Comparative study of the dineutron in Borromean nuclei ^{11}Li and ^{22}C

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A recent knockout-reaction experiment for ^{11}Li measured the mean correlation angle between the momenta of two emitted neutrons,[1)] which is considered to reflect the mean opening angle $\langle\theta_{nn}\rangle_0$ between the momenta $\mathbf{k}_1$ and $\mathbf{k}_2$ of valence neutrons in the ground state. In the current study, I discuss how $\langle\theta_{nn}\rangle_0$ reflects the momentum-space structure of the dineutron in the Borromean nuclei ^{11}Li and ^{22}C.

The three-body model calculation is performed using a finite-range n-n interaction,[3)] which reproduces the ground-state properties of these nuclei. For example, the distance between the core and the center of mass (cm) of the dineutron in ^{11}Li is 5.00 fm, which is in agreement with the observed value of 5.01(32) fm.[2)] $\langle\theta_{nn}\rangle_0$ for each core-n momentum k_n is defined by $\cos\langle\theta_{nn}\rangle_0 = \langle\langle\cos\theta_{12}D_{k_n}\rangle\rangle/\langle\langle D_{k_n}\rangle\rangle$. Here, $\langle\langle f\rangle\rangle = \int d^3k_1 d^3k_2 \rho_2(\mathbf{k}_1,\mathbf{k}_2) f(\mathbf{k}_1,\mathbf{k}_2)$ is the mean value of a function $f(\mathbf{k}_1,\mathbf{k}_2)$ for the two-neutron density distribution $\rho_2(\mathbf{k}_1,\mathbf{k}_2)$. θ_{12} is the opening angle between $\mathbf{k}_1$ and $\mathbf{k}_2$. $D_{k_n}(\mathbf{k}_1,\mathbf{k}_2) = \delta(k_n - |\mathbf{k}_1|)\delta(k_n - |\mathbf{k}_2|)$ picks up the component of $k_n = |\mathbf{k}_1| = |\mathbf{k}_2|$ in ρ_2.

Here, $\mathbf{k}_1$ and $\mathbf{k}_2$ can be expressed as $\mathbf{k}_{\{{1 \atop 2}\}} = \pm\mathbf{k}_{\rm rel} + \mathbf{q}_{\rm cm}/2$ with the relative and cm momenta $\mathbf{k}_{\rm rel}$ and $\mathbf{q}_{\rm cm}$, respectively. As shown below, $\langle\theta_{nn}\rangle_0$ for a given k_n contains the various $q_{\rm cm}$ components of different neutron-pair structures. To illustrate this, Fig. 1(a) shows the density distribution $\rho_{\rm cm} = \langle\langle\delta(q_{\rm cm} - |\mathbf{k}_1 + \mathbf{k}_2|)\rangle\rangle$ as a function of $q_{\rm cm}$. The root-mean-square core-n momentum $\bar{k}_n$ is defined for each $q_{\rm cm}$ in a similar manner. Together with the associated opening angle $\bar{\theta}_{\rm cm} = 2\cos^{-1}(q_{\rm cm}/2\bar{k}_n)$, the parametric curve of $(\bar{k}_n, \bar{\theta}_{\rm cm})$ is shown in Fig. 1(b). For ^{11}Li, symbol A corresponds to the peak position of $\rho_{\rm cm}$. $\bar{k}_n$ has a local maximum (minimum), as indicated by the symbol B (C). The corresponding cm momenta $q^{(A)}$, $q^{(B)}$, and $q^{(C)}$ are 0.20, 0.47, and 0.65 fm^{-1}, respectively. $\bar{\theta}_{\rm cm} > 90°$ at $q_{cm} < q^{(C)}$ indicates the dineutron configuration. The symbols a, b, and c for ^{22}C have the same meaning as A, B, and C for ^{11}Li, respectively.

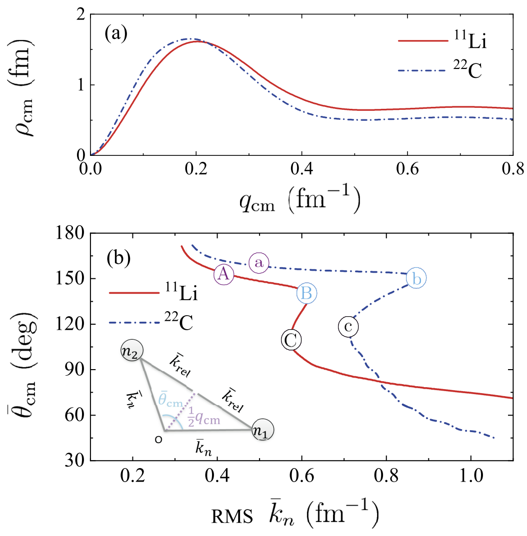

Fig. 1. (a) Two-neutron density distribution $\rho_{\rm cm}$ as a function of $q_{\rm cm}$ in ^{11}Li and ^{22}C. (b) Parametric curve of $(\bar{k}_n, \bar{\theta}_{\rm cm})$. See the text for details.

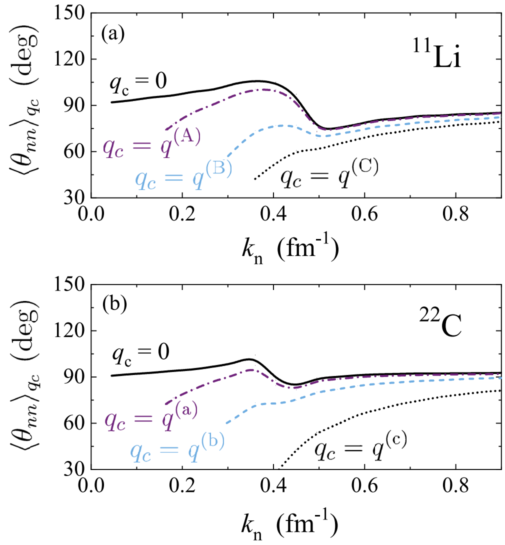

Fig. 2. (a) Mean opening angle $\langle\theta_{nn}\rangle_{q_c}$ in ^{11}Li as a function of k_n. The dependence on the lower cutoff q_c is shown. (b) The same as (a) but for ^{22}C. See the text for details.

The mean opening angle $\langle\theta_{nn}\rangle_{q_c}$, which takes into account the component of $q_{cm} > q_c$ in ρ_2, is also defined. Here, q_c is a lower cutoff. Figure 2 shows $\langle\theta_{nn}\rangle_{q_c}$ in ^{11}Li and ^{22}C. $\langle\theta_{nn}\rangle_0$ has a peak at $k_n \approx 0.35$ fm^{-1}. The peak of $\langle\theta_{nn}\rangle_0$ is cooperatively created by the peak component of $\rho_{\rm cm}$ and the large $\bar{\theta}_{\rm cm}$ in the region of $q_{\rm cm} < q^{(C)}$ ($q^{(c)}$) in ^{11}Li (^{22}C). In ^{22}C, the enlargement of $\langle\theta_{nn}\rangle_0$ due to the low-$q_{\rm cm}$ component appears up to $k_n \approx 0.9$ fm^{-1}, which corresponds to the local maximum value of $\bar{k}_n$. This high local maximum value of $\bar{k}_n$ is due to the d-wave contribution. Such enlargement of $\langle\theta_{nn}\rangle_0$ is not observed at high k_n in ^{11}Li.

In conclusion, I discussed how the mean opening angle $\langle\theta_{nn}\rangle_0$ depends on the momentum-space structure of the dineutron in ^{11}Li and ^{22}C. $\langle\theta_{nn}\rangle_0$ can be a promising probe for revealing the characteristic structure of the dineutron in each Borromean nucleus.

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References

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