BSM CONTRIBUTIONS TO THE $\gamma\gamma$ AND $ZZ\gamma$ SELF COUPLINGS AT HIGH ENERGIES

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Introduction

The CP conserving $Z\gamma\gamma$ and $ZZ\gamma$ couplings in the SM and MSSM models at loop level were investigated. For the both models the coupling parameters $h_{\gamma}^3$, $h_{\gamma}^5$, $f_{\gamma}^2$ were estimated for the energy ranges, accessible at the LHC. Extension of the considered energy range up to 14 TeV leads to a possibility to constrain theories using experimental limits on anomalous couplings from the LHC experiments. It was found that in order to constrain the MSSM model parameters, a measurement accuracy of the order $10^{-7}$ is required.

Loop contribution of the $Z\gamma\gamma$ and $ZZ\gamma$ couplings

We investigate the $h_{\gamma}^3$, $h_{\gamma}^5$, $f_{\gamma}^2$ couplings in the $\gamma \to Z\gamma$, $Z \to Z\gamma$ and $\gamma \to ZZ$ decays, respectively up to 14 TeV for SM and MSSM models because they can make a significant contribution to the decay width in order to be noticeable in the experiment.

The corresponding decay amplitudes can be written as follows [3]:

$$
A_{\gamma\to Z\gamma} = \frac{i}{m_Z} \left( u_{\gamma}^{\alpha \beta} u_{\gamma}^{\alpha \beta} - q_{\gamma}^{\alpha} q_{\gamma}^{\alpha} \right) + \frac{h_{\gamma}^3}{m_Z} \left( (P_{\gamma q2}) u_{\gamma}^{\alpha \beta} - Q_{\gamma}^{\alpha} Q_{\gamma}^{\alpha} \right) - \frac{f_{\gamma}^2}{m_Z} \left( (P_{\gamma q2}) u_{\gamma}^{\alpha \beta} - Q_{\gamma}^{\alpha} Q_{\gamma}^{\alpha} \right)
$$

The results obtained in the work [3] were extended and the possibility to constrain the MSSM parameters by using observational data, obtained at the LHC experiments, was investigated [1, 2]. The effective couplings $h_{\gamma}^3$, $h_{\gamma}^5$, $f_{\gamma}^2$ here defined as the coefficients of the terms $e^{2\phi_1}q_{\gamma2}$ and $e^{\phi_1}(q_{1} - q_{2})$, respectively.

$$
h_{\gamma}^3(j) = -N_s \frac{e^{2\phi_1}q_{\gamma2}}{\sin \Theta_2 \cos \Theta_2} f_{\gamma}^2
$$

$$
h_{\gamma}^5(j) = -N_s \frac{e^{2\phi_1}q_{\gamma2}}{4\pi^2 \sin^2 \Theta_2 \cos^2 \Theta_2} f_{\gamma}^2
$$

$$
f_{\gamma}^2(j) = N_s \frac{e^{\phi_1}(q_{1} - q_{2})}{4\pi^2 \sin^2 \Theta_2 \cos^2 \Theta_2} f_{\gamma}^2
$$

where the expressions for $f_{\gamma}^2$, $f_{\gamma}^1$, $f_{\gamma}^3$ can be taken from [3].

Methodology

The allowed values of the effective couplings $h_{\gamma}^3$, $h_{\gamma}^5$, $f_{\gamma}^2$, extracted from the experiments, lie in the intervals, that shown in table 3.

<table>
<thead>
<tr>
<th>$\sqrt{s}$, TeV</th>
<th>$h_{\gamma}^3$</th>
<th>$h_{\gamma}^5$</th>
<th>$f_{\gamma}^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>$-2.9 \pm 2.9 \cdot 10^{-3}$</td>
<td>$-2.7 \pm 2.7 \cdot 10^{-3}$</td>
<td>$-1.6 \pm 1.6 \cdot 10^{-3}$</td>
</tr>
<tr>
<td>8</td>
<td>$-9.5 \pm 9.9 \cdot 10^{-4}$</td>
<td>$-7.8 \pm 8.6 \cdot 10^{-4}$</td>
<td>$-3.8 \pm 3.8 \cdot 10^{-3}$</td>
</tr>
<tr>
<td>13</td>
<td>$-3.7 \pm 3.7 \cdot 10^{-4}$</td>
<td>$-3.2 \pm 3.3 \cdot 10^{-4}$</td>
<td>$-6.8 \pm 7.5 \cdot 10^{-4}$</td>
</tr>
</tbody>
</table>

In order to calculate the loop amplitudes of the $\gamma \to Z\gamma$, $Z \to Z\gamma$ and $\gamma \to ZZ$ processes, the following Lagrangian was used:

$$
L = -e Q_{\gamma} A_{\gamma} T \frac{e^{2\phi_1}q_{\gamma2}}{2\cos \Theta_2} f_{\gamma}^1 + e^{2\phi_1}q_{\gamma2} \gamma_{\gamma} \gamma_{\gamma} \gamma_{\gamma} \gamma_{\gamma} f_{\gamma}^2
$$

The effective couplings $h_{\gamma}^3$, $h_{\gamma}^5$, $f_{\gamma}^2$ were calculated as the coefficients of the terms $e^{2\phi_1}q_{\gamma2}$ and $e^{\phi_1}(q_{1} - q_{2})$, respectively. In this context, the parameter $\Lambda$ is a free parameter of the MSSM model and the masses of Chargino can be approximated as shown [4]:

$$
M_{\chi^\pm} = \frac{1}{2} \sqrt{\Lambda^2 + m_{\tilde{W}}^2 + \sqrt{(\Lambda^2 + m_{\tilde{W}}^2)^2 - 4(\Lambda^2 - m_{\tilde{W}}^2)(2\phi_1)^2}}
$$

The variation of $M_{\chi^\pm}$ affects the Charginos’ contribution to the $h_{\gamma}^3$, $h_{\gamma}^5$ and $f_{\gamma}^2$ couplings. The goal is to study the possibility to constrain the characteristic energy scale parameter $\Lambda$ from the experimental limits on the couplings.

References


