Aperture Symmetric Quenches in the LHC and QPS Upgrade

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Acknowledgements: J. Steckert and the QPS team

QPS upgrade aperture symmetric quenches – rationale

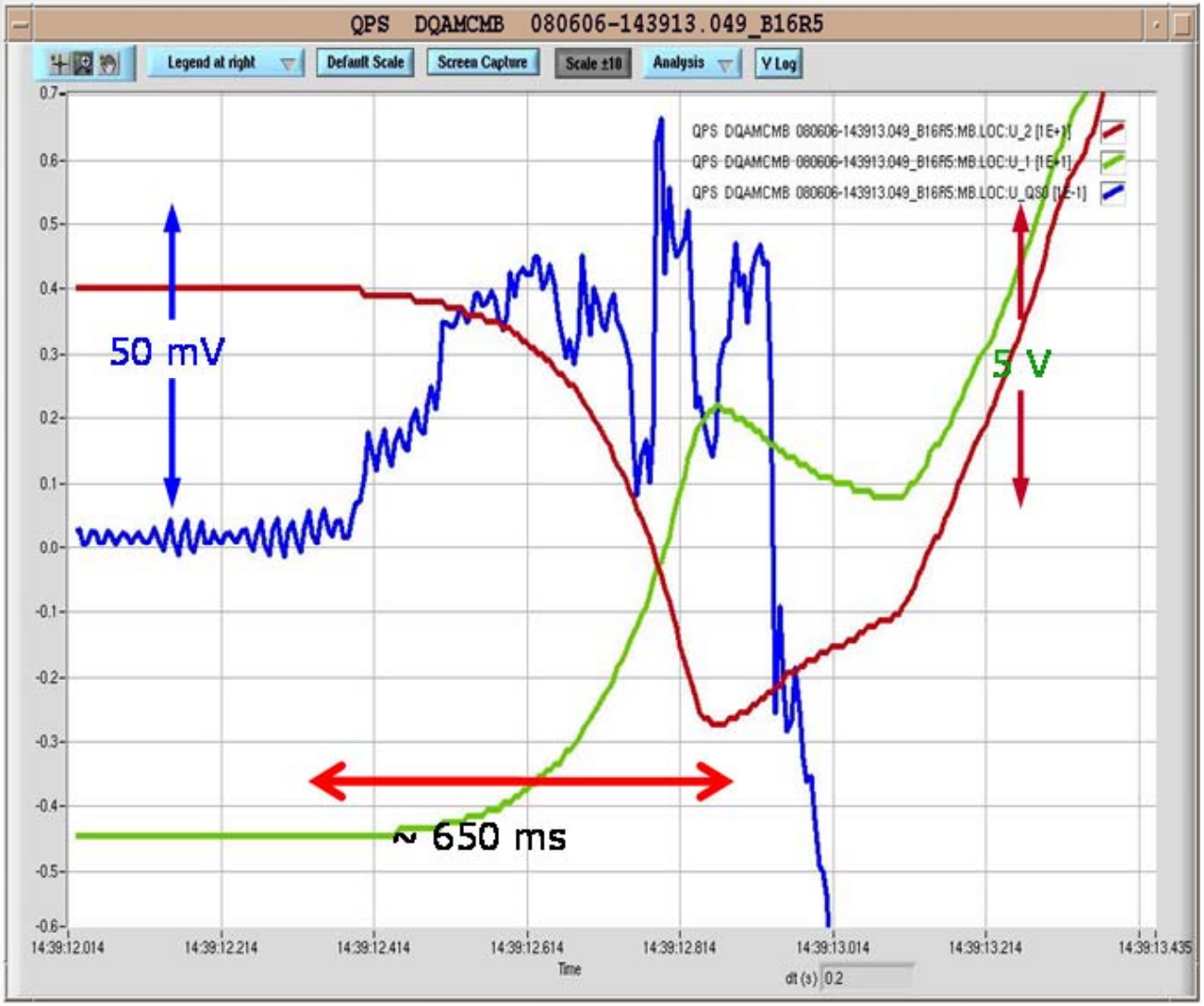
➔ **06.06.2008**: Non-destructive discovery of aperture symmetric quenches in LHC main dipoles

- Late detection of a quench in a main dipole
  - Quench provoked by thermal propagation after an initial normal training quench
  - So far no evidence of damage to the concerned magnet but similar incidents should be avoided
  - Previous experimental studies performed within the STRING II experiment didn't show this kind of problems, especially if using a detection threshold of U_{TH} = 100 mV (10 ms evaluation time)
- Upgrade of existing protection system required in order to detect timely aperture symmetric quenches

QPS upgrade – aperture symmetric quenches

Symmetric Heat-Induced Quench in B16.R5 at ~7.4 kA

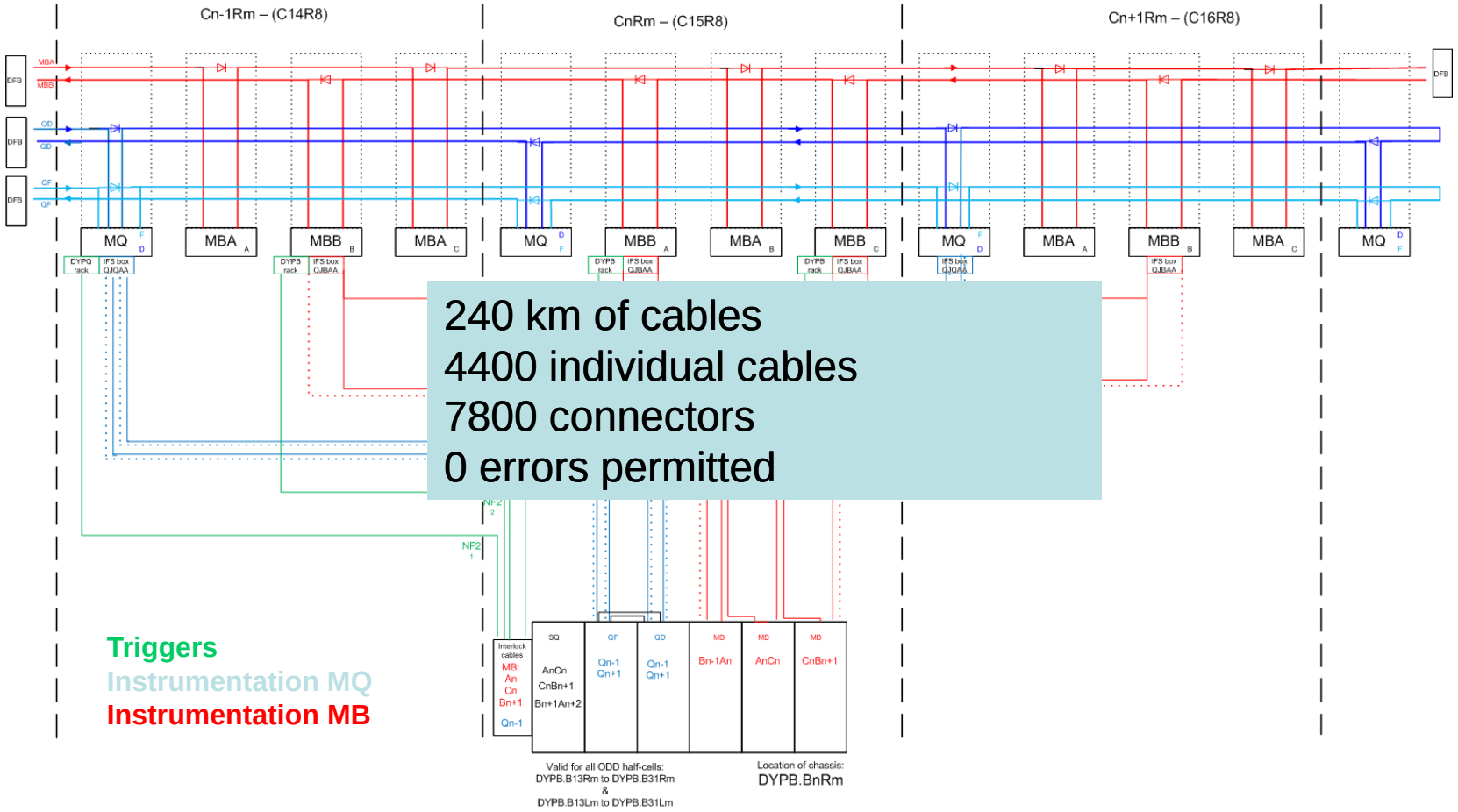
> 50 MA^2 * s



QPS upgrade – aperture symmetric quenches

- Safe detection of symmetric quenches by comparing total voltage drops across magnets
  - System can share the instrumentation cables with the suspicious splice detection system
  - Additional interlock cabling for triggering of quench heater power supplies required
- Multiple magnet evaluation scheme for main dipoles minimizing number of provoked quenches
  - 3+1 magnet reference (interleaved with next unit):
    - 1st and 2nd quench → trigger quenching magnet
    - 3rd quench → trigger remaining magnet of the three connected triggers
- Interleaved two magnet evaluation scheme for quads
- System reacts as well on “normal” quenches → detection threshold must be slightly higher to clearly distinguish different cases (**U_{TH} = 200 mV, 10 ms**)
  - Powered by 2nd UPS → serves as well as back-up for standard QPS

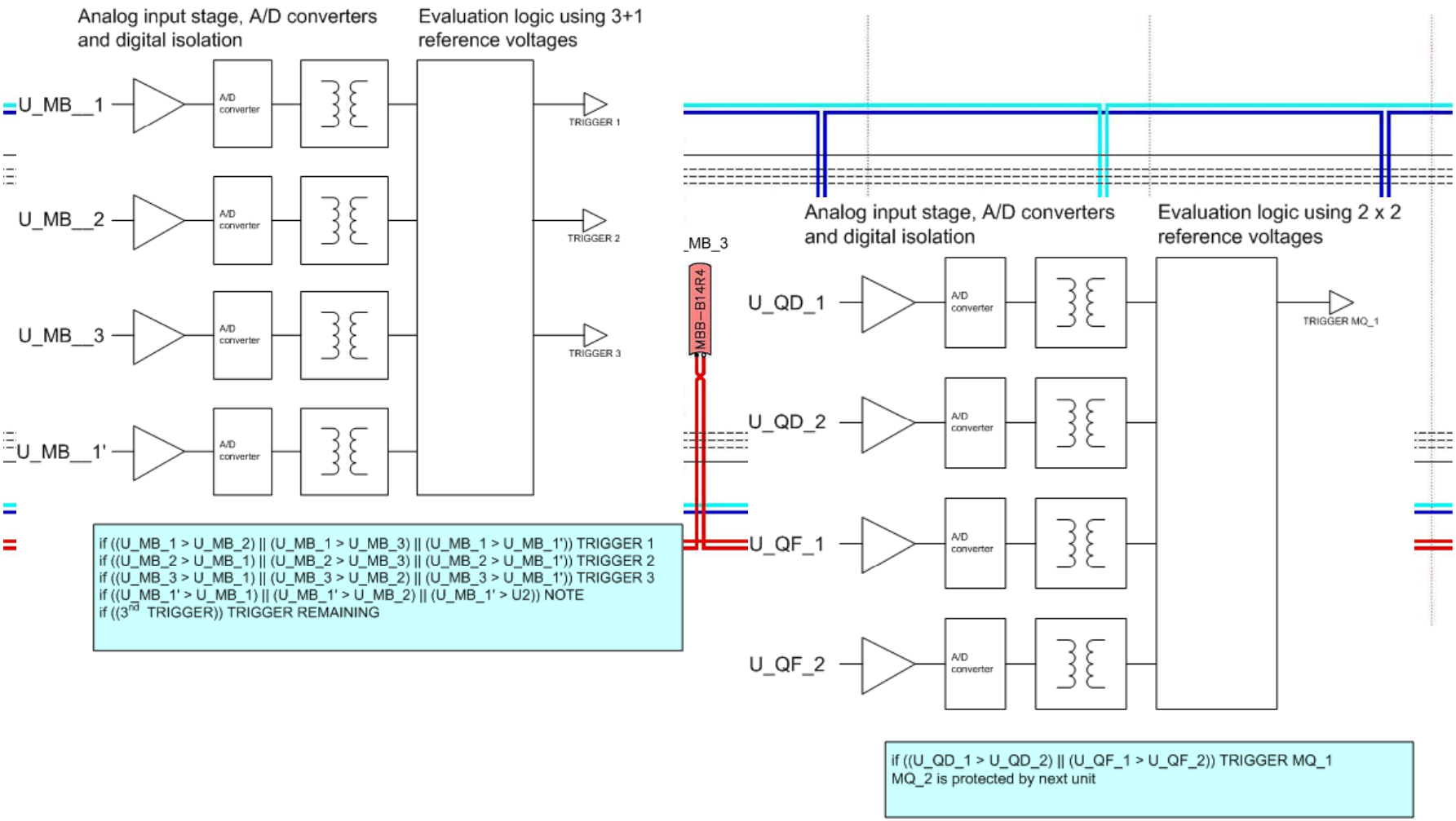
QPS upgrade – basic cabling set-up (odd half-cell)



240 km of cables
4400 individual cables
7800 connectors
0 errors permitted

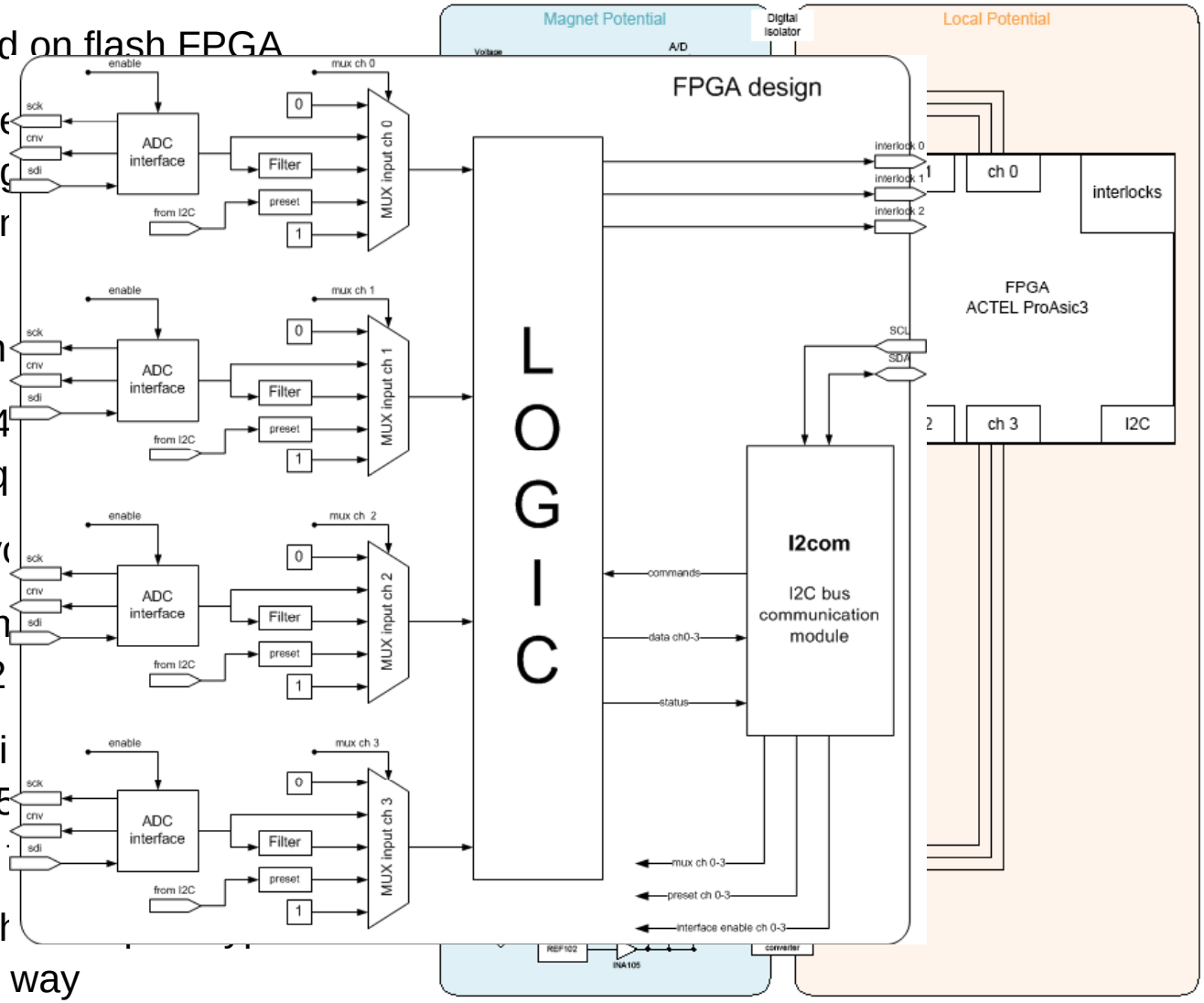
Triggers
Instrumentation MQ
Instrumentation MB

Symmetric quench detection layout



Symmetric quench detection electronics

- New design based on flash FPGA
- Analog input stage
  converters on mag
  evaluation logic or
  potential
  - 2 kV isolation
  - 16 Bit ADC, 4
    sampling freq
  - ±25 V input vo
- Redundant systen
  wired in 1 out of 2
- Communication vi
  fieldbus coupler (5
  transmission rate
- Basic design finish
  production on the way



Symmetric quench detection electronics – type testing

- Prototype production started
  - 4 units for general type tests
  - 3 units for radiation tests
- General type tests
  - Simulation of analog input signals
    - LHC operational scenarios: ramping, coasting, fast discharge
    - Verification of detection logic, thresholds and reaction time
    - Resolution of acquired signals, stability
  - Power consumption
  - Communication with fieldbus coupler via I^2C^{TM} link
    - Data transfer rates, command sequences …
  - Voltage withstand levels
  - Noise immunity (EMC)

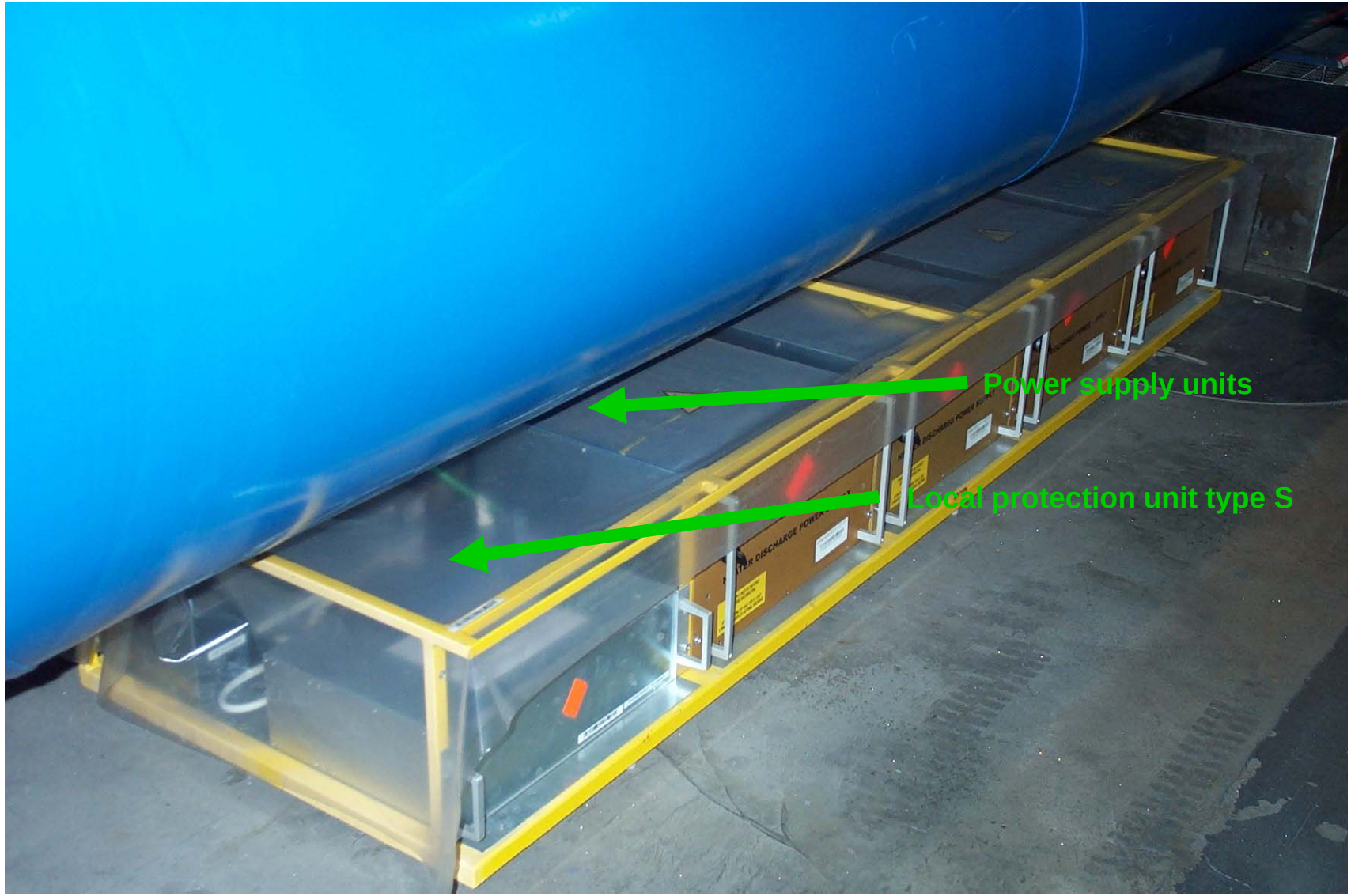
Symmetric quench detection electronics – radiation testing

- Radiation tolerance has been taken into account as a design constraint
  - Selection of core components as FPGA
  - Re-use of radiation tolerant designs (e.g. analog input stages)
  - Firmware uses error correction techniques etc.
- Radiation tests nevertheless mandatory
  - No actual test data available for certain critical devices like ADC
  - Verification of older somewhat outdated test results
- Next test campaign scheduled for 4-5th April 2009 @ PSI
  - 8 hour slot with 250 MeV proton beam focussing on SEE
  - ADCs, DC-DC converters, FPGA, prototype board
  - Components for other parts of the QPS upgrade
    - LDO linear regulators, PhotoMos …
  - Results will be available immediately after the test
- Test campaign @ CERN (CNGS area) later this year

QPS upgrade - integration of new QPS electronics into LHC

- Local Protection Unit type S to be installed in the existing QPS rack type underneath dipole B in each LHC half cell
  - Protection electronics associated to circuits RB, RQD and RQF
  - Suspicious splice protection system
  - Symmetric quench protection system
  - Potential to earth measurement (not required for LHC start-up)
  - Fieldbus coupler linking to QPS supervision
- Crate will be connected to existing infrastructure
  - Acquiring signals from 4 dipoles and 2 quads
  - WorldFip fieldbus and QPS internal interlocks (patches required)
  - One crate per LHC half cell, 54/55 per sector
- Crate will be powered via a dedicated redundant AC-DC power supply
  - Each power supply fed by 230 V 50 Hz single phase UPS
- Impact on existing QPS electronics is minimized

Local protection unit type S – integration into dipole protection rack



Symmetric quench detection – summary

- ➔ Symmetric quench detection layout completed
  - – Cabling campaign in LHC started (within general QPS upgrade)
- ➔ Basic design of the symmetric quench detection electronics ready
  - – Prototype production launched, type testing to be started soon
    - • Prototype device is also required for validation of QPS supervision
    - • Various type tests to be made
    - • Radiation test @ PSI scheduled for 4-5th April
- ➔ Once type testing campaign has been successfully concluded
  - – Final revision of design and layout
  - – Technical specification & procurement of components
  - – Production in May / June → test & installation in July (earliest date)
- ➔ Production, installation and commissioning until re-start of LHC feasible but remains nevertheless challenging