# DAQ data structure for the Muon g-2 experiment

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**Abstract**

This document outlines the DAQ data structure of the Muon g-2 experiment. A detailed list of the MIDAS data bank will be shown and their contents will described.

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# 1 MIDAS DAQ output in a nutshell

The main DAQ framework for the Muon g-2 experiment is based on MIDAS [cite]. MIDAS event structure is as depicted in Fig. 1.

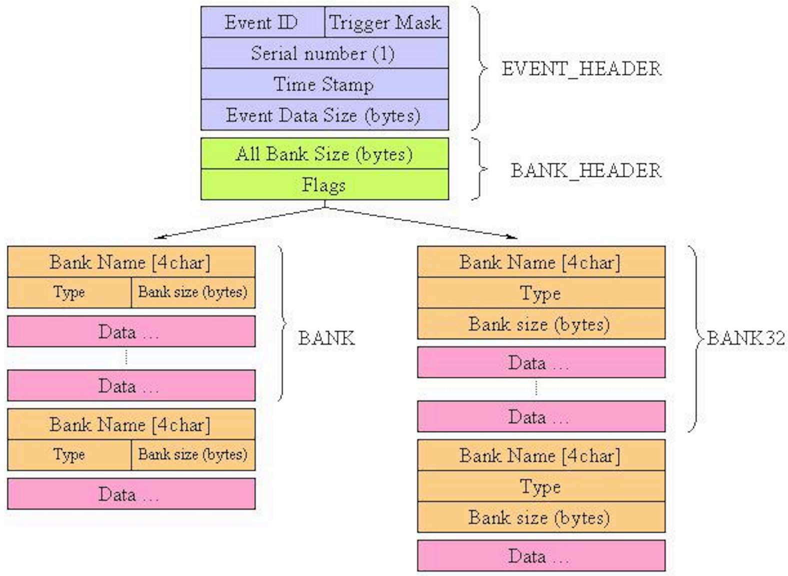



**Figure 1:** *MIDAS event structure. Each event has its header that is followed by the bank header. Then all the banks will appear according the defined order.*

# 2 MIDAS Bank list

Hundred of banks will be stored in each MIDAS event and it is very important to classify them properly. At the moment they can be grouped into 4 categories: calorimeter, auxiliary detector, CCC and magnetic field. Naming of these banks will be described in this section and their contents will be explained in the next section.

## 2.1 Calorimeter-related banks

There are 3 fill types for the calorimeter. `Muon` fill is the typical muon events, laser fill is event dedicated for laser calibration and monitoring events and pedestal fill is trivia from its name. Data from each fill type is identified from the bank name. The muon fill is denoted by "**C**", the laser fill is denoted by "**L**" and the pedestal fill is denoted by "**P**". A summary of the banks is listed in Tab. 1.

**Table 1:** *MIDAS bank list for the calorimetry data.*

| muon fill | laser fill | pedestal fill | Description |
|---|---|---|---|
| Bank name | | | |
| CA | LA | PA | AMC13 Header |
| CB | LB | PB | WFD5 header |
| CC | LC | PC | GPU timing data |
| CF | LF | PF | GPU fitted data |
| CH | LH | PH | per-crystal Q-method data (N-th event, end of run) |
| CL | LL | PL | Clock data |
| CP | LP | PP | Pedestal |
| CQ | LQ | PQ | per-calo Q-method data (every event) |
| CR | LR | PR | WFD5 raw data |
| CT | LT | PT | T-method islands |
| CZ | LZ | PZ | AMC13 CDF trailers |

## 2.2 Auxiliary detector-related banks

A separate T/Q-method is needed for auxiliary detectors. Their data banks are denoted with the initial "**K**". A list of these banks are summarized in Tab. 2.

**Table 2:** *MIDAS bank list for auxiliary T/Q data. This is mainly for the fiber harps, quads and kickers.*

| Bank name | Description |
|---|---|
| KH | Per aux. detector channel Q-method data (N-th event, end of run) |
| KQ | Per aux. detector Q-method data (every event) |
| KT | T-method data |

## 2.3 CCC related banks

This is the bank housing information regarding the CCC system based on FC7. A list of these banks are summarized in Tab. 3.

**Table 3:** *MIDAS bank list for the CCC data.*

| | |
|---|---|
| TTCA | AMC13 Header |
| TTCR | CCC AMC13 Payload |
| TTCZ | AMC13 Trailer |

## 2.4 Field related banks

Overall instructions:

All field-team banks are filled once per event. For many field-team banks, a c struct is defined in the `field_struct.hh` file, accessible for all frontends and unpackers. Programmers should able to cast the read-out bank (array of bytes) onto a pointer of the corresponding struct. A midas bank can be an entire struct (like **TLNP**, **ABPR**, etc) or a array of structs (like **GALI**). A list of these banks are summarized in Tab. 4.

**Table 4:** *MIDAS bank list for the magnetic field related data.*

| System | Name | Description |
|---|---|---|
| Fixed probe | FXPR | Fixed probe, header + NMR waveforms |
| Trolley | TLNP | Trolley NMR Pulse, header + NMR waveforms |
| | TLBC | Trolley Barcode, header + Barcode waveforms |
| | TLMN | Trolley Monitors (temperatures, voltages and pressure), header + voltage waveforms |
| | GALI | Galil (trolley and garage) data, positions + velocities + control voltages + tensions |
| Absolute probes | ABPR | Absolute probe (spherical probe and plunging probe are using the same bank), header + NMR waveforms |
| Flux gate | FLUX | Flux gate, fluxgate waveforms |
| Surface coil | SFCL | Surface coil, current readouts |

# 3 Bank contents

This section details contents of each MIDAS bank.

## 3.1 Calorimeter-related banks

### CA (LA, PA) and CZ (LZ, PZ) banks

This is the bank for the AMC13 to DAQ header information. The first 64-bit word is the CDF header and the next 64-bit word is the payload header.

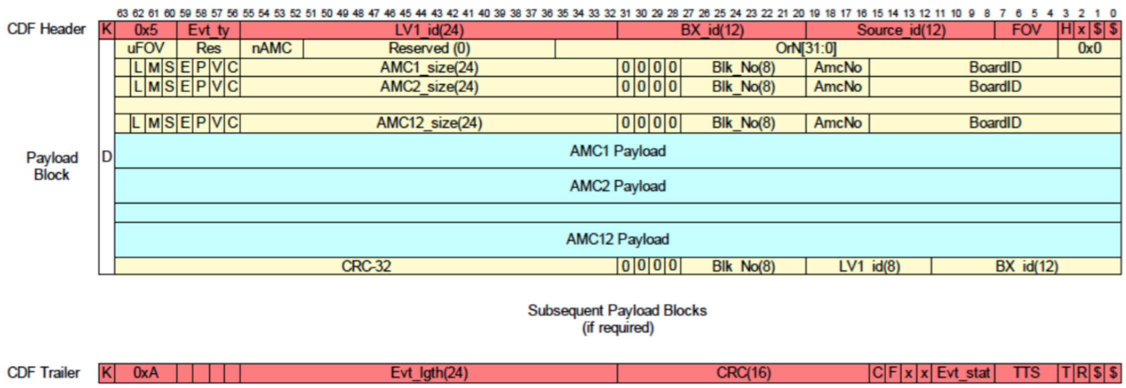



**Figure 2:** *Data structure for AMC13 to DAQ. The first 2 64-bit words are stored in the CA (LA, PA) bank.*

### CB (LB, PB) banks

This is the bank for the WFD5 to AMC13 header information.

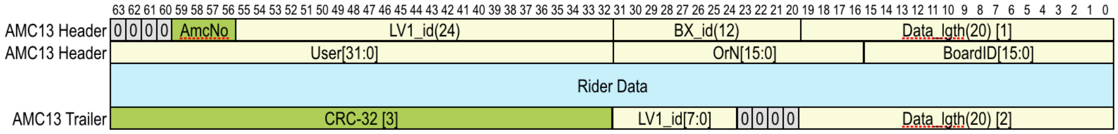



**Figure 3:** *Data structure for Rider to AMC13.*

### CR (LR, PR) banks

This is the bank for the full WFD5 payload.

### CT (LT, PT) banks

This is the bank for calorimeter T-method chopped islands.

### CH (LH, PH) banks

This is the bank for calorimeter segment histograms.

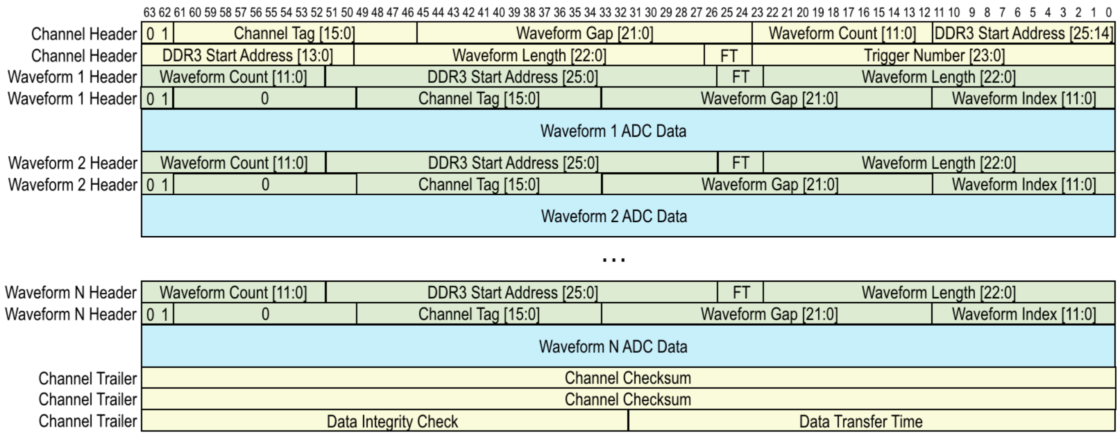



**Figure 4:** *Data structure for the WFD5 raw payload.*

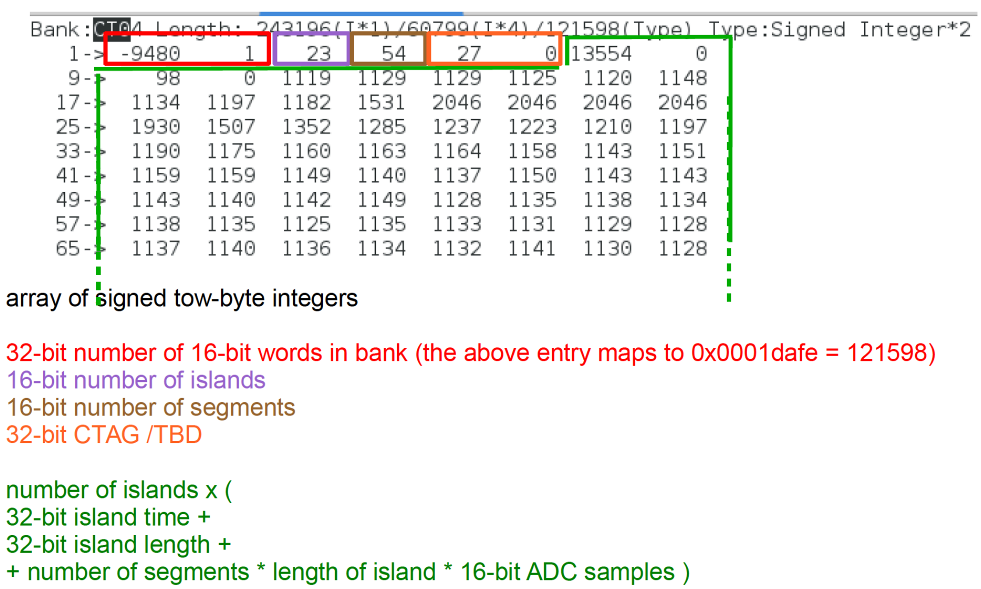
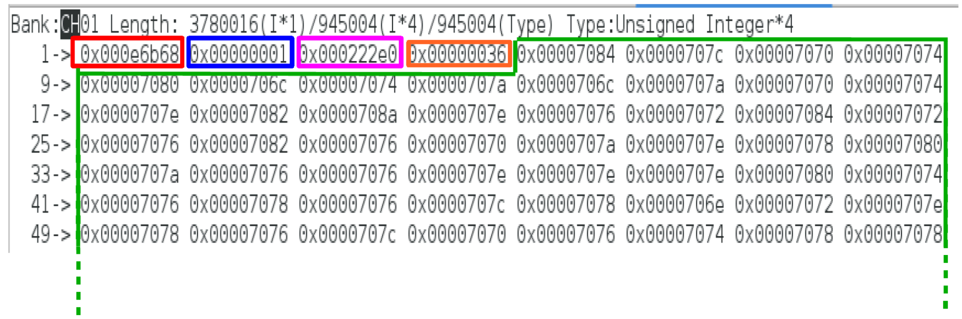



**Figure 5:** *Data structure for the CT bank (T-method chopped islands).*



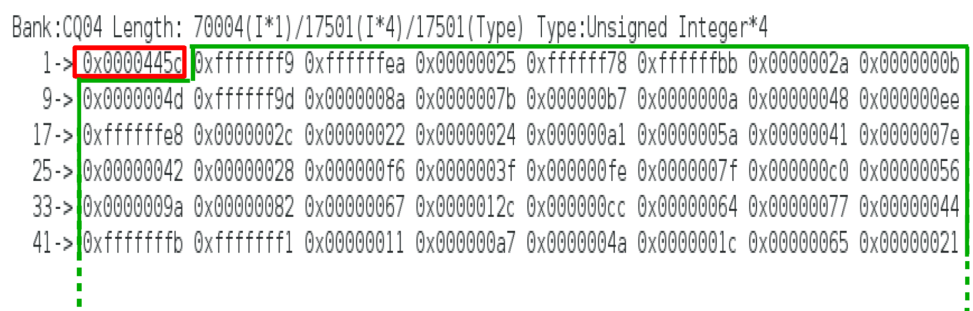

CH databank words are signed 32-bit signed integers

first word - number of array elements of Q method histogram
second word - first ADC sample within fill of Q-method histogram (is an ODB parameter)
third word - last ADC sample within fill of Q-method histogram (is an ODB parameter)
fourth word - number of segments / detectors in histogram (derived from ODB paramters)
remaining words - Q-method histogram array elements of size specified by first word

**Figure 6:** *Data structure for the CH bank (calo segment histograms).*

### CQ (LQ, PQ) banks

This is the bank for calorimeter sum histograms.




(number of histogram array elements + 1) x signed four-byte integers

total number of data words, i.e. histogram array elements + 1
segment summed, time-decimated, pedestal subtracted histogram array elements

**Figure 7:** *Data structure for the CQ bank (calo sum histograms).*

### CP (LP, PP) banks

This is the bank for calorimeter pedestals.

### CC (LC, PC) banks

This is the bank for the calorimeter DAQ performance related information. It has information like tcp timing and gpu timing.

### C? (L?, P?) banks, TBD

This is the bank for the WFD5 payload in the asynchronous mode.

```
Bank:CP04 Length: 220(I*1)/55(I*4)/55(Type) Type:Real*4 (FMT machine dependent)
  1-> 5.400e+01 1.126e+03 1.293e+03 1.301e+03 1.328e+03 1.329e+03 1.780e+03 1.761e+03
  9-> 1.761e+03 1.768e+03 1.781e+03 1.774e+03 1.761e+03 1.751e+03 1.780e+03 1.781e+03
 17-> 1.764e+03 1.736e+03 1.725e+03 1.711e+03 1.767e+03 1.779e+03 1.751e+03 1.759e+03
 25-> 1.768e+03 1.760e+03 1.767e+03 1.752e+03 1.764e+03 1.772e+03 1.765e+03 1.753e+03
 33-> 1.754e+03 1.752e+03 1.783e+03 1.780e+03 1.760e+03 1.747e+03 1.736e+03 1.779e+03
 41-> 1.767e+03 1.753e+03 1.758e+03 1.730e+03 1.755e+03 1.771e+03 1.799e+03 1.765e+03
 49-> 1.779e+03 1.752e+03 1.794e+03 1.753e+03 1.753e+03 1.759e+03 1.742e+03
```

(number of segments + 1) x four bytes float format

number of segments
number of segments x pedestal values

**Figure 8:** *Data structure for the CP bank (T-method pedestals).*

```
Bank:CC04 Length: 152(I*1)/38(I*4)/38(Type) Type:Unsigned Integer*4
  1-> 0x2cf01551 0x0800c0f3 0x584127e1 0x00000000 0x000913c3 0x00000000 0x584127e1 0x00000000
  9-: 0x000913c4 0x00000000 0x584127e1 0x00000000 0x0009e7b6 0x00000000 0x584127e1 0x00000000
 17-: 0x000a1d59 0x00000000 0x584127e1 0x00000000 0x000a0be5 0x00000000 0x584127e1 0x00000000
 25-: 0x000a1d58 0x00000000 0x584127e1 0x00000000 0x000a1d76 0x00000000 0x584127e1 0x00000000
 33-> 0x000a1dce 0x00000000 0x00000e75 0x00000000 0x00000e75 0x00000000
```

array of 64-bit words (sec, usecs are obtained from gettimeofday() and struct timeval in sys/time.h

64-bit CDF header word
TCP proc unlocked / started, first 64-bit word is seconds, second 64-bit word is usecs
got TCP header word, first 64-bit word is seconds, second 64-bit word is usecs
got TCP header word, first 64-bit word is seconds, second 64-bit word is usecs
GPU proc unlocked / started , first 64-bit word is seconds, second 64-bit word is usecs
GPU copy done , first 64-bit word is seconds, second 64-bit word is usecs
GPU proc done , first 64-bit word is seconds, second 64-bit word is usecs
MFE proc unlocked, first 64-bit word is seconds, second 64-bit word is usecs
MFE banks made, first 64-bit word is seconds, second 64-bit word is usecs
current TCP fill number
current GPU fill number

**Figure 9:** *Data structure for the CC bank (calo performance).*

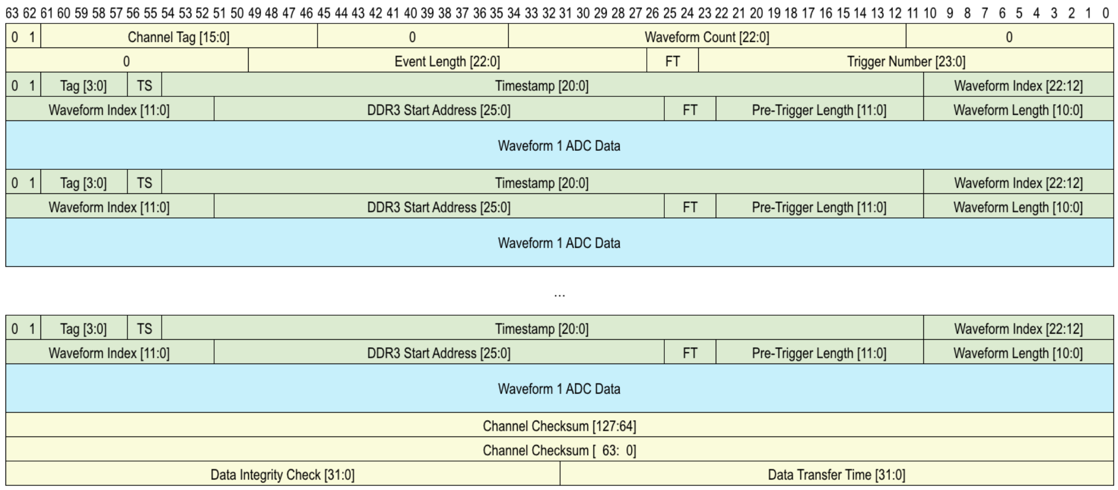



**Figure 10:** *Data structure for asynchronous mode for Rider.*

## 3.2 Auxiliary detector-related banks

### KH and KQ banks

These two banks have the same format as the CH and CQ banks.

### KT bank

This bank has the same format as the CT bank.

## 3.3 CCC related banks

### TTCA, TTCR, TTCZ banks

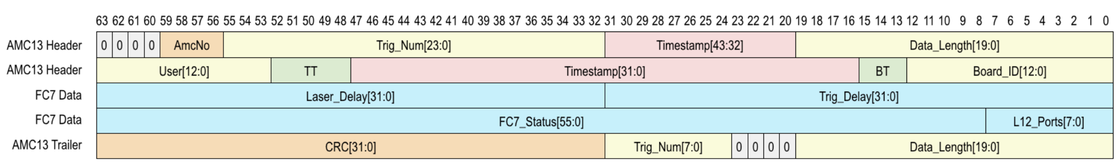



**Figure 11:** *Data structure for encoder FC7.*

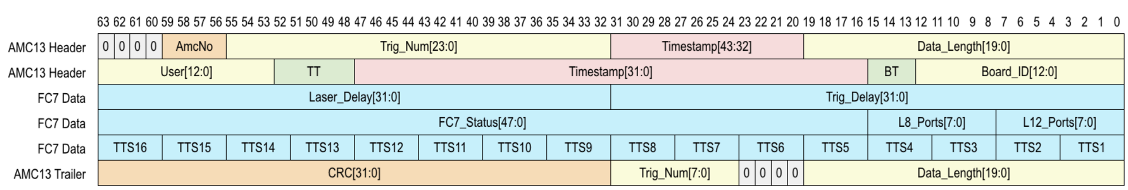



**Figure 12:** *Data structure for fanout FC7.*

## 3.4 Field related banks

### FXPR bank

This is the bank for fixed probes. It consists of a header and NMR waveforms.

**Table 5:** *MIDAS bank structure for the FXPR bank.*

| start word index | type | array length | field name | content | struct name |
|---|---|---|---|---|---|
| 0 | Double_t | num_ch | sys_clock | system clock | fixed_t |
| 4*num_ch | Double_t | num_ch | gps_clock | gps clock | |
| 8*num_ch | Double_t | num_ch | dev_clock | device clock | |
| 12*num_ch | Double_t | num_ch | snr | signal to noise ratio | |
| 16*num_ch | Double_t | num_ch | len | length of each wave form | |
| 20*num_ch | Double_t | num_ch | freq | frequency extracted | |
| 24*num_ch | Double_t | num_ch | ferr | frequency error | |
| 28*num_ch | Double_t | num_ch | freq_zc | frequency extracted, zero crossing | |
| 32*num_ch | Double_t | num_ch | ferr_zc | frequency error, zero crossing | |
| 36*num_ch | UShort_t | num_ch | health | health indicator of probes | |
| 37*num_ch | UShort_t | num_ch | method | frequency extraction method | |
| 38*num_ch | UShort_t | num_ch * rec_len | trace | NMR waveforms: Waveform_Ch1 + Waveform_Ch2 + ... + Waveform_Ch6 | |

**Table 6:** *Hard-coded macros in the FXPR bank.*

| Name in the code | Name in this doc | Value |
|---|---|---|
| NMR_NUM_FIXED_PROBES | num_ch | 378 |
| NMR_FID_LENGTH_RECORD | rec_len | 10000 |

### TLNP bank

This is the bank for Trolley NMR pulses. It consists of a header and NMR waveforms.

### TLBC bank

This is the bank for Trolley barcode readers. It consists of a header and barcode waveforms.

**Table 7:** *MIDAS bank structure for the TLNP bank.*

| start word index | type | array length | field name | content | struct name |
|---|---|---|---|---|---|
| 0 | ULong64_t | 1 | gps_clock | Time stamp of the first NMR sample | trolley_nmr_t |
| 4 | UShort_t | 1 | probe_index | probe index | |
| 5 | UShort_t | 1 | length | length of the NMR waveform | |
| 6 | Short_t | nmr_len | trace | Trolley Probe NMR wavefrom | |

**Table 8:** *Hard-coded macros in the TLNP bank.*

| Name in the code | Name in this doc | Value |
|---|---|---|
| TRLY_NMR_LENGTH | nmr_len | 24000 |

**Table 9:** *MIDAS bank structure for the TLBC bank.*

| start word | index | type | array length | field name content | struct name |
|---|---|---|---|---|---|
| 0 | ULong64_t | 1 | gps_clock | Time stamp of the first barcode sample | trolley_barcode_t |
| 4 | UShort_t | 1 | length_per_ch | length of the barcode waveform per channel | |
| 5 | UShort_t | bc_ch*bc_len | traces | Barcode wavefroms: Waveform_Ch1 + Waveform_Ch2 + ... + Waveform_Ch6 | |

# 4 Parsers for MIDAS bank data

Muon g-2 offline analysis framework relies on parsers in the gm2parser namespace hosted under repository gm2unpackers to decode the data. To checkout the codes,

```
git clone ssh://p-gm2dqm@cdcvs.fnal.gov/cvs/projects/gm2unpackers
```

Alternatively, you can also use

```
mrb g gm2dqm
```

in our g-2 environment.

These parsers are written in C++ and are being used in the *art* producer modules. They can also be used in your standalone C++ codes, if you wish to.