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The Regular Charge-Monopole Theory and Strong Interactions

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Abstract: The paper describes the structure of a regular charge-monopole theory and of its application to hadronic systems. It is shown that this theory explains many hadronic effects whereas QCD fails to explain most of them. Predictions of results of new kinds of experiments are put forward. The success or the failure of these predictions can be used for testing the validity of each of these hadronic theories.

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1. Introduction

This work relies on Maxwellian electrodynamics and shows how charges as well as their dual counterparts, the monopoles, can be incorporated in a unified Regular Charge-Monopole Theory (RCMT) [1]. It is also shown that an application of this theory to hadronic systems provides explanations to a long list of known strong interactions effects. A significant portion of these effects are still unexplained by Quantum Chromo-Dynamics (QCD). Based on the RCMT, explanations are presented for the first EMC effect, the close similarity between the graphs of the nuclear and the molecular potential, the existence and the sign of the nuclear tensor force, the strong CP problem, the proton spin crisis, the frustrating failure of the prolonged experimental attempts to detect pentaquarks, strange quark matter and glueballs, the rise of the elastic cross section graph of very high energy proton-proton scattering and for other hadron related effects. Furthermore, it is shown that the RCMT provides explanation for effects that are also explained by QCD, like the state of the Δ^{++} baryon, the three jet event and the half life time of the π^0 meson.

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The structure of the RCMT is obtained from an application of pure theoretical arguments to Maxwellian electrodynamics. It is explained below that its adaptation to hadrons needs very little experimental data, such as the fact that a baryonic state is characterized by *three* valence quarks, etc. Most of the effects mentioned above as well as many other ones were not used in the construction of the RCMT but are naturally derived from it. For example, the nuclear tensor force is not included in the experimental data used for the construction of the hadronic theory described herein. Now, the sign of the nuclear tensor force is inferred from the prolate shape of the deuteron. It is shown below that if the deuteron would have taken an oblate shape then this hypothetical deuteron would undermine the relevance of the RCMT to strong interactions. The compatibility of the RCMT with this known phenomenon and with many other ones serve as a strong indication that the RCMT provides a good basis for an interpretation of strongly interacting systems.

The second section describes the principles used for the construction of the RCMT. The third section presents motivations for using the RCMT as a basis for a hadronic theory. The fourth section shows how few experimental data enable to cast the RCMT into a hadronic theory. The fifth section compares the structure of this theory with that of QCD. Sections 6-10 discuss many hadronic effects and show that the RCMT explains them whereas most of these effects refute QCD. Section 11 shows that effects that are explained by QCD are also explained by the RCMT. Section 12 describes several new experiments whose results can be used for testing the validity of the RCMT and of QCD. The last section contains concluding remark and a summary table of the effects discussed in this work.

2. The Regular Charge-Monopole Theory

Historically, the theoretical structure of classical electrodynamics has been built on the basis of experimental data. The system consists of electric charges and electromagnetic fields and it contains no monopole. Its main elements are Maxwell equations which are the equations of motion of the fields, the Lorentz law of force which is the equation of motion of massive charged particles and the variational principle used for deriving these equations [2]. The theory's development begins with classical electrodynamics that is derived from the particles' Lagrangian and the fields' Lagrangian density [2]. These quantities are later used for a derivation of quantum theories. This section concentrates on a derivation of a classical charge-monopole theory that relies on a regular Lagrangian density of the fields.

Unlike the case of electric charges, the existence of magnetic monopoles has not been confirmed by experiments. Therefore, a construction of a monopole theory must rely on theoretical arguments. The first task is to define monopoles. This objective is achieved by means of duality transformations which cast a system of fields and charges into a system of fields and monopoles. These transformations are (see [3], pp. 252, 551)

$$\mathbf{E} \to \mathbf{B}, \quad \mathbf{B} \to -\mathbf{E} \tag{1}$$

and

$$e \to g, \quad g \to -e, \tag{2}$$

where g denotes the monopole strength.

An application of these transformations to Maxwellian electrodynamics of electric charges and electromagnetic fields yields a theory of monopoles and electromagnetic fields. This theory holds for systems containing no electric charge. Hence, the next assignment is to construct a unified charge-monopole theory that is consistent with two sub-theories: for systems of charges without monopoles it must agree with the ordinary Maxwellian electrodynamics and for systems of monopoles without charges it must agree with the dual theory described above.

The following two postulates pertain to this topic:

(A) For chargeless systems the unified theory must take a form which is completely dual to the theory of charges and fields and for systems without monopoles it must take the form of Maxwellian electrodynamics.

(B) Electromagnetic fields of a system of monopoles and those of a system of charges have identical dynamical properties.

Hereafter, these postulates are called postulate (A) and (B), respectively. One may be tempted to use both postulates (A) and (B) as fundamental elements of the theory. However, it turns out that this course is unattainable because different sets of equations of motion are obtained from postulate (A) (without (B)) and from postulate (B) (without (A)).

A charge-monopole theory that implicitly uses (B) has been developed by Dirac [4]. This theory contains irregularities that take place along strings, which are connected to every monopole and end at infinity or on another monopole having the opposite sign. The strings of irregularities, which are an inherent element of the Dirac monopole theory, indicate that this theory violates (A).

The RCMT has been derived several decades ago on the basis of (A) [1] and alternatively in [5]. RCMT treats separately bound and radiation fields [6]. This separation relies on the following experimental and theoretical differences between these fields:

- First and foremost, classical electrodynamics is a linear theory. Hence one may cast fields into any kind of sum of separate fields.
- Bound and radiation fields are inherently different objects. Indeed, unlike bound fields, radiation fields represent energy emitted from the system.
- Radiation fields are related to a massless and chargeless particle, the photon, whereas bound fields are related to a massive charged particle.
- Consider the Lorentz invariants of the electromagnetic fields

$$B^2 - E^2 \tag{3}$$

and

$$\mathbf{E} \cdot \mathbf{B}. \tag{4}$$

The invariants (3) and (4) vanish for radiation fields emitted from a system (these relations are obtained from eq. (66.8) of [2], p. 186 and from eqs. (9.4) and (9.5) of [3], p. 392), whereas (3) does not vanish for bound field of a single charge, as can be seen at its instantaneous rest frame.

- The Darwin Lagrangian proves that velocity fields can be eliminated from the system (see [2], p. 181). This property does not hold for radiation fields.

Taking (A) as a basis for the analysis, a regular charge-monopole theory can be constructed [1]. Here a regular Lagrangian density for the fields is obtained together with a regular Lagarngian for massive particles that carry either electric charge or magnetic monopole. Applying standard methods [2], one can use the fields' Lagrangian density and construct their energy momentum tensor [1].

The RCMT yields two important results:

1. Charges do not interact with bound fields of monopoles; monopoles do not interact with bound fields of charges; radiation fields of the systems are identical and charges as well as monopoles interact with them.
2. Unlike the case of the Dirac theory [4], the size of the RCMT elementary monopole unit g is a free parameter.

Later, these results are called the first and the second RCMT results, respectively. It is shown in the next section that the first RCMT result provides a straightforward explanation for the different characteristics of the interaction of electrons and of real photons with nucleons. Referring to the second RCMT result, it is clear that a treatment of the elementary monopole unit as a free parameter is much more favorable than the case where one must cope with the huge and quite unphysical size of the Dirac monopole, where $g^2 \simeq 34$.

3. Electrodynamics and Strong Interactions

The analysis described in the previous section relies on Maxwellian electrodynamics and derives the RCMT by means of pure theoretical arguments. It is explained here how very few kinds of well established experimental data can be used for casting the RCMT into a theory of specific physical processes that are found in our world. Let us begin with an examination of table 1 that describes properties of three kinds of interactions. (For obvious reasons, the gravitational interaction is omitted from the table.) The table presents conservation and violation of two fundamental conservation laws in processes dominated by three kinds of interactions.

The data presented in table 1 suggests that seeking a common foundation for the strong and the electromagnetic interactions is reasonable. Evidently, monopole electrodynamics and Maxwellian electrodynamics are dual theories providing this kind of foundation. For this reason, the table indicates the course that is adopted here for finding the experimental usefulness of the RCMT. Thus, many kinds of physical experiments

Table 1
Validity of parity and flavor conservation under three kinds of interactions

	strong	electromagnetic	weak
parity	yes	yes	no
flavor	yes	yes	no

are discussed in this work and their results indicate why a promising theory of strong interactions can be based on the RCMT. Evidently, a theory of strong interaction that takes a Maxwellian-like form explains why the data are consistent with C, P and CP conservation and does not suffer from the strong CP problem. Similarly, screening effects of electrodynamics provide a self-evident explanation for the vanishing interaction between neutral objects that are not too close to each other. Thus, unlike QCD, this theory does not need to call for the help of an artificial cutoff of the interaction.

Before going into details, let us examine the interaction of electromagnetic objects with nucleons. Experimental data show that electrons (and other leptons) do not participate in strong interactions (see [7], p. 2). Moreover, the electric charge of proton's quarks is not identical to the corresponding quantity of the neutron. It turns out that energetic electrons interact *differently* with quark constituents of protons and neutrons (see [7], p. 200 and [8]). On the other hand, energetic real photons interact strongly with quark targets of protons and neutrons and, in these interactions, protons and neutrons look very much alike [9]. Here the Compton interaction of the photon with the electric charge of the target makes a negligible contribution to the total cross section [10].

This difference between the electron-nucleon and the real photon-nucleon interaction fits perfectly the first result of the RCMT, which is described near the end of the second section. One just needs to regard quarks as particles that carry one unit of monopole charge, electrons as pure electric charges, photons as the quantum form of electromagnetic radiation and to assume that the elementary monopole unit g is much larger than that of charge where $e^2 \simeq 1/137$. The last assumption explains why the electric charge of protons and neutrons can be ignored in the case of their interaction with real hard photon. In order to assess the meaning of this RCMT success, one should recall that the RCMT has been derived from Maxwellian electrodynamics by means of a pure mathematical analysis while the data of electron and hard photon interaction with nucleons has not been used. Evidently, such a success is typical of a good theory whose results cover a wide range of different experimental phenomena.

4. A Model of Hadron Dynamics

The structure of RCMT is bases on pure theoretical arguments relying on fundamental elements of theoretical physics - Maxwellian electrodynamics, the variational principle and duality transformation of electromagnetic systems. Its relevance to strong interactions uses some additional assumptions that are based on experimental data. These assumptions are listed below.

1. The elementary monopole unit is much larger than that of the electric charge.
2. All quarks carry the same monopole unit. (Here the sign of this unit is defined as negative.)
3. Baryons contain *three* valence quarks.
4. Baryons contain a core that carries three positive monopole units.
5. The baryonic core has no electric charge.
6. The baryonic core contains closed shells of quarks of the u,d flavor.

As explained above, the first two assumptions are required for explaining the proton-neutron similarity in hard real photon scattering experiments. As is very well known, the third assumption has a solid experimental support. The fourth assumption is used for explaining baryon stability and its neutrality with respect to monopole charge. The core's electric charge neutrality explains why it has not been detected in deep inelastic electron-proton scattering. It is shown in sections 8 and 9 that both hadronic energy states and high energy proton-proton scattering data support the last assumption.

The assumptions used in this work for a realization of the RCMT can be put in the following illustrative form. A baryon is analogous to a non-ionized atom having three electrons in its outer shell. Quarks are analogous to electrons. Both are Dirac particles that obey the Pauli exclusion principle. Electrons carry one negative unit of electric charge whereas quarks carry one negative unit of magnetic charge and an electric charge that takes the values of $2e/3$ or $-e/3$. The electric charge and the magnetic monopole interactions with fields take a Maxwellian form. The baryonic core is analogous to the nucleus plus all electronic closed shells of this atom. A meson is analogous to the positronium. The analogy between bound systems whose state is determined by electromagnetic and strong interactions is shown in table 2. Here only electrons and u, d quarks are mentioned. An introduction of other kinds of electron and quark flavor can easily be done.

This analogy means that the RCMT regards hadrons as systems whose structure and dynamics are similar to the well established theory of atoms and molecules whose structure and dynamics are determined by laws of electrodynamics. In particular, like the case of an atom that has more than one electron, it is shown in this work that a description of a baryonic state requires many configurations. Below, these physical ideas are called the RCM hadronic theory.

5. The Theoretical Basis of RCM Hadronic Theory and of QCD

It is agreed that Maxwellian electrodynamics is a very successful theory supported by many kinds of experimental results and provides the basis for the modern industry. The very close relationship between the RCMT and Maxwellian electrodynamics means

Table 2
Analogy between electromagnetic and strong systems

Property	Electromagnetic	Strong
Interaction strength	$e^2 \simeq 1/137$	$g^2 \gg e^2$
Dirac Particles	Electron	u, d quarks
Atom-like particles	Atoms	Baryons
Positronium-like particles	Positronium	Mesons
Ionization	Easily done	Impossible
Valence particles	Several possibilities	N=3
Inner closed shells	Exist for $Z > 2$	Exist
Isospin symmetry	Irrelevant	Relevant

that the RCMT takes a form which is very similar to our best theory. On the other hand, the presently accepted theory of strong interactions is QCD. QCD is an SU(3) Yang-Mills extension of Maxwellian electrodynamics and its form has no analog in other physical theories. Some general aspects of QCD that point out its problematic nature are mentioned in this section and other specific examples of this kind are shown later in this work.

The first problem encountered by the QCD developers is the state of the three baryons Δ^{++}, Δ^- and Ω^-. The quantum mechanical state of each of these baryons is based on three valence quarks of the same flavor, which are uuu, ddd and sss, respectively. The lowest energy state of these baryons has the quantum numbers $J^\pi = \frac{3}{2}^+$. For example, let us take the $\Delta^{++}(1232)$ baryon which is a member of the lowest energy isospin quartet of the Δ baryons. The starting point of the QCD construction is based on physical properties of the $\Delta^{++}(1232)$ baryon and uses the following claims:

1. The $I = 3/2$ state shows that isospin is symmetric.
2. The spatial part of the lowest energy state of each of the three uuu quarks must be a symmetric s-wave.
3. The three spins of the quarks must be coupled symmetrically to $J = 3/2$.

Hence, QCD concludes that in order to reconcile spin-1/2 quarks with the Pauli exclusion principle, a new degree of freedom must be introduced.

However, calculations using the Wigner-Racah algebra show that in the foregoing argument, claims (2.) and (3.) are incorrect. As an illustration, consider the helium atom. Its 2-electron ground state $J^\pi = 0^+$ is actually described as a linear combination of a quite large number of terms, each of which is related to a configuration. These configurations are built of many values of the single particle spatial angular momentum and configurations made only of single particle s-wave do not dominate the state [11]. A fortiori, an extremely relativistic 3-quark baryon whose spin is greater than 0, certainly cannot be described by a single spatial s-wave configuration. The higher spatial angular momentum of these configurations indicates that the quark spins are not always parallel. Furthermore, the relativistic dynamics of baryonic states increases spin effects in general, and spin-orbit interaction in particular. It follows that items (2.) and (3.) above are indeed incorrect. A more detailed discussion of this issue can be found [12-14].

It is shown here that QCD has been constructed on the basis of incorrect arguments. One is thus inclined to question how likely it is that a correct theory would have incorrect arguments as its cornerstone? And indeed, the following sections detail many different experiments whose results support the RCM hadronic theory and refute QCD.

The overlook of the multi-configuration structure of a bound state of several Dirac particles is the underlying reason for another serious problem. An experiment has measured the instantaneous spin direction of quarks in a polarized proton [15]. This experiment shows that quarks carry a small part of the proton's spin. This result is known as the second EMC effect and also as the proton spin crisis. However, the proton is a bound system of quarks that are spin 1/2 particles. By assuming that the multiple configuration structure applies to the proton's quarks like it applies to electrons in atoms, it can be concluded that many configurations contain quarks that are not an s-wave. In other words, the state is described by many configurations and in most of which, quarks have a non-vanishing spatial angular momentum. Thus, it can be shown that the multi-configuration structure of this kind of system yields a state where the quarks' instantaneous spin takes either up or down directions and a significant part of its contribution is canceled out [14]. For this reason, one can state that if the experiment described in [15] would have shown that *quarks carry the entire proton's spin then such a result should have been considered as a real crisis of fundamental quantum mechanical principles.* Furthermore, the second EMC effect supports the claim of this section stating that QCD is based on an incorrect basis.

5. Experimental results - Nuclear Properties

The proton and the neutron are the first hadrons to be discovered and their bound states - the nuclei - were the first hadronic systems to be studied by physicists. This section describes briefly several nuclear properties and shows that the results provide a strong support for the RCM hadronic theory which is described in section 4.

The distance dependence of the nuclear potential takes the following form. At short distance it has a strong repulsive behavior that decreases rapidly while outside the repulsive region it has an attractive component. The attractive component decreases much faster than the $1/r$ Coulomb potential. The graph describing the distance dependence of the nuclear potential is shown in fig. 1 (see [16], p. 97).

It turns out that the graph describing the potential found between neutral molecules (or atoms of a noble gas) takes the same shape as that of the nuclear potential of fig. 1 (see [17], p. 15). This close similarity between the shape of the nuclear and the molecular potentials suggests that these interactions rely on similar theories. This physical evidence is clearly in support of the RCM hadronic theory.

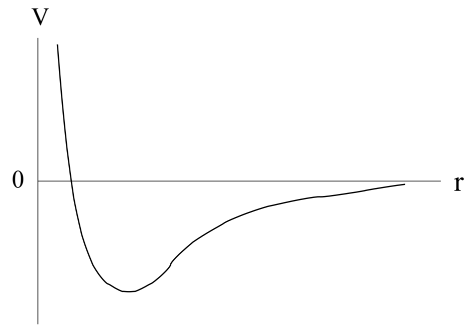

Fig. 1 *The distance dependence of the nuclear potential V.*

A related phenomenon is the uniform density of nucleons in nuclei which is the basis for the nuclear liquid drop model [16]. This model provides good estimates for the mass and the radius of nuclei.

The RCM hadronic theory easily explains these phenomena. Indeed, a treatment of electrons and quarks as ordinary Dirac particles obeying the Pauli exclusion principle explains the molecular and the nuclear hard core property. Indeed, the Pauli principle is the reason for the strong resistance to compression. Therefore, it accounts for the steep decrease of the potential at a short distance and for the uniform density of nucleons in all nuclei, except few very light ones. Quantum effects explain the residual nature of the van der Waals and of the nuclear attractive force.

Another nuclear phenomenon is the nuclear tensor force. The existence of this force is inferred from the deuteron's prolate shape (see [16], p. 65). This kind of force and its sign are consistent with electromagnetic-like interaction between two particles having the same dipole sign relative to their spin direction (see [3], p. 143)

$$V_{DIPOLE} = -\{3(\boldsymbol{\mu}_1 \cdot \boldsymbol{r})(\boldsymbol{\mu}_2 \cdot \boldsymbol{r}) - r^2 \boldsymbol{\mu}_1 \cdot \boldsymbol{\mu}_2\}/r^5. \tag{5}$$

The dipole-dipole interaction (5) proves that the nuclear tensor force is not related to the magnetic moments of the proton and the neutron, because these magnetic moments have opposite signs. The RCMT provides a satisfactory explanation for the origin of the nuclear tensor force. Indeed, the nucleons are spin-1/2 particles whose state is characterized by three u, d quarks of the same isospin structure. By analogy to electrodynamics, spinning monopoles should create an *axial* electric dipole moment and isospin symmetry confirms that they have the same size and sign as required by the RCMT.

The *axial* electric dipole moment that RCMT assigns to nucleons is consistent with the experimentally known vanishing value of the neutron *polar* electric dipole moment. Indeed, the fields of these dipoles are bound fields and not radiation fields. Furthermore, measurements of the neutron's electric dipole moment use ordinary electromagnetic devices. Using the first RCMT result (see near the end of the second section), one realizes that these devices are blind to monopole fields related *axial* electric dipoles. Therefore, the measurements showing a vanishing neutron electric dipole moment just verify the null value of the neutron's *polar* electric dipole moment and that the neutron's state is determined by parity conserving interactions.

Another nuclear effect is the variation of the volume occupied by nucleonic quarks as a function of the number of nucleons in nuclei. A report of this quark distribution has been published in [18] and its results have soon after been confirmed in [19]. The outcome of these experiment is known as the first EMC effect and it shows that quark's volume increases together with the increase of the nucleon number in nuclei. The RCM hadronic theory provides a straightforward explanation for this effect. Indeed, screening effects of Maxwellian electrodynamics hold also for the RCMT monopoles. Hence, quarks penetrate into neighboring nuclei and their volume increases. Evidently, the effect increases with the average number of neighboring nucleons, which means that the effect is larger for heavier nuclei. An analogous effect exists in solids and liquids [20]. In contrast, QCD supporters admit that they still do not provided an adequate explanation for the first EMC effect [21] even though it was discovered several decades ago.

The problematic issues that nuclear data present for QCD were recently admitted by one of the contributors to the present QCD theoretical structure [22]. He states that "... the original problem of understanding nuclear forces has rather fallen by the wayside." He continues as follows: "Ironically, from the perspective of QCD, the foundations of nuclear physics appear distinctly unsound." The author of [22] thinks that some steps towards the solution of these QCD problems have been taken by numerical calculations that use lattice QCD algorithms [23]. The authors of [23] claim that their calculations reproduce the potential graph of fig. 1.

As admitted in [22], the calculations of [23] cannot be regarded as the final word. Two aspects of the questionable status of [23] are mentioned in the following lines. First, the authors of [23] use a pion mass $M_\pi \simeq 0.53\,\mathrm{GeV}$ which is about four times larger than the pionic physical mass. Another issue is their use of a Yukawa interaction mediated by a pion and similarly for vector mesons. The Yukawa analysis relies on a boson wave function of the form $\phi(x^\mu)$ which depends on a single set of space-time coordinates x^μ. It follows that the Yukawa function $\phi(x^\mu)$ describes a point-like structureless elementary particle. However, the pion is certainly a different object: it is not an elementary particle because its state is determined by a quark-antiquark pair. Moreover, it is not a pointlike particle because its mean square charge radius is not much smaller than that of the proton [24]. Hence, an application of mesons, which are quark-antiquark bound states, as carriers of an attractive and a repulsive interactions between particles, is merely a *phenomenological* approach which may be useful for practical purposes but it certainly cannot be regarded as a basis for a substantiation of a theory like QCD.

All the nuclear effects mentioned above are typical of nucleons that are a quantum mechanical bound state of an odd number of Dirac particles, where the dominant interaction takes an electromagnetic-like form. The success of the isospin symmetry shows that this interaction is much stronger than the interaction between electric charges. Thus, the Pauli exclusion principle together with the screening effect of electrodynamics explain the success of the nuclear liquid drop model and the underlying physical reasons for the nuclear potential of fig. 1. The screening feature of electrodynamics also explains the first EMC effect. The electromagnetic dipole-dipole interaction explains the strength and the sign of the nuclear tensor force. All these effects are inherent attributes of the RCM hadronic theory. On the other hand, the QCD status is quite different. Indeed, QCD is characterized by an interaction that satisfies asymptotic freedom at a short distance together with an artificial cutoff at relatively large distance. Furthermore, QCD's additional color degree of freedom removes the hard core effect of the nuclear force [22]. In spite of the long time since QCD inception the discussion presented in this section shows that it still does not provide an adequate explanation for fundamental nuclear properties (see [16], p. 102, [22]).

6. Experimental results - Nucleon Structure

Several aspects of nucleon structure are discussed in this section along with their relevance to the RCMT and to QCD. A profound conclusion of this issue can be uncovered only from an adequate solution of quantum field equations of the nucleon state. This objective is very far beyond the scope of this work. However, it can be shown that clear conclusions of some features of the nucleon's structure can definitely be inferred.

Quarks' momentum. Deep inelastic electron-proton scattering shows that in a Lorentz frame where the proton's momentum is very large, quarks carry about one half of the proton's momentum (see [25], p. 282). This outcome is consistent with the existence of a baryonic core carrying the rest of the momentum. QCD argues that gluons carry this portion of the momentum.

Quark and antiquark distribution in the nucleon. The data on the nucleon's quark and antiquark distribution as a function of their momentum fraction x is described in fig. 2 (see [25], p. 281). The discussion carried out here relies on these graphs and compares the quarks' and the antiquarks' width. Evidently, the antiquarks' data are confined within a smaller x-region. A higher x-width indicates a higher Fermi motion. Therefore, in a nucleon, the Fermi motion of quarks is significantly higher than that of antiquarks. Thus, using the uncertainty principle, one concludes that, in a nucleon, the volume occupied by an antiquark is larger than that of a quark.

The RCMT easily explains this effect, using the analogy between electrostatics of charges and magnetostatics of monopoles. Thus, at inner regions of the nucleon, the magnetic field of the nucleon's core is not completely screened by the quarks. Hence, antiquarks, which have the same sign of magnetic charge as that of the nucleonic core, are pushed towards outer regions of the nucleon. It can be concluded that the RCMT passes successfully this test.

It is not clear how can QCD explain this effect. Indeed, the small energy level of a pion indicates that the quark-antiquark force is very strong. Moreover, the pion's volume is smaller than that of the proton [24]. Hence, one wonders why the four QCD quarks (the three valence quarks and the antiquark's companion) do not attract the antiquark to a volume which is (at least) not larger than the volume occupied by them. As a matter of fact, the data described in figure 2 is known for several decades, and yet the issue presented herein is not discussed in QCD textbooks.

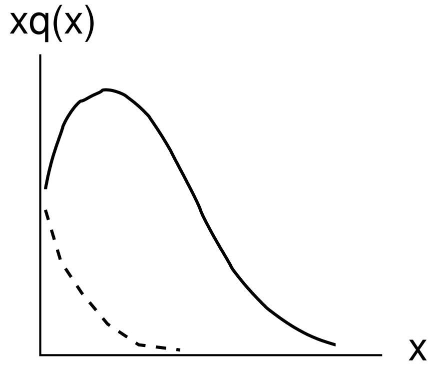

Fig. 2 *The quantity $xq(x)$ is describes qualitatively as a function of x ($q(x)$ denotes quark/antiquark distribution of momentum fraction, respectively). The solid line represents quarks and the broken line represents antiquarks. (The original accurate figure can be found on p. 281 of [25].)*

The neutron's mean-square charge radius. The neutron is an uncharged particle but its mean-square charge radius takes a small negative value [24]. It is shown here that the RCMT provides a qualitative explanation for this property of the neutron. The neutron's state is the isospin analog of the proton's state and it is characterized by the udd valence quarks. It is shown below that two different effects push electrically negative components of the neutron to outer regions. Obviously, these effects increase the negative value of the neutron's mean-square charge radius.

1. A fundamental element of the RCMT is that quarks are ordinary spin-1/2 Dirac particles. As discussed in [12] and by an analogy to one of the Hund's rules, the neutron's state favors spatially antisymmetric terms of the dd quarks. These states can be created by a spatial excitation of one or two d quarks of the neutron. For this reason, the neutron's d quarks are more likely to be found at outer regions. Thus, due to the negative charge of the d quark, the r^2 weight of the neutron's negative charge increases.
2. The neutron contains configurations having additional pairs of $\bar{q}q$ quarks. Using the isospin symmetry of the proton's data of [26], one finds that in the case of a neutron, a $\bar{u}u$ pair is more likely to be found than a $\bar{d}d$ pair. As shown earlier in this section, the antiquarks' volume of the nucleon is larger than that of quarks. The electric charge of the $\bar{u}$ quark is $-2e/3$ whereas that of the $\bar{d}$ quark is $e/3$. The overall arguments presented here boil down to the conclusion that the existence of antiquarks in the neutron increases the contribution to the negative value of the neutron's mean-square charge radius.

These points provide a qualitative explanation for the negative value of the neutron's mean-square charge radius and show that it is consistent with the RCM hadronic theory. Furthermore, a positive value of the neutron's mean-square charge radius would immediately disqualify the RCM hadronic theory. It can be concluded that the RCM hadronic theory passes successfully this test. QCD textbooks do not discuss a theoretical explanation for the negative value of the neutron's mean-square charge radius.

The spatial distribution of quarks in the nucleon. Experimental measurements show that the proton's electric form factor equals its magnetic form factor (see [25], pp 194-197). This equality indicates that both form factors represent quarks' form factor. An appropriate Fourier transform proves that the radial dependence of the proton's quark density decreases exponentially (see [25], p. 196). This density formula is the same as that of the electron in the hydrogen atom, where the state is determined by a Coulomb attraction. This result is compatible with the hadronic structure based on the RCMT. Indeed, according to this theory, quarks carrying a monopole unit are attracted to the baryonic core by a Coulomb-like force. On the other hand, the exponential decrease of quark density is inconsistent with QCD's *Asymptotic Freedom*, where the attractive force tends to zero for a quark-quark vanishing distance. It can be concluded that the RCMT passes successfully this test. On the other hand, theoretical aspects of this issue are not discussed in QCD textbooks.

Flavor asymmetry of nucleon antiquarks. It is mentioned above that experiments show that the probability of finding a $\bar{d}d$ pair in the proton is larger than that of a $\bar{u}u$ pair. This proton asymmetry between the $\bar{u}$ and the $\bar{d}$ antiquarks population is known for more than a decade [26,27]. The RCM hadronic theory provides an obvious and straightforward interpretation for this effect. Quarks are Dirac particles obeying the Pauli exclusion principle. The proton has uud valence quarks. Hence, u quarks occupy more states than those of the d quarks. Thus, an addition of a quark-antiquark pair of the d flavor is energetically easier than an addition of an analogous u pair. For this reason, the probability of finding a $\bar{d}$ antiquark in the proton is larger than that of finding a $\bar{u}$ antiquark. The problem of finding a theoretical explanation for this effect is not discussed in QCD textbooks.

7. Experimental Results - Scattering Processes

For the last one hundred years since the celebrated Rutherford experiment has been carried out, scattering experiments have become a primary experimental tool for understanding the structure and the interactions of particles. The graphs of fig. 3 describe proton-proton elastic and total cross section as a function of the projectile's momentum [24].

Let us examine the relevance of the data of the proton-proton elastic cross section (ECS) depicted in fig. 3 to some very well established physical principles. The discussion is carried out in the rest frame of one proton (the target). The second proton (the projectile) interacts with the potential of the target. As the linear momentum of the projectile increases, its wave length decreases and its wave function changes sign more rapidly. Therefore, spatial regions where the potential varies slowly make a very small contribution to the cross section of a very high energy collision. This general quantum

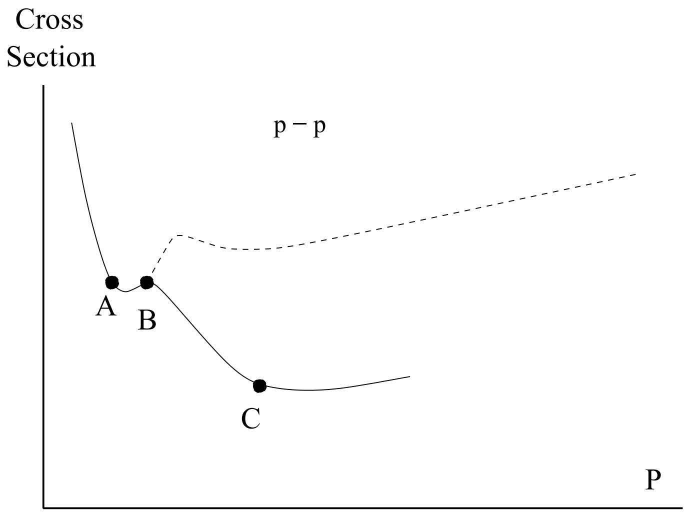

Fig. 3 *The pre-LHC Proton-proton cross section versus the laboratory momentum P. Axes are drawn in a logarithmic scale. The continuous line denotes the elastic cross section and the broken line denotes the total cross section. Points A, B, C will facilitate the discussion (see text). (The accurate figure can be found in [24]).*

mechanical argument proves that in the case of a very short wave length of the projectile, a meaningful contribution to the scattering process is obtained only from regions where the potential varies strongly.

The 1/r variation of the Coulomb potential provides a quantitative information about the slope of the cross section's graph as a function of the projectile's momentum. As is well known, the Coulomb potential leads to the Rutherford and the Mott scattering formulas, where the ECS decreases like $1/p^2$. The data on the left hand side of point A describe a low momentum and a long wavelength. Hence, it pertains to the Coulomb interaction between the electric charge of the two protons and its slope is consistent with these formulas.

The ECS rise between points A-B is explained by the nuclear force which is much stronger than the electric Coulomb force. As shown in fig. 1, this force is characterized by a strong repulsive component at a short distance and an attractive component outside it. If the radial distance increases then the nuclear attractive force decreases much faster than the Coulomb force. As a result, at regions where it is not negligible, the radial variation of the nuclear force is much stronger than that of the Coulomb force. These arguments explain the twist of the graph at the region between points A-B. It can be concluded that the data on the left hand side of point B, together with our knowledge of the Coulomb and the nuclear forces, support the quantum mechanical approach described above.

Let us examine the data for a momentum which is higher than that of point B. Here, like in the case of electron-proton deep inelastic scattering, each proton is regarded not as one particle but as a set of quarks (and of other objects). However, the quantum mechanical laws described above, are assumed to be valid. The projectile's momentum of point B is about 1 GeV/c. The data described in fig. 3 is given for a laboratory momentum up to about 2000 GeV/c and for a much higher momentum found in cosmic rays. Now, even at the smaller momentum range of the more reliable laboratory data, one finds that the cross section describes a physical state which is very, very far from the Coulomb related formulas of Rutherford and Mott. In particular, for a linear momentum larger than that of point C, ECS stops decreasing and begins to increase.

The deep inelastic electron-proton scattering data show that for very high energy inelastic cross section (ICS) decreases with energy but it dominates the process and the value of elastic cross section (ECS) decreases even faster and its relative portion becomes negligible (see [25], p. 266). The proton-proton data of fig. 3 demonstrates completely different properties. Between points B-C, the relative portion of the ECS decreases and becomes practically stable and takes about 15% of the total events. For a projectile momentum larger than that of point C, the ECS stops decreasing and begins to increase.

The baryonic core of RCMT explains this part of the data of fig. 3. For the momentum region between points B-C, the core-core interaction yields elastic events. Here exists a Coulomb-like potential of the cores' monopoles which is screened by valence quarks. Hence, for a shorter distance, its value increases faster than the ordinary $1/r$ formula. For this reason the decreasing slope of the ECS on the right hand side of point B is milder than that of the pure Coulombic interaction which exists on the left hand side of point A. The increase of the ECS on the right hand side of point C emerges from the inner quark closed shells which is an element of the RCMT description of baryons. Like in the case of valence quarks, where the Pauli exclusion principle yields the strong repulsion of the nuclear potential of fig. 1, an analogous effect arises for the inner closed shells. A more detailed discussion of these issues has already been published [28,29].

As is well known, QCD relies on very different baryonic structure and dynamics. QCD states that baryons are made of three valence quarks, quark-antiquark pairs and gluons. Furthermore, it is argued that QCD is characterized by a force that decreases at a short distance between quarks. This QCD property is called asymptotic freedom (see, e.g. [30], p. 364). This fact means that at very short distance, the radial variation of the QCD force is smaller than that of the Coulomb force. Thus, on the basis of the foregoing discussion, one infers that the QCD quark-quark elastic cross section graph is expected to show a steeper decrease than that of the Coulomb interaction, which is seen on the left hand side of point A. This expectation is certainly inconsistent with the data of fig. 3. Therefore, it is not clear how can one reconcile QCD with the data of fig. 3. As a matter of fact, the inconsistency of QCD with the experimental data of fig. 3 has already been pointed out in the literature [29,31].

It can be concluded that the high energy data of proton-proton scattering is consistent with the RCMT and refutes QCD.

Another kind of important scattering experiment is the collision of hard γ photons with nucleons. The appropriate data is known for about half a century and it shows that the interaction of a hard γ photon with a proton is about the same as its interaction with a neutron [9]. Furthermore, the Compton interaction of the photon with the electric charge makes a negligible contribution [10]. As mentioned in the third section, these effects fit perfectly the RCM hadronic theory.

The Standard Model, which incorporates both QCD and Maxwellian electrodynamics, has no explanation for the interaction of real hard photons with nucleons (see [32], section 5 and references therein). The following quotation acknowledges the problem: "No direct translation between the Standard Model and VMD has yet been made" [33].

8. Experimental results - Baryonic Inner Closed Shells

It is pointed out in the previous section that the existence of inner closed shells accounts for the rise of the proton-proton elastic cross section for a momentum greater than that of point C of fig. 3. The issue discussed in this section is the flavor of the quarks that make the inner closed shells. General physical arguments indicate that the inner closed shells are made of quarks having the u, d flavor, because they are the lightest of all quarks. The following discussion uses the RCM hadronic theory where the strong interaction is dual to Maxwellian electrodynamics and baryons have a core and three valence quarks that are analogous to electrons bound to an atom. Relying on these principles one can show that data of hadronic mass and radius support the idea that the inner closed shells are made of u, d quarks.

Measurements show that the charge radius of pions is smaller than that of the proton [24]. In the case of a π^+, a u quark is attracted to an antiquark that carries one monopole unit. On the other hand, in the proton, the uud quarks are attracted to a core that carries three monopole units. In the atomic case, the radius of the two-electron He atom is much smaller than that of the hydrogen atom as well as the ground state of the positronium. The reason is that in the He atom the nuclear attractive force is twice as strong as that of the hydrogen atom and the Pauli exclusion principle does not prevent a compression of the two electrons within a smaller volume. By analogy to this effect, one expects that the proton's uud quarks would be enclosed in a volume which is much smaller than that of the π^+. As stated above, experimental data are in contradiction to this expectation. Thus, the quite large proton radius indicates that the proton contains closed shells of quarks having the u, d flavor. Applying the Pauli exclusion principle, one infers that the wave function of the valence uud quarks must be orthogonal to that of the ud quarks of the closed shells. This state is analogous to a multi-electron atom where atomic radius increases due to inner closed shells of electrons. (For example, the radius of the ground state of the 4-electron Be atom is about 3.5 times larger than that of the 2-electron He atom.)

It can be shown that the proton-pion mass difference supports this conclusion. For this purpose, let use find an estimate for the mass associated by each quark of these particles. The proton contains three valence quarks and a probability of about 0.5 of additional quark-antiquark pair. Let us assume that this probability also holds for the pion. Thus, on the average, the π^+ contains three quarks and each quark carries about 46 MeV. On the other hand, the proton mass is 938 MeV and deep inelastic electron-proton scattering shows that proton's quarks carry about one half of this value. It means that one half of the proton's mass should be divided between four quarks. It follows that

Table 3 Hadronic mass (MeV)

Quarks	Particle	Mass	Δ	Δ_1	Δ_2
uud	p	938	799	-	-
$u\bar{d}$	π^+	139	-	-	-
uus	Σ^+	1189	695	251	251
$u\bar{s}$	K^+	494	-	355	355
uuc	Σ_c^{++}	2455	585	1517	1266
$u\bar{c}$	D^+	1870	-	1731	1376
uub	Σ_b^+	5808	529	4870	3353
$u\bar{b}$	B^+	5279	-	5140	3409

in the proton, a quark mass is about 117 MeV. Comparing these values, one finds that in the pion quarks are attracted more powerfully to the single monopole charge of the antiquark than to the proton's baryonic core that contains three monopole units. In order to resolve this apparent contradiction, one must assume that the proton contains inner closed shells of u, d quarks. Thus, the orthogonality of the valence quark's wave function to that of the ud inner closed shells increases the kinetic energy of the proton's valence quarks and their radius as well. These effects explain why in the proton, the energy per valence quark is larger than the respective quantity in the pion.

Furthermore, it is shown here how hadronic data indicate that the closed shells are (effectively) made *only* of u, d quarks. For this purpose let us compare the mass of baryons and mesons containing only one valence quarks of another flavor [24]. The required data are given in table 3. This table shows the mass of the lightest hadron whose state is determined by u quarks and *one* valence quark having a different flavor. The discussion presented in the rest of this section refers to such hadrons only. Below, the symbol $\hat{q}$ denotes a quark other than a u quark. In table 3, each pair of rows contains data of the baryon and the meson where the valence quark $\hat{q}$ has the same flavor. Δ is the baryon-meson mass difference, Δ_1 is the mass difference between a particle of this pair of lines and the corresponding particle of the first pair of lines. Δ_2 is the mass difference between a particle and the corresponding particle in the pair of lines placed just above.

Let us examine the following energy relations of a proton and a π^+

$$E_p = E_B(u) + E_B(d), \tag{6}$$

$$E_{\pi^+} = E_M(u) + E_M(d). \tag{7}$$

Here the subscripts B, M denote an expression for a baryon or a meson, respectively. The symbol $E_B(u)$ denotes the energy of the baryon that is independent of the $\hat{q}$ component of the system. The symbol $E_B(\hat{q})$ takes the energy not included in $E_B(u)$. In the first approximation, which is used here, $E_B(u)$ takes the same value for all baryons examined herein and analogously for $E_M(u)$. (Note that $E_M(u)$ does not vanish because, like the proton, a meson contains additional quark-antiquark pairs which interact with the u quark.)

Let us see how energy varies if the d quark is replaced by an s quark. Using the data of table 3, one finds for the baryons

$$\begin{aligned} E_{\Sigma^+} - E_p &= E_B(u) + E_B(s) - E_B(u) - E_B(d) \\ &= E_B(s) - E_B(d) \\ &= 251. \end{aligned} \tag{8}$$

The mesons yield the following

$$\begin{aligned} E_{K^+} - E_{\pi^+} &= E_M(u) + E_M(s) - E_M(u) - E_M(d) \\ &= E_M(s) - E_M(d) \\ &= 355. \end{aligned} \tag{9}$$

Assume that the baryon has inner quark closed shells of the s flavor and these shells are analogous to the u, d inner closed shells. Here one expects that, like in the case of the proton, the Σ^+ s quark binding energy would be smaller than that of the K^+ meson. The data shows the opposite relation and the baryonic energy difference of (8) is smaller then the corresponding mesonic value of (9). It follows that inner closed shells of s quarks either do not exist or that their number is smaller than those of the u, d quarks.

Other quantities presented in the Δ_1 column of table 3 show the same relations in support of the previous conclusion. The data of the Δ_1 and Δ_2 columns can be used for a similar analysis. The baryon-meson mass relations described above are consistent with the RCM hadronic theory interpretation of the proton's relatively large volume, as discussed in this section and with the reasonable expectation of effects related to core's closed shells made only of u, d quarks.

9. Experimental results - QCD's Prediction of Specific Particles

The history of theoretical work on strong interactions contains some successful predictions. Two examples are mentioned below:

- In the early 60s of the previous century, M. Gell-Mann and Y. Ne'eman have independently predicted the existence of the Ω^- baryon and its mass. The analysis assumes the existence of spin-1/2 "quarks" that define hadronic structure. The Ω^- baryon was discovered very few years later. This discovery is regarded as a triumph of the spin-1/2 quark structure of hadrons.
- Few years later, the Bjorken and Feynman analysis of deep inelastic electron-proton collision have defined conditions for experimental results that prove the existence of point-like "partons" in the proton. The predictions have been very quickly confirmed by experiments. This outcome provides a dynamical confirmation for the existence of spin-1/2 point-like components in the proton. Thus, the dynamical "partons" are the structural "quarks". These constituents are known by the name "quarks".

It is widely accepted that these successful works establish a remarkable proof of physical properties of hadrons. For this reason, they have quickly found their way into textbooks and are now studied in courses on particle physics. At present there is no doubt about the existence of quarks and of their main properties.

Unlike these cases, QCD has some predictions that have not been confirmed for several decades. Here are three examples:

- QCD supporters have argued that pentaquarks should have been discovered in experiments [34,35]. These objects are strongly bound states of a nucleon and a meson. In spite of more than two decades of searching carried out by a large number of teams, the existence of strongly bound pentaquark has not been established [36].
- QCD supporters have argued that stable nuggets made of electrically neutral baryons, each of which resembles the Λ baryon, should exist [37]. This kind of matter is called Strange Quark Matter (SQM). In spite of more than two decades of searching carried out by a large number of teams, the existence of SQM has not been established [38].
- QCD supporters have argued that a kind of particle called glueball should be observed in experiments [39]. In spite of more than three decades of searching carried out by a large number of teams, the existence of glueballs has not been established [39].

The RCM hadronic theory explains easily these QCD systematic failures by showing that these particles simply do not exist. Thus, a pentaquark is assumed to be a *strongly* bound baryon-meson state. The RCM hadronic theory argues that these particles are neutral with respect to monopole charge. Hence, if a binding force exists then it must be residual, like the nuclear force. Since the lightest mesons are the spinless pions, the pentaquark binding energy should be smaller than the 2.2 MeV of the deuteron. This is certainly not a strongly bound state, because strong interaction energy differences are characterized by hundreds of MeV.

The Λ baryon is neutral with respect to monopole charge and the $\Lambda - \Lambda$ interaction should be residual, like that which binds nucleons to nuclei. Thus, binding energy of an SQM nugget should be about 8 MeV per each Λ. Now, the Λ baryon is heavier than the nucleon by about 180 MeV. Hence, an SQM nugget is unstable and its half-lifetime is about the same as that of the Λ baryon.

The RCMT description of hadrons is based on a Maxwellian-like dynamics of monopoles where the radiation particles are ordinary photons. Hence, glueballs do not exist simply because gluons do not exist.

11. Apparent Success of QCD

It is well known that experimental success can only *support* the veracity of a physical theory whereas an established experimental failure *falsifies* the corresponding theory. These criteria have, for example, been applied to the Bohr-Sommerfeld quantum theory which explained the hydrogen atom energy levels but failed in the case of atoms having two or more electrons. Adopting this approach and recognizing the great number of its independent experimental failures that are described above, one can be assured that QCD is an incorrect theory and that any experimental success cannot save it. Experiments whose results are recognized as a support for QCD are discussed in this section, just for the purpose of showing that the RCM hadronic theory can also explain these results.

- *The three-jet event.* This event is obtained in an electron-positron collision where three hadronic jets are defined and nearly all outgoing particles belong to one of these jets [40,41]. It is agreed that each jet is produced by one outgoing particle created in the primary process of the electron-positron annihilation. The primary process of this event is explained as $e^-e^+ \to q\bar{q}g$ where $q\bar{q}$ denote quark and antiquark, respectively and g denotes a QCD gluon. Here the gluon is produced by a QCD two-quark process which is analog to bremsstrahlung of electrodynamics [41].

  It turns out that the RCM hadronic theory can explain this effect as well. Indeed, in the RCM hadronic theory quarks carry a unit of magnetic monopole and the square of this unit is approximately 100 times stronger than that of the elementary electric charge. Therefore, a magnetic monopole related bremsstrahlung may take place, in a total analogy to the electric charge process in which a photon is emitted. Since the basic unit of the monopole charge is much larger than that of the electric charge, the effect of a bremsstrahlung photon emitted by monopoles is expected to have a much higher probability. In conclusion, the fact that the gluon is the QCD analog of the ordinary electromagnetic photon together with the high value of the elementary monopole unit show that the three-jet event is compatible with the RCM hadronic theory.
- The π^0 decays (mainly) into two γ photons and its half lifetime is short with respect to what is expected on the basis of the quarks' electric charge and a comparison to the lifetime of the corresponding level of the positronium. This phenomenon is regarded as a proof of QCD validity [25].

  The following short discussion explains why the π^0 short lifetime does not disprove the RCM hadronic theory. Unlike the positronium, which is a nonrelativistic system, the π^0 is an ultra-relativistic system. For this reason, one expects that, like the proton, the π^0 state contains additional quark-antiquark pairs. Another relativistic effect is that in the π^0 the absolute value of the coefficient of the lower part of the Dirac spinor is about the same as that of the upper part. In the 0^- state of the π^0, the upper part of the Dirac spinor has a vanishing spatial angular momentum whereas in the lower part the spatial angular momentum is unity. This property means that for the lower part of the Dirac spinor, the probability of a short distance between the quarks is negligible. On the other hand, in the positronium, the corresponding coefficient of the lower part is very small. These effects should be accounted for in any calculation of the π^0 lifetime. Both effects contribute to an *increase* of the π^0 lifetime.

  In the RCM hadronic theory, quarks carry a (negative) monopole unit whose square is much larger than that of the electric charge where $e^2 \simeq 1/137$. This effect *shortens considerably* the π^0 lifetime.

It can be concluded the the π^0 short lifetime does not refute the RCM hadronic theory.

10. Predictions

The correctness of a physical theory is tested by its capability to adequately explain results of experiments that have been carried out within its domain of validity. (Evidently, one may find a shortcut and falsify a physical theory that is based on a mathematical error.) Relevant experiments can be divided into two sets: experiments whose explanation is given *after* their results have been published and experiments whose results have been *predicted* by the theory. From a conceptual point of view the merits of both kinds of experiments are the same. However, humans are much more inclined to be convinced by successful *predictions* because this kind of relationship between theory and experiment is unbiased by already known evidence. This section contains few predictions of the RCM hadronic theory that differ from what is expected from QCD.

- *Pion-Pion cross section.* Unlike protons, pions are characterized by a pair of quark-antiquark and they do not have inner quark shells. Moreover, in deep inelastic electron-proton cross section, the electron collides with one quark at a time. This property should also hold for quark-quark interaction of the pion-pion collision. Therefore, relying on RCM hadronic theory, the pion-pion elastic cross section is analogous to an ordinary electromagnetic elastic cross section of charges. It is well known that this cross section decreases for increasing collision energy.

  Prediction 1: Unlike in the proton case, where the elastic cross section increases for collision energy greater than that of point C of fig 3, a decrease of the elastic cross section is predicted for pion-pion scattering, and its graph will not increase for energies that correspond to those which are greater than that of point C of fig. 3. By analogy to the deep inelastic electron scattering, the total pion-pion cross section should also decrease for increasing collision energy.

  As pointed out in section 8, QCD has no explanation for the high energy proton-proton elastic and total cross sections graphs. Hence, it is not clear how can QCD explain why the characteristics of the high energy pion-pion scattering differ from those of the proton-proton scattering.

- *Pion's momentum carried by quarks.* The deep inelastic electron-proton scattering data are used for calculating the portion of the proton's momentum carried by quarks, as seen in a frame where the proton's momentum is very very large. It turns out that for a proton, the overall quarks' portion is about one half of the total momentum. In the RCM hadronic theory, baryons have a core attracting the 3 valence quarks. The core carries momentum and this is the reason for this effect. Mesons are quark-antiquark bound states and they do not have a core. Hence, in mesons, quarks are practically assumed to carry all the momentum.

Prediction 2: Unlike the proton case, it is predicted that an analogous experiment of deep inelastic electron-pion scattering will prove that in this case the pion's quarks carry all (or nearly all) of the pion's momentum.

QCD argues that a proton and a pion are made of quarks and gluons. QCD further argues that in the case of the proton, one half of the momentum is carried by gluons. Hence, according to QCD it is expected that also in the pion case, gluons will be found to carry about one half of the momentum.

- *Charge radius of the Σ^+ baryon.* There is an analogy between electromagnetic bound states of electrons in an atom and quark bound states in a baryon. This analogy may be used for finding an estimate of physical values pertaining to baryonic structure.
  Prediction 3: Phenomenological calculations based on the RCM hadronic theory and on the experimentally known charge radius of some particles, yield the following estimates for the square of the charge radius of the Σ^+ baryon and for the charge radius itself [42]. The estimates fall in the following ranges:

  $< r^2 > \in\ [0.85, 1.17]\, fm^2$

  $< r > \in\ [0.91, 1.12]\, fm$

  These values are greater than the recently published QCD based estimates [43].

11. Concluding Remarks

This work describes the structure of the RCM hadronic theory and shows a large collection of different kinds of experiments whose results are consistent with this theory. Most of the experiments examine hadronic properties that look quite independent of the experimental data used for the construction of the RCM hadronic theory. For example, the prolate shape of the deuteron is consistent with the theory. If the deuteron takes a spherical or an oblate shape then the RCM hadronic theory is falsified. Similarly, if the descending slope of the proton-proton elastic cross section on the right hand side of point B of fig. 3 be steeper than that which is on the left hand side of point A of this figure then the validity of the RCM hadronic theory is refuted. The paper describes many tests of this kind and all results are consistent with the RCM hadronic theory. Such a success is typical of a good theory whose domain of validity contains many different kinds of effects.

A comparison of experimental results with QCD differs significantly from that of the RCM hadronic theory. Here many inconsistencies are found. Some of these inconsistencies are regarded as QCD problems while others are simply ignored. Table 4 summarizes these effects and shows the section where a relevant discussion can by found.

Table 4: A list of effects and their theoretical status.
The status takes one of the following categories:
A - the effect has a well accepted explanation.
B - the effect does not have a well accepted explanation.
C - the effect appears to refute the theory.

Effect	Experimental Result	RCMT	QCD	Section
The strong CP problem	Hadronic processes conserve C, P and CP	A	B	3
Cutoff	Hadronic interaction vanishes at a distance larger than several fm	A	B	3
Proton Spin Crisis	Quarks carry a small fraction of the proton's spin	A	C	5
Nuclear potential	Very similar to the molecular potential	A	C	6
Nuclear density	Uniform	A	B	6
Nuclear tensor force	Like that of two identical strong dipoles	A	B	6
First EMC effect	Quark's volume increases in heavier nuclei	A	B	6
Quarks' momentum	Quarks carry about one half of the momentum of a high energy proton	A	A	7
Antiquark volume in a nucleon	In a nucleon, the antiquark's volume is larger than that of a quark	A	C	7
Neutron's charge distribution	The neutron's mean square charge radius takes a small negative value	A	C	7
Quark distribution in nucleons	The radial dependence of the quark density decreases exponentially	A	C	7
Antiquark's flavor asymmetry	In a proton, the $\bar{d}$ probability is larger than that of the $\bar{u}$	A	B	7

Proton-proton elastic cross section	In high energy the decreasing slope is milder than that of a Coulomb scattering	A	C	8
Proton-proton elastic cross section	Increases in a very high energy	A	C	8
γ-nucleon scattering	A hard γ photon interacts strongly with nucleons and a proton-neutron similarity exists	A	C	8
Hadronic radii	The proton's radius is larger than that of the pion	A	A	9
Hadronic mass	Flavor dependence of hadronic mass	A	A	9
Pentaquarks	Pentaquarks have not been found	A	C	10
SQM	SQM has not been found	A	C	10
Glueballs	Glueballs have not been found	A	C	10
Δ^{++}	The quantum mechanical $I = \frac{3}{2}$, $J^\pi = \frac{3}{2}^+$ state of the Δ^{++}	A	A	5
3-jets	3-jet events are found in energetic electron-positron collision	A	A	11
π^0 decay	The π^0 half-life time is shorter than expected	A	A	11

Table 4 demonstrates the overwhelming advantage of the RCM hadronic theory over QCD. However, successful predictions of physical effects are of special value for the acceptance of a theory. The pion experiments described in the previous section present two predictions of the RCM hadronic theory. Available pionic beams can be used for carrying out these experiments to determine which theory better complies with reality.

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