PROCEEDINGS OF SCIENCE

Search for resonances in the diphoton channel at the ATLAS experiment of the Large Hadron Collider

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A search has been performed for evidence of a narrow resonance in the diphoton invariant mass spectrum. The analysis uses the ATLAS 2010 data set of proton-proton collisions at a center-of-mass energy of 7 TeV, produced by the CERN Large Hadron Collider, corresponding to an integrated luminosity of 36 pb^{-1}. No evidence of a narrow resonance above the Standard Model background is observed. The results exclude at 95% confidence level Randall-Sundrum graviton masses below 545 GeV (920 GeV), for values of the dimensionless coupling $k/\overline{M}_{\mathrm{Pl}}$ of 0.02 (0.1).

ATL-PHYS-PROC-2011-200
31 October 2011

PoS(EPS-HEP2011)418

The 2011 Europhysics Conference on High Energy Physics-HEP 2011
July 21-27, 2011
Grenoble, Rhône-Alpes, France

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 http://pos.sissa.it/

1. Introduction

The difference in the Standard Model (SM) between the Planck scale and the electroweak scale is known as the hierarchy problem. Recently, there has been great interest in models which resolve the hierarchy problem through the existence of extra spatial dimensions. One popular example is the Randall and Sundrum model (RS) [1], which posits the existence of a fifth dimension with a "warped" geometry, bounded by two three-dimensional branes, with the SM fields localized on one brane and gravity originating on the other. The fundamental Planck scale on one brane is related to the apparent scale on the other by $M_D = M_{Pl}e^{-k\pi r_c}$, where k and r_c are the curvature scale and compactification radius of the extra dimension, respectively. If $kr_c \approx 11$, KK gravitons could be produced in high energy particle collisions, and would appear as resonances that subsequently decay to SM particle-antiparticle pairs. The phenomenology can be described in terms of the mass of the lightest KK graviton excitation (m_G) and the dimensionless coupling to the SM fields, $k/\overline{M}_{\rm Pl}$, where $\overline{M}_{Pl} = M_{Pl}/\sqrt{8\pi}$ is the reduced Planck scale. It is theoretically preferred [2] for $k/\overline{M}_{\rm Pl}$ to have a value in the range from 0.01 to 0.1. In this article, we report on a search for RS graviton resonances in the diphoton final state, using a data sample recorded during 2010 with the ATLAS detector [3] at the Large Hadron Collider (LHC) and corresponding to an integrated luminosity of 36 pb^{-1} of $\sqrt{s} = 7$ TeV proton-proton (pp) collisions [5].

2. Event Selection and Background determination

Photon candidates were required to have $E_T > 25$ GeV, to satisfy $|\eta| < 2.37$ and to be outside the transition region $1.37 < |\eta| < 1.52$ between the barrel and end-cap calorimeters [1]. The analysis uses a "loose" photon identification which includes cuts on the energy in the hadronic calorimeter as well as on variables that require the transverse width of the shower, measured in the second EM calorimeter layer, be consistent with the narrow width expected for an EM shower. The loose selection provides a high photon efficiency ($\approx 94\%$) with modest rejection against the background from jets.

The main backgrounds for this analysis include the irreducible background from SM diphoton production, and reducible backgrounds from QCD γ + jet and multijet events with at least one fake photon. The inclusive shape of the diphoton invariant mass distribution of the background is determined from a fit to a control region of masses between 120 and 500 GeV, which is a region in which the Tevatron results have already excluded an RS graviton within the preferred range of values of $k/\overline{M}_{\rm Pl}$ (< 0.1).

3. Results and Conclusions

The invariant mass spectrum for diphoton candidates passing the selection cuts including loose photon identification is shown in Fig. 1 for the full mass range above 120 GeV. Superimposed are the 1σ and 2σ uncertainty bands on the background prediction.

[1]ATLAS uses a right-handed coordinate system with its origin at the nominal interaction point in the centre of the detector and the z-axis along the beam pipe. Cylindrical coordinates (r,ϕ) are used in the transverse plane, ϕ being the azimuthal angle around the beam pipe. The pseudorapidity η is defined in terms of the polar angle θ by $\eta = -\ln\tan(\theta/2)$.

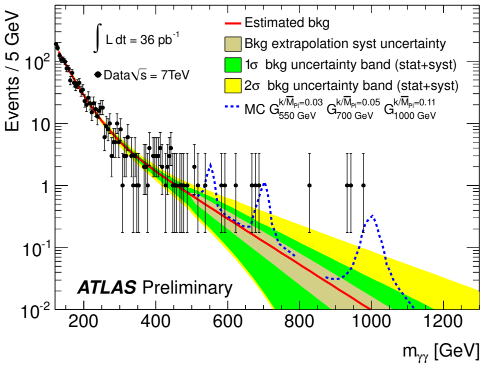

Figure 1: Reconstructed $m_{\gamma\gamma}$ distribution for data (points) and expected background (red line) [5]. Also shown are graviton signals of masses 550, 700 and 1000 GeV and couplings $k/\overline{M}_{\rm Pl}$= 0.03, 0.05 and 0.11, respectively. The signal is normalized to the number of expected events in an integrated luminosity of 36 pb^{-1}.

The data are found to be well described by the smooth background parametrization over the entire mass range, and there is no evidence of a narrow resonance. Therefore, we set limits on graviton production by following the modified frequentist method [4]. Limits at 95% CL on the production cross section times branching ratio of an RS model graviton decaying into two photons as a function of the lightest graviton mass are shown on Figure 2. Also shown are the results interpreted in the $k/\overline{M}_{\rm Pl}$ versus graviton mass plane and the corresponding Tevatron results, for comparison. We exclude masses below 545 GeV (920 GeV), for values of the dimensionless coupling $k/\overline{M}_{\rm Pl}$ of 0.02 (0.1).

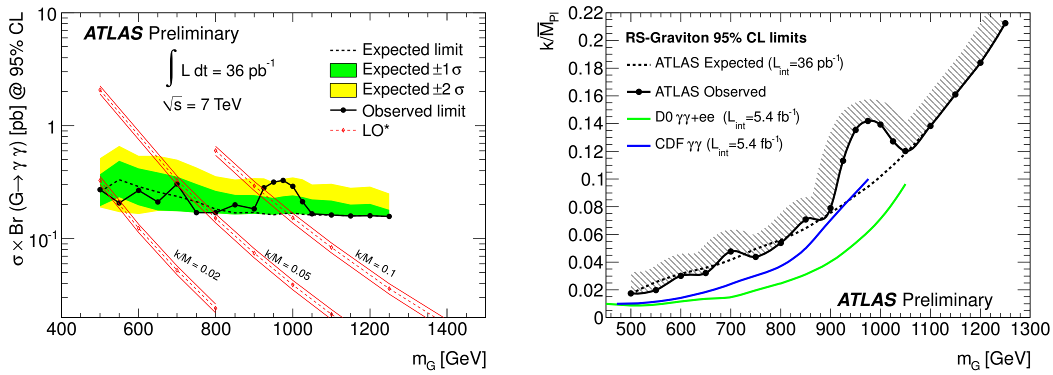

Figure 2: (left) The 95% CL limit on the production cross section times branching ratio of an RS model graviton decaying into two photons as a function of the graviton mass [5]. Superimposed are the theoretical cross section prediction bands for a variety of $k/\overline{M}_{\rm Pl}$ values. (right) 95% CL excluded region in the plane of $k/\overline{M}_{\rm Pl}$ versus graviton mass. Also shown are the expected limit and published limits from the Tevatron experiments [6] [7].

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