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Recent WA76 Results on Central Production

WA76 Collaboration

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presented by Antimo Palano

T.A. Armstrong [1,*)], M. Benayoun [5)], W. Beusch [1)], I.J. Bloodworth [2)], J.N. Carney [2)], R. Childs [2)], B.R. French [1)], B. Ghidini [3)], M. Girone [3)], A. Jacholkowski [1)], J. Kahane [5)], J.B. Kinson [2)], A. Kirk [2)], V. Lenti [3)], Ph. Leruste [5)], A. Malamant [5)], J.L. Narjoux [5)], F. Navach [3)], A. Palano [3)], E. Quercigh [1)], N. Redaelli [1,**)], L. Rossi [1,***)], M. Sene' [5)], R. Sene' [5)], M. Stassinaki [4)], M.T. Trainor [1)], G. Vassiliadis [4)], O. Villalobos Baillie [2)] and M.F. Votruba [2)]

Abstract

The present status is presented on the search for gluonium and hybrid states centrally produced in the reaction $pp \rightarrow p_f(X^0)p_s$ at 300 GeV/c using the CERN Ω spectrometer.

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1) CERN, CH-1211 Geneva 23, Switzerland
2) University of Birmingham, Physics Department,Birmingham,U.K.
3) Dipartimento di Fisica and Sezione INFN, Bari, Italy
4) Athens University, Nuclear Physics Department, Athens, Greece
5) College de France, Paris, France

*) Present address: Pennsylvania State University, University Park, USA
**) Present address: Dipartimento di Fisica and Sezione INFN, Milano, Italy
***) Present address: Dipartimento di Fisica and Sezione INFN, Genova, Italy

1. Introduction

In the last few years, one of the basic motivations of in high energy physics has been the testing of the predictions of QCD, the quantum field theory of strong interactions. The validity of the theory largely depends on the existence of gluons for which experimental evidence has been found in jet studies and in deep inelastic scattering. However, one of the most striking expectations of QCD is the existence of new kinds of matter, built up by valence gluons (glueballs) or by mixtures of quarks and gluons (hybrids).

Experiment WA76 is designed to study exclusive final states in the reaction

$$p\,p \rightarrow p_f\,(X^0)\,p_s$$

where the subscripts f and s indicate the fastest and slowest particles in the laboratory respectively and X^0 represents the central system that is presumed to be produced by a double exchange process. At high centre of mass energies these double exchange processes are believed to be dominated by Double Pomeron Exchange. The Pomeron is thought to have a large gluonic content, so Pomeron − Pomeron scattering could be a source of non $q\bar{q}$ states.

Experiment WA76 has been performed using the CERN Omega spectrometer at two incident beam momenta, 85 and 300 GeV/c, ($\sqrt{s}$ = 12.7 and 23.8 GeV). Results from the 85 GeV/c run can be found in ref. [1], while this paper deals mostly with the analysis of the 300 GeV/c data. Details of the layout of the apparatus, trigger conditions and data processing have been given in a previous publication [2]. This paper gives the present situation regarding our analysis of the $X^0 \rightarrow \pi\pi$, $K\bar{K}$, $K^0_S K^{\pm}\pi^{\mp}$, $\eta\pi^+\pi^-$, $\rho^0\gamma$ and $\pi^+\pi^-\pi^+\pi^-$ final states.

2. Observation of the gluonium candidate $\theta/f_2(1720)$

The K^+K^- channel has been isolated from the other central two − body final states by requiring momentum and energy balance and the request of one of the two Kaons being identified as a K or ambiguous K/p by the Cerenkovs system. In addition, to ensure good geometrical acceptance, only events having the K^+K^- system with Feynman $x_F < 0.$ have been selected. The K^+K^- mass spectrum is shown in fig. 1a.
The spectrum shows evidence for several resonant structures: the $\phi(1020)$ is observed on top of a threshold enhancement and the $f'_2(1525)$ is clearly seen. In addition a $\theta/f_2(1720)$ signal is observed. A fit to this spectrum gives $m = 1713 \pm 10$, $\Gamma = 181 \pm 30$ MeV for the parameters of the $\theta/f_2(1720)$.

The $K^0_S K^0_S$ channel has been isolated from the sample of events having two reconstructed V^0's by requiring total energy and momentum balance. In order to remove the background from random $\pi^+\pi^-$ combinations, a decay length of at least 3 cm was required for each of the two V^0's. The $\pi^+\pi^-$ mass spectrum of the two V^0's (inset fig. 1b) reveals a clear K^0 signal over little background. The $K^0_S K^0_S$ combined spectrum from the 85 GeV/c and 300 GeV/c experiments is shown in fig. 1b and shows evidence for $f'_2(1525)$ and $\theta/f_2(1720)$. A fit to this spectrum yields the following $\theta/f_2(1720)$ parameters: $m = 1706 \pm 10$, $\Gamma = 104 \pm 30$ MeV.

We have fitted the $\theta/f_2(1720)$ angular distributions in the Gottfried − Jackson frame defined in ref. [3] by using the density matrix elements formalism as given in ref. [4] assuming the K^+K^- system to be a mixture of S, P and D interfering waves. The results of the fits are superimposed on the $\cos\theta$ and φ distributions in fig. 2. The fit has a probability of 55% and gives $80 \pm 4\%$ as the D wave contribution indicating that the $\theta/f_2(1720)$ meson is compatible with having $J^{PC} = 2^{++}$. The observation of $\theta/f_2(1720)$, in a kinematic region which has been suggested [5] to be a possible source for the production of glueballs, reinforces the likelihood that the $\theta/f_2(1720)$ is a gluonic state.

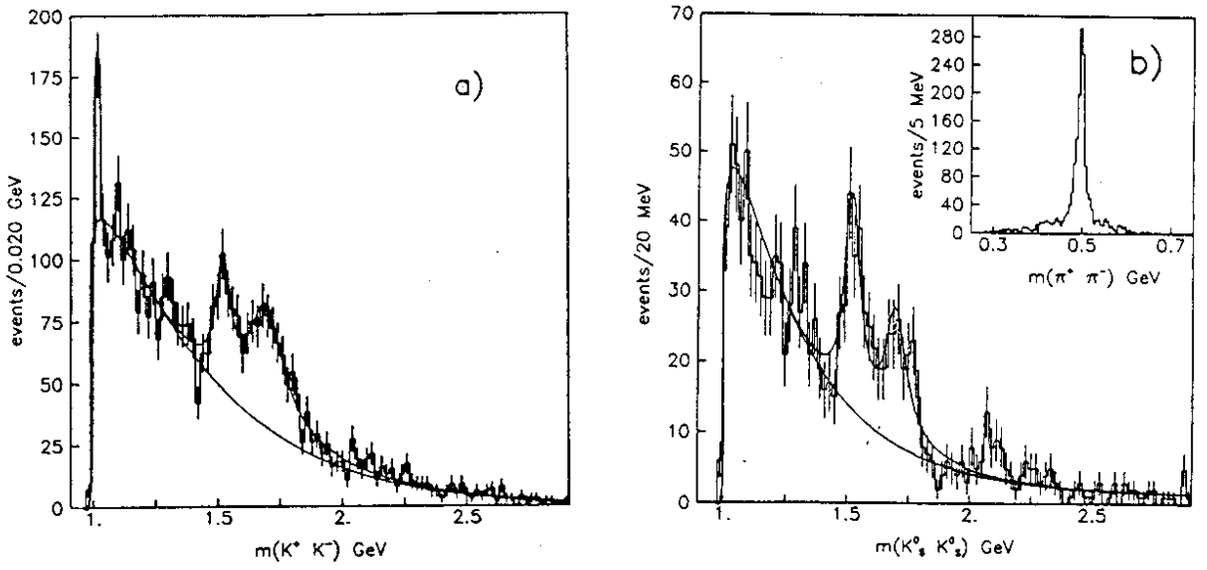

Figure 1: a) K^+K^- effective mass distribution with fit. b) $K^0_SK^0_S$ combined mass spectrum from the 85 GeV/c and 300 GeV/c runs. The inset shows the K^0_S signal.

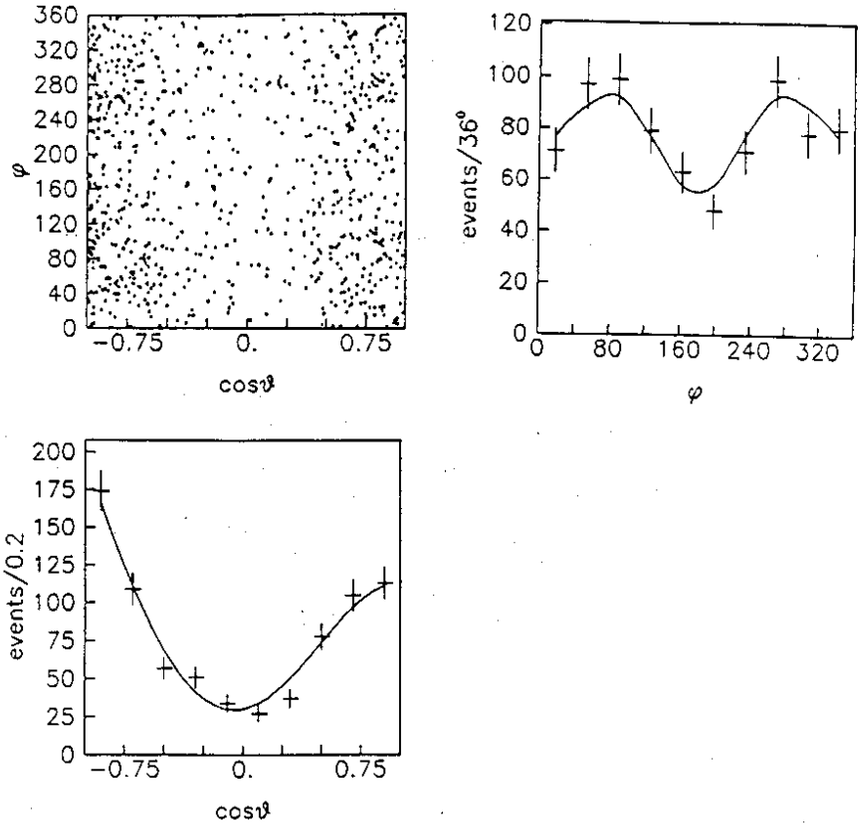

Figure 2: $(\cos\theta,\varphi)$ scatter plot with $\cos\theta$ and φ projections in the Gottfried−Jackson frame for the $\theta/f_2(1720)$ region. The curves are the results of the fit with 80% D wave.

3. The $K^0_S K^{\pm}\pi^{\mp}$ channel

The $K^0_S K^{\pm}\pi^{\mp}$ final state has been selected from the sample of events with one V^0 by requiring momentum and energy balance. In addition compatibility was required with the information coming from the Cerenkov system. Fig. 3a shows the $K^0_S K^{\pm}\pi^{\mp}$ effective mass spectrum.

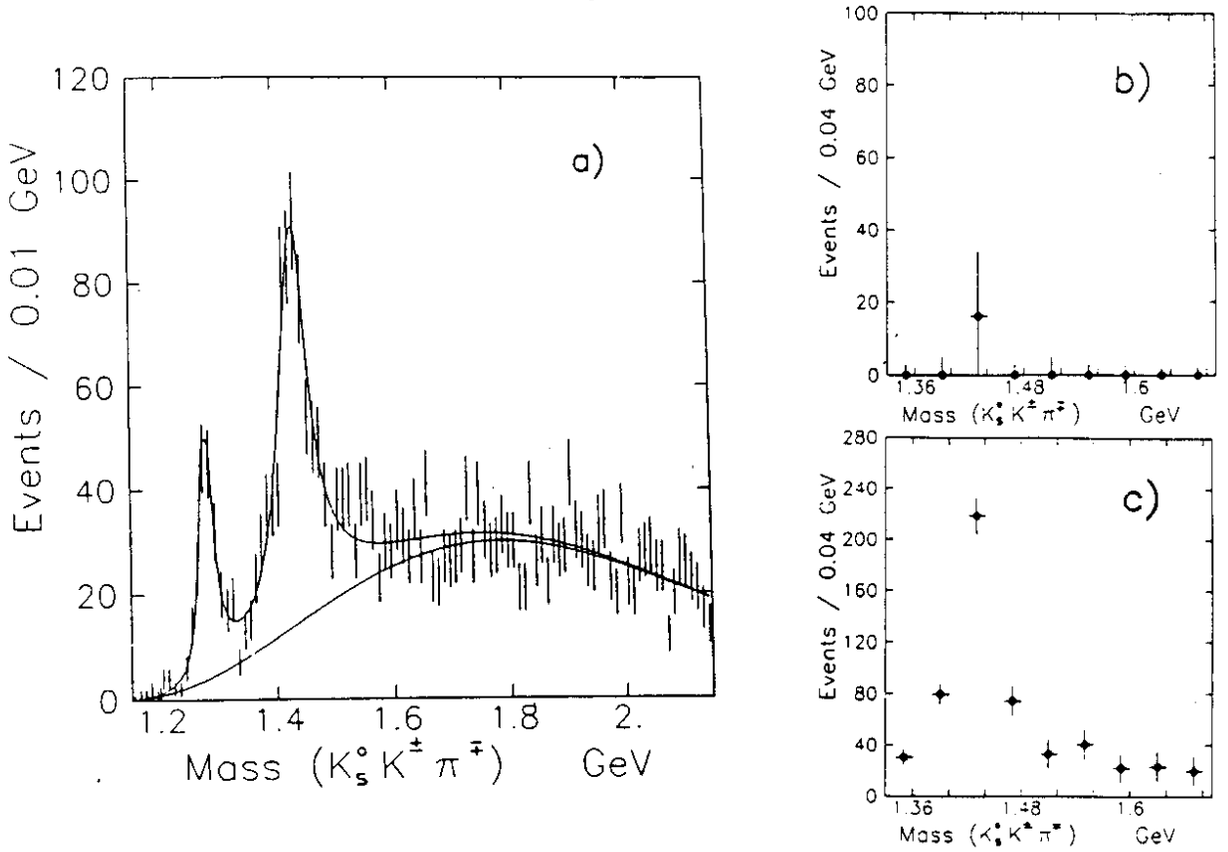

Figure 3: a) $K^0_S K^{\pm}\pi^{\mp}$ effective mass distribution; Results from the Dalitz plot analysis, b) 0^{-+} ($\delta\pi + K^*\bar{K}$), c) 1^{++} $K^*\bar{K}$ contributions.

Clear signals corresponding to the $f_1(1285)$ and $f_1(1420)$ mesons can be observed. A fit to the spectrum yields masses and widths of $f_1(1285)$: $m = 1278 \pm 2$, $\Gamma = 25 \pm 4$ MeV; $f_1(1420)$: $m = 1429 \pm 3$, $\Gamma = 58 \pm 8$ MeV. A Dalitz plot analysis of the $K^0_S K^{\pm}\pi^{\mp}$ mass spectrum has been performed by using the Zemach tensors and an isobar model [6]. The $f_1(1420)$ region has been fitted in 40 MeV slices from 1.33 to 1.69 GeV. Interference between waves having the same spin−parity has been allowed. Interference was also allowed between 1^{++} and 1^{+-} ($K^*\bar{K}$) waves. The $J^{PC} = 0^{-+}$ ($a_0\pi + K^*\bar{K}$) and 1^{++} ($K^*\bar{K}$) contributions are shown in fig. 3b and 3c respectively, all the other contributions other than phase space being consistent with zero. The fit shows that the 1^{++} ($K^*\bar{K}$) is the dominant wave.

4. The $\eta\,\pi^+\,\pi^-$ final state

The $\eta\pi^+\pi^-$ final state has been selected from the sample of events having 2 central tracks and 2 γ's reconstructed in the electromagnetic calorimeter for the $\eta \to \gamma\gamma$ decay mode, and 4 central tracks and 2 γ's for the $\eta \to \pi^+\pi^-\pi^0$ decay mode. Momentum and energy balance was required. Fig. 4a shows the η signal in the $\gamma\gamma$ spectrum, fig. 4b shows the η and ω signals in the $\pi^+\pi^-\pi^0$ mass spectrum. Fig. 4c shows the combined $\eta\pi^+\pi^-$ effective mass distribution where clear $\eta'(980)$ and $f_1(1285)$ signals can be observed.

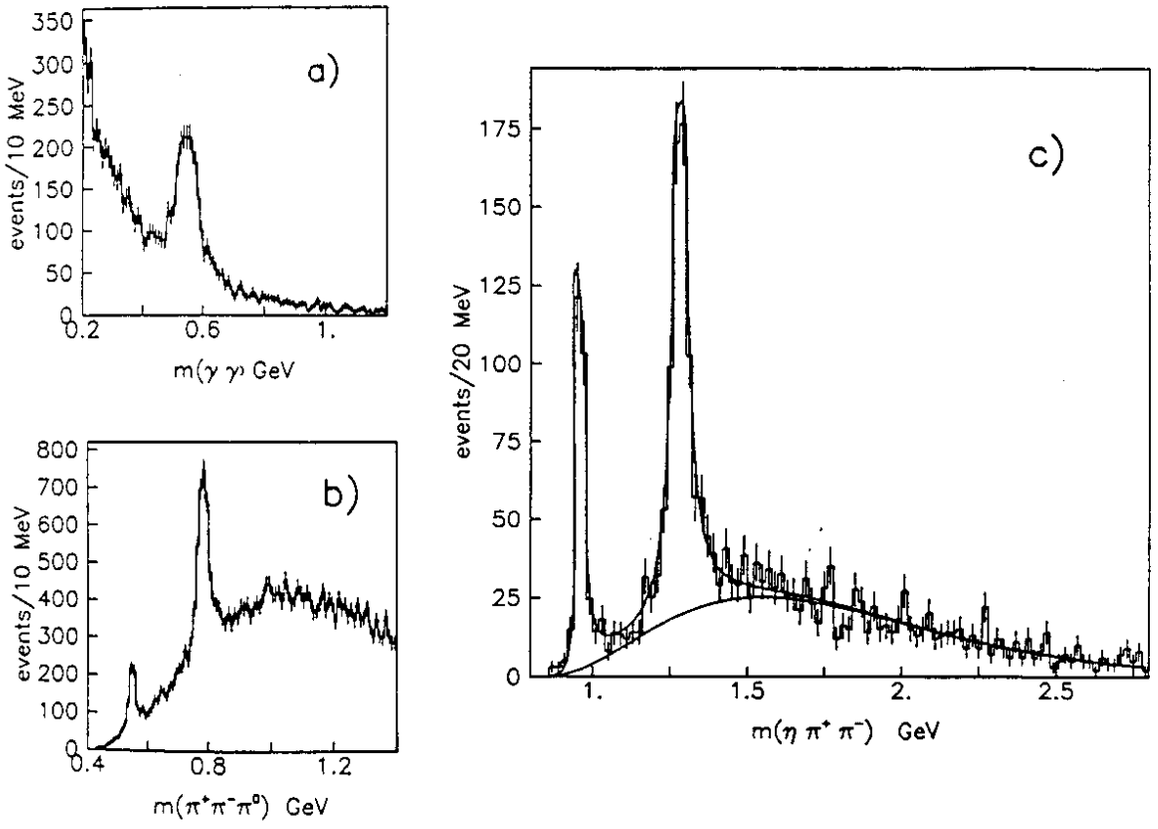

Figure 4: a) η signal in the $\gamma\gamma$ effective mass; b) η and ω signals in the $\pi^+\pi^-\pi^0$ mass distribution; c) combined $\eta\pi^+\pi^-$ effective mass distribution.

No evidence is found for an $\eta\pi^+\pi^-$ decay mode of the $f_1(1420)$. A fit of this spectrum gives $m = 1279 \pm 2$, $\Gamma = 55 \pm 5$ MeV as $f_1(1285)$ parameters where the experimental resolution has not been folded out.

5. The $\rho^0\,\gamma$ final state

The $\rho^0\gamma$ final state has been isolated from the sample of events having two central particles and one single gamma reconstructed in the electromagnetic calorimeter. Balance of momentum and energy was required. The γ was required to have an energy above 2. GeV. The γ centre of mass rapidity was also required to be < 1.3 in order to remove γ's coming from fast π^0 decays where one γ is not detected. In addition, in order to antiselect the $\pi^+\pi^-\pi^0$ which dominates the background under the $\rho^0\gamma$ final state, cuts have been performed on the $\pi^\pm\gamma$ mass in order to antiselect the $\rho^\pm$ reflections which dominate the $\pi^+\pi^-\pi^0$ channel. The resulting $\rho^0\gamma$ spectrum is shown in fig. 5a and clear signals due to the $\eta'(950)$ and $f_1(1285)$ mesons can be seen.
No evidence is found for a $\rho^0\gamma$ decay mode of the $f_1(1420)$. A fit of this spectrum gives $m = 1278 \pm 6$, $\sigma = 38 \pm 6$ MeV as parameters of the $f_1(1285)$. An angular analysis has been performed by measuring the angle between the π^+ and the γ in the ρ^0 rest frame. For a pseudoscalar resonance decaying to $\rho^0\gamma$ the angular distribution should be proportional to $\sin^2\theta_{\pi^+}$ while for an axial vector resonance the distribution should be proportional to $\cos^2\theta_{\pi^+}$ [7]. The angular distribution for the $f_1(1285)$ region is shown in fig. 5b and shows a good agreement with the $J^{PC} = 1^{++}$ hypothesis.

In conclusion, it appear that the only decay observed for the $f_1(1420)$ meson is the $K^*\bar{K}$ mode, which suggests a large $s\bar{s}$ component. It should then be observed in K induced reactions. Instead, a

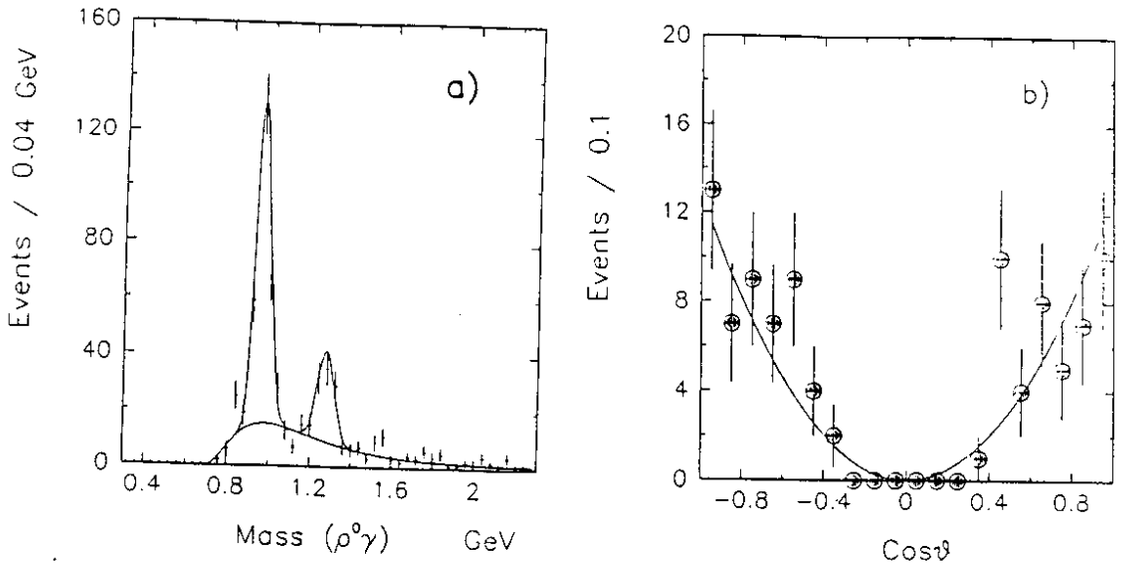

Figure 5: a) $\rho^0\gamma$ effective mass; b) $f_1(1285)$ angular distribution. The curve is a fit for $J^{PC} = 1^{++}$.

different state, the $f_1(1525)$ is observed in this process, which fits into the $J^{PC} = 1^{++}$ nonet better than the $f_1(1420)$. This suggests an exotic nature of the $f_1(1420)$ meson which is a candidate for being a hybrid [8] or a $K^*\bar{K}$ molecule [9].

6. Evidence for new states in the $\pi^+\pi^-\pi^+\pi^-$ channel

The $\pi^+\pi^-\pi^+\pi^-$ final state has been selected by requiring momentum and energy balance and compatibility with the Cerenkov information. Fig. 6a shows the $\pi^+\pi^-\pi^+\pi^-$ effective mass distribution for the sample of events having no γ's detected in the electromagnetic calorimeter.
A clear $f_1(1285)$ signal can be seen, together with two new structures in the 1.45 and 1.9 GeV regions. A fit to the spectrum gives the following parameters for the three structures; $f_1(1285)$: $m = 1281 \pm 1$, $\Gamma = 31 \pm 5$ MeV; X(1450): $m = 1449 \pm 4$, $\Gamma = 78 \pm 18$ MeV; X(1900): $m = 1901 \pm 13$, $\Gamma = 312 \pm 61$ MeV. A channel likelihood fit of the whole channel shows that the $f_1(1285)$ and X(1450) are consistent with decaying entirely through $\rho^0\pi^+\pi^-$, while the X(1900) decays 50% through $a_2(1320)\pi$ and 50% through $f_2(1270)\pi^+\pi^-$. The presence of more than one resonance contribution to the 1.9 structure cannot be excluded. We notice that the X(1450) has a mass which is different from the one measured for the $f_1(1420)$. In addition a study of the t behaviour of the two states shows that they are inconsistent with being the same resonance. A study of the X(1450) angular distribution in both the $\rho(\pi\pi)$ and $(\rho\pi)\pi$ decay modes (fig. 6b) shows that the spin parity of this state is compatible with being 1^- or 2^+. This leaves open the interesting possibility for the X(1450) being an exotic $J^{PC} = 1^{-+}$ state.

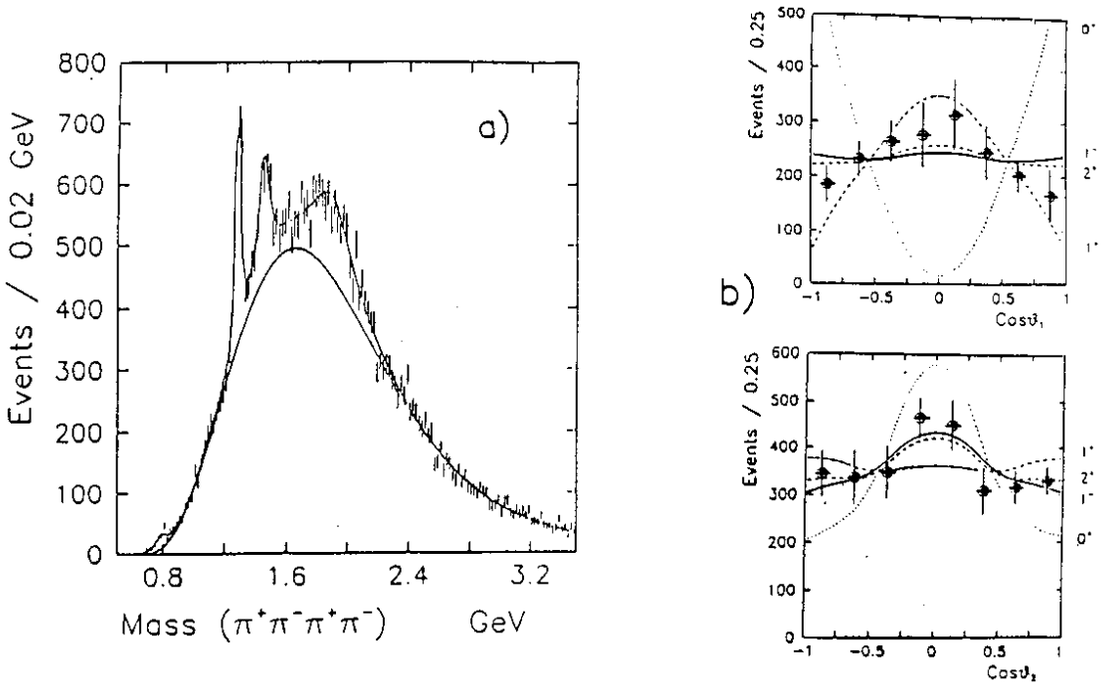

Figure 6: a) $\pi^+\pi^-\pi^+\pi^-$ effective mass distribution; b) X(1450) angular distributions. The curves correspond to J^P assignments for the $(\rho^0\pi)\pi$ decay mode.

7. The $\pi^+\pi^-$ final state

The $\pi^+\pi^-$ final state has been selected by requiring momentum balance and energy conservation. In addition Cerenkov compatibility was required for both pions. The centrally produced $\pi^+\pi^-$ mass spectrum is shown in fig. 7a and contains 310 000 events. We observe little ρ^0 and $f_2(1270)$ production and a large contribution of $S^*/f_0(975)$ in the $K\bar{K}$ threshold region. A fit to this spectrum has been performed by using a Flatte' coupled channel Breit Wigner interfering with the S−wave background. The resulting $S^*/f_0(975)$ parameters are $m_0 = 979 \pm 2$ MeV, $g_\pi = 0.25 \pm 0.02$ and $g_K = 0.20 \pm 0.04$. The number of events predicted to appear in the K^+K^- channel is easily accommodated by the data (fig. 7b).

A fit with ρ^0, $S^*/f_0(975)$ and $f_2(1270)$ only gives a good description of the data in the first part of the $\pi^+\pi^-$ spectrum but fails to describe it in the 1.45 GeV region as can be seen from fig. 8a.

It was found that by introducing an interference between the $f_2(1270)$, $f_2(1525)$ and the background the data could be described reasonably. However, the fit probability is 0.2% and we measure a branching ratio $\Gamma(f_2' \to \pi\pi)/\Gamma(f_2' \to K\bar{K}) = 0.21 \pm 0.08$. If, on the other hand, we leave as free parameters the mass and width of the Breit−Wigner term describing the 1.45 region, the fit probability increases to 49% (fig. 8b) and results in a mass of 1473 ± 11 MeV and a width of 189 ± 20 MeV for this structure.

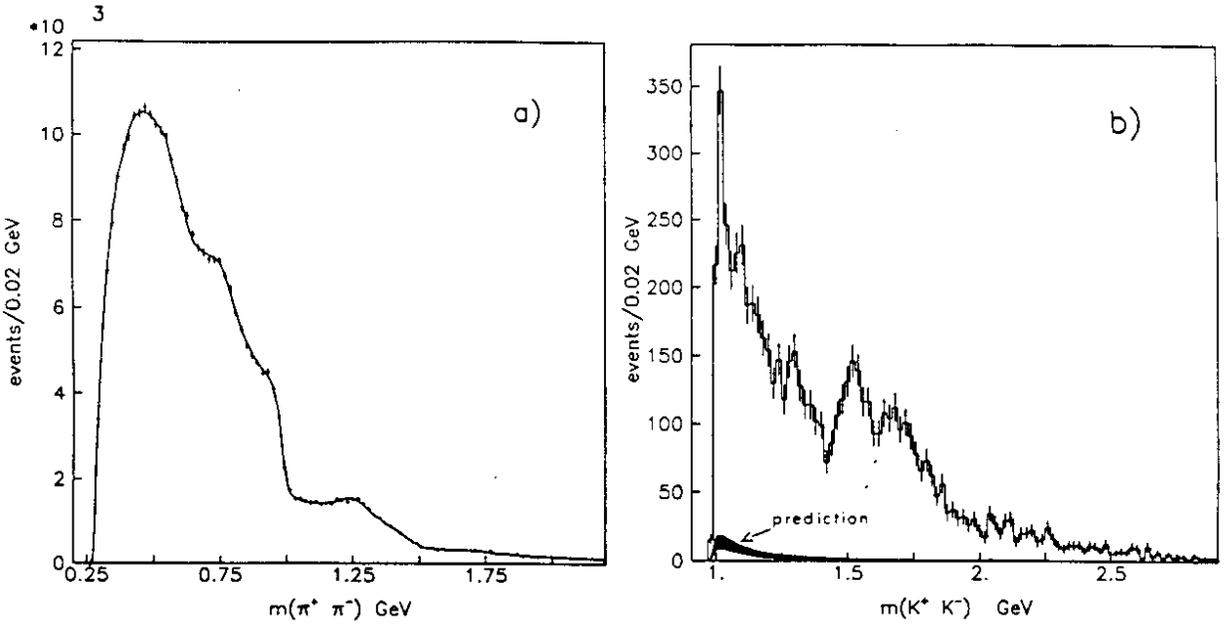

Figure 7: a) $\pi^+\pi^-$ effective mass distribution; b) K^+K^- effective mass distribution. The band drawn in the threshold region represents the estimated contribution from the $S^*/f_0(975)$ measured in the $\pi^+\pi^-$ spectrum with one standard deviation.

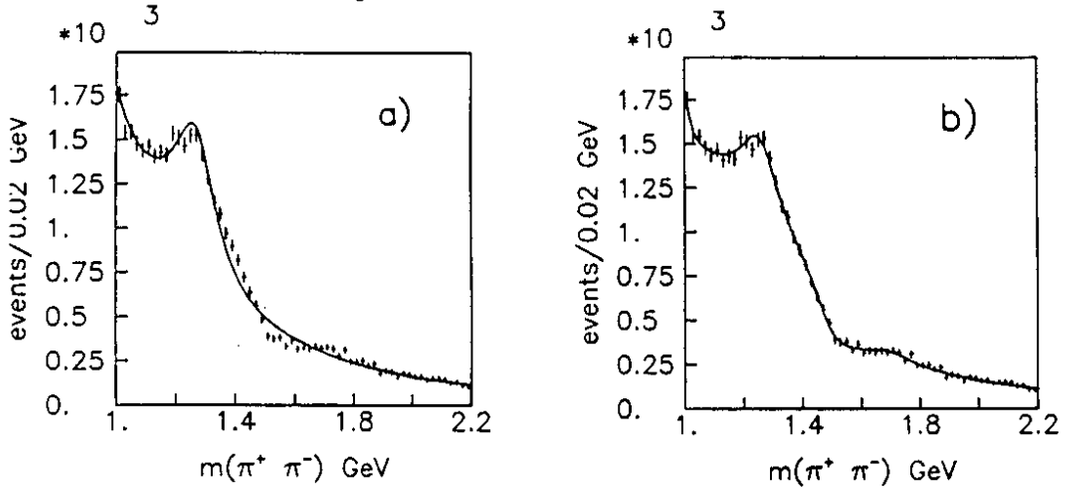

Figure 8: a) Expanded view of the fit to the $\pi^+\pi^-$ spectrum. The fit has been performed without including a Breit – Wigner in the 1.45 GeV region; b) As in a) but with a new Breit – Wigner term to describe the 1.45 GeV region and a $\theta/f_2(1720)$ contribution included in the fit.

8. Conclusions

We have studied the production of mesons in the central region in p p collisions at 300 GeV/c. We find evidence for the states $\theta/f_2(1720)$, $f_1(1420)$, $S^*/f_0(975)$ and a new state X(1450). Each of these mesons has some peculiar characteristic and are candidates for being non $q\bar{q}$ mesons.

9. References

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