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EXPERIMENTAL PROOF THAT THE LEADING PROTONS ARE NOT CORRELATED

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ABSTRACT

The correlations between the two "leading" protons in the x-range $0.4 \le x < 0.9$ are measured to be below ±1%, at the highest ISR energy.

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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.

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 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^{inc} and q_2^{inc} be their four-momenta. The total invariant four-momentum of the two colliding protons is

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

and the invariant mass of the system is

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

where $E_1^{inc} = E_2^{inc} = E^{beam}$ in the (pp) c.m. system. In the standard notation $\sqrt{\left(q_{total}^{inc}\right)^2} = (\sqrt{s})_{pp}$. Let $q_1^{leading}$ and $q_2^{leading}$ 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

$$q_1^{leading} + q_2^{leading} = q_{total}^{leading} . \tag{3}$$

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

$$\sqrt{\left(q_{total}^{had}\right)^2} = \sqrt{\left(q_{total}^{inc} - q_{total}^{leading}\right)^2} . \tag{4}$$

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

The set of 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

$$p_1^{inc} + p_2^{inc} \to p_1^{leading} + p_2^{leading} + \text{anything} , \tag{5}$$

where $p_{1,2}^{inc}$ indicate the two incident protons, and $p_{1,2}^{leading}$ the two leading protons. The data-taking was performed using unbiased events in order to have a set of genuine inclusive (pp) interactions [reaction (5)].

The results are presented in Fig. 1, as a scatter plot in terms of the quantities $x_{1,2}^{leading} = E_{1,2}^{leading}/E_{1,2}^{inc}$. Each point in the $\left(x_1^{leading}, x_2^{leading}\right)$ 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 protons. A more quantitative analysis of the same data is reported in Fig. 2, where in the abscissa a range of $x_1^{leading}$ values is shown, for example $0.5 \leq$ $\leq x_1^{leading} < 0.55$. In the ordinate, the value of the average quantity is reported:

$$\left[\left\langle x_2^{leading}\right\rangle\right]_{0.5 \leq x_1 < 0.55} = \left[\frac{\sum_{i=1}^{N} x_2^{leading}}{N}\right]_{0.5 \leq x_1 < 0.55}$$

The data correspond to a total of 4,841 (pp) events at $(\sqrt{s})_{pp} = 62$ GeV.

In principle there could be many ways in which a correlation could show up between two particles in a given multibody process.

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 ±1%.

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 a key feature. If strong correlations had been present in the leading protons, our analysis would have been on weak physical grounds.

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 Professor 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 much known.

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Figure captions

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 $0.4 \leq x_{1,2}^{leading} < 0.9$, at the (pp) c.m. energy $(\sqrt{s})_{pp} = 62$ GeV.

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

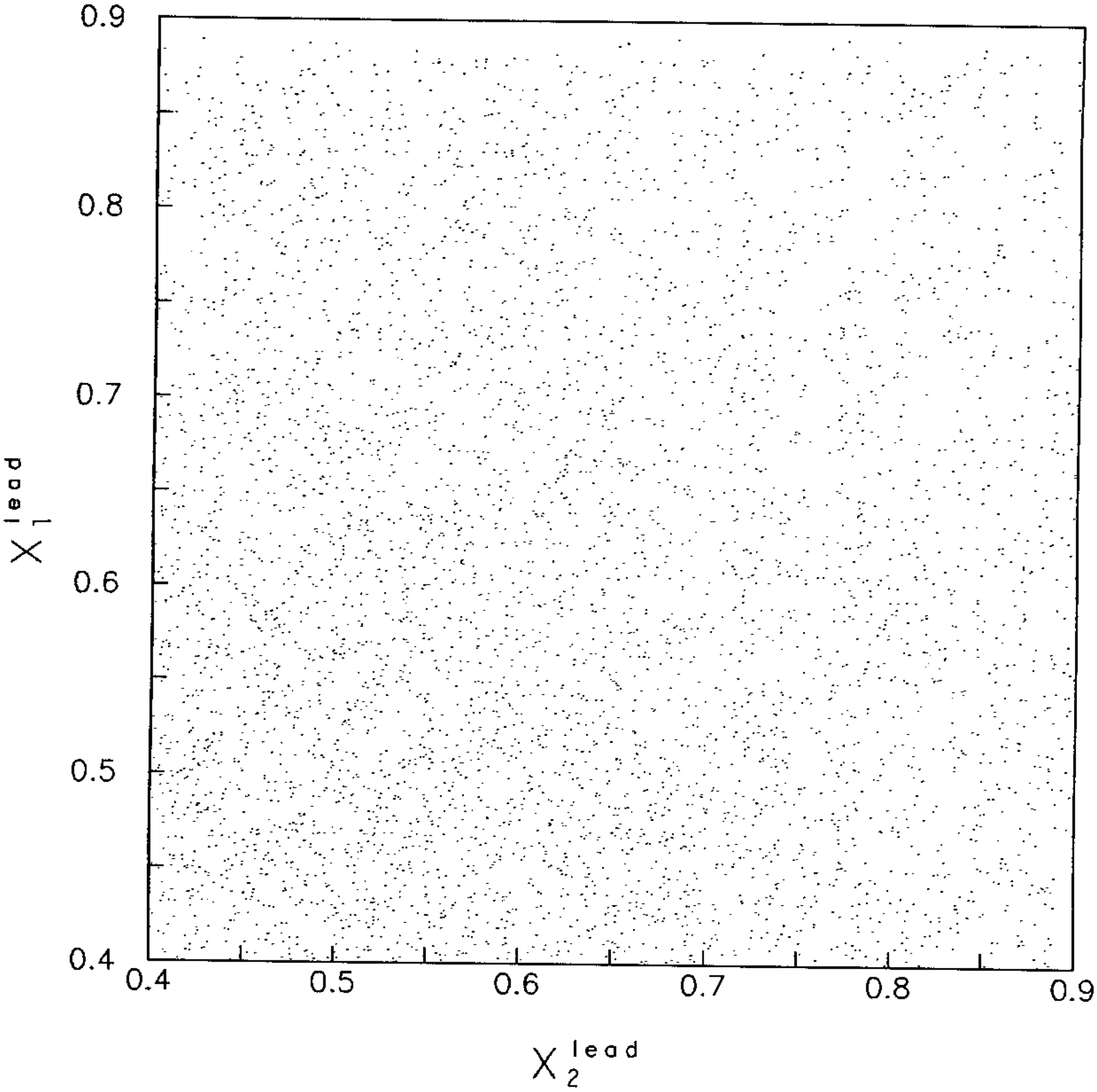

Fig. 1

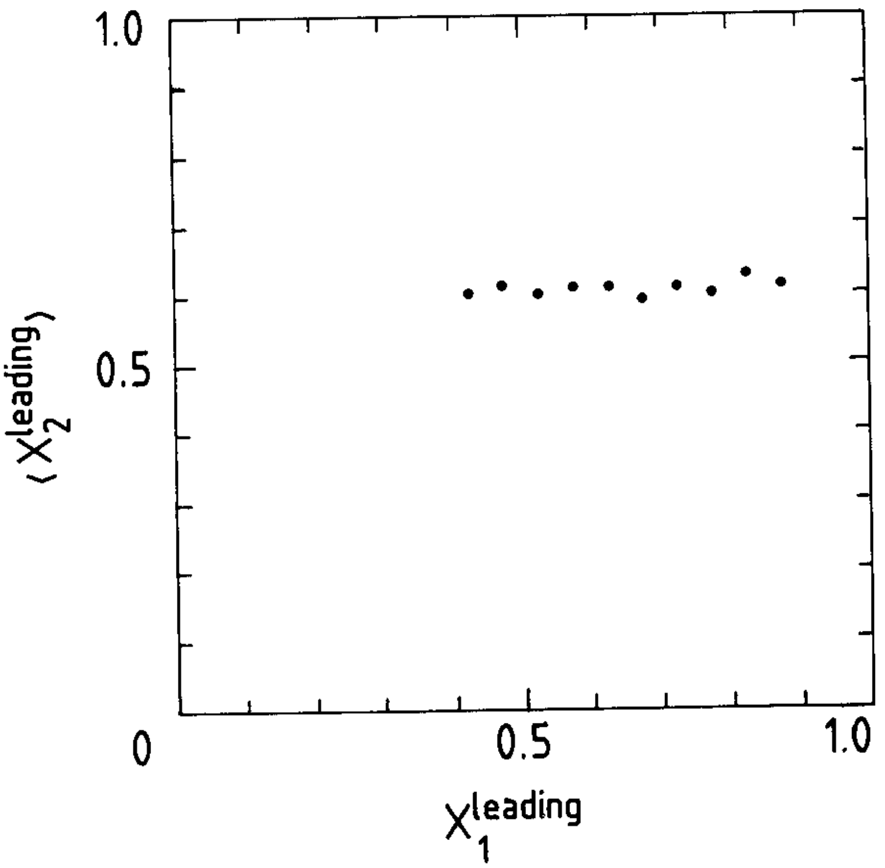

Fig. 2