PROPERTIES OF THE A_1 STUDIED IN 16 GeV/c π^- — INTERACTIONS ON NUCLEI

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We present here preliminary results of a study of the $\pi^+\pi^-\pi^-$ system produced in the Ecole Polytechnique Heavy Liquid Bubble Chamber BP3 [1] by 16 GeV/c π^- of the 03 beam from the CERN. P. S. The Chamber ($1 \times \frac{1}{2} \times \frac{1}{2}$ m^3, magnetic field 20.3 KG) was filled with C_2F_3Cl (density 1.2, radiation length 25 cm). This liquid was chosen mainly because:

— its short radiation length permits $>95\%$ efficiency for detection of at least one of the two γ rays from a decaying π°;

— it contains no hydrogen, and thus offers no possibility of reactions on free protons which could be confused with the reactions on nuclei which we wanted to study.

SELECTION OF EVENTS

We have scanned 145, 000 photos to select event compatible with the reaction:

$$\pi^- + n \rightarrow \pi^-\pi^-\pi^+ + n \qquad (1)$$

where n is a nucleus (C F or Cl). Events were retained if there was no visible γ ray or strange particle associated, and no evidence of nuclear breakup, i. e., no recoil proton, no visible (>150 MeV/c) evaporation prong, nor «blob» at the interaction point.

About 80% of the events thus selected fit reaction (1) with χ^2 probability greater that 5% for n-Fluorine. We also fitted these events for n-Neutron. The results of the two fits were practically identical for recoil momenta less than 300 MeV/c, (which was the case for most of the events). The resulting sample of 969 events fitted with n-Fluorine contains less than 2% background of events with an undetected π^0 produced in addition to the $\pi^+\pi^-\pi^-$.

The production mechanism of these $\pi^+\pi^-\pi^-$ events has already been studied under similar conditions [2—4]. Our recoil momentum (q) distribution (Fig. 1, a) and that of the production angle of the 3-pion system (Fig. 1, b) are similar to the distributions observed in those experiments. Thus, following the interpretations given in these experiments we consider most of our events with small q as interactions on the nucleus as a whole, with angular distribution like that expected for the diffraction process on nuclei.

EVIDENCE ON A_1

The mass distribution for the 3π system (fig. 2) has a strong peak at 1.08 GeV with a shoulder towards higher mass. If we enrich

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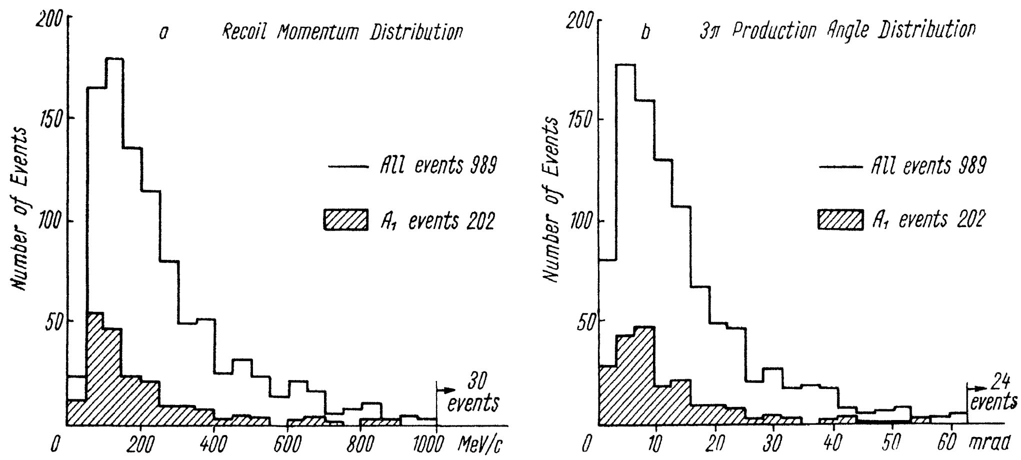

Fig. 1. (a) The laboratory recoil momentum of the nucleus for all 989 events and for the 202 A_1 events (defined as events having $650 \leqslant M_{\pi^+\pi^-} \leqslant 850$ MeV and $1000 \leqslant M_{3\pi} \leqslant 1160$ MeV). The experimental resolution has a standard deviation of the order of 100 MeV/c. (b) The production angle of the 3π's in the laboratory system for all events and for the A_1 events. The experimental resolution has a standard deviation of the order of 6 milliradians.

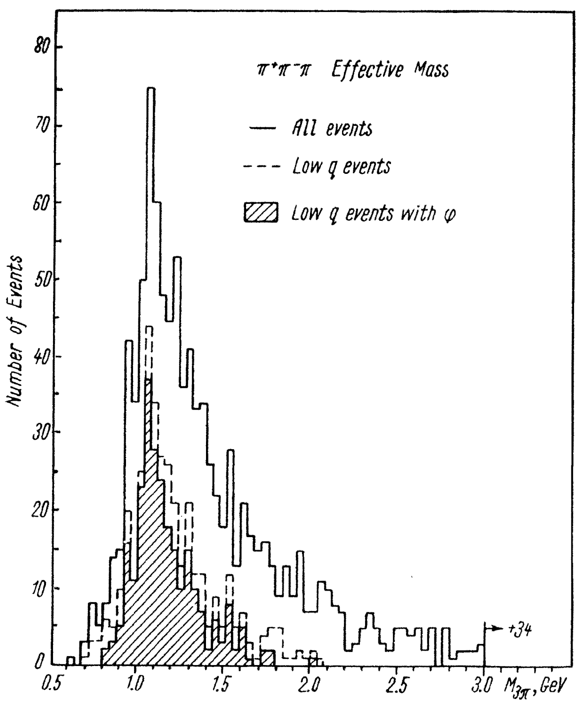

Fig. 2. The $\pi^+\pi^-\pi^-$ effective mass distribution for: 1) all events; ii) events with $q < 150$ MeV/c; iii) events with $q < 150$ MeV/c and $650 < M_{\pi^+\pi^-} < 850$ MeV. The experimental resolution is about $\pm 3\%$.

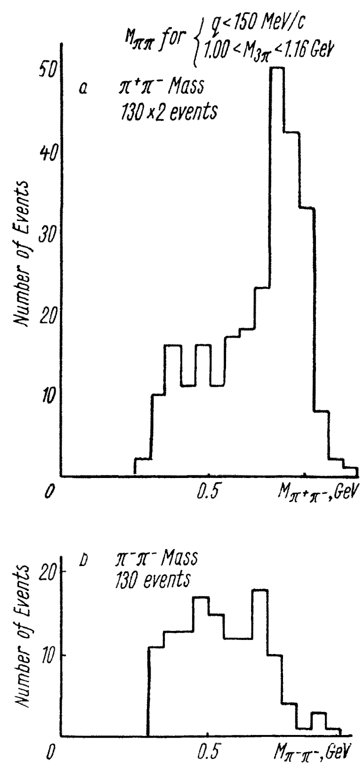

Fig. 3. The two pion mass distributions for events with $q < 150$ MeV/c and $1000 < M_{3\pi} < 1160$ MeV. The experimental resolution is of the order of $\pm 6\%$.

our sample in interactions on the nucleus as a whole by keeping only those events with low (< 150 V/Mec) recoil momentum, the peak remains essentially intact while the background is considerably reduced. There is no clear evidence for the presence of the A_2 resonance (1320 MeV) which has been observed [5—8] in the reactions $\pi^\pm + p \to \pi^\pm + \pi^+ + \pi^- + p$ produced by $\pi^\pm$ of 3 to 4 GeV/c. Some of these experiments also show the first peak (A_1), but less pronounced than the A_2 peak. In contrast to these lower energy experiments in hydrogen we observe much stronger production of A_1 than A_2 by 16 GeV π^- interactions in nuclei. Apart from the much higher energy this might be due to the production mechanism in these diffractionlike interactions.

The $\pi\pi$ mass distributions for the events with 3π mass in the A_1 region ($1.0 \leqslant m_{3\pi} \leqslant$ $\leqslant 1.16$ GeV) are presented in Fig. 3. The $\pi^+\pi^-$ mass distribution shows a strong ϱ peak while the $\pi^-\pi^-$ distribution has no particular structure. Most of the A_1 events (85%) have at least one of the two $\pi^+\pi^-$ mass combinations in the ϱ region (0.65 to 0.85 GeV). Thus, in our case, the A_1 is essentially a $\pi^-\varrho$ system.

It has been suggested [9, 10] that a $\pi\varrho$ interaction could give a peak in the mass distribution around 1.1 GeV. This mechanism makes no precise predictions that can be tested by our present data.

In résumé, we have a strong $\varrho^0\pi^-$ peak in our $\pi^+\pi^-\pi^-$ mass distribution. We have no evidence contrary to the assumption that the A_1 peak is due to a $\pi\varrho$ resonance. The central value is 1.08 ± 0.02 GeV and the width 0.15 GeV.

SPIN AND PARITY OF A^1

To investigate the spin J and parity P of the A_1 state, we studied first the angular distribution of the normal to the decay plane in the A_1 rest system. Fig. 4 shows the polar (θ) and azimuthal (φ) angular distributions of this direction with respect to the beam direction in this system.

The θ distribution is clearly anisotropic (χ^2 probability less than 1%). This allows us to reject the hypothesis 0^- for the J^P of the A_1.

The Dalitz plot of $M^2(\pi^+\pi^-)$ is presented in Fig. 5. The error on the position of an individual point is about 10% of M^2 on the average. Independently of the production mechanism, the density of points in the ϱ band should decrease slowly to zero at the lower limit of $M^2_{\pi^+\pi^-}$ for the «abnormal parity» state 1^-, 2^+, 3^- etc. Fig. 5 b shows the observed distributions of density along the ϱ band in comparison with those expected [12] for some J^P hypotheses. Our result seems inconsistent with the abnormal parity assignments 1^- or 2^+ and is in good agreement with 1^+ and 2^-. (Of course higher spins are not excluded).

In the region where the two ϱ bands overlap, the density remains approximately constant in spite of the reduction of phase space. We thus have no indication of the destructive interference which would be expected for the hypothesis 1^-

We have computed the denstiy matrix elements [13] from the θ and φ angular distributions of the decay plane normal for the 1^+

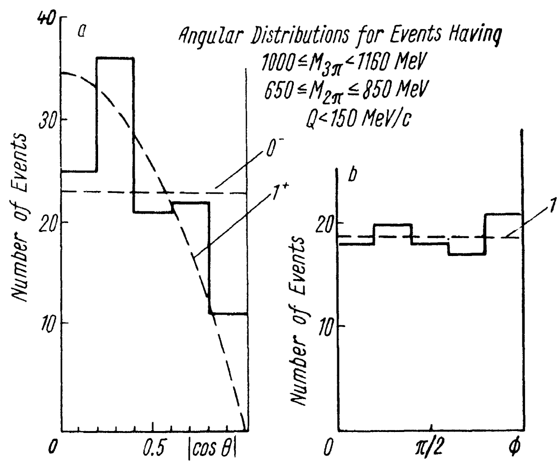

Fig. 4. Angular distribution of the normal to the decay for A_1 events:
(a) decay plane normal dotted into the beam direction, and (b) the azimulthal angle of the decay plane normal about the beam, referred to the production plane. Both angles are calculated in the A_1 rest system. Theoretical predictions for $J^P = 0^-$ and, under the assumption of coherent production, for $J^P = 1^+$. At the small production angles of this experiment the production plane is somewhat poorly defined experimentally; the distribution of the azimuthal angle (used only in the evaluation of the off-diagonal terms of the density matrix) may be considerably affected by this imprecision.

and 2^- hypotheses. The resulting matrix for 1^+ is in good agreement with that expected for coherent production [11] on a nucleus, while for 2^- it seems inconsistent with this production mechanism.

Thus we conclude that the most probable J^P assignments are 1^+ and 2^-. 1^+ would be consistent in addition with the expected coherent production on a nucleus.

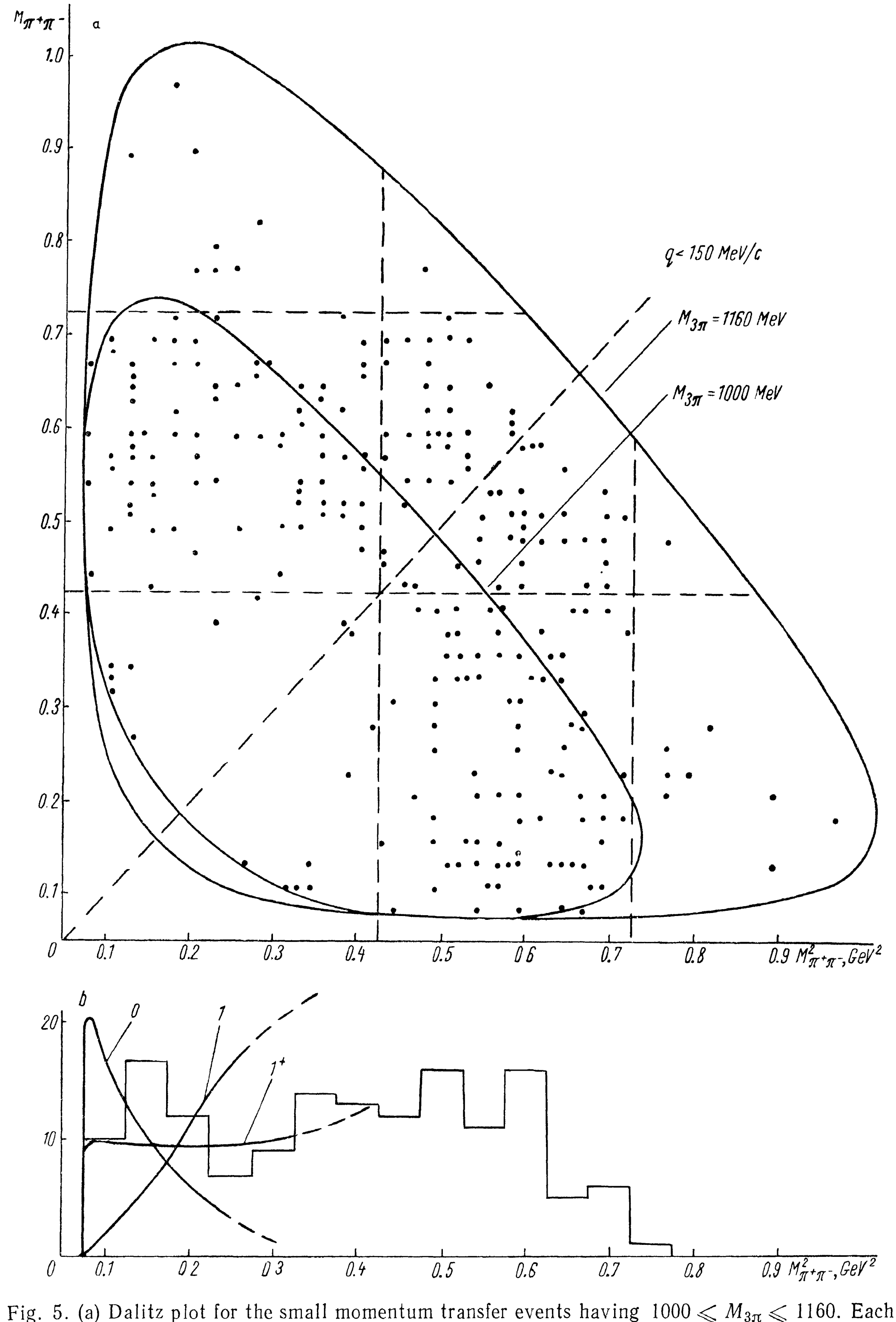

Fig. 5. (a) Dalitz plot for the small momentum transfer events having $1000 \leqslant M_{3\pi} \leqslant 1160$. Each event is represented by two points symmetrically placed about the diagonal. The ϱ-band limits are shown for $M_{\pi^+\pi^-} = 650$ and 850 MeV, and the kinematic limits are shown for $M_{3\pi} = 1000$ and 1160 MeV. (b) Projection of the horizontal ϱ-band. Theoretical predictions (normalized to the data with $M^2_{\pi^+\pi^-} < 3$ GeV^2) of various J^P assignements for $A_1 \to \varrho\pi$ are shown in the noninterference region. The 2^+-prediction is similar to that of the $1^\mp$ prediction.

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