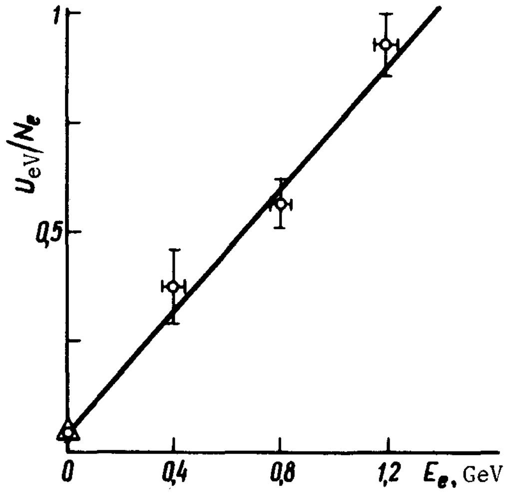

Fig. 2

small face of the target there is mounted a piezoelectric small-displacement detector made of TsTS-19 ceramic and having a sensitive area 6.75 cm^2. A beam of one microsecond duration and containing $N_e = 10^5$ - 10^7 electrons was incident on the center of the largest or middle face of the target, in which it excited acoustic oscillations. The electron-beam diameter d did not exceed 1 cm on the target surface. The electric signal from the piezoacoustic detector was amplified by a broadband transistor detector (mean working frequency approximately 0.3 MHz) and was applied through an emitter follower to the input of the internal amplifier of an IO-4 oscilloscope, the driven sweep of which was triggered by a synchronizing pulse from the accelerator. The measurements were performed at electron energies E_γ = 0.4, 0.8, and 1.2 GeV, so that the depth of the region of penetration of the cascade was much smaller than the linear dimensions of the target.

Figure 2 shows the energy dependence of the amplitude of the acoustic signal, normalized to one electron. The solid line in the figure represents the assumed linear relation $u/N_e \sim E_\gamma$. It is possible to establish with the aid of these measurements that the value of the minimum electron energy that can be detected with this apparatus is on the order of 10^{14} eV.

An experimental estimate shows that at $E_\gamma = 10^{14}$ eV and r = 10 cm, the acoustic displacements due to a single particle ar equal to the threshold of the apparatus $u \simeq 10^{-12}$ cm. On the other hand, a theoretical estimate yields displacements of the same order already at $E_\gamma \simeq 5\times10^{12}$ eV. The difference is due to the incoherence of the signals from different cascades of the beam at high frequencies, which leads to an appreciable suppression of signals with frequencies $\omega >> s_\ell/d_0$. Allowance for such a suppression of high frequencies in the experimental determination of the minimum detectable particle energy E_γ leads to good agreement with the theoretical estimate. We emphasize that the acoustic procedure of recording charged-particle tracks meets with the requirements stipulated in [2] for track apparatus.

In conclusion, we are grateful to B. I. Shramenko for all-out help with the experiments.

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FAST SCALING IN THE MUTIPERIPHERAL MODEL

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The diligently pursued recent and numerous theoretical and experimental investigations have shown that the scaling hypothesis [1], according to which the inclusive spectrum $Ed^3\sigma/d^3p$ depends at high energies only on the momentum fraction $x = p/p_{max}$ carried away by the detected particle and does not depend on the total energy, is far from trivial.

Although the scaling hypothesis was originally advanced for asymptotic energies, it has turned out that in many cases it is approximately valid alread at $E \sim 10 - 30$ GeV (fast scaling), e.g., in the reactions $p \to p$, $p \to K^+$, $p \to \pi$, or $\pi \to \pi$. We shall omit the labels of the targets, since principal attention will be paid to the fragmentation region. At $E \sim 10 - 30$ GeV, when fast scaling is already present, almost the entire spectrum consists of fragmentations. At the same time, there are reactions, e.g., $p \to \bar{p}$ or $p \to K^-$, in which the tendency to scaling is observed only at ISR energies ($E \sim 10^3$ GeV) [2].

The question of fast scaling is quite pressing at present and is under active study since, unlike the "asymptotic" scaling, which is not too sensitive to the choice of the theoretical model, the fast scaling is quite critcal.

To obtain the conditions of fast scaling, it was customary to resort to duality considerations with allowance for the exchange degeneracy in the Mueller-Kancheli diagrams (see the reviews [4]). Figure 1 shows the corresponding diagrams for the fragmentation region (a) and for the central region (b). As a rule, these conditions were tantamount to requiring that a definite

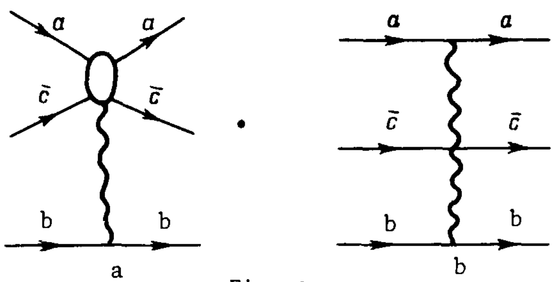

Fig. 1

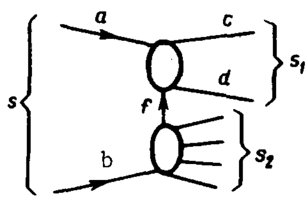

Fig. 2

a definite aggregate of particles (ab, $b\bar{c}$, $a\bar{c}$, or $ab\bar{c}$)be characterized by exotic quantum numbers (a and b are the initial particles, c is the detected one - see Fig. 1). So far, however, no simple condition has been obtained for fast scaling, capable of satisfying the entire aggregate of the experimental data. It was necessary to resort to additional arguments that lend themselves difficultly to estimates (such as "threshold" effects), so that the situation with the fast scaling remained quite indefinite. By way of examples, we cite the spectra of $pp \to \bar{p}$ or of $pp \to K^-$, where all the "exoticity" requirements are satisfied, but there is no fast scaling, and the $p\pi^+ \to \pi^+$ spectrum, for which fast scaling undoubtedly exists, although none of the listed "exoticity" conditions has been satisfied.

In this Letter we formulate a simple rule that explains naturally all the experimental data on fast scaling, using only the principal premises of the multiperipheral model (MPM) [5][1)].

We regard the agreement between this rule and experiment as one of the important confirmations of the MPM.

The inclusive spectrum in the fragmentation region is described [7] with the aid of diagram 2. In the upper block there occurs the scattering of the initial particle a by the virtual particle f, which moves along the multiperipheral chain, with formation of the system cd. The lower block corresponds to the total cross section for the interaction of the virtual particle f with the target b.

For the differential cross section of the process of Fig. 2 we have

$$d\sigma = \frac{1}{2^4\pi^3}\,\frac{\sqrt{\lambda(s_2,\,t,\,m_b^2)\,\lambda(s_1,\,t,\,m_a^2)}}{\lambda(s,\,m_a^2,\,m_b^2)}\,\sigma_2(s_2)ds_2 d\sigma_1 ds_1 F^2(t)dt, \tag{1}$$

where $\lambda(x,\,y,\,z) = x^2 + y^2 + z^2 - 2(xy + yz + zx)$, $F(t)$ is the generalized propagator of the virtual particle f (its concrete form is immaterial here).

We put $\alpha = x_c + x_d$ (in the c.m.s.) For small p and sufficiently high energies we have $\alpha = \alpha(s_1,\,x_0)$ and $s_2 \simeq s(1 - \alpha)$. Taking this into account, we obtain from (1) an expression for the inclusive spectrum

$$E\frac{d^3\sigma}{d^3p} \backsim x_c\frac{d\sigma}{dx_c} \backsim x_c\int ds_1 dt\, d\Omega\,(1 - a)\sqrt{\lambda(s_1,\,t,\,m_a^2)}\,\sigma_2(s_2)F^2(t)\frac{d\sigma_1}{d\Omega}\frac{\partial a}{\partial x_c}, \tag{2}$$

where the integration with respect to to is carried out to $t_{min} \simeq -[(1 - \alpha)/\alpha](s_1 - \alpha m_\alpha^2)$. Formula (2) yields a scaling-invariant expression for the spectrum if, first, the integrand contains significantly large $s_2 >> m^2$ (at which $\sigma_2(s_2) = \sigma_2[s(1 - \alpha)] = \text{const}$), and, second, if the limits of integration with respect to s_1 do not depend on s. These two conditions are satisfied as $s \to \infty$ (asymptotic scaling in the MPM). It is easily seen, however, that they are satisfied at relatively low energies (fast scaling), if the scattering in the upper block has a resonant character. In this case $\sigma_1(s_1 \sim m^2) >> \sigma_1(s_1 >> m^2)$, and the main contribution to the integral in (2) is made by the region $s_1 \sim m^2$. Since $s_1 s_2 \sim m^2 s$ in the MPM, the significant values in the integral are $s_2 \sim s$, and we are justified in expecting an approximate scaling already at energies corresponding to $\sigma(s) \approx$ const ($E \sim 10 - 30$ GeV). In this case scaling will hold with the same accuracy as $\sigma(s) \approx$ const, i.e., accurate to terms of order $s^{-1/2}$. We note that it is precisely these correction terms that are usually discussed in the analysis of the question of fast scaling. These terms are always positive, corresponding to a positive summary contribution of the secondary trajectories. The presence of such terms and their relative values for different spectra are determined by the dependence $\sigma_2(s_2)$ of the cross section of the pion on the target in the lower plock, provided the interaction in the upper block is resonant. It can be verified that the usually considered "exoticity" conditions for $ab\bar{c}$ are connected with this circumstance. At $s \geq 50$ GeV^2 the values of these correction terms are of the order of the accuracy of the experiments. It will be shown below that if the condition of resonant scattering in the upper block is not satisfied, one cannot expect even approximate scaling at energies $E \sim 10 - 100$ GeV. It is also easy to verify that one of the limits of the integration with respect to s_1 is the function x_c, while the second limit is immaterial if $\sigma_1(s_1)$ has a resonant character. We note that the approximations used in the derivation of (2) are valid only if $s_2 >> s_1$.

In order for $\sigma_1(s_1)$ to be concentrated near small s_1, it is essential that the channel af not be exotic, and that d have non-exotic quantum numbers (otherwise large masses assume an important role in the d mass spectrum). In a particular case, the state d may be absent altogether. We assume now that the particle f moving along the multiperipheral chain is mainly a non-strange (isovector) meson (π and ρ lead to idetnical consequences, since the "exoticity" is determined only by the additive quantum numbers), and therefore the af channel can always be non-exotic. With respect to the quantum numbers, there takes place the symbolic equality $d = a/\bar{c}$, and we arrive at the final result - a simple rule for fast scaling in the region of fragmentation, namely, the quantum numbers of the $a\pi\bar{c}$ system must be non-exotic. It can be verified that this rule is satisfied -y all the kneown experiment (cf. supra). It is curious that fast scaling in $\pi \to \pi$ will take place both in the case of the exotic channel $a\bar{c}(\pi^{\pm} \to \pi\ )$ and in the case of the non-exotic ($\pi^{\pm} \to \pi^{\pm}$), since the $\pi\pi\pi$ system can always be chosen non-exotic. We note that the obtained rule can explain also more subtle effects, e.g., the faster scaling in $p \to \pi^+$ compared with $p \to \pi^-$(owing to the high and sharp peak of the (1236) isobar in π^+p scattering).

At the same time, for spectra such as of $p \to \bar{p}$ or $p \to K^-$, the system d has exotic quantum numbers and a large effective mass (therefore $s_1 >> m^2$), which leads to $s_2 << s$ and the onset of scaling is very strongly shifted (by several orders of magnitude) in energy. In this case the approximations used to obtain formula (2) ($s_2 >> m^2$, s) do not hold at $E \sim 10^2$ GeV, and the inclusive spectrum will experience an appreciable growth up to energies at which $\sigma(\sqrt{s}) \approx$ const ($s \sim 10^3$ GeV^2), owing to the growth of the phase volume (including that pertaining to the higher block and making possible the emission of the heavier states d).

The derived rule for fast scaling (non-exoticity of $a\pi\bar{c}$) differs in principle from the rules mentioned earlier (exoticity of ab, $b\bar{c}$, $a\bar{c}$, $ab\bar{c}$) and obtained neglecting the structure of the dynamics of multiple production of particles. In addition to the requirement that there be no exotic resonances (or the exchange degeneracy requirement), a very important factor is the suppression of strange particles and baryons as particles that move along the multiperipheral chain; as already shown, this can lead to diametrically-opposite predictions.

We note in conclusion that the considerations advanced above remain significant also if one considers spectra in the central region, up to energies $E \sim 10^2 - 10^3$ GeV, and lead to analogous consequences in this region.

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