

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 be described.

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1 Introduction

1.1 Data unpacking in a nutshell

The basic idea of data unpacking is to convert compact DAQ information stored in MIDAS banks to well-structured data products, as depicted in Fig. 1. Several unpackers are used to decode the information stored in MIDAS banks and the outputs are stored in different data products which are basically structs in C++ language.

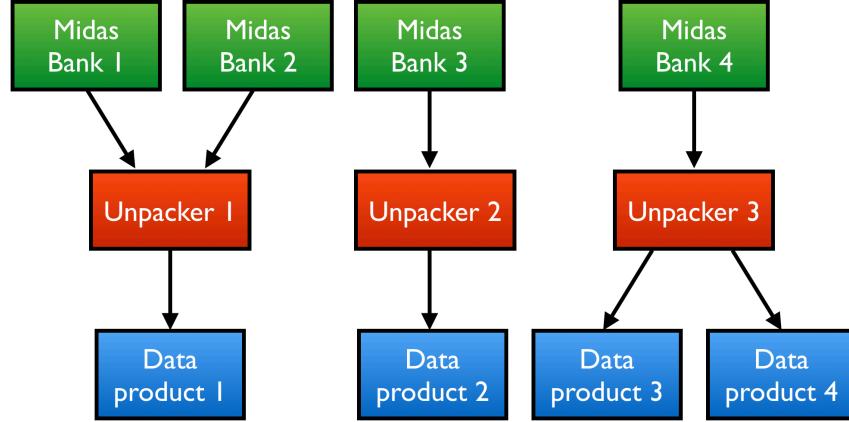


Figure 1: Simplified diagram of the flow of the data unpacking.

1.2 MIDAS DAQ output in a nutshell

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

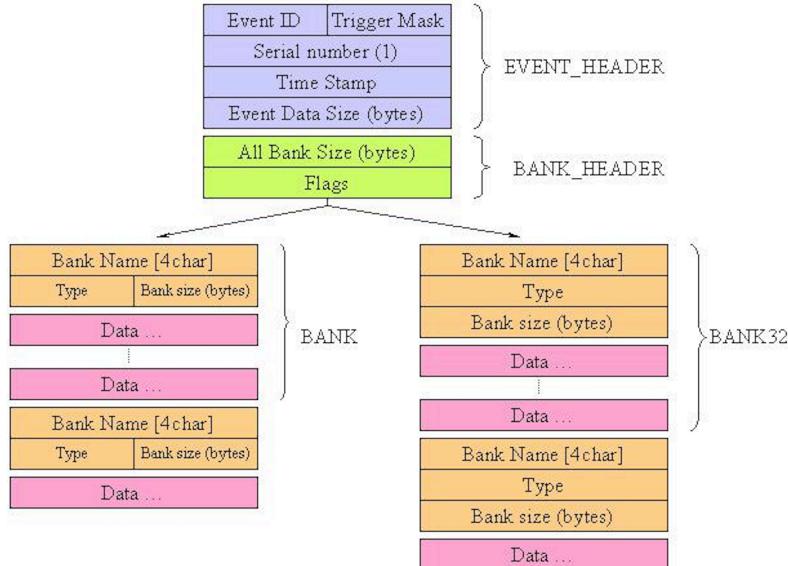


Figure 2: MIDAS event structure. Each event has its header that is followed by the bank header. Then all the banks will appear according the defined order.

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-calorimeter Q-method data (every event) |
| CR | LR | PR | WFD5 raw data |
| CT | LT | PT | T-method islands |
| CZ | LZ | PZ | AMC13 CDF trailers |

Since each bank has to be named exactly four characters, the last 2 characters denoted the calorimeter number, e.g. **CT03** means the T-method bank from calorimeter number 3. Hence the number 01-24 are reserved for the calorimeters and 25 is reserved for the laser system.

2.2 Auxiliary detector-related banks

Systems that fall into the auxiliary detector category are the kickers, quadrupoles, IBMS, T0 counter and fiber harps. Depending on the length of the signal, two different types of digitizers will be used to digitize these signals: Cornell WFD5 and CANE 1742 digitizers. 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. The last 2 characters of the bank name will be decided soon.

2.3 CCC related banks

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

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

| 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 |
| IBMS | IBMS waveforms |

Table 3: MIDAS bank list for the CCC data.

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

2.4 Field related banks

All field-team banks are filled once per event and the definition of an event is different from the one of the ω_a related banks. 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. All the banks are packed in 32-bit word integer regardless of the original format.

3.1 Calorimeter-related banks

CA (LA, PA) 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 as shown in Fig. 3.

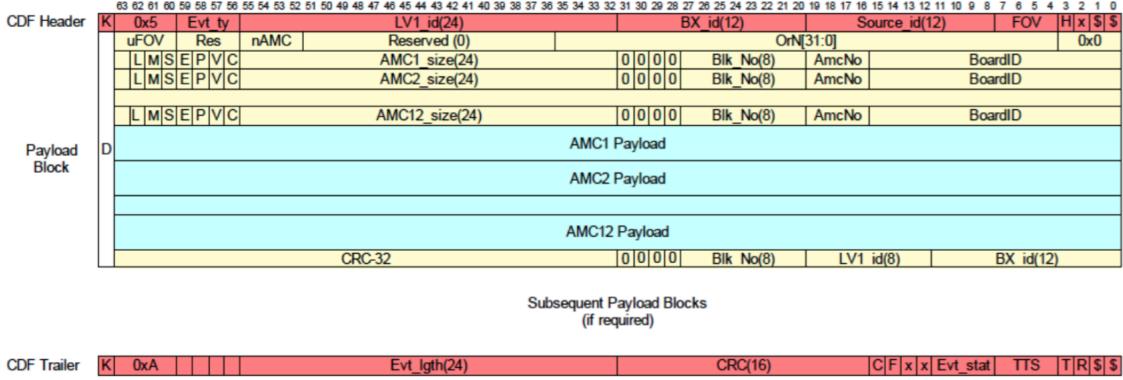


Figure 3: Data structure for AMC13 to DAQ. The first two 64-bit words are stored in the CA (LA, PA) banks and the last two 64-bit words are stored in the CZ (LZ, PZ) banks.

CZ (LZ, PZ) banks

This is the bank for the AMC13 to DAQ trailer information. The first 64-bit word is the last 64-bit word of the payload block and the next 64-bit word is the CDF trailer as shown in Fig. 3.

CB (LB, PB) banks

This is the bank for the WFD5 to AMC13 header information as shown in Fig. 4.

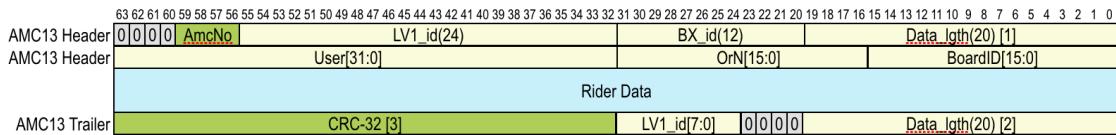


Figure 4: Data structure for Rider to AMC13.

CR (LR, PR) banks

This is the bank for the full WFD5 payload as shown in Fig. 5. Due to the huge data size of raw payload, a pre-scale of about 1000 event is usually being set in the MIDAS ODB.

| | |
|-------------------|---|
| | 63 62 61 60 59 58 57 56 55 54 53 52 51 50 49 48 47 46 45 44 43 42 41 40 39 38 37 36 35 34 33 32 31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 |
| Channel Header | 0 1 Channel Tag [15:0] Waveform Gap [21:0] Waveform Count [11:0] DDR3 Start Address [25:14] |
| Channel Header | DDR3 Start Address [13:0] Waveform Length [22:0] FT Trigger Number [23:0] |
| Waveform 1 Header | Waveform Count [11:0] DDR3 Start Address [25:0] FT Waveform Length [22:0] |
| Waveform 1 Header | 0 1 0 Channel Tag [15:0] Waveform Gap [21:0] Waveform Index [11:0] |
| | Waveform 1 ADC Data |
| Waveform 2 Header | Waveform Count [11:0] DDR3 Start Address [25:0] FT Waveform Length [22:0] |
| Waveform 2 Header | 0 1 0 Channel Tag [15:0] Waveform Gap [21:0] Waveform Index [11:0] |
| | Waveform 2 ADC Data |
| | ... |
| Waveform N Header | Waveform Count [11:0] DDR3 Start Address [25:0] FT Waveform Length [22:0] |
| Waveform N Header | 0 1 0 Channel Tag [15:0] Waveform Gap [21:0] Waveform Index [11:0] |
| | Waveform N ADC Data |
| Channel Trailer | Channel Checksum |
| Channel Trailer | Channel Checksum |
| Channel Trailer | Data Integrity Check Data Transfer Time |

Figure 5: Data structure for the WFD5 raw payload.

CT (LT, PT) banks

This is the bank for calorimeter T-method chopped islands. A collection of 54 islands from 54 crystals/segments are extracted per trigger. The detailed structure is shown in Fig. 6.

| Bank : CT04 Length: 243196(I*1)/60799(I*4)/121598(Type) Type:Signed Integer*2 | | | | | | | | | |
|---|-------|------|------|------|------|------|-------|------|--|
| 1 -> | -9480 | 1 | 23 | 54 | 27 | 0 | 13554 | 0 | |
| 9 -> | 98 | 0 | 1119 | 1129 | 1129 | 1125 | 1120 | 1148 | |
| 17 -> | 1134 | 1197 | 1182 | 1531 | 2046 | 2046 | 2046 | 2046 | |
| 25 -> | 1930 | 1507 | 1352 | 1285 | 1237 | 1223 | 1210 | 1197 | |
| 33 -> | 1190 | 1175 | 1160 | 1163 | 1164 | 1158 | 1143 | 1151 | |
| 41 -> | 1159 | 1159 | 1149 | 1140 | 1137 | 1150 | 1143 | 1143 | |
| 49 -> | 1143 | 1140 | 1142 | 1149 | 1128 | 1135 | 1138 | 1134 | |
| 57 -> | 1138 | 1135 | 1125 | 1135 | 1133 | 1131 | 1129 | 1128 | |
| 65 -> | 1137 | 1140 | 1136 | 1134 | 1132 | 1141 | 1130 | 1128 | |

array of signed tow-byte integers

32-bit number of 16-bit words in bank (the above entry maps to 0x0001dafe = 121598)

16-bit number of islands

16-bit number of segments

32-bit CTAG /TBD

number of islands x (

32-bit island time +

32-bit island length +

+ number of segments * length of island * 16-bit ADC samples)

Figure 6: Data structure for the CT bank (T-method chopped islands).

CH (LH, PH) banks

This is the bank for calorimeter segment histograms. Histogram from each segment is being summed to itself each fill and is flushed out every N-th event. The detailed structure is shown in Fig. 7.

CQ (LQ, PQ) banks

This is the bank for calorimeter sum histograms. Histograms from all segments are summed together and decimated, and then are being flushed out every fill. The detailed structure is

| Bank:CH01 Length: 3780016(I*1)/945004(I*4)/945004(Type) Type:Unsigned Integer*4 | | | | | | | | |
|---|------------|------------|------------|------------|------------|------------|------------|------------|
| 1-> | 0x000e6b68 | 0x00000001 | 0x00222e0 | 0x00000036 | 0x00007084 | 0x0000707c | 0x00007070 | 0x00007074 |
| 9-> | 0x00007080 | 0x0000706c | 0x00007074 | 0x000070/a | 0x0000706c | 0x0000707a | 0x00007070 | 0x00007074 |
| 17-> | 0x0000707e | 0x00007082 | 0x0000708a | 0x0000707e | 0x00007076 | 0x00007072 | 0x00007084 | 0x00007072 |
| 25-> | 0x00007076 | 0x00007082 | 0x00007076 | 0x00007070 | 0x0000707a | 0x0000707e | 0x00007078 | 0x00007080 |
| 33-> | 0x0000707a | 0x00007076 | 0x00007076 | 0x0000707e | 0x0000707a | 0x0000707e | 0x00007080 | 0x00007074 |
| 41-> | 0x00007076 | 0x00007078 | 0x00007076 | 0x0000707c | 0x00007078 | 0x0000706e | 0x00007072 | 0x0000707e |
| 49-> | 0x00007078 | 0x00007076 | 0x0000707c | 0x00007070 | 0x00007076 | 0x00007074 | 0x00007078 | 0x00007078 |

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 parameters)
remaining words - Q-method histogram array elements of size specified by first word

Figure 7: Data structure for the CH bank (calo segment histograms).

shown in Fig. 8.

| Bank:CQ04 Length: 70004(I*1)/17501(I*4)/17501(Type) Type:Unsigned Integer*4 | | | | | | | | |
|---|--------------|--------------|--------------|------------|------------|-------------|------------|------------|
| 1-> | 0x0000445d | 0xfffffffff9 | 0xffffffffea | 0x00000025 | 0xfffffff8 | 0xfffffffbb | 0x0000002a | 0x0000000b |
| 9-> | 0x0000004d | 0xffffffff9d | 0x0000008a | 0x0000007b | 0x000000b7 | 0x0000000a | 0x00000048 | 0x000000ee |
| 17-> | 0xffffffffe8 | 0x0000002c | 0x00000022 | 0x00000024 | 0x000000a1 | 0x0000005a | 0x00000041 | 0x0000007e |
| 25-> | 0x00000042 | 0x00000028 | 0x000000f6 | 0x0000003f | 0x000000fe | 0x0000007f | 0x000000c0 | 0x00000056 |
| 33-> | 0x0000009a | 0x00000082 | 0x00000067 | 0x0000012c | 0x000000cc | 0x00000064 | 0x00000077 | 0x00000044 |
| 41-> | 0xfffffffffb | 0xfffffffff1 | 0x00000011 | 0x000000a7 | 0x0000004a | 0x0000001c | 0x00000065 | 0x00000021 |

(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 8: Data structure for the CQ bank (calo sum histograms).

CP (LP, PP) banks

This is the bank for calorimeter pedestals. The detailed structure is shown in Fig. 9.

CC (LC, PC) banks

This is the bank for the calorimeter DAQ performance related information. It has information like tcp timing and gpu timing. The detailed structure is shown in Fig. 10.

CR (LR, PR) banks, asynchronous

This is the bank for the WFD5 payload in the asynchronous mode. The detailed structure is shown in Fig. 11.

```

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 9: 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 10: Data structure for the CC bank (calo performance).

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|-----------------------------|----|--------------------|----|------------------|---------------------------|----|---------------------|-----------------------|------------------------|---------------------------|---------------------------|----|-----------------------|------------------------|---------------------------|------------------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|---|---|---|---|---|---|---|---|---|---|
| 63 | 62 | 61 | 60 | 59 | 58 | 57 | 56 | 55 | 54 | 53 | 52 | 51 | 50 | 49 | 48 | 47 | 46 | 45 | 44 | 43 | 42 | 41 | 40 | 39 | 38 | 37 | 36 | 35 | 34 | 33 | 32 | 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0 | 1 | Channel Tag [15:0] | | | | | 0 | Waveform Count [22:0] | | | | | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 0 | 1 | 0 | | | | | Event Length [22:0] | | | | | FT | Trigger Number [23:0] | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 0 | 1 | Tag [3:0] | TS | Timestamp [20:0] | | | | | Waveform Index [22:12] | | | | | Waveform Index [22:12] | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Waveform Index [11:0] | | | | | DDR3 Start Address [25:0] | | | | | FT | Pre-Trigger Length [11:0] | | | | | Waveform Length [10:0] | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Waveform 1 ADC Data | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 0 | 1 | Tag [3:0] | TS | Timestamp [20:0] | | | | | Waveform Index [22:12] | | | | | Waveform Index [22:12] | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Waveform Index [11:0] | | | | | DDR3 Start Address [25:0] | | | | | FT | Pre-Trigger Length [11:0] | | | | | Waveform Length [10:0] | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Waveform 1 ADC Data | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| ... | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 0 | 1 | Tag [3:0] | TS | Timestamp [20:0] | | | | | Waveform Index [22:12] | | | | | Waveform Index [22:12] | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Waveform Index [11:0] | | | | | DDR3 Start Address [25:0] | | | | | FT | Pre-Trigger Length [11:0] | | | | | Waveform Length [10:0] | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Waveform 1 ADC Data | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Channel Checksum [127:64] | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Channel Checksum [63: 0] | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Data Integrity Check [31:0] | | | | | Data Transfer Time [31:0] | | | | | Data Transfer Time [31:0] | | | | | Data Transfer Time [31:0] | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

Figure 11: Data structure for asynchronous mode for Rider.

CF banks

This is the bank for GPU fitted results. The bank starts with “unsigned int” that is the number of segments. Then for each of those segments there is a block like this: an “unsigned int” which is the number of pulses and then $nPulses$ blocks of *pulseFinderResult* struct. The struct is shown in Tab. 5.

Table 5: Format of the struct *pulseFinderResult*.

| start word index | type | field name | content |
|------------------|---------|------------|--------------------------|
| 0 | Float_t | time | fitted time |
| 2 | Float_t | phase | fitted phase |
| 4 | Float_t | energy | fitted energy |
| 6 | Float_t | pedestal | fitted pedestal |
| 8 | Float_t | chi2 | chi square of the fit |
| 10 | Float_t | pedestal | fitted pedestal |
| 12 | Int_t | peak_index | index of the fitted peak |
| 13 | Int_t | peak_value | value of the fitted peak |

3.2 Auxiliary detector-related banks

This section will be updated once decision is finalized.

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.

IBMS

This bank will store all the waveforms from CAEN1742. Actual format to be decided.

3.3 CCC related banks

TTCA, TTCR, TTCZ banks

TTCA bank will have the same format as the CA bank in the calorimeter-related data since the uTCA crate has the same data format. TTCZ on the other hand will have the same format as the CZ bank.

There are two types of TTCA banks for the FC7 - encoder and fanout. The data format of the encoder and fanout FC7 are shown in Fig. 12 and Fig. 13, respectively.

| | | | | |
|---------------|-------------------|----------------|------------------|-------------------|
| AMC13 Header | 0 0 0 AmcNo | Trig_Num[23:0] | Timestamp[43:32] | Data_Length[19:0] |
| AMC13 Header | User[12:0] | TT | Timestamp[31:0] | BT Board_ID[12:0] |
| FC7 Data | Laser_Delay[31:0] | | Trig_Delay[31:0] | |
| FC7 Data | FC7_Status[55:0] | | | L12_Ports[7:0] |
| AMC13 Trailer | CRC[31:0] | Trig_Num[7:0] | 0 0 0 | Data_Length[19:0] |

Figure 12: Data structure for encoder FC7.

| | | | | |
|---------------|--|----------------|------------------|------------------------------|
| AMC13 Header | 0 0 0 AmcNo | Trig_Num[23:0] | Timestamp[43:32] | Data_Length[19:0] |
| AMC13 Header | User[12:0] | TT | Timestamp[31:0] | BT Board_ID[12:0] |
| FC7 Data | Laser_Delay[31:0] | | Trig_Delay[31:0] | |
| FC7 Data | FC7_Status[47:0] | | | L8_Ports[7:0] L12_Ports[7:0] |
| FC7 Data | TTS16 TTS15 TTS14 TTS13 TTS12 TTS11 TTS10 TTS9 TTS8 TTS7 TTS6 TTS5 | TTS4 TTS3 | TTS2 TTS1 | |
| AMC13 Trailer | CRC[31:0] | Trig_Num[7:0] | 0 0 0 | Data_Length[19:0] |

Figure 13: 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. Structure of the FXPR bank is summarized in Tab. 6 and its macros are summarized in Tab. 7.

TLNP bank

This is the bank for Trolley NMR pulses. It consists of a header and NMR waveforms. Structure of the TLNP bank is summarized in Tab. 8 and its macros are summarized in Tab. 9.

TLBC bank

This is the bank for Trolley barcode readers. It consists of a header and barcode waveforms. Structure of the TLBC bank is summarized in Tab. 10 and its macros are summarized in Tab. 11.

Table 6: *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 7: *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 |

Table 8: *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 9: *Hard-coded macros in the TLNP bank.*

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

Table 10: *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 waveforms: Waveform_Ch1 + Waveform_Ch2 + ... + Waveform_Ch6 | |

Table 11: *Hard-coded macros in the TLBC bank.*

| Name in the code | Name in this doc | Value |
|-----------------------|------------------|-------|
| TRLY_BARCODE_LENGTH | bc_len | 3000 |
| TRLY_BARCODE_CHANNELS | bc_ch | 6 |

TLMN bank

This is the bank for Trolley monitors. It consists of information like temperatures, voltages and pressures. Structure of the TLMN bank is summarized in Tab. 12 and its macros are summarized in Tab. 13.

GALI bank

This is the bank for trolley and garage data. It has information like the trolley positions and velocities. Structure of the GALI bank is summarized in Tab. 14 and 15, and its macros are summarized in Tab. 16.

ABPR bank

This is the bank for absolute probe data. Both spherical probe and plunging probe are using the same bank. It has information like the header and NMR waveforms. Structure of the ABPR bank is summarized in Tab. 17.

FLUX bank

This is the bank for the fluxgate. It has information like the fluxgate waveforms. Structure of the FLUX bank is summarized in Tab. 18 and its macros are summarized in Tab. 19.

SFCL bank

This is the bank for the surface coil. It has the information like current readouts from the surface coils. Structure of the SFCL bank is summarized in Tab. 20 and its macros are summarized in Tab. 21.

¹Note: the length of the NMR waveform is not fixed from event to event. For each event, its length is determined by the "length" field of the "absolute_nmr_info_t" struct in the header section.

Table 12: MIDAS bank structure for the TLMN bank.

| start word index | type | array length | field name | content | struct name |
|------------------|-----------|--------------|-----------------------|---|-------------------|
| 0 | ULong64_t | 1 | gps_clock_cycle_start | Time stamp of the measurement cycle | trolley_monitor_t |
| 4 | UInt_t | 1 | PMonitorVal | Pressure Monitor readout value | |
| 6 | Uint_t | 1 | PMonitorTemp | Pressure Monitor temperature | |
| 8 | Uint_t | 1 | RFPower1 | RF Power monitor 1 | |
| 10 | Uint_t | 1 | RFPower2 | RF Power monitor 2 | |
| 12 | Uint_t | 1 | NMRCheckSum | NMR waveform check sum, calculated by trolley interface | |
| 14 | Uint_t | 1 | FrameCheckSum | Frame data check sum, calculated by trolley interface | |
| 16 | Uint_t | 1 | FrameSum | Frame data sum calculated by DAQ | |
| 18 | Uint_t | 1 | FrameIndex | Frame index | |
| 20 | UShort_t | 1 | StatusBits | (Bit 5-7)Reserved | |
| 21 | UShort_t | 1 | TMonitorIn | Temperature monitor, interia | |
| 22 | UShort_t | 1 | TMonitorExt1 | Temperature monitor, exteria 1 | |
| 23 | UShort_t | 1 | TMonitorExt2 | Temperature monitor, exteria 2 | |
| 24 | UShort_t | 1 | TMonitorExt3 | Temperature monitor, exteria 3 | |
| 25 | UShort_t | 1 | V1Min | Voltage Monitor 1, minimum | |
| 26 | UShort_t | 1 | V1Max | Voltage Monitor 1, maximum | |
| 27 | UShort_t | 1 | V2Min | Voltage Monitor 2, minimum | |
| 28 | UShort_t | 1 | V2Max | Voltage Monitor 2, maximum | |
| 29 | UShort_t | 1 | length_per_ch | waveform length per channel for the voltage monitors | |
| 30 | UShort_t | mn_len | trace_VMonitor1 | waveform of voltage monitor 1 | |
| 30+mn_len | UShort_t | mn_len | trace_VMonitor2 | waveform of voltage monitor 2 | |

Table 13: Hard-coded macros in the TLMN bank.

| Name in the code | Name in this doc | Value |
|---------------------|------------------|-------|
| TRLY_MONITOR_LENGTH | mn_len | 3000 |

Table 14: MIDAS bank structure for the GALI bank.

| start word index | type | array length | field name | content | struct name |
|------------------|--------------|--------------|------------|--------------------------------|--------------|
| 0 | galil_data_t | group_size | - | Array of structs: galil_data_t | galil_data_t |

Table 15: Format of the struct galil_data_t.

| start word index | type | array length | field name | content |
|------------------|-----------|--------------|------------|---|
| 0 | ULong64_t | 1 | TimeStamp | time stamp of the readout |
| 4 | Int_t | 2 | Tensions | Tensions of the fishing line and the signal cable |
| 8 | Int_t | 3 | Positions | Positions: Motor 1, Motor 2 and Garage |
| 14 | Int_t | 3 | Velocities | Velocities: Motor 1, Motor 2 and Garage |
| 20 | Int_t | 3 | OutputVs | Output voltages: Motor 1, Motor 2 and Garage |

Table 16: Hard-coded macros in the GALI bank.

| Name in the code | Name in this doc | Value |
|--------------------|------------------|-------|
| GALILREADGROUPSIZE | group_size | 50 |

Table 17: MIDAS bank structure for the ABPR bank.

| start word index | type | array length | field name | content | struct name |
|------------------|-----------|--------------|-----------------|------------------------------|---------------------|
| 0 | ULong64_t | 1 | time_stamp | Time stamp of the NMR sample | absolute_nmr_info_t |
| 4 | Uint_t | 1 | length | probe index | |
| 6 | Uint_t | 4 | position | length of the NMR waveform | |
| 14 | UShort_t | 1 | flay_run_number | Trolley Probe NMR waveform | |
| 15 | UShort_t | 1 | probe_index | | |
| 16 | UShort_t | length | - | NMR waveform ¹ | |

Table 18: *MIDAS bank structure for the FLUX bank.*

| start word index | type | array length | field name | content | struct name |
|------------------|---------|--------------------|------------|--|-------------|
| 0 | float64 | num_ch*period*rate | - | Flux gate wave forms for all channels: Waveform_ch1 + Waveform_ch2 + ... | |

Table 19: *Hard-coded macros in the FLUX bank.*

| Name in the code | Name in this doc | Value |
|-------------------|------------------|-------|
| FLUX_NUM_CHANNELS | num_ch | 9 |
| FLUX_TRACE_PERIOD | period | 60 |
| FLUX_RATE | rate | 8000 |

Table 20: *MIDAS bank structure for the SFCL bank.*

| start word index | type | array length | field name | content | struct name |
|------------------|----------|--------------|------------|-----------------------|----------------|
| 0 | Double_t | num_coil | sys_clock | system clock | surface_coil_t |
| 4*num_coil | Double_t | num_coil | gps_clock | gps clock | |
| 8*num_coil | Double_t | num_coil | top_board | top board currents | |
| 12*num_coil | Double_t | num_coil | bot_board | bottom board currents | |

Table 21: *Hard-coded macros in the SFCL bank.*

| Name in the code | Name in this doc | Value |
|------------------|------------------|-------|
| SC_NUM_COILS | num_coil | 100 |

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@cdcv.sfnal.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. The parsers are located at

```
gm2unpackers/calo/parsers
```

at the moment for both calorimeter and CCC related information. This document will be updated accordingly once they are reorganized.

References

- [1] TRIUMF MIDAS homepage, accessed Jan 5, 2017. https://midas.triumf.ca/MidasWiki/index.php/Main_Page