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INTERMITTENCY EFFECTS in π^+p and K^+p COLLISIONS AT 250 GeV/c

EHS/NA22 Collaboration

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ABSTRACT:

Density fluctuations are studied in rapidity, pseudo-rapidity and azimuthal angle, as well as in 2-dimensional distributions in rapidity and azimuthal angle. Evidence for intermittency, i.e. rise of factorial moments with increasing resolution is found in all four distributions. Intermittency is stronger in two dimensions than in one, but the difference is smaller than would be expected from the production of "pencil jets". Contrary to what would be expected from Bose-Einstein interference, no increase by a factor 2 is found in slope when the analysis is restricted to particles of identical charge.

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Unusually large fluctuations of particle multiplicity in very small phase-space regions have been reported within single events [1a] and/or corresponding regions of different events [1b]. To study this effect in detail, A. Białas and R. Peschanski [2] have suggested to analyse multipliciy distributons in terms of scaled factorial moments in smaller and smaller phase-space bins, down to the experimental resolution. These moments can be defined as a double average starting

"horizontally" (over bins): $$\langle F_i \rangle_h = \frac{1}{N_{evt}} \sum_{evt} \frac{\frac{1}{M}\sum_M F_{i,m}}{\langle \frac{n}{M} \rangle^i} \qquad (1a)$$

or "vertically" (over events): $$\langle F_i \rangle_v = \frac{1}{M} \sum_{m} \frac{\frac{1}{N_{evt}}\sum_{evt} F_{i,m}}{\langle n_m \rangle^i} \quad , \qquad (1b)$$

where M is the number of phase-space bins $\delta = \Delta/M$ into which an original region Δ is subdivided, n_m is the multiplicity in bin m ($m = 1, ..., M$), $F_{i,m} = n_m(n_m-1).....(n_m-i+1)$ is the factorial of order i in bin m. $\langle n_m \rangle = \frac{1}{N_{evt}} \sum_{evt} n_m$ is the mean multiplicity in bin m and $\langle n \rangle = \frac{1}{N_{evt}} \sum_{evt} n$ is the mean multipicity in the original region Δ. Definitions (1a) and (1b) coincide if $\langle n_m \rangle$ is the same for all m and equal to $\langle n \rangle / M$.

It has been shown, if non-statistical self-similar fluctuations of many different sizes (usually referred to as "intermittency") exist, then the dependence of the moment on the size of the phase-space bin follows the power law

$$\langle F_i \rangle \propto M^{f i}, \quad f_i > 0 \quad . \qquad (2)$$

Otherwise, saturation of the moments at small δ is expected [3].

Evidence for intermittency has been shown to exist in nucleus-nucleus [4], hadron-nucleus [4a,5], hadron-hadron [6], as well as in e^+e^- collisions [7].

The data presented here come from the NA22 experiment performed at CERN. In this experiment the European Hybrid Spectrometer (EHS) is equipped with the Rapid Cycling Bubble Chamber (RCBC) as a vertex detector and exposed to a 250 GeV/c tagged positive, meson enriched beam. In data taking, a minimum bias interaction trigger is used. The details of the spectrometer and the trigger can be found in previous publications [8].

Charged particle tracks are reconstructed from hits in the wire- and drift-chambers of the two lever-arm magnetic spectrometer and from measurements in the bubble chamber. The average momentum resolution $\langle \Delta p/p \rangle$ varies from a maximum of 2.5% at 30 GeV/c to around 1.5% above 100 GeV/c.

Events are accepted for the present analysis when measured and reconstructed charge multiplicity are consistent, charge balance is satisfied, no electron is detected among the secondary tracks and the number of badly reconstructed (and therefore rejected) tracks is at most 0,1,1,2 and 3 for events with charge multiplicity 2,4,6,8 and >8, respectively. After these cuts, our present inelastic sample consists of 98 600 π^+p and 35 000 K^+p events. For the reported analysis the two samples have been combined since no beam-dependence is observed.

For momenta $p_{LAB} < 0.7$ GeV/c, the range in the bubble chamber and/or the change of track curvature is used for proton identification. In addition, a visual ionization scan has been used for $p_{LAB} < 1.2$ GeV/c on the full K^+p and 62% of the π^+p sample. Particles with momenta $p_{LAB} > 1.2$ GeV/c are not identified in the present analysis and are treated as pions.

A bias leading to *reduced* moments, in principle, has to be expected if the two-track resolution is limited and track losses occur due to limited acceptance or bad reconstruction. On the other hand, a bias leading to *increased* moments has to be expected from double counting of tracks as well as from Dalitz decay, undetected γ conversion and small angle K^0_S, Λ^0 decay close to the vertex.

Because of the 4π visual vertex detector, losses due to limited acceptence or two-track resolution are practically non-existant in our data. Our reconstruction procedure and event selection, furthermore, make double counting of tracks extremely unlikely. In spite of that, events with high local rapidity density ($\delta n/\delta y > 100$) have been checked individually on the scanning table. All of the tracks have been identified individually as existant and the most significant event [1b] has been measured 5 times with the same result.

As mentioned above, losses due to bad reconstruction are allowed in our sample. It has been checked by a comparison to an event sample without reconstruction losses that slopes are not affected by these track losses.

Furthermore, it has been verified by Monte Carlo techniques that undetected Dalitz decay and γ conversion as well as undetected small angle K^0_S and Λ^0 decay do not considerably change our results.

The experimental resolution is better than 0.1 units in all variables used in the analysis.

First results on intermittency from an earlier sample of this experiment have been presented in [6a] where the moments (1a) in small cms rapidity bins δy are considered for all charged particles produced in the region $\Delta y = 4$ ($-2.0 \leq y \leq 2.0$). The data show intermittent behaviour (i.e. are consistent with the power law (2)) and favour an interpretation in terms of cascading over that in terms of a hadronic reaction mechanism, thus excluding hadronic phase transition as the main source. Presently used cascade models such as FRITIOF [9] fail to reproduce the full effect, although they show some increase of $\langle F_i \rangle_h$ with decreasing δy. Further information on possible reaction mechanisms is needed to trace this shortcoming.

To do the analysis on the full K^+p and π^+p sample and to check whether intermittency is observed also in other phase space variables, we first show in Fig. 1a-c the $\ln\langle F_i \rangle_h$ dependence on resolution δ in rapidity y (Δy=4), pseudo-rapidity η ($\Delta\eta$=4) and azimuthal angle ϕ ($\Delta\phi$=2π), respectively. In all cases the data are consistent with intermittent behaviour, i.e. with the power law (2) from a certain resolution δ downwards.

The slopes f_i in the δ regions indicated by the solid lines in Fig.1 are given in Table 1 for the various cases. As shown in Fig.2a, the f_i are quite similar for y and η binning, but ϕ binning leads to smaller slopes.

Can the deviations from model expectations as observed in our earlier paper [6a] be explained by known effects not (yet) included in the models used?

Recently, W. Ochs and J. Wosiek have discussed multiparticle production in terms of a scale invariant branching process [10]. According to that model, the increase of factorial moments is driven by clusters of strongly collimated particles ("pencil jets"). In such a case, local fluctuations in rapidity or pseudo-rapidity correspond to local fluctuations also in the azimuthal angle ϕ. Therefore, it is suggested to investigate a 2-dimensional $y-\phi$ grid, expecting a much more pronounced rise of the moments $\langle G_i \rangle$ defined analogously to $\langle F_i \rangle$ in (1), with M the number of cells of area $\delta\omega = \delta y \delta\phi$ and n_m the number of particles in that area.

Results are shown in Fig.1d. Our statistics does not allow to calculate the 5-th moment at the relevant $\delta\omega$ range. This is a first hint that intermittency is not due to pencil jets, since no events are left with a sufficiently large number of tracks in a small two-dimensional area. As can be seen from a comparison of line 4 of Table 1 with line 1, and from Fig.2b, the $\langle G_i \rangle_h$ moments of order 2 and 3 rise faster by a factor of about 2 with decreasing $\delta\omega$ than the $\langle F_i \rangle_h$ with decreasing δy. However, the difference is less spectacular than the factor 6 expected in [10]. Moreover, the 10 tracks found in the bin $\delta y = 0.1$ in our most significant event [1b] are spread in ϕ. A similar observation has been made in the other events with high local density and from a selection in ϕ. So, also this model cannot account for the effect in our data.

Another possible candidate [11] for a mechanism increasing the slopes f_i would be the Bose-Einstein effect, among other experiments also observed in NA22 [12]. If intermittency originates from Bose-Einstein interference, the slopes are expected to increase by roughly a factor 2 when the analysis is restricted to particles of identical charge. According to [11b], deviations from this rule in e^+e^- and π^+p collisions would give the strongest evidence against the BE origin.

The dependence of $\ln\langle F_i \rangle_v$ on $-\ln \delta y$ for identically charged particles is compared to that for all charged particles in Fig.3. Definition (1b) is used here, because of the difference in the y distribution observed for positives and negatives in [8b]. The slopes for the range $1.0 \geq \delta y \geq 0.1$ are compared in Table 2. While a small increase of the slopes is indeed observed when restricting the analysis to identically charged particles, this increase is far less than the factor 2 expected from BE interference. Furthermore, in TASSO even smaller slopes are observed for the same sign charge than for the full sample of e^+e^- collisions [7b]. We, therefore, conclude that also Bose-Einstein interference cannot be considered the main source of intermittency.

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Table 1. Fitted slopes f_i for the bin size range indicated in Fig.1.

variable	f_2	f_3	f_4	f_5
δy	0.012±0.001	0.048±0.002	0.14±0.01	0.31±0.02
$\delta \eta$	0.011±0.001	0.047±0.002	0.13±0.01	0.24±0.02
$\delta \phi$	0.007±0.002	0.028±0.005	0.09±0.02	0.22±0.06
$\delta y \delta \phi$	0.027±0.002	0.092±0.012		
$\delta \eta \delta \phi$	0.026±0.002	0.045±0.011		

Table 2. Fitted slopes f_i for the bin size range indicated in Fig. 3.

particles	f_2	f_3	f_4	f_5
all charged	0.018±0.001	0.055±0.002	0.14±0.01	0.30±0.02
negatives	0.018±0.001	0.070±0.004	0.17±0.02	
positives	0.025±0.001	0.067±0.003	0.13±0.01	

Figure Captions:

Fig.1 ln$\langle F_i \rangle_h$ as a function of -lnδy, -ln$\delta \eta$, -ln$\delta \phi$ and ln$\langle G_i \rangle_h$ as a function of -ln$\delta \omega$.

Fig.2 The slope f_i as a function of the order i for the moment distribution in the variables indicated.

Fig.3 ln$\langle F_i \rangle_v$ as a function of -lnδy for all charged particles, as well as negative and positive particles, separately.