ATTEMPT AT A REGGE POLE-REGGE CUT DESCRIPTION
OF HIGH ENERGY π N SCATTERING⁺

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ABSTRACT

An attempt is made to fit near forward differential and the full known range of total π N cross sections by a Regge pole-Regge cut model. Possible explanations for the failure of this are discussed.

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1. Introduction.

Ever since the Serpukhov very high energy total cross section data was released¹, various attempts have been made to explain the unexpected features of it. Some explanations involve unconventional models containing baryon ionization², complex Regge poles³, or general failure of the Pomeranchuk theorem⁴. Others keep the Pomeranchuk theorem and use conventional Regge pole theory with cuts added. It is this group to which we give our attention.

2. Classification of Regge Cut Models.

Regge cut absorption models⁵ fall into several classes. One class is the so-called weak or Argonne cut⁶. Here the cut strengths are determined from the absorption model by the pole strengths. The pole residue functions generally include zeroes at wrong signature nonsense points. Dips are generated by cuts only partially filling in pole zeroes.

Another class is the so-called strong or Michigan cut⁷. Here the absorption model cut strengths are increased by a factor $\lambda \approx 2$ to account for the contributions of inelastic intermediate states produced by diffractive dissociation. The pole residues are smooth functions having no zeroes. Dips and bumps are generated by strong interference between poles and cuts⁸.

A third class of cuts is that used by the Barger group⁹. They have applied this to the full range of total cross section data. Their cut is a vacuum-vacuum cut given by a general functional form not explicitly derived from the absorption model. Specific parameters are adjusted to fit data.

3. Description of Model.

Each of the cut models discussed above has been successful in fitting data for particular types of reactions. However we feel that these contain certain unphysical features. So, in our attempt to fit scattering data we use a model containing only well known and generally accepted features. To this end we (1) keep pole zeroes at wrong signature nonsense points, (2) use exchange degeneracy to reduce the number of free parameters, (3) explicitly use the absorption model for calculating raw cuts, but (4) allow the full cut to be the raw multiplied by an adjustable λ factor. We further demand that our model fit both near forward differential and total cross section data. We shall also see how various symmetry predictions [SU(3) or SU(6)] compare to our fits.

For simplicity only pion-nucleon elastic scattering in) (the range 10-65 Gev is considered. The scattering amplitudes are the usual A' (nonflip) and B (flip) of Singh¹⁰. These are given by

$$\begin{aligned} A' &= A'_P + \lambda_A A'_C \\ B &= B_P + \lambda_B B_C \end{aligned} \tag{1}$$

Here A'_P is the sum of three Regge pole terms - Pomeron, f and ρ . A'_C is the cut contribution, an integral over A'_P and B_P , given by the absorption model¹¹. Likewise for B . The λ 's are the cut weighting factors. The j th pole amplitude is parameterized by

$$\begin{aligned}
 A'_{Pj} &= - C_{0j} \alpha_j(\alpha_j+1) e^{C_{1j}t} E^{\alpha_j} \frac{e^{-i\pi\alpha_j + \gamma_j}}{\sin\pi\alpha_j} \\
 B_{Pj} &= - D_{0j} \alpha_j(\alpha_j+1) e^{D_{1j}t} E^{\alpha_j-1} \frac{e^{-i\pi\alpha_j + \gamma_j}}{\sin\pi\alpha_j}
 \end{aligned} \tag{2}$$

multiplied by the appropriate isospin factor. E is the pion lab energy in Gev, t the square of the momentum transfer, γ the signature. C_0, C_1, D_0, D_1 are adjustable constants. Exchange degeneracy relates the f and ρ pole parameters by

$$\alpha_{\rho}(t) = \alpha_f(t) \quad C_{1\rho} = C_{1f} \quad D_{1\rho} = D_{1f} \tag{3}$$

All trajectories are taken as linear - $\alpha(t) = \alpha(0) + \alpha't$. The ρ - f is given the popular form $\alpha(t) = .56 + t$ with t in $(\text{Gev}/c)^2$. The Pomeron is constrained to $\alpha(0) = 1$. The $\alpha(\alpha+1)$ factor is a good approximation at the small t values considered here to the usual gamma function used to generate zeroes at wrong signature nonsense points. The free parameters of our fits are - $C_{0\rho}, D_{0\rho}, C_{1\rho}, D_{1\rho}, C_{0f}, C_{0\rho}, D_{0f}, C_{1\rho} = C_{1f}, D_{1\rho} = D_{1f}, \alpha'_P, \lambda_A, \lambda_B$.

The very complex $t \neq 0$ cut integrals were done by mapping the parabola-bounded kinematic region in t -space into a rectangular strip, and then performing a numerical integration over the strip. Fitting was done using a general function-minimization routine.

4. Results and Discussion.

We consider first just the total cross section. A sample of 35 data^{1,12} in the range 12-65 Gev was used. Reasonable fits were fairly easy to find. Parameters for two of these are shown in the table labelled I and II. I corresponds to a weak cut with $\lambda \approx 1$, II to a strong cut with $\lambda \approx 2$.

Next we give an example of a fit to a set of 39 differential cross section data¹³ in the range 10-17 Gev ($|t| < 1$ (Gev/c)²) plus 12 total cross section data¹² in the range 11-20 Gev. A solution with the cut strength held near $\lambda = 1$ is shown as III in the table. Fits I-III serve only to illustrate the ability of our model to fit restricted data sets. Minimization in these was not carried to completion due to the complexity and thus expense of the numerical computations.

Fitting was next done to the data of III and all total cross section data above 20 Gev, i.e., highest available energy differential plus the full range of total cross section data. Again minima in χ^2 were found for various values of the adjustable parameters. However, these solutions were always of very poor quality. Solution IV in the table was the best found. It is shown in figures 1 and 2. This solution fails in the usual way by falling too fast at very high energies.

It may be interesting to remark that SU(6) symmetry implies the relations

$$R_N \equiv \frac{C_{of}}{C_o} = 3 \quad (4)$$

$$R_F \equiv \frac{D_{of}}{D_o} = .6 \quad (5)$$

Equation (4) also follows from SU(3) symmetry, exchange degeneracy, and vector dominance. In spite of the inadequacy of our fits as far as the highest energy total cross sections are concerned, it is clear from the table that relation (4) is well obeyed by all our fits while (5) is strongly violated by solutions I and II and less strongly by solutions III and IV.

We should also point out that the Pomeron slopes in our fits ranged between about .15 and 0.5 Gev^{-2} . Solution IV that attempts to fit all data has $\alpha'_P = 0.169 \text{ Gev}^{-2}$. We attempted a fit with a larger α'_P but found an essential worsening of the χ^2 .

We now discuss possible explanations of our results.* One possibility is that our parameterization, though at least phenomenologically successful at medium energies, is just not good enough at very high energies. This applies especially to the Pomeron. The mysterious Pomeron, which we treated as a simple pole, may be a more complex object. There have been many conjectures about this¹⁴. The very high energy data suggest this, since it is difficult to see

even qualitatively how the types of functions we have used could generate such a sharp transition between fairly rapidly falling and then flat total cross sections.

A second possibility is that a reasonable fit is possible using our conventional model, but that we simply missed finding it. This seems unlikely, however, due to the relative ease with which restricted data sets (I-III) were fitted.

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References

- 1) J.V. Allaby et. al., Phys. Letters 30B, 500 (1969).
- 2) D. Horn, Phys. Letters 31B, 30 (1970).
- 3) G.F. Chew and D.R. Snider, Phys. Letters 31B, 75 (1970).
- 4) R.J. Eden, University of California, Riverside Preprint UCR-34P107-105.
- 5) J. Finkelstein and M. Jacob, Nuovo Cimento 56A 681 (1968).
- 6) R.C. Arnold, Phys. Rev. 153, 1523 (1967); R.C. Arnold and M.L. Blackmon, Phys. Rev. 176, 2082 (1968).
- 7) F. Henyey, G.L. Kane, J. Pumplin, M. Ross, Phys. Rev. Letters 21, 946 (1968) and Phys. Rev. 182, 1579 (1969).
- 8) F. Drago, A. Love, F.J.N. Phillips, G.A. Ringland, Phys. Letters 31B, 647 (1970).
- 9) V. Barger and R.J.N. Phillips, Phys. Rev. Letters 24, 291 (1970).
- 10) V. Singh, Phys. Rev. 129, 1889 (1963).
- 11) R.J. Rivers and L.M. Saunders, Nuovo Cimento 58A, 385 (1968).
- 12) K.J. Foley et. al., Phys. Rev. Letters 19, 193 (1967).
- 13) K.J. Foley et. al., Phys. Rev. Letters 11, 425 (1963).
- 14) J.H. Schwarz, Phys. Rev. 167, 1342 (1968); T. Sawda, Nuovo Cimento 48A, 534 (1967); R. Oehme, Phys. Rev. Lett. 18, 1222 (1967).

Footnote *

Throughout this discussion we shall assume that the experimental results of reference 1 are correct.

TABLE

Solution	C_{OP}	D_{OP}	C_{1P}	D_{1P}	C_{0e}	D_{0e}	C_{1e}	D_{1e}	R_N	R_F	α'_P	$\lambda \equiv \lambda_A = \lambda_B$	χ^2	Number of p_T Data	Number of $\frac{d\sigma}{dt}$ Data
I	34.5	-23.7	2.83	.452	18.2	107.	-2.18	25.7	2.97	-.289	.183	1.005	51	35	-
II	38.8	-5.97	3.89	-2.53	11.0	133.	2.83	-.499	3.53	-1.13	.463	2.052	25	35	-
III	36.0	-32.8	2.70	.882	14.8	1160.	-1.26	11.0	3.73	.418	.155	.997	91	12	39
IV	34.2	-22.7	2.82	.572	18.6	1130.	-1.63	12.5	3.02	.820	.169	1.000	190	36	39

Table Caption

Parameters of Fits - The C, D, α' parameters are explained in the text.

The units are - C_{OP} , C_{0e} in Gev^{-1} ; D_{OP} , D_{0e} , C_{1P} , D_{1P} , C_{1e} , D_{1e} , α'_P in $(\text{Gev}/c)^{-2}$.

$R_N \equiv C_{Of}/C_{0e}$, $R_F \equiv D_{Of}/D_{0e}$. The constraint $\lambda_A = \lambda_B$ was taken for simplicity.

Caption for Figure 1

$\pi^{\pm}$ p total cross section data of references 1 and 12 compared to solution IV.

Caption for Figure 2

$\pi^{\pm}$ p differential cross section data of reference 13 compared to solution IV. Similar results were found for π^{+} P at 12.66 Gev and π^{-} P at 14.86 Gev.

Fig.1

Fig.2