What Are Partons?

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We discuss and critique some of the evidence that is often invoked to support the idea that partons are quarks. We present an alternative model in which the charged partons are electrons and positrons. This new model explains many experimental observations that the quark model is unable to explain. This paper is not intended to be an exhaustive review of the subject.

Introduction

Electron scattering experiments were used by Friedman et al. to probe deep into the interior of protons and neutrons [1]. The results of these experiments were interpreted as evidence for point-like charged objects in the interior of protons, neutrons and, by extension, all other elementary particles. Feynman named these points of charge "partons" [2].

A few years before these electron scattering results were published Gell-Mann and, independently, Zweig had pointed out that the static properties (mass, spin, parity, etc.) of many of the known elementary particles at the time could be classified using group theory [3, 4]. The basic representation of the mathematical group they chose, SU_3, is a triplet of particles that Gell-Mann named quarks and the name has stuck. The odd property of quarks is that the magnitude of their electrical charge is either (1/3)e or (2/3)e, where e is the electron charge. This was, and still is, a purely theoretical conjecture. No such particles have ever been seen in an experiment. Nevertheless, even though there is experimental evidence against it, the idea that partons are quarks has been gradually adopted by the particle physics community.

The Quark Model and QCD

Most arguments in favor of the quark model are based on static symmetry arguments. All calculations using the quark model give, at best, approximate agreement with experimental results. Quantum Chromo-Dynamics (QCD) is an attempt to extend the static quark model. QCD is unable to make any exact calculations.

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The proton is assumed to be composed of three quarks; one of them is assumed to have a charge of –(1/3)e and the other two have charge +(2/3)e. The neutron is also assumed to be composed of three quarks; one of them has charge +(2/3)e and the other two have charge –(1/3)e. So, the charge of the proton is, by construction, +e and the charge of the neutron is zero. All the hadrons are assumed to be built out of quarks in a similar manner. The quark model is not able to derive expressions for the mass of any of the hadrons. The quark model is also unable to obtain expressions for any of the hadron magnetic moments. The best that can be done is to obtain expressions giving relationships between hadron magnetic moments, and these are, at best, in approximate agreement with experimental results.

As already noted, in the quark model the proton is assumed to be composed of three quarks. The proton is therefore a composite particle. The electron, on the other hand, is a fundamental particle. Quarks and electrons are independent particles subject to different forces. They are not related in any way and there is no known theoretical mechanism that causes the magnitudes of the electron and proton charges to be exactly equal.

Hadron jets seen in hadron-hadron collisions are assumed to be produced by a quark hadronisation process. Yet the charge of a hadron jet is **never** equal to the charge of the quark that became the jet. This feature is not understood and it is usually ignored.

The quark model is unable to explain the stability of the proton and the finite lifetime of the neutron.

There is abundant cross-section data [5] that purports to support the quark model yet on close inspection some of it is self-contradictory and some is very model dependent.

Differential cross-section data can be parameterized in terms of electromagnetic form factors and these can be used to determine the internal charge properties of protons and neutrons. The quark model does not explain or describe the internal charge distribution of either proton or neutron.

A comparison of data using an electron beam versus that using a neutrino beam is often used to support the quark model [6]. Unfortunately there is not enough data using a proton target so usually data on a nuclear target is used. This is a bit unfortunate since model-dependent assumptions have to be made. The term nucleon (N) is used to represent either proton or neutron. Experimentally, the comparison of eN and νN data is clean and direct. The quark model calculations are not so straightforward. For example, the properties of a nucleon are derived by summing the properties of the fundamental particles of which it is composed. However, the summation over the number of flavours is usually chosen. This is illogical and summing over the number of partons would be more correct. Unfortunately, the summation over flavors gives better agreement with data. A parameterization of the differential cross-section data provides structure functions and a comparison of these leads to the observation that 50% of the proton momentum is carried by gluons.

The ratio of πp to pp cross-sections, over a wide range of energies, is approximately 2/3 [5]. This can be described by the quark model if it is assumed there is no gluon contribution to the proton. This is in direct disagreement with the conclusion obtained by comparing eN and νN data.

The ratio of cross-sections for νN to $\bar{\nu}$N is approximately 2. This can be explained by the quark model, but only if there is a significant anti-quark contribution inside the nucleon [6].

The experimentally determined cross-section ratio of e^+e^- to hadrons over e^+e^- to $\mu^+\mu^-$ is usually referred to as the R-ratio. This ratio has been measured over an extensive energy range [5]. The quark-model can be used to determine R and the energy dependence is obtained by assuming that more and more quark flavours contribute as the energy increases. The presence of many resonances complicates the picture, but even so, in the energy regions between resonances, the quark model value of R versus energy is smaller than the experimental results by a factor of 3 or more. It is the quark charges that cause the problem in the theoretical calculation. The data are only consistent with the quark-model if a new *ad hoc* quantum number (colour) is introduced.

An Alternate Model

We have developed a model in which the charged partons are assumed to be electrons and positrons [7-11]. As a starting point, we have deliberately chosen the simplest interpretation in the full knowledge that additional complications might have to be introduced as the model predictions confront additional experimental results. We have stepped back from the Standard Model and avoided the temptation to introduce arbitrary fields (that have no experimental support) and arbitrary quantum numbers (that have no classical physics equivalent). Thus, in our model, there is no isospin, no strangeness, charm, beauty, etc. and no approximate symmetry. There is only one neutrino type and it is its own antiparticle. Electrons, positrons and neutrinos can all exist as right-handed or left-handed particles. There is no Strong field, no Weak field and no Higgs field. There is no spooky Higgs mechanism. The mass of a particle is an intrinsic property like spin and charge.

The electron and the positron are assumed to be point-like objects whose masses originate in an exact balance of electrostatic and gravitational self-energy. We use the measured ratio of electron mass and charge to determine the ratio of the short-distance values of the gravitation and electrostatic parameters. This ratio has to be much larger than the macroscopic value.

The proton and neutron are separate and different particles. The proton is assumed to be composed of $e^+e^+e^-$ and the neutron is composed of $e^+e^+e^-e^-\nu = p^*e^-\nu$, where p^* is an off-mass-shell proton. An approach reminiscent of the Bohr description of the hydrogen atom is used to make calculations. The fields that hold the proton and neutron together are electromagnetism and gravity and the values of the gravitation and electrostatic parameters are in good agreement with those obtained from the electron mass/charge ratio.

In the proton model there is a central electron with two positrons in orbit. The orbital radii are determined by fitting to the internal charge distribution and simple calculations give the exact proton mass and the approximate magnetic moment [7, 9]. The short-distance gravitation parameter, G_0, is the only variable that has to be determined. There are an infinite number of possible positron or electron orbits that give the exact proton mass and they all give a good approximation to the proton magnetic moment. The model automatically gives the magnitude of the proton spin and charge exactly equal to the magnitude of the electron spin and charge.

The neutron model is very similar to the proton model and is also capable of calculating neutron mass, magnetic moment, spin, charge and internal charge distribution [7, 8].

It is worth emphasizing that there are at most two variable parameters in the calculations. The electron mass is determined by the short-distance values of the gravitation parameter G_0 and the electrostatic parameter k_0. The masses, sizes and magnetic moments of proton and neutron depend on G_0. The detailed internal structure depends on G_0 and k_0.

All of the cross-section data can be explained quite naturally using this model without any of the internal inconsistences and odd features that bedevil the quark model. In particular, there is no gluon inconsistency and there is no problem originating in the parton charge.

The Standard Model

The particle physics Standard Model (SM) has been developed quite slowly over the last few decades. It consists of several theoretical components, some more palatable than others. These are: Quantum Electro-Dynamics (QED), the quantum theory of electromagnetism; the Electro-Weak theory (EW), the extension of QED to incorporate the weak interaction; and Quantum Chromo-Dynamics (QCD), the theory of hadrons and the strong interaction based on the quark model. In spite of copious experimental evidence to the contrary, particle masses in the SM are not intrinsic particle properties. Some of them (for example, electrons and quarks) are assumed to be generated by the Higgs mechanism yet there are no detailed calculations. For other composite particles (for example, protons and neutrons) the mass is assumed to mainly reside in the kinetic energy of the constituents, but again there are no detailed calculations. No way has yet been discovered to include General Relativity (GR), the theory of gravity, into the Standard Model.

The SM contains many *ad hoc* assumptions and a large number of parameters that must be determined experimentally. Most particle physicists are of the opinion that it is, at best, an incomplete description of the sub-atomic domain.

We argue that the SM is on the wrong track. The invention of isospin eight decades ago was perhaps one of the first steps in the wrong direction. The proton and the neutron are not the same particle. They have the same spin and almost the same mass, but they have different charge, magnetic moment and lifetime. Calling the proton and the neutron different isospin states of the same particle represents a tacit assumption that a symmetry may be approximate. This is incorrect. The mistake was compounded a couple of decades later with the invention of strangeness and the errors have continued since then. Too many arbitrary quantum numbers have been invented and the resultant SM has become reminiscent of the epicycle model of planetary orbits with multiple patch-ups and *ad hoc* corrections. Just as that model had to be abandoned in favor of the heliocentric model of the solar system, so the particle physics Standard Model must be abandoned. We must go back a hundred years and start anew.

Fortunately, in the years since the conception of the Standard Model, a large quantity of very useful data has been collected and this can be used to guide us as we develop a better model.

Conclusions

The experimental evidence for partons is convincing and strong. The experimental evidence that quarks are real, physical, fundamental particles is unconvincing and weak. The experimental evidence that partons are quarks is at best model-dependent and very weak; at worst it is non-existent.

In this paper we suggest a new approach that is guided by experimental results. We propose that the sub-atomic world is much simpler than the standard model would suggest.

Electrons, positrons and neutrinos are the only fundamental point-like particles and these are the partons. Protons, neutrons, etc. are elementary, finite-sized particles composed of different combinations of these partons. The only two forces are the short-distance versions of gravity and electrostatics. The parameters of these two forces are totally different from the long-range (macroscopic) versions.

As discussed in earlier papers on the subject [7-11], this simple picture allows the detailed calculation of many properties of electrons, protons, neutrons, etc. that give good agreement with experimental measurements.

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