Near Threshold Hyperon-Production at COSY-11 in the Reactions $pp \to pK^+\Lambda$ and $pp \to pK^+\Sigma^0$

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At the internal COSY-11 facility the reactions $pp \to pK^+\Lambda$ and $pp \to pK^+\Sigma^0$ have been measured at excess energies up to 13 MeV. The total cross sections for the Λ-production have been determined to be a factor of ≈ 28 higher than for the Σ^0-production at equivalent excess energies. This observation is in contrast to a cross section ratio of 2-3, obtained at higher excess energies between 300 MeV and 1500 MeV. It is discussed that a strong $\Sigma^0 p$ FSI might cause the low cross section for the Σ^0-production near threshold due to a $\Sigma N \to \Lambda N$ conversion.

1. COSY-11 experiment

At the Cooler Synchrotron COSY high precision measurements of strangeness production have been performed. The COSY-11 collaboration has measured the Λ-production at excess energies between 0.68 and 6.68 MeV [1–3]. This successful program of associated strangeness production very close to threshold has been extended to the Σ^0-production [4]. A sketch of the internal COSY-11 experiment [5] with one typical event pattern of the hyperon production is shown in Fig. 1. A hydrogen cluster target is installed in front of a regular COSY-dipole to separate the charged reaction products from the beam. The direction of the positively charged particles is detected by two drift chamber systems D1 and D2, which allows the momentum determination by ray tracing back through the precisely known magnetic field of the C-shaped dipole to the target position. The scintillators S1 and S3 are used as start and stop detectors for the time of flight measurement of the protons. Because the positively charged kaons do not reach the S3 detector, their velocity has to be determined by a time of flight measurement between the target and the S1 detector. Therefore the starting time of the reaction in the target is calculated using the proton track. Thus it is possible to measure the four-momentum vectors of the proton and K^+ directly, whereas the unobserved neutral hyperon has to be identified by the missing mass method.

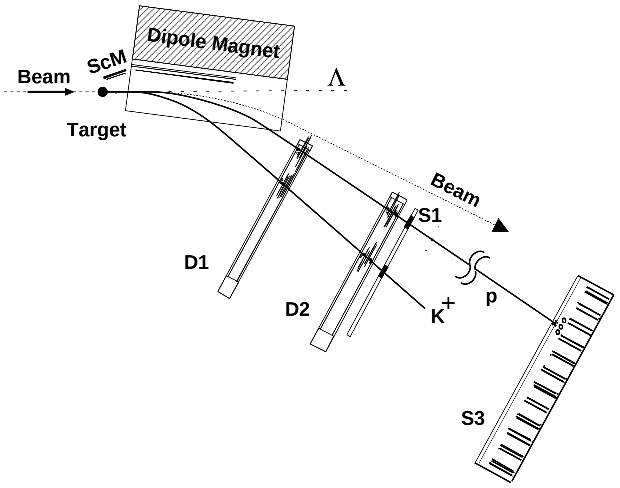

Figure 1. Sketch of the COSY-11 facility.

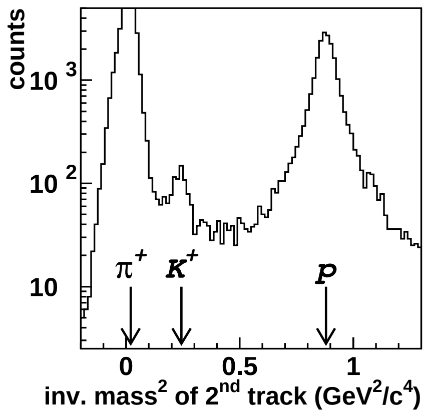

Figure 2. Squared invariant mass of the second particle.

2. Data analysis

To separate the hyperon production events from the raw data, all events with two reconstructed tracks in the drift chamber systems are taken into account. After having one particle identified as a proton using the time of flight between S1 and S3 and the measured momentum, the squared invariant mass m^2_{inv} of the second track can be calculated, which is shown in Fig. 2. Taking events with m^2_{inv} of the second particle in the range of the K^+-mass, the missing mass can be calculated. In Fig. 3 m^2_{inv} of the second track is plotted versus the squared missing mass at an excess energy of 12.9 MeV for the Σ^0-production. Projecting the events between the two lines of Fig. 3, the missing mass spectrum is obtained and plotted in the upper picture of Fig. 4. The projection of events from adjacent bands ($0.10<m^2_{inv}<0.19$ and $0.29<m^2_{inv}<0.34$ GeV^2/c^4) is considered as the background spectrum, which is shown as the solid curve after smoothing and normalizing. The subtraction of the background from the missing mass spectrum leads to the lower picture of Fig. 4. To determine the luminosity the counting rates of elastically scattered protons have been compared with data measured at the EDDA experiment [6]. The detection efficiency of COSY-11 has been calculated by performing GEANT Monte-Carlo simulations with a three-body phase-space generator. The excitation functions of the Λ- and Σ^0-production channels are plotted in Fig. 5 [4]. At equivalent excess energies the

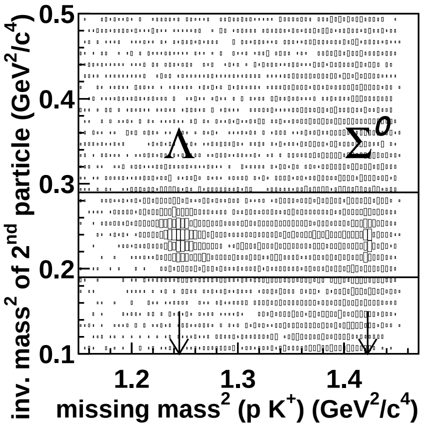

Figure 3. Squared invariant mass of the second particle versus squared missing mass (pK^+), after identification of the first particle as being a proton. The lines indicate the limits of the K^+-mass distribution.

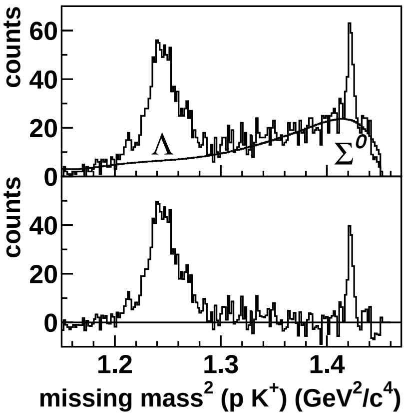

Figure 4. Upper picture: Projection of the events between the two lines of Fig. 3. The solid line represents the smoothed background spectrum, which has been extracted by projecting close sidebands. Lower picture: Spectrum after subtraction of the background.

cross sections of the Λ-production exceed the ones for the Σ^0-production by a factor of 28^{+6}_{-9}, which is in contrast to measurements at higher energies between 300 and 1500 MeV [7]. The dashed lines represent a pure phase-space fit to the data ($\sigma_T \propto Q^2$), whereas the solid curves are based on Eq. 1, taking into account the hyperon-nucleon FSI [8]:

$$\sigma_T = C\,Q^2 \times \left(1 + \sqrt{1 + Q/\epsilon}\right)^{-2} \tag{1}$$

The fit corresponds to the following parameters:

$$\begin{aligned} C_\Lambda &= (21.7 \pm 1.0)\ \mathrm{nb/MeV^2}, \qquad && \epsilon_\Lambda = (7.5 \pm 1.4)\ \mathrm{MeV} \\ C_{\Sigma^0} &= (1.3 \pm 0.6)\ \mathrm{nb/MeV^2}, \qquad && \epsilon_{\Sigma^0} = (3.1 \pm 3.2)\ \mathrm{MeV} \end{aligned} \tag{2}$$

3. Discussion

Considering only K^+ exchange for the production mechanism and neglecting FSI effects the SU(6) prediction for the cross section ratio of 27/1 [9] would perfectly describe the measured data. Nevertheless, one also expects a significant π exchange contribution to the production mechanism. Close to threshold π^- induced Λ- and Σ^0-production data [10] show a cross section ratio of 0.4. Assuming I=1/2 dominance one expects without FSI the same ratio in pp scattering. Thus the cross section ratio obtained at COSY-11 can not be described, if there is any significant π exchange contribution. On the other hand, the unexpected low Σ^0 cross section could be explained, if virtually produced Σ^0s are

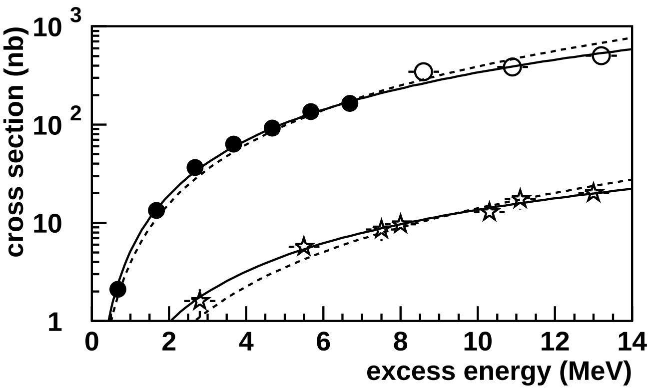

Figure 5. Cross section for $pp \to pK^+\Lambda$ (circles) and $pp \to pK^+\Sigma^0$ (stars). Data of filled circles have been published in [2]; those of open symbols in [4]. The dashed and solid lines are described in the text.

converted into Λs due to a strong hyperon-nucleon FSI. In the literature there are several experimental evidences for a $\Sigma N \to \Lambda N$ conversion. Data of $K^- d \to \pi^- \Lambda p$ [11] show a sharp peak in the Λp-mass distribution directly at the ΣN threshold. A similar effect has also been observed at the COSY-TOF experiment [12] in the reaction $pp \to pK^+\Lambda$ at an excess energy of 155 MeV above threshold.

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