Polarized and Transversity GPDs in Kaon Leptoproduction

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Abstract—We study the kaon leptoproduction on the basis of the handbag approach. We consider the leading-twist contribution together with the transversity twist-3 effects which were found to be important in the description of pseudoscalar meson production. We present our predictions for the cross section and spin asymmetries in the kaon leptoproduction.

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In this report, we analyze the process of kaons leptoproduction at large photon virtualities within the handbag approach, where the amplitudes factorize [1] into hard subprocesses and GPDs which keep the soft physics. Different applications of GPDs were discussed at this conference [2]. At the leading-twist accuracy the reactions of kaon production are sensitive only to the GPDs $\tilde{H}$ and $\tilde{E}$ which contribute to the amplitudes for longitudinally polarized virtual photons [3]. It was observed that to be consistent with experimental data on the pion leptoproduction the contributions of transversity GPDs $H_T$ and $E_T$ are needed [4]. Within the handbag approach the transversity GPDs are accompanied by the twist-3 meson wave function.

We consider here the transversity $H_T$ and $E_T$ effects in the leptoproduction of kaons. We present the model results for the cross section of the $K^\pm \Lambda$ and $K^\pm \Sigma^0$ leptoproduction [4] and predictions for the spin asymmetry in these reactions. It is shown that the $H_T$ effects are essential in the $K^\pm \Lambda$ channel while in the $K^\pm \Sigma^0$ leptoproduction the $E_T$ contribution is important.

In what follows, we calculate the meson leptoproduction on the basis of the handbag approach. The hard subprocess amplitudes are calculated within the modified perturbative approach [5] in which the quark transverse degrees of freedom as well as gluonic radiation, condensed in a Sudakov factor, are taken into account.

The proton non-flip or helicity-flip amplitudes for longitudinally polarized photons $\mathcal{M}^K_{\mp,0+}$ can be written in the form:

$$
\mathcal{M}^K_{\mp,0+} \propto \left[ P^K_{\mp,0+} + \langle \tilde{H}^K \rangle \right];
$$

$$
\mathcal{M}^K_{\pm,0+} \propto \sqrt{-t} \left( m + M_N^2 \right) \left[ P^K_{\mp,0+} + \zeta (\tilde{E}^K) \right].
$$

The amplitudes (1) dominate at large $Q^2$. The corresponding amplitudes with transversally polarized photons are suppressed as $1/Q$.

The $P^K$ terms in (1) represent a kaon pole which appears in this reaction for charged kaon production. We use the kaon–barion coupling constants [4]

$$
g_{K^\mp pA} \sim -13.3; \quad g_{K^\mp p^\prime A} \sim -3.5,
$$

which are close to SU(3) predictions.

The second terms in (1) accumulate the handbag contribution to the kaons production amplitude. The $\langle \tilde{F} \rangle$ in (1) is a convolution of GPD $\tilde{F}$ with the hard subprocess amplitude $\mathcal{H}(\langle \tilde{F} \rangle)$:

$$
\langle \tilde{F} \rangle = \sum_K \int_{\mathcal{R}} \mathcal{H}(\langle \tilde{F} \rangle, \mathcal{F}(\langle \tilde{F} \rangle, \mathcal{F}(\langle \tilde{F} \rangle, t)).
$$

The proton–hyperon transition GPDs in (3) can be related with the proton GPDs by using the SU(3) flavor symmetry [6]

$$
F(p \rightarrow \Lambda) \sim [2F^u - F^d - F^s];
$$

$$
F(p \rightarrow \Sigma^0) \sim [F^d - F^s].
$$

It was found that the asymptotically dominant leading-twist contributions are not sufficient to describe the experimental results on leptoproduction of pseudoscalar mesons [4]. The data require also the contributions from the transversity GPDs.

We estimate this contribution to the $\mathcal{M}_{0\pm,++}$ amplitudes by the transversity GPDs $H_T$, $E_T$, which are considered together with the twist-3 meson wave function [4] in the hard subprocess amplitude

$$
\mathcal{M}^{K,tw3}_{0+,0+} \propto \int_{\mathcal{R}} \mathcal{H}_{0+,0+}(\tilde{x}, \mathcal{F}(\langle \tilde{F} \rangle, t)) H_T^K,
$$

$$
\mathcal{M}^{K,tw3}_{0-,0-} \propto \int_{\mathcal{R}} \mathcal{H}_{0-,0-}(\tilde{x}, \mathcal{F}(\langle \tilde{F} \rangle, t)) E_T^K.
$$
The $H_T$ GPD is connected with transversity PDFs as
\[
H^a_T(x, 0, 0) = \delta^a(x); \quad \text{and} \quad \delta^a(x) = CN_T^a x^{1/2}(1-x)[q_u(x) + \Delta q_d(x)].
\]
We parameterize the PDF $\delta$ using the model [7]. The double distribution representation [8] is used to calculate GPD $H_T$. Due to different signs of $H^a_T$ and $H^d_T$ we find a quite large $H_T$ contribution $K^+\Lambda$ and much smaller effect in the $K^+\Sigma^0$ production (4).

The information on $\bar{E}_T$ is available only from the lattice QCD estimations [9]. It was found that $\bar{E}_T^u$ and $\bar{E}_T^d$ should to be quite large, have the same sign and a similar size. From (4) we can conclude that the $\bar{E}_T$ contributions to different kaon production channels should be similar.

The large transversity $H_T$ effects in the $K^+\Lambda$ channel provide to the large $\sigma_T$ cross section without a forward dip which dominated with respect to $\sigma_L$, see Fig. 1 (Left). For the $K^+\Sigma^0$ production the $H_T$ contribution is much smaller and the $\bar{E}_T$ effects become essential. It provides the cross section with a forward dip, Fig. 1 (Right). In both cases $\sigma_T$ determined by the transversity $H_T$ and $\bar{E}_T$ contribution is large at low $Q^2$ with respect to the leading twist $\sigma_L$ cross section. Note that the twist-3 effects decrease rapidly with $Q^2$ growing and at sufficiently high $Q^2$ the $\sigma_L$ will predominate.

In Fig. 2, we show our predictions for the moments of $A_{UT}$ asymmetry for kaon production. The $\sin(\phi_s)$ moment of asymmetry determined mainly by the $H_T$ contributions to different kaon production channels should be similar.
contribution is quite large in the $K^+\Lambda$ production, Fig. 2 (Left). In the $K^+\Sigma^0$ channel this moment of $A_{UT}$ asymmetry is much smaller, Fig. 2 (Right). The $\sin(\phi - \phi_s)$ moment of $A_{UT}$ asymmetry is predicted to be not small in this process, Fig. 2 (Right) with respect to the $K^+\Lambda$ production.

To summarize, in this report we considered kaon leptoproduction within the handbag approach. We calculated the leading twist and twist-3 transversity contributions together. It was found that the $H_T$ and $E_T$ contribution was quite large. They produce $\sigma_T$ which at low $Q^2$ exceeds substantially the leading twist $\sigma_L$ cross section. We observe the same effect for most reactions of the pseudoscalar meson leptoproduction [4]. The role of transversity effects can be investigated in future COMPASS and JLAB12 experiments.

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