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Nobel Prize in Physics 1984

Carlo Rubbia **Simon van der Meer**

The Nobel Prize in Physics 1984 was awarded jointly to Carlo Rubbia and Simon van der Meer *"for their decisive contributions to the large project, which led to the discovery of the field particles W and Z, communicators of weak interaction"*

Information about winners:

Carlo Rubbia,

CERN, Geneva, Switzerl

Simon Van der Meer,

CERN, Geneva, Switzerland

RESEARCH INFORMATION:

Carlo Rubbia and **Simon Van der Meer** have been awarded this year's Nobel Prize in Physics for "their decisive contributions to the large project, which led to the discovery of the field particles W and Z, communicators of weak interaction". Weak interaction is one of four fundamental force fields in the universe. It operates deep inside matter where quarks and leptones reside. Examples of weak processes are radioactive 6-decays and also the nuclear processes in the sun which control its power.

One expected on theoretical grounds that the weak interaction is communicated by extremely heavy hypothetical particles, W and Z. In 1976 Carlo Rubbia presented an idea to convert an existent large accelerator into a storage ring for protons and antiprotons. The W and Z particles could then be produced in violent head-on collisions between the stored particles. Simon Van der Meer had invented an ingenious method for dense packing and storage of protons, now applied for antiprotons. Rubbia's idea and Van der Meer's invention were combined in a large project and the first collisions in the CERN superaccelerator were observed in 1981. The discovery of the W and Z were announced in 1983 by Rubbia and collaborating large teams of scientists, basing the evidence on signals from detectors, specially designed for this task.

The project at CERN, the European nuclear research organization in Geneva, is the largest that has ever appeared in the context of a Nobel Prize. Two persons in the project are outstanding - Carlo Rubbia, who had and developed the idea, and Simon Van der Meer, whose invention made it feasible.

Background Information

Weak Interaction

The discovery of the heavy field particles W and Z culminates 50 years of scientific investigations of the nature of the weak interaction. A milestone along the road of development was passed by the discoveries of W and Z at CERN in 1983.

Weak interaction is one of four fundamental force fields in the universe. It operates at the deepest level of matter, that of quarks and leptons. Examples are radioactive ß-decays. The power of the sum is also controlled by weak processes.

What roles are played by W and Z ?

The surplus energy in ß-decay radiates in the form of electron and neutrino pairs. These pairs were assumed to be created directly when neutrons were transformed into protons. This was in 1934.

Now, 50 years later, we know that the pair creation is a two-step process. In the first intermediate step the communicator W^- is emitted (in the example of neutron decay). In

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other processes a W^+ is emitted, in yet others a Z^0. In the final step - somewhat further away in time and space - the W disappears and transfers energy etc. to the electron neutrino pair. The distance in space and time is so extremely short that the W has been hidden. The same holds for Z^0. In 1983 they were for the first time displayed in the open.

Relation to electrical forces

The idea of introducing communicators in interactions is an old one in physics. It is used in the modern treatment of electrical forces. Two charged bodies interact at a distance by exchanging photons, as if they were throwing balls to each other.

Beams of free photons from light, radio waves etc. The Nobel Prize in Physics in 1979 was awarded to Sheldon Glashow, Abdus Salam and Steven Weinberg for their mathematical theory of weak interaction. It not only solved some difficulties with the direct process but was based on an intimate unity between weak and electromagnetic interactions. Besides the two heavy charged communicators W^+ and W^- , the theory contains two neutral communicators - one heavy, the other massless. The massless one is the photon. The heavy Z^0 represents something completely new. The first time a process was observed, caused by the hidden Z^0, was in 1973 at CERN by an international team, using the French-built Gargamelle bubble chamber.

The large project at CERN

One could not be certain that the communicators existed as long as they remained hidden. To be convincing, they have to be produced in free form. New research fields will then be opened up. The existence of radio waves was discovered almost one hundred years ago by Heinrich Hertz. The W and Z have been produced and detected at CERN with evidence for their existence as convincing as the one for radio waves by Hertz

The project started in 1976. At that time, energy was nowhere in the world available in sufficient concentration for the creation of the W or the Z. Carlo Rubbia presented a new idea, proposed by him and two American colleagues during an international conference in physics in 1976. Rubbia brought the idea to CERN. Committing himself intensely, exploiting his deep knowledge in broad areas and with catching enthusiasm he succeeded in convincing the CERN management that the project might well be feasible. The method requires a copious supply of antiprotons (antimatter). Provided this problem could be solved, W and Z could be created in frontal collisions between antiprotons and protons in the new superaccelerator, SPS, at CERN. The probability of a successful collision could be estimated. In order to produce about ten communicator particles, about a billion collisions have to occur. To do that on a reasonable time scale the number of antiprotons circulating in the SPS must be enormous, several hundred billions.

Antiprotons do not exist in nature. They can be created in batches in collisions at another of CERN's accelerators. However, only a tiny fraction of one per cent of the required number of antiprotons will be obtained in each batch. Almost insurmountable difficulties are encountered when one tries to collect and densely pack hundreds of thousands of batches of fresh antiprotons.

Simon Van der Meer had some years earlier invented an ingenious method for the dense packing or protons which are circulating in an orbit in a vacuum chamber, guided by magnetic fields. The method is rather sophisticated. Even experts found it hard to believe in the possibility. The method was successfully tested at CERN. It was finetuned for use on the current of antiprotons. Van der Meer and his coworkers finally succeeded in increasing the current of antiprotons several hundred thousands times using a facility specially built for production, storage and dense packing. The first collisions in SPS were made in the summer of 1981. The experiments started in November of the same year. The hunt for expected and unexpected phenomena was on, and still continues.

The few expected W's and Z's had to be found and measured in detail. Measuring apparatus for this purpose was not readily available. Carlo Rubbia gathered a group of scientists around himself for the task of designing and constructing an enormously large detector. It was adapted for the difficult task of catching the communicators and measuring their properties. Another team of scientists also took part in the successful hunt with their detector specially built for this task.

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Scientists and engineers in their hundreds have participated in various phases of these large-scale projects for many years. They come from laboratories in many countries, mainly member states of CERN, and from CERN itself.

The CERN project is the largest which has appeared in connection with a Nobel Prize. Two people are outstanding: Carlo Rubbia, who had and developed the idea, and Simon Van der Meer, whose invention made it feasible.

For more details please visit:

http://www.nobelprize.org/nobel_prizes/physics/laureates/1984/press.html