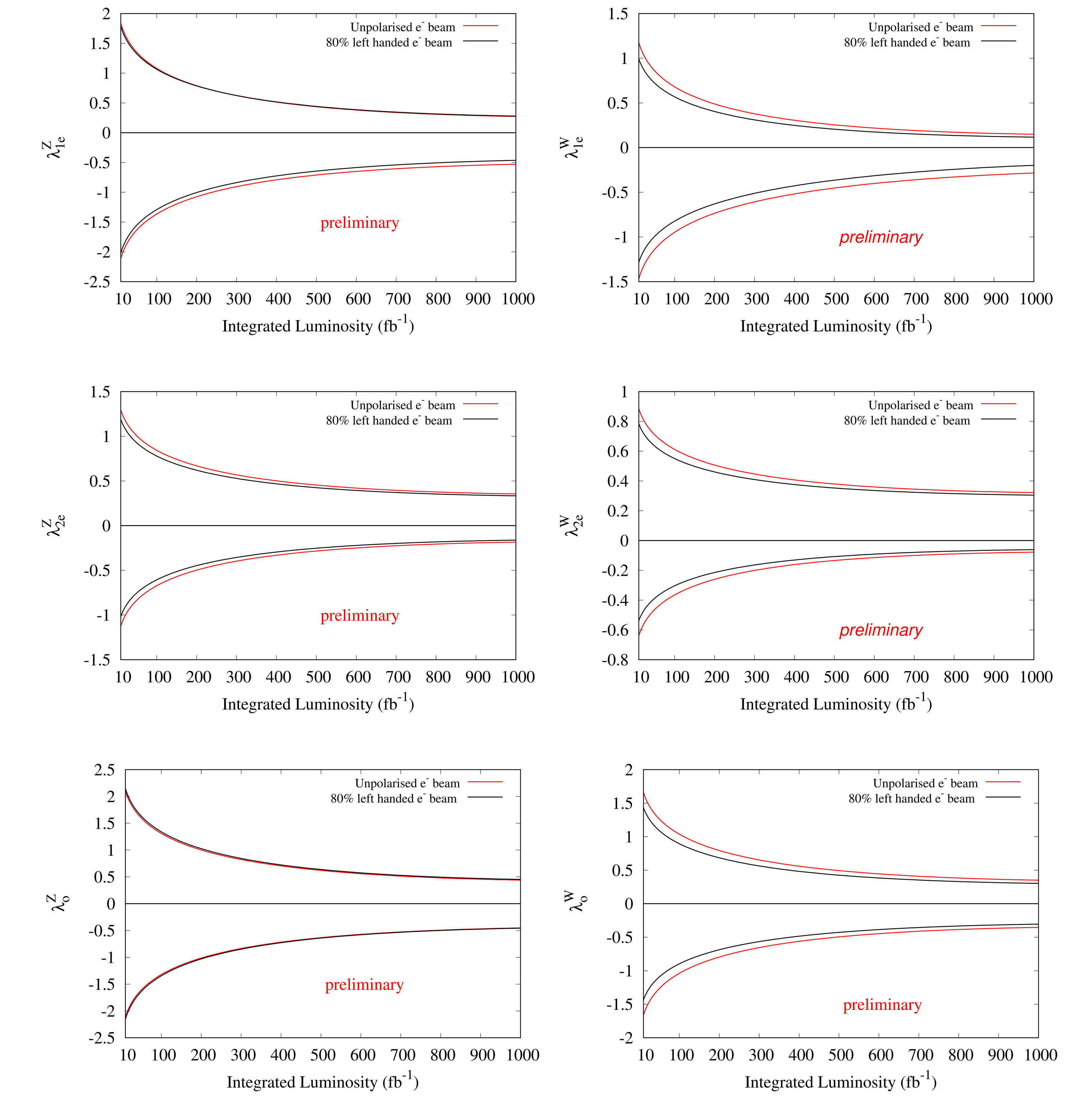

Figure 3. Luminosity as a function of anomalous HZZ (left) and HWW (right) couplings

Conclusion

Based on $\Delta\phi$ distribution, we give a preliminary idea of ssensitivities on BSM couplings with respect to luminosity. Our analysis suggests that the couplings can be constrained in the range 0.2-0.5 at 10^3 fb^{-1} luminosity. We also show that constraints are improved by considering 80% left polarized e^- beam. While λ_{2e} is constrained most, λ_o is constrained least for both HZZ and HWW vertices.

References

[1] S. S. Biswal, R. M. Godbole, B. Mellado and S. Raychaudhuri, Phys. Rev. Lett. **109**, 261801 (2012)