Hyperon production in pn-induced reactions at COSY-11

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Abstract

It is proposed to extend the measurements of the associated strangeness production via the hyperon channel towards the pn-induced reactions using deuterium as a neutron target. To perform such measurements an additional neutron detector was installed at the COSY-11 setup.

The following reactions should be measurable with acceptable detection efficiencies at COSY-11:

1. $pd \to K^+\Lambda pn$
2. $pd \to K^+\Sigma^- pp$
3. $pd \to K^+\Sigma^0 pn$

A comparison with the corresponding pp-induced reactions will allow to separate the production rates at a proton from the production rates at a neutron.

As a first step we request for one week of beam time to check the background and the possible missing mass resolution which is limited in reaction 1 and 3 by the newly installed neutron detector.

1 Motivation

In a recent paper G. Fäldt and C. Wilkin [1] demonstrated the strong similarity between the $pp \to pp\eta$ and $pp \to p\Lambda K^+$ reactions based on measurements of COSY-11 [2]. The authors show that both reactions are dominated by the first and second S_{11} resonance, respectively, where a one-pion-exchange model – exciting these intermediate resonances – reproduces the ratio of the production well.

From the experience gained from exciting the first S_{11} resonance through η production, the production rates with a neutron target as: $pn \to p\Lambda K^0$ or $\to n\Lambda K^+$ are likely to be larger by a factor of 5-10 compared to those in pp-collisions which can be attributed to the isovector dominance.

In order to test the validity of meson exchange models in the hyperon sector and to separate the contributions from the different exchange mesons detailed analysis of various reaction channels are necessary. To simplify the theoretical description a limitation to S-wave hyperon-nucleon interaction, i.e. threshold production, is important.

2 Measurements

It is proposed to measure the pn-induced hyperon production channels :
$pd \to K^+\Lambda pn$, $pd \to K^+\Sigma^- pp$ and $pd \to K^+\Sigma^0 pn$.

The $pd \to KYpn$ reaction suffers from the neutron in the exit channel which is not easy to be experimentally determined in its four-momentum vector. Still we included a scintillator/lead neutral particle detector into our setup. Figure 1 shows a typical $pd \to K\Lambda pn$ event with a neutron detection. The proton and the kaon are detected with the drift chambers D1 and D2 and the scintillation detector S1. Due to the positioning, which is limited by the quadrupole magnet downstream the COSY dipole magnet used by COSY-11, and the efficiency of the detector itself, we expect an overall efficiency of 30-40 % for this detector component. With the identification as a neutron and the time of flight measurement with an accuracy of better than one ns, a missing mass reconstruction is possible as shown in fig. 2. by realistic Monte Carlo calculations for the reaction : $pd \to K^+\Lambda pn$. Due to the performance of the neutron detector the FWHM of the sqared missing mass Λ-peak is about 20 MeV^2/c^2 which is rather large compared to the typical COSY-11 resolution but it still appears to be sufficient for an undoubtful cross section determination. In fig. 3 the acceptance of the COSY-11 detection system for a coincident measurement of p, n and K^+ is shown as a function of the beam momentum above threshold. Compared to the $pp \to pK^+\Lambda$ reaction the efficiency is reduced by a factor of about 10 which will be partly compensated by the higher cross section expected for the pn-channel. Therefore within a factor of 2-5 comparable counting rates are expected.

For a comparison of the Σ-production in the pp and pn channel we would like to measure the $pd \to K^+\Sigma^- pp$ reaction where the four charged particles in the exit channel can be fully determined. In fig. 4 a typical event $pd \to K^+\Sigma^- pp$ is shown with the 2 proton tracks and the kaon track measured with the COSY-11 detection system. The Σ^- four momentum components are calculated from the missing mass. Here the missing mass resolution for the Σ^- is much better as shown by the fig. 5. The acceptance for the detection of this Σ channel, see fig. 6, is comparable to the $pd \to K\Lambda pn$ channel. Due to the 3 measurable charged particles a much higher selectivity can be achieved which allows the measurement of very low cross sections. The preliminary results from the $pp \to pK^+\Sigma^0$ measurements at COSY-11 indicate a cross section in the order of some nb at an excess energy of a few MeV. At least comparable cross sections will be expected for the pn channel.

Since the Σ^- (1197) is 5 MeV heavier than the Σ^0(1192) hyperon a parallel test during this measurement of the $pd \to K^+\Sigma^0 pn$ channel is possible.

3 Beam time request

One week of beam time is requested as a first step towards the hyperon production in the pn-channel. Λ- as well as Σ- production is planned for this week using the following reactions :
$pd \rightarrow K^+\Lambda pn$, 6 MeV/c above threshold,
$pd \rightarrow K^+\Sigma^- pp$, 6 MeV/c above threshold.

The main aim of these measurements will be a rough check of the total cross section which includes the test of the neutron detector and the background determination in the different channels. Such informations are needed for the planning of further experiments in this field.

The luminosity achievable at COSY-11 is in the order of $2{\cdot}10^{30}\,1/cm^2\,1/s$ which results in an eventrate of about 170 events/day/nb. With the acceptance for the two channels which is about 0.25 % and 0.6 % for the Λ and Σ production, respectively, and the cross section data in the corresponding pp-induced channels of $\sigma_{pp\rightarrow pK^+\Lambda} \sim$ 20 nb and $\sigma_{pp\rightarrow pK^+\Sigma^0} \sim$ 1 nb as lower limit counting rates above $\sim$ 8/day and $\sim$ 1/day are expected.

The program for the one week of beam time would be as follows:

reaction	beam momentum	measurement time	expected events
background	1.840 GeV/c	2 days	-
$pd \rightarrow K^+\Lambda pn$	1.850 GeV/c	2 days	> 16
$pd \rightarrow K^+\Sigma^- pp$	2.019 GeV/c	3 days	> 3

References :

[1] G. Fäldt, C. Wilkin, Z.Phys. A 357, (1997) 241
[2] J. T. Balewski et al., Phys. Lett. B 388 (1996) 859

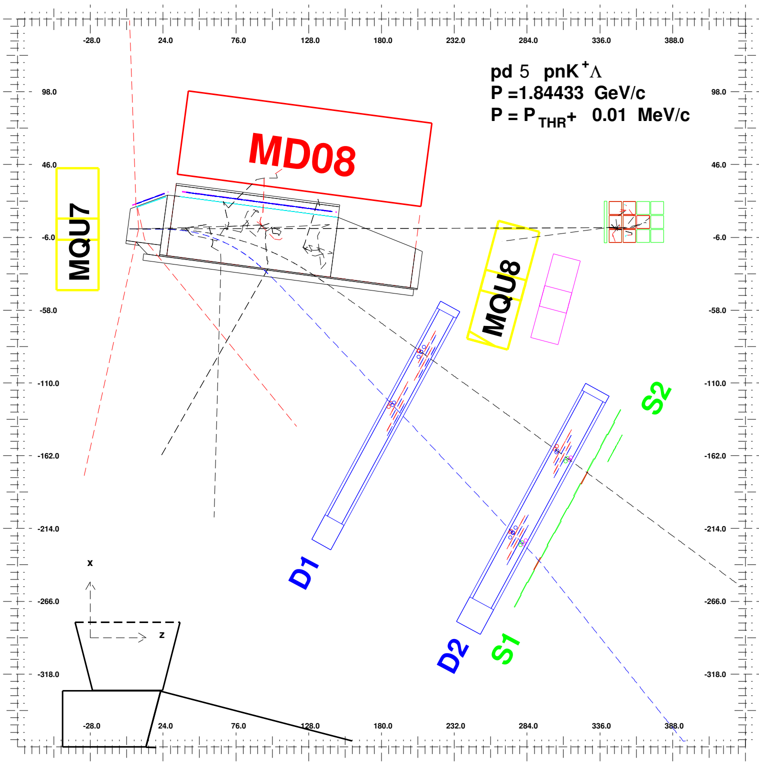

Figure 1: A typical $pd \to pnK^+\Lambda$ event with a neutron detection in the COSY-11 detection system.

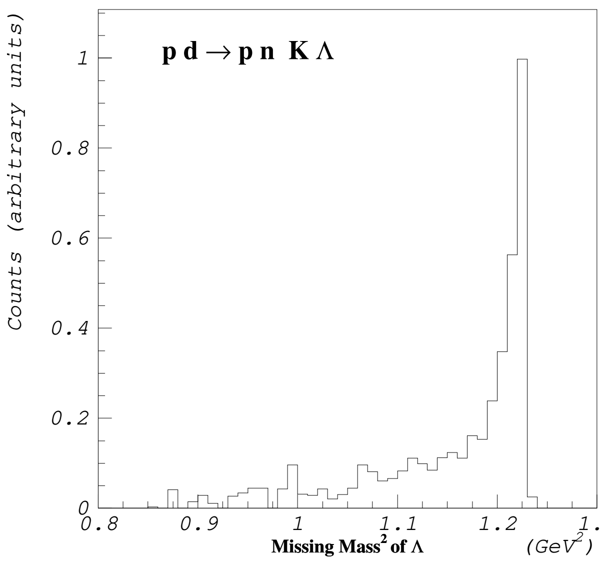

Figure 2: Squared missing mass for the $pd \to pnK^+\Lambda$ events. The poor resolution of about 20 MeV$^2/c^2$ FWHM results from the large uncertainty of the neutron momentum.

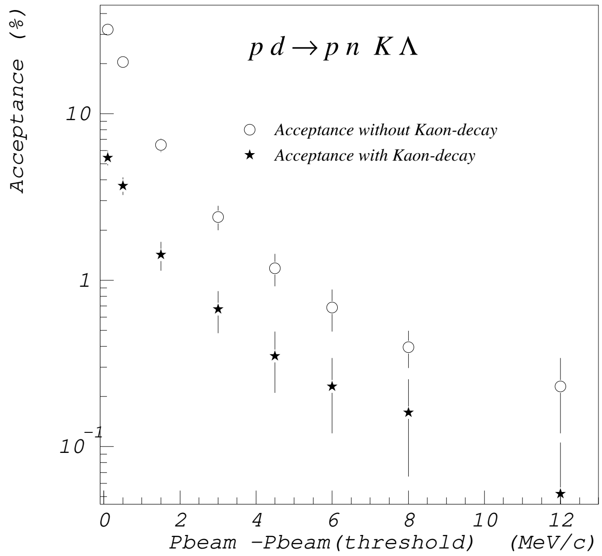

Figure 3: Acceptance for the reconstruction of a $pd \to pnK^+\Lambda$ event as a function of the beam momentum above threshold.

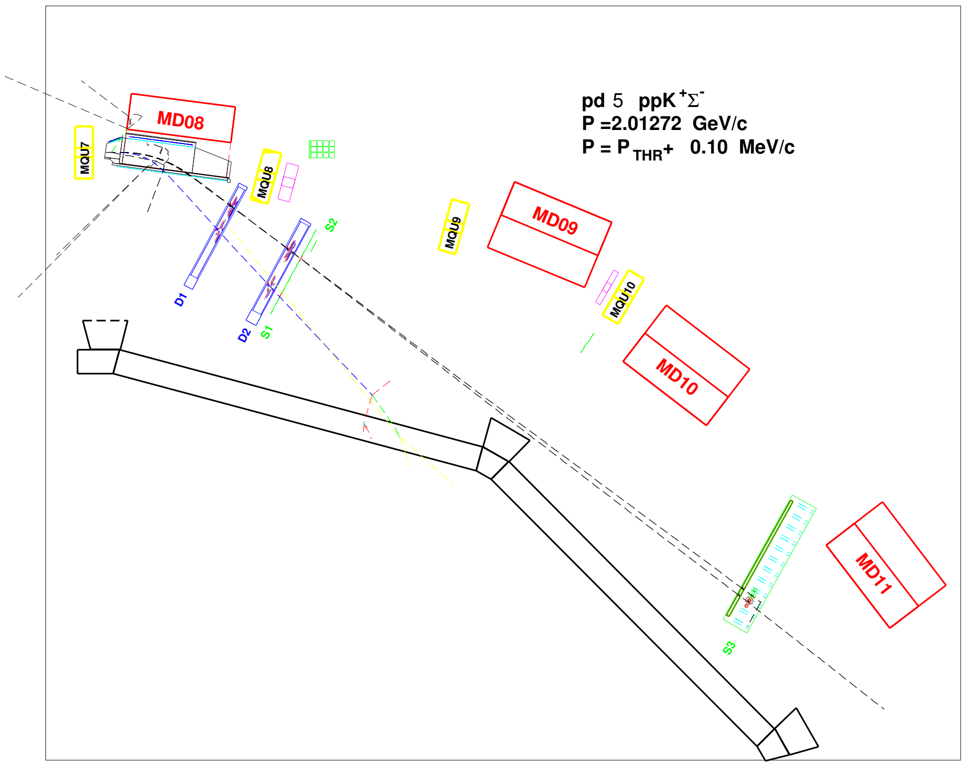

Figure 4: A typical MC event for the reaction $pd \to ppK^+\Sigma^-$ in the COSY-11 detection system. For all three measured particles, the two protons and the K^+, a momentum reconstruction and particle identification is possible.

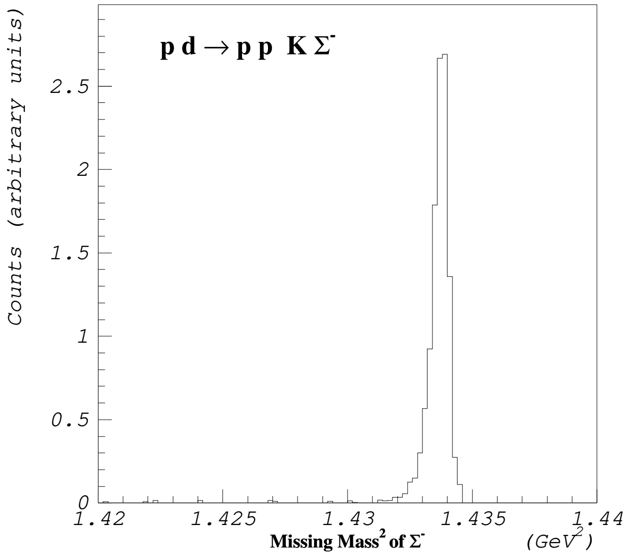

Figure 5: Squared missing mass from MC events of the $pd \to ppK^+\Sigma^-$ reaction.

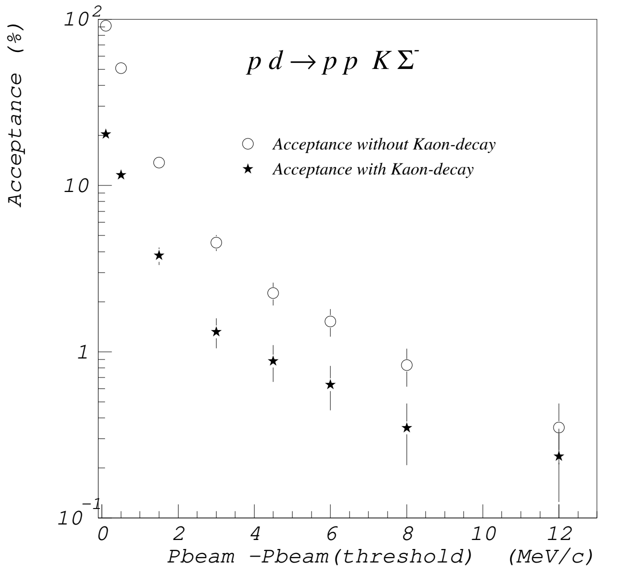

Figure 6: Acceptance for the reconstruction of a $pd \to ppK^+\Sigma^-$ event as a function of the beam momentum above threshold.