PLHC 2011, June 06-11

Searches with di-photon resonances and di-photon plus missing transverse energy final states in ATLAS

Introduction:

Many processes beyond the Standard Model predict di-photon final states accessible at the LHC. The early LHC searches involving such signatures include Universal Extra Dimension (UED) models with gravity mediated decays [2] and Randall-Sundrum (RS) scenarios [1].

In UED models, a di-photon plus large missing transverse energy signature arises from the cascade decay of Kaluza Klein (KK) excitations subsequently followed by the gravitational decay of a KK photon into a graviton and photon. In RS models, on the other hand, graviton decays give rise to di-photon resonance signatures.

These searches have been performed in ATLAS with the full 2010 data corresponding to 36 pb^{-1} (RS model) and the first 3.1 pb^{-1} collected by ATLAS in 2010 (UED model).

No deviations from the Standard Model background have been observed.

Di-photon + Missing Transverse Energy

Motivation and Selection:

Motivation:

Models with UEDs postulate a tower of KK excitations for every standard model particle. Momentum conservation in these extra dimensions manifests itself as KK number conservation. At the LHC, a pair of 1^{st} level KK excitations can be produced via strong interactions which will cascade decay to the Lightest KK Particle (LKP- γ^*). If this model is embedded in N additional eV^{-1}-sized dimensions accessible only to gravity, each LKP could decay gravitationally via $\gamma^* \to \gamma + G$, where G represents a tower of eV^{-1} spaced graviton excitations that would escape detection. The final state would then be $\gamma\gamma + \not{E}_T + X$.

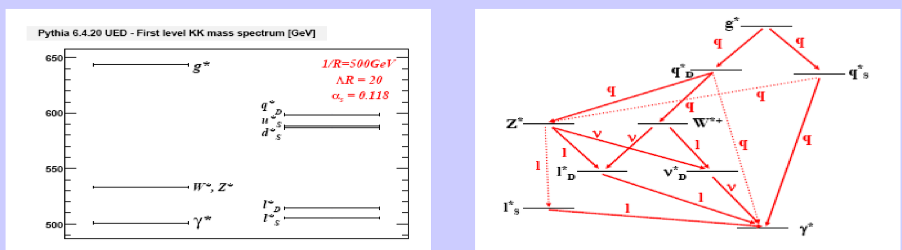


Fig. 1 – An example of KK particle mass spectrum (left). Dominant (solid) and rare (dotted) decays of KK particles.

Selection:

I. Events with at least two photons with E_T>25 GeV and $|\eta|$<1.37 or 1.52<$|\eta|$<1.81

II. Identification of 'Loose' photons includes cuts on the EM shower shape variables in the 2^{nd} layer of the EM calorimter and energy leakage into the hadronic calorimeter.

III. $\not{E}_T$ > 75 GeV

Background Estimation:

The background SM processes in the high $\not{E}_T$ region include:

I. 'QCD' events including $\gamma\gamma$, γ+jet, multijet processes and described by a combination of Z->ee and 'misidentified jets' (one photon fails the identification criterion) control samples.

II. 'W(->ev)+X' $\not{E}_T$ spectrum is scaled down according to the e->γ fake rate.

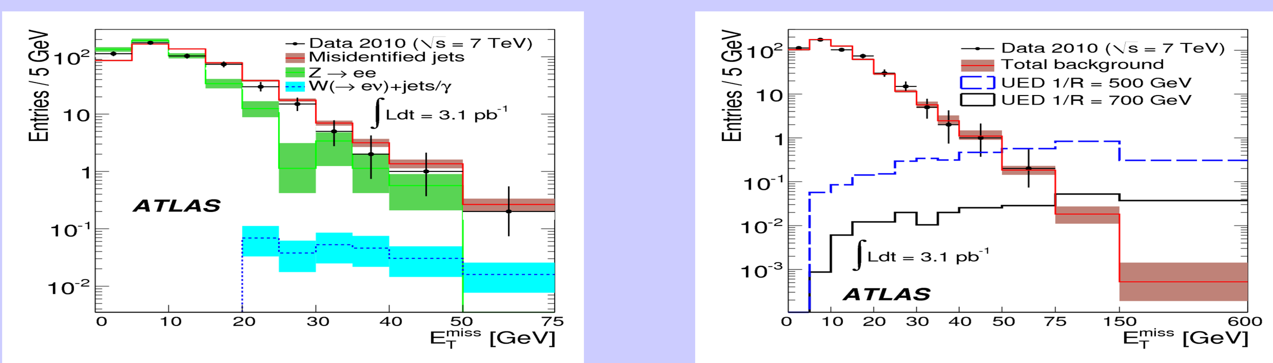
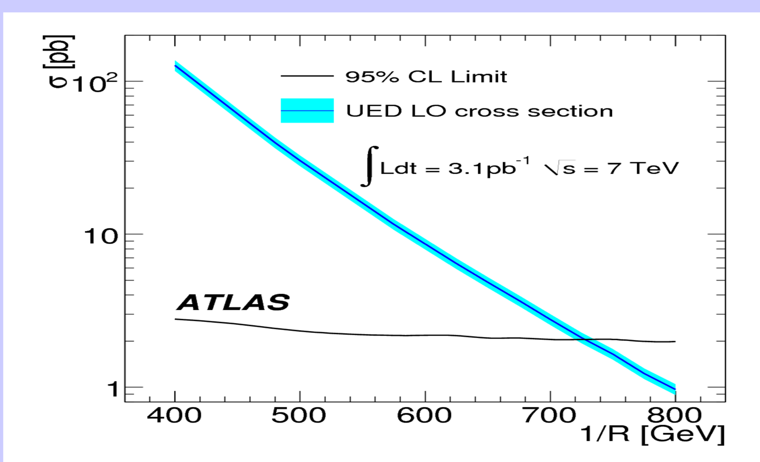


Fig. 3 – $\not{E}_T$ distribution of data in the signal region and background control samples; Z->ee and 'misidentified jets' $\not{E}_T$ spectra (used to model 'QCD' events and normalized to the signal region for $\not{E}_T$<20 GeV) and W(->ev)+X $\not{E}_T$ spectrum (left). $\not{E}_T$ spectrum in data (points) as compared to the expected SM background (brown) and sample UED points (right).

Results:

Fig. 5 – No statistically significant excess is observed in the $\not{E}_T$ spectrum of $\gamma\gamma$ events beyond the predicted SM background. Given the good agreement between the measured $\not{E}_T$ spectrum and the expected SM background prediction, a limit was set on the UED compactification radius R. The observed 95% CL exclusion region is for 1/R < 728 GeV. This limit is the most stringent test of this model to date [3].



Di-photon Resonance

Motivation and Selection:

Motivation:

Minimal RS models postulate the existence of a 'warped' fifth dimension bounded by two (3+1)-dimensional branes. Standard Model (SM) particles are assumed to be localized on one of the branes whereas gravitons are localized on the other and can propagate into the bulk. As a result a tower of Kaluza-Klein (KK) graviton excitations with a universal dimensionless coupling, k/M_{Pl} (where k is the curvature of the 'warped' dimension and M_{Pl} is the reduced planck scale), to the SM fields is predicted. Geometric "warp" factors naturally reduce Planck scales to the TeV range thereby providing a natural solution to the hierarchy problem. The graviton decay to two photons is of particular interest because of its larger cross-section (twice that of charged leptons) and its ability to rule out alternative interpretations (such as Z' bosons). In this scenario, the graviton would be experimentally observed as a narrow di-photon resonance.

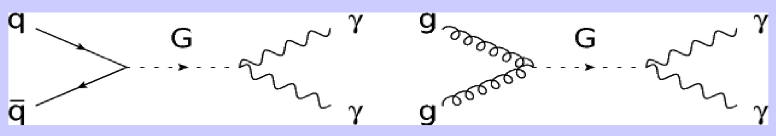


Fig. 2 - LO Feynman diagrams for graviton production and decay to two photons.

Selection:

I. Events with at least two photons with E_T>25 GeV and $|\eta|$<1.37 or 1.52<$|\eta|$<2.37

II. Identification of 'loose' photons includes cuts on the EM shower shape variables in the 2^{nd} layer of the EM calorimeter and energy leakage into the hadronic calorimeter.

Background Estimation:

The background processes in the high mass range are mainly arise from irreducible SM $\gamma\gamma$ and reducible γ+jet and multijet events. This background is estimated from data in the mass range 120-500 GeV (excluded by the Tevatron) by fitting to the sum of two exponentials and extrapolated to the higher mass regions.

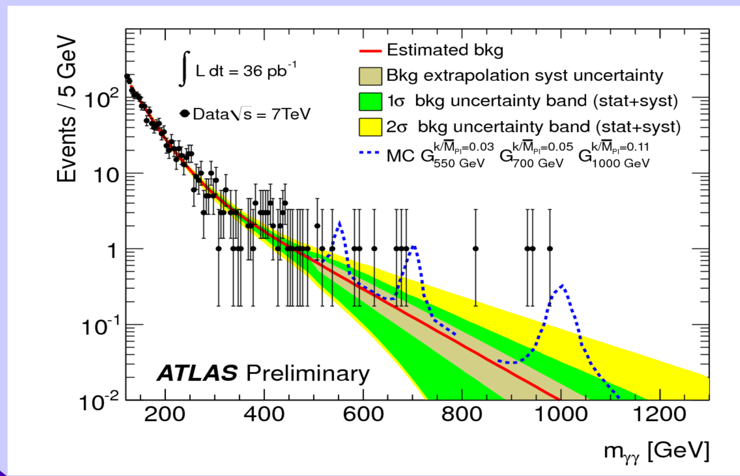
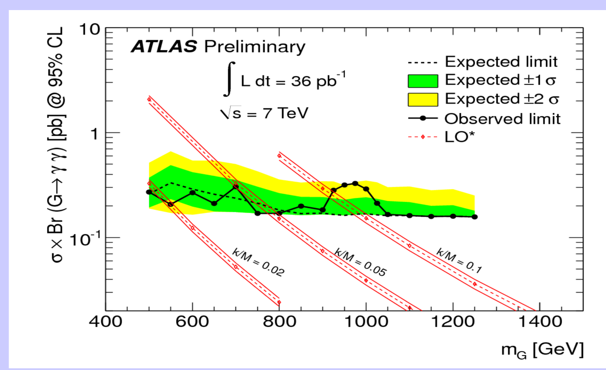


Fig. 4 - Reconstructed $m_{\gamma\gamma}$ distribution for data (points) and expected background (red line). Also shown are graviton signals of masses 550, 700 and 1000 GeV for various couplings.

Results:

Fig. 6 - No statistically significant deviation is observed in the di-photon invariant mass distribution above the estimated SM background. A limit on the graviton->$\gamma\gamma$ cross section has, therefore, been set as a function of graviton mass (M_G). Superimposed are the theoretical cross section prediction bands for a variety of k/M_{pl} values.



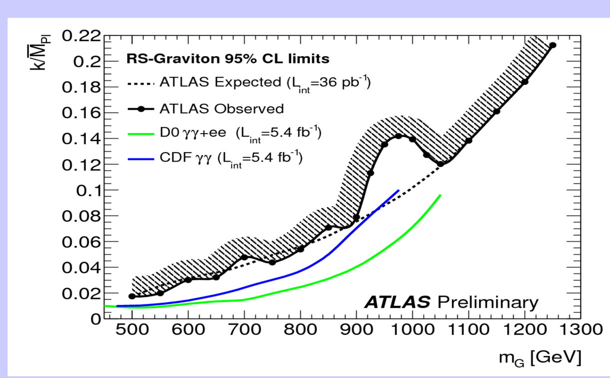


Fig. 7 – Since the graviton->$\gamma\gamma$ cross section also depends on the dimensionless coupling k/M_{pl}, a constraint on the k/Mpl and M_G parameter space can also be set. The result exclude at 95% C.L. RS graviton masses below 545 (920) GeV for the dimensionless RS coupling k/M_{pl}=0.02 (0.1).

References:

[1] The ATLAS Collaboration, "A Search for High Mass Diphoton Resonances in the Context of the Randall-Sundrum Model in √s = 7 TeV pp Collisions", ATL-CONF-2011-044(2011).

[2] The ATLAS Collaboration, "Search for Diphoton Events with Large Missing Transverse Energy in 7 TeV Proton-Proton Collisions with the ATLAS Detector", Phys.Rev.Lett., 106(2011).

[3] D0 Collaboration, "Search for diphoton events with large missing transverse energy in 6.3 fb^{-1} of p-pbar collisions at sqrt(s)=1.96 TeV", Phys.Rev.Lett., 105(2010).

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