EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

CERN/EP 82-53
10 May 1982

COMPARISON OF SHORT RANGE RAPIDITY CORRELATIONS
IN $\bar{p}p$ AND pp INTERACTIONS AT $\sqrt{s} = 53$ GeV

ABCHW Collaboration

A. Breakstone, H.B. Crawley, A. Firestone, M. Gorbics, J.W. Lamsa and
W.T. Meyer
Ames Laboratory and Department of Physics, Iowa State University, Ames, USA

R. Campanini, G.M. Dallavalle, M.M. Deninno, F. Fabbri, G. Giacomelli and
F. Rimondi
Istituto di Fisica dell'Università and INFN, Bologna, Italy

D. Drijard, H.G. Fischer, H. Frehse, W. Geist, M. Heiden, P.G. Innocenti,
G. Mornacchi and O. Ullaland
CERN, European Organization for Nuclear Research, Geneva, Switzerland

W. Hofmann, M. Panter, K. Rauschnabel, J. Spengler and D. Wegener
Institut für Physik der Universität Dortmund, Dortmund, Germany

P. Hanke, W. Herr, E.E. Kluge, T. Nakada, A. Putzer, B. Rensch and M. Wunsch
Institut für Physik der Universität Heidelberg, Germany

K. Doroba, R. Gokieli and R. Sosnowski
Institute for Nuclear Research, Warsaw, Poland

ABSTRACT

Measurements are presented of two-particle rapidity correlations in $\bar{p}p$ and pp at $\sqrt{s} = 53$ GeV. The data were recorded at the CERN-ISR using the Split Field Magnet spectrometer with a minimum bias trigger. Short range correlations in normal inelastic events with measured charged multiplicities $n_{ch} \geq 4$ are observed for pairs of charged particles in all charge combinations. Within the experimental errors no differences are observed between the analogous correlations in pp and $\bar{p}p$ interactions.

Submitted to Physics Letters B

One of the prominent features of multiparticle production in high energy interactions is the presence of two-particle short range correlations in rapidity. These correlations are usually interpreted in the framework of cluster models. Short range correlations of charged hadron pairs produced in proton-proton interactions have been extensively studied at the CERN-ISR [1-4]. The recent storage of antiprotons in the ISR has made it possible for the first time to perform such studies also with $\bar{p}p$ events.

This letter presents results on short range, two-particle rapidity correlations in low transverse momentum $\bar{p}p$ and pp interactions at $\sqrt{s} = 53$ GeV. The correlations studied involve pairs of charged particles in all charge combinations.

In the $\bar{p}p$ runs the stored antiproton current was 2 mA, while the proton current was 10.5 A. This resulted in a luminosity of approximately $7 \times 10^{26} \text{ cm}^{-2} \text{ s}^{-1}$. The pp runs were performed at a luminosity of $7 \times 10^{29} \text{ cm}^{-2} \text{ s}^{-1}$.

Data were taken with the Split Field Magnet (SFM) spectrometer [5] and analysed with the SFM off-line program chain. The detector was used with a minimum bias trigger, which requires at least one charged track candidate in the spectrometer. This trigger accepts $\approx 95\%$ of the inelastic cross section. For the pp data 90% of the triggers are good events (beam-beam interactions), but for the $\bar{p}p$ data only 2-3% of the triggers are good events due to the large background (percentage wise) of beam-gas interactions present in runs with relatively low luminosities. In both cases the beam-gas background is eliminated after event reconstruction by requiring the vertex to lie inside the known overlap region of the beams.

For this analysis we considered 12,200 pp and 9,300 $\bar{p}p$ minimum bias events. Each event was required to have a good vertex fit within the intersection region. The tracks belonging to identified V^0 particles (K_S^0 , Λ^0) were removed on the basis of the analysis performed in ref. [6]. The contamination of electrons from π^0 and γ conversions was estimated to be about 2% [7] and was neglected. Vertex tracks were used for the correlation studies if the error in their curvatures was smaller than 100%.

This insured that the charge was correctly determined for each track. No other corrections, such as for acceptance, were made. This is possible because the acceptance corrections essentially drop out from the correlation coefficients which we are studying; that is, the two-track acceptance is very close to the product of one-track acceptances. The residual acceptance term is negligible since, for this detector, the acceptance corrections represent a small effect.

For the reaction

$$\bar{p}p \rightarrow h_1 + h_2 + X \quad (1)$$

where h_1, h_2 are observed charged hadrons, one defines the two-particle correlation function as

$$R_2(y_1, y_2) = \frac{\rho_2(y_1, y_2)}{\rho_1(y_1)\rho_1(y_2)} - 1 \quad (2)$$

$$= \sigma_{in} \frac{(d^2\sigma/dy_1 dy_2)}{(d\sigma/dy_1)(d\sigma/dy_2)} \quad (3)$$

where

$$\rho_1(y) = \frac{1}{\sigma_{in}} \frac{d\sigma}{dy} \quad (4)$$

is the single particle density distribution, and

$$\rho_2(y_1, y_2) = \frac{1}{\sigma_{in}} \frac{d^2\sigma}{dy_1 dy_2} \quad (5)$$

is the two-particle density distribution. σ_{in} is the inelastic cross section, and y_1 and y_2 are the rapidities of hadrons h_1 and h_2 , respectively.

If hadrons h_1 and h_2 were emitted independently, $\rho_2(y_1, y_2)$ would be the product of the two single particle distribution functions $\rho_1(y_1)\rho_1(y_2)$, and $R_2(y_1, y_2)$ would be zero. Values of R_2 different from zero indicate the existence of correlations between hadrons h_1 and h_2 .

In practice we used the functions

$$R_2(y_1, y_2) = N \frac{N_2(y_1, y_2)}{N_1(y_1) N_1(y_2)} - 1 \quad (6)$$

where, in a sample of N events, $N_1(y)$ tracks are observed at rapidity y within Δy and $N_2(y_1, y_2)$ pairs are observed at rapidities y_1, y_2 within $\Delta y_1, \Delta y_2$. Selection criteria, e.g. multiplicity, affect both N_1 and N_2 .

The ability of the SFM detector to measure the momentum and charge of each produced charged particle allows us to study the correlations R_2^{+-} , R_2^{++} and R_2^{--} , in addition to R_2^{CC} . The superscripts on R_2 give the charges of hadrons h_1 and h_2 . R_2^{CC} is the correlation function for all charged-charged pairs.

Fig. 1 shows the correlation function $R_2^{CC}(y_1, y_2)$ versus y_1 for four different values of y_2 ($y_2 = -1, 0, +1$ and $+2$). The figure contains data for both pp (black points) and $\bar{p}p$ (open circles) interactions with observed charged particle multiplicities $n_{ch} \geq 8$. The maxima at $y_1 = y_2$ are evidence for short range correlations between charged pairs of hadrons. The dashed curved in fig. 1(d) indicates qualitatively the symmetric correlation trend observed for $y_2 = -2$.

The pp correlation data of fig. 1 are in good agreement with those of previous ISR experiments [1,2]. We conclude from fig. 1 that there are no differences between the correlation functions for pp and $\bar{p}p$ events.

In fig. 2 are shown the correlation data at $y_2 = 0$ for the production of pairs of charged hadrons for all charge combinations. As in fig. 1 the data are for both pp and $\bar{p}p$ interactions with observed charged hadron multiplicities $n_{ch} \geq 8$. For all combinations there is a peak at $y_1 = 0$. The maximum value of the correlation function is different for the different charge combinations: it is largest for R_2^{+-} and smallest for R_2^{++} and R_2^{--} . Within errors we find $R_2^{++} = R_2^{--}$ and no differences between pp and $\bar{p}p$ interactions.

Fig. 3 shows R_2^{CC} , R_2^{+-} , R_2^{++} and R_2^{--} for $y_2 = 0$ and for observed charged hadron multiplicities $n_{ch} \geq 4$. One finds the same trends observed in fig. 2, but the maximum values of the corresponding correlation functions are considerably larger. Such a decrease in the maximum for higher multiplicities has been seen previously in other experiments, for example, see ref. [8].

Even though the distributions are not shown for lack of space we observe that the maximum values of R_2^{++} and R_2^{--} decrease significantly for $|y_2| \geq 2$ while the maximum value of R_2^{+-} remains approximately constant.

Our results on R_2^{+-} , R_2^{++} , and R_2^{--} in pp interactions can be compared with results from bubble chamber experiments at lower energies [3,9] and from a previous ISR experiment [2]. The trends are all the same within errors, thus excluding any strong energy dependence between $\sqrt{s} = 13.8$ GeV and ISR energies.

These correlation data in the central region can be described in the framework of a model which incorporates independent emission of charged clusters. In this model one cluster with an average mass of about 1.3 GeV is produced per unit of rapidity and, on the average, each cluster decays into 1.8 charged particles [2]. The evidence for correlations between like charges (figs 2 and 3) indicates that either doubly charged clusters or clusters of more than two charged particles are formed.

In conclusion, the successful operation of the ISR with antiprotons has allowed us to study short range correlations in $\bar{p}p$ interactions with observed charged multiplicities $n_{ch} \geq 4$. We find in $\bar{p}p$ clear evidence for strong short range correlations, which are equal to those found in pp interactions. The analysis of the correlation coefficients R_2^{cc} , R_2^{+-} , R_2^{++} and R_2^{--} indicates that R_2^{+-} is larger than $R_2^{++} = R_2^{--}$ in both pp and $\bar{p}p$ interactions. The correlation coefficients for pp interactions are essentially energy independent.

Acknowledgements

We are especially grateful for the support provided by the SFM detector group and the ISR Experimental Support group. We would also like to thank R. Messerli, U. Schlüpmann and G.P. Siroli for their assistance. The Ames group was supported by the Department of Energy under contract W-7405-eng-82. The Dortmund and the Heidelberg groups were supported by a grant from the Bundesministerium für Wissenschaft und Forschung of the Federal Republic of Germany.

REFERENCES

- [1] S.R. Amendolia et al., Phys. Lett. B48 (1974) 359.
- [2] D. Drijard et al., Nucl. Phys. B155 (1979) 269.
- [3] L. Foa, Phys. Rep. 22C (1975) 1.
- [4] G. Giacomelli and M. Jacob, Phys. Rep. 55 (1979) 1.
- [5] W. Bell et al., Nucl. Instr. Meth. 125 (1975) 437, 156 (1978) 111.
- [6] D. Drijard et al., Zeitschr. für Phys. C12 (1982) 217.
- [7] A. Breakstone et al., Inclusive particle production in pp collisions at $\sqrt{s} = 63$ GeV, to be published.
- [8] V.P. Kenney, Proc. 19th Int. Conf. High Energy Physics, Tokyo (1978) 69.
- [9] R. Singer et al., Phys. Lett. B49 (1974) 481.

FIGURE CAPTIONS

- Fig. 1 The correlation function $R_2(y_1, y_2)$ for charged hadron pairs as a function of y_1 for different values of y_2 ($y_2 = -1, 0, +1, +2$). The $pp(\bar{p}p)$ data are plotted with black points (open circles). The data are for $\sqrt{s} = 53$ GeV and $n_{ch} \geq 8$. The value and bin size (0.5) of y_2 is indicated in each graph. The dashed line in the graph for $y_2 = +2$ indicates the trend of $R_2(y_1, y_2 = -2)$. For clarity, error bars are included for only a few representative points.
- Fig. 2 The correlation function $R_2(y_1, y_2 = 0)$ for the production of $+\tau$, $++$, $--$ and charged-charged hadron pairs in pp and $\bar{p}p$ collisions at $\sqrt{s} = 53$ GeV with $n_{ch} \geq 8$. The value and bin size (0.5) of y_2 is indicated in each graph. The data are plotted in the same way as in fig. 1.
- Fig. 3 The same as in fig. 2, but with $n_{ch} \geq 4$.

Fig. 1

Fig. 2

Fig. 3