COSY Beam Time Request

For Lab. use	
Exp. No.: **E2.1**	Session No. **3**

Collaboration: JEDI

Towards the EDM Polarimetry

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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
Extracted beam of polarized deuterons	**100, 150, 200, 250, 270 MeV**	**10^3**	**10^7**
Experimental area	Safety aspects (if any)	Earliest date of installation	Total beam time (No.of shifts)
LYSO crystals at external BIG KARL area	**none**	**1st November 2016**	**1 week (+ MD)**

JEDI Beam Time Request for the second half of 2016

Towards the EDM Polarimetry (Status report)

for the JEDI collaboration

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

November 10, 2015

Abstract

In this document, we review the progress made since the last CBAC meeting and request beam time for the second step experiment (E2.1) as a part of the JEDI polarimeter development. In the proposed measurements, we will utilize a slowly extracted polarized deuteron beam in the BIG KARL experimental area to measure the differential cross section and vector analyzing power of elastic deuteron-carbon scattering between polar angles of 5° and 20°. These data will be normalized to the results from the WASA database experiment (submitted to the CBAC) including corrections due to deuteron detection efficiencies obtained in the first step experiment. The goal is a combined test of the read-out electronics with the detector modules to verify the performance of the whole prototype system. For the measurements using polarized deuteron beam, we request **one week** of COSY beam time at various energies between 100 and 300 MeV. The setup comprises two arms each consisting of two calorimeter modules and a solid carbon target. The exact energies will be defined after crystals are tested (March 2016) and optimization will be made using MC simulations.

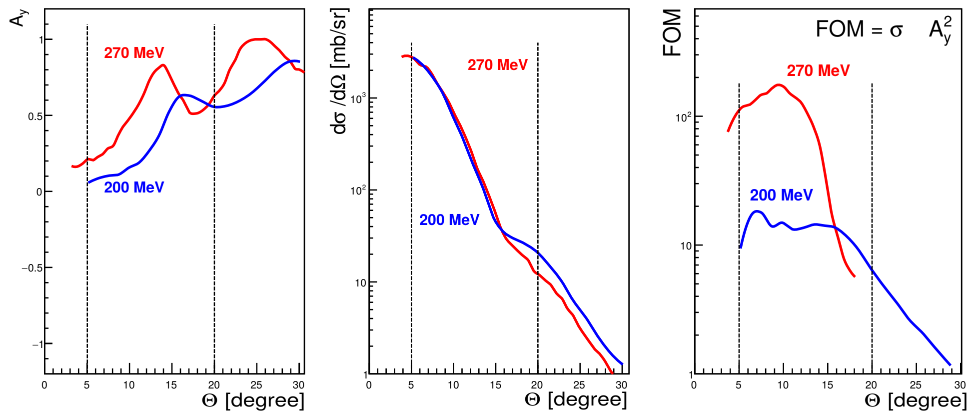

Figure 1: The $dC \to dC$ elastic scattering data at 200 MeV and 270 MeV [1]. Left: vector analyzing power; Middle: differential cross section; Right: Figure-of-merit defined as Eq.:1.

1 Introduction

In the search for an electric dipole moment (EDM) with a storage ring, the polarimeter must be sensitive to very small (10^{-6}) changes in the vertical component of the polarization during a beam store. Such changes require very large data sets; thus the polarimeter must opereate efficiently. Since no EDM has been observed, the precision or calibration of the measurement is not the most important feature. Thus the design of the polarimeter favors thick targets and the observation of elastic scattering, along with low q-value reactions, at forward angles where the spin-orbit interactions creates a large polarization sensitivity. This requirement leads to the use of calorimetric detectors that can easily pick out this data set with the use of a lower threshold on a total energy measurement. In order to maintain good sensitivity to vertical component changes, the detectors and their thresholds must be very stable over time and over changes in rate or beam properties (direction and angle). It is not as necessary to restrict the acceptance to a single or a few reaction channels as would be needed for a nuclear physics study. This leads to the emphasis on forward-angle elastic scattering and the use of single component detectors.

The goal of this test is to provide a set of data taken in a situation that reflects actual operating conditions in the EDM polarimeter, including thick targets, polarized beam, and detectors clustered at small scattering angles. This enables us to see whether there are problems or features that affect the performance of the system for making a polarization measurement. It also provides a set of data that may be compared eventually to Monte Carlo calculations that would be made in the design of the final EDM polarimeter. The Monte Carlo simulation are expected to use the reference data set generated by a parallel proposal to the CBAC that involves the WASA forward detector (featuring a point-like target and good particle tracking). Comparison of these results will help to evaluate issues with the polarimeter concept.

Toward this end, we will also be testing the micromegas detector prototype currenty being constructed at Demokritos. This is a thin detector with good position resolution (using a design ultimately intended for a time-projection tracking chamber). Knowing the location and direction of the particles involved may provide additional information relevant to untangling systematic errors in the EDM experiment. At the same time, their presence in the system will affect our ability to select a stable data set and maintain a clean detector acceptance. These issues need to be understand experimentally as well as through model calculations.

In fig. 1 the vector analyzing power, the differential cross section and the figure-of-merit (FOM) of deuteron carbon elestic scattering at 200 MeV and 270 MeV deuteron kinetic energies are shown. At both energies, the vector analyzing power is positive and quite large over the whole polar angular range covered by the detector. The FOM is calculated as a product of the differential cross section and the square of the analyzing power:

$$FOM = \sigma \times A_y^2 \tag{1}$$

In this case, the assumption made is to have 100% detection efficiency. It indicates the advantage in FOM of the 270 MeV over 200 MeV, due mainly to the growth of the analyzing power. But in the real experiment the detection efficiency (defined as a ratio between identified number of elastically scattered deuterons over the incoming deuterons) must be taken into account. In such a case, the corrected formula deduced from the Eq. 1 can be rewritten in the following form:

$$FOM(E) = \{\sigma(E) \times \varepsilon(E)\} \times A_y^2(E) \tag{2}$$

where the additional parameter $\varepsilon(E)$ is introduced as a detection efficiency. This efficiency is determined by placing a threshold at the lower edge of the

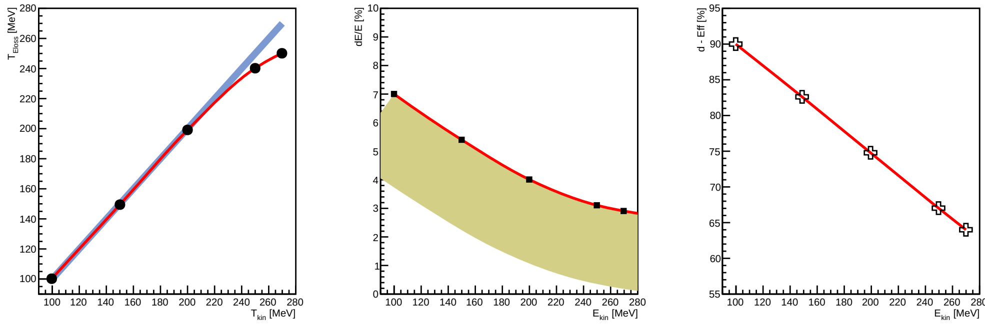

Figure 2: Simulated spectra – Left: reconstructed energy; Middle: measured energy resolution; Right: deuteron identification efficiency for single crystal *vs* incoming deuteron beam energy $(100, 150, 200, 250, 270\ MeV)$.

observed elastic scattering peak, and thus depends on the resolution of the crystals and the features of the reaction and background tail below the peak. The detection efficiency itself will be measured during the first experiment (see proposal E2 [2]), where the LYSO crystals will be directly exposed to the low intensity tagged deuteron beam. The expected behavior of the deuteron detection efficiency reduction *vs* energy is shown in the right panel of Fig. 2. Here the deuteron reconstruction efficiency between 200 and 270 MeV is dropping in the order of 30% whereas the FOM difference between the same energies rises almost a factor of ten (see Fig. 1, right panel).

2 Progress Report

The current concept of the JEDI polarimeter is shown in Fig. 3. In this version, the modular assembly with a standard support structure is shown. Such a construction allows us to build the polarimeter with an arbitrary number of crystals and with an optimal configuration. Also, it can be assembled in two or three different places in the storage ring.

2.1 Equipment

At present, we already own the five LYSO crystals needed to build four independent calorimeter modules. These crystals come from two different

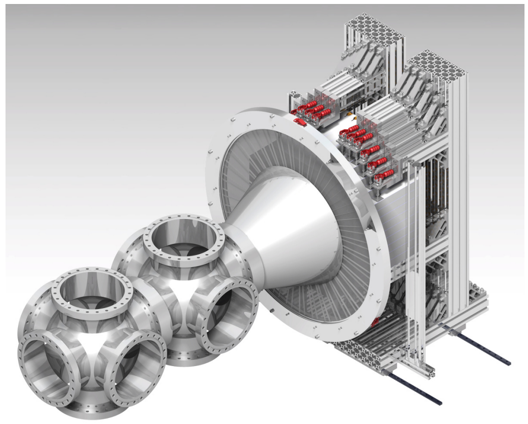

Figure 3: The new JEDI Polarimeter concept is shown. From left to right there are two cross type flanges, one for beam position monitors (BPM) and the second for the target, are drawn. In the middle is a vacuum chamber. After two layer of ϕ sensitive plastic scintillator, the calorimetric detector is shown. This last detector, the LYSO HCAL, is placed to absorb the total energy of the scattered particles.

companies: Saint-Gobain (SG) [3] and EPIC Crystals (EP) [4]. Using these crystals, two different module configurations can be assembled: three for low (large θ angles) and one for high count rate (small θ angles) use. Big crystals ($30 \times 30 \times 100$ mm) with a rectangular shape, built for low count-rate locations, are shown in Fig. 4 (right panel). Two of these are from SG and one is from EP. Two additional crystals, which are of $15 \times 30 \times 100$ mm rectangular shape, can be used to build one high count-rate module. All of the photosensors have a rectangular entrance window 24×24 mm and have separated, dual channel PMT's [5] supplied by a single HV source.

The design of the LYSO modules is final. The third iteration PCB's of the passive HV divider are also ordered. The prototype modules will be assembled and tested in the coming weeks. The first, very simple test has already been performed in the laboratory environment. Left panel of Fig. 5 shows spectra recorded using the $30 \times 30 \times 100$ mm LYSO crystal wrapped in two layers of 50 μm Teflon and covered with one layer of lightly tied 50 μm Tedlar. For this measurement, the optical contact between the crystal and the PMT is made using optical grease. The red data points correspond to measurements with the LYSO crystal plus a ^{60}Co radioactive source and

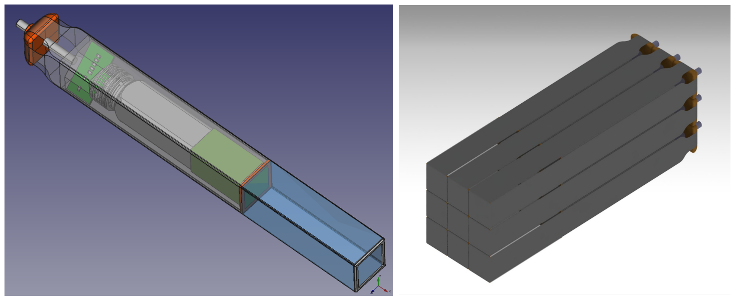

Figure 4: Left: The single HCAL LYSO module, mechanical holding structure; High voltage passive divider; Squared Hamamatsu PMT [5]; Light guide and LYSO crystal. Right: Example of the prototype module combining 3×3 LYSO crystals.

the green data points show the internal radiation of LYSO, which is mainly caused by ^{176}Lu decay. In the difference spectrum (blue), the two peaks of the cobalt sequential decay lines can be observed. Since the crystal size is big, the probability to measure both photons is quite large. The right picture in Fig. 5 shows a model fit to two cobalt photons plus the sum of the two. In this case, the spectrum analyzed just with one photocathode is shown. The resolution ($FWHM/amplitude$) for the 2.5 MeV energy deposition shown here is **8%**, which is already a very promising result.

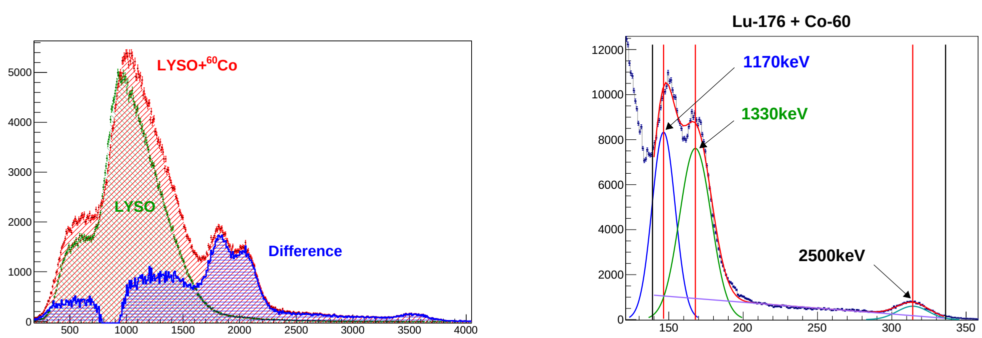

Figure 5: The spectrum of the LYSO crystal internal activity (^{176}Lu) and external ^{60}Co radioactive source.

A holding table for the prototype, with three degrees of freedom (vertical, horizontal, and rotation) is almost completed. A few mechanical part are

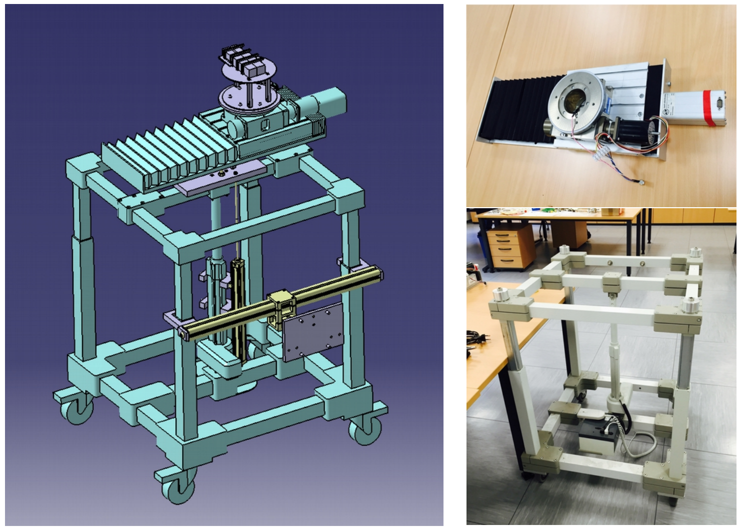

Figure 6: Left: Model of the prototype test setup is shown with five degree of freedom; Right-Up: Prototype holder with left right movement and rotation. Right-Down: The picture of the support table with vertical linear motor.

needed to finalize the table and the slow control system is under intensive development.

2.2 Measurement

All the acquired information after step one (E2) will be an input for the GEANT4 simulation software. Figure 7 describes the test setup for the current beam request. Like step one, the new configuration will utilize the COSY external beam, which gives us an advantage to tag every incoming deuteron, but with polarized beam to be used this time. In fact, deuteron depolarization resonances are not expected to be close to our energy region of interest (270 MeV). As an optional task, the target material can be continuously switched from carbon to aluminum and back (~ 5 *sec*) during the slow extraction. The only requirement of this measurement is to have **constant polarization** over the extraction cycle rather than to know precise value of the polarization. This might be important for the target material choice for the future high-efficiency polarimetry. As a cross check, one can also use already measured and published vector analyzing powers at 270 MeV [1] to confirm COSY beam polarization obtained from low energy polarimetry

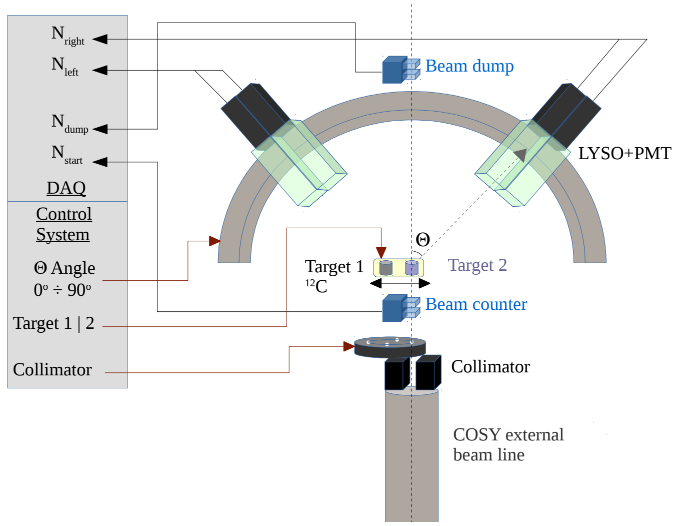

Figure 7: Test setup of the proposed second step measurement.

measurements.

In addition, it will be possible to simultaneously test the first module of the Micromegas TPC Polarimeter produced at the Institute of Nuclear and Particle Physics NCSR Demokritos, Greece (contact person George Fanourakis). If more than one octant is ready for use, we will also have the option to place them on either side as a part of the LYSO system or in a line on one side to investigate particle tracking.

All this measurements must be repeated for the proton beam as well. After all these test steps are taken, there already are plans to run this detector setup (with a limited number of modules) at the internal target station behind the WASA forward detector.

References

[1] Y. Satou et al., Phys. Lett. B **549**, 307 (2002).

[2] JEDI proposal E2: "Towards the EDM polarimetry", (May 2015).

[3] Cerium doped Lutetium PreLude420 crystal.

[4] LYSO Ce scintillator.

[5] Hamamatsu R1548-07.