STUDY OF THE $\eta\pi^-$, $\eta\pi^0$ AND $\eta\eta$ SYSTEMS IN $\pi^- p$ INTERACTIONS AT 18 GeV/c

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The reactions $\pi^- p \to p\eta\pi^-$ and $\pi^- p \to n\eta\pi^0$ at 18 GeV/c are studied using a lead glass hodoscope to detect the photons from η and π^0 decay and using the Brookhaven MultiParticle Spectrometer to measure the charged tracks. Strong enhancements are observed in both reactions in the $a_2(1320)$ mass region. Effective mass distributions as well as decay asymmetries as a function of effective mass are presented. A study of the $\eta\eta$ system in the reaction $\pi^- p \to n\eta\eta$ is also described in which a strong S-wave enhancement is observed near threshold.

1 Introduction

This paper [a] reports preliminary results from experiment E-852 being carried out at Brookhaven National Laboratory. The experiment is motivated in part by previous experiments which have claimed [1,2] to have observed manifestly exotic $J^{PC} = 1^{-+}$ resonant states in the reactions

$$\pi^- p \to n\eta\pi^0 \tag{1}$$

and

$$\pi^- p \to p\eta\pi^-. \tag{2}$$

In another recent experiment [3] however, no evidence for resonant behavior in reaction 2 is observed.

In the present experiment, we study both reactions 1 and 2 at the same incident beam momentum (18 GeV/c) and under common experimental conditions in order to be able to compare the production and decay of potential exotic states in the two charged states. This is important because the production characteristics reported [1] for reaction 1 at 100 GeV/c are quite different from those obtained [2] for reaction 2 at 6 GeV/c incident beam momentum.

This experiment is also analyzing data in a number of different reactions among which is the reaction

$$\pi^- p \to n\eta\eta. \tag{3}$$

This reaction is of particular interest because of the renewed interest in the scalar nonet [4] and scalar glueball candidate [5] being discussed at this meeting. Preliminary results on the analysis of reaction 3 are given in Section 3.3 below.

2 Experimental Arrangement

Experiment E-852 is being carried out at the MultiParticle Spectrometer facility at Brookhaven. The facility has been supplemented with the addition of a 3045 element lead glass detector [6] and a target region containing a thallium-doped cesium iodide detector [7] and a cylindrical drift chamber. The spectrometer is shown schematically in Fig. 1 and consists of three parts.

The first part is the target region (designated as **T** in Fig. 1) which is located near the center of the 1.0 T MPS magnet. In this region, a 30-cm long liquid hydrogen target is surrounded by the cylindrical drift chamber (CDC) which is itself surrounded by the CsI detector. The second part is the charged-particle tracking region downstream of the target, still within the magnet. This

[a] Presented at Hadron95 by N.M. Cason for the E852 collaboration

Figure 1: Diagram of the apparatus.

consists of proportional chambers **P1**, **P2** and **P3**; six 7-plane drift chamber modules **D1-D6**; and a picture-frame lead/scintillator-sandwich photon veto **V**. Finally, the photon calorimeter region downstream of the magnet consists of a large proportional chamber **TDX**, and the lead-glass hodoscope **LGD**.

The experiment took its first data in 1994, obtaining some 200,000 triggers of various types. The second run in 1995 took an additional 800,000 triggers. The data reported on in this paper is based on all of the data from the 1994 run and thus contains approximately 20% of the data taken to date.

3 Analysis

3.1 Study of the reaction $\pi^- p \to p\eta\pi^-$

A sample of events corresponding to reaction 2 was obtained by selecting reconstructed events with a single charged recoil track detected in the CDC, a single negative track in the downstream chamber system and two electromagnetic clusters in the LGD. These events were kinematically constrained to be consistent with reaction 2 using the fitting program SQUAW [8]. Events fitting with a confidence level greater than 2% were then chosen for further analysis.

Shown in Fig.2 is the two-photon effective mass distribution for the events before the kinematic fit requirement and after a missing-mass cut which roughly simulates the 2% confidence level used in the analysis. As can be seen, there is only a small non-η background in the data sample. In Fig.3 is shown the final $\eta\pi^-$ effective mass distribution for reaction 2. The clear peak in the $a_2^-(1320)$ mass region is the region where earlier experiments found evidence for an exotic state.

Figure 2: Two photon effective mass distribution for events of reaction 2. The dashed histogram corresponds to events satisfying a missing mass cut around the proton

Figure 3: M($\eta\pi^-$) for events of reaction 2.

Decay angular distributions in the Gottfried-Jackson frame have been determined as a function of $\eta\pi^-$ effective mass. Forward-backward asymmetry of this decay angle can occur only if there is interference between even and odd partial waves in the decay of the $\eta\pi^-$. We have defined the direction to be forward when the outgoing pion is in the beam direction. Shown in Fig. 4 is this asymmetry as a function of mass and one notes a significant asymmetry in the data beginning at about 1.2 GeV/c suggesting the presence of P-wave interfering with the dominant D-wave of the $a_2^-(1320)$. The presence of the P-wave indicates production of a final state with $J^{PC} = 1^{-+}$, but whether there is resonant production of such a state can only be determined by the full amplitude analysis of the data which is under way.

Figure 4: Forward-backward decay asymmetry in the Gottfried-Jackson frame for events of reaction 2.

3.2 *Study of the reaction* $\pi^- p \to n\eta\pi^0$

In order to study reaction 1, the set of events with no charged tracks and four electromagnetic clusters were selected. The events were tested for kinematic consistency with reaction 1 and were further required to be inconsistent with the reaction $\pi^- p \to n\pi^0\pi^0$. The $\eta\pi^0$ effective mass distribution for these events with $|t| > 0.2(GeV/c)^2$ is shown in Fig. 5. As in the $\eta\pi^-$ spectrum in Fig. 3, a strong signal is observed in the data in the $a_2(1320)$ mass region.

The decay asymmetry for the events consistent with reaction 1 is shown as a function of $\eta\pi^0$ effective mass in Fig. 6. Again a significant asymmetry is observed indicating the presence of $J^{PC} = 1^{-+}$ interfering with D-wave. The character of the asymmetry is somewhat different than that of reaction 2, although the sign of the asymmetry and its magnitude are similar. Here the asymmetry goes negative at about 1.3 GeV and is slightly positive around 1.2 GeV. A full amplitude analysis of this data is also underway to determine the character of the P-wave.

Figure 5: M($\eta\pi^0$) for events of reaction 1.

Figure 6: Forward-backward decay asymmetry in the Gottfried-Jackson frame for events of reaction 1.

3.3 *Study of the reaction* $\pi^- p \to n\eta\eta$

The sample of events for reaction 3 were selected from the same data set as for reaction 1 using similar criteria. The resulting events have a background which is estimated to be less than 15%. Shown in Fig. 7 is the effective mass distribution for the events showing a large threshold enhancement peaking at about 1.27 GeV/c^2. There is no statistically significant evidence for structure at higher mass, particularly in the region of 1.590 GeV/c^2 where previous experiments [9] have reported structure.

The t-distribution for the events in the 1.2-1.4 GeV mass region shown in Fig. 8 is very sharply peaked fitting a distribution of the form $e^{-b|t|}$ with $b = 9.8 \pm 1.1(GeV/c)^2$, consistent with what one might expect if the reaction proceeded via single pion exchange. The corrected decay angular distribution for this mass region is shown in Fig. 9 and is consistent with isotropy. The Trieman-Yang angular distribution (not shown) is also consistent with isotropy. These features lead us to conclude that the events in this mass region are consistent with having $J^{PC} = 0^{++}$ and with being produced by single pion exchange.

Figure 7: Effective mass distribution for the $\eta\eta$ system for events of reaction 3.

Figure 8: t-distribution for the $\eta\eta$ effective mass region from 1.2 to 1.4 GeV/c^2

Figure 9: Decay angular distribution for the $\eta\eta$ effective mass region from 1.2 to 1.4 GeV/c^2

4 Summary and Conclusions

We have presented preliminary data from BNL E-852 based on 20% of the available data. These data show an asymmetry in the $\eta\pi$ decay angular distribution in both reactions $\pi^- p \rightarrow p\eta\pi^-$and $\pi^- p \rightarrow n\eta\pi^0$at 18 GeV/c indicating production of the exotic $J^{PC} = 1^{-+}$ wave. Amplitude analyses are under way to determine whether the waves are resonant. In addition, data from the reaction $\pi^- p \rightarrow n\eta\eta$ shows evidence of scalar production in the region around 1.27 GeV/c^2. An amplitude analysis is under way to determine the nature of of this production.

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