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EVIDENCE FOR THE SAME INCLUSIVE FRACTIONAL ENERGY DISTRIBUTIONS
IN SOFT (pp) INTERACTIONS AND IN (μ p) DEEP INELASTIC SCATTERING

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ABSTRACT

High-energy soft (pp) interactions are analysed exactly as the (μ p) deep-inelastic scattering (DIS) processes. The distributions of the inclusive fractional energy, z , are measured. The results are compared with (μ p) DIS data: a remarkable agreement is observed.

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In a series of papers^{1,16)} we have reported the results of a new method to study high energy soft-(pp)-interactions. The method is based on the subtraction of the leading proton effects.

An impressive series of similarities in the properties of the multiparticle systems produced in (pp) reactions and in (e^+e^-) annihilations was found. The success of this new method in comparing (pp) and (e^+e^-) physics, convinced the authors to extend it to another domain of physics: the deep inelastic scattering (DIS) processes¹⁷⁻²⁰⁾.

In this case, only one of the two leading protons needs to be subtracted, in order to allow a correct comparison between (pp) and (DIS) data. The first quantity investigated was the average charged-particle multiplicity¹⁷⁻²⁰⁾. Once again a striking similarity was found between the values of $\langle n_{ch} \rangle$ measured in DIS^{19,20)} and in (pp)^{17,18)}.

It is very interesting to see if other similarities, in addition to the mean charged-particle multiplicities, exist between (pp) interactions and DIS processes.

Purpose of this paper is to report on the distributions of the fractional energy z of the charged hadrons produced in (pp) interactions at high energy, but low p_T , and to compare the results with those measured in deep inelastic muon-nucleon scattering²¹⁾.

As mentioned above the method is that already introduced in previous papers^{17,18)} in which we have reported on the comparison between the mean charged-particle multiplicities in (pp) interactions and in (νp) and ($\bar{\nu} p$) DIS processes^{19,20)}. The graphs describing schematically the (μp) and (pp) processes are illustrated in Figs. 1a,b.

Figures 2a,b show the basic kinematic variables. Notice that, as mentioned above, in order to compare (pp) with DIS processes, only one leading proton in the final state needs to be removed. The properties of the residual hadronic system are therefore studied as a function of the quantity:

$$W^2 = \left[(q_1^{\text{inc}} - q_1^{\text{leading}}) + q_2^{\text{inc}} \right]^2,$$

where q_1^{inc} , q_2^{inc} , and q_1^{leading} are the four-momenta of the two incident protons and of the observed leading proton. Notice that $\sqrt{W^2}$, defined above, is not the total hadronic energy available for particle production, a quantity which we call $\sqrt{(q_{\text{total}}^{\text{had}})^2}$, or $m_{1,2}$, in previous papers^{1,16}) where (pp) were compared with (e^+e^-) data. In fact $\sqrt{W^2}$ contains one leading proton; on the contrary, the total hadronic energy available for particle production, $\sqrt{(q_{\text{total}}^{\text{had}})^2}$, is calculated by subtracting both the leading protons, i.e.

$$\sqrt{(q_{\text{total}}^{\text{had}})^2} = \sqrt{(q_1^{\text{inc}} - q_1^{\text{leading}} + q_2^{\text{inc}} - q_2^{\text{leading}})^2}$$

where q_1^{inc} , q_2^{inc} , q_1^{leading} and q_2^{leading} are the four-momenta of the two incident protons and of the two leading protons. The choice of the quantity W is made only in order to follow the same DIS formalism.

The fractional energy of the hadrons produced in DIS processes is defined as

$$z = \frac{q_h \cdot q_p}{q \cdot q_p}$$

where q is the four-momentum transferred from the leptonic to the hadronic vertex, q_p and q_h are the four-momenta of the target proton and of a final state hadron, respectively. In the (pp) case we have (see Figs. 2 a,b)

$$z = \frac{q_h \cdot q_2^{\text{inc}}}{(q_1^{\text{inc}} - q_1^{\text{leading}}) \cdot q_2^{\text{inc}}}$$

where q_1^{inc} , q_2^{inc} and q_1^{leading} are the four-momenta of the two incident protons and of the observed leading proton; q_h is the four-momentum of the final state hadron, whose energy distribution is being measured.

The experiment was performed at the CERN Intersecting Storage Rings (ISR) using the Split-Field Magnet (SFM) facility. A detailed description of the apparatus can be found elsewhere²²).

The results reported here were obtained from 2813 events at $(\sqrt{s})_{pp} = 30$ GeV, selected from a sample of "minimum bias" events, by requiring only one leading proton detected in the apparatus. For details concerning the definition of the leading proton, the event selection, and other information, we refer the reader to previous papers^{1,14}).

The results are shown in Figs. 3 and 4, where the z -distributions for (pp) interactions are plotted and compared with the (μp) DIS data²¹). The inclusive distributions of the fractional energy, z , are given for two intervals of W^2 , with mean values of 140 GeV^2 (Fig. 3) and of 350 GeV^2 (Fig. 4).

The (pp) and (μp) data are in very good agreement. This shows that, not only the average charged multiplicities, but also the distributions of the inclusive fractional energy, z , of the multiparticle hadronic systems produced in high energy, but low p_T , (pp) interactions, do agree remarkably well with the results obtained in deep-inelastic scattering processes, if the (pp) data are analysed exactly as the DIS data, i.e. including a leading proton in the multiparticle hadronic system produced in the final state.

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Figure captions

- Fig. 1 : Schematic diagrams of: a) $\mu p \rightarrow \mu H$, and b) $pp \rightarrow pH$ processes. The total hadronic final state is indicated with H.
- Fig. 2 : Kinematic diagrams of: a) $\mu p \rightarrow \mu H$, and b) $pp \rightarrow pH$ processes.
- Fig. 3 : Inclusive distribution of the fractional energy, z , for pp reactions in the energy interval $81 \leq W^2 \leq 225 \text{ GeV}^2$, compared with the data from μp reactions at $\langle W^2 \rangle = 140 \text{ GeV}^2$.
- Fig. 4 : Inclusive distribution of the fractional energy, z , for pp reactions in the energy interval $225 \leq W^2 \leq 529 \text{ GeV}^2$, compared with the data from μp reactions at $\langle W^2 \rangle = 350 \text{ GeV}^2$.

Fig. 1

Fig. 2

Fig. 3

Fig. 4