Dynamics of glueball and $q\bar{q}$ production in the central region of pp collisions

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Abstract. A strong dependence of meson production with different J^{PC} on the angle between the transverse momentum vectors of the outgoing protons is observed. The ϕ and t dependences of several resonances with $J^{PC} = 0^{\pm +}, 1^{++}, 2^{\pm +}$ can be described by a model of double Pomeron exchange for the soft Pomerons acting as non-conserved vector currents. The 0^{++} and 2^{++} sector reveals a systematic behaviour in the data that appears to distinguish between $q\bar{q}$ and non-$q\bar{q}$ or glueball candidates.

INTRODUCTION

The WA102 fixed target experiment [1] at the CERN Omega Spectrometer studies centrally produced exclusive final states formed in the reaction

$$pp \rightarrow p_f X p_s$$

at 450 GeV/c, where subscripts f and s refer to the fastest and slowest particles in the laboratory frame respectively and X represents the central system. Such reactions are predicted to be a source of gluonic final states via double Pomeron exchange (DPE) [2]. There has been an intensive experimental programme in the last two years by the WA102 collaboration which has produced a large and detailed data set in meson spectroscopy [3]. A strong dependence on the angle between the transverse momentum vectors of the outgoing protons was observed in meson production with different J^{PC}.

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THE EFFECT OF NON FLAT AZIMUTHAL ANGLE

The azimuthal angle ϕ is defined as the angle between the p_T vectors of the p_f and p_s in the pp centre of mass. Naively it may be expected that this angle would be flat irrespective of the resonances produced. The experimentally observed ϕ dependences are clearly non flat [3] and considerable variations are found between resonances with different J^{PC}s. Figures 1(a), 2(a), 3(a), 4(a-d) show the ϕ dependences for resonances with $J^{PC} = 0^{-+}$ (the η'), with $J^{PC} = 2^{-+}$ (the $\eta_2(1645)$), with $J^{PC} = 1^{++}$ (the $f_1(1285)$), two with $J^{PC} = 0^{++}$ (the $f_0(1370)$ and $f_0(1500)$) and two with $J^{PC} = 2^{++}$ (the $f_2(1270)$ and $f_2(1950)$) respectively.

THEORETICAL STUDY ON ϕ DEPENDENCE

Several theoretical papers have been published on ϕ dependence [4,5]. All agree that the exchanged particle (it can be Pomeron) must have $J > 0$ and that $J = 1$ is the simplest explanation. Using $\gamma^*\gamma^*$ collisions as an analogy Close and Schuler have calculated the ϕ dependencies for the production of resonances with different J^{PC}s [5]. In their model for DPE the Pomeron acts as non-conserved vector current and the cross section of central production is expressed as follows:

$$\frac{d\sigma}{dt_1 dt_2 d\phi'} \sim {G_E^p}^2(t_1){G_E^p}^2(t_2)F^2(t_1,t_2)A(t_1,t_2,\phi'),$$

where ϕ' is the angle between two pp scattering planes in the Pomeron-Pomeron centre of mass[2]; $G_E^p(t)$ is the proton-Pomeron form factor which is described using the Donnachie Landshoff formalism [6]; $A(t_1,t_2,\phi')$ is the prediction for the interaction of two Pomerons acting like non-conserved vector currents; $F^2(t_1,t_2)$ is the Pomeron-Pomeron-meson form factor which for collisions of two Pomerons with a given polarisation (transverse T or longitudinal L) is parametrized as: $e^{-(b_T t_i + b_L t_j)}, \quad i,j = 1,2.$

0^{-+} – the η'. According to Close-Schuler model

$$A(t_1,t_2,\phi') = t_1 t_2 \sin^2(\phi'), \quad F^2(t_1,t_2) = e^{-b_T(t_1+t_2)}.$$

Fig.1 (a) shows a good agreement of model prediction with experimental ϕ dependence. In order to describe the t dependence, fig.1 (b), one need $b_T = 0.5\ GeV^{-2}$.

1^{++} – the $f_1(1285)$. For 1^{++} states the model predicts that $J_Z = \pm 1$ should dominate, which has been found to be correct [3], and then

$$A(t_1,t_2,\phi') = (\sqrt{t_1} - \sqrt{t_2})^2 + 4\sqrt{t_1 t_2}\sin^2(\phi'/2), \quad F^2(t_1,t_2) = e^{(-b_T t_i + b_L t_j)}.$$

[2] The WA102 collaboration measures the azimuthal angle ϕ in the pp c.m. frame. To compare the experimental result with model predictions the angle ϕ' is transformed to ϕ.

As can be seen from fig.3 (a) the ϕ distribution is in good agreement with prediction. Fixing b_T from the previous case we can determine b_L from the t distribution, fig.3 (b), to be $b_L = 3\ GeV^{-2}$. In addition we have a parameter free prediction of the variation of the ϕ distribution as a function of $|t_1 - t_2|$. Fig. 3 (c) and (d) show the output of the Monte Carlo superimposed on the ϕ for the $f_1(1285)$ for $|t_1 - t_2| \leq 0.2\ GeV^{-2}$ and $|t_1 - t_2| \geq 0.4\ GeV^{-2}$ respectively. The agreement between the data and the prediction is very good.

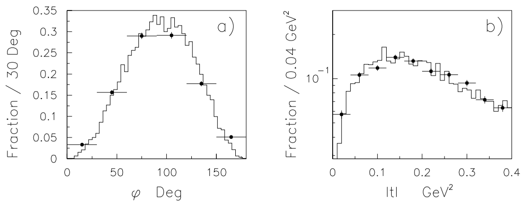

FIGURE 1. (a) The ϕ and (b) t distributions for the η' for the data (dots) and the model predictions from Monte-Carlo (histogram).

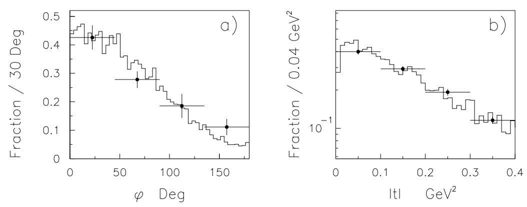

FIGURE 2. (a) The ϕ and (b) t distributions for the $\eta_2(1645)$ for the data (dots) and the Monte-Carlo (histogram).

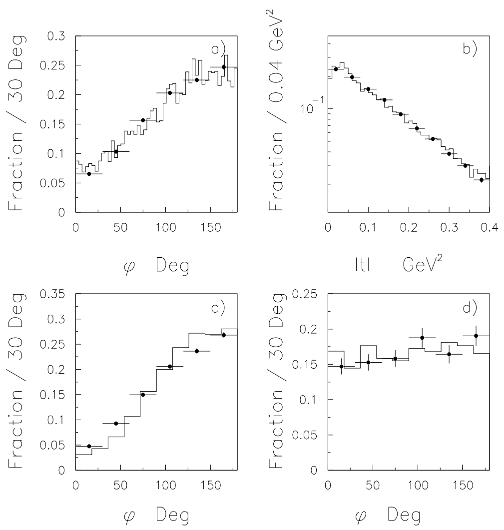

FIGURE 3. (a) The ϕ and (b) t distributions for the $f_1(1285)$ for the data (dots) and the Monte-Carlo (histogram). (c) and (d) the ϕ distributions for $|t_1 - t_2| \leq 0.2$ and $|t_1 - t_2| \geq 0.4$ GeV^2 respectively.

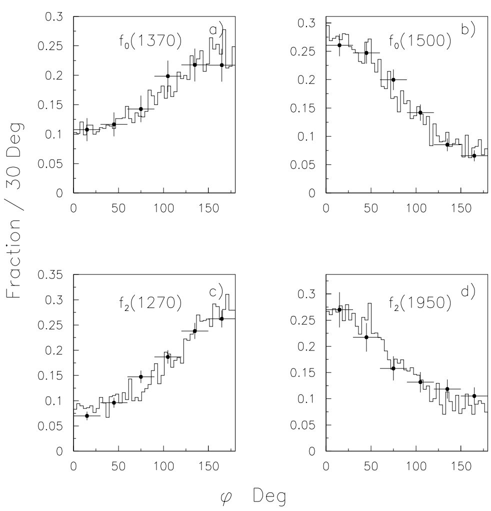

FIGURE 4. The ϕ distributions for the (a) $f_0(1370)$, (b) $f_0(1500)$, (c) $f_2(1270)$ and (d) $f_2(1950)$ for the data (dots) and the Monte-Carlo (histogram).

2^{-+} – the $\eta_2(1645)$. The 2^{-+} states are predicted to be produced polarized and helicity 2 suppressed. This has been found experimentally to be true [3]. In this case

$$A(t_1, t_2, \phi') = (\sqrt{t_1} - \sqrt{t_2})^2 + 4\sqrt{t_1 t_2}\cos^2(\phi'/2), \quad F^2(t_1, t_2) = e^{(-b_T t_i + b_L t_j)}.$$

Parameters b_T and b_L are fixed now. Fig.2 shows the remarkable agreement between the data and parameter free model predictions.

$\underline{J^{PC} = 0^{++} \text{ and } 2^{++}.}$ For 0^{++} and helicity zero amplitude of 2^{++} (which experimentally is found to dominate [3]) the model prediction is

$$F^2(t_1,t_2)A(t_1,t_2,\phi') = t_1t_2[e^{(-\frac{b_L(t_1+t_2)}{2})} + \frac{\sqrt{t_1t_2}}{\mu^2}e^{(-\frac{b_T(t_1+t_2)}{2})}\cos(\phi')]^2.$$

The overall ϕ dependences for the $f_0(1370)$, $f_0(1500)$, $f_2(1270)$ and $f_2(1950)$ can be described by varying the quantity μ^2. Results are shown in fig.4. It is clear that these ϕ dependences discriminate two classes of resonances in the 0^{++} sector and also in the 2^{++}. The $f_0(1370)$ and $f_2(1270)$ can be described using $\mu^2 \approx -0.5$ GeV^2, for the $f_0(1500)$ and $f_2(1950)$ $\mu^2 = +0.7$ GeV^2. If this is the long sought discriminator between $q\bar{q}$ and non-$q\bar{q}$ states or glueballs is for future.

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