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THE PHOTOFISSION OF Bi, Th AND U BETWEEN 300 AND 1000 MEV *

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The fission process produced by high energy γ-rays in heavy nuclei was investigated up to an energy of 500 MeV by Jungerman and Steiner [1], who examined the following nuclei: ^{238}U, ^{235}U, ^{232}Th, ^{209}Bi and ^{197}Au, by means of the University of California and of the Cal. Tech. syncrotrons. The present letter gives our preliminary results on photofission obtained by means of the Frascati syncrotron,

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between 300 and 1000 MeV, with an improved nuclear emulsion technique, on ^{238}U, ^{232}Th and ^{209}Bi. The work is still in progress, but it seems useful to give a preliminary account of it as the U, and Th results are different from those by Jungerman and Steiner [1].

The photoemulsion technique is that described by de Carvalho et al. [2,3], which makes it possible to get only very clear fission tracks, on a background of up to 10^9 decays per square centimeter, under heavy -irradiations (up to 1000r). Bismuth loaded K 0 pellicles were kindly supplied by Ilford Ltd.; U and Th loaded pellicles were prepared from K 0 gel emulsion in this laboratory. Technical details about the loading, the precise (1%) measurement of the weight of the included elements, and the difficulties met with the processing of the loaded emulsions will be described elsewhere.

Emulsions were exposed perpendicularly to the collimated -ray beam. The collimator diameter was very small, so that it was possible to make a complete scanning of the small (8 mm diameter) emulsion area hit by the -rays. Between 1000 and 6000 fission tracks were counted in any scanned plate. The intercalibration of different scanners, with and without a track mapping, was carefully performed and gave a 95% scanning efficiency. Dose and energy measurements were obtained by means of the standard Frascati facilities.

Our results are shown in Figs. 1, 2, 3, in comparison with those by Jungerman and Steiner [1]. The Bismuth results are in good agreement, but on the contrary the U and Th results are rather different: Jungerman and Steiner got rather dispersed points and reached the conclusion that any increase in the yield curve at high energy was masked by the big background coming out from fissions produced by the bremsstrahlung spectrum in the giant resonance region (15 MeV). We found, instead, that when the maximum bremsstrahlung energy E is increased from 300 to 1000 MeV a marked increase of the cross section o_Q^F, per quantum equivalent is observed; our five experimental points (Figs. 1, 2) are aligned along a straight line. Probably some difference of calibration between the two machines used by the previous authors is mainly responsible for this discrepancy. If the straight-line approximation is accepted, as a consequence the cross-section per photon $o_K^F = do_Q^F/d \ln E$ results to be constant and the leastsquare calculations give (see graphs in Figs. 1, 2, 3), in units of 10^{-27} cm^2:

(1) $$o_K^F(U) = 60;$$

(2) $$o_K^F(Th) = 36;$$

(3) $$o_K^F(Bi) = 6.5.$$

The overall experimental errors are evaluated to be of the order of 10%. The above results can be compared with those obtained by several authors [4,5] about the photoproduction of stars in the elements of the photoemulsions. Inside the experimental errors, these results are consistent among them and with the assumption of a cross-section approximately constant between 300 and 1000 MeV.

Now, according to the accepted theoretical scheme [6] the stars are produced by high energy photons via the photoproduction of mesons which are reabsorbed in the nucleus. On the other hand, the experimental photostar cross-section is so high that one must assume that a star is produced any time a photomeson is produced, that is that the reabsorption probability is nearly unity. This conclusion is reached by taking into account any type of multiple meson production, with the appropriate statistical weight [5].

Therefore, it is possible to get a reasonable guess about the photostar production cross-section, in any nucleus, by simply taking account of its number of nucleons (disregarding the rather small difference between the inelastic cross section of -rays against the two kinds of nucleons) [7].

By means of this procedure, starting from the slope of the straight line giving the o_Q^S of photostars in photoemulsions plotted against log E_{max}, we get the following cross-sections for photostar production (in mb)

(1') $$o_K^S(U) = 73;$$

(2') $$o_K^S(Th) = 71;$$

(3') $$o_K^S(Bi) = 64;$$

with errors of 20%. [5]

For the "fissionability defined as $x = o_K^F/o_K^S$ we obtain

$$x(U) = 0.85 ;$$

(4) $$x(Th) = 0.52 ;$$

$$x(Bi) = 0.10 .$$

All these values of x appear to be approximately constant, at least between 500 and 1000 MeV. They are consistent with the fissionabilities obtained by Steiner and Jungerman [8] with protons between 100 and 340 MeV.

Of course much work is still necessary in order to confirm eq. (4) and give them a clearer significance. These points will be discussed in a next paper, when more experimental data will be available. For the moment we want to note two points. The first one is that x depends very strongly on the considered nucleus, but is quite insensitive to the excitation energy. A possible explanation of this behaviour cannot be derived from the fact that the U and Th nuclei (having a low threshold) can undergo fission even when a produced meson is not reabsorbed. In fact the fission probability in an excited nucleus, at low energy, is only 10%. Besides, this argument is not at all able to explain the quoted results with high energy protons [8].

The second point is that some enhancement effect due to a coherent production of π^0-mesons and of $\pi^+\pi^-$ pairs ( ) could contribute to the star production and be partly responsible for the unexpectedly high observed cross sections.

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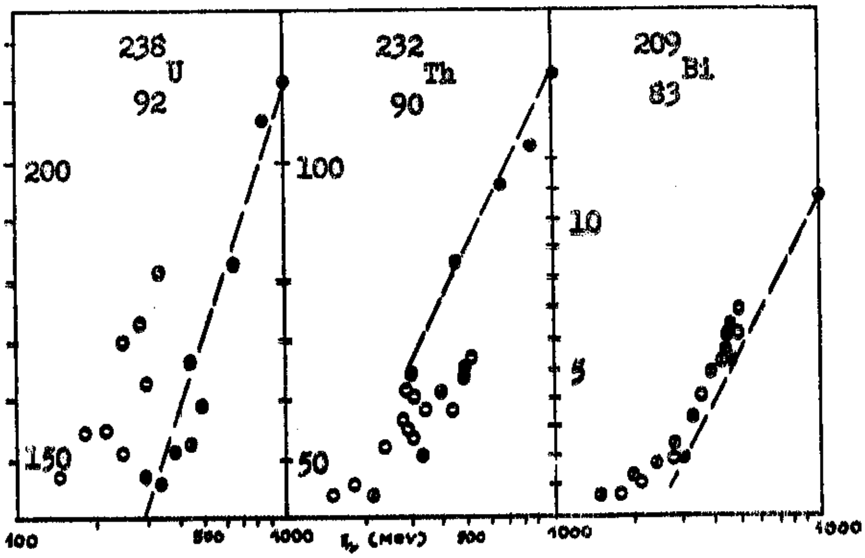

238 U 92
232 Th 90
209 Bi 83
200
150
100
50
10
5
100
500
1000
E_γ (MeV)
500
1000
1000