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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

CERN - Geneva, Switzerland
Dipartimento di Fisica dell'Università - Bologna, Italia
Istituto Nazionale di Fisica Nucleare - Laboratori Nazionali di Frascati, Italia
Istituto Nazionale di Fisica Nucleare - Sezione di Bologna, Italia

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

Summary. – The universality features observed in comparing ISR data with (e^+e^-) and deep-inelastic scattering (DIS), prompt a comparison, at Collider energies, of high-p_T and low-p_T jets with constant $\sqrt{(q_{tot}^{had})^2}$. The expectations of the transverse properties of the particles in the jets are discussed.

A study of the multihadronic systems produced in high-energy (pp) interactions (1-19) at the CERN Intersecting Storage Ring (ISR) has produced the following results.

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Once the (pp) interactions are analysed in a proper way, *i.e.* using the correct variables, a straightforward comparison is possible between the multihadronic final states produced in (pp) interactions, (e^+e^-) annihilation, and deep inelastic scattering (DIS) processes.

The comparison shows that the old myth—based on the belief that in order to compare (pp) with (e^+e^-) and DIS it is necessary to study high-p_T (pp) interactions (*)—has been dispelled. In fact we have compared low-p_T (pp) interactions with (e^+e^-) and DIS (1-19), and we have found that a striking analogy exists between the multihadronic systems produced in (pp), (e^+e^-), and DIS.

So far, the only difference found by us in the comparison between these various ways of producing multihadronic final states is in the p_t of the particles produced. The value of $\langle p_t \rangle$ measured in low-p_T jets produced in (pp) interactions is lower than the value of $\langle p_t \rangle$ measured in (e^+e^-) annihilation (10). However, using the «renormalized» quantity $(p_t/\langle p_t \rangle)$ (7), the (pp) data do coincide with the (e^+e^-) data (see fig. 2). This shows that low-p_T jets produced in (pp) interactions at ISR energy do behave like the jets produced in (e^+e^-) annihilation, except for the lower value of $\langle p_t \rangle$.

This result is suggestive of a very interesting possibility: multiparticle systems with

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(*) Note that p_T indicates the transverse momentum of a jet with respect to the colliding beams axis; p_t indicates the transverse momentum of a particle with respect to the axis of the jet (see fig. 1). The quantity $\langle p_t \rangle$ is the value of p_t averaged over all particles of the jet.

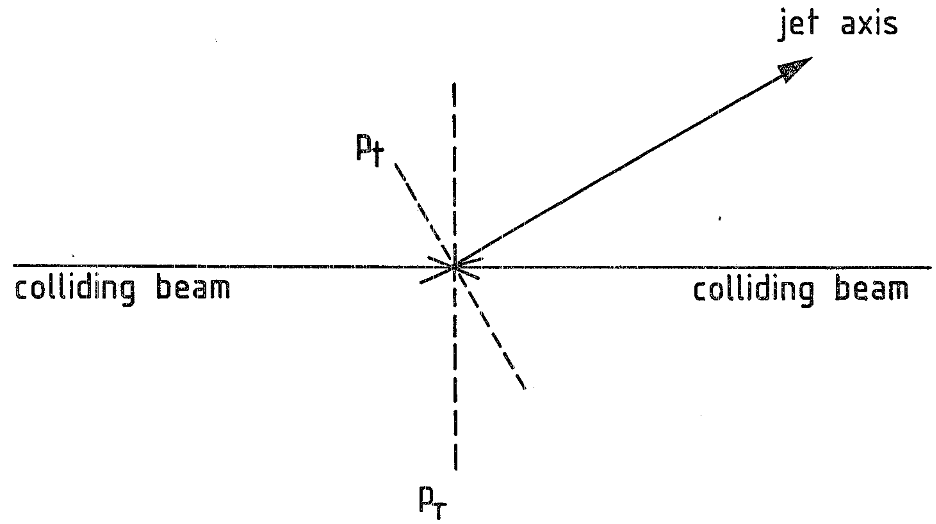

Fig. 1. – Sketch describing the quantities p_T and p_t: Notice that the p_t and p_T planes are both perpendicular to the figure.

equal values of the effective energy available for particle production, $\sqrt{(q_{tot}^{had})^2}$, produced in (pp) interactions at high p_T could have higher values of $\langle p_t \rangle$.

In (pp) interactions, the same values of $\sqrt{(q_{tot}^{had})^2}$ can be produced in two ways:

i) at low p_T: we have seen the striking analogies between the properties of the multihadronic final states produced in (pp), (e^+e^-), and DIS [1,19]—except for $\langle p_t \rangle$;

ii) at high p_T: we have not been able to study, at constant values of $\sqrt{(q_{tot}^{had})^2}$, the multihadronic systems produced at high p_T, the main reason being the lack of ISR machine time. Therefore a comparison between multihadronic final states produced at high p_T and at low p_T in (pp) interactions at ISR energies has been impossible.

It is possible that, had we been allowed to study high-p_T multihadronic systems at the ISR, we would have found the value of $\langle p_t \rangle$ to be identical to the value measured in (e^+e^-) for $(\sqrt{s})_{e^+e^-} = \sqrt{(q_{tot}^{had})^2}$.

What was not possible at the ISR could be done at the CERN $\bar{p}p$ Collider, *i.e.* to compare, for equal values of $\sqrt{(q_{tot}^{had})^2}$, the multihadronic final states produced at low p_T and at high p_T.

Our findings at the ISR suggest that the only difference should be in the value of $\langle p_t \rangle$. As $\langle p_t \rangle$ increases with $(\sqrt{s})_{e^+e^-}$, it is obvious that it should also increase with increasing values of $\sqrt{(q_{tot}^{had})^2}$. Moreover, the comparison between high-p_T and low-p_T jets using the renormalized variable $p_t/\langle p_t \rangle$ should show no difference.

An extrapolation of our method to the CERN $\bar{p}p$ Collider is possible because there are two ways of determining $\sqrt{(q_{tot}^{had})^2}$.

One is to use two «leading» particles.

The other, when the «leading» method is out of experimental reach, is to use the measurements of the total energy carried by two back-to-back jets. In fact, the basic quantity in comparing multihadronic states is the effective energy available for particle production, not the «nominal» one. In the case of two back-to-back jets, it is

$$\sqrt{(q_{tot}^{had})^2} = \left(\sum_{i=1}^{n} E_i\right)_1 + \left(\sum_{i=1}^{m} E_i\right)_2,$$

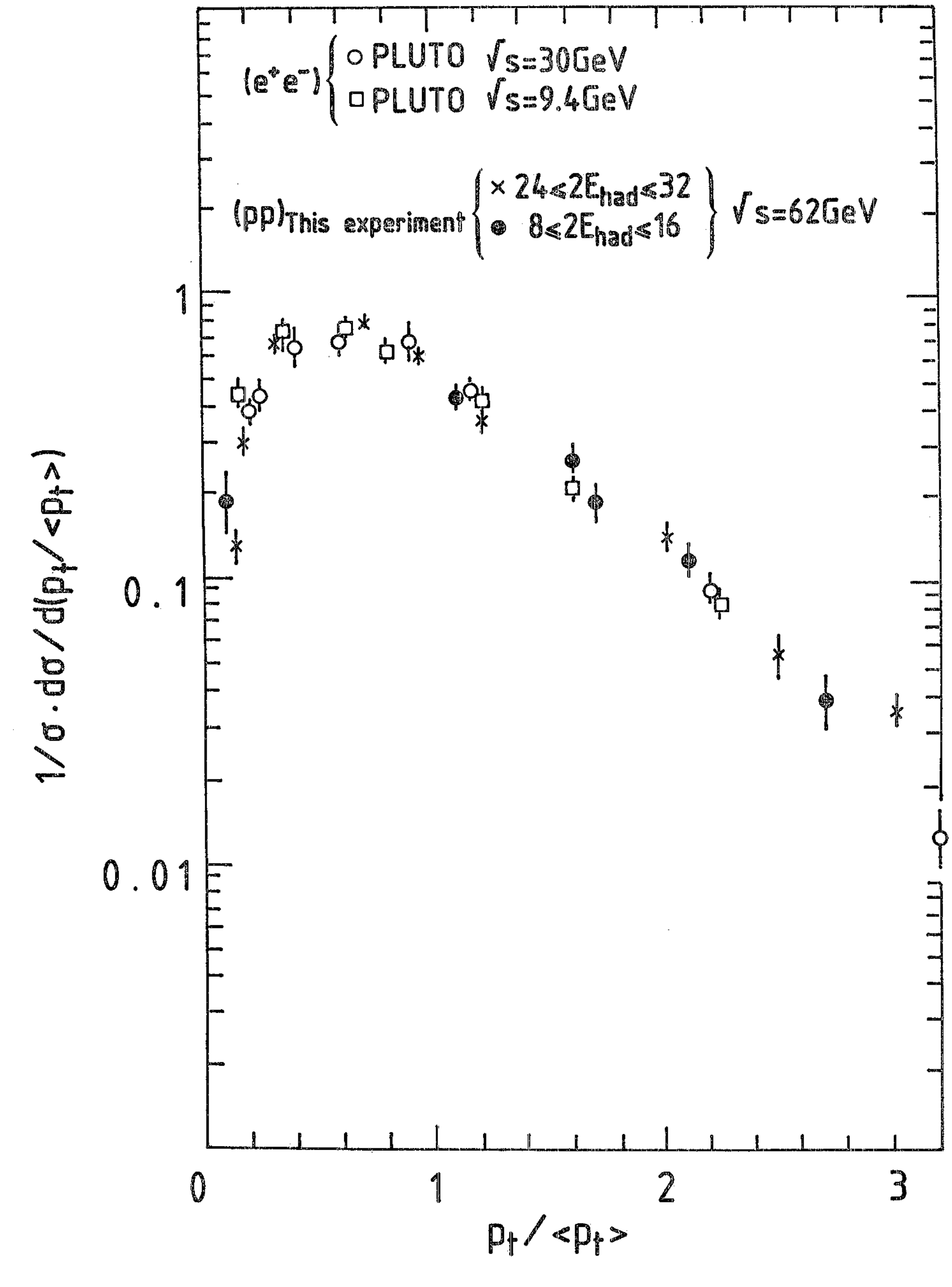

Fig. 2. – The result of our study, using (pp) interactions at ISR, compared with (e^+e^-) data. The « renormalized » value of $p_t/\langle p_t\rangle$ is essential in order to bring all data int good agreement. In fact the (e^+e^-) data at high energy show higher values of $\langle p_t\rangle$ when compared with equivalent values of $(\sqrt{s})_{e^+e^-} = \sqrt{(q_{tot}^{had})^2}$. Notice that $\sqrt{(q_{tot}^{had})^2} \simeq 2E_{had}$.

where E_i is the energy of particle « i » in each of the two back-to-back jets, whose multiplicities are n for jet No. 1 and m for jet No. 2.

There is an important « experimental » difference between the two ways of determining $\sqrt{(q_{tot}^{had})^2}$.

The leading method is straightforward. It only needs the measurement of the two leading particles. The other method needs the measurements of all particles in the two jets, including the neutral ones.

The remarkably unique range of effective hadronic energies available at the Collider allows a large energy jump from ISR energies, and produces clear evidence for or against our expectations based on the results obtained at the ISR.

Let us consider an example. If multiparticle hadronic states at the $\bar{p}p$ Collider are produced at high-p_T with

$$\sqrt{(q_{tot}^{had})^2} = 100 \text{ GeV}$$

they should be very similar to the multihadronic systems produced in (e^+e^-) annihilations, with

$$(\sqrt{s})_{e^+e^-} = 100 \text{ GeV}.$$

Such an (e^+e^-) machine is still not available. What exist and are available now are the low-p_T and the high-p_T jets with $\sqrt{(q_{tot}^{had})^2} = 100$ GeV, produced at the Collider.

Conclusion. To compare, at the Collider, multihadronic final states with the same values of $\sqrt{(q_{tot}^{had})^2}$, at high p_T and at low p_T is of great value in understanding the dynamics of strong interactions.

From our findings at the ISR the only difference between high-p_T and low-p_T jets should be the value of $\langle p_t \rangle$, and the difference should disappear if the variable $p_t/\langle p_t \rangle$ is used.

Moreover, at the $\bar{p}p$ Collider the slope of $\langle p_t \rangle$ *vs.* $\sqrt{(q_{tot}^{had})^2}$ can be measured up to a few hundred GeV. Then we must wait until LEP and Super-LEP will allow us to check these analogies.