Introduction and R2E overview

Rubén García Alía, on behalf of the R2E Project

https://indico.cern.ch/event/760345/

R2E Annual Meeting

- **Main objective:** to provide a global view of the project to those of you participating in it (i.e. promote internal exchange/collaboration, know whom to ask what, etc.)
- **Structure:**
  - First day focused on Work Package presentations (mandate, status, outlook…)
  - Second day focused on more specific technical/scientific topics, typically related to student/fellow work
- **Feedback** welcomed in order to improve for next year's organization

Main R2E building blocks

Radiation Monitoring and Calculation

Rad-tol system development (mainly) based on COTS

Radiation Hardness Assurance

Qualification Approach

Radiation Test Facilities

mitigation → prevention

R2E Work Package structure

A. Operation

A-1: Project Management
[S. Gilardoni/R. Garcia Alia]
A-2: RADWG Support
[S. Danzeca]
A-3: MCWG Support
[Y. Kadi]
A-4: Material Testing and External Facilities
[M. Calviani]
A-5: Injector Chain
[R. Garcia Alia]

B. Infrastructure

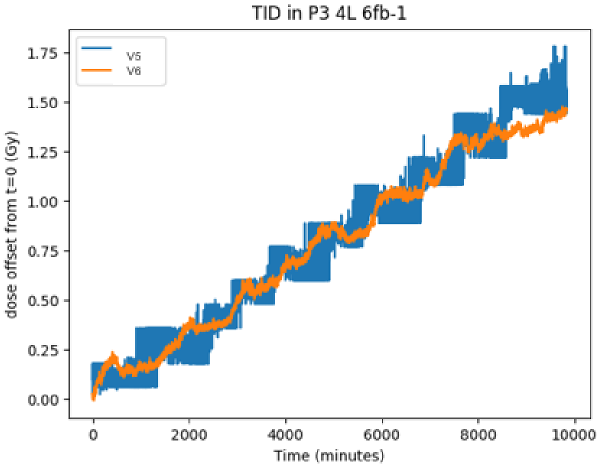
B-1: CERN Facilities
[S. Danzeca]
B-2: RadMON Monitoring
[S. Danzeca]
B-3: Optical Fibre Dosimetry
[Y. Kadi]
B-4: Shielding & Relocation
[M. Lazzaroni]

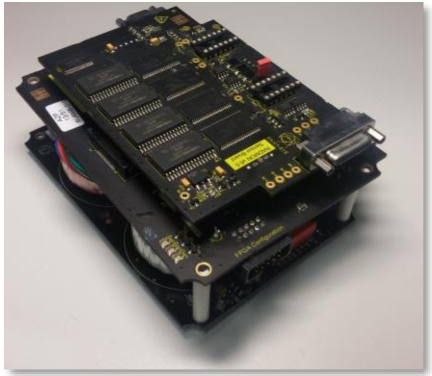
C. Radiation Tolerant Developments

C-1: Common Building Blocks
[S. Danzeca]
C-2: Vacuum
[G. Pigny]
C-3: Beam Instrumentation
[R. Jones/T. Lefevre]
C-4: Quench Protection System
[R. Denz]
C-5: Power Converters
[Y. Thurel]
C-6: Cryogenics
[J. Casas-Cubillo]
C-7: Controls
[J. Serrano]

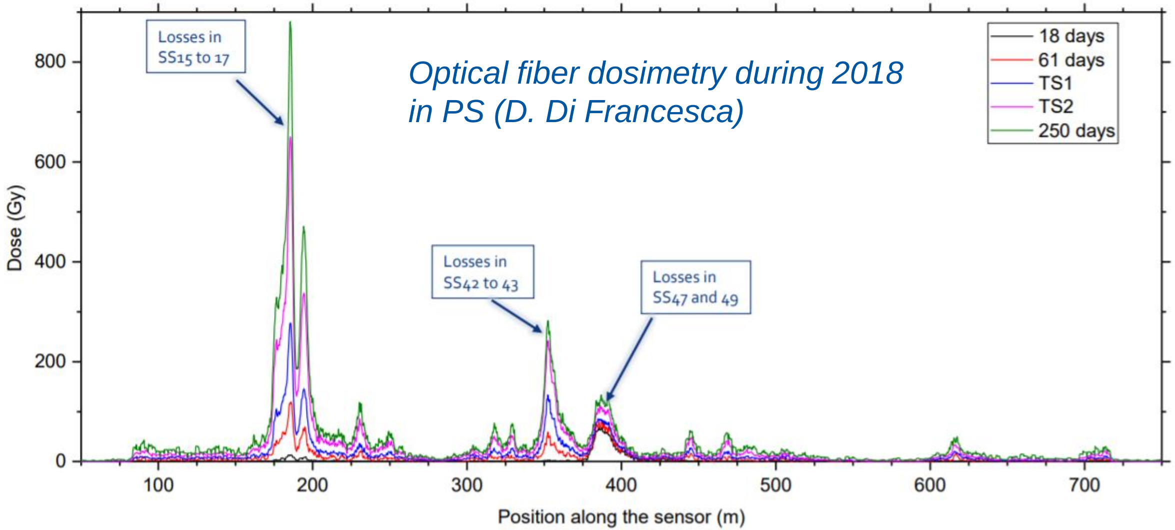
RadMON system

- v6 upgrade for LHC (all points except IP4 and IP6)
  - Enhanced radiation lifetime (~250 Gy)
  - Improved TID and HEH fluence sensitivity
  - Direct thermal neutron (R-factor) measurement
- Important not only for LHC, but also for injectors and experimental areas
- Complemented with passive dosimetry (RadFET, nMOS, BatMON); BatMON v7
  - 65nm Cypress memory, floating gate dosimeter
- Continuous operation/maintenance and development activities
- Strong interest from other accelerator/nuclear facilities, as well as for space





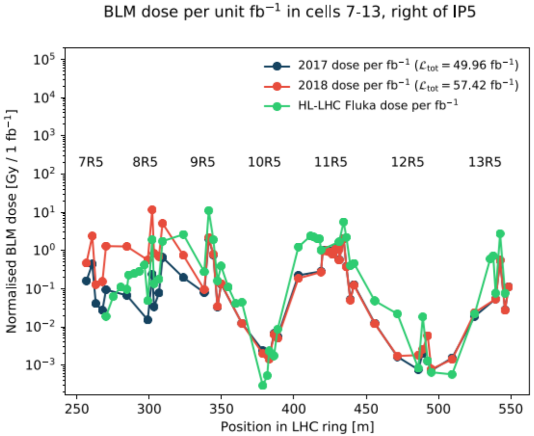
Optical fiber dosimetry

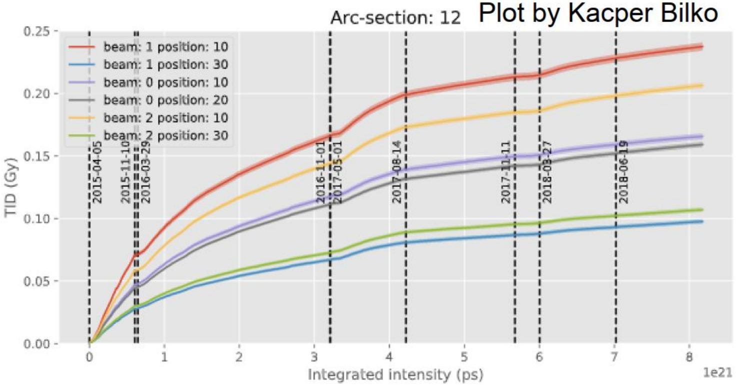


- Presently deployed in PSB and PS
- Large dynamic dose range and continuous (~1m resolution) spatial coverage
- LS2 plans: deployment in SPS and LHC dispersion suppressor (IP1, IP5 and IP7)

Radiation level monitoring & reporting

- Monitoring & reporting activity, both upon specific requests, and in terms of general reports
- **MCWG** radiation level analysis/database: mainly based on processed BLM data (very broad data set), now also including RadMON and extending into injectors
- 2018 LHC radiation level monitoring highlights:
  - Impact of TCL6 collimator settings on RR and DS levels (IP1 and IP5)
  - Increased losses in IP7
  - Evolution of LHC ARC radiation levels
  - Ion BFPP losses

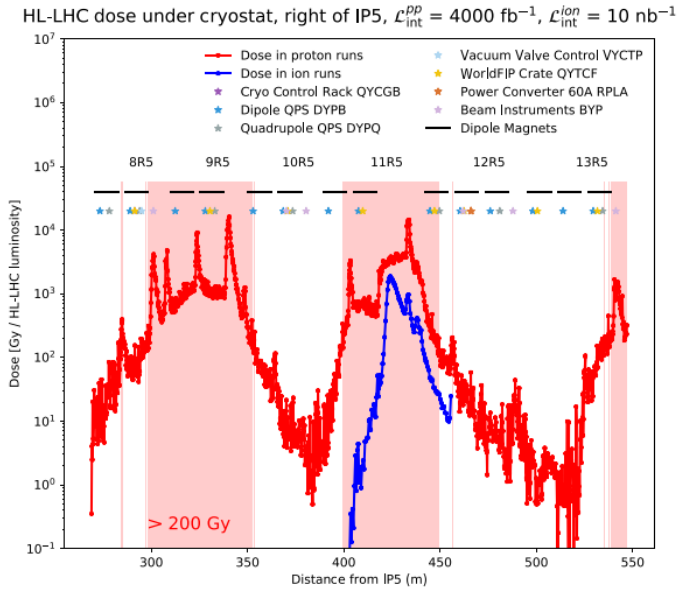




Plot by Kacper Bilko

FLUKA R2E calculations

- Key in determining radiation levels for LIU and HL-LHC configuration and operational conditions
- Efficiently covering large majority of HL-LHC (WP10) areas of concern for equipment groups:
  - Shielded areas (UJ, UL, RR) around IP1, 5 and 7
  - DS in IP1, 5 and 7 (including possible cell 9 location for 11T/TCLD)
- Activity includes also simulations for test facilities (CHARM, CC60) and FCC

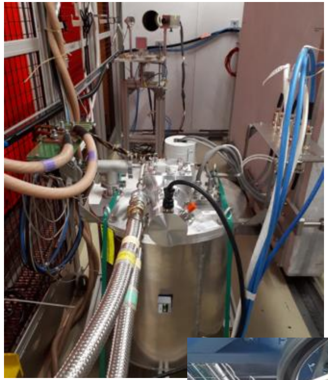


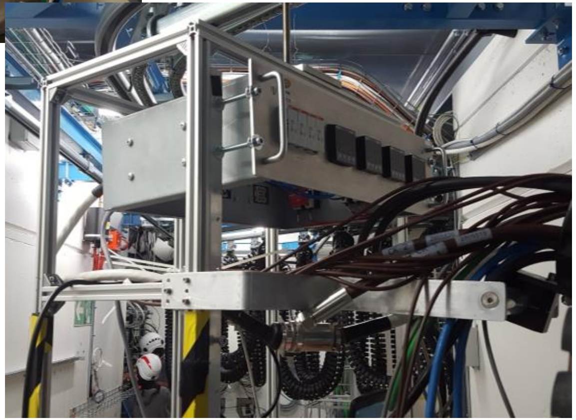
2018 impact of R2E on LHC operation

- Main 2018 LHC **radiation environment** features:
  - Confirmation of very low radiation levels in the LHC arc (<100 mGy/year at equipment location)
  - Increased losses per unit integrated intensity in IP7 due to crossing angle and beta-star settings
  - IP1 & IP5: Tradeoff between RR (lower) and DS (higher) radiation levels
  - BFPP localized ion losses
- **Operational implications**:
  - 2018 EPC RR failures in LHC leading to dump (mainly FGC2 controls and 600A power): 11 (factor ~2 reduction of failures per unit integrated luminosity with respect to 2017)
  - Significant increase in QPS failures due to (i) increased DS levels in proton operation (cell 8-9), (ii) ion operation
    - *First signature of radiation lifetime issues (i.e. not SEE related) on LHC equipment → rising edge of bathtub curve*
  - "Few" SEE-events in commercial systems in shielded areas (e.g. UL PLCs for PIC) → presently in the shadow of operation, but could become more critical with increased radiation levels

R2E test facilities at CERN

- **CHARM:**
  - “Flagship” of CERN radiation facility, tailored for high-energy accelerator environment and system level testing
  - Examples of 2018 CHARM accelerator equipment (LS2) tests: 11T uQDS, quench heater power supplies, cold-by pass diode, current lead temperature controller, electronics for pressure sensors…
  - Key R2E support for facility operation, interface with users, test preparation & interpretation…
- **CC60:**
  - In-house solution for TID testing and component and board level
  - Factor ~10 source activity increase for 2019

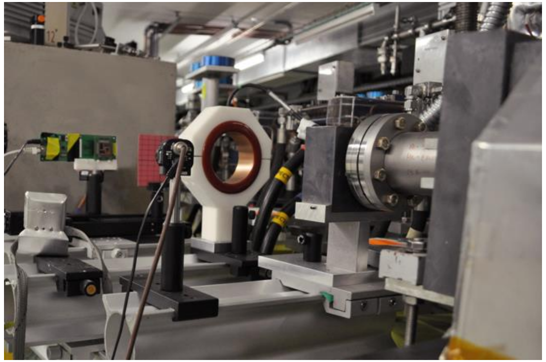




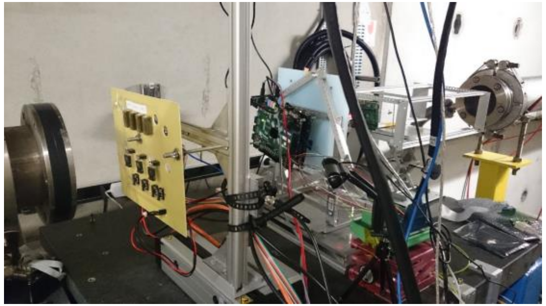
External facilities for regular R2E qualification

- **PSI** (200 MeV protons):
  - For TID/DD/SEE testing of components for equipment groups (i.e. test service)
  - ~70 references tested in 2018, reports available on radiation test database
- TID tests through **Fraunhofer** (~5 MGy target levels)
  - Relatively new R2E activity; crucial in terms of (i) building and preserving associated know-how, (ii) reducing test campaign cost and person-power
  - Passive tests, typically for materials (i.e. requiring post-irradiation analysis at CERN)

Other test facilities for R2E activities



- **Non-conventional irradiation sources & beams at CERN**
  - VESPER at CLEAR (high-energy electrons)
  - Am-Be neutron source (e.g. for SEU setup validation)
  - Ultra-high energy heavy ions at CHARM and North Area
- **Other external test facilities for recent R2E activities**
  - ILL (thermal neutrons) and LPSC (14 MeV neutrons) in Grenoble
  - Low energy protons and ion cocktail at RADEF (Jyvaskyla)
  - Atmospheric-like neutron spectrum for SEE testing at ChipIr (large beam available for board/system level testing)
  - IJS reactor in Ljubljana (mainly displacement damage)
  - Pion testing at PSI (through RADSAGA)
  - GSI high-energy and micro-beam ions



R2E equipment group developments (LS2)

- Power converters:
  - FGClite (already in operation in LHC ARC since EYETS 16-17)
  - 600A & 4-6-8 kA power converters
- GEFE BPM electronics (for SPS)
- QPS:
  - Quench detection system for 11T
  - Upgrade of main quadrupole systems
- Vacuum gauge electronics

Common development examples

- Evaluation of **NanoExplore rad-hard FPGA** for CERN applications
  - EU effort to build ITAR free rad-hard FPGA based on 65nm ST technology (mainly for space applications, strong ESA support)
  - Very promising radiation test results; lot procurement foreseen for 2019; working on implementing and testing accelerator applications
  - Complementary efforts based on **SmartFusion2** (as natural ProAsic3 replacement)
- Support for radiation tolerant elements of **BE/CO DIOT**
  - Ongoing developments (both in-house and through external company collaboration) to provide high-power DCDC converter module (synergies with TE/EPC needs)
  - Initial design and qualification of Powerlink FMC board (baseline solution: soft-core System-on-Chip)

R&D activities related to RHA

- Radiation effects on electronics evolve rapidly, mainly linked to the fast technological evolution
- It is important to keep up-to-date with **radiation effects on emerging technologies** (e.g. deep sub-micron FPGA, wide-bandgap semiconductors for power and RF electronics) due to (i) obsolescence of older technologies and (ii) enhanced performance
- A lot can be learnt from the well-established **radiation effects space community**, but "our" environment and needs are unique
- Examples of ongoing R2E R&D activities with direct RHA implications (i.e. how we qualify electronics for the accelerator):
  - **TID and displacement damage synergy effects** on e.g. bipolar components and opto-couplers (how representative is the test environment of the actual operation conditions?)
  - **Impact of intermediate and thermal neutrons** on soft-error rate for LHC shielded areas (what is their relative contribution for state-of-the-art technologies, and how can we qualify in a representative manner?)
  - Radiation effects on **wide-bandgap semiconductor technologies** (SiC, GaN)

R2E collaboration status

- **Universities** (mainly Montpellier and Jyvaskyla):
  - Collaboration agreements in place (or being implemented); regular student exchange (e.g. trainees, PhDs)
  - Saint Etienne: strong focus on optical fiber dosimetry
- **CNES:**
  - Very active collaboration, mainly focused on common qualification needs and radiation monitoring
  - CNES-CERN Steering Committee Meeting held in May 2018: https://indico.cern.ch/event/731449/
- **ESA**
  - Long-standing collaboration focusing on access to CERN and external radiation facilities and respective R&D studies
  - Finalization of protocol on “radiation environments, technologies and facilities”, to be signed early 2019
- **ITER:**
  - Workshop held in May 2018 to provide overview of radiation effects on electronics activities and possible common points of interest: https://indico.cern.ch/event/708324/ (possible similar event to be held in 2019 with GSI → 2020: more general workshop on “radiation environments and effects on electronics in high-energy accelerators and nuclear facilities”)

RADSAGA Marie Curie network

- Network of 15 students distributed around different universities, laboratories and companies in Europe; coordinated by CERN
- Working on emerging challenges for radiation effects on electronics in space, avionic, ground-level and accelerator applications
- 4 year project, started March 2017
- Main 2018 achievements relevant to R2E:
  - System-level testing in CHARM (e.g. software defined radio for satellite communication) and implications on RHA guidelines
  - Custom design and calibration of variable voltage supply SRAM radiation monitor
  - On-going rad-hard designs (e.g. CMOS imager)

RADSAGA

http://radsaga.web.cern.ch

Many thanks to all!!

(part of the R2E team at RADECS 2018)