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# The EDM Polarimeter Development at COSY-Jülich

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**Abstract** The JEDI (Jülich Electric Dipole moment Investigations) collaboration performs a set of experiments at the COSY storage ring in Jülich, to search for the Electric Dipole Moments (EDMs) of charged particles. A measurement of proton and deuteron EDMs is a sensitive probe of yet unknown CP violation.

The method of charged particle EDM search will exploit stored polarized beams in order to observe a miniscule rotation of the polarization axis as a function of time due to the interaction of a finite EDM with large electric fields. Key challenge is the provision of a sensitive and efficient method to determine the tiny change of the beam polarization. Elastic scattering of the beam particles on carbon nuclei will provide the polarimetry reaction. To perform these measurements, an EDM polarimeter needs to be developed. The polarimetry concept realized within the JEDI collaboration is based on a heavy crystal (LYSO) hadron calorimeter. LYSO as a fast, dense and radiation hard, novel scintillating material was chosen to fulfill these specifications. The polarimeter is designed in a compact and modular fashion consisting of modules made from LYSO crystals coupled to silicon photomultipliers (SiPM).

**Keywords** Polarimetry · LYSO · SiPM · EDM

## 1 Introduction

In a quantum system like the deuteron, there is only one quantization axis which is given by its spin axis. An electric dipole moment (EDM) has to be oriented along this axis, in the same manner as the magnetic dipole moment

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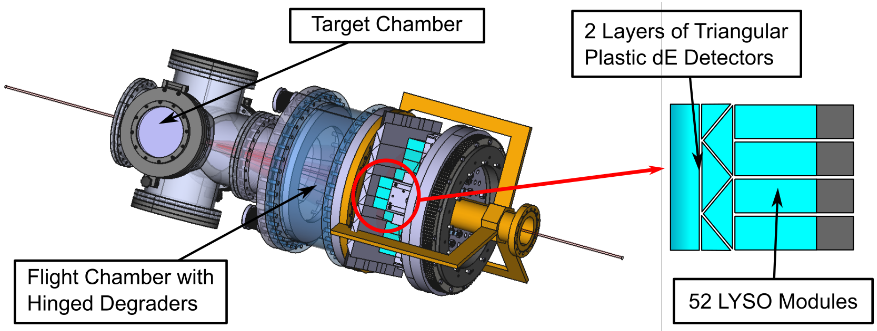


**Fig. 1** Model of the final LYSO-based polarimeter

(MDM) is. To measure the EDM using a storage ring, the following scheme can be applied: The deuterons will be polarized parallel to the momentum vector. When the horizontally polarized deuterons interact with a radial electric field, there will be a small vertical polarization build-up that is proportional to the value of the EDM. To be able to measure this minuscule polarization build-up a very sensitive polarimeter is needed. In the JEDI collaboration, a designated polarimeter is under development. This polarimeter should follow a few design concepts: There should be no strong electric or magnetic fields as they would interfere with the polarization measurement. The polarimeter needs to be able to provide long-time stability as the polarization build-up is very tiny and therefore a long measurement time is necessary. Further, the overall detector design should be chosen such, that it is as simple and compact as possible and provides on-line data during the experiment.

## 2 Design Concept

To fulfill the requirements mentioned above a modular polarimeter concept was chosen. Two orthogonally arranged layers of triangular plastic scintillator bars will be used to obtain the spatial as well as the delta energy information for each track. These two layers will be followed by an array of detector modules that can be rearranged in a way that the asymmetric pattern produced by elastic scattering can be covered most efficiently.

LYSO (Lutetium-yttrium oxyorthosilicate) was chosen for the scintillating material for the modular detector modules. LYSO is an inorganic crystal scintillator with its density of 7.1 g/cm is very heavy and and capable of entirely stopping deuterons accelerated in COSY within a few centimeters (see section 2.1).

This polarimeter should be suitable not only for deuterons but for protons as well. To assure that the lighter protons will be fully stopped in the detector, hinged degraders will be installed in the flight chamber of the polarimeter. These degraders can be flipped in front of the detector array to absorb enough kinetic energy from the protons that they will be stopped in the LYSO crystals.

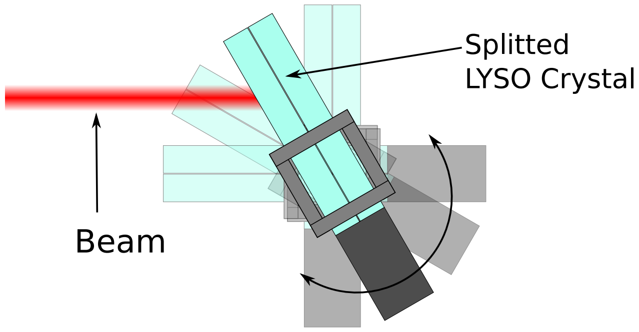


**Fig. 2** Schematic view of the experimental setup of the Bragg-peak measurement. By changing the angle of incidence, the effective path length of the deuterons in the LYSO crystals was varied.

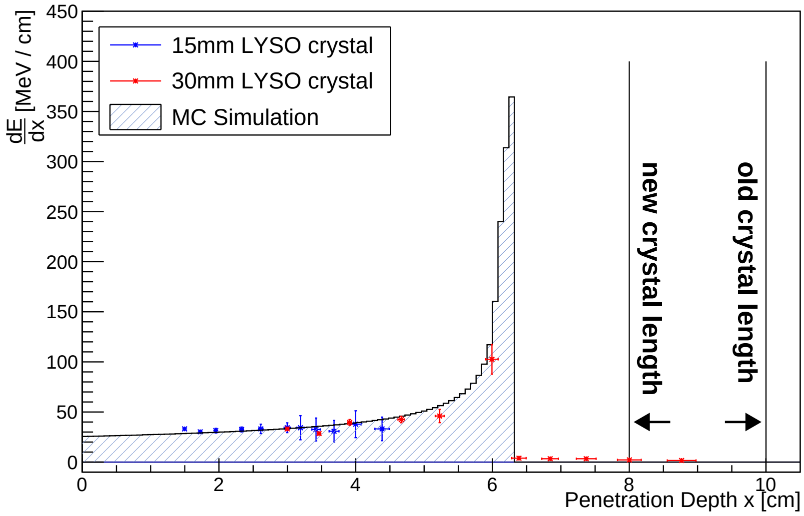


**Fig. 3** Measured Bragg-peak for 270 MeV deuterons in an LYSO crystal. By subsequent rotation of the module in a deuteron beam, the effective path length in a 1.5cm (blue) and 3cm (red) thick LYSO crystal was adjusted, and the deposited energy was measured. The Bragg-peak obtained shows good accordance with the Monte-Carlo simulation.

As target materials for producing the polarimetry reaction, five different material were examined out of which carbon showed the biggest analyzing power and will be used in the final setup.

## 2.1 Detector Module Testing

The LYSO based detector modules were developed in multiple iterations. The first iteration consisted of three modules assembled from a 3cm x 3cm x 10cm

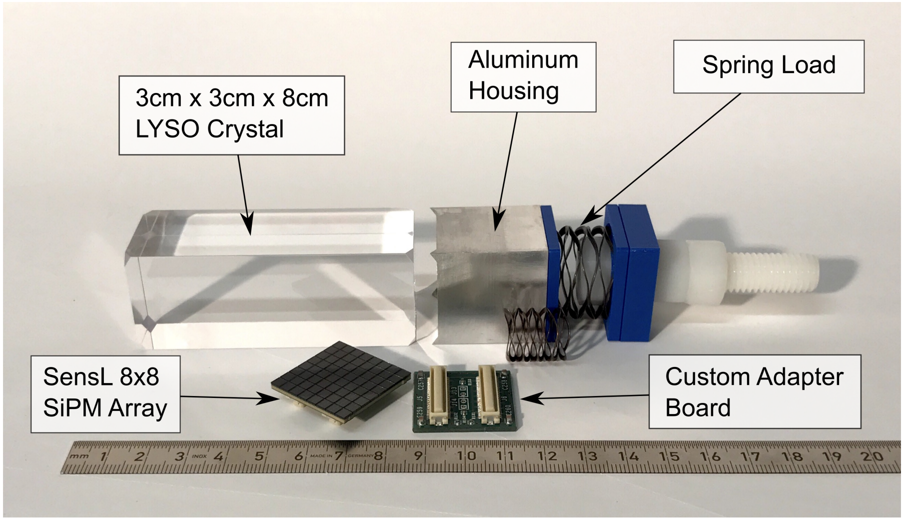


**Fig. 4** Interior of a SiPM based LYSO module.

LYSO crystal that was attached via a light-guide to a dual-channel PMT using a spring-loaded contraption. One module was built from two 1.5cm x 3cm x 10cm LYSO crystals incorporated in one single module. The dual-channel PMT allowed for the individual read-out of each of the two crystals. Mounting these four modules on a rotatable experimental table located close to the exit window of the COSY external beam line allowed for the measurement of the stopping power of LYSO for 270 MeV deuterons by rotating the modules and therefore changing the effective path length for the penetrating deuterons (see figure 2). Varying the particles path length and measure the deposited energy allowed for the measurement of the Bragg-peak of deuterons in LYSO. This measurement showed that 270 MeV deuterons could be stopped within ∼6cm of LYSO (see figure 3) and led to the decision of using 8cm LYSO crystals for the next iteration of detector modules. The measured Bragg-peak was well in accordance with a Monte-Carlo simulation for 270 MeV deuterons in LYSO provided by Paul Maanen.

The next iteration of detector modules was built from 3cm x 3cm x 8cm LYSO crystals coupled to an array of SiPMs (Silicon PhotoMultipliers) using a thin and flexible silicone pad. The whole module is held together again by a spring-load contraption (see figure 4). Using SiPMs instead of PMTs was beneficial for a number of reasons. First, it allows for a much more compact overall module size. Second, the SiPMs are using a much lower bias voltage compared to the PMTs which removes the need for a multi-channel high voltage source for the polarimeter. Measurements of the resolution of the SiPM equipped modules compared to the PMT equipped ones revealed that the usage of SiPMs leads to a better energy resolution of below 1% in the whole energy range between 100 MeV to 270 MeV (see figure 5).

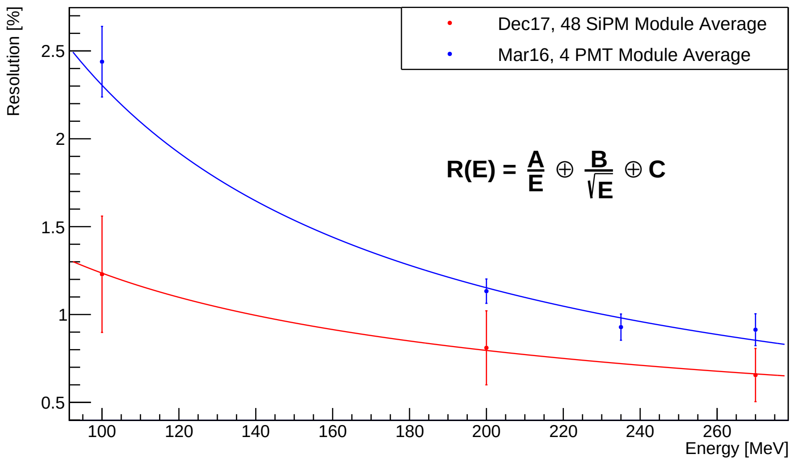


**Fig. 5** Comparison of the energy resolution between the PMT and SiPM based LYSO detector modules for deuterons with kinetic energy between 100 MeV and 270 MeV. The measurement was fitted well with the standard formula of the resolution for electromagnetic calorimeters.

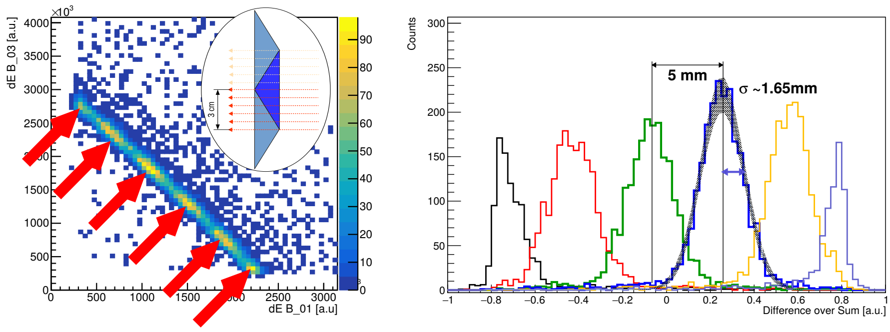


**Fig. 6** **Left:** The deposited energy in the first triangular bar plotted against the second one. The detector was moved in steps of 5mm relative to the beam covering 3cm of the total of 6cm height of triangular base (see small insert). Each detector position and the consequent energy distribution in the two triangular bars shows a distinct peak. **Right:** For each detector position the difference over sum was calculated for the energy fraction in both triangular bars. A spacial resolution of less then 5mm can be achieved since the peaks for each detector position are separated.

During the last beamtime in December 2018 first test of the triangular plastic scintillators were performed. Each scintillator bar was attached to two SiPM arrays mounted on a designated preamplifier board. Preliminary analysis of these tests showed a spacial resolution of less than 5mm while keeping the $\Delta$E information for each deuteron track (see figure 6).

### 2.2 Conclusion

The iterative approach to the development of a designated polarimeter for a future EDM search at the COSY accelerator located at the Research Center Jülich lead to a compact and modular design approach that can be adapted according to the requirements of the respective experiments. LYSO was chosen as the main scintillator due to its exceptional properties like high density, high light yield, radiation hardness and fast signal response. In combination with SiPMs, this allowed the conception of very compact detector modules that can be rearranged in different patterns. First tests of triangular plastic scintillators to be used simultaneously as $\Delta$E and tracking detectors revealed promising results. Nevertheless, further tests and analysis are needed on these detectors.

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