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# Phenomenological Analysis of the Pomeron-$f$ Complex in Hadron Total Cross Sections*)

Avadis HACINLIYAN

*Department of Physics, Middle East Technical University, Ankara*

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Total cross sections in the range $6 \leq p_L \leq 280$ GeV/$c$ are phenomenologically analyzed in order to extract symmetry properties of the Pomeron-$f$ complex. The compatibility of a two component Pomeron with the second component contributing to $NN$, $\pi N$ and $KN$ cross sections in the ratio 9 : 4 : 2 is shown. It is found that $\omega$-$f$ exchange degeneracy critically depends on both $f$ and Pomeron universality. Finally, it is demonstrated that one may interpret the Pomeron contribution as an enhanced cut and the $f$ contribution as a half-enhanced cut as calculated by Gribov.

## § 1. Introduction

A phenomenological analysis of hadron total cross sections in the momentum range of 6 to 280 GeV/$c$ had been previously performed[1] in the framework of Lipkin's[2] "two component" Pomeron ansatz, using a universal functional form for the Pomeron contribution. Lipkin's second component had been identified with the $f$-trajectory contributions in the framework of the algebra of vertex strengths.[3] The data were found to be compatible with universality, but not totally compatible with exchange degeneracy. An extension[4)~6)] of the analysis to forward and non-forward differential charge-exchange cross sections by several authors established compatibility of the parameter values derived from total cross sections, and independently confirmed the absence of strong $\rho$-$A_2$ exchange degeneracy. Preliminary studies of forward elastic cross sections[7] confirm that a high value of $\alpha_f(0)$ is compatible with the data.

A more critical investigation of the $\omega$-$f$ exchange degeneracy situation is necessary for several reasons. The $\rho$-$A_2$ exchange degeneracy situation can easily be subjected to independent tests, since charge exchange cross sections dominated by $\rho$ and $A_2$ exist. On the other hand, the $f$-trajectory has the quantum numbers of the vacuum, and its decoupling will inevitably involve additional assumptions and models concerning the nature of the Pomeron. The important question is beyond the simple assumption of exchange degeneracy. An understanding of the dynamics underlying the increase of total cross sections at high energy and the symmetry properties of this increase, at least on a phenomenological level is involved here. It is the purpose of the present investigation to attempt a clarification

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of the connection between the universality of the Pomeron and $\omega$-$f$ exchange degeneracy, to examine certain clues that may elucidate the dynamical nature of the Pomeron-$f$ complex. Several important questions arise here. It has been recently suggested that the Pomeron and $f$ constitute a single object[8] with an energy dependent trajectory and $SU(3)$ coupling, and the object need not be universal. However, phenomenological investigations based on this proposal[9] indicate a two-component vacuum exchange, with the second component identified as the $f$ trajectory, which is taken to be exchange degenerate with the $\omega$. It is worthwhile to take the alternate viewpoint of stressing a universal Pomeron contribution à la Lipkin[2] and examining compatibility between it and exchange degeneracy. After all, it is well known that even $\rho$-$A_2$ exchange degeneracy which can be tested easily in $\pi N$ charge exchange reactions is violated, while universality of the individual non-vacuum Regge exchange holds very well. Furthermore, the $SU(3)$ content of this singularity as reflected by sum rules[10,11] assuming a second component coupling to the $NN$, $\pi N$ and $KN$ cross sections in the ratio 9:4:2 as investigated in Ref. 1), or a second component with a coupling proportional to the square of the hypercharge, 4:5:8 is also worth investigation. Finally, another important question is that of saturation of the Froissart bound. A recent model proposed by Gribov[12] interprets the increase in total cross sections as an effect arising from an enhanced cut. The functional form involved does not saturate the Froissart bound. Similar results have been also derived on the basis of the Reggeon calculus. In previous fits, forms with a logarithmic increase[1,5] or the equivalent[13] for the Pomeron had been used. It would be worthwhile to see how Gribov's proposal, when it is interpreted as a universal Pomeron contribution agrees with the data and how, half-enhanced cuts which also arize in the theory can be accomodated.

The plan of the paper is as follows. In § 2, we present and analyze our results about the symmetry property of the Pomeron-$f$ complex, and its consequences on the $\omega$-$f$ exchange degeneracy situation. Clues about the dynamical content of the Pomeron-$f$ complex are discussed in § 3. A brief summary of our results is presented in § 4.

## § 2. Symmetry properties of the Pomeron-$f$ complex

The unique and special place of the Pomeron among Regge trajectories has always been a matter of speculation. As mentioned above, the two questions that we shall try to answer here are the symmetry properties of the Pomeron and its dynamical nature. In this section, the symmetry properties will be investigated. Our attention will be directed at the following questions: Does the Pomeron have more than one distinct component? What is the $SU(3)$ nature of each component? Are the components universal, and what is the relation between this universality and exchange degeneracy.

The first question is easy to answer. It has been discussed by Lipkin,[2] Hendrick et al.,[5] Quigg et al.[9] and many others. It seems that, regardless of the viewpoint chosen, there are two distinct vacuum contributions (at least), although the nature of each contribution may be different in each viewpoint. The basic fact that sum rules involving the three cross sections are obeyed[10),11)] to within 1%, while individual quark model predictions are obeyed to within 15% means that a two-component vacuum exchange is highly plausible. This of course does not rule out the conjecture that the two components may have a common dynamical origin. This idea will be pursued in the next section.

Accepting that there is a two-component vacuum exchange, we now turn to the $SU(3)$ content of the second component. The empirical fact,

$$R_D=\frac{2\bar{\sigma}(\pi N)}{2/3\bar{\sigma}(NN)+\bar{\sigma}(KN)}=1.015\pm0.010 \tag{2·1}$$

first observed by Denisov[10] can be accounted for, by giving the Pomeron a second component coupling to the $NN$, $\pi N$ and $KN$ cross sections in the ratio 9:4:2. This was first proposed by Lipkin, and implies a definite symmetry structure for the second component.[1] On the other hand, the sum rule

$$R_Y=\frac{2\bar{\sigma}(\pi N)}{3/4\bar{\sigma}(NN)+7/8\bar{\sigma}(KN)}=0.991\pm0.013 \tag{2·2}$$

has recently been proposed.[11] This latter sum rule can be accounted for, by assuming a second component coupling to the $NN$, $\pi N$ and $KN$ cross sections in the ratio 4:5:8 respectively (proportional to $Y^2$). At first sight, $R_Y\cong1$ seems to be in better argreement with the data than $R_D\cong1$. However, if one tries to make an overall fit, parallel to the work of Ref. 1), using the functional forms

$$t_0=c_1+c_2\ln p_L\,, \tag{2·3}$$

$$t_i=t_i(0)p_L{}^{\alpha_i(0)}\,,\quad i=f,\rho,\omega,A_2 \tag{2·4}$$

$$C_f=a/\ln(p_L/p_0) \tag{2·5}$$

and the parametrization

$$\sigma(\bar{p}p)=6t_0+9t_f+t_{A_2}+9t_\omega+t_\rho+4C_f\,, \tag{2·6}$$

$$\sigma(pp)=6t_0+9t_f+t_{A_2}-9t_\omega-t_\rho+4C_f\,, \tag{2·7}$$

$$\sigma(\bar{p}N)=6t_0+9t_f-t_{A_2}+9t_\omega-t_\rho+4C_f\,, \tag{2·8}$$

$$\sigma(pN)=6t_0+9t_f-t_{A_2}-9t_\omega+t_\rho+4C_f\,, \tag{2·9}$$

$$\sigma(\pi^\pm p)=4t_0+6t_f\mp2t_\rho+5C_f\,, \tag{2·10}$$

$$\sigma(K^\pm p)=4t_0+3t_f+t_{A_2}\mp3t_\omega\pm t_\rho+8C_f\,, \tag{2·11}$$

$$\sigma(K^\pm N)=4t_0+3t_f-t_{A_2}\mp3t_\omega\pm t_\rho+8C_f\,, \tag{2·12}$$

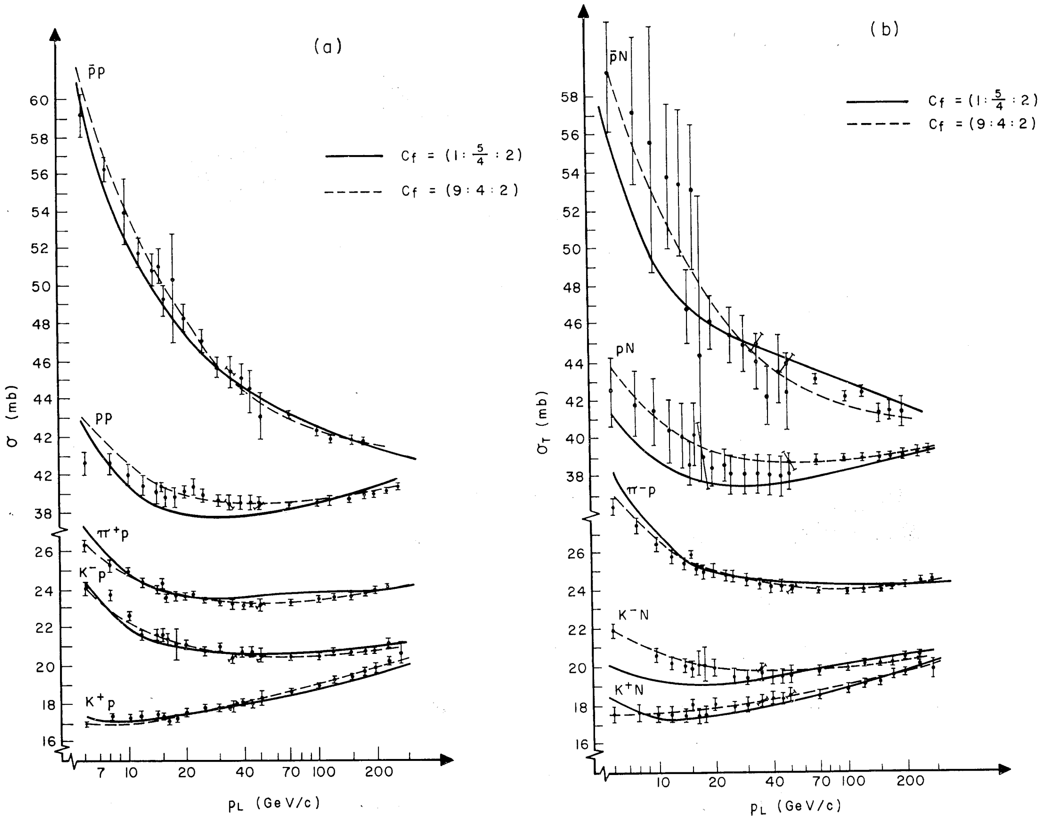


Fig. 1. (a) $\bar{p}p$, $pp$, $\pi^+p$, $K^+p$, $K^-p$ and (b) $\bar{p}n$, $pn$, $\pi^-p$, $K^-n$, $K^+n$ total cross sections in the range $6 \leq p_L \leq 280$ GeV/$c$ overplotted with our fit based on a second component contribution in the ratio (4 : 5 : 8). The fit of Ref. 1) based on a (9 : 4 : 2) contribution is shown by dotted lines for comparison. Data are from Refs. 14), 15), 16), 17).

we obtain the following fitted values for the parameters: $c_1 = 8.20 \pm 0.15$ mb, $c_2 = -0.126 \pm 0.020$ mb, $t_{A_2}(0) = 2.8 \pm 2.6$ mb, $\alpha_{A_2}(0) = 0.37 \pm 0.25$, $t_\omega(0) = 2.30 \pm 0.43$ mb, $\alpha_\omega(0) = 0.46 \pm 0.06$, $t_\rho(0) = 2.51 \pm 1.35$ mb, $\alpha_\rho(0) = 0.41 \pm 0.18$, $t_f(0) = 12.6 \pm 0.6$ mb, $\alpha_f(0) = 0.83 \pm 0.11$, $a = -11.86 \pm 1.55$ mb, $p_0 = 0.015 \pm 0.002$ GeV/$c$.
This fit, and the results of the fit of Ref. 1) (based on a second component contribution in the ratio 9:4:2) are presented in Fig. 1.

A few comments on this fit is in order. Total cross section data in the momentum range 6 to 280 GeV/$c$ were included in the fit,[14)~17)] the $\chi^2$ per degree of freedom is 4.4 if data from Ref. 15) are used with the actually reported errors, which excludes momentum independent, systematic scale errors, and is 1.9 if they are taken into consideration according to the estimates given there. (From now on, the value of $\chi^2$/d.f. with the systemmatic scale errors included will be written in parantheses, immediately after the actual value, for brevity.) It is clear that this fit is poorer than the fit of Ref. 1) based on a $C_f$ contribution in the ratio

9:4:2. Secondly, this fit does not completely restore $\omega$-$f$ exchange degeneracy, it is actually worse than the fit in Ref. 1), with weak $f$-$\omega$, $\rho$-$A_2$ exchange degeneracy forced ($\chi^2$/d.f. = 2.97(1.64)). Thirdly, it tries to simulate the increase in total cross sections by reversing the sign of the second component, and uses a decreasing contribution for the diffractive components. It is well known that such a contribution is not in agreement with the ISR data.

Under these conditions, we must look at the slightly better value obtained for this sum rule a bit closer. The standard deviation on the second sum rule is somewhat larger. This leads us to perform the following test; for both sum rules, fit the resulting value against $p_L$ (and $\ln p_L$) and determine the coefficient of correlation, $r$. If the sum rules were perfect, this should be as close to zero as possible. The results obtained are as follows: For a linear fit, we get

$$R_D = (1.011 \pm 0.027) + (5.586 \pm 3.070) \times 10^{-5} p_L\,, \quad r = 0.35\,, \tag{2·13}$$

$$R_Y = (0.9844 \pm 0.030) + (1.0754 \pm 0.3397) \times 10^{-4} p_L\,, \quad r = 0.55\,, \tag{2·14}$$

while, for a logarithmic fit, we get

$$R_D = (0.9996 \pm 0.0070) + (0.0041 \pm 0.0019) \ln p_L\,, \quad r = 0.42\,, \tag{2·15}$$

$$R_Y = (0.9623 \pm 0.0072) + (0.0080 \pm 0.0020) \ln p_L\,, \quad r = 0.65\,. \tag{2·16}$$

The logarithmic fits, together with the data, are presented in Fig. 2. Two properties of these results are interesting. First of all, the coefficient of the variable term is bigger by a factor of two in the case of $R_Y$. The error bars on the coefficient of the variable term is bigger in the case of $R_D$, and this supports the conjecture that it is more weakly correlated than $R_Y$. Secondly, the ratios of the correlation coefficients when squared give a value of 2.47 (2·40) for the linear (logarithmic) fit. This is close to the ratio of the $\chi^2$ values for the fit based on a (4:5:8) and that based on a (9:4:2) $C_f$ contribution. It thus becomes quite clear that the sum rule based on a current proportional to the square of the hypercharge leaves a residual correlation with $p_L$ and hence, will not yield a good fit to the individual data. The negative sign of the contributions is still another problem. We should therefore adopt, for the present, a two-component picture of the Pomeron, each contributing to $NN$, $\pi N$, $KN$ cross sections in the ratios (3:2:2) and (9:4:2). Furthermore, even with a second component proportional to the square of the hypercharge, $\omega$-$f$ exchange degeneracy cannot be maintained.

In accordance with the work of Ref. 1), we may now identify the second component as the $f$-trajectory. With this identification, we now look at the $\omega$-$f$ exchange degeneracy situation. To this end, we form the sums, $\Sigma NN$, $\Sigma \pi N$, $\Sigma KN$, which are related to the average cross sections used in the sum rules, and which include only Pomeron and $f$ contributions. For simplicity, we parametrize the Pomeron as a simple pole, with an intercept slightly greater than one.[13] For the $f$, we use two alternate hypotheses, a pole with $\alpha_f(0)$ between 0.7 and 0.9, which

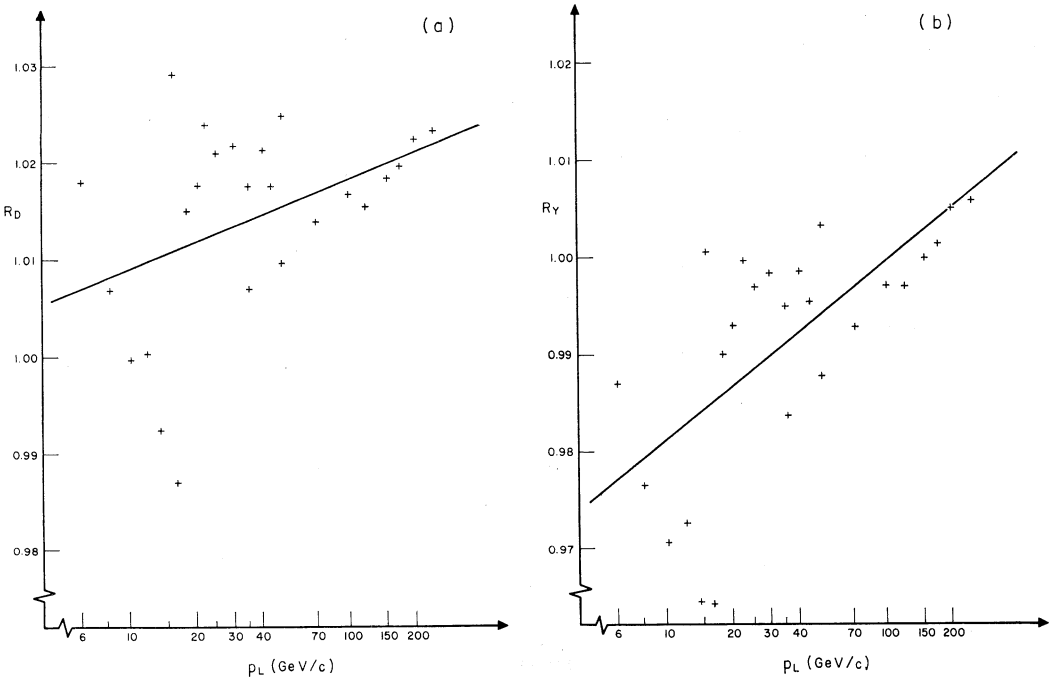


Fig. 2. (a) Values of $R_D$ and (b) values of $R_Y$ plotted against $\ln p_L$, together with our logarithmic regressions. Error bars are omitted to exaggerate the correlation. Data are from Refs. 14), 15), 16), 17).

Table I. Checks of $\omega$-$f$ exchange degeneracy by fitting $\sigma_{\text{tot}}=Ap_L{}^{\alpha_P(0)-1}+Bp_L{}^{\alpha_f(0)-1}$.

| $\sigma_{\text{tot}}$ | Chi-squared for Non Exch. Deg. Case | Chi-squared for Exch. Deg. Case |
|---|---|---|
| $NN$ only | 7.55 | 7.08 |
| $\pi N$ only | 18.15 | 21.51 |
| $KN$ only | 2.10 | 1.78 |
| $NN+KN$ | 23.31 | 85.90 |
| $NN+\pi N$ | 33.29 | 50.54 |
| $\pi N+KN$ | 55.24 | 123.26 |
| Combined | 98.59 | 209.62 |

corresponds to the non-exchange-degenerate case, and a pole with $\alpha_f(0)$ between 0.4 and 0.7, which corresponds to the exchange degenerate case. The relevant results of the fit are summarized below, in Table I.

It is very clearly seen that $NN$, $\pi N$ and $KN$ cross sections, when fitted individually, fit equally well in either case. However, as soon as one combines two or three different channels, the $\chi^2$ values for the non-exchange degenerate case are markedly superior. This implies that $\omega$-$f$ exchange degeneracy necessitates the abandonment of both Pomeron and $f$ universality. The significant difference between the $\chi^2$ values in favor of the non-exchange degenerate case for the $\pi N + KN$ combined fit, where the $t_0$ contributions to the individual channels are equal reinforces this conjecture.

We therefore conclude this section by the following remarks. Presently available data indicate that there is a "two-component" vacuum exchange with the $SU(3)$ properties indicated above and in Ref. 1). $\omega$-$f$ exchange degeneracy can only be maintained at the expense of abandoning Pomeron and $f$ universality. More quantitatively, an analysis is of variance based on the fits above gives a probability of $4\times10^{-5}$ for the compatibility of $\omega$-$f$ exchange degeneracy and Pomeron universality. The corresponding propability for $f$-universality varies between $2.3\times10^{-4}$ and 0.41, depending on whether or not we also insist on Pomeron universality simultaneously.

## § 3. Towards a dynamical interpretation of the Pomeron-$f$ complex. Is it a cut?

In the last section, we found that the total cross sections could adequately be described in terms of a two-component vacuum exchange. The first component contributed in the ratio of 3:2:2 to the $NN$, $\pi N$ and $KN$ cross sections and was a slowly increasing function. The second component contributed in the ratio of 9:4:2 and was a slowly decreasing function.

In this connection, two questions arise. First of all, is it possible that these two components may have a common dynamical origin? Secondly, can anything else be said about the slowly increasing and slowly decreasing functions mentioned above that may clarify their origin?

An indication of the truth of the first conjecture was already found in Ref. 1). There, in the overall fit with $\lambda=1$, the "second component" contribution was interpreted as a Pomeron-$f$-$f$ cut, while the usual $f$ contribution was interpreted as a Pomeron-$f$ cut. An attractive feature of this interpretation was that it enabled one to maintain weak $\omega$-$f$ exchange degeneracy and Pomeron universality simultaneously. On the other hand, it implied decoupling of the $f$ trajectory, and the existence of slowly decreasing cut contributions, rather than a high intercept for the $f$-trajectory.

A recent calculation of Gribov[12] enables one to carry the interpretation one step further. So far, the slowly increasing contribution to total cross sections was taken as a logarithmic increase. There is no a priori reason why the increase should be logarithmic. It is well known that a logarithmic increase would functionally saturate the Froissart bound. On the other hand, Gribov has calculated enhanced cut contributions on the basis of his Reggeon calculus, deducing an increasing contribution to total cross sections of the form

$$t_0=\sigma_0(\ln\zeta)^2, \tag{3·1}$$

where $\zeta$ is given by

$$\zeta = \zeta_0 \ln(E/E_0) = \zeta_0 \ln(p_L/p_0), \tag{3·2}$$

where $E$ is the energy, $E_0$ is a scale factor. The second form is asymptotically equivalent. This functional form clearly does not saturate the Froissart bound. Furthermore, it is a trivial fact that, by proper adjustment of the scale factor $E_0$, the increase in total cross sections can be simulated. However, Gribov also calculates a "half-enhanced" cut contribution of the form

$$t_f = t_f(0)/(\zeta \ln \zeta) \tag{3·3}$$

which is a slowly decreasing function. It is extremely attractive to take this slowly decreasing function as the "second component" contribution, since, except for an overall normalization, the functional form of the second component contributions is completely predicted from that of the first component. If such a conjecture fits the data well, it will also mean that the two components of the Pomeron have a common dynamical origin. This enhances the conjecture of Ref. 1) described above and clarifies the claim that the Pomeron and $f$ are in reality the same object. In our view, it is more attractive to assume universality plus a common dynamical origin, rather than an energy dependent coupling constant and trajectory in identifying the components of the vacuum exchange.

From Eqs. (3·1)$\sim$(3·3) one can derive the identity,

$$t_f^{-1} \cdot t_0^{-1/2} = (\zeta_0/(t_f(0)\,(\sigma_0)^{+1/2}))\,(\ln p_L - \ln p_0) \tag{3·4}$$

which means that, one can extract $t_0$ and $t_f$ using the symmetry properties derived in § 2, then fit $t_f^{-1} \cdot t_0^{-1/2}$ against $\ln p_L$. The regression works with a correlation coefficient of 0.99. Encouraged by this, we now try an overall fit of the forms

$$\sigma(\bar{p}_N{}^p) = 6t_0 + 9\lambda^2 t_f \pm t_{A_2} + 9t_\omega \pm t_\rho\,, \tag{3·5}$$

$$\sigma(p_N{}^p) = 6t_0 + 9\lambda^2 t_f \pm t_{A_2} - 9t_\omega \mp t_\rho\,, \tag{3·6}$$

$$\sigma(\pi^\pm p) = 4t_0 + 6\lambda t_f \mp 2t_\rho\,, \tag{3·7}$$

$$\sigma(K^\pm p) = 4t_0 + 3\lambda t_f + t_{A_2} \mp 3t_\omega \mp t_\rho\,, \tag{3·8}$$

$$\sigma(K^\pm N) = 4t_0 + 3\lambda t_f - t_{A_2} \mp 3t_\omega \pm t_\rho \tag{3·9}$$

with $t_0$ given by Eq. (3·1), $t_f$ given by Eq. (3·3) and

$$t_i = t_i(0)\, p_L{}^{\alpha_i(0)-1}, \quad i = A_2, \rho, \omega\,. \tag{3·10}$$

A very good fit, with $\chi^2$/d.f.$=2.95(1.28)$ is obtained with this parametrization, although the number of parameters involved in this fit is less than the corresponding number in other fits. The fitted values for the parameters are as follows: $p_0 = 0.0965 \pm 0.0087$ GeV/$c$, $\zeta_0 = 1.95 \pm 0.03$, $\sigma_0 = 0.584 \pm 0.044$ mb, $t_f(0) = 46.5 \pm 2.2$ mb, $t_{A_2}(0) = 2.4 \pm 1.2$ mb, $\alpha_{A_2}(0) = 0.38 \pm 0.25$, $t_\omega(0) = 2.61 \pm 1.20$ mb, $\alpha_\omega(0) = 0.433 \pm 0.115$, $t_\rho(0) = 1.27 \pm 0.46$ mb, $\alpha_\rho(0) = 0.587 \pm 0.080$, $\lambda = 1.39 \pm 0.05$. From this fit, it is quite clear that $\rho$-$A_2$ exchange degeneracy is barely supportable within one standard deviation, while $\omega$-$f$ exchange degeneracy is not even supported, $f$

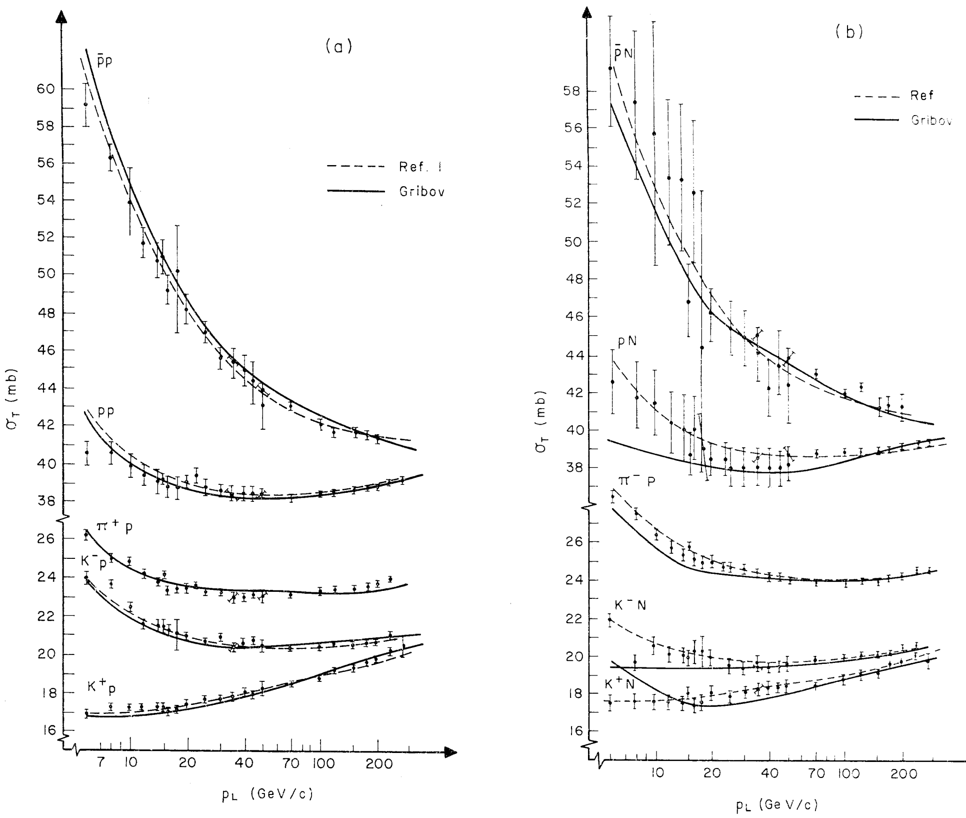


Fig. 3. Same data as in Fig. 1, comparing the fit based on the Gribov (Ref. 12)) parametrization and the fit of Ref. 1) (dotted lines).

is a cut and not a pole. The results of this fit are compared with the data and with the fit of Ref. 1) in Fig. 3.

To ascertain the cut nature of the $f$ contribution a bit more clearly, we repeat the above fit, by assigning a polelike contribution (Eq. (3·10)) for $f$. Although we now have an additional free parameter, the fit is much worse in this case. The $\chi^2$/d.f. value is 7.0 (2.9) and the parameter values are $p_0 = 0.062 \pm 0.007$ GeV/$c$, $\zeta_0 = 1.86 \pm 0.09$, $\sigma_0 = 0.582 \pm 0.018$, $t_f(0) = 31.5 \pm 2.3$ mb, $\alpha_f(0) = 0.794 \pm 0.019$, $t_{A_2}(0) = 2.8 \pm 1.3$ mb, $\alpha_{A_2}(0) = 0.38 \pm 0.26$, $t_\omega(0) = 2.87 \pm 0.38$ mb, $\alpha_\omega(0) = 0.415 \pm 0.027$, $t_\rho(0) = 1.36 \pm 0.30$ mb, $\alpha_\rho(0) = 0.63 \pm 0.09$, $\lambda = 1.39 \pm 0.08$. In both of the above fits, $\lambda$ is a parameter related to the admixture of $D$-type coupling at the nucleon vertices, as described in Ref. 1).

Two things are quite clear here. First of all, unlike the fits in Ref. 1) where it made little difference whether $f$ was taken as a pole or cut, here, the Gribov picture is quite self-consistent. A simple pole for $f$ is not supported by the data, if the Pomeron is interpreted as an enhanced cut. Secondly, even if one forces a pole picture for $f$, its intercept is quite different from that of $\omega$,[18),*)] meaning that $f$ is not a simple pole which is exchange degenerate with $\omega$. It is a cut and very probably, shares a common dynamical origin with the Pomeron.

Another highly speculative piece of evidence for the two component vacuum exchange, and the cut nature of it is the fact that at 19 GeV/$c$, the $\psi P$ cross section is about 1 mb. Although this suppression is very probably a threshold effect, it may also be viewed as a cancellation between the two components. To this let us take the three diagonal $SU(4)$ matrices as follows:

$$I=\begin{bmatrix}1&0&0&0\\0&-1&0&0\\0&0&0&0\\0&0&0&0\end{bmatrix},\quad S=\begin{bmatrix}1&0&0&0\\0&1&0&0\\0&0&-2&0\\0&0&0&0\end{bmatrix},\quad C=\begin{bmatrix}1&0&0&0\\0&1&0&0\\0&0&1&0\\0&0&0&-3\end{bmatrix}. \tag{3·11}$$

The Pomeron coupling to $NN$, $\pi N$, $KN$, $\psi N$ is taken to be proportional to the number of quarks, (3:2:2:2). For the second component, we have two alternatives, either construct the operator

$$T=5I/2+3S/2+5C \tag{3·12}$$

which gives 9:4:2 for non-charmed channels, and gives $-15$ for the charmed channel, or construct the operator

$$F=\tfrac{1}{2}(I+S)+2C \tag{3·13}$$

which generalizes the $\lambda=1f$ contribution to the charmed channel as $(3:2:1:-6)$. The second component, in this case is interpreted as a Pomeron-$f$ cut, with contribution $(9:4:2:-12)$. We see that, with either alternative, the $\psi N$ cross section will be suppressed by cancellation between the two components. More quantitatively, when the second alternative is supplemented with the Gribov fit of this section (after proper adjustment of the normalization of $t_0$ by 2 and $t_f$ by $1/\lambda$) yields a prediction of $1.2\pm0.4$ mb for the $\psi N$ cross section at 19 GeV/$c$. The corresponding number at 100 GeV/$c$ is $6.1\pm0.5$ mb. The hypothesis that the second component contributes in the ratio (4:5:8), when similiarly generalized, does not yield such a cancellation, since the sign of the second component is reversed. Although there are several assumptions behind this above-mentioned claim of cancellation, which may cast serious doubts about its validity, it still remains as an interesting remark.

It has been mentioned that [19)] the ln(ln $E$) increase in the Pomeron contributions is not sufficient to explain the 4 mb increase in the $pp$ total cross sections at the ISR energies ($291\leq p_L\leq 1500$ GeV/$c$). Indeed, using our parametrization, which fits the $pp$ cross section very well at 280 GeV/$c$, we find an increase of

*) The high value of $\alpha_f(0)$ was first derived using intermediate energy data by Kantarovich et al.

only 2.3 mb. It is possible to find a fit to $pp$ cross sections in the range $6 \leq p_L \leq 1500\,\mathrm{GeV}/c$ using the parametrization of this section, with a $\chi^2$/d.f. value of 0.9. However, this may be an accident, since there are dominantly negative Regge trajectory contributions in this channel, and if these decrease sufficiently rapidly, the required increase can be simulated. This conjecture is supported by the fit.

In order to settle the issue of whether or not Pomeron contributions should saturate the Froissart bound, we therefore need higher energy data in channels other than the $pp$, so that we can separate Regge and Pomeron contributions. Of course, it may then be still possible to represent a faster increase by means of Born terms which remain valid for restricted momenta range and superficially violate the Froissart bound at that range. However, the internal consistency of the Gribov picture for the Pomeron-$f$ complex (with "enhanced" cut contributions for the Pomeron and "half-enhanced" contributions for the second component) should be taken as evidence for interpreting the Pomeron-$f$ system as a cut of some sort, even if the nature of the cut may be different from Gribov's detailed conjecture.

## § 4. Conclusions and discussion

Although the conclusions were discussed at the end of the sections, we briefly repeat and summarize them here.

In this work, we have analyzed the total cross section data in order to learn about the phenomenology of the Pomeron-$f$ complex. We have found that, available data support the two component theory of the Pomeron as first proposed by Lipkin.[2] The $SU(3)$ structure of the second component has been phenomenologically analyzed, the results favor a second component contribution to the $NN$, $\pi N$, $KN$ channels in the ratio 9:4:2 respectively. The recently proposed sum rule[11] based on contributions in the ratio 4:5:8 is not in equally good agreement with the data.

The total cross section data do not completely rule out $\rho$-$A_2$ exchange degeneracy, because of the large experimental errors present in the difference from which $A_2$ contributions are extracted. However, that exchange degeneracy is still beyond one standard deviation.

It is clearly seen that $\omega$-$f$ exchange degeneracy can only be maintained at the expense of abandoning Pomeron and $f$-universality (if the $f$ is interpreted as the second component). The theoretical reason behind this conclusion is very probably the fact that the second component is not a simple pole. Although $f$ has distinctly different symmetry properties from the Pomeron, it very probably shares a common dynamical origin with it.

Although, at this stage, it is too early to claim an understanding of the dynamics behind the Pomeron-$f$ complex, we would like to report that Gribov's[12] calculation of enhanced cut effects is an encouraging step in that direction. Gribov's picture also has a certain degree of self-consistency insofar as "half-enhanced" cuts calculated in that model serve as a much better representation of the "second component" than a simple pole. Another meaning of this result is that the increase seen in total cross sections need not saturate the Froissart bound. Of course, this last statement must be treated with caution, since a slowly increasing function in a finite domain can be represented in several ways, and we definitely need data at higher energy to make a clear-cut determination, particularly when the $pp$ ISR data is given due to consideration. On the other hand, evidence for interpreting the Pomeron-$f$ system as a cut is quite strong. In spite of this, we feel that Gribov's result is an important step in clarifying the dynamical nature of the Pomeron, and is in good agreement with the available total cross section data at FNAL energies.

There are several extensions of this work. One is to examine closely sum rules derived from various symmetry and broken symmetry considerations. A far more important application would be to look at elastic forward and nonforward differential cross sections, in order to further clarify the dynamical nature of the Pomeron-$f$ complex. Preliminary analyses confirm[7),20)] our findings. A truly detailed investigation is beset with theoretical difficulties such as the compensation mechanism, the momentum transfer dependence of the residue functions, possible lower trajectory contributions etc. Furthermore, there are technical difficulties such as selection of a proper energy and momentum range, and data in that range so that the analysis can be completed accurately, using a reasonable amount of automatic data processing. Such work is in progress.

The relative merits of universality and exchange degeneracy is another important point that needs to be clarified. It is clear that for this clarification, theoretical work beyond the phenomenological level, leading to a better understanding of the Pomeron-$f$ system is needed.

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