Strangeness Production in the $pp \longrightarrow pK^+\Lambda$ Reaction Close to Threshold.

COSY-11 Collaboration
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Abstract: The $pp \longrightarrow pK^+\Lambda$ reaction was measured at COSY with a proton beam momentum of 2.345 GeV/c, i.e. with an excess energy of 2 MeV above threshold. The total cross section was determined to be 8.2 $\pm$ 1.8 *nb*. The present data point close to the production threshold indicates, that often used phenomenological parametrizations of the total kaon production cross section are insufficient.

It is proposed to measure the energy dependence of the kaon production cross section in the threshold region at COSY-11.

The detailed motivation, description of the experimental procedure and discussion of the first result of the $pp \longrightarrow pK^+\Lambda$ *measurement at COSY-11 are given in Ref. [1]* [1]*, the reconstructed trajectories of charged particles from all 69 events are shown in fig. 1. The COSY-11 facility is described in [2].*

[1] added to this proposal on separate pages

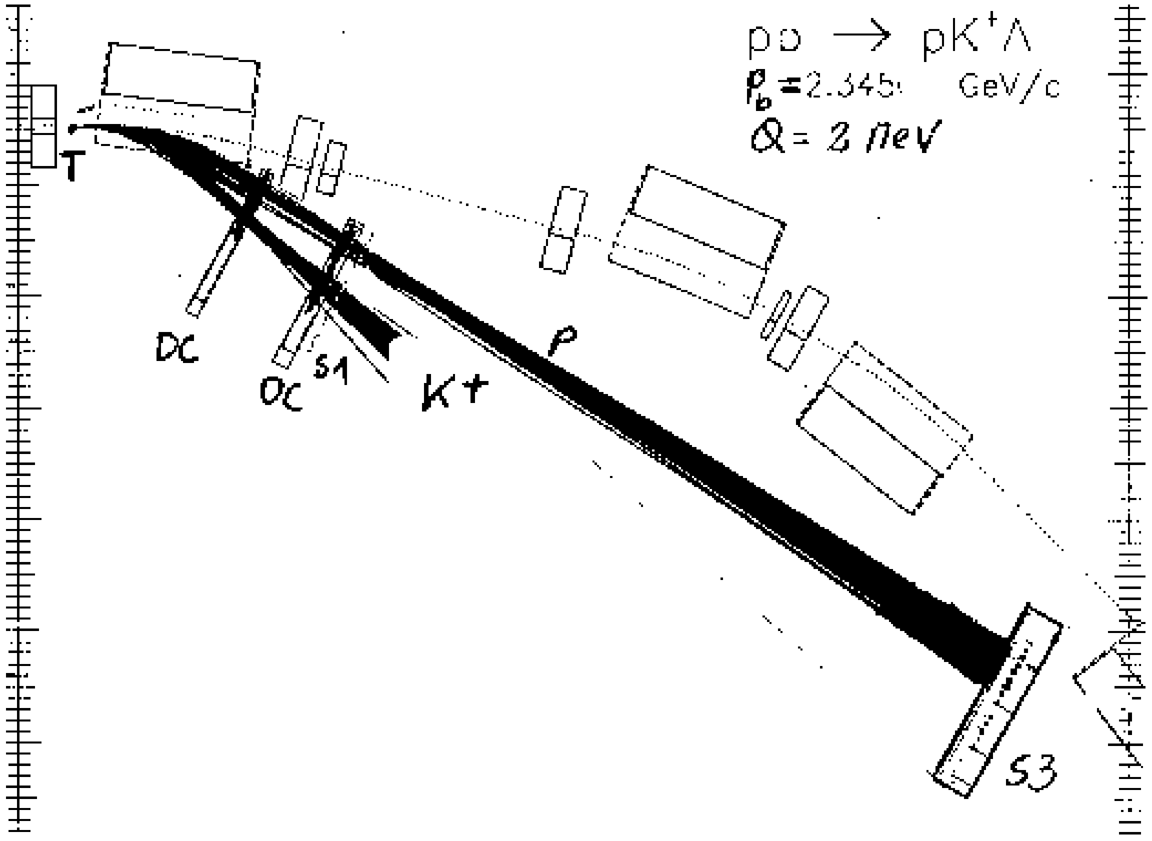

Figure 1: The $pp \longrightarrow pK^+\Lambda$ events measured at beam momenta of 2.345 GeV/c at COSY-11.

1 Motivation of measurement

Since the cross section for the $pp \longrightarrow pK^+\Lambda$ reaction close to threshold was determined only at the beam momentum of 2.345 GeV/c [1], it is proposed to measure an excitation function of this reaction close to threshold. The validity of the energy dependence of the cross section postulated in Ref. [1] should be verified.

Theoretical calculation are in progress at IKP Theory Department.

Furthermore, the reliable parametrization of the elementary kaon production cross section in the N-N interaction is a basis for calculations of the kaon production yield in the collisions of heavier nuclei, e.g. as used for the formalism of Ref. [3] and needed for interpretation of the COSY-13 experiment. Proposed measurements will fill in a gap between the threshold and the BNL measurement [4] at excess energy (Q_{cm}) of 158 MeV and give a solid experimental input for such parametrizations.

Simultaneously with the physics case, we plan to calibrate the absolute value of the COSY beam momentum as well as the width of its distribution. The same experimental data will be used for this purpose.

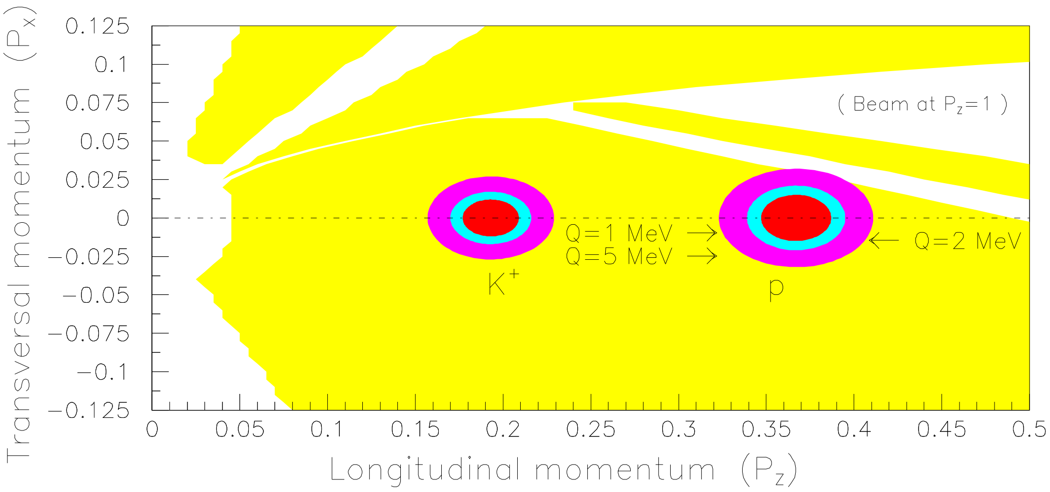

Figure 2: Acceptance of the COSY-11 in horizontal (X-Z) plane. The unit is defined by the beam momentum. The momentum range of protons and K^+ particles, as given by the reaction kinematics at Q_{cm} of 1, 2, and 5 MeV, are indicated.

2 Optimization of the experiment

2.1 Acceptance of COSY-11

The geometrical acceptance for $pp \longrightarrow pK^+\Lambda$ reaction was determined by means of Monte-Carlo simulations. The grey area in fig. 2 shows the general horizontal acceptance for positively charged particles, independent of a particular reaction. For Q_{cm} larger than 4 MeV the horizontal limitations also reduce the acceptance. It decreases with Q_{cm} as shown in fig. 3 (solid line). Approximately

$$Acc(Q_{cm}) = \frac{0.44}{Q_{cm}/MeV} \tag{1}$$

The detailed simulations agree with the formula (1) within 10%.

2.2 Counting rate

According to the FSI approach of Fäldt and Wilkin [5], the cross section close to threshold grows as

$$\sigma(Q_{cm}) = \frac{9.4 \cdot Q_{cm}^2}{\left(1 + \sqrt{1 + Q_{cm}/6.9}\right)^2}, \tag{2}$$

where Q_{cm} is given in MeV and σ in nb. The absolute cross section value is normalized to our first measurement at $Q_{cm} = 2$ MeV, the resulting curve is shown in fig 3 as a dashed line.

3 Beam request

Assuming a luminosity of $L = 2 * 10^{30} cm^{-2} s^{-1}$ and including an efficiency (ϵ_K) for the K^+ detection of 33%, which is due to the K^+ lifetime of $c\tau = 3.7$ m, one may estimate a yield of measured $pp \longrightarrow$

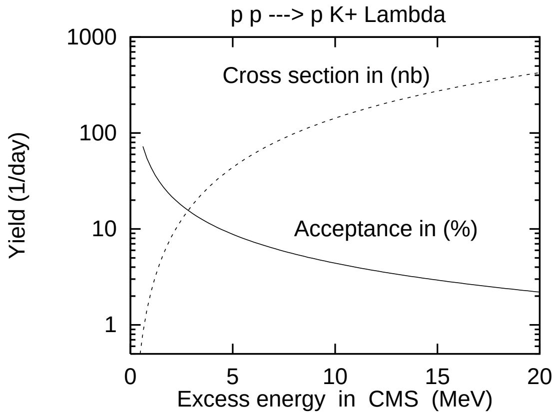

Figure 3: Acceptance of the COSY-11 (solid line) and cross section (dashed line) as given by Eq. 2.

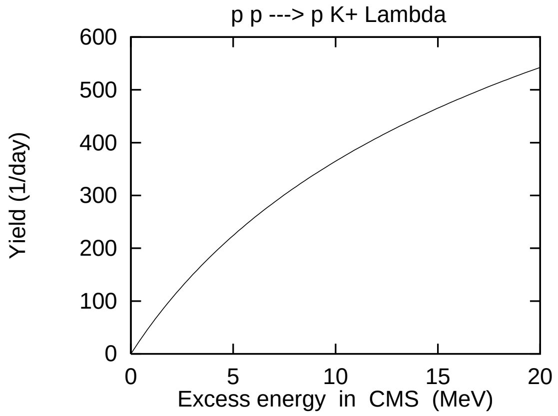

Figure 4: Expected yield for $pp \longrightarrow pK^+\Lambda$ reaction according to Eq. 3.

$pK^+\Lambda$ events per day as:

$$Y = \sigma \cdot L \cdot Acc \cdot \epsilon_K \cdot 1\ day \ \approx \ \frac{240 * Q_{cm}}{\left(1 + \sqrt{1 + Q_{cm}/6.9}\right)^2} \tag{3}$$

As shown in fig 4, a few hundreds counts per day are expected for $Q_{cm} > 2$ MeV and about 60 events at Q_{cm} =1 MeV.

Here it is proposed to measure the cross section for the $pp \longrightarrow pK^+\Lambda$ reaction at six beam momenta, corresponding to Q_{cm} = 1,...,5 MeV and one point below threshold. The nominal momentum resolution of the COSY beam is slightly better than the suggested step size. For the measurement of about 200 events at each setting a schedule as given in Table 1 is proposed.

Q_{cm}	P_b	Acc	Y	time
MeV	GeV/c	%	1/day	days
-2	2.333	-	-	2
1	2.342	43	60	4
2	2.345	22	110	2
3	2.348	17	150	2
4	2.351	12	190	1
5	2.354	10	220	1

Table 1: Schedule for the measurement of $pp \longrightarrow pK^+\Lambda$ reaction at COSY-11.

In order to complete our program for the measurement of the total cross section close to the threshold, we ask for 2 weeks of the COSY beam in the first half of 1997.

Appendix: Determination of the beam momentum

Two approaches are foreseen for the determination of the absolute beam momentum:

1) Using the relation between a measured and calculated yield.
The expected yield (Eq. 3) as function of the excess energy Q_{cm} is shown by the sold line in fig. 5, which crosses the x-axis at $Q_{cm} = 0$ MeV. Let assume, that the *real* beam momentum is larger than the *declared* one and the *real* Q_{cm} is in fact larger by ΔQ for all beam settings. Then, measured the yield ($\diamond$ in fig. 5) will be larger as shown by the dashed line and will the cross x-axis at ΔQ. this method assumes, the validity of Eq. 3 and thus the knowledge of all the inputs.

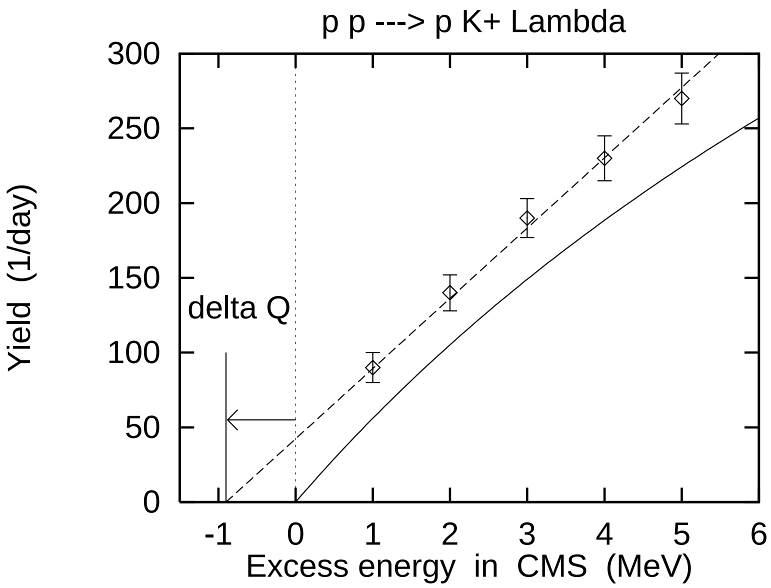

Figure 5: Difference between the calculated (solid line) and measured ($\diamond$) yield may be used for determination of the COSY beam momentum.

2) Using conservation of energy, the beam momentum may be determined from each reconstructed $pp \longrightarrow pK^+\Lambda$ event. After extracting an enreached sample of experimental $pp \longrightarrow pK^+\Lambda$ events, which certainly will have an inaccuracy of the Λ mass, we fix the mass of Λ-hyperon as given by the PDG and take reconstructed momenta vectors of proton $\mathbf{P}_p$ and kaon $\mathbf{P}_{K+}$. Then, the beam momentum (P_b) may be calculated from equation:

$$\sqrt{P_b^2 + m_p^2} \;+\; m_p \;=\; \sqrt{P_p^2 + m_p^2} \;+\; \sqrt{P_{K+}^2 + m_{K+}^2} \;+\; \sqrt{(\mathbf{P}_b - \mathbf{P}_p - \mathbf{P}_{K+})^2 + m_\Lambda^2}.$$

This method gives not only the mean value of the momentum P_b , but also upper limit for its spread, since the detector resolution is involved in the determination of $\mathbf{P}_p$ and $\mathbf{P}_{K+}$.

References

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