Search for high-mass dielectron resonances at ATLAS

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Introduction

Using ~ 1 fb^{-1} of 7 TeV *pp* collision data recorded with the ATLAS detector, we have searched for narrow high-mass resonances decaying into electron pairs.

Models considered in this search:

Spin 1: Sequential Standard Model (SSM) Z'

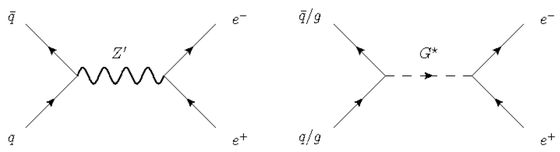
- same couplings as Standard Model Z

Spin 1: Grand Unification Model E_6

- E_6 gauge group broken into SU(5) and two U(1) (ψ and χ)
- $Z'(\theta_{E_6}) = Z'_{\psi}\cos(\theta_{E_6}) + Z'_{\chi}\sin(\theta_{E_6})$
  where $0 \le \theta_E < \pi$ is the mixing angle

Spin 2: Randall-Sundrum (RS) gravition

- additional spatial dimensions as solution to hierarchy problem
- excited Kaluza-Klein modes of graviton
- studied couplings 0.01-0.1 (0.1 as baseline)

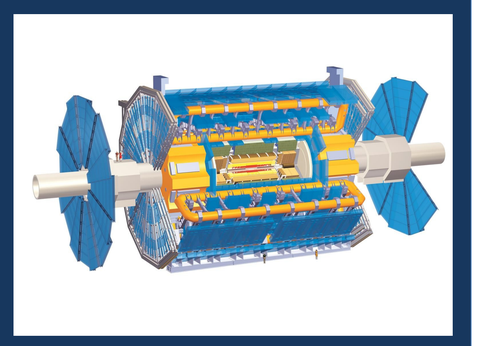


ATLAS Detector

Main detector systems of ATLAS used in this analysis:

Inner Tracking Detector
- Si pixel, Si strips, transition radiation detectors
- immersed in homogeneous 2 T magnetic field
- $|\eta| < 2.5$
- ► reconstructs charged particle tracks and vertices

Calorimeter
- liquid argon-lead sampling for electromagnetic part
- scintillating tiles-iron sampling (central), liquid argon-copper/tungsten ($|\eta| > 1.7$)
- $|\eta| < 4.9$
- ► 3 dimensional reconstruction of particle showers



Electron candidates: Clusters in electromagnetic calorimeter, associated tracks

Event Selection

Single electron trigger (E_T > 20 GeV)

2 electron candidates

- E_T > 25 GeV
- $|\eta| < 2.47$, exclude $1.37 < |\eta| < 1.52$
- cuts on transverse shower shape, leakage into hadronic calorimeter
- track quality, track match cuts
- hit in first layer of pixel detector
- Object Quality (calorimeter region)

Leading electron isolated:

$\Sigma E_T(\Delta R < 0.2) < 7\,GeV$

Acceptance (SSM Z', 1.5 TeV): 67%

Background Estimates

From MC (includes full detector simulation):

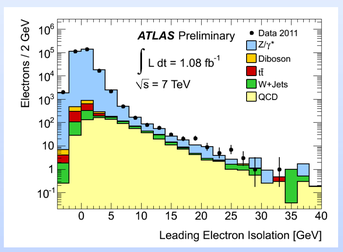
- Drell-Yan (PYTHIA)
- Dibosons (HERWIG)
- W+jets (ALPGEN)
- Top pairs (MC@NLO)

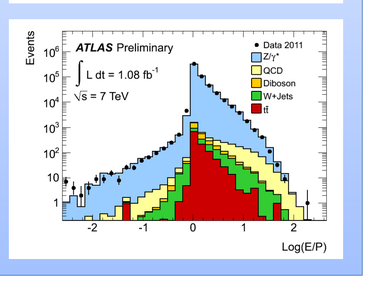
Reverse Identification for QCD dijet estimate (from data):

1. Dijet shapes: Reverse some electron ID cuts on the calorimeter shower width

2. Extrapolation to high masses: Fit dijet invariant mass spectrum with an empirical function

3. Normalization: 2-component template fit (all MC samples added together + dijet shape), using the invariant mass as discriminating variable (in low mass range: 70-200 GeV)





Systematic Uncertainties

All backgrounds are normalized to the data in the invariant mass range 70-110 GeV. Therefore mass-independent systematics cancel out.

Remaining mass-dependent uncertainties include:

Theoretical
- cross section uncertainties (due to PDF and α_s variations)
- NLO and NNLO corrections are applied as mass dependent k-factors to Drell Yan (QCD and EW) and the Z' signals (QCD)

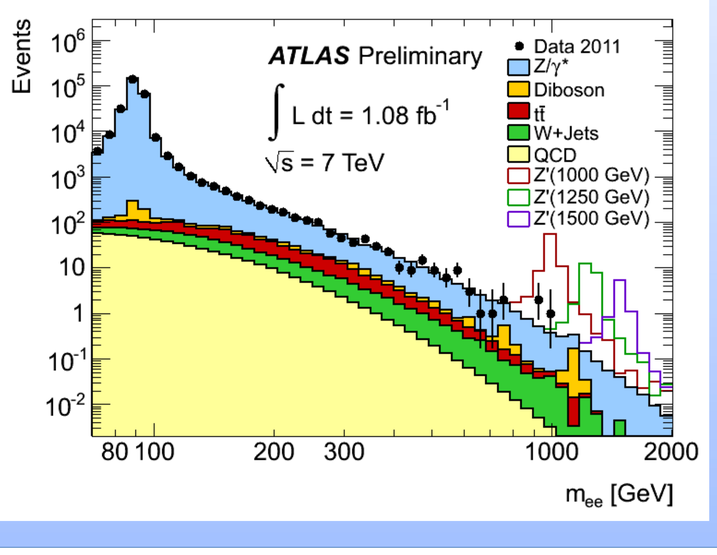
Experimental
- total background fluctuation due to uncertainty on QCD dijet estimate
- energy resolution
- energy scale
- trigger, reconstruction and identification efficiency

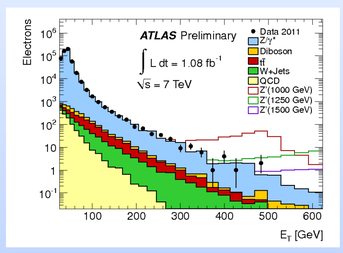
} below 3%

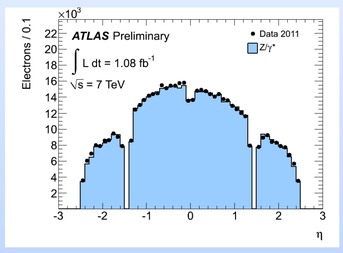
Source	dielectrons	
	Z' (G^*) signal	background
Normalization	5%	NA
PDFs/α_S	10% (12%)	10%
QCD K-factor	3% (NA)	3%
Weak K-factor	NA	4.5%
Total	12% (13%)	12%

Dominant systematic uncertainties on the expected number of events at m_{ee} = 1.5 TeV

Data MC Comparison







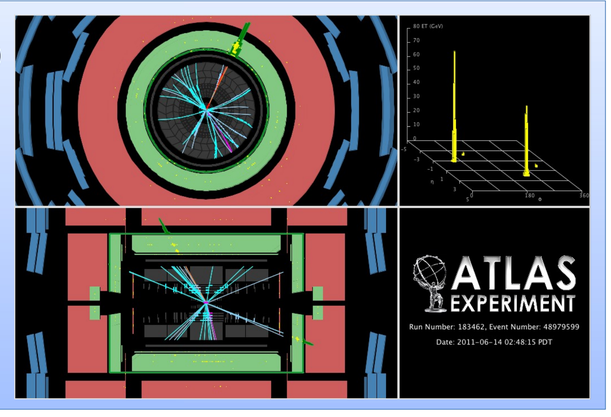
$m_{e^+e^-}$ [GeV]	70-110	110-200	200-400	400-800	800-3000
DY	258481.5±413.9	5449.2±182.6	612.9±25.7	53.8±3.1	2.8±0.1
$t\bar{t}$	218.1±36.4	253.1±9.9	82.2±3.0	5.4±0.3	0.1±0.0
Dibosons	368.2±18.8	85.4±5.1	28.8±2.3	3.1±0.5	0.3±0.1
W+jets	150.1±102.2	149.6±25.9	42.7±9.5	4.6±1.8	0.2±0.4
QCD	332.2±59.1	191.1±75.3	36.1±28.9	1.8±1.4	0.0±0.0
Total	259550.0±509.5	6128.4±199.6	802.7±39.9	68.8±3.9	3.4±0.4
Data	259550	6117	808	65	3

Expected and observed number of events. Both systematic and statistical uncertainties are included, except the total background uncertainty in the normalization region which corresponds to $\sqrt{N_{observed}}$. Entries of 0.0 indicate a value < 0.05.

Highest invariant mass event (993 GeV)

Leading electron
E_T: 257 GeV
(η, Φ): (-0.76, 1.14)

Subleading electron
E_T: 207 GeV
(η, Φ): (2.05, -2.05)

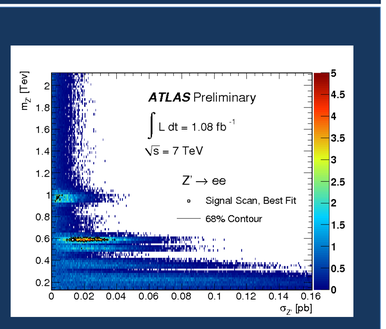


Discovery Statistics and Limits

Significance of signal summarized by p-value
- ratio of pseudo-experiments based on background only, observing an excess at least as signal-like as the one observed in data
- 2D scan in σ(Z') and m(Z')
- log-likelihood ratio for ranking probabilities
- p = 54% for the largest deviation ► no significant excess

$$p = p(LLR > LLR_{obs} | SM\ only)$$

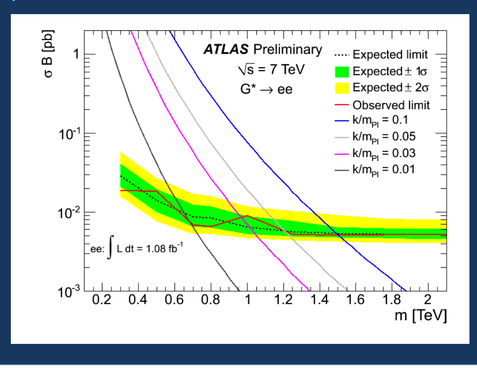
$$LLR = -2\ln\frac{L(data|\hat{N}_{Z'}, \hat{M}_{Z'}, \hat{\theta}_i)}{L(data|(\hat{N}_{Z'}=0), \hat{\theta}_i)}$$

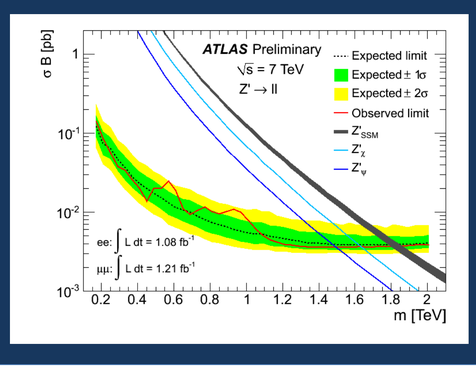


Upper limits on the Z' and G* cross sections
- 95% confidence level
- Bayesian approach
- compare invariant mass distribution in data to the expected background and signal templates
- likelihood function is product of the Poisson probabilities over all mass bins
- systematic uncertainties enter as nuisance parameters and are marginalized
- the limit on the number of Z'/G* events is converted into a limit on σB(Z'/G*):

$$L(N_{Z'}, N_Z | data) = \prod_{k=1}^{N_{bin}} \frac{(N_{Z'} + N_{bg})_k^{N_k^{obs}} e^{-(N_{Z'}+N_{bg})_k}}{N_k^{obs}!}$$

$$\sigma B(Z') = \sigma B(Z)\frac{N_{Z'}A_Z}{N_Z A_{Z'}}$$





Conclusions

Using ~1 fb^{-1} of ATLAS data, we have searched for narrow dielectron (and dimuon) resonances in the invariant mass spectrum.

The observed dilepton invariant mass spectrum is consistent with Standard Model expectations.

We set limits on various Z' models and on Randall-Sundrum Kaluza-Klein gravitons.

	Observed limit mass [TeV]	Expected limit mass [TeV]
$Z'_{SSM} \to e^+e^-$	1.69	1.68
$Z'_{SSM} \to \mu^+\mu^-$	1.60	1.60
$Z'_{SSM} \to \ell^+\ell^-$	1.83	1.82
	Observed limit mass [TeV]	Expected limit mass [TeV]
$G^* \to e^+e^-$	1.50	1.49
$G^* \to \mu^+\mu^-$	1.45	1.44
$G^* \to \ell^+\ell^-$	1.63	1.61

Dielectron, dimuon and combined 95% confidence level mass limits on Z'_{SSM} and G* with a coupling of k/m_{Pl} = 0.1.

	E_6 Z' Models						RS Graviton			
Model/Coupling	Z'_ψ	Z'_N	Z'_η	Z'_I	Z'_S	Z'_χ	0.01	0.03	0.05	0.1
Mass limit [TeV]	1.50	1.52	1.54	1.56	1.60	1.64	0.70	1.03	1.33	1.63

Combined mass limits at 95% confidence level on the E_6 motivated Z' models and on the RS graviton with varying couplings k/m_{Pl}.

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ATLAS EXPERIMENT