

## Angular Distribution of $\mu^+\mu^-$ Pairs in the Reaction $e^+e^- \rightarrow \mu^+\mu^-$ at the $J/\psi$ Energy.

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We report new experimental results obtained at Adone by the MEA Group on the  $J/\psi(3100)$  decay into muon pairs. The statistics has been increased by a factor  $\sim 3$  with respect to previous data <sup>(1)</sup>, and an accurate study of possible energy-dependent effects in the angular distribution has been performed. The Magnet Group experimental set up (fig. 1) is described in detail in ref. <sup>(2)</sup>. The trigger for collinear events is given by the coincidence of counters  $(S_1 \cdot S_2 \cdot S_3 \cdot S_4) \cdot (S'_1 \cdot S'_2 \cdot S'_3 \cdot S'_4)$  and of the multiwire proportional chambers (MWPC,  $2 \times 2$  planes of wires parallel to the beam direction above and below the vacuum chamber). The MWPC provide a fast selection on the radial position of the source with  $\sim \pm 5$  cm acceptance. The trigger requires also a correct timing of the event with respect to the crossing of the  $e^+e^-$  bunches and the correct

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<sup>(2)</sup> W. W. ASH, D. C. CHENG, B. ESPOSITO, F. FELICETTI, H. OGREN, I. PERUZZI, M. PICCOLO, F. RONGA, G. SCHINA, G. T. ZORN, B. BARTOLI, B. COLUZZI, E. CUOMO, A. NIGRO, V. SILVESTRINI, F. VANOLI, D. BISELLO, A. MULAGHÉ, M. NIGRO, L. PESCARA, E. SCHIAVUTA, A. MARINI, P. MONACELLI, L. PAOLUZI, G. PIANO MORTARI, F. SEBASTIANI and L. TRASATTI: *Lett. Nuovo Cimento*, **11**, 705 (1974).

time of flight in the upper part of the apparatus (between  $S_1 \cdot S_2$  and  $S_3$ ). Collinear events which trigger the apparatus and show no interaction in the thick-plate spark chambers ( $C_3$  and  $C'_3$ ) are  $\mu^+\mu^-$  candidates.

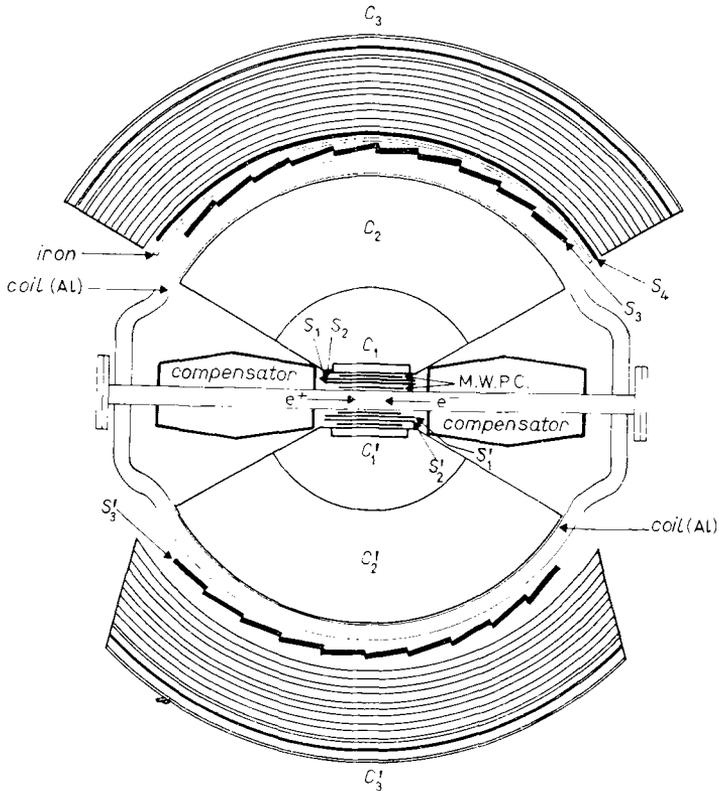


Fig. 1. - Vertical section of the experimental apparatus.  $C_1, C'_1$  are narrow-gap spark chambers;  $C_2, C'_2$  are wide-gap cylindrical spark chambers for momentum analysis;  $C_3, C'_3$  are thick-plate spark chambers for particle identification. MWPC are multiwire proportional chambers;  $S_1, \dots, S_4$  are scintillation counters.

In order to minimize the cosmic-ray contamination in the collected events, further cuts have been imposed off-line on:

- 1) momentum of the particle,
- 2) time of flight,
- 3) radial position of the source.

A first  $\sim 30\%$  reduction on cosmic-ray contamination has been achieved by measuring the sagitta of the tracks directly on the scanning table. For each event the times of flight between  $S_1 \cdot S_2$  and  $S_3, S'_1 \cdot S'_2$  and  $S'_3$ , and of the trigger with respect to the RF signal were recorded on magnetic tape. The radial position of the source was reconstructed using the data from the MWPC.

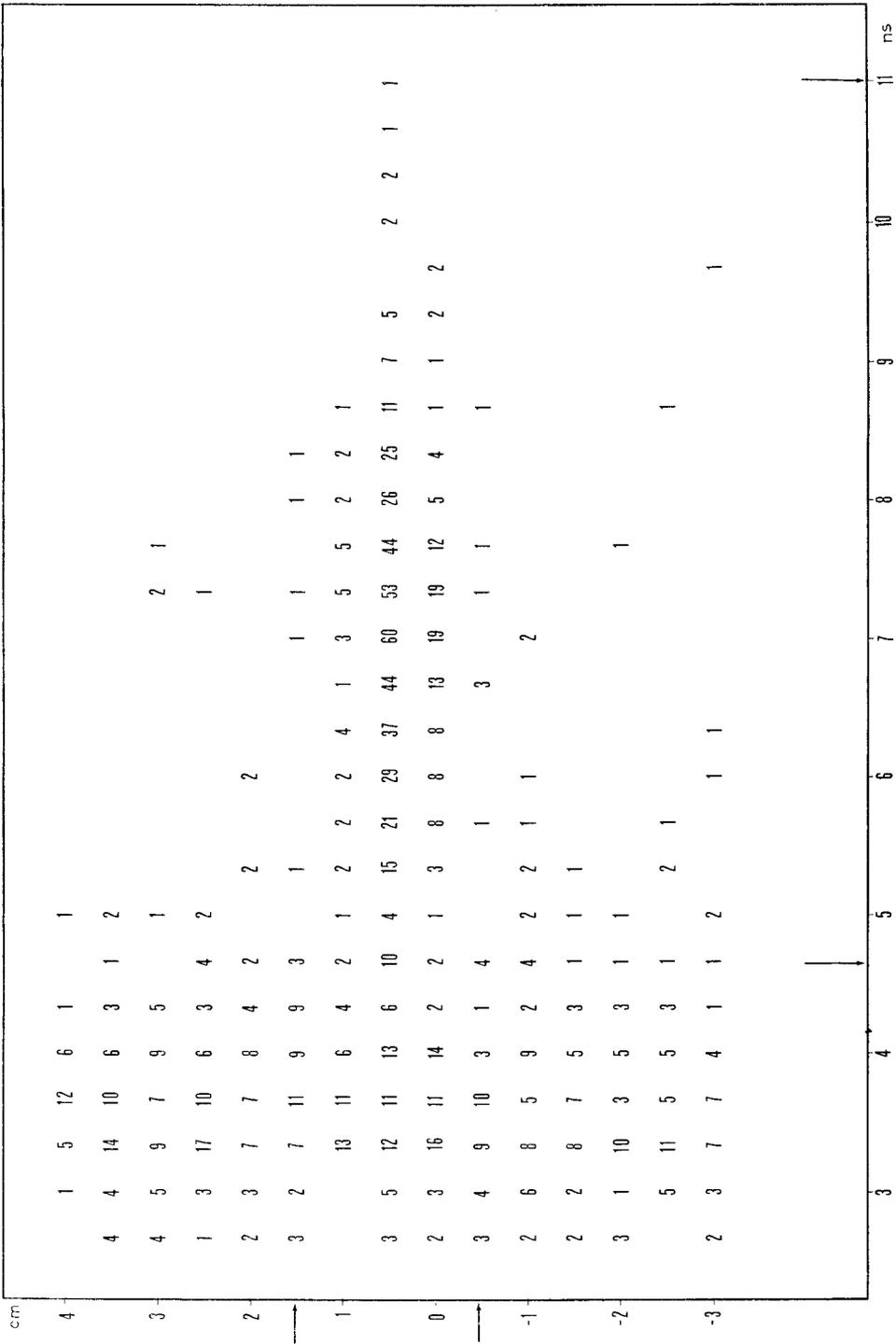


Fig. 2. - Time of flight vs. radial-source correlated spectrum of collinear not-showering events. Origin of time of flight corresponds to the cosmic-ray peak. The arrows indicate the cuts on the source radial position and on the time of flight.

A time of flight and radial source correlated spectrum is shown in fig. 2. Cuts have been chosen on this spectrum such as to reduce cosmic-ray contamination while keeping the loss of events within acceptable limits.

The forward-backward asymmetry is defined as  $A = (F - B)/(F + B)$ , where  $F$  is the number of events with  $\cos \theta > 0$  and  $B$  is the number of events with  $\cos \theta < 0$ , and  $\theta$  is the angle between the directions of the outgoing  $\mu^+$  and the incoming  $e^+$ .

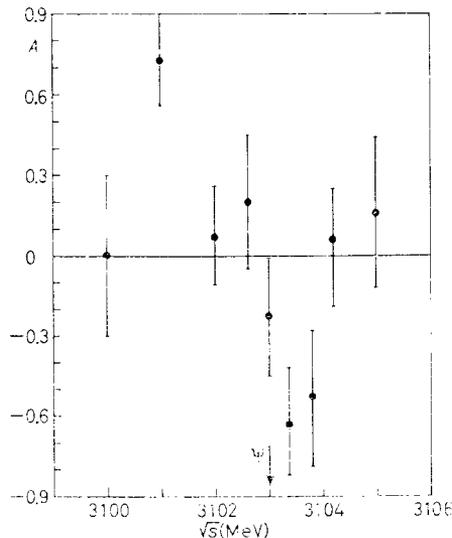


Fig. 3.  $\mu^+\mu^-$  pair production forward-backward asymmetry vs. c.m. energy in the  $J/\psi$  mass region as obtained in a first set of 149 events.

A first set of data<sup>(3,4)</sup> obtained at the beginning of the experiment concerning 149 identified  $\mu^+\mu^-$  pairs gave the result for the asymmetry parameter as a function of energy, which is shown in fig. 3. From these data one gets for the hypothesis of constant zero asymmetry  $\chi^2 = 20$  with 9 degrees of freedom (confidence level  $\sim 2\%$ ). This could raise the suspicion of an energy dependence of the asymmetry parameter. However, the overall asymmetry averaged over the energy range

$$M_{J/\psi} - 5 \text{ MeV} \leq \sqrt{s} < M_{J/\psi} + 5 \text{ MeV}$$

was  $A = -0.03 \pm 0.09$ , and the angular distribution of the sample was consistent with a  $(1 + \cos^2 \theta)$ -dependence<sup>(4)</sup>. No systematic error due to the apparatus was found in order to explain the apparent energy-dependent asymmetry. In particular we have checked that a strong energy-dependent behaviour cannot be explained with some possible asymmetry in the detection efficiency.

(3) B. BARTOLI, D. BISELLO, B. ESPOSITO, F. FELICETTI, P. MONACELLI, M. NIGRO, L. PAOLUZI, I. PERUZZI, G. PIANO MORTARI, M. PICCOLO, F. RONGA, S. SEBASTIANI, L. TRASATTI and F. VANOLI: Frascati Report LNF-74/64(P) (1974).

(4) G. PENSO and M. PICCOLO: Frascati Report LNF-75/15(P) (1975).

A new set of data with the beams of Adone reversed has been collected in order to increase statistics and verify the possible anomalous behaviour of the asymmetry of the previous data.

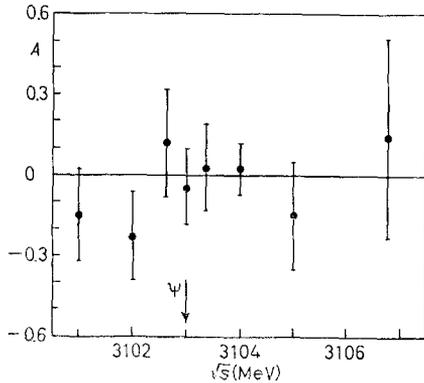


Fig. 4.

Fig. 4. - Forward-backward asymmetry for the new set of 348  $\mu^+\mu^-$ -events vs. c.m. energy in the  $J/\psi$  mass region.

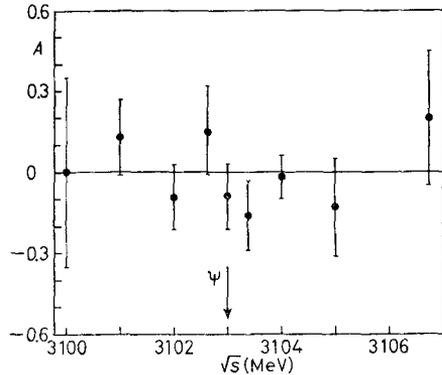


Fig. 5.

Fig. 5. - Forward-backward asymmetry vs. c.m. energy obtained by the whole sample of 497 events.

The total number of  $\mu^+\mu^-$  events in the new set of data was 455 with a cosmic-ray contamination of  $(2.6 \pm 0.7)\%$ . This sample has been subdivided in 8 energy intervals. For the majority of the events (348) it was possible to check the absolute energy

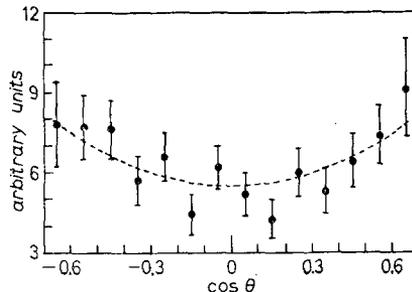


Fig. 6. - Overall angular distribution of the  $\mu^+\mu^-$ -events obtained in the energy region  $\sqrt{s} = (3098 \div 3108)$  MeV. Data are corrected for detection efficiency.  $\theta$  is the angle between the outgoing  $\mu^+$  and the incoming  $e^+$ . The dashed line represents the  $(1 + \cos^2 \theta)$ -distribution.

calibration by looking at the hadronic peak of the  $J/\psi$  obtained in the same runs. In fig. 4 the forward-backward asymmetry vs. the total c.m. energy is shown for these data and it is consistent with the hypothesis of constant zero asymmetry ( $\chi^2 = 4$  with 8 degrees of freedom, confidence level  $\sim 92\%$ ).

By adding the new and old sets of data we obtain the forward-backward asymmetry distribution shown in fig. 5 ( $\chi^2 = 5.4$  with 9 degrees of freedom, 80% confi-

dence level for constant zero asymmetry). The total asymmetry, averaged over the whole energy range is

$$A = -0.03 \pm 0.05 .$$

The overall angular distribution of new and old data is shown in fig. 6. Data are fitted with a  $(1 + \cos^2 \theta)$ -distribution ( $\chi^2 = 10.6$  with 13 degrees of freedom, c.l. = 61%).

We conclude that, within the above quoted statistical errors, the asymmetry parameter is constant and zero in the  $J/\psi$ -energy region.

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