As to the θ^0 decay, the indication of the departure from an isotropic distribution appears to be quite strong. The distribution for θ^0 particles is presented by the histogram in Fig. 4. The standard deviations have been calculated as before from $(\sum_r W_r^2)^{\frac{1}{2}}$ (summing over the number of events in each angular interval) and are indicated by the vertical lines. The dashed curve in the figure represents the $\sin\theta$ distribution, i.e., the isotropic distribution. Taking the 11 nonclassified cases as due to θ^0 particles does not affect the distribution.

It is rather difficult to see how this departure of the observed distribution from isotropy can be explained except by taking $J \gtrsim 1$. It may be of interest to make an estimate for the spin of the θ^0 particle, using the relation[17]

$$J \gtrsim 1/(2\Delta\theta)$$

as deduced from the uncertainty principle. Here $\Delta\theta$ is taken as the total width at half-intensity of the angular distribution as estimated from Fig. 4. Such an estimation gives $J \geqslant 1$.

However, this indication of higher spin for θ^0 particles may be regarded only as a preliminary indication, because the statistics are still low and because there might be some unknown biases which we cannot trace at present.

[17] We should like to thank Dr. D. C. Peaslee for his helpful discussion on the estimation of the spin of the V^0 particle from the angular distribution of the decay products in the rest system, and for his comment on the ratio $N_{\theta^0}/N_{\Lambda^0}$.

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Double-Plate Cloud-Chamber Study of V^0 Particles: Mean Lifetimes of θ^0 and Λ^0 Particles*†‡

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The mean decay times of 35 θ^0 particles and 23 Λ^0 particles have been calculated according to the maximum-likelihood procedure as discussed by Bartlett. For each event, the decay length, the "total potential" decay length and the "plate-potential" decay lengths were measured with the usual caution. The velocity of each V^0 particle was determined from the $\alpha-\epsilon$ plots, and used to convert decay lengths into the corresponding decay times in the rest system. The mean decay time for the 35 θ^0 particles is found to be $(0.8_{-0.2}^{+0.4})\times10^{-10}$ sec, and for the 23 Λ^0 particles $(2.8_{-0.7}^{+1.2})\times10^{-10}$ sec. The differential momentum distributions of the θ^0 and Λ^0 particles are obtained and appear to be different in shape and momentum range for the two types of V^0 particles. The mean detection probability of our chambers has also been studied as a function of the momentum of the V^0 particles.

I. INTRODUCTION

THE mean decay times for θ^0 and Λ^0 particles have been determined by several workers.[1] However, for either type of particle the experimental values for the mean lifetime vary considerably. For example, in the case of Λ^0 particles they lie in the wide range (1 to $10)\times10^{-10}$ sec, while for θ^0 particles they vary from about 1×10^{-10} sec to 4×10^{-10} sec. This is partly due to the fact that the statistics have been very low, particularly for θ^0 particles, and partly because there has not been a single acceptable method of measurement and of analysis. In 1952, Wilson and Butler[2] suggested how the quantities involved in this problem should be measured, and that the maximum-likelihood procedure should be followed to deduce the lifetime. Some of the ideas have already been incorporated in one way or another by other authors[1] in their work. Recently Bartlett[3] has described, from general statistical consideration, the maximum-likelihood procedure for the evaluation of the lifetime of unstable particles observed in a magnet or multiplate cloud chamber. This procedure has been applied by Page and Newth[1] and by Gayther[1] to the estimation of the mean decay times of the V^0 particles.

We have adopted the general methods of measurement as discussed by Wilson and Butler and used by other workers and the statistical procedure put in a more convenient form by Bartlett to determine the mean decay times of our θ^0 and Λ^0 particles, which have

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[1] For examples: Leighton, Wanlass, and Anderson, Phys. Rev. **89**, 148 (1953); Fretter, May, and Nakada, Phys. Rev. **89**, 168 (1953); Bridge, Peyrou, Rossi, and Safford, Phys. Rev. **91**, 362 (1953); D. I. Page and J. A. Newth, Phil. Mag. **45**, 38 (1954); D. B. Gayther, Phil. Mag. **45**, 570 (1954).

[2] J. G. Wilson and C. C. Butler, Phil. Mag. **43**, 993 (1952).

[3] M. S. Bartlett, Phil. Mag. **44**, 249, 1407 (1953).

been classified in the preceding paper,[4] because we feel that these methods are in principle satisfactory. Since the V^0 particles occur very rarely, single groups of workers collect analyzable data rather slowly. Therefore, it is important that the results from many groups be combined in a straightforward manner. In this paper we should like to mention briefly the maximum-likelihood procedure to be used and to discuss the methods of measurement, as well as to report finally our results for the mean decay times of the θ^0 and Λ^0 particles together with the weighted mean values of all the published results including our own.

II. STATISTICAL ESTIMATION

We consider, as a general case, a multiplate cloud chamber to observe the V^0 particles produced in the plates. Then, the probability that the rth (arbitrary) unstable particle undergoes decay in an illuminated region at time[5] t_r in the time interval dt_r is, according to the exponential decay law,[6] given by

$$f(t_r)dt_r = \frac{1}{\tau}\frac{e^{-t_r/\tau}dt_r}{1-e^{-T_r/\tau}+\sum_s(-1)^s e^{-T_{rs}/\tau}}. \qquad (1)$$

The probability of observing a particular set of independent decay times $t_1,\cdots t_r,\cdots t_n$ is therefore equal to the so-called likelihood function H:

$$H=\prod_{r=1}^{n} f(t_r), \quad (0\leqslant t_r \leqslant T_r). \qquad (2)$$

The estimation equation can be obtained from Eq. (2) by employing the maximum-likelihood procedure,[7] i.e., by setting $\partial \ln H/\partial\tau=0$. In the approximation in which T/τ is taken to be small, we have

$$1/\tau \sim -\sum_r(t_r-\tfrac{1}{2}c_r/b_r)/\sum_r X_r, \qquad (3)$$

and the standard error

$$\Delta(1/\tau)=1/(\sum_r X_r)^{\frac{1}{2}}, \qquad (4)$$

where

$$X_r=(d_r/3b_r)-(c_r/2b_r)^2; \qquad (5)$$

$$b_r=T_r-\sum_s(-1)^s T_{rs};\quad c_r=T_r^2-\sum_s(-1)^s T_{rs}^2;\quad d_r=T_r^3-\sum_s(-1)^s T_{rs}^3. \qquad (6)$$

These equations can immediately be reduced, by equating the sums over s to zero, to the corresponding equations[8] for a magnet cloud chamber which does not contain any plate in it.

III. MEASUREMENT OF DECAY LENGTHS: DETERMINATION OF V^0 PARTICLE VELOCITY

The different decay times t_r, T_r, T_{rs} mentioned in the preceding sections are to be obtained from the corresponding decay lengths l_r, L_r, L_{rs}, which are measured in each event along the line of flight of the V^0 particles, using the coincident cloud-chamber picture of the direct and stereoscopic pictures (see, for example, Fig. 1). The boundaries of the useful (uniformly illuminated) volume of our chambers were marked before the start of our experiments and have been used in the measurement of the "potential" decay lengths L_r. These boundaries were measured and clearly marked on our three-dimensional projection system so that the effective illumination edges could be readily marked on each tracing along with the V^0 event, the chamber plates, shower origin, etc. The "fiducal" marks were placed at 6 cm from the back edge of our chamber, 1 cm from the front edge (toward the camera), and 2 cm from each side edge.

The following discussion explains how our decay lengths have been measured. Since in nearly all of our V^0 event pictures, it is difficult to recognize particle tracks within $0.1-0.2$ cm of a plate surface, these

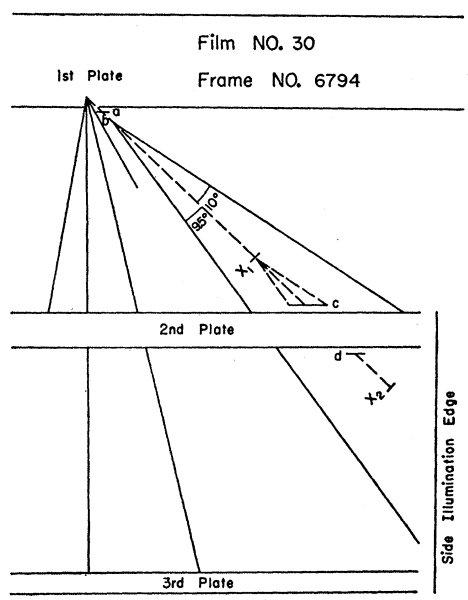

FIG. 1. Tracing the event No. 30-6794, representing a typical picture where measurements of potential lengths (see text) requires careful consideration.

[4] Gupta, Chang, and Snyder, preceding paper [Phys. Rev. **106**, 141 (1957)], hereafter referred to as Part I.

[5] All these times, t_r, T_r, and T_{rs}, are to be measured from the same moment, when the rth particle emerges from the producing plate. t_r is measured to the instant when the actual decay occurs, T_r to the instant when the particle leaves the useful volume (if it does not decay), and T_{rs} to the instant when it enters or leaves a plate, an odd value of s referring to entering and an even one to leaving.

[6] The denominator of Eq. (1) actually represents the probability of decay in the available time T_r in the chamber minus that in $(T_{r2}-T_{r1})$, etc., in the plates. Therefore, normalization with respect to this denominator essentially corrects for those particles which decay outside the chamber and for those which decay inside the plates.

[7] E. T. Whittaker and G. Robinson, *The Calculus of Observations* (Blackie and Son Limited, London, 1942), third edition, p. 186.

[8] M. S. Barlett, Phil. Mag. **44**, 249 (1953). See also W. L. Alford and R. B. Leighton, Phys. Rev. **90**, 622 (1953); Fretter, May, and Nakada, Phys. Rev. **89**, 168 (1953).

lengths have been measured, for each event, from the same point 0.4 cm below the bottom surface of the plate concerned. Similarly the lengths L_{rs} have been measured respectively *to* a point 0.4 cm above the top surface and *to* another point 0.4 cm below the bottom surface of a plate. The "potential" decay length L_r has been measured to a point where the shortest prong (if decay took place at this point) would have 3 cm from the effective illuminaion edge or from the top surface of the last plate. This length of 3 cm is large enough to detect any appreciable multiple scattering even in the case of narrow-angle V^0 events. Since V^0 events in the last gas space were entirely ignored (see Sec. II of the preceding paper), the terminal point of L_r has not been extended to this gas space. As a consequence, we have in general only the lengths L_{r1} and L_{r2} in addition to L_r and l_r, and in some cases only L_r and l_r (see Tables I and II).

Figure 1 is a picture typical of a few difficult cases where measurement of L_r, L_{rs} requires careful consideration. It is an actual tracing of the event (30-6794). Here the penetrating shower origin is in the first plate (2 inches) and the apex of the V^0 event is about 0.8 cm (along the line of flight—the dotted line) from the surface of the plate. The shower particles shown are projected tracks on the plane containing the V^0 event. The dashes (a,c,d) parallel to the plate surfaces indicate the places up to which and from which these decay lengths have to be measured. The point b is the apex of the V^0 event, and so $l_r = ab$ along the line of flight. At first sight one might think that the terminal point L_r should be extended to the point X_2, where the shortest prong would have 3 cm from the side illumination edge; L_r would be then equal to aX_2, L_{r1} equal to ac, and L_{r2} equal to ad. But it should be easily realized that the V^0 event could not have been identified and included in the statistics (see Sec. II of Part I) if it took place at this point. Therefore, L_r was measured to the point X_1, where the would-be prongs are indicated by the dashed lines. Hence, for this event we have $l_r = ab$ and $L_r = aX_1$ only. Of course, if the angle between the two prongs were larger than say, 30° (actually only 19.5°), the terminal point of L_r could have been at X_2, for a large angle itself also provides a good method of identification (i.e., of distinguishing from an electron pair; see Sec. II of Part I).

These decay lengths l_r, L_r, L_{rs} so measured have to be converted into the corresponding decay times t_r, T_r, T_{rs} which are to be used directly for calculating the mean decay time τ of θ^0 or Λ^0 particles. Hence, for each event the velocity of the V^0 particle has to be determined. This can be done more easily by the graphical construction, i.e., by the $\alpha-\epsilon$ plots discussed in the preceding paper. As before, let f_1 and f_2 be the measured distances of the event from the foci F_1 and F_2, respectively. Then the velocity of the V^0 particle can be found by means of the relation

$$1/\beta = (f_1 + f_2)/2\epsilon^*. \tag{7}$$

TABLE I. Lifetime data for 35 θ^0 particles.

Film and frame No.	$\beta\gamma$	l_r (cm)	L_r (cm)	t_r (10^{-10} sec)	T_r (10^{-10} sec)	T_{r1} (10^{-10} sec)	T_{r2} (10^{-10} sec)	W
16-5516	2.98	2.0	20.5	0.22	2.29	1.30	1.62	1.6
16-5583	1.48	0.2	6.3	0.05	1.42	···	···	1.3
17-6595	3.39	2.7	5.9	0.27	0.58	···	···	4.2
18-7359	0.88	2.0	18.7	0.76	7.08	3.67	4.77	2.8
19-8280	9.04	0.9	6.2	0.03	0.23	···	···	4.5
22-0411	1.68	2.0	19.3	0.40	3.83	1.87	2.52	1.8
22-0649*[a]	3.99	0.85	62.2	0.07	2.18	1.13	1.42	1.3
23-1248	2.36	0.2	8.85	0.03	1.25	···	···	1.3
24-1725	2.51	2.8	22.5	0.37	2.99	1.70	2.10	1.8
24-1895	2.83	0.7	12.5	0.08	1.47	···	···	1.3
30-6794	4.50	0.3	12.9	0.02	0.96	···	···	1.5
31-7464	2.83	2.0	7.7	0.24	0.91	···	···	2.3
31-7629	6.37	0.2	6.2	0.01	0.32	···	···	2.9
33-8745	3.13	1.65	6.8	0.18	0.72	···	···	2.5
34-9528	9.04	0.5	8.2	0.02	0.29	···	···	3.4
34-9630(A)	6.37	0.35	8.8	0.02	0.46	···	···	2.3
34-9630(B)	6.37	2.1	6.7	0.11	0.35	···	···	4.2
34-9995	0.93	3.2	8.7	1.15	3.12	···	···	4.9
35-0707	5.17	0.1	5.9	0.01	0.38	···	···	2.6
36-1131	2.83	1.6	7.6	0.19	0.90	···	···	2.1
37-1869	6.37	0.2	23.0	0.01	1.20	0.94	1.16	1.4
38-2438	0.59	0.7	6.0	0.40	3.39	···	···	1.7
38-2954	6.37	0.8	5.6	0.04	0.29	···	···	3.8
38-2976	3.13	2.5	17.8	0.27	1.90	1.06	1.32	1.8
40-4526	9.04	5.8	6.8	0.21	0.25	···	···	27.0
44-8014	6.37	0.4	20.9	0.02	1.09	0.61	0.74	1.5
U2-0938	3.70	1.1	16.0	0.10	1.44	···	···	1.4
U4-2176	1.96	1.0	16.6	0.17	2.82	1.51	1.92	1.4
U4-2300	1.21	3.1	17.3	0.85	4.77	2.60	3.31	3.3
U4-2395	2.28	1.8	20.4	0.26	2.98	1.68	2.12	1.6
U4-2590	6.37	0.8	16.1	0.04	0.84	0.47	0.60	1.9
U7-4253	2.83	0.3	19.5	0.04	2.30	1.30	1.64	1.2
U9-6000	3.99	1.1	11.8	0.09	0.99	···	···	1.6
U13-9043	4.50	1.4	5.9	0.10	0.44	···	···	3.2
U22-5825	1.82	2.0	5.7	0.37	1.04	···	···	2.7
							Total	$W = 106.1$

[a] For definition of starred cases refer to Sec. V.1 of the preceding paper.

As the event has been classified already in Part I, the appropriate value of ϵ^* is known and is given in Table II of Part I. Since τ is to be the mean decay time at rest, the decay times t_r, T_r, T_{rs} have to be measured in the rest system of the V^0 particle. Hence

$$t_r = l_r/(c\beta\gamma), \quad T_r = L_r/(c\beta\gamma), \quad T_{rs} = L_{rs}/(c\beta\gamma), \tag{8}$$

where $\gamma = 1/(1-\beta^2)^{\frac{1}{2}}$. The values of $c\beta\gamma$ ($=P/M$, specific momentum) together with the decay paths l_r, L_r are given in Tables I and II, respectively, for the θ^0 and Λ^0 particles. The values of W in the last columns (calculated in Sec. V) are the weighting factors, a correction for the detection efficiency of the individual events, which have been used in Part I for the discussion of the ratio of θ^0 to Λ^0 particles and the angular distribution of the decay products in the rest system and which are used in the present paper for the discussion of the differential momentum distributions.

IV. RESULTS AND DISCUSSION

In order to estimate the mean decay times of θ^0 and Λ^0 particles and the respective standard errors, we have listed, for each event, the values of $\beta\gamma$, l_r,

TABLE II. Lifetime data for 23 Λ^0 particles.

Film and frame No.	$\beta\gamma$	l_r (cm)	L_r (cm)	t_r (10^{-10} sec)	T_r (10^{-10} sec)	T_{r1} (10^{-10} sec)	T_{r2} (10^{-10} sec)	W
11-2589	1.18	5.1	18.4	1.44	5.20	...	...	2.3
13-3472	0.64	0.6	9.25	0.31	4.82	...	...	1.4
13-4007	0.44	0.2	9.3	0.15	7.05	...	...	1.1
14-4411	0.47	0.15	29.2	0.11	20.67	10.28	12.91	1.1
15-4953	0.67	0.1	16.4	0.05	8.16	4.48	5.62	1.2
15-5010	0.63	0.75	8.0	0.40	4.23	...	...	1.5
15-5400	0.26	2.4	11.9	3.08	15.26	...	...	3.1
16-6182	0.46	0.4	18.0	0.29	13.04	7.03	8.84	1.2
17-6438	0.29	0.4	11.2	0.46	12.87	...	...	1.2
17-6949	0.24	0.5	7.3	0.69	10.14	...	...	1.3
22-0182	0.45	3.7	12.2	2.74	8.96	...	...	3.0
27-4019	0.77	0.45	12.7	0.20	5.48	...	...	1.3
28-4933*[a]	0.43	0.1	19.7	0.08	15.27	8.45	10.39	1.2
30-6394*	0.50	1.1	19.4	0.73	12.93	7.30	9.00	1.4
30-6869	0.61	5.7	6.8	3.11	3.72	...	...	15.6
34-9972*	0.74	0.5	12	0.23	5.41	...	...	1.3
35-0766	0.46	4.7	12.9	3.41	9.35	...	...	3.9
38-2494	0.41	0.2	18.9	0.16	15.37	8.05	10.08	1.1
38-2506*	0.89	0.35	7.9	0.13	2.96	...	...	1.6
U4-2251	0.48	0.65	20.7	0.45	14.38	7.15	9.03	1.2
U9-5775	0.40	1.8	18.7	1.50	15.58	8.92	11.33	1.8
U11-7302*	0.68	0.15	20.2	0.07	9.90	5.25	6.72	1.1
U23-6891*	0.87	2.8	18.0	1.07	6.90	3.79	4.79	1.9
								Total $W=51.8$

[a] For definition of starred cases refer to Sec. V.1 of the preceding paper.

L_r, t_r, T_r, T_{r1}, T_{r2} in Tables I and II (to save space, values of L_{r1} and L_{r2} are omitted). In addition to the standard errors, one has "nonstatistical" errors from the measurements of the decay lengths and the velocity of the V^0 particle as well as from its mass. However, it has been found by actual examination that the effect of errors on the value of τ chiefly comes from the errors in the velocity of the V^0 particle and that in l_r (because of its small magnitude). The effect of the various errors has also been discussed by Page[9] in connection with the magnet cloud-chamber experiments. In our case, the velocity has been determined by Eq. (7), where the values of f_1 and f_2 are naturally affected by the errors in the values of α and ϵ, which are in turn calculated from the measured angles ϕ_1 and ϕ_2 (see Sec. IV of the preceding paper). It is estimated that these different errors together could give rise to an error in τ of as much as 15% which is perhaps smaller than but at any rate comparable with the standard errors.

When one uses Bartlett's statistical procedure, the mean lifetime of θ^0 particles from the measurement of 35 cases[10] is given by

$$1/\tau = (1.32 \pm 0.45) \times 10^{10}\ \text{sec}^{-1} \tag{9}$$

or

$$\tau = (0.8_{-0.2}^{+0.4}) \times 10^{-10}\ \text{sec},$$

and for the 23 Λ^0 particles;

$$1/\tau = (0.36 \pm 0.11) \times 10^{10}\ \text{sec}^{-1}, \tag{10}$$

or

$$\tau = (2.8_{-0.7}^{+1.2}) \times 10^{-10}\ \text{sec}.$$

The errors mentioned include the nonstatistical errors of about 15% as discussed above.

In Table III we have summarized all the published results, including ours, for the mean lifetimes of θ^0 and Λ^0 particles. In order to combine these values to get a weighted mean value for each type of particle, we have used the values of $1/\tau$, which are expected to have an approximately normal distribution. The $1/\tau$ values thus obtained are listed in the third and sixth columns of Table III together with the corresponding symmetrical errors. On the basis of certain arguments,[11] the results of Fretter *et al.* have been excluded, and only the low-Q events of Alford and Leighton have been included for weighting. Some recent results of Blumenfeld *et al.*,[12] which were obtained from V^0 particles produced at the Brookhaven Cosmotron, have not been included in the weighted mean lifetimes so that these values may refer to cosmic-ray experiments only. Thus, the *weighted mean lifetime* for the 83 θ^0 particles studied by different groups of workers is found to be

$$1/\tau_w = (0.72 \pm 0.15) \times 10^{10}\ \text{sec}^{-1} \tag{11}$$

or

$$\tau_w = (1.4_{-0.2}^{+0.4}) \times 10^{-10}\ \text{sec},$$

and the *weighted mean value* for 173 Λ^0 particles is

$$1/\tau_w = (0.27 \pm 0.04) \times 10^{10}\ \text{sec}^{-1} \tag{12}$$

or

$$\tau_w = (3.7_{-0.4}^{+0.6}) \times 10^{-10}\ \text{sec}.$$

V. MOMENTUM DISTRIBUTION OF Λ^0 AND θ^0 PARTICLES

In many cases (e.g., $N_{\theta^0}/N_{\Lambda^0}$, momentum distribution, etc.) one wants to weigh each event for its detection efficiency by the cloud chamber. The weighting factor mainly comes from the corrections for the decay in the plates and that outside the chamber, and it can therefore be calculated as follows: The probability that a V^0 particle decay and be *observed* in our chamber is

$$\mathcal{P} = (e^{-t/\tau} - e^{-T/\tau}) - (e^{-T_1/\tau} - e^{-T_2/\tau}). \tag{13}$$

The first set of parentheses represents the probability that the V^0 particle decays in the time interval $(T-t)$ and the second set of parentheses is the probability that it decays in the second plate. As in previous sections, these times are to be referred to the rest system and are calculated from the corresponding

[9] D. I. Page, Phil. Mag. 45, 863 (1954).

[10] Four of the θ^0 cases with $l_r < 0.4$ cm are not included.

[11] In the experiment of Fretter *et al.*, the correction for the decay in the plates has been neglected. Alford and Leighton have set the dividing Q values at 50 Mev, and therefore the high-Q events may be a mixture of θ^0, Λ^0, and possibly some other particles. [See also Page and Newth, reference 1.]

[12] Blumenfeld, Booth, Lederman, and Chinowsky, Phys. Rev. **102**, 1184 (1956). These authors obtain a mean lifetime value of $(0.8_{-0.2}^{+0.3}) \times 10^{-10}$ sec for their 25 θ^0 particles and $(2.8_{-0.4}^{+0.6}) \times 10^{-10}$ sec for their 65 Λ^0 particles.

lengths by relations similar to the following one:

$$t=\frac{l}{c\beta\gamma}=\frac{l}{3(P/M)}\times 10^{-10}\text{ sec.} \tag{14}$$

Thus, from Eqs. (13) and (14) the detection probability $\mathcal{P}$ depends on the momentum P of the V^0 particle. The lengths, L, L_1, L_2 mainly depend on the disposition of the plates and the dimensions of the chamber. Therefore, their dependence on the momentum P may be neglected. But l depends on P, though its dependence on P is determined by the dimension of the chamber relative to the mean decay length. Hence, the dependence of the probability $\mathcal{P}$ on the momentum P is through l as well as through P explicitly as shown in Eqs. (13) and (14). For each event the weighting factor W is therefore taken as the reciprocal of the detection probability $\mathcal{P}$, i.e.,

$$W\equiv 1/\mathcal{P}. \tag{15}$$

The values of W so calculated for the individual events are given in the last columns of Tables I and II, and have already been used in Part I.

Before discussing the momentum distribution of the θ^0 and Λ^0 particles, it may be interesting to see first how the mean detection probability of our chambers varies with the momentum of the V^0 particle. By "mean detection probability"[13] it is meant that in calculating this probability $\langle\mathcal{P}\rangle_{\text{Av}}$ mean values of l, L, L_1, and L_2 are used, the assumption being made that these mean values are practically independent of the momentum P of the V^0 particle. This variation is represented by the curves in Fig. 2, the dashed one being for θ^0 particles and full one for Λ^0 particles. It is seen that our chamber has a maximum mean detection probability $\sim$0.6 for both θ^0 particles (at $P\sim$1500 Mev/c) and Λ^0 particles (at $P\sim$700 Mev/c). To detect Λ^0 particles of momentum between about 150 Mev/c and 3500 Mev/c or θ^0 particles between about 400 Mev/c and 8000 Mev/c, the chamber still has a mean detection probability between 0.3 and 0.6. Our chamber has therefore the ability to detect particles of either type over a wide range of momentum without losing too much efficiency. This may reflect some idea of the veracity of the momentum distribution, shown in Figs. 3(a) and 3(b) for Λ^0 and θ^0 particles.

TABLE III. Summary of published estimates of the mean lifetimes of Λ^0 and θ^0 particles.

	Λ^0 particles			θ^0 particles		
Groups of workers	No. of events	τ^{-1} (10^{10} sec^{-1})	τ (10^{-10} sec)	No. of events	τ^{-1} (10^{10} sec^{-1})	τ (10^{-10} sec)
Fretter *et al.*[a] (1953)	22		10 ± 7	11		4 ± 3
Alford and Leighton[b] (1953)	74		2.5 ± 0.7			
Alford and Leighton[b] (high Q)	20		1.3 ± 0.5			
Alford and Leighton[b] (low Q)	37	0.34 ± 0.14	2.9 ± 0.8			
Bridge *et al.*[c] (1953)	21	0.29 ± 0.11	$3.5_{-1.0}^{+2.1}$	6	1.11 ± 0.71	$0.9_{-0.3}^{+1.6}$
Deutschmann[d] (1953)	22	0.21 ± 0.07	$4.8_{-1.8}^{+2.6}$	9	0.43 ± 0.20	$2.3_{-0.7}^{+2.1}$
Astbury[e] (1953)				11	0.63 ± 0.37	$1.6_{-0.6}^{+2.2}$
Gayther[f] (1954)	21	0.25 ± 0.12	$4.0_{-1.2}^{+3.7}$	8	$1.8\ \pm0.8$	$0.6_{-0.2}^{+0.4}$
Page and Newth[g] (1954)	26	0.27 ± 0.14	$3.7_{-1.3}^{+3.9}$			
Page[h] (1954,1955)	23	0.28 ± 0.07	$3.6_{-0.7}^{+1.1}$	14	1.43 ± 0.57	$0.7_{-0.2}^{+0.3}$
Present paper	23	0.36 ± 0.11	$2.8_{-0.7}^{+1.2}$	35	1.32 ± 0.45	$0.8_{-0.2}^{+0.4}$

[a] W. B. Fretter *et al.*, reference 1.
[b] W. L. Alford and R. B. Leighton, reference 8; for discussion of the classification of V^0 particles by these authors, see reference 11. For the 37 low-Q events regarded as Λ^0 particles, the $1/\tau$ value is calculated from the τ value given, and the symmetrical error of $1/\tau$ shown is the largest error of $1/\tau$.
[c] The asymmetrical error for τ of Λ^0 particles of Bridge *et al.* is quoted by Page and Newth (reference 1); the value for τ of θ^0 particles is quoted by Gayther (reference 1).
[d] τ values (also number of events) for Λ^0 and for θ^0 particles of Deutschmann are quoted, respectively, by Page and Newth and by Gayther (reference 1).
[e] These results are quoted by Gayther (reference 1).
[f] D. B. Gayther, reference 1. Gayther's τ value for θ^0 particles is his recently corrected value [see Phil. Mag. **46**, 1362 (1955)].
[g] D. I. Page and J. A. Newth, reference 1.
[h] D. I. Page, Phil. Mag. **45**, 863 (1954) for Λ^0 particles; **46**, 103 (1955) for θ^0 particles.

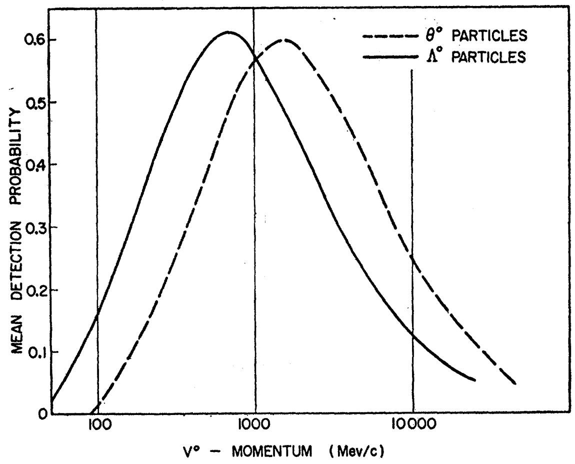

FIG. 2. Mean detection efficiency curve for the cloud-chamber setup used in our experiment.

After weighting each event for the detection efficiency according to Eqs. (13) and (14), we have plotted the momentum distributions in Figs. 3(a) and 3(b), respectively, for Λ^0 and θ^0 particles. The momentum of each event was obtained by multiplying the $\beta\gamma$ in Table I or II by the mass M. The standard deviations are obtained as before from $(\sum_r W_r^2)^{\frac{1}{2}}$ and are shown by the vertical lines. Without discussing some known sources of bias, it may be interesting to note that the two distribution curves are different in the momentum range covered. The θ^0 curve covers the interval approximately from 300 Mev/c to 4500 Mev/c. while the Λ^0 curve runs from about 250 Mev/c to 1300 Mev/c. The number of V^0 particles with low momentum is probably understimated because low-energy V^0 particles probably make large angles with the penetrating shower axis and hence may decay near or in the

[13] D. B. Gayther and C. C. Butler, Phil. Mag. **46**, 467 (1955).

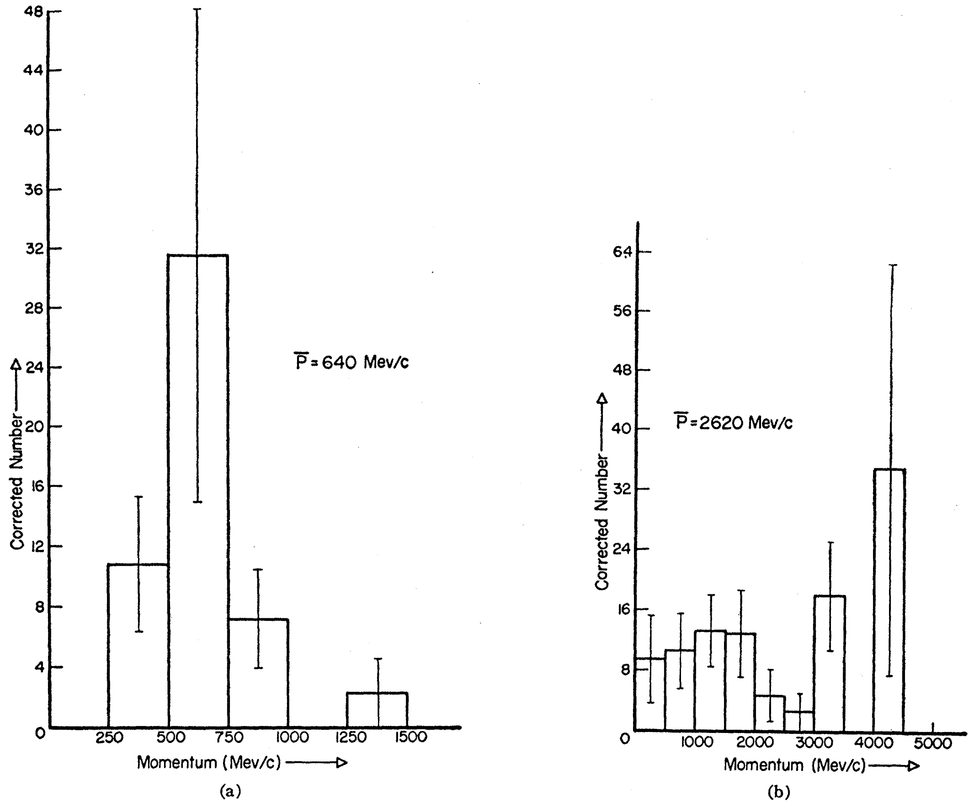

FIG. 3. (a) Momentum distribution for the 52 Λ^0 particles. The weighted mean momentum is about 640 Mev/c for the Λ^0 particles. (b) Momentum distribution for the 106 θ^0 particles. The standard errors shown by the vertical lines in both Figs. 3(a) and 3(b) have been calculated from $(\Sigma_r W_r^2)^{\frac{1}{2}}$ (see text). The weighted mean momentum for the θ^0 particles is about 2620 Mev/c.

producing plate and not be observed. This is more nearly true of Λ^0 than θ^0 particles, since the Λ^0 have on the average much lower momenta. The Λ^0 distribution indicates a decrease[14] in the number of particles towards the high-momentum end.

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[14] Similar indications have been observed by J. Ballam *et al.*, Phys. Rev. **91**, 1019 (1953) and Gayther and Butler (reference 13).