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Search for high-mass dimuon resonances in the ATLAS experiment at $\sqrt{s}$ = 7 TeV

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We present a search for high-mass $\mu^+\mu^-$ resonances in pp collisions at a centre-of-mass energy of 7 TeV recorded by the ATLAS experiment in 2011. No statistically significant excess above the Standard Model expectation is observed in a dataset corresponding to an integrated luminosity of 1.21 fb^{-1}. Consequently, upper limits are set on the cross-section times branching ratio of resonances decaying to muon pairs as a function of the resonance mass. In particular, a Sequential Standard Model Z' is excluded for masses below 1.61 TeV, and a Randall-Sundrum Kaluza-Klein graviton with coupling $k/\overline{M}_{Pl} = 0.1$ is excluded for masses below 1.45 TeV, both at the 95% C.L. Combined limits with the electron channel reach 1.83 TeV and 1.63 TeV respectively.

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Many hypotheses that go beyond the Standard Model predict the existence of new, high-mass resonances decaying into muon pairs. We have searched for such resonances [1] using 1.21 fb^{-1} of pp collision data at a centre-of-mass energy of 7 TeV, recorded with the ATLAS detector [2]. The benchmark signals considered in this search are new neutral vector bosons (Z') from the Sequential Standard Model (SSM) [3] or models involving an E_6 grand unified symmetry group [4], and Randall-Sundrum Kaluza-Klein gravitons (G^*) [5] for couplings $k/\overline{M}_{Pl} \leq 0.1$, where k is the space-time curvature in the extra dimension and $\overline{M}_{Pl} = M_{Pl}/\sqrt{8\pi}$ is the reduced Planck scale.

This search looks for two opposite-sign muons, forming a narrow peak in the invariant mass spectrum. Muon pairs are selected in events passing a single-muon trigger requiring a transverse momentum $p_T > 22$ GeV. Both muons are then required to have $p_T > 25$ GeV, and to pass stringent hit requirements in both the Inner Detector and Muon Spectrometer of ATLAS, to ensure that their track momentum is well-measured. This selection includes a three-layer requirement in the Muon Spectrometer. To suppress background contributions from cosmic rays, the primary collision vertex of the event is required to have at least 3 charged particle tracks, and to be within 20 cm of the centre of the detector. Further, both muon tracks are required to originate within 0.2 mm of the primary vertex in the direction transverse to the beam line, and within 1.0 mm longitudinally. Finally, to reduce background from QCD jets, an isolation requirement is imposed on both muons such that $\Sigma p_T(\Delta R < 0.3)/p_T(\mu) < 0.05$. The signal acceptance for a 1.5 TeV resonance is 40% for $Z' \to \mu^+\mu^-$, and 44% for $G^* \to \mu^+\mu^-$.

The resulting invariant mass distribution of dimuons is shown on Figure 1 (left). Standard Model backgrounds due to the Drell-Yan process and the production of dibosons, W bosons in association with jets, and top quark pairs are evaluated using Monte Carlo event generators, and the full simulation of the ATLAS detector based on GEANT4. The background due to QCD multijets is estimated from data, using a reverse muon isolation cut to obtain the shape, which is scaled using the ratio of isolated to anti-isolated dimuons in QCD Monte Carlo.

The total background estimate is scaled to the data in the invariant mass range 70-110 GeV. Experimental systematic uncertainties include those on the muon momentum scale and resolution (< 2%) and on the trigger and reconstruction efficiencies (4.5%). For a resonance mass of 1.5 GeV, cross-section uncertainties due to parton distribution functions and α_s variations amount to 10%, while uncertainties on the NNLO corrections to the Drell-Yan background are evaluated to 5%. The theoretical uncertainty on the Z boson cross-section is taken to be 5%.

To characterize the signal significance of our data, we calculate the probability of observing an excess at least as signal-like as the one observed in data, assuming that signal is absent (p-value). The outcome of the search is ranked against pseudo-experiments from background processes using a log-likelihood ratio, scanned as a function of signal cross-section and mass. The resulting p-value being 24%, the data are consistent with the Standard Model.

Given the absence of a signal, an upper limit on the signal cross-section times branching ratio (σB) is determined at the 95% confidence level (C.L.), using a Bayesian approach [6]. The invariant mass distribution from data is compared with the expected background and signal templates. The observed limit is then obtained from a likelihood function, derived from the Poisson probability for the observed number of data events given the expectation from the templates. The median expected limit is obtained from an ensemble of pseudo-experiments using events drawn from the background hypothesis. Finally, mass limits are calculated by comparing the limits on σB to theoretical predictions for different Z' models and G^* couplings. Limits for Z' models are shown on Figure 1 (right), and mass limits on Z' and G^* in Table 1.

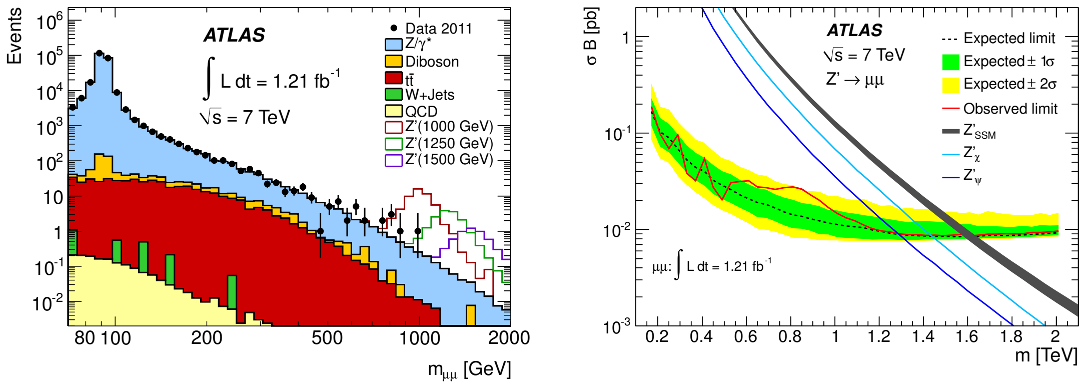

Figure 1: Left: Dimuon invariant mass distribution after final selection, compared to the stacked sum of all expected backgrounds, with three example Z'_{SSM} signals overlaid. The bin width is constant in log $m_{\mu\mu}$. Right: Expected and observed 95% C.L. upper limits on σB as a function of mass for several Z' models. [1]

Table 1: Top: Observed (Expected) 95% C.L. mass lower limits in TeV on Z'_{SSM} and G^* resonances. Bottom: 95% C.L. mass lower limits in TeV on Z'_{E_6} models and on G^* for different values of the coupling $k/\overline{M}_{Pl}$, where both the electron and muon channels are combined.

Model	ee	$\mu\mu$	$\ell\ell$
Z'_{SSM}	1.70 (1.70)	1.61 (1.61)	1.83 (1.83)
G^* ($k/\overline{M}_{Pl}$=0.1)	1.51 (1.50)	1.45 (1.44)	1.63 (1.63)

	Z'_{E_6} Models						G^*			
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]	1.49	1.52	1.54	1.56	1.60	1.64	0.71	1.03	1.33	1.63

In conclusion, using 1.21 fb^{-1} of proton-proton data recorded by ATLAS, we have searched for narrow dimuon resonances in the invariant mass spectrum. Observations are consistent with Standard Model expectations. We therefore set 95% C.L. limits on various Z' models and on Randall-Sundrum Kaluza-Klein gravitons.

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