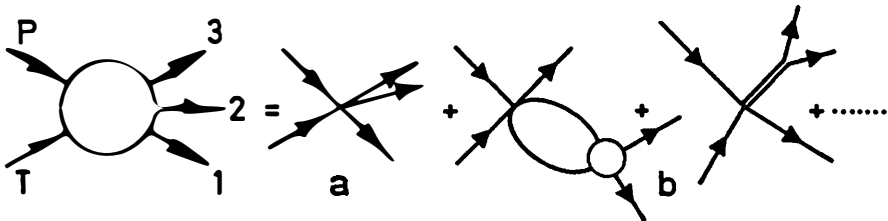


INCLUSIVE SPECTRA OF LIGHT NUCLEUS-NUCLEUS
COLLISIONS-RESULTS AND OPEN PROBLEMS

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Since the early sixties the reaction among light nuclei were described by an infinite series of diagrams whose first few dominant terms are given below for a final state consisting of three particles.



The individual diagrams can be interpreted as follows

- (a) The amplitude is a constant in the whole energy range of emitted particles which means that the interaction between any pair of particles does not depend on their relative momenta.
- (b) The particles produced in the final state are interacting preferentially in pairs via an interaction that is preferentially two body. The first diagram corresponds to what is usually called quasifree scattering or quasifree reactions, while the second diagram corresponds to the so called sequential break-up via resonant or virtual states of two particles.

The mechanisms of the type b) have been extensively studied in the part two decades while the mechanism a) was identified and usually treated as a natural background and ignored as to its origin. However in the recent years a number of experiments were performed that have clearly indicated that processes with a constant matrix element represent usually the bulk of the cross section for the interaction of light nuclei.

The following reactions were studied: $\alpha + \alpha$; ${}^3\text{He} + {}^6\text{Li}$; ${}^3\text{He} + {}^7\text{Li}$; ${}^3\text{He} + {}^9\text{Be}$; ${}^3\text{He} + {}^{10}\text{B}$; $d + {}^9\text{Be}$; $d + {}^{10}\text{B}$; $d + {}^{11}\text{B}$; $p + {}^9\text{Be}$ (1-4). In all these reactions that were measured in a wide range of energies below the meson production threshold remarkably good fits have been obtained (on a logarithmic scale!) using Breit Wigner shapes for resonances and a linear

combination of different n-body phase spaces. We have summarized here the main features that could be extracted from the analyzed data.

i) The leading transition amplitude is connected usually with the most probable three body configuration of the final state. The most probable configuration we call the one that corresponds to no rearrangement among the projectile and the dominant clusters present in the target (e.g. in the case of the α spectra emitted from the interaction of ${}^3\text{He}$ with ${}^7\text{Li}$ the largest amplitude will correspond to the final state with the configuration α -t- ${}^3\text{He}$). The next to it amplitude shall correspond to final states with three particles corresponding to the most obvious rearrangement between the projectile and one of the target's cluster (e.g. in the same reaction as above this will correspond to an interaction between the ${}^3\text{He}$ and the triton in ${}^7\text{Li}$ yielding the final state α nd). After that will follow four and more body final states with much smaller amplitudes. However since the corresponding phase space is much larger, such final states are contributing a large part of the overall cross section.

A direct consequence of the just mentioned feature is that the final channel is strongly influenced by the configuration of the incident channel. This is exemplified by the comparison of the relative strength of final configurations emerging from the reaction ${}^7\text{Li} + {}^3\text{He}$ and ${}^9\text{Be} + p$ respectively, given in table 1.

Table 1

Relative strength coefficients (in arbitrary units) obtained fitting the spectra in the reactions ${}^7\text{Li}({}^3\text{He},\alpha)$ at $E_3 = 42.9$ MeV and $\text{Be}(p,\alpha)$ at $E = 50$ MeV.

| Final channel | R e a c t i o n | |
|------------------------------|---------------------------------------|---------------------------|
| | ${}^7\text{Li}({}^3\text{He},\alpha)$ | ${}^9\text{Be}(p,\alpha)$ |
| α nd | 7.77 ± 0.5 | 8.1 ± 1.3 |
| α t- ${}^3\text{He}$ | 13.8 ± 1 | 1.8 ± 2.5 |
| α - ${}^5\text{He}$ p | - | 15.6 ± 5.4 |
| α α pn | | 0.065 ± 0.026 |
| α t dp | 0.033 ± 0.007 | 0.069 ± 0.047 |

ii) The amplitudes of the matrix elements exhibit distinctive angular distribution. The amplitudes belonging to three body final states are rapidly decreasing with angle while the more complicated breakups do not decrease with angle and in some cases even increase.

iii) In the cases where the same reaction was measured at several energies a decrease in the amplitudes has been observed. Even if one takes into account that with increasing energy the number of final channels that are open increases the total amplitude of all channels decreases.

When searching for the origin of the constant matrix mechanism one way is to search for processes that would allow for a rapid equilibration of energy among the participant particles.

The dependence of the final state on the configuration of the initial state excludes in our opinion a classical compound nucleus formation with subsequent evaporation and coalescence of clusters. Also, it is impossible to explain the equilibration so the result of a multiple scattering⁵⁾ inside the nucleus if one invokes usual 2-body forces.

Namely the relatively large mean free path of nucleons (~6 fm) in nuclear matter results in any case in mean free paths for composite particles that are of the order of radii of the nuclei in collision. Therefore it is not possible to envisage any kind of cascade among the various clusters that would allow the equilibration that we observe. Some authors have tried to explain some features of inclusive spectra introducing a

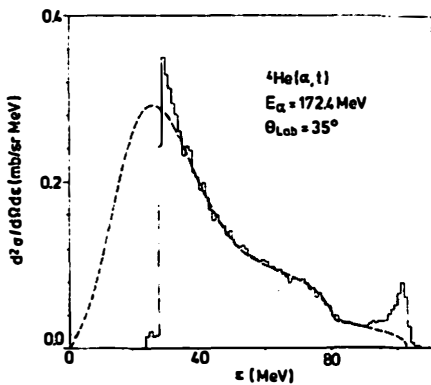


Fig. 1.

picture in which the incoming projectile interacts inelastically and then the remaining residual nucleus decays into the available phase space⁶⁾. However we do not observe this phenomenon in the experiments we have analysed, as is visible from the triton spectrum from the reaction ${}^4\text{He}({}^4\text{He}, t)$, shown in Fig. 1. The dashed curve shows the fit obtained with phase space spectra only. The kink around 80

MeV triton energy corresponds to the onset of the $d\text{-}^3\text{He-t}$ phase space. It is clear that really all particles have shared the available energy. We are therefore forced to conclude that the origin of the mechanisms with a constant amplitude is still open and that one might have to invoke very strong short range interactions between clusters to be able to explain the phenomenological features observed.

The decreasing amplitude of the constant matrix element mechanism with energy is conform to the idea that in the high energy limit the interaction is well described via the quasi free processes on individual nucleons or clusters.

According to the calculations that show that low partial waves do not contribute to the quasifree process⁷⁾ one may suggest that the low partial waves of the incoming particle do contribute to the constant matrix element mechanism.

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