based on the considerably weaker requirement, namely $g_{\Sigma\Lambda\pi} = g_{\Sigma\Sigma\pi}$.

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[1] Fisher, Leontic, Lundby, Meunier, and Stroot, Phys. Rev. Lett. 3, 349 (1959).

[2] Nordberg, Pov, and Barns, ibid. 4, 23 (1960).

[3] D. Kurath, ibid, 4, 180 (1960).

[4] H. A. Weidenmüller, ibid. 4, 299 (1960).

[5] Bardin, Barnes, Fowler, and Seeger, ibid. 5, 323 (1960).

[6] R. Feynman, Report at the Tenth Rochester Conference, 1960.

[7] É. M. Lipmanov, JETP 38, 1233 (1960), Soviet Phys. JETP 11, 891 (1960).

[8] B. L. Ioffe, JETP 38, 1608 (1960), Soviet Phys. JETP 11, 1158 (1960).

[9] B. M. Pontecorvo, JETP 37, 1751 (1959), Soviet Phys. JETP 10, 1236 (1960).

[10] É. M. Lipmanov, JETP 37, 1054 (1959), Soviet Phys. JETP 10, 750 (1960).

[11] A. Pais, Phys. Rev. 111, 574 (1958) and 110, 1480 (1958).

[12] S. B. Treiman, Nuovo cimento 15, 916 (1960).

Translated by J. G. Adashko
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FISSION INDUCED BY MUONS

D. F. ZARETSKII and V. M. NOVIKOV

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THERE is an observable probability that the energy released in the 2p to 1s transition in μ-mesonic atoms is converted into nuclear excitation.[1,2] In uranium and plutonium, the excitation energy amounts to ~ 6.3 Mev. At this energy the nucleus can decay into various channels, namely, by γ emission, neutron emission, and fission.

Grechukhin (private communication) has stated that the fission channel is forbidden. Qualitatively, this effect is due to the fact that the meson in the 1s state near the nucleus hinders the nuclear deformation which would lead to fission. Therefore, the fission barrier is higher with meson present than without the meson. The closer the fission threshold is to the excitation energy, the larger the effect of the presence of the 1s meson is on the fission probability.

Since the rotational energy of the nucleus is much less than the energy of the meson in the ground state, rotational effects and nuclear fission are adiabatic with respect to the mesonic motion. Thus, the calculation of the effect of the meson on fission can be carried out for a fixed orientation of the nuclear axis.

The binding energy of the meson in the ground state decreases when the nucleus is deformed and thus the energy threshold for fission is correspondingly increased, since the potential curve for nuclear fission with the meson present is $E^{\mu}_{\text{nuc}} = E^{0}_{\text{nuc}} + E_{\mu}$ where E^{0}_{nuc} is the potential curve for fission without the meson and E_{μ} is the binding energy of the meson which depends on the nuclear deformation parameters. To find E_{μ}, it is necessary to solve the Schrödinger equation for the meson in the Coulomb field of the deformed nucleus. We assume for simplicity that up to the saddle point the nucleus has the form of an ellipsoid of revolution. The Coulomb potential of a uniformly charged ellipsoid of revolution with semi-axes a and b has the form

$$\begin{aligned}\varphi(\alpha, \beta) = \frac{Ze}{c}\Big\{&[1 - P_2(\operatorname{ch}\alpha) P_2(\cos\beta)] \ln \operatorname{cth}\frac{\alpha_0}{2} \\ &+ \frac{3}{2}\frac{\operatorname{ch}^2\alpha}{\operatorname{ch}\alpha_0} P_2(\cos\beta) \\ &+ \frac{3}{4}\left(1 - \frac{\operatorname{sh}^2\alpha}{\operatorname{sh}^2\alpha_0}\right)\frac{\sin^2\beta}{\operatorname{ch}\alpha_0}\Big\} \quad \text{for } \operatorname{ch}\alpha \leqslant \operatorname{ch}\alpha_0 = \frac{a}{c},\end{aligned}$$

$$\begin{aligned}\varphi(\alpha, \beta) = \frac{Ze}{c}\Big\{&[1 - P_2(\operatorname{ch}\alpha) P_2(\cos\beta)] \ln \operatorname{cth}\frac{\alpha}{2} \\ &+ \frac{3}{2}\operatorname{ch}\alpha P_2(\cos\beta)\Big\} \quad \text{for } \operatorname{ch}\alpha \geqslant \frac{a}{c}, \qquad (1)^*\end{aligned}$$

where Ze is the nuclear charge, $c^2 = a^2 - b^2$, $P_2(x)$ is the Legendre polynomial of order two, and α and β are the degenerate ellipsoidal coordinates.

The Schrödinger equation for the ground state of the mesonic atom with the potential (1) was numerically integrated on an electronic computer. Below are presented the values of the binding energy of the meson in the ground state of the U^{238} mesonic atom as a function of the ratio of the semiaxes of the nucleus

a/b =	1.2	1.4	1.6	1.8	2	2.2	2.5
E_{μ} (Mev) =	11.89	11.79	11.66	11.53	11.36	11.21	11.01

With the hydrodynamic model for fission,[3] it is possible to find the ratio of the nuclear semiaxes at the saddle point, $(a/b)_{\text{sp}}$. This ratio and the increase, ΔE, in the height of the fission barrier for several nuclei are given in the table [$(a/b)_0$ is the statistical nuclear deformation,[4] E_{thr} is the photofission threshold[5]].

Nucleus	$(a/b)_0$	$(a/b)_{sp}$	E_{thr}, Mev	ΔE, Mev
U^{238}	1.30	2.24	5.8	0.6
U^{235}	1.25	2.2	5,75	0,6
Pu^{239}	1.30	2,17	5.48	0,5

It is clear from the table that in U^{238} the fission threshold with the meson present is higher than the excitation energy, while in Pu^{239} it is approximately 0.3 Mev below the excitation energy. Nuclear fission induced by μ mesons via the mechanism discussed here has been studied[6,7] in U^{238}. From this calculation it is clear that Pu^{239} is more suitable for an investigation of this effect.

In conclusion, the authors express their profound gratitude to D. P. Grechukhin for his advice and counsel, and also to V. K. Saul'ev for programming and carrying out the calculation on the electronic computer.

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*ch = cosh; cth = coth; sh = sinh.

[1] D. F. Zaretskii, Soviet Papers of the Second Geneva Conference, M. 1959, v. **1**, p. 462.

[2] D. F. Zaretskii and V. M. Novikov, Nuclear Phys. **14**, 540 (1960).

[3] W. J. Swiatecki, Proceedings of the Second United Nations International Conference on the Peaceful Uses of Atomic Energy, Geneva 1958, v. **15**, p. 248.

[4] Alder, Bohr, Huus, Mottelson, and Winther, Revs. Modern Phys. **28**, 432 (1956).

[5] A. Cameron, Proceedings of the Symposium on the Physics of Fission, Ontario 1956, p. 189.

[6] Belovitskii, Kashchukeev, Mikhul, Petrashku, Romanova, and Tikhomirov, JETP **38**, 404 (1960), Soviet Phys. JETP **11**, 296 (1960).

[7] Diaz, Kaplan, MacDonald, and Pyle, Phys. Rev. Lett. **3**, 234 (1959).

Translated by M. Bolsterli
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OBSERVATION OF RESONANCE ABSORPTION OF THE 23.8-kev GAMMA RAYS OF Sn^{119} *BY USING THE CONVERSION ELECTRONS*

K. P. MITROFANOV and V. S. SHPINEL'

Nuclear Physics Institute, Moscow State University

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THE study of resonance absorption of γ rays by nuclei bound in crystals (the Mössbauer effect) is usually done from the attenuation of the beam of γ rays by filters containing nuclei which can be excited resonantly. Thus the resonance absorption effect is observed on a relatively large background of γ radiation transmitted through the absorber. A considerably larger relative effect can be obtained by observing resonant scattering.[1]

It is also of interest to study the resonance by observing the conversion electrons which are emitted in the de-excitation of the resonance level. Such a method has advantages in those cases where the resonance absorption cross section is much greater than the cross section for the photoeffect, and where the internal conversion coefficient is not too small.

We have used this method to investigate the temperature dependence of the resonance absorption of the 23.8-kev γ rays which occur in the decay of the isomeric state of Sn^{119} at an energy of 89 kev ($T_{1/2} = 250$ days). According to our estimates, the resonance absorption cross section for these γ rays is approximately 30 times greater than that for the photoeffect, while the internal conversion coefficient is 6.3. The recording of the conversion electrons emitted in the deexcitation of the nuclei was done in a double lens β spectrometer whose luminosity with fully open entrance and exit diaphragms was 7%. We used a source which was 0.02 mm thick, with an activity of 30 μC, obtained by irradiation of metallic tin enriched to 94% Sn^{118} with thermal neutrons. The content of Sn^{119} in the source did not exceed 2.3%.

The absorbers were prepared by depositing a thin layer of tin on an aluminum foil by evaporation in vacuum, where we used tin enriched to 75% Sn^{119}, while ordinary tin was used for control measurements. The absorber thickness was ~ 0.1 mg/cm^2. Between the source and absorber we placed a 6 mm thick plate of beryllium to absorb the β radiation