Available online at www.sciencedirect.com

SCIENCE DIRECT®

Physics Letters B 632 (2006) 27–34

PHYSICS LETTERS B

www.elsevier.com/locate/physletb

Hyperon production in the channel $pp \to K^+ \Lambda p$ near the reaction threshold

COSY-TOF Collaboration

S. Abd El-Samad [h], R. Bilger [f], A. Böhm [b], K.-Th. Brinkmann [b], H. Clement [f], S. Dshemuchadse [e,b], W. Eyrich [c,*], A. Erhardt [f], C. Fanara [g], A. Filippi [g], H. Freiesleben [b], M. Fritsch [c,a], R. Geyer [d], J. Hauffe [c], A. Hassan [h], P. Herrmann [a], D. Hesselbarth [d], B. Jakob [b], K. Kilian [d], H. Koch [a], J. Kress [f], E. Kuhlmann [b], S. Marcello [g], S. Marwinski [d], A. Metzger [c], P. Michel [e], K. Möller [e], H.P. Morsch [d], L. Naumann [e], E. Roderburg [d], A. Schamlott [e], P. Schönmeier [b], M. Schulte-Wissermann [b], W. Schroeder [c], M. Steinke [a], F. Stinzing [c], G.Y. Sun [b], J. Wächter [c], G.J. Wagner [f], M. Wagner [c], A. Wilms [a], S. Wirth [c], U. Zielinski [a]

[a] *Ruhr-Universität Bochum, Germany*
[b] *Technische Universität Dresden, Germany*
[c] *Friedrich-Alexander-Universität Erlangen-Nürnberg, Erwin-Rommel-Str. 1, 91058 Erlangen, Germany*
[d] *Forschungszentrum Jülich, Germany*
[e] *Forschungszentrum Rossendorf, Germany*
[f] *Universität Tübingen, Germany*
[g] *INFN Torino, Italy*
[h] *Atomic Energy Authority NRC Cairo, Egypt*

Received 18 April 2005; received in revised form 22 July 2005; accepted 30 September 2005

Available online 14 October 2005

Editor: V. Metag

Abstract

Hyperon production in the threshold region was studied in the reaction $pp \to K^+ \Lambda p$ using the time-of-flight spectrometer COSY-TOF. Exclusive data, covering the full phase-space, were taken at three different beam momenta $p_{\text{beam}} = 2.59$, 2.68 and 2.85 GeV/c (corresponding to excess energies of $\varepsilon = 85$, 115 and 171 MeV). Total cross-sections were deduced to be 7.4 ± 0.5 μb, 8.6 ± 0.6 μb and 16.5 ± 0.4 μb, respectively. Differential observables including Dalitz plots were obtained. From the investigation of the Dalitz plot at $p_{\text{beam}} = 2.85$ GeV/c a dominant contribution of the $N^*(1650)$-resonance to the reaction mechanism was found. In addition the $p\Lambda$-final-state interaction turned out to have a significant influence on the Dalitz plot distribution even 171 MeV above threshold.

PACS: 14.20.Gk; 14.20.Jn; 14.40.Aq

Keywords: Associated strangeness production; Total cross-section; Angular distribution; Dalitz plot

* Corresponding author.
E-mail addresses: wolfgang.eyrich@physik.uni-erlangen.de, eyrich@physik.uni-erlangen.de (W. Eyrich).

doi:10.1016/j.physletb.2005.09.086

1. Introduction

In order to obtain a complete and consistent picture of the structure and dynamics of hadrons, in addition to high energy scattering experiments, precise measurements at medium and low energies are of fundamental interest. In this context strangeness production in elementary reactions plays an important role since the strange quark is not one of the constituent quarks of the proton. To find out the relevant degrees of freedom of these reactions in the near-threshold region, an experimental program was started at the time-of-flight spectrometer COSY-TOF [1].

Up to a few GeV above threshold various meson exchange models including resonance effects have been proposed to describe strangeness production [2–9]. Recently, an effective quark model has also been used to calculate observables [10]. Up to now meson exchange models appear to be the most appropriate way to describe strangeness production in elementary reactions in the near-threshold region. Here the main questions are what is the contribution of the various strange and non-strange mesons and especially what is the role of N^*-resonances in the reaction mechanism. Moreover the nucleon–hyperon (NY) and meson–hyperon (KY) interactions are probed where the NY-final-state interaction is known to be of special importance close to threshold. However, theoretical studies do not yield a conclusive picture at present. Some studies are based on one boson (pion or kaon) exchange amplitudes where kaon exchange was found to be the dominant process [2,11]. In other calculations the total cross-section data at somewhat higher energies are well reproduced by pion exchange [12,13]. In the resonance model approaches [3–7], the $K\Lambda$-production proceeds via the excitation of the $N^*(1650)$-resonance [5] or a combination of the $N^*(1650)$-, $N^*(1710)$- and $N^*(1720)$-resonances. In the calculation of [8], the $N^*(1650)$- and $N^*(1710)$-resonances dominate. To come to conclusive results concerning the $K\Lambda$-production mechanism, the measurements should concentrate on exclusive data covering the full phase-space. Of special interest are experiments near threshold where only a few partial waves contribute, making the situation somewhat more transparent.

An essential part of the program at COSY-TOF aims at the production of Λ-, Σ^0- and Σ^+-hyperons in proton–proton collisions and in a further stage also in proton–neutron reactions (including Σ^--hyperons) by use of a deuterium target. The TOF experiment at the external beam is designed to cover the momentum range from threshold up to the limit of COSY at about 3.5 GeV/c. The concept of the experiment lies in the complete geometrical reconstruction of the events including the delayed decay of the hyperons. Since practically the full phase-space of the primary reaction products is covered by the detector, all differential distributions as well as the total cross-sections can be extracted.

In a first run data of the reaction channel $pp \to K^+\Lambda p$ were taken at two beam momenta $p_{\text{beam}} = 2.50$ and 2.75 GeV/c. Total and differential cross-sections as well as the Λ-polarization and Dalitz plots were presented [1]. In this Letter we report on the results of a second Λ-production run at three different beam momenta of 2.59, 2.68 and 2.85 GeV/c, corresponding to excess energies of $\varepsilon = 85$, 115 and 171 MeV, respectively. Using an upgraded detector and an improved beam compared to the first run we collected much larger data samples especially at the highest momentum of 2.85 GeV/c. This allows detailed analyses in particular of the Dalitz plots, which is the main topic of this Letter.

2. Experiment and analysis

The data were taken with the COSY-TOF detector [14]. A schematic view of the used detector setup is shown in Fig. 1. A few millimeters behind the very small liquid hydrogen target (length 4 mm and diameter 6 mm) [15] the start detector system [16] was installed. The stop detector (quirl) [17] built of three layers of plastic scintillator was positioned at 1.1 m downstream of the target. The whole system had been mounted in a vacuum vessel.

The start detector system was upgraded for the reported experiment. It consists of the “starttorte”, built of two segmented layers of wedge shaped scintillators, a double-sided silicon-ring microstrip detector and two scintillating fiber hodoscopes. The “starttorte” and the first fiber hodoscope were described in [1]. The single-sided ring microstrip detector, used in the first run, was replaced by a double-sided version, where the front side consists of 100 rings and the rear side of 128 sectors. The newly added intermediate scintillating fiber hodoscope consists of two crossed layers of 192 fibers each with 2×2 mm^2 cross-section (cf. Fig. 1).

Apart from a tiny beam hole with a diameter of about 2 mm the experimental setup covers the full phase-space of the primary particles (K^+-meson, Λ-hyperon and proton). The track of the Λ-hyperon is reconstructed from the production vertex in the target, deduced using the primary tracks (K^+ and p), and the vertex of its decay into two charged particles (p and π^-). This delayed decay gives a unique signature for the events of interest and the corresponding increase of the number of charged tracks ($2 \to 4$) is used as trigger condition.

The high granularity of all detector components allows the reconstruction of the events with sufficient precision using only the geometrical information from the hit patterns in the various components. After the reconstruction of the Λ-hyperon the momentum of each of the three primary particles is calculated from the measured directions using momentum conservation together with the beam momentum, which is known with high precision. Assigning the primary charged tracks as K^+ and p, energy conservation allows the reconstruction of the mass of the neutral particle marked by the delayed decay. To improve the selection of the events and reduce combinatorial background, the measured energy loss of the ejectiles in the “starttorte” and the microstrip detector was used in addition to the geometrical information of each primary track. Thus the wrong assignment of K^+ and p tracks could be reduced from 11% to 3% in the final event sample. The analysis was especially optimised to get a nearly background-free event sample, which reduces the reconstruction efficiency to some extent. To control the analysis steps and deduce the reconstruction efficiency, extensive studies with simulated events were performed. The Monte Carlo sim-