Total Cross Section of the Reaction $pp \longrightarrow pK^+\Lambda$ Close to Threshold

J.T. Balewski for the COSY-11 collaboration

Institute of Nuclear Physics, Cracow, Poland

The energy dependence of the total cross section for the $pp \longrightarrow pK^+\Lambda$ reaction was measured in the threshold region covering the excess energy range up to 7 MeV. The measurement was performed at the COSY-Jülich synchrotron using the internal target facility COSY-11 [1] and applying the standard event reconstruction method. The details of this work are given in ref. [3]. Examples of the obtained pK$^+$ squared missing mass (MM^2) spectra, including one measurement below threshold, are shown in fig. 1.

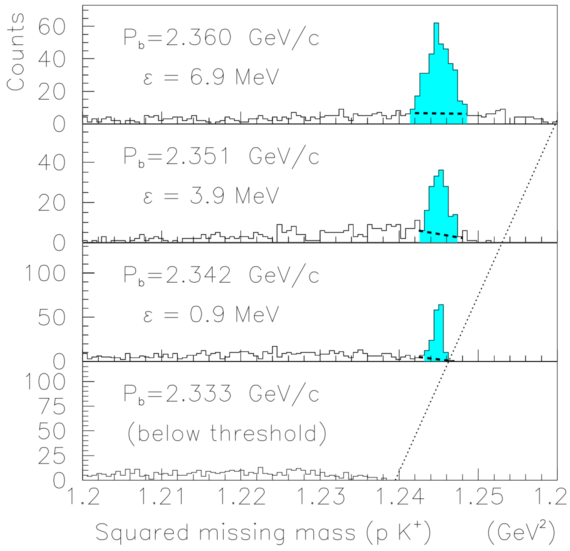

Figure 1: The indicated peaks correspond to the mass of the Λ - particle from the $pp \longrightarrow pK^+\Lambda$ reaction. The dashed line depicts the background level. The dotted line marks the kinematical limit of the MM^2 spectra.

Due to the observed rapid variation of the cross section near threshold, a precise knowledge of the beam momentum is crucial for the precision of this experiment. The uncertainty in the absolute beam momentum is mainly caused by the uncertainty of the effective beam orbit length and amounts to $\Delta p/p = 10^{-3}$.

By measuring the excitation function at seven successive points we were able to determine the absolute value of the beam momentum with the precision of $\Delta p = 180\ keV/c$.

It has been assumed, that close to threshold the cross section follows in first order the three body phase space distribution: $\sigma(\varepsilon) \sim \int d\rho_3 \sim \varepsilon^2$. Corrections due to the Coulomb interaction $f_c(q_{pK})$ and to the dominant p-Λ final state interaction $f_{FSI}(q_{p\Lambda})$ modify smoothly this dependence according to:

$$\sigma(\varepsilon) \quad \sim \quad \int f_c(q_{pK})\ f_{FSI}(q_{p\Lambda})\ d\rho_3 \qquad (1)$$

where q_{ij} stands for the momentum in the $i-j$ 2-particle subsystem.

The experimental ratio of the N number of measured $pK^+\Lambda$ events to the I_0 integrated luminosity is:

$$N/I_0 \quad = \quad E_{ff}(\tilde{\varepsilon} - \Delta\varepsilon) \cdot \sigma(\tilde{\varepsilon} - \Delta\varepsilon) \qquad (2)$$

where E_{ff} denotes the detection efficiency, $\tilde{\varepsilon}$ is the nominal value of the excess energy and $\Delta\varepsilon$ is unknown offset. Figure 2 compares the threshold behavior with and without both Coulomb distortion effects and the final state interaction. It is obvious that the shape of the data is much better described when including these effects. The offset in the excess energy was obtained from a fit of equation (2) to the data resulting in a smaller real excess energy by $\Delta\varepsilon$=220 ± 60 keV .

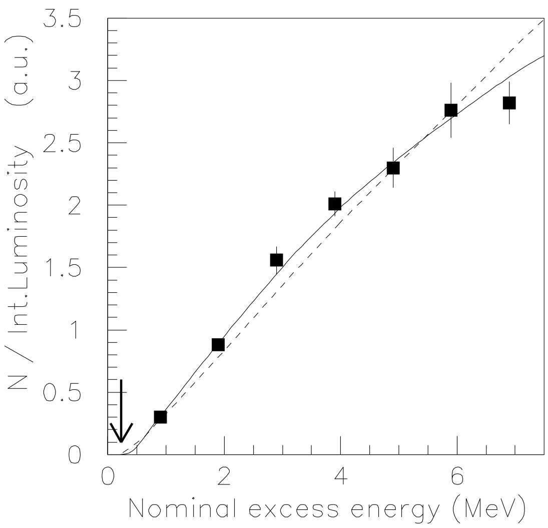

Figure 2: Determination of the beam momentum by means of the experimentally measured $pp \longrightarrow pK^+\Lambda$ event rate. The solid line depicts the best fit of $\Delta\varepsilon$ from equation (2) to the data. The dashed one is the pure phase space prediction. The arrow corresponds to the resulting offset of $\Delta\varepsilon = 220 \pm 60\ keV$.

The obtained values for the $pp \longrightarrow pK^+\Lambda$ cross sections at the corrected excess energies $(\tilde{\varepsilon}_i - \Delta\varepsilon)$ are shown together with the previously published data [2, 8] in fig 3, in two dimensional logarithmic scales. The statistical errors range from 5% to 9% for all data points, the systematical one is of 14%.

Different models for the energy dependence of the $pp \longrightarrow pK^+\Lambda$ cross section have been suggested. As can be also seen from fig. 3, both the square root and the quadratic excess energy approximations of J. Randrup and C.M. Ko [4] and B. Schürmann and W. Zwermann [5], respectively, fail by more than an order of magnitude in describing the present data at threshold. Recently, G. Fäldt and C. Wilkin [6] presented a one pion exchange model which assumes a dominant role of the second S_{11} resonance, the N* (1650), for the K^+ production in p+p interaction. This interpretation is analogous to the η production, which is supposed to be mediated mainly via the first S_{11} resonance, the N* (1535). These two N* resonances are distinguished by a rather large branching ratio into K Λ and η N, respectively. If the two systems η N and K Λ are dominated by these two N^* resonances, the forms of the production operators and all the spin - angular momentum algebra are identical, and the observation of an η or a K merely tags which of the two S_{11} resonances has been excited [6]. The two curves in fig. 3 are due to different Λp scattering parameters used by G. Fäldt and C. Wilkin [6], within a common factor of two to three the data are reproduced.

A similar, more extended model was presented by Sibirtsev [7]. In his calculation of the $NN \longrightarrow$ NYK cross section the one-pion as well as the one-kaon exchange diagrams are included. The amplitudes of the elementary processes ($\pi N \longrightarrow$ KY, KN $\longrightarrow$ KN) are based on phenomenological parametrizations. Contrary to the model of G. Fäldt and C. Wilkin [6], effects of the FSI are, however, not taken into account in Sibirtsev's calculations [7]. Beside the S_{11} $N^*(1650)$ these authors also include other N^* resonances with masses lower than 2000 MeV which decay into kaon - hyperon channels; but they neglect interference terms. Again the absolute rate differs by a factor of 2.5 whereas the shape of the experimental excitation function is well reproduced.

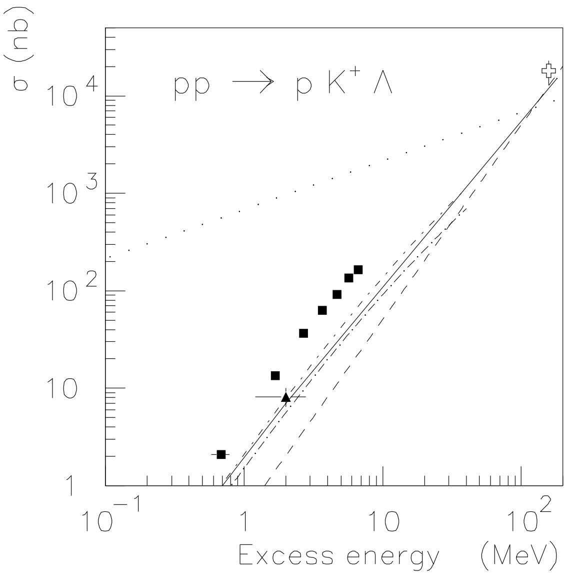

Figure 3: Data and different models describing the energy dependence of the $pp \longrightarrow pK^+\Lambda$ total cross section. The parametrization of Randrup et al. is depicted as a dotted line, of Schürman et al. as a dashed one, of Sibirtsev et al. as a solid and of Fäldt and Wilkin as two types of dash-dotted. Tha data of Fickinger are marked as a cross, of Balewski at al. as a triangle and the present one as squares.

References

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