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ABSTRACT

An analysis of the reactions $\pi^- + p \rightarrow \Lambda^0 + K^0$ and $\Sigma^- + K^+$ at incident momenta of 1500 through 2360 MeV/c is currently in progress. The data resulted from an extensive exposure of the Lawrence Radiation Laboratory's 72-inch liquid-hydrogen bubble chamber to a high energy π^- beam at the Bevatron.

A preliminary partial-wave analysis, currently based on the $\Sigma^- K^+$ data only, indicates that a $J = 9/2$ spin state of the 2190-MeV pion-nucleon resonance recently discovered at Brookhaven National Laboratory's alternating-gradient synchrotron is favored over $J = 7/2$ or $5/2$. This analysis will be continued in the future, with an attempt to understand the general behavior of both reactions in the resonance region.

ROLE OF STRANGE-PARTICLE FINAL STATES IN SPIN ANALYSIS OF NUCLEON ISOBARS*†

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Until recently there were four known excited states of the nucleon: (1) in the T=1/2 state at 1512 and 1688 MeV c.m. energy and (2) in the T=3/2 state at 1238 and 1920 MeV c.m. energy. However, within the past year experiments at the Brookhaven alternating-gradient synchrotron by Diddens et al. uncovered two additional states at higher energy: (1) in the T=1/2 state at 2190 MeV and (2) in the T=3/2 state at 2360 MeV. [1] Various experiments have investigated the question of spin and parity assignments for some of these states with partial or complete success. The discussion presented here bears on the possible spin assignment of the 2190-MeV state as inferred from the cross sections and angular distributions of two-body final states involving strange particles produced from an initial $\pi^- p$ system.

The work of Helland et al. summarizes the efforts of the Berkeley group and others in elastic $\pi^\pm p$ scattering;[2] an analysis of angular distributions with no significant polarization information infers spin assignments of 3/2, 5/2, and 7/2 for the 1512-, 1688-, and 1920-MeV states, respectively. An analysis of photoproduction experiments by Peierls including proton polarization data

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suggests a $3/2^-$ assignment for the 1512-MeV state and somewhat less convincingly indicates a $5/2^+$ assignment for the 1688-MeV state. [3] No significant information is currently available on the parity of the 1920-MeV state; of course, for some time the spin and parity of the 1238-MeV state has been known to be $3/2^+$. The work of Diddens et al. on the 2190- and 2360-MeV states provides no spin, since it was a series of total-cross-section "transmission" experiments without measurement of angular distributions.

Because two-body final states lend themselves nicely to partial-wave analysis, we have selected the reactions $\pi^- p \rightarrow \Lambda^0 K^0$, $\Sigma^- K^+$, and $\Sigma^0 K^0$ for an analysis of angular distributions and polarization in the region of the 2190-MeV resonance. From an exposure of the Lawrence Radiation Laboratory's 72-inch liquid-hydrogen bubble chamber at incident π^- momenta of 1500, 1690, 1900, 2050, 2150, 2250, and 2360 MeV/c (1930, 2020, 2115, 2180, 2225, 2265, and 2309 MeV in the c.m., respectively), 1639 $\Lambda^0 K^0$ and 1199 $\Sigma^- K^+$ events have been found. Because of poor statistics at each of the momenta, the $\Sigma^0 K^0$ reaction is not useful in this discussion. In Fig. 1 we present the (a) $\Lambda^0 K^0$ and (b) $\Sigma^- K^+$ cross sections including the data of a number of other experiments at lower momenta. In each case there is no evidence for an enhancement in the region of the 2190-MeV resonance, indicating that the contribution of this state to these reactions is small compared to the background. The well-known rise of the $\Lambda^0 K^0$ cross section in the region of 1030 MeV/c is also seen; presently the association of this enhancement with the 1688-MeV resonance in the $\pi^- p$ system is not clear.

In Fig. 2 we have plotted the c.m. angular distributions of the hyperon for (a) $\Lambda^0 K^0$ and (b) $\Sigma^- K^+$. The Λ^0's are generally peaked backwards and require high partial waves (*F* waves or greater) with no significant changes observed at the 2190-MeV resonance. On the other hand, the Σ^-'s show striking properties. The data require no more than $\cos^3\theta$ at 1500 MeV/c, and become somewhat less complex such that at 1900 MeV/c only $\cos\theta$ is required. At 2050 MeV/c, a large $\cos^5\theta$ term is required which subsequently dies out above the resonance (2190 MeV in the c.m. = 2080 MeV/c in the lab). We are currently engaged in a phase-shift analysis of these data with the following preliminary results: if one assumes only $S_{1/2}$ and $P_{1/2}$ amplitudes in the background as indicated by the interference term in the 1900-MeV/c data, then a J=9/2-spin hypothesis is favored over 7/2 by a factor of approximately three and over 5/2 by approximately eleven. More general assumptions about the nonresonant background will be made in the future. This analysis with $\Sigma^- K^+$ does not infer the parity.

Lastly, it should be pointed out that the Regge trajectory associated with the nucleon ($1/2^+$) state intersects the J=9/2 axis at almost exactly 2190 MeV if linearly continued through the 1688-MeV resonance ($5/2^+$). However, even if the spin and parity of the 2190-MeV state were conclusively shown to be $9/2^+$, this statement may have no relevance, since, as Professor Chew has pointed out, the trajectory may be expected to turn over well before this point.

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FIGURE LEGENDS

Fig. 1. (a) $\Lambda^0 K^0$ cross sections vs incident π^- momentum. (b) $\Sigma^- K^+$ cross sections vs incident π^- momentum.

Fig. 2. (a) Λ^0 c.m. angular distributions of this experiment. (b) Σ^- c.m. angular distributions of this experiment. All curves are fits to a power series in $\cos\theta$ with maximum order n.

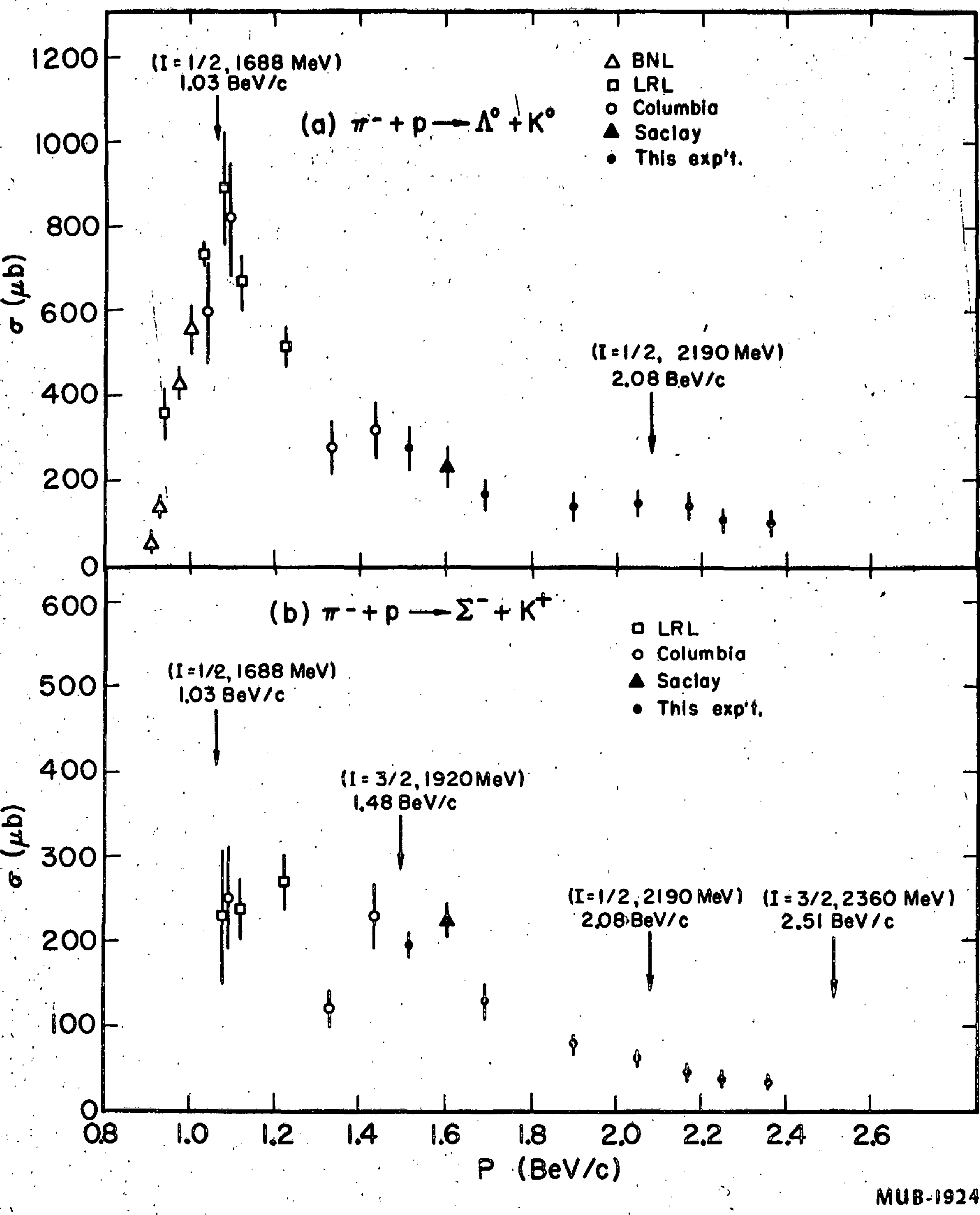
(I = 1/2, 1688 MeV)
1.03 BeV/c
(a) $\pi^- + p \rightarrow \Lambda^0 + K^0$
BNL
LRL
Columbia
Saclay
This exp't.
(I=1/2, 2190 MeV)
2.08 BeV/c
σ (μb)
(b) $\pi^- + p \rightarrow \Sigma^- + K^+$
(I=1/2, 1688 MeV)
1.03 BeV/c
(I = 3/2, 1920 MeV)
1.48 BeV/c
(I=1/2, 2190 MeV)
2.08 BeV/c
(I = 3/2, 2360 MeV)
2.51 BeV/c
P (BeV/c)
MUB-1924

Fig. 1

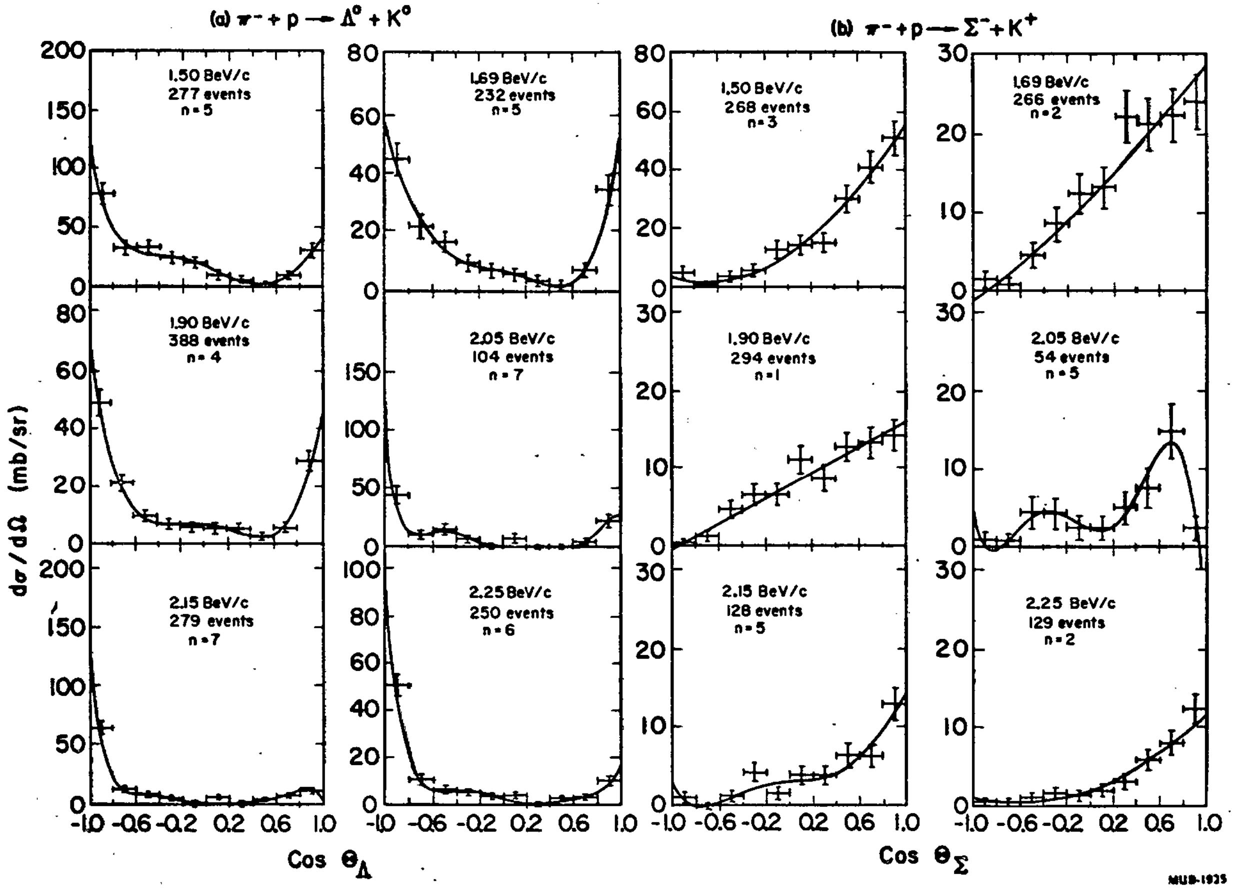
(a) π⁻ + p → Λ° + K°
(b) π⁻ + p → Σ⁻ + K⁺
1.50 BeV/c
277 events
n = 5
1.69 BeV/c
232 events
n = 5
1.50 BeV/c
268 events
n = 3
1.69 BeV/c
266 events
n = 2
1.90 BeV/c
388 events
n = 4
2.05 BeV/c
104 events
n = 7
1.90 BeV/c
294 events
n = 1
2.05 BeV/c
54 events
n = 5
2.15 BeV/c
279 events
n = 7
2.25 BeV/c
250 events
n = 6
2.15 BeV/c
128 events
n = 5
2.25 BeV/c
129 events
n = 2
dσ / dΩ (mb/sr)
Cos θ_Λ
Cos θ_Σ
MUB-1935

Fig. 2