The cross-section estimate for non-resonant K^+K^- production in pn collisions

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At ANKE the total cross-section for the $pn \to d\phi$ reaction will be measured using deuterium target [1]. Nonresonant K^+K^- production, i.e. the $pn \to dK^+K^-$ reaction, will be the main background. Therefore, the magnitude of this cross section determines whether the resonant peak can be identified. The total cross-section for the $pp \to ppK^+K^-$ reaction was measured at low excess energies of ε=17 MeV [2] and 114 MeV [3], respectively. In the following, the total cross-section for the $pn \to dK^+K^-$ reaction is deduced from the experimental data for $pp \to ppK^+K^-$ taking into account the S-wave final-state interaction of the spin-singlet pp state and -triplet $d(pn)$ state (pn denotes the scattering state). According to Ref.[4], if the reaction process is dominated by short-range effects (r<1fm), the scattering wave function of the final nucleons at short distance can be factorized from the total amplitude. Thus the ratio of the scattering amplitudes for the spin-singlet and -triplet state is proportional to the ratio of the final-state wave functions (ϕ) with relative momentum (k), i.e.:

$$\frac{|\phi_s|}{|\phi_t|} \propto g(k) = \frac{|\sin\delta_s(1-r_b/a_s)/C|}{|\sin\delta_t(1-r_b/a_t)|}, \tag{1}$$

where a_s and a_t shows the scattering length of the spin-singlet and -triplet state, respectively and δ_i is the phase shift as a function of k. C is the Coulomb penetration factor [4]. We set $r_b \simeq 1$ fm. Following the arguments of Ref.[5], the spin-triplet scattering wave function at short distances is approximated by the bound state wave function. Thus by using eq.(1) the total cross-section for the final pp-, pn- and d-states are determined by the d-state amplitude (M_d) :

$$\sigma_{pn} = |M_d|^2 \int h(k)(1+Ag^2(k))d\rho_n/f, \tag{2}$$

$$\sigma_{pp} = A|M_d|^2 \int h(k)g^2(k)d\rho_n/f, \tag{3}$$

$$\sigma_d = |M_d|^2 \int d\rho_{n-1}/f, \tag{4}$$

where ρ_n and f are n-body phase-space and flux factor, respectively [6]. $h(k) = 2\pi m_N/[\alpha_t(k^2+\alpha_t^2)]$, α_t=0.232 fm^{-1} and m_N is twice the np reduced mass [5]. A is a parameter, which gives the relative magnitude of the spin-singlet and -triplet state amplitude. Our model is applied to single meson production (n=3), i.e. $NN \to NN(d)\pi$, η and ω, at lower excess energies ε<100 MeV. The results are shown in Fig.1. In the case of π and η production, data for the final pn- and pp-state are fitted by using eqs.(2) and (3), while the total cross-section for the final deuteron state is evaluated using eq.(4). In case of ω production, there are no data available for the final pn-state as well as d-state. Therefore the amplitude $|M_d|^2$ is obtained by fitting eq.(3) to the pp data with fixed $A=\frac{2}{9}$ assuming that the production mechanism is dominated by isovector interaction. The result for the d-state is compared with theoretical calculations [7, 8]. Our model is in qualitative agreement with measured and predicted cross-section for the final d-state.

The kaon and pion exchange mechanisms give a satisfactory description of $pp \to ppK^+K^-$ data [9]. We assume that these mechanisms also dominate for $pn \to dK^+K^-$. In a model independent way we deduce the total cross-section for $pn \to dK^+K^-$ from each $pp \to ppK^+K^-$ data point independently. The expected upper limit of the total cross-section at the beam energy of 2.69 GeV (ε=66.4 MeV) is $\sigma \simeq 0.04\mu$b. On the other hand, the predicted total cross-section for $pn \to d\phi$ at this beam energy (ε=34.6 MeV, where the $pp \to pp\phi$ reaction will be measured at the same excess energy [1]) is 0.3−0.6μb [7, 8]. Therefore we conclude that the resonance peak can be identified on top of a low background of non-resonant K^+K^- production (Fig.2(b)).

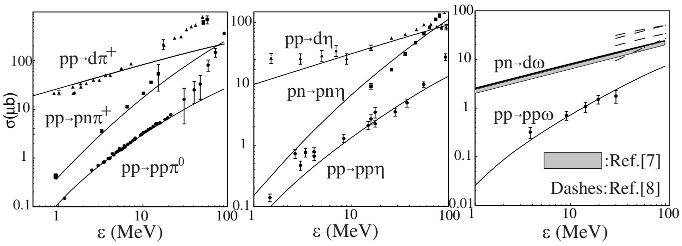

Fig. 1: Total cross-section for the $NN \to NN(d)\pi$,η and ω reactions. Data for π, η and ω production are taken from Refs.[10], [11] and [12], respectively.

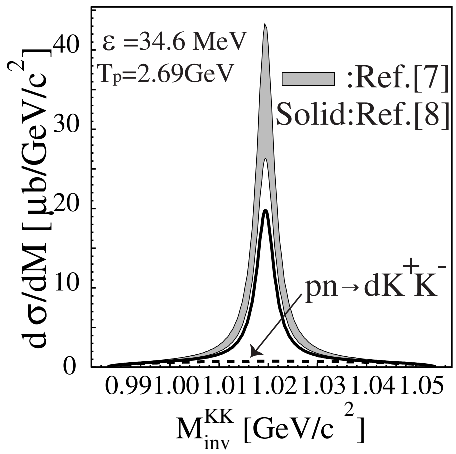

Fig. 2: Expected invariant mass spectra of the K^+K^- system.

References:

[1] M.Hartmann *et al.*, Ann. Rep. 2001 of IKP, (2002).
[2] C.Quentmeier *et al.*, Phys. Lett. **B515**, 276(2001).
[3] F.Balestra *et al.*, Phys. Rev. **C63**, 024004(2001).
[4] R.J.N. Philips *et al.*, Nucl. Phys. **53**, 650(1964).
[5] G. Fäldt *et al.*, Physica. Scripta **56**, 566(1997).
[6] Particle Data Group, Eur. Phys. J. C**3**, 186(1998).
[7] V.Yu.Grishina *et al.*, Phys. Atomic. Nucl **63**, 1824(2000).
[8] K.Nakayama *et al.*, Phys. Rev. **C63**,015201(2000).
[9] A. Sibirtsev *et al.*, Z. Phys. **A358**, 101(1997).
[10] H. Machner *et al.*, J. Phys. G: Nucl. Part. Phys. **25**, R231(1999) and references therein.
[11] H.Calen *et al.*, Phys. Rev. **C58**, 2667(1998) and references therein.
[12] F. Hibou *et al.*, Phys. Rev. Lett. **83**, 492(1999).