STUDY OF THE VECTOR VECTOR FINAL STATES CENTRALLY PRODUCED IN pp INTERACTIONS AT 300 GeV/c

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Abstract

We have performed a search for vector–vector final states centrally produced in the reaction $pp \to p_f(VV)p_s$ at 300 GeV/c using the CERN Ω spectrometer. Evidence is found for $\omega\rho^0$, $\omega\omega$, $\rho^0\rho^0$ and $\rho^+\rho^-$ associated production. No evidence is found for $\omega\phi$ production.

1. Introduction

The search for non $q\bar{q}$ mesons such as glueballs, hybrids and multiquark states is the main motivation of present hadron spectroscopy.

Searches for new resonances decaying to two vector mesons have been extensively performed in hadron induced reactions [1] [2], $\gamma\gamma$ collisions [3] and J/ψ radiative decays [4]. In particular, $\gamma\gamma$ collisions have reported evidence for an anomalous threshold enhancement in the $\rho^0\rho^0$ final state which could be due to the presence of 4-quark resonances [5].

The WA76 experiment, at the CERN Ω spectrometer, has performed a systematic exploration of resonance production in the central region of hadronic collisions. The search for vector–vector final states has provided evidence for centrally produced $\phi\phi$ [6] and $K^{*0}\bar{K}^{*0}$ [7]. It is therefore of interest to study other two vector mesons final states which could give new information and help in the understanding of the dynamics underlying the production of resonances in this kinematical region.

Details on the layout of the apparatus of the WA76 experiment, trigger conditions and data processing have been given in a previous publication [8]. This paper describes the search for

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vector–vector final states in the reactions:

$$pp \rightarrow p_f(VV)p_s$$

at 300 GeV/c, where the subscripts f and s indicate the fastest and the slowest particles in the laboratory respectively and the symbol VV indicates the $\omega\rho^0$, $\omega\phi$, $\omega\omega$, $\rho^0\rho^0$ and $\rho^+\rho^-$ final states.

2. Study of the $\omega\rho^0$ final state

The reaction $pp \rightarrow p_f(2\pi^+2\pi^-\pi^0)p_s$ has been selected from the sample of events having six outgoing charged tracks and only two γ's having an energy greater than 1.0 GeV deposited in the electromagnetic calorimeters, by requiring momentum and energy balance.

Fig. 1a) shows the combinatorial $\pi^+\pi^-\pi^0$ mass spectrum (4 entries per event), where clear η and $\omega(783)$ signals can be observed.

The $\pi^+\pi^-$ effective mass distributions in the $\omega(783)$ region and in its side bands (hatched histogram) are shown in fig. 1b). A $\rho^0(770)$ can be seen in the $\pi^+\pi^-$ mass spectrum associated with the $\omega(783)$, but no signal is observed in the wings, indicating evidence for the production of the $\omega\rho^0$ final state.

The fraction of the $\omega\rho^0$ final state has been estimated by a channel likelihood fit [9]: we find $3.8 \pm 0.6\%$, corresponding to 304 ± 50 events. The resulting $\omega\rho^0$ mass spectrum is shown in fig. 1c).

A spin-parity analysis of the $\omega\rho^0$ system has been performed using Zemach tensors, limiting the orbital momentum between the ρ^0 and the ω to values smaller than 2. If we assume that one wave dominates the spectrum we find that the best description of the data is obtained with $J = 2$, $J^P = 2^-$ being slightly favoured with respect to 2^+.

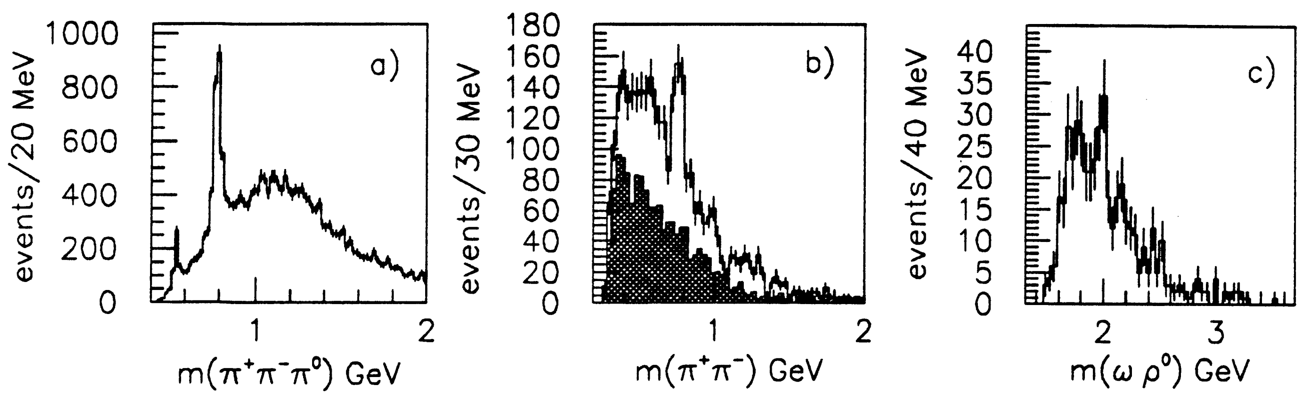

Figure 1: a) Combinatorial $\pi^+\pi^-\pi^0$ effective mass distribution; b) $\pi^+\pi^-$ effective mass distribution opposite to the ω and in its side bands (hatched histogram); c) $\omega\rho^0$ effective mass distribution obtained by the channel likelihood fit.

3. Search for the $\phi\omega$ final state

The reaction $pp \to p_f(K^+K^-\pi^+\pi^-\pi^0)p_s$ has been selected as described in section 2 but requiring, in addition, one K positively identified by the Cherenkov system.

The scatter plot $m(\pi^+\pi^-\pi^0)$ vs $m(K^+K^-)$, not shown, does not present any accumulation of events in the region where the ω and ϕ bands overlap. Therefore we conclude that there is no evidence, with the present statistics, for associated $\omega\phi$ production.

4. Study of the $\omega\omega$ final state

The reaction $pp \to p_f(2\pi^+2\pi^-2\pi^0)p_s$ has been selected from the sample of events having six outgoing charged tracks and only four γ's detected in the electromagnetic calorimeters by requiring momentum and energy balance.

Fig. 2a) shows the combinatorial $\pi^+\pi^-\pi^0$ effective mass where a clear $\omega(783)$ signal can be seen. Requiring one $\pi^+\pi^-\pi^0$ combination to be in the $\omega(783)$ region we obtain the $\pi^+\pi^-\pi^0$ mass spectrum shown in fig. 2b), where the $\omega(783)$ signal can be clearly seen with little background. The $\omega\omega$ mass distribution is shown in fig. 2c).

An analysis of the angular distributions of the $\omega\omega$ system shows that $J^P = 0^-$ is less favoured than 0^+ or 2^+.

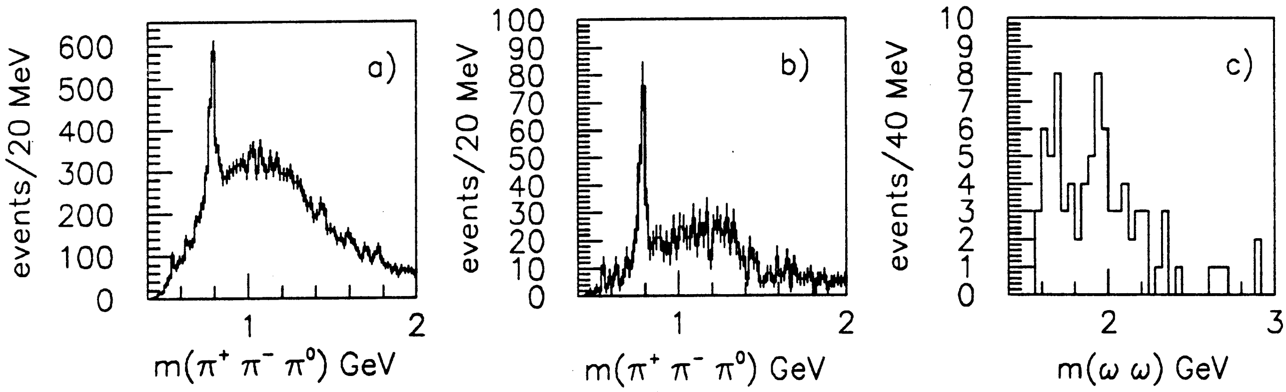

Figure 2: a) Combinatorial $\pi^+\pi^-\pi^0$ effective mass; b) $\pi^+\pi^-\pi^0$ effective mass associated with an ω; c) $\omega\omega$ effective mass distribution.

5. Study of the $\rho^0\rho^0$ and $\rho^+\rho^-$ final states

Fig. 3(a,d) shows the $m(\pi^+\pi^-)$ vs $m(\pi^+\pi^-)$ and $m(\pi^-\pi^0)$ vs $m(\pi^+\pi^0)$ scatter plots together with their projections, after having subtracted the combinatorial background, obtained from the study of reactions $pp \to p_f(2\pi^+2\pi^-)p_s$ and $pp \to p_f(\pi^+\pi^-2\pi^0)p_s$ respectively. An accumulation of events can be observed in each plot in the region of the two overlapping ρ bands, indicating the presence of associated $\rho^0\rho^0$ and $\rho^+\rho^-$ production.

From the channel likelihood fit we find a significant associated $\rho\rho$ production in both channels: $8.2\pm0.6\%$ for the $\rho^0\rho^0$ final state and $11.2\pm1.8\%$ for the $\rho^+\rho^-$ one. The resulting $\rho^0\rho^0$ and $\rho^+\rho^-$ mass distributions are shown in fig. 4. The two spectra have been normalized by using the $f_1(1285)$ signal seen in both $2\pi^+2\pi^-$ and $\pi^+\pi^-2\pi^0$ final states, after having corrected for the geometrical acceptance and Clebsch Gordan coefficients. The ratio between the two cross sections is found to be $\frac{\sigma(\rho^+\rho^-)}{\sigma(\rho^0\rho^0)} = 3.4 \pm 1.1$. Therefore in central production we do not observe a suppression of the $\rho^+\rho^-$ cross section with respect to $\rho^0\rho^0$ as observed in $\gamma\gamma$ collisions.

A spin–parity analysis of the $\rho^0\rho^0$ and $\rho^+\rho^-$ final states has been performed, assuming that only one wave dominates the spectrum. The angular distributions for the $\rho^0\rho^0$ system are well described by the amplitude $J^P = 2^+$, while the $\rho^+\rho^-$ final state requires both 2^+ and 0^+ contributions.

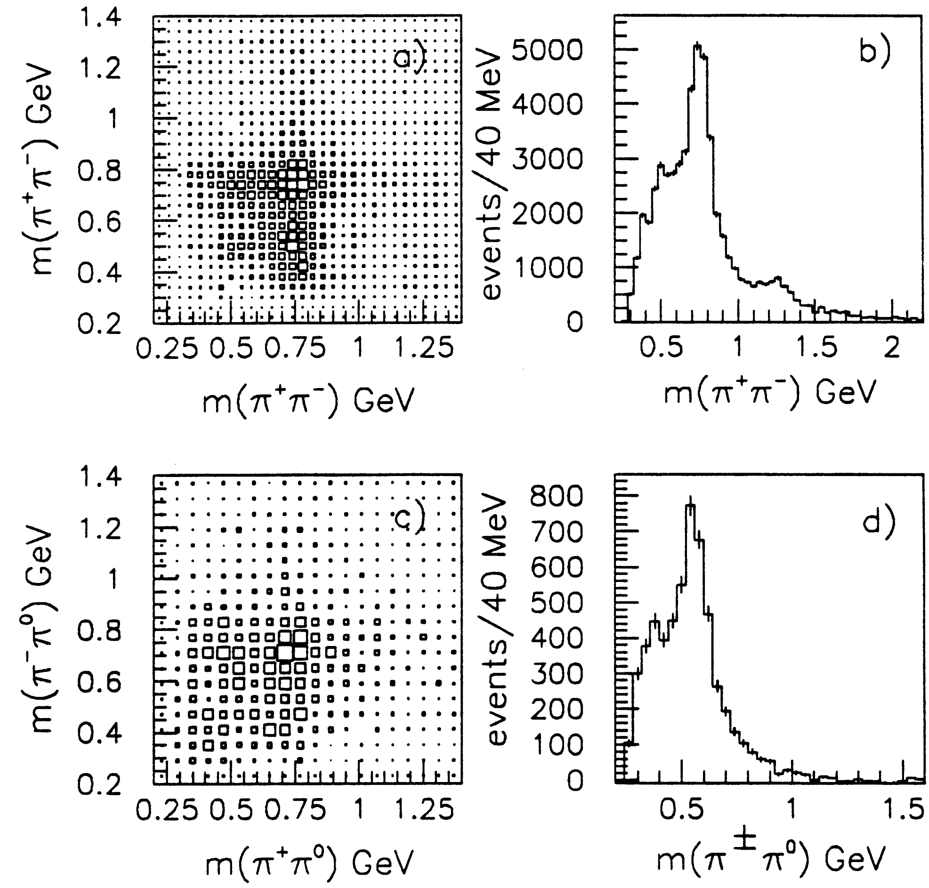

Figure 3: a) $\pi^+\pi^-$ vs $\pi^+\pi^-$ scatter plot and b) its projection; c) $\pi^-\pi^0$ vs $\pi^+\pi^0$ scatter plot and d) its projection.

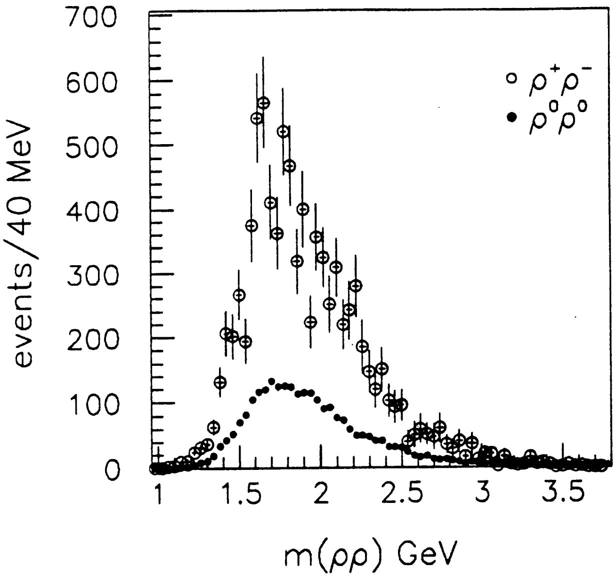

Figure 4: Normalized $\rho^+\rho^-$ and $\rho^0\rho^0$ effective mass distributions.

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