THE IDENTIFICATION OF HIGH-ENERGY $\Lambda^0$S, $\bar{\Lambda}^0$S,
AND $K^0$S IN BUBBLE CHAMBER EXPERIMENTS

by

R.A. Salmeron and R.G.P. Voss.
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THE IDENTIFICATION OF HIGH-ENERGY $\Lambda^0$s, $\bar{\Lambda}^0$s, AND $K^0$s IN BUBBLE CHAMBER EXPERIMENTS

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I. INTRODUCTION *)

In some high-energy bubble chamber experiments involving strange particles one of the difficulties encountered is the identification of the decays:

\[ \Lambda^0 \rightarrow p + \pi^- + 37.6 \text{ MeV} \]
\[ \Lambda^0 \rightarrow \bar{p} + \pi^+ + 37.6 \text{ MeV} \]
\[ K_\pi^0 (\text{or } K_\pi^0) \rightarrow \pi^+ + \pi^- + 218.6 \text{ MeV} , \]

due to the kinematic similarity of those decays at high energies. In this report we present a rough estimate of the probability of identifying a \( \Lambda^0 \), \( \Lambda^0 \), or \( K_\pi^0 \) as a function of the momentum of the decaying particle, in the momentum range from 1 to 25 GeV/c.

Two general cases have been considered. In case A we have assumed that the total decay angle, the partial decay angles, and the two secondary momenta are measurable, whereas in case B the above angles and only one secondary momentum are measurable.

To investigate these problems we considered three methods of analysis of neutral V-events:

a) the calculation of the \( Q \)-value;

b) the use of the \( \alpha - p_t \) diagram;

c) the use of the \( \alpha - \epsilon \) diagram;

where \( \alpha \) and \( \epsilon \) are the well-known parameters of Podclanski and Armenteros1).

We have assumed that the identification of these particles is determined solely by the decay scheme and have ignored the possibility of further information from the production interaction or from interactions of the decay products, or from ionization measurements. Only identification of individual events was studied; for instance, the statistical distribution of the events in the \( (\alpha - 1/p) \) or \( (\alpha - p_t) \) diagram which is often made was not considered.

To estimate the errors in the computed quantities involved, what seem reasonable errors in the measured quantities (momenta and angles) were assumed. Computer programmes have been used to

*) The material of this report had been published as an internal report, PS/Int. EA 60-4, in April 1960.
calculate the kinematics and the associated errors. When experimentally determined measurement errors for a particular chamber are known, it will be a relatively simple matter to replace our guesses at these quantities by the actual values.

In the following an "identifiable $\Lambda^0$" means a $\Upsilon^0$ not compatible with the decay $K^0 \rightarrow p^+\pi^-$. An "identifiable $K^0$" means a $\Upsilon^0$ not compatible with the decays $\Lambda^0 \rightarrow p^+\pi^-$ and $\Lambda^0 \rightarrow \bar{p}^+\pi^-$. Three-body decays have not been considered.

It was assumed that $\Lambda^0$'s, $\Lambda^+$'s, and $K^0$'s decay isotropically in their rest frame.

II. NOMENCLATURE

Below is a list of the symbols used in this report and their meanings.

$P$ = momentum of $\Lambda^0$, $\Lambda^+$, or $K^0$;

$p_+$ = momentum of positive decay product;

$p_-$ = momentum of negative decay product;

$p_t$ = transverse component of momentum of either decay product;

$\phi$ = angle in laboratory system between positive and negative decay products (decay angle);

$\phi_+$ = angle in laboratory system between positive decay product and direction of primary particle;

$\phi_-$ = angle in laboratory system between negative decay product and direction of primary particle;

$\phi^*$ = angle in centre-of-mass system between positive decay product and direction of primary particle.

III. Case A. IDENTIFICATION WHEN $p_+$, $p_-$, $\phi_+$, $\phi_-$ and $\phi$ ARE MEASURABLE

1. Identification by means of $Q$-values

For the case of a $\Lambda^0$ decaying to a proton and a $\pi^-$, for a given momentum $P$ of the $\Lambda^0$, the angle $\phi^*$ was varied between $0^\circ$ and $180^\circ$, and the two secondary momenta $p_+$ and $p_-$ and the decay angle $\phi$ were calculated as a function of $\phi^*$. 

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It was then assumed that these values of \( p_+ \), \( p_- \) and \( \varphi \) referred to a \( K^0 \), and the corresponding \( Q(\pi,\pi) \)-values were calculated. To calculate the errors \( \Delta Q(\pi,\pi) \) in these \( Q(\pi,\pi) \)-values the following assumptions were made.

i) In a heavy liquid bubble chamber the main source of error in momentum measurement seems to be multiple scattering. This error can be calculated, and is found to lie roughly in the range 4-10% for particles of momentum greater than 1 GeV/c in most of the liquids currently used in large chambers, assuming a track length of about 50 cm and a magnetic field of 20,000 gauss. Consequently, the assumption was made that the error in momentum is \( \pm 10\% \) and is independent of the value of the momentum.

ii) The error in \( \varphi \) is \( \pm 1^\circ \), which seems to be a realistic estimate.

iii) The contributions of the errors in these three quantities are independent *)

\[
\Delta Q = \left[ \left( \frac{\partial Q}{\partial p_+} \Delta p_+ \right)^2 + \left( \frac{\partial Q}{\partial p_-} \Delta p_- \right)^2 + \left( \frac{\partial Q}{\partial \varphi} \Delta \varphi \right)^2 \right]^{1/2} . \tag{1}
\]

To be able to conclude that a \( \Lambda^0 \) is not mistaken for a \( K^0 \), it is assumed that the \( Q(\pi,\pi) \)-value as calculated above must be at least two standard deviations away from the \( Q \)-value of the \( K^0 \), this latter incorporating the experimental error.

Accordingly, for a given \( \Lambda^0 \) momentum, curves of \( Q(\pi,\pi) \)
\( Q(\pi,\pi) + 2\Delta Q(\pi,\pi) \), and \( Q(\pi,\pi) - 2\Delta Q(\pi,\pi) \) were plotted as a function of \( \varphi \). On the same graph was plotted the \( Q \)-value of the \( K^0 \),
\( (218.6 \pm 0.6) \) MeV, to which we arbitrarily added a 5 MeV uncertainty. The region of overlap represents those \( \Lambda^0 \)'s which would not be distinguished from a \( K^0 \).

*) The expressions for errors are given in full to indicate precisely which variables were used in their calculation.
Since the curves are plotted as a function of $\varphi^*$ the percentage of $\Lambda^0$'s which are distinguishable is readily obtained.

This procedure was repeated for various $\Lambda^0$ momenta, the diagrams for $\Lambda^0$'s of 1 and 10 GeV/c being shown in Figs. 1 and 2 respectively. The resultant percentage of distinguishable $\Lambda^0$'s is plotted as a function of the $\Lambda^0$ momentum in curve A of Fig. 3.

To find the percentage of $K^0_s$'s which are distinguishable from $\Lambda^0$'s, the above procedure was applied to the $K^0_s$ decays. For a given momentum $P$ of the $K^0_s$, $\varphi^*$ was varied between $0^\circ$ and $180^\circ$, and $p_+$, $p_-$, and $\varphi$ were calculated as a function of $\varphi^*$. The values of $p_+$, $p_-$, and $\varphi$ were used to calculate $Q(p,\pi)-$values on the assumption that they referred to a $\Lambda^0$, and the above criteria were again applied. The diagram for $K^0_s$'s of 5 GeV/c analysed as $\Lambda^0$'s is shown in Fig. 4.

We assumed that if the $Q(p,\pi)+2\Delta Q(p,\pi)$ and $Q(p,\pi)-2\Delta Q(p,\pi)$-values lie in the range 0-50 MeV the $K^0_s$ was not distinguishable. We see from Fig. 4 that even if we extend this range to 0-100 MeV the percentage of identifiable $K^0_s$'s is not greatly affected. The percentage of identifiable $K^0_s$'s as a function of $K^0_s$ momentum is shown in curve A of Fig. 5.

It is important to notice that the $Q$-value criterion gives the percentage of $K^0_s$'s which are distinguishable from $\Lambda^0$'s and from $\bar{\Lambda}^0$'s.

An important feature of the above analysis is the following. In deciding whether a $\Lambda^0$ of a given momentum was distinguishable from a $K^0_s$, no assumption was made about the momentum of the $K^0_s$. Consequently the figures obtained refer to the distinguishability of a $\Lambda^0$ of given momentum from a $K^0_s$ of any momentum, and similarly for the identification of a $K^0_s$.

2. Identification by means of the $\alpha-p_t$ diagram

Let us consider first the $\Lambda^0$'s. As in the case of the $Q$-value criterion, for a given momentum $P$ of the $\Lambda^0$ the angle $\varphi^*$ was varied between $0^\circ$ and $180^\circ$, and $p_+$, $p_-$, $\varphi_+$, $\varphi_-$, and $\varphi$ were
calculated as a function of $\varphi^*$. We then assumed that $p_+$ and $p_-$ being both measurable, the parameter $\alpha$ is calculated from the expression

$$\alpha = \frac{p_+^2 - p_-^2}{p_+^2 + p_-^2 + 2p_+ p_- \cos \varphi}$$

and that its error is then given by

$$\Delta \alpha = \left[ \left( \frac{\partial \alpha}{\partial p_+} \Delta p_+ \right)^2 + \left( \frac{\partial \alpha}{\partial p_-} \Delta p_- \right)^2 + \left( \frac{\partial \alpha}{\partial \varphi} \Delta \varphi \right)^2 \right]^{1/2}.$$  

Due to the fact that in $\Lambda^0$ decay $p_+$ is greater than $p_-$, we used $p_-$ and $\varphi_-$ to calculate $p_t$ in order to keep the errors as small as possible:

$$p_t = p_- \sin \varphi_-.$$  

The curves of $\alpha$ plotted as a function of $p_t$ are ellipses such as those shown in Figs. 6 and 7. The dots on the ellipses correspond to values of $\varphi^*$ from $0^\circ$ to $180^\circ$ in steps of $10^\circ$.

To determine the error in $\alpha$, it was assumed that as before the error in $p_+$ or $p_-$ is constant and equal to $10\%$ of the momentum. The errors in $\varphi_+$ and $\varphi_-$ were optimistically taken to be $\pm 0.5^\circ$, and the error in $\varphi$ to be $\pm 0.7^\circ$. Hence the standard deviations in $\alpha$ and $p_t$ were calculated, and twice these values plotted on the $\alpha - p_t$ diagram for values of $\varphi^*$ from $0^\circ$ to $180^\circ$ in steps of $10^\circ$. This is shown in Fig. 6 for the case of $5$ GeV/c $\Lambda^0$s, the ellipse for the $K^0_s$s and $\Lambda^0$s also corresponding to $5$ GeV/c.

As in the case of the Q-value analysis, it was assumed that for a $\Lambda^0$ to be distinguishable from a $K^0$, the point on the diagram corresponding to it must lie at least two standard deviations away from the $K^0$ curve. The range of values of $\varphi^*$ for which this condition is satisfied gives us the percentage of identifiable $\Lambda^0$s of a given momentum. This percentage is plotted as a function of the $\Lambda^0$ momentum from $1$ to $25$ GeV/c in curve B of Fig. 3.
Referring to Fig. 6 it is seen that the error lines representing two standard deviations in the \( \alpha \)'s of the \( \Lambda^0 \)'s fall very close to the \( \alpha - p_t \) curve of the \( K_t^0 \) for small c.m. angles \( \varphi^* \), and it is largely a matter of taste whether the \( \Lambda^0 \)'s are considered distinguishable or not. The results represented by curve B of Fig. 3 were obtained by applying strictly the criterion described above, i.e. considering as identifiable all \( \Lambda^0 \)'s corresponding to small \( \varphi^* \) for which two standard deviations of \( \alpha \) fall outside the \( \alpha - p_t \) curve of the \( K_t^0 \). The result of this is that the percentage of identifiable \( \Lambda^0 \)'s given by the \( \alpha - p_t \) analysis (curve B of Fig. 3) is apparently appreciably higher than the percentage of identifiable \( \Lambda^0 \)'s given by the Q-value analysis (curve A of Fig. 3). Now, in the Q-value analysis we included the uncertainty of 5 MeV in the accepted Q-value of the \( K_t^0 \), \( (218.6 \pm 0.6) \) MeV. This same uncertainty can be included in the \( \alpha - p_t \) analysis since the \( K_t^0 \) mass uncertainty will lead to an uncertainty in the value of \( \alpha \) for the \( K_t^0 \). If we take this into account, the \( \Lambda^0 \)'s corresponding to small values of \( \varphi^* \) will no longer be identifiable. In this case the number of identifiable \( \Lambda^0 \)'s given by the \( \alpha - p_t \) criterion is the same as that given by the Q-value criterion, i.e. by curve A of Fig. 3.

Similar use of the \( \alpha - p_t \) diagram was made to obtain the percentage of identifiable \( K_t^0 \)'s of a given momentum. Figure 7 shows the plot of two standard deviations of \( \alpha \) and of \( p_t \) for a \( K_t^0 \) of 5 GeV/c, for \( \varphi^* \) ranging from 0° to 180° in steps of 10°. In the same figure the \( \alpha - p_t \) curves for 5 GeV/c \( \Lambda^0 \)'s and \( \bar{\Lambda}^0 \)'s are given.

The percentage of \( K_t^0 \)'s, that are distinguishable from \( \Lambda^0 \)'s and from \( \bar{\Lambda}^0 \)'s as a function of the \( K_t^0 \) momentum, obtained from the \( \alpha - p_t \) diagram, is again given by curve A of Fig. 5. If we ignore the \( \bar{\Lambda}^0 \)'s, the percentage of \( K_t^0 \)'s which are distinguishable from \( \Lambda^0 \)'s is given by curve B of Fig. 5, situated half-way between curve A and the line corresponding to 100%.
3. Identification by means of the $\alpha - \epsilon$ diagram

In order to use the $\alpha$ and $\epsilon$ parameters, we constructed on the $\alpha - \epsilon$ plane three families of curves corresponding to constant $p_+$, $p_-$, and $\varphi^*$, respectively, for the $\Lambda^0$ and the $K^0$ decays. The curves relative to the $K^0$ are shown in Fig. 8.

Let us consider first the identification of $\Lambda^0$s. For a given $\Lambda^0$ momentum, values of $p_+$, $p_-$, $\varphi_+$, $\varphi_-$, and $\varphi$ were calculated as a function of $\varphi^*$, as described in Section III.2. Then $\alpha$ and $\Delta \alpha$ have been calculated from expressions (2) and (3), and $\epsilon$ and $\Delta \epsilon$ from:

$$\epsilon = \frac{2p_+}{P} = \frac{2p_- \sin \varphi_-}{\left[p_+^2 + p_-^2 + 2p_+ p_- \cos \varphi\right]^{1/2}} \quad (5)$$

$$\Delta \epsilon = \sqrt{\left(\frac{\partial \epsilon}{\partial p_+} \Delta p_+\right)^2 + \left(\frac{\partial \epsilon}{\partial p_-} \Delta p_-\right)^2 + \left(\frac{\partial \epsilon}{\partial \varphi_+} \Delta \varphi_+\right)^2 + \left(\frac{\partial \epsilon}{\partial \varphi_-} \Delta \varphi_-\right)^2}. \quad (6)$$

The errors in momenta and angles are the same as those assumed in Section III.2.

For each $\Lambda^0$ momentum we calculated a set of values of $\alpha$, $\Delta \alpha$, $\epsilon$, $\Delta \epsilon$ corresponding to each value of $\varphi^*$ from $0^\circ$ to $180^\circ$ in steps of $10^\circ$. The values of $\alpha \pm 2 \Delta \alpha$ and $\epsilon \pm 2 \Delta \epsilon$ corresponding to a $\Lambda^0$ of a given momentum were plotted on the $\alpha - \epsilon$ plane of the $K^0$ decay. The ranges of values of $p_+$ and $p_-$ covered by these errors were then read from the diagram. The $\Lambda^0$ was considered not identified if these ranges of values of $p_+$ and $p_-$ covered the values corresponding to those of the $\pi^+$ and $\pi^-$ emitted in the decay of a $K^0$. The momentum of this $K^0$ was taken to be equal to that of the $\Lambda^0$, but a spread was considered to take into account the experimental error on the momentum of a $V^*$ obtained from the measured quantities.

Figure 8 shows the plot for $\Lambda^0$s of 1 GeV/c.
This procedure was repeated for various values of the $\Lambda^0$ momentum, so that a curve of probability of identification of a $\Lambda^0$ as a function of the $\Lambda^0$ momentum was obtained. This curve is practically the same as curve A of Fig. 3.

The identification of $K^0_s$'s from the $\alpha$ and $\epsilon$ parameters was treated in a similar way. Values of $\alpha \pm 2\Delta\alpha$ and $\epsilon \pm 2\Delta\epsilon$ corresponding to a given momentum of $K^0_s$ were plotted on the $\alpha - \epsilon$ plane of the $\Lambda^0$ decay. The resulting ranges of $p_\perp$ and $p_\parallel$ were compared with the values corresponding to a $\Lambda^0$, in the same way as described above. The probability of identification of a $K^0_s$ as a function of $K^0_s$ momentum, given by this criterion, is shown by curve D of Fig. 5. If the $K^0_s$'s are to be identified from both $\Lambda^0$'s and $\bar{\Lambda}^0$'s, curve C is obtained.

IV. Case B. IDENTIFICATION WHEN $\varphi_+, \varphi_-, \varphi$, AND ONE MOMENTUM ARE MEASURABLE

When only one secondary momentum can be measured well, the resultant errors in the $Q$-value are so great that the $Q$-value becomes a less reliable criterion. Consequently only the $\alpha - p_\perp$ and $\alpha - \epsilon$ analyses were considered in this case.

1. Identification by means of $\alpha - p_\perp$ diagram

As only one momentum is well measured, it was assumed that $\alpha$ and its errors are calculated from $\varphi_+$ and $\varphi_-$:

$$\alpha = \frac{\sin (\varphi_- - \varphi_+)}{\sin (\varphi_- + \varphi_+)} \quad (7)$$

$$\Delta \alpha = \left[ \left( \frac{\partial \alpha}{\partial \varphi_+} \Delta \varphi_+ \right)^2 + \left( \frac{\partial \alpha}{\partial \varphi_-} \Delta \varphi_- \right)^2 \right]^{1/2} \quad (8)$$

Even with the optimistic assumption mentioned in Section III.2 that $\Delta \varphi_+$ and $\Delta \varphi_-$ are $\pm 0.5^\circ$, the errors in $\alpha$ are now much larger, by a
factor between 2 and 5, than those obtained solely from errors in momentum.

The transverse momentum and its errors were calculated from $p_-$ and $\phi_-$.

By repeating the analysis described in Section III.2, it is concluded that due to the large errors in $\alpha$ the number of identifiable $\Lambda^0$'s is very much reduced. The $\alpha-p_t$ diagram for a $\Lambda^0$ of 5 GeV/c is given in Fig. 9. The percentage of $\Lambda^0$'s which would be identifiable is shown in curve C of Fig. 3 as a function of the $\Lambda^0$ momentum. The percentage of identifiable $\Lambda^0$'s in this case is much smaller than in Case A.

An example of a similar analysis for $K_t^0$'s is given in Fig. 10 for a $K_t^0$ of 5 GeV/c. The percentage of identifiable $K_t^0$'s as a function of the $K_t^0$ momentum is again given by curve A or B of Fig. 5, depending on whether the $\Lambda^0$'s are or are not included in the analysis. The result is that the percentage of identifiable $K_t^0$'s of a given momentum is in this case the same as that obtained in Case A.

2. Identification by means of the $\alpha-\epsilon$ diagram

In Case B it was assumed that $\alpha$ and $\Delta \alpha$ are given by expressions (7) and (8) respectively, and $\epsilon$ and $\Delta \epsilon$ by:

$$\epsilon = \frac{2 \sin \phi_- \sin \phi_+}{\sin (\phi_- + \phi_+)}$$

$$\Delta \epsilon = \left[ \left( \frac{\partial \epsilon}{\partial \phi_+} \Delta \phi_+ \right)^2 + \left( \frac{\partial \epsilon}{\partial \phi_-} \Delta \phi_- \right)^2 \right]^{1/2}.$$  

Even with $\Delta \phi_+ = \Delta \phi_- = \pm 0.5^\circ$ the errors in $\epsilon$ are much larger than those given by expression (6). The curves of constant $p_+$ and $p_-$ on the $\alpha-\epsilon$ plane were used as described in Section III.3. The result for $\Lambda^0$'s is again given by curve C of Fig. 3. In the case
of K_0^0's the result is worse than is shown in Fig. 5, curves C and D, and was not plotted.

V. IDENTIFICATION OF ANTI-Λ^0's

As a consequence of the symmetry in the decays of the Λ^0 and Λ^0, the results given in Fig. 3 are valid also for the Λ^0.

VI. CONCLUSIONS

It is worth repeating that we assumed that the only information available is that from the decay scheme itself, except for the point of production of the V^0 in the case when φ_+ and φ_- need to be determined. We did not consider a statistical distribution of events.

It is also worth emphasizing that, apart from the criteria adopted, the results expressed in Figs. 3 and 5 must be taken as approximate, and should not be trusted to better than 5%.

Under the assumption that the secondary momenta are measured with 10% error and the partial angles to ± 0.5°, the following first two conclusions are reached.

1) When φ_+, φ_-, φ, and both secondary momenta are measurable, the percentage of identifiable Λ^0's as a function of Λ^0 momentum is given by curve A of Fig. 3, whichever of the three methods of analysis is used. The percentage of identifiable K_0^0's as a function of K_0^0 momentum is given in Fig. 5 as explained in the legend.

2) When φ_+, φ_-, φ, and one secondary momentum are measurable, the percentage of identifiable Λ^0's is given by curve C of Fig. 3. Λ^0's with momentum greater than about 3 GeV/c will hardly be identified. The percentage of identifiable K_0^0's will be the same as in Case A, provided one uses the α - p_t diagram.

The reason why the α-p_t diagram gives the same result for the K_0^0's in Cases A and B, and gives a much worse result for Λ^0's
in Case B than in Case A is the following. The identification of a $K^0$ by means of this diagram depends strongly on $p_t$, which was made to have the same errors in both cases, while the identification of a $\Lambda^0$ depends on $\alpha$, which has larger errors in Case B than in Case A.

3) In many cases in practice it will not be possible to measure all the quantities used in Case A (e.g., the decay may occur near the edge of the chamber, the tracks of the secondaries may be shorter than the 50 cm mentioned in Section III.1, the accuracy may not be uniform through the whole chamber, etc.). Since the probability of identification of a $\Lambda^0$ found in Case B is so very much worse than that of Case A, it seems that the realistic probability of identification of $\Lambda^0$s will be appreciably less than that given by curve A of Fig. 3. On the other hand, when the point of production of a $K^0$ is known (which will generally be the case in a bubble chamber), the probability of identifying the $K^0$ decay will never be much smaller than that given by curves A and B of Fig. 5.

4) The percentage of identifiable $\overline{\Lambda}$'s as a function of the $\Lambda$ momentum will be the same as that for the $\Lambda$ in Cases A and B.

Finally, if the errors are different from whose we assumed, the results can easily be changed by substituting in expressions (1), (3), (6), (8) and (10) the new errors assumed.

* * *

We should like to thank Drs. R. Armenteros, B.P. Gregory, and A. Lagarrigue for profitable discussions. The care given by Mrs. R. Develay to the drawing of the figures is gratefully acknowledged.

* * *
REFERENCE


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Q-value of a $\Lambda^0$ particle of 1 GeV/c if analysed as a $K^0$-meson as a function of $\varphi_p^*$ (proton angle in the c.m.s.)

Percentage of identifiable events, taking two standard deviations = 55%
Q-value of a $\Lambda^0$-particle of 10 GeV/c if analysed as a $K^0_L$-meson, as a function of $\varphi_p^*$. Percentage of identifiable events $= 25\%$

Fig. 2
PERCENTAGE OF IDENTIFIABLE $\Lambda^0$'S AS A FUNCTION OF $\Lambda^0$ MOMENTUM

CURVE A - Q-value, $\alpha - P_t$ case I, $\alpha - \epsilon$ case I

CURVE B - $\alpha - P_t$ case I (strict application of criterion — see text)

CURVE C - $\alpha - P_t$ case II, $\alpha - \epsilon$ case II
Q

VALUE OF A K^0 OF 5 GeV/c IF ANALYSED

\[ \text{Percentage of identifiable events} = 80\% \]
PERCENTAGE OF IDENTIFIABLE $K^0$'S AS A FUNCTION OF $K^0$-MOMENTUM

CURVE A: Q-value, $\alpha-P_t$ cases I and II ($\bar{\Lambda}^\circ$ included in the analysis)

CURVE B: $\alpha-P_t$ cases I and II ($\bar{\Lambda}^\circ$ not included in the analysis)

CURVE C: $\alpha-\varepsilon$ case I ($\bar{\Lambda}^\circ$ included in the analysis)

CURVE D: $\alpha-\varepsilon$ case I ($\bar{\Lambda}^\circ$ not included in the analysis)

Fig. 5
\( \alpha - \alpha_t \) Diagram for \( \Lambda^0, \bar{\Lambda}^0 \) and \( K^0 \) of 5 GeV/c.

Values of \( \varphi^* \) refer to positive secondary.

Crosses show \( \pm \Delta \alpha \) and \( \pm 2 \Delta \alpha_t \)
for a \( \Lambda^0 \) of 5 GeV/c in case I.
$\alpha - P_\perp$ DIAGRAM FOR $\Lambda^+$, $\Lambda^-$ and $K^+$ at 5 GeV/c

Values of $\phi^*$ refer to positive secondary

Crosses show $\pm 2 \Delta \alpha$ and $\pm 2 \Delta P_\perp$
for a $K^+$ of 5 GeV/c in case I

Fig. 7
The lines are the diagonals of the rectangles relative to the plot of $\alpha \pm 2\Delta\alpha$ and $E \pm 2\Delta E$ for a $\Lambda^+$ of 1.6 GeV/c for $\beta^*$ of the proton from 0° to 180° in steps of 10°.
$\alpha - p_t$ DIAGRAM FOR 5 GeV/c $\Lambda$, $\bar{\Lambda}$, and $K^0$;
values of $\varphi^*$ refer to positive secondary.

Crosses show $\pm 2 \Delta \alpha$ and $\pm 2 \Delta p_t$ for
a $\Lambda^0$ of 5 GeV/c in case II.
π-π Diagram for 5 GeV/c \( \Lambda^0 \), \( \Xi \) and \( K^0 \)

Values of \( \theta^* \) refer to positive secondary

Crosses show \( \pm 2.0 \sigma \) and \( \pm 2.4 \sigma \)

for a \( K^0 \) of 5 GeV/c in case II

Fig. 10