Momentum-space structure of dineutron in ^{11}Li[†]

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A recent knockout-reaction experiment for the Borromean nucleus ^{11}Li measured the mean correlation angle between the momenta of emitted neutrons n_1 and n_2 in the reaction channel $^{11}\mathrm{Li}(p, pn_1)^{10}\mathrm{Li}^* \rightarrow {}^{9}\mathrm{Li} + n_2$.[1)] The dependence on the missing momentum k of n_1 is considered to reflect the spatial structure of dineutron.

Here, the reflection of the spatial structure of dineutron to the mean opening angle between the momenta $\mathbf{k}_1$ and $\mathbf{k}_2$ of the valence neutrons at the ground state of ^{11}Li is discussed. Further, the similarities with the mean correlation angle are highlighted.

A three-body model calculation is performed in the momentum space using a finite-range n–n interaction, which reproduces the two-neutron ($2n$) separation energy and the matter radius of ^{11}Li. Further, the $2n$ density, $\rho_2(k_1, k_2, \theta_k)$, is calculated using $k_1 = |\mathbf{k}_1|$, $k_2 = |\mathbf{k}_2|$, and the opening angle between $\mathbf{k}_1$ and $\mathbf{k}_2$, θ_k. Figure 1(a) shows $\rho_2(k_1, k_2, \theta_k)$ as a function of both $k_1 = k_2 = k_n$ and θ_k. Figure 1(b) shows the $2n$ density in real space via the Fourier transformation, $\rho_2(r_1, r_2, \theta_r)$, using the radial coordinates, $r_1 = r_2 = r$, and opening angle, θ_r.

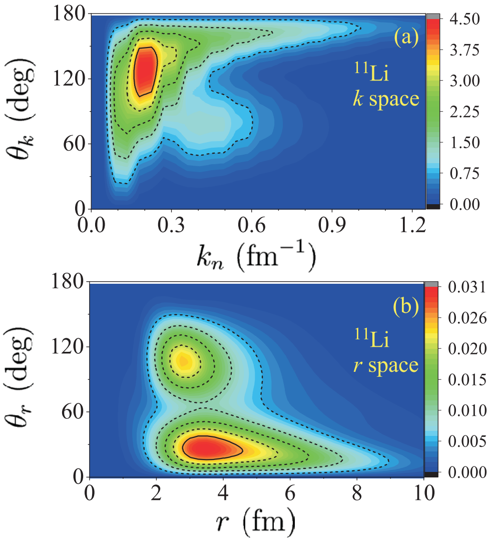

Fig. 1. (a) $2n$ density for ^{11}Li as functions of $k_1 = k_2 = k_n$ and the opening angle θ_k. It is weighted with a factor of $8\pi^2 k_n^4 \sin\theta_k$. (b) Same as (a) but $2n$ density in real space as functions of $r_1 = r_2 = r$ and the opening angle θ_r. It is weighted with a factor of $8\pi^2 r^4 \sin\theta_r$.

The dineutron configuration is obtained at the low-momentum of $(k_n, \theta_k) = (0.18\ \mathrm{fm}^{-1}, 128°)$. It is accompanied by the broad angular distribution, and the long k_n-tail indicates the strong dineutron correlation (the high n–n relative momentum).

The mean opening angle $\langle\theta_k\rangle$ is defined as a function of $k_1 = k_n$ as follows

$$\cos\langle\theta_k\rangle \equiv \left[\int_0^{k_\mathrm{cut}} k_2^2 dk_2 \int_0^{\pi} 2\pi \sin\theta_k d\theta_k \right. \\ \left. \times\, \rho_2(k_n, k_2, \theta_k) \cos\theta_k \right] / \rho_k(k_n), \qquad (1)$$

where $\rho_k(k_n)$ is the one-neutron density distribution. Figure 2(a) shows $\langle\theta_k\rangle$ using the cutoff momenta of $k_\mathrm{cut} = \infty$ (no cutoff) and $k_\mathrm{cut} = k_\mathrm{surf} = 0.62\ \mathrm{fm}^{-1}$.

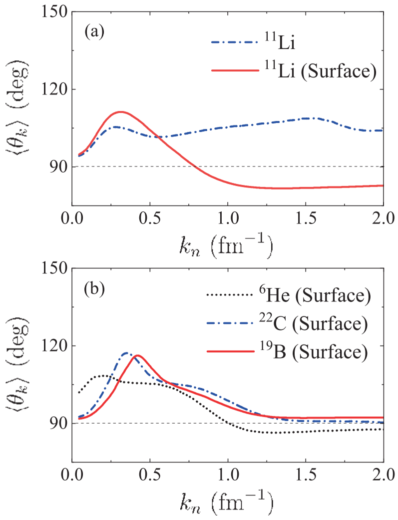

Fig. 2. (a) Mean opening angle $\langle\theta_k\rangle$ as a function of $k_1 = k_n$ for ^{11}Li. "Surface" indicates the cutoff of $k_\mathrm{cut} = k_\mathrm{surf}$. (b) Same as (a) but for ^{6}He, ^{22}C, and ^{19}B.

$\langle\theta_k\rangle$ (no cutoff) exhibits a peak at $k_n = 0.27\ \mathrm{fm}^{-1}$; however, it gradually increases above $k_n \approx 0.5\ \mathrm{fm}^{-1}$.

k_surf characterizes the low-momentum halo region by $k_1, k_2 < k_\mathrm{surf}$. $\langle\theta_k\rangle$ using $k_\mathrm{cut} = k_\mathrm{surf}$ exhibits a peak at $k_n = 0.31\ \mathrm{fm}^{-1}$ and a plateau of $\langle\theta_k\rangle \approx 82°$ above $k_n \approx 1.0\ \mathrm{fm}^{-1}$. These features are consistent with the observed k dependence of the mean correlation angle (the peak at $k \approx 0.3\ \mathrm{fm}^{-1}$ and the plateau of approximately 87° above $k \approx 0.9\ \mathrm{fm}^{-1}$),[1)] which is considered to reflect the $2n$ correlations in the surface region.[2)]

In conclusion, the manner in which the mean opening angle reflects the $2n$ density in ^{11}Li was discussed. For $\langle\theta_k\rangle$, the importance of the surface effect and the similarities with the mean correlation angle in the knockout reaction were highlighted. The same conclusion was obtained for ^{6}He, ^{22}C, and ^{19}B (see Fig. 2(b)), wherein the measurement of the momentum dependence of the angular correlations between the halo neutrons can provide useful information on dineutron correlations at low density.

References

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2) J. Casal *et al.*, Phys. Rev. C **104**, 024618 (2021).

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