Study of the ground and excited states of $\Lambda$ and $\Sigma$ hyperon production at COSY

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Abstract: COSY with a maximum beam momentum of $\sim 3.65$ GeV/c allows the production of ground state ($\Lambda$ and $\Sigma$) and excited hyperons ($\Lambda(1405)$, $\Sigma(1385)$ and $\Lambda(1520)$) in elementary $NN$ interactions. The existing data base in this field is rather poor. A systematic study of the hyperon production at COSY will result in an improvement of our understanding concerning topics like hyperon–nucleon interaction, kaon–nucleon interaction, nucleon resonances, strangeness production mechanism and structure of the $\Lambda(1405)$. Precise data on $\Lambda$ and $\Sigma$ production have been produced at the COSY-11 and TOF installation. With the WASA detector at COSY these studies can be continued and extended to channels including photons in the final state.

1 Introduction

The cooler synchrotron COSY with a maximum beam momentum of $\sim 3.65$ GeV/c allows the production of $\Lambda$ and $\Sigma$ hyperons in elementary $NN$-interactions via the associated strangeness production $NN \rightarrow NYK$. Ground state ($\Lambda, \Sigma^-, \Sigma^0, \Sigma^+$) as well as the excited hyperon states $\Lambda(1405), \Sigma(1385)$ and $\Lambda(1520)$ are accessible.

The physics motivation for the production of ground state hyperons is very different from the motivation to study their excited states. The ground state hyperons are well defined ($qqq$) states of the $J^P = 1/2^+$ baryon octet with $S=-1$ and its properties like mass and decay modes are very well known. Production studies of the ground state hyperon aims at information on the production mechanism and on the interaction with hadrons. Concerning the excited hyperons especially the $\Lambda(1405)$ the main focus is on the resonance shape and its structure. It is under discussion if or how much of the $\Lambda(1405)$ can be attributed to a 3-quark state or a meson-baryon molecule.

From the experimental point of view the studies of ground and excited hyperons are comparable. In both cases delayed decays are involved which
allows very efficient trigger generation and event identification. The multiplicity and particle configuration to be detected in the final states is the same.

In table 1 and 2 some properties of the hyperon states relevant for the experimental studies at COSY are summarized [1].

## 2 Ground state hyperons

A systematic study of the ground state hyperon production will result in an extended data base for the hyperon-nucleon interaction which is an important ingredient in different physics questions. The dynamics of few body systems containing strangeness is not well known. Models describing hyperon–nucleon scattering [2, 3, 4, 5, 6] rely on flavour SU(3) symmetry to fix the baryon–meson couplings and the remaining parameters are fitted to the data. The existing data on hyperon–nucleon scattering are insufficient to prove the validity of this procedure. A better understanding of the hyperon–nucleon interaction has an impact on various topics like the

| state | $I(J^P)$ | $M$ [MeV] | $\Gamma$ [MeV] | decay modes |
|-------|----------|-----------|----------------|-------------|
| Λ(1405) | $0(\frac{1}{2}^-)$ | 1406 ± 4 | 50.0 ± 2.0 | $\Sigma\pi(100\%)$ |
| Λ(1520) | $0(\frac{3}{2}^-)$ | 1519.5 ± 1.0 | 15.6 ± 1.0 | $N\bar{K}(45\%), \Sigma\pi(42\%)$ |
| $\Sigma^+(1385)$ | $1(\frac{1}{2}^+)$ | 1382.8 ± 0.4 | 35.8 ± 0.8 | $\Lambda\pi\pi(10\%)$ |
| $\Sigma^0(1385)$ | $1(\frac{3}{2}^+)$ | 1383.7 ± 1.0 | 36 ± 5 | $\Lambda\pi(88\%), \Sigma\pi(12\%)$ |
| $\Sigma^-(1385)$ | $1(\frac{3}{2}^-)$ | 1387.2 ± 0.5 | 39.4 ± 2.1 | |

Table 1: Properties of Λ and Σ ground state hyperons [1].
formation of hyper-nuclei \[7\] or the structure of neutron stars \[5\].

Data on $\Lambda$ and $\Sigma$ ground state hyperon production related to hyperon–nucleon interaction studies mainly result from hyperon–nucleon scattering extracted from bubble chamber experiments. The hyperon production was induced by a $K^-$ beam via $K^- + p \rightarrow Y\pi$ where $Y$ is a $\Lambda$ or a $\Sigma$ hyperon. These $\Lambda$ and $\Sigma$ hyperons then may scatter elastically on another proton of the hydrogen bubble chamber. Experiments have been performed at CERN \[9,10,11,12,13\] or at SLAC \[14\]. Scattering data for higher $\Lambda$ momentum (1-17 GeV/c) have been produced at BNL by using a proton beam \[15\]. The available data on low energy elastic hyperon scattering are shown in figure 1.

![Figure 1](image-url)

**Figure 1:** Available data on low energy elastic hyperon scattering $Y_p \rightarrow Y_p$ for $\Lambda$ (open circle \[9\], filled circle \[14\], triangle \[13\]), $\Sigma^+$ (\[10\]) and $\Sigma^-$ (\[10\]) hyperons.

Most of the data are available for the $\Lambda$-p system but also here the experimentally extracted low energy parameters of s-wave scattering, the scattering length and the effective range, have large error bars. A detailed analysis of the world data set for elastic $\Lambda p$ scattering result in $a_s = -1.8 \pm (2.3 - 4.2)$ fm and $a_t = -1.6 \pm (1.1 - 0.8)$ fm \[9\] for the spin singlet and spin triplet scattering lengths, respectively, where the errors are strongly correlated. Furthermore a clear separation of the spin singlet and triplet channel is not possible from the data. An analysis within an effective range
approximation has been performed also for the $\Sigma^+$ elastic scattering data but due to the poor data base only a wide region for the scattering lengths could be extracted by applying some model based relations for the scattering lengths with $-6\text{fm} < a_s < +2.5\text{fm}$ and $-2\text{fm} < a_t < 1.3\text{fm}$ in which singlet and triplet scattering lengths are correlated. These secondary scattering experiments are limited at the low momentum end due to the hyperon decay and the necessity to have a detectable track of the scattered proton. Therefore the data have to be extrapolated to the threshold resulting in a large error width.

The data on elastic hyperon scattering will be extended by measurements at KEK where first results on differential observables are published. The hyperons are produced via the $(\pi^+ / \pi^-, K^+)$ reactions and the detection system consists of a scintillating fiber arrangement or a “Scintillating track image camera” where the tracks of charged particles in a scintillator are viewed by ccd cameras.

An alternative way to study the nucleon–hyperon interaction are production reactions with a nucleon and a hyperon in a multi particle exit channel. First data in this field were extracted from the reaction $K^-d \rightarrow \pi^-p\Lambda$ leading to a scattering length of $-2 \pm 0.5\text{fm}$ via fitting the invariant mass distribution to an effective range expansion. The author argued that this value is to be interpreted as the spin triplet scattering length but it is difficult to estimate the theoretical uncertainty, the error given includes the experimental uncertainty only.

Also at COSY a first attempt to determine the low energy parameters of the $\Lambda N$ interaction via the reaction $pp \rightarrow K^+p\Lambda$ has been performed. We extracted an average value of $-2 \pm 0.2\text{fm}$ for the $\Lambda N$ scattering length in a Dalitz plot analysis that utilizes the effective range expansion. The effective range parameters $a$ and $r$ are strongly correlated and for their determination the $\Lambda N$ elastic cross sections data had to be included in the analysis to determine the parameters. Furthermore the spin singlet and triplet $Y-N$ states contributes to the data i.e. only a spin averaged value was extracted.

In Ref. it was suggested to use the reaction $K^-d \rightarrow n\Lambda\gamma$, where the initial state is in an atomic bound state, to determine the $\Lambda N$ scattering lengths. From the experimental side so far, a feasibility study was performed which demonstrated that a separation of background and signal is possible. The reaction $K^-d \rightarrow n\Lambda\gamma$ was studied theoretically in more detail in. The main results especially of the last work are that it is indeed possible to use the radiative $K^-$ capture to extract the $\Lambda N$ scattering lengths and that polarization observables could be used to disentangle the
different spin states.

In a 3 particle exit channel like $pp \rightarrow pK^+\Lambda$ the relative momentum in each individual 2 particle subsystem ranges from the maximum momentum given by the kinematics down to 0. Therefore event samples can be selected with very low relative hyperon–nucleon momentum down to the threshold which is not accessible by conventional elastic scattering. In figure 2 the situation is illustrated in a comparison of the $\Lambda p$ scattering data with a data set of inclusive $K^+$ production via $pp \rightarrow K^+X$ measured at SATURNE. Below the $\Sigma^0$ production threshold the dominant reaction channel is $pp \rightarrow pK^+\Lambda$. Neglecting other reaction channels like $pp \rightarrow pK^+\Lambda\gamma$ the kinetic energy of the $K^+$ is directly related to $m_{\Lambda p}$. In figure 2 it is clearly shown that the $m_{\Lambda p}$ distribution is covered by data points up to the threshold. The extraction of the scattering length by fitting the data with theoretical curves is much more precise than the extrapolation of the scattering data. The different curves fitted to the scattering data cover the present error range for the scattering length. The highest sensitivity is at smallest $m_{\Lambda p}$ values where no data are available. These inclusive $K^+$ data are not really useful to improve the knowledge of the $\Lambda p$ scattering length because singlet and triplet state are not separated. This example should only demonstrate the advantages of the $pp \rightarrow pK^+\Lambda$ reaction for such studies. Another important feature of the $pp \rightarrow pK^+\Lambda$ reaction is the high momentum transfer in the reaction. High momentum transfer is correlated with a production process of short-range nature which is insensitive to details of the production mechanism resulting in reliable error estimates in the theoretical treatment.

The curves in figure 2 result from a new method to determine the $\Lambda p$ scattering lengths proposed in Ref. 29. It allows the extraction of the $YN$ scattering lengths from the production data directly. In particular, an integral representation for the $\Lambda N$ scattering lengths in terms of a differential cross section of reactions with large momentum transfer such as $pp \rightarrow K^+p\Lambda$ or $\gamma d \rightarrow K^+n\Lambda$ was derived. This formula should enable the determination of the scattering lengths to a theoretical uncertainty of at most 0.3 fm. Experimentally production data of sufficient accuracy can be achieved as is seen by the SATURNE data introducing an experimental uncertainty in the extraction of the scattering length of 0.2 fm.

In Ref. 29 it was also shown that already a measurement of a single spin asymmetry in $\bar{p}p \rightarrow YNK$ enables to isolate the spin triplet contribution from the final $YN$ state, since the Pauli Principle strongly limits the number of structures allowed for the initial state. It was especially shown that

$$\frac{d^2\sigma(\uparrow)}{dm'\,2\,dt} - \frac{d^2\sigma(\downarrow)}{dm'\,2\,dt}$$
gets contributions from the spin triplet final state only, as long as the kaon in the final state is emitted at 90° in the cm system and the outgoing \( YN \) is in an \( S \)-wave. The arrows in the above expression denote the polarization of either the beam or the target that is to be chosen perpendicular to the beam axis.

The method in Ref. [29] was derived under the assumption that there is no inelastic channel available for the hyperon–nucleon system. This condition only holds for the \( \Lambda N \), \( \Sigma^+p \) as well as the \( \Sigma^-n \) channel (where for an analysis of the second channel the Coulomb interaction needs to be included in the formalism—work on this straightforward extension of the formalism is in progress). These \( \Sigma N \) channels are purely isospin 3/2 states and thus do not couple to the \( \Lambda N \) channel. The other \( \Sigma N \) channels, however, are inelastic. As a consequence their scattering lengths acquire imaginary parts and the dispersion analysis in Ref. [29] can no longer be applied.

The future studies of the hyperon production at COSY induced by \( NN \) interactions via \( NN \rightarrow NKY \) will significantly extend and improve the data base on the hyperon–nucleon interaction.

But apart from the hyperon–nucleon interaction there is much more physics which can be extracted from these data. First of all the production

Figure 2: Left panel: \( pp \rightarrow K^+X \) inclusive missing mass spectrum at \( T_p = 2.3 \) Gev corrected by the two body phase space. Right panel: world data set on total cross sections for \( \Lambda N \) elastic scattering. In both panels the solid curve represents a best fit to the data. In the right panel two more fits still consistent with the data were added to show the uncertainty in the extrapolation.

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mechanism can be studied. Dalitz plot analysis of \( pp \rightarrow pK^+\Lambda \) data taken at COSY by the TOF collaboration showed that the lowest nucleon resonances which couple to the \( KY \) channel are a dominant strongly energy dependent contribution to the hyperon production \[30\]. At a beam momentum of 2.85 GeV/c (\( Q = 171 \text{ MeV} \)) only the \( N^*(1650) \) is relevant, at 2.95 GeV/c (\( Q = 204 \text{ MeV} \)) also the \( N^*(1710) \) gives a significant contribution and at 3.2 GeV/c (\( Q = 284 \text{ MeV} \)) both, \( N^*(1650) \) and \( N^*(1710) \), contribute with comparable strength. Close to threshold data have been supplied by the COSY-11 collaboration \[31, 32, 33\] resulting in information on the hyperon-nucleon interaction \[21\] as discussed above but especially the comparison of threshold production of different hyperon channels like the \( \Lambda/\Sigma^0 \) comparison \[33, 34\]. will help to disentangle the production mechanisms close to threshold. Spin transfer coefficients by using a polarized proton beam and measuring the \( \Lambda \) polarization \( \vec{p}p \rightarrow pK^+\bar{\Lambda} \) have been produced by the DISTO collaboration at a beam momentum of 3.67 GeV/c (\( Q = 430 \text{ MeV} \)) \[35\]. The model dependent interpretation of the data indicates a production mechanism dominated by kaon exchange.

With the hyperon production data available up to now first indications of the relevant production mechanisms are available but much more informations are still needed.

The kinematically complete measurement of the 3 particle \( NKY \) exit channel allows a detailed investigation of all individual 2-body subsystems. Besides the \( YN \) system also the \( NK \) as well as the \( KY \) system can be studied. The \( KY \) system is mainly important for the investigation of nucleon resonances, especially the \( N^*(1650) \), \( N^*(1710) \) and \( N^*(1720) \) which have large branching ratios into the \( \Lambda K \) channel. In the \( NK \) subsystem the interaction between nucleons and \( K \) mesons can be observed. Of special interest here is the \( \Theta^+ \) resonance which was observed by many experiments and is interpreted as a penta-quark system \[36\] proposed by Diakonov et al. \[37\]. A clear signal of the \( \Theta^+ \) has also been detected in the \( K^0p \) system by the COSY TOF collaboration \[38\]. Further measurements at TOF with improved statistics are on the way and a double polarization experiment to determine the parity of the \( \Theta^+ \) \[39\] is in preparation.

3 Excited hyperons

The most interesting topic in the excited hyperon sector is the shape and the structure of the \( \Lambda(1405) \) resonance. Its a long standing discussion if the \( \Lambda(1405) \) is a 3-quark state or a \( \bar{K}N / \pi\Sigma \) bound state, see \[40\] and references
cited therein.

In a recent study of the poles in the meson-baryon scattering matrix in a chiral unitary approach some resonances are dynamically generated close to the $\Lambda(1405)$ mass \[41\]. It is argued that the $\Lambda(1405)$ is not only one but a superposition of two close resonances which could be experimentally separated due to the different couplings to the $\pi\Sigma$ and $\bar{K}N$ states. Whereas the resonance at lower mass couples stronger to the $\pi\Sigma$ state the resonance at higher mass couples mostly to the $\bar{K}N$ state. Similar results have been obtained in other studies, see \[40, 41\] and the references cited therein. But a definite conclusion about the structure of the $\Lambda(1405)$ can not be drawn from the existing data.

The data in the excited hyperon sector mostly result from production studies in bubble chambers via $\pi^-p$ or $K^-p$ interactions \[42, 43, 44, 15, 46, 36\]. Recently the photoproduction of the $\Lambda(1405)$ has been studied at SPring-8/LEPS via $p(\gamma, K^+\gamma^*)$ \[47\]. In the missing mass distribution the $\Lambda(1405)$ is overlapping with the $\Sigma(1385)$. A separation is achieved in the $(\pi\Sigma)$ invariant mass distribution because the $\Lambda(1405)$ decays with 100% into the $\pi\Sigma$ channel but the $\Sigma(1385)$ has a branching of only 12% into this channel. The comparison of the $\pi^+\Sigma^-$ and the $\pi^-\Sigma^+$ invariant mass distributions shows different line shapes which could be an indication that the $\Lambda(1405)$ is a meson-baryon bound state.

At COSY the production of overlapping $\Lambda^*(1405)$ and $\Sigma^*(1385)$ hyperons have been observed in $pp$ interactions \[48, 49\]. But for a detailed study first of all a separation of these resonances by measuring their decay products is necessary.

4 Experimental study of hyperons at COSY

The experimental details to study the ground and excited hyperons are very similar. Up to now the hyperon production at COSY has been investigated at the COSY-11 and at the TOF installation.

COSY-11 \[52\] is an internal experiment operating with a beam of hydrogen clusters as target in front of a COSY machine dipole used as a magnetic spectrometer for the charged reaction products. The tracks and velocity of positively charged reaction products are measured resulting in the determination of its 4-momentum vectors. This system is limited in acceptance but achieves a high momentum resolution of the measured particles. Hyperon production is studied via $pp \rightarrow NK^+Y$ where the hyperons are identified via the missing mass method. Due to the high missing mass resolution the
hyperons can be clearly identified on a rather low background level. Excitation functions from about 1 - 60 MeV excess energy have been measured for $pp \rightarrow pK^+\Lambda$ and $pp \rightarrow pK^+\Sigma^0$ and data of the $pp \rightarrow nK^+\Sigma^+$ channel are under analysis. For the $pp \rightarrow pK^+\Lambda$ reaction also a Dalitz plot analysis has been performed resulting in the determination of a spin averaged $\Lambda p$ scattering length. These studies will be continued by a measurement with polarized beam. In the analysis the method of Gasparian et al. \[29\] will be used to isolate the spin triplet scattering length which requires the measurement of kaons emitted in 90° in the cm system. Although COSY-11 is a magnetic spectrometer device the special configuration of a C-type magnet, open to the detector side with a thin exit window for the reaction products, allows to measure the full scattering angle distribution for a thin slice in the beam plane. Therefore kaons emitted around 90° cms can be detected. The proposal for this experiment has been accepted and the measurement is planned for spring 2005 \[53\].

The TOF spectrometer \[54\] is a large acceptance external experiment. A small liquid hydrogen cell (a few tens $mm^3$ volume) is used as a target surrounded by a first layer of scintillators followed by a second layer in a distance of a few m dependent on the actual setup. A special decay spectrometer is installed close to the target with several layers of Si-μstrip and scintillating fiber detectors. This decay spectrometer allows to trigger on delayed decays and measures the tracks of charged decay products. The event identification is mainly done by geometry which is sufficient if a precise definition of target vertex and hit positions is realized as it is the case at TOF. Data have been produced for $pp \rightarrow pK^+\Lambda$ for Q values between 55 MeV and 284 MeV resulting in Dalitz plots with a full coverage of the phase space \[30\]. Due to the decay asymmetry of the weak $\Lambda$ decay also the $\Lambda$ polarization could be determined by measuring the tracks of the charged decay particles. Furthermore the reactions $pp \rightarrow pK^+\Sigma^0$, $pp \rightarrow pK^0\Sigma^+$ and $pp \rightarrow nK^+\Sigma^+$ have been studied.

In table \[4\] all ground state hyperon production channels accessible in elementary NN interactions at COSY are listed.

For a systematic detailed study of the hyperon production the full information of the measured events including the 4-momentum vectors of the decay particles is needed. This will allow to extract nearly background free event samples required for Dalitz plot analysis. Some reaction channels in table \[4\] could be studied at TOF as is shown by the produced data but at TOF no photon detector is installed. In most channels one or more $\gamma$'s are included in the exit channel. Therefore the WASA detector \[50, 51\] which will move to COSY in the near future seems to be well suited for
| primary reaction | final state | br. |
|------------------|-------------|-----|
| $pp \to pK^+\Lambda$ | $pK^+p\pi^-$ | 0.64 |
|  | $pK^+n\pi^0 \to pK^+n\gamma\gamma$ | 0.36 |
| $pp \to pK^+\Sigma^0$ | $pK^+\Lambda\gamma \to pK^+p\pi^-\gamma$ | 0.64 |
|  | $pK^+\Lambda\gamma \to pK^+n\pi^0\gamma \to pK^+n\gamma\gamma\gamma$ | 0.36 |
| $pp \to pK^0\Sigma^+$ | $p\pi^0p\pi^0p\pi^0 \to p\gamma\gamma\gamma p\gamma\gamma$ | 0.08 |
|  | $p\pi^+\pi^-n\pi^0 \to p\pi^+\pi^-p\gamma\gamma$ | 0.18 |
|  | $p\pi^0n\pi^+ \to p\gamma\gamma\gamma n\pi^+$ | 0.08 |
|  | $p\pi^+\pi^-n\pi^+$ | 0.16 |
| $pp \to nK^+\Sigma^+$ | $nK^+p\pi^0 \to nK^+p\gamma\gamma$ | 0.52 |
|  | $nK^+n\pi^+$ | 0.48 |
| $pn \to nK^+\Lambda$ | $nK^+p\pi^-$ | 0.64 |
|  | $nK^+n\pi^0 \to nK^+n\gamma\gamma$ | 0.36 |
| $pn \to nK^+\Sigma^0$ | $nK^+\Lambda\gamma \to nK^+p\pi^-\gamma$ | 0.64 |
|  | $nK^+\Lambda\gamma \to nK^+n\pi^0\gamma \to nK^+n\gamma\gamma\gamma$ | 0.36 |
| $pn \to nK^0\Sigma^+$ | $n\pi^0p\pi^0p\pi^0 \to n\gamma\gamma\gamma p\gamma\gamma$ | 0.08 |
|  | $n\pi^+\pi^-n\pi^0 \to n\pi^+\pi^-n\gamma\gamma$ | 0.18 |
|  | $n\pi^0n\pi^+ \to n\gamma\gamma\gamma n\pi^+$ | 0.08 |
|  | $n\pi^+\pi^-n\pi^+$ | 0.16 |
| $pn \to pK^0\Lambda$ | $p\pi^0p\pi^0p\pi^- \to p\gamma\gamma\gamma p\pi^-$ | 0.1 |
|  | $p\pi^+\pi^-p\pi^-$ | 0.22 |
|  | $p\pi^0n\pi^0 \to p\gamma\gamma\gamma n\pi^+$ | 0.06 |
|  | $p\pi^+\pi^-n\pi^0 \to p\pi^+\pi^-n\gamma\gamma$ | 0.12 |
| $pn \to pK^0\Sigma^0$ | $p\pi^0p\pi^0\Lambda\gamma \to p\gamma\gamma\gamma p\pi^-\gamma$ | 0.1 |
|  | $p\pi^+\pi^-\Lambda\gamma \to p\pi^+\pi^-p\pi^-\gamma$ | 0.22 |
|  | $p\pi^0n\pi^0\Lambda\gamma \to p\gamma\gamma\gamma n\gamma\gamma$ | 0.06 |
|  | $p\pi^+\pi^-\Lambda\gamma \to p\pi^+\pi^-n\pi^0\gamma \to p\pi^+\pi^-n\gamma\gamma\gamma$ | 0.12 |
| $pn \to pK^+\Sigma^-$ | $pK^+n\pi^-$ | 1.0 |
these hyperon production studies. WASA includes a detection system for charged particles as well as an electromagnetic calorimeter for the detection of photons.

With the possible production channels of the excited hyperons:

\[ pp \rightarrow \Lambda^*pK^+ / \Sigma^+pK^0 / \Sigma^0pK^+ \] and \[ pn \rightarrow \Lambda^*pK^0 / \Sigma^*pK^0 / \Sigma^*pK^+ \]

a corresponding table for the exit particle configuration can be prepared with the dominant \( Y^* \) decays given in table 2. The final states are similar to the ground state hyperons with a particle multiplicity of about 6 including charged particles and photons. As an example in fig. 3 the momentum distribution of the final state particles in the reaction channel \( pp \rightarrow \Lambda(1405)pK^+ \rightarrow p\pi^-\gamma\gammapK^+ \) is shown for a Monte Carlo generated event sample. The straight lines in the plots indicate the acceptance of the WASA calorimeter for photon detection. The charged particles are mainly emitted in forward direction which requires a high resolution tracking system in this area. How well the existing WASA detection system will be suitable for these hyperon production studies and which modifications would be necessary has to be studied via Monte Carlo event samples. A close to target tracking system, not existing in the present WASA setup, to identify the delayed decay vertices is for sure indispensable to select clean event samples. This point is discussed in letters of intend for possible experiments with WASA at COSY [55].

5 Summary

A systematic study of hyperon production at COSY in the 3-body final state \( NN \rightarrow NKY^* \) will result in detailed information on various topics. By measuring all final state particles including the decay products nearly background free event samples of the various reaction channels can be selected which is important for efficient Dalitz plot analysis. With the use of a polarized beam (and target) and the measurement of the hyperon polarization (at least for \( \Lambda \) and \( \Sigma^+ \) with their high decay asymmetry) very selective studies will be possible.

By selecting appropriate kinematic regions – difficult or even impossible to access by conventional scattering experiments – the interactions of the individual subsystems \( (NY) \), \( (NK) \) and \( (KY) \) can be analyzed. Precise data will result on the hyperon–nucleon interaction, requested for a better understanding of the dynamics in baryon systems with strangeness, the kaon–nucleon system, of special interest in view of the recent observations of the \( \Theta^+ \) resonance and the kaon–hyperon system, important for the investiga-
Figure 3: Momentum distribution of the final state particles for the reaction channel $pp \rightarrow \Lambda(1405) p K^+ \rightarrow p^{(a)} \pi^- p^{(b)} \gamma^{(c)} \gamma^{(d)} p^{(e)} K^+$. The ellipses show the kinematic limits for a $\Lambda(1405)$ production with PDG mass $\pm 25$ MeV. The straight lines indicate the acceptance region covered by the em calorimeter of the WASA detector.
gation of nucleon resonances. In case of the excited hyperons the knowledge about the structure of these resonances will be much improved. Furthermore with these detailed studies the mechanisms of hyperon production can be clarified.

By their results on hyperon production the running experiments have proven that high precision data in this field are possible at COSY. Valuable results have been obtained but much more information is necessary in order to fully understand the strangeness sector.

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