and derived Bjorken's abstract results from a much simpler picture in which electrons scattered from individual, freely moving, pointlike objects inside the proton that he dubbed *partons*. Were these partons the same as quarks?

There were other ways to explain the excess of scattered electrons, too, and the "quark-parton model" of Bjorken and Feynman needed added verification. This proof came in over the next 5 years, however, as the MIT-SLAC team went back and made more measurements. Not only did they measure the rate of electron scattering from protons at many different angles, but they also examined inelastic electron scattering from neutrons.

If the electrons were actually hitting quarks inside the proton and neutron, as Bjorken and Feynman had suggested, the rate of scattering from neutrons should be *smaller* than that from protons. And indeed it was, proof that the objects inside both of them had (previously unencountered) fractional charges. The ratio of electrons scattered forward to those ricocheting backwards was another important test. It came in consistent with the hypothesis that the objects ausing the scattering had spin-1/2, as required by the quark and parton ideas.

By the early 1970's other kinds of experiments were beginning to test what was becoming known as the quark-parton model. Beams of neutrinos made at CERN were fired into a huge bubble chamber almost 5 meters long and containing thousands of liters of liquid propane or freon. From just a few thousand neutrino-nucleon collisions, the Europeans confirmed the SLAC discovery, concluding that quarks were responsible. By 1973 they could say that whatever was causing the scattering had fractional charges and spin-1/2, and that there were *three* of them inside both the proton and neutron.

Experiments in high-energy proton-proton scattering gave further evidence for quark substructure. The large numbers of pions flying out at wide angles from these encounters could be explained fairly easily if a quark in one proton had struck a quark or an antiquark in the other. Such "hard-scattering" phenomena became increasingly common during the 1970's as powerful new accelerators supplied very high-energy projectiles able to penetrate deep into the heart of the nucleons.

By the summer of 1973 the quark-parton picture of nucleon structure had begun to take a firm hold upon the thinking of many physicists. Evidence for quark substructure had been found in experiments involving the strong, weak, and electromagnetic forces. Everything seemed to be coming up quarks.

But there was still one puzzling problem that kept everybody wary. No matter how hard one hit the nucleon, a single, solitary quark never emerged all by itself to leave a track in a particle detector. All physicists had ever observed coming out were the usual hadrons—pions, protons, kaons, and other particles feeling the strong force. Lacking any direct observation of an individual quark, many physicists remained skeptical of their existence.