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"It is better to know nothing
than to know what ain't so."
...Chinese (Joyce Chen) Fortune
Cookie

LARGE MOMENTUM TRANSFER REACTIONS, WITHOUT PARTONS[†]

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ABSTRACT

Three recent experiments involving large 4-momentum transfer are compared to predictions of the hadronic bremsstrahlung model, without partons.

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In view of the recent SPEAR annihilation experiment¹ and the deep-inelastic μp data,² in which predicted parton-like behavior is seriously amiss, it may be useful to summarize several results of a particular class of models designed to account for large momentum transfer reactions, without the explicit introduction of partons. These models employ known particles and resonances, with inelastic processes described by bremsstrahlung, from the scattering hadrons, of massive neutral vector mesons (NVM), which themselves promptly decay into sprays of pions. Many recent experiments suggest that such hadronic bremsstrahlung models (h.b.m.) can provide a reasonable description of various reactions at increasing momentum transfers.

Calculations based upon this h.b.m. were long ago shown³ to provide an excellent two-parameter fit to all measured high-energy, wide-angle elastic pp scattering, together with a related expression for the proton electromagnetic form factors.⁴ Recently, similar predictions for other elastic and quasi-elastic hadronic reactions have been given in some detail.⁵ One finds formulae which are similar to, but in detail contrast with those based upon the parton interchange model;⁶ and it is not yet experimentally possible to distinguish between these different models. However, there are clear indications that the NVM/h.b.m. predictions of certain inelastic reactions do resemble the trends of new experimental data, and it is with three such processes that these remarks are concerned.

It should be emphasized that various formulations of the NVM/h.b.m. are possible, with slightly different approximations generating somewhat differ-

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ent results. There are two main reasons for this ambiguity: (i) the different ways of extracting soft, virtual NVM contributions to relevant integrals which, individually, would correspond to the logarithm of form factors; and (ii) the difficulty of generating explicit 4-momentum conservation while retaining manageable arithmetic approximations to those multiple integrals which describe inelastic NVM production. Item (i) produces answers which typically differ by one power of an appropriate logarithm, while difficulty (ii) is reflected in the apparent lack of precision in the definition of coupling constants for inelastic NVM production. In spite of the mathematical crudeness of these approximation techniques, the underlying physics is simple and intuitive; and may even be correct.

I. Associate Multiplicity

Recent experiments⁷ which count the number N of charged particles as a function of missing mass M and transverse momentum $p_{\perp}$ to the scattered proton, in the reaction $pp \rightarrow pX$, exhibit a gentle decrease and then a marked rise of N with increasing $p_{\perp}$, at all M except the very lowest. This increase of N with $p_{\perp}$ can be understood intuitively on the basis of the h.b.m., and the specific predictions previously made⁸ are easily evaluated (and approximated) for the present kinematical situation. One finds

$$N(p_{\perp}, M) = N_1(p_{\perp}, M) + \xi(M) \ln \left(1 + 4 p_{\perp}^2 / 1 - \frac{M^2}{s} \right) + O \left(\frac{p_{\perp}}{\sqrt{s}} \right),$$

where N_1 represents a slowly decreasing multiplicity expected from any multiperipheral-like mechanism significant only at low $p_{\perp}$; and the remaining terms display predicted effects of the h.b.m. Here, $p_{\perp}$ is to be measured in GeV/c, and the single $\log p_{\perp}$ behavior of N , at large $p_{\perp}$, reflects the simplest form of estimates as mentioned in (i) above; eventual asymptotic appearance of $\log^2 p_{\perp}$ dependence would not be at all surprising. The function $\xi(M)$ is somewhat approximation-dependent within the h.b.m., and displays the calculational uncertainty of item (ii). In reference 8 an estimate^{equivalent} $\xi \sim + \gamma_{el} (1 - \frac{M^2}{s})$

was made (where a $\gamma_{el} \simeq 2.3$ was previously used³ to fit elastic pp scattering), but this choice should not be taken too seriously; better computations within the model are needed.

Most of the present data are at $p_{\perp}$ and M values too small to test this predicted form of N with any precision. However, the general "two-component" feature of a slowly decreasing N_1 plus a rapidly rising $N - N_1$ component (which then slows to logarithmic growth) is certainly compatible with the existing data.

II. Inclusive Cross Sections

At large $p_{\perp}$ the one-proton inclusive distribution in the same reaction displays a power-like fall-off,

$$E \frac{d^2\sigma}{d^2p} \sim G(x_{\perp}) s^{-n},$$

where $x_{\perp} = 2 p_{\perp} / \sqrt{s}$ and $x_{\parallel} \simeq 0$. This behavior is found in both the parton interchange model and h.b.m.; but in the latter the power n was predicted to be an increasing function of $x_{\perp}$, an effect which is clearly present in the data.⁹ The specific choice of function adopted in reference 8, equivalent to the present use of $n = 2 + 4 x_{\perp} \gamma_{el}$, was the simplest choice possible, as described under ambiguity (ii). The values of γ_{el} here needed to fit these large $p_{\perp}$ curves are some 20 - 30% smaller than the corresponding elastic pp scattering value. But the effect - dependence of n on $x_{\perp}$ - should be there.

III. Deep Inelastic Scattering

Recently observed deviations from Bjorken scaling in the μp NAL experiment² suggest that some non-parton mechanism becomes important for sufficiently large ('truly asymptotic') values of q^2 and ν . At least three groups of authors^{10,11,12} have examined the non-scaling h.b.m. predictions for this reaction where one obtains a decreasing $\nu W_2(q^2, \omega)$ at fixed $\omega = 2m\nu/q^2$

and increasing q^2 . The first, crude estimates of reference 10 provide an example of the h.b.m. which, while satisfying the Drell-Yan-West relation, violates scaling in just the manner suggested by the new data.

If, as argued above, the h.b.m. becomes increasingly relevant for large momentum transfer reactions, how is one to understand the apparent Bjorken scaling in deep inelastic processes at non-asymptotic q^2 and ν ? Are there simple, non-parton mechanisms which can, similarly, match the SPEAR data? It would seem that reasonable speculations could be based upon a combination of h.b.m. together with the $\pi\pi\omega$ cascade idea of Islam¹³ and of Craigie and Rothe.¹⁴ For deep inelastic reactions, up to typically SLAC q^2, ν values, the incident lepton's energy is mostly used up in producing cascade pions (and, effectively, low energy NVM-proton scattering) in a manner which Islam has argued may produce effective Bjorken scaling. For larger q^2 , however, the h.b.m. becomes important and scaling is seriously violated. In the annihilation reaction, both the cascade and h.b.m. processes ($p\bar{p}$ production with subsequent bremsstrahlung of ω_s, ρ_s^0) among others must be included; and as Craigie and Rothe have shown, it is possible to have a reasonably constant cross section as q^2 increases. In fact, the really difficult question here is to understand precisely how, and at which q^2 , unitarity effects enter - as they must⁹ - to restore the truly asymptotic $(q^2)^{-1}$ dependence of the cross section. Detailed estimates remain to be performed; but the apparent success to date of the h.b.m. suggests that efforts may well be expended, with profit, in this direction.

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