Comments

The Comments section is for short papers which comment on papers previously published in **The Physical Review**. *Manuscripts intended for this section must be accompanied by a brief abstract for information retrieval purposes and a keyword abstract.*

Impulse distribution of the α-d motion in ^{6}Li

S. Barbarino, M. Lattuada, F. Riggi, C. Spitaleri, and D. Vinciguerra
Istituto di Fisica and Istituto di Scienze Matematiche e Fisiche dell'Università di Catania, Catania, Italy
(Received 30 July 1979)

We have reanalyzed previous data on the ^{6}Li(p,pd) quasifree scattering at 590 MeV incident energy, from which the authors deduce a momentum distribution of the clusters α and d in ^{6}Li with a full width at half maximum around 120 MeV/c. We find instead that the experimental results are compatible with a momentum distribution whose full width at half maximum is about 70 MeV/c, which is in agreement with other experimental findings and with the prediction of the cluster model.

[NUCLEAR REACTIONS ^{6}Li(p,pd), E=590 MeV; the FWHM of the momentum distribution deduced.]

In the cluster model[1] the ^{6}Li nucleus is well described by an α-d structure. To study the wave function of the intercluster motion, quasifree scattering (QFS) has been largely used.[2-14]

It has been shown that[15-17] a proper treatment of a QFS should be performed through a distorted-wave impulse approximation (DWIA) analysis, since the plane-wave impulse approximation (PWIA) does not take into account the wave absorption and distortion, so that no spectroscopic information can be obtained. The calculated cross sections have different absolute values and different behaviors for high values of the momentum p_s of the spectator cluster in the two approaches.

However, the two predictions are almost indistinguishable for not too high p_s values ($\lesssim$100 MeV/c), apart from a different normalization factor. This is the case, for instance, of the ^{6}Li(p,$p\alpha$) reaction at 100 MeV.[16]

From the radial part $R(r)$ of the s-wave intercluster wave function the momentum distribution $G^2(p_s)$ can be obtained in the PWIA through

$$G(p_s) \propto \int R(r) j_0(p_s r) r^2 dr \,.$$

The full width at half maximum (FWHM) of the momentum distribution, which is peaked at $p_s = 0$, is of about 71 MeV/c for the wave function of Ref. 16. About the same value of the FWHM is obtained for other phenomenological wave functions such as the one used in Ref. 13 to fit ^{6}Li(e, $e'\alpha$) and (e, $e'd$) data. For low incident energies, evidence has been found for a pronounced narrowing of the experimental momentum distribution, which has been often interpreted as a consequence of the absorption for small intercluster distances. Since the impulse approximation is expected to be better justified at high momentum transfers, we plot in Fig. 1 the measured FWHM's of the $G^2(p_s)$ reported in the literature as a function of the momentum of each of the two detected particles. When the momenta are different, the FWHM is reported for the average value.

From Fig. 1 it is evident that the experimental width of the momentum distribution increases smoothly toward higher transferred momenta,

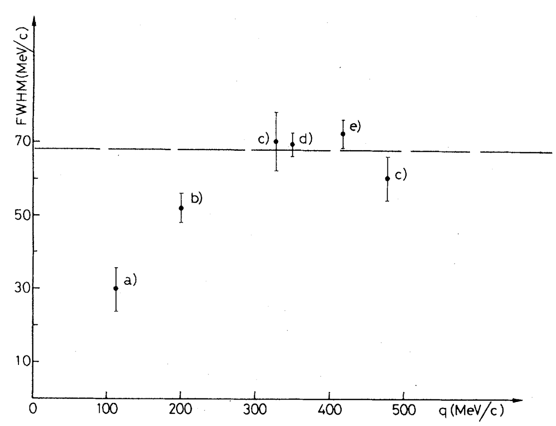

FIG. 1. Experimental widths of the momentum distribution extracted from QF measurements on ^{6}Li, as a function of the momentum transfer. The data are taken from: a) Ref. 11, b) Ref. 25, c) Ref. 8, d) Ref. 13, e) Ref. 14. The value of about 70 MeV/c, indicated by the continuous line, is predicted by both the PWIA and the DWIA (Ref. 16).

reaching a constant value of about 70 MeV/c, which is in agreement with the mentioned theoretical prediction.

In this framework it is rather puzzling that the ^{6}Li(p,pd) reaction measured at 590 MeV (Refs. 18 and 19) with momentum transfers around 900 MeV/c has a reported FWHM of (121.5 ± 2.6) MeV/c. Moreover, the widths of other impulse distributions measured with the same apparatus[20-22] showed comparably large increases. For instance, the ^{3}He(p, $2p$) reaction gives, at 590 MeV, a proton momentum distribution which is 132 MeV/c wide,[21] while the value obtained by other workers[23] with 156 MeV protons is about 97 MeV/c.

It seemed then worthwhile to reconsider critically the experiment described in Ref. 19. The coincidence detection of the two particles and the trajectory reconstruction gives the components $q_\perp$ and $q_\parallel$ of the spectator momentum q (which we have called p_s) in the plane of the reaction. Since no information is known on the out-of-plane components $q_{\rm out}$, except its average value, the authors of Ref. 19 attribute each event to a momentum q given by $(q_\perp^2 + q_\parallel^2 + \langle q_{\rm out}^2 \rangle)^{1/2}$. This procedure is intended to account for a broadening of the impulse distribution, introduced by the indetermination in $q_{\rm out}$, under the assumption that the broadening itself as well as the impulse distribution can be described by Gaussian shapes.

Now it is obvious that each component $q_\perp, q_\parallel$, and $q_{\rm out}$ has the same distribution $G^2(q_x)$, so that performing various measurements always over the same finite range of one of them (e.g., $q_{\rm out}$) does not introduce any broadening to the measured distribution of the other two of them. On the other hand the probability distribution of the in-plane

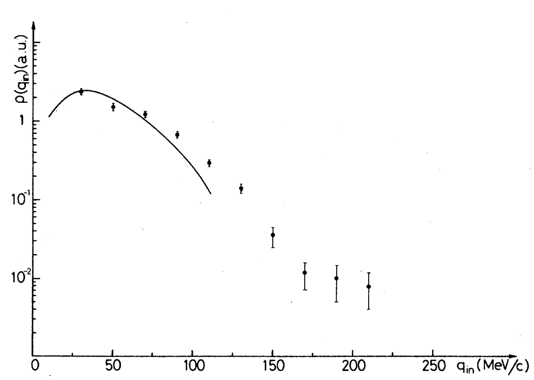

FIG. 2. Experimental data taken from Ref. 19 as a function of $q_{\rm in}$. The distribution $\rho(q_{\rm in})$ is reported as a continuous curve, after averaging over a bin 20 MeV/c wide and after folding in the instrumental indetermination of ± 15 MeV/c.

component $q_{\rm in} = (q_\perp^2 + q_\parallel^2)^{1/2}$ is not given by $G^2(q_{\rm in})$ but rather by the probability of obtaining q from two quantities, $q_\perp$ and $q_\parallel$, each of them having $G^2(q_x)$ as distribution. The probability distribution of $q_{\rm in}$ is easily shown to be $2\pi q_{\rm in} G^2(q_{\rm in})$.

In Fig. 2 are reported the experimental results of Ref. 19 as a function of the in-plane component $q_{\rm in}$. Since the authors report only $q = (q_{\rm in}^2 + \langle q_{\rm out}^2 \rangle)^{1/2}$, a value $\langle q_{\rm out}^2 \rangle^{1/2} = 22.6$ MeV/c was subtracted quadratically from q to obtain $q_{\rm in}$. The above value of $\langle q_{\rm out}^2 \rangle^{1/2}$ is not reported in Ref. 19, but we deduced it from the remark that all the data appear to be reported in $q_{\rm in}$ bins 20 MeV/c wide, so that a sequence $q_{\rm in} = 30, 50, 70, \ldots$ MeV/c can be deduced from the reported sequence $q = 38, 55, 72, \ldots$ MeV/c. The momentum distribution $G^2(q_{\rm in})$ was calculated for the radial wave function reported in Ref. 16. In Fig. 2 the continuous curve is the quantity $\rho(q_{\rm in}) = {\rm const}\, q_{\rm in} G^2(q_{\rm in})$ after averaging over a bin 20 MeV/c wide and after folding in the reported instrumental indetermination of ± 15 MeV/c.

It is evident that the data are in reasonable agreement with the theoretical curve at least for not too large momenta. Actually for momenta larger than about 80 MeV/c the validity of the PWIA is questionable,[16] and for the wave function we used a zero appears in G^2 at 150 MeV/c, which is filled in by the DWIA treatment.[16] Moreover, from the instrumental point of view, other effects are also possible. First, points at very high momenta (around 180 MeV/c) have been measured with a different arrangement of the experimental setup, and second it is possible that limitations are introduced by the detection setup on the measurable range of $q_\parallel$ for large values of $q_{\rm in}$.

In Ref. 18 is also reported for comparison the value of the experimental FWHM of the impulse distribution obtained from the ^{6}Li(π^-, $2n$) reaction.[24] Actually the reported value (122 MeV/c) takes into account a large experimental broadening. In fact the authors of Ref. 24 give an analytical form for the impulse distribution, which has a FWHM of (86 ± 11) MeV/c, and which is reported to fit their data once the experimental effects are folded in.

The reanalysis of the experiment reported in Ref. 19 shows then that all QFS experiments carried on to our knowledge to investigate the α-d cluster structure of ^{6}Li can be interpreted with the same impulse distribution, except for the narrowing shown by measurements at low transferred momentum.

It should be interesting to perform such reanalysis also on the data reported by the same authors in other references,[18, 20-22] where similar broadenings of the extracted momentum distributions are observed. Unfortunately in these papers the description of the experimental setup and/or of the data is not sufficiently complete to allow a critical review.

This work was supported in part by Istituto Nazionale di Fisica Nucleare, Sezione di Catania and by Centro Siciliano di Fisica Nucleare e Struttura della Materia, Catania.

---

[1]H. D. Holmgren, in *International Conference on Clustering Phenomena in Nuclei, Bochum, 1969* (IAEA, Vienna, 1969).
[2]D. F. Jackson and T. Berggren, Nucl. Phys. 62, 353 (1965).
[3]D. F. Jackson and L. R. B. Elton, Proc. Phys. Soc. London 85, 659 (1965).
[4]A. K. Jain and D. F. Jackson, Nucl. Phys. A99, 113 (1967).
[5]A. K. Jain and N. Sarma, Nucl. Phys. A233, 145 (1974).
[6]K. Bahr, T. Becker, O. H. Bilaniuk, and R. Jahr, Phys. Rev. 178, 1706 (1969).
[7]J. R. Pizzi, M. Gaillard, P. Gaillard, A. Guichard, M. Gusakow, G. Reboulet, and C. Ruhla, Nucl. Phys. A136, 496 (1969).
[8]M. Jain, P. G. Roos, H. G. Pugh, and H. D. Holmgren, Nucl. Phys. A153, 49 (1970).
[9]J. M. Lambert, R. J. Kane, P. A. Treado, L. A. Beach, E. L. Petersen, and R. B. Theus, Phys. Rev. C 4, 2010 (1971).
[10]J. W. Watson, H. G. Puch, P. G. Roos, D. A. Goldberg, R. A. J. Riddle, and D. I. Bonbright, Nucl. Phys. A172, 513 (1971).
[11]D. Miljanic, T. Zabel, R. B. Liebert, G. C. Phillips, and V. Valkovic, Nucl. Phys. A215, 221 (1973).
[12]D. Miljanic, J. Hudomalj, G. S. Mutchler, E. Andrade, and G. C. Phillips, Phys. Lett. B50, 330 (1974).
[13]D. Vinciguerra, E. Modica, A. Palmeri, J. Julien, C. Samour, and J. P. Genin, Lett. Nuovo Cimento 14, 333 (1975).
[14]P. G. Roos, D. A. Goldberg, N. S. Chant, and R. Woody III, Nucl. Phys. A257, 317 (1976).
[15]N. S. Chant and P. Roos, Phys. Rev. C 15, 57 (1977).
[16]P. G. Roos, N. S. Chant, A. A. Cowley, D. A. Goldberg, H. D. Holmgren, and R. Woody III, Phys. Rev. C 15, 69 (1977).
[17]R. D. Koshel, Nucl. Phys. A260, 401 (1976).
[18]J. C. Alder, W. Dollhopf, N. Kossler, C. F. Perdrisat, W. K. Roberts, P. Kitching, G. A. Moss, W. C. Olsen, and J. R. Priest, Phys. Rev. C 6, 18 (1972).
[19]P. Kitching, W. C. Olsen, H. S. Sherif, W. Dollhopf, C. Lunke, C. F. Perdrisat, J. R. Priest, and W. K. Roberts, Phys. Rev. C 11, 420 (1975).
[20]W. Dollhopf, C. Lunke, C. F. Perdrisat, P. Kitching, N. C. Olsen, J. R. Priest, and W. K. Roberts, Phys. Rev. C 8, 877 (1973).
[21]P. Kitching, G. A. Moss, W. C. Olsen, W. J. Roberts, J. C. Alder, W. Dollhopf, W. J. Kossler, C. F. Perdrisat, D. R. Lehman, and J. R. Priest, Phys. Rev. C 6, 69 (1972).
[22]W. Dollhopf, C. F. Perdrisat, P. Kitching, and W. C. Olsen, Phys. Lett. 58B, 425 (1975).
[23]R. Frascaria, V. Comparat, N. Marty, M. Morlet, A. Willis, and N. Willis, Nucl. Phys. A178, 307 (1971).
[24]H. Davies, H. Muirhead, and J. N. Woulds, Nucl. Phys. 78, 663 (1966).
[25]S. Barbarino, M. Lattuada, F. Riggi, C. Spitaleri, C. M. Sutera, and D. Vinciguerra, Nuovo Cimento A 53, 327 (1979).