Mass Modification Of π^0 And η Mesons By Their Mixing

Subhrajyoti Biswas

Abstract: We explore the possibility of further modification of the in-medium masses of π^0 and η mesons by their mixing in the asymmetric nuclear matter (ANM) where the unequal neutron-proton densities $(\rho_n \neq \rho_p)$ causes to mix the various isospin pure resonance states like π^0 and η mesons. The $\pi^0-\eta$ mixing amplitude has been calculated within the framework of one boson exchange model (OBEM) considering both the pseudoscalar (PS) and pseudovector (PV) $\pi^0(or\ \eta)$-nucleon interactions. The numerical estimation shows that the mixing reduces the in-medium mass of π^0 and increases the in-medium mass of η and the change in the mixing modified mass is about five times larger for PV interaction compared to the PS interaction at density 1.3 times higher than normal nuclear matter density and at asymmetry 0.2.

Keywords : asymmetric nuclear matter, charge symmetry breaking, mixing modified mass, renormalization

1 INTRODUCTION

The study of various symmetries and symmetry breaking effects is always an interesting topic for research in the area of nuclear physics. Such research is potentially important to understand the underlying physics of strong interactions. The charge symmetry is such a symmetry which is broken by small amount at the quark level and consequently it is also broken at the hadronic level [1],[2],[3]. Because of the up (u) and down (d) quarks mass difference $(m_d - m_u \neq 0)$ various neutral mesons like π^0, η etc. having the same spin and parity but different isospins can mix in vacuum [4],[5],[6]. At the hadronic level mixing of isospin pure resonance states such as $\pi^0-\eta$ mixing in vacuum can take place due to neutron (n) and proton (p) mass difference [7], [8],[9],[10]. Apart from this, there is another class of mixing which is also an effect of symmetry breaking but the origin is different from the usual mechanism as discussed above. This type of mixing stems in the medium if the total number of neutrons is different from that of protons $(N \neq Z)$ i.e. asymmetric nuclear matter (ANM). In nuclear matter, different mesons are emitted and absorbed by the neutron and proton Fermi spheres. In symmetric nuclear matter (SNM) i.e. nuclear matter with N=Z their contributions cancel out if $M_n = M_p$ is considered. But such cancellation does not take place in asymmetric nuclear matter which gives rise to non vanishing mixing amplitude even if the neutron-proton masses are taken equal i.e. $M_n = M_p$. The possibility of such mixing in asymmetric nuclear matter was first studied in [11] and consequently similar investigations have been made in [12],[13] and in [14] the matter induced mixing was studied to incorporate the results of all models of meson properties in the medium. Most of the earlier calculations were performed to study the role of mixing on dilepton spectrum, pion form factor, etc [15],[16],[17] and later such matter induced mixing was used to construct the charge symmetry breaking (CSB) two body potential [18],[19],[20].

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There are several evidences which akin to be the CSB effects. Experimentally, it is observed in in the nn and pp scattering lengths at $^1S_0$ state [21],[22] and the binding energy differences in the mirror nuclei, which is known as the Okamoto-Nolen-Schifer anomaly [23],[24]. If the charge symmetry was exact, then the nn and pp scattering lengths and the binding energies of mirror nuclei would have been equal. In addition, difference of neutron-proton form factors, hadronic correction to $g-2$, etc. are also the manifestation of the CSB. The mixing of various mesons in ANM such as $\rho^0-\omega$ mixing affects the equation of state (EOS) of neutron stars [25] which plays an important role for determining the symmetry energy. In addition, since the mixing amplitude depends on the nuclear density ρ_B and the asymmetry parameter $\alpha = (\rho_n - \rho_p)/\rho_B$ introduce additional changes in the EOS of neutron star which affect the mass-radius relationship [25]. The main motivation of the present work is to investigate the effect of $\pi^0-\eta$ mixing on the propagation of π^0 and η mesons in ANM, particularly the role of mixing to modify the in-medium masses of π^0 and η mesons. Most of the density dependent $\pi^0-\eta$ mixing amplitudes were used to construct the CSB class - III potential in the medium [18],[19],[20]. To explore the role of mixing on mass modification we focus on the hadronic sector. The density dependent self-energies and mixing amplitudes are calculated within the framework of one boson exchange model (OBEM) assuming that the self-energies and the mixing amplitudes are generated by the nucleon-antinucleon loops. The paper is organized into four sections. In section 2 we discuss the formalism and in section 3 we present numerical results.

2 FORMALISM

The properties of π and η mesons are studied employing both the pseudoscalar (PS) and pseudovector (PV) pion (or eta meson)-nucleon interactions which are described by the following Lagrangians [26]:

$$L^{ps}_{NNa} = -ig_a \overline{\Psi}_N \gamma_5 \tau.\Phi_a \Psi_N \tag{1a}$$

$$L^{pv}_{NNa} = -\frac{g_a}{2M_N} \overline{\Psi}_N \gamma_5 \gamma^\mu \partial_\mu \tau.\Phi_a \Psi_N \tag{1b}$$

where, Ψ and Φ_a represent the nucleon and meson fields, respectively. N represents nucleon index i.e. N = n for neutron and p for proton, the meson index is indicated by a = π, η and the bare mass of the nucleon is denoted by M_N.

It is to be mentioned here that B. D. Serot [26] was the first who extended the Walecka model by including pion and rho meson to describe the properties of nuclear matter at higher density. In case of PS coupling of pion with nucleons generate small s-wave scattering length which is consistent with the experimental results. However, it cannot account the pion-nucleon phenomenology. To overcome this problem one should invoke PV coupling for pion-nucleon interaction [26]. But it makes the theory nonrenormalizable [26].

2.1 Self-energies and mixing amplitudes

To study the effect of medium on the π^0 and η mesons propagation and modification of their masses by the mixing we calculate the self-energies and mixing amplitudes at one loop order using the integral [27]:

$$\Pi_{ab}^{N}(q^2) = -i \int \frac{d^4k}{(2\pi)^4} Tr\left[\Gamma_a(q)\tilde{G}_N(k)\Gamma_b(-q)\,\tilde{G}_N(k+q)\right] \quad (2)$$

The meson-nucleon vertex factors are for PS interaction, $\Gamma_a^{ps}(q) = -ig_a$ and $\Gamma_a^{pv}(q) = -i\, g_a\gamma^\mu q_\mu/2M_N$ for PV interaction. g_a indicates the meson-nucleon coupling constant and q = $(q_0, \boldsymbol{q})$ is the four momentum of the mesons.

In Fig. (1) we present the generic diagram for the meson self-energy. Note that in Eq. (2), b also indicates the meson index similar to a, i.e. b = π^0, η and $\tilde{G}_N(k)$ represents the nucleon propagator in the nuclear medium which consists of the Dirac sea contribution $G_v(k)$ and the Fermi sea contribution $G_m(k)$ [28]. They are called the vacuum part and the medium part, respectively.

$$G_v(k) = \frac{\gamma^\mu k_\mu + M_N^*}{k^2 - M_N^{*2} + i\epsilon} \quad (3a)$$

$$G_m(k) = \frac{i\pi}{E_N^*}\left(\gamma^\mu k_\mu + M_N^*\right)\delta(k_0 - E_N^*)\theta(k_N - |\boldsymbol{k}|) \quad (3b)$$

The four momentum and energy of the nucleon are denoted by $k = (k_0, \boldsymbol{k})$ and $E_N^* = \sqrt{M_N^{*2} + \boldsymbol{k}^2}$ where M_N^* is the effective nucleon mass in the nuclear medium. In Eq. (3b) δ function puts the nucleon on-shell and the θ function which is known as Pauli blocking, imposes the condition on the propagation of the nucleon such that the three momentum of the nucleon must be less than the Fermi momentum k_N.

In this work we consider only the effect of neutral scalar field on the nucleon mass [29],[30],[31]:

$$M_N^* = M_N - \frac{g_\sigma^2}{m_\sigma^2}(\rho_p^s + \rho_n^s) \quad (4)$$

while we neglect the energy shift due to vector field as its contribution is small compared to the scalar field [28]. The effective nucleon mass is calculated by solving Eq. (4) self-consistently. Here ρ_N^s denotes the scalar density and g_σ and m_σ represent the mass and coupling constant of scalar meson σ. The scalar density is given by [28],

$$\rho_N^s = \frac{M_N^*}{2\pi^2}\left[E_N^* k_N - M_N^{*2}\ln\left(\frac{E_N^* + k_N}{M_N^*}\right)\right] \quad (5)$$

Note that integral Eq. (2) contains four combinations of $\boldsymbol{\Gamma_a}$, $\boldsymbol{\Gamma_b}$, $\boldsymbol{G_v}$ and $\boldsymbol{G_m}$. The combination $\boldsymbol{\Gamma_a G_v \Gamma_b G_v}$ is called vacuum part and $\boldsymbol{\Gamma_a G_v \Gamma_b G_m} + \boldsymbol{\Gamma_a G_m \Gamma_b G_v}$ is called the medium part. We neglect the term $\boldsymbol{\Gamma_a G_m \Gamma_b G_m}$ as our calculation is restricted to the low-energy excitations. This term is relevant at high-energy excitations where a meson can decays into nucleon-antinucleon pairs as it contains two delta functions.

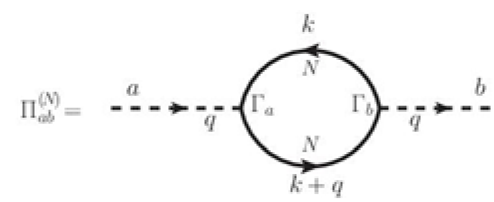

Fig.1. The dashed and solid lines represent the meson and nucleon propagators in the medium.

The self-energy is the sum of p-loop and n-loop contributions:

$$\boldsymbol{\Pi_{ab}(q^2) = \Pi_{ab}^{p}(q^2) + \Pi_{ab}^{n}(q^2)} \quad (6a)$$

while the mixing amplitude is the difference between the p-loop and n-loop contributions:

$$\Pi_{ab}(q^2) = \Pi_{ab}^{p}(q^2) - \Pi_{ab}^{n}(q^2) \quad (6b)$$

The negative sign between the p-loop and n-loop in the mixing amplitude, Eq. (6b) originates from coupling of π^0 meson to the neutron. Both π^0 and η mesons couple to proton with same sign while they couple with neutron with the opposite sign, as shown in Fig. 2. Note that the total self-energy and the mixing amplitude is sum of vacuum and medium contributions:

$$\Pi_{ab}^{N}(q^2) = \Pi_{ab,v}^{N}(q^2) + \Pi_{ab,m}^{N}(q^2) \quad (7)$$

2.1.1 PS interaction

We first consider the PS interaction to calculate the self-energy and mixing amplitude. The vacuum contribution of the nucleon loop (i.e. either proton or neutron loop) reads

$$\Pi_{ab,v}^{N} = 4ig_a g_b \int \frac{d^4k}{(2\pi)^4}\left[\frac{M_N^{*2} - k.(k+q)}{(k^2 - M_N^{*2})((k+q)^2 - M_N^{*2})}\right] \quad (8)$$

The above self-energy integral is found quadratically divergent and it needs to be regularized to isolate the divergent part. There are various techniques of regularization [27]. Here we adopt the dimensional regularization for isolating the divergent part. After regularization the vacuum contribution is given by

$$\Pi^N_{ab,v}(q^2) = \left(\frac{g_a}{2\pi}\right)\left(\frac{g_b}{2\pi}\right)\frac{q^2}{2}\left[-\frac{7}{3}-\frac{1}{\epsilon}+\gamma_E-\ln(4\pi\mu^2) + \ln(M_N^*)+2\frac{\sqrt{4M_N^{*2}-q^2}}{q}\tan^{-1}\left(\frac{q}{\sqrt{4M_N^{*2}-q^2}}\right)\right] \quad (9)$$

where μ and γ_E denote an arbitrary scaling parameter and the Euler-Mascheroni constant. From Eq. (9) it is clear that $\epsilon = \frac{4-D}{2} \to \infty$ as the dimension D=4. It is to be mentioned here that PS interaction is renormalizable; that means one can remove the divergences completely by adding appropriate counter terms to the interaction Lagrangian. The detail of this calculation can be found in [28]. After the inclusion of the appropriate counter terms we obtain the finite vacuum contribution. This renormalized vacuum part is then expanded in terms of the dimensionless quantity $\frac{q^2}{M_N^2}$ keeping terms up to order $\frac{q^2}{M_N^2}$ and making suitable approximation one can write

$$\Pi_{aa,v}(q^2) \approx A_{0a} + A_{1a}\, q^2 \quad . \quad (10)$$

where,

$$A_{0a} = \left(\frac{g_a}{2\pi}\right)^2\left[3(M_p^{*2}-2M_p^2)+2M_p^{*2}\ln\left(\frac{M_p}{M_p^*}\right) + 3(M_n^{*2}-2M_n^2)+2M_n^{*2}\ln\left(\frac{M_n}{M_n^*}\right)\right],$$

$$A_{1a} = 3\left(\frac{g_a}{2\pi}\right)^2(M_n^2+M_p^2)/m_a^2 \quad (10)$$

The mixing amplitude can be obtained from Eq. (9) by subtracting n-loop contribution from the p-loop contribution. Note that this subtraction removes completely the divergent terms and yields finite vacuum mixing amplitude.

$$\Pi_{\pi\eta,v}(q^2) = A_{1\pi\eta}q^2 \quad (11)$$

where, $A_{1\pi\,\eta} = \left(\frac{g_\pi}{2\pi}\right)\left(\frac{g_\eta}{2\pi}\right)\ln\left(\frac{M_p^*}{M_n^*}\right)$ (12)

Now we proceed to calculate the medium contribution of the nucleon loop. Using Eq. (2) and performing the integration over k_0, we can write

$$\Pi^N_{ab,m}(q^2) = -2g_a g_b\int\frac{d^3k}{(2\pi)^3E_N^*}\left[\frac{4(k.q)^2}{q^4-4(k.q)^2}\right]\theta(k_N-|\boldsymbol{k}|) \quad . \quad (13)$$

Evaluating above integral medium part of the self-energy can be written as

$$\Pi_{aa,m}(q^2) \approx B_{0a} + B_{1a}(q_0^2-2\boldsymbol{q}^2) + B_{2a}(q_0^2-\boldsymbol{q}^2) \quad (14)$$

where,

$$B_{0a} = 2\left(\frac{g_a}{2\pi}\right)^2\left[(k_pE_p^*+k_nE_n^*) - \frac{1}{2}\left\{M_p^{*2}\ln\left(\frac{E_p^*+k_p}{E_p^*-k_p}\right)+M_n^{*2}\ln\left(\frac{E_n^*+k_n}{E_n^*-k_n}\right)\right\}\right],$$

$$B_{1a} = \left(\frac{g_a}{2\pi}\right)^2\left[\frac{1}{3}\left(\frac{k_p^3}{E_p^{*3}}+\frac{k_n^3}{E_n^{*3}}\right)\right],$$

$$B_{2a} = \left(\frac{g_a}{2\pi}\right)^2\left[\frac{1}{5}\left(\frac{k_p^5}{E_p^{*5}}+\frac{k_n^5}{E_n^{*5}}\right)\right]$$

(15)

Now we can obtain the medium part of the mixing amplitude from Eq. (13) which reads

$$\Pi_{\pi\eta,m}(q^2) \approx B_{0\pi\eta} + B_{1\pi\eta}(q_0^2-2\boldsymbol{q}^2) + B_{2\pi\eta}(q_0^2-\boldsymbol{q}^2) \quad (16)$$

where,

$$B_{0\pi\eta} = 2\left(\frac{g_\pi}{2\pi}\right)\left(\frac{g_\eta}{2\pi}\right)\left[(k_pE_p^*-k_nE_n^*) - \frac{1}{2}\left\{M_p^{*2}\ln\left(\frac{E_p^*+k_p}{E_p^*-k_p}\right)-M_n^{*2}\ln\left(\frac{E_n^*+k_n}{E_n^*-k_n}\right)\right\}\right],$$

$$B_{1\pi\eta} = \left(\frac{g_\pi}{2\pi}\right)\left(\frac{g_\eta}{2\pi}\right)\left[\frac{1}{3}\left(\frac{k_p^3}{E_p^{*3}}-\frac{k_n^3}{E_n^{*3}}\right)\right],$$

$$B_{2\pi\eta} = \left(\frac{g_\pi}{2\pi}\right)\left(\frac{g_\eta}{2\pi}\right)\left[\frac{1}{5}\left(\frac{k_p^5}{E_p^{*5}}-\frac{k_n^5}{E_n^{*5}}\right)\right] \quad (17)$$

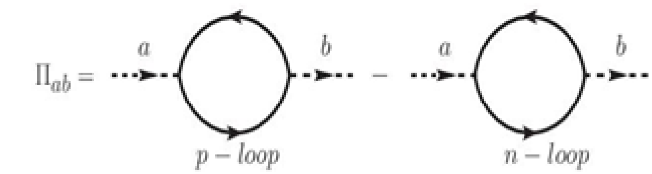

Fig. 2. Mixing amplitude (one loop order)

2.1.2 PV interaction

In this section we calculate the self-energy and mixing amplitude considering the PV interaction. In this case the vacuum contribution of the nucleon loop is

$$\Pi^N_{ab,v}(q^2) = 4i\left(\frac{g_a}{2M_N}\right)\left(\frac{g_b}{2M_N}\right)\int\frac{d^4k}{(2\pi)^4} \times\left[\frac{q^2\left(M_N^{*2}-k.(k+q)\right)-2(k.q)q.(k+q)}{(k^2-M_N^{*2})((k+q)^2-M_N^{*2})}\right] \quad (18)$$

This loop integral is also divergent and we invoke dimensional regularization to isolate the divergences like PS interaction.

$$\Pi^N_{ab,v}(q^2) = \frac{1}{2}\left(\frac{g_a}{2\pi}\right)\left(\frac{g_b}{2\pi}\right)q^2\left(\frac{M_N^*}{M_N}\right)^2\left[-2-\frac{1}{\epsilon}+\gamma_E+\ln(4\pi\mu^2) + 2\ln(M_N^*)+2\frac{\sqrt{4M_N^{*2}-q^2}}{q}\tan^{-1}\left(\frac{q}{\sqrt{4M_N^{*2}-q^2}}\right)\right]$$

(19)

Note that the divergence in Eq. (19) is proportional to the mass term. Because of the derivative term in the Lagrangian, Eq. (1b) the divergences for all orders cannot be removed by particular counter terms. This makes the PV interaction non-renormalizable. Here we use subtraction scheme to eliminate divergence. The finite vacuum part can be written as

$$\Pi_{aa,v}(q^2) \approx A'_{1a}q^2 \quad (20)$$

where,

$$A'_{1a} = \frac{1}{12}\left(\frac{g_a}{2\pi}\right)^2\left(\frac{m_a^2}{M_p^2} + \frac{m_a^2}{M_n^2}\right) \quad (21)$$

The value of the vacuum part of self-energy depends on the renormalization scheme. The vacuum part of the mixing amplitude reads

$$\Pi_{\pi\eta,v}(q^2) \approx A'_{1\pi\eta}q^2 \quad (22)$$

where, $$A'_{1\pi\eta} = \frac{1}{12}\left(\frac{g_\pi}{2\pi}\right)\left(\frac{g_\eta}{2\eta}\right)\left(\frac{m_a^2}{M_p^2} - \frac{m_a^2}{M_n^2}\right) \quad (23)$$

The medium contribution of the nucleon loop is given by

$$\Pi'_{ab,m}(q^2) = \left(\frac{g_a}{2M_N}\right)\left(\frac{g_b}{2M_N}\right)M_N^{*2}q^4 \int \frac{d^3k}{(2\pi)^3E_N^*}\left[\frac{\theta(k_N - |\boldsymbol{k}|)}{q^4 - 4(k.q)^2}\right] \quad (24)$$

This can be written as

$$\Pi'_{aa,m}(q^2) \approx B'_{1a}\,(q_0^2 - 2\boldsymbol{q}^2) + B'_{2a}(q_0^2 - \boldsymbol{q}^2) \quad (25)$$

where,

$$B'_{1a} = \left(\frac{g_a}{2\pi}\right)^2\left[\frac{1}{3}\left(\frac{M_p^{*2}\,k_p^3}{M_p^2E_p^{*3}} + \frac{M_n^{*2}\,k_n^3}{M_n^2E_n^{*3}}\right)\right]$$

$$B'_{2a} = \left(\frac{g_a}{2\pi}\right)^2\left[\frac{1}{3}\left(\frac{M_p^{*2}\,k_p^5}{M_p^2E_p^{*5}} + \frac{M_n^{*2}\,k_n^5}{M_n^2E_n^{*5}}\right)\right] \quad (26)$$

The mixing amplitude is given by

$$\Pi'_{\pi\eta,m}(q^2) \approx B'_{1\pi\eta}\,(q_0^2 - 2\boldsymbol{q}^2) + B'_{2\pi\eta}(q_0^2 - \boldsymbol{q}^2) \quad (27)$$

where, $$B'_{1\pi\eta} = \left(\frac{g_\pi}{2\pi}\right)\left(\frac{g_\eta}{2\pi}\right)\left[\frac{1}{3}\left(\frac{M_p^{*2}\,k_p^3}{M_p^2E_p^{*3}} - \frac{M_n^{*2}\,k_n^3}{M_n^2E_n^{*3}}\right)\right]$$

$$B'_{2\pi\eta} = \left(\frac{g_\pi}{2\pi}\right)\left(\frac{g_\eta}{2\pi}\right)\left[\frac{1}{3}\left(\frac{M_p^{*2}\,k_p^5}{M_p^2E_p^{*5}} - \frac{M_n^{*2}\,k_n^5}{M_n^2E_n^{*5}}\right)\right] \quad (28)$$

2.2 Mixing effect on Mass

In this section we study the effect of mixing on the in-medium masses of π^0 and η mesons. Note that the meson propagators get coupled because of mixing. Such coupled propagators can be represented by 2×2 matrix:

$$M(q_0^2, \boldsymbol{q}^2) = \begin{pmatrix} 1 - \frac{\Pi_{\pi\pi}}{q^2 - m_\pi^2} & \frac{\Pi_{\pi\eta}}{q^2 - m_\pi^2} \\ \frac{\Pi_{\pi\eta}}{q^2 - m_\eta^2} & 1 - \frac{\Pi_{\eta\eta}}{q^2 - m_\eta^2} \end{pmatrix} \quad (29)$$

To obtain the effect of mixing on the in-medium masses of the mesons one needs to solve the equation

$$\det(M(q_0^2, \boldsymbol{q}^2 = 0)) = 0 \quad (30)$$

this on simplification reads

$$(C_\pi q_0^2 - D_\pi)(C_\eta q_0^2 - D_\eta) - (C_{\pi\eta}q_0^2 - D_{\pi\eta})^{\,2} = 0 \quad (31)$$

where the constants C and D are listed in the table given below:

	PS	PV
C_a	$1-(A_{1a}+B_{1a}+B_{2a})$	$1-(A'_{1a} + B'_{1a} + B'_{2a})$
D_a	$m^2_a + A_{0a} + B_{0a}$	m^2_a
C_{ab}	$A_{1ab}+B_{1ab}+B_{2ab}$	$A'_{1ab} + B'_{1ab} + B'_{2ab}$
D_{ab}	B_{0ab}	0

Now solving Eq. (31) we obtain the mixing modified masses of π^0 and η mesons which are given by

$$\widetilde{m}_\pi \approx m_\pi^* - \frac{\Delta_{\pi\eta}}{2m_\pi^*} \quad (32a)$$

and $$\widetilde{m}_\eta \approx m_\eta^* + \frac{\Delta_{\pi\eta}}{2m_\eta^*} \quad (32b)$$

where $$\Delta_{\pi\eta} \approx \frac{m_\pi^{*2}m_\eta^{*2}C_{\pi\eta}^2 + (m_\pi^{*2} + m_\eta^{*2})\,C_{\pi\eta}D_{\pi\eta} + D_{\pi\eta}^2}{C_\pi C_\eta\,(m_\eta^{*2} - m_\pi^{*2})} \quad (33)$$

In Eq. (32), m_π^* and m_η^* represent the in-medium or effective masses of $\pi^0$and η, respectively. The Effective mass is given by

$$m_a^* = \sqrt{\frac{D_a}{C_a}} \quad (34)$$

and it is found by solving the Dyson-Schwinger equation by substituting $\boldsymbol{q}^2 = 0$, i.e.

$$q_0^2 - m_a^2 - \Pi_{aa} = 0 \quad (35)$$

3 RESULT AND DISCUSSION

Here we present numerical results of the present work. To compute numerical results we have taken $m_\pi = 138.6\,MeV$, $m_\eta = 548.0\,MeV$, $\frac{g_\pi^2}{4\pi} = 14.6$ and $\frac{g_\eta^2}{4\pi} = 5.0$ [2][10].

The Fig. 3 and Fig. 4 represent the variation of $\Delta m = m_a^* - m_a$ and $\Delta m^* = \widetilde{m}_a - m_a^*$ with nuclear matter densityρ, (normal nuclear matter density, $\rho_o = 0.148\,fm^{-3}$), and asymmetry parameter $\alpha = 0.2$. Fig. 3 shows that the in-medium masses of π^0 and η mesons increases with the increase of the density. It is clear from this figure that for PS interaction Δm is large compared to that of PV interaction at any density.

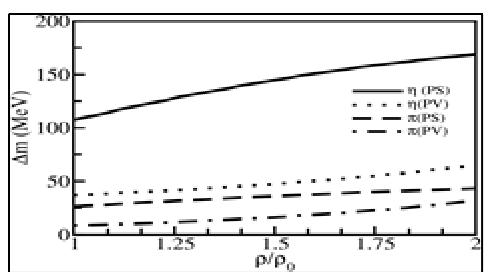

Fig. 3 *Variation of Δm with density ρ*

In the Fig. 4 we present the change of in-medium masses due to further modification by the mixing. It is observed that the mixing causes the in-medium mass of π^0 to decrease and for η meson to increase with the increase of the density. At density $\rho = 1.30\,\rho_0$ and $\alpha = 0.2$, for PS interaction the change of in-medium masses are, $\Delta m_\pi^* = -18\,KeV$, $\Delta m_\eta^* = +5\,KeV$ and for PV interaction $\Delta m_\pi^* = -99\,KeV$, $\Delta m_\eta^* = +25\,KeV$. This numerical values show that the change of in-medium masses by the mixing is five times larger for PV interaction compared to PS interaction.

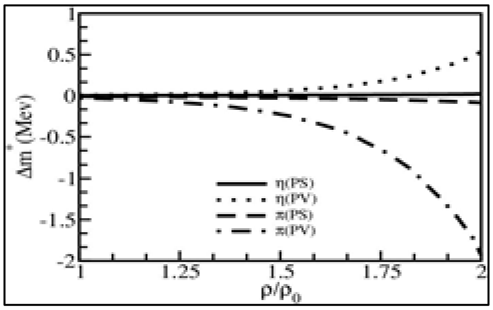

Fig. 4. *Variation of* Δm*^* with density* ρ*.*

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