EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

CERN-EP/84-94
31 July 1984

SCALING IN THE CHARGED PARTICLE MULTIPLICITY DISTRIBUTIONS AT THE ISR AND COMPARISON WITH (e^+e^-) DATA.

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ABSTRACT

The distributions of the charged particle multiplicities at the ISR are studied in terms of the effective energy available for particle production in (pp) interactions.

These distributions are found to scale once the effective energy, obtained via the leading subtraction method, is used.

A comparison with the charged particle distributions measured in (e^+e^-) annihilation shows a clear difference.

This could be interpreted in terms of, gluon induced and quark induced jets; where the gluon induced jets are characterized by a wider multiplicity distribution with respect to quark induced jets.

(Submitted to Nuovo Cimento Letters)

Purpose of this paper is first to show that scale invariance$^{1)}$ is indeed present in the charged multiplicity distributions measured at ISR once the leading effects are taken into due account. Second to compare these results with (e^+e^-) data.

Let us start with the charged multiplicity distributions measured at the ISR. The first step is to analyse these distributions in terms of the effective energy available for particle production. In previous papers$^{2-6)}$ we have indicated this quantity as:

$$\sqrt{(q^{had}_{tot})^2} \equiv \text{Effective hadronic energy}$$

This is obtained from the quadrimomenta of the two incident protons at the ISR, once the two leading quadrimomenta of the outgoing protons are subtracted from the final state: i.e.

$$\sqrt{(q^{had}_{tot})^2} = \sqrt{[(q_1^{inc} - q_1^{leading}) + (q_2^{inc} - q_2^{leading})]^2}$$

Further details on the method can be found in our published papers, and, in particular in reference 4.

We have always emphasized all along our studies that the properties of the multiparticle systems produced in (pp) and (e^+e^-) can be understood once a firm basis for their comparison is established.

The firm basis is the subtraction of the leading effect and the use of the correct variables. This new method produces an impressive series of analogies$^{2-7)}$ between the properties of the multiparticle systems produced in (pp) interactions and in (e^+e^-) annihilation.

In a systematic search for possible differences which should show up between the properties of the multiparticle systems produced in (pp) interactions and in (e^+e^-) annihilation we have focused our attention into the charged multiplicity distributions.

Here, finally, an important difference shows up. As we will see later, the distributions measured in (pp) interactions are wider then those measured[8-11] in (e^+e^-) annihilation. The interesting aspect of this difference is that the mean values of these distributions are identical, within experimental errors, when measured in (pp)[5,6] interactions and in (e^+e^-)[10,12] annihilation, for the same values of effective energies available:

$$\sqrt{(q^{had}_{tot})^2} = (\sqrt{s})_{e^+e^-}$$

This is shown in Fig.1, which is an old result[6] of our studies reported here for the convenience of the reader.

Let us return to the charged multiplicity distributions measured in (pp) interactions. These distributions show a clear scaling behaviour if the effective energy available for particle production

$$\sqrt{(q^{had}_{tot})^2}$$

is used as the correct energy parameter.

We have chosen two ranges of $\sqrt{(q^{had}_{tot})^2}$ well separated, within our accessible range, in order to check the scaling behaviour, i.e.:

$$10 \le \sqrt{(q^{had}_{tot})^2} \le 15 \text{ GeV}$$

and

$$25 \le \sqrt{(q^{had}_{tot})^2} \le 30 \text{ GeV}$$

The results are shown in Fig.2, where the full curve is the best fit to all data. In the same Fig.2 we have reported the best fit to the charged multiplicity distributions measured in (e^+e^-) annihilation[8-11]. It should be noticed that the (e^+e^-) data scale with $(\sqrt{s})_{e^+e^-}$.

The important point to emphasize is that the charged multiplicity distributions measured in (pp) interactions are wider then those measured in (e^+e^-) annihilation.

This is the first clear difference that we have been able to find in the comparison of (pp) and (e^+e^-) data.

Let us close with a remark. The multiparticle systems produced in (e^+e^-) annihilation are produced by two (qq) induced jets. The multiparticle systems produced in (pp) interactions are probably due to a mixture of quark and gluon induced jets.

It is therefore possible that the wider distribution of particle multiplicity is a property which distinguishes gluon induced jets from quark induced jets.

REFERENCES

1) Z. Koba, H.B. Nielsen, P. Olesen, Nucl. Phys. B40 (1972) 317.

2) M. Basile et al., Phys. Lett. 99B (1981) 247; N.C. 65A (1981) 414;
N.C. Lett. 32 (1981) 210; N.C. Lett. 36 (1983) 563;
N.C. Lett. 37 (1983) 246; N.C. Lett. 38 (1983) 289.

3) M. Basile et al., N.C. 79A (1984) 1.

4) A. Zichichi, Proceedings of HEP Conference, EPS, Lisbon, 1981, page 1133.

5) M. Basile et al., Phys. Lett. 95B (1980) 311; N.C. 65A (1981) 400.

6) M. Basile et al., N.C. 67A (1982) 244.

7) M. Basile et al., Phys. Lett. 92B (1980) 367; N.C. 58A (1980) 193;
N.C. Lett. 29 (1980) 491; N.C. 67A (1982) 53.

8) TASSO Coll., R. Brandelik et al., Phys Lett. 89B (1980) 418;
DESY 83-130 (1983).

9) JADE Coll., W. Bartel et al., Z. Phys. 20C (1983) 187.

10) PLUTO Coll., C. Berger et al., Phys. Lett. 95B (1980) 313.

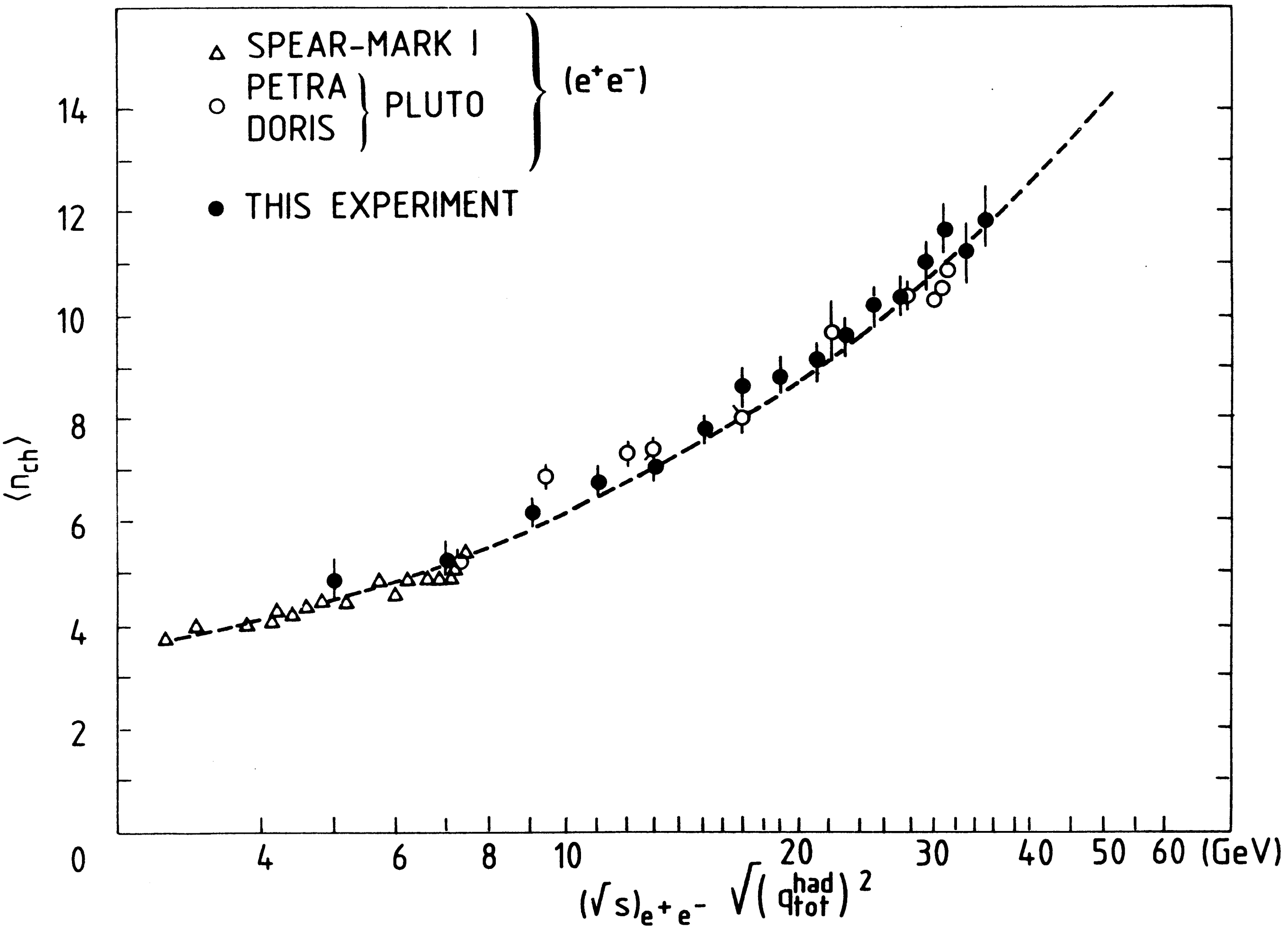
11) LENA Coll., B. Niczyporuk et al., Z. Phys. 9C (1981) 1.

12) J.L. Siegrist, SLAC-Report 255 (1979);
V. Luth et al., Phys Lett. 70B (1977) 120.

FIGURE CAPTIONS

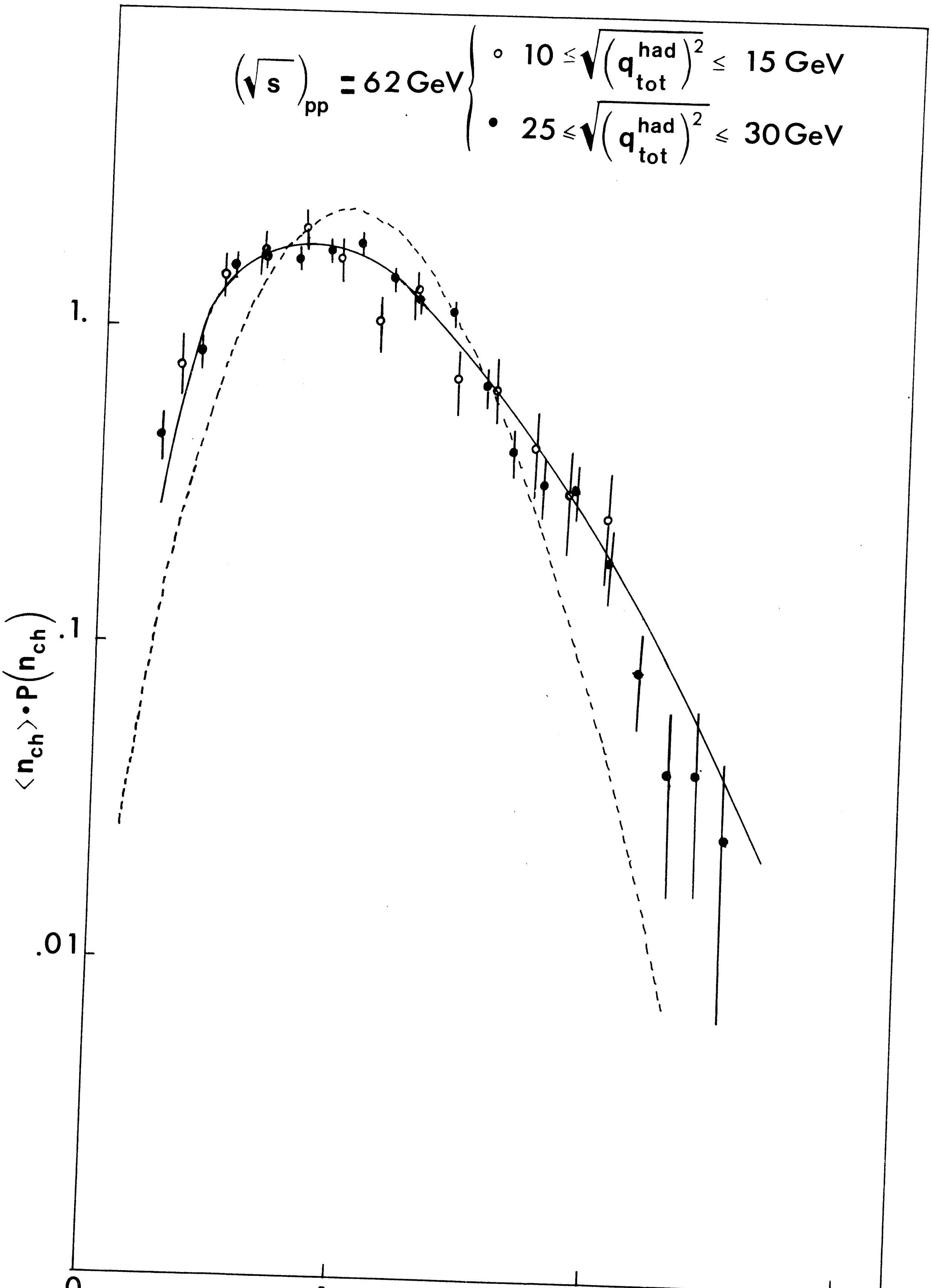
Fig. 1 : The average charged multiplicity measured in (pp)$^{6)}$ and (e^+e^-)$^{10,12)}$. Notice that the (pp) interactions are studied following our method of subtracting the leading proton effect. The quantity $\sqrt{(q^{had}_{tot})^2}$ is the effective energy available in a (pp) interaction once the leading effects are correctly taken into account (see text for its exact definition). The quantity $(\sqrt{s})_{e^+e^-}$ is the energy available in an (e^+e^-) annihilation.

Fig. 2 : The $n_{ch}/\langle n_{ch}\rangle$ distributions measured in our experiment in (pp) interactions , for two different intervals of $\sqrt{(q^{had}_{tot})^2}$ [open circles: $10 \le \sqrt{(q^{had}_{tot})^2} \le 15$ GeV; solid circles:$25 \le \sqrt{(q^{had}_{tot})^2} \le 30$ GeV]. The solid curve is the best fit to the (pp) data (this experiment). The nominal (pp) c.m. energy was $(\sqrt{s})_{pp}= 62$ GeV. The dashed line is the best fit to the (e^+e^-) data$^{8-11)}$



△ SPEAR-MARK I
○ PETRA
DORIS
PLUTO
(e^+e^-)
● THIS EXPERIMENT
$\langle n_{ch} \rangle$
0
2
4
6
8
10
12
14
4
6
8
10
20
30
40
50
60 (GeV)
$(\sqrt{s})_{e^+e^-}$ $\sqrt{(q_{tot}^{had})^2}$

Fig. 1



$\left(\sqrt{s}\right)_{pp} = 62\,\mathrm{GeV}$
○ $10 \leq \sqrt{\left(q_{tot}^{had}\right)^2} \leq 15\,\mathrm{GeV}$
● $25 \leq \sqrt{\left(q_{tot}^{had}\right)^2} \leq 30\,\mathrm{GeV}$
1.
.1
.01
0
1.
2.
3.
$\langle n_{ch} \rangle \cdot P(n_{ch})$
$n_{ch} / \langle n_{ch} \rangle$

Fig. 2