MENU 2007
11th International Conference
on Meson-Nucleon Physics and
the Structure of the Nucleon
September10-14, 2007
IKP, Forschungzentrum Jülich, Germany

GENERALIZED MULTICONFIGURATION MODEL OF DECAY OF THE MULTIPOLE GIANT RESONANCES APPLIED TO ANALYSIS OF REACTION (μ^-N) ON THE NUCLEUS ^{40}Ca

O. Yu. Khetselius[%#] [1] , A. V. Glushkov[⋆%], A. V. Loboda[%],
E.P.Gurnitskaya[%]

[⋆]Inst. of Spectroscopy (ISAN), Russian Acad.Sci., Troitsk-Moscow, Russia
[%]Odessa University, Odessa, Ukraine
[#]Abdus Salam International Centre for Theoretical Physics, Strada Costiera, Trieste, Italy

Abstract

It is presented the generalized multiconfiguration model to describe a decay of high-excited states (the multipole giant resonances), which is based on the mutual using the shell models (with limited basis) and microscopic model of pre-equilibrium decay with statistical account for complex configurations 2p2h, 3p3h etc. The model is applied to analysis of reaction (μ^-n) on the nucleus ^{40}Ca.

1 Introduction

As it is well known, the multipole giant resonances (MGR) are the highly excited states of nuclei, which are interpretated as the collective coherent vibrations with participance of large number of nucleons [1-5]. Two theoretical approaches to the description of MGR are usually used. In the phenomenological theories it is supposed that the strong collectivization of states allows to apply the hydrodynamical models to the desciption of vibrations of the nuclear form and volume. The microscopic theory is based on the shell model of a nucleus. In the simple interpretation an excitation of the MGR is result of transition of the nucleons from one closed shell to another one, i.e. the MGR is an result of coherent summation of many particle-hole (p-h) transitions with necessary momentum and parity. Here we present generalized

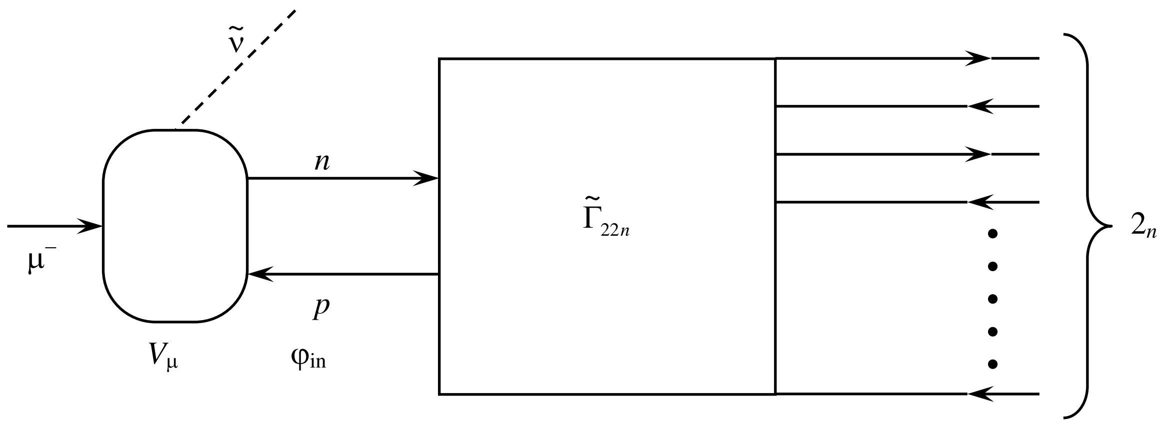
[1]E-mail address:glushkov@paco.net

multiconfiguration model to describe a decay of high-excited states, which is based on the mutual using the shell models (with limited basis) and microscopic Zhivopistsev-Slivnov model of pre-equilibrium decay with statistical account for complex configurations 2p2h, 3p3h etc. The model is applied to analysis of reaction (μ^{-}n) on the nucleus ^{40}Ca. The comparison with experimental and other theoretical data is presented.

2 Generalized multiconfiguration model of the MGR decay

The MGR is treated on the basis of the multiparticle shell model. Process of arising a collective state of MGR and an emission process of nuclons are described by the diagram in fig.1.

Figure 1: Diagram of process for production of the collective state MGR and emission of nucleons (or more complex particles).



Here V$_{\mu}$ is effective hamiltonian of interaction, resulted in capture of muon by nucleus with transformation of proton to neutron and emission by antineutrino. Isobaric analogs of isospin and spin-isospin resonances of finite nucleus are excited. The diagrams for photonuclear reactions look to be analogous; $\tilde{\Gamma}^{n}_{22}$is the full vertex part (full amplitude of interaction, which transfers the interacting p-h pair to the finite npnh state.The full vertex Γ $\tilde{\Gamma}^{n}_{22}$is defined by the system of equations within quantum Green function modified approach [3,11].

All possible configurations are divided on two grops: i). group of complicated configurations "n_1", which must be considered within shell model with account for residual interaction; ii). statistical group "n_2" of complex configurations with large state denstiy p(n,E)¿¿ and strong overlapping the states G_n¿¿D_{n-1}¿D_n (D_n is an averaged distance between states with 2n exciton; G_n is an averaged width). Matrix elements of bond ¡n|V|n'¿ are small and characterized by a little dispersion. To take into account a collectivity of separated complex configurations for input state a diagonalization of residual interaction on the increased basis (ph,ph+phonon, ph+2 phonon) is used. All complex configurations are considered within the pre-equilibrium decay model by Feschbach-Zhivopistsev et al [5,6] with additional account of "n_1" group configurations. The input wave functions of MGR for nuclei with closed or almost closed shells are found from diagonalization of residual interaction on the effective 1p1h basis.

Statistical multistep negative muon capture through scalar intermediate states of compound nucleus is important. Iintensities of nuclon spectra are defined by standard way [6].

The intensity of nucleonic spectra is defined as follows:

$$\frac{dI}{d\varepsilon_f}(E_\mu, l, \varepsilon_f, J\pi) = \sum_{\substack{n=1,\\ \Delta n=1}} \frac{\Gamma_n^{\uparrow}(l,\varepsilon_f,J\pi)}{\Gamma_n(J\pi)} \cdot \left[\prod_{k=1}^{n-1} \frac{\Gamma_k^{\downarrow}(J\pi)}{\Gamma_k(J\pi)}\right] \cdot \Lambda_\mu(E_\mu, J\pi) \quad (1)$$

where

$$\Gamma_n^{\uparrow}(l,\varepsilon_f,J\pi) = 2\pi\cdot <|<\varphi_{N_n}(J\pi)|I_{N_n,N_B+1}|\cdot$$

$$\cdot[\varphi^{(+)}(l,\varepsilon_f)\varphi_{N_B}(U_B,I_B)]_{J\pi} >|^2> \rho(l,\varepsilon_f)\rho^{(b)}(N_B,U_B,I_{B)}$$

$$\Gamma_k^{\uparrow}(J\pi) = \sum_{l,f}\int d\varepsilon_f \Gamma_k^{\uparrow}(l,\varepsilon_f,J\pi)$$

$$\Gamma_k(J\pi) = \Gamma_k^{\uparrow}(J\pi) + \Gamma_k^{\downarrow}(J\pi)$$

$$\Gamma_k^{\downarrow}(J\pi) = 2\pi\cdot <|<\varphi_{N_k}(J\pi)|I_{N_k,N_k+1}|\varphi_{N_{k+1}}(J\pi)>|^2> \rho^{(b)}(N_{k+1},J\pi,E_\mu)$$

$$E_\mu = \varepsilon_f + U_B + B_N$$

Here l is the orbital moment of the emission nucleon, ε_f is its energy; $B_{\rm N}$ is the bond energy of nucleon in the compound nucleus; $\Lambda_\mu(E_\mu, J\pi)$ is probability of μ-capture with excitation of the state $\varphi_{in}(E_\mu,\ J\pi)$ with energy E_μ, spin $J$and parity π. As in ref.[5,6], we neglect the interference between contributions of separated "dangerous" configurations. The above indicated features of the statistical group of configurations ar not fulfilled for the "dangerous" configurations (c.f.[5]). However, the value $\Gamma_n^{\downarrow}(n_1)$ for some dangerous configuration is weakly dependent upon the energy. Indeed, configuration n_1 is the superposition of the large number of configurations, i.e. [5,13]

$$\Gamma_n^{\downarrow}(n_1) = \sum_{n+1} \frac{|<n_1|I_{n_1,n+1}|n+1>|^2}{(E_\mu - E_{n+1})^2 + \Gamma_{n+1}^2/4}$$

The other details of model can be found in refs. [5-7,11-14].

3 Results and conclusion

The wave functions of the input state $\{\varphi_{in}\}$ in the reaction ^{40}Ca (μ^-n) are calculated within the shell model [12,13]. As one could wait for that a collectivity of initial input state leads to significant decreasing $\Gamma_{\rm i}^{\downarrow}$. The separation into groups $\rm n_1$and $\rm n_2$ is naturally accounted for the 2p2h configuration space [5] and the contribution of configurations "ph+phonon" and weakly correlated 2p2h states was revealed [15]. A probability of transition to the "dangerous" configurations $2p2h$ is defined by the value of matrix element:

$$|<\varphi_{in}(ph, J\pi, E)|I_{ph,2p2h}|\varphi(2p2h, J\pi, E)>|^2$$

and additionally by density $\rho(2p2h,J\pi,E)$ for statistical group n_2. The contribution of weakly correlated 2p2h configurations is defined by expression [5]:

$$\Gamma_{2p2h}^{\downarrow} = 2\pi\cdot <|<|I_{ph2p2h}|>|^2> \rho_{2p2h}$$

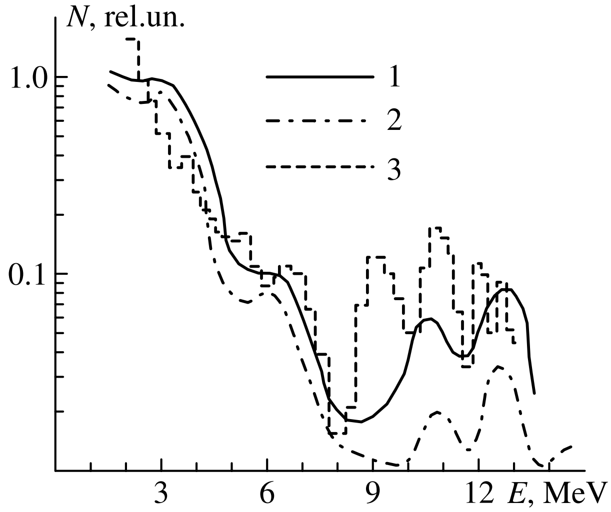
The residual interaction has been choosen in the form of Soper forces:

$$V = g_0(1\text{-}\alpha + \alpha\cdot\sigma_1\sigma_2)\cdot\delta(\boldsymbol{r}_1\text{-}\boldsymbol{r}_2),$$

where $g_0/(4\pi r_o^3)$ =-3 MeV, α=0,135.The phonons have been considered in the collective model and calculation parameters in the collective model and generelized RPA are choosen according to ref.[13]. The phonons contribution is distributed as follows: 2^+ (E=3,9 MeV; β=0,075)$\sim$ 42% , 3^-(E=3,736

MeV; β=0,345)$\sim$8% , 5^- (E=4,491 MeV; β=0,216)$\sim$3% etc. with growth of the phonon moment. Our theoretical results are compared with experimental data and other calculation results [2] in fig.2. In the range of 5-13MeV the experiment gives the intensity $\sim$10% from the equilibrium one. As it has been shown earlier (c.f.[5,6], the 1^-, 2^- states do not the significant contribution. However, they exhaust $\sim$80% of the intensity of μ^--capture.

Figure 2: The comparison of calculated spectra (curve 2) with experimental data (dotted line)[8] and theoretical data by Zhivopistsev-Slivnov (curve 1)[5].



4 Index

Acknowledgments

The authors are very much thankful to Prof. Dr. Hartmut Machner and also Prof.Dr. S. Krewald , Mrs. S. Schadmand for invitation to make contributions on The Eleventh International Conference on Meson-Nucleon Physics and the Structure of the Nucleon-MENU2007 (Juelich, Germany) and support.

5 References

References

[1] O. Bohr, B. Mottelsson, *Structure of Atomic Nucleus*, N-Y., (1975).

[2] I. Izenberg, B. Grainer, *Models of Nuclei. Collective and One-body Phenomena*, N.-Y., (1975).

[3] A. V. Glushkov., S. V. Ambrosov, A. V. Loboda, in: *New Projects and New Lines of Research in Nuclear Physics* eds. G. Fazio, F. Hanappe, Singapore: World Scientific, 242 (2003).

[4] H. Feschbach *et al.*, *Ann. Phys.* **125**, 429 (1980).

[5] F. A. Zhivopistsev, A. M. Slivnov, *Izv. AN USSR. Ser. Phys.* **48**, 821 (1984).

[6] F. A. Zhivopistsev *et al.*, *Izv. AN USSR. Ser. Phys.* **45**, 1935 (1981).

[7] F. A. Zhivopistsev, A. V. Lukashev, V. A. Eltekov, *Vestnik MGU. Ser. Phys.* **2**, 201 (1973).

[8] I. Vaytkowska, *Nucl. Phys.* **15**, 1154 (1972).

[9] A. V. Glushkov, in *Low Energy Antiproton Phys.*, AIP Serie. **796**, 206 (2005).

[10] A. V. Glushkov *et al.*, *Nucl. Phys. A* **734**, e21 (2004).

[11] A. V. Glushkov, S. V. Malinovskaya, A. V. Loboda, in *Proc. III Int. Workshop on Non-equilibrium Green's Functions*, Univ. Kiel (Germany), (2005).

[12] S. V. Malinovskaya, in *Low Energy Antiproton Phys.*, AIP Serie. **796**, 211 (2005).

[13] A. V. Glushkov, S. V. Ambrosov, A. V. Loboda, E. P. Gurnitskaya, O. Yu. Khetselius, *Recent Advances in Theor. Phys. and Chem. Systems* **15**, 301 (2006).

[14] S. V. Malinovskaya, A. V. Glushkov, Yu. V. Dubrovskaya, L. A. Vitavetskaya, *Recent Advances in Theor. Phys. and Chem. Systems* **15**, 285 (2006).

[15] R. A. Broglia *et al.*, *Nucl. Phys. A* **371**, 413 (1981).