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PROTON INDUCED K^+ PRODUCTION AND THE $s\bar{s}$ CONTENT OF THE PROTON *

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We investigate the exclusive proton–induced K^+ production near the kaon threshold. Compared are two models: a meson–exchange model, which includes π, ρ, K and K^* exchange, together with the dominant baryon resonances, and a quark–gluon model, where momentum sharing is provided via the exchange of two gluons. Based on covariant bound state wave functions for the meson and the baryons — which we treat as quark–diquark objects — first results for the $pp \to p\Lambda K^+$ total cross section are presented for both models.

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Numerous calculations in different QCD–inspired quark models have indicated that mesons and baryons can be described qualitatively as objects, which involve dominantly $q\bar{q}$ and $3q$ valence quarks, respectively. Recently, however, particularly with the so called "spin crisis of the nucleon", the question on the admixture of seaquarks in hadrons has been raised [1]. In view of recent experimental activities at various hadron factories, such as COSY or CELSIUS, one promising source of information on the $s\bar{s}$ content of the proton is the exclusive K^+ production in $pp \to NYK$, with Y being a Λ or Σ hyperon: in the simplest picture, the production process can be viewed as the excitation of an $s\bar{s}$ pair in the proton, which is subsequently — during the scattering process — put on its mass shell.

The standard approach to meson production is the meson–exchange model, where the large momentum transfer of typically ≥ 1 GeV/c is shared between the hadrons by meson exchange [2][3] (Fig. 1a). The dominant contributions are expected from the exchange of (π, ρ) in the nonstrange and (K, K^*) in the strange meson sector, whereas the rescattering amplitude

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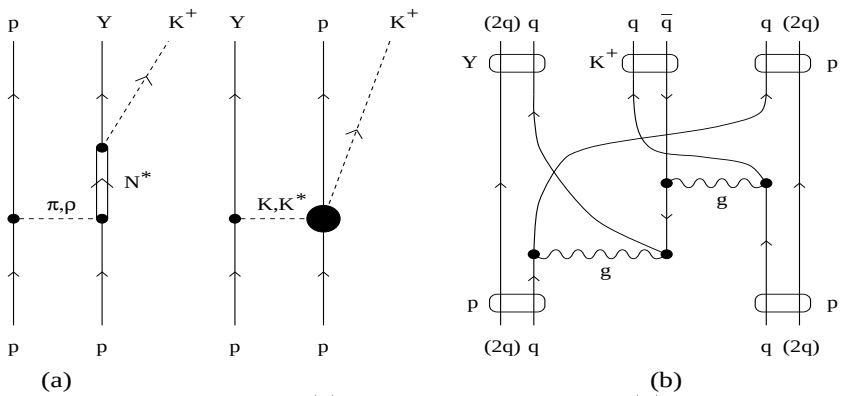

Fig. 1. Meson–exchange model (a) and quark–gluon model (b) for pp–induced K^+ threshold production

is saturated by s– and p–wave baryon–resonances in the region of 1.6 to 1.8 GeV. Preliminary results show that the model reproduces the scarce existing data [4] in a qualitative form. However, the approach shows serious shortcomings, resulting from its — basically — nonrelativistic nature and the significant sensitivity of the results on the parametrization of off–shell effects in the various meson–baryon vertices.

The intrinsic short range scale $\lambda \sim 0.2 - 0.5$ fm of proton induced K production suggest a parametrization of the production mechanism in terms of quark and gluon degrees of freedom. Guided by experience from exclusive high momentum transfer reactions, we employ a simple gluon exchange model: we assume that the large momentum is shared by a two–gluon–exchange mechanism between the interacting constituent quarks, followed by the appropriate interchange of quark lines (to guarantee colourless objects with the right flavour content in the final state; compare Fig. 1b). Soft corrections of higher order are included in addition as standard initial and final state corrections.

We briefly summarize the basic ingredients. To allow for an appropriate organization of the Fock components, we work in the instant (light cone) form. For a covariant description we start from the Bethe–Salpeter equation,

$$\Psi(P,p) \quad = \quad G_{BS}(P,p) \int K(P,p,k)\ \Psi(P,k)\, dk \tag{1}$$

which is reduced to a 3–dimensional covariant Quasi–Potential equation upon integrating out the relative energy component in the BS–Propagator

in the spirit of a spectator picture for the bound particles [5], schematically

$$G_{BS}(P,p) = \frac{1}{(D_1(P,p)+i\varepsilon)(D_2(P,p)+i\varepsilon)} \equiv -\frac{i\pi\delta(D_1(P,p)-D_2(P,p))}{D_1(P,p)} \tag{2}$$

which amounts for the transisition to the light cone in the substitution

$$P=(P_0,P,\underline{0}) \Rightarrow (E,1,\underline{0}) (\text{we used } P_+=1); p=(p_0,\underline{p}) \Rightarrow (E\,x,\underline{p}_\perp), \tag{3}$$

where E is the total energy of the bound hadron and x the momentum fraction carried by the constituent. The interaction kernel is approximated by a one–gluon exchange potential

$$K(P,p,k) \Rightarrow K_{OBE}(x,\underline{p}_\perp) = \frac{C}{(E\,x)^2+\underline{p}_\perp^2} \cdot \frac{\alpha_s(p_0^2)}{\ln\left(1+\dfrac{(E\,x)^2+\underline{p}_\perp^2}{\Lambda_{QCD}^2}\right)} \tag{4}$$

(C absorbs spin and colour factors). As a final step we describe the baryons as Quark–Diquark objects and parametrize their wavefunctions as

$$\Psi(x,\underline{p}_\perp) \quad = \quad N\left(\prod_{i=1}^{3}\left(\underline{p}_\perp^2+\alpha_i^2(x)\right)\right)^{-1} \tag{5}$$

$$\begin{aligned}\alpha_1^2(x) &= (\eta+x)\left(M^2-m^2-(1-\eta-x)\,E^2\right)+m^2\\ \alpha_{2,3}^2(x) &= x\,\left((x+2\eta-1)E^2+M^2-m^2\right)+\Lambda_{2,3}^2\end{aligned} \tag{6}$$

with the quark and diquark masses m and $M=2m$, $\eta=m/(m+M)$, and the scale parameters $\Lambda_2=\Lambda_q$ and $\Lambda_3=\Lambda_{qq}$. In the spirit of the impulse approximation the strangeness content in the proton is defined in the model via the relation

$$\begin{aligned}&\Psi_{3q,s\bar{s}}(P,\underline{q},\underline{k}) = G_{3q,s\bar{s}}(P,\underline{q},\underline{k})\\ &*\int d\underline{p}\left\{V_{q\to qs\bar{s}}(P,\underline{q},\underline{k};\underline{p})+V_{2q\to 2q,s\bar{s}}(P,\underline{q},\underline{k};\underline{p})\right\}\Psi_{3q}(P,\underline{p})\end{aligned} \tag{7}$$

(the notation is understood as light cone coordinates). Preliminary results for the two–gluon–exchange model are shown in Fig. 2b (for $m_{u,d}=330$ MeV, $m_s=505$ MeV, $\Lambda_{QCD}=250$ MeV and $\Lambda=\Lambda_q=\Lambda_{qq}$). In spite of the qualitative agreement with the data, a detailed conclusion on the $s\bar{s}$ content of the proton requires a further study of the numerics and a detailed test of the consistency of the model for other meson channels. Work

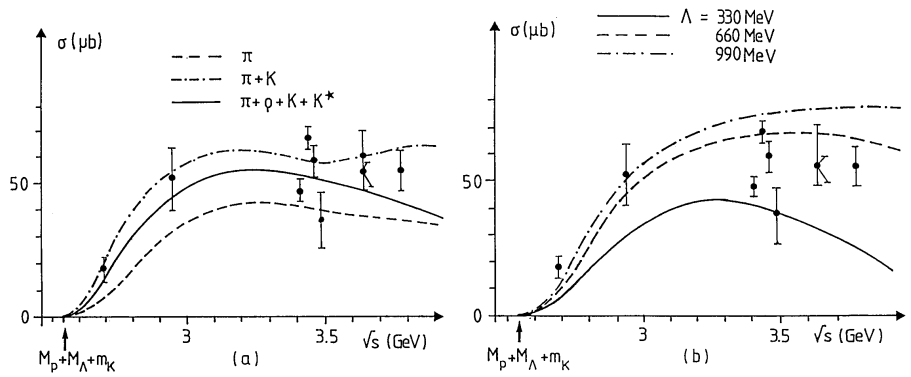

Fig. 2. Preliminary results for the energy dependence of $\sigma_{pp\to p\Lambda K+}$ in the (a) meson–exchange and (b) two gluon–exchange model (comp. Fig. 1).

along this line is in progress [6]. This work was supported in part by the Kernforschungszentrum Jülich under contract No. ER-41154523.

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