ISTITUTO NAZIONALE DI FISICA NUCLEARE
Laboratori Nazionali di Frascati

LNF-80/49

B. Esposito et al. :
STUDY OF $(\pi^+\pi^-\pi^+\pi^-)$ AND $(\pi^+\pi^-\pi^0)$ CHANNEL IN e^+e^- ANNIHILATION AT (1.450-1.875) GeV C.M. ENERGY

Estratto da :
Lett. Nuovo Cimento 28, 195 (1980)

Servizio Documentazione
dei Laboratori Nazionali di Frascati
Cas. Postale 13 - Frascati (Roma)

LETTERE AL NUOVO CIMENTO VOL. 28, N. 6 7 Giugno 1980

Study of $(\pi^+\pi^-\pi^+\pi^-)$ and $(\pi^+\pi^-\pi^0)$ Channel in e^+e^- Annihilation at $(1.450 \div 1.875)$ GeV c.m. Energy.

B. ESPOSITO, A. MARINI and F. RONGA

Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali di Frascati - Frascati, Italia

P. PATTERI

Istituto Nazionale di Fisica Nucleare - Sezione di Napoli, Italia

M. NIGRO and L. PESCARA

Istituto di Fisica dell'Università - Padova
Istituto Nazionale di Fisica Nucleare - Sezione di Padova, Italia

R. BERNABEI, S. D'ANGELO, P. MONACELLI, M. MORICCA, L. PAOLUZI
R. SANTONICO and F. SEBASTIANI

Istituto di Fisica dell'Università - Roma
Istituto Nazionale di Fisica Nucleare - Sezione di Roma, Italia

(ricevuto il 7 Febbraio 1980)

We present final results for the total cross-section of the reactions

(1) $$e^+e^- \to \pi^+\pi^-\pi^0 ,$$

(2) $$e^+e^- \to \pi^+\pi^-\pi^+\pi^- ,$$

for total c.m. energy ranging from 1.45 to 1.875 GeV. The experiment has been performed at Adone, the Frascati e^+e^- storage ring, by using the MEA magnetic detector (fig. 1)(1). In the investigated energy region a ρ-like behaviour around 1.55 GeV has been observed

(1) W. W. ASH, D. C. CHENG, B. ESPOSITO, F. FELICETTI, A. MARINI, H. OGREN, I. PERUZZI, M. PICCOLO, F. RONGA, G. SACERDOTI, L. TRASATTI, G. T. ZORN, B. BARTOLI, B. COLUZZI, A. NIGRO, V. SILVESTRINI, F. VANOLI, D. BISELLO, A. MULACHIÈ, M. NIGRO, L. PESCARA, R. SANTANGELO, E. SCHIAVUTA, D. SCANNICCHIO, P. MONACELLI, L. PAOLUZI, G. PIANO-MORTARI, F. SEBASTIANI: *Nucl. Instrum. Methods*, **143**, 431 (1978).

TABLE I. – *MEA detector main characteristics.*

Magnetic field	2.0k Gauss, perpendicular to e^+e^- beams.
Solid angle acceptance	$\Delta\Omega_c = 0.33 \times 4\pi$ sr, for triggering and for momentum analysis at beam energies $E_e = 0.75$ GeV. $\Delta\Omega_N = 0.27 \times 4\pi$ sr, for particle identification (γ-rays conversion, nuclear interaction, range).
Trigger requirements	at least one particle on one side of the apparatus (with a kinetic energy $T_\pi > 110$ if pion) and another on the opposite part (with $T_\pi > 130$ MeV).
Single-track momentum resolution	$\Delta p/p = 0.05$ at 500 MeV/c (corresponding angular resolution $\Delta\varphi = 1.2°$ and $\Delta\theta = 0.08°$).

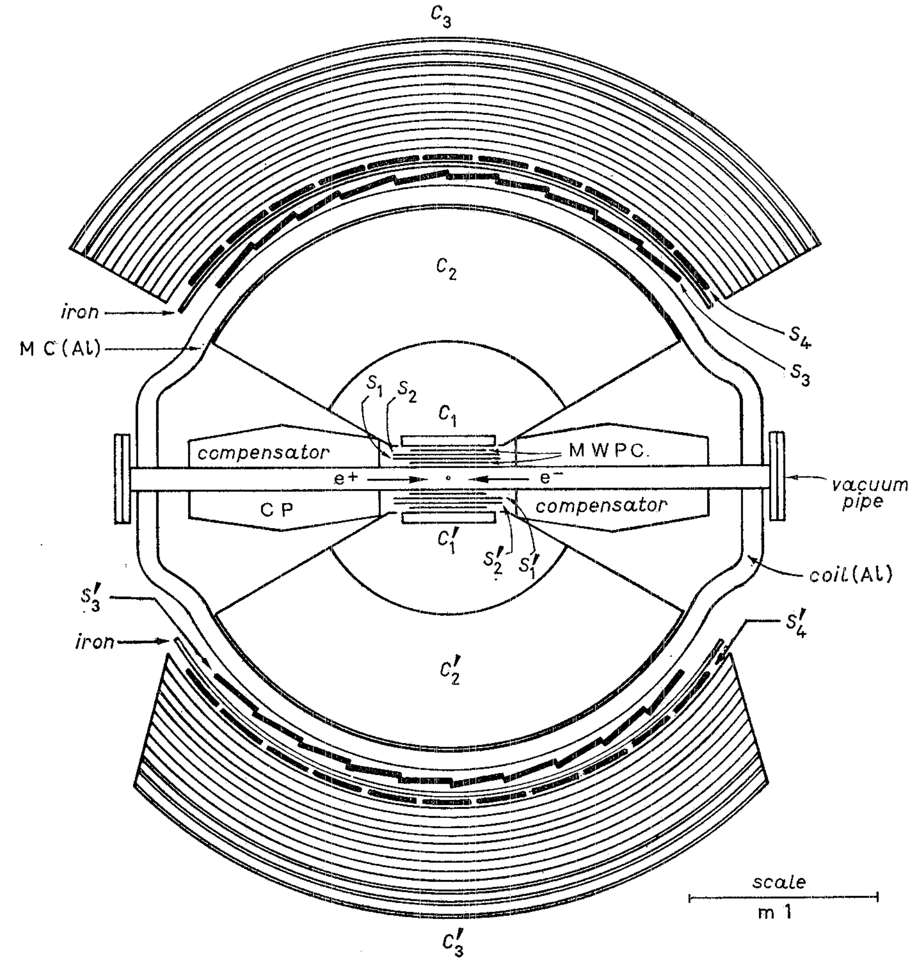

Fig. 1. – Vertical section of the experimental apparatus: C_1C_1' are narrow-gap spark chambers; C_2C_2' wide-gap cylindrical spark chambers for momentum analysis; C_3C_3' thick-plate spark chambers for particle identification; MWPC multiwire proportional chambers; $S_1, S_2, \dots, S_4'$ scintillation counters.

for reaction (2) [2-5] and an ω-like behaviour for the reaction (1) [5]. The study of the final-state correlations for reaction (2), made with an integrated luminosity greater than in our previous paper [4,6], confirms the existence of the process

$$e^+e^- \to \rho'' \to \rho^0\pi^+\pi^- \to \pi^+\pi^-\pi^+\pi^- . \tag{3}$$

The results relative to reaction (1) are in agreement with the results obtained in Orsay [5].

The main characteristics of the MEA apparatus described in detail elsewhere [1], are summarized in table I together with the trigger requirements.

The multiparticle events were selected by requiring at least two charged tracks. The following criteria were applied in the selection [4,6]: the noncoplanarity angle of the track pair and the e^+e^- beams and the noncolinearity angle of the track pair were required to be $>10°$; the reconstructed vertex point of the event should originate in the e^+e^- interaction region and the timing was required to correspond to the bunch-bunch collision time.

All the results are referred to a total integrated luminosity $L = 168\ \text{nb}^{-1}$, as measured collecting the wide-angle Bhabha scattering events in the apparatus.

Events with three (3T) and four (4T) detected tracks and no gamma-rays, belong mainly to reaction (2).

From the squared-missing-mass (M_m^2) distribution, which contains 142 3T events and 22 4T events we selected 92 3T-reconstructed, net charge ± 1, and 13 4T-reconstructed, net charge zero, events, as candidates for reaction (2). Nine of the 3T events have the direction of the missing track inside the apparatus; therefore they have been rejected as coming from $(\pi^+\pi^-\pi^+\pi^-\pi^0)$ or $(\pi^+\pi^-\pi^+\pi^-\pi^0\pi^0)$ channels. This value agrees with the one estimated with a Monte Carlo program, used to simulate the experiment and then to calculate also the efficiencies for all exclusive reactions in the different detected configurations.

From these data we calculated the total cross-section given in table II and reported in fig. 2, together with those already published [3,6-11]. Our data are in agreement with the results of the other experiments in the same energy region interval.

---

(2) M. GRILLI, E. IAROCCI, P. SPILLANTINI, V. VALENTE, R. VISENTIN, B. BORGIA, F. CERADINI, M. CONVERSI, L. PAOLUZI, R. SANTONICO, M. NIGRO, L. TRASATTI and G. T. ZORN: *Nuovo Cimento A*, **13**, 593 (1973).

(3) F. CERADINI, M. CONVERSI, S. D'ANGELO, L. PAOLUZI, R. SANTONICO, K. EKSTRAND, M. GRILLI, E. IAROCCI, P. SPILLANTINI, V. VALENTE, R. VISENTIN and M. NIGRO: *Phys. Lett. B*, **43**, 341 (1973).

(4) B. ESPOSITO, A. MARINI, M. PALLOTTA, G. PIANO-MORTARI, F. RONGA, B. SECHI-ZORN, G. T. ZORN, M. NIGRO, L. PESCARA, R. BERNABEI, S. D'ANGELO, P. MONACELLI, M. MORICCA, L. PAOLUZI, R. SANTONICO and F. SEBASTIANI: *Lett. Nuovo Cimento*, **25**, 5 (1979).

(5) C. COSME, B. DUDELZAK, B. GRELAND, B. JEAN-MARIE, S. JULLIAN, D. LA JANNE, F. LAPLANCHE, V. LEPELTIER, G. PARROUR, C. PAULOT, S. PROTOPOPESCU, R. RISKALLA, PH. RAY and G. SZKLARZ: *Nucl. Phys. B*, **152**, 215 (1979).

(6) B. ESPOSITO, F. FELICETTI, A. MARINI, I. PERUZZI, M. PICCOLO, F. RONGA, A. NIGRO, D. BISELLO, M. NIGRO, L. PESCARA, P. SARTORI, R. BERNABEI, S. D'ANGELO, P. MONACELLI, L. PAOLUZI, G. PIANO-MORTARI, A. SCIUBBA and F. SEBASTIANI: *Lett. Nuovo Cimento*, **19**, 21 (1977).

(7) V. A. SIDOROV: presented at the *1979 International Symposium on Lepton and Photon Interactions at High Energies, Batavia, 1979.*

(8) M. SPINETTI: presented at the *1979 International Symposium on Lepton and Photon Interactions at High Energies, Batavia, 1979.*

(9) A. CORDIER, B. DELCOURT, P. ESCHSTRUTH, F. FULDA, G. GROSDIDIER, J. JEANJEAN, M. JEANJEAN, R. J. MADARAS, J. L. MASNOU, J. PEREZ-Y-JORBA, A. QUENZER, M. RIBES, F. RUMPF, J. L. BERTRAND and J. C. BIZOT: *Phys. Lett. B*, **81**, 389 (1979).

(10) B. DELCOURT: presented at the *1979 International Symposium on Lepton and Photon Interactions at High Energies, Batavia, 1979.*

(11) R. F. SCHWITTERS: *Proceedings of the 1975 International Symposium on Lepton and Photon Interactions* (Stanford, Cal., 1975).

TABLE II. – $\pi^+\pi^-\pi^+\pi^-$ *cross-section.*

W (GeV)	$\sigma(\pi^+\pi^-\pi^+\pi^-)$ (nb)
1.475	22.6 ± 3.2
1.525	21.5 ± 3.6
1.600	20.8 ± 4.4
1.770	10.7 ± 1.7

The same events originate the Dalitz plot shown in fig. 3: the invariant mass of a neutral pion pair $m\ (\pi_1\pi_2)$ is plotted *vs.* the invariant mass $m\ (\pi_3\pi_4)$ of the other neutral pion pair. In fig. 3 the Monte Carlo previsions in a pure invariant-phase-space (IPS)

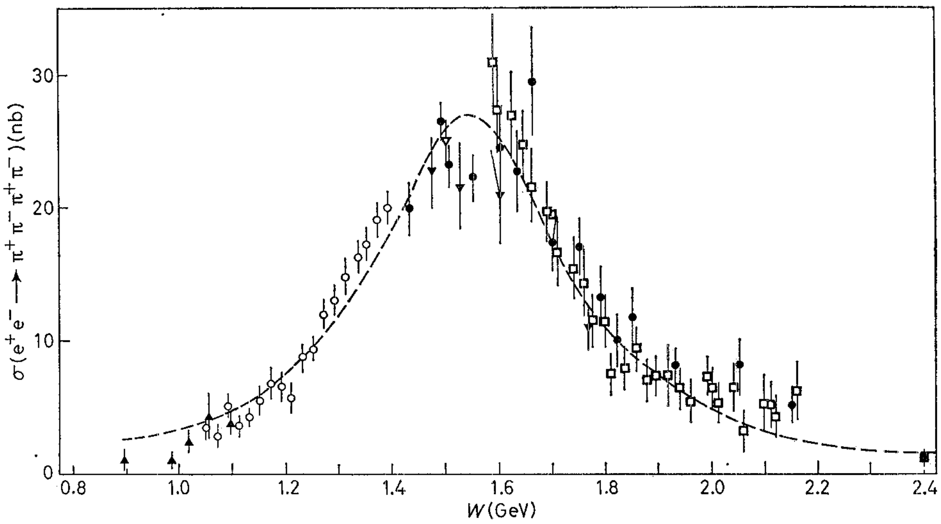

Fig. 2. – Total cross-section $\sigma(e^+e^- \to \pi^+\pi^-\pi^+\pi^-)$ *vs.* the total energy W. The dashed line represents the Breit-Wigner best fit of all the data, with $M = (1546 \pm 3)$ MeV and $\Gamma = (426 \pm 5)$ MeV (χ^2/d.o.f. = 138/70). ▲ ACO-DM 1, ○ VEPP2M-OLYA, ● ADONE-$\gamma\gamma$2, □ DCI-DM1, ■ SPEAR-MARK1, ▽ ADONE-MEA 79, ▼ this experiment.

momentum distribution hypothesis and in the ($\rho^0\pi^+\pi^-$) intermediate-state hypothesis, reaction (3), are also reported. The results for the energy interval $(1.45 \div 1.7)$ GeV, fig. 3*a*), are clearly better in agreement (χ^2/d.o.f. = 2.2/3) with reaction (3); the IPS-hypothesis (χ^2/d.o.f. = 29/3) cannot be accepted. This result is supported by fig. 3*b*), relative to the off-resonant energy interval $(1.7 \div 1.875)$ GeV: the IPS, (χ^2/d.o.f. = = 2.6/2) and ($\rho^0\pi^+\pi^-$) (χ^2/d.o.f. = 1.8/2) production mechanisms cannot be statistically distinguished.

Twenty-one events, kinematically reconstructed as coming from reaction (1), have been identified in order to investigate the ω-like behaviour around 1.654 GeV, observed at ORSAY (5). In table III and in fig. 4 the corresponding calculated cross-section values are given. In fig. 4 the value at 1.5 GeV, already published (4), is also reported. A straight-

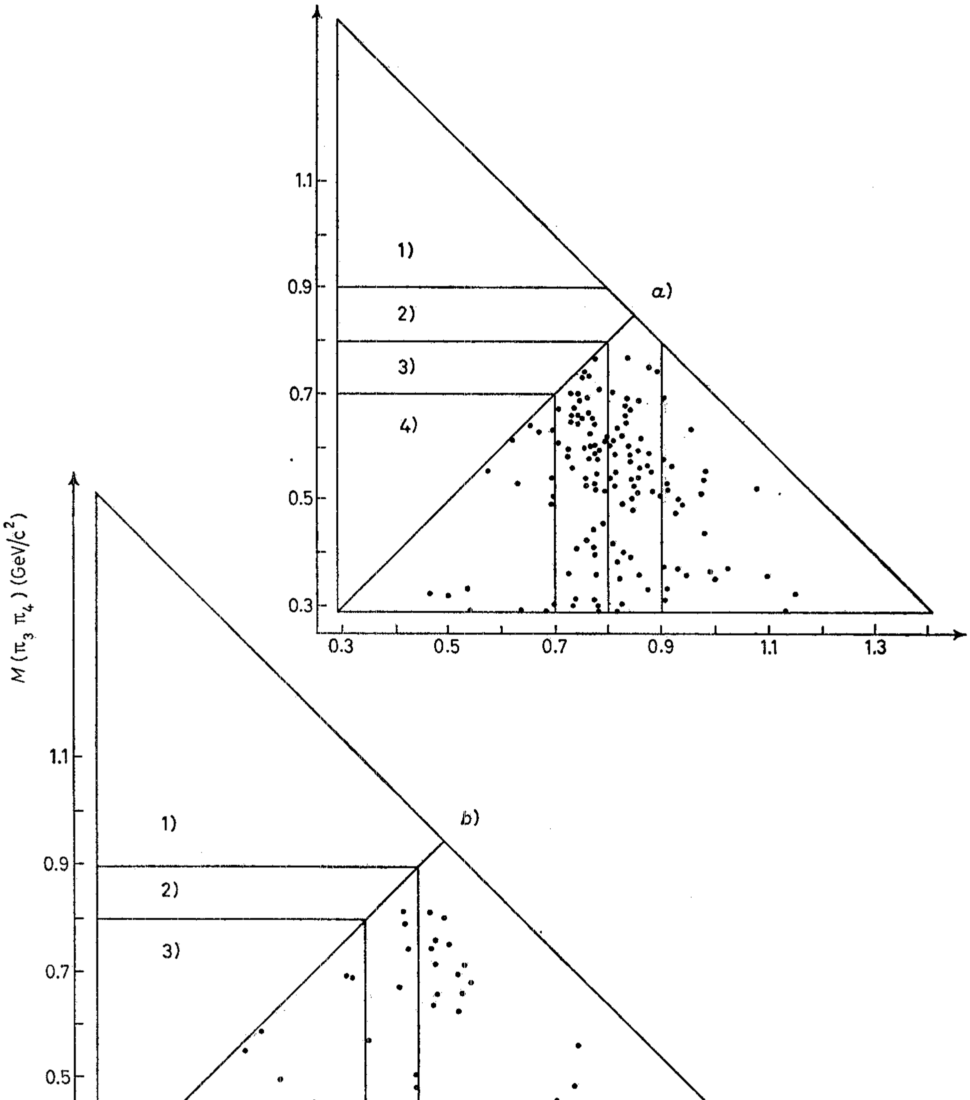

Fig. 3. – Two-pion invariant-mass scatter plot for the events with three or four detected charged particles and no gamma in the apparatus: *a*) $M(\pi_1\pi_2)$ for the $(\pi_1\pi_2)$ system (net charge equal to zero) *vs.* $M(\pi_3\pi_4)$ of remaining neutral pair in the energy interval $(1.45 \div 1.7)$ GeV: 1) IPS $= 0.34$, $\rho^0\pi^+\pi^- = 0.19$, exp. $= 0.18$; 2) IPS $= 0.22$, $\rho^0\pi^+\pi^- = 0.30$, exp. $= 0.32$; 3) IPS $= 0.20$, $\rho^0\pi^+\pi^- = 0.35$, exp. $= 0.38$; 4) IPS $= 0.24$, $\rho^0\pi^+\pi^- = 0.16$, exp. $= 0.12$. *b*) as *a*) $(1.7 \div 1.875)$ GeV: 1) IPS $= 0.43$, $\rho^0\pi^+\pi^- = 0.42$, exp. $= 0.45$; 2) IPS $= 0.20$, $\rho^0\pi^+\pi^- = 0.27$, exp. $= 0.25$; 3) IPS $= 0.37$, $\rho^0\pi^+\pi^- = 0.31$, exp. $= 0.30$.

TABLE III. – $\pi^+\pi^-\pi^0$ *cross-section.*

W (GeV)	$\sigma(\pi^+\pi^-\pi^0)$ (nb)
1.488	4.5 ± 2.0
1.550	4.6 ± 4.6
1.613	6.3 ± 4.4
1.675	14.0 ± 6.0
1.738	8.1 ± 4.1
1.788	6.0 ± 4.3
1.838	2.0 ± 1.4

line best fit of all the data (χ^2/d.o.f. = 7/7) gives a result worse than that of a Breit-Wigner plus a constant background best fit (χ^2/d.o.f. = 1.8/4), with $M = (1.679 \pm 34)$ MeV

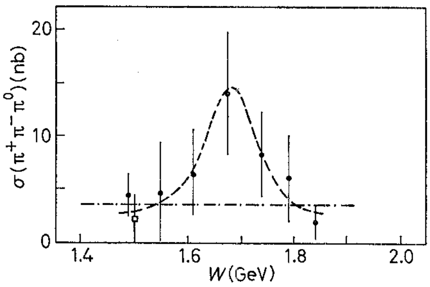

Fig. 4. – Total cross-section $\sigma(e^+e^- \rightarrow \pi^+\pi^-\pi^0)$ *vs.* the total energy W. The dotted line represents the straigth-line best fit (χ^2/d.o.f. = 7/7) and the dashed one the Breit-Wigner plus a constant background best fit, with $M = (1679 \pm 34)$ MeV and $\Gamma = (99 \pm 49$ MeV) (χ^2/d.o.f. = 1.8/4). ▫ Adone MEA '79, • this experiment.

and $\Gamma = (99 \pm 49)$ MeV. Although the results are consistent with Orsay-results [5], they are not sufficient alone to give a statistically significant evidence for an ω-like behaviour.