FCal Test Beam DAQ: description of raw data file format

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Document source: http://atlas-fcaltb.web.cern.ch/atlas-fcaltb/Memos/DAQ/...
C-source codes referred to in the text can be found in pcfcal01:/home/daq/Daq/ (src, lib, include)

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[1] Mistakes in record ID description, section 1.1, are fixed (thanks to Peter Krieger!)

1 FCAL TB Data format overview

1.1 General structure of the data files

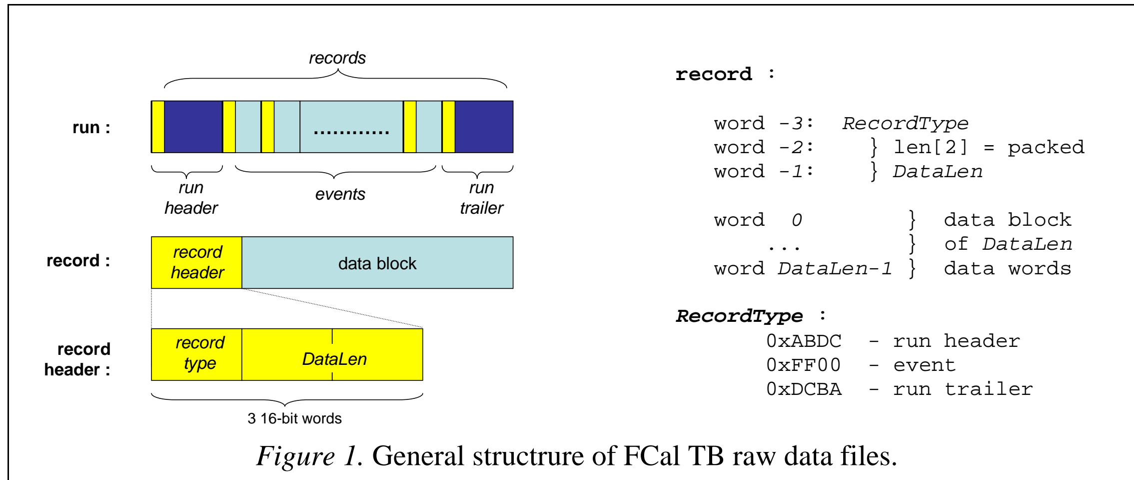


Figure 1. General structrure of FCal TB raw data files.

The structure of the FCal test beam data had been proposed by P. Loch (Ref.[1-1]) and is illustrated in Fig. 1. One *run* makes one binary raw data file, which is a contiguous sequence of variable length *records* ("blocks") of short 16-bit words. All records have the same logical structure, with a 3-word *header*[2] followed by a variable length *data block*. The record header contains the *record type* and the *data block length*.

The first record in every run is a *run header*, the last one is a *run trailer*, all other records are *events*. Respectively, there are only three different record types: `0xABCD`, `0xFF00` and `0xDCBA`.

The number of data words in a record is a 32-bit number *`DataLen`*, packed in two short words len[2] of the record header, as follows:

```
DataLen=(long)len[1] | (long)len[0]<<16 ;
```

The *`DataLen`* representation is encapsulated in DAQ functions `add_blk_header` and `get_blk_header`, also available for offline and monitoring applications as part of `my_event.c` package.

1.2 Data blocks

The data part of the records depends on the record type and may consist of items of type `char[]` (strings), `short` and `int` . If the file is read under Linux then (hopefully!) the numerical items should not require a byte-swapping.

---

[2] In the original event format specification, the block header consisted of 2 short words, with a 16-bit `DataLen`. This was changed to accomodate very long events (with 32 samples and >1 gain).

1.2.1 Run header and trailer records

The run header and trailer are, respectively, the first and the last records in any data file.[3]

The data part in these records is a block of plain ASCII text consisting of 64-character long *key-records* describing the run settings, DAQ configuration, and beam conditions (see Chapter 2 for further details). In brief, the run header can be considered as a portable run-related data base attached to the raw data file.

Run trailers are almost identical to the corresponding run headers and differ from the latter only by the presence of

```
RunStopDate
RunStopTime
Events
```

keys (Section 2.3).

The online `rhlib` package can be, optionally, used in offline applications to retrieve and manipulate the run header information (Chapter 2 and Appendix 2-B).

1.2.2 Event records

The data part in event records is logically split into a (variable) number of of *sub-blocks* having the structure shown in Fig. 2, similar to the record structure: the sub-block starts with a 3-word header, followed by a data-part.

The first sub-block is always the *event header*, decribed in this Chapter. The event header is followed by a number of *data sub-blocks*, described in Chapter 3. The event composition (what kind of sub-blocks it contains) depends on the run type and event type. The order of sub-blocks is not fixed by the event format.

The sub-blocks in an event, like records in a file, follow each other without gaps, so one can iterate over sub-blocks by jumping from one sub-block header to another. However, there is a possibility to access sub-block directly, by using the *event directory* stored in the event header (sub-section 1.2.3.2). This redundancy is useful for event integrity checks.

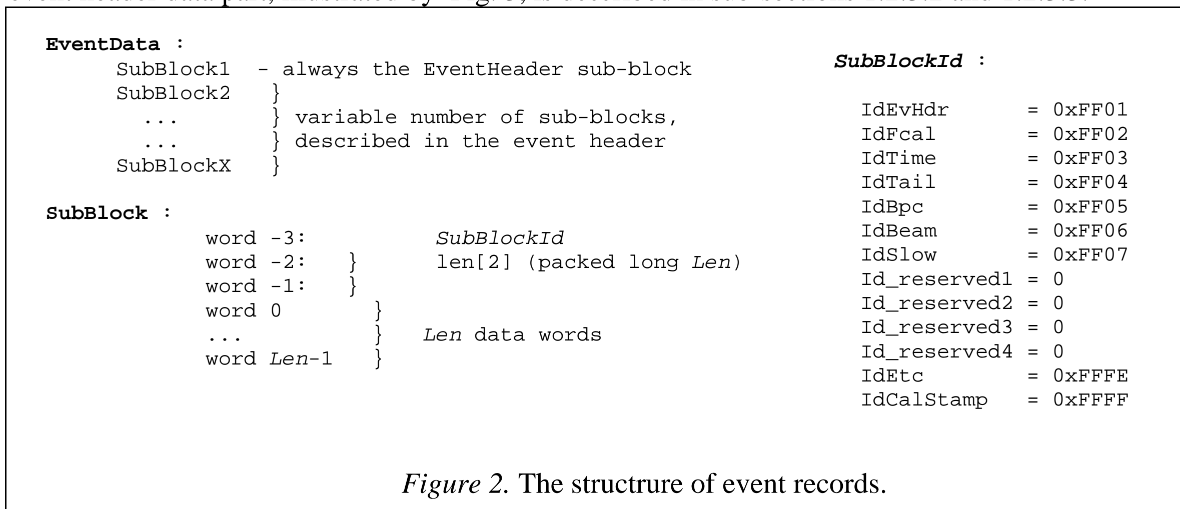
1.2.3 Event header sub-block

1.2.3.1 The sub-block structure

```
SubBlockId   : 0xFF01
Len          : 28
```

[3] Unless the run had finished abnormally (e.g., the DAQ program crashed or was killed by hand) – in which case the run header might be missing.

The event header data part, illustrated by Fig. 3, is described in sub-sections 1.2.3.2 and 1.2.3.3.



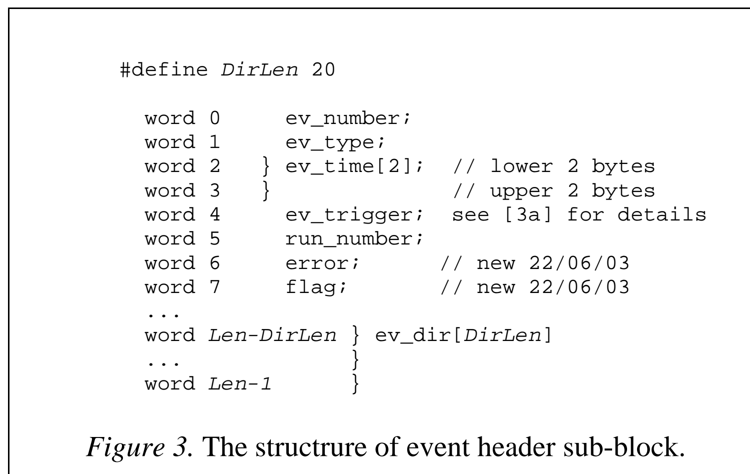
```
EventData :
      SubBlock1  - always the EventHeader sub-block
      SubBlock2   }
        ...       } variable number of sub-blocks,
        ...       } described in the event header
      SubBlockX   }

SubBlock :
             word -3:          SubBlockId
             word -2:   }      len[2] (packed long Len)
             word -1:   }
             word 0       }
             ...          }   Len data words
             word Len-1   }

SubBlockId :

  IdEvHdr      = 0xFF01
  IdFcal       = 0xFF02
  IdTime       = 0xFF03
  IdTail       = 0xFF04
  IdBpc        = 0xFF05
  IdBeam       = 0xFF06
  IdSlow       = 0xFF07
  Id_reserved1 = 0
  Id_reserved2 = 0
  Id_reserved3 = 0
  Id_reserved4 = 0
  IdEtc        = 0xFFFE
  IdCalStamp   = 0xFFFF
```

Figure 2. The structrure of event records.



```
#define DirLen 20

  word 0      ev_number;
  word 1      ev_type;
  word 2    } ev_time[2];  // lower 2 bytes
  word 3    }              // upper 2 bytes
  word 4      ev_trigger;  see [3a] for details
  word 5      run_number;
  word 6      error;      // new 22/06/03
  word 7      flag;       // new 22/06/03
  ...
  word Len-DirLen } ev_dir[DirLen]
  ...             }
  word Len-1      }
```

Figure 3. The structrure of event header sub-block.

The event header format was half-frozen during the 2003 data-taking, in the sense that the first 6 words are reserved for the event ID data and the last 20 words – for the event directory. Extra information could be, optionally, inserted between `word[5]` and `word[Len-DirLen]`, without compromising the event header integrity. Thus, `error` and `flag` words were absent in early runs.

1.2.3.2 The event directory

The array `ev_dir` contains offsets of other data sub-blocks relative to the *reference word* of the event. By convention (Ref.[1-1]), the reference is the `word[-1]` of the event header (that is, the 6th word of the event record). The offsets point to the the 1st word (`SubBlockId`) of the corresponding sub-blocks.

Each directory entry consists of two words, the first one being the sub-block ID (or 0), the second – the corresponding offset (or zero). Zero offset means that the sub-block is not present in the event. Fig. 4 illustrates this by showing a fragment of DAQ code which fills the event directory (the actual code: `.../Daq/lib/my_event.c`).

Note, that the number of directory entries (10) and their order are fixed. In particular, the first entry is always the offset of the Fcal data. On the other hand, the order of actual sub-blocks in an event is *not* fixed: it can be different from the order of the corresponding directory entries.

```
ev_dir[0] =IdFcal;      ev_dir[1]  = offsetFcal ;
ev_dir[2] =IdTime;      ev_dir[3]  = offsetTime ;
ev_dir[4] =IdTail;      ev_dir[5]  = offsetTail ;
ev_dir[6] =IdBpc;       ev_dir[7]  = offsetBpc ;
ev_dir[8] =IdBeam;      ev_dir[9]  = offsetBeam;
ev_dir[10]=IdSlow;      ev_dir[11] = offsetSlow;
ev_dir[8] =0;           ev_dir[9]  = 0;
ev_dir[10]=0;           ev_dir[11] = 0;
ev_dir[12]=0;           ev_dir[13] = 0;
ev_dir[14]=0;           ev_dir[15] = 0;
ev_dir[16]=IdEtc;       ev_dir[17] = offsetEtc ;
ev_dir[18]=IdCalStamp; ev_dir[19] = offsetCalStamp ;
```

Figure 4. Code showing how the event directory is filled in DAQ.

1.2.3.3 Other data words in the event header (event ID)

ev_number (event header word 0)

ev_type (event header word 1): 0=special; 1=physics; 2=FCal calibration (pulser); 3=random (pedestal); 4=BPC calibration

ev_time[2] (event header words 2-3). Contain the readings from the 32-bit 10 MHz decounter restarted at each Start-of_Spill with the initial value 0xFFFFFFFF. Example of unpacking of the event time in Fortran:

```
        integer*2 ev_time(2)
        integer EvTime
        equivalence (EvTime,ev_time)
              ...
* after reading of next event
        ev_time=-1-ev_time ! the event time in 100 ns units
```

Same, in C:

```
        unsigned int EvTime;
        unsigned short ev_time[2];
        ...
        // read next event
        EvTime=0xffffffff-(ev_time[1]<<16 | ev_time[0]);
```

ev_trigger (event header word 4) . Contains various trigger bits latched by CAMAC registers LeCroy 4448 and CEN 2047. See Fig. 5 for details.). The signals are latched by the common busy of CIRQ which is delayed by ~70-80 ns wrt to the trigger.

run_number (event header word 5)

error (event header word 7) if non-zero, indicates fatal read-out anomaly (or anomalies);

LeCroy 4448 48-ch Coincidence register *(N6 "Latch").*
Gate: L1 delayed

```
ch  0   - S1                     ev_trigger bit  0
    1   - S2                                     1
    2   - S3                                     2
    3   - Veto                                   3
    4   - TC123 Sum                              4
    5   - TC456 Sum                              5
    6   - Muon                                   6
    7   - SFiber                                 7
                              CIRQ input (1-6)
    8   - Beam trigger             2             8
    9   - Pedestal trigger         4             9
    10  - Calib trigger            5             10
```

PatternB CEN 2047 *(N15 "Pile-up"). Gate: ??*

```
ch  0  - Late Pileup Flag                        11
    1  - Early Pileup flag                       12

    2  - CEDAR 6/8                               13
    3  - CEDAR 7/8                               14
    4  - CEDAR 8/8                               15
```

Figure 5. The `ev_trigger` word of the event header

`flag` (event header word 7)

```
bit 0 - undefined
bit 1 - out-of-spill flag (an OR of the software and hardware
        out-of-spill flags)
bit 2 - undefined
bit 3 - CIRQ start-of-spill bit
    4 - CIRQ beam trigger bit
    5 - CIRQ end-of-spill bit
    6 - CIRQ random (pedestal) trigger bit
    7 - CIRQ monitor (pulser) trigger bit
    8 - CIRQ BPC calib trigger bit
```

For example: `flag=0x82` means "an out-of-spill" pulser trigger.

1.2.4 An example of an event `hexdump`

Data file: /raid/data/calib/cal550.dat

```
                                 - EvLen -
0000900 .... .... .... ff00 0001 92ae ff01 0000  event header
0000910 001a 0001 0002 0000 0000 0000 0226 ff02
0000920 0029 ff03 0000 ff05 0000 ff06 0000 0000
0000930 0000 0000 0000 0000 0000 0000 0000 fffe
0000940 0000 ffff 001b ffff 0000 000b 0040 0000  id=0xFFFF
0000950 0000 0000 0000 0000 0000 0000 1f40 0000
0000960 0000 ff02 0001 9280 ffff ffff ffff ffff  id=0xFF02
```

```
0000970 ffff ffff ffff ffff ffff ffff ffff ffff
0000980 ffff ffff ffff ffff 4303 4303 0302 0302
0000990 0301 0301 4300 4300 0307 0307 4306 4306
00009a0 4305 4305 0304 0304 0da3 0da3 0da3 0da3
00009b0 0da3 0da3 0da3 0da3 0da3 0da3 0da3 0da3
......
```

1.3 Utilities

The utility programs to manipulate data files are stored in /home/daq/Daq/bin directory, on pcfcal01. The sources and .h files are in /home/daq/Daq/src and /home/daq/Daq/include, respectively.

1.3.1 rd_run, to dump the contents of a data file

```
rd_run <filename>
```

For example: `rd_run /raid/data/calib/cal600.dat`

This program is good for all data files (old and new format).

2 Run Configuration and Control keys

A *key-record* in FCal DAQ is just a text line beginning with an alphanumerical *keyword* followed by one or several *values,* all separated by any number of blanks. It can, optionally, contain a comment. Thus, there is nothing new or special about it: for example, Linux configuration files are based on a similar concept.

For FCalTB DAQ, key-records are important as

- a method of defining the run book-keeping/configuration information;
- a basis of the internal configuration data-base (DB);
- a method of storing the configuration/settings information (*meta-data* in ATLAS jargon) together with the raw data (in run headers, Section 1.2.1).

Having ASCII keyword-based configuration files makes it easy to modify the DAQ configuration and keep it readable, self-documented and compact. The run-settings generated by the run-control panel are also in this format.

If a new keyword with a correct formal syntax is added to any configuration file, it will be automatically copied to the run header and to the internal DAQ data base (DB). The value specified in this new key (or a list of values, for multi-value key-records) can be retrieved in the DAQ by a simple generic call to the internal DAQ DB.

The advantages of retaining this form for the run headers is that

- no special browser is required to see the run configuration for a given data file (e.g., one can use `od –c | more` or even just `more` to see quickly the run header contents);
- most importantly, it provides a natural solution to the test beam Conditions/Configuration data base problem: the relevant DB information is simply *attached* to the data itself, in a portable and flexible form, easily convertible to any post-data-taking data base. We were not bound to any specific DB specification during the data-taking, but our raw data is intrinsically DB-ready. On the other hand, the underlying online software is very light-weight and transparent, with only rudimentary internal DB functionality implemented (store, retrieve, dump).

The configuration and control information is read from several configuration files at a run start. All meaninful records (keys) from these files are copied to the run header as plain 64-byte long character strings (C language `char[64]` type). All keys appearing in FCal data files are described in this Chapter.

The syntax of a key-record is as follows:

```
keyword value [values..] [// comment]
```

The keyword // (double-slash) indicates "end-of-data". All records that follow are ignored.[4] A // in the middle of the record separates the value(s) from an optional comment. The keyword * (asterisk) signifies a purely commentary line. For example:

```
* An example of a short configuration file
RunNumber 287
miniROD   1    2    3
FebAddr    0x22 0x28 0x31  // this is a comment
// -- this is end-of-data, followed by spare records
CalNtrig 1000
CalDac 1000
CalNpatt 1
CalPatt_0 0 7 15 21:47;8 90:127
```

The numerical values are either (signed) decimal integers, or hexadecimal numbers (0x....). Text values need not be quoted. Multivalue keys are detected automatically. The following syntax can be used to specify groups of numbers:

n1:n2[;n3]   A *range*, for example `0:127;16   12:34`

Ntimes*Value   A *multiplier*, for example `20*0`

An example of a complete run header is given in Appendix 2-A.

Some limitations of the key-record syntax, namely:

- the keyword must start in the first character;
- no support for multi-line keys;
- the limited record length (64 characters),

were intentional, to keep the key-record handling codes (`rhlib` package, briefly described in Appendix 2-B) simple and robust. These limitations are compensated by a rich multi-value functionality.

2.1 Keys from the run...par (conditions) file

key	*# of values*	*Default value(s)*	*Value type, description and range*
RunNumber	1	-	int, <65535 *e.g. RunNumber 500*
RunType	1	1	int, 1=phys, 2=calib, 3=ped, 0 = special *e.g. RunType 2*
DataStore	2	0 none	V1=int, raw data destination 0=none, 1=file(directory), 2=dispatcher (@host) V2=text string *e.g. DataStore 1 /raid/data/calib*

[4] This feature is used in the DAQ configuration files to hide spare records behind the //. Neither the // keyword, nor the records that follow are copied to the run header. Purely commentary lines (the ones starting with an *) are also not copied to the run header. On the other hand, some commentary lines can be generated by the DAQ itself (see Section 2.3).

DataStore 2 @pcfcal01
DataStore 0 none

key	*# of values*	*Default value(s)*	*Value type, description and range*
BeamMomentum (22/06/03)	1	0	int, beam momentum in [GeV], always positive *e.g. BeamMomentum 200*
BeamParticle	1	-1	int, the dominant beam particle, if known : 1 =e+, 2 =pi+, 3 =p+, 4 =mu+, 11=e-, 12=pi-, 14=mu-, (22/06/03) -1 unknown/irrelevent *e.g. BeamParticle 11*
CryoX[5]	1	0	int, the cryostat lateral (X) position, in [mm] *e.g. CryoX 25*
CryoAngle[5]	1	0	int, the cryostat angle, in [degrees] *e.g CryoAngle 5*
TableY	1	0	int, the table vertical (Y) offset, in [mm] *e.g. TableY -18*
BeamSpot	1	-1	int, the beam spot position 1 = spot_1 in the Run Control panel 2 = spot_2 -"- 3 = spot_3 -"- 4 = spot_4U -"- 5 = spot_4D -"- -1 = undefined -"-
ReadOutMask	1..10	All	text, list of data blocks to be recorded. All - all connected hardware Fcal - miniRODs Time Tail - tail catcher counters Bpc - wire chambers Soft - software data CalB - calibration board data for calib events XXXX=0 - to suppress block XXXX *e.g. ReadOutMask All Tail=0*
miniROD	1..8	0	int, miniRODs used. The read-out is done in the same order, as they are listed. *e.g. miniROD 1 3 4* *miniROD 1:8*
Bpc	1..6	0	int, BPCss used. The read-out is done in the same order, as they are listed. *e.g. Bpc 1 3* *Bpc 1:6 // all BPCs*
MaxEvents	1	1e10	int, Run limit condition by number of events. This is a soft condition. The actual number of events in a run can be larger, because DAQ never stops in the middle of a spill.

---

[5] 22/06/03 obsolete, replaced with BeamSpot

MaxBursts	1	1e10	int, Run limit condition by number of bursts.
RunDebug	15	all 0	int, Print level for different DAQ components 0 - no print 1 - a few prints per run 2 - a few prints per event 3 - a dozen prints per events 4 - prints too much (debug level)

2.2 Keys from the cal_...par file

key	*# of values*	*Default value(s)*	*Value type, description and range*
CalSDelays	any	0	int, list of calibration pulse delay(s) in the corresponding calibration super-cycles, in [ns]. The CalSDelays key makes a CalDelays key void (ie, the latter will not be taken into account) *e.g. CalSDelays 0:17 // 18 super-sycles with constant delays 0,...,17*
CalNtrig	1	0	int, number of consequtive cal. pulses with the same parameters. *e.g. CalNtrig 1000*
CalDac	1..256	0	int, list of DAC values for each pattern *e.g. CalDac 1000:10000;500* *CalDac 0x12345*
CalNpatt	1	1	int, number of palibration patterns in one super-cycle.
CalPatt_x	1..128	0:127	int, list of FEB pins to be pulsed in the corresponding pattern "x" (x=0..127) (ie, CalPatt_0 - for pattern #0, CalPatt_1 - for pattern #2 etc) *e.g. CalPatt_14 0 7 15 21:47;8 90:127 // a weird pattern*
CalDelays	=CalNpatt	0	int, list of calibration pulse delays in [ns], for each of the requested patterns. This key is ignored if a CalSDelays key appears in the same configuration file. The number of values should be equal to the number of patters requested by CalNpatt key. *e.g. CalNpatt 20* *CalPatt_0 ...* *...* *CalPatt_20 ...* *CalDelays 0:10 9*11 // 0,1...10 ns, followed by 9 delays of 11 ns*

2.3 Keys added by the online software

RunDate	1	-	int, the run start date, as YYYYMMDD *e.g. RunDate 20030512*
RunTime	1	-	int, the run start time, as HHMMSS *e.g. RunTime 142501*

RunStopDate	1	-	int, the run stop date, as YYYYMMDD e.g. RunDate 20030512
RunStopTime	1	-	int, the run stop time, as HHMMSS *e.g. RunTime 142501*
Events	1	-	int, total number of event records in the run
*** pathname**	-	-	a purely commentary line containing the full pathname of the configuration file from which the following key-records are read *e.g. * -------------- /raid/daq/config/par/cam/test_cam.par*

2.4 Keys related to the trigger grading

Define the trigger ratios during the spill and, optionally, disable main types of triggers. Value 0 means "disabled". The mechanism, proposed by A.Savin, works as follows. At start of run the software downcounters for Beam, Pedestal and Calibration triggers are preset with the values defined by the run header keys (see below). Upon reaching 0, the corresponding trigger is disabled until all other downcounters have reached zero values. Then whole cycle repeats. Between the spills, as many pedestal and calibration triggers are taken, as were during the previous spill. Thus, a zero preset value disables the corresponding trigger completely.

key	*# of values*	*Default value(s)*	*Value type, description and range*
TrigBeam	1	0	int, the preset value for "Beam" down-counter
TrigPed	1	0	int, same, for "Pedestal" (random) trigger
TrigFcal	1	0	int, same, for "Calibration" (monitor) trigger

2.5 Keys related to the front-end electronics

FebSamples	1	7	int, the number of samples recorded by FEBs. Range: 3...32 *e.g. FebSamples 32*
FebGains	1..3	0	int, 0=auto, 1=low, 2=med, 3=high Note that in data the notation is different (Section 3.1.1): 0=low, 1=med, 2=high *e.g. FebGains 1 2*
FebAddr	1..8	0	hex, SPAC addresses of installed FEBs, listed in the increasing order of the corresponding miniRODs *e.g. FebAddr 0x28 0x26 0x3F 0x22 0x30 0x3A 0x12 0x21*
FebTimeout	1	1000	int, miniROD time-out, in ms
FebDacOffset	1	0xc00	int, pedestal setting. Value 0xc00 corresponds to about 1000 ADC counts.Increasing this parameter results in *decreasing* of the pedestal. Currently, the default value is the unique setting for all the FEBs.
FebAutoGainThr	2	1150 3500	int, the thresholds (in terms of ADC counts in medium gain) for switching to the high and low gains, respectively. These parameters are only meaningful if the auto-gain mode is selected (FebGains 0)
FebFirstSample	1	3	int, the sample number (counting from 0) whose pullseheight a FEB has to use to choose the gain in the auto-gain mode. A cyclic shift is performed on the first (FebFirstSample+1)

key	# of values	Default value(s)	Value type, description and range
			samples, as described in Section 0 This parameter is ignored for the fixed gain mode(s), when it is reset to 0 (so no sample re-ordering occurs and all the samples appear in data in the chronological order).
FebReadDelay	1	0x11	int, the crude signal time tuning ("trigger latency"), n 25 ns steps
TtcPdgDly	1	200	int, the fine signal time tuning (common PDG delay), in 50 ps steps
TtcFanDly	8	0	int, individual signal time tuning for different FEBs, in 2.5 ns steps.

2.6 Keys related to CAMAC

All keywords starting with `Cam` refer to CAMAC readout. They are usually defined in the `par/cam/....par` file specified by the `ConfCam` key in the run header. There are two groups of such keys: the ones specifying slots (statioN numbers) of all CAMAC hardware modules used in the readout – *module locatorss*, and the ones describing a complete chain of CAMAC calls necessary to read specific detectors – *readout descriptors*.[6] An additional `CamSlTest` key is used for CAMAC debugging purposes. See Appendix 2-A for examples of `Cam…` keys.

Module locators have a variable number of integer values, as there can be several CAMAC modules of the same type (e.g., LeCroy 2249A ADC). The key values are the corresponding slot numbers (ranging from 1 to 23). The syntax permits the crate number to be specified (as C*100+N), but if there is only one CAMAC crate, its number is assumed by default. The available module locator keywords (corresponding to "classes" internally defined in the DAQ) are listed in Table 1.

Table 1. CAMAC module locator keywords

CamBorer	BORER dataway display
Cam2228A	LeCroy 2228A TDC
Cam2249A	LeCroy 2249A ADC
CamSc2551	SEN 2551 Scaler
CamOR2088	SEN 2088 Output Register
CamPattB	Pattern Unit B
Cam4448	LetCroy 4448 48-ch Coincidence
CamRTC	Real Time Clock

[6] Strictly speaking, readout descriptors alone would be sufficient for defining the CAMAC readout. However, the module locators introduce a useful redundancy, helping to reduce a probability of mistakes. Any N (slot number) appearing in readout descriptors is required to be described in module locators. This permits further checks: for example, the BPC time readout checks that the N corresponds to a 2228A TDC and the F is a valid function for it. DAQ has an internal library of "classes" for all CAMAC devices used in the readout.

The readout descriptor defines a list of CAMAC NFA's, encoded as integers N*10000+F*100+A, for each DAQ part read out or interfaced via CAMAC, see Table 2.

Table 2. CAMAC readout descriptor keywords

Keyword	Description
CamEvClock	Trigger timing wrt the 40 MHz clock
CamPattern	Trigger bit pattern, r/o bits
CamBpc_X	X=1-6; beam chambers
CamTime	Trigger signal timing, TDC
CamTail	Tail catcher, ADC
CamBeam	Beam detectors, ADC
CamOutReg	Software pulser

2.7 Keys referring to the configuration files

At a start of run, a global configuration file referred to by the `RunConf` key is specified via the Run Control Panel. This file iself contains references to other configuration files (via `ConfTrig, ConfFeb, ConfCal, ConfCam` keys)[7]. The file names are relative to the base directory defined by the `$DAQ_CONF_PATH` environment variable, usually `/raid/daq/config`

Examples:

RunConf Special/HighG_beam_ped.v0

ConfTrig par/trig/0_300_0.par

ConfFeb par/fe/highG_7sam.par

ConfCal par/cal/cal0.par

ConfCam par/cam/test_cam.par

[7] As well as some other records which are not (yet) configurable via the Run Control Panel, like ReadOutMask, RunDebug etc).

3 Event sub-blocks

The event sub-blocks other than the event header are described below.

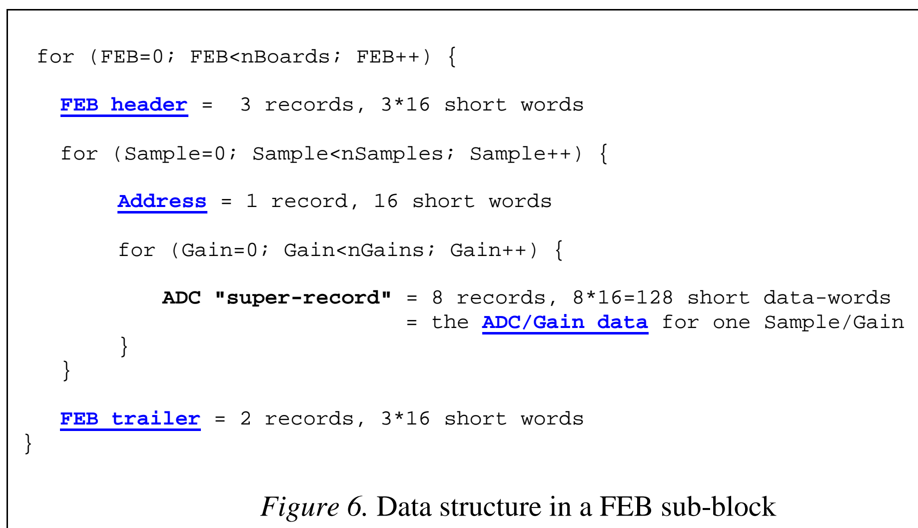
3.1 FEB Data

The information about the FEB data format is sparse and not always consistent. The main source is Ref. [3-3]. A very detailed description of the FEB operation is in Ref. [3-1]. miniRODs (Ref.[3-2]) preserve the FEB data format.

3.1.1 The sub-block structure

```
SubBlockId   : 0xFF02
Len          : nBoards*(3+nSamples*(1+nGains*8)+2)*16
```

The data part is sequence of logical "records" of 16 short integer words. The contents of a record varies depending on the context within the sub-block, as illustrated by Figure 6: it can be one of FEB **header** or **trailer** records, an **address** record, or a **ADC/Gain data** record,



```
 for (FEB=0; FEB<nBoards; FEB++) {

   FEB header =  3 records, 3*16 short words

   for (Sample=0; Sample<nSamples; Sample++) {

       Address = 1 record, 16 short words

       for (Gain=0; Gain<nGains; Gain++) {

          ADC "super-record" = 8 records, 8*16=128 short data-words
                             = the ADC/Gain data for one Sample/Gain
       }
   }

   FEB trailer = 2 records, 3*16 short words
}
```

Figure 6. Data structure in a FEB sub-block

The parameters `nBoards, nSamples, nGains` come from the run header:

nBoards = number of values in the `miniROD` key of the run header
`(e.g., rh_get_int("miniROD", &nBoards, ...) )`

nSamples = the value of the `FebSamples` key of the run header
`(e.g., rh_get_1int("miniROD", &nSamples) )`

nGains = number of values in the `FebGains` key of the run header
`(e.g., rh_get_int("FebGains", &nGains, ...) )`

The FEB control words (header and trailer) contain some fixed patterns (words), which can be checked to test the data integrity.

```
Feb Header:
   record 1:  16* 0xffff = "start-of-event" words
   record 2:  ????
             Example: 4303 4303 0302 0302 0301 0301 4300 4300
                      0307 0307 4306 4306 4305 4305 0304 0304
   record 3:  16* (bits 0-11: "bunch-crossing number", bit 14: OP)
```

The meaning of "record 2" remains unclear. My guess is: bits 0-3=ALTERA #, bits 8-9: ? (always 3), bit 14=OP. See Ref [3-3] p.4 for more insight…

```
Feb Trailer:
   record 1:  16* ( bit 0: 1, bits 1-11: "error word", bit 14: OP)
                                "error word" = 0 means "no errors"

   record 2:  16* 0x0000 = "end-of-event" words
```

The **Address** record should contain the Gray-coded SCA cell number (bits 0-7) and a certain number *nn* (bits 8-11), plus bit 14=OP. According to Ref.[3-3], *nn* is either the ADC number, or the Sample number. The former seems to be excluded, while the latter is yet to be checked. Quite a few tests are applicable here (Grey code, identity of cell numbers). A function `samplecell` to convert the coded cell number to a sequential number is available.

In the ADC data **super-records**, each word contains the **ADC/Gain data** from a certain FEB input channel (input pin). The word order (i.e., the correspondence between the FEB input channels and the word numbers) is described in the Appendix 3-C. It known from F.Lanni's codes and was corrected for the new base-plane design (in addition, it was directly checked with an oscilloscope).

Each ADC **data-word** is formatted as follows (Ref.[3-3], p.3):

```
unsigned int ADCvalue       : 12 bits; // bits 0-11
unsigned int Gain           : 2 bits;  // bits 12-13 (3=high, 2=medium, 1=low)
unsigned int ParityOdd      : 1 bit ;  // bit 14     (OP = odd parity)
unsigned int ADCflag=0      : 1 bit ;  // bit 15
```

Bits 12-15 have special meaning in all FEB records:

- **bits 12** and **13** are both 0, except for ADC/Gain data and start-of-event words;
- **bit 15** is always 0, except for start-of-event words;
- **bit 14** is the odd parity (e.g., 1 if all other bits are 0), except for start-of-event and end-of-event words.

A simple code to unpack one FEB and get a pointer to the next FEB is given in the Appendix 3-A. A summary of FEB- and miniROD related run header key-records is given in Appendix 3-B.

3.1.2 Special considerations for auto-gain runs

In the "auto-gain" mode, one has to determine the sample corresponding to the signal peak and program the Altera FPGA controller accordingly. The FCal test beam trigger timing had been adjusted to have the signal peak close to sample 3 (counting from sample 0), in all FEBs. The FCal DAQ conveys this information to the Altera via the `FebFirstSample` configuration key-record (Section 2.5).

It turned out that if a non-zero `FebFirstSample` parameter is loaded, the Altera performs a cyclic shift of all the samples up to the sample=FebFirstSample.[8] For example, if `FebFirstSample` is `3,` then the sample order in the data is

```
3, 0, 1, 2, [4, 5, 6...]
```

Therefore, the offline programs should re-order the samples when (and only when, see the important remak below) the parameter `FebGains` in the run header is set to 0:

```
FebGains 0  // 0=auto, 1=low, 2=med, 3=high
```

This and all other important parameters can be obtained from the run header (Section 2.5).

Important! For fixed-gain runs (non-zero `FebGains`) the parameter FebFirstSample, even if it is specified with a non-zero value (as was the case for the early FCal test beam runs, up to run 1435), must be ignored, because DAQ resets it to zero internally. The unpacking software should check the value of the FebGains key first and only if it is non-zero, apply the sample re-ordering according to FebFirstSample.

3.2 Beam chambers data

3.2.1 The sub-block structure

```
SubBlockId   : 0xFF05
Len          : nBPC*6 short words
```

The sub-block contains raw amplitide (ADC) and time (TDC) data from the beam profile chambers (BPCs). The data part of the sub-block, as shown in Fig. 7, consists of *nBPC* groups of 6 integers, where *nBPC* comes from the run header:

nBPC = number of enabled BPCs = number of values in the `Bpc key in the run header,`
`(e.g., rh_get_int("Bpc", &nBpcs, ...) )`

[8] That the samples can be sent in a non-sequential order was indicated in Refs.[3-3] and [3-4], as a "possibility". I could not find any other documentation explicitly describing this behaviour.

```
for (BPC=0; BPC<nBpc; BPC++) {

    word 0 : X-plane ADC    }  10 bits data + 1 overflow bit
    word 1 : Y-plane ADC    }  (meaningful values: <1024)

    word 2 : TDC Xright } 11 bit data + 1 overflow bit
    word 3 : TDC Xleft  } (meaningful values: <2048
    word 4 : TDC Yup    }
    word 5 : TDC Ydown  }
}
```

Figure 7. Data structure in a BPC sub-block

3.2.2 A brief description of the BPCs and how to interprete the BPC data

The technical details about the BPCs can be found in Ref.[3-5].

BPC numbering: the BPCs are numbered from 1 to 6, according to their physical location along the beam:

- BPC 1 and 2 are the most upstream chambers (new X-Y type);
- BPC 3 and 4 are the "chambers" located midway to the cryostat; they are, actually, 4 old single-projection ITEP chambers, arranged in two X-Y pairs;
- BPC 5 and 6 are the chambers installed in front of the cryostat (new X-Y type).

Z-positions (in mm, related to Ch.1-X) (courtesy V.Epstein):

```
Z(1X) = 0;     Z(1Y) = 31;    Z(2X) = 177; Z(2Y) =  208;
Z(3X) = 11076; Z(3Y) = 11154; Z(4X)=11219; Z(4Y) =11294;
Z(5X) = 27645; Z(5Y) = 27676; Z(6X)=27745; Z(6Y) =27776;
```

Meaning of the data: each chamber has two wire planes measuring horizontal (X) and vertical (Y) positions of a beam particle. One plane measurement consists of a pair of TDC readings (right/left for X or up/down for Y) and an ADC reading (cathode signal amplitude, needed for event selection and corrections).

The time measurement is done with 11-bit LeCroy 2228A TDCs (Ref.[3-6a]). Bits 0-10 of the TDC words are data, bit 11 signals overflow. Thus, meaningful TDC values are 0-2047. The amplitude measurements are done with LeCroy 2249A ADC (Ref.[3-6b]).

The beam position can be derived from the TDC measurements[9]:

$$X_i = C1_{xi} \cdot (Xleft_i - Xright_i - C2_{xi})$$
$$Y_i = C1_{yi} \cdot (Ydown_i - Yup_i - C2_{yi})$$

The resulting values are in *mm*, with +ve X pointing to Geneva, -ve X – to Jura, +ve Y pointing up and -ve Y – down. This formula is accurate down to better than 0.5 *mm*. The corresponding calibration constants C1 and C2 are listed in Table 3. To obtain the ultimate accuracy of better than 150 μ per plane, one has to apply a specal calibration, on the run-by-run basis (work in progress).

[9] This is a simplified formula, good for the cases when the an accuracy of about 1 mm is sufficient. See Ref. [3-5] for more details.

Table 2. calibration constants (last correction: 04/07/03)

	Up to run 1722	*as of run 1740*		*Up to run 1722*	*as of run 1740*
C1x(1)=	0.0497	0.0518	C1y(1)=	0.0496	0.0523
C1x(2)=	0.0493	0.0513	C1y(2)=	0.0506	0.0521
C1x(3)=	0.0533	0.0532	C1y(3)=	0.0527	0.0525
C1x(4)=	0.0527	0.0526	C1y(4)=	0.0539	0.0539
C1x(5)=	0.0488	0.0489	C1y(5)=	0.0498	0.0499
C1x(6)=	0.0476	0.0477	C1y(6)=	0.0480	0.0480
C2x(1)=	16.	34	C2y(1)=	-4.	2.
C2x(2)=	-9.	2.	C2y(2)=	-11.	-13.
C2x(3)=	-26.	-27.	C2y(3)=	-4.	-3.
C2x(4)=	-7.	-9.	C2y(4)=	3.	5.
C2x(5)=	-13.	-12.	C2y(5)=	-42.	-42.
C2x(6)=	-24.	-22.	Co2y(6)=	-20.	-19.

3.2.3 BPC-related Run Header keys

Obligatory: CAMAC read-out descriptors (NFAs), see Section 2.6.

```
CamBpc_x <list of NFAs>  //  x=1-6
```

Example:

```
Cam2228A  2 4 8 10 // TDC module locator
Cam2249A  12 14 18 // ADC module locator
CamBpc_1 100000 100001 20000:20003 // adc X,Y  tdc R,L,U,D
       ...
CamBpc_6 100010 100011 40004:40007
```

Optional: selection of BPC's to read (default: all); usually defined in the `par/run/...par` file.

```
Bpc <list of enabled BPCs>
```

Example:

```
Bpc 1 2 5 6 // the BPCs will be read-out in that order!
```

3.3 Beam detectors, Tail Catcher, TIME data

3.3.1 Beam detectors sub-block

```
SubBlockId   : 0xFF06
Len          : 11 short words
```

Word	meaning	ch	CAMAC module
0	S1	0	ADC 2249A (N12 "BEAM")
1	S2	1	
2	S3	2	
3	Veto	3	
4	SFiber	4	
5	SFiber-amp	5	amplified??
6	Muon word	6	
7	S2	0	TDC 2228A (N2 "TIME/BEAM")
8	S3	1	
9	Veto OR	2	
10	TC "antenna"	7	ADC 2249A (N12 "BEAM") added on June,27 2003

3.3.2 Tail Catcher sub-block

```
SubBlockId   : 0xFF04
Len          : 12 short words
```

Word	meaning	ch	CAMAC module
0-5	TC1-TC6 High gain	0-5	ADC 2249A (N14 "TAIL")
6-11	TC1-TC6 Low gain	6-11	

3.3.3 Time sub-block: id 0xFF03

```
SubBlockId   : 0xFF03
Len          : 2 short words
```

Word	meaning	ch	CAMAC module
0	40 MHz clock	3	TDC 2228A (N2 "TIME/BEAM")
1	40 MHz clock+12.5ns	4	
2	scaler		time elapsed since the previous particle crossing
3	scaler		same, downscaled

This sub-block is used to determine the phase of the calorimeter signal with respect to the 40 MHz TTC (sampling) clock. The TDC is started by the trigger; the ch. 3 measures the TTC Clock signal (that is, the falling edge of the Clock nearest to the trigger) and the ch. 4 measures the same signal delayed by ~10 ns[10].

[10] The TTC Clock is a 40.08 MHz pulse generator, with a pulse width somewhat smaller that a half-period. The delayed Clock is obtained by inverting the Clock signal.

The redundancy permits a) to calibrate the TDC and b) to resolve the ambiguities occurring when the trigger and the Clock pulse arrive almost simultaneously to the TDC.

3.3.4 Notes about the CAMAC modules

- ADC 2249A (N12 "BEAM"), 10 bits (0-1023)
- TDC 2228A (N2 "TIME/BEAM"), 50 ps res, range: 11 bits (0-2023, bit 11=overflow); Start: S1*Gate
- TDC 2228A (N2 "TIME/BEAM"), 50 ps res, range: 11 bits (0-2023, bit 11=overflow); Start: S1*Gate

3.4 Calibration Board Stamp

3.4.1 The sub-block structure

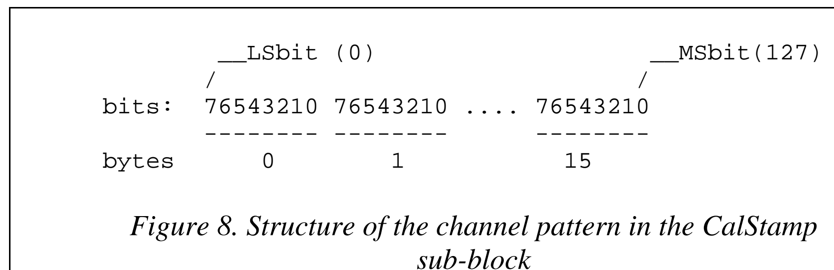
```
SubBlockId   : 0xFFFF
Len          : 11 short words (22 bytes)
```

The sub-block contains a complete pulser board information (a "stamp") for a given event.The data is a direct copy of the byte string read from the pulser board after it had been prepared to deliver the calibration pulse for the given event. This sub-block appears only in pulser events (type 2).

Data format: a string of 22 bytes

```
bytes  0-15 (16 bytes, 128 bits): the bit-pattern of the pulsed channels
                                  (see next subsection for further details)
bytes 16-19 (4 bytes,  32 bits) : the DAC value (pulse amplitude)
                            byte 16 = LSByte
                            ...
                            byte 19 = MSByte
                            For example: f8 2a 00 00 means DAC=11000


byte   20    (1 byte,   8 bits)  : the delay value, in units of ~1 ns
byte   21    (1 byte,   8 bits)  : error word (OK=0, if non-zero, the
                                  event should be discarded)
```



```
          __LSbit (0)                   __MSbit(127)
         /                             /
bits:   76543210 76543210 .... 76543210
        -------- --------      --------
bytes       0        1            15
```

Figure 8. Structure of the channel pattern in the CalStamp sub-block

3.4.2 How to decode the channel pattern

1. Considering bytes 0-15 as a contiguous bit-string (Fig. 8), make a list of non-zero bits, with the bits numbered from 0 to 127.

2. For bit numbers in the ranges (32-63) and (96-127), the bit number coinsides with the FEB input channel number. For all other bits, the odd and even numbers must be swapped (e.g., bits 0 and 1 correspond to the channels 1 and 0, respectively; bits 64 and 65 - to channels 65 and 64 etc).

The code in Fig. 9 illustrates the channel decoding (`/home/daq/Daq/include/my_event.h` and `/home/daq/Daq/lib/my_event.c`)

```
typedef struct {
  union{
    struct {
      unsigned char pattern[16];
      unsigned char dac[4];
      unsigned char delay;
      unsigned char error;
    };
    unsigned char data[22];
  };
} Cal_Stamp_t;
....
//-------------------------------------------------------------
   void cal_stamp_dump (Cal_Stamp_t *cal_stamp) {
//-------------------------------------------------------------
// Print-out the calibration stamp
   int nch,n,j,k;
   unsigned long *Dac;
   unsigned char ch;

   printf("Cal_Stamp: "); for(j=0;j<22;j++) printf("
%02x",cal_stamp->data[j]);

// decode the channel pattern (convert the pattern bits numbers
into FEB pin numbers)
//
   n=0;
   for(j=0;j<16;j++) {
     ch=cal_stamp->pattern[j];
     for (k=7;k>=0;k--) {
       if((ch>>k)&1) {
         if( (n/32)%2 )
           nch=n;
         else
           nch=n%2?n-1:n+1;
         printf("n=%d nch=%d",n,nch);
       }
       n++;
     }
   }
   Dac = (unsigned long *)cal_stamp->dac;
   printf("\n ch=%d DAC=%d delay=%d error=0x%02x \n",
          nch,*Dac,cal_stamp->delay,cal_stamp->error);
   }
```

Figure 9. An example of the channel pattern decoding in the Calibration Board Stamp sub-block

Appendix 2-A: an example of a complete run header block

```
* --------------µ/raid/daq/config/par/runs/run1461.par
RunNumber 1461
RunType 0
RunConf Special/HighG_beam_ped.v0
DataStore 1 /raid/data
BeamMomentum 200 GeV/c
BeamParticle 11 //  e-
BeamSpot 5      // 4D
MaxEvents 1000
* --------------  /raid/daq/config/Special/HighG_beam_ped.v0

ConfTrig par/trig/0_300_0.par
ConfFeb par/fe/highG_7sam.par
ConfCal par/cal/cal0.par
ConfCam par/cam/test_cam.par
ReadOutMask  Fcal Bpc Time Tail Beam

miniROD 1:8

Bpc     1:6

* --------------  /raid/daq/config/par/trig/0_300_0.par
TrigBeam 0
TrigPed  300
TrigFcal 0
* --------------  /raid/daq/config/par/fe/highG_7sam.par
FebSamples      7
FebGains        3
FebAddr         0x28 0x26 0x3F 0x22 0x30 0x3a 0x21 0x12

miniROD         1    2    3    4    5    6    7     8

FebTimeout      1000
FebDacOffset    0xc00
FebAutoGainThr  1350 3500
FebReadDelay    0x11
FebFirstSample  3
TtcPdgDly    150
TtcFanDly  0 0 0 0 0 0 1 0

* --------------  /raid/daq/config/par/cam/test_cam.par
CamBorer  1
Cam2228A  2 4 8 10
Cam2249A  12 14 18
CamSc2551 20
CamOR2088 22
CamPattB  15
Cam4448   6
CamRTC    23
CamEvClock 230000 230001
CamPattern 60200 150200
CamBpc_1 180000 180001 40000:40003
CamBpc_2 180002 180003 40004:40007
CamBpc_3 180004 180005 80000:80003
CamBpc_4 180006 180007 80004:80007
CamBpc_5 180008 180009 100000:100003
CamBpc_6 180010 180011 100004:100007
CamTime  20003:20004
CamTail  140000:140011
CamBeam  120000:120006 20000:20002
CamOutReg 221700
CamSltest 200

RunDate 20030620
```

RunTime 155336

Appendix 2-B: rhlib package, to handle the run-header records

Author: P. Gorbunov
Source: /home/daq/Daq/include/rhlib.h and /home/daq/Daq/lib/rhlib.c
Purpose: The internal DB to manage the run header data

These codes are not DAQ-specific and can be used in offline applications (including Fortran). The following C-functions are available:

void rh_init(void);
To reset the run header structure. The existing structure is dropped.

void rh_import(void *rh_addr, int rh_len) ;
To drop the existing run header structure and copy a new structure of rh_len bytes from the pointer rh_addr

void rh_export(void **rh, size_t *rh_len) ;
Returns the address (rh_addr), the total size in bytes (rh_len) of the run header structure.

void rh_put_str(char *key, char *str) ;
To append the keyword "key" + string "str" to the run header.

int rh_get_str(char *key, int *n, char **str, int max_len, int max_val) ;
To get string fields from the "key" and store them in the array of pointers "str" of size "max_val", each pointing to a string of at least "max_len" bytes.

void rh_put_int(char *key, int n_val, int *values) ;
To add the key-record "key" with "n_val" integer values.

int rh_get_int(char *key, int *n, int *val) ;
To retrieve int value(s) with the key-record "key". *Range* fields f:l[;s] (l>=f, s>0), as well as *multiplier* fields v*m (m>0) are interpreted.

int rh_get_1int(char *key, int *value) ;
To get a single int value from the "key".

void rh_put_1int(char *key, int value) ;
To add a key-record with a single integer value.

void rh_read (char *header_fn) ;
To append the contents of file "header_fn" to the run header structure.

void rh_write (char *header_fn) ;
To write the run header in ASCII form to file **header_fn**.

void rh_dump (void);
To dump the contents of the run header structure

int rh_find_first(char *key) ;
Returns the record number for the first appearance of "key", or -1 if "key" is not found

int rh_find_last(char *key) ;
Returns the record number for the last appearance of "key", or -1 if "key" is not found

int rh_give(char *keyp, char *valp, int *irc, int keyl, int vall) ;

Iterates over the run header records. If `*irc==0`, starts from the beginning. Returns the keyword in `keyp` `(`up to keyl characters), and the value field string in `valp` (up to `vall` characters). Returns `*irc=-1` if the run header is exhausted, otherwise `*irc` is the recird length.

Fortran-callable versions of the following routines are available: **rh_init, rh_read, rh_dump, rh_get_int,rh_put_int, rh_get_1int, rh_give, rh_write.**

The source codes can be found in `/afs/cern.ch/user/p/petr/public/fcaltb/lib` .

Appendix 3-A: An example of the FEB-data unpacking code

```
int *miniROD_unpack1(int *EvBuffer, rdFEB_t *Event ) {

// a simplified FEB block unpacking
// 19/06/03 PG: sample-reordering
//
  static int FCAL_thr=30;
  unsigned int pedestal;
  int i,j,k,next,nch;
  int ns=run_par.nsamples,ng=run_par.ngains;
  int sort[]={
    55, 39, 23, 7, 119, 103, 87, 71,
    54, 38, 22, 6, 118, 102, 86, 70,
    53, 37, 21, 5, 117, 101, 85, 69,
    52, 36, 20, 4, 116, 100, 84, 68,
    51, 35, 19, 3, 115,  99, 83, 67,
    50, 34, 18, 2, 114,  98, 82, 66,
    49, 33, 17, 1, 113,  97, 81, 65,
    48, 32, 16, 0, 112,  96, 80, 64
  };
  int *p= EvBuffer;
  int gain;
  short *a;

  int s; // the sample number
  static int sort_samples[32]=
  { 0, 1, 2, 3, 4, 5, 6, 7, 8, 9,10,
      11,12,13,14,15,16,17,18,19,20,
      21,22,23,24,25,26,27,28,29,30,31};

// re-order the samples for auto-gain runs
//
  if( (run_par.the_gains[0]==0) &&                     // check the gain-selection mode
      (sort_samples[0]=run_par.first_sample)!=0) {     // check for the FebFirstSample != 0
    for(j=0;j<run_par.first_sample;j++) sort_samples[j+1]=j;
  }

  p += NWREC*3;                              // skip the FEB header
  for(i=0; i<ns; i++) {                  // loop over the samples

    s=sort_samples[i];

    p += NWREC;                              // skip the cell record
    for (j=0; j<ng; j++) {               // loop over the gains
      for( next=0; next<64; next++ ) { // loop over the channels
        nch=sort[next];
        a=(short *)p;
       gain= ((a[1]>>12)&3) - 1;
        Event->adc[nch  ][gain][s] = a[1]& 0xfff;
       gain=((a[0]>>12)&3) - 1;
        Event->adc[nch+8][gain][s] = a[0]& 0xfff;
        p++;
      }
    }
  }
  return (p += NWREC*2); // skip the FEB trailer
}
```

Appendix 3-B FEB- and miniROD-related run header keys

Disclaimer: the numbers are not representative...

```
FebSamples      7
FebGains        0 // 0=auto, 1=low (0 in data), 2=med (2 in data), 3=high (2 in
data)
*
FebAddr         0x28 0x26 0x3F 0x22 0x30 0x3a 0x21 0x12 // FEB addr
miniROD         1    2    3    4    5    6    7     8   // the miniRODs to be
read-out
FebTimeout      1000   // ns, miniROD time-out setting
FebDacOffset    0xc00  // DACoffset =  coupleDACoffsets. Offset up, ped down.
0xc00: ped ~ 1000
FebAutoGainThr  1350 3500  // auto-gain thresholds
FebReadDelay    0x11 //  delay up, peak ->; delay down, peak <-
* ------------------------------------------------------------------
FebFirstSample  3  // the peak sample number (starting from 0)
* ------------------------------------------------------------------
*
* TtcPdcDly    0   // Calib pulse delay, 0-4095, in steps of 25 ns (max=6.5 us)
TtcPdgDly    150   // PDG delay  0-4095, in steps of 50 ps (max=200 ns) delay up,
peak <-
TtcFanDly  0 0 0 0 0 0 1 0 // FEB Fan-out delays, 0-7, in steps of 2.5 ns (nax =
20 ns)
```

Appendix 3-C A structure of the FEB ADC "super-record"

A FEB ADC **super-record** (Section 3.1.1) is a sequence of 128 short integers containing a complete FEB ADC data for one sample and one gain. Each word contains packed **ADC** and **Gain** values for one FEB input channel (input pin). The read-out order (*i.e.,* the correspondence between the FEB input channels and the word numbers) is shown in Table A3C.

Logically, the read-out order represents repetitive loops over all 16 ADCs of the FEB:

```
loop over ADC channels (7,6,..,0) {
        for each channel, read ADCs  in this order: (7,6,..0),  (15,14,...8)
}
```

Each ADC has 8 channels and accepts signals from 8 consecutive input pins connected to a pair of 4-channel pre-amplifier hybrid circuits located on the opposite sides of the FEB (Ref ...). The printed conductor path (track) lengths for these 8 channels are roughly the same (within 15%) , but the average track length varies from ~80 mm to ~24 mm for different ADCs. The two halves of a FEB (ADC 0-7 and ADC 8-15) have similar (though not identical) layouts of the input conductors, namely is ADC 15 is similar to ADC7, ... ADC 8 is similar to ADC 0. **Thus, a super-record consists of consequitive groups of 8 words, each group reflecting 8 basic layouts of the input analog part of the FEB PCB.**

Table A3C: FEB read-out order (a correspondence between the FEB input pins and the super-record word numbers). All items are numbered starting from 0.

input pin	ADC number	ADC ch. channel	word number	input pin	ADC number	ADC ch. channel	word number	input pin	ADC number	ADC ch. channel	word number	input pin	ADC number	ADC ch. channel	word number
0	0	0		32	4	0		64	8	0		96	12	0	
1		1		33		1		65		1		97		1	
2		2		34		2		66		2		98		2	
3		3		35		3		67		3		99		3	
4		4		36		4		68		4		100		4	
5		5		37		5		69		5		101		5	
6		6		38		6		70		6		102		6	
7		7	8	39		7	7	71		7	7	103		7	7
8	1	0		40	5	0		72	9	0		104	13	0	
9		1		41		1		73		1		105		1	
10		2		42		2		74		2		106		2	
11		3		43		3		75		3		107		3	
12		4		44		4		76		4		108		4	
13		5		45		5		77		5		109		5	
14		6		46		6		78		6		110		6	
15		7	6	47		7	6	79		7	6	111		7	6
16	2	0		48	6	0		80	10	0		112	14	0	
17		1		49		1		81		1		113		1	
18		2		50		2		82		2		114		2	
19		3		51		3		83		3		115		3	
20		4		52		4		84		4		116		4	
21		5		53		5		85		5		117		5	
22		6		54		6		86		6		118		6	
23		7	5	55		7	5	87		7	5	119		7	5
24	3	0		56	7	0		88	11	0		120	15	0	
25		1		57		1		89		1		121		1	
26		2		58		2		90		2		122		2	
27		3		59		3		91		3		123		3	
28		4		60		4		92		4		124		4	
29		5		61		5		93		5		125		5	
30		6		62		6		94		6		126		6	
31		7	4	63		7	4	95		7	4	127		7	4

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Chapter 3:

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[3-3] ATL-AL-LAL-ES-1.0 *Format for the Data read out from the front-end boards*, E. Auge et al, 1997, http://cern.ch/atlas-fcaltb/Memos/Hardware/FEB0/ATL-AL-LAL-ES-1.0.ps

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