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Some Highlights in Elementary Particle Physics in 1969

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Abstract

A brief summary of some highlights in elementary particle physics in 1969 is presented. The status of the Serpukhov, Batavia, and CERN-ISR research facilities is described. A number of recent experiments of outstanding interest are discussed - total cross section measurements at Serpukhov, the searches for the quark and for tachyons, and the deep inelastic electron scattering work at Stanford.

Introduction

The trend in the late 1960's towards diminishing U. S. Government support for elementary particle physics research continued to be evident in 1969. A brilliant exception to this unhappy picture, however, has been the authorization by the Congress of the construction of a 200-400 BeV* proton synchrotron at the National Accelerator Laboratory at Batavia, Illinois. This machine, to be known when completed as the Enrico Fermi Accelerator, is being built on a fast time schedule, and it is planned to start the first experiments with this new machine in the middle of 1972.

In the USSR, a 75 BeV proton accelerator at Serpukhov, near Moscow has recently been put into operation, and a number of research experiments have already been completed. Individual American physicists are making plans to collaborate with Soviet physicists on some of the experiments at Serpukhov, under the terms of a USA-USSR scientific exchange agreement.

In Western Europe, a major new research facility is being built at CERN - near Geneva, Switzerland. Two intersecting storage rings (ISR), to collect and store 28 BeV protons from CERN's 28 BeV proton accelerator, are being built; in 1971, experiments will be started to investigate the head-on

* 1 BeV = 1 billion electron volts

collisions between the "clashing" beams of protons in the two rings. (In many ways, this is like studying proton-proton collisions with a 1600 BeV proton accelerator beam which strikes a stationary target.) Some very high energy phenomena will be studied for the first time, with the use of the ISR.

Nobel Prize

The 1969 Nobel prize in physics was awarded to Murray Gell-Mann, for his contributions and discoveries concerning the classification of elementary particles and their interactions. In 1953, Gell-Mann produced his theory of "strangeness". This theory explains the behavior of a number of mysterious ('strange') particles which were found to be copiously produced by high-energy proton accelerators. The decay lifetimes of these particles were very long, typically about one ten-billionth (10^{-10}) of a second, which is to be compared with the predicted "natural" lifetime of about 10^{-23} seconds. The puzzle was resolved by Gell-Mann; the idea of the "strangeness" quantum number was invented. Hyperons have strangeness -1; kaons have strangeness +1; antikaons have strangeness -1; more familiar particles (electrons, protons, neutrons, π-mesons) have strangeness zero. Strangeness is a conserved quantity in the strong interactions in which hyperons and kaons are produced (in pairs); but strangeness is not conserved in the (weak) decay processes; so a hyperon or kaon can turn into non-strange particles, but only very slowly (in 10^{-10} second). Since this first great discovery, Gell-Mann has made a number of important discoveries in the theory and classification of elementary particles and their interactions. He has also contributed considerably to the theory of weak interactions. In 1961, he proposed the super-multiplet structure of the mass spectrum of strongly interacting elementary particles - SU (3), which received spectacular verification in the discovery of the Ω^- hyperon in 1965. He has speculated about the possible existence of entities called 'quarks,' which might be the fundamental building blocks out of which the 'elementary' particles - protons, π-mesons, etc., are made. The above are only a few of Gell-Mann's many outstanding contributions to physics.

The 40-year-old Gell-Mann, a native New Yorker and Professor of Physics at California Institute of Technology since 1955, is currently a member of the President's Science Advisory Committee and he has recently become deeply involved with trying to find solutions for problems of the environment.

Surprises from Serpukhov

One of the first experiments done at the new 75 BeV proton accelerator at Serpukhov was to measure the total reaction rates (or "total cross sections") for high-energy π^- and K^- mesons on a target of hydrogen (protons). The very fundamental "Pomeranchuk Theorem" requires that the π^- and π^+ mesons have the same total cross section on protons as the energy approaches infinity (similarly for K^- and K^+ cross sections); and a trend toward the equality of these two cross-sections had been seen in measurements in the early 1960's at Brookhaven National Laboratory. However, the Serpukhov results for π^- mesons appear to contradict this trend, at energies above the 30 BeV which is available at Brookhaven. Measurements of π^+ and K^+ proton total cross sections, to be carried out soon at Serpukhov, are eagerly awaited. The violation of the 'well-established' Pomeranchuk Theorem would be a most interesting, but disturbing discovery with profound effects on the theory of strong interactions between particles.

These total cross section measurements are being carried out by a joint international team of physicists from the USSR and from CERN (The European Organization for Nuclear Research).

Discovery of the "Quark" Claim

Another interesting, and potentially very exciting, development in elementary particle physics is the claim, by a group of physicists from the University of Sydney, in Australia, to have discovered the "quark." This is the fractionally-charged entity which had been suggested by Gell-Mann and Zweig. The Sydney group have obtained photographs of a number of possible quark tracks (about five). They used a cloud chamber in which liquid droplets are formed (and then photographed), along the paths of electrically charged particles which pass through the chamber. Quarks with 2/3 of an electron charge would make tracks of about 1/2 the intensity, in the photographs, of the tracks made by 'normal' particles - such as protons, mu-mesons, π-mesons and electrons. The five low-density tracks were seen by the Sydney group in the course of a study of extensive air showers - these are showers of energetic particles produced by the passage through the earth's atmosphere of an extremely energetic cosmic ray proton or atomic nucleus with an energy in excess of thousands of BeV.

Many physicists are skeptical about the Sydney results; more extensive studies are planned at Sydney and elsewhere. Within a year, it is likely that the quark "discovery" will either be definitely confirmed or contradicted.

Particles Traveling Faster than Light?

In the last year, there has been much speculation about the possible existence and likely behavior of particles traveling at speeds greater than the velocity-of-light, the "maximum speed" barrier suggested by Einstein's theory of special relativity. These hypothetical entities, called "tachyons", would have a number of strange properties. For example, they could never travel as slow as the velocity of light, or slower, but they could travel at any speed between the velocity of light and infinite velocity; and unlike ordinary particles, if the energy of a tachyon is increased, it slows down! No evidence for the actual existence of tachyons has appeared in any experiment done to date; however, it is only in the last year that experiments have been undertaken with the sole purpose of searching for tachyons.

In one of these experiments, performed at Princeton University, a search was made to discover the production of Cerenkov radiation in a vacuum. (Cerenkov radiation is the approximate equivalent, for electromagnetic radiation, of "breaking the sound barrier" for acoustical waves.) While Cerenkov light is produced in gases and liquids by fast, 'normal' particles (protons, electrons, etc.), these 'normal' particles cannot produce Cerenkov light in a vacuum. No Cerenkov light attributable to tachyons was detected in the Princeton experiment, in which a radioactive source was used as the potential "tachyon source." Although there is so far no experimental evidence supporting the existence of tachyons, the search will continue.

New Studies on Structure of the Proton

Some new ideas on the internal structure and behavior of the proton have resulted from electron-proton scattering experiments using the 20 BeV electron beam at the Stanford Linear Accelerator Center. The particular reaction studied is "deep-inelastic" scattering, in which the electron loses a substantial fraction of its energy in the scattering process. The energy and angle of scatter of the scattered electron are measured by a very precise spectrometer.' The other reaction products (protons, π-mesons) from the violent deep-inelastic collisions are not detected in the Stanford experiments.

A striking feature of the experimental data has been the discovery that the magnitude of the scattering cross section, for deep-inelastic collisions, varies spectacularly less rapidly with scattering angle than does the elastic electron-proton scattering (in which the reaction products are an electron and proton only). There has been a great deal of speculation on the part of many theorists, including Nobel laureates Richard Feynman and C. N. Yang, as to the meaning of these new results. Feynman and Yang have independently developed 'parton' models, which describe the electron-scattering as the result of scattering from a number of point-like constituents ('partons') with the proton. The partons in these theories have no relation to Gell-Mann's quarks.

More deep-inelastic scattering experiments are planned in the 1970's both with mu-mesons at Brookhaven, and with electrons, mu-mesons, and neutrinos at the Enrico Fermi Accelerator. These experiments should add further information on the internal structure and properties of the proton.

Note: This report was written as a review for an encyclopedia year-book. It may be of interest to many people in the Laboratory, so is being circulated.

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