CONF-75-099-E
E-0002
#2B
FERMILAB-CONF-75-099-E

MULTIPARTICLE CORRELATIONS

V. Paul Kenney
University of Notre Dame

ABSTRACT

New data on multiparticle correlations presented to this conference are reviewed.

INTRODUCTION

In the most general terms, "correlations" refer to the fact that particles produced in high energy hadron interactions do not come off independently, but in groups or "clusters" with significant regularities characterizing the structure of the events. With increasing energy, the number of clusters is expected to increase but the structure regularities may be energy-independent. We consider new data on correlations or structure regularities for inclusive reactions at FNAL energies reported to this conference.

RAPIDITY CORRELATIONS

Distributions of the correlation variable $R(y_1, \Delta y) = [\rho_2(y_1, y_2)/\rho_1(y_1)\rho_1(y_2)] - 1$, where ρ_1 and ρ_2 are respectively the normalized single-particle and two-particle rapidity densities, are shown in Fig. 1 for 200 GeV/c $\pi^- p$ inclusive reactions in data from Biswas et al.[1]. Dynamical correlations beyond those expected from energy-momentum conservation are clearly evident at small Δy when the data are compared with an independent-emission model (solid line) containing no explicit short-range correlations.

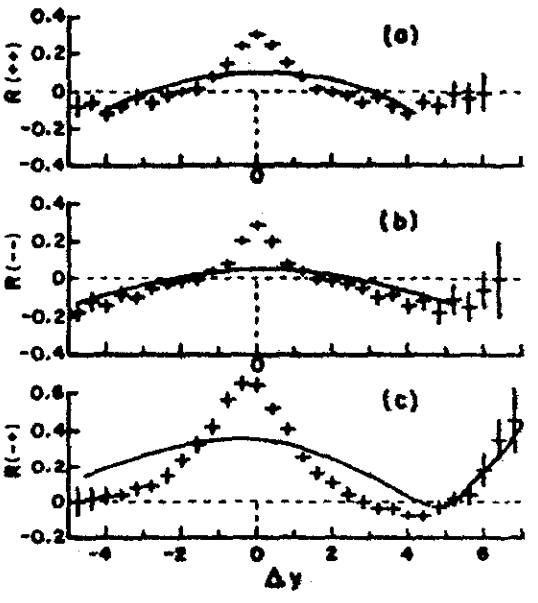

Fig. 1 $R(\Delta y)$ for (a) ++, (b) --, and (c) -+ pairs.

Correlations for both like and unlike particle pairs are present semi-inclusively, as shown for events in the central region, $-1.8 \leq y_1 \leq 1.8$, in Fig. 2. (For like particles, $R'_n = R_n + 1/n_-$

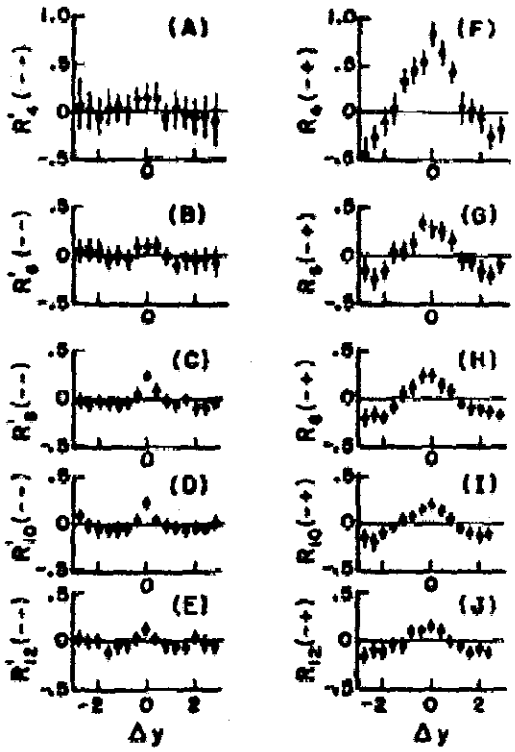

Fig. 2 $R_n(\Delta y)$ and $R'_n(\Delta y)$ for semi-inclusive reactions.

particle R(--) appears only in the data for $\Phi < 45^0$ and is narrow, with a range of ~0.4 rapidity units. The unlike-particle R(+-) is broader, ~1.3 rapidity units wide, independent of Φ. Similar behavior has been observed for pp interactions and for π^-p interactions at lower energy[3]. The narrow R(--) peak is observed semi-inclusively, in the 4-prong and 12-prong events shown.

It would be interesting to know if the narrow R(--) correlation is a manifestation of Bose-Einstein effects, or if the different behavior of R(--) and R(+-) reflects is plotted.) The independent-emission model predicts no significant correlations in the central region; the data for unlike pairs show a positive correlation which decreases with n, while the like pairs show a positive correlation for $n \geq 8$. It is important that rapidity correlations be present semi-inclusively if they are not to be ascribed to the convolution of uncorrelated single-particle spectra and the multiplicity distribution[2].

When the correlations are studied as a function of the azimuth angle Φ between the transverse-momentum vectors of the particles, Fig. 3, the like-

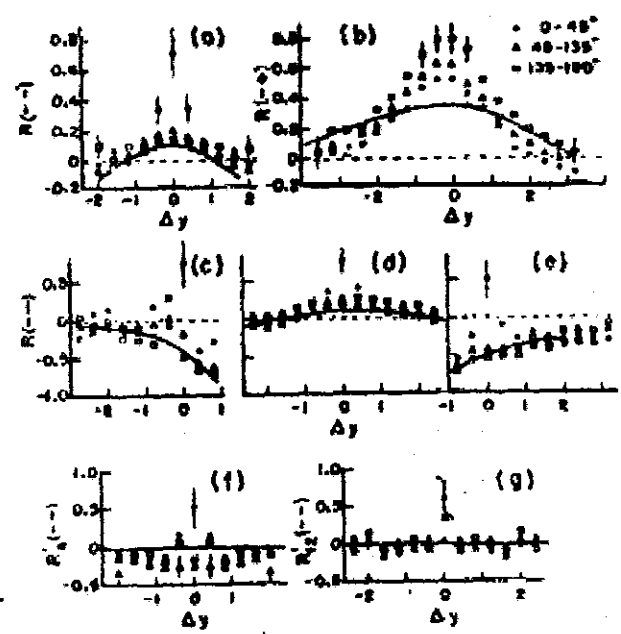

Fig. 3 $R(\Delta y)$ for different Φ ranges: (a) R(--) inclusive; (b) R(-+) inclusive; R(--) inclusive for (c) $y_1 < -2.2$, (d) $-1.8 \leq y_1 \leq 1.8$, (e) $y_1 > 2.2$; semi-inclusive (f) $R'_4(--)$ for 4 prong, and (g) R'_{12} for 12 prong events.

the charge structure of the reaction. An independent cluster emission model[4] including Bose-Einstein effects fits the azimuthal distribution for the like (--) pairs reasonably well, although the corresponding model for unlike pairs fits the (-+) data rather poorly[5]. Better statistics are necessary to resolve this question.

CHARGE STRUCTURE STUDIES

New results on charge exchange across rapidity gaps in 200 GeV/c $\pi^- p$ inclusive reactions are reported by J. Lamsa et al.[6]. Charged particles are ordered in rapidity and the charge exchange across the nth gap, $\Delta Q_n = (\sum_{i=1}^{n} Q_i) - Q_T$, ($Q_i$ refers to the ith particle and Q_T to the target) is studied. An odd-even charge exchange alternation along the rapidity chain is imposed by the requirement that the charge exchange must differ by one unit for adjacent rapidity gaps and for end gaps ΔQ must be even. In the strong-ordering limit in which large ΔQ's are suppressed, $\Delta Q \gtrsim 2$ would not be expected unless there is a breakdown at small Δy where "crossover" might occur (Fig. 4).

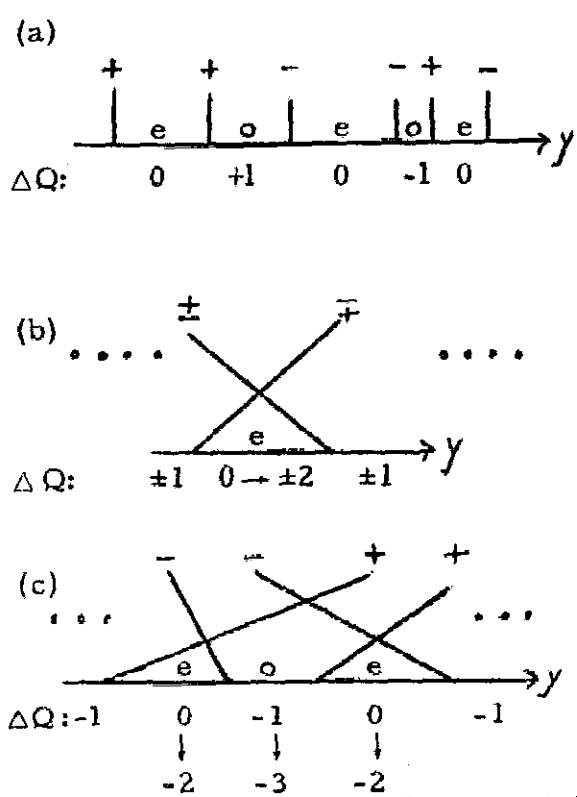

Fig. 4 ΔQ diagrams showing (a) "strong ordering", (b) single crossover, (c) multiple cross over.

Normalized distributions of the probability $P|_{\Delta Q}|(\Delta y)$ suggest that the region in which a single $|\Delta Q| = 2$ crossover occurs has a Gaussian width $\Gamma = 1.32 \pm 0.06$ rapidity units, while the region of "multiple" crossover giving $\Delta Q = 3$ is much smaller, $\Gamma = 0.75 \pm 0.07$ rapidity units. As is shown in Fig. 5, these "charge correlation" lengths are independent of event multiplicity n, and also of the position of the gap in the rapidity chain.

A "zone analysis" of the charge structure of events from the same experiment by V. A. Sreedhar et al.[7] is interesting in that the position distribution of central zones (Fig. 6) shows a pronounced plateau not observed in simi-

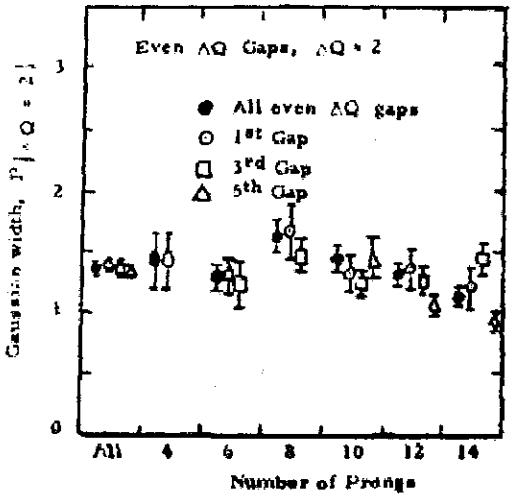

Fig. 5 Gaussian widths for $P_{|\Delta Q = 2|}$ as a function of multiplicity and position along the rapidity chain.

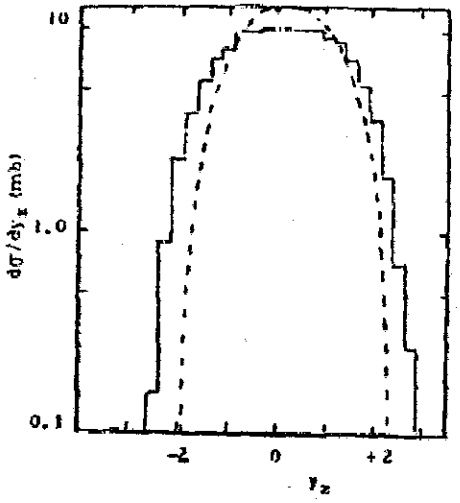

Fig. 6 Position distribution of central zones at 200 GeV/c $\pi^- p$ (solid) and 69 GeV/c pp (dashed), normalized to same area.

lar analyses for lower-energy data. There is therefore some evidence of "saturation" of whatever mechanism (short-range forces, local compensation, etc.) is responsible for the charge structure at these energies. The width distribution of central zones fits the exponential $\exp(-\lambda/\lambda_0)$, with $\lambda_0 = 0.77 \pm 0.01$.

A study of the net charge transfer $\langle \Delta Q \rangle$ between c.m. hemispheres in these same data by B. Schwarzchild[8] suggests that $\sigma(\Delta Q)/\sigma(\text{inelastic})$ plotted against $|\Delta Q - \langle \Delta Q \rangle|$ fall on a universal curve previously described by Breitenlohner[9].

RAPIDITY GAP DISTRIBUTIONS

The study of correlation behavior and clustering phenomena in terms of rapidity gap distributions[10] has been extended by J. Lamsa et al.[11], who show that the distribution of the sum of the n-1 consecutive rapidity-gap lengths $\Delta Y_n = y_{i+n-1} - y_i$ should be described by the Erlangian density distribution $E(\Delta Y_n) = [\lambda^{n-1} (\Delta Y_n)^{n-2} e^{-\lambda \Delta Y_n}]/(n-2)!$ in the absence of correlation effects. Plotting distributions of ΔY_n (weighted by $\Delta Y_n{}^{2-n}$), Fig. 7, and comparing with an uncorrelated emission model (solid curves), they observe a deviation from exponential behavior at small ΔY_n not only for the $n = 2$ case[10] but for all n,

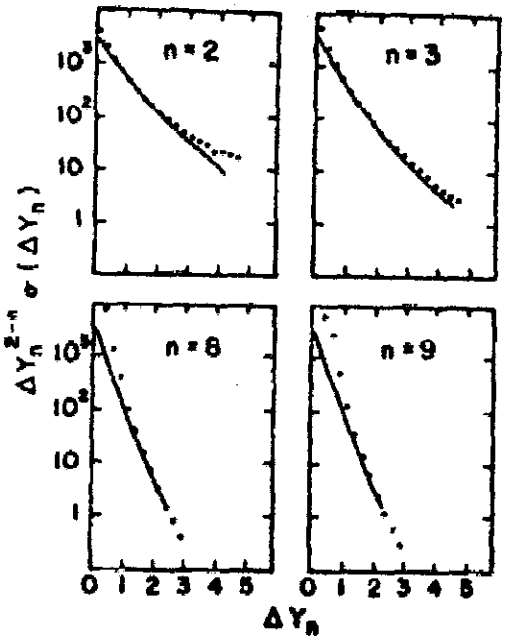

Fig. 7 Distributions of ΔY_n.

suggesting the production of clusters of high multiplicity.

CONCLUSION

New data presented to this conference show consistent regularities in the rapidity and charge structure of secondary pions. There is evidence both that charge is "locally compensated", and that unlike particle pairs are correlated, in a region of ~1.3 rapidity units. What these "clustering" phenomena mean is still unclear. Further understanding will depend on the ability of new experiments to significantly improve their statistics and to include for the first time data on K^o and π^o particles emitted with the $\pi^{\pm}$ along the rapidity chain.

REFERENCES

1. N.N. Biswas et al., Notre Dame-Duke-I.P.P. Canada Collaboration, paper #14 submitted to this conference.
2. J. Erwin et al., Phys. Rev. Letters 32, 254 (1974).
3. B. Oh et al., Mich.St.-ANL-FNAL-Iowa St.-Md. Collaboration, paper #5, published in Phys. Lett. 56B, 400 (1975).
4. G. Ranft and J. Ranft, Phys. Letters 53B, 188 (1974).
5. E. Fokitis, private communication.
6. J. Lamsa et al., Duke-Notre Dame-I.P.P. Canada Collaboration, paper #10 submitted to this conference.
7. V.A. Sreedhar, I.P.P. Canada-Duke-Notre Dame Collaboration, paper #46 submitted to this conference.
8. B. Schwarzchild, private communication.
9. P. Breitenlohner, Proceedings IV International Symposium on Multiparticle Hadrodynamics, Pavia (1973).
10. C. Quigg, P. Pirila, and G.H. Thomas, Phys. Rev. Letters 34, 290 (1975); A. Krzywicki, C. Quigg, and G.H. Thomas, Phys. Letters 57B, 369 (1975).
11. J. Lamsa et al., Duke-Notre Dame-I.P.P. Canada Collaboration, paper #9 submitted to this conference.