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Energy dependence of K* production by natural-parity exchange in the reaction $K^{\pm}p \rightarrow K_s^o \pi^{\pm} p$

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Abstract

The energy dependence of K* production in the reaction $K^{\pm}p \rightarrow K_s^o \pi^{\pm} p$ from data taken at 10 and 50 GeV/c is presented.

The detailed analysis of the 10 GeV/c data has been published elsewhere (Ref. 1-2). In this paper we present a preliminary analysis of the dominant NPE amplitudes in the t-channel frame from the moments of the K^* decay angular distribution at 50 GeV/c.

We fit the t-dependence of the NPE cross section at 10 GeV/c with a simple Regge model and extrapolated the result to 50 GeV/c. We show that the predicted shape is in good agreement with the 50 GeV/c data.

Introduction

In a previous paper (Ref.2) we presented a detailed amplitude analysis of K* production in the reaction $K^{\pm}p \rightarrow K_s^o \pi^{\pm} p$ at 10 GeV/c showing that this reaction is dominated by natural parity exchange.

We show here the preliminary results of a similar analysis for the same reaction at 50 GeV/c in which we see the same essential features. With the data sample which has been analyzed (about half of the total), we can extract with a good precision only the dominant amplitudes.

We have fitted the 10 GeV/c data with a Regge model including ω and f exchange for the K*(890), P, ω and f exchange for K*(1420). The fitted parameters allow us to predict the behaviour of the amplitudes at 50 GeV/c.

Experimental set-up

The experimental set-up (Fig.1) is essentially the same as that used in the previous PS experiment (Ref.1). It consists of:

- a beam spectrometer to identify the incident particle and to measure its direction and momentum
- a recoil arm to measure the direction and time of flight of the recoil proton
- a forward spectrometer to measure the direction of the forward decay particles. A 16 cell Cerenkov counter separates π from K and p, but its information is not used in the present analysis.

Since no magnet is used, the momenta of the forward particles are calculated by momentum conservation.

The data acquisition system has been improved with respect to the PS experiment by the introduction of 7 miniprocessors which allow an acquisition rate of 800 events/1 sec burst and perform the reconstruction of the tracks from the MWPC data during the 7 sec interburst period.

Moments of the Kπ-decay angular distribution

The data reconstruction, the selection procedures and the method of acceptance correction are the same as described in ref.1.

We calculate the acceptance-corrected spherical harmonic moments of the angular distribution of the K^0 in the $K^0\pi$ t-channel helicity frame as a function of t. Fig.2 shows the unnormalized moments $< \mathrm{Re}\, Y_J^M >$ as a function of t in the mass region of the K*(890) ($0.84 < M_{K\pi} < 0.94$) and of the K*(1420) ($1.34 < M_{K\pi} < 1.5$). Only the moments used in the amplitude analysis are shown here.

Amplitude analysis

To extract the K* production amplitudes from the experimental moments we use combinations of helicity amplitudes with definite asymptotic exchange naturality. L_0 and $L_\pm$ describe spin L $K\pi$ production, where L_0 represents helicity-zero production and, to leading order in energy, $L_\pm = \frac{1}{\sqrt{2}}(L_{\lambda=+1} \pm L_{\lambda=-1})$ represent helicity one production by NPE and UPE, respectively.

The moments in Fig.2, in particular the large negative moments $<Y_2^2>$ and $<Y_4^2>$ show that the dominant amplitudes at 50 GeV/c are P_+ and D_+ for K*(890) and K*(1420) production, as was observed at 10 GeV/c. We therefore concentrate here on the discussion of these dominant NPE amplitudes.

The method of extraction of the amplitudes from the moments is described in Ref.2. Fig.3 shows the resulting NPE cross sections at 50 GeV/c compared with our previous data at 10 GeV/c.

General features of the NPE amplitudes

The striking feature we observed in our previous 10 GeV/c data is a cross-over of the dominant NPE amplitudes for both $K^{*\pm}(890)$ and $K^{*\pm}(1420)$ production (Ref.2). The K^- induced reaction has a larger cross section at small t and a steeper slope than the K^+ initiated reaction. The cross-over occurs at the same t-value, $-t_c = 0.3(\text{GeV/c})^2$ for both resonances.

We compare these observations with the results obtained from the analysis of our 50 GeV/c data. As the analysis is still in progress, the absolute normalization of the cross section scale is not yet known. We will therefore discuss only the shape of the differential NPE cross section.

The 50 GeV/c data show evidence for a difference in slope of $|D_+|^2$ between $K^{*+}(1420)$ and $K^{*-}(1420)$ production (Fig.3), consistent with a cross-over effect. There is indication also for a small difference in slope of $|P_+|^2$ describing $K^{*\pm}(890)$ production.

The general shape of the NPE cross section for K*(890) production shows the shrinkage expected for typical Regge-exchanges. However, there is little or no shrinkage for the K*(1420), indicating a sizeable contribution from Pomeron exchange.

Fits to the NPE cross sections

The analysis of the 10 GeV/c data, and the comparison with the corresponding charge-exchange reactions, has shown that K* production in the reactions $K^{\pm}p \rightarrow K^{*\pm}p$ is dominated by isoscalar exchanges (Ref.3):

$$L_+(K^{\pm}) = P + f \mp \omega$$

where $L_+ = P_+$ and D_+ for the K*(890) and K*(1420), respectively. The difference of K^- and K^+ initiated resonance production arises from interference between exchanges with opposite C-parity:

$$\Delta\sigma \equiv |L(K^-)|^2 - |L(K^+)|^2 = 4 \,\mathrm{Re}(\,P + f)\omega^* .$$

Following Ref.4, we describe these exchanges by simple Regge parametrizations. We attempt to separate the different contributions by fitting simultaneously K^{*-} and K^{*+} data at 10 GeV/c. Using the fitted parameters, we then predict the shape at 50 GeV/c, which we compare with the data.

1) K*(890)

If the Pomeron were a pure SU(3) singlet, generalized C-parity would forbid it in K*(890) production. We therefore fit the data with f and ω exchanges only. Since an exchange degenerate pair of f, ω trajectories gives equal differential cross sections, we have to allow for breaking of exchange degeneracy. We have then:

$$P_+(K^{\pm}) = f \mp \omega$$

where the f,ω exchanges are parametrized by the Regge amplitude:

$$R = -\sqrt{-t}\; G_R e^{b_R t}\; \Gamma(1-\alpha_R(t))\,(\xi_R + e^{-i\pi\alpha_R})\,(\frac{S}{S_o})^{\alpha_R - 1} .$$

with R = f,ω, and $\xi_R = \pm 1$ for the f and ω, respectively. The energy scale S_o is chosen to be 1 GeV^2.

We require α_f to pass through the f and h mesons, and α_ω through the ω:

$$\alpha_f = 0.72 + 0.79\ t$$
$$\alpha_\omega = 1 + \alpha'_\omega\ (t - m^2_\omega)$$

We fit this expression to the 10 GeV/c data in the interval $0.1 < -t < 0.6\ (\mathrm{GeV/c})^2$, with G_f, b_f, G_ω, b_ω and α'_ω as free parameters. The results are shown by the curves in Fig.3 and the fitted parameters are given in Table 1. The fit clearly provides a very good description of the shape of $|P_+|^2$ at 10 GeV/c. We then extrapolate the fit to 50 GeV/c and normalize the data to the predicted cross section in the interval $0.1 < -t < 0.6\ (\mathrm{GeV/c})^2$. As Fig.3 shows, the energy dependence of the shape of $|P_+|^2$ is very well described by this simple model.

2) K*(1420)

Pomeron-exchange is allowed in K*(1420) production. Indeed, the absence of shrinkage between 10 and 50 GeV/c indicates a sizeable Pomeron contribution. The simplest possible parametrization contains the Pomeron in addition to a strong exchange-degenerate f,ω pair of trajectories:

$$D_+(K^\pm) = P + (f \pm \omega)_{EXD}$$

The Pomeron is parametrized by

$$P = -\sqrt{-t}\ G_P e^{b_P t}\ e^{-i\pi\alpha_P/2}\ \left(\frac{S}{S_o}\right)^{\alpha_P - 1}$$

with $\alpha_P(t) = 1 + 0.2\ t$. The f and ω are parametrized as above but taken to be exchange-degenerate:

$$\alpha_f(t) = \alpha_\omega(t) = 1 + \alpha'_{EXD}(t - m^2_\omega)$$
$$b_f = b_\omega \equiv b_{EXD}$$
$$G_f = G_\omega \equiv G_{EXD}$$

We fit this expression simultaneously to the $K^{*+}(1420)$ and the $K^{*-}(1420)$ at 10 GeV/c. Again, the data are well described by the model, and our preliminary 50 GeV/c sample is certainly consistent with the predicted shape.

In this fit, we find that the contribution of the Pomeron relative to the f is about 1:1 at -t = 0.2 GeV/c. It is interesting to compare this result to an independent estimation based on the comparison of K*(1420) to A_2 production cross section, both at a single energy of 10 GeV/c (Ref.5). There we found a similar but somewhat larger ratio of about 1.5 : 1.

It is clear that the above fits do not represent a consistent picture of K* resonance production. An attempt was made to fit the K*(1420) data with a Pomeron plus a non exchange-degenerate pair f,ω, with slopes taken over from the fit to the K*(890). The predicted shape at 50 GeV/c, however, does not agree well with the data.

A more precise determination of the amount of Pomeron exchange in these reactions will only be possible when the normalization of the 50 GeV/c cross section will be known. This analysis is at present time in progress.

References

1) R. Baldi et al., Nucl. Phys. B134 (1978) 365

2) R. Baldi et al., Phys. Lett. 70B (1977) 377

3) A.D. Martin et al., Nucl. Phys. B134 (1978) 392

4) P. Estabrooks et al., Phys. Rev. D17 (1978) 658

5) A.D. Martin et al., A study of A_2 and g resonance production in $\pi^- p \rightarrow K^- K^0 p$, submitted to Nucl. Phys. (1978).

Figure captions

Fig. 1 Lay-out of the experiment

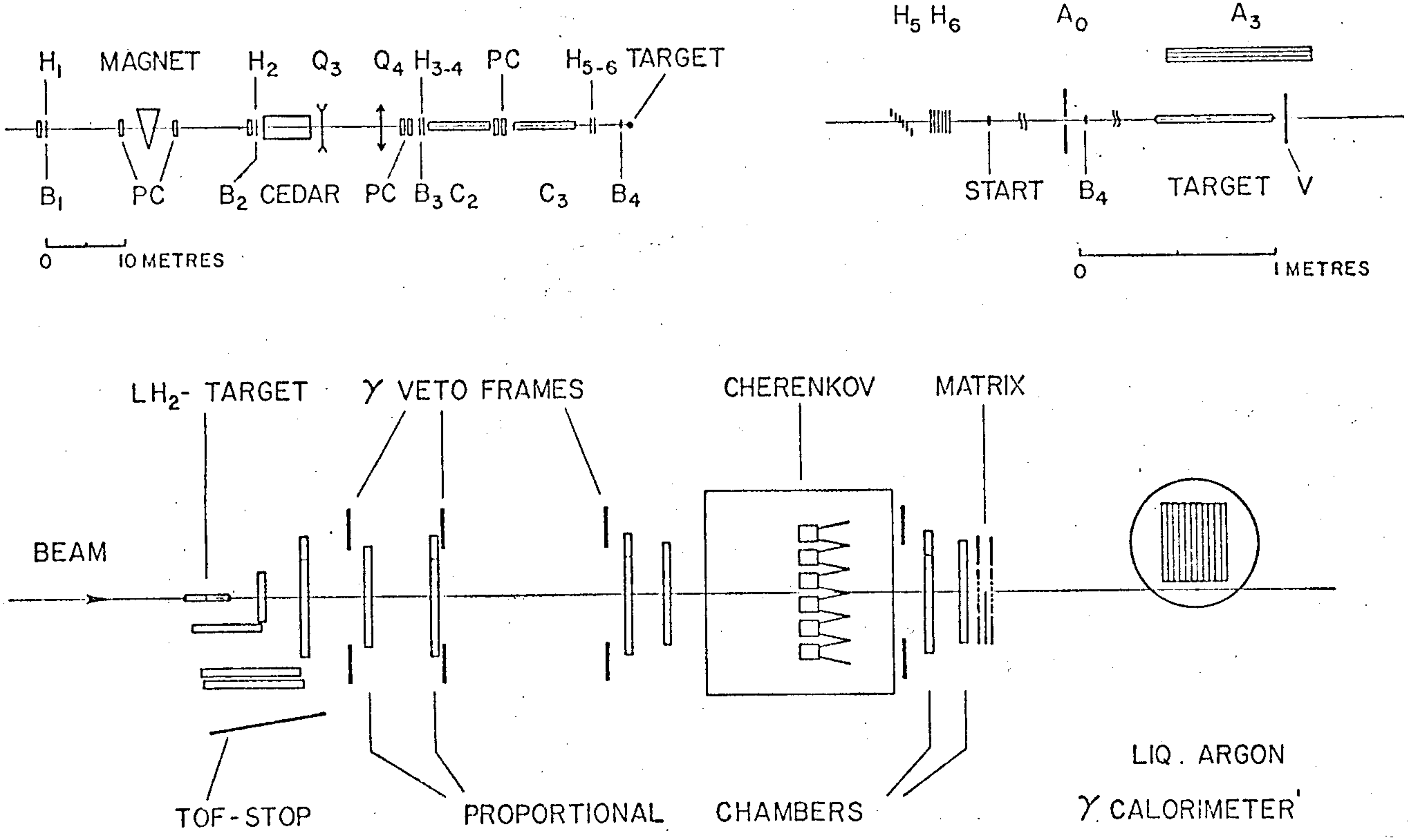
Fig. 2 The moments $< \mathrm{Re}\, Y_J^M >$ $d\sigma/dt$ in the mass region of the K*(890) and the K*(1420) as a function of t.

Fig. 3 The NPE cross sections in the mass region of the K*(890) and the K*(1420) as a function of t. The curves represent fits to the data at 10 GeV/c as described in the text, and extrapolations to 50 GeV/c. The data at 50 GeV/c have been normalized to the predicted cross section in the interval $0.1 < -t < 0.6$ $(\mathrm{GeV}/c)^2$. The cross sections do not include the unseen $K^{*\pm} \to K^{\pm}\pi^{0}$ decay.

K*(890) fFω		K*(1420) + $(fF\omega)_{EXD}$	
G_f	57 ± 1 $\sqrt{\mu b}/(\mathrm{GeV}/c)^2$	G_P	16 ± 3
b_f	1.65 ± 0.01 $(\mathrm{GeV}/c)^{-2}$	b_P	2.26 ± 0.34
G_ω	189 ± 26 $\sqrt{\mu b}/(\mathrm{GeV}/c)^2$	G_{EXD}	55 ± 8
b_ω	2.64 ± 0.40 $(\mathrm{GeV}/c)^{-2}$	b_{EXD}	-0.8 ± 0.3
α'_ω	1.14 ± 0.01 $(\mathrm{GeV}/c)^{-2}$	α'_{EXD}	1.12 ± 0.01

Table 1

The fit parameters to the NPE cross sections at 10 GeV/c



0 1 2 METRES

Fig 1 K^* SPECTROMETER

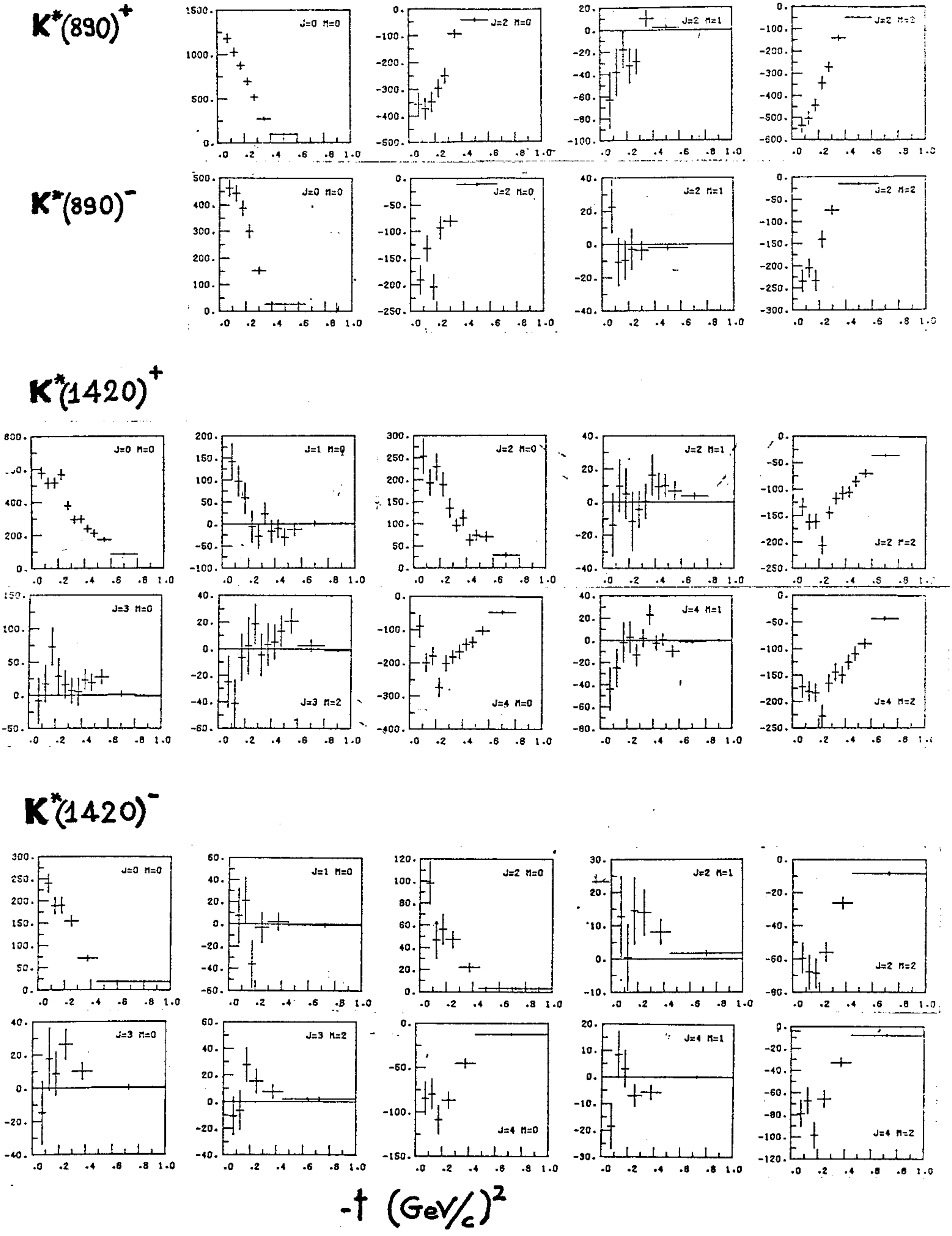

K*(890)+
J=0 M=0
J=2 M=0
J=2 M=1
J=2 M=2
K*(890)-
J=0 M=0
J=2 M=0
J=2 M=1
J=2 M=2
K*(1420)+
J=0 M=0
J=1 M=0
J=2 M=0
J=2 M=1
J=2 M=2
J=3 M=0
J=3 M=2
J=4 M=0
J=4 M=1
J=4 M=2
K*(1420)-
J=0 M=0
J=1 M=0
J=2 M=0
J=2 M=1
J=2 M=2
J=3 M=0
J=3 M=2
J=4 M=0
J=4 M=1
J=4 M=2
.0 .2 .4 .6 .8 1.0
-t (GeV/c)²

Fig 2

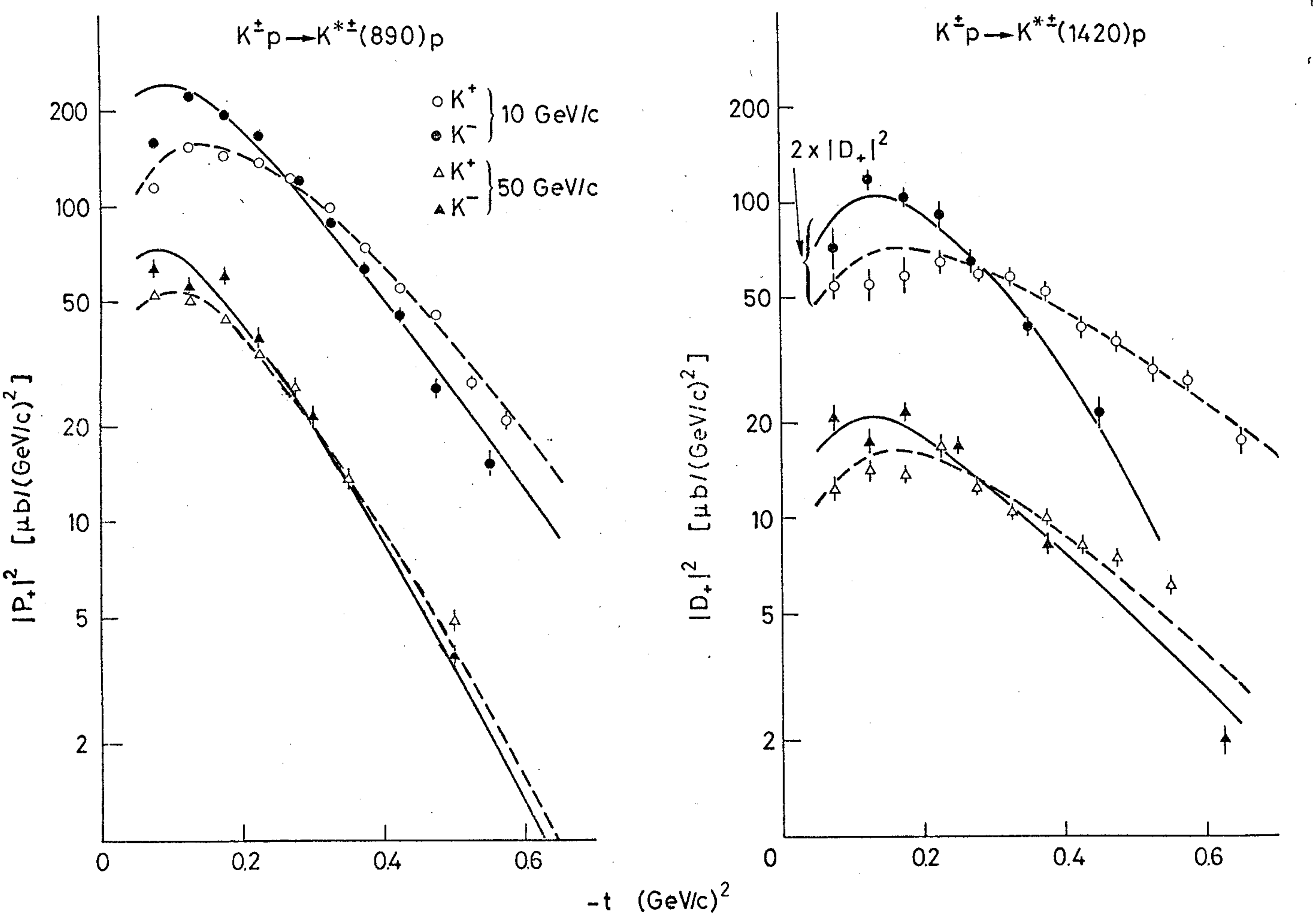

K$^{\pm}$p → K$^{*\pm}$(890)p
○ K$^+$
● K$^-$
10 GeV/c
△ K$^+$
▲ K$^-$
50 GeV/c
$|P_+|^2$ [μb/(GeV/c)^2]
200
100
50
20
10
5
2
0
0.2
0.4
0.6
K$^{\pm}$p → K$^{*\pm}$(1420)p
2 x $|D_+|^2$
$|D_+|^2$ [μb/(GeV/c)^2]
200
100
50
20
10
5
2
0
0.2
0.4
0.6
-t (GeV/c)^2

Fig 3