SNOW: To relax your condition on the polar-equatorial ratio.

CAPPS: I will tell you briefly what I did in adding a background amplitude in the $D_{5/2}$ state (for the $\bar{K}-N$ system). I make the "wrong" parity assumption. If the changing polarization results from the $S_{1/2}-D_{3/2}$ interference, it would then indicate a negative $\cos\eta$. The $D_{5/2}$ amplitude will contribute to the polarization too, but I assume it does not completely reverse the polarization, so that $\cos\eta$ is negative through at least half the 370-410 MeV/c range, so that $|\eta|$ should get at least as big as about 135° somewhere. But if $|\eta| \geqslant 135°$, one can obtain a polar-equatorial ratio as large as 0.28 only by adding a $D_{5/2}$ amplitude at least half as big as the resonance amplitude, even if the phase of the $D_{5/2}$ is chosen in the most favourable way.

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# ON K-MESON HYPERON RESONANCES

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*(presented by V. G. Vaks)*

Dalitz and Tuan $K$-matrix formalism is applied to a phenomenological analysis of strange particle associated production reactions. Data on energy dependence of $\pi^-p\to\Sigma K$, $\pi^-p\to\Lambda K$ cross-sections near the $\Sigma$-$K$ threshold suggest the possibility of the existence of a bound state in $\Sigma$-$K$ system with $T = 1/2$ and a binding energy $E \sim 30$ MeV. This should result in a resonance in the $\pi^-p\to\Lambda K$ reaction below the $\Sigma$-$K$ threshold.

The $K$-matrix for $\pi N$, $\Lambda K$, $\Sigma K$ coupled channels is

$$K = \begin{bmatrix} \alpha_N & \alpha_{N\Lambda} & \beta_N\sqrt{k} \\ \alpha_{N\Lambda} & \alpha_\Lambda & \beta_\Lambda\sqrt{k} \\ \beta_N\sqrt{k} & \beta_\Lambda\sqrt{k} & k/\kappa \end{bmatrix} \qquad (1)$$

where $k$ is $\Sigma$-$K$ relative momentum and $\alpha$, $\beta$, $\kappa$ are assumed to be constant near the threshold. The amplitudes of $\pi N\to\Sigma K$ and $\pi N\to\Lambda K$ reactions can be expressed as :

$$T_{N\Sigma} = \frac{\beta_N(1-i\alpha_\Lambda)+i\alpha_{N\Lambda}\beta_\Lambda}{\Delta(k)}\frac{\sqrt{k}}{1-ik/\kappa}; \qquad (2)$$

$$T_{N\Lambda} = \left(\alpha_{N\Lambda}+i\beta_N\beta_\Lambda\frac{k}{1-ik/\kappa}\right)\frac{1}{\Delta(k)}; \qquad (3)$$

$$\Delta(k) = (1-i\alpha_N)(1-i\alpha_\Lambda)+\alpha_{N\Lambda}^2-\frac{ik}{1-ik/\kappa}[i\beta_N^2(1-i\alpha_\Lambda)+ + i\beta_\Lambda^2(1-i\alpha_N)-2\alpha_{N\Lambda}\beta_N\beta_\Lambda]$$

From the data obtained by Wolf *et al.*[2] in the threshold experiments, it may be concluded that the energy dependence $\Delta(k)$ above and very near the $\Sigma$-$K$ threshold can be neglected. In this case the energy dependence of the cross-section of $\Sigma$ and $K$ production is given by

$$\sigma = \text{const}\; k(k^2+\kappa^2)^{-\frac{1}{2}}$$

and comparing (4) with the experimental data [2, 3] on $\pi^-p\to\Sigma K$ we obtain:

$$|\kappa| \sim 140 \text{ MeV/c} \qquad (4)$$

This means that the $\Sigma$-$K$ system has a virtual or, if $\kappa<0$, a real level with an energy $E\sim30$ MeV. To determine the sign of $\kappa$, data on $\pi^-p\to\Lambda K$ reaction were used. If we neglect, as before, a $k$-dependence of $\Delta$ then from Eq. (3) for the ratio of the partial cross-section in question far from the threshold to the cross-section $\sigma_0$ in the threshold we obtain:

$$\frac{\sigma(|k| \gg |\kappa|)}{\sigma_0} = \left(1 - \frac{\beta_N \beta_\Lambda \kappa}{\alpha_{N\Lambda}}\right)^2 \tag{5}$$

Since the ratio (5) in the experiment is small then:

$$\kappa^{-1} \sim + \beta_N \beta_\Lambda / \alpha_{N\Lambda} \tag{6}$$

To find the sign of $\beta_N \beta_\Lambda \alpha_{N\Lambda}^{-1}$ we use the data pertaining to the shape of the cusp in $\pi^- p \to \Lambda K$ near the $\Sigma$-$K$ threshold. Below the threshold $k \to i|k|$ and a slope of $\sigma_{\Lambda+K}(E)$ curve is due mainly to the numerator of (3):

$$\sigma_{\Lambda+K} = \sigma_{\text{thr}} - 2\sigma_0 \beta_N \beta_\Lambda \alpha_{N\Lambda}^{-1} |k| \tag{7}$$

The experiments (Fig. II in [2]) seem to indicate a rise of $\sigma_{\Lambda+K}$ below the threshold. If it is so then $\beta_N \beta_\Lambda \alpha_{N\Lambda}^{-1} < 0$ and Eq. (6) shows that $\kappa$ is negative i.e. level in $\Sigma$-$K$ system is a real one.

This level should appear in the form of a resonance in the reactions of $\Lambda$ and $K$ production. An estimation of the resonance parameters gives:

$$\mu \approx 1660 \text{ MeV}, \quad \Gamma/2 \sim 15 \text{ MeV} \tag{8}$$

Only 3-channel formulas (2) and (3) were used above. If channels of multiple $\pi$-production are taken into account the amplitudes $T$ have the same form (Eqs. (2) and (3)), but $\alpha, \beta$ in these formulas take the complex values. The experimentally observed steep decrease of $\sigma_{\Lambda+K}(E)$ on both sides of the threshold indicates that the phase of $\beta_N \beta_\Lambda \alpha_{N\Lambda}^{-1}$ is small. Then adding inelastic channels results in a redefinition of the constants only so our qualitative arguments hold. The resonance will influence cross-sections of elastic and inelastic $\pi$-$N$ scattering, too. But in these reactions it would be more difficult to observe it because the cross-sections in this energy region have a large potential scattering background. Besides it is probable that the $\pi N / \Lambda K$ decay ratio of the $\Sigma$-$K$ bound state is small.

Recently Bertanza *et al.*[6] reported that the cross-section $\sigma_{\Lambda+K}(E)$ monotonously decreases between the points $T_\pi = 871$; 829; 793 and 775 MeV without resonance-like rise in this region. Monotonic decrease of the cross-section can be put into accord with the rise $\sigma_{\Lambda+K}(E)$ in passing $T_\pi$ into the region below the $\Sigma + K$ threshold, found in [2] (though on poor statistics) only if our assumption of constancy of $\alpha$, $\beta$, $\kappa$ in Eqs. (2) and (3) is incorrect or if other partial amplitudes depend sharply on the energy in this region. Kuznetsov *et al.*[7] obtained some evidence of the existence of the $\Lambda + K$ resonance in the region in question but it is not clear if it can be interpreted as bound state $\Sigma$-$K$ considered above.

The measurements of $\gamma + p \to \Lambda + K$ cross-section near the $\Lambda + K$ threshold [4] seem to indicate that a virtual or real level with an energy $E \sim 60$ MeV exists in $\Lambda$-$K$-system, too. If the level is a real one the second $\pi$-$N$-resonance should have a fine structure. The existence of the levels in $\Sigma$-$K$ and $\Lambda$-$K$ systems seems to contradict the global symmetry model because it follows from $K$-$p$ and $K$-nuclei experiments that $K$-$N$ interaction at small energies is mostly repulsive.

If we assume that $N\omega$ and $NK^*$ systems could have bound states then the third $\pi N$-resonance at $T_\pi = 900$ MeV can be interpreted as a $N\omega$ level with a binding energy $\sim 40$ MeV and $K^- p$ resonance $\Lambda^*$ of mass 1812 MeV—with the existence of $NK^*$ state with the binding energy $-10$ MeV. If the $N\omega$ and $NK^*$ systems are in the $S$-state then spins of the resonances cannot exceed 3/2. It would be of interest to study the energy dependence of cross-sections of $\omega$ and $K^*$ meson-production near their thresholds.

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## DISCUSSION

CRAWFORD: I believe that at least part of the Baz analysis was based on the fact that a year ago our $\Lambda K$ data at $\Sigma K$ threshold seemed to show a small energy dependence; it was not quite flat. With about three times the data now—I did not show this in my talk—the results are completely flat throughout a 30 MeV/c interval around threshold.

WROBLEWSKI: In my talk I have shown our experimental results concerning the $Q$-value of the $K\Lambda$ system, and you have seen that there is no significant peak at this small energy. As far as I know, the results obtained at Moscow by Kuznetsov and others, which were mentioned by the speaker, were obtained using the propane chamber and it seems to me that the secondary interactions inside the nuclei of carbon might make this apparent $Q$-value of $K\Lambda$ system very small. Moreover, in the abstract of your talk there is some prediction also of possible $\Sigma K$ bound state at a very small $Q$-value. I did not show our $Q$-value distribution for the $\Sigma K$ system: it does not show any peak at this small energy and we have a completely uniform background.