Cross Sections of Various Processes in Pbar P-Interactions

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Problem of description of total cross sections of $\bar{p}p$- and $pp$-interactions is considered within the framework of the Regge theory. Parameters of the pomeron exchange, ordinary meson exchange and exotic meson exchange with hidden baryon number are determined at fitting of experimental data assuming the identical interaction radii of the reggeons with nucleon. An expression is proposed for cross sections of various reactions in the $\bar{p}p$-interactions - cross sections of one and two string creations needed for Monte Carlo simulation of the reactions, and the cross sections are calculated.

1 Introduction

Baryon number flow over large rapidity intervals attracts much theoretical attention now [1, 2, 3]. It is assumed that observed increase of baryon multiplicity over antibaryon multiplicity in the central rapidity region of nucleus-nucleus interactions [4, 5, 6, 7] is connected with a specific space configuration of the gluon field in baryons. The configuration of local maxima of the energy density in the baryon can have the Mercedes star form [8, 9, 10, 11] (see left part of Fig. 1). The global maximum is associated with a string junction in the string model of baryons [12]. It is possible, of course, a $\Delta$-form of baryons (see consideration in Refs. [12, 8, 10, 11]). It is assumed very often that baryon has a compact diquark (see right part of Fig. 1).

![Baryon Structure](image)

Figure 1: A possible baryon structure.

Depending on the assumed structure there can be various final states in baryon-baryon interaction, especially in $pp$ ones. Some of them are shown in Fig. 2. In the process of Fig. 2a the string junctions from colliding baryons represented by dashed lines annihilate, and three strings are created. In the process of Fig. 2b quark and antiquark annihilate, and one string appears. In the process of Fig. 2c quark, antiquark and the string junctions annihilate. In the process of Fig. 2d diquarks annihilate, and so on. Additional to the
annihilations there can be creation of two strings (see Fig. 2g) or creation of one string (Fig. 2h) at the diffraction dissociation of baryon. The process 2f can be responsible for glueball production, and the process 2d – for exotic meson production. So, various final states included glueball and exotic meson production can be in $\bar{p}p$ interactions. One can expect that creation of the antiproton factory at GSI [13] will allow to study most of them.

It is very important for future experimental investigations to estimate production cross sections and dominating modes of the exotic state decays. In the paper estimations of various reaction cross sections obtained within the framework of the standard Regge phenomenology are presented. They can be useful at determination of background condition of the experiments.

According to the Regge phenomenology cross sections of various reactions in the $\bar{p}p$ interactions are connected with various cuts of the elastic scattering amplitude. In the
simplest approach the amplitude is determined as a sum of contributions of different diagrams with different reggeon exchanges, with vacuum (pomeron \(-P\)) and non-vacuum ones \((f, \omega, A_2, \ldots)\).

\[ F_{\bar{p}p} = F_P + F_f + F_\omega + \ldots \]  

(1)

Figure 3: Reggeon exchanges in the elastic scattering.

Contribution of a diagram with one reggeon exchange in the impact parameter representation has a form \(1)\):

\[ F_R(\vec{b}) = i \frac{\eta_R g_{\bar{p}R}(0) g_{pR}(0)}{R_{\bar{p}R}^2 + R_{pR}^2 + \alpha'_R \xi} e^{(\alpha_R(0)-1)\xi} e^{-\vec{b}^2/4(R_{\bar{p}R}^2 + R_{pR}^2 + \alpha'_R \xi)}. \]  

(2)

The quantities \(\alpha_R(0)\) and \(\alpha'_R\) are the intercept and slope of Regge trajectory \(R\), \(g_{\bar{p}R}\) and \(g_{pR}\) are constants of the reggeon interaction with the proton and antiproton, respectively. Parametrization of the interaction vertex dependence on 4 momentum transfer is the gaussian one, \(g_R(t) = g_R(0)e^{R^2t}\). \(R_R\) is the effective radius of the reggeon interaction with the nucleon. \(\eta_R\) is the signature factor, \(\eta_R = 1 + i \cotg(\pi \alpha_R/2)\) for pole with positive signature, and \(\eta_R = -1 + i \tan(\pi \alpha_R/2)\) for pole with negative signature. \(\xi = \ln(s/s_0)\), \(s\) is the square of CMS energy of the \(\bar{p}p\) interaction, \(s_0 = 1\) GeV\(^2\).

The following parameter values are usually used for the pomeron exchange:

\[ \alpha_P(0) = 1.08, \quad \alpha'_P = 0.13 \]

\[ \alpha_P(0) = 1.12, \quad \alpha'_P = 0.13 \]

Increase of the yield of the one-pomeron exchange with energy growth violates the unitarity condition \((\text{Im} F(\vec{b}) \leq 1)\), and the problem of taking into account contributions of the more complicated diagrams arouses. One of its solution is the eikonal approach \(2)\):

\[ F(\vec{b}) = i \left\{ 1 - \exp \left[ i \sum_R F_R(\vec{b}) \right] \right\}. \]  

(3)

\(^1\) Basis of the Regge theory see in Ref. \([14]\).

\(^2\) Expression \(2\) is obtained in the assumption \([15]\) that the nucleon does not convert into a jet of particles with low mass.
This solves also the problem of the unitarization at low energies where increase of the contributions of the non-vacuum exchanges takes place (see Refs. [16], [17]). Typical values of $\alpha_M$ of the meson exchanges are $\approx 0.5$, the nucleon ones $-\alpha_N \approx -0.5$, and so on. However a task of a correct definition of inelastic process cross sections appears.

The total cross section in the chosen representation has a form:

$$\sigma^{tot} = 2\text{Im} \int d^2 b \left\{ 1 - \exp \left[ i \sum_R F_R(\vec{b}) \right] \right\}. \quad (4)$$

The total elastic cross section is given by the expression:

$$\sigma^{el} = \int d^2 b \left\{ 1 - 2\text{Re} \exp \left[ i \sum_R F_R(\vec{b}) \right] + \exp \left[ -2\text{Im} \sum_R F_R(\vec{b}) \right] \right\}. \quad (5)$$

The inelastic cross section is

$$\sigma^{in} = \int d^2 b \left\{ 1 - \exp \left[ -2\text{Im} \sum_R F_R(\vec{b}) \right] \right\}. \quad (6)$$

Considering only the pomeron exchanges, in the high energy approximation, $\sigma^{in}$ can formally be represented as

$$\sigma^{in} = \sum_{n=1}^{\infty} \sigma_n = \sum_{n=1}^{\infty} \int d^2 b \left[ 2\text{Im} F_p(\vec{b}) \right]^n n! \exp \left[ -2\text{Im} \sum_R F_R(\vec{b}) \right]. \quad (7)$$

The same result can be obtained at an application of the asymptotic Abramovski-Gribov-Kancheli cutting rules [18], AGK rules. At this, one can find that $\sigma_n$ is the cross section with $n$ cut pomerons. According to the existing interpretation [19] $\sigma_n$ is the cross section of the process with the creation of $2(n - 1)$ quark–antiquark strings and 2 quark-diquark strings. If we assume that each string produces at least one meson, we obtain a restriction on $n$,

$$n \leq n_{\max} = \sqrt{s}/2M_M, \quad M_M \approx 0.5 \text{ GeV}.$$  

Therefore the series (7) must be effectively restricted, or a principle of the cut diagram yield re-summation must be formulated. It is desirable to save the simple expressions for $\sigma^{tot}$ and $\sigma^{el}$.

The simplest recipe is,

$$\sigma^{in} = \sum_{n=1}^{n_{\max}} \int d^2 b e^{-2\text{Im} F_p} \left( e^{2\text{Im} F_p/n_{\max}} - 1 \right) \times e^{\frac{n-1}{n_{\max}} 2\text{Im} F_p}. \quad (8)$$

The other simple prescription approbated by the additive quark model is,

$$\sigma^{in} = \sum_{n=1}^{n_{\max}} \int d^2 b e^{-\frac{n_{\max}-n}{n_{\max}} 2\text{Im} F_p} \left[ 1 - e^{-2\text{Im} F_p/n_{\max}} \right]^n. \quad (9)$$

The two different representations lead to two different interpretations of the AGK rule application at finite energies, and two different scenarios (mechanisms) of the interaction can be created, respectively.

At a consideration of the other reggeon exchanges we have additional problem of selection of cross sections connected with cutting of different reggeons. For example, as
known jet production takes place in nucleon-nucleon interactions at super high energies. To take them into account the phase function, \( \chi = \sum R F_R \), is represented as \( \chi = \chi_{\text{soft}} + \chi_{\text{jet}} \). This gives

\[
\sigma^{\text{in}} = \int d^2b \left( 1 - e^{-2Im(\chi_{\text{soft}} + \chi_{\text{jet}})} \right) = \sum_{m,n=0, m+n \neq 0}^{\infty} \sigma_{m,n},
\]

or

\[
\sigma_{m,n} = \int d^2b \frac{[2Im\chi_{\text{soft}}]^m}{m!} \frac{[2Im\chi_{\text{jet}}]^n}{n!} e^{-2Im(\chi_{\text{soft}} + \chi_{\text{jet}})}.
\]

\( \sigma_{m,n} \) is interpreted as a cross section of a process with creation of \( 2n \) jets and \( 2m \) strings.

In the case of \( \bar{p}p \) interactions at low energies one needs to consider both energy restriction and different reggeons.

## 2 General expressions

Most of the existing applications of the Regge phenomenology to the description of the \( \bar{p}p \) interactions consider only one-reggeon exchanges,

\[
F(\vec{b}) = \sum R F_R = F_p + F_f + F_\omega + \ldots
\]

In this case the imaginary part of the amplitude is a sum of positive defined terms.

Performing the unitarization and finding the inelastic cross section, we have

\[
\sigma^{\text{in}} = \int d^2b \left[ 1 - e^{-2ImF_p - 2ImF_f - 2ImF_\omega - \ldots} \right].
\]

Of course, one can use for expansion of the \( \sigma^{\text{in}} \) an analogy of the expression (11) and try to take into account the finiteness of the energy. At this one can meet a problem of physical interpretation. The matter is that the expression (11) was obtained in the assumption of non-planar vertexes of the pomeron interactions with the nucleon. At low energies contributions of planar diagrams are dominated in the amplitude.

Consideration of the planar diagrams at the calculation of the \( \sigma_n \) is a rather difficult task. Though, assuming identical dependencies of all \( F_R \) on \( b \) and the same longitudinal structure of the reggeon-baryon interactions we propose the following expression,

\[
\sigma^{\text{in}} = \sum_i \sigma_i, \quad \sigma_i = \frac{ImF_i(0)}{\sum R ImF_R(0)} \int d^2b \left[ 1 - e^{-2Im\sum R F_R} \right].
\]

Each quantity \( \sigma_i \) is the sum of contributions of diagrams shown in Fig. 4 in the assumption that states \( X \) associated with cuts of different reggeons are orthogonal to each other.

It is obvious that there must be gluon exchanges in the \( \bar{p}p \) interactions. Therefore the pomeron contributions must be in the elastic scattering amplitude, and a term proportional to \( s^{\alpha_p(0) - 1} \) must be in the phase function.

One meson exchange must be responsible for the quark and antiquark annihilation. Therefore a corresponding term proportional to \( s^{\alpha_M(0) - 1} \) must be in the phase function. Because the typical values of \( \alpha_M(0) \simeq 0.5 \), the corresponding term is proportional to \( 1/\sqrt{s} \).
The baryon annihilation is connected with the processes shown in Figs. 2a, 2c, 2e. According to the estimations of Ref. [20] the corresponding reggeon trajectories can have intercepts

\[ \alpha_a(0) = 2\alpha_B(0) - 1 + (1 - \alpha_M(0)), \]

\[ \alpha_c(0) = 2\alpha_B(0) - 1 + 2(1 - \alpha_M(0)), \]

\[ \alpha_e(0) = 2\alpha_B(0) - 1 + 3(1 - \alpha_M(0)), \]

where \( \alpha_B \) is the intercept of the leading baryon trajectory.

Using as in Ref. [20, 8] the values of the parameters \( \alpha_B(0) \approx 0, \alpha_M(0) = 0 \), we have \( \alpha_a = 0.5, \alpha_c = 0 \) and \( \alpha_e = -0.5 \). Therefore terms proportional to \( 1/\sqrt{s}, 1/s, 1/s^{1.5} \) can be in the phase function.

The choice of the effective intercept \( \alpha_B(0) \approx 0 \) is seemed reasonable [21] because \( \alpha_N(0) = -0.35 \) and \( \alpha_\Delta(0) = +0.15 \) (see Ref. [14]). Though as it was noted in Ref. [16, 17] it is not known what kind of the exchanges are dominated, and a pessimistic choice \( \alpha_B(0) \approx \alpha_N(0) = -0.35 \) gives the values \( \alpha_a \approx -0.2, \alpha_c \approx -0.7 \) and \( \alpha_e \approx -1.2 \). The value of \( \alpha_N(0) = -0.5 \) is often used last years, it leads to \( \alpha_a \approx -0.5, \alpha_c \approx -1 \) and \( \alpha_e \approx -1.5 \).

In order not to miss any possibilities we have parametrized the phase function by the following form,

\[ \chi(0)_{pp} = a_1\eta_P S^\Delta + \eta_M \frac{a_2}{S^{a_3}} + \eta_c \frac{a_4}{S^{a_1}} + \eta_e \frac{a_5}{S^{1.5}} + \eta_c' \frac{a_6}{S^2} + \eta_e' \frac{a_7}{S^{2.5}} \]  

A choice of the signature factors is a rather complicated question. It is known [14] that the meson trajectories have a strong exchange degeneracy. Therefore in the first approximation we assume \( \eta_M = 1 \) [10]. We suppose a negative signature of the pole responsible for the process of Fig. 2c. We will try to estimate the signature of the pole connected with the process of Fig. 2e. Criteria of the rightness of the choice can be a successful description of the total cross sections of the \( pp \) and \( pp \) interactions, and the ratios of the real to imaginary part of the corresponding elastic scattering amplitudes. In accordance with saying above we choose the phase function of the \( pp \) scattering in the form,

\[ \chi(0)_{pp} = a_1\eta_P S^\Delta + \frac{a_2}{S^{a_3}} - \frac{a_4}{S^{a_1}} \pm \frac{a_5}{S^{1.5}} - \eta_c \frac{a_6}{S^2} - \eta_e \frac{a_7}{S^{2.5}} \]  

\[ ^3 \text{It was used the expression (4) of Ref. [20] and } \alpha_p = 1. \]
The dependence of the phase function was determined as in Ref. [16],

\[ \chi(\vec{b}) = \chi(0)e^{-b^2/2B_{\text{eff}}}, \]

\[ B_{\text{eff}} = B_0 + 2\alpha'p\xi, \quad B_0 = 10 \text{ GeV}^{-2}, \quad \alpha' = 0.13 \text{ GeV}^{-2}. \] (19)

3 Fitting procedure

We have used at fitting of the parameters the experimental data on the total \( \bar{p}p \) and \( pp \) interaction cross sections collected in the Particle Data Group data base [22]. The fit is a rather complicated procedure because:

1. The number of the parameters is large, and the fitting results are unstable;
2. The signatures of the poles are not determined quite well;
3. Application region of the considered approach is not known.

At the beginning we performed the fit taking only the two first terms of the phase function. Such oversimplified approach can be useful at a rough estimation of the cross sections. We present results of the fit in table. 1 and description of the experimental data at \( p_{\text{lab}} \geq 5 \text{ GeV}/c \) in Fig. 5.

Table 1: Results of the experimental data fitting at \( a_4, a_5, a_6, a_7 = 0. \)

| \( \bar{p}p, P_{\text{lab}} \geq 100 \text{ GeV}/c \) | \( a_1 \) | \( a_2 \) | \( a_3 \) | \( \chi^2/\text{NOF} \) |
|----------------|-----|-----|-----|---------|
| 0.443 ± 0.004 | 2.50 ± 0.29 | 0.430 ± 0.026 | 14/22 |
| \( \bar{p}p, P_{\text{lab}} \geq 10 \text{ GeV}/c \) | 0.453 ± 0.003 | 3.71 ± 0.12 | 0.515 ± 0.009 | 37/55 |
| \( \bar{p}p, P_{\text{lab}} \geq 5 \text{ GeV}/c \) | 0.459 ± 0.002 | 4.16 ± 0.11 | 0.545 ± 0.008 | 57/63 |

As seen, the parameters \( a_1 \) for \( \bar{p}p \) and \( pp \) interactions become close to each other with the energy growth. This is not observed for the parameters \( a_2 \) and \( a_3 \). To crown it all, the small value of the parameter \( a_3 \) for the \( pp \) interactions points out that we need to increase the imaginal part of the phase function taking additional exchanges. This contradicts with the starting assumptions. The contradiction can be erased at fixing the parameter \( a_3 \) at the level 0.5. Results of the corresponding fit are given in table 2, and presented in Fig. 5 by the dashed lines. As seen, the results allows one to hope on a father success.

Let us include the additional exchanges. The results of the fit of the experimental data at \( a_3 = 0.5 \) and \( a_5, a_6, a_7 = 0 \) are presented in table 3 and in Fig. 6 by solid lines. As seen, a significant rapprochement of the pomeron exchange parameters has occurred. It is observed a difference between the parameters \( a_2 \) as before. At the same time at \( p_{\text{lab}} \geq 5 \text{ GeV}/c \) the parameters of the trajectory responsible for the process of Fig. 2c become close. It is clear that the next additional exchange must have the positive signature.

\footnote{Behavior of the approximating functions below the fitting region is shown in all the figures in order to determine a direction of father approximation.}
Table 2: Results of the experimental data fitting at $a_3 = 0.5$, $a_4$, $a_5$, $a_6$, $a_7 = 0$.

|                  | $a_1$         | $a_2$         | $a_3$ | $\chi^2$/NOF |
|------------------|---------------|---------------|-------|--------------|
| $\bar{p}p$, $P_{lab} \geq 10$ GeV/c | $0.449 \pm 0.001$ | $3.54 \pm 0.022$ | 0.5   | 38/56        |
| $pp$, $P_{lab} \geq 10$ GeV/c      | $0.464 \pm 0.003$ | $1.718 \pm 0.006$ | 0.5   | 388/110      |

Table 3: Results of the experimental data fitting at $a_3 = 0.5$, $a_5$, $a_6$, $a_7 = 0$.

|                  | $a_1$         | $a_2$         | $a_4$ | $\chi^2$/NOF |
|------------------|---------------|---------------|-------|--------------|
| $\bar{p}p$, $P_{lab} \geq 10$ GeV/c | $0.453 \pm 0.002$ | $3.37 \pm 0.08$ | 1.06  | 35/55        |
| $\bar{p}p$, $P_{lab} \geq 5$ GeV/c | $0.456 \pm 0.002$ | $3.19 \pm 0.06$ | 2.29  | 48/62        |
| $\bar{p}p$, $P_{lab} \geq 4$ GeV/c | $0.461 \pm 0.002$ | $3.00 \pm 0.05$ | 3.50  | 90/66        |

Results of the fit with four terms of the phase function are presented in table 4. As
seen, the fit does not give a self-consistent set of the parameters for $\bar{p}p$ and $pp$ interactions.
Summing up we choose at $p_{lab} \geq 5$ GeV/c the set of the parameters presented in table 5.
Let us consider a pessimistic variant with $\alpha_a = -0.5$. Doing the same as it was
before, we have results presented in table 6 and shown in Fig. 6 by the dashed lines.
Once more, as it was before the parameters $a_1$ and $a_2$ become close at $p_{lab} \sim 5$ GeV/c.
In the same manner we determine that the additional exchange must have the positive
signature. Though taking into account the fifth term of the phase function does not
lead to a rapprochement of the parameters for the $\bar{p}p$ and $pp$ interactions. Therefore we
propose for the region of $p_{lab} \geq 5$ GeV/c the parameter set presented in table 7 for the
considered case.
An explanation is needed for the difference of the parameters $a_2$ for $\bar{p}p$ and $pp$ interaction. Usually it is assumed that the contribution of the one-meson exchange consists from yields of the two poles with negative and positive signatures: $F_{\bar{p}p} = F_P + F_f + F_\omega$, $F_{pp} = F_P + F_f - F_\omega$. In accordance with this one can introduce $a_{2f} = (a_{2\bar{p}p} + a_{2pp})/2$ and $a_{2\omega} = (a_{2\bar{p}p} - a_{2pp})/2$ and repeat the fit once more. However this procedure is rather unstable. It is needed to look at other set of experimental data what is out of the scope of our paper. The simplest receipt for overcoming the problem is neglection by the real part of the second term of the phase function. An apparently consequence of the assumption is that the ratios of the real to imaginary parts of the elastic scattering amplitude for $\bar{p}p$ and $pp$ interactions will be near to zero in the studied energy range. At the same time, it is well known from experiment that the ratio for the $\bar{p}p$ interactions has a positive value at low energies, but the ratio for the $pp$ interactions has a negative value.

The more complicate situation takes place with a description of the elastic scattering cross section (see Fig. 7), and with a description of the data at $p_{lab} \leq 5$ GeV/c. Here one needs to assume various interaction radii of different reggeons with nucleon.

If we restrict ourself by the region of $p_{lab} \geq 5$ GeV/c, we believe that the reached results are acceptable. The results are shown in Fig. 7.

# 4 Cross sections of $\bar{p}p$ interactions

Cross sections of the processes of Fig. 2b, 2c and 2g obtained with a help of Eq. (13) are presented in Fig. 8. There are also inelastic cross sections of $\bar{p}p$ interactions calculated with the HERA-CERN parametrization [23] (upper solid curve) and with the parameter set No 1 (upper dashed curve). As seen, the two parametrization are close to each other.

Let us note that the screening corrections (Eq. (13)) change the energy dependencies of the processes of Fig. 2b and 2c. For example, the cross section of the process of Fig.
the annihilation cross section is given by the process with quark and antiquark annihilation. One needs to assume a new mechanism of the baryon annihilation. It is a subject of specific interest to describe annihilation cross section, the cross section of reaction without baryons in the final state. The known experimental data are presented in Fig. 8 by the open points. The parametrization of the form $1/s$ used in the Ultrarelativistic Quantum Molecular Dynamic (UrQMD) model is given by filled points. As seen, the annihilation can not be explained by the process of Fig. 2c. It can not be a part of the pomeron exchange, as it is often assumed starting from Ref. [20]. One needs to assume a new mechanism of the baryon annihilation.

In Refs. [2, 17] it was assumed that at intermediate energies the main contribution to the annihilation cross section is given by the process with quark and antiquark annihilation with following one-gluon exchange (see Fig. 9a). However the gluon exchange can not change the energy dependence of the type $1/\sqrt{s}$ [2, 17].

We believe that diquark or anti-diquark can emit a meson, and after that the string junction annihilation takes place (see Fig. 9b). Nearly the same mechanism is accepted in UrQMD model [26] which describes quite well experimental data at intermediate energies. Because diquark – anti-diquarks strings are created in the processes of Fig. 2b and 2g, the proposed mechanism can be connected with the main processes of $\bar{p}p$ interactions. The energy dependence of the annihilation can be determined by the fragmentation of the strings. We are going to consider the fragmentation in following paper.

### Table 4: Results of the experimental data fitting at $a_3 = 0.5$, $a_6$, $a_7 = 0$.

| $\bar{p}p, \sqrt{s_{lab}} \geq 10$ GeV/c | $a_1$ | $a_2$ | $a_4$ | $a_5$ | $\chi^2$/NOF |
|-----------------------------------------|-------|-------|-------|-------|---------------|
| $\bar{p}p, \sqrt{s_{lab}} \geq 5$ GeV/c | $a_1$ | $a_2$ | $a_4$ | $a_5$ | $\chi^2$/NOF |
| $\bar{p}p, \sqrt{s_{lab}} \geq 4$ GeV/c | $a_1$ | $a_2$ | $a_4$ | $a_5$ | $\chi^2$/NOF |
| $\bar{p}p, \sqrt{s_{lab}} \geq 3$ GeV/c | $a_1$ | $a_2$ | $a_4$ | $a_5$ | $\chi^2$/NOF |

### Table 5: Set of proposed parameters No 1.

| $\bar{p}p, \sqrt{s_{lab}} \geq 5$ GeV/c | $a_1$ | $a_2$ | $a_3$ | $a_4$ | $a_5$ | $a_6$ | $a_7$ |
|-----------------------------------------|-------|-------|-------|-------|-------|-------|-------|
| $\bar{p}p, \sqrt{s_{lab}} \geq 5$ GeV/c | $a_1$ | $a_2$ | $a_3$ | $a_4$ | $a_5$ | $a_6$ | $a_7$ |

2b falls down more slowly than $1/\sqrt{s}$ with energy increase. One needs to take these into account at a calculation of cross sections of other reactions, e.a. $\bar{p}p \rightarrow K^+K^-$, $\bar{p}p \rightarrow \Lambda\bar{\Lambda}$, in the spirit of Ref. [23].

It is a subject of specific interest to describe annihilation cross section, the cross section of reaction without baryons in the final state. The known experimental data [22] are presented in Fig. 8 by the open points. The parametrization of the form $1/s$ used in the Ultrarelativistic Quantum Molecular Dynamic (UrQMD) model is given by filled points. As seen, the annihilation can not be explained by the process of Fig. 2c. It can not be a constant part of the processes connected with the second term of the phase function due to different energy dependencies of the annihilation and the cross section of the process of Fig. 2b. It can not be a part of the pomeron exchange, as it is often assumed starting from Ref. [20]. One needs to assume a new mechanism of the baryon annihilation.
Table 6: Results of the experimental data fitting at $a_3 = 0.5$, $a_4$, $a_6$, $a_7 = 0$.

| $\bar{p}p, P_{lab} \geq$ GeV/c | $a_1$       | $a_2$       | $a_5$       | $\chi^2$/NOF |
|-------------------------------|------------|------------|------------|--------------|
| $10$                          | $0.452 \pm 0.002$ | $3.44 \pm 0.04$ | $4.33 \pm 1.64$ | $34/55$      |
| $5$                           | $0.454 \pm 0.002$ | $3.39 \pm 0.03$ | $7.12 \pm 0.89$ | $43/62$      |
| $4$                           | $0.455 \pm 0.001$ | $3.36 \pm 0.03$ | $8.11 \pm 0.41$ | $74/66$      |

| $p\bar{p}, P_{lab} \geq$ GeV/c | $a_1$       | $a_2$       | $a_5$       | $\chi^2$/NOF |
|-------------------------------|------------|------------|------------|--------------|
| $10$                          | $0.454 \pm 0.001$ | $2.04 \pm 0.02$ | $10.4 \pm 0.4$ | $100/109$    |
| $5$                           | $0.459 \pm 0.001$ | $1.88 \pm 0.01$ | $5.29 \pm 0.11$ | $279/125$    |
| $4$                           | $0.463 \pm 0.001$ | $1.79 \pm 0.01$ | $3.91 \pm 0.08$ | $530/133$    |

Table 7: Set of proposed parameters No 2.

| $\bar{p}p, P_{lab} \geq$ GeV/c | $a_1$ | $a_2$ | $a_3$ | $a_4$ | $a_5$ | $a_6$ | $a_7$ |
|-------------------------------|-------|-------|-------|-------|-------|-------|-------|
| $5$                           | $0.457$ | $3.39$ | $0.5$ | $0$   | $6.2$ | $0$ | $0$. |
| $5$                           | $0.457$ | $1.88$ | $0.5$ | $0$   | $6.2$ | $0$ | $0$. |

Summary

- The expression is proposed for the calculation of the cross sections of various reactions in $\bar{p}p$ interactions, for the processes with creation of one or two strings, within the framework of the eikonal approach in the assumption of the identical interaction radii of different reggeon with nucleon. The cross sections are needed for Monte Carlo simulation of the reactions.

- The parameters of the pomeron exchange, meson exchange, and exchange of a meson with hidden baryon number are determined at fitting the experimental data on the total $\bar{p}p$ and $pp$ interaction cross sections.

- Using the fitted parameters, the cross sections of $\bar{p}p$ interactions are calculated at $p_{lab} \geq 5$ GeV/c.

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Figure 6: Results of the fitting with three terms of the phase function.
Figure 7: Final results of the experimental data fitting with the parameter set No 1.
Figure 8: Decomposition of the inelastic $\bar{p}p$-interaction cross section. Curves b, c, g represent cross sections of the processes 2b, 2c, 2g. Filled points are UrQMD model parametrization \cite{26} of the annihilation cross section. Open points are the experimental data \cite{24}.
Figure 9: Possible mechanisms of baryon annihilation.