A STORAGE RING EDM POLARIMETER

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Overview

1) EDM

2) JEDI polarimetry
   1) Detector modules
   2) Power supply
   3) Readout system

3) Target development – introduction
   1) Current target Systems
   2) Idea behind new target system

4) Summary
Matter-Antimatter Asymmetry

- Excess of Matter in the Universe:
  \[ \eta = \frac{n_B - n_{\bar{B}}}{n_\gamma} \]
  - observed: \(6 \times 10^{-10}\)
  - SM prediction: \(10^{-18}\)

- Sacharov (1967): CP-violation needed for baryogenesis

- New CP-V sources beyond SM needed
- Could show up in EDMs of elementary particles
EDM – Electric Dipole Moment

- fundamental property of particles (like magnetic moment, mass, charge)
- permanent separation of positive and negative charge
- has nothing to do with electric dipole moments observed in some molecules (e.g. water molecule)
- close connection to “matter-antimatter” asymmetry
- existence of EDM only possible via violation of time reversal $T \leftrightarrow CP$ assuming CPT conservation
Internal and *external* beams

High polarization (*p, d*)

*Spin manipulation !!!*

Energy range (min.-- max.):

- 0.045 – 2.8 GeV (p)
- 0.023 – 2.3 GeV (d)

Max. momentum \(\sim 3.7 \text{ GeV/c}\)

*Electron & Stochastic* cooling
Polarimeter concept
Polarimeter setup in ring

- Target chamber
- dE + tracking pl. scintillators
- LYSO+SiPM modules
- COSY beam

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PLASTIC SCINTILLATOR TRACKER

Triangular plastic scintillator bar for tracking system

BC-408 Bicron Plastic scintillator

6 cm

2 cm

Preamp board with 4 SiPM split into 2 separate channels

Assembled layer with three scintillator bars. Each bar has 2 preamp board with 4 independent amplifier channels and eight 6X6 mm SiPM, 4 for each end

already attached tracker in front of LYSO modules
PLASTIC SCINTILLATOR TRACKER

- Each bar is connected to a SiPM mounted on a designated pre-amp board
- position information extracted using difference over sum: position $\sim \frac{E_{\Delta 1} - E_{\Delta 2}}{E_{\Delta 1} + E_{\Delta 2}}$
- This detector will deliver dE information as well as the position of the particle entering the detector
- First test: resolution of $\sim 5$mm $\rightarrow$ big improvement compared to the $\sim 30$mm resolution provided by the LYSO modules
Detector modules

- 52 independent LYSO modules
- Each module is tested and calibrated separately

Silicon layer
- Optical coupling
- Mechanical stability

Cut corners for mechanical fixation
Voltage supply for detector modules

Basic requirements:

- Modular design
- High output stability (temperature, long/short term, low noise)
- Remote on/off capability (currently organized using Raspberry Pi)
- Voltage adjustment (currently only manual)

1mV change in supply voltage = 0.02% - 0.05% change in gain
Voltage supply for detector modules

Voltage drop is ≈ 12 mV

Voltage drop is ≈ 21 mV
Voltage supply for detector modules

- Voltage monitoring system
- Power supply modules
- Port expander
- Raspberry Pi

\[
V_{\text{in}} = 32 - 40V \\
V_{\text{out}} - \text{Adjustable} \\
V_{\text{reg}} < 1mV \\
T \approx 3.4mV/C^0
\]
Voltage supply online control and monitoring

Turn all channels on/off
RED - Turned off channels
GREEN Turned on channels
Readout system

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Readout system

- 16 channels per module
- 250 MS/s per channel
- 125 MHz analog bandwidth
- 14-bit resolution
- Offset DACs
- Internal/External clock
- Readout in parallel to acquisition
- Capable of working in a chain
- Built-in hardware features (Pile-up detection, averaging and more)
- Self triggering
Different target systems

White Noise

Carbon target
JUDIT
Juelich Ballistic Diamond Pellet Target

Target chamber
Vacuum pipe
C-pellet target
exit window

COSY beam
v=10 m/s
t=1 ms
1 cm

Number of beam particles × 10^15

1s

Jülich Forschungszentrum
Pellet target system

- Synchronization and Triggering unit
- Data readout and processing
- Thrower catcher system
  - Target
  - Vector map

Equations:

\[ V_e = \text{vector map} \]
Pellet target system
Pellet TOF measurement

- Laser
- Target
- PIN photo diode
- Opamp
- Schmitt trigger
Summary

This project has been supported by “Shota Rustaveli National Foundation of Georgia”
"A first-ever measurement of the Electric Dipole Moment (EDM) of the deuteron at COSY"
(SRNSF Grant #217854)

- The detector is fully assembled and installed in COSY.
- The LYSO module production will be continued.
- Triangular plastic scintillating bars for tracking is developed and tested. It will be assembled and installed for next experiment.
- The diamond ballistic pellet target is under development and will be tested until the end of my Ph.D. work.
- We are preparing first beam time after Polarimeter installation at COSY end of October.
Appendix
History of polarimeter

Exp. E002.1
March 2016
First test of:
- LYSO
- PMT
- SiPM
- FADC
- Scans
- ...

Exp. E002.2
Test of:
- 24x LYSO
- New SiPM
- ∆E 5mm
- Software
- Power supply
- ...

Exp. E002.4
Dec. 2017
Exp. E002.5
May 2018
Test 1:
- 52x LYSO
- ∆E 20mm
- Mechanics
- 6x FADC
- Timing

Test 2:
- Front Scans
- Tracker ∆E
- ...

Exp. E002.3
March 2017
Test of:
- Cross sections
- Software
- ∆E 10mm
- V readout
- ...

C, CH₂, Mg, Al, Si
dE vs. E at 300 MeV

- Deuterons
- Protons
- Elastic Peak
- Neutrons
- Break-up in LYSO
Directions of work

- FPGA
- Camera
- Laser & Photo diode
- Geometry
- Timing
- Goal
Time measurement

- Triggering
- Position reconstruction
Image processing

667 MHz dual-core Cortex-A9 processor
High-bandwidth peripheral controllers: 1G Ethernet, USB 2.0, SDIO
1 GB DDR3L RAM
FPGA – XC7Z020-1CLG400C
  Look-up Tables (LUTs) 53,200
  Flip-Flops 106,400

5MP color system-on-chip image sensor
Dual lane MIPI CSI-2 image sensor interface
Supports QSXGA@15Hz, 1080p@30Hz, 720p@60Hz, VGA@90Hz and QVGA@120Hz
Output formats include RAW10, RGB565, CCIR656, YUV422/420, YCbCr422, and JPEG compression
Camera requirements

Minimum camera characteristics with window size 1x4 cm and pellet diameter 100µ:
- Minimum 26 fps to get 2 points (free fall)
- Minimum 400 pixels

**Pco - pco.dimax HS4**
Fps = 2277 @ 4Mpix (2000x2000) or 7039 @ 1MPix (1000x1000)
Interfaces: USB 3.0, GigE/USB 2.0, Camera Link
exposure time range 1.5 μs - 40 ms

**Ximea - CB019MG-LX-X8G3**
Fps = 2500+ @ 2Mpix (1920x1080)
Interfaces: PCI Express (PCIe) Gen3
exposure time range = 1μs – 1sec