Physicists leapfrog accelerators with ultrahigh energy cosmic rays

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An international team of physicists has developed a pioneering approach to using Ultrahigh Energy Cosmic Rays (UHECRs)—the highest energy particles in nature since the Big Bang—to study particle interactions far beyond the reach of human-made accelerators. The work, outlined in the journal *Physical Review Letters*, makes use of UHECR measurements by the Pierre Auger Observatory (PAO) in Argentina, which has been recording UHECR data for about a decade.

The study may also point to the emergence of some new, not-yet-understood physical phenomenon at an order-of-magnitude higher energy than can be accessed with the Large Hadron Collider (LHC), where the Higgs particle was discovered.

The origin of UHECRs remains a mystery, in spite of decades of work aimed at discovering their sources. Yet even before the UHECRs' sources are identified, the particle showers they create in the Earth's atmosphere can be used for exploring fundamental physics.

The cosmic rays are atomic nuclei. When they collide with air particles, hundreds of additional particles are created, which then further interact to produce a cascade of particles in the atmosphere. PAO telescopes measure how the shower develops as it travels through the atmosphere, and the PAO surface detectors gauge the particle content of the shower on the ground. The difficulty of using UHECR air showers to study particle physics, up to now, stemmed from the uncertainty in an individual ray's energy and not knowing exactly what nucleus it is.

New York University Physics Professor Glennys Farrar and Jeff Allen, her graduate student and postdoctoral researcher at the time of the study, circumvented this by using the atmosphere similar to the way a particle detector is employed in laboratory experiments. For the *Physical Review Letters* study, they compared the PAO data for 441 UHECR showers, with computer-simulated showers based on particle physics models derived from experiments at accelerator energies.

"State-of-the-art particle physics models seriously underestimate a key component of these UHECR showers," explains Farrar. "This may point to the emergence of unanticipated physical processes at higher energy than the LHC. Future studies, and planned upgrades to the PAO, should reveal what produces the extra signal, providing a window on particle physics far beyond the reach of accelerators."

Provided by New York University

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