Study of Triple Neutral Gauge Boson Interactions in $e\gamma \to eZ$

Fernando Cornet

Universidad de Granada

with M.G. Caruso

Outline of the talk

1. Introduction
2. Neutral gauge boson effective interactions
3. Bounds from LHC
4. Signals at ILC
5. Conclusions

Introduction

We found the Higgs

BUT there must be Physics Beyond the Standard Model

Introduction

We found the Higgs

BUT there must be Physics Beyond the Standard Model

However no REAL signal has been found of it up to now
(Neutrino masses?)

Introduction

We found the Higgs

BUT there must be Physics Beyond the Standard Model

However no REAL signal has been found of it up to now
(Neutrino masses?)

Task for LHC and Future Colliders $\Longrightarrow$ Search for Physics BSM

Two approaches:

- Take your favorite model
- Take a more general approach (not completely model independent)

Introduction

We found the Higgs

BUT there must be Physics Beyond the Standard Model

However no REAL signal has been found of it up to now
(Neutrino masses?)

Task for LHC and Future Colliders $\Longrightarrow$ Search for Physics BSM

Two approaches:

- Take your favorite model
- Take a more general approach (not completely model independent)

Effective Lagrangians

Effective Couplings

Assuming Lorentz invariance, $U(1)$ gauge invariance and CP invariance:

$$\mathcal{L}_{Z\gamma V} = -e\left[\frac{h_3^V}{M_Z^2}\tilde{F}^{\mu\nu}Z_\mu(\partial_\alpha\partial^\alpha + M_V^2)V_\nu + \frac{h_4^V}{M_Z^4}\tilde{F}^{\mu\nu}Z^\beta(\partial_\alpha\partial^\alpha + M_V^2)\partial_\beta\partial_\mu V_\nu\right]$$

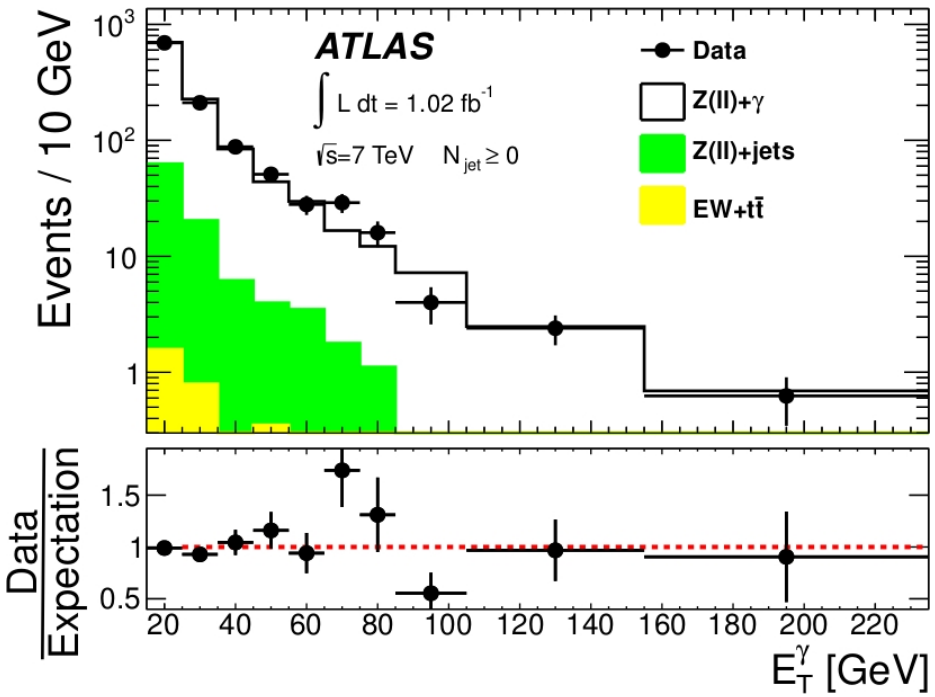
Ellison, Wudka Hagiwara et al.

with $\tilde{F}^{\mu\nu} = \epsilon^{\mu\nu\rho\delta}F_{\rho\delta}$

- $V = \gamma,\ Z$
- Standard Notation (h_1 and h_2 are ~~CP~~)
- V is off mass-shell
- $h_3^V,\ h_4^V \in \mathbb{R}$
- The $\frac{1}{M_Z^2}$ factors are just a definition of the coupling constants
- h_3^V receives contributions at one loop, while h_4^2 at two loops

Present Bounds

ATLAS and CMS have studied diboson production: $pp \to Z\gamma X$ at $\sqrt{s} = 7\ GeV$

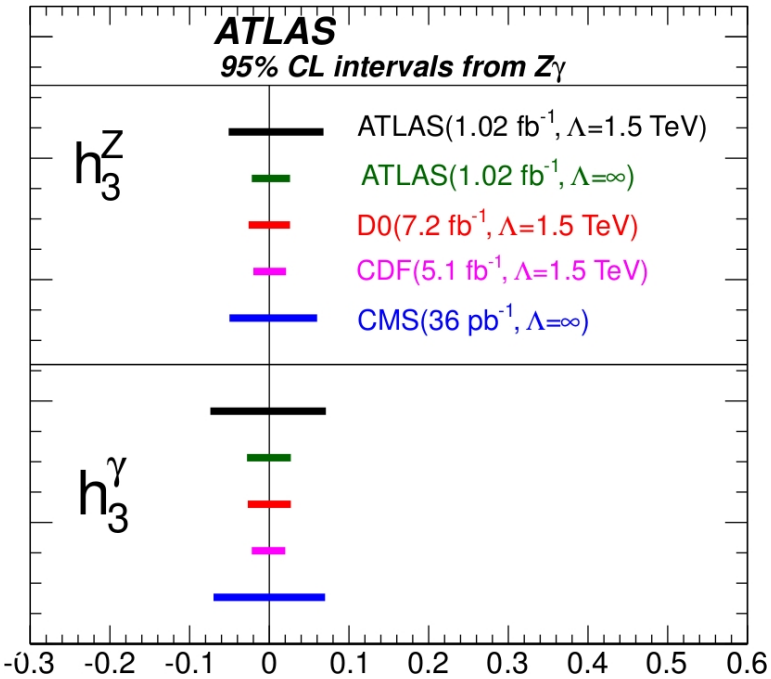


95% *CL* CMS bounds

$\lvert h_3^\gamma \rvert$	$<$	2.9×10^{-3}
$\lvert h_3^Z \rvert$	$<$	2.7×10^{-3}
$\lvert h_4^\gamma \rvert$	$<$	1.5×10^{-5}
$\lvert h_4^Z \rvert$	$<$	1.3×10^{-5}

This bounds are obtained in a different kinematical region

Present Bounds



To avoid unitarity violations add a form factor

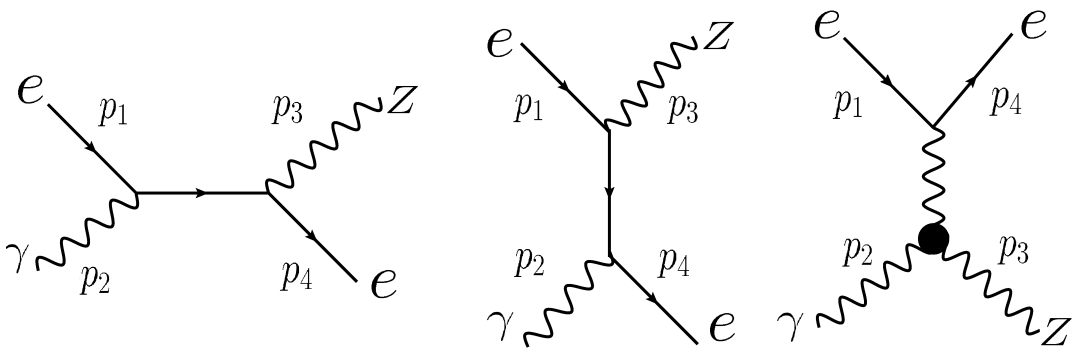
$$h_3 = \frac{h_3^0}{1 + \left(\frac{Q^2}{\Lambda^2}\right)^n}$$

I'll use h_3 constant ($\Lambda \to \infty$)

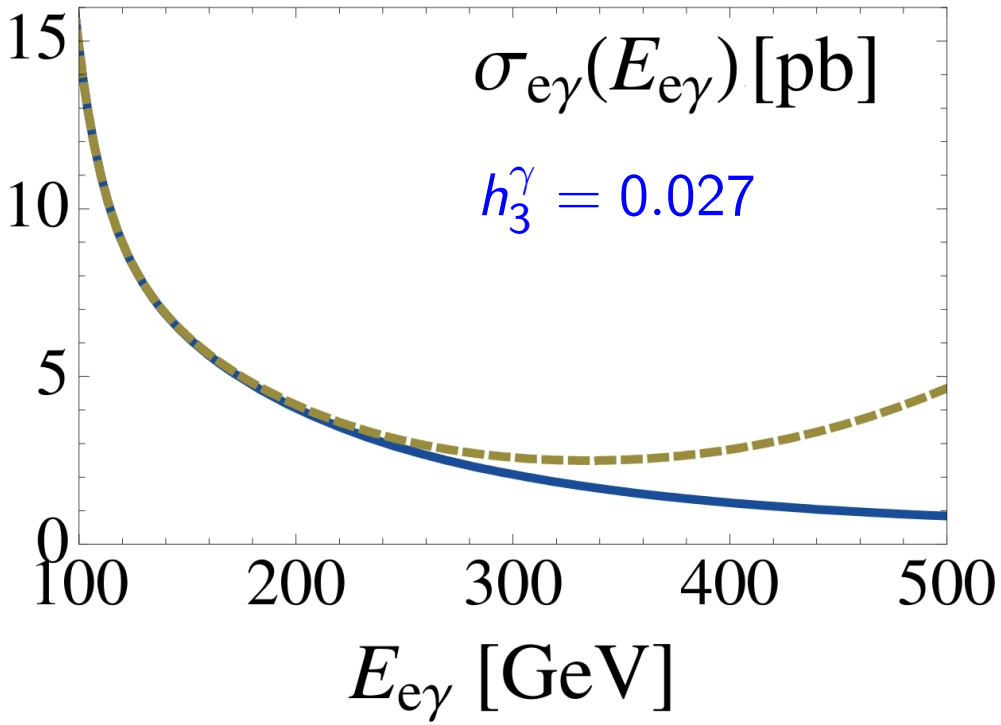
- Too many unknown parameters
- Not clear what is the real Q^2 dependence
  what is the physics behind these couplings.

The first step is to observe a signal!!!

$e\gamma \to eZ$



The first two diagrams are the SM contribution. The third includes the new vertexes.

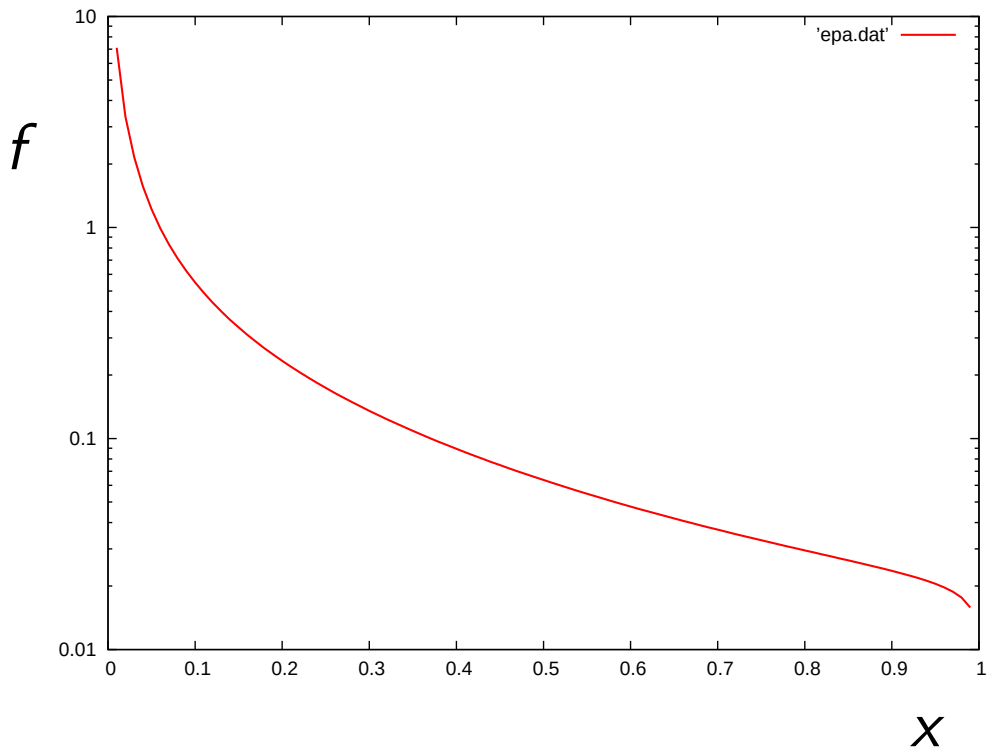


The effects from the $ZZ\gamma$ vertex are very similar.

Equivalent Photon Approximation

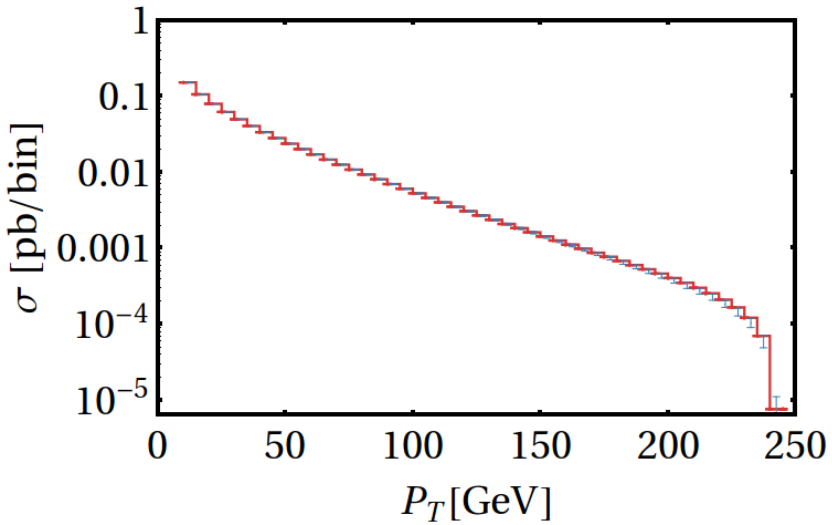
The relation between the $e\gamma$ and the e^+e^- cross sections is given by the EPA.

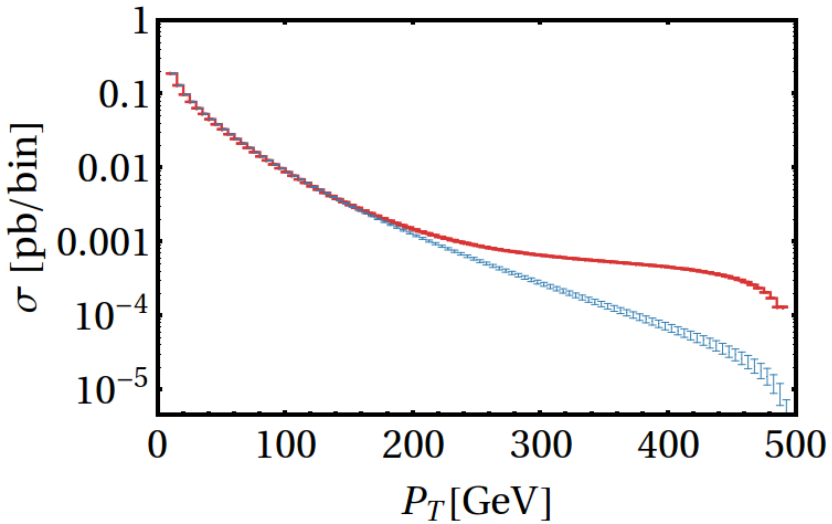
$$\sigma_{e^+e^-}(s) = \int dx f_e(x)\sigma_{e\gamma}(xs)$$

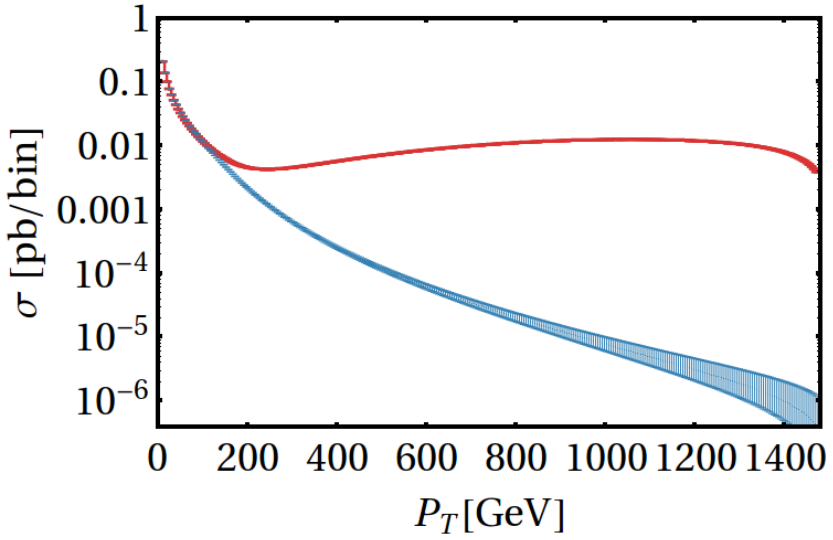


For a given $E_{e\gamma}$ the cross section increases when E_{ee} increases

p_T Distributions







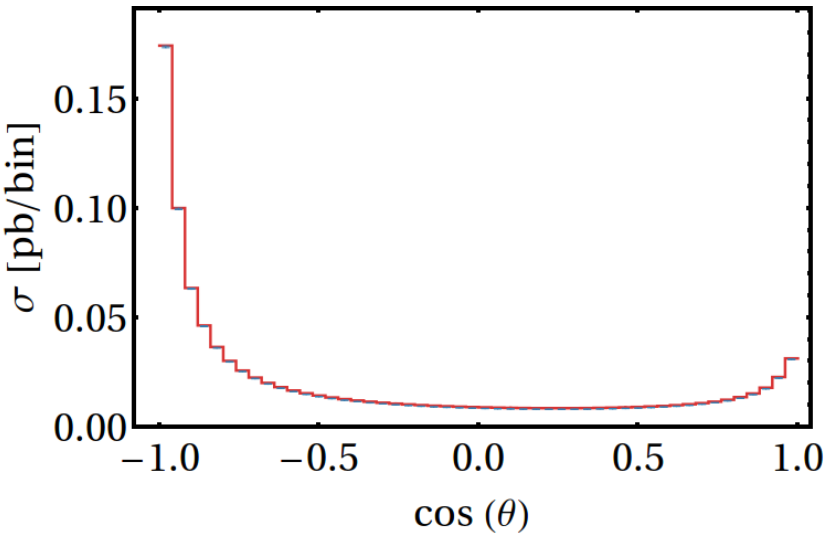
$$h_3^\gamma = 1 \times 10^{-2}$$

We will take $p_T > 150$ *GeV*

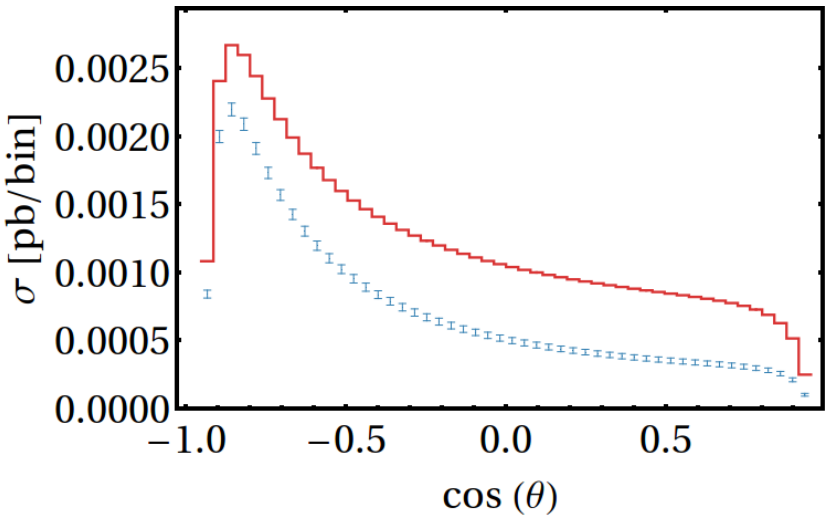
$\cos\theta$ Distributions

$$E_{ee} = 1\ TeV$$

$p_T > 10\ GeV$



$p_T > 150\ GeV$



Energy (GeV)	$h_3^\gamma(95\%C.L.)$
500	$(-1.5\times10^{-4}, 3.5\times10^{-3})$
1000	$(-3.1\times10^{-5}, 3.4\times10^{-4})$
3000	$(-5.5\times10^{-6}, 2.7\times10^{-5})$

Conclusions

- The process $e\gamma \to eZ$ with EPA photons will allow to study the effects of anomalous triple neutral gauge boson couplings.
- These studies are complementary to the ones with other processes ($Z\gamma$ production) due to different kinematical region.
- Present bounds can be improved at $E_{ee} = 1000, 3000\ GeV$.
- For $E_{ee} = 500\ GeV$ bounds similar to the present ones can be obtained for $h_3^\gamma < 0$.
- Very similar bounds for h_3^Z.

To do

- Study the effects of h_4.
- Introduce systematic errors in the analysis.
- Study the situation at an $e\gamma$ collider.
- Sudy the $\not{CP}$ terms.