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An interest for investigations of the inelastic interactions of fast hadrons with nuclei has increased after the last results concerning the question of the generation and cross section of hadron complexes inside nuclei.

A number of papers [1-5] are devoted to the foundation of the question that particle collisions with nuclei are a real test for the multiple generation mechanism of particles in the interactions of hadrons with nucleons.

In order to distinguish two groups of multiple production models in hadron-hadron collisions: models of direct particle production in hadron-hadron collisions (multiperipheral and dualresonanse) and models in which particles are generated via intermediate states (''nova'' model, fragmentation models, fireballs, etc.), the authors of papers [2,3,4,5] propose to use the nucleus as an analyser.

Wider information about particle generation in the collision of fast hadrons with nuclei, about their interactions in nuclei and about nuclear disintegration can be obtained using photoemulsion technique. All this information depends on the atomic weight of nuclei. That is why in our work we have used two kinds of emulsions, the ordinary kind and one enriched with light nuclei of C, N, H, O (by adding CH_2OH). This makes it possible to divide reliably the interactions into those occuring with C, N, O and those with Ag, Br.

The technique and preliminary results were reported in ref. [6].

The experimental data on the interaction of 60 GeV/c π^--mesons and 70 GeV/c protons with nuclei are presented and discussed in this paper for elucidating both the mechanism of multiple generation in hadron-nucleon collisions and the behaviour of generated particles inside the nucleus.

Data concerning nuclei disintegration are used as much as necessary for this purpose.

Table I presents the dependence of the average values characterizing particle generation for some groups of nuclei and their disintegration.

For comparison the table also presents the mean number of charged particles, $\langle n_{ch} \rangle$ and median angles, $\langle \theta_{s,\frac{1}{2}} \rangle$ averaged for interactions with protons and neutrons.

Figure 1 shows the N_h dependence of the ratio $\langle N_s \rangle / \langle n_{ch} \rangle$ for the interactions of pions and protons with nuclei C, N, O and Ag, Br and presents the results of ref. /7/ for the interactions of 200 GeV protons with all emulsion nuclei /7/.

Figure 2 presents the dependence of $\langle N_s \rangle / \langle n_{ch} \rangle$ on the atomic weight.

In figures 3a and 3b, $\langle N_g \rangle$ as a function of N_s and $\langle N_s \rangle$ as a function of N_g are respectively presented for the proton collisions with nuclei. Figures 3a and 3b show a linear dependence of N_s and N_g.

Figure 4 presents the angular distribution of g-particles for the collision of protons with nuclei. In fig. 5 you can see the pseudorapidity distribution ($\ln \mathrm{tg}\, \theta/2$) for the collisions of protons with protons and with nuclei C, N, O and Ag, Br.

Let us at first discuss the most general parameters, the mean number of showers, $\langle N_s \rangle$, and the mean number of g-particles (recoil nucleons) $\langle N_g \rangle$, which characterize particle generation in hadron-nucleon collisions and their subsequent interaction with nucleons inside the nucleus.

In the model, which assumes direct particle production in hadron-hadron collisions and a subsequent development of intranuclear cascade in the interaction of secondary particles with nucleons inside the nucleus /8/, these characteristics are respectively $\langle N_s \rangle = 11.8 \pm 0.6$ and $\langle N_g \rangle = 5.5 \pm 0.2$ for the interaction of 75 GeV protons with the mean photoemulsion nucleus. From our results $\langle N_s \rangle = 9.53 \pm 0.55$ and $\langle N_g \rangle = 2.29 \pm 0.11$. Comparing also the ratio $\langle N_s \rangle / \langle n_{ch} \rangle = R_{Em}$ as a function of energy, the model predicts that this ratio increases with increasing energy. For the interaction of protons with emulsion nuclei this ratio is 1.97 at 75 GeV and 2.8 at 200 GeV. From the comparison of our results with the data of ref. /7/ it follows that this ratio holds within errors ($R_{Em}^{70\,\mathrm{GeV}} = 1.59 \pm 0.11$, $R_{Em}^{200\,\mathrm{GeV}} = 1.7 \pm 0.1$).

9.33

The authors of ref. /9/ propose a modification to the discussed model which is called multiparticle one. This model considers the development of the cascade process in simultaneous interactions of several produced particles collimated forward with the nucleons inside the nucleus. According to this model, $\langle N_s \rangle = 9.3 \pm 0.5$ and $\langle N_g \rangle = 3.45 \pm 0.20$ for the interaction of protons 70 GeV/c with the mean photoemulsion nucleus. The value of R_{Em} in this model slowly increases with increasing energy ($R_{Em}^{80\,\mathrm{GeV}} = 1.6$, $R_{Em}^{500\,\mathrm{GeV}} = 1.8$). The authors of this model indicated /8/ that the mechanism of multiparticle interactions indirectly takes into account the possibility of hadron complex production in hadron-nucleon interactions.

The fundamental of the two-tact model is to generate excited states in hadron-hadron collisions. The evolution of such systems and their interaction with nucleus are considered. It is assumed also that the cross section of this interaction is equal to or less than that of the hadron-hadron collision. Some of these models consider such systems as an excited states of the colliding particles (for example, diffractive excitation /2,3/). The others take into account, apart from the excitation of colliding particles, one or more excited complexes /4/.

Let us dwell upon paper /4/. It is assumed that the hadronic complex is produced in the inelastic hadron-hadron interaction. As a results of this collision, the leading particle cannot interact with subsequent nucleons inside the nucleus because it has little time for recovering its own field[10,11]. In ref.[4] the authors considered: the increase of the complex size as a result of its extension; losses of some of its kinetic energy and the change of the complex internal energy, due to its subsequent collisions with nucleons of the nucleus as a function of the Lorentz-factor of this complex in the given point of the nucleus. The leading particle and complexes, flying forward in the c.m.s., decay into individual particles outside the nucleus due to the Lorentz delay of their own times.

Let us consider the prediction of the two-tact model for the energy dependence of R_{Em}. In ref.[2] this ratio is independent of energy and equals 1.88. Paper[4] gives $R_{Em} = 1.6$ also independent of the energy of incident particle.

In these works $\langle N_s \rangle / \langle n_{ch} \rangle = R$ versus the atomic weight of the target $(R \sim A^n)$ has been investigated. The authors predict a weak dependence of R on A. In ref.[2,3] $n \sim 0.25$, in ref.[4] $n = 0.12$ and according to our data, $n = 0.18 \pm 0.04$.

Considering the correlations between the mean number of s-particles generated in the interaction of hadrons with the nucleus and the number of h-particles characterizing the excitation of this nucleus $\langle N_s \rangle / \langle n_{ch} \rangle = f(N_h)$. Figure 1 shows that the ratio R holds within errors when the incident proton energy varies from 70 to 200 GeV (N_h in fixed). As a result of such behaviour of this ratio, the authors of ref.[12] conclude that the energy dependence of $\langle N_s \rangle$ is implied in the energy dependence of $\langle n_{ch} \rangle$ since $f(N_h)$ is a function of N_h only. Note that the two-tact mechanism which gives the same energy dependence of $\langle N_s \rangle$ for all the nuclei (see ref.[2]) agrees with this conclusion. Paper[4] also gives the constancy of $R = R(N_h)$ with changing energy (see the calculated curve in fig. 1).

It is of interest to perform an analysis of the data on g-particles which mainly include protons with an energy up to 0.5 GeV. According to the pN scattering data in this energy range no big change is expected in the spectrum and angular distribution of g-particles when rescattering inside the nucleus takes place. This is illustrated in fig. 4. Consequently, g-particles can be assumed to be "spectators" in the interaction of fast particles with nucleons inside the nucleus.

Assuming that g-particles are produced in the interaction of primary hadrons and secondary s-particles inside the nucleus, let us estimate the collision multiplicity of one-half of s-particles, flying backward in the c.m.s. in the hadron-nucleon interaction. This half can be created due to the decay of slow complexes inside the nucleus. In our case one-half of s-paticles including π°,s is

$$\frac{\langle n_{ch} \rangle}{2} \cdot \frac{3}{2} = 4.5 .$$

Taking into account neutrons in the hadron-hadron interaction at 60-70 GeV, $\langle n_g \rangle = 0.6$. Using the increase of the number of g-particles for the nuclei groups (neutrons are taken into account), in comparison with the hadron-hadron interaction, and assuming that about 0.8 g-particles are generated in each collision of an s-particle, we obtain the interaction multiplicity of s-particles to be ~ 0.4 for C, N, O and ~ 1.6 for Ag, Br.

These values are close to those estimated in ref.[3]. They are ~ 0.6 for $A = 14$ and ~ 1.5 for $A = 95$ for $\sigma_{\pi p} = 22$ mb.

Consequently, the values of $\langle N_g \rangle$ (in table I) can be explained by the interaction of one half the particles produced in the hadron-nucleon collision inside a nucleus.

Let us consider the behaviour of the leading particle and fast particle complexes inside the nucleus which fly forward in the c.m.s. of hadron-nucleon from the point of view of the two-tact mechanism. Their weak interaction with the nucleus can be considered on the basis of a comparatively weak dependence of $\langle N_s \rangle$ on the atomic weight (fig. 2) and coincidence of the pseudorapidity distributions (fig. 5) in the interval from -7.8 to -3.0. At the same time the difference of the distributions at pseudorapidities larger than -3.0 is explained by the development of the cascade inside the nucleus due to the decay of slow hadron complexes as earlier noted in refs. /13/ . Thus, the conclusion drawn earlier when g-particles were under study is confirmed. Let us compare in Table II the median angles of emission s - and g-particles for C , N , O and Ag , Br with the predictions /4/.

However it should be pointed out that the definition of the inelasticity coefficient and momentum spectrum, of fast particles with different charge signs, as a function of the atomic weight is essential for testing the models (e.g., according to ref. /4/ , the inelasticity coefficient is weakly dependent on A).

Finally, from the data analysis of Table I and figs. 1, 2 it follows that $\langle N_s \rangle$ and $\langle N_g \rangle$ are larger for the interaction of protons than that of π^- -mesons with nuclei. This difference can be explained if we assume that the interaction cross section of the complex inside the nucleus from the PP collision is larger than that form the $\pi^- P$ collision (similar to that the proton-nucleon cross section is by a factor of 1.4 larger than the pion-nucleon one).

As an illustration of this assumption, we present the ratio between the mean values of g-particles for proton and π^- -mesons according to the nuclei group.

$$\frac{\langle N_g \rangle_P}{\langle N_g \rangle_\pi}\,_{C,N,O} = 1.25 \pm 0.16 \qquad \frac{\langle N_g \rangle_P}{\langle N_g \rangle_\pi}\,_{Ag,\,Br} = 1.32 \pm 0.12 .$$

Thus, the bulk of the obtained data agrees with the two-tact model. This supposes complex generation in the hadron-nucleon collision and difference in the interaction of these complexes with the nucleus versus their rapidities in the lab.system.

Consequently, the study of the collision of fast hadrons with nuclei opens up new interesting possibilities.

Table I

π^- - 60 GeV/c

	$\langle A$	$\langle N_s \rangle$	$\langle N_g \rangle$	$\langle N_b \rangle$	$\langle N_n \rangle$	$\theta_s, 1/2$
C, N, O	14	7.42 ± 0,24	0.72 ± 0,08	1.84 ± 0,10	2.56 ± 0,13	8.8° ± 0,8°
Ag, Br	92	8.89 ± 0,30	2.26 ± 0,20	4.80 ±0,30	7.06 ± 0,37	16.4° ± 0.6°
Nucleon	I.	$n_s + n_g = n_{ch}$ 6.2 + 0.2				6°

P 69 GeV/c

	$\langle A \rangle$	$\langle N_s \rangle$	$\langle N_g \rangle$	$\langle N_b \rangle$	$\langle N_h \rangle$	$\theta_s, 1/2$	$\theta_g, 1/2$
C, N, O	14	7.53 0,27	0.90 ± 0,05	2.57 ± 0,13	3.47 ±0,15	9.6° ± I°	60° ± 3°
Ag, Br	92	10.53 ± 0.48	2.98 ± 0.10	6.6 ± 0.5	9.58 ± 0,60	14.0° ± 0.5	66,4° ± 1°
Nucleon	I	$n_s + n_g = n_{ch}$ 6.0 ± 0.2				6,5°	

Table II

	Calculation according to ref./4/	Our data
(θ_s, 1/2) C,N,O	10,5 ÷ 11°	9,6 ± I
(θ_s, 1/2) Ag, Br	15 - 16°	14,0 ± 0,5
(θ_g, 1/2) C,N,O	60°	60 ± 3°
(θ_s, 1/2) Ag, Br	60°	66 ± I°
$\frac{\langle N_h \rangle \ \mathrm{Ag, Br}}{\langle N_h \rangle \ \mathrm{C,N,O}}$	3,2	3.1 ÷ 2.5

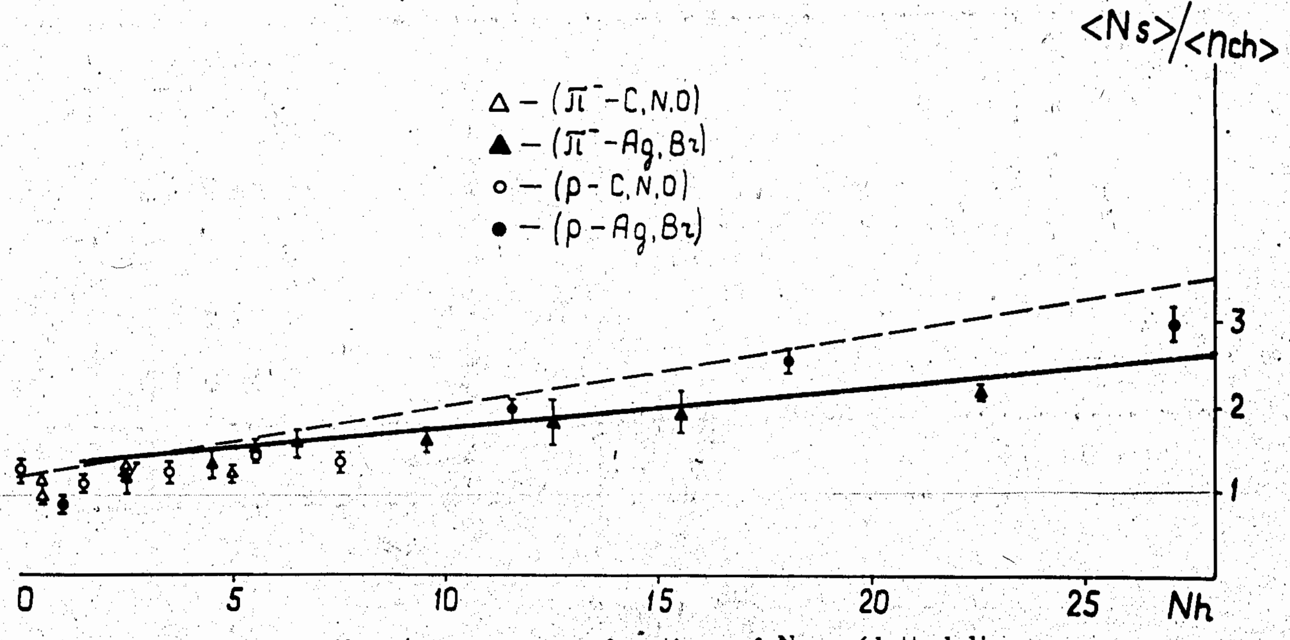

Fig. 1. $\langle N_s \rangle / \langle n_{ch} \rangle$ as a function of N_h (dotted line is the interaction of 200 GeV protons with all the emulsion nuclei /7/ ; the solid line is calculated according to /4/).

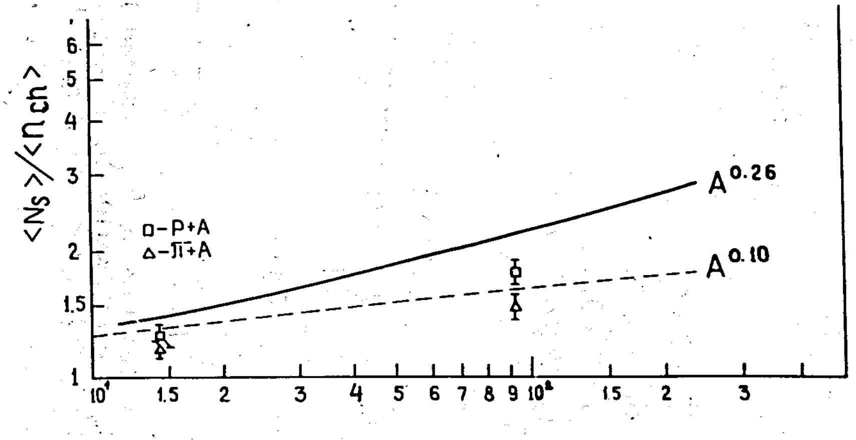

Fig. 2. $<N_s>/<n_{ch}>$ as a function of the atomic weight.

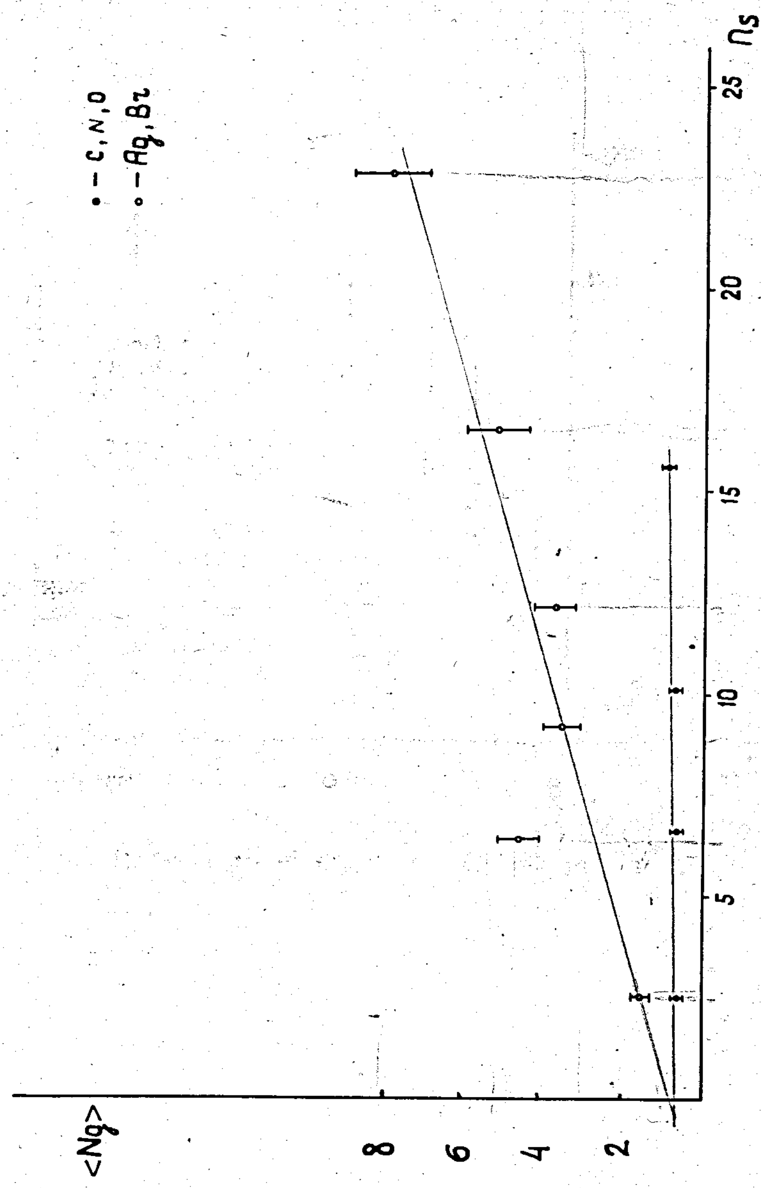

Fig. 3a. $<N_g>$ as a function of N_s .

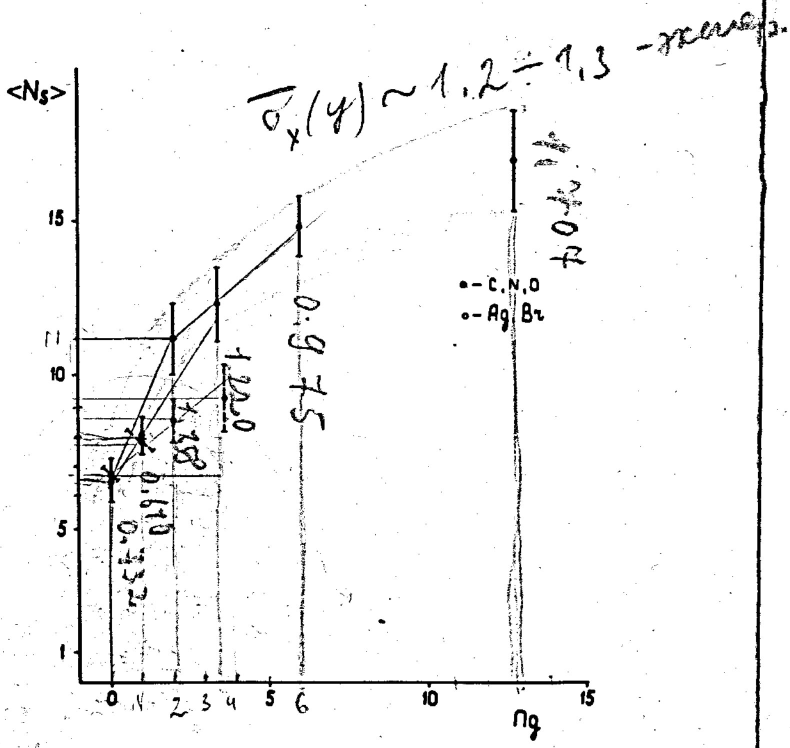

Fig. 3b. $\langle N_s \rangle$ as a function of N_g .

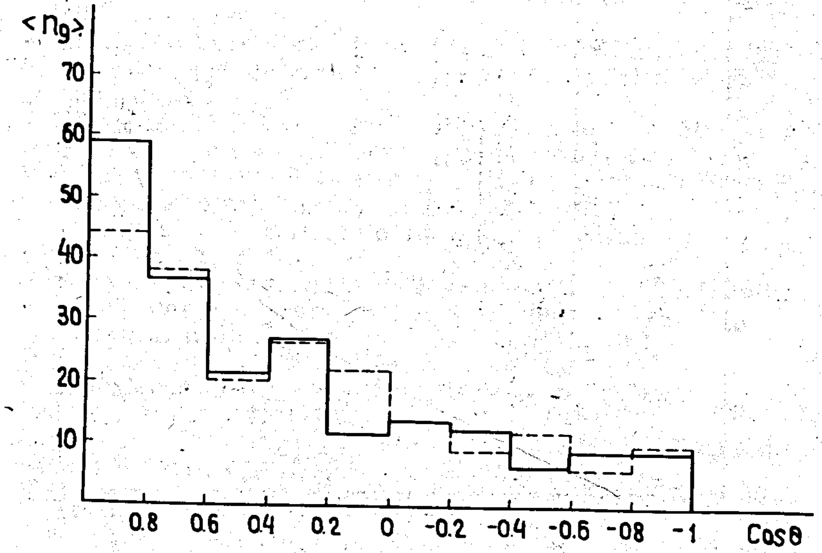

Fig. 4. Angular distributions of g -particles in the collision of protons with nuclei. Solid curve for C , N , O . Dotted curve for Ag , Br .

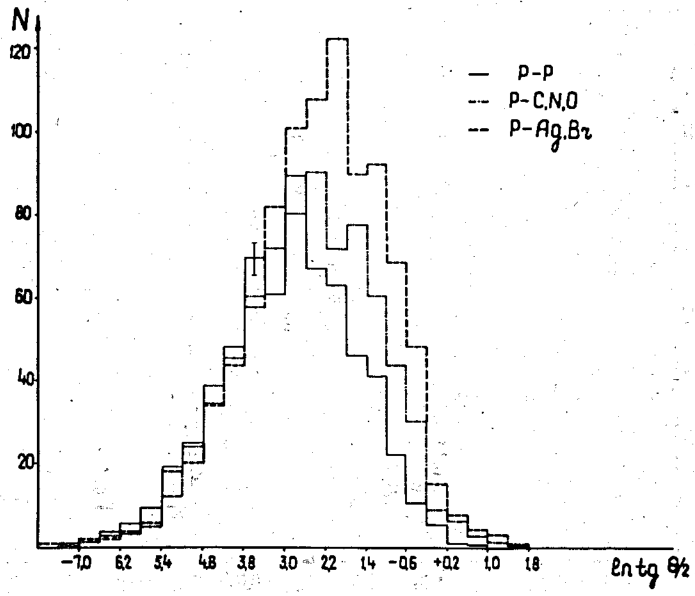

Fig. 5. Pseudorapidity[*] distributions for the interaction of protons with protons, with C , N , O and Ag , Br normalized to the equal number of events.

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[*] Pseudorapidity with the sign minus coincides with the Lobachevsky inverse function applied to /14/ for relativistic particles.

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-7.8	-7.4	-7.0	-6.6	-6.2	-5.8	-5.4	-5.0	-4.6	-4.
1.8	3.8	2.8	3.9	5.9	8.55	11.1	14.3	19.8	29

-3.8	-3.4	-3.0	-2.6	-2.2	-1.8	-0.4	0.	0.4	0.8
46.4	85.2	101,2	99	66	54,6	32.1	16	5,7	0.