EXCITAION OF GIANT RESONANCES IN NUCLEI BY INELASTIC SCATTERING OF PROTONS

M.M. Mirabutalybov
Azerbaijan State Oil Academy
mmmteymur@yahoo.com

On the basis of nonrelativistic scattering of nucleons in nuclei in the high-energy distorted-wave approximation in three-dimensional form, the obtained form-factor for inelastic scattering considering energy losses. By calculating the differential cross section of scattering protons with incident energy of 800 MeV and the giant dipole resonance with the quadruple resonance vibration surface of nuclear ^{208}Pb were investigated.

The increased interest in studying the structure of nuclei by elastic and inelastic scattering of nucleons is due to the appearance of numerous precise experimental data on the number of nuclei at different energies and the large transferred momentum. Getting a simple and accurate analytical expression for the scattering amplitude of the processes a lot of important information about the structure of nuclei can be drawn from these data.

To study the properties of highly excited states of nuclei by inelastic scattering of protons, taking into account the energy loss, we use the scattering amplitude obtained in analytical form by the distorted wave [1]. We write differential cross section in the form:

$$\frac{d\sigma_{if}}{d\Omega}=\frac{k_f}{k_i}\frac{2J_f+1}{2J_i+1}\sum_{LM}\frac{|F_{LM}(q)|^2}{2L+1}\frac{\Gamma_L^2/4}{(E_x-E_L)^2+\Gamma_L^2/4} \qquad (1)$$

Resonant excitation is considered as a form of the Breit-Wigner.

The form-factor $F_{LM}(\mathbf{q})$, of nucleus obtained in [1], has the following form:

$$F_{LM}(\mathbf{q})=\frac{ik\sigma_{NN}(1-i\varepsilon_0)\ell^{\frac{-\beta_0^2q^2}{2}}}{4\pi}\int \ell^{i\mathbf{qr}}\Re(\mathbf{r})\rho_L(r)Y_{LM}^*(\hat{r})d\mathbf{r} \qquad (2)$$

The impulse transmitted to the core (considering energy loss of the incident proton) is written:

$$|\mathbf{q}|=|\mathbf{k}_i-\mathbf{k}_f|=\sqrt{k_i^2+k_f^2-2k_ik_f\cos\vartheta}=(\frac{2m}{\hbar^2})^{1/2}\sqrt{E_i+E_f-2E_i^{1/2}E_f^{1/2}\cos\vartheta} \qquad (3)$$

To study the properties of highly excited states of nuclei in the area of energies where giant resonances exist, we apply the quantum hydrodynamic model of the nucleus.

In the excited nucleus is taken into account the connection the giant resonance with the vibrations of the nuclear surface. At that low-energy collective degrees of freedom are combined with high-energy ones. Let's present the proton density of the excited nucleus as the sum of the equilibrium proton density $\rho_p(\mathbf{r})$ and the density of fluctuations, responsible for the giant resonances $\rho_p(\mathbf{r})\eta^{Gr}(\mathbf{r},t)$ extending from the center to the surface, and vibrations of the nucleus surface $\rho_p(\mathbf{r})\eta^{vib}(\mathbf{r},t)$ as:

$$\rho_p(\mathbf{r},t)=\rho_\rho(\mathbf{r})[1+\eta^{Gr}(\mathbf{r},t)+\eta^{vib}(\mathbf{r},t)] \qquad (4)$$

Nucleons density distribution in the ground state of the nucleus $\rho(r)$ we choose in the form of the Fermi – functions and to reveal the surface effect, the equilibrium density is expressed in the form of two terms [2]:

$$\rho_p(r) = \rho_{0p} S(r - R_0) - \rho_{0p} \frac{\pi^2 z^2}{6} \delta'(r - R_0) \tag{5}$$

where S - a step function, $S = 1$ with $r < R_0$ and $S = 0$ under $r > R_0$, and δ' -derivative of δ - function.

Low-energy spectra of spherical nuclei are often the typical spectra of almost harmonic surface vibrations quadruple type [2]. Therefore, for the transition density, describing the quadruple oscillations of the nuclear surface, we obtain:

$$\rho_2 = A_2 \sqrt{\frac{\hbar}{2B_2^{vib}\varpi_2}} j_2(k_2 r)\rho_p(r) \tag{6}$$

This theory has been applied to the inelastic scattering of protons with incident energy of 800 MeV on the nucleus ^{208}Pb. We have obtained that the giant dipole resonance appears at an excitation energy $\hbar\Omega_1 = 13.18$ MeV with width $\Gamma_1 = 2.3$ MeV and quadruple resonance - $\hbar\Omega_2 = 21.18$ MeV and $\Gamma_2 = 4.1$ MeV. The vibration of surface of the nucleus occurs at energy $\hbar\omega_2 = 4.09$ MeV and the width $\Gamma_{\lambda=2} = 0.23$ MeV.

For the parameter characterizing the mean-square deformation of the excited nucleus was obtained $\beta = 0{,}21$.

References

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