thinks of pointlike constituents inside the proton; these partons have spin ½.

Preliminary results from the NAL deep inelastic muon experiment performed at 150 GeV compare their data for the distribution of scattered muons with those extrapolated from the structure function obtained in the SLAC–MIT experiment. The experimenters plot the ratio of the number of observed muons as a function of q^2. If scaling is correct, they should get a horizontal straight line. At low values of q^2, the ratio is about unity, so that the NAL experiment agrees with the SLAC–MIT observations. Beginning at 10 $(\mathrm{GeV}/c)^2$ the ratio appears to deviate from unity, showing a continuously increasing depletion of muons as q^2 increases to 40 $(\mathrm{GeV}/c)^2$. At the highest value of q^2, they reported the deviation is at the level of 30–40%. (Chen quotes a range because there is a 10% normalization question.) The Michigan State–Cornell–San Diego group estimates that the systematic errors are about half of the magnitude of the effect. The observations have actually been made for q^2 as high as 60 $(\mathrm{GeV}/c)^2$, but the data have not yet been analyzed beyond 40 $(\mathrm{GeV}/c)^2$.

The Michigan State–Cornell–San Diego experiment makes a number of assumptions. Instead of using a hydrogen target, as was done in the SLAC–MIT experiment, the NAL experimenters use an iron target and assume that the iron behaves as the sum of its constituent neutrons and protons. Their results are analyzed assuming the structure function reported by the SLAC–MIT group, rather than in an independent determination. And the assumption is made that the muon and electron behave identically. It is conceivable that the possible effect observed at NAL is caused by a difference in the behavior of muon and electron at high energies.

To eliminate possible uncertainties with the iron target and to check scaling directly, the Michigan State–Cornell–San Diego group is doing a new run this month, with analysis expected by June, which will measure the ratio of the distribution at 150 GeV to the distribution at 56 GeV. That is, they will be able to plot the ratio as a function of q^2. The energies were chosen because they are in the ratio 8 to 3 corresponding to two different scaled configurations of the muon detection apparatus. So if the scaling holds, the actual count rates in one portion of the detector at the two different incident muon energies should scale.

Their apparatus consists of a collection of large magnetized iron toroids with a hole in the center of each, through which the muon beam passes. Then the magnetic field of the toroids focuses the muons onto the detector. With electrons, on the other hand, total absorption of the electron is required. To make an electron beam, a proton beam strikes a low-Z target, producing neutral pions that decay into gamma rays. These then strike a high-Z target, causing pair production of electrons. Such a beam is under construction at NAL that will have an energy of about 200 GeV; the intensity will be a few orders of magnitude less than that available at SLAC, but it will be 1000 times more intense than the present NAL muon beam. Zaven Guiragossian and Robert Hofstadter (Stanford) and collaborators at NAL are planning to use the beam and a large sodium-iodide crystal to detect the scattered electrons. It will, of course, be very important to repeat the muon experiment with electrons in the same region of q^2.

Another point of view about the Michigan State–Cornell–San Diego experiment has been expressed by some observers, who point out that it is remarkable that the experiment confirms scaling to 30–40%. These observers say that they will be interested in learning further results from these experiments to see at what level scaling is violated in the spacelike region.

Bjorken, who originated the scaling concept and has been a parton enthusiast, feels that the NAL muon results are indeed very preliminary. But, if one assumes that they hold up under further examination, what does this mean for scaling and partons? The SPEAR experiment on electron–positron annihilation had already shown that in the timelike region, for q^2 between 10–25 $(\mathrm{GeV}/c)^2$, the ratio of the cross section for producing hadrons to the cross section for producing two muons was not a constant; the parton idea (along with light-cone algebra and asymptotic-freedom concepts) required this ratio to be a constant. Now the NAL muon experiment suggests that in the spacelike region, there is trouble with scaling and partons for q^2 above 10 $(\mathrm{GeV}/c)^2$. "It's perfectly plausible and almost a relief that something like that does happen in their experiment, given the mess the colliding-beam theory is in. If things don't scale in the timelike region, why should they scale in the spacelike region? That would be rather hard to reconcile."

Even if Bjorken scaling doesn't work in the present range of q^2, couldn't it begin to operate again for higher q^2? That is, is it just a question of asymptopia being further away? When we asked Bjorken, he said that would not be the kind of scaling he envisaged. He is sticking to his guns that if scaling occurs, it happens at q^2 of about 1 $(\mathrm{GeV}/c)^2$. But what is possible, he says, is that partons make sense in one range of q^2 but that as the distance gets smaller, they don't make any sense at all.

A way out has been suggested by Michael Chanowitz and Sidney Drell (SLAC), who propose that the parton is not pointlike, that it has an electromagnetic form factor, such as an ordinary hadron would have, only much smaller. With this picture there would be an enhancement away from scaling in the SPEAR electron–positron annihilation and a suppression in the NAL muon experiment, and the effect would be about equal in the two cases. But experimentally, the SPEAR experiment shows an effect of a factor of two or three, Bjorken notes, whereas the NAL experiment shows a 30–40% effect. Subsequently Geoffrey West (Stanford) has extended the Chanowitz–Drell argument to say that the parton also has an anomalous magnetic moment, which causes some magnetic scattering in addition to the straight electric scattering, and this scattering adds to both experiments. Then in the NAL experiment there is a cancellation of the two effects, and in the SPEAR experiment the effects add.

It may be possible that we are trying to stretch the parton idea beyond the breaking point, Bjorken feels. Even though partons were good at interpreting electroproduction and neutrino experiments, they have not yet been good for too much beyond that, he says.

The NAL and SPEAR experiments, if both turn out to be right, seem to indicate a rather large mass scale is operating, Bjorken notes. Just taking the square root of the value of q^2 at which the apparent scaling violation occurs, namely 25 $(\mathrm{GeV}/c)^2$, gives a mass of 5 GeV. It is this large mass, roughly 5 GeV, that theorists will tend to be using in the explanations they come up with.

Bjorken feels it is just as well if the simple parton or quark is not the final answer. Before the synthesis of hadron phenomena with lepton phenomena is made, things will invariably get more complicated. "I'd hate to see it just stop with there being red, white and blue quarks, infinitely tiny, nine of these things with fractional charges as basic building blocks, with that the end of the story. If we are really seeing some kind of structure inside the partons, that means we don't have to wait for higher energies to get further inside." —GBL

in brief

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