This presentation will focus on LHC quench detection systems as the part of the circuit protection mostly affected by HL-LHC operation.

See as well contributions by J. Spasic, E. de Matteis, T. Podzorny and J. Steckert

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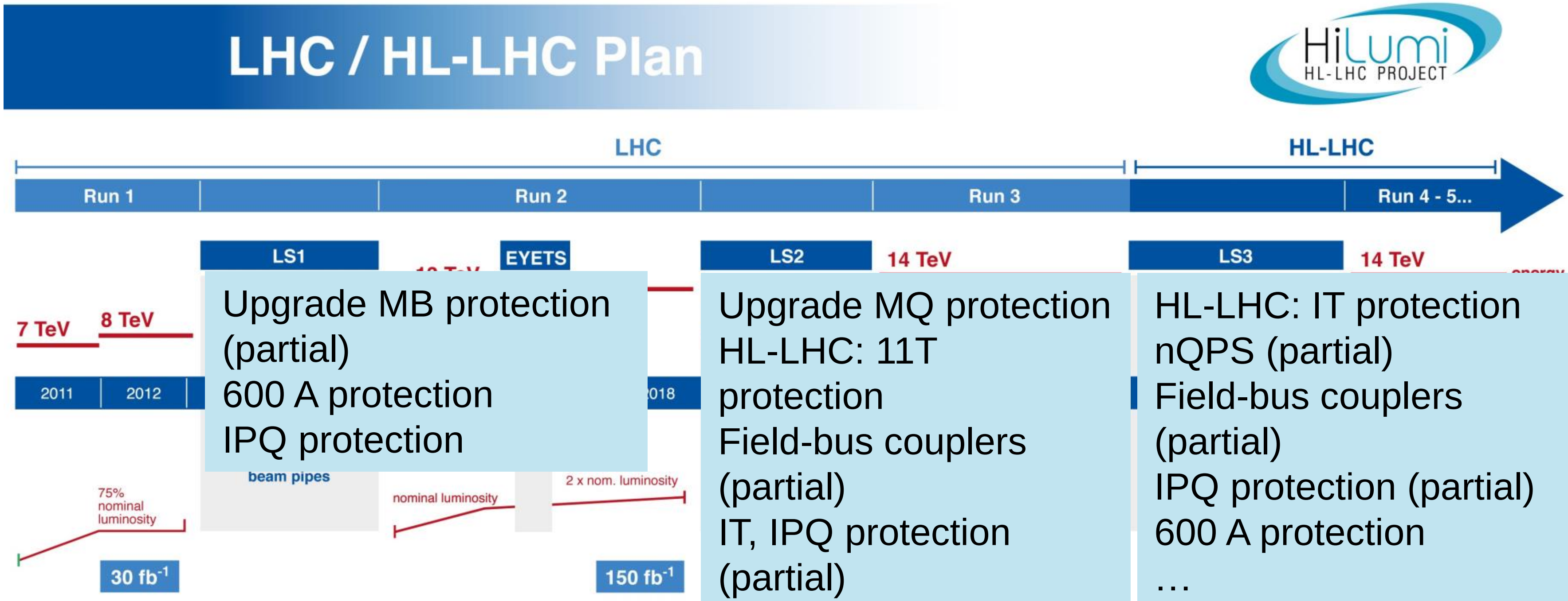
8th HL-LHC Collaboration Meeting

Outline

- Useful expected lifetime of LHC quench protection systems with respect to HL-LHC
- R2E related issues affecting protection equipment
- Upgrade of quench detection systems
- HL-LHC beam operation and specific requirements for quench detection systems
- QPS supervision & HL-LHC
- Upgrades for system diagnostic, test and maintenance
- Summary

Useful expected lifetime of LHC quench detection systems with respect to HL-LHC



Upgrade MB protection (partial)
600 A protection
IPQ protection

Upgrade MQ protection
HL-LHC: 11T protection
Field-bus couplers (partial)
IT, IPQ protection (partial)

HL-LHC: IT protection
nQPS (partial)
Field-bus couplers (partial)
IPQ protection (partial)
600 A protection
…

- Useful lifetime is critical for equipment installed in the LHC tunnel due to the relatively large quantities requiring an LS to perform major changes
- QPS equipment in UA, UJ , RR … can be upgraded during YETS
- Useful lifetime estimated to 25 years (if sufficient spares)
- Likely a major upgrade during LS4 is needed (nQPS & MB protection)

R2E related issues affecting protection

Location	Expected radiation level			
	HL-LHC Annual		HL-LHC Lifetime	
	HEH ($cm^{-2}yr^{-1}$)	SEU rate (yr^{-1})	TID (Gy)	1 MeV n_{eq} (cm^{-2})
LHC arc	1×10^{9}	500	[illegible]	[illegible]
Dispersion Suppressor (below dipoles)	1×10^{10}	5×10^{3}	[illegible]	1×10^{11}
UJ (IP1 and IP5)	5×10^{9}	5×10^{3}	[illegible]	[illegible]
UL (IP1 and IP5)	1×10^{8}	100	2	[illegible]
RR (IP1 and IP5)	3×10^{9}	2×10^{3}	60	[illegible]
RR (IP7)	2×10^{8}	150	5	[illegible]

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- Some equipment installed in the RR may still need to be upgraded to more recent technology
  - E.g. for replacing ΣΔ ADC by more radiation tolerant and recent SAR type

R2E related issues – DS areas

- Simulations show strong gradients in the estimated radiation load →equipment location to be verified and possibly optimized
  - Relying strongly on input from R2E project
- Some equipment needs to be replaced
  - Field-bus couplers based on MicroFIP™ ASIC to be replaced by new design using the NanoFIP IP core (developed by BE-CO)
  - Bus-bar splice protection systems type DQQBS to be replaced by new more radiation tolerant version
    - Technology available (radtol SAR ADC + flash FPGA)

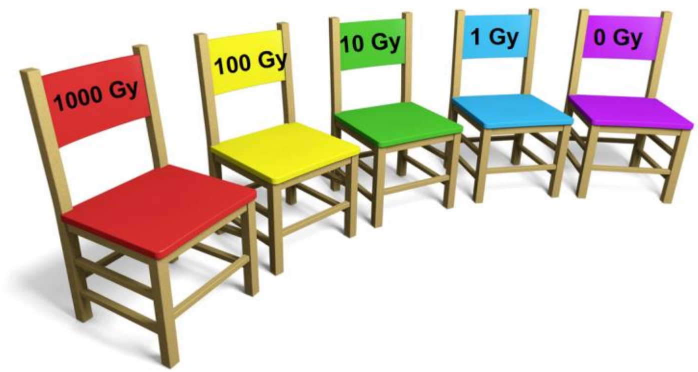
QPS equipment installed in DS areas (half cells 8 – 11) around IP1 and IP5

Equipment	4 x DS / LHC	R2E safe?
Quench heater discharge power supply type DQHDS	176 / 6076	Yes
Quench detection board type DQQBS	**48 / 2048**	
Crate controller type DQCSU	32 / 1232	
Field-bus coupler types DQAMC/DQAMG	**48 / 2016**	

- 96 possibly vulnerable elements in IP1 & 5 matching & dispersion suppressor areas
- Some problems visible in 2018 when operating with TCL6 open

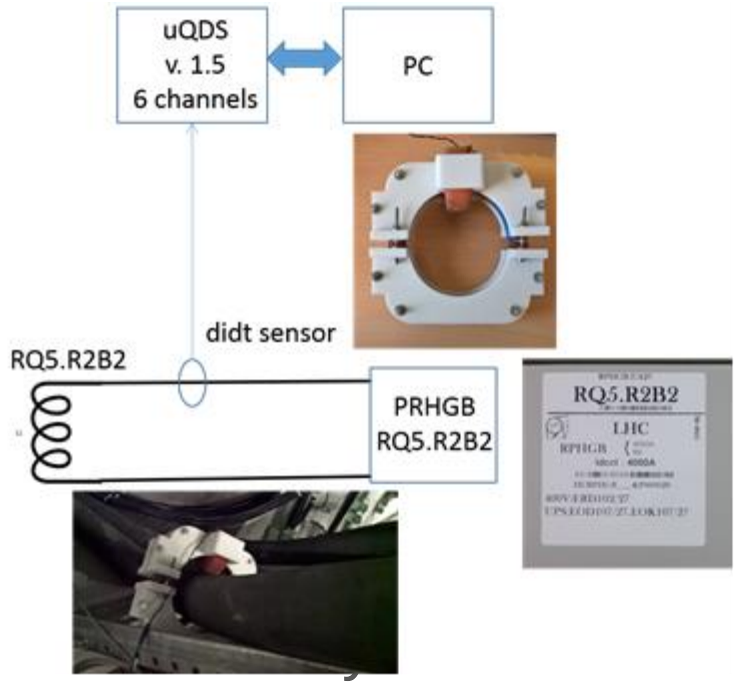
DS areas – maintenance strategies

- In order to avoid to get too close to the TID limits derived from radiation tests, pre-emptive maintenance will be necessary
  - Replace equipment from “hot” areas on a regular basis, e.g. during LS, or rotate with systems installed in low radiation zones
- Radiation tests may need to address not only SEE and TID but as well dose rate effects



Upgrade of quench detection systems

- Symmetric quench detection for insertion region magnets
  - Beam induced quenches more likely with higher intensity
  - Considering that LHC power voltage sources, any rapid cl resistance results in a didt si maximum ramp rate of the ci very safe in detecting quencl
  - The capability of the timely d symmetric quenches is a pre BLM thresholds → affects LH



Upgrade of quench detection systems II

- Fast quench loop controllers
  - Required for sectors 6-7 and 7-8 after 11 T dipole installation (4 units)
  - Fast (<1 ms) transmission of circuit abort signal to powering interlock controller → required to dump the beam prior to quench heater firing in 11 T dipoles
- Reconfiguration of the nQPS layer in sectors 6-7 and 7-8 after 11 T dipole installation
  - 11 T dipoles cannot serve as reference magnets for aperture symmetric quenches

HL-LHC beam operation and specific requirements for quench detection systems

- Requests for faster ramp rates and acceleration for some correctors circuits
  - Some tests to be done at the end of this year

For the readout of the didt sensors a new radiation tolerant (RR level) quench detection board is under development. The board is compatible with existing QPS crates and may be used either for IPQ, IPD or 600 A circuits.

feedback

  - No problem for IP1 and IP5 after LS3 (next generation of orbit correctors with “improved” instrumentation) but challenging for IP2 and IP8
- For both requests didt sensors could be an adequate solution

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QPS supervision & HL-LHC

- Field-bus networks
  - The deployment of the radiation tolerant field-bus coupler in the DS areas will imply major changes in the low level communication layer
  - Ethernet based field-busses will be used for the supervision of the HL-LHC circuits in IP1&5
    - This solution could be relatively easy extended to all QPS systems installed in the UA, RR underground areas
- In general the QPS supervision architecture wiil need to be adapted to:
  - Redundant DAQ systems, higher resolution and sampling rates, enhanced device control, automatic tools for diagnostics and maintenance …

Upgrades for system diagnostic, test and maintenance

- Reduce LHC access as much as possible
  - ALARA: RP classification for DS areas around IP1&5 may change with HL-LHC
  - Time required for access = **substantial** part of total QPS downtime
- Enhance remote capabilities for system diagnostics, test, configuration and maintenance
  - Auto-recovery of certain faults e.g. communication problems (transparent for LHC-OP)
  - Advanced software tools for fault diagnostics and recovery

Summary

- The successful HL-LHC operation not only requires the installation of new protection equipment for the HL-LHC circuits but a substantial upgrade of the existing system
- Particular attention should be drawn to protection equipment installed in the dispersion suppressor areas around IP1/5 and its resistance to ionizing radiation
- QPS availability has meanwhile reached 98.8% but HL-LHC operation may require more