Corrections to the nTGC limits at EFT $O(\Lambda^{-8})$ expansion due to the possible background BSM contributions in $Z(\nu\bar{\nu})\gamma$ production

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ICPPA-2022, 30.11.2022

nTGC — neutral triple gauge couplings
EFT — effective field theory
BSM — beyond the Standard Model

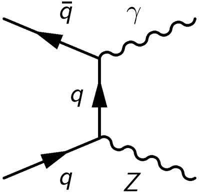
Introduction

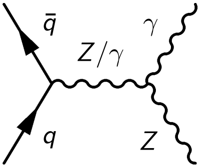
Anonalous couplings are manifestations of new physics.

EFT parameterization of the Lagrangian:

$$\mathcal{L} = \mathcal{L}_{\mathrm{SM}} + \mathcal{L}_5 + \mathcal{L}_6 + \mathcal{L}_7 + \mathcal{L}_8 + \ldots = \mathcal{L}_{\mathrm{SM}} + \sum_i \sum_n \frac{C_{i,n}}{\Lambda^n} \mathcal{O}_i^{n+4}.$$

Inclusive $Z(\nu\bar{\nu})\gamma$ is the process sensitive to nTGC.





EFT framework

Basis of operators for studying nTGC:

$$\mathcal{O}_{\tilde{B}W} = i\Phi^\dagger \tilde{B}_{\mu\nu} \hat{W}^{\mu\rho} \{D_\rho, D^\nu\} \Phi$$ arXiv: 1308.6323

$$\mathcal{O}_{BW} = i\Phi^\dagger B_{\mu\nu} \hat{W}^{\mu\rho} \{D_\rho, D^\nu\} \Phi$$

$$\mathcal{O}_{WW} = i\Phi^\dagger \hat{W}_{\mu\nu} \hat{W}^{\mu\rho} \{D_\rho, D^\nu\} \Phi$$

$$\mathcal{O}_{BB} = i\Phi^\dagger B_{\mu\nu} B^{\mu\rho} \{D_\rho, D^\nu\} \Phi$$

$$\mathcal{O}_{G\pm} = \frac{2}{g}\tilde{B}_{\mu\nu} \mathrm{Tr}\left[\hat{W}^{\mu\rho}\left(D_\rho D_\lambda \hat{W}^{\nu\lambda} \pm D^\nu D^\lambda \hat{W}_{\lambda\rho}\right)\right]$$ arXiv: 2206.11676

Amplitude in case of 1D parameterization:

$$|\mathcal{A}|^2 = \left|\mathcal{A}_{\mathrm{SM}} + \frac{C}{\Lambda^4}\mathcal{A}_{\mathrm{BSM}}\right|^2 = |\mathcal{A}_{\mathrm{SM}}|^2 + \frac{C}{\Lambda^4} 2\mathrm{Re}\left(\mathcal{A}_{\mathrm{SM}}^\dagger \mathcal{A}_{\mathrm{BSM}}\right) + \frac{C^2}{\Lambda^8}|\mathcal{A}_{\mathrm{BSM}}|^2 - O(\Lambda^{-8}) \text{ expansion}$$

Corrections from background BSM contributions

Main idea: The classical method for setting the limits is based on considering the BSM contributions only in the main (signal) process. However, in the general case, one or several background processes can also have a BSM part and contribute to the BSM yields. Changes in the BSM yields lead to corrections in the derived limits. arXiv: 2209.07906

Operator	ZZZ, $ZZ\gamma$, $Z\gamma\gamma$	WWZ	$WW\gamma$
$\mathcal{O}_{\tilde{B}W}$	∘	∘	∘
$\mathcal{O}_{BW}$	∘	∘	∘
$\mathcal{O}_{WW}$	∘	∘	
$\mathcal{O}_{BB}$	∘		
$\mathcal{O}_{G\pm}$	∘	∘	∘

These operators affect also charged TGC.

In the case of current experimental sensitivity corrections lead to the tightening of the limits.

Regions and event selection

Event selection is based on the ATLAS analysis of $Z(\nu\bar{\nu})\gamma$ production with partial Run II dataset (arXiv: 1810.04995).

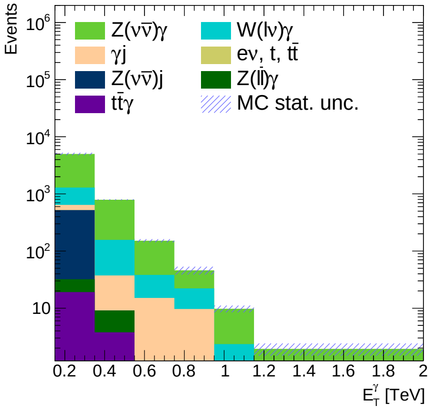
$Z\gamma$ region: $N_\ell = 0$
$W\gamma$ region: $N_\ell = 1$

Integrated luminosity of 139 fb^{-1} is used for calculations.

Only expected limits are set, since this study does not use experimental data.

Systematic uncertainty of 10% is used. It is conservative estimation of total systematic from ATLAS study.

Distribution in $Z\gamma$ region:



E_T^γ in sensitive variable. Its distribution is used for creating the likelihood.

Corrections in $Z\gamma$ region

All limits are given in [TeV^{-4}].

c_{G+}/Λ^4 and c_{G-}/Λ^4 limits are multiplied by factor 10^3.

Coef.	Class. lim.	Corr. lim. (lead.)	Improvement (lead.)	Corr. lim. (all)
$C_{\tilde{B}W}/\Lambda^4$	[-0.194; 0.195]	[-0.141; 0.143]	27.1%	[-0.141; 0.141]
C_{BW}/Λ^4	[-0.357; 0.354]	[-0.270; 0.269]	24.3%	[-0.268; 0.268]
C_{BB}/Λ^4	[-0.154; 0.154]	[-0.154; 0.153]	0.3%	[-0.153; 0.153]
C_{WW}/Λ^4	[-0.392; 0.393]	[-0.367; 0.367]	6.5%	[-0.366; 0.367]
c_{G+}/Λ^4	[-0.805; 0.801]	[-0.503; 0.503]	37.5%	[-0.503; 0.503]
c_{G-}/Λ^4	[-129; 129]	[-9.19; 9.22]	93.0%	[-9.19; 9.21]

Corrections from backgrounds except $W(\ell\nu)\gamma$ are negligible.

Correction from $W(\ell\nu)\gamma$ background is negligible for C_{BB}/Λ^4 limits and is significant for other coefficients.

Corrections in $W\gamma$ region

All limits are given in [TeV^{-4}].

c_{G+}/Λ^4 and c_{G-}/Λ^4 limits are multiplied by factor 10^3.

Coef.	Class. lim.	Corr. lim.	Improvement
$C_{\tilde{B}W}/\Lambda^4$	[-0.147; 0.152]	[-0.147; 0.151]	0.4%
C_{BW}/Λ^4	[-0.301; 0.303]	[-0.299; 0.301]	0.6%
C_{BB}/Λ^4	[-1.42; 1.42]	[-1.10; 1.10]	22.2%
C_{WW}/Λ^4	[-0.802; 0.803]	[-0.794; 0.797]	0.9%
c_{G+}/Λ^4	[-0.536; 0.537]	[-0.536; 0.536]	$\ll$1%
c_{G-}/Λ^4	[-7.37; 7.37]	[-7.37; 7.37]	$\ll$1%

Correction from all backgrounds is significant for C_{BB}/Λ^4 limits (main sources: $t\bar{t}\gamma$, $Z(\nu\bar{\nu})\gamma$, $Z(\ell\bar{\ell})\gamma$) and is negligible for other coefficients.

Corrections in combined region

All limits are given in [TeV^{-4}].

c_{G+}/Λ^4 and c_{G-}/Λ^4 limits are multiplied by factor 10^3.

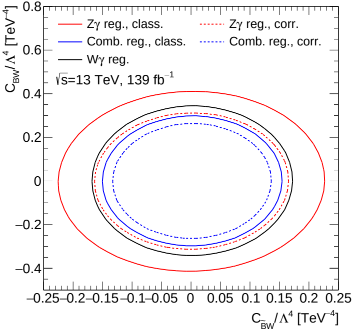
Only leading correction is applied.

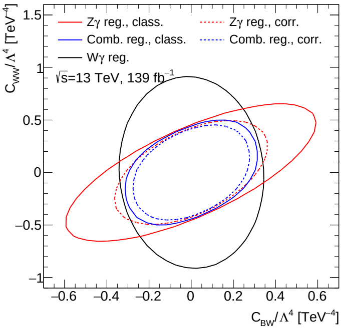
Coef.	Class. lim.	Corr. lim. (lead.)	Improvement
$C_{\tilde{B}W}/\Lambda^4$	[-0.132; 0.136]	[-0.117; 0.120]	12.0%
C_{BW}/Λ^4	[-0.262; 0.263]	[-0.230; 0.231]	12.2%
C_{BB}/Λ^4	[-0.154; 0.154]	[-0.154; 0.153]	0.3%
C_{WW}/Λ^4	[-0.384; 0.384]	[-0.360; 0.361]	6.01%
c_{G+}/Λ^4	[-0.499; 0.499]	[-0.421; 0.421]	15.6%
c_{G-}/Λ^4	[-7.33; 7.33]	[-6.53; 6.54]	10.8%

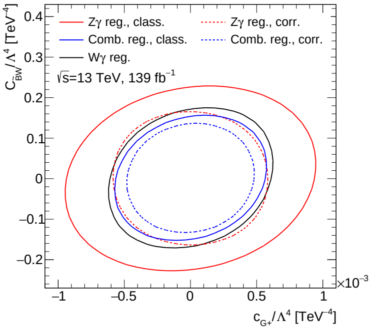
Correction from $W(\ell\nu)\gamma$ background (the leading one) is negligible for C_{BB}/Λ^4 limits and is significant for other coefficients.

Corrections to 2D contours

Only leading correction is applied.







Conclusions

- Corrections for nTGC limits due to the background BSM contributions in $Z(\nu\bar{\nu})\gamma$ and $W(\ell\nu)\gamma$ productions are considered.
- All corrections lead to the tightening of the limits.
- Only background $W(\ell\nu)\gamma$ in $Z\gamma$ region provides significant correction.
- Corrections to the combination of the limits from both regions are also significant.