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THE METHOD OF REMOVING THE LEADING PROTONS IN THE STUDY OF HIGH-ENERGY (pp) REACTIONS, COMPARED WITH THE STANDARD ANALYSIS

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ABSTRACT

The method of removing the leading protons in order to study the properties of multiparticle systems produced in (pp) interactions is compared, in a direct way, with the standard method.

The experimental results show that the remarkable agreement between (pp) interactions and (e^+e^-) annihilations, found by removing the leading protons, is lost if the standard analysis is adopted. This shows the validity and the relevance of our method of subtracting the leading proton effects in order to understand the properties of multiparticle systems produced in strong interactions.

The experiment has been performed using two values of the (pp) c.m. energy, $(\sqrt{s})_{pp}$ = 30 and 62 GeV.

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1. INTRODUCTION

The method[1] of removing the leading proton effects, in the study of the multiparticle systems produced in (pp) interactions, has provided a series of remarkable similarities[1-7] with the simple and well-understood multiparticle production mechanism of (e^+e^-) annihilation.

The purpose of the present paper is to present a straightforward comparison of our new method[1] with the standard one. The latter method is based on the notion that the energy in the (pp) c.m. system, i.e. $\sqrt{s}$, is the basic parameter which characterizes the properties of our event. The new method[1] is based on the notion that the basic parameter in a (pp) interaction is the effective hadronic energy available for particle production. This is obtained taking into account the quadrimomentum carried by the leading protons.

2. THE EXPERIMENTAL APPARATUS AND DATA-TAKING

The experiment was performed at the CERN Intersecting Storage Rings (ISR) using (pp) interactions at two c.m. energies, $(\sqrt{s})_{pp} = 30$ GeV and $(\sqrt{s})_{pp} = 62$ GeV. The apparatus consisted mainly of a large-volume magnetic field, the so-called Split-Field Magnet (SFM), coupled to a powerful system of multiwire proportional chambers (MWPCs). A description of the apparatus has been given elsewhere[8]. The set-up was used in the simplest possible mode, i.e. the "minimum" bias trigger[1-7]. For details on data-taking we refer the reader to our previous papers[1-7].

3. DATA ANALYSIS AND RESULTS

Two sets of data have been taken at two c.m. energies: $(\sqrt{s})_{pp} = 30$ GeV and $(\sqrt{s})_{pp} = 62$ GeV.

3.1 Data at $(\sqrt{s})_{pp} = 30$ GeV

The number of "minimum bias" events at $(\sqrt{s})_{pp} = 30$ GeV was 6473. These events have been analysed in the standard way, i.e. the fractional momentum of a particle, produced in a (pp) interaction, has been expressed by the standard variable

$$x_R = \frac{2|\vec{p}|}{\sqrt{s}} , \qquad (1)$$

where $|\vec{p}|$ is the modulus of the momentum of that particle.

In order to avoid any contamination from the unidentified protons, the inclusive distribution has been done using only negative particles. This is in fact the safest way to avoid a leakage of protons from the initial to the final state.

The inclusive distribution for negative particles is

$$\frac{1}{N_{ev}} \frac{dN(^-)}{dx_R} , \qquad (2)$$

where N_{ev} is the number of events and $dN(^-)$ is the number of negative particles in the interval dx_R. The data are reported in Fig. 1. This distribution has been compared with one half of the distribution for charged particles produced in (e^+e^-) annihilation, i.e.

$$\frac{1}{2} \frac{1}{\sigma} \frac{d\sigma(e^+e^- \to h^\pm + \text{anything})}{dx_R} . \qquad (3)$$

The factor ½ is there because only one sign of charge is considered. The (e^+e^-) data must, of course, be taken at the same c.m. energy, i.e. $(\sqrt{s})_{e^+e^-} = 27.4\text{-}31.6$ GeV. The (e^+e^-) data[9], reported in terms of

$$(s)_{e^+e^-} \frac{d\sigma}{dx_R}$$

have been transformed into

$$\frac{1}{\sigma} \frac{d\sigma}{dx_R}$$

using for the ratio R the value[9]

$$R = \frac{\sigma(e^+e^-) \to \text{hadrons})}{\sigma(e^+e^- \to \mu^+\mu^-)} = 4 .$$

3.2 Data at $(\sqrt{s})_{pp} = 62$ GeV

The number of "minimum bias" events at $(\sqrt{s})_{pp} = 62$ GeV was 62,270. The analysis of these data has been done using the method of removing the leading protons. The method has already been described in previous publications[1-7], where also the details about the overall procedure concerning event selection, track selection, and corrections for detection efficiencies can be found.

The basic quantity, in this method of analysis, is the effective hadronic energy available for multiparticle production, E_{had}. If we call $E_{leading}$ the energy of the leading proton in one hemisphere of the (pp) event, the quantity E_{had} is given by

$$E_{had} = \frac{(\sqrt{s})_{pp}}{2} - E_{leading} . \tag{4}$$

The fractional momentum variable is now

$$x_R^* = \frac{|\vec{p}|}{E_{had}} . \tag{5}$$

The inclusive distribution for negative particles,

$$\frac{2}{N_{ev}} \frac{dN(^-)}{dx_R^*} , \tag{6}$$

is determined in the energy range $2E_{had}$ = 28–32 GeV. This is the value required in order to compare (pp) and (e^+e^-) data at equivalent energies. In this effective hadronic energy range the number of (pp) events is 1471. The factor of two arises because the analysis is made in the hemisphere where we can identify the "leading" proton, and it is a trivial normalization factor to the full event.

The results (see Fig. 1) are compared with the same distribution,

$$\frac{1}{2} \frac{1}{\sigma} \frac{d\sigma}{dx_R} , \tag{7}$$

from (e^+e^-) at $(\sqrt{s})_{e^+e^-}$ = 27.4–31.6 GeV, already used to compare the $(\sqrt{s})_{pp}$ = 30 GeV (pp) data.

4. CONCLUSIONS

The results of the inclusive fractional momentum distribution, obtained using the standard method and our new method of analysis, are reported in Fig. 1 together with the (e^+e^-) data.

The standard method of analysis, based on the c.m. energy in the (pp) system, $(\sqrt{s})_{pp}$, produces an inclusive fractional momentum distribution which clearly differs from the (e^+e^-) data.

The new method of analysis, based on the effective hadronic energy available for multiparticle production, E_{had}, shows a remarkable agreement with (e^+e^-) data, at $(\sqrt{s})_{e^+e^-} = 2E_{had}$. This is a direct proof of the relevance and validity of the method of subtracting the leading proton effects in (pp) interactions.

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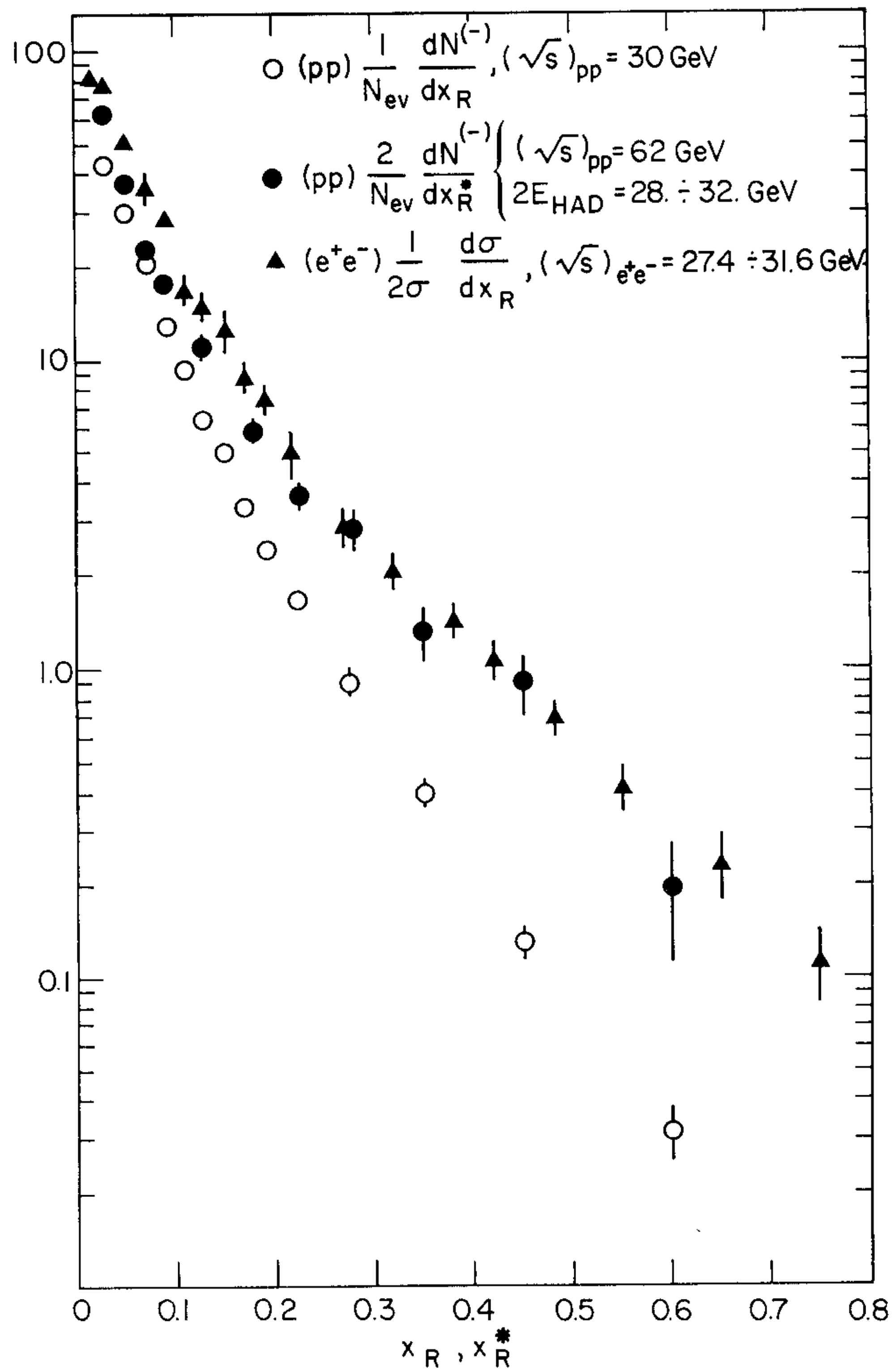
Figure caption

Fig. 1 : The inclusive fractional momentum distributions of negative particles, for (pp) interactions using the standard analysis at $(\sqrt{s})_{pp} = 30$ GeV white circles (○); using the method of removing the leading protons at $(\sqrt{s})_{pp} = 62$ GeV and $2E_{had} = 28-32$ GeV, black circles (●); the e^+e^- data at $(\sqrt{s})_{e^+e^-} = 27.4-31.6$ GeV, black triangles (▲).



100
10
1.0
0.1
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8
x_R, x_R^*
○ (pp) $\frac{1}{N_{ev}} \frac{dN^{(-)}}{dx_R}$, $(\sqrt{s})_{pp} = 30$ GeV
● (pp) $\frac{2}{N_{ev}} \frac{dN^{(-)}}{dx_R^*}$ $(\sqrt{s})_{pp} = 62$ GeV, $2E_{HAD} = 28. \div 32.$ GeV
▲ (e^+e^-) $\frac{1}{2\sigma} \frac{d\sigma}{dx_R}$, $(\sqrt{s})_{e^+e^-} = 27.4 \div 31.6$ GeV

Fig. 1