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# DISTRIBUTIONS OF RAPIDITY INTERVALS, JET RANGES AND MAXIMUM RAPIDITY GAPS IN PROTON-PROTON INTERACTIONS AT 200 GeV/C

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The semiinclusive reaction

$$p+p \rightarrow n \text{ charged particles} + \text{anything} \qquad (1)$$

was investigated with nuclear emulsions irradiated with 200 GeV/c protons at the NAL accelerator(Batavia,USA)[1,2]. We measured angles $\theta$ of all charged particles. In every event particles were ordered on rapidity which was approximated by the value

$$y = -\ln \operatorname{tg} \frac{\theta_{lab}}{2} \qquad (2)$$

In every event particles were numbered on increasing the rapidity. Let us consider, for example, distributions of ordered rapidities and distributions of differences of various ordered rapidities and try to make a physical conclusion from the analysis of these distributions.

Fig.1 shows the distributions of rapidities $y_1$ and $y_2$ for two-prong reaction (1).It is clearly seen from the distributions of $y_1$ and $y_2$ that the positions of maximum distributions coincide with the rapidity of initial interacting protons (0 and 6). For comparison, we reduce distributions $y_1$ and $y_2$ according to

$$f(y_K) = n\, C_{n-1}^{K-1}\, y_K^{K-1} (1-y_K)^{n-K} \qquad (3)$$

where $C_{n-1}^{K-1} = \frac{(n-1)!}{(K-1)!(n-K)!}$. Formula(3) is valid when the particle rapidity distribution density is constant from 0 to $y_{max}$. The comparison of experimental distributions with (3) shows that particles are correlated with the initial ones. Such correlation may be explained by the process of a diffractive dissociation of the interacting particles. Thus, the process of diffractive dissociation dominates for two-prong reaction (1). Making the relative differences of ordered rapidities in every event of n multiplicity[3]

$$\Delta_{kn} = \frac{y_{i+k} - y_i}{y_{max}} \tag{4}$$

(where k=1,2,......n-1,i=1,2,......,n-k), we receive the intervals occupied by k+1 particles. Distributions of these intervals are shown for a different multiplicity in Fig. 2-4. For k=1 we have distributions of rapidity gaps between neighbour particles. For k=n-1 the distributions are those of jet ranges $\Delta_{n-1,n} = \frac{y_n - y_1}{y_{max}}$.

It is interesting to check whether the generating particles in pp-collision are correlated or independent one from another. It is easy to show that at the divided equal distribution density in a relative rapidity interval (0,1) intervals $\Delta_{kn}$ have the distribution density in a form

$$f(\Delta_{kn}) = n C_{n-1}^{k-1} \Delta_{kn}^{k-1} (1 - \Delta_{kn})^{n-k} \tag{5}$$

Indeed, for equal and independent hitting particles on interval(0,1) the probability of a particle position between $y$ and $y+dy$ is $dy$. The integral probability of particles having the rapidity smaller than $y$ is $y$. It follows from the geometrical consideration that the probability for two particles having rapidity difference $\Delta_{kn}$ is $dW = (1 - \Delta_{kn})d\Delta_{kn}$. The probability of k-1 particles hitting the interval $\Delta_{kn}$ is $\Delta_{kn}^{k-1}$, and the probability of n-(k+1) particles not hitting the interval $\Delta_{kn}$ is $(1-\Delta_{kn})^{n-(k+1)}$. Thus, the density of interval distributions obeys formula (5).

The densities of interval distribution(5) are shown by the solid line in Fig.2-4.

For four-prong events the distribution of rapidity gaps agrees with (5), although we may see that experimental points are rising steeper at small values of $\Delta_{1n}$. The distribution of intervals occupied by three particles shows the predominance of small values, which may suggest the contribution of the diffractive dissociation of interacting particles. The small values dominate in the ranges of four-prong jets. We think that this can be interpreted as the essential contribution of pionisation process.

For six-prong and eight-prong events we observed the deflection from distributions (5) beginning from the intervals occupied by four and more parricles. Ranges of jets also displace to small values. It seems that these correlations may be interpreted as manifesting the tendency of forming narrow jets.

The same may be seen from the distributions of intervals $\Delta_{kn}$ in a pionisation range $2,0 \leq y \leq 4,65$. Fig.5 illustrates the distributions of gaps for pp-interactions with various submultiplicity of $n_{\pi}$ particles in the pionisation range. They are compared with distributions(5). As it may be seen from fig.5 distributions for $n_{\pi}=2,3,4$ and 5 are rising steeper to the small $\Delta_{kn}$ than those of (5). This suggests the correlation of neighbour particles on rapidity. For $n_{\pi}>5$ experimental distributions agree with (5).

Fig.6 shows experimental distributions for events with $n_{\pi}=16$ and various k from 2 to 7 and corresponding to the interval distribution (5). The comparison of distribution points out to the correlation of four and more particles generated by the pionisation process.

Fig.7-9 shows experimental distribution functions of four--prong jets when equal m intervals $\Delta_{Kn}$ are smaller than t. In case m=0 the distribution function is the probability that the minimum interval is more than t. For m=3 the distribution function is the probability $\mathcal{P}(\Delta_{max}<t)$ - the distribution function of the maximum interval. The utility of these distributions is doubtless. Indeed, from fig.7 for m=2 we can estimate the number of events which have equal two gaps smaller than t or the same only one gap has the value more than t. For example, the number of events with only one gap more than $\Delta_{1n}$ $y_{max}$=2,8 is 37 from 81. Such integral distributions are described by the law:

$$\mathcal{P}(\text{equally } m \text{ intervals } \Delta_{Kn}<t) = C^{m}_{n-K}\left[\mathcal{F}(t)\right]^{m}\left[1-\mathcal{F}(t)\right]^{n-m-K} \qquad (6)$$

where $F(t)=\int\limits_0^t f(\Delta_{Kn})\,d\Delta_{Kn}$ and $f(\Delta_{Kn})$ is taken according to (5).

For four-prong events the result of comparing experimental distributions with those of (6) is easy to interprete by the effect of two processes:pionisation and diffractive dissociation.

Fig.10 shows the dependence of cross section $d\sigma/d\Delta_{max}$ on the maximum gap $\Delta_{max}$(the maximum difference between neighbour particle rapidities) for the sum of every multiplicity event. In this figure we also perform the theoretical cross section $d\sigma/d\Delta_{max}$ calculated according to Regge pole model for the semiinclusive reaction with taking into account the exchange by pomeron and meson reggeon($\pi,\rho,\omega,A_2$)[4]. The smallest value of the maximum gap $\Delta_{max}$ is $y_{max}/_{n-1}$ for pionisation. The largest value of the maximum gap occurs for the fragmentation process, and it may come to $y_{max}$. The right tail of the curve is due to the same large values $\Delta_{max}$.

Three conclusions follow from the comparison of theoretical and experimental data:

1) There are the events due to the exchange of pomeron, i.e. the fragmentation of interacting particles,

2) There is the maximum due to a nondiffractive generation (in, particular, the process of pionisation),

3) The maximum is displaced to the small value $\Delta_{max}$ that seems to be explained by the correlation of secondary particles generated in a pionisation process.

Thus, the consideration of distribution of the rapidity interval occupied by the particle groups shows that the structure of jets may be explained by the effect of two processes generating particles: pionisation and fragmentation. Besides, there is the jet substructure connected with a correlation of the neighbour particle rapidity and particle group correlation.

## References

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3. Letter to JETP 19, N9 (1974), Preprint FIAN USSR, N30, Moscow, (1974).
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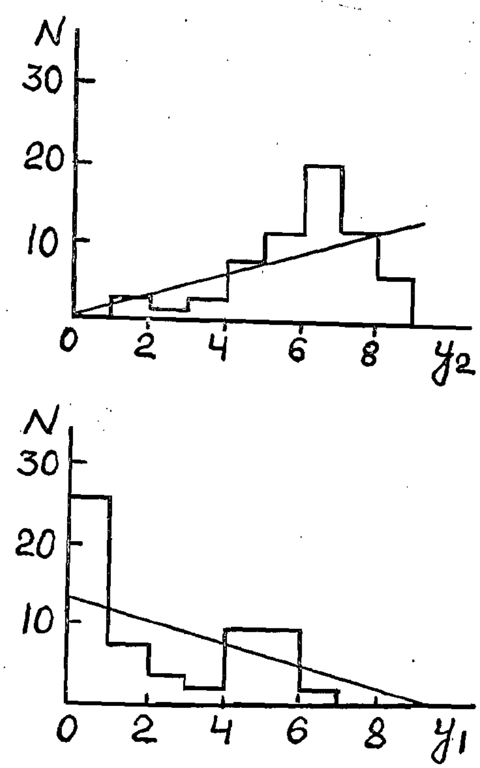


Fig.1. Distributions of the rapidites $y_1$ and $y_2$ for the two-prong events. The distribution /3/ is shown by the solid line.

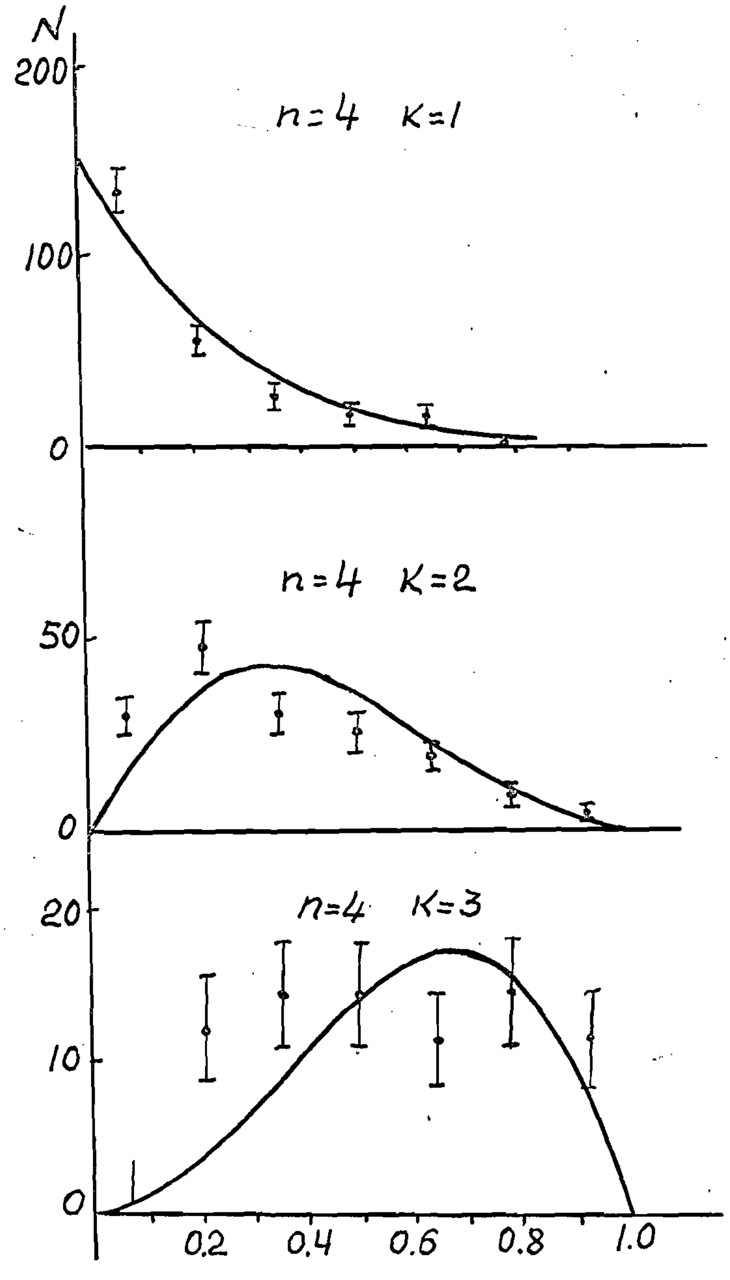


Fig.2. Distributions of the intervals $\Delta_{\kappa n}$ for the four-prong events. The distribution /5/ is shown by the solid line.

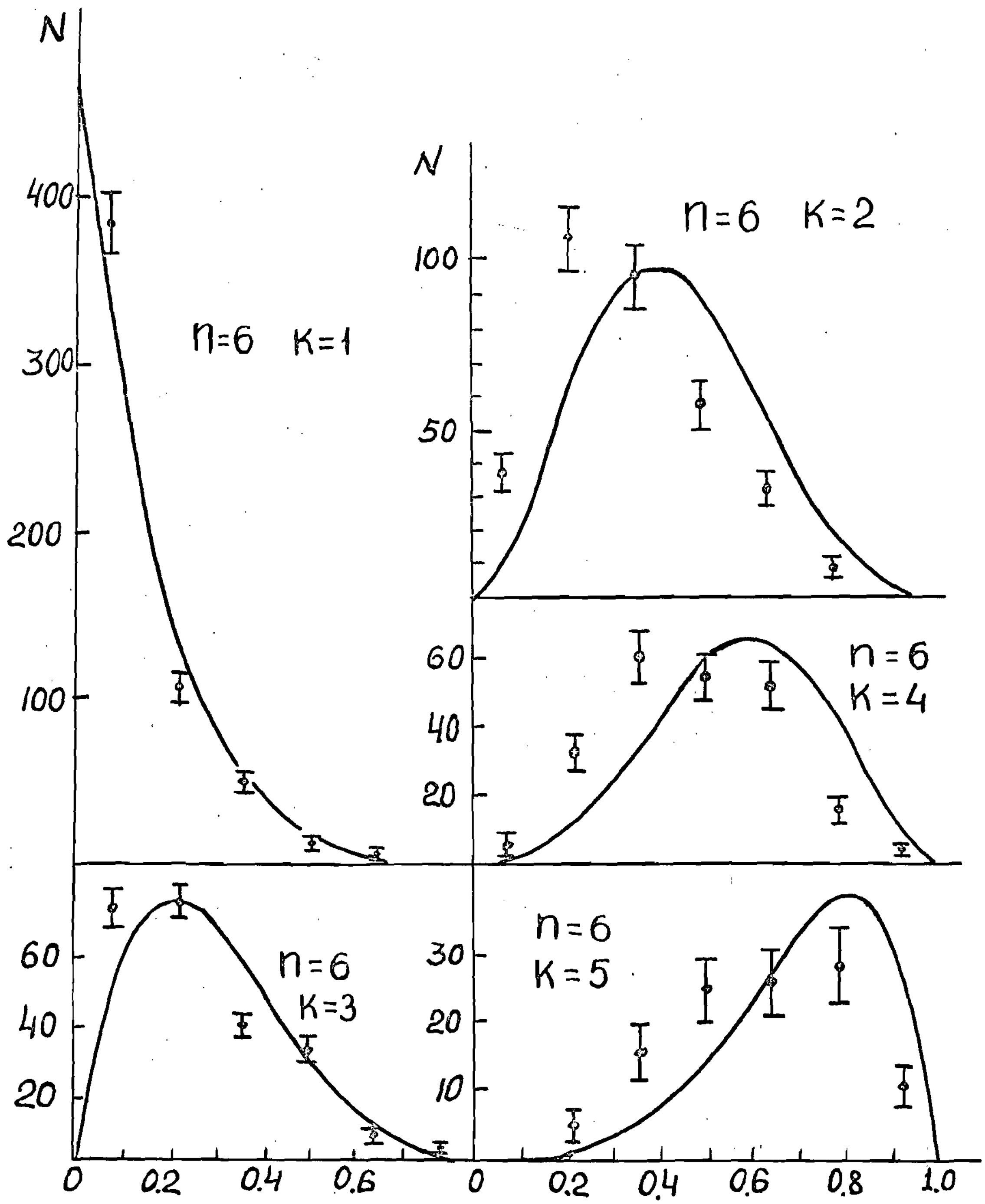


Fig.3. Distributions of the intervals $\Delta_{\kappa n}$ for the six-prong events. The distribution /5/ is shown by the solid line.

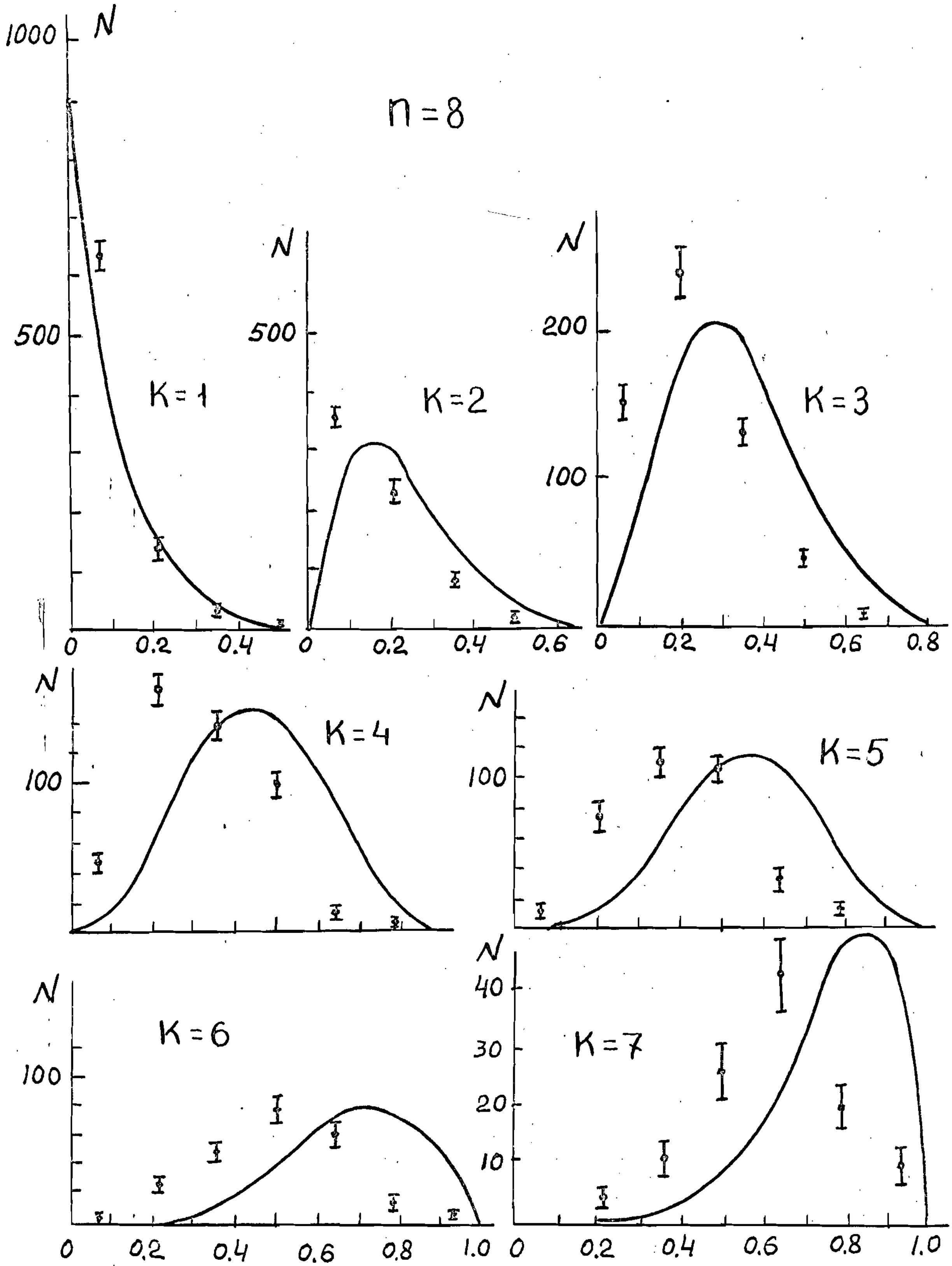


Fig.4. Distributions of the intervals $\Delta_{Kn}$ for the eight-prong events. The distribution /5/ is shown by the solid line.

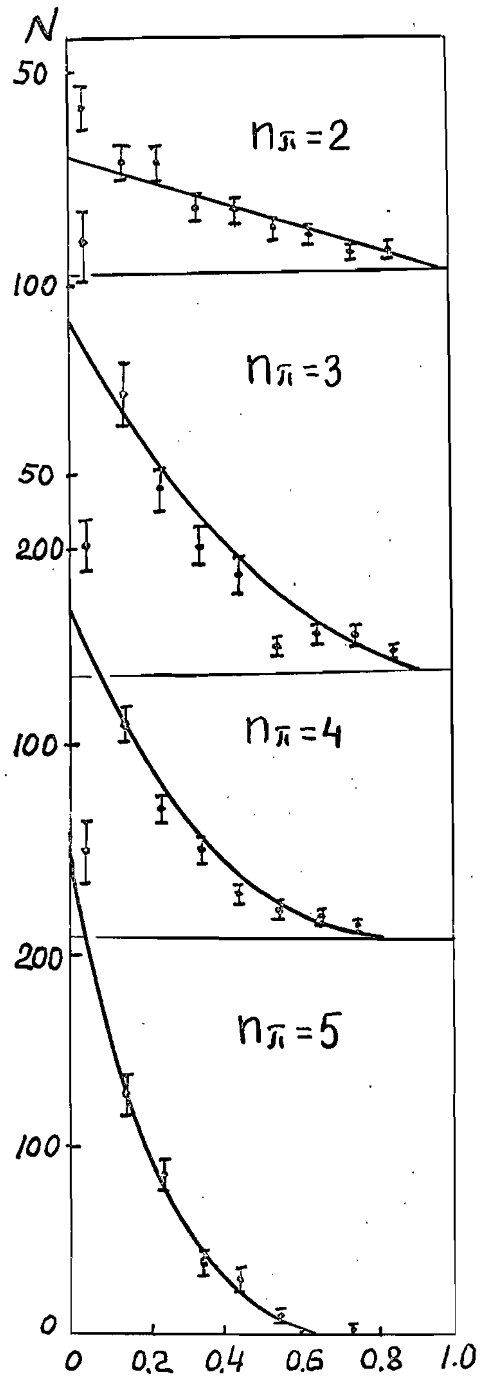


Fig.5. Distributions of the gaps between neighbouring rapidities of particles for the events of different submultiplicity $n_\pi$ in the rapidity interval $2.0 \leqslant y \leqslant 4.65$: The distributions /5/ are shown by the solid line.

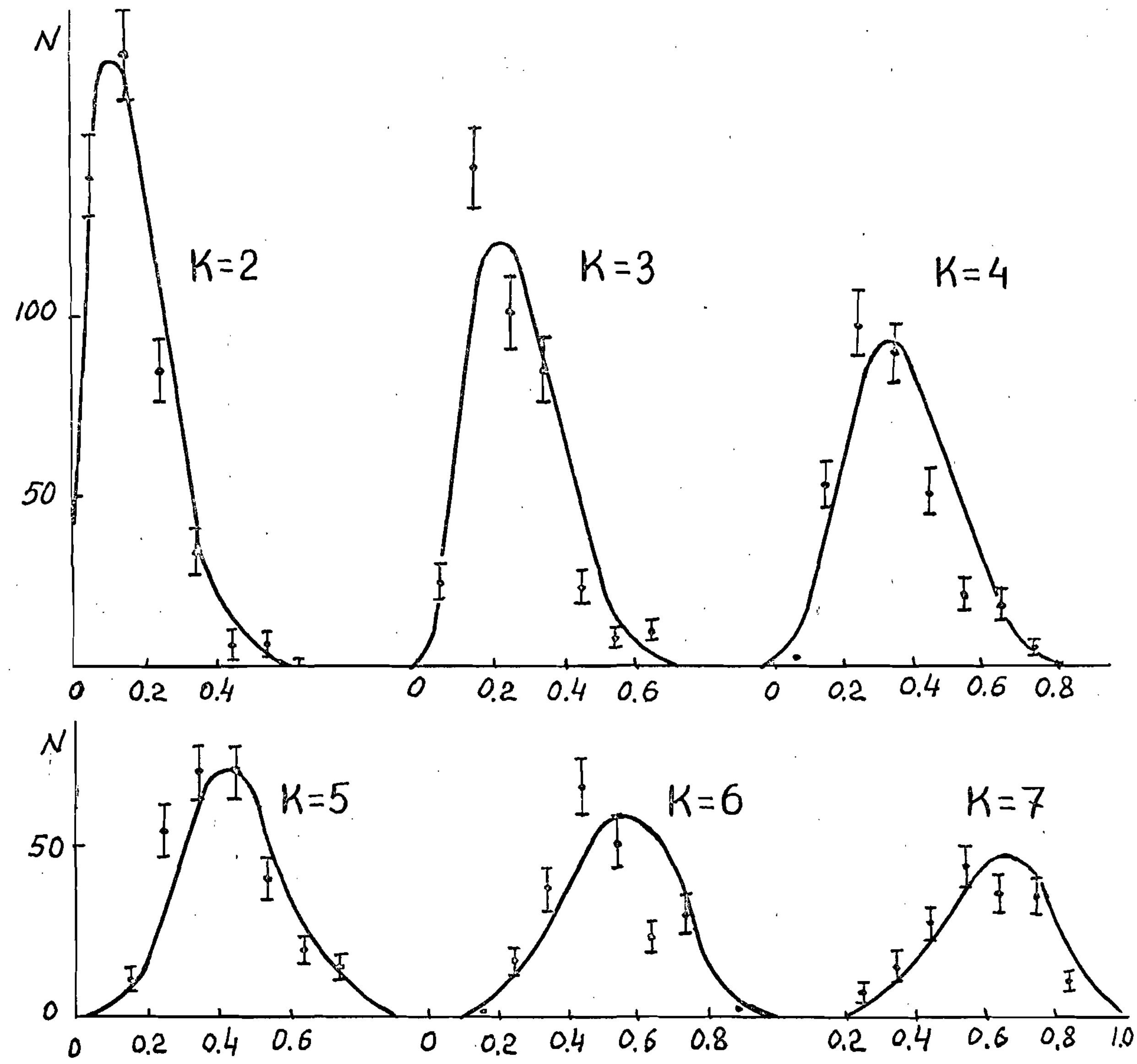


Fig.6. Distributions of the intervals $\Delta_{\kappa n}$ for events with $n_\pi = 10$ and different $K$ . The distributions /5/ are shown by the solid line.

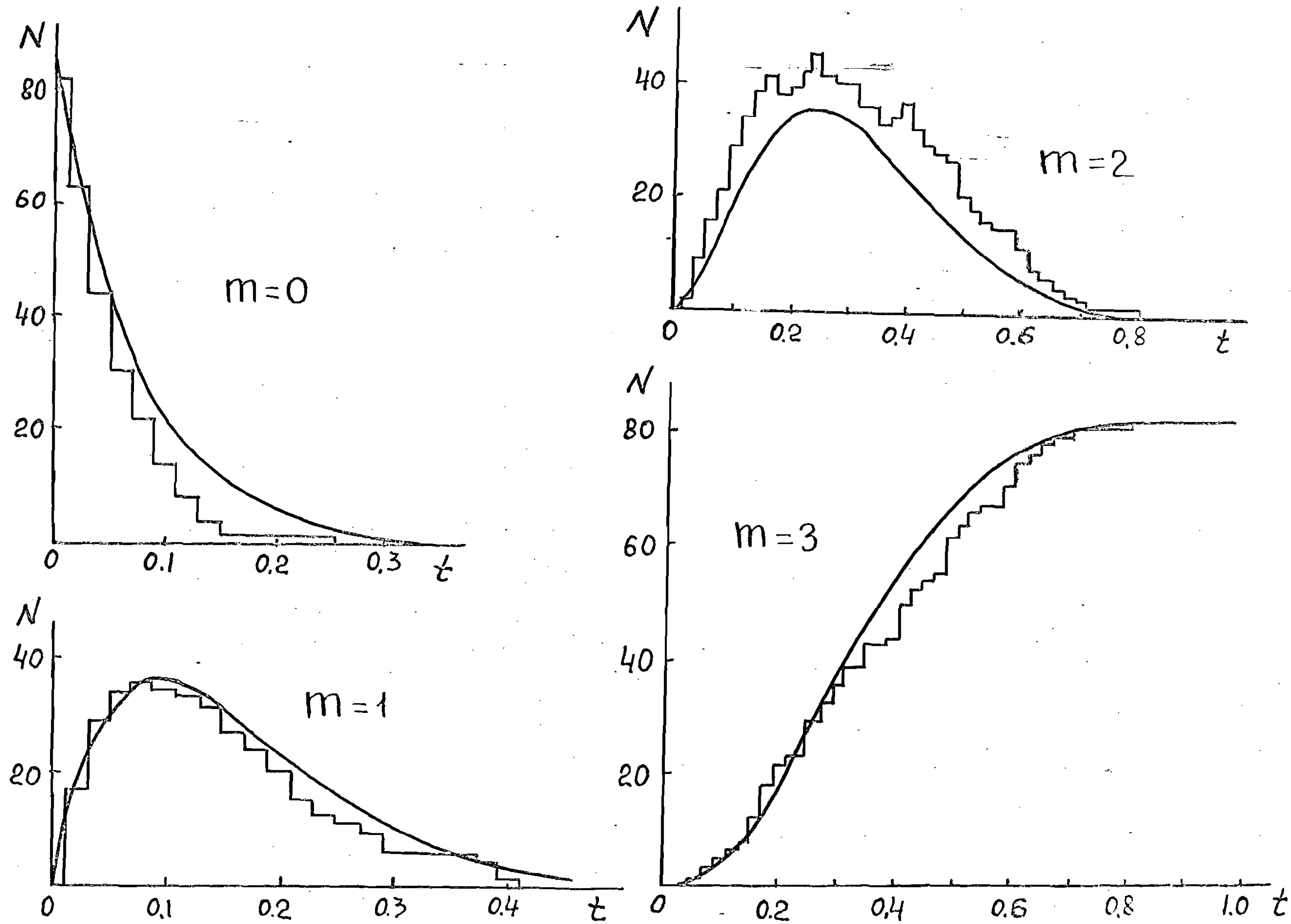


Fig.7. Experimental distribution function $\mathcal{P}$ (equally $m$ intervals $\Delta_{Kn}<t$) for the four-prong events and for $K=1$. The Distributions /6/ are shown by the solid line.

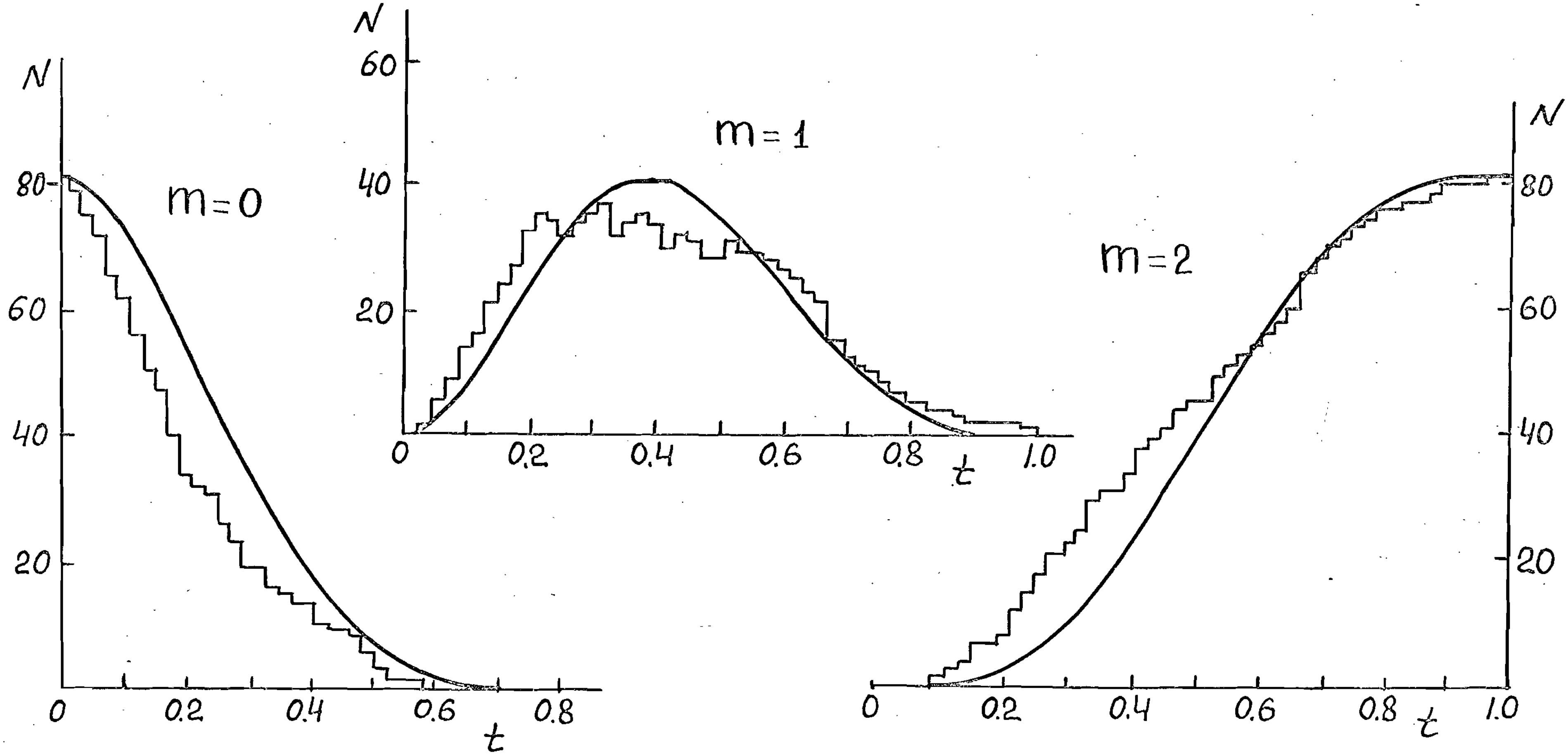


Fig.8. Experimental distributio function $\wp$ ( equally $m$ intervals $\Delta_{kn} < t$) for the four-prong events and for $K$ =2. The distributions /6/ are shown by the solid line.

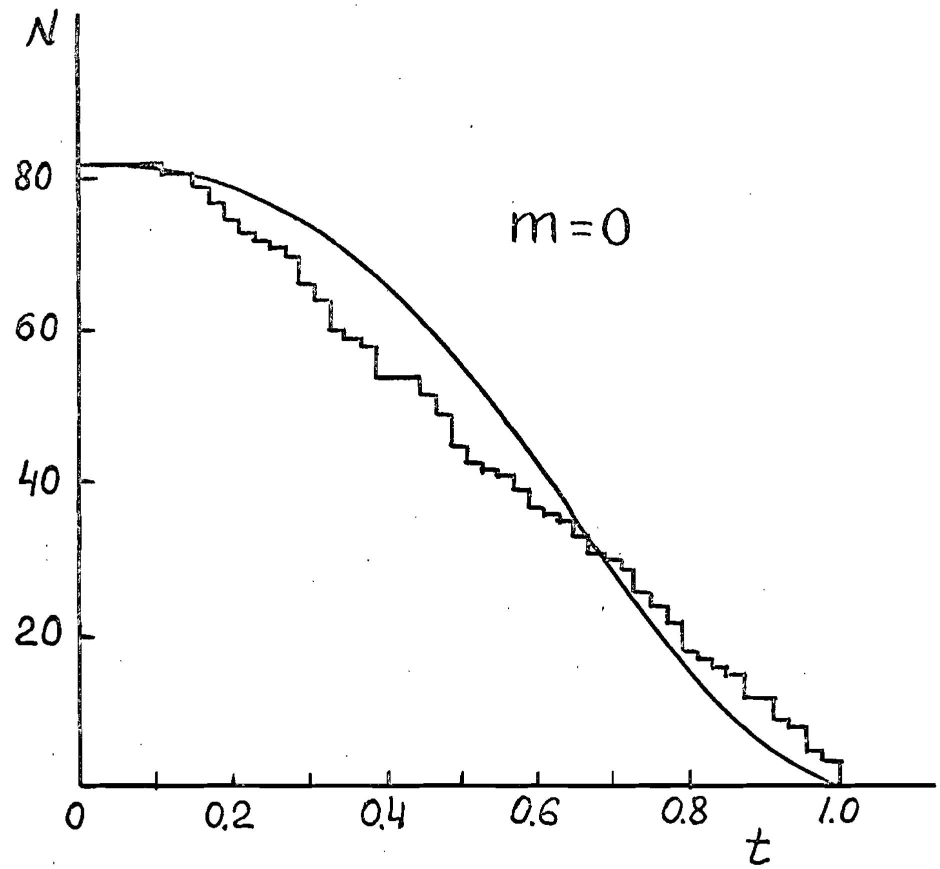


Fig. 9. Experimental distribution function $\mathcal{P}$ (equally $m$ intervals $\Delta_{kn} < t$ ) for the four-prong events and for $K=3$. The distributions /6/ are shovn by the solid line.

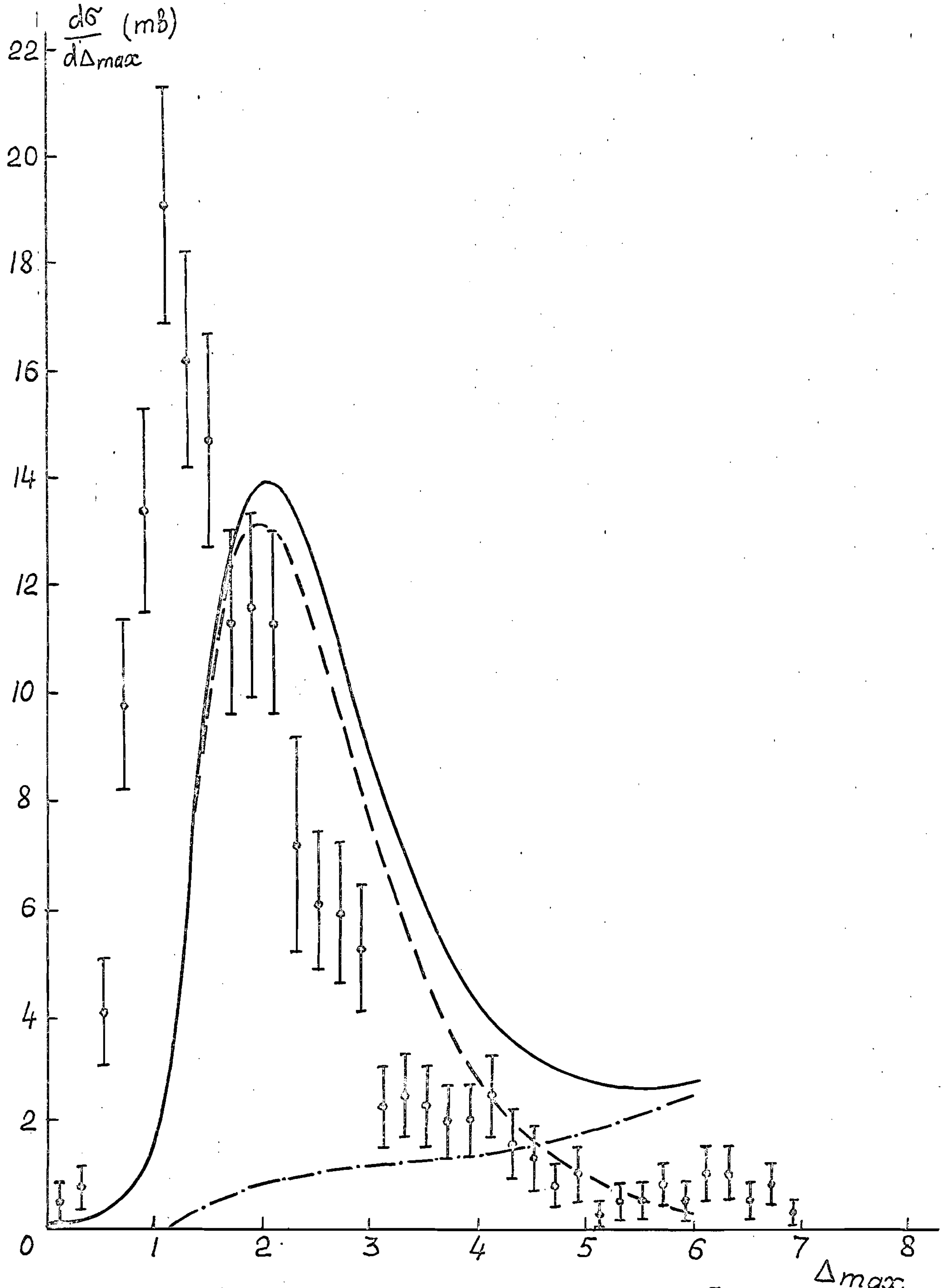


Fig.10. Dependence of differential cross section $\frac{d\sigma}{d\Delta_{max}}$ on the maximum rapidity gap $\Delta_{max}$. Theoretical cross sections are shown by the solid line, nondiffractive cross section is shown by the dashed line, diffractive - dot-dashed line.