PERSPECTIVES OF THE STUDY OF FISSION FRAGMENTS STRUCTURE ON THE BREMSSTRAHLUNG BEAMS IN PROJECT DRIBs (Dubna)

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Fission fragments of heavy nuclei ($Z > 90$) are neutron-rich isotopes of the elements from Zn ($Z = 30$) to Nd ($Z = 60$) with a neutron number of 45 – 90. The large neutron excess in the fission fragments under study (in some cases there are 10 – 15 more neutrons, than in the nuclei situated in the β-stability valley) could lead to an essential change in their structure and radioactive decay characteristics. The anomal ratio of protons and neutrons in such nuclei reflects on spin-orbit interactions and can lead to another order of nucleon shell filling. This change will manifest itself in the appearance of new magic numbers of protons or neutrons, new regions of deformation, of new islands of isomerism. A striking example of such phenomena is found in light neutron-rich nuclei of ^{31}Na and ^{32}Mg at the magic number $N = 20$. Contrary to our knowledge about nuclear structure, these nuclei are strongly deformed [1,2]. The same situation could occur in the case of very neutron-rich isotopes of Cu and Zn near $N = 50$ as well as Ag and Cd near $N = 82$.

A change in nuclear structure can also occur in the know islands of isomerism (nuclei with $N < 50$ and $N < 82$). Highspin levels $g_{9/2}$ and $h_{11/2}$ can be shifted and their decay characteristic will change.

The high energy of β-decay can result in the appearance of new, much rarer, modes of radioactive decay. They are emission of a neutron pair or an α-particle after β-decay (β2n or βα). These decay modes are an important source of new information about nuclear structure.

Thus the spectroscopic properties of fission fragments are very various. They are relatively poorly known, and researching them measurement of the nuclear moments, the level spectra, the decay schemes e. c.) allows one to establish the way in which nuclear structure changes with the increasing neutron excess. A wide set of experimental devices should be used to obtain this information.

Study of the nuclear structure of fission fragments is one of the main directions of the DRIBs project, being developed in the Flerov Laboratory of Nuclear Reactions JINR. The aim of this project is the production of intense beams of accelerated radioactive nuclei in a wide range of Z and A – from He to rare-earth elements. Light neutron-rich nuclei (up to Na) will be obtained in the fragmentation of bombarding ions on the 4-meter isochronous cyclotron U-400M, and nuclei of a medium mass number – in the fission of uranium on the electron accelerator microtron MT-25 .

Nuclei chosen for study will be mass-separated and transported to be accelerated in another 4-meter isochronous, cyclotron U-400.

Study of reactions induced by neutron-rich or neutrondeficient nucle essentially enlarges information about their structure. It is impossible to judg some details of this structure from radioactive decay characteristics. A strikin example is observation of an unusual wide space distribution of neutrons i some neutron-rich nuclei (neutron halo), first in ^{11}Li and then in others [3] These data were obtained from measurement of cross-sections for differen reactions (fusion, stripping, nucleon exchange) with neutron-rich nuclei. Suc multidirection investigation of the properties of nuclei far from the β-stabilit valley definitely widens our knowledge about the changes in nuclear structur with the growing neutron excess and about the appearing of new phenomena.

Reactions with neutron-rich nuclei can be also used for obtainin more neutron-rich nuclei. Really, the compound-nuclei formed in these reactions contain the neutron excess, and the evaporation of charged particles increases this excess. By this technique it is possible to get the most neutron-rich nuclei and to draw near the boundary of nucleon stability.

The success of study of the structure of fission fragments, especially the most neutron-rich fragments, depends to a great degree on their yields. These are determined by their distribution on mass and atomic numbers (A and Z). But there is poor information about these parameters in photofission as compared with neutron fission. Worthy of mention are only investigations performed in Gent (Belgium) [4,5].

The main contribution to the photofission fragment yield is made by the energy range of 10 – 15 MeV (it is the position of the giant dipole resonance in heavy nuclei). This energy range also determines the excitation energy of fissioning nuclei. At such excitation energy, the mass spectra of the photofission fragments are asymmetric with the mean mass numbers 99 and 139 for the light and heavy groups of fragments. Each mass number in these spectra corresponds to some set of nuclides with different atomic numbers Z formed in the rupture of fissioning nuclei. The atomic number distribution of these nuclides is described by the Gauss curve with the half-width $\sigma \sim 1.0 - 1.2$. The nuclides formed in one or several β-decay transitions are added to these nuclides.

To get more detailed information about the isotopic yields we measured the isotopic distributions of Kr and Xe fragments in the photofission of ^{238}U and other heavy nuclei by bremstrahlung with the boundary energy of 25 MeV [6]. The method of transporting fission fragments by a gas flow and stopping in a cryostat with liquid nitrogen was used. The isotopic distributions of Xe fission fragments obtained by this technique is similar to neutron fission. But an enhanced yield of the most neutron-rich nuclides is observed in photofission as compared with thermal neutron fission, this difference increased with the growing neutron excess.

Some examples of these nuclei and their yields are presented in this Table.

Fission fragment and its peculiarities	Y, 1/f	Y, 1/s (DRIBs)
^{80}Zn – closed neutron shell N=50	10^{-6}	10^{5}
^{81}Ge – closed neutron shell N=50	$3\cdot10^{-5}$	$3\cdot10^{6}$
^{131}In – closed neutron shell N=82	10^{-3}	10^{8}
^{132}Sn – duble magic nuclei Z=50, N=82	$3\cdot10^{-3}$	$3\cdot10^{8}$
^{134}Sn – 2 neutrons over closed shell	$8\cdot10^{-4}$	10^{7}
^{100}Zr – beginning of deformation region	10^{-2}	10^{9}
^{104}Zr – strongly deformed nuclei	$5\cdot10^{-4}$	$5\cdot10^{7}$
^{160}Sm – strongly deformed nuclei	10^{-4}	10^{7}
^{134}Sb – delayed two-neutron emitter	10^{-6}	10^{5}
^{140}J – delayed α-emitter	10^{-5}	10^{6}

Thus photofission reactions of heavy nuclei are a very handy and promising way for the production of intense beams of the most neutron-rich nuclides. The small stopping power of the γ-rays allows one to use thick targets. But the low excitation energy of the fissioning nuclei and of the fission fragments results in the small values of the evaporated neutrons. This compensates for the phtofission cross sections being smaller as compared with the cross sections for fission induced by charged particles and neutrons. Moreover electron accelerators are simpler and much cheaper than charged particle accelerators and atomic reactors.

These examples show the wide field of activity in the study o the neutron-rich nuclei structure, and the DRIBs project is the first step on thi way.

REFERENCES

1. G.Huber, F.Touchard, S.Büttgenbach et. al., Phys. Rev **C18**(1978)2342.
2. D.Gillemaud-Müeller, C.Detraz, M.Langevin et. al., Nuc Phys., **A426**(1984)37.
3. I.Tanihata, H.Hamagaki, O.Mashimoto et. al., Phys. Re Lett., **55**(1985)2676.
4. H.Jacobs, H.Tierens, D. De Frenne et. al., Phys. Re **C21**(1980)237.
5. D. De Frenne, H.Tierens, B.Proot et. al., Phys. Re **C26**(1982)1356.
6. Yu.P.Gangrsky, S.N.Dmitriev, V.I.Zhemenik et. al., Particl and Nuclei Letters, 6(2000)5.