Y^* Production in Σ^--Nucleus Reactions*

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A counter–spark-chamber experiment has been done in the alternating-gradient synchrotron's 23-GeV/c charged hyperon beam to study Y^* production in reactions of Σ^- on H_2, Al, Cu, W, and Pb in which the Y^* decays into the Λ^0-π^- final state. We observe the $\Sigma^*(1385)$ and place upper limits on possible diffractively produced Y^* resonances and on the Coulomb production of the $\Sigma^{*-}(1385)$.

We have performed an experiment in the negative hyperon beam at Brookhaven National Laboratory to study the reaction $\Sigma^- + A \to \Lambda^0 + \pi^- +$ anything. We measure the invariant-mass spectrum of the $\Lambda^0\pi^-$ system in this reaction to look for the production of resonant states of strangeness -1 and isospin 1. The mass acceptance of the apparatus is nearly constant over the mass range $1.25 \leq m_{\Lambda^0\pi^-} \leq 2$ GeV/c^2 and falls linearly to zero between 2.0 and 2.4 GeV/c^2. The nuclear targets are H_2, Al, Cu, W, and Pb.

Figure 1 is a plan view of the apparatus. The hyperon beam, which has been described in detail elsewhere,[1] is produced when the slow extracted proton beam of momentum 30 GeV/c strikes an aluminum oxide target (not shown in the figure). The negative hyperons are then transported through a 3.5-m-long magnetic channel which contains a threshold Cherenkov counter whose threshold is set to detect particles of mass slightly above that of the proton, thereby permitting electronic tagging of the hyperon components in the beam (Σ^- or Ξ^-). Although we are not able to separate Σ^-'s from Ξ^-'s, the tagged beam is essentially pure Σ^- with 1% contamination of Ξ^- and 5% contamination of π^-. The beam emerges from the hyperon channel with a $\Delta p/p$ equal to 10% and passes through a high-pressure spark chamber. By measuring the position and direction of each beam particle and knowing the location of the hyperon production target we can further determine its momentum to an accuracy of $\pm 1.5\%$.

Reaction products emerging from the target pass through the front cluster of spark chambers and the first spectrometer magnet. The trigger for the apparatus demands a tagged beam particle and the presence of at least two particles in the final state. This latter requirement is made by demanding a pulse height greater than 1.6 times the mean amplitude from minimum-ionizing particles in each of two 30-cm-diam circular counters of $\frac{1}{4}$-in. thickness which are located downstream of the first spectrometer magnet. Normally it is the two charged decay products of the Λ^0 which satisfy this requirement. The momentum and coordinates of the decay proton and pion from the Λ^0 as well as any other charged particles emerging from the target and passing through the first magnet are established by the spark chamber spectrometer system shown in Fig. 1.

An event of interest contains at least three reconstructed tracks, of which one is positive and two are negative. Assigning the proton mass to the positive track and the pion mass to each negative track, we select events in which one of the pions, when combined with a proton, satisfactorily reconstructs a Λ^0. We then demand that the reconstructed Λ^0 momentum vector, the momentum vector of the remaining negative track, and the incident Σ^- trajectory intersect within the target. All selections are made by applying cuts to the χ^2 for the hypothesis under consideration. The principal background consists of the decay $\Xi^- \to \Lambda^0 + \pi^-$ which can be separated from the products of the production reaction $\Sigma^- + A \to \Lambda^0 + \pi^- +$ anything because of the unique Λ^0-π^- effec-

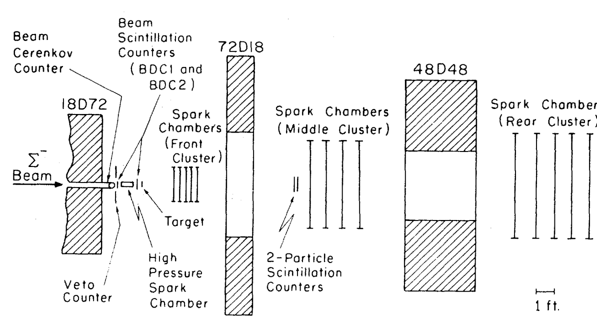

FIG. 1. Plan view of the apparatus.

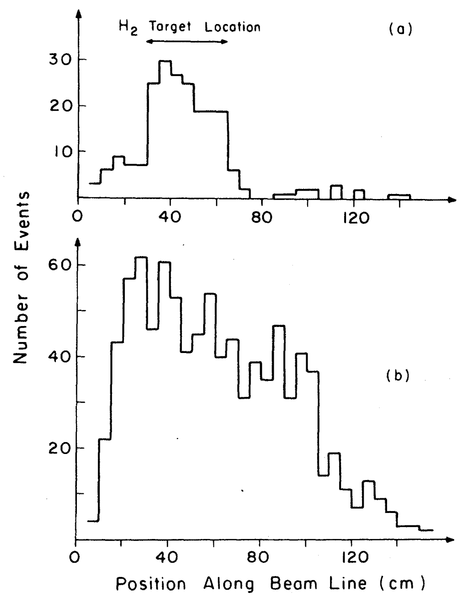

FIG. 2. $\Lambda^0\pi^-$ vertex position along the beam line with target full. (a) $-t > 0.1$ (GeV/c)^2; (b) $-t < 0.1$ (GeV/c)^2.

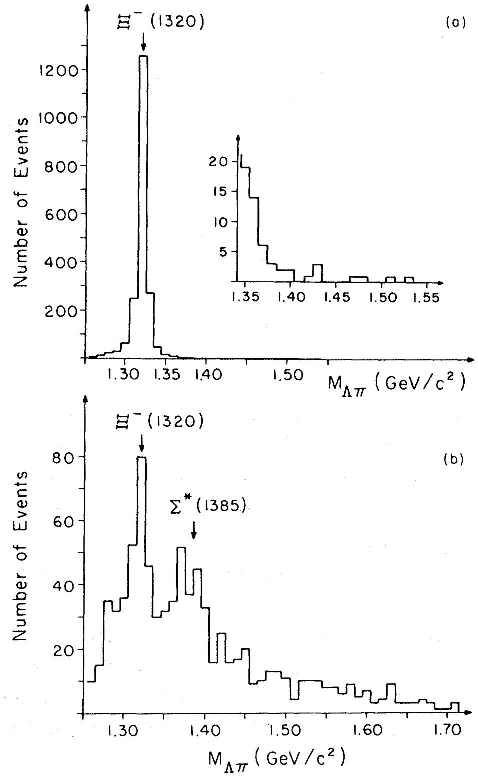

FIG. 3. $\Lambda^0\pi^-$ mass spectrum for all targets. (a) $|t| < 0.1$ (GeV/c)^2; (b) $|t| > 0.1$ (GeV/c)^2.

tive-mass value for this event and the collinearity of the $\Lambda^0\pi^-$ momentum vector with the incident beam track. Besides providing a background, the Ξ^- also serve a useful function in that they monitor the product of the beam intensity and the efficiency of the apparatus. By making use of the known Σ^-/Ξ^- ratio, it is possible to calculate absolute cross sections for the production reaction by making small corrections to the efficiencies due to the kinematic differences between the produced $\Lambda^0\pi^-$ system and Ξ^- decay. These relative efficiencies are calculated using Monte Carlo techniques.

Figure 2 is a plot of the distribution of production vertices for the hydrogen target data. Events with production vertices upstream or downstream of the target region often correspond to a decay of a Ξ^- in the beam, and these events are usually collinear with the incident beam direction. To avoid a large background subtraction of those Ξ^- decays occurring inside the target region, only those events corresponding to a four-momentum transfer $-t$ between the incident Σ^- and the outgoing $\Lambda^0\pi^-$ system greater than 0.1 (GeV/c)^2 were used in the calculation of the nuclear cross section [see Fig. 3(b)].

Figure 3(a) is a $\Lambda^0\pi^-$ mass distribution for events with $-t$ less than 0.1 (GeV/c)^2 summed over all nuclear targets. The data shown in Fig. 3(a) reveal no $\Sigma^*(1385)$ signal and are almost entirely associated with beam Ξ^- decays. These data [for $-t$ less than 0.1 (GeV/c)^2] are in agreement with the results of a previous experiment[2] in which the $\Sigma^*(1385)$ was also not observed at values of $-t < 0.03$ (GeV/c)^2.

Figure 3(b) is a $\Lambda^0\pi^-$ mass distribution for events with $-t$ greater than 0.1 (GeV/c)^2 summed over all nuclear targets. Apparent at a mass value of 1.32 GeV/c^2 are a residual number of Ξ^- decays in which presumably a beam Ξ^- or one of its decay products scattered in the target, causing it to be reconstructed with a value of $-t$ greater than 0.1 (GeV/c)^2, and these events were subtracted from the $\Lambda^0\pi^-$ yield before making the cross-section calculation. Table I presents the nuclear cross sections for each target integrated over all mass values and over $-t$ values between 0.1 and 1.0 (GeV/c)^2. The errors quoted with the cross sections are statistical. The normalization uncertainty for our cross sections is ± 15%, due primarily to the uncertainty in the value of the Σ^-/Ξ^- ratio.

Observed in Fig. 3(b) is the $\Sigma^*(1385)$ resonance with no other resonant states appearing within the

TABLE I. Nuclear cross sections for total $\Lambda^0\pi^-$ yield from each target.

Target	Cross section (mb)	Events per mb
H_2	1.6 ± 0.2	122
Al	7.2 ± 0.7	35
Cu	7.5 ± 0.9	19
W	12.9 ± 1.6	10
Pb	10.6 ± 1.4	11

sensitivity of our experiment. The absence of the $\Sigma^*(1385)$ in the range $0 < -t < 0.1$ $(\mathrm{GeV}/c)^2$ is surprising when compared with the reaction $p + p \rightarrow \Delta^{++}$ + missing mass which appears to be mediated by pion exchange and is characterized by a $d\sigma/dt$ which is strongly peaked in the forward direction.[3]

Table II lists the $\Sigma^*(1385)$ production cross sections for each target nucleus in the range $-t > 0.1$ $(\mathrm{GeV}/c)^2$, using the observed branching ratio for the decay mode $\Sigma^*(1385) \rightarrow \Lambda^0\pi^-$ which is equal to 88%.

Figure 4(a) is a plot of the hydrogen target data in the mass range $1.305 \leq m_{\Lambda^0\pi^-} \leq 1.345$ GeV/c^2 plotted as a function of $-t$. The peak which occurs at the origin is due almost entirely to the decay of the Ξ^- beam component and enables us to establish a precision of ± 0.015 $(\mathrm{GeV}/c)^2$ in our determination of $-t$ for events having values of $-t \leq 1.0$ $(\mathrm{GeV}/c)^2$. Figure 4(b) is a plot of the H_2 target data in the mass range $1.345 \leq m_{\Lambda^0\pi^-} \leq 1.605$ GeV/c^2 plotted as a function of $-t$. Applying a geometric efficiency correction and then fitting a form e^{bt} to the data of Fig. 4(b), we obtain a value for b equal to 1.8 ± 0.2 $(\mathrm{GeV}/c)^{-2}$. We do not observe any Y^* resonant state similar to the $N^*(1470)$ which has a broad mass width but is characterized by a $d\sigma/dt$ distribution which is sharply peaked in the forward direction.[4] We

TABLE II. $\Sigma^*(1385)$ cross sections for each target in the range $0.1 < -t < 1.0$ $(\mathrm{GeV}/c)^2$.

Target	$\Sigma^*(1385)$ cross section per nucleus (mb)
H_2	0.18 ± 0.06
Al	0.5 ± 0.2
Cu	0.4 ± 0.3
W	0.9 ± 0.6
Pb	0.6 (90% confidence level)

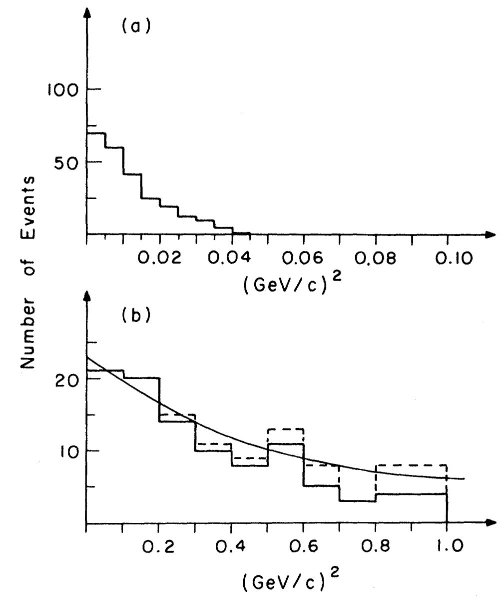

FIG. 4. Hydrogen target data plotted vs $-t$. (a) The mass range $1.305 \leq m_{\Lambda^0\pi^-} \leq 1.345$ GeV/c^2 which contains the Ξ^- decay events; (b) the mass range $1.345 \leq m_{\Lambda^0\pi^-} \leq 1.605$ GeV/c^2. The dashed line represents the data corrected for geometric acceptance and the solid curve is a fit to the data of the form $e^{1.8t}$.

have calculated an upper limit on the product of the production cross section times branching ratio into the $\Lambda^0\pi^-$ mode for an $S = -1$ resonance similar to the $N^*(1470)$ within the mass range 1.345 through 1.605 GeV/c^2. Assuming the value of the slope parameter b for such a resonance to equal 15 $(\mathrm{GeV}/c)^{-2}$ as in the case for the $N^*(1470)$ and observing that 80% of the events associated with such a resonance would fall within the range $0 \leq -t \leq 0.1$ $(\mathrm{GeV}/c)^2$, we obtain from Table I an upper limit $\sigma R(Y^* \rightarrow \Lambda^0\pi^-) \leq 82$ μb at a 90% confidence level (R is the branching ratio).

A consequence of SU(3) symmetry is the conservation of U spin in electromagnetic transitions. This conservation rule permits the Coulomb (Primakoff) production of the $\Sigma^{*+}(1385)$ by positively charged Σ^+ particles in the Coulomb field of a heavy nucleus but prevents $\Sigma^{*-}(1385)$ Coulomb production on a heavy nucleus by an incident Σ^- beam. Assuming that U spin is violated in this reaction, we calculate a production cross section for $\Sigma^{*-}(1385)$ on the lead nucleus equal to about 8 mb in the range $0 < -t < 0.1$ $(\mathrm{GeV}/c)^2$.[5,6] The assumptions involved in this calculation are that the partial decay width for the reaction $\Sigma^{*-}(1385) \rightarrow \Sigma^- + \gamma$ equals the product of the fine-structure constant times the width of the $\Sigma^{*-}(1385)$ or 0.26 MeV/c^2 and that the electric form factor of the lead nucleus $F(t)$ equals 1 over the t range of interest $[-t<10^{-3}\ (\mathrm{GeV}/c)^2]$. Using the observed branching ratio of 88% for the decay mode $\Sigma^{*-}(1385)\to\Lambda^0\pi^-$ and a 64% branching ratio for the decay mode $\Lambda^0\to p+\pi^-$, we estimate a yield of 53 events whereas we observe at most two events from lead in this t range and in the range of mass values $1.375\le m_{Y^*}\le 1.405$ GeV/c^2. We regard this absence of events as evidence for U-spin conservation in electromagnetic transitions and place an upper limit on the partial decay width $\Gamma(\Sigma^{*-}(1385)\to\Sigma^-+\gamma)<0.024$ MeV/c^2.

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Precision Measurement of the $K^-p\to\bar{K}^0n$ Cross Section below 1.1 GeV/c*

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We report the results of a precise measurement of the $K^-p\to\bar{K}^0n$ cross section between 515 and 1065 MeV/c in steps of 10 MeV/c. The statistical errors are less than 1%, a major improvement in accuracy over previous work. No evidence is found for the new $I=1$ $\bar{K}N$ resonances at 546 and 602 MeV/c reported recently by Carroll *et al.*

This Letter presents the results of a counter experiment designed to measure with high precision the total cross section for the reaction $K^-p\to\bar{K}^0n$ in the momentum region from 515 to 1065 MeV/c. The charge-exchange cross section, being proportional to the sum of the squares of the differences between the $I=1$ and $I=0$ amplitudes in each partial wave, is generally small and therefore is sensitive to small changes in either of them. Thus a precise measurement of the energy dependence of this cross section is a valuable indicator of resonant structure.

The experiment was performed in the low-energy separated beam[1] at the Brookhaven National