

Experimental study on photofission of ^{242}Pu , ^{238}U , ^{235}U and ^{232}Th in giant dipole resonance region

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Photofission represents a powerful tool for investigating the double humped fission barrier of actinide, especially for studies on shape isomer, formed by photonuclear reactions. In general, photofission seems to be favourable for investigation of the nuclear structure as in the case electromagnetic interaction is well - known and the theoretical consideration is simplified. Due to the missing Coulomb barrier compound states of low excitation energy are easily populated. The main advantage, however, is spin selectivity of the electromagnetic interaction leads to the favoured excitation of the few specific fission channels compared with particle induced reactions. The giant electric dipole resonance dominates the photoabsorption cross - section in most important energy range (i.e in giant dipole resonance region).

In photofission the mass and charge distributions and the isomeric ratios of fission fragments are ones of the most interesting observables as their parameters can be related to the dynamics of the fission process. For the reasons, we have concentrated our investigations in these characteristics.

In our investigations for photon sources we used electron accelerators of microtron type. Microtrons are high intense photon sources therefore they are suitable for the studies of photonuclear reactions where the reaction cross-sections are small. The targets after irradiation were measured by direct gamma spectroscopic technique without any chemical separation.

Target preparation, irradiation and measurement: We have carried out photofission of Pu242, U235, U238 and Th242. Our first studies were photofissions of Pu242 and U235 started in 1982 at the Joint Institute for Nuclear Research, Dubna, Russia by using microtron MT - 22 (its maximum bremsstrahlung energy can be varied stepwise from 10 to 22 MeV). By that time the data on photofission of Pu242 have not been published, so our results can be considered as first ones.

The target of 3 (+ or -) 0.3 mg of dioxide Plutonium enriched to 94.7% Pu242 was prepared on a 70 micro meters thick aluminium disc of 55 mm diameter. The active layer had a diameter of 20mm. For photofission of U235, the target of 30mg dioxide uranium enriched to 97% U235 was used in the experiment. The plutonium was irradiated for 5 and 6 hours with 18.1 and 20.7MeV bremsstrahlungs respectively. The U235 target was irradiation for 5 hours with 18.1MeV bremsstrahlung. In order to avoid thermal neutron induced fission of U235 the target was packed by Cd envelope of 0.5mm thickness and fast neutron induced fission is less than 0.2% can be negled. For both the Pu242 and U235 targets the catcherfoil technique was used for collecting fission fragments. The catcherfoil which consisted of 0.1mm thick very pure aluminium foil (purity of 99.99%) was placed at a distance of 1mm from the Pu242 and U235 targets and then was measured with high energy resolution semiconductor detector.

The photofissions of Th232 and U238 were performed with 15 MeV bremsstrahlung produced by microtron MT-17 of the National Institute of Physics, Hanoi by 4 hours irradiations. The target of U238 was an amount of 18mg U3O8 enriched to 99.6% U238 prepared on a 0.5mm thick high pure aluminium disk of 20mm in diameter and the target of Th231 was a pure Th sample having diameter of 20mm, thickness of 0.5mm and density of 15mg/cm² wrapped in a thin layer of lapsan on 1mm thick pure aluminium disk. The targets after irradiations were measured with direct gamma spectroscopic technique without any chemical separation.

For measuring gamma spectra of photofission fragments two spectroscopic systems were used. At the National Institute of Physics, Hanoi, the targets were measured by a spectroscopic system consisted of 62 cm³ coaxial HPGe detector ORTEC with a resolution of 2.1 KeV at 1332 KeV gamma ray of Co60, a spectroscopic amplifier CANBERRA mode 2001 and a 4096 channel analyzer mode ND-66B, Nucl. Dat. Inc. coupled with a PDP 11/23 computer for data processing. At the Joint Institute for Nuclear Research, Dubna the measuring system consisted of a 45 cm³ Ge(Li) detector, a NOKIA spectroscopic amplifier, a 4096 channel analyzer NOKIA, model LP-4096 was used.

Mass distributions: The relative cumulative yields for the fission fragments were determined from successive measurements of gamma fission spectra from the catcherfoils and the target. The relative total yields for a given mass chain were obtained from the relative yields by making correction with the expression for charge distribution. The absolute product yields were obtained by normalization to 200% the area under the total mass distribution.

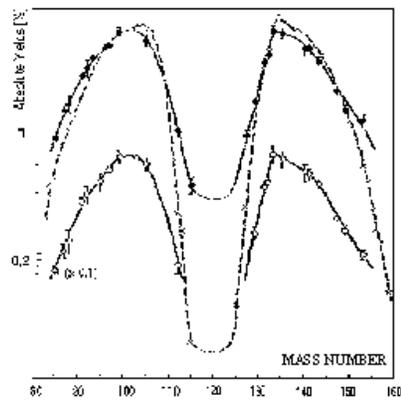


Fig. 1. Mass distribution for photofission of Pu²⁴² with 20.7 (●) and 18.1 MeV (◻) bremsstrahlung, (x) Fission of Pu²⁴¹ with thermal neutrons.

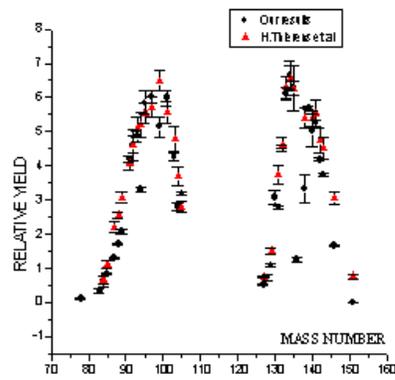


Fig. 2. Mass distribution for photofission of U²³⁸ with 15 MeV bremsstrahlung.

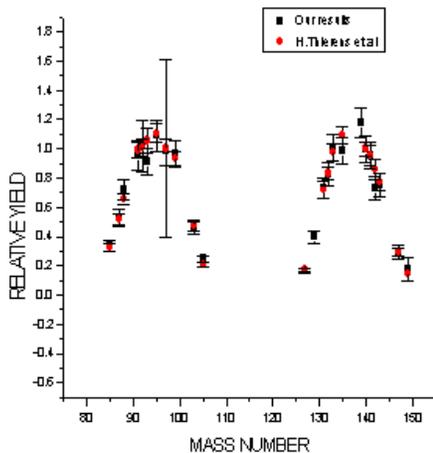


Fig. 3. Mass distribution for photofission of U²³⁵ with 18 MeV bremsstrahlung

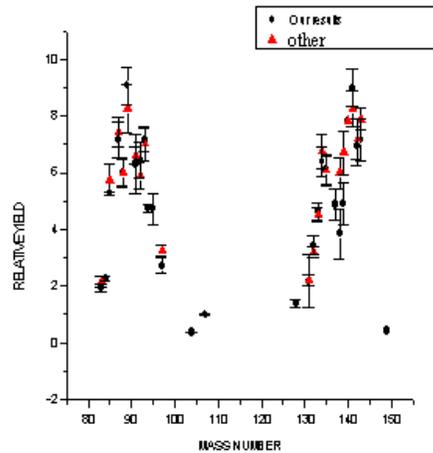


Fig. 4. Mass distribution for photofission of Th²³² with 15 MeV bremsstrahlung radiation

Our experimental results are shown in fig.1, 2, 3 and 4. We have obtained for the Pu242 photofission 25 mass chain. We can see in fig.1 a weak fine structure in mass region 133-135 due to the close neutron shell $N=82$. For the case of U235 photofission 34 product yields were obtained. For U238 the cumulative yields for 44 mass chains have been determined. A fine structure in the mass regions 133 - 135 and 140 - 142 was observed and our results are compared to those of De Frenne et al. For Th232 38 cumulative mass yields have been established. Our results are compared to that obtained by other groups and fine structure is exhibited.

Charge distribution: We have studied the charge distribution for the photofission of U238 with 15 MeV bremsstrahlung. Most of experimental data on photofission charge distribution were obtained from independent yields which were determined using chemical separation or by direct gamma spectroscopic method. In practice there are very small number of mass chain where it has been possible to determine the independent yields of more than one isobar. The data on independent yields for any photofission system available in the literature are very scarce. In the case of U238 photofission the Z_p values lie too far from the beta - stability line. So that in a given mass chain, the isotopes produced with the highest probability have very half - lives, making the measurements of these gamma spectra very difficult. We compromise by assuming that information about charge distribution can be obtained from cumulative yields for products lying far enough away from the line of beta - stability. The charge distributions for mass chains 95, 97, 99, 128, 130, 131, 132, 134, 135, 138, 140 and 141 were investigated. We deduced from cumulative (or independent) yields the most probable charges Z_p for 7 other mass chains based on two methods namely the unchanged charge distribution and the empirical relation.

Fission fragment isomeric yield ratios As it is known in fission the independent isomeric ratios are measure of the primary fission fragment angular momentum. Isomeric yield ratio can be determined if the isomeric pair are screened product, i.e, if the product can be formed only directly in fission process. Up to now the studies on the independent isomeric yield ratios in the photofission of U238 are very limited. In our investigation we succeeded in determining the isomeric yield ratios for the following pairs Sb128m - Sb128m, I132m - I132g and Xe135m - Xe135g.

Beside the above mentioned studies we have also developed the statistical model to predict independent yields and pairing effects which are in good agreement with experimental data. Recently we have applied successfully the multimodal fission model to analyze the mass distribution in fission at low excitation energies.

At the presents time we are investigating spontaneous fission and photofission of transactinide element 96Cm. The results will be published in near future.

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