BEHAVIOR OF THE pp DIFFRACTIVE
CROSS SECTION WITH BOMBARDING ENERGY *

G. C. Bolon and L. S. Osborne

Physics Department and Laboratory for Nuclear Science
Massachusetts Institute of Technology
Cambridge, Massachusetts 02139

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We have analysed high energy proton-proton scattering data and found that cross sections for the low multiplicity component and the diffractive component, as measured by nucleon recoil, are consistent with being the same process. We explain these cross sections and the proton recoil spectrum using a core quark exchange model.

There is evidence for two processes in hadron-hadron scattering. The multiplicity distribution does not fit¹ a single Poisson distribution (PD); it can be fitted² by the sum of two Poisson distributions. Proton recoil spectra³ from the ISR show two distinct distributions in

$$Ed\sigma/dp_{||} = \int dp_{\perp}^2 Ed^3\sigma/dp^3.$$

The first (I) has a maximum at $|u|$ of about 0.5. (We use the symbol u for $p_{||}/p_{||, \max}$ instead of the more common x to avoid confusion with Feynman's x , used subsequently.) The second (II) peaks sharply near $|u|$ of about 1.0 (see Figure 1). It is kinematically reasonable to identify I with the PD which fits high multiplicities and II with the remaining non-Poisson distributed (NPD) cross section.

We have evaluated the NPD cross section, process I, from bubble chamber data^{4,5,6,7} for the inclusive interaction $pp \rightarrow pX$ at incident momenta of 50 to 405 GeV/c, using a method suggested⁴ by the UC Davis-LBL group. We fit the high multiplicity component to a PD, extrapolate the result to low multiplicities, and calculate the cross section corresponding to the extra yield.

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The low multiplicity events are not constrained to fit any particular distribution. Table 1 summarizes our results.

We have estimated the diffractive cross section, process II, from ISR data³ for $pp \rightarrow pX$ at 15.5 GeV beam energy. Although $Ed^3\sigma/dp^3$ distributions for secondary protons are well fitted by Gaussians in $p_\perp$ for $|u| < 0.8$ and $p_\perp < 1.0$ GeV, the fits are poor at higher values of $|u|$, and the slopes vs. $p_\perp$ are steeper³ in this region. We calculate $d\sigma/du$ by using at each value of u only the two points of lowest $p_\perp$, assuming a Gaussian.

To support identifying the NPD cross section with process II, we note that at an incident momentum of 405 GeV/c 89 percent of two-prong events and 72 percent of four-prong events contribute to $\sigma(\text{NPD})$; for these topologies, $d\sigma/du$ is strongly peaked¹⁰ at a value of $|u|$ near 1.0.

A relativistic oscillator model¹¹ can give a qualitative explanation of process I assuming valence quark exchange. We interpret process II as core quark exchange. We assume the probability $G(x)$ that a core quark has fractional momentum x to be proportional to $(1-x)^n/x$. The probability for a total fractional momentum change of $1-u = x+x'$ is given by

$$P(u)du \propto du \int G(x)G(x')d(x-x').$$

Given the form of $G(x)$, the leading behavior of $P(u)$ is

$$P(u) \propto du/(1-u). \quad (1)$$

The physical interpretation of this exchange is that it leads to two types of reaction:

The symbol p^* represents an excited nucleon. We argue that with either reaction the final nucleon exhibits the momentum loss from the quark interchange. This is evident in Reaction 1 but requires for Reaction 2 that meson emission from p^* not distort the u distribution. In any event, kinematics alone requires that Reaction 1 dominate for any proton with u near 1.0. Figure 2 shows the results of our analysis of the ISR data, and a curve fitted to the first eight points agrees with equation (1), yielding a fit with $\chi^2 = 6.5$ for 6 degrees of freedom.

The total cross section for our hypothesized mechanism is obtained by integrating $G(x)$,

$$\sigma(\text{NPD}) \propto \left[\int_{x_{\min}}^1 G(x) dx \right]^2, \text{ with} \quad (2)$$

$$x_{\min} = M^2 - M_0^2/s$$

M = minimum excited nucleon mass from Pomeron exchange

M_0 = proton rest mass

s = square of c.m. energy

We take M from the mass of $N(1520)$. The choice is not critical since it enters logarithmically.

Equation (2), normalized for best fit to the data, is plotted in Figure 3, together with the $\sigma(\text{NPD})$ results and the diffractive cross section derived from ISR data. We obtain the latter by assuming a $1/(1-u)$ dependence at $u > 0.8$. We double the number thus obtained to account for the equivalent interactions with u near -1.0 . For reaction 1, the effect is simply symmetric; for the less likely reaction 2, doubling is justified by the assumption that as many final state neutrons as protons result. The agreement between prediction and data is satisfactory with $n = 7$. Kuti and Weisskopf propose a model¹² with $n = 3$, but others have argued¹³ for $n = 7$.

We conclude that a model using core quark exchange can predict the proton recoil spectrum near $u = 1.0$ and a rise in the low multiplicity "diffractive" component of hadron-hadron interactions which appears proportional to $\log^2 s$.

Table I

p(lab)	Ref.	n Range (a) for fit	$\frac{n}{n_-}$ (b)	$\sigma(\text{NPD})$
50	5	1 - 6	$1.72 \pm .04$	0.4 ± 0.4
69	5	2 - 7	$2.08 \pm .03$	2.2 ± 0.4
102	6	2 - 7	$2.37 \pm .04$	3.2 ± 0.5
205	7	3 - 9	$3.36 \pm .07$	7.0 ± 0.6
405	6	4 - 11	$4.39 \pm .09$	9.7 ± 0.6

(a) n_- is the number of negative secondaries

(b) $\frac{n}{n_-}$ for the fitted PD component

2.7

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FIGURE CAPTIONS

Figure 1 A plot of $d\sigma/du$ versus u for protons from proton-proton collisions at the ISR³, $s = 960 \text{ GeV}^2$. The lines are the expected distributions from valence and core quark exchange.

Figure 2 A plot of $d\sigma/du$ versus u (data from Fig. 1) to illustrate the $1/(1-u)$ behavior of the diffractive portion of the cross section.

Figure 3 A plot of $\sqrt{\sigma(\text{NPD})}$ from Table I versus s . The highest point is from the ISR diffractive cross section. The curves are the predictions of a quark exchange model (equation 2) with $n = 3$ and $n = 7$.

REFERENCES

1. C. Bromberg, et al., Phys. Rev. Lett. 31, 1563 (1973)
2. J. Iach and E. Malamud, Phys. Lett. 44B, 474 (1973).
3. M.G. Albrow, et al., Nucl. Phys. B54, 6 (1973).
4. J. Erwin, et al., Phys. Rev. Lett. 32, 254 (1974).
5. V.V. Ammosov, et al., Phys. Lett. 42B, 519 (1972).
6. C. Bromberg, et al., Phys. Rev. Lett 31, 1563 (1973).
7. G. Charlton, et al., Phys. Rev. Lett. 29, 515 (1972).
8. S. Childress, et al., Phys. Rev. Lett. 32, 389 (1974).
9. F. Sannes, et al., Phys. Rev. Lett. 30, 766 and 31, 1527 and 1530 (1973).
10. J.W. Chapman, et al., Phys. Rev. Lett 32, 257 (1974).
11. L.S. Osborne, Phys. Rev. Lett. 34, 1106 (1975).
12. J. Kuti and V.F. Weisskopf, Phys. Rev. D4, 3418 (1971).
13. Glennys R. Farrar, Calif. Inst. of Tech, Research and Development Report CALT-68-422 (1974), unpublished.