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A COMPARISON OF THE SPIN DENSITY MATRIX ELEMENTS OF K* (892) and N* (1236) RESONANCES PRODUCED IN 5 GeV/c K^+p INTERACTIONS WITH PREDICTIONS OF THE ABSORPTION MODEL

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Abstract. The reaction $K^+p \to K^+p\,\pi^+\pi^-$ at 5 GeV/c proceeds predominantly via the production of $K^*(892)$ and $N^*(1236)$ resonances. The spin density matrix elements ρ_{00}, ρ_{1-1} and $Re\,\rho_{10}$ of the $K^*(892)$ resonance and ρ_{33}, $Re\,\rho_{3-1}$ and $Re\,\rho_{31}$ of the $N^*(1236)$ resonance were determined in five regions of four momentum transfer from the target proton to the outgoing $p\pi^+$ system ($\triangle^2 p \to p\pi^+$) by fitting the resonance decay angular distributions using a maximum likelihood method. The variation of the density matrix elements with $\triangle^2$ agree reasonably well with the predictions of the absorption model.[1]

The CERN 2 m hydrogen bubble chamber was exposed to a 5 GeV/c electrostatically separated K^+ beam. From a sample of about 18000 measured four-prong events 6347 unique fits to the reaction

$$K^+ p \to K^+\pi^+\pi^- p$$

were obtained corresponding to a cross-section of 1.8 ± 0.15 mb. The events were measured by groups at CERN, Brussels and Birmingham and so were checked for compatability before combination for the final analysis. All events fitting the reaction $K^+p \to K^+\pi^+\pi^-p$ were checked for consistency with ionization density.

It is well-known[2] that the above reaction is dominated by the production of $K^*(892)$ and $N^*(1236)$ resonances as shown in Fig. 1. Some production of $K^*(1400)$ is evident in this figure. Approximately one-sixth of the events fitting the reaction

$$K^+p \longrightarrow K^+\pi^+\pi^-p$$

proceed via the quasi two-body process

$$K^+p \longrightarrow K^*(892)\;\; N^*(1236)$$
$$\qquad\qquad \downarrow \to K^+\pi^- \quad \downarrow \to p\pi^+$$

and this sample of events was used to determine the spin density matrix elements of the two resonances. The number of events available (1064) is an improvement on earlier statistics so it seems worthwhile repeating the analysis of George *et al.* ‡[2] who compared

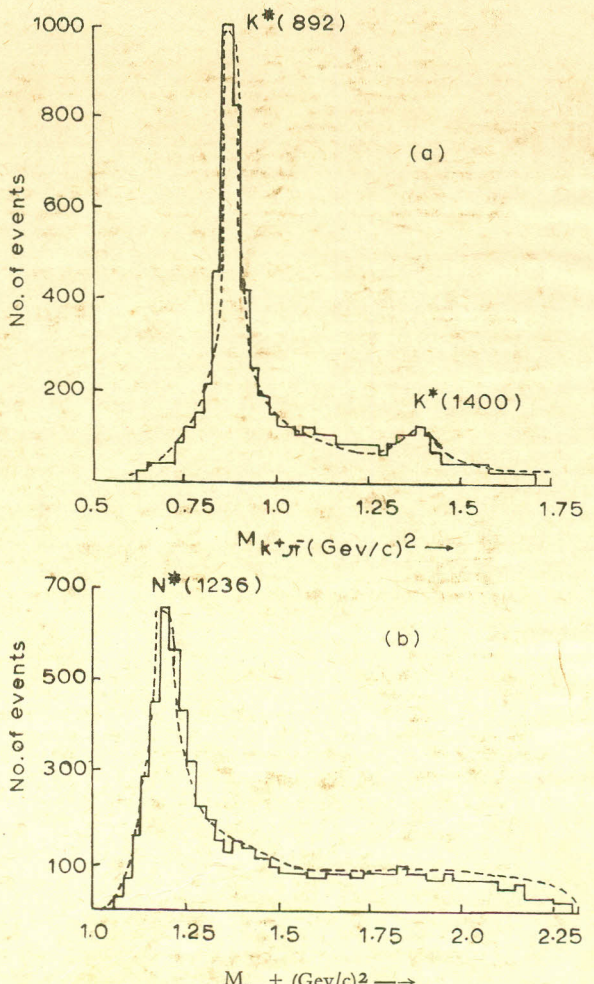

Fig. 1(a). $K^+\pi^-$ effective mass distributions at 0.025 GeV/c^2 interval. The dashed curve is the fitted phase space time Breit-Wigner.

Fig. 1(b). $p\pi^+$ effective mass distributions at 0.025 GeV/c^2 interval. The dashed curve is the fitted phase space times Breit-Wigner.

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‡ The work presented here is an updating of earlier work by George *et al.* performed by the author on a better statistical sample of events.

their data on the above reaction at incident momenta of 3.5 and 5 GeV/c with the predictions of the absorption model.

The Absorption Model. Of interest in a comparison of the data with the predictions of the absorption model are the variations of the density matrix elements with the square of the four momentum transfer from the target proton to the final state $p\pi^+$ system. Within the framework of a simple one pion exchange model, the predicted values of the density matrix elements are

$$\rho_{00} = 1 \text{ and } \rho_{1\,-1} = 0 \text{ at the } K^* \text{ vertex}$$

$$\text{and } \rho_{33} = Re\,\rho_{3\,-1} = Re\,\rho_{31} = 0 \text{ at the } N^* \text{ vertex}$$

If absorption effects, due to inelastic channels other than K^* N^*, are present it is expected that the density matrix elements will vary with four-momentum transfer.

Using a distorted wave born approximation, Gottfried and Jackson have shown[1] that the transition amplitude for the process $a+b \longrightarrow c+d$ with initial and final state helicities (λ_a, λ^b) and $(\lambda_c \lambda_d)$ may be written

$$\langle \lambda_c \lambda_d | T_j | \lambda_a \lambda_b \rangle = e^{i\delta_j^{(-)}} \langle \lambda_c \lambda_d | B_j | \lambda_a \lambda_b \rangle e^{i\delta_j(+)}$$

where $\langle \lambda_c \lambda_d | B_j | \lambda_a \lambda_b \rangle$ is the one particle exchange amplitude for the partial wave of angular momentum j. Following Jackson *et al.*[3] the elastic amplitudes in the initial and final states were approximated by

$$\exp[2i\delta_j^{(\pm)}] \simeq 1 - C\pm \exp[-\gamma\pm(x-\tfrac{1}{2})^2]$$

where $\delta j^{(\pm)}$ are the elastic scattering phase shifts in the initial $(+)$ and final $(-)$ channels.
The absorption paramenters are

$$C_+ = \sigma_T^{(+)}/4A_+ \text{ and } \gamma_+ = 1/(2q^2A_+)$$

with similar expressions for $C-$ and $\gamma-$. Here, $\sigma T^{(+)}$ is the total K^+p cross-section, A_+ is the parameter which appears in the elastic angular distribution $(d\sigma/dt \propto' e^{A+t})$, t is the four-momentum transfer, q is the incident centre-of-mass momentum and x is the total angular monentum. The amount of absorption in the initial state was determined by De Baere

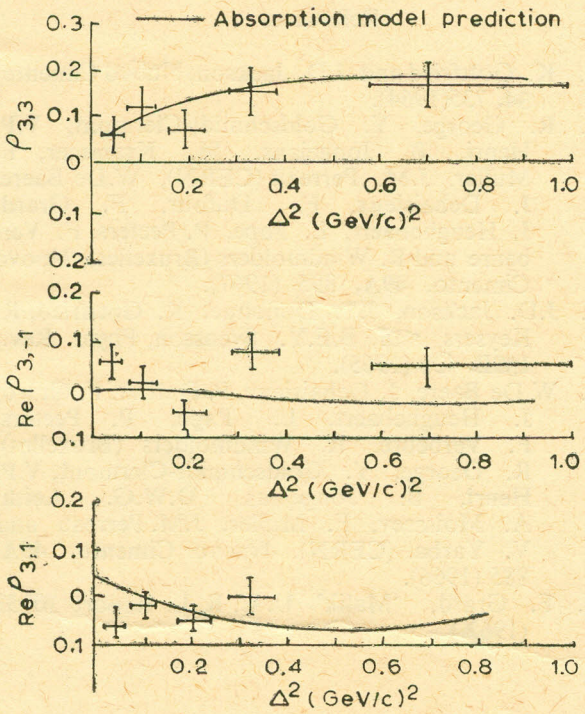

Fig. 2. Density matrix elements of $K^*(892)$ produced in the reaction $K^+p \rightarrow K^*(892)$ $N^*(1236)$ and plotted as the function of $\Delta^2 p — p\pi+$. The solid curve is the prediction of absorption model.

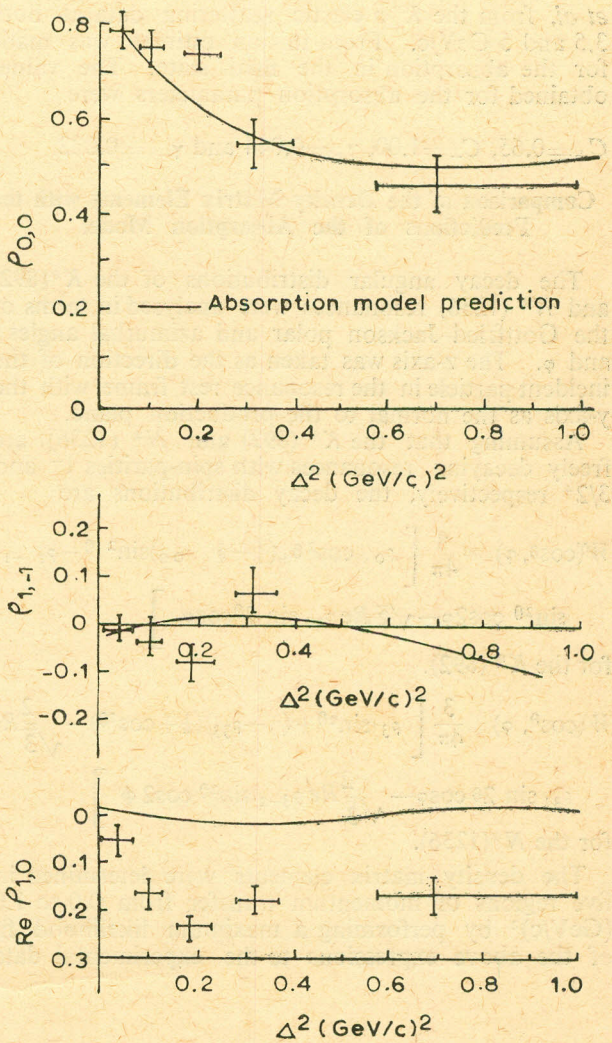

Fig. 3. Density matrix elements of $N^*(1236)$ produced in the reaction $K^*p \rightarrow K^*$ $(892)N^*(1236)$ and plotted as function of $\Delta^2 p$-$p\pi+$ The solid curve is the prediction of the absorption model.

TABLE 1. K*(892) DENSITY MATRIX ELEMENTS.

$\Delta^2_{p-p\pi^+}$ in (GeV/c)^2	No. of events	$\rho_{(0,0)}$	$\rho_{(1,-1)}$	$Re\ \rho_{(1,0)}$
0—0·08	264	0·79±0·04	—0·007±0·027	—0·05±0·03
0·08—0·13	271	0·75±0·04	—0·04±0·026	—0·16±0·03
0·13—0·25	263	0·74±0·03	—0·08±0·03	—0·23±0·02
2·05—0·4	144	0·55±0·05	—0·07±0·04	—0·18±0·03
0·4—1·0	122	0·46±0·06	—0·002±0·054	—0·17±0·04

TABLE 2. N*(1236) DENSITY MATRIX ELEMENTS.

$\Delta_{2p-p\pi}$ in (GeV/c)^2	No. of events	$\rho_{(3,3)}$	$Re\rho_{(3,-1)}$	$Re\rho_{(3,1)}$
0—0·08	264	0·06±0·04	0·06±0·03	—0·06±0·03
0·08—0·13	271	0·12±0·04	0·014±0·030	—0·02±0·03
0·13—0·25	263	0·06±0·04	—0·05±0·03	—0·05±0·04
0·25—0·4	144	0·15±0·05	0·08±0·04	0·003±0·040
0·4—1·0	122	0·16±0·05	0·04±0·04	—0·15±0·04

et al. from the K^+p elastic scattering data at both 3.5 and 5 GeV/c. From this an estimate was made for the absorption in the final state. The values obtained for the absorption parameters were

$C_+=0.65$, $C_-=1.00$, $\gamma_+=0.044$ and $\gamma_- =0.022$.

Comparison of the Density Matrix Elements with the Predictions of the Absorption Model

The decay angular distributions of the $K^*(892)$ and N^* (1236) resonances were analysed in terms of the Gottfried–Jackson polar and azimuthal angles θ and φ. The z-axis was taken as the direction of the incident particle in the resonance rest frame with the y-axis as the normal to the production plane.

Assuming that the K^* (892) and N^* (1236) are freely decaying resonances with spin-parities 1^- and $3/2^+$ respectively, the decay distributions are

$$W(\cos\theta,\varphi)=\frac{3}{4\pi}\left[\rho_{00}\cos^2\theta+(\tfrac{1}{2}-\tfrac{1}{2}\ \rho_{00})\sin^2\theta-\rho_{1-1}\sin^2\theta\cos 2\varphi-\sqrt{2}\,Re\,\rho_{10}\sin 2\theta\cos\varphi\right]$$

for the K^* (892).

$$W(\cos\theta,\varphi)=\frac{3}{4\pi}\left[\rho_{33}\sin^2\theta+(\tfrac{1}{2}-\rho_{33})(\tfrac{1}{3}+\cos^2\theta)-\frac{2}{\sqrt{3}}Re\,\rho_{31}\sin 2\theta\cos\varphi-\frac{2}{\sqrt{3}}Re\,\rho_{3-1}\sin^2\theta\cos 2\phi\right]$$

for the N^*(1236).

The density matrix elements were determined in five regions of momentum transfer from 0.0 to 1.0 (GeV/c)^2 by performing a maximum likelihood fit of the above expressions to the experimental data using the program Malik.[5] The results are summarized in Tables 1 and 2. Figures 2 and 3 show the variation of the density matrix elements of the K^* (892) and N^* (1236) respectively as a function of the four-momentum transfer squared from the target proton to the outgoing $p\pi^+$ system. The curves are the predictions of the absorption model.

Summary and Conclusions

The spin density matrix elements of the $K^*(892)$ and $N^*(1236)$ resonances produced in the reaction

$$K^+p\longrightarrow K^*(892)N^*\ (1236)\ \text{at 5 GeV/c}$$

were determined as a function of four-momentum transfer ($\Delta^2 p\longrightarrow p\pi^+$) from the target proton to the outgoing $p\pi^+$ system. In contrast to the predictions of the simple one pion exchange model variations in the density matrix elements with $\Delta^2 p\longrightarrow p\pi^+$ were found. These variations are in quantitative agreement with the predictions of the absorption model assuming that the reaction is dominated by single pion exchange.

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