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LOWER LIMIT OF THE ABSORPTION RATE OF K^-'S AT REST IN LIQUID HYDROGEN

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To determine the branching ratio between the decay and the absorption rates of K^-'s at rest in liquid hydrogen,[1] we have looked for τ^- decays at rest in pictures of the Saclay 80-cm hydrogen bubble chamber exposed to a stopping K^- beam of the CERN proton synchrotron. The τ^-'s provide, in fact, sensitive tests to detect whether the decay really happened at rest, by means of the coplanarity and the low momenta of the three outgoing pions.[2]

With the sum of the vector momenta of the pions, we have constructed the following mutually orthogonal projections: p_{long} parallel to the incoming K^-, p_{txy} transverse to the K^- and parallel to the plane of the film of the bubble chamber, and p_{tz} also transverse to the K^- and orthogonal to p_{txy}.

In Fig. 1 we show the distribution of p_{txy}. It is reasonably centered around zero, as expected, and has a width of ± 6 MeV/c. This value presumably should be fairly close to the random error in the measurement of p_{long}, if we recall that the incoming K^- was always nearly parallel to the plane of the film of the bubble chamber. The distribution of p_{tz}, not presented here, is very similar to that of p_{txy} but somewhat wider, as expected.[3] Finally we mention that the effective masses of the three pions have a well-shaped distribution around the K^- mass, with a width of ± 7 MeV/c^2, suggesting therefore that small systematic errors, not easily detectable by the p_{txy} and p_{tz} distributions alone, were very likely negligible.

In Fig. 2 we show the distribution of p_{long}.

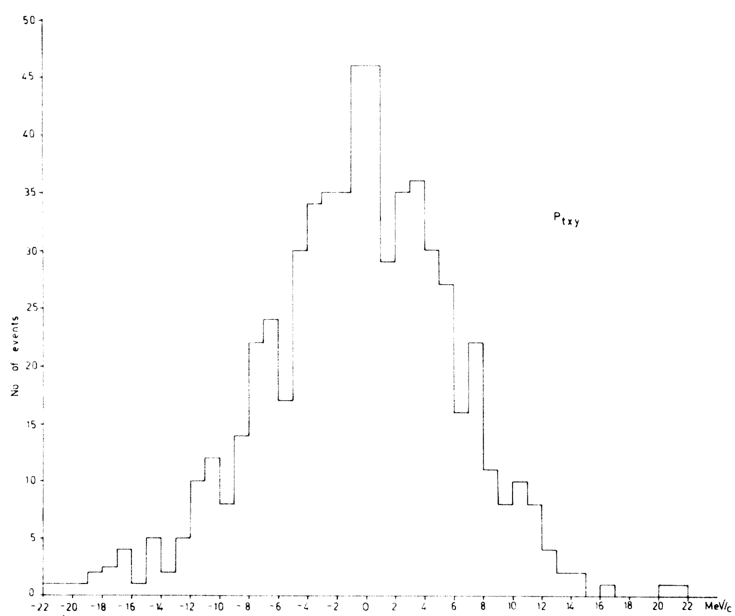

FIG. 1. Distribution of p_{txy} (for the definition of p_{txy} see the text).

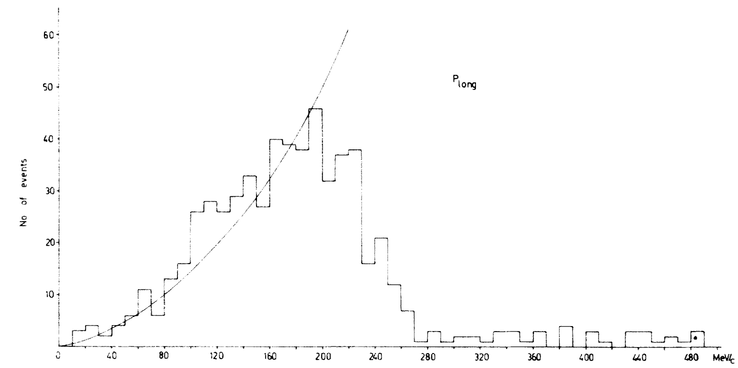

FIG. 2. Distribution of p_{long} (for the definition of p_{long} and the explanation of the curve see the text).

For a better understanding of the distribution, a few remarks might be useful.

(1) The long tail of events at the far right are really due to τ^- decays from a relatively high-energy component of the K^- beam.

(2) The curve drawn in the figure has been computed for a monoenergetic beam stopping at the center of the bubble chamber. Actually the beam stopped nearly uniformly in the hydrogen, so that only an appropriately weighted curve would have represented the experimental distribution.

(3) The errors in the measurements tend to smooth down the steep behavior of the curve, thereby increasing the population at lower momenta.

(4) About one-half of the decays at rest, if there were any, should have a negative p_{long}, because of the errors in the measurements. We do not have any event with negative p_{long}. It is rather difficult to imagine how systematic errors could have distorted the distribution of p_{long} unsymmetrically around zero, without also distorting appreciably the previous distributions. We conclude, then, that the distribution is well consistent with the hypothesis that no τ^- decayed at rest.

As a further check, we have investigated in more detail the "coplanar" events, which could obviously be decays at rest. However, the deviation from coplanarity of the three outgoing pions in the lab system is small also when the K^- decays in flight, in one of the following two configurations in its c.m. system: (1) The line of flight of the K^- makes a small angle with the decay plane; (2) two of the three pions are emitted almost parallel or antiparallel. If we put a cutoff to exclude these decays, the remaining events differ from coplanarity at least four standard deviations, as evaluated by a study of elastic scatterings. This new check strengthens, therefore, the previous conclusion that indeed no τ^- decayed at rest.

In the same fiducial region about 25 000 K^-'s were captured at rest, as estimated by a count of the colinear $\Sigma^-\pi^+$ coming from the absorptions $K^- + p \rightarrow \Sigma^- + \pi^+$, which amount to 45% of the total. Then, using the known values of the K^- lifetime (1.23×10^{-8} sec) and of the branching ratio τ^-/K^- (5.5%), we obtain for the absorption rate the lower limit

$$w_{\text{abs}} > \frac{25\times10^3\times5.5\times10^{-2}}{1.23\times10^{-8}}\,\text{sec}^{-1} = 1.1\times10^{+11}\ \text{sec}^{-1}.$$

Towards the end of its range, in the liquid hydrogen, the K^- is sufficiently slow to be bound by a proton into a K-mesonic atom of large quantum numbers n, 1. The mesonic atom undergoes, then, a cascading process which is dominated mainly by "chemical" reactions with the surrounding hydrogen molecules, as long as n is larger than $\sqrt{M_K}$,[4] and, after that, by the Auger effect.[5,6] Although the radiative transitions contribute also to the cascading process, they become comparable to the Auger transitions only for very small values of n. Obviously, nuclear absorption is also present; its rate is proportional to n^{-3} and is particularly high when l is zero.[7] If l is different from zero, before the absorption and the transition to s orbits become effective, the K-mesonic atom has sufficient time to make several collisions with the surrounding hydrogen atoms. The intense electric field of the struck proton, through the Stark effect, induces a reshuffling of the atomic levels with a non-negligible probability of populating the s states, which are then depleted by nuclear absorption.[8] A careful study of the cascading and the absorption process has shown that the K^-'s are mainly absorbed from s orbits with $n > 4$. The time interval from when the K^- has a momentum of 25 MeV/c to a prescribed orbit of $n \approx \sqrt{M_K}$ is given as ~12 $\times 10^{-12}$ sec. The time required to go from this orbit ($n \approx \sqrt{M_K}$) to the instant of absorption is further given as $\sim 2.4 \times 10^{-12}$ sec.[6] This experiment is in good agreement with these theoretical values.[9]

We take the opportunity to express here our gratitude to Dr. H. Filthuth, and to the numerous people of the bubble chamber and the CERN proton synchrotron staffs who made this experiment possible.

[1]The density of the hydrogen, in this experiment, was 0.61 g/cm^3.

[2]More than 50% of the events had at least one pion stopping inside the bubble chamber.

[3]In general, quantities parallel to the plane of the film are measured more accurately than those in the direction perpendicular to the plane of the film.

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