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ENERGY DEPENDENCE OF CHARGED MULTIPLICITY IN PROTON - NUCLEUS COLLISIONS AND "NUCLEAR" MULTIPLICITY SCALING

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Following up a recent investigation /1,2,3/ of proton collisions with emulsion nuclei at 200 GeV, we present here the results of a similar experiment at 69 GeV.

We begin by stating its main result, viz. that the ratio:

$$\eta \equiv \bar{n}_s(E_2)/\bar{n}_s(E_1) \qquad (1)$$

of the mean multiplicities of fast charged secondaries produced on a nuclear target at energies E_1 and E_2 ($E_1 > 69$ GeV) does not depend on either the size or the degree of excitation and/or break-up of the target nucleus, in contrast to lower energies where a strong dependence of this kind is observed.

Furthermore these η-values are undistinguishible from the η-value for pp (HBC)-collisions.

This result (especially if proved valid at still higher energies) implies a specifical "nuclear" multiplicity scaling, i.e. the possibility to predict multiplicities from nuclear targets, once the multiplicity from pp collisions at the same energy is known (e.g. from I.S.R.- experiments).

A hint that - if such a scaling is realized at all in nature - it might already be observable at the relatively low energies of the IHEP-NAL accelerator pair was provided by recent evidence /4/for the (surprisingly early) onset of KNO scaling/5/ around 50 GeV in pp collisions. The suspicion that essential features of the elementary (pp) process are reflected in the final result of the traversal of nuclear matter by the surviving and produced hadrons prompted the present investigation.

A stack of BR-2 nuclear emulsion pellicles, (10x20x0.06) cm^3 each, was irradiated in the 69 GeV proton beam of the IHEP-Serpukhov accelerator. In order to exclude hydrogen-and hydrogen-like collisions and, especially, in order to make detection of the events insensitive to the number n_s of fast ($\beta > 0.7$) secondaries area scanning was performed under relatively low magnification. Careful prong counts were then performed on all stars with $N_h \geq 3$ *) with high magnification, by at least two independent observers. The observers as well as the whole experimental technique were identical to those used in the analysis of the 200 GeV exposure. The inherent bias against low-N_h stars **) was irrelevant for the purpose pursued here, viz. investigation of the shape of, the n_s-distribution <u>at fixed N_h</u>.

*) N_h is the number of heavily ionizing prongs ($\beta < 0.7$), a convenient measure for the size of the target nucleus and/or its degree of excitation. Thus, e.g. stars with $N_h > 8$ <u>must</u> originate in heavy (Ag, Br) nuclei.

**) Detection efficiencies were estimated by double scanning and found to be $\sim 85\%$ for stars with $N_h = 3 \div 5$ and $> 92\%$ for larger stars.

Estimates for the main parameters of the observed multiplicity distributions, averaged over all N_h are given in Table I, along with the same figures from the 200 GeV exposure /3/ and with those from experiments at lower energies /6/, /7/ *).

As can be seen, at all energies the distributions deviate significantly from a Poisson shape ($f_2 \neq 0$). Furthermore the approximative constancy of the relative dispersion R, known from pp results, is no longer observed.

At all energies the mean n_s at a given N_h is in good enough approximation a linear function of N_h (fig.1). The slope of the linear fit increases monotonically with primary and above 69 GeV it is even proportional to the $N_h = 0$ intercept.

The salient point emerging from these results is illustrated in Table II, where we compare the multiplicity ratios (eq.(1)) at (200/69 GeV) and (21.5/6.2 GeV), respectively, with the same ratios for proton-proton collisions /8,9,10/. It is obvious that, while at lower energies the nuclear (emulsion) multiplicity increases much stronger with energy that the pp multiplicity, above 69 GeV, these two multiplicities increase at exactly the same rate. If we approximate within each energy interval the multiplicity variation by a power law

$$\bar{n}_s \sim E^{\alpha} \qquad (2)$$

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*) In view of the relatively weak energy dependence of the multiplicity, data at 20.5 GeV /1/ and 22.5 GeV /7/ were pooled in order to improve statistics.

the α-values given in Table II show that between $\gtrsim$ 10 GeV and $\gtrsim$ 100 GeV, α drops by a factor of $\gtrsim$ 2 for nuclear targets.

It is interesting to remark that the constancy of η is valid not only for the "average emulsion nucleus", but also for any given value of N_h.

Fig.2 shows the N_h-dependence of η for the two energy ranges, together with straight line least-square fits *). It is obvious **) that in the high-energy range, η does not depend on N_h, i.e. it is the same for light and heavy target nuclei and for all degrees of nuclear excitation and/or break-up.

These results suggest that at high-enough energies the ratio :

$$\zeta \equiv \bar{n}_s(N_h)/\bar{n}_s(pp) \qquad (3)$$

is a $\sim$ linear) function of N_h only. The mean value of ζ (averaged over all emulsions nuclei heavier than hydrogen) is $\gtrsim$ 1.9 ($\gtrsim$ 1.7 if hydrogen is included /2/). Using the pp multiplicities measured at the ISR at 53 GeV c.m.s. energy /11/ one would predict a mean multiplicity of $\gtrsim$ 23 of cosmic-ray jets produced in nuclear emulsion at $\gtrsim$ 1.5 TeV.

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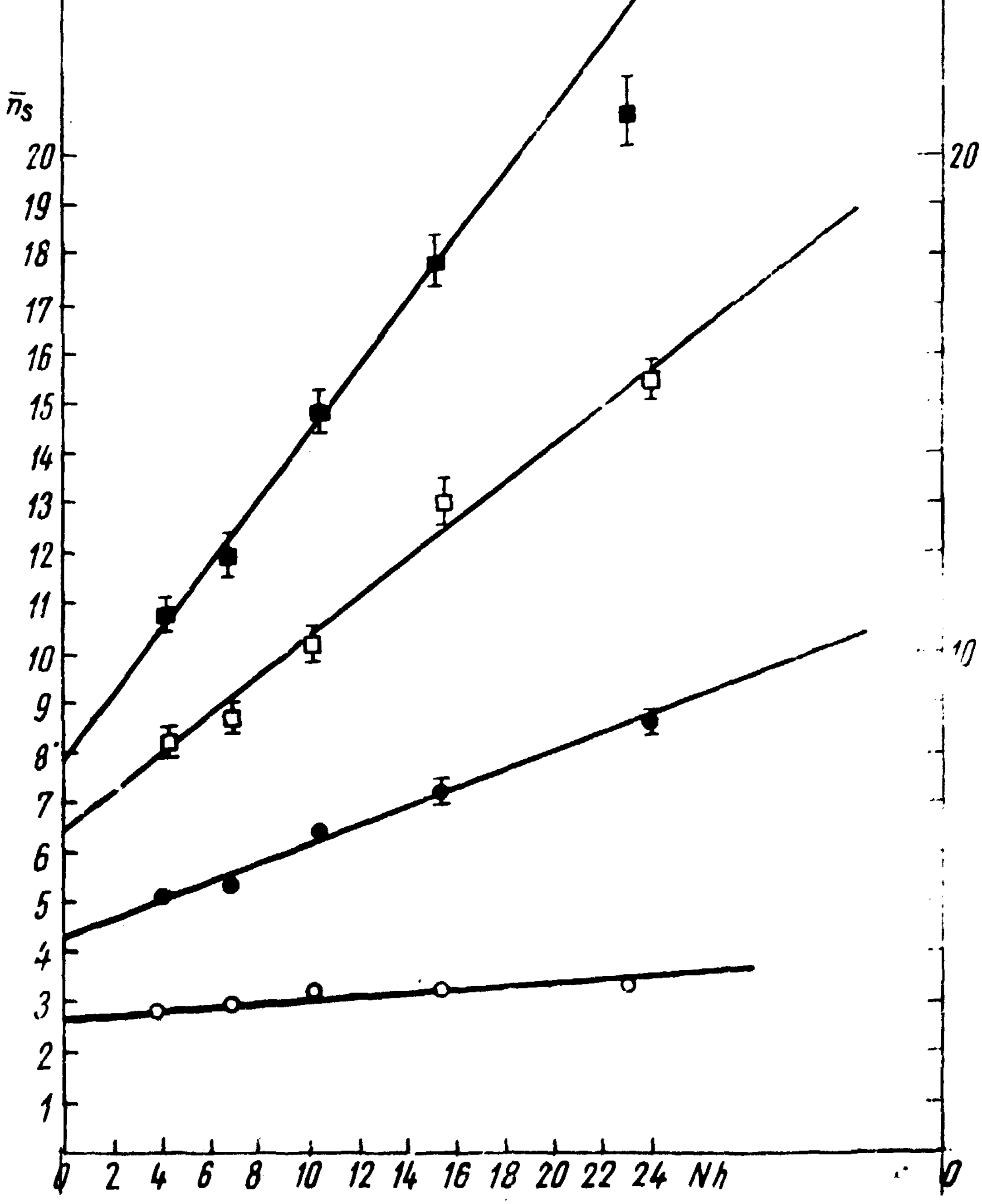
*) The fits were made on η-values at individual values of N_h. The data points in fig.2 are from several pooled N_h intervals, each.

**) χ^2 = 7.3 with 8 degrees of freedom.

Fig.1. Mean multiplicities n_s as a function of N_h. Open circles: 6.2 GeV; full circles 21.5 GeV; open squares 69 GeV (this experiment); full squares 2oo GeV.



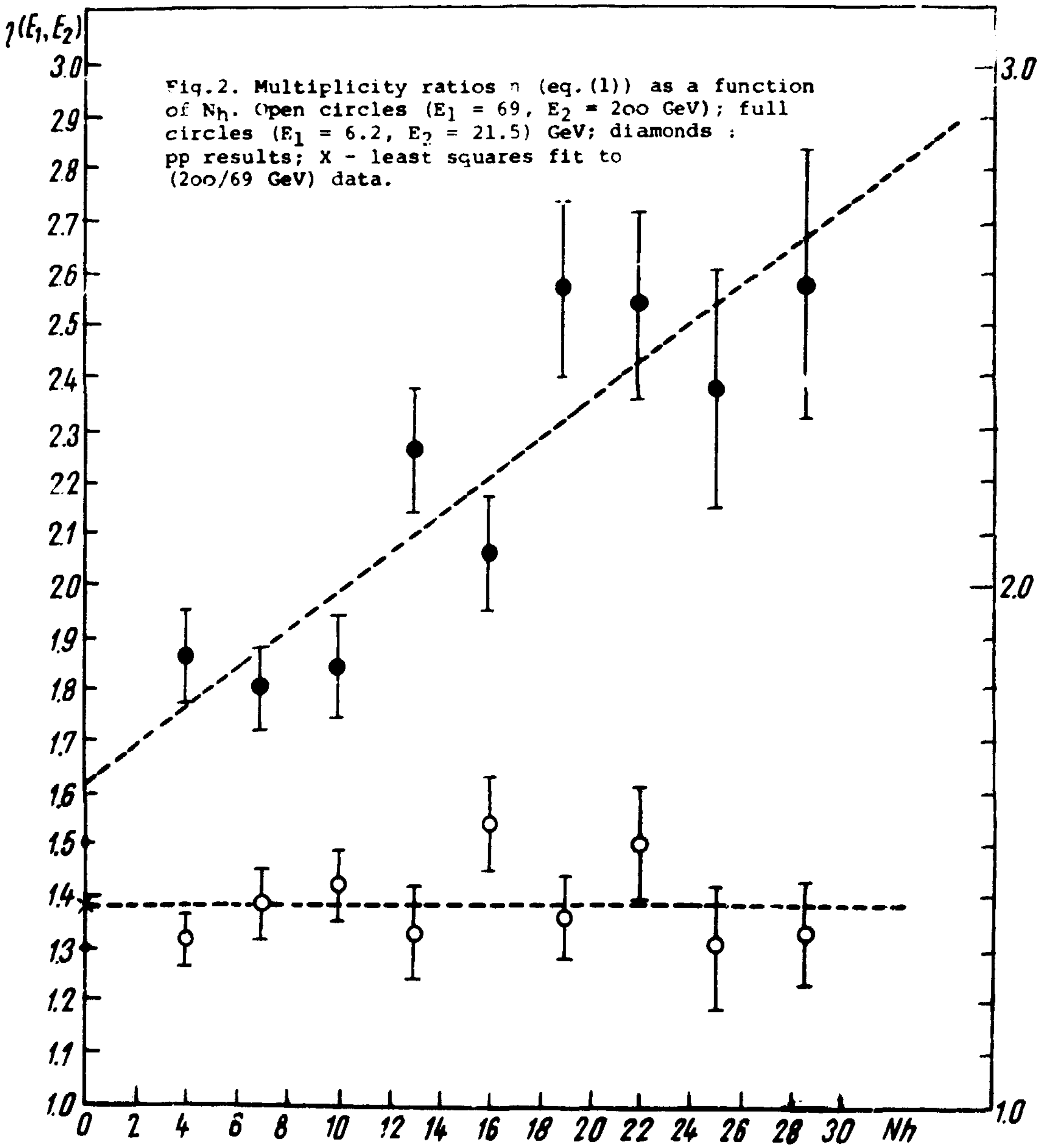


Fig.2. Multiplicity ratios η (eq.(1)) as a function of N_h. Open circles (E_1 = 69, E_2 = 2oo GeV); full circles (E_1 = 6.2, E_2 = 21.5) GeV; diamonds : pp results; X - least squares fit to (2oo/69 GeV) data.

Table I

Beam Energy (GeV)	Nr. of events	$\bar{n}_s$	R *)	f_2 **)	Reference
6.2	1298	3.10±.04	.505±.017	-.65± .11	/6/
21.5	1000	6.28±.11	.538±.021	5.14±.52	/6/,/7/
69	1189	11.08±.18	.548±.019	25.8 ±1.5	This experiment
200	1719	14.53±.22	.623±.018	67.4 ±2.8	/3/ (previous experiment)

*) $R \equiv (\langle n_s^2 \rangle - \langle n_s \rangle^2)^{1/2} / \langle n_s \rangle$

**) $f_2 \equiv \langle n_s^2 \rangle - \langle n_s \rangle^2 - \langle n_s \rangle$

Table II

E_1, E_2	η		α	
	Emulsion	pp	Emulsion	pp
200 / 69	1.31±.03	1.30±.03	.25±.03	.25±.03
21.5/6.3	2.03±.04	1.50±.01	.51±.02	.31±.01

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