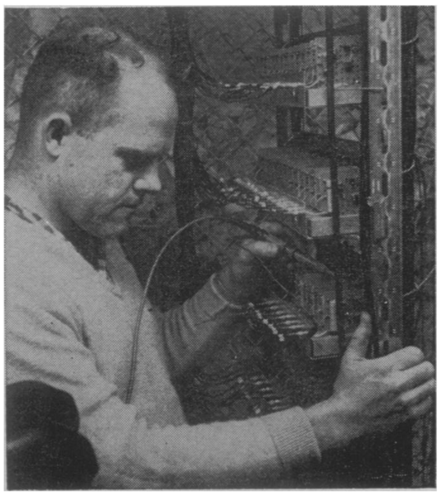
# The W particle may have been found

Physicists distinguish four different kinds of force by which objects in the universe act upon each other: the strong nuclear force, the weak force, electromagnetism and gravity. The developed theory of particle physics outfits each force with a so-called intermediate particle, a particle that, in the language of field theory, is the quantum of the force field in question and that serves to carry the force from place to place much as a tennis ball mediates a force between two rackets.

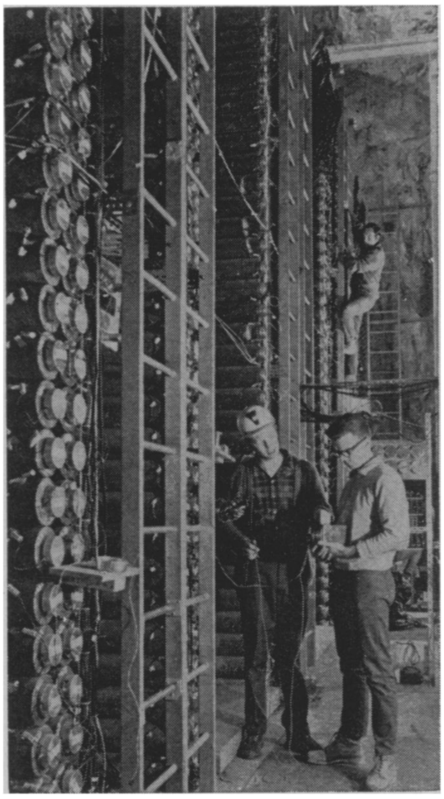
Up to now two such intermediate particles have been identified, the pi meson associated with the strong force and the photon or light particle associated with electromagnetism. Now, from an abandoned silver mine at Park City, Utah, comes strong evidence of the existence of the weak-force quantum, known as the intermediate vector boson or W particle. (Intermediate is for its mediating quality, vector for the mathematical entity that represents it and boson for the statistical law it obeys, Bose-Einstein statistics.)

The evidence comes from cosmic-ray observations by a group of physicists from the University of Utah led by Drs. Jack Keuffel and Haven E. Bergeson. It was reported this week at the 12th International Conference on Cosmic-Ray Physics at Hobart, Tasmania.

In the silver mine at Park City is a large detector that records the arrival of mu mesons produced in the upper atmosphere by cosmic rays. Cosmic rays are mostly protons, and when they strike atomic nuclei in the upper atmosphere, they tend to produce pi mesons and K mesons. If these pi and K mesons can travel far enough without suffering further collisions, they will decay radioactively into mu mesons.



*Bergeson: Years of counting muons.*



*The evidence came from this detector.*

Particles entering the atmosphere from oblique angles have a better chance to avoid collision, so the experimenters supposed that the detector would see more mu mesons coming from directions near the horizon than from directions near the vertical. (The detector was placed underground to screen out relatively low-energy particles produced in the lower atmosphere.)

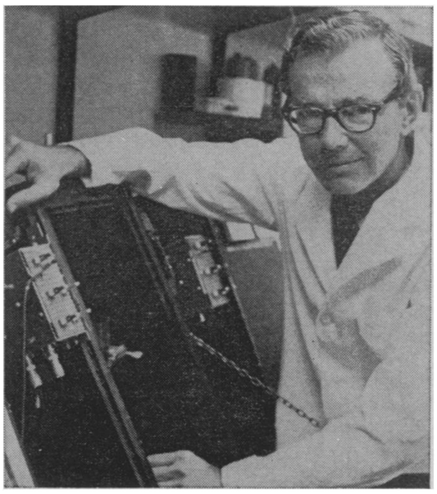
The record of more than 200,000 mu mesons in the last three years shows an anomaly, the so-called Utah effect. The proportion of mu mesons arriving from vertical directions is higher than it should be and rises as the depth below the earth's surface (and therefore the energy of the mu mesons) increases. "The ratio reaches a peak at a depth of about 4,000 feet and then begins to taper off again," says Dr. James Morrison, another member of the team.

These anomalous high-energy mu mesons cannot be explained as the products of the decay of pi or K mesons. Among the hypotheses that can explain them and that will explain their increase and decrease with energy is that mu mesons are produced by the decay of W particles that are formed when cosmic-ray protons strike the upper atmosphere and that the W-produced mu mesons are selectively absorbed underground in a way that pi- and K-produced mu mesons are not. Over the years the members of the Utah group have seen more and more evidence to favor the W hypothesis. Now they say it is the best one and that their observations give, in Dr. Keuffel's words, "strong evidence for the existence of the intermediate boson."

They also say that their hypothesis explains some strange things that have been seen in other experiments, particularly an experiment set up under Mont Blanc by a group of Italian physicists. This experiment sees 10 times more low-energy pi mesons than might be produced by the ordinary muons. Bringing W-produced mu mesons into the calculation predicts the number of pi mesons correctly, the Utah physicists say.

The existence of the W particle, if it is confirmed, fulfills a theoretical prediction. It also indicates that at high energies the weak force behaves as if it were only semiweak, and it opens to investigation a new class of supermassive particles.

The domain of the weak force is one of the odder corners of particle physics. When physicists first began to explore atomic nuclei, they found that the force that holds nuclei together is different from either the gravitational or the electromagnetic forces they were familiar with. Because it appeared much stronger than anything else, physicists called this new force the strong interaction.



Photos: Univ. of Utah

*Keuffel: It changes the ball game.*

But there were a few subnuclear particles around that did not respond to the strong force, the electron, the mu meson, the neutrino. There were also a number of radioactive decay processes, especially the beta decay of nuclei, that took a long time by particle-physics standards, indicating that a much weaker force than the strong interaction was operating in them. Theorists put all these various phenomena into a bag marked weak interaction and tried to devise a theory that would explain them all as particular cases of the action of a weak force. In doing so they predicted the existence of the W particle. They knew the W would be hard to find because the theory required it to be a very heavy particle, but exactly how heavy the theory didn't say.

**The Utah experiment** gives an estimate, a mass of approximately 37 billion electron-volts (GeV). By comparison, a proton's mass is 0.938 GeV, and the heaviest particles heretofore known are no more than a few GeV. Because of certain characteristics of the W particle, says Dr. Keuffel, its existence requires the existence of other particles in the mass range 30 to 40 GeV. This would be a whole new class of particles interacting among themselves, and for high-energy physics, says Dr. Keuffel, "It changes the ball game."

At the high energies where the W particle appears (in the thousands of GeV), says Dr. Keuffel, the ordinary weakly interacting particles behave in a strange semiweak way. One of the consequences of the weakness of the weak interaction is a very low probability that a weak-force particle will interact with other matter. A neutrino can pass through the whole earth, for example, without interacting with anything else on the way.

But at these ultrahigh energies, says Dr. Keuffel, a neutrino should be stopped after about 1,000 feet of rock. Such high-energy neutrinos should also be able to decay into mu mesons, something that low-energy neutrinos do not, and a number of other strange things should happen. "It opens up a whole fascinating speculation," he says.

It may also lead to an independent test of the W-particle hypothesis. If all this is true, neutrinos with energies of 1,000 or 2,000 GeV should produce spectacular and visible events as they interact in the rock, and the Utah physicists intend to look for these events.

Dr. Keuffel says that other physicists who have been given advance notice of the finding have reacted with great interest, but also with great caution. Final acceptance will depend on confirmation of the results. This, he says, may be difficult since no other detector is as big as the Utah one. □

LUNAR GEOLOGY

## Analyzing the Genesis Rock and others

NASA

*Astronaut Scott examines the "Genesis Rock" in its germ-free chamber.*

It has long been an open secret that lunar scientists are less than happy about the policy of sending pilots to the moon to do geology. Thus, last week, it came as a singular honor to the Apollo 15 astronauts, David R. Scott, James B. Irwin and Alfred M. Worden—all Air Force pilots—when they were described repeatedly as "new geologists in the profession."

"The astronauts have apparently the best understanding yet of that site [Hadley/Apennine]," says Dr. Paul Gast, chief of the planetary and earth sciences division at the Manned Spacecraft Center, "and this may remain that way for a long time."

"In all cases so far," said Dr. W. C. Phinney, chief of the geology branch at MSC, "where we have looked at what the rocks are, they match exactly what the astronauts said they were [on the lunar surface]." Scott and Irwin had seen green rocks, white rocks and pink rocks. They had identified some as breccias, some as basalts, and one in particular as an anorthosite.

**As bag** number 196 with the anorthosite was unwrapped last week in the Lunar Receiving Laboratory, all hopes were realized. The one-half pound white rock—called by some the "Genesis Rock"—was an anorthosite—a crystalline rock of the sort formed at great depths in the earth and therefore likely to represent the original crust of the moon. To prove it means showing the rock is 4.6 billion years old, the best current estimate for the moon's age.

The anorthosite is probably a calcium aluminum silicate and could therefore be a confirmation from the ground of what the Apollo 15 orbital X-ray instrument was recording—that the highlands were richer in aluminum than the maria. From the returns of Apollos 11 and 12, geologists knew that the maria were rich in iron—one thing that makes them appear darker than surrounding areas. The scientists had hypothesized that the highlands could be rich in aluminum, which would give them their lighter color. If this were true, then the highlands could also be made up of anorthositic material—possibly remnants of the original lunar crust.

But dating the rock may be very difficult. Early this week the white rock was tested: it had the lowest concentrations of radioactive thorium, uranium and potassium of any sample yet returned from the moon. This makes the standard age-dating methods—by comparing concentrations of the products of radioactive-decay chains with concentrations of the elements that start them—largely ineffective.

**Geologists** are also anxious to see if the rare Apollo 14 material, called KREEP, which has a high content of potassium, rare earths, uranium and phosphorus, shows up in the Apollo 15 samples. How KREEP relates to the material believed to be the lunar crust is another problem. One hypothesis is that during the partial melting of the moon, the crustal materials—such as the anorthosite—would be the first to melt and crystallize. The KREEP would be what is left over after the crust had been formed.

Another important source of information has been the core sample which took several man-hours of drilling to secure from beneath the moon's surface. "This is the best thing we ever did on the moon," remarked Scott of the 8-foot core. An X-ray of one-half the core (the top three sections) revealed 24 distinct layers, each differing in grain size, distribution and thickness. "We are now sure that we have in that core a record of the events at the Hadley site probably over billions of years," says Dr. Phinney.

What that history is may be slow in unraveling. This week scientists debriefed the astronauts. Next week the preliminary examination team at MSC will begin the three-month chemical analyses of the returns.