Unitarity and analyticity in nuclear reaction theory

Greben, Jan Meinte

SUMMARY

In this thesis we analyze and extend the applicability of a rather novel, dispersion-like treatment of nuclear reactions.

The first chapter contains a brief motivation for the use of this N/D method to low energy scattering, while the second chapter serves as an introduction to the theoretical foundations and concepts in N/D theory. In Chapter 3 we compare approximate N/D and exact amplitudes in potential scattering. Some (un)physical properties of the N/D amplitudes are analysed and criteria for the validity of the approximations are formulated.

The analytic structure of the (repeated) one cluster exchange amplitudes in nuclear reactions is studied in Chapter 4. Explicit formulae for the second order input functions are given, and a general method for determining the left-hand branch points of amplitudes of arbitrary high order is presented. In contrast to the first and second order input-functions, the third and higher input-functions appear to have quite distant singularities, whose positions are mainly dependent on the ranges of the forces at the vertices.

The complexities arising in N/D theory due to the occurrence of anomalous thresholds - which usually occur for processes involving loosely bound particles - are the subject of Chapter 5. The necessity of including higher order input terms in order to obtain unique amplitudes with the usual reality properties is demonstrated. An extended formalism for this case is developed and reduced to a form which is amenable to numerical calculations.

In Chapter 6 the usefulness of a multi-variable N/D scheme, which describes three particle channels explicitly, is discussed. We further improve upon earlier attempts to treat breakup effects in an approximate fashion.

In Chapter 7 the N/D formalism is applied to n-d scattering. In the doublet case the singlet channel is treated as a bound state channel which necessitates a detailed description of the breakup inelasticities λ. Although our numerical results indicate that for low energies two channel (anomalous) calculations are preferable to one channel calculations as they can qualitatively reproduce the threshold behaviour of the exact inelastic parameters ${}^2\eta_0$, the quantitative agreement depends strongly on the poorly established off-shell functions X. For higher energies (30-40 MeV) the coupling to the second channel does not improve the phase shift results. We give strong arguments that the inclusion of hitherto neglected elements of the inelasticity λ will resolve this discrepancy. Quartet scattering lends itself very well to an N/D description as the input is sufficiently well represented by the lowest order terms and all breakup inelasticities involved can be computed with the extensions of Chapter 6. For the simple off-shell model $X = 1$ a perfect agreement between exact and N/D results is obtained. As the quartet amplitudes dominate the physical cross-sections, the N/D method - suitably extended - is able to give a good description of the quantities which are usually measured in nucleon-deuteron scattering.