Next generation of radiation tolerant field-bus clients for QPS

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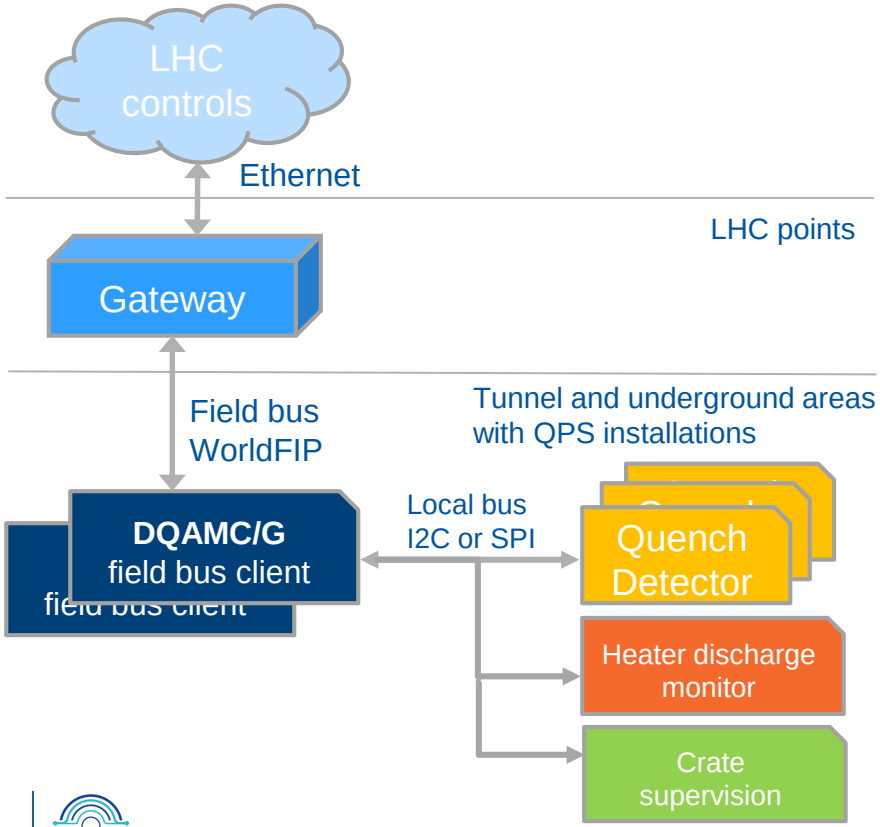
Field-bus clients in QPS



- There are 2532 QPS field-bus clients
- Processing data from quench detectors, crate and heater discharge monitors
- Connecting Quench Protection Systems (QPS) via WorldFIP to the controls system and providing data for:
  - Operator screens and expert consoles
  - Software interlock
  - LHC logging database
  - Post mortem servers, viewers and automatic analysis
  - Warning generation (email) for pre-defined faults states (e.g. loss of a quench heater power supply)

One of the QPS clients – DQAMC

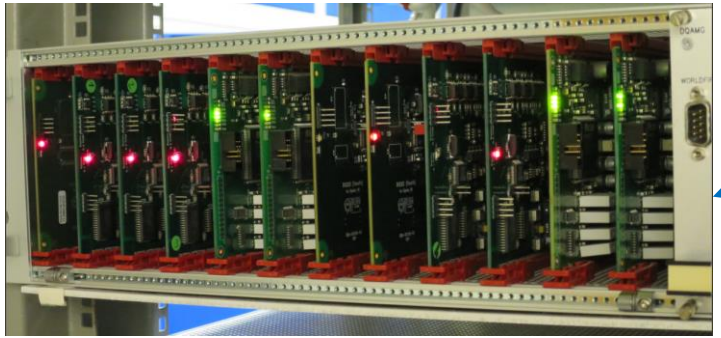
- DQAMC = Acquisition and Monitoring Controller
- 1624 DQAMC in MB&MQ (asymmetric) quench detection systems in LHC

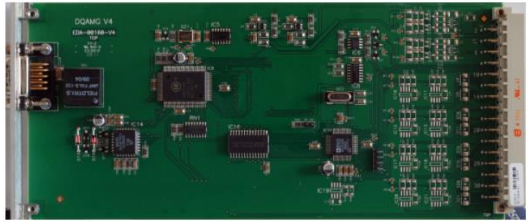
DQLPU-A
MB

DQLPU-B
MQ

Another one of the QPS clients – DQAMGS

- DQAMGS = Acquisition and Monitoring Controller
- 436 DQAMGS for MB&MQ (symmetric) quench detection systems in LHC





DQLPU-S
MB&MQ

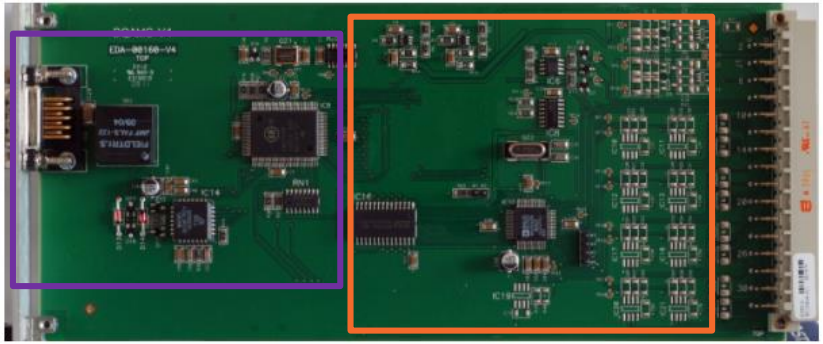
QPS field-bus clients – closer look

QDS controller

- ADuC831 8-bit µC
- Interface circuits for local (in-the-crate) communication
- Analogue stage for heater discharge supply monitoring

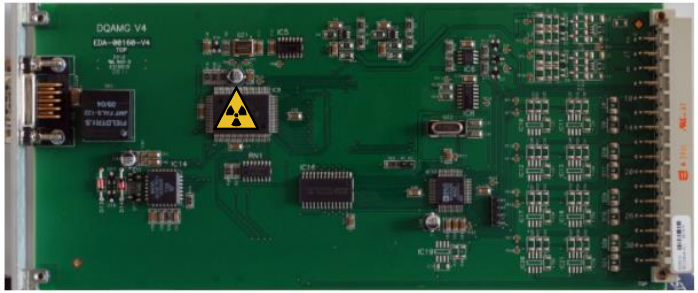
WorldFIP

- MicroFIP component
- Field-drive line driver
- Line transformer



Development motivation

- DQAMC/GS in half-cell 8 and 9 around P1, P2, P5 were affected by radiation in Run2
- Vulnerable component (moreover obsolete): MicroFIP – 13 faults in 2018
  - Timing data corruption → prevents data transmission to (NX)CALS
  - MicroFIP data corruption → could trigger beam dump
  - Command transmission corrupted → could delay LHC refill
  - Hardware failures → could trigger beam dump



Solution strategy 1/2

- Make one design implementing both DQAMC and DQAMGS
- Remove circuits not in use anymore after recent upgrades (e.g., monitoring of heater discharge supplies)
- Implement WorldFIP client functionality in a radiation tolerant FPGA
  - Use BE-CO nanoFIP IP core
  - Implement interface between the core and the µC
- Keep QPS controller implementation in µC
- Exchange DQAMC/DQAMGS in radiation-critical positions

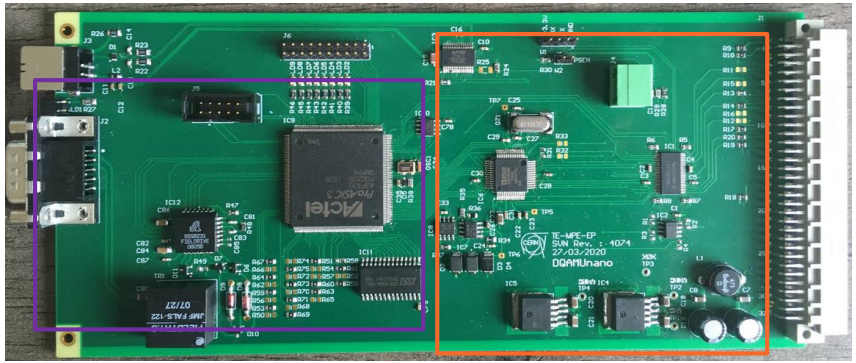
Solution strategy 2/2

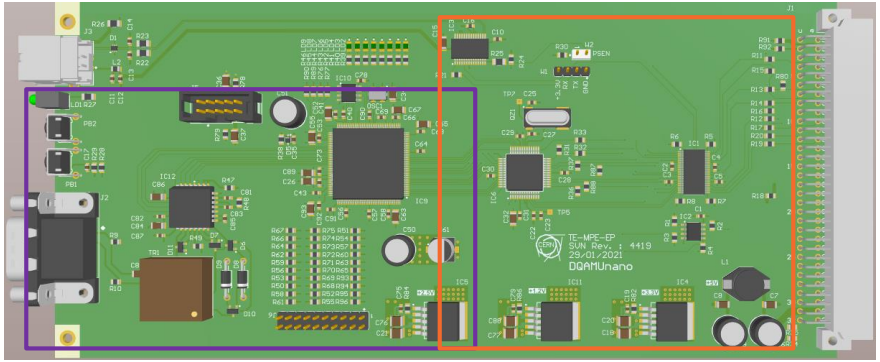
- According to estimated radiation levels in DS areas of 10 Gy/year and 100 Gy/year[1]
  - → Exchange planned in 8 to 12 half-cells of P1, P5, (P7), P2 and P8
  - → 140 DQAMC and 60 DQAMGS boards to be changed
- Board exchange planned to be done in multiple exchange campaigns
- The earliest board exchange could be during the annual closure 2021/2022
- If this is not possible, exchange will be during the YETS 2022/2023
  - Should not be an issue as 2022 radiation levels are expected to be moderate

[1]https://edms.cern.ch/ui/file/2302154/1.0/HLLHC_Specification_Document_v1.0.pdf

Development status

- First prototype based on ProASIC FPGA produced and functional
- Second prototype based on IGLOO2 FPGA will be sent for production in the coming days
- Both prototypes replace both DQAMC and DQAMGS





Development status 2/2

- nanoFIP IP core (BE-CO) adapted to local communication in QPS
- FPGA firmware uses different SEU mitigation techniques
  - TMR and fail-safe state machines → currently under test
- µC firmware under development&test
- Remote fault mitigation techniques implemented (µC and gateway level)
- Software stack for QPS supervision yet to be modified!
- Design expected to be ready for production in Q3 2021

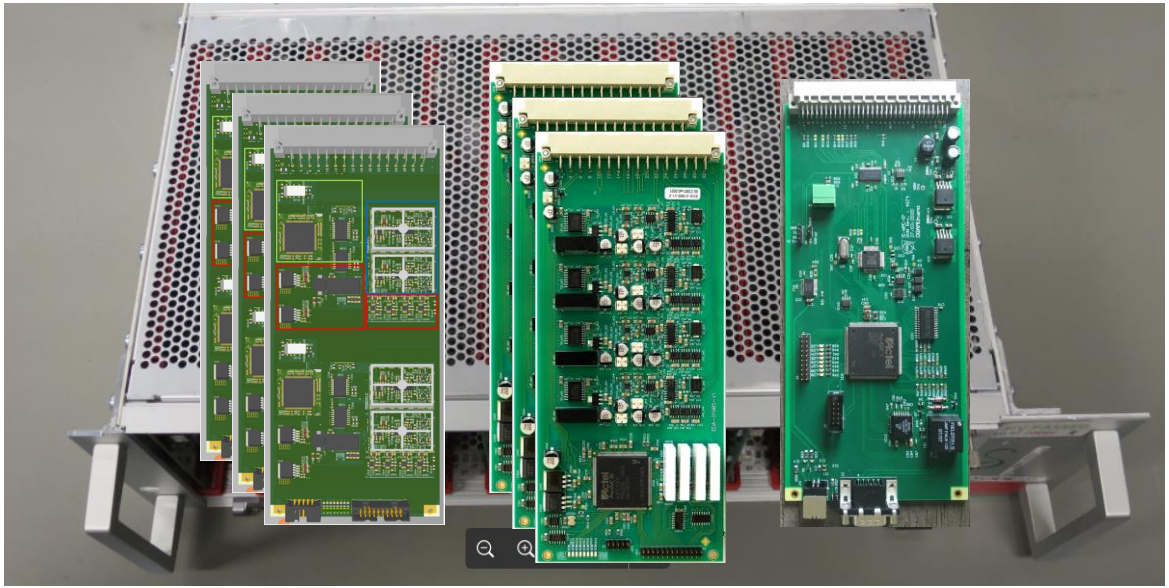
Component-level R2E considerations

- P82B96TD to be tested in PSI
- SSSB231, ADUC831BSZ could be tested within system-level CHARM test
- M2GL010 not tested, but family tested
- Diodes could be tested with Co60

Component	Component class	Status	Results
P82B96TD	Bus buffer	Used in QPS in the tunnel	
SN74LVTH16245ADGGR	Bus Transceiver	Tested by R2E	Works fine up to 500 Gy
SSSB231	FIELDDRIVE line driver	Used in QPS in the tunnel	
AT25DN512C-SSHF-B	Flash Memory	Tested by R2E	Works fine up to 500 Gy
LT3083EQ#PBF	Linear Regulator	Tested by R2E	Works fine up to 1000 Gy
ADUC831BSZ	MCU	Used in QPS in the tunnel	
LFSPXO018042	Oscillator	24&25MHz of the same series tested	
M2GL010-TQ144	IGLOO2 FPGA	Family tested by R2E	Works fine up to 450 Gy
A3P400-1PQG208I	ProASIC3 FPGA	Used in QPS in the tunnel	
PMEG4002EJ	Shottky diode	CHARM test by TE-MPE-EP	Survived 130 Gy
BAV99LT1G	Diode	Used in QPS in the tunnel	
BZX85C3V9	Zener Diode	Tested by R2E Co60	Works fine up to 1000 Gy
BZX85C6V2	Zener Diode	Tested by R2E Co60	Works fine up to 1000 Gy

System-level R2E considerations

- If schedule allows, system-level test should be done in CHARM up to 500 Gy for a modified DQLPU-S crate that hosts new DQQBS boards, DQQDS boards (symmetric quench detection for MB&MQ) and new nanoFIP field-bus clients



Summary

- Two prototypes of the FPGA (nanoFIP IP) based field-bus QPS clients have been designed to replace vulnerable QPS field-bus clients in the LHC
- Few (non-critical) components left to be qualified in radiation
- Testing the DQLPU-S crate hosting new field-bus client and new bus-bar detection board would be beneficial
- Prototype evaluation expected to be finished in coming months
  - → Expected production in Q3 2021
- Deployment campaign might start in 2021

Thank you for your attention!

Questions?