Aiming for the points within protons

The type of experiment that produced evidence for the existence of partons seems to have a fruitful future in physics

by Dietrick E. Thomsen

In August 1971 two experiments were being set up at the Stanford Linear Accelerator Center. Both were concerned broadly with the question of the internal construction of protons and neutrons, whether protons and neutrons are built up out of point-like constituents called partons (SN: 11/20/71, p. 346). In April 1973 results of these two experiments were presented to the American Physical Society at its meeting in Washington.

Yet these two dates tell only part of the story, for, before the actual setting up, the experiments had gone the lengthy road from conception to planning to approval by the managers of the laboratory to design of the equipment (some of it new and unique). They had been inspired by a sequence of experiments reaching back into the 1960's which can be gathered under the general rubric of "deep inelastic scattering." Early work in the sequence had seemed to reveal the existence of partons and had led to what may have been the first public disquisition about them at a meeting in Boulder, Colo., held in August 1969 (SN: 8/30/69, p. 164).

And the sequence of deep-inelastic-scattering experiments is likely to continue into the later 1970's and perhaps further. The present results ask interesting questions as well as answering some, and the answers to the new questions are likely to be sought.

It can thus be seen that a course of experiments of this kind can take a sizable part of a physicist's working life. Of course not everyone involved in these experiments has been in it from the beginning. Some of the people who were in at the beginning have since gone on to other things; some have been pursuing parallel interests at the same time. Yet if a single experiment takes three years or so from conception to completion, a physicist who chooses an experiment or a direction of experimental work had better be reasonably sure the direction is a fruitful one.

It appears at present that deep inelastic scattering is likely to be such a fruitful direction. It has already given evidence of the existence of partons and may in the long run provide support for a fundamental theory of the make-up of physical particles, the quark theory of Murray Gell-Mann and George Zweig.

Deep inelastic scattering defines experiments in which a proton or neutron target is struck by a projectile in such a way that large amounts of energy and momentum are transferred from the projectile to the target. The early experiments uncovered a phenomenon called scaling: The cross sections (probabilities) for interaction, instead of having a complicated dependence on the energy transferred, came to depend rather simply on the ratio of energy transferred to momentum transferred.

This simplification was a surprise since it seemed to indicate that the projectile electron was bouncing off a point-like particle. Since the proton is known to have spatial extent and form, the inference was that the electrons were bouncing off point-like constituents inside the proton. These constituents were given the name partons by Richard P. Feynman so as not to identify them too readily with the quarks of Gell-Mann and Zweig. However, lately there is more and more of a tendency to identify partons and quarks. In a report about one of the recent SLAC experiments prepared for distribution to the press at the Physical Society meeting the identification tends to be implied.

The two present experiments were looking for refinements on the previously available information. One of them used muons as projectiles and to look at the final states of the secondary particles produced in the collisions. The other used electrons as projectiles, but was particularly interested in examining what happened as the virtual photon, which in the collision is exchanged between projectile and target, struck the target. That is, it was primarily interested in the production of secondary particles by electromagnetic means, electroproduction.

The results of the muon experiment, as reported by Charles Y. Prescott, indicate something rather strange in the pattern of secondary particles produced. It begins to appear almost as if the multiplicities of the secondary particles —the numbers of secondaries produced per collision—also obey a kind of scaling law. As of now Prescott says: "It is difficult to say that we have seen scaling in the multiplicities." If that should turn out to be so, it will call for theoretical revisions, because, as Prescott puts it, "The parton model is not able to explain scaling in multiplicities." Further investigation seems definitely warranted.

The electroproduction experiment, as reported by J. T. Dakin, tends to reinforce the parton picture. Whether targets were protons or neutrons, the secondaries produced tended to be more positively charged than negatively charged. This was first found to be so in the case of protons, and was then checked with neutron targets. In the neutron case the excess of positively charged particles is more surprising because of the overall electrical neutrality of the neutron.

Yet, if, as quark theory would have it, the neutron is built of two quarks each with a negative charge of one-third the electron charge and one quark with a positive charge of two-thirds of the electron charge, the result can be understood because the positive quark would be twice as attractive to the electron as the others and would tend to be hit more often. The particles that come out are not free quarks—according to Gell-Mann single quarks cannot come free. The particles produced in the experiment are of types already well known, but the favoritism for positive charges seems in some way to be related to the existence of the plus two-thirds quark inside the neutron.

Thus the experiments have taken the deep-inelastic-scattering business a step or two forward. Questions for further investigation include whether there is in fact scaling in the multiplicities and what this may mean for the theory. Another question is whether the electroproduction results are evidence for the existence of the theoretically predicted quarks within the neutron and proton.

Physicists will want to investigate further. In spite of the uncertainties of predicting the future, it seems safe to say that these experiments will have successors. The question is not likely to be left hanging where it is. □