The energy dependence of the $pp \longrightarrow pK^+\Lambda\ /\ \Sigma^0$ cross sections close to the Σ production thresholds

COSY-11 Collaboration

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Abstract: It is proposed to measure simultaneously both, the total cross section of the Σ^0 production in the p+p interaction and the momentum spectra of kaons produced in the $pp \longrightarrow pK^+\Lambda$ reaction in the vicinity of the Σ thresholds, in order to observe possible cusp effects caused by coupling between Λ and Σ baryons.

1 Motivation

The correlated creation of a hyperon-nucleon pair like Λ-p or Σ-p provides a possibility of determining their interaction and allows to check the various models of the baryon-baryon interaction [1, 2]. On the other hand, the knowledge of the kaon production cross section in the elementary N-N interaction is interesting on its own and necessary for studies of e.g. the production of hyper-nuclei in nucleon interaction with nuclei [4]. The knowledge of the strangeness production mechanism in heavy ion collisions, may provide information about hot, dense nuclear matter or eventual existence of a gluon-quark plasma [5].

The COSY-11 collaboration proposes to continue the study of the associated strangeness production at the Jülich synchrotron COSY. In the present proposal we want to scan the energy range close to the Σ production thresholds, i.e. at beam momenta around 2.57 GeV/c.

Since the Λ and Σ^0 baryons have the same quark content and differ only in isospin and mass, one expects a strong coupling between them. Such effect for the N-Λ interaction was predicted e.g. in the work of Holzenkamp [1] (fig. 1). According to model A (solid line) in ref. [1], the cusp is predicted near the Σ production thresholds, at the Λ momentum of about 640 MeV/c. No experimental data for N-Λ scattering are available in this momentum range.

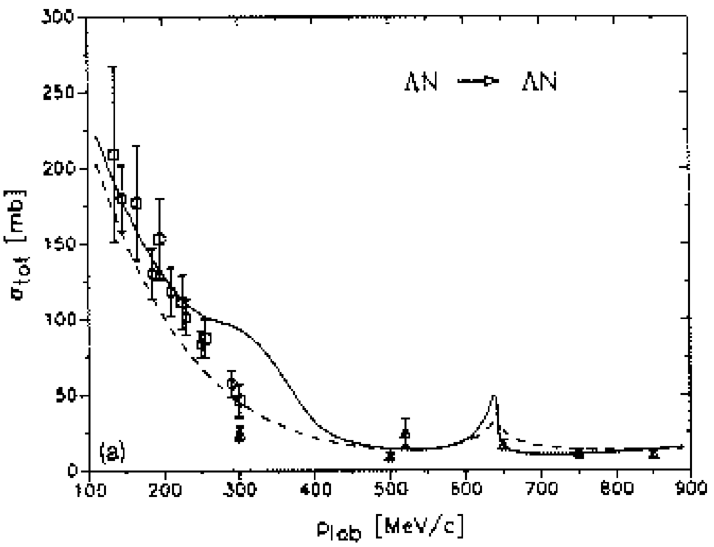

Figure 1: Λ-N cross section as a function of the Λ-hyperon laboratory momentum.

We propose to investigate the $pp \longrightarrow pK^+\Lambda$ reaction. Since in this 3 body reaction the relative Λ-N momentum ($\mathbf{q_{\Lambda N}}$) may vary, even for a fixed excess energy in the $pK^+\Lambda$ system, one has to integrate contributions over the whole range of $\mathbf{q_{\Lambda N}}$. According to estimations of Haidenbauer and Hanhart [8], it is unlikely that the total cross section will exhibit any structure around the Σ thresholds. However, detailed calculations, using model A of ref. [1], show a remarkable variation of the kaon CMS momentum distribution in the low momentum region (fig. 2), reflecting the cusp induced by the strong a ΛN – ΣN coupling.

In the work of Laget [3], a similar cusp is seen in the data measured at P_b =3.1 GeV/c. But in this experiment only kaons were identified, without distinguishing between Λ and Σ production channels.

We propose to verify experimentally the existence of the cusp in the exclusive $pp \longrightarrow pK^+\Lambda$ measurement at few MeV/c above the Σ production threshold.

The detection efficiency of the COSY-11 spectrometer is rather small, i.e. $\sim 10^{-3}$, due to the large excess energy in the $pK^+\Lambda$ system of about 80 MeV. It is mainly caused by the narrow dipole gap which limits mainly a vertical momentum component of detected proton and kaon. According to the Monte-Carlo simulation, no holes in acceptance are expected with respect to the kaon momentum. On the other hand the $pK^+\Lambda$ cross section is $\sim$4000 nb and hundreds of events per day will be detected.

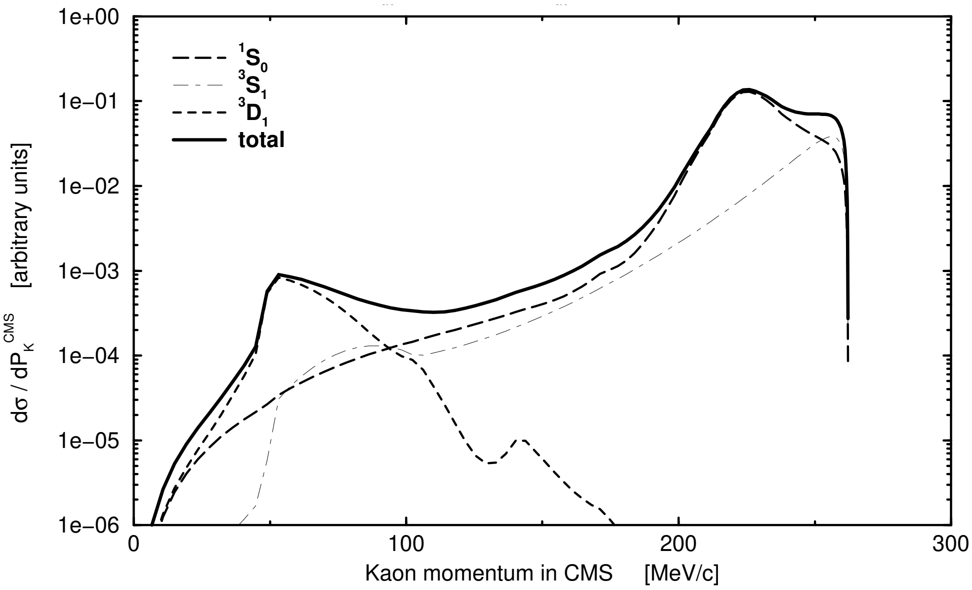

Figure 2: Distribution of the kaon momentum produced in the $pp \longrightarrow pK^+\Lambda$ reaction, calculated for P_b =2.581 GeV/c, i.e. excess energy of 80 MeV/c. The contributions from different partial waves are shown. Note the enhancement around P_K^{CMS} of 60 MeV/c due to the $^3D_1$ wave.

The COSY-11 collaboration suggests the measurement of the $pp \longrightarrow pK^+\Sigma^0$ reaction. Up to now, only data taken far above the threshold exist [6, 7], i.e. for Q > 200 MeV. We propose to measure the excitation function at threshold, for excess energies of only a few MeV. This would be complementary to the already performed measurement for the $pp \longrightarrow pK^+\Lambda$ reaction, where first results have been published [9].

2 Present status

In January'97 the COSY-11 collaboration had its $pp \longrightarrow pK^+\Lambda$ production run for seven Q values between -2 MeV and 7 MeV. The analysis is in progress. An example of the mass spectra for selected excess energies, shown in fig. 3, illustrates the quality of the COSY-11 spectrometer.

Figure 3: Squared kaon mass vs. missing mass of the (pK^+) system at different excess energies, measured 11–27.01.97. No structure around the kaon mass is observed below threshold.

At the same run short samples of data were taken at beam momenta of P_b =2.581 and 2.560 GeV/c, which corresponds to 15 MeV/c above and 6 MeV/c below the Σ^0 production threshold. Despite of the small acceptance for the $pp \longrightarrow pK^+\Lambda$ reaction, about 200 events were detected, as shown in fig. 4.

The spectrum of the kaon CMS momentum, for events accepted as $pp \longrightarrow pK^+\Lambda$, is shown on fig. 5. About 15 events were measured between 30 and 180 MeV/c, i.e. in the region where the cusp is expected (see also fig. 2). On the basis of this result, the time schedule for the next run was planned.

$pp \longrightarrow pK^+\Sigma^0$ events were also identified in the data measured at P_b =2.581 GeV/c. The

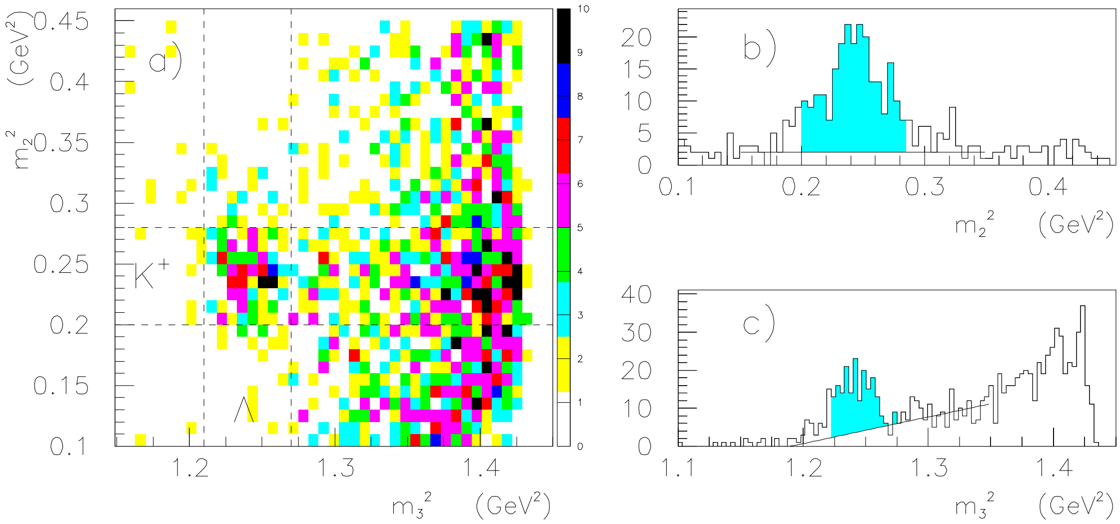

Figure 4: a) Squared kaon mass vs. missing mass of (pK^+), measured at P_b =2.581 GeV/c. Projection of the events within the dashed lines on the vertical and horizontal axes are shown on fig. b) and c) respectively. Solid lines depict the background level.

resulting Σ^0 production cross section seems to be up to one order of magnitude smaller then the Λ-hyperon one, at the same excess energy Q=5 MeV. Nevertheless, about 25 $pK^+\Sigma^0$ events seem to appear above background, as shown in fig. 6. Investigations on an improved background subtraction, which is larger than for measurements close to Λ production threshold, are in progress.

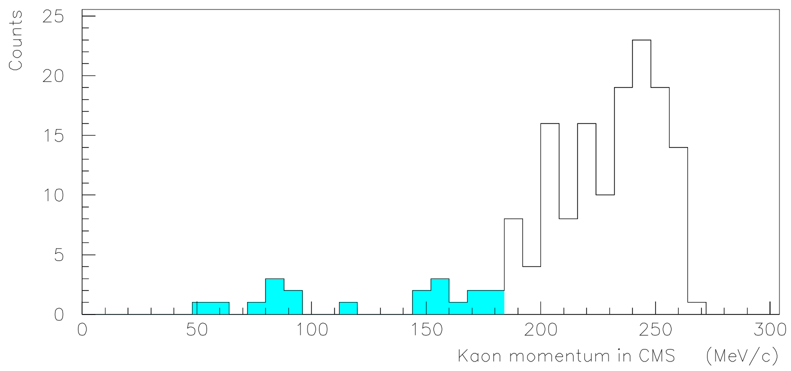

Figure 5: Experimental spectrum of CMS momentum for kaons from the $pp \longrightarrow pK^+\Lambda$ reaction, measured at P_b =2.581 GeV/c. The marked events between 30 and 180 MeV/c are in the critical region, where the cusp effect should appear.

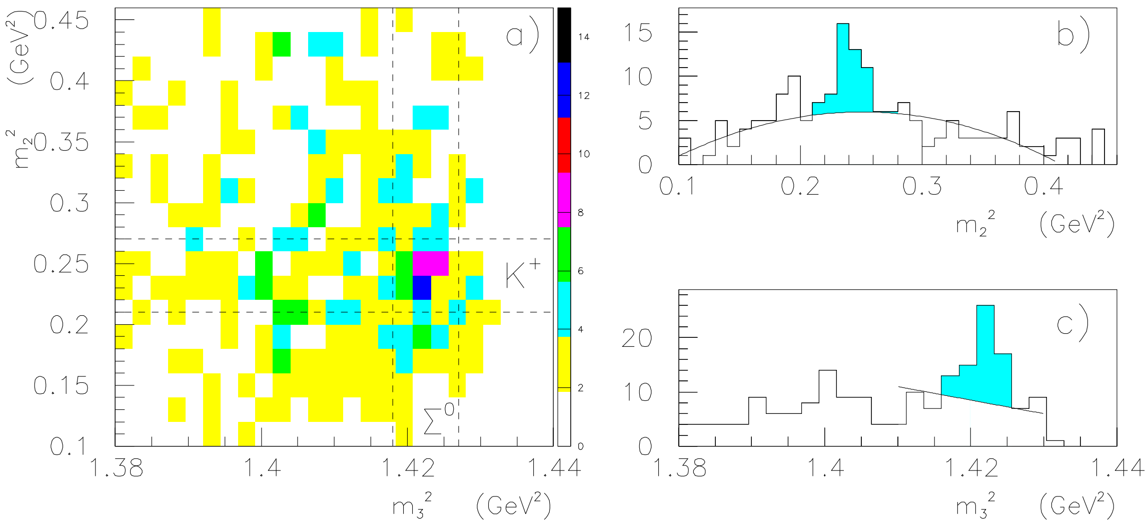

Figure 6: a), b) and c) as on fig. 4.

3 Beam request

We ask for 28 days of beam time at COSY-11 for the simultaneously measurement of the $pp \longrightarrow pK^+\Lambda$ and $pp \longrightarrow pK^+\Sigma^0$ reactions, details are given in table 1.

References

[1] B. Holzenkamp et al., Nucl. Phys. A 500 (1989) 485

[2] P.M.M. Maessen et al., Phys. Rev. C 40 (1989) 2226

[3] J.M. Laget Phys. Let. B 259 (1991) 24

beam momentum	requested time	$pp \longrightarrow pK^+\Sigma^0$					$pK^+\Lambda$	
		Q $^{a})$	$\sigma(Q)$ $^{b})$	Acc $^{c})$	rate $^{d})$	expected counts $^{d})$	Q $^{a})$	expected counts $^{d,e})$
(GeV/c)	(day)	(MeV)	(nb)	%	(1/day)		(MeV)	
2.563	4	-1	-	-	-	-	74	60
2.566 threshold for $pp \longrightarrow pK^+\Sigma^0$ reaction								
2.575	9	3	1.4	13	11	99	78	135
2.581	**6**	**5**	**4±2** $^{f})$	**8**	**18**	**108**	**80**	**90**
2.587	9	7	8	6	25	225	82	135
	Σ **28**							

[a] excess energy

[b] normalized to the already measured value at P_b =2.581 GeV/c and scaled according to phasespace ($\sim Q^2$)

[c] geometrical acceptance of COSY-11, scales with $1/Q$

[d] with a luminosity of $I_0 = 2 \cdot 10^{30} cm^{-2} s^{-1}$ and 30% kaon detection efficiency

[e] assuming a counting rate of 15 events/day, from the run at P_b =2.581 GeV/c

[f] preliminary

Table 1: Schedule for the measurement of $pp \longrightarrow pK^+\Lambda$ / Σ^0 reactions at COSY-11.

[4] Z.Rudy et al., Zeitschrift für Physik A 345 (1996) 445

[5] S. Nagamiya, Nucl. Phys. A 544 (1992) 5

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