Belle II readout

Trigger and DAQ workshop 2025-10-22

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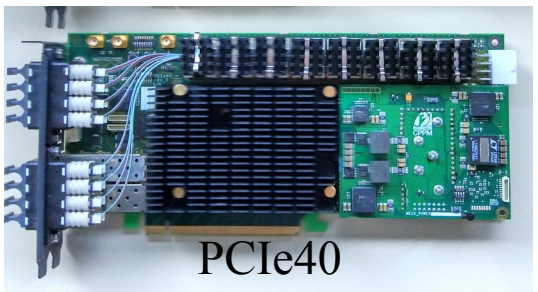
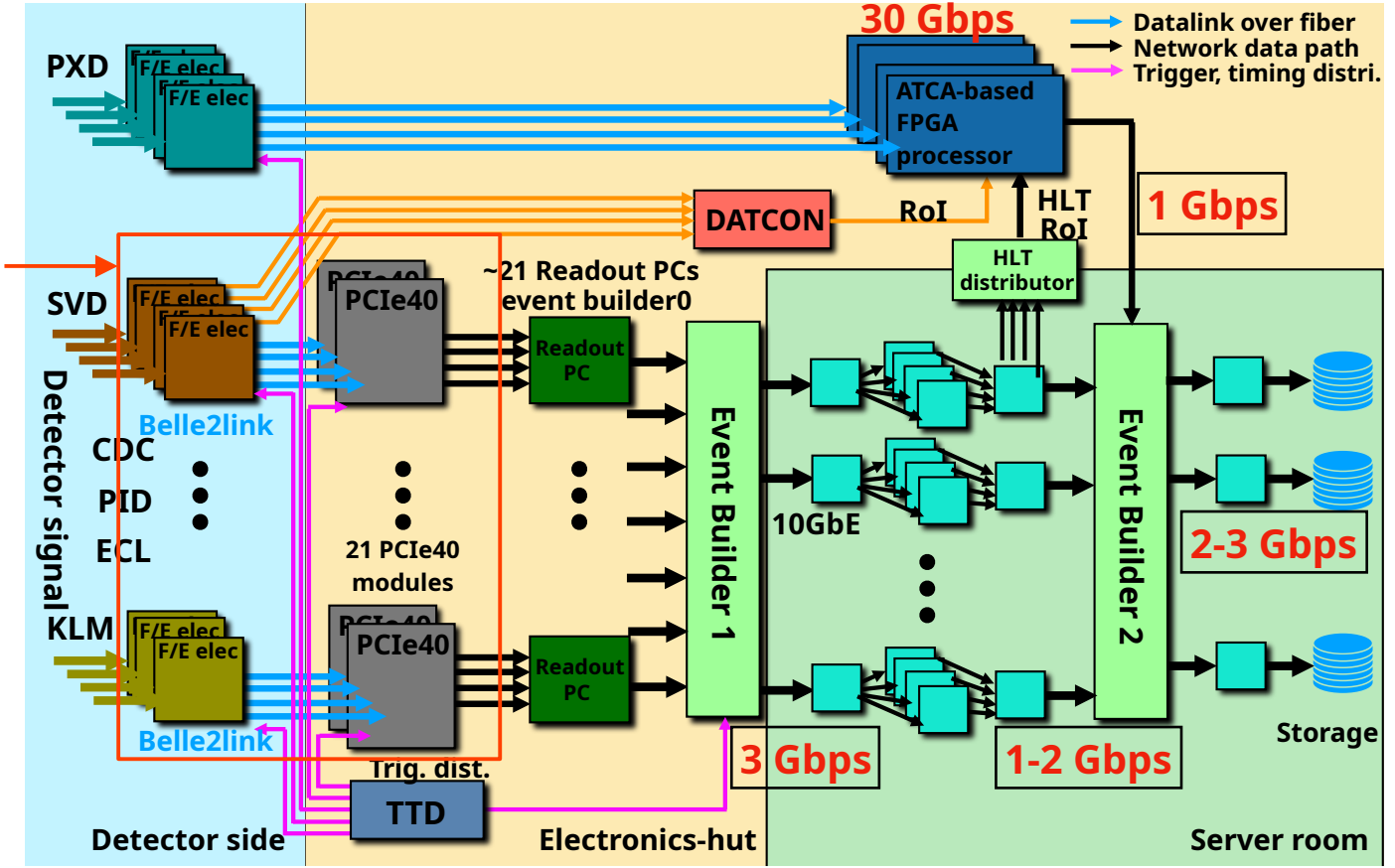
Belle II data acquisition system

* Belle II readout has a common readout for every subsystem except PXD.
  - Belle2link protocol
  - PCIe40 boards
    (replacing previous COPPER boards)

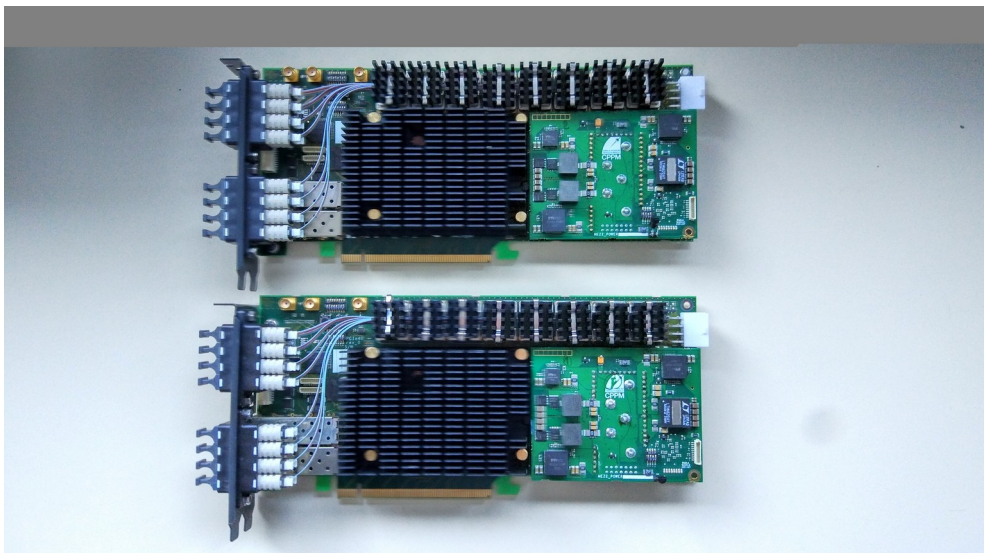




from Qi-Dong Zhou's slides

PCIe40 boards

- Based on ARRIA 10 GX115 FPGA
- 48 transceivers.
- PCIe 16x Gen3 (2 8x lanes)
- DMA Transfer up to 100 Gbps.
- External clock synchronisation capability.
- Up to 66 Mbit internal memory in FPGA
- External memory by the server (Giga Byte)



from 2019 TRGDAQ workshop, Daniel Charlet's talk

PCIe40: PCIexpress transfer

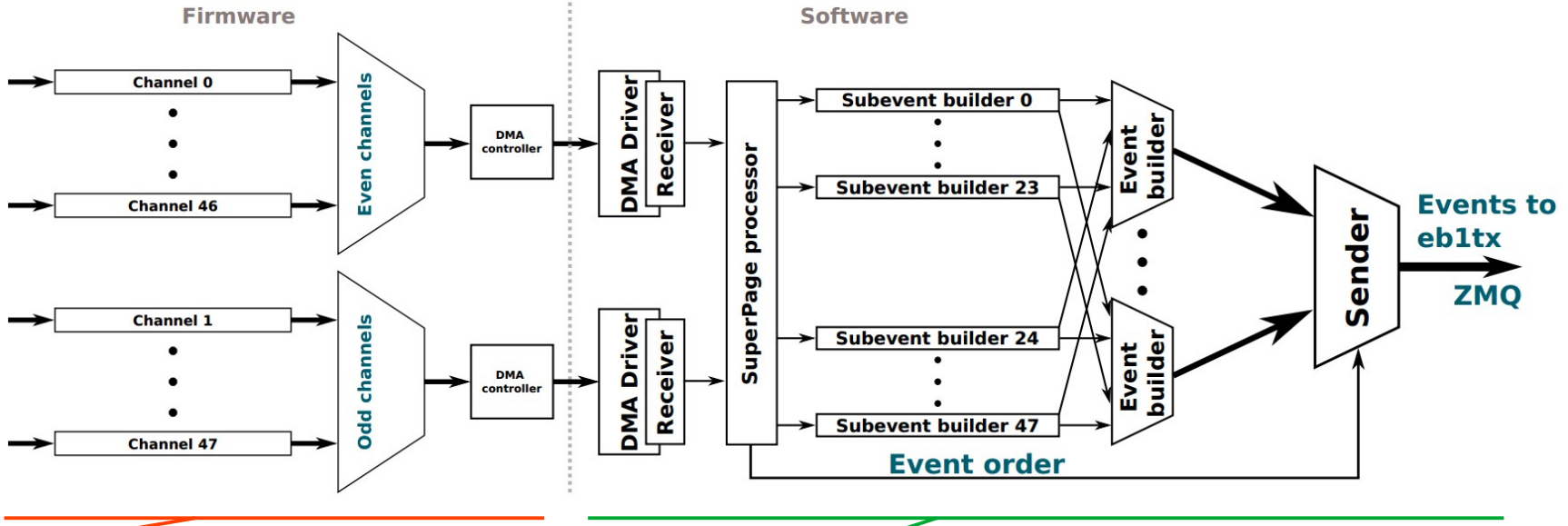
- Data transferred to PC via PCIexpress.
- Two types of transfer:
  - read/write to *registers* (BAR), for « slow » data : slow control and PCIe40 internal configuration
  - Read by *DMA* for fast data acquisition: is used for data coming from Front-End

- **PCIe40 uses *2x8 lanes busses*, not 1x16**: if one wants to use the 2x8 configuration, the server must implement the « PCIe bifurcation » feature, not available on all of them
  - (I think all current readout PCs support this feature)

- For the moment, current firmware development based on 1x8 PCIe interface: bandwith limited to 50 Gb/*s* (but large enough since ultimately the data transfered out of the PC server is limited to 10 Gb/*s* by the ethernet connection)
- Upgrade to 100 Gb/*s* will also be possible in the future

from 2019 TRGDAQ workshop, Daniel Charlet's talk

Updates to the PCIe40 readout software



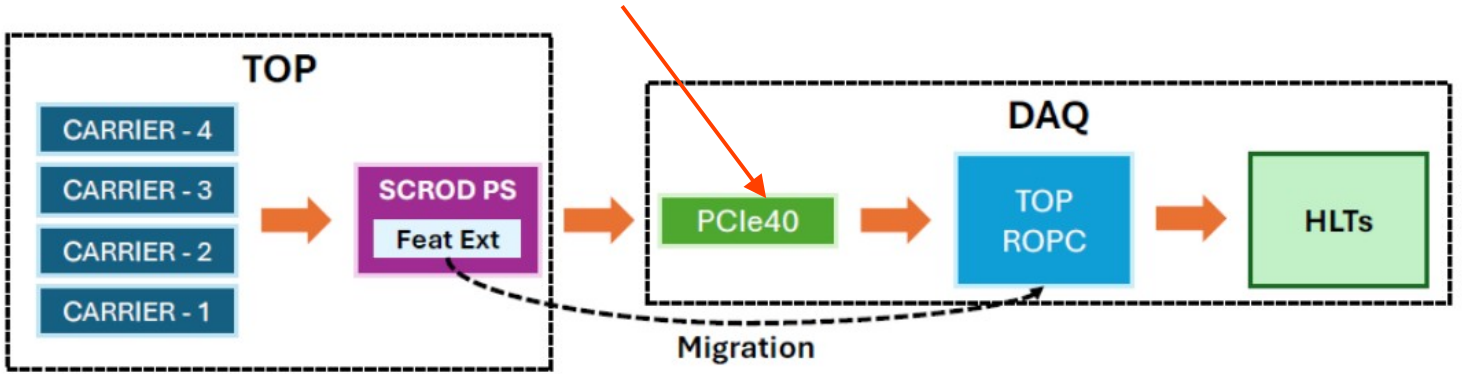
* Merged Dima Levit's code for 2x8 PCIe support into pcie40_software.
  - For the pcie40_firmware, Dima's code for 2x8 PCIe support is yet to be merged.
* Updated DMA driver to compile on both newer (readout PCs) and older (testbench PC) kernels.
* Updated slow control scripts for PCIe40.

Updates are being included in the current stable branch
and a testing branch for TOP feature extraction.

TOP feature extraction

* In order to reduce radiation induced SCROD PS lockups, TOP group has decided to move TOP feature extraction functionality to the readout PC software.

* This requires updates to the PCIe40 readout software.



from 52nd B2GM, Kenji Inami-san's talk

* TOP feature extraction code has been migrated to pcie40_software by Harsh Purwar and Shahab Kohani.

* Updates to the core pcie40_software have been prepared by Yamada-san (MR 54)
  - The subevent building has been extended to allow waveform saving in TOP data.

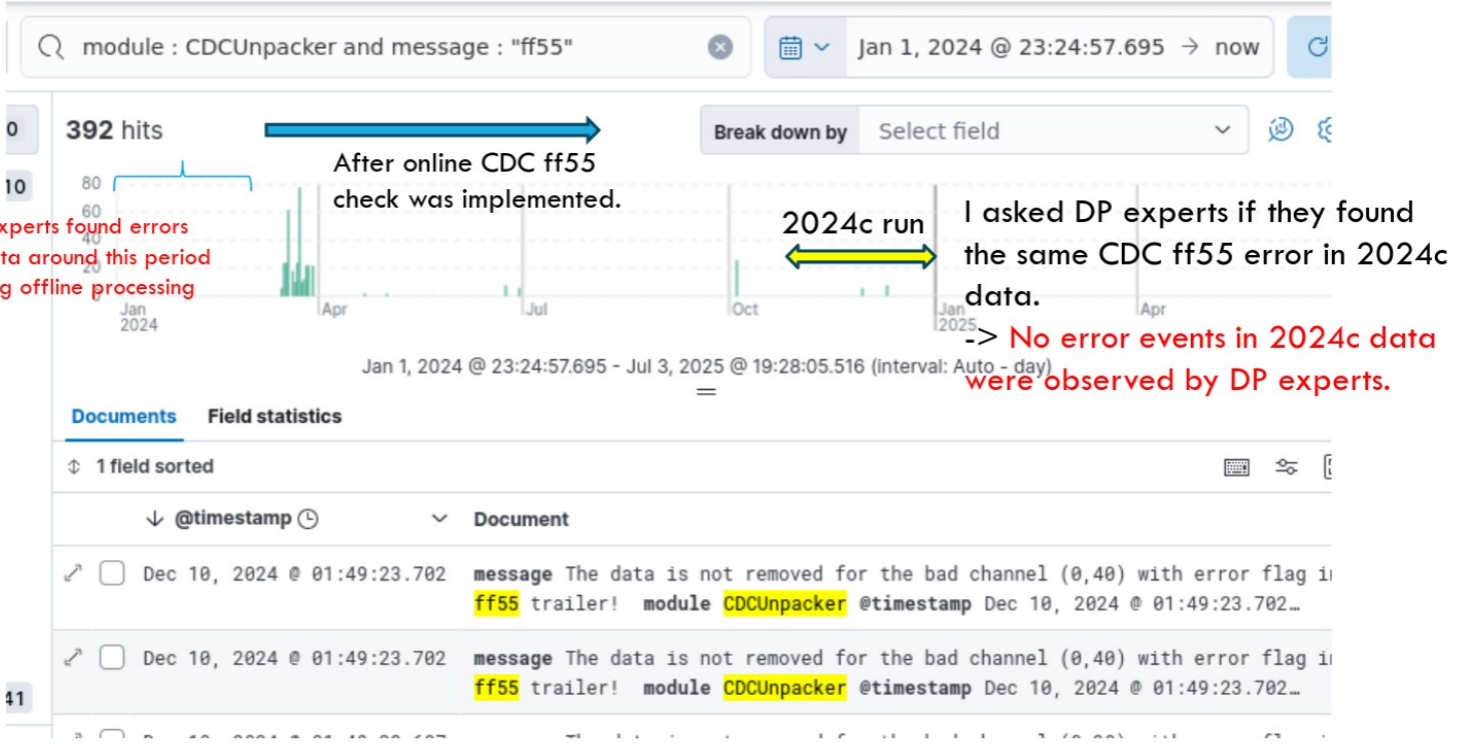
Data corruption (event mixing) in 2024ab runs

AFTER THE CDC UNPACKER CHECK IS IMPLEMENTED DURING EXP30…

https://gitlab.desy.de/belle2/software/basf2/-/issues/10803

- After the CDC "ff55 trailer" check was implemented on Mar. 12, this error can be detected by online only for CDC. ('drwxr-xr-x 46 cvmfs cvmfs 4096 Mar 12 2024 release-08-01-01

)

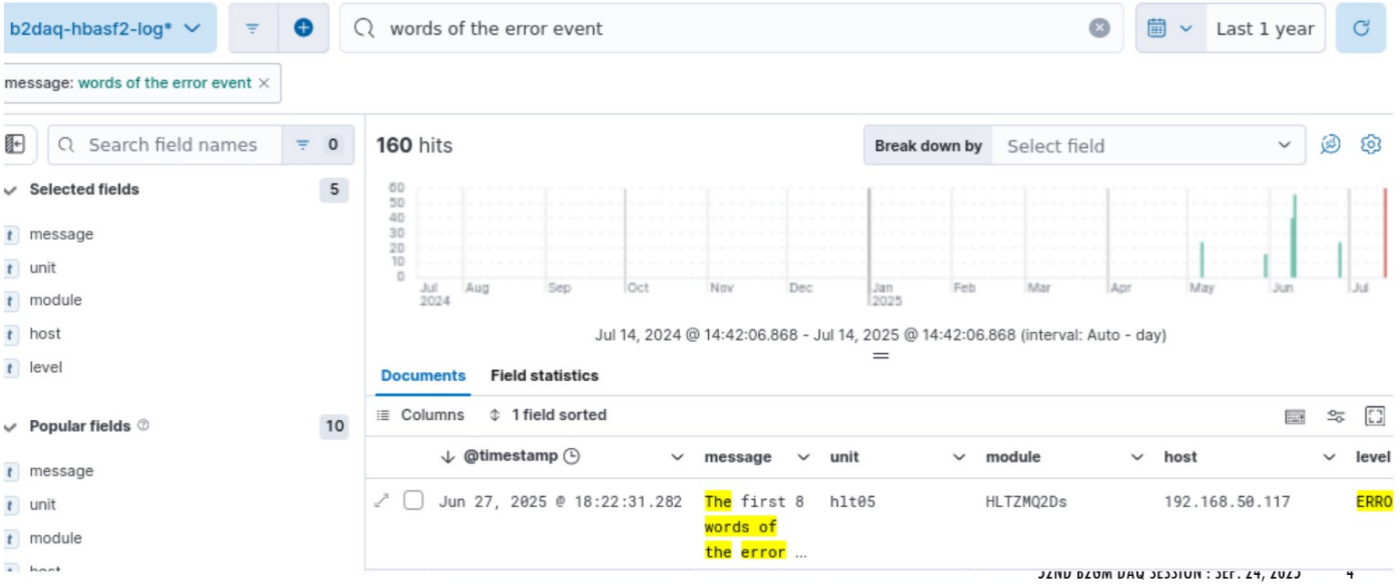


from Yamada-san's talk on the 52nd B2GM

HEX DUMP IN LOG IN HLT WORKER NODE

https://gitlab.desy.de/belle2/software/basf2/-/merge_requests/4251

- HLTZMQ2Ds checks the magic words of RawCOPPER header and trailer on an hlt worer node.
- When invalid pattern is detected, it goes to FATAL state and record 6 words in b2daq-hbasf2-log in ElasticSearch.
- SeokHee implemented it in HLT around April. He gave me a querry to get the hex dump.
  - http://b2srv1.daqnet.kek.jp/s/daq/app/discover#/?_g=(filters:!(),refreshInterval:(pause:!t,value:60000),time:(from:now-1w,to:now))&_a=(columns:!(message,unit,module,host,level),filters:!(('$state':(store:appState),meta:(alias:!n,disabled:!f,field:message,index:b1fe1cad-30f3-515d-afe9-08775c2ad8a1,key:message,negate:!f,params:(query:'words%20of%20the%20error%20event'),type:phrase),query:(match_phrase:(message:'words%20of%20the%20error%20event')))),grid:(columns:(host:(width:153),level:(width:112),module:(width:142),unit:(width:124))),index:b1fe1cad-30f3-515d-afe9-08775c2ad8a1,interval:auto,query:(language:kuery,query:'words%20of%20the%20error%20event'),sort:!(!('@timestamp',desc)))

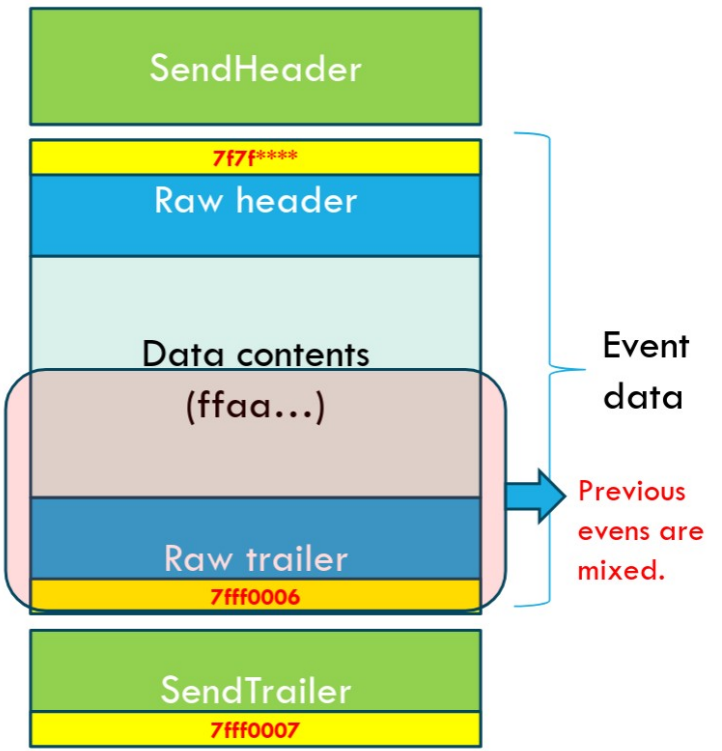


from Yamada-san's talk on the 52nd B2GM

ARE THOSE HLTZMQ2DS ERRORS SIMILAR TO THE ONES OBSERVED BY DP EXPERTS IN 2024AB RUNS ?

- HLTZMQ2Ds errors :160 entries found in ElasticSearch
  - Actual # or unique error events was 38, considering multiple error messages for the same error.
  - # of runs with the errors = 14
    - Error at the same time in multiple HLT units
- Header magic #(7f7f….) appeared to be fine.
  - This is consistent with the errors found by DP group.
- Trailer magic word was apparantly invalid.
  - This is also consistent with the errors found by DP group.

Corrupted event reported by DP experts



from Yamada-san's talk on the 52nd B2GM

Checking RawCOPPER trailer magic words in eb1rx(running on hltin) by Yamagata-san

The patch checks 3 times (Yamagata-san)

- receive from eb1tx

```
uint32_t * second_word_p = (uint32_t *)(m_buffer) + 1;
if (0x7F7F0000 != (0xFFFF0000 & *second_word_p)) {
  log("[FATAL] wrong second word (%08x) from eb1tx\n", *second_word_p);
}
```

- receive from internal ZMQ

```
uint32_t * second_word_p = (uint32_t *)(m_zbody.data()) + 1;
if (0x7F7F0000 != (0xFFFF0000 & *second_word_p)) {
  log("[FATAL] wrong second word (%08x) from inproc ZMQ\n", *second_word_p);
}
```

- before sending to HLT

```
uint32_t * second_word_p = (uint32_t *)(m_zbody.data()) + 1;
if (0x7F7F0000 != (0xFFFF0000 & *second_word_p)) {
  log("[FATAL] wrong second word (%08x) will be sent to HLT\n", *second_word_p);
}
```

3

from Yamada-san's talk on the 52nd B2GM

Most of them reported the trailer word of 0x00000000(it must be 0x7fff0006) but sometimes there were nonzero but wrong trailer magic words observed.

Some data patterns found in the HLT hex dumps match the error messages of eb1rx.
(The timestamp and HLT unit number also match.)

@timestamp	HLT hex dump messages	unit	eb1rx log	eb1rx log
Jun 9, 2025 @ 13:15:23.239	The last 8 words: 00080000 00020a09 23090200 23000104 40040200 40050509 a0950082 **16090201**	hlt11	16090201	
Jun 9, 2025 @ 15:54:38.786	The last 8 words: a84700c3 a94700ca aa4700dd 4e070404 4e03030a ab4700de 66030203 **66040308**	hlt11	66040308	
Jun 10, 2025 @ 13:33:51.462	The last 8 words: 9fba0084 00050e00 00050300 16020106 16040709 38030000 38000009 **68020200**	hlt03	68020200	
Jun 27, 2025 @ 18:22:31.277	The first 8 words: 0000015f 7f7f0438 0904c300 **00000ed4** 14018603 685e62d7 02000006 00000000	hlt11	00000ed4	
May 30, 2025 @ 20:06:54.009	The last 8 words: 00000000 2d100004 001f0074 00005bd6 00000000 2d100004 001f0074 **00005bd6**	hlt12	00005bd6	
May 30, 2025 @ 20:06:54.006	The last 8 words: 0ec437b0 00001fff 23100004 001f0074 00005bcc 00000000 23100004 **001f0074**	hlt02	001f0074	
May 30, 2025 @ 20:06:54.006	The last 8 words: 00000000 7fff0006 5d89778e 7fff0007 00000000 24100005 001f01bc **10005bcd**	hlt11	10005bcd	
Jun 10, 2025 @ 13:33:51.460	The last 8 words: d40b07fd 80c900ec 27000104 270b0700 81c900e7 05020007 05000c07 **1703070b**	hlt12	1703070b	
Jun 9, 2025 @ 13:15:23.238	The la) 7e03060d 9c850fdb **2b00020f**	hlt12	2b00020f	
Jun 10, 2025 @ 13:33:51.459	The la 250d0706 2b010001 **2b080b07**	hlt04	2b080b07	
Jun 9, 2025 @ 15:54:38.785	The la 46000000 a99300bb **2c070103**	hlt02	2c070103	
Jun 10, 2025 @ 13:33:51.461	The last 8 words: 7d080900 7d0b0b01 7e000005 7e0d0000 8d4a00e8 2c040801 2c070b07 **4b000003**	hlt02	4b000003	
Jun 9, 2025 @ 14:25:44.488	The last 8 words: 1c00070a 1c000000 1d090103 1d000104 1f090001 1f030000 7e050c01 **7e010001**	hlt02	7e010001	
Jun 10, 2025 @ 13:33:51.460	The last 8 words: e0000000 ff55cd56 5f060500 5f04060a e0000000 ff55efe3 fe74ee0c **ff550000**	hlt11	ff550000	
Jun 27, 2025 @ 18:22:31.273	The last 8 words: **00000ec9** 0ec9cd3f ff550000 ffaa1ec9 113e5240 20000068 254b0000 **00000ec9**	hlt03	ff550000	00000ec9
Jun 27, 2025 @ 18:22:31.277	The last 8 words: ffaa25c4 0f2a1380 20000048 05fb0000 00000ec4 0ec4116b **ff550000** **ffaa27c4**	hlt11	ff550000	ffaa27c4
Jun 27, 2025 @ 18:22:31.278	The last 8 words: 20000066 75230000 00000ec8 0ec84ec7 **ff550000** ffaa29c8 10e3f200 **2000008d**	hlt02	ff550000	2000008d
Jun 27, 2025 @ 18:22:31.278	The last 8 words: ffaa25c4 0f2a1380 20000048 05fb0000 00000ec4 0ec4116b **ff550000** **ffaa27c4**	hlt11	ff550000	ffaa27c4
Jun 10, 2025 @ 13:33:51.461	The last 8 words: 7e050000 ac9c00ec 7e06010c 7e000004 ad9c00f1 04030001 0404050b **4e000206**	hlt05	4b000206	

Naturally, the corrupted data resulted in errors on both eb1rx and HLTZMQ2Ds.

from Yamada-san's talk on the 52nd B2GM

Correlations between “RawCOPPER header/trailer error in HLT” and “invalid trailer word error” in eb1rx

	message : "magic number" and NOT unit: hlt13
2025/6/27 18:21	After a long error period, run was restart by STOP-START
2025/6/9 13:00	after 433sec. Run
2025/6/9 13:15	after 179sec. Run
2025/6/9 14:10	after 191sec. Run
2025/6/9 14:25	after 760sec. Run
2025/6/9 15:54	after 833sec. Run
2025/6/10 11:50	after 158sec. Run
2025/6/10 13:33	after 89sec. Run
2025/6/10 13:49	after 832sec. Run
	Ack, sorry, I have accidentally rebooted recl1 instead of my PC.
2025/5/30 20:06	5556sec. Run
2025/5/6 23:20	ECL was runing for about 1min. The stopped.

For all those 11 header/trailer errors detected by HLT, eb1rx also issued non-zero invalid trailer errors at the same time.

➔ A clear correlation between them.

  ➔ Sometimes, eb1rx error occurred but no HLT error was reported, though.

➔ So, the recently observed HLT RawCOPPER header/trailer errors reported on the prev. page seems to be related to data corruption before eb1rx ?

➔ According to Yamagata-san, those corrupted data detected by eb1rx are anyway sent to HLT.

from Yamada-san’s talk on the 52nd B2GM

Data-corruption:

- The error reported by DP experts for 2024ab run likely occurs between eb1tx and eb1rx. This guess is supported by :
  - The error occurred in different HLTs at the same time
  - Eb1rx already detected corrupted data.
- A header and trailer checking function was implemented in HLTZMQ2Ds running on hlt worker nodes, which will block such corrupted events from being recorded in the 2025c run.

from Yamada-san's talk on the 52nd B2GM

Summary

* Several updates to PCIe40 software have been added:
  - Added 2xPCIe support, updated driver code, added few more minor updates.
  - For TOP feature extraction, subevent building has been extended.

Data-corruption:

- The error reported by DP experts for 2024ab run likely occurs between eb1tx and eb1rx. This guess is supported by :
  - The error occurred in different HLTs at the same time
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- A header and trailer checking function was implemented in HLTZMQ2Ds running on hlt worker nodes, which will block such corrupted events from being recorded in the 2025c run.