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**Autor:** Fischer, Walter E.

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## Possibility for a Large Spin-Flip Part in the Scattering Amplitudes of $K^- p$ Charge Exchange at 9,5 GeV/c

by **Walter E. Fischer** \*)

CERN-Geneva

(12. 6. 65)

An experiment on  $K^- p$  charge exchange, carried out recently at CERN<sup>1)</sup>, shows a momentum transfer distribution in which the cross section bends downwards towards  $t = 0$ , while the maximum is situated at  $t = -0.1$ . The same behaviour appears also in  $\pi^- p$  charge exchange<sup>2)</sup>. This is incompatible with pure exponential behaviour of the elastic scattering at small  $t$ . In this letter, which must be considered as an additional remark to the already published paper of the CERN/ETH group<sup>1)</sup>, we try to explain this somewhat strange behaviour of the momentum transfer distribution by a strong spin-flip part in the scattering amplitude.

Consider now the reaction



Convenient variables for the description of this system are the squares of the centre-of-mass total energies in the three channels  $s$ ,  $u$ , and  $t$ , with

$$s + u + t = 2 M^2 + 2 m^2.$$

We denote the nucleon and  $K$  mass by  $M$  and  $m$ , respectively. The differential cross section in the c.m. is given by:

$$\frac{d\sigma}{dt} = \frac{1}{\pi} \left( \frac{M}{4Wk} \right)^2 \sum | \bar{u}_2 T u_1 |^2$$

where the sum is taken over final spin states and the average over the initial spin states and

$$T = -A(s, t) + \frac{i}{2} \gamma_\mu (q_1 + q_2)_\mu B(s, t)$$

$k$  is the c.m. momentum and  $W$  the c.m. energy.  $q_1$  and  $q_2$  are the c.m. four-momenta of the  $K^-$  and the  $\bar{K}^0$ , respectively.

Omitting the modification due to Coulomb interaction, the barycentric kaon-nucleon differential cross section is also given by:

$$\frac{d\sigma}{dt} = \frac{\pi}{k^2} | f_1(k \cos\vartheta) + \cos\vartheta f_2(k \cos\vartheta) |^2 + \sin^2\vartheta | f_2(k \cos\vartheta) |^2$$

\*) Member of the ETH-visiting group.

where the first term of the right-hand side is the non-spin-flip part and the second the spin-flip part of the amplitude.  $\vartheta$  is the scattering angle in the barycentric system.

In terms of helicity state amplitudes

$$f_{\lambda\lambda'} = -\frac{M}{4\pi W} \bar{u}(-p_2, \lambda) \left( -A + \frac{i}{2} \gamma_\mu (q_1 + q_2)_\mu B \right) u(p_1, \lambda')$$

one gets the differential cross section

$$\frac{d\sigma}{dt} = \frac{\pi}{h^2} \left[ \left( 1 - \frac{t}{4M^2} \right) |f_{1/2\ 1/2}|^2 - \frac{t(t+4q^2)s}{4(4M^2-t^2)M^2} |f_{1/2-1/2}|^2 \right].$$

Fitting this formula to the experimental cross section and assuming that

$$|f_{1/2\ 1/2}|^2 = a e^{\alpha t} \text{ and } |f_{1/2-1/2}|^2 = b e^{\alpha t}$$

we get for the three parameters

$$a = 229 \frac{\mu b}{\text{ster}}, \quad b = 114 \frac{\mu b}{\text{ster}}, \quad \alpha = 7.4 (GeV/c)^{-2}.$$

Of course these parameters have a meaning only for momentum transfer  $|t| < 0.8$ . For higher values the parametrization no longer fits the experimental distribution, as one can see in Figure 1. These results were published before<sup>1)</sup> in order to explain the maximum in the experimental differential cross section at small momentum transfer.

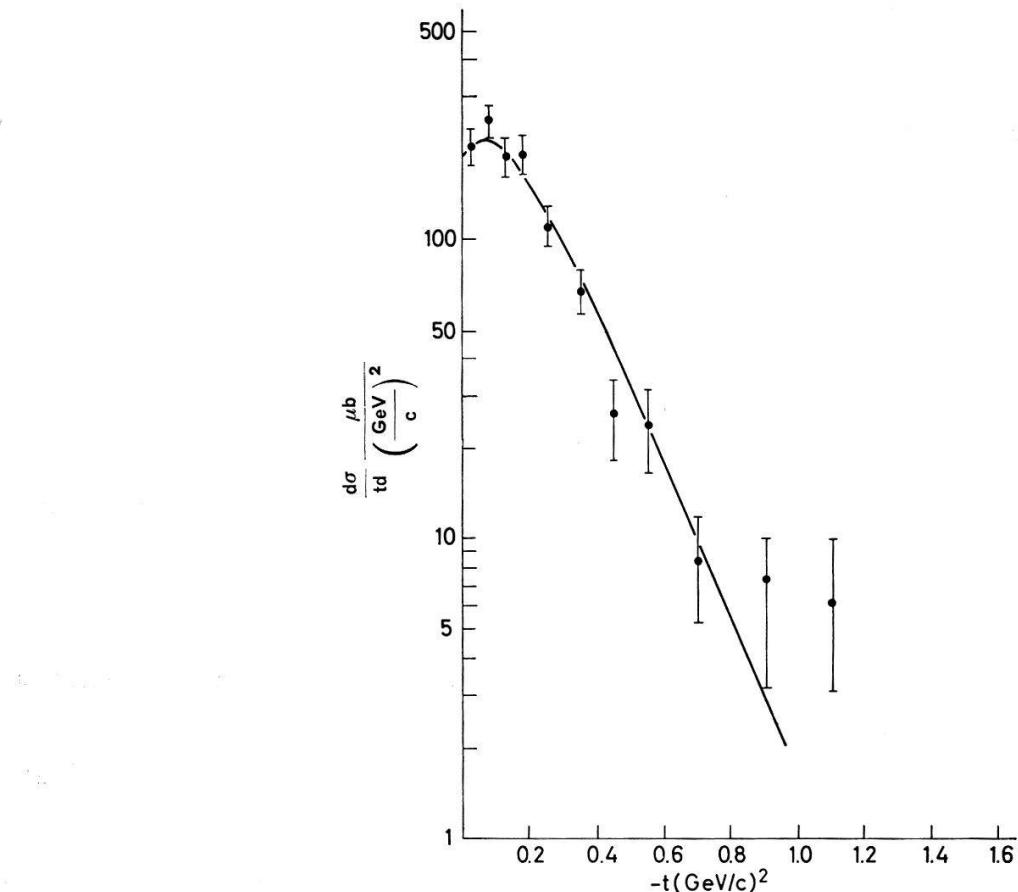


Figure 1  
Experimental momentum transfer distribution and parametrization fit

It is now interesting to see what this parametrisation means in terms of spin-flip and non spin-flip amplitudes. The ratio of spin-flip to non spin-flip terms as a function of the momentum transfer can be seen in Figure 2.

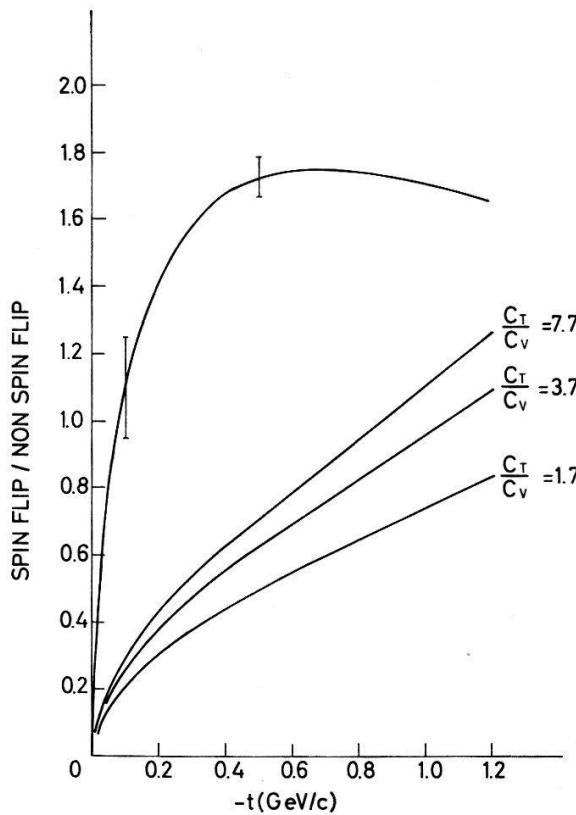


Figure 2

Spin-flip to non-spin-flip ratio for the parametrization and for a  $N\varrho N$  coupling model

We compare now this result with the peripheral model. Assuming that this charge-exchange reaction is dominated by a  $\varrho$ -exchange, we define the  $N\varrho N$ -coupling with the Lagrangian

$$\mathcal{L} = \frac{i}{2} \gamma_{N\varrho N} (\bar{N} \gamma_\mu N) \varrho^\mu + \frac{\mu_{N\varrho N}}{8 M} (\bar{N} \sigma_{\mu\nu} N) (\partial_\mu \varrho^\nu - \partial_\nu \varrho^\mu)$$

where  $\gamma_{N\varrho N}$  is the  $N\varrho N$ -coupling constant and  $\mu_{N\varrho N}$  the difference of the anomalous magnetic moments of the nucleons. If we believe in a  $\varrho$ -photon analogy, we take

$$\frac{\mu_{N\varrho N}}{\gamma_{N\varrho N}} = 3.7$$

which is just the ratio of the tensor to the vector coupling in the  $N\varrho N$ -coupling. The pseudoscalars  $K^-$  and  $\bar{K}^0$  are coupled to the  $\varrho$ -meson by

$$L = \gamma_{K\varrho K} (\phi \partial_\mu \phi^* - \phi^* \partial_\mu \phi) \varrho^\mu$$

$\phi$  and  $\varrho^\mu$  are the pseudoscalar- and vector-field operators respectively.  $\gamma_{K\varrho K}$  is the coupling constant of the  $\varrho$ -meson to the  $K$ -mesons. With this model we get the following matrix  $T$ ,

$$T = \gamma_{K\varrho K} \frac{1}{m_\varrho^2 - t} \bar{u}_2(-\not{p}_2) \left\{ \frac{u-s}{4 M} \mu_{N\varrho N} + \frac{i}{2} \gamma_\mu (q_1 + q_2)_\mu (\gamma_{N\varrho N} + \mu_{N\varrho N}) \right\} u_1(\not{p}_1)$$

$\bar{u}_2$  and  $u_1$  are the Dirac-spinors of the neutron and the proton.  $1/(m_\varrho^2 - t)$  of course comes from the  $\varrho$ -meson propagator.

It is now an easy thing to calculate the spin-flip to non spin-flip ratio for this matrix. Since we are only interested in this ratio, we are not bothered by the somewhat unknown  $K \varrho K$ -coupling constant. This ratio is also plotted in Figure 2. One sees that the relatively strong spin-flip term in this coupling is still smaller than demanded by the parametrisation. Therefore it is hopeless to try to reproduce the momentum transfer distribution with a first order perturbation model of the  $\varrho$ -exchange type.

Apart from this, there also arises the difficulty that the  $\varrho$ -meson propagator is too flat if one does not introduce a form factor which is strongly  $t$  dependent. One also sees that a change of the ratio  $C_T/C_V$  does not improve the situation. Even if we go over to the model of GOTTFRIED and JACKSON<sup>3)</sup> and take into account the absorption effects in the incoming and outgoing channels, the model is still not able to reproduce the experimental momentum transfer distribution, although the spin-flip to non spin-flip ratio is shifted in the right direction<sup>4)</sup>. Although there is a spin-flip contribution in the  $N \varrho N$ -coupling the recoil neutron is not polarized. (Both, the electric and magnetic part of the coupling are real.) In our parametrisation, however, the relative phase of the amplitudes  $a$  and  $b$  can be such that, due to the large spin-flip term, a polarisation of the recoil neutron is required. This could be checked by an experiment on polarized target<sup>5)</sup>.

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- <sup>5)</sup> An experiment of this kind for  $\pi p$ -charge exchange is now prepared at CERN, by the Saclay-Orsay group (see Ref. <sup>2)</sup>).