# RCDAQ, a lightweight yet powerful data acquisition system

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## Contents

# 1 Changelog

## 1.1 March 13, 2018

- I added a new built-in pseudo device `device_rtclock`. It allows you ti measure the event timing, and the distance in time to the most recent event. See chaper **??**

## 1.2 February 22, 2017

- I added the concept of a named RCDAQ instance. We found that we are often running multiple RCDAQ systems (such as the main DAQ and the wirechamber readout at Fermilab). This has sometimes led to confusion which instance you are interacting with. The name defaults to the hostname, and can be set with `rcdaq_client daq_setname`, and retrieved with `rcdaq_client daq_getname`. The aliases have also been updated to make the command shortcuts, and the GUIs show the name now, too.
- The `daq_status` used to show "logging enabled", and nothing if disabled. So the absence of the "enabled" message indicated that we are not logging. That has led to a number of operator errors. `daq_status` now shows "enabled" or "disabled".
- I have added the start of the web service on the standard port 8899 in the template setup script "`setup.sh`". If this port is taken on your system, you need to change it.

## 1.3 August 30, 2016

- Added documentation about the newly implemented web-based controls.

## 1.4 February 28, 2016

- expanded the chapter **??** with many more details and step-by-step instructions
- added a chapter about the PSI DRS4 evaluation board

## 1.5 August 27, 2015

- added two new devices device_file_delete and device_filenumbers_delete, which delete the file after it has been read. See page **??** for a description and application.

## 1.6 August 15, 2015

- the rcdaq_server process now defines a number of environmental variables, principally for the benefit of device_command. The resulting process, usually a script, can use the variables to obtain important information it might need. See page **??**.

# 2 Introduction

## 2.1 What This is About

RCDAQ is a data acquisition package which is used in the R&D efforts of the PHENIX and sPHENIX experiments at the Relativistic Heavy Ion Collider. The experiment has its main data acquisition which fills a room about size of a squash court. For a variety of R&D efforts, it was necessary to get a smaller, portable, and lightweight data acquisition system which would support test beams, electronics developments, cosmic ray tests, and the like.

Meanwhile, the system is in use for a number of other projects, such as a number of PET scanners for medical imaging applications, the readout of a GEM detector, and for tests and the characterization of Silicon Photomultipliers.

The development of RCDAQ was governed by a number of design principles:

**format-compatible with the main PHENIX data acquisition system.** In this way, the readout of a new device needs to get implemented and debugged only once, and is ready to go once the new component is integrated in the main DAQ system. This also allows to reuse most tools, such as online monitoring components, during the running of the main experiment.

**compatible with the PHENIX online monitoring and analysis framework.** This allows to reuse the code developed during the R&D phase and test beams once the new detector or component is installed in PHENIX. The online monitoring of several new detectors has its roots in the online monitoring used and refined in a test beam.

**lightweight and able to run on most modern Linux distributions.** You do not have to devote your system to the task of running the DAQ. (As a rule of thumb, if your system has a working version of the root package, you will be able to install RCDAQ and the assorted components). RCDAQ is also able to build and run on a Raspberry Pi.

**powerful and fast.** The most demanding device supported by RCDAQ produces sustained data rates of 400 MB/s.

**client-server based.** This will allow you to work in a network-transparent way, for example, control the main DAQ running on a powerful server natively from your desktop or laptop.

**based on a plugin concept.** In order to make the package adaptable to a large number of tasks, most of the actual readout capabilities and support for the readout of particular devices is added through plugins. In this way, we are able to make the core package available outside the PHENIX collaboration because no proprietary or commercial libraries or drivers (which are needed for some PHENIX hardware) need to be distributed.

**extensive support for automated, scripted acquisitions.**

**no configuration *files*.** By definition, configuration files require you to learn their syntax. In most cases, configuration file formats, say, XML, do not support loops, conditions, formal parameters, or error handling, which is why most systems have moved away from the much-hyped XML format. We already have the best parser for configuration input – the Unix shell. It fulfills all of the above requirements (loops, conditions, parameters, and error handling). Each interaction with RCDAQ is a Unix shell command. In this way, there are no configuration files, but configuration *scripts* which you execute to configure your system.

**Elog Support.** RCDAQ natively supports the *elog* electronic logbook, developed and maintained by Stefan Ritt at the Paul-Scherrer Institute in Switzerland. RCDAQ can be configured to make automated elog entries to help you keep track of the data you acquire. You can add to the automatically generated entries, for example, detailing that the High Voltage tripped during the acquisition, or attach plots or other image files. It gives you an easily accessible timeline of your data taking efforts.

In the following discussions, you will see the term *"Run"* a lot. A Run is a collection of events, say, a certain time interval worth of data, or data taken with a given settings of some parameters. It is identified by a Run Number that should always increase during the course of your acquisition. The combination of run number and event number in that run uniquely identifies an Event that was read out.

## 2.2 What? No configuration files?

In my opinion, the above-mentioned fact that there are no configuration files, only scripts, is one of the most versatile features of this DAQ system. *Each* instruction is a separate command executed on the shell. Besides the facts that you do not need to learn a new command interpreter, have loops, conditions, etc, at your fingertips, the most important feature is that you are not trapped within the always limited command set of an application. You can freely interleave RCDAQ commands with other shell commands, and so write a scripted data acquisition protocol tailored to your needs.

To the best of my knowledge, a group from the Physics Department at Stony Brook has so far designed the most versatile application of this concept. The task at hand was to certify a readout plane of a GEM detector. It involved connecting a probe to a specific pad on the plane, taking some data, and verify that the correct channel did see the signal, then moving on to the next pad. It was hard to take either the probe or your eyes off the board without losing the position.

The group came up with a script that would loop through the pads, *reading* the pad coordinates and other commands to the operator by way of a text-to-speech program (festival), so the operator was free to keep the eyes (and the probe) on the plane at all times. This is possible because you never leave the shell to interact with RCDAQ.

## 3 Data Format Basics

The PHENIX raw data format defines a number of data structures, most importantly the concept of *Events* and *Packets*.

Think of a Packet as the data from a given readout device, such as an ADC board, a digitizer, or something similar. Typically, modern readout devices provide their data in some form of compact data structure, which needs to be unpacked later. All that RCDAQ does is to store the data unmodified with what we call *envelope information*. That envelope information, here the Packet header, holds a packet id which uniquely identifies *what* is being read out.

That id is a number chosen by you more or less arbitrarily, as long you keep that assignment the same. For example, a typical event in PHENIX consists of data from about 600 different readout devices (which we call FEM, Front-End Module), and the same number of packets in one event. We chose to assign the ids by "subsystem number". The PHENIX Pad Chamber, Subsystem number 4, gets Packet IDs 4001, 4002, and so on. A given Packet id is meant to identify a particular set of channels on the detector (those connected to the FEM), and it is your responsibility to make sure that a given id assignment remains the same. It is not uncommon in PHENIX to refer to a given Front-End Module by its never-changing Packet id ("Last night we had trouble with Pad Chamber Packets 4036 and 4037, and had to adjust the supply voltage slightly").

The Packet id, however, does not specify how the data are stored within the Packet. That is done by another field, historically called the *hitformat*, which indicates what kind of data is kept in that Packet. This is the field that in the end identifies a decoding algorithm for the data, and which assures that your analysis code is shielded from changes in the low-level data format of a given FEM or other readout device.

Over the course of the operation of the PHENIX detector, the low-level data formats of the FEMs of a given subsystem have changed several times, usually to make the data more compact by improving the bit-packing of data, or by removing redundancy in the data which was initially needed to test and certify the data integrity. Packets with data in such a different format are simply tagged with a different hitformat number, which in turn selects a different decoding algorithm. Your analysis code is never exposed to those internals. In this way we are free to change the FEM data formats without ever breaking existing analysis code.

An *Event* structure is simply a collection/concatenation of such packets, with the next layer of envelope information, this time the Event header. This header holds an Event number, event type, a timestamp, length, and similar bookkeeping information.

Events and Packets are the only objects you will likely encounter in the course of analyzing data taken with RCDAQ. The raw data files group a number of Events in what we call a *Buffer*, although this is just a storage-technology concept and mostly invisible to you. I say "mostly" because the design is such that, although your code is shielded from internals such as buffers and hitformat differences, the interface libraries still make it easy to access this kind of information for debugging purposes.

The raw data files are lightweight, and have a number of convenient features, most notably the fact that one can concatenate two valid raw data files and obtain again a valid file.

All interfaces to the raw data are provided in what we call the *Event Library*, which loads in root and teaches root how to deal with our data format. Although it is rare to write an actual main program, the library also exists without root bindings.

There is a ton of documentation on the PHENIX web pages about the software, to be found at `http://www.phenix.bnl.gov/~phoncs/oncs/code_documentation/Event/index.html`.

You should definitely familiarize yourself with the concepts and read the "Events and Packets" chapter `http://www.phenix.bnl.gov/~phoncs/oncs/code_documentation/Event/Eventsandpackets.html`, and also learn about the indispensable data inspection tools such as `dlist` and `ddump` in `http://www.phenix.bnl.gov/~phoncs/oncs/code_documentation/Event/dlistddumpanddpipe.html`.

## 4 RCDAQ Principles of Operation

The rcdaq main process is formally a server running in the background. It writes a very modest amount of output to a log file, but does not accept any kind of input directly.

All control is performed by clients connecting to the RCDAQ process and instructing it to perform a particular task, such as loading a plugin, start or stop taking data, setting parameters, and the like. The underlying protocol is a *Remote Procedure Call* (RPC), a network protocol for client-server interaction. It is widely used and stable because the extremely common Network File system (NFS) is based on the RPC protocol, and is available on virtually any operating system.

At the core of the readout is the *readlist.* This is a list of devices registered with RCDAQ to be read out. When an external trigger arrives (more about this is a minute), RCDAQ goes through the readlist, and each defined readout device adds a Packet to the Event structure under construction.

The RPC protocol makes the interaction with RCDAQ network-transparent. Your client doesn't need to run on the same machine (of course it can); in fact, it can be anywhere as long as the RPC protocol is able to traverse the routers and firewalls.

## 5 Running RCDAQ

Let's take RCDAQ for a quick spin. RCDAQ knows a built-in "pseudo device" which pretends to be reading out some kind of ADC or TDC, except that it fills in some random numbers. I made this "device" in order to allow to test-drive RCDAQ without the need for any actual acquisition hardware.

☞ I provide a guaranteed-to-work setup script "`setup.sh`" with the RCDAQ source code. It exercises a number of features that will be presented in the next chapters. It uses the pseudo devices we will see in a minute. This script allows you to test the proper working of a RCDAQ installation.

For now, get yourself two terminal windows on the machine that has RCDAQ installed. We will run the RCDAQ server and clients interactively. Later, you will likely run the actual server in the background that writes to a logfile.
In terminal 1 (after the one sole command we will leave this alone), type

```
rcdaq_server
```

Just to see that we communicate to the just-started server, we type, in terminal 2,

```
rcdaq_client daq_status
```

and you should see the answer "Stopped". In a moment, we will see how to make those unwieldy "rcdaq_client ...." commands more convenient, but for now, we will continue with this style for a few more commands.

The "-l" switch we will see in the next command stands for "long". Multiple "-l" switches will accumulate, although at this stage there is no more information to be had. Later we will look at a "double-ell" – "-ll" – switch output.

```
$ daq_status -l
Stopped
Logging disabled
Filerule:     rcdaq-%08d-%04d.evt
Buffer Sizes:     32832 KB adaptive buffering: 15 s
Web control Port:  8899
Elog: not defined
 -- defined Run Types:  (none)
No Plugins loaded
```

The last line says that we have not acquainted RCDAQ with any particular hardware – as I said in the introduction, except for a very small number of natively built-in "devices", all support for actual readout hardware is loaded by the assorted plugin.

The "Buffer Sizes" and their setting are of interest and can be tweaked in a number of situations; we will ignore this for now.

The Filerule will govern the generation of data file names later. It is used as a "printf"-style format statement, where the printf takes two integer parameters. The "%08d" and "%04d" formats make an 8- and 4-digit number field padded with leading zeroes:

```
$ printf rcdaq-%08d-%04d.evt 1333 0
rcdaq-00001333-0000.evt
```

The first number is the current run number, and the second is a "file sequence number" which is in use in the main PHENIX DAQ but currently unused and 0 in

RCDAQ. I may implement it later; it is used to make data of a given run roll over into a new file if that file is getting too large for convenient handling.

The file rule can be changed at any time. The next data file will be named according to the current rule.

Note that the rule above with the zero-padded fields will prevent spaces in file names, but the rule can really be set to anything. You must check that your rule generates valid and useful file names. You would normally choose a full path, such as

```
/data/rcdaq/beamdata-%08d-%04d.evt
```

Finally we create a new readout device that fills our pretend-ADC data with random numbers:

```
rcdaq_client create_device device_random 1 1001 32 0 2048 1
```

The command "create_device" takes the device type (device_random), the event type in which it is read out (1), the packet id (1001), how many "channels" we want our device to have (32), the lower and upper bounds of the random number distribution (0 - 2048). In general, the parameters past the packet id are highly device-specific and will configure the device as in this example. The final "1" means that we designate this device as the one which actually generates the trigger for the DAQ. We might have multiple devices which are trigger-capable, so we need to specify this. If you do not specify any trigger device, you will not get any events.

As a convention (which you can ignore, of course), most RCDAQ users use packet ids above 1000 in devices read in data events, and in the 800 or 900 block for other event types (which we haven't mentioned yet). It's just a convention.

We can look at the defined readlist with

```
$ rcdaq_client daq_list_readlist
Random Device  Event Type: 1 Subevent id: 1001 n_words: 32 range: 0 - 2048 ** Trigger enabled
$
```

which gives a brief description of the device and the parameters.

Now we start a run with number 1 (but keep in mind that we have not specified that we want to write any data to disk yet):

```
$ rcdaq_client daq_begin 1
Run 1 started
```

After a moment, we look at the status:

```
$ rcdaq_client daq_status
Run 1 Event: 1054 Volume: 0.176605
```

It now indicates that we have a run 1, and we are currently at event 1054. The volume is given in megabytes.

After a while we end the run:

```
$ rcdaq_client daq_end
Run 1 ended
```

When we start the next run without a number, the next number will be used:

```
$ rcdaq_client daq_begin
Run 2 started
$ rcdaq_client daq_end
Run 2 ended
```

Now we specify that we want to actually write data to disk, start a run (number 3), and look at the "long" status:

```
$ rcdaq_client daq_open
$ rcdaq_client daq_begin
Run 3 started
$ daq_status -l
Running
Run Number:   3
Event:        2
Run Volume:   3.05176e-05 MB
Filename:     rcdaq-00000003-0000.evt
Duration:     34 s
Filerule:     rcdaq-%08d-%04d.evt
Buffer Sizes:     32832 KB adaptive buffering: 15 s
Web control Port:  8899
Elog: not defined
 -- defined Run Types:  (none)
No Plugins loaded
```

We see that in addition to the file rule, we now also see the actual open file name that was derived from the rule.

After you end the run, you will find (in this case with the default file rule) that file in the directory where you started the rcdaq_server.

Let's take a quick peek at the data file. Without going into all the details, let's run "dlist", which lists the packets found in a data event:

```
$ dlist -i rcdaq-00000003-0000.evt
 -- Event     2 Run:     3 length:    44 type:  1 (Data Event)  1363583279
Packet  1001    36 -1 (ONCS Packet)  6 (ID4EVT)
$
```

ddump will inspect a packet and print out its content in an interpreted fashion. ddump is a versatile utility which allows to inspect the data in a myriad of ways. Here is one:

```
$ ddump -i rcdaq-00000003-0000.evt
 -- Event     2 Run:     3 length:    44 type:  1 (Data Event)  1363583279
Packet  1001    36 -1 (ONCS Packet)  6 (ID4EVT)

    0 |       5dd      512      403      152
    4 |       160      51d      380      399
    8 |       6d8       12      557      19d
    c |       672      4f4      525       48
   10 |       759      33a      759      51a
   14 |       6aa      7fd      270       c8
   18 |       4bd      4df      22a      6cf
   1c |       1cb      7ff      3fa      653
$
```

This says it is event number 2. We can look at event 3 with the "-e 3" switch:

```
$ ddump  -i -e 3 rcdaq-00000003-0000.evt
 -- Event     3 Run:     3 length:    44 type:  1 (Data Event)  1363583279
Packet  1001    36 -1 (ONCS Packet)  6 (ID4EVT)

    0 |        b0      529       22      306
    4 |       77e      4e1      3a0       bd
    8 |       1c0      7ce      717      6a0
    c |       1dd      343      4db      3e0
   10 |       5e5      4e9      761      179
   14 |       324      50f      705      3a6
   18 |        f7       17       c8      178
   1c |       127       16      409      11a
$
```

This is just to show that the next event has different (random) numbers.

## 6 Making the commands more convenient

We have so far used the "long" versions of each rcdaq command, such as

```
$ rcdaq_client daq_begin 1
```

That is a lot of typing, and so we provide a script which you can source and which sets up each command as a short-hand alias, for example, `daq_begin` will be an alias for `rcdaq_client daq_begin`.

There are two versions of the script, one for the bash shell (aliases.sh), and one for csh and its derivatives. You simple execute (note the back-ticks)

```
$ source `which aliases.sh`
```

or

```
> source `which aliases.csh`
```

depending on your preferred shell.

In scripts you should *always* use the long form of the commands.

Here are the aliases that you get:

```
alias daq_begin='rcdaq_client  daq_begin'
alias daq_end='rcdaq_client  daq_end'
alias daq_setrunnumberfile='rcdaq_client  daq_setrunnumberfile'
alias daq_define_runtype='rcdaq_client  daq_define_runtype'
alias daq_set_runtype='rcdaq_client  daq_set_runtype'
alias daq_get_runtype='rcdaq_client  daq_get_runtype'
alias daq_list_runtypes='rcdaq_client  daq_list_runtypes'
alias daq_setfilerule='rcdaq_client  daq_setfilerule'
alias daq_open='rcdaq_client  daq_open'
alias daq_close='rcdaq_client  daq_close'
alias daq_fake_trigger='rcdaq_client  daq_fake_trigger'
alias daq_list_readlist='rcdaq_client  daq_list_readlist'
alias daq_clear_readlist='rcdaq_client  daq_clear_readlist'
alias daq_status='rcdaq_client  daq_status'
alias daq_set_maxevents='rcdaq_client  daq_set_maxevents'
alias daq_set_maxvolume='rcdaq_client  daq_set_maxvolume'
alias daq_set_maxbuffersize='rcdaq_client  daq_set_maxbuffersize'
alias daq_setname='rcdaq_client  daq_setname'
alias daq_set_adaptivebuffering='rcdaq_client  daq_set_adaptivebuffering'
alias daq_shutdown='rcdaq_client  daq_shutdown'
alias daq_webcontrol='rcdaq_client daq_webcontrol'
```

If you routinely use a specific account for rcdaq work, you should add the respective source command to the login files.

## 7 Event types and what they are good for

A program able to read the data from your detector and writing the data to a file does not yet qualify as a data acquisition - what is needed are features that allow you to automate acquisitions, and add arbitrary "outside" data to your data stream. It also needs to support your online monitoring needs.

Let's say that you want to perform a gain scan by varying some HV setting for your detector in a number of steps. In the old days, you would probably have made a table in a paper logbook:

| Run Number | HV | Gain |
|---|---|---|
| 2001 | 1710 | |
| 2002 | 1720 | |
| 2003 | 1730 | |
| 2004 | 1740 | |
| 2005 | 1750 | |
| ... | ... | |

In the analysis phase, you would need to communicate these values to your analysis process somehow, probably ending up with a text file which tabulates HV and gain values with some error information which you use to finally produce the desired plot.

This looks like a lot of tedious, manual, and error-prone labor – it is easy to make a mistake transcribing the HV values to the table, or "slip" an entry and get the alignment of the columns wrong. It is also largely not automated. In my experience, you will re-do the analysis of such data sets many times over, and automation of the procedure will help save a lot of time.

One of the most powerful features of RCDAQ, which is at the core of those acquisitions and later analysis of the data "on autopilot", are different *Event Types*. You would typically think of a data acquisition as something that "reads out your detector" – the ADCs and TDCs and whatever it is you want to read out. In addition, however, there is often the need to read other devices at different times.

Here is a real-world example from a previous DAQ of mine at the CERN-SPS, which has also been used at BNL's AGS. Both accelerators feature an extraction cycle – the ring gets filled, the beam accelerated, and then the beam is extracted and delivered to your beamline. The SPS cycle is about 14s, 10s of acceleration followed by about 4s of extracted beam. The accelerator furnishes you with two signals, one that indicates that the extraction is imminent ("Spill on"), the other saying that the extraction has ended ("Spill off"). During the extraction, you obviously want to "read your detector", but most likely you will also need to know what the intensity of each extraction (spill) was, in order to make intensity-dependent corrections later, or study the effects on the detector's gain by the delivered beam intensity. In order to do that, you will need to read out some scalers which count the signals from your beam counter, and likely other signals as well.

At CERN and at the AGS, I used the accelerator signals to trigger special "spill on" and "spill off" events.[1] They get assigned different event types, and when those events are generated, they traverse different readlists. You would typically set the different readlists up in a way that the spill-on event doesn't actually read anything, but simply resets the scalers. The readlist of the spill-off event has then the actual readout of the scaler. This setup allows you to know the intensity of each spill. Remember – different event types mean different readlists.

In addition, two more special events are automatically generated in each run. One is the *Begin-Run Event*, the other the *End-Run Event*. You cannot prevent the generation of those events, and all the promised benefits come with these two event types.

Let me convince you that the begin- and end-run events are actually present in the data file we just took. dlist and dpipe, by default, only look at data events, and we have to explicitly ask to see special events:

```
$ dlist  -i -t S rcdaq-00000003-0000.evt
 -- Event     1 Run:     3 length:     8 type:  9 (Begin Run Event)  1363583279
$ dlist -i -t 12 rcdaq-00000003-0000.evt
 -- Event 23125 Run:     3 length:     8 type: 12 (End Run Event)  1363583519
$
```

Since we have not specified any devices to be read in the begin- or end-run event, no packets are listed. Those events are present but empty.

Before I explain why those special events are so tremendously useful, let me first list the defined event types. You should *not* invent new event types, since those are not known and understood by the analysis software (never mind that RCDAQ cannot generate them anyway, unless you modify the code).

[1]At this point in time, spill-on or -off special events can only be generated if you use a CAEN V1718 VME-USB bridge.

| Event type | meaning | comment |
|---|---|---|
| 1 | Data Event | Readout of your detector hardware |
| 2 . . . 7 | Data Events | Not normally used by RCDAQ |
| 8 | Spill-On Event | |
| 9 | Begin-Run Event | Automatically generated by RCDAQ |
| 12 | End-Run Event | Automatically generated by RCDAQ |
| 14 | Scaler Event | Not normally used by RCDAQ |
| 16 | Spill-Off Event | |

You may notice that the events which can be triggered by a hardware signal ( Data, spill-on, spill-off) have numbers which are powers of 2. The historic reason for this is that you typically use some kind of input register to distinguish the source of a hardware trigger, and the binary value of such a register then reads 1,2,4,8,... for the different inputs.

At long last, here's why those special events (the ones actually generated by RCDAQ) are so useful.

- it is guaranteed that the begin-run event is the first event of a given run in the data stream. Similarly, the end-run event will be the last event in the run. If you have a continuous data stream that keeps on delivering events, such as the stream that feeds your online monitoring processes, those events can serve as convenient markers that a run has started or ended. On receipt of the begin-run event, you would typically clear your monitoring histograms and start histogramming the data from the new run. When you recognize the end-run event, you might choose to save the histograms for later review.
- you can add information such as the aforementioned HV setting to the begin-run event (this is not actually specific to special events, but it will probably only make sense here). I will show you in the next chapter how to accomplish this. In the begin-run event you will then find some packets that contain the data which you are interested in.

Lets now see how you would go about adding some arbitrary information to your data stream.

## 7.1 Pseudo Devices

"Pseudo Devices" are those which do not connect to any actual readout hardware, or just perform some action without reading any data. The "device_random" we have used before is in this group.

The most prominent pseudo devices are

**device_file** this device absorbs the contents of another (small[2]) file as its readout.

[2]Without going into all the details: if your file is expected to be larger than 128KB, you need to say how big it is. RCDAQ needs to calculate the worst-case maximum event size per event type, although virtually all events will be smaller due to zero-suppression. RCDAQ knows the maximum sizes of each device except this one.

In this way, you can add the contents of any other file to your data stream. You can use this to add a description, or add automatically generated files, or even an image to the data stream. If the file does not exist, no packet is generated. You can see on page **??** how we use this feature to self-document the RCDAQ setup itself. It is not uncommon to have a large number of such file devices in the begin-run event – at a recent test beam we had about 60 of them to capture all relevant detector settings for each run.

**device_file_delete** like device_file, except that this device also deletes the file after it has been read. **Use this device with caution.** This device was added to allow you to *occasionally* add some information to the data stream. Let's say that you want some "slow" readout added, for eample, a temperature reading. Since no packet is generated if the file does not exist, you can define a device_file_delete to the readout of data events, and most events will not have the packet. But every few minutes, an external process, such as a cron job, could generate the file with the temperature information. It will be added as a packet in the next event and subsequently deleted, so it would be added to one event only. In this way you could track the temperature over time.

**device_filenumbers** this device reads a text file and looks for (integer) numbers on a line all by themselves. While the device_file adds the original text, device_filenumbers discards the text and adds those numbers in binary form. This makes them much easier accessible in the later analysis.

**device_filenumbers_delete** like device_filenumbers, except that this device also deletes the file after it has been read. See the explanation of device_file_delete above.

**device_command** this device does not add any data but executes an arbitrary command. This way, you can trigger actions at certain times. **You must not call rcdaq_client commands from the command, as this leads to a deadlock.** As a convenience, rcdaq defines a number of environmental variables to the process executing the command, which make it easier for a script to obtain dynamic information. The variables defined are

**DAQ_RUNNUMBER** The current runnumber

**DAQ_FILERULE** The current file rule that generates the file names

**DAQ_STARTTIME** The starttime of the run as a Unix timestamp value

**DAQ_FILENAME** The current file name. If logging is not enabled, this variable will be empty. In this way you can find out if we are logging.

**DAQ_ELOGHOST, DAQ_ELOGPORT, DAQ_ELOGLOGBOOK** the coordinates of the elog server. This allows you to add or edit elog entries from a script. If no Elog is defined, the variables are empty.

**device_random** we have already seen the random number-generating device in the example above.

**device_deadtime** this device can add a configurable amount of artificial deadtime anywhere in the traversal of the readlist. I could envision a few applications in actual data taking, but mostly this is a debugging tool that can be used to slow down the data rate, but also to make the event loop run as fast as possible (enable this device to trigger but set zero deadtime) for benchmarks or debugging. It can optionally pretend to generate adjustable amounts of data. Different from daq_device_random, it wastes no time to fill in any meaningful values. If you then enable writing, one can benchmark the "empty" DAQ speed. See chapter **??** for details.

**device_rtclock** this device records the current high-resolution system clock value, as well as the same value from the most-recent event where this "device" was read. See chapter **??** for an example how to use this.

Be sure to read to the end of the chapter where, after the following explanations, I point out a nice self-documentation feature.

Now let's go and get the HV setting of our detector added to the data stream. We typically have some kind of command interface to the HV system. I use the PHENIX hvclient here in the example, but let me stress that any such utility which can print some output to the screen will fit the bill.

We add two devices to the begin-run event:

```
$ rcdaq_client create_device device_file 9 910 hv_readback.txt
$ rcdaq_client create_device device_filenumbers 9 911 hv_readings.txt
```

Out readlist now looks like this:

```
$ rcdaq_client daq_list_readlist
Random Device  Event Type: 1 Subevent id: 1001 n_words: 32 range: 0 - 2048 ** Trigger enabled
File Device  Event Type: 9 Subevent id: 910 reading from  hv_readback.txt
File Number Reader  Event Type: 9 Subevent id: 911 reading from  hv_readings.txt
$
```

I then capture the output of the HV command interface in the "hv_readback.txt" file:

```
$ hvclient -b -s BB dv > hv_readback.txt
$ cat hv_readback.txt
HV_BB_S-1                1461   -1724.2 -1725.7 -2443.8  1     1    13
HV_BB_S-2                1461   -2057.4   -2059 -2578.3  1     1    13
HV_BB_S-3                1461   -1809.8 -1811.5 -2886.6  1     1    13
HV_BB_S-4                1461   -2227.1 -2227.6 -3157.1  1     1    13
HV_BB_S-5                1461   -2170.4 -2171.2 -3075.6  1     1    13
HV_BB_S-6                1461   -1563.2 -1563.7 -1938.1  1     1    13
HV_BB_S-7                1461   -1739.4 -1738.8   -2785  1     1    13
HV_BB_S-8                1461   -2080.9 -2081.8 -2955.1  1     1    13
HV_BB_N-1                1461   -1641.6 -1641.8   -2276  1     1    13
HV_BB_N-2                1461   -2494.2 -2494.5 -3089.6  1     1    13
HV_BB_N-3                1461   -1779.7 -1781.3 -2839.2  1     1    13
HV_BB_N-4                1461   -1956.6 -1957.9 -2711.5  1     1    13
HV_BB_N-5                1461   -1492.8 -1493.2 -2107.1  1     1    13
```

```
HV_BB_N-6                  1461   -2220.2 -2221.1 -2754.8  1     1    13
HV_BB_N-7                  1461   -1998.8 -1999.2 -3192.7  1     1    13
HV_BB_N-8
$
```

This gives the name of the HV channel, the hardware (LeCroy 1461), the demand voltage, the actual voltage, and so on. This file will end up in packet 910 as normal text.

Now we process the file to take the 4th column (the actual voltage), multiply by 100 to get an integer with the right range, and write to a new file "hv_readings.txt":

```
$ cat hv_readback.txt | awk '{print $4 , "*100"}' | bc | sed 's/\..*//' > hv_readings.txt
$ cat hv_readings.txt
-172570
-205900
-181150
-222760
-217120
-156370
-173880
-208180
-164180
-249450
-178130
-195790
-149320
-222110
-199920
-175350
```

Each number on a line will be added to packet 911 in binary.

Now we start and end a run:

```
$ rcdaq_client daq_begin
Run 4 started
$ daq_status -l
Running
Run Number:   4
Event:        1324
Run Volume:   0.5662 MB
Filename:     rcdaq-00000004-0000.evt
Duration:     28 s
Filerule:     rcdaq-%08d-%04d.evt
Buffer Sizes:     32832 KB adaptive buffering: 15 s
Web control Port:  8899
Elog: not defined
 -- defined Run Types:  (none)
No Plugins loaded
$ rcdaq_client daq_end
Run 4 ended
$
```

If we now look what the begin-run event has, we see

```
$ dlist -i -t 9 rcdaq-00000004-0000.evt
```

```
 -- Event     1 Run:     4 length:   324 type:  9 (Begin Run Event)  1363614653
Packet   910   296 -1 (ONCS Packet)  4 (IDCSTR)
Packet   911    20 -1 (ONCS Packet)  6 (ID4EVT)
$
```

We see packet 910, which says it is a "IDCSTR" packet, meaning it contains text, and 911, which is of type "I4EVT" (the same as our random-number packet), which contains a vector of integer numbers. Let's look inside:

```
$ ddump -i -t 9 -p 910 rcdaq-00000004-0000.evt
 -- Event     1 Run:     4 length:   324 type:  9 (Begin Run Event)  1363614653
HV_BB_S-1                 1461   -1724.2 -1725.7 -2443.8  1     1    13
HV_BB_S-2                 1461   -2057.4   -2059 -2578.3  1     1    13
HV_BB_S-3                 1461   -1809.8 -1811.5 -2886.6  1     1    13
HV_BB_S-4                 1461   -2227.1 -2227.6 -3157.1  1     1    13
HV_BB_S-5                 1461   -2170.4 -2171.2 -3075.6  1     1    13
HV_BB_S-6                 1461   -1563.2 -1563.7 -1938.1  1     1    13
HV_BB_S-7                 1461   -1739.4 -1738.8   -2785  1     1    13
HV_BB_S-8                 1461   -2080.9 -2081.8 -2955.1  1     1    13
HV_BB_N-1                 1461   -1641.6 -1641.8   -2276  1     1    13
HV_BB_N-2                 1461   -2494.2 -2494.5 -3089.6  1     1    13
HV_BB_N-3                 1461   -1779.7 -1781.3 -2839.2  1     1    13
HV_BB_N-4                 1461   -1956.6 -1957.9 -2711.5  1     1    13
HV_BB_N-5                 1461   -1492.8 -1493.2 -2107.1  1     1    13
HV_BB_N-6                 1461   -2220.2 -2221.1 -2754.8  1     1    13
HV_BB_N-7                 1461   -1998.8 -1999.2 -3192.7  1     1    13
HV_BB_N-8                 1461   -1752.2 -1753.5 -2485.3  1     1    13
$ ddump -t 9 -p 911 -g -d rcdaq-00000004-0000.evt
Packet   911    20 -1 (ONCS Packet)  6 (ID4EVT)

    0 |     -172570    -205900    -181150    -222760    -217120    -156370
    6 |     -173880    -208180    -164180    -249450    -178130    -195790
   12 |     -149320    -222110    -199920    -175350
$
```

Mission (almost) accomplished. If you run an HV scan from a script that steps through a number of HV settings, it is easy to add the HV-capturing commands to that script. However, if you are in a mode where you start and stop runs manually, it is easy to forget to update the files each time.

This is where our final pseudo device is coming in, the "device_command". We will use this to automatically execute the HV-capturing commands at begin-run. Since especially the second command has a large number of characters which would need to be escaped when used on the command line, we sidestep all those issues and put the two commands into a script, and then just execute the script.

```
$ cat hvcapture.sh
#! /bin/sh
hvclient -b -s BB dv > hv_readback.txt
cat hv_readback.txt | awk '{print $4 , "*100"}' | bc | sed 's/\..*//' > hv_readings.txt
$
```

First, we need to start over with our readlist, because we have to make it so that the new command is executed *before* the files are accessed. We delete the readlist:

```
$ rcdaq_client daq_clear_readlist
Readlist cleared
$
```

Now we add the command, and the two file-reading devices. You need to make sure that the script is executable and properly found by the server process. You would probably want to specify an absolute path to the script later.

```
$ rcdaq_client create_device device_command 9 0 './hvcapture.sh'
$ rcdaq_client create_device device_file 9 910 hv_readback.txt
$ rcdaq_client create_device device_filenumbers 9 911 hv_readings.txt
$ rcdaq_client daq_list_readlist
Command Device  Event Type: 9 executing ./hvcapture.sh
File Device  Event Type: 9 Subevent id: 910 reading from  hv_readback.txt
File Number Reader  Event Type: 9 Subevent id: 911 reading from  hv_readings.txt
$
```

Now all this is on autopilot, and we will always have the current HV readback in the data file.

## 7.2 Self-documenting your setup

Let me quickly point out a trick that allows you to go back to your raw data and see how RCDAQ was configured in the first place.

We have seen the commands

```
rcdaq_client create_device device_file 9 910 hv_readback.txt
rcdaq_client create_device device_filenumbers 9 911 hv_readings.txt
```

which we gave, ostensibly from the command line, to configure rcdaq.

Of course, in almost all cases, you are not going to type this in on the fly, but put this into a script, such as this "setup.sh":

```
#! /bin/sh

rcdaq_client create_device device_file 9 910 hv_readback.txt
rcdaq_client create_device device_filenumbers 9 911 hv_readings.txt
```

Now you could (but wait!) just add another device

```
#! /bin/sh

rcdaq_client create_device device_file 9 900 "$0"
rcdaq_client create_device device_file 9 910 hv_readback.txt
rcdaq_client create_device device_filenumbers 9 911 hv_readings.txt
```

You see packet 900 with "$0"? That of course refers to the name of the script itself, "setup.sh", and it will then be added and captured in packet 900 in the begin-run, so you can later see how rcdaq was configured to begin with.

However, there is one small problem. You will likely invoke the script as

```
./setup.sh
```

so the “$0” parameter will be “./setup.sh”. If the rcdaq server process is not run from the exact same directory where that script resides, it will not be able to find the script.

You could either be disciplined enough to *always* invoke the script by its full pathname (not very likely to succeed), or you could rewrite it as follows:

```
#! /bin/sh

D=`dirname "$0"`
B=`basename "$0"`
MYSELF="`cd \"$D\" 2>/dev/null && pwd || echo \"$D\"`/$B"

rcdaq_client create_device device_file 9 900 "$MYSELF"
rcdaq_client create_device device_file 9 910 hv_readback.txt
rcdaq_client create_device device_filenumbers 9 911 hv_readings.txt
```

In the standard setup is a full-blown example script (`setup.sh`)which you can use as a template.

## 8 Command overview

The command `rcdaq_client help` lists all available rcdaq commands:

```
   help                                 show this help text
   daq_status [-s] [-l]                 display status [short] [long]
   daq_open                             enable logging
   daq_begin [run-number]              start taking data for run-number, or auto-increment
   daq_end                              end the run
   daq_close                            disable logging
   daq_setfilerule file-rule            set the file rule default rcdaq-%08d-%04d.evt

   daq_list_readlist                    display the current readout list
   daq_clear_readlist                   clear the current readout list

   daq_define_runtype type file-rule    define a run type, such as "calibration"
   daq_set_runtype type                 activate a predefined run type
   daq_get_runtype [-l]                 list the active runtype (if any)
   daq_list_runtypes [-s]               list defined run types

   daq_set_maxevents nevt               set automatic end at so many events
   daq_set_maxvolume n_MB               set automatic end at n_MB MegaByte

   load  shared_library_name            load a "plugin" shared library
   create_device [device-specific parameters]

   daq_setname <string>               define an identifying string for this RCDAQ instance
   daq_setrunnumberfile file            define a file to maintain the current run number
   daq_set_maxbuffersize n_KB           adjust the size of buffers written to n KB
   daq_set_adaptivebuffering seconds    enable adaptive buffering at n seconds (0 = off)

   daq_webcontrol <port number>         restart web controls on a new port (default 8080)
```

```
elog elog-server port               specify coordinates for an Elog server

daq_shutdown                        terminate the rcdaq backend
```

The "short" versions of the commands (with the `-s` flag, which at some point actually stood for "script") are generally there for the benefit of scripts (typically the GUIs, which are all written in Perl/Tk). The output is usually easy to parse by a script, but less easy to digest by humans, such as

```
$ daq_status -s
-1 0 0 0 0 0
```

Let's go through the commands:

**daq_status** This displays the status of RCDAQ. The `-l` flags accumulate and increase the detail of the status report.

**daq_open** This enables the writing out of data to disk. You may wonder why one would choose to not log the data, but there are many situations where you are timing in your trigger, test the readout speed, or exercise the DAQ without cluttering your storage with files taken with ever-changing settings.

**daq_begin** Start taking data. If you supply a run number, this run number will be used. Without a run number, the last run number will be incremented. Also see the `daq_setrunnumberfile` command which allows you to make run numbers persistent between restarts of the rcdaq_server.

**daq_end** Ends the run.

**daq_close** Disables logging.

**daq_setfilerule file-rule** Set the file rule. You should always set a specific rule because with the default rule, `rcdaq-%08d-%04d.evt`, the data files will end up in the same area where rcdaq was started from. Be sure to have a look at the 4 commands managing run types, such as `daq_define_runtype`, which allows you to pre-set a few file rules, and switch between them quickly.

**daq_list_readlist** Displays the current readout list.

**daq_clear_readlist** Clears the current readout list.

**daq_define_runtype** This command, which takes a "mnemonic" and a file rule as parameters, allows you to pre-set an arbitrary number of different file rules. You will be able to switch between them quickly. In chapter **??** we show a convenient GUI to quickly switch between what I call *run types*, which uses the following example. Here I define

```
rcdaq_client daq_define_runtype pedestal     /data/rcdaq/pedestal/pedestal_%010d-%04d.evt
rcdaq_client daq_define_runtype beam         /data/rcdaq/beam/beam_%010d-%04d.evt
rcdaq_client daq_define_runtype calibration  /data/rcdaq/calibration/calibration_%010d-%04d.evt
rcdaq_client daq_define_runtype junk         /data/rcdaq/junk/junk_%010d-%04d.evt
```

and then quickly switch between them, making the data appear in the specified location. This allows you to keep, say, pedestal or calibration runs apart from actual beam runs, and have more meaningful file names. There is no practical limit to the number of such types. However, it is no more than a convenient shortcut to set file rules. You can still manually set a file rule which is different from any of the defined ones.

**daq_set_runtype type** This sets the file rule to the predefined file rule, such as (from the example above)

```
rcdaq_client daq_set_runtype beam
```

**daq_get_runtype** This lists the active run type (if any – if the file rule is not set to any of the predefined ones, it will return nothing). It takes the "long" `-l` switch. Without it, it will just list the type, with the long flag it will also list the rule.

**daq_list_runtypes** Lists the defined run types, the short version just the names, else also the rules.

**daq_set_maxevents nevt** Set an automatic end of a run at so many events. Setting it to 0 resets the event limit.

**daq_set_maxvolume nMB** Set an automatic end of a run after so many megabytes of data have been accumulated. Setting it to 0 resets the size limit.

**load shared_library_name** This loads a "plugin" shared library. Since rcdaq doesn't really know about any meaningful devices to read, you will have to load at least one plugin for serious work.

**create_device** This sets up a device to be read out. The parameters past the packet id are very device-specific.

**daq_setrunnumberfile filename** This defines a file where rcdaq maintains the current run number. Normally, the rcdaq server remembers the most recent run number, and it gets incremented for each run. When the server is started, however, the run number defaults to 0, and for the first run, you have to set it manually. This mechanism lets you make that process persistent across restarts of the server. Example:

```
rcdaq_client daq_setrunnumberfile $HOME/.last_rcdaq_runnumber.txt
```

**daq_set_maxbuffersize n_KB** Adjust the size of buffers to n KB. With the advent of "adaptive buffering" (next command), this can largely be ignored. This command was available mostly for the benfit of the online monitoring, since the monitoring receives one buffer at a time. If you have a low data rate (think a cosmics telescope) and small events, it can take several minutes (or even hours) for a large buffer to be filled and the monitoring to receive data. This was the reason why one could reduce the buffer size, to feed the online monitoring a more steady data stream. This was very sub-optimal, because the data taking efficiency is lower with smaller buffers, so one (small) size does not fit all. This brings us to the next command:

**daq_set_adaptivebuffering seconds** This is a much better solution for the above problem. By default, adaptive buffering is enabled and preset to 15 seconds. A buffer is now flushed when it is either full or the time period has elapsed, and there are no more rate-dependent adjustments. Unless there there is a specific reason, you should leave the adaptive buffering switched on. Setting the time to 0 disables adaptive buffering.

**daq_webcontrol port_number** Start the web-based controls on the given port number (defaults to port 8899 if omitted). See chapter **??** for details.

**elog elog-server port logbook** Specify the whereabouts for an Elog server where rcdaq can make automated entries.

**daq_shutdown** Ask the rcdaq_server to gracefully shut down. It will not shut down if a run is in progress.

# 9 Standard GUIs

There are 4 standard GUIs which come with rcdaq. There is a control GUI, a status display (essentially the control GUI without the action buttons), a "Run Type Chooser" GUI, and a configuration GUI which will take a bit more explanation.

The most important design concept is that all standard GUIs are *stateless*. You can start a run from the control GUI, end it via the command, or have multiple copies of the same GUI and click "Start" in one and "Stop" in the other. All GUIs and buttons will (with a minimal time lag of about one second) always adapt to the state of the DAQ. A particular GUI does not remember that it was it which started the run, etc.

The GUIs are resilient and deal with a shutdown of the rcdaq_server gracefully, so you can let them sit on the screen and they will always reflect the status of the DAQ.

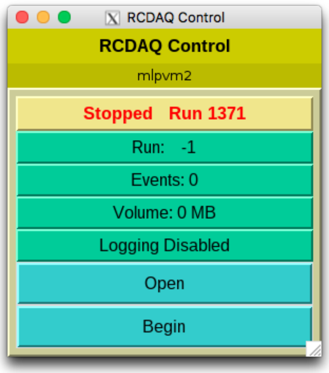
## 9.1 The Control Gui

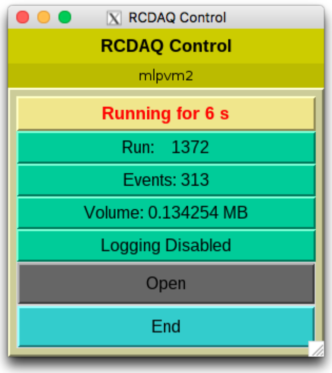
This is the workhorse GUI which allows to control the "operational" aspects of RCADQ - `daq_open`, `daq_begin`, `daq_end`, and `daq_close`. It will also display some useful information, such as the run number, duration of the run, the currently open file, if any, and so on.

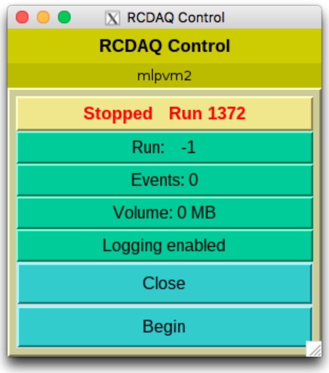
You start the GUI with

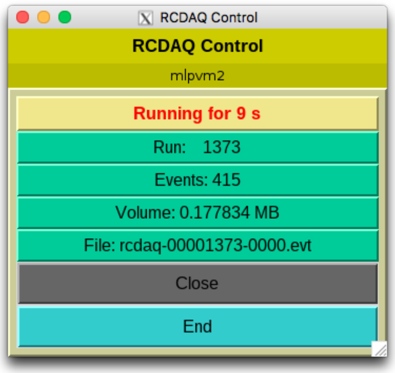
```
rcdaq_control.pl &
```

The GUI is shown here in different states; first with logging disabled, stopped and running; and logging enabled, stopped and running. You can see the different information displayed.


RCDAQ Control
mlpvm2
Stopped Run 1371
Run: -1
Events: 0
Volume: 0 MB
Logging Disabled


RCDAQ Control
mlpvm2
Running for 6 s
Run: 1372
Events: 313
Volume: 0.134254 MB
Logging Disabled


RCDAQ Control
mlpvm2
Stopped Run 1372
Run: -1
Events: 0
Volume: 0 MB
Logging enabled


RCDAQ Control
mlpvm2
Running for 9 s
Run: 1373
Events: 415
Volume: 0.177834 MB
File: rcdaq-00001373-0000.evt

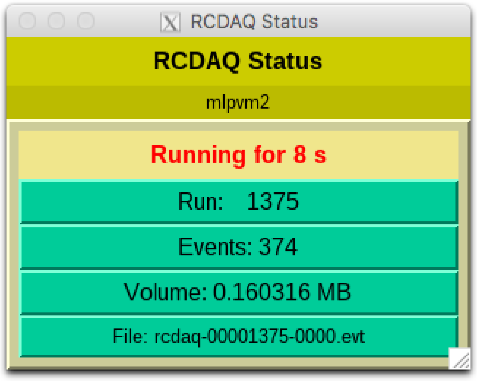
## 9.2 The Status GUI

This GUI is essentially a stripped-down version of the control GUI. It does not have the action buttons. If you just want to keep an eye on the status, there is no danger that you inadvertently click a button and interfere with the data taking.

You start it with

```
rcdaq_status.pl &
```

and get



Since this is a completely passive GUI, you can also use it to display the status on an overhead monitor which is found in many control rooms. For that reason, it supports three options, `--large`, `--display=<display>`, and `--geometry=<geometry>`. The `--large` option enlarges the GUI so that you can see it from a distance, and the other options allow you to send it to a remote display and position it properly, for example

```
rcdaq_status.pl --display=phnxtv1.phenix.bnl.gov:0.0 --geometry=+100+100 --large &
```

## 9.3 The Run Type Chooser GUI

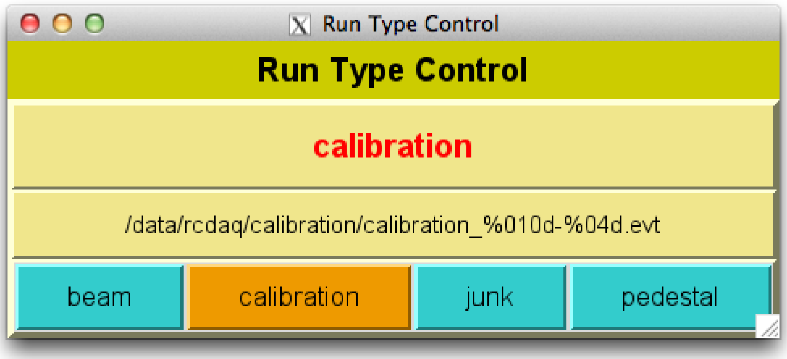
If you have run types defined, say, along the example from before

```
$ daq_list_runtypes
             beam - /data/rcdaq/beam/beam_%010d-%04d.evt
      calibration - /data/rcdaq/calibration/calibration_%010d-%04d.evt
             junk - /data/rcdaq/junk/junk_%010d-%04d.evt
         pedestal - /data/rcdaq/pedestal/pedestal_%010d-%04d.evt
```

then you can easily select the type with this GUI. Type

```
rcdaq_runtypechooser.pl &
```

and you will get



Each defined type brings up a button which allows you to select the run type easily.

Despite appearances, this GUI is stateless, too. The buttons merely set the run type in the rcdaq_server, but the display is updated not from the button click but from information from the server, so the GUI will reflect the changes if you change the run type from the command line.

This GUI will gracefully deal with a shutdown of the server, however, it will get confused if you change the list of run types. I think this is a small inconvenience, because the run types are usually pretty static. If they do change, this GUI needs to be restarted.

## 9.4 The Configuration GUI

This brings us to our last GUI, which is a bit more complex. We are supporting setups where the researchers are used to selecting the setup from a long scroll-down list of pre-made standard configurations, depending on what the experiment of the day is. This in itself is not so difficult, but soon you run into a complication in defining what such a "setup" actually is.

You will likely find the area teeming with a number of shell or perl scripts for different purposes, along with the top-level scripts which define the various setups. It is good practice to have those individual setup scripts call more generic other scripts with the proper parameters, in order to avoid a proliferation of "flat" all-in-one scripts. This immediately leads to the need to identify the actual top-level scripts which are meant to be listed in that GUI. Attempts to seclude those in a particular area only have, quite predictably, not worked.

For this reason, we invented a scheme in which we identify those "GUI-grade" scripts by certain tags, which are comments in the script.

If you look at the `setup.sh` example script in the main rcdaq source directory, you will see the following comments:

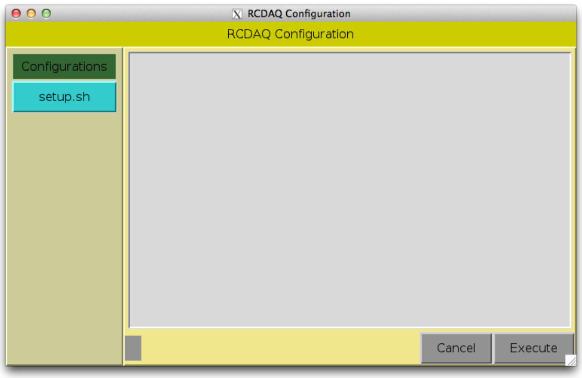
```
#! /bin/sh

# the following line identifies this script as one to be
# listed in the configuration GUI

# --RCDAQGUI

# lines starting with the "--SC" tag are short comments
# (can be only one, later ones override earlier ones)

# --SC Top Level setup script with a random device

# lines starting with the "--SC" tag are long comments

# --LC This setup script is part of the RCDAQ distribution.
# --LC It uses the random device (i.e. no particular hardware)
# --LC and can run on any machine to give RCDAQ a spin.
# --LC It can serve as a template to develop your own setups.
```

The `--RCDAQGUI` tag identifies this script as one to be listed in the GUI. Then there are “short comments”, which act as tooltip help (when you hover the mouse), and “long comments”, which are displayed once you select the GUI.

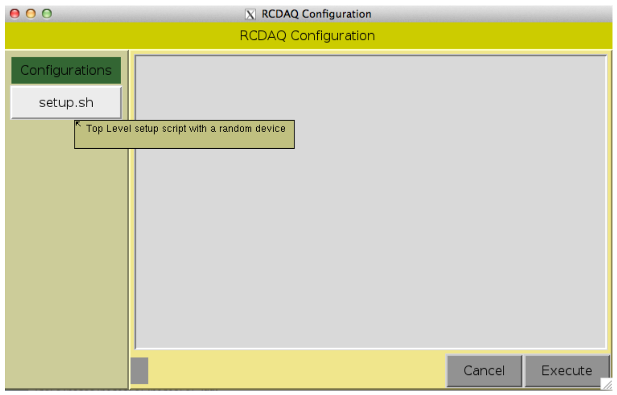
If you run

```
rcdaq_configmenu.pl &
```

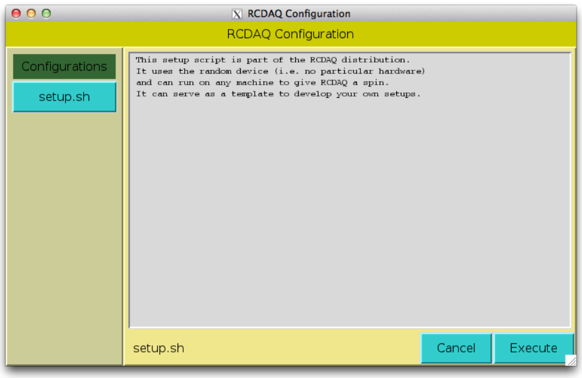
in the directory where this `setup.sh` script resides, you will see



(in this case there is only one such script, but all “GUI-enabled” scripts will be shown but not any others. If you hover the mouse, you will see the tooltip with the “short comment” (which can only be one line):



Selecting this then displays the longer help text, and you can see if this script is what you wanted:



```
This setup script is part of the RCDAQ distribution.
It uses the random device (i.e. no particular hardware)
and can run on any machine to give RCDAQ a spin.
It can serve as a template to develop your own setups.
```

Once selected, you can then choose to execute the script, or cancel.

# 10 Web-based Controls

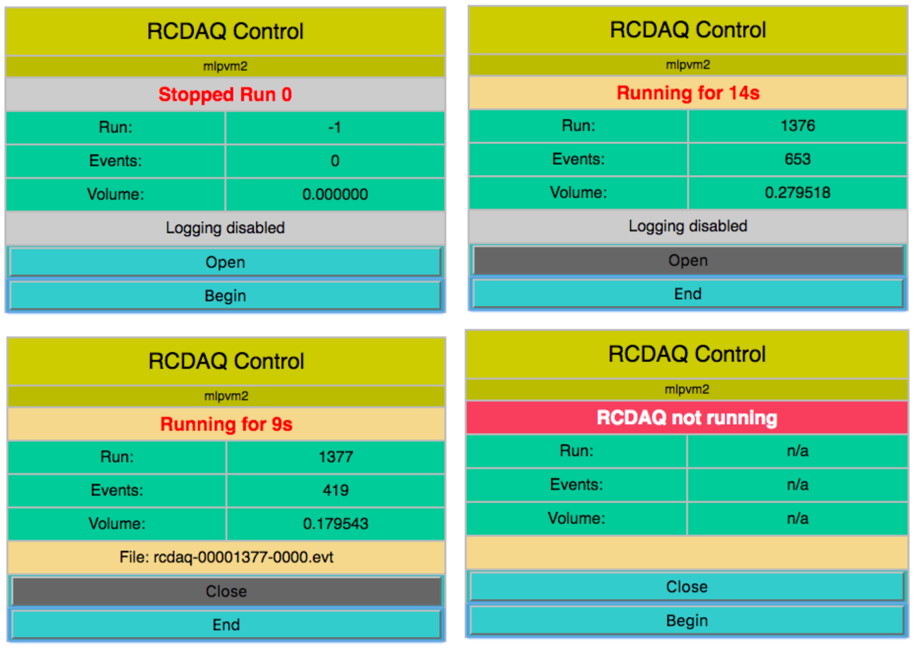
The GUIs shown in the previous chapter are based on the "Tk" graphics widget set and are implemented in Perl. While extremely versatile, Perl-Tk is not readily available on every platform, and requires additional libraries to be installed. On several Linux flavors in widespread use, such as RedHat and Scientific Linux, Tk can be installed but is not part of the software management system, and needs to be installed from source. In addition, the Tk system requires the availability of the X11 graphics system, which eliminates all platforms that do no support X11, such as iPads and iPhones. On other platforms like Windows and most smart phones and tablets, the "Tk" component is extremely difficult to install or is not available at all.

Recent advances in web technologies have converted the web browser into a viable platform for slow controls, with the advantage that the underlying technologies are available in most modern browsers on virtually any platform, including smart phones and tablets.

By adding a GUI technology that uses web-based controls, it is possible to implement the RCDAQ GUIs in a truly platform-independent fashion. This makes them available on platforms which could not support the GUIs before, such as smart phones, tablets, and even iPads, which have the most restrictive execution environment of all platforms.

## 10.1 The Web-based RCDAQ Control GUI

The web-based control interface acts like a web server running on the chosen port. Since the RCDAQ system cannot make any assumptions about port numbers available on your system, the web-based control interface cannot be brought up automatically at startup. The default port is 8899, but you can choose any port number that is available on your system.
You need to start the web control interface with the command


RCDAQ Control
mlpvm2
Stopped Run 0
Run: -1
Events: 0
Volume: 0.000000
Logging disabled

RCDAQ Control
mlpvm2
Running for 14s
Run: 1376
Events: 653
Volume: 0.279518
Logging disabled

RCDAQ Control
mlpvm2
Running for 9s
Run: 1377
Events: 419
Volume: 0.179543
File: rcdaq-00001377-0000.evt

RCDAQ Control
mlpvm2
RCDAQ not running
Run: n/a
Events: n/a
Volume: n/a

Figure 1: The new web-based control GUI for the RCDAQ system in various states of the RCDAQ operation. The upper left shows the GUI in the idle state, then in the running state, while logging, and when the RCDAQ server has been shut down.

```
rcdaq_client  daq_webcontrol <port number>
```

For example,

```
rcdaq_client  daq_webcontrol
```

starts the interface on the default port number 8899. You can then access the web-based controls on your local machine where RCDAQ is running as

```
http://localhost:8899
```

or on another system as

```
http://your.daq.machine:8899
```

It is highly recommended that you add the web control startup command to your startup script.

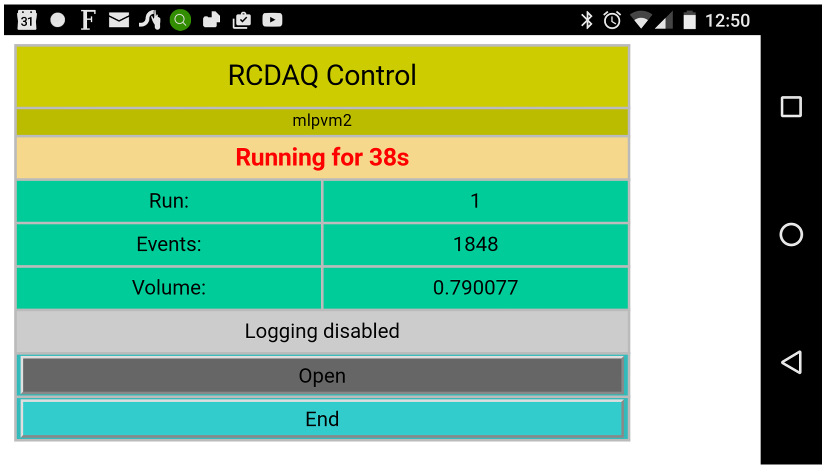
---

⚠ Keep in mind that RCDAQ is running without special privileges and cannot use any privileged ports such as the "http" port 80. If you use a port number different from the default, you *must* use a non-privileged port higher than 1024, and it is recommended that you use a port number above 8000.

---

At this point in time, only the equivalent of the standard control GUI has been implemented as a web-based control. The web-based equivalent of the "Status" GUI, shown on page **??**, will be implemented in an upcoming version.

Over time, the web controls will make it easy to add other amenities such as ready-made strip charts of the system performance, such as "events taken per minute" or "data volume as a function of time".



| | |
|---|---|
| RCDAQ Control | |
| mlpvm2 | |
| Running for 38s | |
| Run: | 1 |
| Events: | 1848 |
| Volume: | 0.790077 |
| Logging disabled | |

Figure 2: The new web-based controls for the RCDAQ system running in the web browser on an Android phone.

To show the enhanced possibilities of the web-based controls, Fig. **??** shows a screen shot of the controls running in the browser on my Android phone. In the same way, it is now possible to run the controls on iPads and basically any platform with a modern web browser.

## 11 pmonitor, the Monitoring and Analysis Framework

Virtually all analysis of raw data in PHENIX takes place in a framework called *pmonitor*. Designed as an online monitoring framework to be run within root, it has a number of features which make it a true monitoring package, most importantly, the ability to look at or in general manipulate histograms or similar objects *while* they are filled with new data. However, if you leave the online capabilities alone, you have an offline analysis framework. An existing online monitoring project can be run in an offline setting without changes.

Pmonitor is not a program but a framework, which allows you to quickly code up the monitoring or analysis needed for your specific setup. It relieves you from most repetitive and mundane tasks, such as opening or closing data streams, programming an event loop, adding code to save histograms, and the like. It also shields you from the effort and pitfalls of programming a multi-threaded program; it is already multi-threaded to allow the analysis of the event stream (and filling of histograms etc) in the background.

The setup-specific pmonitor projects (a "project" is what we call a particular piece of code running in the pmonitor framework) are easy to make, and usually lightweight. It is not uncommon to have a number of different projects, for example, one to help timing in the detector, one for the expert-level online monitoring, and more for the offline analysis (although that "offline" analysis can be run just the same in an online setting if this makes sense for your setup).

The pmonitor package comes with a script to generate the code for an "empty" pmonitor skeleton project which you can hash out with code to analyze your data. The script writes a Makefile for you, the required Linkdef file so it can get root bindings, a header file, and the C++ code stub which has all required routines. The unmodified skeleton code compiles and can be run, but doesn't do anything useful, obviously. The distribution ships with several examples which you can build and run with data taken with RCDAQ.

# A Examples

I show a few examples of real-life setups that were used in the past.

I will expand on this chapter as time progresses.

## A.1 Running Speed Tests

Let's say that you want to see how fast your system can take data when you pull out all the stops. Actually reading out devices later will invariably slow you down, but it is good to know where the limits of your disk, CPU, and network are.

I mentioned the `daq_device_deadtime` pseudo-device. It may sound odd that you can use a device that adds artificial deadtime for a speed test, but here is how it works.

Let me first show how to actually generate artificial deadtime. At the time I write this at the FermiLab Test Beam Facility, it is unclear if we will need this for the benefit of a MWPC, which may be able run at only 100Hz (remains to be seen). Then we would add, say, 150 microseconds deadtime:

```
rcdaq_client create_device device_deadtime 1 0 150
```

The 3rd parameter is the deadtime added in units of the Unix `usleep` system call, which is meant to be microseconds, but you may have to calibrate and adjust the unit on your system a little bit.

With the above parameters, it will not add anything to the data stream (that's why the packet id is set to 0). It can, however, add an adjustable amount of data to the event (and generate a packet, obviously). And it can also provide the system trigger. That allows you to dial in any desired data rate. Here is how you run the speed test: You set the deadtime to 0 (no deadtime), set a packet id (I chose 1005 here), have the device add 64 (32-bit) words to the event, and provide the system trigger (the last "1"). Since this is now the only device defined in a data event, it will run as fast as it can:

```
rcdaq_client create_device device_deadtime 1 1005 0 64 1
```

You can reduce the number of words to test the inner mechanics of RCDAQ on your PC (how fast it can go through the paces to kick off the event reading), or increase the number to test the limits of your storage system.

Be warned, though, that the artificial data do not have meaningful values. Different from the `device_random`, this devices wastes no time filling in any actual values; it just says that it has added so many words, no matter what the contents of the packet payload are.

## A.2 Measuring Event Timing

Especially under test beam conditions, it is often useful to see what the "spacing" in time between events is. Ideally, you would expect a somewhat balanced distribution with events being apart in time by roughly the same amount, but very often you find that there is a macroscopic structure in that distribution for a myriad of reasons.

If you see that in a beam setting, you should definitely find out why that is. This usually points to some undesired feature in the beam, which might have a microstructure, or some other structure.

A trivial way of getting such an artificial structure is to have a really slow file system to write the data to, such as a USB stick or something similarly slow. Then the time it takes to write out a buffer to storage is much longer than the time it takes to fill it. RCDAQ uses a double-buffering scheme so one buffer is getting filled while another one is being written to disk. In modern solid-state disks and especially in today's RAID systems, the writing is virtually always faster than the filling. However, if the writing is slow, the readout needs to wait for the writing to complete before that buffer becomes available again, and the busy goes up.

In order to measure the distance between events, the system offers a built-in pseudo device `device_rtclock`. This device uses the `clock_gettime` system service and retrieves the `CLOCK_MONOTONIC_RAW` system clock, which is strictly continuous and not affected by "jumps" due to NTP-driven or manual time adjustments. The clock reports clock ticks in units of nanoseconds, but that may need a system-dependent calibration. Still, it provides a "heartbeat" to gauge the relative timing of events.

The device records both the current clock value, as well as the same value from the last event where the "device" was read out. This makes it easy to compute the relative timing of events.

Here is an example how to set up such a pseude device in a data event:

```
rcdaq_client create_device device_deadtime 1 1010
```

It does not take any configuration parameters, only the event type and the packet id.

## A.3 Adding a webcam picture to a packet

In this setup we use a detector that gets positioned with a step motor. While we save the motor positions in the begin-run event, it is nice to have a visual confirmation that the detector is in the right place. To get this, we add a webcam picture to the begin-run event. The webcam looks at the detector with a ruler in the background, so you get a rough verification that the detector at least moves in the right direction.

While there are many ways to get a webcam picture, the most flexible solution is to run the "`motion`" utility on the system. `motion` is a surveillance tool designed to monitor a video stream and record video whenever *motion* is detected in the feed, where motion can be defined in a highly flexible manner. In addition, the utility provides a web interface to a live video stream, and has the ability to take snapshots in predefined intervals independent of detected motion in the picture. All streams and pictures carry a time stamp.

I usually adjust the threshold for motion recognition rather high so no actual video gets recorded, although that of course depends on your setup. The sequence of snapshot files later provides a rough timeline of events if needed. The web interface allows to remotely monitor the camera at any time. For getting a picture from the camera, I provide a simple perl script in the distribution which reads the web live stream and extracts and saves one frame.

The script is called "`motion_cam_parse.pl`" and takes the URL of the webcam feed as an argument. Assuming that motion runs on the local machine and the live feed appears on the standard port 8081, we can get one picture:

```
motion_cam_parse.pl http://localhost:8081 > cam_picture.jpg
```

I usually wrap this into a shell script "`capture_picture.sh`":

```
#! /bin/sh
# this captures a picture to the provided filename,
# or cam_picture.jpg

FILE="$1"
[ -z "$FILE" ] && FILE=cam_picture.jpg
motion_cam_parse.pl > "$FILE"
```

and then we configure rcdaq as follows:

```
#! /bin/sh

D=‘dirname "$0"‘
B=‘basename "$0"‘
MYSELF="‘cd \"$D\" 2>/dev/null && pwd || echo \"$D\"‘/$B"
rcdaq_client create_device device_file 9 900 "$MYSELF"
```

```
# add the camera picture
rcdaq_client create_device device_command 9 0 "/home/eic/capture_picture.sh /home/eic/cam_picture.jpg"
rcdaq_client create_device device_file_delete 9 940 /home/eic/cam_picture.jpg

# .. lines deleted...
```

We use `device_file_delete` so it is impossible to add a stale picture if there is a problem getting the current one.

## A.4 The GEM Detector Readout at the FermiLab Test Beam, February 2014

This setup is building on the previous example in the sense that we are adding a lot of configuration information and two camera snapshots to the begin-run event. We also have 5 different run types defined.

First, we let the main RCDAQ configuration script figure out if there is a `rcdaq_server` running by issuing a `daq_status` command and testing its return status. If that fails, we need to start the server. At this point, we also define the Elog whereabouts.

```
#! /bin/sh

if ! rcdaq_client daq_status > /dev/null 2>&1 ; then
    echo "No rcdaq_server running, starting..."
    rcdaq_server > $HOME/log/rcdaq.log 2>&1 &
    sleep 2
    ELOG=$(which elog 2>/dev/null)
    [ -n "$ELOG" ]  && rcdaq_client elog localhost 666 RCDAQLog
fi
```

This is the “make an absolute path” routine you already know:

```
# we need the $0 as absolute path b/c we pass it on to a "file" device further down
D=‘dirname "$0"‘
B=‘basename "$0"‘
MYSELF="‘cd \"$D\" 2>/dev/null && pwd || echo \"$D\"‘/$B"
```

We make the current run number persistent:

```
rcdaq_client daq_setrunnumberfile $HOME/.last_rcdaq_runnumber.txt
```

And we find out if the SRS plugin is loaded already:

```
if ! rcdaq_client daq_status -l | grep -q "SRS Plugin" ; then
    echo "SRS plugin not loaded yet, loading..."
    rcdaq_client load librcdaqplugin_srs.so
fi
```

And now we assemble the pieces that we want to add to the begin-run event.

- Packet 900 will hold the configuration script itself

- we execute the command `srs_control readapv > $HOME/apv.txt`. It extracts most of the relevant setup parameters from the SRS crate and writes it to the file.
- we execute `/home/eic/rcdaq_setup/prepare_run.sh`. This script
  - reaches out to the motor rotation controller, queries the current position, and writes the value into `current_position.txt`;
  - turns on a small light underneath the turntable for a moment and takes a picture from a webcam which looks at the scale for visual confirmation; the picture goes into an image file called "`snapshot.jpg`";
  - it makes a similar snapshot from a permanently mounted overhead camera as "`overhead_snapshot.jpg`".
- we then add the "`apv.txt`" file as packet 910;
- we add "`current_position.txt`" as packet 940;
- we add "`snapshot.jpg`" as packet 941;
- and we add "`overhead_snapshot.jpg`" as packet 942.

```
# we add this very file to the begin-run event
rcdaq_client create_device device_file 9 900 $MYSELF

rcdaq_client create_device device_command 9 0 "srs_control readapv > $HOME/apv.txt"
rcdaq_client create_device device_command 9 0 "/home/eic/rcdaq_setup/prepare_run.sh"

rcdaq_client create_device device_file 9 910  $HOME/apv.txt
rcdaq_client create_device device_file 9 940  $HOME/current_position.txt
rcdaq_client create_device device_file 9 941  $HOME/snapshot.jpg 128000
rcdaq_client create_device device_file 9 942  $HOME/overhead_snapshot.jpg 128000
```

The remainder of the set up script is straightforward; we set up the run types, set "junk" as default, and finally define the readout of the SRS crate:

```
rcdaq_client daq_define_runtype beam    /data/gem/beam/beam_%010d-%04d.evt
rcdaq_client daq_define_runtype noSi    /data/gem/noSi/no_si_%010d-%04d.evt
rcdaq_client daq_define_runtype junk    /data/gem/junk/junk_%010d-%04d.evt
rcdaq_client daq_define_runtype calibration /data/gem/calibration/calibration_%010d-%04d.evt
rcdaq_client daq_define_runtype pedestal /data/gem/pedestal/pedestal_%010d-%04d.evt
rcdaq_client daq_setruntype junk

rcdaq_client create_device device_srs 1 1010 10.0.0.2 1
```

And here is the composition of the begin-run event:

```
$ dlist -i -t 9 beam_0000000451-0000.evt
 -- Event     1 Run:   451 length: 17431 type:  9 (Begin Run Event)  1392306649
Packet   900   614 -1 (ONCS Packet)  4 (IDCSTR)
Packet   910   142 -1 (ONCS Packet)  4 (IDCSTR)
Packet   940     7 -1 (ONCS Packet)  4 (IDCSTR)
Packet   941  3643 -1 (ONCS Packet)  4 (IDCSTR)
Packet   942 13017 -1 (ONCS Packet)  4 (IDCSTR)
```

If we now want to find out the position of the turntable, we can have a look at packet 940:

```
$ ddump -t 9 -p 940  /media/psf/Home/srs/GEM/beam/beam_0000000472-0000.evt
-0000020
$
```

( -20 is actually the “zero” position, 80 ticks mean one degree, the the zero marks are aligned at this value.)

Here is another run:

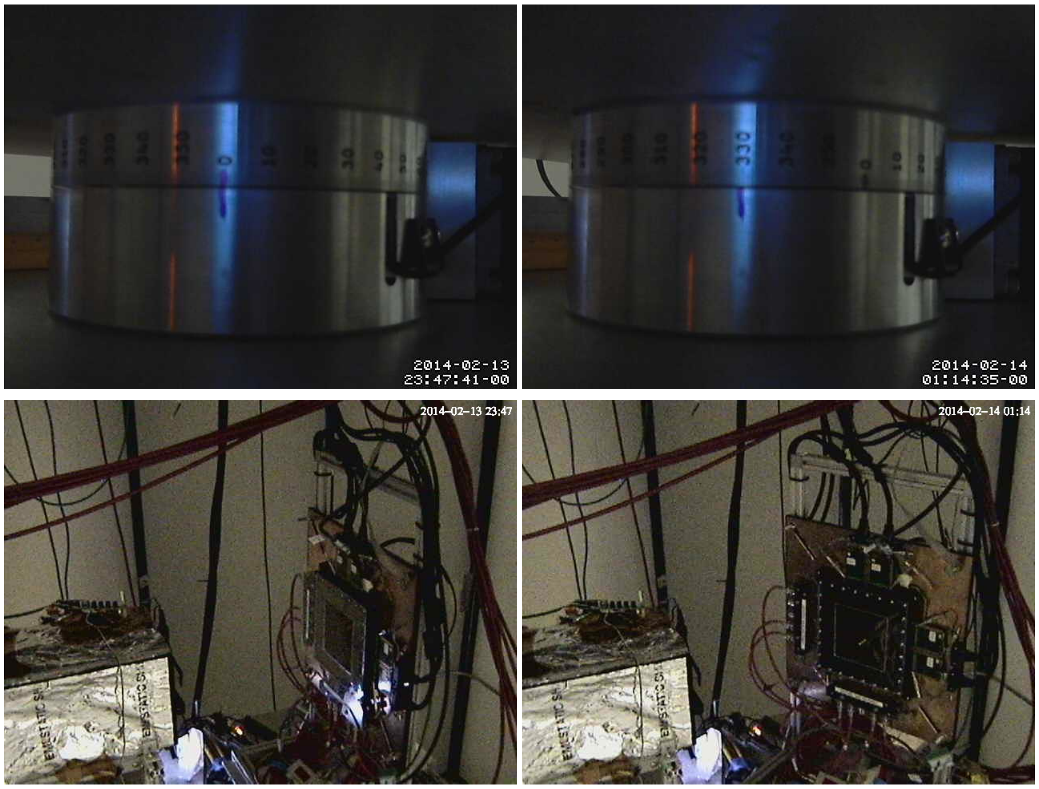
```
$ ddump  -t 9 -p 940  /media/psf/Home/srs/GEM/beam/beam_0000000474-0000.evt
+0002380
$
```

which is at 2380 (+20) ticks (30 degrees).

In case there seems something wrong, one can extract the webcam snapshots:

```
$ ddump  -t 9 -p 941 beam_0000000472-0000.evt > 472.jpg
$ ddump  -t 9 -p 942 beam_0000000472-0000.evt > 472_overhead.jpg
$ ddump  -t 9 -p 941 beam_0000000474-0000.evt > 474.jpg
$ ddump  -t 9 -p 942 beam_0000000474-0000.evt > 474_overhead.jpg
```

Here you can see these snapshots:



This is great for potential forensics and a visual conformation that the detector was at the right position.

# B Installation

## B.1 Installing the software

The installation is rather straightforward. You put the rcdaq distribution in a good place in your file system, make a "build" and an "install" directory, and build in the standard way. In this example, I have the distribution in the `/home/purschke/softwarerepo` area. In there is the rcdaq directory, as well as any rcdaq plugin distribution you may need (I also have built the "srs" plugin here, as well as the online_distribution, which we need for the analysis and monitoring packages).

```
$ pwd
/home/purschke/softwarerepo
$  ls
build  install  online_distribution rcdaq srs
```

In the build area, I make matching directories to build each package in:

```
$ ls build/
online_distribution  rcdaq srs
```

I then cd to the build/rcdaq area, and execute

```
$ cd build/rcdaq
$ ../../rcdaq/autogen.sh  --prefix=/home/purschke/softwarerepo/install
$ make install
```

Although not technically part of this manual, let me also show how to install the online_distribution. It goes analogous to the procedure shown for rcdaq and srs. However, since it always has a fixed order of building the collection of sub-areas, there is a ready-made script which executes the commands in the right order:

```
$ cd ../online_distribution
$ pwd
/home/purschke/softwarerepo/build/online_distribution
$ ../../online_distribution/simple_install.sh /home/purschke/softwarerepo/install
```

**Important:** You need to define an environmental variable `ONLINE_MAIN` to point to the installation area (in this example here, to `/home/purschke/softwarerepo/install`):

```
$ export ONLINE_DISTRIBUTION=/home/purschke/softwarerepo/install
```

or, should you still be using a csh-derivative:

```
$ setenv ONLINE_DISTRIBUTION /home/purschke/softwarerepo/install
```

Then you should add (or define as) `$ONLINE_MAIN/lib` to `LD_LIBRARY_PATH`, and add `$ONLINE_MAIN/bin` to your PATH.

Here is my `$HOME/.bash_login` file:

```
export ONLINE_MAIN=/home/purschke/softwarerepo/install
PATH=$PATH:$ONLINE_MAIN/bin
export LD_LIBRARY_PATH=$ONLINE_MAIN/lib
source $ONLINE_MAIN/bin/aliases.sh
```

Check first if your system already defines a `LD_LIBRARY_PATH`. You can find this out by issuing `echo $LD_LIBRARY_PATH` *before* you modify your login file. Sometimes this is done if other custom packages are installed. In that case, you want to append to it, and the second last line becomes

```
LD_LIBRARY_PATH=$LD_LIBRARY_PATH:$ONLINE_MAIN/lib
```

The very last line

```
source $ONLINE_MAIN/bin/aliases.sh
```

sets up the aliases that make your commands more convenient. See chapter **??** for the details.

## B.2 System Requirements

RCDAQ runs without special privileges. The only system service it needs is `rpcbind`, which typically gets started at boot time of your system. The only modification to the usual way the rpcbind service is run is that it needs the "-i" flag. The end result must be that rpcbind is running with that flag, as in

```
$ ps ax | grep rpcbind
 2273 ?        Ss     0:00 /sbin/rpcbind -i
 5626 pts/0    S+     0:00 grep --colour=auto rpcbind
$
```

How this is accomplished varies a lot between Linux distributions. Here are a few of the more mainstream ones:

**Gentoo** Create or edit the file `/etc/conf.d/rpcbind`. Add a line

```
RPCBIND_OPTS="-i"
```

**Scientific Linux** Create or edit the file `/etc/sysconfig/rpcbind`. Add a line

```
RPCBIND_ARGS="-i"
```

**Ubuntu** Create or edit the file `/etc/default/rpcbind`. Add a line

```
OPTIONS="-i"
```

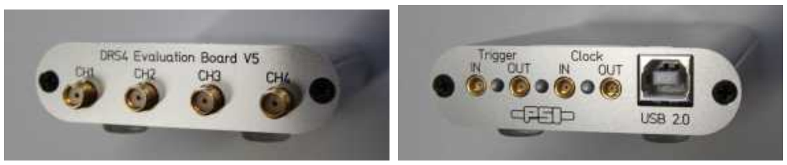


Figure 3: The PSI DRS4 Evaluation Board.

## C A Selection of Currently Implemented Readout Devices

### C.1 The PSI DRS4 Evaluation Board

The DRS4 chip is a switched capacitor array capable of sampling at a speed of up to 5 Gigasamples/s. This device supports sampling rates of 0.7, 1, 2, and 5 GS/s.

The PSI DRS4 evaluation board is one of the workhorse systems in small setups. It offers 4 waveform digitizing channels with sample rates of up to 5GS/s. Since it is a USB-based device, it can be run on virtually any Linux system without the need for special interfaces. Fig. **??** shows pictures of the board.

This is the only device implemented in RCDAQ so far that is capable of being read out with a Raspberry Pi. The RCDAQ core will work on a Pi just fine, but most of the other readout devices will not be supported. The DRS4 evaluation board is the exception. I have personally used the board with a Pi for a long-term cosmic calibration measurement, where I didn't want to commit a more powerful PC to acquire the data.

To start, you need to make sure that your system has all the libraries needed to interface with the DRS4 evaluation board in the first place. Follow the instructions on the PSI website what to install and configure. You should be able to run the `drsosc` "oscilloscope" application, shown in Fig. **??**, on your system *before* you start with RCDAQ.

The installation of the plugin follows the recipe outlined in chapter **??** exactly. Go back to the place where you already installed RCDAQ, in my example from above `/home/purschke/softwarerepo`. Then get the software:

```
wget -O - http://www.phenix.bnl.gov/~purschke/rcdaq/drs4.tar.gz | tar xvz
```

and you will have a new directory "drs4". Now go to your build area, `/home/purschke/softwarerepo/build` in the example, make a new directory "drs4", and configure:

```
$ pwd
  /home/purschke/softwarerepo/build
$ mkdir drs4
$ cd drs4
$ ../../drs4/autogen.sh --prefix=/home/purschke/softwarerepo/install
$ make install
```

This will install `librcdaqplugin_drs.so` in your `$ONLINE_MAIN/lib` area, which

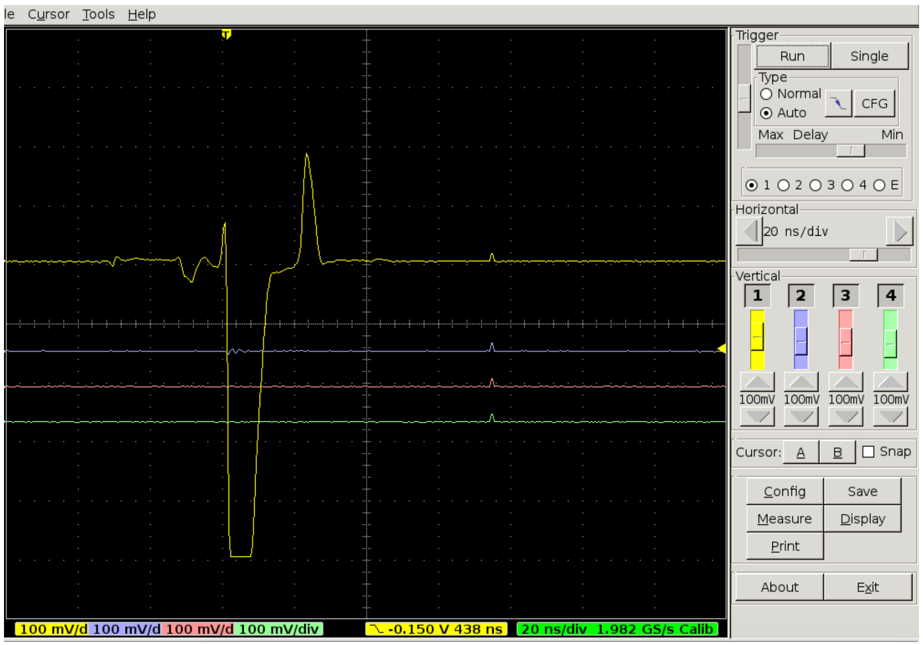


Figure 4: A screenshot of the drsosc application. Make sure that you can sucessfully run this application before you start setting up RCDAQ.

is the plugin that teaches RCDAQ how to read the Evaluation Board.

This is the way how you install every other plugin as well, just replace the name accordingly.

You can now load the plugin, and see the effect with the `daq_status -ll` command:

```
$ rcdaq_client load librcdaqplugin_drs.so
$ daq_status -ll
Stopped
Logging enabled
have a trigger object
Filerule:     rcdaq-%08d-%04d.evt
Buffer Sizes:     32832 KB adaptive buffering: 15 s
Web control Port:  8899
Elog: not defined
 -- defined Run Types:  (none)
List of loaded Plugins:
 - DRS Plugin, provides -
 -     device_drs (evttype, subid, triggerchannel, triggerthreshold[mV], slope[n/p], delay[ns],
                  speed, start_ch, nch, baseline[mV]) - DRS4 Eval Board
 -     device_drs_by_serialnumber (evttype, subid, serialnumber, triggerchannel,
                  triggerthreshold[mV], slope[n/p], delay[ns],
                  speed, start_ch, nch, baseline[mV]) - DRS4 Eval Board
```

The only slightly complicated setting is the `triggerchannel` parameter, which is a bit-mapped value. You will usually see some value such as `0x21` here. The 5 least significant bits denote the 4 inputs and the external trigger as triggers for the board.

Keep in mind that there are two different triggers here – one is triggering the board itself, and the other is whether or not this board also provides the system trigger for RCDAQ (see chapter **??** for the explanation). So bits 0-4 switch on or off the 5 possible sources of board triggers, and bit 5 says if this board generates the system trigger. So `0x21` – bits 0 and 5 are set – is saying that channel 1 triggers the board, and the board also makes the system trigger. `0x30` means the system trigger, and the external trigger triggers the board. Keep in mind that if you choose to *not* make the system trigger here, you need another device to do that; you will not get any events else.

There is another specialty in the standard Linux parameter parsing that you need to think of and which is shown in this setup example:

```
rcdaq_client create_device device_drs -- 1 1001 0x21 -150 negative 438 2
```

Since we need to prevent the parser from interpreting the `-150` as options ( -1, -5, -0), you need to tell it to stop the option parsing with the the "double-dash" – `--`. This is standard Unix shell behavior, but you need to remember that.

The above line sets the board up to trigger on channel 1, negative trigger with a -150 mV threshold, an internal delay of 438 ticks (that's how far we "look back" in the waveform before the trigger), and 2GS/s speed. The final "2" parameter happens to mean 2GS/s, but this parameter is enumerated:

| parameter | speed |
|---|---|
| 0 | 700 MS/s |
| 1 | 1 GS/s |
| 2 | 2 GS/s |
| 3 | 5 GS/s |

By the way: The way I derive the delay and speed parameters is to run `drsosc`, adjust everything the way I want it, and then transcribe the parameters from `drsosc` to the setup command. If you look at Fig. **??**, you will see that I used the same settings (2 GS/s and a delay of 438 ticks) in the setup example above.

There are two more "hidden" parameters which assume default values when omitted. The above setup command is equivalent to

```
rcdaq_client create_device device_drs -- 1 1001 0x21 -150 negative 438 2 0 1024
```

where the last two parameters mean "start channel" and "number of samples". Setting the former to a non-zero value will cut out the early part of the waveform. I *strongly* advise against using this parameter, since this will actually slow down your system as it involves copying the desired part of the waveform to the right place. You can virtually always accomplish the same by adjusting the delay value (or delaying the hardware trigger). It is here more out of a sense of completeness.

With the "number of samples" parameter you can cut out the later part of the waveform. For example, if your signal is confined to the first 250 samples in your waveform, you can store just those first 250 samples. This will *only* save storage

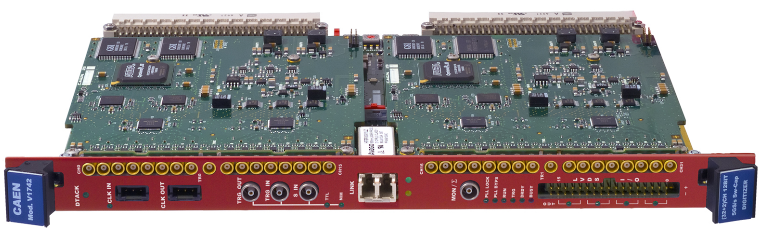


Figure 5: The CAEN V1742 module.

space and not gain any significant readout speed, since we still need to read the full waveform and only discard the unwanted tail end. Different from discarding the front part, the tail end can be discarded without an expensive copy operation.

## C.2 The CAEN DRS4 1742V System

The CAEN V1742 module, shown in Fig. **??**, is one of the more complex modules implemented in RCDAQ. At its core, it has 4 DRS4 chips inside, providing 32 primary input channels, plus one “side” channel per chip. Two of those can be used to digitize the NIM input signal if so desired.

Different from the evaluation board, it supports sampling speeds of 1, 2.5, and 5 GS/s.

The assorted RCDAQ plugin, `librcdaqplugin_CAENdrs.so`, provides two different devices to readout the V1742. One, called `device_CAENdrs`, uses the preconfigured V1742 as-is, without changing any “non-essential” registers. This device makes the full configuration space available that the V1742 has to offer. It comes with a companion utility `caen_client`, which can be used to adjust any available register as needed. I said “non-essential” registers, because RCDAQ still sets up the registers that govern the actual readout the way it needs it; there is not much choice in that matter. Still, in this way one can set up any conceivable trigger mode, readout length, sample, rate, and so on, essentially any configuration parameter. Here is a list of parameters that the `caen_client` utility can set and read:

```
$ caen_client status
MaxNumEventsBLT:        1
ExtTriggerInputMode:    3 (ACQ_AND_EXTOUT)
FastTriggerDigitizing:  0 (Disabled)
FastTriggerMode:        0 (Disabled)
OutputSignalMode:       0 (TRIGGER)
Sampling Frequency:     2 (DRS4_1GHz)
RecordLength:           1024 samples
PostTriggerSize:        0
IOLevel()               0 (NIM)
AcquisitionMode         0 (software controlled)
GroupEnableMask         0xf
TriggerPolarity (F - falling edge / R - rising edge) :
  R  R  R  R  R  R  R  R
  R  R  R  R  R  R  R  R
  R  R  R  R  R  R  R  R
  R  R  R  R  R  R  R  R

ChannelDCOffset:
  0x8f00  0x8f00  0x8f00  0x8f00  0x8f00  0x8f00  0x8f00  0x8f00
  0x8f00  0x8f00  0x8f00  0x8f00  0x8f00  0x8f00  0x8f00  0x8f00
  0x8f00  0x8f00  0x8f00  0x8f00  0x8f00  0x8f00  0x8f00  0x8f00
  0x8f00  0x8f00  0x8f00  0x8f00  0x8f00  0x8f00  0x8f00  0x8f00
```

This pretty much covers the entire configuration space of the device.

The other device you can define is `device_CAENdrs_std`, which is a no-frills standard configuration. It can also be adjusted by using `device_CAENdrs` and `caen_client`, but for a novice user it provides a guaranted-to-work way to configure the device. This device will not obey the `caen_client` changes but re-set everything to its defaults at each begin-run. It takes a NIM signal on the trigger line, and adjusts the offsets to a range of ±500 mV.

The syntax is

```
device_CAENdrs_std evttype  subid  trigger  speed  delay
```

where "trigger" means whether or not the device provides the system trigger.