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At Fermilab, the Race Is on for the ‘God Particle’

By DENNIS OVERBYE

In 1977, Steven Weinberg, then two years shy of the Nobel Prize in Physics, decided to do a little of what some theorists call “ambulance chasing.”

He heard a rumor, while spending a year at Stanford, that collisions at the Fermi National Accelerator Laboratory were spitting out weird triplets of particles known as muons, which are sort of fat electrons. Dr. Weinberg canceled reservations at a lodge in Yosemite National Park to spend the weekend with his colleague Benjamin Lee, trying to concoct a theory to explain the trimuons.

But the only theory he and Dr. Lee could come up with was ugly. A few weeks later it turned out that the triplet effect wasn’t true.

“I’ve always been embarrassed that we managed to come up with a theory,” Dr. Weinberg, now at the University of Texas at Austin, said recently.

Dr. Weinberg said that 30 years later, he still has not gotten to Yosemite.

“And we never got trimuons either,” he added.

And therein lies a lesson — or not — for the world’s physicists.

Earlier this summer, the physics world was jolted by a rumor that a team of scientists from the Fermi National Accelerator Laboratory, or Fermilab, in Batavia, Ill., had found a bump in their data that might be a legendary particle that has haunted physicists for a generation. It is known colloquially as the Higgs boson and sometimes grandly as the “God particle.” According to the Standard Model that has ruled physics for 30 years, the Higgs endows elementary particles in the universe with mass.

The history of physics is full of bumps that could have been revolutionary but have disappeared like ghosts in the night, and this rumor of a possible Higgs sighting was not even the first this year. Most physicists who have heard this rumor think that this bump is likely to be another of those disappearing anomalies, like the trimuons that frustrated Dr. Weinberg. But then these same physicists point out that you never know.

The team, known as the D Zero collaboration and numbering some 600 physicists from 19 countries and 88 institutions, will not even say whether there is a bump in its data until the scientists have decided for sure that it is nature calling and not just a random statistical fluctuation.

“It’s a rigorous process; we don’t want to make a trivial mistake,” explained Dmitri Denisov of Fermilab, one of the co-leaders, or spokesmen, of the team, which is named for the giant detector it built to record the remains of smashups of trillion-electron-volt protons and antiprotons in Fermilab’s Tevatron particle accelerator.

D Zero is the younger of two rival detectors at the accelerator. The other, known as the Collider Detector Facility, or C.D.F., was built and staffed by an equally large group that is scouring its own data for the Higgs and other new phenomena.

As the analyses proceed and the Tevatron hums its trillion-electron-volt tune, this is a summer of rumors, hope and hype. Whatever the outcome for this particular Higgs rumor, the buzz about it illuminates the galloping expectations, tensions and rivalries roiling physicists as they await the inauguration next summer of the Large Hadron Collider, a giant accelerator at CERN, the nuclear laboratory outside Geneva expressly designed to find the Higgs particle and explore new realms of nature.

The excitement has been ratcheted up by the speed and ubiquity of information on the Internet.

“It is exciting even if you think the chances of it being true are only 0 or 10 percent,” said Tommaso Dorigo, from the University of Padua in Italy, who helped spread the D Zero rumor in June on his blog, A Quantum Diaries Survivor (http://dorigo.wordpress.com). “It’s something you were looking for and would be very happy to find.”

Joe Lykken, a Fermilab theorist who said he first learned of the rumored bump the old-fashioned way, over lunch in the laboratory cafeteria, said: “Pre-blog, this sort of rumor would have circulated among perhaps a few dozen physicists. Now with blogs even string theorists who can’t spell Higgs became immediately aware of inside information about D Zero data.”

Jacobo Konigsberg, of the University of Florida, co-leader of the rival C.D.F. group, grumbled, “These blogs put a powerful loudspeaker in the mouths of a few people.”

Confirming the rumored bump would confirm a profound conjecture about how nature works, cementing into place the last missing piece of the so-called Standard Model and perhaps pointing the way to a deeper theory that could answer questions the current model leaves open — such as why the universe is full of matter but not antimatter — a New World of physics.

It would also be an enormous coup for American science, a last Hail Mary touchdown before the new European collider fires up its beams of protons, which will collide with seven trillion electron volts of energy apiece.

The CERN collider is the future of physics, Dr. Konigsberg said: “But it would be a fantastic feat to add one more jewel to the crown of discoveries from the Tevatron. We have our pride.”

According to the Standard Model, a suite of equations that describe all the forces but gravity, elementary particles and forces are born equal and without mass. Some then acquire mass by wading through a sort of a cosmic molasses called the Higgs field (named after the physicist Peter Higgs) the way a V.I.P. acquires an entourage pushing through a cocktail party.

Unfortunately, the model does not say how heavy the Higgs boson itself — the quantum personification of this field — should be. And so physicists have to search for it the old-fashioned train-wreck way, by smashing subatomic particles together to create primordial fireballs and then seeing what materializes out.

The Higgs, if formed, would decay into smaller jets of quarks or other particles, depending on its mass. The heavier it is, the more kinds of particles it can decay into. These would be recorded and counted by the detectors.

Unfortunately, as Dr. Weinberg pointed out, ordinary collisions also produce showers of the same particles coming out, and so the game has changed.

Once upon a time, physicists would look for what they called “a gold-plated event.”

“You looked at a bubble chamber and saw tracks and decays,” Dr. Weinberg recalled. “You knew what you were seeing: ‘Aha! This is the omega minus,’ ” referring to a famous particle whose discovery clinched the case for quarks in 1964.

Now, he explained, high-energy physics is all statistical. Out of 100,000 events, are a few more at various energies statistically significant? The job, he said, is to build up statistics to the point where a definite statement can be made.

That job is further complicated by quantum randomness, the dice-rolling quality of subatomic interactions, which ensures that there will be bumps and fluctuations in the data even in the absence of any unusual physics. “A bump is going to happen somewhere,” said Dr. Dorigo, who added that determining the significance of these bumps was the hardest part of the process to explain to the general public. To physicists, the gold standard for a discovery is what they call a “5-sigma” bump, where sigma is a measure of bumpiness known as a standard deviation. A bump that high means that the odds are less than 1 in 3.5 million that it was produced by chance.

The rumored signal from D Zero is said to be in that range, but to some physicists, that only increases its suspiciousness. Since the statistics get better with more measurements, Terry Wyatt, the other co-leader of the D Zero team, said that at a machine like the Tevatron, which is running at constant energy, physicists do not expect to go overnight from seeing nothing to a clear discovery.

“It will slowly creep up on us as we get more data,” Dr. Wyatt said.

Dr. Konigsberg said the same thing, calling the discovery process “a bit of a nerve-racking game.”

“You can get lucky or not get lucky on an experiment,” Dr. Konigsberg said.

The first and most famous bump in the Higgs race happened at CERN’s Large Electron-Positron Collider, or L.E.P., just before it was shut down in 2000 to make way for the new collider. It suggested that the Higgs might be waiting to be discovered just above 114 billion electron volts, in the energy-mass units physicists prefer to use.

If so, the Tevatron has a good shot at finding it, scientists said.

“We certainly have the reach,” said Dr. Konigsberg. “For us lighter is better, because we wouldn’t see it if it was heavier.”

Moreover, he said, the CERN collider will likely have a slow start.

Dr. Wyatt said: “It gives us a little window of opportunity. The scientific community has its eyes on the Tevatron.”

The Tevatron, which began running in its current configuration in 2001, is just entering its prime. It is now slated to run until at least 2009, by which time, if all goes well, the two big experiments will have collected just barely enough data between them to find the Higgs if it lies in the right range of masses.

Robin Erbacher of the University of California, Davis, said, “We’re absolutely in the game.” It would be a shame, she added, if a Higgs signal overlooked at Fermilab is discovered and trumpeted at the CERN collider.

“Looking right at it and not reporting it — that would be very embarrassing,” Dr. Erbacher said.

Rather than undercutting the rationale for CERN’s collider, finding the Higgs at Fermilab would only whet the world’s appetite for the bigger machine, physicists on both sides of the Atlantic said. The best Fermilab can hope for is a glimpse of the Higgs, and probably a hint of new mysteries and discoveries to be made.

“It will be the tip of the iceberg if we can say anything at all,” said Robert Roser of Fermilab, the other co-leader of the C.D.F. team.

On the other hand, as Judy Jackson, Fermilab’s director of public affairs, put it, people remember Columbus, who discovered the New World, more than they do Lewis and Clark, who explored it.

And so the race is on. It’s a funny kind of race because many of the 1,200 or so physicists from dozens of countries who are now working on the two big experiments at Fermilab are also on the teams building the detectors for the CERN collider.

The race is further complicated on the American side by the rivalry between the C.D.F. and D Zero groups. Earlier this summer, Fermilab had to schedule a pair of back-to-back seminars so each group could announce its own discovery of a new particle, a combination of quarks called the cascade-b. But all the data from both groups will be needed if Fermilab is to win the Higgs race, the scientists said.

When John Conway, a professor at the University of California, Davis, found a suspicious bump in the data he was analyzing last winter, “the hair literally rose up on the back of my neck,” as he later wrote on the blog Cosmic Variance. Dr. Conway, a member of Fermilab’s C.D.F. team, had been searching for the Higgs particle for 20 years.

Was this it?

He and his colleagues, Amit Lath and Anton Anastassov, from Rutgers University, had found an excess in the number of pairs of taus, which are very heavy relatives of the electron, coming out of the proton collisions. If these were coming from a decaying Higgs particle, it meant that the Higgs mass was about 150 billion electron volts.

But the bump in the data was not big enough to inspire complete confidence. It was only about 2-sigma — far below the 5-sigma gold standard — meaning there was a greater than 2 percent chance that it was caused by random events.

“Two-sigma shouldn’t get anyone excited,” said Dr. Conway. He showed the C.D.F. data at a conference in Aspen, Colo., in January, concluding that the bump was probably just a statistical fluctuation and that more data were needed. In fact, he soon learned that the rival D Zero group had a deficit in the same channel where he had a bump, strengthening the idea that his result was a statistical fluke.

“So there you go,” he said. But once his bump was out there, other people talked it up, he said. The result was a flurry of invitations and publicity, including articles in publications like New Scientist and The Economist.

“Things got out of hand quickly,” said Dr. Conway, who expects to have a new analysis with almost twice as much data by the end of the summer. His experience, he said, underscores how excited people are about the Higgs hunt and how important it is for physicists to get their message out clearly if they want to maintain their credibility.

“Our only product is our physics result,” he said. “Careers are made and broken on how things come out.”

This was only a warm-up.

On May 28, an anonymous physicist wrote to the comments section of Dr. Dorigo’s blog, asking if it was true that D Zero was seeing an excess of so-called b-quarks spitting from the Tevatron. This excess, or bump, was supposedly at the level of 4-sigma or 5-sigma and thus, if it withstood scrutiny, it would have to be taken seriously as a sign that the Higgs boson was there with a mass of about 180 billion electron volts.

Dr. Dorigo is in the C.D.F. collaboration and thus had no inside knowledge, but repeated that he had also heard the rumor. The rumor was picked up by the publications Slate and Wired.

In response, Gordon Watts, a physicist from the University of Washington and longtime member of the D Zero team, scolded Dr. Dorigo for speculating on rumors.

“Dude! If you get called by the press to comment on this rumor — you will be making secondhand comments on rumors!” Dr. Watts wrote on his blog, Life as a Physicist.

Dr. Watts pointed out that until a result had passed several levels of rigorous reviews within the team, including redoing analyses with different computer programs, there was no result, and nothing to say in public. “I don’t think D Zero has ever had an analysis that was given this much external scrutiny before its official release,” Dr. Watts wrote in an e-mail message, adding that the blogs had already quieted down.

Dr. Konigsberg, of the rival team, said they had their own analysis of their own b-quark measurements underway. He compared the rumor to a game of telephone that “starts one way, ends up the other.”

Dr. Dorigo said, “Right now there is nothing to build a story around.” Things could heat up again at conferences this summer in Karlsruhe, Germany, and Daegu, South Korea, where particle physics results are traditionally presented — or never.

The official silence did not stop speculation. If it is a Higgs, theorists say, it is probably not the one prescribed by the Standard Model, which would not be produced plentifully enough to be seen yet.

The leading alternative is that it would be one of five Higgs bosons predicted by a theory called supersymmetry, which theorists have been yearning for as the next step toward a more all-embracing, unified theory of nature. One bonus of supersymmetry is that it predicts the existence of more, yet undiscovered elementary particles, one of which might be the mysterious dark matter that binds galaxies together in the universe. All this would fall into the lap of the Large Hadron Collider scientists, if it exists, which is one reason the CERN physicists will be happy no matter what the outcome.

But if that is the case, the Tevatron should have already seen it, physicists said.

“If it’s real, it’s quite a weird object,” said Dr. Lykken, who had been discussing possible theoretical models with his Higgs-savvy colleagues just in case the anomaly does not go away. It would be hard to reconcile this result with all the data already collected by Fermilab and the L.E.P. at the European laboratory, he explained.

“I don’t know if we pinned down nature, or if nature has pinned us down, but there are many corners you can’t get into anymore,” Dr. Lykken said.

Dr. Weinberg, who acknowledged his rooting interest in the Higgs discovery, as the particle is at the center of Nobel Prize work, said he had heard the sighting rumor but did not know what to make of it. “I’m more patient now,” he said.

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