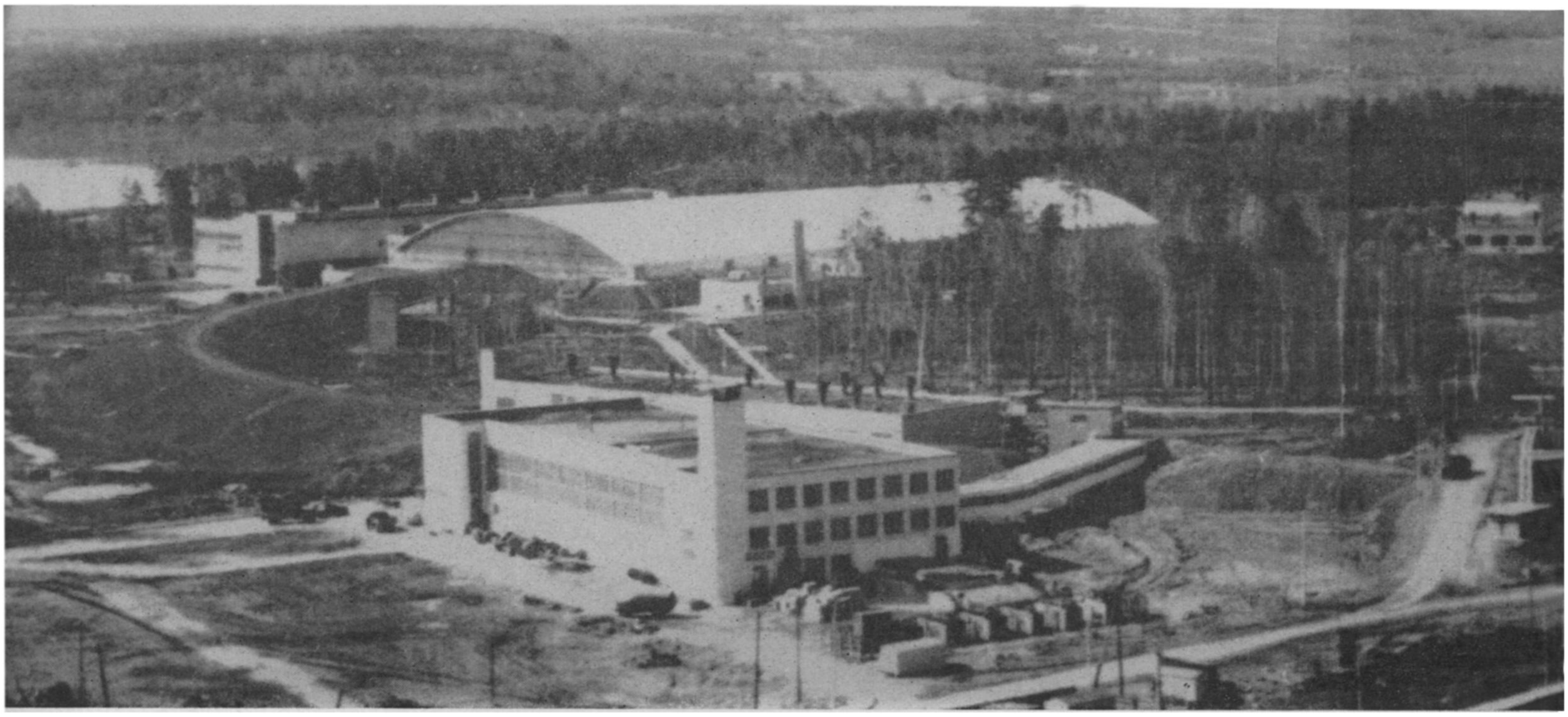


PARTICLE PHYSICS

76 GeV synchrotron at Serpukhov is world's most powerful. Some think it strong enough to create intermediate vector bosons.

Looking for the W

Theory requires a particle that carries weak subnuclear forces. Ten years of search have been fruitless, but success may be near.

by Dietrick E. Thomsen

The world's most powerful particle accelerator, the 76-billion-electron-volt synchrotron now beginning experimentation at Serpukhov in Russia, is expected to look for many things never before seen in the world of particle physics. One of them may be the long sought, intermediate vector boson.

"We are trying hard to persuade them to set up to look for it," says Prof. R. E. Marshak of the University of Rochester, who has spent many years studying the kinds of interactions in which the boson ought to play a role. He explains that Serpukhov is the only accelerator in the world that can put enough energy into a particle collision so that there is a hope of creating it.

Intermediate vector boson is more a classification than a name. Intermediate stands for its function as the carrier of a force—in particle physics it has proven profitable to regard a force between two particles as if it were embodied and carried by a third and intermediate particle. Vector is the name of the mathematical entity that is used in describing the particle's activities. Boson means that such particles would obey statistical behavior laws derived by S. N. Bose and Albert Einstein.

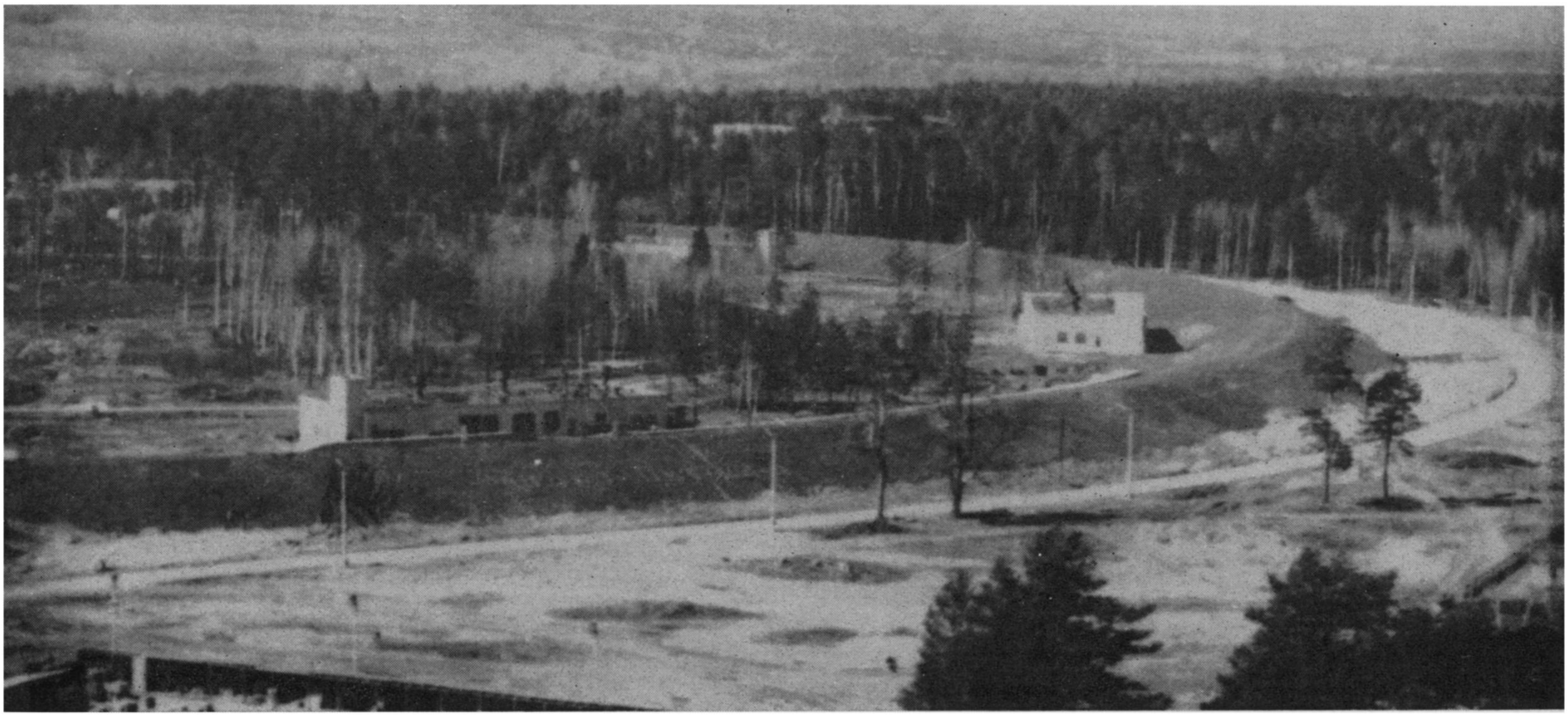
For short, this postulated particle is usually designated W, in recognition of its hypothetical function as carrier of the weak subatomic forces.

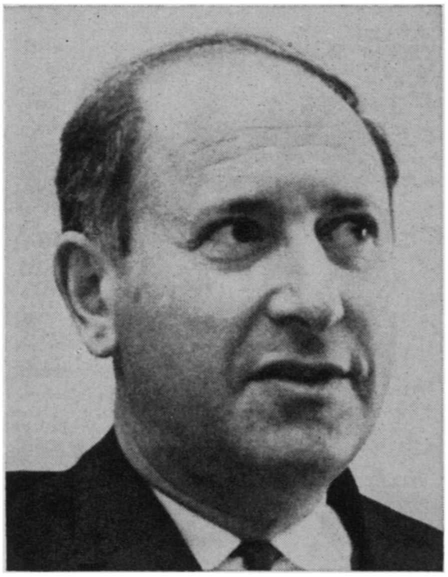
The weak force is one of the large puzzles in particle physics; the way it fits into the rest of the universe is far from clear. It looked superfluous when it was discovereed, and no one is yet sure what function it serves.

When physicists started to investigate atomic nuclei, they were already familiar with two general classes of forces, gravitational and electromagnetic. It soon became clear that the force that held nuclei together represented a third class. It was much stronger than the other two, it took no notice of electric charges and its range, unlike the infinite range of the macroscopic forces, was confined to a space about the size of the largest nucleus.

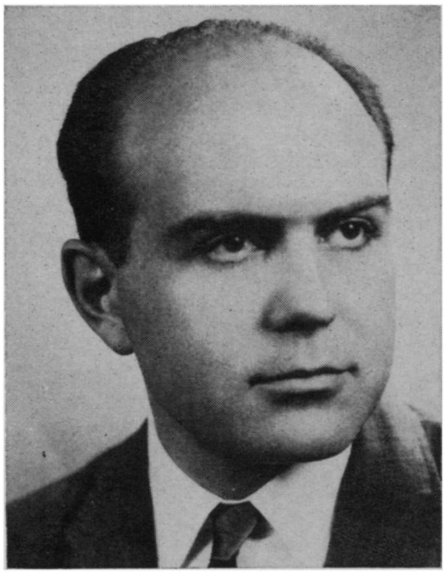
But there was one nuclear phenomenon that this strong force did not explain—beta decay. In certain radioactive nuclei a neutron will spontaneously turn into a proton, emitting by the way an electron—a beta particle—and an antineutrino. This also happens to free neutrons.

The force involved in beta decay, though also of short range, was much weaker than the strong force and even than the electromagnetic. And it was far slower than the strong force: The life-





University of Rochester
Marshak: W's are made in pairs.



New York University
Zumino: For symmetry we need three.

University of Rochester
Okubo: All three don't do same thing.

time of a free neutron is about 12 minutes; particles that decay by the strong force disappear in billionths of a second.

In the late 1940's, about 15 years after the elucidation of beta decay, came the discovery of strange particles—called strange because no one could figure out what they were for—and among these were a number that participated in interactions with the same weakness and slowness as beta decay. From this circumstance arose the desire for a universal weak interaction theory—one that would explain the whole group of occurrences as results of the operation of a single, general class of force.

In the late 1950's Prof. Marshak and Dr. E. G. Sudarshan developed such a universal theory to describe the operations of the weak force. A similar theory was put forward shortly afterward by Profs. Murray Gell-Mann and Richard P. Feynman of the California Institute of Technology. Later another independent derivation came from Dr. J. J. Sakurai of the University of Chicago.

Although it seemed at first wildly contradictory to experiment, recent work shows that in low energy interactions the theory's predictions are, in Prof. Marshak's words, "spectacularly confirmed."

This does not mean that W has been seen.

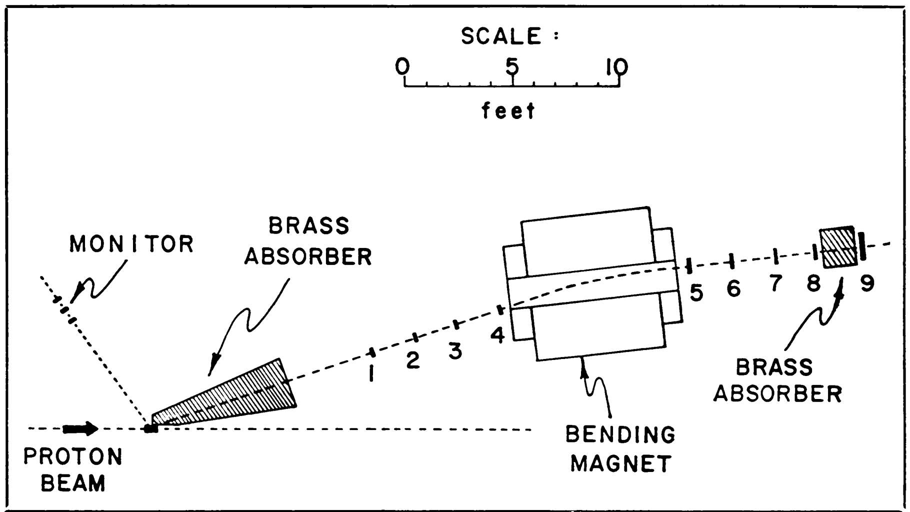
In these low energy cases it does not really matter, says Prof. Marshak, whether the W particle makes an appearance. The theory explains them well enough whether W's are included or not.

It is at high energies that the W's become important. The weak force, unlike any other, gets stronger as the energy of interaction goes up. If this trend continued indefinitely, the weak force would become as strong as the strong one at an energy of about 300 GeV, calculated with respect to the center of mass of the interacting particles.

(Accelerators are rated by the energy they impart with respect to the laboratory, always a great deal more than the center-of-mass energy because the center of mass is always in motion with respect to the laboratory.)

In practice this steady climb in weak force strength does not happen. It seems now that it should reach a maximum at 5 GeV (center-of-mass energy) and remain constant. Why this cutoff occurs cannot be explained by a theory without W's, but if W's exist, it can be connected with their existence if the W mass is equal to 5 GeV or some explicable multiple of that figure.

. . . the W particle



A 1965 experiment at Argonne National Laboratory did not find the W.

One high energy interaction, which involves the difference in mass between two kinds of K meson—a discrepancy of 1/100,000 electron volt in 500 million electron volts—is a center of current excitement. Three groups, says Dr. Marshak, one working with him, one with Dr. B. L. Ioffe in the Soviet Union and one with Prof. Gell-Mann at Caltech, are trying to see "what we can determine about the existence of the W from the higher energy weak processes."

More satisfying would be producing and directly identifying the W in the collision of a particle beam with a target. This has been tried without success. Dr. Marshak's hope for Serpukov is based on the higher energy there.

The scientists feel they are getting close to the particle, though they are not certain what it looks like.

The W started out very simply as a pair of theoretical particles, one with positive and one with negative electric charge. A neutral member of the group was disallowed because its existence would permit some hypothetical interactions that are never seen.

But later, Drs. Bruno Zumino of New York University and Tsung-Dao Lee of Columbia University have introduced a neutral member. They have had to do this to make the W's fit into the general scheme that physicists have constructed to show relations among the other elementary particles.

To make the W's fit this general symmetry scheme, Profs. Lee and Zumino admit, they have to scrap the notion of a single, universal weak interaction. They contend that the weak force occurrences have to be separated into two classes, one in which the neutral W can operate and one in which it cannot. This must be done to prevent the theory from allowing events that are never seen.

Dr. Marshak feels that the W's should appear in pairs when they appear. He agrees that a neutral member would solve many problems and does not find the two-class system unacceptable. Since he expects the mass of a W to be between two and five billion electron volts, to make a pair of them requires up to ten billion electron volts in the center of mass system. Serpukhov alone among the world's accelerators can supply this.

Dr. Marshak's Rochester colleague, Dr. Susumu Okubo, has another theory in which there are three W's: positive, negative and neutral. Dr. Okubo is as concerned as Lee and Zumino about symmetry, which in cases like this requires triplets. But he gives his neutral W only the job of carrying the electromagnetic forces that occur among weakly interacting particles, leaving the charged ones to carry the weak force.

Which of these and others may be closest to reality awaits results from Serpukhov, unless something more definite than has happened up to now comes out of the underground experiments being conducted in various mines around the world (SN: 5/9, p. 424). These were set up mainly to study cosmic ray neutrinos, but some of them, notably one run by the University of Utah and one in a South African gold mine, have been noticing what looks like pairs of muons proceeding from the same source. Such pairs of muons would be evidence—still indirect, however—of the passing existence of W's.

But in these experiments it is hard to tell a mu meson from a pi meson, and if members of these muon pairs are actually pions then what is seen can be explained without the W, on the basis of particles already on record.

Through the last year, as these underground results have been coming in, physicists have argued over their meaning, so far without decision.