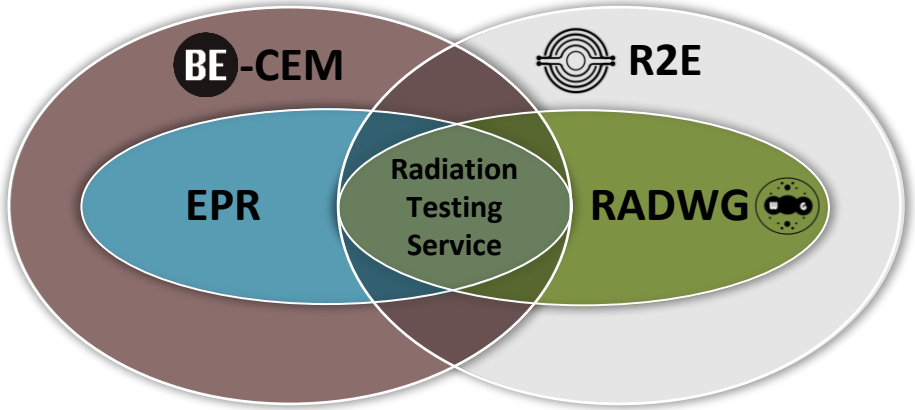
Radiation Test Service for Equipment Groups

Rudy Ferraro (BE-CEM-EPR)

R2E Annual Meeting – 1-2 March, 2022

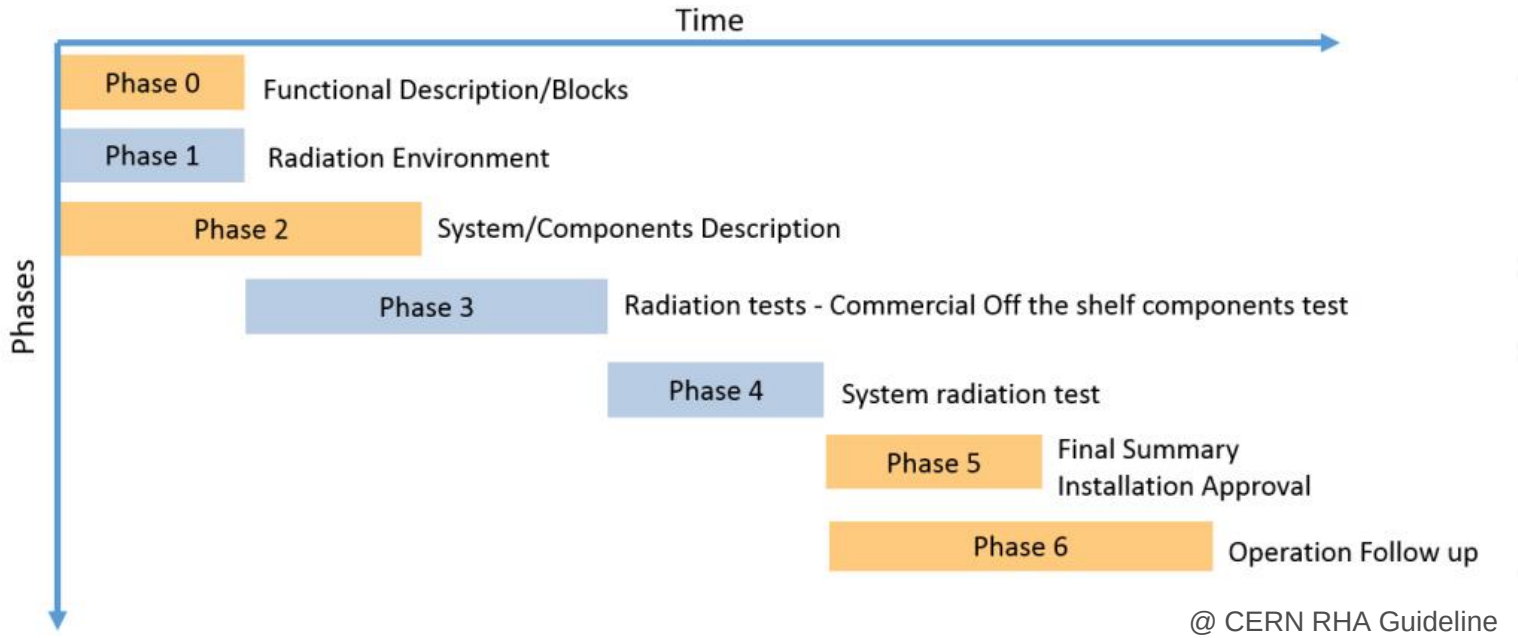
Radiation Test Service

- BE-CEM-EPR provides, through R2E resources, the service of radiation testing of electronic components supporting the Radiation Working Group (RadWG)
- The RadWG **supports** the accelerator sector equipment groups for the assessment of radiation tolerance of electronic equipment to be installed in radiation exposed areas.
- It is as a **forum** for electronic engineers to discuss
  - Design practices
  - Radiation tests
  - Radiation induced failures in the accelerators.
- The RadWG is one of the pillars of the R2E project



CERN RHA Guideline for COTS-based system

Within the R2E project we have defined the process for system qualification:



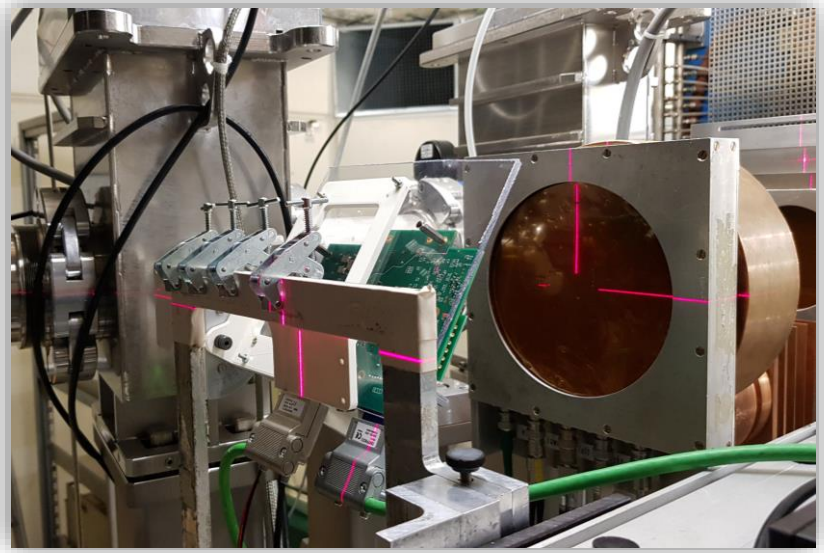
@ CERN RHA Guideline

- Provide advices and support for component type & technology choice
- Collect Test request
- Test & Reporting
- Provide support on system failure analysis and mitigation

- Provide advices in early development stages for component choice
- Help analyzing system failure observed in operation or during system-level test and propose mitigation techniques or part replacement candidates

Radiation test as a sector-wide service

- Radiation testing requires:
  - Knowledge of radiation effects on electronic
  - Tests setup
  - Instrumentation
  - Facilities
  - Result comprehension and reporting
- Objectives:
  - Reduce and help the equipment groups to lower the burden of the radiation test by giving the support as a service
  - Still keep high the knowledge sharing and the collaborations
  - Maintain Radiation Database
  - Provide reusable test data



CERN - WorldFip repeater system on beamline

Radiation test service – BE-CEM-EPR

Request collection

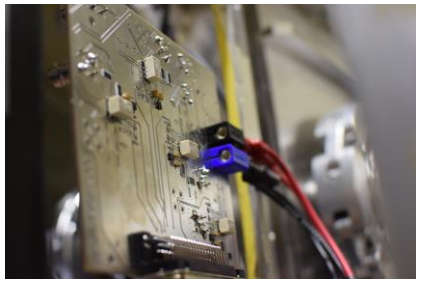
The requests for radiation testing are collected and processed selecting the most suitable methodology and facilities

Test planning and structure

Each component/system is analyzed, and all the possible radiation effects are taken into account for planning the test and structure it

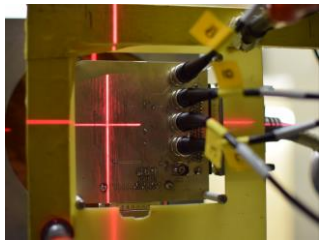
Board and instrumentation preparation

For each component a dedicated set of test board is prepared and the associated instrumentation is chosen to face the complexity of the radiation test



Testing

The test are carried out at CERN facilities such as CHARM or Co60 and in external facilities. The transport, personnel and instrumentation are selected considering the peculiar aspect of each facility



Result analysis

The results are analyzed during and after the tests for each component considering the end application and the possible operational issues

Database and Publication

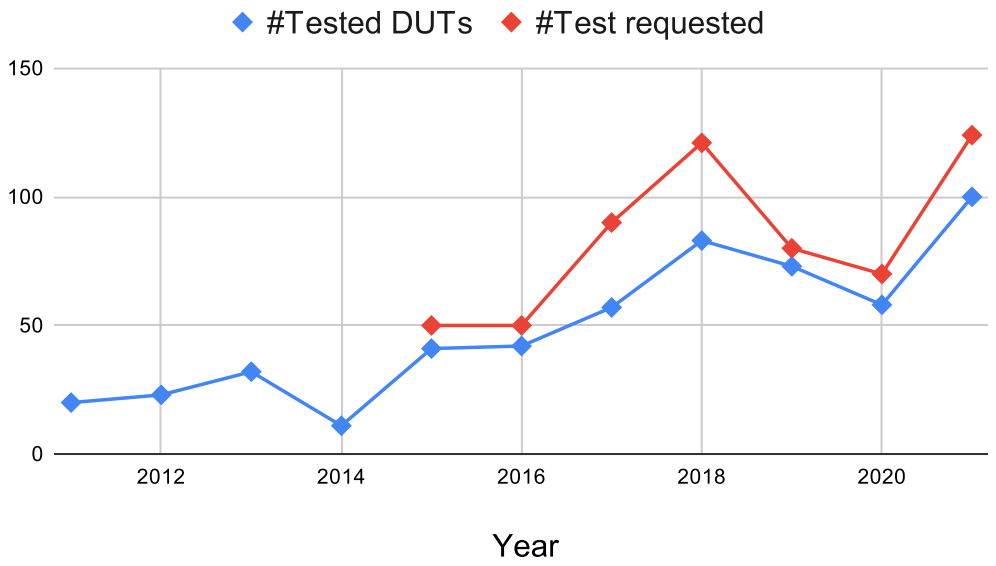
The results are collected, stored and in EDMS and published in the RADWG database to allow an easy research of the best candidates for the new radiation tolerant des

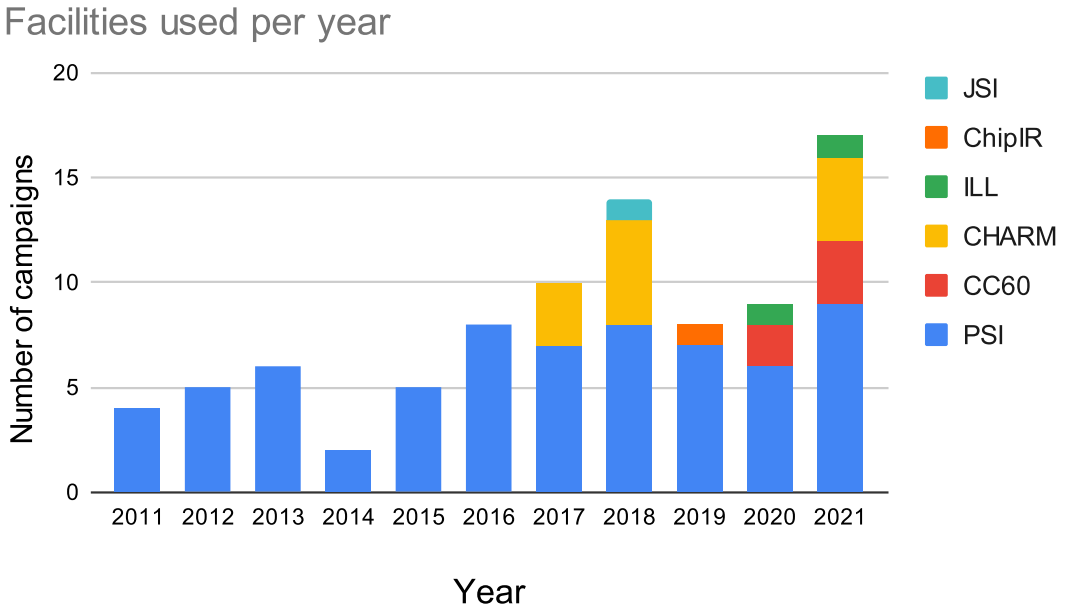
2021 in Numbers: Test Campaigns

- 124 requests collected
- 100 components tested
  - New components but also lot qualification
- 17 Radiation campaigns done:
  - (9*PSI, 3*CC60, 1*ILL, 4*CHARM)

Breaking records:

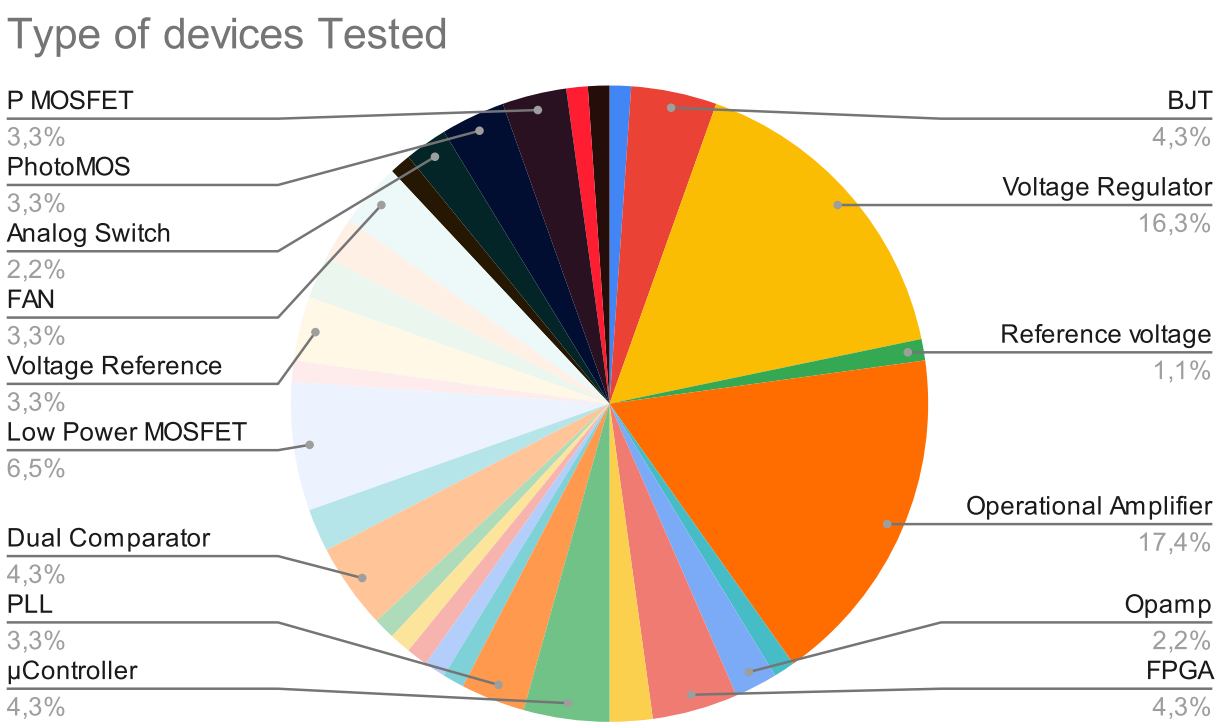
- Highest number of DUTs
- Highest number of campaigns

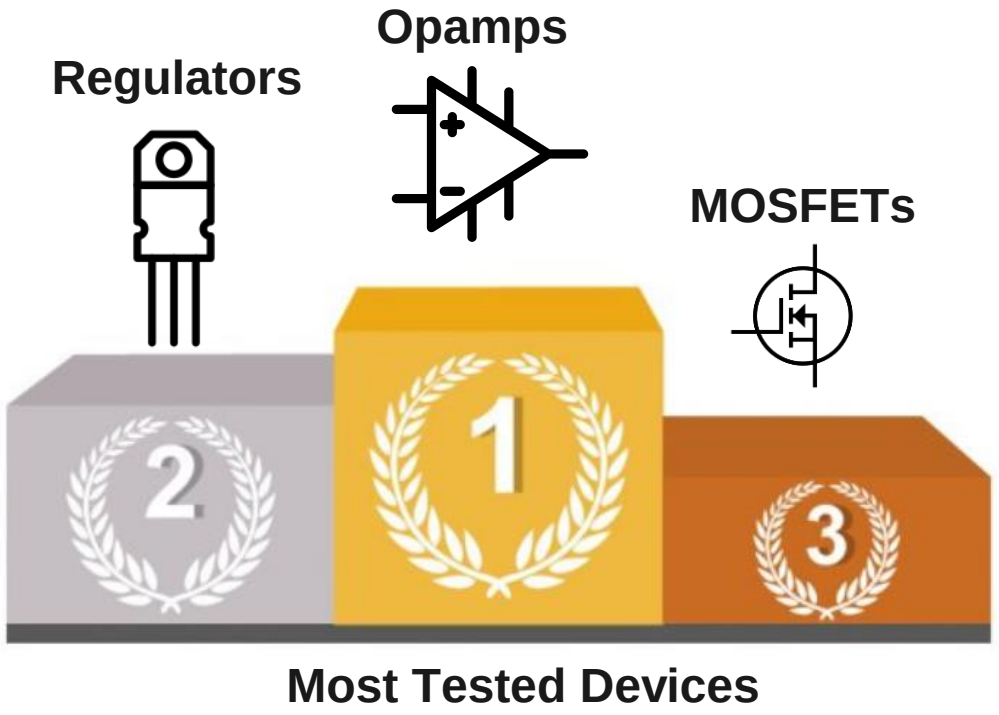




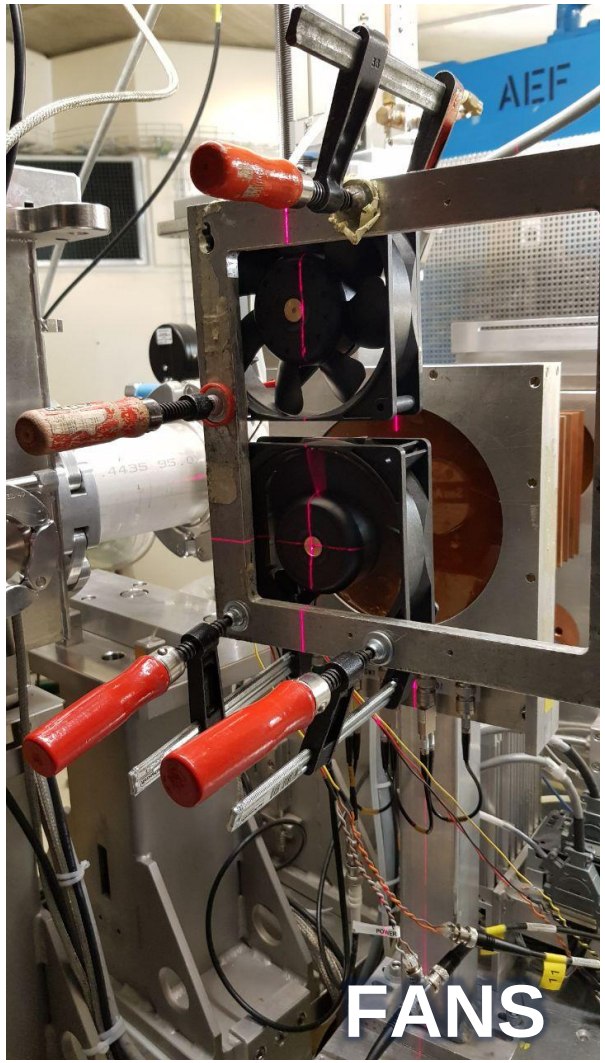
2021 in Numbers: DUT distribution

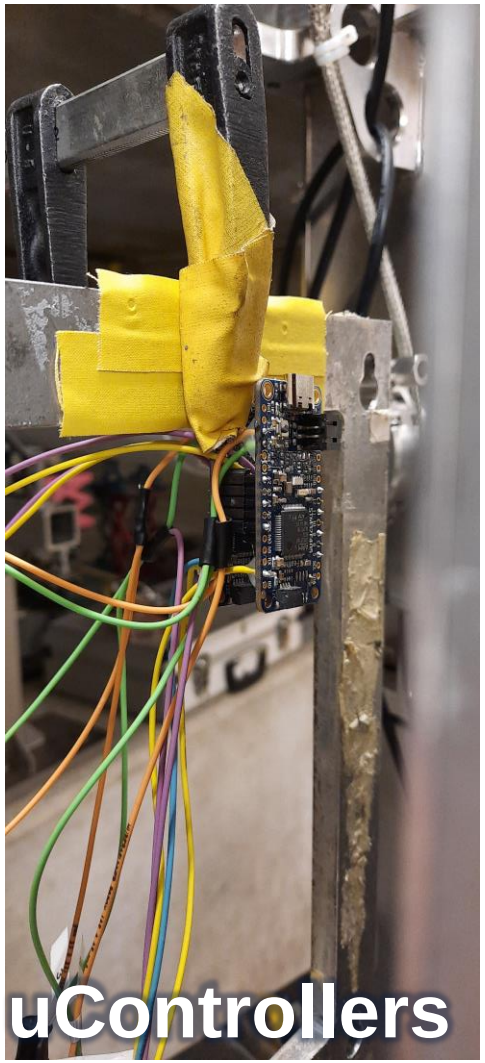
- We tested from the simplest component (BJT) to the most complex ones (FPGAs) and even complete systems.



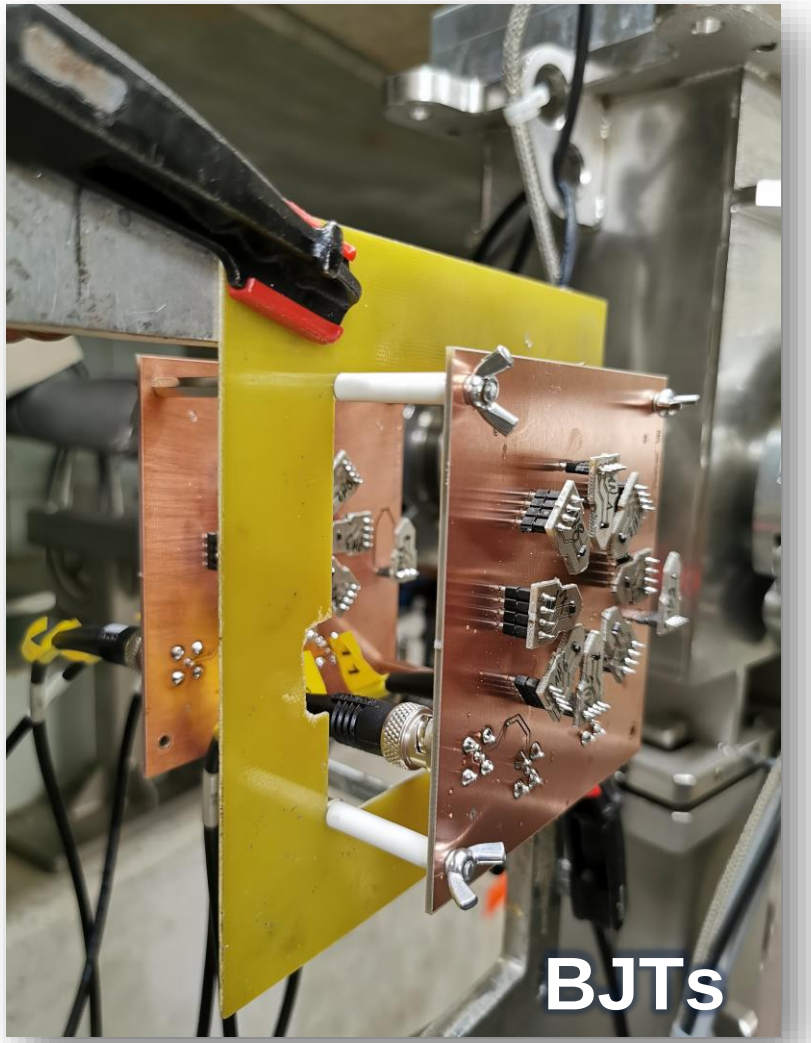


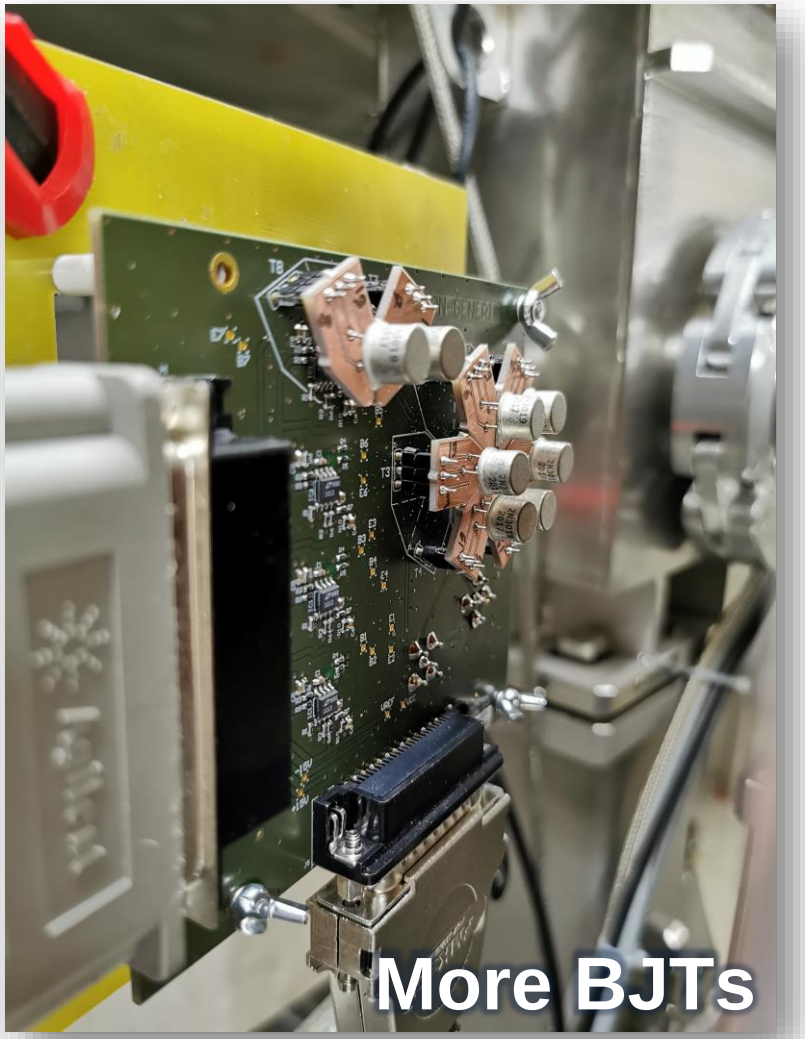
2021 in pictures

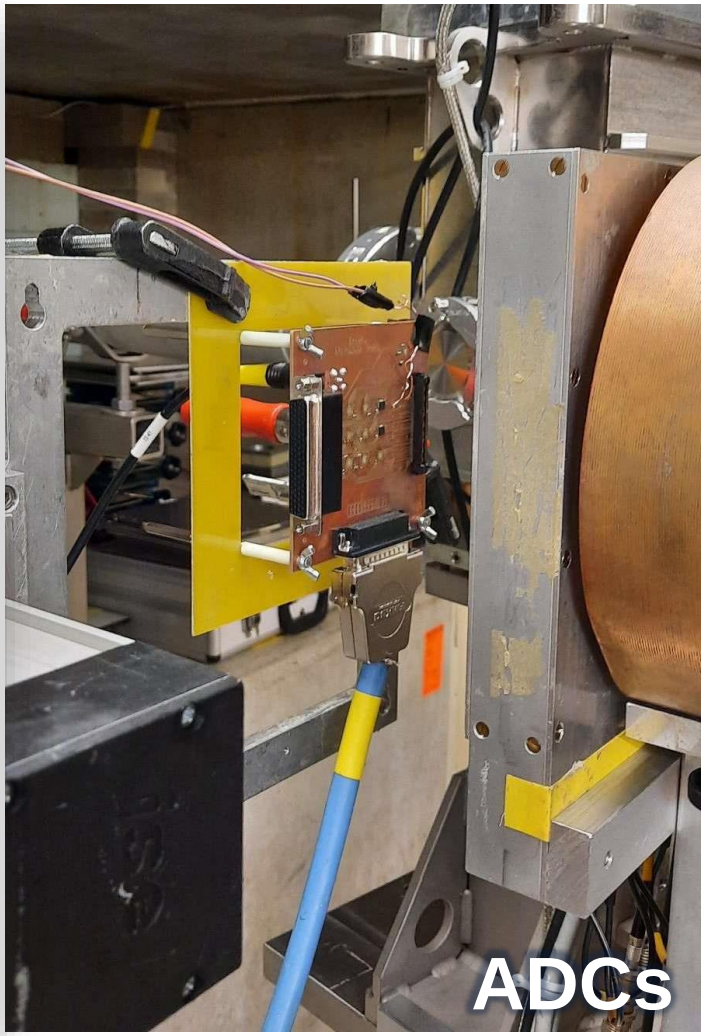




2021 in pictures

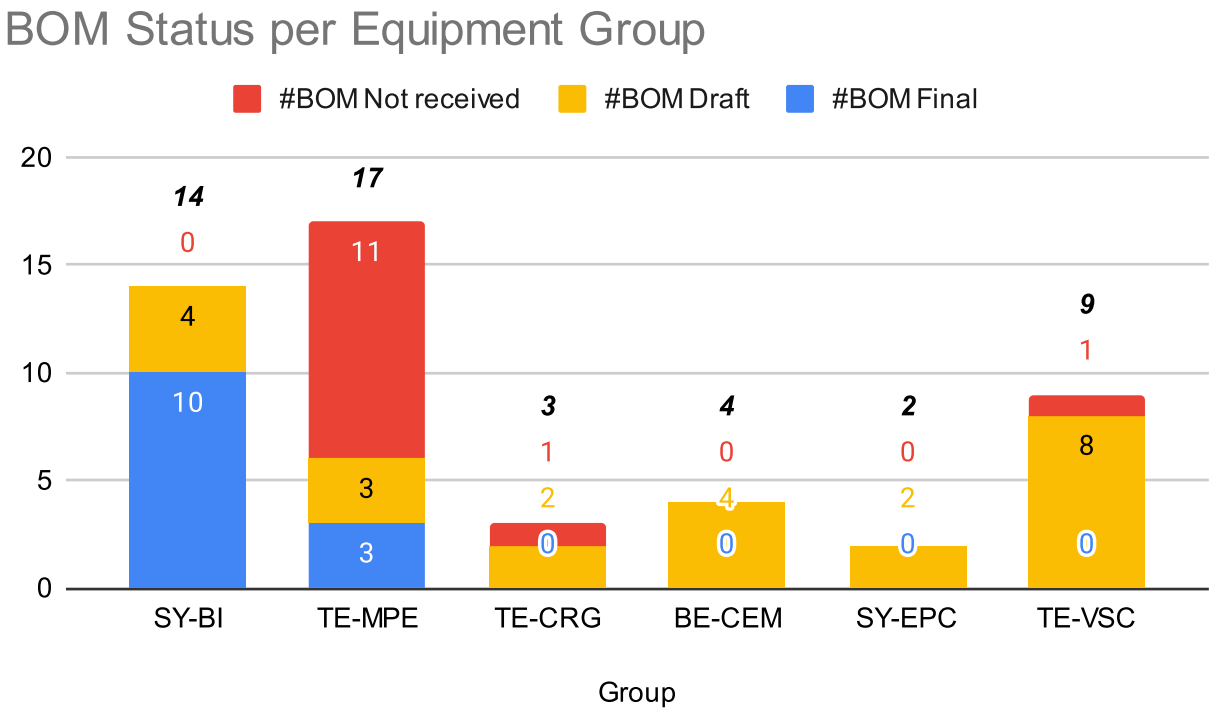






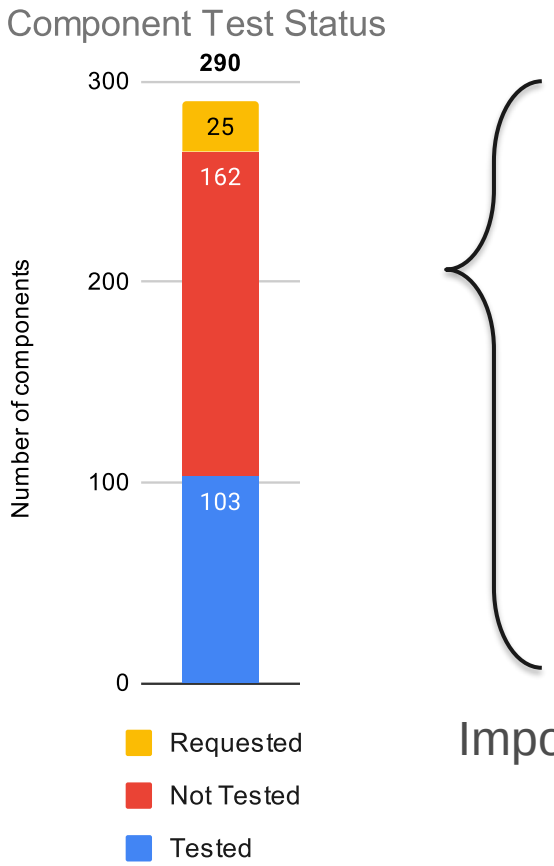
R2E Projects Survey

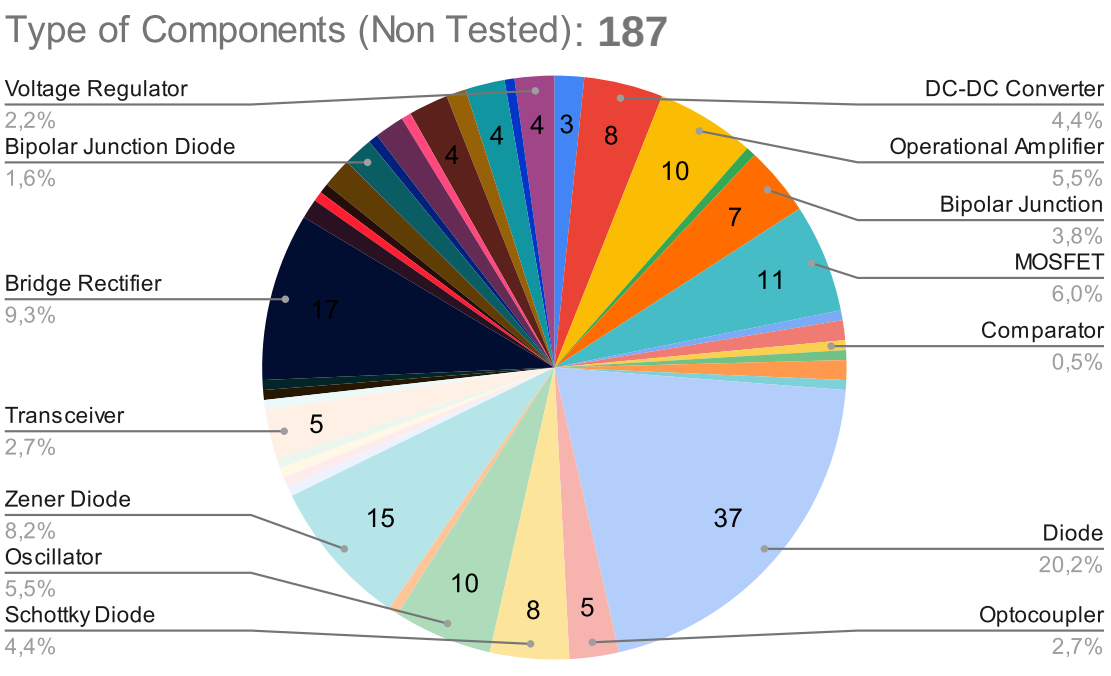
- Through the RADWG we asked the equipment groups to provide the BOM of the designs which were declared as R2E related
- This would allow to understand the status of the project
  - Number of components selected & tested
  - Number of components never tested
- This in order to:
  - Understand the workload
  - Plan time and resources
    - → Workforce & also beam time
- Most of the BOM have been received
- 47 Projects in total:
  - ❑ 20 Projects completed
  - ❑ 16 Projects in development
  - ❑ 11 Unknown status



R2E Components Analysis

- For each BOM we sorted out all the active components:





Important considerations:

- **162 components** are completely new to testing
- At least 2-3 candidates per component are tested to have backup options

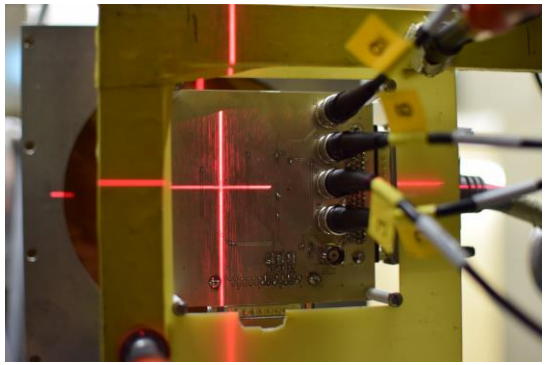
→ This easily become >300 devices to be tested for the next years

How do we prepare the tests?

- Acquired know-how and development of standard test structures and instrumentation to be used allows a test every month on new devices
- Tests are not limited to the requested parameters monitoring but general parameters are measured to be as general as possible and allow other users to verify the suitability of the devices for their purposes.
- Key points:
  - Ability to produce test cards and setup within days
  - Ability to quickly develop firmware and software suited for the tests
  - Availability of high-end instrumentation to face the most difficult task (i.e fA measurements under irradiation, Single Event Transient)

19/1-019 Rapid Prototyping lab

107/1-A10 Main PCB Assembly Atelier

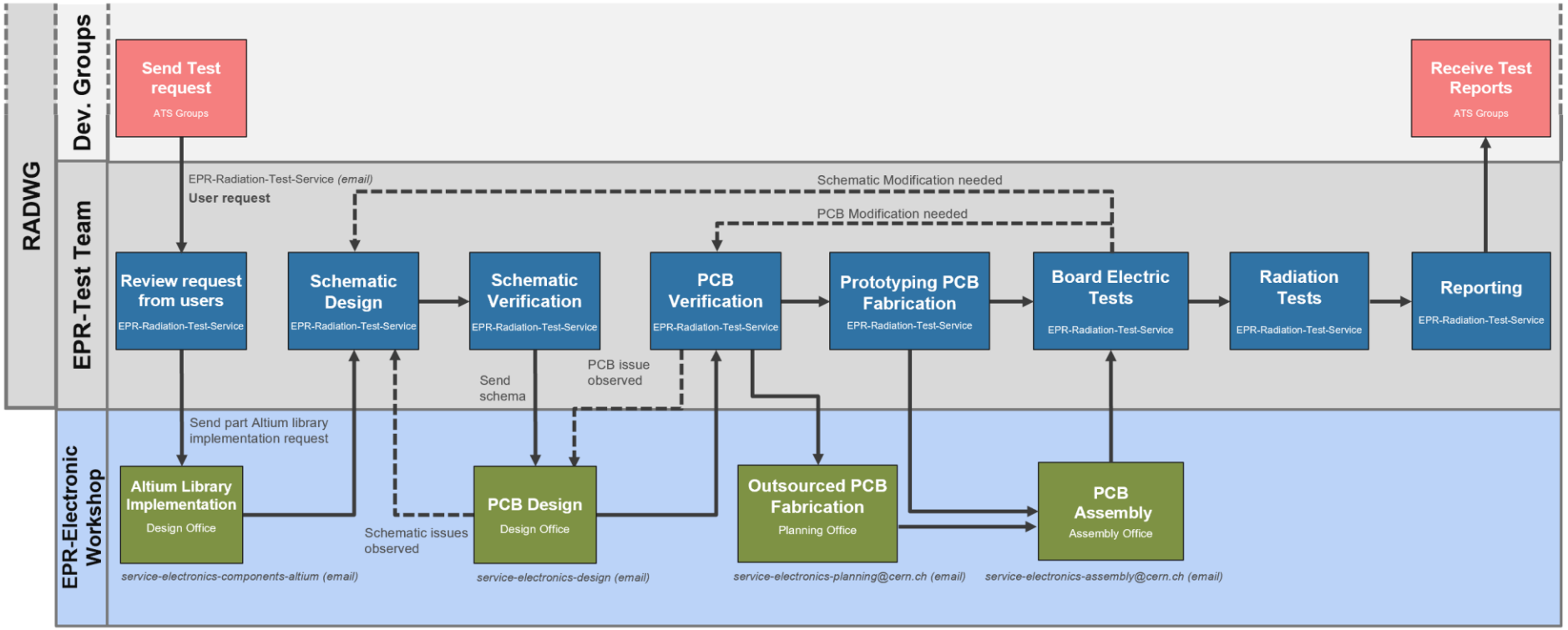


PSI Beam Line

CC60 Instrumentation

New synergies in the BE-CEM-EPR section

- New test PCB Production workflow:



- Several tasks distributed to electronic workshop: PCB Design, PCB Assembly
- Leaving the Radiation Test Team focus on the test preparation, firmware, test reporting.

Where do we test: Key point is the facilities

PSI-PIF – Switzerland, Viligen
- 30-220 MeV Proton beam
- Combined **SEE**, **TID**, **DD** Tests
- **5 Years collaboration agreement with CERN up to 2027**

JSI – Slovenia, Ljubljana
- Triga Mark II Nuclear Reactor
- **DD**, TID
- **Punctual use, possibility to make a contract**

ILL – Genoble, France
- Thermal Neutron Beam
- Thermal neutron sensitivity Tests
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CC60 – Switzerland, CERN
- 10 & 110 Tb Cobalt 60 Sources
- **TID** Tests
- **Available all the year**

CHARM – Switzerland, CERN
- Representative LHC Radiation mixed-fields
- SEE, TID, DD
- **Not available during technical stops**

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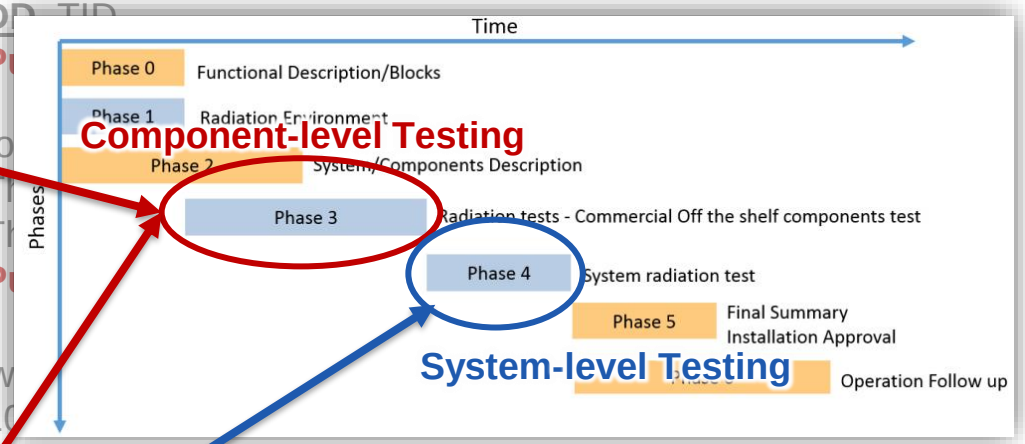

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See "*Overview of CC-60 facility activity in 2021 and outlook for 2022*" presentation from M. Brucoli, *today at 14:50*

CHARM – Switzerland, CERN
- Representative LHC Radiation mixed-fields
- SEE, TID, DD
- **Not available during technical stops**

See "*Overview of CHARM facility activity in 2021 and outlook for 2022*" presentation from J. Lendaro, *today at 15:30*

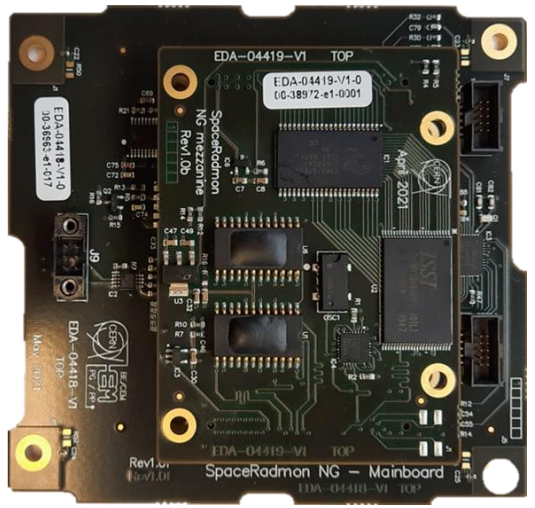
Testing R&D

- Different researches were conducted to face new radiation tolerance challenges imposed by the High-Luminosity LHC update:
- **System-Level testing:**
  1) Testing and Validation Methodology for a Radiation Monitoring Systems for Electronics in Particle Accelerators
     → **Provides advices and considerations for system-level testing**

  2) Development and Qualification of a Radiation Tolerant Monitoring platform for Space application
     → **Allows developing, and testing new mitigation techniques, new architecture schemes and system-level test techniques**

- **FPGA Testing Techniques & LHC failure estimation:**
  3) Search & Qualification of new robust FPGA for LHC application
     → **Provides FPGA test guidelines & methodology for failure rate estimation in the LHC**
     → **Provide qualification of state-of-the-art FPGA to the CERN equipment groups (common building blocks)**

"IoT BatMon: Wireless radiation monitoring at CERN"



"Space RadMon, a radiation tolerant monitor device for cubesats"

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  see presentation: "*IoT BatMon: Wireless radiation monitoring at CERN***", from Alessandro Zimmaro** *tomorrow at 9:45 today*

  2) Development and Qualification of a Radiation Tolerant Monitoring platform for Space application
     → **Allow ... architecture schemes and system-level test techniques**

  see presentation: "*Space RadMon, a radiation tolerant monitor device for cubesats***"**, from P. Gkountoumis *tomorrow at 10:45*

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  see presentation: "Common building blocks: FPGA testing, *tomorrow at 9:30 today*

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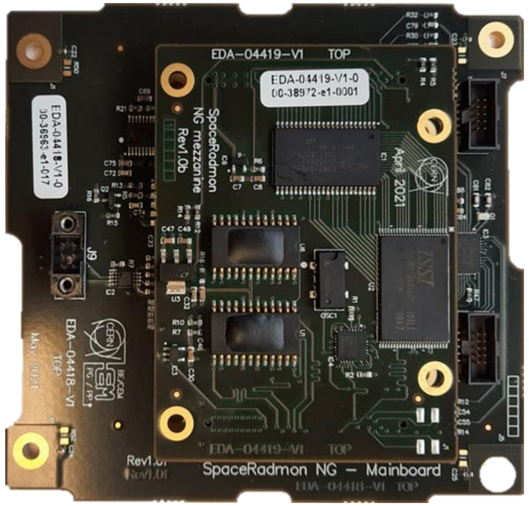
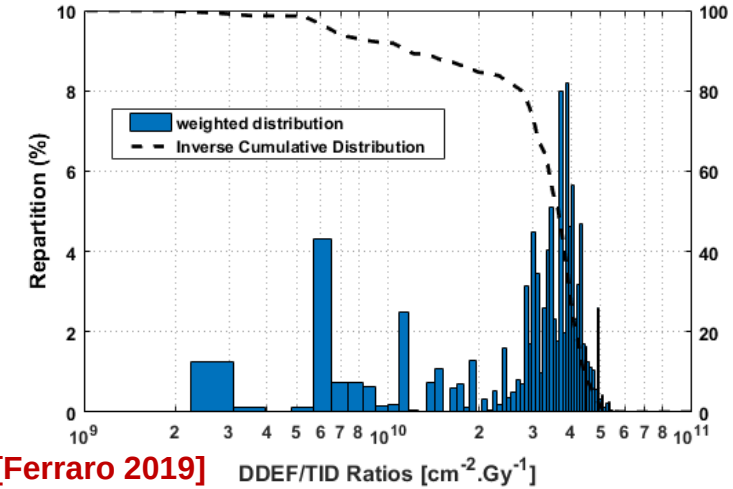


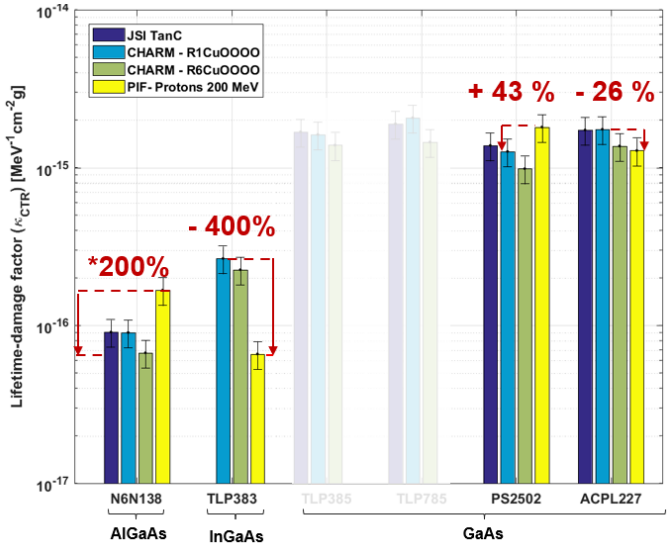
"Space RadMon, a radiation tolerant monitor device for cubesats"

Testing R&D

- **Component Test Methodology for CERN environments:**
  4) Study of the Impact of the LHC Radiation Environments on the Synergistic DD and TID Effect on Electronic Components
     (*R.Ferraro, IEEE Trans. Nucl. Sci. 66 (2019) 1548 - 1556*)
     → **Proved the importance of selecting the correct TID/DD rate ratio to obtain reliable degradation profiles**
  5) COTS Optocoupler Radiation Qualification Process for LHC Applications Based on Mixed-Field Irradiations
     (*R.Ferraro, EEE Trans. Nucl. Sci. 67 (2020) 1395-1403*)
     → **Proved the importance of carefully selecting the test environments to obtain reliable degradation rates**
  6) Single Event Transient response in Mixed-Field:
     → **Evaluation from monoenergetic component response to mixed-field response**



[Ferraro 2019]



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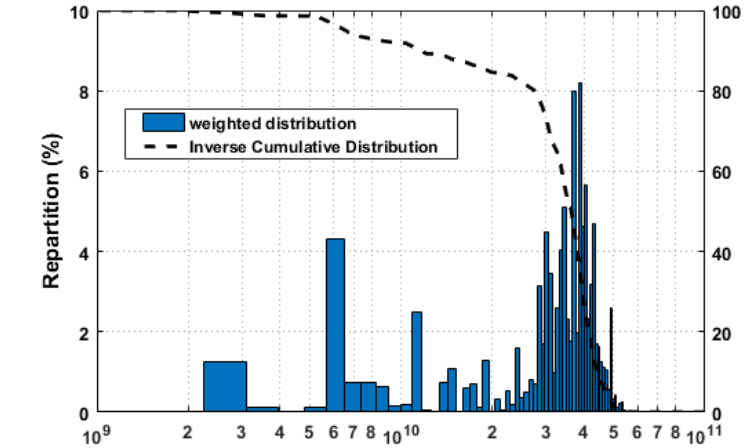
6) Single Event Transient response in Mixed-Field:

→ **Evaluation from monoenergetic component response to mixed-field response**

see dedicated presentation: *"Radiation hardness assurance and testing"* **from Rudy Ferraro (me),** *tomorrow at 10:15 today*



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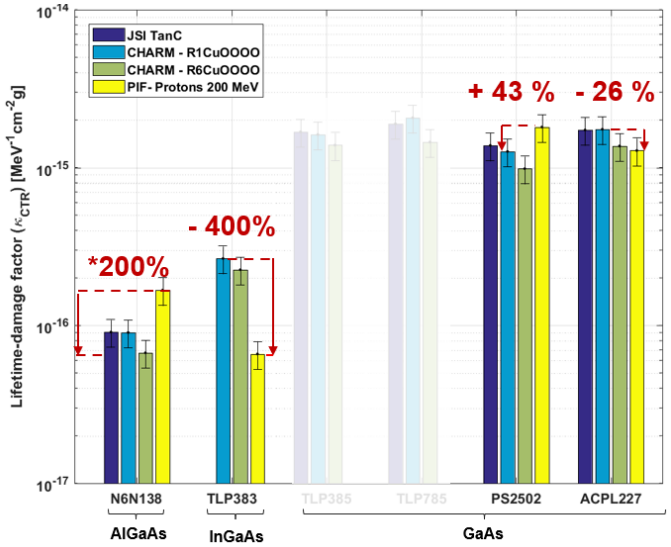
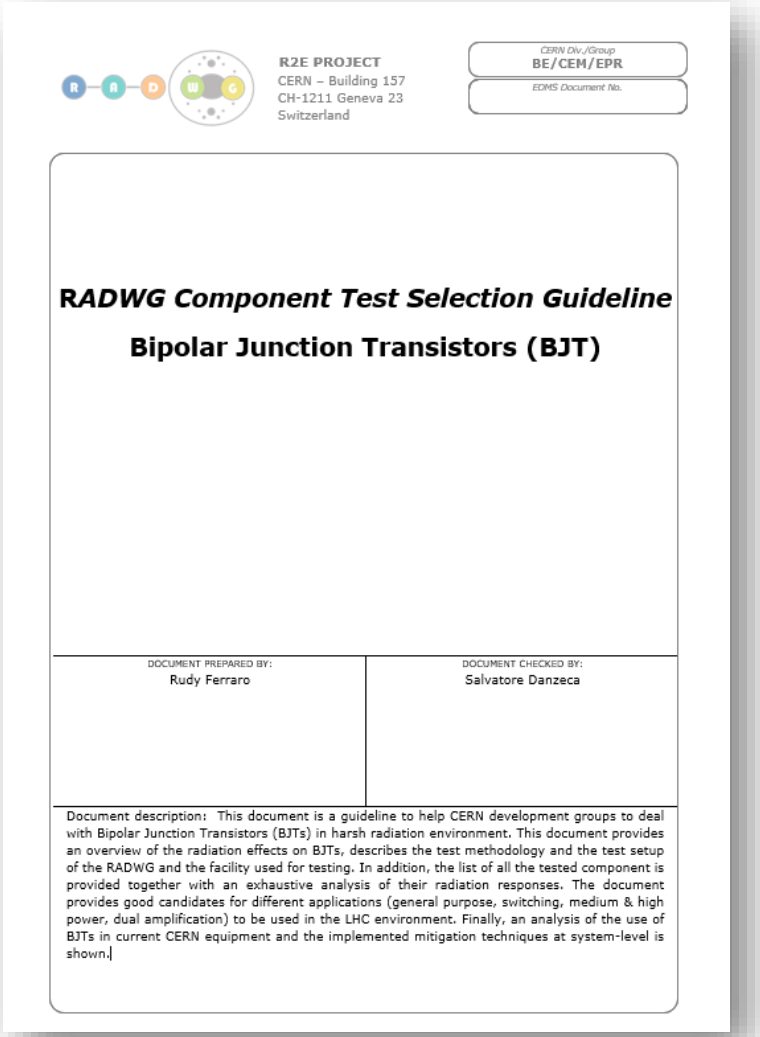


[Ferraro 2020]

2021 Initiative : RADWG Selection Guideline

- Kick-off of the '*RadWG Component Selection Guideline*' documents!
- First one dedicated to Bipolar Junction Transistor(s)
  - Presentation Focus-On: https://indico.cern.ch/event/1040413/timetable/
  - Link (draft): https://edms.cern.ch/project/CERN-0000227750
- The writing of this document implied a tremendous amount of work:
  - (Re-)processing of test data from 39 test campaigns
  - Analysis made complex due to various test data format used through the years
- **Guideline & Presentation summary:**
  - Radiation effects on BJTs
  - LHC environment and qualification implications
  - Test circuit & setup
  - Test methodology
  - Analysis of BJTs response



R2E PROJECT
CERN – Building 157
CH-1211 Geneva 23
Switzerland

CERN Div./Group
BE/CEM/EPR

EDMS Document No.

RADWG Component Test Selection Guideline

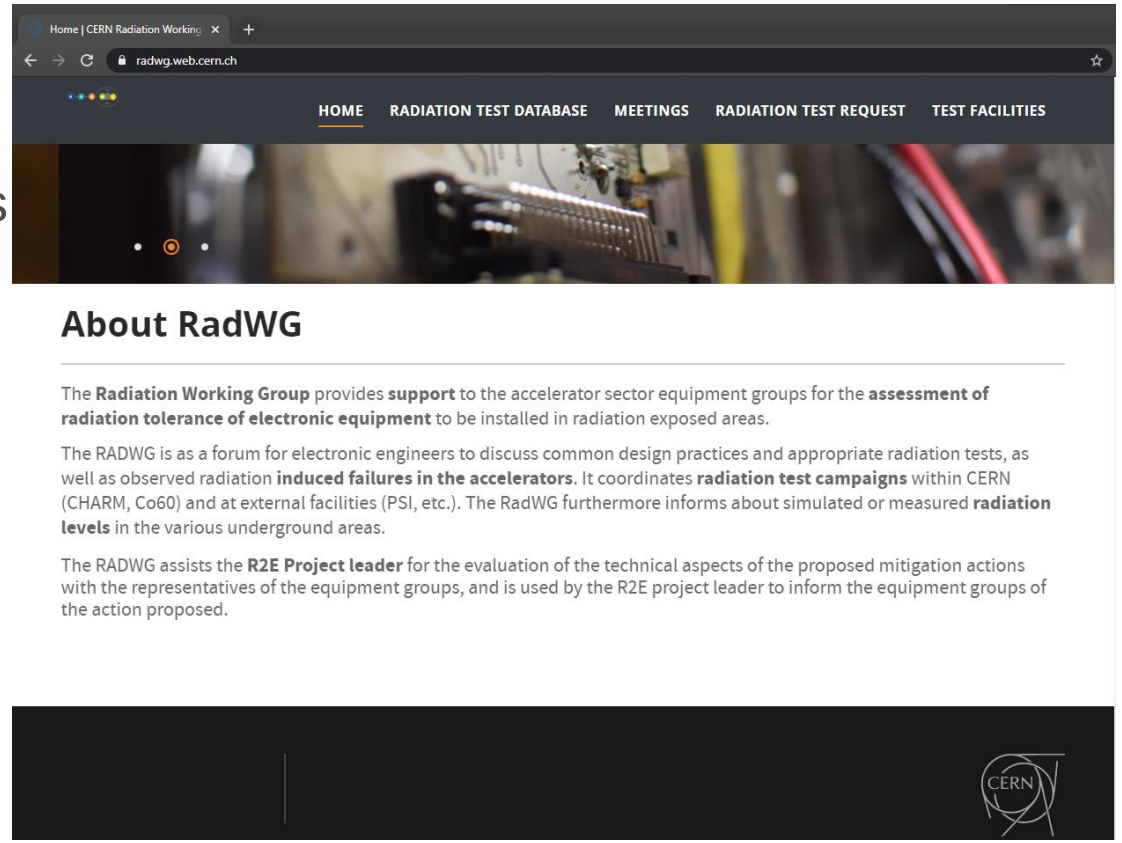
Bipolar Junction Transistors (BJT)

DOCUMENT PREPARED BY:	DOCUMENT CHECKED BY:
Rudy Ferraro	Salvatore Danzeca

Document description: This document is a guideline to help CERN development groups to deal with Bipolar Junction Transistors (BJTs) in harsh radiation environment. This document provides an overview of the radiation effects on BJTs, describes the test methodology and the test setup of the RADWG and the facility used for testing. In addition, the list of all the tested component is provided together with an exhaustive analysis of their radiation responses. The document provides good candidates for different applications (general purpose, switching, medium & high power, dual amplification) to be used in the LHC environment. Finally, an analysis of the use of BJTs in current CERN equipment and the implemented mitigation techniques at system-level is shown.

Test results analysis and reporting

- 206 users subscribed to the mailing list ***lhc-proj-radwg-members***
- The website https://radwg.web.cern.ch/ embeds an User-Friendly database
  - More than **512 reports** from the 2011 up to 2022
- The service produces reports in a common template for all the components tested
  - Test reports template ensure a coherent reporting
- The service maintains two databases accessible by all the equipment groups



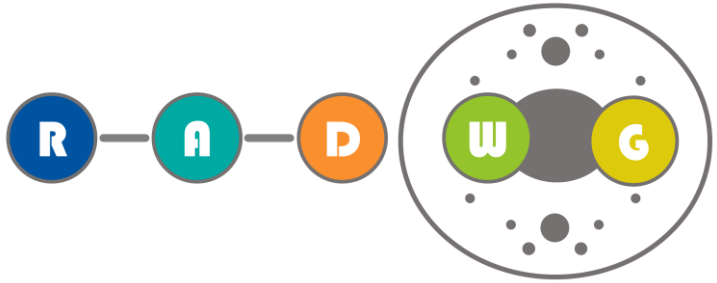
https://radwg.web.cern.ch

- New mail address for request & support: EPR-Radiation-Test-Team@cern.ch

Conclusions

- BE-CEM-EPR provides the service of radiation testing of electronic components supporting the Radiation Working Group (RadWG)
- The service mandate is to provide radiation test data to the equipment groups developing rad-tolerant design profiting of the well-established know-how in radiation testing
- The radiation test service covers all the steps for a radiation campaign, from the test specification up to the reporting.
- Tests are carried out to be more general as possible in order to create the common building blocks that can be re-usable by many other equipment groups
- The service maintains the website and the database with more than 512 tested components accessible to all the CERN equipment groups
- Very intensive testing activity in 2021: Highest number of test campaign / DUT Tested

- The R2E project survey pointed out a huge number of components to be tested in the coming years

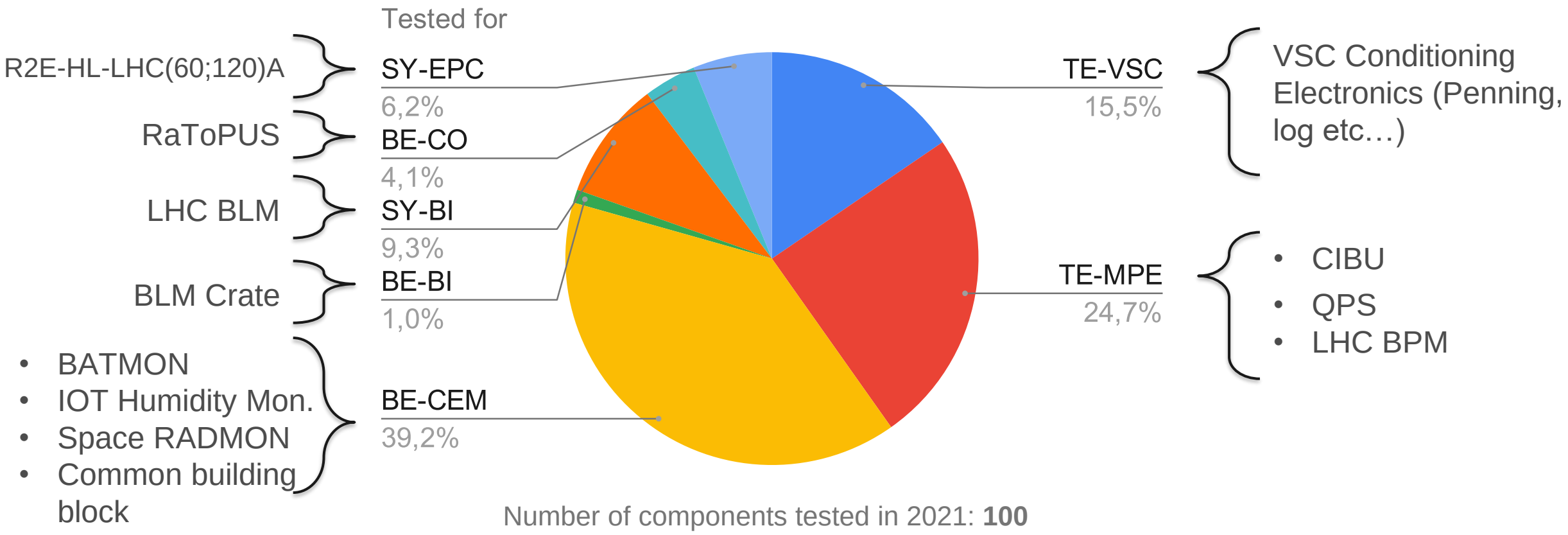


Thank you for your attention!

Controls
Electronics &
Mechatronics

2021 in Numbers: User distribution

- Basically the equipment groups in charge of new developments requested to qualify their selected components



Number of components tested in 2021: **100**