ON THE ROLE OF DIRECT AND SEQUENTIAL PROJECTILE BREAKUP BELOW 20 MeV/NUCLEON

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Direct projectile breakup - well established for the classic example of the deuteron, but beyond this demonstrated[1] only up to ^{7}Li - has supposed to play an important role also for heavier projectiles, where it has been invoked notably for the interpretation of inclusive cross sections above 10 MeV/nucleon. Coincidence experiments, however, yield contradictory results. Sequential breakup (excitation of the projectile into long-living particle-unstable states, which subsequently decay by particle emission) has definitely been observed[2,3,10], and many groups find that their results don't contradict the assumption of pure sequential breakup[3-7], while others[8,10] claim to find evidence for a direct breakup into the continuum not proceeding through intermediate excited states of the projectile. Also the "uncorrelated emission"[2,9] belongs to this category. These contradictions are partly due to experimental difficulties and the fact, that both types of breakup correspond to similar kinematical conditions. To clarify the situation we made a careful coincidence experiment characterized by good energy and angle resolution, large angular range, a clean target (gold) and an appropriate projectile (^{20}Ne) whose cluster structure should favour its direct breakup into α-^{16}O. The ^{20}Ne beam supplied by the VICKSI accelerator of the Hahn-Meitner-Institut Berlin had an energy of 290 MeV. Projectile-like fragments and α-particles were detected in coincidence by means of solid-state detector telescopes.

We first consider the results for <u>elastic</u> α-^{16}O coincidences ($|Q-Q_{ggg}|<2$MeV) and <u>quasielastic</u> α-^{15}N coincidences ($|Q-Q_{ggg}|<50$MeV). From the energies of the coincident ejectiles one may deduce, in addition to the three-body Q-value, the distribution of relative energies (fig. 1c) of the α-^{16}O and α-^{15}N pairs which correspond to excitation energies of the ^{20}Ne or ^{19}F fragments prior to their decay. The concentration of strength on known narrow levels of the intermediate ^{20}Ne and ^{19}F fragments proves that the α-particles are sequentially emitted from these fragments formed in the first reaction step. The same is demonstrated by the display of the coincident events in the

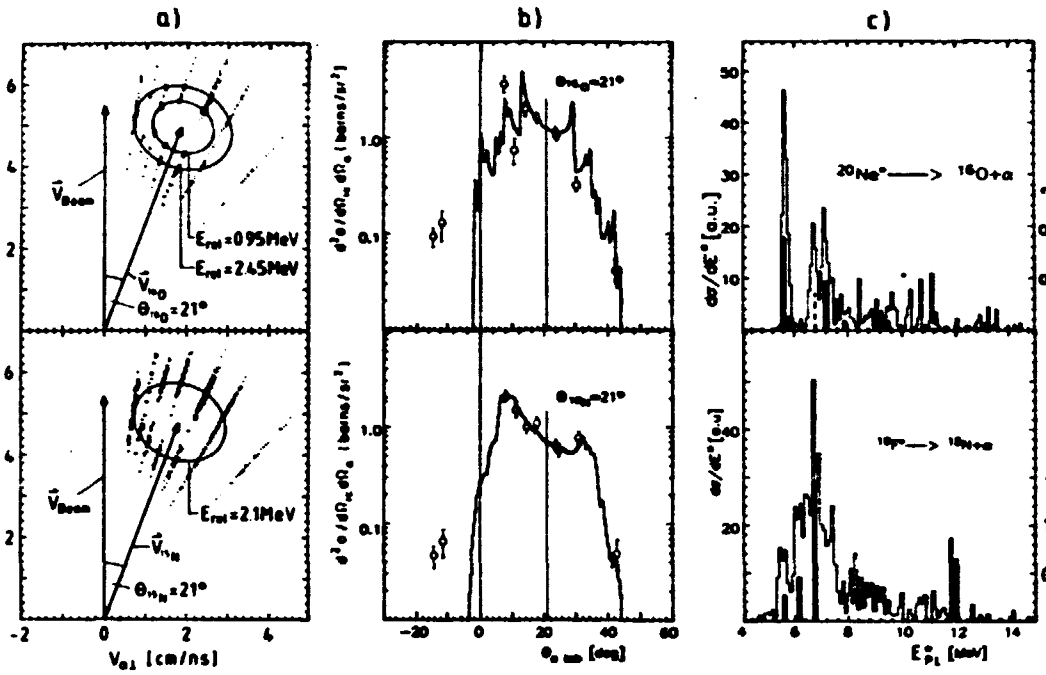

Fig. 1

velocity plane (fig. 1a) where the α-particles emitted from a certain level are found on ellipses around the velocity vector of the emitting fragment. Taking the strengths of the ^{20}Ne and ^{19}F levels from the measured α-particle intensities at 24°, one may calculate the angular correlation. This has been done (fig. 1b) assuming isotropic emission from the decaying fragment, and taking the angular distribution of the primary ^{20}Ne and ^{19}F from the inclusive ^{19}F angular distribution. The agreement with the measured (energy-integrated) angular correlation is very good, except for negative angles where the calculation has a cutoff at -3° due to an upper and lower threshold of the α-detector at 24° (limiting the detected excitation energies of the emitting fragments, which serve as input in the correlation calculation, to 14 MeV). The measured values agree, however, with the extrapolated trend of the calculated sequential-decay correlation and there is no need to attribute this cross section to quasielastic direct breakup or uncorrelated emission. Even when doing so one obtains a very small cross section. The new information connected with the present results is (i) that the dominant part of the total coincident quasielastic cross section is concentrated at discrete excitation energies of the primary projectile-like fragments (fig. 1c) demonstrating the dominance of sequential decay from these fragments, and (ii) that the strength distribution in fig. 2c closely ressembles that extracted from inelastic scattering[11] or proton pickup[12] from ^{20}Ne as measured with light projectiles (displayed by bars in fig. 1c). This indicates that the first reaction step

belongs to the well-known class of direct reactions (inelastic scattering, transfer). (iii). The analysis of the angular correlation (fig. 1b) leaves little if any cross section for uncorrelated emission[2,9] or direct breakup[1,8]. We have also repeated the $^{20}Ne+^{40}Ca$ experiment[8] and find by the same analysis that the $\alpha-^{16}O$ angular correlation - considered in ref.8 as verification of direct breakup - is completely due to sequential breakup.
The situation changes if we consider <u>deep-inelastic</u> events, as done in fig.2 for $\alpha-^{15}N$ coincidences with $|Q|>70$ MeV. We performed an analysis completely equivalent to that described above to obtain the energy-integrated angular correlation of the sequential-decay component. Here at negative angles the measured correlation (after subtraction of background from contaminant carbon) exceeds the sequential-decay correlation by about one order of magnitude. The corresponding α-particles, therefore, are not sequentially emitted by long-living ^{19}F fragments but rather emerge in an early reaction phase. The preferential correlation with ^{15}N fragments on the opposite side of the beam indicates at the same time that these deep-inelastic fragments have undergone orbiting.

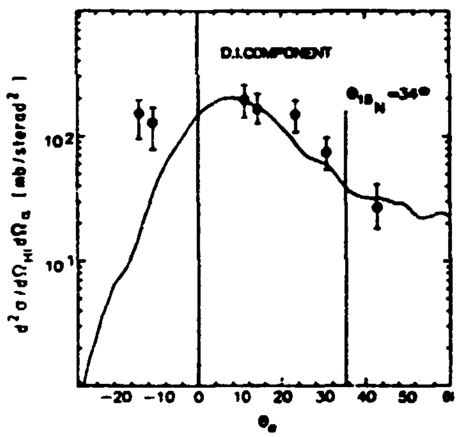

Fig. 2

In sum we have shown with ^{20}Ne projectiles of 290 MeV that direct breakup plays little if any role in quasielastic collisions, but shows up to a certain extent in deep-inelastic collisions.

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