ОБЪЕДИНЕННЫЙ
ИНСТИТУТ
ЯДЕРНЫХ
ИССЛЕДОВАНИЙ
ДУБНА

E1 - 11924

A.Abdivaliev, C.Besliu, F.Cotorobai, A.P.Gasparian, S.Gruia, A.P.Ierusalimov, D.K.Kopylova, V.I.Moroz, A.V.Nikitin, Yu.A.Troyan

OBSERVATION OF ANOMALY IN THE $(\pi^+\pi^-)$ EFFECTIVE MASS SPECTRUM WITH $M_{\pi^+\pi^-} = 0.40$ GeV/c^2 AND $\Gamma < 0.03$ GeV/c^2 IN THE REACTION $np \to d\pi^+\pi^-$ AT A NEUTRON INCIDENT MOMENTUM OF $P_n = 1.73$ GeV/c

1978

E1 - 11924

A.Abdivaliev, C.Besliu,* F.Cotorobai,* A.P.Gasparian, S.Gruia, A.P.Ierusalimov, D.K.Kopylova, V.I.Moroz, A.V.Nikitin, Yu.A.Troyan

OBSERVATION OF ANOMALY IN THE $(\pi^+\pi^-)$ EFFECTIVE MASS SPECTRUM WITH $M_{\pi^+\pi^-} = 0.40$ GeV/c^2 AND $\Gamma < 0.03$ GeV/c^2 IN THE REACTION $np \to d\pi^+\pi^-$ AT A NEUTRON INCIDENT MOMENTUM OF $P_n = 1.73$ GeV/c

Submitted to ЯФ

* *Bucharest University, Romania.*

Абдивалиев А. и др. **E1- 11924**

Наблюдение аномалии в спектре эффективных масс $(\pi^+\pi^-)$ мезонов с $M_{\pi^+\pi^-} = 0{,}40$ ГэВ/с^2 и $\Gamma < 0{,}03$ ГэВ/с^2 в реакции $np \to d\pi^+\pi^-$ при импульсе нейтрона $P_n = 1{,}73$ ГэВ/с

Представлен экспериментальный материал по исследованию реакций $np \to d\pi^+\pi^-$ и $np \to np\pi^+\pi^-$ при импульсах падающего нейтрона P_n = (1,73; 2,23) ГэВ/с. Получены сечения реакции $np \to d\pi^+\pi^-$ в интервале импульсов P_n = (1÷5) ГэВ/с. Наблюдена новая аномалия в спектре эффективных масс $M_{\pi^+\pi^-}$ реакции $np \to d\pi^+\pi^-$ при P_n = 1,73 ГэВ/с. Пик находится при $M_{\pi^+\pi^-} = 0{,}40$ ГэВ/с^2 и имеет полную ширину Γ меньше 0,03 ГэВ/с^2. Дан обзор экспериментальных данных по аномалии в районе масс 0,33 ГэВ/с^2. Для понимания природы особенностей в спектре масс $M_{\pi^+\pi^-}$ нужна теоретическая интерпретация.

Работа выполнена в Лаборатории высоких энергий, ОИЯИ.

Препринт Объединенного института ядерных исследований. Дубна 1978

Abdivaliev A. et al. **E1 - 11924**

Observation of Anomaly in the $(\pi^+\pi^-)$ Effective Mass Spectrum with $M_{\pi^+\pi^-} = 0.40$ GeV/c^2 and $\Gamma < 0.03$ GeV/c^2 in the Reaction $np \to d\pi^+\pi^-$ at a Neutron Incident Momentum of $P_n = 1.73$ GeV/c

Experimental data are presented on a study of the reactions $np \to d\pi^+\pi^-$ and $np \to np\pi^+\pi^-$ at incident neutron momenta P_n=(1.73; 2.23) GeV/c. The cross sections of the reaction $np \to d\pi^+\pi^-$ have been obtained in a range of momenta P_n= (1÷5) GeV/c. A new anomaly has been observed in the $M_{\pi^+\pi^-}$ effective mass spectra of the reaction $np \to d\pi^+\pi^-$ at $P_n = 1.73$ GeV/c. The peak position is at 0.40 GeV/c^2 and its full width is 0.03 GeV/c^2.

The investigation has been performed at the Laboratory of High Energies, JINR.

Preprint of the Joint Institute for Nuclear Research. Dubna 1978

INTRODUCTION

A series of experiments [2-6] have been recently carried out to study the so-called ABC-anomaly [1]. The ABC effect was clearly observed in the missing mass spectra $(mm)^\circ$ for the reactions

$$np \to d + (mm)^\circ \; [2], \tag{1}$$

$$dp \to {}^3He + (mm)^\circ \; [3], \tag{2}$$

$$dd \to {}^4He + (mm)^\circ \; [4]. \tag{3}$$

In the reactions, where the missing mass is positive,

$$pp \to d + (mm)^+, \tag{4}$$

$$dp \to t + (mm)^+ \tag{5}$$

no anomaly was observed. This fact was a foundation for a formal attribution of isospin $I=0$ to the anomaly. The experiments [2-4] were performed at incident momenta per nucleon P_0 = (1÷2) GeV/c. The peak position shifts to the right from 0.30 GeV/c^2 to 0.36 GeV/c^2 with increasing momentum P_0. The production cross section of the ABC-anomaly rapidly decreases with growing P_0. So, for $P_0 \simeq 2$ GeV/c the peak practically disappears. The full width of the anomaly, Γ, is about 60 MeV/c^2. To illustrate the significance of the effect, figure 1 presents experimental data on the reaction (3) for a deutron incident momentum of P_d = 2.5 GeV/c

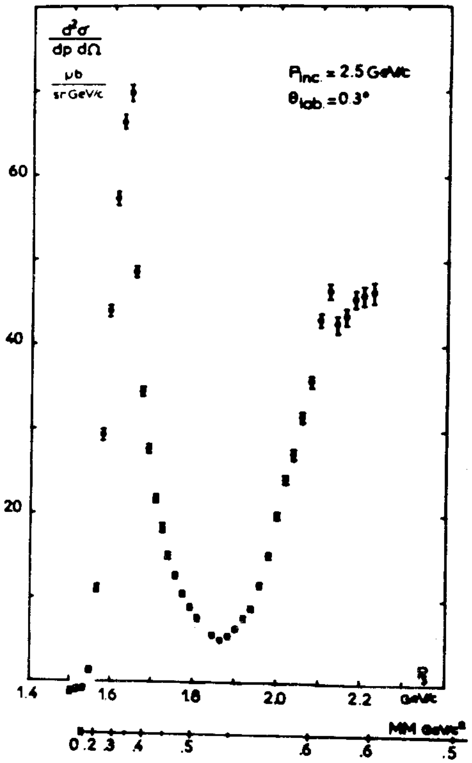


Fig. 1. ^{4}He nucleus momentum distributions in the laboratory system in the reaction dd → ^{4}He + + (mm)$^\circ$ at P_d = 2.56 GeV/c and θ_{He} = 0.3°.

at a detection angle of α-particles $\theta_{^4He}$ = = 0.3°. One can see a sharp peak corresponding to the ABC-anomaly.

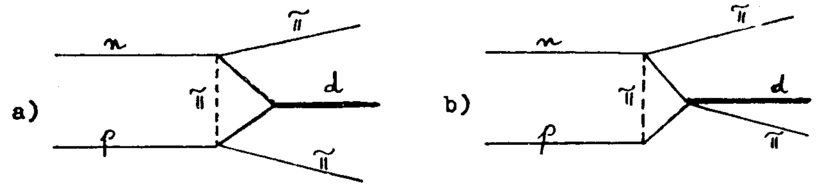
The reaction

$$np \to d\pi^+\pi^- \qquad (6)$$

has been studied in the continuous neutron spectrum P_n = (1 ÷ 4) GeV/c using the bubble chamber technique /5/.

Different theoretical models /7,8/ have been proposed to explain the ABC-anomaly. In particular, for the reaction (6) the contributions of the following diagrams are significant:

a) b)



This means that there are two important points in ABC-anomaly formation: πN scattering, in which the first isobar (Δ) dominates at small energy, and the deutron production formfactor.

It is interesting to note that an insignificant anomaly was observed at 0.45 GeV/c^2 (DEF) in studies of the reaction (2) in one of the missing mass spectra /4/ at P_d = =3.49 GeV/c and a registration angle of $\theta_{^3He}$ = 2.8°. In other reactions this peak was not observed.

Previously /6/ we presented some experimental data on the reaction (6) obtained in a neutron beam. In the $M_{\pi^+\pi^-}$ effective mass spectrum at P_n = 1.73 GeV/c we observed a new anomaly with a mass of 0.4o GeV/c^2 and a width of Γ < 0.03 GeV/c^2. This paper is a continuation of this study.

EXPERIMENTAL DATA

The JINR one-meter hydrogen bubble chamber was exposed to a quasimonochromatic neutron beam [9] obtained from the deutron stripping on an Al target. The momentum neutron spread $\Delta p/p$ did not exceed 3%. The angular spread of the beam was ~0.3 mrad. In this paper we present the experimental data at four neutron momenta: P_n=(1.73; 2.23; 3.83; 5.10) GeV/c.

About 70 000 3-prong events were treated. The fraction of unmeasurable events did not exceed 3%. The reaction $np \to d\pi^+\pi^-$ was selected by the χ^2-method followed by visual particle identification. At P_n= 1.73 and 2.23 GeV/c the numbers of events from the reaction (6) were 1447 and 697, respectively. The contamination from the other channels was not larger than a few per cent. At P_n= =3.83 and 5.10 GeV/c the separation of the reaction becomes difficult due to a large contamination. The use of the method of separation from different hypotheses [10] according to their relative probability makes it possible to estimate the cross section of the reaction (6) at P_n = 3.83 and 5.10GeV/c. The cross section σ_d of the process at all energies was determined by the formula

$$\sigma_d = \frac{N_d}{N_3}\sigma_3, \qquad (7)$$

where N_d is the number of events attributed to the reaction (6); N_3 is the total number of 3-prong events; σ_3 is the topological cross section of 3-prong events [11].

Figure 2 shows the reaction cross section versus the neutron momentum P_n. The cross sections, we have determined, are given in

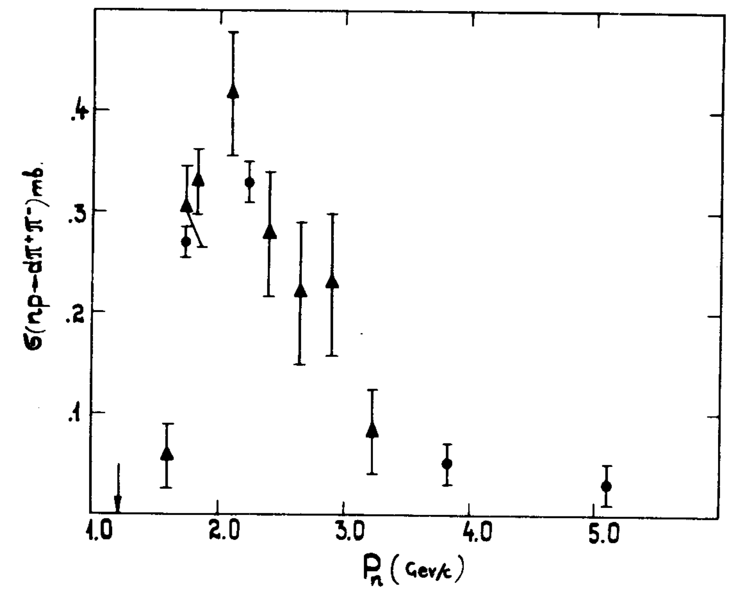


Fig. 2. The cross section of the $np \to d\pi^+\pi^-$ reaction versus neutron momentum.

the table. The cross sections, taken from paper [5], are denoted by triangles. It is seen that the cross section has its maximum in the vicinity of $P_n \simeq 2$ GeV/c, and then it sharply falls to a few tens of microbarns.

Table

P_n (GeV/c)	1.73	2.23	3.83	5.10
σ_d (mb)	0.270±0.015	0.330±0.020	0.050±0.020	0.030±0.020

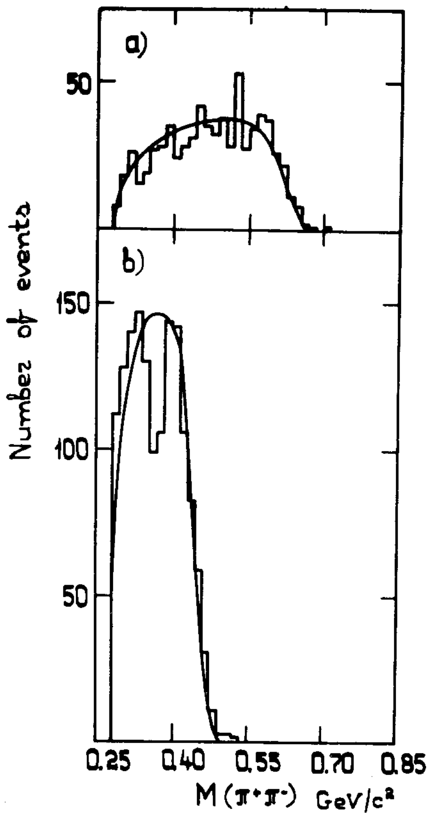


Fig. 3. The $M_{\pi^+\pi^-}$ effective mass in the reaction $np \to d\pi^+\pi^-$.
a) P_n = 2.23 GeV/c;
b) P_n= 1.73 GeV/c.
The solid line corresponds to the phase space curve.

In fig. 3 we present the $M_{\pi^+\pi^-}$ effective mass distributions. Here and later on the solid line corresponds to the phase space normalized to the total number of events. The lower histograms correspond to the data at P_n = 1.73 GeV/c, the upper ones at 2.23 GeV/c. The $M_{\pi^+\pi^-}$ experimental resolution is ~10 MeV/c^2. The upper histogram is satisfactorily described by the phase space curve while two anomalies are clearly seen in the distribution at P_n= 1.73 GeV/c. The maxima of the peaks are positioned at $M_{\pi^+\pi^-} \simeq$ 0.33 and 0.40 GeV/c^2. The full width of the second anomaly is Γ < 0.03 GeV/c^2. If the first peak corresponds to the ABC-anomaly, the second one is a new anomaly. If the phase space curve is normalized to the height of the maximum between the two peaks in the $M_{\pi^+\pi^-}$ distribution at P_n=1.73 GeV/c, the excess over such a background is ~6 standard deviations. The cross section of the second anomaly is ~20 microbarns.

In fig. 4 one can see the θ^* distribution in the c.m.s. of the reaction for deutrons and $\pi^\pm$-mesons. Due to the isotopic symmetry of the reaction (6), the angular distributions of π^+-mesons are added to the mirror reflected distributions for π^-- mesons. It should be noted that all the distributions for isotopically conjugated values are in good agreement. From fig. 4 it is seen that the angular distributions of deutrons and $\pi^\pm$-mesons are close to isotropic ones.

Figure 5 gives the distributions over $\cos\phi^*$ between π^+- and π^--mesons in the c.m.s. of the reaction. It is seen that the number of events decreases at P_n=1.73 GeV/c near $\phi^* \simeq 0°$. It has been found that the number of events for $1 < \cos\phi^* < 0.2$, $0.2 < \cos\phi^* < -0.2$ and $-0.2 < \cos\phi^* < -1$ practically coincides with the number of events in the first peak, between the peaks and in the second peak (fig. 3b). Figure 6 presents the momentum distributions of deuterons in the c.m.s. Here one can also see two enhancements at P_n = 1.73 GeV/c which are in agreement with the data of fig. 3b. In fig. 7 we present the $\pi^\pm$ momentum distributions in the c.m.s.

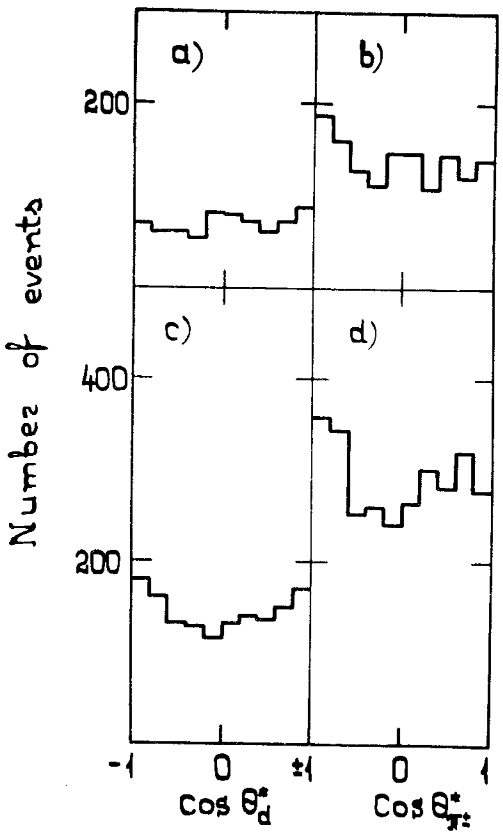


Fig. 4. The angular distributions in the c.m.s. of the reaction $np \to d\pi^+\pi^-$ for deutrons and $\pi^\pm$-mesons. a), b) P_n = 2.23 GeV/c and c),d) P_n =1.73 GeV/c.

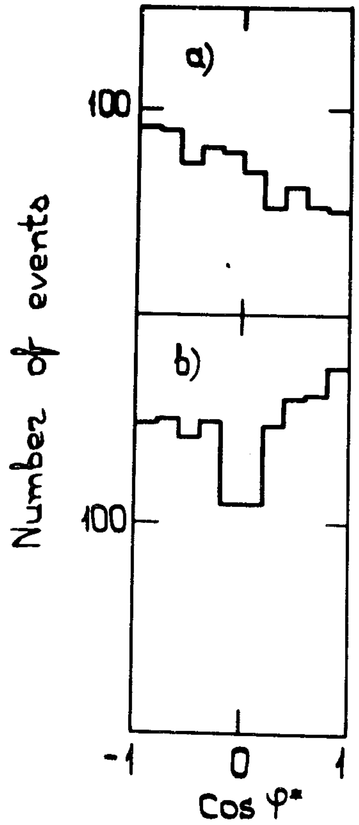


Fig. 5. Distributions over $\cos\phi^*$ between π^+ and π^- mesons in the c.m.s. of the reaction $np \to d\pi^+\pi^-$.
a) P_n=2.23 GeV/c;
b) P_n= 1.73 GeV/c.

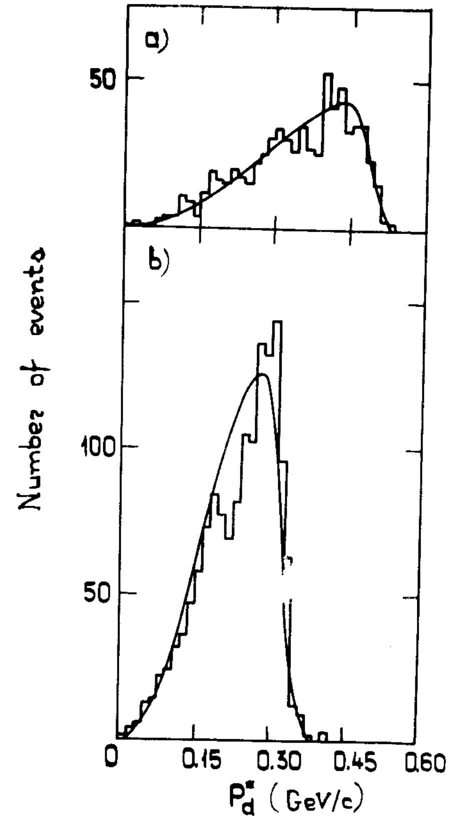


Fig. 6. Deutron momentum distributions in the c.m.s. of the reaction $np \to d\pi^+\pi^-$.
a) P_n= 2.23 GeV/c; b) P_n = 1.73 GeV/c. The solid line corresponds to the phase space curve.

Figure 8 shows the $M_{d\pi^\pm}$ effective mass distributions. One can observe an excess over the phase curve. Such an effect is

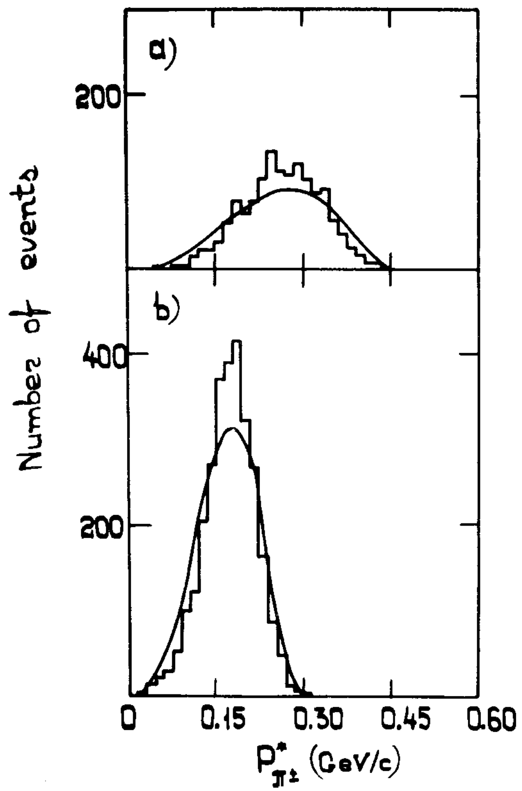


Fig. 7. $\pi^\pm$ momentum distributions in the c.m.s. of the reaction $np \to d\pi^+\pi^-$.
a) $P_n = 2.23$ GeV/c; b) $P_n = 1.73$ GeV/c. The solid line corresponds to the phase space curve.

often interpreted as a d* anomaly. The mean value of $M_{d\pi^\pm}$ is shifted to the right from 2.11 GeV/c^2 at $P_n = 1.73$ GeV/c to 2.19 GeV/c^2 at $P_n = 2.23$ GeV/c.

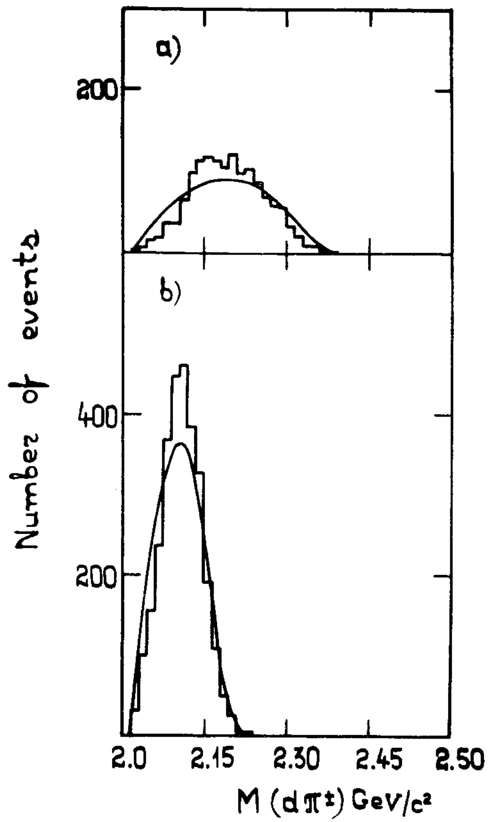


Fig. 8. The $M_{d\pi^\pm}$ effective mass in the reaction $np \to d\pi^+\pi^-$.
a) $P_n = 2.23$ GeV/c;
b) $P_n = 1.73$ GeV/c.
The solid line corresponds to the phase space curve.

It is of interest to compare the experimental distributions for the reaction $np \to d\pi^+\pi^-$ with the data for the reaction

$$np \to np\pi^+\pi^-, \qquad (8)$$

where the secondary neutron and proton are not bound together to deuteron. We present some experimental data at $P_n = 1.73$ and

2.23 GeV/c. Reaction (8) was selected by the χ^2 method with a subsequent visual identification of secondary particles. The contamination from the other channels was not larger than 5%. The numbers of events are 834 and 3585, and the cross sections of the reaction (8) are (0.55 ± 0.05) mb and (4.05 ± 0.25) mb at $P_n = 1.73$ GeV/c and 2.23 GeV/c, respectively.

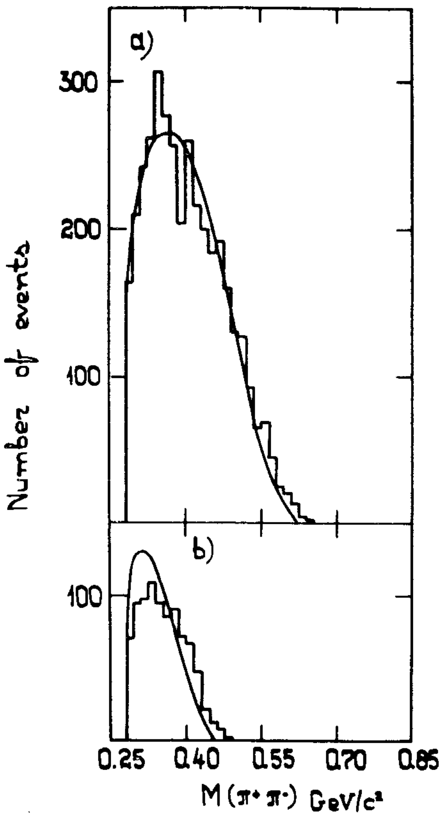
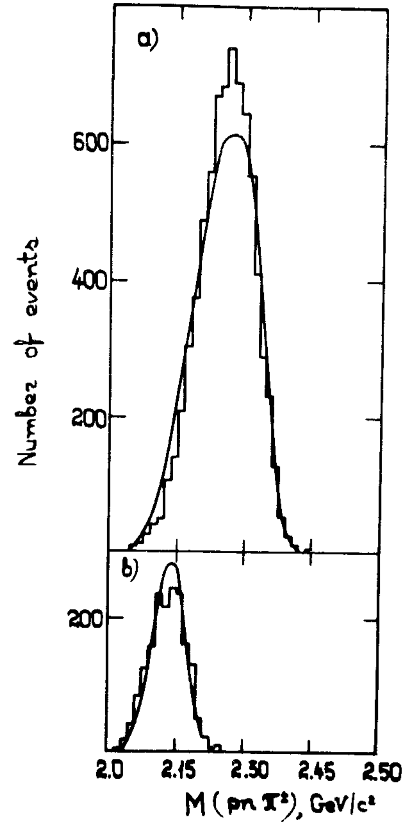


Fig. 9. The $M_{\pi^+\pi^-}$ effective mass in the reaction $np \rightarrow np\pi^+\pi^-$. a) $P_n = 2.23$ GeV/c; b) $P_n = 1.73$ GeV/c. The solid line corresponds to the phase space curve.

In fig. 9 we present the $M_{\pi^+\pi^-}$ effective mass distributions from the reaction $np \rightarrow np\pi^+\pi^-$.One can see that there are no significant peaks in these effective mass distributions. The $M_{pn\pi^\pm}$ effective mass distributions are given in fig. 10. The mean value of $M_{pn\pi^\pm}$ is shifted to the right from 2.12 GeV/c^2 at $P_n = 1.73$ GeV/c to 2.25 GeV/c^2 at $P_n = 2.23$ GeV/c.

Fig. 10. The $M_{pn\pi^\pm}$ effective mass in the reaction $np \rightarrow np\pi^+\pi^-$
a) $P_n = 2.23$ GeV/c;
b) $P_n = 1.73$ GeV/c. The solid line corresponds to the phase space curve.



CONCLUSION

The peak with a mass of 0.40 GeV/c^2 is not observed in the reactions $np \to d + (mm)^\circ$ [2] at P_n = 1.88 GeV/c and $np \to d\pi^+\pi^-$ [5] at P_n< 1.83 GeV/c. For the first reaction the missing mass spectrum is preliminary and can be changed by (10-20)%. Moreover, the experimental resolution mass $(mm)^\circ$ was insufficient to observe the two anomalies. In the second reaction the absence of the anomaly can be explained by a wide momentum spectrum of incident neutrons, i.e., the position of the ABC-anomaly is shifted with changing momentum P_n.

Thus, a new anomaly is observed in the $M_{\pi^+\pi^-}$ effective mass spectrum for the reaction $np \to d\pi^+\pi^-$ at P_n = 1.73 GeV/c. The peak position is at 0.40 GeV/c^2, and its full width is $\Gamma < 0.03$ GeV/c^2. For understanding the nature of the anomaly, a theoretical interpretatuon is needed.

REFERENCES

1. Abashian A., Booth N.E., Crowe K.M. Phys.Rev.Lett., 1960, 5, p.258, 1961, 7, p.35. Abashian A. et al. Phys.Rev., 1963, 132, p.2296.
2. Bizard G. et al. Caen-Saclay Collaboration, Proc. 5th Int. Conf. on High Energy Phys. and Nuclear Structure, Uppsala, Sweden, 1973.
3. Banaigs J. et al. Nucl.Phys., 1973, B67, 1.
4. Banaigs J. et al. Nucl.Phys., 1976, B105, p.52.
5. Bar-Nir I. et al. Nucl.Phys., 1973, B54, p.17.
6. Abdivaliev A. et al. JINR, 1-10034, Dubna, 1976.
7. Barry G.W. Nucl.Phys., 1975, B85, p.239.
8. Bar-Nir I. et al. Nucl.Phys., 1975, B87, p.109.
9. Gasparian A.P. et al. JINR, 1-9111, Dubna, 1975.
10. Moroz V.I. et al. Yad.Fiz., 1967, 6, p.90.
11. Abdivaliev A. et al. JINR, 1-8565, Dubna, 1975, Nucl.Phys., 1975, B99, p.445.

Received by Publishing Department
on October 3 1978.