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Edited by: I. DREMIN
K. GULAMOV

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SESSION

SOFT HADRONIC INTERACTIONS

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SOFT AND SEMI-HARD HADRONIC COMPARED TO e^+e^- AND lh COLLISIONS

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ABSTRACT

Multiparticle production in soft and semi-hard hadronic collisions is reviewed in terms of correlations, where possible in comparison to e^+e^- and lepton-hadron collisions. Important differences are listed between these types of collision, but models based on QCD can be tuned to describe most of the observations in all three. Recent decisive data force these models to an increased convergence.

1. INTRODUCTION

The aim of our game is a unified description of multiparticle production in hadron-hadron, lepton-hadron and e^+e^- collisions. In this game, particle production is assumed to proceed in two steps, excitation of a colour field and hadronization of the quarks and gluons produced in this field. The excitation is supposed to be of a hard scattering type in lh and e^+e^- collisions, but soft or at most "semi-hard" in normal (low p_T) hh collisions. Hadronization is seen as a soft process in all three. The aim is still hidden in the fog of non-perturbative QCD, expected to hold for the soft component. Since no theory exists so far, there is plenty of space for exploratory experimentation and modelling.

A three-dimensional scheme relating the many ideas can be found in ref.[1], while recent critical comparisons of the most successful ones can be found in refs.[2-4]. Since ref.[4] is published in these proceedings, I will not attempt to review all the ideas, but will refer to models where recent data have caused major modifications.

Data are plentiful as well. We shall, therefore, restrict ourselves to results on correlations recently made available by a limited number of detailed experiments as listed below. Correlations are considered in the production of two or more particles, as well as between two variables describing the production of one particle.

	Experiments		
Type of correlation	hh	lh	e^+e^-
multiplicities	UA5, NA22, NA5	EMC	HRS
forward-backward	UA5, NA22	EMC	HRS,TASSO
$\langle p_T \rangle$vs.n	UA1, SFM, NA22		
$\langle p_T \rangle$vs.x_F	NA22, NA23	EMC	TASSO
short range	NA23, UA5	EMC	MARKII, TASSO, TPC
Bose-Einstein	AFS, SFM, NA22	EMC	TASSO, CLEO, TPC
diffraction	R608, UA4, NA22		
density spikes	UA5, NA22		
e/π ratio	AFS		

The game is a difficult one, but probably worth the trouble. Since it has to do with hadronization, it has to do with confinement and confinement is one of the central issues of QCD. Furthermore, how can we know what hard is really like, if we don't know what soft is like. We, finally, will have to understand collisions of hadrons, if we want to understand collisions of ultrarelativistic nuclei. In any case, with the CERN Collider being upgraded, the FNAL Tevatron just starting on 2 TeV physics, the Serpukhov UNK and the US SSC planning experiments and the CERN LHC being discussed, hadron-hadron physics has the most diversive future.

2. FINAL STATE MULTIPLICITY

2.1 The Multiplicity Distribution and its Rapidity Dependence

Although the number of charged particles (the charge multiplicity n) is only a global measure of the characteristics of the final state of a high energy collision, it is proving a fundamental tool in the study of particle production. Independent emission of single particles leads to a Poissonian multiplicity distribution. Deviations from this shape, therefore, reveal correlations.

Multiplicity distributions can be studied in full phase space as well as in limited parts of it. First, if different basic sub-processes contribute in different regions of phase space, a study in various limited parts is appropriate. Second, while energy-momentum and charge conservation influence the multiplicity distribution for full phase space, the distribution in the central region is largely free from these constraints and hence can give a more direct measure of the production mechanism.

Multiplicity distributions of the form P_n versus n are often compared in terms of the so-called KNO [5] form

$$\langle n\rangle P_n = \psi(z) \tag{1}$$

with P_n being the probability for charge multiplicity n in the final state and z the scaled multiplicity $z = n/\langle n\rangle$.

In Fig.1a-d, the UA5 charge multiplicity distribution at 546 GeV [6] is given for several central pseudo-rapidity intervals limited by $|\eta| < \eta_{cut}$. The distributions in Figs.1a,c and d are in KNO form, those in Fig.1b in $P_n$vs.n. One observes a strong dependence of the shape of the distribution on the η_{cut} value. In KNO form, the distribution widens as η_{cut} is reduced. A similar behaviour is seen for e^+e^- collisions at $\sqrt{s} = 29$ GeV [7] for rapidity intervals $|y| < y_{cut}$ in Fig.1e.

In Fig.1a-d, furthermore, four currently used models are compared to the UA5 data, Pythia [8], Fritiof [9], the Dual Parton Model [10] and the Three Fireball Model [11,12]. The first two are Monte Carlo versions based on the Lund fragmentation scheme [13], the second two are analytical calculations. At first sight (on logarithmic scale) the models are all reasonably good and even follow the change of the shape with decreasing η_{cut}. At second inspection, Pythia, Fritiof and TFM tend to be too wide, in particular at larger η_{cut}, while DPM tends to be too narrow. For e^+e^-, both the Lund model [13] with 2nd order corrections and the Webber model [14] have been compared [15] and, as shown in Fig.1e for the case of Webber, describe the distributions at present energies.

On the other hand, Fialkowski [16] shows that the dependence on the rapidity cut can be understood already from a "minimal model" of independent cluster emission, when the full phase space multiplicity distribution is taken from experiment.

2.2 Energy Dependence, KNO or NO Scaling?

KNO scaling [5] supposed to hold at asymptotic energies implies a universal form of the multiplicity distribution (1) and, therefore, constant normalized moments

$$C_q = \langle n^q\rangle/\langle n\rangle^q \quad . \tag{2}$$

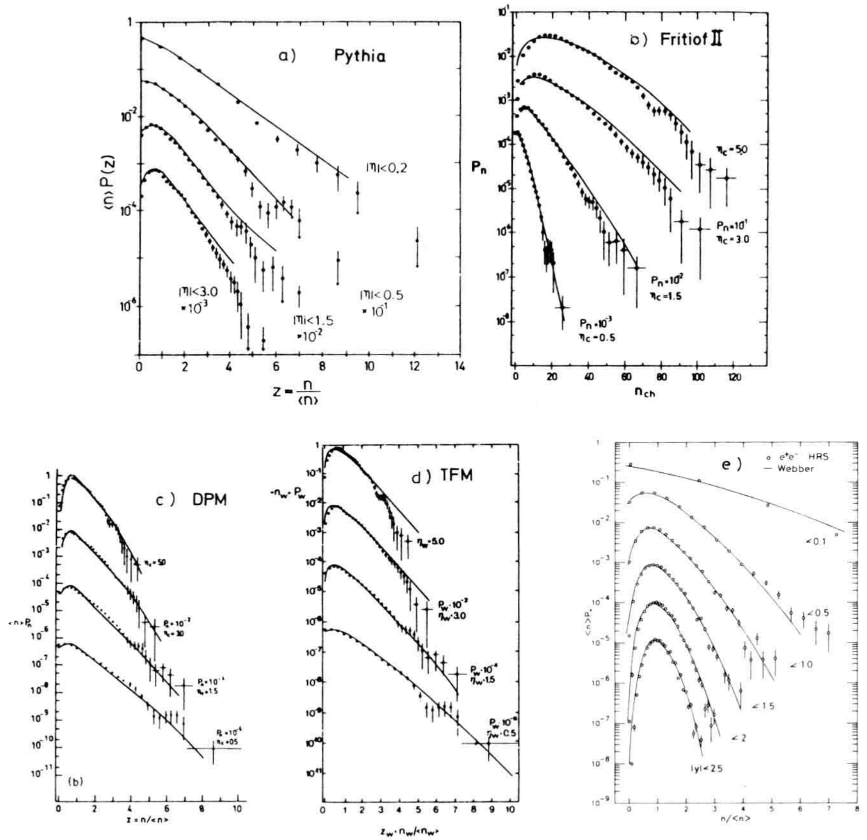

Fig.1: Charge multiplicity distribution for a)-d) non-single diffractive $p\bar{p}$ collisions in central pseudo-rapidity intervals $|\eta| \leq \eta_{cut}$ [6], compared to Pythia [8], Fritiof [9b], DPM [10] and TFM [11], e) e^+e^-collisions at $\sqrt{s} = 29$ GeV in central rapidity intervals $|y| \leq y_{cut}$ [7], compared [15] to the Webber model [14].

For full phase space, UA5 [17,18] has shown KNO scaling to be violated up to $\sqrt{s} \approx 1$ TeV (see Fig.2 for the energy dependence of the $C_2 - C_5$ moments).

The multiplicity distribution in the central region of rapidity was first suggested to obey KNO scaling between ISR and SPS collider energies. In particular, this appeared to hold for the region $|\eta| < 1.3$ at $\sqrt{s} = 53$ GeV and $|\eta| < 1.5$ at $\sqrt{s} = 63$ GeV [19] compared to $\sqrt{s} = 546$ GeV [20]. However, these experiments use different trigger requirements and the data are selected to exclude zero prong events. Because of the different values of $\langle n \rangle$ at the two energies, the latter selection changes the z-values differently at the two energies.

A comparison of the data at 22 GeV [21] with (in part preliminary) UA5 Collider data [6,22] now allows for a systematic study over a large energy range. In both experiments, events with zero charged tracks in the interval considered are consistently included. In Fig.3, the energy variation of the C_2 to C_4 moments of non-diffractive charge multiplicity distributions are shown for the intervals $|\eta| < 0.5$, $|\eta| < 1.0$ and $|\eta| < 1.5$. The moments for the two bigger intervals are seen to