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# Resonant K*(892) Production in Multihadron $e^+e^-$ Annihilation.

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Preliminary results on resonant K*(892) production in $e^+e^-$ annihilation at centre-of-mass energy $W \simeq 2.1$ GeV has already been presented by the MEA experimental group at Adone [1,2]. Our attention was first directed to this energy region during a search for J/ψ-like resonances in the multihadron cross-section. No evidence for such narrow resonances was found in the energy interval explored [3] but some anomalies in the behaviour of the yield of detected multihadron events were observed in the interval $2.070 < W < 2.200$ GeV, called data sample I. Subsequently additional data, data sample II, were collected at $W = 2.13$, 2.25 and 2.30 GeV to investigate this anomalous behaviour. The yield of multihadron events with at least 3 charged particles detected is shown in fig. 1.

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(1) R. BERNABEI *et al.*: Frascati Report LNF-78/64 (1976).
(2) C. BEMPORAD: invited talk at the *Hamburg 1977 International Symposium on Lepton and Photon Interactions at High Energies.*
(3) B. ESPOSITO, F. FELICETTI, I. PERUZZI, M. PICCOLO, F. RONGA, A. MARINI, B. BARTOLI, A. NIGRO, F. VANOLI, D. BISELLO, M. NIGRO, L. PESCARA, P. MONACELLI, L. PAOLUZI, G. PIANO-MORTARI, R. SANTONICO and F. SEBASTIANI: *Phys. Lett.*, **58** B, 478 (1975).

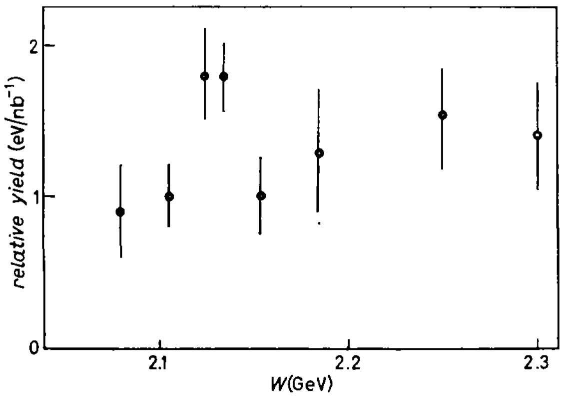


Fig. 1. – Yield of multihadron events with a least 3 charged particles detected *vs.* total c.m. energy $W$.

The experimental apparatus is described in detail elsewhere [4]. The detector consists of wide-gap and narrow-gap spark chambers operated in a magnetic field perpendicular to the $e^+e^-$ beams at Adone. The trigger, which utilizes both scintillation counters and proportional chambers, required at least two charged particles each with a minimum kinetic energy of $\sim 130$ MeV if a pion or $\sim 210$ MeV if a kaon, and having an angle between them $\alpha > 90°$. Photographs of the spark chambers were scanned for candidate multihadron events satisfying one of the following conditions:

*a*) more than two charged particles detected,

*b*) two charged particles observed with a noncoplanarity angle relative to the beam of $\Delta\varphi < 10°$.

In the selection of $e^+e^-$ multihadron events we have restricted our attention to events with at least three charged particles detected, where background contamination was found to be negligible. The following conditions also were imposed:

*a*) the detected tracks as recorded by the multiwire proportional chambers were required to converge to within $\sim 1$ cm of the interaction point;

*b*) track pairs which were consistent with the characteristics of gamma-rays converted in the wall of the vacuum chamber were excluded.

A total of 200 such events was observed with a total collected luminosity $L = 138\ \text{nb}^{-1}$. Of the detected particles some reached the range chambers located outside the magnet coils thus allowing range measurements. From range-momentum measurements about 25% of measured tracks could be identified as pions. Furthermore for the sample of data collected at fixed energies $W = 2.13$, 2.25, 2.30 GeV (sample II) the experimental set-up was improved by adding a time-of-flight measurement made over a distance of 1.0 m to a precision of $\sigma_{\Delta t} = \pm 0.8$ ns, and the momentum to a precision of $\Delta p/p = \pm 0.04$ at 500 MeV/c. From these measurements the probabilities for a particle to be a pion and a kaon were determined.

In order to study possible dynamical correlations between the outgoing particles we have examined the invariant-mass distributions of two-particle neutral systems assuming that each particle pair was either $\pi^\pm\pi^\mp$, $K^\pm\pi^\mp$ or $K^\pm K^\mp$, but the mass of each particle was required to be consistent with a particle identification made through the range-momentum measurements. For unidentifiable tracks each was assumed to be

[4] W. W. ASH *et al.*: to be published in *Nucl. Instr. Meth.*

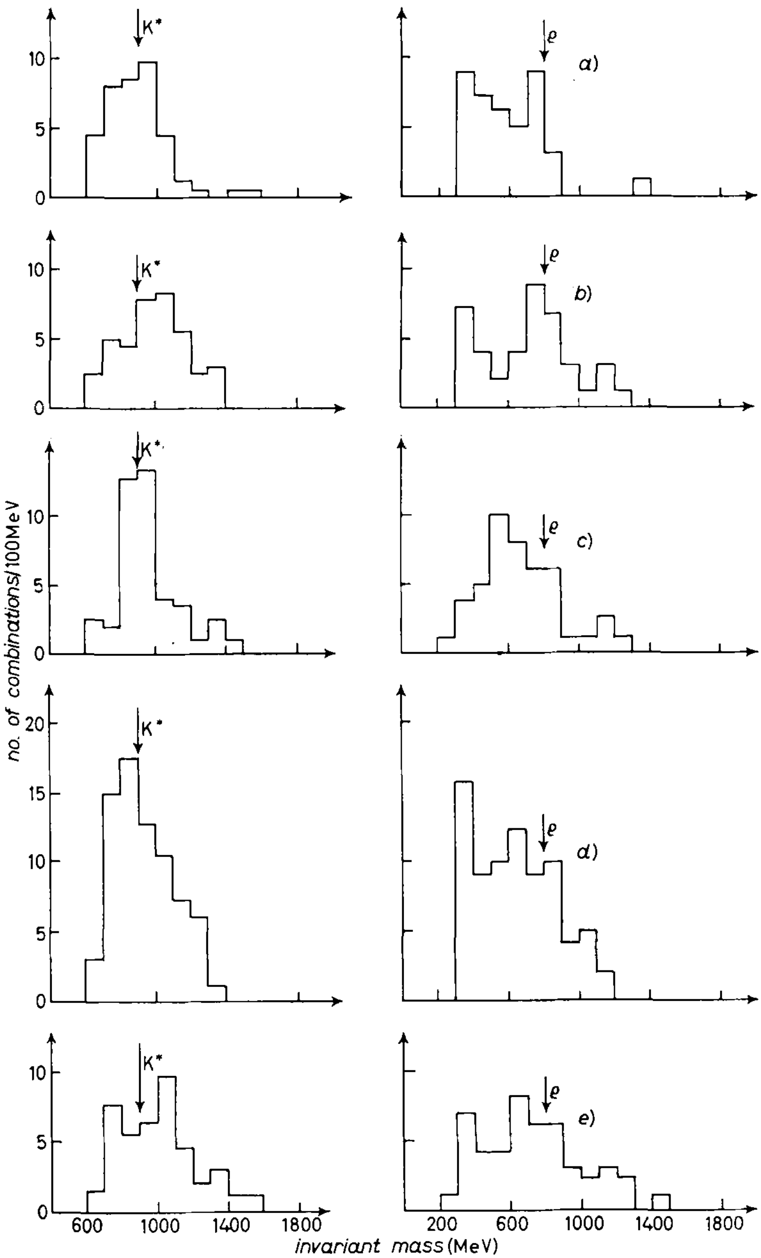


Fig. 2. – Invariant-mass distributions for $K^{\pm}\pi^{\mp}$ and $\pi^{\pm}\pi^{\mp}$ two-particle neutral systems at different total c.m. energies, $W$. *a*) $W = 2250$, 2300 GeV, sample II; *b*) $2200 \geqslant W \geqslant 2140$ GeV, sample I; *c*) $W = 2130$ GeV, sample II; *d*) $2120 \leqslant W \leqslant 2140$ GeV, sample I; *e*) $2070 \leqslant W \leqslant 2120$ GeV, sample I.

in turn a pion and a kaon. Each time a pair of particles contributed to more than one mass combination, an appropriate weight was assigned to each mass combination so that the total contribution of each particle pair to the invariant-mass distribution always equaled unity. In fig. 2 the invariant-mass distributions for $\pi^\pm\pi^\mp$ and $K^\pm\pi^\mp$ neutral systems are shown at different overlapping energies intervals for data sample I and II separately. We note that the agreement between sample I and sample II in the overlapping energy region is quite good, thus confirming the initial suggestion of $K^*$ production at $W \simeq 2.13$ GeV and allowing the two samples to be added together. The mass resolution, as determined by Monte Carlo calculation, is

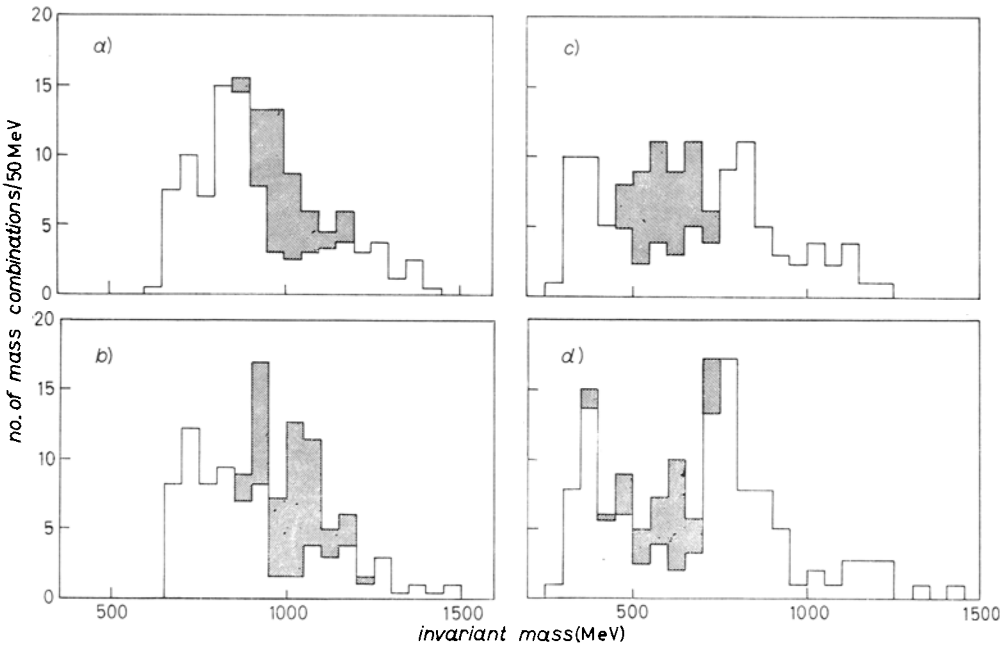


Fig. 3. – Invariant-mass distributions for $K^\pm\pi^\mp$ and $\pi^\pm\pi^\mp$ two-particle neutral systems, *a*), *c*) $W = (2.12 \div 2.14)$ GeV; *b*), *d*) $W \leqslant 2.12$ GeV and $W \geqslant 2.14$ GeV. Cross-hatched areas show respectively the reflection of $\varrho$ production (670 MeV $\leqslant M_{\pi\pi} \leqslant$ 870 MeV) in the $K^\pm\pi^\mp$ mass distribution and of $K^*$ production ($840 \leqslant M_{K\pi} \leqslant 940$ MeV) in the $\pi^\pm\pi^\mp$ mass distribution. *a*), *b*) $K\pi$; *c*), *d*) $\pi\pi$

$\Delta M/M \simeq \pm 0.05$ in the $K^*$ mass region. In fig. 3 the $\pi^\pm\pi^\mp$ and $K^\pm\pi^\mp$ invariant-mass distributions for the combined sample are shown for the data collected at $W = (2.12 \div 2.14)$ GeV and outside this energy interval. A 50 MeV invariant-mass binning is used in fig. 3 consistently with the quoted mass resolution. The $\pi^\pm\pi^\mp$ mass distributons show an enhancement at the $\varrho$ mass both at energies larger and smaller than $W \simeq 2.13$ GeV. This effect although also present at $W \simeq 2.13$ GeV is less evident at this energy because particle pairs which actually originate from $K^*$ decay, when they are assumed to be both pions, give invariant masses centred around 600 MeV.

In fig. 3*a*) and *b*) the contribution of those particle pairs which, when considered both pions, give invariant masses in the $\rho$ region (670 MeV $\leqslant M_{\pi\pi} \leqslant$ 870 MeV) is shown as a cross hatched area. One can see that a $K^*$ signal cannot be the result of a reflection from the $\rho$. Actually particle pairs originating from $\rho$-decay give a contribution to the $K\pi$ invariant-mass distribution centred around 1050 MeV. Conversely the cross hatched area in fig. 3c) and d) shows the reflection of K* production (840 MeV $< M_{K\pi} <$ 940 MeV) in the $\pi\pi$ spectrum.

A clear K* signal shows up in the energy interval $W = (2.12 \div 2.14)$ GeV, while ρ-production is present over all the energy range explored. It is important to recall that the invariant-mass distributions for pairs of tracks having the same charge do not show any anomalous behaviour either in the $\pi^\pm\pi^\mp$ or in the $K^\pm\pi^\mp$ system, thus no evidence of experimental bias is present in either sample ([1]).

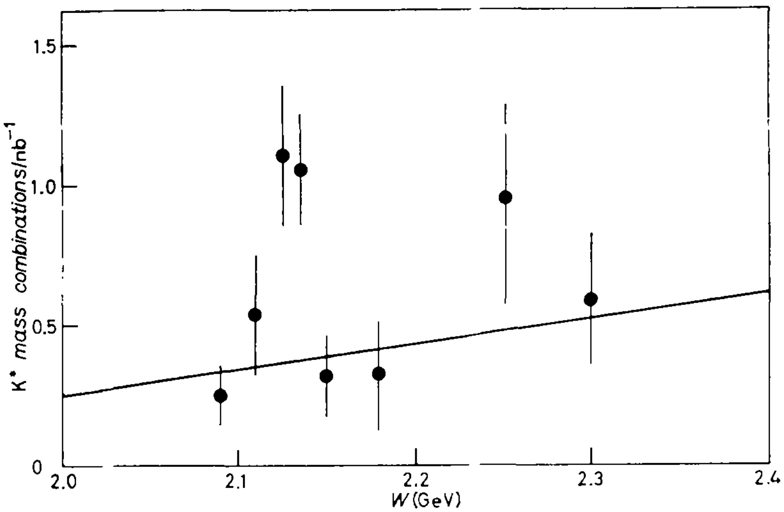


Fig. 4. – Yield of K* mass combinations ($800 \leqslant M_K \leqslant 1000$ MeV) vs. total c.m. energy $W$. A straight-line fit excluding data between (2.12÷2.14) GeV is shown.

The energy dependence of K* production is presented in fig. 4. Here, the yield of K* mass combinations ($800 < M_{K\pi} < 1000$ MeV) is plotted as a function of the total c.m. energy. In the calculation of K* yields the contributions of the particle pairs which, when assumed to be both pions, gave invariant masses in the ρ-region (670 MeV $<$ $< M_{\pi\pi} <$ 870 MeV) were substracted out. The excitation curve in fig. 4 shows a resonant behaviour centred at $W \simeq 2.13$ GeV with a width $\Gamma \simeq 30$ MeV.

In table I the observed number of K* mass combinations in the energy interval $W = (2.12 \div 2.14)$ GeV and the expected number as evaluated by a linear fit to the data outside this energy interval are given.

TABLE I.

| | |
|---|---|
| Expected K* mass combinations | $13.1 \pm 2.5$ |
| Observed K* mass combinations | $40.5 \pm 5.8$ |

The excess of K*-mass combinations above the background is $27.4 \pm 6.3$ which is an enhancement of over four standard deviations.

An independent check of K* production was obtained from data sample II, where K identification was possible by the time-of-flight system. The collected luminosity available for TOF measurements was 37.5 $nb^{-1}$.

The $K^{\pm}\pi^{\mp}$ invariant-mass spectra obtained by weighting each track with the probability to be a K or a $\pi$ according to time-of-flight measurement are shown in fig. 5*a*) at $W = 2.13$ GeV and in fig. 5*b*) at $W = 2.25$, 2.30 GeV. In spite of the limited statistics a clear K* signal is seen at $W = 2.13$ GeV.

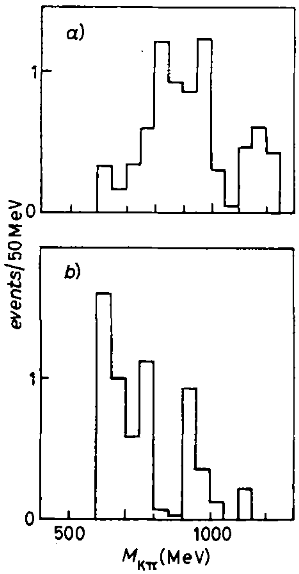


Fig. 5. – Invariant-mass distributions for $K^{\pm}\pi^{\mp}$ two-particle neutral systems for data sample II. Mass combinations have been weighted taking into account the probability of each particle to be a $\pi$ or a K according to the time of flight information. *a*) $W = 2130$ GeV, 20.1 $nb^{-1}$; *b*) $W = 2250$' 2300 GeV, 17.4 $nb^{-1}$.

To summarize, evidence has been presented for resonant K* production in multihadron events in the energy interval $W = (2.12 \div 2.14)$ GeV. Our data do not allow us to definitely determine the actual final state produced. However, strangeness conservation and detected multiplicity (events with more than four charged prongs have been observed) lead us to consider channels such as

$$e^+e^- \to K^*K\pi\,, \qquad (1)$$

$$e^+e^- \to K^*K\pi\pi \qquad (2)$$

as possible candidates to explain the data. Actually several events have been found which fulfill the kinematical constraints of the final state $K^*K\pi$. Detection efficiencies of the MEA apparatus for reaction (1) and (2) are, however, very small and no reliable value can be given for the cross-section.

It is interesting to note that a resonant structure in the $K^+K^-\pi^+\pi^-$ system at an invariant mass $W \simeq 2.1$ GeV has also been observed by an electroproduction experiment at Cornell ([5]). This effect is enhanced when at least one of the $K\pi$ pairs is required to have the K* mass.

([5]) L. N. HAND: invited talk at the *Hamburg 1977 International Symposium on Lepton and Photon Interactions at High Energies*.

We recall that the mass region where the observed K* production appears, coincides with that theoretically expected for the third recurrence of the φ-meson ([6]). Also the total width $\Gamma \sim 30$ MeV would favour the interpretation of this new resonance as a member of the φ-family. Moreover, recent results at Adone ([7]) and DCI ([8]) provided evidence for the existence of new vector mesons in the mass region $(1.4 \div 1.9)$ GeV which also fits well into the picture of recurrencies of the known vector mesons ρ, ω, and φ.

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([6]) M. GRECO: Frascati report LNF-76/55 (1976).

([7]) B. ESPOSITO, F. FELICETTI, A. MARINI, F. RONGA, B. SECHI-ZORN, G. T. ZORN, A. NIGRO, M. NIGRO, L. PESCARA, R. BERNABEI, S. D'ANGELO, P. MONACELLI, M. MORICCA, L. PAOLUZI, G. PIANO-MORTARI, A. SCIUBBA and F. SEBASTIANI: *Phys. Lett.*, **68** B, 389 (1977).

([8]) F. LAPLACE: invited talk at the *Hamburg 1977 International Symposium on Lepton and Photon Interactions at High Energies.*