Partial Wave Analysis of $\pi^-\pi^-\pi^+\eta$ in the Reaction $\pi^- p \to \pi^-\pi^-\pi^+\eta p$ at 18 GeV/c

Joachim Kuhn
for the E852 collaboration

Rensselaer Polytechnic Institute, Dept. of Physics, 110 8th Street, Troy, NY 12180, USA

Abstract. A partial wave analysis of $\pi^-\pi^-\pi^+\eta$ was performed on data taken during the 1995 running period of Experiment 852 (E852) at the Multiple Particle Spectrometer at Brookhaven National Laboratory.

New $J^{PC} = 1^{++}$ and $J^{PC} = 2^{-+}$ states were found in $f_1(1285)\pi^-$, $a_2^-(1320)\eta$, $a_0^-(980)\rho$ and $a_1^-(1265)\eta$ decays. Considerable strength was also observed in the $J^{PC} = 1^{-+}$ waves in the $f_1(1285)\pi^-$ and $a_0(980)\rho$ decay channels, but the process seems not to be dominated by the previously discovered $\pi_1(1600)$.

INTRODUCTION

The search for exotic mesons has been the main focus of meson spectroscopy for many years, but only recently states which are not composed of a $q\bar{q}$ system have been established experimentally[1, 2, 3]. All of these states have been detected looking for resonances with unusual combinations of spin J, parity P and charge conjugation C, J^{PC}, which cannot be accessed by a $q\bar{q}$ meson. Of special interest are $J^{PC} = 1^{-+}$ hybrids, which are predicted to be lowest in mass[4, 5, 6, 7]. According to the flux tube model[4, 5] this state should primarily decay into S- and P-wave mesons, for example $b_1(1235)\pi$ or $f_1(1285)\pi$.

The analysis on the $\pi^-\pi^-\pi^+\eta$ final state presented in this work makes use of the $\pi^-\pi^+\eta$ decay mode of the $f_1(1285)$, in the hope to extract evidence for a $J^{PC} = 1^{-+}$ exotic state.

DATA SELECTION

During the 1995 data taking run of E852 at the MPS facility at Brookhaven National Laboratory a total of 710×10^6 events were recorded, 265×10^6 of which were of the required trigger topology of three downstream charged tracks in coincidence with a large angle recoil. Two clusters were required in a lead glass calorimeter, in agreement with the decay of $\eta \to \gamma\gamma$. After reconstruction, topological and kinematical selection 82,645 events of the type $\pi^- p \to \pi^-\pi^-\pi^+\eta p$ remained. It is noteworthy that, in order to limit the possible number of waves, a cut was performed to remove events of the type $\pi^- p \to \eta'(958)\pi^- p$. The effect of this cut can be seen in figure 1, which also shows the

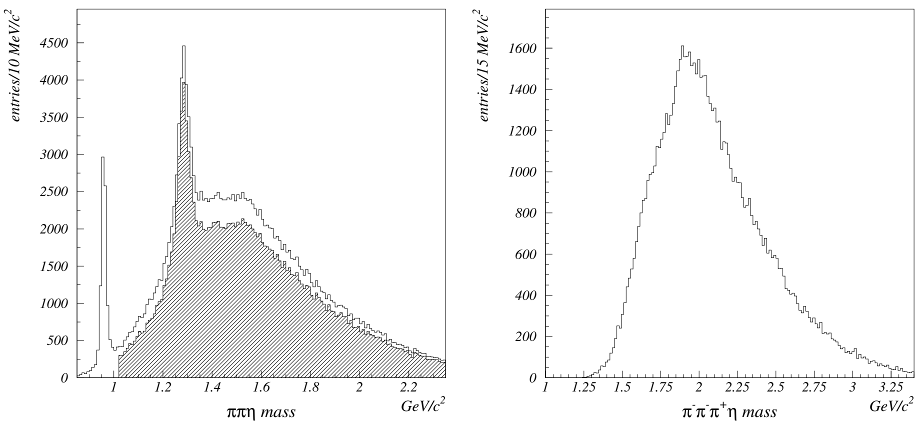

FIGURE 1. **Left:** $\pi^-\pi^+\eta$ mass. The shaded histogram is the distribution for the final data set, the unshaded shows the distribution before removing events from the reaction $\eta' \to \pi\pi\eta$. **Right:** $\pi^-\pi^-\pi^+\eta$ mass for the final data set.

total meson mass spectrum for the final data set.

PARTIAL WAVE ANALYSIS

A full partial wave analysis was performed in order to extract the spin and parity of the meson X^- in the reaction $\pi^- p \to X^- p \to \pi^-\pi^-\pi^+\eta p$. The decay of this state was assumed to populate two body intermediate states. The following possibilities were considered as intermediate states: $f_1(1285)\pi^-$, $\eta(1295)\pi^-$, $a_2^-(1320)\eta$, $a_1^-(1260)\eta$, $a_0^-(980)\rho$ and $a_2^-(1320)\rho$.

The partial wave analysis was performed in the four meson mass range from 1.30 GeV/c^2 to 2.90 GeV/c^2, in bins of 0.08 GeV/c^2. The 4-momentum transfer t was required to be between -0.1 GeV^2/c^2 and -1.5 GeV^2/c^2. This limited the data set to 68,900 events.

The intensity and phase distributions were fitted pairwise over mass ranges where the coherence between the two waves in consideration was high. The results of these fits can be seen in figures 2 and 3. Figure 4 shows the intensity from the mass-independent analysis for the $J^{PC} = 1^{-+}$ waves in the $f_1(1285)\pi^-$ and $a_0^-(980)\rho$ decay mode. Since there are still studies underway for these two waves the Breit-Wigner fit is not shown. However, the distribution suggests that the mass of the state in $f_1(1285)\pi^-$ is inconsistent with the $\pi_1(1600)$ excitation alone.

CONCLUSIONS

A data set of 68,900 events consistent with the reaction $\pi^- p \to \pi^-\pi^-\pi^+\eta p$ has been selected from the 1995 run period of E852 at BNL. A partial wave analysis of this

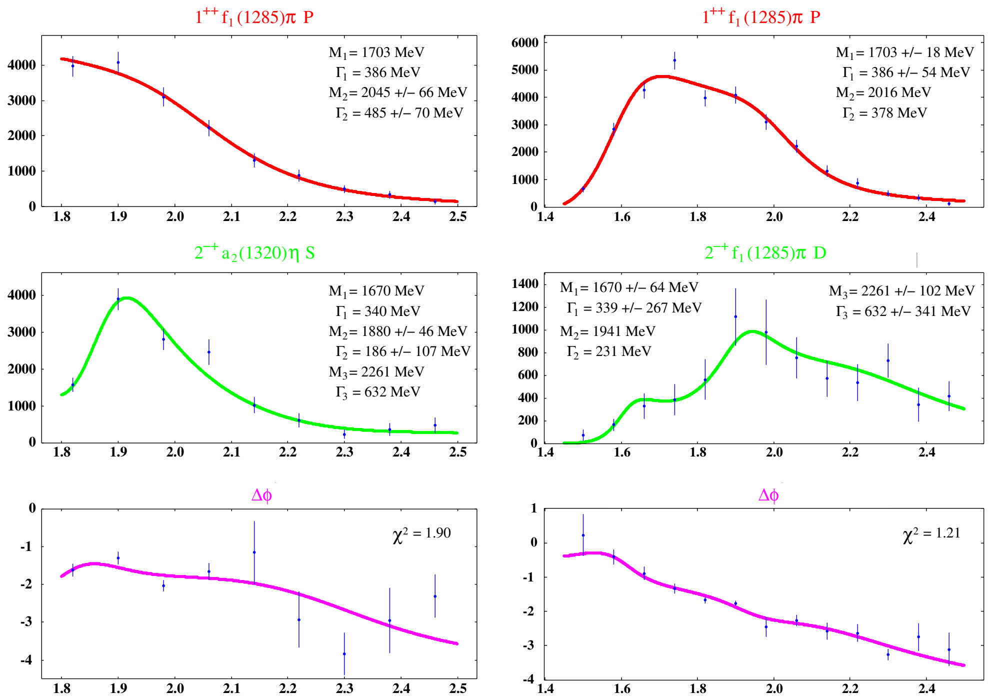

FIGURE 2. Results of the PWA fit and the Breit-Wigner fit. The plots are grouped in three: $\Delta\phi$ is the difference of the phase of the wave in the top and the wave in the middle plot.

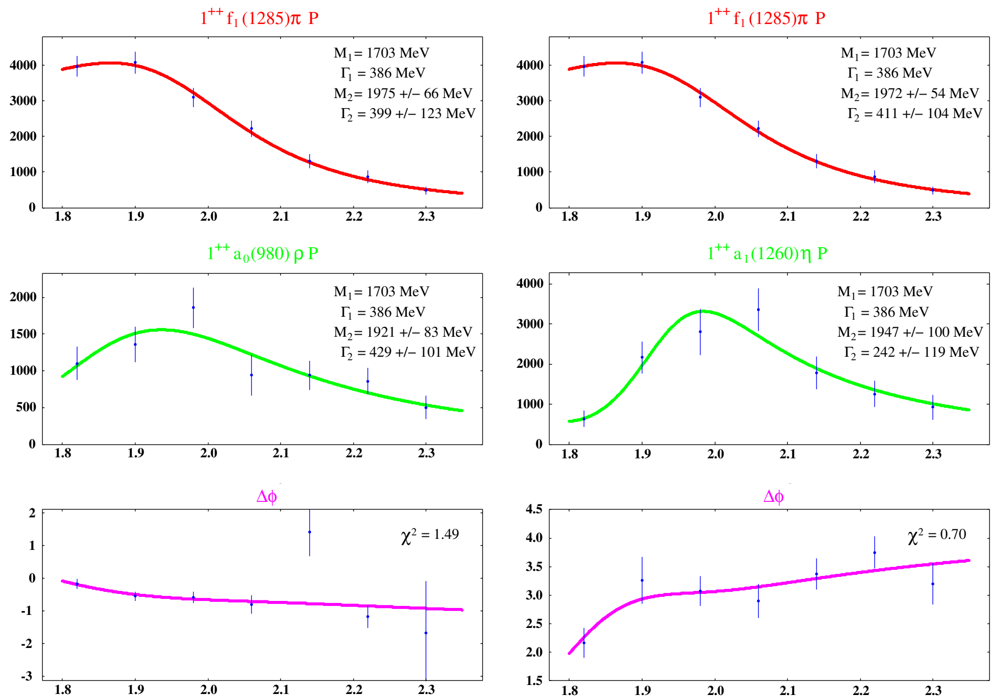

FIGURE 3. Results of the PWA fit and the Breit-Wigner fit. The plots are grouped in three: $\Delta\phi$ is the difference of the phase of the wave in the top and the wave in the middle plot.

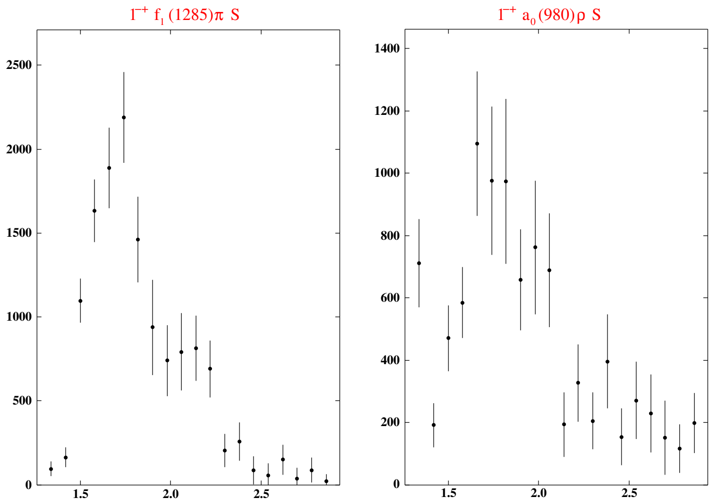

FIGURE 4. Intensities of the $J^{PC} = 1^{-+}$ exotic waves in the PWA fit.

data set shows that most of the intesity is produced via natural parity exchange. The strongest intensities are observed in the waves with $J^{PC} = 1^{++}$ in the channels $f_1(1285)\pi^- P$, $a_0^-(980)\rho P$, $a_1^-(1260)\eta P$ and in the waves with $J^{PC} = 2^{-+}$ in the channels $f_1(1285)\pi^- D$ and $a_2^-(1320)\eta S$.

The intensities of theses waves and the phases between them can be well described by Breit-Wigner shapes. There is strong evidence for two $J^{PC} = 1^{++}$ states with masses ${}^{(1^+)}\mathrm{M}_1 = 1.703\ \mathrm{GeV}/c^2$ and ${}^{(1^+)}\mathrm{M}_2 = 2.016\ \mathrm{GeV}/c^2$ and widths ${}^{(1^+)}\Gamma_1 = 0.386\ \mathrm{GeV}/c^2$ and ${}^{(1^+)}\Gamma_2 = 0.378\ \mathrm{GeV}/c^2$. The $J^{PC} = 2^{-+}$ waves can succesfully be fitted to three Breit-Wigner resonances with masses ${}^{(2^-)}\mathrm{M}_1 = 1.670\ \mathrm{GeV}/c^2$, ${}^{(2^-)}\mathrm{M}_2 = 1.941\ \mathrm{GeV}/c^2$ and ${}^{(2^-)}\mathrm{M}_3 = 2.261\ \mathrm{GeV}/c^2$ and widths ${}^{(2^-)}\Gamma_1 = 0.339\ \mathrm{GeV}/c^2$, ${}^{(2^-)}\Gamma_2 = 0.231\ \mathrm{GeV}/c^2$ and ${}^{(2^-)}\Gamma_3 = 0.632\ \mathrm{GeV}/c^2$. ${}^{(1^+)}\mathrm{M}_1$, ${}^{(2^-)}\mathrm{M}_1$ and ${}^{(2^-)}\mathrm{M}_3$ and the corresponding widths are consistent with previously observed states, listed in[8].

There is also considerable strength in the $J^{PC} = 1^{-+}$ waves in the $f_1(1285)\pi^-$ and $a_0^-(980)\rho$ final state. The process however does not seem to be dominated by the previously observed $\pi_1(1600)$ and a Breit-Wigner fit to the intensity alone yields a mass above $1.6\ \mathrm{GeV}/c^2$. Systematic studies are currently underway to determine parameters for the exotic signal.

REFERENCES

1. Adams, G. S. *et al.*, *Phys. Rev. Lett.*, **81**, 5760 (1998).
2. Chung, S. U. *et al.*, *Phys. Rev. D*, **60**, 92001 (1999).
3. Ivanov, E. I. *et al.*, *Phys. Rev. Lett.*, **86**, 3977 (2001).
4. Kokoski, R., and Isgur, N., *Phys. Rev. D*, **35**, 907 (1987).
5. Close, F. E., and Page, P. R., *Nucl. Phys. B*, **443**, 233 (1995).
6. Lacock, P. *et al.*, *Phys. Lett. B*, **401**, 308 (1997).
7. Bernard, C. *et al.*, *Phys. Rev. D*, **56**, 7039 (1997).
8. The Particle Data Group, *Eur. Jou. of Phys. C*, **3**, 1–794 (1998).