

SLAC Inelastic Data Challenges Theorists

Since the preliminary reports on deep inelastic electron-proton scattering were made by SLAC experimenters in mid-1968, waves of theoretical speculation have been spreading over the high-energy physics community. Now some of the results have finally been published by the MIT-SLAC collaboration,^{1,2} but it is too soon to say they have been adequately explained by any theory.

With the 20-GeV electron beam from the SLAC machine, one has a new kinematic region for probing the electromagnetic structure and interactions of the proton. The SLAC-MIT group measured inelastic electron-proton scattering by detecting electrons scattered from a liquid-hydrogen target. They varied incident energies from $E = 7$ to 17 GeV and report data for scattering angles of $\theta = 6$ and 10 deg. At the International Conference on Electron and Photon Interactions, held in Daresbury, Richard Taylor of SLAC reported preliminary results on 18, 26 and 34 deg. The experimenters measured scattering with large electron-energy loss $\nu = E - E'$ (where E' is final electron energy) and high four-momentum transfer squared, q^2 , where $q^2 = 2EE' (1 - \cos \theta)$.

Before the SLAC inelastic measurements, some physicists expected that the inelastic cross sections would fall off rapidly with q^2 , just as elastic electron-proton scattering had done. Such a rapid decline in the elastic cross section with increasing q^2 suggested that the proton had no hard core, but a rather diffuse structure in which charge distributions were spread out in space. Many felt that one could expect the same kind of scattering from a diffuse charge distribution no matter what process you looked at. However, other observers had speculated that the total electron-proton scattering might not fall off very rapidly; so if elastic did fall rapidly, inelastic would not.

The SLAC experimenters find that inelastic cross sections do decrease very rapidly (as expected) with increasing q^2 as long as one excites nucleon resonances. But beyond a final-state energy of about 2 GeV, cross sections show only a weak dependence on mo-

mentum transfer, decreasing slowly with increasing q^2 . For higher final-state energies the decline of cross section with q^2 becomes slower and slower.

Many observers believe that the data show the scaling behavior suggested on general arguments by J. D. Bjorken (SLAC),³ even before the data were analyzed. Although the double differential cross section usually is expressed as the product of the Mott differential cross section times $W_2 + 2W_1 \tan^2 \theta/2$ where W_2 and W_1 are functions of ν and q^2 , Bjorken had suggested that W_2 could have the form $(1/\nu) F(\omega)$ where $\omega = 2M\nu/q^2$. $F(\omega)$ would be valid for large values of ν and q^2 and would show scale invariance, that is, it would depend only on the ratio ν/q^2 .

The large-angle data presented by Taylor at Daresbury provided a rough separation of W_1 and W_2 . Taylor said these results indicated that the transverse part of the inelastic scattering is dominant and indicated that 6- and 10-deg results are consistent with the scaling hypothesis (within the measurement error—about 10%).

Many different models have been proposed to explain the SLAC results. Richard P. Feynman of Cal Tech and others have suggested a "parton" model, in which the electron scatters incoherently from many pointlike constituents inside the proton. They argue that such pointlike behavior implies scaling.

Partons, like quarks, do not seem to be in immediate agreement with the picture of hadrons in which one visualizes the hadron as a cloud of other virtual strongly interacting particles; this cloud extends over a large region, about a fermi in size; all known stable hadrons appear to have this fundamental dimension. However, Sidney Drell and his collaborators (SLAC)⁴ have derived a parton model from conventional field theory.

A number of attempts have been made to use Regge exchange ideas in interpretation of the SLAC data, for example, that by H. D. Abarbanel, M. L. Goldberger and Sam B. Treiman (Princeton).⁵

Diffraction models have been successful in explaining elastic data. An

extension of the diffraction picture to inelastic processes is the hypothesis of limiting fragmentation made by C. N. Yang and his collaborators at Stony Brook;⁶ in this picture one thinks of two hadrons colliding with each other as two semitransparent objects that go through each other, causing excitations that later decay into fragments; the momentum distribution and the number of fragments produced approach a limit for infinitely high-energy collisions. (In describing it, Yang asked: "Did I make myself semiclear?") An electron-hadron scattering is a special case; the electron does not fragment.

The vector-dominance model emphasizes the structure of the virtual photon, which turns into a vector meson, such as a rho. One such model was proposed by J. J. Sakurai (University of Chicago).⁷

An interesting but difficult experiment to try now is detection of the kinds of strongly interacting particles emitted by the target; the present experiment only detected outgoing electrons.

—GBL

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Bubble Chambers Are Ready to Study Neutrinos

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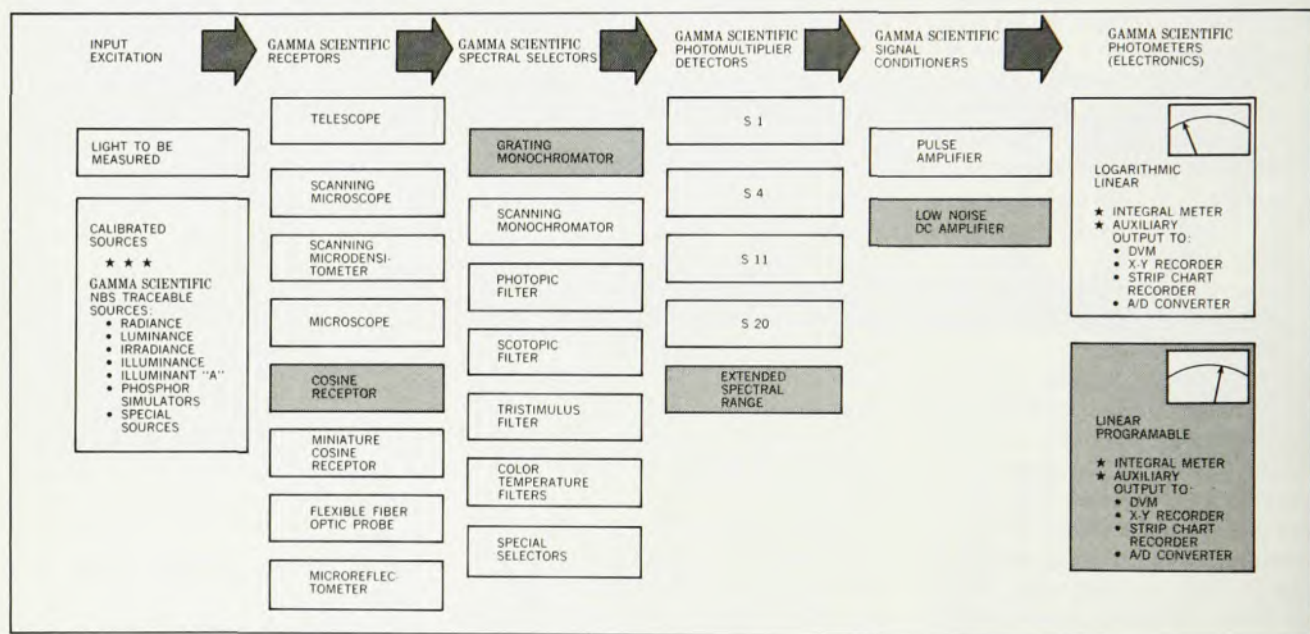
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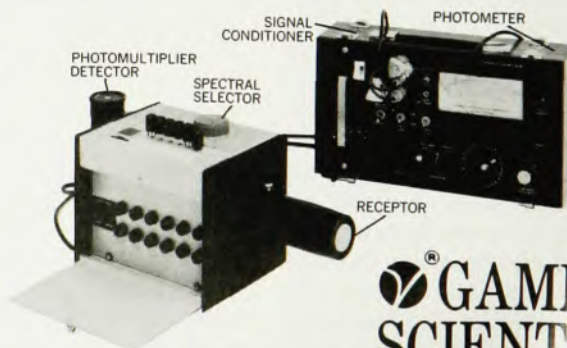


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One of the chambers, the largest ever built, was constructed at Argonne by a team headed by E. G. Pewitt (PHYSICS TODAY, February 1968, page 57). The second chamber, built at Brookhaven under the direction of Ralph P. Shutt, is a prototype of a 25-foot chamber planned for the National Accelerator Laboratory (NAL).

The Argonne chamber is 3.7 meters in diameter and 2.2 meters deep, and the Brookhaven chamber is 2.2 meters in diameter and 2.8 meters deep. Cameras are mounted on the dome-shaped upper surfaces, and they view the chambers through fish-eye lenses. Argonne's 18-kG superconducting mag-

net was successfully operated a year ago. Brookhaven has run its superconducting magnet at 16.5 kG and plans to operate it at 30 kG.

The experiments performed in these new chambers will initiate the long-awaited exploration of neutrino-nucleon elastic and inelastic scattering. Because neutrinos interact only weakly with matter, one needs a large volume to accumulate sufficient statistics. Both groups expect about 1 event for every 1000 pictures. After an exposure of 500 000 pictures in hydrogen, Argonne will take 1 000 000 pictures in deuterium. Brookhaven is planning to make an initial exposure of 1 000 000 pictures with deuterium in the chamber.

Neutrino beams can be produced with a momentum range up to 1 GeV/c at Argonne, up to 2 GeV/c at Brookhaven and hopefully up to 6 GeV/c at NAL. Because of these different energy ranges, the neutrino experiments at the various labs may complement one another. Malcolm Derrick at Argonne feels that the determination of the axial-vector form factor from the elastic reactions, $\nu + n \rightarrow \mu^- + n$ and $\bar{\nu} + p \rightarrow \mu^+ + n$, will be most sensitive at the lower energies. The higher-energy experiments will be the best measurements of the inelastic neutrino interactions; these measurements may provide interesting comparisons with the inelastic electron-proton experiment at SLAC.

An Interview with Peter Kapitsa

Peter Kapitsa had come to Columbia University to receive an honorary degree. It was his first visit to the US, and at 75, even after a hectic month of travel, his eyes were sparkling and his conversation lively. "Are you a physicist?" he asked. I said, "Yes." "Good," he said, "The journalists sometimes ask stupid questions." He told me he does not work in low-temperature physics any more; his latest paper, 135 pages long, was to be published in the December *JETP*. It is on controlled thermonuclear fusion.

For Kapitsa the work is perhaps an

outgrowth of his long-standing interest in ball lightning. In 1955 he had proposed that the energy source needed to maintain the luminosity of the "ball" might be microwaves generated in thunderclouds and guided to the place where the ball appears. Power could be fed to the ball either by directional radiation from clouds or by propagation from clouds to the earth along the long cylinder of strong ionization that appears after a lightning discharge. Kapitsa's hypothesis inspired a recent experiment by workers at his Institute for Physical Problems;

they observed weak radiation in the 20–40-cm range at an altitude of 2000 meters during a thunderstorm (*Sov. Phys-Tech. Phys.* 13, 1475, 1969). Institute experimenters are also using high-power microwaves to create artificial ball lightning.

In controlled-fusion experiments, Kapitsa would like to contain the plasma with microwaves and use a superconducting cavity to get a high Q .

During the Columbia ceremonies Polykarp Kusch, who is vice-president and dean of faculties at Columbia, paid tribute to Kapitsa: "When I was a graduate student in the early 1930's, I and my fellow students were fascinated by Kapitsa's novel helium liquefier [which he developed while head of the Mond Laboratory at Cambridge University]. In fact, his interest in cryogenic machines has been fruitful for decades. We were also interested in the several techniques that he used for producing pulses of magnetic field of an intensity not previously attainable in experimental work. In general, all of his work is marked by an extraordinary technical imagination.

"Dr Kapitsa has shown great scientific taste in the problems that he has chosen to attack. He has made striking contributions to the physics of matter at very high magnetic fields. He has made critically important observations of the phenomena that occur in that remarkable state of matter, the superfluid state of helium II.

"I note that as early as 1922, Kapitsa wrote a paper with the title 'On the Possibility of an Experimental Determination of the Magnetic Moment of an Atom.' It makes excellent sense



KUSCH AND KAPITSA at Columbia ceremonies honoring Kapitsa.