Executive summary for "COSY Test Beam Time"

For Lab. use

Exp. No.:	Session No.

Collaboration JEDI

Spokesperson for test beam time: Name: **Andreas Lehrach (Jülich)**
Jörg Pretz (Aachen)
Frank Rathmann (Jülich)

Address:
Institut für Kernphysik
Forschungszentrum Jülich
52428 Jülich
Germany

Phone: **+49 2461 614558** Fax: **+49 2461 613930** E-mail: **a.lehrach@fz-juelich.de**
pretz@physik.rwth-aachen.de
f.rathmann@fz-juelich.de

Total number of particles and type of beam (p,d,polarization)	Momentum range (MeV/c)	Intensity or internal reaction rate (particles per second)	
		minimum needed	maximum useful
polarized deuterons	**~970 MeV/c**	**stored 10^9**	**stored 10^{10}**
Experimental area	Safety aspects (if any)	Earliest date of installation	Total beam time (No.of shifts)
EDDA detector and electron cooler	**none**	**April 2015**	**5 weeks + 1 MD**

What equipment, floor space etc. is expected from Forschungszentrum Jülich/IKP?

Description of request (motivation, milestone(s), goals; maximum 5 pages)

JEDI Beam Time Request for the first half of 2015

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

November 19, 2014

Abstract

This report describes the achievements of the last beam time in the fall of 2014. In the first half of 2015 we would like to address a number of additional items. This requires 5 consecutive weeks of beam time in a row, preceded by one MD week.

1 Achievements of previous beam time in fall 2014

The longterm plans and activities of the JEDI collaboration are described in Refs. [1, 2].

1.1 Spin Coherence Time

The goal of the portion of the 2014 running time devoted to spin coherence studies with deuteron beam at 970 MeV/c was to demonstrate any close connection between the sextupole magnet settings leading to large polarization lifetimes and zero chromaticity. Horizontal polarization lifetimes depend on various contributions to the spread of spin tune values in the beam, including emittance and the longitudinal momentum spread associated with synchrotron oscillations. To explore these degrees of freedom, studies were made with two beam preparations: (1) a beam whose horizontal emittance was expanded using white noise applied to a pair of electric field plates, and (2) a period of electron cooling followed by bunching in order to produce a spread of synchrotron amplitudes. Initial cooling of the beam reduced contributions from other degrees of freedom. The three families of arc sextupole fields (MXS, MXL, and MXG) were adjusted to find those settings where both the X and Y chromaticity were zero. Those places were found to lie along lines parallel each other and to the MXS by MXG plane; and the lines could be brought together with a suitable choice of MXL strength. For each of the two beam preparations, scans were made of either MXS or MXG while holding the other constant. Along each scan, measurements were made of the horizontal polarization lifetime. The scan with the longest polarization lifetime was found to be a function of MXG with MXS = 10% of full power supply scale and a beam containing enlarged synchrotron oscillations, as shown in Fig. 1.

Out of each scan, the sextupole settings for the point of largest polarization lifetime was found and plotted as a function of MXS and MXG, as seen in Fig. 2. The lines represent the sextupole settings that generate zero X and Y chromaticity, along with bands that indicate the uncertainties from the tune measurements. The black dots (horizontally wide beam) and red circles (long beam) locate the places where the horizontal polarization is the largest. These overlap each other and the lines of zero chromaticity to within errors. This experiment demonstrates the possibility to achieve horizontal polarization lifetimes of about 1000 s based on a combination of beam bunching, electron cooling, and the setting

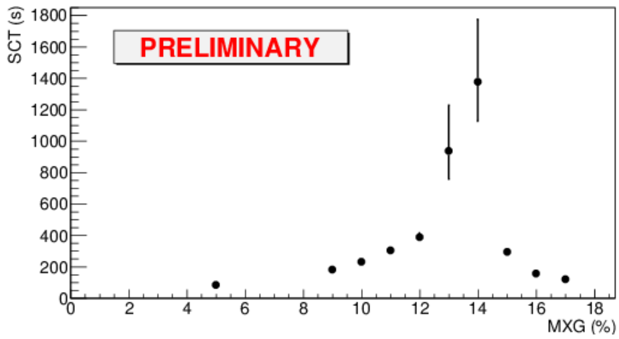

Figure 1: Measurements of the horizontal polarization lifetime as a function of the strength of the MXG sextupole family with MXS set to 10% and MXL set to −1.45% of power supply full scale (see Ref. [3])

.

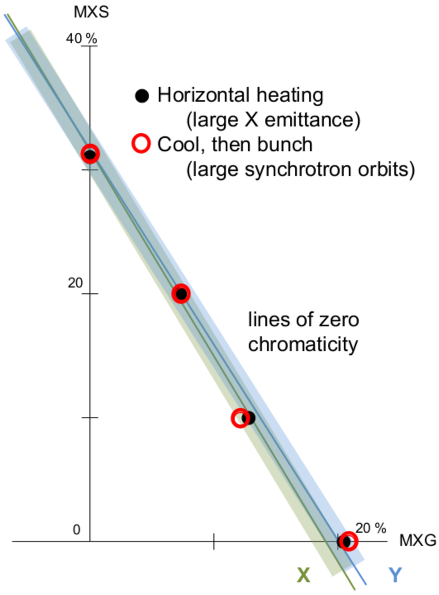

Figure 2: Locations of the maximal horizontal polarization lifetime from scans involving a horizontally wide or a long beam overlaid onto the lines of zero X and Y chromaticity.

of sextupole fields near places where both the X and Y chromaticities vanish and large individual sextupole fields are avoided. Details are described in Ref. [3].

1.2 Spin Tune Measurements

To first approximation the spin tune is given by the number of spin rotations per particle revolution. We are now able, with dedicated analysis tools, to determine the spin tune with a precision of 10^{-10} in one accelerator cycle of 100 s (see Fig. 3). The upper panel shows independent spin tune measurements performed every 2 s. In the lower panel it is assumed that the spin tune change is linear over the time of the cycle (≈ 90 s). This allows a much more precise spin tune determination. We reach a precision of about 10^{-10} at $t = 40\,\mathrm{s}$ as shown in the lower panel in Fig. 3 (see Ref. [4]).

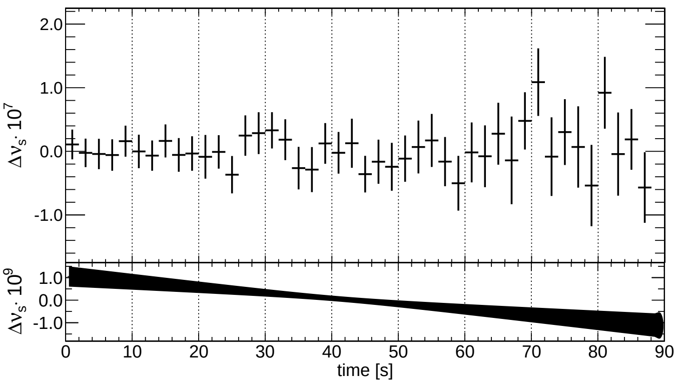

Figure 3: Deviation of the spin tune from the value $\nu_s^0 = -0.1609754335$ as a function of time (from Ref. [5]). Top panel: Spin tune determined in every 2 s time interval making no assumption about spin tune changes vs. time. Bottom panel: Spin tune determined over the whole cycle assuming a linear spin tune change over time. The error band shows the statistical error which is smallest at $t = 40\,\mathrm{s}$, reaching 10^{-10}.

These spin tune measurements now serve as a tool to study systematic effects. For example, spin tune changes predicted by simulations as function of magnet settings in COSY can be compared to the measurements and help to validate the simulations. During the beam time many runs were taken where solenoid or steerer magnets were powered during parts of the cycle. Figure 4 shows one example. In this case a solenoid was powered in the time interval $20\,\mathrm{s} < t < 45\,\mathrm{s}$. The resulting spin tune change is clearly visible.

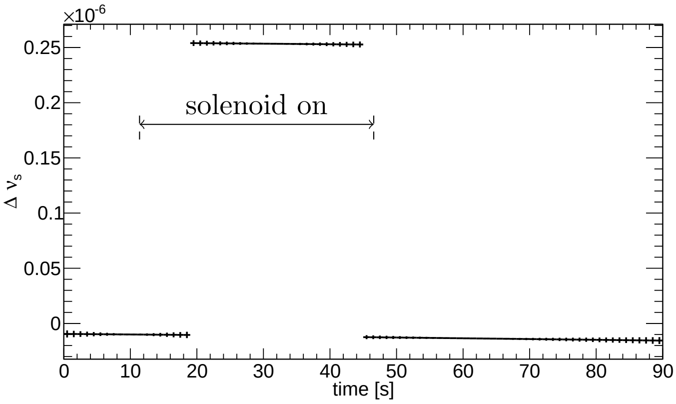

Figure 4: Deviation of the spin tune from $\nu_s^0 = -0.16097108$ as a function of time. In the time interval $20\,\mathrm{s} < t < 45\,\mathrm{s}$ solenoid magnets were set to a value different from 0. The resulting spin tune change of $2.5 \cdot 10^{-7}$ is clearly visible.

1.3 Commissioning of an RF Wienfilter

In 2014, a prototype RF-E×B dipole with perpendicular electric and magnetic fields has been successfully commissioned and utilized during two weeks of beam time. We were able to verify that the device can be operated in a Wien-Filter configuration to flip the vertical polarization of a 970 MeV/c deuteron beam without exciting coherent beam oscillations. For the determination of the resonance strength necessary to induce the spin flip, the RF-E×B dipole with B-field in radial and E-field in vertical direction was operated at the $f_{\mathrm{rev}}(\gamma G - 1)$ harmonic of the spin precession frequency at 871 kHz (G denotes the magnetic anomaly and γ the relativistic Lorentz factor). During the year 2015, similar measurements at the $f_{\mathrm{rev}}(\gamma G + 1) = 630\,\mathrm{kHz}$ harmonic are planned. The benefit of lower RF frequency is less damping of the induced oscillation of the vertical polarization component. The spin flipping efficiency of the RF-E×B dipole has to be measured by observing the remaining vertical polarization after a series of Foissart-Stora-Scans. Furthermore, a comparison of the resonance strength and spin flipping efficiency with a polarized proton beam is necessary for the final proton/ deuteron storage ring experiments. Once the spin manipulation behaviour of the system is determined, it will be rotated by 90° around the beam axis. In this configuration, the RF-E×B dipole in Wien filter mode will no longer directly act on the particles' MDM, but still modulate their spin-tune γG. In conjunction with the imperfection fields distributed along the accelerator ring this can lead to an EDM induced build-up of the vertical polarization component. The system is going to be used for systematic investigations of sources for false EDM signals (see Ref. [6]).

2 Request for beam time first half of 2015

In the first half of 2015 we would like to address the items listed below. This requires roughly 5 weeks of beam time in a row using a polarized deuteron beam. Since switching from deuteron to proton beam takes time, and in addition, further simulation studies for polarized protons are needed, we will ask for proton beam time in the second half of 2015.

1. **Explore other energies with EDDA**
   Up to now spin coherence times were only studied for deuterons at $T = 235.98\,\mathrm{MeV}$ ($p = 970\,\mathrm{MeV/c}$). There are indications that the damping of RF-driven spin-oscillations may depend on the beam energy as well (see Fig. 1 of Ref. [7]). Therefore, we would like to explore higher energies around $T = 1\,\mathrm{GeV}$ with EDDA, where the analyzing powers A_y^d are known to be sizeable [8, 9].

2. **EDDA fiber target**
   Presently, the beam is extracted using electro-magnetic fields which will have an influence on the spin precession. Using a fiber target which runs through the beam this influence can be avoided. In addition if offers the possibility to study the polarization and spin tune as a function of position in the beam.

3. **Quartered Rogowski coil to be installed in the ANKE target chamber**
   An exact knowledge of beam properties is mandatory for the EDM experiment. Testing a quartered Rogowski coil is a first step in developing SQUID beam position monitors.

4. **RF Wien filter at 630 kHz**
   During the last beam time this frequency was not yet explored (see section 1.3).

5. **SCT studies with the straight section sextupoles**
In the past beam times only the influence of the sextupoles in the arcs on the SCT was studied. We propose to use the sextupoles located in the straight section as well to suppress third order field contributions.

6. **Study effect of a variation of the electron cooler beam current on the SCT**
For the studies performed up to now the electron cooler beam was switched off during the idle precession of spins in the horizontal plane. We propose to study the influence of the electron cooler beam current on the SCT. The non-linear field of the electron beam will influence the SCT by additional spin kicks. The magnitude of these spin kicks depends on the position of the beam particles inside the electron beam. Due to the interplay of beam cooling and heating processes by intra-beam scattering beam mixing could also lengthen the SCT. To observe this small effect the phase space distribution of the beam has to stay in equilibrium during the cooling process. This can be achieved, if the cooling rate is constantly adjusted by changing the electron cooler beam current to match the intra-beam heating rate.

7. **Beam Extraction onto EDDA target with ANKE cluster or WASA pellet target**
This was tried in the past, but this was before any experience with ramped or white noise extraction.

In total we request 5 weeks of beam time, plus one MD week preceeding the activities.

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/proposals.shtml

[3] G. Guidoboni, *Spin coherence time studies of a horizontally polarized deuteron beam at COSY*, STORI 2014, September 29 - October 3, 2014. St. Goar, Germany. Available from Ref. [2].

[4] J. Pretz, *Measurement of Electric Dipole Moments at Storage Rings*, STORI 2014, September 29 - October 3, 2014. St. Goar, Germany. Available from Available from Ref. [2].

[5] Publication in preparation.

[6] F. Rathmann *et al.* [JEDI and srEDM Collaborations], J. Phys. Conf. Ser. **447** (2013) 012011.

[7] *Search for Permanent Electric Dipole Moments at COSY Step 1: Spin coherence and systematic error studies (#216.0)*, May 2, 2012. Available from Ref. [2].

[8] N. E. Cheung, C. F. Perdrisat, J. Oh, K. Beard, V. Punjabi, J. Yonnet, R. Beurtey and M. Boivin *et al.*, Nucl. Instrum. Meth. A **363**, 561 (1995).

[9] V. P. Ladygin, E. Tomasi-Gustafsson, J. Ball, L. Bimbot, Y. Bisson, M. Boivin, J. L. Boyard and N. E. Cheung *et al.*, Nucl. Instrum. Meth. A **404**, 129 (1998).