Exotic Di-Photon Resonances at the ATLAS Experiment

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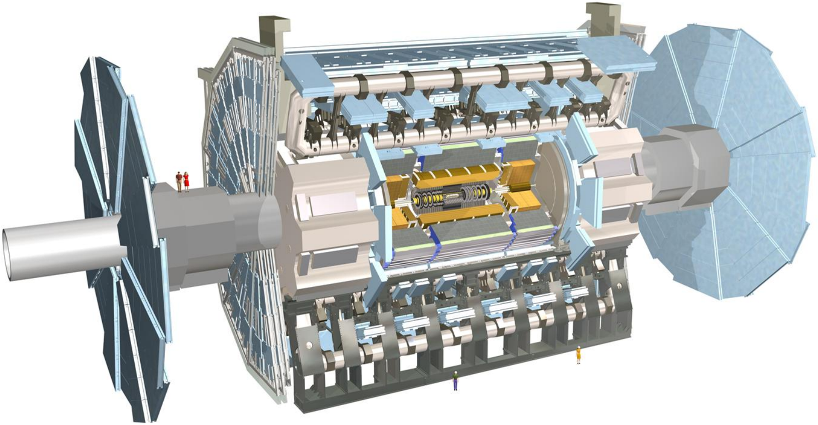
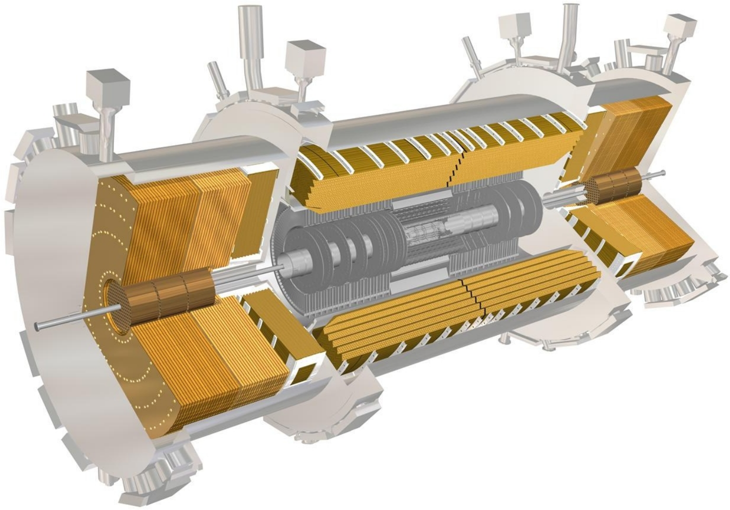
ATLAS

A general purpose particle detector



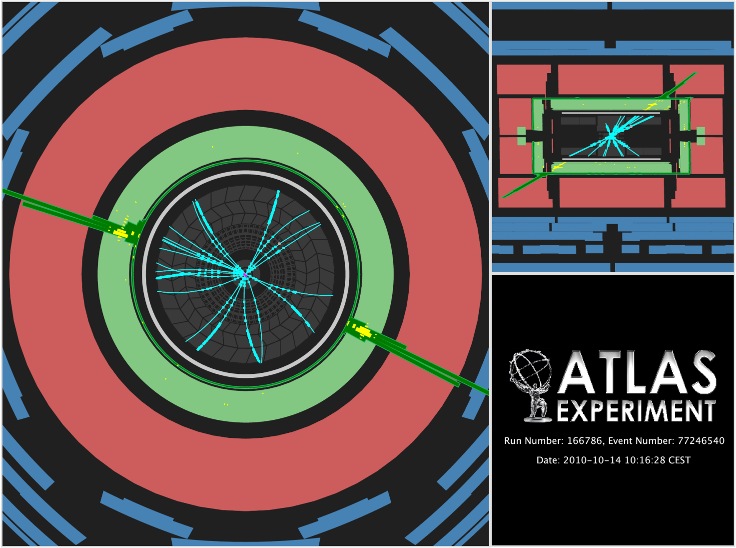
By now, a familiar image.

The EM Calorimeter

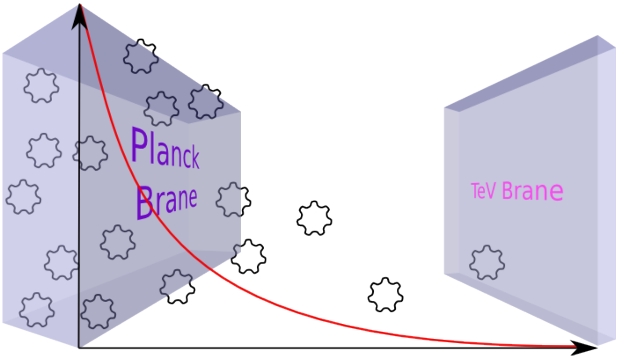


Provides good resolution and efficiency out to high energies.
Barrel: $|\eta| < 2.5$, inner layer granularity $\Delta\eta \times \Delta\phi = 0.05 \times 0.05$

Highest invariant mass $\gamma\gamma$ pair ATLAS saw in 2010



Brane worlds - a solution to the heirarchy problem?

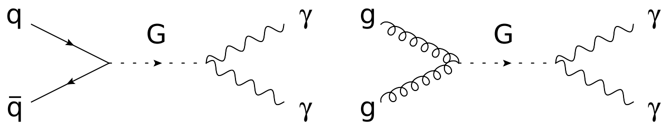


Distance in additional dimension

- The Randall Sundrum model
- Could solve the Hierarchy problem, explaining why Gravity is weak compared with the other forces.
- Components of momentum in the additional dimension would manifest themselves as mass in ours.

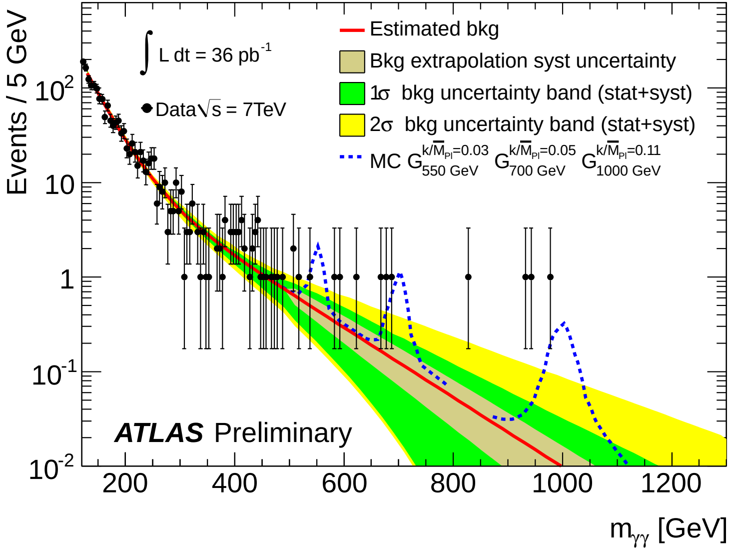
Interesting features of $G \to \gamma\gamma$

Through Kaluza Klein, the G would have a number of massive states, of which we might observe the first.
Resonant production at LHC:



- Model has two free parameters, M_G and $k/\overline{M_{pl}}$
  - Resonance width (Γ) and cross section $(\sigma) \propto k/\overline{M_{pl}}$
- $\gamma\gamma$ channel is particularly interesting because the branching ratio is enhanced relative to leptons.
- Backgrounds:
  - Irreducible: SM diphoton
  - Reducible: fakes from rare QCD and multi-jet configurations
- Both fall rapidly with increasing mass. If the Graviton existed, it would appear strongly above the background.

Mass spectrum



Searching for a narrow resonance on a smoothly falling background, therefore it is necessary to know the expected number of signal and background events. Once we have these, we can apply $\mathrm{CL_S}$ to obtain frequentist limits.

> *"What is the maximum $\sigma \times Br$ that this process is allowed to have, given our data, with 95% confidence?"*

Analysis Strategy

Selection

- Standard ATLAS $E\gamma$ data, object quality and jet cleaning cuts
- Primary vertex requirement
- η outside crack region and inside barrel
- $p_T > 25$ GeV
- Loose γ identification cuts
  - (greater mass reach, preserved background shape, limit doesn't get worse)
- Diphoton pair with $M_{\gamma\gamma} > 120$ GeV.

1,650 candidates after selections

Analysis Strategy

Background determination

- Background determination
  - Not possible use Monte-Carlo for QCD background - it is known not to be modelled very well and would require simulating our detector for more events than is feasible
  - Therefore it is necessary to use data-driven methods

1. Pick a control region, in which G is ruled out by previous experiments (e.g. $M_{\gamma\gamma} < 500$ GeV)
2. Model with a double exponential and fit to the data
3. Extrapolate
4. Compute uncertainties for anything which can affect the shape of the extrapolated curve.

Analysis Strategy

Uncertainties which affect background extrapolation

Systematic uncertainties on the shape are important, for example:

- Statistical uncertainty on fit
- NLO corrections
- Choice of fit window
- Detector response
  - Energy scale
  - Resolution
  - Identification
  - Efficiency

.. and their extrapolation to high $M_{\gamma\gamma}$.

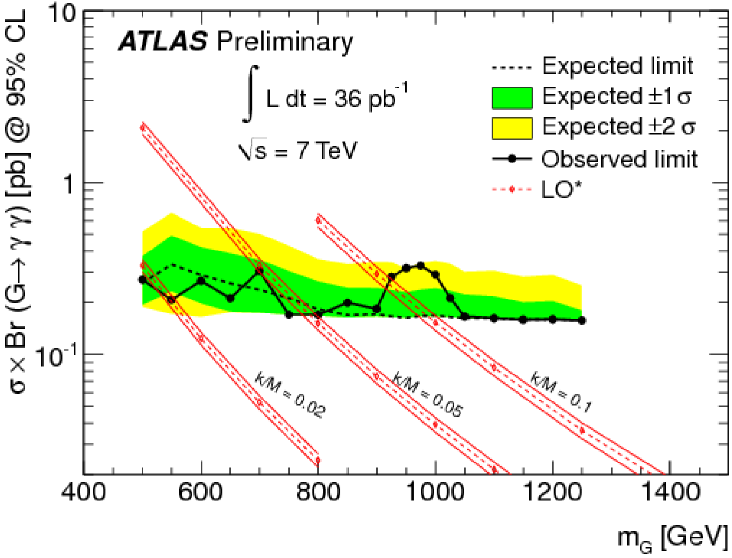
Analysis Strategy

Search and limit setting

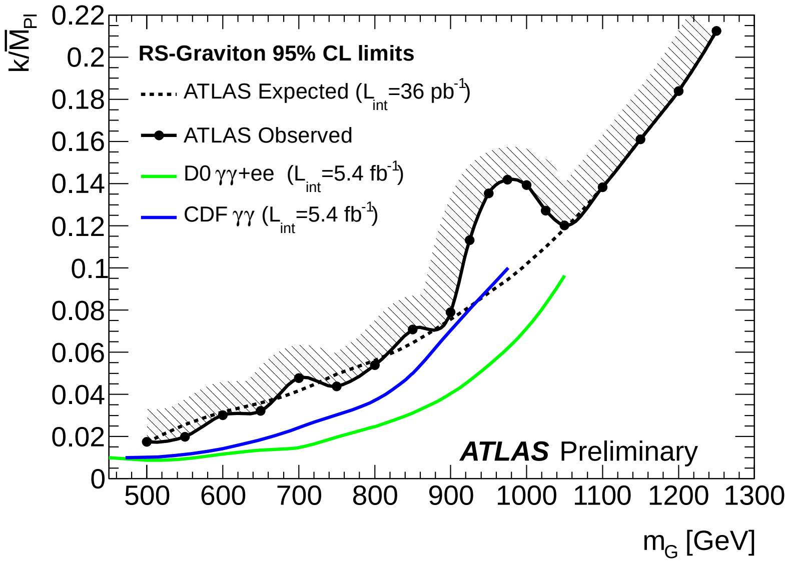
Using the modified frequentist method in the spirit of $\mathrm{CL_S}$, perform many pseudo-experiments with a test statistic for each one.
For each experiment:

- Simulate signal and background in multiple mass windows
- Define likelihood $\mathscr{L}$ as the probability to observe the data given just the background (B), or the signal + background ($S+B$).
- Log likelihood ratio: $LLR = \ln \mathscr{L}(S+B) - \ln \mathscr{L}(B)$
- Take the sum of the log likelihood ratio across bins
- Perform many pseudo-experiments under both $S+B$ and B hypotheses
- Scale the cross section to find the point at which $\mathrm{CL_S} = 0.05$

CLs $\sigma \times$ Br Limits



Graviton exclusion



Conclusion and outlook

- ATLAS is rapidly catching up with DØ and CDF sensitivity for the Randall Sundrum model, obtaining similar limits with 150× less data
- Gravitons excluded for masses below 500 GeV
  - (1200 GeV for larger couplings)
- What next?
  - Combination with e^+e^- and $\mu^+\mu^-$ channels
  - Looking forward to 2011 data!

Paper reference: ATLAS-CONF-2011-044