Structure functions generated by zero sound excitations

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We study the form of the structure functions connected to the zero sound excitations in the symmetric and asymmetric nuclear matter (ANM). The density response $\Pi(\omega, k)$ (the retarded polarization operator) of ANM on the weak external field $V_0(\omega, k) = \tau_z e^{i\vec{q}\vec{r} - i(\omega + i\eta)t}$ is considered. The structure functions $S(\omega, k)$ is defined as $S(\omega, k) = -\frac{1}{\pi}\mathrm{Im}\,\Pi(\omega, k)$ [1].

In [2] the three complex branches of the zero sound excitations in ANM were obtained: $\omega_{si}(k)$, $i = n, p, np$. We calculate these branches as solutions of the dispersion equation $E(\omega, k) = 0$. Calculations were made in the framework of RPA with the Landau-Migdal quasiparticle-quasihole isovector interaction $F'(\vec{\tau}, \vec{\tau}')$.

It was shown that in the external field $V_0(\omega, k)$ the total polarization operator is the sum [4]: $\Pi = \Pi^{pp} + \Pi^{nn} - \Pi^{pn} - \Pi^{np}$. Expressions for $\Pi^{\tau,\tau'}$ are obtained from the system of the type similar to the system for the effective fields in [3, 4]: $\Pi^{pp} = \Pi_0^p(1 - \Pi_0^n\, F^{nn})/\det M(\omega, k) \equiv D^{pp}/\det M(\omega, k)$, $\Pi^{np} = \Pi_0^p\,\Pi_0^n\, F^{np}/\det M(\omega, k) \equiv D^{np}/\det M(\omega, k)$. Changing $p \leftrightarrow n$ we obtain Π^{nn}, Π^{pn}. Dispersion equation for the frequencies of zero sound excitations is $E(\omega, k) \equiv \det M(\omega, k) = 0$. So, the branches $\omega_{si}(k)$ are the zeros of $\det M(\omega, k)$ and the poles of $\Pi^{\tau,\tau'}$ by construction.

In our approach $S(\omega, k)$ must be considered as a sum over three independent processes: the widths of the different $\omega_{si}(k)$ correspond to the different decays of excitations. The imaginary part of $\omega_{sn}(k)$ describes in nuclei the semidirect decay due to emission of a neutron, reaction (γ, n). Decay of $\omega_{sp}(k)$ accompanied by emission of proton. About of $\omega_{snp}(k)$ we can say that one nucleon is emitted and its isospin is not fixed [2]. We rewrite $S(\omega, k) = \Sigma_i S(\omega, k)_i$.

Near the pole at $\omega \approx \mathrm{Re}(\omega_{si})$ we approximate $\det M(\omega, k))^{-1} = R^i(\omega_{si}, k)/(\omega - \omega_{si}) + Reg(\omega, k)$. Here $Reg(\omega, k)$ is a smooth function near the pole. This permits us to write $S(\omega, k)_i = -\frac{1}{\pi}\mathrm{Im}\left[\Sigma_{\tau,\tau'}(D^{\tau\tau'}(\omega, k))\, R^i(\omega_{si}, k)/(\omega - \omega_{si}) + Reg\right]$. Then, let define the envelope curve of the pole terms $S^e(\omega, k) = -\frac{1}{\pi}\Sigma_{\tau,\tau'}\mathrm{Im}\left[D^{\tau,\tau'}(\omega, k)\;\; \Sigma_i\, R^i(\omega_{si}, k)/(\omega - \omega_{si})\right]$.

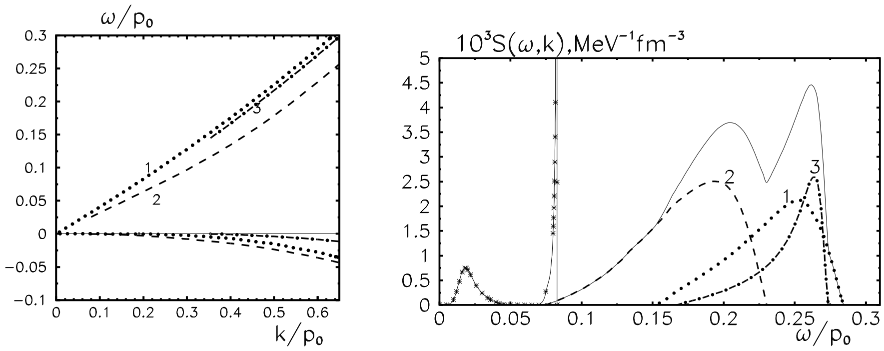

Figure 1: $left$: $\omega_{sn}(k)$ (dotted curve, 1), $\omega_{sp}(k)$ (dashed curve, 2), $\omega_{snp}(k)$ (dash-dotted, 3). At $\omega > 0$ ($\omega < 0$) the real (imaginary) parts of $\omega_{si}(k)$ are demonstrated; $right:$ the pole terms of $S(\omega, k)_i$, $i = n, p, np$ (numbers $1, 2, 3$) are shown. The envelope curve $S^e(\omega, k)$ is marked by the solid curve for $k/p_0 = 0.6$ and by the solid with stars for $k/p_0 = 0.2$.

We demonstrate results for ANM with asymmetry parameter $\beta = 0.2$. In the left figure the branches $\omega_{sn}(k)$, $i = n, p, np$ are shown [2]. In the right figure $S^e(\omega, k)$ are presented for $k/p_0 = 0.6$ and $k/p_0 = 0.2$ ($p_0 = 0.268\,\mathrm{GeV}$). For $k/p_0 = 0.6$ the structure functions for the different processes $S(\omega, k)_i$, $i = n, p, np$ are presented (the numbers $1, 2, 3$, correspondingly). As it was expected the form of the structure function is decomposed over the contributions of the definite processes, corresponding to $\omega_{si}(k)$. The widths of maxima ($right$) are determined by the imaginary parts of ω_{si} ($left$).

References

[1] E. Lipparini, "Modern Many-particle Physics", 2003, World Scientific Publishing Co.

[2] Sadovnikova V.A., Sokolov M.A. , Bull. Russ. Acad. Sci. Phys., **80**, 981 (2016); eprint 1807.09580

[3] Migdal A.B., Zaretsky D.F., Lushnikov A.A., Nucl. Phys. **A 66**, 193 (1965).

[4] A. Pastore, D. Davesne, J Navarro, Phys. Rept.**563**, 1 (2015).