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Effective Deuteron-Nucleus Interaction and Mass Distributions of Nuclei from a Fourier-Bessel Study of Elastic Scattering of Polarized Deuterons at 52 MeV[+)]

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The effective interaction in deuteron scattering at 52 MeV and its dependence on the underlying mass distribution of nuclei has been investigated by the elastic scattering of polarized deuterons. Measurements have been performed at the Karlsruhe isochronus cyclotron on a series of sd-shell nuclei of different isospin. From the measurements on N=Z-nuclei, where due to their isoscalar character the neutron distributions are identical to the proton distributions known from electron scattering, we derive the effective deuteron-nucleon interaction. With the interaction fixed in this way we can deduce then mass and neutron distributions for N≠Z nuclei from the corresponding measurements.

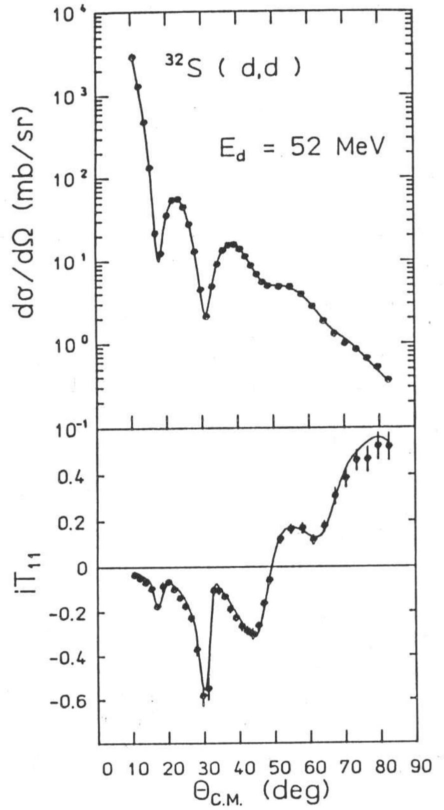

Fig. 1: data and FB-analysis for the elastic scattering from ^{32}S

The analysis of the data has been performed in the framework of the model unrestricted Fourier-Bessel (FB)-method. The inclusion of FB-series in the central part of the optical potential leads to a substantially improved description of the data (solid lines in fig. 1). In the analysis the analyzing power data turned out to be essential for a reliable determination of the central potential, especially at the nuclear surface, where the spin-orbit interaction plays a substantial role.

The real central part of the effective scattering potential resulting from the FB-analysis is shown in fig. 2 for ^{32}S as an example. The dashed area gives the uncertainties derived from the χ^2-error matrix. Compared to the situation at lower deuteron energy[1)] the error band is smaller at the surface of the potential but increases in the interior somewhat more. Due to the limited angular range of the data we found difficulties to fix the potential definitely for radii smaller than 1 fm in the sense that there are solutions which do not overlap completely within their error bands. Therefore the uncertainties for small radii are plotted in fig. 2 twice as large as given by the error matrix. Nevertheless the error band at small radii is still reasonably small compared to similar studies with strongly absorptive probes like high energy protons and alphas. A remarkable feature of the FB-potential is its radial distribution at the surface, which is very close to that of global optical potentials both for deuterons[1)] and nucleons[3)].

The FB-potential is compared in fig. 2 to double folding calculations utilizing the density-dependent M3Y-interaction including exchange[4)], which gives very reasonable results for nucleon, alpha and heavy ion scattering. Initially the calculations have been based on the frozen density approximation, which for the target density certainly is a reasonable assumption, since CC-calculations show virtual collective target excitations to play a minor role at 52 MeV. Then for N=Z-target-nuclei like ^{32}S the mass distribution is given by just twice the experimental proton density distribution. For the deuteron density distribution we used initially the Reid[5] soft core wave function. The resulting folding potential (dotted curve in fig.2) resembles closely single folding calculations of Watanabe[6] type, though being slightly more diffuse due to the dependence of the nucleon-nucleon interaction on the deuteron density. A striking but obvious feature of the folding potential is its surface diffuseness, which is much larger than that of the FB-potential.

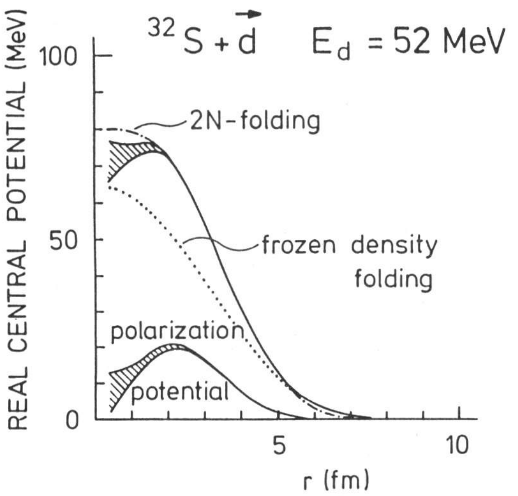

Fig. 2: real central potential for ^{32}S resulting from the FB-analysis in comparison with frozen density folding (dotted line) and 2N-folding (dash-dotted line)

Since the folding concept works successfully for nucleon scattering and also CC-effects due to virtual target excitations are very small the failure of the frozen density folding is attributed to the deuteron breakup. Indeed the dynamical polarization potential, which accounts for the coupling of elastic and breakup channels and which is given by the difference of FB- and folding potentials (fig.2), is similar to that found[1] at lower energy and agrees qualitatively with the trend in the energy dependence predicted by M. Nakano et al.[7].

Guided by the empirical finding mentioned above that the geometries of nucleon and deuteron optical potentials are very close for the real central part, we performed a folding calculation where we accounted for the deuteron breakup by assuming simply a delta function for the effective deuteron point density ("2N-folding"). By renormalizing the result of this calculation with λ=.88, which is very close to the value found at lower energies[1], we get a strikingly good description of the FB-potential, especially at the surface where the error band is very small. From this success we conclude that the effective size of the deuteron in nuclear matter must be very small, i.e. deuterons, which survive the interaction process with the target nucleus, behave inside the target simply like closely spaced pairs of nucleons.

With the deuteron-nucleon interaction thus fixed we derive mass and neutron distributions for N≠Z -nuclei by evaluating the corresponding measurements. First results for ^{40}Ar indicate that the neutron distribution in this nucleus has a shape slightly different from that of the proton distribution.

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