Effect of Fermionic Operators on the Gauge Legacy of the LHC Run I

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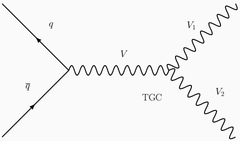
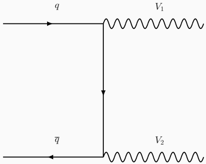
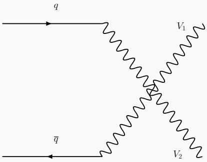
Motivation

- Within the framework of the SM, the trilinear and quartic vector-boson couplings are completely determined by the gauge symmetry.
- The scrutiny these interactions can either lead to an additional confirmation of the SM or give some hint on the existence of new phenomena at a higher scale.
- TGCs as well as fermion pair-gauge boson couplings contribute to WW and WZ productions.







Motivation

- A popular approach is to study possible shifts in the SM using a model indepenedent framework, an effective Lagrangian,

$$\mathcal{L}_{\rm eff} = \mathcal{L}_{\rm SM} + \sum_{n>4,j} \frac{f_{n,j}}{\Lambda^{n-4}} \mathcal{O}_{n,j} \ ,$$

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- And for TGC, the most relevant ***C***- and ***P***-conserving **dimension–six bosonic operators** belong to the following subset (HISZ basis):

$$\mathcal{O}_W = (D_\mu \Phi)^\dagger \widehat{W}^{\mu\nu} (D_\nu \Phi) \ , \quad \mathcal{O}_B = (D_\mu \Phi)^\dagger \widehat{B}^{\mu\nu} (D_\nu \Phi) \ ,$$
$$(1)\mathcal{O}_{BW} = \Phi^\dagger \widehat{B}_{\mu\nu} \widehat{W}^{\mu\nu} \Phi \ , \quad (1)\mathcal{O}_{\Phi,1} = (D_\mu \Phi)^\dagger \Phi \Phi^\dagger (D^\mu \Phi) \ ,$$
$$\mathcal{O}_{WWW} = \mathrm{Tr}[\widehat{W}_\mu^\nu \widehat{W}_\nu^\rho \widehat{W}_\rho^\mu] \ .$$

(1) In Buttler, Eboli et al. [1604.03105] $\mathcal{O}_{BW}$ and $\mathcal{O}_{\Phi,1}$ were not included in the analysis because of EWPD.

Motivation

- These operators introduce changes in the TGCs:

$$\Delta\mathcal{L} = -ie\,\Delta\kappa_\gamma\; W^+_\mu W^-_\nu \gamma^{\mu\nu} - \frac{ie\lambda_\gamma}{2M_W^2}\; W^+_{\mu\nu} W^{-\nu\rho}\gamma_\rho{}^\mu - \frac{ie c_W \lambda_Z}{2M_W^2}\; W^+_{\mu\nu} W^{-\nu\rho} Z_\rho{}^\mu$$
$$- ie c_W\,\Delta\kappa_Z\; W^+_\mu W^-_\nu Z^{\mu\nu} - ie c_W\,\Delta g_1^Z\left(W^+_{\mu\nu} W^{-\mu} Z^\nu - W^+_\mu Z_\nu W^{-\mu\nu}\right)$$

such that the TGC effective couplings are:

$$\Delta\kappa_\gamma = \frac{e^2 v^2}{8 s_W^2 \Lambda^2}\left(f_W + f_B - 2f_{BW}\right)$$

$$\Delta g_1^Z = \frac{e^2 v^2}{8 s_W^2 c_W^2 \Lambda^2}\left(f_W + \frac{2s_W^2}{c_{2\theta_W}} f_{BW}\right) - \frac{1}{4c_{2\theta_W}}\frac{v^2}{\Lambda^2} f_{\Phi,1}$$

$$\Delta\kappa_Z = \Delta g_1^Z - \frac{s_W^2}{c_W^2}\Delta\kappa_\gamma$$

$$\lambda_\gamma = \lambda_Z = \frac{3e^2 M_W^2}{2 s_W^2 \Lambda^2} f_{WWW}$$

Our Goal

- $V\bar{f}f$ can play a role in the diboson production even taking into account the EWPD constraints. Z. Zhang [1610.01618]; Baglio, Dawson, Lewis [1708.03332]

$$\mathcal{O}^{(1)}_{\Phi L,ij} = \Phi^\dagger(i\overleftrightarrow{D}_\mu\Phi)(\bar{L}_i\gamma^\mu L_j)\,,\ \mathcal{O}^{(3)}_{\Phi L,ij} = \Phi^\dagger(i\overleftrightarrow{D}^a_\mu\Phi)(\bar{L}_i\gamma^\mu T_a L_j),$$

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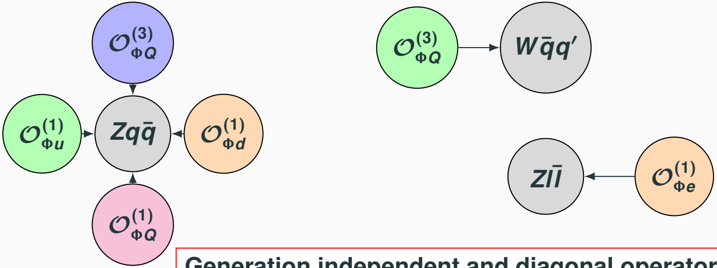

Generation independent and diagonal operators!

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Main goal: revisit the 8 TeV LHC Run I data and study the impact of the fermionic operators on the TGC bounds:)

Analysis Framework

- Kinematic distribuitions from the leptonic $W^+ W^-$ and $W^\pm Z$ channels.

Channel (a)	Distribution	Data set
$WW \to \ell^+\ell'^- + \not{E}_T\ (0j)$	$p_T^{\text{leading,lepton}}$	ATLAS 8 TeV, 20.3 fb^{-1}
$WW \to \ell^+\ell^{(\prime)-} + \not{E}_T\ (0j)$	$m_{\ell\ell^{(\prime)}}$	CMS 8 TeV, 19.4 fb^{-1}
$WZ \to \ell^+\ell^-\ell^{(\prime)\pm}$	m_T^{WZ}	ATLAS 8 TeV, 20.3 fb^{-1}
$WZ \to \ell^+\ell^-\ell^{(\prime)\pm} + \not{E}_T$	Z candidate $p_T^{\ell\ell}$	CMS 8 TeV, 19.6 fb^{-1}

Validation: **95%** CL allowed regions

$\Downarrow$

Same cuts on the distributions of each collaboration

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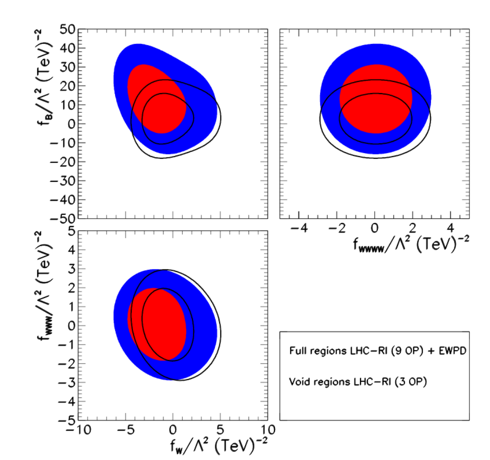
- We construct a χ^2 including the EWPD, ATLAS and CMS 8 TeV data for WW and WZ productions:

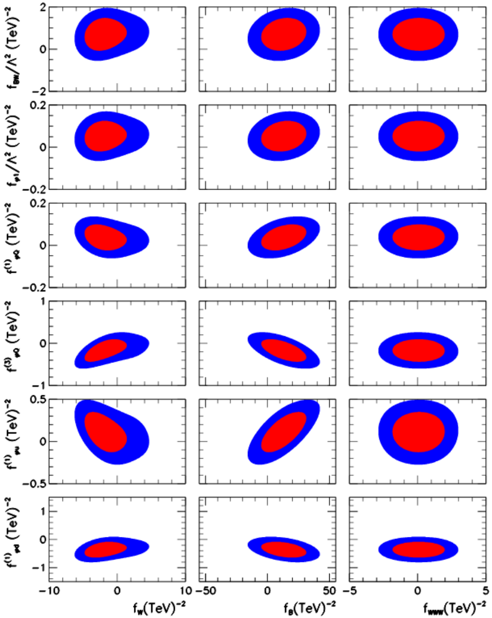
$$\begin{aligned}\chi^2_{\rm LHC-RI+EWPD} \equiv\ & \chi^2_{\rm LHC-RI}(f_W, f_B, f_{WWW}, f_{BW}, f_{\Phi,1}, f^{(1)}_{\phi,Q}, f^{(3)}_{\phi,Q}, f^{(1)}_{\phi,u}, f^{(1)}_{\phi,d}) \\ + \ & \chi^2_{\rm EWPD}(f_{BW}, f_{\Phi,1}, f^{(1)}_{\phi,Q}, f^{(3)}_{\phi,Q}, f^{(1)}_{\phi,u}, f^{(1)}_{\phi,d}, f^{(1)}_{\phi,e})\end{aligned}$$

How the bounds of the TGC "canonical" coefficients change?

- The **1 σ** and **95%** CL allowed regions obtained combining all channels and experiments for the two scenarios: **with and without the new operators.**



The effect of each of the additional operators



Summary

- The inclusion of anomalous couplings of gauge bosons to fermions modifies the TGC measurement at LHC.
- The addition of the new operators **modifies the TGC bounds on f_B/Λ^2 and f_W/Λ^2, although the limit on f_{WWW}/Λ^2 remains almost unchanged.**

Summary

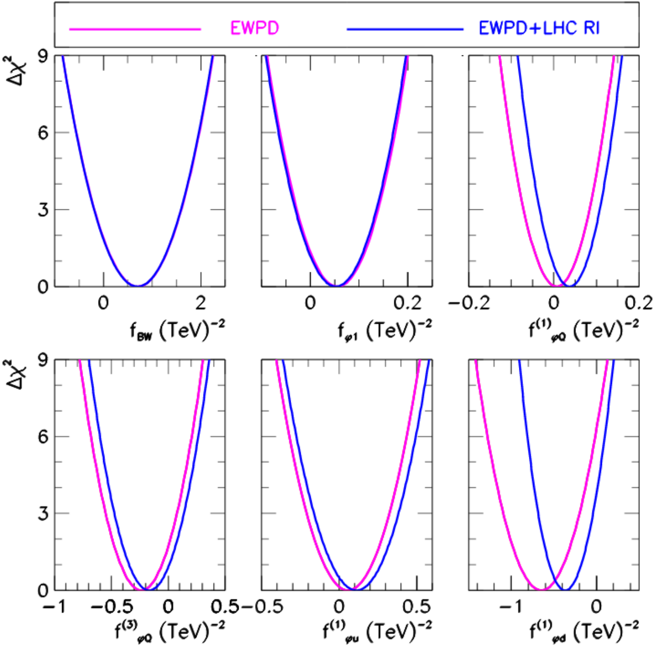
- The inclusion of anomalous couplings of gauge bosons to fermions modifies the TGC measurement at LHC.
- The addition of the new operators **modifies the TGC bounds on f_B/Λ^2 and f_W/Λ^2, although the limit on f_{WWW}/Λ^2 remains almost unchanged.**

Danke schön!

Backup

coupling	95% allowed range (TeV^{-2})	
	EWPD	LHC RI (9 OP) + EWPD
f_{BW}	$(-0.32\,,\ 1.7)$	$(-0.33\,,\ 1.7)$
$f_{\Phi 1}$	$(-0.040\,,\ 0.15)$	$(-0.042\,,\ 0.15)$
$f_{\Phi Q}^{(1)}$	$(-0.083\,,\ 0.10)$	$(-0.048\,,\ 0.12)$
$f_{\Phi Q}^{(3)}$	$(-0.60\,,\ 0.12)$	$(-0.52\,,\ 0.18)$
$f_{\Phi u}^{(1)}$	$(-0.25\,,\ 0.37)$	$(-0.19\,,\ 0.42)$
$f_{\Phi d}^{(1)}$	$(-1.2\,,\ -0.13)$	$(-0.73\,,\ 0.023)$

Table 1: 95% C.L. allowed ranges for the Wilson coefficients of the dimension–six operators that contribute to the studied processes in gauge boson pair production at LHC.



EWPD
EWPD+LHC RI
Δχ²
9
6
3
0
−0.2
0.2
0.5
−0.5
−1
f_BW (TeV)^-2
f_φ1 (TeV)^-2
f^(1)_φQ (TeV)^-2
f^(3)_φQ (TeV)^-2
f^(1)_φu (TeV)^-2
f^(1)_φd (TeV)^-2