SEARCH FOR GLUEBALLS IN Ω

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WA76 Collaboration

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Abstract

Results are presented on a search for glueballs and hybrids centrally produced in the reaction $pp \rightarrow p_f(X^0)p_s$ at 85 and 300 GeV/c incident momentum using the CERN Ω spectrometer. In particular, contribution to the search for the scalar glueball is presented through the study of $\pi\pi$ and $K\bar{K}$ final states. New contribution to the E/ι puzzle are presented by studying the $\eta\pi\pi$ and $\rho^0\gamma$ final states.

1. Introduction

In this paper we describe the results from a search for gluonium and hybrid states centrally produced in the reaction $pp \rightarrow p_f(X^0)p_s$, where X=$\pi\pi$, $K\bar{K}$, $\eta\pi^+\pi^-$ and $\rho^0\gamma$, at 85 and 300 GeV/c incident beam momentum. At high centre of mass energies these double exchange processes are believed to be dominated by Double Pomeron Exchange (DPE). Since the Pomeron is thought to have a large gluonic content, Pomeron-Pomeron scattering could be a source of non $q\bar{q}$ states. The data come from the WA76 experiment performed at the CERN Ω spectrometer. Details of the layout of the apparatus, trigger conditions and data processing have been given in a previous publication [1].

2. Study of the $\pi\pi$ and $K\bar{K}$ systems

The scalar mesons are still a problem for hadron spectroscopy with the $S^*/f_0(975)$ resonance indicated as a possible glueball state [2] or a $K\bar{K}$ molecule [3]. A study of the $S^*/f_0(975)$ problem has been performed by using the centrally produced $\pi\pi$ and $K\bar{K}$ final states.

The reaction

$$pp \rightarrow p_f(\pi^+\pi^-)p_s$$

has been isolated from the sample of 4-prong events by requiring momentum and energy balance. The sample consists of 303K events whose $\pi^+\pi^-$ effective mass spectrum is shown in fig. 1a). We observe a small $\rho(770)$ signal, some $f_2(1270)$ and a sharp drop around 1 GeV due to the presence of the $S^*/f_0(975)$ resonance.

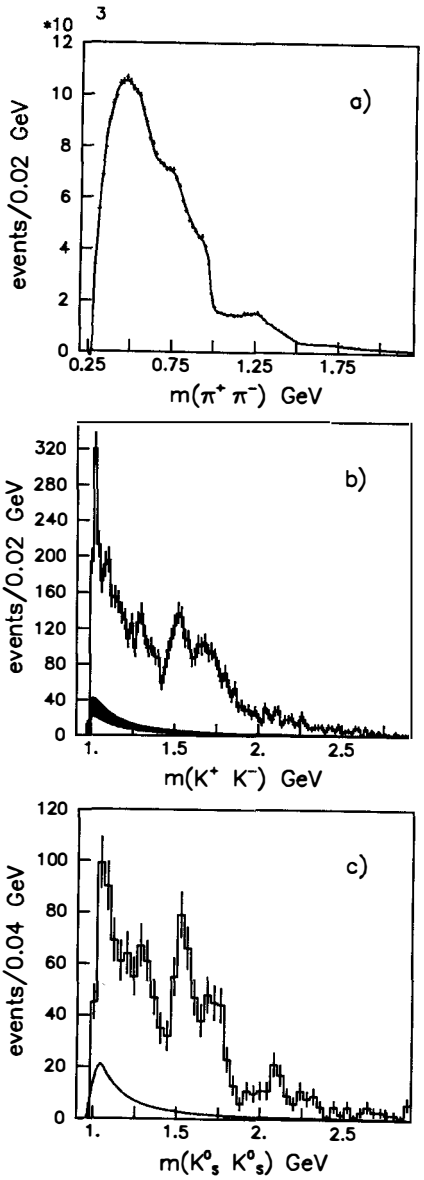

Figure 1
a) $\pi^+\pi^-$, b) K^+K^- and c) $K^0_SK^0_S$ mass distributions.

In order to extract the $S^*/f_0(975)$ parameters, a fit to the $\pi^+\pi^-$ mass spectrum has been performed using a coupled channel Breit-Wigner [4]

$$F_\pi(m) = \frac{m_0\sqrt{\Gamma_i}\sqrt{\Gamma_\pi}}{m_0^2 - m^2 - im_0(\Gamma_\pi + \Gamma_K)} \tag{1}$$

to describe the $S^*/f_0(975)$ region. In eq. (1), Γ_π and Γ_K are the partial widths of $S^*/f_0(975)$ to the $\pi\pi$ and $K\bar{K}$ systems. In order to have a satisfactory description of the $S^*/f_0(975)$ region it was found necessary to introduce an interference between the coupled channel Breit Wigner $F_\pi(m)$ and the background. The S-wave contribution then was parametrized as $B_s(m) = |1+A_sF_\pi(m)e^{i\delta}|^2$ where δ is a mass independent phase. The resulting $S^*/f_0(975)$ parameters are: $m_0 = 979\pm4$ MeV, $g_\pi = 0.28\pm0.04$, $g_K = 0.56\pm0.18$, $\delta = 23\pm4^0$, with a pole position on sheet II at $(1001\pm2) - i(36\pm4)$ MeV. The result of the fit is shown, as a curve superimposed on the data, in fig. 1a). We notice that, while the description of the $S^*/f_0(975)$ requires a large coupling to the $K\bar{K}$ system, the resulting parameters are quite different from what expected for a $K\bar{K}$ molecule [3].

Using the results from the fit to the $\pi^+\pi^-$ spectrum it is possible to have an absolute prediction of the expected number of events for the $S^*/f_0(975)$ in the K^+K^- and $K_S^0K_S^0$ spectra. The black band drawn in the threshold region of fig. 1b) and the curve drawn in the threshold region of fig. 1c), represent the predicted $S^*/f_0(975)$ contribution after having taken into account the different geometrical acceptance between the channels and Clebsch-Gordan coefficients. The band shows the prediction of $\pm1\sigma$ where σ is the statistical error. Such a contribution is easily accommodated in the threshold region of the $K\bar{K}$ mass spectra.

Thus it is possible to describe the $S^*/f_0(975)$ region of the centrally produced $\pi\pi$ and $K\bar{K}$ systems with a single resonance.

3. Study of the t dependence

It is interesting to compare the production characteristics of the centrally produced resonances observed in this experiment with what expected for production via DPE. Expected features of DPE are: i) a cross section constant or increasing with the centre of mass energy; ii) a simple exponential behaviour as a function of t ($1/t\ dN/dt \sim e^{-bt}$); iii) production of resonances with J^{PC} =even^{++}.

We have studied the t dependence (where $t = |t_1 + t_2|$ where t_1 and t_2 are the four-momentum transfer from the upper and lower protons vertices respectively) of the resonances observed in the $\pi^+\pi^-$ and K^+K^- mass spectra by dividing the data sample into different t regions. The corrected and uncorrected t distributions for $S^*/f_0(975)$, $f_2(1270)$, $\rho(770)$ $\phi(1020)$, $f_2'(1525)$ and $\theta/f_2(1720)$ are shown in fig. 2. It can be noticed

that, while the $S^*/f_0(975)$ and $\theta/f_2(1720)$ behave like simple exponentials having slopes of 8.7 ± 0.2 GeV^{-2} and 9.6 ± 0.4 GeV^{-2} respectively, the $\rho(770)$ $f_2(1270)$ and $\phi(1020)$ are consistent with zero in the first t interval suggesting a turn over at low t. Fitting the $f_2'(1525)$ with a simple exponential we obtain a slope of 6.1 ± 0.4 GeV^{-2}. Thus we observe enhanced production of $\theta/f_2(1720)$ at low t, in contrast with the behaviour of $f_2(1270)$ and $f_2'(1525)$.

It is interesting to compare the cross section for production of $\rho(770)$,$S^*/f_0(975)$ and $f_2(1270)$ in the 85 GeV/c and in the 300 GeV/c experiment. We obtain

$$\sigma(\rho(770))_{300}/\sigma(\rho(770))_{85} = 0.44 \pm 0.07$$
$$\sigma(S^*/f_0(975))_{300}/\sigma(S^*/f_0(975))_{85} = 3.12 \pm 1.00$$
$$\sigma(f_2(1270))_{300}/\sigma(f_2(1270))_{85} = 0.83 \pm 0.20$$

Thus, we observe a decrease of the $\rho(770)$ and an increase of the $S^*/f_0(975)$ cross sections as a function of energy. In conclusion, the production of $S^*/f_0(975)$ (and perhaps of the $\theta/f_2(1720)$) is consistent with what expected from DPE.

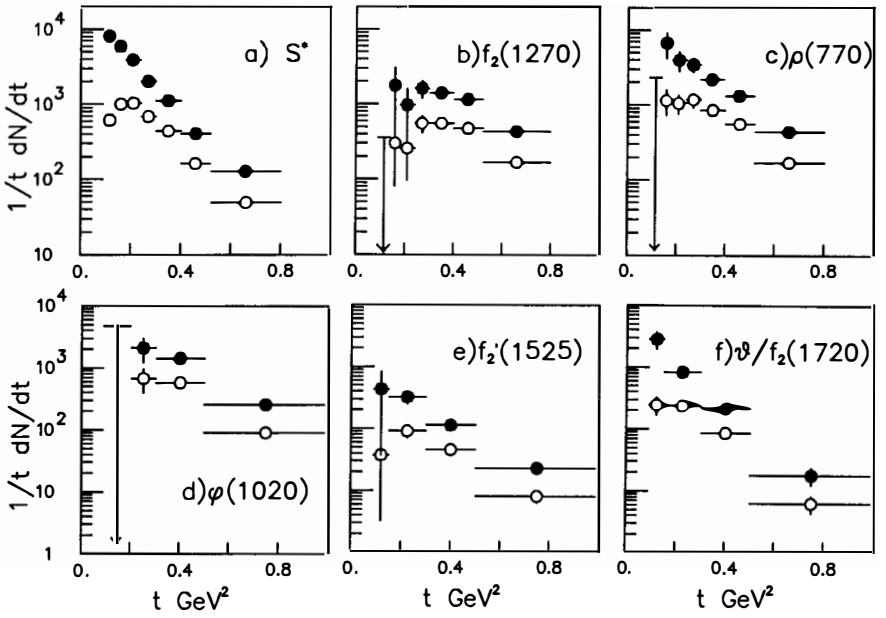

Figure 2
1/t dN/dt distributions (in arbitrary units) for: a) $S^*/f_0(975)$, b) $f_2(1270)$, c) $\rho(770)$, d) $\phi(1020)$, e) $f_2'(1525)$ and f) $\theta/f_2(1720)$. Open points: uncorrected data, black points: corrected data.

4. Study of the reactions $pp \to p_f(\eta\pi^+\pi^-)p_s$ and $pp \to p_f(\rho^0\gamma)p_s$

The $E/f_1(1420)$ meson is still a problem for hadron spectroscopy. It has been indicated as a possible hybrid [5] or a molecular state [6]. It has been observed in the reaction

$$pp \to p_f(K^0_S K^\pm \pi^\mp)p_s \qquad (2)$$

from the 85 GeV/c and 300 GeV/c runs of the WA76 experiment (see fig. 3a)). The $E/f_1(1420)$ meson has a dominant $K^*\bar{K}$ decay mode but other possible decays are not excluded. We have searched for $E/f_1(1420) \to 2\pi^+2\pi^-$ (fig. 3b)) but, instead, a different resonance is observed having a mass of 1449 ± 4 and $\Gamma = 78 \pm 18$ MeV [7].

The reaction

$$pp \to p_f(\eta\pi^+\pi^-)p_s$$

where $\eta \to \gamma\gamma$ and $\eta \to \pi^+\pi^-\pi^0$ have been selected from the sample of events balancing momentum and energy and having only two γ's reconstructed in the electromagnetic calorimeters. Showers in the calorimeters associated to charged tracks have been removed. The $\eta\pi^+\pi^-$ effective mass distribution is shown in fig. 3c). We observe clear peaks at the $\eta'(975)$ and $f_1(1285)$ masses and no evidence for structure in the E/ι region. No evidence is also seen for the new resonance X(1900) recently observed in the reaction $\gamma\gamma \to \eta\pi\pi$ [8]. Fitting the $\eta\pi^+\pi^-$ mass spectrum of fig. 3c) with a Breit-Wigner (Γ=25 MeV) convoluted with a Gaussian to describe the $f_1(1285)$ region we obtain $m_{f_1(1285)} = 1282 \pm 2$ MeV and $\sigma_{f_1(1285)} = 19 \pm 2$ MeV.

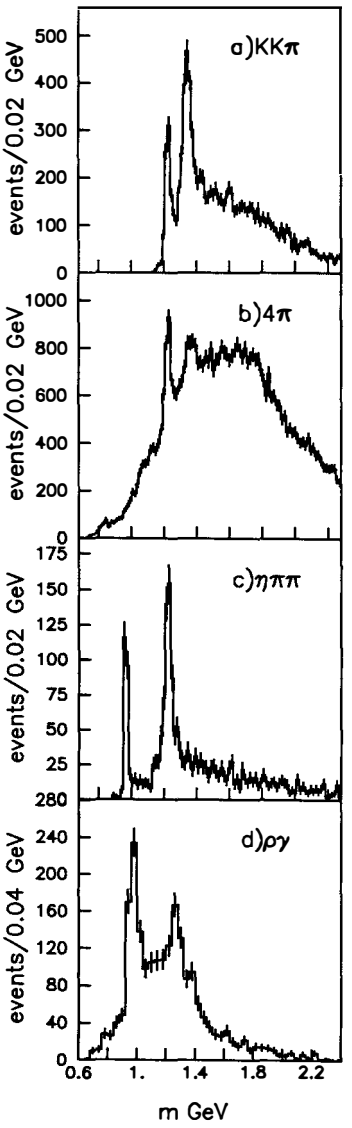

Figure 3
a) $K^0_S K^\pm \pi^\mp$ effective mass from the 85 GeV/c and 300 GeV/c data. b) $2\pi^+2\pi^-$, c) $\eta\pi^+\pi^-$ and d) $\rho^0\gamma$ mass spectra from the 300 GeV/c data.

Fig. 4 shows the $\eta\pi^{\pm}$ effective mass distribution after having removed the η' region (i.e. $m_{\eta\pi\pi} < 1.1$ GeV). The $\eta\pi^{\pm}$ mass spectrum shows a strong $\delta/a_0(980)$ along with some $a_2(1320)$. Describing the $\delta/a_0(980)$ by means of a relativistic S-wave Breit-Wigner convoluted with a Gaussian having a σ=20 MeV, we obtain $m(a_0) = 984 \pm 3$ MeV and $\Gamma(a_0) = 95 \pm 10$ MeV.

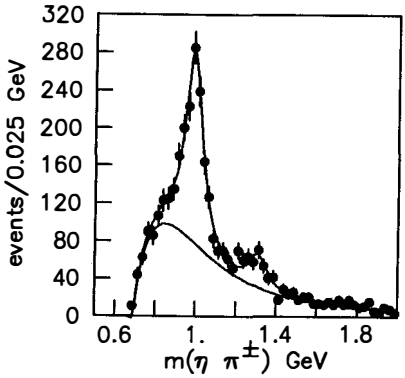

Figure 4
$\eta\pi^{\pm}$ mass spectrum from the $\eta\pi^{+}\pi^{-}$ final state.

A mass dependent spin parity analysis of the $\eta\pi^{+}\pi^{-}$ system has been performed in order to establish the nature of the structure observed in the 1.28 GeV region and search for other resonances. Maximum likelihood fits were performed on the Dalitz plot of the $\eta\pi\pi$ system using the Zemach tensor formalism. An isobar model is used assuming the $\delta/a_0(980)\pi$, $\epsilon/f_0(1400)\eta$ and $\rho(770)\eta$ intermediate states. Waves having small statistical significance have been removed from the fit.

The results are shown in fig. 5 and can be summarized as follows:

(a) The $J^{PC} = 1^{++}$ $\delta/a_0(980)\pi$ is the dominant wave and peaks at the $f_1(1285)$ mass. No evidence is seen for other resonant states; in particular, no evidence is seen for $E/f_1(1420)$ production. This confirms the results from the spin analysis of the centrally produced $K^0_S K^{\pm}\pi^{\mp}$ system [9] which gave a $\delta/a_0(980)\pi$ contribution consistent with zero in the $E/f_1(1420)$ region.

(b) The $J^{PC} = 0^{-+}$ waves are small and do not show resonant behaviour. In particular, no evidence is seen for $\eta(1270)$ or the pseudoscalar states observed in radiative J/ψ decay.

We have used the $K^0_S K^{\pm}\pi^{\mp}$ data from the 300 GeV/c experiment to compute an upper limit for the dacay $E/f_1(1420) \rightarrow \eta\pi\pi$. Taking as reference the presence of the $f_1(1285)$ in both the $\eta\pi\pi$ and $K^0_S K^{\pm}\pi^{\mp}$ mass spectra, and assuming an $f_1(1285)$ branching ratio to $K\bar{K}\pi$ of 12 %, we measure an upper limit for the decay of $E/f_1(1420)$ to $\eta\pi\pi$

$$B.R.(E/f_1(1420) \rightarrow \eta\pi\pi) < 0.1 \quad 95\% c.l.$$

The reaction

$$pp \rightarrow p_f(\pi^{+}\pi^{-}\gamma)p_s$$

has been selected from the sample of 4-prong events having only one γ reconstructed in the

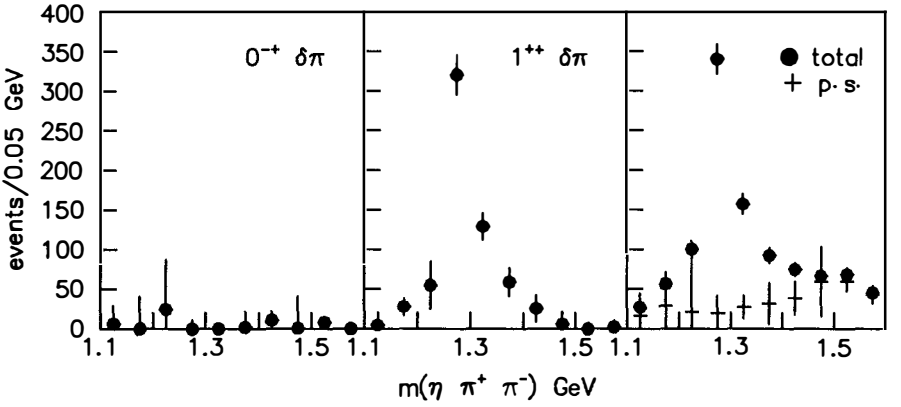

Figure 5
Results from the $\eta\pi^+\pi^-$ spin-parity analysis.

electromagnetic calorimeters and balancing momentum and energy. Requiring the $\pi^+\pi^-$ system to be in the ρ^0 band we obtain the mass spectrum shown in fig. 3d) where, above the η' a signal in the $f_1(1285)$ region can be seen. No signal is observed in the $E/f_1(1420)$ region.

In conclusion, no evidence is found for $E/f_1(1420)$ decay to $\eta\pi\pi$ or $\rho\gamma$. This result is particularly relevant in establishing the $E/f_1(1420)$ meson properties. The decay pattern observed in hadronic J/ψ decay to $\phi K\bar{K}\pi$ and $\omega K\bar{K}\pi$ [10] indicates a substantial $u\bar{u}$ and $d\bar{d}$ quark composition of the $E/f_1(1420)$ meson which would lead one to expect $\eta\pi\pi$, $\rho\gamma$ or 4π decay modes. However, this expectation is in contradiction with the non observation of the $E/f_1(1420)$ decay to other than the $K^*\bar{K}$ mode.

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