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Operational Safety Procedure Review and Approval Form # 55499
(See [ES&H Manual Chapter 3310 Appendix T1 Operational Safety Procedure \(OSP\) and Temporary OSP Procedure](#) for Instructions)

Type:

OSP [Click for OSP/TOSP Procedure Form](#)
[Click for LOSP Procedure Form](#)

Serial Number:

ENP-15-55499-OSP

Issue Date:

12/14/2015

Expiration Date:

12/14/2018

Title:

Commissioning of Hall A High-Field Moller Polarimeter

Location:
(where work is being performed)

Experimental Hall A

Location Detail:
(specifics about where in the selected location(s) the work is being performed)

beam line

Risk Classification:

Without mitigation measures (3 or 4):

3

(See [ES&H Manual Chapter 3210 Appendix T3 Risk Code Assignment](#))

With mitigation measures in place (N, 1, or 2):

1

Reason:

This document is written to mitigate hazard issues that are :
Determined to have an unmitigated Risk code of 3 or 4

Owning Organization:

PHALLA

Document Owner(s):

Gomez, Javier (gomez@jlab.org) Primary

Supplemental Technical Validations

Static Magnetic Fields >5G: Fringe, High, & Quench Effect (Dick Owen, Jennifer Williams)

Other Hazards:

electrical/electronic (Jack Segal)

Document History

Revision	Reason for revision or update	Serial number of superceded document
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Comments for reviewers/approvers:

Attachments

Procedure: **3310T1Form.pdf**

THA: **Document-17166_updated.pdf**

Additional Files: **20151207_moller_osp.pdf**

[Convert to PDF](#)

Review Signatures

Person : Physics ES&H Liaison

Signed on 12/14/2015 8:28:19 AM by Bert Manzlak
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Person : Subject Matter Expert : electrical/electronic

Signed on 12/10/2015 4:38:51 PM by Jack Segal
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Subject Matter Expert : Static Magnetic Fields >5G:
Fringe-> High-> & Quench Effect

Signed on 12/11/2015 10:05:48 AM by Jennifer
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Approval Signatures

Division Safety Officer : PHALLA

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Operational Safety Procedure Form
 (See [ES&H Manual Chapter 3310 Appendix T1 Operational Safety Procedure \(OSP\) and Temporary OSP Procedure for instructions.](#))

Click
For Word Doc

DEFINE THE SCOPE OF WORK

Title:	Commissioning of High-Field Moller polarimeter		
Location:	Hall A	Type:	<input checked="" type="checkbox"/> OSP <input type="checkbox"/> TOSP
Risk Classification (per Task Hazard Analysis attached) (See ESH&Q Manual Chapter 3210 Appendix T3 Risk Code Assignment.)	Highest Risk Code Before Mitigation (3 or 4):	3	
	Highest Risk Code after Mitigation (N, 1, or 2):	1	
Owning Organization:	Physics/Hall A	Date:	12/10/2015
Document Owner(s):	Javier Gomez		

Document History (Optional)

Revision:	Reason for revision or update:	Serial number of superseded document

ANALYZE THE HAZARDS

1. Purpose of the Procedure – Describe in detail the reason for the procedure (what is being done and why).

This document describes the upgraded Hall A Moller polarimeter with a high-field superconducting magnet, its operation and hazards. Concurrence is sought that it can be operated by staff and users for experiments without further mitigating measures

2. Scope – include all operations, people, and/or areas that the procedure will affect.

Operation of the Hall A Moller polarimeter for Physics

3. Description of the Facility – include floor plans and layout of a typical experiment or operation.

See attached document

4. Authority and Responsibility:

4.1 Who has authority to implement/terminate

Work coordinator or designee

4.2 Who is responsible for key tasks

Javier Gomez

4.3 Who analyzes the special or unusual hazards (See [ES&H Manual Chapter 3210 Appendix T1 Work Planning, Control, and Authorization Procedure](#))

Work coordinator or designee

4.4	What are the Training Requirements (See http://www.jlab.org/div_dept/train/poc.pdf)
	Read attached document
5. Personal and Environmental Hazard Controls Including:	
5.1	Shielding
	N/A
5.2	Interlocks
	See attached document
5.3	Monitoring systems
	N/A
5.4	Ventilation
	N/A
5.5	Other (Electrical, ODH, Trip, Ladder) (Attach related Temporary Work Permits or Safety Reviews as appropriate.)
	See attached document
6. List of Safety Equipment:	
6.1	List of Safety Equipment:
	N/A
6.2	Special Tools:
	N/A

DEVELOP THE PROCEDURE

1. Associated Administrative Controls	
	None
2. Operating Guidelines	
	See attached document
3. Notification of Affected Personnel (who, how, and when)	
	See list of authorized Personnel on attached document
4. List the Steps Required to Execute the Procedure: from start to finish.	
	See attached document
5. Back Out Procedure(s) i.e. steps necessary to restore the equipment/area to a safe level.	
	none
6. Special environmental control requirements:	
6.1	Environmental impacts (See EMP-04 Project/Activity/Experiment Environmental Review)
	none
6.2	Abatement steps (secondary containment or special packaging requirements)
7. Unusual/Emergency Procedures (e.g., loss of power, spills, fire, etc.)	
	None

8. Instrument Calibration Requirements (e.g., safety system/device recertification, RF probe calibration)

None

9. Inspection Schedules

None

10. References/Associated Documentation

Attached device description, operating procedure & hazards

11. List of Records Generated (Include Location / Review and Approved procedure)

[Click](#)

To Submit OSP
 for Electronic Signatures

Distribution: Copies to: affected area, authors, Division Safety Officer

Expiration: Forward to ESH&Q Document Control

Form Revision Summary

Qualifying Periodic Review – 02/19/14 – No substantive changes required.

Revision 1.3 – 11/27/13 – Added “Owning Organization” to more accurately reflect laboratory operations.

Revision 1.2 – 09/15/12 – Update form to conform to electronic review.

Revision 1.1 – 04/03/12 – Risk Code 0 switched to N to be consistent with [3210 T3 Risk Code Assignment](#).

Revision 1.0 – 12/01/11 – Added reasoning for OSP to aid in appropriate review determination.

Revision 0 – 10/05/09 – Updated to reflect current laboratory operations

ISSUING AUTHORITY	FORM TECHNICAL POINT-OF-CONTACT	APPROVAL DATE	REVIEW DATE	REV.
ESH&Q Division	Harry Fanning	02/19/14	02/19/17	1.3

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Task Hazard Analysis (THA) Worksheet

(See [ES&H Manual Chapter 3210 Appendix T1](#)
[Work Planning, Control, and Authorization Procedure](#))

Click

Author: Javier Gomez	Date: December 10, 2015	Task #: If applicable	
Complete all information. Use as many sheets as necessary			
Task Title: Commissioning and Operation of Hall A High-Field Moller Polarimeter	Task Location: Hall A		
Division: Physics	Department: Hall A	Frequency of use:	
Lead Worker:			
Mitigation already in place: Standard Protecting Measures Work Control Documents	Transparent insulating covers are use to cover the magnet electrical connections. Magnet power supplies have their connections either secured inside a locked cabinet or covered with transparent insulating covers.		

Sequence of Task Steps	Task Steps/Potential Hazards	Consequence Level	Probability Level	Risk Code (before mitigation)	Proposed Mitigation (Required for Risk Code >2)	Safety Procedures/ Practices/Controls/Training	Risk Code (after mitigation)
	Work near beam line bellows and windows under vacuum	M	M	3	Use ear acoustic earmuffs when working in the neighborhood of these windows and bellows		1
	Detector High Voltage (up to 3kV)	M	L	2	Turn-off HV channel before connecting/disconnecting HV		1
	Magnetic field effect on individuals with electronic/ferromagnetic medical implants	M	M	3	Entire hall designated as area with magnetic fields > 5G Magnet On sign above magnets		1

Task Hazard Analysis (THA) Worksheet

(See [ES&H Manual Chapter 3210 Appendix T1](#)
[Work Planning, Control, and Authorization Procedure](#))

Sequence of Task Steps	Task Steps/Potential Hazards	Consequence Level	Probability Level	Risk Code (before mitigation)	Proposed Mitigation (Required for Risk Code >2)	Safety Procedures/ Practices/Controls/Training	Risk Code (after mitigation)
	Magnetic field effect on tools	M	M	2	Magnet On sign		1

Highest Risk Code before Mitigation:

3

Highest Risk Code after Mitigation:

1

When completed, if the analysis indicates that the Risk Code before mitigation for any steps is “medium” or higher (RC≥3), then a formal [Work Control Document](#) (WCD) is developed for the task. Attach this completed Task Hazard Analysis Worksheet. Have the package reviewed and approved prior to beginning work. (See [ES&H Manual Chapter 3310 Operational Safety Procedure Program](#).)

Form Revision Summary

Revision 0.1 – 06/19/12 - Triennial Review. Update to format.

Revision 0.0 – 10/05/09 – Written to document current laboratory operational procedure.

ISSUING AUTHORITY	FORM TECHNICAL POINT-OF-CONTACT	APPROVAL DATE	EXPIRATION DATE	REV.
ESH&Q Division	Harry Fanning	06/19/12	06/19/15	0.1

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Hall A Møller Polarimeter

1 Purpose and Layout

The Hall A polarimeter is used to measure the polarization of the beam being delivered to Hall A.¹ This document provides an overview of the instrument and its operation as well as making the operators of this instrument aware of the hazards that this device presents. The system consists of (see Fig.1),

- A magnetized ferromagnetic foil placed in the beam path. The foil acts as a polarized electron target and it can be selected from a set of four different foils. The in-beam foil is magnetized by an adjustable field superconducting magnet. The foils are located 17.5 m upstream from the nominal pivot point of the Hall A High Resolution Spectrometers.
- A magnetic spectrometer system consisting of four quadrupole magnets and a dipole magnet. The spectrometer focuses the electrons scattered in a particular kinematic range onto the Møller detector package.
- A detector package and its associated shielding house.
- Two stand-alone data acquisition systems.
- An off-line analysis software package to extract the beam polarization. Roughly, the beam polarization is calculated by taking the difference in the counting rates of two different beam helicity samples.

2 Principles of Operation

The cross-section (σ) for Møller scattering $e^- + e^- \rightarrow e^- + e^-$ depends on the beam and target polarizations \mathcal{P}^{beam} and \mathcal{P}^{target} as:

$$\sigma \propto 1 + \sum_{i=X,Y,Z} (A_{ii} \cdot \mathcal{P}_i^{target} \cdot \mathcal{P}_i^{beam})$$

where $i = X, Y, Z$ defines the projections of the polarizations. The analyzing powers A_{ii} depend on the scattering angle in the Center-of-Mass (CM) frame θ_{CM} . Assuming that the beam direction is along the Z-axis and that the scattering happens in the ZX plane of a right-handed Cartesian reference frame, then:

$$A_{ZZ} = -\frac{\sin^2 \theta_{CM} \cdot (7 + \cos^2 \theta_{CM})}{(3 + \cos^2 \theta_{CM})^2},$$

¹(Home page: <http://hallaweb.jlab.org/equipment/moller/>)

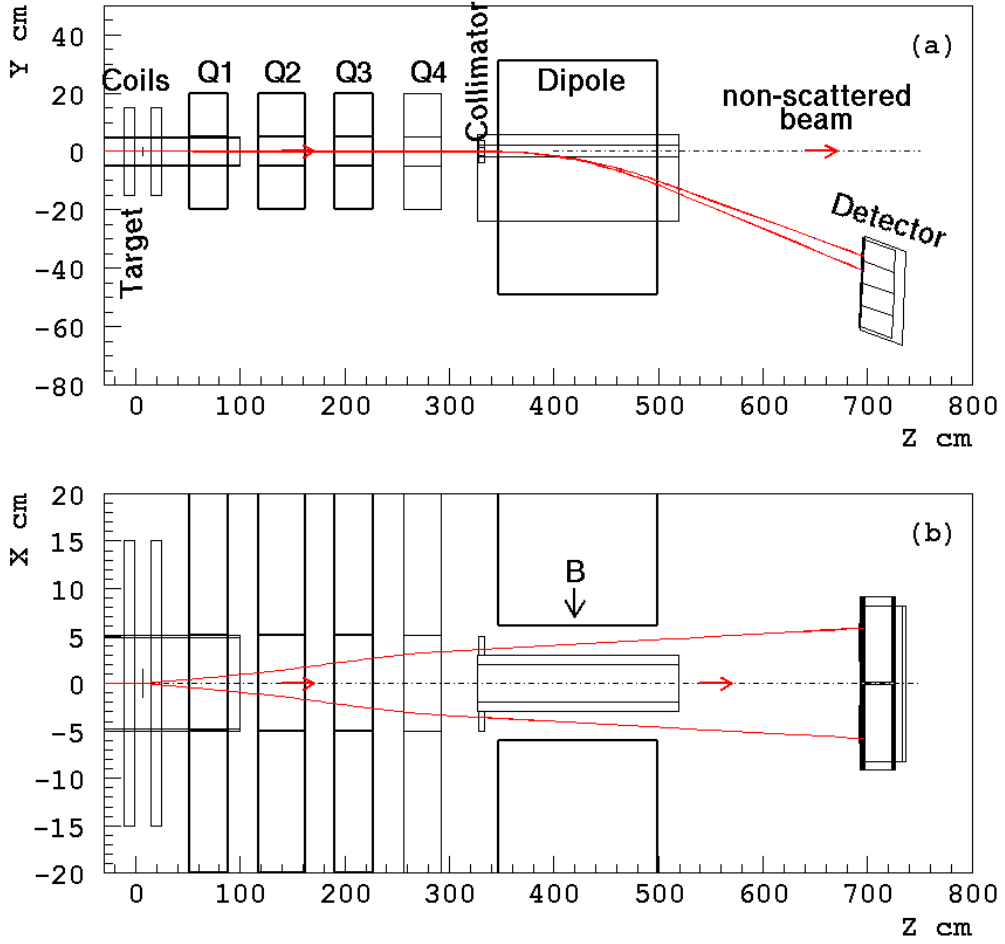


Figure 1: Layout of Møller polarimeter. The origin of the coordinate frame is at the center of the polarimeter target, which is 17.5 m upstream of the Hall A target.

$$A_{XX} = -\frac{\sin^4 \theta_{CM}}{(3 + \cos^2 \theta_{CM})^2},$$

$$A_{YY} = -A_{XX}$$

A_{ZZ} is called the longitudinal analyzing power while A_{XX} and A_{YY} are referred to as the transverse analyzing powers. The analyzing powers do not depend on the beam energy and they reach their maximum values when $\theta_{CM} = 90^\circ$,

$$A_{ZZ}^{max} = 7/9,$$

$$A_{XX}^{max} = -A_{YY}^{max} = A_{ZZ}^{max} / 7$$

The main purpose of the polarimeter is to measure the longitudinal component of the beam polarization. The Møller polarimeter of Hall A detects pairs of scattered electrons in a range of $75^\circ < \theta_{CM} < 105^\circ$ with an average analyzing power of about $\langle A_{ZZ} \rangle = 0.76$.

The target consists of a thin magnetically saturated ferromagnetic foil. In such a material, about 2 electrons per atom can be polarized. The maximal electron polarization for fully saturated pure iron is 8.52%. In Hall A Møller polarimeter the foil is magnetized by a 3 T field parallel to the beam axis and perpendicular to the foil plane.

The scattered electron pairs pass through a magnetic spectrometer which selects particles in a particular kinematic region. Two electrons are detected with a two-arm detector system and the coincidence counting rate of the two arms is measured. The beam longitudinal polarization is then calculated as:

$$\mathcal{P}_Z^{beam} = \frac{N_+ - N_-}{N_+ + N_-} \cdot \frac{1}{\mathcal{P}^{foil} \cdot \langle A_{ZZ} \rangle},$$

where N_+ and N_- are the measured counting rates with two opposite mutual orientation of the beam and target polarizations, while $\langle A_{ZZ} \rangle$ is obtained using Monte-Carlo calculation of the Møller spectrometer acceptance. \mathcal{P}^{foil} is derived from special magnetization measurements in bulk material.

3 Description of Components

3.1 Polarimeter Control

Control of the Møller polarimeter is divided into two separate sections,

- The operators in the Machine Control Center (MCC) have sole control over target motion and currents settings of the quadrupoles & dipole that make up the magnetic spectrometer of the polarimeter. To access the Graphical User Interface (GUI) screens used for control of the polarimeter,
 - Launch **NewTools** application located in any of the Hall A control computers.
 - Select **JTABS** → **Accelerator Main Menu** → **Beam Setup**.
 - On the new screen select **Hall A** → **Combo**. Fig. 2 shows the final screen.
- The user has control over the superconducting magnet current used to magnetically saturate the in-beam target. See section 3.2.1.

3.2 Polarized Electron Target

Fig. 3 shows the Møller Polarized Electron Target. The target is located on the beam line 17.5 m upstream of the main Hall A physics target and it consists of,

- A split-coil, 5 T superconducting magnet with field oriented parallel to the beam (Z-axis)
- A target system with four (4) iron foils. The system moves along the vertical axis (Y-axis) to bring the foils in and out the beam path. The target system can also rotate the foils around the Y-axis. The foils are described on Table 3.

The screenshot displays the Moller MCC control interface, which is organized into several functional sections:

- Beamline Diagram:** Located at the top, it shows the path of the particle beam from the BEAMLINE through H-COILS, a TARGET, and various magnet stations (MQO1H02, MQM1H02, MQO1H03, MQO1H03A, MMA1H01) to a DETECTOR.
- Beam Structure Control:** This section allows for adjusting the pulse width settings. It includes buttons for 'MOLLER ON' and 'MOLLER OFF', and a 'Beam Off' indicator. The 'Normal Mode' is currently selected with a 'Duty Factor' of 0.00.
- Solenoid Status:** A panel for monitoring the 'Moller Solenoid Field (Tesla)', currently showing 0.000.
- Target Motion Control:** This section manages the 'Rotary' and 'Linear' positions of the target. The rotary position is set to -0.012 degrees, and the linear position is 0.000 mm. It includes jog and park buttons for both axes.
- Magnet Control Panels:** A central area for controlling individual magnets. It lists magnet names (MQO1H02, MQM1H02, MQO1H03, MQO1H03A, MMA1H01) and their status (On/Off). It also displays 'Integrated Field Set Point' and 'Nominal Field' values.
- Current Readbacks:** A section showing 'Current Readbacks (amps)' for each magnet, with values such as 232.01, 230.64, 99.970, and 199.69.
- Current Setpoints:** A section for setting 'Current Setpoint (amps)' for each magnet, with values like 232.884, 231.704, -39.505, and 202.968.
- Current Readbacks (Amps):** A section showing 'Requested' and 'Actual' current values, with a requested value of 5.000 and an actual value of 5.013.
- Magnet Current Monitors:** Five real-time graphs showing 'Magnet Current' for MMA1H01, MQO1H03A, MQO1H03, MQM1H02, and MQO1H02. Each graph plots current in Amperes (A) over time in minutes.
- Strip Tool:** A utility tool located at the bottom right of the interface.

Figure 2: The Møller MCC control screen.

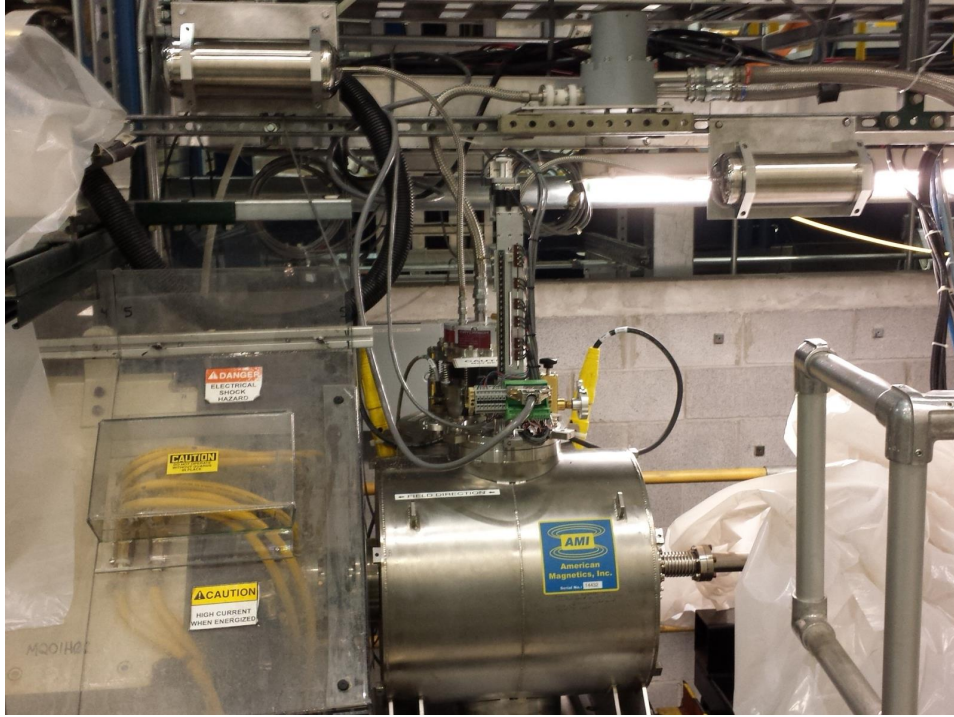


Figure 3: The Møller target area. The beam propagates from right to left.

3.2.1 5T Magnet

A cryogen-free, split coil, superconducting magnet from American Magnetics Inc. (AMI) is used to saturate the in-beam iron foil. Fig. 4 shows a drawing of the magnet system with relevant dimensions while Fig. 5 shows the main characteristics of the magnet. To minimize stresses on the magnet that could induce a quench, field changes above 4.5 T proceed very slowly. While recovery from a magnet quench does not require operator intervention, it does take 36-48 hours for the magnet to reach back its operating temperature. To avoid waisting time while running experiments, the magnet has been set to be operated routinely up to 80 A (~ 4.28 T). A 3 T field is typically used to saturate the iron foils.

The magnet is conduction cooled by a pulse tube cryogenic refrigerator, model PT415-RM, from CryoMech. The cryogenic refrigerator cold head is labeled PT CRYOCOOLER on Fig. 4. Fig. 6 shows the various components of the cryogenic refrigerator. Two 66 ft long flexible lines, a “high-side” and a “low-side”, connect the compressor with the cold head. Two gauges on the compressor show the helium pressure on those lines. When the CP1110 compressor is not operating, the two gauges will show a pressure of ~ 220 psi. When the compressor begins operation and the cold head is at ambient temperature, the differential pressure between the high and low side lines is typically 220 to 250 psi. The differential pressure will decrease as the cold head cools down. If the high side pressure becomes larger than 360 psi, the compressor will trip. To reset the fault, the high side

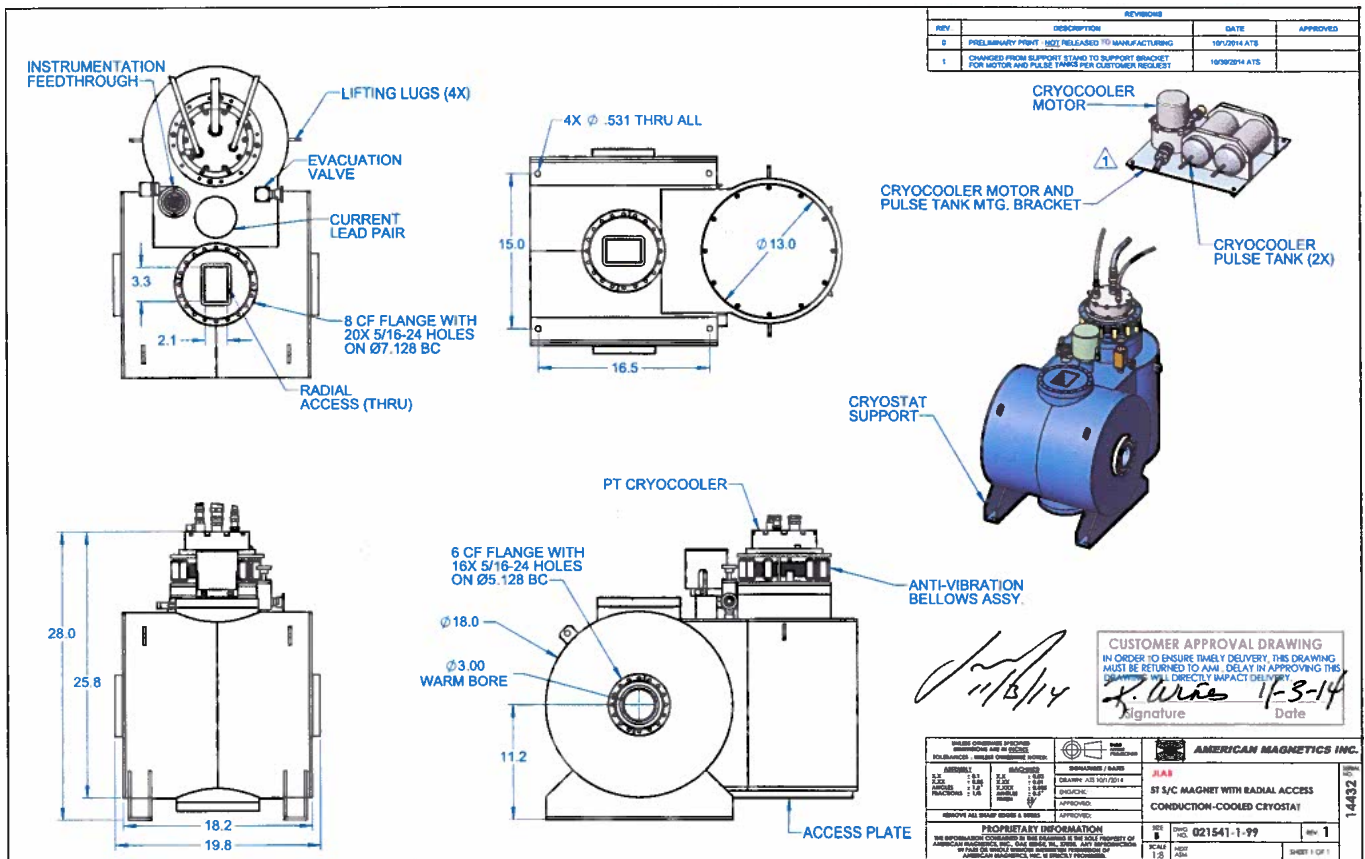


Figure 4: The 5 T target magnet from AMI. The electron beam travels along the 3-inch diameter warm bore of the magnet. The target system ladder moves in and out of the beam path along the vertical opening labeled RADIAL ACCESS on the drawing.



MAGNET SPECIFICATIONS

AMI JOB #021541-1-1 MAGNET #14432

TYPE: **CRYOGEN-FREE HORIZONTAL FIELD MAGNET SYSTEM**

MODEL: **SPLIT COIL ACCESS**

FOR: **JEFFERSON SCIENCE ASSOCIATES - JLAB**

TEST DATE: 6/17/2015

Rated Central Field ¹ -----	50 kG [5.0 T]
Rated Current-----	93.28 amp
Field to Current Ratio-----	0.536 kG/amp
Homogeneity over 1 cm DSV-----	±1.0%
Measured Inductance-----	39.8 henrys
Ramp Rate from 0 to 85A-----	0.0254 amp/sec. (1.0 V)
Ramp Rate from 85A to 93.28A-----	0.0031 amp/sec. (0.13 V)
Room Temperature Vertical Radial Access Port-----	2.1" x 3.3"
Room Temperature Horizontal Axial Bore-----	3.0"
System Cooldown Time from 300K to 4K ² -----	~30 hours
Total Magnet/Switch Resistance ³ -----	20 ohms
Persistent Switch Heater Current-----	20.0 mA
Persistent Switch Cooldown time-----	600 sec.
Persistent Switch Heat time-----	20 sec.
Approx. System Weight.....	475.5 lbs (215.68 kg)

1. Magnet not warranted for operation above 50 kG.
2. Compressor input power: 460-480 VAC/60 Hz (3 Phase)
3. All resistance measurements made at room temperature at magnet power connectors.

Figure 5: Møller target magnet specifications.

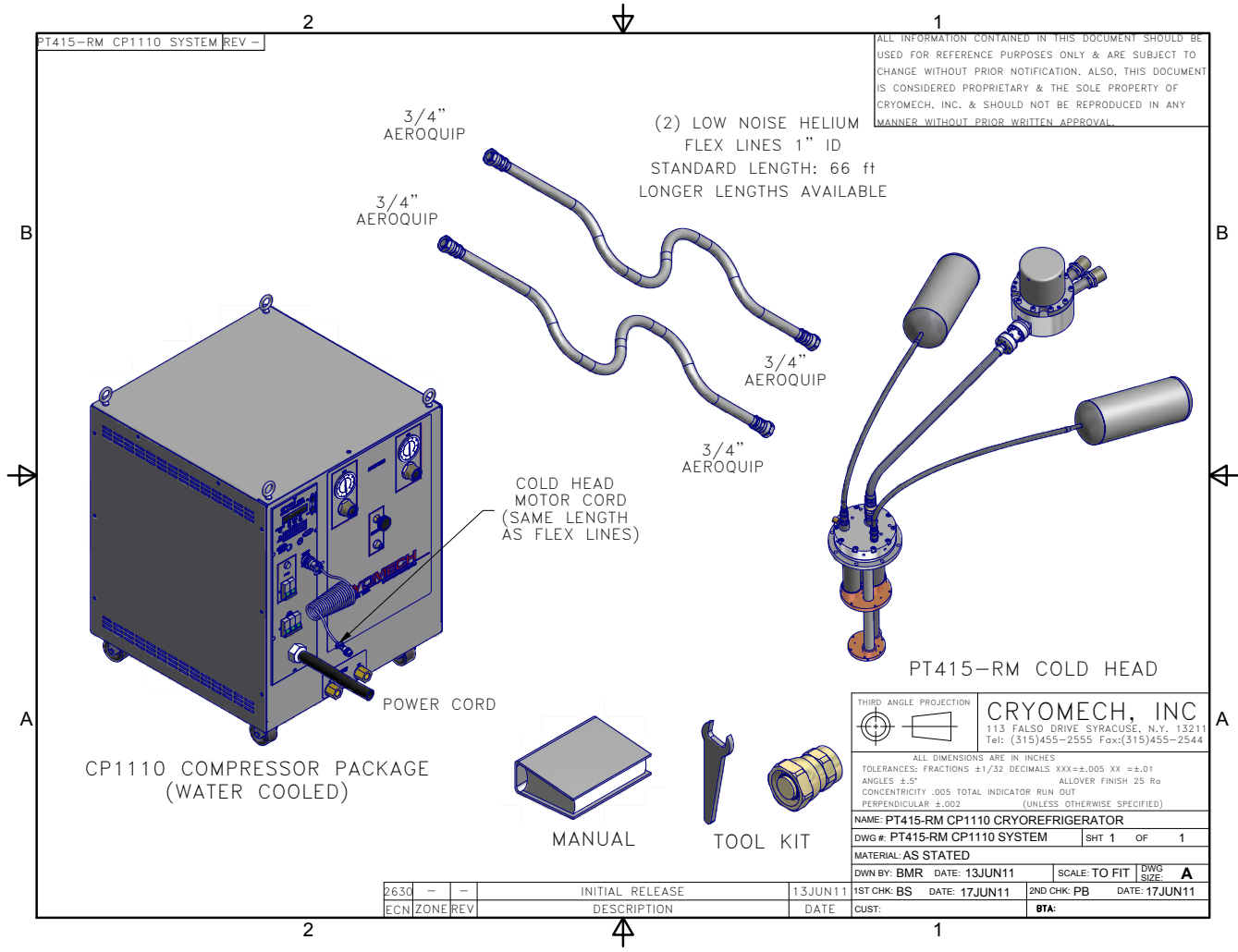


Figure 6: The various components of the PT415RM pulsed-tube cryogenic refrigerator.



Figure 7: An Advantage Engineering M1-3A water chiller provides the water cooling needed by the CP1110 compressor.

pressure needs to drop to 359 psi or below. The compressor is equipped with a over-pressure relief to atmosphere valve set at 420 ± 5 PSIG. The cold head is equipped with a relief to atmosphere valve set to 425 ± 5 PSIG. The total amount of helium in the system corresponds to ~ 850 liters NTP.

An Advantage Engineering M1-3A water chiller (see Fig. 7) provides the water cooling needed by the CP1110 compressor. The M1-3A is an air cooled, 3 refrigeration-tons unit. The M1-3A and the CP1110 form a closed water circuit. Water temperature is set to 20°C (68°F).

Operation of the superconducting magnet and status of the supporting equipment can be gained through various EPICS screens,

- Launch **NewTools**.
- Select **EDM(HLA)** \rightarrow **JTabs(HLA)**. In the new screen select **Moller**.
- On the new screen select **Temperature, Gaussmeter, Power Supply** or **Compressor**.
 - **Compressor** CryoMech CP1110 (see Fig. 8) shows the status of the cryogenic refrigerator system. There are no user adjustable parameters in this system. Notify the primary contact (see Table 4) if questions or problems arise with the cryogenic refrigerator of water chiller.

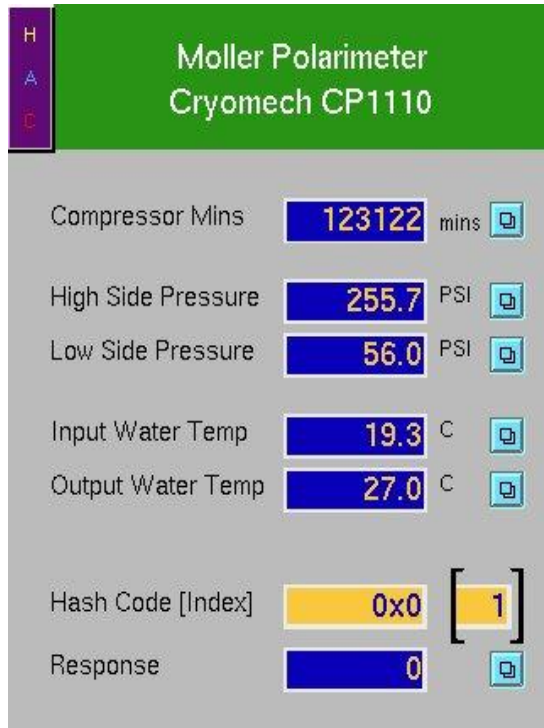


Figure 8: CryoMech CP1110 refrigerator status.

- **Temperature** (see Fig. 9) LakeShore displays the various temperatures of the magnet.
- **Gaussmeter** (see Fig. 10) displays a magnetic field measured by axial LakeShore Hall probe which located on a flange upstream of the magnet.
- **Power Supply** (see Fig. 11) allows to operate & monitor the magnet.

Temperature Sensor	° K
Cryocooler (T1)	3.3 - 3.6
Magnet (T2)	3.7
Magnet Lead #1 (T6)	42.7
Magnet Lead #2 (T7)	41.8

Table 1: Magnet temperatures in the superconducting state with no current flowing through the magnet.

Before operating the magnet, check that the magnet temperatures (see Fig. 9) shown by the Lakeshore temperature measurement unit are close to those shown on Table 1. If they are, bring up the Power GUI (see Fig. 11) and follow the sequence to operate,

1. If persistent switch status is **OFF**, press switch and wait indicated countdown. Otherwise skip step.

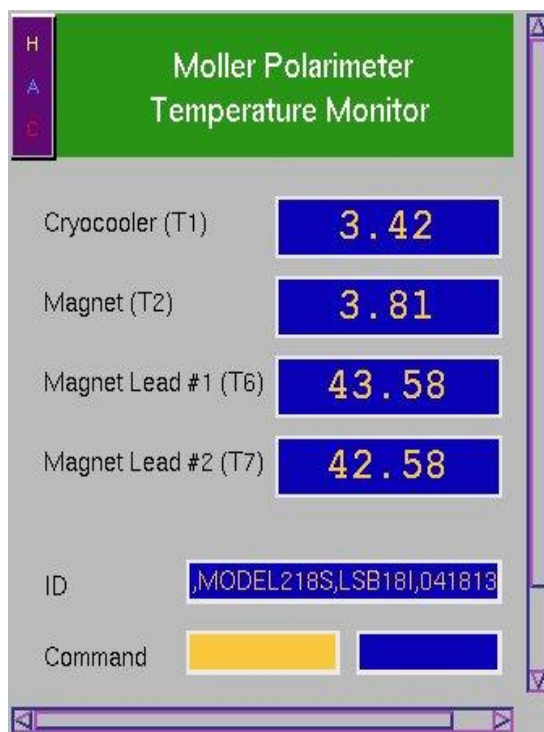


Figure 9: Magnet temperature status.

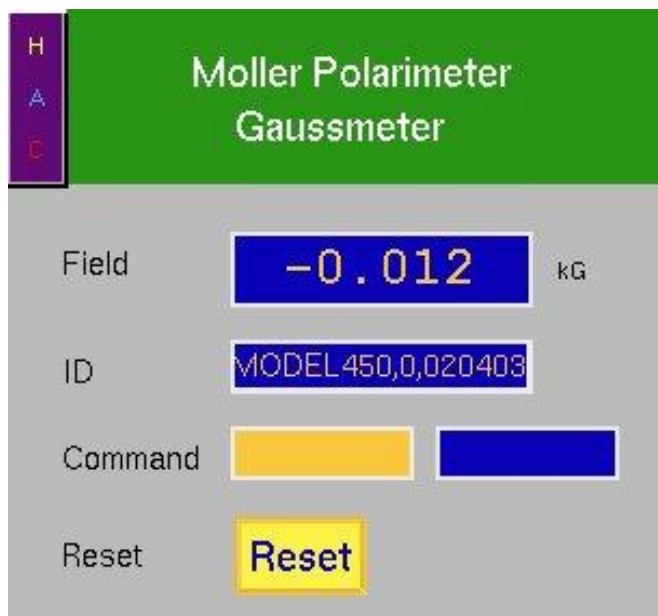


Figure 10: Magnetic field measured by LakeShore Hall Probe.



Figure 11: Control and operation of the magnet.

2. set the new target current (field);
3. use command **RAMP/PAUSE**;
4. wait until "Field at Target" is set;
5. proceed with measurements;
6. set a new target current (field) - ramping will start immediately unless pause has been engaged;
7. when finished with measurements:
 - (a) set target current (field) equal to 0;
 - (b) when current (field) at target and current leads energized goes off, press persistent switch to turn it off

The supply is located in the Hall A corridor leading to Hall A. It is an 4Q06125PS-430 from AMI. It is a polarity reversible device so, the sign of the **Current Target Setpoint** entry is important - if necessary, the magnet will automatically ramp through zero to reach the new value. The maximum voltage across the magnet when ramping is 1 V (3 V across the power supply terminals). The current is limited to a maximum of ± 80 A. Use the provided external "witness" gaussmeter (see Fig. 10) to determine that the field is ramping and its orientation. Recall that this meter does not measure

the field at the center of the magnet but at a convenient location outside the magnet. Table 2 shows the relation between the “witness” gaussmeter and the superconducting magnet current.

Field (kG)	Current (A)
5.4	60
4.9	55
4.0	45
3.1	35
2.2	25
1.3	15
-1.3	-15
-2.7	-30
-4.0	-45
-5.4	-60

Table 2: “Witness” gaussmeter field vs superconducting magnet current.

3.2.2 Møller Target Foils

Figures 12 and 13 show a general view of the target system and a close up of the target ladder itself. Operation of the target slider (see Fig. 12) is accomplished through the edm screen shown in Fig. 14. Pressing the blue button next to the label ”Target Motion Control” in Fig. 2 opens an expert screen (see Fig. 14).

	Position				
	0	1	2	3	4
Material	none	Fe	Fe	Fe	Fe
Purity (%)		99.85	99.99	99.99	99.99
Thickness (μm)	-	1	4	12.5	25
Polarization (%)	-	8.52	8.52	8.52	8.52
Comment	Retracted target position			Annealed @ 930°C for 1hr in vaccum	

Table 3: Target foil parameters. Purity and thickness are as quoted by manufacturer, Goodfellow Corporation. An “Extended Limit” stops the motion of the target slider a short distance past foil# 4 and the FSD interlock will not allow for beam delivery. In the “Retracted Target Position” (Position 0), the slider edge is several inches away from the beam.

The target holder (see Fig. 13) can be moved vertically, placing different foils into the beam. The whole target holder can also be rotated around Y-axes in an angle range $\pm 10^\circ$ with an accuracy $\sim 0.1^\circ$. The rotation allows to adjust the foil angular orientation vs. the beam to 90° .



Figure 12: Target system. The target ladder with four foils installed can be seen at the bottom of the system.

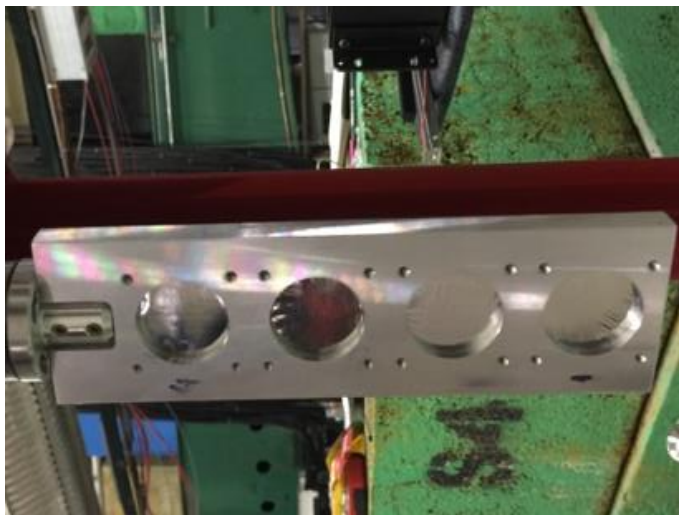


Figure 13: Target ladder with foils.

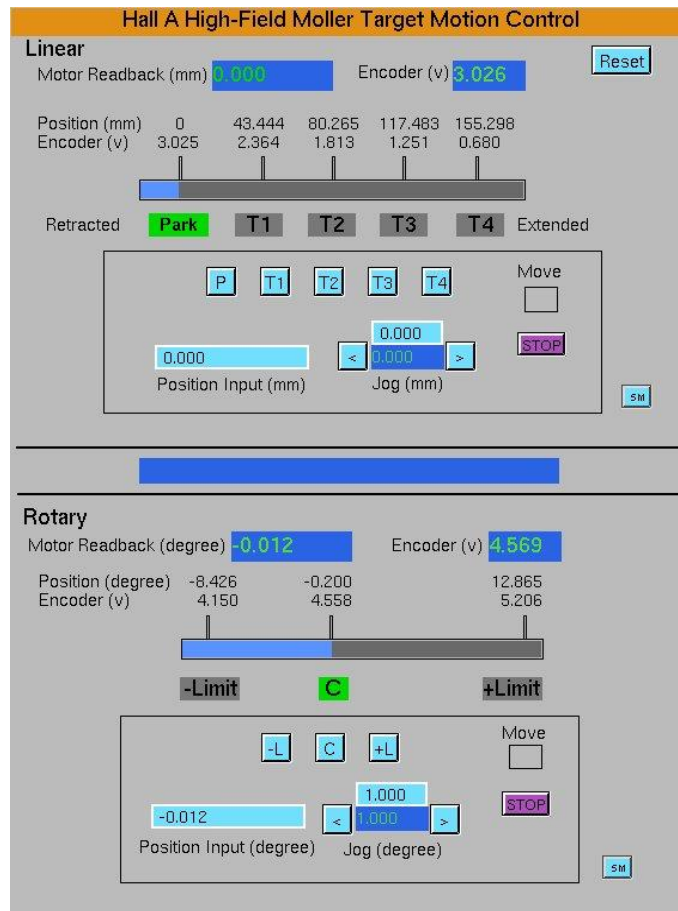


Figure 14: Target motion/rotation and control screen.



Figure 15: The Møller target motion may cause the Fast ShutDown (FSD) of the accelerator. The LEDs in the top right corner show the appropriate signals from the target. The top LED lit indicates no FSD signal.

The MCC operator must “**mask**” the Møller target motion before performing any target motion. Authorized Hall A personnel (see section 6) are also allowed to move the target.

Three closed-circuit TV cameras, located in the Hall A Counting House, are used to observe the target motion. One camera looks from the side and shows the angular orientation of the target to the beam and two limit switches corresponding the target angle -10° and $+10^\circ$ accordingly. The second camera shows the vertical position of the target rail. The third camera looks from the bottom of the magnet camera through the window and shows the target loader inside the magnet.

Data Acquisition “dead time” typically limits the beam current that can be used to perform a beam polarization measurement to about $1.0 \mu\text{A}$ while localized beam heating of the iron foils (which causes some loss of target polarization) would limit the beam currents to less than $2 \mu\text{A}$.

Møller target position interlocks, used to indicate when the various targets are properly located in the beam path, are routed to the Fast ShutDown (FSD) system of the accelerator. Fig. 15 shows the crate which controls the signals. The Møller FSD crate is located in Hall A rack 02. Target control is via EPICS (ref) Input & Output Controller (IOC) **IOCHLA**. The master section of this IOC is located in the corridor leading to Hall A, in the bottom of rack 1H75L05 (see Fig. 16). The slave crate with the field wirings is located in Hall A rack 02 below the Møller FSD crates (see Fig. 15).



Figure 16: EPICS IOC **IOCHLA** master crate is located in the corridor leading to Hall A in the bottom of rack 1H75L05.

3.3 Spectrometer Description

The Møller polarimeter spectrometer consists of four quadrupole magnets and one dipole magnet. Fig.17 shows a side view of the spectrometer,

- quadrupole **MQM1H02A** (white color, there is no label on the yoke);
- quadrupole **MQM1H02** (red color, on the yoke labeled *PATSY*);
- quadrupole **MQO1H03** (blue color, on the yoke labeled *TESSA*);
- quadrupole **MQO1H03A** (blue color, on the yoke labeled *FELICIA*);
- dipole **MMA1H01** (on the yoke marked as *University of Kentucky*).

All of these magnetic elements are controlled by MCC operators since they can steer the beam.

The spectrometer accepts electrons scattered close to the horizontal plane (see Fig.1). The acceptance in the azimuthal angle is limited by a collimator in front of the dipole magnet, while the detector vertical size and the magnetic field in the dipole magnet limit the acceptance in the scattering angle θ_{CM} .

The electrons have to pass through the beam pipe in the region of the quads, through the collimator in front of the dipole magnet, with a slit of 0-4 cm high, through two vertical slits in the dipole, about 2 cm wide, positioned at ± 4 cm from the beam. These slits are terminated with vacuum tight windows at the end of the dipole. The dipole deflects the scattered electrons down, towards the detector. The detector, consisting of 2 arms - 2 vertical columns - is positioned such that electrons,

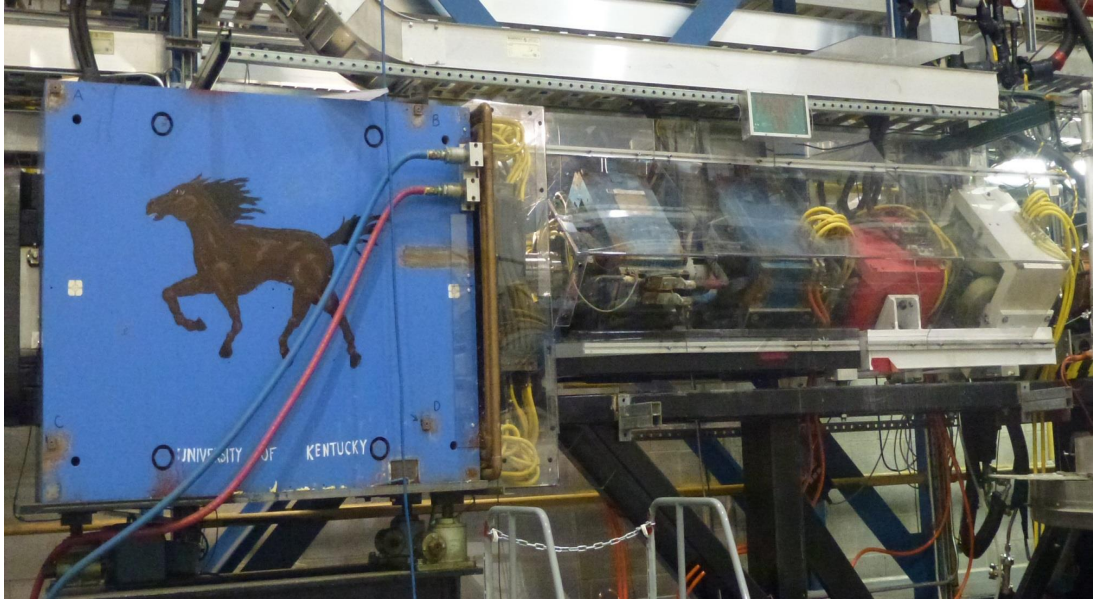


Figure 17: The Møller spectrometer. The target is located at the right side of the photograph.

scattered at $\theta_{CM} = 90^\circ$ pass close to its center. This acceptance is about $76 < \theta_{CM} < 104^\circ$. At beam energies below 1 GeV the vertical slits in the dipole limit the acceptance to about $83 < \theta_{CM} < 97^\circ$.

Energy range of the spectrometer is 1.0 GeV \div 11.0 GeV. For a given beam energy there is an optimal setting of the currents in these 5 magnets.

Typically, the dipole magnet should be turned on only for the Møller measurements.

3.4 Detector

The Møller polarimeter detector is located in the shielding box downstream of the dipole and consists of two identical modules placed symmetrically about a vertical plane containing the beam axis, thus enabling coincidence measurements (see Fig. 18). Each part of the detector includes:

- An aperture detector consists of four scintillators with light guides and Hamamatsu R4124 (13 mm diameter) photomultiplier tubes connected to each segment. Size of the aperture assembled detector is $31 \times 4 \times 3.8$ cm.
- A *spaghetti* lead - scintillating fiber calorimeter², consisting of 2 blocks $9 \times 15 \times 30$ cm³, each separated into 2 channels equipped with Photonis XP2282B (2 inch) photomultiplier tubes. Thus, each of the vertical detectors is segmented into 4 calorimeter channels.

²before summer 2002 a lead glass calorimeter consisting of $48 \times 8 \times 30$ cm³ was used. It lost a big fraction of the amplitude due to the radiation damage and deterioration of the optical contact.

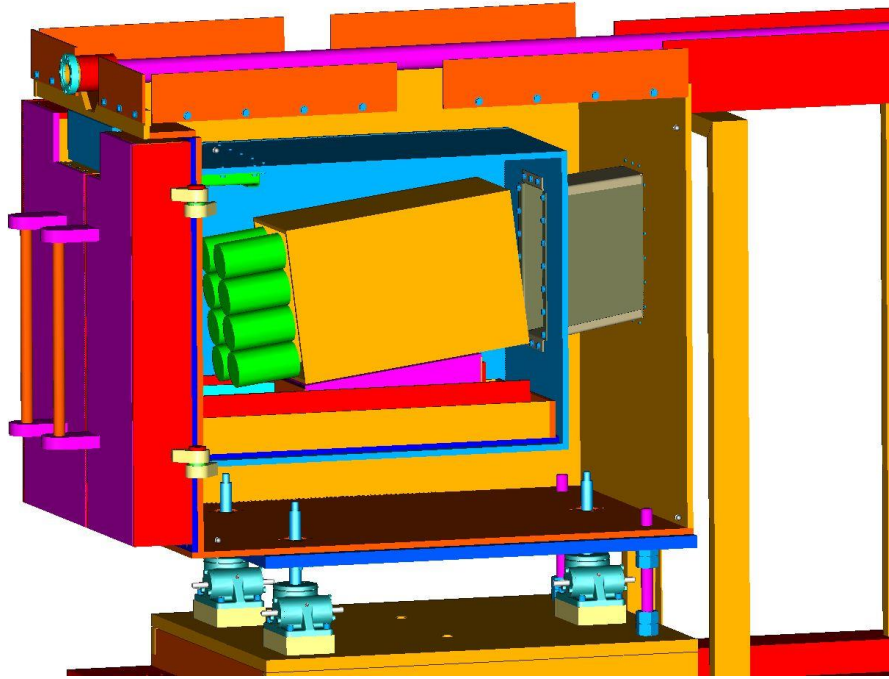


Figure 18: The Møller detector in the shielding box. The aperture detector on the face of the lead - scintillating fiber calorimeter is not shown.

The HV crate is located in the Hall A rack 15 (see. Fig. 19) and is connected to a portserver **hatsv5**, port **3**. HV for the various calorimeter blocks is tuned in order to align the Møller peak position at a ADC channel 300 for each module.

3.5 Electronics

The electronics, used for Møller polarimetry, is located in several crates in the Hall (racks 12, 14, 15):

1. VME, board computer **hallavme5** - for DAQ;
2. CAMAC - for the trigger and data handling;
3. NIM - for the trigger and data handling;
4. LeCroy 1450 - HV crate, slots **5** and **6** (calorimeter and aperture detector).

The photograph on Fig. 20 shows (from left to right) the DAQ crates in rack 14, power supplies for the Møller spectrometer quadrupole magnets in rack 13 and FADC DAQ crates in rack 12. Rack 14 from the top to bottom: crate with delay lines (blue), two Møller target Helmholtz coils power supplies. Crate below the power supplies is the VME DAQ crate and Helmholtz coils control, the next one is the CAMAC crate and the bottom one is the NIM crate.

One can connect to the CPU boards and the HV crate via a portserver:

1. **hallavme5** - **hatsv5** port **4**;
4. LeCroy 1450 - **hatsv5** port **3**.

3.6 DAQ

Two data acquisition (DAQ) systems in are used. The original DAQ³ is based on CODA [1] and runs on *adaql2*. The database server for CODA is running on *adaql1*. A more recent DAQ system, still undergoing evaluation, is based on Flash Analogue-to-Digital Converters (FADC) in VME format. This system runs on the *hamoller* computer and it uses Portserver *hatsv12 port 5* to connect to the VME modules. Data is stored on *hamoller:/data1/raw/*. The FADC DAQ electronics is located in the Hall rack 12 (see Fig. 21).

3.7 Slow Control

The Helmholtz coils are controlled via a script starting automatically at the beginning of each CODA run. The polarity of the current in the coils is reversed at every new run.

³(More details in: http://hallaweb.jlab.org/equipment/moller/guide1.2_linux.html)

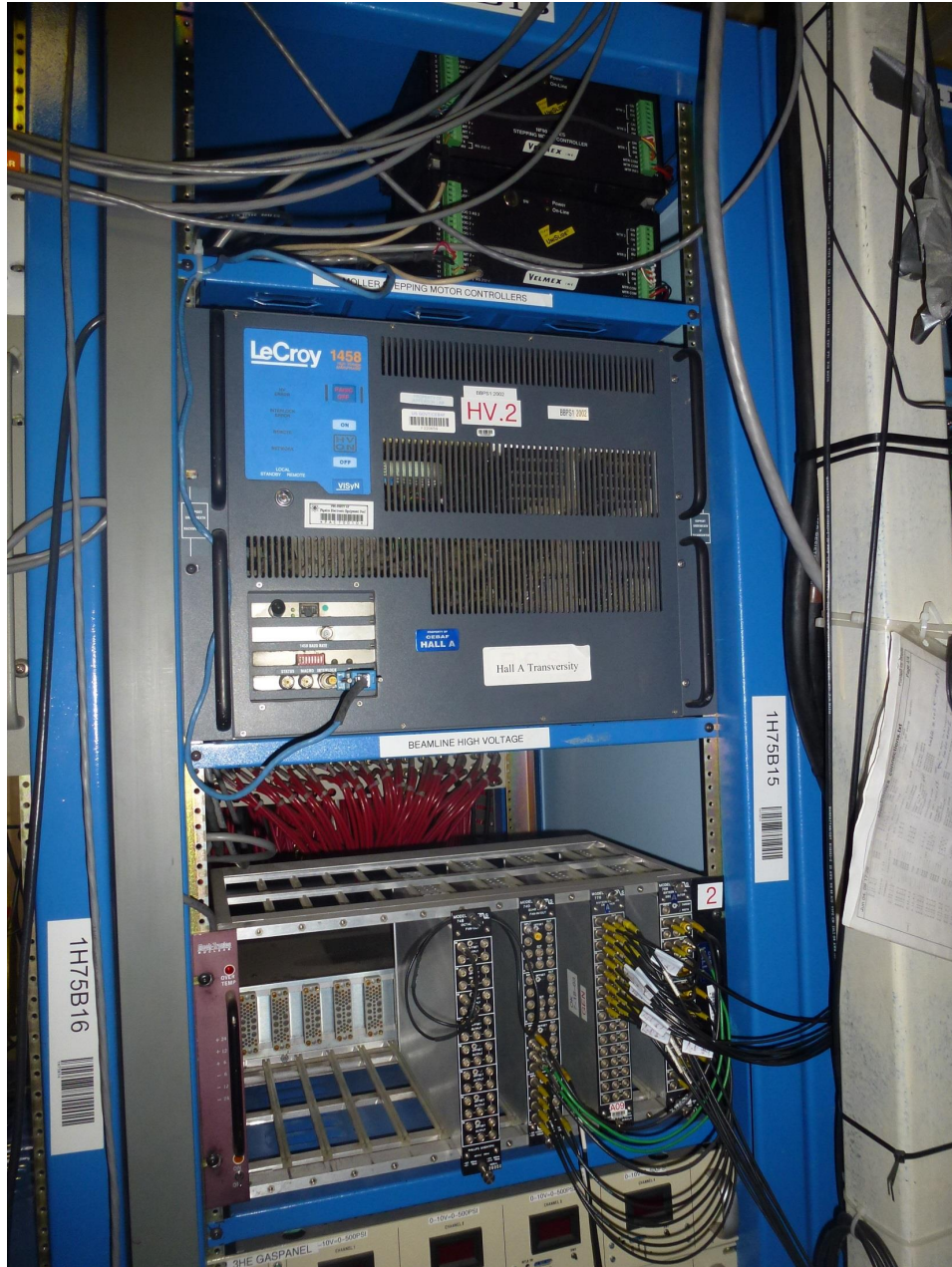


Figure 19: The Møller HV crate (LeCroy1458) and part of the Møller DAQ (crate below HV crate).

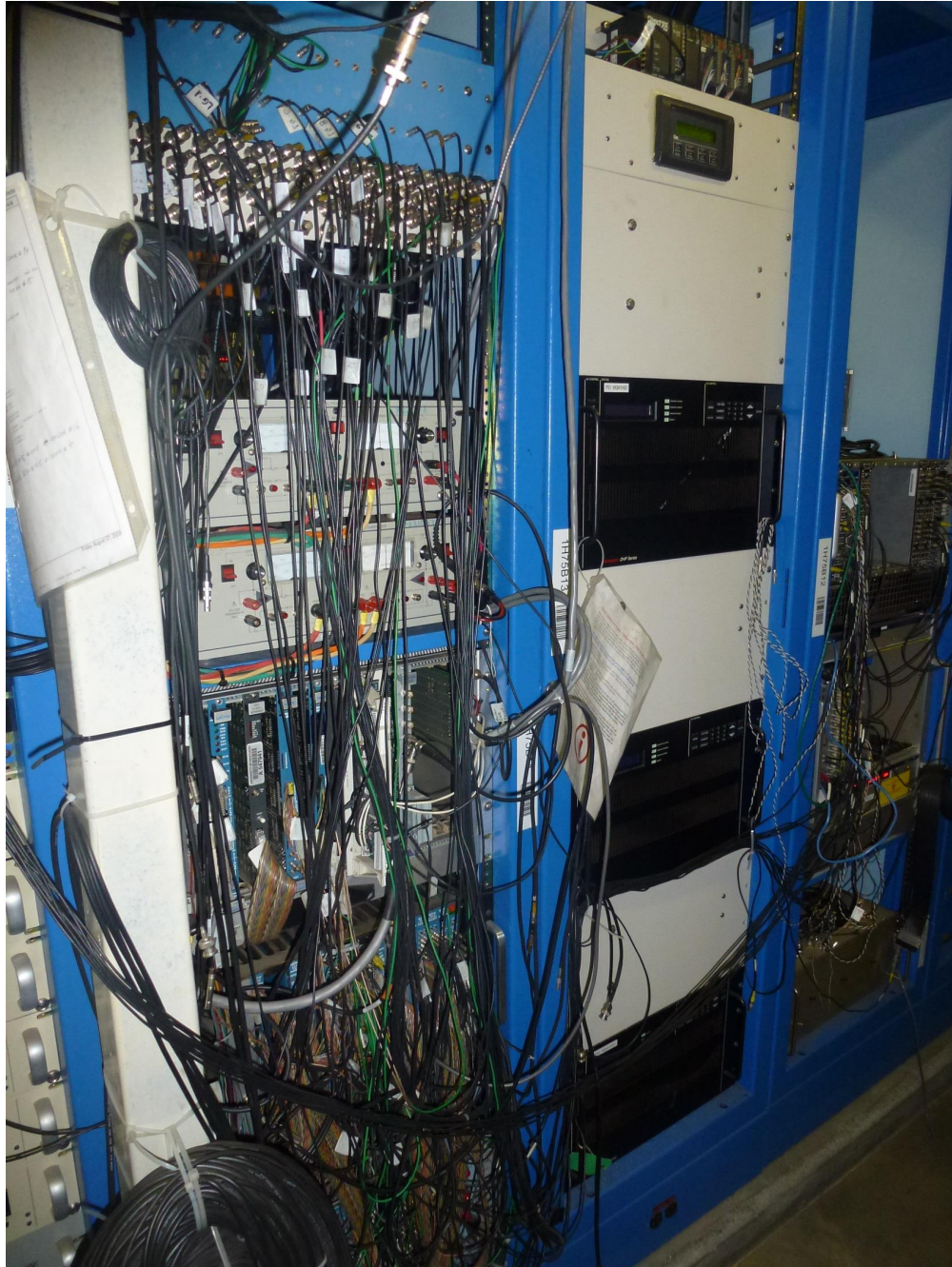


Figure 20: Møller electronics, located in the Hall, at the right side of the beam line. From left to right: the DAQ crates in rack 14, power supplies for the Møller spectrometer quadrupole magnets in rack 13 and FADC DAQ crates in rack 12.

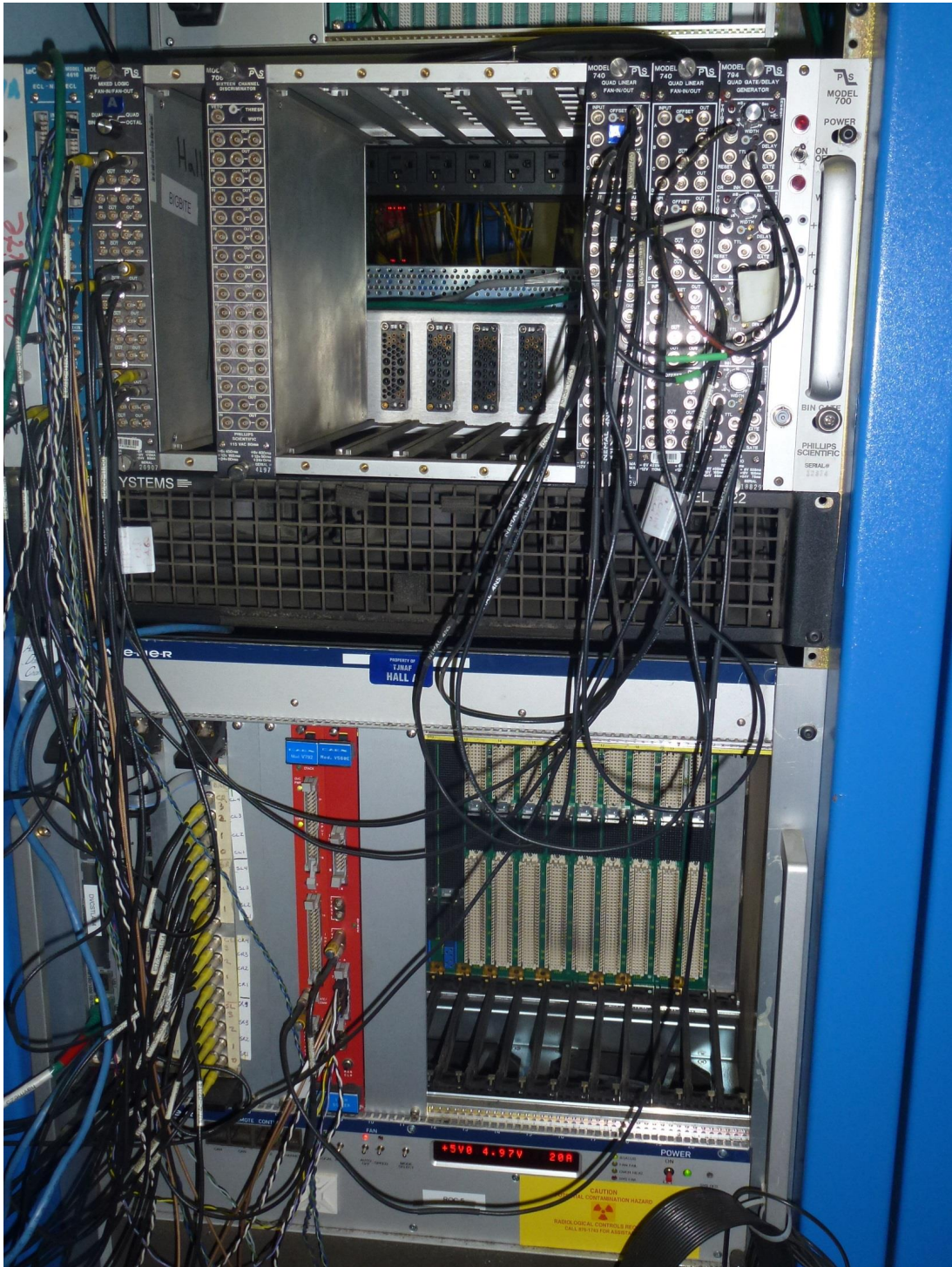


Figure 21: The Møller FADC crates.

The HV, the electronics settings and the collimator position are controlled from a Java program with a GUI⁴.

Procedure to start the slow control task,

- Login to *adaql1* as *moller*;
- *adaql1> cd Java/msetting/*
- *adaql1> ./mpc* ⇐ it starts the slow control task.

It may take about a minute to start all the components and read out the proper data from the electronic crates.

The slow control GUI is presented on Fig. 22.

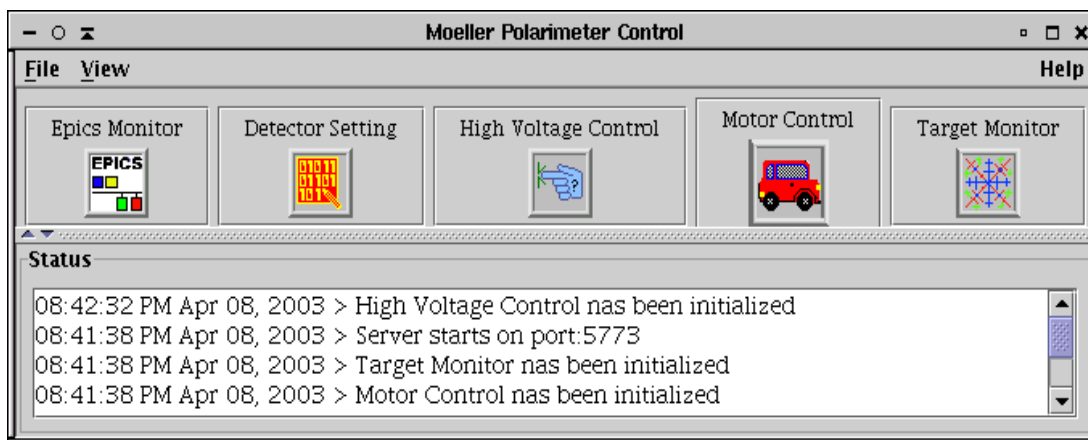


Figure 22: The slow control GUI (Java).

The components are:

- [EPICS \[2\] Monitor](#): these EPICS variables are stored for every DAQ run
- [Detector Settings](#) is used to set up the thresholds, delays etc.
- [High Voltage Control](#) for the photomultiplier tubes
- [Motor Control](#) to move the collimator
- [Target Monitor](#) information on the target position, magnets etc.

High voltage can be changed or turned on/off using the HV GUI window (Fig. 23), where the first eight channels belong to the calorimeter and the other eight channels belong to the aperture counters.

The settings of the CAMAC electronics used to select the trigger and control DAQ are controlled using the [Detector Setting](#) window (Fig. 24):

⁴More details in http://hallaweb.jlab.org/equipment/moller/slow_mpc.html

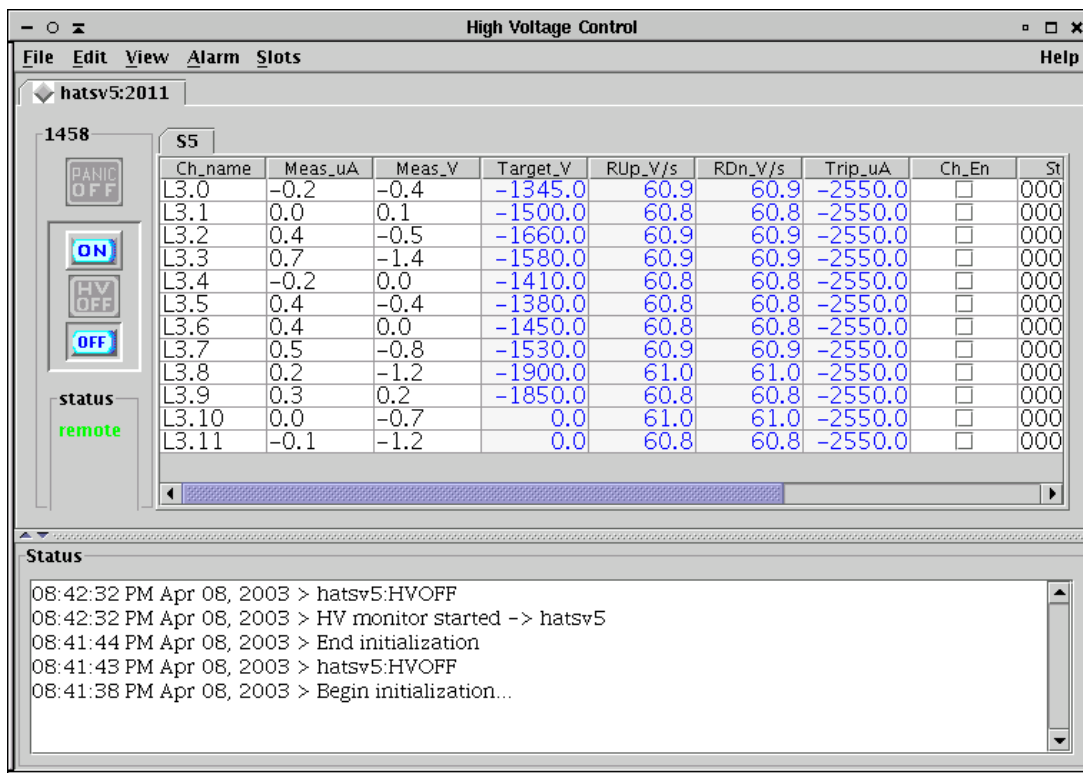


Figure 23: HV control GUI window.

- [Delay line](#) - the delays for the calorimeter and aperture counter signals;
- [LedDiscriminator](#) - discriminator thresholds for the calorimeter and the counters
- [PLU Module](#) - settings of the logical unit

The collimator width can be changed using [Motor Control](#) window (Fig. 25).

4 Operating Procedure

The procedure includes general steps as follows:

- “Non-invasive” preparations - start the appropriate computer processes, turn on the HV and learn the magnet settings needed;
- “Invasive” preparations: beam tuning with the regular magnet settings, loading the Møller settings, beam tuning, if necessary, installing the Møller target;
- Detector check/tuning;
- Measurements;
- Restoring the regular settings.

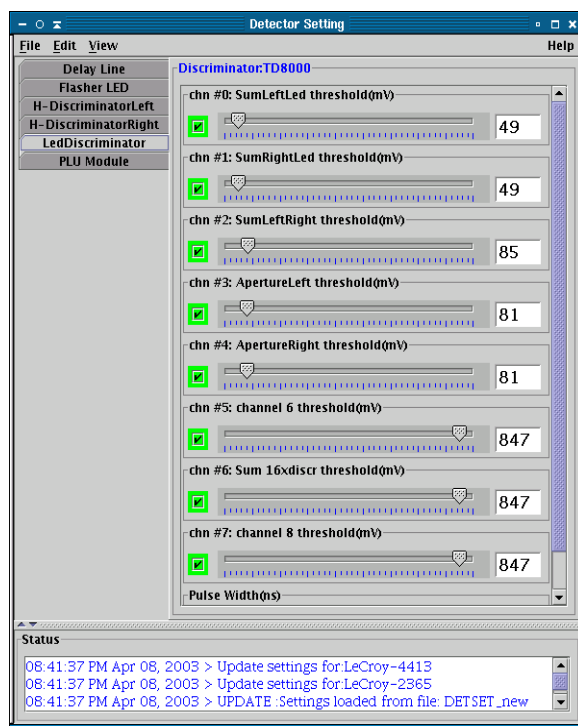


Figure 24: Detector setting GUI window.

The “non-invasive” preparations can be done without disturbing the running program in the Hall. It is reasonable to perform these preparations before starting the “invasive” part.

In more details, the “invasive” procedure looks as follows:

- Remove the main target;
- Load the Møller settings in the magnets, keep the dipole off;
- Tune the beam position with any convenient beam current;
- Turn on the Møller dipole;
- Check the beam position;
- Tune the beam to $\sim 0.5 \mu\text{A}$ for Møller measurements;
- Pull in the Møller target, using the TV camera to make sure the foil is at the window center;
- Make at least two CODA runs in order to use both coil polarities;

4.1 Initialization

In order to control the operations, several terminal sessions of the **moller** account must be opened on **adaql1**,.... The data analysis and some initial calculations are done using a PAW [3] session on **adaql1**:

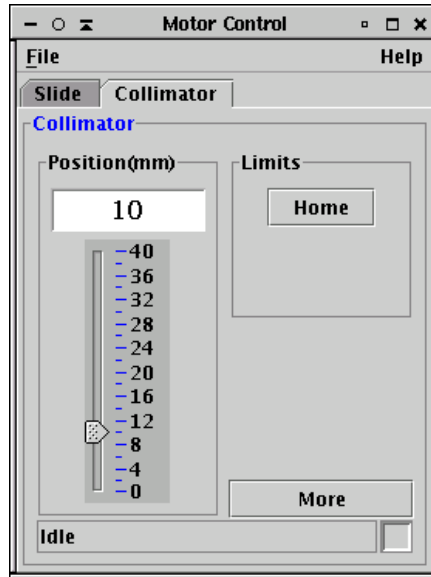


Figure 25: GUI window to control the dipole collimator size (and also the slide, which is not relevant here).

- Login to **adaql1** as **moller**;
- **adaql1> cd paw/analysis**, start PAW (type **paw**), select Workstation type 3.

Check that the portserver connections are available:

- Try **telnet hatsv5 2003** and **telnet hatsv5 2004**;
- If a connection is refused - clean it up, by connecting **telnet hatsv5** as root and typing **kill 3** or **kill 4**, see instructions in `~adaq/doc/portserver.doc`.

Slow control:

- Login to **adaql1** as **moller**;
- Start the slow control (see section 3.7);
- Load the regular settings and the appropriate HV.

CODA runs on **adaql1**:

- Login to **adaql1** as **moller**, make two sessions;
- **adaql2> kcola** - clean up the old coda;
- Reset the VME board **hallavme5** by: **telnet hatsv5 2004, -> reboot**;
- **adaql2> start_coda** - start CODA;
- Click **Connect** and select the configuration **beam_pol**;
- Click **Download** to download the program into the VME board.

4.2 Initial Beam Tune

Typically, the Møller measurements are taken during the regular Hall A running, when the beam has been tuned for this running. However, the Møller measurements require a different magnetic setting. At least the dipole magnet has to be turned on. This magnet slightly deflects the beam downward. The deflection at the main target could be < 3 mm, depending on the beam energy. It is, therefore, useful to tune the beam position before the dipole is turned on. It can be done before the magnets are set to the Møller mode. The requirements for straight beam are:

- On BPM IPM1H01 (in front of the Møller target) $|X| < 0.1$ mm, $|Y| < 0.1$ mm.
- On BPM IPM1H04 (downstream of the Møller detector) $|X| < 0.1$ mm, $|Y| < 0.1$ mm.

These requirements should be given to MCC.

4.3 The Magnet Settings

The proper Møller magnets (quads and dipole) settings for the given beam energy have to be provided to MCC by the Møller polarimeter team.⁵ The beam must be turned off when the magnets are being tuned.

4.4 Final Beam Tune

The beam parameters for Møller measurements are:

- beam currents between $\sim 0.5 \mu\text{A}$ and $< 2 \mu\text{A}$;
- the beam current should be reduced mainly by closing the “slit” in the injector (not by the laser attenuator), in order to reduce the effect of current leak-through from the other halls.

4.5 Target Motion

The procedure is as follows:

- Ask the MCC to mask the main target (cryotarget or whatever) motion and remove the main target, then ask the MCC to unmask the motion;
- Ask the MCC to mask the Møller target motion;
- Move to target to the position needed (say, 4) using the MEDM screen (see Fig. 14). Check that the target is close to the center of the window in the TV camera screen.

⁵A reasonable accuracy in the magnets settings is about 1-2%.

4.6 Detector Tuning and Checking

The goal is to check that the detector is working, that the counting rates are normal and that the Møller peaks are located at about ADC channel 300 for all the calorimeter blocks.

A. Data taking with CODA

1. Take a RUN for about 20k events. Let us assume the run number is 9911.

B. Data analysis with PAW

1. **PAW> exec run run=9911**: build an NTUPLE and attach it to the PAW session;
2. **PAW> exec lg_spectra icut=60 run=9911**: look at the ADC distributions. The peaks should be at about ADC channel 300 for all 8 modules. If the peaks are off - try to adjust the HV (do not go beyond 1990V).

C. Check of the background

1. Raise the thresholds to 240 mV of the channels 1 and 2 of the discriminator, using the slow control window (see section 3.7);
2. Take a run of about 20k events, say run=9915;
3. **PAW> exec lg_spectra icut=60 cut=11 run=9915**: look at the ADC distributions. The peaks should be at about ADC channel 300 for all 8 modules. The histograms 9 and 10 present the sums of the left and right arms. The histogram 11 (sum of both arms) should contain a clean peak at about channel 600;
4. **PAW> exec asymu run=9915**: polarization analysis should provide a reasonable number. Check the scaler rates per second. The counting rates in each arm should not exceed 600kHz. If they are higher ask the MCC to reduce the beam current.

4.7 Polarization Measurement

1. Take an even (say, 2) number of runs of data, each run of about 20-30 k events (30 k at $E_{beam} < 2$ GeV).
2. Analyze the data
 1. **PAW> exec run run=Run_Number** and
 2. **PAW> exec asymu run=Run_Number**, for each RUN,

4.8 Polarization Measurement with FADC

ROOT[4] based analyzer is used to process data from FADC DAQ. Data analysis is performed on **hamoller** computer under “a-onl” account. One should go to directory **moller\moller_fadc-18Feb2011** and type command:

a-onl> source root-setup.sh

Move into the analysis directory:

a-onl> cd onlana

To replay a new run ($\langle Run_Number \rangle$) and generate a new .root file:

a-onl> analyzer

In analyzer terminal type:

ROOT> replay_test($\langle Run_Number \rangle$)

To analyse run ($\langle Nevents \rangle$ is number of events to analyze, -1 - all events) type:

ROOT> t = T($\langle Run_Number \rangle$)

ROOT> t-> Loop($\langle Nevents \rangle$)

Few graphic windows will be pop up and calculated asymmetries are printed in analyzer terminal.

5 Safety Assessment

5.1 Magnets

Particular care must be taken in working in the vicinity of the magnetic elements of the polarimeter as they can have large currents running in them. The quadrupole magnets and the leads for the dipole magnet are protected with Plexiglas shields. Removal of these shields requires following JLab's "Lock out / Tag out" procedure and ESH&Q rules. Concurrence from the Hall A work Coordinator must be obtained before proceeding with such work.

As with all elements of the polarimeter which can affect the beamline, the magnets are controlled by MCC. There is a light panel "MAGNET ON" (see Fig. 26) which indicates the status of the Møller polarimeter magnets (quadrupole magnets **MQM1H02A**, **MQM1H02**, **MQO1H03**, **MQO1H03A** and dipole magnet **MMA1H01**). The light panel is placed on the top of Møller magnets plastic shielding box and lighting when any one of the Møller magnets is energized.

The power supply (62 V, 500 A rating) for the dipole is located in the Beam Switch yard Building (Building 98). The maximum current for the dipole is 450A. The power supplies for quadrupoles **MQM1H02**, **MQO1H03** and **MQO1H03A** (40 V, 330 A rating) are located in Hall A electronics rack 13 (see Fig. 20). The power supply for quadrupole **MQM1H02A** is located behind the Hall A electronics racks (see Fig. 27). The status of the quadrupole power supplies is on the checklist for closing up Hall A.

5.2 Vacuum System

One must be careful in working near the downstream side of the dipole magnet, as there are two 2 by 16 cm, 4 mil thick titanium windows. The windows are partially protected by a lead collimator downstream of the dipole. Only members of the Møller polarimeter group should work in this area. If work is done on the collimators, the appropriate ear and eye protection should be used.



Figure 26: “MAGNET ON” light panel on the top of the Møller spectrometer shielding guard.

5.3 High Voltage

There are 16 photomultiplier tubes within the detector shielding hut, with a maximum voltage of 3000 V. The detector is serviced by sliding it back on movable rails. The high voltage must be turned off during any detector movement. Only members of the Møller group should move the detector.

5.4 Target

To avoid damage to the Møller target, the target should not be in the beam if the beam current is greater than $5\mu\text{A}$. The experimenters are responsible for ensuring that the Møller target is removed from the beam for regular running and that its position is unmasked.

6 Authorized Personnel

The list of the presently authorized personnel is given in Table 4. Other individuals must notify and receive permission from the contact person before adding their names to the above list.



Figure 27: Power supply for the Møller quadrupole magnet **MQM1H02A** located in the Hall A.

References

- [1] CODA documentation. WWW page. URL <http://coda.jlab.org/>.
- [2] EPICS Documentation. WWW page. URL <http://www.epics.org/>. see also <http://www.aps.anl.gov/asd/controls/epics/EpicsDocumentation/WWWPages/EpicsDoc.html>.
- [3] PAW Documentation. WWW page. URL <http://wwwasd.web.cern.ch/wwwasd/paw/>.
- [4] CERN. ROOT Package. URL <http://root.cern.ch>.

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Javier	Gomez	JLab	7498	gomez@jlab.org	
William	Henry	Temple U.	-	billyh@temple.edu	-
Jim	Napolitano	Temple U.	-	tuf43817@temple.edu	-
Roman	Pomatsalyuk	Kharkov	5395	romanip@jlab.org	
James	Wilhelmi	Temple U.	-	wilhejames@gmail.com	-

Table 4: Moller Polarimeter: authorized personnel.

