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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

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(12. 6. 65)

An experiment on $K^- p$ charge exchange, carried out recently at CERN¹⁾, 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 exchange²⁾. 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 group¹⁾, 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

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

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:

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

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:

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

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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. ϑ 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

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

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 before¹⁾ in order to explain the maximum in the experimental differential cross section at small momentum transfer.

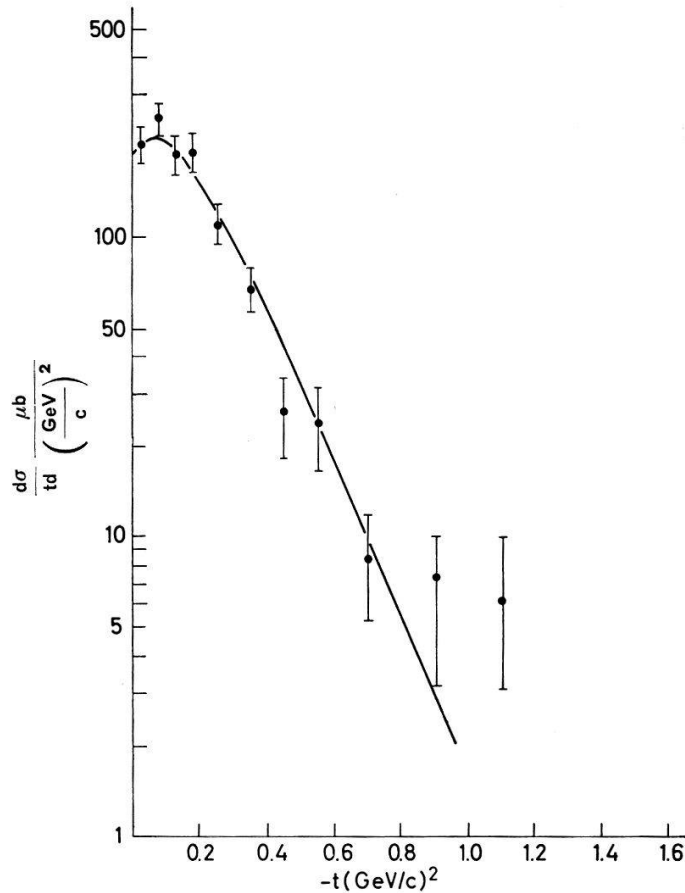


Figure 1

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.

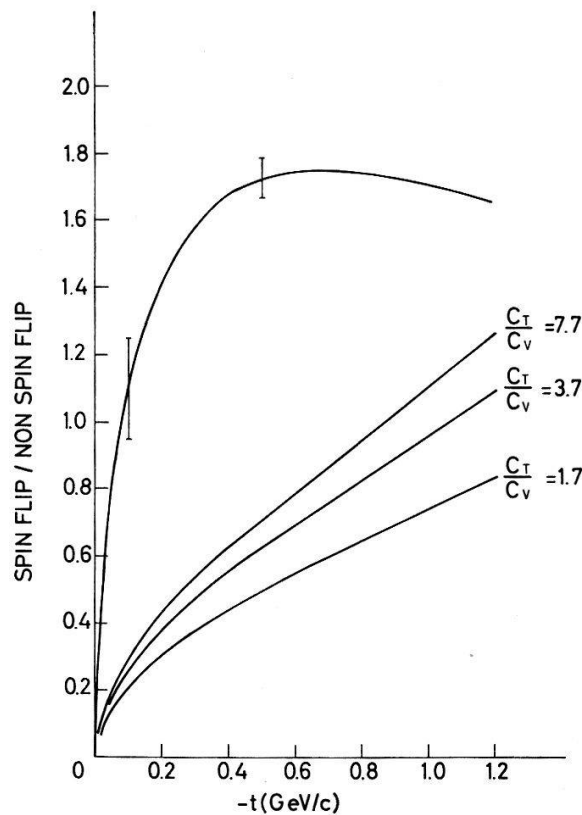


Figure 2

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 ϱ -exchange, we define the $N \varrho N$ -coupling with the Lagrangian

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

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 ϱ -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 ϱ -meson by

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

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

$$T = \gamma_{K\varrho K} \frac{1}{m_\varrho^2 - t} \bar{u}_2(-p_2) \left\{ \frac{u-s}{4M} \mu_{N\varrho N} + \frac{i}{2} \gamma_\mu (q_1 + q_2)_\mu (\gamma_{N\varrho N} + \mu_{N\varrho N}) \right\} u_1(p_1)$$

\bar{u}_2 and u_1 are the Dirac-spinors of the neutron and the proton. $1/(m_\rho^2 - t)$ of course comes from the ρ -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 $K \rho K$ -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 ρ -exchange type.

Apart from this, there also arises the difficulty that the ρ -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 JACKSON³⁾ 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 direction⁴⁾. Although there is a spin-flip contribution in the $N \rho N$ -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 target⁵⁾.

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