SEARCH FOR DELAYED FISSION IN NEUTRON-RICH NUCLEI AND COSMOCHRONOLOGY

K. A. Mezilev, Yu. N. Novikov, A. V. Popov,
Yu. Ya. Sergeyev, V. I. Tikhonov

Estimates of the age of th Universe made with the help of nuclear cosmochronology with heavy chronometers (^{232}Th, ^{238}U, ^{235}U) depend on the beta-delayed fission rates in neutron-rich nuclei which take part in the process of nucleosynthesis.

For the first time the existence of delayed fission islands of nuclei and their role in the production of heavy elements in the astrophysical r-process has been pointed out in papers /1,2/. Recently performed theoretical investigation /3/ have led to the conclusion that a wide region of delayed fission was located on the path of formation of the cosmochronometers. Delayed fission, as shown in /3/, supresses its production. The Universe age value $T_u = 21.8(+2, -5)$ Gyr, given in /4/, disagrees with the earlier adopted value $T_u = 11.5 \pm 2.3$ Gyr obtained without taking into consideration the delayed fission.

This work is devoted to experimental identification of the delayed fission in the neutron-rich nuclei. The experiments have been carried out at the IRIS-facility on-line with the 1 GeV proton beam. For the first time the search for delayed fission has been performed using a mass-separator. It provides an unambiguous identification of the mass number. The use of the uranium target UC_x (60 g of uranium) at the temperature of $\sim 2300^\circ$ C has made it possible to extract alkalines with half-lives of a few tenths of a second.

Table

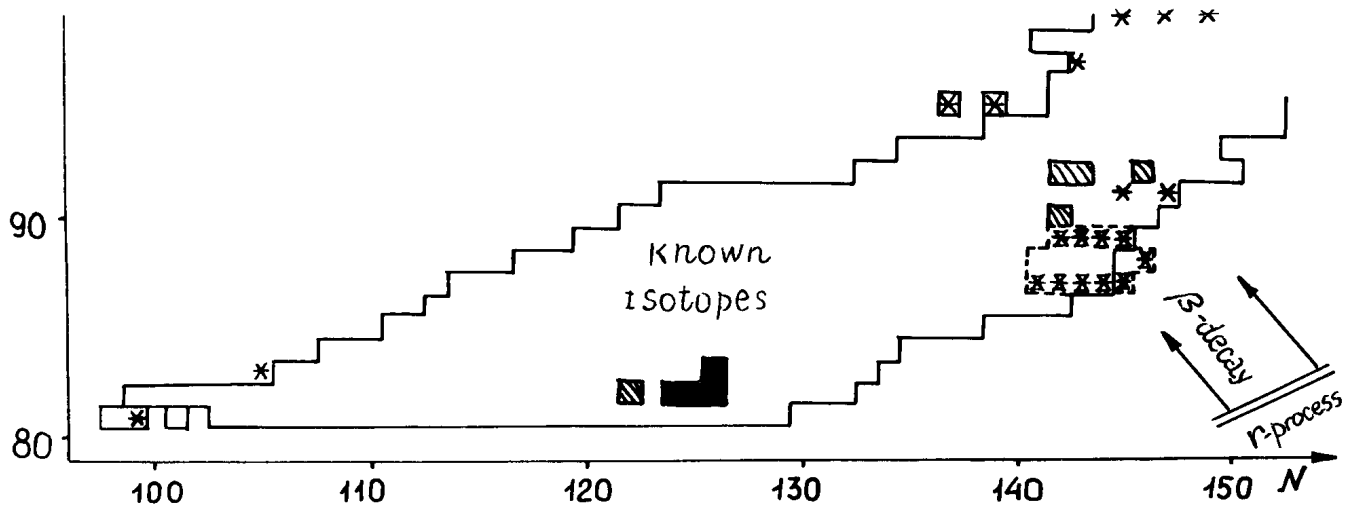
Limits of delayed fission probability for some neutron-rich nuclides

Nuclide	$T_{1/2}$, s	E_γ, keV	I_γ, % per decay	P_{df}
^{228}Fr	39	474	20	$<2\times10(-7)$
^{230}Fr	19	129	(100)*	$<3\times10(-6)$
^{232}Fr	5	15.3	(100)*	$<2\times10(-6)$
		125	(100)*	$<5\times10(-5)$
		β		$<7\times10(-4)$
^{232}Ac	35	665	15.3	$<$ 10(—6)

* Value adopted for estimation of P_{df} limit.

Due to this technique the new isotopes ^{232}Fr ($T_{1/2} = 5 \pm 1$ s), ^{233}Ra (30 ± 5 s) and ^{234}Ra (30 ± 10 s) have been identified by using solid state detectors for registration of the β-, γ- and X-radiations /5/. The daughter actinium isotopes have been detected as well as other well known lighter Fr and Ra-isotopes.

At the same time the solid state detector Si(Au) has been used to detect fission fragments. No fission fragments have been detected during the total exposition time for each of the investigated nuclides. This fact allows us to set the upper limits for the probability of delayed fission.



Part of nuclear chart. ■ — beta-stable nuclei, ▨ — nuclei with half-lives >0.1 Myr., ⌐ — boundary of known nuclei, × — known delayed fission precursors, --- — boundary of neutron-rich nuclei region, where search for delayed fission has been performed in this work

The data on the decay of Fr and Ac isotopes are presented in the table /6/. Delayed fission was not observed also for nuclei ^{229}Fr, ^{231}Fr, ^{233}Ac and, as it was expected, for Ra isotopes with mass numbers A=229—234 as well. The region of the nuclei which were under investigation is indicated in the figure by a dotted line.

The limits for the delayed fission of the nuclei with mass number A=232 have a special interest. The absence of this phenomenon for ^{232}Fr and ^{232}Ac leads to the same result for other nuclei of this isobaric chain — ^{232}At and ^{232}Bi because the relations of the beta-decay energies and barrier height values for these nuclei are approximately the same as for ^{232}Fr. This is the reason why the delayed fission does not suppress the production of the cosmochronometer ^{232}Th on the direct path of isotope formation through the isobaric chain A=232. This conclusion requires reconsideration of the Universe age value adopted recently in literature.

REFERENCES

1. *Berlovich E. Ye., Novikov Yu. N.* Phys. Lett., 1969. V. 29B. P. 155.

2. *Berlovich E. Ye., Novikov Yu. N.* Pisma JETF, 1969. V. 9. P. 708.

3. *Thielemann F. K., Metzinger J., Klapdor H. V.* Z. Phys., 1983. V. A309. P. 301.

4. *Klapdor H. V.* Fortschr. Phys., 1985. V. 33. P. 1.

5. *Bolshakov V. A., Mezilev K. A., Novikov Yu. N., Polyakov A. G., Popov A. V., Sergeyev Yu. Ya., Tikhonov V. I.* Preprint LNPI—1517. Leningrad. 1989. 22 p.

6. *Mezilev K. A., Novikov Yu. N., Popov A. V., Sergeyev Yu. Ya., Tikhonov V. I.* Preprint LNPI—1529. Leningrad. 1989. 22 p.