Anomalous effects in alpha particle scattering by ^{9}Be around 40 MeV?

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Introduction

The cluster structure of nuclei and especially the existence of alpha clusters have been extensively studied by means of nuclear reactions and quasifree scattering. We investigate the possibility to demonstrate the cluster structure effects using elastic and inelastic scattering of alpha particles. There are two ways to study clustering effects in a scattering experiment:

i) the study of the backward scattering which is supposed to be dominated by the exchange term of the interaction.

ii) the study of forward effects in the elastic scattering due to the alpha-alpha interactions.

We decided to investigate the latter possibility making use of the well known α - α resonance at 40 MeV (lab. system) Should interactions occur between the incident alpha and the clusters in the target nucleus one would expect to observe an anomaly around 40 MeV (it is supposed that the first step is a pure α - α interaction, the remainder of the nucleus being a spectator) in the forward hemisphere. It should be pointed out that the data on ^{6}Li(α,α)^{6}Li by Bernas et al.[1] in the same energy region indicate departures from the optical model fit. We have chosen a ^{9}Be target which is known to have a strong alpha-cluster structure.

Experimental method

The alpha-particle beam was produced by the isochronous cyclotron of the University of Louvain, and focused on a 2.3 mgs/cm^2 ^{9}Be target located in the center of a 1 m diameter scattering chamber. Four semiconductor detectors were placed, 10° apart, around the target and connected to four preamplifier-amplifier chains. Data were taken at 8 incident energies (35,38,40,42,44,46,48 and 89 MeV) and they were analyzed together with the 104 MeV data reported by Hauser et al.$^{4)}$

The center of mass angles ranged from 35° to 177° (12° to 118° at 89 MeV).

Results and analysis

The experimental results are shown in Fig. 1. for the energy interval from 35 to 48 MeV. One observes in the angular distributions a gradual transition from a distinct diffraction-like pattern in the forward direction to a more or less smoothly decreasing behaviour at the higher energies. No spectacular modification is visible in the shape of the angular distribution around 40 MeV.

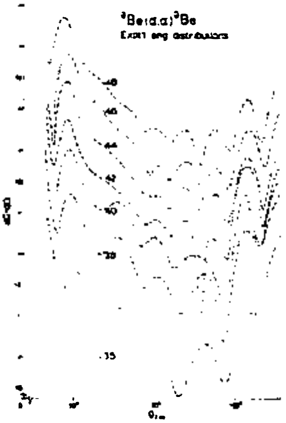


Fig. 1.

The only visible effect we have observed is a maximum at 40 MeV in the integrated forward cross section (30°- 90°) which is 10-20% higher than the slowly rising trend of the cross section in that region. In the backward hemisphere all angular distributions have an oscillatory pattern whose magnitude is about 1-2 order of magnitude above $\frac{d\sigma}{d\Omega}$ Ruth. Various interpretations were attempted:

1. As was done for earlier analyses$^{3)}$ an optical model with a Saxon-Wood form factor was tried in the forward angular region. This was tried in the forward angular region. This was

tried in the forward angular region. This was unsatisfactory. For instance we need an imaginary potential depth W of 51 MeV to reproduce our experimental 42 MeV data. But, unless we assume an unrealistic energy dependence of W we are unable to reproduce even qualitatively our results at 35 MeV.

2. A transposition of the classical Young experiment in optics seems attractive for ^{9}Be(α,α)^{9}Be due to the well known $\alpha + \alpha + n$ cluster structure. In this extreme cluster model the differential cross section factorizes in two terms: a factor representing the α-α interaction and an interference term

$$\frac{d\sigma}{d\Omega}(\alpha-{}^{8}\mathrm{Be}) \propto |f_{\alpha\alpha}(\theta)|^2 \left[1+\frac{\sin q}{q}\right] \text{where } q = 2kR \sin^2\frac{\theta}{2}$$

R being the fixed distance between the alpha scatterers. Blair et al.$^{4)}$ have shown the neglected neutron-alpha interaction contributes to the above expression with a slowly varying modulation factor.

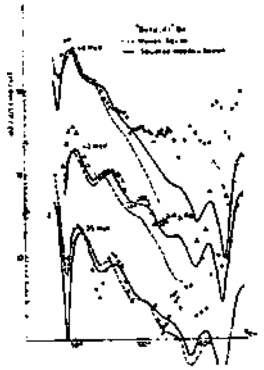
In this framework one thus expects to find in the ^{9}Be(α,α)^{9}Be angular distributions all the features of the α-α scattering distributions. This is even true for more elaborate cluster models. The confrontation with experiment shows however a complete disagreement (oscillations out-of-phase).

3. As far as the backward oscillations are concerned, the excitation functions at 120° as well as the integrated backward cross sections (140° to 180°) do not show any peculiar behaviour as was shown for other target nuclei (as ^{16}O and ^{12}C). We expect exchange processes occur there.

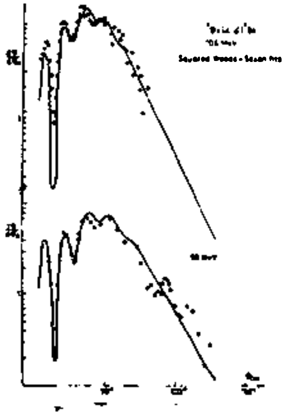
4. On the other hand the integrated forward cross sections (30°- 90°) present a slowly increasing trend to which is superposed a maximum at about 40 MeV. An "anomaly" is seen also for the second excited state cross section. Two conclusions may be drawn:

a) The relative importance of the cross sections for the ground state and 2nd excited state shows coupling is not negligible. This implies a coupled channel analysis has to be done.

b) Is the anomaly around 40 MeV due to the interaction of the projectile with alpha clusters in ^{9}Be?



The only thing that can be ascertained is that the evidence for the anomaly cannot be wiped out in the present stage of theoretical analysis. The studies$^{5)}$ of alpha scattering on calcium isotopes have shown the importance of an adequate radial dependence of the nuclear potential. We tried the same approach in the ^{9}Be case using a squared Saxon-Woods radial dependence for both real and imaginary parts: it gives a good agreement between theory and experiment.



The fits in Figs. 2a) and b) do show a slight improvement upon the regular Saxon-Woods shape but they still require a 10% increase of the potential depth at 40 MeV above the one expected from a monotonic behaviour. The link between the observed anomaly and our initial assumption cannot be fully proved but cannot be a priori discarded.

References

1. M. Bernas et al., Nucl. Phys. A242 (1975) 149
2. G. Hauser et al., Nucl. Phys. A128 (1969) 81
3. F. zu Bentheim et al., Zeit. Phys. A279 (1976) 163
4. J.S. Blair et al., Phys. Rev. 112 (1958) 2029
5. Louvain-Krakow-Münich-Mons collaboration (to be published)