# Searching for Exotic Particles from Cosmic-Ray Collisions

April 5 2007, By Laura Mgrdichian

Our planet is constantly bombarded with cosmic rays. Most collide with atoms in our atmosphere, producing sprays of particles that fall to the ground, thousands striking each square meter every second. Cosmic rays with extremely high energies are infrequent, but their interactions in the atmosphere open a tiny but important window to ultra-high-energy physics – a window that even the most advanced particle accelerators are incapable of achieving. Recently, three physicists took a peek in.

The interaction of a cosmic ray from outer space (typically a proton) with the atmosphere may result in the production of an exotic massive particle. This particle would be inside a shower of thousands of other particles. However, if it is long-lived, it will survive the shower without decaying and may be detected in a neutrino telescope or other detector. Here, the researchers focused on two theoretical exotic massive particles they believe are likely produced during these interactions: the gluino, a heavy twin of the gluon, and the "weakly interacting massive particle" (WIMP), which scientists believe could be a candidate for dark matter.

"WIMPs seem undetectable among cosmic rays, but we still may have the opportunity to learn new physics from gluinos," said University of Granada physicist Jose Ignacio Illana, one of the scientists involved in the study, to *PhysOrg.com*.

Illana and his colleagues came to this conclusion by calculating some key cosmic-ray statistics. When a single cosmic ray collides with a nucleus in the atmosphere, several secondary particles are produced. Many of them are “hadrons” – particles composed of quarks (examples are protons, neutrons, pions, and kaons). Depending on the ray's initial energy, many of the secondary hadrons are energetic enough to produce an exotic massive particle when they interact with other atmospheric nuclei.

The researchers first determined the total flux of hadrons – the cosmic rays, considered “primary” hadrons, and the secondary hadrons. In this case, the flux is a measure of the number of hadrons passing through a square kilometer of atmosphere in one year, at any atmospheric depth. Hadrons with energies of $10^4$ GeV (10,000 billion electron volts) have a flux of about a trillion per square kilometer per year (most of these are absorbed by the atmosphere). On the other hand, hadrons with energies around $10^{11}$ GeV correspond to a flux of less than one hadron per square kilometer per year. These high-energy rays produce collisions that are 30 times as energetic than the ones to be produced at the world's largest particle accelerator, the Large Hadron Collider at CERN, in Switzerland.

Next, the group estimated how often collisions between cosmic rays and atmospheric nuclei would produce gluinos (actually, gluino pairs, as gluinos are not expected to stand alone). A gluino pair, they calculated, could arrive at most just once per square kilometer per year if its mass is above the present experimental lower mass limit for gluinos.

The researchers repeated the calculation for a stable WIMP and found an even smaller production rate for WIMPs with moderate masses (although for very light WIMPs they have not ruled out production rates comparable to that of the gluino). The problem with WIMPs is that they are much more difficult to detect than the strongly-interacting gluinos, and at the predicted rate the probability of detecting them is close to zero. That leaves the gluino. To have any chance of detection, the gluino would have to be long-lived, since its decay particles – which scientists look for when they want to detect a short-lived particle – would be lost amidst the other particles in the cascade. If this is the case, there are two experiments that might be able to detect it.

The first is the IceCube Neutrino Detector, a giant neutrino telescope under construction in the South Pole. Designed to detect high-energy neutrinos, IceCube will consist of thousands of spherical optical sensors embedded in the polar ice, covering a full square kilometer of area. In theory, then, IceCube might be able to "see" the flux of gluino pairs – one pair per year.

The second is the Pierre Auger Observatory, an even larger project nearing completion in the plains of western Argentina. One portion of the observatory is a grid of 1,600 giant water tanks, each mounted with photomultiplier tubes and separated from neighboring tanks by 1.5 kilometers. The tanks will detect particles based on their interactions with the water. Illana and his group estimate that 20 gluino events per year could be detected at Auger.

"We think that the possibility of detecting gluinos at Auger deserves a more detailed analysis," said Illana.

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