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FISSION OF Au INDUCED BY THE COHERENT PHOTON BEAM FROM 1 GeV ELECTRONS*

G.Bologna
Laboratori Nazionali del CNEN,Frascati,Italy

and

V.Emma, A.S.Figuera, S.Lo Nigro, C.Milone
Istituto di Fisica Generale dell'Università,Catania,Italy and Istituto Nazionale di Fisica Nucleare, Sezione di Catania, Catania,Italy.

Abstract: Fission measurements on Au have been performed by means of coherent bremsstrahlung photon beam from 1 GeV electrons. The photofission cross section deduced from the experimental yields by an unfolding method shows a resonance at photon energy 320 MeV.

In recent years the photofission measurements at phothon energies $K>100$ MeV have been extended to elements with $Z\leq 83$ in several laboratories [1÷10] by using bremsstrahlung beams as photon sources.

The quantity experimentally measured is the cross section "per equivalent γ quantum" (photofission yield), σ_q, as a function of the maximum energies of the bremsstrahlung spectrum; the cross section per photon, σ_f, is then deduced by knowing the photon energy spectrum.

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The general features of the photofission cross section σ_f obtained from the experimental data unexpectedly disagree among the different authors so that it is difficult to give an obvious interpretation of the photofission mechanism at K>100 MeV energies. In fact, some authors [2,3,6,7,9] find a constant fission cross section in the energy range 300÷1000 MeV, some [4,5,10] deduce that the cross section reaches a constant value at photon energies corresponding to the first resonance in photopion production and a more or less pronunced decrease for higher energies, some [1,8] still evidence a broad peak around 300 MeV wich agree with the behaviour of the total cross section for photopion production.

This ambiguity in the results is connected with the type of the photon spectrum generally used and with the analysis procedure of the experimental data: the integral equation from wich the σ_f cross section is extracted is "unstable".

The ideal situation would be that of using monoenergetic photons. But, because of the low intensities of monochromatic γ beams at present available, we came to a reasonable compromise that it is provided by the coherent bremsstrahlung photons beam obtained by allowing the electron beam of the Frascati 1 GeV electrosyncrotron to strike a diamond single crystal [12÷14].

Two typical spectra of coherent photons obtained for two different orientations of diamond crystal are shown in fig.1. The dots and the triangles represent the measured intensities

KN(K), the solid curves are the best fits calculated by the least-square method taking into account the theoretical cross section of coherent bremsstrahlung.

By varying the crystal orientation it is possible to change the energy K_p of the main first peak of coherent photons; in fig.1 for instance the main peaks fall at K_p=220 MeV and K_p=490 MeV.

By using this type of photon beam we have carried out photofission measurements for several elements with $Z \leq 83$; in this letter we report only the preliminary results on Au.

The fission fragments have been detected by means of the glass sandwiches tecnique we used in previous photofission measurements and described in other papers [5,11].

The irradiation has been performed at 16 different energies of the main peak of photons, in the energetic interval between 220 to 490 MeV, by varying the crystal orientation and fixing the energy E_o of electron beam at 1000 MeV.
The measurements have not been extended to main peak energies higher than 500 MeV because the amplitude of the first peak decreases by increasing its energy for E_o constant, as fig.1 shows.

All the photons spectra have been measured simultaneously to the irradiation of the fissionable samples by means of a pair spectrometer and a real time acquisition system with an on-line computer.

The irradiation has been performed by a collimated γ-ray beam with an 1 mrad acceptance angle; the dose was measured by a Wilson quantameter: for each exposure the dose was about $3\cdot10^{12}$ equivalent quanta, corresponding to irradiation time of about 4 hours.

The glass plates used as fission fragments detectors were scanned,after the etching procedure, by means of an optical microscope connected to a telecamera and video display*.

The results relative to the Au photofission are reported in fig.2; the dots give, in arbitrary units, the experimental yields per equivalent quantum with the bars representing the combination of the statistical and the scanning accidental errors. The continous curve represents the calculated yield by assuming a constant fission cross section for photon energies between 100 MeV to 1000 MeV. All the data are reported as a function of the first peak energy of the photon spectrum.

The departure of the experimental results from the continous curve of fig.2 clearly shows the existence of structures in the photofission cross section and it stresses the advantage of using the coherent bremsstrahlung beam.
In fact for a normal bremsstrahlung beam the observed departure would be much less.

*MICROVIDEOMAT system made by C.Zeiss,Oberkochen,West Germany.

The photofission cross section σ_f is related to the experimental yields $Y(K_p)$ by the following Fredholm integral equation of the first kind:

$$Y(K_p) = \int_{E_{th}}^{E_o} N(K_p,K)\,\sigma_f(K)\,dK \tag{1}$$

where K_p represents the energy of the main peak in the bremsstrahlung coherent spectrum, E_{th} is the energy of the photofission threshold (we assume E_{th}=100 MeV for Au), E_o the electron energy (1 GeV in our case); $N(K_p,K)$ represents the number of photons in unit interval of K energy, for a given peak position K_p.

For solving eq.(1) with respect to $\sigma_f(K)$ we developed an unfolding method similar to that described by Phillips [15], Twomey [16], Cook [17] and Tesch [18] with the modifications due to the different shape of the photons spectrum. The details of our procedure will be reported in a successive paper.

The obtained solution of eq.(1) is drawn in fig.3 in arbitrary units. The vertical bars represent the error propagated by the errors in the experimental $Y(K_p)$ values. The solution gives informations also at energies higher than 500 MeV (see the dashed curve in fig.3); because the experimental measurements have been performed only for K_p energies up to 500 MeV (for the reasons explained before) we think that the behaviour of σ_f obtained for K>500 MeV is less reliable than for K<500 MeV.

Consequently we give for sure the presence of a first resonance at K≃320 MeV with FWHH≃140 MeV whilst there is only an hint of a second very broad and flat resonance centred at K≃700 MeV The smoothing introduced in the method of solution for obtaining the results of fig.3 has been fixed in such a way to give an estimated yield function with a standard error equal to 1. These estimated yields are given in fig.2 by the dashed curve. The position of resonance evidenced by our unfolding procedure is in a very good agreement with the energy of the first photopion resonance. This indicates that the photomesonic mechanism predominates at energies about the resonance for the Au photofission process.

A similar result has been suggested by Vartapetyan et al.[8].However it must be remarked that these authors [8] only folded a Schiff bremsstrahlung spectrum with a σ_f cross section calculated from a model of photomesonic production and showed that the deduced yields were not incompatible with the experimental ones.

On the other hand our unfolding method shows that a photofission cross section with a resonance at K=320 MeV is requested to explain the experimental data, while a constant photofission cross section in the range 100÷1000 MeV is inconsistent with them.

It is our aim to complete the analysis of the Au experimental data and to extend it to the other elements already irradiated, and so to have a more complete picture on the photofission cross section behaviour for the medium-heavy nuclei.

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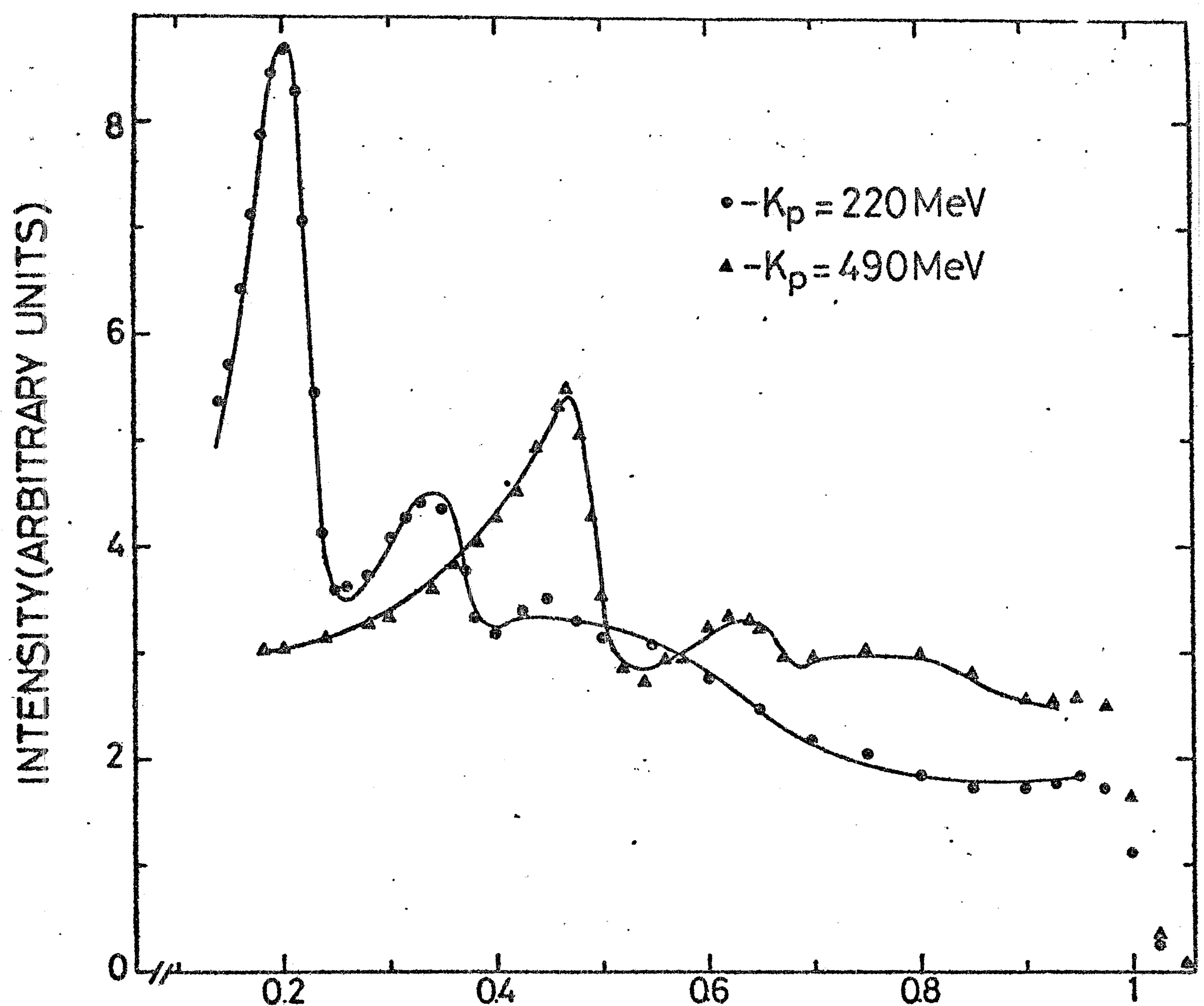

Fig.1 - Coherent bremsstrahlung intensity of E_o=1 GeV electrons in a diamond single crystal versus the photon energy K. The solid curves are the best fits.

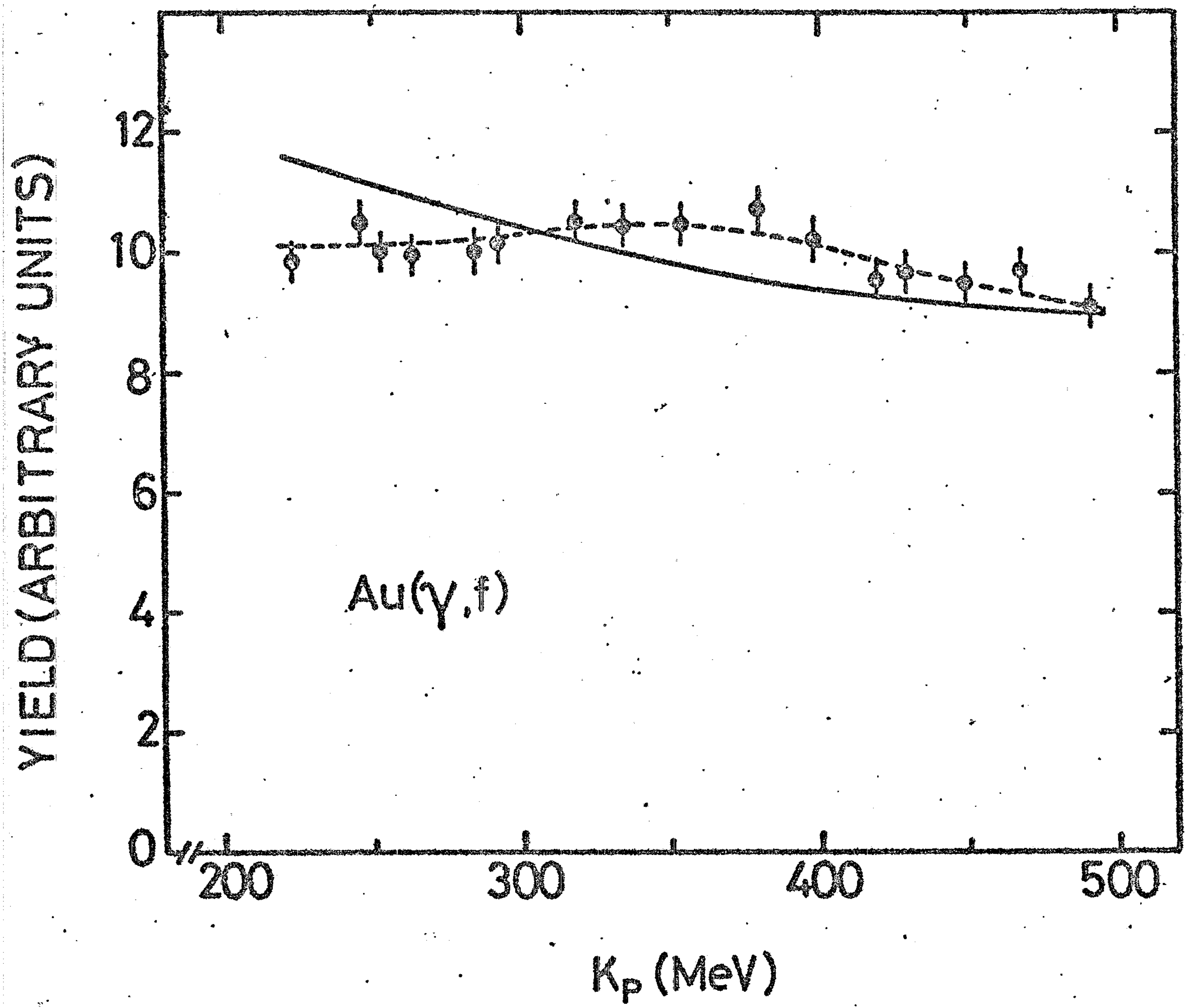

Fig.2 - Yields per equivalent quantum of the Au photofission as a function of the first peak energy K_p of photons. The dots are the experimental data.

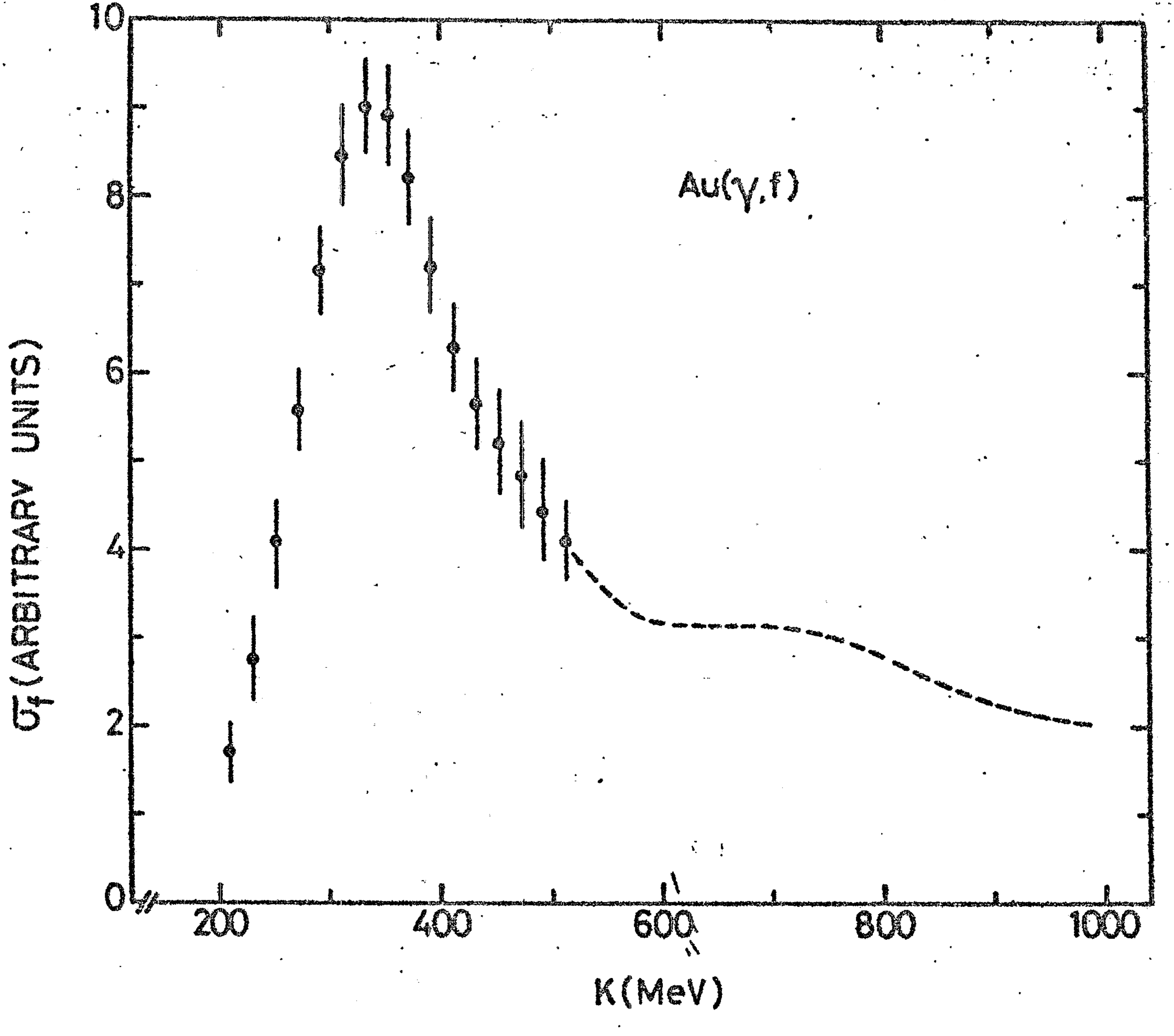

Fig.3 - Photofission cross section σ_f of Au deduced from the experimental yields.