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ABSORPTION AND EXCHANGE DEGENERACY : $\pi N \to KY$ REACTIONS

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ABSTRACT : We apply a Regge Model with absorption to the analysis of hypercharge exchange reactions. The purpose of this paper is to verify the compatibility of exchange degeneracy with the existence of Regge cuts. We present some fits to ex -

perimental data which are qualitatively good.

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SECTION I : INTRODUCTION

The analysis of the inelastic reactions

$$\pi N \rightarrow KY \qquad (a)$$

and

$$KN \rightarrow \pi Y \qquad (b) \text{ line reversed}$$

is a good test for high energy phenomenological models.

In fact one can see that reaction (b) which is the u-channel of (a) is exotic in the direct channel. Therefore, according to duality, the leading Regge poles, K^* and K^{**} are exchange degenerate. In the framework of a pure Regge model, this implies in particular

i) $(\frac{d\sigma}{dt})_{(a)} = (\frac{d\sigma}{dt})_{(b)}$.

ii) The polarization of the final hyperon is predicted to be zero.

None of this two predictions is verified by experiment.

The introduction of Regge cuts with a non flat Pomeron enables us to describe the experimental data without violating the exchange degeneracy [1]. We shall use the so-called Regge cut model with exchange degenerate poles which has been applied successfully to elastic reactions, πN , KN and NN [2] . In order to check the coherence and the predictive power of this model we shall borrow whenever it will be possible the values of the parameters used in [2]. However we shall not assume factorization explicitly, since we do not have enough reactions to get significant information on the vertex couplings.

In section II we give the parametrization of the model for the study of reactions (a) and (b). For a detailled formulation we refer the reader to [2] (see footnote [3]).

Finally in Section III we present the results which are in good agreement with experiment and draw some conclusions in favor of this model.

SECTION II : PARAMETRISATION

In the framework of the absorptive model we are dealing with, the helicity amplitudes have the following form :

$$(2.1) \qquad \mathcal{M}_{(i)}(s,t) = R_{(i)}(s,t) + \frac{i}{8\pi} A_{(i)} [A_{(i)} * R_{(i)}](s,t)$$

where the index $i = a,b$ labels the reactions.

$R_{(i)}(s,t)$ are the pole terms, $R_{(b)}$ is real and $R_{(a)} = R_{(b)} e^{-i\pi\alpha(t)}$.

The functions $A_{(i)}(s,t)$ represent the contribution of the Pomeron :

$A_{(a)}$ is the leading amplitude of the process $\pi N \to \pi N$ and contains informations about it.

In the same way $A_{(b)}$ is related to the elastic KN scattering.

The cut terms $(A * R)_{(i)}(s,t)$ have been enhanced by multiplicative factors $\Lambda_{(i)}$, which take into account the diffractive dissociations. We use the following parametrization :

i) - The trajectory :

In the case of linear approximation, the trajectory is completely determined by the masses of K^{*} and K^{**}.

We take :

(2.2) $$\alpha(t) \cong 0.8\, t + 0.35$$

ii) - The Regge amplitudes :

We reggeize in the direct channel following [4] ; there is two independent helicity Regge amplitudes

(2.3) $$R_{++}(s,t) = g_{++}(t)\, \Gamma(1-\alpha(t))\, [1 + \zeta\, e^{-i\pi\alpha(t)}] (s/s_0)^{\alpha(t)},$$

$$(2.4)\quad R_{+-}(s,t) = g_{+-}(t)\sqrt{t_o-t}\;\Gamma(1-\alpha(t))[1+\zeta e^{-i\pi\alpha(t)}](s/s_o)^{\alpha(t)}$$

where $t_o = t$ for $\cos\theta_s = 1$.

The residues are chosen to be constant and we can exhibit the isospin dependence of $g_{\lambda\lambda'}$ by

$$(2.5)\qquad g_{\lambda\lambda'} = \eta(-)^I\, g(-)^{m_3-m_1} < I_3m_3|I_1Im_1,m_3-m_1> \\ < I_4m_4|I_2I,m_2,m_4-m_2> \gamma_{\lambda\lambda'}$$

where η, I, g are the parity, the isospin and the G parity of the exchanged particle respectively. There are therefore five parameters

$$s_o\ ,\quad \gamma^{\Sigma}_{++}\ ,\quad \gamma^{\Sigma}_{+-}\ ,\quad \gamma^{\Lambda}_{++}\ ,\quad \gamma^{\Lambda}_{+-}$$

We take $s_o = 1.\ Gev^2$ which was the value chosen in [2]. There now remain four free parameters ; this number will be further reduced as we shall see.

iii) - <u>The absorption functions</u> :

A suitable form is :

$$(2.6) \quad A_{(i)}(s,t) = i\,\sigma^{\infty}_{(i)}\, S \exp[a_{(i)} + \alpha'_p(\log s - \frac{i\pi}{2})]t$$

where :

α'_p is the slope of the Pomeron trajectory, whose intercept is 1 ;

$\sigma^{\infty}_{(a)}$ and $\sigma^{\infty}_{(b)}$ are the asymptotic total cross sections of the elastic reactions πN and KN ;

$a_{(a)}$ and $a_{(b)}$ are related to the "geometrical size" of the Pomeron.

This introduces five new parameters :

$$\alpha'_p \;,\; \sigma^{\infty}_{(a)} \;,\; \sigma^{\infty}_{(b)} \;,\; a_{(a)} \;,\; a_{(b)} \;.$$

However these parameters are connected with reactions studied and well described in [2] , it seems natural to use the numerical values already obtained, i.e.

$$\alpha'_p - 0.6\ [\text{Gev}/c]^{-2}$$

$$\sigma^{\infty}_{(a)} \equiv \sigma^{\infty}(\pi N) \cong 21.2 \text{ mb}$$

$$\sigma^{\infty}_{(b)} \equiv \sigma^{\infty}(KN) \cong 17. \text{ mb}$$

$$a_{(a)} \cong 1.8 \text{ Gev}^{-2}$$

$$a_{(b)} \cong 1. \text{ Gev}^{-2}$$

iv) - The absorption enhancement :

There are two factors to be determined, namely Λ^{Σ} and Λ^{Λ} according to the hyperon (Σ or Λ) occuring in the final state. If one assumes factorization of the Λ factors. We shall see that it is in fact very difficult to maintain this factorization assumption.

SECTION III : RESULTS AND CONCLUSIONS

(See references [5] ... [7])

i) - Réactions $\pi N \rightarrow K\Sigma$:

We have fitted the data of ref [5] on $\pi^+ p^+ \rightarrow K^+\Sigma^+$. The experimental data close to the forward direction given in [6] are very precise and in agreement with those of [5] . It is then possible to determine γ^{Σ}_{++} in a correct way and this allows us to reduce by one the number of free parameters. Defining the ratio $r^{\Sigma} \equiv \gamma^{\Sigma}_{+-} / \gamma^{\Sigma}_{++}$ we are left with only two free parameters r^{Σ} and Λ^{Σ} . In order to improve the fits it is however necessary to modify $a_{(a)}$ slightly and to take $a_{(a)} \sim 1.5\ (GeV/c)^{-2}$. This value is satisfactory for all the calculations. In so far as the differential cross-sections (D.C.S.) are concerned, one gets quite good agreement both for the energy dependance and the momentum transfert behaviour. In particular the "break" at $t \sim 0.5$ is well reproduced. The results obtained for the polarization are excellent.

Imposing SU(2) [See formula (2.5)] one obtains

$$\frac{d\sigma}{dt}(\pi^+ p \to K^+\Sigma^+) = 2\,\frac{d\sigma}{dt}\,(\pi^- p \to K^\circ\Sigma^\circ)$$

which is well verified.

If we use the values of the parameters so far determined to fit the line reversed reactions $\bar{K}N \to \pi\Sigma$ [8] [9] we get the dashed curves, which are only satisfactory at low energy. However Irving et al [10] have suggested that one should renormalize the high energy data by a factor 0.66 . In this case our fit is quite good.

Another way out consists to drop the factorization hypothesis of the $\Lambda_{(i)}$ which was in [2] a very crude assumption. One then gets results represented by solid curves, which are better.

Improved experimental results would be welcome to cut short the dispute.

ii) - Reactions $\pi N \rightarrow K\Lambda$ [11] :

Here the analysis is more difficult since the data are not precise and the difference between $(\frac{d\sigma}{dt})_{(a)}$ and $(\frac{d\sigma}{dt})_{(b)}$ is larger than in the case where the Σ is produced. The essential points are that one needs a greater ratio r^{Λ} and very different Λ factors for (a) and (b) reactions.

In a general way the agreement is less good than for the reactions analyzed in (i) . The structure of the D.C.S. is well described qualitatively and the polarizations obtained are satisfactory.

iii) - Presentation of results :

The numerical values for the parameters are listed in Table I and corresponding curves are given in Fig. 1 to Fig. 12 . We must point out that slight variations of the parameters about the values chosen for presenting the curves do not affect the quality of the fits very much. It furthermore appeared in the course of the computation that the fits were only sensitive to variations on $\Lambda_{(i)}$ and $r^{\Sigma,\Lambda}$.

TABLE 1 : Values of the Parameters

	Y_{++}	r	Λ
$\pi N \rightarrow K\Sigma$	20.	-.67	1.12
$\bar{K}N \rightarrow \pi\Sigma$	20.	-.67	1.12 dashed curves 1.0 solid curves
$\pi N \rightarrow K\Lambda$	27.	+1.25	1.07
$\bar{K}N \rightarrow \pi\Lambda$	27.	+1.25	1.4

iv) - Conclusions :

If we look at the SU(3) constraints for $K^{*} - K^{**}$ couplings, the ratio $Y^{\Sigma_o} / Y_{\Lambda} = \frac{\sqrt{3}(F-D)}{3F+D}$ leads to $F/D \sim -4.9$ for the nonflip case and to $F/D \sim +.44$ for the spin flip case. These two values are compatible with other evidence [12].

In all the cases, the good agreement obtained for the polarizations tells us that the model produces realistic phases.

Our results are convincing for this model if one considers the small number of free parameters used. It is clear that by adding parameters (in such a way as to describe non constant residues, energy depending absorption, ... etc.). One can qualitatively improve the fits which depend any way on the often questionnable normalisations of the experiments. The magnitude of the polarization and the structure of angular distribution do not depend of these questions.

From this point of view, we find our model satisfactory.

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[3] There is some misprint in reference [2] the partial wave amplitude must be written

$$T^{J}_{ji}(s) = 8\pi \langle j | \frac{S^{J}-1}{i} | i \rangle$$

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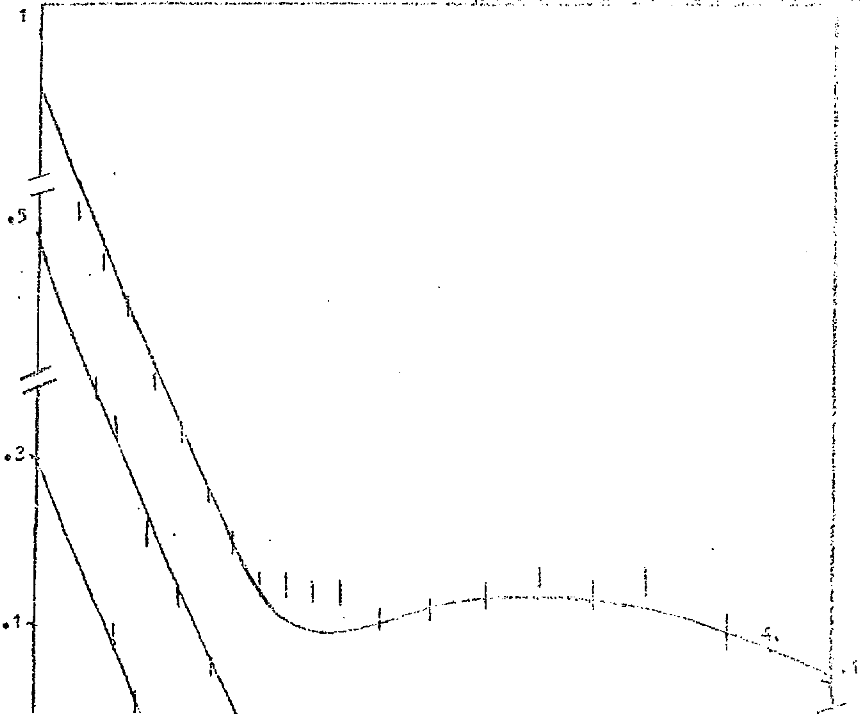
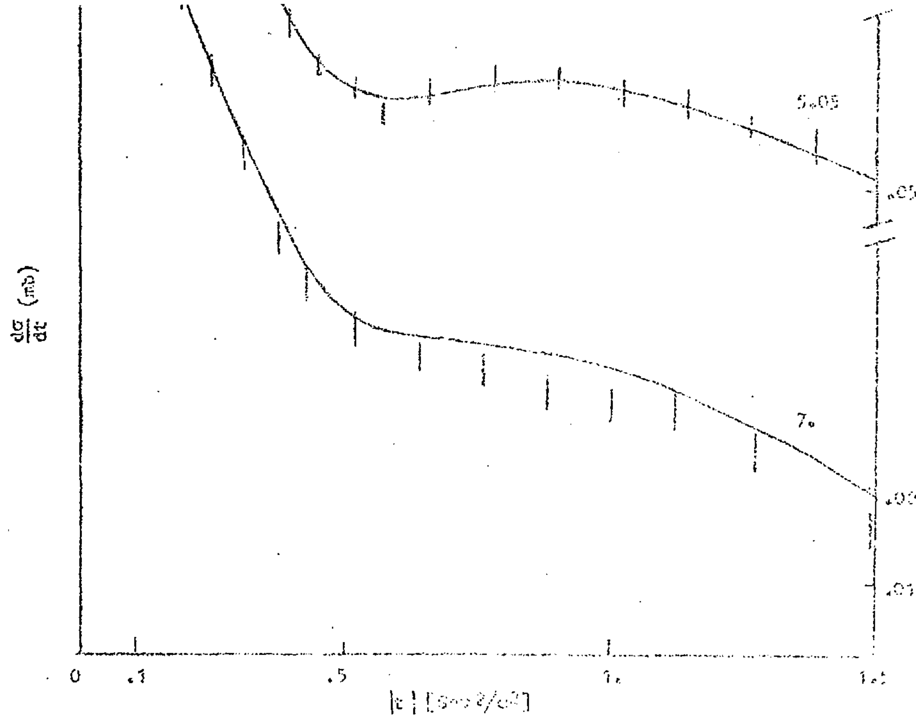
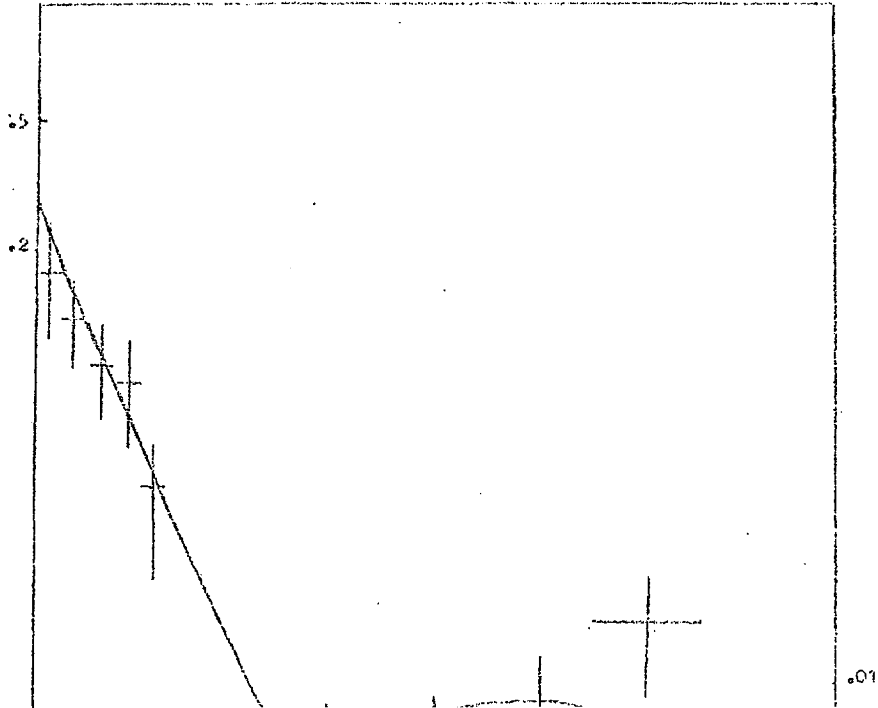
Fig 1 : D.C.S. $\pi^+ p \to K^+ \Sigma^+$ [5]





5.05
7.
.05
.05
.01
dσ/dt (mb)
0
.1
.5
1.
1.5
|t| [GeV²/c²]

Fig. 2 : D.C.S. $\pi^- p \rightarrow K^0 \Sigma^0$ [7]



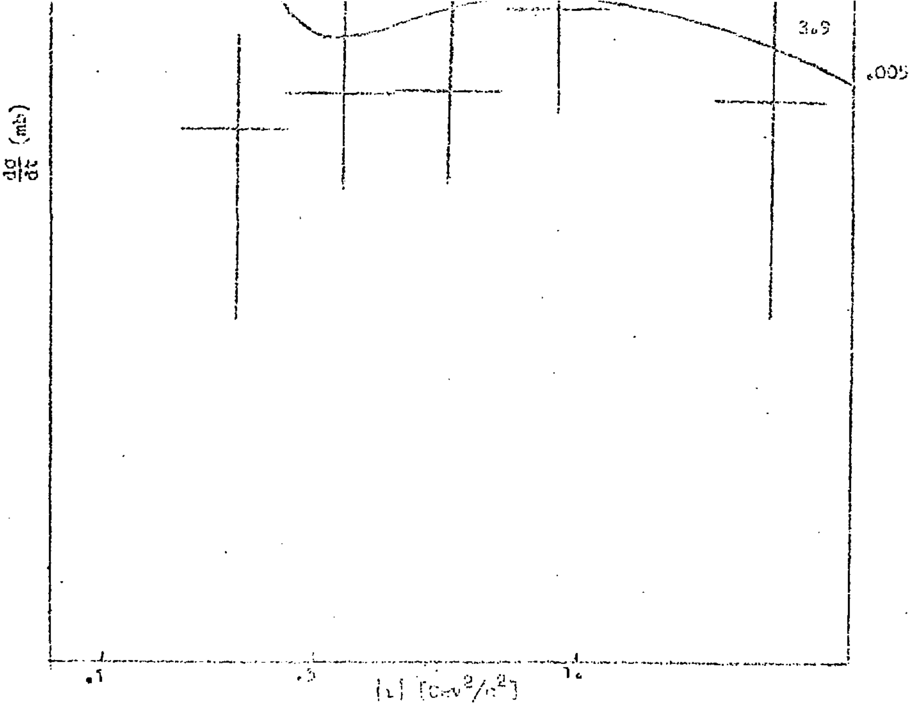
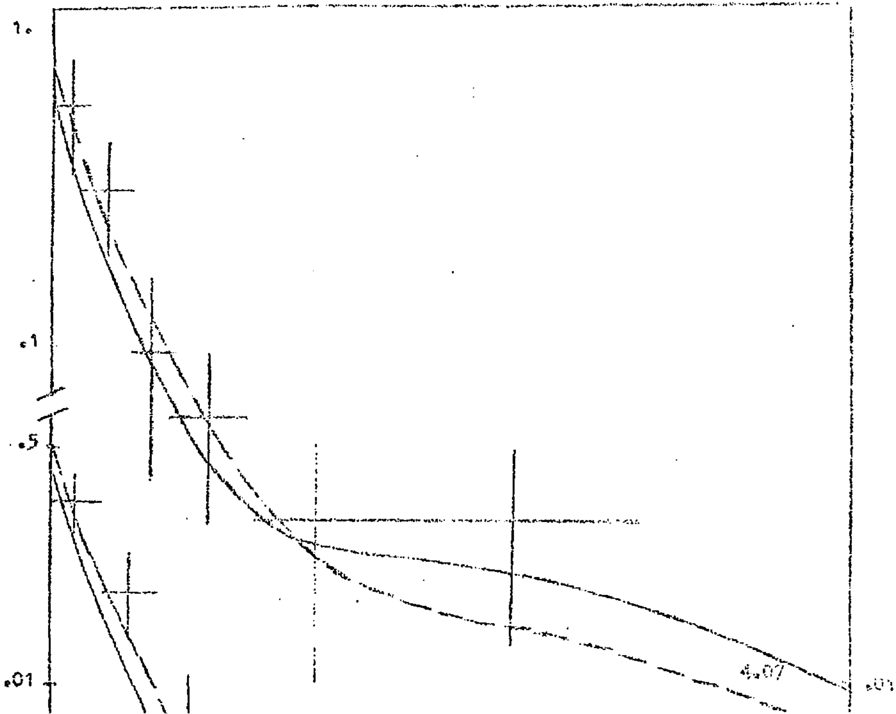
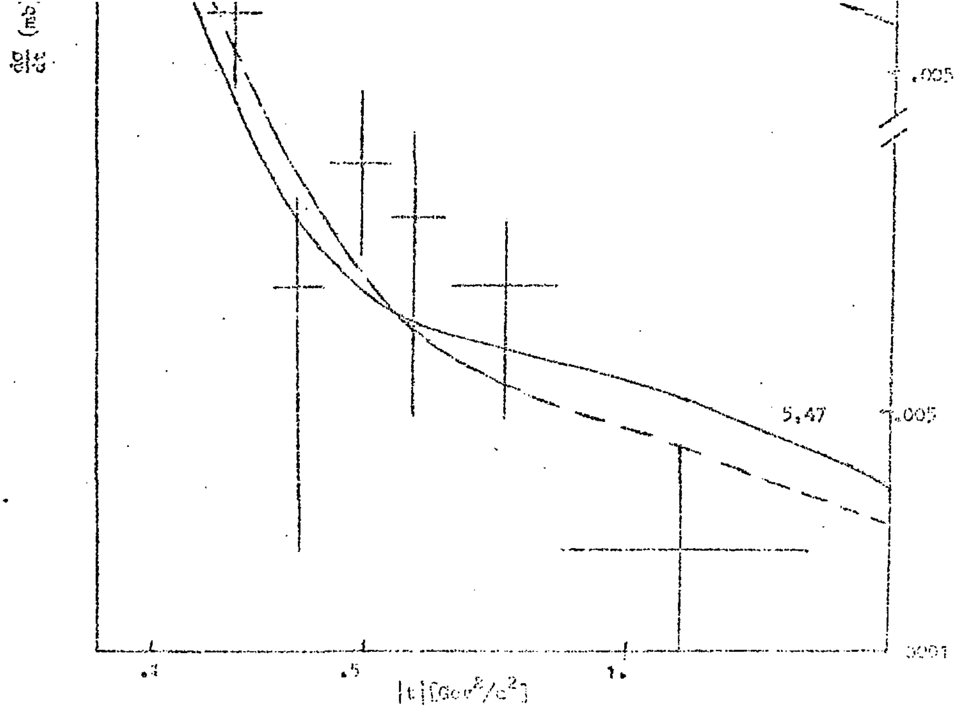

3.9
.005
$\frac{d\sigma}{dt}$ (mb)
.1
.5
1.
|t| [GeV^2/c^2]

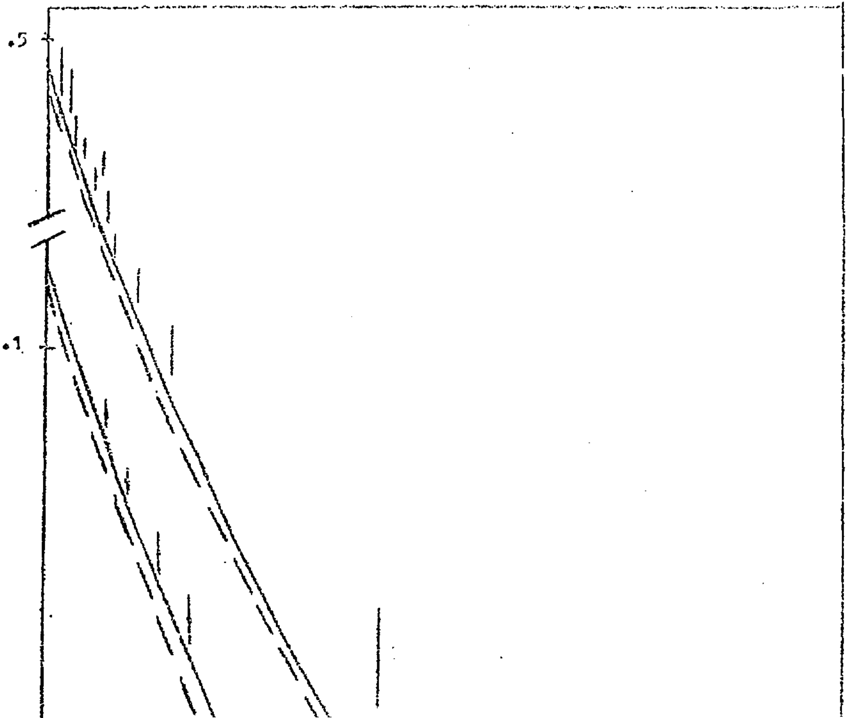
Fig. 3 : D.C.S. $K^-p \to \pi^-\Sigma^+$ [8]

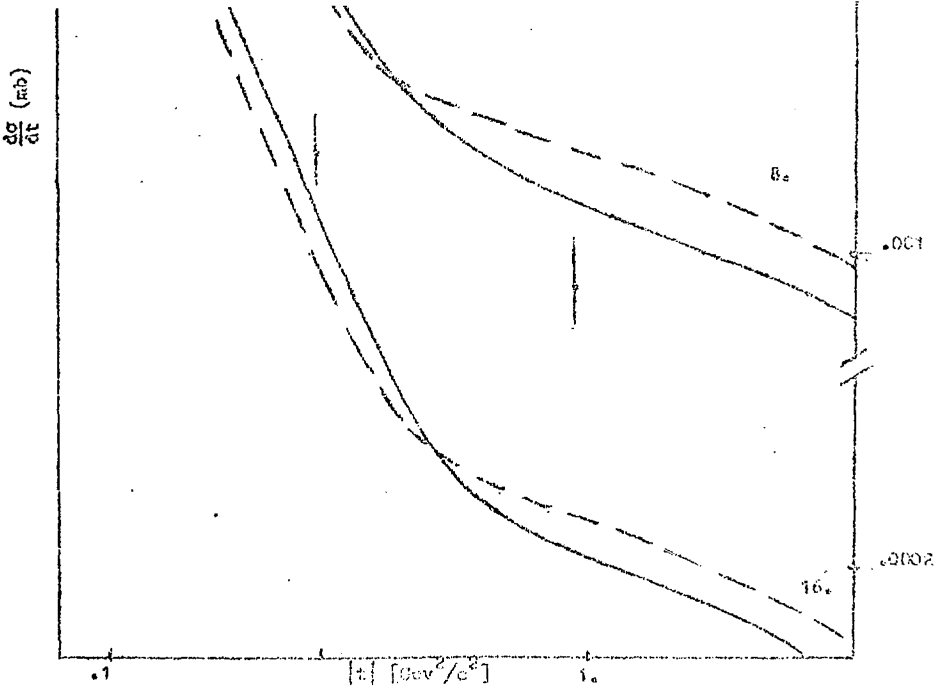




dσ/dt (mb
.005
5.47
.005
.001
.3
.5
1.
|t| [GeV²/c²]

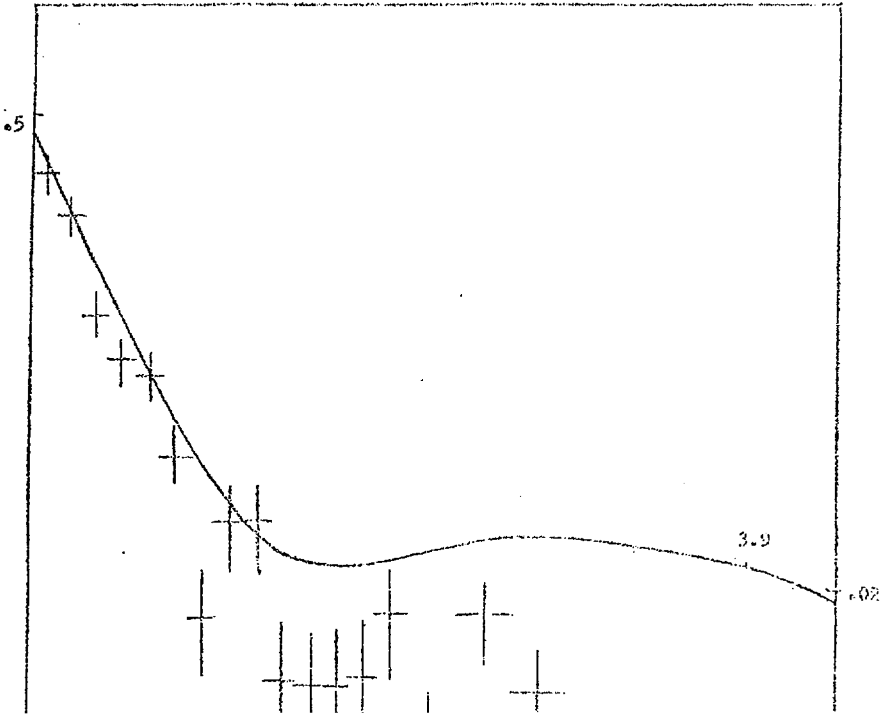
Fig. 4 : D.C.S. $K^-p \to \pi^0\Sigma^+$ [y]

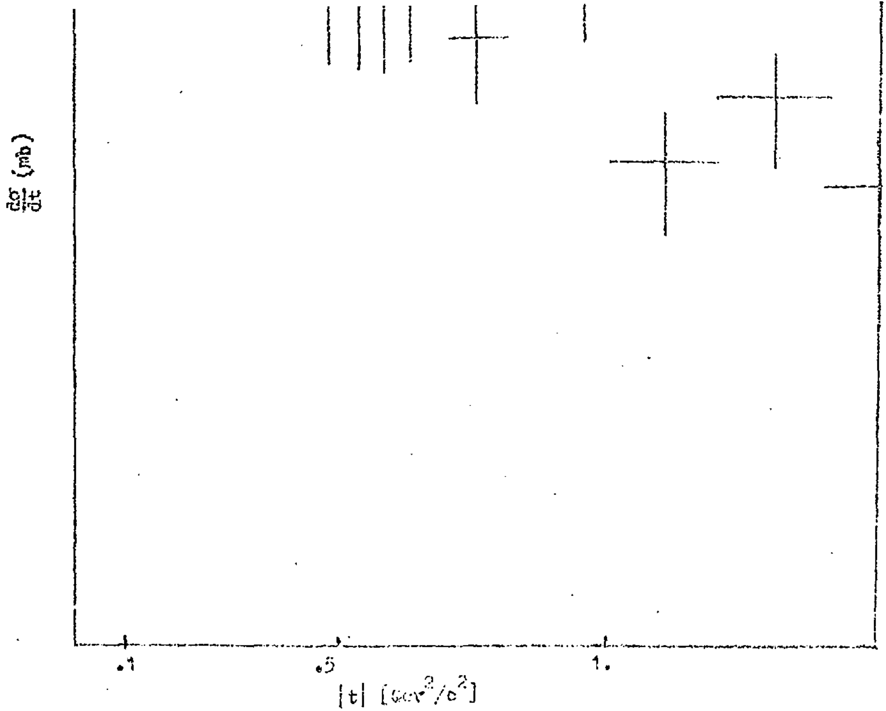


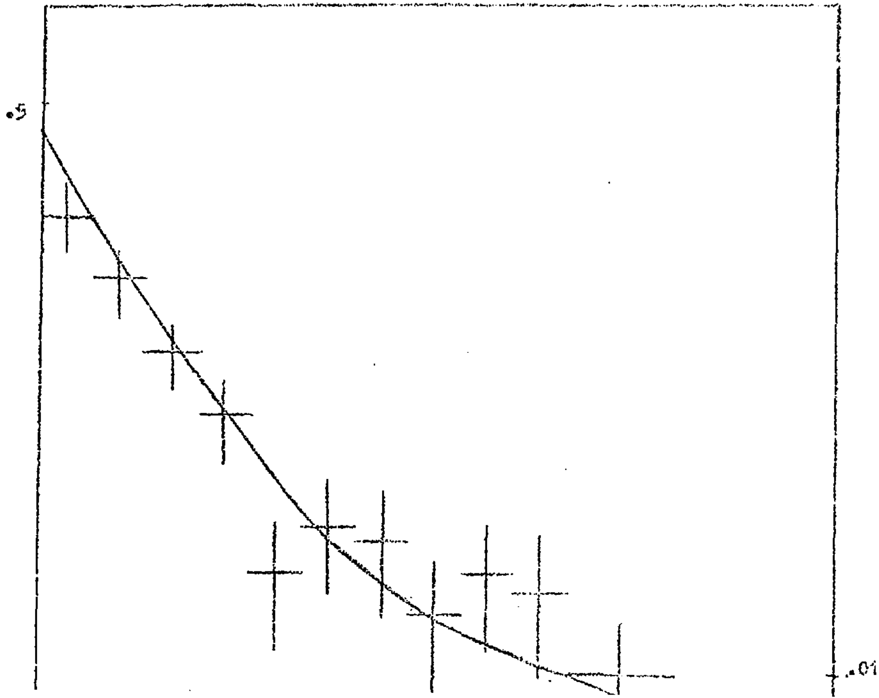


dσ/dt (mb)
8.
.001
.0002
16.
.1
|t| [Gev²/c²]
1.

Fig. 2 : D.C.S. $\pi^- p \to K^0 \Lambda$ [7]




dσ/dt (mb)
.1
.5
1.
|t| [GeV²/c²]


.5
.01

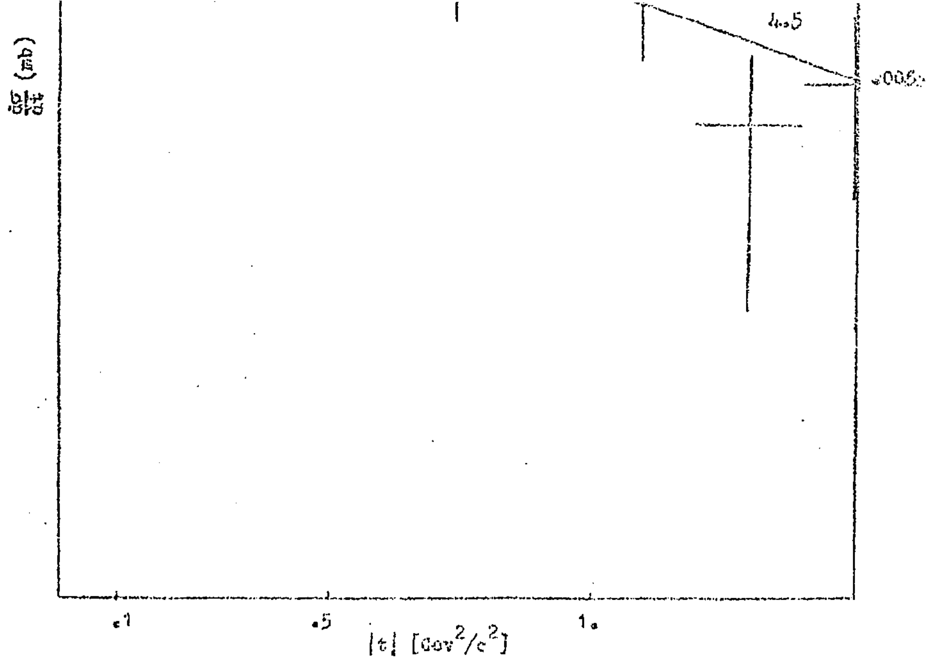
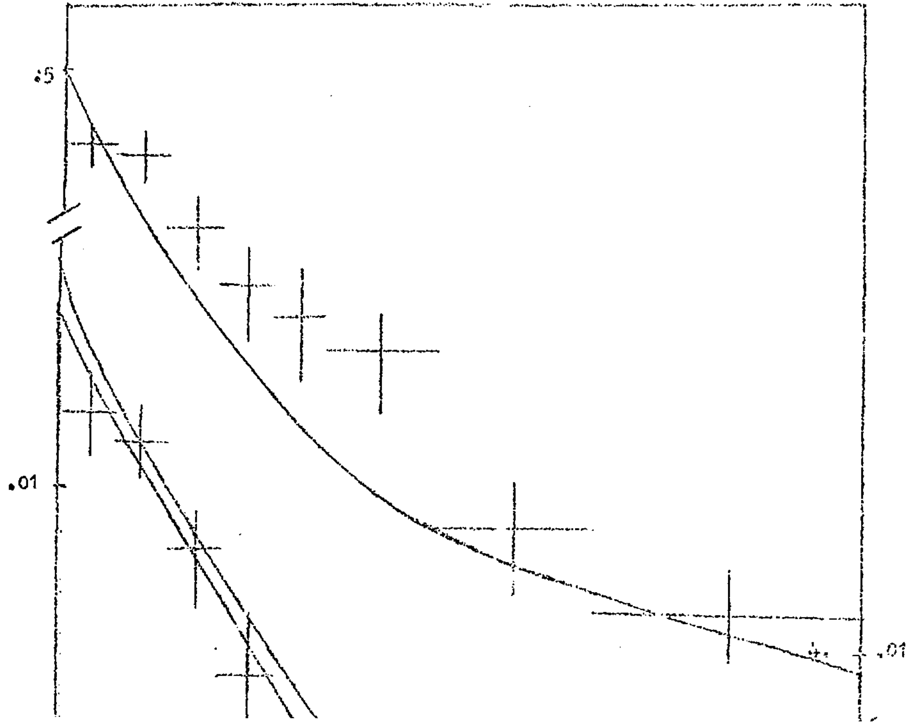
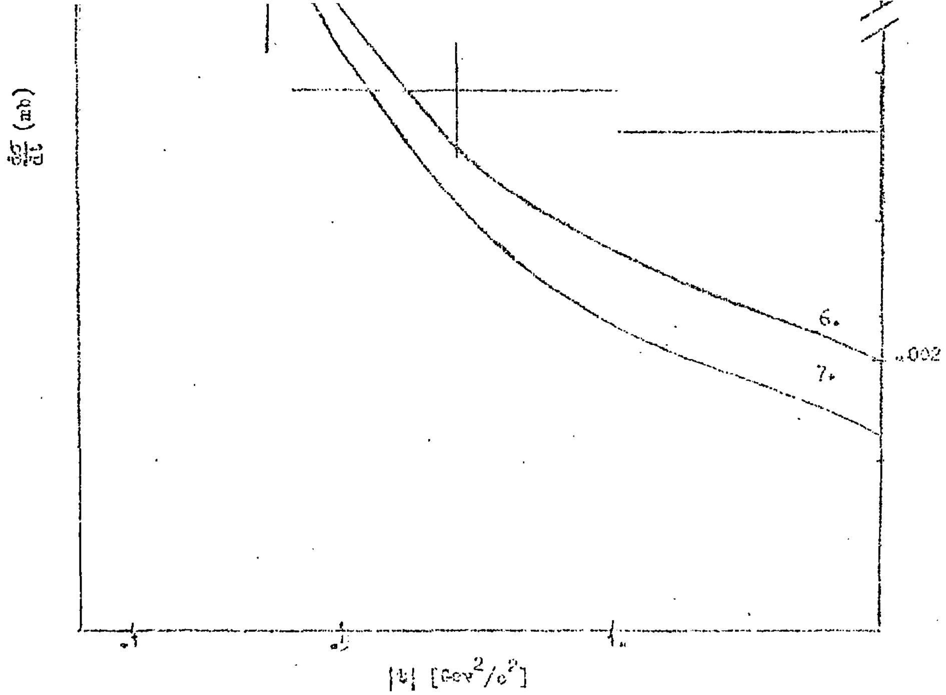
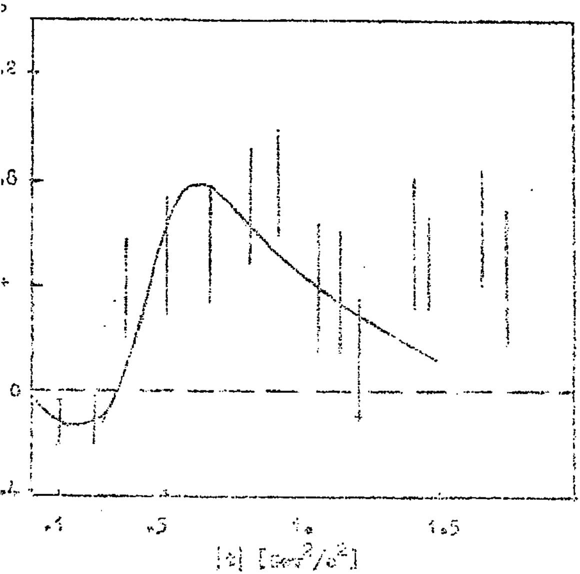


Fig. 6 : D.C.S. $K^- n \to \pi^- \Lambda^0$ [10]

Fig. 7 : D.C.S. $\bar{K}p \to \pi^0\Lambda$ [10]

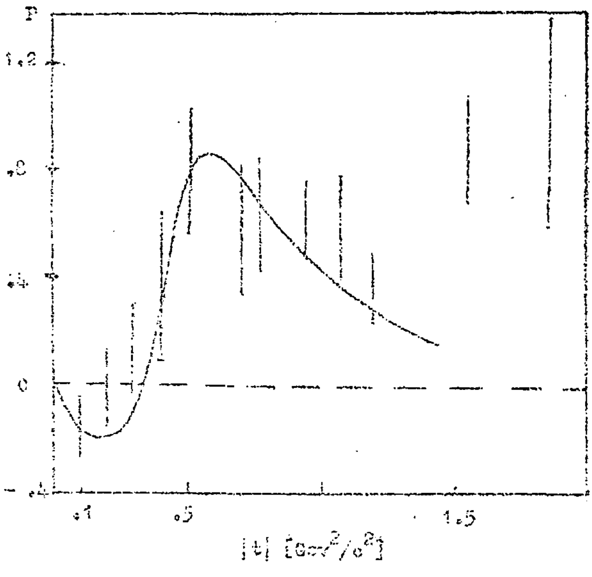



dσ/dt (mb)
6.
7.
.002
|t| [Gev²/c²]



(b) P_{lab} = 3.25 GeV/c

zation in the reaction $\pi^+ p \rightarrow K^+ \Sigma^+$ [5]



(a) P_{lab} = 40 GeV/c

Fig. 8 : Polari

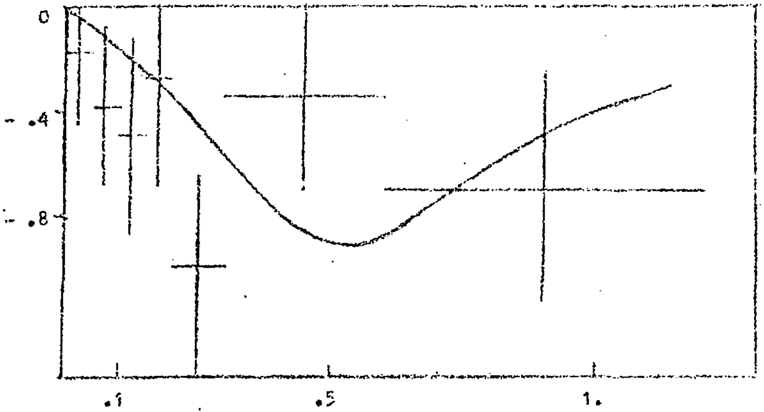
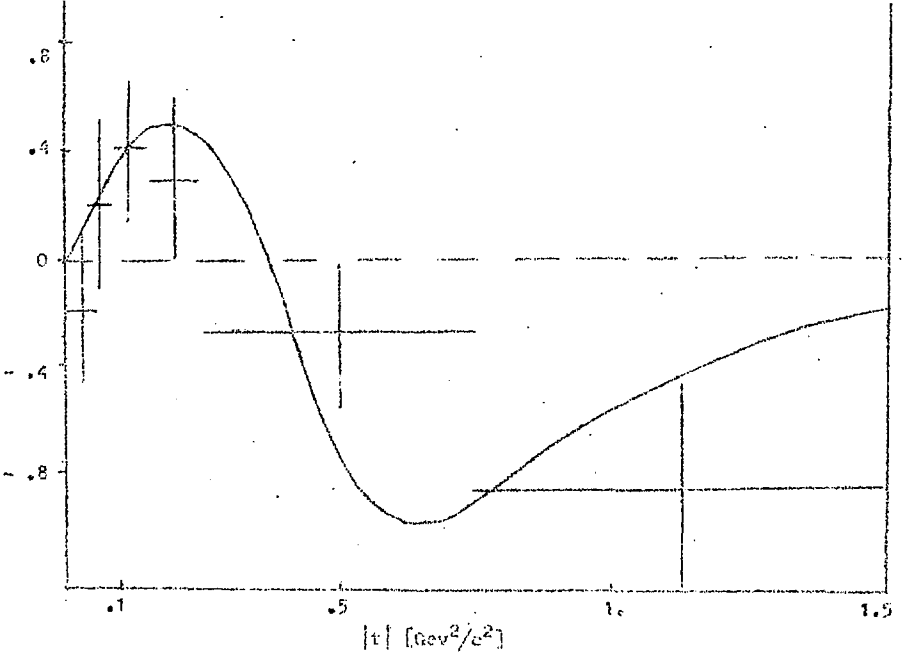


Fig. 9 Polarization in the reaction $K^-p \to \pi^-\Sigma^+$ [8]

Fig. 10 Polarization in the reaction $\pi^-p \to K^0\Lambda$ [7]


.8
.4
0
-.4
-.8
.1
.5
1.
1.5
|t| [Gev²/c²]

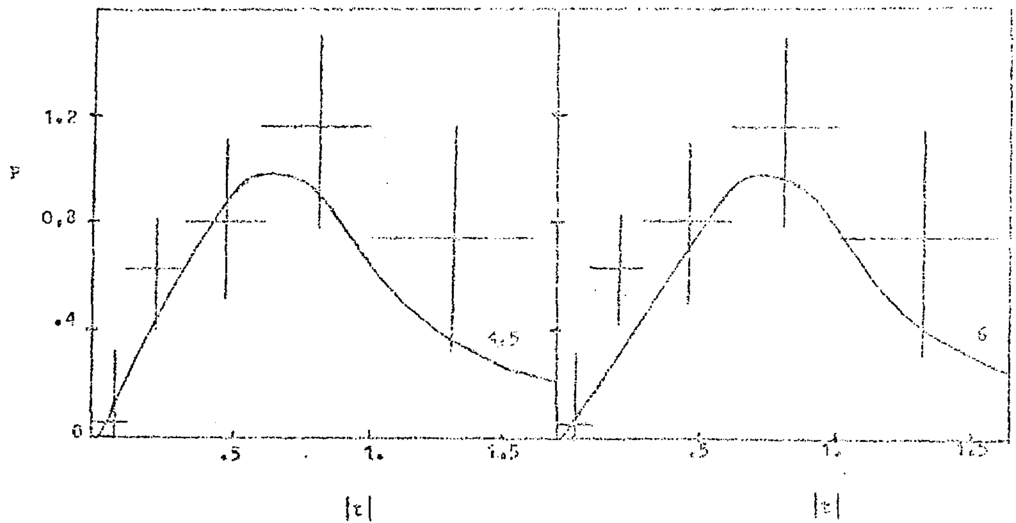


fig.11 Polarization in the reaction $\bar{K}^0 p \to \pi^+ \Lambda$ [11]

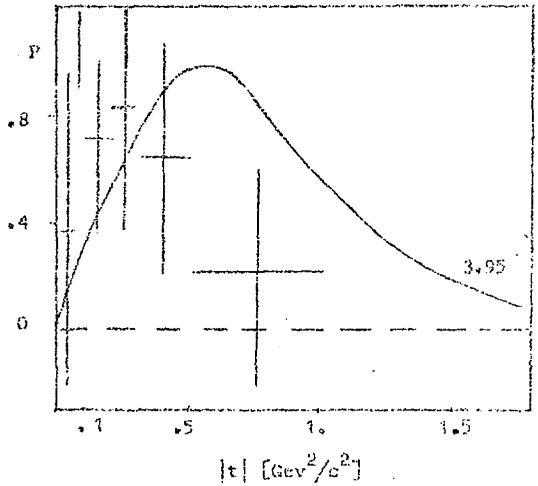


Fig. 12 Polarization in the reaction $K^-p \rightarrow \pi^0\Lambda$ [8]

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