COSY Beam Time Request

For Lab. use

Exp. No.:	Session No.
E2.3	**5**

Collaboration: JEDI

Towards the EDM Polarimetry

Spokespersons for the beam time: **Irakli Keshelashvili (Jülich)**
Bernd Lorentz (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 615603** Fax: **+49 2461 613930** E-mail: **a.lehrach@fz-juelich.de**
pretz@physik.rwth-aachen.de
f.rathmann@fz-juelich.de

i.keshelashvili@fz-juelich.de
b.lorentz@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
Extracted beam of polarized deuterons	**100, 150, 200, 235, 270 MeV**	**10^3**	**10^7**
Experimental area	Safety aspects (if any)	Earliest date of installation	Total beam time (No.of shifts)
Set-up with LYSO crystals at BIG KARL area	**none**	**1st March 2017**	**1 week (+ MD)**

JEDI Beam Time Request for the first half of 2017

Towards the EDM Polarimetry (Progress report)

for the JEDI collaboration

http://collaborations.fz-juelich.de/ikp/jedi

November 7, 2016

Abstract

In this document, we overview the progress made since the last CBAC meeting (June 2016) towards the EDM polarimeter development and request the beam time for expanded test in spring 2017. In the proposed measurements, the slowly extracted polarized deuteron beam will be used at the BIG KARL experimental area. The goal of the new request is further development and optimization of the DAQ performance and the new SiPM based LYSO modules. During this measurements, the differential cross sections and vector analyzing power will be extracted for the deuteron induced elastic reactions on different targets (which is the main difference compared to the 2016 run). With the specific target revolver, the above-mentioned physical parameters for Magnesium, Carbon, Silicon, and Aluminum will be studied. The setup comprises 24 LYSO modules divided into two arms, each consisting of 12 calorimeter modules (two rows including 6 crystals each), and seven solid targets (with different thickness of 2 to 5 mm).

If arrangements can be made, we would be willing to incorporate high granularity tracking chambers from Greece or South Korea in order to evaluate their compatibility and performance in conjunction with the LYSO calorimeter.

For the planned measurements using the polarized deuteron beam, we request **one week** of COSY beam time at a few beam energies between 100 and 300 MeV at the BIG KARL experimental area (as in December 2016).

1 Introduction

All the measurement plans for the development of the new EDM polarimeter, along with the first test results, were described in the previous proposal (E2.2). The achievements from the upcoming run in December (calendar week 50) will be presented during the CBAC session (December 19). A summary of this development is given below.

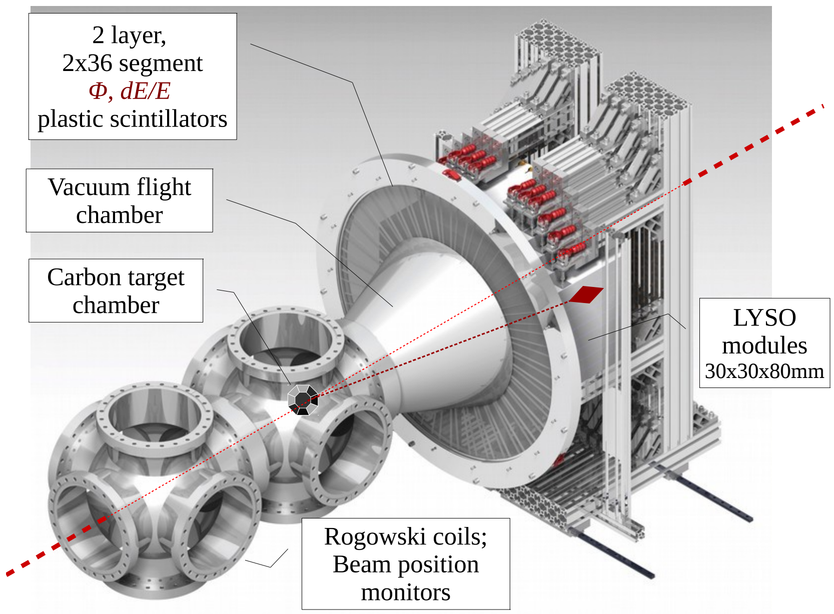

Figure 1: Detector concept for the final detector setup. The target stations and expansion chamber are similar to that now installed at the old WASA location. The polarimeter consists of the segmented scintillator and LYSO arrays.

The figure 1 shows the JEDI polarimetry concept based on the novel LYSO scintillating material. The detector is modular so that it can be assembled step by step with different configurations and numbers of crystals. It can also be split and used at various places inside the storage ring to measure the polarization of the beam. The mechanical part of the detector is constructed with standard building materials which makes it easy and cost-effective to build. This concept was discussed in previous proposals or progress reports [1]. To realize this project, we have already made the first steps by testing LYSO crystals.

In the very short first beam time, we used proton beams of 100 and 150 MeV to measure the detector response. After that we irradiated LYSO modules with deuteron beams of five different energies between 100 and 270 MeV. The results were summarized in the previous proposals and presentations. The essential characteristics we learned from these first tests are:

- The light output from LYSO scintillating material was very linear with energy up to 270 MeV deuteron energy loss, which is the required energy range.

- Reaction losses in the LYSO material reduced the efficiency in the full energy peak to levels as low as 70% at 270 MeV deuteron kinetic energy. The main problem is the break-up reactions within the crystal. The rest of the spectrum was also recorded and compared qualitatively with the GEANT4 simulation results.

- The resolution of the full energy peak *vs* incoming deuteron energy was studied using the dual channel photomultiplier tube [2] and silicon photomultiplier [3]. Both modules gave energy resolutions as good as or below 1% at 270 MeV deuteron energy. The dominant contributions to this effect may be coming from the fluctuations in the light generated by the scintillating material and variations in the light collection from different parts of the crystal.

- The crystals for these tests were provided by two different vendors: Saint-Gobain [4] and EPIC Crystals [5]. The results were compared, and the decision was made to favor the European provider due to warranty and safety conditions. Other than that, both crystals have a very similar performance and price. They were also substantially lower in price than three other companies where we obtained quotations.

- Using a horizontal rotation (relative to COSY beam) of a vertically split crystal (which is described in the previous proposals), the particle range and Bragg peak characteristics of the LYSO material for 270 MeV deuterons has been reconstructed. The test shows that the beam is absorbed within the first 60 mm. With this information, the length of new crystals was reduced from 100 mm to 80 mm. Even with an 80 mm crystal length, one can reduce the effects of radiation damage at the Bragg-peak by simply flipping the crystal along the beam axis.

- In the second version of the LYSO modules, the crystals have cut off (chamfered) corners at both ends. The joints with the holding structure, which is made of aluminum, have teeth to engage these corners. This guarantees the a fixed relative position between crystal and photosensor. The packaging and the spring loading configuration has also improved (see figure 2).

- The readout of the modules during the last beam test has been made using 12-bit high linearity charge integrating ADC [6] and 14-bit 250 MS/s flash ADC [7]. The results were compatible, and for the detailed studies, the flash ADC with full signal shape recording has been used. The data have been monitored online and finally analyzed in a more careful way offline.

- In parallel, we also tested the SiPM readout of the 5 mm thick plastic scintillator veto counters and developed an OpAmp-based preamplifier. This experience will be used for the designing of the dE/E plastic scintillator wall in front of the calorimeter.

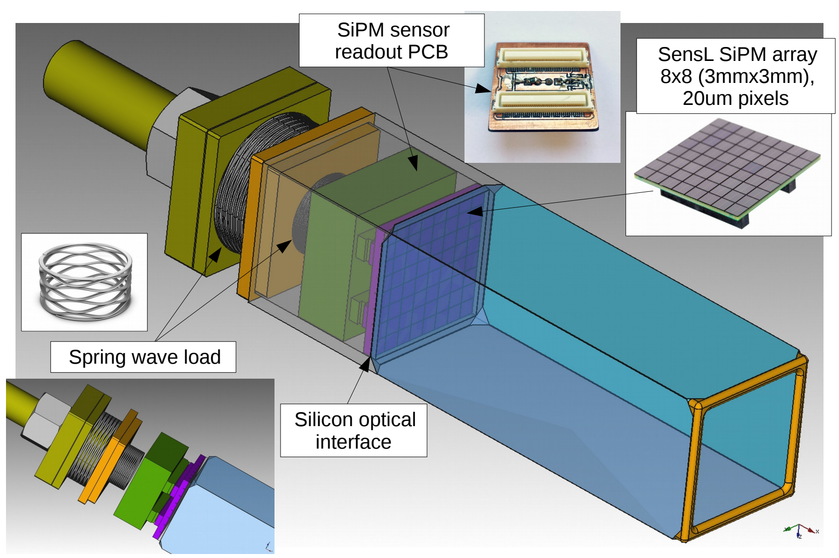

Figure 2: The second version of LYSO polarimeter module with SiPM readout.

2 Current status (as of November 7^{th})

We are in the process of assembling the test setup inside the Big KARL experimental hall. For the moment the mechanical construction is preassembled in another experimental area. Some minor changes will be made before its transportation to the final destination. All mechanical parts, including wave springs, aluminum housing and 3D printed front and back holders, are ready for the assembly. Importantly, all 24 LYSO crystals are delivered and are undergoing lab tests. The silicon interface and the wrapping materials are prepared for the module assembly.

In parallel, our collaborators from the University of Ferrara are finalizing the readout PCBs. Also, we are producing newly designed high-precision voltage supplies based on a special voltage regulator IC and a high-end external reference IC. For the first time, we will use three FADC modules in parallel readout mode synchronized via common clock. Online and offline analysis software is also under development. The iron collimator thought to be needed for background suppression from the exit window scattering is already assembled and ready for use. The slow control software is available; the web browser based GUI system has been developed using the Flask framework based on Python.

3 Next beam-time request

In the proposed measurements, the slowly extracted polarized deuteron beam will be used at the BIG KARL experimental area. The goal is to investigate and optimize the performance of the DAQ and new SiPM based LYSO modules. During this measurements, the differential cross sections and vector analyzing power will be extracted for the deuteron induced elastic reactions on different targets. All target materials (Magnesium, Silicon, and Aluminum in addition to Carbon) will be available as 50-mm discs with thicknesses between 2 and 5 mm. These targets will go into the target revolver. An Additional CH_2 target will be installed for normalization of the Carbon cross section against d+p elastic scattering. The sample changer will be slotted to allow two neighboring targets to be interchanged often during a single beam extraction in order to transport the beam current calibration from one target to another. This, along with analyizing power measurements, will allow the direct comparison of the figure of merit from different target materials. The

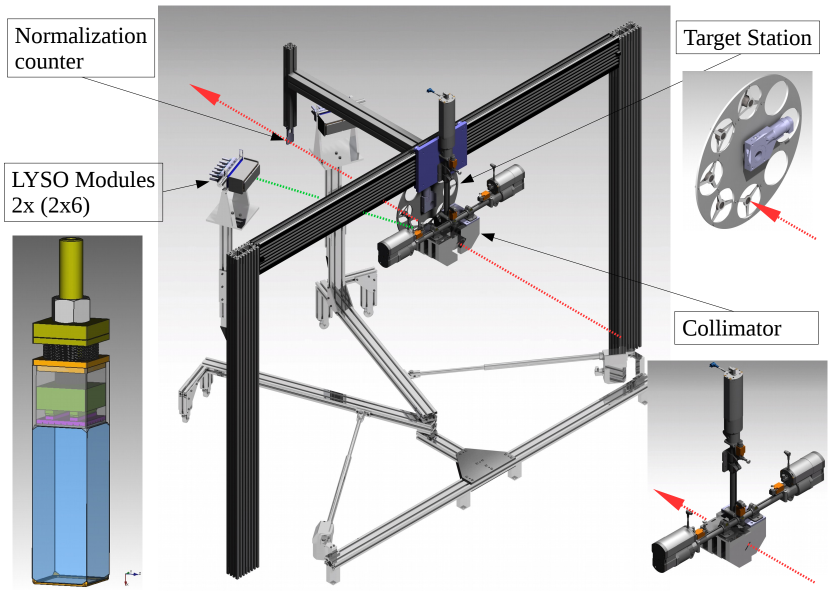

Figure 3: Test setup of the proposed measurement.

setup will comprise 24 LYSO modules divided into two arms, each consisting of 12 calorimeter modules (two rows including 6 crystals each), and up to seven solid targets (with different thickness of 2 to 5 mm) at once.

For the planned measurements using the polarized deuteron beam, we request **one week** of COSY beam time at a few deuteron energies between 100 and 300 MeV at the BIG KARL experimental area (as in December 2016).

For monitoring particle tracks, we are looking at a collaboration with possibly two other groups who have experience building thin, position-sensitive detectors with moderate to high granularity. One group [8] has developed a micromegas tracking detector with 8 octants arranged in a circle specifically for use with an EDM polarimeter. One of the octants has been tested successfully twice at the CERN muon test beam. Two such octants are expected to be available for testing at COSY in 2017. The operating mode may be extended to a time projection chamber if the additional angle readout proves beneficial to the design.

On a longer time scale, another group [9] at KAIST in South Korea is developing a GEM detector with a similar purpose. A test setup is expected to be available in about a year or less. More details about the assembly, as

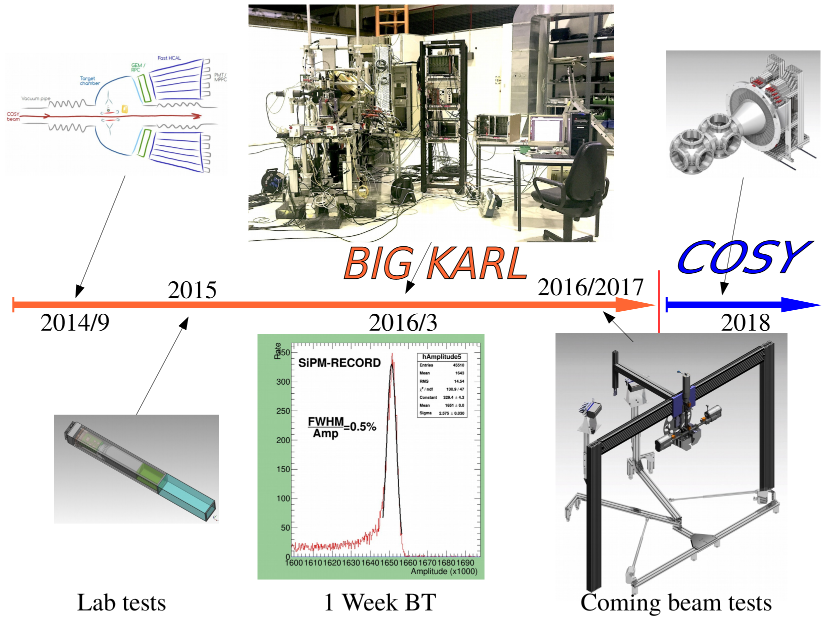

Figure 4: The timeline of the JEDI polarimeter development.

well as the outline of the steps for EDM polarimeter development at COSY (depicted in figure 4), will be given during the oral presentation at the CBAC meeting in December 2016.

References

[1] JEDI proposals E1, E2: “Towards the EDM polarimetry”, (May 2015/June 2016).

[2] Hamamatsu R1548-07.
($http://www.hamamatsu.com/us/en/R1548-07.html$)

[3] SensL SiPM MicroFC-60035-SMT.
($http://sensl.com/estore/microfc-60035-smt/$)

[4] Cerium doped Lutetium PreLude420 crystal.
($http://www.crystals.saint-gobain.com/PreLude\_420\_Scintillator.aspx$)

[5] LYSO Ce scintillator.
($http://www.epic-crystal.com/shop\_reviews/lyso-scintillator/$)

[6] Phillips Scientific 16 Channel Charge ADC CAMAC Model 7166.
($http://www.phillipsscientific.com/pdf/7166ds.pdf$)

[7] SIS3316-250-14 16 channel 250 MSPS 14-bit.
($http://www.struck.de/sis3316.html$)

[8] Georgios Fanourakis (NCSR, Demokritos) and Spyros Tzamarias (Aristotle University of Thessaloniki), private communication

[9] Seongtae Park, Center for Axion and Precision Physics, KAIST, South Korea