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THE BINARY AND TERNARY DECAY OF HOT HEAVY NUCLEI PRODUCED IN THE REACTION ^{14}N (34 AMeV) + ^{197}Au*

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1. INTRODUCTION

Nuclear fission is for a large interval of excitation energy the dominating decay mode of sufficiently intense heated heavy nuclei. This binary disintegration into two fission fragments (FF) of nearly equal mass mainly competes with the emission of neutrons and — at temperatures higher than 3 MeV [1] — light charged particles (LCP). Recently, a combined dynamical-statistical description of this complex interplay has been developed [2]. It should be well established now that the fission of heavy nuclei represents an overdamped collective motion over a saddle in the hyperplane of potential energy to a considerably large-deformed scission configuration, and proceeds in a time scale of several units times 10^{-20} s [3].

The total kinetic energy release (TKE) of the fragments is then defined by the Coulomb repulsion between the preformed FF at the scission point. A first empirical parametrization of the mean TKE was already given in 1966 [4], considering that being explicitly governed by the Coulomb term $Z^2 / A^{1/3}$ where Z and A denote the atomic and the mass number of the fissioning nucleus, respectively.

The emission of light particles from a heated nucleus, as treated by the statistical model, is usually considered to be an evaporation process. The probability P_{ev} is then given by the level density which for a Fermi - gas takes the asymptotical form of a Bolzmann factor

$\rho(E^*) \sim \exp(2\sqrt{a E^*})$, where E* is the excitation energy, and the level density parameter - a - is proportional to A. In the case of LCP one has to take account of the Coulomb barrier (B_C) getting $P_{ev} \sim \exp(2\sqrt{a (E^*-B_C)})$. The characteristic time for particle evaporation can be evaluated by $\tau_{ev} \sim 1 / P_{ev}$ keeping in mind the statistical nature of the decay. The inclusive spectra of the particles are well described by Maxwell distributions characterized by the temperature of the emitting nucleus. For *charged* particles, the spectra have a lower limit at B_C. Of course, the nucleus is no heat bath, but cools down during particle emission what is essential in describing long evaporation cascades. The combined dynamical-statistical model of fission mentioned above is an attempt to take this feed-back into account in the fission-evaporation competition.

Investigations of heavy-ion induced reactions at intermediate energies — in the so-called Fermi-energy domain — which became possible in the 1980's, showed that, besides LCP, also complex fragments of intermediate mass (IMF) are emitted. Somewhat arbitrarily one defined the IMF as being fragments of mass $4 < M_{IMF} < 20 \div 30$ (or $2 < Z_{IMF} < 10 \div 15$) but, in any case, of mass between that of the evaporative LCP and the FF. They can be of very different origin (cf. ref. [5]). For the present, we want to consider only such IMF which were emitted from an *equilibrated* (compound-like) source. The formation of an excited compound nucleus due to an incomplete fusion reaction, characterized by only partial linear momentum transfer (LMT < 1), has been observed in many experiments (e.g. refs. [6, 7]). From pure statistical considerations Moretto et al. [5] already presumed that "fission and evaporation are the two particularly (but accidentally) obvious extremes of a single statistical decay process, the connection being provided in a very natural way by the mass asymmetry coordinate". Since the transition-state model of fission delivers for the fission probability $P_f \sim \exp(2\sqrt{a^* (E^* - B_f)})$, i.e. an expression of the same form as for evaporation, at sufficiently high E* the fission yield should be only governed by the energetically allowed phase space flux over the "ridge line" [8], the line connecting the conditional saddle points (B_f) for all possible mass splitting.

The statistical approach treating the disintegration of the compound nucleus as being controlled by the phase space only, of course, neglects any fission dynamics. The transient times in the fission process [3], on the other hand, document the presence of dynamical hindrances mainly caused by the action of the nuclear viscosity. It is, therefore, of interest to investigate how they affect other observables like, e.g., the TKE-M-distribution.

We here presuppose the binary character of the decay. Although it is known that binary decays dominate up to considerably high E* [9, 10], one has to check each event for complete massive fragment detection.

In this work we analyzed the TKE-M-distribution of binary fragments measured for the reaction ^{14}N (34 AMeV) + ^{197}Au [11].

In the range of excitation energy E* considered here, fission is not only accompanied with the emission of many neutrons and some LCP, but in a small amount of events also an IMF is observed together with two FF [12, 13]. The origin of these IMF is another interesting question. Here, the time development of the disintegration process is essential. If the IMF was emitted well before fission starts, both the excitation energy and the fissionability of the heavy remnant were reduced much more than in the case of a prior-to-fission emitted light particle. A time-scale analysis of three-fragment decays of the composite system produced in the reaction ^{22}Ne (60 AMeV) + ^{197}Au was performed by considering angular and velocity correlations in ref. [14]. The best agreement between the data and the results of trajectory calculations there was obtained if a rather fast sequential process has been assumed. The mean time interval between the two fragment separations amounted to 10^{-21} s.

Another distinct low-energy IMF-component was found in ref. [15]. Because of the focusing of its yield into angles near 90° with respect to the fission axis, the effect was interpreted as an emission out of the neck formed during fission.

In the reaction ^{14}N (34 AMeV) + ^{197}Au we also recorded three-fragment events. We performed a correlation analysis which is especially sensitive to the time interval between the IMF emission and the final fission of the system. On the basis of the limited statistics of the present experiment, however, only a qualitative discussion is possible. A more detailed analysis of three-fragment correlations is planned to be performed on the basis of a high-statistics data body recently recorded for the reactions ^{14}N (53 AMeV) + ^{197}Au and ^{14}N (34 AMeV) + ^{232}Th.

2. THE EXPERIMENTAL METHOD

The measurement has been carried out at the heavy-ion beam of the U-400M cyclotron of the FLNR JINR Dubna using the 4π-fragment-spectrometer FOBOS [16].

This multi-detector array consists of 30 combined detector modules mounted on the facets of a truncated isocahedron, and realizing a so-called logarithmic detector device. Three shells of

i) position-sensitive avalanche counters,
ii) axial-field (Bragg-) ionization chambers, and
iii) CsI (Tl)-scintillators

measure the coordinates (ϑ,φ), the time-of-flight (TOF), the residual energy (E), and the Bragg-peak height (BP ~ Z) of the fragments, as well as scintillator signals suited for the LCP identification by use of the pulse-shape analysis method [17].

From the measured quantities the individual fragment masses (M_F) and the momentum vectors (P_F) can be derived applying the TOF-E-method "event by event" without any kinematical assumption [18]. For two-fragment decays the sum of the parallel momenta $(P_{F1} + P_{F2})_{||}$ was checked to select events of large LMT $\approx$ 0.8. The LMT has been used as a rough measure of E* of the composite system. A sufficiently large value of the total fragment mass ($M_{F1} + M_{F2}$) together with a limited transverse momentum $(P_{F1} + P_{F2})_{\perp} < 500$ MeV/c were used as criteria for the selection of coplanar binary decays. The TKE was calculated from the both independently measured masses and the relative velocity. This method excludes any influence of prior-to-scission processes (fluctuations in incomplete fusion and in the evaporation cascade) on the result.

We must emphasize here that in the very asymmetric reaction induced by the light ^{14}N projectile fragments of $M_F \geq 14$ should only originate from the *decay of a compound-like system*, and deep-inelastic components are excluded. In reactions induced, e.g., by heavier projectiles (like ^{40}Ar, ^{27}Al; see Refs. [9, 19]) this is in general not the case, and the picture becomes more complicate. An additional condition for ruling out of any possible fast processes was the selection of only such events for the further analysis where the lighter of the both fragments was emitted "backwards" in the c.m. frame.

At energies of E* ≤ 400 MeV of the hot system produced by the given reaction, the amount of three-body decays (IMF-accompanied fission) amounts to less than 1 % [13], and the bulk of the data is due to binary disintegrations. The recorded three-fragment events were checked by the same criteria as in the binary case, but the sums were taken over three fragments, and the entire LMT-range was accepted.

A special method has been applied to study proximity effects in IMF-accompanied fission. The c.m. frame (v) of *the two heavy fragments* (F1, F2) was determined from both their masses and momentum vectors (eq. 1), and the velocity (v^{lab}) of the third fragment (IMF) was then transformed (eq. 2) into this frame (v^{rel}).

$$v_{F1\,F2} = (P_{F1} + P_{F2}) / (M_{F1} + M_{F2}) \tag{1}$$

$$v^{rel}_{IMF} = v^{lab}_{IMF} - v_{F1\,F2} \tag{2}$$

The angle between the direction of the emitted IMF and the fission axis with respect to (F1, F2) was determined in the same frame.

3. TWO - FRAGMENT DECAY

3.1 Experimental results

Binary events restricted by the above formulated conditions are shown in the TKE versus M contour plot of fig. 1. To demonstrate the large full width of this distribution in mass and energy, and to illustrate the resolution obtained by the application of the TOF-E-method, we chose a logarithmic intensity scale with a factor of 2 between subsequent contour lines.

The main yield in fig. 1 is due to normal symmetric multi-chance fission of the hot equilibrated system, but very asymmetric mass splitting extends to fragment pairs usually classified by their masses as IMF and heavy residues, respectively. The mean value $< M_F > =$ 176 a.m.u. corresponds to an average mass-loss (with respect to complete fusion) of 36 a.m.u. due to pre-compound particle emission (incomplete fusion) as well as prior-to- and post-scission evaporation. The branch of the heavy fragment is slightly broader than that of the light one because of the larger corrections for energy losses in the detector window materials and, therefore, slightly larger uncertainties in the mass determination.

The large TOF-path of the FOBOS array (50 cm), and the timing properties of the position-sensitive avalanche counters allow an accurate measurement of the fragment velocities (v_F). The derived relative velocities between binary fragment pairs (v_{rel}) are drawn in symmetric fission of $< v_{rel} >^{sym} = 2.4$ cm / ns is in accordance with the systematics of ref. [4].

By scaling of the TKE - formula [4] with the asymmetry factor $4M_1 M_2 / (M_1+M_2)^2$, accordance of the experimental data $< v_{rel} >$ with the evaluated values is observed for asymmetric mass splitting down to dependence on M_F in the contour plot of fig. 2. The mean value at

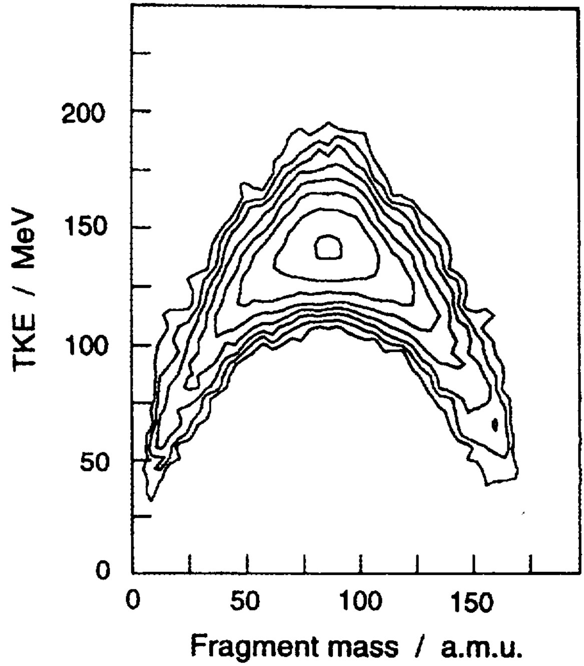

Fig. 1 TKE-M-distribution of binary fragment pairs of the hot compound system formed after incomplete fusion (LMT ≈ 0.8) in the reaction ^{14}N (34 AMeV) + ^{197}Au [20].

about 1 : 3. At larger mass asymmetry of the decay the $< v_{rel} >$ considerably deviate from a parabola, as can directly be seen in fig. 2. A similar deviation of measured $< v_{rel} >$ from a Coulomb calculation was earlier observed for asymmetric binary decays in the reaction ^{139}La (18 AMeV) + ^{12}C (cf. fig. 23 in ref. [5]). There, the $< v_{rel} >$ are found to be increasingly larger than the calculated values with decreasing atomic number of the fragments starting at Z < 20. Our observations agree with this set-in of some deviation.

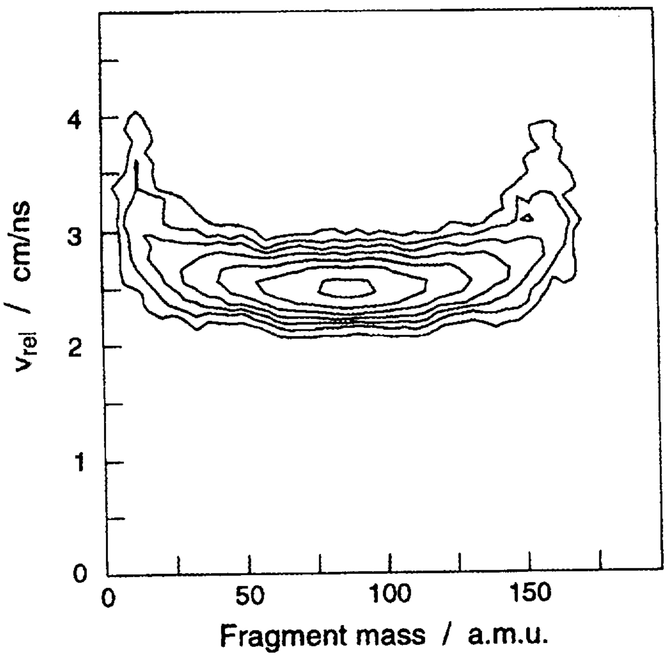

Fig. 2 v_{rel} -M-distribution for the same events like in fig. 1 [20].

3.2 Analysis of the TKE - M - distribution

On the basis of the data presented in fig. 1 and fig. 2 we analyzed the TKE-spectra for mass bins of ΔM_F = 5 a.m.u. These spectra have a symmetric shape except for the smallest fragment masses at

M_F < 25 a.m.u. The mean values <TKE> are plotted versus the mean values of the mass bins in fig. 3.

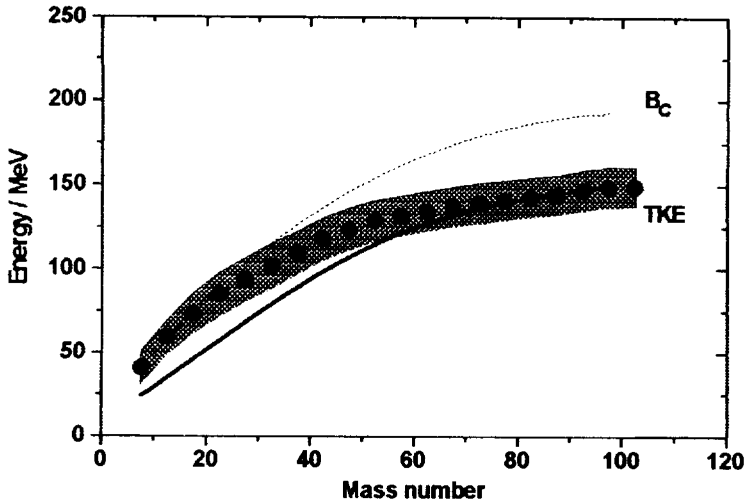

Fig. 3 Measured <TKE> (full circles) versus the fragment mass. The hatched area corresponds to $\pm\ \sigma$ (TKE). The full line is calculated using the TKE - formula [4] scaled for asymmetric mass splitting, the dotted line represents a B_C -calculation.

The <TKE> and the standard deviations σ (TKE) were determined by Gauss-fits over ranges in these spectra where the yield exceeds 10 % of the maximum. For comparison, we also plotted the calculated TKE [4] and the Coulomb barrier B_C [21].

Starting from symmetric fission, one observes that the <TKE>, being the "most probable" TKE-values for the mass bins considered, at first follow the line calculated by use of the TKE - formula, and then smoothly approach to the B_C-line. Below $M_F \approx 50$ a.m.u. the deviation from the calculated TKE exceeds one σ(TKE), and below $M_F \approx 25 \div 30$ a.m.u. the <TKE> are well reproduced by the Coulomb barrier B_C.

Presuming for fission of hot nuclei that $M_1 / M_2 = Z_1 / Z_2$ (where the compound nucleus is given by $M = M_1 + M_2$ and $Z = Z_1 + Z_2$), the scaling factor for the calculation of the TKE at asymmetric mass splitting can be taken as $4M_1 M_2 / (M_1+M_2)^2$ or $4Z_1 Z_2 / (Z_1+Z_2)^2$. It is obv ious that in this manner one takes only account of a re-distribution of the charge of the fissioning nucleus between the fragments. In the framework of the two-spheres approximation [4], the Coulomb repulsion at scission is responsible for the TKE. It also changes with the effective distance (D_{sc}) between the fragments. Formally, one gets $D_{sc} \sim A_1^{1/3} + A_2^{1/3} \leq (A / 2)^{1/3} \sim D_{sc}^{sym}$. This approximation does not hold for more asymmetric mass splitting. Consequently, the average scission shapes should become more compact leading to an enhanced Coulomb repulsion and, therefore, to the larger <TKE> values observed (fig. 3).

This behaviour of the <TKE> reflects the approaching of the conditional scission points to the ridge line of conditional saddle points with increasing asymmetry of the binary decay. Furthermore, as the descent from the saddle to the scission point is responsible for a large amount of the fission transient time [3], this should be a hint that more asymmetric disintegrations proceed faster than symmetric fission because they are less damped.

If we understand the difference between the barrier B_C and the measured <TKE> as the mean amount of dissipated energy (E_{Diss}) on the fission path to scission, the vanishing damping at sufficiently large mass asymmetry becomes evident. With the expression $A_1 A_2 / A^2$ chosen for the mass asymmetry, the dependence of the dissipation on this parameter becomes linear in a fairly wide region (fig. 4). For the most asymmetric mass splitting, E_{Diss} becomes formally even negative reflecting the amount of kinetic energy which the light cluster gets from the hot emitting nucleus in an evaporation process.

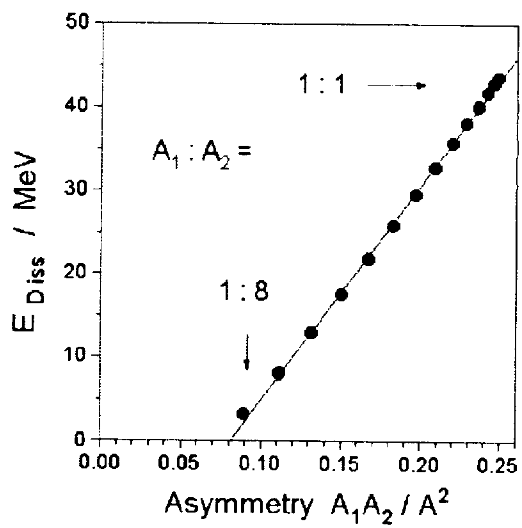

Fig. 4 Mean dissipated energy $E_{Diss} = B_C$ - <TKE> in dependence on the mass asymmetry expressed as $A_1 A_2 / A^2$.

4. THREE - FRAGMENT DECAY

4.1 Experimental results

From the 1200 three-fragment events recorded in this experiment, we estimated an integral ternary to binary decay ratio of $4 \cdot 10^{-3}$ for the reaction ^{14}N (34 AMeV) + ^{197}Au. The necessary correction for the geometrical acceptances leading to different registration efficiencies for binary and ternary events are based on a Monte-Carlo simulation.

The spectra of the relative velocities between IMF (A = 10 ÷ 20) and either the heavy partner in a binary decay (v_{rel}^{bin}) or the center-of-mass of the two heavy fragments in a ternary decay (v^{rel}_{IMF}) are shown in fig. 5.

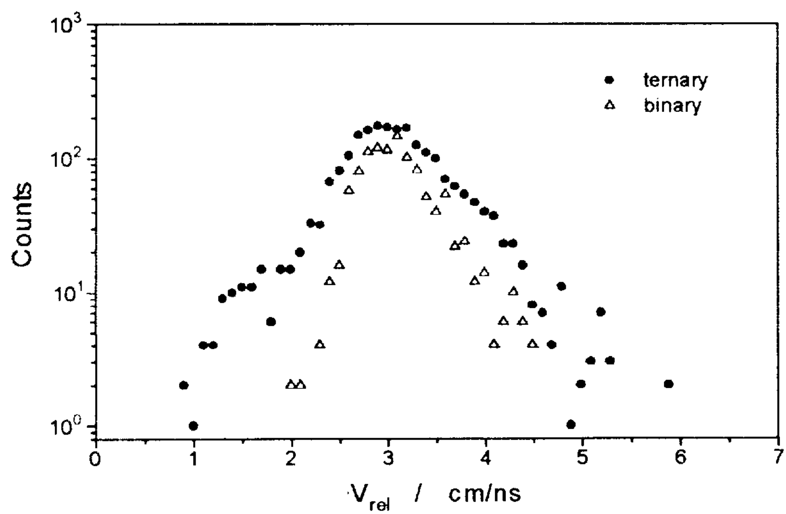

Fig. 5 Relative velocities between IMF of 10 ÷ 20 a.m.u. and their heavy partner in asymmetric binary decays (v_{rel}^{bin}) and between IMF and the c.m. frame of the two fission fragments in ternary decays (v^{rel}_{IMF}).

The peaks in the two spectra coincide. Furthermore, a second component at lower velocity is evident in the v^{rel}_{IMF} - distribution. In ref. [15] such a low-energy component was interpreted as an IMF-emission out of the neck region of the fissioning nucleus where the Coulomb repulsion is reduced. In this case, some Coulomb focusing should be observed, and, therefore, we plotted in fig. 6 the ratio of the low-velocity to the high-velocity IMF-yield versus the emission angle with respect to the fission axis. In this ratio effects due to geometrical acceptances are excluded. A certain enhancement near 90° is really observed, but some events are observed also at other angles.

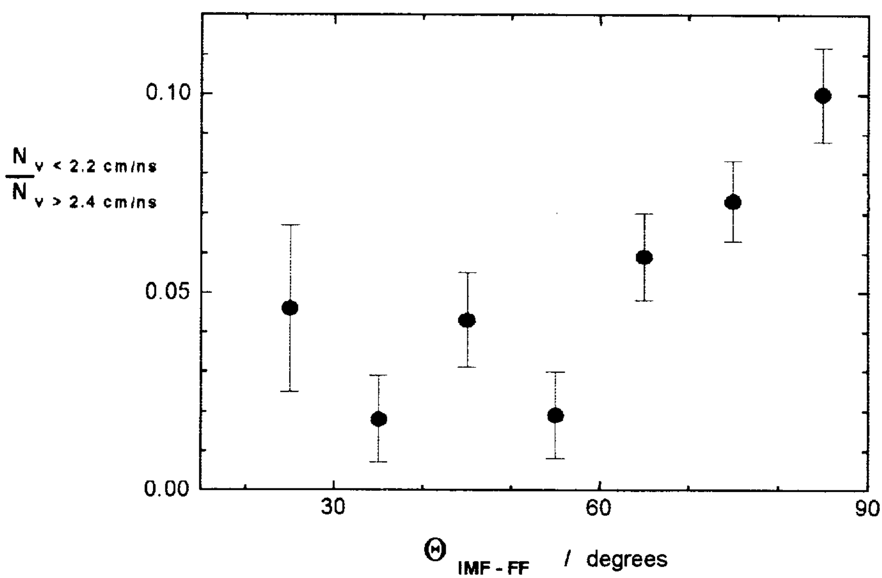

Fig. 6 Angular distribution of low - velocity IMF with respect to the fission axis.

The influence of a third fragment (IMF) on the relative velocity between the two fission fragments is demonstrated in fig. 7. In the events where the IMF have a high velocity, the FF have a mean relative velocity of 2.4 cm / ns what one expects for a usual fission process [4]. The emission of an IMF with low velocity, on the other hand, leads to a remarkable enhancement of the relative velocity between the remaining two heavy fragments.

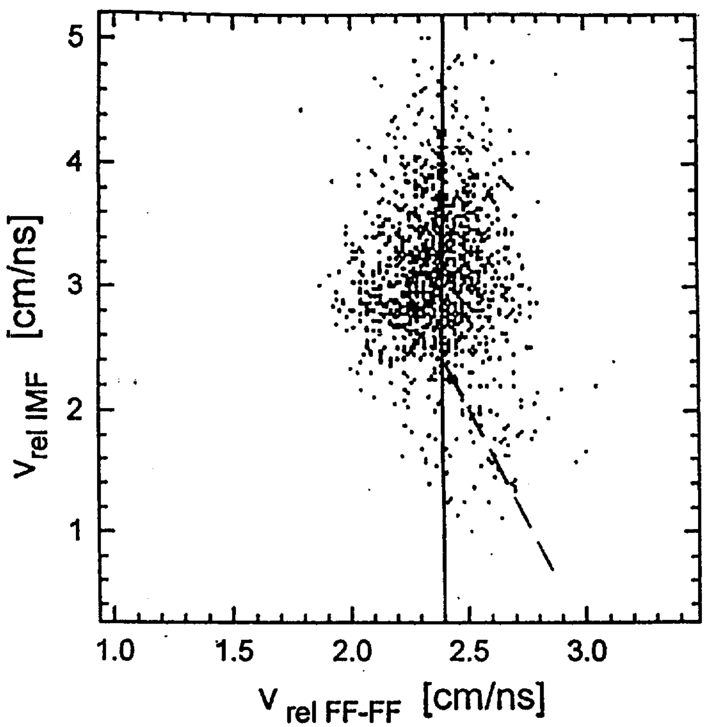

Fig. 7 Scatter plot of the IMF-velocity relative to the fission fragment c.m. frame versus the relativ velocity between both fission fragments in ternary events.

The yields of the both ternary components per binary fission are shown in fig. 8 in dependence on the LMT determined from the sum of the momenta of the three fragments. The yield of the high v^{rel}_{IMF} - component strongly increases with increasing LMT, whereas the low-velocity component remains almost constant.

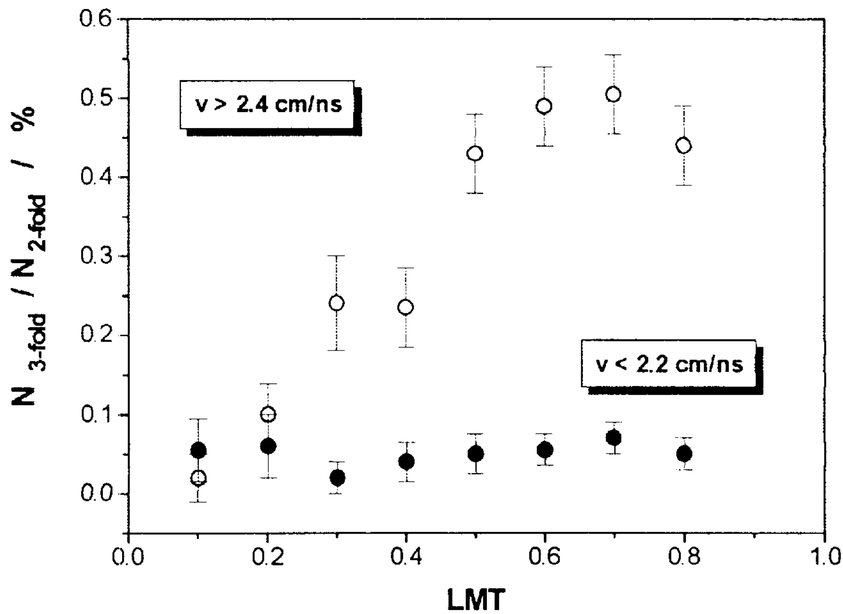

Fig. 8 Yields of the two components of ternary decays per binary fission in dependence on the transferred linear momentum.

The Z-distributions of IMF emitted with high and low relative velocities, respectively, are compared in fig. 9. The high-velocity component decreases much stronger with increasing Z than the low-velocity one. The second component also shows an odd-even effect up to $Z = 10$.

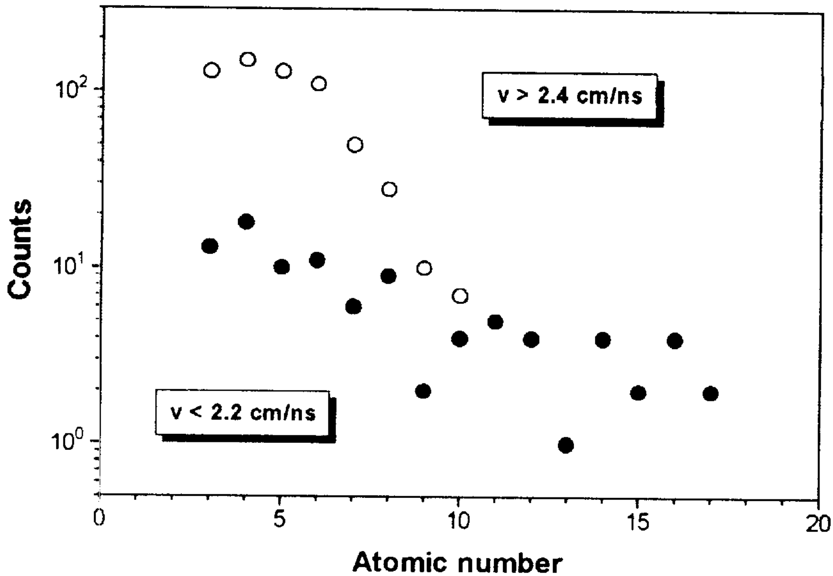

Fig. 9 Z - distributions of IMF observed in ternary events at low and high relative velocities.

4.2 Discussion of the ternary decays

The coincidence of the peak of the high - $v^{rel}{}_{IMF}$ component in ternary decays with that of the relative velocities between IMF of comparable mass and the heavy remnants in binary events ($v_{rel}{}^{bin}$; fig. 7) lead us to the conclusion that both components have the same origin. The only difference between them is that the heavy remnant, which remained after the IMF was emitted, further on might undergo fission or not.

This means that in the three-fragment decay the fission process happened later, and did not influence the IMF-velocity.
As the IMF needs about $3 \cdot 10^{-21}$ s to be accelerated to ≈ 80 % of its asymptotic velocity by the action of the Coulomb force, we can conclude that the time interval between the IMF-emission and the subsequent fission amounts to at least several units times 10^{-21} s. Consequently, the escaped IMF only left a lighter and less excited nucleus, but otherwise did not influence the subsequent fission process. This fact is also confirmed by the observed relative velocity between the two FF (fig. 7) which is the same as in a binary decay. Such IMF-accompanied ternary events are of clear sequential nature — i.e. the IMF is emitted "prior-to-fission".
On the other hand, we interpret such ternary decays which contain a low-velocity IMF-component as fission combined with a neck-emission. The neck region of the fissioning nucleus should be confirmed as the source of these IMF not only by the Coulomb focusing (like in ref. [15]), but, furthermore, also by our new observation of an *increased relative velocity of the FF* (fig. 7). A third fragment, when created "between" the two separating FF, introduces an additional Coulomb repulsion. On condition that roughly the total (potential) Coulomb energy of the three nearby-formed fragments in a ternary decay is transformed into kinetic energy, a decrease of the kinetic energy of the IMF should somehow lead to an increase of the kinetic energy of the

FF. Quantitative conclusions, of course, will only be possible by the comparison with trajectory calculations planned for the future.

(Such calculations should also clarify the origin of the observed low-velocity, but *non-focused* IMF. Possible scenarii one can imagine are, e.g. :

i) an emission not from the neck, but out of the deforming nucleus during fission when the Coulomb barrier is lowered or

ii) a slightly delayed second neck-rupture between the nascent fragments.)

There is a striking difference between the excitation functions (fig. 8) of the two IMF-components discussed (taking the LMT as a measure of E*). Such a behaviour has already been found in the analysis of IMF-accompanied fission observed in the reaction ^{7}Li (43 AMeV) + ^{232}Th [22]. We interpret this fact as a consequence of the dynamics of the fission process. If the emission times are different, it should be obvious, that the "early-emitted " high-velocity component is more affected by the primary excitation energy (E*) of the compound nucleus than the neck component. The systematics of the excitation energy remaining in the FF [3] shows a very weak dependence on E*. Consequently, the excitation energy of the fissioning system near scission should also only weakly depend on E*. This leads to the nearly constant yield of the neck component with LMT (fig. 8).

The odd-even effect evident in the Z-distribution of the low-velocity component (fig. 9) is a further hint that the excitation energy near scission is rather small. The Z-distribution of the prior-to-fission emitted IMF does not show any odd-even effect, and at $Z_{IMF} > 6$ it falls steeply down. These IMF emitted at high excitation energies — i.e. in an early stage of the de-excitation process — progressively suppress the fission probability of the heavy remnant with increasing Z_{IMF}, and the less fissile and less excited remnant gets more and more chance to survive as a heavy residue. This means that early-emitted IMF of large Z_{IMF} "gain" the binary decay.

In this connection there is an interesting intercept with the observations discussed above in consideration with *very asymmetric binary decays*. Namely, extrapolating the steep slope of the Z-distribution of the prior-to-fission emitted IMF (fig. 9) to zero, and assuming $A_{IMF} = 2 \cdot Z_{IMF}$, one gets a mass number of $A^{max}_{pre} \approx 26$. This is roughly the mass region, where the <TKE> of very asymmetric binary decays approaches to the Coulomb barrier B_C (fig. 3), and this behaviour we interpreted as the gradual disappearance of the dissipation during the disintegration process. The extrapolation of the curve in fig. 4 gives A_{ev} ($E_{Diss} = 0$) $\approx 15 \div 16$ for the system considered. Approximately, one can assume that light "clusters" of mass up to about A_{ev} ($Z_{ev} \approx 7 \div 8$) can be *evaporated* by the hot compound nucleus during the de-excitation cascade. Indeed, the steep slope of the Z-distribution of the prior-to-fission emitted IMF (fig. 9) sets in at $Z_{IMF} = 7$, and the yield at $Z_{IMF} \leq 6$ is rather constant.

Reminding that we found the prior-to-fission IMF-component as not being affected by a later happening fission process and, therefore, supposed it as being emitted "earlier ", i.e. at high E*, we can assume that $E^* >> B_C$, and the probability $P_{ev} \sim \exp(2\sqrt{a\ (E^*-B_C)})$ reduces (neglecting phase space constants) formally to $P_{ev} \sim \exp(2\sqrt{a E^*}) = f(E^*)$.

Starting from some critical A^{max}, dynamical considerations come into play, and the IMF-emission loses its statistical feature and further on follows a dynamical time scale. This means that the nature of the decay process changes over from *evaporation-like* to *fission-like* [5]. The more asymmetric the mass splitting is, the lower is the dissipation (fig.4), and, in all probability, the faster is the disintegration. The drop down of the yield of the prior-to-fission emitted IMF-component at some $Z_{ev}^{\ max}$ is in agreement with such a scenario. Of course, at higher incident energies than in the reaction considered, the yields of ternary IMF with higher Z_{IMF} should increase, and the decay mechanism should develop from (sequential) IMF-accompanied fission to the limit of ternary fission [23]. This process should be governed by the dynamics of the collective motion of the nuclear matter involved.

From energetical considerations, namely, that the fission barrier increases, but the Q-value of reaction decreases with increasing mass asymmetry of the binary decay, the disintegration into very asymmetric fragments carrying away a TKE > Q principally needs a larger amount of E* to occur than the symmetric fission of the same system. This means that the effect of the intrinsic single-particle motion on the collective degrees of freedom responsible for a fission-like process should be temperature-dependent. More asymmetric modes are generated only at sufficiently large E*, or fission at asymmetric mass splitting should proceed faster, i.e. at a time when the system has not yet been cooled considerably by particle evaporation. Up to now there is no consistent description of the complex interplay of light particle as well as IMF evaporation and fission into the broad range of mass splitting observed experimentally. The method of ref. [2] which combines statistical as well as dynamical aspects of this process should at present be the most adequate one, but it has to be extended by including of more degrees of freedom what seams to be a very complicate task.

Furthermore, the broad Z-distribution observed for IMF emitted from the neck cannot be explained by simple assumptions about excitation energies, emission barriers, a. s. o. Up to now, there is no theory describing the neck emission of IMF in the given energy range. Probably, it is also governed by the complex dynamics of the fission process including the formation of the scission configuration and the rupture of the neck.

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15.	Experimental physics of nuclear reactions at low energies
16.	Health physics. Shieldings
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Вагнер В. и др. E7-97-131
Двухтельный и трехтельный распады горячих тяжелых ядер, полученных в реакции ^{14}N (34 AMeV) + ^{197}Au

На 4π-спектрометре ФОБОС были исследованы двухтельный и трехтельный распады горячих тяжелых атомных ядер, полученных в реакции неполного слияния ^{14}N (34 AMeV) + ^{197}Au. Массы, скорости и энергии фрагментов определялись по методике TOF-E. Анализ TKE-M-распределений показал, что при достаточно большой энергии возбуждения промежуточного ядра, то есть при больших переданных импульсах, наблюдаются два граничных механизма двухтельного распада, а именно: деление при маленькой массовой асимметрии фрагментов и испарение при большой асимметрии.

Два источника фрагментов промежуточных масс, связанных с делением, были определены путем анализа относительных скоростей, угловых распределений, функций возбуждения и зарядовых выходов фрагментов. Помимо высокоэнергетической эмиссии из промежуточного ядра до деления наблюдалась низкоэнергетическая компонента, испускаемая из шейки делящегося ядра. Кроме того, третья компонента может быть связана с задержанным двойным разрывом шейки делящегося ядра.

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Wagner W. et al. E7-97-131
The Binary and Ternary Decay of Hot Heavy Nuclei Produced in the Reaction ^{14}N (34 AMeV) + ^{197}Au

The binary and ternary decay of hot heavy nuclei produced by incomplete fusion in the reaction ^{14}N (34 AMeV) + ^{197}Au has been investigated at the 4π-array FOBOS. The fragment masses, velocities and energies have been derived using the TOF-E-method. The analysis of the TKE-M-distribution of binary decays showed that at sufficient excitation energy of the composite system, i.e. for large transferred linear momentum, one observes the two limits of the decay mechanism, namely fission-like and evaporation-like binary disintegrations at small and large mass asymmetry of the fragments, respectively.

Two sources of IMF emission associated with fission are well separated by consideration of the relative velocities, angular distributions, excitation functions and charge yields. Besides the high-energetic compound emission of IMF before fission the low-energy neck-emission during fission has been observed. Evidence has been found for a third IMF-component which possibly originates from a delayed double neck-rupture of the deformed fissioning system.

The investigation has been performed at the Flerov Laboratory of Nuclear Reactions, JINR.

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