New results from WA102 experiment

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A study of central meson production as a function of the azimuthal angle ϕ between the two outgoing protons show that the ϕ distributions are different for the different J^{PC} of the central system and that the observed distributions are consistent with the DPE mediated by two vector Pomerons. In addition, the distributions of the difference in transverse momentum (dP_T) of exchange particles are significantly different for the undisputed $q\bar{q}$ states and the glueball candidates.

The S-wave spectrum of the centrally produced $K\bar{K}$, and $\pi\pi$ systems show evidence on $f_0(980)$, $f_0(1370)$, $f_0(1500)$ and $f_J(1710)$ states production. The spin of $f_J(1710)$ is unambiguously identified as J=0.

1. INTRODUCTION

The Central Production process is considered for a long time [2] as a source of the gluon-rich meson states, in particular glueballs, because it contains the Double Pomeron Exchange (DPE) and the Pomeron is thought to be a multi-gluon object [3].

The WA102 experiment at CERN Omega Spectrometer, the fixed target central production experiment, studies exclusive final states produced in reaction:

$$p_{beam}p_{target} \rightarrow p_f X^0 p_s \tag{1}$$

where the subscripts f and s refer to the fastest and slowest particle in the laboratory frame respectively and X^0 represents the central system, at the beam momentum of 450 GeV/c. The double exchange process is selected kinematically at the trigger level by requirement of the sufficient rapidity gap between the central particles and fast and slow protons.

The rapidity gap selection should be equally efficient for any double exchange process, i.e. Reggeon-Reggeon (RR), Reggeon-Pomeron (RP) and Pomeron-Pomeron (PP). The fraction of DPE in the total double exchange cross section at $\sqrt{s} = 29.1$ GeV is estimated to about 50% [4]. Although for every exclusive meson system production the fractions of different exchanges could strongly depend on the meson system coupling to the RR, RP and PP pairs.

Hence the observed process is, in general, a mixture of different double exchanges, which could make the analysis of the produced meson state, in particular Partial Wave Analysis (PWA), rather complicated and ambiguous. The clean PWA results obtained by several central production experiments [5–7] indicate that the production in each case is dominated by one exchange or, if several, by the exchanges with the same naturality.

The dependence of the central production cross section of different meson states on the difference of the protons momenta transfer (dP_T)[8] and the azimuthal angle ϕ between outgoing protons [9], observed by the WA102 experiment, give more interesting information on the central production dynamics.

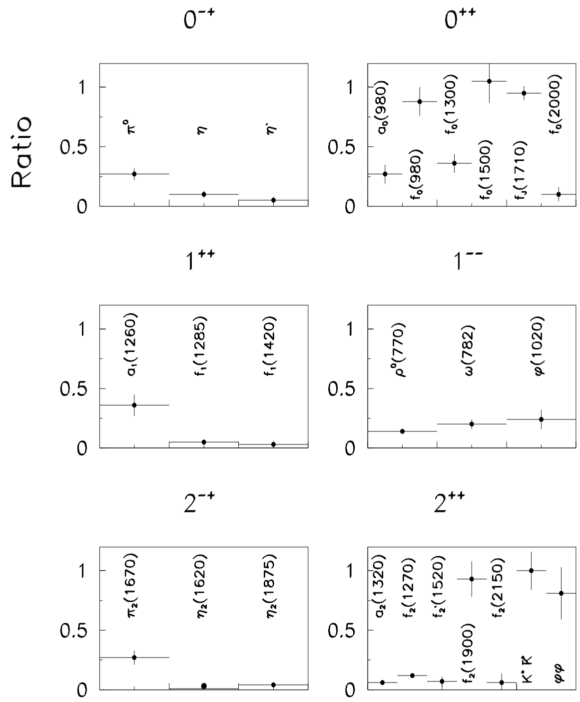

Figure 1. The ratio of the amount of resonance with $dP_T < 0.2$ to the amount with $dP_T > 0.5$GeV.

2. AN UPGRADE OF THE CENTRAL PRODUCTION DYNAMICS

There are two experimental effects inconsistent with the naive model of the central meson production via completely uncorrelated Reggeon emission from the proton vertices followed by the central Reggeon-Reggeon fusion. The first one is the resonance production dependence on the difference in the transverse momentum (dP_T) between the particles exchanged from the fast and slow vertices [8]. The ratio of the amount of resonance with $dP_T < 0.2$ to the amount with $dP_T > 0.5$ is different for the $q\bar{q}$ mesons and the mesons with possibly enriched glue component (fig.1). The second one is the significantly different azimuthal angle ϕ distribution for different final states, where ϕ is defined as the angle between the p_T vectors of the two protons[9]. Both variables should not be essential for the fully factorized double exchanged process and ϕ distribution should be flat. The observed distributions are clearly not flat (fig.2).

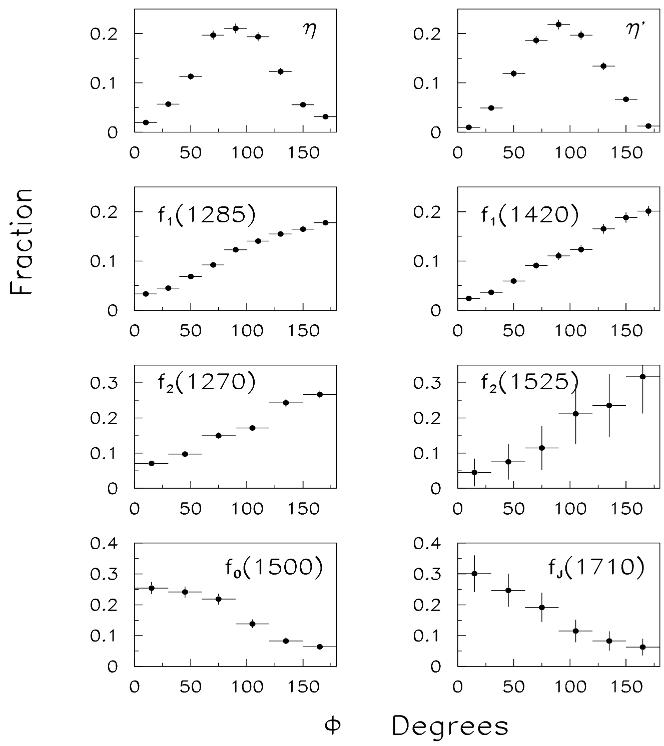

Figure 2. The azimuthal angle between the fast and slow protons ϕ for various resonances.

The dP_T and ϕ effects are not completely understood. First, dP_T and ϕ are correlated variables: $\cos\phi = \frac{dP_T^2 - P_T^2}{4t_s t_f}$ and it is not yet clear whether all observed dependences can be explained by the single effect.

Several papers have been published on the ϕ effects [13,14]. 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 [14] have calculated the ϕ dependencies for the production of resonances with different J^{PC}.

The simplest situation is for the production of $J^{PC}=0^{-+}$ states where the model predict:

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

where t_1 and t_2 are the four momentum transfer at the beam-fast and target-slow vertices respectively. Fig. 3a) show the experimental ϕ distribution for the η'. The distribution have been fitted to the form $\alpha\sin^2\phi$ which describes the data well.

For the $J^{PC}=1^{++}$ states the model predicts that $J_Z=\pm1$ should dominate and that:

$$\frac{d^3\sigma}{d\phi dt_1 dt_2} \propto (\sqrt{t_1} - \sqrt{t_2})^2 + 4\sqrt{t_1 t_2}\sin^2\phi/2 \tag{3}$$

Fig. 3b) show the ϕ distribution for the $f_1(1285)$. The distribution if fitted to the form $\alpha + \beta\sin^2\phi/2$ which describes the data well. The interesting feature of the equation (3) is that if the difference of t_1 and t_2 is large, the ϕ distribution should be close to constant while for the small $(t_1 - t_2)$ absolute values it should be $\propto \sin^2\phi/2$. The experimental distributions (fig. 4) are consistent with this dependence.

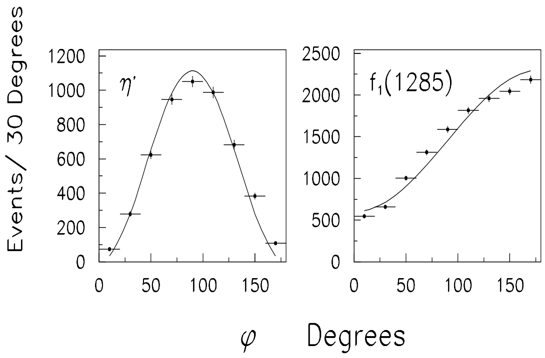

Figure 3. The azimuthal angle ϕ between fast and slow protons for η' and $f_1(1285)$.

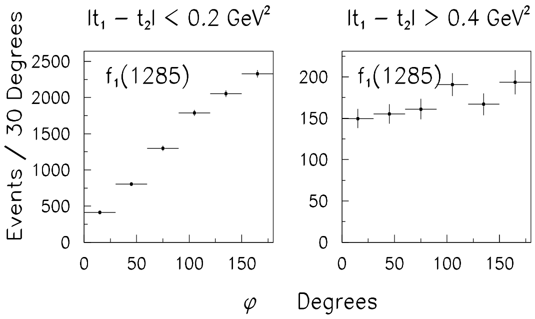

Figure 4. The azimuthal angle ϕ between fast and slow protons the $f_1(1285)$ for $|t_1 - t_2| \leq 0.2$ and $|t_1 - t_2| \geq 0.4$.

The model proposed by Close and Kirk [12] assume that the dP_T dependencies are due to the two gluon coupling to the final state. In this model Pomeron is a color singlet gluonic system and if gluon is exchanged between Pomerons then a gluonic state is produced, whereas if a quark is exchanged then a $q\bar{q}$ state is produced. The small differences in transverse momentum between the two exchanged particles should kinematicaly enhance gluon exchange, hence gluonic systems production. Applying this model to the experimental dP_T spectra (fig.1) one can conclude that the states with the enhanced glue component are $f_0(980)$, $f_0(1500)$, $f_0(1710)$ and $f_2(1900)$. It is interesting to mention that K^*K^* [15] and $\phi\phi$ [16] states are also consistent with being enriched by glue. Unfortunately the low statistics do not allow detailed study of these systems.

3. NEW RESULTS ON THE MESON SPECTROSCOPY

The current understanding of the scalar and tensor glueballs is that these states are strongly mixed with the $q\bar{q}$ neighbors and cannot be observed as a pure gg states. This means that good understanding of $q\bar{q}$ nonets is needed for the glue-exotic search.

The partial wave analysis of the centrally produced high statistics $\pi\pi$ [5] and $K\bar{K}$ [6] data samples gave several new interesting results. First, the $f_J(1710)$ state is clearly seen in the K^+K^- S-wave spectrum (fig.5). The two other S-wave peaks are attributed to $f_0(980)$ and $f_0(1500)$ states. Hence the spin of $f_J(1710)$ state has to be set to J=0. No

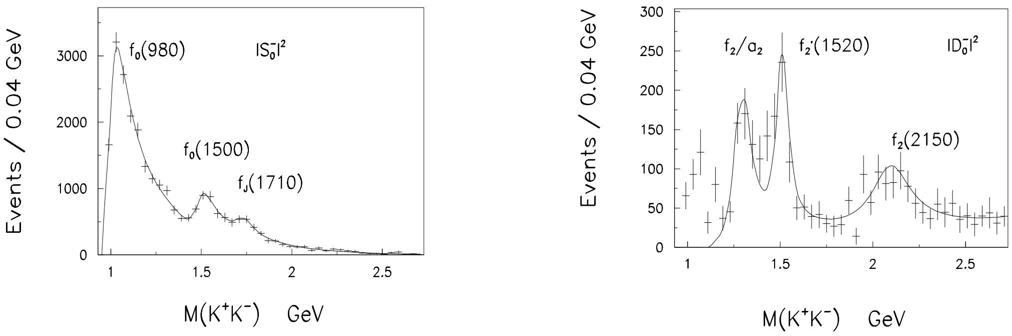

Figure 5. The S_0^- and D_0^- - waves resulting from a partial wave analysis of the K^+K^- system.

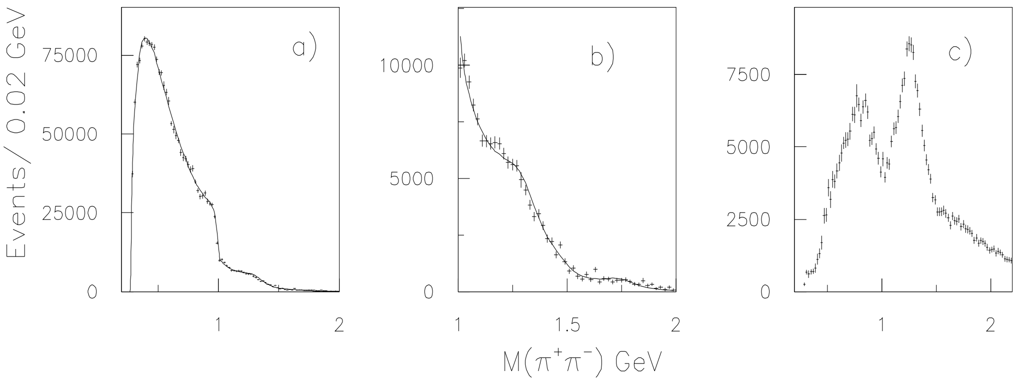

Figure 6. The S and D- waves resulting from a partial wave analysis of the $\pi^+\pi^-$ system: a) - S_0^-, b) - S_0^- at high mass and c) - D_0^-.

sign of $f(1710)$ state can be observed in the K^+K^- D-wave. The $\pi\pi$ S-wave shows a clear threshold enhancement followed by a sharp drop at 1 GeV (fig.6). The S-wave spectrum fits well to the background and Breit-Wigners corresponding to $f_0(980)$, $f_0(1370)$, $f_0(1500)$ and $f_J(1710)$ states. There is a clear evidence for $f_2(1270)$ in the D_0^- wave. An interesting feature of the D_0^- wave is the presence of a structure below 1 GeV (fig. 6c).

In order to check that the observed particular partial waves behavior is not affected by the acceptance uncertainties or problems due to non-central events, both $\pi\pi$ and $K\bar{K}$ data where reanalyzed using a series of different cuts. Also the neutral and charged pairs where analyzed separately: $\pi^+\pi^-$ and $\pi^0\pi^0$ [5], and K^+K^- and $K_S^0K_S^0$ [6] respectively. The charged and neutral systems have not simply a different acceptance but different sets of allowed partial waves which leads to eight ambiguous solutions for the charged pairs case and only two for the neutral ones. The selected unique physical solutions [5,6] are the same for both $\pi^+\pi^-$ - $\pi^0\pi^0$ and K^+K^- - $K_S^0K_S^0$ cases.

The S-wave from both $\pi^+\pi^-$ and K^+K^- channels was fitted using interfering Breit-Wigners and a background. The $f_0(980)$, $f_0(1370)$, $f_0(1500)$ and $f_0(1710)$ states where required by the fit. A T-matrix and K-matrix analysis of the same data was also done [10]. The pole position for both cases are in a good agreement with the Breit-Wigners parameters. To obtain the branching ratios to $\pi\pi$ and $K\bar{K}$ and the pole positions of all resonances, a coupled channel fit has been performed using all three method mentioned above. The following parameters are a mean from the three methods. The sheet II pole positions are:

$$
\begin{array}{lrcl}
f_0(980): & M & = & (\ 987 \pm \ 6 \pm \ 6) - i(\ 48 \pm 12 \pm \ 8)\ \mathrm{MeV} \\
f_0(1370): & M & = & (1312 \pm 25 \pm 10) - i(109 \pm 22 \pm 15)\ \mathrm{MeV} \\
f_0(1500): & M & = & (1502 \pm 12 \pm 10) - i(\ 49 \pm \ 9 \pm \ 8)\ \mathrm{MeV} \\
f_0(1710): & M & = & (1727 \pm 12 \pm 11) - i(\ 63 \pm \ 8 \pm \ 9)\ \mathrm{MeV}
\end{array}
$$

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

$$\frac{f_0(1370) \to K\bar{K}}{f_0(1370) \to \pi\pi} = 0.46 \pm 0.15 \pm 0.11$$
$$\frac{f_0(1500) \to K\bar{K}}{f_0(1500) \to \pi\pi} = 0.33 \pm 0.03 \pm 0.07$$
$$\frac{f_0(1710) \to K\bar{K}}{f_0(1710) \to \pi\pi} = 5.0 \pm 0.6 \pm 0.9$$

The pole parameters are consistent with the PDG [11] values for this resonances, whereas the branching ratios are somewhat different.

The suppression of 0^{-+} states in central production [17] help to determine the characteristics of $f_1(1285)$ and $f_1(1420)$ more precisely than is possible in other experiments which see both 0^{-+} and 1^{++} states and have to separate contribution of $f_1(1285)$ from $\eta(1295)$ and $f_1(1420)$ from $\eta(1440)$. The $f_1(1285)$ was observed in 4 decay modes and $f_1(1420)$ - in 3 decay modes [18]. The measured branching fractions are presented in tables 1 and 2 respectively. The precision is significantly improved with respect to the current PDG values [11].

Table 1
The branching fractions of the $f_1(1285)$

Decay mode	Fraction (%)
$\pi\pi\pi\pi$	33.0 ± 1.5 ± 1.5
$K\bar{K}\pi$	8.7 ± 0.4 ± 0.4
$\eta\pi\pi$	52.8 ± 3.8 ± 2.5
$\rho^0\gamma$	5.4 ± 0.4 ± 0.3
$\phi\gamma$	< 0.043 (95% c.l.)

Table 2
The branching fractions of the $f_1(1420)$

Decay mode	Fraction (%)
$K*(980)\bar{K}$	96.0 ± 1.0 ± 1.0
$a_0(980)\pi$	4.0 ± 1.0 ± 1.0
$\phi\gamma$	0.3 ± 0.12 ± 0.2

4. SUMMARY

A study of the central production dynamics show that there are two variables sensitive to the nature of the produced meson states: a difference in the exchanged particles transverse momentum dP_T and azimuthal angle between outgoing protons ϕ. According to the proposed models, ϕ dependencies are consistent with the DPE mediated by the vector Pomeron and the shape of dP_T spectrum filter out glueballs over the $q\bar{q}$ states.

The S-wave spectrum of the centrally produced $K\bar{K}$, and $\pi\pi$ systems show evidence on $f_0(980)$, $f_0(1370)$, $f_0(1500)$ and $f_J(1710)$ states production. The spin of $f_J(1710)$ is unambiguously identified as J=0. The branching fractions of the vector $f_1(1285)$ and $f_1(1420)$ mesons decays are defined with the high precision.

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