In 1995 a cryogenic target was constructed comprising a cylinder of 160 *mm* diameter and 400 mm length filled with 1-2 atm hydrogen at 70-80 K temperature. The pion producting target containing 20 tungsten foils with the total thickness 2 mm along the proton beam is placed inside the cylinder in the shadow of the multi-slit collimator plates. Negative pions are produced by a proton beam passing through the foils. Some part of them stop in hydrogen forming pionic atoms. About 300 W of the heat produced by the 50 μA proton beam is removed by a forced circulation of the hydrogen gas in the target volume and by liquid nytrogen cooling. According to calculations to keep hydrogen inside the target at 80 K it is enough to provide the gas velocity 0.5 m/s, the foil temperature remaining below 290 K. The distance from the cold source and the target amounts to 8 m. The liquid nytrogen expenditure is 170 l per day. The cryogenic target connected with the multi-slit 3 m length collimator should be placed into a barrel filled with helium (to decrease the absorption of the soft X-radiation). Solid-state mesic X-ray targets, if necessary, can be located close to the tungsten foils, circulating hydrogen being used to remove the heat produced by the beam.

In 1996 the experimental equipment will be mounted in the MMF experimental hall for testing. When the proton beam of proper parameters is available (energy not less than 500 MeV, current 30-50 μA) we plan to begin measurements.

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NUCLEAR FISSION BEYOND TWO-BODY KINEMATICS

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Collinear tripartition of highly excited ^{238}U nuclei [1] requires a generalization of the nuclear fission mechanism. The detection of two massive fragments separating collinearly does not confirm unambiguously the two-body character of the nuclear fission reaction. This experimental result is a necessary but not a sufficient sign of two-body kinematics. Sticking to the experimentally observed two collinear fragments one can see, that this situation could have been realized in a more general case, when the classical liquid drop is fissioning into three fragments, the third fragment being at rest.

The nuclear fission reaction should be written in this case as

$$^{M_0}Z_0 \rightarrow ^{M_1} Z_1 + ^{M_3} Z_3 + ^{M_2} Z_2, \qquad (1)$$

where M_k and Z_k are the mass numbers and electric charges of the initial fissioning nucleus and of three fragments. The conservation of the mass and the charge leads to

$$M_0 = \sum_{i=1}^{3} M_i \qquad \text{and} \qquad Z_0 = \sum_{i=1}^{3} Z_i. \tag{2}$$

The fragment $^{M_3}Z_3$, being between the two others, will not move, if the two repulsive Coulomb forces are equal:

$$\frac{e^2 Z_1 Z_3}{x_{13}^2} = \frac{e^2 Z_2 Z_3}{x_{23}^2}, \tag{3}$$

where x_{13} and x_{23} are the distances between the centres of the fragments' charges. As follows from (3),

$$x_{13} = \sqrt{Z_1/Z_2}\ x_{23}, \tag{4}$$

and this relation should hold for all the time of the fragments separation. This means that the fragment with a larger charge should be always at a larger distance from the third fragment, which is at rest. Differentiating the identity (4) in time, one gets the relation for velocities:

$$\dot{x}_{13} = \sqrt{Z_1/Z_2}\ \dot{x}_{23}. \tag{5}$$

Using the momentum balance of the moving fragments as a condition for the third one to be at rest, from

$$M_1\ \dot{x}_{13} = M_2\ \dot{x}_{23} \tag{6}$$

one obtains a relation

$$M_1/M_2 = \sqrt{Z_2/Z_1}, \tag{7}$$

which requires that the fragment with higher mass has a smaller charge, and vice versa. This corresponds to a charge polarization of the fissioning nucleus and should lead to the appearance of the neutron-deficient fragments, together with their neutron-rich partners. Neutron-deficient fragments have never yet been observed experimentally in the fission processes at low energies. However they were observed in the process of the ^{238}U fission induced by 1 GeV protons.

Collinear tripartition of ^{238}U nuclei, induced by 1 GeV protons [1] may be treated using chemical symbols. The results are given in the Table for four events chosen as examples in which the third fragment is at rest. A small uncertain value ν denotes several cascade nucleons, compensating the momentum of the incident proton.

In order to calculate the distance between the outer fragments in the last column of the Table one should obtain the Coulomb energy of the three collinearly located charges. Using eq.(4) one gets

$$U_3 = e^2 Z_1 Z_3/x_{13} + e^2 Z_2 Z_3/x_{23} + e^2 Z_1 Z_2/(x_{13} + x_{23}). \tag{8}$$

Table

Selected events of the collinear tripartition of ^{238}U nucleus induced by 1 GeV protons

$E_1 + E_2$, MeV	Tentative nuclear rection	D_3, fm
186 ± 4	$^{78}\mathrm{Rb} + {}^{75-x}\mathrm{Cr} + {}^{86}\mathrm{Ga} + x$ $Z_1 = 37 \quad Z_3 = 24 \quad Z_2 = 31$	34.2 ± 0.7
145 ± 3	$^{67}\mathrm{As} + {}^{98-x}\mathrm{Ga} + {}^{74}\mathrm{Ni} + x$ $Z_1 = 33 \quad Z_3 = 31 \quad Z_2 = 28$	46.9 ± 1.0
156 ± 3	$^{65}\mathrm{Ge} + {}^{104-x}\mathrm{As} + {}^{70}\mathrm{Co} + x$ $Z_1 = 32 \quad Z_3 = 33 \quad Z_2 = 27$	47.5 ± 0.9
137 ± 3	$^{63}\mathrm{Co} + {}^{115-x}\mathrm{Kr} + {}^{61}\mathrm{Cu} + x$ $Z_1 = 27 \quad Z_3 = 36 \quad Z_2 = 29$	50.6 ± 1.0

Expressing all the denominators via

$$D_3 = x_{13} + x_{23}, \tag{9}$$

one has finally

$$U_3 = e^2[Z_1Z_2 + Z_3\,(\sqrt{Z_1} + \sqrt{Z_2})^2]/D_3. \tag{10}$$

Equating this expression to the measured total kinetic energy of two fragments one obtains D_3 value.

The obtained D_3 values for the three-fragment collinear disintegration of ^{238}U, being dispersed considerably, exceed the double of the interfragment distance for the same nucleus, undergoing the binary fission at lower excitation energies [1]. Since the three-body collinear disintegration includes the binary fission as a particular case, it would be very important to observe this process at low energy. One should expect that the three-fragment collinear disintegration might be interpreted in some experiments as a binary fission. The main purpose of the analysis to follow is to consider these experiments from the standpoint of the three-body kinematics.

According to (7) the only possibility to observe the process of the collinear three-body fission without the nucleon polarization of the fissioning nucleus is determined by the two conditions:

$$M_1 = M_2 \qquad \text{and} \qquad Z_1 = Z_2. \tag{11}$$

This is a strictly symmetric fission, when the masses and charges of the two fragments are equal. Denoting the initial distance between the outer charges as D_{3S}, one obtains for the Coulomb energy of three charged bodies

$$\begin{aligned} U_{3S} &= \frac{e^2}{D_{3S}}[(Z_0 - Z_3)^2/4 + 2Z_3(Z_0 - Z_3)] \\ &= \frac{e^2}{D_{3S}}[Z_0^2/4 + (3/2)Z_0Z_3 - (7/4)Z_3^2]. \end{aligned} \tag{12}$$

It can be measured experimentally as an average total kinetic energy of the two detected fragments:

$$< TKE >= \frac{e^2}{D_{3S}}[Z_0^2/4 + (3/2)Z_0Z_3 - (7/4)Z_3^2]. \quad (13)$$

From (13) it is clear that $< TKE >$ of the two symmetric fragments in the process of the collinear tripartition is a function of the third charge Z_3. It is easy to show, that for binary fission, when $Z_3 = 0$, $< TKE >$ is always smaller than that for the collinear tripartition, if

$$Z_3 < \frac{6}{7} Z_0. \quad (14)$$

The maximum $< TKE >$ is reached at

$$Z_3 = \frac{3}{7} Z_0. \quad (15)$$

Thus in the experiment at low energy the sign of the collinear tripartition might have been strictly symmetric fragments with the enhanced average TKE. It is known that both these features are observed in the spontaneous fission of the isotope $^{258}_{100}$Fm, as well as of some other heavier nuclei [2]. It should be noted that the observed in the experiment symmetric mass distribution of the fragments was obtained from the equality of measured kinetic energies

$$E_1 = E_2. \quad (16)$$

However it is clear that this equality does not allow one to determine the fragments' masses unambiguously. This just means that

$$M_1 = M_2. \quad (17)$$

Nowadays, assuming the two-body kinematics, one usually supposes the formation of two symmetric fragments such as $_{50}$Sn with mass numbers close to the double-magic value $A = 132 = 50 + 82$. In this case $Z_3 = 0$. However, there is no experimental ground for such a choice. Anyway, experimental data do not contradict any other choice of $Z_3 \neq 0$ within the range (14).

The important experimental result is also the partition of the TKE spectrum into two components, which have different average values. In particular, for the spontaneous $^{258}_{100}$Fm fission these values are equal to 232 and 205 MeV respectively. The most conventional explanation for such an experimental result is at present the assumption about compact and elongated forms of the fissioning nucleus, splitting into the same fragments. In this picture the compact form is responsible for the large $< TKE >$ values, while the elongated one – for the smaller. In the collinear tripartition $< TKE >$ value depends on Z_3. For this reason two $< TKE >$ values observed might correspond to two different Z_3 values and, therefore, to two different symmetric fragments registered. The initial deformations D_{3S} in these two cases may be different enough so that the process with larger $< TKE >$ may have larger deformation. One cannot exclude, however, that the deformations are equal in both cases. Then to describe selfconsistently the experimental data [2] one needs two kinds of the decay process with $Z_3 = 0$ and $Z_3 = 2$ or 3. It is important that the collinear tripartition of heavy nuclei is a more general case of the decay, which includes the traditional binary fission as a particular case when $Z_3 = 0$. For small $Z_3 \neq 0$ the strictly symmetric fragments with

enhanced $< TKE >$ appear. When all three charges are comparable, e.g. as in the reactions shown in the Table, the process of the collinear three-body splitting of the heavy nucleus, induced by relativistic protons, takes place. As Z_3 comes to its limit Z_0 the process turns into the double α-decay or to two proton radioactivity.

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COMBINED ANALYSIS OF NEUTRON ENERGY DEPENDENCES OF P-ODD, P-EVEN LEFT-RIGHT AND P-EVEN FORWARD-BACKWARD ASYMMETRY EFFECTS OF ^{233}U FISSION FRAGMENT EMISSION

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It is well known that in the field of low neutron energies (E_n < keV) fission fragment angular distributions can be presented with a good aproximation as follows:

$$\frac{d\sigma}{d\Omega} \sim |f^s_{PC}|^2 + 2 \cdot f^s_{PC} \cdot f^p_{PC} + 2 \cdot f^s_{PC} \cdot f^s_{PNC} + |f^p_{PC}|^2 \qquad (1)$$

with $f^{s,p}_{PC}$ and f^s_{PNC} being the reaction amplitudes conserving (PC) and nonconserving (PNC) the space parity, as for E_n < keV it is essential to take into account s- and p-wave neutron capture only.

The first term is isotropic and the last one is relatively small for the energies (<10 eV) investigated in this work. Two terms remained contain the odd spherical harmonies resulting in the asymmetry the proper angular distributions relative to $\pi/2$ angle. These angular distributions are proportional to the unit vectors products as follows:

$(\vec{\sigma}_n \cdot \vec{p}_f)$ – P-odd asymmetry,

$\vec{\sigma}_n \cdot [\vec{p}_n \times \vec{p}_f]$ – P-even left-right asymmetry,

$(\vec{p}_n \cdot \vec{p}_f)$ – P-even forward-backward asymmetry.

Here $\vec{\sigma}_n, \vec{p}_n$ and $\vec{p}_f$ are unit vectors of neutron polarization and linear momentum and $\vec{p}_f$ - light fission fragment momentum relatively.

All these interference effects are considered by the modern theory [1,2] as having very similar mechanismes of arising in fission reaction, and their combined investigations seems to be very fruitful to extract a new information both about the weak interaction in complex nuclei and reactions and about reaction mechanizm itself. Certainly, if to speak about weak interaction P-even asymmetries play some auxiliary role as they can give information about mixed p-wave resonances parameters. The broad program of P-odd and P-even left-right asymmetry investigations as a function of polarized neutron energies have been performing at the polarizing crystal-difraction monochromator of WWR-M reactor since 1980 [3]. Neutron energy dependence of P-even forward-backward asymmetry in ^{233}U fission was studied at