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# Study of alpha cluster states in light nuclei for nuclear physics and astrophysics

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It is well recognized that current interest in $\alpha$ particle interaction with nuclei is strongly motivated by astrophysics [1]. Even if astrophysical reactions involving helium do not proceed through the strong $\alpha$-cluster states (because of their high excitation energy), these states can provide α width to the levels that are closer to the region of astrophysical interest through configuration mixing.

We used a low energy heavy ion cyclotron in Astana (Kazakhstan) to study resonance reactions induced by ions of \textsuperscript{13}C[2], \textsuperscript{15}N[3],\textsuperscript{16}O, \textsuperscript{17}O in helium and hydrogen gas target. The Thick Target Inverse Kinematics Method [3,4,5] was used to obtain the continuous in energy excitation functions in the large angular interval using 1.9 MeV/u initial energy of the accelerated ions. The experimental excitation functions were analyzed using multilevel multichannel R matrix code [6], and the data on over 100 levels were obtained. We did not use any background resonances in the fit. New data were obtained even for a well-studied case \textsuperscript{20}Ne nucleus populated in the \textsuperscript{16}O+ $\alpha$ resonance elastic scattering. The \textsuperscript{17}O+ $\alpha$ resonance elastic scattering has not been studied before. The nuclear structure theoretical calculations were made in the framework of the cluster-nucleon configuration interaction model [7].

In the talk we present the experimental results (Fig.1.), evaluate a shell model approach progress in the description of the cluster states, and consider modifications and a possible progress of the experimental approach.

\begin{figure}[h]
\centering
\includegraphics{fig-1-NPA8.jpeg}
\caption{The 180° excitation function for the \textsuperscript{16}O+ $\alpha$ resonance elastic scattering together with R matrix fit.}
\label{fig:awesome_image2}
\end{figure}

\bigskip
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\noindent [1] A. Aprahamian et al. Nuclear structure aspects in nuclear astrophysics, Progress in Particle and Nuclear Physics. 54 (2005) 535–613. doi:10.1016/j.ppnp.2004.09.002;

\noindent [2] N.A.Mynbayev et al. J.Exper.Theo.Phys. 119, 663 (2014); Zh.Eksp.Teor.Fiz. 146, 754 (2014);

\noindent [3] A.K. Nurmukhanbetova et al. Implementation of TTIK method and time of flight for resonance reaction studies at heavy ion accelerator DC-60, Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment. 847 (2017) 125–129. doi:10.1016/j.nima.2016.11.053;

\noindent [4] K. P. Artemov, et al., Sov. J. Nucl. Phys. 52, 634 (1990);

\noindent [5] G. V. Rogachev, et. al AIP Conf. Proc. 1213, 137 (2010);

\noindent [6] E.D.Johnson, Ph.D. thesis, Florida State University, 2013;

\noindent [7] A. Volya et al. Nuclear clustering using a modern shell model approach, Physical Review C. 91 (2015) 44319. doi:10.1103/PhysRevC.91.044319.

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**Session Classification:** Poster session