PROC. 19th INT. CONF. HIGH ENERGY PHYSICS
TOKYO, 1978

A 3 Rapidity and Charge Correlations

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§1. Two-Particle Correlations: Energy and Multiplicity Dependence

Central-region hadrons produced in high energy inclusive reactions are emitted in "clusters," correlated in rapidity. It seem unlikely that conventional resonance can account for most of the correlation observed, except at low multiplicities where diffraction dissociation is important. With the usual definitions:

$$\rho_1(y)=\sigma^{-1}\,\mathrm{d}\sigma/\mathrm{d}y,$$

the single particle rapidity density;

$$\rho_2(y_1, y_2)=\sigma^{-1}\mathrm{d}^2\sigma/\mathrm{d}y_1\mathrm{d}y_2,$$

the two particle density; we study

$$R_n(y_1, y_2)=R_n(\Delta y, y_+) =[(\rho_2(y_1, y_2)/\rho_1(y_1)\rho_1(y_2)]-1,$$

the normalized semi-inclusive correlation function, for each multiplicity at four energies for π^-p collisions at 18.5, 100, 200 and 360 GeV/c.

Semi-inclusive correlations at 360 GeV/c are shown for $n=4-20$ in Fig. 1. For unlike $(-+)$ pairs, Fig. 1a, significant correlation near $y=0$ is evident for all orders of charge multiplicity n. Values of $R_n(0, 0)$ for 360 GeV/c data are shown in Fig. 2a; $R_n(0, 0)$ as a function of s for $n=8$ multiplicity (for $n\lesssim\langle n\rangle$, diffraction dissociation is not negligible)[1] is shown in Fig. 2b. The data of Fig. 2 may be fit with a cluster model incorporating a narrow cluster multiplicity distribution[2] for which Berger shows

$$R_n(0, 0)^{-+}=\frac{\ln s}{n}\left[\frac{\langle k\rangle^{-+}}{2\delta\sqrt{\pi}}-\frac{\langle k\rangle^{-+}}{\ln s}\right]. \quad (1)$$

Fitting the two distributions jointly yields the measurement of cluster parameters: cluster

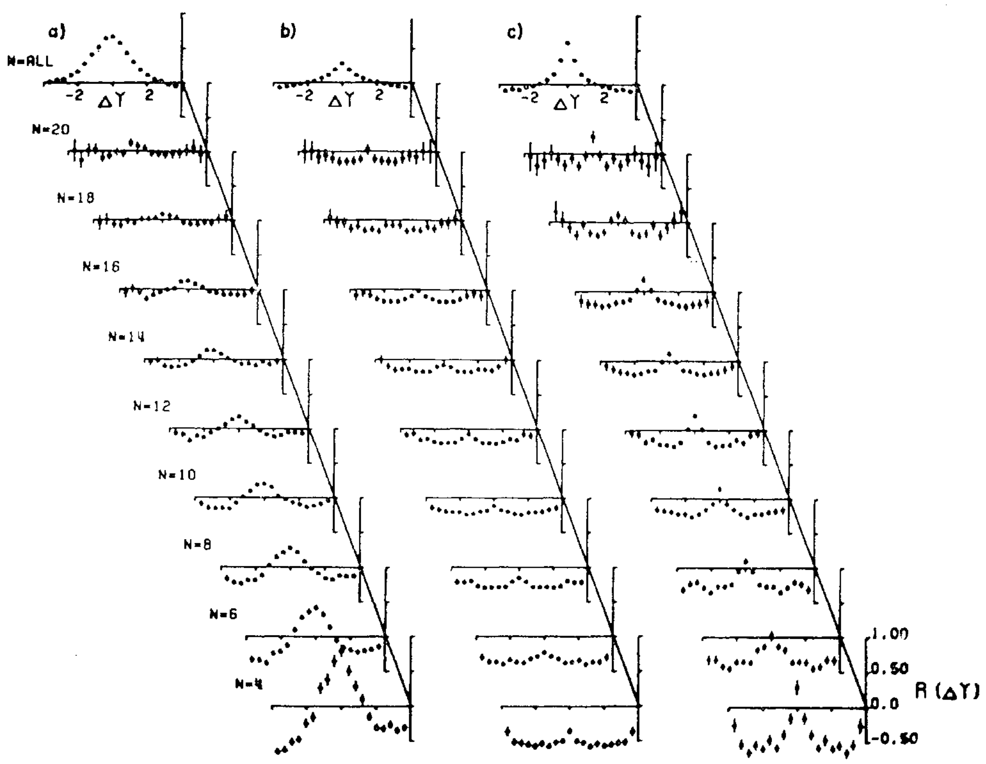

Fig. 1. Semi-inclusive correlations $R_n(\Delta y, y)$ as a function of Δy, integrated over a central region $-4.05\leq y_+\leq 4.05$, for the data at 360 GeV/c. (a) Correlations for $(-+)$ pairs. (b) Correlations for $(--)$ pairs. (c) Correlations for $(--)$ pairs for which the azimuthal restriction $\phi\leq 45°$ is imposed.

multiplicity $\langle k\rangle^{-+}=1.60\pm0.12$, correlation length $\delta=0.99\pm0.03$. The data are inconsistent with Berger's expression for a broad multiplicity distribution.

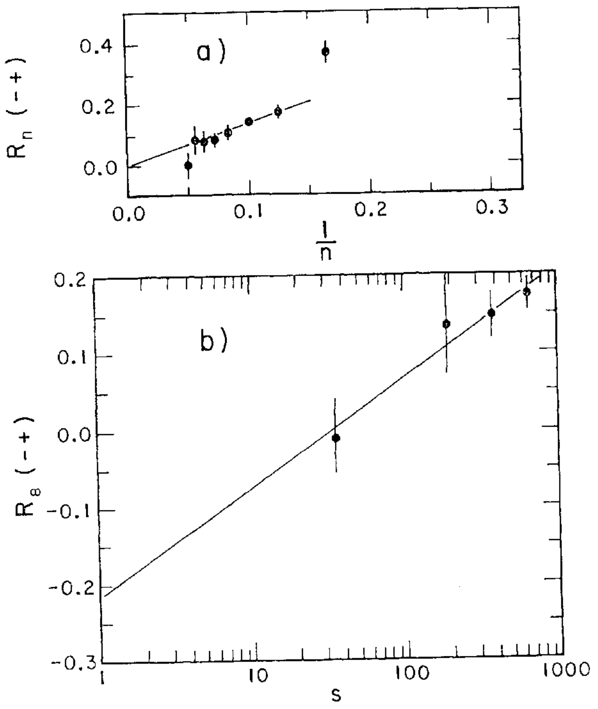

Fig. 2. Energy and multiplicity dependence of the correlation functions for (−+) unlike-charge pairs. (a) $R_n(0, 0)^{-+}$ as a function of $1/n$ for 360 GeV/c interactions. (b) $R_n(0, 0)^{-+}$ as a function of s for $n=8$ events.

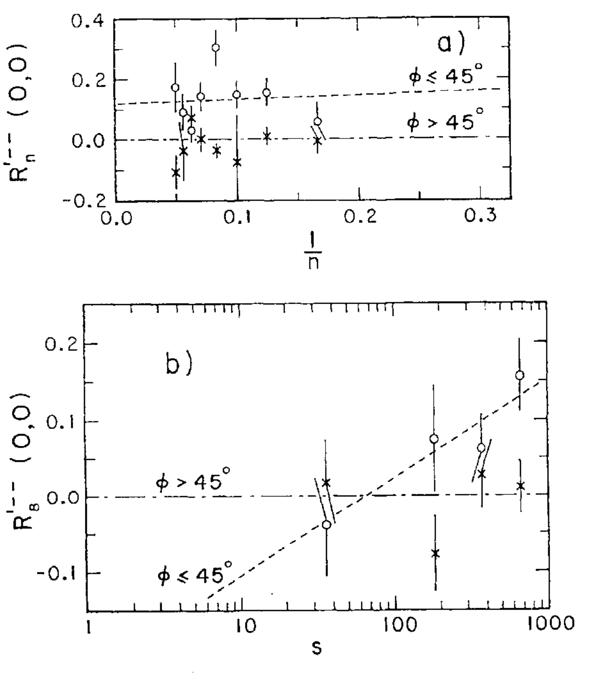

Fig. 3. Energy and multiplicity dependence of the correlation functions for (−−) like-charge pairs. (a) $R_n'(0, 0)^{--}$ as a function of $1/n$ for 360 GeV/c interactions. Events for which $0\leq\phi\leq45°$. (Bose-Einstein cut) are shown as circles, $45°\leq\phi\leq180°$ as crosses. (b) $R_n'(0, 0)^{--}$ as a function of s for $n=8$ events, with ϕ cut as above.

For particle pairs of like charge, we attempt to distinguish the consequence of Bose-Einstein effects by distinguishing between all (−−) pairs, Fig. 1b, and (−−) pairs for which which the azimuthal difference $\phi<45°$, Fig. 1c. For like-charge pairs, the function $R_n'(y_1, y_2)=R_n+(1/n_-)$ is zero in the absence of correlation. This quantity is shown as a function of $1/n$ for 360 GeV/c (−−) data, and as a function of s for $n=8$ data, in Fig. 3a and 3b respectively. Data for $\phi<45°$ (Bose–Einstein region) and $\phi<45°$ are plotted separately. The correlation function for $\phi<45°$ is consistent with zero for all orders of multiplicity, at all energies. We conclude that clusters are objects with small multiplicity $\langle k\rangle$, confined to a narrow rapidity range δ, decaying predominantly to (−+) pairs.

§2. Three-Particle Correlations

If the conclusion above is correct, we would expect the 3-particle correlation to be a small effect. Previous experiments[3] have observed no clear evidence for 3-particle correlations, within the limits of statistics. Taking $\rho_3(y)=\sigma^{-1}\,d^3\sigma/dy_1dy_2dy_3$, the normalized 3-particle correlation function

$$\begin{aligned} R_3(y_1, y_2, y_3)=[&\rho_3(y_1, y_2, y_3) \\ &+2\rho_1(y_1)\rho_1(y_2)\rho_1(y_3)-\rho_2(y_1y_2) \\ &\rho_1(y_3)-\rho_2(y_2, y_3)\rho_1(y_2) \\ &-\rho_2(y_3, y_1)\rho_1(y_2)]/[\rho_1(y_1)\rho_1(y_2)\rho_1(y_3)]. \end{aligned} \tag{2}$$

The terms in this expression can be understood more clearly by considering

$$\begin{aligned} R_3'(y_1, y_2, y_3)=[&\rho_3(y_1, y_2, y_3) \\ &-\rho_1(y_1)\rho_1(y_2)\rho_1(y_3)]/[\rho_1(y_1)\rho_1(y_2)\rho_1(y_3)], \end{aligned}$$

the excess of the normalized 3-particle density over the combinatorial product of single particle densities, and

$$\begin{aligned} R_3''(y_1, y_2, y_3)=[&\rho_2(y_1, y_2)\rho_1(y_3) \\ &+\rho_2(y_2, y_3)\rho_1(y_1)+\rho_2(y_3, y_1)\rho_1(y_2) \\ &+3\rho_1(y_1)\rho_1(y_2)\rho_1(y_3)]/[\rho_1(y_1)\rho_1(y_2)\rho_1(y_3)], \end{aligned} \tag{3}$$

a background term arising from the presence of real 2-particle correlations in the data. Then the true, physically significant correlation

$$R_3(y_1, y_2, y_3)=R_3'(y_1, y_2, y_3)-R_3''(y_1, y_2, y_3).$$

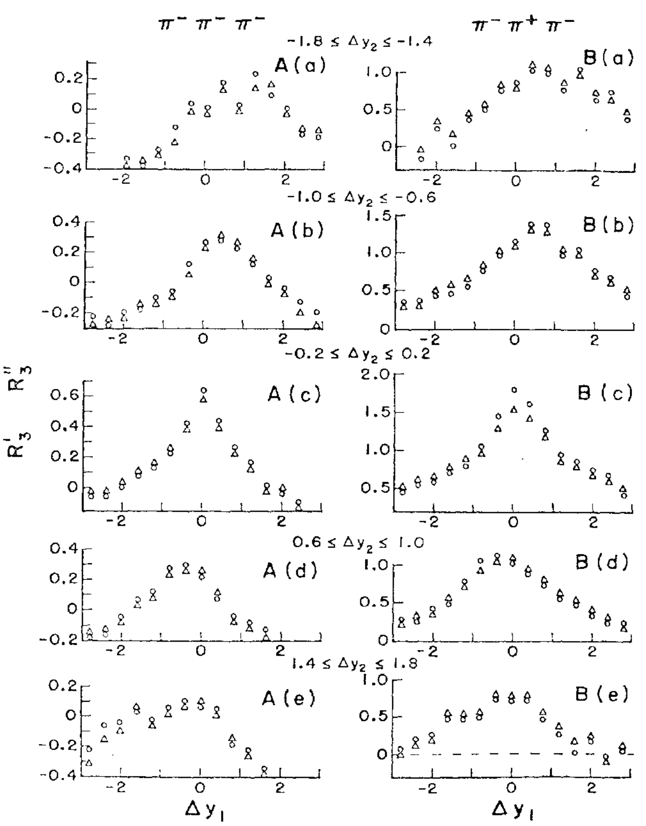

Fig. 4. Values of $R_3'(\Delta y_1, \Delta y_2)$ (circles) and $R_3''(\Delta y_1, \Delta y_2)$ (triangles) as a function of $\Delta y_1 = y_1 - y_2$ for different intervals for $\Delta y_2 = y_2 - y_3$. Values for the $(---)$ charge combination are shown on the left, A(a)–(e); values for the $(-+-)$ charge combination are shown on the right, B(a)–(e).

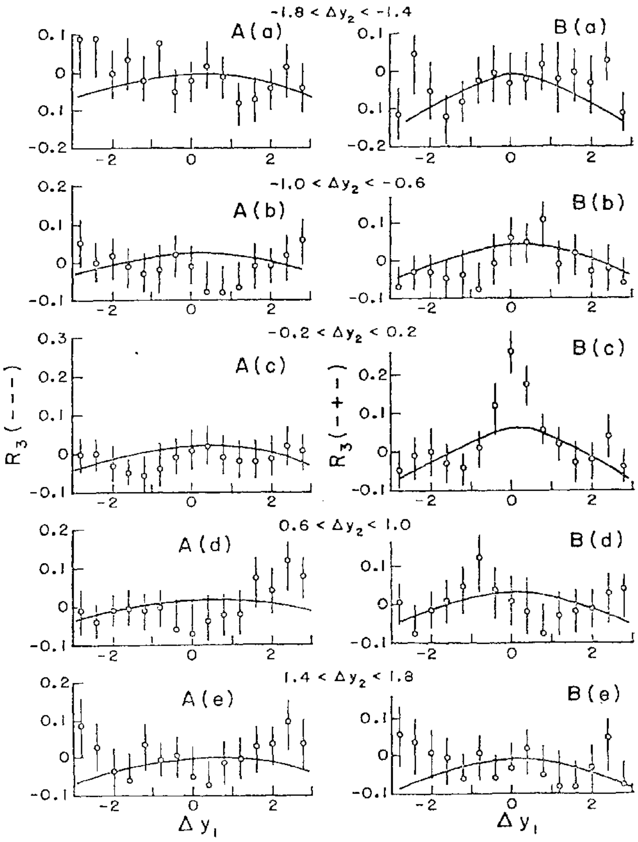

Fig. 5. Values of the true dynamical correlation $R_3(\Delta y_1, \Delta y_2) = R_3'(\Delta y_1, \Delta y_2) - R_3''c(\Delta y_1, \Delta y_2)$ as a function of Δy_1 for various intervals of Δy_2. Values for the $(---)$ charge combination are shown on the left, A(a)–(e); values for the $(-+-)$ charge combination are shown on the right, B(a)–(e).

The signal R_3' can be compared with the background term R_3'' for like-charge $(---)$ and unlike-charged $(-+-)$ 200 GeV/c data in Fig. 4. The only regions where a significant effect is seen is that in which $\Delta y_1 = y_1 - y_2$ and $\Delta y_2 = y_2 - y_3$ are both small. The subtracted correlation R_3 $(-+-)$ shows a substantial peak in Fig. 5b(c), in contrast with the corresponding R_3 $(---)$ for like-charge data, Fig. 5a(c). It is clear that 3-particle correlations do exist; it is also clear that they are a small effect, consistent with the conclusions of the previous section.

References

1. F. T. Dao *et al.*: Phys. Letters **45B** (1973) 402; J. Lämsa *et al.*: Phys. Rev., to be published.
2. E. L. Berger: Nucl. Phys. **B85** (1975) 61 and private communication.
3. K. Eggert *et al.*: Nucl. Phys. **B86** (1975) 201; M. Pratap *et al.*: Nucl. Phys. **B116** (1976) 1; T. Kafka *et al.*: Phys. Rev. **D16** (1977) 1261.