Searches for new physics in dijet and diphoton final states with ATLAS

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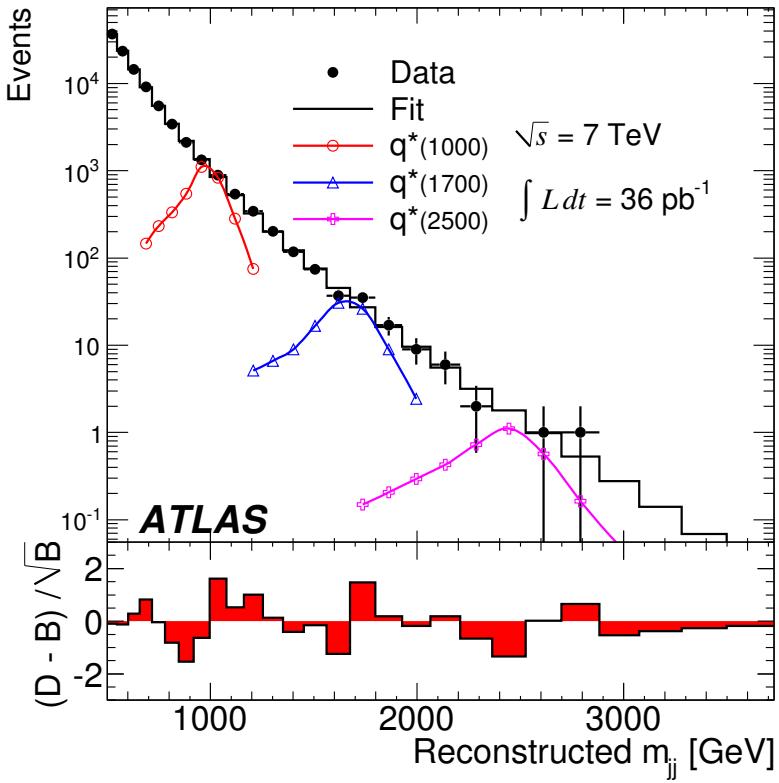
Introduction

- Several results from the ATLAS experiment are available in searches for new physics in dijet and diphoton final states
  1. Search for New Physics in dijet Mass and Angular Distributions in pp Collisions at $\sqrt{s} = 7$ TeV Measured with the ATLAS Detector [arxiv:1103.3864]
  2. A Search for Randall-Sundrum Gravitons Decaying to Photon Pairs in $\sqrt{s} = 7$ TeV pp Collisions [ATLAS-CONF-2011-044]
  3. Search for a two photon + E_T^{miss} final state in $\sqrt{s} = 7$ TeV pp collisions at the LHC using the ATLAS detector in the context of the One Universal Extra Dimension model with gravity mediated decays [arxiv:1012.4272]
- These results are based on proton-proton collision data collected in 2010 at a centre-of-mass energy of $\sqrt{s} = 7$ TeV

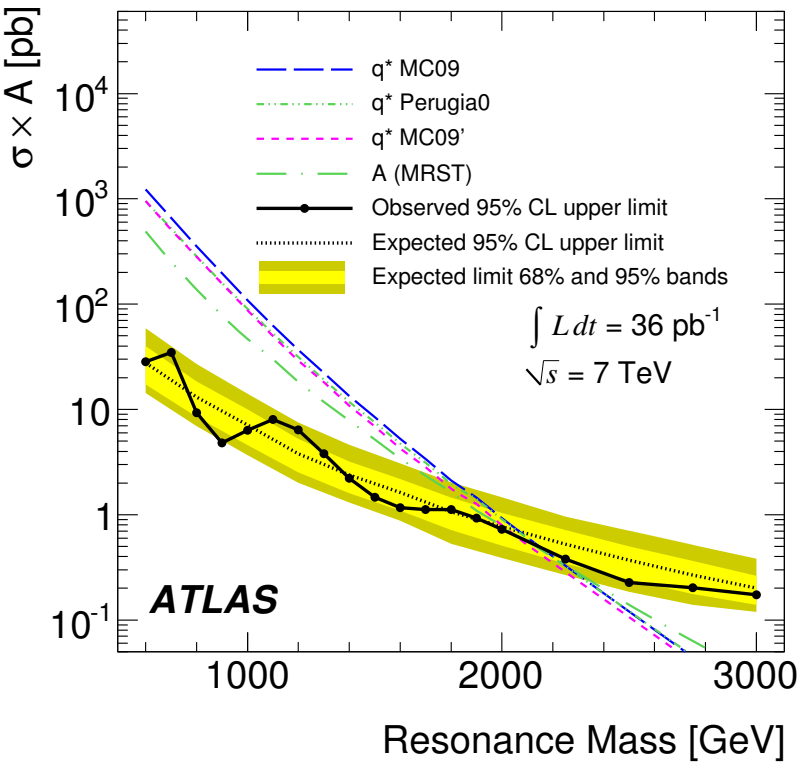
dijet analysis

- This analysis focuses on those final states where two very energetic jets of particles are produced with large transverse momentum (p_T) transfer.
- Although these '$2 \rightarrow 2$' scattering processes are well described within the Standard Model (SM), they could also arise from the production of a new massive particle that then decays into a dijet final state, or their rate could be enhanced through a new force.
- We perform searches for new phenomena by studying both the dijet invariant mass, m_{jj}, and the angular distributions of energetic jets relative to the beam axis, usually described by the polar scattering angle in the two-parton CM frame, θ^*

Limit setting(I)



The observed (D) dijet mass fitted using a binned QCD background (B)



The 95% C.L. upper limits on the cross section times acceptance

Limit setting(II)

- Excited Quark Production: Exclude at 95% C.L. q^* masses in the interval $0.60 < m_{q^*} < 2.15$ TeV. The expected limit excludes $m_{q^*} < 2.07$ TeV.
- Axigluon Production: Exclude at 95% C.L. axigluon masses in the interval $0.60 < m < 2.10$ TeV. The expected lower limit is $m < 2.01$ TeV.
- Quantum Black Hole Production:

Number of Extra Dimensions	Observed M_D Limit [TeV]		Expected M_D Limit [TeV]	
	Stat. $\oplus$ Syst.	Stat. only	Stat. $\oplus$ Syst.	Stat. only
2	3.20	3.22	3.18	3.20
3	3.38	3.39	3.35	3.37
4	3.51	3.52	3.48	3.50
5	3.60	3.61	3.58	3.59
6	3.67	3.68	3.64	3.66
7	3.73	3.74	3.71	3.72

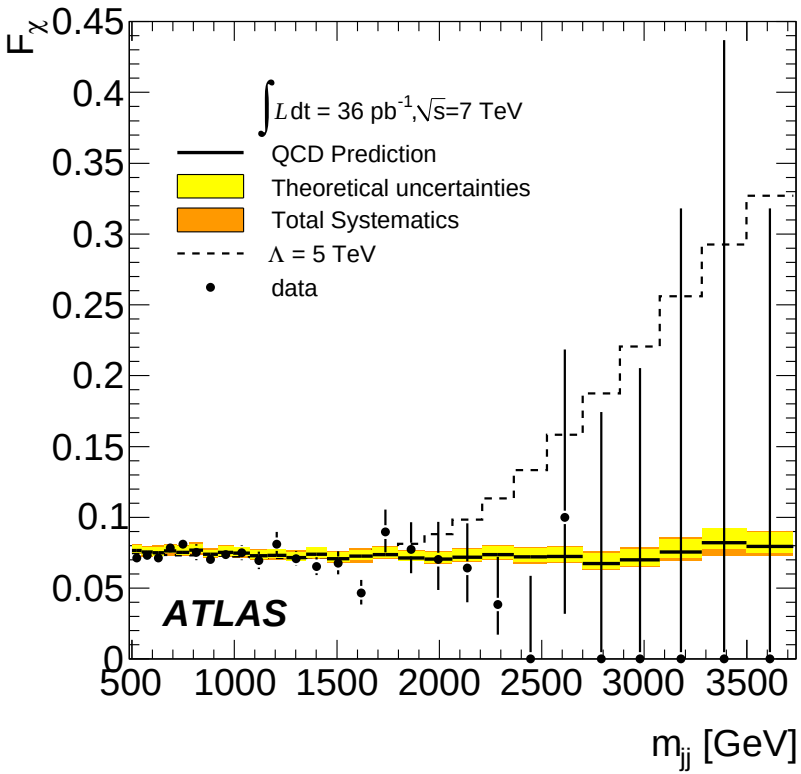
- Randall-Sundrum gravitons: No exclusion, the lower production cross section and our selection criteria reduce the sensitivity

Event selection and Some definitions

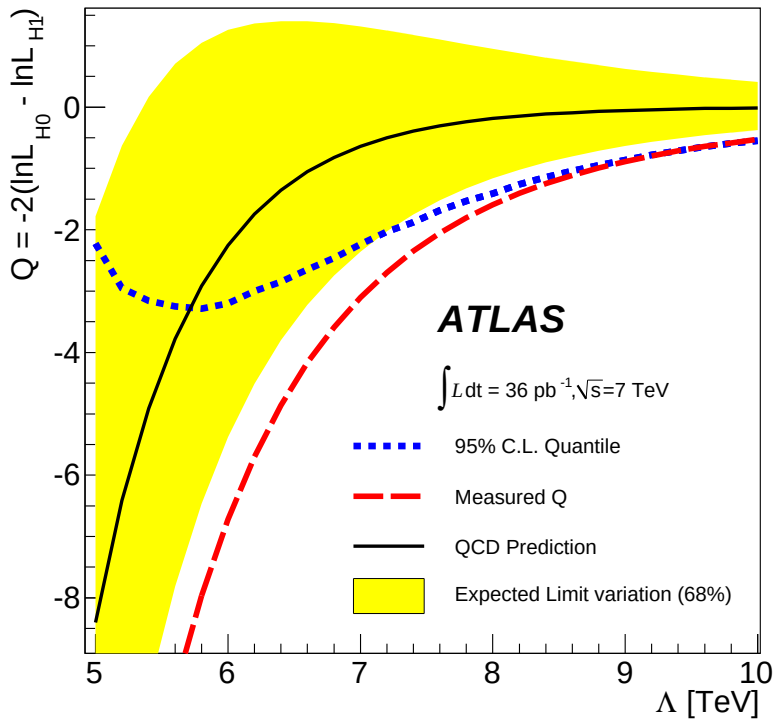
- $p_T^{j_1} > 60$ GeV and $p_T^{j_2} > 30$ GeV
- χ distributions are accumulated only for events that satisfy $|y_B| < 1.10$ and $|y^*| < 1.70$
  - For a given scattering angle θ^*, the corresponding rapidity in the parton CM frame is $y^* = \frac{1}{2}\ln(\frac{1+|\cos\theta^*|}{1-|\cos\theta^*|})$.
  - $y^* = \frac{1}{2}(y_1 - y_2)$ and $y_B = \frac{1}{2}(y_1 + y_2)$
- $\chi \equiv \exp(|y_1 - y_2|) = \exp(2|y^*|)$.
  - The χ distributions associated with QCD interactions are relatively flat compared with the distributions associated with new particles or interactions
- A measure of isotropy based on y^* intervals:

$$F_\chi\left(\left[m_{jj}^{min} + m_{jj}^{max}\right]/2\right) \equiv \frac{N_{events}(|y^*| < 0.6, m_{jj}^{min}, m_{jj}^{max})}{N_{events}(|y^*| < 1.7, m_{jj}^{min}, m_{jj}^{max})} \quad (1)$$

Exclusion Limits(I)



The $F_\chi(m_{jj})$ distribution as a function of m_{jj}



The log-likelihood ratio versus the interaction strength

Exclusion Limits(II)

- Limits on Quark Contact Interactions: Observed $\Lambda = 9.5$ TeV, expected $\Lambda = 5.7$ TeV
- Limits on Excited Quark Production: Observed $m_{q^*} = 2.64$ TeV, expected $m_{q^*} = 2.12$ TeV
- Quantum Black Hole Production:

The 95% C.L. exclusion limits on M_D

n Extra Dimensions	Expected Limit (TeV)	Observed Limit (TeV)
2	2.91	3.26
3	3.08	3.41
4	3.20	3.53
5	3.29	3.62
6	3.37	3.69
7	3.43	3.75

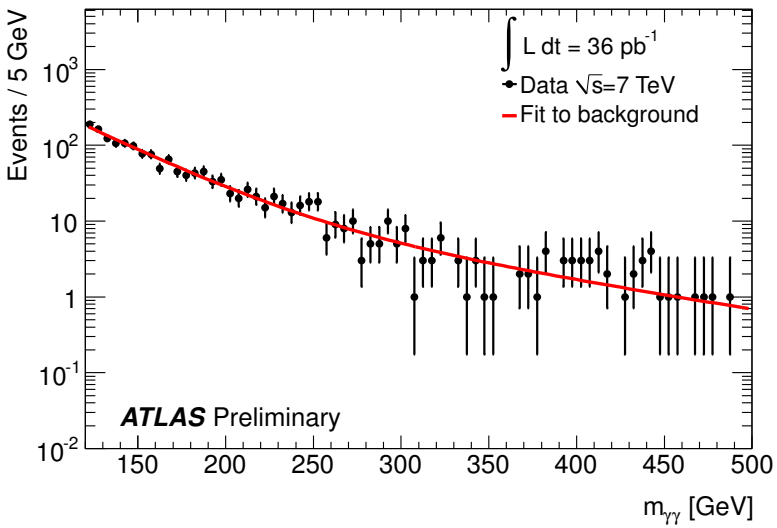
General description

- A variety of new physics models predict signatures of photons accessible at LHC
- The models to which LHC early data are senstive include:
  - Universal Extra Dimension (UED) where diphoton events with large transverse missing energy could be produced from excited Kaluza-Klein (KK) particles' cascade decay
  - Randall-Sundrum (RS) model which predicts a graviton production followed by the decay to two photons
- The search for diphoton events with large transverse missing energy is performed with the first 3.1 pb^{-1} collected in 2010, while the search for RS graviton resonance used the full data recorded in 2010, namely 36 pb^{-1}

Motivation

- RS model is a popular theoretical resolution to the hierarchy problem through the existence of extra spatial dimensions
- A striking signature of the RS model at hadron colliders would be graviton production, followed by their decay to pairs of SM fermions or bosons.
- The graviton decay $G \rightarrow \gamma\gamma$ is particularly interesting
  - Observation of a resonance in the diphoton final state would rule out some possible alternative interpretations, such as Z'.
  - The production cross section is expected to be twice that of charged leptons
  - The experimental backgrounds are relatively low, and the excellent energy resolution would provide a good mass resolution

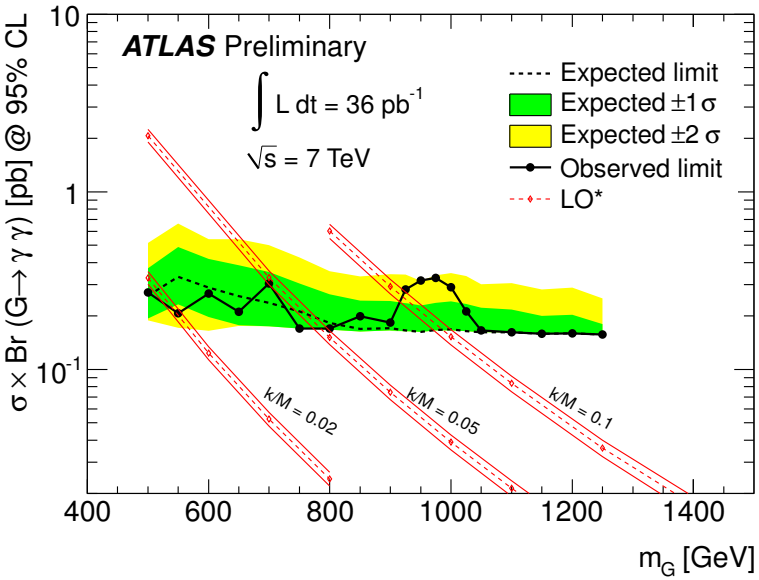
Background estimation



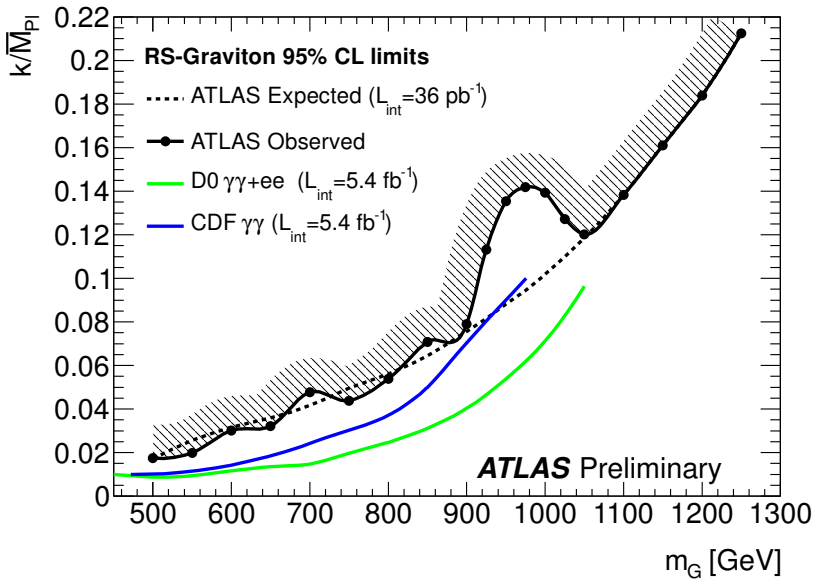
diphoton candidate invariant mass distribution measured in the control region of 120 - 500 GeV

- The main backgrounds for this analysis include:
  - SM diphoton production
  - QCD γ + jet and multijet events
- The background is determined from a fit (a sum of two exponential functions) to a control region

Exclusion limit



The 95% CL on the production cross section times branching ratio of an RS model graviton decaying into two photons as a function of the graviton mass

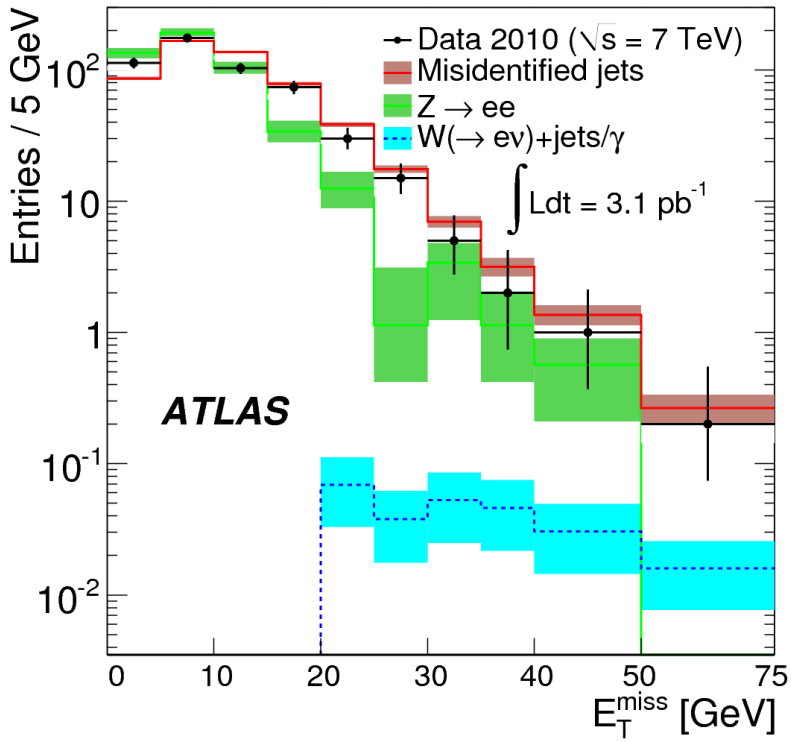


95% CL excluded region in the plane of $k/\overline{M}_{\mathrm{Pl}}$ versus graviton mass. Also shown are the expected limit and published limits from the Tevatron experiments

Motivation

- The One Universal Extra Dimension (UED) model with one TeV^{-1} sized extra dimension can be considered as an effective theory valid below some cutoff scale $\Lambda > 1/R$, where 1/R is the curvature of the extra dimension.
  1. In this model, each SM particle has $n = 1, 2, 3, ...$ Kaluza Klein (KK) excitations
  2. If the $(4+1)$-dimensional UED space is embedded into a larger space of $(4+N)$ dimensions, then gravity mediated decays also become possible
- At LHC, two KK paticles are produced which then hadronize and cascade decay down to two lightest KK particles (LKP, which is excited photon)
  1. The final state consists of soft jets from the cascade decay, two photons and two gravitons.
  2. The two gravitons in the event are undetectable and will produce missing transverse energy E_T^{miss}

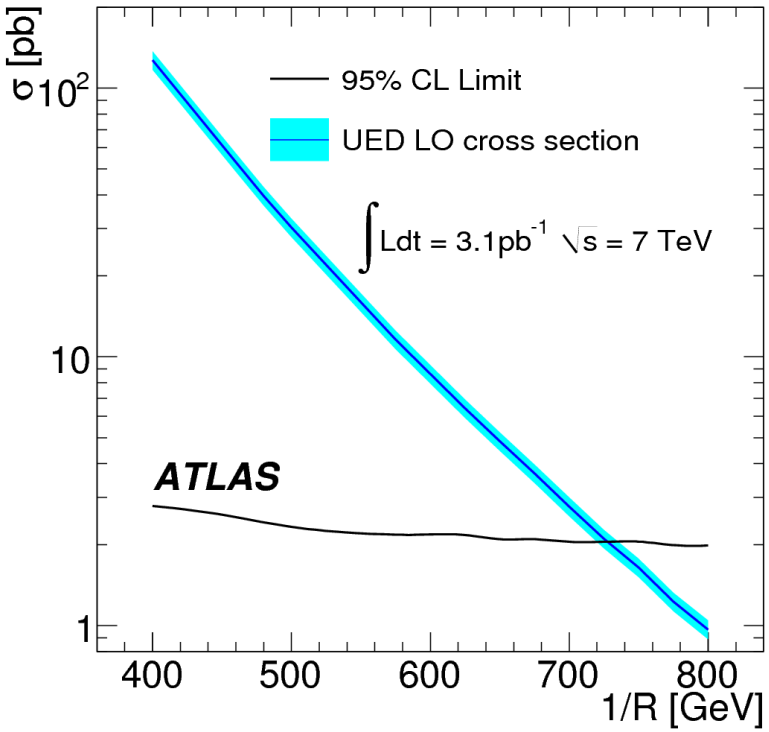
Background estimation



E_T^{miss} distributions

- Events with "fake" E_T^{miss}
  - SM diphoton production, γ+jet and dijet events
  - The background is described by a linear combination of $\mathrm{Z} \rightarrow \mathrm{ee}$ E_T^{miss} spectrum and misidentified jets E_T^{miss} spectrum
- W boson events
  - $\mathrm{W}(\rightarrow \mathrm{e}\nu) + \mathrm{jets}/\gamma$ E_T^{miss} spectrum is scaled down according to $e \rightarrow \gamma$ misidentification rate

Limit on the curvature of the UED 1/R



95% CL upper limits on the UED production cross section

- We are setting Bayesian limit, different priors have been tested (number of events in table)

1/R [GeV]	**Gaussian**	**Log-Normal**	**Uniform**
300	3.25	3.19	3.07
460	3.24	3.18	3.06
600	3.24	3.18	3.06
700	3.24	3.18	3.06
800	3.24	3.18	3.06

- For 3.1 pb^{-1}, we can exclude $1/R \leq 724$ GeV with 95% C.L.

Summary

- Several ATLAS search results for new physics beyond Standard Model in dijet and diphoton final states are presented.
- There is no evidence of an excess. Limits are set on a series on theoretical models:
  - dijet resonance: Excited Quark, Quantum Black Hole, Randall-Sundrum Graviton
  - dijet angular: Quark Contact Interaction, Excited Quark, Quantum Black Hole
  - diphoton resonance: Randall-Sundrum Graviton
  - diphoton + E_T^{miss}: One Universal Extra Dimension Model
- ATLAS/LHC is operated efficiently, much more data is coming.