CDMS II Data Acquisition Functional Specifications

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Overall Specifications
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The data acquisition system must be capable of taking and logging physics triggers at 1 Hz (calibration at up to 10 Hz) with a live time greater than 80% for the full complement of CDMS II detectors (42 Ge/Si detectors and 44 muon veto scintillators).

The analysis chain must be able to keep up with the acquisition, while reducing the data volume by at least an order of magnitude. The analysis will initially be based on Matlab, with C code included as needed for speed.

The planned acquisition scheme would produce a data flow for physics (calibration) of 1 Hz (10 Hz) * 42 detectors * 6 chs./detector * 4096 Bytes/ch. = 1 (10.3) MB/s = 89 (892) GB/day. Hence the main event stream must be capable of data flow in excess of 10 MB/s from crates to tape. Asynchronous (monitoring) data should be included in the data stream as needed without compromising data flow.

Remote control and monitoring of the data acquisition system and the data must be possible unless locked out by local operations. Ideally, such remote operation and control will be achieved via standard web browsers.

The data acquisition system will be modular, consisting of separate pieces to: (1) digitize and readout detectors, (2) readout muon veto, (3) form the experiment global trigger, (4) build events, (5) control runs, (6) manage data, (7) monitor the experiment, (8) control electronics and trigger, (9) serve data and diagnostics, (10) log and handle status and error information, and (11) analyze data. See DAQ Layout.pdf for a diagram of this structure.

Software for the main event loop will be optimized C code. Other modules can be coded in various programming languages as long as each module adheres to communications standards and has a viable code management system (CVS for text-based code).

The data acquisition system can be under constant development but a working version must always be maintained and documented. Changes must be thoroughly tested before being integrated with the functioning system. Code backups must be kept so that it is always possible to restore the previous system.

Detector Digitizers
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Waveform digitizers capable of sampling at rates up to 10 MS/s at 12 bit accuracy constitute the primary readout for the Ge/Si detectors. The only economically viable candidate at present is the Joerger VTR812 VME 8-channel digitizer. We will need at least 32 VTR812's to readout 42 detectors (6 channels/detector) and we should have 4 spares for a total of 36 VTR812's (to match the CDMS II project funding profile, the digitizers will be purchased only 4 months before they will be needed). Signals will arrive at the digitizers via lemo cables from the RTF electronics.
Four VME crates will be used to house the digitizers. Each crate will have a digital input module (current candidate is VMIVME-1101) which will allow synchronization with the global trigger and selective download of digitizers if desired.

Each crate of digitizers will be read out via VME to a crate computer at speeds > 15 MB/s. The computer may be either "in-crate" or external, connected via an interface. This has already been demonstrated using Motorola MVME "in-crate" computers and an SBS BIT3 VME interface to a standard PC to readout the Joerger VTR812's.

Muon Veto
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There will be a maximum of 44 veto photomultiplier tubes in the initial CDMS II configuration. Each PMT will have a high voltage cable and a signal cable. HV cables will be fed by a CAEN SY2527 Power Supply. Signal cables will terminate at a patch panel in the data acquisition racks.

A pretrigger history of at least 1 ms and a posttrigger history of at least 100 us must be kept for all veto counters on each event.

Ideally, the veto history will be achieved by stretching the veto PMT pulses so that they can be sampled by existing COMET waveform digitizers. This analog history buffer preserves the maximum information on veto correlations with detector pulses. Alternatively, each veto counter may be discriminated (with commercial VME discriminators) and the resulting logic pulses stored in a digital history buffer (current candidate is SIS3400). The discriminators should have thresholds as low as 10 mV and these should be settable via VME.

Trigger
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The trigger conditioner consists of two separate boards in slots 10 (left) and 11 (right) in each of 3 RTF crates; a 4th RTF crate has only a slot 10 (left) conditioner, since it services only 1 tower of detectors. The function of the conditioner boards is to route any combination of detector trigger signals from the RTF P2 backplane to the history buffer and trigger logic.

The trigger logic board will be a single 9U module which will occupy several slots in the right-hand side of the 4th RTF crate. Inputs come from the trigger conditioners, veto, random pulser, and front-end trigger. Outputs include veto, random trigger, ISR trigger, global trigger and trigger enable signals to the history buffer, realtime and livetime clocks to the scalers, and trigger masks and the global trigger to digital I/O modules in each of the 4 VME digitizer crates. The board uses programmable logic to implement at least the following global triggers:

1. Global OR of selected detector triggers
2. Reject trigger if too many detector "HI" signals
3. Reject trigger if muon veto signal

The trigger mode must be selectable. Any trigger mode which would result in rejection of triggers must have logic for prescaling (i.e. allowing a settable fraction of such triggers through). Any particular detector trigger can be turned off if desired. All of these choices should have readback latches so one can easily determine the state of the trigger logic. The board can also form a detector readout mask based on the trigger bits. Detectors with nothing above threshold (possibly a lower "WISPER" threshold) can have readout suppressed but use of this mask must be programmable. The readout mask is output to digital I/O modules located in the digitizer crates and read by the digitizer computers. Note that use of selective readout and trigger rejection based on energy thresholds should allow an order
of magnitude reduction in data flow requirements during calibration.

A time history extending at least 1 ms before and 1 ms after each global trigger must be kept for all triggers. The current candidate for this history buffer is a commercial VME module (SIS3400) from Struck.

Event Builder
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The event builder will have Gigabit Ethernet connections to the VME crate computers. A separate Ethernet loop will connect the Event Builder with all other DAQ computers except the Data Server, to communicate data records, configuration, errors, and run control. A 3rd Ethernet loop will connect all of the computers except the crate computers and Event Builder to the outside world, allowing remote access and monitoring.

The event builder will have priority access to fast SCSI disk arrays for writing data. These disks must be readable from other computers without disrupting data flow. The most likely implementation of this is via Fiber Channel (rated at > 20 MB/s).

The event builder software will consist of optimized C code and drivers to maintain speed. It will build triggered events consisting of detector, trigger, and veto information. In addition, asynchronous monitoring and electronics records will be accepted and written to the data stream.

Events will be written in a standard, documented format which must be changed rarely and in a coordinated way with offline software. Events will be written in reasonably-sized files (~1000 events) which carry the standard date/time stamped file names used in CDMS I. The file size will be determined by balancing the overhead of changing files with the desire to sample the data in "near-real-time".

The event builder/crate computer loop must be robust enough to continue operation if any of the other modules disappear.

Run Control
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Run control must implement at least the following functions: (1) setup, (2) start run, (3) stop run, (4) pause, (5) resume, and (6) abort run. These commands will be passed in a standard, documented format to the event builder, electronics/trigger control, monitoring, data management, data server, and error/status handler computers. Only the error/status handler can call for an "abort run".

Run Control must have the ability to configure the setup for the run. This involves (a) scripts sent to Electronics Control to determine that state of the detector electronics and trigger, (b) setup for the acquisition electronics (mainly digitizers) which is passed to the crate computers, (c) configuration of monitoring processes which is passed to Monitoring, and (d) software configuration passed to the Event Builder.

Electronics Control and Monitoring must be interlocked against changes (from either local or remote sources) which would alter the character of a run while it is in progress. Similarly, the Event Builder and crate computers must acknowledge only Stop, Pause, Resume, and Abort during a run. We should implement a "switch" which bypasses these lockouts during testing.

Local run control must be possible from the experimental control room. Remote run control will be achieved from a web browser window. Remote operation can be disabled from the control room.

Data Management
The tasks of data management are: (1) archive event data to local tape, (2) maintain a database of data runs, (3) handle transfer of data over network to FNAL (if fast network becomes available), (4) coordinate the running of the first analysis pass (aka DarkPipe), (5) archiving the reduced quantities (RQs) from the analysis pass to tape, and (6) maintaining a data base for the RQs. It is likely, at least during the initial stages, that (1)-(3) will be handled by processes running on computers at Soudan, while (4)-(6) will be done by a separate set of processes running on computers at FNAL.

Event data will be compressed as it is written to tape, with a transfer rate exceeding 15 MB/s. The current candidate for tape drives is the Exabyte 8mm Mammoth 2 which is capable of hardware compression (2.5:1), yielding a transfer rate of 30 MB/s and 150 GB/tape. During physics (calibration) running, this would mean writing 0.6 (6) tapes/day. RQ data, which will be roughly an order of magnitude smaller than raw data, will also be archived to 8mm tape.

Event data tapes will be written and copied once at Soudan. The original will be stored locally and the copy sent to FNAL for further analysis as needed. RQ data tapes will also be copied once, with the copy returned to Soudan for archiving with the raw data tapes.

If possible, a package in use at FNAL should be used for data management, since this will be the main analysis and archive site. However, use of Perl scripts (already in use for DarkPipe analysis) may be a viable alternative, especially in the short term.

Monitoring
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The primary tasks for monitoring are: (1) control and monitoring of the dilution refrigerator and cryogenic systems and (2) monitoring other environmental aspects of the experiment (e.g. temperatures, detector rates, detector offsets, trigger thresholds, ...).

Monitoring processes run asynchronously with the data stream and will make no demands on data flow. Monitoring information will be packaged as records in a documented format which will be sent to the event builder for inclusion in the data stream when possible. Such records will carry a timestamp to allow correlations with event data. Run Control will determine when such information is to be passed.

Fridge monitoring and control will be accomplished using a commercial system. This will be interfaced via GPIB to the monitoring computer.

64-channel, 32-bit VME scalers (current candidate is Joerger VSC64) will be used to monitor veto and trigger rates; 6 of these modules will be required (4-trigger, 1-veto, 1-spare). A local display will always be available in the experiment control room and a remote display will be provided via a web browser.

64-channel 14-bit VME ADCs (current candidate is VMIVME 3128) will be used to monitor detector offsets and trigger thresholds. These may also be used to monitor environmental conditions. We will need 9 of these modules (3-offsets, 4-trigger, 1-environ., 1-spare). A local display will always be available in the experiment control room and a remote display will be provided via a web browser.

LabVIEW is currently the best candidate for monitoring software.

Electronics and Trigger Control
The main goals for this module are: (1) communicate settings with the detector front-end (9U), RTF, and trigger boards, (2) cycle the settings during a data run by some pre-arranged script, and (3) pass those settings as records to the event builder for inclusion in the event data stream.

The GPIB communication protocols for the detector and trigger boards can be found on the UCB, FNAL, and UCSB web sites associated with construction and testing of those boards.

Two separate systems already exist for electronics and trigger control; one is LabVIEW-based and the other is Perl-based. We need to choose which system to integrate with the Event Builder and Run Control.

Data Server
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The main goal of the data server is to prepare diagnostic plots from a fast analysis of the data in "near-real-time", defined roughly as a few hours old. In practice, this means analysing data from files that the event builder has already finished. The plots will be served to the outside world via web browsers.

An additional goal for the data server would be to serve a raw data file to a remote site for analysis. Network bandwidth may be the limiting factor in whether this can be achieved.

The data server must not affect the acquisition of data.

Error/Status Logger/Handler
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All of the DAQ computers must report their status and any error conditions periodically to the error/status logger/handler. The initial goal of this software is first to log the information in a file which is served to the Internet (via web browsers). An extended goal is to have algorithms and/or tables which make decisions based on the status and error information (e.g. tell Run Control to Abort because the Event Builder has lost communications with a crate).

Packages have been developed for other experiments to perform the logging functions (see for example the package used by VIRGO at http://www.lal.in2p3.fr/recherche/virgo/developments.html). We need to survey whether such packages are a good match for CDMS.

Offline Analysis
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Offline analysis will be based on Matlab and C code already written for CDMS I and will run on Linux computers.

A first pass analysis similar to the present DarkPipe will produce reduced quantities (RQs) which serve as the basis for later analysis. The reduction in data at this stage should be at least one order of magnitude, mainly from fitting the detector pulses. The primary site for this pass will be FNAL.

A uniform analysis framework (similar to the present CAP) will provide tools for analysis of RQs.

Both production and development versions of the analysis software will be maintained at FNAL for all to download.

RQs will be available to the entire collaboration, either via tape
Documentation
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Each module of the data acquisition will have documentation consisting of at least: (1) a user's guide, and (2) a functional description. Links must be provided to the source code. In addition, the current data format and interprocess communications formats will be maintained in human-readable form.

All documentation will reside on a web site available to the CDMS collaboration. The documentation format will be either HTML or PDF.