as pointed out by I. Ia. Pomeranchuk, that the neutrino energy is always at least several orders of magnitude larger than $m_\nu c^2$ (m_ν = neutrino rest mass), and therefore one has in the laboratory system a considerable relativistic dilation of the transformation time, one is faced with the question whether the condition $T \lesssim 10^{-8}$ sec is not completely improbable even under assumptions (a) and (b). The time T is related to the mass difference Δm between the particles ν_1 and ν_2. Δm is proportional to the first power of the matrix element H for the transition $\nu \rightleftarrows \tilde{\nu}$, about which unfortunately nothing definite can be said without some more detailed assumptions regarding the β-process — such as, for example, the Preston scheme,[8] according to which the scalar covariant in the interaction is responsible for the emission of neutrinos, the tensor for the antineutrinos, with comparable although different coupling constants. In that case the transformation $\nu \to \tilde{\nu}$ is caused by two successive virtual transitions, each of which is characterized by a coupling constant on the order of the constant G of weak interactions ($G \sim 10^{-7} - 10^{-6}$ in units $\hbar = c = \mu = 1$, where μ = π-meson mass); hence H will be proportional to G^2 and $\Delta m \sim 10^{-11} m_e$. The time[9] T turns out to be $\sim 10^{-10} \times$ (neutrino energy)/($m_\nu c^2$) sec, which is considerably longer than 10^{-8} sec.

However, one cannot exclude a direct (first order in G) interaction responsible for the neutrino-antineutrino transformation

$$\nu \to (\tilde{\nu} + N + \tilde{N}) \to \tilde{\nu}.$$

In this case Δm is proportional to the first power of the coupling constant,[9] and $T \sim 10^{-16} \times$ (neutrino energy)/($m_\nu c^2$) sec. For a neutrino of 1 Mev energy with $m_\nu c^2 = 100$ ev (experiments[10] show that $m_\nu c^2 \lesssim 500$ ev), one gets $T \sim 10^{-12}$ sec.

In conclusion we wish to emphasize that, independently of the probability of the concrete effects discussed above and of the form of the theory, nonconservation of neutrino charge with distinct neutrino and antineutrino (or, what is the same, the existence of two Majorana neutrinos with different combined parity) inescapably leads to effects of the Gell-Mann — Pais — Piccioni[2] type. The effects due to neutrino-antineutrino transformations may not be observable in the laboratory, owing to the large R but they will take place on an astronomical scale.

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ANGULAR ANISOTROPY IN THE EMISSION OF FRAGMENTS UPON FISSION OF Pu^{239} *BY 14-MEV NEUTRONS*

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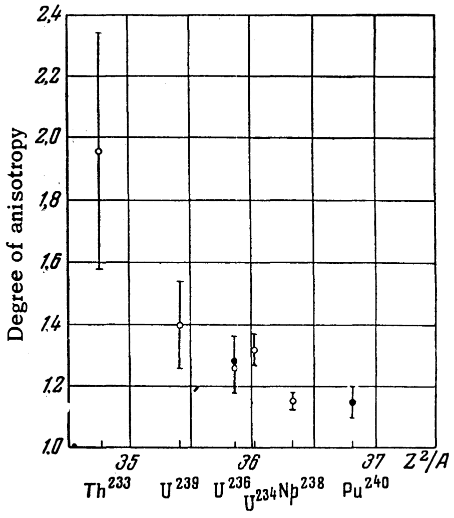
It was found in previous work[1-5] that the angular distribution of fission fragments, where the fission is induced by fast particles, is anisotropic, and that the extent of the anisotropy (the ratio of the probability of emission of the fragments in directions parallel and perpendicular to the incident particle beam) depends on the nature of the target nucleus.

From considerations developed by A. Bohr,[6] one would expect a large anisotropy in the fast-neutron fission of Pu^{239}, which has a small spin $I = \frac{1}{2}$ and which forms an even-even compound nucleus on capturing a neutron.

An ionization chamber was used to determine the magnitude of the anisotropy in the fission of Pu^{239}. The target of Pu^{239} (with a surface density of about $300 \mu g/cm^2$) was placed on a collimator whose apertures were drilled at an angle of 45° to its surface. The fission was induced by 14.8-Mev neutrons, while the axis of the neutron beam made an angle of 45° with the surface of the target and the collimator. As in the work of Brolley and Dickinson,[2] a simple rotation of the chamber around its axis (perpendicular to the surface of the collimator) switched the count from the fragments parallel to the neutron beam to the fragments perpendicular to the beam. The maximum angle between the direction of emission of the fragments and the fixed direction (0° and 90°) was 25°. The flux of neutrons on the plutonium target was determined from the number of fission events originating in a layer of U^{235} placed on the back of the plutonium layer.

The degree of anisotropy of Pu^{239} was found to be 1.14. For comparison with the results of Ref. 2, the anisotropy of U^{235} was also determined and was found to be 1.25. The values measured were corrected for the motion of the center of mass, for the finite angular resolution, and for the background of scattered neutrons. Taking the accidental errors in the experiment (mainly random) into account, it was found finally that the extent of the anisotropy is 1.15 ± 0.05 for Pu^{239} and 1.28 ± 0.07 for U^{235}.

The observation of a smaller anisotropy for Pu^{239} than for U^{235} ($I = 7/2$) is not in agreement with the predictions of A. Bohr[6] and thus shows that the anisotropy of nuclei of a given parity cannot be determined by the spin of the target nucleus alone. This was noted previously by Frank[7] in the analysis of the results of the work of Cohen et al.[5] In connection with this, it is interesting to note that the anisotropy of different nuclei fissioned by 14-Mev neutrons decreases as the parameter Z^2/A increases, as shown in the figure. A similar dependence of the anisotropy on the parameter Z^2/A (for neutron energies of about 7 Mev and for a smaller range of studied nuclei) was also noted by Henkel and Brolley.[4] Unfortunately, the scant and not very accurate experimental data do not permit searching for a more specific dependence on nuclear parameters. Besides, the decrease in the anisotropy with increasing Z^2/A may be related to the large anisotropy in asymmetric fis-



o – Data of Refs. 2 – 4; • – Data from this work. The parameters Z^2/A of the compound nuclei are shown.

sion[5,8] and the reduced relative probability of asymmetric fission with increasing Z^2/A (Ref. 9). In the case of heavier nuclei, the quantum effects discussed in Refs. 6 and 10 may appear in the form of some deviations from the basic tendency toward decreased anisotropy.

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