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AN EXPERIMENT ON THE *A*-DEPENDENCE OF THE CROSS SECTION FOR RELATIVISTIC DEUTERON FRAGMENTATION INTO CUMULATIVE PIONS

SPHERE Collaboration

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The power value of the *A*-dependence of the cross-section for 4.5 GeV/c·A 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.

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

Эксперимент по A-зависимости сечения фрагментации релятивистских дейтронов в кумулятивные пионы

С.В.Афанасьев и др.

Измерен показатель степени A-зависимости сечения фрагментации дейтронов с импульсом 4,5 ГэВ/с·A в кумулятивные пионы на ядрах углерода, алюминия, меди, свинца в интервале кумулятивного числа 0,8-1,2. Его средняя величина в этом интервале равна 0,27±0,09, что указывает на качественное отличие зависимости сечения от атомного веса ядра-мишени, установленной для сечения рождения кумулятивных пионов фрагментации ядра-мишени, где наблюдается зависимость объемного типа.

Работа выполнена в Лаборатории высоких энергий ОИЯИ.

Introduction

Observation of relativistic deuteron fragmentation into cumulative pions [1] has initiated detailed studies of the secondary particle spectra over a wide range of atomic nuclei [2]. The measurements were performed in target nucleus fragmentation region. An experiment with a cumulative particle produced in projectile fragmentation region will 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 parametrization, A^{α}. The parameter α, as a function of the cumulative number, is useful for an understanding of a 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.

The fractions of the 4-momenta of colliding nuclei, $X_{\rm I}$ and $X_{\rm II}$, 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 [3]:

$$(X_{\rm I}P_{\rm I} + X_{\rm II}P_{\rm II} - P_1)^2 = (X_{\rm I}m_0 + X_{\rm II}m_0 + m_2)^2,$$

where $P_{\rm I}$ and $P_{\rm II}$ are the 4-momenta of colliding nuclei per nucleon; P_1, the 4-momentum of produced particle; m_0 = 931 MeV (atomic mass unit); m_2, the mass of additional particles needed to satisfy quantum number conservation laws. Putting $X_{\rm II} = 1$ for the target nucleus, one can derive an expression for X_I (projectile nucleus) with mass corrections taken into account[3] (for pions $m_2 = 0$):

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

We measured relativistic deuteron fragmentation into straightforward produced pions at $X_I \approx 1$. To do this, the following problems were solved:

- the spectrometer was calibrated by primary beam momenta to obtain an experimental estimate of its momentum resolution;
- an effective trigger for the selection of cumulative pions was realized;
- background problems were investigated;
- the investigation of the cumulative effect was shown to be realistic in single count mode of the setup for primary beam rate.

Setup Description

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

- a primary beam monitoring telescope consisting of three scintillation counters;

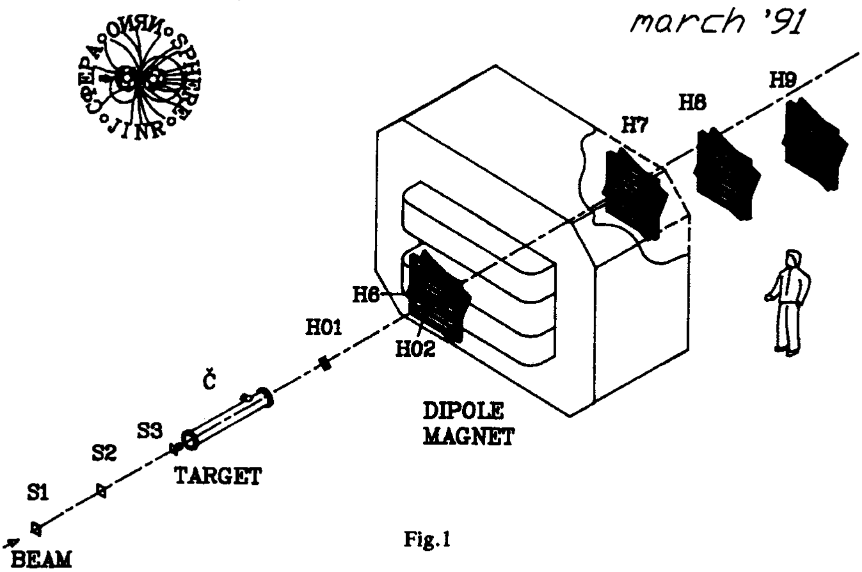

Fig.1

- a changeable target placed at 700 cm in front of magnet center;
- a dipole frame type magnet with a 68 cm gap; the poles are 100 cm wide and 150 cm long; the maximum field in magnet center is .82 T;
- a high-pressure threshold Čerenkov counter;
- two 16x16 cm^2 hodoscopes; each hodoscope consists of two planes containing 16 counters 160x9x3 mm^3 in size; these hodoscopes are placed at a distances of 400 and 230 cm upstream of the magnet;
- four three-coordinate hodoscopes with an area of 1 m^2 [4]; three of them are placed downstream of the magnet center at distances of 200, 320, 520 cm and one is placed directly in front of the magnet.

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

Trigger and Data Acquisition

The applied trigger logic is similar to that used in[4] and modified for an effective selection of relativistic negative pions (see fig.2). Pretrigger is provided by coincidence of signals from the beam monitor, Čerenkov counter and X-planes of hodoscopes H7, H8, H9. A positive trigger solution is issued in the case of a coincidence between a pretrigger signal and the signals from four planes of the HOXY and HOUV hodoscopes. At a typical beam intensity of 10^6 the monitor rate was about $8 \cdot 10^5$; the pile-up detection circuit rate, $7 \cdot 10^4$; the monitor and Čerenkov counter coincidence rate, 10^3; the pretrigger rate, 20; and the trigger rate, 4-5.

Besides, a parallel interface transferring data buffers directly from «Elektronika-60" to PC/XT computer was added to our data acquisition system[4]. A novel VME module transferred data into the remote computer center (EC1055 computer).

Event Recognition and Momentum Calibration

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

We have developed a first version of a track recognition program MULTITRACK for the SPHERE forward spectrometer on VAX computer. Its correctness was verified visually by a graphic version of this program, MULTIHIGZ, based on the HIGZ program interface[5]. The PAW interactive program[6] was applied to analyze and fit

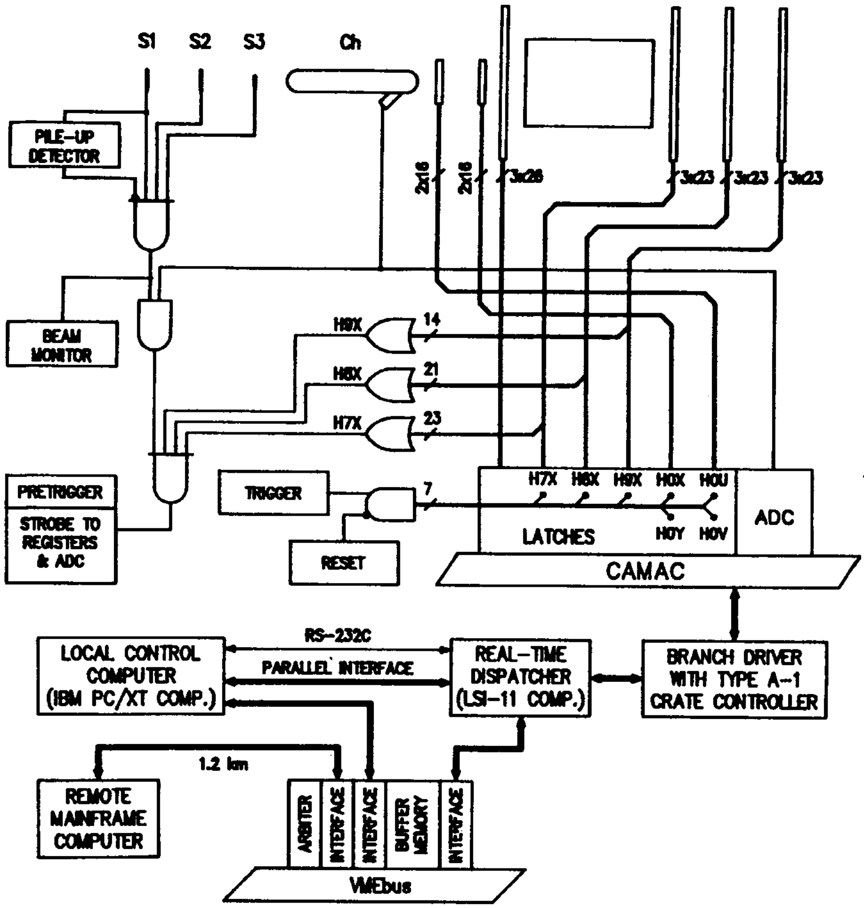

Fig.2

experimental distributions. In future we plan to apply the MULTITRACK program for an on-line data filtering.

Let us describe the algorithm of event recognition and selection. The recognition program decodes hit counter numbers and links them with a real geometry of the experiment. A track search starts from a segment of the hodoscopes placed downstream of the magnet. The parameters of linear fit and values of χ^2 are calculated for each combination of X/Y- and X/U-crossing centers of the hit counters. If these parameters satisfy selection criteria, they are stored in a bank of track candidates. The following cuts are applied:

- due to angular acceptance on each hodoscope the crossing center of the hit counters lies within the vertical limits, ±28 cm;
- the distance between the crossing center and the corresponding fit point (DX and DY) does not exceed 5 cm on both projections;

- the vertical track projection is placed within 50 cm from the target at target Z-coordinate;

- the horizontal track projection is placed > 54 cm aside of the target to reflect the kinematical limit of a spectrum (6 GeV/c);

- the horizontal track projection intersects the setup axis within the edges of magnet poles.

At this stage the number of track candidates is overestimated due to correlated X/Y- and X/U-crossings. Each candidate is tested with a minimum value of χ^2 among the others which cross the backward hodoscope in the vicinity of 9 cm. This value is determined by a two-track resolution. An event is rejected when more than one locally best track is found. In our case the fraction of such events does not exceed 3%. This done, a search for a track candidate starts in the forward segment of the hodoscopes.

The angular dispersion of the track coming into the magnet ($< 10^{-2}$ rad) is significantly smaller than the mean deflection angle ($> 10^{-1}$ rad) in a covered momentum range. Only the presence of at least one well-fitted track candidate in the forward segment is verified in a similar way. The momentum is calculated from the angle between the horizontal projection of the deflected track and the primary beam axis.

The calibration constant linking the deflection angle, a particle momentum, and a current in the magnet was obtained for a beam of 6.6 GeV/c deuterons. This value was checked in a π^- beam at 3 and 4 GeV/c. Fitting the momentum spectra by a Gaussian gives an estimate of the resolution, $\sigma_p/P = (5.0 \pm 0.1)\%$ for a 3.75 GeV/c particle at .815 T. The recognition program was tested on a 3 GeV/c statistics. The track recognition efficiency is $\approx 75\%$ with cuts corresponding to the trigger. In physical statistics 30% of events contain recognizable tracks.

The distribution of the number of tracks per event upstream and downstream of the magnet is shown in fig.3 (upper and lower histograms, respectively). The contribution of two-track events is negligible downstream of the magnet while the upstream track multiplicity has a significant dispersion. An amplitude of a signal from the Čerenkov counter switched in the trigger was not included in the present analysis. The amplitude spectrum of the counter (fig.4) demonstrates the selection of relativistic pions. The polarity of magnet switching defines the charge sign of a particle. The total spectrum of pion momenta and the cumulative number distribution are presented in fig.5.

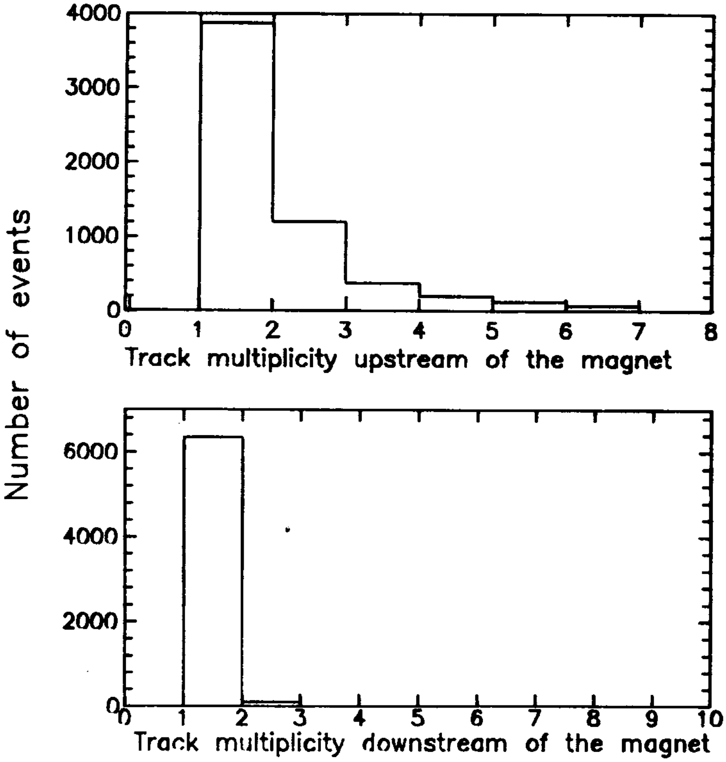

Fig.3

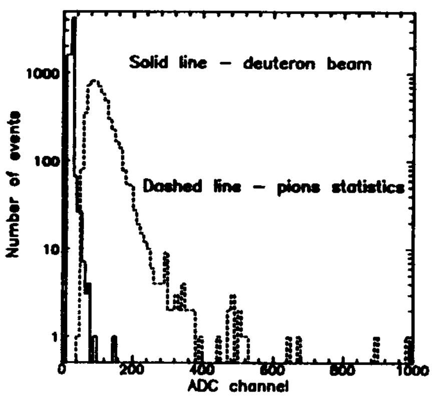

Fig.4

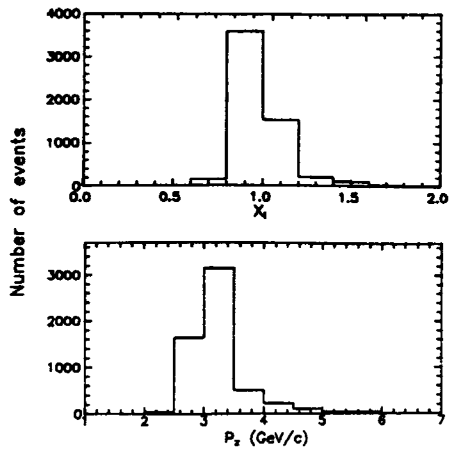

Fig.5

Data Analysis and Discussion

Figure 5 shows that two intervals of cumulative number corresponding to the distribution maximum have a sufficient statistics. The events belonging to these intervals were separately summed for each target and normalized relative to the beam monitor count. By subtracting the normalized count of the empty target, the data were normalized with respect to target thicknesses (see fig.6a and 6b). The fitting results for the $A^{\alpha - 1}$ dependence are shown in the same figures. Both values coincide within relatively wide error limits (parameter α in fig.6). For the interval $0.8 < X_I < 1.2$ the mean value of α is 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. Formerly similar conclusion was drawn by two Berkeley groups[7,8] for a fragmentation of light relativistic nuclei into pions - a power value of 0.4 was obtained for α-particles. This conclusion should be verified in correlation experiments with a measurable multiplicity of target and projectile nucleus fragmentation.

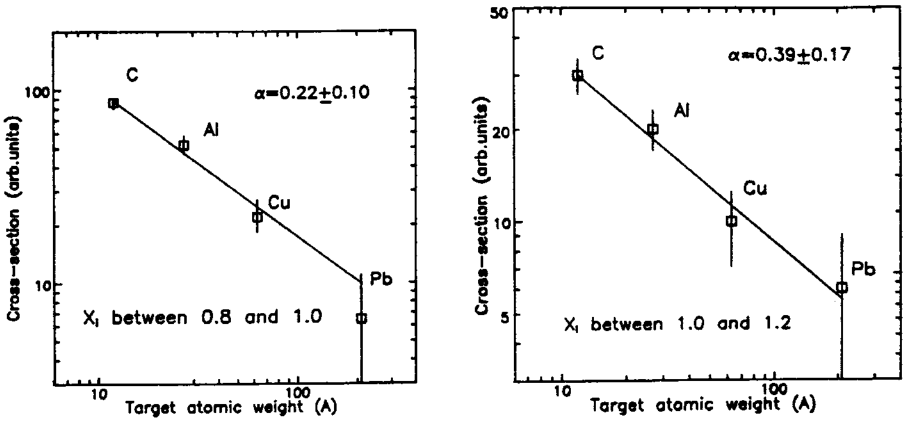

Fig.6a,b

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 the quark-parton structure function of nucleus[3]. From this point of view our approach permits «tagging» of cumulative production and opens up possibility of studying details of the hadronization process in correlation measurements.

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