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STUDY OF CHARGED MULTIPLICITY IN CUMULATIVE PION PRODUCTION

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The power value of the A-dependence of the cross section for $4.5 \cdot A$ GeV/c deuteron fragmentation into cumulative pions has been measured on carbon, aluminium, copper and lead nuclei for cumulative numbers within 0.8 — 1.2. The mean value is equal to 0.27 ± 0.09 in this interval.

The target atomic weight dependence significantly differs from the volume type dependence on the atomic weight of fragmenting nucleus. A multiplicity of a target nucleus fragmentation points on a peripheral character of the process.

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

Изучение зарядовой множественности при рождении кумулятивных пионов

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Измерен показатель степени A-зависимости сечения фрагментации дейтронов с импульсом 4,5 · A ГэВ/с в кумулятивные пионы на ядрах углерода, алюминия, меди и свинца для кумулятивных чисел в пределах 0,8 — 1,2. Средняя величина для этого интервала равна 0,27 ± 0,09. Эта зависимость от атомного веса мишени существенно отличается от зависимости объемного типа, характерной для фрагментирующего ядра. Множественность указывает на периферический характер изучаемого процесса.

Работа выполнена в Лаборатории высоких энергий ОИЯИ.

1. Introduction

Observation of relativistic deuteron fragmentation into cumulative pions, i.e., pions produced in a region kinematically forbidden for nucleon-nucleon collisions, initiated detailed studies of the secondary particle spectra over a wide range of fragmenting nuclei [1,2]. The measurements were performed in a target nucleus fragmentation region. An experiment with a cumulative particle produced in the projectile fragmentation region could enable us to study correlated phenomena in target nucleus. The dependence of the projectile nucleus fragmentation cross section on the atomic weight of the target nucleus gives one a possibility of studying an interaction between a cumulative particle and a target nucleus.

The A-dependence is usually described by a power law parameterization, A^{α}. The parameter α, as a function of the cumulative number, is useful for an understanding of mechanism of cumulative pion production and verification of the so-called «cold» and «hot» models of cumulative production. On the other hand, its value is important for experimental design purposes.

Let us define a kinematical region for cumulative production. The minimum fractions of the 4-momenta per nucleon of colliding nuclei, X_I and X_{II}, satisfying the energy-momentum conservation law for particle production with a given momentum and mass is expressed by the following relativistic invariant equation for a squared minimum 4-momentum of reaction recoil [4]:

$$\left(X_I P_I + X_{II} P_{II} - P_1\right)^2 = \left(X_I m_0 + X_{II} m_0 + m_2\right)^2,$$

where P_I and P_{II} are the 4-momenta of colliding nuclei per nucleon; P_1, the 4-momentum of produced particle; m_0, nucleon mass; m_2, the mass of additional particles needed to satisfy quantum number conservation laws. Putting $X_{II} = 1$ for the target nucleus, one can derive an expression for X_I (projectile nucleus) with mass corrections taken into account [3,4] (for pions $m_2 = 0$):

$$X_I = \frac{(P_{II} P_I) + m_0 m_2 + (m_2^2 - m_1^2)/2}{\left(P_I P_{II}\right) - m_0^2 - \left(P_I P_1\right) - m_0 m_2}.$$

We begin to study target dependence of 4.5 GeV/c per nucleon deuteron fragmentation into straightforward produced pions beyond kinematical limit of nucleon-nucleon collisions in a projectile nucleus fragmentation region which corresponds to $X_I > 1$ or longitudinal momentum $P_z > 3$ GeV/c. It corresponds to a situation when more than one nucleon transfers its energy to a pion.

2. Experiment Description

The measurements were taken on a 4.5·A GeV/c deuteron beam with an intensity of 10^6 per cycle on Dubna Synchrophasotron. The magnetic spectrometer includes (see fig.1):

- a primary beam monitoring telescope consisting of three scintillation counters;
- a changeable target placed at 700 cm in front of the magnet center;
- a two-layer cylindrical scintillation hodoscope intended for a total and hard charged multiplicity tagging in an azimuthal angle from 20° to 90°;
- a dipole frame type magnet with a 68 cm gap; the poles are 100 cm wide and 150 cm long; the maximum field in the magnet center is 0.82 T;
- a high-pressure gas threshold Cherenkov counter;
- two 16×16 cm^2 hodoscopes; each hodoscope consists of two planes containing 16 counters $160\times9\times3$ mm^3 in size;
- four three-coordinate hodoscopes with an area of 1 m^2.

The angular acceptance of the setup is about 10^{-4}sr and the momentum acceptance extends from 2.5 to 6 GeV/c.

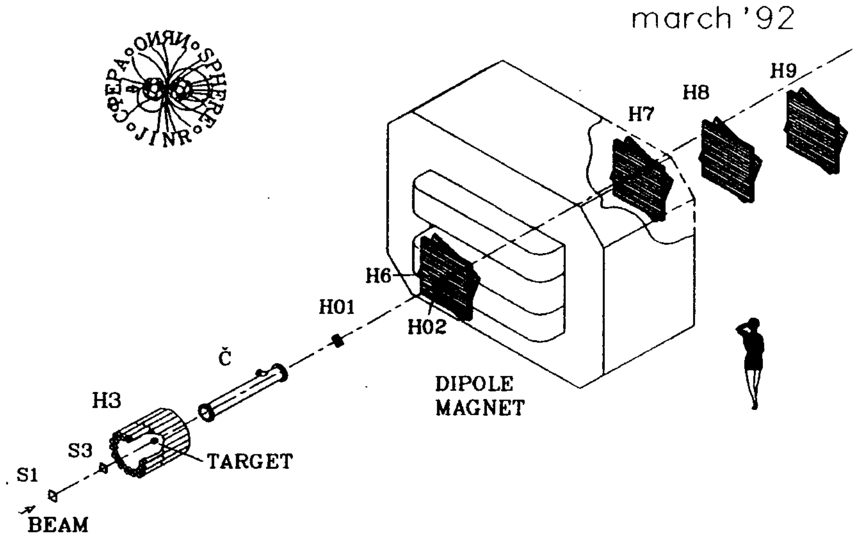

Fig.1. Spectrometer layout

About 19000 triggers were recorded on carbon, aluminium, copper, lead and empty targets during a 20h run. Each target was exposed to a total flux of $\approx 1 - 2 \cdot 10^9$ deuterons. The thickness of each target was about 5 g/cm^2.

3. Data Analysis and Conclusions

Cross-sections per nucleon of target nuclei are shown in fig.2. In assumption of the $A^{\alpha - 1}$ dependence the mean value of a parameter for the interval $0.8 < X_I < 1.2$ is found to be equal to:

$$\alpha = 0.27 \pm 0.09.$$

The obtained value seems to indicate a peripheral character of the interaction between a target nucleus and a deuteron fragmenting into a cumulative pion [5]. Formerly similar conclusions were drawn by the Berkeley group [6] for a fragmentation of light relativistic nuclei into pions — a power value of 0.4 was obtained for α-particles. For a lead to carbon ratio of cross sections (fig.3) we observe a weak X-dependence which is in a correspondance with a limiting fragmentation picture of a cumulative production. Charged multiplicity distributions are shown in fig.4. The mean values as well as fractions of hard component ($P_T > 600$ MeV/c) show a weak dependence on an atomic weight of a fragmenting nucleus.

The cumulative pion production and correlated phenomena should be studied in more detail since the spectra of cumulative pions are considered to be a manifestation of a quark-parton structure function of nucleus [4]. From this point of view our approach permits «tagging» of cumulative production and opens up possibility of studying details of the hadronization processes in correlation measurements. Besides, it appears to be particularly interesting to study nuclear collisions in a region where both X are essential. For instance, highly inelastic collision could lead to a dramatic change of a power of the A-dependence. In this case a cumulative particle tag a process of collision of high momentum components in both nuclei or fluctuations of nuclear density.

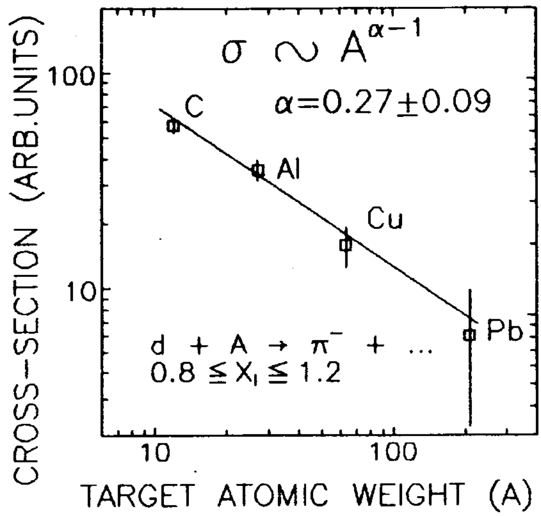

Fig.2. A-dependence of the cross section per nucleon of a target nucleus

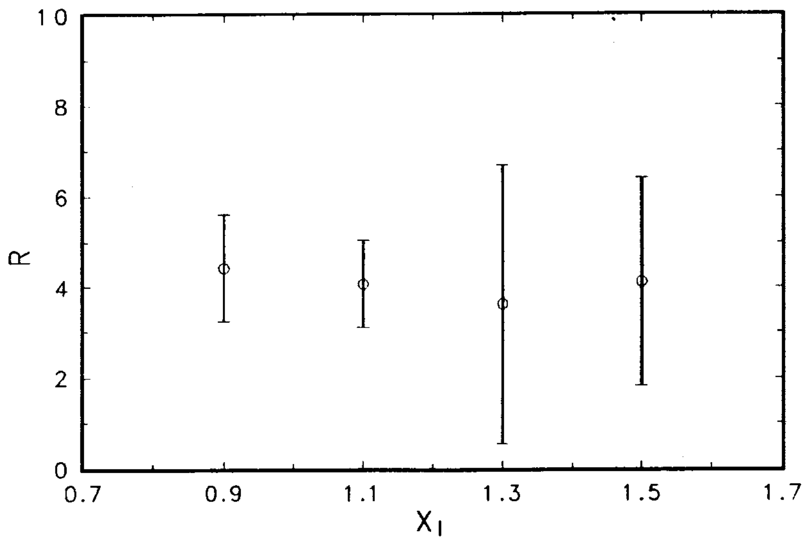

Fig.3. Lead to carbon ratio (R) vs a cumulative number (X_I)

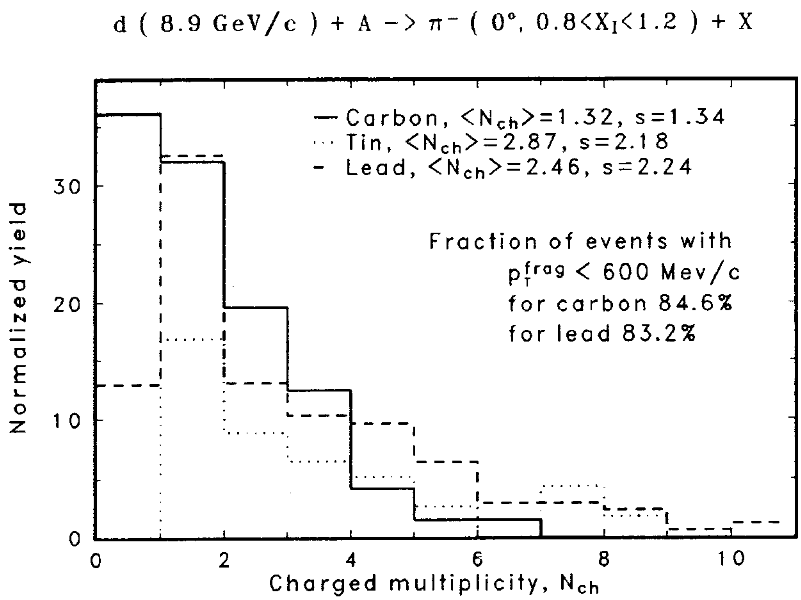

Fig.4. Charged multiplicity distributions for a deuteron fragmentation on carbon, tin and lead nuclei

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