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(revised version)

INELASTIC MESON-BARYON SCATTERING WITH REGGE POLES
AND SU₃ SYMMETRY

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A B S T R A C T

Inelastic meson-baryon scattering of type $0^- + \frac{1}{2}^+ \rightarrow 0^- + \frac{1}{2}^+$ is studied on the basis of Regge poles and exact SU₃ symmetry. The exchanged trajectories considered are ρ , A₂, K* (890) and K** (1411). Good agreement is obtained for the differential cross-section in the forward direction for different reactions. The f/d ratio is found to be -11 for the 1⁻ octet and 0.25 for the 2⁺ octet.

This revised version contains new experimental results. At the same time the parametrization of the ρ amplitudes has been changed in order to take into account the "cross-over" mechanism, and an unfortunate mistake in the cross-section corrected. All this implies some modifications in the numerical estimations of the K^* parameters.

We are much indebted to Dr. R.J.N. Phillips for a correspondence concerning the "cross-over" problem.

1. INTRODUCTION

We study in this paper some inelastic two-body meson-baryon scattering ($M_1 B_1 \rightarrow M_2 B_2$, with $M = 0^-$ meson, $B = \frac{1}{2}^+$ baryon and $M_1 \neq M_2$, $B_1 \neq B_2$), in the forward direction, on the basis of Regge pole exchange in the t channel, and exact SU_3 symmetry. We have restricted ourselves to those reactions which are experimentally feasible, i.e., reactions in which the target is a nucleon and the incident particle a charged meson. Then reactions studied are:

$$\begin{aligned} \pi^- p &\rightarrow \pi^0 n \quad ; \quad \pi^- p \rightarrow \eta n \quad ; \quad K^- p \rightarrow \bar{K}^0 n \\ \pi N &\rightarrow KY \quad ; \quad \bar{K} N \rightarrow \pi Y \quad ; \quad \bar{K} N \rightarrow \eta Y \\ (Y &= \Lambda \text{ or } \Sigma) \end{aligned}$$

We have assumed that the whole interaction in the forward direction might be simulated with exchange of the $V(1^-)$ and $T(2^+)$ meson octets trajectories in the t channel, the residues of the amplitudes being related from one process to another by exact SU_3 symmetry. As a consequence, we assume no exchange in the t channel, with quantum numbers $I = \frac{3}{2}$ or $S = -2$, so that the following cross-sections should be zero in the forward direction

$$\bar{K}N \rightarrow K\Xi; \pi^-p \rightarrow \Sigma^-K^+; \pi^+N \rightarrow \Sigma^+K^0; K^-p \rightarrow \Sigma^-\pi^+$$

It is well known that for all these reactions the cross-sections are negligible when compared to equivalent processes, for energies above 3 GeV/c¹⁾⁻³⁾. This means that the direct channel contributions for all reactions studied in this paper are already small at this energy.

In the following Section we give the cross-section and scattering amplitudes. Then these formulae are compared with experimental data. We have not tried an over-all best fit for the whole set of experimental data, because we think that present experimental information relative to $\pi^-p \rightarrow \pi^0n$ or $\eta + n$ are much more reliable than those related to hyperon production. The ρ and A_2 parameters are derived from previous works and then it is shown that only two parameters are left free for all other reactions, namely the two f/d ratio.

In Section 3 experimental results are compared with the model and finally, in Section 4, we show that at present time all meson-baryon scattering data are compatible with the SU_3 Regge pole model, with the exception of the isoscalar trajectories for which there remains, in our opinion, open questions.

2. CROSS-SECTIONS AND SCATTERING AMPLITUDES

The classical reggeization of scattering amplitudes for elastic π^-N scattering has been given, for example, by Singh⁴⁾. In terms of the usual invariant functions A and B, one defines a new set A' and B such that

$$A' = A - m \frac{q_t}{p_t} \cos\theta_t B$$

where q_t , p_t and θ_t are respectively the pion momentum, nucleon momentum and scattering angle in the c.m. system of the t channel. A' and B are related to the helicity amplitudes in the following way

$$f_{00\frac{1}{2}\frac{1}{2}} = -p_t A'$$

$$f_{00\frac{1}{2}-\frac{1}{2}} = \frac{1}{2} q_t \sqrt{t} \sin \theta_t B$$

Spin summation, using customary rules, leads to the following cross-section

$$\frac{d\sigma}{dt} = \frac{1}{64\pi s k^2} \left[(4m^2 - t) |A'|^2 - t q_t^2 \sin^2 \theta_t |B|^2 \right] \quad (1)$$

where k^2 is the c.m. momentum of initial particles in the s channel.

The alternative approach, which is in fact equivalent to the preceding one for phenomenology, follows Wang's ⁵⁾ prescriptions. One defines the two helicity amplitudes F_1 and F_2 free of kinematical singularities

$$F_1 = [t - (m_2 + m_4)^2]^{\frac{1}{2}} f_{00\frac{1}{2}\frac{1}{2}}$$

$$F_2 = [t - (m_2 - m_4)^2]^{\frac{1}{2}} q_t \sin \theta_t f_{00\frac{1}{2}-\frac{1}{2}}$$

in terms of which the differential cross-section is given by

$$\frac{d\sigma}{dt} = \frac{1}{64\pi s k^2} \frac{1}{(m_2 + m_4)^2 - t} \left[|F_1|^2 + \Phi |F_2|^2 \right] \quad (2)$$

4.

with

$$\begin{aligned} \Phi = & S t (m_1^2 + m_2^2 + m_3^2 + m_4^2 - S - t) - S (m_2^2 - m_4^2)(m_1^2 - m_3^2) - \\ & - t (m_1^2 - m_2^2)(m_3^2 - m_4^2) - (m_1^2 m_4^2 - m_2^2 m_3^2)(m_1^2 + m_4^2 - m_2^2 - m_3^2) \end{aligned}$$

The two sets of amplitudes (A', B) and (F_1, F_2) are assumed to be reggeizable. Nevertheless, A' in the first set, and A when expressed in terms of F_1 and F_2 , in the second one, are both singular for $t = (m_2 + m_4)^2$. This implies in fact a constraint among amplitudes, which might be reasonably neglected because this singular point is very far from the physical domain.

In their well-known analysis Phillips and Rarita⁶⁾ used formula (1). Because, up to some extent, it is easier to work with helicity amplitudes in the unequal mass case, we shall use Eq. (2) for the cross-section.

We now come to the problem of reggeization of the two helicity amplitudes F_1 and F_2 . We assume that the whole forward differential cross-section is dominated by 1^- and 2^+ octets exchange, that is by ρ and A_2 exchange for the three processes with strangeness exchange zero and by $K^*(890)$ and $K^{**}(1420)$ for the others.

As input we need the ρ and A_2 exchange amplitudes, which are of course deduced from $\pi^- p \rightarrow \pi^0 n$ and $\pi^- p \rightarrow \eta n$. Despite the fact that it is not possible to explain the polarization data of $\pi^- N$ charge exchange with A_2 alone, we make the optimistic assumption that, whatever the mechanism responsible of this polarization is, it does not alter too much the one-trajectory fit of the differential cross-section

It is well known that there are some ambiguities in the parametrization of Regge residues ⁷⁾. We have chosen the recent analysis of Reeder and Sarma ⁸⁾, because these authors have performed an over-all best fit of the three reactions $\pi^- p \rightarrow \pi^0 n$, $\pi^- p \rightarrow \eta n$ and $K^- p \rightarrow \bar{K}^0 n$ with exact SU_3 symmetry, up to rather large values of the momentum transfer, which is exactly the thing we need.

Their parametrization for ρ and A_2 exchange is

$$\begin{aligned} F_1^\rho &= \gamma_1^\rho (\alpha_\rho + 1)^2 \left(1 + \frac{t}{t_\rho}\right) \left(i + \tan \frac{\pi}{2} \alpha_\rho\right) R_1^\rho \\ F_2^\rho &= \gamma_2^\rho \alpha_\rho (\alpha_\rho + 1)^2 \left(i + \tan \frac{\pi}{2} \alpha_\rho\right) R_2^\rho \end{aligned} \quad (3)$$

$$F_1^{A_2} = \gamma_1^A \alpha_A (\alpha_A + 1) \left(i - \cot \frac{\pi}{2} \alpha_A\right) R_1^A$$

$$F_2^{A_2} = \gamma_2^A \alpha_A^2 (\alpha_A + 1) \left(i - \cot \frac{\pi}{2} \alpha_A\right) R_2^A$$

where

$$R_1^i = \left(\frac{s-u}{2s_1^i}\right)^{\alpha_i}$$

$$R_2^i = \left(\frac{s-u}{2s_2^i}\right)^{\alpha_i - 1}$$

The factor $(1 + (t/t_e))$ in F_1^{ρ} accounts for the cross-over mechanism discussed in Ref. 6), and the two trajectories are given by

$$\alpha_{\rho}(t) = 0.56 + 1.03 t + 0.16 t^2 \quad (4)$$

$$\alpha_A(t) = 0.41 + 0.41 t$$

In the following we shall assume that the SU_3 relations hold on γ_1 and γ_2 . Nevertheless, it should be noted that this is completely equivalent to the assumption that the whole helicity amplitudes are related through SU_3 relations at fixed $\alpha(t)$.

Though the Regge pole model is only reliable at asymptotic energies, it is of interest to notice that even at 3 GeV, the fit is already quite acceptable in the forward direction. It is nevertheless possible to feel whether or not one is not too far from asymptotic behaviour by looking at the total cross-section as a function of energy. This we have done for the reactions studied in the following.

3. HYPERON PRODUCTION

The amplitudes for ρ and A_2 exchange are now completely determined. To compute the scattering amplitudes for hyperon production with K^* and K^{**} exchange we have only two parameters free, which are the two f/d ratio at the NY vertex.

a. SU₃ coefficients

If we denote by A_V and A_T respectively, the scattering amplitudes with exchange of the 1^- and 2^+ octets, we obtain the following linear combinations

$$\begin{aligned}
 1) \quad \pi^- p \rightarrow \pi^0 n & \quad -\sqrt{2} A_V \\
 2) \quad \pi^- p \rightarrow \eta n & \quad \sqrt{2}/\sqrt{3} A_T \\
 3) \quad K^- p \rightarrow \bar{K}^0 n & \quad A_V + A_T \\
 4) \quad \pi^+ p \rightarrow \Sigma^+ K^+ & \quad -A_V(1-2\alpha) - A_T(1-2\alpha') \\
 5) \quad \pi^- p \rightarrow \Lambda K^0 & \quad -\sqrt{\frac{3}{2}} A_V(1-\frac{2\alpha}{3}) - \sqrt{\frac{3}{2}} A_T(1-\frac{2\alpha'}{3}) \\
 6) \quad K^- p \rightarrow \Lambda^0 \pi^0 & \quad \frac{\sqrt{3}}{2} A_V(1-\frac{2\alpha}{3}) - \frac{\sqrt{3}}{2} A_T(1-\frac{2\alpha'}{3}) \\
 7) \quad K^- p \rightarrow \bar{\Sigma}^0 \pi^0 & \quad \frac{1}{2} A_V(1-2\alpha) - \frac{A_T}{2}(1-2\alpha') \\
 8) \quad K^- p \rightarrow \bar{\Sigma}^0 \eta & \quad \frac{\sqrt{3}}{2} A_V(1-2\alpha) + \frac{1}{2\sqrt{3}} A_T(1-2\alpha') \\
 9) \quad K^- p \rightarrow \Lambda^0 \eta & \quad \frac{3}{2} A_V(1-\frac{2\alpha}{3}) + \frac{A_T}{2}(1-\frac{2\alpha'}{3})
 \end{aligned} \tag{5}$$

where α and α' are equal to $d/(f+d)$, respectively for the V and T octets.

Because we cannot have $I = \frac{3}{2}$ in the t channel we get the following relations, due to charge independence, between amplitudes:

$$\begin{aligned}
 \pi^+ p \rightarrow \Sigma^+ K^+ &= \sqrt{2} \pi^- p \rightarrow \bar{\Sigma}^0 K^0 = -\sqrt{2} \pi^+ n \rightarrow \bar{\Sigma}^0 K^+ = \pi^- n \rightarrow \bar{\Sigma}^- K^0 \\
 \pi^- p \rightarrow \Lambda^0 K^0 &= \pi^+ n \rightarrow \Lambda^0 K^+
 \end{aligned}$$

$$K^- p \rightarrow \Lambda \pi^0 = \frac{1}{\sqrt{2}} K^- n \rightarrow \Lambda^0 \pi^-$$

$$K^- p \rightarrow \Sigma^0 \pi^0 = \frac{1}{\sqrt{2}} K^- n \rightarrow \Sigma^- \pi^0 = -\frac{1}{\sqrt{2}} K^- \bar{n} \rightarrow \Sigma^0 \pi^- = \frac{1}{2} K^- p \rightarrow \Sigma^+ \pi^-$$

$$K^- p \rightarrow \Sigma^0 \eta = \frac{1}{\sqrt{2}} K^- n \rightarrow \Sigma^- \eta$$

We have found only two sets of experimental data which might be used to test these relations: differential cross-sections for $\pi^+ p \rightarrow \Sigma^+ K^+$ at 3.23 GeV ⁹⁾ and for $\pi^- p \rightarrow \Sigma^0 K^0$ at 3 GeV ¹⁰⁾. It may be seen on Figs. 1 and 2 that the equality

$$\frac{d\sigma}{dt}(\pi^+ p \rightarrow \Sigma^+ K^+) = 2 \frac{d\sigma}{dt}(\pi^- p \rightarrow \Sigma^0 K^0)$$

is well satisfied, except in the very forward direction.

Using the parametrization of helicity amplitudes (3), the SU_3 coefficients (5) and the cross-section expression (2), we may now evaluate the differential cross-sections for reactions 4) to 9), for which the exchanged trajectories are K^* and K^{**} .

We recall that at this stage we have only two free parameters α and α' . Nevertheless, nothing is known up to now with regard to the K^* and K^{**} trajectories, though it is generally believed that they should be similar to the ρ and A_2 trajectories. We have then allowed the K^* and K^{**} trajectories to vary parallelly to the ρ and A_2 trajectories respectively, the distance from one trajectory to the other being equal to the mass difference.

b. Predictions for $f/d = -2$

A first result to be quoted is that the value $f/d = -2$, given by Barger and Olsson ¹¹⁾ is completely ruled out. But one should bear in mind that this value for f/d has been derived by Barger and Olsson, through isoscalar exchange only. There are certainly strong complications induced by the mixing and this problem has not been treated correctly up to now, in our opinion. We think that our derivation of the f/d ratio is much more tenable.

We compare in the Table the theoretical predictions with $f/d = -2$ and the experimental cross-sections. Even at 3 GeV, the theoretical cross-sections are considerably larger than the experimental ones, though one would expect just the contrary.

Reaction	$\pi^+ p \rightarrow \Sigma^+ K^+$	$\pi^- p \rightarrow \Lambda K^0$	$K^- p \rightarrow \Lambda \pi^0$	$K^- p \rightarrow \Sigma^+ \pi^-$	$K^- p \rightarrow \Lambda^0 \eta$
R	9	5.5	3	8	4

Ratio: cross-section with $f/d = -2$ over experimental cross-section.

c. Data

The Regge pole model is currently assumed to hold only for high energies, at least something like 6 GeV. But we found no angular distributions with incident momentum larger than 4 GeV/c, except for $\pi^- p \rightarrow Y^0 K^0$ at 6 GeV/c. Nevertheless, we have tried to use as much as possible all experimental data at present time. We look also to total cross-sections to decide whether or not the energy might be considered as nearly asymptotic or not. Our aim was to get a qualitative description of the phenomena at intermediate energies, but it turned out that even some kind of quantitative interpretation could be possible.

Because we felt much in trouble in determining which of the data were reliable to be fitted, we have not tried to perform a kind of best fit, with χ^2 analysis. In our opinion this would have been meaningless, due to the lack of coherent experimental data and to the rather debatable validity of our model at energies considered.

We have only computed the cross-sections for various sets of α and α' and looked at the fit. By no means do we claim then that our fit is the best which might be achieved, nor that it is the only one. We only claim that we found no contradictions between the SU_3 Regge pole model and the experimental data.

Our preferred solution is:

for the 1^- octet $\alpha \simeq -0.1$ or $f/d \simeq -11$
 for the 2^+ octet $\alpha' \simeq 0.8$ or $f/d \simeq 0.25$.

With regard to the trajectory parameters, we found that the best fit corresponds to

$$\alpha_{K^*} = \alpha_\rho = 0.56 + 1.03t + 0.16t^2$$

$$\alpha_{K^{**}} = 0.29 + 0.41t$$

1) $\pi^+ p \rightarrow \Sigma^+ K^+$ and $\pi^- p \rightarrow \Sigma^0 K^0$

As we already mentioned in our model $d\sigma/dt(\Sigma^+) = 2d\sigma/dt(\Sigma^0)$. Using the results of Ref. 9), 10) at 3 GeV/c, one notices that this relation is well fulfilled for $|t| > 0.2(\text{GeV}/c)^2$, but not in the forward direction. This reflected in the fact that our fit for $\pi^+ p \rightarrow \Sigma^+ K^+$ (Fig. 1) is not as good in the forward direction, as it is for $\pi^- p \rightarrow \Sigma^0 K^0$ at 3 GeV/c (Fig. 2) and 4 GeV/c (Fig. 3). The dip which is predicted by the model, and experimentally observed in both processes for $t \simeq -0.6(\text{GeV}/c)^2$, is due to the vanishing of the trajectories, near this energy.

On Figs. 4 and 5, the total cross-sections ¹²⁾ are also shown for these two reactions. The decrease of the total cross-section seems to be in good agreement with the observed one.

The last piece of information we have, is the polarization of Σ^+ at 3 GeV/c⁹⁾ (Fig. 6). Agreement is at best qualitative, but these data were not included in the fit.

2) $\pi^- p \rightarrow \Lambda^0 K^0$

The general features of both experimental and theoretical results do not differ much for this reaction from the preceding one. The differential cross-section at 3 and 4 GeV/c¹⁰⁾ are plotted on Figs. 7 and 8, and at 6 GeV/c¹³⁾ for $\pi^- p \rightarrow (\Lambda^0 K^0 + \Sigma^0 K^0)$, (Fig. 9). The total cross-section is shown on Fig. 5. All our results for total cross-section seem in agreement with Morrison¹⁴⁾ analysis.

Once more, agreement for Λ polarization (Fig. 10), is qualitative.

3) $K^- p \rightarrow \Lambda^0 \pi^0$

The differential cross-section at 3 GeV/c¹⁾ is plotted on Fig. 11 and the total cross-section on Fig. 12. Due to the very important contribution of resonant states, especially the $Y^*(2035)$ at 1.53 GeV, it is clear that the cross-section has not yet got its asymptotic behaviour below 3 GeV.

4) $K^- p \rightarrow \Sigma^+ \pi^-$

The theoretical curves are compared on Fig. 13 with the experimental data at 3 GeV¹⁾ and on Fig. 14 at 3.5 GeV¹⁵⁾. The dip at $t = -0.6$ (GeV/c)² is not experimentally observed. The total cross-section is also shown on Fig. 12, and it is interesting to notice that most of the cross-sections could be accounted for by our model, even at low energy. There are no results for $K^- p \rightarrow \Sigma^0 \pi^0$ whose cross-section is predicted to be 1/4 of $K^- p \rightarrow \Sigma^+ \pi^-$.

5) $\underline{K^-p \rightarrow Y^0 \eta}$

This is the worst result of our analysis, because our predicted cross-sections are about 1.5 time larger than the experimental ones. On Fig. 15 is shown the differential cross-section for $K^-p \rightarrow \Lambda \eta$ ¹⁾. The cross-section for $K^-p \rightarrow \Sigma^0 \eta$ is predicted to be about 1/3 of the preceding one. This last process does not seem to have been observed at high energy.

4. SOME REMARKS ABOUT SU_3 IN MESON-BARYON SCATTERING

An impressive agreement with existing experimental data has already been found with the SU_3 + Regge pole model, for such reactions, or combinations of reactions which involved only isovector exchange. We quote only some of these results.

- i. Ahmadzadeh and Chan ¹⁶⁾ have derived, among others, the following sum rule

$$2 \frac{d\sigma}{dt}(K^-p \rightarrow \bar{K}^0 n) = \frac{d\sigma}{dt}(\pi^-p \rightarrow \pi^0 n) + 3 \frac{d\sigma}{dt}(\pi^-p \rightarrow \eta n)$$

in very good agreement with experiment.

- ii. More recently Barger and Olsson ¹⁷⁾ have studied six independent combinations of cross-section data in the forward direction, involving only ρ and A_2 exchange and no isoscalar trajectory:

$$\pi^-p \rightarrow \pi^0 n$$

$$\pi^-p \rightarrow \eta n \quad \text{and}$$

$$K^-p \rightarrow \bar{K}^0 n$$

$$\Delta_{\pi p}$$

$$\Delta_{\kappa p} - \Delta_{\kappa n}$$

$$\Sigma_{\kappa p} - \Sigma_{\kappa n}$$

They found the following ratios between Regge pole residues

$$(\rho_{\bar{K}K} / \rho_{\pi\pi}) = 1.12 \pm 0.12$$

$$(A_2 \bar{K}K / A_2 \pi\eta) = 1.07 \pm 0.15$$

consistent with exact symmetry values of 1.

- iii. The same agreement is found also in Phillips and Rarita ⁶⁾ analysis though the conclusions may not be so clear due to isoscalar contributions. They found for instance

$$A_e(KN \rightarrow KN) / A_e(\pi N \rightarrow \pi N) = 0.527 \quad \text{instead of } \frac{1}{2}$$

$$A_R(KN \rightarrow KN) / A_R(\pi^- p \rightarrow \eta n) = 1.72 \quad \text{instead of } \frac{2\sqrt{2}}{\sqrt{3}} = 1.63$$

- iv. The situation is not so clear with regard to isoscalar contributions. This is reflected by the fact that there exist large discrepancies between various analyses.

Phillips and Rarita found that the Pomeranchuk trajectory behaves as an isosinglet. This predicts that the πN and KN elastic cross-sections should become equal at high energy, which is presently questionable.

On the other hand, the P' behaves neither as an isosinglet nor as an isoscalar member of an octet and one is also in trouble with the ω trajectory.

All these facts clearly indicate that the question of isoscalar trajectories is up to now an open question. The mixing problem has probably something to do with that, but we think that all present approaches are not yet successful.

7. CONCLUSIONS

This investigation clearly shows that there is no contradiction at the present time between the theoretical SU_3 Regge pole model and experimental data, and even indicates that it is a realistic interpretation of the data, total and differential cross-section, with the exception of polarization data, which have not been coherently explained up to now.

Though the data we used in this paper are rather preliminary we think that a more refined analysis, with more precise data, will not exhibit strong violations of the SU_3 Regge pole model (larger than 10 or 20%) and that the exact values one should get for the f/d ratios should not be too different from those we obtained.

If one believes in this model we think that a small number of rather accurate experimental data for energies between 3 and 10 GeV should allow an exact determination of the f/d ratio, to which the magnitude of the cross-sections is very sensitive, as well as a better estimate of the K^* and K^{**} trajectory shapes.

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$$|t| < 1.2(\text{GeV}/c)^2$$

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FIGURE CAPTIONS

- Figure 1 $\pi^+p \rightarrow \Sigma^+K^+$ differential cross-section at 3 GeV/c, data from Ref. 9).
- Figure 2 $\pi^-p \rightarrow \Sigma^0K^0$ differential cross-section at 3 GeV/c, data from Ref. 10).
- Figure 3 $\pi^-p \rightarrow \Sigma^0K^0$ differential cross-section at 4 GeV/c, data from Ref. 10).
- Figure 4 $\pi^+p \rightarrow \Sigma^+K^+$ and $\pi^-p \rightarrow (\Lambda^0\pi^0 + \Sigma^0\pi^0)$ total cross-section compilation from Ref. 14).
- Figure 5 $\pi^-p \rightarrow \Sigma^0K^0$ and $\pi^-p \rightarrow \Lambda^0K^0$ total cross-section, data from Ref. 10).
- Figure 6 Σ^+ polarization from reaction $\pi^+p \rightarrow \Sigma^+K^+$ at 3 GeV/c, data from Ref. 9).
- Figure 7 $\pi^-p \rightarrow \Lambda^0K^0$ differential cross-section at 3 GeV/c, data from Ref. 10).
- Figure 8 $\pi^-p \rightarrow \Sigma^0K^0$ differential cross-section at 4 GeV/c, data from Ref. 10).
- Figure 9 $\pi^-p \rightarrow (\Sigma^0K^0 + \Lambda^0K^0)$ differential cross-section at 6 GeV/c, data from Ref. 13).
- Figure 10 Λ^0 polarization from reaction $\pi^-p \rightarrow \Lambda^0K^0$ at 6 GeV/c, data from Ref. 13).

Figure 11 $K^-p \rightarrow \Lambda^0 \pi^0$ differential cross-section at 3 GeV/c, data from Ref. 1).

Figure 12 $K^-p \rightarrow \Sigma^+ \pi^-$ and $K^-p \rightarrow \Lambda \pi^0$ total cross-section, compilation from Ref. 14).

Figure 13 $K^-p \rightarrow \Sigma^+ \eta^-$ differential cross-section at 3 GeV/c, data from Ref. 1).

Figure 14 $K^-p \rightarrow \Sigma^+ \pi^-$ differential cross-section at 3.5 GeV/c, data from Ref. 15).

Figure 15 $K^-p \rightarrow \Lambda \eta$ differential cross-section at 3 GeV/c, data from Ref. 1).

Fig. 1

Fig.2

Fig. 3

Fig. 4

Fig. 5

Fig. 6

Fig. 7

Fig.8

Fig.9

Fig. 10

Fig. 11

Fig. 12

Fig. 14

Fig. 15