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Authors
Firestone, A.
Gold-haber, G.
Lissauer, D.
et al.

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LAWRENCE RADIATION LABORATORY
UNIVERSITY of CALIFORNIA BERKELEY

OBSERVATION OF THE ANTI-OMEGA*

A. Firestone, G. Goldhaber, D. Lissauer, B. M. Sheldon, and G. H. Trilling

Department of Physics and Lawrence Radiation Laboratory
University of California, Berkeley, California 94720

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ABSTRACT

We have observed an $\overline{\Omega}$ event. The $\overline{\Omega}$ is produced in the reaction $K^+d \rightarrow \overline{\Omega}\Lambda\Lambda p\pi^+\pi^-$ at 12 GeV/c, and decays via the mode $\overline{\Omega} \rightarrow \overline{\Lambda}K^+$. 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 anti-omega ($\overline{\Omega}$).[1] The decay mode is

$$\overline{\Omega}^+ \rightarrow \overline{\Lambda} + K^+ \quad .$$

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 $\overline{\Omega} \rightarrow \overline{\Lambda}K^+$ and $\overline{\Xi} \rightarrow \overline{\Lambda}\pi^+$. The experiment is a study of the K^+d interaction at 12 GeV/c carried out in the 82-inch 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:

$$\overline{\Xi}^+ \rightarrow \overline{\Lambda} + \pi^+ \qquad (45 \text{ events})$$

$$\Xi^- \rightarrow \Lambda + \pi^- \qquad (15 \text{ events})$$

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

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

$$K^{+}d \rightarrow \bar{\Omega}^{+}\Lambda\Lambda p\pi^{+}\pi^{-} \quad ,$$

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

$$\bar{\Lambda} \rightarrow \bar{p} + \pi^{+} \quad ,$$

in which the anti-proton 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 $\bar{\Xi}$ and $\bar{\Omega}$ events[2]:

$$\alpha = \frac{P_{\parallel}^{\bar{\Lambda}} - P_{\parallel}^{m}}{P_{\parallel}^{\bar{\Lambda}} + P_{\parallel}^{m}} \quad .$$

Here the symbol $P_{\parallel}$ means longitudinal momentum, and the superscript $\bar{\Lambda}$ refers to the antilambda, while m refers to either the π^{+} meson or the K^{+} meson. The kinematic ellipses for $\bar{\Xi} \rightarrow \bar{\Lambda}\pi$ and $\bar{\Omega} \rightarrow \bar{\Lambda}K$ decays, shown in Fig. 2, are calculated for a $\bar{\Xi}$ or $\bar{\Omega}$ momentum of 2708 MeV/c, the momentum of the $\bar{\Omega}$ 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 $\bar{\Xi}$ events and the $\bar{\Omega}$ event. In this calculation the $\bar{\Lambda}$ momentum is taken from a three-constraint fit for each $\bar{\Lambda}$ to the charged vee decay vertex. The meson momentum and the 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 $\overline{\Lambda}$ as a six-constraint fit to hypotheses (1) and (2):[3]

$$\overline{\Omega}^{+} \to \overline{\Lambda} + K^{+}, \quad \overline{\Lambda} \to \overline{p} + \pi^{+} \qquad (1)$$

$$\overline{\Xi}^{+} \to \overline{\Lambda} + \pi^{+}, \quad \overline{\Lambda} \to \overline{p} + \pi^{+} . \qquad (2)$$

The observed event fits hypothesis (1) with a χ^2 value of 9.2, while it fails hypothesis (2) completely with a very large χ^2 value. 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 to 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 $\overline{\Xi}$ mass while the $\overline{\Omega}$ event, misinterpreted as a $\overline{\Lambda} + \pi^{+}$ decay gives a mass value of $M = 1430.4 \pm 2.6$ MeV, which is very far from the known $\overline{\Xi}$ mass of 1321.25 ± 0.18 MeV. For the $\overline{\Omega}$ event, interpreted correctly 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 $\overline{\Omega}$ event decays with almost its maximally allowed transverse momentum.

In addition, the charged track from the $\overline{\Omega}$ decay has a momentum of 866 ± 8 MeV. If this track were a π^{+} from the decay $\overline{\Xi} \to \overline{\Lambda}\pi^{+}$ it would be a minimum ionizing track, while a K^{+} of this momentum from the decay $\overline{\Omega} \to \overline{\Lambda}K^{+}$ 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.

Table I lists the kinematic quantities for the particles associated with the production vertex in the reaction $K^+d \rightarrow \bar{\Omega}\Lambda\Lambda p\pi^+\pi^-$. 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 Hulthèn 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^+ 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 $\bar{\Omega}^+ \rightarrow \bar{\Lambda}K^+$ and $\bar{\Omega}^+ \rightarrow \bar{\Xi}^+\pi^0$, but completely ignores the possible decay mode $\bar{\Omega}^+ \rightarrow \bar{\Xi}^0\pi^+$ 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-inch 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.

REFERENCES

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1. This is the antiparticle of the Ω^-, discovered by V. E. Barnes et al., Phys. Rev. Letters 12, 204 (1964) and predicted by M. Gell-Mann and Y. Ne'eman. See for example, The Eightfold Way (W. A. Benjamin and Co., New York, 1964).

2. See for example, B. Rossi, Nuovo Cimento Suppl., Vol. II, Series 10, p. 163 (1955).

3. What would normally be a seven-constraint fit is reduced to six constraints because the determination of the momentum of the short charged decaying track is very poor.

4. Particle Data Group, Physics Letters 33B, 1 (1970).

FIGURE CAPTIONS

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

Fig. 2. The quantity α vs $P_\perp$ for the $\bar{\Omega}$ event and the $\bar{\Xi}$ events. The solid curves are the kinematic ellipses, calculated for the decays $\bar{\Omega} \rightarrow \bar{\Lambda}K$ and $\bar{\Xi} \rightarrow \bar{\Lambda}\pi$ with an antihyperon momentum of 2708 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 deliberately misinterpreted as decaying into $\bar{\Lambda} + \pi^+$.

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

Particle	Mass (MeV)	Azimuth[a] (degrees)	Dip[a] (degrees)	Momentum (MeV/c)
K^+ incident	494	88.15±0.02	0.30±0.07	11800±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.

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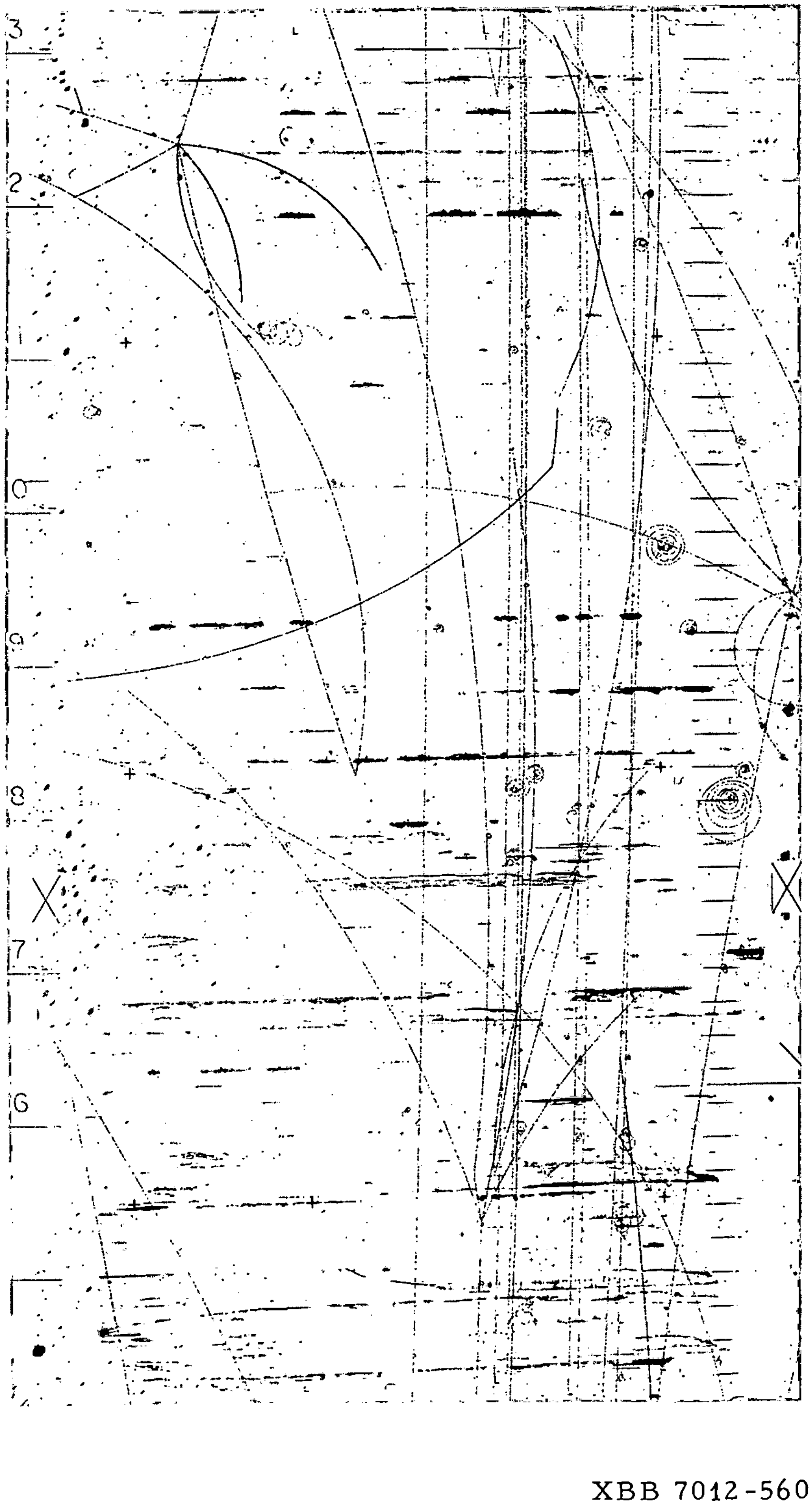

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Fig. 1

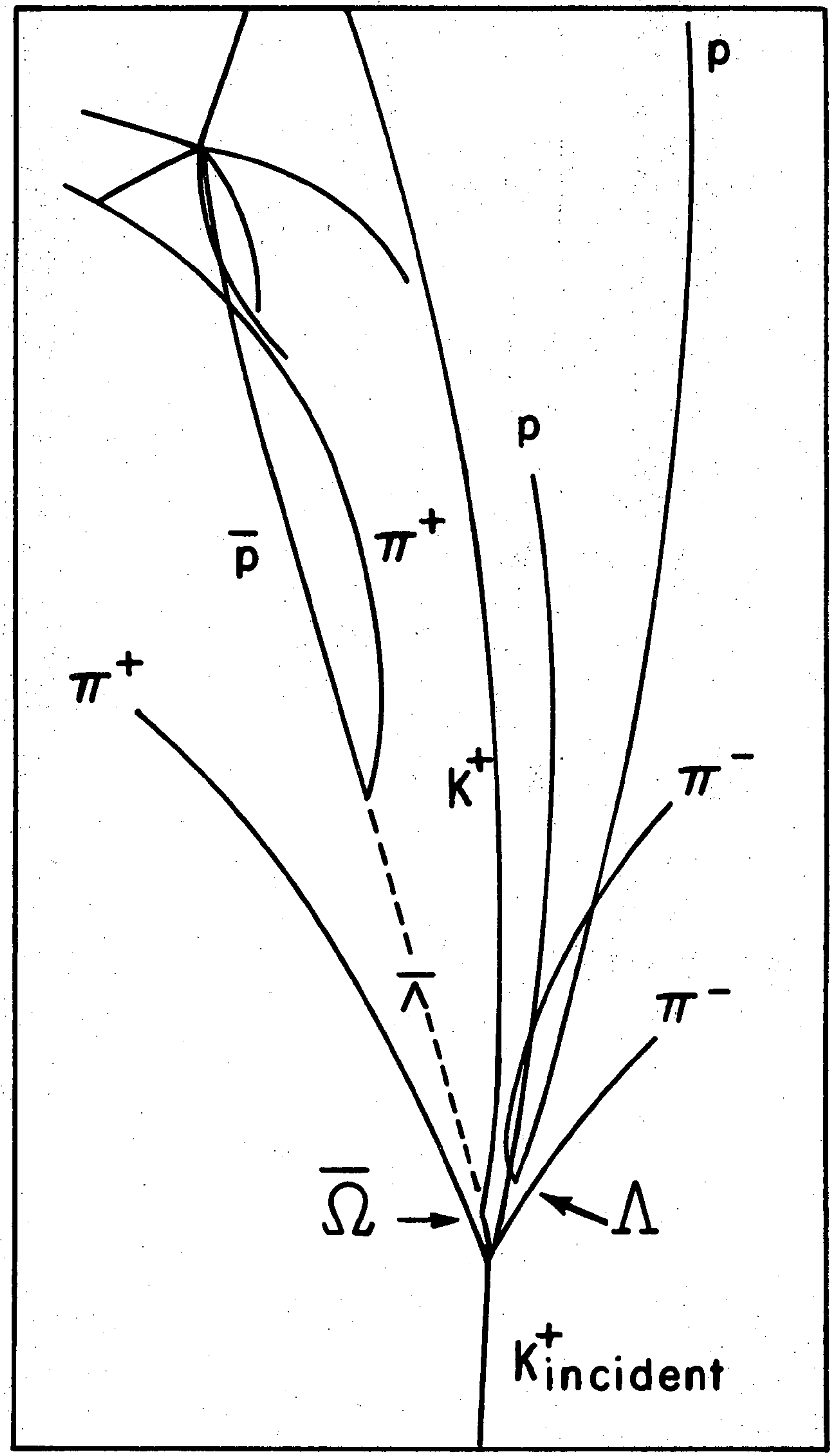

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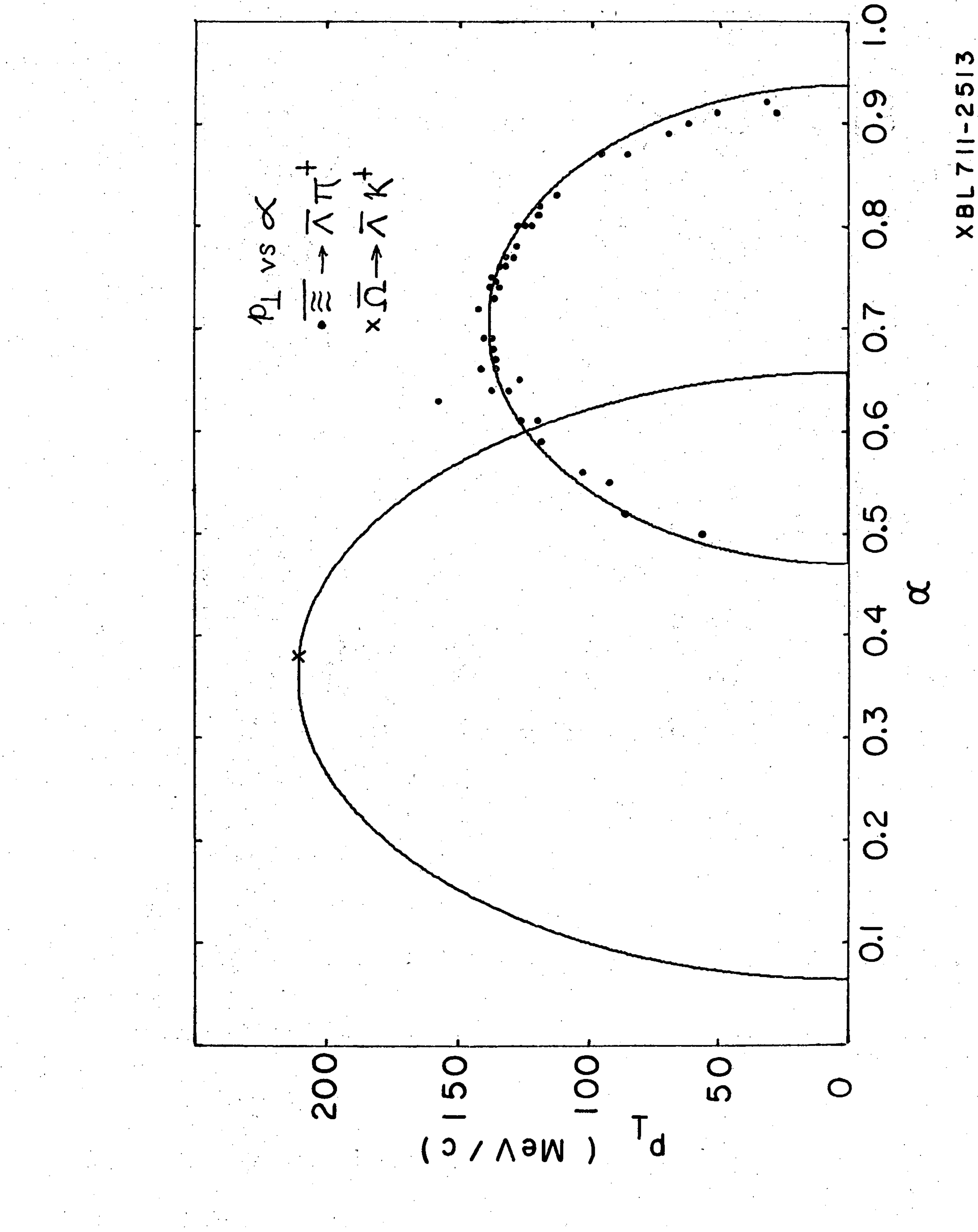
Fig. 1 (Continued)



$p_\perp$ vs α
• $\bar{\Xi} \to \bar{\Lambda}\pi^+$
× $\bar{\Omega} \to \bar{\Lambda}K^+$
$p_\perp$ (MeV / c)
0
50
100
150
200
α
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
XBL 711-2513

Fig. 2

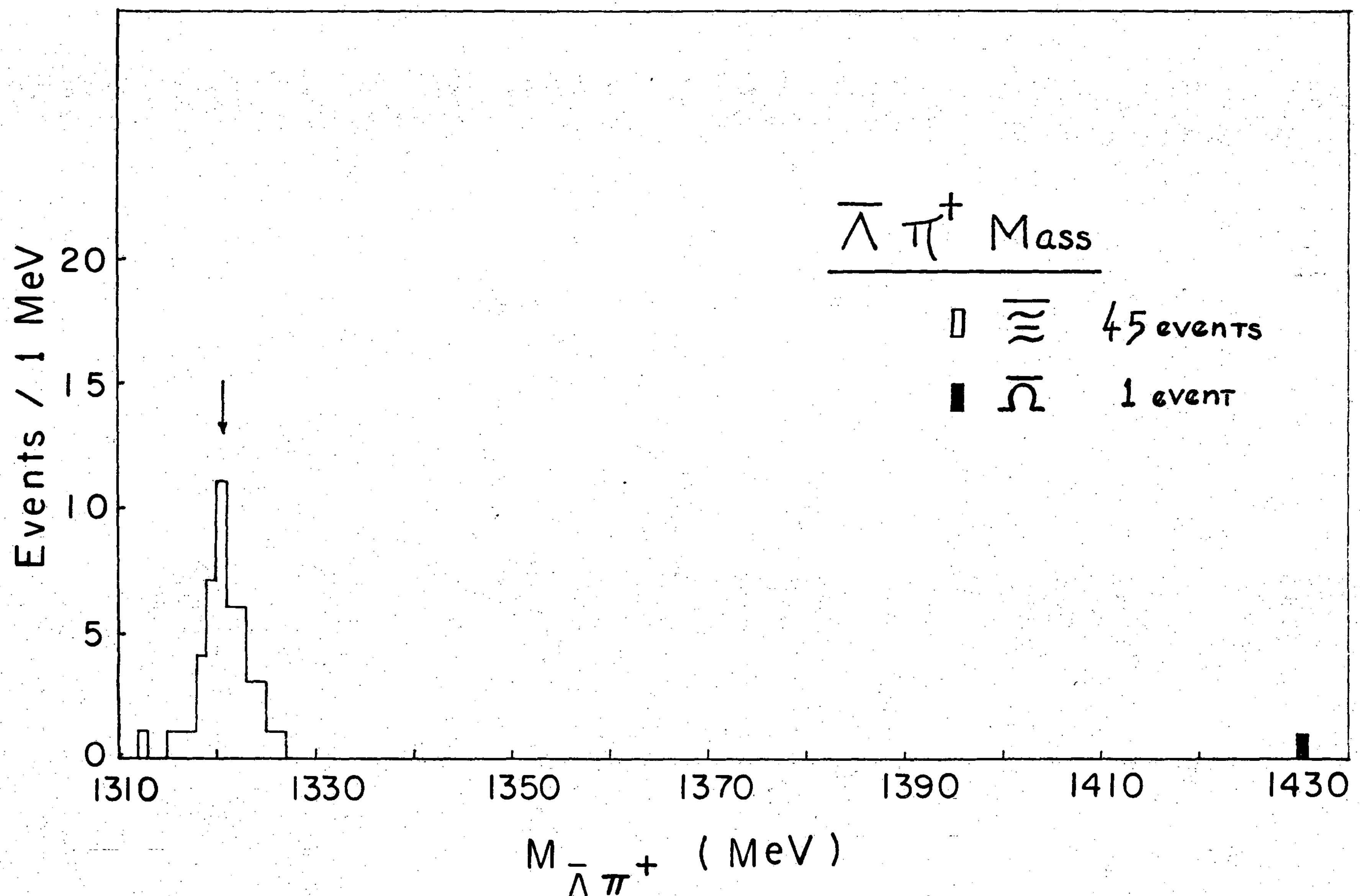


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Fig. 3

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LAWRENCE RADIATION LABORATORY
UNIVERSITY OF CALIFORNIA
BERKELEY, CALIFORNIA 94720