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ЕРЕВАНСКИЙ ФИЗИЧЕСКИЙ ИНСТИТУТ

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G.G.ARAKELYAN, SH.S.EREMYAN, A.E.NAZARYAN

A NEW DESCRIPTION OF HYPERCHARGE-EXCHANGE REACTIONS
IN QUASIEIKONAL MODELS

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1. Introduction

Recently there appeared new experimental data [1-4] on measurements of differential cross sections and polarizations in hypercharge-exchange reactions (HER) in the wide energy interval from 5 to 140 GeV and $|t| \sim 0 + 2 \text{ (GeV/c)}^2$. Earlier we have tried [5,6] to describe HER ($\pi N \rightarrow KY$, $\bar{K}N \rightarrow \pi Y$ where $Y = \Sigma, \Lambda$) in the framework of quasieikonal model (QEM). The obtained theoretical results, when compared with the measurements available before 1978 (see data report in [6,7]), proved to agree satisfactorily with the experiment. However, the values of some free parameters of the model were defined with insufficient accuracy due to lack of experimental data on differential cross sections in a wide energy interval and scarcity of data on polarizations of hyperons in HER (there were inconsistent data in the energy interval 3 + 5 GeV, except for the reaction $\pi^+ p \rightarrow K^+ \Sigma^+$ where the polarization was measured up to 14 GeV). The data available before 1978, indicating the breaking of exchange degeneracy (equality of parameters of strange trajectories K^* and K^{**} is a weak exchange degeneracy, equa-

lity also of residues is a strong exchange degeneracy), didn't give an unambiguous explanation of the mechanism of this breaking.

New measurements [1-4] of the reaction $\pi^+p \rightarrow K^+\Sigma^+$ and its line-reversed partners $K^-p \rightarrow \bar{\pi}^-\Sigma^+$ make possible a better understanding of the nature of exchange degeneracy (see e.g. [1, 4, 8, 9]), as well as the refinement of the values of KEM parameters defined with insufficient accuracy.

In this work analysing the whole set of new and old data on HER [1-4] (see data report obtained before 1978 in [6,7]), the authors come to a conclusion that beginning with energies 11.5 GeV within the limits of errors there occurs an exchange degeneracy. The KEM predictions reveal a 10% breaking of the weak exchange degeneracy at low energies. With the increase of energy the difference between differential cross sections of the processes $\pi^+p \rightarrow K^+\Sigma^+$ and $K^-p \rightarrow \bar{\pi}^-\Sigma^+$ decreases up to almost complete vanishing at 70 GeV. Thus, with the increase of energy the breaking of weak exchange degeneracy is eliminated. In section 2 the description of the used model is given, and in section 3 the comparison of experimental data on HER and the theoretical results obtained in the framework of KEM is presented. The basic conclusion arising from the analysis of experimental data and predictions of quasieikonal model are presented in section 4.

2. Formulation of the model

Here is a brief formulation of the quasieikonal model.

In the present work, making use of the results obtained in

refs. [5,6,10,11], we accept the breaking of exchange degeneracy for poles (i.e. inequality of residues and trajectories as well as of parameters of SU(3)-symmetry of vector and tensor exchanges). For convenience we present here the Table [6] of SU(3)-symmetry relations connecting the poles K^* and K^{**} in HER with the poles ρ and A_2 in the reactions $\pi^+p \rightarrow \bar{\pi}^0n$ and $\pi^-p \rightarrow \eta n$. The renormalization of all amplitudes and observed values is the same as in ref. [12]. For the description of HER the quasieikonal formulae of charge-exchange reactions have been used:

$$M_0(s, t) = \int \frac{d^2b}{2\pi} e^{i\vec{x}\vec{b}} f_0(s, \vec{b}), \quad (1)$$

$$M_{\pm}(s, t) = \int \frac{d^2b}{2\pi} e^{i\vec{x}\vec{b}} f_{\pm}(s, \vec{b}), \quad (2)$$

where \vec{b} is the impact parameter, $f_{0,\pm}(s, t)$ are the partial amplitudes in \vec{b} -representation for the spin nonflip and flip amplitudes, respectively:

$$f_0(s, \vec{b}) = \frac{1}{2ic} \left\{ e^{\chi_0', I=0} \left[\chi_1', I=1/2 \operatorname{sh} \chi_1', I=0 + \chi_0', I=1/2 \operatorname{ch} \chi_1', I=0 \right] - \chi_0', I=1/2 + c' \chi_0', I=1/2 \right\}, \quad (3)$$

$$f_{\pm}(s, \vec{b}) = \frac{1}{2ic} \left\{ e^{\chi_0', I=0} \left[\chi_0', I=1/2 \operatorname{sh} \chi_1', I=0 + \chi_1', I=1/2 \operatorname{ch} \chi_1', I=0 \right] - \chi_1', I=1/2 + c' \chi_1', I=1/2 \right\}. \quad (4)$$

In the formulae (3), (4) the following notations are used:

$$\chi'_{0,1}{}^{I=0} = \sum_{i=P,P'} \chi'_{i0,1} ; \quad \chi'_{0,1}{}^{I=1/2} = \sum_{i=K^*,K^{**}} \chi'_{i0,1} , \quad (5)$$

$$\chi'_{i0} = c_{i0} \chi_{i0} = 2i c_{i0} = \int \frac{d^2 \alpha}{2\pi} e^{-i\vec{\alpha} \vec{b}} F_{i0}(s,t), \quad (6)$$

$$\chi'_{i1} = c_{i1} \chi_{i1} = 2i c_{i1} = \int \frac{d^2 \alpha}{2\pi} e^{-i\vec{\alpha} \vec{b}} F_{i1}(s,t), \quad (7)$$

where $t = -\alpha^2$, $I=0,1/2$ are the isospins of corresponding contributions. The values $\chi_{0,1}$ and $\chi'_{0,1}$ are the eikonal and "quasieikonal", respectively; $c_{i0,1}$ are the jet-enhancement coefficients (JEC) (see in detail in [6,13]).

The parametrization of pole amplitudes P, P' as well as of vector K^* and tensor K^{**} poles $F_{0,1}(s,t)$ is the same as in refs. [10,11]. The rescatterings on P, P' -poles are taken into account as in ref. [6].

As free parameters of the model for the description of HER remain the parameters of trajectories $\alpha_R = \alpha_R^0 + \alpha_R' t$, of JEC $c_{0,1}^R$ ($R=K^*, K^{**}$), parameters of SU(3)-symmetry $F_{0,1}^R$, parameters of tensor pole residue γ_0 and R_0^2 in the spin nonflip amplitude. In order to define the values of free parameters of the model, the experimental data on differential cross sections and hyperon polarization on the reactions $\bar{\pi}^+ p \rightarrow K^+ \Sigma^+$ and $K^- p \rightarrow \bar{\pi}^- \Sigma^+$ [1-4] were processed. The obtained values of free parameters of the model are presented below:

- | | |
|---|------------------------------------|
| 1. $\alpha_{K^*}^0 = 0.39 \pm 0.042$ | 6. $F_0^{K^{**}} = 1.42 \pm 0.045$ |
| 2. $\alpha_{K^{**}}^0 = 0.37 \pm 0.0079$ | 7. $F_1^{K^*} = 0.2 \pm 0.061$ |
| 3. $\alpha'_{K^*} = \alpha'_{K^{**}} = 0.68 \pm 0.14$ | 8. $F_0^{K^{**}} = 1.74 \pm 0.028$ |
| 4. $\gamma_0 = 0.28 \pm 0.011$ | 9. $F_1^{K^{**}} = 0.24 \pm 0.078$ |
| 5. $R_0^2 = 2.5 \pm 0.15$ | |

The JEC for the reactions $\bar{\pi} N \rightarrow K Y$ are:

- | | |
|---------------------------------|-------------------------------------|
| 10. $c_0^{K^*} = 1 \pm 0.049$ | 12. $c_0^{K^{**}} = 0.41 \pm 0.061$ |
| 11. $c_1^{K^*} = 0.41 \pm 0.35$ | 13. $c_1^{K^{**}} = 0.19 \pm 0.029$ |

and for the reactions $\bar{K} N \rightarrow \bar{\pi} Y$ they are:

- | | |
|----------------------------------|-------------------------------------|
| 14. $c_0^{K^*} = 1.91 \pm 0.055$ | 16. $c_0^{K^{**}} = 0.67 \pm 0.13$ |
| 15. $c_1^{K^*} = -1 \pm 1.1$ | 17. $c_1^{K^{**}} = 0.54 \pm 0.067$ |

As it is seen, the values of the parameters of vector and tensor pole trajectories differ slightly, i.e. there occurs a breaking of the pole weak exchange degeneracy of the order 5%. However, the consideration of absorptive corrections results in the increase of exchange degeneracy at low energies. The model predictions show that with the energy increase the value of breaking decreases. This question will be considered in detail in the next section. The obtained values of the SU(3)-symmetry parameters coincide with the results of ref. [6]. This comes to show that the values of these parameters, obtained from the processing of measurements available before 1978, were defined with a fairly good accuracy.

3. Discussion of the results

A. Complete amplitudes of vector and tensor exchanges in the reactions $\bar{\eta}^+ p \rightarrow K^+ \Sigma^+$, $K \bar{p} \rightarrow \bar{\eta}^- \Sigma^+$

As already mentioned, the values of the parameters of "strange" trajectories obtained from the comparison with the experiment indicate (within the limits of errors) the existence of weak exchange degeneracy on the pole level. In fig. 1 the graphs of the amplitudes of the processes $\bar{\eta}^+ p \rightarrow K^+ \Sigma^+$ and $K \bar{p} \rightarrow \bar{\eta}^- \Sigma^+$ at 7 GeV are given. The main contribution of the HER cross section make the spin nonflip amplitudes. In the reaction $\bar{\eta}^+ p \rightarrow K^+ \Sigma^+$ at small momentum transfers dominates the contribution of the imaginary part of the complete spin nonflip amplitude, and in the process $K \bar{p} \rightarrow \bar{\eta}^- \Sigma^+$ - the contribution of the real part. The result we have obtained agrees with the conclusions of Harari and Rosner^{14,15}. From the graphs depicted in fig. 1 it is seen that the total contributions of the vector K^* and tensor K^{**} trajectory exchanges in the imaginary part of the spinflip amplitude are equal in their value to within 10% and differ in their sign, i.e. the consideration of the contributions of branchings leads to a 10% breaking of weak exchange degeneracy. This agrees with the well known result from dual models (see e.g. [16]) that these trajectories are degenerated on the planar level, and the degeneracy is broken when cylindrical and higher corrections for $1/N$ expansion are taken into account [17]. This breaking corresponds by the order of its value to the result we have obtained from the comparison of theoretical for-

mulae with the experiment. The amplitudes with the spin turnover, presented in the lower part of fig. 1, provide the correct behaviour of differential cross sections at relatively large momentum transfers and a finer effect of the hyperon polarization in HER.

B. Differential cross sections

In fig. 2 the experimental data and predictions of KEM are presented for differential cross sections of the process $\bar{\eta}^+ p \rightarrow K^+ \Sigma^+$ at $|t|$ in the range $0 + 1.4$ (GeV/c)² and the wide energy interval from 5 to 140 GeV. The measurements of this reaction at 7, 10.1, 11.5, 70, 140 GeV [1,3,4] as well as the data on the process $K \bar{p} \rightarrow \bar{\eta}^- \Sigma^+$ at the same energy values [1,3,4] have been used to define the values of the model free parameters. The large slope in differential cross sections at small $|t| \lesssim 0.3$ is due to the imaginary part of the spin nonflip amplitude M_0 , which makes the main contribution in this region. At $0.3 \lesssim |t| \lesssim 0.6$ the contributions of the spin flip amplitude M_1 and of the imaginary part of M_0 ($Im M_0$ changes its sign at $|t| \sim 0.4$ (GeV/c)²) provide the absence of the dip in differential cross sections. In the region $|t| > 0.6$ (GeV/c)² the $Im M_0$ dominates which provides the flat behaviour of the cross section. The slope of $d\sigma/dt$ at small $|t|$ increases with the energy, and at large momentum transfers, after a weak flattening in the region $0.55 \lesssim |t| \lesssim 0.65$ (GeV/c)², the cross section becomes less flat. Such a behaviour, despite the lack of experimental data at large energies and momentum transfers, seems realistic.

In fig. 3 graphs and experimental data of differential cross sections of the reactions $K\bar{p} \rightarrow \bar{\pi}^- \Sigma^+$ in the energy interval $5.47 + 140$ GeV and at $|t|$ up to 1.4 $(\text{GeV}/c)^2$ are presented. In the region $|t| \lesssim 0.4$ $(\text{GeV}/c)^2$, as already mentioned, this process is determined by $Re M_0$ the contribution of tensor amplitude in which is larger than that of the vector one approximately by 25%. The cross-section slope in this region is less than that of the process $\bar{\pi}^+ p \rightarrow K^+ \Sigma^+$ at low energies, and with the increase of energy this difference decreases almost up to vanishing beginning with 14 GeV. At $0.5 \lesssim |t| \lesssim 1.2$ $(\text{GeV}/c)^2$ the leading contributions are those of $Im M_0$ and $Re M_2$, the decrease of which with the increase of $|t|$ determines the further behaviour of $d\sigma/dt$. As distinct from the reaction $\bar{\pi}^+ p \rightarrow K^+ \Sigma^+$, here the flattening of $d\sigma/dt$ is not observed, at high energies, though, in the region $|t| \sim 0.5$ $(\text{GeV}/c)^2$ there are certain tendencies to flattening. With the energy increase also the increase of the slope at large momentum transfers ($|t| \sim 1$ $(\text{GeV}/c)^2$) is observed. It follows from the analysis of experimental data of $d\sigma/dt$ of the processes $\bar{\pi}^+ p \rightarrow K^+ \Sigma^+$ and $K\bar{p} \rightarrow \bar{\pi}^- \Sigma^+$ that with the increase of energy the difference between the cross sections of these processes decreases. Comparing the model predictions one can see that with the increase of energy the difference between the cross sections of line-reversed reactions decreases as well, right up to almost complete vanishing at 70 GeV.

In figs. 4-7 the model predictions for other HER are given. For the definition of the values of the model free parameters the available experimental data on these processes (in a fairly

narrow energy interval $5 + 15.7$ GeV) have not been processed. As seen on these figures, the KEM predictions are in fairly good agreement with the available measurements.

In fig. 8 the experimental data and KEM predictions for differential cross sections of the processes $K\bar{p} \rightarrow \eta \Lambda$ and $K\bar{p} \rightarrow \eta' \Lambda$ are presented. These processes can be described using the obtained values of the vector and tensor exchange amplitudes and of the SU(3)-symmetry relation, connecting the amplitudes of these reactions with amplitudes of other HER (e.g. $K\bar{p} \rightarrow \bar{\pi}^0 \Lambda$) [18,19,20]

$$F(K\bar{p} \rightarrow \bar{\pi}^0 \Lambda) = -K^{**} - K^*$$

$$F(K\bar{p} \rightarrow \eta \Lambda) = \frac{1}{\sqrt{3}} (\cos \theta + 2 S_T \sin \theta) K^{**} - \sqrt{3} \cos \theta \cdot K^*$$

$$F(K\bar{p} \rightarrow \eta' \Lambda) = \frac{1}{\sqrt{3}} (\sin \theta - 2 S_T \cos \theta) K^{**} - \sqrt{3} \cos \theta \cdot K^*$$

Here K^* and K^{**} are the amplitudes of vector and tensor exchanges, respectively; θ is the η, η' -mixing angle; S_T is the relation of singlet and octet coupling constant $\bar{\eta}$ with $\eta \Lambda_2$. The values of the parameters θ and S_T are taken from other analyses as equal to $\theta = -11^\circ$ and $S_T = 1.1$ [19,20]. As seen on fig. 8, the KEM predictions are in fairly good agreement with experimental data.

C. Polarization and parameters of the spin correlation

The experimental measurements and KEM predictions on the hyperon polarization in HER are presented in figs. 9,10. The process $\bar{\pi}^+ p \rightarrow K^+ \Sigma^+$ is the one experimentally best investigated. Data are available in the energy interval $5 + 140$ GeV and

at some values of energy up to $|t| \sim 2 \text{ (GeV/c)}^2$. The polarization in this reaction has a positive value. The peak of the order of a unit is in the region $|t| \sim 0.8 \text{ (GeV/c)}^2$. With the increase of energy the peak, without changing its value, shifts slightly to the left (at 70, 140 GeV the peak is in the region $|t| \sim 0.6 \text{ (GeV/c)}^2$). With the increase of energy a more abrupt decrease of the polarization value is observed, and the shape of the peak becomes sharper, and beginning with the energy 35 GeV at $|t| \sim 1.4 \text{ (GeV/c)}^2$ the polarization changes its sign. In the process $K^- p \rightarrow \pi^- \Sigma^+$ the polarization has an inverse value and by its behaviour is like the one in the reaction $\pi^+ p \rightarrow K^+ \Sigma^+$ except for the fact that the change of the sign occurs beginning with the energy 7 GeV and at smaller $|t|$. The fact that the polarizations in line-reversed reactions: $\pi^+ p \rightarrow K^+ \Sigma^+$ and $K^- p \rightarrow \pi^- \Sigma^+$ have an inverse sign and are similar in their behaviour also indicate the presence of weak exchange degeneracy within the limit of errors. The experimental data on polarization and the model predictions for the reactions $K^- p \rightarrow \eta \Lambda$ and $K^- p \rightarrow \eta' \Lambda$ are presented in fig. 11. Recently no new measurements of polarizations and parameters of spin correlations S, T were carried out. As seen in figs. 10 and 11, there is a satisfactory agreement between the KEM predictions and the data available.

4. Conclusion

The analysis of the whole set of experimental data on HER (for new data see [1-4], for the report of measurements before 1978 see [6,7]) indicates the presence of weak exchange degene-

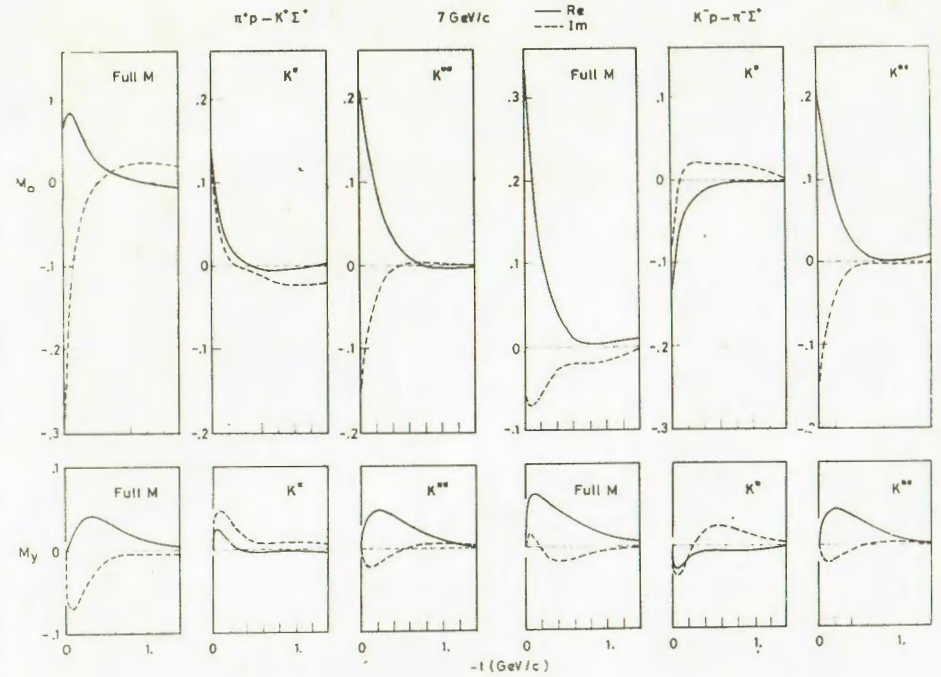
racy within the limit of errors. Within the KEM framework the weak exchange degeneracy of "strange" trajectories K^* and K^{*} occurs on the pole level, but the consideration of the contributions of branchings leads to a 10% breaking of this degeneracy at low energies. However with the increase of energy the breaking is eliminated and beginning with the energy 70 GeV almost entirely vanishes. The carried out analysis shows also that the system of residues of main Regge poles obtained from the analysis of elastic processes [10,11,12,21] has a universal character, and when using the SU(3)-symmetry, it can be applied for the description of a completely different class of reactions (HER). The correct consideration of the contributions of branchings obtained in KEM allows to describe well all the values measured in the experiment: differential cross sections, polarizations and parameters of spin correlation, in all reactions simultaneously, as distinct from the ordinary Regge models where at best only one class of processes is described correctly.

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Table

of the SU(3)-coupling for the reactions

pole amplitudes of reactions	exchanges	SU(3)-amplitudes
$F(\pi^- p \rightarrow \pi^0 n)$	ρ	$\sqrt{2} A_V$
$F(\pi^- p \rightarrow \eta n)$	A_2	A_T
$F(\pi^+ p \rightarrow K^+ \Sigma^+) =$ $= F(\pi^+ n \rightarrow K^0 \Sigma^+) =$ $= \sqrt{2} F(\pi^+ p \rightarrow K^0 \Sigma^0) =$ $= -\sqrt{2} F(\pi^+ n \rightarrow K^+ \Sigma^0)$	K^*, K^{**}	$\sqrt{\frac{3}{2}} (1 - 2F_T) A_T -$ $-(1 - 2F_V) A_V$
$F(K^- p \rightarrow \pi^- \Sigma^+) =$ $= 2F(K^- p \rightarrow \pi^0 \Sigma^0) =$ $= \sqrt{2} F(K^0 p \rightarrow \pi^+ \Sigma^0) =$ $= \sqrt{2} F(K^- n \rightarrow \pi^- \Sigma^0) =$ $= \sqrt{2} F(K^- n \rightarrow \pi^0 \Sigma^-)$	K^*, K^{**}	$\sqrt{\frac{3}{2}} (1 - 2F_T) A_T +$ $+(1 - 2F_V) A_V$
$F(\pi^- p \rightarrow K^0 \Lambda) =$ $= F(\pi^+ n \rightarrow K^+ \Lambda)$	K^*, K^{**}	$-\frac{1}{2} (1 + 2F_T) A_T +$ $+\frac{1}{\sqrt{6}} (1 + 2F_V) A_V$
$F(K^0 p \rightarrow \pi^+ \Lambda) =$ $= F(K^- n \rightarrow \pi^- \Lambda) =$ $= \sqrt{2} F(K^- p \rightarrow \pi^0 \Lambda)$	K^*, K^{**}	$-\frac{1}{2} (1 + 2F_T) A_T -$ $-\frac{1}{\sqrt{6}} (1 + 2F_V) A_V$

Fig. 1 Behaviour of complete amplitudes, vector and tensor exchanges in the processes $\pi^+ p \rightarrow K^+ \Sigma^+$ and $K^- p \rightarrow \pi^- \Sigma^+$ at 7 GeV.

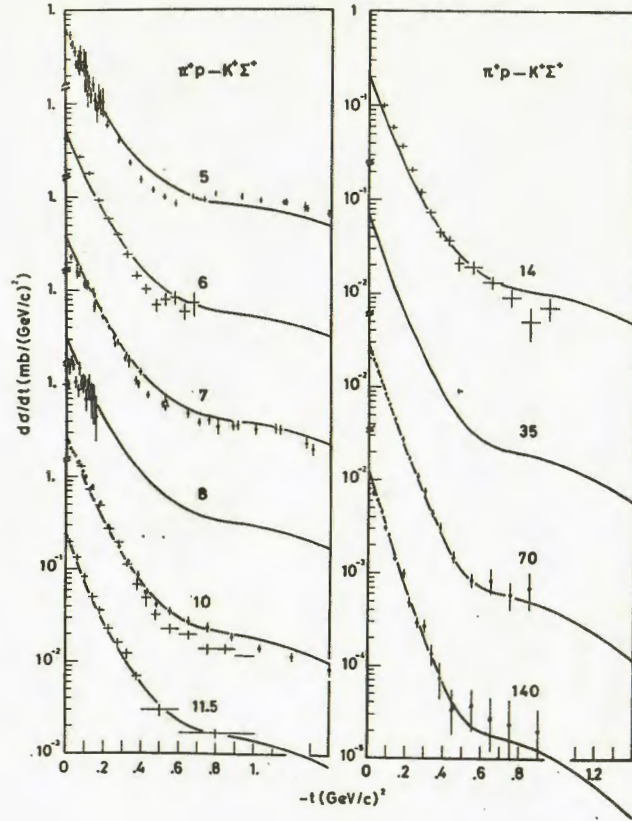


Fig. 2 Differential cross sections of the reaction $\pi^+ p \rightarrow K^+ \Sigma^+$

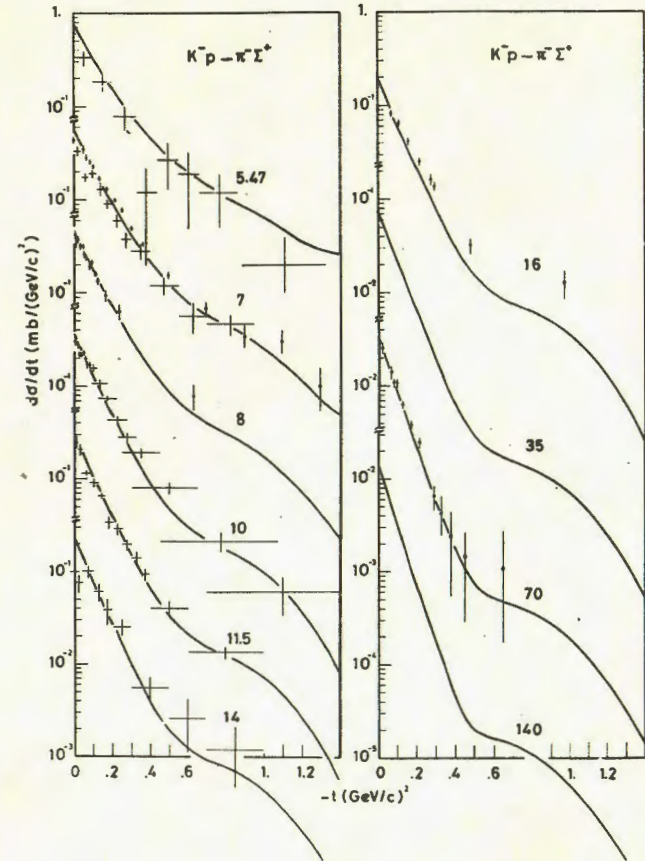


Fig. 3 Differential cross sections of the reaction $K^- p \rightarrow \pi^- \Sigma^+$

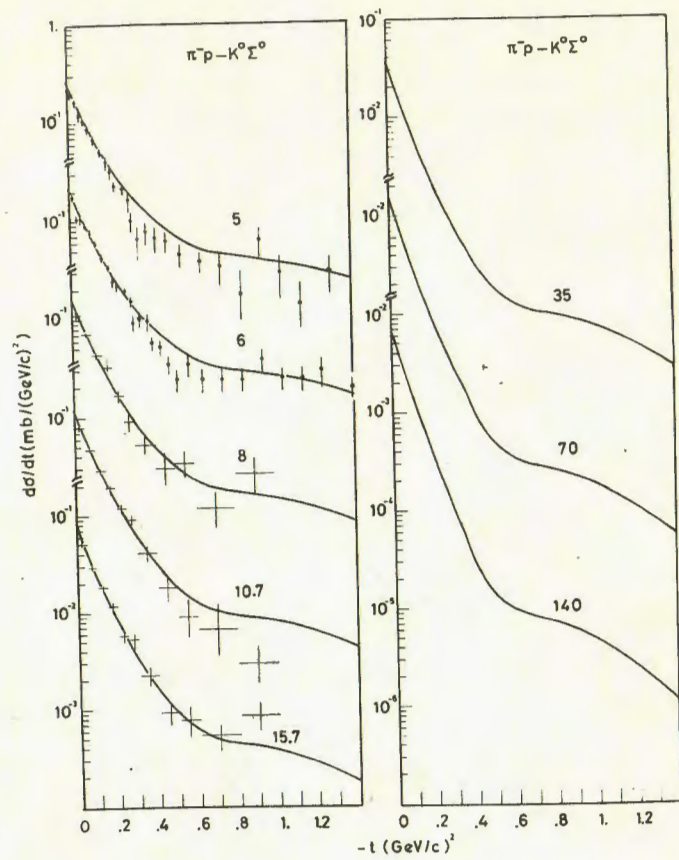


Fig. 4 KEM predictions for differential cross sections of the reaction $\pi^- p \rightarrow K^0 \Sigma^0$

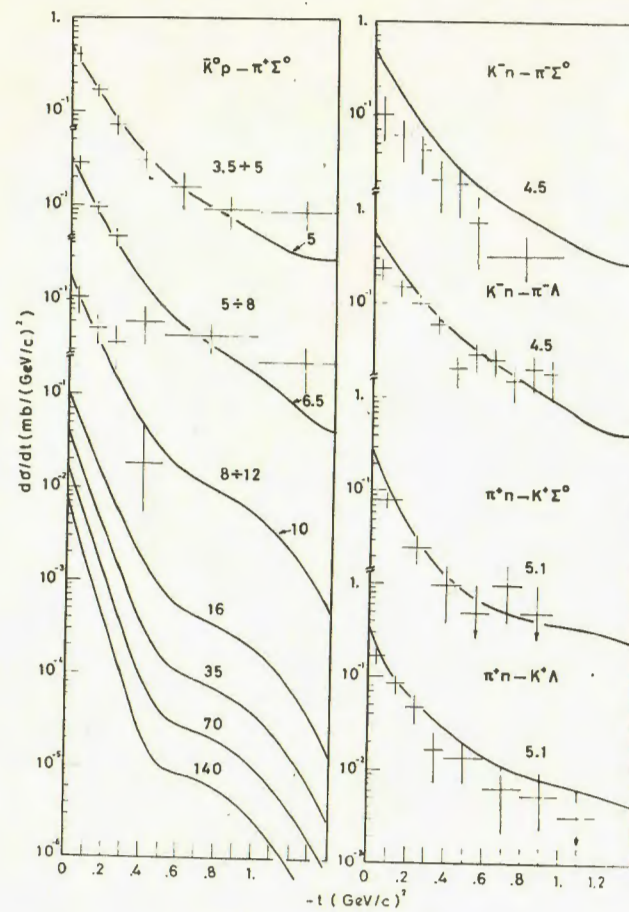


Fig. 5 KEM predictions for differential cross sections of the reactions $K^0 p \rightarrow \pi^+ \Sigma^0$ and $K^- n \rightarrow \pi^- \Sigma^0$

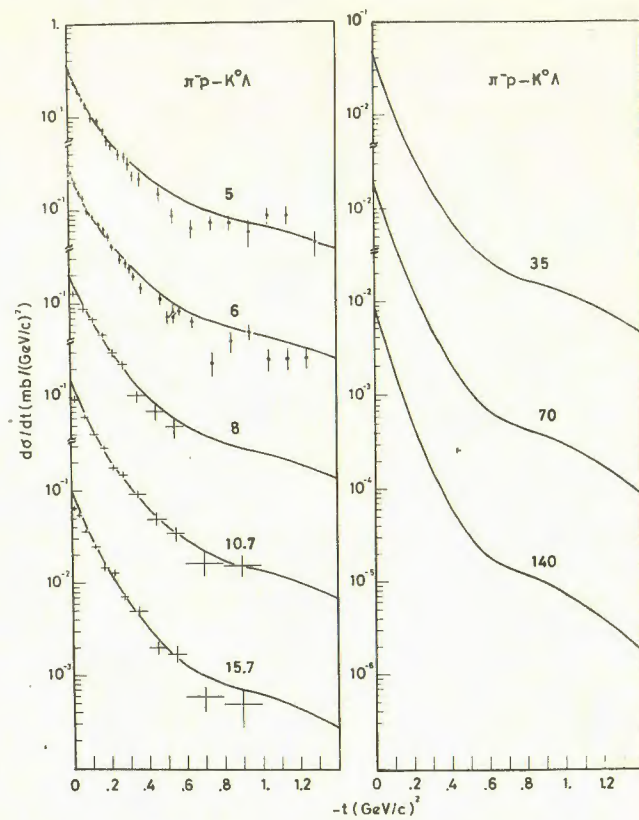


Fig. 6 KEM predictions for differential cross sections of the reaction $\pi^- p \rightarrow K^0 \Lambda$

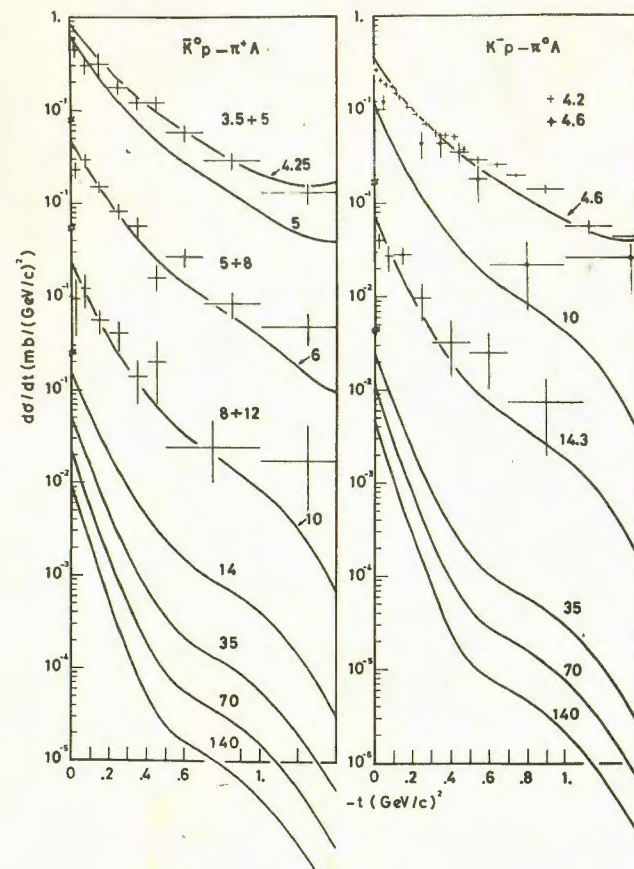


Fig. 7 KEM predictions for differential cross sections of the reactions $\bar{K}^0 p \rightarrow \pi^- \Lambda$ and $K^- p \rightarrow \pi^0 \Lambda$

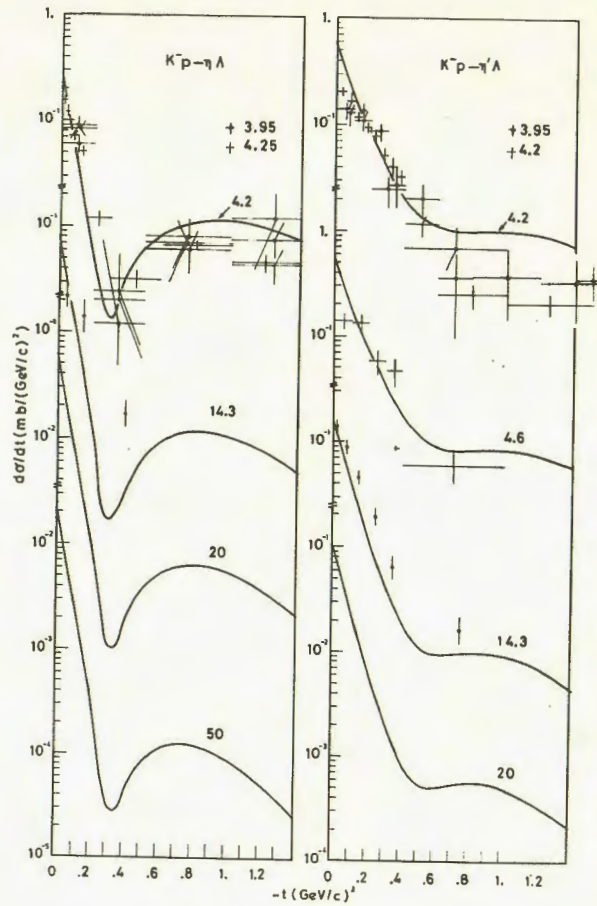


Fig. 8 KEM predictions for differential cross sections of the reactions $K\bar{p} \rightarrow \eta\Lambda$ and $K\bar{p} \rightarrow \eta'\Lambda$

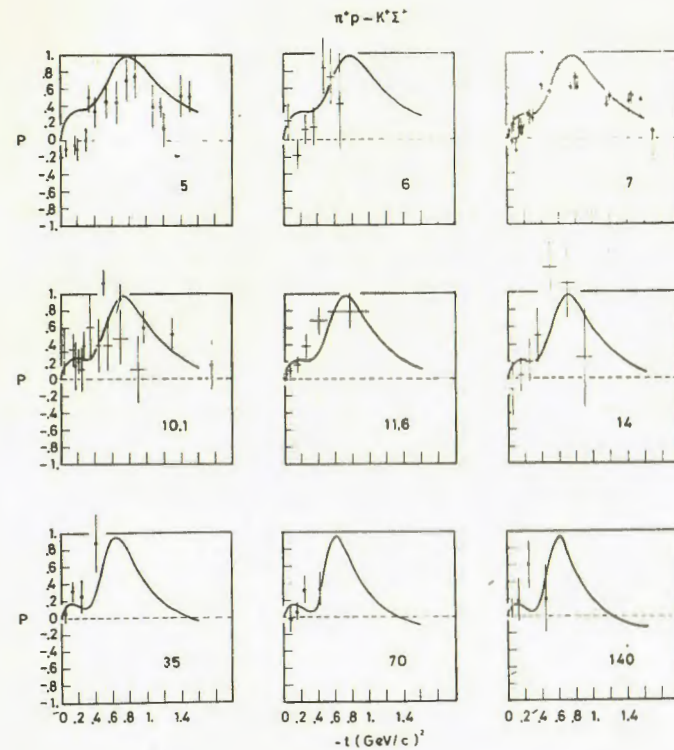


Fig. 9 Polarization of the reaction $\pi^+p \rightarrow K^+\Sigma^+$

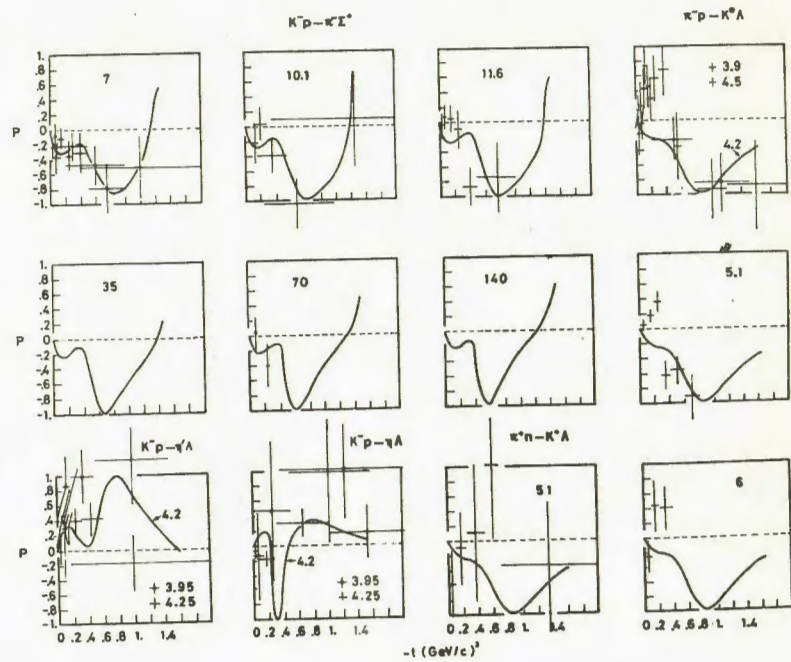


Fig. 10 Polarization of other HER.

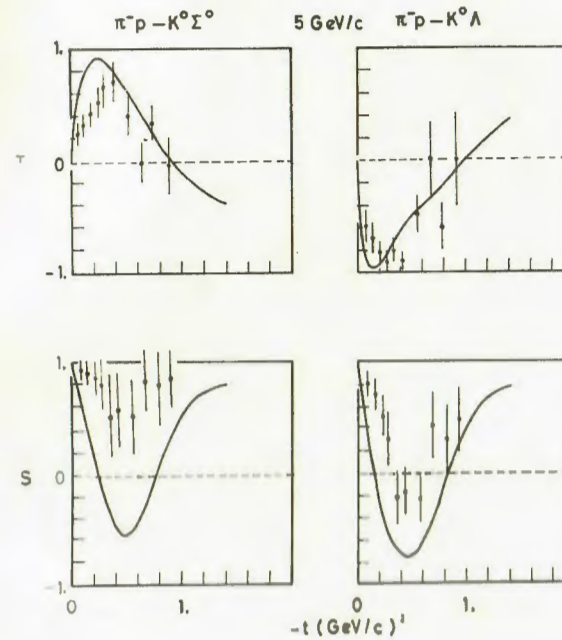


Fig. 11 Predictions for the parameters of spin correlation T and S .

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Г.Г. АРАКЕЛЯН, Ш.С. ЕРЕМЯН, А.Э. НАЗАРЯН
НОВОЕ ОПИСАНИЕ РЕАКЦИИ С ОБМЕНОМ
ИМПУЛЬСОМ В КВАЗИЭЙКОНАЛЬНОЙ МОДЕЛИ
(на английском языке, перевод Л.Н. Багдасаряна)

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