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MULTIHADRONIC DECAYS AND PARTIAL WIDTHS OF THE J/ψ(3100) RESONANCE PRODUCED IN e^+e^- ANNIHILATION AT ADONE.

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ABSTRACT. -

The reactions $e^+e^- \rightarrow$ hadrons and $e^+e^- \rightarrow e^+e^-$ have been studied at the J/ψ (3100) resonance). The relative weights of the topological cross sections for fixed charged multiplicity are $\sigma_2 = (32 \pm 5)\%$, $\sigma_4 = (49 \pm 8)\%$, $\sigma_6 = (18 \pm 3)\%$, and $\sigma_8 = (1 \pm 0.6)\%$. The average pion multiplicities are $\langle n_{ch} \rangle = 3.8 \pm 0.3$ and $\langle n_{\pi^o} \rangle = 3.1 \pm 0.8$. The decay widths are $\Gamma_e = (4.6 \pm 0.8)$ KeV, $\Gamma_h = (59 \pm 24)$ KeV, and $\Gamma = (68 \pm 26)$ KeV.

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A set of preliminary experimental results obtained at ADONE, the e^+e^- storage ring of the Frascati National Laboratory, on the production and decay modes of the J/ψ (3100) resonance[1] has been already published[2, 3].

In this paper further results are presented concerning the reactions:

(1) $$e^+e^- \longrightarrow \text{hadrons}$$

(2) $$e^+e^- \longrightarrow e^+e^-$$

around total c.m. energy W = 3.1 GeV.

As far as the multihadronic production is concerned, the relative weights of the topological cross sections at fixed charged multiplicity σ_2, σ_4, σ_6 and σ_8 have been determined, where, as usual, $\sigma_2 = \sigma(e^+e^- \longrightarrow \pi^+\pi^- + \text{any number of } \pi^0\text{'s})$, $\sigma_4 = \sigma(2\pi^+2\pi^- + \text{any number of } \pi^0\text{'s})$, etc. The average number of π^0's associated with each of these reaction groups, namely $\langle n_{\pi^0}\rangle_2$, $\langle n_{\pi^0}\rangle_4$, $\langle n_{\pi^0}\rangle_6$, have also been derived.

The partial decay widths $\Gamma_e = \Gamma(J/\psi \longrightarrow e^+e^-)$, $\Gamma_h = \Gamma(J/\psi \longrightarrow \text{hadrons})$, and $\Gamma = \Gamma(J/\psi \rightarrow \text{all})$ have been determined by a best fit procedure on the excitation curves for the processes (1) and (2). This analysis takes into account the effects of radiative corrections[4, 5], which were not yet applied in ref. (2).

The experimental set-up has been already described elsewhere[2, 3]. It mainly consists of two large semi-cylindrical telescopes (counters, lead converters and optical spark chambers) located above and below the interaction region, with their axes perpendicular to the $e^\pm$ beams. This part of the set-up covers a total solid angle, for a point-like source, of $(0.41 \times 4\pi)$ sr for trigger and $(0.66 \times 4\pi)$ sr for tracking. The trigger logic requires at least one charged particle in the upper telescope and at least either one charged particle or one photon in the lower telescope ("charged-charged" or "charged - neutral" configurations respectively). The absolute luminosity of the machine is measured by the small angle Bhabha scattering and the double bremsstrahlung as detected in a different straight section of ADONE.

The present analysis refers to a sample of about one thousand multihadronic events. For each event the number of charged prongs N_{ch}, and converted photons N_γ, detected in the optical spark chambers, has been determined. Typical charged prong and photon multiplicity distributions, referring to different classes of configurations, are shown in Fig. 1. From configurations with total (charged + neutral) multiplicities larger than 2, information has been extracted on cross

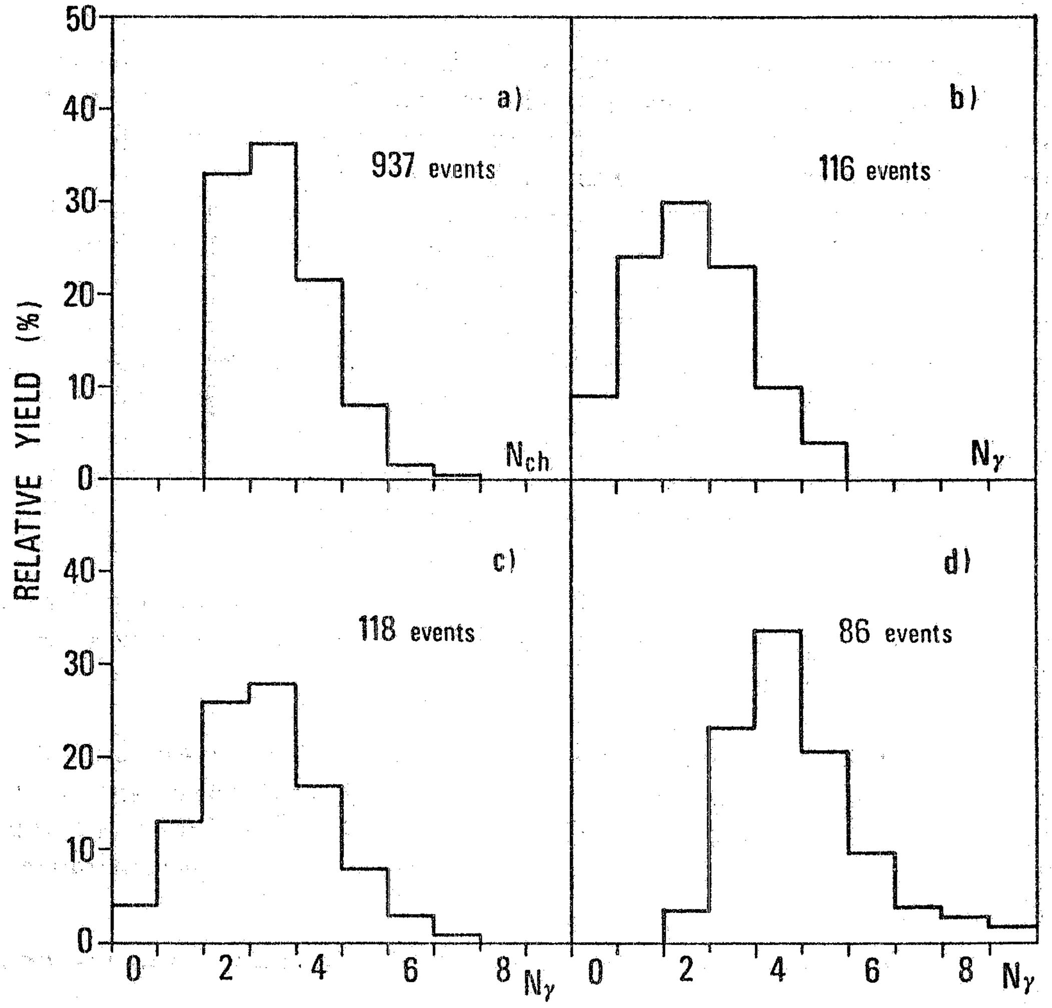

FIG. 1 - Charged prong and photon multiplicity distribution as detected in the optical spark chambers. a) charged prong multiplicity distribution ("charged-charged" configurations). N_{ch} if the number of detected charged prongs.
Detected photon multiplicities associated with different charged prong configurations; N_γ is the number of photons detected in: b) events with at least 5 charged prongs; this spectrum is predominantly due to reactions contributing to σ_6; c) events with 3 charged prongs; in this spectrum the reactions contributing to σ_2 are ruled out; d) events with only one charged prong in the set-up ("charged-neutral" configurations); the relative detection efficiency for such a configuration favours the reactions of the group σ_2.

sections and charged and neutral pion multiplicities, by an overall fit procedure performed on a system of equations connecting the counting rates for the various detected configurations to the unknown partial cross sections for the process $e^+e^- \longrightarrow$ hadrons. The detection efficiencies have been calculated by MonteCarlo method assuming an invariant phase space momentum distribution[2]. In this calculation, the set of possible processes contributing to the multihadronic events, has been limited to reactions in which only pions with maximum multiplicity 10 are produced. A possible charged kaon contamination up to 15÷20% does not appreciably affect the conclusions of the present work. As far as the neutral kaons are concerned, only the short lived component can be detected in the set-up, and shows up as charged pions coming from the beam line, owing to the limited spatial resolution of the present measurement. The calculated triggering efficiency ranges from 15% to 40%, depending on the number of charged pions produced. A remarkable feature of this efficiency is that it depends only weakly on the number of accompanying π^0's. In other words σ_2, σ_4, σ_6, σ_8, can be determined with an accuracy which is practically unaffected by the uncertainty on the photon detection efficiency.

Systematic uncertainties indeed affect the tracking efficiencies for low energy photons as detected in the spark chamber system for many prong events.

The results of the present analysis are reported in the following. The quoted errors, take into account both statistical and systematic uncertainties (such as monitoring, triggering efficiencies, nuclear interactions, etc.) The background from beam-gas interactions is found to be negligeable.

i) The relative weights of σ_2, σ_4, σ_6 and σ_8 at the energy of the J/ψ (3100) are:

(3) $\sigma_2 = (32 \pm 5)\%$, $\sigma_4 = (49 \pm 8)\%$, $\sigma_6 = (18 \pm 3)\%$, $\sigma_8 = (1 \pm 0.6)\%$.

This gives for the average number of charged pions:

$$\langle n_{ch} \rangle = 3.8 \pm 0.3.$$

The corresponding number outside the resonance measured at Spear[6] is 3.55 ± 0.04 at 3.0 GeV and 3.89 ± 0.12 at 3.2 GeV.

ii) The experimental features of the detector prevent isolating the single hadronic reaction channels. However a reliable evaluation is obtained for the average neutral pion multiplicities associated with the classes of reactions contributing to σ_2, σ_4 and σ_6 ($\langle n_{\pi^0} \rangle_2$, $\langle n_{\pi^0} \rangle_4$ and $\langle n_{\pi^0} \rangle_6$ respectively):

(4) $\langle n_{\pi^0} \rangle_2 = 3.6 \pm 0.9$; $\langle n_{\pi^0} \rangle_4 = 3.1 \pm 0.7$; $\langle n_{\pi^0} \rangle_6 = 2.3 \pm 0.6$.

The average total neutral pion multiplicity is deduced from (3) and (4):

$$\langle n_{\pi^o} \rangle = 3.1 \pm 0.8.$$

The results on the pion average multiplicities reported in i) and ii) give the following value for the ratio:

$$\frac{\langle n_{ch} \rangle}{\langle n_{\pi^o} \rangle} = 1.2 \pm 0.4$$

in the J/ψ decay.

It has to be noted that assuming an I = 0 assignement for the resonance and neglecting intermediate states electromagnetically decaying into pions (such as η's), the expected value for this ratio is larger than 2. In making this estimate the presence of kaonic decays and virtual photon mediated decays ($\Gamma(e^+e^- \rightarrow \gamma \rightarrow \psi \rightarrow \gamma \rightarrow$ hadrons) = 12 KeV[6]) are taken into account.

iii) The total hadronic cross section $\sigma_h = \sigma(e^+e^- \rightarrow$ hadrons) has been measured as a function of the total c.m. energy. The excitation curve is shown in fig. 2 (a), where the full line represents a fit to the experimental points calculated including the effects of the radiative corrections[4] and of the total energy spread of machine Γ_W. From this best fit it follows:

(5) $$\frac{\Gamma_e \Gamma_h}{\Gamma} = (4.0 \pm 0.8) \text{ KeV}; \qquad \Gamma_W = (3.1 \pm 0.2) \text{ MeV} \quad \text{(FWHM)}.$$

At energies lower than 3.1 GeV, where a statistically limited sample of events has been analyzed, the value of the total hadronic cross section is found to be (25 ± 8) nb, which is in good agreement with previous results[7, 8].

The excitation curve for the $e^+e^- \rightarrow e^+e^-$ reaction is shown in Fig. 2(b). The events have been selected by requiring the electron pairs to be collinear within 10^o and to lie in the angular range $50^o \leq \theta \leq 130^o$, θ being the angle with respect to the beam line. The full line represents the fit to the experimental points including radiative corrections[4]. These data have been fitted with the value of Γ_W quoted in (5), and varying the ratio Γ_e^2/Γ. The bestfit value for this ratio is

(6) $$\frac{\Gamma_e^2}{\Gamma} = (0.32 \pm 0.07) \text{ KeV}$$

The quoted error is statistical only: in this case monitoring and detec-

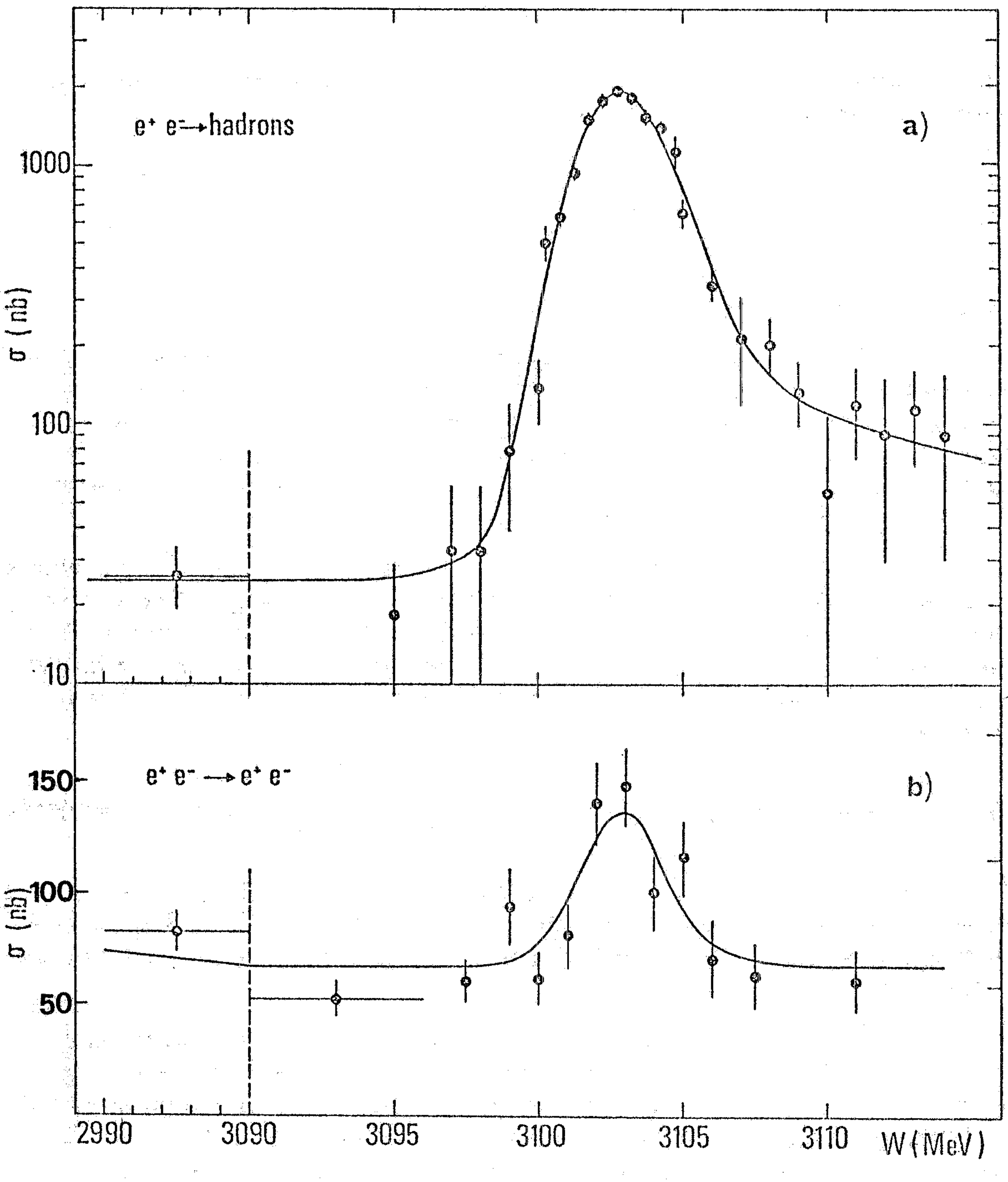

FIG. 2 - a) Total $e^+e^- \to$ hadrons cross section versus total c.m. energy. The mass of the J/ψ turns out to be 3103 MeV with a systematic error of $\pm$ 8 MeV due to Adone magnetic field calibration. b) $e^+e^- \to e^+e^-$ cross section, integrated over the interval $50^o \leq \theta \leq 130^o$, versus total c.m. energy. All the errors are statistical only.

tor efficiency errors are eliminated through normalization to the observed Bhabha scattering rate outside the resonance (QED level). By assuming $\Gamma = \Gamma_e + \Gamma_\mu + \Gamma_h$, and $\Gamma_e = \Gamma_\mu$ it is possible, from (5) and (6), to derive the widths Γ_e, Γ_h and Γ :

$$\Gamma_e = (4.6 \pm 0.8)\,\mathrm{KeV}, \quad \Gamma_h = (59 \pm 24)\,\mathrm{KeV}, \quad \Gamma = (68 \pm 26)\,\mathrm{KeV}.$$

These results are in good agreement with the results from Spear(6) and Doris(9).

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