A candidate layout for the JEDI polarimeter

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The proposed method for a search for an Electric Dipole Moment of charged particles consists of storing the particles in a storage ring and letting the charged particles interact with a radial electric field. Starting with a horizontally polarized beam, the EDM signal would be a vertical polarization build-up. If the EDMs of deuteron and proton are in the order of 10^{-29}e·cm, the polarization build-up due to the EDM is in the order of nrad/s. Assuming a horizontal polarization lifetime of 1000 s, this means the vertical polarization to be detected is in the order of 10^{-5}.
For the polarization measurement, nuclear scattering which uses spin-dependent asymmetries in the nuclear scattering cross section to measure the beam polarization was chosen. A vertical polarization is associated with a left-right asymmetry in the scattering cross section while a longitudinal polarization leads to an up-down asymmetry.

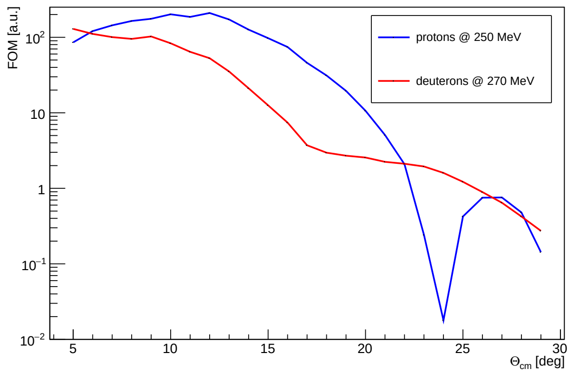

Figure 1: red: Differential FOM for Deuteron-Carbon scattering at T_d = 270 MeV [2] blue: The same quantity for Proton-Carbon scattering at $T_p = 250$ MeV[3].

Polarimeter design goals

To achieve the necessary precision, the EDM polarimeter should achieve the following goals:

- Large statistical figure of merit
- Minimal influence on the beam
- High sensitivity to systematic effects
- Good long term stability and reproducibility
- Simple concept

The statistical figure of merit of a polarimeter is defined as $\mathcal{F} = \sigma \cdot A_y^2$ which means to maximize the statistical accuracy of a polarimeter one has to simply choose the process with the highest possible cross section and analyzing power. The influence on the beam should be minimal because even the slightest pertubation can influence the beam on a noticeable level. In the past it has been demonstrated that it is possible to control the systematic uncertainties to the 10^{-6} level by calibration of the detector by inducing large errors in the beam and measuring the variation of the output [1].

Target material

Different target materials have been evaluated for their applicability as a polarimetry target. Carbon has been chosen as the most suitable candidate. Figure 1 the differential FOM for Deuteron-Carbon and Proton-Carbon elastic scattering are shown. As one can clearly see, the differential Figure of Merit for both the deuteron-carbon and proton-carbon scattering is heavily concentrated in the forward direction. This should allow one to use the same polarimeter for both proton and deuteron EDM measurements.

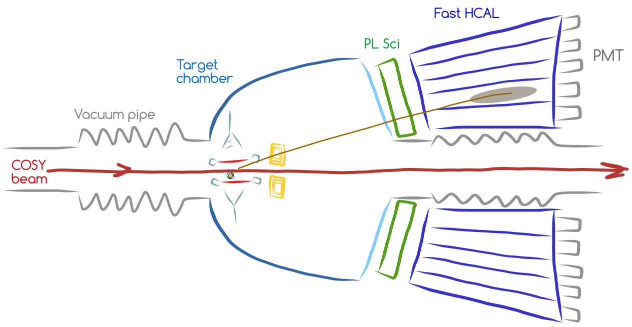

Figure 2: The current JEDI candidate detector concept.

Target type

In principle, many different target types are available for use. Solid State Targets in general are easier to handle than cluster and gas targets and target densities in the order of magnitude of 10^{20} cm^{-2} are easily achievable. Cluster targets can achieve target densities of up to 10^{14} cm^{-2} - 10^{15} cm^{-2}. The target currently used for R&D measurements is a carbon slab with several cm in thickness. For extraction the beam is placed close to the target and then heated by application of white noise [4]. Recently, a research has begun to develop a new type of target that uses small diamond pellets to continuosly extract the beam without needing external electrical fields [5].

Detector concept

The current candidate concept is shown in figure 2. It envisions a segmented plastic scintillator to measure the direction of the outgoing particles and a fast hadronic calorimeter to stop the particles and provide a accurate energy measurement of the particle to select only elastically scattered particles. The material cur-

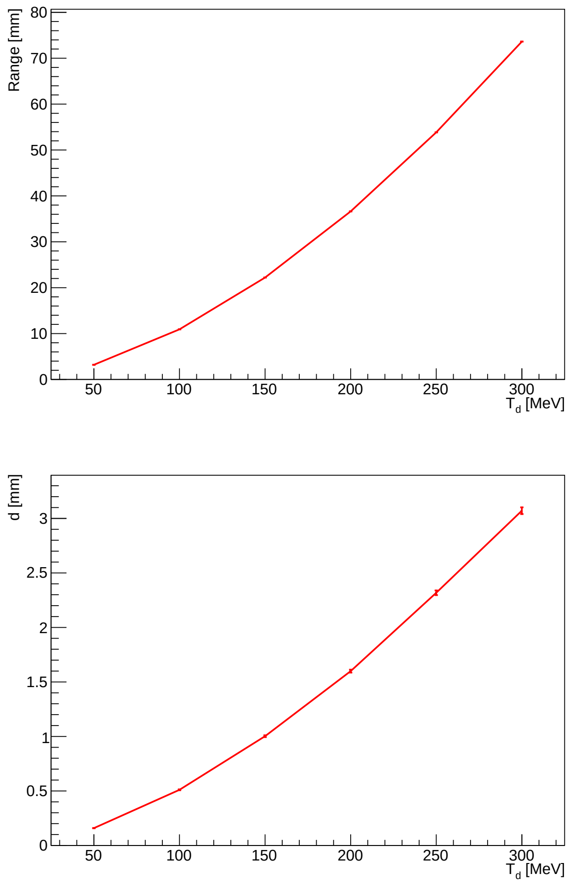

Figure 3: top: Range of deuterons in LYSO for different deuteron kinetic energies. bottom: Average displacement in x-direction of deuterons for the same energies.

rently under evalution is the anorganic scintillator LYSO $Lu_{1.8}Y_{0.2}SiO_2(Ce)$. Figure 3 shows the range and lateral displacement of an incoming deuteron beam in LYSO for different deuteron energies. As can be seen, a crystal of around 100 mm length and 10 mm − 30 mm width is able to completely absorb an incoming deuteron beam. Accordingly, LYSO crystals of the sizes $30\times30\times100\,\mathrm{mm}^3$ and $15\times30\times100\,\mathrm{mm}^3$ have been ordered and are unter investigation. Hardware tests with cosmic muons have demonstrated an energy of $\mathcal{O}(20\%)$ are achievable [6].

Conclusion

A detector concept has been chosen and Monte-Carlo simulations and prototype measurements are ongoing to further refine the components for the polarimeter. First test measurements with deuterons are planned for the March 2016 beam time.

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References

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