Polarimetry Concept Based on Heavy Crystal Hadron Calorimeter

for the JEDI Collaboration | CALOR 2016 |
- Introduction
- JEDI Polarimetry Concept
- MC Simulations
- Laboratory and Beam Tests
- Outlook
- Summary
Introduction
EDM – Electric Dipole Moment

JEDI – Jülich Electric Dipole moment Investigation

Collaboration members: 122

Baryogenesis

Standard Model
- not enough CP violation

nEDM

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Why Storage Ring?
Measuring EDM for Charged Pericles

- Store polarized deuterons (COSY)
- Interact with an E-field (Wien-Filter)
- **Analyze Polarization Build-up (this talk)**

\[
\frac{d \mathbf{s}}{dt} = \mathbf{d} \times \mathbf{E} + \mathbf{d} \times (\mathbf{v} \times \mathbf{B})
\]
COSY (COoler SYnchrotron)

at Forschungszentrum Jülich (Germany)

- Energy range:
  - $0.045 - 2.8$ GeV (p)
  - $0.023 - 2.3$ GeV (d)
- Max. momentum $\sim 3.7$ GeV/c
- Electron and Stochastic cooling
- Internal and external beams
- High polarisation (p,d)
- Spin manipulation !!!
srEDM – *Precision Experiment*

*complementary*

*LHC – Energy Frontier*

➢ Reaction with Large $A_y$ : Best $dC \rightarrow dC$ !!

➢ Maximum Detection & Data Taking Efficiency !!

➢ Full $\phi$ in Reasonable FOM($\theta$) region !!

➢ No Magnetic / Electric Field !!

➢ Stability – Long / Short Term !!!
\[ \vec{d}C \rightarrow dC \] Elastic Scattering @ 270 MeV


\[ FOM = A_y^2 \cdot \sigma \]
JEDI Polarimetry Concept
Optimized for $\bar{d}C \rightarrow dC$ Reaction

Diagram:
- **COSY beam**
- **Target chamber**
- **Vacuum pipe**
- **C-block**
- **Ballistic diamond pellet target**
- **BPM**
- **LYSO HCAL**
- **PMT**

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LYSO Based Polarimeter

Modular Setup / Easy Splitting

- Two layer, 2x36 segment dE/E plastic scintillators
- Vacuum flight chamber
- Carbon target chamber
- LYSO modules 30x30x80mm
- Rogowski coils; Beam position monitors
FADC Based DAQ

~ 100 % Data Taking Efficiency

Struck SIS 3316
14 bit resol. -2V to +2V
16 channel – 64MS/ch
250MS/s – 4ns per S.

Pile-Up

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LYSO Modules
First and Second Generation

\[ n = \sqrt{n_1 \cdot n_2} = 1.66 \]

Mechanical Holding
Magnetic Shielding
ST-37

LYSO Crystal
30x30x100mm
\( n_1 = 1.82 \)

Aluminum Housing

SensL C / J
6x6 mm Sensor
35um Pixel
2x2 Array

LYSO Crystal
30x30x80mm
\( n_1 = 1.82 \)
LYSO Module
Assembly and Mechanical Stability

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LYSO Crystal Wrapping and Homogeneity Test

50μm Teflon

270 MeV deuteron beam

Double Layer Teflon

Laser reflection

50μm Tedlar

Amplitude

Horizontal Position

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LYSO ($^{176}$Lu) + $^{60}$Co Tests

8 % Resolution at 2.5 MeV Photons

1170keV

1330keV

2500keV
G4: Elastic $dC \rightarrow dC$ Scattering

Very Clear Signature

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G4: Inelastic $dC \rightarrow X$ Simulation

Far Below Elastic E-Spectrum
Prototype Test – BIG KARL Area

External Proton and Deuteron Beam

a) Front view
   LYSO crystal
   optical properties
   comparison w. Lithrani

b) Top view
   Bragg peak scan.
   dE/dx characterization

c) Top view
   Absorption length determination

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Prototype Test – BIG KARL Area
External Proton and Deuteron Beam
Time Resolution
Cosmic and External Beam

- Time Resolution with 250 MS/s Far Below 1 ns
- QDC Energy Resolution at 200 MeV roughly 4 %
- Deuteron Reconstruction Efficiency at 80 % (Threshold 90 %)
Prototype Characterization

Using External Beam

- Incident vs Reconstructed $d - T_{\text{kin}}$
- Reconstructed Energy Resolution vs Incident $d - T_{\text{kin}}$
- Deuteron Identification Efficiency
- Bragg Peak, Absorption $\lambda$, Radiation Hardness

\[ \frac{\Delta E}{E} = \frac{p_0}{E} \oplus \frac{p_1}{E} \oplus p_2 \]

\[
\chi^2 / \text{ndf} = 43.35 / 2
p_0 = 0 \pm 0
p_1 = 0.6649 \pm 0.01297
p_2 = 0.0001226 \pm 5.541e-05
\]

\[
\chi^2 / \text{ndf} = 0.05017 / 2
p_0 = 212.1 \pm 47.99
p_1 = 25.44 \pm 2.955
p_2 = 0 \pm 68.18
\]

\[
\epsilon = A_E e^{\lambda \cdot E}
\]

\[
\chi^2 / \text{ndf} = 1.319 / 3
\text{Constant} = 4.687 \pm 0.01191
\text{Slope} = -0.001888 \pm 6.363e-05
\]

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Next with 2x10 LYSO Modules
Polarized Deuteron Beam / 6 Different Targets
Summary

- Direct shot of protons and deuterons on LYSO
  Unpolarized deuteron and proton of: 100, 150, 200, 235, 270 MeV

- LYSO module development and mechanical construction:
  LYSO (2 types), PMT (2 types) and SiPM/MPPC (KETEK, SensL)

- 2 (+2) LYSO crystals will be tested:
  Saint–Gobain (EU) 2x(30x30x100 mm)
  EPIC–Crystals (China) 1x(30x30x100 mm)
  Saint–Gobain 2x(15x30x100 mm)

- 2x 10x LYSO modules in readout with polarized deuterons
  Analyzing power / FOM comparison of different targets
Cosmic Signal vs Intrinsic Radiation

![Graph showing cosmic signal and intrinsic radiation with Amplitude [V] from 1 to -0.8, and TIME [s] from 0.05 to 0.15.]

Intrinsic radiation:
-740 mV
30 MeV
50 ns

-Cosmic Signal:
-40 mV

LeCroy

Timebase -152 ns
Trigger C1 DC
20.0 mV/div
50.0 ns/div
60.00 mV ofst
1.00 kS
Edge Negative

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EDDA@COSY Targets
Optimized for $\bar{d}C \rightarrow dC$ Reaction

White Noise
C-block target

C-wire target
New Idea!

COSY beam

Target chamber

Vacuum pipe

exit window

Carbon

v=10m/s
t= 1ms

1cm
JEDI Polarimetry Concept

Variable Effective Target Thickness

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Cosmic Calibration
K. Nowakowski, C. Dziwok

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<td>Mean</td>
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<tr>
<td>Sigma</td>
<td>356.1 ± 9.0</td>
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23.6%
G4: Cosmic Simulation

P. Maanen, LYSO 30x30x100 mm with 0°, 45°, 90°

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