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Can Nucleon Tell Where the Couplings Run?

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In the world of particles neutron and proton play a very special role being the main building blocks of matter. In some sense they are very similar in other - very different. They are similar because they are just different members of one isospin multiplet - nucleon and their masses are very close: the difference of masses is only about 0.1% of the mass, this is not observed for other baryons. And they are really very different: one is a charged particle, another one has no charge; one is stable, another one is not and so on. The new era of quarks introduced by Zweig and Gell-Mann announced that their quark contents are uud and udd and made the situation really intriguing. It looks like we should just compare the observables for neutron and proton one by one and this will give us all? But we have three quarks and only two particles. The idea proposed by Ida and Kobayashi [1] and Lingenfeld and Tassie [2] that nucleon is composed of quark and a diquark gave a balance: two particles and two constituents. Now, the question is: if to make comparison, step by step, of the properties of nucleons exploiting the fact that their masses are very close, and trying to use only the well fixed observables, what one can gain from this comparison? One attempt to do this was described in Ref.3. If to assume that magnetic moment of a nucleon can be expressed as the sum of Dirac magnetic moments of different quarks

$$\mathbf{m} = m_N.\mathbf{S}e_i g_i \mathbf{J}_i \quad (1)$$

here e_i, g_i and $\mathbf{J}_i$ are the charge, factor of Lande and moment of a constituent quark, m_N - is a nuclear magneton, then one can write the system of two equations: for magnetic moments of neutron and proton as different members of one isospin multiplet. The expression (1) assumes that the only representative mass parameter here is a mass of a nucleon which determines the overall scale. This supposition is quite natural for confined quarks.

So if to take into account that diquark can exist as a pair of like quarks and as a pair of different quarks two systems of equations can be written:

Case I: n = u + dd p = d + uu

$$\begin{cases} \frac{2}{3}g_1J_1 - \frac{2}{3}g_2J_2 = -1.913 \\ -\frac{1}{3}g_1J_1 + \frac{4}{3}g_2J_2 = 2.793 \end{cases}$$

From here it follows that: g_1J_1 = -1.033 and g_2J_2 =1.836

The fact that g_1J_1 turned out to be very close to 1 means that the single quark acts as elementary particle placed at the center of nucleon, some extra of 0.033 may be assumed here as a correction similar to the Schwinger correction to magnetic moment of electron.

Case II. The similar equations can be written for the case when diquark **ud** is in a state $^3S_1$, only here g_1J_1 is the value assigned to the single quarks, constituents of a diquark **ud**:

n = ud + d p = ud + u

$$\begin{cases} \frac{1}{3}g_1J_1 - \frac{1}{3}g_2J_2 = -1.913 \\ \frac{1}{3}g_1J_1 + \frac{2}{3}g_2J_2 = 2.793 \end{cases}$$

To satisfy this system one should take: g_1J_1 = -1.033 and g_2J_2 =4.7. The fact that g_1J_1 turned out to be close to 1 (with the same correction) agrees perfectly with the assumption $^3S_1$. Generally we have two more states in this case: one with a spin of a peripheral quark up, and another one - with a spin down.

The argument in favor that the model presented here is realistic is that one finds agreement with the measured magnetic moments of both nucleons if quarks at the center of nucleon act as elementary particles, this is observed for all three states. Qualitatively this conforms the parton model of the nucleon and *x*-scaling behavior in deep-inelastic lepton scattering. A notable thing is also that if to consider a center of nucleon as the place of the highest priority, the couple of mixed quarks is ?stronger? then a single quark which is ?stronger? then a couple of like quarks. This explains why there is no place for any symmetrization in this scheme. Figure 1 of Ref.1 illustrates these states. The question why these states can be the stationary states is discussed in Ref. 4. Of course the arguments presented here are very speculative but if these states are real and will be found [5,6], this can be important in view of their possible application in practice.

Another question: the correction factor of 0.033 obtained here, does it contain some significant piece of information? It appears to be very similar to the Schwinger correction which is known to be a+o(a), here $a=e^2/hc$. The wondrous thing is that this correction 0.033 is very close by magnitude to the universal coupling, i.e. the value where all the couplings unite around $a^{-1}=30$. Certainly, we have no reasons to claim this, it is just our fantasy based on a free comparison of different values. But what will happen if the value where all the couplings unite is changed, will it not produce the change in the observables of a nucleon? This turnover probably does not look like a great surprise because the undisturbed nucleon is a stationary system which should be described by fixed coupling. By contrast the scattering on quarks is a dynamic process having a certain scale, hence it should be described by running coupling taken at this scale. The case of $a^{-1}=30$ corresponds to nearly constant value of a_2 what generally is not excluded because it is expected for example in some of the ?realistic? string models [7].

References.

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