

Anomalous Photon-Gauge-Boson Coupling Contribution to the Exclusive Vector Boson Pair Production from Two Photon Exchange in pp Collision at 8 TeV

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Forward Physics

CERN/ISR $p p \rightarrow p \ell^+ \ell^- p$ for \mathcal{L} measurements

very small lepton p_T **low statistics** **failed**

Tevatron $p \bar{p}$ **quasi-real photons**

- ▶ two opposite charge tracks (μ electrons)
- ▶ no other activity in the central detectors

LHC with new dedicated detectors **P P S**

high-energy $\gamma\gamma$ **collider**

$\gamma\gamma$ processes \Rightarrow standard for calibration

Equivalent Photon Approximation (EPA)

$p p \rightarrow p X p$ large M_X two photon exchange $\gamma\gamma \rightarrow X$
 $\sigma_{pp} \sim \sigma_{\gamma\gamma} \times$ two equivalent photon fluxes

Photon virtuality $1 \sim 2 \text{ GeV}^2 > Q^2 > Q_{min}^2 \approx M_p^2 \frac{x^2}{1-x}$

$$W_{\gamma\gamma}^2 \approx x_1 x_2 s \quad \text{where } x = \frac{E_\gamma}{E_p}, \quad \sqrt{s} = E_{CM}$$

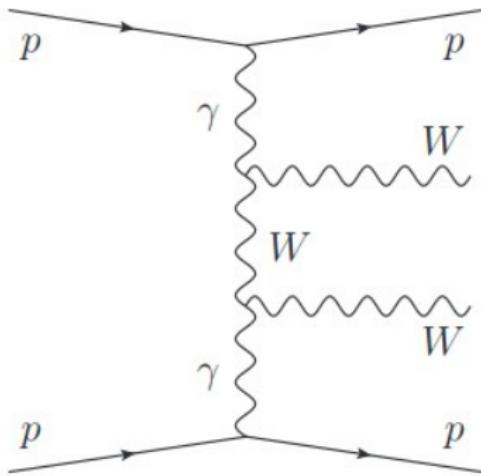
Luminosity spectrum $f_\gamma \Rightarrow \gamma\gamma$ relative luminosity

$$\frac{dL_{\gamma\gamma}}{dW_{\gamma\gamma}} = \int_{W_{\gamma\gamma}^2/s}^1 2W_{\gamma\gamma} f_\gamma(x) f_\gamma\left(\frac{W_{\gamma\gamma}^2}{xs}\right) \frac{dx}{xs}$$

Two-photon cross section $\sigma_{pp} = \int_{W_0}^{\sqrt{s}} \sigma_{\gamma\gamma} \frac{dL_{\gamma\gamma}}{dW_{\gamma\gamma}} dW_{\gamma\gamma},$

small $\sigma_{\gamma\gamma}$ & huge LHC luminosity \Rightarrow large event rates

Two-photon exchange W pair production



Topologies at LHC

1. two very forward protons measured far away
2. few centrally produced particles
3. high p_T for leading lepton

Large bkg from parton-parton suppressed by \cancel{E}_T

EPA - Two-photon cross sections

SM calculation 14 TeV

Process	$\sigma(\text{fb})$	$\sigma_{LPAIR}(\text{fb})$	Deviation
a) $\gamma\gamma \rightarrow \mu^\pm \mu^\mp$	80460	72500	10.9%
b) $\gamma\gamma \rightarrow \mu^\pm \mu^\mp$	1107	1340	17.3%

Calculation from MadGraph/MadEvent (first column)
compared with LPAIR result (second column)[2]

- a) for $p_T^\mu > 2 \text{ GeV}$ and $|\eta^\mu| < 3.1$,
- b) for $p_T^\mu > 10 \text{ GeV}$ and $|\eta^\mu| < 2.5$,

Beyond the Standard Model Physics

Theoretical Questions

- ▶ Origin of mass
- ▶ Strong CP problem
- ▶ Neutrino oscillation
- ▶ Dark matter
- ▶ Dark energy

New particle discoveries

- ▶ Minimal Supersymmetric Standard Model
- ▶ Extra dimensions
- ▶ Extended models (3-3-1, Left-Right . . .)



Introduce new particle couplings

Anomalous photon - W couplings

Effective lagrangian for low energy behavior of possible extensions
of the SM

$$\frac{e^2}{8\Lambda^2} \left(a_0^W F_{\mu\nu} F^{\mu\nu} W^{+\alpha} W_\alpha^- - \frac{a_c^W}{2} F_{\mu\alpha} F^{\mu\beta} (W^{+\alpha} W_\beta^- + W^{-\alpha} W_\beta^+) \right)$$

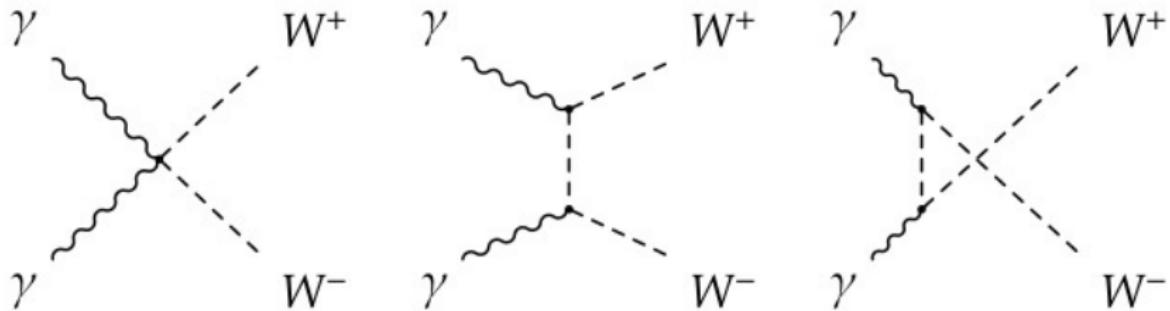
where Λ is the energy scale of the **new physics** ≈ 1 TeV

di-lepton signature: two leptons within $|\eta| < 2.5$ and $p_T > 10$ GeV

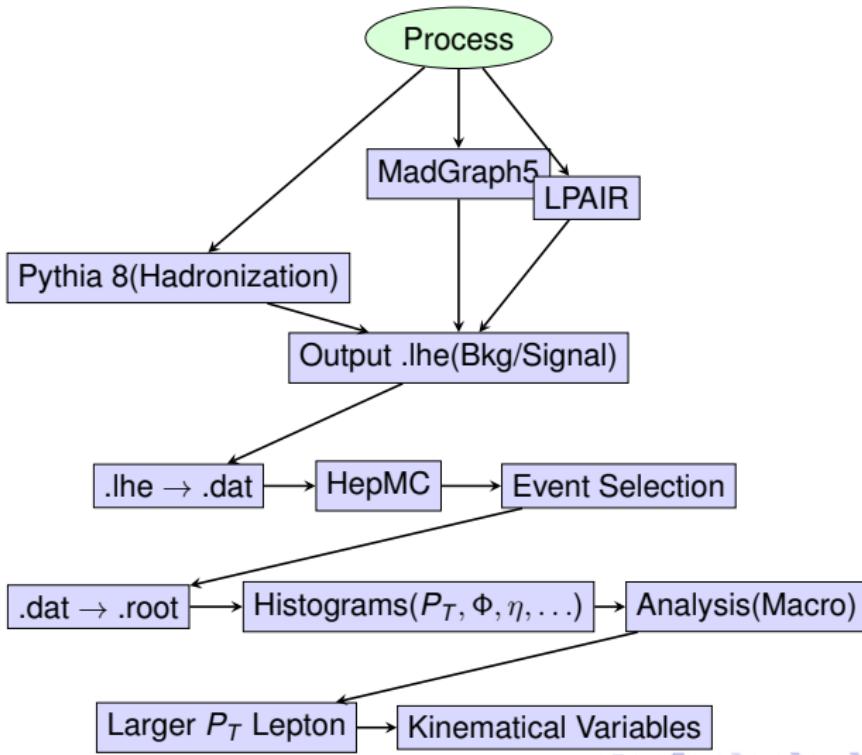
Subprocess $\gamma\gamma \rightarrow W^+ W^- \rightarrow \ell^+ \ell^- \nu \bar{\nu}$ ($\ell = e$ or μ)

The SM inclusive pp and $\gamma\gamma$ production of WW are bkg sources

Diagrams and $\gamma\gamma$ Energy



Files coupling orders, couplings, decays, **form factors**,
function library, lorentz, parameters, particles, propagators



Normalization

$$\text{scale} = \frac{\sigma \times \mathcal{L}}{\# \text{ events}}$$

libraries must be linked

Total cross section $\sqrt{s} = 7 \text{ TeV}$ $\mathcal{L} = 5 \text{ fb}^{-1}$

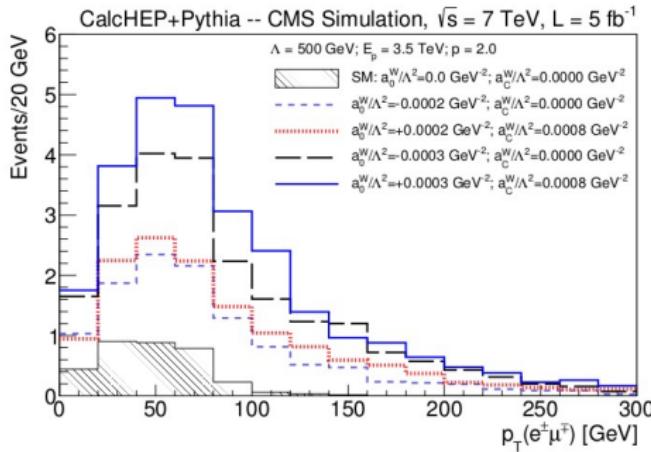
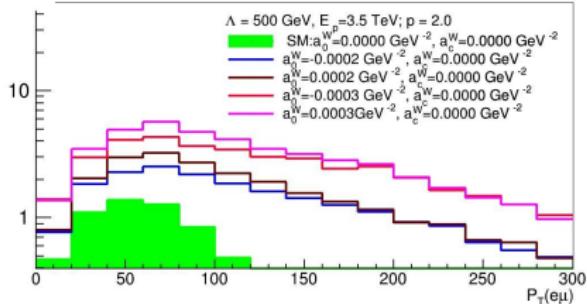
Process	$\sigma_{\text{tot}}(\text{fb})$	Deviation
$\gamma\gamma \rightarrow W^+W^-$	42.57	6%
" $\times \text{BR}(e^\pm\mu^\mp)$	1.25	5%

Anomalous couplings

a_0^W	a_c^W	$\sigma_{\text{tot}}(\text{fb})$
-200	0	4.40
+200	800	17.58
-300	0	8.60
+300	800	25.63

Total muon-electron transverse momentum

Events/10 GeV

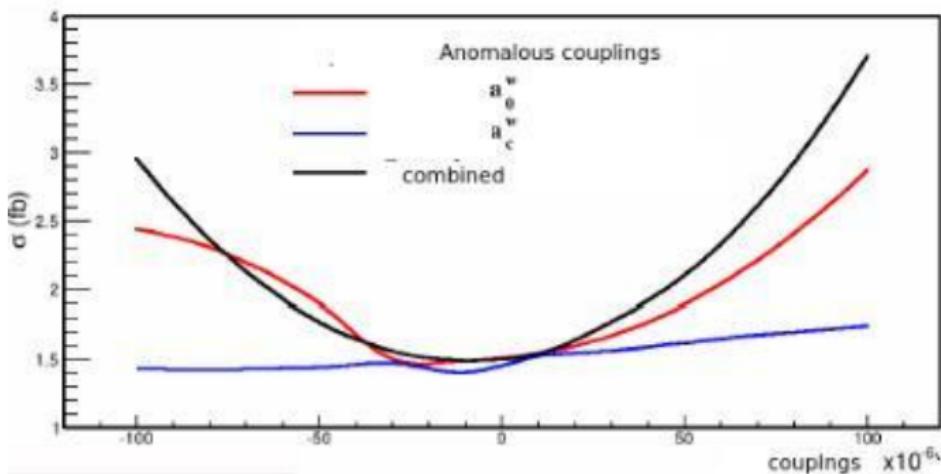


Cross section behaviour

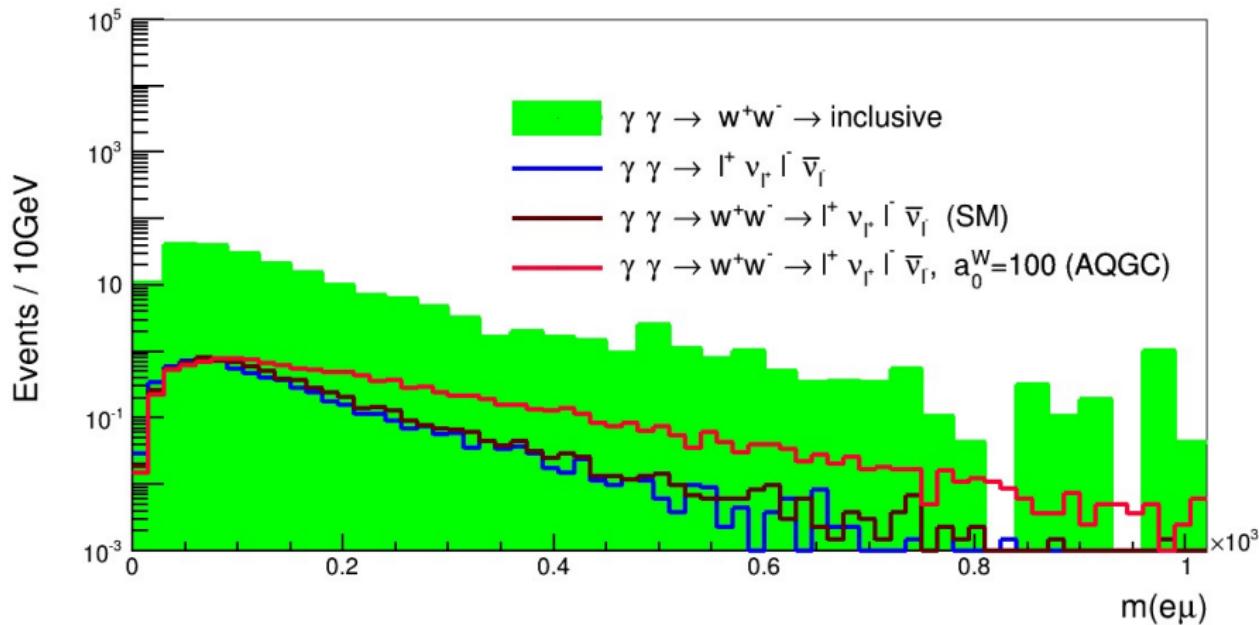
no unitarity violation $a_0^W \approx 10^{-6} \text{ GeV}^{-2}$

Form factor $a_{0,c}^W \rightarrow \frac{a_{0,c}^W}{(1 + W_{\gamma\gamma}/\Lambda)^2}$

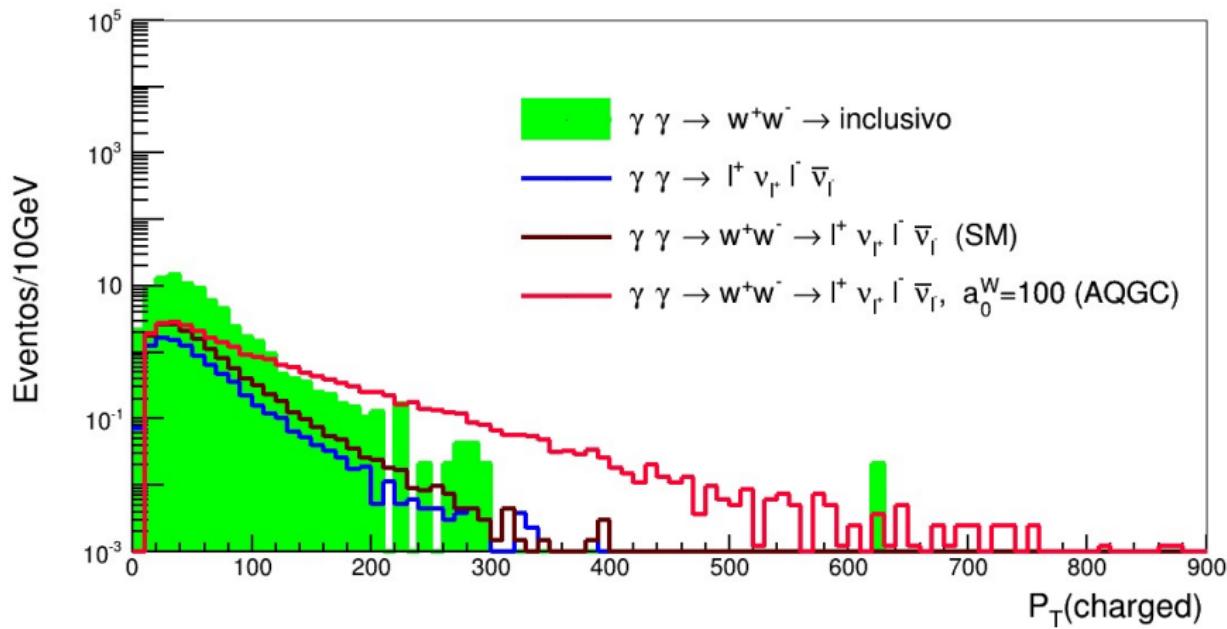
$W_{\gamma\gamma}$ available system energy Λ cutoff parameter $\sim 500 \text{ GeV}$



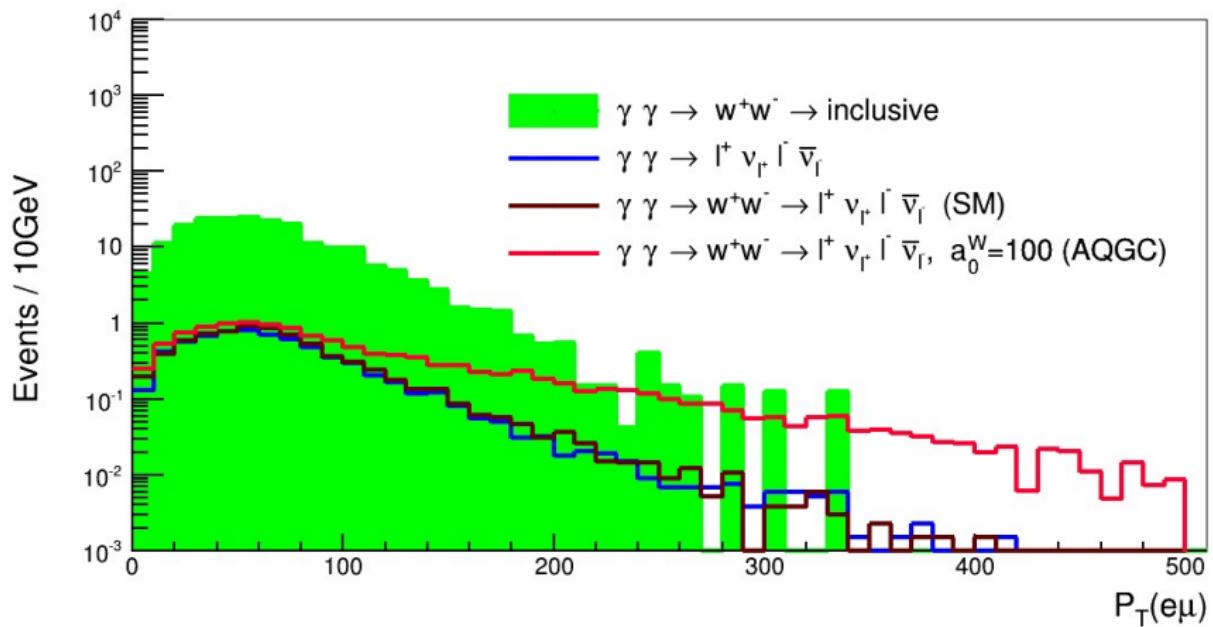
Invariant mass electron-muon system



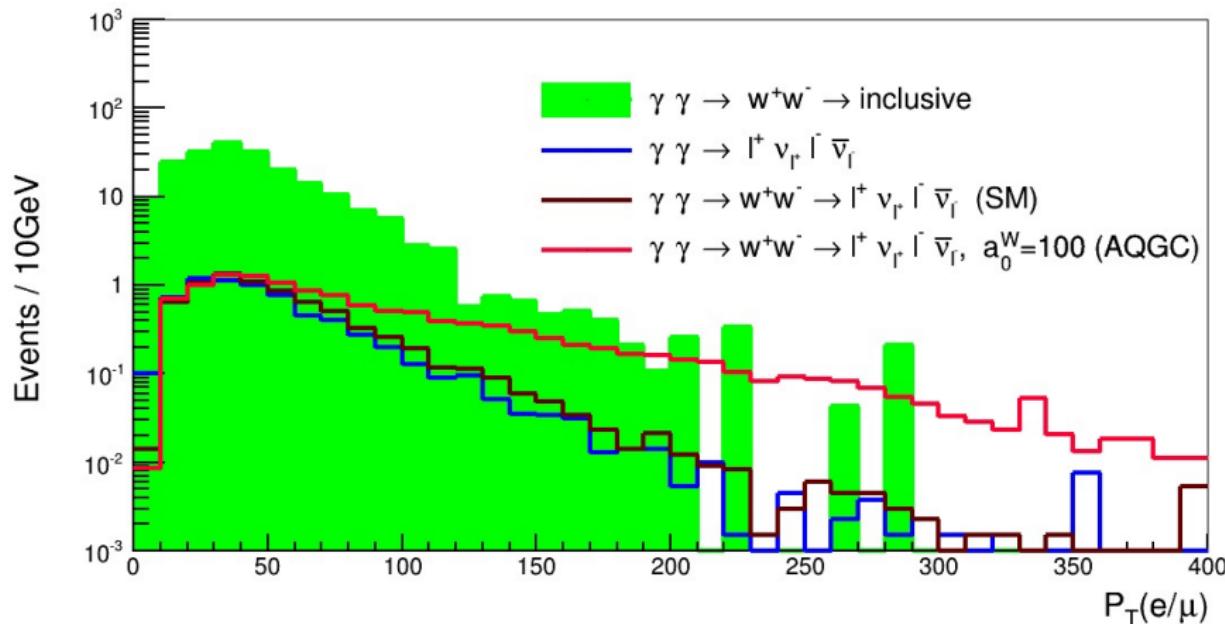
Charged particles p_T distribution



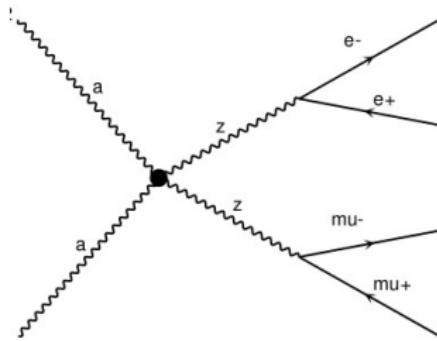
Lepton transverse momentum distribution



Lepton transverse momentum distribution



ZZ Production

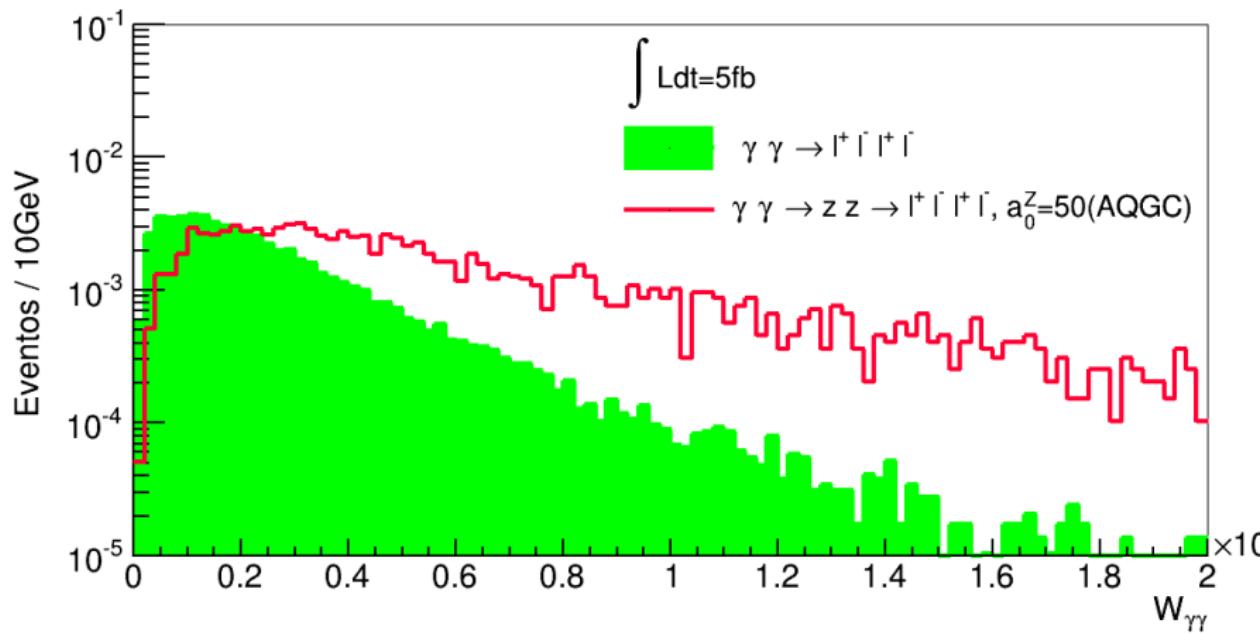


$$a^W \Rightarrow \frac{a^Z}{2 \cos \theta_W}$$

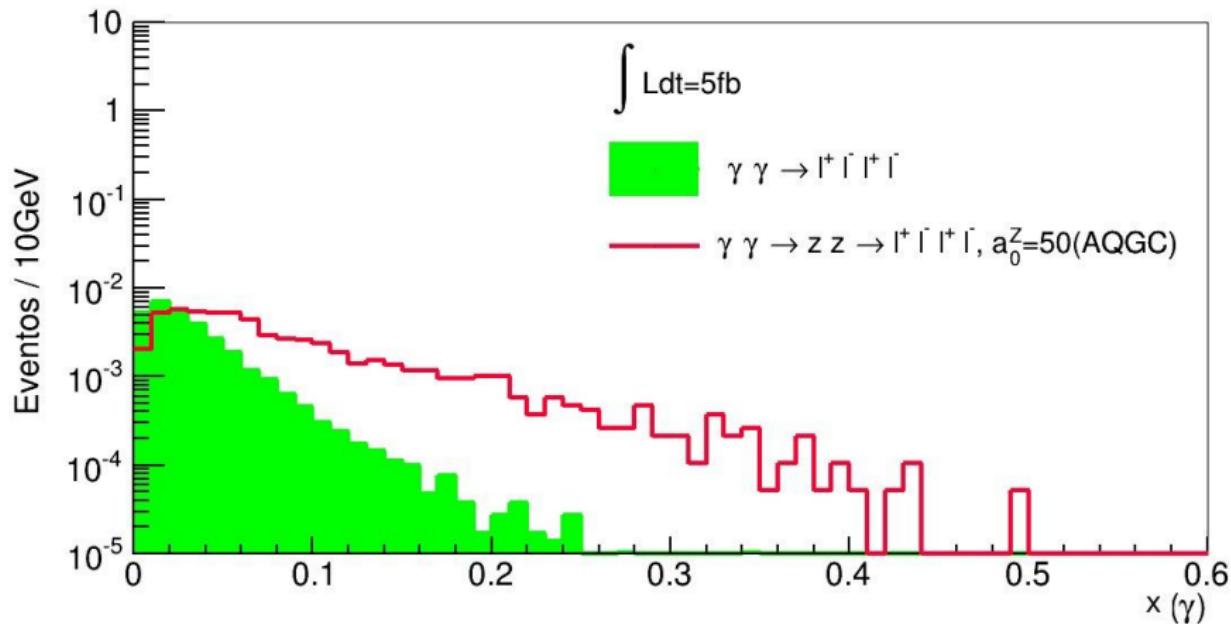
$$\sigma(\gamma\gamma \rightarrow 4\ell) = 6.88 \times 10^{-3} fb$$

$$\sigma(\gamma\gamma \rightarrow ZZ \rightarrow 4\ell) = 1.5 \times 10^{-2} fb \quad \text{for} \quad a_0^Z = 50$$

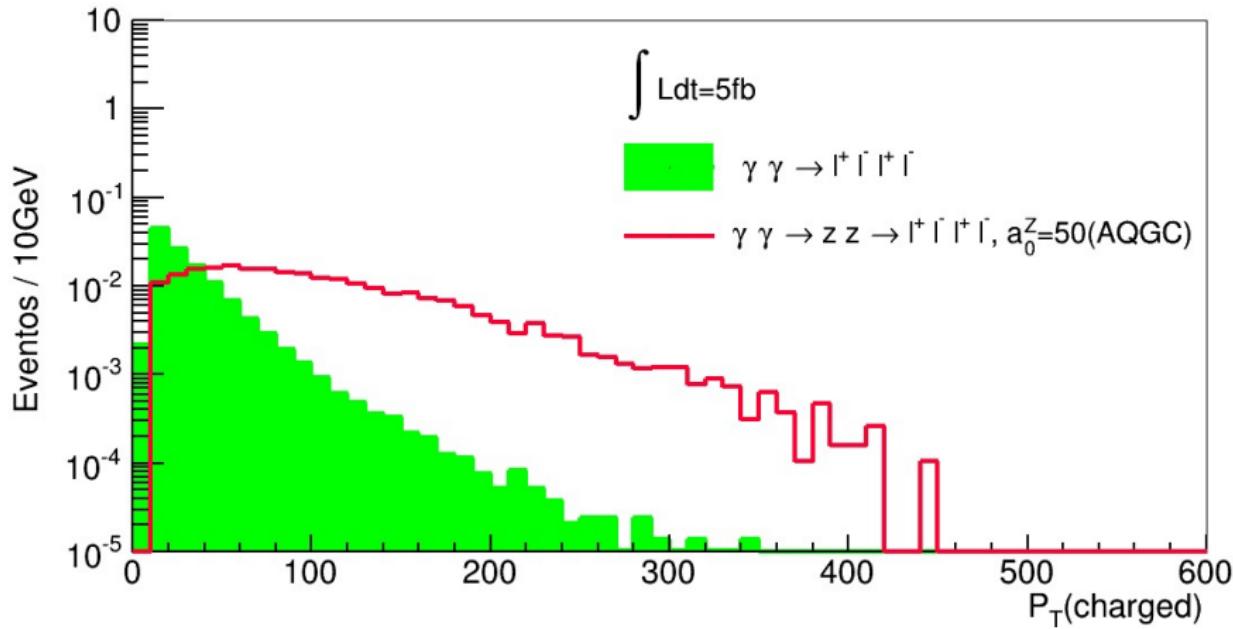
$\gamma \gamma$ Energy



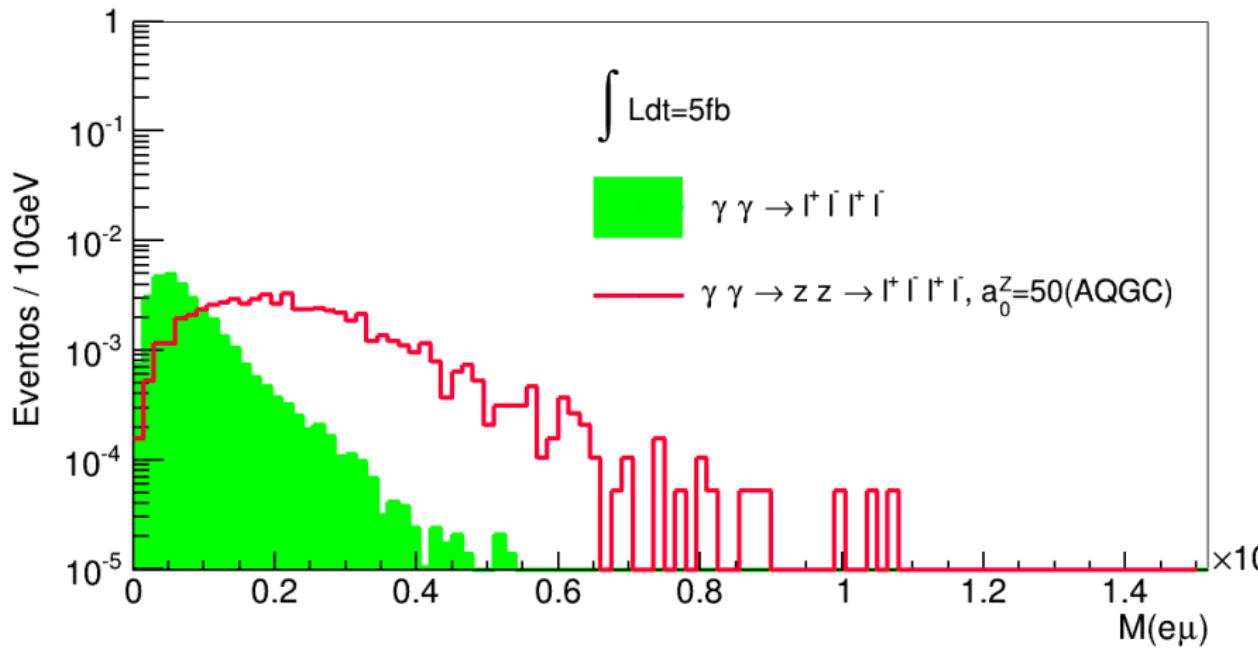
Momentum Fraction of the Photon



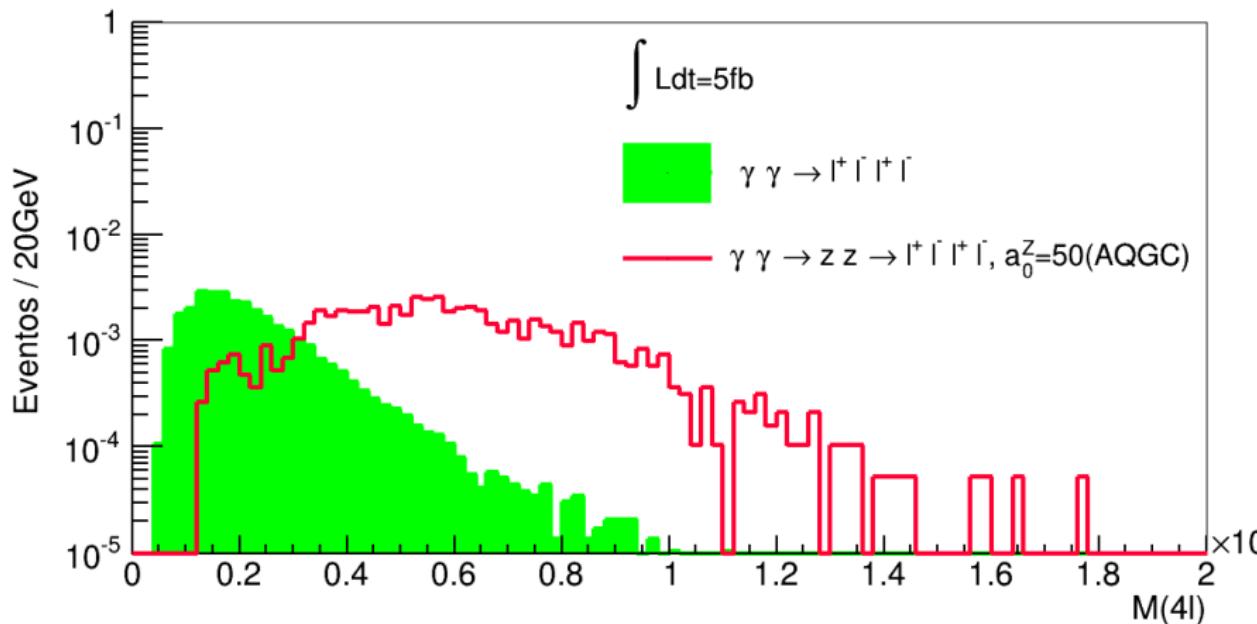
Charged Particles p_T Distribution



Lepton Invariant Mass Distribution



ZZ Pair four lepton production



Perspectives

Preliminary results $8 \text{ TeV} \Rightarrow 13 \text{ TeV}$

Package implementation: MadGraph, HepMC 2, Root, LPAIR

More effort on ZZ four lepton production

Introduce dim-8 operators

Mixing ZZ' (3-3-1 model)

THANK

YOU

References

1. E. chapon , C. Royon, O. Kepka – Anomalous quartic WWaa, ZZaa. and trilinear WWa couplings in two photon process at high luminosity at the LHC 28/12/2009- arXiv:0912.5161v1
2. J. de Favereau de Jeneret, V. Lemaitre, Y. Liua , S. Ovyn, T. Pierzchala, K. Piotrzkowski, X. Roubyb , N. Schul, and M. Vander Donck– High energy photon interactions at the LHC- 14/08/2009
3. CMS-Colaboration- Study of exclusive two-photon production of W W in pp collisions at $s = 7$ TeV and constraints on anomalous quartic gauge couplings 30/07/2013- CMS-FSQ-12-010