Ratio of the $\Lambda\,/\,\Sigma^0$ hyperon production via the excitation of the $N^*(1650)S_{11}$ resonance

P. Kowina* and W. Oelert for the COSY–11 collaboration

In a simple constituent quark model the two hyperons Λ and Σ^0 have a rather similar structure consisting of the light up and down quarks and the heavier strange quark. Having the same total spin S = 1/2 these two hyperons differ in the spin coupling of the two light quarks and the isospin.
First order isospin arguments would suggest that the cross section ratio for the Λ/Σ^0 production is in the order of three. In fact, such values of the ratio were observed in proton–proton scattering experiments at high excess energies [1] as well as in antiproton–proton annihilations leading to $\bar{\Lambda}$–Λ, $\bar{\Sigma}^0$–$\Lambda + c.c.$ and $\bar{\Sigma}^{\pm}$–$\Sigma^{\mp}$ as performed by the experiment PS185 at LEAR [2, 3].
However, the ratio of the total cross sections for the Λ and Σ^0 production near threshold was measured at COSY–11 [4] via the reactions $pp \to pK^+\Lambda(\Sigma^0)$ and the most remarkable feature of the data is that – at the same excess energy – the total cross section for the Σ^0 production appears to be about a factor of 28^{+6}_{-9} smaller than for the Λ particle.
It was suggested [4] that strong $\Sigma^0 p$ final state interactions, and in particular a $\Sigma N \to \Lambda p$ conversion, were the likely cause of the depletion in the Σ^0 signal. This hypothesis is in line with other experimental evidence.
Still, a quantitative explanation of the relatively low Σ^0 production rate observed in pp collisions near threshold must await detailed theoretical efforts. In any case, the first COSY–11 data stimulated several theoretical investigations.

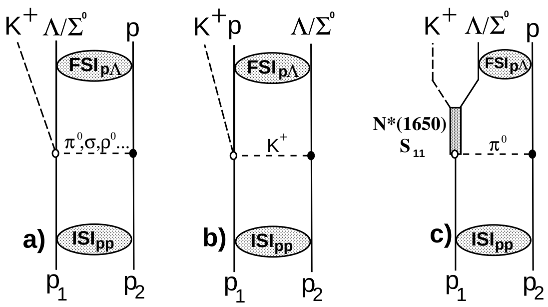

Fig. 1: Graphs for the hyperon production.

Calculations within a meson exchange model taking into account pion and kaon exchange (Fig. 1 **a)** and **b)**) reproduce the measured ratio by a destructive interference of π and K exchange amplitudes [5]. While the Λ production channel appears to be dominated by the K exchange, the interference becomes significant in the Σ^0 case. Even the absolute production cross section is described when employing a reasonable initial and final state interaction. The authors [5] claim that the data calls for a destructive interference of the π and K exchange contributions independently of the hyperon–nucleon potential used.
Within a factor of two also other models describe the data by including heavier exchange mesons and/or nucleon resonances [6, 7, 8].

Here we present an additional idea for a qualitative understanding. If the $N^*(1650)S_{11}$ is excited in the first step of the reaction it decays either into the $K^+\Sigma^0$ or the $K^+\Lambda$ channel (Fig. 1 **c)**). Other possible channels will not be considered.

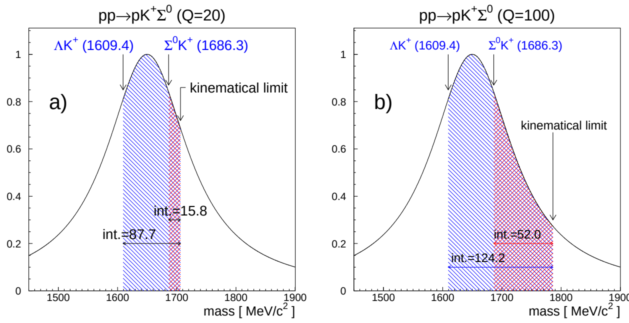

Fig. 2: The Breit–Wigner distribution of the $N^*(1650)S_{11}$ resonance. The available phase space for the decay into the K-hyperon channel at the smaller **a)** and larger **b)** excess energy is depicted by the dashed areas.

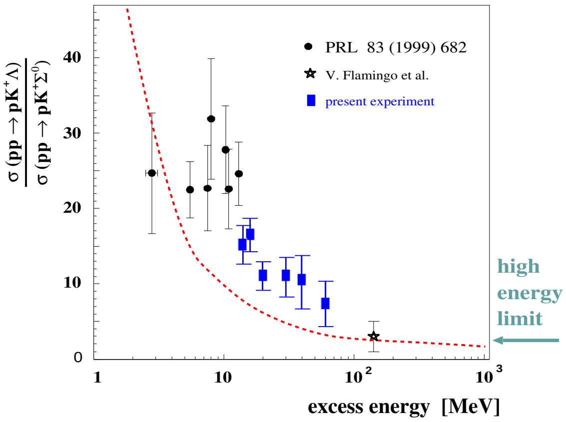

Fig. 3: Cross section ratio of the $\Lambda\,/\,\Sigma^0$ production as a function of the excess energy. The dashed line depicts the ratio of the integration of the phase space available for the decay into the $K-\Lambda$ and $K-\Sigma^0$ channels.

One can estimate the probability for the decay into one of the two channels with the available phace space by integrating the Breit–Wigner distribution [9] in the range of the kinematical limit and the rest mass of the $K^+\Sigma^0$ or $K^+\Lambda$ systems, respectively, see Fig. 2 **a)** and **b)**.
In Figure 3 the calculated ratio of the available phase space for the two channels considered is plotted by the dashed line together with the experimental data. Please note that no absolute normalization of the ratio has been included. Still, the shape of the excitation function for the production ratio is well described by the simple model presented.

References:

[1] V. Flaminio et al., CERN HERA **84–01** (1984).
[2] P. Barnes et al., Phys.Rev. **C 54** (1996) 2831.
[3] P. Barnes et al., Phys. Lett. **B 402** (1997) 227.
[4] S. Sewerin et al., Phys. Rev. Lett. **83** (1999) 682.
[5] A.M. Gasparian et al., Phys. Lett. **B 480** (2000) 273.
[6] R. Shyam et al., Phys. Rev. **C63** (2001) 022202.
[7] A. Sibirtsev et al., nucl-th/0004022.
[8] J.-M. Laget, hep-ph/0101047.
[9] Eur. Phys. J. **C 15** (2000), 705.

* on leave from: Institute of Physics, Silesian University, Pl-40-007 Katowice, Poland