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ABSTRACT

New measurements of the masses of the charged sigma hyperons and the negative K-meson are reported. The results obtained are:

$$M_{\Sigma^+} = 1189.3 \pm 0.3 \text{ Mev.}$$

$$M_{\Sigma^-} = 1195.8 \pm 0.5 \text{ Mev.}$$

$$M_{K^-} = 493.87 \pm 0.46 \text{ Mev.}$$

No evidence for more than one K^- - meson mass was found. The terminal behavior of the Σ^- hyperons was also studied.

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In continuation of our program of precise mass measurements, we have obtained some improved data on the reactions of negative K mesons with protons in which charged hyperons are formed. Measurements of this sort are best made in calibrated nuclear-track emulsions, and for good statistics one requires a large sample of K-meson capture events. Preliminary results of an effort to improve the K-meson beam from the Bevatron were reported earlier.[1] This beam has been further exploited, and a new type of beam developed by J. J. Murray has also been successfully employed.[2] We have taken data from three emulsion stacks, two of Ilford-G.5 emulsion and one of K.5, all carefully calibrated with respect to density, and have adhered to our previously decribed conventions for range measurements.[3]

About 4700 negative K-meson interactions at rest were examined, and 20 events were found to consist of colinear pion and hyperon tracks with a clean common point of origin at the terminus of the K-meson track. These events we have assumed were examples of the capture of the K meson by a free proton. Two of the hyperons decayed in flight, and 18 came to rest. Of the hyperons coming to rest, two were observed to decay into a charged pion, and five decayed into a proton. They are, therefore, classified as positive sigma hyperons, and the decay ratio $\Sigma^+ \to p / \Sigma^+ \to n = 5/2$, although high, is not inconsistent with the ratio 48/42 we have found for all Σ^+ hyperons. The corrected ranges of the Σ^+ hyperons lie between 801.0 and 848.2 microns (μ), and the standard deviation is 17.3 μ. The mean range found is 821.0 $\pm$ 6.5 μ. The distribution is in good accord with that expected when allowance is made for the various known straggling

effects.[4] There is no evidence either from this group of events or from the even-more-restricted range distribution of the negative hyperons that the K-meson capture was not at rest, or that two equally abundant types of K⁻ mesons with masses differing by more than about 0.5 Mev could have been present in the sample studied. This difference is smaller than the present upper limit of the mass difference between the positive θ and τ mesons;[5] there are now no measurements to indicate that both are not zero.

Earlier we reported our measurement of the decay energy of the positive sigma hyperon via the proton decay mode.[6] We found

$$M_{\Sigma^+} = 1189.3 \pm 0.3 \text{ Mev.}$$

Recently additional data have been considered,[7] and the weighted mean value found was $M_{\Sigma^+} = 1189.4 \pm 0.25$ Mev. From this and the observed energy of reaction, we obtain for the mass of the K⁻ meson:

$$M_{K^-} = 493.87 \pm 0.46 \text{ Mev.}$$

This is to be compared with 494.0 ± 0.2 Mev, the best value for the positive τ meson.[7]

The negative hyperons come to rest with a mean range of 711.9 ± 4.2 μ, the spread being 688.6 to 738.4 μ and the standard deviation of a single measurement being 14.1 μ. From energy conservation and the range-energy relation we obtain the following empirical formula for the mass difference, ΔM, between the negative and positive hyperon as a function of the absolute value of the range difference, ΔR:

$$\Delta M = 5.567 \times 10^{-2} \Delta R + 2.70 \times 10^{-5} \Delta R^2.$$

This is valid for standard emulsion in the vicinity of ΔR = 109.0 ± 7.7 μ, which is the observed difference of ranges. Then

$$\Delta M = 6.39 \pm 0.47 \text{ Mev.}$$

Our estimate of the Σ⁻ mass therefore is:

$$M_{\Sigma^-} = 1195.8 \pm 0.5 \text{ Mev.}$$

The error is calculated by combining all the independent uncertainties quadratically. The errors we list are standard deviations. (The pion and nucleon masses we obtain from Cohen, Crowe, and DuMond.[8])

Sigma hyperons that come to rest and do not decay are presumed to be negative. A knowledge of their terminal behavior is important because the terminal behavior is the only practical criterion one now has for separating reaction products that are hyperons from protons or deuterons. Using the reaction $K^- + p \rightarrow \pi^+ + \Sigma^-$ to identify a group of Σ^- hyperons in emulsion insures that one has a representative sample. Of the 11 events we observed, all but two gave evidence of an interaction by the presence of an electron or a "blob" at the terminus. Two hyperons each produced a prong, judged not to be an electron, that was more than $2\,\mu$ in length. Only a single event could be classed as a two-prong star. This star consisted of a 250-μ prong and a recoil 2μ in length. The maximum visible energy release - 18 Mev - was that assignable to the two-prong star. In a previous study, we found that most Σ^- capture stars originate in light elements and are of low energy.[9] A large energy release may indicate that the event in question is a hyperfragment.

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