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# THE MULTIPLICITY IN FRAGMENTATION AND PIONISATION REGIONS IN pp-INTERACTIONS AT 200 Gev/c

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Two BR-2 emulsion stacks 20cmx10cmx100x0,06 cm in size were irradiated by 200 Gev/c protons at the NAL accelerator in Batavia (USA). The scanning along the track was performed. We observed 9339 inelastic interactions on the track length of 3303 m of primary protons.

## 1. The averaged values of multiplicity distributions.

The events of proton-nucleon interactions were selected using the criteria given in works [1,2] . Charged particle multiplicity distributions in pp and pn- interactions are shown in table 1. The efficiency of scanning and Dalitz pairs have been used to make the correction to the numbers of charged particles. The multiplicity distribution of charged particles generated on coherent proton interaction with nuclei is also shown in table 1.

It should be noted that the multiplicity distribution in pp and pn- interactions are similar. The coherent multiplicity distribution is narrower than that of proton-nucleon and has no more than 7 prongs.

The averaged characteristics of multiplicity distributions are shown in table 2. The averaged charged particle multiplicity was obtained

$$\langle n \rangle_{pp} = 8,2 \pm 0,2 \qquad (1)$$

for pp-interaction at 200 Gev/c and one for pn-interaction was obtained

$$\langle n \rangle_{pn} = 7,7 \pm 0,2 \qquad (2)$$

The value $\langle n \rangle_{pp} - \langle n \rangle_{pn} = 0,5 \pm 0,2$ was explained as the difference of fragmentation of a proton and neutron. The averaged charged particle multiplicity in coherent proton-nucleus interactions is $$\langle n \rangle_{coh} = 2{,}7 \pm 0{,}1 \qquad (3)$$

Apparently, this value is somewhat overestimated, because we do not take into account coherent inelastic one-prong events in the region of elastic interactions.

The values

$$\langle n \rangle_{pp} = 6{,}4 \pm 0{,}2 \quad , \qquad \langle n \rangle_{pn} = 6{,}0 \pm 0{,}2 \qquad (4)$$

$$\langle n \rangle_{coh} = 2{,}5 \pm 0{,}2$$

were obtained as a result of the investigation of proton-nucleon and proton-nucleus interactions at 67 Gev/c [1].

Thus, the averaged multiplicity of the coherent interaction and the difference $\langle n \rangle_{pp} - \langle n \rangle_{pn}$ in all probability do not depend on energy.

Averaged multiplicities $\langle n \rangle$, ratios of $\langle n \rangle$ to the dispersion D and moments $f_2$ are shown in table 2. for three types of interactions. Moments $f_2$ are the characyerestics of multiplicity distributions. It is noted that pp and pn - distributions are broader than the Poisson distribution, and coherent interaction distributions agree with the Poisson distribution.

2. Forward-backward hemisphere multiplicity.

It is interesting to study the multiplicity of charged particles produced in a pp-collision and define $n = n_f + n_b$, where superscripts f and b refer to the forward and back hemispheres in the cm system for the outgoing momenta. The hemisphere f is defined as the one for which the longitudibal momentum is $p_{\parallel} > 0$. In independent emission models (statistic model, multiperipheral model, etc) wide multiplicity fluctuations are quite unlikely. However, according to the hypothesis of a limiting fragmentation [3] wide fluctuations are allowed because the fragmentation into very few fragments is expected to occur with a finite probability, although the average multiplicity continues to increase with energy [4]. According to the hypothesis of the limiting fragmentation for a fixed energy averaged forward-back multiplicity should be submitted to

$$\langle n_f \cdot n_b \rangle / (\langle n_f \rangle \langle n_b \rangle) = 1$$

$$\langle n_f^2 \rangle \equiv \langle n^2 b \rangle \gg \langle n_f \cdot n_b \rangle \qquad (5)$$

at $E \to \infty$ .

We divided particles of the every event into two parts relative to $90^\circ$ in cms corresponding to momentum $p_{\parallel}=0$ in cms. For this we use the value

$$\langle u \rangle = \lg \operatorname{tg} \theta \Big|_{p_{\parallel}=0} \cong -\lg \gamma_c + \int_0^\infty \lg \frac{p_\perp}{\sqrt{p_\perp^2 + m_\pi^2}} \cdot \frac{p_\perp}{p_0} \cdot \exp\left(-\frac{p_\perp}{p_0}\right) dp_\perp \qquad (6)$$

It is equal to the averaged value $\lg \operatorname{tg} \theta \Big|_{p_{\parallel}=0}$

For the

$$p_0 = \langle p_\perp \rangle / 2 = 0,17 \qquad (7)$$

it is

$$\langle u \rangle = -1,11 \qquad (8)$$

Marking $n_b$ and $n_f$ as before the numbers of the particles of the every event with $\lg \operatorname{tg} \theta$ larger and smaller than -1,11 it is easy to check eq.(5). Our experimental study of pp-collision yields

$$\langle n_f \cdot n_b \rangle / (\langle n_f \rangle \langle n_b \rangle) = 1,12 \pm 0,06 \qquad (9)$$

( $\langle n_f \rangle = 4,2 \pm 0,1$ and $\langle n_b \rangle = 4,1 \pm 0,1$ as it was expected are equal within the errors.

and

$$\left(\frac{\langle n_f^2\rangle+\langle n_b^2\rangle}{2}\right)\Big/\langle n_f\cdot n_b\rangle \qquad =1,24 \pm 0,07 \quad (10)$$

The received data, on the one hand, do not contradict to the hypothesis of the limiting fragmentation: charged particle forward and back multiplicity could be believed independent. On the other hand, the second relation (5) does not satisfy to the total extent. Evidently we can't believe that the limiting behaviour is achieved. Besides, we think that there is a process of independent generation of particles.

Let us consider the cross section to produce $n_f$ charged particles in the forward hemisphere for the fixed multiplicity n as a function of $n_f$. In proton-proton collisions this distribution is necessarily symmetric about the point $n_f=n/2$. But, its behaviour near the symmetry point is sensitive to the model of the particle generation. In the limiting fragmenation model cross section $\sigma(n_f,n-n_f)$ is minimum for $n_f=n/2$. In a simple multiperipheral model it is maximum for $n_f=n/2$. In Fig. 1 the experimental distribution $\sigma(n_f,n-n_f)$ is shown for n=6, 8,10,12 and 14. As it is seen from fig.1 for $n>\langle n\rangle$ the data suggest rather the multiperipheral model than the limiting fragmentation. For the multiplicity n=6 the shape of the dependence on $n_f$ may be explained with the help of two models: multiperipheral and fragmentation.

## 3. The multiplicity of charged particles generated in a process of fragmentation and pionisation

The dependence of $\frac{1}{\sigma_{inel}}\cdot\frac{d\sigma}{d\sigma}$ on rapidity $y=-\ln tg\frac{\theta_L}{2}$ for a proton-proton collision is shown in fig.2. This distribution increases up to y=2, has a wide maximum in the range

$2 \leqslant y \leqslant 4{,}65$, and the fall down. The observation of the wide maximum in a cross section near $90^{\circ}$ suggests that there are two production mechanisms: fragmenation and pionisation. We investigated multiplicity distributions in three different rapidity ranges $y < 2{,}0$, $y > 4{,}65$ and $2{,}0 \leqslant y \leqslant 4{,}65$. We define the process in the first two ranges as fragmentation of interacting particles, however, the process in the third range - as pionisation, although it is expected that these ranges are overlapping. We obtained charged particle multiplicity distributions in these ranges. Reults are shown in Fig.3. The multiplicity distribution in the pionisation range is broader than that in the fragmentation range.

The averaged multiplicities and momenta of the above-mentioned multiplicity distribution are shown in table 3. The averaged fragmentation multiplicity $\langle n \rangle_f = 3{,}6 \pm 0{,}1$. Th latter value is interesting to compare with the value 3,6 predicted by diffractive model Nova[5]. Let us note that the sum of averaged multiplicity is somewhat more of the averaged multiplicity obtained in the second section. It is connected with the fact that the consideration of multiplicity in different rapidity ranges is carried out without correction for the events missing, because we can show only the value of missing rather than the rapidity distribution of missing events.

The value $f_2$ shown in table 3 suggests that fragmenation multiplicity distribution in pp-collision at 200 GeV agree with the Poisson one , and pionisation multiplicity distribution is broader than the Poisson one.

## Conclusion

The obtained data suggest two mechanisms of a multiple generation of charged particles. The pionisation process dominates at large multiplicities. The averaged multiplicity of pionisation particles is more by the factor 1,5 than that of fragmentation. The correlation momentum of pionisation multiplicity distribution is a positive value, and this suggests the correlation of generating particles.

## References

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Table I

Multiplicity distribution of charged relativistic particles

| n | Number of obteined events | $N_{pp}$ | $N_{pn}$ | $N_{pA}$ |
|---|---|---|---|---|
| I | I56 | – | 63 ± 8 | II8 ± II |
| 2 | 59 | 67 ± 8 | – | – |
| 3 | 240 | – | I02 ± I0 | I46 ± I2 |
| 4 | 8I | 90 ± I0 | – | – |
| 5 | I45 | – | 98 ± I0 | 56 ± 8 |
| 6 | III | II9 ± II | – | – |
| 7 | I38 | – | I3I ± II | 7 ± 3 |
| 8 | II3 | II3 ± II | – | – |
| 9 | I05 | – | I05 ± I0 | – |
| I0 | 97 | 97 ± I0 | – | – |
| II | 77 | – | 77 ± 9 | – |
| I2 | 80 | 80 ± 9 | – | – |
| I3 | 53 | – | 53 ± 7 | – |
| I4 | 37 | 37 ± 6 | – | – |
| I5 | 42 | – | 42 ± 7 | – |
| I6 | 3I | 3I ± 6 | – | – |
| I7 | I9 | – | I9 ± 4 | – |
| I8 | I2 | I2 ± 3 | – | – |
| I9 | I2 | – | I2 ± 3 | – |
| 20 | 8 | 8 ± 3 | – | – |
| 2I | 3 | – | 3 ± 3 | – |
| 22 | – | – | – | – |
| 23 | – | – | – | – |
| 24 | – | – | – | – |
| 25 | – | – | – | – |
| 26 | I | I ± I | – | – |

Table 2

Averaged characteristics of multiplicity distributions in proton-proton, proton-neutron and coherent proton-nucleus interactions.

| | pp | pn | pA |
|---|---|---|---|
| n | 8.2 ± .2 | 7.7 ± .2 | 2.7 ± .I |
| n/D | I.96 ± .I7 | I.74 ± .I8 | I.73 ± .06 |
| $f_2$ | I0.0± 4.3 | I2.3 ± 4.0 | -( .3 ± .5) |

Table 3

Momenta for multiplicity distributions for pp-collision in two rapidity ranges.

| | Ranges of fragmentation $y < 2$ and $y > 4.65$ | Range of pionisation $2.0 \leqslant y \leqslant 4.65$ |
|---|---|---|
| n | 3.6 ± .I | 4.90 ± .I5 |
| $f_2$ | -( .03 ± .80 ) | 7.0 ± 2.0 |

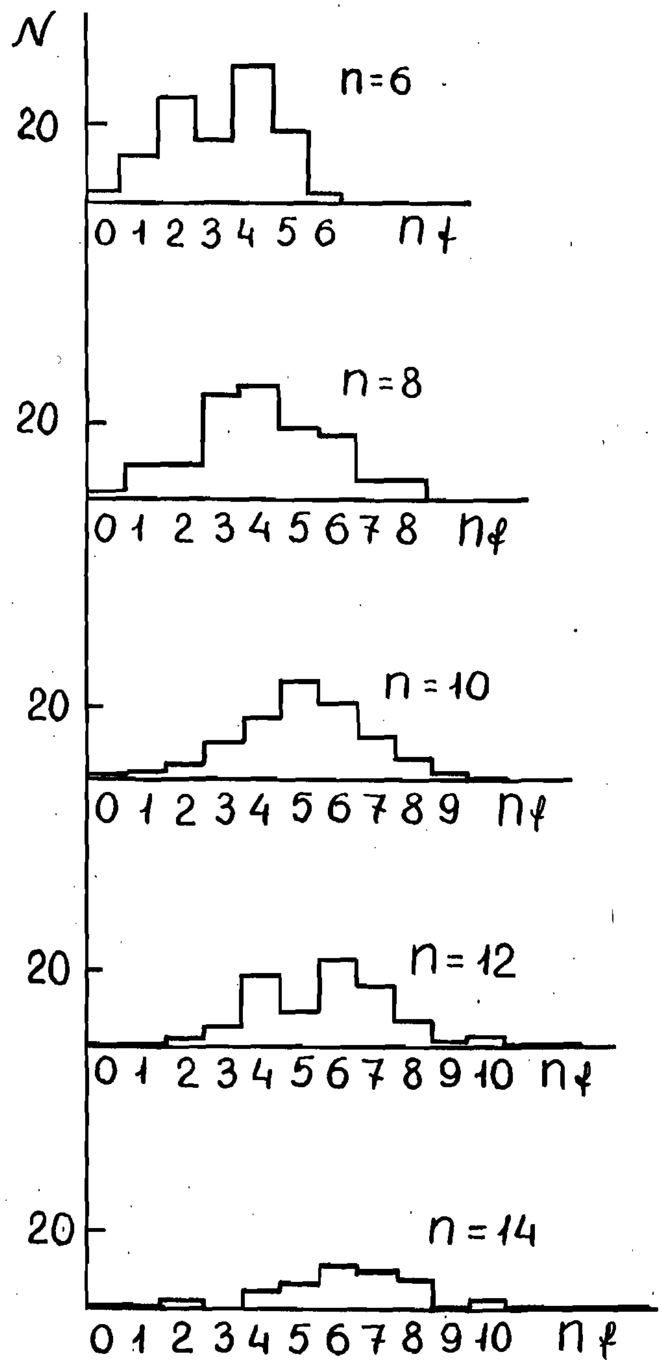


Fig.1. Multiplicity distribution of particles generated in forward hemisphere in CM system for different values of event multiplicity: n = 6, 8, 10, 12, 14.

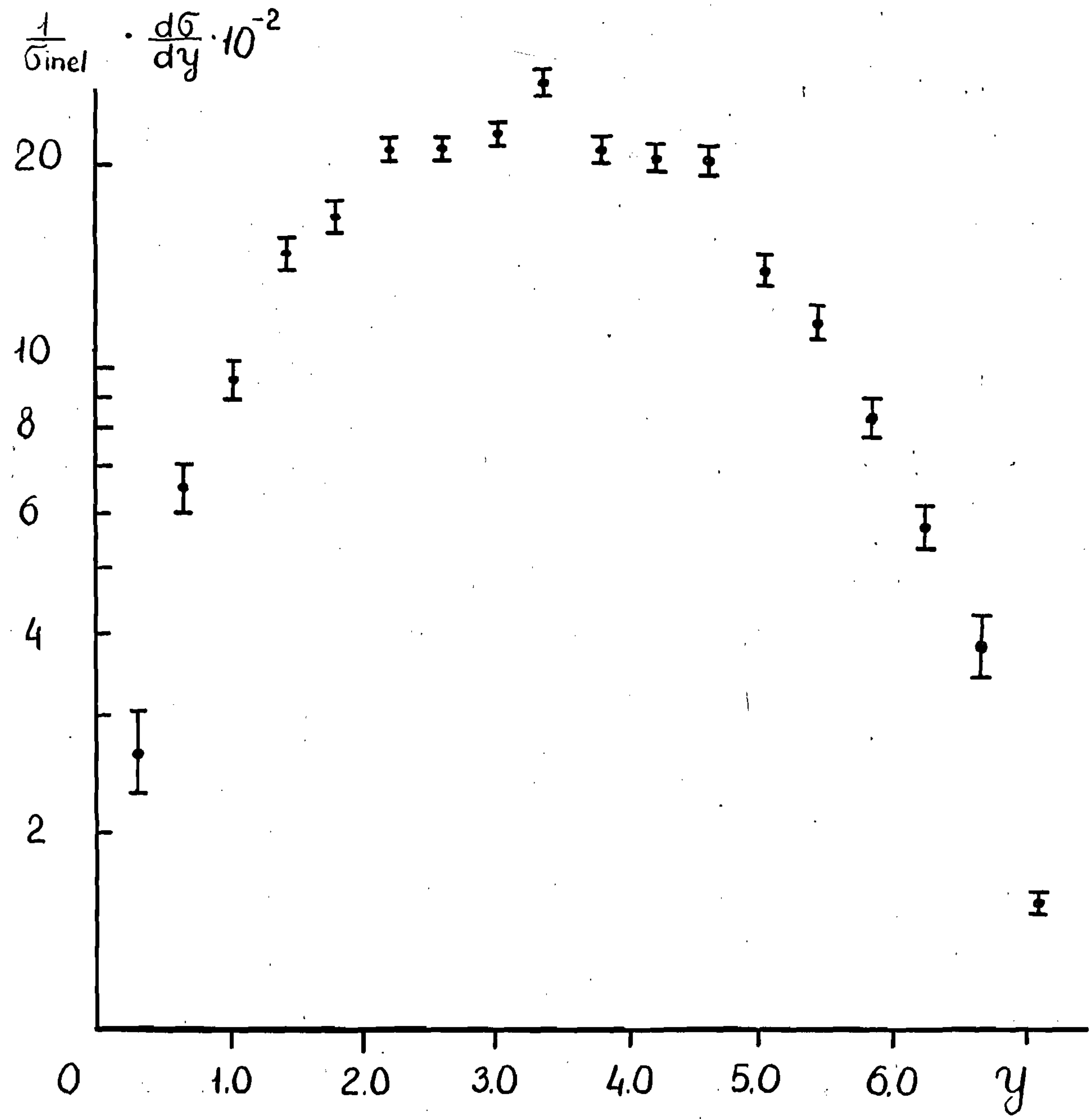


Fig.2. Dependence $\frac{1}{\sigma_{inel}} \frac{d\sigma}{dy}$ on rapidity $y = -\ln tg \theta/2$ for PP-collision at 200 Gev/C.

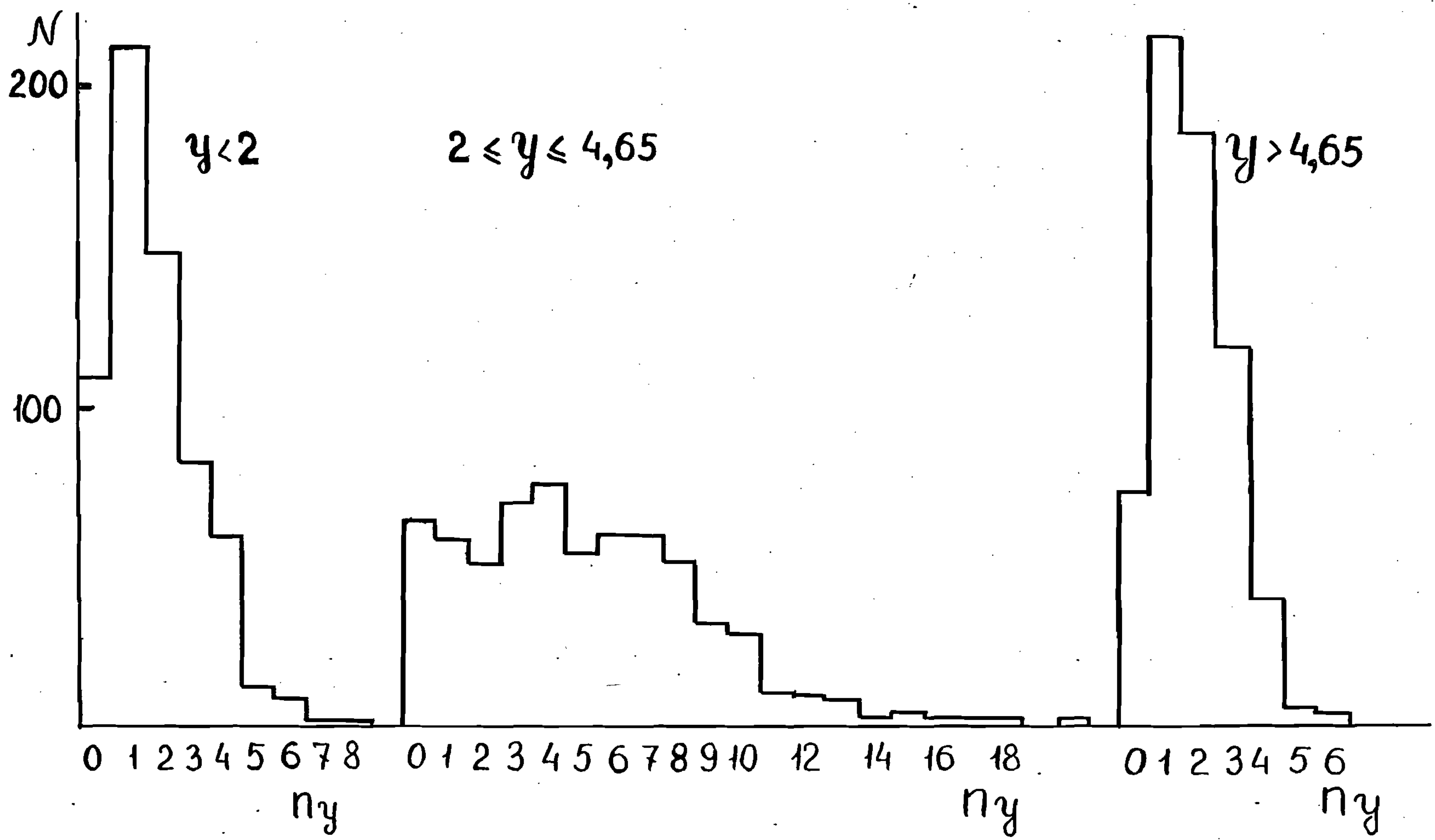


Fig.3. Multiplicity distribution of particles in rapidity ranges $y < 2$, $2 \leq y \leq 4{,}65$ and $y > 4{,}65$.