COSY Beam Time Request

For Lab. use

Exp. No.:	Session No.
E1	**2**

Collaboration: JEDI

Spin Coherence Time Studies with Protons

Spokespersons for the beam time:
Andreas Lehrach (Jülich)
Marcel Rosenthal (Jülich)
Fabian Hinder (Jülich)
Fabian Trinkel (Jülich)

Spokespersons for the collaboration:
Andreas Lehrach (Jülich)
Jörg Pretz (Aachen)
Frank Rathmann (Jülich)

Address:
Institut für Kernphysik
Forschungszentrum Jülich
52428 Jülich
Germany

Phone: **+49 2461 616453** Fax: **+49 2461 613930** E-mail: **a.lehrach@fz-juelich.de**
pretz@physik.rwth-aachen.de
f.rathmann@fz-juelich.de
m.rosenthal@fz-juelich.de
f.hinder@fz-juelich.de
f.trinkel@fz-juelich.de

Total number of particles and type of beam (p,d,polarization)	Kinetic energy (MeV)	Intensity or internal reaction rate (particles per second) minimum needed	Intensity or internal reaction rate (particles per second) maximum useful
polarized protons	**100 ∸ 200 MeV (one fixed energy in this interval)**	**stored 10^9**	**stored 10^{10}**
Experimental area	Safety aspects (if any)	Earliest date of installation	Total beam time (No.of shifts)
EDDA detector, electron cooler and RF solenoid	**none**	**1st November 2015**	**3 weeks (+ MD)**

JEDI Beam Time Request for the second half of 2015

The JEDI collaboration
http://collaborations.fz-juelich.de/ikp/jedi/index.shtml

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Abstract

This document outlines beam times of the JEDI collaboration in fall 2015 and beyond. Up to now the JEDI collaboration used only polarized deuterons. In the second half of 2015 we would like to have a first run with **polarized protons** to study spin coherence time (SCT) and spin tune (ST). In parallel tests of beam position monitors (BPM) are foreseen.

In addition to this document 2 other proposals concerning the JEDI activities on polarimeter tests and a feedback system are submitted.

1 Status und plans of the JEDI activities

The longterm plans and activities of the JEDI collaboration are described in Refs. [1, 2]. The analysis of the spin tune was recently published in a preprint [3] (arxiv1504.00635). The status of the various projects are summarized in the annual report 2014.

Future plans are summarized in the following table:

Topic	beam	beam time request/week
1) Spin Coherence Time (SCT) for protons	pol. p	1(MD)+3
Beam Position Monitors		parallel to 1)
2) Polarimeter tests	unpol. d external beam	1
3) Active feedback system (2016)	pol. d	1

Item 1) will be discussed in this document. Item 2) and 3) will be discussed in separate proposals. In addition to the activities described in these documents, parasitic tests with the low energy polarimeter at the cyclotron are foreseen.

2 Spin Coherence time for protons

A successful realization of a long spin coherence time is a mandatory requirement for future proton EDM measurements. Furthermore it will verify theoretical predictions of the simulations codes and the credibility of the theoretical calculations for the planned EDM measurement methods.

In the previous beam times the performed studies for cooled and bunched deuterons at $p = 970\,\mathrm{MeV/c}$ showed that the sextupole configurations, which lead to small chromaticities in horizontal and vertical plane, result in a long spin coherence time. Spin tracking simulations have been performed to understand the connection between beam chromaticities and the long spin coherence time. They confirmed that small beam chromaticities are required for a long spin coherence time in case of the apparently used COSY lattice setup and for deuterons at this particular momentum. Studies for required lattice configurations in the case of protons are ongoing. Due to the larger anomalous magnetic moment, the spin decoherence is expected to be naturally significantly stronger. This statement is supported by the outcome of spin tracking studies. Due to this fact, intrinsic spin resonances are significantly larger and have to be avoided. In the aimed kinetic energy range 100 MeV($p \approx 450$ MeV/c) to 150 MeV($p \approx 550$ MeV/c) the spin tune for protons is in the order of $\nu_s = 1.98$ to $\nu_s = 2.08$. The lower limit is set by required analyzing powers for polarimetry, the upper limit is set by the desired usage of the 100 kV-electron-cooler. In previous beam setups the betatron tunes $Q_x \approx 3.64$ and $Q_y \approx 3.57$ were chosen. For that reason, intrinsic resonances fulfilling the condition $\nu_s = k \pm Q_y, k \in \mathbb{Z}$ are not present in the given energy range. But higher order spin resonances at $\nu_s = k \pm m \cdot Q_x \pm n \cdot Q_y$ as well as the imperfection resonance at $\nu_s = 2$ have to be considered. For example, at a kinetic energy of 130 MeV($p \approx 511$ MeV/c) the spin tune is $\nu_s = 2.04$, which is away from 2.07 ($k = 2, m = n = 1$) and 2.14 ($k = -5, m = 0, n = 2 \text{resp.} k = m = n = 2$). If one of these energies is chosen, the betatron tunes have to be changed accordingly to stay away from this kind of spin resonances. The revolution frequency for this energy is $f_{\text{rev}} \approx 781$ kHz and radio-frequency devices, like the rf solenoid and the rf Wien filter are intended to be used at 751 kHz or 810 kHz for spin manipulation (see below).

First results of more detailed simulation studies indicate that for the lattice configuration with minimized dispersion in the straights, which was used for the deuteron studies, a long spin coherence time could not be achieved by minimizing the chromaticities. Furthermore the calculated required sextupole corrections for preserving the spin coherence lead to an unstable beam motion. During the beam time studies it is planned to vary the momentum compaction of the lattice using different quadrupole configurations to improve the situation. The optimum lattice configuration for the desired energy is currently worked out. The goals of the working package are the following:

- Establish a measurement of the spin coherence time (SCT) with protons for the first time.
- Study the influence of sextupole corrections on SCT.
- Study the influence of different quadrupole configurations paired with sextupole corrections on SCT.

To accomplish the planned studies, one week of measurement time for each bullet + one week MD is desired. This results in 4 weeks in total for this working package. During this time, the following steps will be conducted:

1. Setup machine for protons in desired energy range. Use minimized dispersion in straights lattice configuration.
2. Setup electron cooler.
3. Perform orbit correction based on Orbit Response Analysis.
4. Iterate last 2 steps for optimized results.
5. Measure natural chromaticities.

6. Use sextupole corrections to adjust chromaticities in both planes (to zero for comparison with deuteron case and according to the outcome of theoretical calculations).

7. Find rf- induced spin resonance and bring polarization into horizontal plane.

8. Measure spin coherence time.

9. Vary sextupole settings to find a maximum SCT (if SCT is reasonable large).

10. Vary quadrupole configuration and iterate previous points.

3 Beam Position Monitors

Towards an EDM measurement an orbit control system with a high accuracy is necessary. Such a system consists of beam position monitors (BPMs), installed around the accelerator ring. At COSY the BPMs are capacitive pickup electrodes with a length of around 20 cm. The installation of additional BPMs is not possible, since lack of space. A new development is a smaller inductive BPM, measuring the magnetic field of the particle beam. The BPM consists of a torus (radius from center to middle of the torus: $R = 10.5$ cm and radius of the tube $a = 0.5$ cm) wounded with a cooper wire. The winding is divided into four segments, each covering an angle range of $\pi/2$. The system benefits from its small geometrical size. The BPM uses only 1/20 of the space compared to the conventional BPM. In addition the Rogowski coil BPM response is proportional to the particle revolution frequency. This leads to high voltages induced in the coil. One intended installation is at both sides of the planned Wien-Filter.

A measurement in the laboratory shows, that a position measurement of a wire, simulating the particle beam, is possible.

First measurement in accelerator environment at the ANKE chamber with a coil, which was not divided, shows that the Rogowski coil measures the beam current. A second measurement with a halved coil is planned for the beamtime May and June 2015. This measurement should show the principle of measuring the position of the particle beam in one plane.

The new planned measurement combines two quartered coils, installed in the ANKE chamber, Fig. 1 One coil installed at a known fixed position and a second coil installed at a piezo $x - y$ table. This design allows a position measurement relative to one fixed position. The plan is to keep the beam stable and move one coil relative to the beam. The stability of the beam is monitored with the fixed coil. By moving the $x - y$ table with a well known precision, up to a few μm, the calibration and characterizing of the Rogowski coil is possible. The measurements will be compared with analytical calculations.

In addition, a test of a 0 detector is planned: The beam will be moved by using COSY steerers. The movable coil registers this movement and follows the beam in a way, that the measured voltages at all four segments are equal. In this configuration the beam is centered relative to the coil. The position of the coil itself represents than the position of the particle beam. This activity can run parasitically and does not require additional beam time.

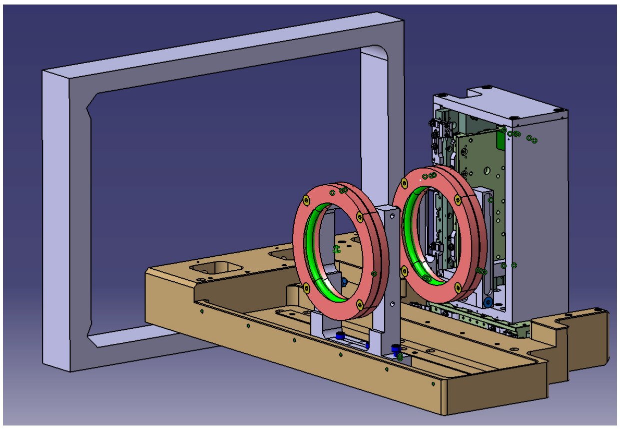

Figure 1: Construction of the fixed and movable Rogowski coil, which will be mounted inside the ANKE chamber.

References

[1] *Novel precision storage rings for Electric Dipole Moment searches*, Design Study "EDM" submitted to the EU under the call H2020-INFRADEV-1-2014-1, Research and Innovation action, proposal number 653939. Available from Ref. [2].

[2] The JEDI proposals are available from: http://collaborations.fz-juelich.de/ikp/jedi/documents/

[3] D. Eversmann et al., (JEDI collaboration) subm. to PRL, arXiv:1504.00635 (2015).