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Observation of the $\overline{\Omega}$ †

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We have observed an $\overline{\Omega}$ event. The $\overline{\Omega}$ is produced in the reaction $K^+d \to \overline{\Omega}\Lambda\Lambda p\pi^+\pi^-$ at 12 GeV/c, and decays via the mode $\overline{\Omega} \to \overline{\Lambda}K^+$. The fitted mass for this particle is $M_{\overline{\Omega}} = 1673.1 \pm 1.0$ MeV. The $\overline{\Omega}$-production cross section is of the order of 0.1 μb.

We have observed an example of the $\overline{\Omega}$.[1] The decay mode is

$$\overline{\Omega}^+ \to \overline{\Lambda} + K^+.$$

The event is observed in a systematic search for interactions with a charged vee and associated neutral vee. This signature with a positively charged vee is characteristic of the possible decays $\overline{\Omega} \to \overline{\Lambda}K^+$ and $\overline{\Xi} \to \overline{\Lambda}\pi^+$. The experiment is a study of the K^+d interaction at 12 GeV/c carried out in the 82-in. Stanford Linear Accelerator Center (SLAC) bubble chamber. A total of 500 000 pictures were taken. So far we have examined 60% of the film in this systematic search, and have observed the following:

$$\overline{\Xi}^+ \to \overline{\Lambda} + \pi^+ \text{ (45 events)},$$

$$\Xi^- \to \Lambda + \pi^- \text{ (15 events)},$$

and

$$\overline{\Omega}^+ \to \overline{\Lambda} + K^+ \text{ (1 event)}.$$

In Fig. 1 we show the $\overline{\Omega}$ event. The reaction has been fitted uniquely by the hypothesis

$$K^+d \to \overline{\Omega}\Lambda\Lambda p\pi^+\pi^-,$$

where only one of the Λ's decays by the charged mode in the bubble chamber. The $\overline{\Lambda}$ from the $\overline{\Omega}$ decay can be seen on the left, and decays via the mode

$$\overline{\Lambda} \to \overline{p} + \pi^+,$$

in which the antiproton annihilates with a proton of one of the deuterons in the chamber.

Figure 2 shows a plot of $P_\perp$ (transverse momentum) versus α for the $\overline{\Xi}$ and $\overline{\Omega}$ events[2]:

$$\alpha = (P_\parallel{}^{\overline{\Lambda}} - P_\parallel{}^m)/(P_\parallel{}^{\overline{\Lambda}} + P_\parallel{}^m).$$

Here the symbol $P_\parallel$ means longitudinal momentum, and the superscript $\overline{\Lambda}$ refers to the antilambda, while m refers to either the π^+ or K^+ meson. The kinematic ellipses for $\overline{\Xi} \to \overline{\Lambda}\pi$ and $\overline{\Omega} \to \overline{\Lambda}K$ decays, shown in Fig. 2, are calculated for a $\overline{\Xi}$ or $\overline{\Omega}$ momentum of 2708 MeV/c, the momentum of the $\overline{\Omega}$ event. The horizontal axis of each ellipse will shrink slightly with increasing incident momentum, but the effect is small. There is a small region of kinematic ambiguity at the intersection of the two ellipses, but most of the regions are well separated. In Fig. 2 we have plotted the $\overline{\Xi}$ events and the $\overline{\Omega}$ event. In this calculation the $\overline{\Lambda}$ momentum is taken from a three-constraint fit for each $\overline{\Lambda}$ to the charged-vee decay vertex. The meson momentum and the

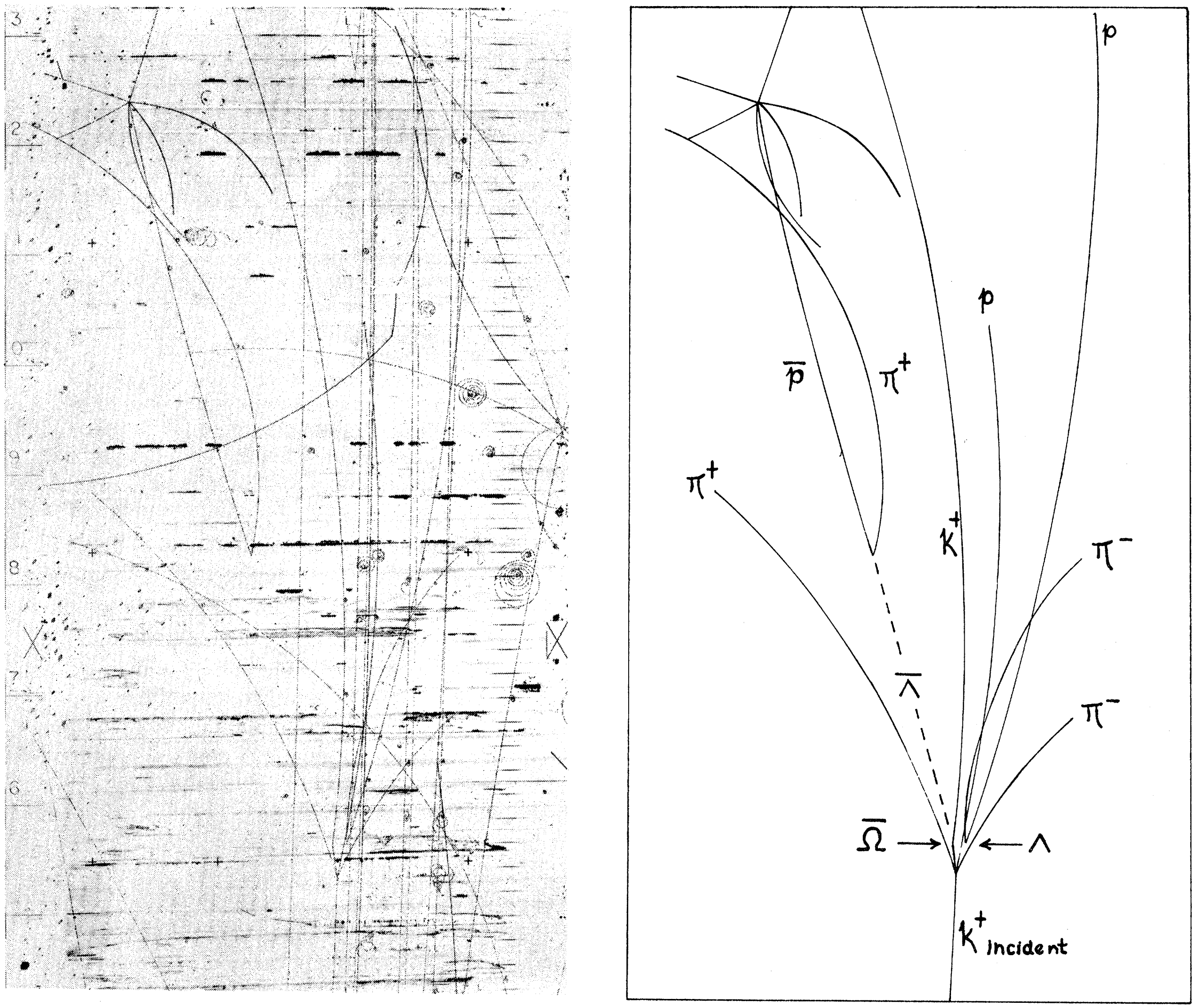

FIG. 1. The $\bar{\Omega}$ event. The production reaction is $K^+d \to \bar{\Omega}\Lambda\Lambda p \pi^+\pi^-$ and the decay is $\bar{\Omega} \to \bar{\Lambda}K^+$.

charged-hyperon direction are taken directly from the measurements for each event. The $\bar{\Omega}$ event is clearly separated from the $\bar{\Xi}$ events. If the fitted rather than measured quantities are used in the calculation, the events lie very close to the solid curves; a slight broadening is due to the spread in $\bar{\Xi}$ momenta. The spread in points about the smooth curve for the $\bar{\Xi}$ events is a measure of the errors introduced in the measurement process.

Each charged-vee decay vertex was fitted together with the $\bar{\Lambda}$ as a six-constraint fit by the following hypotheses[3]:

$$\bar{\Omega}^+ \to \bar{\Lambda} + K^+, \quad \bar{\Lambda} \to \bar{p} + \pi^+, \tag{1}$$

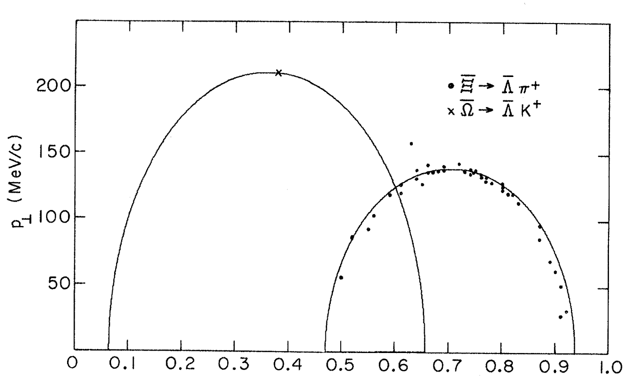

FIG. 2. The quantity $P_\perp$ vs α for the $\bar{\Omega}$ event and the $\bar{\Xi}$ events. The solid curves are the kinematic ellipses, calculated for the decays $\bar{\Omega} \to \bar{\Lambda}K$ and $\bar{\Xi} \to \bar{\Lambda}\pi$ with an antihyperon momentum of 2708 MeV/c.

$$\bar{\Xi}^+ \to \bar{\Lambda} + \pi^+ \qquad \bar{\Lambda} \to \bar{p} + \pi^+. \tag{2}$$

For hypothesis (1) the observed event fits with a χ^2 value of 9.2, while for hypothesis (2) the fit completely fails to converge. Furthermore, we have also performed a five-constraint fit to each event, in which the mass of the decaying charged hyperon is left free; that is, a fit by hypotheses (1) and (2) where the mass of the decaying particle is left as an unknown quantity.

In Fig. 3 we show the resulting mass measurements. We get an excellent measurement of the $\bar{\Xi}$ mass while the $\bar{\Omega}$ event, if interpreted as a $\bar{\Lambda}+\pi^+$ decay, gives a mass value of $M=1430.4\pm 2.6$ MeV, which is very far from the known $\bar{\Xi}$ mass of 1321.25 ± 0.18 MeV. For the $\bar{\Omega}$ event, interpreted as in hypothesis (1) above, we perform the six-constraint fit to the mass and find $M=1673.1\pm 1.0$ MeV, which is in excellent agreement with the known mass of the Ω: $M=1672.5\pm 0.5$ MeV.[4] We point out that this excellent mass determination is due in part to the fortuitous circumstance that this particular $\bar{\Omega}$ event decays with almost its maximally allowed transverse momentum.

In addition, the charged track from the $\bar{\Omega}$ decay has a momentum of 866 ± 8 MeV/c. If this track were a π^+ from the decay $\bar{\Xi}\to\bar{\Lambda}\pi^+$ it would be a minimum-ionizing track, while a K^+ of this momentum from the decay $\bar{\Omega}\to\bar{\Lambda}K^+$ would have an ionization of 1.3 times minimum ionizing. Visual estimates of the ionization indicate that this track appears darker than minimum ionizing but this determination is at the limit of any possible discrimination. The $\bar{\Lambda}$ from the $\bar{\Omega}$ decay has a momentum of 1885 ± 15 MeV/c.

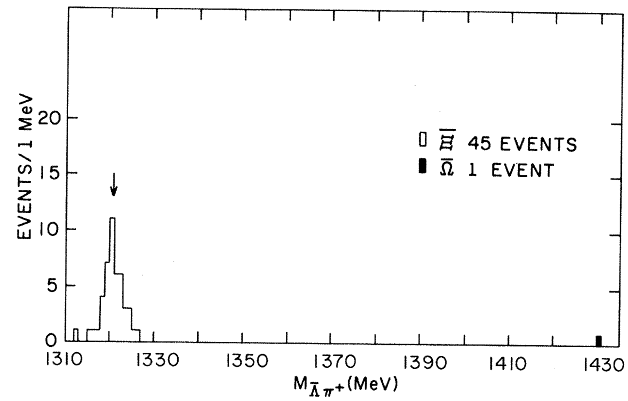

FIG. 3. The distribution in $M(\bar{\Lambda}\pi^+)$ for the $\bar{\Xi}$ and $\bar{\Omega}$ events. For this calculation the $\bar{\Omega}$ event has been interpreted as decaying into $\bar{\Lambda}+\pi^+$, rather than $\bar{\Lambda}+K^+$. The arrow indicates the position of the $\bar{\Xi}$ mass.

Table I lists the kinematic quantities for the particles associated with the production vertex in the reaction $K^+d\to\bar{\Omega}\Lambda\Lambda p\pi^+\pi^-$. We point out that the proton (presumably the spectator in the deuteron) has a momentum in the laboratory of 729 ± 11 MeV/c and is emitted approximately in the forward direction in the laboratory. Either there was a secondary interaction involving the spectator proton to give it this relatively large momentum, or this particular event occurs well out on the Hulthén wave function, i.e., the incident neutron in the deuteron at the time of collision with the K^+ was traveling with a momentum of about 700 MeV/c in approximately the backward direction in the laboratory. We point out that the total center-of-mass energy for a head-on collision of a 12-GeV/c K^+ meson with a 700-MeV/c neutron is 6.9 GeV, while the total center-of-mass energy for a collision of a 12-GeV/c K^+

Table I. Fitted parameters in the laboratory frame for the event $K^+d\to\bar{\Omega}^+\Lambda(\Lambda)p\pi^+\pi^-$.

Particle	Mass (MeV)	Azimuth[a] (degrees)	Dip[a] (degrees)	Momentum (MeV/c)
K^+ incident	494	88.15 ± 0.02	0.30 ± 0.07	$11\,800\pm 25$
$\bar{\Omega}$	1675	96.88 ± 0.07	9.84 ± 0.08	2708 ± 18
Λ	1115	74.99 ± 0.09	-11.25 ± 0.15	1354 ± 11
(Λ)[b]	1115	87.51 ± 0.07	4.41 ± 0.15	6739 ± 32
p[c]	938	78.61 ± 0.14	-22.43 ± 0.20	729 ± 11
π^+[c]	140	110.85 ± 0.16	-24.62 ± 0.22	417 ± 6
π^-	140	63.81 ± 0.32	-53.64 ± 0.30	252 ± 7

[a]The azimuthal angle is defined in the plane perpendicular to the camera axis, and the dip angle is defined with respect to this plane.

[b]The symbol (Λ) refers to the Λ hyperon which does not decay visibly in the bubble chamber.

[c]The π^+ and proton tracks can be identified by using ionization on the scan table.

meson with a neutron at rest is only 4.8 GeV.

The path length observed in the systematic study so far corresponds to about 15 events/μb. Taking into account that our analysis method only detects events with a charged decay of the $\bar{\Lambda}$ and allowing for detection efficiency, we estimate $\sigma(\bar{\Omega}) \approx 0.1$ μb in the K^+d reaction at 12 GeV/c. We emphasize that this cross-section estimate is based solely on a search for the $\bar{\Omega}$ decay modes $\bar{\Omega}^+ \to \bar{\Lambda}K^+$ and $\bar{\Omega}^+ \to \bar{\Xi}^+\pi^0$, but completely ignores the possible decay mode $\bar{\Omega}^+ \to \bar{\Xi}^0\pi^+$ which we have not attempted to detect so far.

We gratefully acknowledge the help of the SLAC accelerator operation group, and in particular we thank J. Murray, R. Gearhart, R. Watt, and the staff of the 82-in. bubble chamber for help with the exposure. We acknowledge the valuable support given by our scanning, programming, and computing staff, especially P. W. Weber, B. Sieh, E. R. Burns, and A. H. Habegger. The $\bar{\Omega}$ event was noted in the scanning by J. H. Allardt.

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Observation of the K^0K^- Mass Spectrum in the A_2-Meson Region*†

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We have measured the effective-mass spectrum of $K^-K_s^0$ particles produced in the forward direction in the reaction $\pi^- + p \to K^- + K_s^0 + p$ at 20.3 GeV/c. A broad peak corresponding to the A_2 meson is seen. The shape is fitted well by a single Breit-Wigner curve. A double-pole formula does not fit the data. A narrow peak in the K^-K^0 spectrum is seen at 1.425 GeV.

We have directly measured the effective-mass spectrum of $K^-K_s^0$ particle pairs produced in π^--p interactions at an incident π^- momentum of 20.3 GeV/c. The experiment was motivated by the apparent disagreement between the shape of the A_2 in the CERN missing-mass spectrometer data[1] on π^--p interactions up to 7 GeV and in the Lawrence Radiation Laboraotory bubble-chamber data[2] on π^+-p interactions at 7 GeV/c.

The data were taken with the Brookhaven double-vee magnetic spectrometer. The apparatus is discussed in detail elsewhere.[3] For this experiment we used only the forward spectrometer (a large-aperture magnetic spectrometer with wire-chamber detectors) which has an angular resolution of 0.25 mrad and a momentum resolution of 0.5%. In order to select K^-K^0 events, the following trigger scheme was used: A counter immediately downstream of the hydrogen target ("veto counter") was used, via pulse-height selection, to reject events where more than one charged particle was emitted from the target in the forward direction. At a distance of 100 in. downstream from the target we placed a 35-element scintillation-counter hodoscope and demanded that it count three charged particles. Two more hodoscopes located at the end of the apparatus were also set to demand three particles. The trigger rate was 1 per 5×10^3 beam particles. The data were monitored with the model PDP-10 computer of the Brookhaven on-line data facility which carried out complete on-line analysis of ~20% of the events in addition to monitoring the magnets, etc.

The data were analyzed requiring the K^0 to be a two-prong vertex, originating downstream of

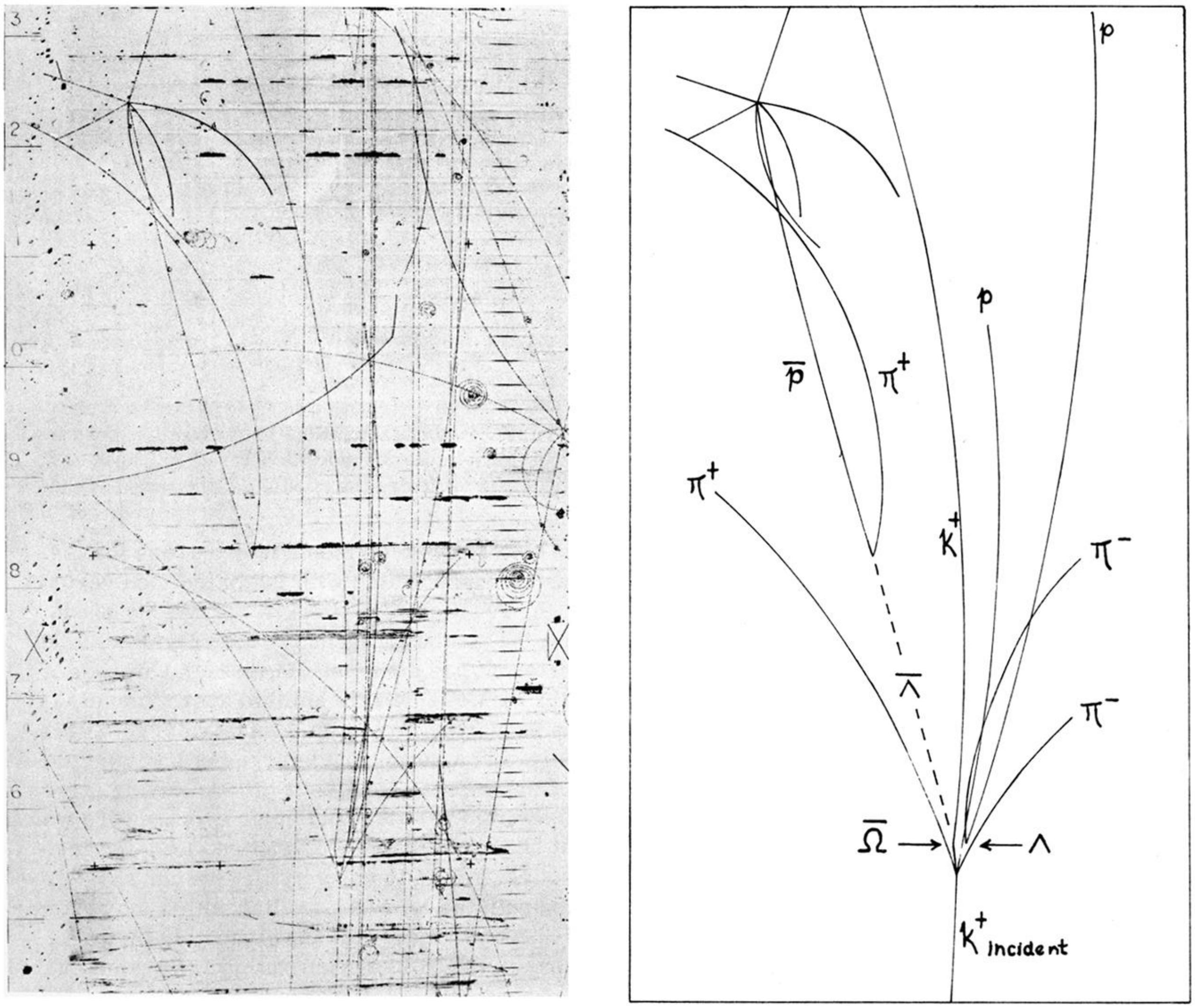

FIG. 1. The $\bar{\Omega}$ event. The production reaction is $K^+d \to \bar{\Omega}\Lambda\Lambda p\pi^+\pi^-$ and the decay is $\bar{\Omega} \to \bar{\Lambda}K^+$.