Energy dependence of the $pp \to K^+n\Sigma^+$ reaction

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In contrast to the neuttral light hyperons, Λ and Σ^0, very little is known about Σ^+ production in pp collisions. The $pp \to K^+n\Sigma^+$ reaction can be measured by detecting K^+n in the final state and identifying the Σ^+ via a missing-mass spectrum. Using this method, values of the total cross section for this reaction were obtained for the first time at two close-to-threshold energies by the COSY-11 collaboration [1]. It was found, surprisingly, that the values thus obtained were extremely high. At the lowest energy where measurements were performed (13 MeV above the threshold) it is as high as the total cross section for the $pp \to K^+p\Lambda$ reaction. Furthermore, the ratio $\sigma(\Sigma^+)/\sigma(\Sigma^0)$ of the total cross sections for Σ^+ and Σ^0 production was found to be 230 ± 70 and 90 ± 40 at $\varepsilon = 13$ MeV (1.826 GeV) and $\varepsilon = 60$ MeV (1.958 GeV), respectively.

The COSY-11 publication triggered studies of Σ^+ production at ANKE. Our measurement of the total cross section at $\varepsilon = 129$ MeV [2] showed that at this energy the production in this channel is roughly equal to that for Σ^0. Following the acceptance of the ANKE proposal in 2007 [3], the cross section of the $pp \to K^+n\Sigma^+$ reaction has been studied at four energies between the Σ^+ threshold and 2.02 GeV. A measurement below the Σ^+ threshold was also performed to provide a cross-check. At ANKE we avoid neutron detection and its associated problems, relying instead on the excellent K^+ identification provided by our range telescopes. These detect K^+ decay products and allow us to identify unambiguously the kaons even if the background is 10^6 higher. K^+p correlation spectra were constructed by measuring the proton in the positive side detector as well as the forward detector.

At the energies where measurements have been performed, there are only three possible reactions channels that lead to K^+ production in pp collisions: $pp \to K^+p\Lambda$, $pp \to K^+p\Sigma^0$, and $pp \to K^+n\Sigma^+$. All the hyperons produced in these three reactions have a decay mode which has a proton in the final state. Signals from all the reactions can therefore be found, not only in the K^+ inclusive spectra, but also in the K^+p coincidence spectra. However, only the Σ^+ hyperon decays (BR $= 48.51\%$) with a π^+ in the final state. As a consequence, by detecting a K^+ in coincidence with π^+, one can identify the $pp \to K^+n\Sigma^+$ reaction unambiguously.

Studies of the $pp \to K^+n\Sigma^+$ reaction at ANKE are undertaken through the simultaneous analysis of K^+p and $K^+\pi^+$ correlations as well as inclusive K^+ production. In Fig. 1 the missing-mass spectra from K^+p correlations are presented at the five energies where measurements were undertaken at ANKE. The experimental data are compared with the phase-space simulations of K^+p correlations expected for all three contributing channels. The known total cross sections for Λ and Σ^0 production were used as weights in the simulations for two of the channels. For the third, it was assumed that $\sigma_{\Sigma^0} = \sigma_{\Sigma^+}$. Individual contributions to the K^+p missing mass spectra from the Σ^+ production, normalised to the number of Σ^0 events, are presented in the Fig. 1 by the dotted line. Since this represents the dominant contribution at large missing masses, these data are also quite sensitive to the value of the Σ^+ cross section.

A publication presenting a simultaneous analysis of all three experimental spectra is in the course of preparation.

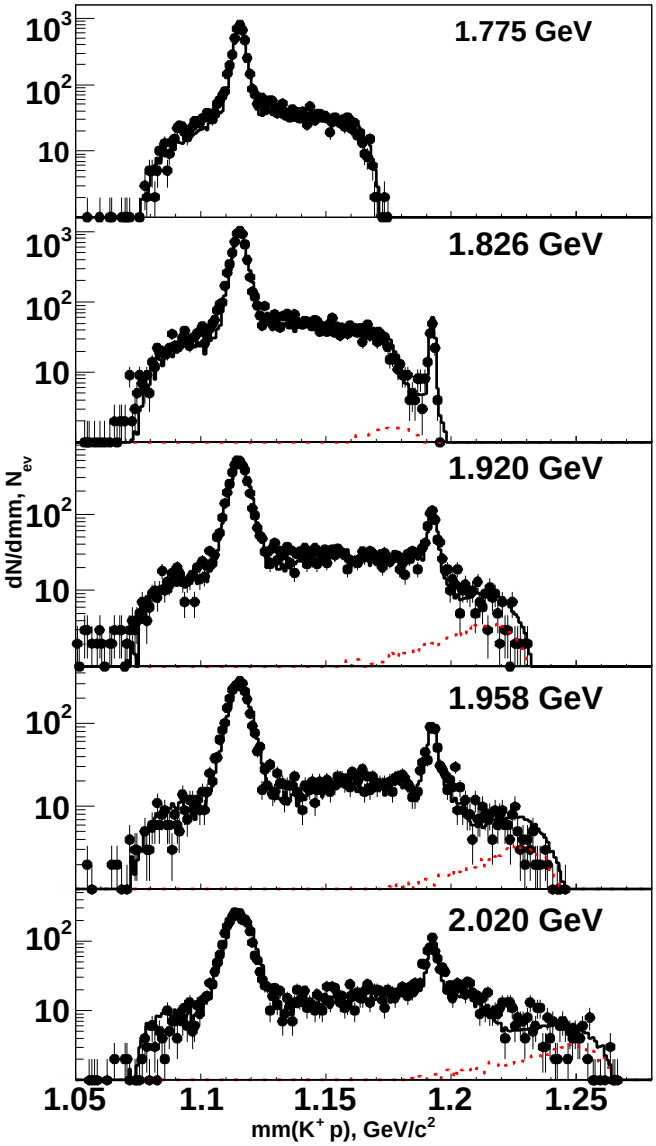

Fig. 1: K^+p missing-mass spectra measured at five different energies (circles with error bars). The solid line shows the sum of the simulations of the individual contributions from all the different possible channels. The individual contribution from the $pp \to K^+n\Sigma^+$ reaction is shown by the dotted line.

References:

[1] T. Rożek et al., Phys. Lett. B 643 (2006) 251.
[2] Yu. Valdau et al., Phys. Lett. B 652 (2007) 245.
[3] Yu. Valdau et al., COSY proposal #171, http://www.fz-juelich.de/ikp/anke/en/proposals.shtml

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