# DETERMINATION OF THE K＊（1800）SPIN PARITY＊ 

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#### Abstract

A spherical harmonic moment analysis of the reactions $\mathrm{K}^{-} \mathrm{p} \rightarrow \mathrm{K}^{-} \pi^{+} \mathrm{n}$ and $\mathrm{K}^{+} \mathrm{p} \rightarrow \mathrm{K}^{+} \pi^{-} \Delta^{++}$at $13 \mathrm{GeV} / \mathrm{c}$ demonstrates the existence of a broad $\mathrm{K}^{*}$ state with mass in the vicinity of 1800 MeV and spin parity $3^{-}$．


（Submitted to Phys．Letters．）

[^0]We have studied the reactions

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\begin{equation*}
\mathrm{K}^{-} \mathrm{p} \rightarrow \mathrm{~K}^{-} \pi^{+} \mathrm{n} \tag{1}
\end{equation*}
$$

and

$$
\begin{equation*}
\mathrm{K}^{+} \mathrm{p} \rightarrow \mathrm{~K}^{+} \pi^{-} \Delta^{++} \tag{2}
\end{equation*}
$$

using a magnetostrictive wire chamber spectrometer in an rf separated 13 GeV $K$ beam at SLAC [1]. These reactions involve charge exchange in the $t$ channel and are dominated by $\pi$ exchange at small values of momentum transfer. They can therefore be used to study the properties of $\mathrm{K} \pi$ scattering. In particular, in the region of 1800 MeV a spin three $\mathrm{K}^{*}$, the strange member of the g meson $3^{-}$octet, is expected. Several experiments have investigated the $\mathrm{K}_{\pi}$ mass spectrum near $1800 \mathrm{MeV}[2,3,4]$. However, the nature of the structures observed in the mass spectrum in this region have differed substantially between experiments. In this paper we clearly demonstrate the existence of the spin parity $3^{-} \mathrm{K}^{*}$ state near 1800 MeV through a spherical harmonic moment analysis of the data from reactions (1) and (2).

The spectrometer system detects the incoming beam particle and the outgoing $K$ and $\pi$ in reactions (1) and (2). The neutron and $\Delta$ final states are identified by cuts on the missing mass of the recoiling system: for the neutron, $0.7<\mathrm{MM}<1.0 \mathrm{GeV}$, and for the $\Delta^{++}, 1.00<\mathrm{MM}<1.4 \mathrm{GeV}$. The observed missing mass resolution of 200 MeV FWHM is sufficient to separate the neutron from $\Delta^{\circ}$ leaving little contamination in reaction (1).

The acceptance of the apparatus is determined by Monte Carlo techniques and accounts for geometrical apertures, decays, resolution, absorption of secondary particles, apparatus efficiencies as well as incorporating all of the cuts we apply to the data. Using this acceptance we then fit the observed $\mathrm{K} \pi$ angular distributions in the Gottfried Jackson frame with an expansion of spherical
harmonics. In fig. 1 we show the corrected $\mathrm{K} \pi$ mass distributions for the two final states separately. The results were obtained using spherical harmonics, $\mathrm{Y}_{\ell \mathrm{m}}$, with $\mathrm{m} \leq 1$ and $\ell \leq 4$ for $K \pi$ mass below $1.25 \mathrm{GeV}, \ell \leq 5$ below 1.55 GeV and $\ell \leq 6$ at higher masses. In addition to the prominent $K^{*}(890)$ and $K^{*}(1420)$ we observe an increase in cross section near 1800 MeV . In order to study this region in more detail we have combined the two data samples. For $\mathrm{K} \pi$ masses between 1.6 and 2.0 GeV , the $\mathrm{K}^{+}$and $\mathrm{K}^{-}$data samples are of approximately equal size and yield a total of 4600 events in this region. Furthermore, the observed mass distribution, angular distribution, and the spherical harmonic moments for the $\mathrm{K}^{-} \pi^{+}$system are similar to those of the $\mathrm{K}^{+} \pi^{-}$data in this region。

Figure 2 shows the unnormalized spherical harmonic moments $\mathrm{Y}_{00}, \mathrm{Y}_{40}$, $Y_{50}$, and $Y_{60}$ between 1.2 and 2.2 GeV in the Gottfried Jackson frame for the combined data samples for $\mathrm{t}^{\prime}<0.2 \mathrm{GeV}^{2}$. These moments were obtained from a fit restricted to spherical harmonics with $\ell \leq 6$ and $m \leq 1$ for the entire mass range. Separate fits were performed including spherical harmonics with $\ell \leq 8$. $Y_{70}$ and $Y_{80}$ were found to be zero within errors below 2.0 GeV . The $\mathrm{K}^{*}(1420)$ is clearly evident in the $\mathrm{Y}_{40}, \mathrm{Y}_{20}$ (not shown), and $\mathrm{Y}_{00}$ mass distributions, whereas $Y_{60}$ remains zero in this region confirming the spin parity $2^{+}$assignment for the $\mathrm{K}^{*}(1420)$.

The combined data clearly demonstrate the existence of a rather broad spin three $\mathrm{K}^{*}$ resonance in the region of 1800 MeV . The rapid rise of the $\mathrm{Y}_{30}$ (not shown) and $\mathrm{Y}_{50}$ moments near 1750 MeV reflects interference between waves of even and odd $\ell$ and indicates the presence of a substantial $f$ wave in this region. The behavior of the $Y_{50}$ moment in this region is most plausibly ascribed to the interference of a relatively broad $f$ wave resonance with the tail of the $d$ wave $\mathrm{K}^{*}(1420)$. Similarly the rise and fall of the $\mathrm{Y}_{60}$ moment is indicative of a broad
spin three resonance. At lower masses in the region of $K^{*}(1420)$ the $Y_{50}$ moment again changes sign implying that the $f$ wave extends over a wide region.

We have attempted to describe the $Y_{40}, Y_{50}$, and $Y_{60}$ mass distributions shown in fig. 2 by a very simple amplitude consisting of just the sum of a $d$ wave and an $f$ wave resonance. Fits [5] of this amplitude to $Y_{40}, Y_{50}$, and $Y_{60}$ indicate a mass of $\sim 1.776 \pm .026 \mathrm{GeV}$ and a total width of $\sim 0.270 \pm .070 \mathrm{GeV}$ for the spin three resonance. However these values are sensitive to the uncertainties in the description of the $K^{*}(1420)$ tail and the choice of parametrization used. Thus the errors quoted have been increased to indicate the range of values in which the mass and width of the spin three $K^{*}$ might lie. This result for the width differs from two earlier results $[2,4]$ which interpreted a narrow enhancement observed at 1760 MeV as the expected spin three $\mathrm{K}^{*}$.

In conclusion we have demonstrated the existence of a broad spin parity $3^{-}$resonance in the vicinity of 1800 MeV , which may be interpreted as the strange partner of the g-meson.

## References

[1] G. W. Brandenburg et al., to be submitted to Nucl. Instr. and Methods.
[2] D. D. Carmony et al., Phys. Rev. Letters 27 (1971) 1160.
[3] A. Firestone et al., Phys. Letters 36B (1971) 513.
[4] M. Aguilar-Benitez et al., Phys. Rev. Letters 30 (1973) 672.
[5] In order to perform these fits we used nonrelativistic Breit-Wigner amplitudes for the $2^{+}$and $3^{-}$resonances. The $2^{+}$parameters were taken from the Particle Data Tables and a p wave barrier factor used in the total width for both resonances. Thus the results are not meant to be definitive but only represent approximate values for the mass and width of the $3^{-}$ resonance.

## Figure Captions

1. The $K \pi$ mass distributions for the reactions $\mathrm{K}^{+} \mathrm{p} \rightarrow \mathrm{K}^{+} \pi^{-} \Delta^{++}$and $\mathrm{K}^{-} \mathrm{p} \rightarrow \mathrm{K}^{-} \pi^{+} \mathrm{n}$. The histogram and solid points show the data before and after correction for spectrometer acceptance. The latter have been scaled by an arbitrary factor of 0.3 for plotting purposes.
2. The unnormalized $Y_{00}, Y_{40}, Y_{50}$, and $Y_{60}$ moments from the combined $\mathrm{K}^{+} \mathrm{p} \rightarrow \mathrm{K}^{+} \pi^{-} \Delta^{++}$and $\mathrm{K}^{-} \mathrm{p} \rightarrow \mathrm{K}^{-} \pi^{+} \mathrm{n}$ data samples for $1.2 \leq \mathrm{M}(\mathrm{K} \pi) \leq 2.2 \mathrm{GeV}$ and $t^{\prime}<.2 \mathrm{GeV}^{2}$, obtained in a fit with $\ell \leq 6$ and $m \leq 1$.


Fig. 1


Fig. 2


[^0]:    ＊Work supported by the U．S．Energy Research and Development Administration．
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