Search for Stable Massive Particles with the ATLAS detector in proton–proton collisions at $\sqrt{s}$ = 13 TeV

Sascha Mehlhase on behalf of the ATLAS Collaboration

Abstract

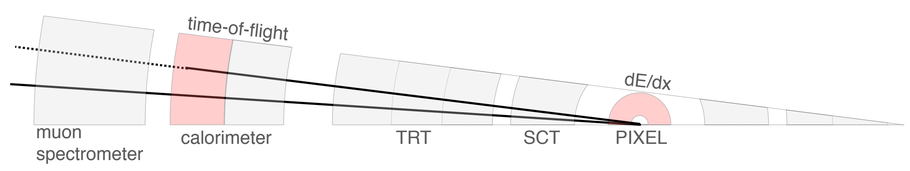
A search for heavy long-lived charged R-hadrons is reported using a data sample corresponding to 3.2 fb^{-1} of proton–proton collisions at $\sqrt{s}$ = 13 TeV collected by the ATLAS experiment at the Large Hadron Collider at CERN.

Introduction

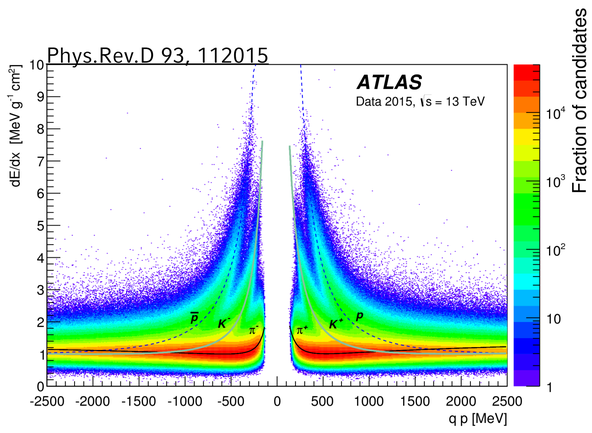
- heavy charged R-hadrons are predicted by a variety of supersymmetric extensions of the Standard Model (SM)
- coloured squarks and gluinos, hadronising with a light SM quark system to form R-hadrons, can become stable enough to reach and leave the detector
- heavy long-lived particles can be identified in ATLAS via anomalous energy depositions (dE/dx) and time-of-flight ($\beta < 1$)
- first analysis with 13 TeV data addresses gluino and squark R-hadrons, using a muon-spectrometer-agnostic search

ATLAS detector and observables

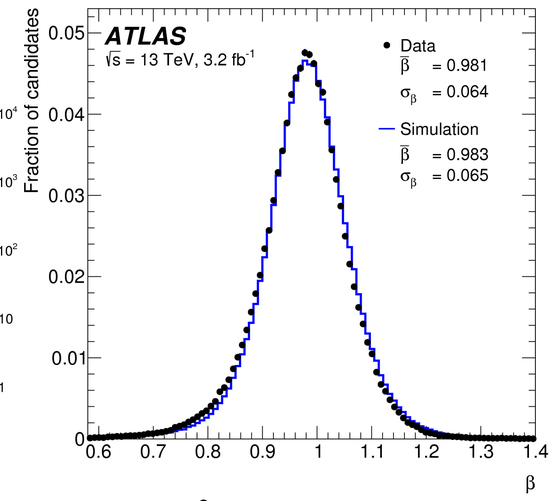
- multi-purpose particle detector with a forward-backward symmetric cylindrical geometry and near 4π coverage in solid angle



- pixel detector allows for a $\beta\gamma$ / mass estimate using dE/dx and momentum (p) measurements fitted to an empirical Bethe-Bloch function (calibrated using low-momentum pions, kaons and protons)
- hadronic tile-calorimeter allows for a β / mass estimate using time-of-flight measurements in cells crossed by extrapolated candidate tracks (calibrated using $Z \rightarrow \mu\mu$ events)



dE/dx vs. charge signed momentum (qp) for minimum-bias event tracks. Distributions of the MPV for fitted PDF of pions, kaons and protons are superimposed.



Distributions of β for data and simulation after a $Z \rightarrow \mu\mu$ selection. Values taken from Gaussian functions matched to data and simulation.

Data and simulated samples

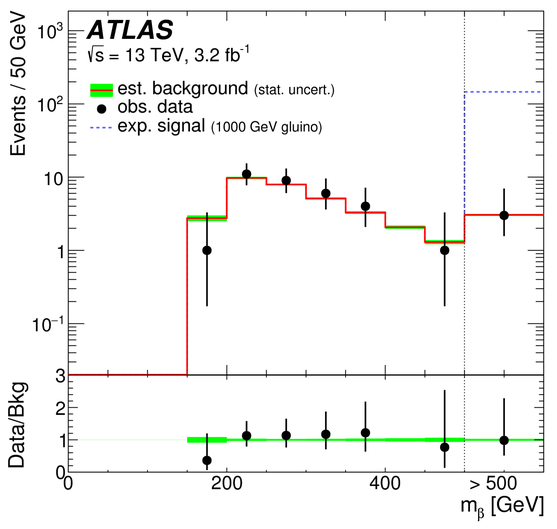
- 3.2 fb^{-1} of proton-proton collision data collected at a centre-of-mass energy $\sqrt{s}$ = 13 TeV in 2015
- gluino/squark pairs simulated in PYTHIA6, with specialised hadronisation and GEANT4 routines (10% gluino-ball fraction) for mass hypotheses between 600 GeV and 2 TeV
- MG5_aMC@NLO di-sparticle samples to reweight PYTHIA6 events to more accurate QCD initial-state radiation description
- $Z \rightarrow \mu\mu$ samples in data and simulation for calibration studies

Event and candidate selection

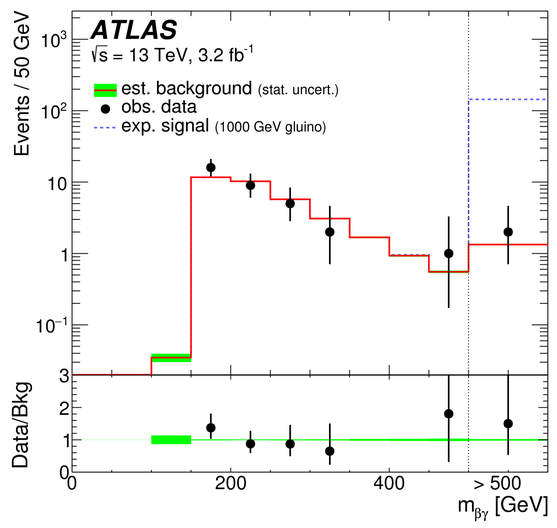
- 70 GeV missing transverse momentum trigger; relevant detector components fully operational; primary vertex (PV) built from at least two well-reconstructed charged-particle tracks (p_T > 400 MeV); at least one R-hadron candidate track
- central, high-p_T inner detector candidate tracks, with quality requirements aiming at ensuring a good momentum, dE/dx and β measurements
- selection up to here also used as basis for background estimate
- final requirements: p > 200 GeV; $\beta\gamma < 1.35$ (≤ 1.4 TeV) / 1.15 (> 1.4 TeV) and $\beta < 0.75$; mass-hypothesis-dependent requirements on $m_{\beta\gamma}$ and m_β (about 2σ below nominal R-hadron mass, given expected resolution)

Background estimation

- background evaluated in data-driven manner
- PDFs in momentum, β and $\beta\gamma$ values determined from data
- using candidates passing initial selection, but fall in sidebands of the signal region
  (p PDFs produced using events passing p cut, but failing β and $\beta\gamma$ requirements and $\beta < 1$ and $\beta\gamma < 2.5$; β and $\beta\gamma$ PDFs produced using events passing respective β and $\beta\gamma$ selection and p between 50 GeV and 200 GeV)
- background distributions in m_β and $m_{\beta\gamma}$ obtained by randomly sampling the PDFs and normalising them to data events outside the signal region (not passing both mass requirements of hypothesis in question)
- separate background estimate for each mass hypothesis



Data and background estimates for m_β for the 1000 GeV gluino R-hadron search.



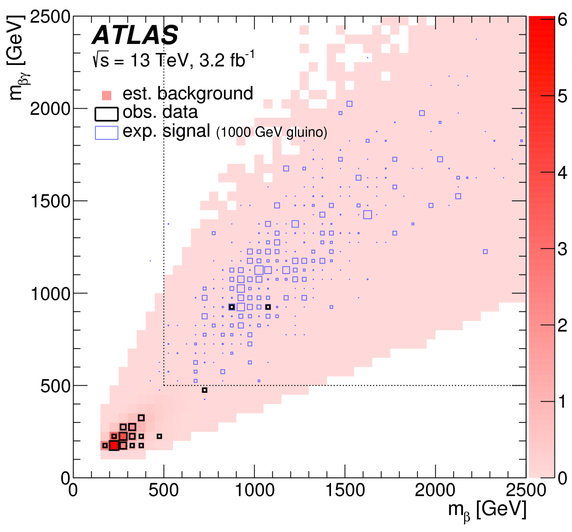
Data and background estimates for $m_{\beta\gamma}$ for the 1000 GeV gluino R-hadron search.

Systematic uncertainties

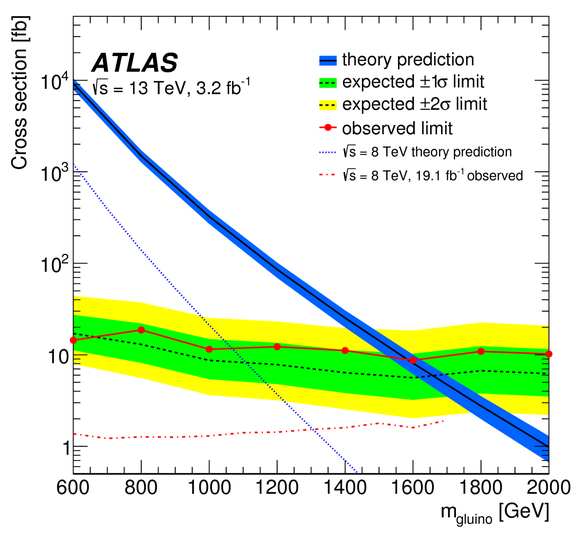
- signal cross sections: 14% – 57% (increasing with mass hypothesis)
- signal efficiency: 20% – 16% (decreasing with mass hypothesis)
- background estimate: 30% – 43% (increasing with mass hypothesis)
- luminosity: 5%

Results

- search for heavy long-lived particles in the form of composite colourless states of squarks or gluinos together with SM quarks and gluons, called R-hadrons, and taking advantage of both ionisation and time-of-flight measurements is presented
- no statistically significant excess of events above the expected background is found for any R-hadron mass hypothesis
- stable R-hadrons containing a gluino, bottom or top squark are excluded at 95% CL for masses up to 1580 GeV, 805 GeV and 890 GeV, respectively
- results substantially extend previous ATLAS and CMS limits from 8 TeV Run-1 data in case of gluino R-hadrons and are complementary to searches for SUSY particles which decay promptly



Data and background estimates for $m_{\beta\gamma}$ vs. m_β for the 1000 GeV gluino R-hadron search.



Expected and observed 95% CL upper limits on the cross section as a function of mass for gluino R-hadrons.

All presented results can be found in arXiv:1606.05129 (submitted to PLB). Related and previous ATLAS results can be found in Phys.Rev.D 93, 112015 and JHEP 2015-01, 68.

Dr. Sascha Mehlhase - Ludwig-Maximilians-Universität München
on behalf of the ATLAS Collaboration
sascha.mehlhase@cern.ch - https://sascha.mehlhase.info/
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