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ABSORPTION TIME OF NEGATIVE K^- MESONS IN LIQUID HYDROGEN*

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A measurement of the absorption time of negative K^- mesons in liquid hydrogen can be used as an indirect test of the validity of the prediction by Day, Snow, and Sucher[1] that stopping K^- mesons are absorbed predominantly from s states of high principal quantum number n. Using this model of "Stark-effect" mixing, Bethe and Leon[2] have predicted that the K^--meson cascade time (from initial atomic formation to nuclear s-wave absorption) is $T_1 = (2.4^{+0.8}_{-1.3}) \times 10^{-12}$ sec. On the other hand, if there were no "Stark-effect" mixing, their calculations of the Auger and radiative transition rates indicate that the K^--meson cascade time would be $T_2 \approx 30 \times 10^{-12}$ sec.

In this note we report a measurement of this cascade time. We find $T_{\text{expt.}} \lesssim 4 \times 10^{-12}$ sec in good agreement with the "Stark-effect" prediction, T_1.

The experimental method consists in observing the τ decay mode of K^- mesons in the Saclay 81-cm hydrogen bubble chamber exposed at CERN.[3,4] The τ mode of decay is the only channel in which all the decay energy of the K^- appears as charged tracks in the bubble chamber. This allows the K^- momentum at decay to be determined with an accuracy of ± 5-10 MeV/c. Such momentum resolution implies that in-flight K^- mesons with velocity $\beta > 0.02$ can be distinguished from at-rest K^- decays. [In traversing the internal $\beta = 0.02$ to atomic capture, the K^- meson spends a time $\sim 1 \times 10^{-12}$ sec.[5] Any K^- mesons that decay in this interval form an irreducible but small background to the number of decays at rest.] A similar method has already been employed to determine the K^- capture time in liquid helium.[6]

The scanning procedure consisted in locating and recording a number of different kinds of K^--meson events. One of these configurations was the τ decay mode of the K^- meson. Since we are interested in finding the τ decays at rest, we have devised a procedure which retains all the τ decays at rest and rejects most of the τ decays in flight. This drastically reduces the number of events to be measured. The procedure can be understood by referring to Fig. 1, which shows a typical τ decay at rest and a typical τ decay in flight. The test is applied to two of the three stereo views of the film and involves placing a straight edge across the τ decay vertex and adjusting the straight edge in an attempt to determine whether all three pion tracks fall in the half-plane to one side of the straight edge. Those events that clearly pass the test cannot be τ decays at rest, since momentum would not be conserved, and are classified as definite τ decays in flight.

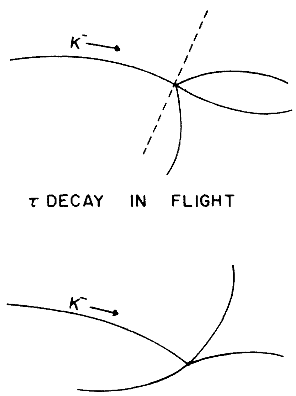

FIG. 1. Line drawing of a typical τ decay at rest and a typical τ decay in flight.

A total of 86 events failed the test. These were retained as candidates for τ decays at rest and were measured. The measurements were tested against the hypothesis of a τ decay at rest and of a τ decay in flight. In this way we have identified one and only one τ decay at rest in a total sample of $(8.4 \pm 0.9) \times 10^4$ stopping K^- mesons. This one at-rest τ decay was measured a total of three times, and each time gave an excellent fit to the at-rest hypothesis ($\chi^2 \sim 1.7$ for the four-constraint fit). The vector sum of the unfitted momenta was $\sim 2.5 \pm 5$ MeV/c ($\beta = 0.005 \pm 0.01$). The in-flight τ decays of lowest momentum had momenta in the interval 20-30 MeV/c (two events). These events had probabilities $\ll 10^{-4}$ for the at-rest hypothesis.

The experimental best estimate of the time T_k for K^- mesons to go from $\beta = 0.02$ to nuclear capture is calculated from the relation

$$T_k = \frac{\tau n}{r N \mathrm{Ef}} \sim 4 \times 10^{-12} \text{ sec},$$

where $\tau = K^-$ lifetime $= 1.23 \times 10^{-8}$ sec,[7] n = number of K^- decays at rest = 1, $r = \tau$-decay branching ratio = 0.055,[7] N = number of stopping K^- mesons in sample = $(8.4 \pm 0.9) \times 10^4$, Ef = efficiency for finding τ decays = $(70 \pm 7)\%$.

The number of stopping K^- mesons was determined by first counting the number of Σ^- absorption events $[\Sigma^- + p \to (\Sigma^0 \text{ or } \Lambda) + n]$ from (K^-, p) interactions at rest. This number is then scaled up to obtain the number of stopping K^- mesons, by using the experimental values for the fraction of $\Sigma^-\pi^+$ produced[8] and for the fraction of these Σ^- that are absorbed at the end of their range (0.10 ± 0.01).[9]

The scanning efficiency for finding τ decays was determined by checking the scanning results against a second independent scan covering a large portion (70%) of the film. In this way we determined the single scanning efficiency to be $(70 \pm 7)\%$. The configurations of the three pions from K^- mesons at rest are sufficiently similar to the configurations from in-flight K^- mesons, $p_{K^-} \lesssim 100$ MeV/c, so that no relative scanning bias between at-rest and in-flight K^- mesons is expected.

The experimental result $T_k \sim 4 \times 10^{-12}$ sec agrees very well with the predicted time spent by a K^- meson to go from a velocity $\beta \sim 0.02$ to nuclear capture, assuming the Stark mixing effect, $T_{\text{pred}} = (2.4 + 1) \times 10^{-12}$ sec.

Similar good agreement has been obtained between the experimental and theoretical capture time for π^- mesons coming to rest in liquid hydrogen.[2,5,10] On the other hand, the long capture time found[6] for K^- mesons in liquid helium $[(1.5 \pm 0.5) \times 10^{-10}$ sec$]$ is apparently inconsistent with the hypothesis that the (K^-, He) atom is influenced appreciably by a Stark mixing effect leading to s-state capture. The electric fields due to neighboring atoms can have very different effects on the two types of mesonic atoms (K^-, p) and (K^-, He). For in the (K^-, p) case, the mesonic atom is neutral and can easily penetrate within a hydrogenic Bohr orbit, whereas in the (K^-, He) case, the mesonic atom is positively charged and cannot penetrate the Bohr orbits of neighboring He atoms.

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ERRATUM

MAGNETIC RELAXATION AND ASYMMETRIC QUADRUPOLE DOUBLETS IN THE MÖSSBAUER EFFECT. M. Blume [Phys. Rev. Letters 14, 96 (1965)].

The following is a paraphrase of a communication to the author from Dr. V. I. Goldanskii:

In your paper, the mechanism of the effect, observed by us,[1,2] of over-all asymmetry of Mössbauer spectral lines connected to the anisotropy of thermal vibrations, is ascribed by you to Goldanskii, Makarov, and Khrapov,[2] and is called the "Goldanskii mechanism." This mechanism should be attributed to Karyagin rather than Goldanskii, as it was proposed by Karyagin,[3] although it appeared for the first time in our paper with Karyagin which was submitted at the same time as reference 3.

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