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I.K.Potashnicova

TRIPLE REGGE PHENOMENOLOGY IN THE REACTION $p + p \longrightarrow p + X$

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1. Introduction

There are many experimental and theoretical papers, devoted to the investigation of the process

$$p + p \longrightarrow p + X \tag{1}$$

at high energy, appeared last time. The essential interest excites the opportunity to carry out the analysis of the hard proton spectrum and to determine the values of the triple Regge couplings. Depending on the $t=0$ value of the triple Pomeron vertex $g_{PPP}(t)$ (zero or nonzero?) one has different possibilities of the theory: weak coupling /1/ ($g_{PPP}(0)=0$) or strong coupling /2/ ($g_{PPP}(0)\neq 0$).

Differential cross section of the reaction can be tied by means of the unitarity condition with the triple Regge graphs contribution. (see.fig.1).

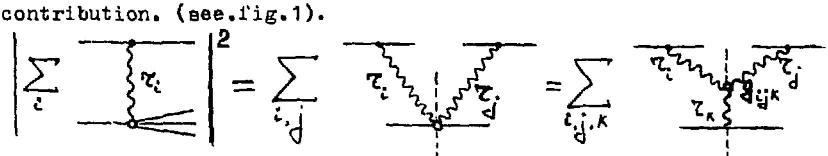


Fig. 1

The summing up on fig. 1 is carried out with Pomeron P and Reggeons f, ω, ρ, A_2. Because of the nearness of the secondary Reggeon trajectories it is hard to distinct them, so they are usually substituted by contribution of the effective pole R.

The expression for the differential inclusive cross section, which has been used in the analysis, has a form:

$$s\frac{d^2\sigma}{dM^2dt} = \sum_{i,j,k=P,R} G_{ijk}(t)\,(1-x)^{\alpha_k(0)-\alpha_i(t)-\alpha_j(t)}\left(\frac{s}{s_0}\right)^{\alpha_k(0)-1} +$$

$$+\left(s\frac{d^2\sigma}{dM^2dt}\right)_{\pi\pi P} \tag{2}$$

Here, M is an effective mass of the produced shower; t - 4-momentum transferred squared; $x = P_L / P_{max} \simeq 1 - M^2/s$, were P_L -longitudinal component of scattered proton momentum, $P_{max} = max(P_L)$, s - c. m. protons energy squared. Last term in (2) arises from one pion exchange contribution and has a form /3/

$$\left(s \frac{d^2\sigma}{dM^2 dt} \right)_{\pi\pi P} = \frac{g^2}{(4\pi)^2} \sigma^{\pi N}_{tot} \frac{(-t)}{(\mu^2 - t)^2} (1-x) \, e^{R^2 t} . \qquad (3)$$

Here μ is a pion mass; $g^2/4\pi \simeq 15$; $R^2 = 3.3 \, (Gev/c)^{-2}$.

The main purpose of this paper is the attempt for the determination of the phenomenological functions $G_{ijk}(t)$ by means of the comparison of (2) with experimental data in the region of $x \geq 0.85$, $M^2 \geq 5 \; Gev^2$, $|t| < 0.6 \, (Gev/c)^2$. The preliminary results of this analysis were published in /4/.

Between existing papers on questions considered it worth while refer to /5-7/, where the necessity of triple Pomeron term in (2) was first shown, and to /8, 9/, where the whole ammount of experimental information was used in the fitting. As a justification to our work it ought to note, that in the previous analysis the interference terms contribution has been neglected. The fit procedure contained some shortcomings, which are considered in section 3. The uniqueness of the finding solutions was not checked, so some good solutions have been loosed. The finite mass sum rule, used in /9,8/ for the extraction of the supplementary information from the region of small M^2 , is not a very reliable source, and itself needs for the verification on the analysis results. It is seen from our solutions, that RRR contribution is extracted from the data in high M^2 region with a good precision.

The content of the paper is constructed as follows: in section 2 the parametrization of the phenomenological functions $G_{ijk}(t)$ is explained. Some restrictions on the interference terms value, which follows from the Buniakowsky-Schwarz inequality, are found.

In section 3 experimental data, included in analysis, are listened. Some details of fit procedure are considered. Special attention is drawn to the relative normalization of the data.

In section 4 the results of the analysis are submitted. Two types of solutions with a good values of $\chi^2 \simeq \overline{\chi^2}$ are found. The corresponding sets of the parameters are accomodated into the tables, and the agreement with the experimental data is illustrated on figures for one of the solutions.

The experimental data, which have not been included in the analysis, are compared with the solutions founded in section 5.

Some troubles in the triple Regge phenomenology, when it is used in the region of low $x \lesssim 0.85$, or small energy $s \lesssim 50\ GeV^2$, make us to consider in sec. 6 the mechanism, which can cause another x and S-dependences. It is shown that the growth of spectra with the decreasing of x in data /10/ may be explained by the R-R cut contribution.

Section 7 is devoted to the consideration of the one pion exchange model (OPE) for the triple Regge vertex. The calculations, carried out, show that the OPE-model agrees well with the experimental results.

In section 8 some reactions are proposed for the further investigation of the triple Regge vertices. The polarization effects in the process (1) are discussed.

2. The parametrization of the expression (2)

Some parameters, contained in (2), were fixed from the properties of the binary reactions. For $\alpha_i(t)=\alpha_i(0)+\alpha_i' t$ the following values were adopted:

$\alpha_P(0)=1;\quad \alpha_P'=0.3\ (GeV/c)^{-2}$

$\alpha_R(0)=0.5;\ \alpha_R'=0.75\ (GeV/c)^{-2}$

The $\pi\pi P$ -diagram contribution was determined in /3/ from the data on reaction $pp\to nX$.

All the functions $G_{ijk}(t)$, besides interference terms G_{PRk} (see below) were parametrized as

$$G_{iik}(t)=G_{iik}(0)\exp(R^2_{iik}\cdot t) \tag{4}$$

On the $G_{iik}(0)$ the restriction $G_{iik}(0)\geqslant 0$ was imposed.

The interference terms. The parameters of the functions

$$G_{PRk}(t)+G_{RPk}(t)=2\,\mathrm{Re}\,G_{PRk}(t) \tag{5}$$

are not complitely free, because they are connected by Byniakovsky-Schwarz inequalities to the values of $G_{PPk}(t)$ and $G_{RRk}(t)$.

To obtain the corresponding restrictions, let us neglect for the ρ and A_2 contributions, because their couplings with a nucleon are small.

RPP. It is clear, that only Reggeon from R, which can give the contribution here is f-pole. Because the phase of fPP is determined by the signature factors of f and P, the Huniakonsky-Schwarz inequality takes the form:

$$2\,\mathrm{Re}\, G_{fPP}(t) \leq 2\cos\left[\tfrac{\pi}{2}\left(\alpha_P(t)-\alpha_f(t)\right)\right]\left[G_{ffP}(t)\,G_{PPP}(t)\right]^{1/2} . \tag{6}$$

If one recalls that $G_{ffP}(t) \leq G_{RRP}(t)$, then

$$\mathrm{Re}\, G_{RPP}(t) \leq \cos\left[\tfrac{\pi}{2}\left(\alpha_P(t)-\alpha_f(t)\right)\right]\left[G_{RRP}(t)\,G_{PPP}(t)\right]^{1/2} . \tag{7}$$

According to (6) and (7) let us adopt following parametrization for $G_{RPP}(t)$:

$$\mathrm{Re}\, G_{RPP}(t) = \sqrt{2}\;\mathrm{Re}\; G_{RPP}(0)\exp\left(R^2_{RPP}\cdot t\right)\cos\left[\tfrac{\pi}{2}\left(\alpha_P(t)-\alpha_R(t)\right)\right] . \tag{8}$$

The substitution of (8) into (7) gives the restrictions on the values of the parameters

$$\left[G_{RPP}(0)\right]^2 \leq \tfrac{1}{2}\, G_{RRP}(0)\,G_{PPP}(0)\exp\left[\left(R^2_{PPP}+R^2_{RRP}-2R^2_{RPP}\right)t\right] . \tag{9}$$

The necessity of the analogous restrictions for $G_{RPR}(t)$ is not so obvious, because R-exchange does not give a leading contribution to absorbtion part, shown in fig.1. Nevertheless it can be picked out if one uses an idea of duality and integration of the created particles momenta replaces by summation on production cross section of resonances. Then the Buniakowsky-Schwarz inequality can be written for the nonscaling terms separately.

The PRR contribution contains Pff and $P\omega\omega$ parts. There are restrictions for each of them:

$$2\,\mathrm{Re}\,G_{Pff}(t) \leq 2\cos\left[\tfrac{\pi}{2}(\alpha_P(t)-\alpha_f(t))\right]\left[G_{fff}(t)G_{PPf}(t)\right]^{1/2}. \tag{10}$$

$$2\,\mathrm{Re}\,G_{P\omega\omega}(t) \leq 2\sin\left[\tfrac{\pi}{2}(\alpha_P(t)-\alpha_\omega(t))\right]\left[G_{\omega\omega f}(t)\,G_{PPf}(t)\right]^{1/2}. \tag{11}$$

The distinction between (10) and (11) arose from difference of the ω and f signatures. For the same reason $G_{f\omega\omega}(t)=0$ and $G_{RRR}=G_{fff}+G_{\omega\omega f}$.

By adding (10) to (11) we have

$$\mathrm{Re}\,G_{RPR}(t) \leq \left[G_{RRR}(t)G_{PPR}(t)\right]^{1/2}. \tag{12}$$

So, unlike to (8) the convenient parametrization for $G_{RPR}(t)$ is following

$$\mathrm{Re}\,G_{RPR}(t) = \mathrm{Re}\,G_{RPR}(0)\exp(R^2_{RPR}\cdot t). \tag{13}$$

Then we have for this parameters:

$$\left[\mathrm{Re}\,G_{RPR}(0)\right]^2 \leq G_{RRR}(0)\,G_{PPR}(0)\exp\left[(R^2_{PPR}+R^2_{RRR}-2R^2_{RPR})t\right]. \tag{14}$$

Such parametrization corresponds to the strong coupling variant of the theory /2/. In the weak coupling theory /1/ all the functions $G_{ijk}(t)$, besides $G_{RRK}(t)$ should tend to zero as $t\to 0$. But the parametrization of $G_{ijk}(t)$ in such pure form is meaningless. This is because of the cut contribution which can strongly affect the t-dependence of $G_{ijk}(t)$ /11/. The last fact follows from the fact, for instance, that in the weak coupling theory all total cross sections should be equal, and the observed large differencies ought to be connected with the cut contribution, which in this case comprises about 100%. So, we restricted ourselves by strong coupling variant only.

3. The fit procedure.

The fitting was carried out by means of the minimization of the functional:

$$\chi^2 = \sum_i \frac{\left(\Psi_i - N_K \Psi_i^{teor}\right)^2}{(\Delta \Psi_i)^2} + \sum_K \frac{(N_K - 1)^2}{(\Delta N_K)^2} + \\ + \sum_j \frac{(\Phi_j)^2}{(\Delta \Phi_j)^2} \qquad (15)$$

Here Ψ_i is the i-th experimental point for the inclusive cross section; Ψ_i^{teor} - their value, given by (2); $\Delta \Psi_i$ - the experimental error. N_K is a scale factor, which has been introduced for the k-th set of the experimental points (see table I). About Φ_j see below. A normalization problem deserves of the consideration.

In the papers /8,9/ and in the most of existing fittings the normalization factors are fixed by 1. As a result one has strongly enchanced value of χ^2 . Besides the experimental data with a high statistics and incorrect norm can cause a large deviation in the parameters value. Another opportunity, frequently used, is a free variation of N_K in the first sum in exp. (15). This approach is not satisfactory also, because the difference in the normalization precision for distinct experiments is not taken into account. In addition, some experimental energy or angular dependences can be distorted and attracted to theoretical ones by means of the norm variation. In the last case the χ^2 value is too little.

In this work the norms N_K have been varied as a free parameters but in accordance with the normalization errors ΔN_K , given by the experimentators. This has been achieved by introducing in the functional (15) of the second term. Unfortunately, the normalization error is not always given by the experimentators. In such cases it has been taken to be equal to the systematical error. In table 1 there are shown the experimental data, which have been used in present analysis, and some their characteristics including the normalization error values.

Table 1.

Experiment	Energy s(Gev^2)	Momentum transfered $\|t\|$(Gev/c)^2	ΔN	$\eta^{(1)}$	$\eta^{(2)}$
CERN-Holland-Lancaster-Manchester/12/	s=529	0,24 </t/< 0,55	15%	0.86± 0.03	0.86± 0.03
	s=551	0,15 < /t/< 0,55	10%	0.89± 0.03	0.91± 0.03
	s=930	0.35 < /t/ < 0.55	10%	1.09± 0.03	1.07± 0.03
	s=1995	0.55 < /t/ < 0.59		1	1
Imperial College Rutgers/13,16/	s=80 ÷ 480	/t/=0.33	25%	0.98± 0.03	0.94± 0.03
		/t/=0.45	25%	0.92± 0.03	0.88± 0.03
	s=108, 213, 285, 503, 752	0.14 < /t/< 0.18	15%	0.95± 0.03	0.95± 0.03
		0.18 < /t/ < 0.22	15%	0.95± 0.03	0.95± 0.03
		0.22 < /t/< 0.28	15%	0.92± 0.03	0.91± 0.03
		0.28< /t/< 0.38	15%	0.87± 0.03	0.85± 0.03
ANL-NAL/14/	s=386	0.02< /t/< 0.37		1	1
Michigan-Rocnester/15/	s=193	0.05< /t/< 0.5	10%	1.05± 0.05	1.04± 0.04
	s=762	0.05< /t/< 0.5	25%	0.86± 0.07	0.72± 0.07
Bonn-Hamburg-München/16/	s=46.8	0.05< /t/< 0.43	10%	1.27± 0.04	1.24± 0.04
J.V.Allaby/17/	s=46.8	0.1 < /t/< 0.4	10%	1.3 ± 0.04	1.27± 0.04
S.W.Anderson/18/	s=58.1	0.16 < /t/< 0.43	10%	0.98± 0.03	0.96± 0.03

The norm for the s=1995 data has not been varied, because they contain only a few points with $/t/ < 0.6\ (\mathrm{Gev/c})^2$. The norm of the ANL-NAL data has also been fixed by 1, because the correspon-ding systematical and normalization errors both are unknown. This does not play a signigicant role in view of the fact that the data contains not very large amount of the points with such statistical errors, that normalization error may be neglected.

The norms N_K for the data /10,13/ were introduced at each value of t separately, because an error in the differential cross section slope value, which was used in the normalization pocedure, should bring to the monotonous t-dependence of N_k.

Let us explain now, how the Buniakowsky-Schwarz restrictions for the interference terms value have been supplied. For this purpose the last term in (15) has been introduced with a notation

$$\Phi_j = \exp(B\Lambda_j) ,$$

where j numerates the inequalities (9) and (14).

Λ_j in the case of inequality (9), for instance, has the following form:

$$\Lambda_j = \left[\mathrm{Re}\, G_{RPP}(0)\right]^2 - \tfrac{1}{2} G_{RRP}(0) G_{PPP}(0) \exp\left[\left(R^2_{RRP} + R^2_{PPP} - 2R^2_{RPP}\right)t\right] .$$

If the value of B is chosen sufficiently large, then one can suppose with needed precision that

$$\Phi_j \gg 1 \quad \text{for} \quad \Lambda_j > 0 ,$$

and

$$\Phi_j \ll 1 \quad \text{for} \quad \Lambda_j < 0 .$$

So, the last term in (15) generates a sharp increase of χ^2 value as one of the inequalities (9) or (14) is violated. At the same time the value of error $\Delta\Phi_j$ has been chosen large enough, for the (15) last term contribution to the final value of χ^2 to be negligible small.

4. The fit results

The conditions of validity of expression (2) are typical for the Regge pole model:

$$s/M^2 \gg 1 \, , \; M^2/s_0 \gg 1 \, , \; |t| \lesssim m^2$$

The maximum value of /t/ and minimum of x, for which the final results were obtained, have been chosen so, that the narrowing of the analysed intervals for /t/ below $|t|_{max}$ and for x above x_{min} should not affect the parameter values in the error limits. The following values have been found:

$$|t|_{max} = 0.6 \, (Gev/c)^2 ; \quad x_{min} = 0.85$$

The upper bound of x is determined by the energy value, at which the Regge behaviour begins. It was chosen $M^2_{min} = 5 \, Gev^2$. Together with x_{min} this defines the lower value of s in the table I. It worthwhile to note, that the leading protons can be emerged from the $\Delta(1236)$ decay. The description of such cases by graphs RRk is sensible only with a reference to the duality. But, the Δ-production contribution has a maximum at $x \simeq 0.6$ and is negligibly small in the chosen region $x > 0,85$ /19/. In this interval of x and t data from table I contain 554 experimental points. A few solutions were found, which give a good description of the data. Those of them, which were recognised to be satisfactory, are shown in tables II, III.

Table II. Solution 1. $\chi^2/\overline{\chi^2} = 0.91$

	G_{PPP}	G_{RRP}	$2ReG_{RPP}$	G_{PPR}	G_{RRR}	$2ReG_{PRR}$
$G_{ijk}(0)\frac{mb}{Gev^2}$	3.24 $\pm$0.35	7.2 $\pm$1.9	6.9 $\pm$1.1	3.2 $\pm$0.6	5.19 $\pm$7.8	-9.3 $\pm$2.2
$R^2(Gev/c)^{-2}$	4.25 $\pm$0.24	-1.2 $\pm$0.50	8.5 $\pm$3.7	1.7 $\pm$0.4	0	0

Table III. Solution 2. $\chi^2/\overline{\chi^2} = 0.93$

	G_{PPP}	G_{RRP}	$2ReG_{RPP}$	G_{PPR}	G_{RRR}	$2ReG_{PRR}$
$G_{ijk}(0)\frac{mb}{Gev^2}$	3.23 $\pm$0.35	13.2 $\pm$0.9	5.7 $\pm$4.9	2 $\pm$1	23.6 $\pm$5.0	13.4 $\pm$4.5
$R^2_{ijk}(Gev/c)^{-2}$	4.2 $\pm$0.3	0	19.5 $\pm$16.1	1.8 $\pm$1.1	0	9.7 $\pm$7.6

The norms values are placed in table I.

The quality of the experimental data description by the expression (2) with the parameter values from the first solution is demonstrated on figs.2-8.

It is seen from table I that in the most of cases N_K differ from 1 by the value of an order of ΔN_K. But the low energy data deserve a care: the norms of two experiments from three in this energy region are out of two standard deviations from 1. May be this fact indicates that exp.(2) is invalid at such energies.*) Nevertheless, this data were included in the

*)To avoid this difficulty in[20] supplementary terms with $\alpha_K(0) \leq 0$ have been introduced.

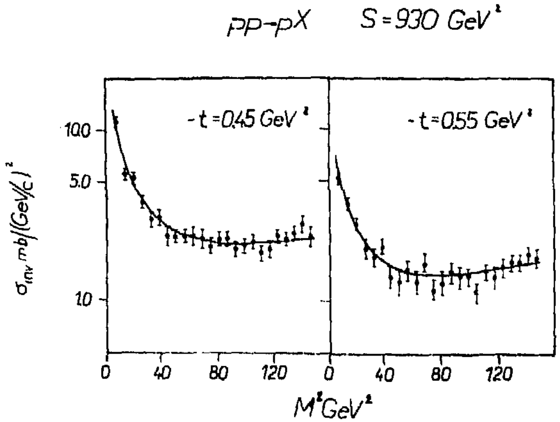


Fig.2.CERN-Holland-Lancaster-Manchester data at s=930 Gev^2.

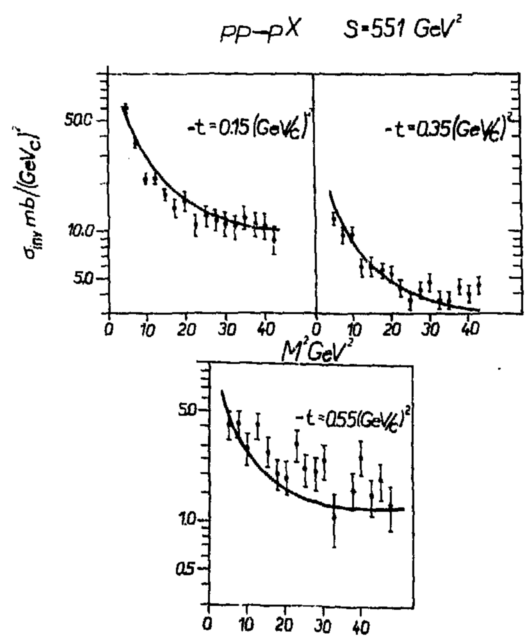


Fig.3 The same as on fig.2 at s=551 Gev^2.

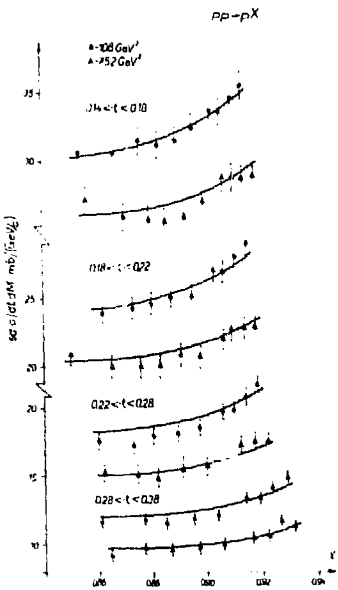


Fig.4

Imperial College-Rutgers data.

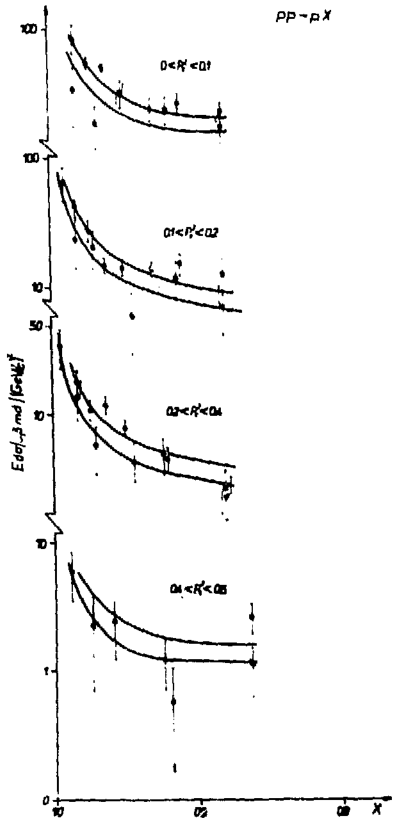


Fig.6
Michigan-Rochester data.
o - s=193 Gev^2
• - s=762 Gev^2.

Fig.5

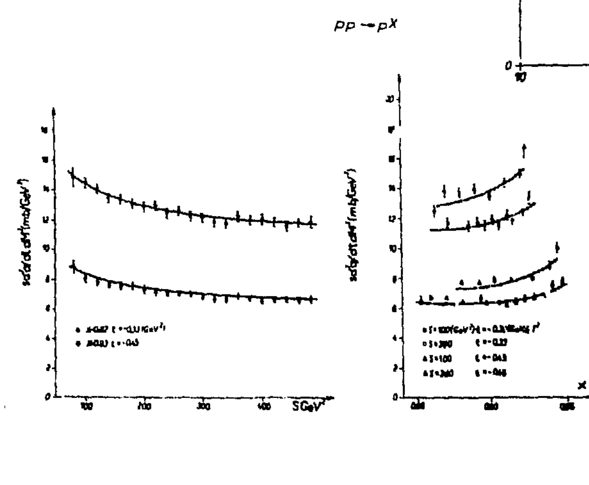


Fig.7

ANL-FNAL data at $s=386 Gev^2$

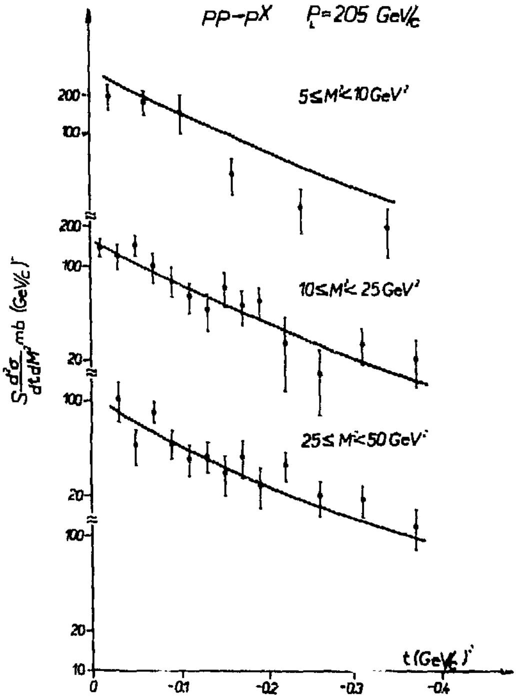
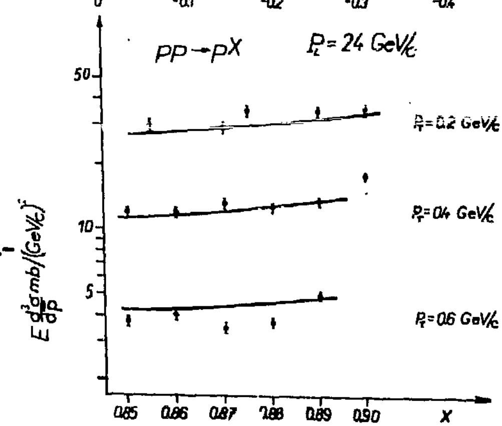


Fig8.

Bonn-Hamburg-Munchen data. $s=46.8 Gev^2$. Only statistical errors are shown.



analysis, because at normalization errors, prescribed to them, they don't affect noticeably the parameter values. Below, in sec. 6, we shall come back to this question.

It worth while to note that a solution was found, which has large values of $G_{RRR}(0) \sim 600 \frac{mb}{GeV^2}$ and $R^2_{RRR} \sim 30 (GeV/c)^2$. This is a surprising result from the point of view of the numerical estimations in the one pion exchange model, fulfilled in sect. 7. So such solutions were rejected.

5. Some predictions

Using parameters, obtained above, one can give some predictions. For this purpose we chose those experiments, which have not been included in the analysis.

The results of the experiments /21/ at $69\ GeV/c$ and /22/ at $s = 565\ GeV^2$ which have been published after our work completion, are shown in figs.9,10 together with our predictions.

The reaction $pd \to Xd$ has been studied in the work /23/. We can give predictions for this reaction, with some reservations. At first, one should avoid the $\pi\pi P$ term and the ρ, A_2 contributions from (2). The latter are suppressed by small couplings and can be neglected. Then one ought to multiply (2) by deutron formfactor squared (normalising to 1) and some factor. This factor can differ from the total deutron and proton cross section ratio squared, because the Glauber corrections in the inelastic reaction are governed by another set of graphs than in elastic one. Indeed we find that this factor is 20% lower that $(\sigma^{\pi d}_{tot}/\sigma^{\pi N}_{tot})^2$. So the Glauber corrections, in the $pd \to Xd$ are about 10% larger than in the elastic scattering. Our predictions, normalized to the data are showen on fig. 11.

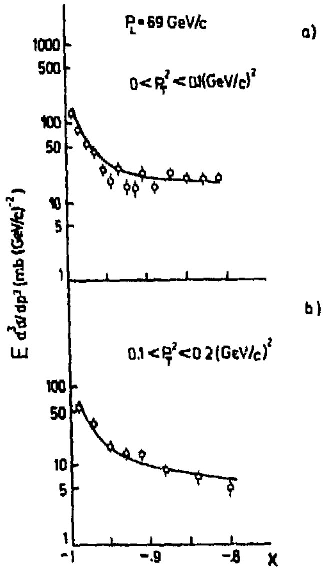


Fig. 9

The comparison of the calculations results with experimental data at P_{lab}=69 Gev/c. /21/

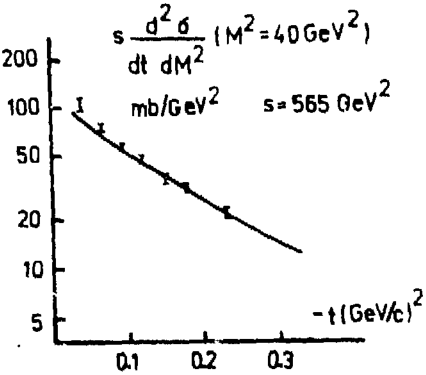


Fig. 10

The same as on fig. 9 at s=565 Gev^2 and M^2=40 Gev^2. /22/

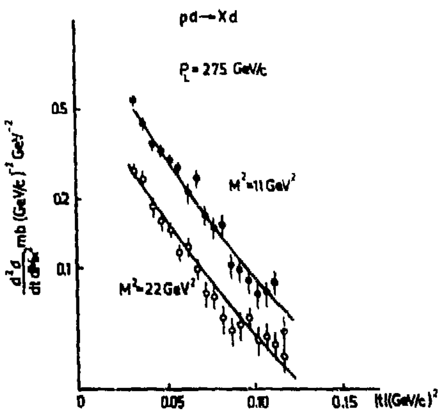


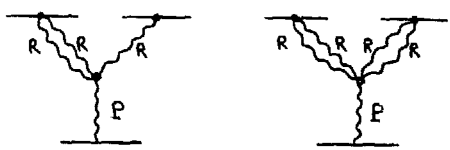
Fig. 11

The same as on fig. 9, but for reaction d+p→d+X at P_{lab}=275 Gev/c and M^2=11 Gev^2. For details see the text.

6. Some troubles and possible explanations.

1. The main reason for choosing $x_{min}=0.85$ is a fast growth of inclusive spectra with decreasing of x below x_{min} found in /10, 13/. Such behaviour cannot be described by (2) and can be tied with some other mechanisms.

The expression (2) corresponds to the triple Regge graphs, e.g., pure Regge pole model. It is clear however, that P-P and R-P cuts give an effective contribution to (2) also. As for the R-R cut, it does not contribute to (2) because of its special x-dependence. The influence of R-R cut can in principle explain the difficulty, considered above. To be convinced of this, let us give a crude estimation of diagrams on fig.12 contribution.



a b

Fig. 12

If to identify R with f for simplicity and to make use of the quasieiconal model, then one can write for fig.12a and b graphs contribution:

$$\Delta\left(s\frac{d^2\sigma}{dM^2dt}\right)=\left(s\frac{d^2\sigma}{dM^2dt}\right)_{RRP}\frac{2z}{\left[\lambda^2+\left(\frac{\pi}{4}\right)^2\right]}\left(z-\lambda+\frac{\pi}{4}\right), \qquad (16)$$

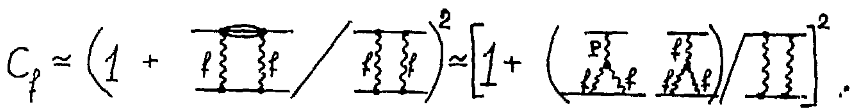
where

$$z=\frac{C_f\sigma_0}{32\pi}\sqrt{1-x}\;e^{-\frac{\lambda t}{2}}$$

$$\lambda=R_f^2-\alpha_R'\ln(1-x).$$

Here we assume, that f -exchange takes place between the proton and one of the fast (in the lab.s.) particles in the produced shower. The f-particle couplings are supposed to be the same as for Pomeron. So, we chose $\sigma_0 \simeq 30$ mb and $R_f^2 \sim 1\,(\text{Gev}/c)^{-2}$. $(s\,d^2\sigma/dM^2dt)_{RRP}$ in the right-hand side of (16) is the RRP graph contribution, which has been written out in (2).

C_f is a factor, increasing f-f cut contribution at the expense of inelasticity in the intermediate state. Figure 13 shows x-dependence of $\Delta\left(s\frac{d^2\sigma}{dM^2dt}\right)$ at different values of C_f. It is seen that at $C_f \simeq 8$ one can describe the experimental data behaviour for $x < 0.85$. Such value of C_f can seem surprisingly large in comparison with corresponding strengthening factor C_P for the vacuum cut: $C_P \lesssim 2$. Nevertheless, we can give some arguments in favour of this result. Let us estimate C_f, using the concept of duality. Then the correction to the eikonal due to resonances and showes in the intermediate state can be estimated by means of substitution, shown graphically in (17):



(17)

The contribution of the Pff and fff graphs to the absorbtive part of amplitude can be calculated by using the results of the present work. If M^2 integration is restricted above by $M_0^2 = 4\,\text{Gev}^2$, then (17) takes a form

$$C_f \simeq \left[1+\left(\frac{3\,G_{RRP}(0)}{R^2_{RRP}+\alpha'_R\ln(s/s_0)} + \frac{2\,G_{RRR}(0)}{R^2_{RRR}+2\alpha'_R\ln(s/s_0)}\right)\Big/\frac{s_0\sigma_0^2}{32\pi(R_f^2+\alpha'_R\ln(s/s_0))}\right]^2 \simeq$$

$$\underset{s\to\infty}{\simeq}\left[1+\frac{16\pi}{\sigma_0^2}\left(3\,G_{RRP}(0)+2\,G_{RRR}(0)\right)\right]^2.$$

(18)

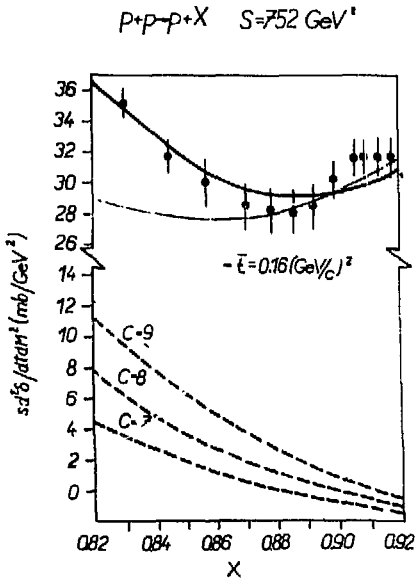


Fig. 13

Imperial College - Rutgers data at s=752 Gev^2 and t =-0.16(Gev/c)^2. Thin curve is a calculated cross section according to exp. (2). Dotted lines are the calculation results with using of (16) for different factor C_f values. Thick curve is a sum of (2) and (16) at C_f=8.

The substitution of the parameters from solution II leads to the value $C_f \simeq 9$, which agrees with above conclusion. It is clear now from (17) and (18) why C_f is so large in comparison with C_P . This is a consequence of the more general result: the diffractive inelastic production (PPP and PPR) is suppressed in comparison with Reggeon contribution (RRP and RRR). That can be seen from tables II-III, and would be under discussion in the next section.

So R-R cuts cannot be neglected in the region of $x < 0.85$. At the same time the considerable compensation of Fig.12a and b graphs contributions allows to believe that R-R cut influence for $x > 0.85$ is not large.

2. As was mentioned above the normalization factors N_K for the experiments at low energy $s \simeq 40 \div 60\ GeV^2$ differ from 1 to about 20%. Let us examine a few mechanisms with a more rapid s-dependence than (2) can give.

The diagram on fig. 14 does not give any contribution to the inclusive cross section. It can be shown that the sum of different contributions to the absorbtive part of the Reggeon-particle scattering amplitude is complitely reduced (an amplitude with $\alpha_c(0) = 0$ is real).

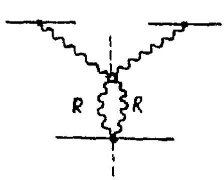


Fig. 14

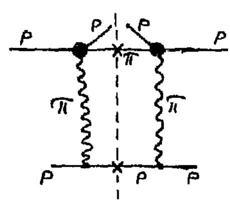


Fig. 15

The observed deviation from $s^{-1/2}$ dependence can be tied with the reaction $pp \to pN\pi$, described in the Deck model, as is shown on fig. 15. This graph contribution into X-spectrum rapidly dies with energy as s^{-2}, but at low energy comprises about 10% /19/.

3. At s and M^2 sufficiently large a deviation from formula (2) will emerge again. It would be caused by the Reggeon--particle cross section growth, which is not containd in the expression (2). It is natural, that in M^2 interval, where the analysis was performed, this effect did not develop.

7. Comparison with the one-pion exchange model (OPE)

Let us compare the sets of parameters, founded in sec.5, with the OPE calculation results. The triple Regge couplings have been estimated in papers /24-26/. In addition, the reaction (1) was considered in the Reggeised OPE model in /19/.

We shall give a short derivation more simple then in /24/ of the OPE expression for the triple Regge couplings.

In OPE model a graph from fig.2 can be redrawn as:

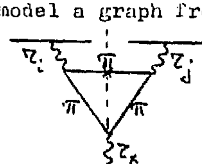


Fig. 16

If $t=0$ it corresponds to the following expression for $G_{ijk}(0)$

$$G_{ijk}(0) = g_{NNi}\, g_{NNj}\, g_{NNk}\, g_{\pi\pi i}\, g_{\pi\pi j}\, g_{\pi\pi k}\, \eta_i(0)\, \eta_j^*(0)\, I_{ijk}\,, \tag{19}$$

where g_{NNi} and $g_{\pi\pi i}$ – the emission vertex of Reggeon by N and π. $\eta_i(t)$ is the signature factor.

$$I_{ijk}=\frac{3}{(4\pi)^4 s_0}\int\limits_{-\infty}^{0}\frac{du}{(\mu^2-u)^2}\left(\frac{\mu^2-u}{s_0}\right)^{\alpha_i(0)+\alpha_j(0)}F(u)\int\limits_{0}^{\frac{-u}{\mu^2-u}}\left(\frac{M_1^2}{M^2}\right)^{\alpha_k(0)}d\left(\frac{M_1^2}{M^2}\right). \tag{20}$$

Here u is the virtual pion 4-momentum squared, μ - its mass; M_1 - is the energy, corresponding to the τ_k -exchange. The structure of (20) is understandable. The factor 3 takes into account the three charge states of π-meson. $(\mu^2-u)^{-2}$ corresponds to the virtual pion propagator.

The energy, which attitudes to the τ_i and τ_j exchanges, equals to $(\mu^2+\varkappa_\perp^2)S/(M^2-M_1^2)$, where $\varkappa_\perp$ is a transverse momentum of the produced pion. So, it is seen from the comparison with (2) that factor $\left[(\mu^2+\varkappa_\perp^2)M^2/s_0(M^2-M_1^2)\right]^{\alpha_i+\alpha_j}$ should be included into G_{ijk}. It is not difficult to see, that

$$\mu^2+\varkappa_\perp^2=(\mu^2-u)(1-M_1^2/M^2) \tag{21}$$

So, $\left[(\mu^2-u)/s_0\right]^{\alpha_i+\alpha_j}$ arises in (20).

The form factor $F(u)$ takes into account the off mass shell effects. $F(u)\simeq\exp(R^2u)$, where $R^2\simeq 1(\mathrm{Gev}/c)^{-2}$ /19/.

The minimum value of $|u|$ is equal to

$$|u|_{min}=\left(\frac{M_1^2-m^2}{M^2-M_1^2}\right)\mu^2$$

Consequently, the M_1^2/M^2 integration is restricted by the value $(-u)/(\mu^2-u)$.

The $G_{ijk}(0)$ values, calculated in accordance with (19) and (20) are displayed in table IV.

Table IV. G_{ijk} (mb/Gev^2)

$G_{PPP}(o)$	$G_{RRP}(o)$	$2ReG_{RPP}(o)$	$G_{PPR}(o)$	$G_{RRR}(o)$	$2ReG_{PRR}(o)$
4	17	10,7	5,4	27,4	15

At this calculations R was identified with f, because ρ and A_2 contributions are suppressed, and ω -exchange on graph is forbidden (more about ω see below). It was adopted also that

$$g_{NNf}\, g_{\pi\pi f} \simeq g_{NNP}\, g_{\pi\pi P} = S_0 \sigma_{tot}^{\pi N} \ .$$

The comparison of table IV with the fit results shows a good agreement. At the same time, one gets a natural explanation for the experimental fact that $G_{PPk} \ll G_{RRk}$, because, if $\tau_i = \tau_j = R$, then the expression (21) is singular at $\mu^2 \to 0$.

The t-dependence of $G_{ijk}(t)$, predicted by OPE is more steep than the experimental one. It is not very surprising because we did not introduced the cut corrections.

As for ω-contribution to R, the following diagrams can be drawn in this case, for instance:

Fig. 17

The graph a) on fig. 17 contribution is few times suppressed if compare with fig. 16 one. This is explained by the above-mentioned singularity at $\mu^2 \to 0$ in the expression (21) for ff^k. To estimate the graph b) on fig. 17 role, let us use π^0- photoproduction data and vector dominance. Then it is easy to get

$$G_{\omega\omega k}(0) = \frac{3 g_{NN k} g_{\pi\pi k}}{(4\pi)^{2} \pi (\alpha_k+1)} \frac{f_\rho^2}{4\pi\alpha} \left.\frac{d\sigma^{\gamma N \to \pi^0 N}(s/M^2)}{dt}\right|_{t=0} \left(\frac{s}{M^2}\right)^{2-2\alpha_\omega(0)} I_{\omega\omega k} \quad , \tag{22}$$

where

$$I_{\omega\omega k} = \int_{-\infty}^{0} \frac{du}{(\mu^2-u)^2} \left(\frac{m_\rho^2-u}{s_0}\right)^{2\alpha_\omega(0)} \left(\frac{-u}{m_\rho^2-u}\right)^{1+\alpha_k(0)} e^{R_1^2 u} \quad . \tag{23}$$

Here f_ρ is the γ-ρ coupling, $f_\rho^2/4\pi \simeq 2$; $\alpha = 1/137$ - the fine structure constant. After simple calculations, one finds from (22), (23) that $G_{\omega\omega k}(0)$ is approximately by an order suppressed in comparison with $G_{ffk}(0)$.

So, one of the main predictions of OPE is the f-dominance among the secondary trajectories (in opposite to the exchange degeneracy in the binary reactions).

8. What is interesting to measure?

It is desirable to extract f, ρ, ω and A_2 contribution to R separately.

At first, let us discussed the scaling term $G_{RRP}(t)$. It is easy to see that the poles with the different quantum numbers don't interfere here; i.e.,

$$G_{RRP}(t) = G_{ffP} + G_{\omega\omega P} + G_{\rho\rho P} + G_{A_2 A_2 P} \quad . \tag{24}$$

It follows from (24) that the value of $G_{RRP}(t)$ in the reaction $\bar{p}p \to \bar{p}X$ should be the same. The ω, ρ and A_2 contributions to (24) can be found separately from the study of the other reactions for example

$$\gamma p \to \pi^0 X \ , \tag{25a}$$

$$\pi^- p \to \pi^0 X \ , \tag{25b}$$

$$\pi^- p \to \eta^0 X \ . \tag{25c}$$

In the non scaling part $G_{RRR}(t)$ the number of different combinations from f, ω, ρ, A_2 is much more than in (24).
So we omit the discussion of their separation methods.
The next interesting point is the polarization effects. Their measurement is most sensitive one to the cut corrections. First of all, it is needed to emphasize that there is a great difference between the cases, when the target or the beam are polarized (which is different from the case of elastic scattering).

In the triple Regge region of the beam, when a target is polarized no asymmetry of scattering would emerge, if one uses a pole approach /27/. Only cut corrections generate some asymmetry. We believe, that the multipomeron cuts give a small spin flip amplitude, so the great effect should arise due to secondary Reggeon-Pomeron cuts and be non scaling, i.e. die as $s^{-1/2}$ /28/.

In the case of polarized beam an asymmetry can arise in principle. But as was shown above, the secondary Reggeons don't interfere in the scaling part. Asymmetry in the pole approach can originate from the Pomeron-f Reggeon interference. But both are known to give very small spin flip amplitude (in the binary reactions), so we conclude, that the scaling polarization effects for the beam should be negligible in the pole case. The situation is like to the well-known $\pi^- p$ charge exchange reaction. The polarization effects (in the asymptotic limit) are totaly caused by cut corrections.

Let us see the x-dependence for the scale part of the polarization parameter P_0 in the case of polarized beam. One can write

$$P_0^{(scale)}(x,t)\frac{s\,d^2\sigma}{dM^2dt} = P_0^{(PPP)}(t)\frac{G_{PPP}(t)}{(1-x)^{1+2\alpha_P' t}} + P_0^{(fPP)}(t)\frac{2\,Re\,G_{RPP}(t)}{(1-x)^{1/2+(\alpha_R'+\alpha_P')t}} +$$

$$+\sum_{i=f,\omega,\rho,A_2} P_0^{(iiP)}(t)\frac{G_{iiP}(t)}{(1-x)^{2\alpha_R' t}} . \tag{26}$$

Here $P_0^{(ijk)}(t)$ is the polarization arisen in the case, when only diagram ijk is present. It is clear that $P_0^{(ijk)}(t)$ does not depend on x. It is implied in (26) that all vacuum rescattering corrections are included. If one neglects by the first and second terms in (26) then he gets for x-dependence

$$P_0^{(scale)}(x,t) \sim (1-x)^{-2\alpha_R' t}\Big/ s\frac{d^2\sigma}{dM^2dt} \tag{27}$$

Here we are interested in x-dependence only. At $x\to 1$, the triple Pomeron part only dominates in the denominator of (27), then

$$P_0^{(scale)}(x,t) \underset{x\to 1}{\sim} (1-x)^{1-2\alpha_R' t} \tag{28}$$

8. Conclusion

The analysis, fullfiled above, has showed, that the triple Regge phenomenology permits one to get a good description of the $p+p \to p+X$ experimental data in the region $x \geq 0.85$, $|t| \leq 0.6 (GeV/c)^2$, $M^2 \geq 5 GeV^2$. The parametrization, which has been used for the vertex functions, corresponds to the strong coupling variant of the theory. But the good quality of description does not give any argument in favour of this variant, In the weak coupling case the large cut contribution radically changes the t-dependence and can simulate the strong coupling /11 /.

Unlike to the previous works we have taken into consideration the nondiagonal diagrams and carefully performed the fit procedure. As a result few solutions have been founded. The predictions done on this ground are in good agreement with the new data at the small t-values. The comparison with the $pd \to Xd$ data shows also the noticable distinction between the elastic and inelastic Glauber corrections.

Some mechanisms additional to the triple Regge one, which can give important corrections, have been discussed. The Deck diagram yields another s-dependence; R-R cuts can give abnormal x - behaviour.

The OPE-model calculations have been compared with the fit results. A good correspondence was established.

The set of reactions to be measured for the distinction of the secondary trajectory contributions to the scaling part has been proposed. The polarization effects as a method for the cut correction investigation have been discussed.

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