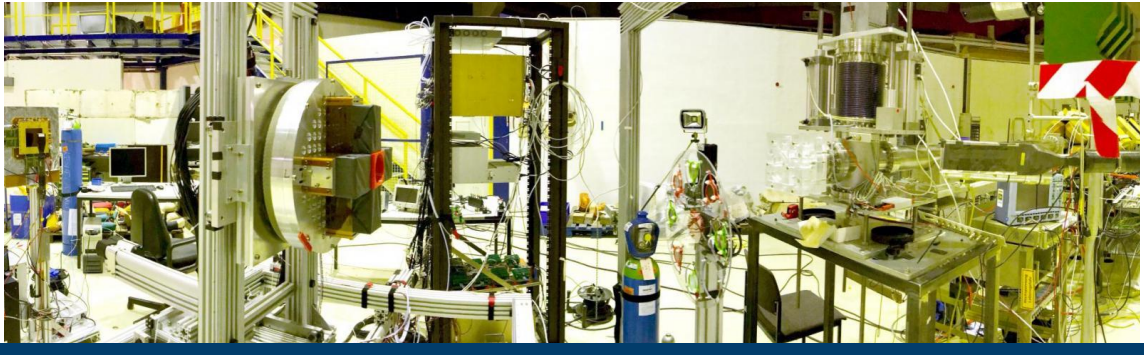


EDM POLARIMETER DEVELOPMENT AT COSY
for the JEDI Collaboration

28th February 2018, DPG Spring Meeting | Fabian Müller | IKP 2

RWTH AACHEN UNIVERSITY

JEDI

JÜLICH Forschungszentrum

ELECTRIC DIPOLE MOMENT

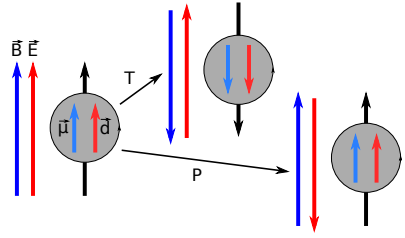
Electric **D**ipole **M**oment (EDM): $\vec{d} = d\vec{S}$
Magnetic **D**ipole **M**oment (MDM): $\vec{\mu} = \mu\vec{S}$

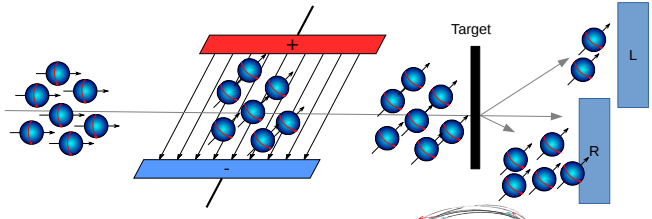
$$H = -d\vec{S} \cdot \vec{E} - \mu\vec{S} \cdot \vec{B}$$

$$T : H = +d\vec{S} \cdot \vec{E} - \mu\vec{S} \cdot \vec{B}$$

$$P : H = +d\vec{S} \cdot \vec{E} - \mu\vec{S} \cdot \vec{B}$$

→ EDM violates both CP and P symmetry!
→ Talk by Maria Żurek (HK 41.1)





Simplified EDM measurement procedure

- Horizontally polarize deuteron
- Horizontal $\vec{E}$-Field creates vertical spin build-up
- Elastic scattering creates asymmetry proportional to vertical polarization
- EDM is proportional to polarization build-up

RWTH AACHEN UNIVERSITY

JEDI

JÜLICH Forschungszentrum

POLARIMETER CONCEPTS

Fundamental Polarimetry Concept

Measure Asymmetry ϵ of elastic scattering $\rightarrow$ with known Analyzing Power A_y calculate Polarization P_y

Polarimeter Working Principle

- Polarized Cross Section:

$$\sigma_{pol}(\Theta) = \sigma_{unpol}(\Theta)[1 + \frac{3}{2} P_y A_y(\Theta)\cos(\Phi)]$$

- Asymmetry ϵ:

$$\epsilon = \frac{3}{2} P_y A_y$$

- Cross Ratio ϵ_{CR}:

$$\epsilon_{CR} = \frac{r-1}{r+1} \text{ with } r^2 = \frac{N_L^{\uparrow} N_R^{\downarrow}}{N_L^{\downarrow} N_R^{\uparrow}}$$

Key features for an EDM polarimeter

- Ability to measure tiny polarization build-up:

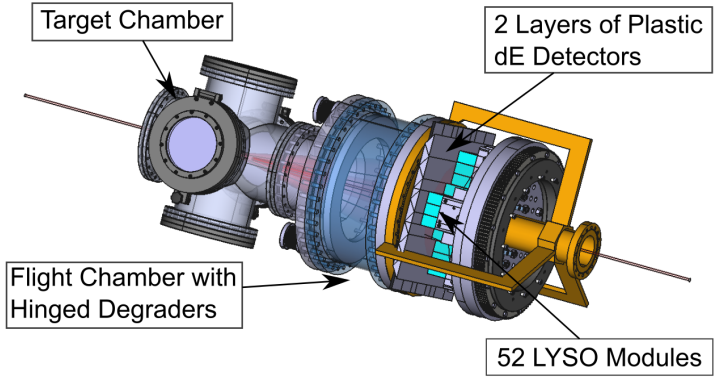
$$\frac{\partial \vec{S}}{\partial t} \approx nrad/s$$

- Long term stability:
  - $\rightarrow$ continuous measurement for a long time due to the smallness of the EDM
- High accuracy:
  - $\rightarrow$ high resolution
  - $\rightarrow$ ability to identify elastically scattered deuterons

LYSO BASED POLARIMETER DEVELOPMENT

Advantages of the LYSO polarimeter

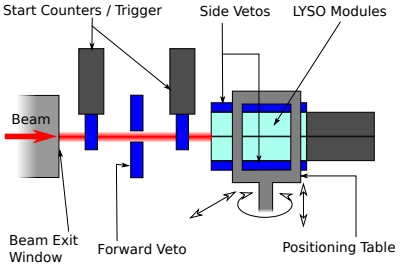
- Simple construction:
  - → No strong $\vec{E}$ and $\vec{B}$ fields
  - → Only two detection layers
- Modular setup:
  - → Modules can be easily rearranged
- Long term stability:
  - → LYSO is a radiation hard scintillator
- High accuracy:
  - → LYSO + SiPM modules have a high resolution
  - → Plastic and LYSO scintillators to create dE vs E plots for particle identification

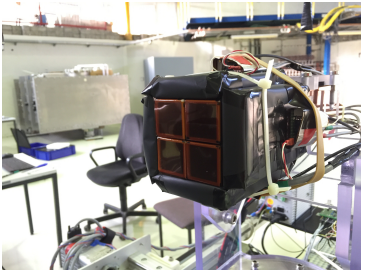


Model of the full EDM polarimeter built from LYSO detector modules

HISTORY OF LYSO POLARIMETER DEVELOPMENT

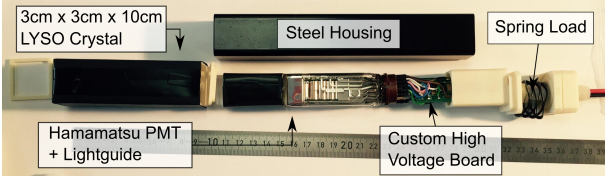
1st Iteration





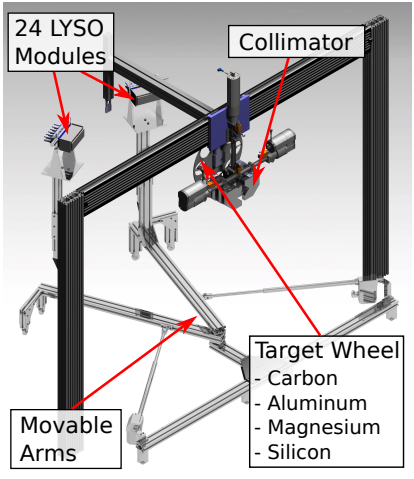
1st Iteration

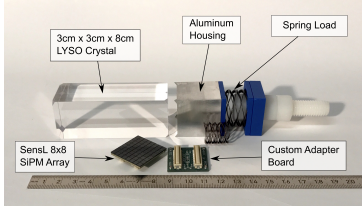
- 4 Modules were tested
- PMTs + 10cm LYSO crystals were used
- Bragg peak measurement showed: 8cm LYSO crystal is sufficient
- First experiment with SiPMs



HISTORY OF LYSO POLARIMETER DEVELOPMENT

2nd Iteration



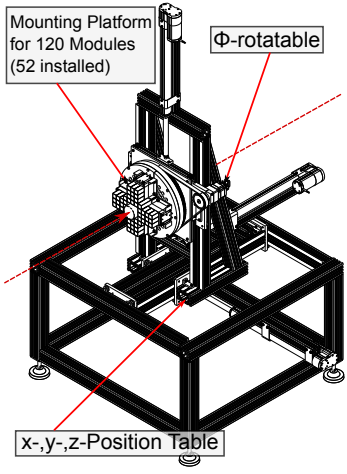


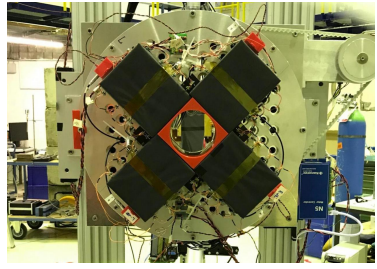
2nd Iteration

- 24 Modules were tested
- SiPMs + 8cm LYSO crystals were used
- 4 different target material were tested
- Plastic scintillators in front of the modules for dE vs E plots
- Custom voltage supply for the SiPMs → Talk by Dito Shergelashvili (HK 36.6)

HISTORY OF LYSO POLARIMETER DEVELOPMENT

3rd Iteration

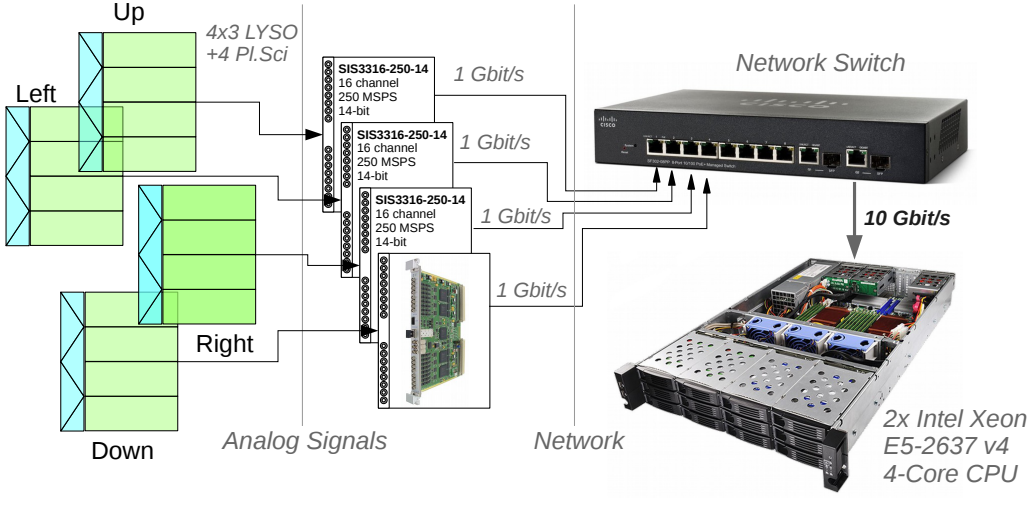




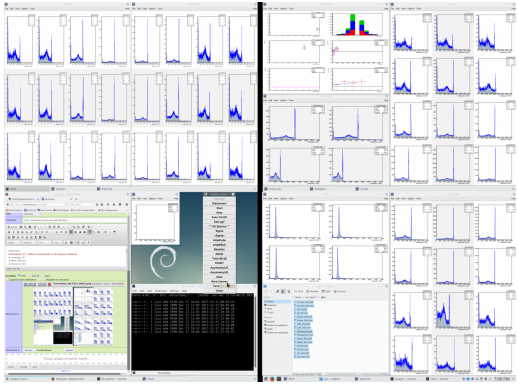
3rd Iteration

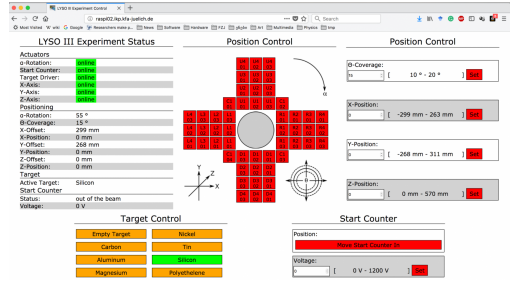
- 52 Modules were examined
- 2 types of SiPM array (SensL and KETEK)
- 7 different target material were used
- Final mounting platform was tested

DAQ SYSTEM


Up
Left
Right
Down
4x3 LYSO
+4 Pl.Sci
SIS3316-250-14
16 channel
250 MSPS
14-bit
SIS3316-250-14
16 channel
250 MSPS
14-bit
SIS3316-250-14
16 channel
250 MSPS
14-bit
1 Gbit/s
1 Gbit/s
1 Gbit/s
1 Gbit/s
Network Switch
10 Gbit/s
2x Intel Xeon
E5-2637 v4
4-Core CPU
Analog Signals
Network

DAQ SYSTEM

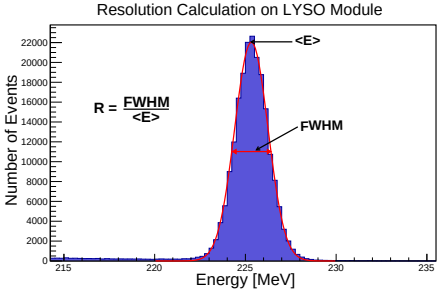


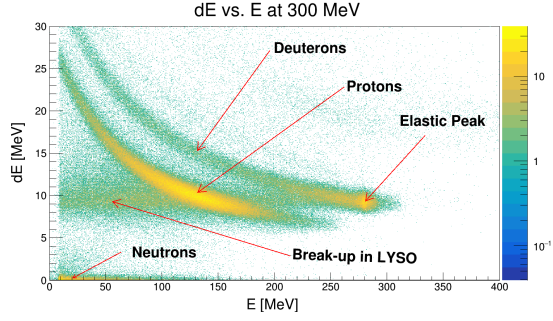


Slow Control & Online Analysis

- Spectra of all 52 module can be monitored online
- Online calculation of asymmetry and cross ratio
- Web interface for the slow control of the whole detector

RESULTS

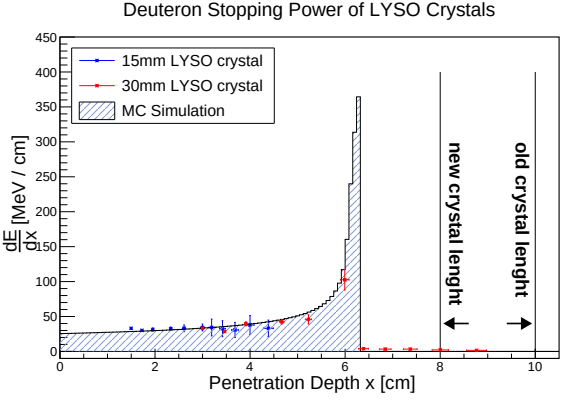


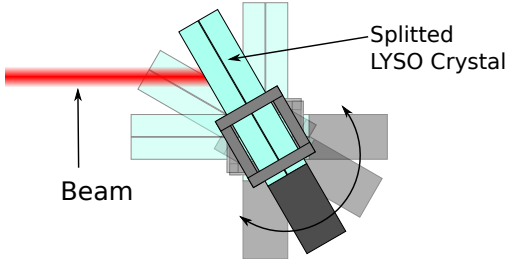


Resolution / dE vs E plot for PID

- Resolution below 1.5 % for SiPM modules
- Plastic- and LYSO scintillators allows for the creation of dE vs E plots
- Elastically scattered deuterons can be clearly identified

RESULTS





Bragg Peak at 270 MeV

- Rotating split LYSO crystal → dE as a function of the penetration depth x_n
- $\frac{dE}{dx} = \frac{dE_{x_n} - dE_{x_{n-1}}}{X_n - x_{n-1}}$
- Measurement is in alignment with the simulation
- 8 cm of LYSO crystal is enough to stop 270 MeV deuterons

SUMMARY AND OUTLOOK

Summary

- Precise measurement of the polarization build-up is needed for EDM investigation
- A designated LYSO based polarimeter for EDM measurement is under development
- Tests of 52 LYSO based detection modules and a polarimetry setup were performed and show promising results
- Online analysis and slow control software was developed and successfully tested

Outlook

- Development of triangular plastic scintillator array for improved angular resolution
- Assembly of full polarimeter including target- and flight vacuum chamber
- Installation and test of the polarimeter inside of the COSY accelerator ring