Search for LED in the diphoton mode at the LHC with the CMS detector

Juan Francisco González Hernández
Daniel Fernández Moreno
Alejandro Barranco

1 Introduction: The experiment

The CMS collaboration has searched for large extra dimensions (LED) with proton-proton collisions at the LHC. The paper given, [1], studies the relevant s-channel is given by a virtual graviton exchange via gluon fusion considering a sample data collection of pp collisions[1] at $\sqrt{s} = 7$ TeV and integrated luminosity of $36pb^{-1}$. Hadronic collisions produces photon pairs by quark–antiquark annihilation as well as by gluon–gluon fusion. The analytic cross-sections are also reviewed, e.g., in [2], both theoretically and experimentally as well. The graviton decays into two photons as the graviton spin is two, and then, it can not decay into two $+1/2$ fermions. Moreover, the gravitons propagate through compact extra dimensions and we have to impose periodic boundary conditions to the wave function(symmetric wavefunction for bosons). The Kaluza-Klein (KK)spectrum is therefore discrete with a gap $\Delta E \sim 1/R$, where R is the size of the compact extra dimension. At the LED scenario, the extra dimension size R is "large", $R >> 1$, and so, the gap is so tiny that we have indeed an apparent continuous diphoton spectrum instead of different resonances.

2 The cut-off scale

The KK modes provide a divergent cross-section. It means that our theory is an effective theory valid up to the cut-off scale M_S (not necessarily equal to the Planck scale energy M_P). Thus, we are forced to integrate the cross-section $dE/d\sigma$ up to this ultraviolet (UV) scale M_S only. The UV cut-off depends on the specific features of the effective theory we consider and it is usually parametrized by a single parameter $\eta_G = \mathcal{F}/M_S^4$ that encodes the graviton effects in the cross-section. Previous experiments at HERA, LEP and Tevatron have provided strong bounds on M_S ($M_S > 1.3 - 2.1$ TeV), at the 95% confidence level (CL).

3 Event selection

The ECAL crystals only capture the EM energy due to photons and we have to reconstruct it and track where it came from. The main issue is that we

[1] The Tevatron searches include the alternative s-channel mode given by a quark-antiquark fusion. See the figures given in the appendix A.

can misidentify photons with hard hadron jets made with neutral pions or eta mesons, for instance. To avoid this happens, we impose some conditions on the signal (e.g. a bound on the hadronic energy of the cluster left in the ECAL, a condition on transverse momentum p_T and additional conditions on the transverse energy E_T) in order to identify the photon in a more consistent and unbiased way. We have also to optimize the data selection to be sensitive to the cutoff scale M_S and the number of extra dimensions n_{ED} with some extra lower bounds to the diphoton invariant mass $M_{\gamma\gamma} > 500$ GeV and a pseudorapidity band restriction to $|\eta| < 1.4$.

4 Background estimation

MonteCarlo (MC) simulations are used for event reconstruction. SHERPA generator for the LED scenario is used to capture different points for the cutoff and extra dimensions number, and it is followed by a CMS detector simulation. The main 2 background sources for misindentified events are: multijet production and prompt (fast) photons coming from jets plus a photon. The misidentification rate or ratio between isolated photons and non-isolated photons is measured from the simulation.

5 Results: analysis

A count of diphotons with the previous experimental conditions is made in the region with $M_{\gamma\gamma} > 500$ GeV and the quantity $S = (\sigma_{total} - \sigma_{SM})\,\beta\mathcal{A}$ is defined, where σ_{total} is the total observed diphoton production cross-section and σ_{SM} is the SM prediction. The beta parameter measures the signal branching ratio versus diphotons and the $\mathcal{A}$ is the aceptance of the signal. A bayesian approach is carried out for the systematics (cross-section, integrated luminosity, signal efficiency and background), choosing a flat prior for the cross-section and log-normal for the nuisance parameters. Thus, the likelihood function is constructed from Poisson probability (N events given S). The observed (expected)upper limit for SM signals is $S = 0.11(0.13)$ pb (95% CL) and we deduce from this limits on LED parameters with a simple idea: the expected deviation due to virtual graviton exchange that interfere with the SM processes is translated into the total cross-section $\sigma_{total} = \sigma_{SM} + \eta_a\sigma_{int} + \eta_G^2\sigma_{ED}$. For a given number of LED, η_G puts a limit on the cut-off scale M_S. For $S = 0.11(0.13)$ pb is deduced that $\eta_G < 0.070$ TeV^{-4} and $1/M_S^4 < 0.078$ TeV^{-4} (this last result for 2 LEDs). To every possible number of extra dimensions a bound on the cutoff-scale is deduced from these observables (table 3 in [1]).

6 Conclusions

The absence of an excess over the expected diphoton background from the SM predictions, a new stronger lower limit on M_S is established: $\mathbf{M_S > 1.6 - 2.3}$ TeV (95% CL). This new bound is higher than the one found in previous experiments (Tevatron, Hera,...). The search for extra dimensions in the diphoton channel continues.

A Figures

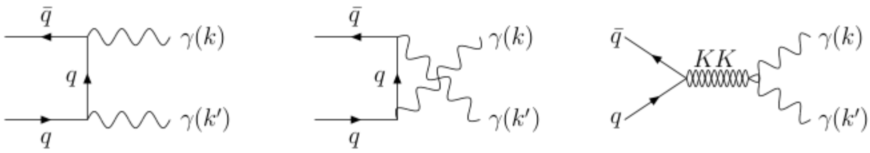

FIG. 1. Feynman diagrams contributing to the subprocess $q\bar{q} \to \gamma\gamma$, including the Kaluza–Klein graviton relevant for some colliders (Tevatron, Hera,. . .). Note that the most important diphoton production in this case will be top production and the Drell-Yan process (giving jet plus missing transverse energy).

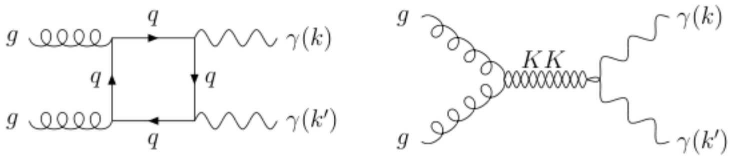

FIG. 2. Feynman diagrams contributing to the subprocess $gg \to \gamma\gamma$, including the Kaluza–Klein graviton exchange relevant for LHC searches of extra dimensions. Only the s-channel is sketched, the crossed diagrams are not displayed. At the LHC there are a very large gluon–gluon luminosity.

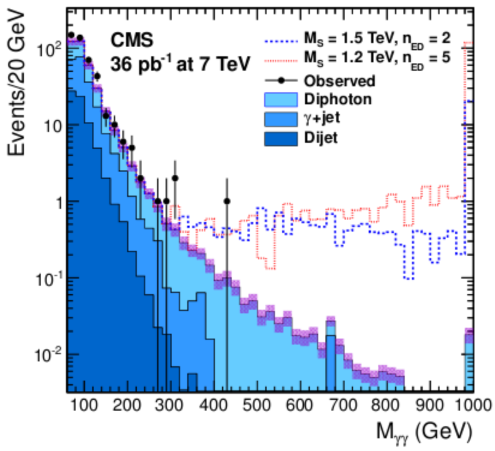

Fig. 3. Observed data and background expectations as a function of the diphoton invariant mass (fig.3 in [1])

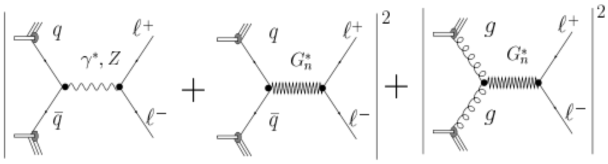

Fig. 4. The Drell-Yan for graviton virtual exchange in proton-antiproton collisions.

References

[1] *Search for Large Extra Dimensions in the Diphoton Final State at the Large Hadron Collider*, arxiv:1103.4279v1.

[2] *Diphoton Signals for Large Extra Dimensions at the Tevatron and CERN LHC*, arXiv:hep-ph/9908358v1