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PHOTON-HADRON FRAGMENTATION: THEORETICAL SITUATION

by

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I will concentrate on models of hadronic fragmentation and their phenomenological comparison using a selection of new experimental results. Indeed a convenient *theory* of hadronic fragmentation - for instance based on Q.C.D. - does not exist: low $P_\perp$ fragmentation involves the badly known hadronic long-range forces. Models should clarify the situation in the prospect of an eventual future theory.

1 . Models

Most modern fragmentation models rely on the assumption of an underlying mechanism involving the parton-constituents of the fragmenting hadron. These partons are excited in a first stage, then interact and fragment into hadrons. The interaction range may be of the order of a hadron size ($1/Q_0 \approx$ 1fermi) or even less. On contrary the parton excitation or fragmentation are time-dilated and long range.

In such a picture hadron and parton fragmentation are related, and various predictions are possible. But this is the only common characteristics of models since they disagree on the features of both the short-range interaction and the long-range process excitation or fragmentation . In table I, we show the main rough differencies between various types of models.

MODEL TYPE	LONG RANGE STAGE	INTERACTION SCALE	
Quark a) Recombination or fusion (1)	excitation of a valence quark	Q_o^2	"soft" Fragmentation models
Quark (2-4) b) Fragmentation	fragmentation of a valence quark	Q_o^2	
c) offshell quark fragmentation (5)	fragmentation of a valence quark	$Q^2 \geq Q_o^2$	"hard" Fragmentation models
d) gluon Bremmsstrahlung (6,7)	Quark and/ gluon excitation and fragmentation.	$\langle Q^2 \rangle >> Q_o^2$	

Table I: Gross features of different fragmentation models

I call "soft" fragmentation the models of refs (1-4) since the interaction mechanism (recombination, fusion or fragmentation) has the hadronic scale Q_o^2. For a shorter interaction range, the "hard" fragmentation models (5-7) may use perturbative QCD.

2 . Phenomenology

Let me stress the main experimental observables which are relevant to the discussion of fragmentation mechanisms.

i) *Features of particle production*

In the energy range up to the ISR energy, a lot of information on inclusive production of various hadrons is now available. There are interesting model predictions, mainly from "soft"fragmentation using as an input the relevant data on parton fragmentation or structure functions (see papers 111, 268, 287, 326, 327, 330). Nevertheless confirming last years discussion, it remains difficult to distinguish between the proposed mechanisms. As an example, it has been noticed by E.A. De WOLF (4) that the predictions for charged particle ratios $R^{\eta} = \langle n_{\eta} \rangle_{\bar{p}p} / \langle n_{\eta} \rangle_{pp}$, which have been previously advocated as a test of a specific mechanism (2) are also satisfactory in the different framework of the Lund model (4) : see table II.

Detected Hadron	R^h Data(AFS 1983)	R^h Lund(ref 2)	R^h (DPM(ref 3)
$\pm$	$.999 \pm .002$	1.00 ± 0.01	1.02 - 1.03
$+$	$.974 \pm .003$	0.97 ± 0.01	0.98 - 1.0
$-$	$1.026 \pm .003$	1.03 ± 0.01	1.05 - 1.06
$K^+ + K^-$	1.021 ± 0.013	0.99 ± 0.01	1.06 - 1.07
K^+	$.961 \pm .020$	0.93 ± 0.02	0.97 - 1.01
K^-	$1.086 \pm .020$	1.05 ± 0.03	1.14 - 1.17
$p + \bar{p}$	1.022 ± 0.016	1.01 ± 0.02	1.06 - 1.08
p	$.84 \pm 0.02$	0.89 ± 0.03	0.92 - 0.97
$\bar{p}$	1.32 ± 0.03	1.17 ± 0.04	1.21 - 1.26

Table II: Ratios $R^h=(n)_{\bar{p}p}/(n)_{pp}$ of charged particle average multiplicities in $\bar{p}p$ and pp collisions at $\sqrt{s}=53$GeV in the range $|y| < 0.8$ and $p_T < 1.5$GeV/c (AFS, 1983 = T. AKESSON et al, CERN EP/83-75).

ii) *Energy Dependance of rapidity Distributions*

Plotted as a function of the Lab. frame pseudo rapidity η_{Lab}, the distributions measured at ISR and SPS collider by the UA5 group are shown in fig 1. The energy variation is large, when one has in mind the previous expectations of a limiting rapidity plateau. Only the very edge of the distribution (y<2-3) appears in rough agreement with the concept of limiting fragmentation. Concerning model predictions, some soft fragmentation models (1) exclude the central region from the analysis, due to the mixing of fragmentation and interaction effects. In other cases (2,3) a rather natural extension of the model is to add up valence and sea quark fragmentation (see Fig. 2). On the other hand, "hard" fragmentation models intepret the energy dependance as the effect of a moderate growth in the scale of the fragmenting partons: $Q^2 \alpha S^{1/2}$ (6) or $<Q^2> \alpha S^{1/3}$ (7) leading to a "semi-hard" interaction picture of fragmentation where a large gluon Bremmstrahlung hides the hardness of the interaction at the level of the outgoing low-$P_\perp$ hadrons.

iii) *Energy Dependance of the Multiplicity Distribution*

At collider energies, the multiplicity distribution shows very interesting features. KNO scaling is violated, but only for very high multiplicity (see R.E Ansorge's talk at this conference). As a consequence higher order dispersions $D_q = <(n-<n>)^q>^{1/q}$ for $q > 2$ deviate from the straight line prediction of KNO scaling (see Fig. 2). Such a deviation - though with a too large amount - has been predicted in Ref. 4 in a soft fragmentation model. On contrary, rather general arguments imply a different pattern for hard fragmentation models (6), with a weaker but opposite-in-sign effect at Tevatron energies (see Fig. 2). Ultimately even more general arguments (P. Carruthers, Los Alamos preprint LA-UR-83-2041) leads to exact KNO scaling at these energies. Studying multiplicity distributions in the region of high energy and large multiplicities is clearly needed to disentangle the situation.

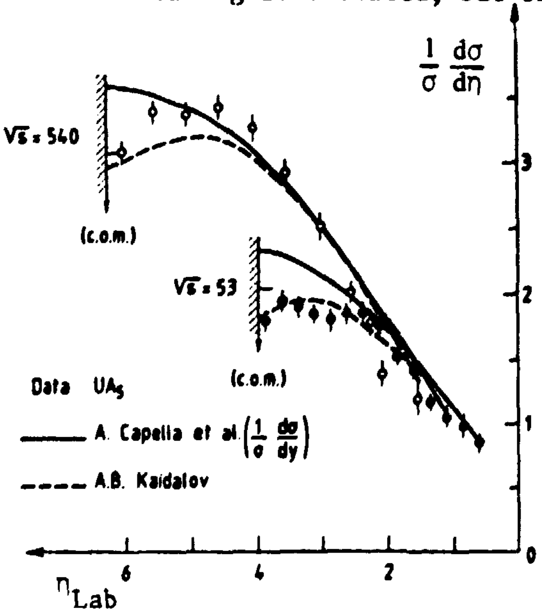

Fig. 1: Pseudo rapidity distributions as a function of laboratory frame rapidity measured at ISR and CERN collider.

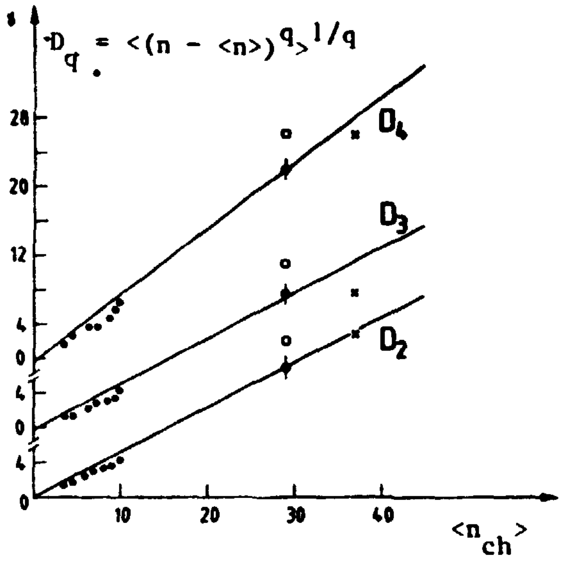

Fig. 2: Dispersions of the multiplicity distribution as a function of the average charged multiplicity (data are from UA5 and lower energy range. Squared from ref(3). crosses from ref(6). KNO scaling is straightlines).

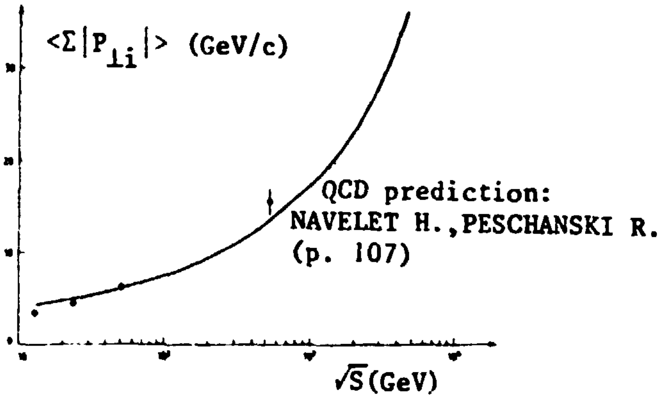

Fig 3: Mean total transverse momentum as a function of energy. The line is the QCD prediction(7).

iV) *Tranverse radiation*

I call transverse radiation, the transverse energy or momentum flow produced in hadron fragmentation. Unusual features appear at collider energies such the increase of the mean transverse$\langle P_T \rangle$and the larger $\langle P_\perp \rangle$ for high multiplicity events. It seems that these features are deeply related to the inner mechanisms of hadronic fragmentation. For instance, in paper 107, it is shown that a QCD prediction can be proposed for the quantity $\langle \Sigma |P_{\perp i}| \rangle$ which is in good agreement with data (see fig. 3). In paper 321, of the dual Parton model prediction for the distribution $\langle P_\perp^2 \rangle$ versus multiplicity is to be related to the intrinsic movement of the sea quarks in the Nucleon. We suggest that Transverse Radiation may provide clear tests of the mechanisms of hadron fragmentation and their possible relation to fundamental interaction processes.

I apologize for all absent subjects due to the lack of place.

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