FORMATION MECHANISMS FOR MASSIVE FRAGMENTS PRODUCED IN RELATIVISTIC PROTON INTERACTION WITH HEAVY NUCLEI

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A violent fission phenomenon was observed as an important process in the experimental study of heavy nucleus disintegration induced by 1 GeV protons /1/. Further investigations were performed on the massive fragment formation in heavy nuclei by proton beams at the Gatchina synchrocyclotron. Large nucleon losses were determined in the fission process, detected by two independent experimental installations.

The two-stage on-line mass spectrometer and the multiparameter SAVEC (Spectrometer of Angle-Velocity-Energy Correlation) arrangement /2/ made it possible to find that the nucleon losses could reach a value of $\Delta M = (45 \pm 2)$ u for neutron-deficient Rb-fragments in the ^{238}U fission by 1 GeV protons /3/. The time-of-flight measurements /4/ showed still larger nucleon losses. It was also shown /1/ that the fragment transverse momentum distributions corresponded to a random nucleon emission with a mean nucleon rms momentum $q = (123 \pm 4)$ MeV/c. This conslusion is correct only for events where nucleon losses ΔM are not larger than 45u. Beginning with the threshold $\Delta M = (45 \pm 5)$ u the transferred transverse momentum distributions could not be accounted for by a random nucleon emission. The experimentally measured mean transverse velocities of the missing mass

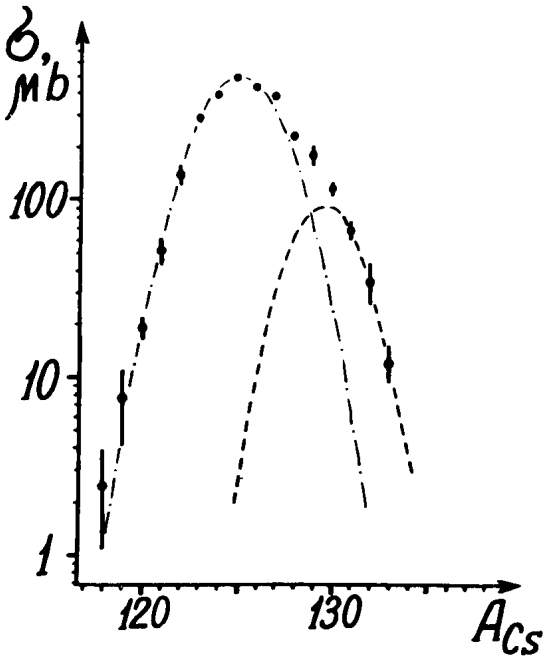

Fig. 1. Cs isotopic distribution obtained in Ir disintegrations by 1 GeV protons

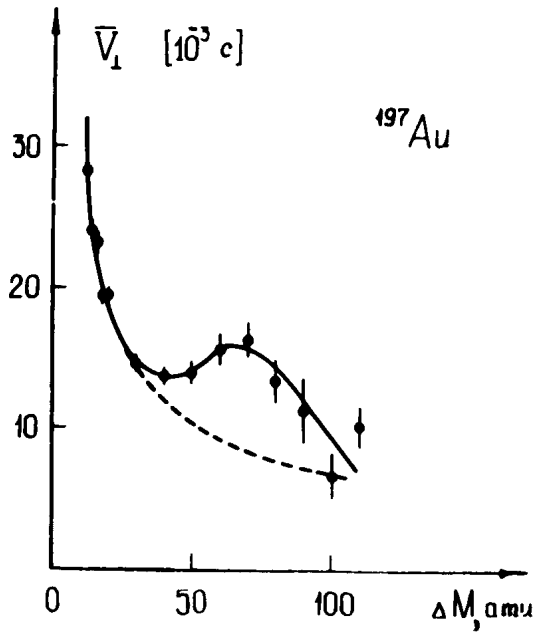

Fig. 2. Missing mass mean transverse velocity dependence on value of nucleon losses in ^{197}Au fission process

are always larger than the calculated ones. This gives evidence of transition from two-body to three-body fission kinematics in the missing mass region of (60—70) u.

Experiments were continued with nuclear emulsions loaded with ^{238}U nuclei /5/ in order to elucidate the role of the fission process into three fragments of comparable masses. It was found that the cross section ratio for ternary and binary fissions of ^{238}U by 1 GeV protons was equal to $(4.7\pm\pm0.5)\cdot10^{-4}$. The probability of violent fission was estimated to be $(1.4\pm0.5)\cdot10^{-2}$ (of the total number of detected fission events) for collinear geometry and $(2.4\pm0.3)\cdot10^{-2}$ for noncollinear geometry /6/. The nucleon losses in violent fission were sufficient for the formation of the third massive fragment. Meanwhile events with two massive fragments accompanied by large nucleon losses were detected more frequently than ternary fissions. Agreement between all experimental data may be achieved if the formation of particle-unstable massive fragments in heavy nucleus disintegrations is induced by 1 GeV protons. The collective motion of the large missing mass may be inherent not only for the ternary fission process but for the spallation reaction as well, when a single massive residual fragment is formed. This phenomenon was studied with the help of an on-line mass spectrometer in disintegration of Ir nuclei by 1 GeV protons /7,8/. The shapes of the obtained isotopic distributions differ from the normal ones due to additional yields of neutron-rich isotopes. The deviation of the experimental data from normal distribution turned out to be equal to (4 ± 1)% for $^{88-92}$Rb, (5 ± 2)% for $^{90-94}$Sr, and (13 ± 2)% for $^{128-133}$Cs. The most interesting case for Cs distribution is shown in fig. 1. The experimental data can be described as two normal distributions. The mean mass value of the first normal distribution is equal to (125.2 ± 0.1) u which corresponds to the calculated mean mass of heavy fragments. The second distribution shown in fig. 1 has a mean mass value of (129.8 ± 0.2) u and cannot be accounted for by the cascade-evaporation calculation. The missing masses, corresponding to the second distribution, occupy the region of (59—68) u. It is in good agreement with the mass range for the maximum recoil velocity, shown in fig. 2, for the missing mass of the ^{197}Au fission process induced by 1 GeV protons. This coincidence gives important support in favour of the particle-unstable fragment formation as a limiting case of collective interaction of relativistic protons with heavy nuclei /9/.

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