Nucleon-Nucleus Scattering and the Choice between Sets of Nucleon-Nucleon Phase Shifts

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It has become fairly common practice to use the elastic scattering of nucleons from nuclei to differentiate between various sets of nucleon-nucleon phase shifts. The usual procedure is to use the impulse approximation to calculate a nucleon-nucleus optical potential and then to obtain the scattering polarization from this potential in first Born approximation: In effect this gives the scattering resulting from the direct interaction between the incident nucleon and one nuclear nucleon, the nucleus then recoiling as a unit. If the scattering angle is sufficiently small, it is assumed that the effects of being off the energy shell can be neglected and the nucleon-nucleus scattering amplitude can then be expressed in terms of free nucleon-nucleon scattering phase shifts. Sakamoto has carried out such a calculation at several energies in an attempt to distinguish between the phase shift sets given by meson theory, by Gammel and Thaler, and by Signell and Marshak. The purpose of this note is to point out that multiple scattering effects can be expected to obscure the differences between polarizations calculated with different sets and hence make choices based upon the Born approximation unreliable.

At 150 Mev, the predicted polarization is the same for all three phase shift sets at laboratory scattering angles less than 5°, so that an experimental choice between the three calculations of Sakamoto is only possible in the range 5° to 15° where the predicted polarizations differ by about 0.1 and the experimental points range from 0.4 to 0.6. Over this angular interval, the meson polarization rises from 0.3 to 0.5, the Gammel-Thaler polarization goes from 0.4 to 0.6, and the Signell-Marshak curve goes from 0.5 to 0.7 so that the Gammel-Thaler phase shifts are preferred if the Born approximation polarization is to be believed.

However, over this same angular interval, absorption effects due to multiple scattering can decrease the Born approximation polarization by at least 0.1, bringing the Signell-Marshak curve down so as to give an excellent fit to the experimental data and dropping the Gammel-Thaler results below the data. At 90 Mev, absorption effects...
are expected to be even greater, the effect decreasing with increasing energy. One could then assume that it is the Signell-Marshak phase shift set which is now to be preferred. However, it would be wiser at this time, before multiple scattering effects are more thoroughly understood, to make no such conclusions and to rely on additional free-nucleon scattering data which is becoming available for a differentiation among the different sets of scattering parameters.

1) See, for example, Y. Sakamoto, Prog. Theor. Phys. 24 (1960), 783, and references listed therein.