PAX-Note-3/2006

Towards Spin Filtering Experiments at COSY and AD

($\mathcal{PAX}$ Collaboration)

Luca Barion, Paolo Lenisa, Alexander Nass, and Frank Rathmann

Jülich, June 23, 2006

PAX-Note-3/2006

Towards Spin Filtering Experiments at COSY and AD

($\mathcal{PAX}$ Collaboration)

Abstract

This note is presented in form of a structured list of tasks, which is meant as a starting point for further discussions. In Sec. 1, we discuss a few organizatorical issues (phone-meetings, parameter lists, request for written notes) and the responsibilities within the collaboration (coordinators, deputies, and local contacts). In Sec. 2 we discuss the experimental program, addressing the theoretical expectations for the polarization buildup with protons and antiprotons (Sec. 2.4), and beam and target polarimetry issues (Sec. 2.5). In Sec. 3, a conceptual layout of the experimental setup for the filtering studies at COSY and at the AD is presented. Section 4 discusses the design of the low-β section. Detailed lattice studies for the AD and for COSY have to be carried out (Sec. 5). Beam lifetime studies at COSY need to be performed (Sec. 6), and beam diagnostics tools such as beam position and beam profile monitors are required both for COSY and AD (Sec. 7). Aspects relevant to the polarized target, including storage cell, holding field configurations, and the vacuum system need to be elaborated (Sec. 8). The detector system (Sec. 9), as we envision it now, should be based on the present development of the Silcon Tracking Telescopes of ANKE.

Our aim is to have a full proposal for the filtering studies at COSY ready for the Fall 2006 meeting of the COSY Program Advisory Committee.

Contents

1 Organizatorical Issues

1.1 Meetings and Phone-Conferences

We would like to have a regular weekly PAX group meeting, which we foresee to be held on Tuesdays 10:00 to 11:30. Outside members should participate via a phone conference connection. We will provide the members of the coordination board with a phone number to dial up together with a verification code number before the first meeting. We envision to have documents, drawings etc. that are necessary for the discussions during a meeting to be available online from the PAX website. In order to have this material available at the meeting, the documents should be sent by email to Luca Barion (`l.barion@fz-juelich.de`) one day before the meeting.

1.2 Parameter List

A parameter list is kept to have always available the current status of all parameters relevant to the experiment. This list will be started by Sig Martin, and will later be managed by Luca Barion. The parameter list should contain the primary parameters of the experiment. A clear prescription of secondary parameters, derived from the primary ones should be given. If necessary, a specific parameter should reference to a separate PAX note, where the context and meaning of the parameter is explained.

1.3 PAX Notes

We request that the collaborators provide written PAX-Notes in form of a pdf-file about all items that concern the realization of the experiment, software development, etc. Each note should be clearly written, and should provide information about the subject, author, and date on the front page together with the note number (e.g. PAX-note-3/2006). Each PAX-note should have a short abstract. These notes should be sent to David Chiladze (`d.chiladze@fz-juelich.de`), who will make them available in the internal section of the PAX web-site, which is available at `www.fz-juelich.de/ikp/pax`, David will also announce by email to the PAX general mailing list (`pax@fz-juelich.de`) that a new note is available. The PAX internal section is password protected.

1.4 Electronic mail archive

We have provided the following email addresses for PAX to allow for more specific discussions in the subgroups. Some access restrictions apply to some of the mailing lists.

PAX Email Addresses	**Mailing List**	**Access to email archive**
pax@fz-juelich.de	General	All PAX members
pax-board@fz-juelich.de	Coordination Board	Coordination Board Members
pax-leader@fz-juelich.de	Group Leader	PAX Group Leaders
pax-accel@fz-juelich.de	Accelerator Group	All PAX members
pax-analysis@fz-juelich.de	Simulations and Data Analysis Group	All PAX members
pax-aquisition@fz-juelich.de	Data Aquisition Group	All PAX members
pax-detector@fz-juelich.de	Detector Group	All PAX members
pax-slowcontrol@fz-juelich.de	Slow Control Group	All PAX members
pax-target@fz-juelich.de	Target Group	All PAX members
pax-theory@fz-juelich.de	Theory Group	All PAX members

All PAX members will soon be informed about the subscription procedures for these mailing lists. We will soon start to provide an electronic archive for the emails sent to the above addresses, which will be accessible by all members of the collaboration. This archive will be administrated by Luca Barion (l.barion@fz-juelich.de).

1.5 Responsibilities within PAX

Given below in Table 1 is a list of coordinators for the various subgroups.

	Spokespersons: P. Lenisa and F. Rathmann					
	Technical Coordinator: P. Lenisa and F. Rathmann (until Technical Coordinator is named)					
Target + BRP	**Detector**	**Slow Control**	**DAQ**	**Simulation and Data Analysis**	**Accelerator**	**Theory**
Coordinator A. Nass	Coordinator R. Schleichert	Coordinator H. Kleines	Coordinator S. Trusov	Coordinator M. Nekipelov	Coordinator B. Lorentz	Coordinator K. Nikolaev
Deputy M. Capiluppi	Deputy M. Contalbrigo	Deputy G. Tagliente	Deputy P. Wüstner	Deputy G. Macharashvili	Deputy A. Lehrach	Deputy J. Haidenbauer [a]
Local Contact A. Nass	Local Contact R. Schleichert	Local Contact H. Kleines	Local Contact P. Wüstner	Local Contact M. Nekipelov	Local Contact B. Lorentz	Local Contact J. Haidenbauer

Table 1: PAX Organization and Coordination.

[a] to be confirmed

2 Experimental Program

In this document, we discuss the basic experimental objectives of the PAX filtering studies. For further reading, please consult the two Letters-of-Intent for spin filtering studies at COSY [1] and at the AD [2]. The physics program of PAX is described in the PAX Technical Proposal [3].

2.1 Filtering Studies at COSY

At COSY we want to clarify how an initially unpolarized beam is polarized. Different predictions exist how this process actually takes place. In particular the role of the polarized electrons in the polarized gas target for the polarization buildup should be clarified using proton beams at COSY. The studies at COSY should result in a fully commissioned experimental setup for the AD experiments.

2.2 Filtering Studies at the AD

These studies basically aim at the determination of the spin-dependent total hadronic $\bar{p}p$ cross section in the enery range of about 50 MeV to 200 MeV. Based on these measurements, we want to provide clear predictions about the degree of antiproton beam polarization which one can expect from a dedicated Antiproton Polarizer Ring.

2.3 Time Table

Below we give a time table for the spin filtering studies at COSY and at the AD.

2006–2008	Design and construction phase.
Fall 2006	Proposal to COSY Program Advisory Comittee.
Summer 2008	Installation of new low–β section, PIT, BRP, and detection system at TP1 of COSY.
Fall 2008	Full Proposal to SPS Committee at CERN.
Fall 2008 until Summer 2009	Polarization buildup studies at COSY.
Fall 2009	Installation of all components at the AD, including the Snake.
Spring 2010	2 months of beam time at the AD with transverse target polarization.
Fall 2010	2 months of beam time at the AD with longitudinal target polarization and the Siberian Snake.

2.4 Theoretical Expectations

2.4.1 Polarization buildup at COSY

Topic	**Responsible**
1. The Meyer-Horowitz predictions for transverse and longitudinal buildup as function of beam energy for a fixed polarized Hydrogen gas target containing polarized electrons are available [4, 5].	Misha Nekipelov
2. The calculations based on the Budker-Jülich approach [6, 7] are available for the transverse polarization buildup only. The longitudinal case needs to be treated as well.	Kolya Nikolaev Feja Pavlov

2.4.2 Polarization buildup at AD

Topic	**Responsible**
1. Predictions for antiprotons up to now are available only from J. Haidenbauer for two different models [8, 9]. It would be good to get some additional input e.g. from Rob Timmermanns models.	Johan Haidenbauer, Frank Rathmann

2.4.3 Compilation of Theoretical Estimates

Topic	**Responsible**
1. We need a complete compilation of these predictions from the Meyer-Horowitz and from the Budker-Jülich approach into one PAX note for later reference.	Misha Nekipelov, Kolya Nikolaev, Feja Pavlov, Alexander Milstein, and Vladimir Strakhovenko
2. We should also assess the situation with a polarized deuterium target. Therefore, predictions for the polarization buildup by spin filtering using polarized deuterons need to be generated. A pilot filtering experiment with polarized deuterons in the target could be also done at COSY.	Kolya Nikolaev, Feja Pavlov, Alessandro Drago, Johann Haidenbauer

2.5 Beam Polarimetry for Filtering with a Polarized Hydrogen Target

We first give an introduction into the polarimetry issue for the beam and target polarizations using *pp* elastic scattering, including some discussion of which method can be applied in which situation. The Breit-Rabi polarimeter (BRP) will be included in the experimental setup.

2.5.1 Elastic *pp* observables

In a right-handed coordinate system with z pointing along the beam direction, y vertical up, and x to the left, the *pp* elastic spin-dependent cross section for polarized beam with components $P_{x,y,z}$ and polarized target with components $Q_{x,y,z}$ in units of the unpolarized cross section σ_0 is e.g. given in ref. [10]

$$\begin{aligned}\sigma/\sigma_0 = 1 \quad &+ \quad A_y[(P_y + Q_y)\cos\phi - (P_x + Q_x)\sin\phi] \\ &+ \quad A_{xx}[P_xQ_x\cos^2\phi + P_yQ_y\sin^2\phi + (P_xQ_y + P_yQ_x)\sin\phi\cos\phi] \\ &+ \quad A_{yy}[P_xQ_x\sin^2\phi + P_yQ_y\cos^2\phi - (P_xQ_y + P_yQ_x)\sin\phi\cos\phi] \\ &+ \quad A_{xz}[(P_xQ_z + P_zQ_x)\cos\phi + (P_yQ_z + P_zQ_y)\sin\phi] \\ &+ \quad A_{zz}P_zQ_z\end{aligned} \tag{1}$$

The azimuthal angle ϕ is measured in clockwise direction starting from the x-axis. Since beam and target are identical, no distinction needs to be made between beam and target analyzing power. If one assumes $P_x = P_z = 0$, which is to a good approximation the case in a storage ring with transverse beam polarization, Eq. (1) simplifies to

$$\begin{aligned}\sigma/\sigma_0 = 1 \quad &+ \quad A_y[(P_y + Q_y)\cos\phi - Q_x\sin\phi] \\ &+ \quad A_{xx}[P_yQ_y\sin^2\phi + P_yQ_x\sin\phi\cos\phi] \\ &+ \quad A_{yy}[P_yQ_y\cos^2\phi - P_yQ_x\sin\phi\cos\phi] \\ &+ \quad A_{xz}P_yQ_z\sin\phi]\end{aligned} \tag{2}$$

In Fig. 1, we show for the COSY injection energy of $T_p \approx 40$ MeV the differential cross section $\frac{d\sigma}{d\Omega}$, analyzing power A_y, the spin correlation parameters A_{xx}, A_{yy}, A_{zx}, and A_{zz} as function of θ_{lab}. The *pp* analyzing power is small at injection energy (Fig. 1). Therefore, the resulting transverse beam polarization after spin filtering needs to be measured using spin correlations A_{xx} or A_{yy}. For the longitudinal beam polarization P_z after filtering, the spin correlation A_{xz} turns out to be small as well, thus in this case A_{zz} should be used. From a measurement with transverse beam and target polarizations, we would determine the asymmetry $\varepsilon = P_y \cdot Q_y \cdot A_{xx} \cdot \langle\sin^2\phi\rangle$ and $\varepsilon = P_y \cdot Q_y \cdot A_{yy} \cdot \langle\cos^2\phi\rangle$, while with both aligned longitudinally, the asymmetry $\varepsilon = P_z \cdot Q_z \cdot A_{zz}$ would be determined[1]. The determination of the beam polarization after filtering thus in any case requires to know the target polarization.

The measurement of the target polarization requires acceleration of the beam to energies above 800 MeV, where stochastic cooling can compensate the beam heating and allow us to operate the storage cell target in a low background situation. The analyzing power A_y

[1]The averages over the trigonometric functions determined by the azimuthal detector acceptance are denoted by e.g. $\langle\cos\phi\rangle$

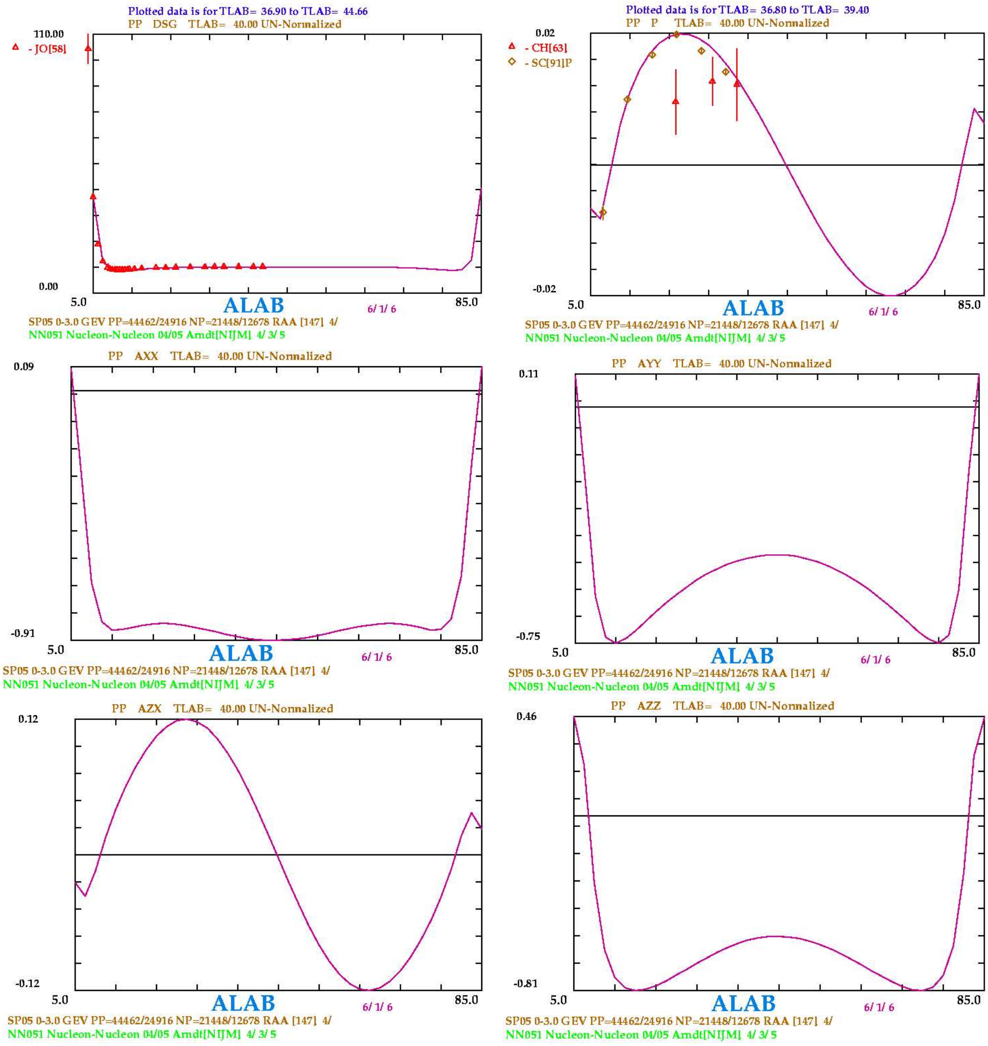

Figure 1: Differential cross section (top row, left panel), analyzing power A_y (top, right), and spin correlation parameters A_{xx} (middle, left), A_{yy} (middle, right), A_{zx} (bottom, left) and A_{zz} (bottom, right) for *pp* elastic scattering at $T_p = 40$ MeV as function of θ_{lab}.

at $T_p = 800$ MeV is shown in Fig. 2. It seems possible to measure the target polarization from the asymmetry $\varepsilon = P_y \cdot A_y \cdot \langle \cos\phi \rangle$ using the weak transverse guide field. For a measurement of the target polarization using a transversely polarized beam (P_y) impinging on the longitudinally polarized target, the spin correlation parameter A_{xz} at 800 MeV is small, as shown in Fig. 2. Thus it seems not feasible to carry out a measurement of the target polarization for the strong longitudinal field based on *pp* elastic scattering at an energy of 800 MeV using the asymmetry $\varepsilon = P_y \cdot Q_z \cdot A_{xz} \langle \sin\phi \rangle$. Inspecting the differential cross section, analyzing power A_y, and spin correlation parameter A_{xz} at other energies shows that at maximum COSY energies around $T_p = 2800$ MeV, A_{xz} becomes sizeable again (Fig. 3). Thus the longitudinal target polarization Q_z can be determined at highest

COSY energies using a transversely polarized beam, where the proton beam polarization is measured using the asymmetry $\varepsilon = P_y \cdot A_y \cdot \langle \cos\phi \rangle$.

Topic	**Responsible**
With the optimium positions of the detectors for the beam and target polarization measurement after spin filtering at injection energy (see Sec. 9.2), how well can we measure the beam and target polarizations at $T_p = 800$ and at 2800 MeV?	Mirian Tabidze, Misha Nekipleov

2.5.2 Summary for Proton Spin Filtering with a Hydrogen Gas Target

In Table 2, we give an overview of the intended measurements grouped into four categories (**W**eak **T**ransverse, **W**eak **L**ongitudinal, **S**trong **N**uclear, **S**trong **E**lectron) for the polarized target, together with a description of a strategy for the determination of beam and target polarizations, required to determine the beam polarization after spin filtering. It is important to note that a calibration of the BRP is possible by comparison with the measured asymmetries of *pp* elastic scattering for **WT**, **WL**, and **SN**. It seems that for the purely electron polarized target (**SE**), we have to completely rely on the BRP.

2.5.3 Elastic $\bar{p}p$ observables

For the $\bar{p}p$ case, because of charge conjugation, again no distinction needs to be made between proton target and antiproton beam analyzing powers, thus $A_y^p = A_y^{\bar{p}}$ and Eqs. (1) and (2) can be applied as well [11]. The available differential cross section and analyzing power data of $\bar{p}p$ elastic scattering are discussed in the PAX-note 1/2006 [12].

2.6 Filtering with a Polarized Deuterium Gas Target

2.6.1 COSY

At COSY, we have to test the experimental setup including the BRP during some spin filtering runs with deuterons with the main aim to commission the equipment for the AD experiments. We assume here that the questions concerning the role of the polarized electrons will be settled at COSY, and for now we assume that at the AD we will operate the target using a weak guide field. The COSY setup should allow us to measure the target polarization of the deuterons using the BRP, when we inject Deuterium in state $|1\rangle$. Reversal of the target polarization in the weak field would be done like for Hydrogen by reversing the holding field along the cell. We can carry out an independent measurement of the deuteron target polarization using $p\vec{d}$ elastic scattering. At ANKE, we have just recently published a paper on the deuteron beam polarimetry [13], where the $p\vec{d}$ analyzing powers from Argonne were used [14], which were measured at $T_p = 800$ MeV and exhibit a maximum $A_y^d = 0.35$ near $t = -0.2$ (GeV/c)^2 ($\theta^p_{\mathrm{lab}} = 18°$, $\theta^d_{\mathrm{lab}} = 73°$).

Category	**Target**	**Guide Field**	**Measurement**	**BRP**
WT	H $\|1\rangle$	weak ($\uparrow$, $\downarrow$), $\pm Q_y$ reversal by field	Filtering with transverse target at $T_p = 40$ MeV. A_y is small. Beam polarization P_y after filtering determined from $\varepsilon = P_y \cdot Q_y \cdot A_{xx} \cdot \langle \sin^2 \phi \rangle$ or $\varepsilon = P_y \cdot Q_y \cdot A_{yy} \cdot \langle \cos^2 \phi \rangle$. Determination of target polarization Q_y from measurement with P_y at $T_p = 800$ MeV using for P_y the asymmetry $\varepsilon = P_y \cdot A_y \cdot \langle \cos \phi \rangle$ and for Q_y then $\varepsilon = P_y \cdot Q_y \cdot A_{xx} \cdot \langle \sin^2 \phi \rangle$ or $\varepsilon = P_y \cdot Q_y \cdot A_{yy} \cdot \langle \cos^2 \phi \rangle$.	Calibration of BRP by comparison of Q_y from *pp* asymmetries with Q_y from BRP. Independent determination of electron polarization Q^e_y by BRP.
WL	H $\|1\rangle$	weak ($\leftarrow$, $\rightarrow$), $\pm Q_z$ reversal by field	Filtering with longitudinal target at $T_p = 40$ MeV. A_z is zero. Beam polarization P_z after filtering determined from $\varepsilon = P_z \cdot Q_z \cdot A_{zz}$. Since A_{xz} is small at $T_p = 40$ MeV, Q_z determined with transverse beam polarization P_y and longitudinal target Q_z at $T_p = 2800$ MeV from $\varepsilon = P_y \cdot Q_z \cdot A_{xz} \cdot \langle \sin \phi \rangle$.	Calibration of BRP by comparison of Q_z from *pp* asymmetries with Q_z of BRP. Independent determination of electron polarization Q^e_z by BRP.
SN	H $\|1\rangle + \|4\rangle$ or $\|2\rangle + \|3\rangle$	strong ($\leftarrow$, $\rightarrow$), $\pm Q_z$, by field reversal or by injection of different states	Filtering with pure nuclear polarized target at $T_p = 40$ MeV. Beam polarization P_z after filtering determined from $\varepsilon = P_z \cdot Q_z \cdot A_{zz}$. Like for **WL**, Q_z determined with transverse beam polarization P_y and longitudinal target Q_z at $T_p = 2800$ MeV from $\varepsilon = P_y \cdot Q_z \cdot \langle \sin \phi \rangle$.	Nuclear polarization in strong could be different from the one in a weak field. Calibration of BRP by comparison of Q_z from *pp* asymmetries with Q_z of BRP. Independent determination of Q^e_z, which should be zero.
SE	H $\|1\rangle + \|2\rangle$	strong ($\leftarrow$, $\rightarrow$), $\pm Q^e_z$ by reversal of field.	Filtering with pure electron polarized target at $T_p = 40$ MeV. Beam polarization P_z after filtering determined from $\varepsilon = P_z \cdot Q_z \cdot A_{zz}$. Determination of P_z Like for **WL** and **SN**.	Electron polarization in strong could be different from the one in a weak field, thus BRP needed to determine Q^e_z. Calibration of BRP by comparison of Q_z from *pp* asymmetries, where Q_z should be zero.

Table 2: Strategy for the polarimetry of the measurements of the four categories (**W**eak **T**ransverse, **W**eak **L**ongitudinal, **S**trong **N**uclear, **S**trong **E**lectron) for the polarized Hydrogen target.

2.6.2 AD

Spin filtering an antiproton beam with a vector polarized Deuterium gas target may well prove more efficient than using Hydrogen. We need a scheme for the polarimetry using a deuterium gas target for the AD experiment. In view of the absence of $\vec{\bar{p}}\vec{d}$ observables, the AD studies definitely require to use the BRP for the determination of the target polarization during filtering.

2.6.2.1 Option to run ABS and BRP with Hydrogen and Deuterium It would be conceivable to run the PIT at the AD during filtering with Deuterium and then for the measurement of the resulting beam polarization, switch the ABS and the BRP back to Hydrogen operation, where the beam polarization at least in the transverse target case can be determined using the known $\bar{p}p$ analyzing powers. This is important issue and should be further elaborated, because it implies several changes in the hardware setup of ABS and BRP.

2.7 How do we do the beam and target polarimetry at the AD?

Topic	**Responsible**
Available are only $\bar{p}p$ analyzing powers (see ref. [12]). Since after filtering the luminosity in the AD is rather low, one way to increase the luminosity after filtering is to replace the target gas by unpolarized hydrogen.	Mirian Tabidze, Misha Nekipleov

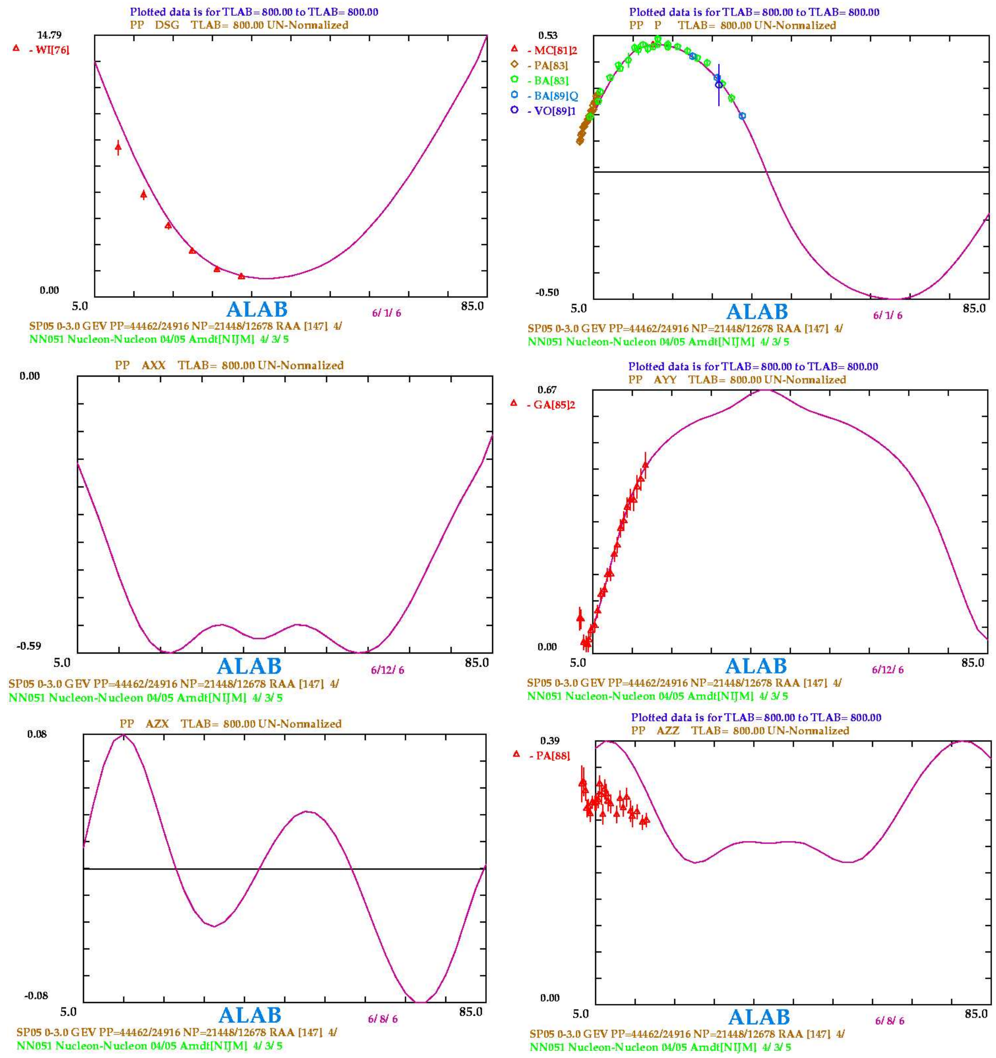

Figure 2: Differential cross section (top left) and analyzing power A_y (top right), spin correlation parameters A_{xx} (middle, left), A_{yy} (middle, right), A_{zx} (bottom, left) and A_{zz} (bottom, right) for pp elastic scattering at $T_p = 800$ MeV as function of θ_{lab}.

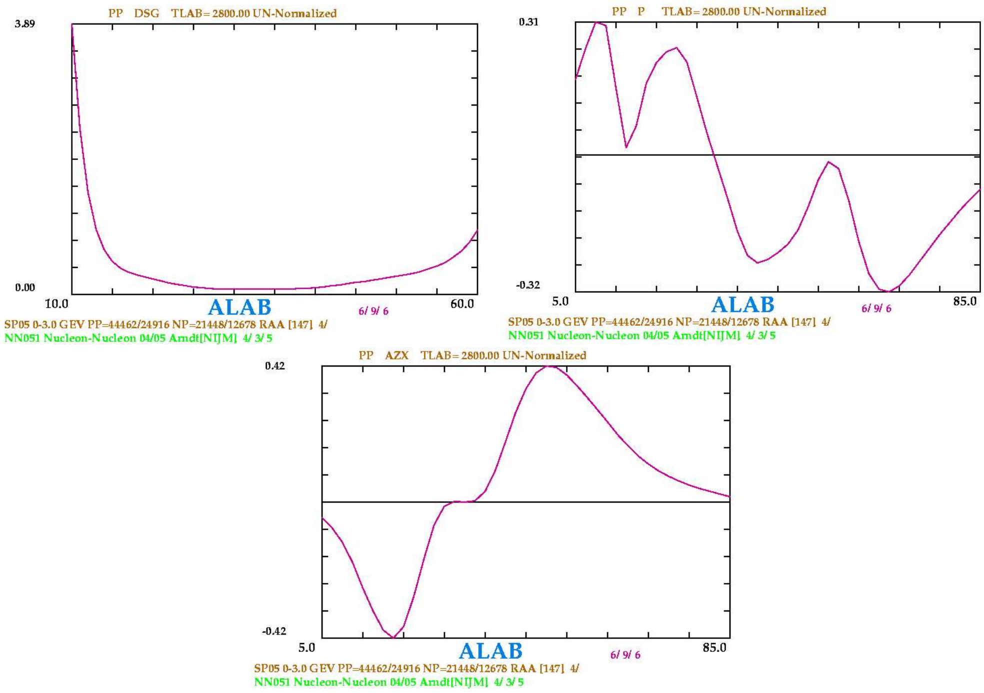

Figure 3: Differential cross section (top left) and analyzing power A_y (top right), and spin correlation parameters A_{zx} (bottom) for *pp* elastic scattering at $T_p = 2800$ MeV as function of $\theta_{\rm lab}$.

3 Conceptual Layout

We have started to come up with a zeroth-order layout of the experimental setup for the filtering studies at COSY and AD, including the low-β section at TP 1. In Fig. 4, we show the COSY ring with the existing installations.

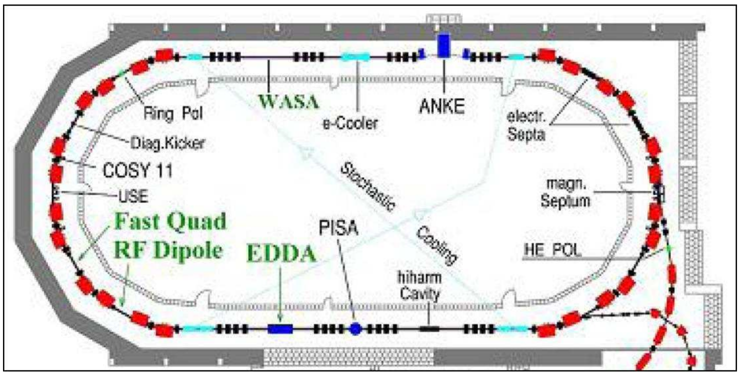

Figure 4: COSY and its internal experimental facilities.

A side view of the forseen interaction region at TP 1(former PISA section) with dimensions is shown in Fig. 5.

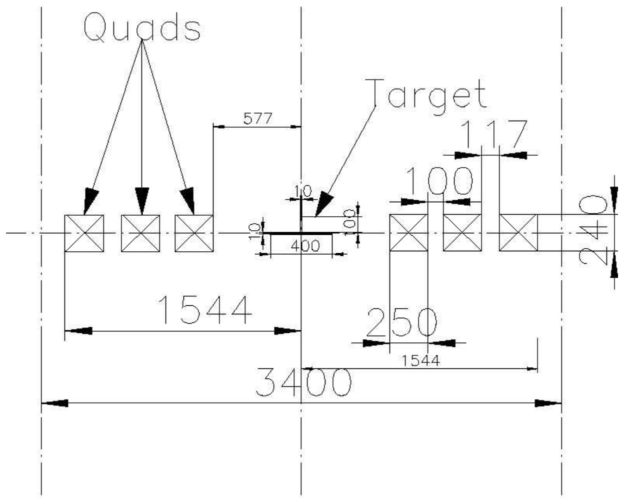

Figure 5: Three superconducting quadrupole magnets are arranged left and right of the target cell. The quadrupole magnets provide a bore of 100 mm diameter.

Figure 6 also shows a sketch of the target region between the existing quadrupole magnets at TP 1. The dimensions take into account the available 3.4 m of space between the shutoff valves. The size of the quadrupole magnets is tentative, with a length corresponding to the recent lattice calculation by Archil Garishvili, Bernd Lorentz, and Sig Martin. The transverse dimensions of the chamber layout are sufficient for the implementation of the Silicon Tracking Telescopes (STT). The frame structure of the vacuum chamber is similar

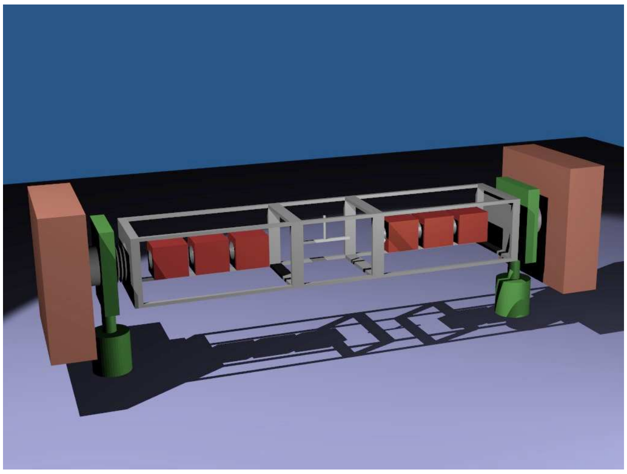

Figure 6: Tentative layout of the low-β insertion between the shutoff valves at the existing COSY quadrupoles at TP 1. The vacuum chamber consists of a frame structure similar to the concept employed at ANKE.

to the makeup of the ANKE target chamber, shown in Fig. 7. It allows for the mounting of large metal sealed flanges on the frames.

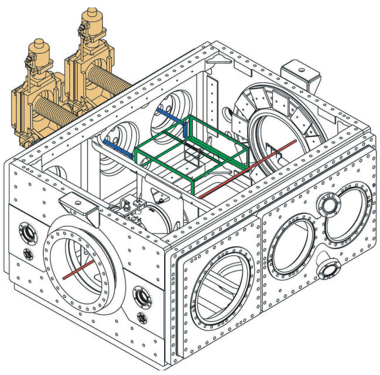

Figure 7: Target chamber presently installed at ANKE. It has a length of about 800 mm, a width of about 600 mm wide, and a height of about 400 mm.

4 Low-β Section, Superconducting Quadrupoles

Topic	**Responsible**
1. Superconducting quadrupoles	Archil Garishvili, Bernd Lorentz, Sig Martin, Marco Statera, ZAT
1.1. Mechanical Design	ZAT
2. Definition of overall dimensions, field gradient, length, bore diameter	Sig Martin, ZAT
3. Is it possible to mount each triplet in one cryostat?	ZAT
4. We need calculated field maps of the quadrupole magnets. In particular to answer the questions about the stray field of the SC quadrupoles in the target region away from the axis? Do we need to shield this stray field in order to apply a weak transverse or longitudinal guide field of about 10 G?	Marco Statera, ZAT
5. What are the forces between the quadrupoles?	ZAT
6. What are the forces on the SC solenoidal field needed for the measurements in a strong longitudinal guide field of ≈ 3 kG at COSY?	ZAT

5 Lattice Studies

5.1 How do we make longitudinal beam polarization at AD and at COSY-TP 1?

Topic	**Responsible**
1. Longitudinal beam polarization at AD: Here we need a Snake design that works in the range between 50 and 200 MeV beam energy. We would have to be able to switch this snake adiabatically off. Otherwise, how would we be able measure the beam polarization, if $A_z = 0$ and none of the spin correlations necessary for such a measurement A_{xz} and A_{zz} are known?	Andreas Lehrach, Bernd Lorentz
2. Longitudinal beam polarization at COSY. Here we may be able to use a combination of WASA solenoid and electron cooler solenoids. What is actually needed to make such a system work? Skewed quadrupoles? Where would these have to be installed? The snake at COSY does not have to be ramped. It would be required for the measurements with either pure electron polarized target or pure nuclear polarized target, which would be done in a strong longitudinal guide field (≈ 3 kG).	Andreas Lehrach, Bernd Lorentz, Dieter Prasuhn
2.1 Do we have to locally compensate the strong longitudinal guide field?	Andreas Lehrach

5.2 AD Experiments

Topic	**Responsible**
1. Lattice calculation when PAX is running	Bernd Lorentz, Archil Garishvili
2. Lattice calculation when PAX is running with a snake	Andreas Lehrach, Bernd Lorentz, Archil Garishvili
3. Lattice calculation for the AD when others are running	Bernd Lorentz, Archil Garishvili
4. What is the maximum target thickness, the AD electron-cooler can tolerate?	Sig Martin, Alexander Smirnow
5. At the AD we will need to switch on and off adiabatically the Siberian Snake. How efficient this can be done needs to be tested at COSY.	Andreas Lehrach

5.3 COSY Experiments

Topic	**Responsible**
1. Lattice calculation with target section at TP 1 for COSY experiments	Bernd Lorentz, Archil Garishvili
2. Lattice calculation with target section at TP 1 for COSY experiments with longitudinal beam polarization	Andreas Lehrach, Bernd Lorentz, Archil Garishvili

6 Lifetime Studies at COSY

Topic	**Responsible**
1. Calculation of beam lifetime in COSY using $\beta(s)$ at injection energy.	Misha Nekipelov
2. Need to improve beam lifetimes at injection energy with electron cooling. The presently observed beam lifetime of 15 min is about a factor 100 below the expectations [15, 16]: Machine time for this should be requested already together with the full proposal (due for the Fall PAC 2006).	Jochen Stein
Ways to improve present situation:	
2.1 Optimize beam orbit along COSY	COSY crew
2.2 Fix the vacuum leaks in COSY. The rest gas pressure in COSY should be about 10^{-9} mbar dominated by Hydrogen, thus in particular air leaks should be fixed.	Ulf Bechstedt

7 Beam Diagnostics

7.1 Beam Profile Monitor

Topic	Responsible
1. For the experimental determination of the COSY acceptance angle at the target location, we need a **Beam Profile Monitor** in COSY that works for high beam intensities.	Jürgen Dietrich
2. At the AD such a Beam Profile Monitor is available. For the measurements of the acceptance angle at the target without electron cooling, it may be required to upgrade this device with larger Multi-Channel plates, as the present onces allow only for beam widths of up to 2 cm.	G. Tranquille, Jürgen Dietrich

7.2 Beam Position Monitors

Topic	Responsible
2. Beam tuning before the installation of the detector system requires before and behind the target cell **Beam Position Monitors** (BPMs) for x and y. These should be an integral part of the SC magnet design, thus the BPMs should reside inside the bore of the quadrupole magnets.	Jürgen Dietrich

8 Polarized Target

8.1 Atomic Beam Source

Topic	**Responsible**
1. Optimization of HERMES ABS optics for maximum beam intensity into the storage cell	Alexander Nass, Marco Capiluppi
2. Source modes:	Alexander Nass, Marco Capiluppi
2.1 Injection of single hyperfine state $\|1\rangle$ and reorientation using a weak guide field	
2.2 Injection of pure nuclear polarization is achieved by injection of states $\|1\rangle + \|4\rangle$ (or states $\|2\rangle + \|3\rangle$). Injection of pure electron polarization is achieved by injection of states $\|1\rangle + \|2\rangle$. In both cases, with the same states injected, the opposite polarization buildup could be achieved also by reversing the holding field at the target.	
2.3 Necessary changes to run with a deuterium target.	

8.1.1 Injection modes for data taking

	B (mT)	HFT's (betw. 6-poles)	HFT's (app.)	inj. states	P_e	P_z	P_{zz}
H	1	MFT $2-3$	—	$\|1\rangle$	+1	+1	
	300	—	—	$\|1\rangle$, $\|2\rangle$	+1	0	
	300	—	SFT $2-4$	$\|1\rangle$, $\|4\rangle$	0	+1	
D	1	SFT $2-6$, MFT $3-4$	—	$\|1\rangle$	+1	+1	+1
	300	—	—	$\|1\rangle$, $\|2\rangle$, $\|3\rangle$	+1	0	0

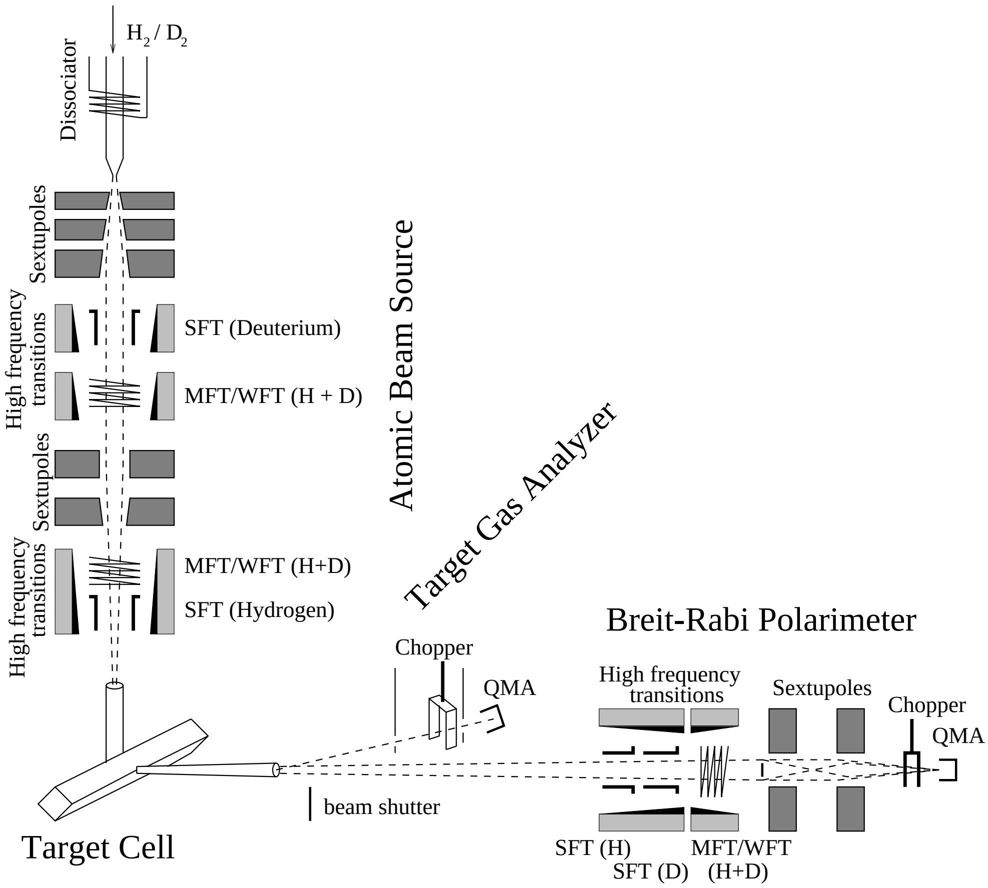

Figure 8: Setup of the Atomic Beam Source (ABS), target gas analyzer (TGA), and the Breit-Rabi polarimeter (BRP).

8.1.2 Other possible modes for calibration

	B (mT)	HFT's (betw. 6-poles)	HFT's (app.)	inj. states	P_e	P_z	P_{zz}
H	300	MFT 1 – 3	—	$\|2\rangle$	+1	−1	
	300	MFT 1 – 3	SFT 2 – 4	$\|3\rangle$	−1	−1	
	300	MFT 2 – 3	WFT 1 – 3	$\|4\rangle$	−1	+1	
	300	—	WFT 1 – 3	$\|2\rangle$, $\|3\rangle$	0	−1	
D	300	SFT 3 – 5, WFT 1 – 4	—	$\|2\rangle$	+1	0	−2
	300	SFT 2 – 6, WFT 1 – 4	—	$\|3\rangle$	+1	−1	+1
	300	SFT 2 – 6	—	$\|1\rangle$, $\|3\rangle$	+1	0	+1
	300	MFT 3 – 4	—	$\|1\rangle$, $\|2\rangle$	+1	+1/2	−1/2
	300	WFT 1 – 4	—	$\|2\rangle$, $\|3\rangle$	+1	−1/2	−1/2
	300	SFT 3 – 5	—	$\|1\rangle$, $\|2\rangle$	+1	+1/2	−1/2
	300	SFT 2 – 5	WFT 1 – 4	$\|3\rangle$, $\|4\rangle$	0	−1	+1
	300	SFT 2 – 6, MFT 3 – 4	WFT 1 – 4	$\|4\rangle$	−1	−1	+1

8.2 Purely nuclear and purely electron polarized Target

We want to compare the polarization buildup using state $|1\rangle$ in a weak longitudinal field ($Q_e = Q_p = 0.8$) with the one observed when states $|1\rangle + |4\rangle$ (or $|2\rangle + |3\rangle$) are injected in a longitudinal strong field ($P_e = 0, P_p = (-)0.8$). We also want to have a direct observation of the polarization buildup with a purely electron polarized target, requiring injection of states $|1\rangle + |2\rangle$. For a measurement with states $|1\rangle + |2\rangle$ in a strong longitudinal field we should determine the electron polarization in a Teflon coated cell. We can expect that in this case the electron polarization will be about 0.7 based on measurements (H. Kolster [17], B. Braun [18], measurements with a Deuterium target are described in [19]). Moreover, the depolarization of electrons can be tested in a weak field. If in a weak field, the measured nuclear polarization of states $|1\rangle + |2\rangle$ is low, i.e. much less than 0.5, we know we have a bad surface. If the nuclear polarization is high, around $0.4 - 0.45$, as expected for Teflon cells, based on TSR [20], IUCF[10], Braun [18] and Kolster [17], it most likely will remain high also in a strong field. Nevertheless, we should not leave any loopholes, thus a direct measurement of the electron polarization appears to be required. For this, we need the Breit-Rabi polarimeter to be installed at the target cell, and the TGA to determine the degree of dissociation α in the target.

Topic	**Responsible**
Hans-Otto Meyer recently suggested that if polarized electron do polarize a stored proton beam, then unpolarized electrons should lead to a depolarization of the beam. We should investigate whether we can obtain a limit on the depolarizing effect using the existing ANKE data taken with polarized protons impinging on an unpolarized D_2 cluster target, which contains two unpolarized electrons per molecule. We typically took data using cycles of about 5 min duration at $T_p = 500$ and 800 MeV. We are interested to know whether there is a difference in the value of the beam polarization in the first part (first minute) of the cycle compared to the last part (last minute).	Gogi Macharashvili

8.3 Breit-Rabi Target Polarimeter

Topic	**Responsible**
3. Target polarimetry:	
3.1 We will measure the target polarization by means of elastic *pp* scattering. This will probe the nuclear polarization of the target. A direct measurement of the electron polarization of the target is necessary to quantify our results in case there is a non-vanishing polarization buildup when states $\|1\rangle + \|2\rangle$ are injected in a strong longitudinal field. We will measure the electron polarization using the Breit-Rabi polarimeter.	Marco Capiluppi, Kirill Grigoriev, Alexander Nass
3.2 At present, the magnet system of the polarimeter is optimized for a cold cell. Since we will run with a warm cell, it has to be optimized for a room temperature cell.	Michelle Stancari, Marco Capiluppi
3.3 The use of a Breit-Rabi polarimeter brings into the game the limits of the sampling technique. Sampling corrections have to be introduced to relate the measured polarization of the sampled beam with the average polarization in the cell. At COSY we will have the possibility to directly measure the sampling correction for the nuclear polarization case, by directly measuring the average polarization in the cell with *pp* elastic scattering. A direct measurement of the average polarization in the cell for a pure electron polarized target is not possible. So assumptions have to be made in this case. In principle, deterioration of the cell surface in the COSY environment with a proton beam should not be as severe as at HERA, where the electron beam generates synchrotron radiation, so the assumption of a homogeneous cell might be reasonable. This can be tested for the nuclear polarization, which is a necessary (but not sufficient) condition for the electron polarization. Everything should be much easier if with the BRP we measure a value for the pure electron polarized target as high as for the pure nuclear polarized target. To precisely estimate the uncertainty of the electron polarization, the Monte Carlo simulation techniques developed at HERMES for the determination of the sampling corrections have to be applied.	Paolo Lenisa, Michelle Stancari, Kirill Grigoriev

Topic	**Responsible**
3.4 Spin filtering studies with a deuterium target require the BRP in particular for the AD experiments. The BRP in that case should be able to measure the deuteron target polarization during filtering. After the polarization buildup is completed, we could switch both ABS and BRP to Hydrogen and determine the resulting polarization of the antiproton beam using the $\bar{p}p$ elastic analyzing powers. For the transverse target case, when the beam polarization after filtering is also transverse, unpolarized Hydrogen could be used. For the longitudinal case, it is necessary to adiabatically switch off the snake to again have vertical beam polarization.	Marco Capiluppi, Michelle Stancari, Alexander Nass
3.5 An independent determination of the target polarization with the target polarimeter requires also the measurement of the atomic fraction in the target cell. For this reason also the Target Gas Analyzer (TGA) will be implemented together with the BRP.	Marco Capiluppi
3.6 The implementation of the BRP requires setting up a DAQ system for the target polarimetry. Interlock and control system might be integrated into the interlock system of ABS. In order to be efficient with the setting up of such a system, a slow control architecture similar to the one developed for the ANKE PIT should be employed, which is described in ref. [21].	H. Kleines, J. Sarkadi, G. Tagliente, Alexander Nass, Marco Capiluppi
3.7 For the tuning of the transition units, we will install a small chamber below the target chamber which will house a sextupole magnet and a pressure gauge.	Alexander Nass

8.4 Storage cell

Topic	Responsible
1. Target density estimates should include the real conductances of the injection and beam tubes	Marco Capiluppi
2. Draw picture of beta function inside the target cell for AD and for COSY. How large is the beam at the entrance and exit of the cell?	Archil Garishvili
3. Cell design: Could be made from thin-walled teflon foil or from Al foil coated with Teflon. A cell construction similar to the one used for the PINTEX pp elastic measurements could be our solution [22, 23]. This setup is shown in Fig. 9. Feeding tube from the top and four detectors 45 deg above and below the horizontal plane:	Paolo Lenisa, Frank Rathmann, Kirill Grigoriev
3.1 Mechanical design for closed cell configuration	Vito Carassiti, Giuseppe Ciullo, ZAT
3.2 Mechanical Design for openable cell	Vito Carassiti, Giuseppe Ciullo, ZAT

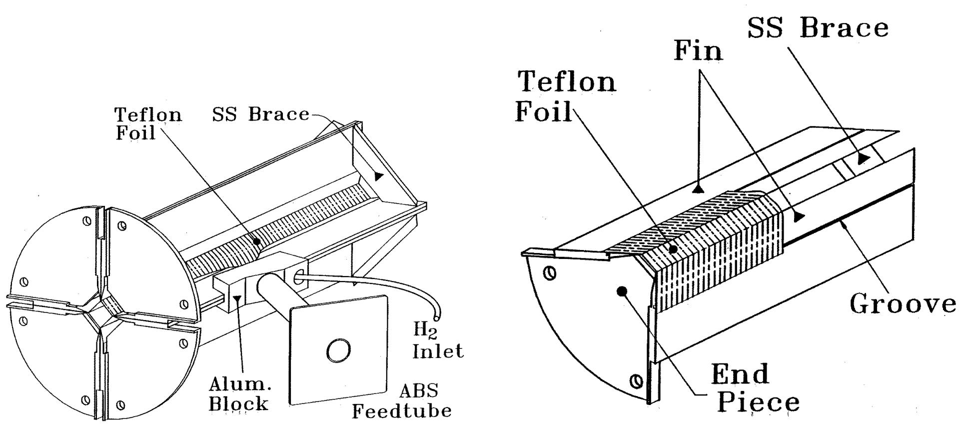

Figure 9: PINTEX storage cell setup for the *pp* elastic measurements [22, 23].

8.5 Holding field scheme for the target

Topic	Responsible
1. Weak field arrangement for COSY and AD experiments For spin filtering with a transverse target polarization, the weak guide field of about 10 G should be vertical along the axis of the cell. For longitudinal filtering, the orientation of the weak guide field must be longitudinal at the target. In Fig. 10, we show a tentative sketch of how weak longitudinal and transverse fields could be generated.	Alexander Nass, Marco Capiluppi, Marco Statera
1.1 Do we have to compensate the weak transverse guide field to avoid beam deflection in the cell?	Marco Capiluppi, Alexander Nass, Marco Statera
2. Strong field for COSY Experiments: We need to understand why electron polarization in a strong field at HERMES is low ($P_e \approx 25\%$.), while at TSR and at PINTEX with teflon coated or teflon foil cells, we had both high nuclear AND electron polarizations in a weak field. Why should the electron polarization simply drop because the field is increased? At HERMES the reason could come from the different drifilm used to coat the cell and the low cell temperature of 100 K.	Paolo Lenisa, Alexander Nass, Marco Capiluppi

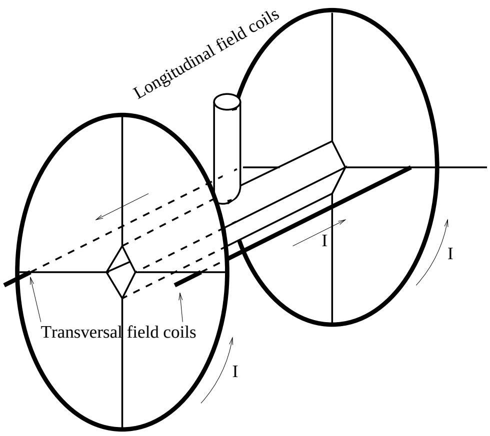

Figure 10: System of target near weak guide field coils (longitudinal) and wires (transverse) that could be used in the experimental setup around the storage cell.

8.6 Detector Layout

A tentative layout of the detector system together with the cell is shown in Figs. 11 and 12 together with two projections (along the beam direction and a top view).

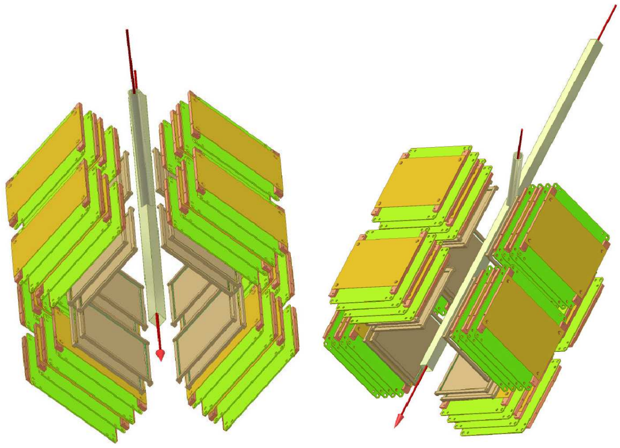

Figure 11: Arrangement of the Silicon Tracking Telescopes (STT) around the storage cell.

8.7 Vacuum System

Topic	Responsible
1. For the AD setup in addition to the differential pumping system, we need movable flow limiters in the target section to prevent the target gas from entering into the adjacent sections of the ring. A first layout is shown in Fig. 13. In that context, we need to estimate the pumping speed and capacity of the cold bore SC magnets. Should these be covered by active coal like the cryopumps?	Alexander Nass, Marco Capiluppi
2. Which type of pumps do we employ?	Alexander Nass
3. What is the predicted pressure distribution along the target section?	Marco Capiluppi
4. What do the COSY and AD vacuum people require from us in terms of pressure at the exit of the target section?	Marco Capiluppi
5. Which is the maximum gas flow which is tolerable in the target cell with the forseen pumping system? This point needs clarification, because we could measure the beam polarization after spin filtering by injection of unpolarized Hydrogen into the storage cell.	Alexander Nass, Marco Capiluppi

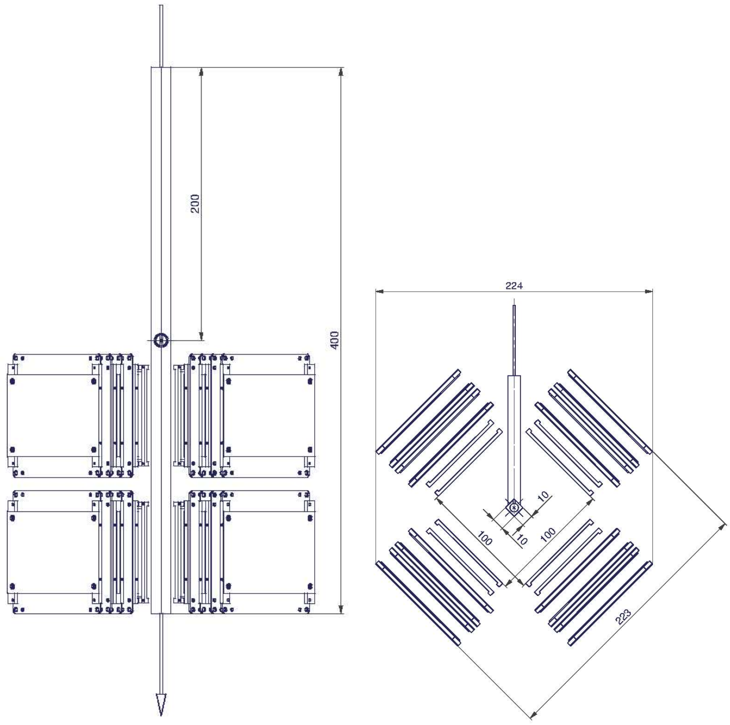

Figure 12: Arrangement of the Silicon Tracking Telescopes (STT) around the storage cell, showing a view along the beam axis and a top view.

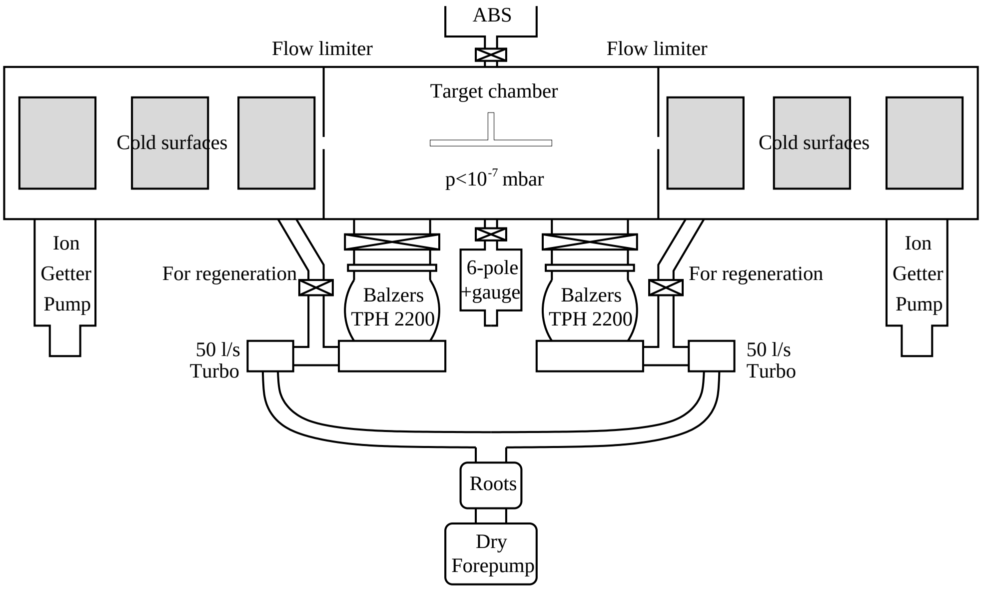

Figure 13: Scheme of the vacuum system in the target region.

9 Detector System

9.1 What do we gain from a Forward detector based on scintillators

Topic	Responsible
If only for the purpose of beam tuning and initial rate estimates before the STT is used, could we use simple surface barrier detectors? Could these serve also as luminosity monitors?	Mirian Tabidze, David Yamandize, Anatoly Kulikov

9.2 Monte Carlo Simulations

Topic	Responsible
1. Optimization of the detector positions requires rate and acceptance calculations using GEANT and Figure of Merit of the detector for polarization analysis of the beam and target. Here both the COSY and the AD experiments should be treated.	Misha Nekipelov, David Yamandize, Mirian Tabidze
2. How many layers do we need for clean tracking of both recoil proton and scattered (anti)proton?	
3. Which pitch should the detectors have to suppress background from annihilation in the AD experiments?	
4. Which wall thickness can we tolerate: Options are Teflon coated Al cell (thickness 25 μm) or Teflon foil cell (5 μm).	

9.3 Data Acquisition, Detector Electronics, and Analysis Software

Topic	Responsible
1. We need to provide a framework for the Data Acquisition	Sergey Trusov, Peter Wüstner
2. Data Acquisition Software	Sergey Trusov, Peter Wüstner, G. Tagliente
3. Data Analysis Software	Misha Nekipelov, Gogi Macharashvili

9.4 Manufacturing of the STT's

Topic	Responsible
1. Once the design parameters of the STT system are available, we need to produce a prototype STT for our experiments.	R. Schleichert, Dieter Oellers, Marco Contalbrigo, A. Cotta, ZAT
2. Once we have an operating STT prototype detector, the detectors should be manufactured.	R. Schleichert, Dieter Oellers, Marco Contalbrigo, A. Cotta, E. Cisbani
3. Detector Electronics	Sergey Merzliakov

References

[1] Letter of intent for *Spin–Filtering Studies at COSY*, PAX Collaboration, spokespersons: P. Lenisa (Ferrara University, Italy) and F. Rathmann (Forschungszentrum Jülich, Germany), available from `http://www.fz-juelich.de/ikp/pax`.

[2] Letter–of–Intent for *Measurement of the Spin–Dependence of the $\bar{p}p$ Interaction at the AD–Ring*, PAX Collaboration, spokespersons: P. Lenisa (Ferrara University, Italy) and F. Rathmann (Forschungszentrum Jülich, Germany), available from arXiv:hep-ex/0512021 (2005).

[3] Technical Proposal for *Antiproton–Proton Scattering Experiments with Polarization*, PAX Collaboration, spokespersons: P. Lenisa (Ferrara University, Italy) and F. Rathmann (Forschungszentrum Jülich, Germany), available from arXiv:hep-ex/0505054 (2005). An update of this proposal can be found at the PAX website `http://www.fz-juelich.de/ikp/pax`.

[4] H.O. Meyer, Phys. Rev. E **50**, 1485 (1994).

[5] C.J. Horowitz and H.O. Meyer, Phys. Rev. Lett. **72** (1994) 3981.

[6] A.I. Milstein and V.M. Strakhovenko, Phys. Rev. E **72**, 066503 (2005).

[7] N. N. Nikolaev and F. F. Pavlov, Buildup of stored protons and antiprotons: FILTEX result and arXiv:hep-ex:0601184.

[8] T. Hippchen, J. Haidenbauer, K. Holinde, V. Mull, Phys. Rev. C **44**, 1323 (1991); V. Mull, J. Haidenbauer, T. Hippchen, K. Holinde, Phys. Rev. C **44**, 1337 (1991).

[9] V. Mull, K. Holinde, Phys. Rev. C **51**, 2360 (1995).

[10] F. Rathmann *et al.*, Phys. Rev. C **58**, 658 (1998).

[11] E. Klempt, F. Bradamante, A. Martin, and J.–M. Richard, Phys. Rep. **368** (2002) 119.

[12] M. Tabidze *et al.*, PAX-note-1/2006, available from the internal section of the PAX-web-site at `www.fz-juelich.de/ikp/pax`.

[13] D. Chiladze *et al.*, Phys. Rev. ST-AB **9**, 050101 (2006).

[14] M. Haji-Said *et al.*, Phys. Rev. C **36**, 2010 (1987).

[15] J. Dietrich *et al.*, *Characteristic features of Electron Cooling at COSY*, COSY Annual Report 2004, available from `http://www.fz-juelich.de/ikp/publications/AR2004/en/chap03.shtml`.

[16] H.J. Stein and D. Prasuhn *et al.*, *A Test of Electron Cooling at 70 keV Electron Energy* COSY Annual Report 2005, available from `http://www.fz-juelich.de/ikp/publications/AR2005`.

[17] H. Kolster, The HERMES Gaseous Internal Polarized Proton Target and its use in the HERA Positron Storage Ring Dissertation, Ludwig-Maximilians-Universität München (1998). Available from `http://www-hermes.desy.de/`.

[18] B. Braun, *Spin Relaxation of Hydrogen and Deuterium in Storage Cells*, Dissertation, Ludwig-Maximilians-Universität, München (English translation) (1995). Available from `http://www-hermes.desy.de/`.

[19] C. Baumgarten, *Studies of Spin Relaxation and Recombination at the HERMES Hydrogen/Deuterium Gas Target*, Dissertation, Ludwig-Maximilians Universität München (2000). Available from `http://www-hermes.desy.de/`.

[20] K. Zapfe et al., Nucl. Instrum and Meth. **A 368**, 293 (1996).

[21] H. Kleines *et al.*, Nucl. Instrum and Meth. A, **560**, 503 (2006).

[22] W.A. Dezarn *et al.*, Nucl. Instrum and Meth. A **362**, 36 (1995).

[23] W.R. Lozowski *et al.*, Nucl. Instrum and Meth. A **362**, 189 (1995).