

A search for an excited muon decaying to a muon and two jets in pp collisions at $\sqrt{s} = 8$ TeV with the ATLAS detector postprint

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Abstract

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Full Text

Preamble

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The ATLAS Collaboration

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are set at the 95% confidence level on the cross section times branching ratio as a function of the excited-muon mass m_{μ^*} . For m_{μ^*} between 1.3 TeV and 3.0 TeV, the upper limit on $\sigma B(\mu^* \rightarrow \mu q \bar{q})$ is between 0.6 and 1 fb. These limits are converted to lower bounds on the compositeness scale Λ . In the limiting case $\Lambda = m_{\mu^*}$, excited muons with masses below 2.8 TeV are excluded. With the same model assumptions, these limits at larger μ^* masses improve upon previous limits from traditional searches based on the gauge-mediated decay $\mu^* \rightarrow \mu \gamma$.

1 Introduction

The Standard Model (SM) of particle physics successfully describes a wide range of phenomena but does not explain the generational structure and mass hierarchy of quarks and leptons. Composite models of fermions [1–7] aim to reduce the number of matter constituents by postulating that SM fermions are bound states of more fundamental particles. A direct consequence of substructure would be the existence of excited fermion states. This paper reports on a search for an excited muon μ^* using 20.3 fb⁻¹ of pp collision data at a center-of-mass energy of $\sqrt{s} = 8$ TeV recorded in 2012 with the ATLAS detector at the Large Hadron Collider (LHC). The search is based on a benchmark model [7] that describes excited-fermion interactions with an effective Lagrangian containing four-fermion contact interactions and gauge-mediated interactions. A novel contact interaction decay signature, $\mu^* \rightarrow \mu jj$ (where j represents a jet), not previously employed in excited lepton searches is used.

In this paper, as in Ref. [7], the model is assumed to be valid for μ^* masses up to the compositeness scale. The contact interaction terms are described by the Lagrangian $\mathcal{L}_{\text{contact}} = \frac{g^2}{2\Lambda^2} j_\mu j^\mu$, with $j_\mu = \eta_f \bar{f}_L \gamma_\mu f_L + \eta'_f \bar{f}_L^* \gamma_\mu f_L^* + \eta''_f \bar{f}_L^* \gamma_\mu f_L + \text{h.c.}$, where Λ is the compositeness scale, j_μ is the fermion current for ground states (f) and excited states (f^*), g and the η 's are constants, “h.c.” stands for Hermitian conjugate, and only left-handed fermion interactions are assumed. As is done in Ref. [7], g^2 is set to 4π , and η , η' , and η'' are taken to be one.

The search described here focuses on the predominant single- μ^* production via the contact interaction $qq \rightarrow \mu \mu^*$ followed by the decay of the excited muon via the contact interaction to $\mu q \bar{q}$ (where q is any quark except a top quark), leading to a final state with two muons and two jets (figure 1). Previous searches at LEP [8–11], HERA [12, 13], the Tevatron [14–17], and the LHC [18–22] looked for the gauge-mediated decay $\mu^* \rightarrow \mu \gamma$. In the model of Ref. [7], this decay is dominant at low μ^* mass, but for $m_{\mu^*} \gtrsim 0.25\Lambda$, the decay $\mu^* \rightarrow \mu q \bar{q}$ is expected to have the largest branching ratio, rising to 65% for $m_{\mu^*} = \Lambda$. The search reported here complements the search in the $\mu \gamma$ channel and increases the sensitivity of the search for excited muons at higher masses. The ATLAS Collaboration recently published [23] another new search signature for excited muons decaying via a contact interaction to $\mu \ell \ell$, where ℓ is an electron or a muon.

2 ATLAS Detector

The ATLAS experiment [24] uses a multi-purpose particle detector with a forward-backward symmetric cylindrical geometry and nearly 4π coverage in solid angle. It consists of an inner tracking detector surrounded by a thin superconducting solenoid providing a 2 T axial magnetic field, electromagnetic and hadron calorimeters, and a muon spectrometer. The inner tracking detector covers the pseudorapidity range $|\eta| < 2.5$ and consists of silicon pixel, silicon microstrip, and transition radiation tracking detectors.

Lead/liquid-argon (LAr) sampling calorimeters provide electromagnetic (EM) energy measurements with high granularity. A hadronic steel/scintillator-tile calorimeter covers the central pseudorapidity range $|\eta| < 1.7$. The endcap and forward regions are instrumented with LAr calorimeters for EM and hadronic energy measurements up to $|\eta| = 4.9$. The muon spectrometer surrounding the calorimeters covers the pseudorapidity range $|\eta| < 2.7$ and is based on three large air-core toroid superconducting magnets with eight coils each. Their bending power is in the range from 2.0 to 7.5 T · m. The muon spectrometer consists of three stations of precision tracking chambers and fast detectors for triggering. The majority of the precision tracking chambers are composed of drift tubes, while cathode-strip chambers provide coverage in the inner stations of the forward region for $2.0 < |\eta| < 2.7$.

A three-level trigger system is used to select events. The first-level trigger is implemented in hardware and uses a subset of the detector information to reduce the accepted rate to at most 75 kHz. This is followed by two software-based trigger levels that together reduce the accepted event rate to 400 Hz on average, depending on the data-taking conditions during 2012.

ATLAS uses a right-handed coordinate system with its origin at the nominal interaction point (IP) in the centre of the detector and the z -axis along the beam pipe. The x -axis points from the IP to the centre of the LHC ring, and the y -axis points upwards. Cylindrical coordinates (r, ϕ) are used in the transverse plane, ϕ being the azimuthal angle around the z -axis. The pseudorapidity is defined in terms of the polar angle θ as $\eta = -\ln \tan(\theta/2)$. Angular distance is measured in terms of $\sqrt{(\Delta\eta)^2 + (\Delta\phi)^2}$.

3 Signal and Background Simulation

Simulation of the excited-muon signal is based on calculations from Ref. [7]. Signal samples are generated at leading order (LO) with CompHEP 4.5.1 [25] using MSTW2008lo [26] parton distribution functions (PDFs). CompHEP is interfaced with Pythia 8.170 [27, 28] with the AU2 parameter settings [29] for the simulation of parton showers and hadronization. Only the production of $\mu\mu^*$ followed by the decay $\mu^* \rightarrow \mu q \bar{q}$ is simulated. Signal samples are produced for $\Lambda = 5$ TeV and for the μ^* masses given in table 2. The distributions of kinematic variables should be independent of Λ , which was checked with generator-level studies. For a compositeness scale of $\Lambda = 5$ TeV, cross section

times branching ratios are 10.4, 2.9, and 0.21 fb for μ^* masses of 500, 1500, and 2500 GeV, respectively. The intrinsic total width of the μ^* is expected to be less than 8% for $m_{\mu^*} < \Lambda$, which is smaller than the mass resolution of about 20% over the range of μ^* masses considered here.

The dominant background is from the process $Z/\gamma^* \rightarrow \mu\mu$ produced in association with jets ($Z/\gamma^* + \text{jets}$). The second most important background is $t\bar{t}$ production. Other processes, such as diboson (WW , WZ , and ZZ), single-top, $W + \text{jets}$, and multi-jet production, give small contributions to the background.

The $Z/\gamma^* + \text{jets}$ samples are produced by the multi-leg LO generator Sherpa 1.4.1 [30] using CT10 [31] PDFs. The cross section for $Z/\gamma^* \rightarrow \mu\mu$ ($m_{\mu\mu} > 70$ GeV) plus any number of jets is 1.24 nb, calculated at next-to-leading order (NLO), corrected by a K -factor [32, 33] to next-to-next-to-leading order (NNLO) in QCD couplings and NLO in electroweak couplings. The $t\bar{t}$ events are generated at the parton level at NLO with Powheg 1.0 [34] and the Perugia 2011c parameter settings [35], and the parton showering is done with Pythia 6.426 [36]. At least one of the t or $\bar{t}$ must have a semileptonic decay (e , μ , or τ), giving a cross section for this process of 137 pb, calculated at NNLO + next-to-next-to-leading-log (NNLL) accuracy [37].

The diboson background samples are produced at LO by Herwig 6.52 [38] with the AUET2 parameter settings [39] using CTEQ6L1 PDFs, and it is required that at least one light lepton (e or μ) with transverse momentum (p_T) above 10 GeV be produced. The $W + \text{jets}$ samples are produced by the multi-leg LO generator Alpgen 2.14 [40] with Jimmy 4.31 [41] and Herwig 6.52 using the AUET2 parameter settings with CTEQ6L1 PDFs, and the cross section is calculated at NNLO [32, 33]. The multi-jet samples are generated at LO by Pythia 8.160 using the AU2 parameter settings with CT10 PDFs. The single-top t -channel samples are generated at LO corrected to NLO + NNLL by AcerMC 3.8 [42] using the AUET2B parameter settings [43] with the CTEQ6L1 PDFs, and the parton showering is done with Pythia 6.426. The single-top s - and Wt -channel samples are generated at NLO with MC@NLO 4.01 [44–46] using the AUET2 parameter settings with CT10 PDFs.

The background predictions from the $Z/\gamma^* + \text{jets}$ and $t\bar{t}$ samples are normalized using control regions discussed in Section 5. Cross sections for diboson processes are evaluated at NLO [47] with an uncertainty of 5%. The $W + \text{jets}$ and multi-jet backgrounds are determined from the Monte Carlo (MC) samples but are verified using data-driven methods. A summary of the Standard Model samples used in this analysis is given in table 1.

The generated samples are processed using a detailed detector simulation [48] based on Geant4 [49] to propagate the particles through the detector material and account for the detector response. Simulated minimum-bias events are overlaid on both the signal and background samples to reproduce the effect of additional pp collisions. The simulated events are weighted to give a distribution of the number of interactions per bunch crossing that agrees with the

data. The simulated background and signal events are processed with the same reconstruction programs as used for the data.

4 Data Set and Event Selection

The data were collected in 2012 during stable-beam periods of $\sqrt{s} = 8$ TeV pp collisions. After selecting events where the relevant parts of the detector were functioning properly, the data correspond to an integrated luminosity of 20.3 fb^{-1} . The events are required to pass at least one of two single-muon triggers. The first has a nominal p_T threshold of 36 GeV, and the second has a lower nominal threshold of 24 GeV but also includes an isolation requirement: the sum of the p_T of tracks with $p_T > 1$ GeV within a distance of $\Delta R = 0.2$ of the muon (excluding the muon itself) divided by the p_T of the muon must be less than 0.12.

A primary vertex with at least three tracks with $p_T > 0.4$ GeV within 200 mm of the centre of the detector along the beam direction is required. If there is more than one primary vertex in an event, the one with the highest sum of p_T^2 is selected, where the sum is over all tracks associated with the vertex.

Each muon candidate must be reconstructed independently in both the inner detector and the muon spectrometer. Its momentum is determined by a combination of the two measurements using their covariance matrices. Only muon candidates with p_T^μ above 30 GeV are considered. Muons must have a minimum number of hits in the inner detector and hits in each of the inner, middle, and outer layers of the muon spectrometer. These hit requirements, which restrict the muon acceptance to $|\eta| < 2.5$, guarantee a precise momentum measurement. To suppress background from cosmic rays, the muon tracks are required to have transverse and longitudinal impact parameters $|d_0| < 1$ mm and $|z_0| < 1$ mm with respect to the selected primary vertex. To reduce background from semileptonic decays of heavy-flavour hadrons, each muon is required to be isolated such that $\sum p_T/p_T^\mu < 0.05$, where the sum is over inner-detector tracks with $p_T > 1$ GeV within a distance $\Delta R = 0.3$ of the candidate muon, excluding the muon from the sum. The muon trigger and reconstruction efficiencies are evaluated using tag-and-probe techniques with $\mu\mu$ events [50, 51], and p_T - and η -dependent corrections are applied to simulated events. Events are required to have exactly two muons of opposite charge that meet these selection requirements.

Although electrons are not part of the signal for this search, they are used to define one of the control regions (see Section 5). Each electron candidate is formed from the energy in a cluster of cells in the electromagnetic calorimeter associated with a charged-particle track in the inner detector. Each electron must have $p_T > 30$ GeV and $|\eta| < 2.47$ but not be in the interval $1.37 < |\eta| < 1.52$ to avoid the transition region between the barrel and endcap calorimeters. The ATLAS tight electron identification criteria (based on the methodology described in [52] and updated for 2012 running conditions) for the transverse shower shape, longitudinal leakage into the hadronic calorimeter, the association

with an inner-detector track, and hits in the transition radiation detector are applied to the cluster. An electron track is required to have transverse and longitudinal impact parameters $|d_0| < 1$ mm and $|z_0| < 5$ mm with respect to the selected primary vertex. Finally, the electrons must pass the isolation requirement $\sum E_T < 0.007 E_T^e + 5$ GeV, where the sum is of transverse energies deposited in cells within a cone of $\Delta R = 0.2$ around the electron, excluding those cells associated with the electron.

Jets of hadrons are reconstructed using the anti- k_t algorithm [53] with a radius parameter of $R = 0.4$ applied to clusters of calorimeter cells that are topologically connected. The jets are calibrated using energy- and η -dependent correction factors derived from simulation and with residual corrections from in situ measurements [54]. Jets are required to have $|\eta| < 2.8$ and $p_T > 30$ GeV. Jets that overlap ($\Delta R < 0.4$) with any electron or muon candidate satisfying the selection criteria described above are removed. The two jets with the highest p_T are then selected.

The missing transverse momentum vector is the negative of the vector sum of the transverse momenta of muons, electrons, photons, jets, and clusters of calibrated calorimeter cells not associated with these objects. The missing transverse energy is the magnitude of the missing transverse momentum vector.

5 Background Determination

Most of the SM background contributions are estimated from the MC samples. The expected yields from the $Z/\gamma^* +$ jets and $t\bar{t}$ production processes are normalized to the data using control regions. The $Z/\gamma^* +$ jets control region is defined by $70 < m_{\mu\mu} < 110$ GeV in addition to the selection criteria given in Section 4. The contribution from signal events in this control region is at most 0.7% for a compositeness scale of 5 TeV for any μ^* mass considered here. The $t\bar{t}$ control region is defined as events that meet the selection requirements given in Section 4, except there is exactly one muon and one electron of opposite sign, so it should contain no signal events. The normalization scale factors are determined from a simultaneous fit to data in the control and signal regions (see Section 8). From the fit, the scale factor is $1.010^{+0.087}_{-0.066}$ for the $Z/\gamma^* +$ jets sample and is $1.050^{+0.013}_{-0.013}$ for the $t\bar{t}$ sample. The MC predictions agree well with the data in the control regions, as can be seen, for example, in figure 2(a) [Figure 2: see original paper].

A jet can produce a prompt muon candidate either from the semileptonic decay of a heavy quark or from misidentification of a charged hadron in the jet as a muon. The expected background from jets, primarily from $W +$ jets and multi-jet processes, is determined from MC samples, giving zero expected events. This prediction is checked by the data-driven matrix method [55], which uses isolated and non-isolated muons and their data-determined efficiencies and misidentification rates to determine the number of prompt muons. The matrix method predicts 0.55 events from these backgrounds.

6 Signal Regions

Signal regions (SR) are defined by three kinematic variables: the dimuon invariant mass $m_{\mu\mu}$, the invariant mass $m_{\mu\mu jj}$ of the two muons and two jets, and S_T , the scalar sum of transverse momenta of the four signal objects, that is, $S_T = p_T^{\mu_1} + p_T^{\mu_2} + p_T^{j_1} + p_T^{j_2}$. For all three of these variables, the signal tends to have higher values than the backgrounds, so all criteria are lower bounds in the selection. The values of these bounds are chosen to maximize the search sensitivity for each signal mass considered by scanning the three-dimensional parameter space for the values that minimize the expected 95% confidence level (CL) upper limit on the cross section times branching ratio. The selection criteria for the signal regions are shown in table 2. The $m_{\mu\mu jj}$ and S_T criteria increase with increasing signal mass, but the $m_{\mu\mu}$ criterion decreases. The latter is because the increase in the other parameters sufficiently reduces the expected background so that the signal efficiency may be increased by decreasing the $m_{\mu\mu}$ criterion.

The dominant background in all signal regions is from the $Z/\gamma^* + \text{jets}$ process, which constitutes 50% of the background in SR 1, rising to 90% or more in SR 5 through SR 10. The $t\bar{t}$ process contributes 40% of the background in SR 1, but this contribution falls quickly to 10% or less in SR 3 through SR 10. The contribution to the background from all other processes is between 10% and 20% in SR 1 through SR 5 and is less than 5% for SR 6 through SR 10.

7 Systematic Uncertainties

Contributions to the systematic uncertainties in the background and signal yield predictions stem from both experimental and theoretical sources, as discussed below. The μjj invariant mass was considered as a discriminating variable instead of one of the three selection variables. Several methods for selecting the correct μjj combination and the possibility of using both μjj combinations were considered, but no method that improved the sensitivity was found.

The luminosity is derived using the methodology in Ref. [56] and has an uncertainty of 2.8%. The luminosity uncertainty for the backgrounds is less than this because the largest backgrounds ($Z/\gamma^* + \text{jets}$ and $t\bar{t}$) are normalized using control regions.

Uncertainties in the MC modeling of the detector, particularly for muons and jets in this analysis, must be taken into account and are derived from detailed studies of data. One-standard-deviation variation of a given parameter is determined, and then the parameter is varied up and down in the simulation by this amount to determine the effect on the signal and background yields.

The uncertainty in the jet energy scale is the largest contribution to the systematic uncertainty in the signal yield and a significant contribution to the uncertainty in the backgrounds. The uncertainty in the jet energy resolution also makes a contribution. These uncertainties are determined from p_T balance

in γ +jet and Z +jet events and in events with high- p_T jets recoiling against multiple, low- p_T jets [54, 57]. Contributions from additional energy deposited in the calorimeters from other pp interactions in the event are also included. The various effects are investigated separately and combined to give the values summarized in tables 3 and 4 [TABLE:3, TABLE:4].

Muon performance is determined in $Z \rightarrow \mu\mu$ events. The most important parameters for this analysis are the muon efficiency and the muon spectrometer p_T resolution. The inner-detector resolution and the muon p_T scale are found to have negligible effect. The uncertainty in the trigger efficiency is less than 2% for the backgrounds and less than 1% for the signal yield.

The uncertainties in the signal and background yield predictions due to uncertainties in PDFs have two contributions. The first is from one-standard-deviation variation of the parameters of the relevant PDFs (Section 3). The second is a comparison with the alternative NNPDF2.1 PDF set [58]. These variations produce changes in the predicted cross section and in kinematical distributions, which in turn affect the acceptance times efficiency. For the background, both effects are included in the systematic uncertainty. For the signal yield, the uncertainty in the acceptance times efficiency is included, but the uncertainty in the cross section is considered part of the uncertainty in the theoretical prediction and is not included in the statistical analysis.

The uncertainty in the background modeling in the signal regions is estimated by examining how well the MC prediction agrees with the data in two validation regions selected to be similar in kinematics to the signal regions but containing no signal. Both validation regions require the same selection as the signal regions except that $m_{\mu\mu jj} < 500$ GeV and $m_{\mu\mu} > 200$ GeV with no selection on S_T . Requiring the missing transverse energy be greater (less) than 50 GeV (40 GeV) selects a validation region dominated by $t\bar{t}$ (Z/γ^*) events. For some of the kinematic variables, an extrapolation of the predicted yield from the validation regions to the signal regions is necessary to evaluate possible mismodeling effects. Of the several kinematic variables studied, only the modeling of the S_T variable is found to have a significant effect. A linear fit to the ratio of the number of data events to the MC expectation is extrapolated to higher values of S_T , and the deviation from unity symmetrized about zero gives the uncertainty, referred to as “ Z/γ^* +jets modeling” and “ $t\bar{t}$ modeling” in table 4. For both validation regions, the linear fit is consistent within the uncertainties with a flat line at a ratio of one.

To produce sufficient numbers of events for high dimuon masses, the Z/γ^* MC samples were produced in bins of dimuon mass above the Z mass. For the S_T and $m_{\mu\mu jj}$ criteria in this analysis, this yields zero events in SR 7 through SR 10 for some ranges of the $m_{\mu\mu}$ distribution (for example, 110 to 400 GeV for SR 10). For these signal regions, an additional systematic uncertainty (referred to as “ Z/γ^* +jets extrapolation” in table 4) is estimated by loosening the S_T criteria and extrapolating into the signal region. The uncertainty introduced by this procedure is small except in SR 10, where the effect on the statistical

analysis is still small because the predicted number of background events is only 0.2.

Additional sources of uncertainty in the acceptance times efficiency are initial-state radiation, final-state radiation, renormalization and factorization scales, and the beam energy. The effects of initial- and final-state radiation are determined in generator-level studies by varying the relevant Pythia parameters and are less than 1%. The effect of the beam energy uncertainty (0.65%) [59] is determined by varying the momentum fraction of the initial partons in the PDFs by this amount, giving a change of less than 1%. The renormalization and factorization scales are independently varied in the simulation by factors of 2 and 1/2, changing the expected signal yield by about 2% at low mass and by less than 1% for masses above 750 GeV.

The uncertainties in the signal yield depend on the μ^* mass, and the largest contributions are summarized in table 3 for three representative masses. For the signal yield, uncertainties in jet energy scale, PDFs, and luminosity are the dominant sources. The uncertainties in the background depend on the signal region, and the largest contributions are shown in table 4 for three representative regions. The most significant contributions to the background uncertainty are from the modeling of the $Z/\gamma^* + \text{jets}$ and $t\bar{t}$ processes. The jet energy scale and the parton distribution functions also make significant contributions. Any source of systematic uncertainty contributing less than 2% to the background for all signal regions and less than 1% to the signal yield for all μ^* masses would have negligible effect in the statistical analysis in Section 8 and is not included.

8 Results

The numbers of events in the control and signal regions are fit [60] using a profile likelihood method [61, 62]. The likelihood function models the number of events as a Poisson distribution and the systematic effects are modeled using nuisance parameters with lognormal constraints. The parameters of interest in the fit are the signal yield in each signal region and the normalizations of the Z/γ^* and $t\bar{t}$ backgrounds, with the latter two being primarily determined in the fit by the events in the control regions. Correlations of the systematic uncertainties are taken into account.

As an example of the result of the fit, the $m_{\mu\mu jj}$ distribution for signal region 2 is shown in figure 2(b) [Figure 2: see original paper] for the data, expected backgrounds, and three signal predictions for $\Lambda = 5$ TeV (the signal regions for the higher masses have fewer background events). The expected and observed numbers of events for each signal mass considered are shown in table 2 for $\Lambda = 5$ TeV. The data are consistent with the Standard Model expectations, and no significant excess is observed. Thus, limits on the cross section times branching ratio as a function of the μ^* mass are calculated.

A modified frequentist CL_s method [63, 64] is used to derive the 95% CL upper limits on the signal yield. The expected limit is the median limit for a large

number of background-only pseudo-experiments. The one- and two-standard-deviation bands cover 68% and 95%, respectively, of the pseudo-experiment limits. The observed limit is the 95% CL limit for the observed number of events. The p -value is a measure of how well the background-only hypothesis models the data. For a signal region, it is the fraction of background-only pseudo-experiments where the fitted signal value is greater than that for the observed data.

The smallest p -values are for SR 9 and 10 with values of 0.034 and 0.099, respectively, corresponding to 1.8 and 1.3 standard deviations on one side of a Gaussian distribution. Some kinematic properties of the events in these signal regions are given in table 5. There is one event (event A) that is in all signal regions.

An upper limit on the cross section times branching ratio $\sigma(pp \rightarrow \mu\mu^*)B(\mu^* \rightarrow \mu q\bar{q})$ (figure 3) [Figure 3: see original paper] is determined for each signal mass from the limit on the signal yield at the 95% CL. The theoretical uncertainties are not included in either the σB or Λ limit determinations. For m_{μ^*} above 1.3 TeV, the limit is between 0.6 and 1 fb. The theoretical expectation for $\Lambda = m_{\mu^*}$ is also shown. The theoretical band represents uncertainties from PDFs and from renormalization and factorization scales.

The expected cross section and branching ratio depend on the μ^* mass and on Λ [7]. For each signal mass, the limit on σB is translated into a lower bound on the compositeness scale (figure 4) [Figure 4: see original paper]. The bound is the value of Λ for which the theoretical prediction of $\sigma B(m_{\mu^*}, \Lambda)$ is equal to the upper limit on σB . The region with $m_{\mu^*} > \Lambda$ is unphysical. For the limiting case where $\Lambda = m_{\mu^*}$, excited-muon masses below 2.8 TeV are excluded. Previous limits set by ATLAS [19, 23] are also shown. The analysis presented here improves upon the limits from $\mu^* \rightarrow \mu\gamma$ for masses above 1100 GeV and upon those from $\mu^* \rightarrow \mu\ell\ell$ for masses from 700 to 2100 GeV.

9 Conclusion

The results of a search for excited muons decaying to μjj via a contact interaction are reported based on data from $\sqrt{s} = 8$ TeV pp collisions collected with the ATLAS detector at the LHC corresponding to an integrated luminosity of 20.3 fb^{-1} . The observed data are consistent with SM expectations. An upper limit is set at 95% CL on the cross section times branching ratio $\sigma B(\mu^* \rightarrow \mu q\bar{q})$ as a function of the excited-muon mass. For m_{μ^*} between 1.3 and 3.0 TeV, the limit on σB is between 0.6 and 1 fb.

The σB upper limits are converted to lower bounds on the compositeness scale Λ . In the limiting case where $\Lambda = m_{\mu^*}$, excited-muon masses below 2.8 TeV are excluded. At higher μ^* masses, the signature explored in this paper, $\mu^* \rightarrow \mu jj$, has better sensitivity than the traditional signature $\mu^* \rightarrow \mu\gamma$. For μ^* masses above 0.8 TeV, the sensitivity is up to 15% better than a previous search using the signature $\mu^* \rightarrow \mu\ell\ell$. In models other than the benchmark model used here,

the branching ratios to these modes could be different, affecting their relative importance for limits on the compositeness scale.

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