A Prediction of Results

of the Large Hadron Collider

E. Comay*

Charactell Ltd.

P.O. Box 39019, Tel Aviv 61390

Israel

Abstract:

This work points out an application of the regular theory of charge-monopole electrodynamics to the new experiments of very high energy. Unlike QCD, the regular theory of charge-monopole electrodynamics shows that the strong force is a force between monopoles. Expected results of the new regions of high energy interactions which will soon be explored by CERN's Large Hadron Collider are discussed. Relying on the regular charge-monopole theory and on relevant experimental data, it is explained why a significant increase of the cross section above its QCD predicted value is very likely to be found.

Key Words: proton-proton collision, very high energy, Large Hadron Collider, Magnetic Monopoles

1. Introduction

In physics, theoretical predictions of new experimental results rely mainly on the mathematical structure of the relevant theory. In this sense, the activity in theoretical physics is analogous to that of mathematics. However, unlike problems belonging to the realm of mathematical investigation, there are physical problems where the theoretical analysis cannot proceed without a knowledge of some experimental data that describe specific properties of the system. These two elements are used below in an explanation of the possibility that the data which will be obtained from CERN's Large Hadron Collider (LHC) may show a significant increase of the cross section for regions of very high energy that have not been explored before.

2. The Experimental Data

Preliminary results of the experimental data needed for the analysis have been reported nearly 10 years ago [1-3]. These experiments have been carried out at HERA and use e^+p colliding beams. Both H1 and ZEUS experiments show a significant excess of the number of events for regions where $Q^2 > T$ GeV^2. Here Q^2 is the absolute value of the squared 4-momentum transferred in the interaction and T denotes the threshold used, which is 15000, 35000 GeV^2, respectively. The validity of this result is crucial for the discussion carried out below. The main problem with the data reported in [1-3] is the small number of events found in the analysis. Thus, different analyses use different cuts of the kinematic region and the number of events found ranges between 2 and 12 [1-3]. Hence, more data are needed.

Further publications that use a larger set of data obtained from the HERA facility have been published since then. It turns out that recent publications [4,5] which rely

on all the relevant HERA data still leave this issue undecided. Thus, unlike the first publications that use Q^2 as a parameter for grouping the data, the new analyses use the value of the transverse momentum p_T. (In the latter calculations the contribution of the longitudinal component of Q^2 is lost and it becomes more difficult to detect events restricted to very high Q^2.) The recent analyses [4,5] show that the two HERA groups, H1 and ZEUS, do not agree now on the issue described above and that the excess of the number of events found is still too small.

This state of affairs explains why today it is not clear whether or not there is a significant increase of the cross section for events where Q^2 is very high.

The foregoing discussion explains why the following statement takes the status of a conjecture.

A. The increase of the cross section reported in [1-3] is just the tip of the iceberg. A significant increase will be found in the data of more energetic interactions.

Henceforth, this statement is called conjecture A. It is explained why also the theoretical analysis carried out below indicates that several alternatives are possible and that conjecture A is consistent with one of them.

The HERA facility contains a beam of protons that collide with a beam of leptons. The leptonic beam is made of electrons or positrons. In the theoretical analysis described below it is explained why results of the proton-proton LHC facility are relevant to the problem presented above.

3. A Theoretical Discussion

The theory used herein is the Regular Charge-Monopole Theory (RCMT) [6,7] and its application to strong interactions [8]. Let us begin with a brief description

3

of relevant properties of RCMT. As usual, the term "monopole" is used sometimes instead of "magnetic charge". Thus, monopoles are defined by the following duality transformation (called also duality rotation by $\pi/2$)

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

and

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

where g denotes the magnetic charge of monopoles.

Now, Maxwellian electrodynamics is a theory of electric charges and electromagnetic fields. It contains no monopoles. Hence, applying the duality transformations (1) and (2) to Maxwellian electrodynamics, one obtains a dual theory of monopoles and electromagnetic fields. This theory does not contain charges. Thus, at this point we have two separate electromagnetic-like theories.

RCMT is the union of these theories. Its structure [6,7] conserves the duality relations between these electromagnetic theories. It is important to note that this theory can be derived from a regular Lagrangian density. Hence, the corresponding quantum mechanical theory can be constructed in a straightforward manner[9]. The main result of RCMT can be put in the following words: Charges do not interact with bound fields of monopoles and monopoles do not interact with bound fields of charges. Charges interact with all fields of charges and with radiation fields emitted from monopoles. Monopoles interact with all fields of monopoles and with radiation fields emitted from charges. Another important result of RCMT is that the unit of the elementary magnetic charge g is a free parameter. However, hadronic data indicate that this unit is much larger than that of the electric charge $g^2 \gg e^2 \simeq 1/137$. More details of RCMT can be found in [6-8].

These properties of RCMT fit like a glove the data of electromagnetic projectiles interacting with nucleons (see [8], pp. 90, 91). Thus, protons and neutrons do not

4

look alike in cases of charged lepton scattering whereas they look very similar if the projectile is a hard enough photon [10]. It is also shown [8,11,12] that an application of RCMT provides explanation for other physical properties in general and for hadronic properties in particular. Thus, explanations are obtained for the following properties: the reason why magnetic monopoles have not been detected in our instruments; the uniform density of nuclear matter; the fact that a system of six valence quarks is a deuteron, which is a proton-neutron loosely bound state; the fact that *strongly* bound states of pentaquarks do not exist; the reason why antiquarks of nucleons occupy a larger spatial volume than that of quarks; the EMC effect [13,14] which shows that in a nucleus, the mean volume of a single quark increases together with the increase of the nucleon number A.

These results encourage one to continue the examination of the relevance of RCMT to the baryonic structure. The main baryonic property inferred from RCMT is that baryons have a core whose magnetic charge is $3g$ and each quark has one negative unit of magnetic charge $-g$. Therefore, baryons are neutral with respect to magnetic charge. (The existence of a baryonic core is consistent with the portion of linear momentum of a very energetic nucleon, which is carried by quarks [15].) At this point, RCMT can say nothing more on the structure of the baryonic core. In particular, it is not clear whether the core is an elementary structureless object or a complicated system which contains closed shells of quarks. However, the following arguments support the second alternative:

- Here a comparison of atomic size with that of the nucleon and of the π meson provides another hint. The size of the radial variable of the positronium's ground state is very nearly two times larger than that of the hydrogen atom ground state. However, for the hydrogen atom the classical meaning of this variable represents the Bohr atomic radius $r = 0.53$ Å. On the other hand, in

5

the case of the positronium it represents the diameter of the system. Thus, one concludes that the geometrical size of the positronium's ground state is roughly the same as that of the hydrogen atom.

Now let us examine the helium atom. Here the strength of the Coulomb attraction of the nucleus is twice as large as that of the hydrogen atom and the Pauli exclusion principle allows the two electrons to be in the lowest orbital. Thus, due to the stronger attraction of the nucleus, one finds that the radius of the ground state of the helium atom, $r = 0.31$ Å, is considerably smaller than that of the corresponding state of the hydrogen atom and of the positronium as well.

Let us turn to the corresponding hadronic data and examine the π meson and the proton. Here the π meson, which consists of a $\bar{q}q$ pair, corresponds to the positronium's ground state. In the case of the proton, we have *uud* quarks and, like in the case of the helium atom, the Pauli exclusion principle allows all these quarks to be in the lowest empty orbital. Thus, if the analogy with the atomic data mentioned above is relevant to this case then one expects that the size of the proton should be considerably smaller than that of the π meson. The experimental data is inconsistent with this expectation and the effective radius of the π meson is smaller than that of the proton $r_\pi \simeq 0.8\, r_p$ (see [16], pp. 539, 956).

These experimental data can be interpreted as follows. The proton (as well as all other baryons) has a core charged with monopole units *and* inner closed shells of quarks. The net monopole units of the core and the closed shells of quarks is $+3$ and it attracts the three valence quarks. The entire system is neutral with respect to magnetic monopole charge. Since the orbitals of the three valence quarks are orthogonal to those of the closed shells, the former are pushed outwards. This effect explains the rather large geometrical size of the

proton.

- An elementary structureless baryonic core is certainly simpler than a core containing closed shells of quarks. Thus, if one does not expect to find that Nature is too simple then he should be ready to realize that the baryonic core has closed shells of quarks.

Following these arguments, it is assumed here that

B. Baryons have a core which contains closed shells of quarks.

Clearly, the previous statement is a conjecture which is called below conjecture B. The following discussion shows how conjecture B can explain conjecture A.

As of today, the energies used in collisions which involve nucleons are analyzed by the interaction of the valence quarks and the associated $\bar{q}q$ pairs [15]. Now, according to conjecture B, the closed shells of quarks at the baryonic core make a quantum mechanical bound system. Thus, in cases of interactions with projectiles having a relatively low energy, the baryonic core behaves like an inert object. On the other hand, interactions that involve a high enough energy may excite quarks of the baryonic core. This scenario is analogous to the effect demonstrated by the Franck-Hertz experiment which is known for more than 90 years [17]. Thus, if the projectile has enough energy then quarks of the outer closed shell of the baryonic core begin to participate in the scattering process. The contribution of the new participants should increase the number of events.

Now, interactions of the projectiles with the three valence quarks (and with the additional $\bar{q}q$) explain the data of the lower Q^2 part of the HERA experiments whereas an excess of events is found for the higher Q^2 values [1-3]. According to conjecture A, this effect is significant. Thus, these reports indicate that the energies of the HERA facility are just above the threshold of the energy required for exciting quarks of the

7

closed baryonic shells. Evidently, due to phase space consideration, one expects that the excess of the number of events will be more significant for energies which are higher than those of the HERA facility.

4. Concluding Remarks

The theoretical analysis of the previous Section examines the conditions required for the excitation of the closed shells of quarks belonging to the baryonic core. Therefore, it is relevant to scattering processes that include baryons. For this reason, the data obtained from the electron-positron CERN's LEP collider cannot cast light on this problem. Similarly, the TEVATRON proton-antiproton collider cannot be used for this purpose. Indeed, by definition, in a particle-antiparticle collision, *all* constituents participate in the mutual annihilation. This property is independent of the collision energy. It follows that the quark analog of the Franck-Hertz effect cannot be seen in this case. Restricting the discussion to facilities that have been used till now, one finds that the HERA facility is the sole source of data required for a confirmation of conjecture B of Section 3. The HERA data provide us with no more than a hint indicating that for higher energies, the excess of the number of events may be significant [1-3]. This hint enables one to make conjecture A of Section 2.

The operation of the LHC will yield data of proton-proton collisions at very high energy. This experiment differs from those of HERA, where a proton collides with an electron (positron). However, if conjectures A, B hold then the analogue of the Franck-Hertz effect of the closed shells of quarks should be seen in the LHC data.

At the time when this work is finished the LHC has not yet begun to work. Hence, at present, it is still not known whether its data will support conjecture A. As explained in the previous Section, an experimental verification of conjecture A

supports conjecture B stating that the baryonic core contains closed shells of quarks. Three different kinds of explanation can be used for a case where the LHC data will not support this prediction: the regular charge-monopole theory is irrelevant to baryons; the baryonic core is an elementary structureless object which contains no closed shells of quarks; closed shells of the baryonic core exist but the LHC energy is lower than the threshold required for their excitation. Let us wait and see.

References:

* Email: elicomay@post.tau.ac.il

  Internet site: http://www.tau.ac.il/∼elicomay

[1] C. Adloff et al. *Z. Phys. C* **74** (1997) 191.

[2] J. Breitweg et al. *Z. Phys. C* **74** (1997) 207.

[3] A. Wagner *Tr. J. of Physics* **22** (1998) 525.

[4] D. M. South hep-ex/0605119

[5] C. Diaconu hep-ex/0610041

[6] E. Comay *Nuovo Cimento B* **80** (1984) 159.

[7] E. Comay *Nuovo Cimento B* **110** (1995) 1347.

[8] E. Comay *A Regular Theory of Magnetic Monopoles and Its Implications* in *Has the Last Word Been Said on Classical Electrodynamics?* ed. A. Chubykalo, V. Onoochin, A. Espinoza and R. Smirnov-Rueda (Rinton Press, Paramus, NJ, 2004).

[9] J. D. Bjorken and S.D. Drell, *Relativistic Quantum Fields* (McGraw-Hill, New York, 1965). (See pp. 1-22).

[10] T. H. Bauer, R. D. Spital, D. R. Yennie and F. M. Pipkin *Rev. Mod. Phys.* **50** (1978) 261.

[11] E. Comay *Apeiron* **13** (2006) 162.

[12] E. Comay *Lett. Nuovo Cimento* **43** (1985) 150.

[13] J. J. Aubert et al. (EMC) *Phys. Lett. B* **123** (1983) 275.

[14] A. Bodek et al. *Phys. Rev. Lett.* **50** (1983) 1431.

[15] D. H. Perkins *Introductions to High Energy Physics* (Addison-Wesley, Menlo Park, 1987) 3rd edn. (See pp. 275-283)

[16] W. -M. Yao et al. *J. Phys. G* **33** (2006) 1.

[17] A. Messiah *Quantum Mechanics* (North Holland, Amsterdam, 1961). (See p. 24).