NEW EFFECTS OBSERVED IN CENTRAL PRODUCTION BY THE WA102 EXPERIMENT AT THE CERN OMEGA SPECTROMETER

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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. In addition, 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 [2].

The Omega central production experiments (WA76, WA91 and WA102) are designed to study 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. Such reactions are expected to be mediated by double exchange processes where both Pomeron and Reggeon exchange can occur.

The trigger was designed to enhance double exchange processes with respect to single exchange and elastic processes. Details of the trigger conditions, the data processing and event selection have been given in previous publications [3].

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

The experiments have been performed at incident beam momenta of 85, 300 and 450 GeV/c, corresponding to centre-of-mass energies of $\sqrt{s}$ = 12.7, 23.8

and 28 GeV. Theoretical predictions[4] of the evolution of the different exchange mechanisms with centre of mass energy, $\sqrt{s}$, suggest that

$$\begin{aligned}\sigma(RR) &\sim s^{-1},\\ \sigma(RP) &\sim s^{-0.5},\\ \sigma(PP) &\sim constant,\end{aligned} \tag{2}$$

where RR, RP and PP refer to Reggeon-Reggeon, Reggeon-Pomeron and Pomeron-Pomeron exchange respectively. Hence we expect Double Pomeron Exchange (DPE) to be more significant at high energies, whereas the Reggeon-Reggeon and Reggeon-Pomeron mechanisms will be of decreasing importance. The decrease of the non-DPE cross section with energy can be inferred from data taken by the WA76 collaboration using pp interactions at $\sqrt{s}$ of 12.7 GeV and 23.8 GeV [5]. The $\pi^+\pi^-$ mass spectra for the two cases show that the signal-to-background ratio for the $\rho^0(770)$ is much lower at high energy, and the WA76 collaboration report that the ratio of the $\rho^0(770)$ cross sections at 23.8 GeV and 12.7 GeV is 0.44 $\pm$ 0.07. Since isospin 1 states such as the $\rho^0(770)$ cannot be produced by DPE, the decrease of the $\rho^0(770)$ signal at high $\sqrt{s}$ is consistent with DPE becoming relatively more important with increasing energy with respect to other 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 (see figures 1a) and b) respectively).

The WA91 collaboration has published a paper[6] showing that the observed centrally produced resonances depend on the angle between the outgoing slow and fast protons. 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 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 difference in the transverse momentum vectors (dP_T) is defined to be

$$dP_T = \sqrt{(P_{y1} - P_{y2})^2 + (P_{z1} - P_{z2})^2} \tag{3}$$

where Py_i, Pz_i are the y and z components of the momentum of the ith exchanged particle in the pp centre of mass system[8].

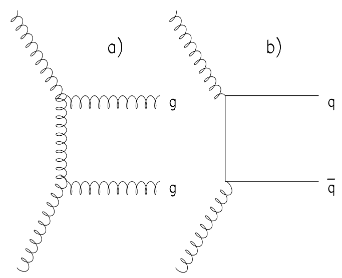

Figure 1: Schematic diagrams of the coupling of the exchange particles into the final state meson for a) gluon exchange and b) quark exchange.

Figures 2a), b) and c) show the effect of the dP_T cut on the K^+K^- mass spectrum where structures can be observed in the 1.5 and 1.7 GeV mass region which have been previously identified as the $f_2'(1525)$ and the $f_J(1710)$ [9]. As can be seen, the $f_2'(1525)$ is produced dominantly at high dP_T, whereas the $f_J(1710)$ is produced dominantly at low dP_T.

In the $\pi^+\pi^-\pi^+\pi^-$ mass spectrum a dramatic effect is observed, see figures 2d), e) and f). The $f_1(1285)$ signal has virtually disappeared at low dP_T whereas the $f_0(1500)$ and $f_2(1930)$ signals remain.

In fact it has been observed [10] that all the undisputed $q\overline{q}$ states (i.e. $\rho^0(770)$, η', $f_2(1270)$, $f_1(1285)$, $f_2'(1525)$ etc.) are suppressed as dP_T goes to zero, whereas the glueball candidates $f_J(1710)$, $f_0(1500)$ and $f_2(1930)$ survive. It is also interesting to note that the enigmatic $f_0(980)$, a possible non-$q\overline{q}$ meson or $K\overline{K}$ molecule state does not behave as a normal $q\overline{q}$ state.

A Monte Carlo simulation of the trigger, detector acceptances and reconstruction program shows that there is very little difference in the acceptance as a function of dP_T in the different mass intervals considered within a given channel and hence the observed differences in resonance production can not be explained as acceptance effects.

3 Summary of the effects of the dP_T filter

In order to calculate the contribution of each resonance as a function of the dP_T the mass spectra have been fitted with the parameters of the resonances fixed to those obtained from the fits to the total data. Figure 3 shows 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. It can be 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

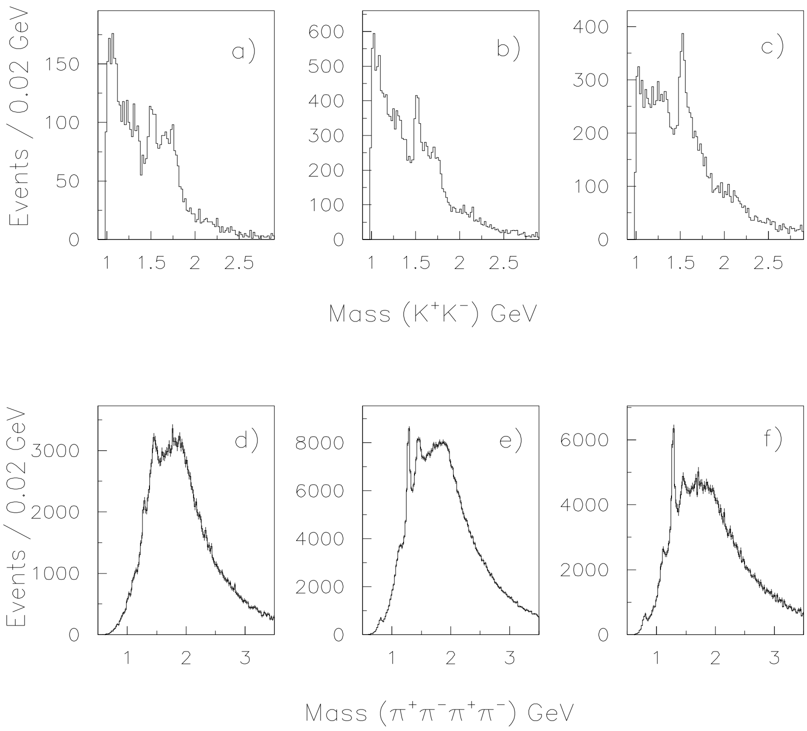

Figure 2: K^+K^- mass spectrum for a) $dP_T < 0.2$ GeV, b) $0.2 < dP_T < 0.5$ GeV and c) $dP_T > 0.5$ GeV and the $\pi^+\pi^-\pi^+\pi^-$ mass spectrum for d) $dP_T < 0.2$ GeV, e) $0.2 < dP_T < 0.5$ GeV and f) $dP_T > 0.5$ GeV.

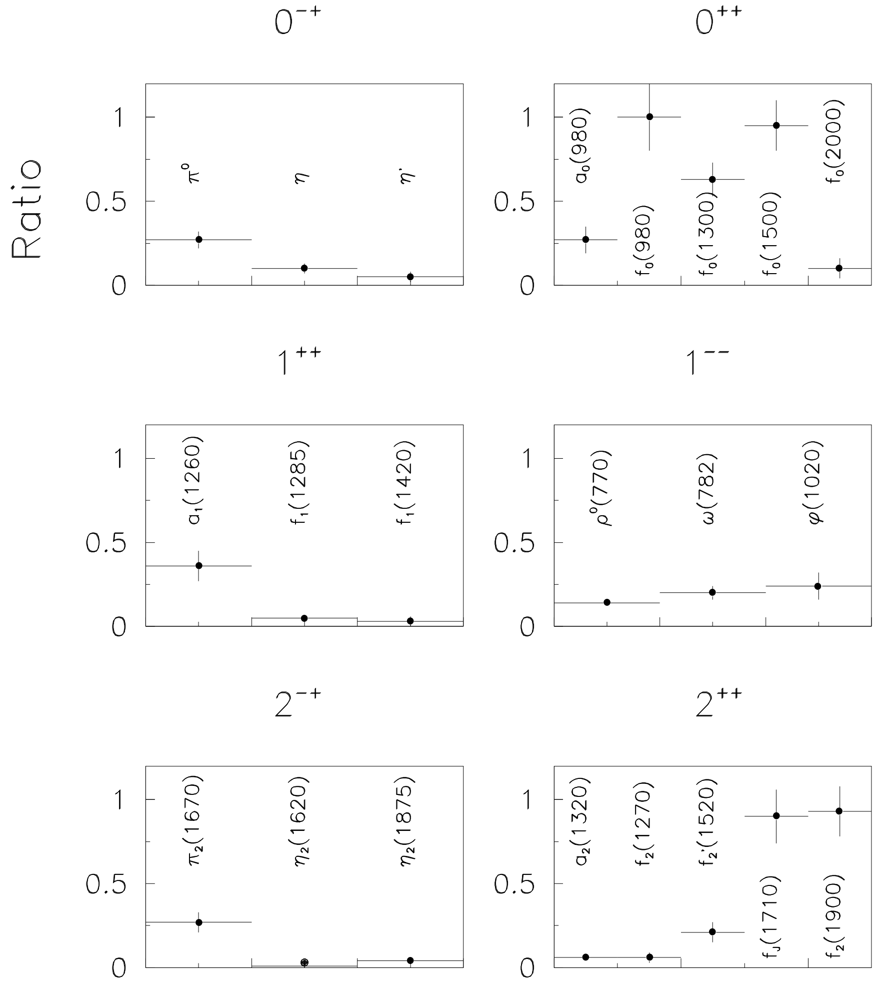

Figure 3: The ratio of the amount of resonance with $dP_T \leq 0.2$ to the amount with $dP_T \geq 0.5$ GeV.

are suppressed relative to the interesting states, i.e. those which could have a gluonic component, which have a large value for this ratio.

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. 4 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.

5 Implications of the dP_T and azimuthal angle effects

The underlying physics behind the dP_T and azimuthal angle (ϕ) effects is still not fully understood. They are not an artifact of the WA102 experiment since they have been subsequently verified by the NA12/2 experiment. The angle ϕ is related to dP_T by

$$cos\phi = \frac{dP_T^2 - P_T^2}{4t_s t_f} \tag{4}$$

where P_T is the transverse momentum of the central system. It is not possible, however, based on this relation alone to explain the ϕ distribution for the η and η^prime.

It has been suggested that it may be possible to explain the results if the particles exchanged in the formation of the central system carry non-zero spin [11,12]. Hence the results may have implications for the spin structure of the Pomeron.

6 Conclusions

A study of centrally produced pp interactions show that there is the possibility of a glueball-$q\overline{q}$ filter mechanism. 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.

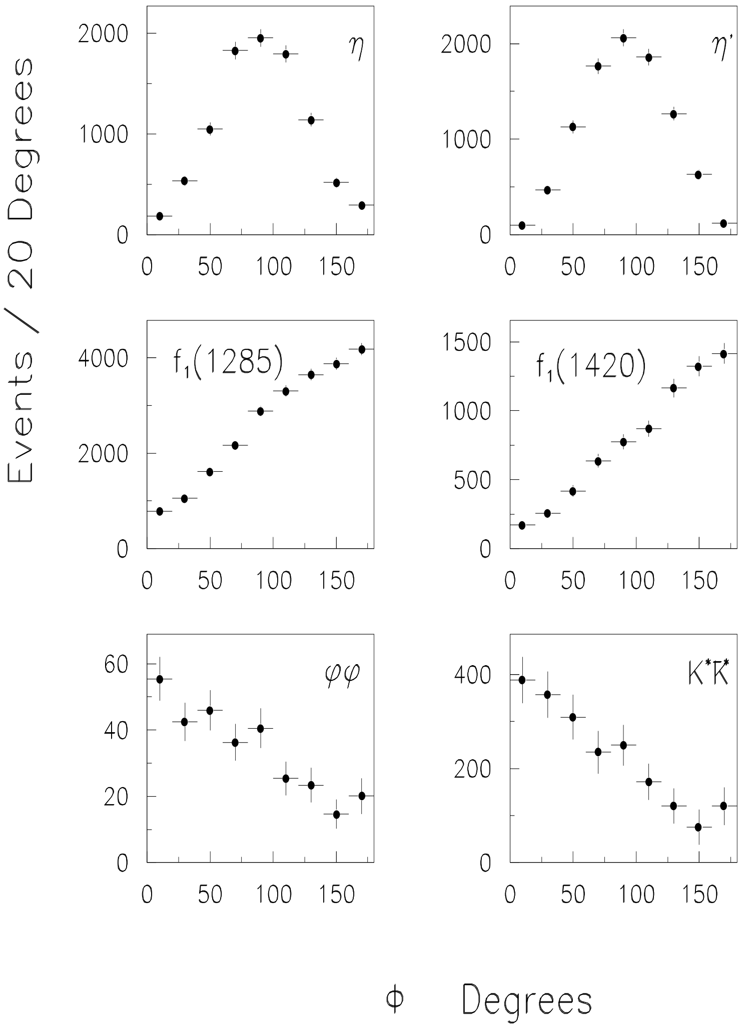

Figure 4: The azimuthal angle between the fast and slow protons (ϕ) for various final states.

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