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Plenary Session VI

STRONG INTERACTIONS OF STRONG PARTICLES

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The strong interactions of strange particles are predominantly an experimental subject. At the sessions in which Professor Gregory and I have been rapporteurs, the time spent was in the ratio

$$\frac{\text{Theory}}{\text{Experiment}} = \frac{0.5}{2.5} = 0.2 \pm ?$$

I would rather not discuss the statistical significance of this number.

My talk will, by necessity, be closely tied to the experimental situation. I will try to cover the following topics :

I) $\bar{K}\Lambda N$ parity

II) $\bar{K}\Sigma N$ parity

III) discussion of K^* spin

IV) review of $K^{\pm}p$ scattering.

I) $\bar{K}\Lambda N$ parity

You are all very familiar with the argument about the $\bar{K}\Lambda N$ parity. Block et al. [1] have observed the reactions

$$\begin{aligned} K^- + He^4 &\rightarrow {}_\Lambda H^4 + \pi^0 \\ &\rightarrow {}_\Lambda He^4 + \pi^- . \end{aligned} \qquad (1)$$

If $J({}_\Lambda H^4) = 0$ parity conservation for this reaction demands that

$$P_{\bar{K}}(-1)^{\ell_i} = -(-1)^{\ell_f} \quad .$$

Angular momentum conservation implies $\ell_i = \ell_f$.

We adopt the convention of positive parity for the Λ relative to the nucleon. Hence it follows that P_K is -1. Dalitz [2] and collaborators have analyzed the binding energy of low mass hyperfragments and deduced that the singlet Λ-N interaction is stronger than the triplet Λ-N interaction which implies that the ground states of $_\Lambda H^4$ and $_\Lambda He^4$ are J=0. This is confirmed by the high branching ratio of the two-body break-up $_\Lambda H^4 \rightarrow He^4 + \pi^-$ compared to all pionic decays of $_\Lambda H^4$. This ratio is

$$R_4 = 0.67 \pm {}^{0.06}_{0.05}$$

as observed by the Chicago-Northwestern emulsion collaboration [3]. Dalitz and Liu [4] have calculated R_4 as a function of the (p/s) wave ratio of the free decay $\Lambda^o \rightarrow p + \pi^-$. This ratio has been measured by Beall et al. [5] and by Cronin and Overseth [6], who find

$$\frac{p^2}{p^2+s^2} = 0.11 \pm 0.03 \ .$$

With this small ratio, Dalitz and Liu predict $R_4(J=0) = 0.75$ and $R_4(J=1) = 0.18$, hence $J(_\Lambda H^4) = 0$ is confirmed. Block et al. [1] have also obtained some independent confirmation of this spin assignment by observing the angular distribution of $_\Lambda H^4 \rightarrow He^4 + \pi^-$ decays relative to $\vec{p}(_\Lambda H^4)$ following the $K^- + He^4 \rightarrow {}_\Lambda H^4 + \pi^o$ reaction. Assuming predominant s state capture in the initial state [7], $_\Lambda H^4$ is aligned and this angular distribution is unique, i.e.,

$$J = 1 : \cos^2\theta$$

$$J = 0 : \text{isotropic.}$$

Block et al. [1] find excellent agreement with isotropy for a sample of $35(_\Lambda H^4 \rightarrow He^4 + \pi^-)$ events.

There is still, however, one loop-hole in the argument. If the $J=1(_{\Lambda}H^4)$ system is bound [8], with a binding energy of several hundred keV, then the observations of Block et al. do <u>not</u> determine the $\bar{K}\Lambda N$ parity without further investigation. For one can have the chain

$$K^- + He \rightarrow (_{\Lambda}H^4)^*_{J=1} + \pi^0$$
$$\hookrightarrow (_{\Lambda}H^4)_{J=0} + \gamma \qquad (2)$$
$$\hookrightarrow He^4 + \pi^-$$

If the $\bar{K}\Lambda N$ parity is <u>even</u>, reaction (2) is allowed from the S orbital state of the K^- He system, while $K^- + He \rightarrow (_{\Lambda}H^4)_{J=0} + \pi^0$ is forbidden by angular momentum and parity conservation. Block et al. have reported at this conference that the branching ratio

$$K^- + He^4 \rightarrow \frac{_{\Lambda}He^4 + \pi^-}{He^3 + \Lambda^0 + \pi^-} = 0.24 \pm 30\ \%$$

Although this branching ratio is rather high, it is probably not incompatible with the even $\bar{K}\Lambda N$ assignment if the binding energy of $(_{\Lambda}H^4)_{J=1}$ is greater than a few hundred keV.

In conclusion I would say that the present evidence strongly suggests that the $\bar{K}\Lambda N$ parity is <u>odd</u>, but the even parity hypothesis has not been excluded. As suggested by Dalitz, a determination of the presence or absence of nuclear γ-rays from the decay $(_{\Lambda}H^4)^*_{J=1} \rightarrow (_{\Lambda}H^4)_{J=0}$ or $(_{\Lambda}He^4)^*_{J=1} \rightarrow (_{\Lambda}He^4)_{J=0}$ would conclusively resolve the remaining ambiguity.

II) The $\bar{K}\Sigma N$ relative parity

In the two recent articles by Ferro-Luzzi, Tripp and Watson [9], the authors claim to have determined the $\bar{K}\Sigma N$ parity to be odd. It is a little unfair to discuss this experiment here since none of the authors of these important results are at the meeting. On the other hand, Professor Capps, whose original considerations [10] on this method of attack on the $\bar{K}\Sigma N$ parity determination have played an important role, has presented a paper [11] to this conference that analyzes some of the published experimental data, also concluding that the $\bar{K}\Sigma N$ parity is odd. The uniqueness of this conclusion on the $\bar{K}\Sigma N$ parity from this experiment has been challenged by some physicists, particularly Professor Adair. I will try to present a short résumé of my understanding of this rather complex situation.

The Alvarez group has been studying low energy K^-p interactions for many years. Tripp et al. [9] have discovered the existence of a resonant state at $p_{K^-} = 400$ MeV/c, corresponding to a mass of the K^-p system of 1520 ± 3 MeV. The possible reactions are :

$$
\begin{aligned}
K^- + p \quad &\rightarrow \quad K^- + p \\
(I=0,1) \quad &\rightarrow \quad \bar{K}^0 + n \\
&\rightarrow \quad \Sigma^{+,0,-} + \pi^{-,0,+} \\
&\rightarrow \quad \Lambda^0 + \pi^0 \\
&\rightarrow \quad \Lambda^0 + \pi^{+,0} + \pi^{-,0}.
\end{aligned}
$$

The $\Sigma^0\pi^0$ channel is purely $I=0$, $\Lambda^0\pi^0$ purely $I=1$, and the other channels are mixtures of $I=0$ and $I=1$ states. The resonant behaviour in the 1520 MeV region shows up in many different ways :

a) the total cross-sections for $\overline{K}^0 n$ and $\Lambda \pi^+ \pi^-$ have sharp bumps in their total cross-sections. Experimentally, these two channels allow the most precise energy determination for each event (the K^- momentum resolution for a fitted event of either of these classes being much smaller than the momentum spread in the incident K^- beam), and hence the position and the width (Γ) of the resonance is determined from these two reactions ($\Gamma \approx 15$ MeV).

b) when one looks at $K^- p$ elastic scattering, an expansion of the type :

$$\frac{d\sigma}{d\Omega}_{el} = A + B\cos\theta + C\cos^2\theta$$

fits the data, with C showing a sharp peak in the resonant region. This suggests that the resonance has $J = 3/2$, since no powers higher than $\cos^2\theta$ are needed in the fit. Furthermore, the B coefficient is rather small throughout this energy region. The argument is then made that, since the low energy $K^- p$ data is known to be dominated by the $\ell = 0$ state at much lower energy, it is still this S wave that is the dominant non-resonant background in this region. Therefore, the absence of $\cos\theta$ terms implies that the resonant state is $D_{3/2}$ rather than $P_{3/2}$, that is, of the same parity as the $S_{1/2}$ dominant non-resonant $K^- p$ state.

Examination of the $\Sigma \pi$ and $\Lambda \pi$ channels indicates a peaking in the $(\Sigma \pi)_{I=0} = 3(\Sigma^0 \pi^0)$ channel, but not in the

$$(\Sigma \pi)_{I=1} = (\Sigma^+ \pi^-) + (\Sigma^- \pi^+) - 2(\Sigma^0 \pi^0)$$

channel, or the $(\Lambda \pi^0)_{I=1}$ channel.

The properties of the resonant state are :

$M = 1520 \pm 3$ MeV

$\Gamma = 15$ MeV

$J = 3/2$

Parity = even with respect to K^-p, i.e., $D_{3/2}$

Branching ratio = $(\bar{K}n):(\Sigma\pi):(\Lambda 2\pi) = 3:5:1$.

Accepting all of this, if one can determine the parity of the resonant state in the $\Sigma\pi$ channel ($P_{3/2}$ or $D_{3/2}$), one would determine the $\bar{K}\Sigma N$ parity (even or odd, respectively, since the intrinsic parity of the pion is odd). A generalized Minami ambiguity intervenes at this point.

To illustrate this, consider the simplest case of $(S_{1/2}, D_{3/2})$ K^-p waves only.

(K^-p)		$(\Sigma\pi)$	$P(\bar{K}\Sigma n)$
$(S_{1/2}, D_{3/2})$	↗	$(S_{1/2}, D_{3/2})$	-1
	↘	$(P_{1/2}, P_{3/2})$	$+1$

$\sigma(\theta)$ is identical for these two cases, but the Σ polarization is opposite. On the other hand, one can make both $\sigma(\theta)$ and $P(\theta)\sigma(\theta)$ the same for the two hypotheses by replacing $(S_{1/2}, D_{3/2})$ by $(P^*_{1/2}, P^*_{3/2})$, since the sign of $P(\theta)$ is reversed by complex conjugation

$$P(\theta) \sim \mathrm{Im}(A_0^* A_2 - A_{1-}^* A_{1+}) \quad .$$

To distinguish these two ambiguous solutions, one now imposes the Wigner condition (related to causality) that requires a rapidly varying resonant phase to increase with increasing energy. Stated more precisely, the resonant amplitude should go in a counter-clockwise direction in the complex plane. The sign of the polarization of the Σ^0 in the $I=0(\Sigma^0\pi^0)$ channel is the most significant for the parity argument but it is extremely difficult to measure. In fact, the argument of Tripp et al. hinges on the correlations between the $\Sigma^+\pi^-$ angular distributions and the $\sin\theta\cos\theta\ (\alpha_{\Sigma^+}\bar{P}_{\Sigma^+})$ polarization terms in the resonance region. The absolute sign of $P_{\Sigma^+}(\theta)$ is determined using the results of Beall et al.[5] on the $\Sigma^+ \rightarrow p+\pi^0$ asymmetry parameter. To make the $\bar{K}\Sigma N$ analysis one makes the following assumptions :

1) the resonant state is $D_{3/2}$ relative to K^-p.

2) the $S_{1/2}$ K^-p amplitude is the only large non-resonant amplitude in the resonance region.

3) only the resonant $J=3/2$ amplitude varies rapidly in the energy region of the resonance.

With these assumptions and including small slowly varying $P_{1/2}$ and more recently $P_{3/2}$ amplitudes, Tripp et al. can get a good fit to the data only for $\bar{K}\Sigma^+N$ odd. Capps has stressed the model independence of this conclusion subject, <u>however</u>, to these assumptions. Adair raises the following points :

a) the presence of an appreciable non-resonant amplitude in the resonant channel is suggested by lack of equality of resonant $\Sigma^+\pi^-$, $\Sigma^0\pi^0$ and $\Sigma^-\pi^+$ cross-sections. Such a term will complicate the analysis and allow the phase to decrease rapidly even while resonant amplitude goes counter-clockwise.

b) the possible lack of charge independence of the resonant position was not included in the analysis. ($\Gamma/2$ is comparable to Σ^-, Σ^+ mass difference.)

c) energy dependence of the partial widths were not taken into account.

d) the resonance occurs at the Y_1^* threshold so that other amplitudes may also be varying rapidly over the resonance region. If one assumes $\bar{K}\Sigma N$ even, one could invoke some small $D_{5/2}$ as well as $D_{3/2}$ waves to improve the fit to the data.

I think it is clear that if one adopts all the freedom available in principle, there is certainly not enough data available to make a unique fit, and hence a unique conclusion on the $\bar{K}\Sigma N$ parity. On the other hand, such a fit has not been produced as yet and it is not trivial to do so.

In conclusion, it is remarkable that the general description given by Tripp et al. gives a plausible fit to a large amount of data with relatively few parameters, so that his result $\bar{K}\Sigma N$ parity odd is certainly favoured by the data. Nevertheless, in view of the freedom inherent in the problem I do not think that this important parameter can be considered to be definitively established as yet.

Adopting the fit of Tripp et al., Akiba and Capps [12] have pointed out that the relative phase φ (I=0) - φ (I=1) in the $S_{1/2}$ $\Sigma\pi$ channels is determined to be $\approx -110^{\circ}$. This result makes solution II of Humphrey and Ross more probable than solution I. I do not have the time to discuss in detail the very low energy K^-p interactions, but I can refer you to the invited paper of Dalitz, presented to this conference for such a review. If solution II is preferred, it allows the possibility of interpreting the Y_0^* (1405 MeV) resonant state as dynamically related to the negative zero energy K^-p scattering amplitude in the I=0 state, i.e., the $Y_0^* = \frac{1}{2}^-$. However, one word of caution, to make this solution compatible with the K_2^0+p data of Luers et al. [13] one must assume a non-zero effective range in at least one of the $S_{1/2}$ amplitudes. This effect is not necessarily consistent with the zero range fit of Humphrey and Ross in the 0 to 200 MeV/c p_{K^-} region ; and hence the whole analysis chain may have to be redone with more unknown parameters (i.e., including I=0,1 effective ranges $\neq 0$).

III) Spin of the K^*

There have been two major contributions to this conference that bear on the $(K^o)^*$ spin.

a) One of Alston et al. [14] presented by Ticho on the analysis of the reaction

$$K^- + p \rightarrow K^{*-} + p \qquad \text{at} \quad p_{K^-} = 1.22 \text{ GeV/c}$$
$$\hookrightarrow K_1^o + \pi^-$$

Fig. 1 shows the Dalitz plot of $K^o \pi^- p$ system (558 events). The K^* is clearly visible. There is no clear evidence of the $p\pi^-$ system in the (33) resonant state, but it must be borne in mind that it does cross the central region of the diagram. Fig. 2 shows the proton CM angular distribution for the K^* events. It shows a complicated angular distribution not consistent with a simple one-pion exchange diagram prediction. The authors have plotted all possible decay angular distributions of the K^* as shown in Figs. 3 and 4. If the spin of the K^* is 0, then all three angular distributions must be isotropic. On the other hand if $J(K^*) = 1$, one can have an arbitrary distribution of the type $A+B\cos^2\theta$. Any $\cos\theta$ terms imply that the K^* production amplitude interferes with other amplitudes, assuming parity conservation. There is no statistically significant deviation from isotropy in any of these curves, hence this "lends circumstantial evidence to the assignment $J_{K^*} = 0$". However, since there is no unique prediction for any of these distributions if $J_{K^*} = 1$, (the Adair analysis fails because the other particle in the reaction, the proton, has spin 1/2), one cannot make any definite conclusion as to the spin of the K^* from this data.

b) Armenteros et al. [15] have a completely different approach to the K^* spin determination. This makes use of the reaction

$$\bar{p} + p \rightarrow K_1^o + (K^*)^o$$

and the appropriate selection rules of J, P and C conservation. This method can only be applied if S wave $\bar{p}$-p capture predominates. B. d'Espagnat [16] has pointed out that one can test the prediction [17] of predominant S wave capture for the $\bar{p}$-p system by observing the ratio of $\bar{p}+p \rightarrow K_1^o+K_1^o$ to $\bar{p}+p \rightarrow K_1^o+K_2^o$. J and P conservation imply that the reaction $\bar{p}+p \rightarrow K+\bar{K}$ can occur only from triplet states. Since the charge conjugation quantum number $C(^3S_1) = -1$, S state capture implies that $\bar{p}+p \rightarrow K_1^o+K_2^o$ only.

M. Schwartz [18] has presented the argument on the K^* spin assuming S state capture. Consider first the hypothesis $J(K^*) = 0$, $P(K^*) = +1$. The ^1S_o initial state $(C = +1)$ can give a final state $\bar{K}^o+(K^*)^o$ with relative angular momentum $(\ell = 0)$, but the $^3S_1$ initial state is forbidden to go to $\bar{K}^o+(K^*)^o$ by J and P conservation. Since $C|\pi^o\rangle = +|\pi^o\rangle$, C conservation allows only the possibilities

$$\bar{p}+p \rightarrow \left\{ \begin{array}{l} \bar{K}^o+(K^*)^o \\ K^o+(\bar{K}^*)^o \end{array} \right\} \rightarrow \left\{ \begin{array}{l} K_1^o+K_1^o+\pi^o \\ K_2^o+K_2^o+\pi^o. \end{array} \right.$$

Recall that the branching ratio of K_1^o decay is

$$\frac{K_1^o(V)}{K_1^o(I)} = \frac{K_1^o \rightarrow \pi^+ + \pi^-}{K_1^o \rightarrow \pi^o + \pi^o} \approx \frac{2}{1} \qquad (V \equiv \text{visible}, \quad I \equiv \text{invisible}).$$

Hence, if one concentrates one's attention on the events of the type $K_1^o+(K^*)^o$ where K_1^o is visible, S state capture together with the hypothesis $J(K^*) = 0$ implies that

$$K_1^o(V)\ (K_1^o(V)\pi^o)^* \approx 2\ K_1^o(V)\ (K_1^o(I)\ \pi^o)^* \qquad (3)$$

On the other hand, if $J(K^*) = 1$, both ^1S_o and $^3S_1$ states can yield $\bar{K}^o+(K^o)^*$, so that Eq. (3) no longer holds. In this case one cannot predict the ratio $[K_1^o(V)\ (K_1^o(V)\pi^o)^* / K_1^o(V)\ (K^o(I)\pi^o)^*]$, although a priori one expects this ratio to be less than 1 rather than 2. Fig. 5 [15) contains the histogram of the K_1^o (Visible) momenta from all events with one visible K_1^o and the same histogram from all events with two visible K_1^o's. [These events in these two histograms have no other charged tracks.] This figure illustrates the data pertinent to :

i) the S state capture hypothesis and,

ii) the (K^*) spin determination.

i) The CERN, Ecole Polytechnique, College de France collaboration find

$$\frac{\bar{p}+p \longrightarrow K_1^o+K_1^o}{\bar{p}+p \longrightarrow K_1^o+K_2^o} = \frac{0}{54}\ .$$

[At Oxford in a small sample of the $\bar{p}$-p film, one $K_1^o+K_1^o$ event has been found.]

Comparing this experimental result with d'Espagnat's argument, one concludes that S wave capture predominates in the $\bar{p}+p \longrightarrow \bar{K}^o+K^o$ reaction, and the simplest assumption is to extend this result of S state predominance in the capture process to all inelastic channels as suggested theoretically [17).

[Note that a 20% P state capture still has $\sim$ 10% probability given the experimental result noted above].

ii) At $p_{K_1^0}$ = 610 MeV/c, corresponding to K_0^* mass = 890 MeV, there are peaks in both histograms of Fig. 5. These yield the following results

	Reaction	Experimental	Prediction for (A) given (B) and vice versa if $J(K^*) = 0$
(A)	$\bar{p}+p \rightarrow K_1^0(V)+(K(I)+\pi^0)^*$	43±14	6.5± 5
(B)	$\bar{p}+p \rightarrow K_1^0(V)+(K_1^0(V)+\pi^0)^*$	13±11	86 ±28

Subtracting (A) (predicted) from (A) (experimental) yields 36.5±15 events of the $\bar{p}+p \rightarrow K_1^0+K_2^0+\pi^0$.

The experimental errors include the uncertainty in how to subtract the background. It is clear that if one extends the S wave capture argument to the reaction $\bar{p}+p \rightarrow K+\bar{K}^*$, this data, is rather incompatible with $J(K^*) = 0$. Hence $J(K^*) = 1$ is strongly favoured.

In this same $\bar{p}$-p stopping experiment the following two-body reaction rates have been observed as shown in Fig. 6. These rates have some importance with respect to selection rules obtained from different group theoretic models of the strong reactions as will be discussed by d'Espagnat in Plenary Session XI.

IV) $K^{\pm}p$ scattering

I have time only for the briefest review of a substantial amount of data presented to the conference on this subject.

a) S. Goldhaber et al. [19] presented their final results on K^+-p scattering from 140 to 800 MeV/c. This work was done using a hydrogen bubble chamber and the results for the total K^+-p cross-section are somewhat lower than earlier counter measurements. This is illustrated in Fig. 7. All the data are consistent with a repulsive S wave K^+-p interaction and no P waves. Except for the point at 810 MeV/c, the S wave phase shift is consistent with one deduced from a repulsive core potential with radius $r_c = 0.31 \pm 0.01$ f. Including the 810 MeV/c momentum result, one can fit the S wave energy dependence with two parameters, the scattering amplitude $a = -0.29 \pm 0.015$ f and the effective range $r_o = 0.5 \pm 0.15$ F. Costa et al. [20] have tried to fit the $S_{1/2}$ and $P_{1/2}$ phase shifts described above using dispersion relation methods. They tried a Born term dominant solution and a ρ meson exchange term dominant solution, (as illustrated in Fig. 8). In each case the N/D method was employed, the cuts for each type of solution were approximated by two poles and one background subtraction constant in $N(w)$ was added. The cuts in the complex w plane are illustrated in Fig. 9 for each type of diagram. No good fit to the data was found for either of the simple types of solutions attempted. This is illustrated for the Born type fit in Fig. 10. As soon as one increases the number of theoretical parameters, the K^+-p data does not provide sufficient constraints to yield a unique solution.

b) Cook et al. [21] have measured K^+-p elastic scattering at $p_{K^+} = 0.97$, 1.17 and 1.97 GeV/c. Fig. 11 shows the experimental set-up which uses spark chambers and a counter hodoscope. Fig. 12 shows $\sigma_{K^+p}(\theta)$ at 1.17 GeV/c. The angular distribution is far from isotropic.

Fig. 13 gives the total and elastic scattering K^+-p cross-sections as a function of energy. The authors have applied the forward angle dispersion theory relations to all the K^+-p and K^--p data. The data are compatible with a single subtracted dispersion relation, with a residue of the pole term given by -0.12 ± 0.32. More data are needed on the K^--p scattering amplitude at zero angle to make this analysis more definite. No conclusion is possible on the (Σ, Λ) parity from the sign of this pole term.

c) Beall et al.[22] have presented preliminary results on K^--p elastic scattering cross-sections at ten momenta in the region $p_{K^-} = 700$ to 1400 MeV/c. The elaborate spark chamber plus hydrogen target set-up is shown in Fig. 14. Fig. 15 shows typical results for $\sigma_{K^-p}(\theta)$ elastic at three of the ten momenta measured. Fig. 16 shows the total and elastic K^--p cross-sections as a function of energy.

One of the purposes of this experiment is to try to determine the angular momentum and parity of the I=0 Y_0^{***} (1815 MeV) K^--p resonance. $\sigma_{K^-p}(\theta)$ elastic in the neighbourhood of this resonance requires terms of $\cos\theta$ to the <u>5th</u> power. This is consistent with an assignment of $F_{5/2}$ to the resonant state, but the data and analysis are too preliminary to make a definite assignment of quantum numbers.

d) Ferro-Luzzi et al.[23] have presented data on the charge exchange reaction $K^- + p \rightarrow K^0 + n$ at 1.22 GeV/c. There is a large backward peak in the angular distribution of the K^0's, and terms $\sim (\cos\theta)^6$ are needed to fit this angular distribution (Fig. 17). At this momentum, one is slightly above the Y_0^{***} (1815) resonance, and these high power of $\cos\theta$ in σ_{cx} are consistent with the high powers of $\cos\theta$ in $\sigma_{el}(K^-p)$ found by Beall et al.[22] in the same energy region. At $p_{K^-} = 1.5$ GeV/c, the pronounced backward peak in $\sigma_{cx}(\theta)$ has largely disappeared (see Fig. 18).

REFERENCES

1) M.M. Block, Phys. Rev. Letters 3, 291 (1959) ;
M.M. Block, L. Lendinara and L. Monari, "Determination of the K^- parity", (Session 6A).

2) R.H. Dalitz, "Strong interaction physics and the strange particles", Lectures at the Summer School in Theoretical Physics, 1961, EFINS 61-69, a list of references to the original literature is given in this article.

3) R.G. Ammar, R. Levi-Setti, W.E. Slater, S. Limentani, P.E. Schlein and P.H. Steinberg, Nuovo Cimento 19, 20 (1961) ;
See also Block et al., Ref. [1], paper at this conference.

4) R.H. Dalitz and L. Liu, Phys. Rev. 116, 1312 (1959).

5) E.F. Beall, B. Cork, D. Keefe, P.G. Murphy and W.A. Wenzel, Phys. Rev. Letters 7, 285 (1961).

6) J.W. Cronin and O.E. Overseth, "Measurement of the decay parameters for the Λ^o particle", (Session 4B).

7) T.B. Day and G.A. Snow, Phys. Rev. Letters 2, 59 (1959) ;
T.B. Day, Nuovo Cimento 18, 381 (1960).

8) R.H. Dalitz and B.W. Downs, Phys. Rev. 111, 967 (1958) ;
However, K. Dietrich, R. Folk and M. Mang, "Proceedings of the Rutherford Jubilee International Conference (1961)", predict no J=1 bound state. The question is probably too subtle to be resolved by theoretical calculation.

9) M. Ferro-Luzzi, R. Tripp and M. Watson, Phys. Rev. Letters 8, 28 (1962) ; and 8, 175 (1962).

10) R.H. Capps, Phys. Rev. Letters 6, 375 (1961) ;
and Phys. Rev., May 15, (1962).

11) R.H. Capps, "The evidence for odd $K\Sigma N$ parity", (Session 1B).

12) T. Akiba and R.H. Capps, Phys. Rev. Letters 8, 457 (1962).

13) D. Luers, I.S. Mittra, W.J. Willis and S.S. Yamamoto, Phys. Rev. Letters 7, 255 (1961).

14) M.H. Alston, G.R. Kalbfleisch, H.K. Ticho and S.G. Wojcicki, "K^* production and decay", (Session 3A).

15) R. Armenteros, L. Montanet, D. Morrison, A. Shapira, S. Nilsson, J. Vandermeulen, C. d'Andlau, A. Astier, J. Ballam, C. Ghesquière, B.P. Gregory, D. Rahm, P. Rivet and F. Solmitz, "$\bar{p}$-p annihilations at rest into two mesons", (Session 6A).

16) B. d'Espagnat, Nuovo Cimento 20, 1217 (1961).

17) T.B. Day, G.A. Snow and J. Sucher, Phys. Rev. Letters 3, 61 (1959) ; B.P. Desai, Phys. Rev. 119, 1385 (1960).

18) M. Schwartz, Phys. Rev. Letters 6, 556 (1961).

19) S. Goldhaber, W. Chinowsky, G. Goldhaber, W. Lee, T. O'Halloran, T.F. Stubbs, G.M. Pjerrou, D.H. Stork and H.K. Ticho, "K^+p interaction from 140 to 642 MeV/c", (Session 6A).

20) G. Costa, R. Gluckstern and A. Zimerman, "On the K^+-p interaction at low energy", (Session 6A).

21) V. Cook, D. Keefe, L.T. Kerth, P.G. Murphy, W.A. Wenzel and T.F. Zipf, "Elastic K^+p scattering at 0.97, 1.17 and 1.97 GeV/c", (Session 6A).

22) E.F. Beall, W. Holley, D. Keefe, L.T. Kerth, J.J. Thresher, C.L. Wang and W.A. Wenzel, "Elastic K^-p scattering between 700 and 1400 MeV/c", (Session 6A).

23) M. Ferro-Luzzi, F.T. Solmitz, M.L. Stevenson, "K^-p charge exchange at 1.22 GeV/c", (Session 6A).