Comparison of the Sensitivities to Dimension-eight Operators for Anomalous Neutral Triple Gauge Couplings Through pp→$\nu\nu\gamma$ Process at HL/HE-LHC and FCC-hh

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ABSTRACT

We study the effects of dimension-eight operators giving rise to anomalous neutral triple gauge boson interactions in Zγγ and ZγZ vertices through the $\nu\nu\gamma$ production at HL/HE-LHC and FCC-hh. The analysis is performed using transverse momentum of photon in the final state including a realistic detector effects for the future hadron colliders. The sensitivity to CP-conserving $C_{\tilde{B}W}$ and CP-violating C_{BB} couplings are obtained at 95% C.L. The results are compared to the current experimental limits from ATLAS results.

THEORETICAL FRAMEWORK

The Lagrangian in the framework of an effective field theory for neutral Triple Gauge Couplings (nTGC) imposing local $U(1)_{EM}$ and Lorentz symmetry can be written as [1]

$$\mathcal{L}^{nTGC} = \mathcal{L}^{SM} + \sum_i \frac{C_i}{\Lambda^4}(\mathcal{O}_i + \mathcal{O}_i^\dagger)$$

where i run over the label of the four operators which are expressed as

$$\mathcal{O}_{BW} = iH^\dagger B_{\mu\nu} W^{\mu\rho}\{D_\rho, D^\nu\}H$$
$$\mathcal{O}_{WW} = iH^\dagger W_{\mu\nu} W^{\mu\rho}\{D_\rho, D^\nu\}H$$
$$\mathcal{O}_{BB} = iH^\dagger B_{\mu\nu} B^{\mu\rho}\{D_\rho, D^\nu\}H$$
$$\mathcal{O}_{\tilde{B}W} = iH^\dagger \tilde{B}_{\mu\nu} W^{\mu\rho}\{D_\rho, D^\nu\}H$$

where

$$W_{\mu\nu} = \sigma^I(\partial_\mu W_\nu^I - \partial_\nu W_\mu^I + g\epsilon_{IJK} W_\mu^J W_\nu^K)$$
$$B_{\mu\nu} = (\partial_\mu B_\nu - \partial_\nu B_\mu)$$
$$\langle \sigma^I \sigma^J \rangle = \delta^{IJ}/2 \qquad D_\mu \equiv \partial_\mu - i\frac{g'}{2} B_\mu Y - i g_w W_\mu^i \sigma^i$$

The coefficients of these four dimension-eight operators describing anomalous Neutral Triple Gauge Couplings (aNTGC) are CP-conserving $C_{\tilde{B}W}$ and CP-violating C_{BB} , C_{BW} , C_{WW} . They are related to dimension-six operators aNTGC as described in Ref. [1].

CROSS SECTIONS

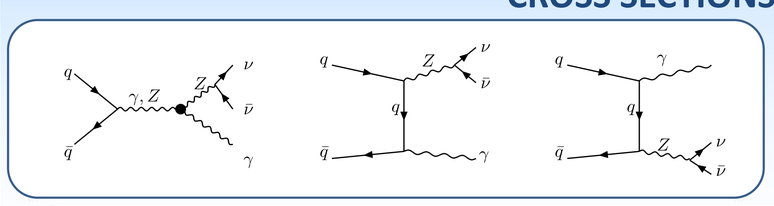


Figure 1 : Feynman diagrams for pp → $\nu\nu\gamma$ process contributing in the SM and anomalous ZZγ, Zγγ vertices.

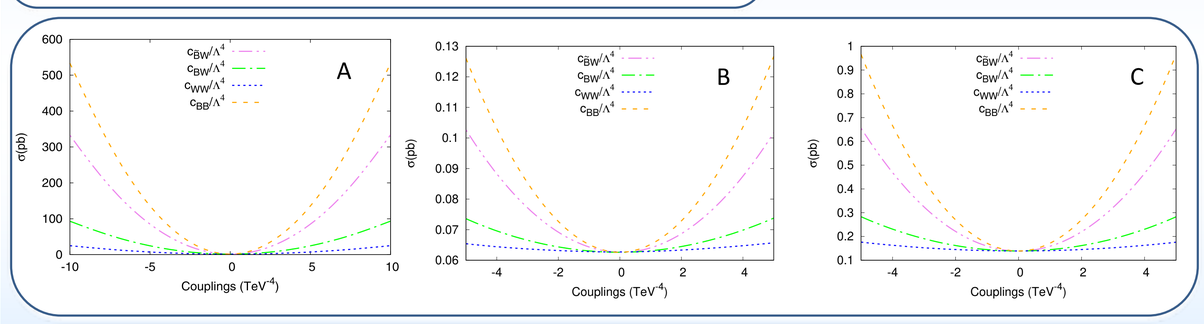
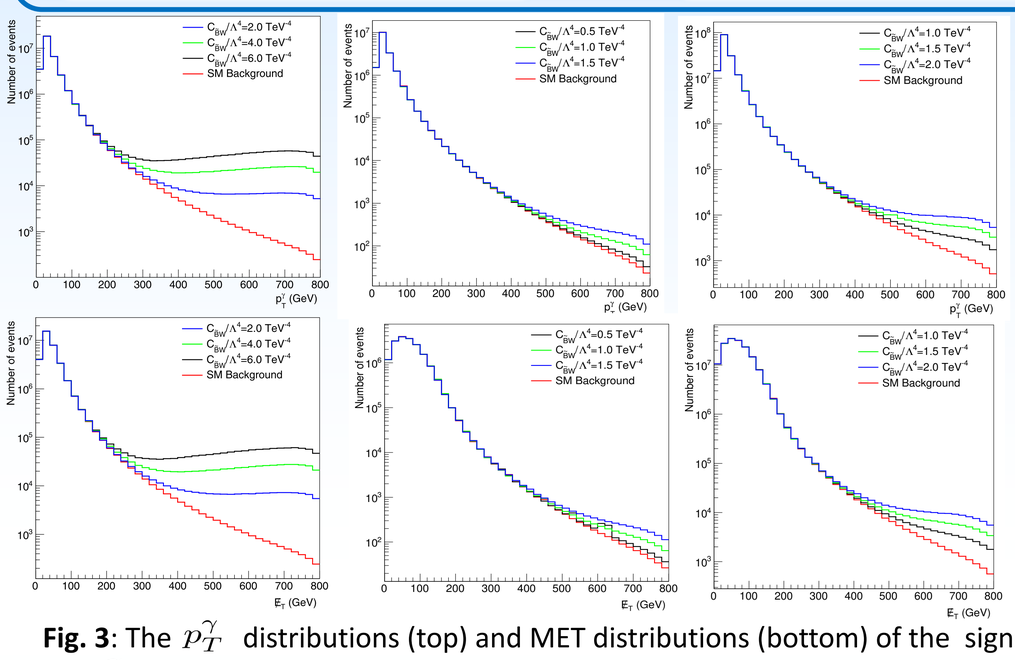


Fig.2: The signal cross sections of $pp \to \nu\bar{\nu}\gamma$ depending on dimension-8 couplings at FCC-hh (A), HL-LHC (B) and HE-LHC © with $p_T^\gamma > 100$ GeV.

ANALYSIS AND SIMULATION DETAILS

Event generation by **MadGraph5_aMC@NLO [2]** signal and all background process → Parton Shower and Hadronization by **PYTHIA 8 [3]** → Fast Simulation by **Delphes 3.4.1 [4]** with FCC-hh.tcl and CMS_phaseII_140PU_conf4.tcl → All events are analyzed by **ExRootAnalysis [5]** utility



Pre-selection

- MET
- $N_\gamma > 0$
- $|\eta^\gamma| < 2.5$
- $p_T^\gamma > 10$ GeV

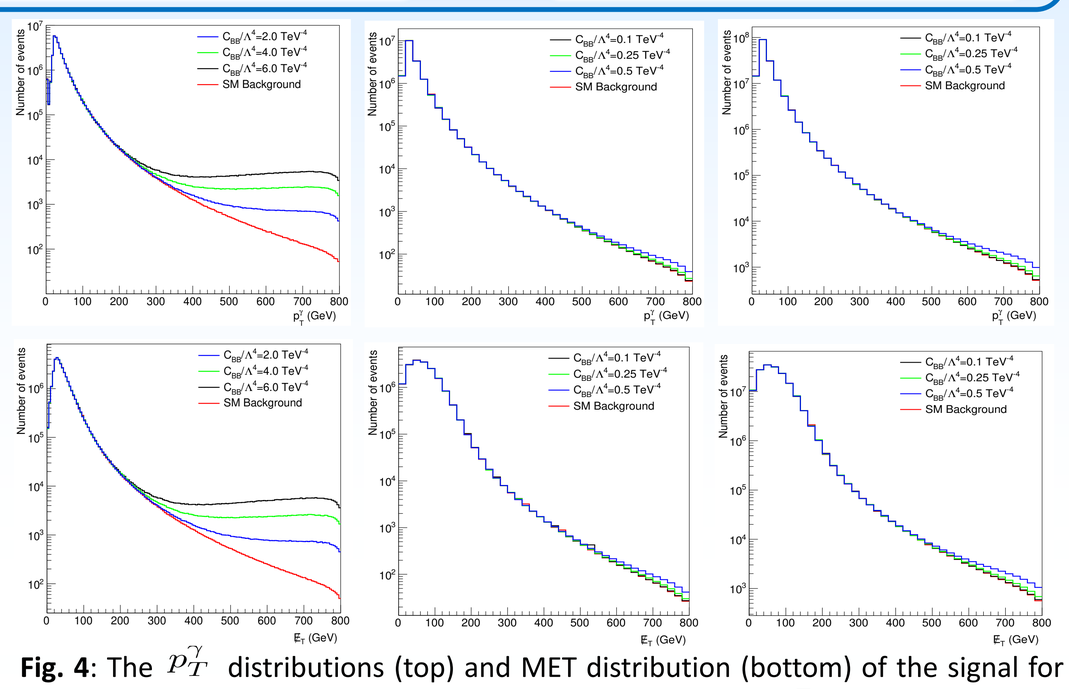


Fig. 3: The p_T^γ distributions (top) and MET distributions (bottom) of the signal for $C_{\tilde{B}W}$ coupling and corresponding SM background of $pp \to \nu\bar{\nu}\gamma$ process. Columns correspond to FCC-hh, HL-LHC and HE-LHC, respectively.

Fig. 4: The p_T^γ distributions (top) and MET distribution (bottom) of the signal for C_{BB} coupling and corresponding SM background of $pp \to \nu\bar{\nu}\gamma$ process. Columns correspond to FCC-hh, HL-LHC and HE-LHC, respectively.

We use the p_T^γ and MET distributions to obtain χ^2 values with and without a systematic error

$$\chi^2 = \sum_i^{n_{bins}} \left(\frac{N_i^{NP} - N_i^B}{N_i^B \Delta_i} \right)^2$$

$$\Delta_i = \sqrt{\delta_{sys}^2 + \frac{1}{N_i^B}}$$

CUTS used:

$p_T^\gamma > 400$ GeV & MET > 400 GeV

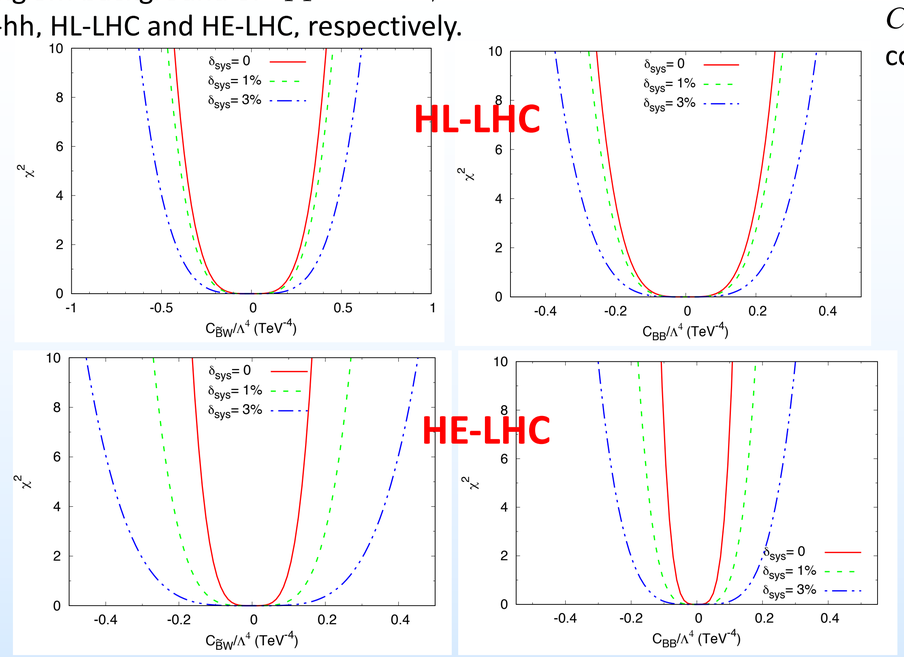


Fig. 5: Obtained χ^2 as a function of $C_{\tilde{B}W}$ (left column) and C_{BB} (right column) couplings for HL-LHC (top) and HE-LHC (bottom).

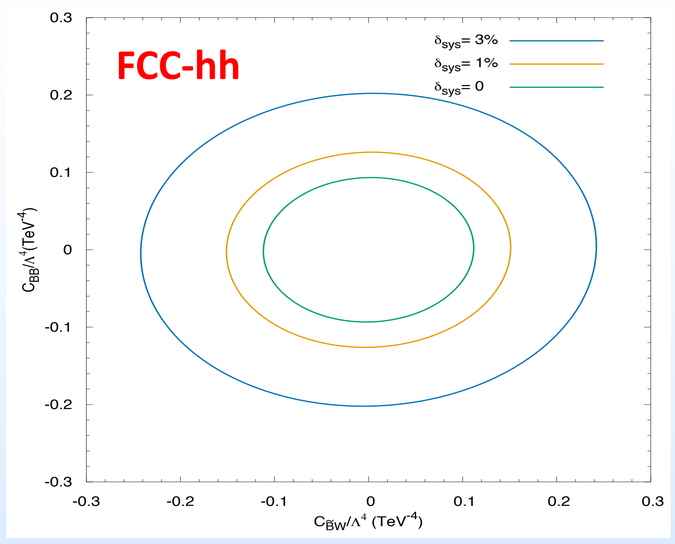
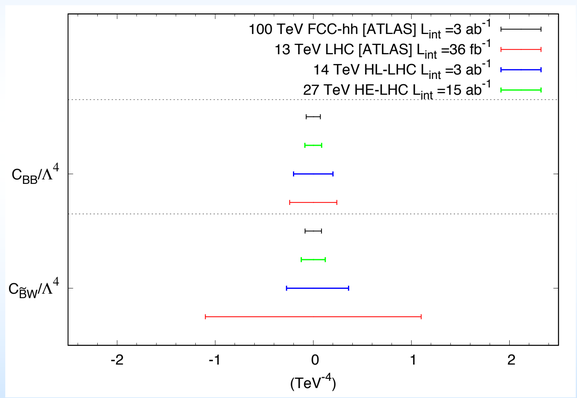


Fig. 6: Two dimensional 95% C.L. Intervals in a plane of $C_{\tilde{B}W}$ and C_{BB} couplings with taking 0%, 1% and 3% systematic errors at L_{int} = 3 ab^{-1} [7].

RESULTS AND DISCUSSION

The current limits on dimension-8 aNTG couplings $C_{\tilde{B}W}$ and C_{BB} from ATLAS collaboration (Ref.[6]) compared with our expected limits at 95% C.L. for HL-LHC with L_{int} = 3 ab^{-1} , HE-LHC with L_{int} = 15 ab^{-1} and FCC-hh with L_{int} = 3 ab^{-1} .



Couplings (TeV^{-4})	ATLAS	HL-LHC	HE-LHC	FCC-hh
$C_{\tilde{B}W}/\Lambda^4$	$-1.1, +1.1$	$-0.27, +0.36$	$-0.12, +0.12$	$-0.084, +0.084$
C_{BB}/Λ^4	$-0.24, +0.24$	$-0.20, +0.20$	$-0.085, +0.085$	$-0.072, 0.072$

FCC-hh provides one order of magnitude better limits than latest LHC results (Ref.[6]) on dimension-8 aNTG couplings; $C_{\tilde{B}W}$ and C_{BB} .

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