Proposal

Commissioning and Initial Research with the Polarised Gas Target at ANKE

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Abstract

The proposal concerns the commissioning of the polarised internal target at ANKE and the initial research phase. The installation consists of an atomic beam source feeding a storage cell and a Lamb–shift polarimeter. The anticipated physics programme of single and double–polarisation measurements is briefly outlined. The status of the different components is discussed and a time schedule is presented for the target implementation. For the activities outlined in the proposal, **three weeks** in total are requested. The **first week** is mainly needed to commission the polarised internal target, while the last **two weeks** are required to determine the target polarisation and the target density using $d\vec{p}$ elastic scattering.

1 Introduction

The polarised internal hydrogen and deuterium storage–cell target (PIT) [1] will be installed at the ANKE spectrometer in the summer of 2005. Three weeks have been foreseen by the COSY infrastructure group for the preparatory work and this should be carried out within the framework of the available maintenance weeks. The PIT and the cluster target could be exchanged later, within one of the maintenance weeks. Following these three weeks, one week of beam time is required for PIT commissioning at ANKE. The Lamb–shift polarimeter (LSP) [2] will be used as a tool to adjust the transition units of the polarised atomic beam source (ABS) [3] that are utilised to feed the storage cell. Furthermore, two weeks of COSY–deuteron beam are requested to achieve the main goal of this proposal, *i.e.* to measure the nuclear polarisation of the target and its density by using elastic $d\vec{p}$ scattering. These measurements also serve to calibrate the LSP. After these six weeks of installation, commissioning, and initial research, the PIT and the LSP can be moved to their off–beam position outside the COSY ring, depending on the ANKE and COSY experimental schedule.

The results achieved during the first phase of initial research with the PIT at ANKE will constitute the experimental basis for the future programme of single and double–polarisation measurements at ANKE. It is expected that this will include:

- Studies of the small momentum transfer charge exchange in the $\vec{d}\vec{p}$ reaction with the forward emission of two protons [4]. The first (approved) stage with an unpolarised target will be carried out early in 2005, with the aim of determining the magnitudes of the three np charge–exchange spin–flip amplitudes out to $\theta_{cm} \approx 15°$, a region over which the one–pion–exchange amplitude varies significantly. The current status of the deuteron beam polarimetry, essential for this purpose, is described in ref. [5], where it is also shown that, even in a short test measurement, we are already at the precision of the np charge–exchange database. To determine the relative phases of these amplitudes will entail measurements of spin–correlation parameters, thus requiring also the polarised target. It is important to stress that such np data are almost non–existent above the Los Alamos energy of 800 MeV.

- The polarised deuteron beam only allows the investigation of the np charge–exchange amplitudes up to a maximum COSY energy of $\frac{1}{2}T_d \approx 1.1$ GeV. It is suggested to extend this range up to about 3 GeV by using a polarised proton beam incident on a polarised deuterium target and detecting TWO slow protons in an array of solid state spectator telescopes [6]. The interaction vertex is then very well located within the long target, making it unnecessary to measure the fast neutron in the ANKE facility to identify the $\vec{d}(\vec{p}, pp)n$ reaction. Events of this type have already been identified within the very limited angular acceptance of a single telescope [7].

- Simultaneously with the charge–exchange investigation we would, however, measure a fast proton in ANKE in coincidence with one slow (spectator) proton in the silicon telescope array. This would allow measurements of the elastic $\vec{p}\vec{n} \to pn$ polarisation observables in the forward cone below $\theta_{cm} \approx 30°$. The combination of this and the previous two items would have a major impact on the isospin–zero nucleon–nucleon phase–shift determinations, for which data are sadly lacking above 800 MeV. As a by–product one will also obtain data on inclusive pion production in polarised proton–neutron collisions, $\vec{p}\vec{n} \to \pi X$.

- We have already investigated the high–momentum–transfer deuteron breakup reaction, $pd \to (pp)n$, with an unpolarised beam and target in order to determine the differential cross section [8, 9, 10]. Using a polarised proton beam, we have also obtained the angular distributions of the analysing power at $T_p = 500$ and 800 MeV [11]. Considerable clarification of the dominant reaction mechanism will be obtained through the measurement of a combination of the deuteron tensor analysing power and the transverse $\vec{p}\vec{d}$ spin–correlation parameter [12].

- The acceptance of ANKE for detecting the production of a heavy meson X in proton–proton collisions *via* the missing mass is very good. Unpolarised differential cross sections are, however, insufficient to identify the dominant reaction mechanism and proton analysing powers are generally small. We therefore envisage embarking on a series of studies of double–polarisation observables in $\vec{p}\vec{p} \to pp\,X$ [13]. Of particular interest would be a comparison of the spin correlations in $\vec{p}\vec{p} \to pp\,\omega/\phi$ to investigate the OZI rule [14] in well–defined spin states, rather than in just some unpolarised average [15, 16].

  The spin–isospin selection rules are very different in $\vec{p}\vec{n} \to dX$ and we would wish to extend our programme to these channels as well.

- The reaction $pp \to pp\pi^0$, away from threshold, but in the region of small pp excitation energies is a good test bed for pion–nucleon physics to parallel that of $pp \to d\pi^+$. We have already shown that the unpolarised reaction can be well identified in ANKE at small production angles [9] and this will be complemented by measurements of the proton analysing power and, in particular, the transverse spin correlation, which should be particularly informative. With a polarised deuterium target it will also be possible to extract the third independent isospin combination, *viz.* $\vec{p}\vec{n} \to pp\pi^-$.

Once the experimental goals of the present proposal have been achieved, we will submit a dedicated proposal for single and double–polarisation measurements at ANKE to the COSY PAC.

Future Perspectives: The proposal outlined here to utilise a PIT for research in an ion storage ring is of relevance also for the future Facility for Antiproton and Ion Research (FAIR) at GSI Darmstadt. A Letter–of–Intent for spin–physics experiments has recently been submitted by the PAX collaboration [17] and this suggests employing a polarised antiproton beam incident on a polarised internal storage cell target. A beam of polarised antiprotons would enable new experiments, such as the first measurement of the transversity distribution of the valence quarks in the proton, a test of the predicted opposite sign of the Sivers–function, related to the quark distribution inside a transversely polarised nucleon, in Drell–Yan production as compared to semi–inclusive deep–inelastic scattering, and a first measurement of the moduli and the relative phase of the time–like electric and magnetic form factors $G_{\mathrm{E,M}}$ of the proton [17]. It is suggested to polarise antiprotons through the spin–dependent interaction in an electron–polarised hydrogen gas target in a separate antiproton polariser ring [18]. The polarising process is based on spin transfer from the polarised electrons of the target atoms to the orbiting antiprotons [19, 20, 21].

- For the development of such an antiproton polariser ring, a direct measurement of the electron to proton spin–transfer cross section at COSY, with the goal to confirm the theoretical prediction [21], would constitute an important milestone.

2 Status of the PIT and LSP development

The new large–volume target chamber, the differential pumping system in the ANKE section, two additional beam–position monitors in front of the storage–cell and between the ANKE dipole magnets D2 and D3, and additional vertical beam steerers have already been installed in order to facilitate the use of the PIT. The ABS and the LSP are ready for installation. In October 2004 they will be transferred from the laboratory to their off–beam position in the COSY hall outside the COSY tunnel. The ABS will there be mounted on a new bridge, designed to support it at the in–beam position above the ANKE–target chamber. The LSP will be mounted on a separate support, designed taking into account the spatial boundary conditions in the target area and the movement of both the D2 dipole magnet and the target chamber. All the supply units for the ABS and the LSP, as well as the slow–control system, will be mounted on a common transport platform. An additional vacuum chamber of dimensions identical to those of the ANKE–target chamber has been produced and this allows the necessary preparatory tests in the off–beam position. A very limited number of crane movements is thus required to transfer the complete setup to the ANKE position. Adjacent to the ANKE target place, an elevated support has been installed, which will carry the supply platform. Figure 1 shows the setup in the in–beam

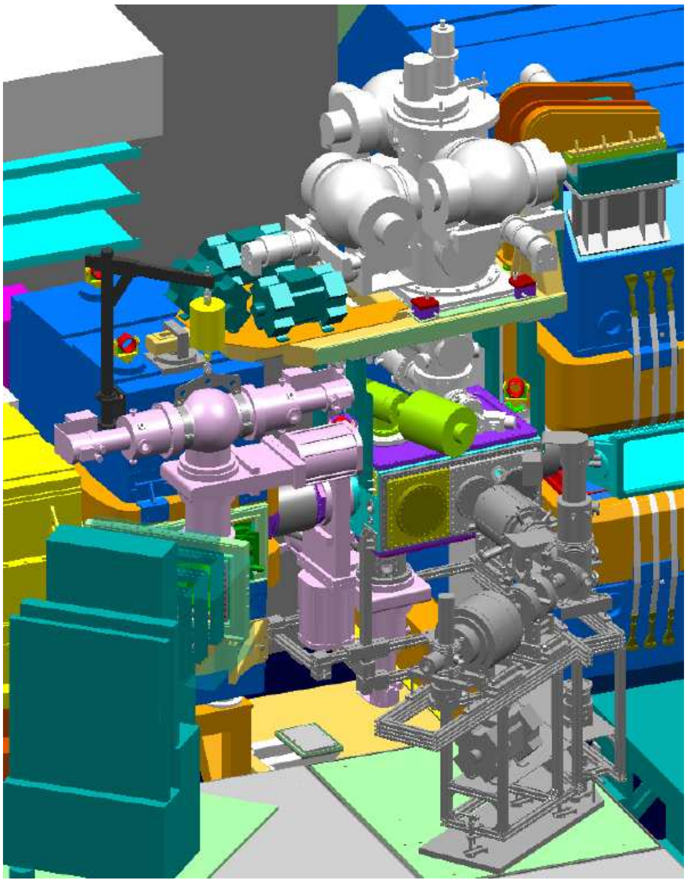

Figure 1: Polarised Internal Target at the in–beam position at ANKE.

position, whereas the off–beam setup is shown in Fig. 2.

The measurements to study the COSY–beam properties at the ANKE target, *i.e.* at the storage–cell position, and to determine the lateral dimensions for an optimised storage–cell have been started with the setup shown in Fig 3. The external positioning control, which is part of the PIT slow–control system, allows one to centre different diaphragms and prototype cells onto the COSY beam axis and to move them stepwise for beam cross section and lifetime studies. According to our preliminary results, a cell tube of about

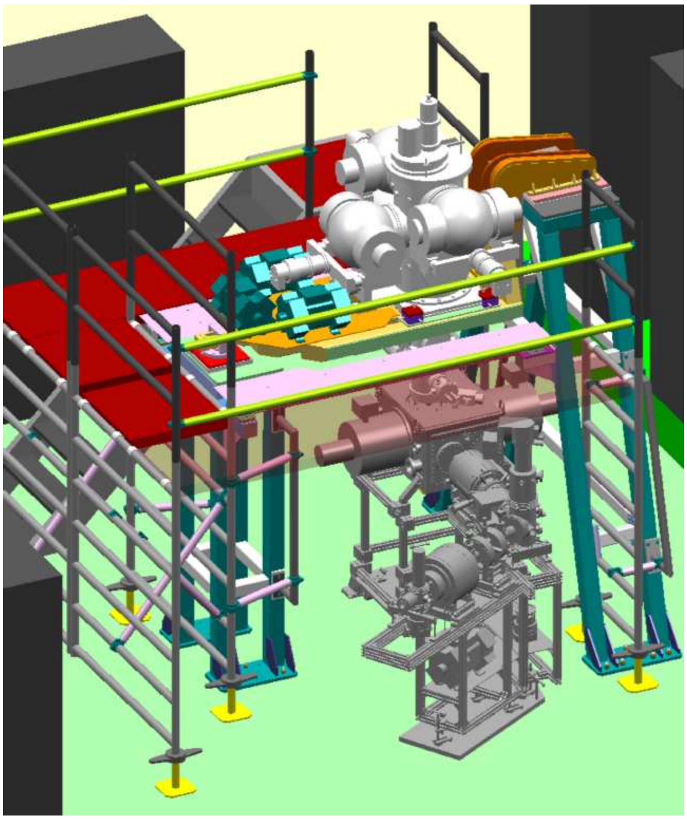

Figure 2: Polarised Internal Target installation at the off–beam position.

15 mm diameter (and about 350 mm length) can be installed at the beam. However, due to the fact that these measurements had to be done without dedicated COSY beam optimisation, and in view of the strong dependence of the target density upon the lateral extension of the cell tube, further measurements are needed. These studies will therefore be continued at the beginning of 2005 during the one week of beam time allocated for that purpose by the 28^{th} PAC, in April 2004. In the framework of these measurements, the calibrated supply system for unpolarised gases will be utilised to feed the storage cell for investigations of *e.g.* beam heating effects and for measurements of the pressure distribution in the section in and around the ANKE target chamber. Unlike the standard methodology, based on comparisons with known scattering cross sections, the density of the polarised gas target can also be inferred by comparison with detector rates obtained with a calibrated unpolarised flux of hydrogen gas admitted into the centre of the storage cell. This method is described in detail in ref. [22].

3 Time schedule

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

1. The three maintenance weeks, needed for the preparatory work and installation of the PIT components and the LSP, according to the time estimate by the COSY team and the participating contributors of Zentralabteilung Technologie, should come <u>before</u> the beginning of the summer school vacations in Northrhein–Westfalia. [Following strong requests to the infrastructure division, maintenance weeks are usually not

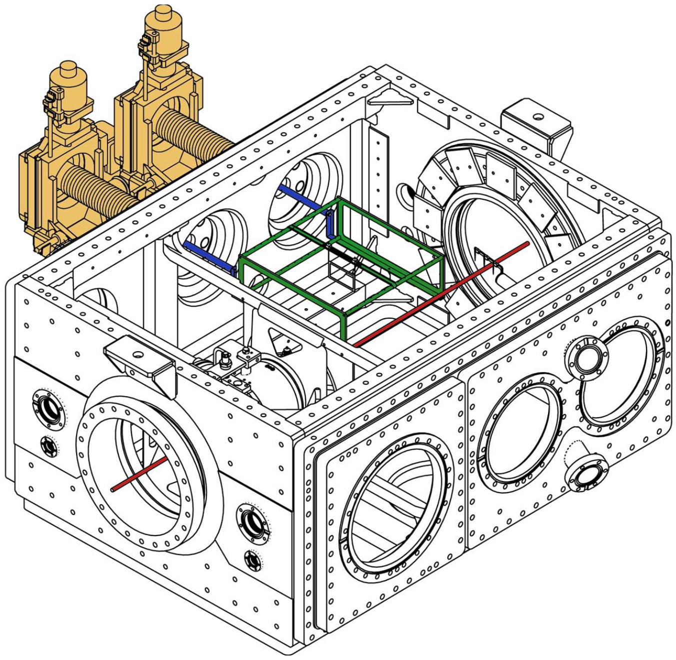

Figure 3: Setup of the movable support for the storage cell inside the new target chamber at ANKE.

scheduled during this period.] Thus the calendar weeks 23 to 25 (June 6 to 26) or 24 to 26 (June 13 to July 4) would be favoured.

2. One week for commissioning of PIT and LSP and tuning of the ABS should directly follow the three maintenance weeks, which means that this week should lie in calendar week 26 or 27. The commissioning and tuning work necessitates temporary ramped and static fields of the ANKE dipole magnets and also short periods of proton or deuteron beam in COSY.

3. The above week should be followed by about six weeks, available for the implementation of possible small modifications at the PIT or the LSP. These six weeks should be given to experiments at any installation but ANKE or at ANKE, if the required installations, *e.g.* the PIT itself, do not collide with these other experiments. Such a solution would allow for the ABS and the LSP to remain mounted at the ANKE target chamber since there would be no reason to move the PIT to the off–beam position. The support of the storage cell within the target chamber can be moved to a position which avoids interference with the COSY beam operation. During these six weeks, access for short periods of time to the ANKE target area should be made possible.

4. Following the six weeks, given to other experiments, two weeks are requested for the initial research with the PIT. They would lie around end of August/beginning of September 2005. The main goal is to accomplish a measurement of the target performance, *i.e.* target polarisation and target density. A suitable reaction to measure the target density is $d\vec{p}$ elastic scattering. As shown in Fig. 4, the analysing power has been well studied in the angular range representing the ANKE acceptance [23].

   Once the target polarisation has been determined, the data sample obtained can be used to derive the analysing power of the charge–exchange reaction $d\vec{p} \to (pp)n$.

However, experience gained during the short test experiment with a polarised deuteron beam and a hydrogen target [5] has shown that the acceptance of ANKE is such that several reactions will be recorded simultaneously and among these will for example be quasi–free $n\vec{p} \to np$ and $n\vec{p} \to d\pi^0$, both with a fast *spectator* proton, and $d\vec{p} \to {}^3\mathrm{He}\,\pi^0/\,{}^3\mathrm{H}\,\pi^+$.

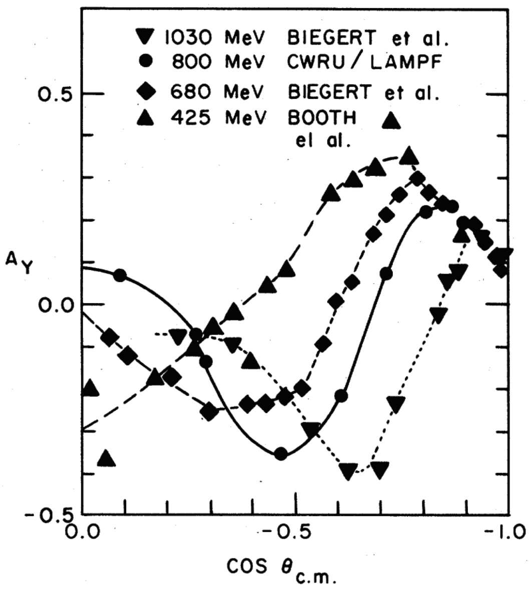

Figure 4: Analysing power data for $d\vec{p}$ elastic scattering. Here the ANKE acceptance ranges from $\cos\theta_{\mathrm{cm}} \approx -0.77$ to -0.98.

5. Following these two weeks of beam time, one maintenance week is mandatory in order to move the ABS and the LSP back to the off–beam position. Both are needed for experiments in the framework of another project (ISTC), which deals with the measurement of the nuclear polarisation of recombined hydrogen and deuterium molecules [24]. If the removal of PIT and LSP takes less than a week, the time saved could be distributed to the following experiment.

4 Beam–time request

For the activities outlined under items 2 and 4 in Sec. 3, **three weeks** in total are requested:

- The **first week** (item 2) is mainly needed to commission the polarised internal target at ANKE.
- The main goal of the last **two weeks** (item 4) is to determine the target polarisation and the target density using $d\vec{p}$ elastic scattering. The first week and the other two should be separated by about six weeks.

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