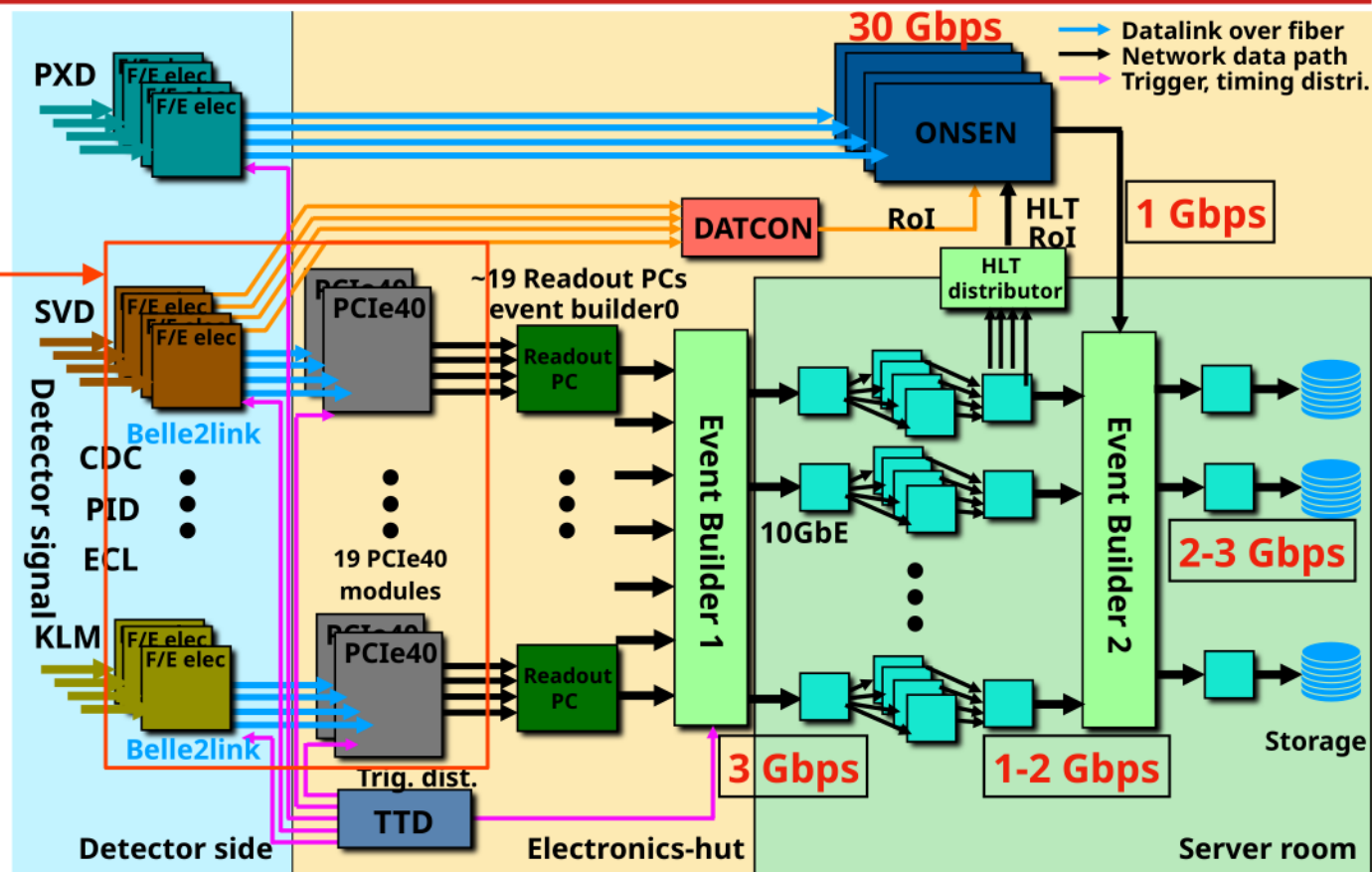
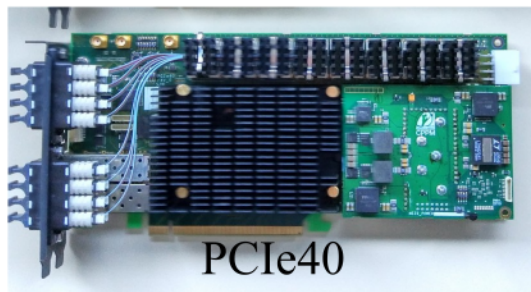


Belle II readout

Trigger and DAQ workshop 2025-10-22
Mikhail Remnev

Belle II data acquisition system

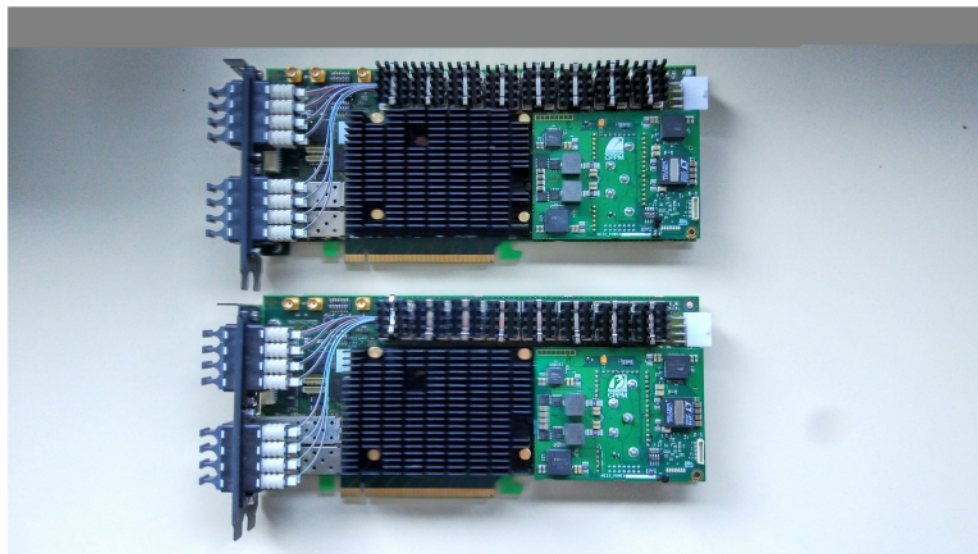
- * Belle II readout has a common readout for every subsystem except PXD.
 - Belle2link protocol
 - PCIe40 boards (replacing previous COPPER boards)



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)

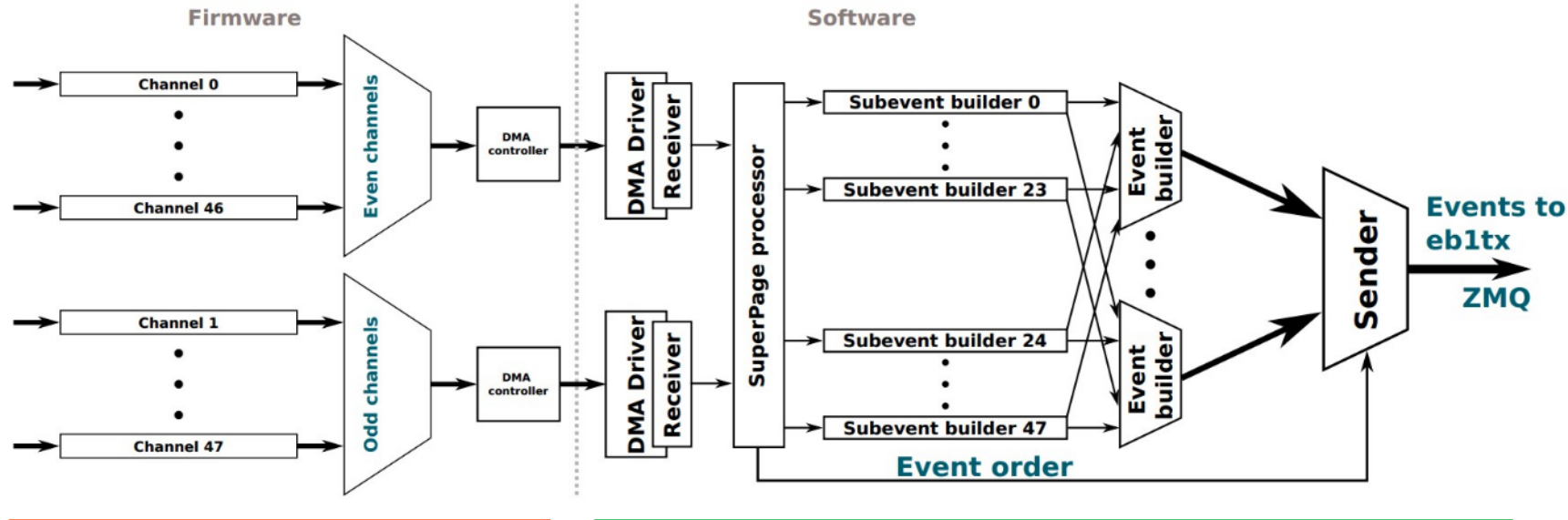


PCIe40: PCIe express transfer



- Data transferred to PC via PCIe express.
- 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: bandwidth limited to 50 Gb/s (but large enough since ultimately the data transferred 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

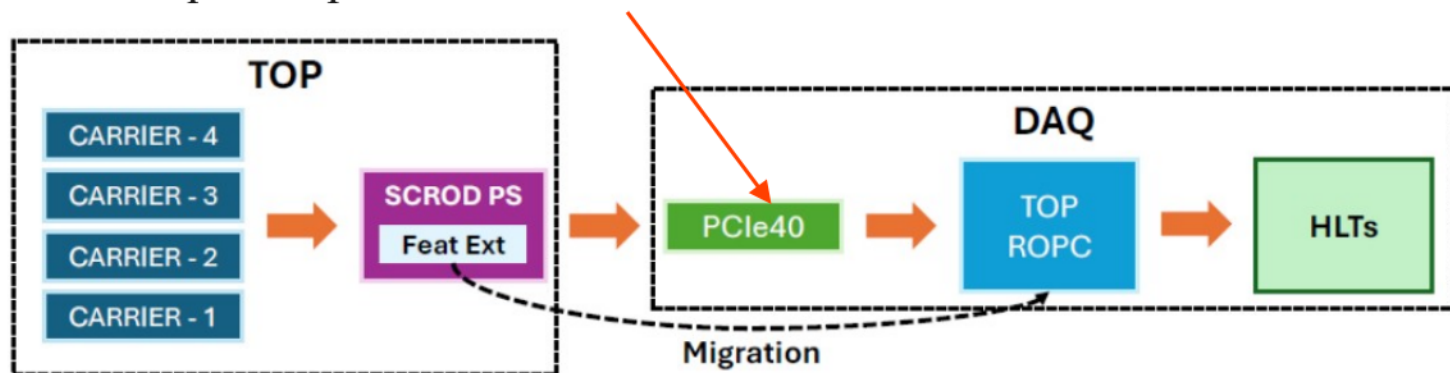
Updates to the PCIe40 readout software



- * 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.

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.



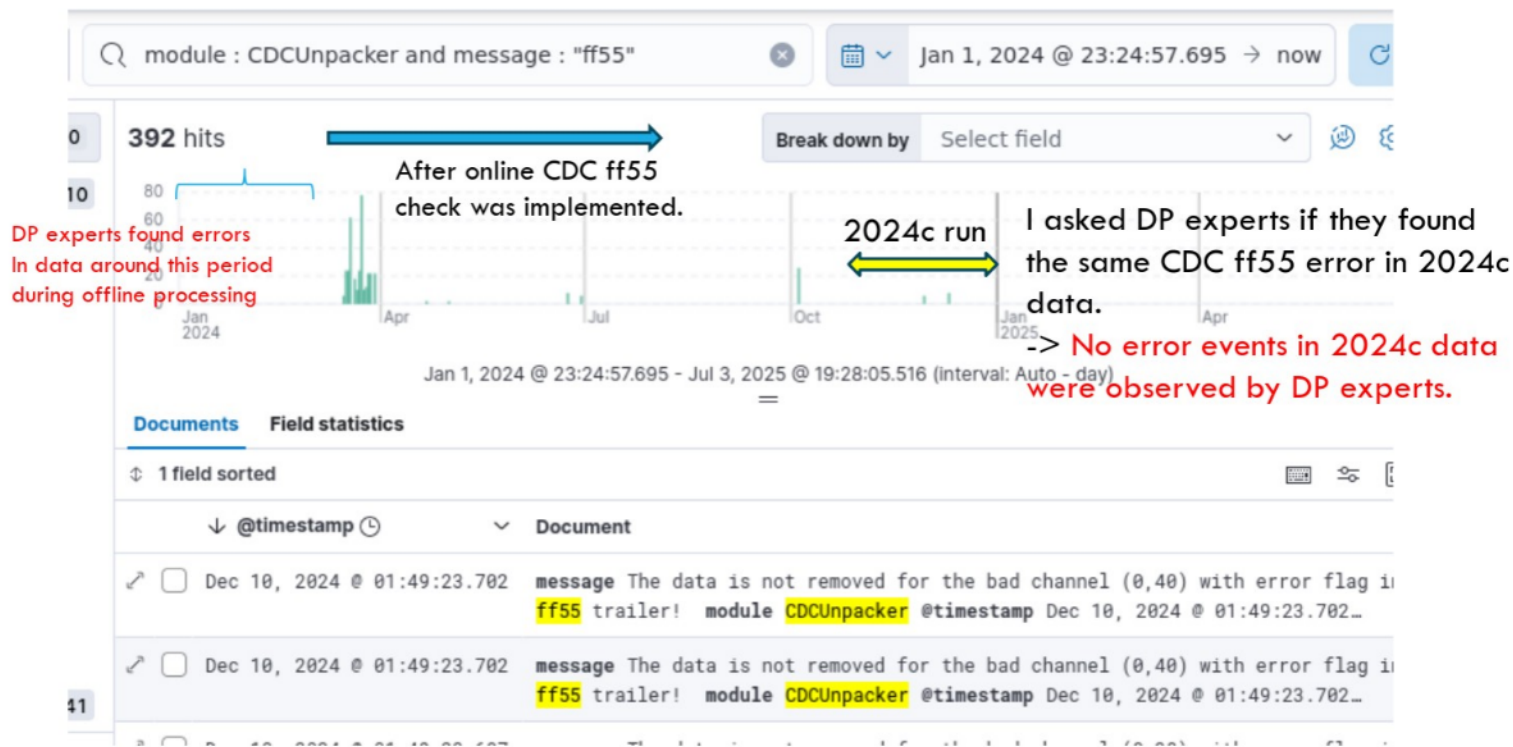
- * TOP feature extraction code has been migrated to pcie40_software by Harsh Purwar and Shahab Kohani.
- * Updates to the core pcie40_software have been prepared by Yamada-san ([MR 54](#))
 - The subevent building has been extended to allow waveform saving in TOP data.

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>

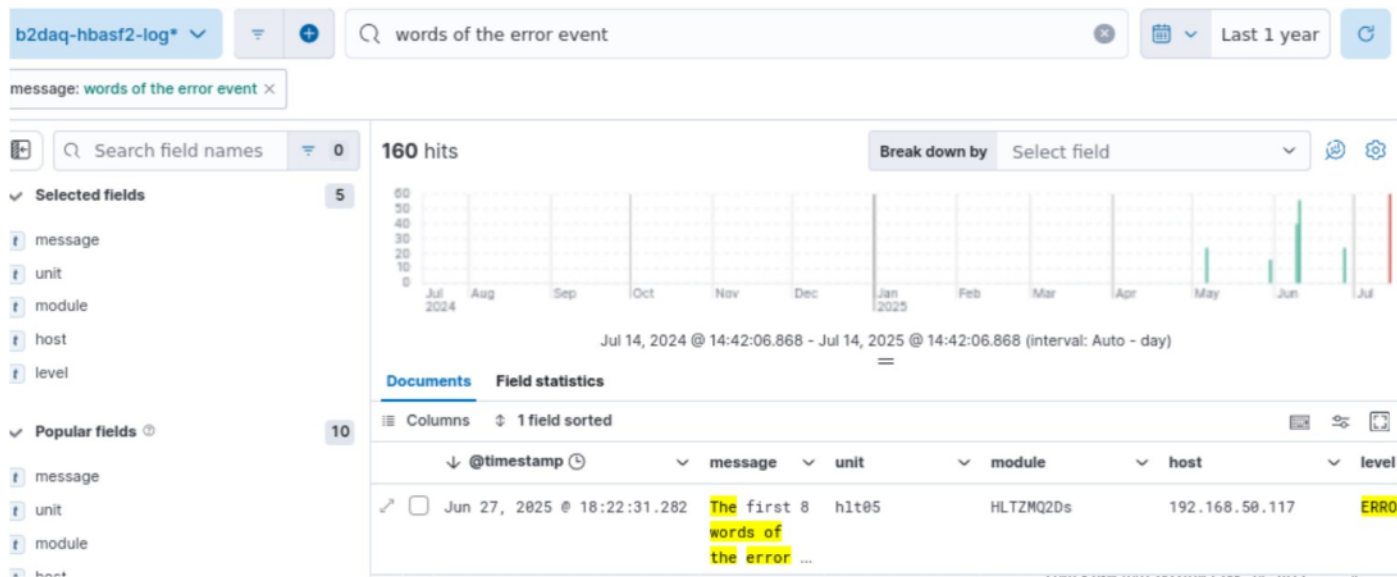
- After the CDC “ff55 trailer” check was implemented on Mar. 12, this error can be detected by online **only for CDC**. (‘drwxr-xr-x 46 cvmfs cvmfs 4096 Mar 12 2024 release-08-01-01



HEX DUMP IN LOG IN HLT WORKER NODE

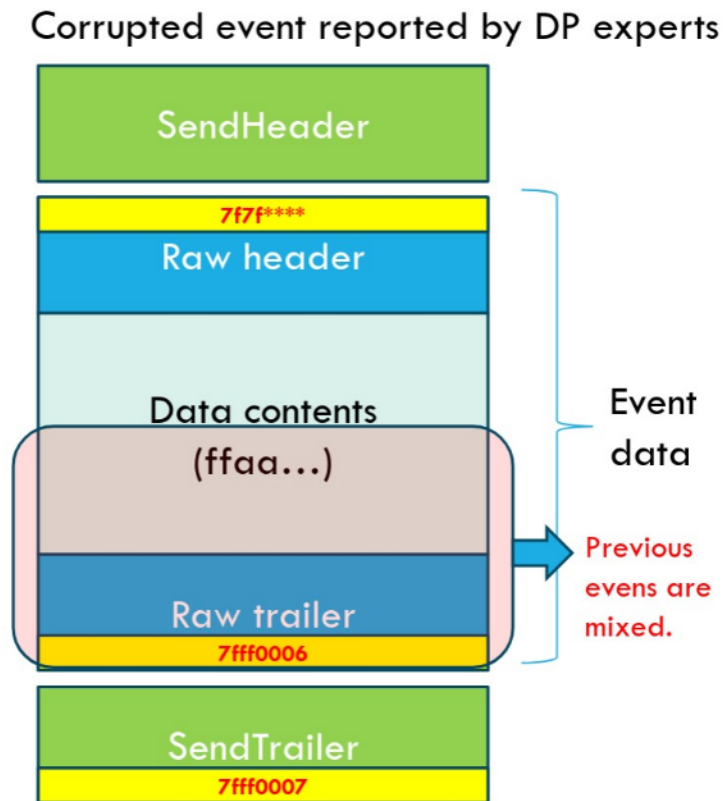
https://gitlab.desy.de/belle2/software/basf2/-/merge_requests/4251

- HLTZMQ2Ds checks the magic words of RawCOPPER header and trailer on an hlt worker 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 query to get the hex dump.
 - `http://b2srv1.daqnet.kek.jp/s/daq/app/discover/#/?g=(filters:[],refreshInterval:(pause:1t,value:60000),time:(from:now-1w,to:now))&_a=(columns:[message,unit,module,host,level],filters:[('$state':{store:app$state}),meta:{alias:ln,disabled:lf,field:message,index:b1fe1cad-30f3-515d-afe9-08775c2ad8a1,key:message,negate:lf,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)])}`



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 apparently invalid.
 - This is also consistent with the errors found by DP group.



(Yamagata-san)

The patch checks 3 times

- 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

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	hlt1	16090201	
Jun 9, 2025 @ 15:54:38.786	The last 8 words: a84700c3 a94700ca aa4700dd 4e070404 4e03030a ab4700de 66030203 66040308	hlt1	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	hlt1	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	hlt1	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 last 8 words: 07e0306d 9c850fdb 2b00020f	hlt12	2b00020f	
Jun 10, 2025 @ 13:33:51.459	The last 8 words: 250d0706 2b010001 2b080b07	hlt04	2b080b07	
Jun 9, 2025 @ 15:54:38.785	The last 8 words: 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	hlt1	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	hlt1	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	hlt1	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.



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.

Data-corruption:

- The error reported by DP experts for 2024ab run likely occurs between eb1 tx and eb1 rx. This guess is supported by :
 - The error occurred in different HLTs at the same time
 - Eb1 rx 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.

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 eb1 tx and eb1 rx. This guess is supported by :
 - The error occurred in different HLTs at the same time
 - Eb1 rx 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.