Краткие сообщения ОИЯИ №2[35]-89 *JINR Rapid Communications No.2[35]-89*
УДК 539.126.34

INVESTIGATION OF ANOMALOUS PION PRODUCTION IN THE REACTION Cu(p, π^+)X BY 350 MeV PROTONS

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The narrow structure in the energy dependence of the charged pion yields generated by protons on the copper nucleus at 90° in the laboratory frame was investigated. A new upper limit of the structure width (FWHM) $\Delta T_p \leqslant 5$ MeV in the incident proton energy is obtained. For the first time the manifestation of the structure is observed at 115 and 125° angles in the laboratory frame on the same nucleus.

The investigation has been performed at the Laboratory of Nuclear Problems, JINR.

Исследование аномального рождения пионов в реакции Cu(p, π^+) X при энергии протонов 350 МэВ

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Подтверждено наличие узкой структуры в энергетической зависимости выхода заряженных пионов, генерированных протонами на ядре под углом 90° в лабораторной системе. Получена новая верхняя граница ширины структуры $\Delta T_p \leqslant 5$ МэВ по энергии падающего протона. Впервые наблюдено проявление этой же структуры под углами 115 и 125° в лабораторной системе на том же ядре.

Работа выполнена в Лаборатории ядерных проблем ОИЯИ.

In recent years the investigations of inelastic channels of intermediate energy proton interactions (energies of the operating meson physics facilities) with nucleons and nuclei have aroused greater interest. For proton-nucleus interaction this energy region is of special interest, since collective phenomena, for example, formation of bound states of the isobar in the nucleus or dibaryonic states, can manifest themselves here.

At the end of the 70s in the Laboratory of Nuclear Problems (JINR, Dubna) collaborating with INR (Moscow) the investigation of π-meson production process in proton-nucleus interactions began /1/. Observation of anomaly in the energy dependence of charged pions yield at 90° in collision of protons and copper nuclei[2] was one of the interesting results. The anomaly consisted in dramatic changes in the shape of the inclusive spectrum of generated pions through enrichment of the low energy part of the spectrum at the incident proton energy 350 MeV. In 1984 similar measurements in the experiment at the Saturne accelerator (Saclay) confirmed the existence of the narrow structure in incident proton energy[3].

For explanation of the observed anomaly the dibaryonic interpretation seems very attractive. This mechanism was qualitatively considered in papers[2-5]. There is another explanation based on the assumption that creation of the bound delta-isobar in a nucleus causes additional low energy pions[6]. To clear up the nature of the observed effect, it is necessary to continue experimental investigations.

In 1987 new experiments began at the phasotron of LNP (Dubna). Here we report the first results.

The experimental setup[7] consisted of a time-of-flight (TOF) spectrometer and a scintillation total absorption spectrometer. TOF, total energy and energy losses in TOF-system scintillation counters allow quite reliable identification of the type of outgoing charged particles (pions, protons, deuterons, ...) and determination of their initial energy. The energy threshold value for the registration of pions was 20 MeV. The proton beam was characterised by the energy spread $\Delta T/T = 0.5 - 1.0\%$, the intensity $J = 10^8 - 10^9\,s^{-1}$, the possibility of continuous variation of the proton energy from 50 to 650 MeV. For accurate determination of the proton beam energy and the energy spread another TOF-system with the intrinsic energy-resolution ~180 ps was used. The TOF-system allowed us to control the beam energy characteristics and to optimise its resolution.

Double differential cross sections of charged pion production on the copper nucleus were measured at the angles of 90,115 and 125°. At each angle the measurement was performed for six-eight proton energies (326, 344, 348, 352, 353, 361, 369 and 409 MeV). Particular attention was given to the measurement in the energy region corresponding to the earlier observed anomaly.

The spectrum shape parameter of the generated pions is shown in Fig. 1 as a function of the incident proton energy. The parameter of spectrum shape is the yield ratio of lower energy pions to higher energy pions. In Fig. 1 the yield ratios of 20-60 MeV pions to 60 – 100 MeV ones are presented. A distinct anomaly is observed near $T_p = 350$ MeV confirming the earlier noticed phenomenon[1,2]. From the presented results one can see that the structure width is ≤5 MeV.

To interpret this structure it is important to investigate its manifestations at angles other than 90°. Fig. 2 shows the results of the si-

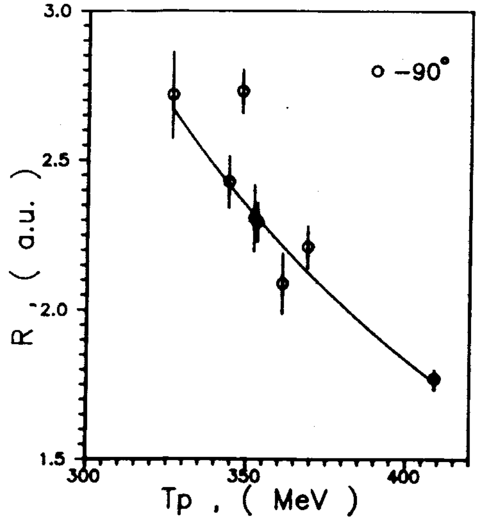

Fig. 1. Yield ratios of low energy pions (20 – 60 MeV) to high energy pions (60 – 100 MeV) versus the incident proton energy for the angle 90° in the laboratory frame. The solid line fits all points except that at $T_p = 348$ MeV by a power function.

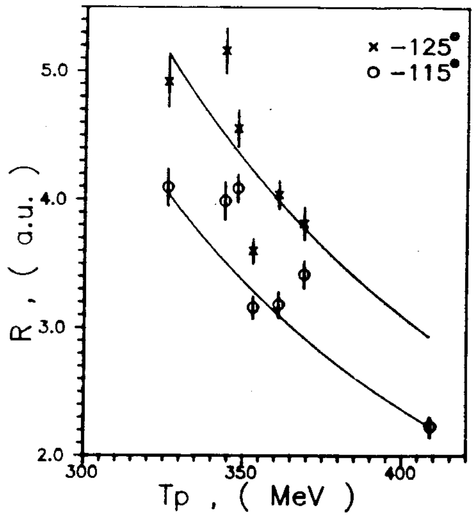

Fig. 2. The same as in fig. 1 for the angles 115 and 125°. The solid lines are to guide the eye.

milar measurements at 115° and 125°. As is seen the resonance-like structure takes place at these angles too, though lower statistics.

The main feature of observed effect is its narrowness in energy of incident protons. This fact allows the assumption that the effect is related to the interaction of incident protons with the whole nucleus or with its part. In the case of nucleon-nucleon interaction the momentum distribution of bound nucleons must lead to a structure width much larger than 5 MeV. If the momentum of the incident proton is transferred to the whole nucleus, the incident energy 350 MeV corresponds to the threshold production of the dibaryon with the mass 2220 MeV. If a 350 MeV proton interacts with a single nucleon at rest, it corresponds to the dibaryon mass 2040 MeV. The maximum pion energy from the decay of this state is 25 MeV. So it is difficult to observe the contribution of the pions to the spectrum when the setup has the 20 MeV cut of pion energy.

The main argument in favour of the dibaryonic interpretation of the anomaly in question is its narrowness. It is necessary to search for it in all possible experiments. Since the dibaryonic effect is expected to be small, it is important to choose the optimum processes and kinematic conditions.

The process selected in this way has some advantages. One of them is caused by the predicted vanishing of the dibaryon resonance elasticity[8, 9], which makes it preferable to search for their signal in the inelastic process of pion production. Another important factor is the use of the nuclear process. The nucleus can serve as a kind of filter to separate definite channels, dibaryonic in our case, and to suppress other ones.

To understand this interesting phenomenon new experiments are necessary for other nuclei, for generated pions of different sign.

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Received on February 24, 1989.