Online Monitoring Software for MOLLER

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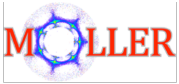
MOLLER Experimental Readiness Review
July 29–31, 2025



Charge

3. What monitoring systems are in place during the operation of the experiment to track critical parameters and ensure accurate measurements? Additionally, what is the current status of their construction and implementation?

Experiment Monitoring Overview

- Critical Parameters
  - Detector operational status (HV, LV, field, gas, etc.)
  - Detector raw signals
  - Helicity window completeness & sync
  - Beam properties (positions, charge, transverse polarization, etc.)
  - Data quality indicators (trends, correlations, backgrounds, etc.)
- Monitoring Systems
  - Hardware
    - Slow controls devices (sensors, etc.)
    - Beamline monitors (BPMs, BCMs, etc.)
    - Auxiliary detectors (SAMs, LAMs, DBMs)
  - Software
    - EPICS alarm system
    - Realtime analysis & visualization
    - Prompt analysis, data aggregation

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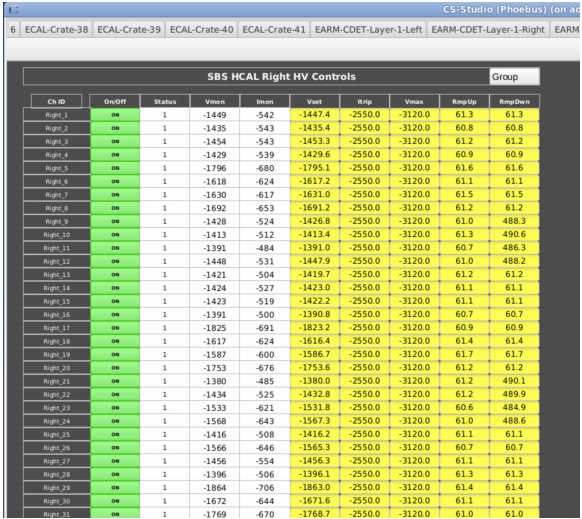
- Monitoring Systems
  - Hardware
    - ⋆ Slow controls devices (sensors, etc.) ($\rightarrow$ misc. other talks)
    - ⋆ Beamline monitors (BPMs, BCMs, etc.) ($\rightarrow$ yesterday's talks)
    - ⋆ Auxiliary detectors (SAMs, LAMs, DBMs) ($\rightarrow$ yesterday's talks)
  - **Software**
    - ⋆ EPICS alarm system
    - ⋆ Realtime analysis & visualization
    - ⋆ Prompt analysis, data aggregation ($\rightarrow$ next talk)

Slow Controls

- Probably will use MEDM/EPICS for most controls
- Phoebus software (CS Studio) for HV controls (well tested, used by SBS etc.)
- EPICS alarm handler for monitoring. Extensively used in previous experiments.
- To-do
  - Compile comprehensive channel list
  - Configure MEDM control screens. Configure stripcharts
  - Configure alarm handler channels & setpoints
  - Develop LV controls GUI & EPICS interface
  - Develop other displays, as needed (TBD)
- Slow Controls systems mostly well established. No significant difficulties expected.

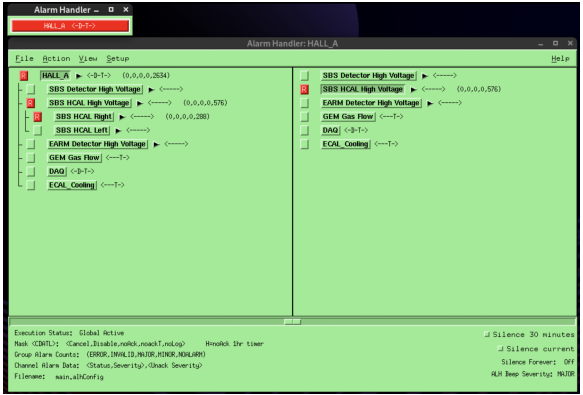
Slow Controls GUI Examples

HV Controls (connects to Alarm Handler →)



Ch ID	On/Off	Status	Vmon	Imon	Vset	Rrlp	Vmax	RmpUp	RmpDwn
Right_1	ON	1	-1449	-542	-1447.4	-2550.0	-3120.0	61.3	61.3
Right_2	ON	1	-1435	-543	-1435.4	-2550.0	-3120.0	60.8	60.8
Right_3	ON	1	-1454	-543	-1453.3	-2550.0	-3120.0	61.2	61.2
Right_4	ON	1	-1429	-539	-1429.6	-2550.0	-3120.0	60.9	60.9
Right_5	ON	1	-1796	-680	-1795.1	-2550.0	-3120.0	61.6	61.6
Right_6	ON	1	-1618	-624	-1617.2	-2550.0	-3120.0	61.1	61.1
Right_7	ON	1	-1630	-617	-1631.0	-2550.0	-3120.0	61.5	61.5
Right_8	ON	1	-1692	-653	-1691.2	-2550.0	-3120.0	61.2	61.2
Right_9	ON	1	-1428	-524	-1426.8	-2550.0	-3120.0	61.0	488.3
Right_10	ON	1	-1413	-512	-1413.4	-2550.0	-3120.0	61.3	490.6
Right_11	ON	1	-1391	-484	-1391.0	-2550.0	-3120.0	60.7	486.3
Right_12	ON	1	-1448	-531	-1447.9	-2550.0	-3120.0	61.0	488.2
Right_13	ON	1	-1421	-504	-1419.7	-2550.0	-3120.0	61.2	61.2
Right_14	ON	1	-1424	-527	-1423.0	-2550.0	-3120.0	61.1	61.1
Right_15	ON	1	-1423	-519	-1422.2	-2550.0	-3120.0	61.1	61.1
Right_16	ON	1	-1391	-500	-1390.8	-2550.0	-3120.0	60.7	60.7
Right_17	ON	1	-1825	-691	-1823.2	-2550.0	-3120.0	60.9	60.9
Right_18	ON	1	-1617	-624	-1616.4	-2550.0	-3120.0	61.4	61.4
Right_19	ON	1	-1587	-600	-1586.7	-2550.0	-3120.0	61.7	61.7
Right_20	ON	1	-1753	-676	-1753.6	-2550.0	-3120.0	61.2	61.2
Right_21	ON	1	-1380	-485	-1380.0	-2550.0	-3120.0	61.2	490.1
Right_22	ON	1	-1434	-525	-1432.8	-2550.0	-3120.0	61.2	489.9
Right_23	ON	1	-1533	-621	-1531.8	-2550.0	-3120.0	60.6	484.9
Right_24	ON	1	-1568	-643	-1567.3	-2550.0	-3120.0	61.0	488.6
Right_25	ON	1	-1416	-508	-1416.2	-2550.0	-3120.0	61.1	61.1
Right_26	ON	1	-1566	-646	-1565.3	-2550.0	-3120.0	60.7	60.7
Right_27	ON	1	-1456	-554	-1456.3	-2550.0	-3120.0	61.1	61.1
Right_28	ON	1	-1396	-506	-1396.1	-2550.0	-3120.0	61.3	61.3
Right_29	ON	1	-1864	-706	-1863.0	-2550.0	-3120.0	61.4	61.4
Right_30	ON	1	-1672	-644	-1671.6	-2550.0	-3120.0	61.1	61.1
Right_31	ON	1	-1769	-670	-1768.7	-2550.0	-3120.0	61.0	61.0

Alarm Handler (visual & audio alerts)



Realtime Analysis

- Connects to live data stream via network using the CODA ET system
- Analysis with JAPAN (integrating mode) and Hall A Analyzer/Podd (counting mode). Does not need 100% throughput. May skip blocks of events.
  - JAPAN keeps ring buffer of several minutes of data
  - Podd analyzes event-by-event over one "run" of arbitrary duration
- Live visualization of histograms in via Panguin graphical viewer (see later)
- Longer-term trends will require higher-level analysis ($\rightarrow$ next talk)
- Status
  - Both JAPAN and Podd have been upgraded to read CODA3 ET data
  - Shared-memory data transfer from JAPAN to Panguin (via ROOT `TMapFile`) was already implemented for past parity experiments. Needs re-testing.
  - Podd currently has no shared-memory output module. Needs to be written.
    Fallback: 50k event "prompt" analysis for counting mode, like SBS.
  - Panguin software essentially ready
- Main components in place. Some work required for full desired functionality.

Integrating Mode Software — JAPAN (**J**ust **A**nother **P**arity **AN**alyzer)

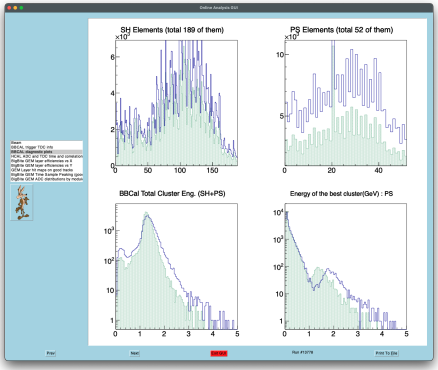
- Based on software/experience from earlier parity experiments (Qweak, PREX/CREX).
- Processes raw CODA (EVIO v5) files to calculate asymmetries (see next)
- Output to ROOT files, shared memory, and SQL database (latter TBD).
- Includes mock-data generator for benchmarking and analysis modeling
- Single-threaded C++ command-line app. Main dependencies: ROOT, boost, EVIO.
- GitHub repository: japan-MOLLER
- Maintenance underway (CODA 3 support, new detectors, test suite, docs, output, parallelization?). Partly completed. Detailed task list under development (GitHub issues).

JAPAN Analysis Flow (adapted from P. King's slides)

- Event level (single helicity window)
  - Decode raw data. Correct ADCs for pedestals and gains
  - Form multi-channel combined quantities (beam positions, etc.)
  - Apply cuts. Use recent event history ("event ring") for beam trip cuts, etc.
  - Calculate composite quantities (position-corrected single-event yields, etc.)
- Pattern level (normally 8 helicity windows)
  - Collect complete pattern. Calculate yields and asymmetries.
  - Determine composite quantities (position-corrected asymmetries, etc.)
- Fill ROOT histograms at event, pattern, and minirun (group of patterns) level
- Calculate average quantities and rms for a minirun
- At end of run (1 file), calculate file-level averages and rms $\rightarrow$ summary.

Visualization: Panguin (Online GUI)

- Data visualization tool for ROOT data (tree variables, histograms, custom macros).
- Works with both integrating and counting mode online analyses.
- Outputs: PDF files for upload to logbook; image files (JPEG, PNG) for AI-based analysis



Panguin 2.8 Command Line Options

```
$ panguin --version
Panguin version 2.8 (17-May-2024)
$ panguin --help
panguin: configurable ROOT data visualization tool
Usage: panguin [OPTIONS]

Options:
-h,--help                      Print this help message and exit
-f,--config-file <file name> [default.cfg] Job configuration file
-r,--run <run number>          Run number
-R,--root-file <file name>     ROOT file to process
-G,--goldenroot-file <file name> Reference ROOT file
-P,-b,--batch                  No GUI. Save plots to summary file(s)
-E,--plot-format <fmt>         Plot format (pdf, png, jpg ...)
-C,--config-path,--config-dir <path>
  Search path for configuration files & macros (":"-separated)
--root-dir <path>              ROOT files search path (":"-separated)
-O,--plots-dir <dir>           Output directory for summary plots
-I,--images                    Save individual plots as images (implies -P)
-F,--image-format <fmt>        Image file format (png, jpg ...)
-H,--images-dir <dir>          Output directory for individual images
-v,--verbosity <level>         Set verbosity level (>=0)
--inspect <file name>          List objects in given ROOT file
-V,--version                   Display program version information and exit
```

Milestones & Timeline (draft)

Task(s)	Approach	Approximate Completion
JAPAN → Panguin works	Arbitrary mock data	2025-09
ET → Podd works	Cosmics data	2025-12
Podd shared memory output	C++ development	2026-03
Podd → Panguin works	Simulated data	2026-03
Integrating analysis plot list	Mock data studies	2026-06
Slow controls signal list	Input from other WGs	2026-06
Counting analysis plot list	Input from other WGs	2026-09
Alarm system set up & tested	End-to-end system test	2026-09
Anomaly detection software (AI?)	Collab. w/data science?	2026-12

Organization, Personnel

- "Online Monitoring Software" working group was recently established (July 2025), along with other software working groups
- Convener: myself. Co-convener and other members TBD.
- Regular meetings and Wiki space to be organized
- Task management probably via GitHub issues

Summary

3. What monitoring systems are in place during the operation of the experiment to track critical parameters and ensure accurate measurements? Additionally, what is the current status of their construction and implementation?

- Critical parameters will be monitored by the slow controls alarm system and the real-time analysis setup in the counting house
- Alerts/visual diagnostics will be generated instantaneously or near real time
- Prompt analysis will provide additional important checks on the timescale of hours to about 1–2 days (see next talk)
- Hardware components (sensors) will be installed along with the MOLLER apparatus
- Most software components are well developed from previous experiments (parity and non-parity) and are therefore largely in place.
- Detailed configuration, testing, and fine-tuning will be done over the next few months.

Backup

PITA Feedback Analysis

- Real-time, 100% throughput required
- Connects to live data stream via network using the CODA ET system
- Custom software, written for and extensively tested during Qweak and PREX/CREX
- Calculates charge asymmetries and beam position differences, averaged over adjustable time scales (typ. 10 sec)
- Determines modified values for INJ control devices (RTP cell, helicity magnets, etc.) to correct helicity correlation of beam parameters to zero. Communication via EPICS.
- Status: Feedback system exists and is operational at this time