THE SPIN OF THE $f_J(1710)$ AND NEW EFFECTS OBSERVED IN THE WA102 EXPERIMENT

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A partial wave analysis of the centrally produced $K\overline{K}$ and $\pi\pi$ systems shows that the $f_J(1710)$ has J = 0. In addition, a study of central meson production as a function of the difference in transverse momentum (dP_T) of the exchanged particles shows that undisputed $q\overline{q}$ mesons are suppressed at small dP_T whereas the glueball candidates are enhanced and that the production cross section for different resonances depends strongly on the azimuthal angle between the two outgoing protons.

1 Introduction

There is considerable current interest in trying to isolate the lightest glueball. Several experiments have been performed using glue-rich production mechanisms. One such mechanism is Double Pomeron Exchange (DPE) where the Pomeron is thought to be a multi-gluonic object. Consequently it has been anticipated that production of glueballs may be especially favoured in this process [1].

The WA102 experiment at the CERN Omega Spectrometer studies centrally produced exclusive final states formed in the reaction

$$pp \longrightarrow p_f X^0 p_s, \tag{1}$$

where the subscripts f and s refer to the fastest and slowest particles in the laboratory frame respectively and X^0 represents the central system.

2 A partial wave analysis of the $K\overline{K}$ system

The isolation of the reaction

$$pp \rightarrow p_f(K^+K^-)p_s \tag{2}$$

has been described in detail in a previous publication [2]. A Partial Wave Analysis (PWA) of the centrally produced K^+K^- system has been performed, using the reflectivity basis [3], in 40 MeV intervals of the K^+K^- mass spectrum using an event-by-event maximum likelihood method [2]. The S_0^- and D_0^--Waves from the physical solution are shown in fig. 1.

The S_0^--wave shows a threshold enhancement; the peaks at 1.5 GeV and 1.7 GeV are interpreted as being due to the $f_0(1500)$ and $f_J(1710)$ with J = 0. A fit has been performed to the S_0^- wave using three interfering Breit-Wigners to describe the $f_0(980)$, $f_0(1500)$ and $f_J(1710)$ and a background of the form $a(m-m_{th})^b exp(-cm-dm^2)$, where m is the K^+K^- mass, m_{th} is the K^+K^- threshold mass and a, b, c, d are fit parameters. The resulting fit is shown in fig. 1 and

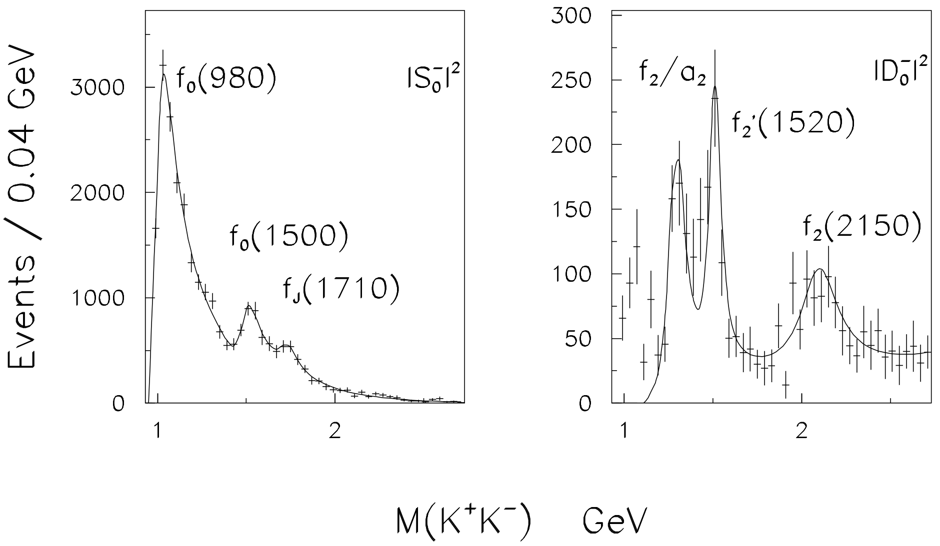

Figure 1: The S_0^- and D_0^--Waves resulting from a partial wave analysis of the K^+K^- system.

gives for the $f_0(980)$ M $= 985 \pm 10$ MeV, $\Gamma = 65 \pm 20$ MeV, for the $f_0(1500)$ M $= 1497 \pm 10$ MeV, $\Gamma = 104 \pm 25$ MeV and for the $f_0(1710)$ M $= 1730 \pm 15$ MeV, $\Gamma = 100 \pm 25$ MeV parameters which are consistent with the PDG [4] values for these resonances.

The D_0^--wave shows peaks in the 1.3 and 1.5 GeV regions, presumably due to the $f_2(1270)/a_2(1320)$ and $f_2'(1525)$ and a wide structure above 2 GeV. There is no evidence for any significant structure in the D-wave in the region of the $f_J(1710)$. In addition, there are no statistically significant structures in any of the other waves. A fit has been performed to the D_0^- wave above 1.2 GeV using three incoherent relativistic spin 2 Breit-Wigners to describe the $f_2(1270)/a_2(1320)$, $f_2'(1525)$ and the peak at 2.2 GeV and a background of the form described above. The resulting fit is shown in fig. 1 and gives for the $f_2(1270)/a_2(1320)$ M $= 1305 \pm 20$ MeV, $\Gamma = 132 \pm 25$ MeV, for the $f_2'(1525)$ M $= 1515 \pm 15$ MeV, $\Gamma = 70 \pm 25$ MeV and for the $f_2(2150)$ M $= 2130 \pm 35$ MeV, $\Gamma = 270 \pm 50$ MeV.

3 A partial wave analysis of the $\pi\pi$ system

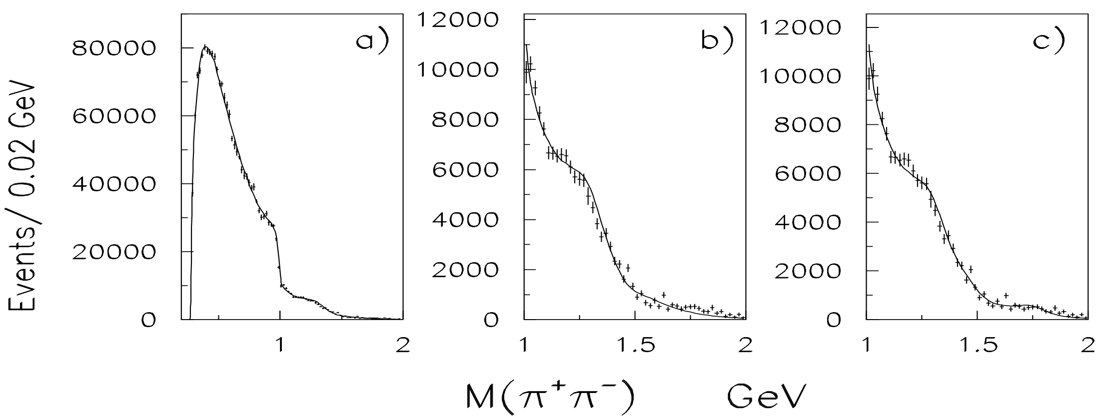

Figure 2: a), b), c) The S_0^- wave resulting from a partial wave analysis of the $\pi^+\pi^-$ system.

The isolation of the reaction

$$pp \to p_f(\pi^+\pi^-)p_s \tag{3}$$

has been described in detail in a previous publication [5]. The resulting centrally produced $\pi^+\pi^-$ system consists of 2.87 million events. A PWA of the centrally produced $\pi^+\pi^-$ system has been performed, using the reflectivity basis [3], in 20 MeV intervals of the $\pi^+\pi^-$ mass spectrum using an event-by-event maximum likelihood method [5]. The S_0^--wave from the physical solution is shown in fig. 2. and shows a clear threshold enhancement followed by a sharp drop at 1 GeV.

In order to obtain a satisfactory fit to the S_0^- wave from threshold to 2 GeV it has been found to be necessary to use three interfering Breit-Wigners to describe the $f_0(980)$, $f_0(1300)$ and $f_0(1500)$ and a background of the form $a(m-m_{th})^b exp(-cm-dm^2)$, where m is the $\pi^+\pi^-$ mass, m_{th} is the $\pi^+\pi^-$ threshold mass and a, b, c, d are fit parameters. The fit is shown in fig. 2a) for the entire mass range and in fig. 2b) for masses above 1 GeV. The resulting parameters are for the $f_0(980)$ M = 982 $\pm$ 3 MeV, Γ = 80 $\pm$ 10 MeV, for the $f_0(1300)$ M = 1308 $\pm$ 10 MeV, Γ = 222 $\pm$ 20 MeV and for the $f_0(1500)$ M = 1502 $\pm$ 10 MeV, Γ = 131 $\pm$ 15 MeV which are consistent with the PDG [4] values for these resonances. As can be seen, the fit describes the data well for masses below 1 GeV. It was not possible to describe the data above 1 GeV without the addition of both the $f_0(1300)$ and $f_0(1500)$ resonances. However, even with this fit using three Breit-Wigners it can be seen that the fit does not describe well the 1.7 GeV region. This could be due to a $\pi^+\pi^-$ decay mode of the $f_J(1710)$ with J = 0. Including a fourth Breit-Wigner in this mass region decreases the χ^2 from 256 to 203 and yields for the $f_J(1710)$ M = 1750 $\pm$ 20 MeV and Γ = 160 $\pm$ 30 MeV parameters which are consistent with the PDG [4] values for the $f_J(1710)$. The fit is shown in fig. 2c) for masses above 1 GeV.

4 A Glueball-$q\overline{q}$ filter in central production ?

The WA102 experiment studies mesons produced in double exchange processes. However, even in the case of pure DPE the exchanged particles still have to couple to a final state meson. The coupling of the two exchanged particles can either be by gluon exchange or quark exchange. Assuming the Pomeron is a colour singlet gluonic system if a gluon is exchanged then a gluonic state is produced, whereas if a quark is exchanged then a $q\overline{q}$ state is produced [6]. In order to describe the data in terms of a physical model, Close and Kirk [6], have proposed that the data be analysed in terms of the difference in transverse momentum (dP_T) between the particles exchanged from the fast and slow vertices. The idea being that for small differences in transverse momentum between the two exchanged particles an enhancement in the production of glueballs relative to $q\overline{q}$ states may occur.

The ratio of the number of events for $dP_T < 0.2$ GeV to the number of events for $dP_T >$ 0.5 GeV for each resonance considered has been calculated [7]. It has been observed that all the undisputed $q\overline{q}$ states which can be produced in DPE, namely those with positive G parity and $I = 0$, have a very small value for this ratio (≤ 0.1). Some of the states with $I = 1$ or G parity negative, which can not be produced by DPE, have a slightly higher value (≈ 0.25). However, all of these states are suppressed relative to the the glueball candidates the $f_0(1500)$, $f_J(1710)$, and $f_2(1930)$, together with the enigmatic $f_0(980)$, which have a large value for this ratio.

5 The azimuthal angle between the outgoing protons

The azimuthal angle (ϕ) is defined as the angle between the p_T vectors of the two protons. Naively it may be expected that this angle would be flat irrespective of the resonances produced. Fig. 3 shows the ϕ dependence for two $J^{PC} = 0^{-+}$ final states (the η and η'), two $J^{PC} = 1^{++}$ final states (the $f_1(1285)$ and $f_1(1420)$) and two $J^{PC} = 2^{++}$ final states (the $\phi\phi$ and $K^*(892)\overline{K}^*(892)$ systems). The ϕ dependence is clearly not flat and considerable variation is observed between final states with different J^{PC}s.

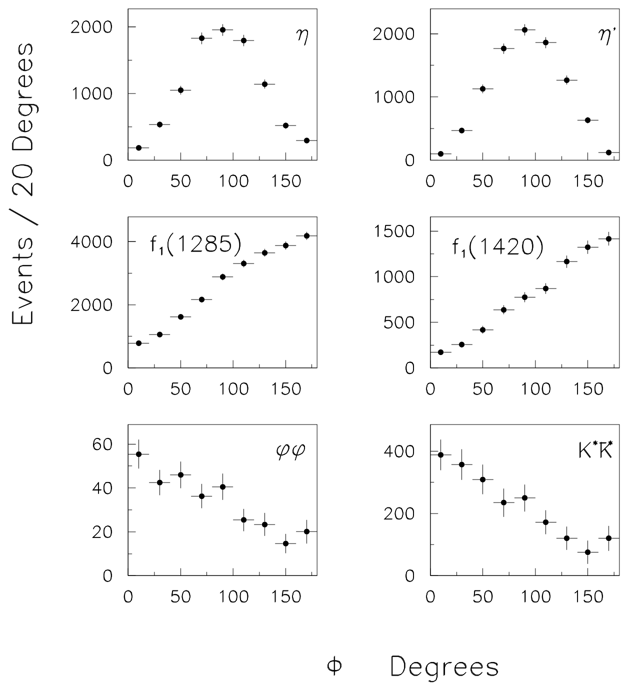

Figure 3: The azimuthal angle between the fast and slow protons (ϕ) for various final states.

6 Summary

In conclusion, a partial wave analysis of the centrally produced $K\overline{K}$ system has been performed. The striking feature is the observation of peaks in the S_0^--wave corresponding to the $f_0(1500)$ and $f_J(1710)$ with J = 0. In addition, a partial wave analysis of a high statistics sample of centrally produced $\pi^+\pi^-$ events shows that the S_0^--wave is composed of a broad enhancement at threshold, a sharp drop at 1 GeV due to the interference between the $f_0(980)$ and the S-wave background, the $f_0(1300)$, the $f_0(1500)$ and the $f_J(1710)$ with J = 0.

A study of centrally produced pp interactions show that there is the possibility of a glueball-$q\overline{q}$ filter mechanism (dP_T). All the undisputed $q\overline{q}$ states are observed to be suppressed at small dP_T, but the glueball candidates $f_0(1500)$, $f_J(1710)$, and $f_2(1930)$, together with the enigmatic $f_0(980)$, survive. In addition, the production cross section for different resonances depends strongly on the azimuthal angle between the two outgoing protons.

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