KFKI
26/1968

# On the Azimuthal Effects of Two Prong $\pi N$ and Three Prong DD Events Produced by 17,2 GeV/c $\pi^-$-mesons

G. Bozóki, É. Gombosi and G. Surányi

HUNGARIAN ACADEMY OF SCIENCES
CENTRAL RESEARCH INSTITUTE FOR PHYSICS

BUDAPEST

# On the Azimuthal Effects of Two Prong $\pi N$ and Three Prong DD Events Produced by 17,2 GeV/c $\pi^-$ mesons

G.Bozóki, É.Gombosi and G.Surányi
Central Research Institute of Physics, Budapest

## Summary

A deviation from isotropy in the azimuthal angular distribution of secondary particles of two and three prong pion-nucleon interactions is observed in emulsion at 17,2 GeV/c. Attempts are made using Monte Carlo calculations for the interpretation of these azimuthal effects on the basis of (i) the kinematics of reactions $\pi^- p \rightarrow p\pi^-(k\pi^\circ)$ and $\pi^- p \rightarrow n\pi^+\pi^-(k'\pi^\circ)$ and (ii) the diffraction dissociation of pions on nuclei. A new method is given for the selection of the contribution of DD interactions from the three prong events. Using this method $\lambda_{DD} = (1065 \pm 288)$ m and $\lambda_{DD} = (113 \pm 13)$ m are obtained for the mean free path of the diffraction dissociation in emulsion at $\sim 7$ and 17,2 GeV/c, respectively. The possible influence of the Deck-effect in case of the three prong events is also investigated.

## 1. Introduction

In the last years several attempts have been made to detect azimuthal effects in the angular distribution of secondary particles generated in high energy interactions at accelerator energies /e.g.[ 1 ]/ as well as in the cosmic ray energy region /e.g. [ 2 ] /. The importance of these studies - as it was pointed out in refs. [ 3 - 7 ] - is given by the following: If in the distribution of azimuthal angles of secondary particles a deviation from isotropy would be found, then this fact would render important information about the production mechanism - especially about the production of fireballs or other resonant states associated with large angular momenta.

The aim of the present analysis is to investigate the possible azimuthal effects in pion-nucleon ($\pi$N) interactions at 17,2 GeV/c. The work can be taken as a continuation of a similar investigation, carried out earlier on $\pi$ N interactions at a primary momentum of ~ 7 GeV/c [8]. In that paper it was reported about an azimuthal anisotropy in the two and three prong events, while at higher multiplicities such an effect could not be detected.

Since the results of different authors [1] , [6 - 11] concerning the question of azimuthal effects are rather contradictory or inconclusive it seemd to be worthwile to check our earlier results and carry out a new measurement.

## 2. Experimental

For the present analysis a total of 928 inelastic $\pi^-$ N interaction found in Ilford G5 plates by along the track scanning /for details of the scanning and measurement see refs. [12][13]/ was used[x]. The interactions satisfied appropriate selection criteria summarised in ref. [ 14][xx]. This sample of events containes mostly the inelastic interactions of the primary pion on free and quasi-free nucleons and in a certain amount the so called diffraction dissociation /DD/ events which also satisfy the above selection criteria. Thus our sample is - apart from the DD events - almost free from the more complex pion-nucleus / $\pi\mathcal{N}$ / interactions, which can maske the possible azimuthal effects.

---

[x] We are indebted to the Alma-Ata group for kindly providing us with their data concerning the 2-, 3- and 4- prong events, which are included in the above sample.

[xx] These selection criteria were the same, which have been applied for the ~7 GeV/c material.

It is remarkable, that in general the complex nuclear interactions are not separated in the majority of the samples used so for investigating azimuthal anisotopy.

## 3. Results

In order to detect a possible azimuthal anisotropy the frequently applied "method of consecutive angles" [5], [15] was used. According to this method the observed distribution of consecutive azimuthal angles /i.e. of the separation angle $\Phi = \phi_{i+1}-\phi_i$ between the azimuthal angles of the successive prongs/ for events of a given multiplicity has to be compared with the corresponding random distribution.

In case of azimuthal isotropy the probability distribution of $\Phi$ for n-prong events is given by the following expression:

$$N(\Phi)d\Phi = (n-1)\left(1 - \frac{\Phi}{2\pi}\right)^{n-2} \frac{d\Phi}{2\pi} \qquad /1/$$

The observed distributions together with the random ones obtained from expression /1/ for events having different number of prongs /n=2,3,4,5, 6,≥7/ are shown in Fig.1. the curve for $n \geq 7$ was obtained by calculating weighted average of the curves for n=7,8,9,10,11,12, where the weighting factors were the number of events of the corresponding multiplicities.

A $\chi^2$ -test shows /see Table I./, that in cases of the two and three prong events, there exists a significant deviation from the azimuthal isotopy, whereas at higher multiplicities such deviations could not be detected.

Table I.

| Number of prongs n | $P(\chi^2)$ |
|---|---|
| 2 | 0,01 % |
| 3 | 0,01 % |
| 4 | 3 %[x] |
| 5 | 5 %[x] |
| 6 | 6 %[x] |
| ≥7 | 55 % |

---

[x] Calculating $P(\chi^2)$, cells containing only a small number of particles were grouped together. which procedure - though a little arbitrary - is generally used in $\chi^2$ - tests.

These results are in agreement with those obtained earlier at ~7 GeV/c. Our samples in neither cases contain events lying within 50 $\mu$, /in processed emulsion/ from either surface of the emulsion, avoiding thus the biases due to the omission of dipping shower tracks. The fact, that these unbiased samples show a significant deviation from azimuthal isotropy is against the conclusion of the authors of ref. [1].

In order to get information about the possible causes of the observed azimuthal anisotropy of the two and three prong events, the following analyses were carried out.

## 4. Analysis of the two-prong events

The distributions of the consecutive azimuthal angles are plotted on Fig.2 for those events in which both of the charged secondaries were identified and were found to be p $\pi^-$ /Fig. 2a/ or $\pi^+\pi^-$ /Fig. 2b/ particles respectively[x]; i.e. for reactions

$$\pi^- p \to p\pi^-(k\pi^0) \qquad k = 1,2,\ldots \qquad /2a/$$

and

$$\pi^- p \to n\pi^+\pi^-(k'\pi^0) \qquad k' = 0,1,\ldots \qquad /2b/$$

The isotropic distributions and distributions calculated by a Monte Carlo method /the matrix element of the interactions was chosen to be constant, for the different channels, see Appendix 1./ are also drawn into the figure.

One can see that

/1/ In case of reaction /2a/ there is, both in the experimental and Monte Carlo distributions a pronounced and comparatively narrow peak around $\Phi = 180^\circ$ /the interval $150^\circ < \Phi < 210^\circ$ containes 46 % of all the measured events/. This peak is much less pronounced and narrow for reaction /2b/ as can be seen from both the experimental and Monte Carlo distributions /the same intervall containes only 20 % of all the measured events/.

---

[x] For these distributions appropriate geometrical factors were used /see refs. [12,] [13] /.

/2/ The Monte Carlo curves agree quite well with the experimental distributions except at the very edges for the reaction /2b/. This is probably due to peripheral collisions where the $\pi^+$ and $\pi^-$ particles are emitted from the upper vertex at small angles with the primary direction in the laboratory system, which process was not taken into account in our Monte Carlo calculation.

The result of a $\chi^2$ -test for the isotropic and Monte Carlo distributions can be seen in Table II. In the last column of the table, $P'_{MC}(\chi^2)$ means the Pearson probabilities if we do not take into account the first and last cells.

Thus our analysis shows, that the observed deviation from isotropy only partly can be explained by the kinematics of the processes.

Table II.

| reaction | $P_I(\chi^2)$ | $P_{MC}(\chi^2)$ | $P'_{MC}(\chi^2)$ |
|---|---|---|---|
| /2a/ | 0,01 % | 14 % | |
| /2b/ | 0,2 % | 0,03 % | 25 % |
| total with n = 2 | 0,01 % | 3 % | 50 % |

## 5. Analysis of the three-prong events

As it was mentioned before, the three prong events have a certain contamination of DD interactions [13], [16-18].

Therefore our sample is subdivided into three parts:

(a) Events containing an identified proton.

(b) Events without an identified proton, for which $\sum_{i=1}^{3} \sin\Theta_i \geq 0,44$ /where $\Theta_i$ is the emission space angle of the i-th track/.

(c) Events without an identified proton, for which $\sum_{i=1}^{3} \sin\Theta_i < 0,44$; i.e. the DD-candidates.

The azimuthal angular distribution of events belonging to subsamples (a), (b) and their sum can be seen on Fig. 3a /distiributions quoted by 1,2 and 3/. The corresponding random distributions are also indicated. As can be seen from the figure and from the values of $P(\chi^2)$ /indicated on the figure/ there is no azimuthal effect in either cases.

The distribution of subsample (c), however has a shape quite different from that of the random one. It has a peak at around $\Phi = 180^{\circ}$, and after a rapid fall, a tail at $\Phi$ -values greater that $\Phi = 210^{\circ}$ /see Fig. 3b/.

This characteristic shape automatically suggests the assumption that this subsample consists of two types of events; (i) events, which yield the isotropic part of the distribution, and (ii) events, which cause the deviation from isotropy.

In order to separate this two types of events a straight line was fitted to the tail of the distribution and it was extrapolated down to $\Phi = 0^{\circ}$. Then subtracting the area under this line from the distribution of events belonging to subsample (c) a new distribution corresponding to the <u>events causing the deviation from isotropy</u> can be obtained.

A comparison of this new distribution /distribution 1 in Fig.4/ with that calculated by Monte Carlo method for DD interactions /for details see Appendix 2./ of types

$$\pi^- \mathcal{N} \to \mathcal{N} X^-_{M^*} \to \mathcal{N} \rho^0 \pi^- \qquad /3a/$$

and

$$\pi^- \mathcal{N} \to \mathcal{N} X^-_{M^*} \to \mathcal{N} \pi^+ \pi^- \pi^- \qquad /3b/$$

where $X^-_{M^*}$ is the coherently produced system having an effective mass $M^*$, shows /distributions 2 and 3 in Fig.4/, that there is an excellent agreement with the distribution caloulated for reaction /3a/.[x] Thus we can conclude that the distribution obtained by the above procedure is due to only DD events /presumably of type /3a/ /. This means that <u>this "subtraction" procedure gives a possibility to select DD events</u> from a sample of three prong events.

Knowing this result, we can make the subtraction more precisely, eliminating the inaccuracy in the extrapolation. Denote by $y_i$ the number of angles in the i-th cell in the consecutive azimuthal angular distribution, by $m_i$ and $h_i$ the same quantities obtained by the Monte Carlo calculation for

---

[x] In this calculation the spin parity assignement of the $X^-_{M^*}$ -system was not taken into account since it is shown in Appendix 2, that the shape of the distribution of consecutive azimuthal angles is not sensitive to the possible spin parity assignements.

reaction /3a/, and from Eq. /1/, respectively. Then the expected value of $y_i$ will be $\langle y_i \rangle = Am_i + Bh_i$ where A and B are the constants to be determined, and the probability that in the i-th cell $y_i$ is observed instead of $\langle y_i \rangle$ is

$$P_i = \frac{\langle y_i \rangle^{y_i}}{y_i\,!}\, e^{-\langle y_i \rangle}$$

Applying the maximum likelihood method, A and B were determined.

Using the obtained values of the constants, the real number of DD-events /$N_{DD}$/ among the events belonging to subsample (c), /$N_{(c)}$/, and thus the mean free path of the DD process in question in emulsion can be obtained[x]. The calculation was carried out for the ~7 GeV/c material as well[xx]. The results can be seen in Table III.

Table III.

| | $N_{(c)}$ | $A\ .\ \Sigma m_i$ | $B\ .\ \Sigma h_i$ | $N_{DD}$ | $\lambda_{DD}$ |
|---|---|---|---|---|---|
| 17,2 GeV/c | 173 | 255 ± 29 | 260 ± 29 | 83,1 ± 9,5 | (113 ± 13)m |
| ~7 GeV/c | 20 | 28,0 ± 7,6 | 31,0 ± 7,8 | 9,3 ± 2,5 | (1065 ± 288)m |

---

[x] It is worth to mention, that if this subtraction procedure is applied to all the three prong events the result for $\lambda_{DD}$ excelletly agrees with the result shown in Table III, which shows the reliablity of the method.

[xx] In case of the ~7 GeV/c material the result of a separate Monte Carlo calculation corresponding to this primary energy was applied.

The above values of $\lambda_{DD}$ are within the interval obtained earlier [13] from the same material[x]

$$(61 \pm 5)\mathrm{m} \le \lambda_{DD}^{17,2\mathrm{GeV/c}} \le (300 \pm 83)\mathrm{m}$$
$$(555 \pm 131)\mathrm{m} \le \lambda_{DD}^{\sim 7\ \mathrm{GeV/c}} \le (1600 \pm 800)\mathrm{m}$$

The possible influence of a $\pi^- n \to n \rho^0 \pi^-$ Deck-mechanism [19] to the shape of the distribution of consecutive angles was also investigated, by a separate Monte Carlo calculation /see Appendix 3/. The calculation yielded the following results:

a./ Only 10 % of the generated events fulfilles the $\sum_{i=1}^{3} \sin\Theta_i < 0,44$ criterion.

b./ The maximum of the consecutive azimuthal angular distribution of events fulfilling the $\sum_{i=1}^{3} \sin\Theta_i < 0,44$ criterion is a little shifted towards lower $\Phi$ -values comparing with the distribution of DD process /see Fig.5a/

c./ The shape of the distribution of events having $\sum_{i=1}^{3} \sin\Theta_i > 0,44$ is very different from the experimentally observed one /see Fig. 5b/.

If the small enhancements /hatched areas in Fig. 3a/ in the distribution of events belonging to subsample (b) in the regions $120^\circ \le \Phi \le 150^\circ$ and $180^\circ \le \Phi \le 210^\circ$ are supposed to be due to Deck mechanism, then the contribution of the Deck mechanism /in case of subsample (b) /can be estimated as $\lesssim 10$ % /which correspond to $\lesssim 17$ events/ and it is neglible for the subsample (c).

## 6. Discussion and conclusions

1./ Analysing the consecutive azimuthal angular distribution of $\pi^- N$ interactions at 17,2 GeV/c, azimuthal anisotropy was found for the two and three prong events. At higher multiplicities azimuthal effects were not detected.

---

[x] The lower limit was obtained using selection criteria

1, $n=3$, $N_g = N_h = 0$

2, $\sum_{i=1}^{3} \sin\Theta_i < 0,44$,

while for the upper limit three more criteria were used:

3, all the three particles have to be identified as pions.

4, $q_\perp \le 200$ MeV/c, where $q_\perp$ is the transverse momentum transferred to the nucleus,

5, $\sum_{i=1}^{3} E > 0,7\ E_0$, where $E_0$ and $E_i$ are the total energy of the primary and of the i-th pion.

2./ As concerns the two prong events it was pointed out that the anisotropy found can be partly attributed to kinematical effects.

3./ As concers the three prong events the observed anisotropy was found to be due to DD processes.

4./ A new "subtraction" method was found for the selection of DD-events from a sample of three prong events. Using this method

$$\lambda_{DD}^{\sim 7GeV/c} = (1065 \pm 288)m \quad \text{and} \quad \lambda_{DD}^{17,2GeV/c} = (113 \pm 13)m$$

were obtained for the mean free path of DD-processes at ~7 and 17,2 GeV/c primary momenta.

5./ Since in DD events there is an azimuthal anisotropy, one can assume that the azimuthal effects found in cosmic ray jets /mainly in secondary ones/ having small number of heavy prongs and shower particles /e.g. refs. [20] , [21]/ are partly due to DD processes. Thus it is desirable to study separately the azimuthal effects of DD and non-DD events in the future cosmic ray works.

6./ The absence of azimuthal effect at charged multiplicities $n \geqslant 3$ /apart from the DD-events/ can be attributed to the follwing cause:

Inelastic channels of different multiplicity are superimposed at a given number of charged prongs and this superposition can yield a nearly "random" distribution in spite of the possible azimuthal effects in the separate channels.

Therefore the possibility of the production of fireballs at this energy is not necessarily ruled out. /As a matter of fact fireballs production was detected by e.g. C.W.Akerlof et al. [22] in p-p collisions./

To get more information in this respect, it seems to be worthwile to investigate azimuthal effects using the "method of consecutive angles" /or an improved, more sensitive method/ in the separate inelastic channels, and to study the azimuthal correlations between likely and unlikely charged secondaries.

The authors are grateful to Dr. P. Király for his critical comments.

## Figure captions

Fig.1. Observed and calculated from eq. /1/ distributions of consecutive azimuthal angles for events having different numbers /$n \geq 2$/ of prongs. The dotted line in case of $n=2$ corresponds to the Monte Carlo distribution.

Fig.2. Distributions of consecutive azimuthal angles observed a./ in reaction /2a/ and

b./ in reaction /2b/.

The dotted /-----------/ and the broken /-.-.-.-.-.-/ lines correspond to the Monte Carlo and the random distributions respectively.

Fig.3. Distributions of consecutive azimuthal angles for three prong events belonging

a/ to subsamples (a) /distribution 1/, (b) /distribution 2/ and to their sum /distribution 3/ and

b/ to subsample (c).

The straight lines correspond to the random distributions.

Fig.4. Distributions of consecutive azimuthal angles obtained by the subtraction method /full line/. The distributions drown with dotted /------------/ and broken /-.-.-.-.-.-./ lines correspond to Monte Carlo distributions calculated for DD-interactions of types /3a/ and /3b/.

Fig.5. Monte Carlo distributions of consecutive azimuthal angles of three prong events corresponding to Deck mechanism and

a/ satisfying the $\sum_{i=1}^{3} \sin\Theta_i < 0{,}44$ criterion

b/ do not satisfying the above criterion.

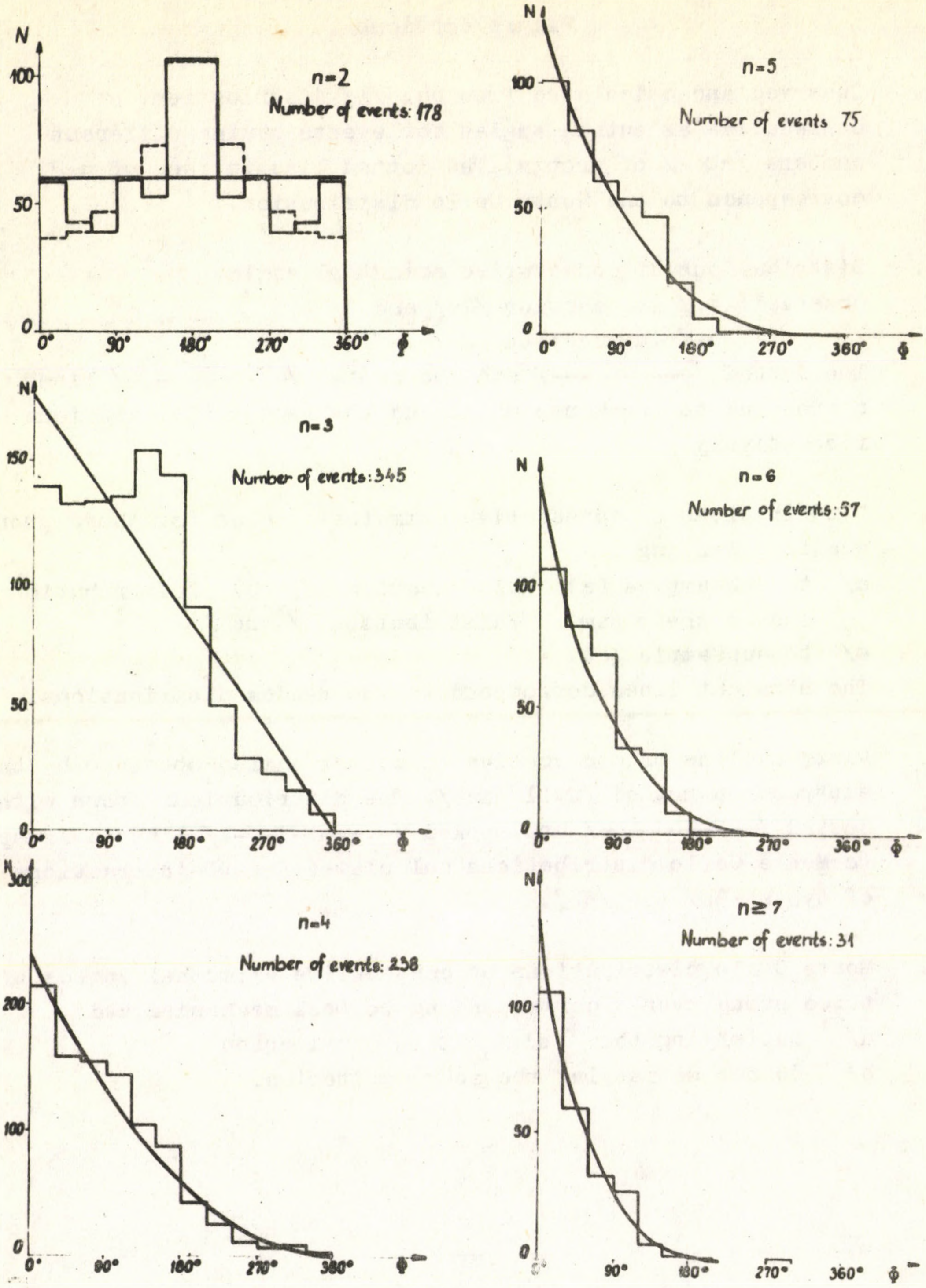
N
100
50
0
n=2
Number of events: 178
0°
90°
180°
270°
360°
Φ
N
100
50
0
n=5
Number of events 75
0°
90°
180°
270°
360°
Φ
N
150
100
50
0
n=3
Number of events: 345
0°
90°
180°
270°
360°
Φ
N
100
50
0
n=6
Number of events: 57
0°
90°
180°
270°
360°
Φ
N
300
200
100
0
n=4
Number of events: 238
0°
90°
180°
270°
360°
Φ
N
100
50
0
n≥7
Number of events: 31
0°
90°
180°
270°
360°
Φ

Fig.1.

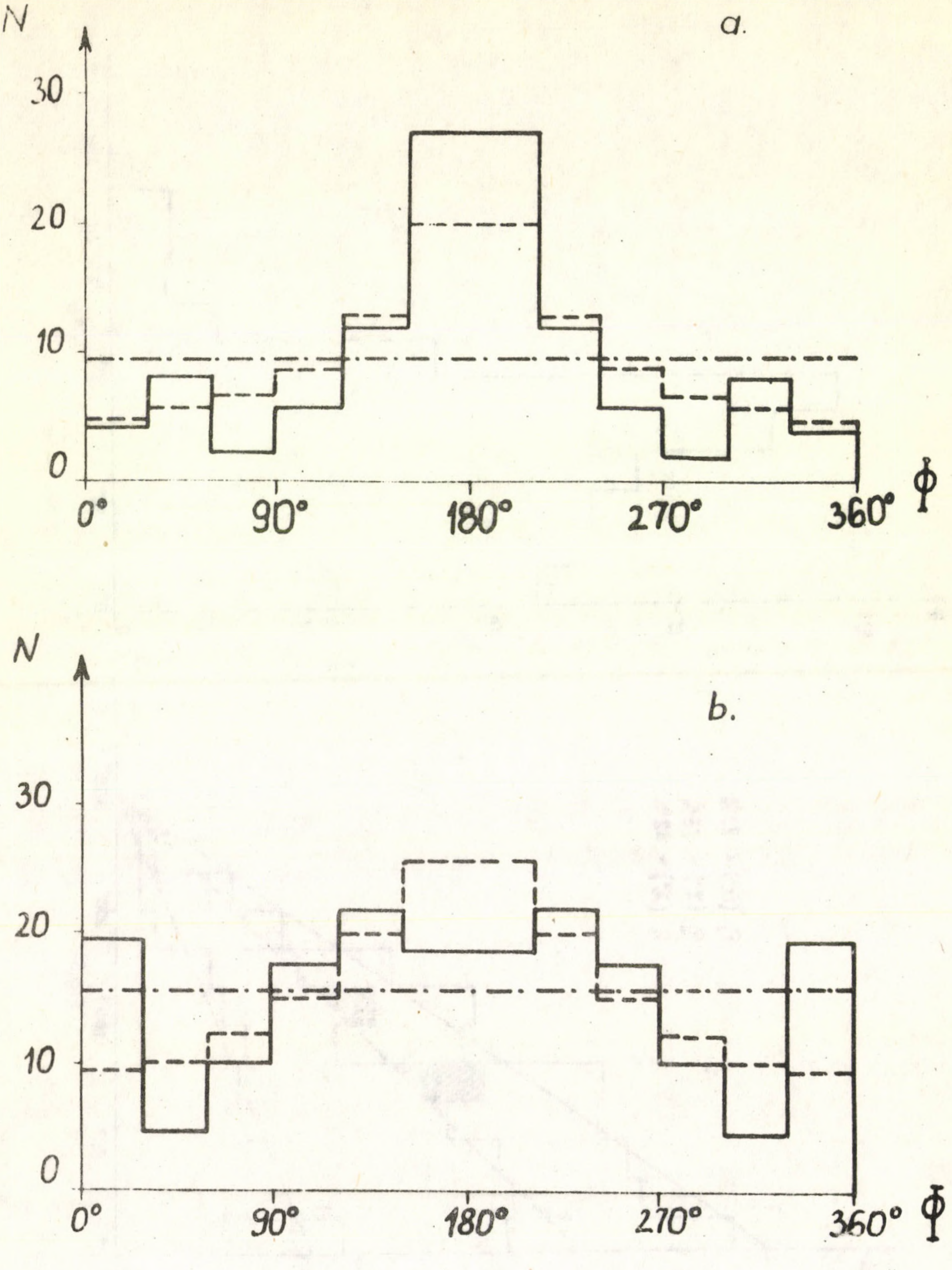

Fig. 2.

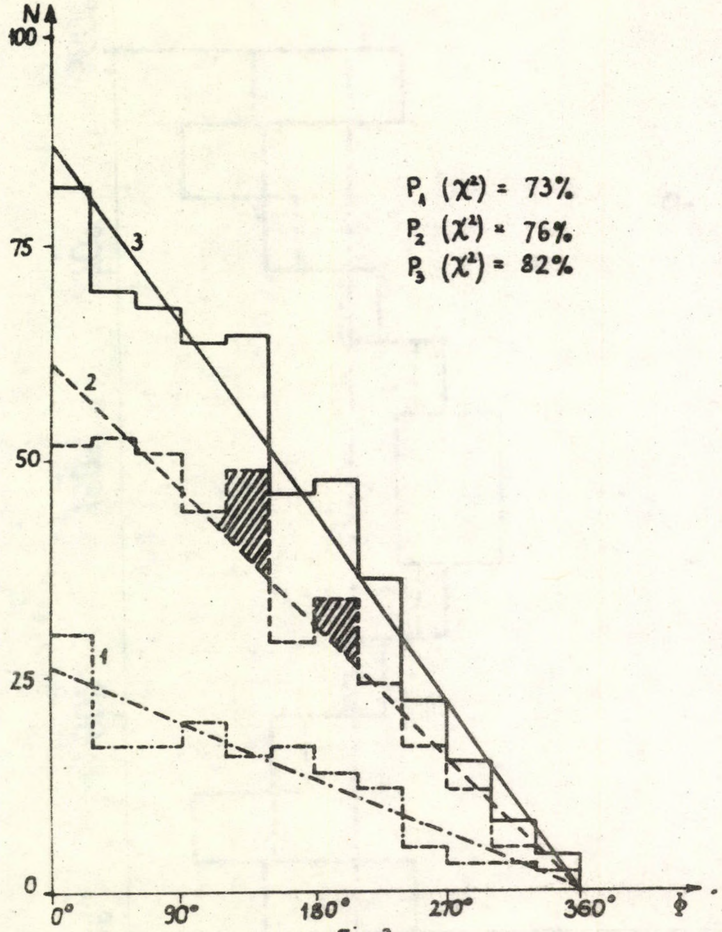
N
100
75
50
25
0
0°
90°
180°
270°
360°
Φ
1
2
3
P₁ (χ²) = 73%
P₂ (χ²) = 76%
P₃ (χ²) = 82%

Fig.3a

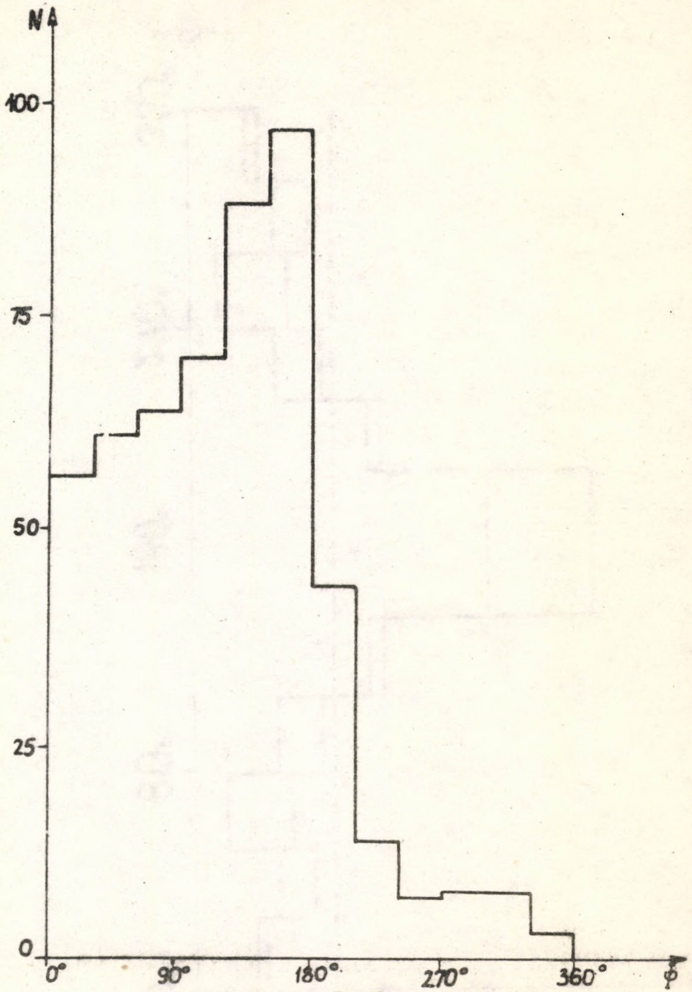
N
100
75
50
25
0
0°
90°
180°
270°
360°
Φ

Fig.3b

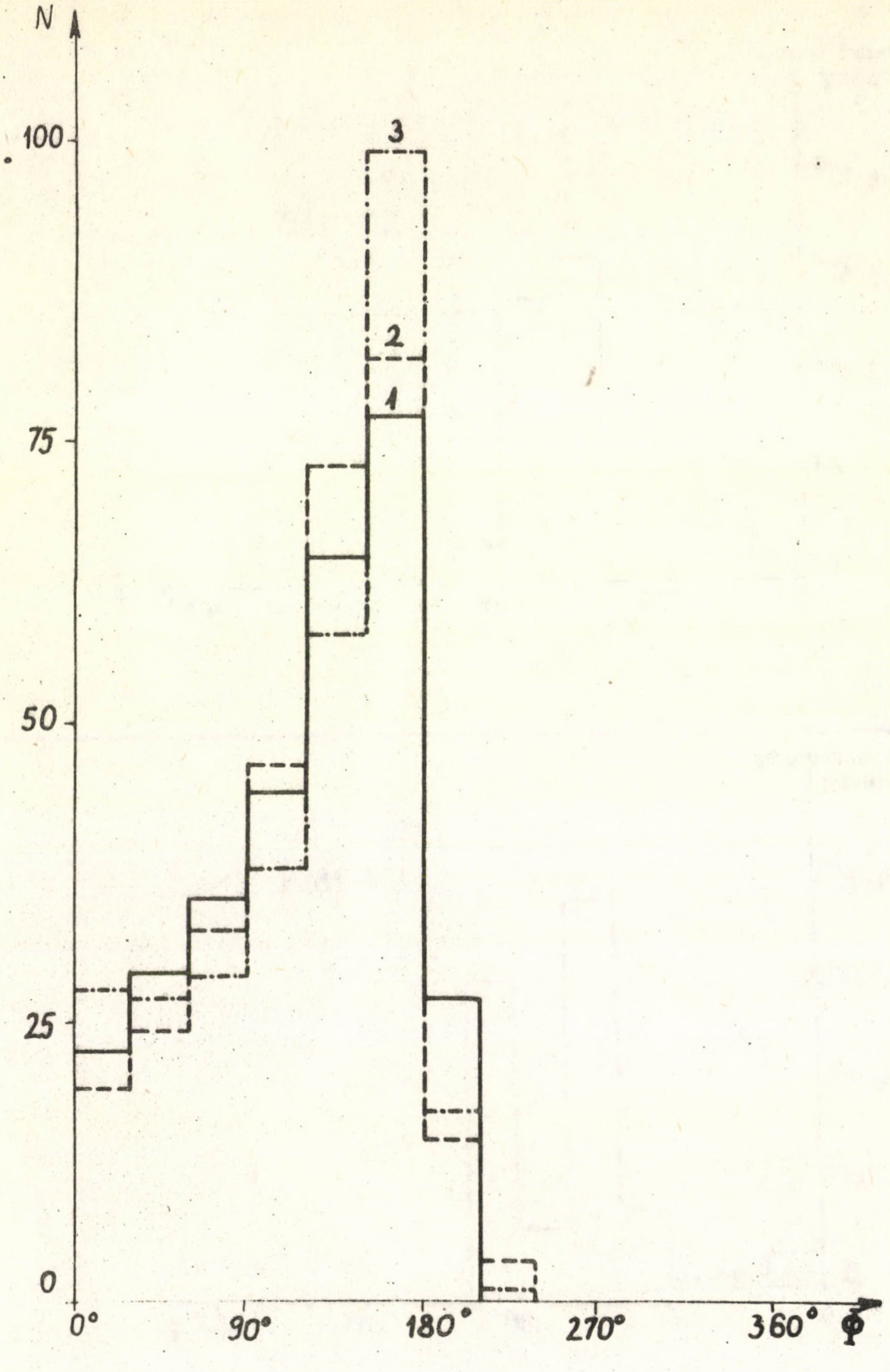

Fig.4.

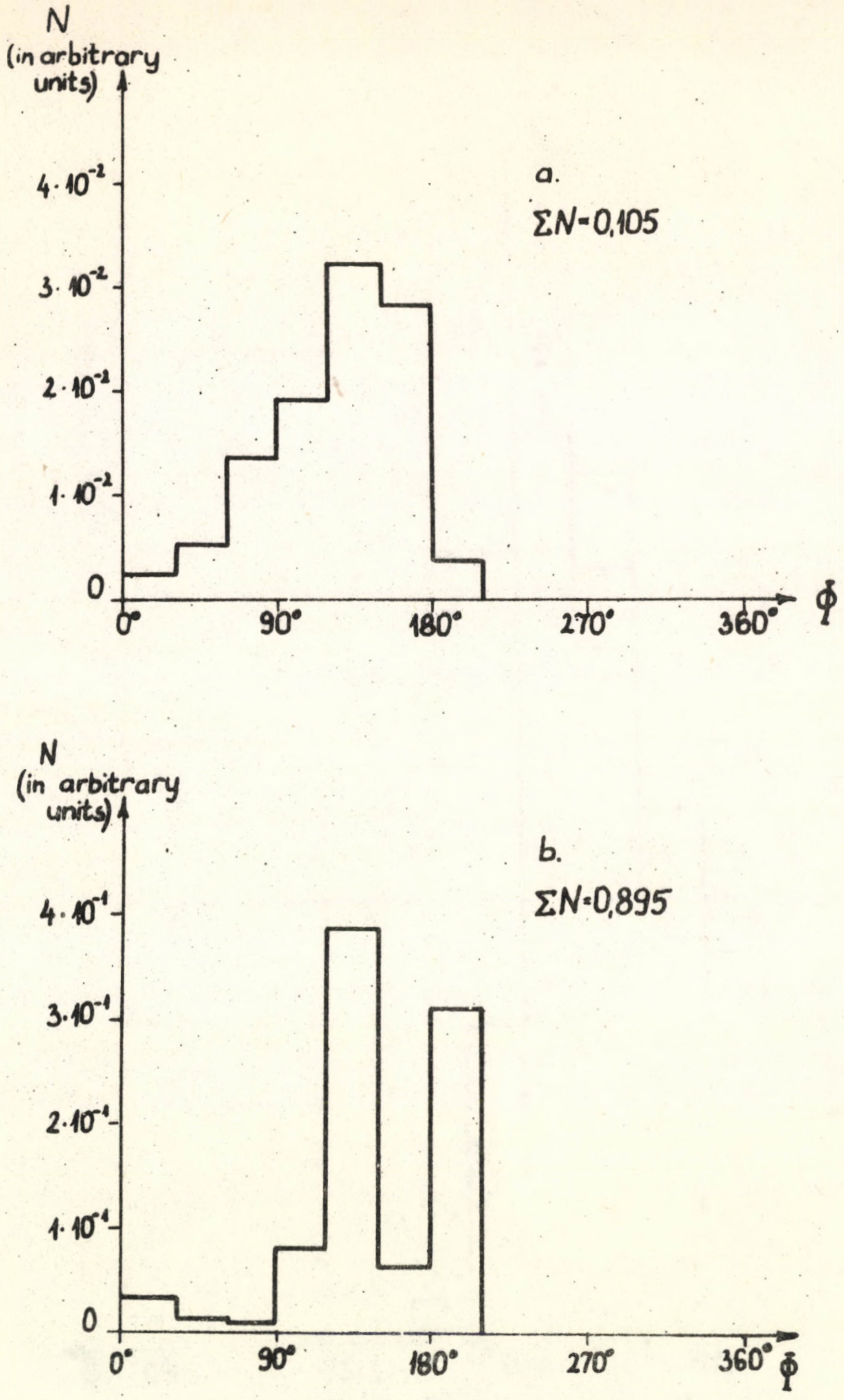
N
(in arbitrary units)
$4 \cdot 10^{-2}$
$3 \cdot 10^{-2}$
$2 \cdot 10^{-2}$
$1 \cdot 10^{-2}$
0
0°
90°
180°
270°
360°
$\Phi$
a.
$\Sigma N = 0{,}105$
N
(in arbitrary units)
$4 \cdot 10^{-1}$
$3 \cdot 10^{-1}$
$2 \cdot 10^{-1}$
$1 \cdot 10^{-1}$
0
0°
90°
180°
270°
360°
$\Phi$
b.
$\Sigma N = 0{,}895$

Fig. 5.

## Appendix 1.

The distributions of consecutive azimuthal angles were calculated for reaction channels

$$\begin{aligned}\pi^- p \to\ & p\pi^-\pi^0 \\ & p\pi^- 2\pi^0 \\ & p\pi^- 3\pi^0 \quad * \\ & \\ & n\pi^+\pi^- \\ & n\pi^+\pi^-\pi^0 \\ & n\pi^+\pi^- 2\pi^0 \\ & n\pi^+\pi^- 3\pi^0 \quad *\end{aligned}$$

separately by generating these types of many body final states supposing a uniform distribution in the phase space; i.e. supposing a constant transition matrix element /for the detailes of the programming of this calculation see in ref. [23]/. The result of these Monte Carlo distributions can be seen in Fig. A1.

These distributions were summed up using the measured proportions [24] of the above reaction channels as weighting factors. Distributions thus obtained are compared with the experimental ones in Figs. 1a, 2a and 2b.

---

[x] Reaction channels with more then $3\pi^0$ were not calculated since their relative occurence are very small [24].

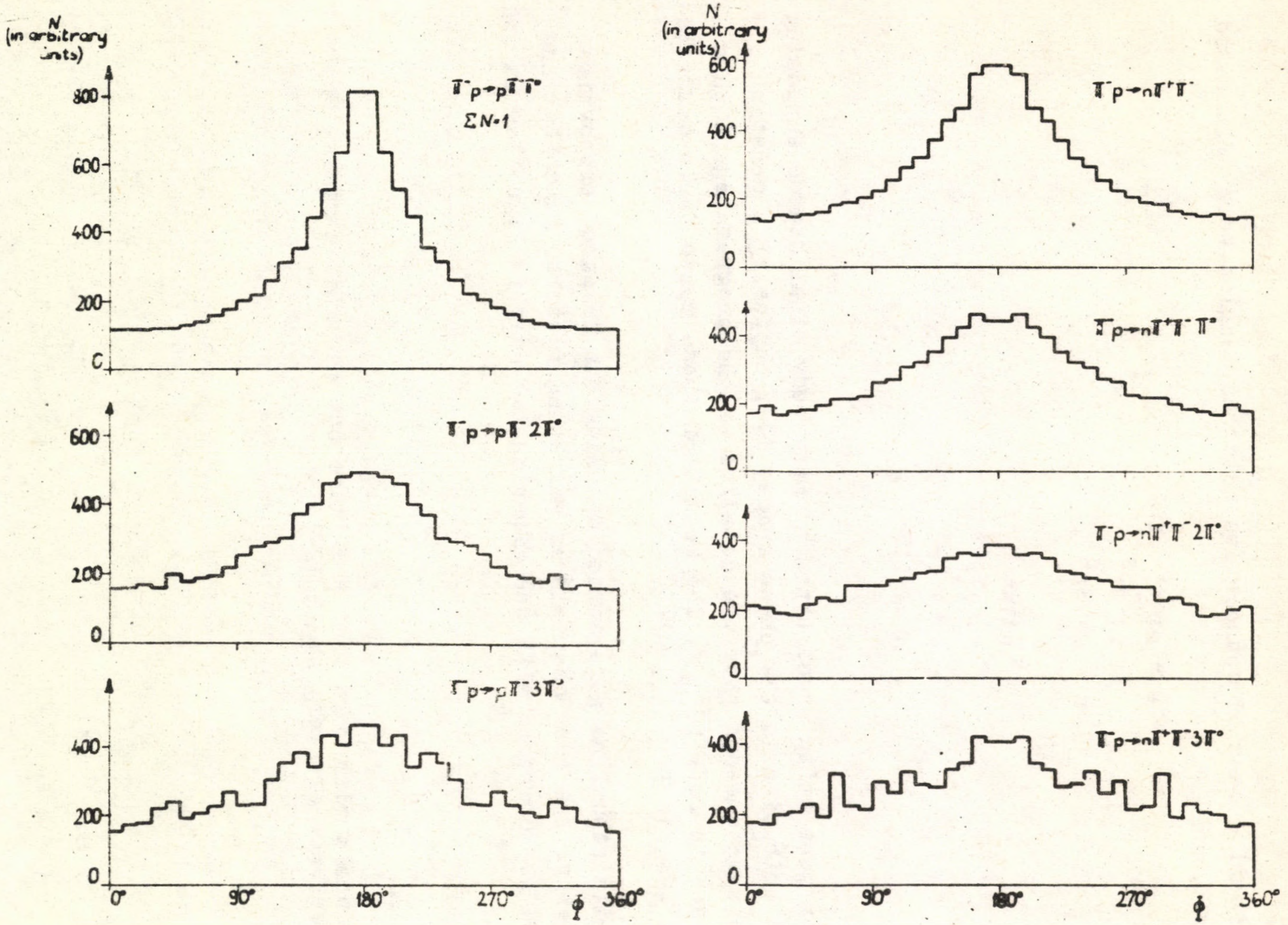

Fig.A1. Monte Carlo distributions of consecutive azimuthal angles calculated for reactions $\pi^-p \rightarrow p\pi^-(k\pi^0)$ k=1,2,3 and $\pi^-p\rightarrow n\pi^+\pi^-(k'\pi^0)$ k'=0,1,2,3 .

## Appendix 2.

A distinct Monte Carlo program was written for the generation of coherent events using the kinematics of coherent production. The method of generation was the following. A value for the effective mass $/M^x/$ of the coherently produced system was randomly chosen from the experimentally measured distribution given in ref. [25]. The momentum, transferred to the target nucleus /in ourcase to a carbon nucleus/ was calculated by choosing random trtransverse momentum from the distribution

$$f(q_\perp)\,dq_\perp = \begin{cases} q_\perp\, e^{-\left(\frac{q_\perp}{2} m_\pi^{-1} A^{1/3}\right)^2} dq_\perp\,, & \text{if } q_\perp \leq 200 \text{ MeV/c} \\ 0\,, & \text{if } q_\perp > 200 \text{ MeV/c} \end{cases}$$

The longitudinal component of this momentum was determined by the use of the formula

$$q_\parallel = q_\perp^2 \frac{M_A + P_o}{2M_A P_o} + \frac{M^{*2} - m_\pi^2}{2P_o}$$

where $M_A$ is the mass of the nucleus and $P_o$ is the primary momentum in the laboratory system. /They were set equal with 12 and 17,2 GeV/c respectively./

Then the momenta and the azimuthal angles of the three pions were calculated in the laboratory system assuming that coherently produced $X_{M^*}$ system decays in its rest system as

$$X^-_{M^*} \to \rho^o \pi^- \to \pi^+\pi^-\pi^- \qquad /i/$$

$$X^-_{M^*} \to \pi^+\pi^-\pi^- \qquad /ii/$$

To take into account the possible spin effects, a further calulation was made for reaction /i/, in which the experimentally measured distribution [26] of the direction of the normal of the decay plane in the $X_{M^*}$ rest system was used. /These distributions can be attributed to the possible $1^+$ or $2^-$ spin-parity assignements for the produced system./

The results of the above calculations can be seen in Fig. A2.

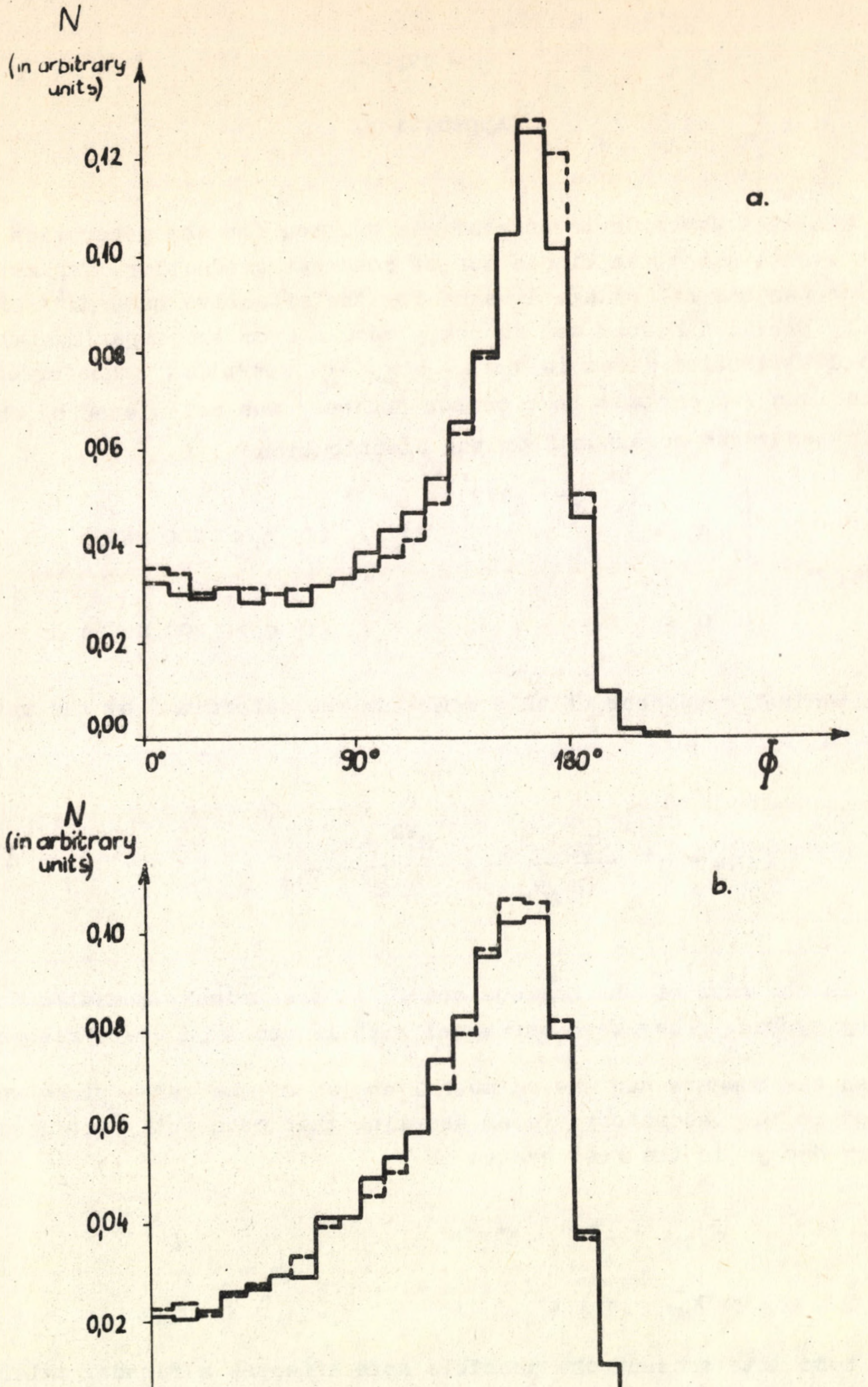

**Fig.A2.** Monte Carlo distributions of consecutive azimuthal angles of DD-events of types a/ $\pi^- \mathcal{N} \to \mathcal{N} \pi^+ \pi^- \pi^-$
and b/ $\pi^- \mathcal{N} \to \mathcal{N} \rho^0 \pi^-$
Distributions drown with full and dotted lines correspond to calculations, including and neglecting spin-effects, respectively.

## Appendix 3.

In order to see the effect due to a $\pi^- n \to n\rho^0\pi^-$ Deck mechanism [19], the distribution of consecutive azimuthal angles was calculated by Monte Carlo method. The calculation was carried out by integrating the Deck matrix element on the $n\rho\pi$ phase space with a value of the diffraction peak parameter $\kappa=9$ GeV$^{-2}$. The matrix element corresponding to the graph in Fig. A3. can be written as:

$$|M|^2 = \frac{\omega^2 \, e^{-\kappa t}}{(\Delta - m_\pi^2)^2}$$

where $\omega^2=(q_1+q_2)^2$, $t = (q_1-p_1)^2$, $\Delta=(q_3-p_2)^2$ and the symbols q, t, $\Delta$ correspond to the notations of Fig. A3.

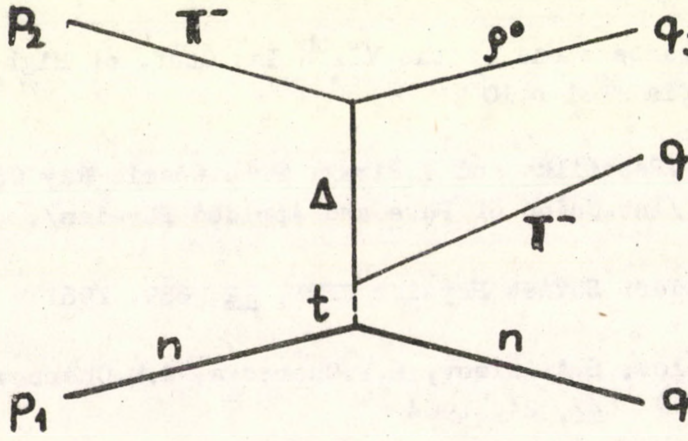

Fig.A3. Graph corresponding to the Deck mechanism in the $\pi^- n \to n\rho^0\pi^-$ reaction. $p_1, p_2, q_1, q_2, q_3$, $\Delta$ and t are the four momenta involved in the interaction.

## References

[1] G.K.Rao and A.A.Kamal: Proc.Phys.Soc., 91, 894, 1967
G.K.Rao /to be published in Acta Phys.Hung./

[2] Z.Czachowska, A.Jurak and A.Linscheid: Rep.No 788/VI/PH Warsaw 1967

[3] W.L.Kraushaar and L.J.Marks: Phys.Rev., 93, 326, 1954

[4] Z.Koba and S.Takagi: Nuovo Cim., 10, 755, 1958

[5] D.P.Stern: Supp.Nuovo Cim., 10, 251, 1960

[6] C.Castagnoli, C.Lamborizio, J.Ortalli and A.Barbaro-Caltierio: Nuovo Cim., 20, 416, 1961

[7] S.A.Azimov, L.P.Chernova, G.M.Chernov, V.M.Chudakov and B.K. Nikiskin: Nuovo Cim., 22, 235, 1961

[8] G.Bozóki: Transactions of the VII$^{th}$ Int.Conf. of High Energy Physics, Sofia 1961 p.10

[9] J.Pernegr, V.Petržilka and V.Šimak: Proc.Cosmic Ray Conf., Moscow, Vol.I, 1960 /Int.Union of Pure and Applied Physics/.

[10] E.M.Friedländer: Soviet Physics JETP, 12, 669, 1961

[11] Sh.Abduzhamilov, S.A.Azimov, L.P.Chernova, G.M.Chernov and V.M. Chudakov: ЖЭТФ 47, 24, 1964

[12] G.Bozóki, É.Gombosi and L.Vanicsek /to be published/

[13] E.Gombosi: /Theses/ Magy.Fiz.Folyóirat, 16, 189, 1968

[14] J.M.Gramenicki: Rep. No 553, Dubna 1960

[15] P.Ciok, M.Danysz, T.Saniewska and P.Zielinski: Transactions of the VIIth Int.Conf. of High Energy Physics, Sofia 1961 p.23.

Printed in the Central Research Institute for Physics, Budapest
Kiadja a Könyvtár- és Kiadói Osztály. O.v.: dr. Farkas Istvánné
Szakmai lektor: Király Péter. Nyelvi lektor: Sebestyén Ákos

Példányszám: 115 Munkaszám: KFKI 3964 Budapest, 1968. október 4.
Készült a KFKI házi sokszorositójában, f.v.: Gyenes Imre