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# Pauli resonances in single- and many-channel systems

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In this report, we present results of systematic investigations of peculiarities of redundant solutions of the resonating group method (RGM), which are known as the Pauli resonance states. Such resonance states appear when one tries to use more advanced (more precise) wave functions describing internal structure of interacting clusters. It is generally recognized that the Pauli resonance states are spurious solutions which blur real physical quantities such as phase shifts, cross sections. Their appearance cannot be attributed to enlarging of centrifugal and Coulomb barriers, they also appear in a single-channel approximation and thus the Pauli resonance cannot be considered as the Feshbach resonances.
The subject of our investigations is continuos spectrum states of light nuclei $^6$Li, $^7$Li, $^8$Be, $^9$Be and $^{10}$B, which are considered as two-cluster systems. Special attention is paid to the Pauli resonance states which appear in interaction of $^6$Li with neutrons, deuterons, tritons and alpha particles. All investigations are carried out in a three-cluster microscopic model, which was formulated in Ref. [1]. In this model dominant three-cluster configuration is transformed into a set of binary channels. One of the constituents of the binary channel is considered as a two-cluster subsystem. Spectrum of bound states and corresponding wave functions of the subsystem are obtained by solving the two-cluster Schrödinger equation. This allows us to use more adequate wave functions describing the internal structure of the two-cluster subsystem. This is rather important for two-cluster subsystems with a small separation energy, such as deuteron, $^6$Li and so on. Within the model, Gaussian functions are used to describe relative motion of clusters in bound states of a two-cluster subsystem and oscillator functions are utilized to expand wave function of continuous spectrum states of compound nucleus. At the first stage of our investigation, we use single-channel approximation in order to detect and analyze the Pauli resonance states.
It is found that the Pauli resonance states in selected nuclei lie in the energy range between 11 and 45 MeV, and their widths are varied from 8 keV to 8 MeV. The most dense area of resonance states are concentrated in the interval $16 < E < 21$ MeV. Two dense area of widths of resonance states are located in intervals $0.008 < \Gamma < 0.22$ MeV and $0.9 < \Gamma < 1.2$ MeV. In many cases only one Pauli resonance state appeared in a binary channel. We also determined several cases with two resonance states. It was demonstrated, the number of the Pauli resonance states are correlated with number of the Pauli forbidden states in a simple version of the RGM, when simple functions of the many-particle shell-model are employed for describing internal motion of nucleons within each cluster.
We also investigate properties of the Pauli resonances in a many-channel model of $^6$Li. This nucleus is studied within a three-cluster model which involves two three-cluster configurations $\alpha + p + n$ and $t + d + p$. These cluster configurations allowed us to take into account all dominant binary decay channels of the nucleus. It is shown that the Pauli resonances are observed in the $\alpha + d$, $^5$He+$p$, $^5$Li+$n$, $^3$He+$t$ channels when they are treated separately. When channels are coupled, the Pauli resonances migrate from one to another channel and substantially change their energy and width. We demonstrated how Pauli resonances in single- and many-channel systems can be effectively eliminated with minimal effects on the ground and shape resonance states.

References

[1] V. S. Vasilevsky, F. Arickx, J. Broeckhove, and T. P. Kovalenko, "A microscopic three-cluster model with nuclear polarization applied to the resonances of $^7$Be and the reaction $^6$Li($p$,$^3$He)$^4$He," Nucl. Phys. A, vol. 824, pp. 37–57, 2009.

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