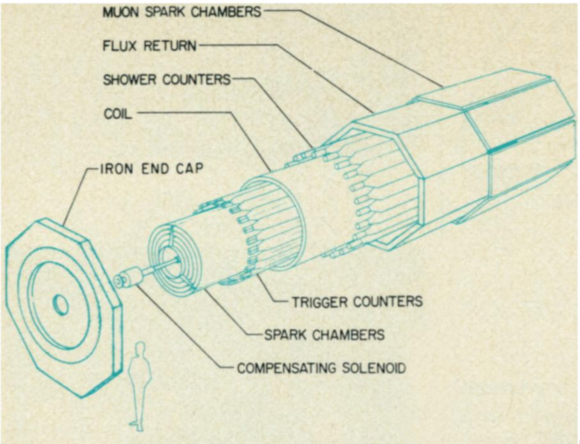


Schematic of SPEAR detector.

Seeking the parts of partons

Evidence appears to show that protons are made of entities called partons. Now there are already hints that partons have their own internal structure. An experiment seeks evidence for this next level of matter.

by Dietrick E. Thomsen

Physicists have been repeatedly frustrated in their attempts to find the ultimate, fundamental constituents out of which matter is made. Successively on the level of atoms, atomic nuclei and the neutrons and protons that make up the nuclei, the search for the simple, point-like, structureless, fundamental bodies, the truly *atomos*, the uncuttable, has failed. Each new level of investigation revealed structure and complication within the bodies supposed to be fundamental.

For the physicists who persevere in the search (some have given up, declaring there are no simple constituents) the discovery that the proton appears to be made up of point-like constituents called partons was very heartening (SN: 10/24/70, p. 333). Here at last might be the truly fundamental level.

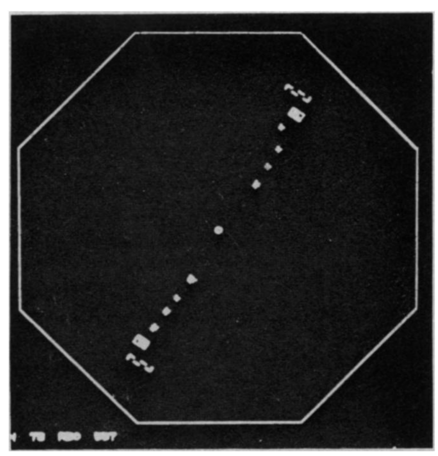
But not so fast. What happened before seems to be happening again. Evidence already in hand gives some hint of structure in the parton. As Michael S. Chanowitz and Sidney D. Drell of the Stanford Linear Accelerator Center put it, "It is tempting to proclaim that we have glimpsed the elementary, structureless building blocks from which hadrons [particles susceptible to the strong nuclear force, including protons, neutrons and many others] are constructed. . . . we wish to propose a less exuberant perspective: . . . that [the discovery of the parton] represents the probing of just another layer of matter, and that hints of the structures to be discovered in the next layer are already in evidence."

The hints are contained in data about the behavior of the proton's magnetic form factor (its apparent magnetic shape) and in the results of experiments in which colliding beams of electrons and positrons annihilate each other and produce hadrons. To follow up the hints an experiment is now running at SLAC's SPEAR storage ring.

The purpose of the experiment, according to Rudolf R. Larsen, the spokesman for the group that is doing it, is to compare the cross sections for the formation of hadrons in the annihilation of electron and positron with the cross section for the production of muons by the same event. Muons are to all appearances point particles, and therefore a comparison of the two cross sections should tell whether the parton constituents of the hadrons are point particles.

In the experiment a beam of electrons will be moving in one direction in the SPEAR ring, a beam of positrons in the other. They will be made to collide with each other. Electron and positron, having the same energy, will more or less stop each other cold. They will annihilate each other, forming a photon. The photon will exist for a short while and then change into a pair of particles, maybe a pair of hadrons, maybe muons, maybe another electron-positron pair.

The end products may come off in any direction so Larsen and his associates designed a detector that will record particles coming off at any angle greater than 10 degrees away from the direction of the colliding beams. That is equal to about 95 percent of a sphere. The detector is built around a solenoid magnet three meters in diameter and three meters long. The solenoid is filled with spark chambers to show the trajectories of particles coming out of the interaction. Scintillation counters to trigger the spark chambers are attached to them. Outside the magnetic coil is an array of shower counters to distinguish electrons from hadrons. Outside the array of shower counters is another



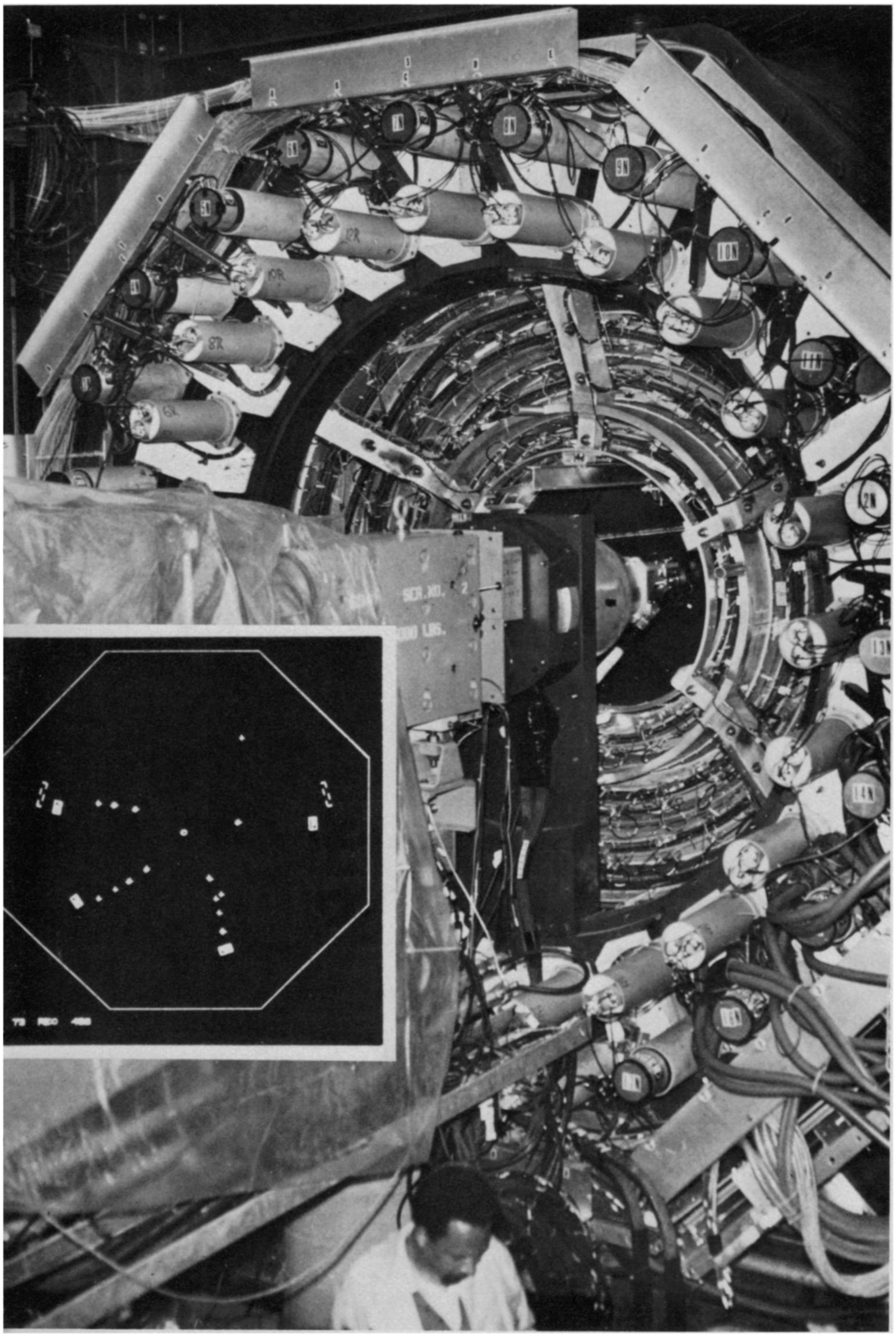
Illustrations: SLAC

End view of the detector surrounding one of the interaction regions of the new SPEAR storage ring (right). Two oscilloscope traces of detector data (inset right and above).

assembly of spark chambers to record particles that get through all the rest. These are likely to be muons. Thus the apparatus can distinguish electrons, muons and hadrons from each other and measure their momenta, the angles at which they leave the interaction region and their velocities within certain limitations.

An on-line computer will analyze some of the data but most will be analyzed off line. The energy range in which the work is done is a few billion electron-volts per beam, and it will be covered in small increments. Larsen expects results by the end of the year.

In addition to comparing production cross sections, the experiment will also yield information on the form factors, what one might call the shapes of the hadrons as they appear in relation to the real photons produced in the electron-positron annihilation, and this may also provide some information about the nature of their constituents. Previous form-factor measurements were done in connection with virtual photons exchanged by the proton and some probe particle as they interacted with each other. In the jargon of special relativity the virtual-photon form factors are called spacelike, the real-photon ones timelike. The entry into the domain of the timelike form factors is "really a whole new field of physics," says Larsen. It may throw light on many other questions besides the structure or lack of it of the hadron's constituents.



If the partons lack structure, the ratio of the cross section for producing hadrons to that for producing muons should be one. The reason for much of the theoretical and experimental activity is that it doesn't seem to be. Evidence already in from the Cambridge Electron Accelerator and the Adone storage ring at Frascati, Italy, indicate a value of at least two. The ratio also appears to increase with increasing energy, another departure from what is expected for point-like particles. But the data so far are rather fragmentary. The Stanford experiment is intended to check them with better statistics (larger numbers of individual annihilations) and over a somewhat wider energy range than has been done so far.

There are a number of theories that predict a departure of the cross section ratio from unity. They endow partons with various characteristics sometimes called "charm" or "color" (there is even a theory of red, white and blue partons). Most predict that the ratio, be it three or four instead of one, should remain constant. Chanowitz and Drell predict the rise with energy that seems to be taking place and may be confirmed in the current experiment.

The picture of the parton presented by Chanowitz and Drell is similar in a number of respects to the ordinary picture of the proton. The proton is supposed to consist of a hard core surrounded by a spongy cloud of mesons. These mesons are the nuclear "glue." Constant exchange of mesons between the different protons and neutrons in the nucleus holds the nucleus together.

Chanowitz and Drell propose a parton with a core surrounded by a cloud of entities they call gluons. The function of the gluons, as their name indicates, is to be the glue that holds the partons together to form a hadron. The mass of the gluon can be estimated from current evidence as 10 billion or possibly several tens of billions of electron-volts. The mass suggests a distance scale characteristic of the gluons' interaction of about 10^{-15} centimeters (the radius of a proton is taken to be about 10^{-13} centimeters), "on which qualitatively new phenomena will occur," Chanowitz and Drell propose.

And deep inside the core of the parton will physicists finally find the point-like, structureless elementary constituent of matter that has eluded them for lo these 80 years? We shall have to wait to find out, but the cautious may be forgiven for not making book on it. □