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CUMULATIVE PRODUCTION OF PROTONS AND Λ -HYPERONS IN THE INTERACTIONS OF FAST NEGATIVE PIONS AND NEUTRONS WITH CARBON NUCLEI

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CUMULATIVE PRODUCTION OF PROTONS AND Λ -HYPERONS IN THE INTERACTIONS OF FAST NEGATIVE PIONS AND NEUTRONS WITH CARBON NUCLEI

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Кумулятивное образование протонов и Λ-гиперонов во взаимодействиях быстрых π^--мезонов и нейтронов с ядрами углерода

Исследуется инклюзивное образование протонов и Λ-гиперонов во взаимодействиях $\pi^- \, ^{12}C$ при p_{π^-} = 4,0 ГэВ/с и $n \, ^{12}C$ при $\langle p_n \rangle$ = 7,0 ГэВ/с в кинематической области, запрещенной для реакций на свободном нуклоне. Обнаружено, что поведение поляризации Λ-гиперонов в функции угла вылета в пределах ошибок эксперимента не зависит от природы и энергии бомбардирующих частиц.

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Cumulative Production of Protons and Λ-Hyperons in the Interactions of Fast Negative Pions and Neutrons with Carbon Nuclei

The inclusive production of protons and Λ-hyperons outside the kinematical region for the reactions on free nucleons, in $\pi^- \, ^{12}C$ at P=4.0 GeV/c and in $n \, ^{12}C$ at $\langle p_n \rangle$=7.0 GeV/c has been investigated. The behaviour of the Λ-hyperon polarization as a function of emission angle does not depend on the nature of the incident particle used and on its energy.

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

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The hypothesis on cumulative production of particles on nuclei, brought up by A.M.Baldin [1], and its confirmation in experiments [2] have initiated a large number of experimental and theoretical works [3]. The assumption that the local characteristics of the interaction itself, but not the geometrical features of interacting particles [1], are the most important for cumulative particle production, has been confirmed in various experiments.

Thus the extension of the scaling invariance concept up to the interactions of elementary particles and relativistic nuclei with nuclei permitted one to explain basic features of the effect considered.

On the other hand, it is evident that one is in great need of more detailed experimental information which would permit one to reduce the presently existing multitude of theoretical models based on various physical premises and more or less successfully explaining experimental data.

A study of the cumulative production of protons and Λ-hyperons, using the same experimental methods, seems to help one to refine the physics of the phenomenon. Protons are included in the target nuclei and should thereby carry information on its state just at the moment of interaction. On the contrary, the Λ-hyperons are produced in the interaction act and are able to reflect its characteristics. Moreover, parity violation in the weak Λ decay permits one to easily measure their polarization, the existence of which is critical for all theoretical conjectures. The only experimental work, in which the production of cumulative Λ-hyperons has been studied and their polarizations have been measured, was performed in the $\pi^- + A(C, Xe) \to \Lambda + X$ reaction at 2.9 *GeV/c*[4]. There exists only one theoretical model[5] which semiquantitatively explains this fact and predicts the polarization independence of the nature and energy of the incident particle.

Preliminary results have been obtained in the reactions

$n + {}^{12}C \to \Lambda + X$	~3400 events	(1)
$n + {}^{12}C \to mp + X,\ m=2\div 6$	~13700 events	(2)
$\pi^- + {}^{12}C \to \Lambda + X$	~1100 events	(3)
$\pi^- + {}^{12}C \to mp + X,\ m=2\div 6$	~2000 events	(4)

studied in the 55 *cm* JINR propane bubble chamber exposed to neutron and π^--meson beams at $\langle p_n \rangle = 7.0$ and $p_{\pi^-} = 4.0$ *GeV/c*, respectively. The data processing methods have been described earlier[6].

CUMULATIVE Λ-HYPERONS

Lambda-hyperons cannot be produced via the reaction (3) on a rest nucleon at emission angle θ_Λ in the laboratory system if $\cos\theta_\Lambda < 0.64$. The neutron momenta initiating the reaction (1) had a Gaussian distribution with a standard deviation of 2.84 *GeV/c*. Therefore we took as a limiting angle $(\cos\theta_\Lambda)_{max} = 0.637$ which corresponded to a neutron momentum of 11 GeV/c.

The distributions $\frac{E}{p^2}\frac{dN}{dp} = \frac{1}{p}\frac{dN}{dT} = \sum_{i \in \Delta T} \frac{1}{p_i}$, where p, E, T are the momentum, energy and kinetic energy of Λ-hyperon, are shown in *figure 1*. We failed to fit the experimental points by the exponent e^{-aT} (solid curves). The hypothesis cannot be considered to be significant due to the high χ^2 values obtained.

The polarization of hyperons was defined using the $\Lambda \to p + \pi^-$ decay angular distribution

$$W(\theta_p^*) = \frac{1}{2}(1 + \alpha P \cos\theta_p^*),$$

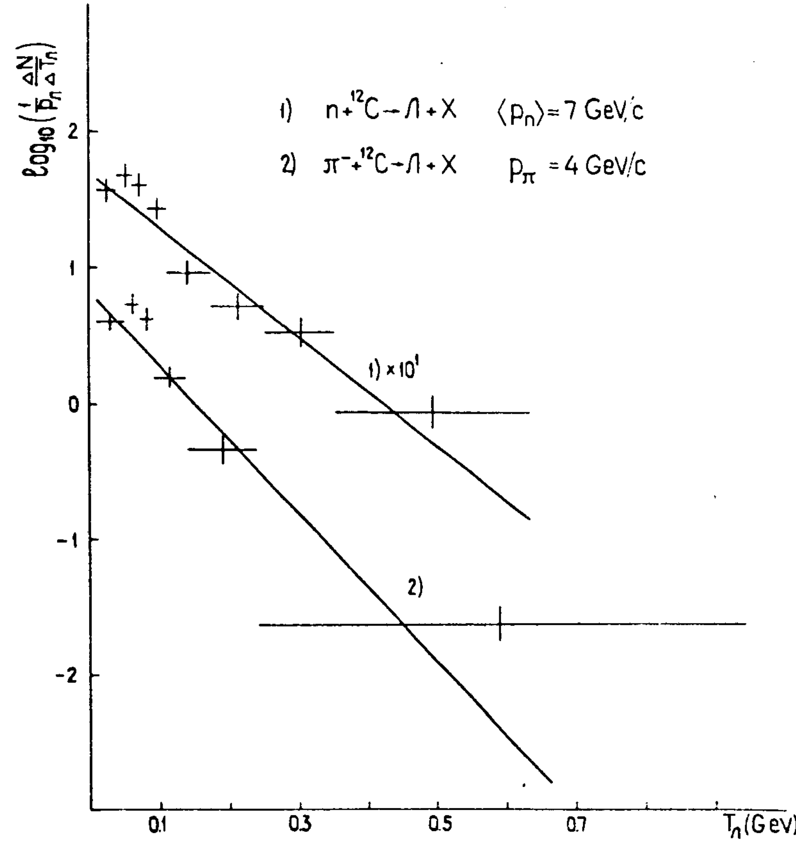

Fig. 1

where $\cos\theta_p^* = \vec{p}_p^{\,*} \cdot \vec{n}$, $\vec{n} = \vec{p}_\Lambda \times \vec{p}_n / |\vec{p}_\Lambda \times \vec{p}_n|$, $\vec{p}_p^{\,*}$ is the proton momentum in the Λ-hyperon rest frame. We made use of the method of moments according to which the polarization is equal to $P = \frac{1}{\alpha} \langle \cos\theta_p^* \rangle / \langle \cos^2\theta_p^* \rangle$. If the Λ-hyperon detection efficientcy does not depend on $\cos\theta_p^*$ or is its even function, this method ensures the correct determination of polarization[7]. For the sake of control we have calculated the polarization taking into account the detection efficiency according to the known expression $P = \frac{3}{\alpha}\langle \cos\theta_p^* \rangle_W = \frac{3}{\alpha}\sum_i W_i \cos\theta_{pi}^* / \sum_i W_i$. Both methods resulted in well consistent values of polarization. The Λ -hyperon polarization versus its emission angle in the laboratory system is shown in *figure 2*. It is clearly seen that the Λ -hyperons produced via both reactions reveal a very similar dependence of the polarization on emission angle. One can state that the maximal polarization occurs in both cases at $\theta \sim 90°$. The last result

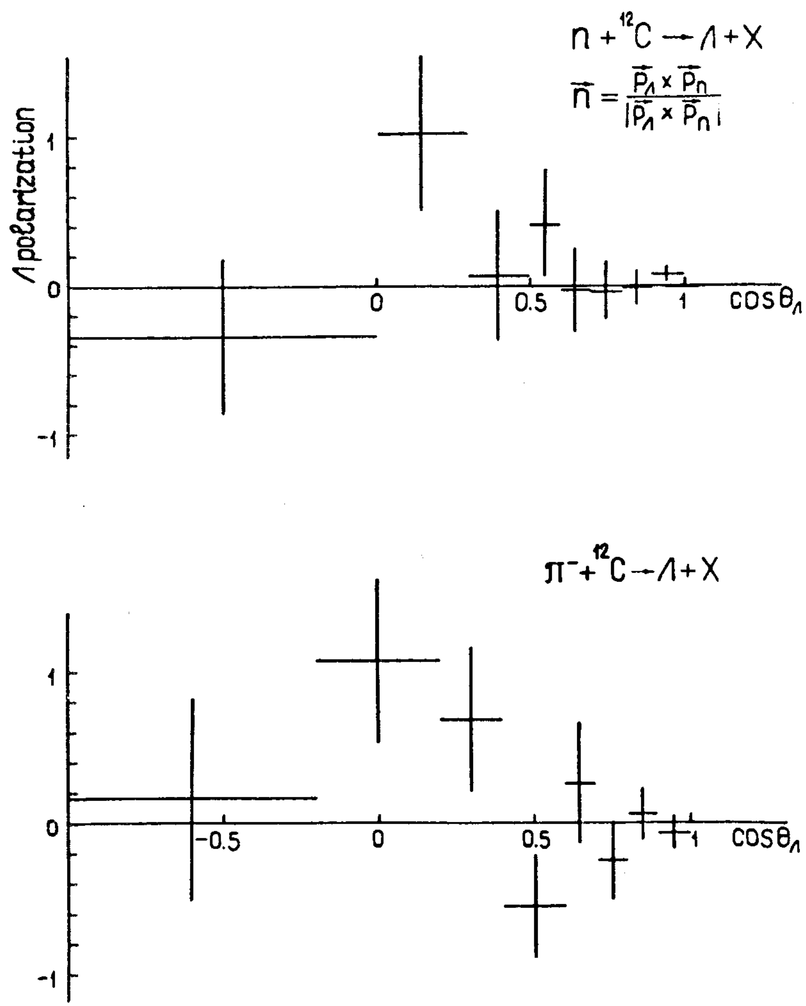

Fig. 2

is in agreement with the results of the above paper [4] (different signs are due to the opposite choice of positive sign of the normal $\vec{n}$ to the reaction plane). The independence of the results obtained of the nature and energy of the incident particles affirms a quark-parton version of the cumulative Λ -hyperon production. [5]

PROTONS, EMITTED AT ANGLES LARGER THAN 90°

Unlike pions and Λ -hyperons, protons are included in nuclei, therefore it is natural to expect that various intranuclear processes will superimpose on the process in question complicating thereby the physical picture. It has been noted earlier [8,9] that the invariant effective cross section for proton production in the backward hemisphere cannot be described by a simple exponent as a function of kinetic energy T. At $T < 30$ *MeV* the cross section has a steep slope and at $T > 30$ *MeV* it became an "ordinary" cumulative exponent. Probably, slow protons ($T < 30$ *MeV*) are due to the evaporation process.

The $\frac{1}{p}\frac{dN}{dT}$ distributions for protons emitted in the backward hemisphere for the reactions (2) and (4) are shown in *figures 3,4*. As errors, the 2.3 standard deviations are shown. We have tried to fit the experimental points with a sum of two exponents (solid lines). The results of the fit will be given in a more detailed paper. A preliminary analysis has shown that the sum of two exponents does not describe the experimental distributions. It is seen that, besides the steepest slope for the domain $T < 30$ *MeV*, one can distinguish three more peculiarities.

1. In the region $30 < T < 150$ *MeV* the distributions are not exponential.
2. At $T > 150$ *MeV* the slope reduces.
3. The distributions for all proton multiplicities as well as for the nature and energy of the incident particles are similar which is in agreement with the results of recent paper [10].

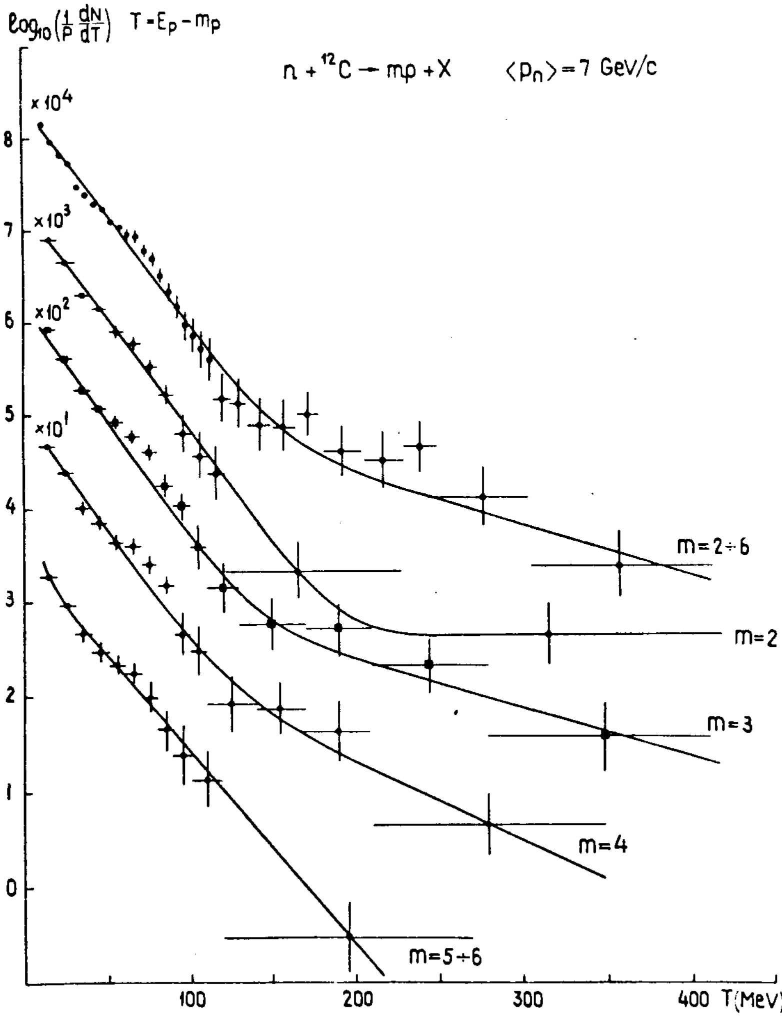

Fig. 3

To investigate the angular dependence of the results obtained, the same distributions have been found in three $\cos\theta_p$ intervals: $-1 \div -\frac{2}{3}$; $-\frac{2}{3} \div -\frac{1}{3}$; $-\frac{1}{3} \div 0$. The above results are the same in each angular interval. This fact shows also that the losses of protons emitted near

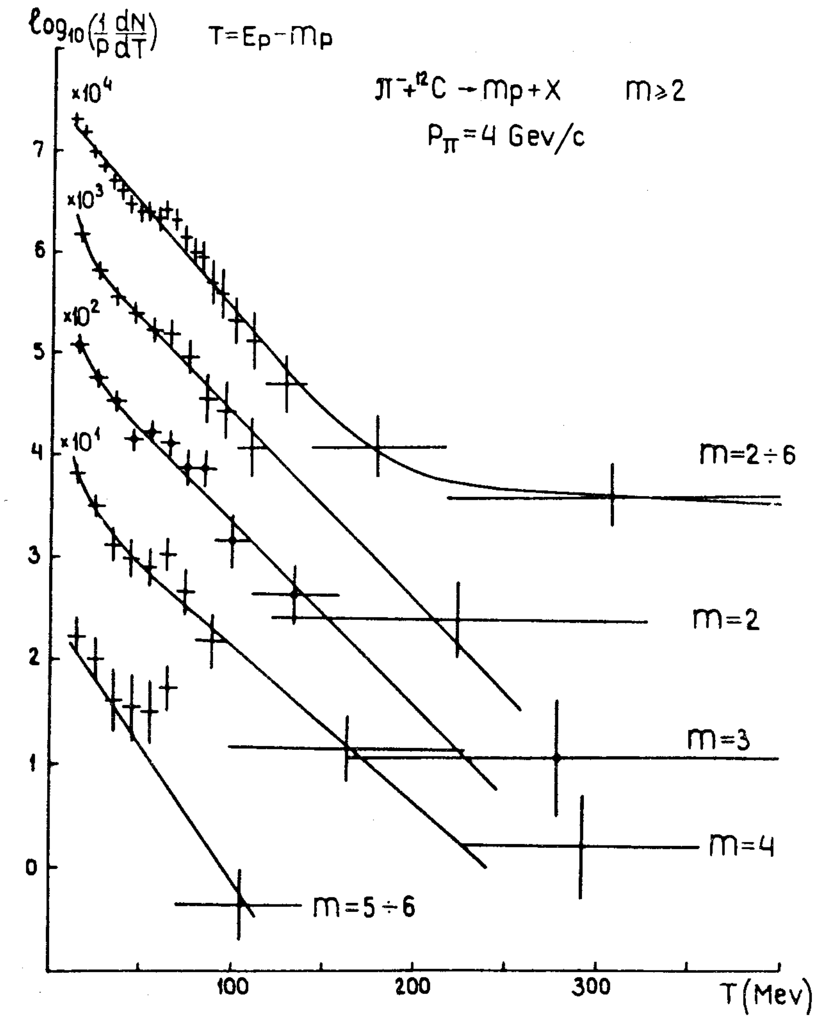

Fig. 4

90° do not affect the results. The restrictions imposed on proton momentum measurement errors and the variation of the fiducial volume also have no influence on our conclusions.

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