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SOME OFF-BEAT ASPECTS OF PROTON-PROTON PRODUCTION PROCESSES*

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ABSTRACT

We discuss four aspects of the phenomenology of high energy production processes: the approach to scaling, the relation between inclusive cross-sections and total cross-sections, the rapidity charge density, and left-right multiplicity distributions. The goal of the discussion is to provide a slightly different slant on important features of the data.

INTRODUCTION

In the absence of a solid theory, the quest for an adequate description of the data frequently involves casting for relations among unfamiliar quantities. The following describes some recent efforts in which the author has been involved to find an empirical understanding of production processes.

THE APPROACH TO SCALING

At a gathering like this, it's often important to reflect on subjects which are no longer fashionable. Sometimes the decrease in interest in a certain topic masks a good deal of valuable physics. That seems to be true in the case of the subject of the approach to scaling of the inclusive process

$$f^c_{ab}(s, \vec{p}_c) = \sigma^{-1}_{ab} E_c d^3\sigma/d^3p_c \; . \tag{1}$$

The flurry of papers[1-2] concerning various exoticity conditions (ab, $a\bar{c}$, $ab\bar{c}$, etc.) represented an important attempt to carry over into Mueller-Regge analysis ideas about duality which proved valuable in 2-2 and 2-3 body reactions.[3] The effort was not a success in that most of the simple ideas did not work. For example, the fact that all the produced particles (as opposed to the leading particles) in pp collisions approach scaling from below is just the opposite of the naive dual prediction that the secondary contributions to inclusive cross sections — just like those in total cross sections — should be positive.[2]

The energy sum rule[4]

$$\sqrt{s} = \sum_c \int \frac{d^3\vec{p}_c}{E_c} (E_c) f^c_{ab}(s, \vec{p}_c) \tag{2}$$

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has implications for the approach to scaling in that the behavior of the energy fraction

$$\eta_c(s) = \int \frac{d^3\vec{p}_c}{E_c} \frac{E_c}{\sqrt{s}} f^c_{ab}(s, \vec{p}_c)$$
$$= \frac{1}{2}\int dx\, d^2\vec{p}_T\, f^c_{ab}(x, \vec{p}_T, s) \qquad (3)$$

describes the "average" approach the asymptotic behavior of the inclusive cross section. Data[5] on energy fractions in pp collisions is shown in Fig. 1. The figure illustrates how the fall of the leading proton spectrum is balanced by the rise of the produced particles. It turns out not necessary to invoke Muller-Regge ideas to describe the behavior of the energy fractions. Although a dual scheme consistent with the energy sum rule can be constructed,[6] the behavior of the data are fairly well described in terms of kinematic reflections of the known dyamical mechanisms.[5] This is illustrated for the case of $pp \rightarrow \pi$ and $pp \rightarrow \bar{p}$ in terms of a prediction of a simple "phase-space" model[5,7] in Fig. 2. The same model describes the approach to scaling of $K\bar{K}$ and the large p_T component of inclusive distributions. It's not necessarily surprising that phase space effects are important. What is surprising is that within the framework of duality it should prove so awkward to incorporate the simple kinematic consequences of well known dynamic effects in Mueller-Regge models.

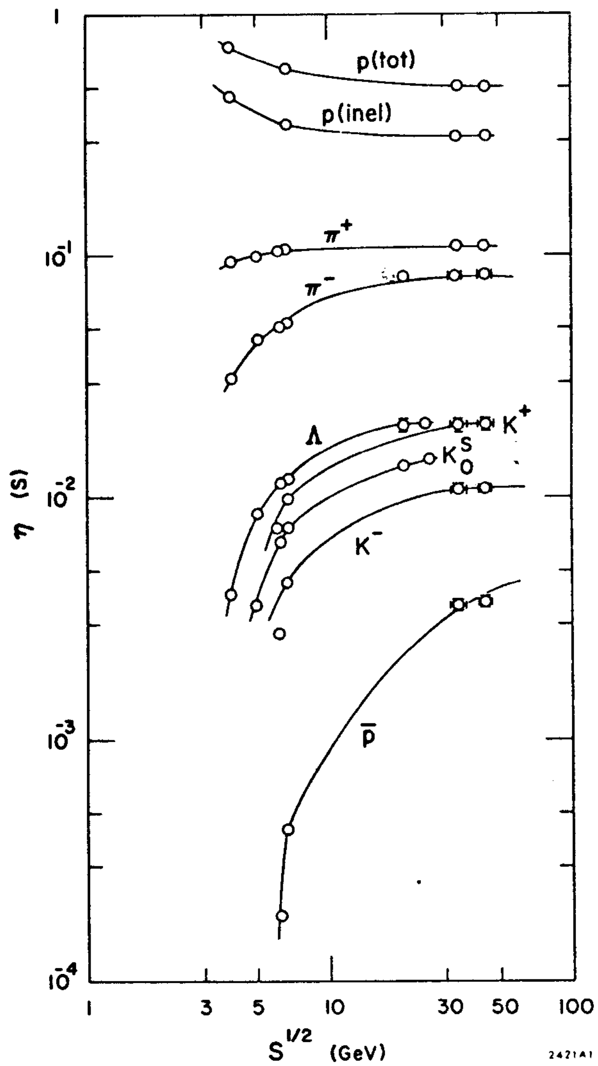

FIG. 1--Taken from Ref. 5, this figure displays the average fraction of cm energy carried off by different final particles. The relation of the energy fraction through the sum rule (2) to the approach to scaling.

TOTAL CROSS SECTIONS

The fact that the sudden rise in the cross section for producing $\bar{p}$ [illustrated in Figs. 1 and 2] takes place at the same energy

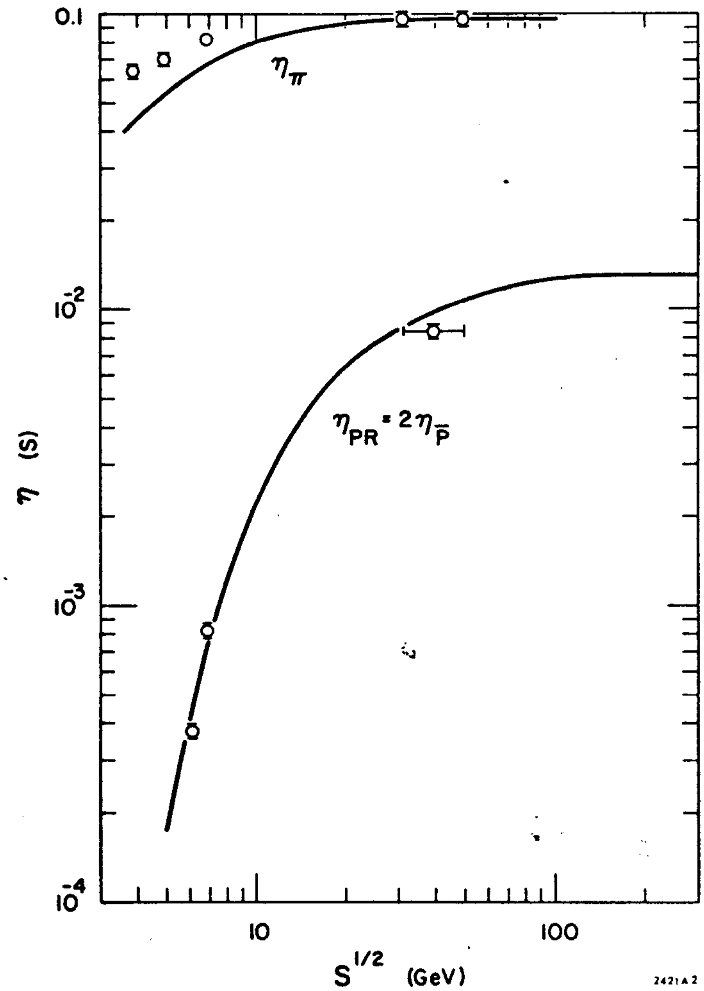

FIG. 2--A simple phase space model calculation of the behavior of the energy fraction as a function of s is compared with data on $\bar{p}$ and π production. The calculation demonstrates that the late rise in the $\bar{p}$ yield can be understood as a kinematic reflection of well-known dynamic features. Taken from Ref. 5.

where structure is seen in the total pp cross section has caused speculation that these two effects might be connected.[8,9]

Neglecting multiple production of baryon-antibaryon pairs, the cross section

$$\sigma_{B\bar{B}} \cong \langle n_{\bar{B}} \rangle \, \sigma_{inel} \qquad (4)$$

rises by about 6 millibarns through the ISR region.[10] This information can be combined with the fact that, within the context of the eikonal model, there should be a drop in σ_{tot} of 2-3 mb over the same energy range due to increased shadowing of high mass diffractive channels.[11] A combination of these two mechanisms—the rise in $B\bar{B}$ production and the growth of high mass diffraction — might therefore be able to explain the energy dependence of the total cross section. However, it remains to be seen whether this type of description would provide the peripheral increase in the overlap integral indicated from analyses of the differential cross section.[12]

RAPIDITY CHARGE DENSITY

One simple thing that can be done with single particle inclusive distributions is to combine the inclusive spectra $ab \to c_1$, $ab \to c_2$, etc., to form a charge density,

$$\delta\, Q^{ab}(s, \vec{p}) = \sigma_{ab}^{-1} \sum_i Q_i \left[E_i \frac{d^3\sigma}{d^3 p_i}^{ab \to c_i}(s, \vec{p}) \right]. \qquad (5)$$

Because charge is conserved, the integral over invariant phase space of the charge density must, of course, be given by the charge in the initial state[13]

$$\int \frac{d^3p}{E}\, \delta\, Q^{ab}(s,\, p) = \sum_i Q_i <n_i(s)> = Q_a + Q_b\ . \tag{6}$$

In Fig. 3 the charge density in pp inelastic collisions for 4 different energies[14] is integrated over transverse momentum and plotted as a function of laboratory (or target) rapidity, $y = \sinh^{-1}\left(p_L/(m^2 + p_T{}^2)^{1/2}\right)$,

$$\delta\, Q^{ab}(y,\, y-Y) = \int d\, \vec{p}_T\, \delta\, Q(s,\, \vec{p})\ . \tag{7}$$

In Eq. (7), $Y = \cosh^{-1}(s^{1/2}/m_p)$ is the rapidity of the beam in the target rest frame.

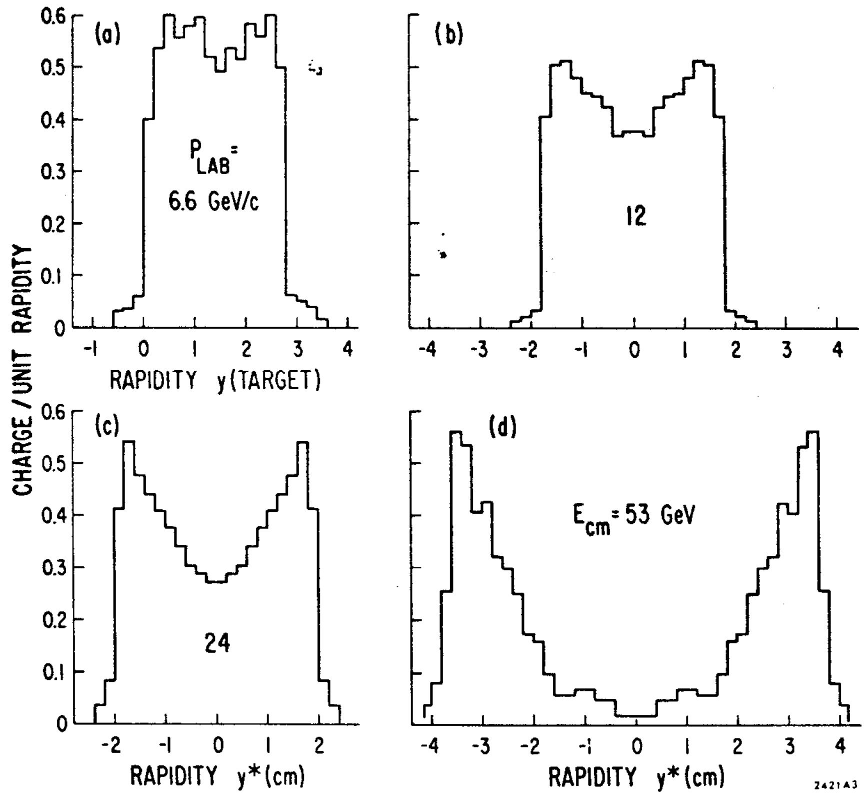

FIG. 3--The average charge per unit rapidity in the final state of a pp collision. Taken from Ref. 14.

Because the R.H.S. of (6) only contains the initial particle's charge, the charge density provides a convenient tool for the study of what has come to be called the leading particle effect. As emphasized by Morrison,[15] the term "leading particle effect" applied to inclusive data represents a correlation between the properties of the initial particles and those of final particles.

Mueller-Regge analysis connects this effect to the types of correlations we see in 2-particle inclusives in the central region. It is therefore not surprising that the "initial-particle-final particle charge correlation" found in the charge density is of short range as is the correlation found in pp $\to \pi\gamma$ and pp $\to \pi\pi$ in the central region. The indication is that the double-Regge expansion valid in the central region continues smoothly into the single-Regge expansions valid in the experimental region. Here is a place where Mueller-Regge ideas work well.

LEFT-RIGHT MULTIPLICITIES

A left-right multiplicity distribution consists of data on the number of charged particles going left (backward) and going right (forward) in the cm system of a production process.[16] It is an interesting oversize to see how coarse-grained data of this type can prove to be quite a sensitive test of models for the production process. Because the pomeron has I=0 and cannot contribute to charge transfer, pomeron exchange will only be important in those cross sections which have an odd number of particles in each hemisphere. This property proves to be very valuable in separating the two components of a hybrid, diffraction plus short range order, model. Figure 4 shows cross-sections at 205 GeV/c,[17] for producing different charge configurations when the total prong number is fixed. The data support the two component concept quite emphatically.[18]

Left-right multiplicities and related experimental quantities such as the average number of particles in the right hemisphere with a fixed multiplicity in the left hemisphere can also provide interesting factorization tests.[19] Since data of this type are comparatively easy to obtain and since calculations indicate that it is not necessary to go to very high energies to get important information, it would be valuable if more data on left-right multiplicities were made available.

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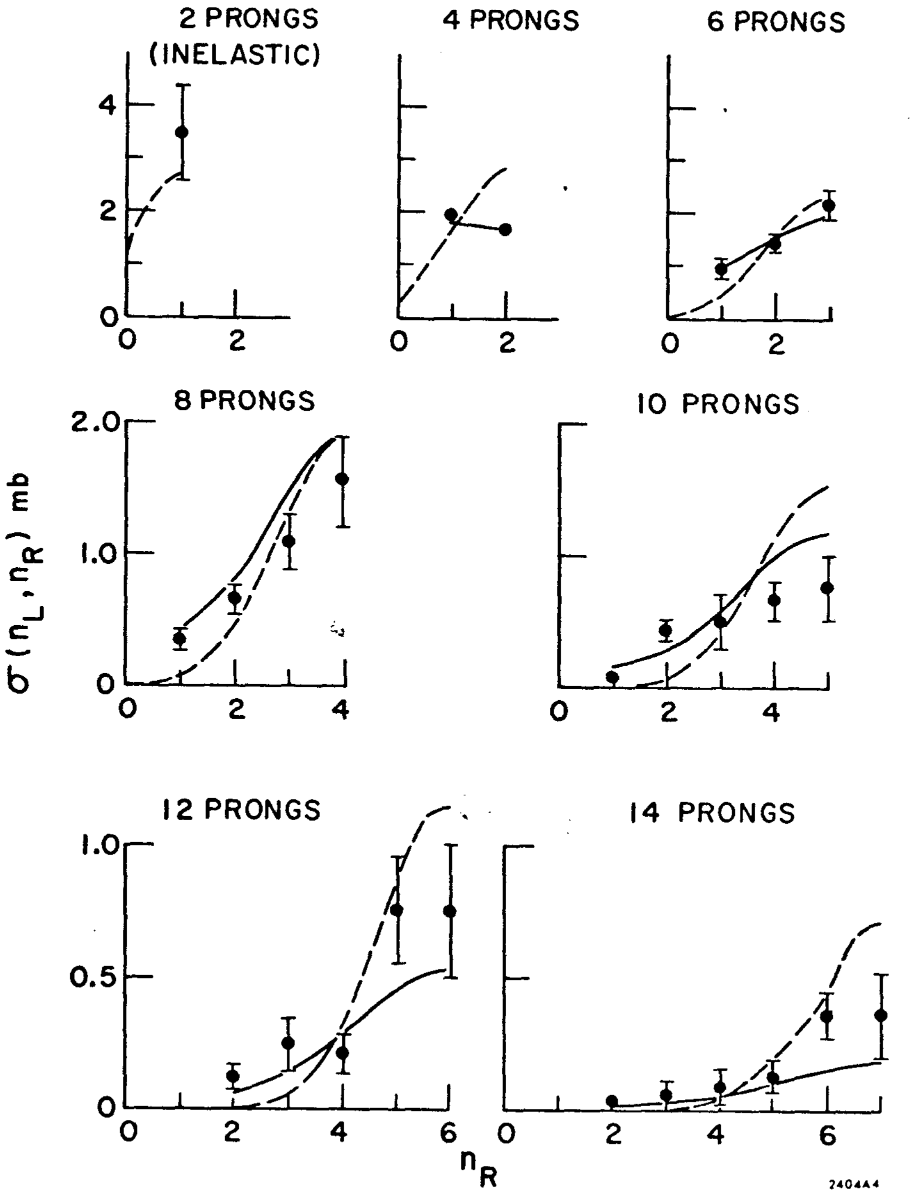

FIG. 4--Cross sections for left-right multiplicity configurations. The solid curve represents a 2-component model and the dashed curve a gas analog model explained in Ref. 16.

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