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9 Giugno 1976

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M. E. Biagini[(x)], D. Bisello[(o)], B. Esposito, F. Felicetti, A. Marini, P. Monacelli[(x)], A. Nigro[(+)], M. Nigro[(o)], L. Paoluzi[(x)], I. Peruzzi, G. Piano Mortari[(x)], M. Piccolo, F. Ronga, A. Sciubba[(x)], F. Sebastiani[(x)] and F. Vanoli[(+)]: ANGULAR DISTRIBUTION OF $\mu^+\mu^-$ PAIRS IN THE REACTION $e^+e^- \to \mu^+\mu^-$ AT THE J/ψ ENERGY.

ABSTRACT. -

New data at the reaction $e^+e^- \to \mu^+\mu^-$ has been collected at Adone using the MEA apparatus in the J/ψ energy region. The angular distribution of the $\mu^+\mu^-$ pairs was studied as a function of the c.m. energy; no significant forward-backward asymmetry has been observed.

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We report new experimental results obtained at Adone by the MEA Group on the J/ψ (3100) decay into muon pairs. The statistics has been increased by a factor ~ 3 with respect to previous data[1], 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. (2). 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 x 2 planes of wires parallel to the beam direction above and below the vacuum chamber). The MWPC give an "on line" selection

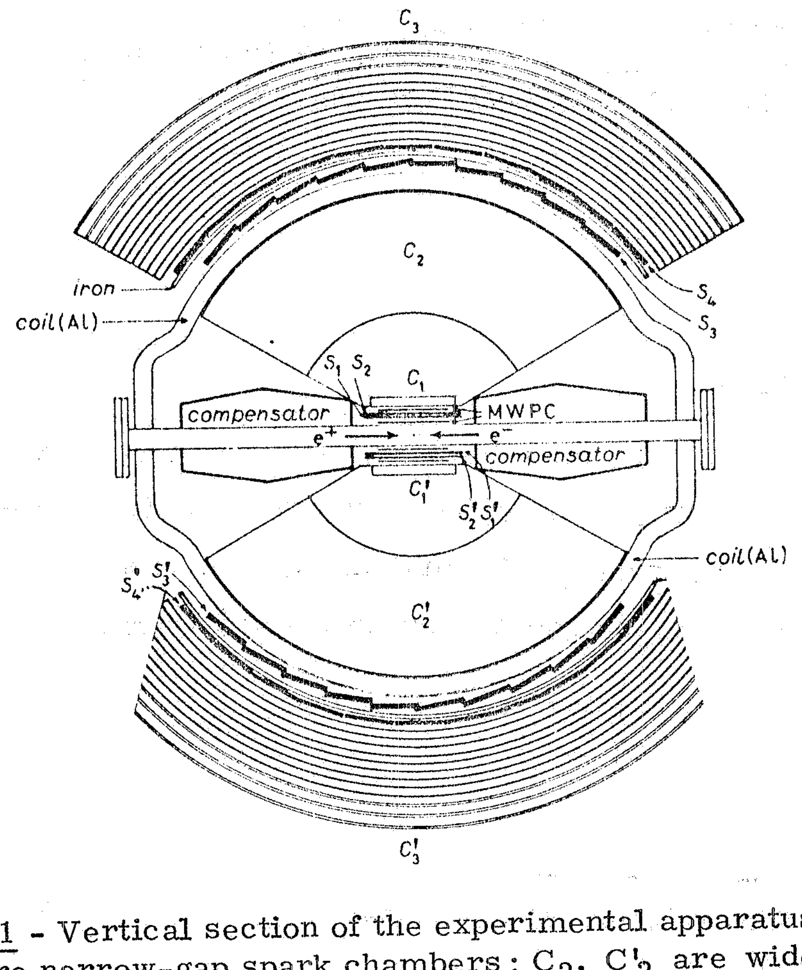

FIG. 1 - Vertical section of the experimental apparatus. C_1, C'_1 are narrow-gap spark chambers ; C_2, C'_2 are wide-gap cylindrical spark chambers for momentum analysis ; C_3, C'_3 are thick plate spark chambers for particle identification. MWPC are multiwire proportional chambers ; S_1, ..., S_4 are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

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 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.

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

1) Momentum of the particles;

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.

A time of flight and radial source correlated spectrum is shown in Fig. 2. Cuts have been choosen on these spectra such as to reduce cosmic ray contamination while keeping the loss of events within acceptable limits. The time of flight spectrum for the events with proper source position is shown in Fig. 3. The radial source distribution for events with proper time of flight is shown in Fig. 4.

A first set of data 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. 5.

The forward-backward asymmetry is defined as $A = \frac{F - B}{F + B}$, where F is the number of events with $\cos\theta > 0$ and B is the number of events with $\cos\theta < 0$, and θ is the angle between the directions of the outcoming μ^+ and the incoming e^+. From these data one gets for the hypothesis of constant zero asymmetry

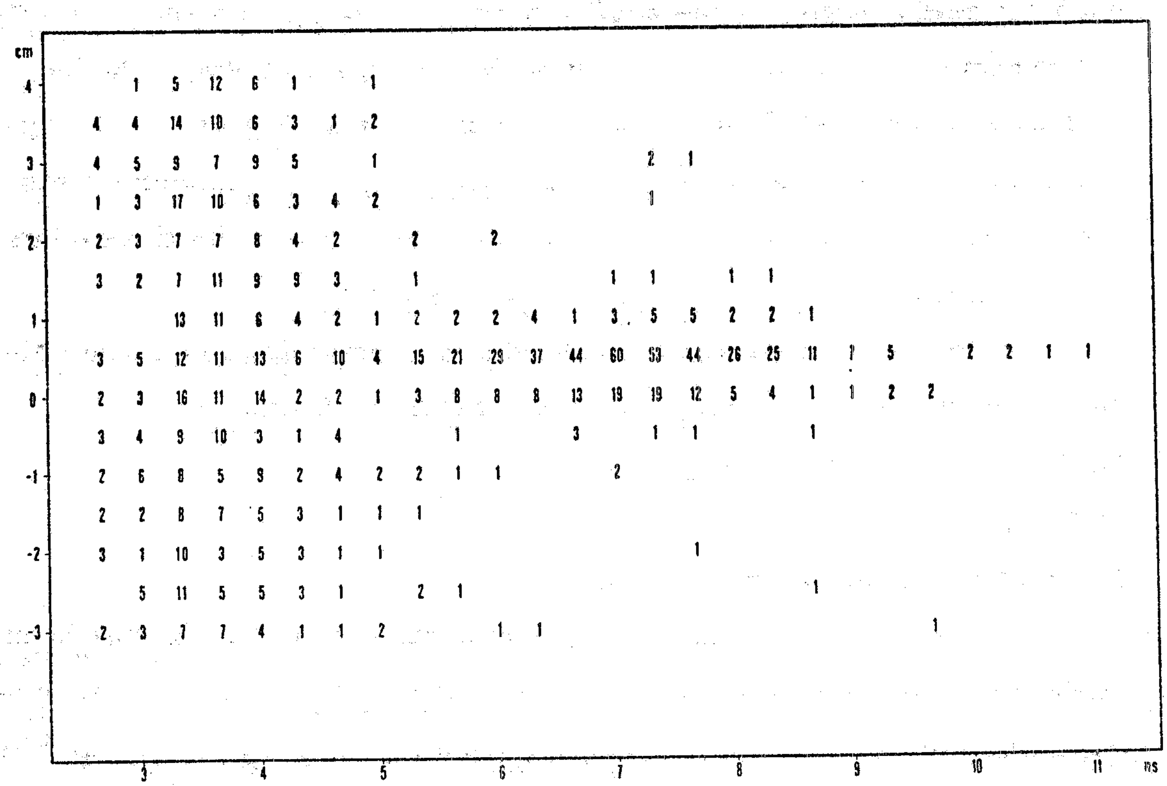

FIG. 2 - Time of flight versus radial source correlated spectrum of collinear not-showering events. Origin of time of flight corresponds to cosmic ray peak.

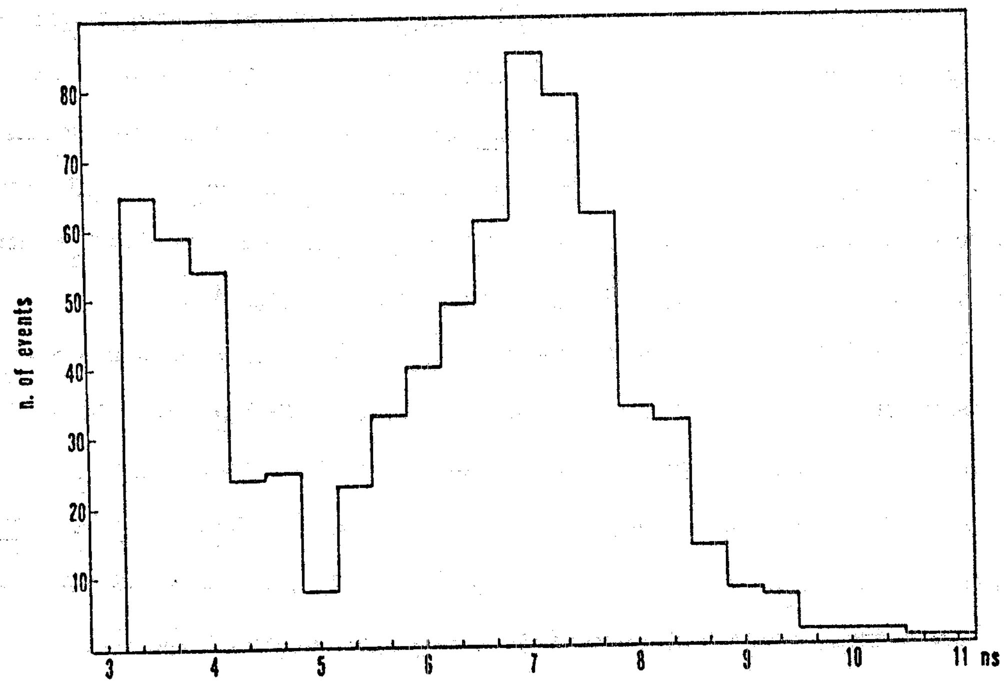

FIG. 3 - Time of flight spectrum for "in source" collinear events (accepted radial source : - 0.4 ÷ +1.4 cm ; the origin is arbitrary).

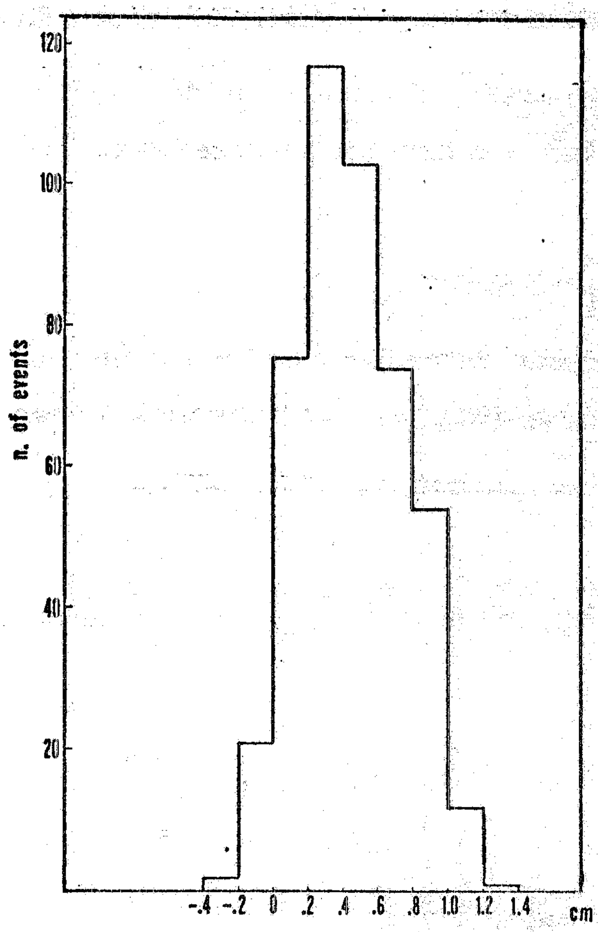

FIG. 4 - Radial source spectrum for collinear events with proper time of flight (distance from cosmic ray peak 4.6 ns). Events with radial source > 1.4 cm or < - 0.4 cm (origin is arbitrary) have been rejected.

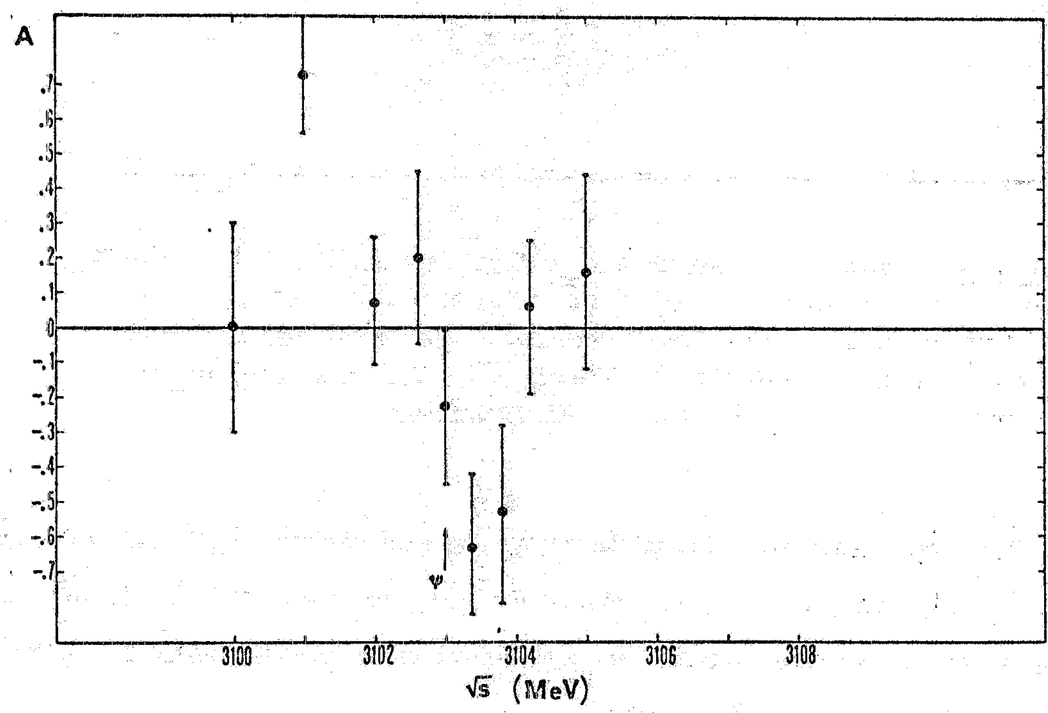

FIG. 5 - $\mu^+\mu^-$ pair production forward-backward asymmetry versus c.m. energy in the J/ψ mass region as obtained in a first set of 149 events.

$\chi^2 = 20$ with 9 degrees of freedom (confidence level $\sim 2\%$).

This could raise the suspicion of an energy dependence in the asymmetry parameter. However, the overall asymmetry averaged over the energy range :

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

was $A = -0.03 \pm 0.09$, and the angular distribution of the sample was consistent with a $1+\cos^2\theta$ dependence (Fig. 6). No sistematic error

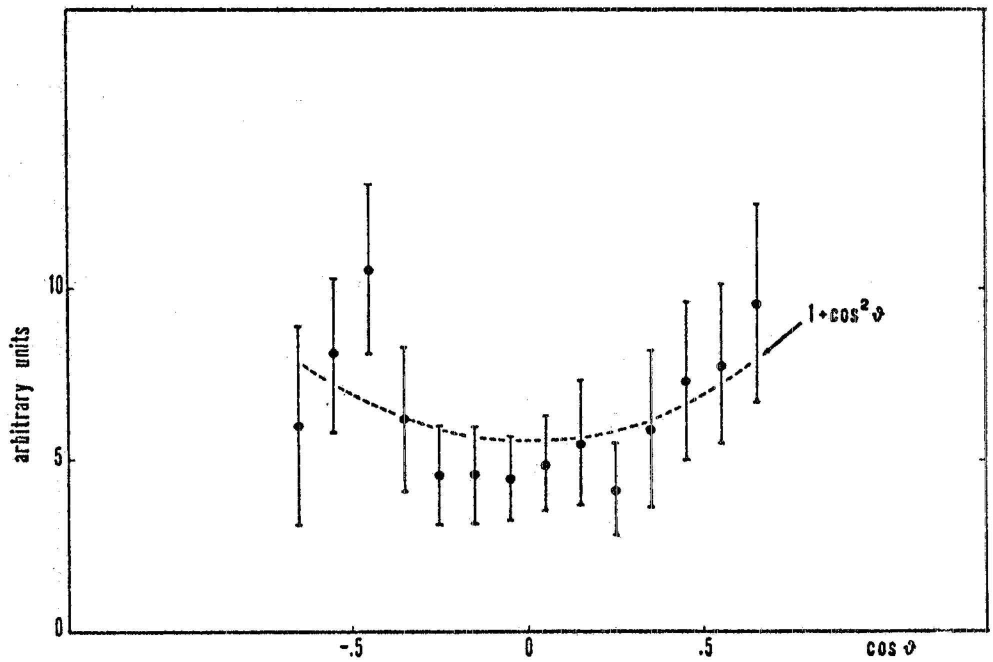

FIG. 6 - Angular distribution of a first set of 149 $\mu^+\mu^-$ events obtained in the energy region $\sqrt{s}$ = (3098 - 3108) MeV. Data are corrected for detection efficiency. θ is the angle between the outcoming μ^+ and the incoming e^+. The dashed line represents the $1+\cos^2\theta$ angular distribution.

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.

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.

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 energy intervals. For the majority of the events, it was possible to check the absolute energy calibration by looking at the hadronic peak of the J/ψ obtained in the same runs. In Fig. 7 the forward-backward asymmetry versus the total c.m. energy is shown for

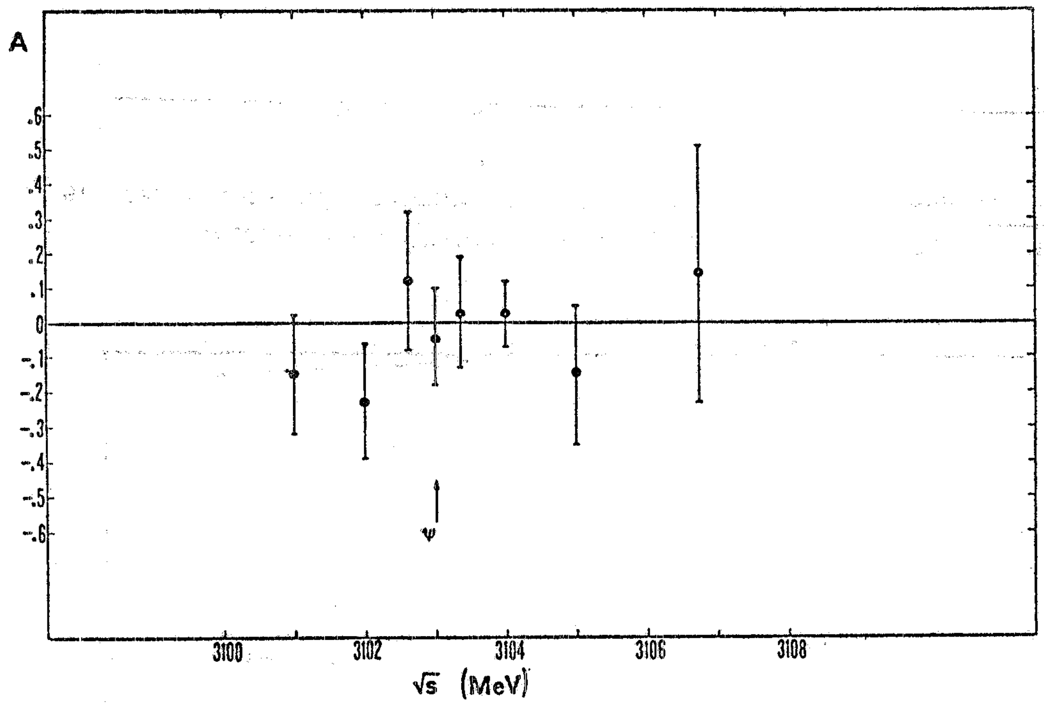

FIG. 7 - Forward-backward asymmetry for the new set of 348 $\mu^+\mu^-$ events versus c.m. energy in the J/ψ mass region.

these data. The hypothesis of constant zero asymmetry has a $\chi^2 = 4$ 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. 8 ($\chi^2 = 5.4$ with 9 degrees of freedom, 80% confidence level for constant zero asymmetry). The total asymmetry, averaged over the whole energy range is

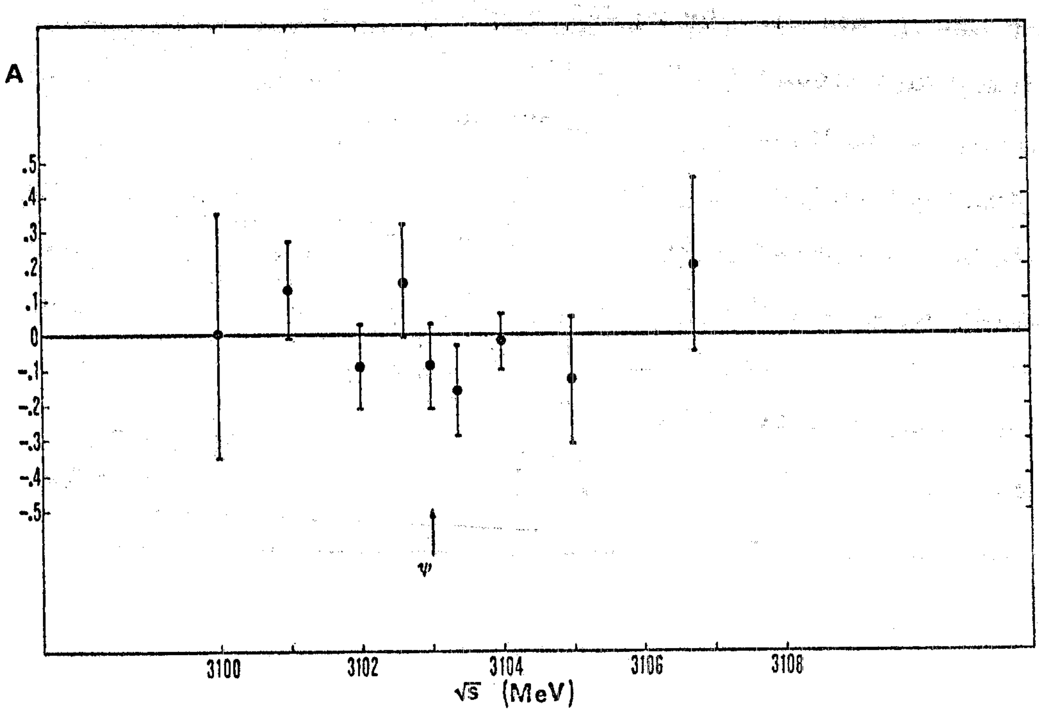

FIG. 8 - Forward-backward $\mu^+\mu^-$ production asymmetry versus c.m. energy obtained by the whole sample of 497 events.

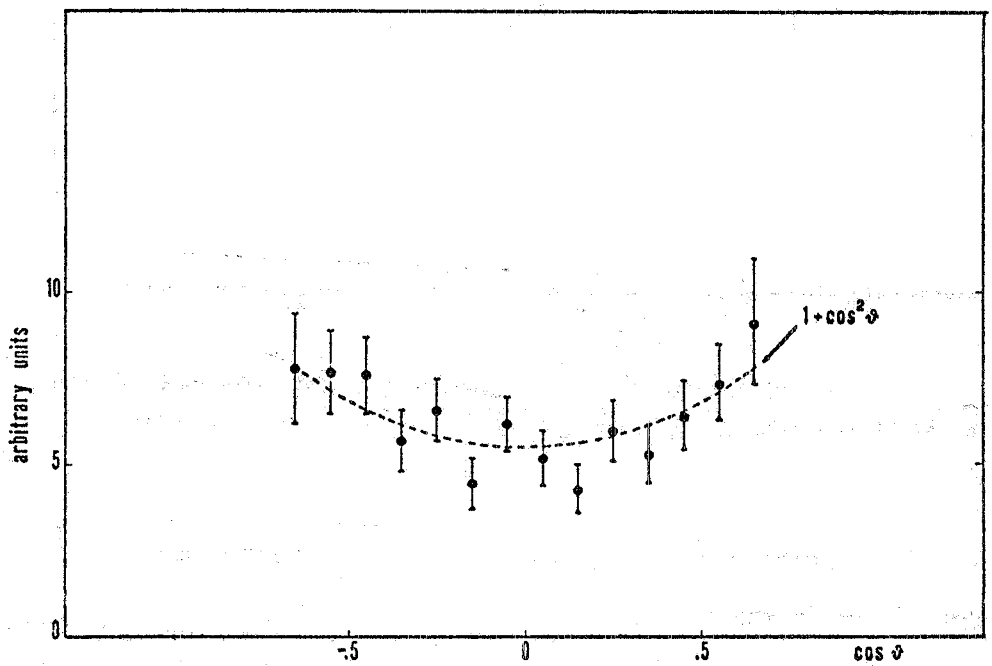

FIG. 9 - Overall angular distribution of the $\mu^+\mu^-$ events obtained in the energy region $\sqrt{s}$ = (3098 - 3108) MeV. Data are corrected for detection efficiency. θ is the angle between the outcoming μ^+ and the incoming e^+. The dashed line represents the $1+\cos^2\theta$ distribution.

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

The overall angular distribution of new and old data is shown in Fig. 9. 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, to within the above quoted statistical errors, asymmetry parameter is constant and zero in the J/ψ energy region.

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(2) - B. Bartoli et al., Lett. Nuovo Cimento 11, 705 (1974).

(3) - B. Bartoli et al., Frascati report LNF-74/64 (1974).

(4) - M. Piccolo and G. Penso, Frascati report LNF-75/15(P) (1975).