COSY Beam Time Request

For Lab. use

Exp. No.:	Session No.
E 005.3	**6**

Collaboration: JEDI

First exploratory deuteron EDM experiments with the waveguide RF Wien Filter

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Total number of particles and type of beam (p, d, polarization)	Kinetic energy (MeV)	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)
WASA detector, RF Wien filter in PAX section, and electron cooler	**none**	**November 01, 2017**	**granted September run: + 1 week** **1 MD + 3 weeks**

First exploratory deuteron EDM experiments with the waveguide RF Wien Filter

The JEDI collaboration

May 19, 2017

Abstract

The RF Wien filter is based on a parallel plane waveguide, *i.e.*, a pair of conductors oriented parallel to the beam direction produces electric and magnetic fields. Thereby, the orthogonality condition $\vec{E} \times \vec{B}$ for a Wien filter is fulfilled very accurately by design. The device has been designed to perform a first direct measurement of the Electric Dipole Moment (EDM) of the deuteron at COSY. The plans for commissioning and first use of the waveguide RF Wien filter have already been outlined in the previous JEDI proposal *Waveguide RF Wien Filter: Commissioning and initial investigations.*

The RF Wien filter has been installed at COSY together with the driving circuit and the device is fully operational. The RF system currently provides an RF input power of about 3.2 kW. The experimental setup at the PAX location includes two Rogowski coils up- and downstream of the RF Wien filter, which will be used to make sure that the deuteron beam passes the RF Wien filter accurately on the symmetry axis of the device.

The commissioning of the RF Wien filter will be carried out in the two beam times already granted by the CBAC in June and September 2017 with vector polarized deuteron beam at 970 MeV/c. **We ask for one additional week to be appended to the second JEDI run in September of 2017, which shall be used to implement the spin tune feedback from the WASA detector.** For the first exploratory EDM experiments with the complete system (but without ferrites) **we ask for three weeks of beam time, preceded by one machine development (MD) week in the 4^{th} quarter of 2017.**

1 The waveguide RF Wien filter

1.1 Introduction

The transverse electromagnetic (TEM) mode of a waveguide comes closest to the requirement of orthogonal electric and magnetic fields. Therefore, for the use of the RF Wien filter at frequencies of about 100 kHz to 2 MHz, a parallel-plate waveguide was chosen as the basic geometry. The axis of the waveguide points along the beam direction (z). The plates are separated along the x-direction by 10 cm, and the width of the plates extends along the y-direction, parallel to the magnetic field. This setup ensures that the main component of the electric field is in the x-direction, while the main component of the magnetic field points along the y-direction. Figure 1 shows a model of the RF Wien filter[1], recently published in Ref. [1]. In particular, for the electric dipole moment measurement, it is important to quantify the field errors systematically. Since Monte-Carlo

[1]The design of the RF Wien filter has been worked out by a PhD student, Jamal Slim, from the Institute of High Frequency Technology, led by Prof. Dr.-Ing. Dirk Heberling, RWTH Aachen University.

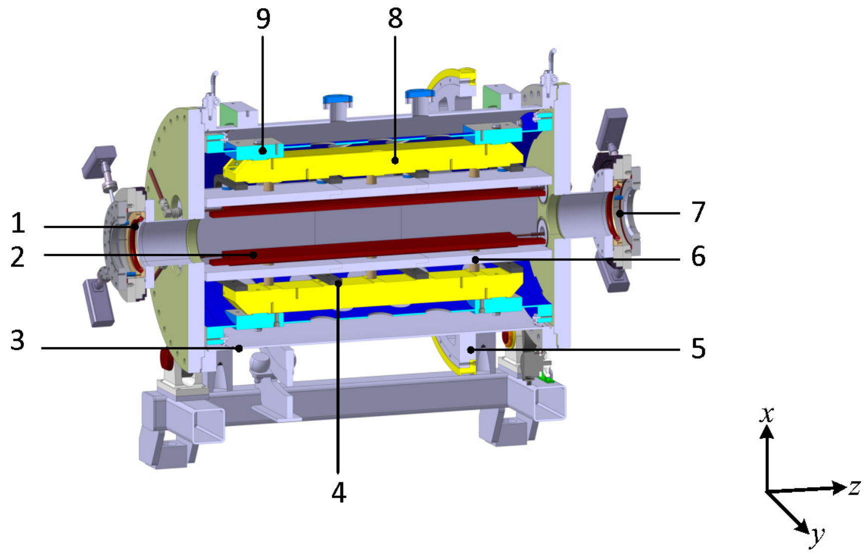


Figure 1: Design model of the RF Wien filter showing the parallel-plates waveguide and the support structure. 1: beam position monitor (BPM); 2: copper electrodes; 3: vacuum vessel; 4: clamps to hold the ferrite cage; 5: belt drive for 90° rotation, with a precision of 0.01° (0.17 mrad); 6: ferrite cage; 7: CF160 rotatable flange; 8: support structure of the electrodes; 9: inner support tube. The axis of the waveguide points along the z-direction, the plates are separated along x, and the plate width extends along y. During the EDM studies, the main field component E_x points radially outwards and H_y upwards with respect to the stored beam. (Figure taken from Ref. [1].)

simulations are computationally very expensive, an efficient surrogate modeling scheme based on the Polynomial Chaos Expansion method to compute the field quality in the presence of tolerances and misalignments has been recently published as well [2].

We intend to start the commissioning effort of the new waveguide RF Wien filter with deuterons at $T = 235\,\text{MeV}$ for which $\beta = 0.459$. The device is generally capable to be operated at frequencies in the range from about 100 kHz to 2 MHz. This range of frequencies will later on enable us to carry out EDM measurements for deuterons and protons at COSY. The working frequencies of the RF Wien filter are given by

$$f_{\text{RF}} = f_{\text{rev}}|k + \gamma G|, k \in \mathbb{Z} \tag{1}$$

where k is the harmonic number, G the gyromagnetic anomaly, γG the spin tune, and f_{rev} the revolution frequency. Table 1 summarizes the resonance frequencies for different harmonics for protons and deuterons. For the first deuteron EDM measurements, the two harmonics at $k = \pm 1$ have been tested in the laboratory setup. Slight modifications of the electric driving circuit are required in order to make the harmonics at $k = \pm 2$ also available in the experiments.

1.2 Electromagnetic design

The electromagnetic full-wave simulations using CST Microwave Studio[2] were capable to model the field with an accuracy of 10^{-6}. In order to provide a zero net Lorentz force,

[2]CST - Computer Simulation Technology AG, Darmstadt, Germany, `http://www.cst.com`

	$f_{\rm rev}$ [kHz]	G	β	γ	γG
d	750.2	-0.143	0.459	1.126	-0.161
p	791.6	1.793	0.485	1.143	2.050

	$f_{\rm RF}$ [kHz]						
	$k=-4$	$k=-3$	$k=-2$	$k=-1$	$k=0$	$k=+1$	$k=+2$
d	3121.6	2371.4	**1621.2**	**871.0**	**120.8**	**629.4**	**1379.6**
p	**1543.9**	**752.2**	39.4	**831.0**	**1622.7**	2414.3	3206.0

Table 1: Operating frequencies $f_{\rm RF}$ (from Eq. (1)) of the waveguide RF Wien filter for deuterons (d) at a momentum of 970 MeV/c and for protons (p) at 520 MeV/c in COSY for the harmonic numbers k. The frequencies $f_{\rm RF}$ shown in bold fit in the frequency range from 100 kHz to 2 MHz. The revolution frequency $f_{\rm rev}$, G factors, Lorentz β and γ, and the spin tune γG are given as well.

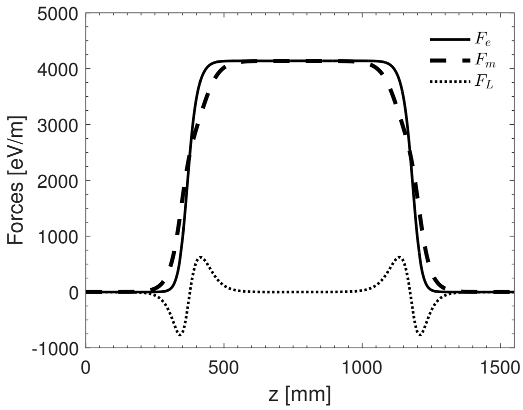


Figure 2: Electric, magnetic, and Lorentz force $F_{\rm L}$ as function of position along the beam direction (z coordinate) for an input power of 1 kW. (Figure taken from Ref. [1].)

the electric and magnetic forces must be matched at the center and the edges of the RF Wien filter. At the edges however, a special solution is required, because the rise and drop of the electric and magnetic forces are not the same, resulting in kicks on the particles passing through the device. The chosen solution aims to decompose the kicks at each side into two kicks of opposite directions in a way that they average out. To do so, the fields at the edges were decoupled, keeping the electric field unchanged while manipulating the magnetic field so that the rise and drops cross each other, as shown in Fig. 2.

The Lorentz force is given by

$$\vec{F}_{\rm L} = q\left(\vec{E} + \vec{v}\times\vec{B}\right) , \tag{2}$$

where q is the charge of the particle, $\vec{v} = c(0,0,\beta)$ is the velocity vector, $\vec{E} = (E_x, E_y, E_z)$ and $\vec{B} = \mu_0(H_x, H_y, H_z)$ denote the components of the electric and magnetic fields, and μ_0 the vacuum permeability.

Integrating and averaging the Lorentz force $\vec{F}_{\rm L}$, given in Eq. (2), along the axis of the RF Wien filter for the geometry shown in Fig. 1 that includes the ferrites at an input power of 3.2 kW, yields

$$\frac{q}{\ell}\int_{-\ell/2}^{\ell/2}\begin{pmatrix} E_x - c\beta B_y \\ E_y + c\beta B_x \\ E_z \end{pmatrix} dz = \begin{pmatrix} 1.07\times10^{-3} \\ 1.43\times10^{-3} \\ 2.27\times10^{-21} \end{pmatrix} \text{eV/m}\,, \tag{3}$$

where $\ell = 1550\,\text{mm}$ denotes the active length of the RF Wien filter, defined as the region where the fields are non-zero.

The waveguide RF Wien filter can be rated according to its ability to manipulate the spins of the stored particles, and as a figure of merit, the field integral of $\vec{B}$ along the beam axis is evaluated, yielding for an input power of 3.2 kW,

$$\int_{-\ell/2}^{\ell/2}\vec{B}dz = \begin{pmatrix} 4.88\times10^{-9} \\ 4.87\times10^{-2} \\ 1.25\times10^{-6} \end{pmatrix} \text{T mm}\,. \tag{4}$$

Under these conditions, the corresponding integrated electric field components are given by

$$\int_{-\ell/2}^{\ell/2}\vec{E}dz = \begin{pmatrix} 5947.18 \\ 0.03 \\ 0.01 \end{pmatrix} \text{V}\,. \tag{5}$$

1.3 Mechanical realization

The RF Wien Filter has been installed in the low-beta section of the COSY accelerator (see Fig. 3). It is equipped with an ion pump. The complete tank is rotatable up to 90° with a precision of 0.01° using a belt with a stepper motor[3] and a brake[4] to secure the position. The position of the tank is determined with a rotary encoder[5] situated on the outside of one of the big flanges. Some features of the device are described below:

- Large-angle rotations require to re-cable the RF Wien filter without breaking of the vacuum.
- Small angle rotations can be accomplished in-situ, *i.e.*, when the RF Wien filter is operating.
- In order to allow for the option of clock-wise and counter-clock-wise beam circulation in the machine, the same cables will be used when replacing input and output.
- The driving circuit is placed inside the tunnel on top of the RF Wien filter (see Fig. 3).
- Remote control of all relevant parameters is taken care of by a Labview control system.

[3] Nanotec ST5918 Stepper Motor
[4] Nanotec BKE
[5] Haidenhain ROQ 437

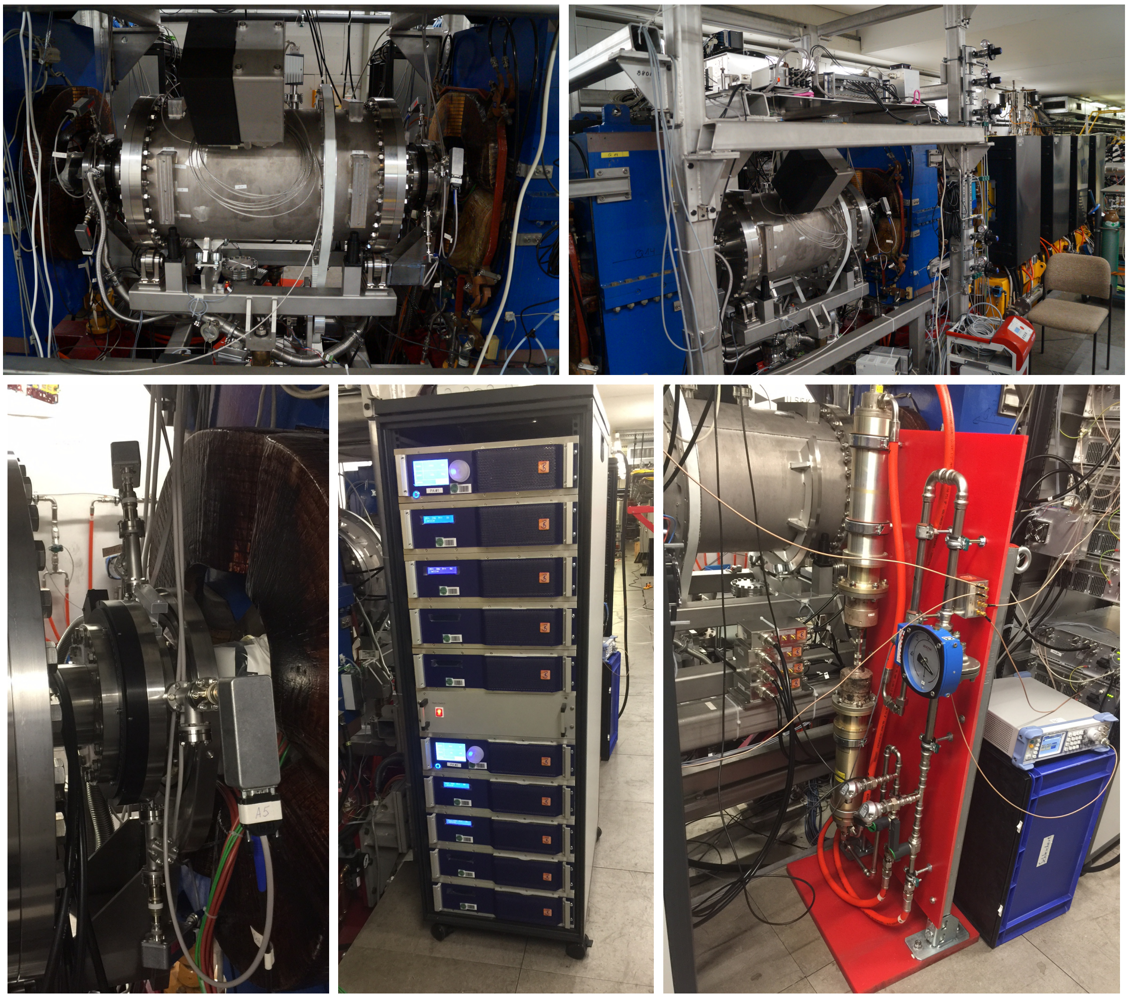


Figure 3: Top row: Photographs of the RF Wien filter mounted at the PAX experimental area in COSY. Bottom row, left panel: Upstream Rogowski coil. Middle panel: One of the two racks with the power amplifiers. Each of the two units, composed of a master and two slaves can deliver up to 500 W. Right panel: Water-cooled 25 Ω resistor.

1.4 Driving circuit

The driving circuit for the waveguide RF Wien filter has been manufactured by the company Barthel[6]. The original circuit diagram (shown in Fig. 3 of Ref. [1] has been modified, since it is difficult to realize (or buy) high-power variable inductances and resistors. Instead, four variable capacitors are now inserted in the modified circuit, shown in Fig. 4. The power splitters are replaced by four amplifiers each connected to the feedthroughs individually. The $1 : 0.5$ transformer has also been removed. Eight -30 dB directional couplers are installed between the amplifiers and the feedthroughs to monitor the magnitudes and the corresponding phases of the current and voltages going in and out the RF Wien filter.

A comparison between the simulated and measured reflected power of the complete circuit is depicted in Fig. 5, indicating the high-level of precision of the simulation carried out using CST[2].

[6] Barthel HF-Technik GmbH `http://www.barthel-hf.de/`

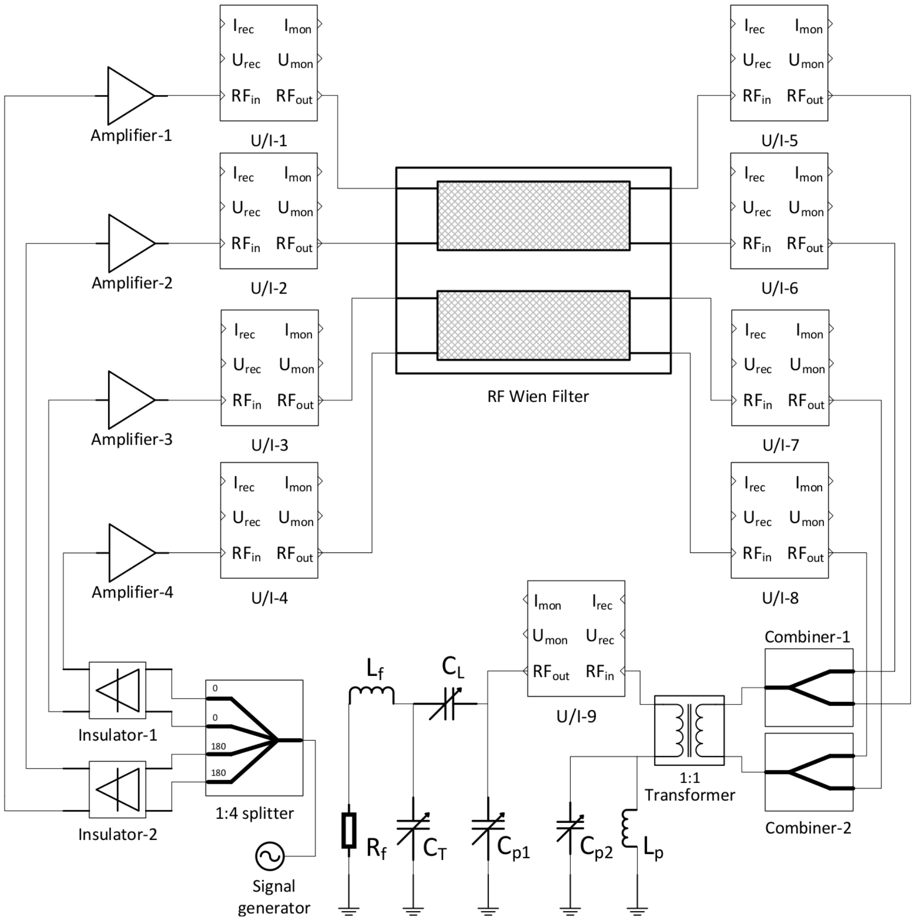


Figure 4: Modified driving circuit for the RF Wien filter. Different from the circuit shown in Fig. 3 of Ref. [1], a fixed $R_{\mathrm{f}} = 25\,\Omega$ resistor is used here. The variable elements in this circuit are labeled C_{p1}, C_{p2}, C_{L}, and C_{T}. The two fixed inductances are $L_{\mathrm{f}} = 28.8\,\mu\mathrm{H}$ and $L_{\mathrm{p}} = 5.07\,\mu\mathrm{H}$.

2 Feedback loops

To ensure stable operation of the RF Wien filter, in total four feedback loops are required. These are depicted in Fig. 6 and briefly described below:

Loop 1 Maintains phase-lock between the spin-frequency measured with the polarimeter and the RF of the Wien filter by adjusting the frequency f_{RF} of the RF Wien filter.

Loop 2 Minimizes the Lorentz force F_{L} through a measurement with a BPM in COSY and automatic adjustment of the variable elements in the driving circuit (see Fig. 4).

Loop 3 An internal feedback system stabilizes the phase between E and B inside the RF Wien filter circuit using the variable elements in the driving circuit (see Fig. 4).

- $-30\,$dB couplers (see Fig. 4) are used to couple the power to $50\,\Omega$. At this point current, voltage, and the phase shift between electric and magnetic field is measured. Similar elements have been inserted at nine points in the driving circuit of the RF Wien filter.

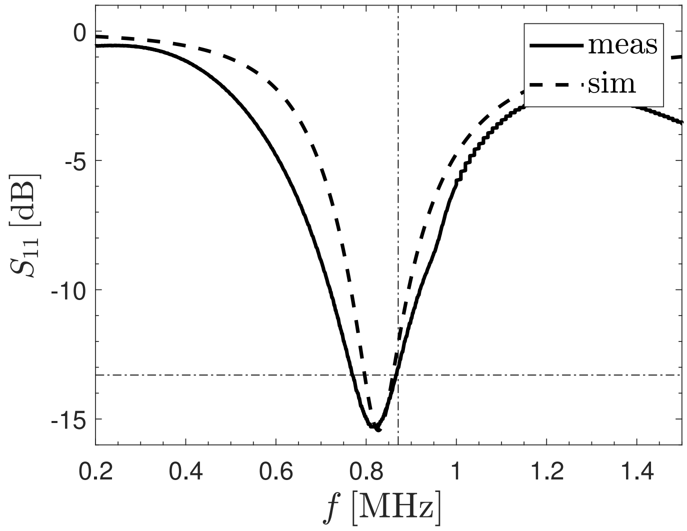


Figure 5: Measured and simulated S_{11} parameter of the driving circuit, evidencing the good theoretical understanding of the RF system and the low-level of power reflected.

Loop 4 This loop keeps the beam centered on the axis of the RF Wien Filter. The signals from the Rogowski coils at the entrance and exit of the RF Wien filter are used to actively adjust two 4-steerer bumps, one for the horizontal and one for the vertical direction. The readout system is depicted in Fig. 11.

It should be noted that the feedback Loops 2 and 3 are actually coupled. The magnitude of the field quotient, and thus the resulting Lorentz force is related to all adjustable elements, and all of these elements also affect the phase between the electric $\vec{E}$ and magnetic $\vec{B}$ fields.

2.1 Spin tune feedback (Loop 1)

The spin-tune feedback (Loop 1) serves two purposes: *i)* it ensures that the RF Wien filter is operating on the spin-tune resonance frequency and *ii)* maintains the relative phase ϕ between the spin direction and the oscillation frequency of the RF Wien filter. This is achieved by monitoring deuteron-carbon scattering events, the COSY RF and the Wien filter RF continuously by one long-range TDC with a single time reference. The details of the technique are described in Ref. [3], accepted for publication in Phys. Rev. Lett.

In order to make sure that there are no discontinuities present in the wave train from the RF generator to the RF field inside the Wien filter, the response using the monitor output U/I-7 (see Fig. 4), right behind the plates of the RF Wien filter to a gradual change of the frequency of the RF generator was measured. As shown in Fig. 7, a very smooth transition from one frequency ($f_{\mathrm{RF}} = 871\,000\,\mathrm{Hz}$) to slightly higher frequency is observed.

2.2 Lorentz force feedback (Loop 2)

This feedback loop is required in order to ensure a minimal Lorentz force during operation. The Lorentz force is given by Eq. (2), where q is the charge of the particle, $\vec{v} = c(0, 0, \beta)$ is the velocity vector, $\vec{E} = (E_x, E_y, E_z)$ and $\vec{B} = \mu_0(H_x, H_y, H_z)$ denote the components of

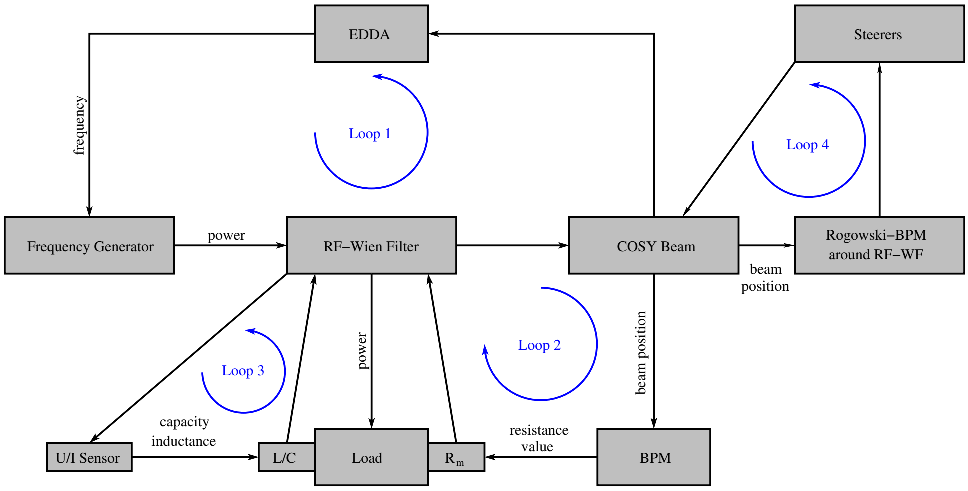


Figure 6: The three feedback loops for the operation of the RF Wien filter. **Loop 1** takes care of phase-locking the spin precession in COSY to the RF of the Wien filter. **Loop 2** minimizes the Lorentz force exerted on the beam during operation. **Loop 3** is an internal loop in the circuit of the RF Wien filter to make sure that the phase between E and B is constant. **Loop 4** makes sure the beam passes on the central axis through the Wien filter.

the electric and magnetic fields, and μ_0 the vacuum permeability. For a vanishing Lorentz force $\vec{F}_\mathrm{L} = 0$, the required field quotient Z_q is determined, which yields

$$\begin{aligned} E_x &= -c \cdot \beta \cdot \mu_0 \cdot H_y \, , \\ Z_q &= -\frac{E_x}{H_y} = c \cdot \beta \cdot \mu_0 \approx 173 \ \Omega \, . \end{aligned} \tag{6}$$

A non-vanishing Lorentz force, generated for example by a slight change of the Lorentz β of the beam, leads to an excitation of the beam at the frequency f_RF of the RF Wien filter. This excitation will be detected using a suitable BPM in COSY. This signal will then be used to adjust the variable elements in the driving circuit (see Fig. 4) to minimize the Lorentz force during operation with beam.

Tracking simulations were carried out with two different beam settings, both with zero-dispersion, one with and one without the low-β section switched on. The largest orbit RMS in the horizontal plane for zero dispersion is observed at the position of BPM #16. When the low beta section is switched on, BPM #16 is also one of the most sensitive BPMs.

The largest sensitivity in the vertical plane (100% for zero dispersion and 78% for low-β section on) was found at the location of BPM #11, located 30m upstream of BPM #16. In order to have similar vacuum and noise conditions, two nearby BPMs are preferable, and thus BPM #16 (horizontal plane) and BPM #17 (vertical plane). The sensitivity in the vertical plane of BPM #17 is not ideal (90% and 46% respectively), but sufficiently large for a measurement of beam orbit displacements.

For the measurement raw signals are taken from the left and right plates of the BPM #16 and the up and down plates of BPM #17. These signals are distributed from the conventional COSY BPM electronics behind the operational amplifier and are already preamplified in the tunnel. Reading of the signals is accomplished by two lock-in ampli-

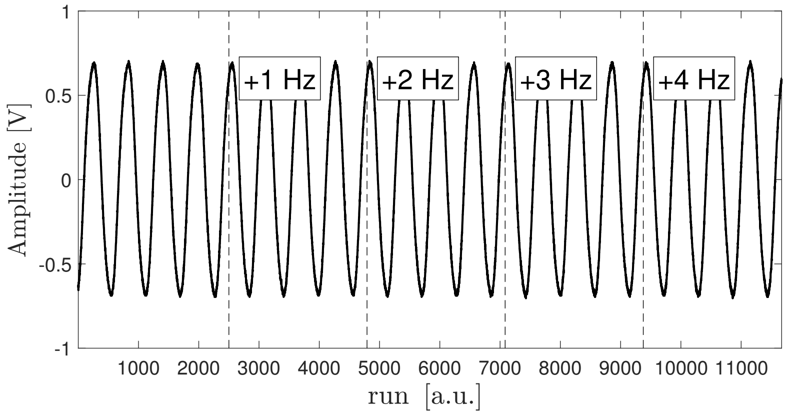


Figure 7: Response of the monitor signal U/I-7 (see Fig. 4) at $f_{\rm RF} = 871\,000\,$Hz to a gradual small change of the frequency driving the RF circuit.

fiers[7], locked at the COSY frequency, are used. Beam positions will be analyzed and sent to the COSY EPICS system for further distribution. The scheme of the Lorentz-force detection system is depicted in Fig. 8.

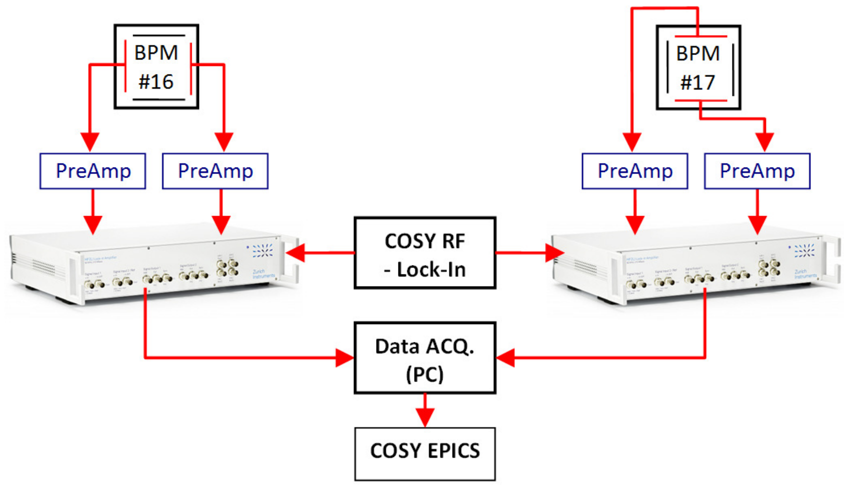


Figure 8: Lorentz-force detection scheme for BPM #16 and #17 based on two lock-in amplifiers[7].

2.3 Internal $\vec{E} \times \vec{B}$ feedback (Loop 3)

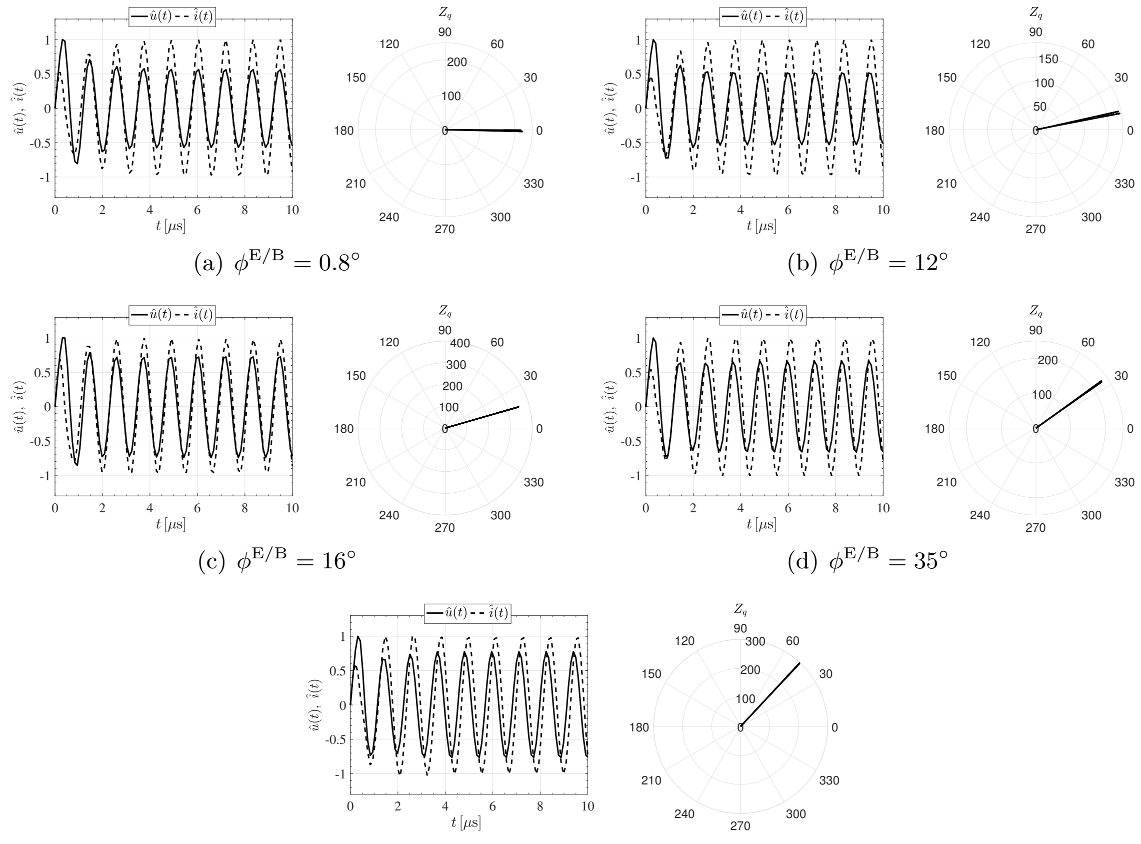
The orthogonality of $\vec{E}$ and $\vec{B}$ in the RF Wien filter is ensured by measuring voltages, currents, and the phase between them in the driving circuit (shown in Fig. 4) and by actively adjusting the variable elements in the driving circuit to make sure that voltage and current are in phase.

The capabilities of the driving circuit are illustrated in Fig. 9, where after some tuning of the variable elements, the phase between E and B (equivalent to the phase between voltage $\hat{u}$ and current $\hat{i}$) was adjusted to a specified values using the variable circuit

[7]Zurich Instruments, HF2LI lock-in amplifier `https://www.zhinst.com/`

elements. The angle between the imaginary and the real part of the impedance yields the phase between electric (E) and magnetic field (B) in the RF Wien filter, given by

$$\phi^{\mathrm{E/B}} = \arctan\left[\frac{\Re(Z_q)}{\Im(Z_q)}\right] . \tag{7}$$



(a) $\phi^{\mathrm{E/B}} = 0.8°$ (b) $\phi^{\mathrm{E/B}} = 12°$

(c) $\phi^{\mathrm{E/B}} = 16°$ (d) $\phi^{\mathrm{E/B}} = 35°$

(e) $\phi^{\mathrm{E/B}} = 46°$

Figure 9: Voltage $\hat{u}$ and current $\hat{i}$ in the driving circuit for different phase angles $\phi^{\mathrm{E/B}}$ [Eq. (7)], adjusted using the variable elements of the driving circuit, shown in Fig. 4.

In Fig. 10, we show that a nearly perfect zeroing of the phase between voltage and current in the driving circuit can be achieved using all variable elements.

2.4 Beam position feedback (Loop 4)

In order to control the beam position during spin manipulation measurements with the RF Wien filter, two Rogowski coils are employed to measure the beam position at the entrance and exit of the RF Wien filter (see Fig. 3). A schematic diagram for the readout scheme of one Rogowski coil is shown in Fig. 11. Each Rogowski coil is divided into four segments. The bunched beam passes the Rogowski coil and induces a voltage in each segment. Each coil segment is connected to a pre-amplifier to increase the induced signal. For the read out of the induced voltages, two lock-in amplifiers[7] are used. The lock-in

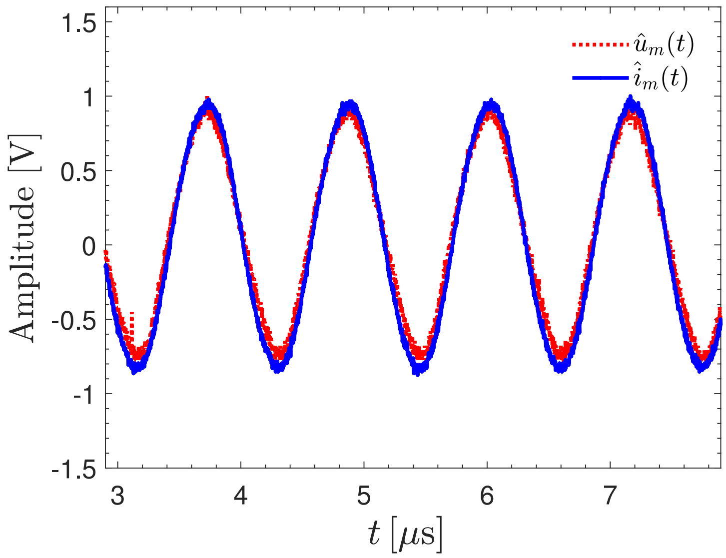


Figure 10: Using an additional lock-in amplifier[7] and the measured monitor output of U/I-9, the measured phase between the voltage $\hat{u}_{\mathrm{m}}$ and the current $\hat{i}_{\mathrm{m}}$ amounts to $\phi^{E/B} = -0.1°$.

amplifiers are locked to the COSY-RF (after conversion to a TTL-signal). A measurement with the synchronized lock-in amplifiers is performed, when a BPM trigger signal is sent.

The sampling rate of the lock-in amplifier is around 450 MS/s. The data acquisition is performed with a PC. The raw data measurement time is adjustable and the resulting averaged horizontal and vertical beam positions are communicated to the COSY control system via Ethernet.

The COSY BPM control system has been upgraded involving an external company[8]. Thereby, active control of the beam orbit in COSY during the cycle has become available. Maintaining the beam position at the entrance and exit of the RF Wien filter (**loop 4**) will be facilitated by a feedback loop implemented inside the upgraded COSYLAB system based on the input from the two Rogowski coils at the RF Wien filter.

3 First tests with the waveguide RF Wien filter

The waveguide RF Wien filter has been installed at the PAX interaction point at COSY. Proper alignment of the beam position in the device will be accomplished by a pair of Rogowski coils at the entrance and exit of the vessel that serve as BPMs [4] (see label 1 in Fig. 1). The β-functions at the PAX interaction point can be adjusted in the range between about $\beta = 0.4$ to 4 m, whereby the beam size can be changed accordingly. With respect to the commissioning of the waveguide RF Wien filter, we would like to repeat some of the procedures developed during the commissioning of the prototype RF Wien filter [5], in order to show that the device is performing as expected.

In conjunction with the imperfection fields distributed along the accelerator ring, an RF Wien filter with radial electric fields can lead to an EDM induced build-up of a vertical polarization component. It is foreseen to use the new waveguide RF Wien filter for systematic investigations of sources for false EDM signals. To this end, extensive

[8]COSYLAB `http://www.cosylab.com/`

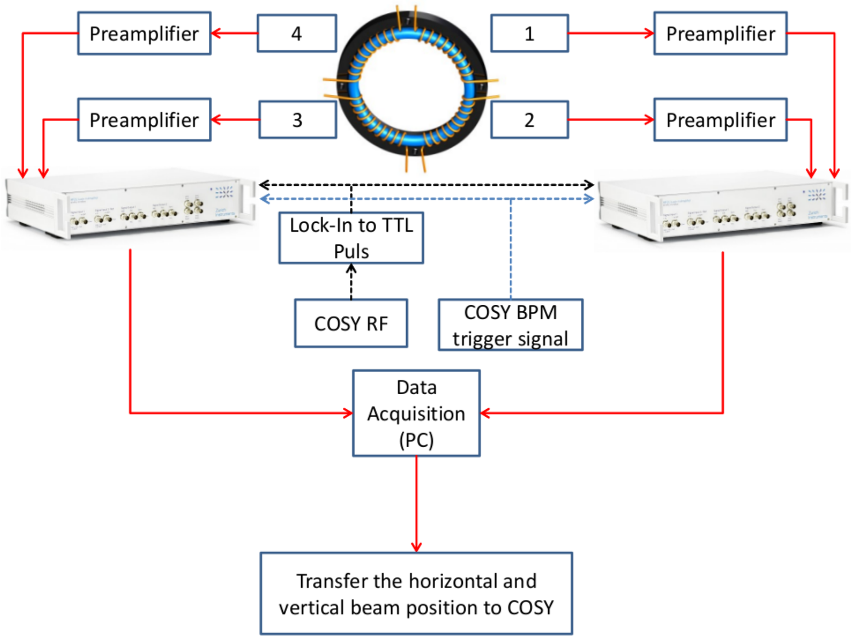


Figure 11: Schematic readout diagram for Rogowski coil beam position determination.

simulation studies about the polarization buildup using an RF Wien filter to detect the EDM signal were carried out by JEDI. These are described in Ref. [6, 7], where it is shown that *e.g.*, in particular quadrupole misalignments mimic the buildup of polarization due to an EDM (see Figs. 4 and 5 of Ref. [8]).

As explained above, the commissioning of the prototype RF Wien filter took about one week for each of the employed harmonics ($k = -1$ and $+1$, see Table 1). It proved time consuming to set up the machine near a betatron resonance, because in order to gain a high sensitivity to the induced beam oscillations, the accelerators optics needed to be modified so that a vertical betatron sideband is shifted exactly to the RF E×B frequency at 871.0 kHz (see Fig. 5 of Ref [5]). In this reference, details about the measurement procedure are described as well. Once the machine is setup near the betatron resonance, testing the performance of the waveguide RF Wien filter at the $K = -1$ harmonic should be achievable during the already allocated beam time in the 2$^{\text{nd}}$ Quarter of 2017.

3.1 Plan for the upcoming beam times in 2017

The CBAC has already granted two times two weeks of beam time, plus one MD week preceding each of the beam time periods in 2017. These two beam time periods shall be used to accomplish the items described in the following:

1. **2$^{\text{nd}}$ Quarter 2017:** (granted: 1 MD + 2 weeks)

   - The Wien filter has been installed in the PAX section at COSY. It is also possible to operate it with a radial B field, *i.e.*, rotated by 90° with respect to EDM measurement mode. During the laboratory tests, the internal **feedback loop 3** has been implemented.
   - During the upcoming commissioning beam time periods, the RF Wien filter will be operated at the $K = -1$ harmonics at $f_{\text{RF}} = 871.0$ kHz.

- The beam position feedback **loop 4** to maintain a stable beam position at the entrance and exit of the RF Wien filter using the new COSYLAB control system will be implemented during the MD preceding the JEDI run.
- All hardware to take into operation the **Lorentz force feedback loop 2** has been installed.
  - Depending on the resulting sensitivities, beam position response measurements near the betatron resonance may be carried out as well.
  - The influence of the betatron amplitude at the RF Wien filter on the Lorentz force shall also be investigated.

2. 3rd **Quarter 2017:** (granted: 1 MD + 2 weeks; **Request: + 1 week**)

   - **Implementation of the spin tune feedback loop 1 using the WASA detector.**

During the beamtime in November 2015 (E3), we have demonstrated the concept of a spin tune feedback using the EDDA detector as polarimeter (see also Ref. [3]). We showed that the relative phase between the spin precession and the RF signal of the solenoid could be controlled on the level of 0.2 rad using the frequency on the COSY RF cavity as control parameter.

For the operation of the RF Wien filter we plan to use the WASA Forward Detector as polarimeter instead. We already successfully used the WASA detector in experiment E4 to systematically investigate the cross sections and analyzing powers in polarized dC scattering. WASA has the advantage of a much larger angular coverage (compared to EDDA), and thus a much better efficiency. In order to put the feedback system into operation at the WASA detector we are asking for one additional week of beam time for the already scheduled run in September 2017, *i.e.*, extending this run from two to three weeks.

3.2 New request: 4th quarter 2017

3. 4th **Quarter 2017: (Request: 3 weeks + 1 MD)**

   - **We would like to accomplish a test of the complete RF Wien filter system (without ferrites) with vector polarized deuteron beam, where all four feedback loops are active.**

All measurements in the requested beam time period will be carried out without ferrites. The delivery of the ferrites by the company[9] has been announced for August 2017. We anticipate that the RF Wien filter will be upgraded with the Ferrites in the 1st quarter 2018 and that a first experimental run with the full system shall then take place at the beginning of the 2nd quarter 2018.

Already prepared is the operation of the RF system also at the $K = +1$ harmonic at 629.4 kHz. Other frequencies will be made available later.

During this beamtime, various systematic investigation of the performance of the RF Wien filter shall be caried out:

[9] National Magnetics Group, `http://magneticsgroup.com/index.html`.

- A study of the interplay of the feedback loops is foreseen.
- Study of the effect of the rotation of the RF Wien filter into the EDM mode with horizontal E field and vertical B field.
- Sensitivity study with horizontal B field and decreasing B field to test the sensitivity limit of the WASA polarimeter.
- As discussed in Ref. [9] (accepted for publication in Phys. Rev. Accel. Beams), together with the presently available solenoidal magnetic fields, we would like to scan the resonance strength of the RF Wien filter as function of the RF Wien filter rotation angle and the static solenoid fields in COSY. When the RF Wien filter axis is precisely aligned along the stable spin axis, the resonance strength should vanish.

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