PHENOMENOLOGICAL STUDY OF HIGH ENERGY EXCHANGESBASED ON MULTIPERIPHERAL IDEASC. Ferro Fontan ^{*)}, L. Masperi ^{**)}

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We observe that typical P' pole parametrizations in the intermediate energy range are globally dual to the combination of integrated elastic cross-sections with vacuum quantum numbers in the t channel. Since in simple multiperipheral models this elastic part is related to a cut, we abandon the usual interpretation of P' as a pole and propose a cut parametrization for the second vacuum singularity, considering the Pomeron as the leading pole. This new picture agrees with all accepted ideas, such as EXD, for energies less than ~ 10 GeV. Moreover, it is quantitatively satisfactory up to the highest energies.

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Several years ago, the ABFST multiperipheral model ¹⁾ suggested that the inelastic contributions to the unitarity equation build up the asymptotic behaviour which corresponds to a Regge pole, whereas the elastic part seemed to be related to more complex singularities in the J plane, i.e., cuts. The same scheme for the vacuum exchanges emerged from a simple multi-Regge model ²⁾ where a Regge pole (the Pomeron) accounted for the shadow of all open inelastic channels while a cut represented the elastic contribution to the unitarity sum. Regarding the non-vacuum exchanges, it has been noted ³⁾ that at $t = 0$ the ρ Regge pole seems to be dual to the part of the non-flip amplitude which is built from the difference of the inelastic cross-sections for π^-p and π^+p scattering. This is related to the scheme of "annihilation duality" ⁴⁾.

The phenomenological study we present here is based on the following empirical observation : typical P' pole parametrizations ⁵⁾ in the intermediate energy range reproduce, in the global duality sense, the combinations of total (integrated) elastic cross-sections with the quantum numbers of the vacuum in the crossed channel. At this point, one wonders whether the second vacuum singularity is really a pole or, in the spirit of multiperipheralism, it is a more complex singularity which, at intermediate energies, behaves as a pole with an intercept of $\frac{1}{2}$ ⁶⁾. We examine this second possibility and find that it does not contradict any of the accepted ideas, as for example exchange degeneracy, if the energy is not very large. Moreover, we have been fairly successful in reproducing the features of Serpukhov total cross-sections. In particular, the rise of the K^+p σ_T is explained with a natural mechanism for the breaking of exchange degeneracy. Finally, we are able to predict reasonable values for the total elastic cross-sections up to the highest energies.

We start separating the unitarity relation for forward scattering into two parts, corresponding to elastic or inelastic intermediate states

$$\text{Im } F_{el}^{(\pm)}(\nu, t=0) = \frac{p_L}{2} (\sigma_{\bar{X}p}^{el} \pm \sigma_{Xp}^{el}), \quad (1)$$

$$\text{Im } F_{inel}^{(\pm)}(\nu, t=0) = \frac{p_L}{2} (\sigma_{\bar{X}p}^{inel} \pm \sigma_{Xp}^{inel}), \quad (2)$$

where $\nu = \omega_L$ and p_L are respectively the lab energy and momentum of the incident X (or $\bar{X}$) particle. We choose to include $\sigma_{ch.exch.}$ into $\sigma_{\bar{X}p}^{el}$. Clearly the complete amplitudes are $F^{(\pm)} = F_{el}^{(\pm)} + F_{inel}^{(\pm)}$

We have evaluated the amplitudes of Eqs. (1) and (2) with experimental data ⁷⁾ in the intermediate energy range for the best known processes, i.e., $\pi^\pm p$, $K^\pm p$, pp and $\bar{p}p$. In all cases it turns out that $F_{el}^{(-)} \approx 0$, a well-known fact that can be explained in the framework of the dual absorptive model ⁸⁾.

In Figs. 1, 2, 3 we compare them with the current Regge parametrizations ⁵⁾ of the complete amplitude

$$\text{Im } F^{(\pm)}(\nu, t=0) \rightarrow \sum_i \beta_i(t=0) \nu^{\alpha_i(t=0)} \quad (3)$$

These figures give support to a global duality of the type

$$\begin{aligned} \text{Inelastic part} &\Leftrightarrow \text{Regge poles } \rho, \omega, P \\ \text{Elastic part} &\Leftrightarrow P'. \end{aligned} \quad (4)$$

This idea can be tested numerically by means of FESR. We have found that they are always satisfied within 10%. It is also interesting to observe the relations among cross-sections which arise by imposing the compatibility of our scheme with exchange degeneracy between P' and ω :

$$\sigma_{K^-p}^{\text{inel}} - \sigma_{K^+p}^{\text{inel}} = \sigma_{K^-p}^{\text{el}} + \sigma_{K^+p}^{\text{el}} \quad (5)$$

$$\sigma_{\bar{p}p}^{\text{inel}} - \sigma_{pp}^{\text{inel}} = \sigma_{\bar{p}p}^{\text{el}} + \sigma_{pp}^{\text{el}} \quad (6)$$

Equation (5) is experimentally well satisfied for $3 \text{ GeV} \leq \nu \leq 8 \text{ GeV}$, whereas the right-hand side of Eq. (6) turns out to be about twice the left-hand side in the same range, discrepancy which is likely due to the failure of exchange degeneracy in NN collisions.

We now turn our attention to the high energy data. The flatness of the elastic cross-sections, as said before, constrains us to allow for a more complicated singularity for P' to maintain the correspondence (4). As suggested by the multipheripheral calculations, we should represent P' by a cut starting near $J = 1$, or, more economically, by a finite number of poles

with the leading one very near the Pomeron. It is clear that in a fit of total cross-sections these two poles cannot be separated, but we can achieve this goal just imposing one σ_{el} point, say at 5 GeV, to be reproduced by P' in agreement with the correspondence of Eq. (4).

Therefore we fitted the total cross-sections (including the Serpukhov data ⁹⁾) and one point for elastic cross-sections with a parametrization consisting of Regge poles P , ρ and ω and several possible representations for P' . Since for all of them the results were very similar, for simplicity we quote here only the two-pole picture, as it is seen in the Table. For comparison, we also give the representative values for the parameters taken from the literature and used in Figs. 1, 2 and 3. The parameters of the vector meson exchange are well determined by the difference of total cross-sections; the values of residue and intercept that we obtained are (3.24, 0.54) for πN , (7.62, 0.52) for KN and (27.2, 0.40) for NN . The fit of total cross-sections with our parameters is given in Fig. 4. Its most interesting feature is the rise of K^+p total cross-section in the Serpukhov range. At variance with other mechanisms ¹⁰⁾, we explain this fact by a breaking of the exchange degeneracy between ω and P' . This comes from the high intercept component of our P' which takes over at high energy. However, we recall that this exchange degeneracy is still good at intermediate energy. In Fig. 5, we show our prediction for the total elastic cross-sections. We see that in all cases the results are fairly good and a comparison with Figs. 1c, 2c, 3c shows that the parametrization for σ_{el} joins rather smoothly with the usual P' pole at intermediate energy. It has to be remarked, however, that in the nucleon-nucleon case it was not possible to determine the residue of Pomeron even by imposing the above constraint of σ_{el} at 5 GeV; therefore, we took the P residue fixed at the value given in the literature, determining by the fit only the P' parameters.

A word of caution has to be said regarding the naive extrapolation of our simple model to the highest energies (ISR) despite the encouraging agreement of our prediction for the asymptotic pp elastic cross-section and the experimental measurement ¹¹⁾ at $\sqrt{s} = 492$ GeV. In fact, a more careful examination of the multiperipheral ideas has shown ⁶⁾ that the scheme supplied by Ref. 2) is only valid if the effects of the weakly coupled internal Pomeron, related to diffraction dissociation and to the triple-Pomeron vertex, are neglected. At ISR energies, terms of the first order in the internal Pomeron coupling could be important since theoretical arguments ¹²⁾ can explain with them the behaviour of the slope of the diffraction peak in pp elastic scattering.

In conclusion, we do not claim to have a model for high energy scattering. Our aim was just to show how the gross features of experimental data can be explained equally well using rather unusual ideas, closer to the multiperipheral bootstrap. Finally, it is interesting to point out that in the framework of the present paper, the "f coupled Pomeron" hypothesis ¹³⁾ or "f to P universality" is equivalent to the statement that the ratio σ_{el}/σ_T becomes a universal parameter at high energies, after neglecting the annihilation channels.

ACKNOWLEDGEMENTS

We are grateful to Dr. A. Garcia for many discussions. Thanks are also due to Professor D. Amati and Professor J.R. Fulco for stimulating conversations. One of us (C.F.F.) acknowledges the hospitality at Centro Atomico Bariloche during the first part of this work. Finally, two of us (C.F.F. and L.M.) wish to express their gratitude to the Theoretical Study Division at CERN for the hospitality extended to them.

	Parameters from present fit				Parameters from literature 5)		
	β_P	A	B	α	β_P	$\beta_{P'}$	$\alpha_{P'}$
πN	20.8	1.35	11.1	0.48	21.5	16.8	0.41
K N	16.8	2.13	7.67	0.06	16.8	5.9	0.62
N N	33.0	6.83	55.6	0.08	32.9	35.8	0.58

TABLE

Vacuum singularities determined from present fit of high and low energy total cross-sections and elastic cross-section at ~ 5 GeV are confronted with parametrizations available in the literature. In our fit, apart from the Pomeron, we consider a singularity $A + B \sqrt{s}^{\alpha-1}$ identified with σ_{el} . Normalizations are taken according to Eqs. (1)-(3), and residues are given in $[\text{mb GeV}]$.

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FIGURE CAPTIONS

Figure_1 Comparison of $\pi^\pm p$ amplitudes for $t = 0$ at intermediate energies with Regge poles. The solid curves represent the experimental data ⁷⁾, the dashed lines are standard Regge contributions ⁵⁾.

(a)

$$\text{Im } F_{\text{inel}}^{(-)} = \frac{1}{2} p_L (\sigma_{\pi\bar{p}}^{\text{inel}} - \sigma_{\pi^+p}^{\text{inel}}) \quad \text{vs. } \rho \text{ pole};$$

(b)

$$\text{Im } F_{\text{inel}}^{(+)} = \frac{1}{2} p_L (\sigma_{\pi\bar{p}}^{\text{inel}} + \sigma_{\pi^+p}^{\text{inel}}) \quad \text{vs. } P;$$

(c)

$$\text{Im } F_{\text{el}}^{(+)} = \frac{1}{2} p_L (\sigma_{\pi\bar{p}}^{\text{el}} + \sigma_{\pi^+p}^{\text{el}}) \quad \text{vs. } P'.$$

Figure_2 The same comparison for $K^\pm p$ amplitudes.

Figure_3 The same comparison for $\bar{p}p$ and pp amplitudes.

Figure_4 Fit of high energy total cross-sections with vacuum exchange parameters from the Table. Residues and intercepts for ρ and ω are given in the text.

Figure_5 Predictions for the average of total elastic cross-sections given by parameters of the Table. Curves show our predictions :

-. - . - . $\pi^\pm p$; - - - - - $K^\pm p$, ——— $p(\bar{p})p$.

Points are indicative experimental data :

$\otimes$ $\pi^\pm p$, $\odot$ $K^\pm p$, $\bullet$ $p(\bar{p})p$.

At ISR energies we assumed $\sigma^{\text{el}}(pp) = \sigma^{\text{el}}(p\bar{p})$.

FIG.1

FIG.2

FIG.3

FIG. 4

FIG.5