

# A search for non- $q\bar{q}$ mesons in the WA102 experiment at the CERN Omega Spectrometer

Andrew Kirk\*  
and The WA102 collaboration<sup>[1]</sup>

*\* School of Physics and Astronomy, Birmingham University*

**Abstract.** A study of central meson production as a function of the difference in transverse momentum ( $dP_T$ ) of the exchanged particles shows that undispersed  $q\bar{q}$  mesons are suppressed at small  $dP_T$  whereas the glueball candidates are enhanced.

*Invited talk at Hadron 97, August 1997*

## 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

$$pp \longrightarrow p_f X^0 p_s,$$

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.

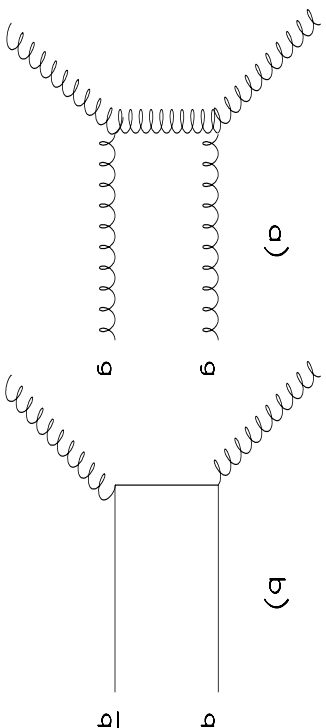
The trigger was designed to enhance double exchange processes with respect to single exchange and elastic processes. Details of the trigger conditions, the data processing and event selection have been given in previous publications [3].

## A GLOBALL- $Q\bar{Q}$ 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

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

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

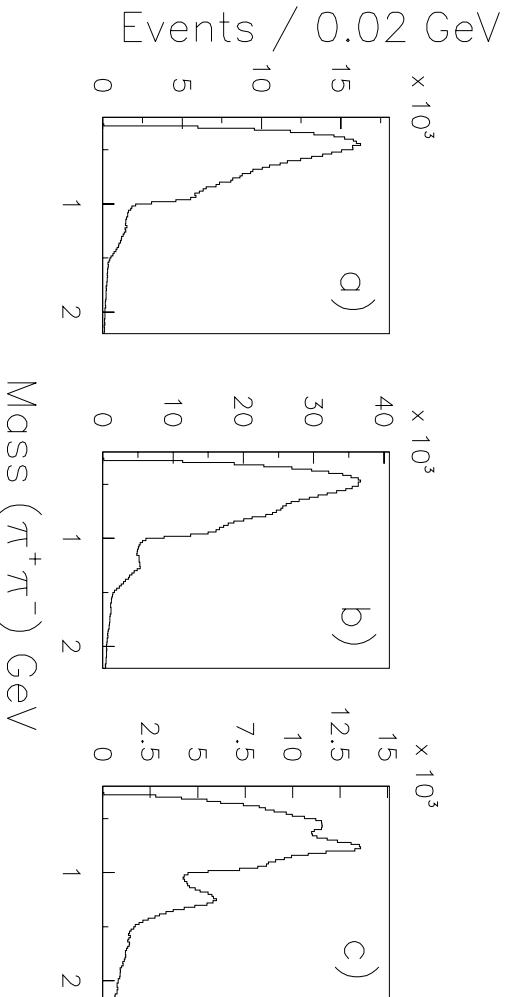


**FIGURE 1.** Schematic diagrams of the coupling of the exchange particles into the final state meson for a) gluon exchange and b) quark exchange.

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  $q\bar{q}$  state is produced (see figures 1a) and b) respectively). It has been suggested recently [6] that for small differences in transverse momentum between the two exchanged particles an enhancement in the production of glueballs relative to  $q\bar{q}$  states may occur.

Recently the WA91 collaboration has published a paper [7] 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 [6], 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 difference in the transverse momentum vectors ( $dP_T$ ) is defined to be

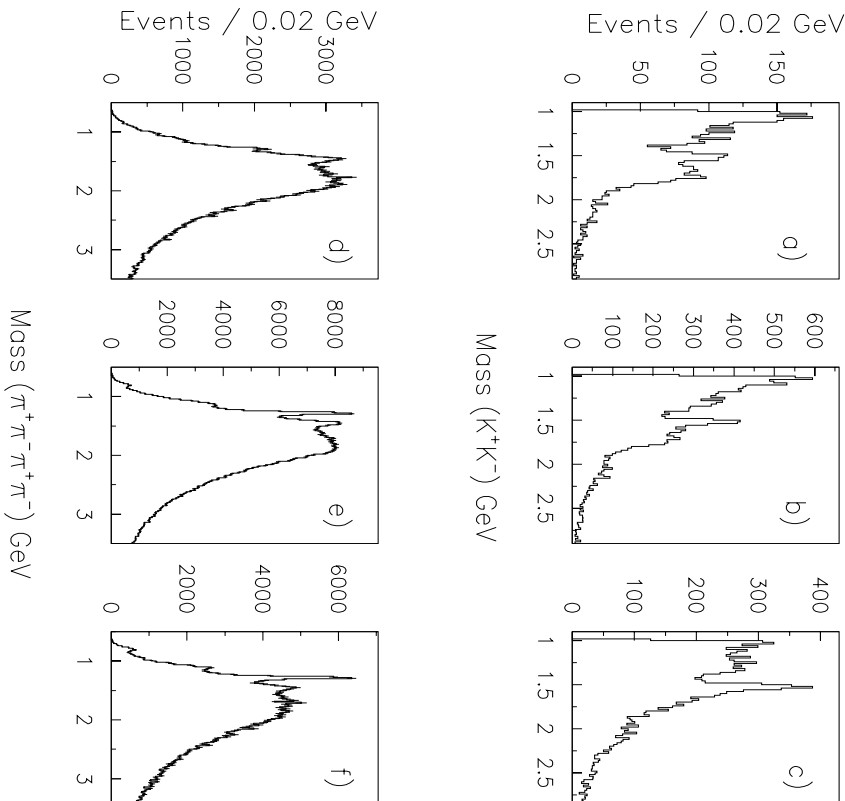


**FIGURE 2.** The  $\pi^+\pi^-$  mass spectrum for a)  $dP_T < 0.2$  GeV, b)  $0.2 < dP_T < 0.5$  GeV and c)  $dP_T > 0.5$  GeV.

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

where  $P_{yi}$ ,  $P_{zi}$  are the y and z components of the momentum of the  $i$ th exchanged particle in the pp centre of mass system [8].

The effect that different cuts in  $dP_T$  have on the  $\pi^+\pi^-$  mass spectrum are shown in figures 2a), b) and c). As can be seen, for  $dP_T < 0.2$  GeV there is effectively no  $\rho^0(770)$  or  $f_2(1270)$  signals. These signals only become apparent as  $dP_T$  increases. However the  $f_0(980)$ , which is responsible for the sharp drop in the spectrum around 1 GeV, is clearly visible in the small  $dP_T$  sample.



**FIGURE 3.**  $K^+K^-$  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.

Figures 3a), 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 3d), 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.

A spin-parity analysis of the  $\pi^+\pi^-\pi^+\pi^-$  channel has been performed [10] using an isobar model [11]. The  $f_1(1285)$  is clearly seen in the  $J^P = 1^+ \rho\rho$  and the  $f_1(1285)$  signal almost disappears at small  $dP_T$ . In the  $J^P = 0^+ \rho\rho$  distribution a peak is observed at 1.45 GeV together with a broad enhancement around 2 GeV. The peak in the  $J^P = 0^+ \rho\rho$  wave around 1.45 GeV remains for  $dP_T \leq 0.2$  GeV while the  $J^P = 0^+$  enhancement at 2.0 GeV becomes less important: which shows that the  $dP_T$  effect is not simply a  $J^P$  filter.

A fit has first been performed to the total  $J^P = 0^+ \rho\rho$  distribution using a K matrix formalism [12] including poles to describe the peak at 1.45 GeV as an interference between the  $f_0(1300)$ , the  $f_0(1500)$  together with a possible state at 2 GeV. The resulting resonance parameters for the  $f_0(1300)$  and  $f_0(1500)$  are very similar to those found by Crystal Barrel [13].

The peak observed at 1.9 GeV, called the  $f_2(1900)$ , is found to decay to  $a_2(1320)\pi$  and  $f_2(1270)\pi\pi$  with  $J^{PC} = 2^{++}$ . At small  $dP_T$  the  $f_2(1900)$  signal is still important. This is the first evidence of a non-zero spin resonance produced at small  $dP_T$  and hence shows that the  $dP_T$  effect is not just a  $J^P = 0^+$  filter.

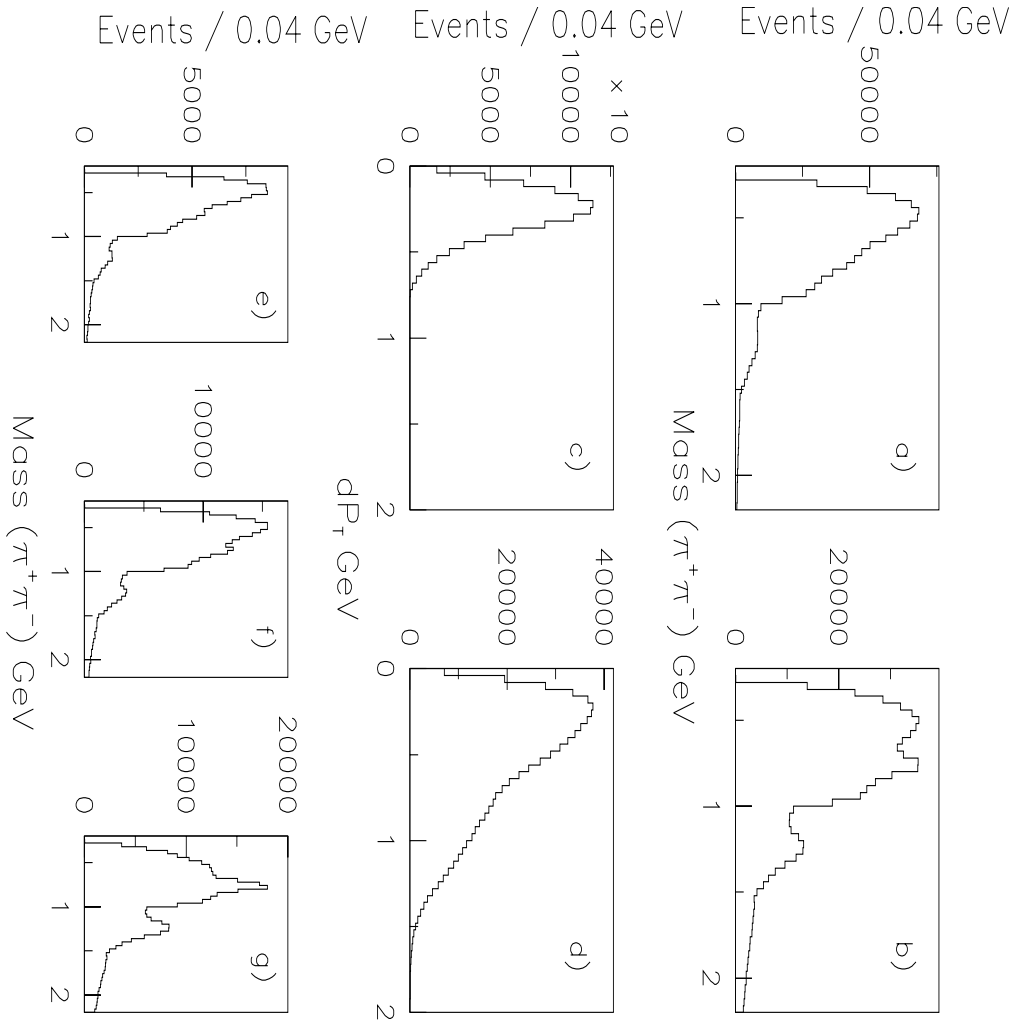
In addition to these waves, a  $J^P = 2^- a_2(1320)\pi$  wave was required in the fit. The  $J^P = 2^- a_2(1320)\pi$  wave observed in this experiment is consistent with the two  $\eta_2$  resonances observed by Crystal Barrel [14] with both states decaying to  $a_2(1320)\pi$ . The  $2^{-+} a_2(1320)\pi$  signal is suppressed at small  $dP_T$ . This behaviour is consistent with the signals being due to standard  $q\bar{q}$  states [6].

A similar effect is observed in the  $K_S^0 K^\pm \pi^\mp$  [15] and  $\eta\pi^+\pi^-$  [8] channels where the  $f_1(1285)$ ,  $f_1(1420)$  and  $\eta'$  are all more prominent in the large  $dP_T$  sample and start to disappear at low  $dP_T$ .

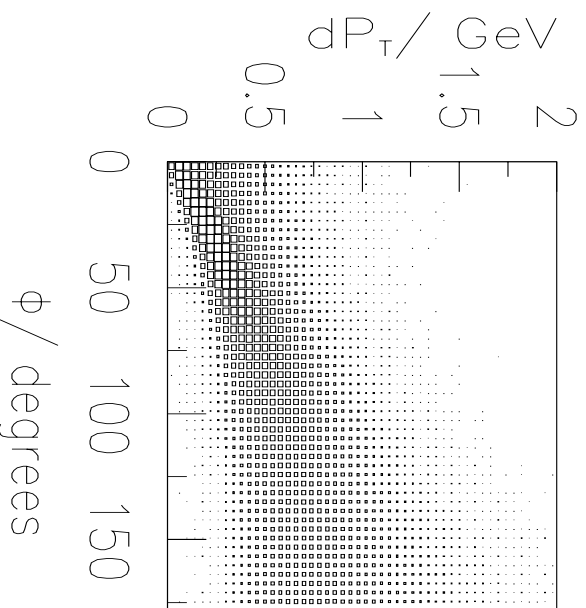
In fact it has been observed that all the undisputed  $q\bar{q}$  states (i.e.  $\rho^0(770)$ ,  $\eta'$ ,  $f_2(1270)$ ,  $f_1(1285)$ ,  $f_2'(1525)$  etc.) are suppressed as  $dP_T$  goes to zero, whereas the glueball candidates  $f_J(1710)$ ,  $f_0(1500)$  and  $f_2(1930)$  survive. It is also interesting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

It has previously been observed that the resonances produced in the central region depend on the four momentum transferred from the fast ( $t_f$ ) and slow



**FIGURE 4.** Results of cutting on the four momentum transferred at the proton vertices. The  $\pi^+\pi^-$  mass spectrum for a)  $|t_f| < 0.15$  and  $|t_s| < 0.15$  GeV<sup>2</sup> and c)  $|t_f| > 0.15$  and  $|t_s| > 0.15$  GeV<sup>2</sup>. The  $dP_T$  distribution for e)  $|t_f| < 0.15$  and  $|t_s| < 0.15$  GeV<sup>2</sup> and d)  $|t_f| > 0.15$  and  $|t_s| > 0.15$  GeV<sup>2</sup>. The  $\pi^+\pi^-$  mass spectrum for g)  $|t_f| > 0.15$  and  $|t_s| > 0.15$  GeV<sup>2</sup> and e)  $dP_T < 0.2$  GeV, f)  $0.2 < dP_T < 0.5$  GeV and g)  $dP_T > 0.5$  GeV.



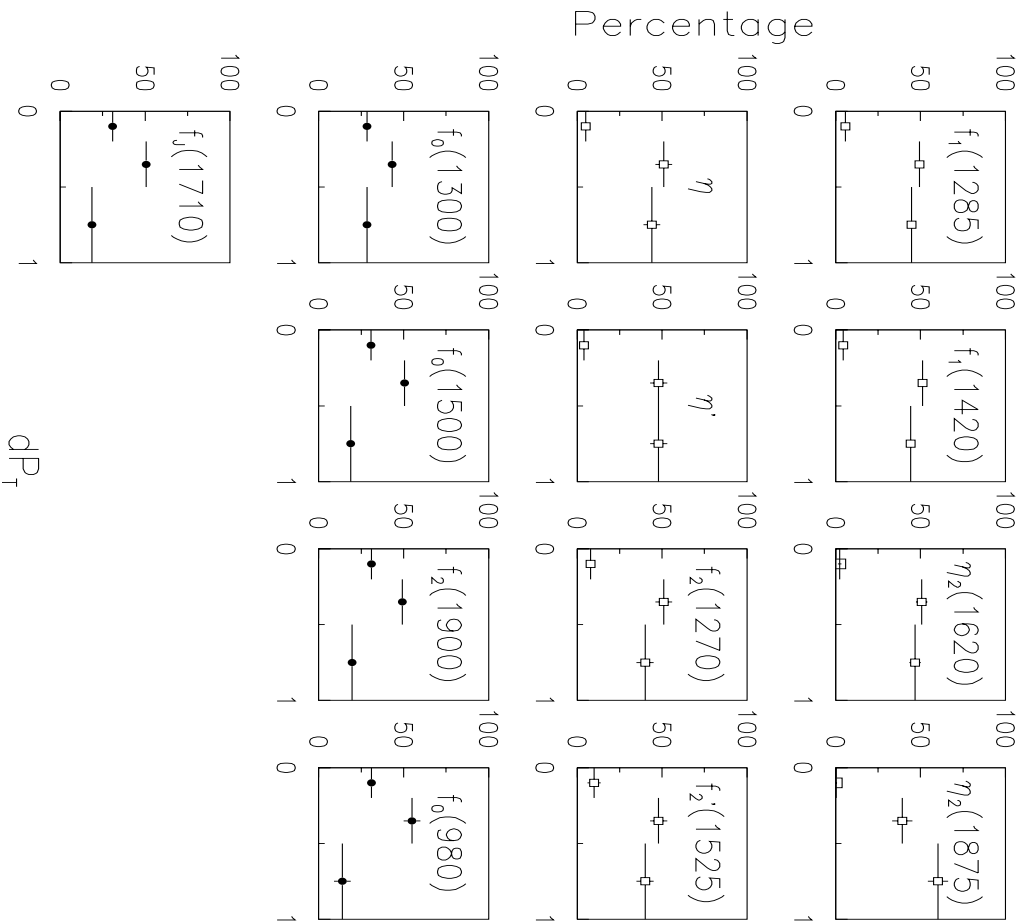
**FIGURE 5.**  $dP_T$  versus the azimuthal angle between the fast and slow protons ( $\phi$ ).

vertices ( $t_s$ ) [5]. The  $\pi^+\pi^-$  mass spectrum is shown for the case where  $|t_f|$  and  $|t_s|$  are both less than 0.15 GeV<sup>2</sup> in figure 4a) and in figure 4b) for the case when  $|t_f|$  and  $|t_s|$  are both greater than 0.15 GeV<sup>2</sup>. As can be seen the amount of  $\rho^0(770)$  and  $f_2(1270)$  does change as a function of this cut. However, in figures 4c) and d) the  $dP_T$  distribution for these two cases is shown where it can be seen the events that have small  $|t|$  are restricted to small values of  $dP_T$ . To show that  $dP_T$  is the most important underlying dynamical effect the  $dP_T$  cut has been applied to the sample of events with large  $|t|$ . Figures 4e), f) and g) show the events when  $|t_f|$  and  $|t_s|$  are both greater than 0.15 GeV<sup>2</sup> for  $dP_T \leq 0.2$  GeV,  $0.2 \leq dP_T \leq 0.5$  GeV and  $dP_T \geq 0.5$  GeV respectively. As can be seen the  $dP_T$  cut still works in this sample and hence it would seem that  $dP_T$  is the most important cut to be used.

An effect on the resonances observed has also been seen when cuts have been made on the azimuthal angle ( $\phi$ ) between the fast and slow proton. This angle  $\phi$  is related to  $dP_T$  by

$$\cos\phi = \frac{dP_\pi^2 - P_\pi^2}{4s t_f}$$

where  $P_T$  is the transverse momentum of the central system. The correlation between  $dP_T$  and  $\phi$  is shown in figure 5. Although cuts in  $\phi$  do produce an

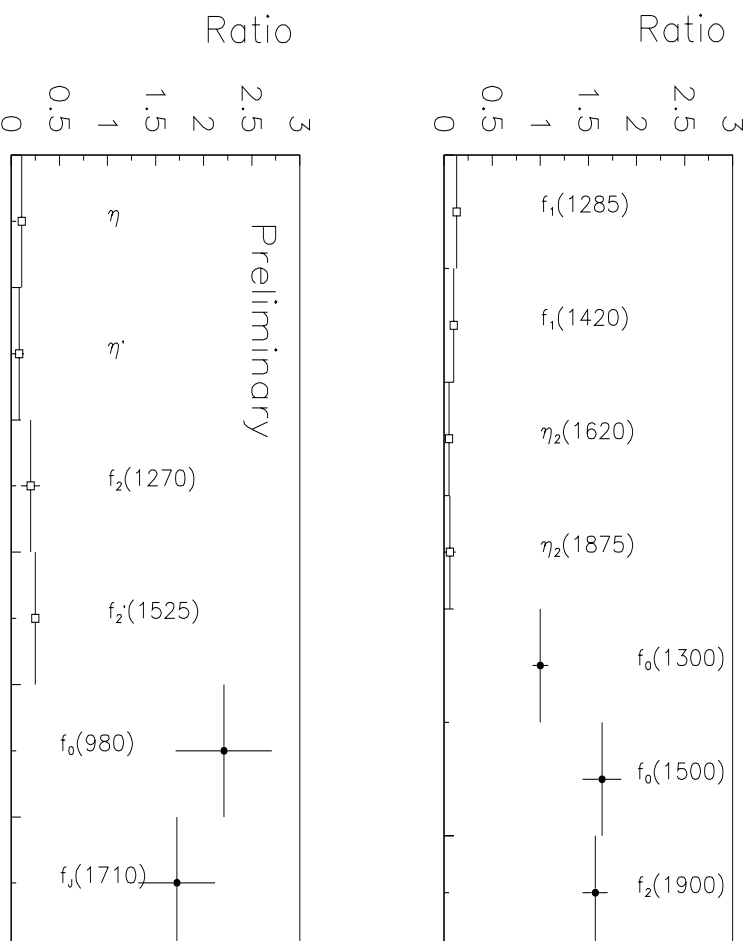


**FIGURE 6.** The percentage of the resonance as a function of  $dP_T$  effect on the resonances observed the effect is not as clear compared to cuts in  $dP_T$ .

## 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. The results of these fits are summarised in figure 6 where the percentage of each resonance as a function of  $dP_T$  is presented. Figure 7 shows the ratio of the number of





**FIGURE 7.** The ratio of the amount of resonance with  $dP_T \leq 0.2$  to the amount with  $dP_T \geq 0.5$  GeV.

events for  $dP_T < 0.2$  GeV to the number of events for  $dP_T > 0.5$  GeV for each resonance considered. As can be seen all the undisputed  $q\bar{q}$  states have a small value for this ratio whereas the interesting states have a high value.

## CONCLUSIONS

Preliminary results show that there is the possibility of a glueball- $q\bar{q}$  filter mechanism in central production. All the undisputed  $q\bar{q}$  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.

## REFERENCES

1. The WA102 collaboration: D. Barberis, W. Beusch, F.G. Binon, A.M. Blick, F.E. Close, K.M. Danielsen, A.V. Dolgoplov, S.V. Donskov, B.C. Earl, D. Evans, B.R. French, T. Hino, S. Inaba, A.V. Inyakin, T. Ishida, A. Jacholkowski, T. Jacobsen, G.V. Khaustov, T. Kinashi, J.B. Kinson, A. Kirk, W. Klempf, V. Kolosov, A.A. Kondashov, A.A. Lednev, V. Lenti, S. Maljukov, P. Martinengo, I. Minashvili, K. Myklebost, T. Nakagawa, K.L. Norman, J.M. Olsen, J.P. Peigneux, S.A. Polovnikov, V.A. Polyakov, Yu.D. Prokoshkin, V. Romanovsky, H. Rotscheidt, V. Rumyantsev, N. Russakovich, V.D. Samoylenko, A. Semenov, M. Sené, R. Sené, P.M. Shaqin, H. Shimizu, A.V. Singovsky, A. Sobol, A. Solovjev, M. Stassinaki, J.P. Stroot, V.P. Sugonyayev, K. Takamatsu, G. Tchatchidze, T. Tsuru, G. Vassiliadis, M. Venables, O. Villalobos Bailie, M.F. Votruba, Y. Yasu.
2. D.Robson, Nucl Phys **B130** (1977) 328;
3. F.E. Close, Rep. Prog. Phys. **51** (1988) 833.
4. T.A. Armstrong *et al.*, Nucl. Instr. and Methods **A274** (1989) 165; F. Antinori *et al.*, Il Nuovo Cimento **A107** (1994) 1857.
5. S.N. Ganguli and D.P. Roy, Phys. Rep. **67** (1980) 203.
6. T.A. Armstrong *et al.*, Zeit. Phys. **C 51** (1991) 351.
7. F.E. Close and A. Kirk, Phys. Lett. **B397** (1997) 333.
8. D. Barberis *et al.*, Phys. Lett. **B 397** (1997) 339.
9. D. Barberis *et al.*, Phys. Lett. **B 388** (1996) 853.
10. T.A. Armstrong *et al.*, Phys. Lett. **B 227** (1989) 186.
11. D. Barberis *et al.*, CERN/PPE 97-89. To be published in Phys. Lett.
12. S. Abatzis *et al.*, Phys. Lett. **B324** (1994) 509.
13. S.U. Chung *et al.*, Ann. d. Physik. **4** (1995) 404.
14. A. Abele *et al.*, Nucl. Phys. **A609** (1996) 562.
15. C. Anslser *et al.*, Zeit. Phys. **C71** (1996) 227.
16. D. Barberis *et al.*, CERN/PPE 97-88. To be published in Phys. Lett.