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MULTIHADRON PRODUCTION FROM e^+e^- ANNIHILATION AT 1.6 c.m. ENERGY.

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Multihadron Production from e^+e^- Annihilation at 1.6 c.m. Energy.

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(ricevuto il 26 Gennaio 1977)

We have studied the reaction

$$e^+e^- \rightarrow \text{many hadrons} \qquad (1)$$

at the total centre-of-mass energy $W = 1.6$ GeV. The experiment was performed at Adone, the Frascati e^+e^- storage ring, some months before the discovery of the J/ψ (3100)-particle. The results refer to an integrated luminosity $\mathscr{L} \simeq 8.5 \cdot 10^{33}$ cm^{-2}. Multihadron production in this range of energies has been already investigated at Orsay [1,2], Novosibirsk [3,4] and at Adone [5-15] with three independent apparata,

(1) G. PARROUR: *International Meeting on Storage Ring Physics, Flaine, February 1976*, L.A.L.-preprint 1285, Orsay (1976).
(2) D. BENAKSAS, G. COSME, B. JEAN-MARIE, S. JULLIAN, F. LAPLACE, J. LEFRANÇOIS, A. D. LIBERMAN, G. PARROUR, J. P. REPELLIN and G. SAUVAGE: *Phys. Lett.*, **39** B, 289 (1972).
(3) L. M. KURDADZE, A. P. ONUCHIN, S. I. SEREDNYAKOV, V. A. SIDOROV and S. I. EIDELMAN: *Phys. Lett.*, **42** B, 515 (1972).
(4) V. A. SIDOROV: *Preliminary results of experimentr at* VEEP-2M, presented at *XVIII High-Energy Physics, Tbilisi, 1976*.
(5) B. BARTOLI, F. FELICETTI, G. MARINI, A. NIGRO, H. OGREEN, N. SPINELLI, V. SILVESTRINI and F. VANOLI: *Phys. Lett.*, **36** B, 598 (1971).
(6) B. BARTOLI, F. FELICETTI, G. MARINI, A. NIGRO, H. OGREEN, V. SILVESTRINI and F. VANOLI: *Phys.*

not using magnetic field. The magnetic analysis allows a significant analysis also with poor statistics. The total cross-section and the partial cross-section have been obtained for the different channels of reaction (1). The single-charged-pion momentum distribution, the average multiplicity $\langle n_c \rangle$ and $\langle n_\pi \rangle$ of charged and charged-plus-neutral pions produced are also given.

The MEA experimental set-up (fig. 1) has already been described [16]. We recall here the angular acceptance of the experimental apparatus and the event identification criteria used in the analysis. The solid angle of the apparatus, useful to study reaction (1), for pointlike source is $\Delta\Omega_c = 0.33 \times 4\pi$ ($40° \leqslant \theta \leqslant 140°$) for trigger and momentum analysis and $\Delta\Omega_{\mathcal{N}} = 0.27 \times 4\pi$ for particle identification. The momentum measurement was made on a track length $l = 80$ cm C_1C_2 ($C_1'C_2'$) in a magnetic field $B = 2.0$ KG. The detection of showers and of nuclear interactions has been performed in the system of 10 cylindrical thick-plate spark chambers (C_3, C_3') mounted outside the magnetic coil. Their total thickness is $\simeq 9$ radiation lengths and $\simeq 1.5$ collision lengths. In the trigger we require at least one particle going in the upper part of the apparatus ($S_1S_2S_3$) and another going in the lower part ($S_1'S_2'S_3'$) both with the minimum kinetic energy of ~ 110 MeV (if pions). For two prong events tracks with small-dip angle are rejected in order to reduce background [16].

The selection of good events is made by using both picture measurements and computer-recorded informations [16].

Events from reactions (1) are required to present:

a) two noncolinear ($\Delta\theta \geqslant 10°$) and acoplanar ($\Delta\varphi \geqslant 10°$) tracks or more than two in the wide-gap chambers (C_2, C_2') and at least one track in C_3 (C_3');

b) the proper position of the source point in the radial and longitudinal direction;

c) a correct timing with the beam-beam interaction.

γ-rays, with an energy roughly greater than 200 MeV, are identified by the shower produced in the thick-plate chambers C_3(C_3').

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(8) F. CERADINI, R. SANTONICO, M. CONVERSI, L. PAOLUZI M. GRILLI, E. IARUCCI. P. SPILLANTINI, V. VALENTE, R. VISENTIN and M. NIGRO: *Phys. Lett.*, **42** B, 501 (1972).

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(16) W. W. ASH, D. C. CHENG, B. ESPOSITO, F. FELICETTI, H. OGREEN, I. PERUZZI, M. PICCOLO, F. RONGA, G. SCHINA, G. T. ZORN, B. BARTOLI, B. COLUZZI, E. CUOMO, A. NIGRO, L. PESCARA, E. SCHIAVUTA, A. MARINI, P. MONACELLI, L. PAOLUZI, G. PIANO-MORTARI, F. SEBASTIANI and L. TRASATTI: *Lett. Nuovo Cimento*, **14**, 705 (1974).

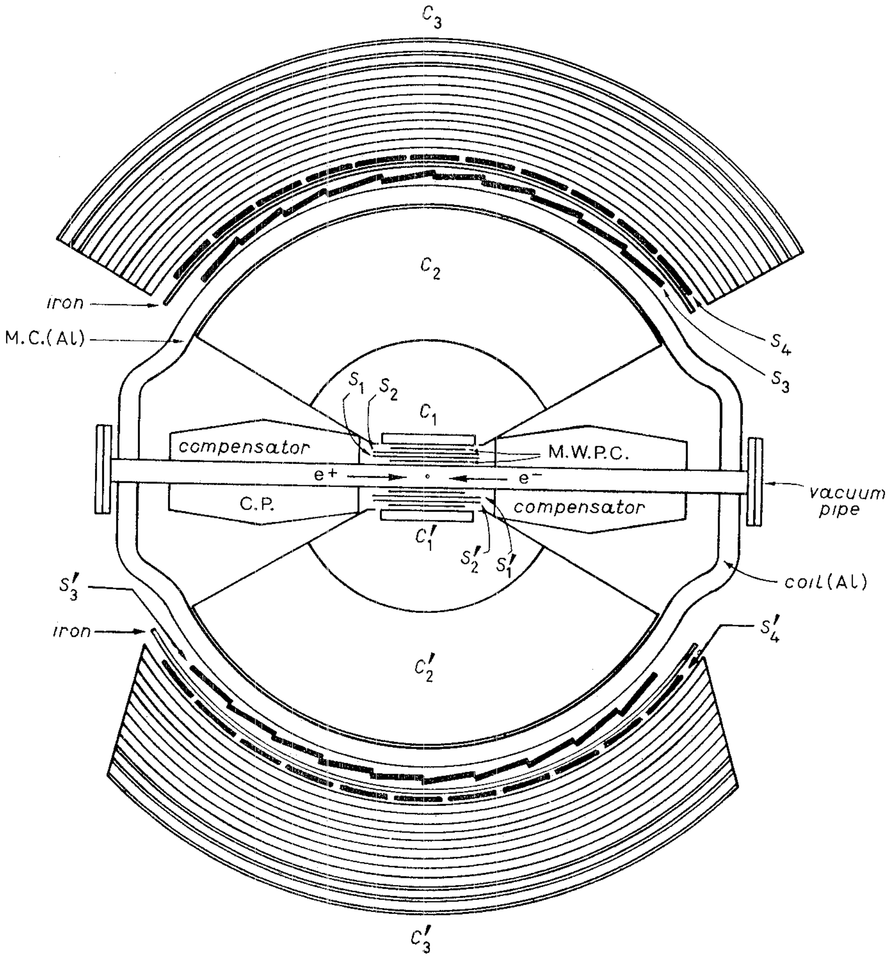

Fig. 1. – Vertical section of the experimental apparatus: C_1C_1' are narrow-gap spark chambers; C_2C_2' wide-gap cylindrical spark chambers for momentum analysis; C_3C_3' thick-plate spark chambers for particle identification; MWPC multiwire proportional chambers; $S_1, S_2, \ldots, S_4'$ scintillation counters (S_4, S_4' were not used in this experiment).

The cuts on $\Delta\theta$ and $\Delta\varphi$ are determined from the analysis of the μ-pairs of the reaction

$$e^+e^- \to \mu^+\mu^- \tag{2}$$

detected in the apparatus. From the study of the $\Delta\varphi$ acoplanarity distribution for the events of the reaction (2) ($\Delta\varphi$ is the difference between the azimuthal angles of the μ^+ and μ^- tracks) and the $\Delta\theta$ noncolinear distribution for the same events ($\Delta\theta$ is the difference between the polar angles of the μ^+ and μ^- tracks), we deduce the cuts $\Delta\theta \geqslant 10°$ for the two-track events.

These cuts reduce also the background due to several well-known radiative and γ-γ processes as $e^+e^- \to \mu^+\mu^-\gamma$, $e^+e^- \to e^+e^-\mu^+\mu^-$, $e^+e^- \to \pi^+\pi^-$. The radial-source dimension is obtained from the events of Bhabha electron-positron scattering $e^+e^- \to e^+e^-$, as detected from the MWPC (16). At Adone the radial dimension is about 1 mm; the observed spread $\pm$ 3 mm (FWHM) is due to the wire chamber resolution and to the multiple scattering in the vacuum chamber wales. The spread in the reconstruction of the z–co-ordinate of the interaction point along the beam line was measured from the μ-pairs produced in reaction (2). Defining Δz as the difference between the z–co-ordinates of the μ^+ and μ^- tracks, we determine a maximum spread $\Delta z = 6$ mm for particles with $p_\beta = 0.785$ GeV/c. In Fig. 2 we report the scatter plot $(\Delta z - p)$ for every pair of detected

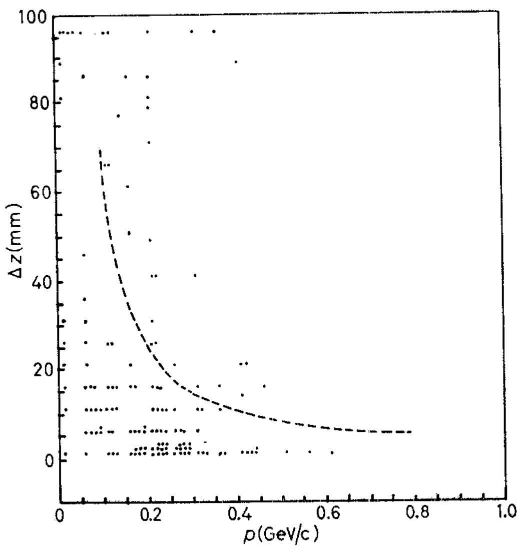

Fig. 2. – Scatter plot $(\Delta z - p)$ for the events candidate as multihadron events; Δz is the difference between the z–co-ordinate of a pair of charged particles having momenta p_1 and p_2, p is the minimum value between p_1 and p_2. The dotted line is the $\Delta z - p$ limit for multiple scattering (see text).

charged particles of momenta p_1 and p_2 of candidate events of reaction (1); for p we choose the smaller between p_1 and p_2. The plotted $\Delta z \cdot p\beta = 8$ (mm·GeV/c) line, as predicted from multiple scattering, delimits the region of the accepted events. The integrated luminosity $\mathscr{L}$ has been determined from the rate of the wide-angle Bhabha scattering measured in our apparatus. From the 770 wide-angle events and from the calculated cross-section integrated on the apparatus $\langle\sigma\rangle_{ee} = 91.1 \cdot 10^{-33}$ cm^2 we deduce $\mathscr{L} = (8.45 \pm 0.3) \cdot 10^{33}$ cm^{-2}. This value is in good agreement with the luminosity obtained from the measured rate of small-angle Bhabha scattering observed by the Adone machine group in a different interaction region ($\mathscr{L} = 8.8 \cdot 10^{33}$ cm^{-2}). In order to give an independent check of the efficiency of the whole apparatus, from the identified μ-pair events, we deduce the cross-section of the reaction (2):

$$\sigma_{\mu^+\mu^-} = \frac{N_{\mu^+\mu^-}}{\mathscr{L} \cdot \varepsilon_{\mu^+\mu^-}} = \frac{40 \cdot 10^{-33}}{8.45 \cdot 0.17} = (28 \pm 5) \cdot 10^{-33}\ \text{cm}^2\,,$$

where $\varepsilon_{\mu\mu} = 0.17$ is the detection efficiency of the apparatus for reaction (2) evaluated by a Monte Carlo calculation taking into account the longitudinal distribution of the source. This value agrees with the value $\sigma \simeq 33 \cdot 10^{-33}\ \text{cm}^2$, obtained in the μ-e universality hypothesis, and with previous measurements [17,18].

The experimental results are summarized in the last column of table I. The collected multihadronic events ($N = 50$) are classified according to the detected configuration: $2T(0, 0\gamma)$ = two charged particles of opposite charge and no γ-ray associated; $2T(C, 1\gamma)$ = two charged particles with the same charge ($C = \pm 2$) and 1γ associated; for the $3T$-configuration, corresponding at three detected tracks: $3T(3M, 0\gamma)$ = three charged particles analysed in momentum (*i.e.* seen in the wide-gap chambers (C_2, C_2')) and no γ associated; $3T(2M, 0\gamma)$ = three charged particles, two of which analysed in momentum and one detected only in $C_1(C_1')$ and no γ; all the events of the $3T(3M, 0\gamma)$-configuration have a net charge of ± 1. $4T(0\gamma)$, $[4T(1\gamma)]$ four charged particles and no (1) of which two, at least, momentum analysed and $0\gamma[1\gamma]$. The detection efficiencies reported in table I are discussed further on.

An inclusive momentum distribution can be made directly from the momenta of all the particles of the selected and measured events. The momentum resolution of the whole sistem apparatus + mangiaspago has been determined from the μ-pair events.

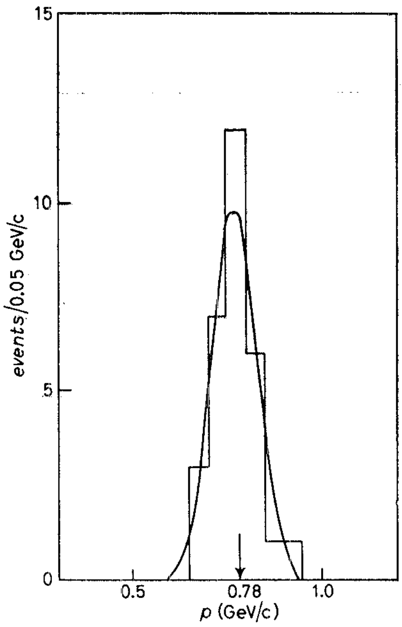

Fig. 3. – Momentum distribution of the μ produced in the $e^+e^- \to \mu^+\mu^-$ process. $\sigma_p = \pm 0.06$ GeV/c, $\sigma_p/p = 0.078$.

In fig. 3 we report the momentum distribution, for these events from which we deduce a standard resolution $\Delta p/p = 0.08$ at $p = 0.785$ GeV/c. The sensibility of the mangiaspago system, evaluated from the measurements of the cosmic-ray tracks crossing the apparatus without magnetic field is about 3%.

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(18) B. Borgia, F. Ceradini, M. Conversi, L. Paoluzi, R. Santonico, G. Barbiellini, M. Grilli, P. Spillantini, R. Visentin and F. Grianti: *Lett. Nuovo Cimento*, **3**, 115 (1972).

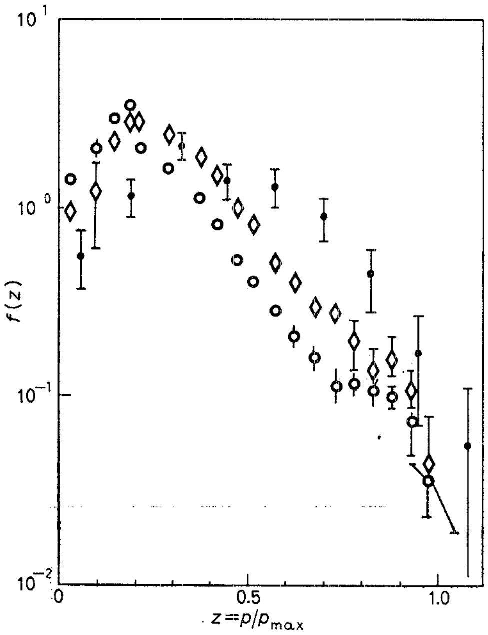

Fig. 4. – Single charged particle momentum distribution $F(z)$ *vs.* z, where $z = p/p_{max}$ ($F(z)$ is normalized to $\int_0^1 F(z)\,dz = 1$) (◇ 3.0 GeV, ○ 3.8 GeV: SLAC-LBL Collaboration; • 1.6 GeV: Adone-Mea).

Figure 4 shows the normalized distribution of $F(z)$, defined as

$$F(z) = \frac{1}{\langle N_c \rangle \sigma_{had}} \frac{\Delta\sigma_{had}}{\Delta z} = \frac{1}{N}\frac{\Delta N}{\Delta z},$$

where $z = p/p_{max}$ and σ_{had} is the multihadron total cross-section. The distribution of $F(z)$ at higher energies as measured by the SLAC-LNL Collaboration ([19,20]) are also plotted.

The average value of p for charged particles

$$\langle p_{ch} \rangle = \int_0^1 pF(z)\,dz$$

([19]) SLAC-LAL Collaboration: J. E. Augustin, A. M. Boyarsky, M. Breindelbach, F. Biells, J. T. Dakin, G. J. Feldman, G. E. Fisher, D. Freyberger, G. Hanson, B. Jean-Marie, R. R. Larsen, V. Lüth, H. L. Lynch, D. Lyon, C. C. Morehouse, J. M. Paterson, M. L. Perl, B. Richter, R. F. Schwitters, F. Vannucci, G. S. Abrams, D. Briggs, W. Chinowsky, C. E. Friedergen, G. Goldhaber, R. J. Hollebeek, J. A. Kadyk, G. H. Trilling, J. S. Whitaker and J. E. Zipse: data taken from G. J. Feldmann and M. L. Perl: *Phys. Reports*, **49**, 233 (1975).

([20]) B. Richter: *Proceedings of the XVII International Conference on High-Energy Physics* (Rutherford, 1974).

as well as $\langle z \rangle = \langle p/p_{max} \rangle$ is shown in fig. 5, together with the results of the SLAC-LNL collaboration [19,20]. The values of our measurements at $W = 2.08$ GeV are also reported. Our results indicate that $\langle p_{ch} \rangle$ decreases slowly with decreasing energy W and that $F(z)$ decreases in the low z-region and correspondingly, increases in the high z-region.

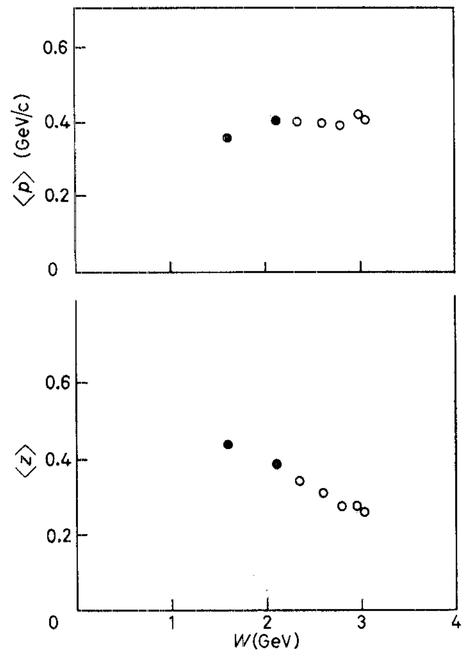

Fig. 5. – *a*) The main value $\langle p \rangle$ for charged particles *vs.* the total energy W; *b*) $\langle z \rangle = \langle p/p_{max} \rangle$ for charged particles *vs.* W. (○ SLAC-LBL Collaboration; ● Adone-MEA).

In fig. 6 the invariant cross-section in arbitrary units is plotted; the cut in the momentum of the apparatus is about $p \simeq 0.08$ GeV/c. The data are consistent with a distribution

$$\frac{E}{p^2}\frac{d\sigma_{had}}{dp} = \text{constant}\cdot\exp\left[-E/E_0\right]$$

with $E_0 = 0.164$ GeV as measured from the SLAC-LNL collaboration [20,21], with π^-, k^- and antiproton at $W = 4.8$ GeV (the best fit of our data gives $E_0 = 0.14$ GeV).

A Monte Carlo program was used to simulate the experiment and to calculate the efficiencies for the final states in the different detected configurations. In these calculation particles were generated according to phase-space momentum distsibution. Events, for a particular final state, were generated along the beam line with a Gaussian distribution ($\sigma_l = 12$ cm). In the calculations of the detection efficiency, the nuclear interactions of pions were taken into account using the data reported in ref. [22]. Only in the generation of three-body final states ($\pi^+\pi^-\pi^0$) was used, for each event, a dynamic factor $\sin^2\omega \sin^2\theta$ [23], where ω is the angle between the e^+e^- beam direction and the normal

(21) R. F. Schwitters: SLAC-LBL-PUB-1666 (November 1975).
(22) H. Ogreen: L.N.F.-International Report LNF/71/89 (Frascati, 1971).
(23) N. Cabibbo and R. Gatto: *Phys. Rev.*, **424**, 1577 (1961).

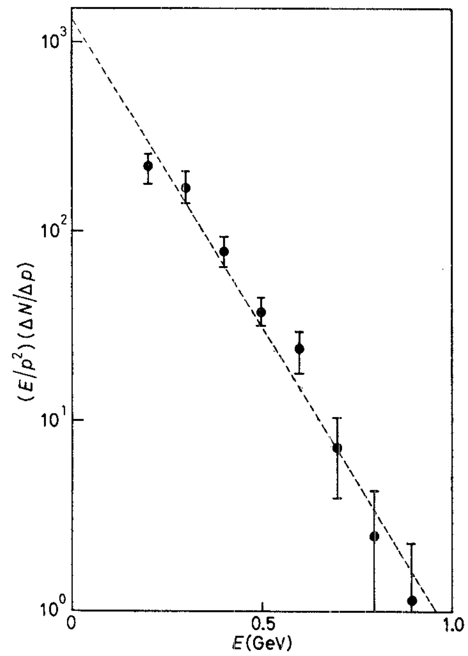

Fig. 6. – (E/p^2), $N/\Delta p$ for π^+ *vs.* the particle energy E. The line const·exp $[-E/E_0]\Delta$ where $E_0 = 0.164$ GeV, as measured at SLAC ([20]) at $W = 4.8$ GeV is plotted.

TABLE I. – *Efficiencies (in %) in various configurations for the detection of different final states.* In the last column the collected events are reported.

	$\pi^+\pi^-\pi^0$	$\pi^+\pi^-\pi^0\pi^0$	$\pi^+\pi^-3\pi^0$	$2\pi^+2\pi^-$	$2\pi^+2\pi^-\pi^0$	$2(\pi^+\pi^-\pi^0)$	$3\pi^+3\pi^-$	Events
$2T(0, 0\gamma)$	1.58	1.59	0.46	3.1	1.06	0.48	0.66	11
$2T(0, 1\gamma)$	0.57	1.09	0.73	—	0.44	0.33	—	3
$2T(0, 2\gamma)$	0.08	0.32	0.50	—	0	0.05	—	1
$2T(C, 0\gamma)$	—	—	—	1.55	0.53	0.24	0.44	5
$2T(C, 1\gamma)$	—	—	—	—	0.22	0.17	—	0
$3T(2M, 0\gamma)$	—	—	—	3.32	1.8	0.54	1.48	7
$3T(3M, 0\gamma)$	—	—	—	4.27	1.8	0.73	1.59	12
$3T(1\gamma)$	—	—	—	—	1.05	0.96	—	2
$4T(0\gamma)$	—	—	—	4.26	1.48	0.45	3.66	9
$4T(1\gamma)$	—	—	—	—	0.69	0.44	—	0
ε_T (Trigger efficiency)	2.23	3	1.75	16.5	9.4	4.8	10	50 (Total number of events)

to the production plane and θ is the angle between the two charged pions. A minimum energy $E_\gamma = 200$ MeV was assumed for the detection of γ-rays from the π^0 decays.

The detection efficiencies for the different final states and for the detected configurations are summarized in table I. The efficiencies for the different reactions lie in the range $\varepsilon_T\,(0.02 \div 16)$. The low efficiencies for the reactions with only two charged particles in the final state $e^+e^- \to \pi^+\pi^- n\pi^0$ ($n = 1, 2, 3$) derive mainly from the trigger requirement to have the charged particles in the two opposite sides of the apparatus and also from the rejection of the tracks with small-dip angle. For the reaction with four or more charged particles, table I shows that the detection of the configurations with three of four charged particles $(3T+4T)$ are favoured with respect to the configuration with two particles $(2T)$ in the apparatus. The observed ratio for the detected charged multiplicity is $(3T + 4T)/2T \simeq 30/20 = 1.5$. Another result of the calculation is that the configurations with 2 detected gamma-rays from π^0's decay are strongly depressed. In fact, only one event with 2 gammas has been observed.

If we suppose that also $K^\pm$ mesons are produced, from the previous considerations the most efficient channel is $e^+e^- \to K^+K^-\pi^+\pi^-$. Since the total energy is only 330 MeV higher than the threshold of this reaction, we obtain a total trigger efficiency $\varepsilon_T \approx 0.003$. For this reason we assume that all detected hadrons are pions.

The statistical error on the values of the efficiencies are between 5% and 10%.

The following reactions have been supposed to contribute to the multihadronic events reported in table I:

$$e^+e^- \to \begin{cases} \pi^+\pi^-\pi^0\,, \\ \pi^+\pi^-\pi^0\pi^0\,, \\ \pi^+\pi^-\pi^0\pi^0\pi^0\,, \\ \pi^+\pi^-\pi^+\pi^-\,, \\ \pi^+\pi^-\pi^+\pi^-\pi^0\,, \\ \pi^+\pi^-\pi^+\pi^-\pi^0\pi^0\,, \\ \pi^+\pi^-\pi^+\pi^-\pi^+\pi^-\,. \end{cases} \tag{3}$$

The calculation of the cross-sections of the various reactions (3) was made solving the system of k equations

$$N_k = \sum_i \varepsilon_{ki}\sigma_i\,, \tag{4}$$

where N_k is the total number of events belonging to one of the 10 categories listed in table I, $\mathscr{L}$ the total luminosity, σ_i the cross-sections for the reactions (3), ε_{ki} the efficiency for detecting reaction i in the k-configuration (table I).

Taking into account statistical errors for N_k, we have searched for the best solution of these equations using standard programs which minimize the χ^2-function.

In solving these equations we obtained the weight of some channels as $e^+e^- \to \pi^+\pi^-\pi^+\pi^-$, $\pi^+\pi^-\pi^+\pi^-\pi^0$ as well as the total contribution of the channels $e^+e^- \to \pi^+\pi^- n\pi^0$ $n = 1, 2, 3$). However, because of the small number of $2T$ events it has not been possible to determine independently the cross-section of the three reactions $e^+e^- \to \pi^+\pi^-\pi^0$, $\pi^+\pi^-\pi^0\pi^0$ and $\pi^+\pi^-\pi^0\pi^0\pi^0$. So we have solved the system considering separately only the channel $e^+e^- \to \pi^+\pi^-\pi^0\pi^0$ and adding up the cross-sections of the two channels with an odd number of π^0's. This choice is suggested also by the previous experimental results [11] which indicate that the production of final states with G parity $= +1$ are more abundant than those with G parity $= -1$. For the efficiency of the combination $\sigma(\pi^+\pi^-\pi^0) + \sigma(\pi^+\pi^-\pi^0\pi^0\pi^0)$ in the different configurations we have taken the average value $\bar{\varepsilon}_k = \frac{1}{2}[\varepsilon_k(\pi^+\pi^-\pi^0) + \varepsilon_k(\pi^+\pi^-\pi^0\pi^0\pi^0)]$. The results of the analysis are summarized in table II. The total cross-section is the sum of the partial cross-sections, the main con-

TABLE II. – *Summary of the cross-sections.*

	$\cdot 10^{-33}$ cm²
$\sigma(\pi^+\pi^-\pi^0) + \sigma(\pi^+\pi^-\pi^0\pi^0\pi^0)$	9.5 ± 9
$\sigma(\pi^+\pi^-\pi^0\pi^0)$	24 ± 16
$\sigma(\pi^+\pi^-\pi^+\pi^-)$	27 ± 11
$\sigma(\pi^+\pi^-\pi^+\pi^-\pi^0)$	4.7 ± 3
$\sigma(\pi^+\pi^-\pi^+\pi^-\pi^0\pi^0)$	4.8 ± 3
$\sigma(\pi^+\pi^-\pi^+\pi^-\pi^+\pi^-)$	1 ± 0.2
$\sigma_{tot}(e^+e^- \to \text{hadrons})$	70 ± 10
$\sigma_{2n}(\pi^+\pi^- n\pi^0)$ $(n = 1, 2, 3)$	33.5 ± 18
$\sigma_{4n}(\pi^+\pi^-\pi^+\pi^- n\pi^0)$ $(n = 1, 2)$	9.5 ± 6
$\sigma_+(e^+e^- \to G = +1$ parity final states)	55.8 ± 19
$\sigma_-(e^+e^- \to G = -1$ parity final states)	14.2 ± 9
$\sigma_{4c}(e^+e^- \to \pi^+\pi^-\pi^+\pi^- +$ anything)	36.5 ± 12

tribution coming from the reactions $e^+e^- = \pi^+\pi^-\pi^0\pi^0$, $\pi^+\pi^-\pi^+\pi^-$ and $\pi^+\pi^-\pi^+\pi^-\pi^0$. A pointed out from a previous experiment (11), in which the energy dependence of the cross-section $\sigma(\pi^+\pi^-\pi^+\pi^-)$ around $\sqrt{s} = 1.6$ GeV has been studied, the two final states with four pions could be the main decay modes of a vector meson ϱ'', of mass $m_{\varrho''} \simeq 1.6$ GeV/c², full width $\Gamma_\varrho \simeq 350$ MeV.

From the partial cross-sections we deduce also the average multiplicity of charge pions $\langle n_c \rangle = 3.0 \pm 0.2$ and of charged-plus-neutral pions $\langle n_\pi \rangle = 4.2 \pm 0.2$. The results are in agreement with the data of the other experiments made at Adone (8,24).

From $\langle n_\pi \rangle$ we calculate the average momentum of the pion $\langle p_\pi \rangle = 337^{+24}_{-35}$ MeV/c in good agreement with $\langle p_\pi \rangle = 341 \pm 20$ MeV/c evaluated directly from the inclusive momentum distribution.

Considering the events with three and four detected particles and no gamma rays, which belong mainly to the reaction $e^+e^- \to \pi^+\pi^-\pi^+\pi^-$ we obtain for the invariant squared-mass the results plotted in fig. 7. In fig. 7 results obtained at $W = 1.6$ GeV are compared with similar results at 2.08 GeV; two mass distributions are plotted according to the charge of the $(\pi\pi)$-system: fig. 7*a*) and *b*) show at $W = 1.6$ the distribution of the squared-mass of neutral systems $m^2(\pi^+\pi^-)$ and charged systems $m^2(\pi^\pm\pi^\pm)$, respectively. Figure 7*c*) and *d*) show the same distributions at $W = 2.08$ GeV. In the figures the Monte Carlo previsions are also plotted; in fig. 7*a*) the normalization is made at the total number of events outside the $(0.58 < m^2 < 0.68)$ GeV² region. At

(24) C. BACCI, R. BALDINI-CELIO, G. CAPON, R. DEL FABBRO, M. GRILLI, E. IAROCCI, C. MENCUCCINI, G. P. MURTAS, G. PENSO, B. STELLA and V. VALENTE: Results presented at *XVIII High-Energy Physics Conference, Tbilisi, 1976.*

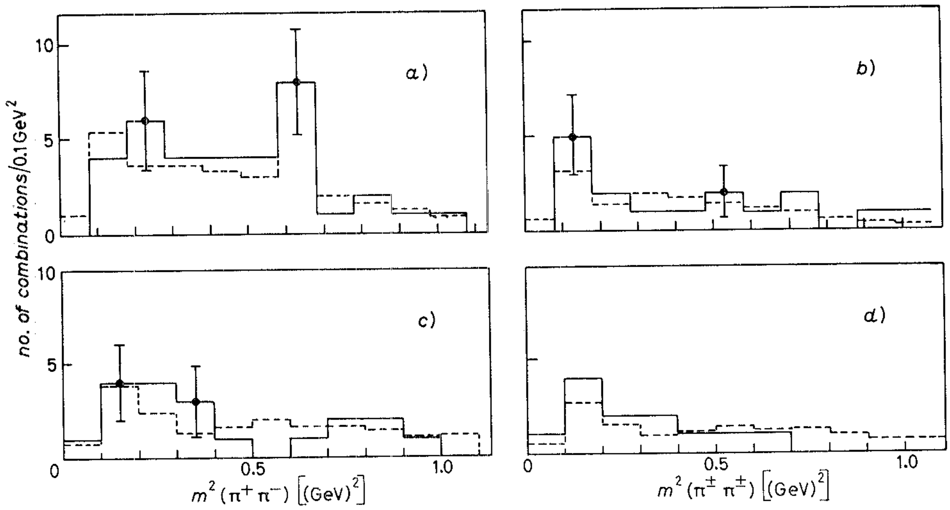

Fig. 7. – Two-pion invariant squared-mass distribution $M^2(\pi\pi)$, for the events with three or four detected charged particles and no gamma in the apparatus. *a*) $M^2(\pi^+\pi^-)$ distribution at $W = 1.6$ GeV for the $(\pi^+\pi^-)$ system (net charge equal to zero); *b*) $M^2(\pi^\pm\pi^\pm)$ distribution at $W = 1.6$ GeV for $(\pi^\pm\pi^\pm)$-system (net charge equal to $\pm$ 2); *c*) as *a*) at $W = 2.08$ GeV; *d*) as *b*) at $W = 2.08$ GeV. The dotted lines are the Monte Carlo previsions: the normalization in *a*) was made at the total number of events outside the ρ^0-mass–region.

$W = 1.6$ GeV an excess of combinations appears in the ϱ^0-mass–region of neutral-system distribution, which does not appear in the distribution of charged systems. The distributions 7*c*) and *d*) at $W = 2.08$ GeV are in agreement with the Monte Carlo previsions. This result, showing the possible presence of the final state $\rho^0\pi^+\pi^-$, is in agreement with the existence [12] at this energy of the process $e^+e^- \to \rho'' \to \rho^0\pi^+\pi^-$.

The main results of this analysis may be summarized as follows:

1) The multihadron total cross-section at $W = 1.6$ GeV is $\sigma_{tot} = (74 \pm 10)\cdot 10^{-33}$ cm². From σ_{tot} we deduce that:

$$R = \frac{\sigma_{tot}(e^+e^- \to \text{hadrons})}{\sigma(e^+e^- \to \mu^+\mu^-)} = 2.1 \pm 0.3 \, .$$

2) The average pion multiplicity is found to be $\langle n_\pi \rangle = 4.2 \pm 0.2$. The average momentum of the pion determined from the single-charged-pion momentum distribution and from the average pion multiplicity is found to be $\langle p_\pi \rangle = (0.340 \pm 0.025)$ GeV/c.

3) Even *G*-parity final states, which contribute for the 80% to the total cross-section, are made up mostly by four pions: $\sigma(\pi^+\pi^-\pi^0\pi^0) + \sigma(\pi^+\pi^-\pi^+\pi^-) \sim 0.7\sigma_{tot}$.

4) The invariant squared-mass distribution of the $(\pi^+\pi^-)$-system suggests that the $(\rho^0\pi^+\pi^-)$-state is produced abundantly.