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MULTIPLICITY DISTRIBUTION FROM COHERENT INTERACTIONS OF PROTONS WITH NUCLEI IN THE ENERGY RANGE 20 - 200 GEV/C

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ABSTRACT

The experimental data on the charged particles multiplicity distribution from the diffractive coherent reactions of protons with nuclei at incident momenta 20.8, 50, 67, and 200 Gev/c are presented and discussed. The comparison with the corresponding data from the diffraction dissociation in proton-proton interactions was made. It is shown that the diffractive processes have an universal character.

Discussion on the multiplicity distribution of diffractively-produced particles has been of increasing interest lately [1] in connection with the two-component models of multiple production. Unfortunately, the obtaining of the experimental information about this subject is very delicate problem since the separation of the diffraction channels from hadron-nucleon data is not free from biases, especially in the large masses region of the excited systems [2].

Therefore it is very attractive to obtain the data on the multiplicity distribution in the coherent production from nuclei. Apart from the obvious and independent interest in these data, they may be compared with the corresponding data from interactions with nucleon target for instance in the framework of the Glauber model. It must be noted that in the case of the nuclear production the background conditions are considerably better than in the case of the diffraction dissociation on nucleons.

In this letter we report the experimental results on the multiplicity of the charged particles produced in the coherent interactions of P_L= 20.8, 50, 67, and 200 Gev/c protons with the emulsion nuclei, which were obtained by the uniform method from high (for emulsion technique) statistical material.

The selection of events associated with the coherent reactions

$$p + A \longrightarrow N + k\pi^{\pm} + l\pi^{0} + A \qquad (1)$$

(where A is target nucleus with A nucleons, $k,l \geqslant 0$, $k+l \geqslant 1$ and the number of charged particles n is odd and equal to k, if N is the neutron, or k+1, if N is the proton) was done from the inelastic interactions, which were found by the "along-the--track" scanning of emulsion stacks exposured at CERN, INEP and NAL accelerators. The details of the exposures, scanning and measurements were given in [3-6]; some statistical data are represented in the Table 1.

The selection of the reactions (1) was carried out by using of the well-known inequality $q_{\parallel} \leqslant R_A^{-1}$ ($q_{\parallel}$ is the longitudinal momentum transferred to the target, R_A is the radius of the target) which leads to the more stronger angular collimation of secondaries from these reactions than in the odd-prong proton-neutron collisions. As a very rough, but rather effective approximation of the $q_{\parallel}$, the parameter $\sum_{i=1}^{n} \sin\theta_i$ has been applied for this selection.

Fig.1a shows, as an example, the $\sum_i \sin\theta_i$ -distributions for the quasicoherent "clean" (without any visible indication to the excitation or break-up of target) and background three-prong events at 200 Gev/c. The difference between these distributions is very appreciable. Assuming that the abundance of the "clean" stars at small $\sum_i \sin\theta_i$-values is due to the coherent reactions it is easy to estimate their number normalizing the $\sum_i \sin\theta_i$ -distributions in the region $\sum_i \sin\theta_i > (\sum_i \sin\theta_i)^{max}$, where the last value is the conventional upper limit for reactions (1). The number of coherent events N_{coh} monotonously grows with the increasing of the parameter $(\sum_i \sin\theta_i)^{max}$ and attains a "plateau", the height of which gives the true value of the N_{coh} . This procedure for n= 3, 5, and 7 at 200 Gev/c is shown in Fig.1b and was used also for all incident momenta and multiplicities.

There were used additional assumptions to define the cross-sections of the one-prong reactions (1). At first we estimated the number of such events from the above described procedure for the region $\theta > \theta_{el}$, where θ_{el} is the angle at which the number of elastic scattering events with $\theta > \theta_{el}$ is negligible. Assuming then the azimuthal isotropy of the one-prong events and introducing the similarity of the angular distributions of the charged particles in the events with n= 1 and n= 3 there were made corrections 1) to the number of the coherent one--prong stars lossed in the scanning and 2) the events which were in the elastic scattering region. The percentage of the each of these corrections was about 15-20 % of the $N_{coh}^{(1)}$. At 20.8 Gev/c the cross-section for one-prong reactions was estimated in the framework of the statistical isospin model [8] from data of the paper [7].

Our results are presented in the Fig.2 and Tables 1 and 2. The given values of the topological cross-sections are corresponded to the mean emulsion nucleus (<A>= 47) and were obtained under assumption that $\sigma_{coh} \sim A^{2/3}$. In the last line of the Table 1 there are presented the data for the reaction

$$p + A \longrightarrow p + \pi^{+} + \pi^{-} + A \qquad (2)$$

at 20.8, 50, and 67 Gev/c. These data were obtained by the momentum measurements (see [3]).

From an analysis of the quoted data one can conclude:

(i) The total and topological cross-sections for the coherent production induced by protons on the emulsion nuclei noticeably increase (from 8 mb at 21 Gev/c up to 22 mb at 200 Gev/c); the most rise is observed for multiprong channels. However it should be noted that in this energy interval σ_{coh} composes only small fraction of the total inelastic cross-section ($\sigma^{inel} \sim 10^3$ mb).

(ii) The growth of the coherent cross-sections is associated with the opening of the new channels with higher total multiplicities, i.e. with larger masses of the excited state (Nova). It can be seen, for example, from comparison of the energy dependences for σ_{3prong} and $\sigma_{p\pi^+\pi^-}$ or from the cross-sections for 5-prong and 7-prong channels (see Table 1).

(iii) The shape of charged particles multiplicity distributions in diffractive coherent reactions (1) is independent apparently from energy in investigated energy range. The comparison of the negative particles multiplicity distributions with the Poisson distribution in the Fig.2a shows that the agreement is very poor at all incident momenta. Indeed it is impossible to exclude the Poisson distribution entirely because of the experimental uncertainty (~20-30 %) in cross-sections for one-prong reactions (1).

It is very striking that for the multiplicity distributions in coherent reactions the KNO scaling law [9] is fulfilled; moreover it is easy to see from Fig.2b that experimental points are described by the same curve, which was proposed by Slattery [10] for proton-proton data.

(iv) The average charged particles multiplicity in reactions (1) grows slowly with the increasing of the P_L (see Table 2 and Fig.2c). The energy dependence agrees well with the linear approximation in ln P_L :

$$\langle n_- \rangle = 0.1 \ln P_L + 0.26 \qquad (3)$$

In the Fig.2c we have plotted also the data from NAL HBC for the proton beam fragmentation [2]. It is known that the cross-sections and mean multiplicities as quoted in the review [2] are only the lowest limits of the corresponding quantities because of unfavourable background conditions in the high masses region. Therefore we can conclude that the mean multiplicities and the shape of the multiplicity distributions in the proton beam dissociation are possibly independent on the nature of the target. This indicates the factorization in the Pomeron exchange. It should be noted that in both cases mass spectra of the excited system are approximately similar.

(v) The correlation parameter $f_2 = \langle n(n-1) \rangle - \langle n \rangle^2$ also coincides for pN and pA collisions and seems to be independent from the energy. Its values are consistent with the diffractive nature of investigated processes and indicate an universal character of this phenomena.

We hope to realize more detail study of the diffractive coherent reactions in the nearest future.

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REFERENCES

1. L.Van Hove, Phys.Lett.43B (1973) 65
   W.R.Frazer and D.R.Snider, Phys.Lett.45B (1973) 136
   K.Kajantie and P.V.Ruuskanen, Phys.Lett.45B (1973) 149
   R.C.Roberts and D.P.Roy, Phys.Lett.46B (1973) 201
2. J.Whimore, NAL-PUB-73/70-EXP (1973)
3. S.A.Azimov et.al.,Doklady Academy of Sci.USSR 192(1970)1241
4. S.A.Azimov et al.,Doklady Academy of Sci.USSR 212(1973)1323
5. Alma-Ata-Cracow-Dubna-Leningrad-Moscow-Tashkent-Ulan-Bator collaboration, Phys.Lett.39B (1972) 285
6. Alma-Ata-Leningrad)-Moscow-Taskent collaboration, JETP Pizma 18 (1973) 19; Yadernaya Fizika 19 (1974) 322
7. M.J.Longo et.al., Phys.Lett.36B (1971) 560
8. J.Bartke, INP Report No 719/PH, Cracow (1970)
9. Z.Koba et.al., Nucl.Phys.40B (1972) 317
10. P.Slattery, Phys.Rev.Lett.29 (1972) 1624;
    Phys.Rev.7D (1973) 2073

FIGURE CAPTIONS

Figure 1. separation of the conerent reactions from quasinucleon events: a) $\sum_{i=1}^{3} \sin\theta_i$-distributions for "clean" quasicoherent and background three-prong stars at 200 Gev/c; b) the estimation of the N_{coh} from dependence $N_{coh}^{(n)}$ vs $(\sum_i \sin\theta_i)^{max}$ at 200 Gev/c.

Figure 2. Multiplicity distributions in reactions (1) (a,b) and the energy dependences of the $\langle n_- \rangle$ and f_2 for pA (full circles) and pp dissociation (open circles). Curves are: in Fig.2a - Poisson distributions; in Fig.2b - an universal KNO function for pp collisions [10].

Table 1. Topological cross-sections in coherent proton-nucleus collisions

Incident momenta in Gev/c	20.8	50	67	200
Total scanned length in kilometers	2.6	2.6	3.1*	5.3**
Number of inelastic events in thousands	7.3	7.2	8.2	15.0
σ_{1prong}(mb/nucleus)	(3.9 ± 2.0)***	(4.0 ± 1.1)	(6.2 ± 1.6)	(8.7 ± 1.6)
σ_{3prong}(mb/nucleus)	(3.9 ± 0.7)	(5.4 ± 0.8)	(6.9 ± 1.0)	(9.6 ± 0.8)
σ_{5prong}(mb/nucleus)	(0.3 ± 0.2)	(0.8 ± 0.3)	(0.8 ± 0.3)	(3.2 ± 0.5)
σ_{7prong}(mb/nucleus)	(~ 0)	(~ 0)	(~ 0)	(0.6 ± 0.2)
$\sigma_{coh} = \sum_n \sigma_{nprong}$	(8.1 ± 2.3)	(10.3 ± 1.7)	(14.0 ± 1.9)	(22.1 ± 2.0)
$\sigma_{p\pi^+\pi^-}$ (mb/nucleus)	(3.1 ± 0.6)	(2.6 ± 0.6)	(3.0 ± 1.0)	---

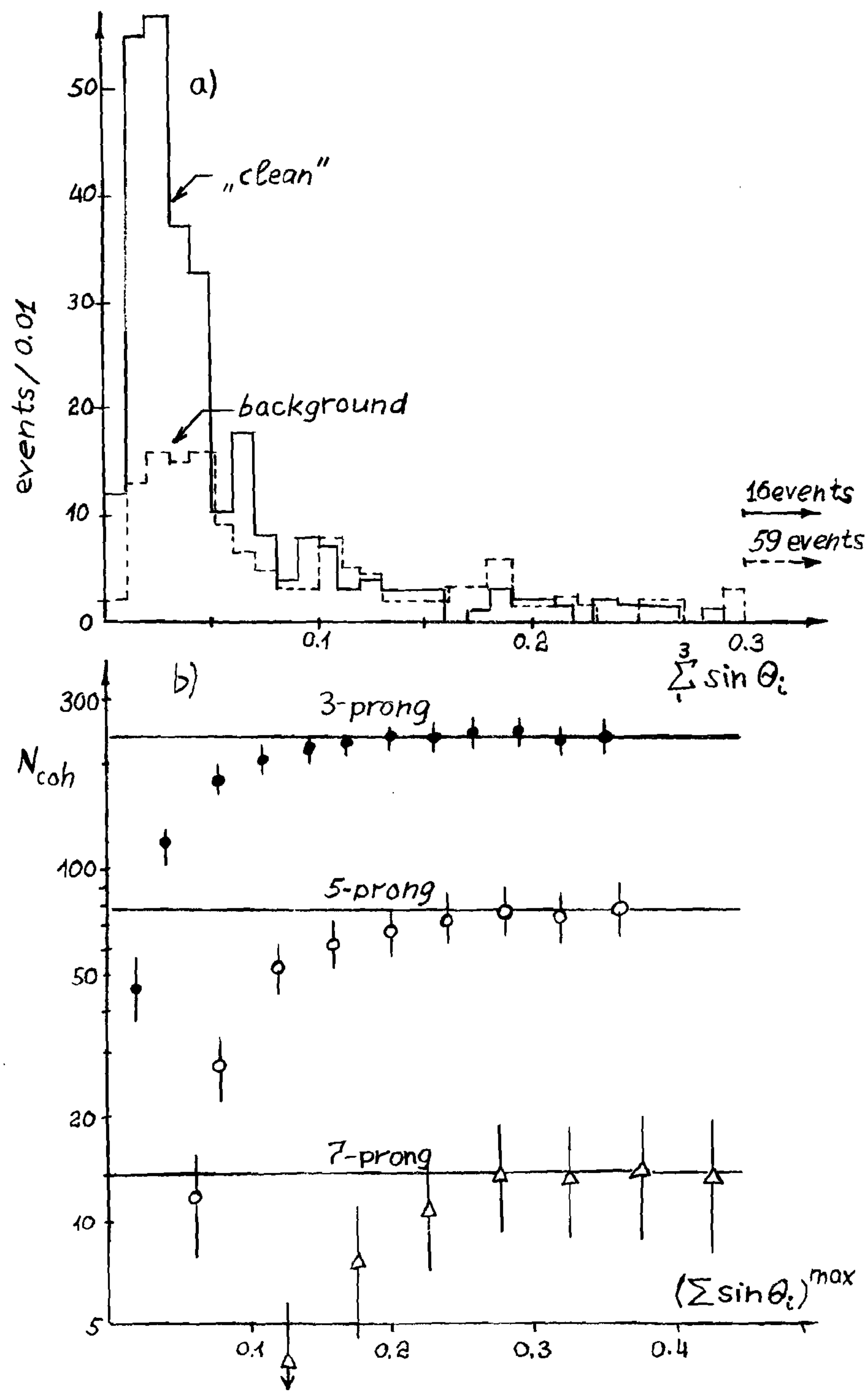
(*) Material of the ACDLMTU collaboration [5].

(**) 3.3 km from ALMT collaboration [6].

(***) Estimated from [7], see text.

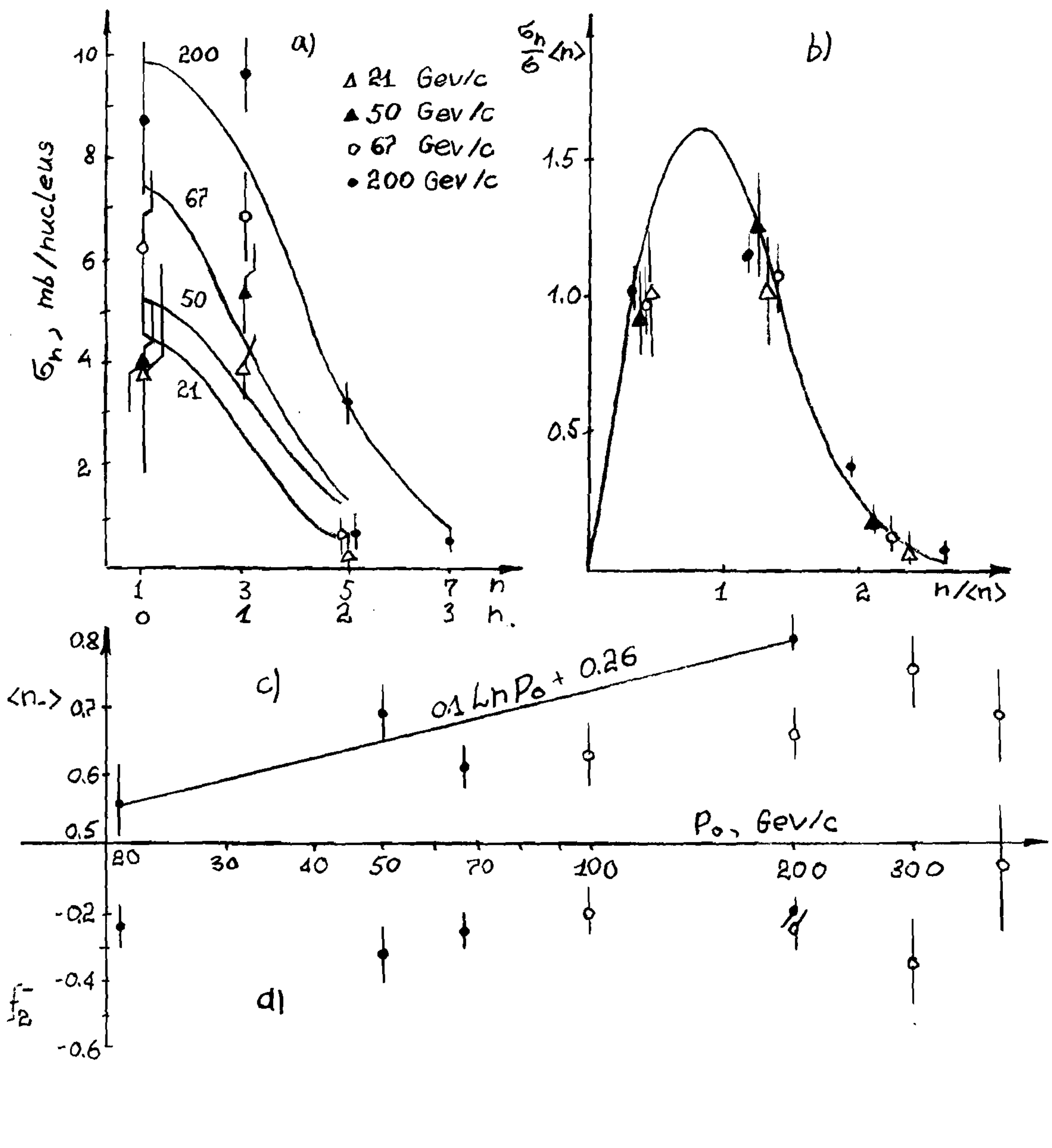
Table 2. Multiplicity distribution moments in coherent pA reactions

	P_L in Gev/c	$\langle n \rangle$	$\langle n(n-1) \rangle$	$D = [\langle n^2 \rangle - \langle n \rangle^2]^{1/2}$	f_2
For all tracks	20.8	(2.11 ± 0.11)	(3.06 ± 0.45)	(1.12 ± 0.26)	(-0.86 ± 0.67)
	50	(2.38 ± 0.11)	(4.75 ± 0.47)	(1.21 ± 0.24)	(-0.89 ± 0.69)
	67	(2.21 ± 0.08)	(4.10 ± 0.34)	(1.19 ± 0.18)	(-0.80 ± 0.50)
	200	(2.61 ± 0.07)	(6.61 ± 0.37)	(1.56 ± 0.14)	(-0.18 ± 0.51)
For negative only	20.8	(0.56 ± 0.06)	(0.07 ± 0.04)	(0.56 ± 0.09)	(-0.24 ± 0.08)
	50	(0.69 ± 0.05)	(0.16 ± 0.05)	(0.61 ± 0.09)	(-0.32 ± 0.09)
	67	(0.61 ± 0.04)	(0.12 ± 0.03)	(0.60 ± 0.07)	(-0.25 ± 0.06)
	200	(0.80 ± 0.03)	(0.45 ± 0.05)	(0.78 ± 0.05)	(-0.20 ± 0.07)



a)
"clean"
background
events/ 0.01
16 events
59 events
$\sum_1^3 \sin\theta_i$
b)
3-prong
5-prong
7-prong
N_{coh}
$(\sum \sin\theta_i)^{max}$

Fig 1.



a)
b)
c)
d)
200
67
50
21
Δ 21 Gev/c
▲ 50 Gev/c
o 67 Gev/c
• 200 Gev/c
σn , mb/nucleus
n
h.
n/<n>
<n->
0.1 Ln P0 + 0.26
P0 , Gev/c

Fig 2.