THE EFFECT OF THE RELATIVE NUCLEAR SIZE ON THE NUCLEUS-NUCLEUS INTERACTIONS

I.N. Erofeeva, V.S. Murzin, S.Yu. Sivoklokov and L.N. Smirnova

Institute of Nuclear Physics, Moscow State University, Moscow II9899, USSR

Abstract. The experimental data on the interactions of light nuclei (d, He^4, C^{12}) at the momentum 4.2 GeV/c·A with the carbon nuclei were taken in the 2-m propane bubble chamber. The distributions in the number of interacting nucleons, the spectra of protons, the mean energies of secondary pions and protons, the mean fractions of energy transferred to the pion and nucleon components are presented. The results of investigation of the mechanism of nucleus-nucleus interactions can be used to calculate the nuclear cascades in the atmosphere.

Experimental Data

We analyze 2400 dC, II60 He^4C^{12} and I800 $C^{12}C^{12}$ events detected in the 2-m propane chamber at the momentum of projectile nuclei P_0 = 4.2 GeV/c·A. The momenta of all protons and nuclear fragments with P I50 MeV/c and charged $\pi^{\pm}$ mesons with P_{π} > 70 MeV/c have been measured. All negatively charged particles were regarded as π^--mesons (the admixture of other species < I%). The event was identified as an interaction on carbon if one of the following conditions was satisfied /I/: a) $n_+ - n_- > (Z_{A_i} + I)$; b) $n_p > I$; c) $n_{\tilde{p}}^{b} > 0$; d) $n_{\gamma} > 2$; e) $n_{\pm}$ is odd for the dC events. Z_{A_i} is the incident nucleus charge, n_p is the number of slow (with P < 750 MeV/c) protons, $n_{\tilde{p}}^{b}$ is the number of backward emitted protons in the lab-system, $n_{\pm}$ is the number of charged particles in the event. Using these criteria we selected 70 to 80% of inelastic interactions on the carbon nucleus. The remainder events were statistically separated taking into account the known cross sections on a proton and carbon /2/ and the detection efficiency.

The spectra of protons are obtained by the subtraction of the π^--meson spectrum from the spectrum of all positive particles. The spectra of π^+ and π^--mesons were assumed to be identical because of the isotopic symmetry of colliding nuclei.

The Number of Interacting Nucleons

The distribution $P(\nu)$ in the number of interacting nucleons of the projectile nucleus in dC and He^4C^{12}-interactions was obtained on the basis of the data on the number of stripping particles and on the multiplicity of π^--mesons in the events with a different total charge of the stripping particles. The stripping particles are those ones with momentum P > 3 GeV/c and emission angle θ < 4°. The production in the interaction of a nucleon of the projectile nucleus is assumed to be independent of the other nucle-

on's interactions. The use of additional data on the multiplicity of π^--mesons in pC and dC-interactions /3/ enabled us to obtain six equations with unknown $P(\nu)(\nu = I...4)$ for He⁴C interactions /4/. The obtained probabilities $P(\nu)$ of the interaction of ν nucleons of the projectile nucleus for dC and He⁴C interactions are given in Table I together. with the predictions of the multiscattering model (MSM) /5/. $P(I)$ and $P(4)$ in He⁴C-interactions are in disagreement with the MSM results.

Table I

The interaction probabilities $P(\nu)$ of ν nucleons of the projectile nucleus A_i

A_iA_t \ $P(\nu)$	P(I)	P(2)	P(3)	P(4)	
dC	0.68±0.04	0.32±0.04	-	-	I.32±0.08
He⁴C	0.24±0.06	0.33±0.I5	0.20±0.I3	0.23±0.05	2.42±0.08
He⁴C /5/	0.44	0.25	0.I9	0.I2	2.00

Table 2

The mean characteristics of dC, He⁴C and CC-interactions

		d C	He⁴C	CC
$\langle n_- \rangle$		0.6I ± 0.03	I.00 ± 0.04	I.5I ± 0.05
$\langle E_- \rangle$	GeV	0.62 ± 0.02	0.64 ± 0.02	0.64 ± 0.02
$\langle n_p \rangle$		2.7 ± 0.I	3.9 ± 0.I	5.2 ± 0.2
$\langle T_p \rangle$	GeV	0.67 ± 0.06	0.80 ± 0.06	I.II ± 0.06
ε_{π^-}	GeV	0.38 ± 0.02	0.64 ± 0.03	0.97 ± 0.04
ε_p	GeV	I.6 ± 0.2	3.I ± 0.2	5.7 ± 0.3
$\Sigma\varepsilon_i$		4.3 ± 0.2	8.I ± 0.5	I4.5 ± 0.5
T_0	GeV	4.4 ± 0.2	8.I ± 0.2	I2.9
α_π		0.26 ± 0.02	0.24 ± 0.02	0.23 ± 0.02
α_N		0.74 ± 0.07	0.76 ± 0.07	0.9I ± 0.09

The Partial Coefficients of Inelasticity of Pions and Nucleons

Table 2 lists the mean multiplicities and energies $\langle E_- \rangle$ of π^--mesons, the multiplicities and kinetic energies $\langle T_p \rangle$ of protons and also the mean energy of all π^--mesons ε_{π^-} and protons ε_p in an event.

Assuming that the mean multiplicities and energies of all species of π-mesons and nucleons are equal ($\langle n_{\pi^-} \rangle = \langle n_{\pi^0} \rangle = \langle n_{\pi^+} \rangle$, $\langle E_{\pi^-} \rangle = \langle E_{\pi^0} \rangle = \langle E_{\pi^+} \rangle$, $\langle n_p \rangle = \langle n_n \rangle$, $\langle T_p \rangle = \langle T_n \rangle$) we can determine the total energy of all secondaries: $\Sigma\varepsilon_i = 2\varepsilon_p + 3\varepsilon_{\pi^-}$. This value must coincide with the initial kinetic energy of interacting nucleons $T_\rho = 3.37 \langle \nu \rangle_{AC}$ (GeV) to within the energy of particles below the detection threshold. For CC-interactions the magnitude $\langle \nu \rangle_{CC} = 3.83$ was taken from ref./3/. Table 2 presents also the partial coefficients of inelasticity for pions $\alpha_\pi = 3\varepsilon_{\pi^-}/T_0$ and protons $\alpha_N = 2\varepsilon_p/T_0$. The fraction of energy transferred to π-mesons is considered to be the same for all reactions in question. It is

much lower than the value of α_π for the nucleonic interactions at the energies > 20 GeV /6/.

The Momentum Spectra of Protons

The momentum spectra of protons in dC, He^{4}C and CC-interactions in the lab-system are presented in fig.I. The spectra are normalyzed to the mean number of protons in an event. Approximation of the spectra by the function $\exp(-\beta P))$ at P = I-3 GeV/c gives the following values of the parameter β : 0.62 ± 0.04 for dC, 0.49 ± 0.05 for He^{4}C and 0.29 ± 0.03 for CC-interactions. At the momenta > 3 GeV/c the spectra tend to steepen slightly, which is well seen in the case of CC interactions, yet, they are everywhere well outside the value P_0 = 4.2 GeV/c. If in dC-collisions the part of the plot P > P_0 is due to the errors in measuring of the particles momenta and to the cumulative particles contribution the increased yield of fragments with Z=I in this part in He^{4}C and CC-interactions requires an additional mechanism. The interacting many-nucleon fragments of the projectile nuclei with P > P_0 can contribute to the high-momentum part of the spectrum in these interactions.

The mean momenta of protons in dC, He^{4}C and CC-interactions are plotted in fig.2 versus the ratio of atomic weights of the colliding nuclei A_i/A_t. The mean value of $<P_p>$ increases by a factor of I.5 in the transition of A_i from d to C, approaching the estimated value of the mean momentum of a proton in pp-collisions at 4.2 GeV/c. This implies that the cascade becomes less important inside the carbon nucleus for secondary nucleons in He^{4}C and CC-interactions. This effect is seemingly present in any collisions of the nuclei with comparable sizes.

Conclusions

The chief results are the following: I) the distribution in the number of interacting nucleons of the He^4 nucleus in the carbon nucleus is nearly uniform which is in contradiction to the MSM results /5/; 2) the partial coefficients of inelasticity for pions and nucleons are actually the same for dC, He^{4}C and CC-interactions; 3) the momentum spectra of protons and the mean values of their momenta are different for each type of interactions. The experimental results permit us to infer the presence of many-nucleon fragments in the spectrum of interacting particles and the minor role of cascade in the interactions of nuclei with identical atomic weights.

References

I. Agakishiev H.N. et al. JINR, I-83-662, Dubna, I983.
2. Angelov N. et al. JINR, PI-80-473, Dubna, I980; Yad.Fiz. I98I, 33, I046.
3. Agakishiev H.N. et al. JINR, EI-84-32I, Dubna, I984; Proc. XXII Int.Conf. on High Energy Physics, Leipzig, I98I.

4. Gasparyan A.P. et al. Proc. I6th ICRC, Kyoto, I979, 6, HE 3-6, I76.
5. Gasparyan A.P. et al. JINR, I-80-853, Dubna, I980; Yad.Fiz., I98I, 34, I328.
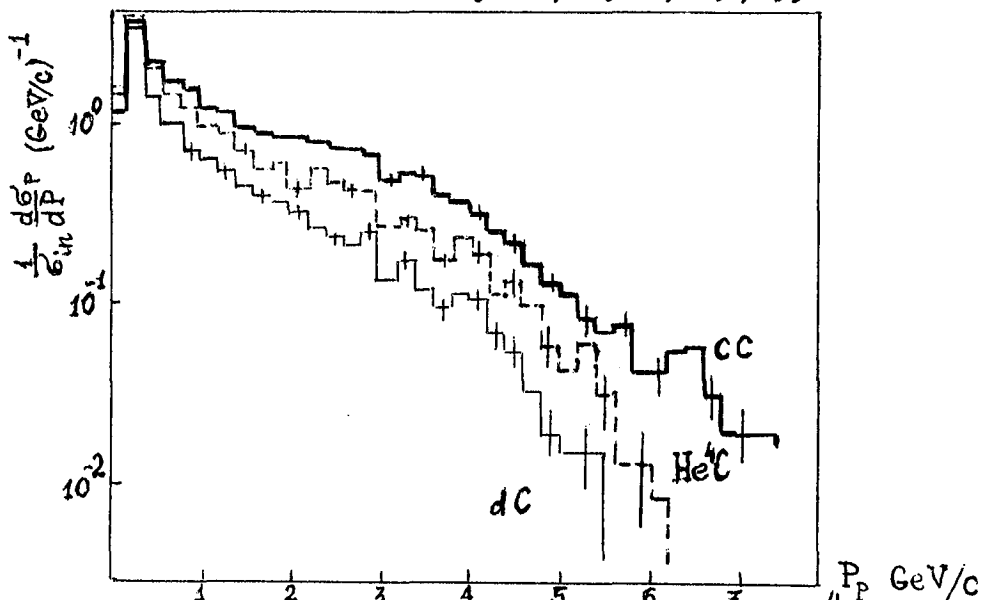6. Vlasov E.V. et al. Z.Phys.C, I982, I3, 95.

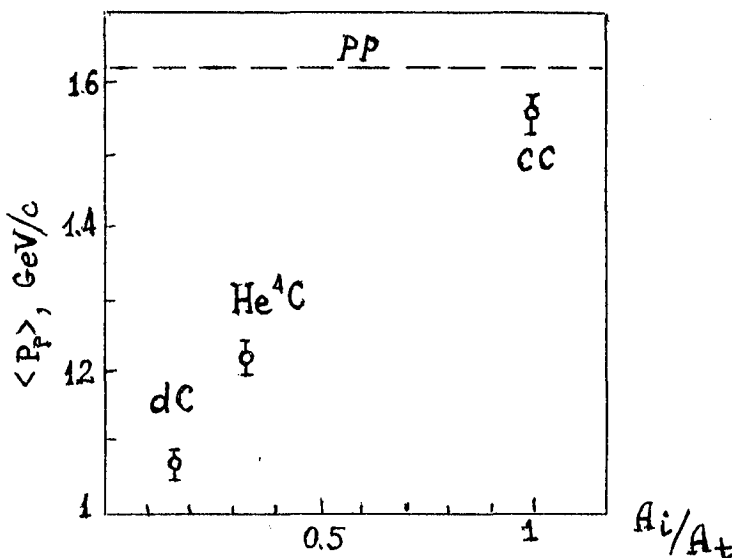Fig. I. Momentum spectra of protons in dC, He^{4}C and CC-interactions

Fig. 2. Mean momentum of protons versus the ratio of atomic weights of colliding nuclei.