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Years of Research Yield Nothing, And That's Good News for Physicists

By GEORGE JOHNSON

Last week in a quiet triumph, Fermilab, the high-energy physics laboratory outside Chicago, announced a discovery of great importance in the search for a theory of everything -- the seamless intellectual framework that would explain how the universe is made.

Firing up the Tevatron, the most powerful particle accelerator in the world, an international team of scientists slammed together matter and antimatter, creating volleys of silent, invisible explosions. Then they sifted the debris through their computers, looking for the long-sought prey: exotic wisps called supersymmetric particles -- SUSY's for short.

In the Jan. 28 issue of Physical Review Letters, the scientists revealed the results. They didn't find anything. And if that seems like dubious cause for a paper to be published in so prestigious a journal, then consider: In searching for SUSY's (pronounced "Suzies"), physicists now at least have a better idea of where not to look.

"If one were hunting for gold, this would be the map of where not to dig," said Dr. Maria Spiropulu, who earned her Ph.D. from Harvard by leading the analysis. She is now an Enrico Fermi fellow at the University of Chicago.

As the physicists put it, the experiment has established "a new lower limit" on the mass of the hypothetical particle, a member of the SUSY family called the gluino. The heavier a particle, the more energy it takes to produce it in an accelerator. So if gluinos indeed exist -- and they had better, lest a number of pet theories be wrong -- then the particles are apparently so massive that producing them requires more than 195 billion electron-volts.

"If the gluino is there it has to be heavier than that," said Dr. Joseph D. Lykken, a theorist at Fermilab (more properly called the Fermi National Accelerator Laboratory). Physicists, the most enthusiastic mixers of metaphors, speak of particles "weighing" so many electron-volts. They also like to picture the range of energies generated in the accelerators as a great expanse -- a vast, abstract rain forest (not a desert, they hope) teeming with hidden beasts.

Not everyone agrees that the experiment, which took years to complete, is definitive. Dr. Michael E. Peskin, a theorist at the Stanford Linear Accelerator Center in California, called the paper "a major advance" in the art of particle hunting. But he noted that the analysis was based on a number of assumptions -- like the nature of the particles that gluinos decay into -- that might turn out to be mistaken.

But the champions of the experiment stand by their conclusions. "Theorists write hundreds of papers arguing about what is and is not possible in SUSY," Dr. Lykken said, "but I think we are getting the bottom line correctly here."

Having found no trace of the particles in nearby terrain, the researchers will now reach further out. The data analyzed for the hunt were from the first run of the Tevatron, finished in 1996. It took another three years to make sense of the results and two more to double-check the details and write it all up. Next comes Run 2 at which the accelerator will be cranked to a slightly higher energy and run with a brighter beam.

"If it is there, we are going to find it," Dr. Spiropulu said. If it isn't, then the spotlight moves on to the Large Hadron Collider at CERN, the European researcher center in Geneva. When the collider begins operating several years from now, it will surpass the Tevatron as the world's largest accelerator.

The Fermilab physicists have more than political reasons for wanting to find SUSY's first. If the particles turn out to be so heavy that they cannot be created at these energies, that would mess up some nice, neat theories. "We're starting to push the area where all the theorists say SUSY should be," Dr. Lykken said. "The first thing you do is retreat a bit and say, 'Well, it could be a little heavier, and I can tweak my theory here and there.' But you can only get away with that for so long."

Many physicists have long believed that for all the building blocks of the world -- the quarks, electrons, photons and so forth -- to fit neatly together, there must be these things called supersymmetric particles. Quarks must have hidden partners called "squarks," electrons must be accompanied by "selectrons," photons by "photinos." "Sparticles," they sometimes call these inhabitants of the shadow world.

The Fermilab experimenters are seeking squarks and "gluinos," the hypothetical twin of the gluon, which makes quarks stick together to form protons, neutrons and other familiar particles. Had they found a gluino, it might have been front page news.

"SUSY's are a whole other half of the universe," said Dr. Henry J. Frisch, a University of Chicago physicist. "Finding them would certainly seem to deserve some recognition."

Dr. Frisch was head "godparent" of the search, meaning that he led a kind of quality control effort that approved the integrity of the analysis. "Blessing the experiment," the process is called.

Cosmologists are also following the hunt. Beyond their aesthetic appeal to particle physicists, SUSY's are a prime candidate for dark matter, the invisible gunk that may account for some 90 percent of the universe.

"When you discover gluinos," Dr. Lykken said, "you have also succeeded in manufacturing dark matter in the laboratory."

Most important, perhaps, SUSY's would fill a gaping theoretical hole. One of the great unanswered questions is why particles have mass. In a simpler world they would all be weightless like photons. But there is believed to be a particle called the Higgs that interacts with the others and bestows them with their various masses. There is a problem though: nothing in the current theory prevents the Higgs from reacting with itself, becoming heavier and heavier in an infinite regress. Everything else would become infinitely heavy too, and the whole universe would congeal into a frigid, dark lump.

Since this is apparently not the case, theorists are looking to explain what keeps the Higgs in check. SUSY's seem to fill the bill. When plugged into the equations they serve to cancel out the infinite Higgs mass.

Hoping to provide this keystone, experimenters turned to the Tevatron. Beams of protons and antiprotons were sent circling in opposite directions around the accelerator's four-mile track. When they met head on they exploded in an energetic spray of particles, an event that was recorded by a 5,000-ton, four-story-high device -- one of the most complex pieces of electronics ever made -- called the C.D.F., or Collider Detector at Fermilab. Funneled through nearly a thousand miles of labyrinthine wires and cables, the signals were scrutinized for the patterns theorists believe SUSY's make.

A mark of how intricate these experiments are is the number of coauthors on a typical paper -- 486 on the gluino report, the names and institutional affiliations sprawling across more than a third of the six pages. The tradition is to recognize everyone who contributes to the building and running of the detector, including people who may not have actually read the paper or even know it exists.

Not everyone thinks this is a good idea. As Dr. Frisch once put it in a memorandum: "A short list of papers that one has actually written carries much more weight than five pages of titles all attributed to A. Aardvark et al." (The gluino paper will be enshrined under the name of Anthony Affolder, a graduate student at Lawrence Berkeley National Laboratory.)

There are good reasons why SUSY hunting draws on so broad a range of expertise. The gluinos can't be detected themselves. They immediately break down before they can leave a trace. But the progeny of the decay may include lighter supersymmetric particles that cannot disintegrate any further, and are called, with uncharacteristic lack of luster, L.S.P.'s, for "lightest supersymmetric particles." Finding them, the theory goes, means there must have been gluinos.

But the L.S.P.'s themselves are also maddeningly elusive, speeding from the scene unnoticed. They can be inferred, however, by the holes they leave behind -- the "missing energy" they carry away. All things being equal (and they never quite are) particles from the collision of the accelerator beams would fan out in every direction like a fiery asterisk. Any gaps in the pattern could mean L.S.P.'s and, thus, gluinos.

Matters are complicated by the fact that energy can be missing for more mundane reasons. There are inevitably flaws in the detector -- called cracks or holes -- that show up as gaps. And other less exotic particles, like neutrinos, can also cause leaks.

To make sure she had accounted for these factors, Dr. Spiropulu did something unusual in particle physics -- a blind analysis much like those in drug experiments. Using banks of computers, she spent years looking only at data where no one expected SUSY's to be. This taught her how to identify and "subtract out" phenomena that could masquerade as gluino events.

To guard against bias -- seeing pictures in the clouds -- the portion of data in which theorists hoped to find gluinos was kept hidden until the very end. Dr. Spiropulu vividly remembers the day she finally "opened the box" to see what was inside. Sitting in her office with some of the godparents, she pressed a button on her laptop and the final calculations began.

"It was very, very suspenseful," she recalled. It was immediately clear that her analysis was right on. "If it hadn't been done blind, no one would have believed it," Dr. Frisch said. "It was quite a moment -- a tour de force, a beautiful job."

But on closer scrutiny, no obvious gluinos appeared. "I was extremely disappointed," Dr. Spiropulu said. "Everybody else was clapping and I was about to cry."

Actually there were two events that might have been gluinos. But, Dr. Lykken said, that isn't enough to be statistically significant: "It could just be the detector having a bad day."

Run 2 should provide a clearer picture. If no SUSY's are there, it will be on to CERN.

"Even the theorists would have to admit if the L.H.C. doesn't find them, then supersymmetry is wrong," Dr. Lykken said. "That is the point where everybody gives up."