Executive summary for
"Complex commissioning of JEDI Polarimeter"

Exp. No.:	Session No.
E2.8	**12**

Collaboration: JEDI

Spokesperson for beam time: Irakli Keshelashvili, David Mchedlishvili

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Is support* from the LSF program of the EU requested?

<u>Yes</u> ~~No~~

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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
Internal beam of polarized deuterons	**970 MeV/c**	**10^8**	**10^{10}**
Experimental area	Safety aspects (if any)	Earliest date of installation	Total beam time (No.of shifts)
COSY Ring: JEDI Polarimeter (JePo) RF Solenoid, E-cooler	**none**	**Q4 2020**	**1 week MD. + 2 weeks EXP.**

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

***EU-Support:**
The European Commission supports access to COSY for users outside Germany from European and associated states within the STRONG-2020 integrating activity.
For details see http://www.ikp.fz-juelich.de/strong2020.

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

Complex commissioning of JEDI Polarimeter

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on behalf of the JEDI collaboration

September 1, 2020

The JEDI polarimeter (JePo) has been installed at COSY as an internal polarimeter in Summer 2019. It has replaced the EDDA detector, which was used together with the WASA detector as polarimeters. Since then, JePo was commissioned twice, December 2019, and February 2020. First, it was tested with a vertically polarized deuteron beam where the main goal was an automatic block target and LYSO-SiPM module check. In the second commissioning beam time, the main emphasis was to adopt the online software for the horizontally polarized deuteron beam. Both beam times went very successfully.

Before the JEDI collaboration performs the precursor experiment, three upgrades are planned to be finished. The target system will be improved to scrape the beam from all sides (up, down, left, and right). The delta E detectors will be replaced by a new system, which will imply the precise extraction of a hit position. And the feedback system will be made using only JePo readout system.

With this proposal we are asking for 3 weeks of beam time (1 MD + 2 experiment) in Q1 of 2021.

1 Introduction

Since summer 2019 the JEDI polarimeter (JePo) has been installed in the COSY ring as an internal beam polarimeter at the former EDDA detector section. It consists of three main components. The vacuum chamber, which was tested before installation into the ring at the laboratory environment and excellent performance, was reaching 10^{-12} mbar pressure. Second, the carbon block target system, which can approach vertically and horizontally to beam. The system is fully automatized and has monitoring cameras for both directions. The general COSY archiving system is regularly logging the positions of the target. The cameras can be monitored at any place using a dedicated web page. And third, the detector part comprises the 2 cm thick plastic scintillator ΔE layer in front of LYSO crystals [1]. Four plastic scintillators cover the full polarimeter: up, down, left, and right detector arms.

Each arm consists of 12 LYSO crystals and one corner crystal. In total, 52 LYSO modules are installed and are fully functional. Custom made hi precision voltage regulators do the power supply of all SiPM sensors [2]. The system whole system is automatized and can be powered on / off while beginning and end the COSY cycle. The voltages are also regularly archived by the central COSY EPICS system. The readout of the detector is done using

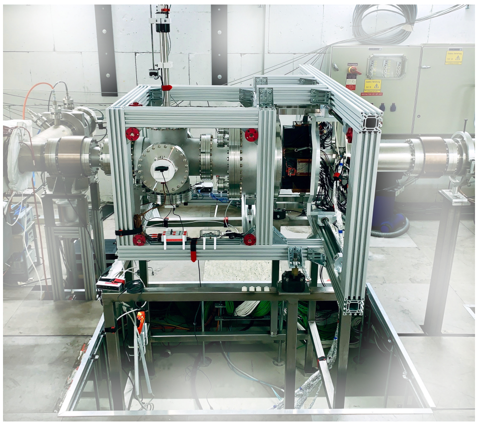

Figure 1: A new JEDI polarimeter (JePo) as it is installed at COSY. The beam direction is from left to right. From the left, the first flange is a target chamber with a 2 cm thick carbon target. Then the vacuum flight chamber is seen and at the right LYSO-SiPM modules itself.

six 16 channel sampling ADC modules by Struck [3]. This is a high precision 14-bit, high sampling rate 250 MSPS digitizers capable of time stamp all events. All modules are daisy-chained and have a common sampling clock. The readout system is also digitizing the COSY RF cavity, RF solenoid, RF Wien filter, and 10 MHz synchronization signals. All this information can successfully be analyzed to monitor the horizontal polarization in the ring.

So far, we had two commissioning beam times at the end of 2019, and at the beginning of 2020. The first one has been done with a vertically polarized deuteron beam, and the later, we already turned the polarization vector into the horizontal plane. Both experiments have been done successfully.

2 New Block Target

The current target system consists of two carbon block targets (See fig.: 2). This is mounted on a magnetic feed through controlled by the stepper motor linear actuators. With the magnetic feed troughs, we have total isolation of the COSY UHV. With the help of stepper motors, we can control the target position better then 0.1 mm. The position control system is fully automatized and very flexible. With the dedicated software, the beam position can be found by slowly approaching the beam and monitoring the detector rates. Also, the target has a retraction possibility. During the injection and cooling time, the target is off from the beam by roughly 20 mm. Only before data acquisition it approaches the beam. The extraction is achieved by EM excitation of the beam. The few kHz wide, white noise is added to the vertical or horizontal betatron frequency to hit the vertical or horizontal target, respectively. So, only one target at the time can be used. With the current configuration, we can only approach the beam from the beam's top or one horizontal side. Also, both targets have the same thickness of 2 cm.

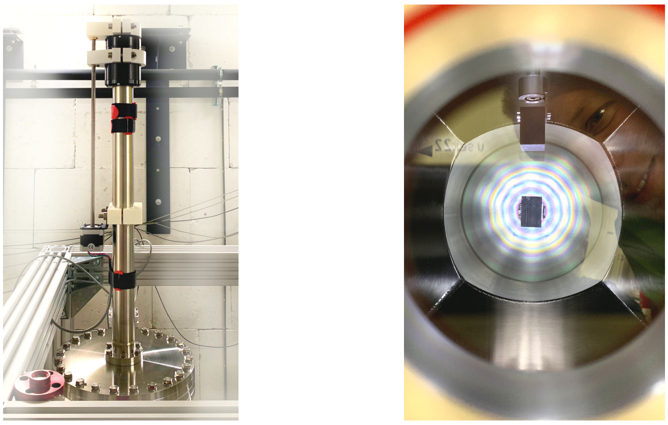

Figure 2: Left: the vertical target system at the time of installation. Right: inside the target chamber. The vertical and horizontal block targets are seen.

We can approach the beam from the top and bottom with the new target modification, also left and right side. In total, as it is shown in figure 3, we can also have four target block inside the vacuum chamber. The side block can also be thinner if low energy measurement is needed. As a by-product, not only the beam position can be found using this configuration, but also the beam vertical and horizontal size can be estimated.

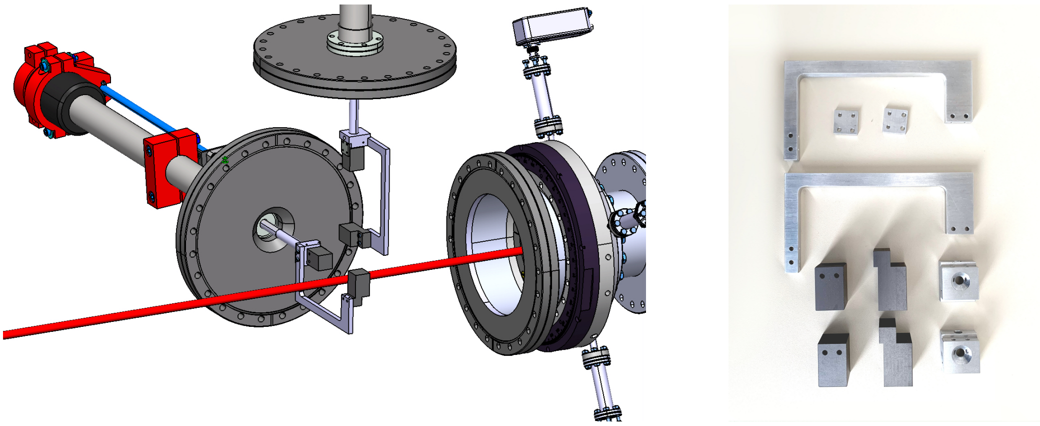

Figure 3: Left: the drawing of the target modification. Two targets per feed trough is installed. Right: the hardware for the installation is shown.

All this will gives us more control over the systematic error estimation. As shown in figure 3, the hardware is ready and is planned to be installed during the next maintenance period. This plan has been delayed due to Corona pandemic restrictions.

3 New Tracker + ΔE

Six plastic scintillator counters were tested in the last external beam test dedicated to the polarimeter development at the Big Karl experimental area (see fig.: 4). The test aimed to estimate the position resolution of half overlapping triangular plastic scintillator bars. The new fast SiPM signal amplifiers have been developed and also tested during the beam

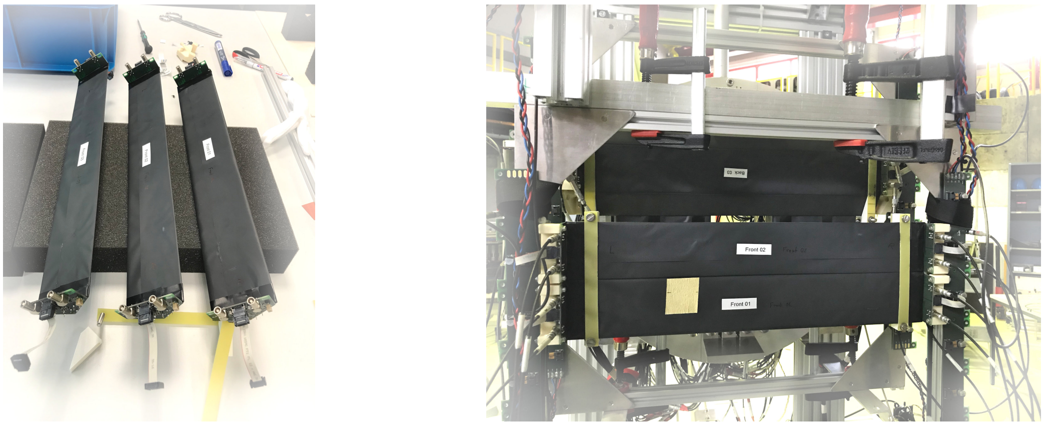

Figure 4: Left: individual plastic scintillator bars during the assembly and laboratory test phase. Right: six scintillator bars were installed during the test beam time at the Big Karl experimental area in 2018.

test. The results was also reported during the CBAC meeting July 2018 [4]. In contrast to the current ΔE counters, the new system will allocate the hit position within the 2 mm precision in two dimensions. Currently, we relay to LYSO crystal face which is 3x3 cm^2. The detector's total thickness will be 2+2 cm (currently 2 cm) split into two layers, vertical and horizontal. The layer thickness is maintained to be constant. The calibrated sum

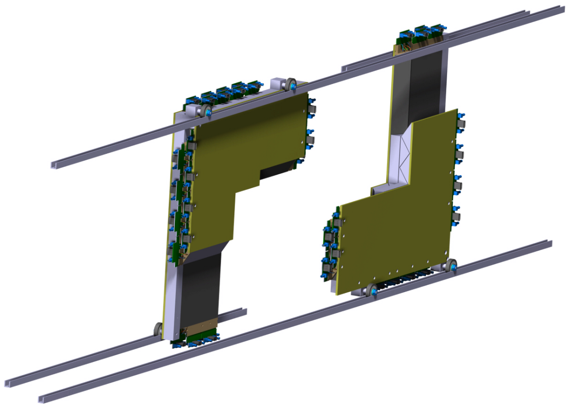

Figure 5: New rail system for the scintillator bars to mount at JePo.

signal of all layers will measure the energy loss information, which can be later used for particle identification using a ΔE over E technique. And the difference over the sum will give us the precise allocation of the hit. With precise coordinates, we would extract much enhanced angular distributions for the asymmetry measurement. Consequently, it will improve our understanding of the systematic errors of the measurement. Figure 5 shows the design of the new support structure for the ΔE scintillator wall. The former design, which was developed in 2018, has been changed due to mechanical collisions after polarimeter installation. All scintillator material, amplifiers, and SiPM sensors are acquired and are ready for assembly. This project has also been delayed due to Corona pandemic as all hardware activities were limited. The necessary analysis modules and its implementation in Geant 4 simulation have been done already long ago.

4 New Feedback

During the summer shut down 2020, COSY is equipped with a signal distribution system. This is done using optical fiber, distributing timing signals at the particular stations and then converting it into TTL signals. With this system, we are getting precise timing signals from four essential systems for the EDM experiment, which is used for spin tracking analysis. This signals are: COSY RF cavity, RF solenoid, RF Wien filter, and 10 MHz GPS clock signal for synchronization. All RF signals are down-scaled by a factor of 256 and the 10 MHz clock by the factor of 10^4 to have kHz range oscillations and avoid a very high data rate. Until now, JePo was using timing signals from the WASA feedback system and sending detector count rates back. During the last commissioning beam time, we have demonstrated the online performance of the JePo readout system in parallel to WASA spin tracking software. We have cross-checked our analysis, and the results are satisfactory. In contrast to the old system, we can deal with much higher count rates since our time stamping system is modern. The beam time goal will be to generate feedback signals for COSY with the JePo standalone software and move everything to a new polarimeter.

Besides, the plan is to create FPGA based 10 MHz clock multiplayer with the programable (remotely controlled) multiplication factor and phase shift. This will exchange the internal sampling clock of digitizers (ADC's) and provide more straightforward data analysis methods.

The polarimeter count rate will also generate the feedback for beam extraction white noise amplitude and will substitute the current analog system. This may need to develop a network controlled board to provide a signal level for the COSY stripline amplifiers.

Beam request

In order to make efficient use of the available beam time and man power — given the overhead for setting up the experimental environment — we ask for 3 (1 MD + 2 EXP) weeks (one week of machine development followed by two weeks of measurement time) in the first quarter of 2021 using cooled polarized deuterons at a kinetic energy of $T_d = 230$ MeV.

References

[1] F. Müller, PhD thesis, *Polarimeter Development for Electric Dipole Moment Measurements in Storage Rings*,
http://collaborations.fz-juelich.de/ikp/jedi/public_files/theses/thesis_fabian_mueller_final_version.pdf

[2] O. Javakhishvili *et al.*, *Development of a multi-channel power supply for silicon photomultipliers reading out inorganic scintillators*, Nucl. Instrum. Methods Phys. Res. A **977** (2020) 164337
https://doi.org/10.1016/j.nima.2020.164337

[3] SIS3316-250-14 16 channel 250 MSPS 14-bit.
http://www.struck.de/sis3316.html

[4] TOWARDS THE EDM POLARIMETRY, CBAC July 2018, Exp. No.: E002.6
http://collaborations.fz-juelich.de/ikp/jedi/public_files/usual_event/i.keshelashvili_CBAC2018.07.02.pdf