The Particles Inside the Proton

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It shows here that the results of the electron-proton deep inelastic scattering experiments can be interpreted to show that the proton and the neutron are made of eight pions. The experiments also appear to show that the pions are made of electrons and positrons. Consequently, the proton appears to be made of 917 electrons and 918 positrons.

1. Introduction

In the early 1960s, Murray Gell-Mann and others showed that baryons like protons and neutrons could be represented as unitary triplets such as (b, t, $\bar{t}$).[1] Here, the fundamental particles were a neutral baryon b, a singlet s with a charge of z, and a doublet (u, d) with charges z+1 and z, respectively. The $\bar{t}$ is the antiparticle of t having the opposite charge of it and z is in units of the absolute value of the electron charge, $|e|$. He considered triplets with spin ½ and $z = -1$, making four particles d^-, s^-, u^0 and b^0 that look like leptons. Then, the proton became (b, u, $\bar{d}$), with a charge of $0 + 0 + -(-1) = +1$.

In 1964, Gell-Mann noticed that a "simpler more elegant scheme" evolved if the fundamental particles carried non-integral charges.[2] When $z = -⅓$, the particles become $d^{-⅓}$, $s^{-⅓}$ and $u^{⅔}$. He dubbed these particles "quarks" (q). With quarks, baryons could be constructed in triplets of (q, q, q) without needing the neutral baryon b. In this scheme, the proton becomes the triplet (u, u, d), which has charge $⅔ + ⅔ + (-⅓) = +1$.

Initially, Gell-Mann appeared to suggest that, with fractional charges, his quarks were merely mathematical entities, not real particles[3] (although later he claimed otherwise[4]). The $z = -⅓$ made the math simpler but did not necessarily imply that particles with this charge or $z = ⅔$ really exist in nature. When he introduced quarks in 1964, nearly everyone agreed quarks could not be real particles.[5]

In 1967, particle physicists from MIT and Stanford began collecting data from the newly built Stanford Linear Accelerator Center (SLAC).[6] The experiments, called deep inelastic scattering, fired extremely high-energy electrons (up to 30 GeV) at stationary proton targets. While Hofstadter had shown that protons are not point particles about a decade earlier,[7] physicists thought them to be homogeneous particles and expected the electrons to pass through them.

To their surprise, the data revealed electrons were scattering at angles indicating the protons have internal structure. Analyses of the data showed that the electrons were scattering off charged particles inside the protons with half-integer spins.[8,9]

2. They Could Be Quarks

The discovery of charged particles inside the proton caused physicists to reconsider the prospect that Gell-Mann's quarks might exist. In 1969, Bjorken and Paschos analyzed the scattering data collected to date, intending to show that the proton was, indeed, made of the three quarks Gell-Mann predicted.[10]

Richard Feynman had developed a theory of how particles inside the proton would behave. He suggested that the electrons likely scattered off particles inside the proton he called partons.[11] Similar to Gell-Mann's quarks, Feynman's partons were small, charged particles inside the hadrons. In his model, the electron-proton scattering occurs in the infinite momentum frame of reference.[12]

In the infinite momentum frame, the center-of-mass frame of reference is assumed. There, even though the accelerator fires the electron at the proton, the electron appears to be standing still and the proton moving at near light speed toward the electron. As a result, relativistic time dilation slows down the motion of the particles inside the proton. Then, an impulse approximation[13] is applied to the high-energy collisions between them and the electrons.

The impulse approximation instantaneously frees the individual partons inside the proton from the other particles within the proton. This causes the incident electrons to scatter incoherently off the partons while they are not interacting with other partons. Now, the electron scatters off the partons are elastic, and the scatters give information about the momentum of the individual partons.

While his partons appeared to be similar to Gell-Mann's quarks, it seems Feynman did not initially say that they were or were not quarks. However, upon seeing the results of the initial scattering experiments at SLAC, Feynman did realize that his parton model could explain unexpected scaling behavior observed in the scattering.

Bjorken and Paschos used Feynman's parton theory for their analysis. Scattering cross sections derived from the scattering data were used to produce an F_2 structure function curve.[14] The F_2 values were plotted as a function of the fractions of the proton's momentum, x, particles within the proton struck by electrons carried. In parton theory, F_2 of a proton made of a finite number of particles peaks at the x value that is the reciprocal of the number of particles within the proton. From there, F_2 goes to zero as x approaches zero.

3. But They Are Not Quarks

Bjorken and Paschos expected the proton F_2 curve to peak at about $x = \frac{1}{3}$, something like the plot on the top in Fig. 1. This would show that the proton was made of three particles, as Gell-Mann predicted. It did not. Instead, the measured data gave the curve on the bottom in Fig. 1.

Approaching zero from $x = 1$, the F_2 curve rose until about $x = \frac{1}{5}$ and appeared to remain constant within a wide scattering of data points for the duration of the available data. From this result, Bjorken and Paschos concluded that the proton was not made of just three particles and therefore, not made of Gell-Mann's three quarks.

To salvage Gell-Mann's quarks, Bjorken and Paschos determined that the F_2 values would remain constant as x approached zero only if, in addition to the three quarks, the proton contained an indefinite number of quark-antiquark pairs they called a "pion cloud." Since the quark-antiquark pairs are electrically neutral, three additional quarks are still needed to give the proton charge of +1.

The three quarks became the valence quarks and the quark-antiquark pairs became the sea quarks of the current proton model. After that, the particles inside the proton were always treated as up, down and strange quarks, with the charges $+\frac{2}{3}$, $-\frac{1}{3}$ and $-\frac{1}{3}$, respectively. This, even though no particles having charges of $-\frac{1}{3}$ or $+\frac{2}{3}$ had ever been observed in nature, much less, exiting a proton or nucleus.

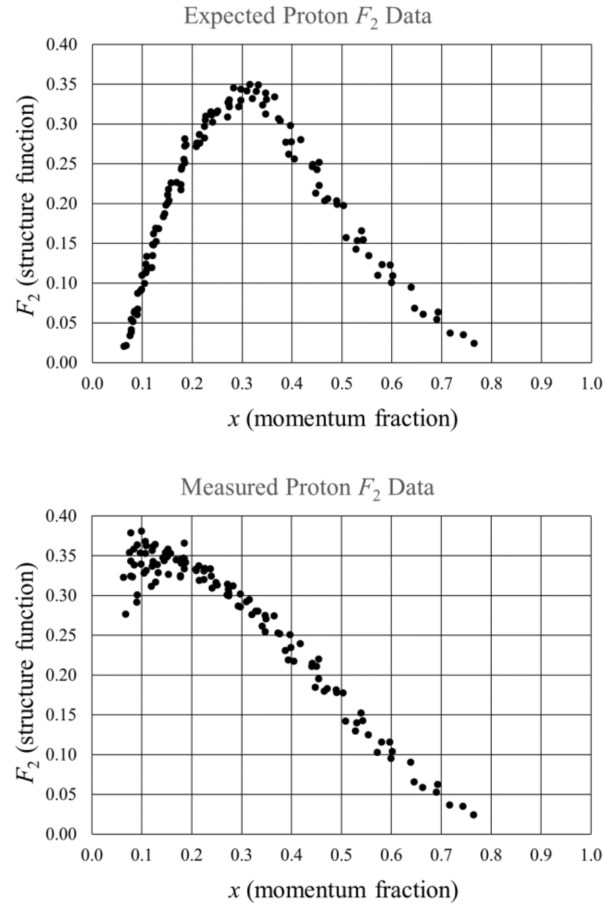


Fig. 1: Expected and measured proton F_2 curves. *Type of proton F_2 curve expected for a three-quark proton (top) compared to F_2 curve generated from measured proton data (bottom).*

In 1971, Kuti and Weisskopf showed that adding chargeless gluons to the proton model resolved differences between the measurements and the model in the distribution of momentum among the quarks.[15] Without gluons in the proton model, calculations indicated that the up quarks carried about 18% of the proton's momentum, the down quarks, 6%, and the strange quarks, 76%.

That the strange quarks carried four times the momentum as the up quarks and more than 12 times that of the down quarks seemed out of line with what measurements suggested. When gluons were added to the calculations, the up quarks carried 29% of the momentum, the down quarks carried 19% of the momentum, the strange quarks, 17%, and the gluons, 34% of the momentum. This was considered much more in line with observations. The addition of gluons completed the model of the proton generally recognized today.

4. They Look Like Muons (or Pions?)

There is, however, another way to interpret the SLAC deep inelastic scattering results. This interpretation suggests a proton made of particles readily observed in nature, having charges that are integer multiples of the electron charge. It offers a new paradigm for the structure of the proton that the experimental data also supports.

The alternate interpretation arises from analyzing the SLAC deep inelastic scattering data combined with data collected after the quark model was established that apparently has been overlook. In the following, this new interpretation will be described and contrasted to the current quark paradigm.

The graph in Fig. 2 is a composite of the data from the SLAC deep inelastic scattering experiments from the 1960s and experiments performed at the Thomas Jefferson National Accelerator Facility (JLAB) in 1999.[16] The JLAB experiments covered the momentum fraction range from $0 < x < 0.06$ not covered by the SLAC experiments.

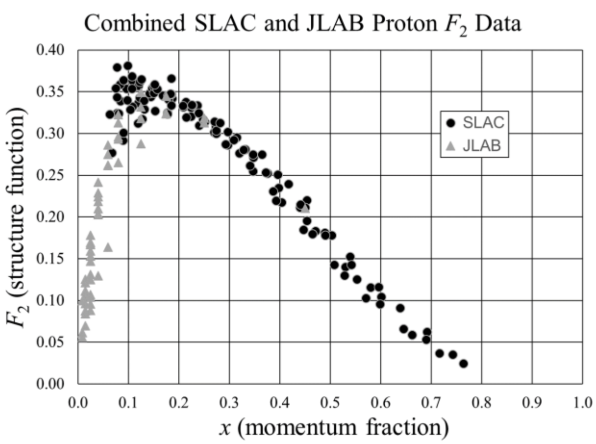


Fig. 2: **Combined JLAB and SLAC proton F_2 data.** *The combined data shows that the proton F_2 structure function at low-Q^2 peaks at approximately $x = 0.11$. JLAB points at x equals 0.125, 0.25 and 0.45 show that the two curves are comparable.*

The range from $0 < x < 0.06$ is that Bjorken and Paschos assumed to stay constant, prompting them to propose the proton model containing valence quarks and sea quarks. In both sets of data displayed, the momentum transferred during the collision between the electron and the proton, Q^2, was less than 3 GeV^2 for x values less than 0.4. This makes the JLAB data comparable to the SLAC data.

The graph shows that, with the JLAB data, the proton F_2 values approach zero as x approaches zero after peaking somewhere between $0.10 \leq x \leq 0.125$. Several of the JLAB points fall within the cluster of SLAC points between $0.06 \leq x \leq 0.20$, and the four points beyond $x = 0.20$ fall well within the scatter of SLAC data in their vicinities. These all show that the JLAB data is comparable to the SLAC data.

This additional data is experimental proof contradicting the assumption made by Bjorken and Paschos in 1969 that the proton F_2 values remain constant for this x region. The assumption they used to justify the existence of three valence quarks and a sea of quark-antiquark pairs as proton components.

According to parton theory, the F_2 curve peaks at the fraction of momentum the particles within the proton carry. This makes it the reciprocal of the number of particles in the proton. The peak F_2 occurring between $0.10 \leq x \leq 0.125$ means that the scattering electrons apparently see between 8 and 10 particles inside the proton.

From the earlier discussions, the particles inside the proton are charged, and they are spin-½ particles. A survey of subatomic particles reveals that the charged, spin-½ particle that is about $\frac{1}{9}$ the mass of the proton is the muon.[17] If electrons are finding nine particles inside the proton, one candidate for the particles is the muon.

At a mass of 206.768 electron masses, the free muons are slightly more massive than 204.017 electron masses, one-ninth the proton's mass of 1,836.153 electron masses. Parton theory predicts such a mass difference based on the shape of the proton F_2 curve. The blunt peak of ~ 0.35 (<< 1.0) indicates that the particles inside the proton interact strongly, which suggests binding and mass defect.

However, but for the requirement that the particles inside the proton be spin-½ particles, they could also be pions. Pions are slightly more massive than muons, 273 free electron masses versus 207. Therefore, a proton made of pions is likely made of only eight pions, the lower limit prescribed by the electron-proton deep inelastic scattering F_2 analysis.

Eight pions in a proton would have a mass defect of 45 free electron masses per pion, making the binding energy per pion in the proton about 22 MeV. This is nearly the sum of the all the bonds holding an alpha particle together. Being made of eight particles, each with a mass defect of 45 free electron masses means it would take about 178 MeV to completely break a proton into its components.

In contrast, nine free muons, at 207 free electron masses, would only experience a mass defect of about three free electron masses or 1.5 MeV each inside the proton. This would mean that the total proton mass defect would be only 13.5 MeV. This is less than half that of the alpha particle.

Fig. 3 shows a photograph of a proton-antiproton collision in a bubble chamber, with a diagram labeling some of the particles evolving in the collision under it. The diagram shows that emerging from the alleged point of impact are eight tracks claimed to be pions. Four of the tracks curve clockwise, making them negative pions (π^-), and the other four tracks curve counterclockwise, making them positive pions (π^+). This seems to suggest that protons are made of a collection of pions.

The problem with pions as proton components is that they are spin-0 particles. According to an interpretation of some data taken at SLAC, the particles inside the proton are spin-½ particles. The observation that the electrons scattered off particles inside the proton during the scattering is the basis for this conclusion.

The electron-proton deep inelastic scattering is thought to occur because the scattering electron dispatches a virtual photon that is absorbed by the target proton. There is a magnetic interaction between the virtual photon and the proton (F_1 structure function) and an electromagnetic interaction between the two (F_2 structure function).

For the magnetic interaction to occur, the virtual photons must be longitudinal, requiring the target to have a longitudinal cross section, σ_L, to absorb them. The electromagnetic interaction occurs when the photons are transverse, requiring the target to have a transverse cross section, σ_T, to absorb them. The electrons emit virtual photons with helicity ±1, which makes them transverse virtual photons.

Using current algebra, Curtis Callan and David Gross showed that spin-0 particles absorb longitudinal virtual photons, but spin-½ particles absorb transverse virtual photons.[18] They determined that for the particles inside the proton,

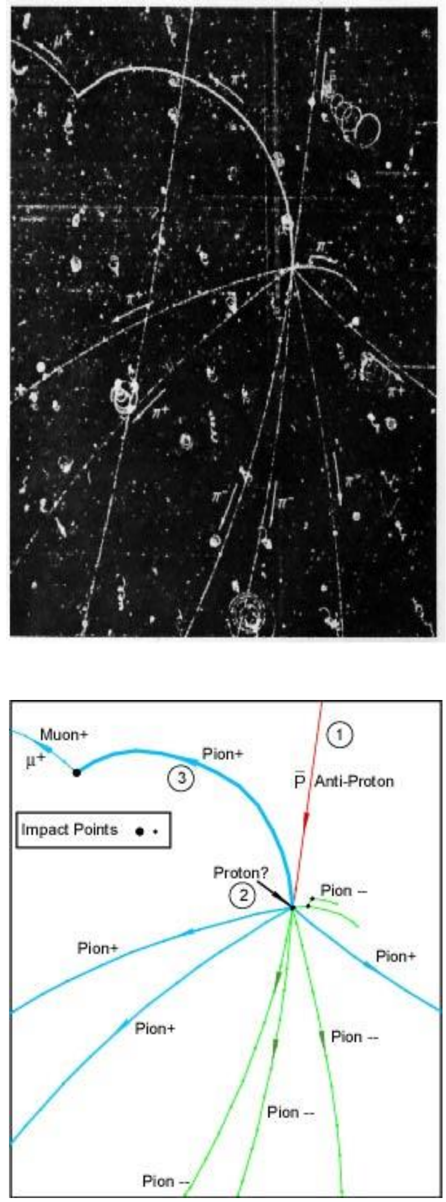


Fig. 3: **Pions from proton – antiproton collision.** ***Top:*** *Photograph of a collision of an antiproton with a proton in a bubble chamber.* ***Bottom:*** *Diagram of the photo identifying the particles created by the collision. It shows four positive pions and four negative pions formed in the collision. (Lawrence Berkeley National Laboratory Science Photo Library - K003/4377)*

$$\omega F_1(\omega) = \frac{1}{4\pi\alpha} \lim_{q2\to-\infty} q^2\, \sigma_T(\omega, q^2), \qquad (1)$$

$$F_2(\omega) - \omega F_1(\omega) = \frac{1}{4\pi\alpha} \lim_{q2\to-\infty} q^2\, \sigma_L(\omega, q^2), \qquad (2)$$

where $\omega = 2Mx$, q^2 is the negative momentum transfer and $M = 1$, the mass of the proton.

If there are spin-0 particles in the proton, then their $\sigma_L > 0$, but their $\sigma_T = 0$. Therefore, the spin-0 particles cannot absorb the transverse virtual photons emitted by the electrons. From equation (1), this makes $F_1 = 0$ for them.

Note, however, since their $\sigma_L > 0$, equation (2) shows that the spin-0 particles produce nonzero F_2 values. Therefore, the scatterings still produce information about the particles inside the proton, even though the virtual photon is not absorbed.

If there are spin-½ particles inside the proton, then their $\sigma_T > 0$ and their $\sigma_L = 0$. These particles can absorb the virtual photons emitted by the electrons. Now, equation (2) becomes $F_2 = 2xF_1$.

This means that if the measured F_1 and F_2 structure function data satisfies the ratio $2xF_1/F_2 = 1$, then the particles inside the proton are spin-½ particles. However, if $2xF_1/F_2 = 0$ for $x \neq 0$, then F_1 must equal zero and the particles inside the proton are spin-0 particles. If the ratio falls between zero and one, then the virtual photons are apparently encountering a mix of spin-0 and spin-½ particles.

The graph in Fig. 4 is a plot of $2xF_1/F_2$ using data from some early SLAC electron-proton deep inelastic scattering experiments. It is done for three momentum transfer (Q^2) ranges and shows that, in all three cases, for $x > 0.25$, the ratio hovers about the value 1.0. This was interpreted to indicate the virtual photons were seeing spin-½ particles inside the proton.

However, for the particles the deep inelastic scattering found inside the proton, $0.10 \leq x \leq 0.125$. For $x < 0.25$, the ratio appears to be steadily declining. This likely indicates that for the smaller x values, the virtual photons are encountering a mix of spin-0 and spin-½ particles. In fact, since the photons probably cannot see the particles inside the proton at $x > 0.25$; there, they are likely responding to the entire proton. The spin-½ they see there is the spin of the proton.

This suggests that, as x gets smaller and the virtual photons focus in on the particles inside the proton, they are encountering spin-0 particles. The virtual photons not being able to see these particles, combined with them still being able to see the entire proton, slowly causes the overall $2xF_1/F_2$ ratio at a given x as $x \to 0$ to get smaller.

Now, the particles inside the proton look like pions, not muons. As a matter of fact, one could probably argue that a line could just as significantly be drawn through a set of points at the ratio value of about 0.8 that spans the x-range of the data. This may be an indication that the virtual photons are seeing spin-0 particles along with the whole proton across the whole span of x-values.

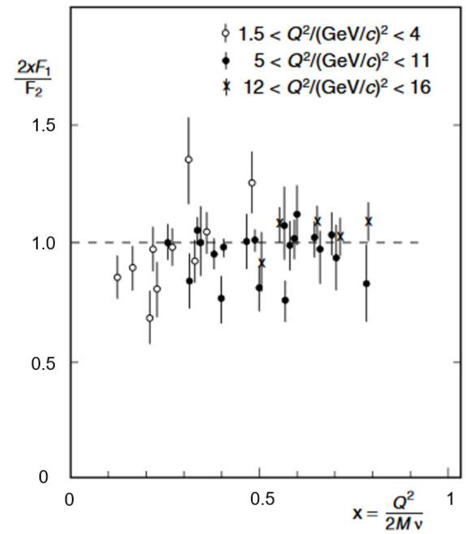


Fig. 4: **Plot of $2xF_1/F_2$ for electron-proton scattering.** *The graph appears to show that for electron-proton scattering,* $2xF_1/F_2 = 1$, *indicating spin-½ particles inside the proton.*

It may be that, in their zeal to see a spin-½ particle, the MIT-SLAC researchers did not question why the low-x values of the ratio on the graph were moving away from 1 as $x \to 0$. Or, maybe it did not occur to them that at higher x values, the virtual photons could be interacting with the whole proton and not the particles within it.

Whatever the reason for this apparent oversight; if valid, it is a severe strike against the concept of a proton made of quarks. If the quarks are spin-½ particles as declared, but the particles found inside the proton are spin-0 particles, then the particles inside the proton cannot be quarks.

A proton made of pions does appear to be consistent with what is seen coming out of other baryons. Essentially all the baryons discussed, the Σ, the Λ, the Δ, the Ξ and the Ω, emit a pion during their decay.[19] Only the neutron and the proton do not release a pion. However, as shown above, protons shatter into pions.

The revelation that protons are made of pions, which means that neutrons are also made of pions, seems to imply that all baryons are made of pions. Pions appear to be structural units of the baryons. That is why they appear in the $\bar{p}p$ collision shown in Fig. 3.

Therefore, even though nine muons satisfy the apparent requirement that the proton component particles be spin-½ particles; for now, the component particles of the proton revealed by the deep inelastic scattering are assumed to be eight pions.

Consequently, the JLAB data together with the SLAC data appear to show that the proton is made of eight pions, not three valence quarks and a sea of quark-antiquark pairs as Bjorken and Paschos claimed. Since the proton has a net charge of +1, it is apparently made of positive, negative and neutral pions.

5. And Are Made of Smaller Particles

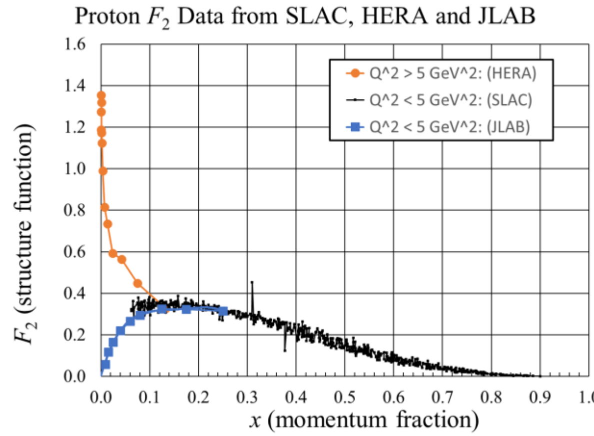
In 1992, the Hadron Electron Ring Accelerator (HERA) produced its first set of electron-proton scattering data.[20, 21] Unlike the linear accelerator in SLAC, which fired electrons at stationary proton targets; in the ring accelerator, both the electrons and the target protons move. This allows it to produce collisions with much higher momentum transfers (Q^2) than the linear accelerator, making it able to resolve much smaller particles.[22]

The second HERA campaign, in 1993,[23] produced electron-proton scattering data for Q^2 from 4.5 to 1600 GeV^2 and x from 0.13 down to 0.000178. At the time (before JLAB), this appeared to fill the gap from $0 < x < 0.06$ left by the SLAC experiments.

The graphs in Fig. 5 compare the SLAC, JLAB and HERA F_2 data. The SLAC curve is the result of fitting the 660 data points to a 20-point moving average. The JLAB points are estimated scaling values at given x values from the measured data. The curve is a fourth-order polynomial fit through the points. The HERA points are also estimated scaling values at given x values. The curve through the points is just a smoothed line through points.

The top graph shows that the JLAB data and the HERA data fork at about $x = 0.13$, the peak of the low-Q^2 SLAC-JLAB curve. It seems that from $x = 1$ down to $x = 0.13$, all three experiments see the same thing when the electrons scatter off the proton. However, once the scattering resolves the eight particles inside the proton, the low-Q^2 scatters have seen all they can see. As the momentum fractions, x, approach zero, their wavelengths are too long to resolve anything smaller than those particles.

The high-Q^2 HERA scatters have electrons with much shorter wavelengths. The fact that the F_2 rises beyond $x = 0.13$ as the momentum fraction, x, approaches zero, indicates that those electrons see smaller details within the proton than the low-Q^2 electrons could see.



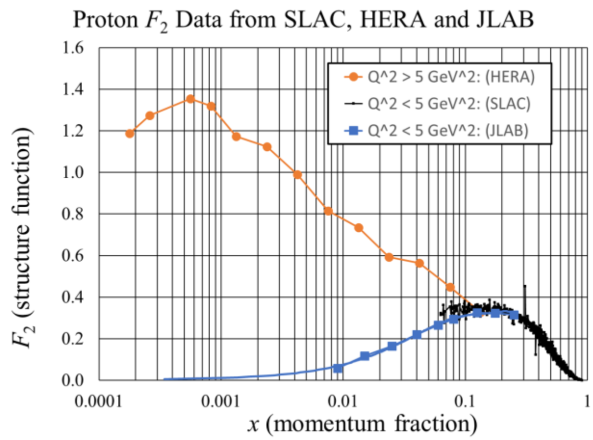


Fig. 5: **The SLAC, HERA and JLAB proton F_2 data.** *The linear (top) and log (bottom) plots of the combined data showing that the proton F_2 structure function forks at about $x = 0.13$. The low-Q^2 JLAB data goes to zero as x approaches zero and the high-Q^2 HERA data rises. The log-version of the graph shows the high-Q^2 data behaves like the low-Q^2 data in a tighter range of x.*

The bottom graph in Fig. 5 is the top graph with a logarithmic momentum fraction axis. It shows that the high-Q^2 HERA data, starting from $x = 0.13$ and approaching zero, behaves like the low-Q^2 SLAC data from $x = 1$, approaching zero. This shows that the HERA electron scattering is resolving particles inside the particles the SLAC-JLAB electrons resolved. The HERA scattering is looking inside the pions that form the proton.

The top graph in Fig. 6 shows the HERA proton F_2 data for the particles inside the proton with momentum fractions less than 0.125. The graph rises sharply as x approaches zero from 0.125 and peaks near, but at slightly greater than $x = 0$, around $x = 0.0005$. From there, it declines as it continues toward zero.

The sharp peak indicates that the particles that the HERA scattering sees, which are presumably inside the pion, do not interact strongly with each other. This contrasts with the blunt peak the SLAC-JLAB scattering found for the pions inside the proton. They, the pions, apparently interact relatively strongly with each other. They are probably bound to each other like atoms within a molecule.

The particles inside the pions are likely not bound to each other. They are influenced by each other and are probably in orbits or energy levels within the pion like electrons within an atom.

The bottom graph in Fig. 6 is the HERA proton F_2 structure function curve (top graph) normalized to a pion F_2 curve. Inspection of the graph reveals that it is the same as the top graph except the values on the axes have changed. This was necessary to make the conversion from the proton curve to the pion curve.

First, the proton is apparently made of eight pions, so each pion carries one-eighth of the proton's momentum. That means that a particle found inside the proton carrying a given fraction of the proton's momentum carries eight times that fraction of the pion's momentum. This makes the proton momentum fraction of 0.125 equal to the pion momentum fraction of 1.0. Consequently, to convert the proton momentum fraction axis to the pion momentum fraction, just multiply its values by eight.

Similarly, the proton F_2 graph shows that at $x = 0.125$, the HERA F_2 value is about $F_2 = 0.35$. This is where the pion momentum fraction is $x = 1.0$. Therefore, by definition, the pion F_2 at this point is $F_2 = 0$. The simplest way to adjust the proton F_2 values to the pion F_2 values is to set $F_2 = 0.35$ for the proton to $F_2 = 0$ for the pion. This is done by subtracting 0.35 from the proton values. This makes the $F_2 = 0.35$ at $x = 0.125$ for the proton, $F_2 = 0$ at $x = 1.0$ for the pion.

The normalized graph shows that when the adjustments are made, the peak F_2 for the particles inside the pion is in the vicinity of $F_2 = 1$. This is another indication that the particles inside the pion are not bound together. The F_2 for completely independent particles would be a δ-function with a spike of $F_2 = 1$.

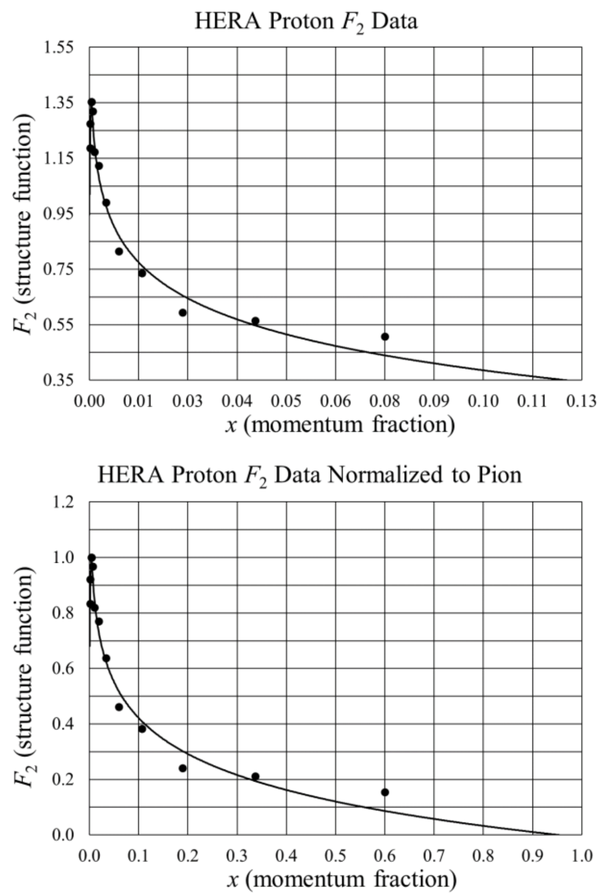


Fig. 6: **HERA F_2 data for the proton and the pion.** ***Top***: *HERA proton F_2 data plotted for $0 < x < 0.125$. The graph shows the F_2 has a sharp peak near $x = 0$, indicating particles that do not interact strongly with each other.* ***Bottom***: *The HERA proton F_2 curve (top) normalized to a pion F_2 curve. The x-axis is multiplied by 8 to show the fraction of the pion's momentum the particles carry and the F_2 axis has been shifted down by 0.35, the F_2 value where the HERA scattering begins seeing the particles inside the pions.*

6. That Look Like Electrons

The graph in Fig. 7 shows the pion F_2 curve for pion momentum fractions x between 0 and 0.1. It clearly shows that the pion F_2 values peak at $F_2 \approx 1$ at $x \approx 0.005$. It also shows that the shape of the curve is like that of the proton F_2 curve of the pions. From $x = 0$, it rises to a peak F_2 value, then falls as $x \rightarrow 1$. The curve in the figure has been broken into two segments. One segment containing points one through three (triangles), and the other starting at point three and including the remainder of the points (dots). Each set of points has been fitted with a simple logarithmic fit shown on the graph.

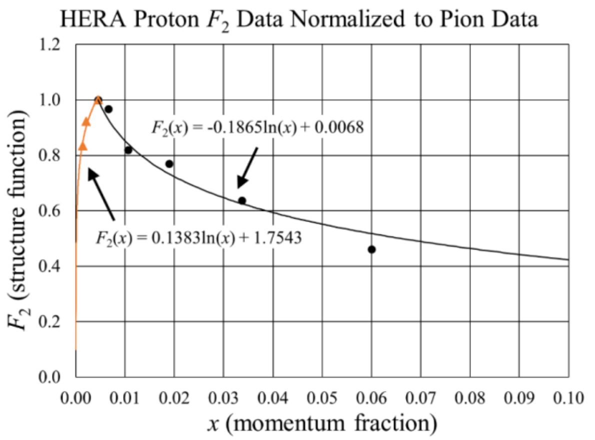


Fig. 7: **HERA pion F_2 data plotted for $0 < x < 0.1$.** *The pion F_2 curve in two segments. The first (triangles) rises from $F_2 \approx 0$ at $x = 0$ to $F_2 \approx 1$ at $x \approx 0.005$. The second (dots) falls from $F_2 \approx 0.005$ as x rises from 0.005.*

The x value where the peak occurs on the normalized F_2 curve indicates the fraction of the pion's momentum its component particles carry. Assuming the two fits should meet at the x-value of the peak F_2, setting the fit equations equal and solving for x should give a good approximate x-value of the peak F_2. The resulting solution is $x = 0.004418$. The reciprocal of this pion x value is 226.3, which means that HERA sees in the neighborhood of 226 particles inside each of the eight pions in the proton.

Eight pions in the proton each having 226 component particles would give the proton 1,808 minor component particles. This is very close to the 1,836 electron masses that makeup the proton. In fact, 1,836 ÷ 8 = 229.5, which means that the pions likely contain an average of 229 particles. The reciprocal of 229 would make $x = 0.004367$ the momentum fraction of the peak F_2 on the pion curve, within just 1.2% of the approximation.

At an average of 229 particles inside the pions in the proton, the pion's components look a lot like electrons (and positrons). For the eight pions of the proton to give it a +1 charge, four could have +1 charges, three, -1, and one, 0. If the four with the +1 charge contain 231 particles, 116 positrons and 115 electrons; the three with the -1 charge contain 231 particles, 115 positrons and 116 electrons; and the neutral one 218 particles, 109 positrons and 109 electrons, the proton would contain 918 positrons and 917 electrons. This would give it 1,835 particles and a charge of +1. The mass of the free pion is about 273 electron masses. If pions are the components of protons, they appear to be made of electrons and positrons.

If this interpretation of the scattering data is valid, then the quark-gluon model of the proton missed this feature of internal proton structure, entirely. The major particles that make up the proton, apparently eight pions, also have structure inside them (Fig. 8, top). The quark-gluon model assumes the proton is essentially a container with an unstructured collection of quarks and gluons within it (Fig. 8, bottom). Instead, it appears to have levels of substructure within it.

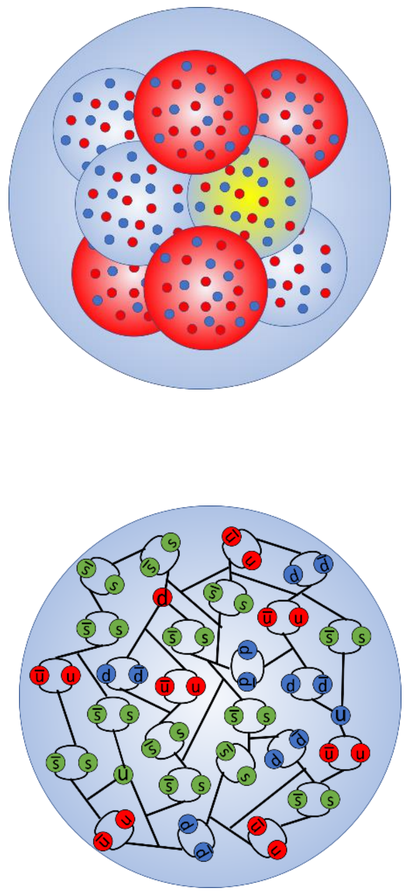


Fig. 8: **Proton models from scattering data analyses.** ***Top***: *Model implied by the reanalysis of the data from SLAC, JLAB and HERA.* ***Bottom***: *Model implied from quark-gluon interpretation of the scattering data.*

7. A New Model of the Proton

From the experiments performed at SLAC, HERA and JLAB facilities, a clear model of the proton emerges. Critical analyses of their electron-proton deep inelastic scattering data strongly suggest that the proton is likely made of eight pions: possibly four positives, three negatives, each made of about 231 electrons and positrons, and one neutral, pion with 218 electrons and positrons in it. Like the quark-gluon model, a pion-electron model can address why quarks and gluons are never seen leaving the nucleus – because there are none in it!

Unlike quarks and gluons, electrons and positrons are routinely seen exiting the nuclei of many radioactive isotopes. As for pions, physicists have been aware of pions in the debris of proton collisions since the 1950s.[24] Pions are the result of cosmic rays (high-energy protons) colliding with molecules in the Earth's atmosphere[25] and proton-nucleon collisions[26]. It has been known that several pions show up in the debris of proton-proton inelastic scattering collisions since the 1990s.[27]

When a proton comes apart, either pions or electrons and positrons seem to always show up. Consequently, with the pion-electron model of the proton, there is no need for an explanation of why the proton components never appear when a proton is smashed, as is the case for the quark-gluon proton model. The components show up everywhere, all the time.

The low-Q^2 proton F_2 curve indicates that the particles found inside the proton each carry about 12.5% of the proton's momentum. At a mass of 273.132 free electron masses, the pion mass is 0.149 times the proton mass of 1,836.153 free electron masses. The blunt shape of the proton F_2 curve, along with its relatively low peak value of ~ 0.35, indicate that the eight particles inside the proton interact strongly with each other. They are probably bound to each other in clusters, like how nucleons bond to form nuclei.

The total mass of eight pions, 2,185.059 free electron masses, is 348.906 free electron masses greater than the mass of a proton. That converts into 178.291 MeV of mass defect to act as the binding energy that holds the pions inside the proton together. The simplest model of the binding would have the eight pions sharing 349 electrons and positrons between them. That would give each pion a deficit of 45 particles, on average. The pion bonds would be like covalent bonds atoms form in molecules by sharing electrons.

The F_2 curve for the pion indicates that there are likely electrons and positrons contained within it, and that they do not interact strongly with each other. They do not appear to be bound to each other inside the pion like the pions are inside the proton. Instead, since the pion F_2 curve peaks so close to $F_2 = 1$, the electrons and positrons inside it are likely in "orbits" or "shells" within the pion like electrons around the nucleus of an atom.

An orbital configuration can hold the electrons and positrons within the pion without having them cluster together on each other. However, the prospect of this configuration begs the question: If the electrons and positrons making up the pion are in orbits, what are they orbiting? Pion decay suggests that the likely orbital center is a cluster of electrons and positrons.

Finally, eight spherical pions packed tightly within a spherical proton would each have a radius of about 0.378 times the radius of the proton[28]. The charge radius of the proton is about 0.875×10^{-15}m. If the charge is uniformly distributed throughout the proton, then its radius is equal to its charge radius. That would make the radius of the pion about 0.33×10^{-15}m.

8. References

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