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UNEXPECTED APPARENT TRANSPARENCE OF NUCLEAR MATTER FOR HIGH-ENERGY HADRONS, OBSERVED IN p-NUCLEUS COLLISION AT 200 GeV

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The aim of this letter is to draw attention to some regularities of the angular distribution of fast secondaries from collisions of 2oo GeV protons in nuclear emulsions. Beam and exposure conditions, as well as the general features of the interactions have been given in ref./1/ and /2/. The results presented here refer to data collected in the Bucharest fraction of the stack,only.

The usual division of particles into a narrow and a wide cone reveals some new facts which are hard to understand starting from any conventional picture of hardon propagation through nuclear matter* and which can briefly be stated as follows :

a) The increase of multiplicity due to traversals of increasing path-lengths in nuclear matter appears to be localized essentially in the wide cone.

b) The narrow ($u \equiv \lg \mathrm{tg}\, \theta \leq -1.35$) cone, containing on the average one half of the particles produced in a pp collision, behaves practically as if these hadrons would not feel the presence of nuclear matter which they penetrate.

* Like, e.g. cascade or tube mechanism.

c) In spite of the strong increase in numbers with increasing complexity of the collision, the angular distribution of particles in the wide cone remains unchanged.

The stars were collected by area scanning under low (1o x 1.5 x 1o) magnification in order to make detection of events independent on the multiplicity n_s of relativistic prongs ($\beta >$ o.7). Only stars with $N_h > 3$ *) were retained in the analysis. Since this analysis refers to angular distributions at given N_h, the different relative detection efficiencies for low N_h and high N_h-stars (85% for $N_h \leq 5$, $\geq$ 92% for $N_h \geq 6$) are irrelevant. Careful prong counts were then made under high magnification on all events by at least two observers. Angular measurements were performed on all relativistic prongs of 455 stars **).

Before presenting the experimental evidence for our initial statements (a-c), we have to recall what one would expect from a conventional cascade picture. With increasing path length available in nuclear matter ***), the forward cone should be increasingly populated by succesive collisions of the surviving baryon. Moreover the wide cone should increase similarly in numbers due to cascade multiplication of wide-angle mesons, the angular distribution of which should get wider with increasing multiplicity.

A look at figs. 1 and 2 reveals, however, a completely different picture.

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*) N_h is the number of heavily ionizing ($\beta <$ o.7) prongs.

**) Within this sample, stars with $N_h \leq 5$ and ≥ 6 are not represented in natural proportion, but their numbers (248 and 2o7, respectively) were chosen arbitrarily so as to ensure roughly equal numbers of relativistic prongs in different N_h intervals.

***) [illegible] increasing number ν of collisions in the nucleus of which N_h is a convenient measure.

Fig.1 shows plots of mean values of the partial relativistic prong multiplicity $(\bar{n}_s)_\theta$ within given angular intervals against N_h. From integral angular distribution plots at different N_h, we convinced ourselves that one half of the charged multiplicity n_o in pp collisions at 200 GeV /3/ (viz. ~ 3.8 particles) are for all N_h - contained within a cone of opening $u = (-1.3)-(-1.4)$. This partial multiplicity is seen to increase with N_h much slower than the total multiplicity $\bar{n}_s$ /2/. (circular symbols)

A cone only slightly narrower than that, viz. $u \leq -1.5$ (triangles in fig.1) appears to contain a constant number of about three particles irrespective of N_h.

Square symbols in the same figure show $(\bar{n}_s)$ for the rest of the particles. It is obvious that the wide cone is solely responsible for the increase of $\bar{n}_s$ with N_h.

In fig.2 the angular distribution of all particles is pictured via the mean value of u (circles) for different interval of N_h. The monotonous decrease of $|\bar{u}|$ as N_h increases is, by itself, not surprising. However it is easy to show that this decrease is not due to an overall widening of the angular distribution. Indeed, the mean value of u for the excess tracks, i.e. of those produced at a given N_h beyond the pp multiplicity (squares in fig.2) is obviously independent of N_h. The points were obtained by formally splitting up the angular distribution into a group with mean population n_o /3/ with a mean u equal to u_o and the rest (n_s-n_o) of the particles with an unspecified and in principle N_h- dependent mean u-value viz. u'. Then, for each N_h, from the measured value $\bar{u}$ for all particles we have

$$(\bar{n}_s - n_o)\, u' = \bar{n}_s \bar{u} - n_o u_o \, . \qquad (1)$$

Since /2/ $\bar{n}_s$ is a linear function of N_h,

$$u' = \bar{u}(1 + bN_h) - u_o \, /bN_h \qquad (2)$$

where b is the slope of (n_s, N_h) dependence.

The constancy of u'-values proves that the monotonous decrease of $|\bar{u}|$ with N_h is due only to a shift in relative weight towards higher population of the wide cone, without altering the shape of its angular distribution.

The results presented in fig.1 could be understood in one of the following two ways :

a) Either nuclear matter has an abnormally high transparency for the fast products of the first proton-nucleon collision in the nucleus, or

b) This transparency in only apparent, the forward cone being absorbed and reemitted in a multistep process.

Assumption a) meets at once wi serious objections.Indeed in this case the fast forward products do not contribute to the increase in multiplicity and this is localized in the wide cone only. This agrees with fig.1, but contradicts fig.2, since, by virtue of energy conservation the angles in the wide cone should increase considerably.

On the other hand absorption and reemission of the forward cone shifts responsability for the n_s increase with N_h to this very process *) so that slow particles with roughly the same angular characteristics are produced throughout the whole nucleus without altering the structure of the forward cone itself.

One possible model incorporating these features (viz. the energy-flux cascade) has been recently presented by Gottfried /4/.

REFERENCES

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/3/ G.Charlton et al., Phys.Rev.Lett., 29, 519, 1972

/4/ K.Gottfried, CERN prepr.TH 1[illegible]35, Invited Paper pres.at the Fifth Intern.Conf.on High-Energy Physics and Nuclear Structure, Uppsala, Sweden (1973).

*) Since the bulk of the primary energy is carried by the forward cone.

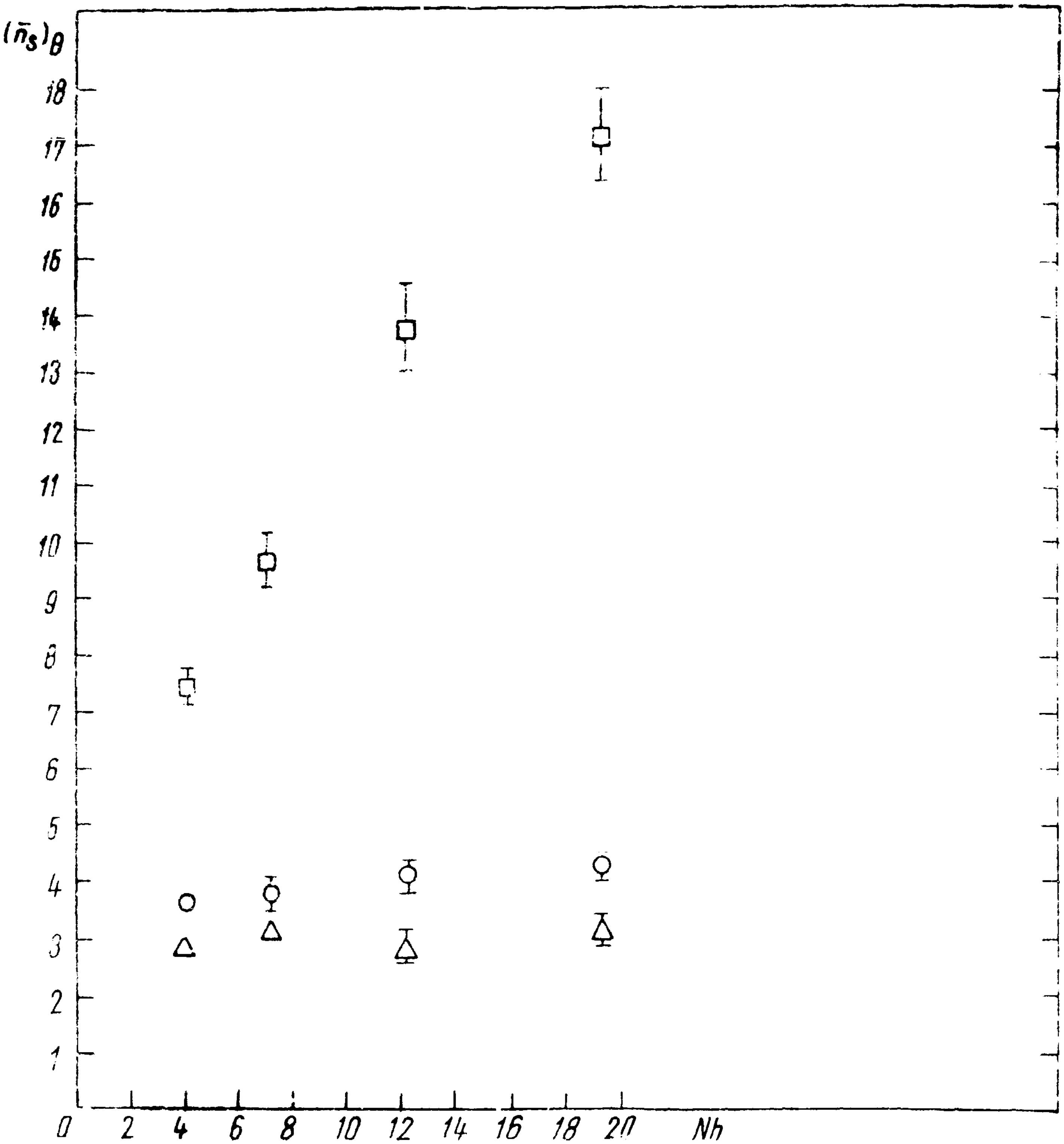

Fig.1. N_h - dependence on mean multiplicity in restricted angular intervals of :
Circles $U \leq -1.35$; triangles $U \leq -1.5$; squares - $U \geq -1.5$.

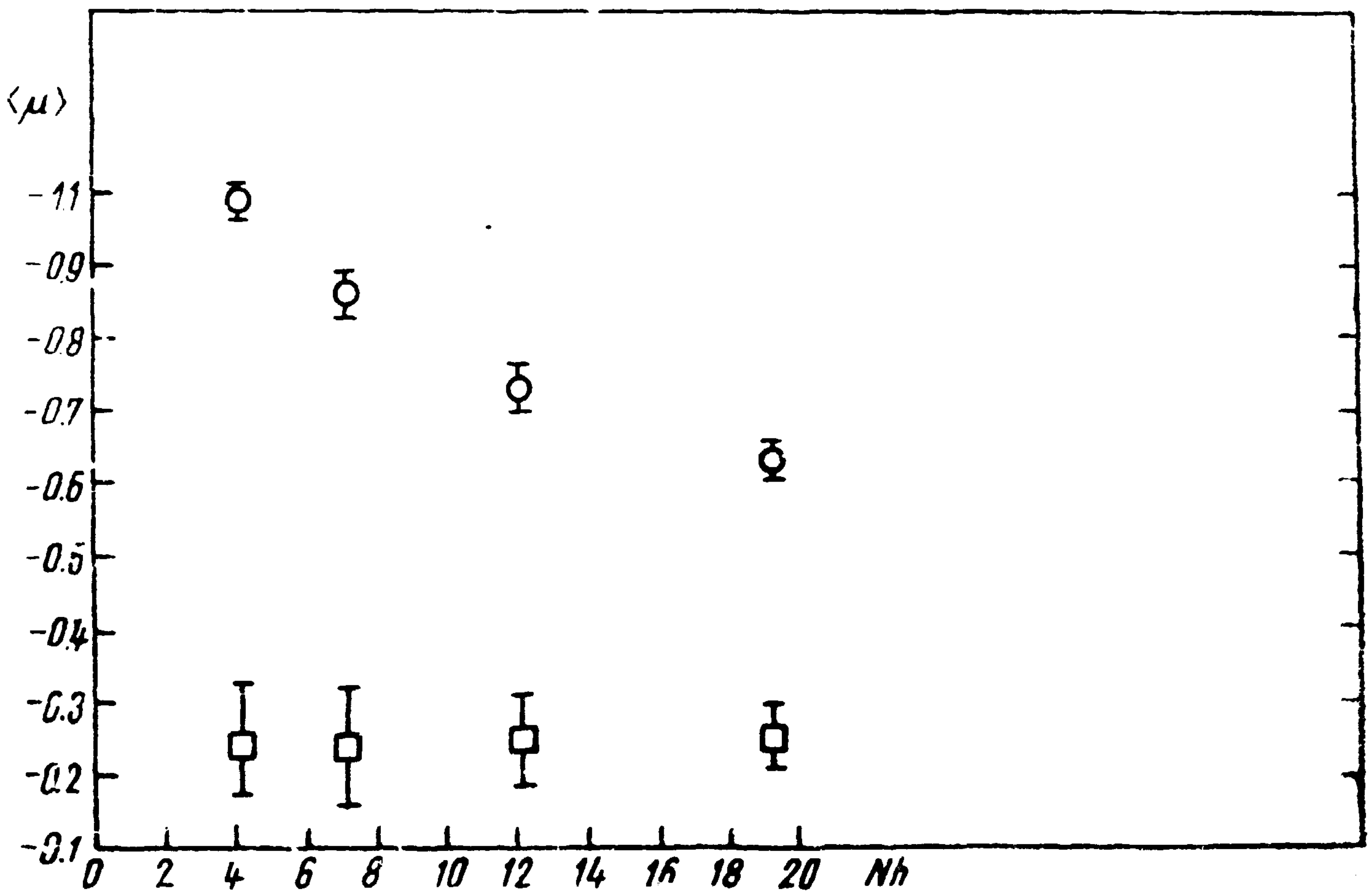

Fig.2. Angular characteristics as a function of N_h : Circles - mean value of $U \equiv$ lg.tg θ for the whole angular distribution; squares - estimates for the mean u of excess tracks (see text.)