ISTITUTO NAZIONALE DI FISICA NUCLEARE
Laboratori Nazionali di Frascati

LNF-83/82

M. Basile et al. : SCALE-BREAKING EFFECTS IN (pp) INTERACTIONS AND COMPARISON WITH (e^+e^-) ANNIHILATIONS

Estratto da:
Lett. Nuovo Cimento 38, 289 (1983)

Servizio Documentazione
dei Laboratori Nazionali di Frascati
Cas. Postale 13 - Frascati (Roma)

LETTERE AL NUOVO CIMENTO VOL. 38, N. 8 22 Ottobre 1983

Scale-Breaking Effects in (pp) Interactions and Comparison with (e^+e^-) Annihilations.

M. Basile, G. Bonvicini, G. Cara Romeo, L. Cifarelli, A. Contin, M. Curatolo, G. D'Alí, C. Del Papa, B. Esposito, P. Giusti, T. Massam, R. Nania, F. Palmonari, G. Sartorelli, G. Susinno, L. Votano and A. Zichichi

CERN - Geneva, Switzerland
Istituto di Fisica dell'Università - Bologna, Italia
Istituto Nazionale di Fisica Nucleare, Laboratori Nazionali di Frascati - Frascati
Istituto Nazionale di Fisica Nucleare - Sezione di Bologna, Italia

(ricevuto il 29 Luglio 1983)

PACS. 13.85. – Hadron-induced high- and superhigh-energy interactions, energy > 10 GeV.

Summary. – 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.

According to 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 investigated (1), 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) interactions (2). The introduction of this new method of analysis has yielded a series of impressive analogies between the

(1) R. Brandelik *et al.* (TASSO Collaboration): *Phys. Lett. B*, **114**, 65 (1982).
(2) M. Basile, G. Cara Romeo, L. Cifarelli, A. Contin, G. D'Alí, P. Di Cesare, B. Esposito, P. Giusti, T. Massam, F. Palmonari, G. Sartorelli, G. Valenti and A. Zichichi: *Phys. Lett. B*, **92**, 367 (1980).

properties of the multiparticle systems produced in (pp) interactions and those produced in (e^+e^-) annihilation ([2-15]) and in deep inelastic processes ([16-18]).

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 elsewhere ([19]).

Let us recall a key point of our analysis. Having two colliding beams of protons, the total energy available for particle production is not derivable from the sum of the four-momenta. In fact, in a (pp) collision the energy taken by the two protons in the final state, can be a large fraction of the initial energy (~50% on the average); this reduces

---

([3]) M. BASILE, G. CARA ROMEO, L. CIFARELLI, A. CONTIN, G. D'ALÍ, P. DI CESARE, B. ESPOSITO, P. GIUSTI, T. MASSAM, R. NANIA, F. PALMONARI, G. SARTORELLI, G. VALENTI and A. ZICHICHI: *Nuovo Cimento A*, **58**, 193 (1980).

([4]) M. BASILE, G. CARA ROMEO, L. CIFARELLI, A. CONTIN, G. D'ALÍ, P. DI CESARE, B. ESPOSITO, P. GIUSTI, T. MASSAM, R. NANIA, F. PALMONARI, G. SARTORELLI, G. VALENTI and A. ZICHICHI: *Phys. Lett. B*, **95**, 311 (1980).

([5]) M. BASILE, G. CARA ROMEO, L. CIFARELLI, A. CONTIN, G. D'ALÍ, P. DI CESARE, B. ESPOSITO, P. GIUSTI, T. MASSAM, R. NANIA, F. PALMONARI, G. SARTORELLI, G. VALENTI and A. ZICHICHI: *Lett. Nuovo Cimento*, **29**, 491 (1980).

([6]) M. BASILE, G. CARA ROMEO, L. CIFARELLI, A. CONTIN, G. D'ALÍ, P. DI CESARE, B. ESPOSITO, P. GIUSTI, T. MASSAM, R. NANIA, F. PALMONARI, G. SARTORELLI, M. SPINETTI, G. SUSINNO, G. VALENTI and A. ZICHICHI: *Phys. Lett. B*, **99**, 247 (1981).

([7]) M. BASILE, G. CARA ROMEO, L. CIFARELLI, A. CONTIN, G. D'ALÍ, P. DI CESARE, B. ESPOSITO, P. GIUSTI, T. MASSAM, R. NANIA, F. PALMONARI, G. SARTORELLI, M. SPINETTI, G. SUSINNO, G. VALENTI and A. ZICHICHI: *Lett. Nuovo Cimento*, **30**, 389 (1981).

([8]) M. BASILE, G. CARA ROMEO, L. CIFARELLI, A. CONTIN, G. D'ALÍ, P. DI CESARE, B. ESPOSITO, P. GIUSTI, T. MASSAM, R. NANIA, F. PALMONARI, G. SARTORELLI, M. SPINETTI, G. SUSINNO, G. VALENTI, L. VOTANO and A. ZICHICHI: *Lett. Nuovo Cimento*, **31**, 273 (1981).

([9]) M. BASILE, G. CARA ROMEO, L. CIFARELLI, A. CONTIN, G. D'ALÍ, P. DI CESARE, B. ESPOSITO, P. GIUSTI, T. MASSAM, R. NANIA, F. PALMONARI, V. ROSSI, G. SARTORELLI, M. SPINETTI, G. SUSINNO, G. VALENTI, L. VOTANO and A. ZICHICHI: *Nuovo Cimento A*, **65**, 400 (1981).

([10]) M. BASILE, G. CARA ROMEO, L. CIFARELLI, A. CONTIN, G. D'ALÍ, P. DI CESARE, B. ESPOSITO, P. GIUSTI, T. MASSAM, R. NANIA, F. PALMONARI, V. ROSSI, G. SARTORELLI, M. SPINETTI, G. SUSINNO, G. VALENTI, L. VOTANO and A. ZICHICHI: *Nuovo Cimento A*, **65**, 414 (1981).

([11]) M. BASILE, G. CARA ROMEO, L. CIFARELLI, A. CONTIN, G. D'ALÍ, P. DI CESARE, B. ESPOSITO, P. GIUSTI, T. MASSAM, R. NANIA, F. PALMONARI, V. ROSSI, G. SARTORELLI, M. SPINETTI, G. SUSINNO, G. VALENTI, L. VOTANO and A. ZICHICHI: *Lett. Nuovo Cimento*, **32**, 210 (1981).

([12]) M. BASILE, G. CARA ROMEO, L. CIFARELLI, A. CONTIN, G. D'ALÍ, P. DI CESARE, B. ESPOSITO, P. GIUSTI, T. MASSAM, R. NANIA, F. PALMONARI, V. ROSSI, F. ROHRBACH, G. SARTORELLI, M. SPINETTI, G. SUSINNO, G. VALENTI, L. VOTANO and A. ZICHICHI: *Nuovo Cimento A*, **67**, 53 (1982).

([13]) M. BASILE, G. BONVICINI, G. CARA ROMEO, L. CIFARELLI, A. CONTIN, M. CURATOLO, G. D'ALÍ, P. DI CESARE, B. ESPOSITO, P. GIUSTI, T. MASSAM, R. NANIA, F. PALMONARI, A. PETROSINO, V. ROSSI, G. SARTORELLI, M. SPINETTI, G. SUSINNO, G. VALENTI, L. VOTANO and A. ZICHICHI: *Nuovo Cimento A*, **67**, 244 (1982).

([14]) M. BASILE, G. BONVICINI, G. CARA ROMEO, L. CIFARELLI, A. CONTIN, M. CURATOLO, G. D'ALÍ, C. DEL PAPA, B. ESPOSITO, P. GIUSTI, T. MASSAM, R. NANIA, F. PALMONARI, G. SARTORELLI, M. SPINETTI, G. SUSINNO, L. VOTANO and A. ZICHICHI: *Nuovo Cimento*, **73**, 329 (1983).

([15]) J. BERBIERS, G. BONVICINI, G. CARA ROMEO, L. CIFARELLI, A. CONTIN, M. CURATOLO, G. D'ALÍ, C. DEL PAPA, B. ESPOSITO, P. GIUSTI, T. MASSAM, R. NANIA, G. NATALE, F. PALMONARI, G. SARTORELLI, G. SUSINNO, L. VOTANO and A. ZICHICHI: *Lett. Nuovo Cimento* **36**, 563 (1983).

([16]) M. BASILE, G. BONVICINI, G. CARA ROMEO, L. CIFARELLI, A. CONTIN, M. CURATOLO, G. D'ALÍ, C. DEL PAPA, B. ESPOSITO, P. GIUSTI, T. MASSAM, R. NANIA, F. PALMONARI, G. SARTORELLI, G. SUSINNO, L. VOTANO and A. ZICHICHI: *Lett. Nuovo Cimento*, **36**, 303 (1983).

([17]) G. BONVICINI, G. CARA ROMEO, L. CIFARELLI, A. CONTIN, M. CURATOLO, G. D'ALÍ, C. DEL PAPA, B. ESPOSITO, P. GIUSTI, T. MASSAM, R. NANIA, F. PALMONARI, G. SARTORELLI, G. SUSINNO, L. VOTANO and A. ZICHICHI: *Lett. Nuovo Cimento*, **36**, 555 (1983).

([18]) G. BONVICINI, G. CARA ROMEO, L. CIFARELLI, A. CONTIN, M. CURATOLO, G. D'ALÍ, C. DEL PAPA, B. ESPOSITO, P. GIUSTI, T. MASSAM, R. NANIA, G. SARTORELLI, G. SUSINNO, L. VOTANO and A. ZICHICHI: *Lett. Nuovo Cimento* **37**, 289 (1983).

([19]) R. BOUCLIER, R. C. A. BROWN, E. CHESI, L. DUMPS, H. G. FISCHER, P. G. INNOCENTI, G. MAURIN, A. MINTEN, L. NAUMANN, F. PIUZ and O. ULLALAND: *Nucl. Instrum. Methods*, **125**, 19 (1975).

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],

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

where $q_{1,2}^{inc}$ and $q_{1,2}^{leading}$ 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 papers [2-15].

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 $\sqrt{(q_{tot}^{had})^2}$ as the basic variable for comparing with $(\sqrt{s})_{e^+e^-}$. Moreover, we have defined accordingly, the fractional momentum of the inclusively produced particle $x_R^* = 2p/\sqrt{(q_{tot}^{had})^2}$, where p is the modulus of the observed particle momentum, in the correct c.m. system.

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

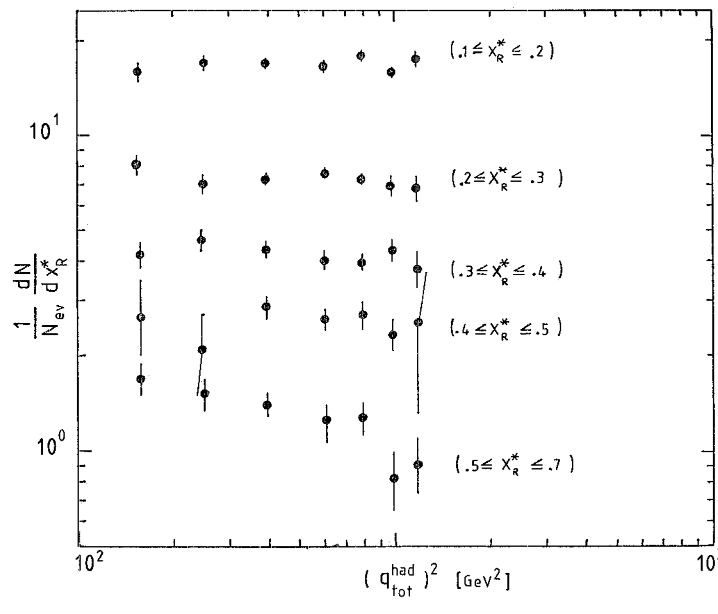

Fig. 1. – The quantity $(1/N_{ev})(dN/dx_R^*)$ is plotted *vs.* $(q_{tot}^{had})^2$, for different ranges of x_R^*.

([20]) M. Basile, G. Bonvicini, G. Cara Romeo, L. Cifarelli, A. Contin, M. Curatolo, G. D'Alí, C. Del Papa, B. Esposito, P. Giusti, T. Massam, R. Nania, F. Palmonari, G. Sartorelli, G. Susinno, L. Votano and A. Zichichi: *Universality features in* (pp), (e^+e^-) *and deep inelastic scattering processes*, preprint CERN-EP/83-116 (1983), submitted to *Nuovo Cimento*.

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:

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

The values of the parameter C *vs.* x_R^* are reported in fig. 2. The values for the same parameter C, obtained in (e^+e^-) events at PETRA (1), are also reported for comparison.

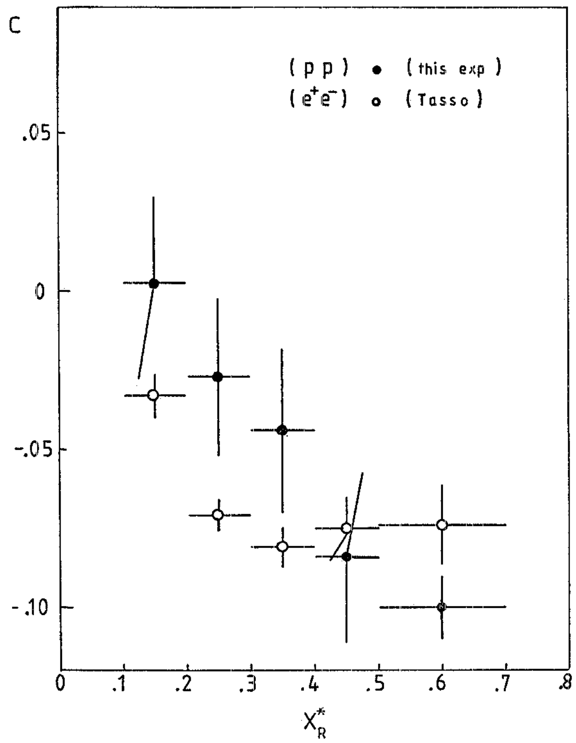

Fig. 2. – The values of the coefficient C *vs.* x_R^*, as measured in (pp) interactions (this experiment) and in (e^+e^-) annihilation.

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.

M. BASILE, *et al.*
22 Ottobre 1983
Lettere al Nuovo Cimento
Serie 2, Vol. 38, pag. 289-292