A quick summary of R2E in 2021

Rubén García Alía (for the CERN R2E project)

R2E Annual Meeting – 1-2 March, 2022
https://indico.cern.ch/event/r2e-2022

R2E Annual Meeting 2022

2021: what continued

- **Radiation testing as a highly qualified technical service across the ATS sector**
  - **Radiation effects testing of electronic components, mainly at the PSI facility, with high-energy (200 MeV) protons**

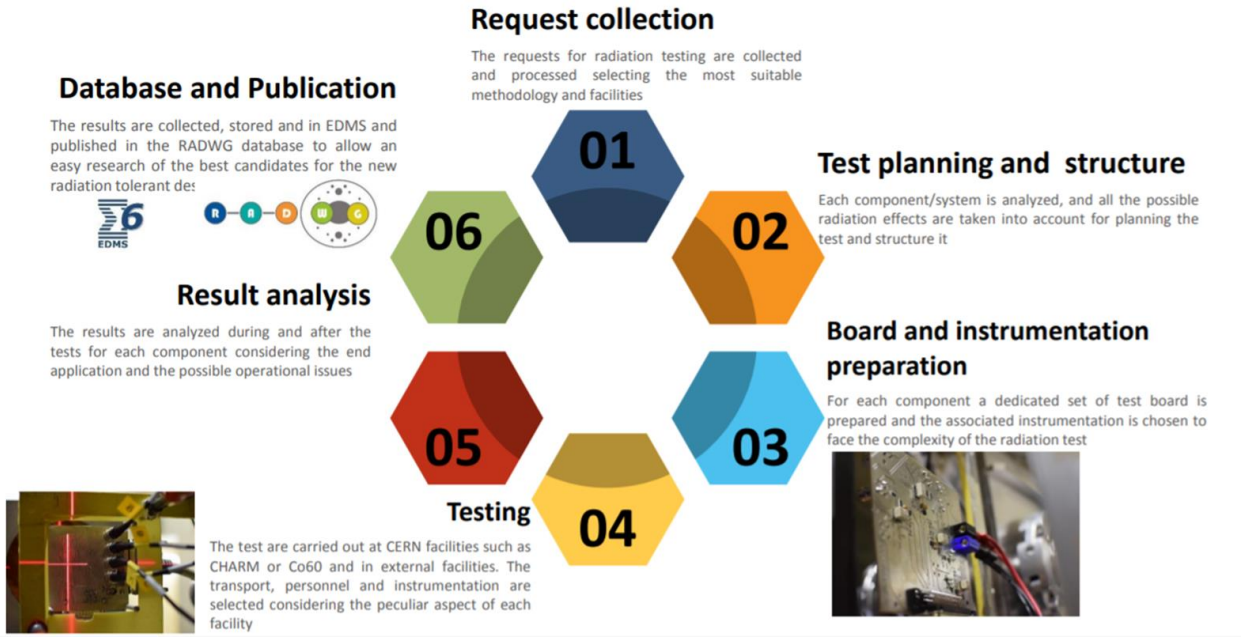
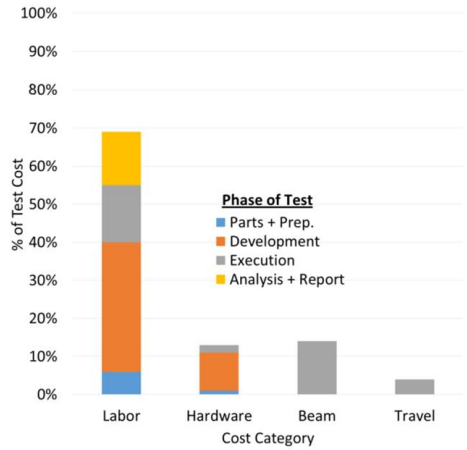


TABLE 3.2.1 Approximate Single-Event Effects Test Cost for Various Part Complexities and Packages (in thousands of dollars)

Part Complexity/Package Difficulty	Easy	Moderate	Difficult
Simple (Op. Amp, Comparator, etc.)	25–35	35–45	>50
Moderately Simple (ADC, DAC, SRAM, etc.)	40–75	50–85	>100
Difficult (Flash, DRAM, Simple Processor, etc.)	85–150	100–200	>250
Very Difficult (FPGA, Complex Processor, other highly complex and highly integrated components)	>500	>550	>600

NOTE: ADC, analog-to-digital converter; DAC, digital-to-analog converter; DRAM, dynamic random-access memory; FPGA, field-programmable gate array; SRAM, static random-access memory.



https://indico.cern.ch/event/1084973/contributions/4562392/attachments/2327022/3964418/RADWG%20Activities%20Overview%20v2.pdf
https://www.nap.edu/catalog/24993/testing-at-the-speed-of-light-the-state-of-us

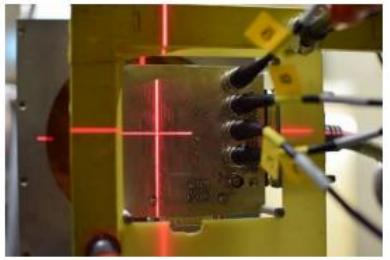
2021: what continued

- **Radiation testing as a highly qualified technical service across the ATS sector**
  - **Radiation effects testing of electronic components, mainly at the PSI facility, with high-energy (200 MeV) protons**

➢BE-CEM-EPR provides, through R2E resources, the service of radiation testing of electronic components supporting the Radiation Working Group (RadWG)

19/1-019 Rapid Prototyping lab

107/1-A10 Main PCB Assembly Atelier



PSI Beam Line

CC60 Instrumentation

https://indico.cern.ch/event/1084973/contributions/4562392/attachments/2327022/3964418/RADWG%20Activities%20Overview%20v2.pdf

2021: what continued

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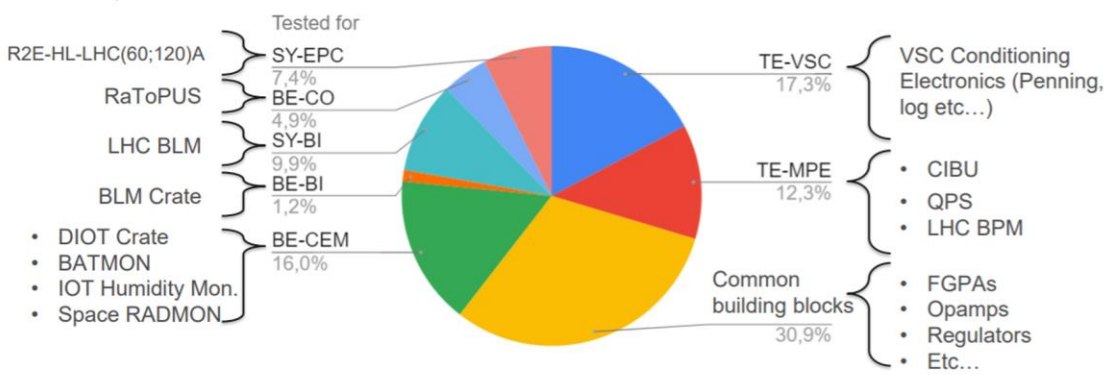
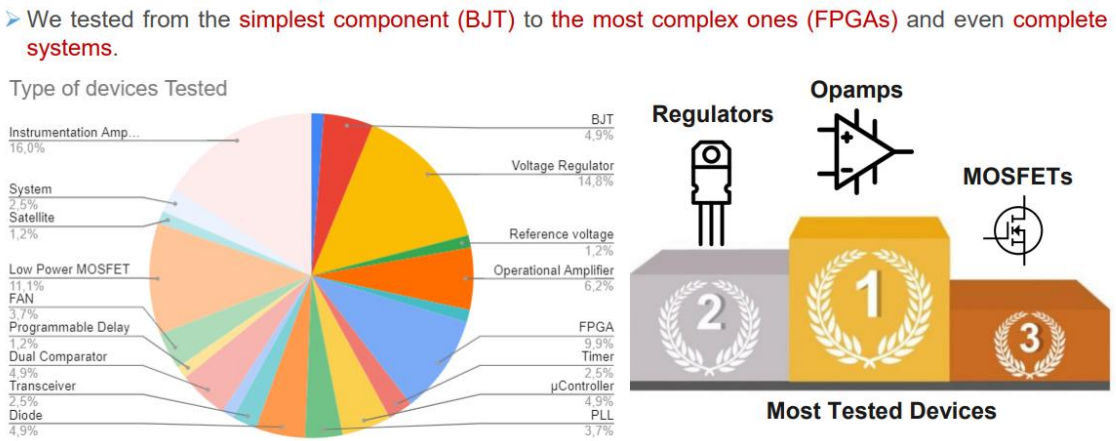


2021 user distribution of radiation testing service



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2021: what continued

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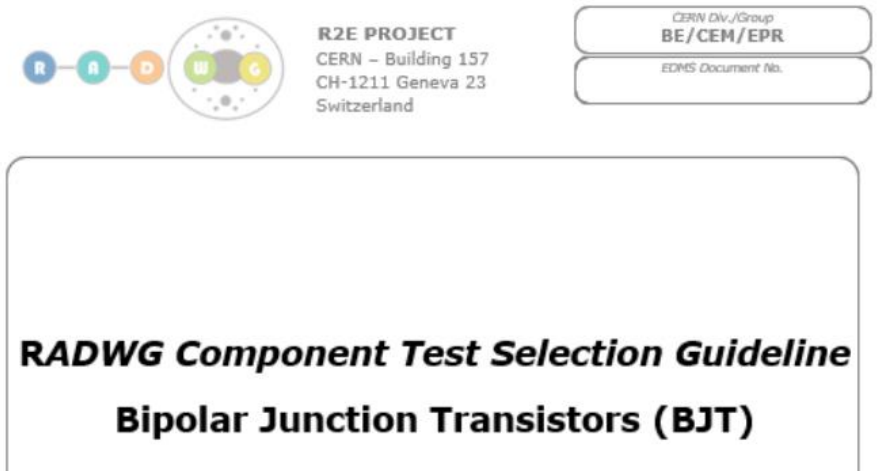
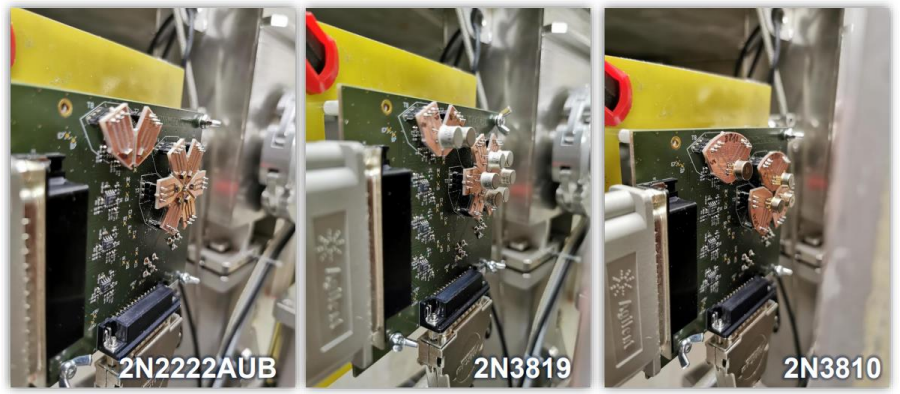


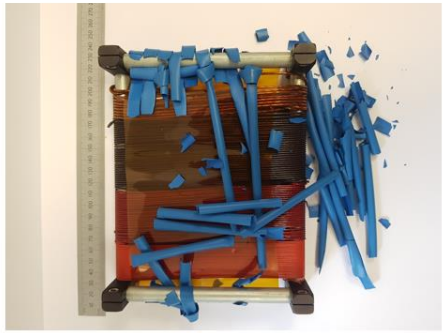


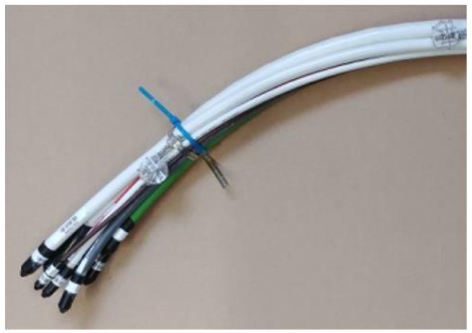
https://indico.cern.ch/event/1040413/contributions/4370062/attachments/2260432/3836573/Focus%20on%20BJT.pdf

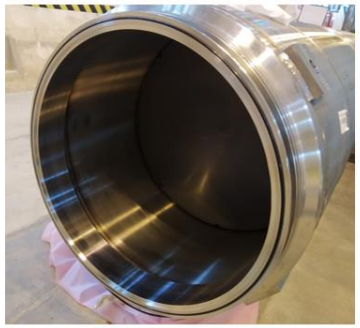
2021: what continued

- **Radiation testing as a highly qualified technical service across the ATS sector**
  - **Technical coordination of R2M testing in external gamma facilities**

Magnet spacers (grout)


Instrumentation wires


Cables for high-rad areas


Elastomeric seals for Beam Intercepting Devices


Protective covers for magnets

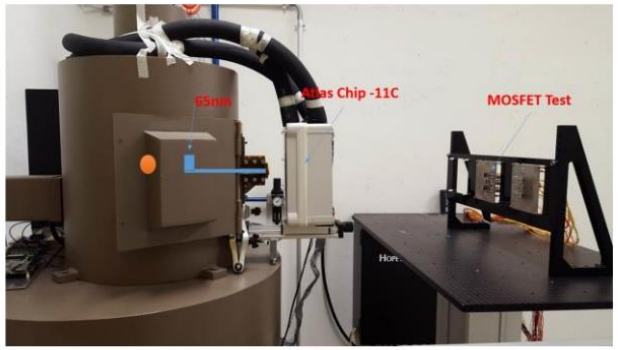

Vacuum assemblies

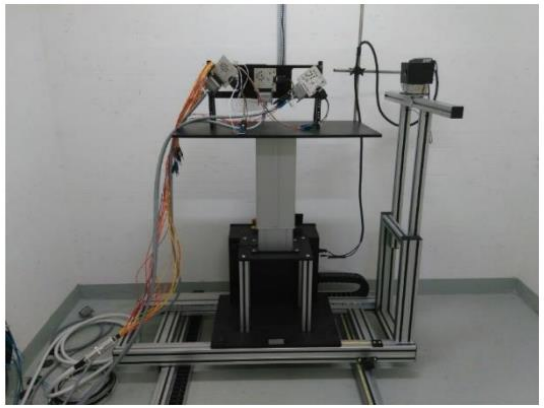

Lubricated equipment

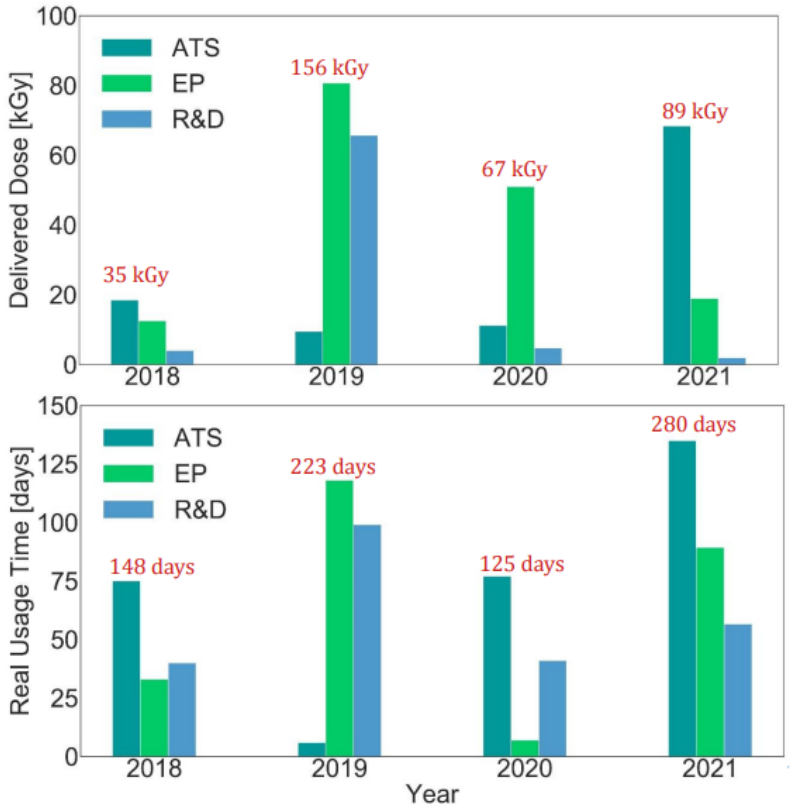
Large variety of commercial and custom-made materials and components whose radiation resistance is unknown: irradiation tests are needed

2021: what continued

- **Cobalt-60 (CC60) facility operation and user support**



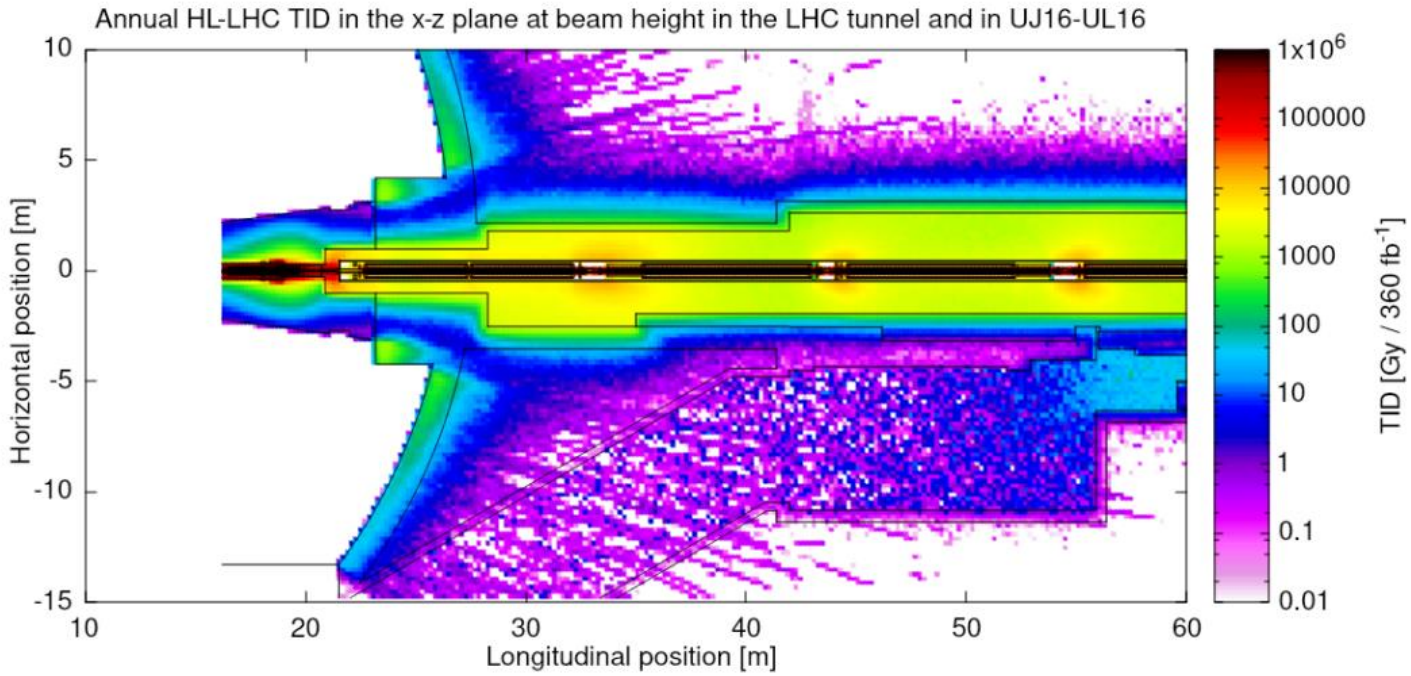




2021: what continued

- **Monitoring and Calculation Working Groups requests and studies**
  - ***From the mGy to the MGy***

MCWG



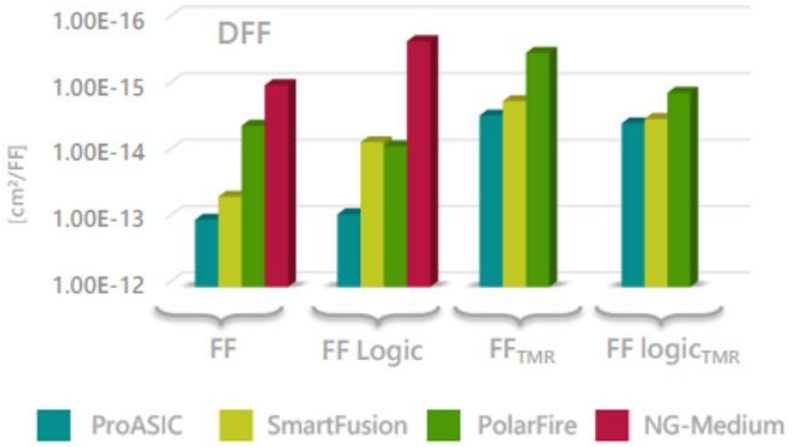
Rad-hard electronics, material damage

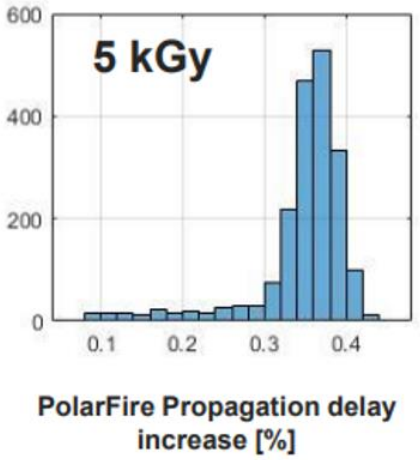
Possible SEE impact on commercial components and systems

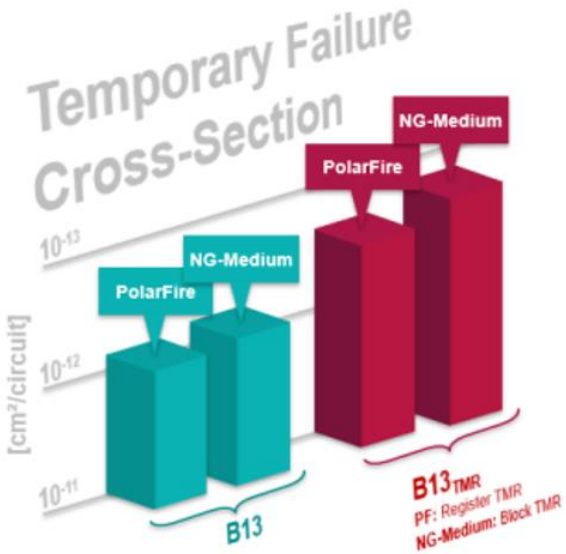
https://edms.cern.ch/ui/file/2302154/1.0/HLLHC_Specification_Document_v1.0.pdf

2021: what continued

- **R&D activities on radiation effects on electronics**



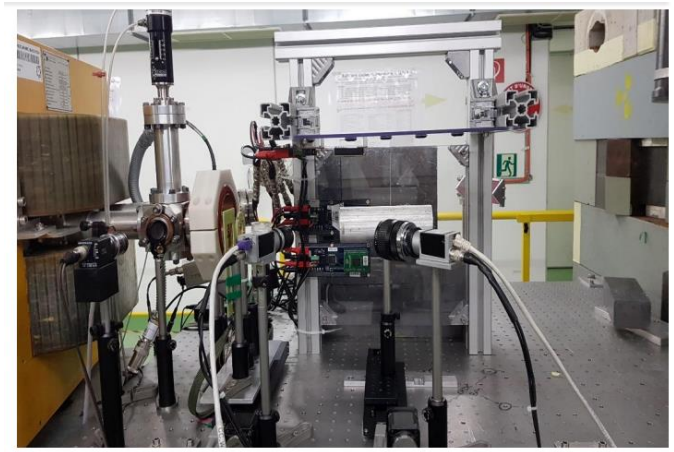




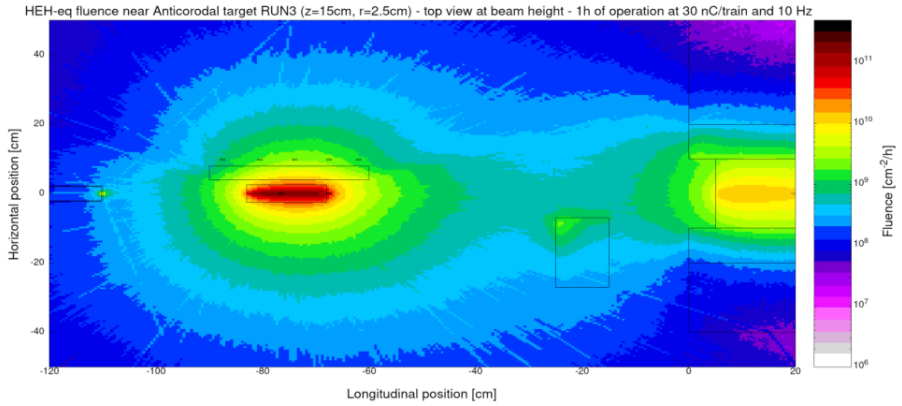
A.Scialdone 'FPGA Qualification and Failure Rate estimation Methodology for LHC Environments Using Benchmarks Test Circuits', oral RADECS2021

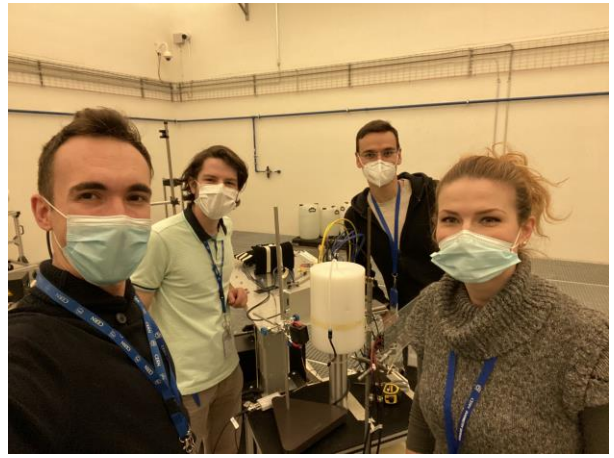
2021: what continued

- **R&D activities on internal and external facility assessment and cross-calibration**



Mixed-field testing with 200 MeV electrons on target, at the CLEAR facility at CERN



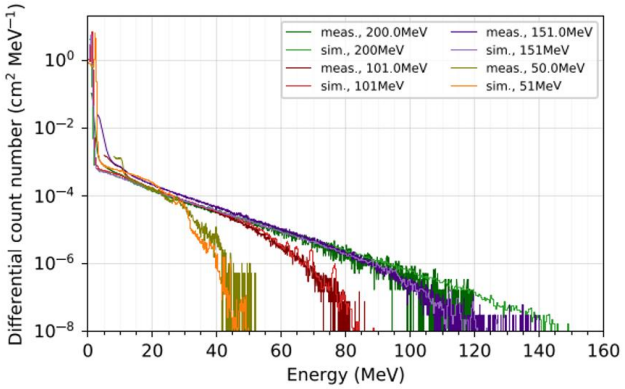


Radiation detector testing in AmBe neutron field at CERN

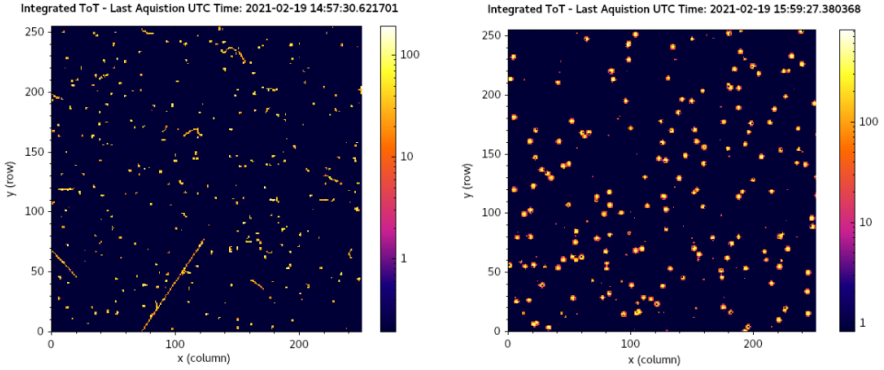
https://indico.cern.ch/event/1069803/contributions/4498695/attachments/2304288/3922252/CLEAR_test_results_presentation.pdf

2021: what continued

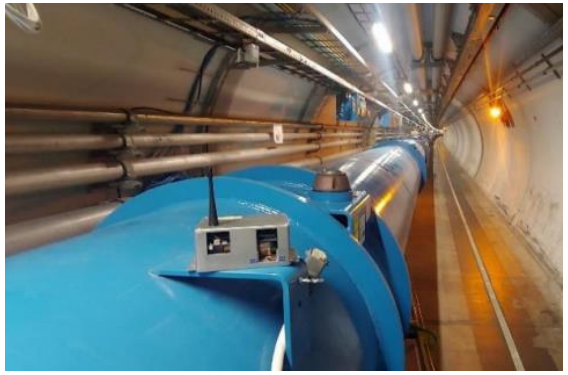
- **R&D activities on development and calibration of radiation monitors**



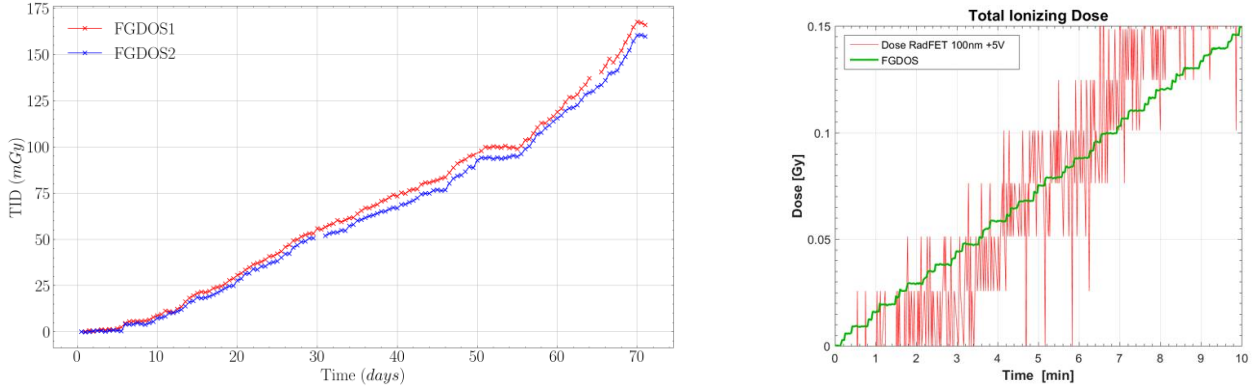
Silicon diode with high-energy protons



TimePix3 as R2E detector (setup and support from SY/BI – many thanks!)



IoT BatMON



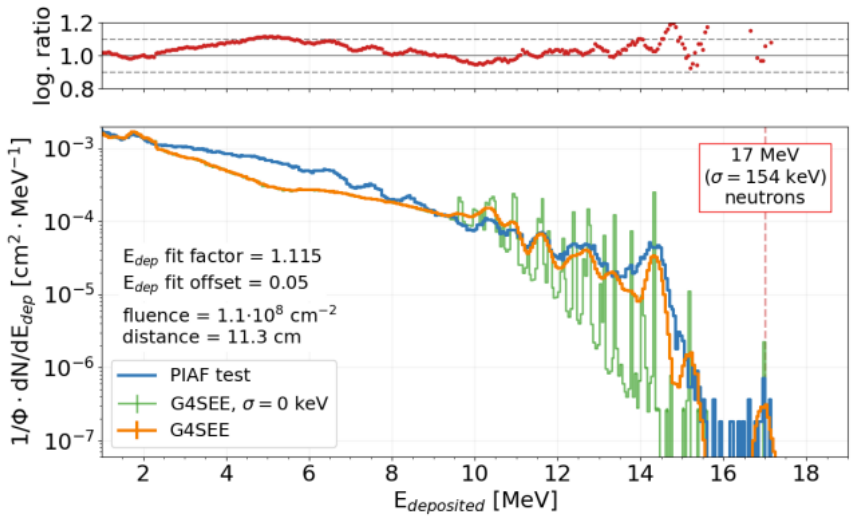
Floating Gate dosimeter, in the SPS BA1 (left) and CHARM (right, compared with RadFET)

2021: what continued

- **Monte Carlo development and application for radiation effects modelling**

G4SEE

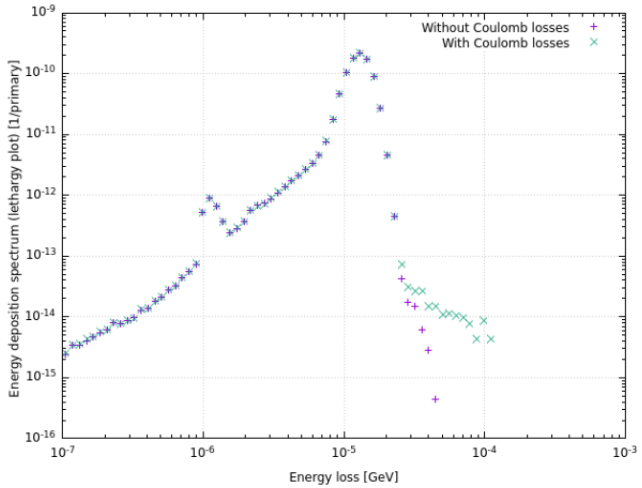
Toolkit for simulating radiation effects in electronics



17 MeV neutrons on silicon diode (measurements + simulation)

https://g4see.web.cern.ch/

FLUKA



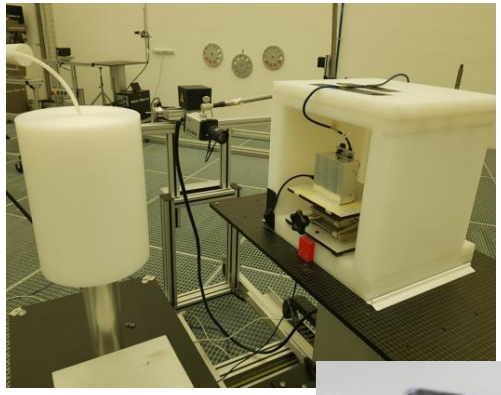
(a) $T_0 = 1\,\mathrm{MeV}$.

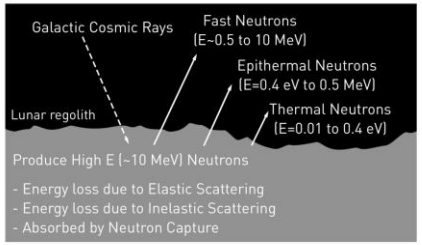
1 MeV proton energy deposition in silicon, with and without Coulomb scattering

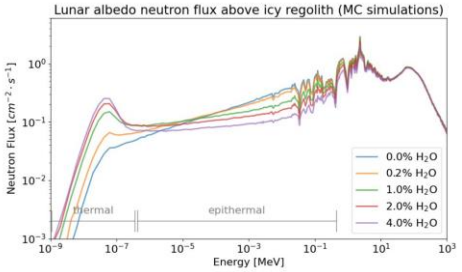
https://cds.cern.ch/record/2782105/files/report_willeke_jan.pdf
https://fluka.cern/

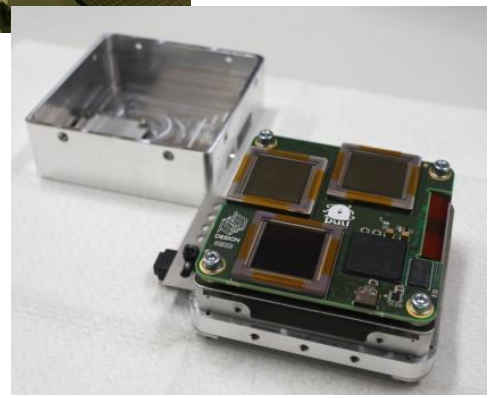
2021: what continued

- **R2E collaborations with universities, research centers, agencies and industry**

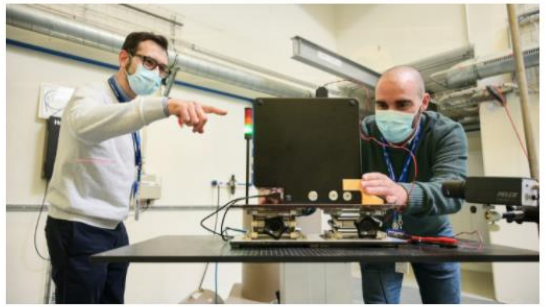








Puli Lunar Water Snooper for Lunar albedo neutron detection



Calibration tests of the Lumina dosimeter in the irradiation facilities at CERN. (Image: CERN)

CERN-tested optical fibres now on the International Space Station

Astronaut Thomas Pesquet has activated Lumina, an optical fibre-based dosimetry experiment on board the International Space Station

20 AUGUST, 2021 | By Antoine Le Gall

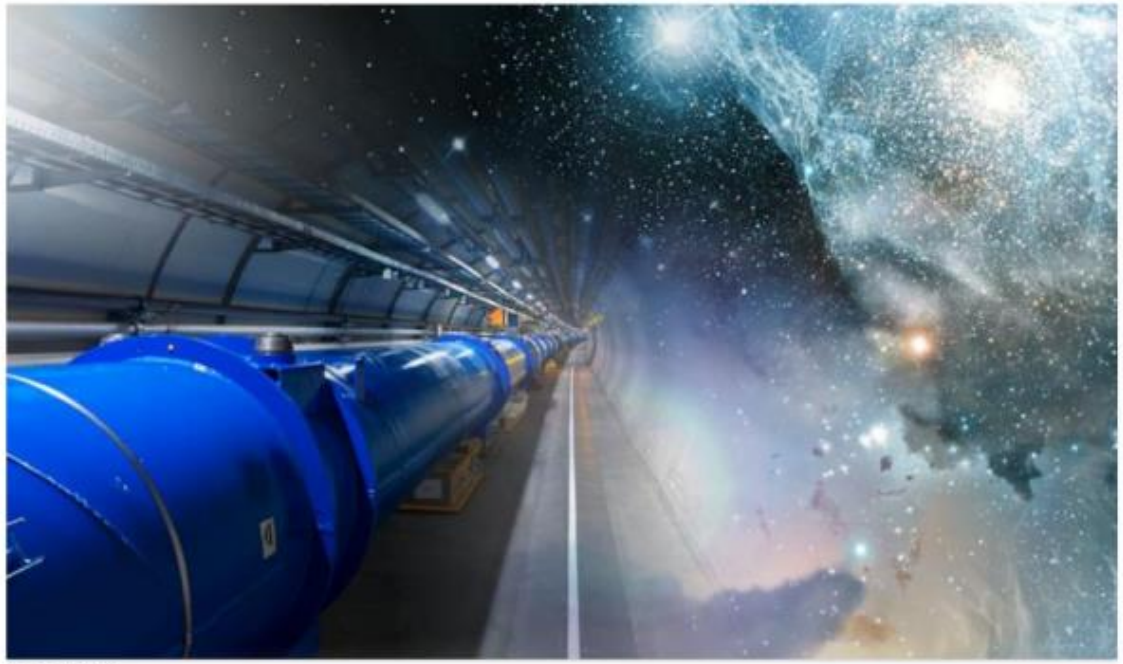
ESA astronaut Thomas Pesquet with the Lumina experiment inside the International Space Station. (Image credit: ESA/NASA) (Image: CERN)

LUMINA optical fibre dosimeter

2021: what continued

CERN and ESA forge closer ties through cooperation protocol

26 JULY, 2019



(Image: CERN)

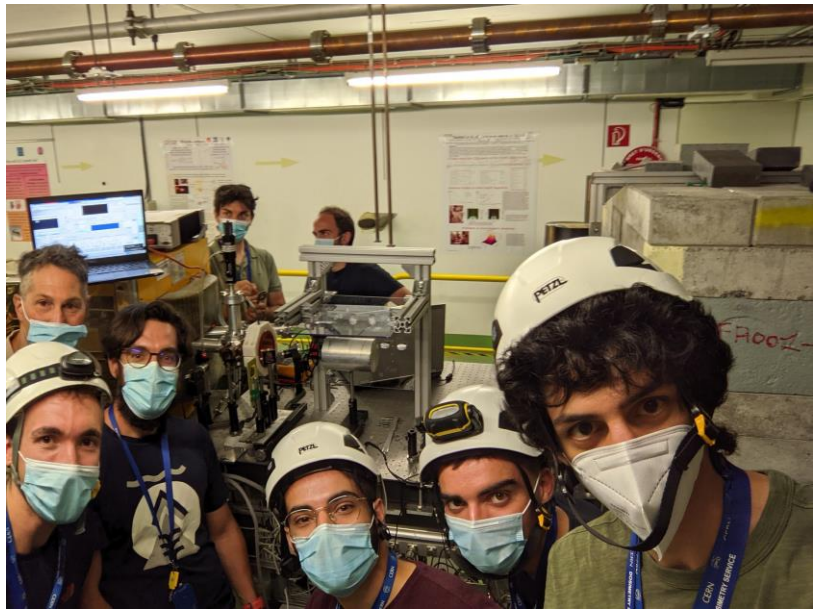
- "A new collaboration agreement between CERN and ESA, signed on 11 July, will address the challenge of operating in harsh radiation environments, which are found in both particle-physics facilities and outer space. The agreement concerns radiation environments, technologies and **facilities** with potential applications in both space systems and particle-physics experiments or accelerators."
- "The agreement identifies seven specific high-priority projects: high-energy electron tests; **high-penetration heavy-ion tests**; assessment of EEE(*) commercial components and modules (COTS); in-orbit technology demonstration; "radiation-hard" and "radiation-tolerant" components and modules; radiation detectors, monitors and dosimeters; and simulation tools for radiation effects."

(plus many other space collaborations, e.g. CNES, NASA, Airbus, Thales Alenia Space, through RADSAGA and RADNEXT EU projects, etc.)

https://home.cern/news/news/knowledge-sharing/cern-and-esa-forge-closer-ties-through-cooperation-protocol

2021: what continued

- **Contributions to international conferences, doctoral theses completion, lectures at universities and radiation effects schools, CERN internship and Summer students…**



Radiation tests at CLEAR, as part of an internship project

R2E at RADECS

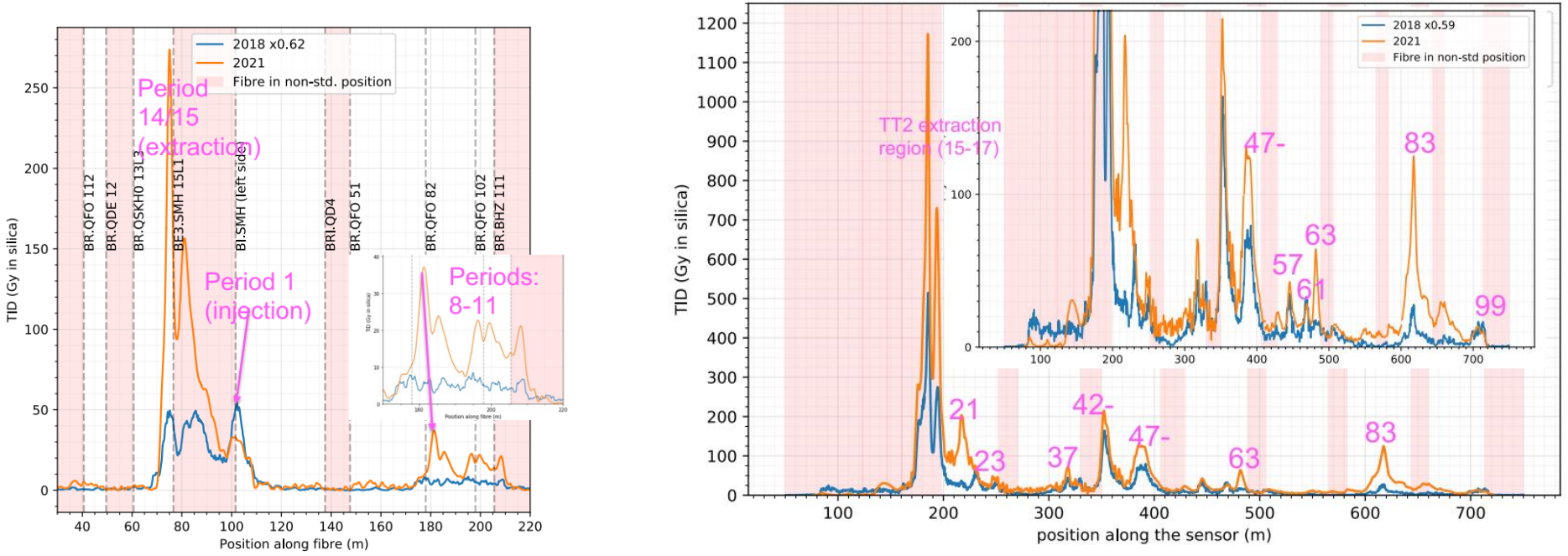
Submitted by sievers on Fri, 12/31/2021 - 10:12

Last month, the hybrid RADECS 2021, Sept. 13th-17th, Vienna conference took place, with a very strong representation of the Radiation to Electronics (R2E) @CERN project in **Vienna**, as well as a rich and varied set of contributions.

https://r2e.web.cern.ch/

2021: what (re-)started

- **LHC injector complex restart, after LS2 and with LIU capacity**
  - **Radiation level monitoring**



Radiation levels in PSB (left) and PS (right), as measured by the optical fiber dosimetry system, for 2018 and 2021

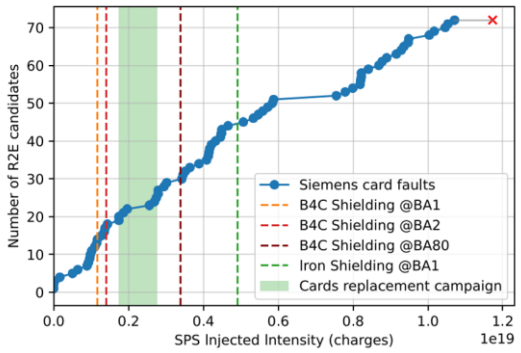
https://indico.cern.ch/event/1107029/contributions/4657879/attachments/2372176/4051489/IPP_prompt_radiation_levels_in_injectors_kbilko_Jan2022.pdf

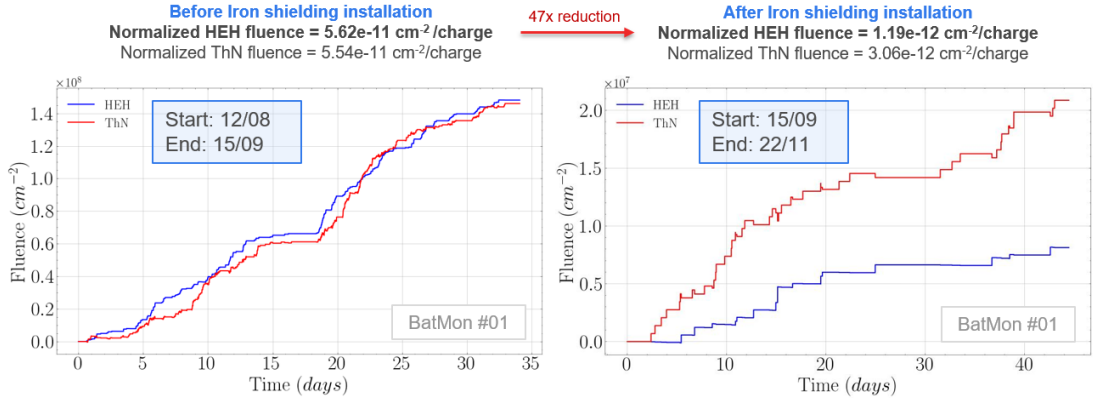
2021: what (re-)started

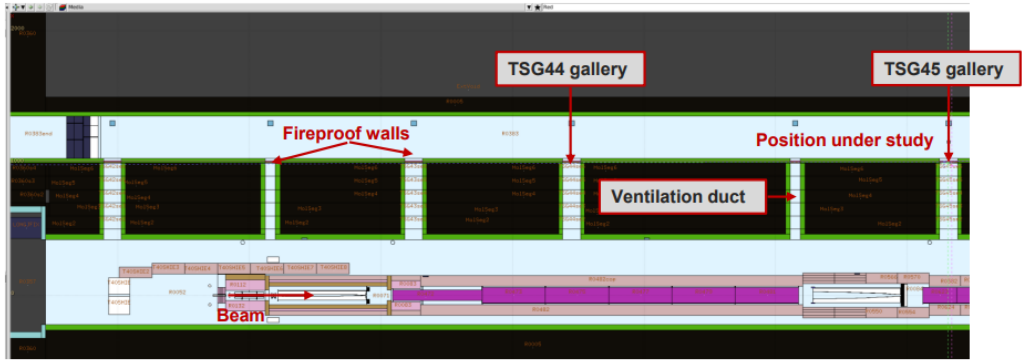
- **LHC injector complex restart, after LS2 and with LIU capacity**
  - **Operation follow-up and mitigation of R2E events**

Beam Availability Overview 2021
(since the start of SPS North Area physics)

Facility	Destination	Expected 2021 Total [%]	Achieved 2021 Total [%]*
LINAC4	-	95	97.3
PSB	PS	90	94.5
	ISOLDE		
PS	SPS	87	88.1
	nTOF		
	AD		
	East Area		
SPS	LHC	84	73.4
	North Area		
	AWAKE		
	HiRadMat		

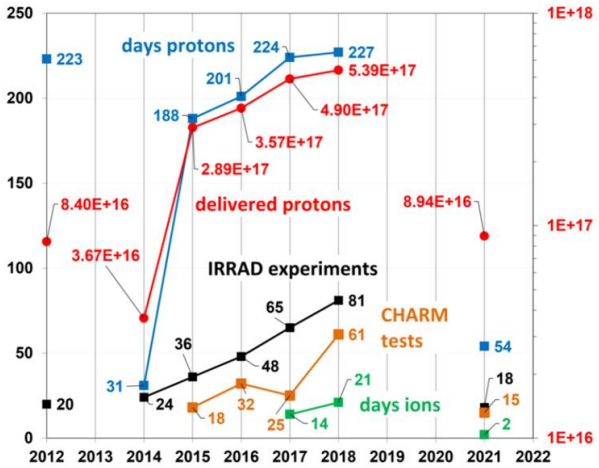


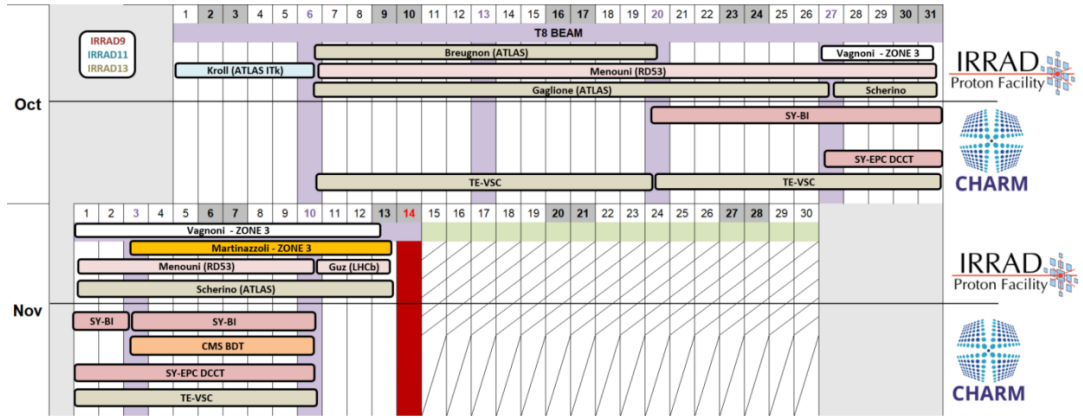




2021: what (re-)started

- **CHARM facility operation**

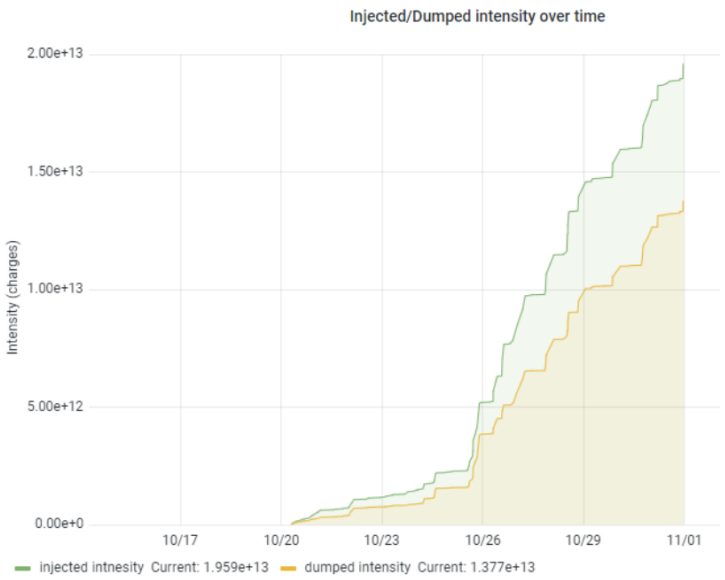


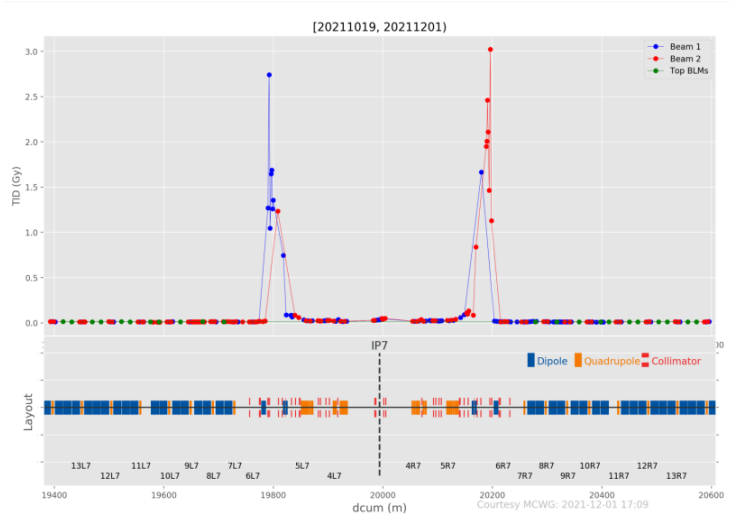


https://indico.cern.ch/event/1084973/contributions/4561763/attachments/2327014/3964279/RADWG%20Meeting%20October%202021.pdf

2021: what (re-)started

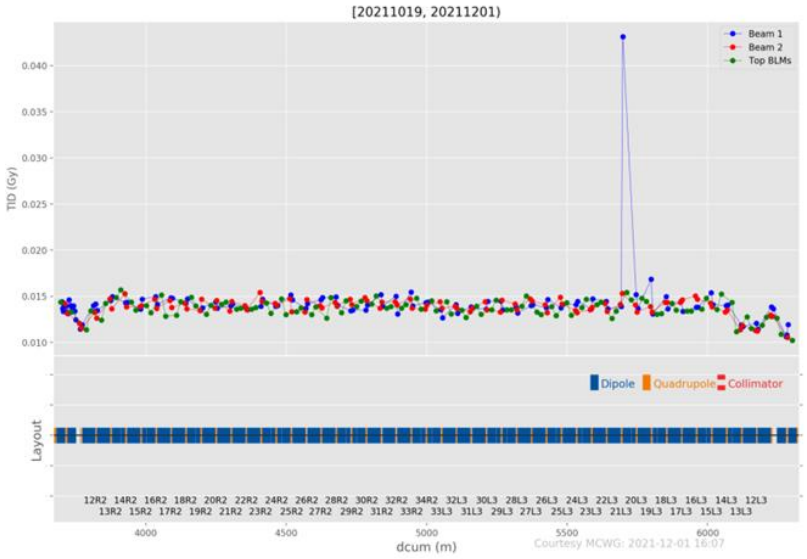
- **Pilot beam in the LHC**





BLM radiation levels in IR7, and arc sector 23, during 2021 LHC pilot beam

https://edms.cern.ch/ui/file/2668649/1/LHC_BLM_TID_preRun3_kbilko_pptx_cpdf.pdf



2021: what started

- **CC60 source upgrade, from 4.6 TBq to 110 TBq**

2021: what started

- **RADNEXT EU project aimed at enhancing accessibility to accelerator infrastructure for irradiation testing**

Partners & Associates

Coordinator: CERN (Int.)

Facilities:

- GSI (DE)
- UMCG PARTREC (NL)
- GANIL (FR)
- RADEF (FI)
- UCLouvain (BE)
- PSI (CH)
- CNA (ES)
- NPI CAS (CZ)
- TRIUMF (CA)
- STFC-ISIS (GB)
- ENEA-FSN (IT)
- CNRS LPSC (FR)
- UU NESSA (SE)
- ILL (Int.)
- Centre Spatial Liege (BE)
- HZDR (DE)
- ESRF (Int.)
- ELI Beamlines (CZ)
- CLPU (ES)
- PTB (DE)
- Seibersdorf Laboratories (AT)
- ATRON (FR)

WP01/MGT Project management

Networking Activities

WP02/NA1 Communication, dissemination, exploitation and training

WP03/NA2 Transnational access management and harmonization

WP04/NA3 Roadmap and pre-design of future irradiation facilities

Joint Research Activities

WP05/JRA1 Radiation monitors, dosimeters and beam characterization

WP06/JRA2 Standardization of system level radiation qualification methodology

WP07/JRA3 Cumulative radiation effects on electronics

WP08/JRA4 Complementary modelling tools

Transnational Access

WP09/TA1 Neutron, muon and mixed-field spallation facilities and irradiation

WP10/TA2 Proton, heavy ion and alternative beams and irradiation

https://radnext.web.cern.ch/

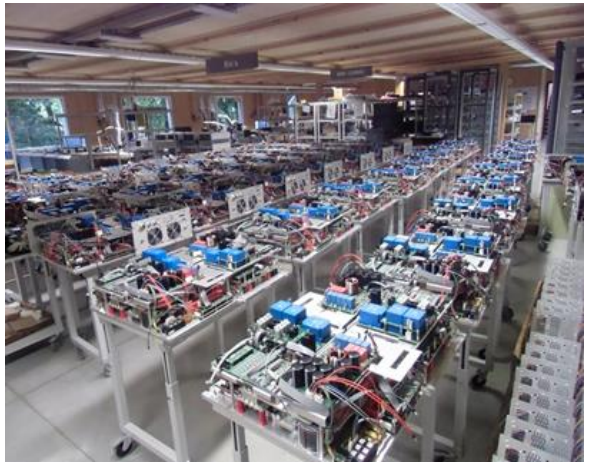
2021: what started

- **Installation and commissioning of R2E systems for LHC, in view of 2022 restart**

R2E-LHC600A-10V Converter

Parameter	Min Target Value	Results (± 30%)
TID (Gy) [Per module]	200	**315**
HEHeq Fluence Power Module (cm^{-2}) [Total]	$1.73 \cdot 10^{12}$	**$3.89 \cdot 10^{12}$**
HEHeq Fluence CPM Module (cm^{-2}) [Total]	$1.79 \cdot 10^{12}$	**$3.89 \cdot 10^{12}$**
1-MeV Eq. Fluence Power Module (cm^{-2}) [Per module]	$6 \cdot 10^{11}$	**$2.11 \cdot 10^{12}$**
1-MeV Eq. Fluence Control & Protection Module (cm^{-2}) [Per module]	$6 \cdot 10^{11}$	**$2.11 \cdot 10^{12}$**
Dump/Year	<1	**<<1**

Radiation tolerance requirements and achievements

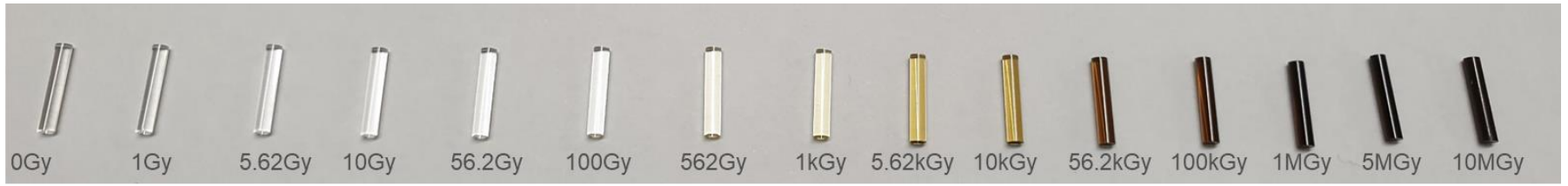


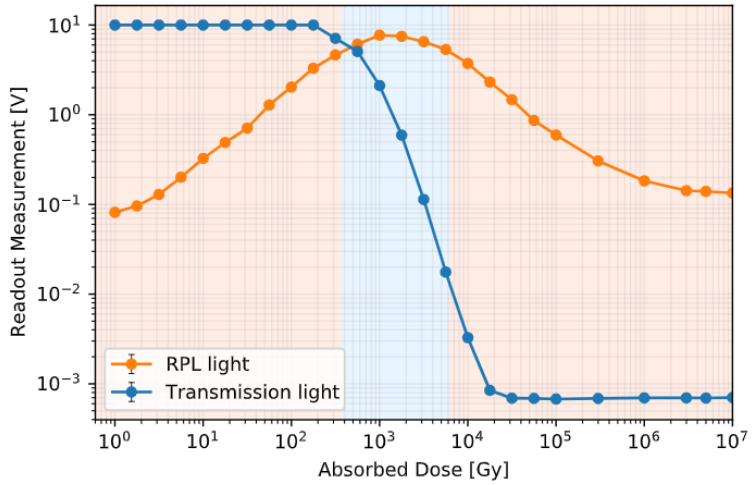
Converter under production

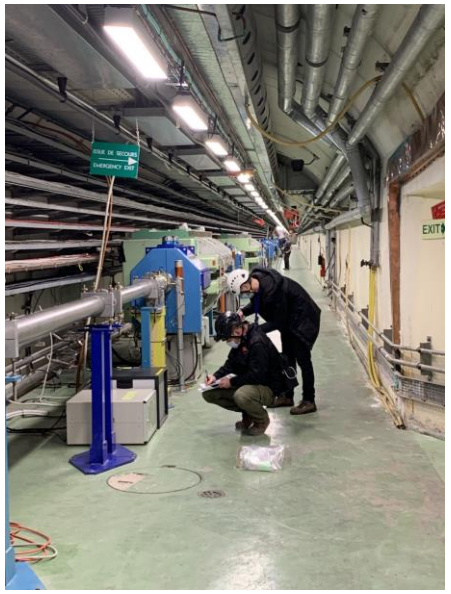
Converters installed in LHC (104x)

2021: what started

- **High Level Dosimetry (HLD) integrated in MCWG and R2E**





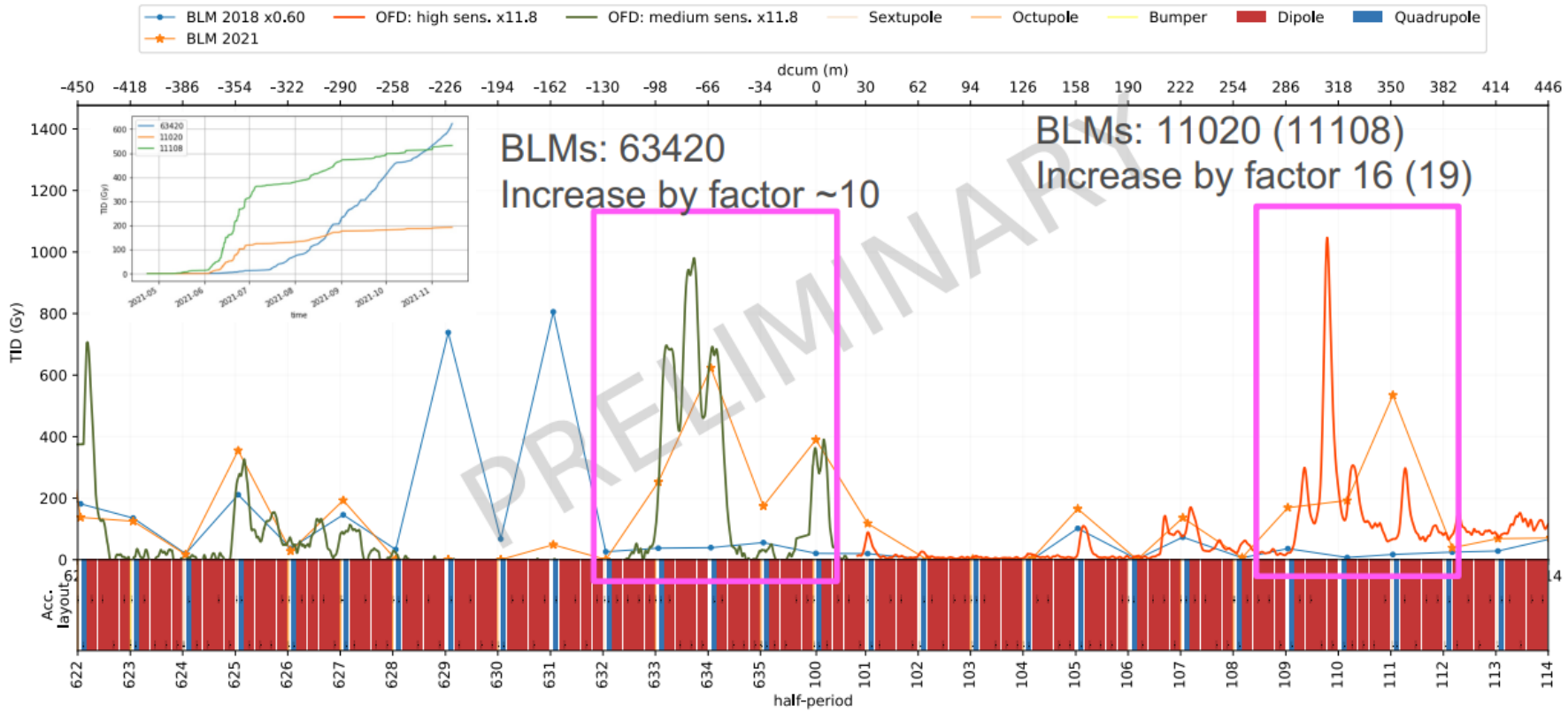


RPL installation in transfer lines

RPLs for MGy cable irradiation

2021: what started

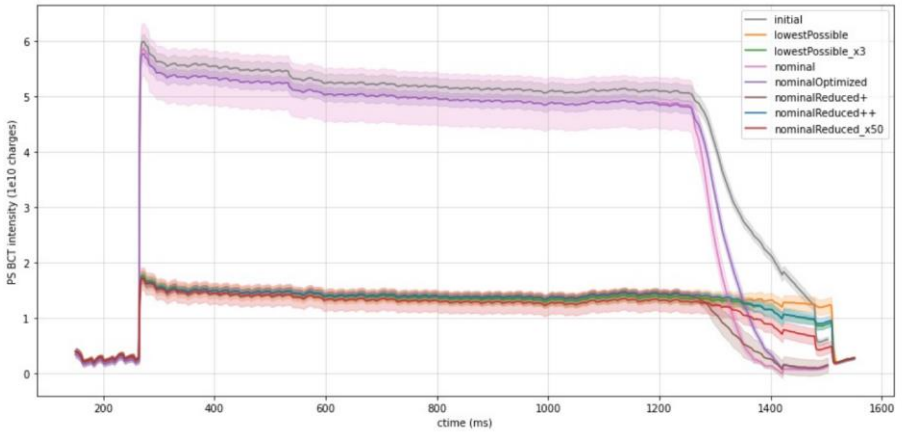
- **Distributed optical fiber dosimetry system in the SPS**



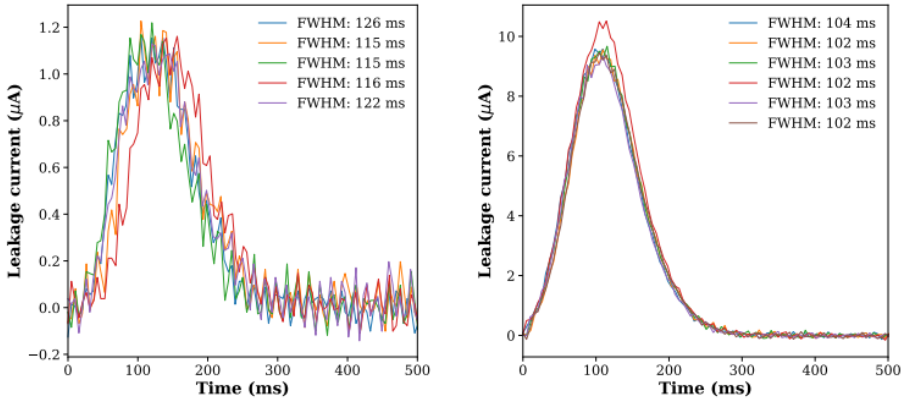
https://indico.cern.ch/event/1107029/contributions/4657879/attachments/2372176/4051489/IPP_prompt_radiation_levels_in_injectors_kbilko_Jan2022.pdf

2021: what started

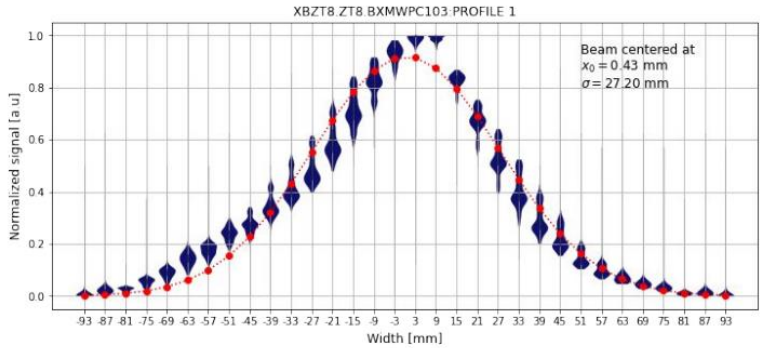
- **Heavy ions in CHARM: CHIMERA**

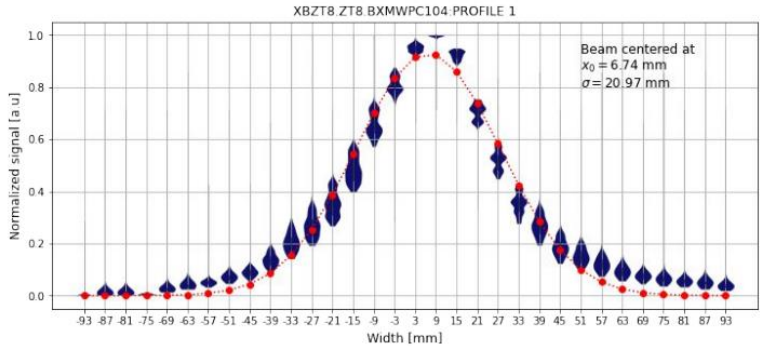


PS intensity for broad range of extracted ion fluxes



Spill time profile



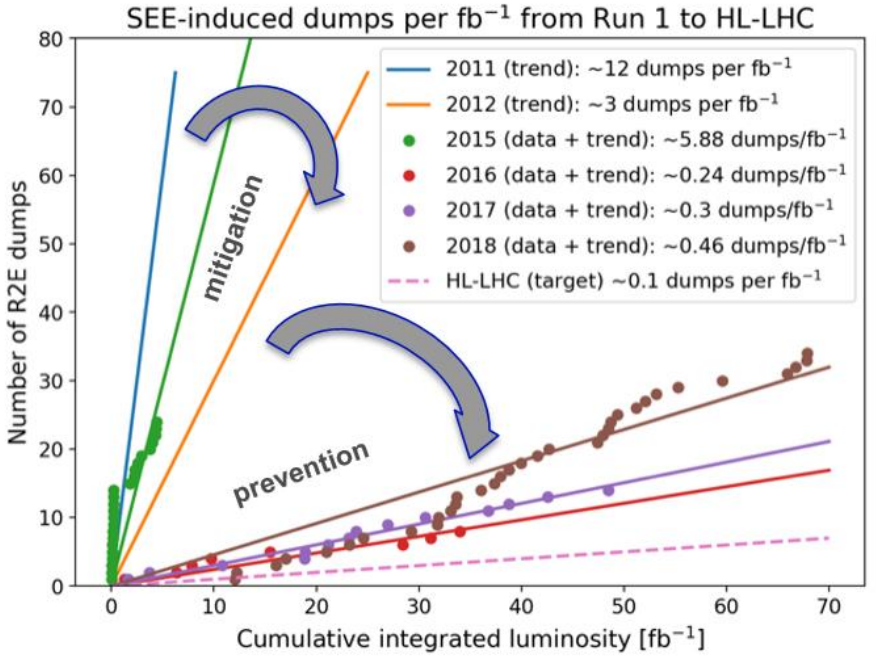


Beam profile

https://indico.cern.ch/event/1107452/contributions

2022: some challenges ahead

- **LHC restart**



2022: some challenges ahead

- **Chip shortage**

Radiation Testing of an SAR ADC for Use in Quench Detection Systems for the HiLumi LHC

Jelena Spasic, Reiner Denz, Josef Kopal, and Jens Steckert

***Abstract*—This work presents a radiation assessment of a successive-approximation-register (SAR) analog-to-digital converter (ADC) for purposes of a new generation of quench detection systems (QDS) that will be used in the radiation environment of High-Luminosity Large Hadron Collider (HL-LHC). The assessment has been performed by conducting an irradiation testing campaign using a proton beam with radiation doses up to 1 kGy. The test results render the selected ADC highly robust for use in future applications of quench protection in the LHC superconducting magnet circuits.**

***Index Terms*—radiation, SAR ADC, quench detection, LHC.**

I. Introduction

In the scope of the High-Luminosity Large Hadron Collider (HL-LHC) project [7], there is a planned upgrade of the LHC to increase its luminosity and thus, increase its discovery potential. As a part of the upgrade, new high-field superconducting magnets, such as the Nb_3Sn-based

tested in radiation conditions similar to those in the LHC to verify the radiation behavior of the ADC before its deployment.

High-precision 24-bit ∑Δ ADCs, such as ADS1281 [5], have already been used in the QDS for the LHC. Despite having a proper precision, these converters did not provide the satisfactory performance when exposed to radiation [2]. Moreover, their built-in signal filters introduce a significant signal latency. In contrast, a 16-bit 200 kHz successive-approximation-register (SAR) ADC has been successfully used within the QDS in the radiation environment of the LHC. In addition, SAR ADCs have a simpler structure than ∑Δ ADCs, hence they have lower power consumption and low latency. Therefore, selecting a 20-bit 1 MHz SAR ADC LTC2378-20 [8] came as a natural solution. To assess its behavior when exposed to radiation, an irradiation testing campaign has been performed, as presented further in this work.

II. Test Setup

https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=8696225

Details

Mouser Part No:	584-LTC2378CMS-20PBF
Mfr.'s Part No:	LTC2378CMS-20#PBF
Description:	20-Bit, 1Msps, 104dB SNR, 0.5pmm INL, 21mW, SAR ADC with Serial Interface
Stock:	No Stock
On Order:	358 Expected 04/17/2023 222 Expected 06/08/2023
Factory Lead Time:	85 Weeks

CERN SY STI R2E

Thank you for your attention!