SP-to-DDU Event Record Structure

Petersburg Nuclear Physics Institute / University of Florida
April 25, 2006
Version 4.0

The SP readout format fully complies with the DMB-to-DDU Event Record structure, as described at [http://www.physics.ohio-state.edu/~cms/ddu/ddu_pro.html](http://www.physics.ohio-state.edu/~cms/ddu/ddu_pro.html), so a mix of DMB and SP fibers are allowed to the same DDU module.

The format for the 16-bit SP output / DDU input is designed to easily interface with a 64-bit readout system through an S-LINK64 card. This requires that all data sent to the DDU be an integer multiple of 4 16-bit words for each event.

The highest bit of each SP 16-bit word is reserved as a special flag for DDU Code words, so only 15 bits are available for physics data. When the MSB of the 16-bit word is high, the 4 most significant bits indicate the DDU Code word. When the MSB is low, the other 15 bits are data.

The DDU Code words and the SP Data are always sent in groups of 4 to make a 64-bit word.

The Event Record has the following structure:
- Event Record Header
- Event Data
- Event Record Trailer

Both the Event Record Header and Event Record Trailer consist of two 64-bit words each. The Event Data can consist of any number of 64-bit words from 0 to 154, depending on the Event Record Configuration settings; see the DD/CSR_DFC register description for details.

Table below lists maximum Event Record sizes in 16-bit words for 1 to 8 Time Bins for different trigger boards.

**Table 1: Event Record sizes for 0 to 8 TBIN values**

<table>
<thead>
<tr>
<th>TBIN</th>
<th>SP</th>
<th>DMB</th>
<th>ALCT-288</th>
<th>ALCT-384</th>
<th>ALCT-672</th>
<th>TMB</th>
<th>CFEB</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>16</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>104</td>
<td>48</td>
<td>60</td>
<td>96</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>192</td>
<td>84</td>
<td>108</td>
<td>180</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>280</td>
<td>120</td>
<td>156</td>
<td>264</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>368</td>
<td>156</td>
<td>204</td>
<td>348</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>456</td>
<td>192</td>
<td>252</td>
<td>432</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>544</td>
<td>228</td>
<td>300</td>
<td>516</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>632</td>
<td>264</td>
<td>348</td>
<td>600</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>-</td>
<td>1500</td>
<td>300</td>
<td>396</td>
<td>684</td>
<td>???</td>
<td>800</td>
</tr>
</tbody>
</table>

For SP, the maximum Event Record size is \((22 + 4 = 26)\) 64-bit words per one TBIN plus 22 64-bit words per any additional TBIN. For TBIN=7, event size comes to \(158/632\) 64/16-bit words in total, or 7.9 \(\mu\)sec readout time. The latter corresponds to a L1A rate of 126 kHz.
**Event Record Header**

The Event Record Header consists of 8 16-bit words, where the most significant hex digit is the DDU Code word 0x9 and 0xA. Green cells in Table 2 carry the SP-specific configuration settings; tan cells carry the SP-specific status; the content of all other cells complies with the DDU requirement.

**Table 2: Event Record Header**

<table>
<thead>
<tr>
<th>D15</th>
<th>D14</th>
<th>D13</th>
<th>D12</th>
<th>D11</th>
<th>D10</th>
<th>D9</th>
<th>D8</th>
<th>D7</th>
<th>D6</th>
<th>D5</th>
<th>D4</th>
<th>D3</th>
<th>D2</th>
<th>D1</th>
<th>D0</th>
<th>Word</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x9</td>
<td>L1A</td>
<td>[11:0]</td>
<td>HD1a</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0x9</td>
<td>L1A</td>
<td>[23:12]</td>
<td>HD1b</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0x9</td>
<td>0</td>
<td>HD1c</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0x9</td>
<td>L1A_BXN</td>
<td>[11:0]</td>
<td>HD1d</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0xA</td>
<td>0</td>
<td>HD2a</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0x9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0x9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0x9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0xA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0xA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0xA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0xA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0xA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0xA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0xA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Here:
- Spare cells are shown in yellow;
- L1A [23:0] – Event Number picked from a 24-bit Event Counter, located in the DDU_FPGA;
- L1A_BXN [11:0] – Event Bunch Crossing Number (L1A arrival time) picked from a 12-bit Bunch Counter, located in the DDU_FPGA and running at TTC timing;
- DD/CSR_BID [11:0] = DDU_FPGA / Board ID register:
  - SP_LARD [3:0] – SP Logical Address composed of:
    - SP_LARD[3] = MEZ = 0 (-Z) / 1 (+Z) – EMU side;
    - SP_LARD[2:0] = MES_ID [2:0] = 1…6 – EMU 60° Sector number;
  - SP_PADR [4:0] = 6…11, 16…21 – SP Physical Address (slot number);
- DD/CSR_DFC [11:0] = DDU_FPGA / DAQ FIFO (i.e. DDU Event Record) Configuration register:
  - F1A = 0 / 1 (default) – FRONT_FPGA Active bit. If the bit is set to 1, then the F1 is considered to be ACTIVE and is queried for CSC muon LCT(s) ME1a, ME1b, ME1c;
  - F2A = 0 / 1 (default) – FRONT_FPGA Active bit. If the bit is set to 1, then the F2 is considered to be ACTIVE and is queried for CSC muon LCT(s) ME1d, ME1e, ME1f;
  - F3A = 0 / 1 (default) – FRONT_FPGA Active bit. If the bit is set to 1, then the F3 is considered to be ACTIVE and is queried for CSC muon LCT(s) ME2a, ME2b, ME2c;
  - F4A = 0 / 1 (default) – FRONT_FPGA Active bit. If the bit is set to 1, then the F4 is considered to be ACTIVE and is queried for CSC muon LCT(s) ME3a, ME3b, ME3c;
  - F5A = 0 / 1 (default) – FRONT_FPGA Active bit. If the bit is set to 1, then the F5 is considered to be ACTIVE and is queried for CSC muon LCT(s) ME4a, ME4b, ME4c;
♦ DTA = 0 / 1 (default) – Drift Tube Active. If the bit is set to 1, then the Drift Tube interface is considered to be ACTIVE and the SP_FPGA is queried for DT muon Stub(s) MB1a, ME1d;

♦ SPA = 0 / 1 (default) – Sector Processor Active. If the bit is set to 1, then the Sector Processor output is considered to be ACTIVE and the SP_FPGA is queried for SP muon Track(s) SP1, SP2, SP3;

♦ ZS = 0 / 1 (default) – Zero Suppression bit. If set to 1, then only valid LCT(s), Stub(s) and Track(s) are collected;

♦ TBIN [2:0] = 0…7 (default = 4) – DDU_FPGA collects data from 0…7 Time Bins (bunch crossings). SP_LADR [3:0] – SP Logical Address composed of:
  - SP_OSY – the SP_FPGA local L1A number does not match the DDU_FPGA L1A number shown in the Event Header, words {HD1b, HD1a}. This is an Out-of-Synch condition between event data fragments, which may (if it is persistent) or may not (if it is occasional) require a L1 Reset signal.
  - FA_OSY – the FRONT_FPGA local L1A number from one or more FRONT_FPGA chips does not match the DDU_FPGA L1A number shown in the Event Header, words {HD1b, HD1a}. This is an Out-of-Synch condition between data fragments, which may (if it is persistent) or may not (if it is occasional) require a L1 Reset signal.
  - SKIP – if the SKIP bit is set to 1, then the Event Data is skipped for the current event, and the event shrinks to the Event Record Header and Event Record Trailer only, as if the TBIN equals 0 (although actually not), see details on the L1A Finite State Machine (FSM) below.

All FMM signals carry signal values at the time the DDU_FPGA composes the current Event Record Header, and NOT at the time L1A has been received. This is a copy of signals the DDU_FPGA sends over to the VME_FPGA. The VME_FPGA collects same signals from all the FRONT_FPGAs and the SP_FPGA and finally generates the SP FMM output. According to http://cmsdoc.cern.ch/cms/TRIDAS/horizontal/RUWG/DAQ_IF_guide/DAQ_IF_guide.html the L1A FSM may be in one of the following states:
o 1000 = RDY – Ready => L1A rate is fine.  
The Event Record Structure is per DD/CSR_DFC.

o 0001 = WOF – Warning OverFlow  
=> L1A rate is too high.  
Event queue in the LF has reached the  
LF_WOF_HI level.
If, despite the WOF condition reported, the event  
queue keeps growing and reaches the LF_BSY_LO  
level, then for every event above the LF_BSY_LO  
level the SKIP bit will be set. The SKIP bit acts as  
a local backup for trigger throttling system. It can  
not actually throttle down the L1A rate; instead it  
shortens the readout time in order to prevent the  
FSM from getting into the BSY state.

o 0100 = BSY – Busy => L1A rate is still very high.  
Event queue in the LF has reached the LF_BSY_HI  
level. To prevent the LF from overflow, some of  
the following events will be flushed, until the event  
queue drops to the LF_BSY_LO level and the FSM switches back to WOF  
state.

o 0010 = OSY – Out-of-Synch.  
May be caused by:
  - L1A very high rate persists and LF overflow is imminent, despite all  
efforts to throttle it down via FMM and locally. Given the above measures  
for preventing the LF overflow this should never happen.
  - FA_OSY and SP_OSY bits are set for a number of consecutive Event  
Records. Apparently, something goes wrong and a L1 Reset is required.

**Event Data**

The Event Data consists of the data blocks repeated TBIN times (0 to 7):
- Data Block
- ---------------
-            
- Data Block

**Data Block**

The Data Block content is determined by the Event Configuration Word  
/DD/CSR_DFC/ and the proper data and consists of 1 to 88 16-bit words, going in the  
following order:
- 8 16-bit words for a Data Block Header;
- 4 16-bit ME Data words per each CSC EMU MEx LCT;
- 4 16-bit DT Data words per each DT Barrel MBBy Stub;
- 4 16-bit SP Data words per SPz Track.

Here:
- MEx is one of the following muon LCTs:
  ME1a | ME1b | ME1c => set Active for readout with F1A;
  ME1d | ME1e | ME1f => set Active for readout with F2A;
  ME2a | ME2b | ME2c => set Active for readout with F3A;
  ME3a | ME3b | ME3c => set Active for readout with F4A;
  ME4a | ME4b | ME4c => set Active for readout with F5A.

**Muon order always goes from ME1a to ME4c.**

- MBy is one of the following muon Stubs:
  MBa | MBd => set Active for readout with DTA.

**Muon order always goes from MBa to MBd.**

- SPz is one of the 3 output Tracks:
  SP1, SP2, SP3 => set Active for readout with SPA.

**Track order always goes from SP1 to SP3.**

**Data Block Header**

The Data Block Header consists of 8 16-bit words BH1a thru BH1d and BH2a thru BH2d and is present for every time bin.

Words BH1a and BH1b provide the contents of a Data Block followed:

**MEx Data** is present, if:
1. The corresponding FnA bit is set to 1 (ACTIVE)
   AND
2. Either (ZS = 0) OR (ZS = 1 AND VPx = 1).

**MBy Data** is present, if:
1. The DTA bit is set to 1 (ACTIVE)
   AND
2. Either (ZS = 0) OR (ZS = 1 AND QBy = 1).

**SPz Data** is present if:
1. The SPA bit is set to 1 (ACTIVE)
   AND
2. Either (ZS = 0) OR (ZS = 1 AND MODEz > 0).

**Table 3: Data Block Header**

| D15 | D14 | D13 | D12 | D11 | D10 | D9 | D8 | D7 | D6 | D5 | D4 | D3 | D2 | D1 | D0 | Word |
|-----|-----|-----|-----|-----|-----|----|----|----|----|----|----|----|----|----|-----|
| F5  | F4  | F3  | F2  | F1  |     |    |    |    |    |    |    |    |    |    |     |
| 0   | VP4c| VP4b| VP4a| VP3c| VP3b| VP3a| VP2c| VP2b| VP2a| VP1f| VP1e| VP1d| VP1c| VP1b| VP1a| BH1a|
| 0   | 0   | 0   | VQd | VQa |     |    |    |    |    |    |    |    |    |    |    |     |
| 0   | SE4c| SE4b| SE4a| SE3c| SE3b| SE3a| SE2c| SE2b| SE2a| SE1f| SE1e| SE1d| SE1c| SE1b| SE1a| BH1b|
| 0   | SM4c| SM4b| SM4a| SM3c| SM3b| SM3a| SM2c| SM2b| SM2a| SM1f| SM1e| SM1d| SM1c| SM1b| SM1a| BH1d|
| 0   | AF4c| AF4b| AF4a| AF3c| AF3b| AF3a| AF2c| AF2b| AF2a| AF1f| AF1e| AF1d| AF1c| AF1b| AF1a| BH2a|
| 0   | BX4c| BX4b| BX4a| BX3c| BX3b| BX3a| BX2c| BX2b| BX2a| BX1f| BX1e| BX1d| BX1c| BX1b| BX1a| BH2b|
| 0   | 0   | AFBd| AFBa| 0   | 0   | 0   | PT_LUT | 1:0 |    |    |    |    |    |    |    | SP/M[PT_LUT]/DAT_PT [7:0] | BH2c|
| 0   | 0   | BXBd| BXBa| 0   | 0   | 0   | 0    |    |    |    |    |    |    |    |    | SP/M[PT_LUT]/DAT_PT [15:8] | BH2d|

Here:
- Spare cells are shown in yellow;
- VPx – Valid Pattern bits for 15 MEx LCTs, as they have been received;
- VQy – Valid Quality (Q > 0) bits for 2 MBy Stubs;
− MODEz – Mode values for 3 SP output Tracks ;
− SEx – Synch Error bits for 15 MEx LCTs, as they have been received;
− SMx – Modified Synch Error bits for 15 MEx LCTs; modification performed into the FRONT_FPGA and based on the Optical Link status, Alignment FIFO status and Bunch Crossing Counter status;
− AFx – Alignment FIFO status bits for 15 MEx Links. AFx bit is reset to 0 on L1RES and is set to 1, if the Alignment FIFO word count slips any time after L1RES. So, this word monitors link’s “locked to the received data stream” status;
− BXx – Bunch Crossing Counter status bits for 15 MEx links; BXx bit is set to 1, when link’s BC0 timing mark arrives early or late, and it is reset back to 0, if any next BC0 timing mark arrives in time. So, this bit monitors the ALCT/TMB/MPC timing and post-marks irregular orbits;
− AFBy – Alignment FIFO status bits for 2 MBy data streams; AFBy bit is reset to 0 on L1RES and is set to 1, if the Alignment FIFO word count slips any time after L1RES. So, these bits monitor the data stream clocking status;
− BXy – Bunch Crossing Counter status bits for 2 MBy data streams; BXy bit is set to 1, when link’s BC0 timing mark arrives early or late, and it is reset back to 0, if any next BC0 timing mark arrives in time. So, this bit monitors the DT timing and post-marks irregular orbits;
− PT_LUT[1:0] – PT LUT number is a copy of the SP/CSR_SFC[13:12], and is used to monitor the PT LUT outputs:
  • PT_LUT = 0 => no PT_LUT is monitored;
  • PT_LUT = 1 => PT_LUT1 is monitored;
  • PT_LUT = 2 => PT_LUT2 is monitored;
  • PT_LUT = 3 => PT_LUT3 is monitored.
− SP/M[PT_LUT]/DAT_PT[15:0] – PT LUT data, if PT_LUT > 0.

ME Data

ME Data for each MEx consists of 4 16-bit words: MEa, MEb, MEc, MEd.

MEa word carries Frame1 of LCT data, as it has been received from MPC with rearranged frame fields for better readability in hex and VPx bit omitted, since it has already been extracted to the Data Block Header BH1a.

MEb word carries Frame2 of LCT data, as it has been received from MPC with rearranged frame fields for better readability in hex and SEx bit omitted, since it has already been extracted to the Data Block Header BH1c.
Table 4: ME Data

<table>
<thead>
<tr>
<th>D15</th>
<th>D14</th>
<th>D13</th>
<th>D12</th>
<th>D11</th>
<th>D10</th>
<th>D9</th>
<th>D8</th>
<th>D7</th>
<th>D6</th>
<th>D5</th>
<th>D4</th>
<th>D3</th>
<th>D2</th>
<th>D1</th>
<th>D0</th>
<th>Word</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Wire Group ID [6:0]</td>
<td>Quality [3:0]</td>
<td>CLCT Pattern # [3:0]</td>
<td>MEa</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>BC0</td>
<td>BXN0</td>
<td>L/R</td>
<td>CSC ID [3:0]</td>
<td>CLCT Pattern ID [7:0]</td>
<td>MEb</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>AFFF</td>
<td>RDV1</td>
<td>RER1</td>
<td>ME_BXN [11:0]</td>
<td>MEc</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>AFEF</td>
<td>RDV2</td>
<td>RER2</td>
<td>EPC [3:0]</td>
<td>MPC_LINK_ID [7:0]</td>
<td>MBa</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>MPC # [5:0]</td>
<td>LINK # [1:0]</td>
<td>MBb</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Here:
- CLCT Pattern # [3:0] – 4-bit pattern number encodes the number of layers and whether the pattern consists of half-strips or di-strips. Higher pattern numbers are assigned to straighter high-momentum tracks with more layers hit;
- Quality [3:0] – the more hits the higher LCT Quality;
- Wire Group ID [6:0] – 7-bit Wire Group ID indicates the position of the pattern within the chamber and runs from 0 to 111;
- CLCT Pattern ID [7:0] – For high pT patterns, the 8-bit half-strip ID is between 0 and 159. For low pT patterns, the 8-bit di-strip ID is between 0 and 39. This number corresponds to the position of the pattern selected at the third or “key” layer of the chamber;
- CSC ID [3:0] – 4-bit CSC ID indicates the chamber # and runs from 1 to 9;
- L/R – Left/Right bend bit indicates whether the track is heading towards lower or higher strip number;
- BXN0 – Bunch Crossing Number least significant bit;
- BC0 – Bunch Crossing Zero flag marks that next BXN = 0;
- ME_BXN [11:0] – LCT Bunch Crossing Number (LCT arrival time) picked from a local 12-bit Bunch Counter and running at link timing;
- MPC_LINK_ID [7:0] - MPC Link Identifier consists of:
  - LINK # [1:0] = 0 (default), 1, 2, 3 – MPC Link number;
  - MPC # [5:0] = 0 (default)…63 – MPC Crate number.
  The MPC_LINK_ID is reported by MPC on every L1 Reset.
- { RDV, RER } [1:2] = {Receive Data Valid, Receive Error} – Receive Status Signals; Receive Normal Data Character combination validates frame1 and frame2 of the LCT data:
  - {RDV, RER} = {0,0} – Receive Idle Character;
  - {RDV, RER} = {0,1} – Receive Carrier Extend;
  - {RDV, RER} = {1,0} – Receive Normal Data Character;
  - {RDV, RER} = {1,1} – Receive Error Propagation;
- AFFF – Alignment FIFO Full Flag, should be 0, if AF has been initialized successfully by L1RES;
- AFEF – Alignment FIFO Empty Flag, should be 0, if AF has been initialized successfully by L1RES;
- EPC [3:0] – the Error Propagation counter at the Alignment FIFO output accumulates the “Receive Error Propagation” occurrences since last L1RES.

DT Data

DT Data for each MBy consists of 4 16-bit words: DTa, DTb, DTc, DTd.
DTa and DTb words carry MBY Stub data, as it has been received from the DT Track Finder. The DTa / DTb data format matches the 2-frame SP/DAT_TFB and SP/DAT_SFB formats with the exception of VQ bit for the latter.

Table 5: DT Data

| D15 | D14 | D13 | D12 | D11 | D10 | D9  | D8  | D7  | D6  | D5  | D4  | D3  | D2  | D1  | D0 | Word |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|----|------|
| 0   | 0   | CAL | FLAG| 0   | 0   | 0   | PHI | BEND| [4:0]| 0   | Q   | [2:0]|
| 0   | BC0| BXN0| BXN1| PHI | [11:0]|
| 0   | 0   | 0   | MB  | BXN | [11:0]|
| 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | DTa |

Here:
- Spare cells are shown in yellow;
- Q [2:0] = 0…7 – Muon Quality; For valid data Quality is always > 0;
- PHI BEND [4:0] – Phi Bend angle;
- PHI [11:0] – Azimuth Coordinate;
- FLAG, if 1 then it is a second muon from previous bunch crossing;
- CAL – a DT special mode flag;
- BXN0, BXN1 – two LSBs of the DT Bunch Crossing Number;
- BC0 – Bunch crossing zero timing mark.
- MB_BXN [11:0] – MBY Stub Bunch Crossing Number (Stub arrival time) picked from a local 12-bit Bunch Counter and running at data stream timing;

SP Data

SP Data for each SPy consists of 4 16-bit words: SPa, SPb, SPc, SPd.

SPa and SPb words carry the output track data. The data format matches the SP/DAT_TF and SP/DAT_SF formats with the following exceptions:
- The RSV bit omitted;
- The MODE bits omitted, since they have been extracted to the MB/TF block header earlier;
- The BC0 and BXN0 timing bits added.

Table 6: SP Data

| D15 | D14 | D13 | D12 | D11 | D10 | D9  | D8  | D7  | D6  | D5  | D4  | D3  | D2  | D1  | D0 | Word |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|----|------|
| 0   | SE  | HL  | ETA | [4:0]|
| 0   | BC0 | BXN0| 0   | D23 | PHI | [3:0]|

Here:
- PHI [4:0] is the Azimuth Coordinate;
- ETA [4:0] is the Pseudo rapidity, the Eta [4:1] is a part of the PT LUT address;
- SIGN – Delta Phi Sign bit is a part of the PT LUT address;
- FR – Front/Rear bit;
- CHRG – Muon Charge or Sign bit;
- HL – Halo bit;
- SE – Synchronization Error bit is an OR (or some other Boolean function => to be determined) of Modified Synch Error bits for 15 MEx LCTs and similar bits for 2 MBY Stubs;
- BXN0 – an OR (or some other Boolean function => to be determined) of same signals received with ME LCTs and MB stubs, and passed to the MS;
- BC0 – an OR (or some other Boolean function => to be determined) of same signals received with ME LCTs and MB stubs and passed to the MS;
- D12_Phi[7:0] is a part of the PT LUT address;
- D23_Phi[3:0] is a part of the PT LUT address;
- ME1_ID[2:0], ME2_ID[1:0], ME3_ID[1:0], ME4_ID[1:0], MB_ID[2:0] – track stubs used to build up the track => see Table 7 for the ID interpretation.
- ME1_TBIN[2:0], ME2_TBIN[2:0], ME3_TBIN[2:0], ME4_TBIN[2:0], MB_TBIN[2:0] – Time Bins of the above track stubs used to build up a track.

<table>
<thead>
<tr>
<th>Muon ID</th>
<th>Muon #</th>
<th>Look for track stub into the Spy FIFO:</th>
</tr>
</thead>
<tbody>
<tr>
<td>ME1_ID = 1</td>
<td>ME1a</td>
<td>SP/DAT_SF1/M1</td>
</tr>
<tr>
<td>ME1_ID = 2</td>
<td>ME1b</td>
<td>SP/DAT_SF1/M2</td>
</tr>
<tr>
<td>ME1_ID = 3</td>
<td>ME1c</td>
<td>SP/DAT_SF1/M3</td>
</tr>
<tr>
<td>ME1_ID = 4</td>
<td>ME1d</td>
<td>SP/DAT_SF2/M1</td>
</tr>
<tr>
<td>ME1_ID = 5</td>
<td>ME1e</td>
<td>SP/DAT_SF2/M2</td>
</tr>
<tr>
<td>ME1_ID = 6</td>
<td>ME1f</td>
<td>SP/DAT_SF2/M3</td>
</tr>
<tr>
<td>ME2_ID = 1</td>
<td>ME2a</td>
<td>SP/DAT_SF3/M1</td>
</tr>
<tr>
<td>ME2_ID = 2</td>
<td>ME2b</td>
<td>SP/DAT_SF3/M2</td>
</tr>
<tr>
<td>ME2_ID = 3</td>
<td>ME2c</td>
<td>SP/DAT_SF3/M3</td>
</tr>
<tr>
<td>ME3_ID = 1</td>
<td>ME3a</td>
<td>SP/DAT_SF4/M1</td>
</tr>
<tr>
<td>ME3_ID = 2</td>
<td>ME3b</td>
<td>SP/DAT_SF4/M2</td>
</tr>
<tr>
<td>ME3_ID = 3</td>
<td>ME3c</td>
<td>SP/DAT_SF4/M3</td>
</tr>
<tr>
<td>ME4_ID = 1</td>
<td>ME4a</td>
<td>SP/DAT_SF5/M1</td>
</tr>
<tr>
<td>ME4_ID = 2</td>
<td>ME4b</td>
<td>SP/DAT_SF5/M2</td>
</tr>
<tr>
<td>ME4_ID = 3</td>
<td>ME4c</td>
<td>SP/DAT_SF5/M3</td>
</tr>
<tr>
<td>MB_ID = 1</td>
<td>MB1a</td>
<td>SP/DAT_SFB/M1</td>
</tr>
<tr>
<td>MB_ID = 2</td>
<td>MB1a</td>
<td>SP/DAT_SFB/M1 – next bx</td>
</tr>
<tr>
<td>MB_ID = 3</td>
<td>MB1d</td>
<td>SP/DAT_SFB/M2</td>
</tr>
<tr>
<td>MB_ID = 4</td>
<td>MB1d</td>
<td>SP/DAT_SFB/M2 – next bx</td>
</tr>
</tbody>
</table>
**Event Record Trailer**

The Event Record Trailer consists of 8 16-bit words, where the most significant hex digit is the DDU Code word 0xF and 0xE. **Green cells** in Table 8 show SP-specific configuration settings, **tan cells** carry the SP-specific status, **yellow cells** are spare, and the content of all other cells is per DDU requirements.

**Table 8: Event Record Trailer**

<table>
<thead>
<tr>
<th>D15</th>
<th>D14</th>
<th>D13</th>
<th>D12</th>
<th>D11</th>
<th>D10</th>
<th>D9</th>
<th>D8</th>
<th>D7</th>
<th>D6</th>
<th>D5</th>
<th>D4</th>
<th>D3</th>
<th>D2</th>
<th>D1</th>
<th>D0</th>
<th>Word</th>
</tr>
</thead>
<tbody>
<tr>
<td>0xF</td>
<td>DD/CSR_LF [3:0]</td>
<td>L1A [7:0]</td>
<td>TR1a</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0xF</td>
<td>DD/CSR_LF [7:4]</td>
<td>LFFF</td>
<td>0x7</td>
<td>0xF</td>
<td>TR1b</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0xF</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>SP/CSR_SID [15:8]</td>
<td>YY [3:0]</td>
<td>MM [3:0]</td>
<td>TR1c</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0xF</td>
<td>SP/CSR_SCC [11:0]</td>
<td>TR1d</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0xE</td>
<td>0</td>
<td>SP/CSR_SID [4:0]</td>
<td>DD [4:0]</td>
<td>TR2a</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0xE</td>
<td>DD/CSR_BID [11:0]</td>
<td>TR2b</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0xE</td>
<td>LP</td>
<td>CRC-22 [10:0]</td>
<td>TR2c</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0xE</td>
<td>HP</td>
<td>CRC-22 [21:11]</td>
<td>TR2d</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Here:

- L1A [7:0] – Event Number, lower byte, same as HD1a [7:0];
- DD/CSR_LF [7:0] = 0…255 – DDU_FPGA L1A FIFO word count. Shows the L1A queue size at the moment of transmitting TR1a;
- LFFF = DD/CSR_LF[15] – L1A FIFO Full Flag (LF word count = 256) at the moment of transmitting TR1a;
- SP/CSR_SID [15:8] = {YY [3:0], MM [3:0]} – SP Core Identifier Register: Year and Month of the Core release date;
- SP/CSR_SID [4:0] = DD [4:0] – SP Core Identifier Register: Day of the Core release date;
- SP/CSR_SCC [11:0] – SP Core Configuration Register;
- TR2b == HD2b;
- LP – Low Parity => Even Parity bit for CRC-22 [10:0]
- CRC-22 [21:0] – the last 4 Event Record Trailer words are not included in the CRC
**History**

Version DRAFT – March 20, 2006 – initial release

**Version DRAFT 2.0 – April 05, 2006**

1. In Table 2 references to configuration registers added
2. HD2b fields notation changed
3. HD2c changed completely, explanation of FMM state per Atilla’s document added
4. AFFF and AFEF added to Table 4
5. DD/CSR_LF added to TR1a, TR1b and TR1c in Table 8

**Version DRAFT 2.1 – April 10, 2006**

1. TR2c and TR2d words in Table 8 shared by Parity bits and CRC-22.

**Version DRAFT 2.2 – April 10, 2006**

1. Swapped Quality bits and CLCT Pattern # bits in Table 4
2. Shuffled bits in Table 6 to match layout with SP/DAT_TF and SP/DAT_SF

**Version DRAFT 2.3 – April 13, 2006**

1. Bits BC0, BX0 in Table 6 moved bit left to match same bit positions in Table 4 and Table 5
2. Bits BX0, BX1 swapped in Table 5 to match same bit positions in Table 4 and Table 6

**Version DRAFT 3.0 – April 19, 2006**

1. Consolidated ME and MB/TF Data Blocks into a single Data Block.
2. Changed all tables.