PARTICLE PHYSICS

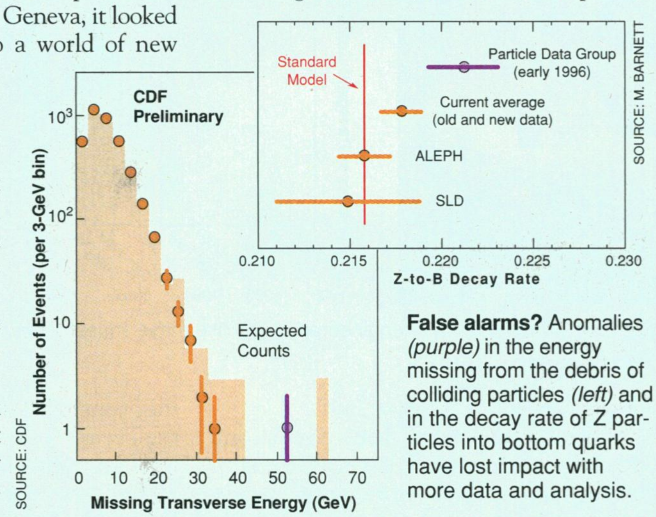
Year of Strange Events Leaves Standard Theory Unscathed

To open her talk at a recent meeting of particle physicists, JoAnne Hewett of the Stanford Linear Accelerator Center (SLAC) put up a slide headed: "1996: THE YEAR THE STANDARD MODEL CRACKED." As the year began, after all, the field had been energized by a handful of results that couldn't readily be explained by the well-established set of theories called the Standard Model. From a bizarre blip in the Tevatron accelerator at the Fermi National Accelerator Laboratory (Fermilab) in Illinois to inexplicable decay rates for the fundamental particles called Z bosons at CERN, the European laboratory for particle physics in Geneva, it looked like the first glimpse into a world of new physics might have arrived (*Science*, 26 April, p. 474). By late summer, however, new data had transformed the picture. Hewett's next slide told the story: It had the same heading, but in place of "CRACKED" was "SURVIVED."

That might sound like good news, but it's a disappointment to many particle theorists, who think the Standard Model must eventually be replaced by a more complete and consistent theory. The new results, presented last August at a meeting of the American Physical Society's division of particles and fields in Minneapolis, have not completely snuffed out the possibility that the original findings held a glimmer of new physics—in particular, evidence for a theory known as supersymmetry. Still, says Michael Barnett of Lawrence Berkeley National Laboratory, who was in the audience for Hewett's general review of the field, her revision "was a good summary of what this year was about. There was a whole set of anomalies, but for the most part they've been fading into the background."

That leaves physicists back where they have been for more than a decade: with the Standard Model, which describes the families of elementary particles called quarks and leptons and how they interact via the strong and weak nuclear forces and electromagnetism. While the theory gives phenomenally accurate predictions, it has shortcomings, such as its inability to explain the very different strengths of the three forces or describe how they would merge into a single force at the ultrahigh energies of the nascent universe, as theorists suspect they must. Supersymmetry is the most popular candidate to fill these gaps, and its signature would be the presence of a massive partner for each ordinary particle.

These partners could exist only at very high energies—too high, some theorists say, for them to materialize in existing accelerators. But hopes rose last year when CDF detected "one of the strangest things that ever popped up on a computer screen," says David Toback, a CDF collaborator at the University of Chicago. Produced when beams of protons and antiprotons collided with 90 billion electron volts of energy in the Tevatron, it consisted of two photons, an electron, and a positron (the electron's antimatter counterpart). It was also marked by a large amount of energy missing from the debris products flying out from the beams, as if something fairly energetic had escaped detection entirely, stealing away with the energy. "That is the kind of thing you expect from [a supersymmetric particle]," says Gordon Kane, a theorist from the University of Michigan.



False alarms? Anomalies *(purple)* in the energy missing from the debris of colliding particles *(left)* and in the decay rate of Z particles into bottom quarks have lost impact with more data and analysis.

If the event heralded supersymmetry, though, it should not be one of a kind. Assuming the energetic particle that escaped was a gravitino, the supersymmetric partner of a hypothetical force-carrying particle for gravity, roughly 30 similar events should be lurking among the trillions of collisions recorded in CDF. So Toback, Chicago's Henry Frisch, and their collaborators searched for other two-photon events with large amounts of missing energy. The result: "There doesn't seem to be anything there at all," says Toback (see graphic).

More data have also deflated the hopes raised by the anomaly in the Z-decay rates, seen in events in which Z particles decayed into bottom quarks—massive, short-lived cousins to the up and down quarks in ordinary matter. Supersymmetric particles might have helped explain the results by occasionally flitting in and out of existence and changing the routes that the decay into bottom quarks could take. That possibility sparked "a lot of speculation and excitement," says Marcel Demarteau, a Fermilab researcher with the DZero detector group. However, since early this year, developments at several detector groups have driven down the decay rate by about 1.5%, as averaged over all the experiments—a dramatic swing in the precision world of particle physics.

The most important contributor to the reduction is a new analysis of the decay rate, done by researchers at the ALEPH particle detector at CERN's Large Electron-Positron Collider using five times as much data as before. In another improvement, the group added a mass "tag" or discriminator to its analysis, says Andrew Bazarko, a collaborator from CERN who is now at Princeton University, by adding up the masses of all the charged particles that emerge when the bottom quarks themselves decay. By requiring that the total be above a certain threshold for an event to be counted, the team reduces contamination from decays into the lighter charm quarks. "The measurement with this high precision is extremely difficult," says ALEPH collaborator Alain Blondel of the École Polytechnique in Paris.

While the world average for the decay rate is still a little higher than the Standard Model predicts—a discrepancy that some supersymmetry enthusiasts still find significant—"you can't get excited about that," says Su Dong, a physicist collaborating on similar measurements at SLAC's SLD detector. "I'm not worrying about it, myself," adds Fermilab's Demarteau.

Is that the end of the story for supersymmetry? Unlikely, for the theory comes in many different versions, each with its own set of predictions. "This is just the first piece," says Toback of his team's work. "The idea is to broaden the search." Other physicists need no prompting. In a paper to appear later this month in *Physical Review Letters*, for example, Barnett and Lawrence Hall of the University of California, Berkeley, suggest that three quirky events seen in data from CDF and DZero could possibly signal the presence of supersymmetric particles called squarks.

"A few events are a few events," says Toback, a cautious experimenter, but the conjecture "could give us new places to search." That's the point, says Barnett: This year the Standard Model "survived again. Maybe next time it won't."

–James Glanz