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A SPIN DETERMINATION OF THE $E^*(1820)$ RESONANCE

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ABSTRACT

Using a spin test proposed recently by Minnaert, we determine the spin of the $E^*(1820)$ resonance to be $3/2$.

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The $\Xi^*(1820)$ resonance is believed [1] to be the strangeness -2 member of the $3/2^-$ SU(3) nonet (N(1520), $\Lambda(1520)$, $\Lambda(1670)$, $\Sigma(1670)$, $\Xi(1820)$). Following the measurement [2] of the $\Xi^{*-}(1820)$ decay rates, a comparison [3] with the predicted SU(6)_W decay rates of the $(70, 1^-)$ super multiplet [4] indicated that the $J^P = 3/2^-$ assignment was possible. In the absence of other strangeness -2 members of the $(70, 1^-)$, a definite measurement of J^P is clearly desirable. A previous study [2] of the $\Xi^{*-}(1820)$ in K^-p interactions at 4.2 GeV/c which analysed separately the decay modes ΛK^- and $\Xi^{*0}(1530)\pi^-$ was able only to eliminate the $J = 1/2$ assignment.

A recent paper by Minnaert [5] has pointed out that the two main decay modes

$$\Xi^{*-}(1820) \rightarrow \Lambda K^- \quad (J^P \rightarrow 1/2^+ 0^-) \quad (1)$$

$$\Xi^{*-}(1820) \rightarrow \Xi^{*0}(1530)\pi^- \quad (J^P \rightarrow 3/2^+ 0^-) \quad (2)$$

can jointly provide spin discrimination. One of the tests proposed involves a comparison of the moments $\langle Y_L^M \rangle$ of the angular distribution of the decays via the relation

$$\langle Y_L^M \rangle_{\Xi^*(1530)} = \left[1 - \frac{2L(L+1)(1-\gamma')}{(2J+3)(2J-1)} \right] \langle Y_L^M \rangle_{\Lambda}, \quad (3)$$

where the parameter γ' , defined in terms of the helicity amplitudes of the decay (2), can be measured from the subsequent decay

$$\Xi^{*0}(1530) \rightarrow \Xi^- \pi^+, \quad (4)$$

via the longitudinal angular distribution

$$I(\psi) = \frac{1}{2} \left[1 + \gamma' P_2(\cos\psi) \right], \quad (5)$$

where ψ is the angle of the Ξ^- relative to the $\Xi^{*0}(1530)$ line-of-flight. Thus, a measurement of γ' via (5), combined with moment determinations for the two decays (1) and (2), enables an evaluation of spin J from relationship (3).

The data reported here come from a three million picture exposure of the CERN 2m hydrogen bubble chamber to a K^- beam of 4.2 GeV/c incident momentum. All of the exposure is now fully analysed for strange particle final states and the sensitivity of the data used here is 133 events/ μ b. A previous publication [2] reported evidence for the $\Xi^{*-}(1820)$ with $\sim 2/3$ of the final statistics. The two channels of interest for the current study are

$$K^- p \rightarrow \Lambda K^+ K^- \quad 4892 \text{ events} \quad (6)$$

$$K^- p \rightarrow \Xi^- K^+ \pi^+ \pi^- \quad 2212 \text{ events.} \quad (7)$$

Both channels are four-constraint production fits (the Λ^0 charged decay being required in reaction (6)) and have been chosen within a limited fiducial region. The events have been weighted to compensate for cuts applied to the projected length of the Ξ^- ($\ell_{\text{proj}} < 0.5$ cm) and the Λ^0 ($\ell_{\text{proj}} < 0.3$ cm) and to the projected Ξ^- opening angle ($\theta_{\text{proj}} < 0.06$ radians). Furthermore, to reduce the non-resonant background, we have applied a four-momentum transfer cut, $u_p \rightarrow K^+ < 1.0 \text{ GeV}^2$. The $\Xi^{*0}(1530)$ in reaction (7) is defined by the mass selection $1.520 < M(\Xi^- \pi^+) < 1.546 \text{ GeV}$. Fig. 1 shows the resulting ΛK^- and $\Xi^{*0}(1530)\pi^-$ mass spectra. In both distributions the $\Xi^*(1820)$ signal is prominent and sits on a small background.

For subsequent analysis we define the $\Xi^*(1820)$ to be within the mass bands 1.785 - 1.855 GeV and 1.795 - 1.845 GeV for $\Xi^{*0}(1530)\pi^-$ and ΛK^- channels respectively. This choice was the best compromise in order to maximize the background subtracted $\langle Y_L^M \rangle / \Delta \langle Y_L^M \rangle$ (where $\Delta \langle Y_L^M \rangle$ is the statistical error of the moment $\langle Y_L^M \rangle$) of all the relevant moments. (The procedure for background subtraction will be explained presently). The

moments determined for the events within these bands have been corrected by a method of background subtraction. To do this, a background polynomial + Breit Wigner fit has been made to each mass spectrum below 2.0 GeV. This fit enables an estimation of the signal/background ratio within the $\Xi^*(1820)$ band and also within the $\Xi^*(1820)$ bands and also within the remaining parts of the considered mass spectra. The ratios have been used to evaluate the background subtracted moments. All moments have been evaluated in the u-channel transversity frame.

In agreement with our previous analysis [2], the existence of significant moments with $L = 2$ allows to reject the $J = 1/2$ possibility (for example, $\langle Y_2^0 \rangle_\Lambda = -0.075 \pm 0.025$). The longitudinal $\Xi^{*0}(1530) \rightarrow \Xi^- \pi^+$ angular distribution provides our estimate of γ'

$$\gamma' = -0.62 \pm 0.40$$

which again allows to reject $J = 1/2$ (Merrill et al. [6] have shown that $\gamma' = 1.0$ for $J = 1/2$). With this value of γ' , eq. (1) now defines a relationship between $\langle Y_L^M \rangle_\Lambda$ and $\langle Y_L^M \rangle_{\Xi^*(1530)}$ which depends only on J and L . Thus, if we plot $\langle Y_L^M \rangle_\Lambda$ versus $\langle Y_L^M \rangle_{\Xi^*(1530)}$ for a given L value, all the possible M moments should lie on a straight line passing through the origin, whose slope is determined by J . For our data the only set of moments containing at least one significant value are those with $L = 2$, and they are plotted in fig. 2. $\langle \text{Re } Y_2^1 \rangle$ and $\langle \text{Im } Y_2^1 \rangle$ are consistent with zero, as expected for parity conservation, and hence were not used. The shaded area for $J = 3/2$ and $5/2$ represents the range of slopes corresponding to $\gamma' \pm \Delta\gamma'$. Clearly the current data favour unambiguously $J = 3/2$. To show the discrimination on a more quantitative basis, we have reformed eq. (3) as a χ^2 test for variable J . The variation of this χ^2 with J is shown in fig. 3. One sees a clear χ^2 minimum close to the $J = 3/2$ possibility. At this value the χ^2 of 2.12 with three data points gives a probability of $\sim 55\%$. The next best possibility has $J = 5/2$ and gives a χ^2 of 14.1 and corresponding probability $\sim 0.3\%$. We conclude that the data determine the $\Xi^*(1820)$ spin to be $J = 3/2$.

We also attempted to obtain a parity assignment by means of numerous tests proposed in the literature [7], but no significant discrimination was found.

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FIGURE CAPTIONS

- Fig. 1 (a) ΛK^- mass distribution from $K^- p \rightarrow \Lambda K^- K^+$ with ϕ removed and $u_{p \rightarrow K^+} < 1.0 \text{ GeV}^2$.
- (b) $E^{*0}(1530)\pi^-$ mass distribution from $K^- p \rightarrow E^- \pi^+ \pi^- K^+$ with $u_{p \rightarrow K^+} < 1.0 \text{ GeV}^2$. $E^*(1530)$ is defined to be in the mass interval $1.520 < M(E^- \pi^+) < 1.546 \text{ GeV}$.
- Fig. 2 The experimental moments $\langle Y_L^M \rangle_\Lambda$ and $\langle Y_L^M \rangle_{E^*(1530)}$ with $L = 2$ in the u-channel transversity frame. The ellipses correspond to 1 s.d. errors. For a discussion of this plot see the text.
- Fig. 3 Variation of chisquare with $E^*(1820)$ spin J.

Fig. 1

Fig. 2

Fig. 3