

# MOLLER Accelerator Jobs

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This document summarizes the accelerator jobs to be performed in preparation for the MOLLER experiment in Hall A (starting installation in March 2025 and physics run in March 2026). This document lists the MOLLER action items which rely on the operation of the CEBAF Accelerator.

MOLLER has other requirements that can be found here: [MOLLER Requirements Document](#).

Groups described in the jobs are listed here:

Abbreviation	Staff/People	Group
CIS	Accelerator	Center for Injectors and Sources
CASA	Accelerator	Center for Advanced Studies of Accelerators
Ops-Inj	Accelerator	Injector group
Ops-SW	Accelerator	Accelerator software Group
Ops-MCC	Accelerator	MCC Operations Group
I&C	Engineering	Instrumentation and Controls Group (EESICS)
SSG	Engineering	Safety Systems Group
Fast Electronics	Physics	Fast Electronics Group
Hall A	Physics	Hall A group
RCG	EH&S	Radiological Control Group
MOLLER	Users	MOLLER Collaboration

## 1. Helicity Generator boards (June 2024)

- Groups (CIS, MOLLER, Fast Electronics, Ops-SW)
- Deliverable – New helicity settings (Free Clock Mode at 1920 Hz, 10  $\mu$ s T\_Settle, 510.85  $\mu$ s T\_Stable, 64-window pattern, and 128-window delay). New updated firmware is needed. The firmware should be installed to CEBAF board and operate reliably, be accessible with EPICS control. 8 boards (out of 13 total) will be available for MOLLER for detector and data acquisition development.
- Tasks:
  1. CIS is responsible for coordination
  2. MOLLER should provide a requirements document
  3. Fast Electronics Group (Physics Division) should develop new firmware, install on board, and test for functionality and reliability
  4. Ops-SW should develop new EPICS controls
  5. MOLLER and CIS should test that the updated board generate the required settings

## 2. Helicity Decoder boards (August 2024)

- Groups (CIS, MOLLER, Fast Electronics)
- Deliverable – Newly designed board to prevent mis-identification of real helicity events in counting mode for the 2 kHz MOLLER helicity reversal. With shorter 10  $\mu$ s Pockels cell settling time ( $T_{Settle}$ ), the travel time from Pockels cell in the Injector Laser Room to four Halls becomes relevant. Travel times must be accounted for in this new board such that recorded events have correct helicity at physics interaction time (i.e., the time when the electron beam interacts with the experimental target). A total of 20 boards needs to be fabricated and installed in data acquisition systems of four Halls and for all helicity or polarimeter data acquisition systems (DAQ's).
- Tasks:
  1. CIS is responsible for coordination
  2. MOLLER should provide a requirements document
  3. Fast Electronics Group should design the board and develop new firmware and required CODA library
  4. MOLLER, CIS, and Fast Electronics Group should test for proper operation and distribute boards to users

### 3. New RTP High Voltage (HV) Driver (June 2024)

- Groups (CIS, MOLLER, I&C, Ops-SW)
- Deliverable – Jefferson Lab should design and fabricate a HV driver similar to the one used at CEBAF today built by university collaborators. The driver is designed to reverse the HV of the Rubidium Titanyl Phosphate (RTP) Pockels cell. Critical system requirements are complete electrical isolation, control of 8 HV channels for helicity control and position feedback and reliable reversal within the required 10  $\mu$ s T\_Settle time.
- Tasks:
  1. CIS is responsible for coordination
  2. MOLLER should provide a requirements document
  3. I&C should design and fabricate the HV driver, participate in the testing
  4. CIS should provide an RTP cell and laser setup for a test bench, participate in the testing
  5. Ops-SW should develop and deploy new EPICS controls for test bench and CEBAF injector
  6. MOLLER should provide parity DAQ/support to characterize the helicity reversal performance in the bench test
  7. MOLLER, CIS and I&C should perform laser and beam tests
  8. CIS should provide operational support

#### 4. Upgrade laser Intensity-Attenuator (IA) system (August 2024)

- Groups (CIS, MOLLER, I&C, Ops-SW)
- Deliverable – The existing voltage driver supports three Halls and the KD\*P IA cells may not have sufficient settling time (to be determined Apr-May 2023). The new driver will provide four channels (one for each Hall) and will need to support a new fourth IA system for Hall D. A new IA cell must also be installed in the Laser Room. Critical system requirements are complete electrical isolation, remote EPICS control of the IA settings (like exist today), and can reverse the voltage on the IA cell within the required  $10\ \mu\text{s}$   $T_{\text{Settle}}$  time.
- Tasks:
  1. CIS is responsible for coordination
  2. MOLLER should provide a requirements document
  3. I&C should design and build the HV driver
  4. CIS and I&C should document the laser grounding system
  5. CIS should provide laser setup for a test bench
  6. Ops should develop new EPICS controls
  7. MOLLER should provide parity DAQ/support to characterize the helicity reversal performance in the bench test
  8. MOLLER and CIS should perform laser and beam tests
  9. CIS should provide operational support

## 5. Upgrade Helicity Magnets control (December 2024)

- Groups (CIS, CASA, MOLLER, I&C)
- Deliverable – The current control system of four fast magnets for helicity correlated position/angle electron beam control is obsolete and has been disabled. A new modern control system utilizing existing magnets is required. The magnets will be used to apply helicity correlated position/angle feedback and perform position scans during MOLLER to measure the transfer function between the magnets and the hall. The system should control the current on the helicity magnets within 10  $\mu$ s T\_Settle time.
- Tasks:
  1. CIS is responsible for coordination
  2. CIS should model helicity magnet to find higher multipoles
  3. MOLLER should provide a requirements document
  4. I&C should design and build the new controller
  5. CIS should provide a helicity magnet for a test bench
  6. Ops-SW should develop new EPICS controls
  7. MOLLER should provide parity DAQ/support to characterize the helicity reversal performance in the bench test
  8. Ops-Inj and CASA should find the optimal location of the helicity magnets in the injector 5 MeV beamline
  9. MOLLER, CIS, Ops-Inj, and CASA should perform beam tests
  10. CIS should provide operational support

## 6. Feedback on polarization orientation (March 2025)

- Groups (CIS, Ops-Inj, MOLLER, CASA)
- Deliverable – MOLLER is highly sensitive to components of transverse polarization. The experiment will require regular correction for both vertical and horizontal transverse polarization. These polarization components will be measured continually in the experimental hall, with corrections for drifts envisioned to occur daily during regular running, or in a shorter time scale after any significant linac energy rebalancing. The changes are expected to be about 1-2° and applied to the nominal Injector Wiens angles.
- Tasks:
  1. CIS is responsible for coordination
  2. MOLLER should provide a requirements document
  3. CIS, Ops-Inj, and MOLLER should study parity-quality beam properties with small variations in Wiens angles
  4. Ops-Inj and CIS should provide the optimal protocol to apply the required changes
  5. MOLLER, Ops-Inj, and CIS should perform beam tests
  6. MOLLER and CASA should find out if the feedback can be done by the beam energy instead

## 7. Wien filters slow reversal – Wien Flip (December 2024)

- Groups (Ops-Inj, CIS, MOLLER)
- Deliverable – MOLLER will use the two Wien filters and Spin Solenoids to apply a spin rotation with a period of about 5-7 days. These are referred to as Flip-Right or Flip-Left settings. The preservation of beam properties under polarization reversal is key to the utility of this flip. The planned high frequency of the flip will require the ability to perform a rapid configuration change.
- Tasks:
  1. Ops-Inj is responsible for coordination
  2. Ops-Inj and CIS should study beam properties of different Wien Flips
  3. MOLLER should provide a parity DAQ/support to characterize the helicity reversal performance
  4. MOLLER, Ops-Inj, and CIS should find the optimal flip settings by studying beam properties



## 8. Injector transmission and parity-quality beam (December 2024)

- Groups (Ops-Inj, MOLLER)
- Deliverable – Significant clipping of the electron beam between the photocathode and the Hall can create excessive charge jitter or helicity correlated systematics on the beam. MOLLER requires very clean electron transmission from source to target with minimal beam interception. As a general rule, changes in mean value of the charge asymmetry should be kept to less than 20 ppm, and the width change less than 50 ppm, through the injector and into the hall (transmission of 95% can achieve this).
- Tasks:
  1. Ops-Inj is responsible for coordination
  2. Ops-Inj should optimize MOLLER beam in injector
  3. MOLLER should revive the injector parity data acquisition system and analysis tools, train CIS or CASA personnel on operation and interpretation, and support beam tests in injector
  4. Ops-Inj should check and re-optimize on regular basis during the experiment

## 9. Matching and adiabatic damping from 200 keV to Hall A (December 2024)

- Groups (CASA, CIS, Ops-Inj, MOLLER)
- Deliverable – Accelerator optics must be “well matched” during the MOLLER experiment. In particular, the helicity-correlated beam asymmetries are exacerbated if beam optics do not match design throughout the injector and Linacs. If the beam is not matched through the Beam-Switch Yard (BSY) and into the hall, then beam spot sizes and beta-function phases are not well described by the optics model, and the various constraints on the beam line optics are more difficult to meet. It is therefore expected that matching must be done from the injector through delivery into Hall A. Factor of 100 in suppression of transverse orbit amplitude is desired, a factor of 10 suppression is required. Damping should be checked with RTP cell and Helicity magnet scans.
- Tasks:
  1. CASA and Ops-Inj responsible for coordination
  2. CASA will consider and develop the possible matching strategies
  3. CASA should explain to MOLLER the concepts and expectations of matching and adiabatic damping and should agree on achievable goals
  4. CIS is responsible for providing beam size/emittance data about the source
  5. CASA should match beam from injector to Hall
  6. MOLLER should measure adiabatic damping and provide info to CASA
  7. CASA should monitor beam to Hall A and re-visit the match whenever needed

## 10. Fast Feedback (FFB) system resurrection (December 2024)

- Groups (CASA, Ops-SW, I&C)
- Deliverable – A fast feedback system for position and energy lock will be needed. The ability to pause the data collection and feedback on both the position and energy will be required during Beam Modulation periods. The fast feedback system should reduce and not increase the beam noise in the experimental hall at the helicity flip rate.
- Tasks:
  1. CASA is responsible for coordination
  2. CASA should test the existing system
  3. CASA, Ops-SW, and I&C should formulate a plan to maintain the FFB system

## 11. Compton Polarimeter setup (March 2025)

- Groups (CASA, Hall A)
- Deliverable – In order to meet the precision goals of the experiment, it will be necessary to have reliable data from the Compton polarimeter continuously during production. It is therefore necessary that the beam be suitable for the use of the Compton polarimeter. A commonly used criteria for operation of the Compton is a counting rate of 100 Hz/ $\mu$ A in the Compton photon and electron detector, with the Compton laser off. The halo restriction is such that the Compton detector is the only instrument available at CEBAF which is suitable for monitoring this parameter at this level. This specification matches the requirement for use of the Compton system for most of the operational lifetime of the system. Meeting this criterion additionally protects the Compton system from long term damage.
- Tasks:
  1. CASA and Hall A is responsible for coordination
  2. CASA should setup beam through the Compton polarimeter
  3. Hall A should have polarimeter ready/functional for testing
  4. CASA should develop plan to keep halo low during the experiment

## 12. Beam Modulation (March 2025)

- Groups (Hall A, CASA, Ops-SW, I&C, MOLLER)
- Deliverable – Air core steering coils in the Hall A beamline and the energy vernier (in South Linac – Cryomodule #20) will be used to modulate beam position, angle, and energy in order to measure sensitivity to those parameters. It will be necessary to “pause” position lock and energy lock during these modulation periods. This calibration cycles will be run every few minutes during data taking, with a total duty cycle between 5-15%.
- Tasks:
  1. Hall A is responsible for coordination
  2. CASA & MOLLER should verify operational at 11 GeV
  3. I&C should do hot checkout of the hardware and maintain it
  4. Ops-SW should do hot checkout of the EPICS control system
  5. MOLLER should do beam tests

### 13. Phase Advance (March 2025):

- Groups (CASA, MOLLER)
- Deliverable – The successful use of the beam modulation system requires a significant phase advance between the modulation magnets and between the monitors used to characterize the beam motion, so that independent motions spanning the beam phase space can be observed. The MOLLER Collaboration will work with CASA to design optics with sufficient phase advance between modulation magnets.
- Tasks:
  1. CASA is responsible for coordination
  2. MOLLER should work with CASA to design optics with sufficient phase advance between modulation magnets

#### 14. Study co-operation of MOLLER with K-long experiment in Hall D (June 2024)

- Groups (CIS, Ops-Inj, CASA, MOLLER, Hall A)
- Deliverable – Study the effect of low frequency beam (0.32 pC at 15.6 MHz, 64 ns, 5  $\mu$ A average beam current) to Hall D on MOLLER. Determine whether there are conflicts between K-long and MOLLER.
- Tasks:
  1. CIS and Ops-INJ are responsible for coordination
  2. CIS should install new Hall D laser amplifier
    - a. Ops-SW should develop new EPICS controls
  3. Ops-Inj should setup beam to inline dump
  4. CASA should model the sub-harmonic beam loading in the SRF cavities, what is the expected energy spread?
  5. Ops-Inj should model the response of the bunchers
  6. CASA should investigate response of beam instrumentations (e.g. Beam Position Monitors) to low frequency beam
  7. Ops-Inj should do beam test in Injector to study Injector optimization for parity-quality beam (transmission and Wien Flip) vs K-long
  8. CIS should do beam tests to study photocathode effects
  9. MOLLER, Ops-Inj, and CIS should characterize beam properties
  10. MOLLER and CASA should measure any effect on beam halo in Hall A Compton Polarimeter
  11. CIS should write a summary report to the Physics Division

## 15. Control of charge asymmetry on Halls B, C, and D beams (March 2025)

- Groups (MOLLER, CIS, Ops-SW)
- Deliverable – MOLLER will require feedback mechanisms to control the helicity-correlated charge asymmetry of the Hall B and Hall D lasers (measured before the slit) and the Hall C laser. This has typically been accomplished with IA cells on each laser beamline.
- Tasks:
  1. MOLLER is responsible for coordination
  2. CIS should provide laser Intensity-Attenuator (IA) system for each Hall
  3. Ops-SW should develop new EPICS controls
  4. MOLLER should provide a plan on how to implement the charge feedback
  5. MOLLER should coordinate with the Halls and agree on the plan
  6. MOLLER should perform the required feedback



## 16. Parity-Quality Beam (PQB) studies in Injector and Hall (March 2025)

- Groups (MOLLER, CIS, Ops-INJ, CASA)
- Deliverable – Measure PQB and confirm it meets the MOLLER requirements.

This includes the qualification of the upgraded injector. From mid-June, operations are expected in the upgraded injector.

- Tasks:
  1. MOLLER is responsible for coordination
  2. MOLLER should provide real-time analysis of beam properties to support injector re-tuning
  3. CIS should have polarized source ready for Moller
  4. Ops-Inj and CASA should setup beam to the required destination
  5. MOLLER should do beam tests (here is the list: [MOLLER PQB List](#))

## 17. Halo Monitors in Hall A (March 2025)

- Groups (Hall A, MOLLER, I&C, Ops-SW, SSG)
- Deliverable – Measure beam halo in Hall A.
- Tasks:
  1. Hall A is responsible for coordination
  2. MOLLER should provide a requirements document
  3. MOLLER should provide the halo target and detectors
  4. I&C should install the halo target
  5. SSG should provide Fast Shutdown (FSD) system
  10. Ops-SW should develop new EPICS controls
  11. MOLLER should provide halo EPICS readbacks to MCC
  6. MOLLER should measure beam halo

## **18. Robust beam mis-steer protection / fast shutdown detectors in MOLLER apparatus (March 2025)**

- Groups (Hall A, MOLLER, RadCon, Ops-MCC)
- Deliverable – MOLLER requires robust protection from beam mis-steering accidents. High luminosity experiments such as MOLLER sometimes have challenges achieving sufficient contrast between mis-steer events and high luminosity running. Protection must also be available during return from beam trips. Ion chambers positioning should be evaluated for contrast in mis-steer accidents. Alternative or secondary FSD protection systems (e.g. software-based orbit readback protection) may also be considered.

The complicated MOLLER apparatus may require additional planning for any required hardware, including ion chambers. This work should be coordinated with the MOLLER design and Hall A installation teams.

- Tasks:
  1. Hall A is responsible for coordination
  2. MOLLER will assist to evaluate and beam protection systems
  3. RadCon should specify and evaluate ion chamber locations for machine protection
  4. Ops-MCC should consider accident scenarios and propose protection strategies

**19. New BPM Digital Receivers in Hall A line – instead of Sample/Hold cards (March 2025)**

- Groups (Hall A, MOLLER, I&C, Ops-SW)
- Deliverable – Install new Digital BPM Receivers. Maintain two SEE BPM processors for critical BPM locations. All antenna BPM pickups replaced by stripline pickups.
- Tasks:
  1. Hall A is responsible for coordination
  2. I&C should verify that SEE processor electronics will work with stripline transducers
  3. MOLLER should evaluate the performance and usability of the new BPM electronics, including calibration procedures, for high precision asymmetry measurement and for low beam current counting measurements. Benchmarking against well-known existing hardware is expected.
  4. Ops-SW should develop new EPICS controls

## 20. New BCMs electronics in Hall A line (March 2025)

- Groups (Hall A, MOLLER, I&C, Ops-SW)
- Deliverable – Install new BCM digital receivers.
- Tasks:
  1. Hall A is responsible for coordination
  2. I&C should install Digital Receiver (which is the same one used for BPM's).
  3. MOLLER should evaluate the performance and usability of the new BCM electronics, including calibration procedures and resolution assessment, for high precision asymmetry measurements. Benchmarking against well-known existing hardware is expected.
  4. Ops-SW should develop new EPICS controls

## **21. Parity-Quality-Beam Liaison**

- Groups (CIS)
- Deliverable – Accelerator Division will assign a staff scientist to be the Parity-Quality-Beam Liaison.
- Tasks:
  1. CIS will provide contact for the jobs
  2. Overall coordination between MOLLER and Accelerator
  3. Attend and present at MOLLER collaboration meeting
  4. Represent Accelerator in MOLLER reviews
  5. Organize the Parity-Quality-Beam Meeting