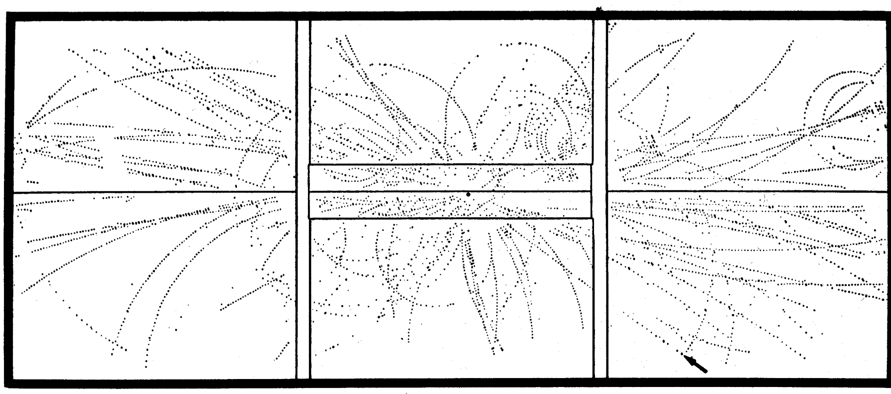
W Particle, Physics Missing Link, Found

They are particles called intermediate vector bosons—usually designated by the letters W^+, W^-, and Z^0. In one theoretical form or another they have been the object of searches by physicists for decades. In their present form they are indispensable to the theory known by the names Weinberg-Salam-Glashow, which is the most successful step toward a single theory that would explain all of physics, and for which a Nobel prize has already been given. Evidence for the discovery of the two Ws was presented at last week's meeting in New York of the American Physical Society by representatives of two experimental groups working at the European international physics laboratory called CERN in Geneva.


CERN

W decay event. Large dot in center marks proton-antiproton collision point. Arrow indicates energetic electron track. Neutrino, being neutral, does not show up.

The stakes in such a discovery are quite high. Commentators heard in the corridors were assuming that sooner or later a Nobel prize will be given for the experiment, too. The tension between wanting to be first and wanting to be certain was evident. Carlo Rubbia of Harvard University, representing the 120 physicists from 11 institutions in Europe and one in the United States known as the UA1 collaboration, claimed flatly that the W^+ and W^- had been found. Alan Rothenberg of CERN, representing the almost equally large and international UA2 collaboration, said that the evidence looked like Ws but that further tests are necessary to be sure they are not something unexpected that look very much like what Ws are expected to look like. Such mistakes have occurred before. UA1's conclusions are based on five events; UA2's on four.

The story really begins back in the 1930s with theoretical work of the Japanese physicist Hideki Yukawa. Yukawa gave physicists the idea of intermediate particles, particles that embody a given kind of force. In the Yukawa picture, if a force of a certain kind exists between two particles, that is equivalent to saying that the two particles are exchanging a third particle, the intermediate particle proper to the force in question.

Physicists divide natural forces into four classes: gravity, electromagnetism, the weak interaction and the color or chromodynamic interaction. The different classes tend to act on different kinds of particles and to follow different laws with respect to their strength and other behavioral details. Each has one or more intermediate particles of its own: for gravity the (undiscovered) graviton, for electromagnetism the photon, for chromodynamics eight kinds of gluon and for the weak interaction the Ws and the Z.

The second part of the background involves the search for a unified field theory. Force, or interaction, as physicists would prefer to say, is a single concept. It ought not to be divided into four unrelated categories. For about a hundred years physicists have looked for a fundamental underlying unity, a theory that would show a basic connection among them all and explain their differences.

In the last decade or so work by Steven Weinberg of the University of Texas at Austin, Abdus Salam of the International Center for Theoretical Physics in Trieste, Italy, and Sheldon L. Glashow of Harvard University has produced a theory that makes an important and successful step in the direction of that unity. It links electromagnetism and the weak interaction in what is now being called "electroweak."

In the W-S-G theory the Ws, the Z and the photon are combined into a symmetric family of intermediate particles, but the symmetry is not perfect. It is slightly broken: The Ws and the Z have certain rest masses; the photon has no rest mass. That the symmetry exists permits physicists to show the basic unity of electromagnetic and weak-interaction phenomena. That the symmetry is slightly broken, and broken in just the right way, permits them nevertheless to distinguish the two classes. This idea of slightly broken symmetry is the driving force in theoretical physics nowadays. Theorists are seeking to establish a hierarchy of symmetries until they reach the one that contains everything and has just the right breaks to explain the differences among everything.

Enters now the CERN proton-antiproton collider. This apparatus started in life as a conventional proton accelerator, the Super Proton Synchrotron. In 1977 Rubbia suggested turning it into a machine in which protons and antiprotons would circulate in opposite directions around a circular pipe and be brought together in head-on collisions at several interaction points. This was accomplished over the next five years. The W data are its first important result.

When such a proton and antiproton come together, they annihilate each other and produce a blob of pure energy, which can become anything the combined energy (540 billion electron-volts) and the conservation laws of physics permit. Once in a long while a W particle will be produced along with another undetermined particle. The W decays almost immediately. The most likely decay route is W^- to electron and neutrino, W^+ to positron and neutrino.

Rubbia's talk to the physical society was intended to justify in detail the procedures that narrowed down the results of a billion proton-antiproton collisions to just five candidates. The final criteria, which were the same for both experiments, are that the event exhibit the track of an energetic electron or positron coming away from the collision point and that adding and subtracting energies can determine that a neutrino went off in the diametrically opposite direction.

Having the candidates, a check is to add up the energies of the electron or positron and the neutrino to determine the rest mass of the W. This comes out right on the money: 81 ± 5 billion electron-volts compared with a theoretical prediction of 82 ± 2.4. Another check is that the theory gives statistics for calculating how many W decays you can expect to see in this kind of experimental run. That comes out right, too. Says Rothenberg about the UA2 statistics: "You expect four; you get four." The experiment has confirmed electroweak unification, Rubbia says.

The experiment lasted 30 days. The next step, commencing in April, is planned to last three months. It will be looking for rarer decays of the Ws — into muons and neutrinos or tau particles and neutrinos — and for Zs. Zs, with predicted rest masses of 93 billion electron-volts, should be harder to find in this kind of experiment, and it is not surprising that the short run didn't find any. —*D.E. Thomsen*