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EXCITED HYPERONS AT 1760 AND 1820 MeV

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A detailed investigation of the charge-exchange reaction $K^-p \rightarrow \overline{K^0}n$ has been performed in the K^- momentum range from 800 to 1200 MeV/c. Our results for the partial and differential cross-section of this reaction demonstrate the presence of two distinct resonant regions centred respectively at the momenta P_K = 930 MeV/c and P_K = 1060 MeV/c. We attribute these phenomena to the excitation of two neighbouring resonances of the K^-p system : $Y^*(1760)$ with a mass M = (1760 ± 10) MeV, width Γ = (90 ± 10) MeV, elasticity 0.5, and $Y^*(1820)$ with mass M = (1820 ± 10) MeV, width Γ = (45 ± 5) MeV, elasticity ~ 0.7. These phenomena occur in a momentum range where an earlier study [1] of the total K^-p cross-section had revealed the presence of a broad and asymmetric enhancement which was since referred to as the $Y^*(1815)$ resonance; as opposed to the latter, the $Y^*(1820)$ observed here has a much narrower width. The possibility of a structure in the K^-p interaction around this momentum region was first pointed out by Barbaro-Galtieri et al.[2] ; they studied the reaction $K^-n \rightarrow K^-p\pi^-$ at P_K = 1510 MeV/c and observed an enhancement in the K^-p effective-mass spectrum having the general features of the $Y^*(1760)$ reported here. The conclusions of our study are that, interpreting the data in terms of a two-resonance model, the resonances have spin 5/2 with opposite parities and different isospins [3].

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The results presented are based on a total of ~ 150,000 pictures taken in the 81cm Saclay hydrogen bubble chamber exposed to a separated K^- beam at the CERN proton synchrotron [4]. A list of the 20 momenta at which the exposures have been made is given in Table I. The average momentum spread at the chamber entrance is of ± 10 MeV/c. The average yield of the experiment is 0.2 events per μb at each individual momentum setting.

In Figure 1 the results of total cross-section measurements from different experiments [1, 5] are shown, together with preliminary values obtained in this experiment [6]. In order to investigate this structure more fully, different channels open to the K^-p system have been examined separately. In this Letter only the charge-exchange reaction will be considered.

The film has been scanned and rescanned for the zero-prong-plus-V^0 and the three-prong topologies within a reduced fiducial volume. It is estimated that, after the two scans, the fraction of events lost is less than 1°/o. The three-prong events were fitted to the τ-decay hypothesis and the K^- momenta thus obtained were used to determine precisely the average momentum of each run. These events were also used to find the total K^- path length at each run. The τ-decay branching fraction was taken to be 0.055 ± 0.001 [7].

The reactions responsible for the zero-prong-plus-V^0 topology are of two main types : a) $K^- + p \rightarrow \overline{K^0}$ + neutrals, b) $K^- + p \rightarrow \Lambda$ (or Σ^0) + neutrals. The extraction of the charge-exchange reaction from the above events was easily accomplished by kinematical fitting and, when necessary, ionization estimates. Finally, a weight was assigned to each event, depending on its escape probability and the detection loss in the chamber [8]. In this way a total of ~ 3,600 charge-exchange events and of ~ 4,500 τ-decays were identified over all momenta. Table I lists the values of the cross-sections obtained at each momentum. The dependence of this cross-section on the laboratory momentum, P_K, is shown on Figure 2. Here the cross-sections have been divided by $4\pi\lambda\!\!\!^{-2}$ with $\lambda\!\!\!^{-} = \hbar/p$ where p is the K^- c.m. momentum. The removal of this geometrical factor isolates the momentum dependence of the amplitudes under study. Results of previous experiments are also shown on the graph, which covers the momentum region from threshold to 2000 MeV/c [9].

In the momentum region where the total cross-section exhibits a broad asymmetric enhancement, the charge-exchange now shows a rapid rise followed by a large plateau and then a prominent and narrow peak. This peak has a shape of the Breit-Wigner form centred at $\sim$1820 MeV. We attribute the latter phenomenon to the decay of a resonance, $Y^{*}(1820)$, into the $\overline{K^{o}}n$ channel. As for the plateau, this can be understood as the occurrence of a second, broader resonance centred at 1760 MeV. The unorthodox appearance of the second enhancement is the expected result of the proximity of the two resonances, together with their respective widths and elasticities. With this interpretation, we can now proceed to determine the parameters of the two resonances. The charge-exchange cross-section for each resonance is expressed as

$$\sigma = \pi \lambda\!\!\!^{-2} \left(J + \frac{1}{2}\right) \frac{(\Gamma_e/\Gamma)^2}{(M - E)^2 + \frac{\Gamma^2}{4}}$$

where M = resonance mass, Γ = full width, $\frac{\Gamma_e}{\Gamma}$ = elasticity. In conformity with the angular distributions discussed below, both resonances are assumed to have a spin $J = 5/2$. The energy dependence of Γ is taken to correspond to a D-wave and F-wave resonance for the lower and upper resonance, respectively. With a background assumed to be constant at 0.06, a least square fit to the data of Figure 2 has been performed. The parameters thus determined are listed in Table II. The momentum dependence of the charge-exchange cross-section using these parameters is shown in Figure 2, while the enhancement expected in the total cross-section is indicated in Figure 1.

Confirmatory evidence of the interpretation offered above is found in the differential cross-sections. The angular distributions at each momentum have been fitted to a series of the form

$$\frac{d\sigma}{d\Omega} = \lambda\!\!\!^{-2} \sum_{o}^{n_{max}} A_n P_n (\cos \Theta)$$

where $P_n (\cos \Theta)$ are the Legendre polynomials. The analysis shows that no higher terms than the fifth are necessary throughout the region under study, whereas A_5 is definitely required. This immediately sets an upper limit of $J \leq 5/2$ to the spin of either resonance. Let us now examine the momentum dependence of the coefficients, where the resonant amplitudes ought to produce characteristic effects. The coefficients are shown in Figure 3. The lower coefficients, A_1 to A_3 ($A_0 = \sigma/4\pi\lambda\!\!\!^-{}^2$ has already been shown in Figure 2) are not immediately interpretable since they include contributions from many partial waves; however, the presence of a structure in the region of 1760 to 1820 MeV is noticeable in all of them. These structures would be difficult to simulate without postulating the existence of resonant amplitudes. While a more complete analysis is in progress, useful information can already be obtained from the more readily interpretable higher coefficients. Thus, when no partial waves with $J > 5/2$ are present,

$$A_4 = \left(\frac{18}{7}\right) \text{Re} \left(|D_{5/2}|^2 + |F_{5/2}|^2\right) + \left(\frac{72}{7}\right) \text{Re} \left(D^*_{3/2} D_{5/2} + P^*_{3/2} F_{5/2}\right)$$

$$A_5 = \left(\frac{100}{7}\right) \text{Re} \left(D^*_{5/2} F_{5/2}\right).$$

The data in Figure 3 show that both A_4 and A_5 undergo rapid variations strongly suggestive of a resonant behaviour. The structure of A_5 in particular, leads to the conclusion that there are two resonant waves of $J = 5/2$ and opposite parity. Using the parameters listed in Table II, the expected behaviour of the A_5 coefficient has been calculated and is shown on Figure 3. From this, one can see that the predictions of the two-resonance model are in agreement with the data, although a more complicated situation cannot be excluded. Notice that, due to the Minami ambiguity, it is not possible from these data alone to determine which is the $D_{5/2}$ and which the $F_{5/2}$ resonance.

By the same model, the A_4 coefficient should exhibit the characteristic resonant behaviour required by the $|D_{5/2}|^2$ and $|F_{5/2}|^2$ terms, in addition to a background due to unknown $J = 3/2$ waves. Disregarding these background waves, one obtains the curve shown for A_4 on Figure 3. Here again the qualitative agreement is correct, particularly if one makes allowance for some $J = 3/2$ interference, in order to explain the absolute magnitude of the effect.

We conclude that the data are consistent with the attribution of $J = 5/2$ and opposite parity for the two resonances. We may also comment that the negative sign of the A_5 coefficient, taken together with the positive A_5 assignment of the existing elastic scattering data in this energy region[10], dictates that the two resonances have different isospin. Further, the results of Reference 1 established that isospin 0 is the most likely attribution for the resonance in the region around 1820 MeV. Consequently, the isospin of $Y^*(1760)$ is inferred to be 1 [11].

Finally, we want to make some reservations about the simple interpretation offered for the lower resonance : a) the width of $Y^*(1760)$ observed in this formation experiment is much larger than that in the production experiment of Reference 2, b) the A_4 and A_5 coefficients show deviation in magnitude and energy dependence from the expected picture. These effects may be attributable to the preliminary nature of the data but may also represent a more complex situation.

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6. A quick measurement of the total cross-section was performed from a careful scan of $\sim$500 photographs at each momentum, in which all events together with the number of beam tracks and associated δ-rays were recorded. A value of the π and μ contamination (typically less than $5^{o}/o$) was derived for each run by means of the δ-ray count.

7. A.H. Rosenfeld, A. Barbaro-Galtieri, W.H. Barkas, P.L. Bastien, J. Kirz and M. Roos, UCRL Report 8030 Rev. (March 1965).

8. When the K^{o} is emitted backwards in the laboratory, the tracks from its decay may be collinear, so that the absence of a visible kink will make the detection efficiency for such an event lower than that for other configurations. Such a loss of events can be experimentally detected by observing, at each centre of mass production angle θ_{K^o}, the distribution of events as a function of the K^{o} decay angle. This distribution, which should be isotropic in the absence of biases in the event detection, was found to have an appreciable anisotropy only for $\cos\theta_{K^o} < -0.95$. The observed deviation from isotropy was attributed to the events lost and was used to apply a correction which in no case exceeded $\sim 12^{o}/o$.

References (continued)

9. The following sources have been used :

   (a) W.E. Humphrey and R.R. Ross, Phys.Rev. 127, 1305 (1962), for $P_K < 300$ MeV/c.

   (b) Reference 5 for $300 < P_K < 900$ MeV/c.

   (c) C.G. Wohl, F.T. Solmitz and H.L. Stevenson, Bull.Am.Phys.Soc. 10, 529 (1965) for $P_K > 1200$ MeV/c.

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11. Preliminary results on the reaction $K^- + p \dashrightarrow Y^*(1520) + \pi^0$ show that a large part of this cross-section proceeds through the formation and decay of $Y^*(1760)$. This is possible only if $Y^*(1760)$ has isospin 1.

Table I

Charge exchange cross-section as a function of K^- momentum

Momentum (MeV/c)	c.m. energy (MeV)	$\sigma\ (K^- p \rightarrow \overline{K^o} n)$ (mb) a)
777	1688	3.26 ± 0.45
806	1702	3.64 ± 0.46
853	1725	5.56 ± 0.75
874	1735	5.00 ± 0.53
894	1745	5.48 ± 0.67
916	1755	4.75 ± 0.35
935	1764	5.19 ± 0.51
954	1772	5.06 ± 0.53
973	1781	5.33 ± 0.38
991	1791	5.12 ± 0.51
1022	1805	6.55 ± 0.55
1044	1814	7.00 ± 0.69
1061	1822	8.05 ± 0.54
1080	1831	6.59 ± 0.68
1102	1841	5.50 ± 0.49
1117	1847	4.59 ± 0.39
1130	1853	3.24 ± 0.91
1153	1863	3.31 ± 0.66
1169	1871	3.93 ± 0.57
1185	1879	3.91 ± 0.44

a) Corrected for invisible K^o decay modes, and for detection loss in the chamber.

Table II

Parameters of the fit

Mass (MeV)	Γ (MeV)	Γ_{el}/Γ	J^P (input)
1760 ± 10	90 ± 10	0.7	$5/2^-$
1820 ± 5	45 ± 5	0.5	$5/2^+$

Figure Captions

Figure 1 K^-p total cross-section as a function of the laboratory momentum. The open circles are data from the experiments of References 1 and 5, the black points are preliminary values from the present experiment. The curve shows the enhancement expected in the total cross-section from $Y^*(1760)$ and $Y^*(1820)$ with the parameters of Table II.

Figure 2 Charge-exchange cross-section divided by $4\pi\lambda\!\!\!^{-2}$ as a function of the laboratory momentum. The open circles are data from the experiments of Reference 9, the black points are results of the present experiment. The curve shows the best fit to the data under the assumption that there are two resonances, $Y^*(1760)$ and $Y^*(1820)$, superposed to a constant background equal to 0.06.

Figure 3 Shown as a function of the laboratory momentum, these are the coefficients of the expansion in Legendre polynomials of the differential cross-section for charge-exchange. The curves through the A_4 and A_5 data represent the expected behaviour of these coefficients when only the $J = 5/2$ partial waves corresponding to $Y^*(1760)$ and $Y^*(1820)$ with the parameters of Table II are taken into account.