Theory of Nucleonic-Sea Asymmetry

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Abstract: Here, applying the atom-like structure of baryons, we described the down to up antiquark asymmetry of the nucleonic sea which depends on the momentum fraction i.e. the fraction of a proton's momentum that the sea antiquarks carry. The obtained theoretical results are consistent with the E866/NuSea-Experiment data. We should modify the internal structure of nucleons and the strong interactions.

1. Introduction

In the NuSea Experiment [1] there was measured the asymmetry of the nucleonic sea. Experimentalists measured the ratio of the number of the down-antiquarks ($\bar{d}$) to the number of the up-antiquarks ($\bar{u}$) as the function of the momentum fractions x_R i.e. the fraction of a proton's momentum that the sea antiquarks carry. For the interval of x_R in approximation (0, 0.30), they obtained an excess of $\bar{d}$ quarks relative to $\bar{u}$ quarks. Moreover, they obtained that the ratio $\bar{d}/\bar{u}$ first increases and then decreases. It suggests that we do not understand wholly the internal structure of proton and the strong interactions. The gluon splitting are the symmetrical processes so they should generate nearly equal number of anti-down and anti-up quarks. There is the asymmetric Drell-Yan process associated with production of the virtual pions but it does not explain completely the asymmetry.

The E-906/SeaQuest experiment is an extended version of the NuSea Experiment (E866). It extends previous down to up antiquark measurements to larger Bjorken-x_R.

The d-bar/u-bar asymmetry and the origin of the nucleon sea are described in following papers [2], [3].

Here, we present the theory of the $\bar{d}/\bar{u}$ asymmetry within the atom-like structure of baryons described within the lacking part of ultimate theory i.e. the Scale-Symmetric Theory (SST) [4].

The General Relativity leads to the non-gravitating Higgs field composed of tachyons [4A]. On the other hand, the Scale-Symmetric Theory shows that the succeeding phase transitions of such Higgs field lead to the different scales of sizes [4A]. Due to the saturation of interactions via the Higgs field and due to the law of conservation of the half-integral spin that is obligatory for all scales, there consequently appear the superluminal binary systems of closed strings (entanglons) responsible for the quantum entanglement, stable neutrinos and luminal neutrino-antineutrino pairs which are the components of the luminal Einstein spacetime (it is the Planck scale), cores of baryons, and the cosmic structures (protoworlds) that evolution leads to the dark matter, dark energy and expanding universes [4A], [4B]. The non-gravitating tachyons have infinitesimal spin so all listed structures have internal helicity (helicities) which distinguishes particles from their antiparticles [4A].

During the inflation, the liquid-like inflation field (the non-gravitating superluminal Higgs field) transformed partially into the luminal Einstein spacetime [4A].

Due to the symmetrical decays of bosons on the equator of the core of baryons, there appears the atom-like structure of baryons described by the Titius-Bode orbits for the nuclear strong interactions [4A].

The mass of the charged core in a nucleon is $H^+ = 727.440$ MeV whereas of the neutral core is $H^o = 724.777$ [4A]. The relativistic mass of the charged pion in the $d = 1$ state is $W^{+,-} = 215.760$ MeV whereas of the neutral pion is $W^o = 208.643$ MeV [4A]. There is probability $y = 0.50839$ that proton is in state H^+W^o and probability $1 - y$ that is in state H^oW^+ [4A]. There is probability $x = 0.62255$ that neutron is in state H^+W^- and probability $1 - x$ that is in state H^oW^o [4A]. The neutral pion is the binary system of loops composed of gluons. Such pions are produced inside the core of nucleons [4A]. The atom-like model of nucleons leads to their masses, magnetic moments, mean square charges and spins consistent with experimental data [4A].

2. Calculations

In a nucleon there are very quickly simultaneous transitions from the charged to neutral and from neutral to charged states of the H and W objects. It is due to the exchanged elementary electric charge. The probabilities cause that mean charges of the H and W are fractional. It gives the illusion that the quarks carry the fractional electric charges [4A], [4D]. Due to such transitions there are produced the quark-antiquark pairs.

The $u\bar{u}$ pairs appear due to following transitions characteristic for interacting proton

$$(W^{+,-} - W^o) - (H^+ - H^o) = (H^o + W^+) - (H^+ + W^o) = u\bar{u} = 2 \cdot 2.23 \text{ MeV}. \quad (1)$$

The $d\bar{d}$ pairs appear due to following transitions characteristic for interacting neutron

$$(W^{+,-} - W^o) + (H^+ - H^o) = (H^+ + W^-) - (H^o + W^o) = d\bar{d} = 2 \cdot 4.89 \text{ MeV}. \quad (2)$$

Masses of all quarks are calculated here [4A].

How we should reformulate the picture of the interaction of the atom-like structure of a proton with the sea of the quark-antiquark pairs in the target?

The rate of the production of the virtual quark-antiquark pairs depends on frequency of emission of the virtual pions by the charged core of baryons. Since it looks the same for proton and neutron so inside deuteron there is the same number of the virtual $u\bar{u}$ and $d\bar{d}$ pairs. In the atomic nuclei containing more neutrons than protons, the ratio $\bar{d}/\bar{u}$ for the nucleonic sea is greater than 1 and for the most massive nuclei is approximately 1.56. But what phenomena take place when a proton collides with, for example, a deuterium target?

From the energy of collisions of the H and W in a proton in the beam with the H and W in the target, there are produced the real neutral pions by the core and there are produced the relativistic e^+e^- pairs in the $d = 0$ state [4A]. Then, there appear the asymmetrical processes:

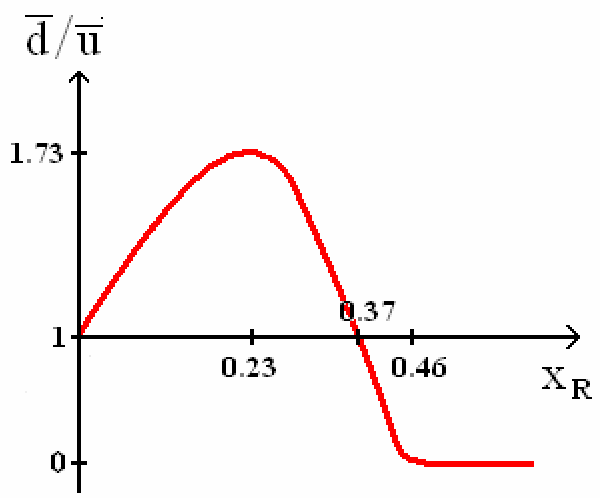
the relativistic electrons and neutral pions transform into the negative charged W^- and force out the neutral W^o from proton whereas the relativistic positrons and neutral H^o transform into the positively charged H^+ in the protons (due to the internal structure of protons, the other processes are impossible). These two processes cause that protons behave as neutrons i.e. instead the $u\bar{u}$ pairs there appear the $d\bar{d}$ pairs. Now there can appear the Drell-Yan process that leads to the $\mu^+\mu^-$.

The replacements of the W^o for the W^+ cause that nucleons behave as protons and number of produced real additional $u\bar{u}$ pairs is proportional to the ratio of probabilities of the initial state H^oW^+, i.e. $1 - y$, and the final state H^+W^o, i.e. y. The replacements of the W^o for the W^- cause that nucleons behave as neutrons and number of produced real additional $d\bar{d}$ pairs is proportional to the ratio of probabilities of the initial state H^+W^-, i.e. x, and the final state H^oW^o, i.e. $1 - x$.

The maximum value of the ratio $\bar{d}/\bar{u}$ is for the momentum fraction $x_R = W^- / M_{proton} \approx$ 0.23:

$$\bar{d} / \bar{u} = [x / (1 - x)] / [(1 - y) / y] \approx 1.73. \qquad (3)$$

For a momentum fraction greater than $x_R > 0.23$, there appears more and more the W^-W^+ annihilations and for $x_R = (W^- + W^+) / M_{proton} \approx 0.46$ all W^-W^+ pairs annihilate i.e. the ratio of the anti-down to anti-up is equal to zero.



The proton's excess of anti-down quarks relative to anti-up quarks in collisions of proton beam with neutron-proton pairs or alpha particles in atomic nuclei

3. Summary

Here, within the atom-like structure of baryons, we described the down to up antiquark asymmetry of the nucleonic sea which depends on the momentum fraction i.e. the fraction of a proton's momentum that the sea antiquarks carry.

The $\bar{d}/\bar{u}$ asymmetry follows from the atom-like structure of baryons. The transitions between the two different states of protons and neutrons cause that there appear the quark-antiquark pairs i.e. the nucleonic sea. The increase in the ratio $\bar{d}/\bar{u}$ for the interval $(0, 0.23)$ follows from production of the e^+e^- pairs and, next, the asymmetric processes. This changes the probabilities of the two states of proton in such a way that the maximum value for the ratio $\bar{d}/\bar{u}$ is 1.73 and is for the Bjorken-x_R equal to the ratio of the masses of the charged W^- and proton: $x_R \approx 0.23$. For momentum fraction greater than $x_R > 0.23$ there appear more and more annihilations of the W^+W^- pairs and for $x > 0.46$ such annihilations dominate so there once more are restored the probabilities characteristic for the free protons i.e. the ratio $\bar{d}/\bar{u}$ is equal to zero.

Within presented here model, we answered following questions: why there is the asymmetry of the nucleonic sea, and why does the ratio $\bar{d}/\bar{u}$ first increase and then decrease to zero? The obtained results are consistent with experimental data and it suggests that the Scale-Symmetric Theory, which leads to the atom-like structure of baryons, is correct. We should modify the structure of baryons and the description of the strong interactions.

References

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