Protection Device Supervision Unit – Prototype and Test Results

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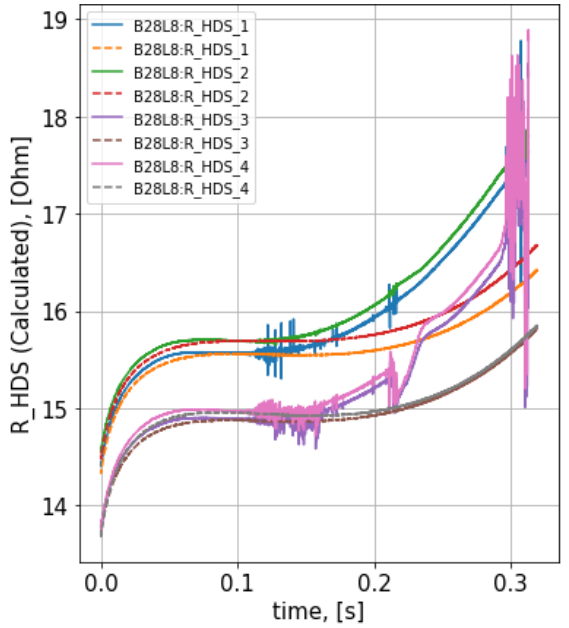
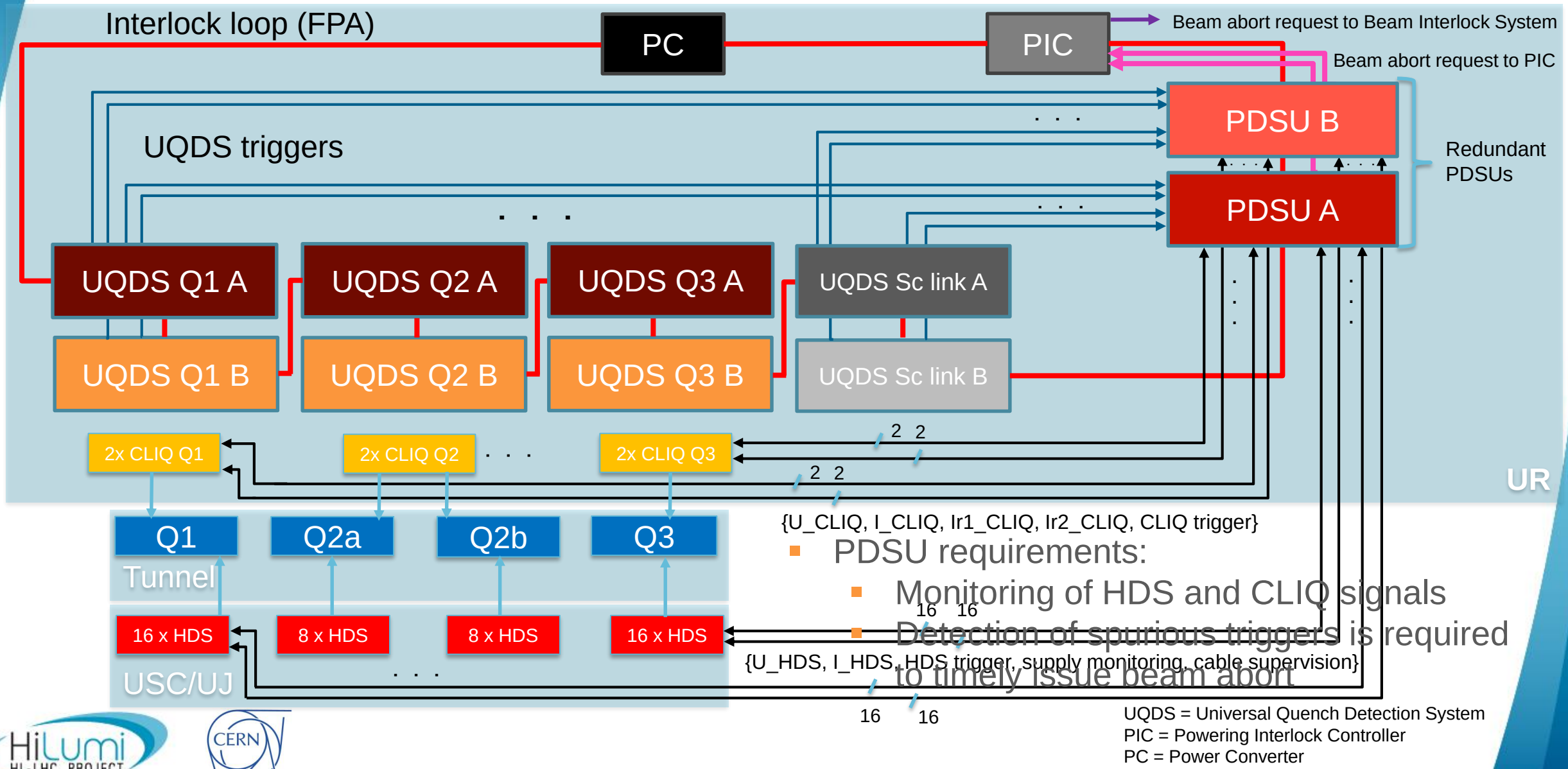
Introduction



- LHC magnets:
  - Health of quench heaters is monitored through dedicated circuits implemented within quench detection crates
  - Up to 8 Heater Discharge Supplies (HDS) are triggered by quench detectors only
  - More margin in terms of QH
- Monitoring of quench heaters shows signs of issues with magnets: LHC HWC 2021 B28L8 issue
- With new magnet designs more rigorous supervision is needed:
  - IT magnets upgrade → 8 HDS (4oo8 allowed to fail) vs 48 HDS (12oo48, i.e., 2oo8 per magnet, allowed to fail, provided that CLIQ is fine), and 6 CLIQ (Coupling Loss Induced Quench – new magnet quench protection method)
  - **Detection of spurious triggers is required to timely issue beam abort**

Protection Devices Supervision Unit (PDSU) for IT

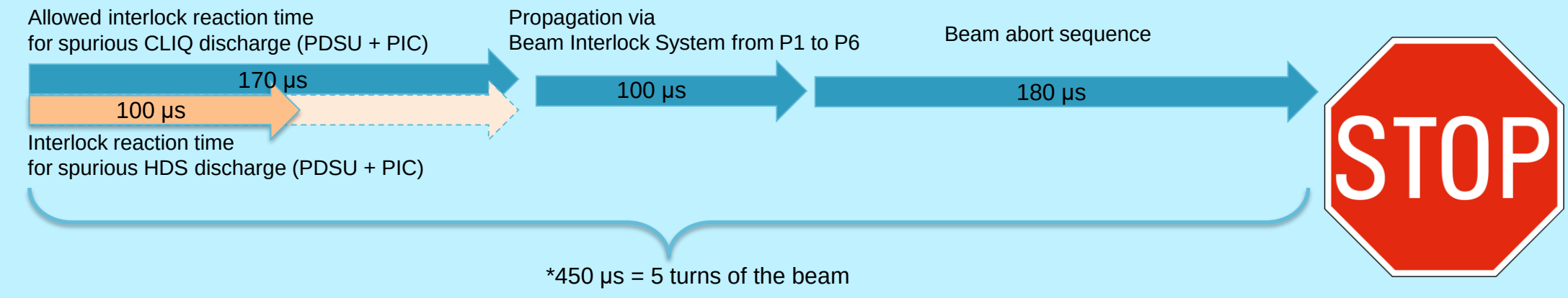


- PDSU requirements:
  - Monitoring of HDS and CLIQ signals
  - Detection of spurious triggers is required to timely issue beam abort

UQDS = Universal Quench Detection System
PIC = Powering Interlock Controller
PC = Power Converter

PDSU IT – Requirements

- For the first time PDSU activates HDS/CLIQ discharge and acts on Interlock loop
  - In case of spurious discharge of HDS or CLIQ, the PDSU unit issues a fast power abort and beam abort signals to the powering interlock controller and forces the trigger of the not yet activated HDS/CLIQ units
  - Redundancy needed!

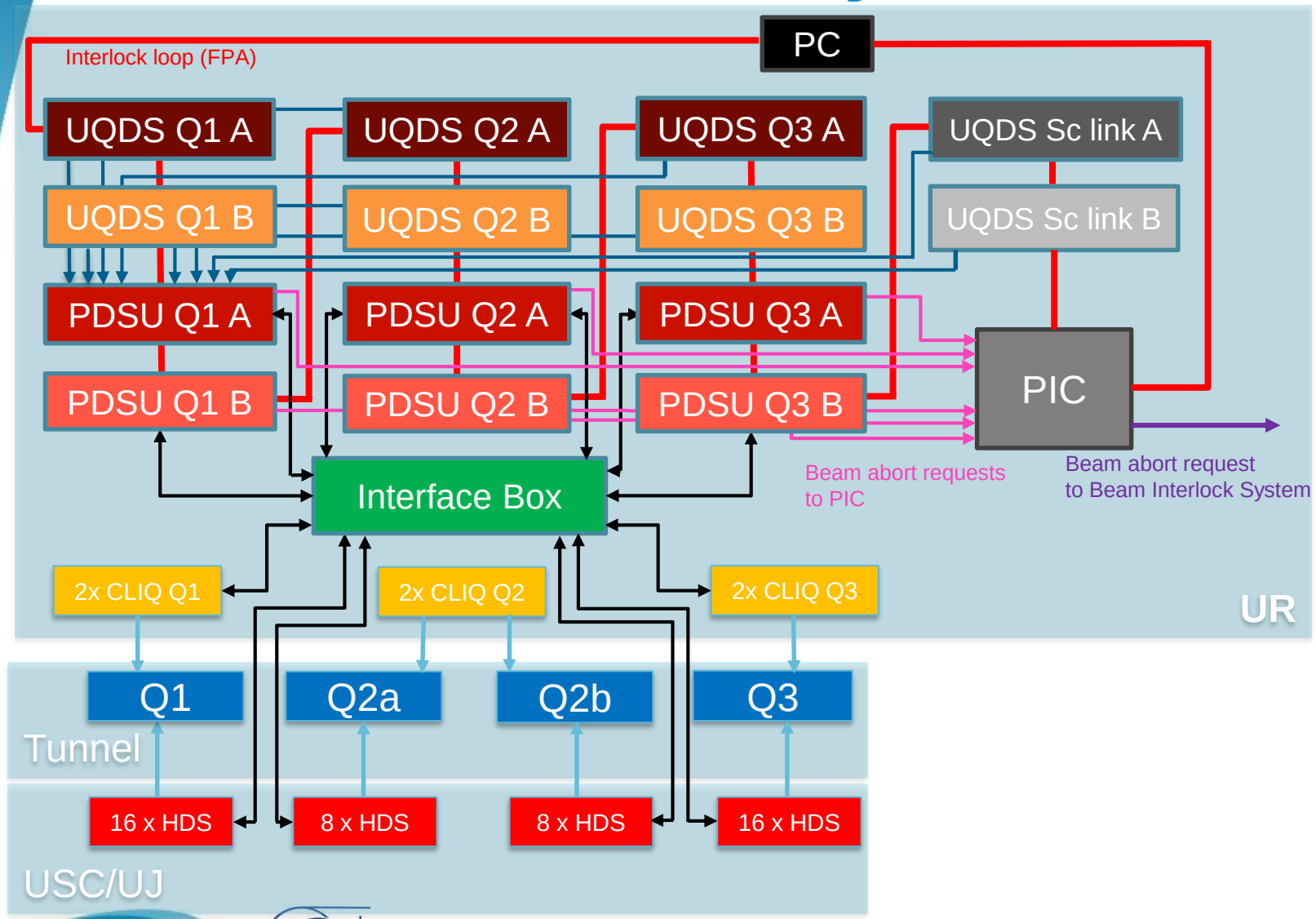


- Per IT (redundancy included)
  - 2x4 UQDS trigger links to couple and fan out to 96 HDS trigger links and 12 CLIQ trigger links
  - 540 signals to monitor

→ challenging integration and electronics design

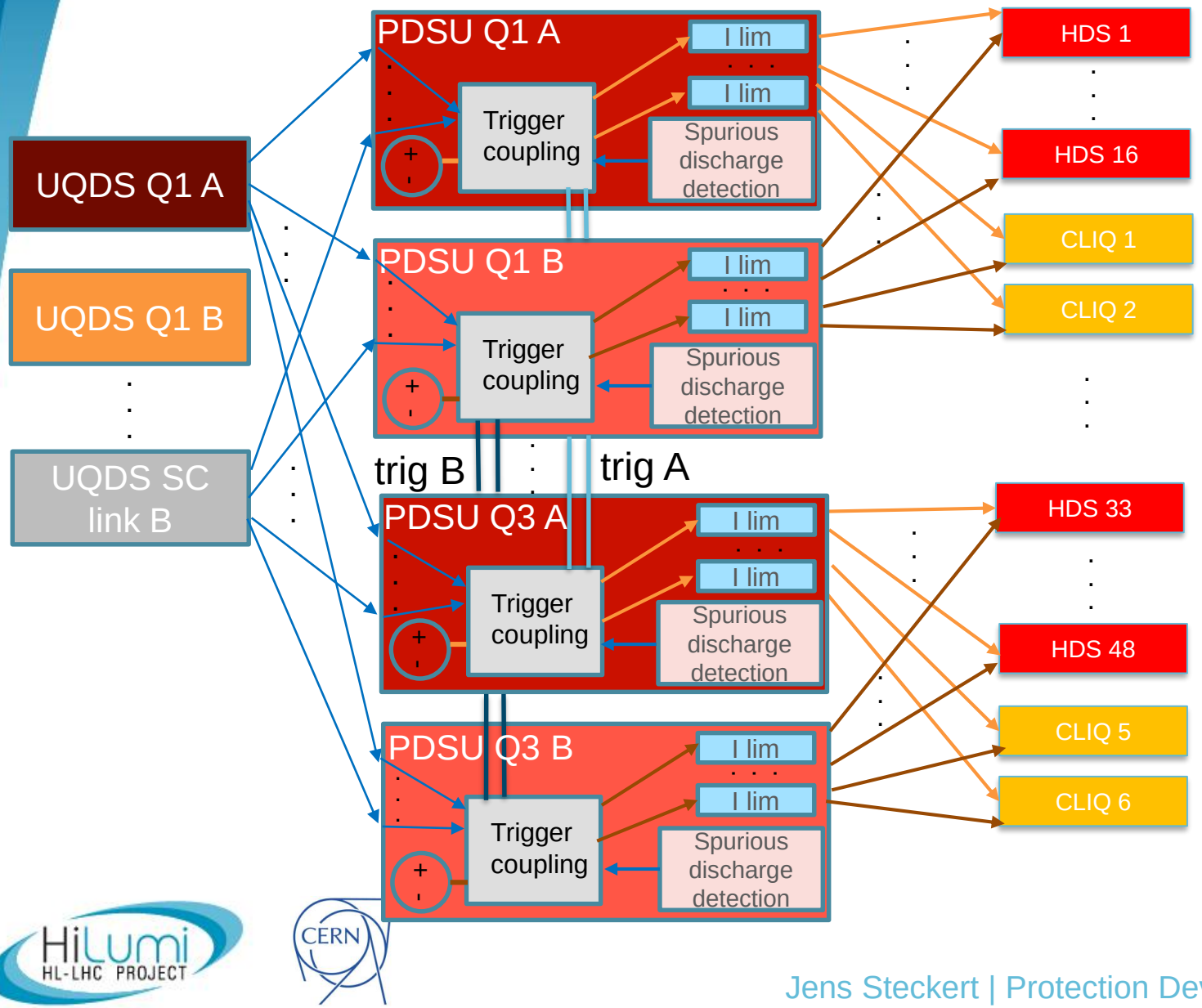
*Courtesy of C. Hernalsteens

PDSU IT – System Architecture



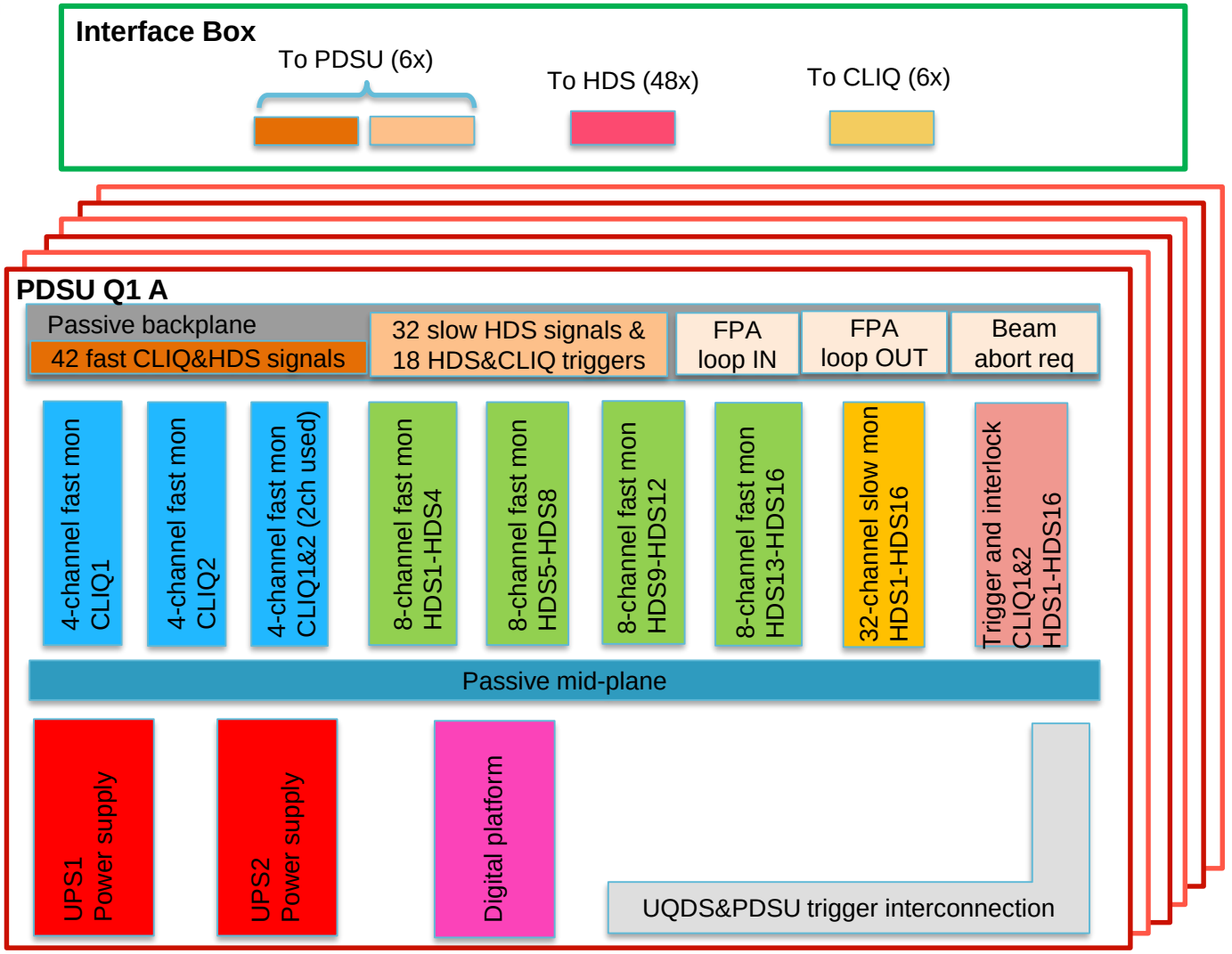
- 540 signals to monitor and 108 triggers to distribute
  → system partitioning is necessary and crucial
- PDSUs need to request FPA
- Interface box is needed between PDSUs, and CLIQ and HDS to distribute the signals
- Triggers from all UQDS units are coupled in each PDSU (figure shows only triggers coming to PDSU Q1 A for the sake of figure clarity)
- Fast links are needed between PDSUs and PIC to timely request beam abort

PDSU IT – Conceptual Design: Focus on Triggering



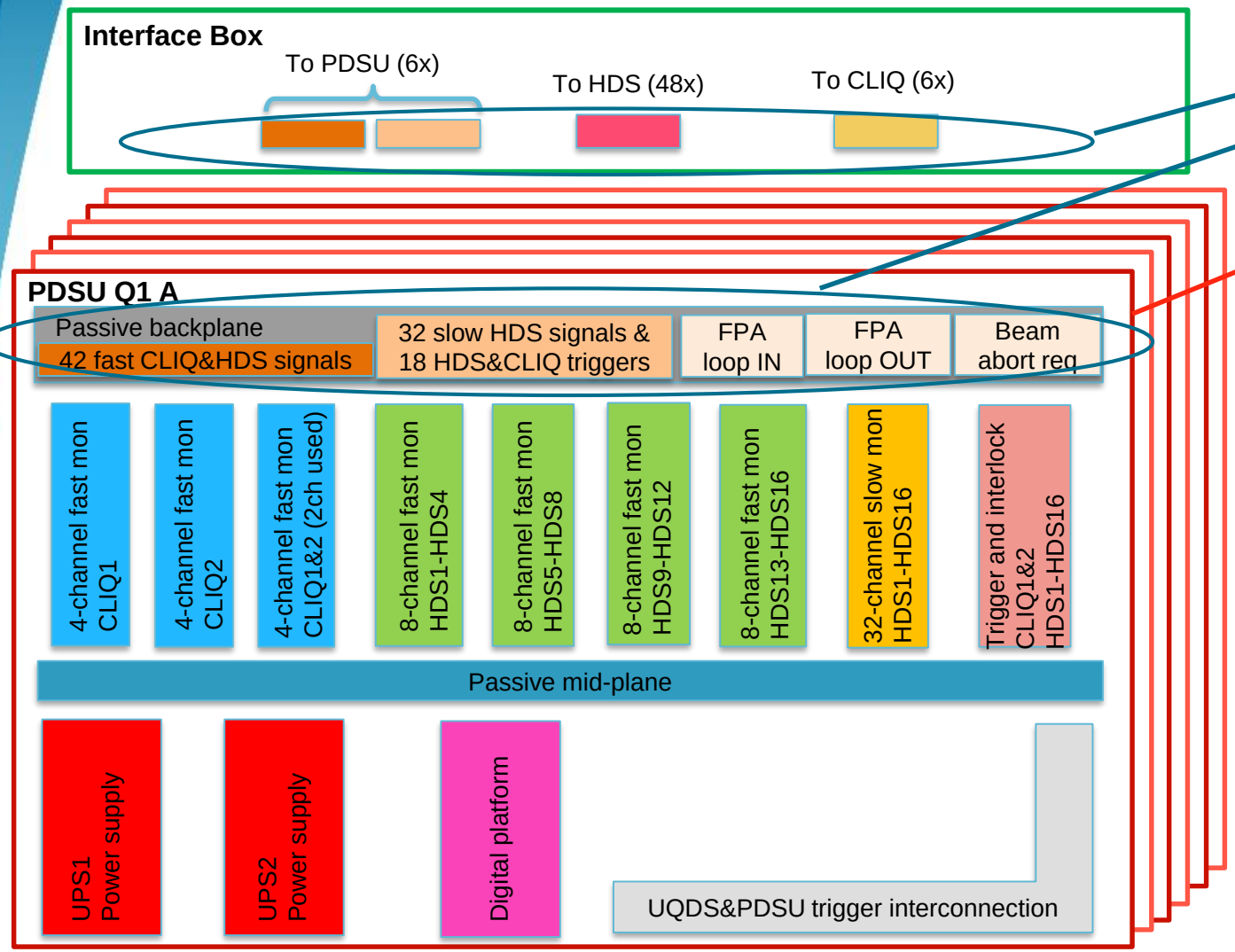
- We have 3 (*2) identical PDSU units
- Triggers from *4 (*2)* UQDS units are coupled in each PDSU
- Power trigger is generated in each PDSU
- Information on trigger detection communicated among the PDSUs (trig A, trig B) forcing trigger of not yet triggered CLIQ and HDS units
- Current limit is implemented in each HDS/CLIQ trigger line to increase robustness of the PDSU triggering system

PDSU IT – Hardware architecture



- Modular system
- Dedicated analog front-ends
  - Based on UQDS analog front-end design for CLIQ monitoring
  - Based on HDS monitoring for main LHC dipoles
  - New trigger monitoring design
  - New slow signals monitoring design
- Central FPGA-based digital platform performing all logic
  - Advanced signal filtering
  - Dynamic setting of discharge detection parameters for efficient operation
- Ethernet-based controls interface within the digital platform
- Redundant power supplies, diode coupled and monitored
- Passive mid-plane and backplane

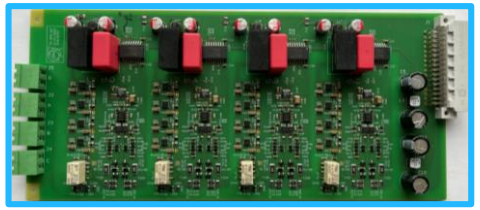
PDSU IT – Current Design (IT String)



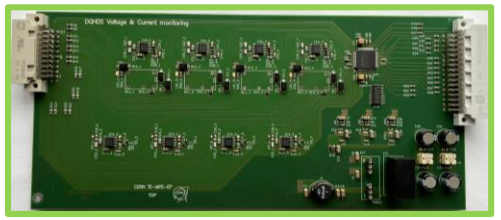
Industrial Harting connectors

3U UQDS-based chassis

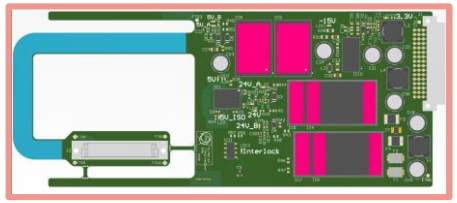
4-channel fast mon



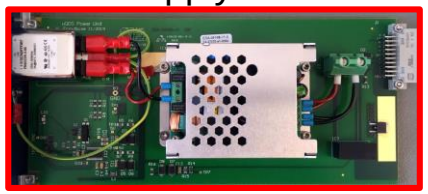
8-channel fast mon



Trigger and interlock

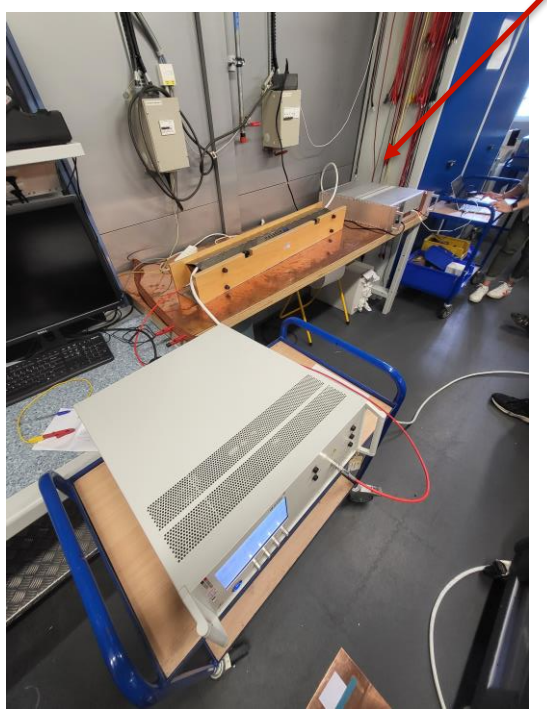


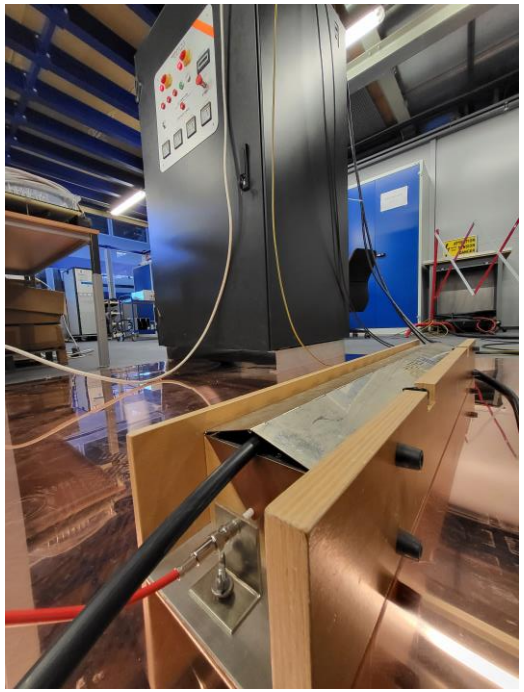
Power supply



Digital platform

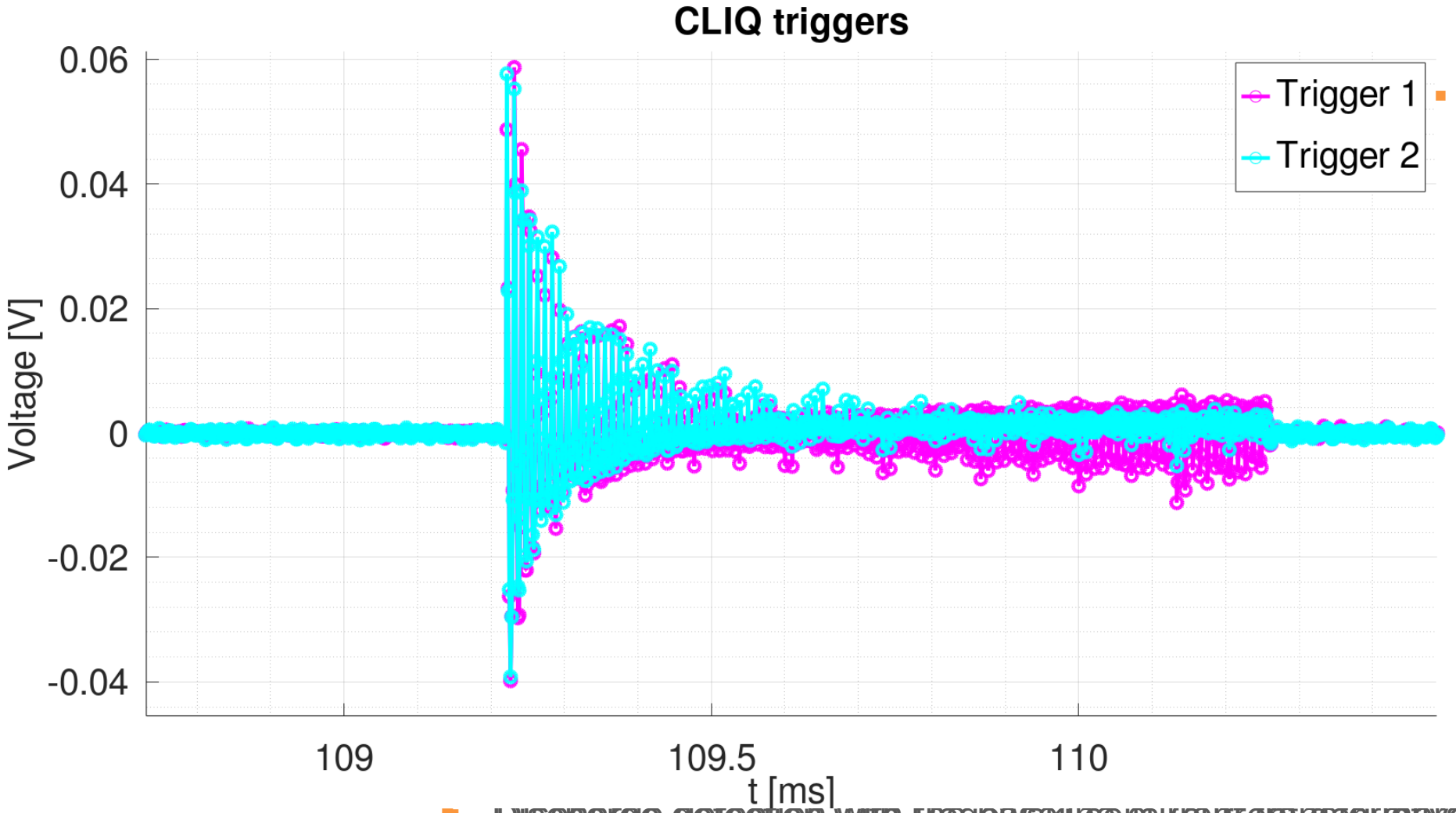
Tests and Results – PDSU + CLIQ 1/2



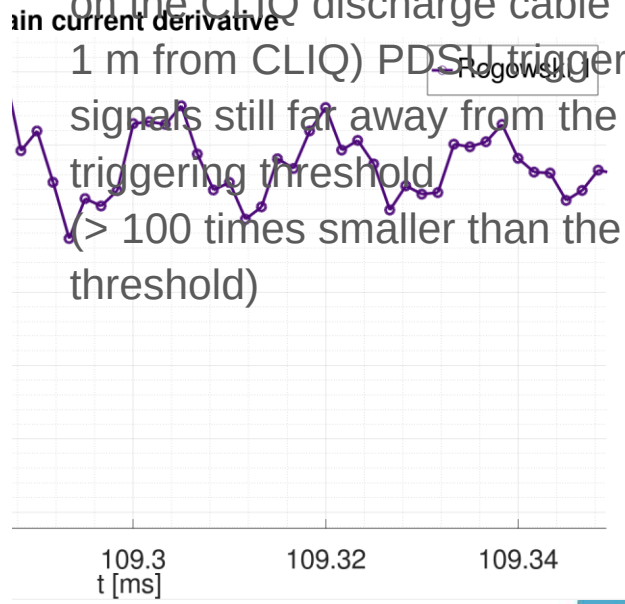


- To assess the discharge detection and monitoring sensors, a measurement campaign was performed in the CLIQ lab in B272
- The campaign consisted of the tests in quiet and noisy (fast transients/bursts) environments
- A modified UQDS was used as a PDSU with 8 analogue front-end channels to record all CLIQ signals dedicated to PDSU
- CLIQ discharge trigger was generated by UQDS/PDSU

Tests and Results – PDSU + CLIQ 2/2



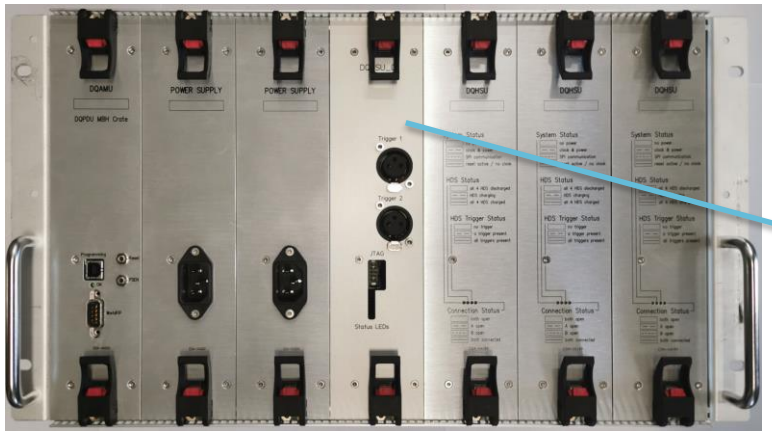
- With the worst noise pick-up (*4 kV, 100 kHz, 1 ms burst duration, 1 s burst period* on the CLIQ discharge cable 1 m from CLIQ) PDSU trigger signals still far away from the triggering threshold (> 100 times smaller than the threshold)



- Discharge detection with Rogowski coils (current derivative measurement)

Tests and Results – PDSU + PIC

- 11T PDSU prototype adapted for CLIQ discharge monitoring in SM18 Cluster F was used to act on the PIC interlock loop (quench loop) to evaluate timing of different solutions for the FPA interlock loop and beam abort request



- Different switch devices in the PDSU were evaluated for the quench loop (for both FPA and beam abort)
  - PhotoMOSes and relays work fine for the FPA current loop but are not fast enough for the beam abort
- An alternative to current loop solution for the beam abort request could be a direct link to PIC – an isolated digital signal (e.g., RS485 transceiver)

Summary

- PDSU for IT design planned to be deployed in IT-String is currently under development and test
- Component procurement is ongoing, however the production will need to cope with the semiconductor shortage
- Discharge test and EMC bursts immunity tests were performed with CLIQ and showed promising results
- Some solutions for the FPA interlock loop and fast beam abort request were evaluated with PIC → more tests to be performed
- Type tests are ongoing
- Long (reliability) tests in MPE labs to be performed
- Final functional and timing test of PDSU in the IT String is crucial

Thank you for your attention