Relativistic description of nuclear surface with vacuum fluctuation

Naoko Nose-Togawa, and Hiroshi Toki
Research Center for Nuclear Physics (RCNP), Osaka University, Ibaraki, Osaka 567-0047, Japan

Several authors have studied nuclear surface properties for the semi-infinite nuclear system under the relativistic mean field theory (RMF)[1][2]. In RMF, however the negative-energy nucleons are not handled explicitly. In this work we study the nuclear surface properties under the relativistic Hartree approximation (RHA), especially concentrating on the effect from the vacuum fluctuation.

We employ an $\sigma - \omega$ Lagrangian with cubic and quartic self-energy terms in the σ fields. In the semi-infinite system it keeps the Dirac fields the translational invariant in the x- and y- axes, and then the meson fields depend only on z. The corresponding Dirac equation should be solved under suitable boundary conditions, namely the Dirac wave function forms a plane-wave solution in nuclear matter at $z \longrightarrow -\infty$ and an exponentially damping at $z \longrightarrow \infty$.

A derivative expansion method are employed in order to calculate the contribution of the vacuum fluctuation [3]. The results of saturation and surface properties are listed in Table 1. The empirical value of thickness t and surface energy coefficient a_s are 2.2-2.5[fm] and 16.5-21[MeV] respectively. The RMF calculation cannot adequately explain the empirical surface properties. Meanwhile including the vacuum polarization, the incompressibility K is small because of softening of the meson fields. Accordingly the thickness becomes wide and the surface energy coefficient becomes large which are near the empirical value. The calculated vector densities are shown in Figure . The vacuum fluctuation moderates oscillations in the surface region. We can conclude that a treatment of the vacuum fluctuation is crucial to describe both nuclear saturation and surface properties simultaneously.

	RMF	RHA	
	W600	RHA0	RHA1
m_σ[MeV]	600	615	458
m_ω[MeV]	783	916.502	816.508
C_s	16.36	15.155	14.547
C_V	14.01	12.096	10.166
b[fm^{-1}]	0	0	-12.0435
c	0	0	-2.6656
ρ_0[fm^{-3}]	0.1934	0.1514	0.1524
E/A[MeV]	-15.81	-17.40	-16.98
m^*/M	0.5545	0.7247	0.7884
K[MeV]	553.24	481.79	293.75
t[fm]	1.41	1.89	2.09
a_S[MeV]	15.1	17.7	16.5

Table 1 : The results of surface properties for some parameter sets. Corresponding saturation properties are also listed.

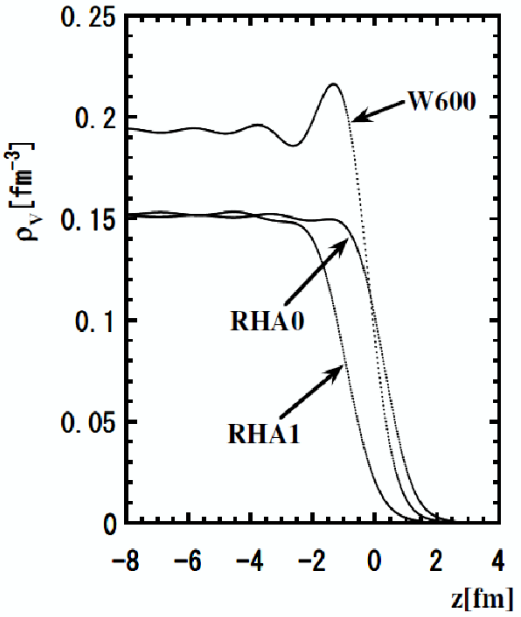

Figure 1 : The calculated vector densities.

References

[1] J. Boguta, and A. R. Bodmer, Nucl. Phys. **A292** (1977) 413.
[2] D. Hofer, and W. Stocker, Nucl. Phys. **A492** (1989) 637.
[3] G. Mao, Phys. Rev. **C67** (2003) 044318.