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## EVIDENCE OF THE SAME MULTIPARTICLE PRODUCTION MECHANISM IN p-p COLLISIONS AS IN $e^+e^-$ ANNIHILATION

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The split-field magnet spectrometer at the CERN intersecting storage rings was used to measure, in p-p collisions at  $\sqrt{s} = 62$  GeV, the inclusive momentum distribution of the charged particles produced in the same hemisphere as the leading proton ( $x > 0.4$ ). A new scaling variable was introduced in order to take into account baryon-number conservation effects in p-p interactions. It is shown that distributions in this variable are in good agreement with the momentum distribution of the hadrons produced in  $e^+e^-$  annihilation. The results suggest that the multiparticle production mechanism in p-p collisions is the same as in  $e^+e^-$  provided that the effects of baryon-number conservation are removed.

**1. Introduction.** The parton picture of hadrons provides a unifying framework for describing and relating different processes such as lepton deep inelastic scattering, hadron-hadron high- $p_T$  reactions, and  $e^+e^-$  annihilation.

The bulk of the hadron-hadron interactions, which are mostly at low  $p_T$ , are still not understood. Recently, many attempts have been made [1] to relate the hadron longitudinal momentum distributions in the fragmentation region of the proton to the quark distributions inside the proton. These attempts are model dependent, relying on the assumption of a particular recombination function of the constituents to form a pion. Furthermore, they are limited to the tail of the  $x$  distribution ( $x > 0.5$ ).

We have used a completely new approach to study the inclusive momentum distributions of charged particles produced in p-p reactions and to compare them as closely as possible with the results from  $e^+e^-$  annihilation.

The system of hadrons produced in a p-p interaction must have a baryon number equal to two, but in  $e^+e^-$  annihilation the baryon number is zero. To in-

vestigate whether it is just baryon-number conservation that makes the difference between the multiparticle distributions in the two kinds of interaction, we have attempted to remove the effects of baryon-number conservation by selecting events with a leading proton and redefining the fractional variables of the particles so that they may "forget" the existence of that proton.

**2. Data collection and analysis.** The experiment was performed at the CERN intersecting storage rings (ISR) at  $\sqrt{s} = 62$  GeV, using the split-field magnet (SFM) and its multiwire proportional chamber (MWPC) detector. A detailed description of the facility can be found elsewhere [2].

The detector was operated in the simplest possible triggering mode, which required two or more charged tracks anywhere in the chambers. Under these conditions the trigger efficiency is effectively 100%, and only corrections for individual track efficiencies have to be applied. These events were reconstructed, and only the tracks whose momentum was determined with an estimated precision  $\delta p/p < 0.3$  were retained.

Events with a probable proton were then selected,

using the criterion that the fastest particle in either hemisphere centred on the direction of the beams should be positive and should have a value of  $x = 2|p_L|/\sqrt{s}$  between 0.4 and 0.8. Since no direct particle identification was available, the choice of the lower value of  $x$  was suggested by the over-all inclusive particle distributions. At  $x = 0.4$  the  $\pi^+$  production rate is comparable with that of the protons. As  $x$  increases, the ratio  $p/\pi^+$  increases, and so the assumption that the leading positive particle is a proton becomes more accurate; a  $\delta p/p \lesssim 8\%$  for this leading particle was also required. After this selection, 4149 of the available sample of 38883 "minimum bias" events remained.

All other particles in the same hemisphere were assumed to be the hadronic system associated with that proton. The total energy of this "associated hadronic system" was computed from the energy of the beam,  $\sqrt{s}/2$ , and the fractional longitudinal momentum of the proton,  $x_{\text{proton}} = 2p_L/\sqrt{s}$ :

$$E_{\text{had}} = \frac{1}{2}\sqrt{s}(1 - |x_{\text{proton}}|).$$

The inclusive momentum distribution of the particles of the "associated hadronic system" was expressed in terms of a new fractional variable  $x_R^*$ , defined as

$$x_R^* = p/E_{\text{had}};$$

that is, dividing the momentum  $p$  of the particle by the energy of the hadronic system rather than by the energy of the beams. For transforming their momenta from the laboratory system to the p-p centre-of-mass system where  $x$  and  $x_R^*$  were evaluated, the particles were assumed to be pions. A correction for the acceptance of the detector for single tracks, including the effects of momentum resolution cuts, was applied.

**3. Results.** Fig. 1 shows the results for various bands of the energy  $E_{\text{had}}$  of the hadronic system. These inclusive distributions are normalized by dividing the number of particles per bin of  $x_R^*$  by the total number of events. Only statistical errors are shown. Systematic errors in the acceptance calculations are up to 20% of the reported values.

In fig. 2 we compare our data for the energy bands  $E_{\text{had}} = 5-8$  GeV, 8-11 GeV, and 14-16 GeV, with the  $e^+e^-$  data from Tasso at PETRA [3] at corresponding beam energies  $E_{\text{beam}} = 6.5$  GeV, 8.5-11 GeV, and

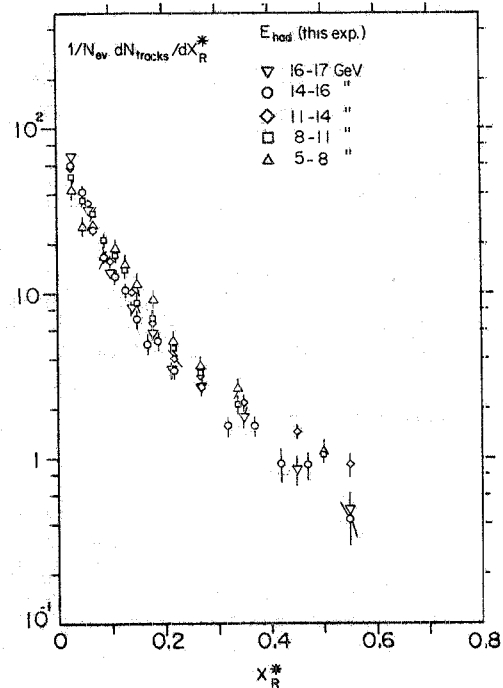


Fig. 1. Normalized single-particle inclusive distribution ( $1/N_{\text{ev}}$ ) ( $dN/dx_R^*$ ) versus  $x_R^*$  for various bands of  $E_{\text{had}}$ , obtained from p-p collisions.

13.7-15.8 GeV. The quantity  $s(d\sigma/dx_R)$  (with  $x_R = 2p/\sqrt{s}$ ) given by the Tasso experiment has been multiplied by a factor  $1/(2sR\sigma_{\mu\mu})$ , where  $\sigma_{\mu\mu}$  is the point-like  $\mu$  cross section, and the values of  $R = \sigma_{\text{had}}/\sigma_{\mu\mu}$  are taken from the same authors [4]. In this way we obtain the Tasso distributions normalized relative to only one half hemisphere, so that we can make an absolute comparison with our distributions as well as compare the shapes.

Figs. 2a,b and c show that the distribution as well as fractional momentum  $x_R^*$  of the hadrons produced in p-p collisions in our experiment is very similar, both in shape and absolute value (mean charged multiplicity), to the distribution of the fractional momentum of the hadrons produced in  $e^+e^-$  annihilation.

**4. Conclusions.** The agreement between the momentum distributions obtained in  $e^+e^-$  annihilation and p-p collisions suggests that the mechanism for transforming energy into particles in these two processes, so far considered very different, must be the

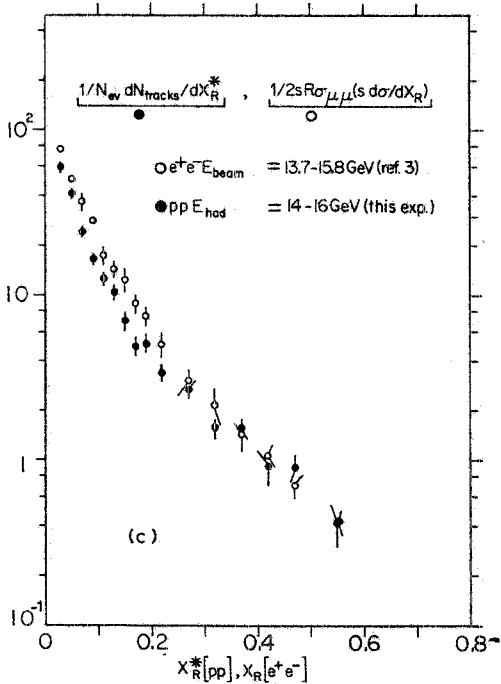
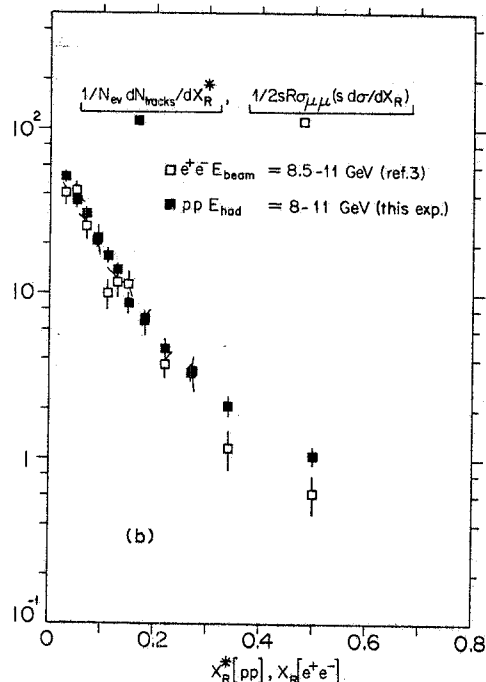
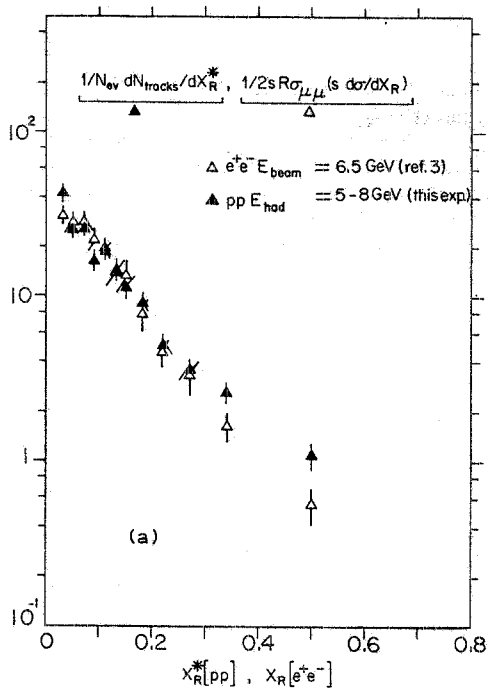


Fig. 2. The p-p single-particle inclusive distributions in terms of the variable  $X_R^*$ , are compared to the single-particle inclusive distributions obtained in  $e^+e^-$  annihilation; (a)  $E_{had} = 5-8$  GeV, (b)  $E_{had} = 8-11$  GeV, (c)  $E_{had} = 14-16$  GeV.

same. In fact the main point of our work is to disentangle the kinematic effects of baryon-number conservation in p-p collisions. The results of our analysis could then provide a key to deeper understanding of the hadron-hadron reactions.

More studies, both experimental and theoretical, along these lines are certainly needed, and the results from the high-energy antiproton-proton colliders that are under construction will be particularly relevant.

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