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# $\Lambda\pi\pi$ STRUCTURE FROM 1600 TO 1740 MeV*

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Total cross sections for the processes $K^-p\rightarrow\Lambda\pi^+\pi^-$ and $K^-n\rightarrow\Lambda\pi^-\pi^0$ (pure $T=1$) have been measured as a function of center-of-mass energy. From these the $\Lambda\pi\pi$ $T=0$ cross section was determined. The data indicate the existence of a $\Lambda\pi\pi$ decay of the $Y_0^*(1690)$.

In order to study $S=-1$ baryon systems in the center-of-mass energy region from about 1600 to 1740 MeV, we have made use of a $K^-$-deuterium exposure in the Brookhaven National Laboratory 30-in. bubble chamber. Pictures were taken at six incident $K^-$ momenta: 670, 720, 770, 810, 850, and 910 MeV/$c$.

A number of $S=-1$ baryon resonances have been seen previously in this general energy region.[1] In the $T=1$ channel there is a 1660-MeV $\frac{3}{2}^-$ resonance which seems to decay mainly into $Y_0^*(1405)\pi$, a 1690-MeV resonance which decays into $\bar{K}N$, $\Lambda\pi$, $\Sigma\pi$, and $Y_1^*(1385)\pi$, and a 1770-MeV $\frac{5}{2}^-$ resonance which decays into $\Lambda\pi\pi$, $\bar{K}N$, and other modes. In the $T=0$ channel evidence exists for a 1670-MeV $\frac{1}{2}^-$ resonance which decays mainly to $\Lambda\eta$ and $\bar{K}N$, and for a 1690-MeV resonance which is seen in the $\bar{K}N$ and $\Sigma\pi$ channels and is probably $\frac{3}{2}^-$.

We have looked for resonance effects in the $\Lambda\pi\pi$ final state coming from both $K^-n$ and $K^-p$ initial states. This gives information on both $T=0$ and $T=1$ channels of the $\bar{K}N$ system.

The film was scanned for events having a two-prong "vee" topology with a scanning efficiency in excess of 90%. The events were measured on film plane devices and then processed through the NP-54, GRIND sequence. The candidates for the final state included a sample which did not fit the $\Lambda\pi\pi$ hypothesis. This sample should be due to genuine $\Lambda\pi\pi$ events with high $\chi^2$ and both $\Lambda\pi\pi\pi$ and $\Sigma^0\pi\pi$ events which have a high $\chi^2$ when fitted as $\Lambda\pi\pi$. On the basis of previously measured cross sections[2] we determined the expected number of $\Lambda\pi\pi\pi$ and $\Sigma^0\pi\pi$ for our experiment. The sample which did not fit $\Lambda\pi\pi$ essentially accounts for all of these, which indicates that the contamination of the accepted events by events faking the $\Lambda\pi\pi$ topology is negligible.

To determine the cross sections an appropriate center-of-mass energy distribution for each beam momentum was calculated. To do this we made use of a slightly modified Johns Hopkins University computer program.[3] The following factors are taken into account: (1) a correction for the spread of the beam momentum, (2) the Fermi momentum of the target particles (the Hulthén distribution is used), (3) a correction for the variation in relative velocity and relative flux due to the Fermi motion, and (4) a geometric correction in the case where the spectator nucleon is a proton. This last correction is because there is a lower limit to the range of the spectator protons which can be observed. This limit was found by assuming several values and comparing the predicted distribution of the spectator protons with the observed one. In this way we arrived at a value of $R_{\rm min}=0.8$ mm and so obtained the appropriate distribution.

The distributions for each of the six $K^-$ momenta were then normalized to the incident number of $K$'s at each momentum and added. This produced a combined distribution to be compared with the experimental mass distribution of all our events.

To obtain the experimental distribution each event was weighted with an appropriate correction factor. This factor took into account the number of $\Lambda$'s which decayed outside our fiducial volume and the number which decayed with a length less than our lower cutoff, which was 2 mm. In addition, compensation was made for the following factors: a correction for events with $\chi^2$ probability below our cutoff, scanning efficiency, and a 50% increase to account for the neutral decay of the $\Lambda$. We also used an upper cutoff on the spectator momentum of 280 MeV/$c$ for which a 3% correction was necessary. Finally, for the $K^-n\to\Lambda\pi^-\pi^0$ events we corrected for the fact that we did not observe that part of the Hulthén distribution corresponding to spectator protons of range below the value $R_{\rm min}=0.8$ mm mentioned above. In addition, a final correction was necessary in combining the data due to different measuring efficiencies at the different institutions.

By comparing our corrected mass distribution with the calculated one we obtained the cross section as a function of energy. Then to transfrom the $K^-d$ cross sections into $K^-n$ and $K^-p$ cross sections we made a correction for screening according to the model of Glauber[4] as follows:

$$\sigma(K^-d\to\Lambda\pi^-\pi^0p)=\sigma(K^-n\to\Lambda\pi^-\pi^0)\left[1-\frac{\sigma_T(K^-p)}{8\pi}\left\langle\frac{1}{r^2}\right\rangle\right],$$

$$\sigma(K^-d\to\Lambda\pi^-\pi^+n)=\sigma(K^-p\to\Lambda\pi^-\pi^+)\left[1-\frac{\sigma_T(K^-n)}{8\pi}\left\langle\frac{1}{r^2}\right\rangle\right].$$

Values for the total cross sections for $K^-p$ and $K^-n$ were taken from Davies et al.[5] For $\langle 1/r^2\rangle$ we used the value 0.423 $\text{mb}^{-1}$.[6]

Finally, we considered possible systematic errors. One such error is connected with the fact that we observed a larger percentage of spectators in the high-momentum tail than is predicted by the Hulthén distribution (we observed 15% compared with the predicted 3%). Many of these may be due to final-state rescattering from the spectator nucleon. We cannot say with confidence how large this effect may be. In addition there may be some uncertainty in the identification of $\tau$ decays which formed the basis of the $K$ flux determination.

In order to eliminate the effect of such systematic errors we uniformly normalized all our cross sections so that the $\Lambda\pi^+\pi^-$ cross section agrees with the values of Bastien and Berge.[2] This amounted to a 15% reduction. The final results are shown in Figs. 1(a) and 1(b). The $K^-n\to\Lambda\pi^-\pi^0$ cross section is based on a total of 619 events and the $K^-p\to\Lambda\pi^-\pi^+$ cross section on a total of 1572 events. On Fig. 1(a) we have also plotted the three points measured by Bastien and Berge for comparison.

The mass distribution of the $\Lambda\pi$ system indicates that, in this energy region, the $\Lambda\pi\pi$ final state is reached entirely via the $Y_1^*(1385)\pi$ intermediate state.[7] Under these circumstances the $T=1$ and $T=0$ interference terms cancel[8] and the pure $T=0$ cross section can be obtained by using the following relation:

$$\sigma(T=0)=\tfrac{3}{2}\left[2\sigma(K^-p\to\Lambda\pi^-\pi^+)-\sigma(K^-n\to\Lambda\pi^-\pi^0)\right].$$

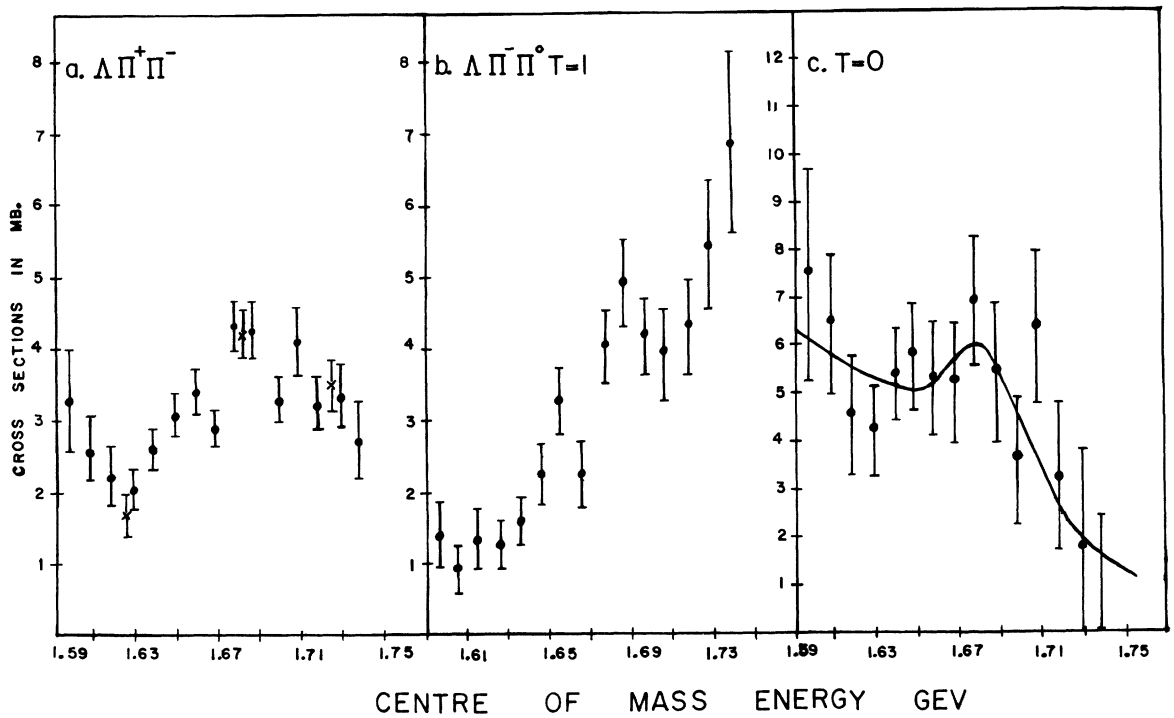


FIG. 1. $\Lambda\pi\pi$ production cross sections. The crosses indicated in Fig. 1(a) are due to Bastien and Berge (Ref. 2). The curve in Fig. 1(c) is the best fit to the data. The $\chi^2$ for the five-parameter fits is 8.

This cross section is shown in Fig. 1(c).

We note that the cross-section data for the mixed-$T$ final state indicates a resonant structure with a cross-section maximum of about 4.1 mb at 1690 MeV. The pure $T=1$ data are consistent with a general rise of the cross section from a value of about 1 mb at 1600 MeV to about 7 mb at 1730 MeV with perhaps a shoulder at 1690 MeV where a contribution from the $Y_1^*(1690)$ might be expected. The pure $T=0$ cross section, derived from the previous two, shows the resonant structure indicated in the mixed-$T$ state. A fit to the $T=0$ data assuming a Breit-Wigner form for the resonance superimposed on a background linearly decreasing with energy gives values of $1681 \pm 8$ MeV and $48 \pm 15$ MeV, respectively, for the mass and width of the resonance. The maximum of the resonance has a value of $1.97 \pm 0.34$ mb. The best-fit curve is indicated in Fig. 1(c). These values for the resonance parameters indicate that we are probably observing the established $Y_0^*(1690)$ resonance which, however, has not been previously observed to decay via the $\Lambda\pi\pi$ channel. Using for the elasticity of the resonance the value given by Davies et al.,[5] we calculate the branching fraction for decay into the channel to be $0.25 \pm 0.04$. Such a value is in good accord with the measured branching fractions for the other known decay modes which are 0.25 and 0.46 for the $NK$ and $\Sigma\pi$ channels, respectively.[5,9]

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# SEARCH FOR MULTIPION RESONANCES WITH $I=2$*

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We have performed a search for $I=2$ multipion resonances ($\chi^{--}$) in reactions of the type $\pi^-n\rightarrow p\chi^{--}$, where $\chi^{--}$ decays into $\pi^-\pi^+\pi^-\pi^-$ with or without extra $\pi^0$ mesons. Our results at a $\pi^-$ beam momentum of 7 GeV/$c$ indicate that if these resonant states exist and if they have widths of $\leq$160 MeV, then they are produced only with cross sections which are one to two orders of magnitude lower than the production cross sections measured for the well-established resonances.

Although the nonrelativistic quark model[1] has been applied with considerable success to the classification of known elementary-particle states, it has been the absence of hadrons belonging to $\underline{27}$ multiplets of SU(3) which has served as one of the major experimental supports for this model.[2] By postulating a $q\bar{q}$ structure for mesons and a $qqq$ structure for baryons, rather than more complicated configurations, the quark model has accounted for the well established particle states.[3] Another particle classification scheme, based on SU(6)$_W$ symmetry and no orbital excitation of quark systems, has been proposed and also found to be in substantial agreement with the data.[4] In this scheme, however, resonances having large spins must be accommodated in SU(6) supermultiplets which contain $\underline{27}$ multiplets of SU(3). Proponents of the SU(6) method of particle classification have pointed out that these $\underline{27}$ multiplets may indeed exist and that the reason they have not been observed may be due to the presence of selection rules influencing the production and decay of these "exotic" objects.[5] These authors stress that if hadrons are composed of more complicated quark systems, (e.g., $qq\bar{q}\bar{q}$ for mesons) then the channels which are normally expected to dominate in the production and decay of these exotic particles (and which are usually experimentally accessible) are in fact closed. They point out that simple decays of mesons (with high hypercharge or isospin) into two pseudoscalars or into a vector plus a pseudoscalar meson are often forbidden to occur because of SU(6)$_W$ selection rules.

We are reporting the results of a search for $I=2$ mesons from our investigation of five- and six-pronged events observed in an 84 000-picture exposure of the 80-in. Brookhaven National Laboratory deuterium-filled bubble chamber to 7-GeV/$c$ $\pi^-$ mesons from the high-energy electrostatically separated beam at the alternating-gradient synchrotron. The final states studied are the reactions

$$\pi^-d\rightarrow p_S p\pi^+\pi^-\pi^-\pi^-, \tag{1}$$

$$\pi^-d\rightarrow p_S p\pi^+\pi^-\pi^-\pi^-\pi^0. \tag{2}$$

Often, the spectator proton ($p_S$) has too little momentum to leave a visible track in the bubble chamber. When this occurs, only five outgoing prongs are observed and measured.[6] Our interest is centered mainly on possible $(4\pi)^{--}$ and $(5\pi)^{--}$ resonant states produced in association with the proton.[7]

The 84 000-picture exposure was scanned for those events which had two identifiable protons. The six-prongs had to have at least two heavily ionizing positive tracks, while the five-pronged events had to have at least one heavily ionizing track to be accepted for measurement.[8] Approximately 800 acceptable six-pronged events and 1600 acceptable five-pronged events were found and were subsequently measured. Table I gives the number of events in each sample of data and an estimate of the background in each event category.[9] In these data one event corresponds to a cross section of 0.14 $\mu$b.

In Fig. 1 we show the outcome of our search for $I=2$ resonances. Figure 1(a) displays the distribution of the mass of the multipion system recoiling from the two observed protons. All the five-pronged and six-pronged measurements are included in the graph. (The difference between the five-pronged and six-pronged mass spectra in Fig. 1 is due to the larger Fermi mo-