

# Comprehensive explanation of ultrahigh energy cosmic ray "anomalies": Quark matter formation by heavy nuclear primaries

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The Pierre Auger Collaboration has reported an excess in the number of muons of a few tens of percent over expectations computed using extrapolation of hadronic interaction models tuned to accommodate LHC data, I'll present an explanation for the muon excess assuming the formation of a deconfined quark matter (fireball) state in central collisions of ultrarelativistic cosmic rays with air nuclei. At the first stage of its evolution, the fireball contains gluons as well as  $u$  and  $d$  quarks. The very high baryochemical potential inhibits gluons from fragmenting into  $u\bar{u}$  and  $d\bar{d}$ , and so they fragment predominantly into  $s\bar{s}$  pairs. The hadronization which follows this leads to the strong suppression of pions and hence photons, but allows heavy hadrons to be emitted carrying away strangeness. In this manner, the extreme imbalance of hadron-to-photon content provides a way to enhance the muon component of the air shower. I'll also discuss theoretical systematics from hadronic interaction models used to describe the cascades of secondary particles produced in the fireball explosion. I'll compare the predictions of the leading LHC-tuned models (EPOS-LHC and QGSJet-II-04) considered in the Auger analysis.

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