ISTITUTO NAZIONALE DI FISICA NUCLEARE
Laboratori Nazionali di Frascati

LNF-83/27

M. Basile et al. : EXPERIMENTAL PROOF THAT THE LEADING PROTONS ARE NOT CORRELATED

Estratto da:
Nuovo Cimento 73A, 329 (1983)

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

IL NUOVO CIMENTO VOL. 73 A, N. 4 21 Febbraio 1983

# Experimental Proof that the Leading Protons are not Correlated.

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, Italia*
*Istituto Nazionale di Fisica Nucleare - Sezione di Bologna, Italia*
*Istituto di Fisica dell'Università - Perugia, Italia*

(ricevuto il 19 Novembre 1982)

**Summary.** — The correlations between the two « leading » protons in the $x$-range $0.4 \leqslant x < 0.9$ are measured to be below $\pm 1\%$, at the highest ISR energy.

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

In previous papers we have reported [1-15] on the relevance of studying proton-proton interactions with the technique of subtracting the « leading »-proton effects.

(1) 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).
(2) 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).
(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. VA-

Here we report on the study of the correlations between the two leading protons, a study which is relevant in that it is the first step that has to be taken before trying to understand if there are similarities among the correlations

---

LENTI and A. ZICHICHI: *Phys. Lett. B*, **95**, 311 (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: *Lett. Nuovo Cimento*, **29**, 491 (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, M. SPINETTI, S. SUSINNO, G. VALENTI and A. ZICHICHI: *Phys. Lett. B*, **99**, 247 (1981).

(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: *Lett. Nuovo Cimento*, **30**, 389 (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, L. VOTANO and A. ZICHICHI: *Lett. Nuovo Cimento*, **31**, 273 (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, V. ROSSI, G. SARTORELLI, M. SPINETTI, G. SUSINNO, G. VALENTI, L. VOTANO and A. ZICHICHI: *Nuovo Cimento A*, **65**, 400 (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**, 414 (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: *Lett. Nuovo Cimento*, **32**, 210 (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: *Nuovo Cimento A*, **66**, 129 (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, G. SARTORELLI, M. SPINETTI, G. SUSINNO, G. VALENTI, L. VOTANO and A. ZICHICHI: *Lett. Nuovo Cimento*, **32**, 321 (1981).

(13) 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).

(14) 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).

(15) M. BASILE, 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: preprint CERN-EP/81-147 (1981).

existing in multiparticle hadronic systems produced in ($e^+e^-$) annihilations and in (pp) interactions ([16]).

The correlations studied in the (pp) channels have so far ([16]) been made without the subtraction of the leading protons. Nevertheless, conclusions have been proposed ([16]) in terms of differences existing between (pp) and ($e^+e^-$) cases.

We have reported in previous papers ([1-15]) that the « leading »-particle effect is a basic feature of hadronic physics. We, therefore, believe that the first step in trying to understand the comparison between (pp) and ($e^+e^-$) is to start with the key phenomenon that governs the multiparticle hadronic systems produced in (pp) interactions, *i.e.* the study of the correlation between the two leading protons. In fact the basic quantity which, according to our studies ([1-15]), governs the multiparticle production process in (pp) interaction is the total effective hadronic energy available. This quantity is obtained by subtracting, from the total invariant four-momentum of the initial state, the total invariant four-momentum carried out by the two leading protons.

Let us recall the main points of this argument. Given two protons in the initial state, let $q_1^{\text{inc}}$ and $q_2^{\text{inc}}$ be their four-momenta. The total invariant four-momentum of the two colliding protons is

$$q_{\text{total}}^{\text{inc}} = q_1^{\text{inc}} + q_2^{\text{inc}}, \tag{1}$$

and the invariant mass of the system is

$$\sqrt{(q_{\text{total}}^{\text{inc}})^2} = 2E_{1,2}^{\text{inc}}, \tag{2}$$

where $E_1^{\text{inc}} = E_2^{\text{inc}} = E^{\text{beam}}$ in the (pp) c.m. system. In the standard notation

$$\sqrt{(q_{\text{total}}^{\text{inc}})^2} = (\sqrt{s})_{\text{pp}}. \tag{3}$$

Let $q_1^{\text{leading}}$ and $q_2^{\text{leading}}$ be the invariant four-momenta of the two leading protons in the final state. The total invariant four-momentum carried away by the two leading protons will be

$$q_1^{\text{leading}} + q_2^{\text{leading}} = q_{\text{total}}^{\text{leading}}. \tag{4}$$

This is the basic quantity to subtract from $q_{\text{total}}^{\text{inc}}$ in order to know the effective total hadronic energy available for particle production in a (pp) collision:

$$\sqrt{(q_{\text{total}}^{\text{had}})^2} = \sqrt{(q_{\text{total}}^{\text{inc}} - q_{\text{total}}^{\text{leading}})^2}. \tag{5}$$

---

([16]) For a review on and references to the original work, see W. KOCH: *Proceedings of the XIII International Symposium on Multiparticle Dynamics* (Volendam, 1982), to be published.

The main point of the present analysis is to study if the two leading protons are correlated.

The data used in the present analysis have been taken at the CERN Intersecting Storage Rings (ISR) using a system of multiwire proportional chambers in a large-volume magnetic field ([1-15]). The reaction studied was

$$p_1^{inc}+p_2^{inc}\to p_1^{leading}+p_2^{leading}+\text{anything}\,, \tag{6}$$

where $p_{1,2}^{inc}$ indicate the two incident protons, and $p_{1,2}^{leading}$ the two leading protons. The data taking was performed by using unbiased events in order to have a set of genuine inclusive (pp) interactions (reaction (6)).

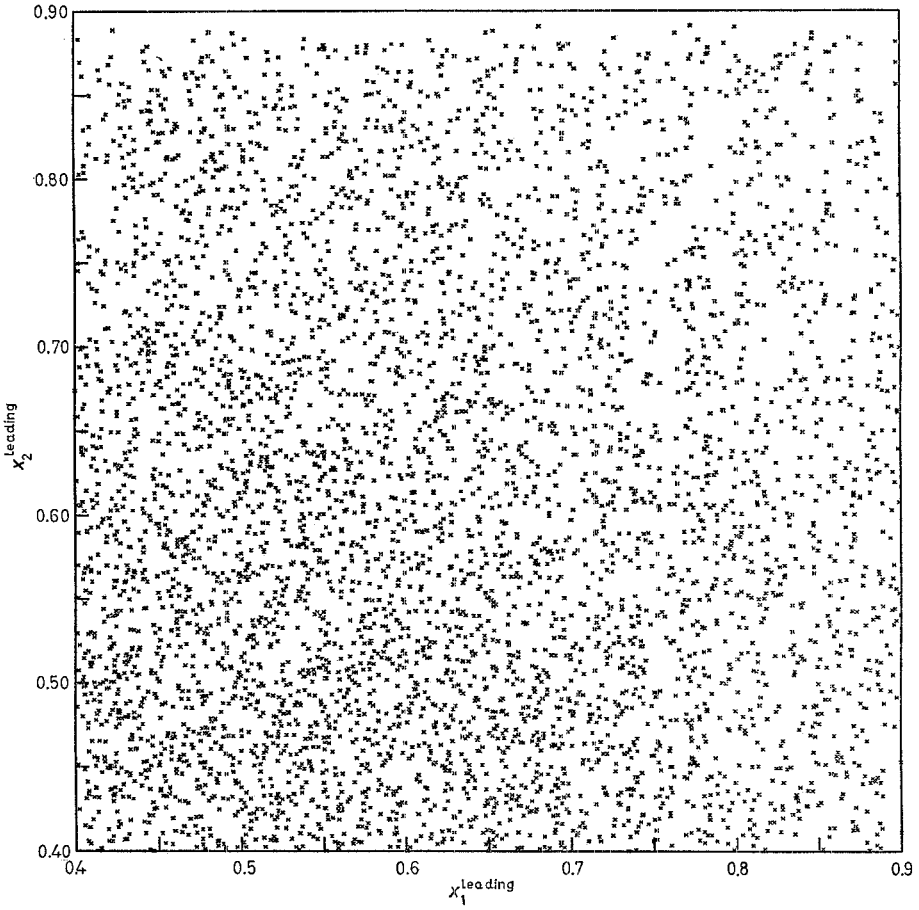


Fig. 1. – Scatter plot of the fractional energies of the two leading protons, $x_{1,2}^{leading}=E_{1,2}^{leading}/E_{1,2}^{inc}$, in the range $0.4\leqslant x_{1\,2}^{leading}<0.9$, at the (pp) c.m. energy $(\sqrt{s})_{pp}=62$ GeV.

The results are presented in fig. 1, as a scatter plot in terms of the quantities $x_{1,2}^{\text{leading}} = E_{1,2}^{\text{leading}}/E_{1,2}^{\text{inc}}$. Each point in the $(x_1^{\text{leading}}, x_2^{\text{leading}})$ scatter plot represents an event. The uniformity of the distribution of the events in the scatter plot is the proof that there is no correlation between the two leading

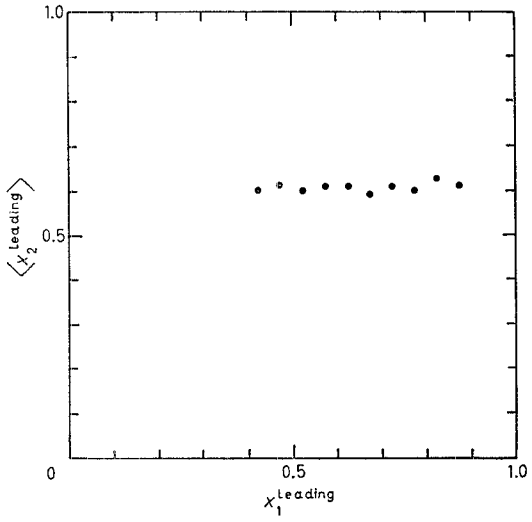


Fig. 2. – The average value $\langle x_2^{\text{leading}} \rangle$ for fixed $x_1^{\text{leading}}$ is plotted *vs.* $x_1^{\text{leading}}$. This is obtained from the scatter plot of fig. 1.

protons. A more quantitative analysis of the same data is reported in fig. 2, where the average value $\langle x_2^{\text{leading}} \rangle$ at fixed $x_1$

$$[\langle x_2^{\text{leading}} \rangle]_{x_1 \text{ fixed}} = \left[ \frac{\sum_{i=1}^{N} x_2^{\text{leading}}}{N} \right]_{x_1 \text{ fixed}}$$

is plotted *vs.* $x_1$. The data correspond to a total of 4841 (pp) events at $(\sqrt{s})_{pp} = 62$ GeV.

The basic features of the data presented in fig. 2 are:

i) All $\langle x_2^{\text{leading}} \rangle$ values are known with a precision which ranges from 1 % to 1.5 %. Within their statistical error, all $\langle x_2^{\text{leading}} \rangle$ values are compatible with a constant value, their average.

ii) The maximum slope, compatible with the uncertainty of all data, corresponds to a maximum variation in $\langle x_2^{\text{leading}} \rangle$ of $\pm 1$ %.

Any correlation between the two leading protons, should it be there, must be so small that it does not produce effects above the quoted $\pm 1$ % level.

The fact that the two leading protons were not correlated is a result that

we had already obtained during the very early stage of our studies. It has been presented at many seminars and conferences but never published, because, in our new way of analysing multiparticle hadronic systems produced in (pp) collisions, the absence of a correlation between the two leading protons was the starting point. If strong correlations had been present between the leading protons, our analysis would have lost its very simple nature and would have needed involved and complicated arguments.

The results of our studies on two-body correlations [17] and on charge correlations [18] among the particles produced in (pp) interactions, once the « leading protons » have been subtracted, will be reported elsewhere [17,18].

* * *

We thank Prof. G. WOLF for having suggested to us the publication of the leading-proton correlation studies. We were not aware of the fact that this basic feature of our new way of analysing multiparticle hadronic systems produced in (pp) interactions was not so well known.

---

[17] 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: *Comparison of two-particle correlations in* (pp) *interactions and* ($e^+e^-$) *annihilation*, in preparation.

[18] 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: *Charge correlation studies in* (pp) *compared with* ($e^+e^-$), in preparation.

● RIASSUNTO

Nelle interazioni protone-protone alla piú alta energia degli ISR, la correlazione in $x$ tra i due protoni « leading » misurata nell'intervallo $0.4 \leqslant x \leqslant 0.9$ è stata trovata inferiore a $\pm 1\%$.

Резюме не получено.