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D. Bollini, F. Fossati and S. Rovera: KINETIC ENERGY OF FRAGMENTS FROM U^{235} PHOTOFISSION. -

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D. Bollini, F. Fossati and S. Rovera: KINETIC ENERGY OF FRAGMENTS FROM U^{235} PHOTOFISSION(x).

SUMMARY -

The total kinetic energy distribution of fragments have been investigated in U^{235} fission induced by Bremsstrahlung γ-rays with $E_{\gamma max}$ = 42 MeV. Silicon surface barrier detectors were used to detect fission fragments.

The mean total kinetic energy value of the U^{235} photofission is 167,5 $\pm$ 2 MeV, with only 4 MeV variation between symmetric and asymmetric fission energy.

In order to achieve better understanding of the fission process, it is worth studying the fragment kinetic energy distribution and the dependence of total kinetic energy upon the fragment masses.

In the last year, a series of experiments was carried out in which fragment kinetic energies distribution was measured in fission induced by thermal neutron, fast neutron and charged particles of moderate energy, and in spontaneous fission with solid state and time of

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flight techniques. Generally it was observed a marked decrease in the total kinetic energy as symmetrical fission is approached (i.e. for the thermal neutron induced fission the dip in kinetic energy is approximately 25 to 40 MeV).

As regard the photofission of heavy nuclei, the fragments energy distribution has not yet been investigated with sufficient thoroughness: Bochagov and co-workers(1) studied the energy distribution of U^{238} photofission fragments with a double ionization chamber and a Bremsstrahlung spectrum with $E_{\gamma max}$ = 70 MeV; the same authors(2), using a similar experimental arrangement, determined that the average total kinetic energy remains practically constant, within the limits of experimental errors, with change in $E_{\gamma max}$ = 17,5; 30; 50 MeV. They report 169 MeV in the asymmetric region, while the reported values in the symmetric region are: 157 $\pm$ 3 MeV; 159 $\pm$ 3 MeV; 160 $\pm$ 3 MeV.

More recently G.R. Hogg(3) measured the fragment mass yield distribution from the photofission of U^{238} induced by 33 MeV Bremsstrahlung for various range of total fission fragment kinetic energy release; in this experiment the fragment energies were detected by solid state detectors.

Our research project concerns the study of the fragments total kinetic energy and the variation of average kinetic energy in the regions of symmetric and asymmetric fission induced by γ-rays on odd-A nuclei. In this paper we refer on measurements performed by irradiating a U^{235} layer (99% enriched in U^{235}) of 360-400 μgr/cm^2 thickness in a 42 MeV X-ray beam produced by a Siemens Betatron at the Radiology Institute of the University of Pavia. The U^{235} sample were deposited on a VYNS + Au backing about 10 μgr/cm^2 thick. We used samples of the above thickness in order to get an adeguate yield of fission fragments (considering the fact that the average intensity is about 10^8 γ/(min-cm^2) on the target, located about 1,30 m from the platinum target and the photofission cross section is only about 50 mbarn at 20 MeV). In this arrangement, the correction for energy losses in the source thickness amounts only to 8-10%.

The energies of two coincident fission fragments have been measured by two silicon-gold-surface barrier detectors (Ortec type 300 mm^2 and 500 Ω/cm) in a back-to-back arrangement. To avoid the detectors pile-up, the target was placed at an angle of 45^o in respect to the beam direction. The semiconductors were fixed 4 cm away from the target, in such a way that they were screened by a 30 cm thick Pb cylinder with a 19 mm collimation hole. Rounded perspex collimators, 12 mm diameter, were used in front of silicon detectors to minimize low energy tailing effects in the fragment pulse. The surface barrier detectors were operated in the saturation region of the pulse-height versus applied bias curve.

A schematic diagram of the experimental arrangement is shown

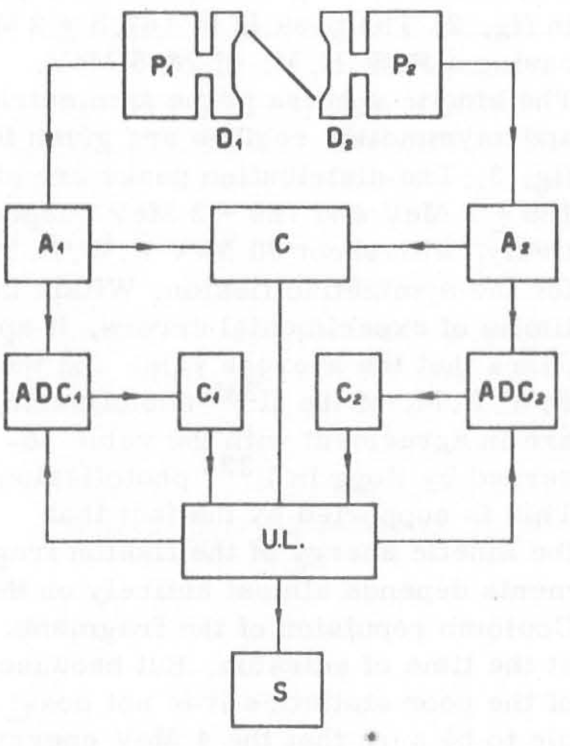

FIG. 1 - Schematic diagram of experimental lay-out and block diagram of electronics.

in fig. 1. The charges produced by fission fragments in the solid-state detectors were integrated using charge sensitive preamplifiers and successively linear amplifiers.

The pulses were analysed in a two-dimensional analyzer consisting of two 200-channel analog to digital AD converters, which were gated by a coincidence between the two fission detectors signals.

The numbers corresponding to pulse-height are classified by counters C_1 and C_2. A logic unit prints such numbers and, as soon as the cycle is over, resets the whole circuit for the next cycle.

We used solid state detectors because of their high counting efficiency; besides, they present a pulse-height versus energy linear response for a given ion mass and a reasonably good resolution for heavy ions and fission fragments i.e. $\lesssim$ 1.5 MeV F.W.H.M.

The main disavantages are: 1) the loss and dispersion in the kinetic energies due to neutron emission from the moving fragments; 2) the energy loss of fragments crossing the thin Au window of the detector; 3) the fission fragment pulse-height defect, which is mass dependent.

Due to the difficulty to evaluate the corresponding corrections in order to obtain the initial fragment kinetic energies, we have made an energy calibration of detectors using a Cf^{252} source, according to the Unik-Huizenga method[4]. We have assumed a one-to-one correspondence between equivalent points of the initial kinetic energy spectrum obtained for time of flight measurements as reported by Whetstone[5] and the final pulse-height spectrum from surface barrier detectors. Precisely we have attributed to the light and heavy fragments peaks, derived from a least-squares fit, the most probable values taken from the analog fit of Wheatstone, after correction for neutron emission.

Corrections for the fragments energy loss in the target were performed using the formula for the average energy loss per centimeter, given by Bohr[6], where we have neglected the energy loss due to nuclear collision, as its contribution in the formula is practically negligible.

The fragment total energy spectrum of U^{235} photofission is shown in fig. 2. The peak is at 167,5 $\pm$ 2 MeV, having a F.W.H.M. of 26,5 MeV. The kinetic spectra in the symmetric and asymmetric regions are given in fig. 3. The distribution peaks are at 165 $\pm$ 2 MeV and 169 $\pm$ 2 MeV respectively, with about 30 MeV F.W.H.M. for the symmetric fission. Within the limits of experimental errors, it appears that the average value and the F.W.H.M. of the U^{235} photofission, are in agreement with the value observed by Hogg in U^{238} photofission. This is supported by the fact that the kinetic energy of the fission fragments depends almost entirely on the Coulomb repulsion of the fragments at the time of scission. But because of the poor statistics it is not possible to be sure that the 4 MeV energy variation between the symmetric and asymmetric fission is a real effect in U^{235} photofission.

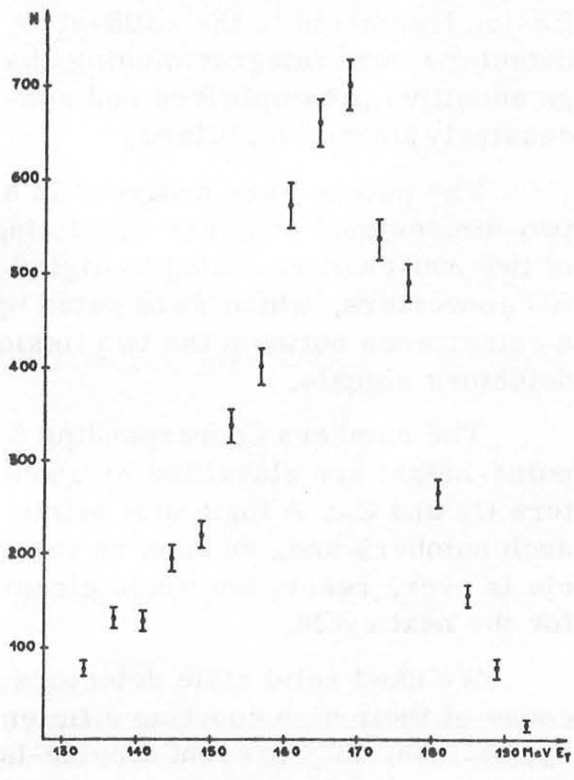

FIG. 2 - Total kinetic energy distribution for U^{235} photofission.

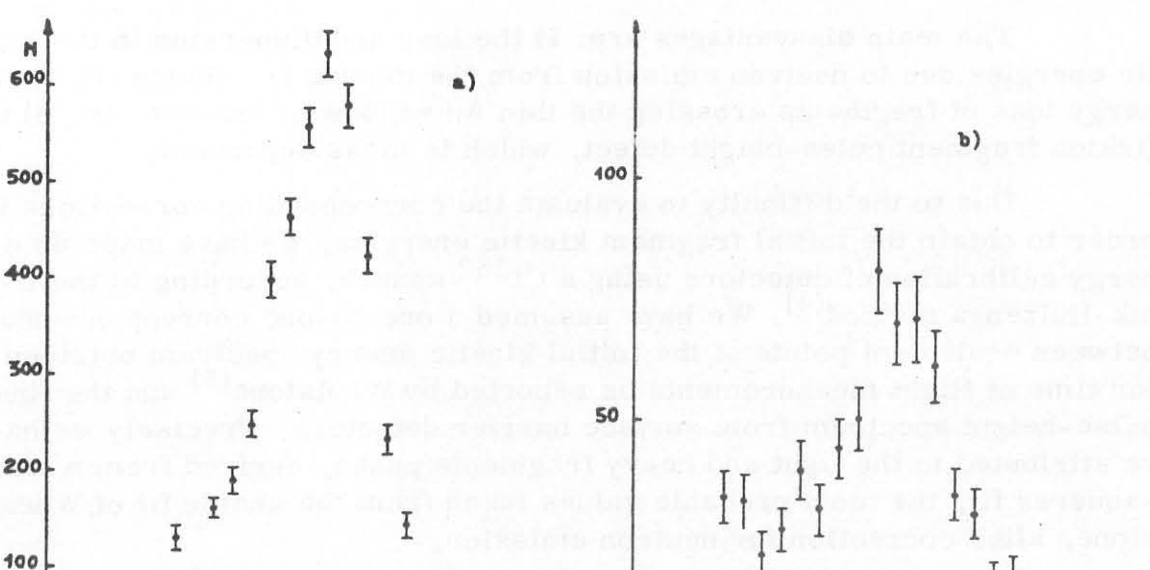

FIG. 3 - Spectra of the total fragments kinetic energy from: a) asymmetric photofission; b) symmetric photofission.

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