ISTITUTO NAZIONALE DI FISICA NUCLEARE
Laboratori Nazionali di Frascati

LNF-80/57

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Estratto da :
Nuovo Cimento 58A, 193 (1980)

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

IL NUOVO CIMENTO VOL. 58 A, N. 3 1 Agosto 1980

The Fractional Momentum Distribution in p-p Collisions Compared with e^+e^- Annihilation.

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(ricevuto il 27 Giugno 1980)

Summary. — The fractional momentum distribution for hadrons produced in p-p interactions at $\sqrt{s} = 62$ GeV has been studied in terms of the effective energy available for particle production, E_{had}, once the leading baryon energy has been subtracted. This has been done comparing the experimental data with a Monte Carlo prediction based on i) the inclusive x_F distributions of the protons produced in p-p collisions integrated over p_T, ii) the inclusive fractional momentum distribution of the hadrons produced in e^+e^-, iii) the average charged multiplicity $\langle n_{\text{ch}} \rangle$ as obtained in e^+e^-. The results show that our analysis in terms of the effective energy available for particle production in p-p interactions, E_{had}, can be extended to all ranges of available energies and can account for the inclusive fractional momentum particle production in p-p interactions without any special model, but in terms of the known properties of hadron production in e^+e^- annihilation.

We have recently reported [1] a striking similarity between p-p and e^+e^- processes. This new finding was based on a comparison of the momentum distribution of the hadrons produced in p-p reactions and the momentum distribution of the hadrons produced in e^+e^- annihilation. This result was obtained at $\sqrt{s} = 62$ GeV, using the Split Field Magnet (SFM) facility [2] of the CERN Intersecting Storage Rings (ISR).

Our results were based on the analysis of events selected from a sample of « minimum bias » events. The selection required the presence of a « leading » positive particle with a value of $x_F = 2p_L/\sqrt{s}$ greated than 0.4, where p_L is the longitudinal momentum of the particle and $\sqrt{s}$ is the total c.m.s. energy of the two incident protons.

The basic idea of our analysis is to take away the « leading » proton effects. This allows us to identify the correct hadronic energy available for particle production—a quantity which we call E_{had}, the energy to be used when making the comparison with e^+e^- data.

The momentum distribution of the hadrons (all assumed to be pions) produced in the same hemisphere as that of the « leading » proton was expressed in terms of the new fractional variable

$$x_R^* = p/E_{had}, \tag{1}$$

where p is the momentum of the produced particle.

This new variable takes into account the fact that the energy of the system of hadrons associated with the « leading » proton is reduced by the energy taken away by the proton itself. In fact, in terms of the old variables,

$$x_F^{proton} = 2p_L/\sqrt{s},$$

the above quantity (1) reads

$$x_R^* = 2p/[\sqrt{s}(1 - |x_F^{proton}|)].$$

For more details we refer the reader to ref. [1].

The purpose of the present paper is to examine whether the previous result, obtained with a sample of selected events, can be extended to the totality of p-p events produced in p-p interactions. The bulk of p-p collisions con-

(1) M. BASILE, G. CARA ROMEO, L. CIFARELLI, A. CONTIN, G. D'ALI, 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) 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).

tains many events where the fractional proton momentum reaches very low values. These low values are very interesting because they correspond to high hadronic energies E_{had}. For example, at $\sqrt{s} = 62$ GeV, when $x_F^{\text{proton}} \simeq 0.1$, $E_{\text{had}} \simeq 28$ GeV. If our new way of looking at p-p interactions is correct, this would correspond to studying particle production at an equivalent e^+e^- energy as high as 56 GeV.

Notice that the sample of « minimum bias » events is ten times larger than the sample of selected events used in ref. (1), if we no longer require the presence of a « leading proton ».

In the present analysis we compare the distribution of the standard fractional momentum of hadrons,

$$x_R = 2p/\sqrt{s}\,,$$

measured in our experiment, with the results of a Monte Carlo calculation.

This Monte Carlo calculation must obviously be based on the hypothesis that the mechanism of hadron production discovered in our previous work (1), using a sample of selected events with the « leading proton », can be extended to very low values of x_F. The basic inputs of the Monte Carlo were, therefore, the following:

i) The shape of the inclusive x_F distribution of the proton, obtained by integrating FNAL and ISR data (3) over p_T at various c.m.s. energies. This shape was fitted with an exponential and, following existing experimental evidence, it was assumed to be the same at our energy ($\sqrt{s} = 62$ GeV).

ii) The shape of the inclusive distribution of the fractional momentum of the hadrons produced in e^+e^- annihilation; as these distributions seem to scale (4), it was assumed that they had the same shape at all energies. As mentioned above, our data extend over the present PETRA energies. We have assumed that they scale up to the highest energy of our sample (*i.e.* $2E_{\text{had}} \simeq 62$ GeV).

iii) The average charged multiplicity $\langle n_{\text{ch}} \rangle$, as measured in e^+e^- annihilation (5). This gives the absolute weight to the inclusive momentum distributions at different energies. Here again we needed to extend the present data to higher energies. We have used the following formulae (4,5) as fits to

(3) J. W. Chapman, J. W. Cooper, N. Green, A. A. Seidl, J. C. Vander Velde, C. M. Bromberg, D. Cohen, T. Ferbel and P. Slattery: *Phys. Rev. Lett.*, **32**, 257 (1974); P. Capiluppi, G. Giacomelli, A. M. Rossi, G. Vannini and A. Bussière: *Nucl. Phys. B*, **70**, 1 (1974).

(4) TASSO Collaboration (R. Brandelik *et al.*): *Phys. Lett. B*, **89**, 418 (1980).

(5) G. Wolf: *Proceedings of the EPS International Conference on High-Energy Physics, Geneva, 1979*, Vol. **1** (Geneva, 1980), p. 220.

e^+e^- data:

$$\langle n_{ch}\rangle = 2 + 0.2 \ln(s) + 0.18 [\ln(s)]^2 , \tag{2}$$

$$\langle n_{ch}\rangle = 2.92 + 0.0029 \exp[2.85 \sqrt{\ln(s/\Lambda^2)}] , \tag{3}$$

with $\Lambda = 0.5$ GeV.

The Monte Carlo simulation was done by generating a proton according to the x_F distribution (point i) above). From the fractional momentum of the proton we get E_{had}. This gives the e^+e^- energy, $2E_{had} = E(e^+e^-)$, from which we get the hadron fractional momentum distribution, as discussed in point ii) above. Each hadron was then weighted with the appropriate average charged multiplicity, measured in e^+e^- at the same $E(e^+e^-) = 2E_{had}$, as discussed in point iii) above.

All this gives the fractional momentum distribution of hadrons expressed in terms of x_R^*. The Monte Carlo finally works out the fractional momentum (or energy) distribution of hadrons produced in pp interactions at $\sqrt{s} = 62$ GeV, in terms of the standard variable

$$x_R = 2p/\sqrt{s} ,$$

by means of the relation

$$x_R = x_R^*(1 - |x_F^{proton}|) .$$

Figure 1 shows the results. The Monte Carlo predictions, as mentioned in point iii) above, are worked out by assuming two different fits to $\langle n_{ch}\rangle$ as a function of the $E(e^+e^-)$. The agreement, both in shape and in absolute value (charged multiplicity), shows that inclusive particle production in p-p interactions at high energy can be understood simply in terms of the known properties of hadron production in e^+e^- annihilation.

This confirms our previous finding [1] and extends its validity to the totality of p-p interactions, independently of the fact that a « leading » proton must have $x_F > 0.4$. The basic point of this agreement is that in a p-p interaction, once the energy associated with the primary baryon is removed, the rest of the events follows the same trend as that measured in e^+e^- annihilation. The capability of the Monte Carlo simulation to reproduce the data so well seems to indicate that we have really isolated the crucial point of the mechanism of particle production in p-p interactions, at least in so far as we limit ourselves to the class of « minimum bias events ». In other words, when two protons collide, the mechanism of particle production, in the low-p_T range, *i.e.* in the most likely case, shows characteristics very similar to those of the e^+e^- case, this similarity being at the $(20 \div 30)\,\%$ level.

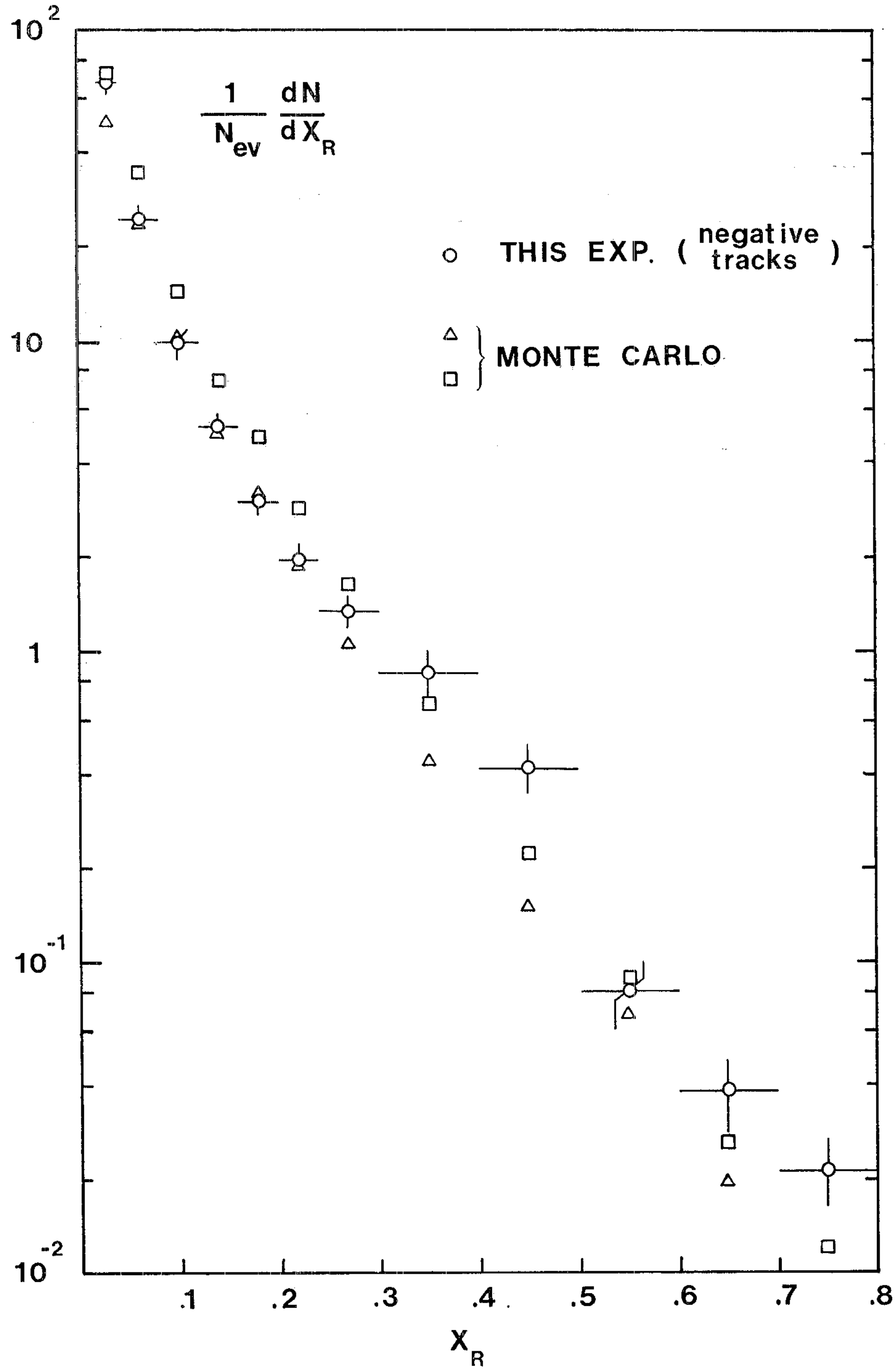

Fig. 1. – Inclusive fractional momentum distribution for hadrons produced in p-p interactions at $\sqrt{s} = 62$ GeV. ○ experimental data; △ and □ Monte Carlo predictions, using formulae (2) and (3) of the text, respectively, as fits to $\langle n_{ch} \rangle$ *vs.* $E(e^+e^-)$.

● RIASSUNTO

La distribuzione inclusiva di particelle prodotte nell'urto p-p a $\sqrt{s} = 62$ GeV è stata studiata col metodo dell'energia effettivamente utilizzabile per produzione di particelle, E_{had}, una volta che gli effetti del barione « leading » sono stati sottratti. Questo è stato fatto confrontando i dati sperimentali con un Montecarlo basato su i) la distribuzione inclusiva di x_F dei protoni prodotti negli urti p-p, integrata su p_T; ii) la distribuzione inclusiva di adroni prodotti in e^+e^-; iii) la molteplicità carica misurata in e^+e^-. I risultati dimostrano che la nostra analisi, in funzione dell'energia E_{had}, effettivamente utilizzabile per produzione di particelle nelle interazioni p-p, può essere estesa a tutti i valori di E_{had}. Detta analisi permette di interpretare le distribuzioni inclusive di particelle prodotte nell'urto p-p in funzione delle proprietà misurate nell'annichilazione e^+e^-, senza bisogno di particolari modelli *ad hoc*.

Резюме не получено.