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.

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
- Block of Counters (starting with SP_ERSV = 1);
- Event Data
- Event Record Trailer

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

Table below lists maximum SP Event Record sizes in 16-bit words for 0 to 7 Time Bins.

### Table 1: SP Event Record sizes for 0 to 7 TBIN values

<table>
<thead>
<tr>
<th>TBIN</th>
<th>16-bit Words</th>
<th>64-bit Words</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>20</td>
<td>5</td>
</tr>
<tr>
<td>1</td>
<td>108</td>
<td>27</td>
</tr>
<tr>
<td>2</td>
<td>196</td>
<td>49</td>
</tr>
<tr>
<td>3</td>
<td>284</td>
<td>71</td>
</tr>
<tr>
<td>4</td>
<td>372</td>
<td>93</td>
</tr>
<tr>
<td>5</td>
<td>460</td>
<td>115</td>
</tr>
<tr>
<td>6</td>
<td>548</td>
<td>137</td>
</tr>
<tr>
<td>7</td>
<td>636</td>
<td>159</td>
</tr>
</tbody>
</table>

Maximum Event Record size is 5 64-bit words for Headers/Counters/Trailers plus 22 64-bit words per a TBIN. For TBIN=7, event size comes to 159 of 64-bit or 636 of 16-bit words in total, or 8.0 µsec readout time. The latter corresponds to a L1A rate of 125 kHz.
1 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. The SP_ERSV = 0 refers to the Event Record Structure format valid for SP firmware releases dated before June 27, 2007 that lacks Block of Counters. Block of Counters has been introduced in the Event Record starting with SP_ERSV = 1.

Table 2: Event Record Header

| D15 | D14 | D13 | D12 | D11 | D10 | D9 | D8 | D7 | D6 | D5 | D4 | D3 | D2 | D1 | D0 | Word |
|-----|-----|-----|-----|-----|-----|----|----|----|----|----|----|----|----|----|-----|
| 0x9 | L1A [11:0] | HD1a |
| 0x9 | L1A [23:12] | HD1b |
| 0x9 | 0 | HD1c |
| 0x9 | L1A_BXN [11:0] | HD1d |
| 0xA | 0 | HD2a |
| 0xA | 0 | 0 | DDM | SP_OSY | FA_OSY | RDY | BSY | OSY | WOP | HD2c |
| 0xA | SKIP | DD/CSR_DFC [10:0] | SPA | DTA | F5A | F4A | F3A | F2A | F1A | ZS | TBIN [2:0] | HD2d |

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_TS [3:0] – SP Trigger Sector 1, 2, 3, 4, 5, 6 for +Z EMU side and 7, 8, 9, 10, 11, 12 for –Z EMU side:
  ♦ SP_ERSV [2:0] = 0,...,7 – SP Event Record Structure Version;
    • SP_ERSV = 0 => Jun 14, 2006, Version 4.2 (no Block of Counters);
    • SP_ERSV = 1 => Jul 06, 2007, Version 5.1 (with Block of Counters);
    • SP_ERSV = 2 => TBD;
    • SP_ERSV = 3 => TBD;
    • SP_ERSV = 4 => TBD;
    • SP_ERSV = 5 => TBD;
    • SP_ERSV = 6 => TBD;
    • SP_ERSV = 7 => TBD;
  ♦ SP_PADR [4:0] = 6...11, 16...21 – SP Physical Address (Slot Number);
− DDM = DD/CSR_DFC [15] = 0 (default) / 1 – DDU (default) / VME Readout Mode.
− DD/CSR_DFC [10:0] = DDU_FPGA / DAQ FIFO 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, MB1d;
♦ 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 Resync signal. The SP_OSY condition is checked only if the SPA = 1.
  − 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 Resync signal. The FA_OSY condition is checked only for FRONT_FPGAs with ACTIVE bit set.
  − 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, Block of Counters 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
the L1A FSM may be in one of the following states:

- **1000 = RDY** – Ready => L1A rate is fine. The Event Record Structure is per DD/CSR_DFC.
- **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.
- **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.
- **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 Resync is required.

2 **Block of Counters**

The Block of Counters consists of 2 30-bit counters:
- Track Counter;
- Orbit Counter.
Table 3: Block of Counters

<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></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>BCa</td>
</tr>
<tr>
<td>0</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>BCb</td>
</tr>
<tr>
<td>0</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>BCc</td>
</tr>
<tr>
<td>0</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>BCd</td>
</tr>
</tbody>
</table>

The Track Counter (TC) counts tracks found by the SP core logic and sent to the Muon Sorter (MS). It increments by 1, if only one track found; by 2, if 2 tracks found and by 3, if 3 tracks found in the current Bunch Crossing. The Orbit Counter counts LHC orbits to give time reference to the TC counter. Both counters are reset on an Orbit Counter Reset (OC0) TTC command. The counters are read out on L1A signal prior to be incremented by number of Tracks found or BC0 TTC command, either or both of which may happen to be in the same Bunch Crossing.

3 Event Data

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

3.1 Data Block

The Data Block content is determined by the Event Configuration Word (DD/CSR_DFC) and the proper data and consists of 12 to 92 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 MB Data words per each DT Barrel MBy 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:
  - MB1a | MB1d = set Active for readout with DTA.
  **Muon order always goes from MB1a to MB1d.**
- 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.**

3.1.1 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 4: Data Block Header

<table>
<thead>
<tr>
<th>D15 D14 D13 D12</th>
<th>D11 D10 D9 D8</th>
<th>D7 D6 D5 D4</th>
<th>D3 D2 D1 D0</th>
<th>Word</th>
</tr>
</thead>
<tbody>
<tr>
<td>F5 F4 F3 F2 F1</td>
<td>F5 F4 F3 F2 F1</td>
<td>F5 F4 F3 F2 F1</td>
<td>F5 F4 F3 F2 F1</td>
<td>F5 F4 F3 F2 F1</td>
</tr>
<tr>
<td>0 VP4c VP4b VP4a</td>
<td>0 VP3c VP3b VP3a</td>
<td>0 VP2c VP2b VP2a</td>
<td>0 VP1c VP1b VP1a</td>
<td></td>
</tr>
<tr>
<td>0 0 VQd VQa</td>
<td>MODE3</td>
<td>MODE2</td>
<td>MODE1</td>
<td>BH1a</td>
</tr>
<tr>
<td>0 SE4c SE4b SE4a</td>
<td>0 SE3c SE3b SE3a</td>
<td>0 SE2c SE2b SE2a</td>
<td>0 SE1c SE1b SE1a</td>
<td></td>
</tr>
<tr>
<td>0 SM4c SM4b SM4a</td>
<td>0 SM3c SM3b SM3a</td>
<td>0 SM2c SM2b SM2a</td>
<td>0 SM1c SM1b SM1a</td>
<td></td>
</tr>
<tr>
<td>0 AF4c AF4b AF4a</td>
<td>0 AF3c AF3b AF3a</td>
<td>0 AF2c AF2b AF2a</td>
<td>0 AF1c AF1b AF1a</td>
<td></td>
</tr>
<tr>
<td>0 BX4c BX4b BX4a</td>
<td>0 BX3c BX3b BX3a</td>
<td>0 BX2c BX2b BX2a</td>
<td>0 BX1c BX1b BX1a</td>
<td></td>
</tr>
<tr>
<td>0 0 AFBd AFBa</td>
<td>0 0 0 0</td>
<td>PT_LUT [1:0]</td>
<td>SP/M[PT_LUT]/DAT_PT [7:0]</td>
<td>BH2c</td>
</tr>
<tr>
<td>0 0 BXBd BXBa</td>
<td>0 0 0 0</td>
<td>0 0 0 0</td>
<td>SP/M[PT_LUT]/DAT_PT [15:8]</td>
<td>BH2d</td>
</tr>
</tbody>
</table>

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 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.

### 3.1.2 ME Data Record

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

The 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.

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

<table>
<thead>
<tr>
<th>Table 5: MEx Data Record</th>
</tr>
</thead>
<tbody>
<tr>
<td>D15 D14 D13 D12 D11 D10 D9 D8 D7 D6 D5 D4 D3 D2 D1 D0 Word</td>
</tr>
<tr>
<td>0 Wire Group ID [6:0] Quality [3:0] CLCT Pattern # [3:0] MEa</td>
</tr>
<tr>
<td>0 BC0 BXN0 L/R CSC ID [3:0] CLCT Pattern ID [7:0] MEb</td>
</tr>
<tr>
<td>0 AFFF RDV1 RER1 ME_BXN [11:0] MEc</td>
</tr>
<tr>
<td>0 AFEF RDV2 RER2 EPC [3:0] ME_ED [15:0] MEd</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 [1:0] – 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:
  o LINK # [1:0] = 0 (default), 1, 2, 3 – MPC Link number;
  o MPC # [5:0] = 0 (default)...63 – MPC Crate number.
The MPC_LINK_ID is reported by MPC on every Resync.
− { 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:
  o {RDV, RER} = {0,0} – Receive Idle Character;
  o {RDV, RER} = {0,1} – Receive Carrier Extend;
  o {RDV, RER} = {1,0} – Receive Normal Data Character;
  o {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.

3.1.3 MB Data Record

The Data Record for each MBy consists of 4 16-bit words: MBa, MBb, MBc, MBd.

The MBa and MBb words carry MBy Stub data, as it has been received from the DT Track Finder. The MBa / MBb data format matches the 2-frame SP/DAT_TFB and SP/DAT_SFB formats with the exception of VQ bit for the latter.

Table 6: MBy Data Record

<table>
<thead>
<tr>
<th>D15 D14 D13 D12</th>
<th>D11 D10 D9 D8</th>
<th>D7 D6 D5 D4</th>
<th>D3 D2 D1 D0</th>
<th>Word</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 0 CAL FLAG</td>
<td>0 0 PHI BEND [4:0]</td>
<td>0 Q [2:0]</td>
<td>MBa</td>
<td></td>
</tr>
<tr>
<td>0 BC0 BXN0 BXN1</td>
<td>PHI [11:0]</td>
<td>MBb</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 0</td>
<td>MB_BXN [11:0]</td>
<td>MBc</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 0</td>
<td></td>
<td></td>
<td>MBd</td>
<td></td>
</tr>
</tbody>
</table>

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 MBy special mode flag;
− BXN0, BXN1 – two LSBs of the MBy 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;
3.1.4 SP Data Record

The Data Record for each SPz consists of 4 16-bit words: SPa, SPb, SPc, SPd.

The 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 block header earlier;
- The BC0 and BXN0 timing bits added.

Table 7: SPz Data Record

| D15 | D14 | D13 | D12 | D11 | D10 | D9  | D8  | D7  | D6  | D5  | D4  | D3  | D2  | D1  | D0  | Word   |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-------|
| 0   | SE  | HL  | ETA [4:0] | CHRG | FR  | SIGN | PHI [4:0] |       |       |       |     |     |     |     | SPa   |
| 0   | BC0 | BXN0 | 0     | D23_PHI [3:0] | D12_PHI [7:0] |       |       |     |     |     |     |     |     |       |

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 8 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 8: Spy FIFO to Muon ID Correspondence

<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>

4 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 9 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 9: 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></td>
<td>DD/CSR_LF [3:0]</td>
<td></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>
</tr>
<tr>
<td>0xF</td>
<td></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>
</tr>
<tr>
<td>0xF</td>
<td></td>
<td>DD/CSR_BID [7,15:8]</td>
<td></td>
<td>B</td>
<td>DD/CSR_BID [7,15:8]</td>
<td>TR1c</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></td>
<td>SP/CSR_SCC [11:0]</td>
<td></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>
</tr>
<tr>
<td>0xE</td>
<td></td>
<td>DD/CSR_BID [4:0]</td>
<td></td>
<td>DD/CSR_BID [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>
</tr>
<tr>
<td>0xE</td>
<td></td>
<td>SP_LADR [3:0]</td>
<td>SP_ERSV [2:0]</td>
<td>SP_PADR [4:0]</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>
</tr>
<tr>
<td>0xE</td>
<td>LP</td>
<td></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>
</tr>
<tr>
<td>0xE</td>
<td>HP</td>
<td></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>
</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;
- DD/CSR_BID [7] = {BB} – SP readout configuration year base (0 / 16);
- DD/CSR_BID [15:8] = {YY [3:0], MM [3:0]} – SP readout configuration year (2000 + 16*BB + YY) and month (MM);
- DD/CSR_BID [4:0] = DD [4:0] – SP readout configuration day;
- 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

1. **Version DRAFT – March 20, 2006 – initial release**

2. **Version DRAFT 2.0 – April 05, 2006**
   a. In Table 2 references to configuration registers added
   b. HD2b fields notation changed
   c. HD2c changed completely, explanation of FMM state per Atilla’s document added
   d. AFFF and AFEF added to Table 5
   e. DD/CSR_LF added to TR1a, TR1b and TR1c in Table 9

3. **Version DRAFT 2.1 – April 10, 2006**
   a. TR2c and TR2d words in Table 9 shared by Parity bits and CRC-22.

4. **Version DRAFT 2.2 – April 10, 2006**
   a. Swapped Quality bits and CLCT Pattern # bits in Table 5
   b. Shuffled bits in Table 7 to match layout with SP/DAT_TF and SP/DAT_SF

5. **Version DRAFT 2.3 – April 13, 2006**
   a. Bits BC0, BX0 in Table 7 moved bit left to match same bit positions in Table 5 and Table 6
   b. Bits BX0, BX1 swapped in Table 6 to match same bit positions in Table 5 and Table 7

6. **Version DRAFT 3.0 – April 19, 2006**
   a. Consolidated ME and MB/TF Data Blocks into a single Data Block.
   b. Changed all tables.

7. **Version 4.0 – April 25, 2006**
   a. First non-draft version

8. **Version 4.1 – May 10, 2006**
   a. Style edits
9. **Version 4.2 – June 14, 2006**
   a. TR1c, TR2a: SP/CSR_SID replaced with SP/CSR_CID
   b. HD2c: Added DDM = DD/CSR_DFC[15]

10. **Version 5.0 – June 28, 2007**
    a. HD2b: added SP_ERSV hard coded field in DD/CSR_BID register to distinguish between different Event Record Structure formats.
       Version 5.0 is identified with SP_ERSV = 1.
    b. Added Block of Counters just after Event Record Header

11. **Version 5.1 – July 06, 2007**
    a. 24-bit Track and Orbit counters expanded to 30-bit counters

12. **Version 5.2 – September 11, 2007**
    a. Reassigned HD2b / TR2b from SP configuration settings to SP status
    b. TR1c and TR2a carries the DD/CSR_BID register value with SP configuration date

13. **Version 5.2A – December 06, 2007**
    a. Updated SP_ERSV = 2 on KK request.
       Update valid for DD/CSR_CID date equal to or later Dec 06, 2007.