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Left-Right Multiplicities and the Two-Component Model*

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Left-right multiplicities provide a more sensitive measure of the relative amount of diffractive dissociation in the total cross section than total multiplicity distributions. New 200-GeV/c left-right cross sections are found to be in qualitative agreement with the two-component model of Frazer, Peccei, Pinsky, and Tan.

Recently the 205-GeV/c pp bubble-chamber data[1] have been analyzed by Cho, Engelmann, Fields, Hyman, Singer, Voyvodic, and Whitmore to determine the "charged left-right multiplicity distribution."[2] That is, the cross sections for a pp collision at 205 Gev/c to produce an event with n_l charged prongs in the center-of-mass forward hemisphere and n_r charged prongs in the backward hemisphere, σ^{n_l, n_r}, were determined. As we shall see, these data provide a more sensitive test of the relative magnitudes of the diffractive dissociation and multiperipheral (short-ranged) components of the two-component model than do the total charged multiplicity distribution data, $\sigma^{(n)}$,[3]

$$\sigma^{(n)} = \sum_{n_l} \sigma^{n_l, n-n_l}.$$

Recently numerous analyses of the total charged multiplicity distribution have used various forms of the two-component model.[4,5] Here we will develop further and test the particular two-component model and fit of Frazer, Peccei, Pinsky, and Tan (FPPT).[5] Their model consisted mainly of a multiperipheral component (~80% of the inelastic cross section) but contained some diffractive dissociation in the low multiplicities. Actually almost all multiplicity models in the past have been two-component models, since, of the total cross section, they only claimed to fit the inelastic part. The elastic cross section has always been recognized as due to Pomeron exchange. FPPT allowed this Pomeron (P) exchange to contribute also to the low-multiplicity events (sometimes called quasielastic). However, once one allows this possibility it is nearly impossible, just from the multiplicity distributions, to decide what part of the inelastic cross section is generated by which mechanism. They used a questionable simplicity argument to do the separation. (Their article even contained another fit.) In place of this simplicity argument we will substitute the assumption that the mechanism producing diffraction is a factorizable Pomeron. We will see that their simplicity argument predicts about the same percent of diffraction as implied by the left-right multiplicity data and the factorizable-Pomeron assumption.

The left-right multiplicity distribution is particularly useful for determining relative amounts of the two components since P exchange only contributes to neutral partitions of the total charge into the two hemispheres. On the other hand, in the multiperipheral component charge exchange is as important as neutral exchange.

For instance, consider 6-prong events from pp collisions, say $pp \to pp2\pi^+2\pi^-$ + any π^0's. When n_l = 0, 2, 4, or 6 there must be at least one unit of charged transferred between the hemispheres. Neutral exchange (and double charge exchange) can contribute only to odd values of n_l. Thus for the distribution in n_l, for a fixed number of prongs, we expect to see a sawtooth pattern due to Pomeron exchange superimposed on the smoothly varying multiperipheral component. This will facilitate the separation of the two components.

The model of FPPT is

$$\sigma^{(n)} = \sigma_D^{(n)} + \sigma_{\mathrm{SRC}}^{(n)},$$

where n is the total number of prongs in the final state; D represents diffractive dissociation and SRC represents the short-ranged component. The multiperipheral or short-range component is

$$\sigma_{\mathrm{SRC}}^{(n)} = \sigma_M \frac{N^{(n/2-1)}}{(\frac{1}{2}n-1)!} e^{-N}.$$

N is the average number of negatives produced by this component, and was determined from fits of the high-multiplicity cross sections at 100, 200, and 300 GeV/c to be

$$N = -4.56 + 1.33 \ln s.$$

Since we are only comparing with data at 205 GeV/c we have $N = 3.36$. Their fit gave $\sigma_M = 28.6$ mb. FPPT also found the diffractive dissociation component, determined by subtraction, to be $\sigma_D^{(2)} = 2.0$ mb, $\sigma_D^{(4)} = 2.7$ mb, and $\sigma_D^{(6)} = 1.7$ mb independent of energy.

To calculate the left-right distribution for the multiperipheral (SRC) portion of the cross section we use the partition that the simplest multiperipheral model implies, a binomial partition.

However, there is some question about what the appropriate variable should be. If we were considering all the particles, since there always must be one particle in each hemisphere to conserve momentum, we might take $n_l - 1$ as the appropriate variable. But relying on the neutrals to conserve momentum we want to allow for the possibility that all the charged particles end up in one hemisphere. Thus we will simply take n_l and n_r as the variables. It is also interesting to note that, since there must be an even number of prongs overall, $\frac{1}{2}n$ (or $\frac{1}{2}n-1$) is the more natural variable for the over-all multiplicity distribution, but that, since a hemisphere can have odd or even number of prongs, n_l is the more natural variable there. We have then

$$\sigma_{\mathrm{SRC}}^{n_l, n_r} = \frac{(n_l+n_r)!}{n_l!\,n_r!}\frac{1}{2^{n_l+n_r}}\sigma_{\mathrm{SRC}}^{(n_l+n_r)}$$
$$= \tfrac{1}{4}\sigma_M e^{-N}(\tfrac{1}{4}N)^{(n_l+n_r)/2-1} \times \frac{(n_l+n_r)!}{n_l!\,n_r!\,[\frac{1}{2}(n_l+n_r)-1]!}\,.$$

This assumption of a binomial partition and the accompanying assumptions of the proper choice of variables are certainly simplifying assumptions. Probably no isospin-conserving multiperipheral model will make these exact predictions although most of those which are reasonably consistent with the charge transfer distribution data[1] can be expected to yield similar predictions.[6]

To calculate the left-right cross section for the diffractive component we will use factorization of the Pomeron pole. To do this we must include σ^{el} and calculate σ^{tot}. Hence we define

$$\sigma_{D\,\mathrm{tot}}^{(2)} = \sigma^{\mathrm{el}} + \sigma_D^{(2)} = 8.8 \text{ mb.}$$

We assume that the entire σ_D is quasielastic so that the dissociation products from one projectile stay in the corresponding hemisphere. Let "a" be the total Pomeron–proton–charged-particle (plus any number of neutrals) vertex squared. It contains the Ppp vertex squared, plus the $Ppp\pi^0$ and the $Ppn\pi^+$ amplitudes squared integrated over the internal variables, plus other squared amplitudes with more neutrals. Similarly we define b as the $pP \to 3$ charged particle "vertex" and c as the $pP \to 5$ charged particle "vertex."[7]

Then we must have from factorization

$$a^2 = \sigma^{\mathrm{el}} + \sigma_D^{(2)} = 8.8 \text{ mb,}$$
$$2ab = \sigma_D^{(4)} = 2.7 \text{ mb,}$$
$$b^2 + 2ac = \sigma_D^{(6)} = 1.7 \text{ mb.}$$

These yield $a = 2.97$ mb$^{1/2}$, $b = 0.45$ mb$^{1/2}$, and $c = 0.25$ mb$^{1/2}$.

From these we calculate the diffractive dissociation left-right multiplicity cross section, $\sigma_D^{n_l, n_r}$, to be

$$\sigma_{D,\mathrm{tot}}^{1,1} = 8.8 \text{ mb or } \sigma_D^{1,1} = 2.0 \text{ mb ,}$$
$$\sigma_D^{1,3} = 1.35 \text{ mb,}$$
$$\sigma_D^{1,5} = 0.745 \text{ mb,}$$
$$\sigma_D^{3,3} = 0.206 \text{ mb,}$$
$$\sigma_D^{3,5} = 0.114 \text{ mb,}$$
$$\sigma_D^{5,5} = 0.063 \text{ mb.}$$

To be consistent with FPPT one might set the last two cross sections above equal to zero since they only had diffractive contributions in the six- (and fewer-) prong cases. We will keep them to satisfy factorization. The comparison of the model with the data is shown in Fig. 1. Since $\sigma^{n_l, n_r} = \sigma^{n_r, n_l}$ only the results for $n_r \geq n_l$ are presented. One can see that the model explains the general trends in the data. In the high-multiplicity data, where only the SRC contributes, the data (roughly) show this smooth tendency toward the symmetric partition.

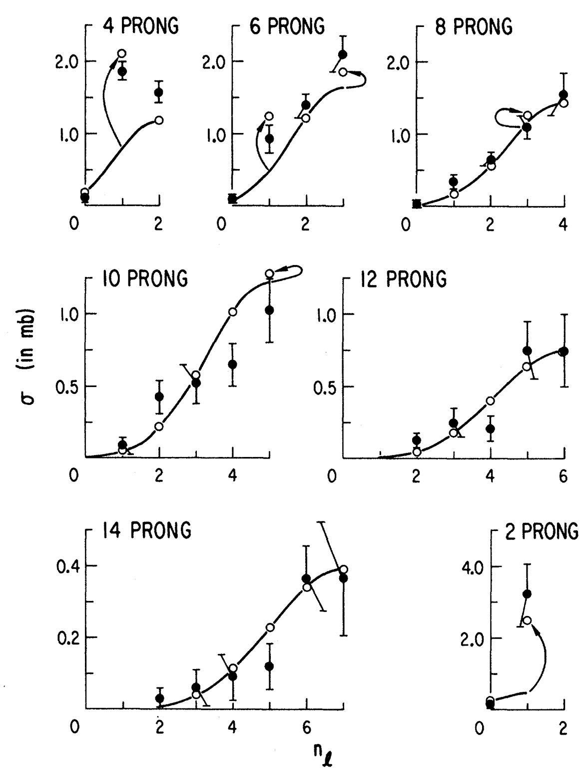

FIG. 1. The left-right cross section at 205 GeV/c. The open circles are the predictions of the two-component model. The smooth line is the contribution of the short-ranged component. The arrows indicate the increase from adding on the diffractive component.

However, the low-multiplicity data, for 2 and 4 prongs (and to a lesser extent 6 prongs), show the definite tendency to favor the odd partitions (which, we conjecture, are actually neutral partitions). We also see that the amount of diffractive dissociation added is about right. The χ^2 for the *test* is 50 for 30 degrees of freedom. We emphasize that this is a comparison or test, *not a fit*; there are *no* free parameters. Perhaps one could lower χ^2 by varying the a, b, and c parameters slightly, but it probably is not worthwhile with these data at only this energy.

Finally, we want to point out that within the context of a general multiperipheral model containing Pomeron exchange, the two-component model results as the zeroth-order term of an expansion in $g_{PPP} \ln s$.[8] Some of the implications of the first-order term, high-mass diffractive dissociation (the *third* component) for various effects have already been considered.[9] For the left-right multiplicity distribution the third component enters in about the same way as the second and thus is hard to distinguish. The only difference that will be evident in the left-right multiplicity is that the high-mass diffraction has a higher average multiplicity than the low-mass diffraction. Thus the indication of some diffractive dissociation in the six-prong events (near the average charge multiplicity), if true, is suggestive of the third component (high-mass diffractive dissociation). This would be consistent with a recent fit to exclusive data over an energy range including 200 GeV/c which needs a nonzero g_{PPP}.[10]

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[1]G. Charlton *et al.*, Phys. Rev. Lett. 29, 515 (1972).

[2]Presented by J. Whitmore at the Nashville conference, 1973 (unpublished). These data are preliminary and contain statistical errors only.

[3]Dennis Sivers and Gerald H. Thomas have also discussed in a general way the importance of left-right multiplicities [Phys. Rev. D (to be published)]. However they did not point out the distinguishing characteristics of different components: the charge transferred.

[4]K. Fiałkowski, Phys. Lett. 41B, 379 (1972); K. Fiałkowski and H. Miettinen, *ibid.* 43B, 61 (1973); H. Harari and E. Rabinovici, *ibid.* 43B, 49 (1973); L. Van Hove, *ibid.* 43B, 65 (1973).

[5]W. Frazer, R. Peccei, S. Pinsky, and C.-I Tan, Phys. Rev. D 7, 2647 (1973).

[6]Support, but not proof, for this conjecture can be found in Philip W. Coulter and D. R. Snider, this issue, Phys. Rev. D 8, 4055 (1973).

[7]To use factorization for cross sections instead of amplitudes we are assuming that all elastic and diffractive dissociation cross sections have about the same t_P dependence.

[8]H. D. I. Abarbanel, G. F. Chew, M. L. Goldberger, and L. M. Saunders, Ann. Phys. (N.Y.) 73, 156 (1972); M. Bishari and J. Koplik, Phys. Lett. B44, 175 (1973); W. R. Frazer, D. R. Snider, and C.-I Tan, Phys. Rev. D 8, 3180 (1973).

[9]W. R. Frazer and D. R. Snider, Phys. Lett. 45B, 136 (1973).

[10]F. Sannes *et al.*, Phys. Rev. Lett. 30, 776 (1973).