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SCALE-BREAKING EFFECTS IN (pp) INTERACTIONS
AND COMPARISON WITH (e⁺e⁻) ANNIHILATIONS

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ABSTRACT

Scale-breaking effects have been measured in (pp) interactions, using the new method of analysis which allows the properties of the multiparticle systems produced in (pp) collisions to be compared with those produced in (e⁺e⁻) annihilation. A striking agreement is found in the values of the coefficients C measured in (pp) and in (e⁺e⁻), using the correct values of the fractional momentum x_R^* in (pp) interactions at equivalent effective hadronic energy.

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Following the most popular theoretical trend, scale-breaking effects are not expected in simple quark-parton models. They are predicted to exist by QCD as a consequence of the emission of gluons from the primary quarks.

These effects have been looked for in the multiparticle hadronic states produced in (e^+e^-) annihilation. More precisely, the fragmentation function $(1/\sigma)(d\sigma/dx)$ (x is the fractional momentum of the observed particles) of the inclusive charged particle production in (e^+e^-) annihilation has been investigated¹⁾, and the scale-breaking effects have been observed.

The interest in studying whether the same effect is present in the multiparticle states produced in (pp) interactions is obvious. This study can be done once the correct variables are used in the analysis of the (pp) interactions²⁾. The introduction of this new method of analysis has yielded a series of impressive analogies between the properties of the multiparticle systems produced in (pp) interactions and those produced in (e^+e^-) annihilation²⁻¹⁵⁾ and in deep inelastic processes¹⁶⁻¹⁸⁾.

We have used the (pp) data at $(\sqrt{s})_{pp} = 62$ GeV, collected at the CERN Intersecting Storage Rings (ISR), using the Split Field Magnet (SFM) facility. A detailed description of the apparatus, together with other information, can be found elsewhere¹⁹⁾.

Let us recall a key point of our analysis. Having two colliding beams of protons, the total energy available for particle production is not given by the sum of the four-momenta. In fact, in a (pp) collision the energy taken by the two protons in the final state, which is a large fraction of the initial energy ($\sim 50\%$ on the average), reduces the amount of the energy effectively available for particle production. In order to compare the properties of the multiparticle states produced in (pp) and (e^+e^-) , it is necessary to classify each (pp) collision according to the energy effectively available for particle production. This means that the leading protons have to be subtracted. The correct quantity is therefore^{6,20)}

$$\left(q_{\text{tot}}^{\text{had}}\right)^2 = \left(q_1^{\text{inc}} + q_2^{\text{inc}} - q_1^{\text{leading}} - q_2^{\text{leading}}\right)^2, \quad (1)$$

where $q_{1,2}^{\text{inc}}$ and $q_{1,2}^{\text{leading}}$ are the four-momenta of the two incident protons and of the two leading protons.

For more details about this new method of analysis, we refer the reader to our previous papers²⁻¹⁵).

In order to study scale-breaking effects in the multiparticle systems produced in (pp) interactions, we have analysed our data, using the effective hadronic energy $\sqrt{(q_{\text{tot}}^{\text{had}})^2}$ as the basic variable for comparing with $(\sqrt{s})_{e^+e^-}$. Moreover, we have defined accordingly the inclusive fractional momentum of the particles, $x_R^* = 2p/\sqrt{(q_{\text{tot}}^{\text{had}})^2}$, where p is the modulus of the observed particle momentum.

The results are given in Fig. 1, where the quantity $(1/N_{\text{ev}})(dN/dx_R^*)$ versus $(q_{\text{tot}}^{\text{had}})^2$, for different ranges of x_R^* , is shown. Notice that N_{ev} = number of events and N = number of particles; the other quantity has already been defined. The data are grouped in seven values of $(q_{\text{tot}}^{\text{had}})^2$ and for five intervals of x_R^* . The depletion of particles at high x_R^* with increasing values of $(q_{\text{tot}}^{\text{had}})^2$ is indeed present in our data, as in (e^+e^-) data.

A more quantitative way of comparing our results with (e^+e^-) annihilation data is to fit the data of each x_R^* interval with the following function

$$\frac{1}{N_{\text{ev}}} \frac{dN}{dx_R^*} = A \left[1 + C \ln \left((q_{\text{tot}}^{\text{had}})^2 \right) \right].$$

The values of the parameter C versus x_R^* are reported in Fig. 2. The values for the same parameter C , obtained in (e^+e^-) events at PETRA¹⁾, are also reported for comparison.

The values of C measured in (pp) and (e^+e^-) are in good agreement. This shows that, also in the scale-breaking effects, the multiparticle systems produced in (pp) interactions show striking analogies with the multiparticle systems produced in (e^+e^-) annihilation.

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Figure captions

- Fig. 1 : The quantity $(1/N_{ev})(dN/dx_R^*)$ is plotted versus $(q_{tot}^{had})^2$, for different ranges of x_R^* .
- Fig. 2 : The values of the coefficient C versus x_R^* , as measured in (pp) interactions (this experiment) and in (e^+e^-) annihilation.

Fig. 1

Fig. 2