New effects observed in central production by experiment WA102 at the CERN Omega Spectrometer

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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 COUPLED CHANNEL ANALYSIS OF THE $K\overline{K}$ AND $\pi\pi$ SYSTEMS

Recently the WA102 collaboration has published the results of a partial wave analysis of the centrally produced K^+K^- [2] and $\pi^+\pi^-$ [3] channels. Fig. 1 shows the the S_0^--wave from the K^+K^- and $\pi^+\pi^-$ channels. The S_0^--wave from the K^+K^- channel shows a threshold enhancement; the peaks at 1.5 GeV and 1.7 GeV are due to the $f_0(1500)$ and $f_J(1710)$ with J = 0 [2]. In order to obtain a satisfactory fit to the S_0^- wave from the $\pi^+\pi^-$ channel from threshold to 2 GeV it has been found to be necessary to use Breit-Wigners to describe the $f_0(980)$, $f_0(1370)$ and $f_0(1500)$ and $f_J(1710)$ [3].

A coupled channel fit has been performed to the K^+K^- and $\pi^+\pi^-$ S-wave distributions and the results are shown in fig. 1. The sheet II pole positions for the resonances observed are

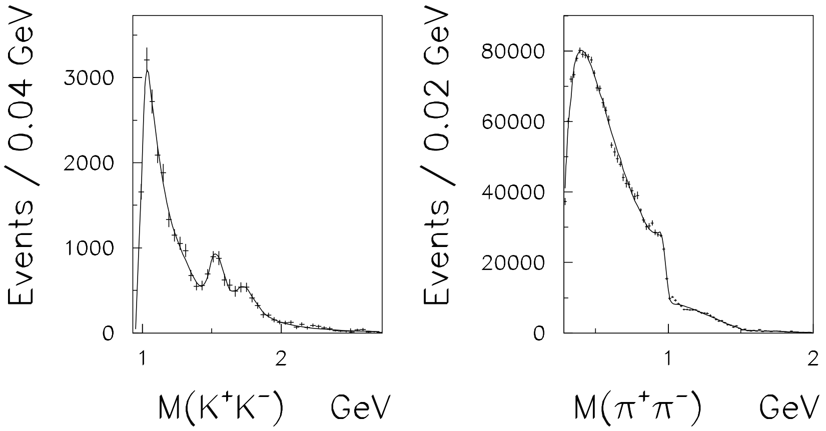

Figure 1. The S_0^--Waves resulting from a partial wave analysis of the K^+K^- and $\pi^+\pi^-$ -systems.

$f_0(980)$	M	$= (\ 987 \pm \ 6 \pm \ 6) \ -i(\ 48 \pm 12 \pm \ 8)$	MeV
$f_0(1370)$	M	$= (1312 \pm 25 \pm 10) \ -i(109 \pm 22 \pm 15)$	MeV
$f_0(1500)$	M	$= (1502 \pm 12 \pm 10) \ -i(\ 49 \pm \ 9 \pm \ 8)$	MeV
$f_J(1710)$	M	$= (1727 \pm 12 \pm 11) \ -i(\ 63 \pm \ 8 \pm \ 9)$	MeV

These parameters are consistent with the PDG [4] values for these resonances. For the $f_0(980)$ the couplings were determined to be $g_\pi = 0.19 \pm 0.03 \pm 0.04$ and $g_K = 0.40 \pm 0.04 \pm 0.04$.

The branching ratios for the $f_0(1370)$, $f_0(1500)$ and $f_J(1710)$ have been calculated to be:

$$\frac{f_0(1370) \to K\overline{K}}{f_0(1370) \to \pi\pi} = 0.46 \pm 0.15 \pm 0.11$$

$$\frac{f_0(1500) \to K\overline{K}}{f_0(1500) \to \pi\pi} = 0.33 \pm 0.03 \pm 0.07$$

$$\frac{f_J(1710) \to K\overline{K}}{f_J(1710) \to \pi\pi} = 5.0 \pm 0.6 \pm 0.9$$

these values are to be compared with the PDG [4] values of 1.35 ± 0.68 for the $f_0(1370)$, 0.19 ± 0.07 for the $f_0(1500)$, which comes from the Crystal Barrel experiment [5], and 2.56 ± 0.9 for the $f_J(1710)$ which comes from the WA76 experiment [6].

3. 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

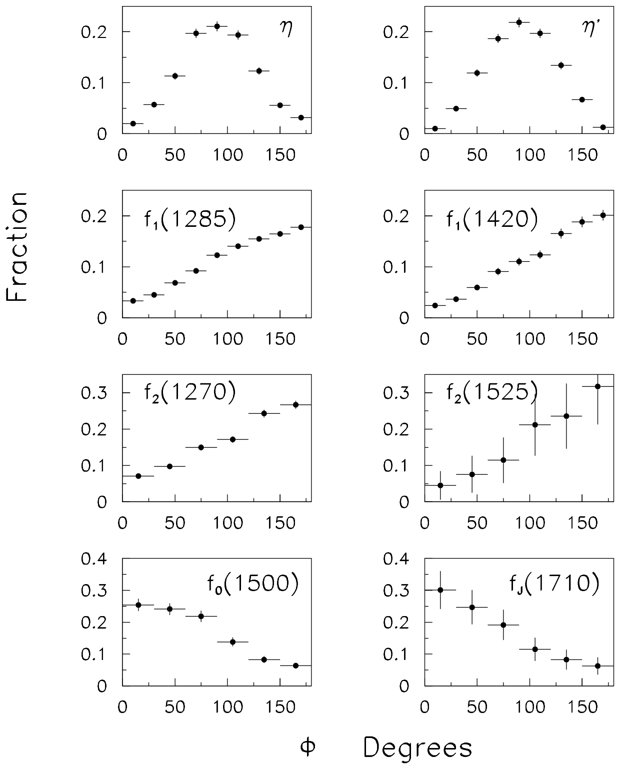

Figure 2. The azimuthal angle between the fast and slow protons ϕ for various resonances.

is exchanged then a gluonic state is produced, whereas if a quark is exchanged then a $q\overline{q}$ state is produced [7]. In order to describe the data in terms of a physical model, Close and Kirk [7], 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 [8]. 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 [8].

4. 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. 2 shows the ϕ dependence for two resonances with $J^{PC} = 0^{-+}$ (the η and η'), two with $J^{PC} = 1^{++}$ (the $f_1(1285)$ and $f_1(1420)$), two with $J^{PC} = 2^{++}$ (the $f_2(1270)$ and $f_2'(1525)$) and two with $J^{PC} = 0^{++}$ (the $f_0(1500)$ and $f_J(1710)$). The ϕ dependence

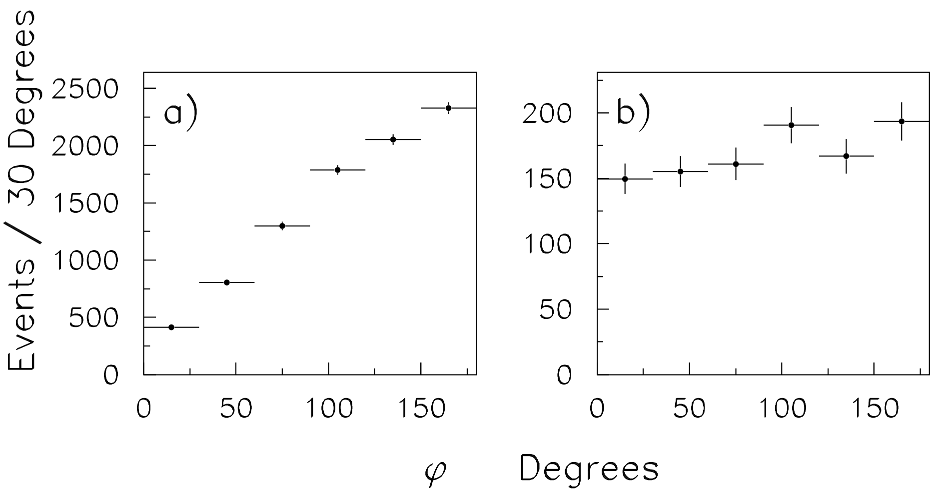

Figure 3. The azimuthal angle between the fast and slow protons ϕ for the $f_1(1285)$ for a) $|t_1 - t_2| \leq 0.2$ and b) $|t_1 - t_2| \geq 0.4$

is clearly not flat and considerable variation is observed between resonances with different J^{PC}s.

Several theoretical papers have been published on these effects [9,10]. All agree that the exchanged particle (Pomeron) must have J > 0 and that J = 1 is the simplest explanation. Using $\gamma^*\gamma^*$ collisions as an analogy Close and Schuler[10] have calculated the ϕ dependencies for the production of resonances with different J^{PC}s. They have found that for a $J^{PC} = 0^{-+}$ state

$$\frac{d^3\sigma}{d\phi dt_1 dt_2} \propto t_1 t_2 sin^2\phi \tag{2}$$

as can be seen from fig. 2 the ϕ distributions are proportional to $sin^2\phi$ and it has been found experimentally that $d\sigma/dt$ is proportional to t [11]. For the $J^{PC} = 1^{++}$ states this model predicts that $J_Z = \pm 1$ should dominate, which has been found to be correct [12], and

$$\frac{d^3\sigma}{d\phi dt_1 dt_2} \propto (\sqrt{t_2} - \sqrt{t_1})^2 + \sqrt{t_1 t_2} sin^2\phi/2 \tag{3}$$

As can be seen from fig. 2 the ϕ distributions are proportional to $\alpha + \beta sin^2\phi/2$. In addition equation(3) would predict that when $|t_2 - t_1|$ is small $d\sigma/d\phi$ should be proportional to $sin^2\phi/2$ while when $|t_2 - t_1|$ is large $d\sigma/d\phi$ should be constant. As shown in fig. 3 this trend is observed in the data. The aim now is to study the ϕ dependences of other known $q\overline{q}$ states in order to understand more about the nature of the Pomeron and then to use this information as a probe for non-$q\overline{q}$ states.

5. SUMMARY

In conclusion, a partial wave analysis of the centrally produced K^+K^- and $\pi^+\pi^-$ systems has been performed. The striking feature is the observation of the $f_J(1710)$ with J = 0 in the S_0^--wave.

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 which may give information on the nature of the Pomeron.

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