STRUCTURE IN THE KK DECAY MODE OF THE A₂ MESON

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Evidence from the KK decay mode for the splitting of the A₂ meson is presented.

convincing evidence has been presented for
a splitting of the A₂ meson [1]. The A₂ was
produced in π⁺p interactions and the relevant
mass distribution was calculated from the
momentum spectrum of the proton. A good fit
was obtained with a dipole interpretation, i.e.:

\[ N(M^2) = \frac{4}{(M^2 - M_0^2)^2 M_0^2 \Gamma_0^2} \left[ (M^2 - M_0^2)^2 + M_0^2 \Gamma_0^2 \right] \]

with:

\[ M_0 = [1298 \pm 5] \text{ MeV} \]
\[ \Gamma_0 = [28 \pm 5] \text{ MeV} \]

An equally acceptable fit was obtained using
two coherent Breit-Wigner amplitudes, but in this
case three extra parameters are in general re-
quired. A poor fit was obtained with two incoherent
Breit-Wigner amplitudes.

Cremnel et al. [2], studying the same reaction
at 6 GeV/c in a bubble chamber, reported a similar
structure in the A₂ observed decaying into
π⁻MM. They suggested, however, that this
splitting is associated only with the πσ decay mode
and not with the KK mode since their observed
K⁺K⁻ mass distribution (389 events) shows a
single narrow peak (Γ = 21 MeV) at a mass
\[ M = 1311 \text{ MeV} \]. This conclusion is obviously
incompatible with the double pole interpretation
of the A₂.

In this paper, we present results on the
K⁺K⁻ decay mode of the A₂ meson, as ob-
served in four experiments on pp annihilations.

We observe the A₂ in reaction (1):

\[ pp \rightarrow K⁺K⁻\gamma \rightarrow 4452 \text{ events} \]  \hspace{1cm} (1)

These experiments were performed at the
CERN PS using the 81 cm Saclay hydrogen
bubble chamber and the 2 m hydrogen bubble
chamber. Details of the experimental data are
given in table 1.

The 1553 events at rest differ from those
presented in ref. 3 in the following respects.
Events from the first runs have not been included.
From the other runs, only those events giving
four constraint fits in a restricted fiducial volume
were accepted. These selection criteria improved
the average mass resolution for the K⁺K⁻ spec-
trum at rest. The resolution was estimated from
the observed width of the η meson, (15 ± 1) MeV,
for both the events at rest [7] and at 0.7 GeV/c

<table>
<thead>
<tr>
<th>Beam momentum GeV/c</th>
<th>Number of events K⁺K⁻π⁺ Reaction (1)</th>
<th>Number of events K⁺K⁻π⁻ Reaction (2)</th>
<th>Reference</th>
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<tbody>
<tr>
<td>0.0</td>
<td>1553</td>
<td>364</td>
<td>[3]</td>
</tr>
<tr>
<td>0.7</td>
<td>1553</td>
<td>135</td>
<td>[4]</td>
</tr>
<tr>
<td>1.2</td>
<td>749</td>
<td>92</td>
<td>[5]</td>
</tr>
<tr>
<td>1.2</td>
<td>866</td>
<td>not yet studied</td>
<td>[6]</td>
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and from the width of the $K^0_L$ meson produced in reaction (1). The CERN program MILLSTONE was used to displace the $K^0_L$ to the annihilation vertex thus forming a pseudo-four-body event which was then fitted with four constraints. The resolution function was obtained directly as the effective mass distribution of the two pions associated with the $K^0_L$. For the experiments at rest and at 0.7 GeV/c the full width at half height was $(\pm 2)$ MeV in the region of the $A_2$. The resolution at 1.2 GeV/c is not as good: it is of the order of 10 MeV.

We do not present detailed information on the reaction
\[
p p \to K^0_L K^0_L \pi^0
\]
because the number of events is small (see Table 1): the $I = 1$ $K\bar{K}$ contribution in reaction (2) is depressed by a factor of at least 6 relative to that of reaction (1) because of isospin coefficients and the probability of observing the $K^0_L$($K^0_L$) decay. Moreover, the neutral spectrum

<table>
<thead>
<tr>
<th>Experiment $\bar{p}$ momentum</th>
<th>Type of fit</th>
<th>$M_0$(MeV)</th>
<th>$\Gamma_0$(MeV)</th>
<th>$M_2$(MeV)</th>
<th>$\Gamma_2$(MeV)</th>
<th>Relative Intensities</th>
<th>Confidence Level</th>
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<td>Dipole</td>
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<td>32</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>59%</td>
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<tr>
<td></td>
<td>$\pm 3$</td>
<td>$\pm 6$</td>
<td></td>
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<td></td>
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<tr>
<td>0.7</td>
<td>Dipole</td>
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<td>26</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>99%</td>
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<tr>
<td></td>
<td>$\pm 3$</td>
<td>$\pm 5$</td>
<td></td>
<td></td>
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<tr>
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<td>1273</td>
<td>13</td>
<td>1314</td>
<td>13</td>
<td>0.99 $\pm$ 0.27</td>
<td>69%</td>
</tr>
<tr>
<td></td>
<td>$\pm 20$</td>
<td>$\pm 3$</td>
<td></td>
<td></td>
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<tr>
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<td>Breit-Wigner</td>
<td>Single</td>
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<td>69</td>
<td>-</td>
<td>-</td>
<td>22%</td>
</tr>
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<td>$\pm 20$</td>
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<tr>
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<td>Dipole</td>
<td>1308</td>
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<td>-</td>
<td>-</td>
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<td>10%</td>
</tr>
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<td></td>
<td>$\pm 10$</td>
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<td>-</td>
<td>-</td>
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<td>65%</td>
</tr>
<tr>
<td></td>
<td>$\pm 4$</td>
<td></td>
<td></td>
<td></td>
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<tr>
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<td>22</td>
<td>1325</td>
<td>22</td>
<td>0.97 $\pm$ 0.01</td>
<td>28%</td>
</tr>
<tr>
<td></td>
<td>$\pm 10$</td>
<td>$\pm 3$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
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<td>Total</td>
<td>1296</td>
<td>124</td>
<td>-</td>
<td>-</td>
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</tr>
<tr>
<td></td>
<td>$\pm 41$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>$\pm 27$</td>
<td></td>
<td></td>
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</table>

Table 2

RESULTS

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is more complicated than the charged one since it can have isospin zero or one; in particular the presence of the $f^0$ cannot be excluded.

In fig. 1 we show the total mass squared ($KK^1$) spectrum. A broad enhancement, the $A_2$, is observed between 1.5 and 1.9 GeV$^2$. The solid curve in fig. 1 corresponds to a $\chi^2$ fit using a Breit-Wigner distribution and a fifth order polynomial as an approximation to the background: we did not attempt to fit the threshold enhancement nor the high mass region.

In fig. 2 we have improved the $A_2$ to background ratio by removing events within the $K^+$ bands $(0.745 < M^2(K\pi) < 0.855$ GeV$^2)$ at 0.7 and 1.2 GeV/c. For $\bar{p}$ at rest this selection was not made, mainly because the $A_2$ is observed [3] in strong interference with the $K^+$ and therefore the cut does not improve the signal to noise ratio. If the $KK$ decay mode of the $A_2$ has the same two peak structure as that observed in ref. 1, with our statistics and mass resolution we should expect to observe such a structure in our data. Indeed, fig. 2 shows an effect which is compatible with this assumption, having a significance of 3 $\sigma$. Clearly, the statistical significance of such a narrow effect can be reduced by the binning; it can be made to go down to 1.5 $\sigma$. Associating the $KK$ peaks with the $A_2$ meson decaying into three pions determines the $C$ parity to be $-1$.

This, in turn, restricts the spin parity to the series $2^-, 4^-, \ldots$ Under these assumptions the most likely spin parity is $2^-$. Therefore, we fit the data using again a fifth order polynomial approximation to the background and a dipole interpretation for the resonance region; the solid curve shown in fig. 2 is the result of this fit.

The parameters obtained in the fit are displayed in table 2 where the confidence levels quoted are for the restricted mass squared region $1.49 < M^2(KK) < 1.85$ GeV$^2$. In fig. 3a, we show this restricted region with curves corresponding to the dipole and single Breit-Wigner fits already mentioned. It is clear that our data are compatible with the dipole hypothesis. Different spin-parities for the two peaks are allowed if they are not associated with three pions. The incoherent sum of the two Breit-Wigners is then a valid hypothesis. The result of this fit is shown in fig. 3a, and the parameters are given in table 2. Our data are also in agreement with this hypothesis.

In order to demonstrate that the double-peaked structure is not generated by the summation of different experiments, we show in fig. 3b the $(KK)^1$ spectrum for the events from the experiment [4] at 0.7 GeV/c where the effect under analysis is most significant. The events shown are those with $M^2(K\pi) > 0.9$ GeV$^2$. Again we have made the same three fits as we did for the total data. We have used the form for the background as obtained from the fit to the Dalitz plot as a whole. For the region selected, the background differs very little from phase space. A comparison of the fits is shown in table 2, where, again, the confidence levels are for the restricted mass region defined earlier. Fig. 3b shows the results from these three fits. They are clearly compatible with those obtained for the overall data.

In table 2 we also present results from similar fits to the other individual experiments. Within the errors, which are statistical only, these fits are compatible. We have not folded in the experimental resolution in any of the fits.

Although this $(KK)^1$ data does not show unambiguously a splitting of the $A_2$, meson, it does agree with that obtained in the mass spectrometer experiments of ref. 1. Neither experiment can discriminate between the dipole or the two resonance hypothesis but, if we take for granted that the total $A_2$ effect decays partially into three pions, our results imply that the parity of the $A_2$ is positive; the spin parity must be even and bigger than zero, i.e. $J^P = 2^-, 4^-$, $\ldots$. The simplest hypothesis would be to assume that the total $A_2$ spin is $2^-$, although to verify this a study of angular correlations would be necessary.

It is difficult to reconcile the present results on the $K_L^0 K^2$ data with those obtained by Crennell et al., on their $K_L^0 K^0_L$ data.
We are grateful to Dr. R. Armenteros for his keen interest and constant encouragement. We would also like to express our appreciation for the help and discussion provided by Drs. R. A. Donald and D. N. Edwards and the comments of Prof. A. Astier which stimulated us to pursue this work further.

References
   See also B. Conforte et al. Nuclear Physics B3 (1967) 469.

4. A complete analysis of the three body channels will be published later. Preliminary results on the $K\pi$ decay mode of the $A_2$ were presented at the Fourteenth International Conference on High-Energy Physics, Vienna 1968, (paper 265). See, for example, Fig. 35, Meson resonances, rapporteur's talk by B. French.
6. Partial data from an experiment in progress, University of Liverpool and Institut de Physique Nucléaire, Paris collaboration.