Anomalous gauge coupling in photon-photon interactions

Sensitivity in generic experiments at the LHC

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See: O. Kepka, C. Royon, Phys. Rev. D78 (2008) 073005 ; other review paper to be submitted
See also: T. Pierzchala, K. Piotrzkowski, arXiv:0807.1121v1 [hep-ph]

Outline

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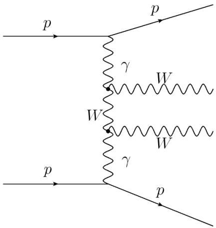
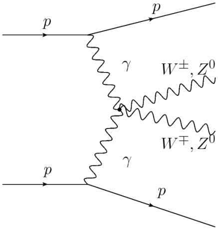
WW and ZZ production at hadronic colliders

- Study of the QED processes $pp \to ppWW$ and $pp \to ppZZ$
- Using photon equivalent approximation (Budnev flux) : low photon virtuality Q^2 but possibly high photon energy. In particular we can have high missing mass $M_{\gamma\gamma} = \sqrt{s\xi_1\xi_2}$ (where ξ is the momentum fraction loss of the proton)
- Low cross section in the Standard Model ($\sigma_{pp\to ppWW} = 95.6$ fb at $\sqrt{s} = 14$ TeV, $pp \to ppZZ$ is forbidden at tree level)
- With anomalous couplings we expect much more events for these processes





Lagrangians

Lagrangian for anomalous quartic gauge couplings:

$$\mathcal{L}_6^0 = \frac{-e^2}{8}\frac{a_0^W}{\Lambda^2} F_{\mu\nu}F^{\mu\nu}W^{+\alpha}W^-_\alpha - \frac{e^2}{16\cos^2\Theta_W}\frac{a_0^Z}{\Lambda^2}F_{\mu\nu}F^{\mu\nu}Z^\alpha Z_\alpha$$

$$\mathcal{L}_6^C = \frac{-e^2}{16}\frac{a_C^W}{\Lambda^2} F_{\mu\alpha}F^{\mu\beta}(W^{+\alpha}W^-_\beta + W^{-\alpha}W^+_\beta) - \frac{e^2}{16\cos^2\Theta_W}\frac{a_C^Z}{\Lambda^2}F_{\mu\alpha}F^{\mu\beta}Z^\alpha Z_\beta$$

where $F_{\mu\nu}$ is the electromagnetic field tensor $F_{\mu\nu} = \partial_\mu A_\nu - \partial_\nu A_\mu$

Lagrangian for anomalous triple gauge couplings:

$$\mathcal{L}_{\mathrm{TGC}}/ig_{WW\gamma} = \left(W^\dagger_{\mu\nu}W^\mu A^\nu - W_{\mu\nu}W^{\dagger\mu}A^\nu\right) + (1+\Delta\kappa^\gamma)\,W^\dagger_\mu W_\nu A^{\mu\nu} + \frac{\lambda^\gamma}{M_W^2}W^\dagger_{\rho\mu}W^\mu_\nu A^{\nu\rho}$$

All anomalous parameters a_0^W, a_C^W, a_0^Z, a_C^Z, λ^γ and $\Delta\kappa^\gamma$ are 0 in the Standard Model. We study them independently.

Framework

- The photon flux increases with beam energy: the LHC is a good place for photon studies.
- Cross section at the LHC for $pp \rightarrow ppWW$ through photon exchange: $\sigma_{WW}(10\ \text{TeV}) = 62$ fb, $\sigma_{WW}(14\ \text{TeV}) = 95$ fb
- Events generated with FPMC (Forward Physics Monte Carlo) and reconstructed with standalone ATLFast (fast simulation).

We focus on the sensitivity reachable with early data at the LHC ($\sqrt{s} = 10$ TeV, a few hundreds of pb^{-1}during the first year of data taking, no pile-up).

Signal and backgrounds to WW

Signal

Two-photon WW events with two leptons in the final state, and nothing else in the detector.

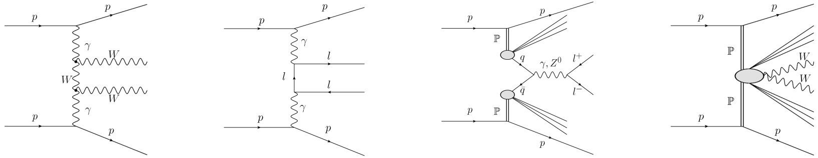
Possible backgrounds:

Inelastic WW: Characterized by large energy flow in forward regions

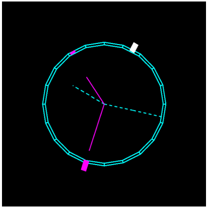
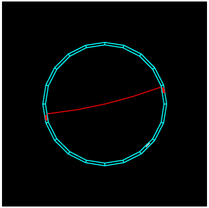
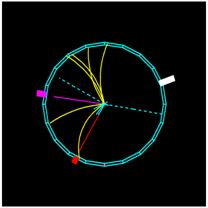
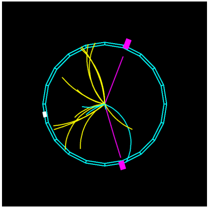
Dilepton through photon exchange: Leptons produced back to back, no missing E_T

Dilepton through double pomeron exchange (DPE): Characterized by energy flow in the forward regions and higher number of tracks due to pomeron remnants

WW through double pomeron exchange: Same as before

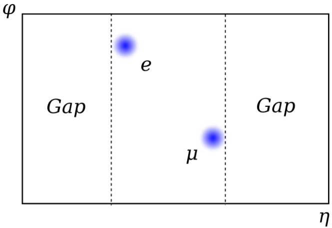


Some event displays: (x, y) view of the detector

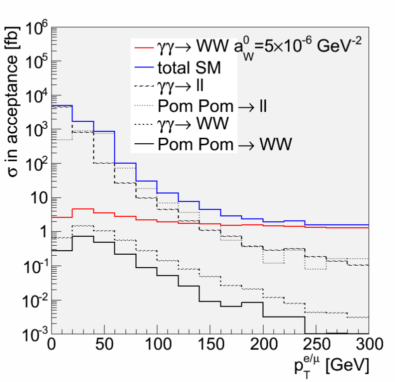
	W pair	lepton pair
Photon exchange		
DPE		

Background rejection

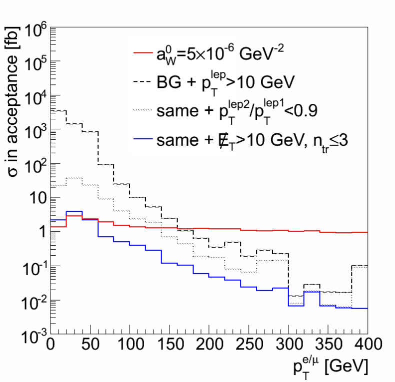
- Require 2 reconstructed leptons (ee, $e\mu$ or $\mu\mu$) with $|\eta^{e,\mu}| < 2.5$ and $p_T^{e,\mu} > 10$GeV, and nothing else.
- Rejection of non diffractive WW background and double pomeron exchange:
  - Cut on number of tracks, exclusivity of the event (only 2 reconstructed leptons)
- Rejection of exclusive two-photon dilepton production:
  - cut on missing E_T and on the ratio of p_T of the two leptons



Signal and background: p_T distributions of the reconstructed leptons

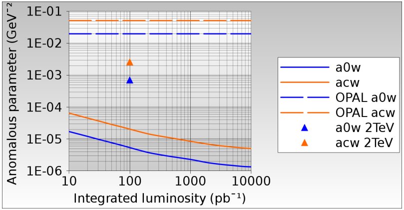


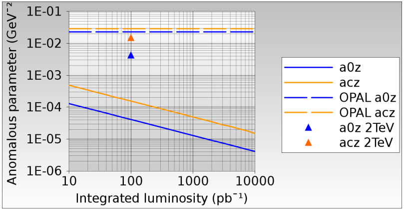
Contribution of various background processes, before background rejection (only 2 e or μ with $p_T > 10$ GeV)



Effect of the different cuts on the background

Results





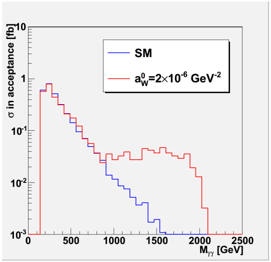
Couplings	OPAL limits $[GeV^{-2}]$	Limits @ 10 TeV $[GeV^{-2}]$ $\mathcal{L} = 10$ pb^{-1}	Limits @ 10 TeV $[GeV^{-2}]$ $\mathcal{L} = 100$ pb^{-1}	Limit @ 2 TeV $[GeV^{-2}]$ $\mathcal{L} = 100$ pb^{-1}
a_0^W/Λ^2	[-0.020, 0.020]	1.72×10^{-5}	5.4×10^{-6}	7×10^{-4}
a_C^W/Λ^2	[-0.052, 0.037]	6.50×10^{-5}	2.05×10^{-5}	2.6×10^{-3}
a_0^Z/Λ^2	[-0.007, 0.023]	1.29×10^{-4}	4.10×10^{-5}	4.25×10^{-3}
a_C^Z/Λ^2	[-0.029, 0.029]	4.85×10^{-4}	1.55×10^{-4}	1.5×10^{-2}

Note: we present the expected 95% confidence level upper limits on the parameters.

Improvement of a factor up to 1 000 with respect to the OPAL limits

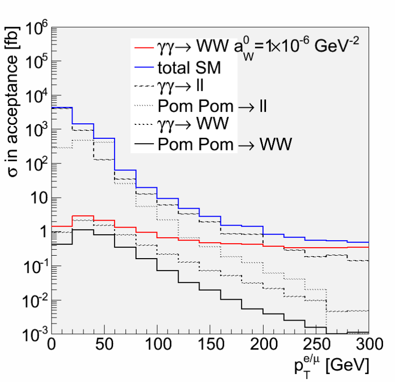
Specificities with high integrated luminosity

- Main difficulty at high instantaneous luminosity: multiple interactions and pile-up.
- Forward detectors installed in ATLAS/CMS.
  - Acceptance on momentum fraction loss ξ: $0.0015 < \xi < 0.15$ for ATLAS
- Changes in the analysis:
  - Additional hadronic activity due to pile-up. Ask for tagged protons in the forward detectors on both sides, to reject the non-diffractive background.
  - Now require at least one lepton with $p_T > 160$ GeV.
  - Also cut on the missing mass $M_{\gamma\gamma} = \sqrt{s\xi_1\xi_2}$ reconstructed from the forward detectors: $M_{\gamma\gamma} > 800$ GeV.



Gain a factor ~ 5 in sensitivity with respect to the low integrated luminosity scenario

Signal and background: p_T distributions of the reconstructed leptons



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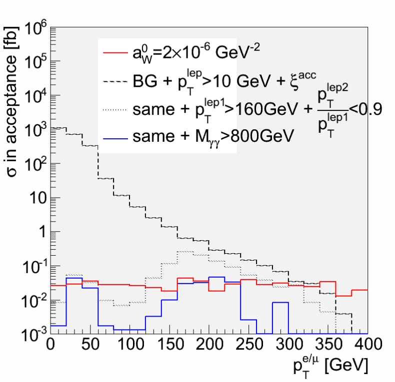
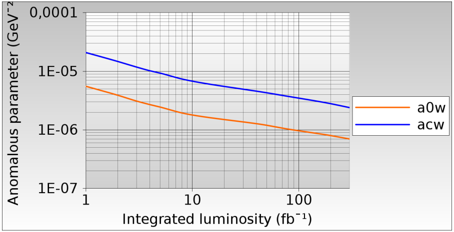


Effect of the different cuts on the background

Final sensitivity



Couplings	Limits from LEP $[\,GeV^{-2}]$	Limits @ 14 TeV $\mathcal{L} = 30$ fb^{-1}	$\mathcal{L} = 200$ fb^{-1}
a_0^W/Λ^2	$[-0.020, 0.020]$	1.3×10^{-6} GeV^{-2}	8×10^{-7} GeV^{-2}
a_C^W/Λ^2	$[-0.052, 0.037]$	4.8×10^{-6} GeV^{-2}	2.8×10^{-6} GeV^{-2}
λ^γ	[-0.098, 0.101]	[-0.033,0.026]	[-0.024,0.017]
$\Delta\kappa^\gamma$	[-0.044, 0.047]	[-0.034,0.029]	[-0.013,0.012]

Physics at the LHC as a photon-collider