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# New Physics at UHE energies

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Ultrahigh energy cosmic rays (UHECRs) are the highest energy particles in the Universe, recorded to have energies up to 100 million times greater than the LHC beams. Whether they are protons or nuclei and how they are accelerated are presently unknown. The particle cascades created when these UHECRs interact in the atmosphere are not well-described by
simulations, but since the primary composition is unknown and the particle physics models must be extrapolated far beyond accelerator energies, the origin and extent of the discrepancies have not been clear. By combining information from the longitudinal and lateral properties of the showers, measured in detail by the Pierre Auger Observatory, we are lead to the seemingly-inescapable conclusion that there is a fundamental change in the nature of the final states produced in ultrahigh energy interactions. It has distinctive features which suggest that a new phase of matter is being produced, and we conjecture it results from the restoration of chiral symmetry in a new high temperature regime of Quantum Chromodynamics, not accessible in accelerator experiments. In the conditions probed in particle physics experiments to date, chiral symmetry is broken and the lightest strongly interacting particle is the pion, a quark - anti-quark bound state. Chiral symmetry restoration has been predicted theoretically at temperatures above the Deconfinement Phase Transition, responsible for the Quark-Gluon Plasma created in relativistic heavy ion collisions, but its possible creation in 1 UHE collisions was not anticipated. Although pions and other mesons would not exist in
a chiral symmetric phase, we present theoretical arguments that baryons and anti-baryons remain bound. As a result, baryons and anti-baryons could be produced much more abundantly relative to mesons, than at accelerator energies. This picture provides the first consistent description of the published Auger observations on both the magnitude and zenith angle dependence of the ground signal, and the longitudinal profiles. Auger measurements should be able to test our claim that new physics is needed to explain UHE air showers, explore how the meson-baryon balance evolves with energy, and possibly determine the composition of the UHECRs. With a substantially larger sample of UHE hybrid events, it should be possible to investigate in considerable detail the production and properties of this ultimate phase of
matter.

**Primary author:** Prof. FARRAR, Glennys (New York University)

**Presenter:** Prof. FARRAR, Glennys (New York University)

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