ON THE INTENSITY OF RADIATIONLESS TRANSITIONS IN THE μ-MESIC ATOMS OF Pb, Bi, Th, U^{235}, U^{238}

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(presented by A. I. Mukhin)

In a paper by Balatz et al [1] experiments were described showing that the intensity of meson X-ray photons corresponding to the transition $2P \rightarrow 1S$ is smaller in U^{238} than in Pb. This indicates the presence in heavy mesic atoms of radiationless transitions, in which the $2P \rightarrow 1S$ energy is not released in the form of one X-ray photon. Assuming that the probability of radiationless transitions in meso-lead

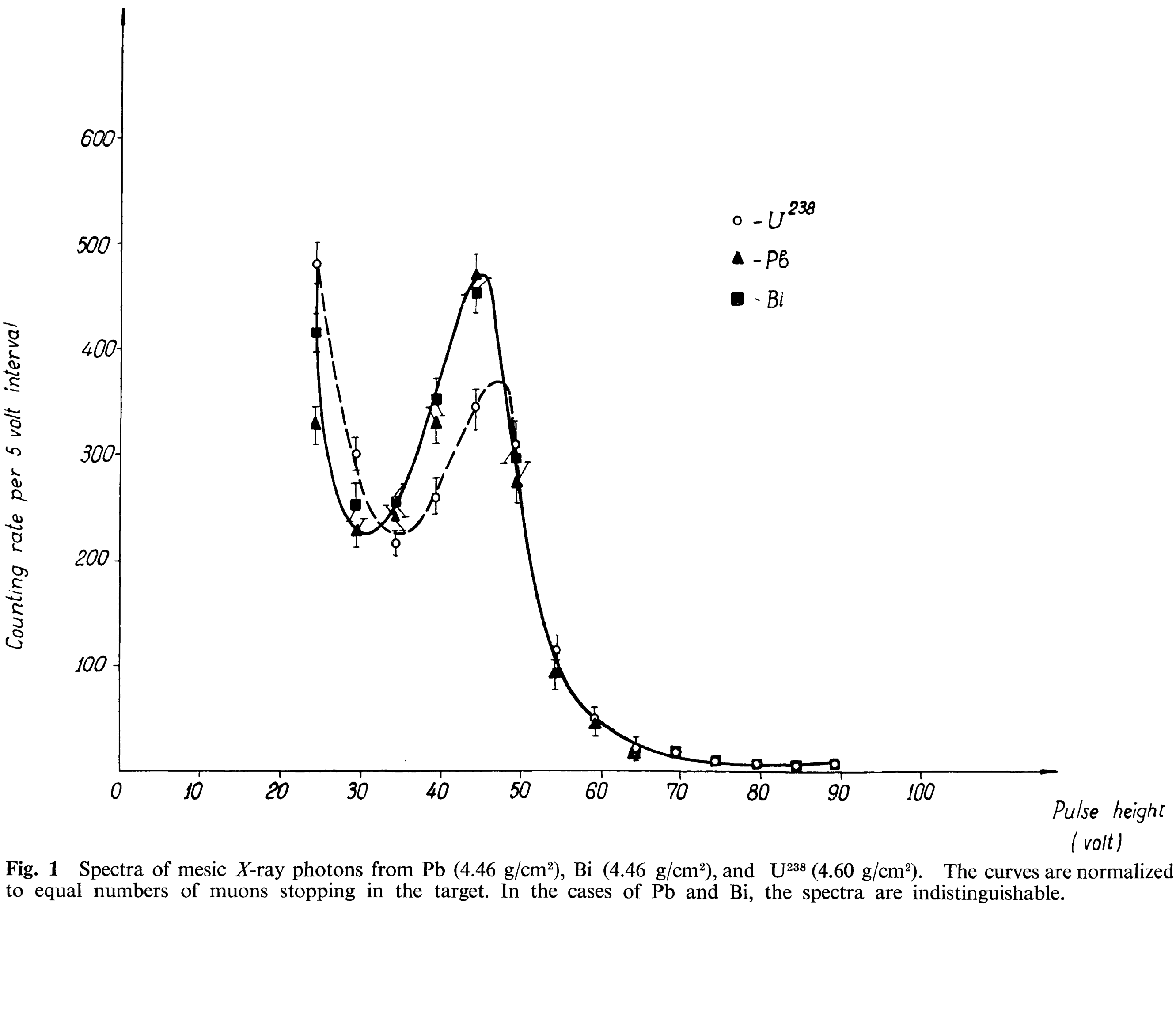

Fig. 1 Spectra of mesic *X*-ray photons from Pb (4.46 g/cm²), Bi (4.46 g/cm²), and U^{238} (4.60 g/cm²). The curves are normalized to equal numbers of muons stopping in the target. In the cases of Pb and Bi, the spectra are indistinguishable.

$(W_{exc})_{Pb}$ is much smaller than the probability $(W_{h\nu})_{Pb}$ of emitting one photon $((W_{h\nu})_{Pb} = 1)$, it was concluded that

$$1 > \frac{W_{exc}(U^{238})}{W_{h\nu}(U^{238})} > 0.1 .$$

This year a systematic investigation of the intensities of the $2P \to 1S$ transitions in the mesic atoms of Pb, Bi, Th, U^{235}, U^{238} is presented. The experimental set-up is similar to that used before. With a scintillation spectrometer triggered by a muon stopping in the element under investigation, the spectra of the meson X-rays were measured in the energy region corresponding to the $2P \to 1S$ transition. Special attention was paid to the determination of the background level, i.e., of the Na I detector counting rate with a pulse amplitude in the corresponding $2P \to 1S$ transition region, but not connected with such transitions.

The intensity of this background was sharply decreased with a gas Čerenkov threshold counter suppressing practically all the electrons. The pion intensity in the beam was several times less than the muon intensity. Moreover, the background produced in the region of pulse amplitudes corresponding to the $2P \to 1S$ transition by other transitions of the mesic atoms under investigation (mainly $3D \to 2P$) was studied in separate experiments by means of Mo and Cd samples. In this way the form of the $3D \to 2P$ lines of the mesic atom investigated was measured.

As an example, in Figs. 1 and 2, are presented the spectra of the $2P \to 1S$ photons from Pb, Bi, U^{238} and from Pb, U^{235}, respectively.

In Table I the intensities of the meson X-rays emitted in the $2P \to 1S$ transitions, normalized to an equal number of muons stopping in the target, are given in relative units.

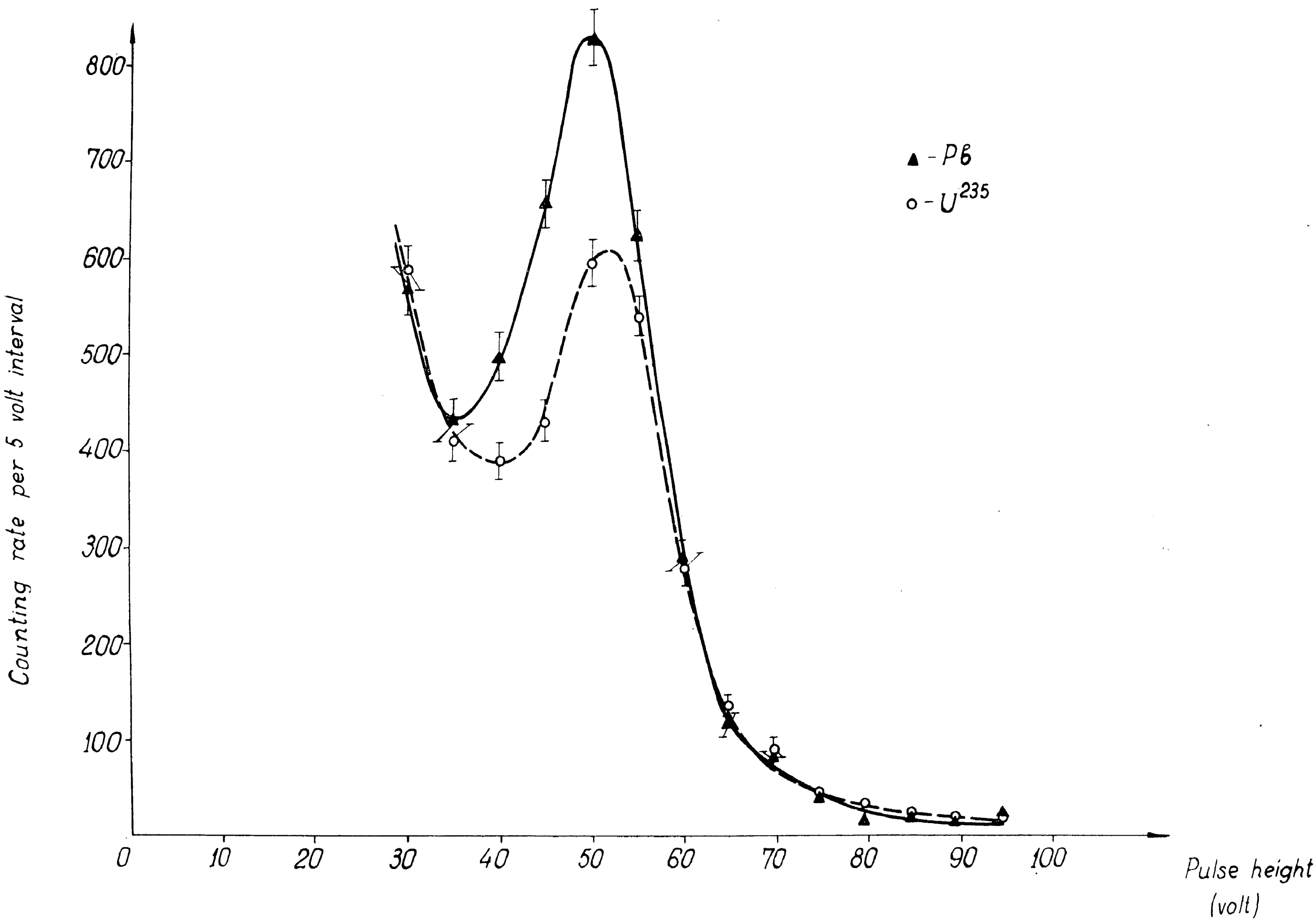

Fig. 2 Spectra of mesic X-ray photons from Pb (5.55 g/cm²) and U^{235} (5.59 g/cm²). The curves are normalized to equal numbers of muons stopping in the target.

Table I.

	Corrected intensity of the $2P \to 1S$ meson X-ray radiation
Pb	1
Bi	1 ± 0.06
Th	0.85 ± 0.0
U^{235}	0.71 ± 0.05
U^{238}	0.77 ± 0.04

The values given in Table I were affected by corrections, taking into account that the samples used had equal stopping power for muons, and, therefore, were not exactly equivalent from the point of view of photon absorption (different energies and different Z).

As is seen from this Table, the intensities in Pb and Bi are equal. This can be understood in terms of the anomalously small density of nuclear levels in Pb and Bi, which makes the fraction of radiationless transitions practically equal to zero. In the other nuclei the effect of radiationless transitions is noticeable.

A priori the excitation of nuclei resulting from radiationless transitions may lead to :

1. Fission.
2. Disintegration accompanied by the emission of one neutron, and
3. Photon cascade, making the nucleus return to its ground state (this phenomenon resembles the Mandelstam-Landsberg-Raman effect in optics).

Radiationless fission is unlikely because of the muon Coulomb field. Neutron emission is impossible on energy grounds in Th. The threshold for neutron photoproduction in U^{235} is considerably smaller than in U^{238} (the thresholds for photoneutron emission are equal to 6.35 ± 0.04, 5.97 ± 0.10, 5.1 ± 0.1 MeV respectively for Th, U^{238}, U^{235}, while the $2P \to 1S$ energy is close to ~ 6 MeV for all mesic atoms in question).

The fact that the intensities of radiationless $2P \to 1S$ transitions in U^{238} and U^{235} are not very different suggest that the mechanism 3 (photon cascade), plays an essential role in " radiationless transitions ".

LIST OF REFERENCES AND NOTES

1. Balatz, M. J., Kondratiev, L. N., Landsberg, L. G., Lebedev, P. T., Obukhov, Yu. V. and Pontecorvo, B. JETP **38**, p. 1715 (1960).

DISCUSSION

HINCKS : I would like to ask two questions about this experiment.

(1) What was the size of the NaI crystal?

(2) How were the values of the yields determined from the experimental curves; would they be affected by variations in the shape of the K-peak?

MUKHIN : I do not know the exact dimensions of the crystal; it had a diameter of approximately 3 to 4 cm and about the same thickness. The yields were determined by measuring the areas under the peaks after subtracting the background, and so would not be affected by differences in shape.