Constraints on Anomalous Quartic Couplings through exclusive and quasi-exclusive W^+W^- production by two-photon exchange at CMS

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Abstract

A search for exclusive and quasi-exclusive two-photon production of $W^{\pm}W^{\mp}$ in the fully leptonic channel, $pp \to p^{(*)}W^+W^-p^{(*)} \to p^{(*)}\mu^{\pm}e^{\mp}p^{(*)}$, was performed using $5.05 fb^{-1}$ of data collected at $\sqrt{s} = 7$ TeV by the CMS detector in 2011. The presence of quartic gauge boson couplings (QGC) emerges naturally from the non-abelian gauge symmetry structure of the Standard Model. The study of QGC is mainly motivated by the hope that some new physics might result in deviations of them. Considering genuine anomalous quartic operators, via an effective Lagrangian approach, the limits obtained on the anomalous quartic gauge couplings parameters are approximately one order of magnitude more stringent than the limits obtained at LEP.

Overview

In this analysis the $l^+l^- + \not{E}_T$ final state samples were used to search for fully exclusive (elastic) $pp \to pW^+W^-p$ production as well as quasi-exclusive (inelastic or proton dissociative) $pp \to p^{(*)}W^+W^-p^{(*)}$ production - where one or both incident protons dissociate into a low mass system that escapes detection, denoted as $p^{(*)}$ - at $\sqrt{s} = 7$ TeV collected with CMS detector during 2011 with an integrated luminosity of 5.05fb^{-1}. Since backgrounds from same-flavor decays of W^+W^- are huge, only $\mu^{\pm}e^{\mp}$ channel is considered on quasi-exclusive signal. The exclusive $\mu^+\mu^-$ production was adopted as a test benchmark for high-mass lepton pair detection, due to the small theoretical uncertainties on the cross section. This sample is then used to validate the efficiency of the vertexing and exclusivity selection, and the dependence on different pile-up conditions. The $\gamma\gamma \to WW \to \mu^{\pm}e^{\mp}$ signal is therefore comprised of both the elastic and inelastic contributions. In this context, beyond WW production studies, the tails of $p_T(\mu^{\pm}e^{\mp})$ were investigated in the region where the SM $\gamma\gamma \to WW$ contribution is expected to be small, to look for pure anomalous quartic gauge couplings (aQGC).

Event selection

In the $\mu^{\pm}e^{\mp} + \not{E}_T$ channel, the SM $\gamma\gamma \to WW$ signal region was defined to have zero extra tracks associated to the $\mu^{\pm}e^{\mp}$ vertex, and $p_T(\mu^{\pm}e^{\mp}) > 30$ GeV to suppress $\tau^+\tau^-$ backgrounds, beyond requesting to fail the $\mu^{\pm}\mu^{\mp}$ selection in order to reject muons misidentified as eletrons.

For aQGC search, $p_T(\mu^{\pm}e^{\mp}) > 100$ GeV was used to reduce the expected SM signal region to ≈ 0.1 events after all selection requirements, while retaining sensitivity to anomalous couplings of order 10^{-4} for $\Lambda = 500$ GeV and larger.

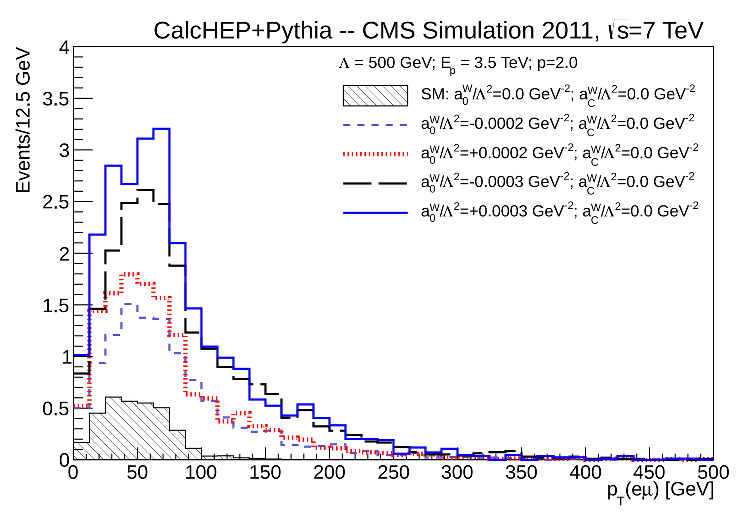

Figure 1: $p_T(\mu^{\pm}e^{\mp})$ at generator level (left) in the SM (shaded histogram), and for several values of AQGC parameter (open histograms). All distributions are scaled to a integrated luminosity of 5.05 fb-1.

Theory and simulation

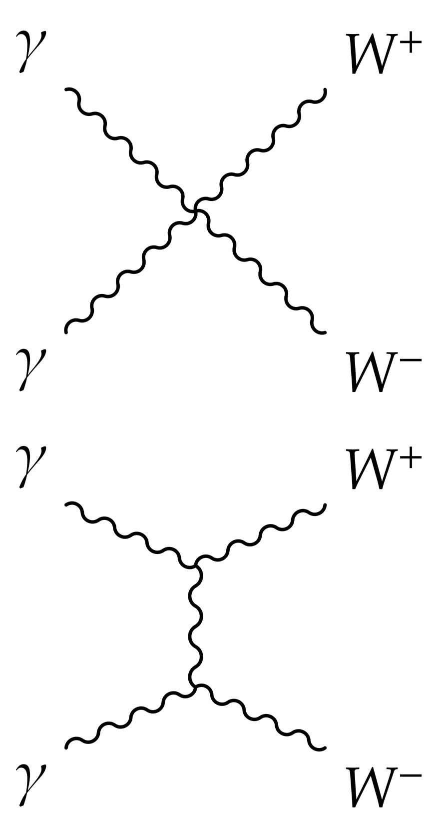

Figure 4: Quartic and t-channel W exchange diagrams contributing to the $\gamma\gamma \to W^+W^-$ process at LO in the SM.

$\gamma\gamma \to W^+W^-$ signal was generated by CalcHEP. W^+W^- pair decays via PYTHIA6. Genuine AQGC (no contribution from triple gauge couplings deviations assumed) were introduced through the following dim-6 effective lagrangian terms, respecting local $U(1)_{EM}$ and global custodial $SU(2)_C$ symmetry as well as C- and P-symmetry

$$L_6^0 = -\frac{e^2 a_0^W}{8\,\Lambda^2} F_{\mu\nu}F^{\mu\nu}W^{+\alpha}W^-_{\alpha} - \frac{e^2}{16\,c_W^2}\frac{a_0^Z}{\Lambda^2} F_{\mu\nu}F^{\mu\nu}Z^{\alpha}Z_{\alpha}$$

$$L_6^C = -\frac{e^2 a_C^W}{16\,\Lambda^2} F_{\mu\alpha}F^{\mu\beta}(W^{+\alpha}W^-_{\beta} - W^{-\alpha}W^+_{\beta}) - \frac{e^2}{16\,c_W^2}\frac{a_C^Z}{\Lambda^2} F_{\mu\alpha}F^{\mu\beta}Z^{\alpha}Z_{\beta},$$

where Λ is the scale for new physics. Since $\gamma\gamma \to W^+W^-$ violates unitarity for high-energy $\gamma\gamma$ interactions already for collisions with $W_{\gamma\gamma} \approx 1$ TeV then to tame the cross section rising one usually multiply anomalous parameters by a dipole form factor

$$a_{0,C}^W(W_{\gamma\gamma}^2) = \frac{a_{0,C}}{(1 + \frac{W_{\gamma\gamma}^2}{\Lambda^2})^p} \qquad (2)$$

where $W_{\gamma\gamma}$ is the $\gamma\gamma$ center-of-mass energy and p a free parameter (conventionally set to 2). In the present analysis consider both a scenario with dipole form factors with $\Lambda = 500$ GeV and with no form factors.

Backgrounds samples for W^+W^-+ jets (scaled to the NLO prediction), W+ jets and $t\bar{t}$ processes were produced with MADGRAPH, and PYTHIA6 associated to POWHEG for $\tau^+\tau^-$ pairs produced via the Drell-Yan process. Diffractive W^+W^- background was produced using POMPYT, while the $\gamma\gamma \to \mu^+\mu^-$ and $\gamma\gamma \to \tau^+\tau^-$ were produced using LPAIR. VBFNLO generator was used to study $WW \to WW$ scattering with Pythia6 used for hadronization and decay of the WW pair.

&&&&&&&&&& RESULTS &&&&&&&&&&

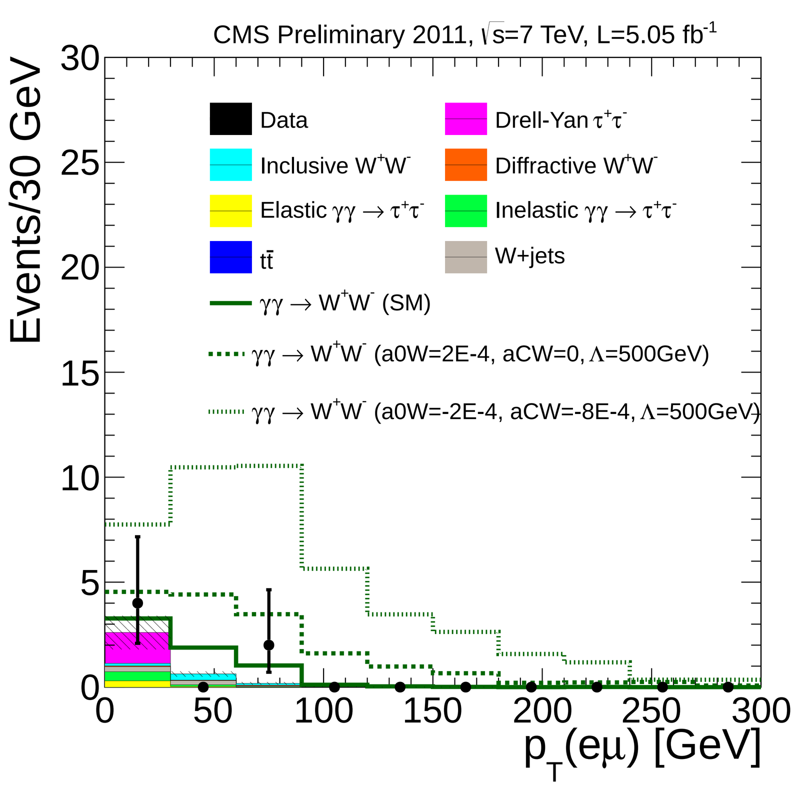

Figure 2: Full $p_T(\mu^{\pm}e^{\mp})$ distribution for events with 0 extra tracks (right). The backgrounds (solid histograms) are stacked with statistical uncertainties indicated by the shaded region, the signal histogram (open histogram) is stacked on top of the backgrounds.

In the region with $p_T(\mu^{\pm}e^{\mp}) > 100$ GeV zero SM-like events were observed, limiting the partial cross section times branching fraction, within the additional acceptance of

$$p_T(\mu, e) > 20GeV, \qquad |\eta(\mu, e)| < 2.4$$

as

$$\sigma(pp \to p^{(*)}\mu^{\pm}e^{\mp}p^{(*)}) < 1.9 \text{ fb}. \qquad (1)$$

Systematics uncertainties affecting the signal were considered as well, being exclusivity and pile-up dependence combined with proton dissociation factor the most important contributing each one with 10% and 20%, respectively.

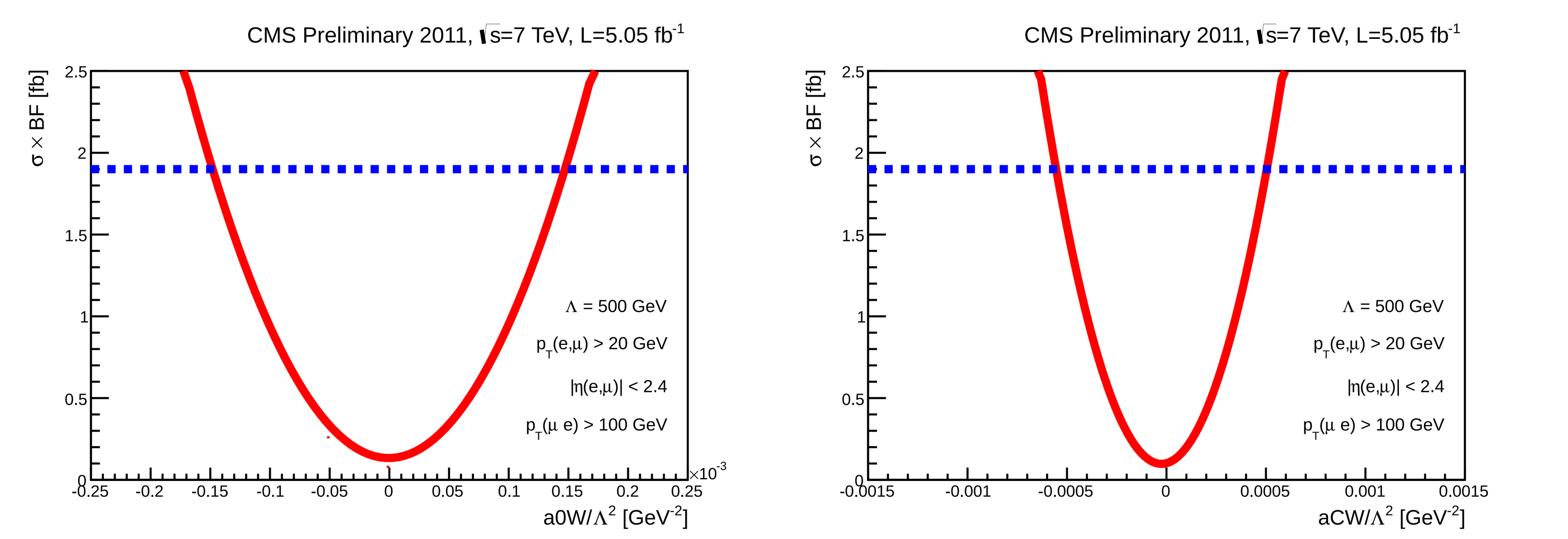

Figure 3: Expected partial cross sections times branching fraction with $\Lambda = 500$ GeV when each parameter contributes independently. The prediction (solid line) and excluded value (dashed line) are both shown for $p_T(\mu, e) > 20$ GeV, $|\eta(\mu, e)| < 2.4$, $p_T(\mu^{\pm}e^{\mp}) > 100$ GeV. The prediction is rescaled to include the contribution from proton dissociation.

Using sample (1) , the following AQGC limits were reached

- with dipole form factor (Eq. (2) with $\Lambda = 500$ GeV and $p = 2$) :

$$|a_0^W/\Lambda^2| < 1.7 \times 10^{-4} \text{ GeV}^{-2}$$
$$|a_C^W/\Lambda^2| < 6 \times 10^{-4} \text{ GeV}^{-2}$$

- no form factor

$$|a_0^W/\Lambda^2| < 2.8 \times 10^{-6} \text{ GeV}^{-2}$$
$$|a_C^W/\Lambda^2| < 1.2 \times 10^{-5} \text{ GeV}^{-2}$$

In Fig. 5, the area outside the ellipse corresponds to values of the anomalous couplings that would result in a partial cross section times branching fraction above 1.9 fb.

Assuming dipole form factor, Eq. (2), these limits are approximately 100 times more stringent than the limits obtained at LEP.

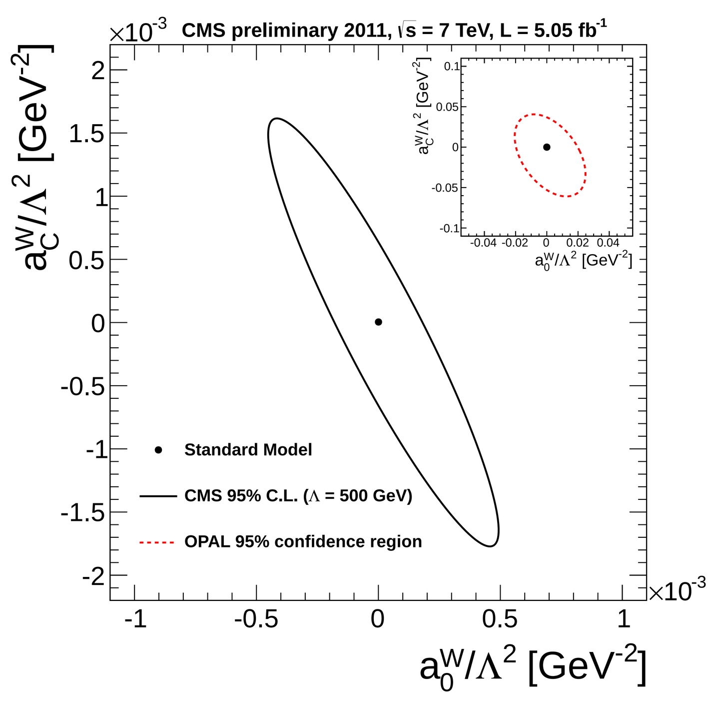

Figure 5: Excluded values of AQGC parameters a_0/Λ^2 and a_C^W/Λ^2 with $\Lambda = 500$ GeV. Area outside solid line indicates AQGC values for which the predicted cross section is above the 95% CL upper limit of 1.9fb obtained for $p_T(\mu e) > 20$ GeV, $|\eta(\mu, e)| < 2.4$, $p_T(\mu^{\pm}e^{\mp}) > 100$ GeV. The predicted cross sections are rescaled to include the contribution from proton dissociation. The inset shows LEP constraints obtained from a maximum likelihood fit with the two anomalous couplings as free parameters.

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References

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