α-cluster structure of ^{18}O

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The concept of α-clustering has been successfully applied to explain multiple features in nuclear spectrum. In particular, a number of known structure peculiarities in light N=Z, 4N nuclei, such as ^{8}Be, ^{12}C, ^{16}O, and ^{20}Ne is associated with clustering. The most striking are the twin α-cluster, inversion doublet, quasi-rotational bands. All members of these bands that have excitation energies above the α-decay threshold have α-reduced widths close to the single particle limit, indicating their extreme α-cluster character. Extensive experimental and theoretical studies ([1] and references therein) lead to understanding of these bands as well developed α+core structures.

It proved to be far more difficult to study clustering phenomena in non-self-conjugate nuclei. Clustering might manifest itself in a much more complex way in these nuclei. This is because the ``extra'' nucleons introduce additional degrees of freedom which may modify: enhance or destroy cluster structures. In addition to that there are difficulties of the experimental studies, which require a more complicated analysis due to the presence of low-lying nucleon decay channels and higher level density. On the other hand, the investigation in this region seems very promising because the structure and decay information about states in non-self-conjugate nuclei allows one to explore the interplay between the single nucleon and cluster degrees of freedom. An ^{18}O nucleus represents an attractive target for such investigation, it is a non-self-conjugate nucleus that is in close proximity to the ^{16}O and ^{20}Ne, nuclei with well developed and extensively studied cluster structure.

The cluster structure of ^{18}O was studied using detailed R-matrix analysis of the α+^{14}C elastic scattering excitation functions. Measurements were performed at the John D. Fox Superconducting Linear accelerator facility at the Florida State University using Thick Target Inverse Kinematics technique. The complete excitation function for 180^{o} in c.m. for the entire energy range measured in this experiment is shown in Fig. 1.

We have performed detailed R-matrix analysis. Spin-parity assignments, excitation energies and partial widths were determined for 54 excited states in ^{18}O. Detailed description of the 18O level structure will be published in [2]. The $^{14}C(\alpha,\alpha)$ elastic scattering is particularly sensitive to the states that have α+^{14}C(g.s.) configuration and completeness of experimental data complemented by the detailed R-matrix analysis allows for most accurate assessment of α-clustering phenomena in ^{18}O.

Search for α-cluster inversion doublet rotational bands in ^{18}O has been a subject of many experimental and theoretical studies [3-7], but corresponding assignments remained controversial. Based on the results of this work we conclude that unlike for N=Z, ^{16}O and ^{20}Ne nuclei, the α-strength is split about evenly between two or more states for each spin-parity and it is not possible to define an inversion doublet rotational bands in the same sense as for ^{16}O and ^{20}Ne nuclei. This splitting is likely the result of configuration mixing. The Cluster-Nucleon Configuration Interaction Model (CNCIM) [8] calculations

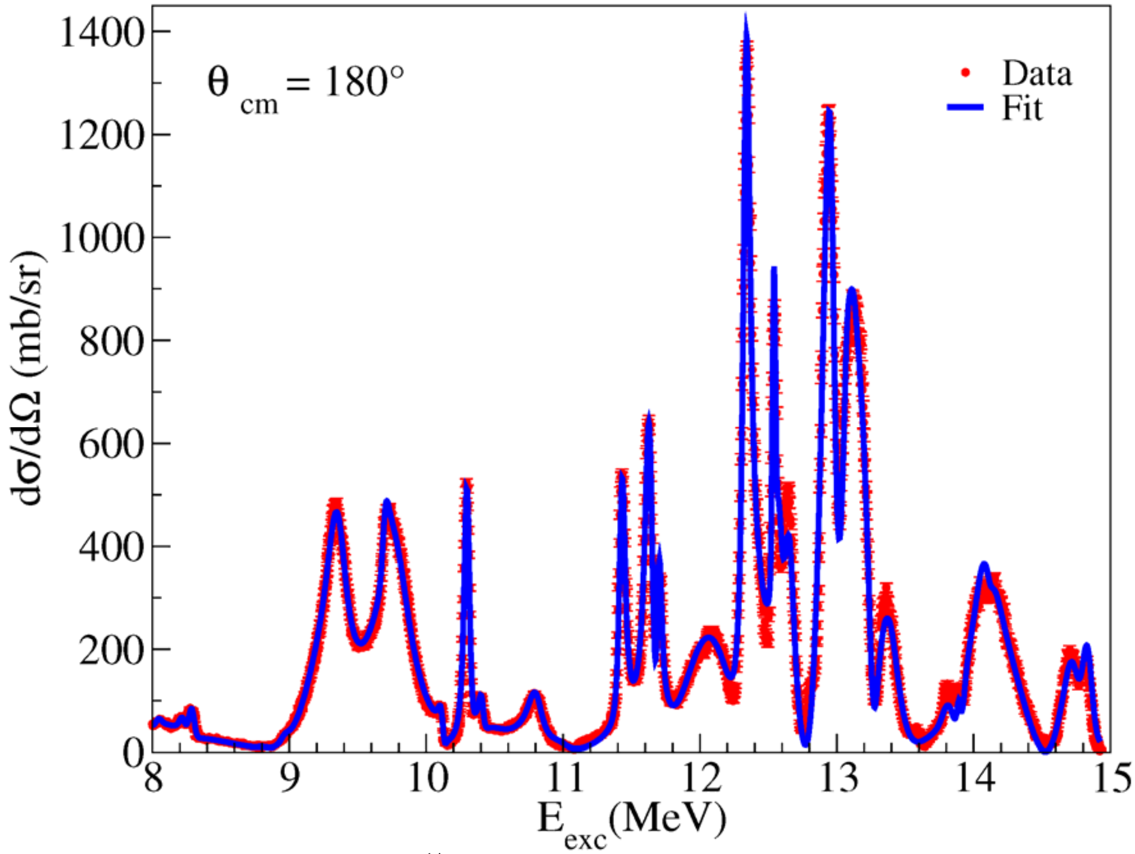

FIG. 1. The excitation function for α+^{14}C elastic scattering at 180◦ in c.m. for the entire energy range measured in this experiment. The solid curve is the best R-matrix fit.

performed for 18O in this work indicate that splitting of α-strength for the positive parity band is the result of $(1s0d)^4$, and $(0p)^2(1s0d)^2$, configuration mixing. For the negative parity states the (1p0f) shell (not included in the CNCIM) probably play an important role. These findings highlight importance of considering the nucleon and cluster degrees of freedom on an equal footing for the non-self-conjugate nuclei.

Assignment of the α-cluster rotational bands without knowledge of partial α-width is dangerous. The most striking example is the assignment of a 0^- inversion doublet rotational band in [3], where authors did the best they could without this crucial information. It turns out that all states in the 0^- rotational band suggested in [3] have α-strength that is at least a factor of 10 smaller than the α-strength of the strongest cluster state with the corresponding spin-parity. This obviously excludes them from being the members of the 0^- inversion doublet rotational band.

The broad, purely α-cluster 0^+ and 2^+ states at 9.9 MeV and 12.9 MeV were observed in ^{18}O. Most likely these states have similar nature (and configuration) as the well known 0^+ and 2^+ broad states in ^{20}Ne at 8.7 and 8.9 MeV [9].

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