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Evidence for the Same Two-Particle Correlations in Rapidity Space in (pp) Collisions and (e^+e^-) Annihilation.

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PACS. 13.90. – Other topics in specific reactions and phenomenology of elementary particles.

Summary. – Evidence is reported for the same two-particle correlations in rapidity space in soft, high-energy (pp) collisions and (e^+e^-) annihilation when the leading baryons' effects are taken into account.

The comparison between two-particle correlations in (e^+e^-) annihilation and (pp) interactions is important for a deeper insight in the hadronization mechanism which is at work in these two basic ways of producing multiparticle states.

We have already found striking similarities between the properties of multiparticle systems produced in (e^+e^-) annihilation and in soft (pp) collisions, the basic principle being to subtract the leading-particle effects ([1-16]).

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([5]) M. BASILE, G. CARA ROMEO, L. CIFARELLI, A. CONTIN, G. D'ALÍ, P. DI CESARE, B. ESPOSITO,

So far a comparison between (e^+e^-) and (pp) collisions was believed to be valid, if the (pp) interactions were selected at high transverse momenta. The subtraction of the leading protons in (pp) interactions [1-16] has brought the vast amount of soft (low p_T) (pp) collisions into the interesting area of comparison with (e^+e^-) annihilation.

Two-particle correlation in rapidity space is a typical tool for demonstrating how the comparison of (e^+e^-) annihilation and low-p_T (pp) collisions could be misunderstood when the leading-particle effects, present in the last process, are not taken into account.

In the case of no correlation, the two-particle density function, $\varrho_2(y, y')$, should be related with the single-particle density, $\varrho_1(y)$, $\varrho_1(y')$, through

$$\varrho_2(y, y') = f\varrho_1(y)\varrho_1(y') ,$$

where $\varrho_1(y)$ is the rapidity single-particle density

$$\varrho_1(y) = \frac{1}{\sigma_{in}} \frac{d\sigma(y)}{dy}$$

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and $\varrho_2(y, y')$ is the rapidity two-particle density

$$\varrho_2(y, y') = \frac{1}{\sigma_{\text{in}}} \frac{\mathrm{d}\sigma(y, y')}{\mathrm{d}y\,\mathrm{d}y'} .$$

The parameter $f = \langle n_{\text{ch}}(n_{\text{ch}} - 1)\rangle / \langle n_{\text{ch}}\rangle^2$ assures the correct normalization. The correlation function $R(y, y')$ is defined as

$$R(y, y') = \frac{\varrho_2(y, y')}{f\varrho_1(y)\,\varrho_1(y')} - 1 .$$

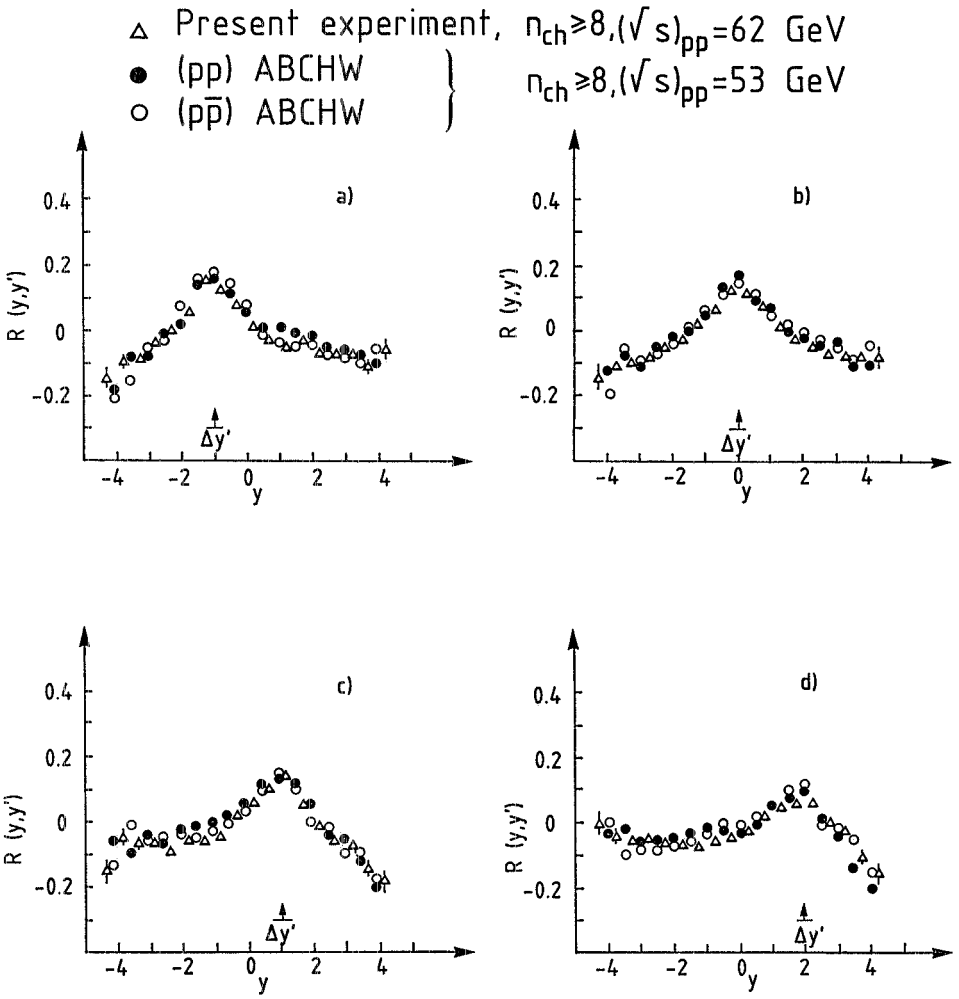

Fig. 1. – Two-particle correlations in rapidity space for different y' intervals (a) $-1.75 \leqslant y' \leqslant -0.75$, b) $-0.25 \leqslant y' \leqslant 0.25$, c) $0.75 \leqslant y' \leqslant 1.25$, d) $1.75 \leqslant y' \leqslant 2.25$) as measured by the ABCHW collaboration at $(\sqrt{s})_{\text{pp}} = 53$ GeV in (pp) (black points) and ($\text{p}\bar{\text{p}}$) (open circles) collisions and by the present experiment (open triangles) at $(\sqrt{s})_{\text{pp}} = 62$ GeV in (pp) collisions. These results are obtained from minimum-bias events without leading-proton subtraction for an observed charged multiplicity: $n_{\text{ch}} \geqslant 8$.

Two-particle correlations in rapidity space were measured by the TASSO collaboration ([17,18]) in (e^+e^-) annihilation and by the ABCHW collaboration ([19]) with the SFM ([20]) facility at the CERN ISR in (pp) and ($p\bar{p}$) collisions. On the basis of these results the following conclusions ([17]) were reached:

1) two-particle correlations in (e^+e^-) annihilation are well described by the Field-Feynman jet fragmentation model ([21]),

2) the maximum of $R(y, y')$ at $y = y' = 0$ is about twice as high in (e^+e^-) annihilation than in (pp) and ($p\bar{p}$) collisions,

3) the local maximum of R at $y = y'$ decreases with increasing $|y'|$ much faster for (e^+e^-) than for (pp) and ($p\bar{p}$).

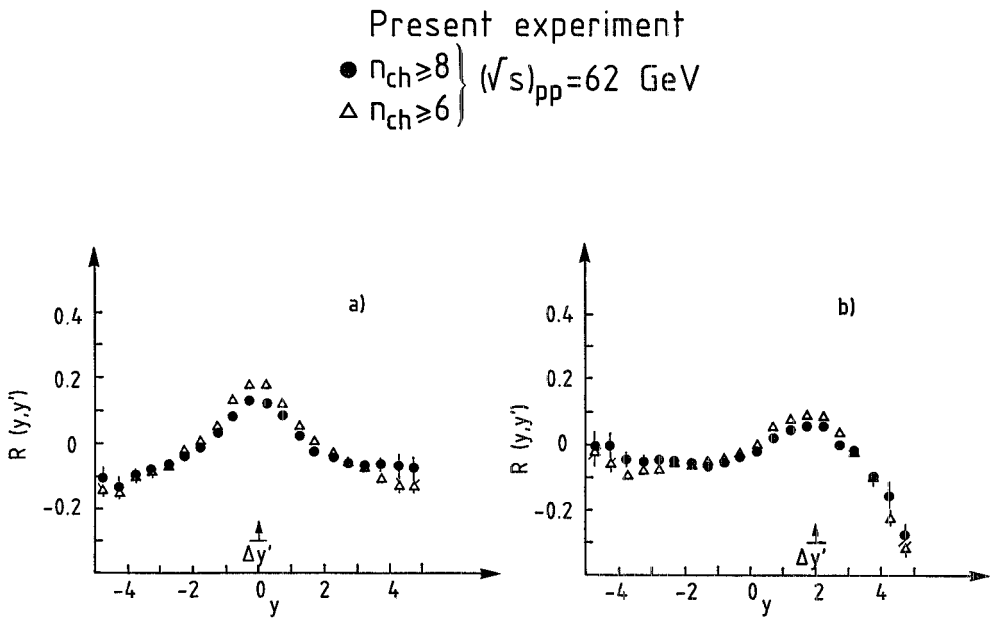

Fig. 2. – Two-particle correlation in rapidity space for different y' intervals (*a*) $-0.25 \leqslant y' \leqslant 0.25$, *b*) $1.75 \leqslant y' \leqslant 2.25$) as measured in the present experiment in (pp) collisions at $(\sqrt{s})_{pp} = 62$ GeV with different multiplicity cuts. The data with $n_{ch} \geqslant 8$ are plotted with black points and the data with $n_{ch} \geqslant 6$ are plotted with open triangles. These results are obtained without leading-proton subtraction.

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These differences between (e^+e^-) and (pp), ($p\bar{p}$) processes were explained ([17]) as being due to the fact that in (e^+e^-) annihilation a single $q\bar{q}$ chain is present in the final state, while at least a double chain is present in the final state of (pp) collisions ([22]).

We have measured $R(y, y')$ for our « minimum bias » events, taken with the SFM ([20]) facility at the CERN ISR, in (pp) collisions at $(\sqrt{s})_{pp} = 62$ GeV and we have compared these data with the measurements of the ABCHW collaboration ([19]) at

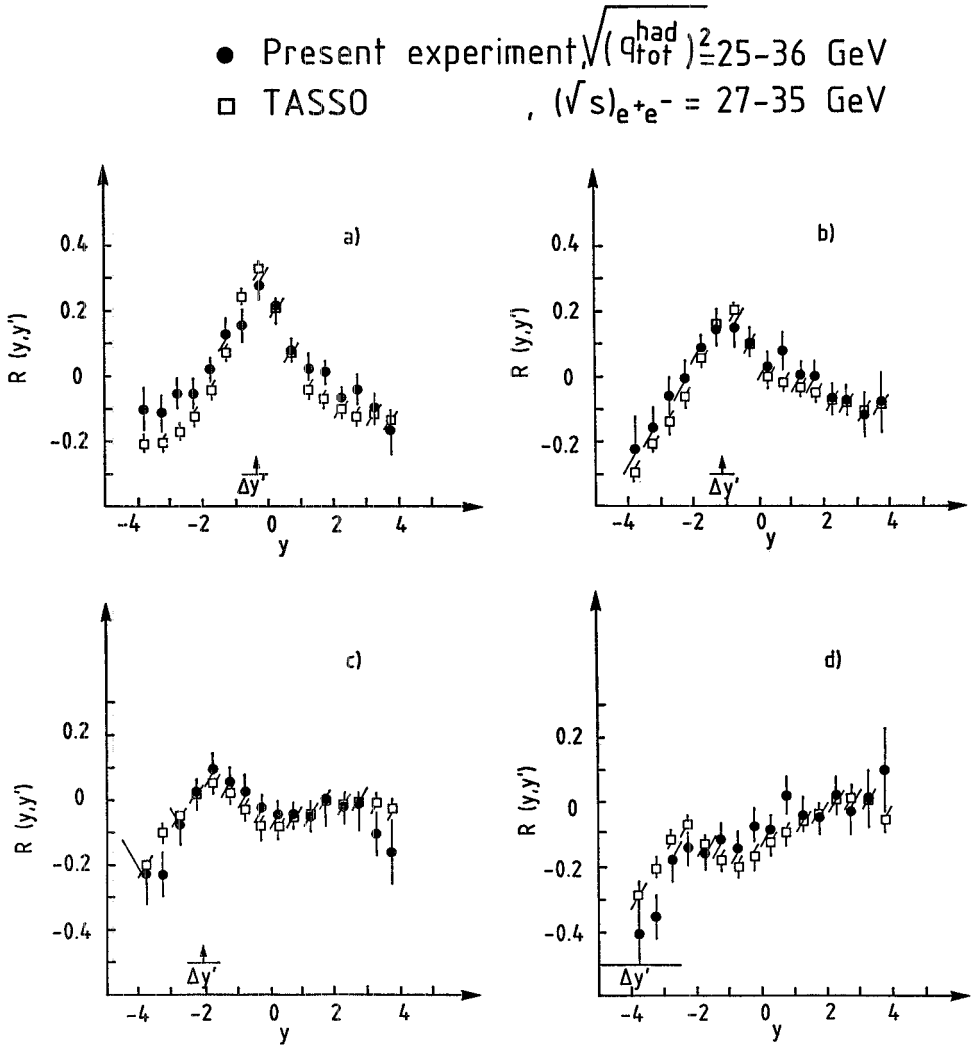

Fig. 3. – Two-particle correlation in rapidity space for different y' intervals (a): $-0.75 \leqslant y' \leqslant 0$ b) $-1.5 \leqslant y' \leqslant -0.75$, c) $-2.5 \leqslant y' \leqslant -1.5$, d) $-5.5 \leqslant y' \leqslant -2.5$) as measured in the present experiment after the leading proton subtraction in the $\sqrt{(q_{tot}^{had})^2}$ range ($25 \div 36$) GeV (black points), compared with results by the TASSO collaboration at $(\sqrt{s})_{e^+e^-}$ between 27 and 35 GeV, as measured in (e^+e^-) annihilation (open squares).

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$(\sqrt{s})_{pp} = 53$ GeV. The two sets of data are in very good agreement as is shown in fig. 1*a*), *b*), *c*), *d*). This proves that, when ignoring the leading-proton effects, our data reproduce the ABCHW results.

In this comparison, following the criteria adopted by the ABCHW collaboration, tracks are selected with $\Delta p/p \leqslant 100\%$, and events are taken with eight or more observed charged tracks. The number of analysed events is 52 332.

If a multiplicity cut of six observed tracks, as used by the TASSO collaboration [17] analysing (e^+e^-) data is applied, the two-particle correlations do not vary much, as is shown in fig. 2*a*), *b*).

Now, the key point: let us apply our method of subtracting the leading protons [1,16]. This allows us to calculate the effective c.m. energy available for particle production $\sqrt{(q_{tot}^{had})^2}$, and to define the reference system as the one in which q_{tot}^{had} is at rest:

$$q_{tot}^{had} = q_1^{inc} + q_2^{inc} - q_1^{leading} - q_2^{leading},$$

where $q_{1,2}^{inc}$ are the four-vectors of the incident protons and $q_{1,2}^{leading}$ the four-vectors of the leading protons. Following the (e^+e^-) method the rapidity is calculated with respect to the sphericity axis.

Protons are identified in our analysis as the positive tracks in each hemisphere with the highest Feynman x_F. Only events with protons in the range $0.4 \leqslant x_F \leqslant 0.9$ are retained. Moreover, for these tracks $\Delta p/p \leqslant 8\%$ is required. With these cuts, the contamination from pions in the identified proton tracks is about 25% at $x_F = 0.4$ and falls quickly down, with increasing x_F: it is about 1% at $x_F = 0.9$ [23,24]. Only events with two identified protons and at least four observed charged tracks, besides the protons, are retained for this analysis.

The $\sqrt{(q_{tot}^{had})^2}$ range was chosen to be between 25 and 36 GeV for the comparison with (e^+e^-) results evaluated by the TASSO collaboration from events observed at $(\sqrt{s})_{e^+e^-}$ between 27 and 35 GeV. The final number of events is 1288.

Results on two-particle correlations are presented in fig. 3*a*)-*d*), where the (e^+e^-) data are also reported.

As can be seen, the conclusions previously reached [17] in comparing (e^+e^-) and (pp) processes are not valid.

Once the leading protons' effects are subtracted out, our analysis of the two-particle correlations in rapidity space show that (pp) interactions and (e^+e^-) annihilation follow the same trends, in both processes.

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