Inclusive Production of Ω^- and $\overline{\Omega}^+$ by K_L^0-Carbon Interactions in the Energy Range 80–280 GeV/c

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We have measured the total cross sections of Ω^- and $\overline{\Omega}^+$ forward ($x_F \geq 0$) inclusive production in K_L^0-carbon interactions in the range $E_{K^0} = 80$ to 280 GeV to be 3.5 ± 1.4 and 2.4 ± 1.0 μb, respectively. We observe that the x_F distributions for both of these states are increasing from $x_F = 0$ to $x_F \approx 0.6$. The $p_\perp^2$ distributions are described as an exponential function in $p_\perp$ with an average $p_\perp^2$ of 0.540 GeV^2/c^2.

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Since its discovery in 1971, the $\overline{\Omega}^+$ has been seen in a total of sixteen events: one in a K^+d bubble-chamber experiment[1] and fifteen in a p-BeO spectrometer experiment.[2] Both experiments observed the decay $\overline{\Omega}^+ \to \overline{\Lambda} K^+$. The bubble-chamber event fixed the mass at 1673 ± 1.0 MeV/c^2. The spectrometer experiment established a relative production rate, $\overline{\Omega}^+/\pi^- = (1.6 \pm 0.4) \times 10^{-4}$ at the point $x_F = 0.48$, $p_\perp^2 = (600\ \text{MeV}/c)^2$, and an incident proton momentum of 240 GeV/c. We have observed both $\overline{\Omega}^+$ and Ω^- in a study of hyperons produced in the wide-band neutral beam at Fermilab.[3] The details of the 0^0 broadband neutral beamline are discussed in Ref. 3. The beam composition at the experimental enclosure is γ, K_L^0, and n arriving with the relative flux ratio $1{:}8 \times 10^{-3}{:}1 \times 10^{-3}$. For 25% of the data taking, six radiation lengths of Pb were introduced into the beamline. This reduced the γ component of the beam, which resulted in a relative flux ratio of 0.125:1:0.125. These data provided information on hyperon and antihyperon backgrounds from photoproduction. The 2-cm-thick (2.3% interaction lengths) scintillator target was exposed to 1.8×10^9 K_L^0 in the momentum range between 80 and 280 GeV/c. Reaction products were detected in the multiparticle spectrometer described in Ref. 3. Two Cherenkov counts with pion thresholds of 6 and 12 GeV were used for particle identification. The hyperon events were collected by means of a trigger requiring more than two tracks but fewer than or equal to eight tracks in the spectrometer, and greater than or equal to 50 GeV deposited in all calorimeters with at least 10 GeV in the hadron calorimeter.

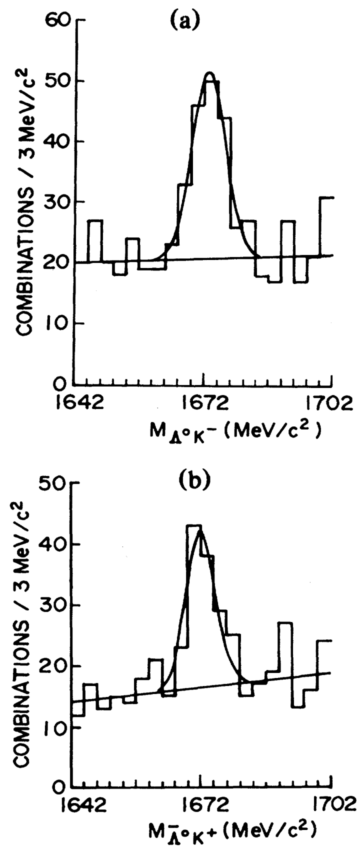

FIG. 1. (a) ΛK^- invariant-mass distributions in 3-MeV/c^2 bins. (b) $\overline{\Lambda} K^+$ invariant-mass distributions in 3-MeV/c^2 bins.

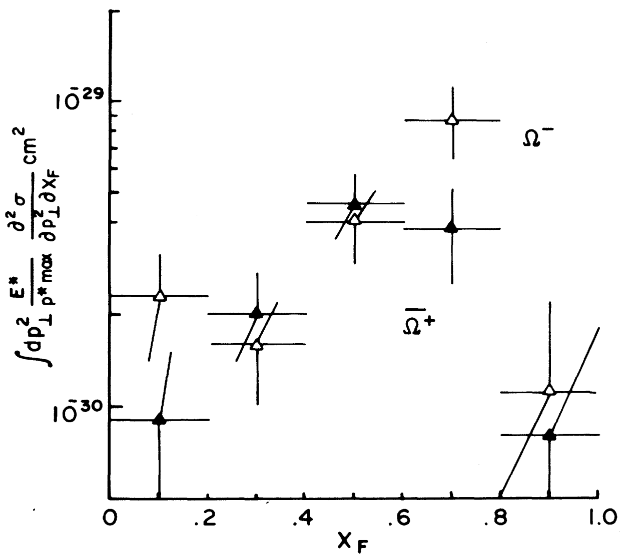

FIG. 2. The invariant x_F distribution for Ω^- (open triangles) and $\overline{\Omega}^+$ (filled triangles).

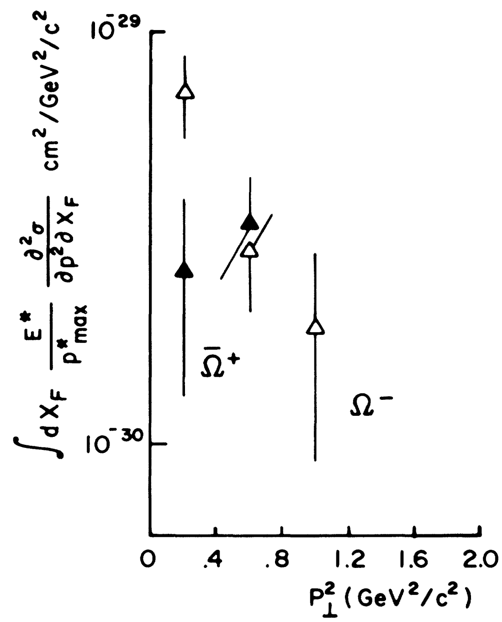

FIG. 3. The invariant $p_\perp^2$ distributions for Ω^- (open triangles) and $\overline{\Omega}^+$ (filled triangles).

The hyperon events were selected from the 30×10^6 recorded triggers by requiring a V^0 with a $p\pi$ mass within 30 MeV/c^2 of the Λ^0 mass. This reduced the data sample to 2.2×10^6 events. The additional topologic constraint of $\Lambda +$ (charged particle) vertex downstream from the primary vertex and upstream of the Λ vertex reduced the sample to 2.1×10^5 events. The Ω candidates were defined from the $\Lambda +$ (charged particle) sample by requiring the correct particle assignments, i.e., $\Lambda +$ (charged particle)$^-$ or $\overline{\Lambda}$ + (charged particle)$^+$. For these, only combinations for which the charged particle was identified as a heavy particle by the Cherenkov count were used. The events were required to have a total visible energy in the range between 80 and 280 GeV. Approximately 2000 events survived these requirements.

The histograms of invariant ΛK^- and ΛK^+ mass shown in Figs. 1(a) and 1(b) were fitted by the sum of a Gaussian and a linear function (shown by the solid lines). The results of these fits yielded the mass values

$$m_{\Omega^-} = 1673 \pm 1 \text{ MeV}/c^2,$$

$$m_{\overline{\Omega}^+} = 1672 \pm 1 \text{ MeV}/c^2.$$

The χ^2 per degree of freedom for these fits were $\chi^2/\text{d.o.f.} = \frac{11.2}{15}$ for $m_{\Lambda K^-}$ and $\frac{12.4}{15}$ for $m_{\overline{\Lambda} K^+}$. The number of Ω^- and $\overline{\Omega}^+$ found were 100 ± 14 and 72 ± 12, respectively. These values include the error in the background under the mass peaks. The standard deviation of the Gaussian distributions was $\sigma \approx 3$ MeV/c^2 which agreed with calculations of the mass resolution of the spectrometer for these final states.

The invariant cross-section distributions in x_F and $p_\perp^2$ for the production of Ω^- and $\overline{\Omega}^+$ have been corrected for geometric acceptance, trigger efficiency, event reconstruction efficiency, and electronics deadtime. Backgrounds from γ- and n-induced reactions have been measured to be at the 10% level and have not been subtracted from the distributions. The $\Omega \to \Lambda K$ branching ratio 68.3% was used for both Ω^- and $\overline{\Omega}^+$ states.[4] The estimated absolute normalization error was $\pm 40\%$ for these final states. The resultant total cross sections (for $x_F \geq 0$) were

$$\sigma(K_L^0 + \text{C} \to \Omega^- + X) = 3.5 \pm 0.6 \pm 1.4\ \mu\text{b/nucleon},$$

$$\sigma(K_L^0 + \text{C} \to \overline{\Omega}^+ + X) = 2.4 \pm 0.4 \pm 1.0\ \mu\text{b/nucleon},$$

where the errors are firstly statistical and secondly systematic.

The invariant-mass distributions were then plotted in bins of $p_\perp^2$ and x_F separately. For each bin, the invariant-mass distribution was fitted with the Gaussian and linear function. Figure 2 shows the resulting inclusive distribution,

$$\int dp_\perp^2 \frac{E^*}{p^*_{\max}} \frac{\partial^2}{\partial x_F\, \partial p_\perp^2} \sigma(K_L^0 + \text{C} \to \Omega + X),$$

for Ω^- and $\overline{\Omega}^+$. The distribution increases with x_F until $x_F \approx 0.6$, after which it rapidly decreases as $x_F \to 1$.

The inclusive distribution,

$$\int dx_F \frac{E^*}{p^*_{\max}} \frac{\partial^2}{\partial x_F \partial p_\perp^2} \sigma(K_L^0 + \text{C} \to \Omega + X),$$

is shown in Fig. 3. The Ω^- distribution has an average value of $\langle p_\perp^2 \rangle = 0.540\ \text{GeV}^2/c^2$. (The errors shown in Figs. 2 and 3 are statistical only.)

In conclusion, we have observed the inclusive production of Ω^- and $\overline{\Omega}^+$ with masses 1673 MeV/c^2 [which sets a new value for validity of the *CPT* symmetry[5] for the Ω^--$\overline{\Omega}^+$ system: $\Delta m/\langle m \rangle = (6.0 \pm 4.2) \times 10^{-4}$] and cross sections 3.5 ± 1.4 and 2.4 ± 1.0 μb/nucleon, respectively. The inclusive distributions in x_F for these states increase with increasing x_F for $0 \leqslant x_\text{F} < 0.6$. This is consistent with other observations[6] of hyperons produced in kaon interactions. The average $p_\perp^2$ for Ω^- production was found to be $\langle p_\perp \rangle^2 \simeq 0.54\ \text{GeV}^2/c^2$. The x_F and $p_\perp^2$ distributions for the Ω^- and $\overline{\Omega}^+$ seem to differ only in absolute scale from each other.

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