e^+e^- ANNIHILATION AT DCI WITH THE MAGNETIC DETECTOR DM1 FOR $1.4 < \sqrt{s} < 2.2$ GeV. DISCOVERY AND STUDY OF ϕ' AT $\sqrt{S} = 1.65$ WITH $\Gamma = .15$ GeV[†]

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ABSTRACT

The ϕ' is discovered and studied in e^+e^- annihilation into KK^*, $K\bar{K}$, $\omega\pi\pi$; The ρ' is analysed with high statistics in $4\pi^{\pm}$ and also in $\rho\eta$, K^*K, $K\bar{K}$. Above $\sqrt{S} = 1.8$ GeV $e^+e^- \to K^*K\pi$ and $6\pi^{\pm}$ are also observed. OZI rule is checked using $e^+e^- \to \phi\pi$, $\phi\pi\pi$.

INTRODUCTION

The e^+e^- annihilation into hadrons has been studied for $1.4 < \sqrt{s} < 2.2$ GeV. The total integrated luminosity was 1500 nb^{-1} over the whole energy range. Accurate magnetic analysis of charged particle momenta allowed a constrained kinematical reconstruction of events with at most one neutral missing.

Cross sections are given for production of the following exclusive channels : $\pi^+\pi^+\pi^-\pi^-$ (including $\rho^\circ\pi^+\pi^-$), $\rho\eta$, $\omega\pi^+\pi^-$, K^+K^-, $K^0_SK^0_L$, $K^0_SK^{\pm}\pi^{\mp}$ (including K^*K), $K^+K^-\pi^+\pi^-$ (including $K^*K\pi$). Upper limits are given for O.Z.I. violating channels $e^+e^- \to \phi\pi$ and $\phi\pi\pi$ as well as for $\phi\eta$.

The ρ' is observed in the $4\pi^{\pm}$ channel with high statistics and in $\rho\eta$. A small bump in the $\omega\pi^+\pi^-$ channel is observed near 1.65 GeV differing from 0 by 6.2 standard deviation. $K\bar{K}\pi$ has a rather large cross-section in the same region ; the dynamics of this channel, exhibiting an I = 0, I = 1 interference, shows that this bump is due to a new ϕ' vector meson rather than to an ω'. This new ϕ' (1.65 GeV) has a 150 MeV width and decays mainly into KK^*.

The experimental set-up DM1, the selection of events, the luminosity measurement and the efficiency determination have been described in detail elsewhere (1), (2), (3). In summary DM1 consists of four cylindrical MWPC in a solenoidal magnet (1.8 m diameter, 1.2 m length and .82 T magnetic field). The solid angle covered by the detector is $0.6 \times 4\pi$ sr. The momentum resolution $\frac{\sigma(p)}{p}$ is proportional to the particle momentum and amounts to 2.5 % for 500 MeV/c particles.

The results on $e^+e^- \to p\bar{p}$, R_K and $\gamma\gamma$ were already presented at the last lepton photon conference (2) and did not significantly change since this time. The $p\bar{p}$ and $\gamma\gamma$ results are already published (2) as well as the K^+K^- (3) and $K^0_SK^0_L$ (4).

The following topics will be discussed below :

I - ϕ' discovery and study at M = 1.65 GeV, with $\Gamma = .15$ GeV.
II - ρ' analysis.
III - Cross-sections above $\sqrt{s} = 1.8$ GeV, mainly $K^*K\pi$ and $6\pi^{\pm}$.
IV - O.Z.I. rule checks in $e^+e^- \to \phi\pi$ and $\phi\pi\pi$.

I - ϕ' DISCOVERY AND STUDY

$K_S^0 K^\pm \pi^\mp$ production (230 events)

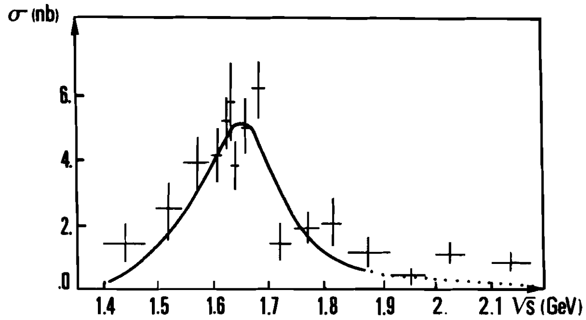


Fig.1 : Cross-section of $e^+e^- \to K_S^0 K^\mp \pi^\pm$

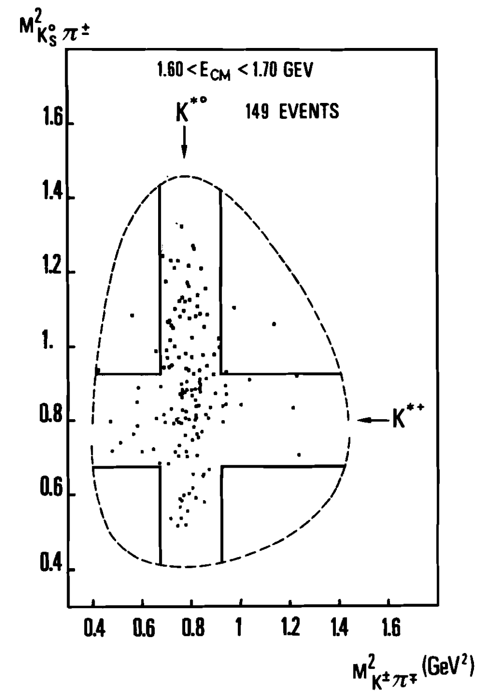


Fig.2 : Dalitz plot of $K_S^0 K^\mp \pi^\pm$

This channel is selected from events with 3 or 4 visible tracks, two of them compatible with a decay $K_S^0 \to \pi^+\pi^-$. No cut on the K_S^0 flight distance is necessary for the four prong events, as the contamination by other channels is small. We also require the reconstructed total energy, assigning a $K^\pm$ mass and a $\pi^\mp$ mass to the two remaining tracks (one missing at most), to be equal to the centre of mass energy within 2.5 %.

The cross-section (Fig.1) shows a bump in the 1550-1700 MeV region ; it must be observed that this effect of the cross-section might be a K^*K threshold effect, even if it is rather narrow.

The Dalitz plot of $K_S^0 K^\pm \pi^\mp$ is shown on the Fig.2. Two main observations can be made from it :

i. The actual process is KK^{*0}, as approximately no event falls outside the $K^{*\pm}$ or K^{*0} stripes.

ii. The production of K^0K^{*0} is much larger than $K^\mp K^{*\pm}$, and this can be explained, in the SU(3) model framework, by an interference between the ρ' and a new ϕ' vector meson belonging to the same nonet. This can be explained by drawing the quark lines :

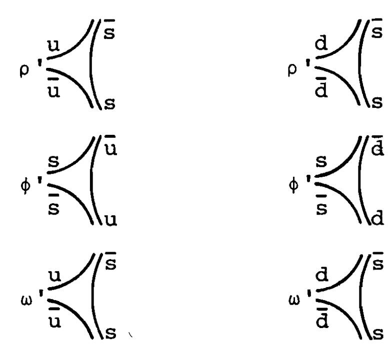
$e^+e^- \to$ $\qquad$ $K^{*\pm}K^\mp$ $\qquad$ $K^{*0}K^0$

$\downarrow$

$$\rho' = \frac{u\bar{u} - d\bar{d}}{\sqrt{2}}$$

$$\phi' = -s\bar{s}$$

$$\omega' = \frac{u\bar{u} + d\bar{d}}{\sqrt{2}}$$



First, without interference of vector mesons, the productions of $K^\mp K^{*\pm}$ and K^0K^{*0} are equal since the three quarks are treated identically in SU(3). Second, for KK^*, we are dealing with a symmetric octet, and, the sign of interference is given by the relative sign, in the wave function, before the initial quarks ; for instance, it is destructive for $K^\pm K^{*\mp}$ production by both $\rho'(+\frac{u\bar{u}}{\sqrt{2}})$ and $\phi'(-s\bar{s})$ and constructive in K^0K^{*0} $(-\frac{d\bar{d}}{\sqrt{2}}$ with $-s\bar{s})$ which is then expected to be dominant ; the signs of interference are reversed for ω', for which K^0K^{*0} should be smaller than $K^\pm K^{*\mp}$, which is not the case. Our result clearly indicates ρ' and ϕ' interference and is uncompatible with ρ' ω' interference.

From the Dalitz plot population, we can extract separately the ϕ' and ρ' cross section (Fig.3a). In the 1.55 - 1.7 GeV range, the isoscalar cross-section is larger than the isovector one, and shows a bump around 1650 MeV. Moreover the phase difference of ρ' and ϕ' can also be deduced ; taking for ρ' the Breit Wigner phase deduced from $e^+e^- \to 4\pi^\pm$ analysis, we get the energy dependence of the ϕ' phase (Fig. 3b), which shows a resonance behaviour : the characteristic crossing through 90° is observed near 1650 MeV.

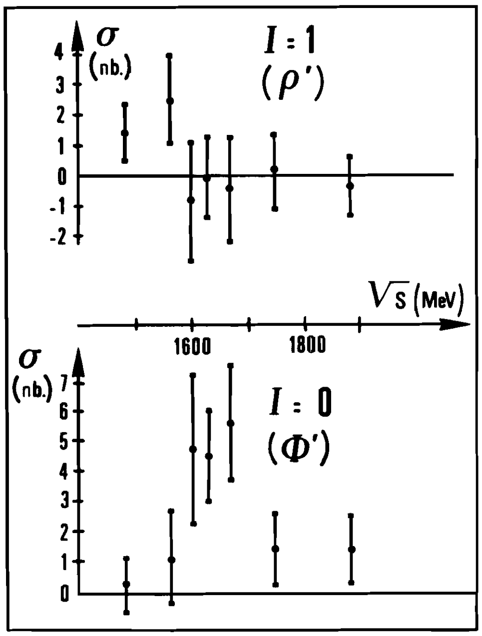


Fig.3a : Isospin amplitudes for $e^+e^- \to K^0_S K^\mp \pi^\pm$

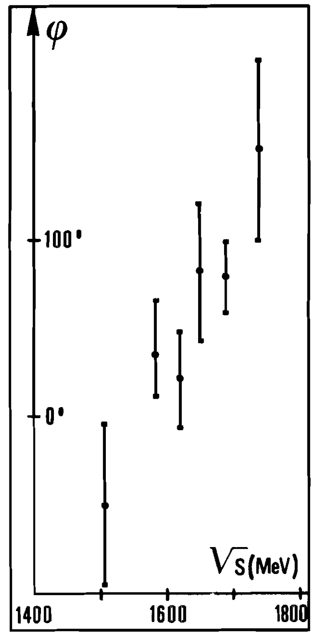


Fig.3b : ϕ' phase

Let us remark that the K^*K dynamics imply that the total $\bar{K}K\pi$ rate is three times the $K^0_S K^\pm \pi^\mp$ one : the two other thirds ($K^0_L K^\pm \pi^\mp$, $K^0_S K^0_L \pi^0$, $K^+K^-\pi^0$) are not separated from background in our apparatus. So the KK^* production is rather strong just near threshold.

<u>$\pi^+\pi^-\pi^+\pi^-\pi^0$ production (450 events)</u>

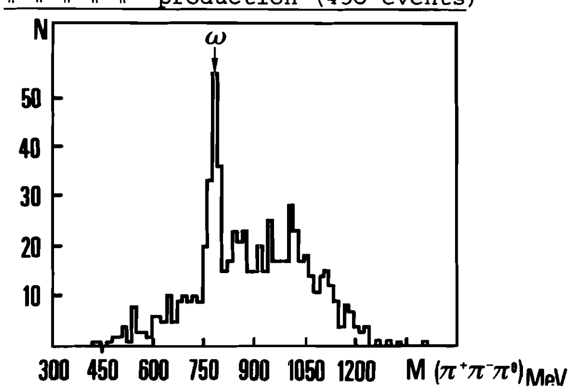


Fig.4 : $\pi^+\pi^-\pi^+\pi^-\pi^0$ events. $\pi^+\pi^-\pi^0$ invariant-mass distribution (4 entries/event) $1600 < \sqrt{s} < 1700$ MeV.

In the 1400-1700 MeV energy range, the channel $e^+e^- \to \pi^+\pi^-\pi^+\pi^-\pi^0$ is dominated by $\omega\pi^+\pi^-$ production (Fig.4) but no other structure is found either in the $\omega\pi^\pm$ invariant mass distribution or in the $\pi^+\pi^-$ mass recoiling from the ω.

In order to correctly analyse the $\omega\pi^+\pi^-$ production, one must subtract the events compatible with $e^+e^- \to 4\pi^\pm\pi^0$ or $4\pi^\pm\gamma$ and giving, by chance, at least one $\pi^+\pi^-\pi^0$ combination within the ω mass window. This correction has been estimated from the distribution of the side bins of the ω in the spectrum of all the $\pi^+\pi^-\pi^0$ invariant masses in the $4\pi^\pm\pi^0$ events, (Fig.4).

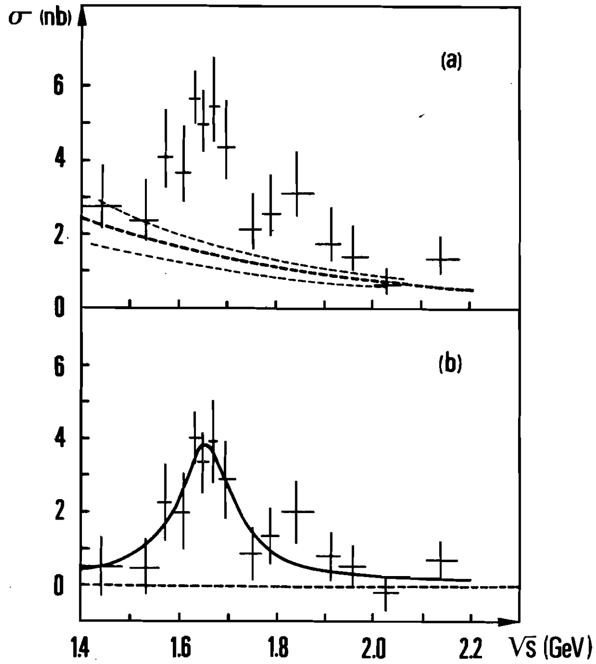


Fig.5 : $e^+e^- \to \omega\pi^+\pi^-$ cross-section
(a) without subtraction
---contamination of "5π"--- (± 1 s.d.)
(b) after subtraction
fit by Breit-Wigner curve plus incoherent flat background

After this subtraction, the $\omega\pi^+\pi^-$ cross-section is shown in Fig.5. A clear bump is seen near 1650 MeV.

The efficiency depends on the dynamics : 6.5 % for $\omega\pi^+\pi^-$ assuming correct s wave dynamics, 10.7 % for $\omega\pi^+\pi^-$ in naive phase space. The cross-section is computed with the former value, the angular distributions of the ω decay products being compatible with s wave dynamics.

The $\omega\pi^+\pi^-$ cross-section after subtraction has been fitted by a Breit-Wigner curve plus an incoherent flat background.

The statistical significance of the bump around 1650 MeV is given by the uncertainty on the assumed resonant cross-section at peak : 4.0 ± .64 nb. The effect is at 6.2 s.d. from a zero cross-section giving a 2×10^{-7} C.L. for the opposite hypothesis of no resonance.

This analysis supports the existence of a new isoscalar vector meson (1^{--}) with a mass 1657 ± 13 MeV, width 136 ± 46 MeV. The product $\Gamma_{ee}\cdot B$ of its leptonic width Γ_{ee} and its branching ratio B into $\omega\pi\pi$ (including $\omega\pi^0\pi^0$) is 140 ± 46 eV. The flat background is small : .21 ± .26 nb.

The interpretation with only this new isoscalar vector meson is hardly coherent with the expected ω', companion of the ρ' (1600) : it is too narrow, 136 MeV instead of some 500 MeV for the ρ' while the $\omega\pi^+\pi^-$ phase space is as largely open as the $\rho\pi^+\pi^-$ one ; on the other hand, from the above values, the product of the partial e^+e^- decay width of this resonance and its branching ratio into $\omega\pi^+\pi^-$ is 140 eV which is rather small even for an ω' vector meson. Finally, this peak occurs at nearly the same place as the KK^* and $K\bar{K}$ ones, and we try below to rely all these channels.

$K\bar{K}$ production (490 K^+K^- events, 57 $K^0_SK^0_L$ events)

Let us remind the already published (3), (4), results concerning $e^+e^- \to K\bar{K}$. The squared form factors are shown in Fig.6. The tail of the low energy vector mesons ρ,ω,φ is not high enough to fit the K^+K^- results. If we try to add the ρ' contribution, a fit of our points together with the Novosibirsk ones leads to an unsatisfactory χ^2 value : 105 for 26 degrees of freedom. It does not succeed to reproduce either the Novosibirsk (13) results in K^+K^-, nor the fast drop of both form factors around 1.7 GeV.

Other vector mesons are needed. Nevertherless, below 1.4 GeV, confident conclusions can hardly be derived in the absence of neutral kaon form factor measurements ; we restrict ourselves here to the 1.4 - 1.85 GeV energy range where we have measured both form factors, with a non-negligible statistical accuracy. A fit with ρ,ω,φ and ρ' in this energy range gives again a too large χ^2 value : 51 for 18 d.o.f.

In order to achieve a better fit of our results, we must add an isoscalar amplitude, interfering with the ρ' one, constructively in K^+K^- and destructively in $K^0_SK^0_L$. If we take a Breit-Wigner form for such an amplitude the fit of our data

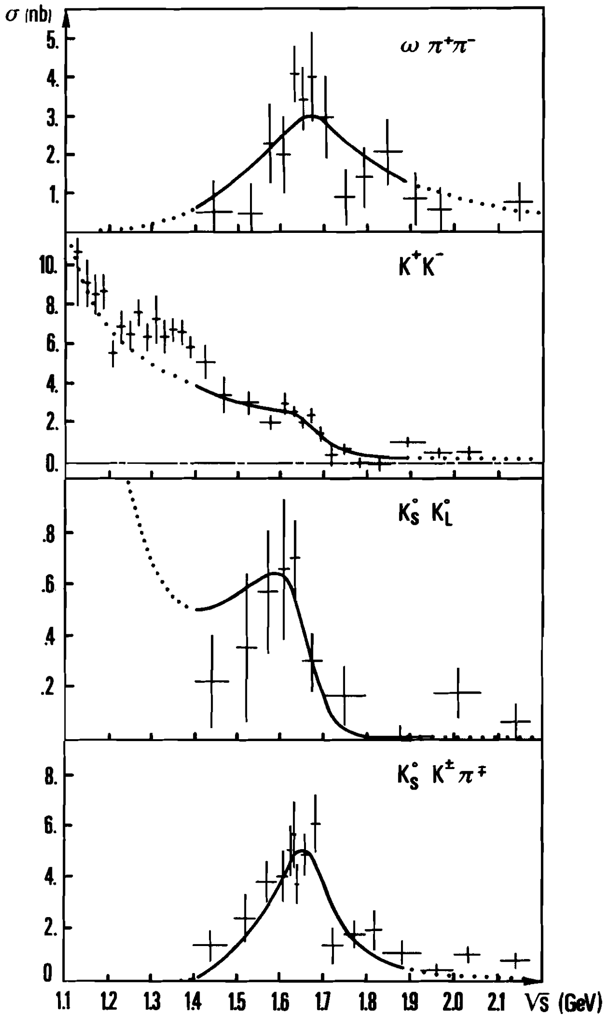


Fig.6 : Global fit of four channels

between 1.4 and 1.85 GeV leads to the following parameters of this isoscalar resonance :

M = 1674 ± 6 MeV Γ = 94 ± 30 MeV

Its electronic width Γ_{ee} times its $K\bar{K}$ branching ratio $B_{K\bar{K}}$ is 15 ± 13 eV. The same product $\Gamma_{ee}B_{K\bar{K}}$ for the ρ' is 83 ± 19 eV. The χ^2value of this fit is 19.3 for 15 degrees of freedom.

It is striking to find a mass and a width very similar to what is found in the $\omega\pi^+\pi^-$ and $K^S_O K^{\pm}\pi^{\mp}$ channels.

Besides, in this fit of $K\bar{K}$ data, we assume a 0° phase between the $\rho'$and the isoscalar resonance, but the phase between ρ and ρ' is free, and its resulting value is 170° ± 10°. The opposite phase between the ρ and its first excited state could be explained by models dealing with nodes in the initial $q\bar{q}$ wave function (see Le Yaouanc et al. (5) and also Eichten et al. (6) for heavy quarks). In this model, the $q\bar{q}$ radial wave function has no node for ρ, and one node for ρ' ; if now the $K\bar{K}$ channel is produced by large distance $q\bar{q}$ interaction, that is for q and $\bar{q}$ more distant than the first node of ρ', we get a reversed sign for ρ' with respect to ρ (7).

Global fits of these data

To fit all these cross-sections ($K^O_S K^{\pm}\pi^{\mp}$, $\omega\pi^+\pi^-$, $K^O_S K^O_L$ and K^+K^-), we used SU(3) relations with different hypothesis on the $\omega'\phi'$ mixing angle :

1. - Ideal mixing

$\omega\pi\pi$ is only due to the $\omega' = \frac{u\bar{u} + d\bar{d}}{\sqrt{2}}$,

M = 1.66, Γ = .14 GeV, $\Gamma_{ee}B$ = 210 70 eV (including $\omega\pi^O\pi^O$ assuming $\omega(\pi^+\pi^-)$ dynamics).

The KK^* signal is the result of subtraction of ϕ' and ω' interferences with ρ' (1600) ; we find a large value for Γ_{ee} (ϕ') B(KK^*) : 1.2 KeV. The characteristics of the ϕ' are found to be : M = 1.66 GeV, Γ = .15 GeV (the same as the $\omega\pi\pi$ peak).

This possibility cannot be rejected even though :

- the ω' seems too narrow and little coupled to photon, if one considers that $\omega\pi\pi$ is the main decay channel of the ω', like $\rho\pi\pi$ for the ρ'.
- the ϕ'seems too coupled to photon : one expects it to have an electronic width less than the one of ϕ (1.3 KeV), as in the case of the ψ and Υ families.

2. - Pure SU(3)

To take into account the fact that KK^*, $\omega\pi\pi^+$, K^+K^- and $K^O_S K^O_L$ exhibit a signal at the same energy, one could be tempted to consider the following scenario :

$\omega'_1 = \frac{u\bar{u} + d\bar{d} + s\bar{s}}{\sqrt{3}}$ (SU(3) singlet) does not couple to e^+e^-.

$\phi'_8 = \frac{2s\bar{s} - u\bar{u} - d\bar{d}}{\sqrt{6}}$ accounts for KK^*, $\omega\pi\pi$ and $K\bar{K}$, the $\omega\pi\pi$ peak parameters being the same as in the preceding hypothesis.

The fit works well, but this hypothesis can be rejected by the following argument : $\phi'_8 \to KK^*$ is related by SU(3) to $\phi'_8 \to \rho\pi$ and a huge cross-section for this channel is expected (>100 nb) ; the channel $e^+e^- \to \rho\pi$ is not separated here from the reaction $e^+e^- \to e^+e^-\gamma \to \rho^0\gamma$ (radiative return on the ρ) ; nevertheless the measured cross-section of the sum of these 2 channels is of the order of 10 nb in this energy range, by far less than the preceding expectation (see also ref. 11, 12). Let us remark also that it would be amazing, in this case, that $\Gamma_{ee}(\phi'_8)\cdot B(\omega\pi\pi) < \Gamma_{ee}(\phi'_8)\cdot B(KK^*)$ as the $\omega\pi\pi$ channel is much more open than KK^*.

3. Most favoured explanation

Two assumptions : the ω' is degenerate with the ρ' (same mass 1.57 GeV and width Γ = .50 GeV), and the ϕ' has a small $(u\bar{u} + d\bar{d})$ component ; the $\omega\pi\pi$ signal is then due to an interference between the ω' and the ϕ'. In particular, a $\Gamma_{ee}\cdot B(\phi' \to \omega\pi\pi)$ of only 10 eV is enough to explain the results.

If the ω' is degenerate with the ρ', the following $\Gamma_{ee}B$ values of ρ' and ϕ' are computed :

	ρ'	ϕ'
$\Gamma_{ee}B(K\bar{K})$	40 ± 25 eV	90 ± 45 eV
$\Gamma_{ee}B(KK^*)$	380 ± 70 eV	600 ± 65 eV
$\Gamma_{ee}B(\omega\pi\pi)$	0	< 150 eV

The resulting fit of all data is shown on Fig.6 for $e^+e^- \to KK^*$, K^+K^-, $K^S_0K^L_0$, $\omega\pi\pi$, which show the striking coïncidence between the peaks observed in three of these channels, and the interference shape occuring in the fourth $(e^+e^- \to K^+K^-)$.

II - ρ' ANALYSIS

1. - $4\pi^\pm$ cross-section (11000 events)

On Fig.7, we show the cross-section of $e^+e^- \to 4\pi^\pm$ obtained with our apparatus. On Fig.8, we show the invariant mass spectrum of all the $\pi^+\pi^-$ masses, which agree very well with $e^+e^- \to \rho^0\pi^+\pi^-$ dynamics, the $\pi^+\pi^-$ system being in an S-wave.

Our results are in statistical agreement with the one of the previous experiment on DCI (M3N), but in clear discrepancy with extrapolation to our energy range of points of Novosibirsk (13) (not corrected for radiative effects), and with the Frascati (10),(11) measurements below 1.6 GeV.

Taking this into account we have fitted only our cross-section from DCI and ACO (at lower energy). The behaviour of the cross-section above 1.9 GeV cannot be explained with only the ρ' (1600) vector meson and we stopped the fit at this energy.

$\rho' \to \rho^\circ\pi^+\pi^-$ fitting procedure

The Breit-Wigner form $\sigma = \frac{12\pi}{s} \frac{M^4 B\Gamma_{ee}\Gamma(s)}{(M^2-s)^2+M^2\Gamma^2(s)}$ does not fit the data if $\Gamma \propto$ L.I.P.S. and one has to compensate the growth of phase space with energy. 2 parameterizations were done :

$$\Gamma(s) = \frac{\phi(s)/s}{a + b\phi(s)/s} \qquad \text{with } \Phi = \text{L.I.P.S.}$$

$\Gamma(s) \;\alpha\; \Phi(s)\; e^{\frac{-2\sqrt{s}}{T}}$, with T = 750 MeV.

The temperature T found is higher than the one indicated by Bjorken and Brodsky (14), but the $4\pi^{\pm}$ was predicted by them at a much lower resonance energy.

This phase space compensation, which in fact corresponds to a limitation of final momenta, suggests a large size of the $q\bar{q}$ distances (using the uncertainty relations), and especially of the initial $q\bar{q}$ state.

Remark : Large interference effects between ρ' and non resonant πA_1 channel may be present. (Cf. Penso and Truong (15))

Results of the fits : M = 1.57 ± .05 GeV $B\Gamma_{ee}$ = 2.6 ± .2 KeV
(DM1 only) Γ = .51 ± .02 GeV

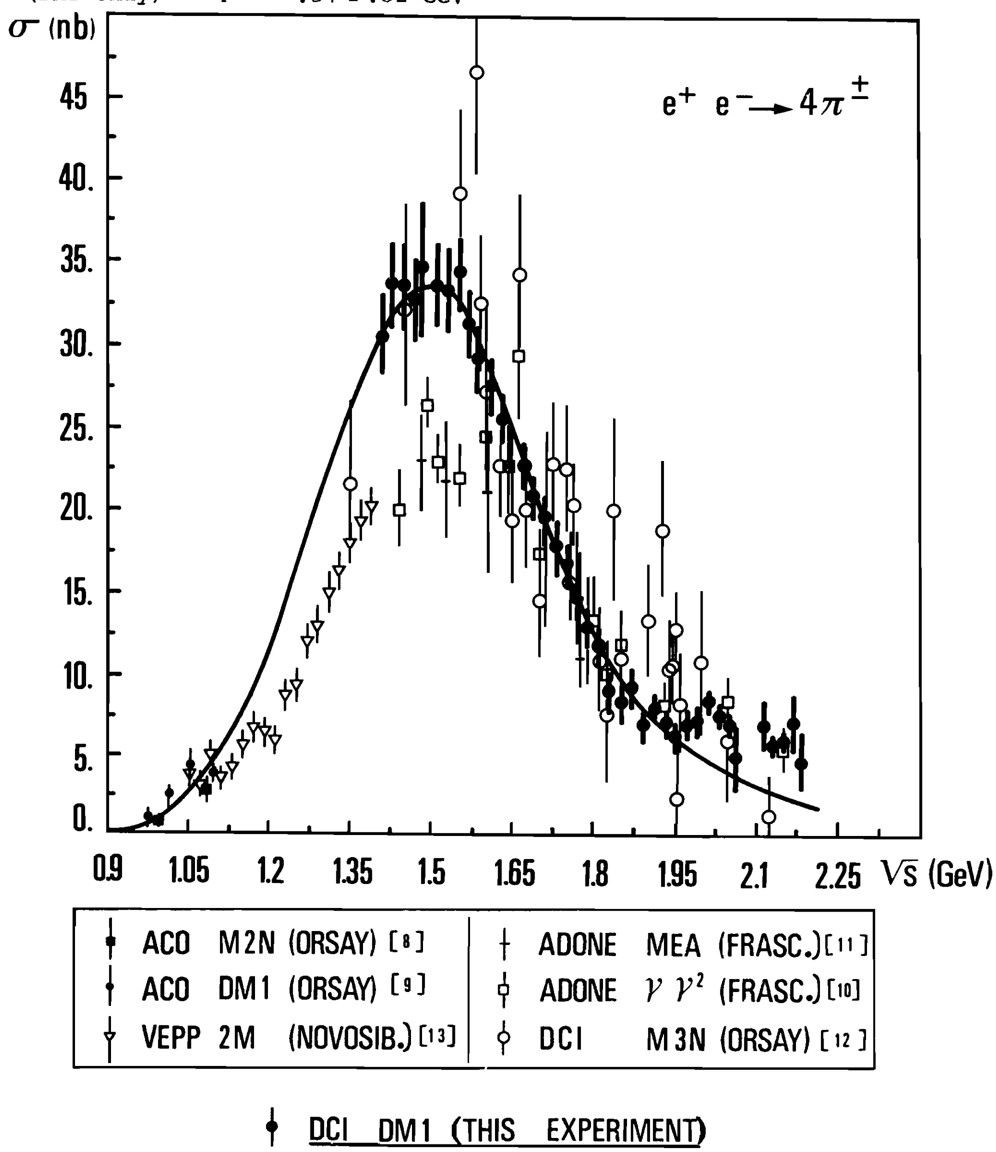


Fig.7 : $e^+e^- \to 4\pi^{\pm}$

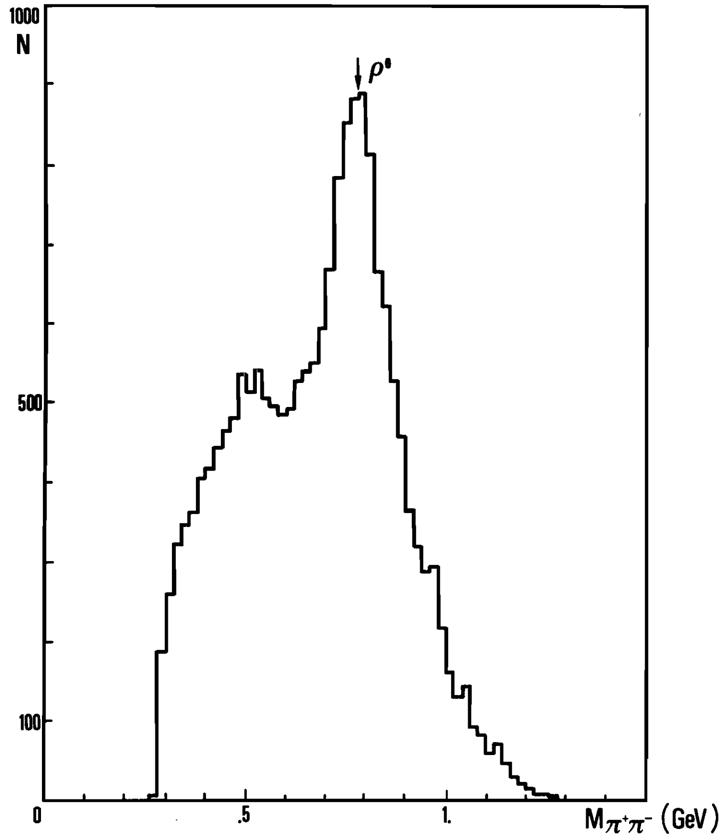


Fig.8 :

Invariant mass of all the $\pi^+\pi^-$ couples in the $4\pi^\pm$ events (4 entries/event)

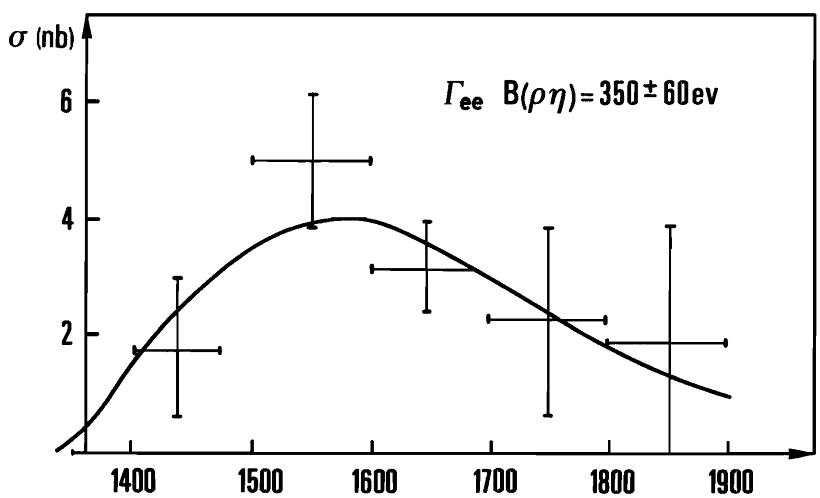


Fig.9 : Cross-section of $e^+e^- \to \rho\eta$.
The curve is a fit using the ρ'(1600) mass and width calculated from $e^+e^- \to \rho\pi\pi$

2. $e^+e^- \to \rho\eta$ cross-section

The fig.9 shows the first measurement of this channel, which was performed using the $\pi^+\pi^-$ invariant mass-missing mass scatter plot. If we fit these results with the preceding values obtained from the $\rho' \to 4\pi^\pm$, we find $B\Gamma_{ee}$ = 350 ± 60 eV. This can be related by SU(3) to the value of $\phi \to KK^*$ extracted from the global fit used from the φ' study : the agreement is reasonable.

Total electronic width of the $\rho'(1600)$

Assuming that the ρ' dominates the $4\pi^\pm$ production, one can try to estimate the ρ' total electronic width : one adds to the $4\pi^\pm$ channel 1.3 KeV for $2\pi^\pm\ 2\pi^\circ$ (which could be twice this value if the $A_1\pi$ dynamics is dominant as suggested by results of the photoproduction experiment WA57 presented by Dr. E. Paul in this meeting) ; then one estimates the unseen channels by SU(3) (mainly $\omega\pi^\circ$, which is evaluated from $\rho'\to\rho\eta$ or $\phi\to KK^*$ to be about 2 KeV), and one finds finally :

$\Gamma_{ee}\ (\rho') = 7.5 \pm 1.5$ KeV ; this is of the same order as for the ρ.

Let us summarize what we know about the ρ', ω', Φ' puzzles:

Data available

ρ' { Mass $1.57 \pm .06$ GeV, width $\Gamma = .51 \pm .05$ GeV
Decays mainly into $\rho\pi\pi$ and also into $\rho\eta$, $K\bar{K}$, KK^*

Φ' { Mass 1.66 ± 0.02 GeV, width $.17 \pm .03$ GeV
Decays mainly into KK^*, and also into $K\bar{K}$, KK^*

Proof of the $\Phi'(s\bar{s})$ nature

-Dalitz plot of the KK^* (dominance of $K^{*o}K^o$ vs. $K^{*\pm}K^\mp$)

$-\Gamma_{ee}B\ (\omega\pi\pi) < \Gamma_{ee}B(KK^*)$, difficult to explain with ω' hypothesis ($\omega\pi\pi$ phase space much larger than KK^*).

Missing

All about ω'.

III CROSS SECTIONS ABOVE 1.8 GeV, ANOTHER TYPE OF PRODUCTION

We have already seen that the high energy behaviour of the $4\pi^\pm$ cross-section is not completely related to the $\rho'(1600)$ vector meson. Above 1.8 GeV we separated also two other channels, namely $e^+e^- \to K^{*o}K\pi$ and $e^+e^- \to 6\pi^\pm$.

$e^+e^- \to K^*K\pi$ (500 events)

Fig.10 shows the $K^+K^-\pi^+\pi^-$ cross-section and the dynamics of this channel ; the reaction is in fact $e^+e^- \to K^{*o}K^\pm\pi^\mp$, as we find one K^* per event. We do not find any structure in the $K\pi$ system recoiling from the K^* nor in the K^*K or K^+K^- systems. We did not observe the $\phi\eta$ channel in the K^+K^- invariant mass-missing mass scatter plot, and give upper limits on Fig.10 ; this may be related to the fact that, at lower energy the $\rho\eta$ production is less than the $\rho\pi\pi$ one (see above).

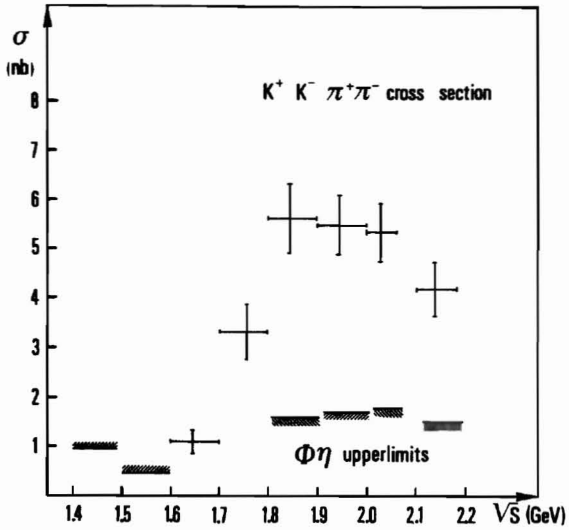
Three possibilities to explain $e^+e^- \to K^*K\pi$:

i. It is due to an unique vector meson ; one finds then :
$M = 2.05 \pm .27$ GeV
$\Gamma = .65 \pm .26$ GeV
$B\Gamma_{ee} = .78 \pm .24$ KeV.

ii. It is due to several vector mesons.

iii. It is only a threshold effect of the channel $e^+e^- \to K^*K\pi$, with a maximum for mean momenta of final particles of the order of 300-400 MeV/c (that is for $\sqrt{s} \sim 2$ GeV), and then a drop for faster particles.

Cf. - Thermodynamic models (Bjorken, Brodsky (14)).
- Models like the one of Le Yaouanc et al (15), Bradley and Robson (16) dealing with initial $q\bar{q}$ wave function (nodes especially) or of Eichten et al (6) for heavy quarks.



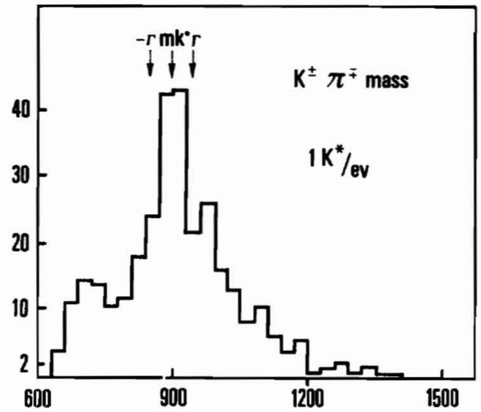
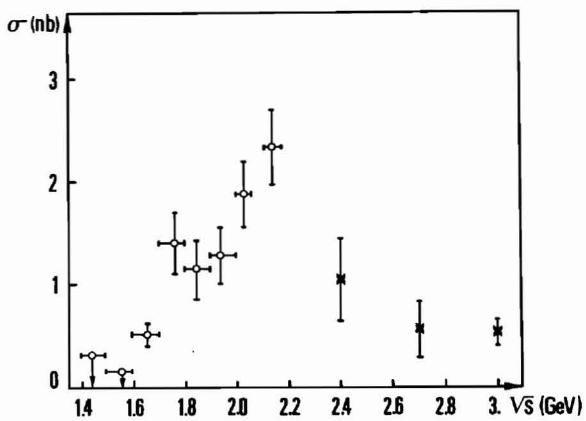


Fig.10 :

Cross-section of $e^+e^- \to K^+K^-\pi$ and spectrum of $K\pi$ invariant masses (2 entries/event)

In any case, the final limitation of momentum has to do something with large size of initial $q\bar{q}$ state, like in the $4\pi^\pm$ case.

$e^+e^- \to 6\pi^\pm$ (150 events)



o this experiment
✖ Spear (17)

Fig.11 : Cross-section of $e^+e^- \to 6\pi^\pm$

Fig.11 shows the $6\pi^\pm$ cross-section ; the dynamics study shows that, at least one ρ per event is present. There is a rapid rise near threshold, a maximum in the 2 GeV range, and the Spear points (17) show a decrease at higher energies. The same remarks than for $e^+e^- \to K^*K\pi$ apply here : is it a new vector meson, or only a threshold effect with a maximum when all particles have a mean momentum of 300-400 MeV/c? Not shown here are the points of ref. (12) and (20) which agree with this measurement.

IV - O.Z.I. RULE CHECKS

We have made two tests of the O.Z.I. rule, using the following reactions : $e^+e^- \to \phi\pi$, $e^+e^- \to \phi\pi\pi$ which violate the O.Z.I. rule if we consider that the ϕ is a pure $s\bar{s}$ state.

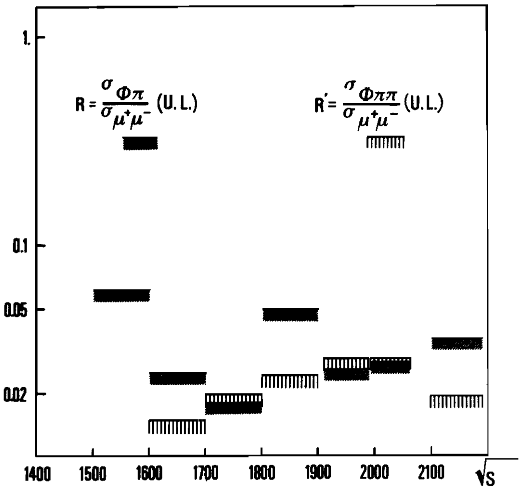


Fig.12 : Upper limits (90 % C.L.) on $e^+e^- \to \phi\pi$ and $e^+e^- \to \phi\pi\pi$ in terms of $\sigma_{\mu\mu}$ cross-sections.

The ϕ was detected by its K^+K^- decay ; for $e^+e^- \to \phi\pi$, the ϕ missing mass spectrum was studied ; for $e^+e^- \to \phi\pi^+\pi^-$, we used the $K^+K^-\pi^+\pi^-$ events. No significant signal was seen in both reactions, and we are only able to give the 90 % C.L. upper limits, shown in Fig.12, in terms of $\sigma_{\mu\mu}$. For $e^+e^- \to \phi\pi$, there was an hypothesis by Close and Lipkin[18] that baryonium could happen in this channel and give cross-sections of 1 - 3 nb ($R \sim 0.05 - 0.15$ at $\sqrt{s} = 2$ GeV) in this energy region, which we clearly exclude here. Nevertheless, the same authors predict a background to the O.Z.I. rule, mainly due to the small $u\bar{u} + d\bar{d}$ component of the ϕ, which is of the order of 0.002, a value we are unable to reach with this experiment.

For $e^+e^- \to \phi\pi\pi$, our upper limits are to be compared to the ones obtained by a photoproduction experiment [19] ; these authors indicate that the $\phi\pi\pi$ cross-section is of the order of magnitude of 1/2 the $K^*K^{\pm}\pi^{\mp}$ cross-section ($\sigma_{\phi\pi\pi} = 13.3$ $\sigma_{K^*oK^{\mp}\pi^{\pm}} = 19.3$), whereas we exclude a ratio larger than .1 ($\sigma_{\phi\pi\pi} < 1$ nb $\sigma_{K^*oK^{\pm}\pi^{\mp}} \sim 10$ nb). This discrepancy could be explained either by an energy dependance of this ratio, as we take only the low energy part of the photoproduction spectrum, or by a different mechanism of $\phi\pi\pi$ production in e^+e^- and photoproduction experiments.

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