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ABSTRACT

Our program of study on the interactions of K^- mesons in nuclear track emulsion has led to estimates of the masses of K^-, $\Sigma^{\pm}$, and Λ^o particles. To obtain reliable measurements particular attention was placed in the determination of the emulsion density and shrinkage factor. The range measurement techniques employed are the same as those developed in an extensive study of the range-energy relation for emulsion.[1] Area scanning for Λ^o decays in the region of the stopped K^- mesons has been initiated, and to date 27 $\Lambda^o \rightarrow p + \pi^-$ decays have been tentatively identified. The Λ^o mass and its Q value are results based upon 23 events completely analyzed. The proton and pion masses assumed are 938.21 ± 0.01 and 139.63 ± 0.06 Mev, respectively. The mass measurement results are as follows:

K^- :	493.2 ± 0.6 Mev
Σ^+ :	1189.39 ± 0.3 Mev
Σ^- :	1195.8 ± 0.7 Mev
Λ^o :	1115.30 ± 0.16 Mev
Q_{Λ^o} :	37.45 ± 0.17 Mev

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* This work was performed under the auspices of the Atomic Energy Commission.

1 W. H. Barkas et al., The Range-Energy Relation in Emulsion, University of California Radiation Laboratory Report No. UCRL-3768 and UCRL-3769, Parts I and II, April 9, 1957.

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An analysis of strange particle reactions and decay events in nuclear track emulsion can yield mass measurements of the Λ^0, $\Sigma^{\pm}$ and K^- particles provided the emulsion is carefully calibrated as to density and shrinkage factor, and a reliable range-energy relation is available for translating the range measurements into momenta and energies. In our current study of K^- mesons interactions in nuclear emulsion, we feel these requirements are well met. The techniques of range measurements in this work are the same as those employed in our extensive study of the range-energy relation for emulsion.[1]

Mass of the Λ^0 Hyperon

We have now completely analyzed 23 of 27 tentatively identified $\Lambda^0 \rightarrow \pi^- + p$ decays that were located by area scanning in the region of stopping K^- mesons. To eliminate measurement errors, two independent measurements were carried out upon each event, the ranges being measured to $\pm$ 0.5%, the projected angles to $\pm\frac{1}{2}^{\circ}$ and the dip angles to $\pm$ 1°. Since the original shrinkage factor for each pellicle had been determined to within 1%, effective shrinkage factors were found by remeasuring pellicle thicknesses at the time range measurements were made in them, allowing us to compensate for any changes in the shrinkage factor owing to humidity fluctuations. The IBM 650 data processing machine was used in calculating the ranges. Small corrections were made to the measured ranges, normalizing them to a standard emulsion density of 3.815 gm/cc.

Figure 1 is an ideogram of the 23 events for which the mass of the Λ^0 has been determined. Five of these events appear to be background, having apparent mass values differing from the mean by more than 3 times the standard deviation of the distribution(S. D. = ± 0.56 Mev). On the basis of the remaining eithteen events, the mass of the lambda is 1115.30 ± 0.16 Mev, the corresponding Q value being 37.45 ± 0.17 Mev. The proto and pion masses assumed were 938.21 ± 0.01 Mev and 139.63 ± 0.06 Mev, respectively. The errors quoted are standard deviations, and include statistical and systematic errors. Here, also, use of the IBM 650 was made in calculating the mass values and associated errors.

In evaluating the internal statistical error associated with each event, errors arising from range straggle and multiple scattering were compounded with observational errors in the measurement of the particle ranges, projected and dip angles. The estimate for the systematic error in the mass measurement includes errors in 1) the shrinkage factor, ± 1%; 2) the range-energy relation ± 0.3 to 0.5% and 3) the errors in the rest masses of protons and pions. Based upon these estimates, the average systematic error in the Λ^0 mass is ± 0.09 Mev. The internal and external statistical errors of the 18 events are in agreement to better than 1%.

Masses of the $\Sigma^{\pm}$ and K^- Particles

A measurement of the Σ^+ mass is most readily obtained from the decay process $\Sigma^+ \rightarrow P + \pi^0$. The mean range of the proton, based upon 31 events is 1674.2 ± 4.5μ, which corresponds to a momentum of 188.92 ± .31 Mev/c. Assuming a π^0 mass of 135.03 ± .15 Mev, and an uncertainty of ± 0.5% in the range-energy relation, we deduce that

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

In emulsion, approximately 0.3% of K^- meson interactions at rest will be with hydrogen nuclei. To date, we have observed 4 interactions of the type $K^- + p \rightarrow \Sigma^+ + \pi^-$ and 3 interactions producing $\Sigma^- + \pi^+$. Our observations give a difference in the mean ranges of the Σ^+ and Σ^- particles in these reactions of $R_{\Sigma^+} - R_{\Sigma^-} = 113.1 \pm 10.4\mu$, and hence a mass difference

$$M_{\Sigma^-} - M_{\Sigma^+} = 6.56 \pm .66 \text{ Mev}$$

This mass difference is independent of the K particle mass and the range-energy relation.

The mass of the Σ^- hyperon is then

$$M_{\Sigma^-} = 1195.8 \pm 0.7 \text{ Mev}$$

The mass of the K^- meson, as derived from the $\Sigma^+ \rightarrow$ proton decay mode and the $K^- + p \rightarrow \Sigma^+ + \pi^-$ reaction is

$$M_{K^-} = 493.2 \pm 0.6 \text{ Mev}$$

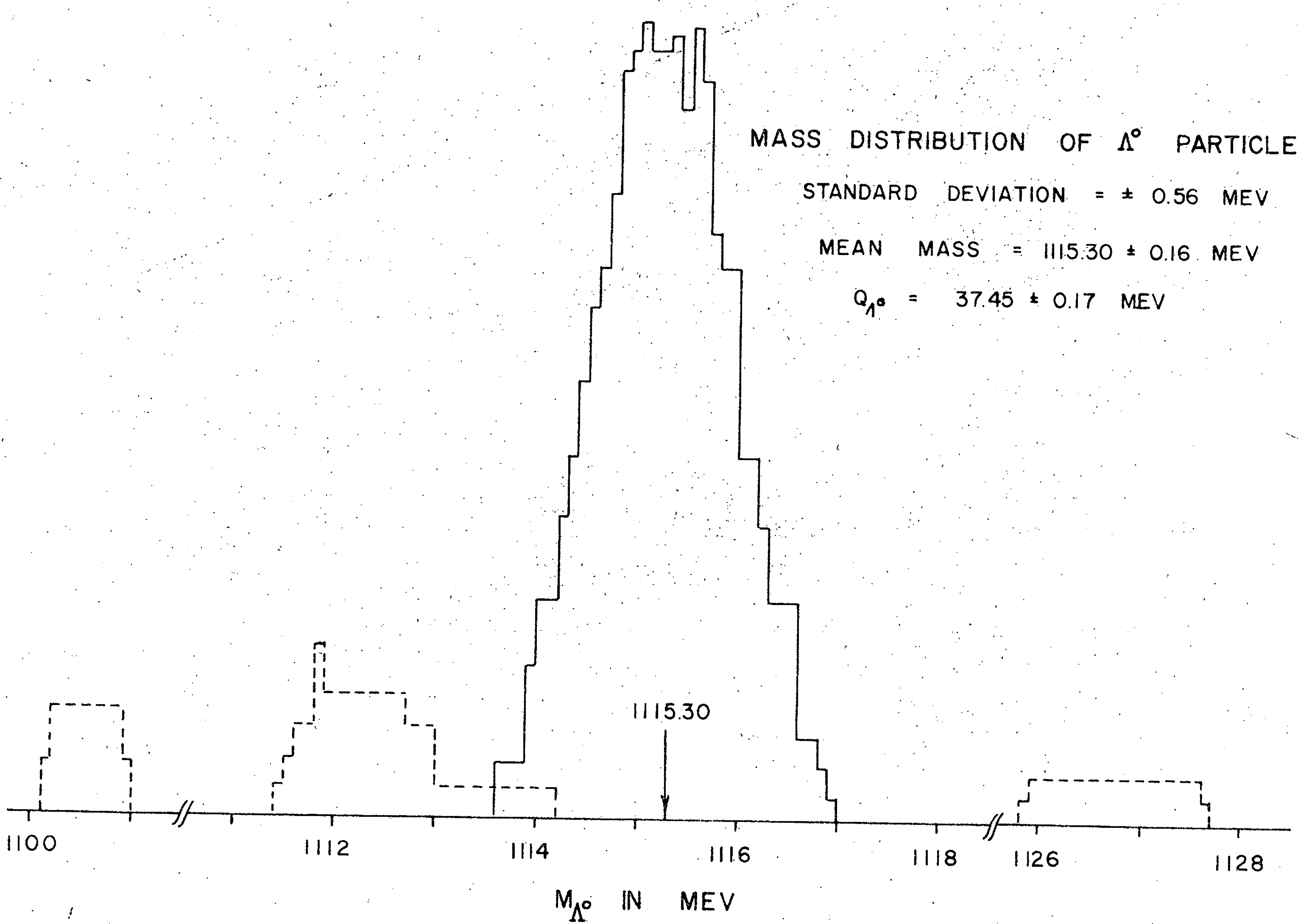
In all cases, the quoted errors are standard deviations and include both statistical and systematic errors.

REFERENCES

1. W. H. Barkas et al., The Range-Energy Relation in Emulsion, Parts I and II, University of California Radiation Laboratory Reports Nos. UCRL-3768 and UCRL-3769, April 9, 19557.

Fig. 1:

Mass distribution of Λ^0 particles based on 23 events. The dashed events (5) are considered to be background. The 18 remaining events give a mean Λ^0 mass of 1115.30 $\pm$ 0.16 Mev, and $Q = 37.45 \pm 0.17$ Mev.


MASS DISTRIBUTION OF Λ° PARTICLES
STANDARD DEVIATION = ± 0.56 MEV
MEAN MASS = 1115.30 ± 0.16 MEV
$Q_{\Lambda^{\circ}}$ = 37.45 ± 0.17 MEV
1115.30
1100
1112
1114
1116
1118
1126
1128
$M_{\Lambda^{\circ}}$ IN MEV