Observation of the $\eta(1295)$ and $\eta(1440)$ produced in the Reaction $\pi^- p \to \eta\pi^+\pi^- n$ at 18 Gev/c

Joseph J. Manak for the E852 Collaboration

Thomas Jefferson National Accelerator Laboratory, Newport News, VA, 23606

Abstract. A partial-wave analysis of 9082 $\eta\pi^+\pi^- n$ events produced in the reaction $\pi^- p \to \eta\pi^+\pi^- n$ at 18.3 Gev/c has been carried out using data from experiment E852 at Brookhaven National Laboratory. The data is dominated by $J^{PC} = 0^{-+}$ partial waves consistent with observation of the $\eta(1295)$ and the $\eta(1440)$. The mass and width of the $\eta(1295)$ was determined to be 1282 ± 5 MeV and 66 ± 13 MeV respectively while the $\eta(1440)$ was observed with a mass of 1404 ± 6 MeV and a width of 80 ± 21 MeV. Other partial waves of importance include the 1^{++} and the 1^{+-} waves. Results of the partial wave analysis are combined with results of other experiments to estimate $f_1(1285)$ branching fractions. These values are considerably different from current values determined without the aid of amplitude analyses.

INTRODUCTION

A partial-wave analysis of 9082 events of the type

$$\pi^- p \to \eta\pi^+\pi^- n, \quad \eta \to 2\gamma \tag{1}$$

was performed on the $\eta\pi^+\pi^-$ system in the 1.21 to 1.53 GeV/c^2 mass region at 18.3 GeV/c. The data sample was collected during the summer of 1994 using the Multi-Particle Spectrometer (MPS) at the Alternating Gradient Synchrotron (AGS) facility of Brookhaven National Laboratory (BNL).

I ANALYSIS

The formalism used in this analysis is based on the papers of Chung [1] and Chung and Trueman [2]. The analysis technique involved the use of the reflectivity basis to describe the individual partial waves and the maximization of an extended log likelihood function in the fitting procedure. The procedure and analysis programs are described by Cummings and Weygand [3].

The analysis was restricted to σ/f_0, a_0 and ρ isobars and $J < 2$ partial waves. The ρ isobar was modeled by a relativistic Breit-Wigner with parameters extracted from the Particle Data Book [5], while the a_0 was modeled as a Breit-Wigner form with a mass of 980 MeV and a width of 72 MeV. The $\pi\pi$ S-wave (the σ/f_0) was represented by a parameterization of the $\pi^+\pi^-$ S-wave provided by K. L. Au *et al.* [4]. In addition, the analysis required a rank 2 fit including both spin-flip and spin-non-flip amplitudes to describe the data set.

A fit with 30 MeV $\eta\pi^+\pi^-$ mass bins and a set of 6 partial waves was chosen to best describe the data. The partial waves used in the fit were: $0^{-+}a_0\pi$, $0^{-+}\sigma\eta$, $1^{+-}\rho\eta$, $1^{++}a_0\pi$, $1^{++}\sigma/f_0\eta$ and $1^{--}\rho\eta$.

II RESULTS

The results of the fit for the 0^{-+} partial waves are shown in Fig. 1. In Fig. 1a is the $0^{-+}a_0\pi$ intensity as a function of $\eta\pi^+\pi^-$ effective mass. A sharp peak in the D region is evident, consistent with the observation of $\eta(1295) \to a_0\pi$ as well as some intensity extending out to $1.4 GeV/c^2$. Fig. 1b shows the $0^{-+}\sigma\eta$ wave, evident is a two peaked structure with enhancements at 1.3 and 1.4 GeV/c^2. The coherent sum of the 0^{-+} partial waves is shown in Fig. 1c. Two peaks are clearly evident, consistent with the production of $\eta(1295)$ and $\eta(1440)$ production.

Shown in Fig. 2 are the $J^{PC} = 1^{++}$ partial waves. Fig. 2a is the 1^{++} $a_0\pi$ partial wave intensity distribution. This wave shows evidence of f_1 production. In Fig. 2b is shown the 1^{++} $\sigma\eta$ partial wave intensity distribution. The intensity observed at higher mass was found to be unstable under the addition and subtraction of other partial waves and is not considered significant. Fig. 2c is the coherent sum of the $J^{PC} = 1^{++}$ partial waves. When a comparison to the coherent sum of the 0^{-+}

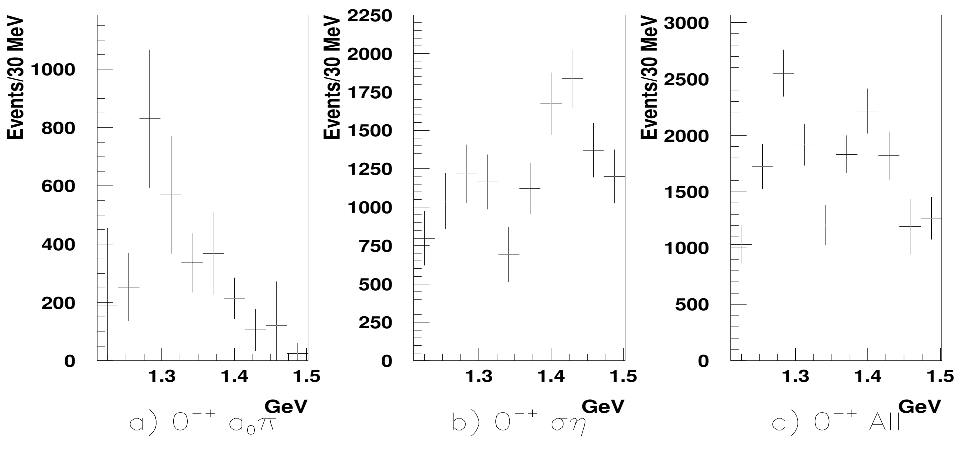

FIGURE 1. a: $0^{-+}a_0\pi$ intensity, b: $0^{-+}\sigma\eta$ intensity, c: Total 0^{-+} intensity

partial waves (Fig. 1c) is made one observes that the majority of signal in the 1.3 and 1.4 GeV/c^2 regions arises not from 1^{++} partial waves but from the 0^{-+} waves. This observation has important implications on the f_1 branching ratio to $\eta\pi^+\pi^-$ (see conclusions).

Shown in figures 3a and 3b are the intensity distributions for the $1^{+-}\rho\eta$ and $1^{--}\rho\eta$ partial waves. Previous experiments [7] have claimed the $1^{+-}\rho\eta$ wave to be evidence for for production of the $b_1(1235)$ with a $\rho\eta$ decay mode. However the lack of structure in the 1^{+-} wave discourages this interpretation. The $1^{--}\rho\eta$ partial wave is the only negative reflectivity partial wave and does not interfere with any other partial waves in the fit. The wave steadily increases throughout the low-mass region and its behavior is consistent with it being the low-mass tail of the $\rho(1700)$.

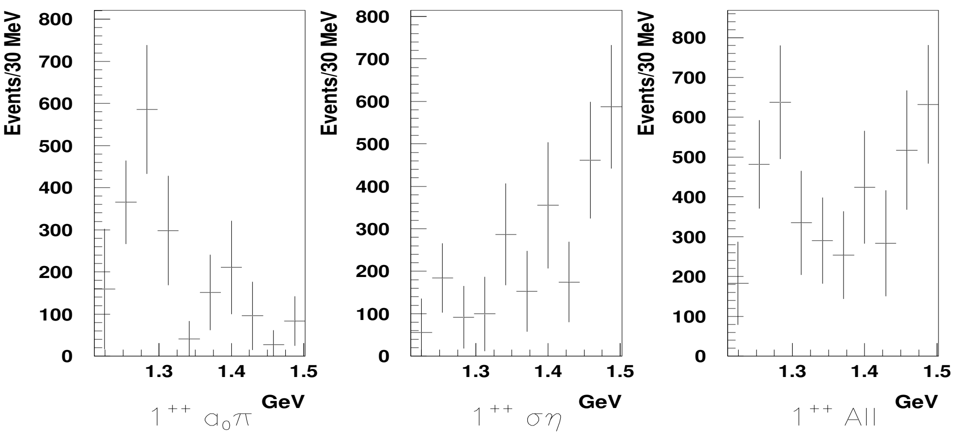

FIGURE 2. a: $1^{++}a_0\pi$ intensity, b: $1^{++}\sigma\eta$ intensity, c: Total 1^{++} intensity

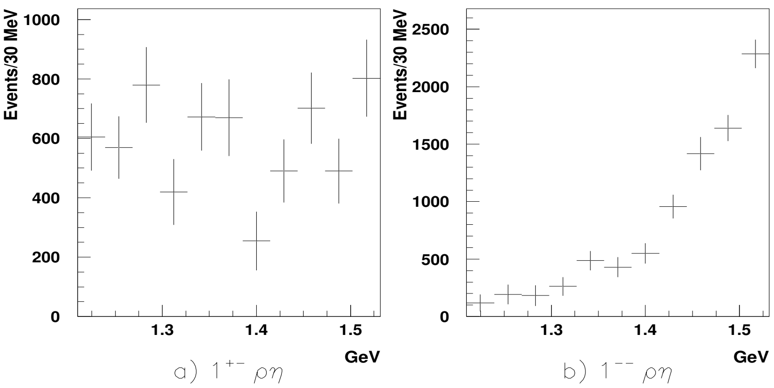

FIGURE 3. a: $1^{+-}\rho\eta$ intensity, b: $1^{--}\rho\eta$ intensity

III CONCLUSIONS

From this analysis it is clear that $\eta(1295)$ production dominates the 1.3 GeV/c^2 region accounting for roughly 80% of the peak. This conclusion is inconsistent with the assumptions of previous analysis [6] which determined the $f_1 \rightarrow \eta\pi^+\pi^-$ branching fractions assuming the peak in the $\eta\pi^+\pi^-$ mass spectrum consisted of only single f_1 state ($J^{PC} = 1^{++}$) resting on top on an incoherent background. This assumption is clearly incorrect, and values for the branching fractions must be corrected.

Corden *et al.* [6] studied the reactions $\pi^- p \rightarrow \eta\pi^+\pi^- n$ and $\pi^- p \rightarrow K\overline{K}\pi n$ at 15 GeV/c. In their analysis they obtained a $K\overline{K}\pi/\eta\pi\pi$ branching ratio in the D region of 0.5 ± 0.2 without the aid of a partial wave analysis. Using this result, one can estimate the true $f_1 \rightarrow \eta\pi^+\pi^-$ branching ratio using the results of this analysis. Assuming the 80% of the signal in the 1.3 GeV/c^2 peak is caused by the production of $\eta(1295)$ one can examine the effect of this result of the f_1 branching fractions. The results of this analysis are suggest a $f_1 \rightarrow 4\pi$ branching fraction of $59 \pm 17 \pm ?\%$, $f_1 \rightarrow \eta\pi\pi$ of $8 \pm 3 \pm ?\%$, $f_1 \rightarrow \gamma\rho$ of $13 \pm 8 \pm ?\%$ and $f_1 \rightarrow K\overline{K}\pi$ of $20 \pm 7 \pm ?\%$.

Assigning systematic errors to these $f_1(1285)$ branching fractions is difficult due to the undetermined uncertainties in branching ratios for the 4π and $\gamma\rho^0$ decay modes. However it is clear from this exercise that the $f_1(1285)$ branching fractions as listed in the particle data book need to be corrected.

In addition, the $\eta(1295)$ was seen to decay to both $a_0\pi$ and $\sigma\eta$. The $a_0\pi/\sigma\eta$ branching ratio for $\eta(1295)$ was estimated to be 0.48 ± 0.22 with a large undetermined systematic error. The mass and width of the $\eta(1295)$ were determined to be 1282 ± 5 MeV and 66 ± 13 MeV respectively.

The 1.4 GeV/c^2 region was found to be dominated by a large $0^{-+} f_0/\sigma\eta$ signal present in the second rank of the fit. This signal is consistent with production of a single state, the $\eta(1440)$. The mass and width of the $\eta(1440)$ are estimated to be 1404 ± 6 MeV and 80 ± 21 MeV. This result is remarkably consistent with the Particle Data Group weighted average value for the mass and width of the $\eta(1440)$ of 1415 ± 10 MeV and 60 ± 20 MeV.

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