COSY Proposal and Beam Request

Measurement of the spin correlation parameter $A_{x,z}$ of the quasi-free $\vec{p}\vec{n} \to \{pp\}_s\pi^-$ reaction at ANKE: Initial research with a longitudinally polarised proton beam

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Abstract

The final step in the pion production programme outlined in the ANKE spin document is the measurement of the spin-correlation coefficient $A_{x,z}$ of the $\vec{p}\vec{n} \to \{pp\}_s\pi^-$ reaction for excitation energies of the final diproton less than 3 MeV. The results will be of relevance for Chiral Perturbation Theory. In order to test the feasibility of this experiment, and to provide a robust estimation of the beam time required, the ANKE collaboration proposes a preparatory measurement to be carried out in the conditions of the main experiment. This requires the use of a longitudinally polarised proton beam of 353 MeV energy and a transversely polarised deuterium target, equipped with an openable cell, and four Silicon Tracking Telescopes at ANKE.

In the current document, we ask for **TWO weeks** of beam time to prove the suggested concept of polarimetry and to gain experience in handling the data collected for the first time with the longitudinally polarised beam at ANKE. In addition to that, an important result of the beam time would be to understand the background conditions when measuring the $\vec{p}\vec{n} \to \{pp\}_s\pi^-$ reaction with an openable cell at 353 MeV, and the optimisation of the cell dimensions. The data acquired will allow a test of the detection and the process identification scheme proposed for the main experiment.

As by-products of the experiment, data on the vector analysing power and the spin-correlation parameters $A_{x,x}$, $A_{y,y}$, and $A_{x,z}$ will be obtained at 353 MeV for the quasi-free $pn \to d\pi^0$ and $pn \to pn$ processes and $pd \to pd$ elastic scattering.

The physics case of this proposal was accepted positively by the PAC session 40, but the final decision was postponed until the installation of the Siberian snake at COSY. The present document contains an update of the proposal originally presented.

Contents

1 Introduction

There is an extensive programme of near-threshold measurements of $NN \to \{pp\}_s\pi$ at the COSY-ANKE facility of the Forschungszentrum Jülich [1, 2]. Here $\{pp\}_s$ denotes a proton-proton system with very low excitation energy, E_{pp}, which is overwhelmingly in the $^1S_0$ state with antiparallel proton spins. The primary aim of these experiments is to carry out a full partial wave analysis (PWA), which would lead to a determination of the relevant pion p-wave production strength in the $^3S_1 \to {}^1S_0p$ wave that could provide links with other intermediate energy phenomena. The measurement of the spin correlation parameter $A_{x,z}$ will provide new constraints on the PWA and test the important assumptions made in the analysis, as explained in detail in section 2.

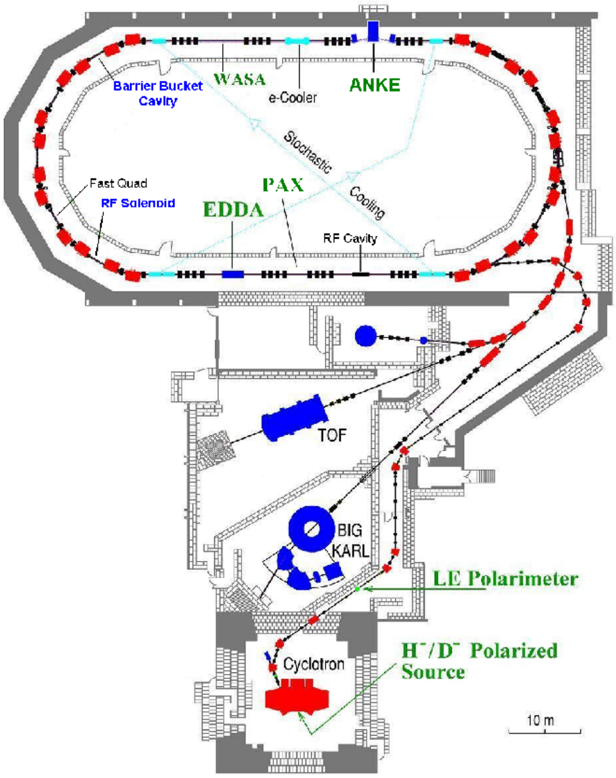

Figure 1: Floor plan of the COoler SYnchrotron COSY at Forschungszentrum Jülich. In addition to the injector cyclotron, the locations of the major facilities are indicated.

A measurement of $A_{x,z}$ requires the use of a longitudinally polarised proton beam at COSY. By means of a Siberian snake acting on the closed orbit of COSY [3], the spin at the location of the polarised target can be aligned along the direction of motion of the stored particles. The Siberian snake is planned to be installed in the 'low-β' section at the PAX interaction point (see Fig. 1). The time line for the first installation, commissioning and 'running-in' of the Siberian snake (solenoid) using the EDDA facility has been prepared by the accelerator group. The commissioning of the snake is foreseen for the summer 2013 shutdown.

The proposed measurement is our first experience with a longitudinally polarised beam and one of the most technically involved experiments at COSY. It requires a beam development with electron cooling and stacking injection and the use of the internal polarised target [4, 5] with an openable cell, surrounded by four Silicon Tracking Telescopes (STTs). Many crucial questions have to be studied prior the main experiment: the longitudinal beam polarimetry, the optimal size of the openable cell, and the background conditions with the proposed setup. In order to answer these questions and gain experience of running the Siberian snake with the polarised gas target, we request **TWO weeks** of beam time.

2 Motivation for the $A_{x,z}$ measurement in the $\vec{p}\vec{N} \to \{pp\}_s\pi$ reactions at $T_p = 353$ MeV

The theoretical interest in the problem of pion production in nucleon-nucleon collisions was revitalised around 15 years when it was suggested [6] that the process may be studied in a model-independent way within chiral perturbation theory (ChPT) – the modern low-energy effective field theory of QCD. Indeed, emission of a low-energy pion and the important role of the two-body ingredients, πN and NN interactions, have been successfully investigated within ChPT. This makes ChPT the most natural framework for describing the production mechanism.

Within the context of ChPT, a significant step forward in our understanding of pion physics at low energies would be to establish that the same short-ranged $NN \to NN\pi$ vertex contributes to p-wave pion production, to low energy three-nucleon scattering [7, 8, 9], $\gamma d \to \pi NN$ [10, 11] and $\pi d \to \gamma NN$ [12], as well as in weak reactions such as tritium beta decay [13, 14, 15, 16] and in muon absorption on deuterium $\mu^- d \to nn\nu_\mu$ [17, 18].

The experimental programme for pion production undertaken at ANKE includes measurements of the cross section and analysing power, as well as double-polarisation experiments [19]. As a part of this programme, we have already presented data on the cross section and analysing power of the $\vec{p}p \to \{pp\}_s\pi^0$and $\vec{p}n \to \{pp\}_s\pi^-$ reactions at 353 MeV [20, 21] which allowed us to perform a partial wave analysis (PWA). In the PWA, the following partial waves were included: Ps, Pd, Fd, Sp, and Dp, where the latter two contribute only in the $\vec{p}n \to \{pp\}_s\pi^-$channel. We are here specifying the initial NN orbital angular momentum and the final pion angular momentum which, since the final NN state is ${}^1S_0$, is equal to the total angular momentum. Note that the initial NN state is always a spin-triplet.

Quantity	Fit Value [$\sqrt{\text{nb/sr}}$]
M_s^P	$(55.3 \pm 0.4) - (14.7 \pm 0.1)$i
M_d^P	$(-26.6 \pm 1.1) - (8.6 \pm 0.4)$i
M_d^F	5.3 ± 2.3
M_p^S	$(-32.4 \pm 2.2) + (17.3 \pm 2.7)$i
M_p^D	$(-109.6 \pm 9.6) + (140.7 \pm 4.0)$i
$\chi^2_{\text{min}}/\text{dof}$	$88.2/77$

Table 1: Fitted values of the amplitudes; the errors shown are purely statistical.

A pivotal point of the PWA are assumptions about the phases of the amplitudes M_d^P and M_d^F. These provide additional constraints, which allow one to extract unambiguously these amplitudes, along with the absolute value of M_s^P, just from data on the cross section and analysing power of $\vec{p}p \to \{pp\}_s\pi^0$. For a pion produced in an s-wave, the initial NN pair are in the uncoupled triplet ${}^3P_0$ state. The inelasticities in this partial wave are very small so that the Watson theorem can be applied to fix the phase of M_s^P. In contrast, for d-wave production the initial NN states are the coupled triplet ${}^3P_2$–${}^3F_2$, where the strict conditions of the Watson theorem are not met. However, at 353 MeV the mixing parameter in these coupled states, as well as the inelasticities, are both very small. This means that, to a good approximation, one may neglect the coupling and also use here the Watson theorem. This assumption was checked by explicit calculations of the d-wave production amplitudes within ChPT to third order, and using two potential models to parameterise the NN interaction. These suggest that the phase assumptions should be valid to within $\pm 2^\circ$. It should be noted that this phase approximation is also crucial for the analysis of the $\vec{p}n \to \{pp\}_s\pi^-$channel, the knowledge of M_s^P, M_d^P, and M_d^F being necessary prerequisites for the extraction of the p-wave production amplitudes.

Another theoretical assumption included in our PWA is that d-wave pion production is less important than that in s- and p-waves, to the extent that one can neglect squares of M_d^P and M_d^F and their interference in the expressions for observables.

These two assumptions allowed us to extract the set of partial wave amplitudes given in Table 1. The statistical uncertainties are very small and the description of the combined data is very good, with a $\chi^2/\text{d.o.f.} \simeq 1$. On the other hand, the uncertainties inherent in the theoretical assumptions cannot be quantified. Moreover, it must be checked whether the truncation of the higher partial waves in the analysis is justified so that the solution found in the analysis is stable. Additional experimental data will be very useful in this respect in that they will lead to a better understanding of the procedures involved and provide new constraints on the amplitudes.

$A_{x,z}$ times the unpolarised cross section is of the form

$$A_{x,z}\frac{d\sigma}{d\Omega} = -\frac{k}{4p}\left(d_0 + d_1\cos\theta + d_2\cos^2\theta + d_3\cos^3\theta\right)\sin\theta, \tag{1}$$

where p is the incident c.m. momentum and k that of the produced pion. At 353 MeV the momenta are $p = 407$ MeV/c and $k \approx 94$ MeV/c. The coefficients can be expressed in terms of the partial wave amplitudes, and this we do separately for the two reactions.

2.1 $pp \to \{pp\}_s\,\pi^0$

The coefficients in this channels read

$$\begin{aligned}
d_0 &= 0,\\
d_1 &= 2\text{Re}\left[M_s^{P*}\left(M_d^P - \frac{2M_d^F}{5}\right) - \frac{M_d^P M_d^{P*}}{3} - \frac{M_d^P M_d^{F*}}{15} + \frac{2M_d^F M_d^{F*}}{25}\right],\\
d_2 &= 0,\\
d_3 &= 2\text{Re}\left[M_d^P M_d^{P*} + \frac{M_d^{P*} M_d^F}{5} - \frac{6M_d^F M_d^{F*}}{25}\right].
\end{aligned} \tag{2}$$

The largest contribution in d_1, *viz.* $2\text{Re}[M_s^P M_d^{P*}]$, is in effect redundant since it can be expressed in terms of the slope in $\cos^2\theta$ of the differential cross section. Corrections to it stem from the squares of d-wave amplitudes and the interference between M_s^P and M_d^F. High accuracy in the data here would allow one to test the analysis of all $pp \to \{pp\}_s\,\pi^0$ data and hence improve the accuracy of the extraction of the s- and d-wave amplitudes. The values of the coefficients d_1 and d_3 predicted from the amplitude analysis, including the squares of the d-wave amplitudes, based on the values of A_y and $d\sigma/d\Omega$ measured in $pp \to pp\pi^0$ are shown in Table 2. (See also the left panel of Fig. 2). The sizes of the coefficients (even after subtracting the redundant term) are, in principle, comparable to those already extracted from the previous experiments, e.g., from A_y, which testifies to the feasibility of the measurement. In spite of being on the same level of the $NN\pi$ power counting scheme as the squares of d-waves, the s-g interference is expected to be small due to the suppression of the s-wave contribution. This can be also checked by comparing the extended analysis with data.

If this part of the project is successful, one may also take s- and d-waves directly from $pp \to \{pp\}_s \pi^0$ and perform a direct fit of the $pn \to \{pp\}_s\pi^-$ channel (with d-waves squared included) to improve the accuracy of the extraction of the p-waves. One may also ask if f-waves are significant. This can be checked *a posteriori* by comparing the analysis with data.

According to the simulations, the phase of the M_d^P amplitude can be determined from a 10 week measurement of $A_{x,z}$ in the $pp \to \{pp\}_s \pi^0$reaction with the precision of 3°. This would provide an excellent check for the applicability of the Watson theorem.

2.2 $pn \to \{pp\}_s\pi^-$

The measurement of $A_{x,z}$ in this channel is very important since it probes directly the p-wave amplitudes. As shown in Table 2, two coefficients d_1 and d_2 are sizable in $A_{x,z}$ since they depend mainly on either p-waves squared or on p-d interference, terms not previously extracted.

$$\begin{aligned}
d_0 &= \mathrm{Re}\left[\left(M_p^S - \frac{M_p^D}{3}\right)\left(M_s^{P*} - \frac{1}{3}\left(M_d^{p*} + \frac{3M_d^{F*}}{5}\right)\right)\right],\\
d_1 &= \mathrm{Re}\left[\left(M_p^S - \frac{M_p^D}{3}\right)\left(M_p^{S*} + \frac{2M_p^{D*}}{3}\right) + M_s^{P*}\left(M_d^P - \frac{2M_d^F}{5}\right)\right.\\
&\quad \left. -\frac{M_d^P M_d^{P*}}{3} - \frac{M_d^P M_d^{F*}}{15} + \frac{2M_d^F M_d^{F*}}{25}\right],\\
d_2 &= \mathrm{Re}\left[2\left(M_p^S + \frac{M_p^D}{6}\right)M_d^{P*} + \frac{1}{5}\left(M_p^S - \frac{7M_p^D}{3}\right)M_d^{F*}\right],\\
d_3 &= \mathrm{Re}\left[M_d^P M_d^{P*} + \frac{M_d^{P*}M_d^F}{5} - \frac{6M_d^F M_d^{F*}}{25}\right].
\end{aligned} \tag{3}$$

The coefficient d_1, in particular, contains a large combination of p-waves squared in addition to the coefficient $\frac{1}{2}d_1(pp)$ from $pp \to pp\pi^0$. This provides additional justification for a simultaneous measurement of both reaction channels at the same laboratory kinetic energy. If both $d_1(pn)$ and $d_1(pp)$ are determined, one could directly extract the large combination of p-waves, with the only assumption being that the f-waves are small. Even if only the charged channel were measured, this non-trivial coefficient is ideal to test the PWA and to increase the accuracy in the extraction of the p-wave amplitudes. The coefficient d_2 can also play a role since it depends solely on the p-d interference terms. Therefore, assuming that d-waves are extracted from the π^0 channel, it provides access to p-waves. Thus, $A_{x,z}$ appears to be an excellent test of p-waves.

It should be noted that the coefficient d_0, although it depends on s-p interference, is numerically small due to cancellations. The coefficient d_3, which originates from the squares of d-wave terms, is the same in $pp \to pp\pi^0$ and $pn \to pp\pi^-$ up to contributions from f-waves. In spite of its relative smallness, this fact could be of use in the case of simultaneous measurements to test the importance of higher partial waves.

If one had very high quality data, one could also test explicitly the underlying assumption of the small coupling between ${}^3P_2-{}^3F_2$ by including the corresponding phases directly into the amplitude analysis.

Quantity	Predicted Value [μb/sr]
$d_1(pp)$	$-3.4(-1.2)$
$d_3(pp)$	1.7
$d_0(pn)$	0.6
$d_1(pn)$	-5.4
$d_2(pn)$	2.2
$d_3(pn)$	0.8

Table 2: Values of the coefficients d_i of Eq. (1) for $pp \to pp\pi^0$ and $pn \to pp\pi^-$. The number in brackets for $d_1(pp)$ is found after subtracting the redundant term determined from the slope of the unpolarised differential cross section.

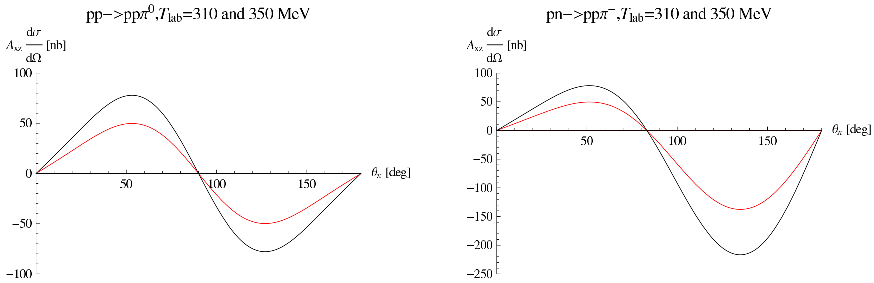

Figure 2: $A_{x,z} \cdot d\sigma/d\Omega$ for $pp \to \{pp\}_s\pi^0$ (left panel) and $pn \to \{pp\}_s\pi^-$ (right panel). Red curves correspond to the calculation at $T_{\rm lab} = 310$ MeV, whereas the black ones to that at $T_{\rm lab} = 350$ MeV. Squares of $d-$-waves are neglected in the calculations.

2.3 Ambiguity of the current PWA solution

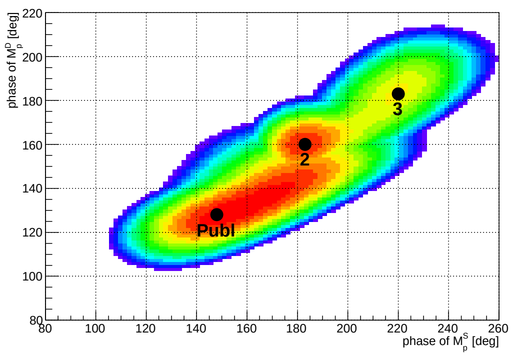

Figure 3: χ^2 as function of the phases of the $p-$wave amplitudes. The positions of the minima are marked, the published solution is denoted as “Publ”.

An extended study of the PWA fit properties revealed existence of several solutions satisfying the available data with close χ^2 values. The situation is demonstrated in Fig. 3. Here, the $s-$ and $d-$ wave amplitudes are fixed, predominantly by the π^0 production data, and for each combination of the phases of the M_p^S and M_p^D amplitudes, the best χ^2 value is plotted. The presently available data on the differential cross-section and A_y, as well as the newly measured spin-correlation coefficients $A_{x,x}$ and $A_{y,y}$ of the $\vec{n}\vec{p} \to \{pp\}_s\pi^-$ reactions, do not resolve this ambiguity. In contrast, as one see from Fig. 4, the $A_{x,z}$ spin-correlation coefficient is very sensitive to the choice of the solution and even very modest precision $A_{x,z}$ data would let one select one of the minima.

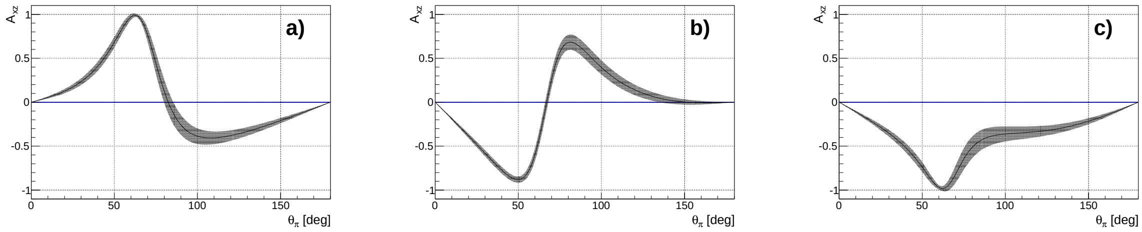

Figure 4: $A_{x,z}$ for $pn \to \{pp\}_s\pi^-$ at 350 MeV for the three PWA solutions shown in Fig. 3: a) the published solution, b) the solution "2", c) the solution "3".

2.4 Results of the measurement of $A_{x,x}$ and $A_{y,y}$ in $\vec{n}\vec{p} \to \{pp\}_s\,\pi^-$

The spin-correlation coefficients $A_{x,x}$ and $A_{y,y}$ of the quasi-free $\vec{n}\vec{p} \to \{pp\}_s\,\pi^-$ reaction were measured at ANKE in 2011 by using the vector polarised deuteron beam and the hydrogen polarised target, equipped with a long storage cell [22]. The main source of background in this measurement was the interaction of a beam particles with the aluminum storage cell walls. In order to obtain the shape of the background in the missing mass spectra, a dedicated measurement was made with the N_2 gas in the storage cell.

The $A_{y,y}$ results are shown in Fig. 5 in terms of the pion emission angle. As expected, $A_{y,y}$ is consistent with unity over the whole angular range. To reduce the uncertainty in the extraction of $A_{x,x}$, it was assumed that $A_{y,y} = 1$ and the analysis repeated, leading to the results shown in Fig. 6.

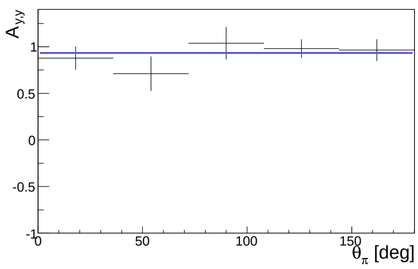

Figure 5: The spin-correlation coefficient $A_{y,y}$ for the $\vec{n}\vec{p} \to \{pp\}_s\,\pi^-$ reaction measured at 353 MeV (preliminary).

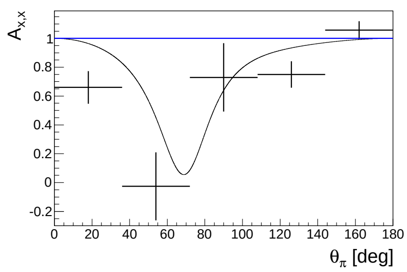

Figure 6: The spin-correlation coefficient $A_{x,x}$ for the $\vec{n}\vec{p} \to \{pp\}_s\,\pi^-$ reaction measured at 353 MeV (preliminary).

For the $np \to \{pp\}_s\pi^-$process, $(1 - A_{x,x}) \cdot d\sigma/d\Omega \sim |\delta|^2 \sin^2\vartheta_\pi$, where $|\delta|^2$ is the square of one of the p-wave production amplitudes that is linked to the $4N\pi$ contact interaction [19]. The differential cross section and the preliminary spin-correlation data give $(1 - A_{x,x}) \cdot d\sigma/d\Omega(90^\circ) = (96 \pm 25)$ nb/sr. This is not inconsistent with the results of the partial wave analysis [21], which predicts a value of 52 nb/sr.

This measurement yielded as well a new determination of the differential cross-section and A_y for $pn \to pp\pi^-$ reaction. These results, obtained in a dp experiment, provide a good cross-check for the measurements with the proton beam. The newly obtained cross-section and A_y are completely consistent with the published data. The results of the double polarization measurement are being prepared for publication in PRC.

2.5 Conclusions

From the point of view of experiment, the investigation of both these channels is a very challenging task. The main obstacle in the π^0 case is the limited azimuthal acceptance of the setup, making it hard to measure the up-down count rate asymmetry. Although the value of $A_{x,z}$ in this channel is predicted to be large, only a part of it provides new information for the PWA, that raises the precision requirements for the experiment. Nevertheless, such a measurement can provide a good test of the Watson theorem applicability for the weakly coupled $^3P_2$–$^3F_2$ channels.

Due to the Fermi motion, the problem of azimuthal acceptance is less important in the π^- case, although the necessity to detect an extra particle in the quasi-free kinematics complicates the measurement significantly. A measurement of $A_{x,z}$ in the π^- channel is extremely interesting since it can resolve the present ambiguity in the PWA solutions for the p-waves. Taking this into account, we consider this experiment a first priority for the pion production programme at ANKE.

3 Detection system for the new measurements at ANKE

After completing by the COSY crew the first part of the commissioning of the new solenoid using the EDDA detection system as a polarimeter, the machine development can be initiated for the ANKE experiment. For safety reasons, the STT detectors should be installed in the target chamber only if the beam orbit is optimised and the losses on the storage cell walls at injection and during acceleration are small. We plan to use the openable cell for new measurements [22]. The four telescopes will be mounted on the left and right sides of the ANKE target chamber and installed as close as possible to each other (see Fig. 7).

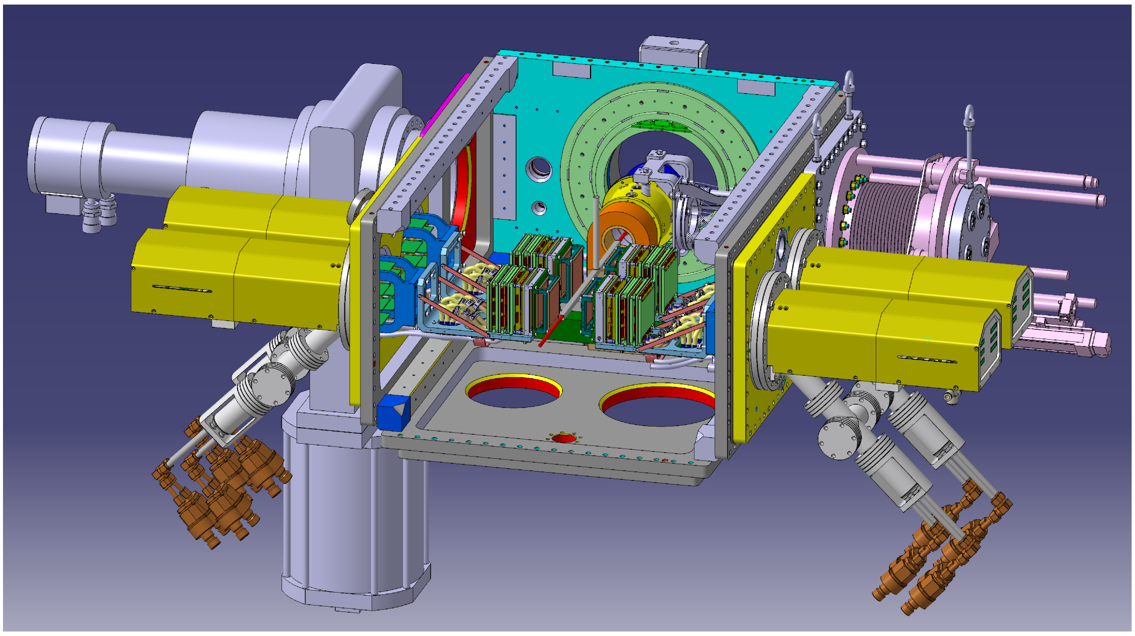

Figure 7: A scheme of the ANKE target chamber showing the storage cell surrounded by the four STT detectors.

The deuterium atomic beam source (ABS) has been commissioned at ANKE in the

June 2012 beam time [23]. The results of the commissioning run as well as the status of the openable cell tests will be presented during the PAC session.

4 Polarimetry with a longitudinally polarised beam at 353 MeV

The primary goal of the proposed experiment is to study the possibilities for determining the longitudinal beam polarisation in a double-polarised experiment at ANKE.

The beam or target polarisation, $P_y(Q_y)$, when the spin is oriented perpendicular to the COSY plane, can be determined through the use of the nuclear reactions for which the vector analysing power is known. Obvious candidates at 353 MeV are the quasi-free $pn \to d\pi^0$ reaction and pp elastic scattering. In both cases, A_y has been measured with good precision at nearby energies and the SAID PWA provides a very good description of these data. Due to the absence of a left-right symmetry in the experimental setup, one has to reverse the directions of the spin for both beam and target in order to measure the experimental asymmetry. To determine the target polarisation, one can use the unpolarised average over the beam spin modes, and similarly for the beam polarisation. This method has been successfully applied during the measurement of the vector analysing power in the $\vec{p}n \to \{pp\}_s\pi^-$reaction at 353 MeV [21].

The main purpose of the Siberian snake would be to rotate the spin vector from the vertical direction to the horizontal plane [3]. This is achieved by turning on the snake adiabatically. After that, the beam should arrive at the snake position transversely polarised in the horizontal plane and the snake should rotate it by 180° about the beam direction (z-axis). The spin vector of the circulating beam will be rotating then in the horizontal plane and become longitudinally aligned at the ANKE target position. It is generally accepted that the spin-rotation efficiency with the snake can be calculated very reliably [24, 25], one can control this in the experiment by measuring a left-right asymmetry in two STT telescopes. Thus, knowing the value of P_y before the rotation, one can calculate the value of P_z when the snake is switched ON. After the measurement with the longitudinal polarisation, the initial vertical spin direction can be restored and the beam polarisation can be measured once again to check for possible polarisation loss. The proposed sequence is shown schematically in Fig. 8. An analogous idea of a three-flat-top super-cycle was exploited at COSY to export the beam polarisation from an energy where calibration data exist to the energy required in an experiment [26, 27, 28]. Although similar in spirit, the two procedures involve completely different operations on the beam.

Another way of defining the longitudinal beam polarisation would be to use the available high precision IUCF data on the spin-correlation parameters $A_{x,z}$ and $A_{x,x}$ in pp elastic scattering at 350 MeV [29] (see Fig. 9). One cause for concern here is the accuracy of the quasi-free approximation at the small momentum transfers at which we can detect the reaction. One of the goals of the beam time is to explore this possibility and establish the procedure of polarimetry with nuclear reactions for the longitudinally polarised beam. As a valuable by-product, we intend to obtain the data on the spin-correlation parameters in the quasi-free $pn \to d\pi^0$ and $pn \to pn$ processes and $pd \to pd$ elastic scattering.

5 Studies of the background conditions and optimisation of the cell size

The cross-section for $pn \to \{pn\}_s\pi^-$ at 353 MeV falls as low as $d\sigma/d\Omega = 51 \pm 13$ nb/sr. The background conditions in a double-polarised measurement of this process is therefore a crucial issue that may decide the feasibility of the experiment at ANKE. The main source

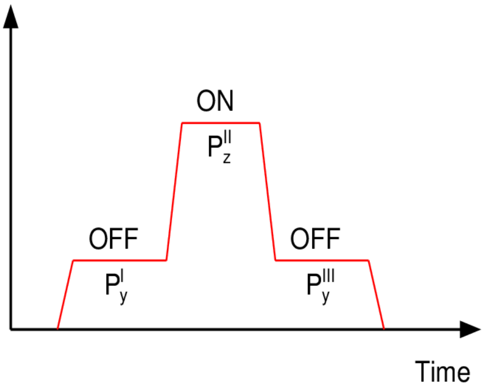

Figure 8: The super-cycle for the determination of the longitudinal component (P_z - snake 'ON') of the initially transversely polarised (P_y - snake 'OFF') COSY beam at a fixed energy (353 MeV). In the ideal case we should expect that $P_y^{\mathrm{I}} = P_y^{\mathrm{III}}$.

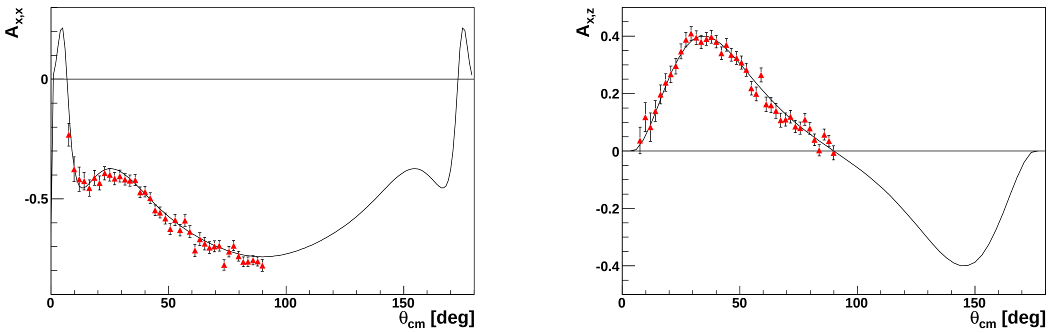

Figure 9: Spin-correlation coefficients $A_{x,x}$ (left panel) and $A_{x,z}$ (right panel) in pp elastic scattering at 353 MeV. The lines represent the results of SAID PWA; the IUCF data at 350 MeV [29] are shown with error bars.

of background is the interaction of the beam particles with the walls of the storage cell and the intensity of this depends on the cell's transverse size. On the other hand, these dimensions should be made as small as possible in order to increase the target gas density.

One of the goals of the proposed measurement is to decide the optimal size of the cell. This will require an accurate beam development to avoid the beam diverging during the acceleration. The conclusions about the cell size will be based on the direct measurement of the size of the accelerated beam and on the observed background count rates. Both these factors can be predicted only very provisionally and their measurement is clearly necessary.

Due to the Fermi motion in the deuteron, the effective energy of the quasi-free pn scattering, defined as the neutron beam energy that would give the true $\sqrt{s}$ in free pn collisions, scans the interval $T_{\text{free}} = 310 - 390$ MeV in our conditions. To limit this range, one has to reconstruct both the spectator proton energy and its direction. Protons with energies $3-7$ MeV are detected in the first two layers of the STT, and their trajectories can be reconstructed. To use the slower protons, which stop in the first STT layer, one needs to know the reaction vertex, which might be fixed by tracing the π^- particles through all three STT layers. Detecting these events would more than double the statistics collected. However, use of the first STT layer alone makes the requirements for the background conditions even more severe. The feasibility of the pion trajectory reconstruction and the selection of spectator particles with energies below 3 MeV has to be proved experimentally.

6 Beam-time request and time line

For the measurements described, we request **TWO weeks** of beam time with a longitudinally polarised proton beam at an energy of $T_p = 353$ MeV.

The main goals of the beam time are (*i*) to demonstrate the validity of the proposed polarimetry techniques using the complex ANKE system, and (*ii*) to study the background conditions in an experiment with an openable storage cell. It is necessary to learn how to handle data on pion production using the longitudinally polarised proton beam provided by the Siberian snake located at the 'low-β' section of the PAX interaction point.

Based on the experience that we will gain in collecting data on the $\vec{p}\vec{n} \to \{pp\}\pi^-$ reaction with longitudinally/(or) and transversely polarised beams, we will be able to estimate accurately the time required for the measurement of the $A_{x,z}$ parameter in this process. A dedicated Beam-time Request will then be submitted to the next COSY PAC.

The time line foreseen for the activities listed above is as follows:

- The delivery and installation of the Siberian snake magnet (solenoid) is expected in Spring 2013.
- The first commissioning ('running-in') is planned during the summer shutdown 2013.
- It should be possible to use the preparatory **beam time requested in this document** after the snake commissioning with EDDA, in the second half of 2013.
- A pion production run at ANKE should be possible in 2014.

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