# Properties of Nucleon in Nuclear Matter

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## Introduction

The modification in the internal structure of nucleon in nuclear matter was has been predicted by EMC[1] in early 1980's. The experiment indicates the swelling of nucleon in nuclear matter and suggested a substantial change of the other properties of nucleon in nuclear medium. Nucleon (proton and neutron) in the conventional quark model is color singlet composed of three quark (uud and udd respectively). Recent experimental data[2] suggests that proton has a substantial strange quark contribution to it's magnetic moment. This result triggered the idea to incorporate a strange quark contribution to the proton structure [3] and to describe it as a five quark system like uudss(bar).

In this current article the effect of the nuclear medium on nuclear properties like swelling, incompressibility, roper resonance of nucleon have been investigated. The contribution of the strange sea quark have been incorporated in the structure of proton considering proton as a five quark system with uudss-bar whereas neutron have been considered as a three quark system as in the conventional quark model. The diquark picture of three quark and five quark syatem allow us to consider proton as $[ud]_0[us]_0$s-bar and neutron as $[ud]_0$d-bar. The quasi particle model of diquark have been employed to estimate the diquark effective mass. The results that are obtained are in good agreement with the available data.

## Quasi Particle Model of Diquark

We have suggested a quasi particle model [4 ] for diquark where two quark are assumed to be correlated to form a low energy configuration forming a diqaurk and behaving like a quasi particle in an analogy with the electron behaving as a quasi particle in crystal lattice and the motion of the quasi particle get modified by the interactions within the system. It have been assumed that diquark is a fundamental entity behaving like independent body which is under two types of forces. One is short-range interaction (due to Background meson cloud) and other is long-range interaction (external force of harmonic oscillator type) of confinement type. Therefore the total interaction potential ($V_{ij}$) can be expressed as, $V_{ij} = -\alpha/r + ar^2$ , where the symbol have the same meaning.The effective mass of diquark($m_D$) in the background of the quark field gets modified in the quasi particle approximation as it happens in the crystal lattice[5]. The constituent quark mass($m_q$) and the diquark mass ratio is obtained as,

$\{(m_q + m_q)/ m_D\} = 1 + \{\alpha/(2ar^3)\}$ …………….(1)

where 'r' is the radius of the diquark.

## Nucleon in Medium

In the context of flux tube model considering nucleon in diquark-quark system Mathieu et al.[6] has suggested the Hamiltonian for an isolated nucleon ,$H=[P^2/2\mu + \sigma r - (4\alpha_s/3r)]$ where '$\mu$','p','$\sigma$','$\alpha_s$' are the reduced mass, relative momentum, string tension and strong coupling constant of the system respectively. In presence of nuclear matter the Hamiltonian changes due to the effect of neighboring nucleons. When the constituent of the two nucleons are very close to each other then the flux tubes can be redistributed among the constituents to yield a topology with the lowering in total length for the flux tube. Considering the effect of perturbing nucleon the linear potential and the gluon exchange term modified to $V_{Leff}$, $V_{Ceff}$ respectively including the density part in expression of potential [6] the modified Hamiltonian can be written as:

$\langle H\rangle = \langle P^2/2\mu\rangle + \langle V(r,\rho)\rangle$ ………………..(2)

Where, $\mu$ is the reduced mass of proton (which is considered as diquark-diquark-antiquark configuration and neutron (which is considered as diquark-quark configuration) and $\langle V(r,\rho)\rangle$ is the average of the total effective potential($V_{Leff}$+ $V_{Ceff}$) .

$\langle V\rangle = \int (V_{Leff} + V_{Ceff}) |\Psi(r)|^2 d^3r$ ……………(3)

In the context of statistical model[7] we have suggested a wave function:

$$|\Psi(r)|^2=(315/64\pi\, r_0^{9/2})(r_0-r)^{3/2}\theta(r_0-r) \qquad \text{.......(4)}$$

Where $r_0$ is the radius of the corresponding hadron and $\theta(r_0-r)$ is the step function.

Minimizing the Hamiltonian we have studied various properties of proton and neutron in nuclear matter.

## Results:

**Table-1:** Modification of the properties of nucleon in nuclear matter.

| Property | Our work | Others work |
|---|---|---|
| Swelling in medium at critical density | 18 % (proton) ; | 10-16%[8 ] (nucleon) |
| | 13 % (neutron) | |
| Critical density of nuclear matter at which the nucleon ceases to exist | $4.17\rho_0$ (proton) ; $\rho_0$ = normal nuclear density | $4.5\ \rho_0$ [6 ] $8\ \rho_0$ [9 ] (nucleon) |
| | $4.69\rho_0$ (neutron) | |
| Roper resonance at normal nuclear density | 699MeV (proton) | 300-600 MeV[10] |
| | 678MeV (neutron) | |
| Incompressibility | K=2.601GeV (at $\rho_{=0}$); ΔK=-0.156 GeV(from free to normal ρ) (proton) | K=1.2 GeV[11] ΔK=0.041 GeV [6] (nucleon) |
| | K=2.5GeV(at $\rho_{=0}$); ΔK=-0.132 GeV(from free to normal ρ) (neutron) | |

## Discussions

In this present work we have investigated the modification in the properties of nucleons in nuclear medium. Properties like swelling, incompressibility, roper resonance have been studied considering proton and neutron as a five quark and three quark system respectively and the results have been shown in Table-1. The main aim of this work is to study the strange quark contribution to proton structure and as a whole the medium modification to the properties. It is interesting to see how the incorporation of the strange quark degrees of freedom to proton reproduce the properties of proton and can make differences of neutron-proton properties in medium. Result shows that the swelling of proton is greater than that of neutron in medium indicating the effect of medium is more pronounced in proton. The decrease in incompressibility of proton is more than that of neutron means neutron is more compressible than proton in medium. The medium density affects the virtual quark sea. It is challenging to reveal proton structure. However more investigation in this direction is needed.

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