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EXPERIMENTAL EVIDENCE FOR THE EMISSION OF HIGH-ENERGY GAMMA-RAYS FROM THE DINUCLEAR SYSTEM FORMED AT THE FIRST STAGE OF THE FUSION REACTIONS $^{nat}Sn + ^{20}Ne$ (164,196 MeV)

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$^{119}_{50}Sn$ $^{20}_{10}Ne$

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1. Introduction

The broad "bumps" in the gamma-spectra measured at energies $E_\gamma > 8$ MeV in heavy ion reactions are used to be associated with the decay of the giant dipole isovector resonance (GDR) built upon the high excitation states of the compound nucleus [1]. However the life time of the typical GDR is of the order of several times 10^{-21} seconds [2], which is comparable with the life time of the typical dinuclear systems formed during the first stage of the heavy ion fusion reactions [3]. Therefore, in principle, the corresponding high-energy gamma-rays can be associated both with the dinuclear system or the compound nucleus. The time scale for the emission of the preequilibrium alpha particles in the reactions with light ions is assumed to be about 10^{-22} seconds [4], as compared to the time scale for the evaporation of alpha particles, which is about 10^{-20} seconds. So, one can use coincidences with alpha particles as a trigger to study experimentally the time scale for the emission of high-energy gamma-rays in heavy ion fusion reactions. The first results of such a study follow.

2. Experiment

The beam of ^{20}Ne ions from the U-400 cyclotron of the Laboratory of Nuclear Reactions of JINR hit a thick ^{nat}Sn target. The energies of neon ions were 164 MeV and 196 MeV. Gamma-rays were registered by a BGO Ø 46x60 mm detector placed perpendicularly to the beam direction at a distance of 100 mm from the target. The preequilibrium alpha particles, which dominate at forward angles, were registered by a silicon telescope placed after the thick target and the evaporated alpha particles were recorded by a ring detector with a mean angle of 140 degrees to the beam direction.

3. Results

It is known that the yield of high-energy gamma-rays is governed mainly by the excitation energy of the compound nucleus [1]. Therefore, if the high-energy gamma-rays were emitted at times longer than 10^{-20} seconds, e.g. after the evaporation of alpha particles, both gamma-spectra are expected to be the same. However the gamma-spectra associated with forward peaked alpha particles (lower curves) clearly differ from those associated with backward ones (upper curves), see Figs. 1 and 2. If the high-energy gamma-rays are emitted before particle evaporation, but after the preequilibrium ones, one can expect a decrease in the ratio of the gamma-ray yields associated with forward and backward alphas, as the excitation energy of the nuclear system at the time of gamma-ray emission is lower for gamma's emitted after preequilibrium alphas. This is clearly not the case, as is seen from the ratio increase above the gamma-ray energy of 8 MeV, Figs.3 and 4. On the other hand, the double humped form that manifests itself in the experimental data, leads us to assume the split of the GDR into two components, in correspondence with the expected deformation of the gamma-ray emitter. In the framework of this assumption we tried to fit experimental data. The results are given in Table 1, and demonstrated by full lines in Figs.1, 2, 3 and 4. It is natural to relate the energy difference between the two components to the degree of the deformation of the emitter of high-energy gamma-rays. In such a framework, from the analysis given above one can conclude that the deformation of the gamma-ray emitter is larger in the case of forward alphas as compared to the case of backward alphas in both of the reactions studied. It should be noted that in the reaction Sn+Ne(164 MeV) the corresponding value of the deformation parameter β is about 0,7. This value is expected for the case of the dinuclear system [3].

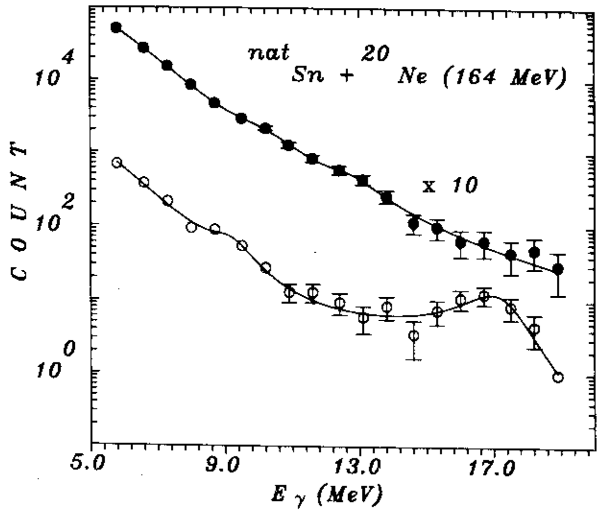

Fig.1. Spectra of gamma-rays gated by registration of backward (closed symbols) and forward (open symbols) emitted alpha particles in the reaction $^{nat}Sn+^{20}Ne$(164 MeV).

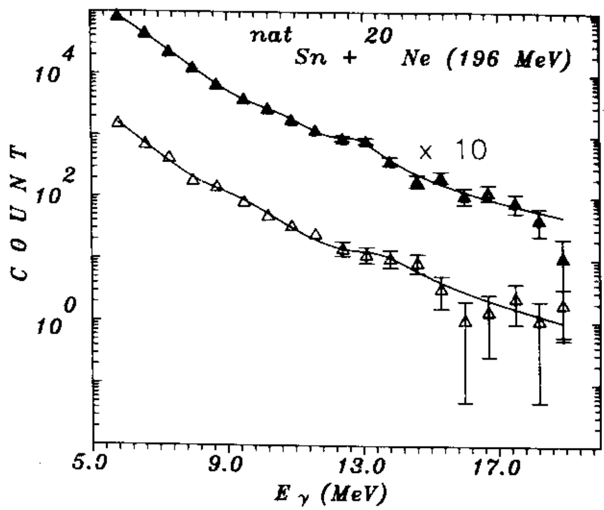

Fig.2. Spectra of gamma-rays gated by registration of backward (closed symbols) and forward (open symbols) emitted alpha particles in the reaction $^{nat}Sn+^{20}Ne$(196 MeV).

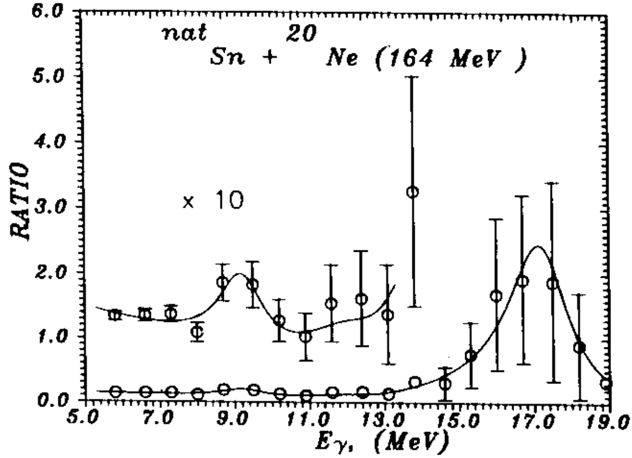

Fig.3. Ratio of the yields of gamma-rays gated by registration of forward and backward emitted alpha particles in the reaction $^{nat}Sn+^{20}Ne$(164 MeV). Full line is the result of the fit.

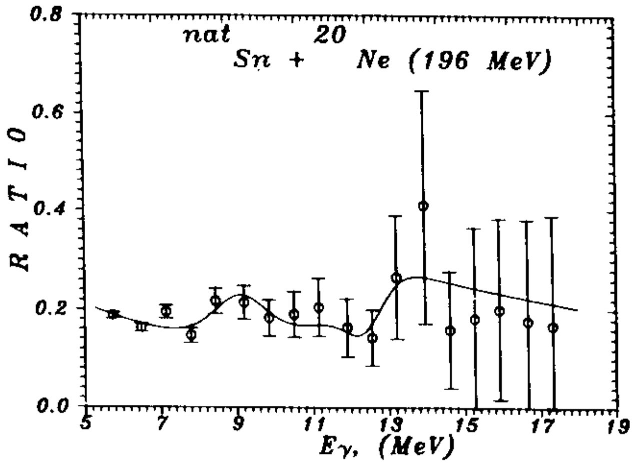

Fig.4. Ratio of the yields of gamma-rays gated by registration of forward and backward emitted alpha particles in the reaction $^{nat}Sn+^{20}Ne$(196 MeV). Full line is the result of the fit.

Table I : Parameters of the fit

E_{ion}	164 MeV			196 MeV		
DETECTOR	E_1	E_2	Γ	E_1	E_2	Γ
" 0° "	9,1	16,7	2,4	10,9	13,9	2,8
"140°"	10,0	13,2	3,0	10,6	12,4	3,0

4.Conclusion

The experimental gamma-spectra associated with forward and backward alphas in the reactions $^{nat}Sn+^{20}Ne$(164,196 MeV) can be described assuming the GDR splitting into two components. The corresponding deformation of the gamma-ray emitter increases in the case of forward "fast" alpha particles. These facts can be interpreted as an observation of the emission of high-energy gamma-rays from a strongly elongated dinuclear system after the emission of preequilibrium alpha particles.

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