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G. Bonvicini et al. : EVIDENCE FOR THE SAME INCLUSIVE FRACTIONAL-ENERGY DISTRIBUTIONS IN SOFT (pp) INTERACTIONS AND IN (μp) DEEP INELASTIC SCATTERING

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Evidence for the Same Inclusive Fractional-Energy Distributions in Soft (pp) Interactions and in (μp) Deep Inelastic Scattering.

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(ricevuto il 21 Marzo 1983)

PACS. 13.90. – Other topics in specific reactions and phenomenology of elementary particles.

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

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.

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(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. VALENTI 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,

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) processes [17-20].

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

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P. GIUSTI, T. MASSAM, R. NANIA, F. PALMONARI, G. SARTORELLI, M. SPINETTI, G. SUSINNO, G. VALENTI and A. ZICHICHI: *Phys. Lett. B*, **99**, 247 (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, 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).

[16] 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: *Nuovo Cimento*, **73**, 329 (1983).

[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, G. SUSINNO, L. VOTANO and A. ZICHICHI: *Lett. Nuovo Cimento*, **36**, 303 (1983).

[18] 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: *Lett. Nuovo Cimento*, **36**, 555 (1983).

[19] P. ALLEN, J. BLIETSCHAU, H. GRÄSSLER, D. LANSKE, R. SCHULTE, H. H. SEYFERT, K. BÖCKMANN, C. GEICH-GIMBEL, T. KOKOTT, B. NELLEN, R. PECH, H. SAARIKKO, P. BOSETTI, V. T. COCCONI, B. CONFORTO, A. GRANT, P. O. HULTH, G. KELLNER, D. R. O. MORRISON, R. ORAVA, L. PAPE, P. SCHMID, W. G. SCOTT, H. WACHSMUTH, M. ADERHOLZ, N. SCHMITZ, R. SETTLES, K. L. WERNHARD, W. WITTEK, R. BATLEY, R. GILES, P. GROSSMANN, R. MCGOW, G. MYATT, D. H. PERKINS, D. RADOJICIC, P. RENTON and B. SAITTA: *Nucl. Phys. B*, **181**, 385 (1981).

[20] M. DERRICK, P. GREGORY, F. LOPINTO, B. MUSGRAVE, J. SCHLERETH, P. SCHREINER, R. SINGER, S. J. BARISH, R. BROCK, A. ENGLER, T. KIKUCHI, R. W. KRAEMER, F. MESSING, B. J. STACEY, M. TABAK, V. E. BARNES, D. D. CARMONY, E. FERNANDEZ, A. F. GARFINKEL and A. T. LAASANEN: *Phys. Rev. D*, **24**, 1071 (1981).

investigated was the average charged-particle multiplicity ([17-20]). 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 scattering ([21]).

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 fig. 1*a*), *b*).

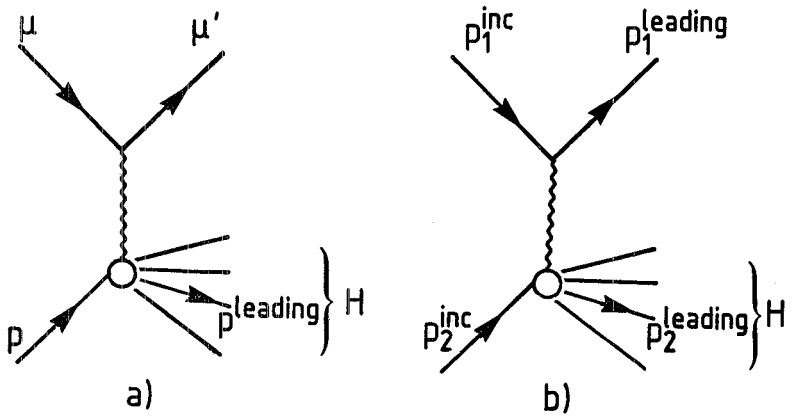

Fig. 1. – Schematic diagrams of: *a*) $\mu p \to \mu H$ and *b*) $pp \to pH$ processes. The total hadronic final state is indicated with H.

Figures 2*a*), *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

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

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 $\sqrt{(q_{total}^{had})^2}$, 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

([21]) J. J. AUBERT *et al.* (EUROPEAN MUON COLLABORATION): *Measurement of the Q^2, x and W^2 dependence of single-hadron production in deep inelastic muon scattering*, preprint CERN-EP/82-47, submitted to *Phys. Lett.*

particle production, $\sqrt{(q^{\mathrm{had}}_{\mathrm{total}})^2}$, is calculated by subtracting both the leading protons, *i.e.*

$$\sqrt{(q^{\mathrm{had}}_{\mathrm{total}})^2} = \sqrt{(q_1^{\mathrm{inc}} - q_1^{\mathrm{leading}} + q_2^{\mathrm{inc}} - q_2^{\mathrm{leading}})^2}\,,$$

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.

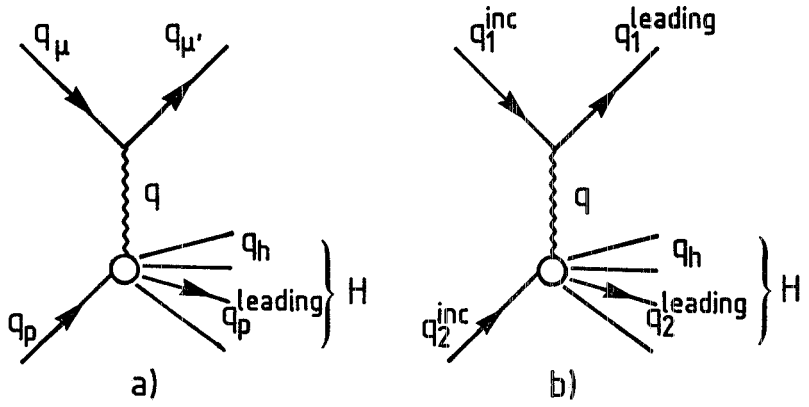

Fig. 2. – Kinematic diagrams of: *a*) $\mu p \to \mu H$ and *b*) $pp \to pH$ processes.

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

$$z = \frac{q_{\mathrm{h}} \cdot q_{\mathrm{p}}}{q \cdot q_{\mathrm{p}}}\,,$$

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 fig. 2*a*), *b*))

$$z = \frac{q_{\mathrm{h}} \cdot q_2^{\mathrm{inc}}}{(q_1^{\mathrm{inc}} - q_1^{\mathrm{leading}}) \cdot q_2^{\mathrm{inc}}}\,,$$

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 elsewhere ([22]).

([22]) 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).

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 fig. 3 and 4, where the z-distributions for (pp) interactions are plotted and compared with the (μp) DIS data [21]. 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).

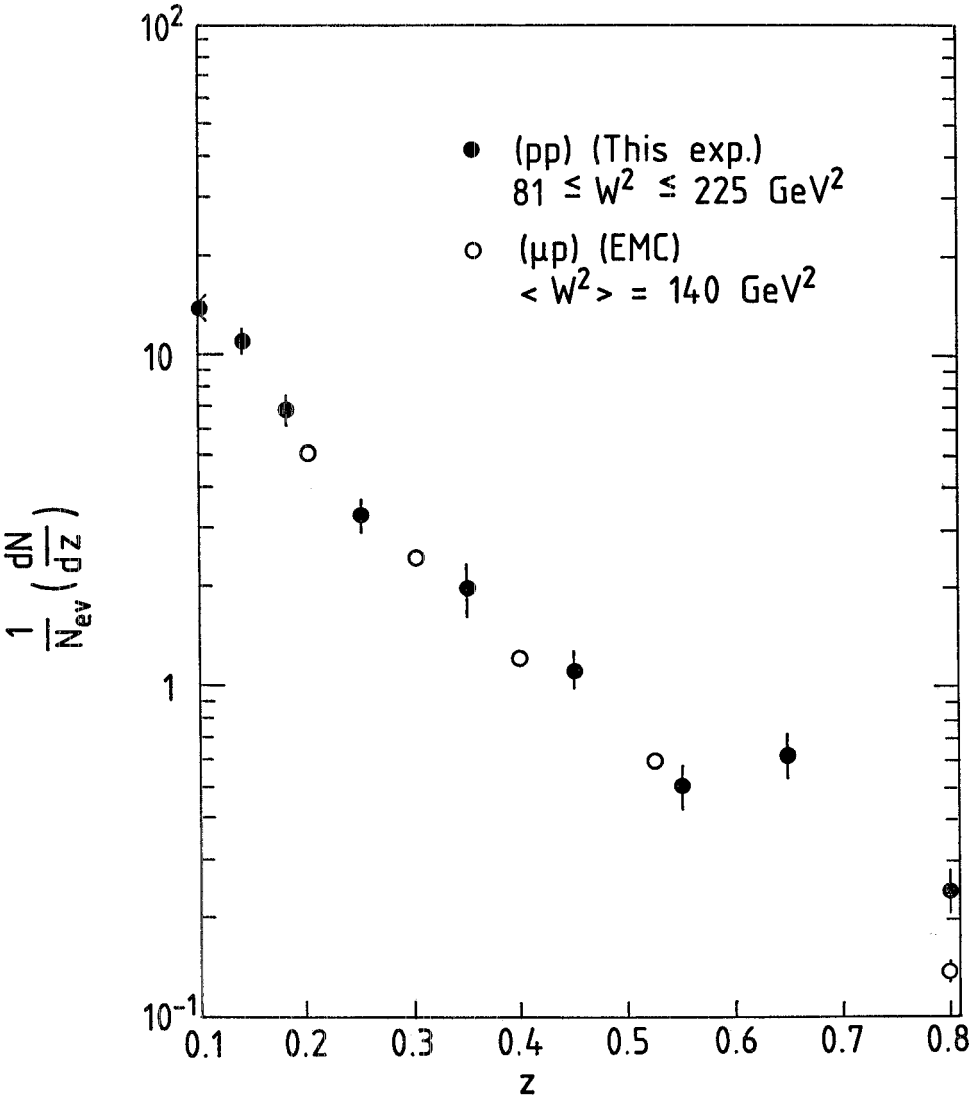

Fig. 3. – Inclusive distribution of the fractional energy, z, for pp reactions in the energy interval $81 \leqslant W^2 \leqslant 225$ (GeV)^2, compared with the data from μp reactions at $\langle W^2 \rangle = 140$ (GeV)^2.

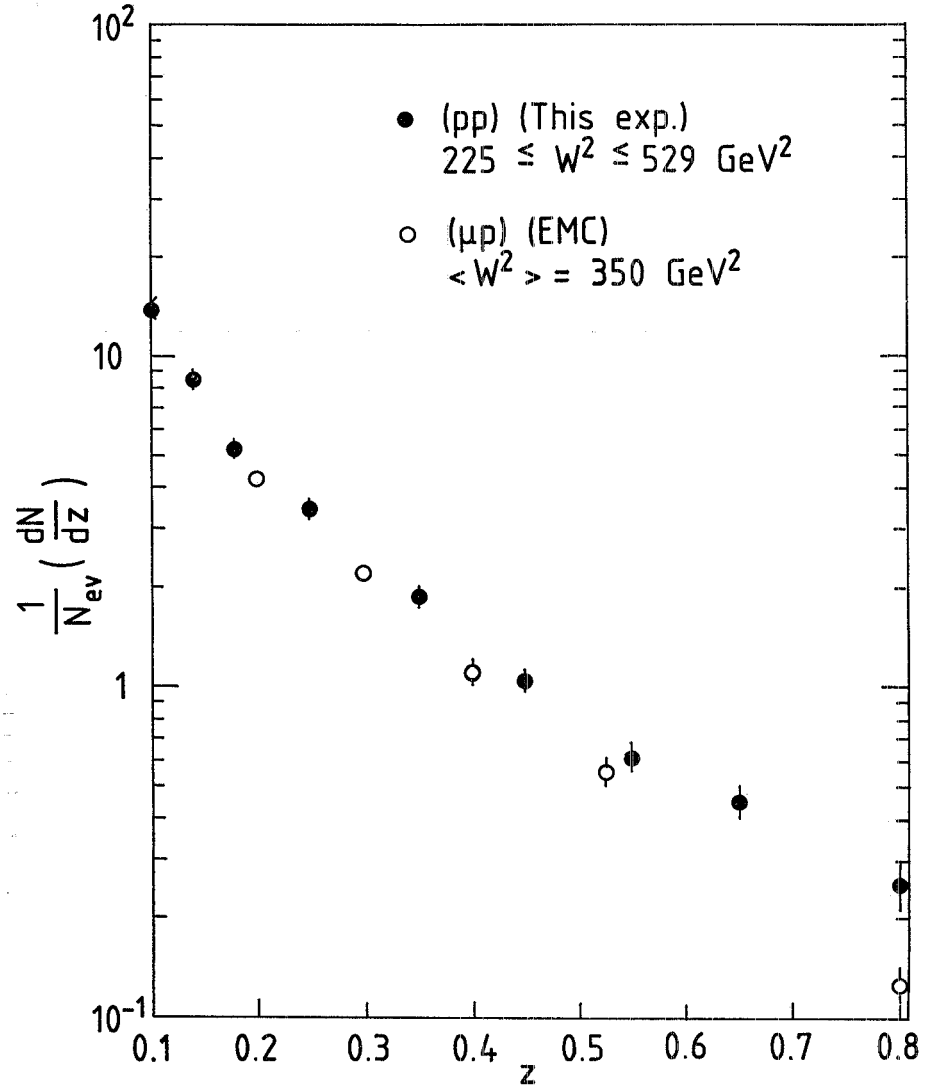

Fig. 4. – Inclusive distribution of the fractional energy, z, for pp reactions in the energy interval $225 \leqslant W^2 \leqslant 529$ (GeV)^2, compared with the data from μp reactions at $\langle W^2 \rangle = 350$ (GeV)^2.

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.