Remote radiation hardness campaigns at facilities: Challenges and Perspectives

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Radiation testing demands

- **Demands for COTS in radiation environments is more and more strong**

- Particularly important for the space community and for particle accelerators
- Lower cost compared to Radiation Hardened by Design
- Faster and cost-effective testing

- **Achieving a high-reliability through radiation qualification is not easy**

1. Several irradiations are required to qualify a component/system
2. Radiation testing requires a lot of efforts for organization and execution
3. It requires budget that probably many small players cannot afford

Radiation testing challenges

- A reliable qualification of a component/system is obtained through a variety of knowledge and activities

Representativity of test radiation environment

- Radiation Effects
- Type/Energy of test particles
- Flux/Dose rate

Representativity of biasing test conditions

- Passive? Active?
- Dynamic or static biasing?

Coverability of the test

- Circuit-level degradation
- Knowledge of failure modes

Usability of the test metrics

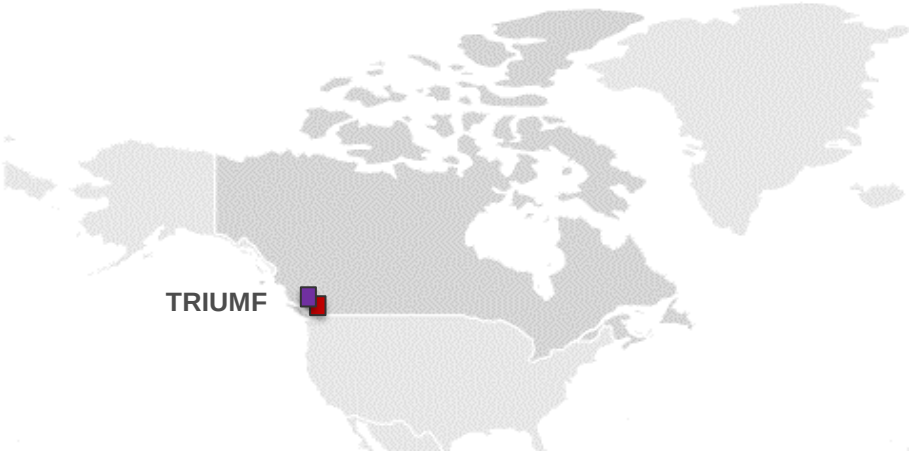
- Should allow failure rate estimation in operation

- **Not all the facilities are ready to perform a complete characterization for a component/system**

- Each facility is unique! Energy, particle, test mode, test setup are different for each facilities

Radiation test facilities

- **Facilities are spread across the world**
- **One complete component/system qualification might require multiple tests in different facilities**



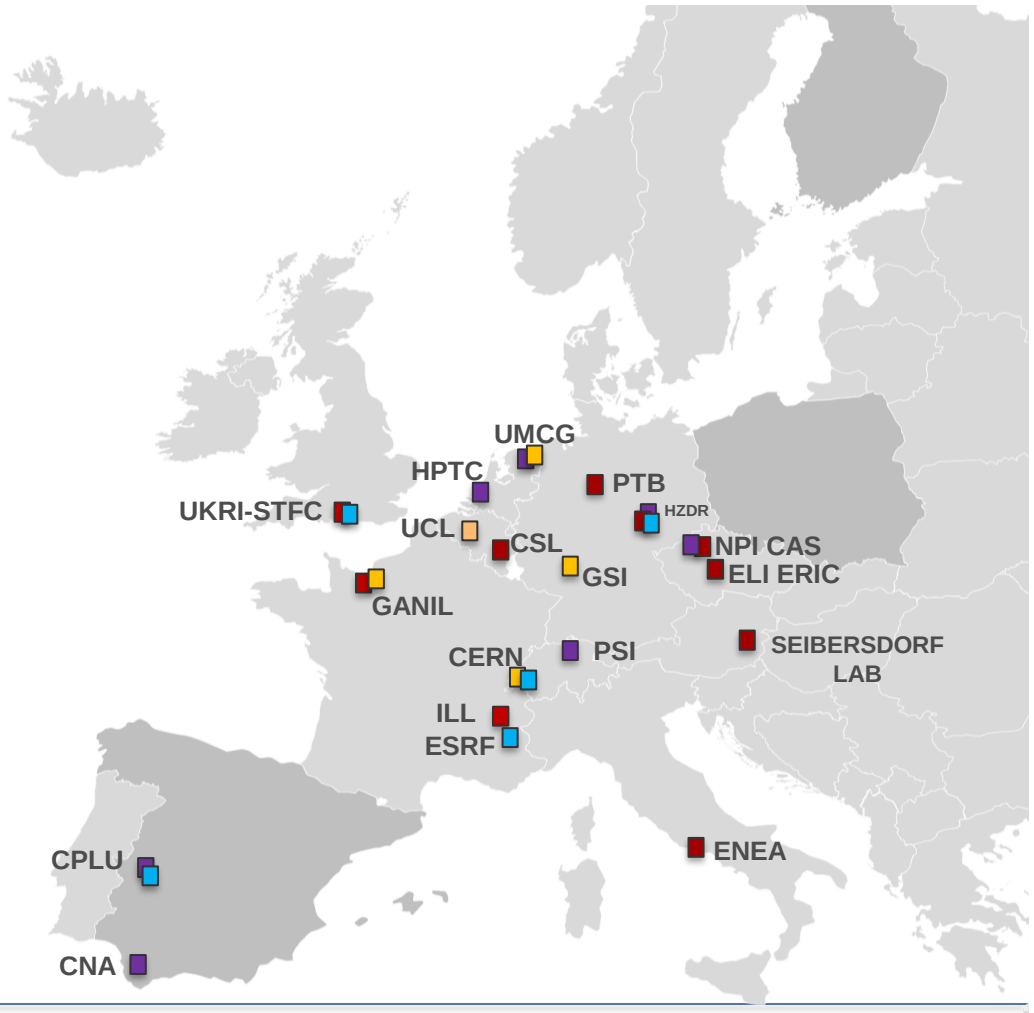
Neutron

Proton

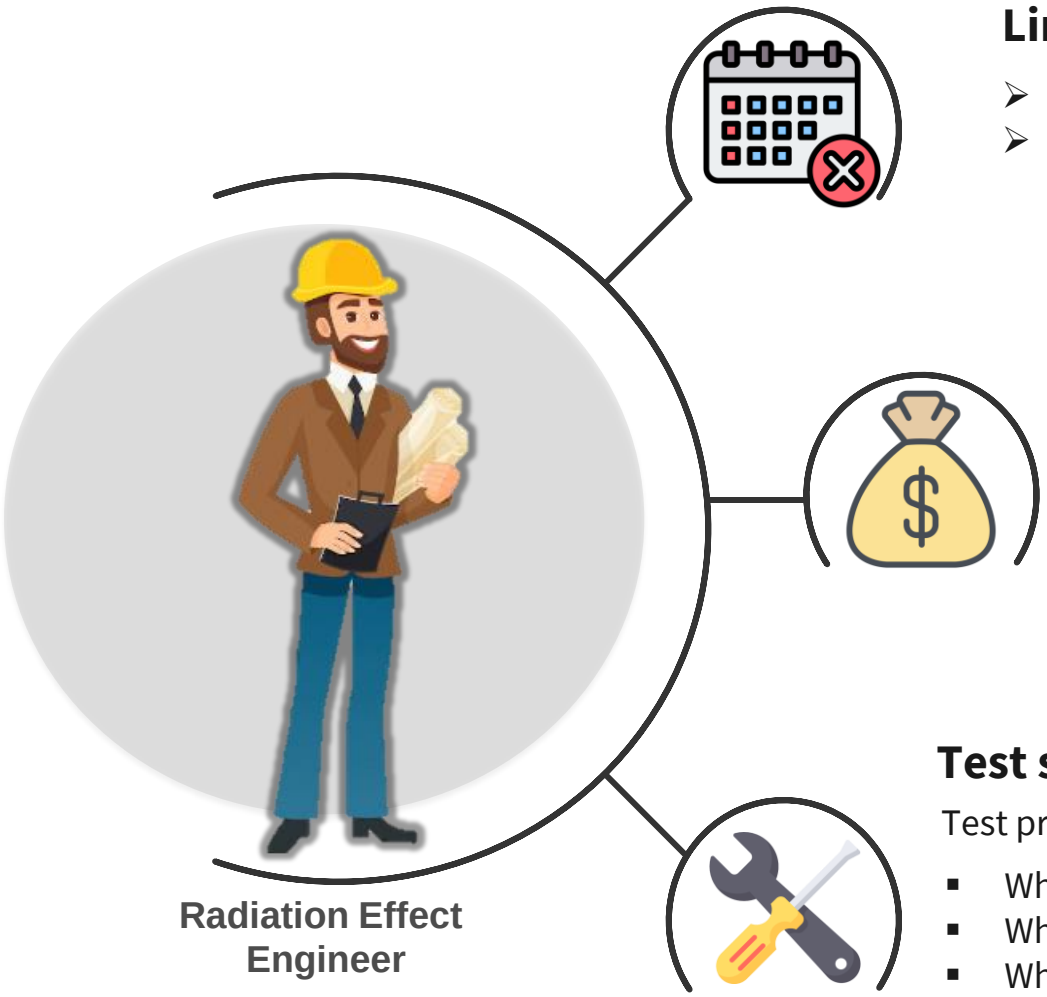
Heavy-Ion

Alternative

RADNEXT facilities for transnational-access



Radiation test campaign: organization



Limited availability

- Facilities are not always available
- Scheduling the radiation test campaign with other activities in parallel can be challenging

Expensive

- Beam time is not cheap
- Travel and accommodation
- Development of custom test board for the device to test

Test setup preparation

Test preparation according to the facility. One setup may not work everywhere

- What instruments are necessary ? What is already available there?
- What cable length to use for the DUT ?
- What is the patch panel configuration between control/irradiation room?

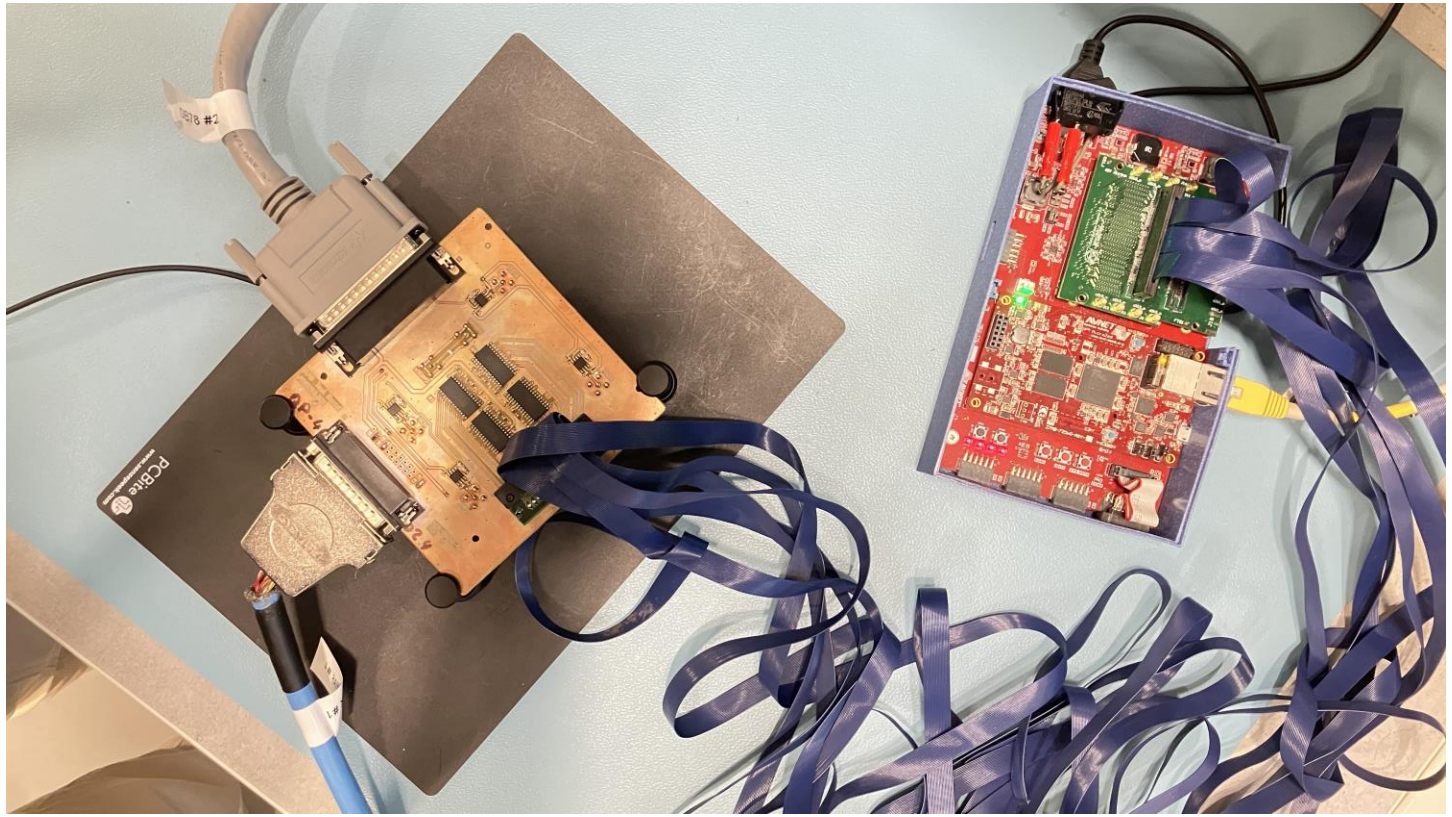
Radiation test campaign: execution

Preparation

Prepare the instrumentation

Develop the test board, tester, and related software

Execute “dry run” with the same facility settings



Radiation test campaign: execution

Preparation

Prepare the instrumentation

Develop the test board, tester, and related software

Execute “dry run” with the same facility settings

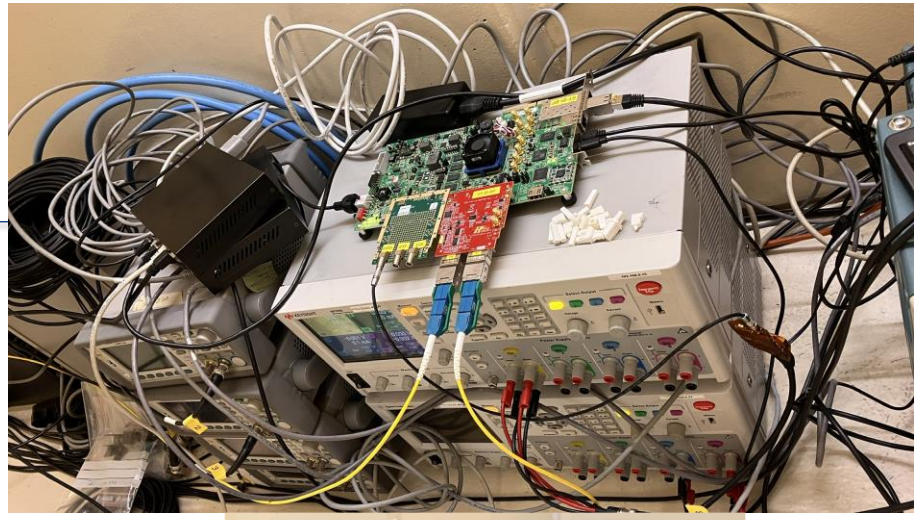
Arrival at the facility

Unpack the equipment

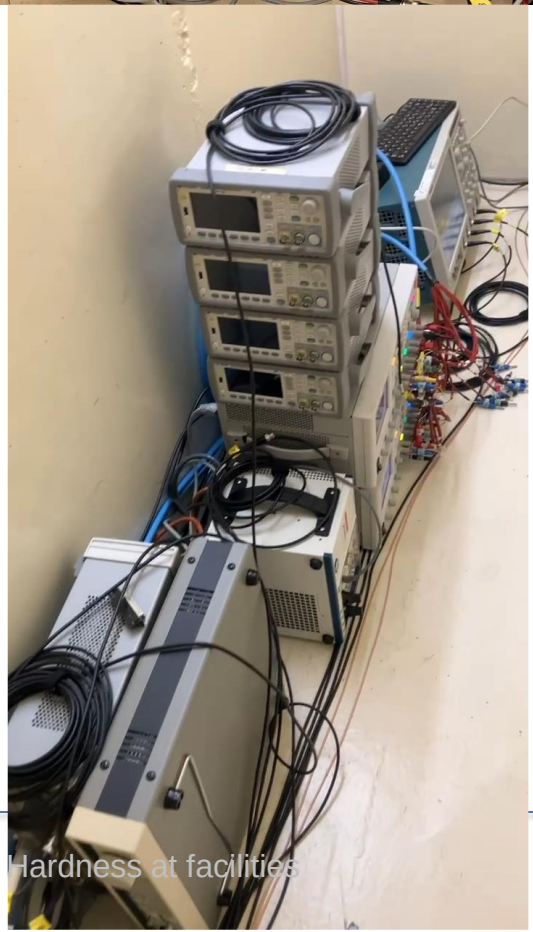
Mount the setup

Verify that everything works correctly

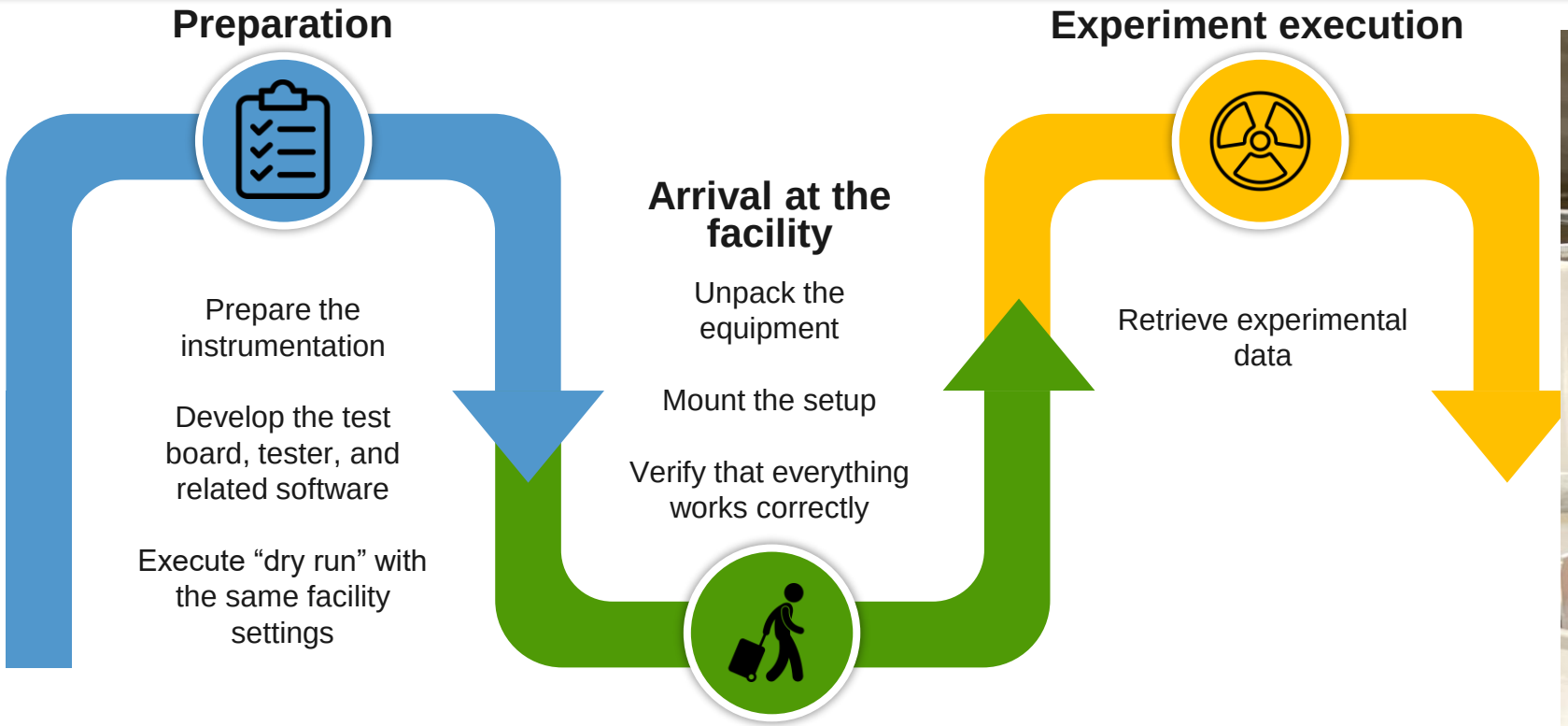
“Rushed” setup



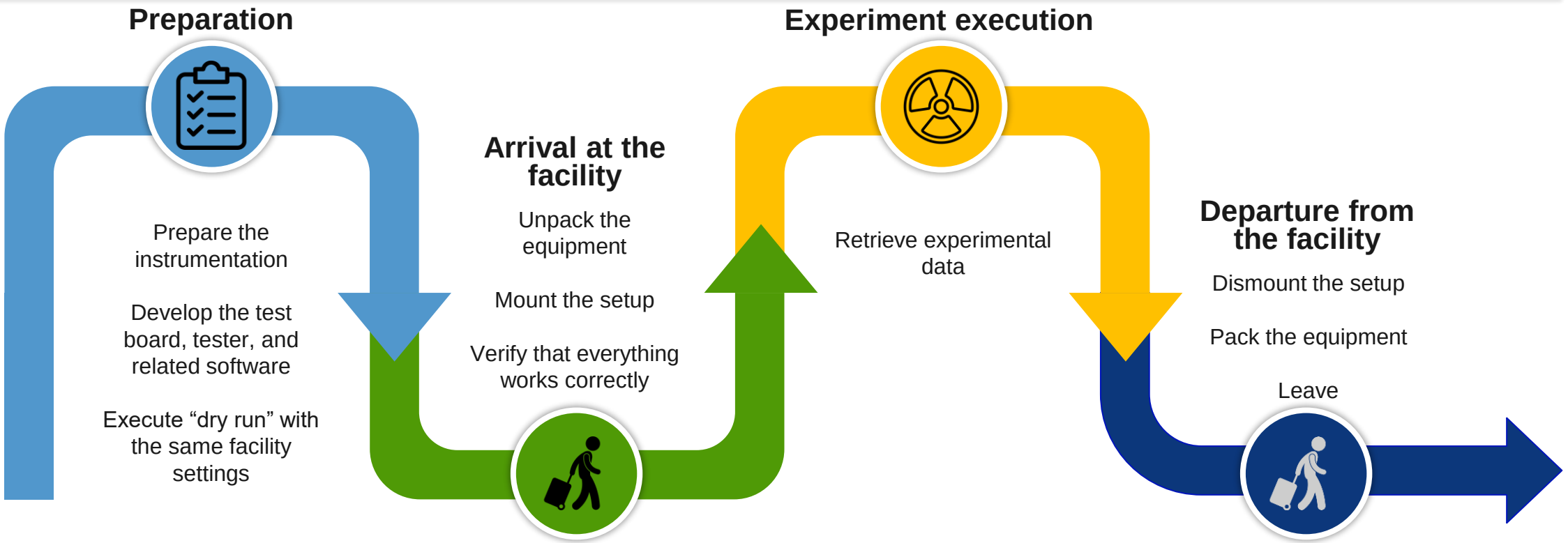
Well done setup and cabling



Radiation test campaign: execution

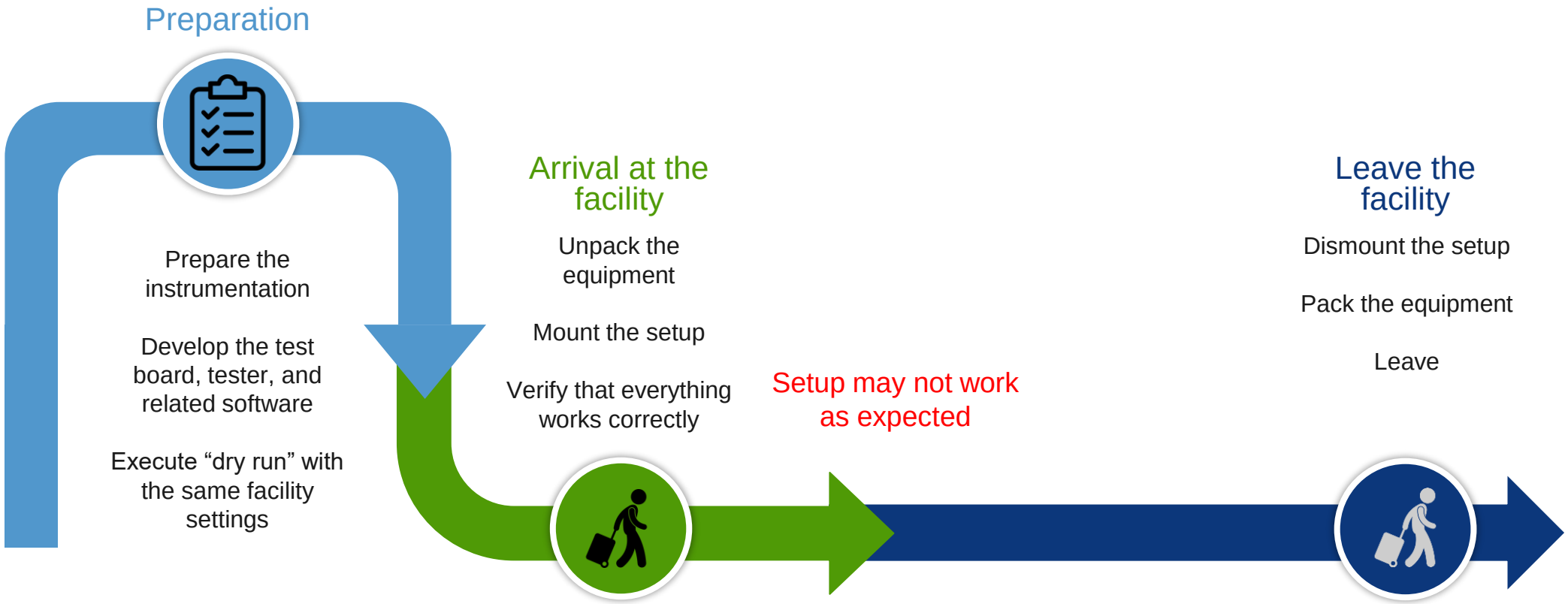


Radiation test campaign: execution



Radiation test campaign: execution

- **Problems may arise once at the facility**
- Setup does not work as in the lab. Why? Cabling, instrument issues?
- Mistakes can <u>always</u> happen



What can be improved

Some efforts could be made to improve this situation

- Having a fixed installation for users, including instrumentation, cabling, computers
- Campaign organization will be easier
- Installation and removal of the test setup would be faster

- A fixed/common patch panel configuration, shared among different facilities
- The same test setup could be used for different experiments
- Reduce the time to test
- Easier to collect experimental data

- **Remote testing**
- If the installation is easy (like a plug and play solution) it could be done by the facility staff on site
- Users could send their DUT and collect their data remotely
- Faster organization, less issues, cheaper for everyone

Remote Radiation Hardness

- **Objective:** Perform radiation tests without going to the facility

Phases

Preparation

Develop the test board, tester, and related software

Execute “dry run” in the lab with the same facility settings

DUT could be shipped to the facility

Installation

The facility staff mounts the DUT on the fixed installation

Experiment

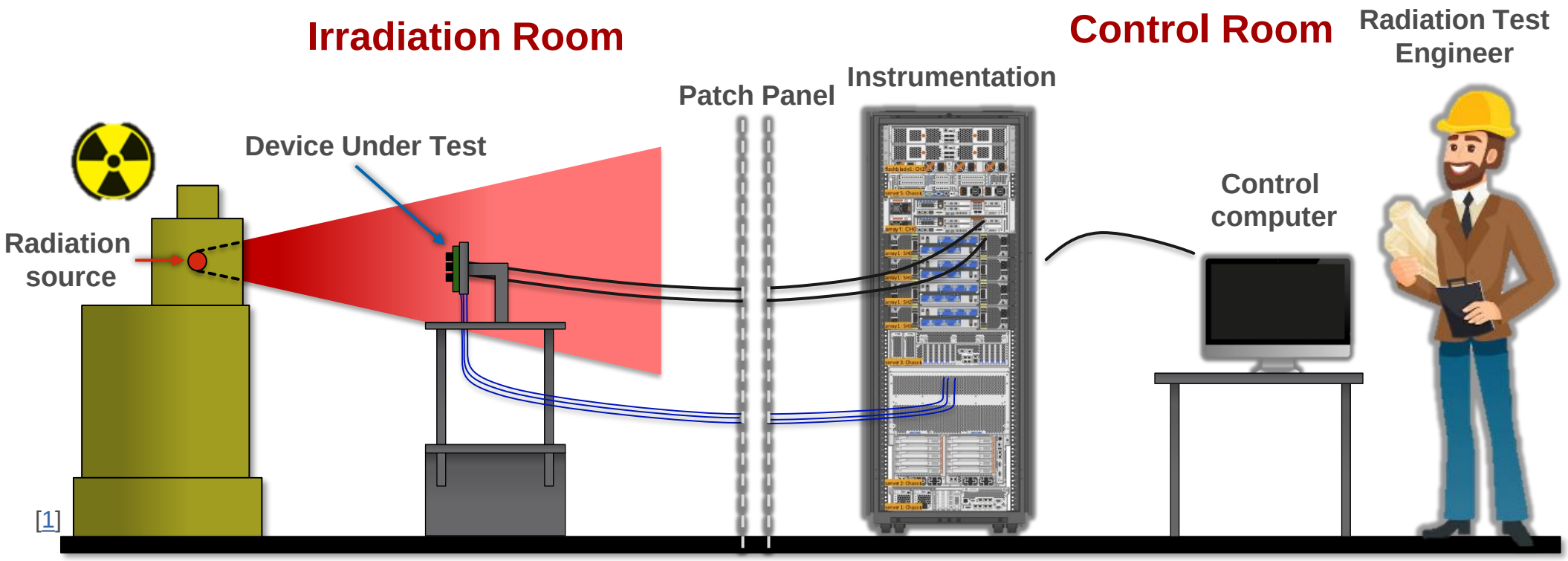
Users access remotely the setup and collect their data

Removal

DUT is dismounted by the facility staff

- How to reach this objective?
- We need to understand which are the main requirements and constraints for a radiation test

Radiation testing in practice



- What radiation source?
- What flux/dose rate?
- Continuous flux?

- What to test?
- What to measure
- What to expect?

- How to test?
- Real-time? Step-by-step?

Remote Radiation Hardness: Challenges

Two types of test can be identified

- Exploratory

- They involve test of devices whose response under radiation is not known
- The application may suffer from unexpected failure which are difficult to handle without supervision
  (i.e. the test software was non built for this failure)
- User may need to change firmware on the fly to adapt

- Standard qualification

- The outcome of the test is well known (e.g. measuring how the MOSFET characteristics change with the dose)

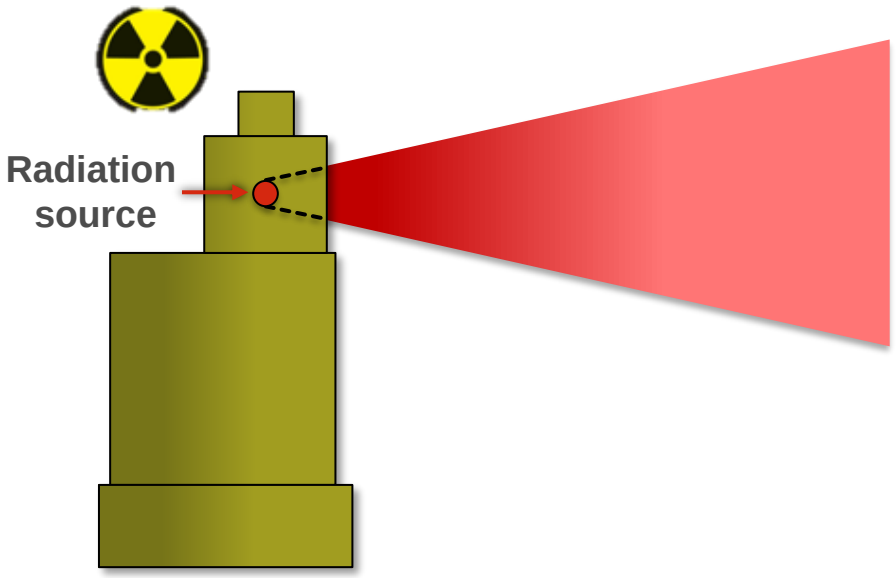
- Test has already been performed
  Acquisition software, Firmware etc.. are confirmed to be working and there is no need to apply modification

- Requires active supervision

- Could be performed without active supervision

Remote Radiation Hardness: Challenges

1. How to control the radiation source?

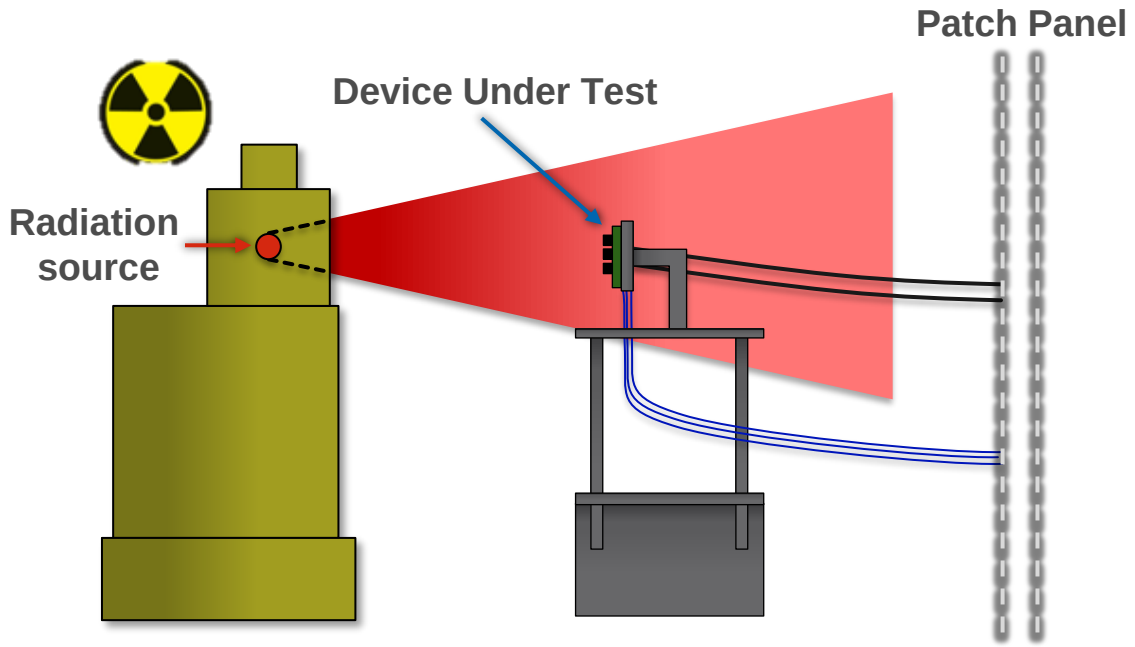


- **Remote control**
- The user should be able to control remotely the radiation source
  - Beam on/off, flux, target dose/fluence
- Grant control of the beam to people outside of the facility network
- **Preferable for exploratory tests:**
- User may need to stop the beam to apply modification to its firmware, reduce the flux to observe different failure modes etc..

- **No remote control**
- No need to grant external access to beam controls
- Beam parameters are defined prior to the experiment and cannot change:
  (Target dose/fluence, flux settings)
- Experiment will run without interruption, so very unlikely that the user can adapt his test during irradiation to cope with some failures..
- **Ok for standard qualification tests:**
- The user knows what he is looking for (cumulate statistics for some SEE, measure MOSFET characteristic with the dose)

Remote Radiation Hardness: Challenges

2. How to deal with test setup?



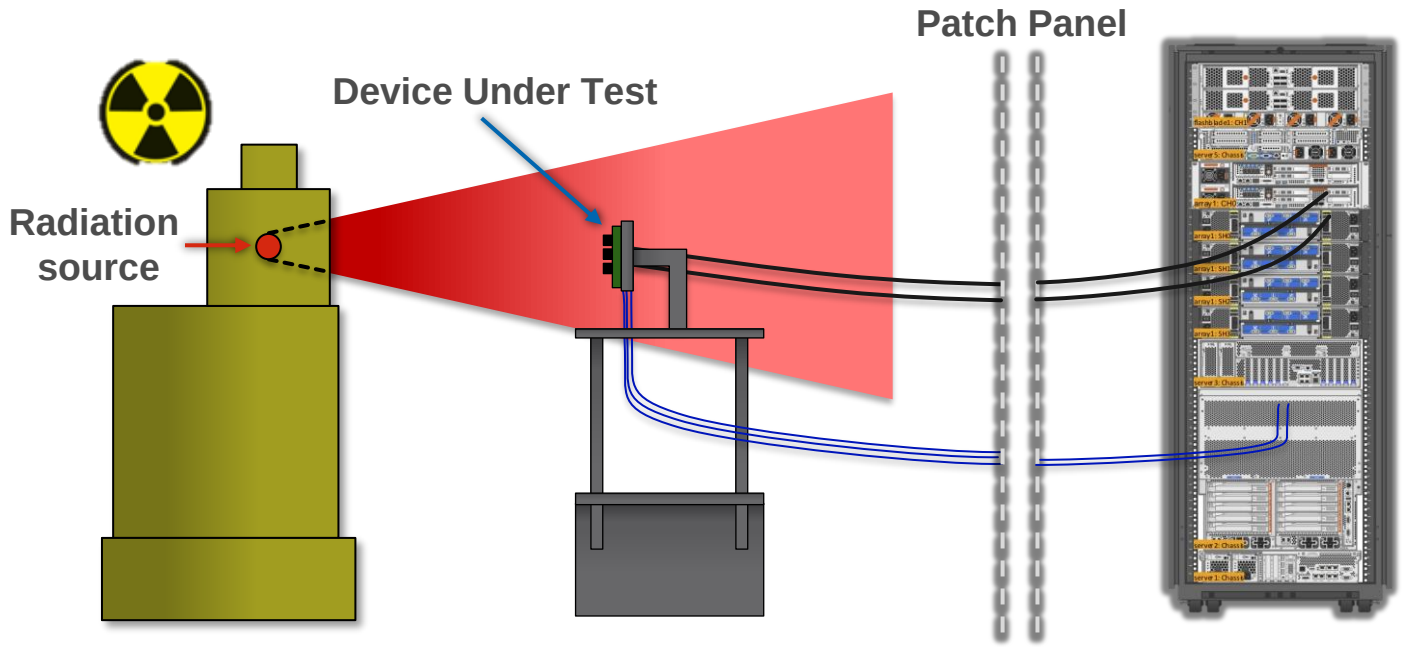
- **(Fixed) Installation**
- It must be easy for both explorative and standard tests
- Could be permanent? The facility staff just mounts the DUT for each test on a predefined support
- Plug and play solution would be desirable to reduce issues (Some examples later..)

- **Supported devices**
- Which kind of devices can be tested? Analog? Digital? SoC, FPGA?
- How many lines the user needs to monitor/control the test ?
- Which kind of connectivity is required?
- **Fixed (or at least common) settings would be beneficial:**
- Setup could be used in multiple facilities
- Much faster to collect experimental data
- More people could use the same test setup! Less time to test, less development time → Cheaper !

- **<u>Which are the common needs between the users?</u>**

Remote Radiation Hardness: Challenges

3. Instrumentation



- **Which instruments are necessary?**

- DAQ, Supply, Vector Analyzers, Oscilloscopes
- Laptop for instrument control and monitoring
- Used for both exploratory and standard tests

- Additional devices (i.e. tester FPGAs) for exploratory tests. How? (A standard platform could be defined if there are common needs)

- **Remote control**
- Grant access to instrumentation on the facility network to people outside
- Necessary for both explorative and standard tests (it is always good to know that everything is going well)
- Users will need to upload new firmware (for example different FPGA bitstream)

Summary of challenges for adopting remote testing

- **Test setup**
- Fast and easy installation: ideally just plug something into a a test board

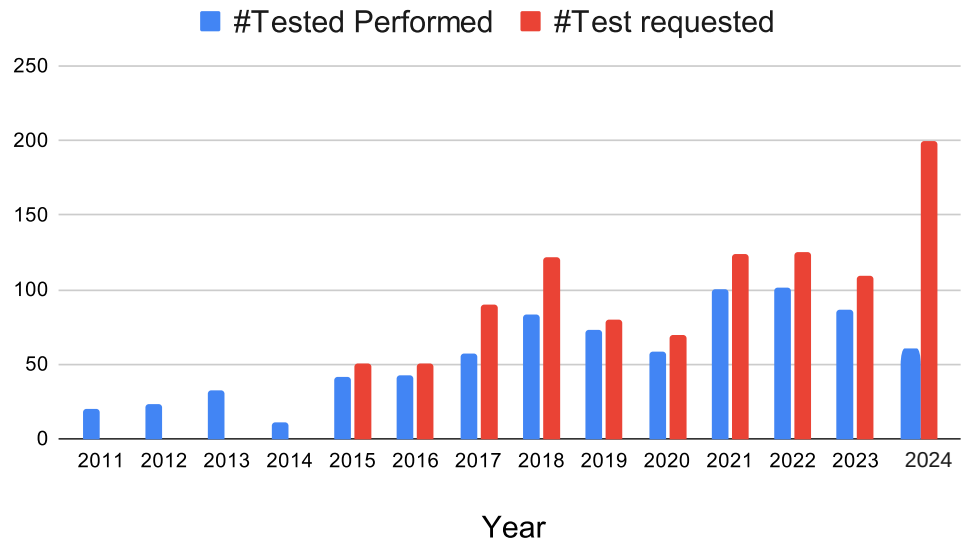
- **Instrumentation**
- Fixed instrumentations, connections, and software already connected and ready for the test

- **Versatility**
- Allow for testing of various components, including complex devices

- **Remote control**
- Give access to external users to radiation source and instrumentation

Feedbacks from the CERN Radiation Test Service

- **The Electronic Production and Radiation tolerance (EPR) section at CERN provides the Radiation Test Service**
- Study and development of the Radiation Hardness Assurance (RHA) for CERN applications in the LHC
- Radiation qualification of components and systems for the LHC accelerator sector



- **How can we deal with so many tests?**

1. We use multiple facilities
2. We are already trying to solve some of the challenges presented

Feedbacks from the CERN Radiation Test Service

1. We make use of multiple facilities to cope with the high-demand of radiation test requests

PSI-PIF – Switzerland, Viligen
- 30-220 MeV Proton beam
- Combined SEE, TID, DD Tests

CC60 – Switzerland, CERN
- 10 & 110 Tb Cobalt 60 Sources
- TID Tests

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

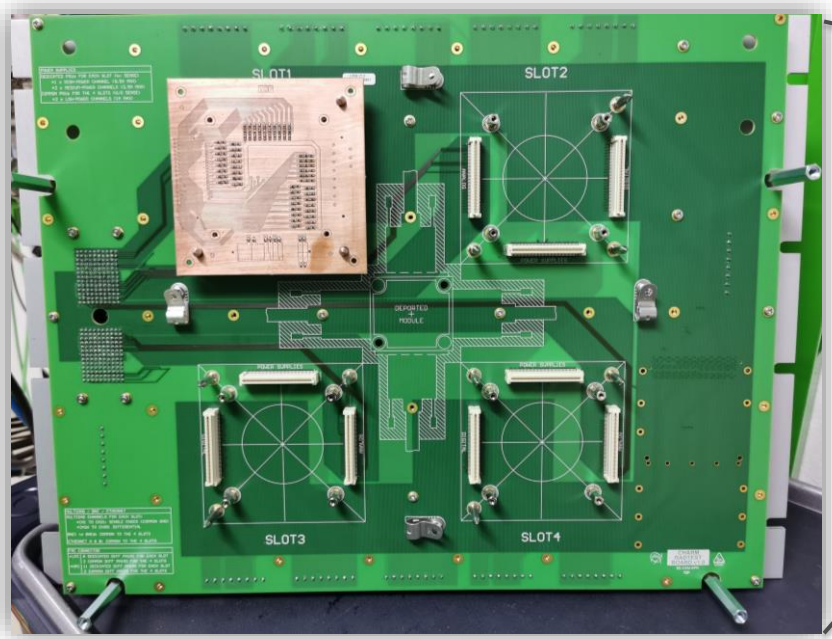
Feedbacks from the CERN Radiation Test Service

- **How do we test at the CHARM facility?**
- We developed a **Test Board** which can hosts DUT on a standardized slot

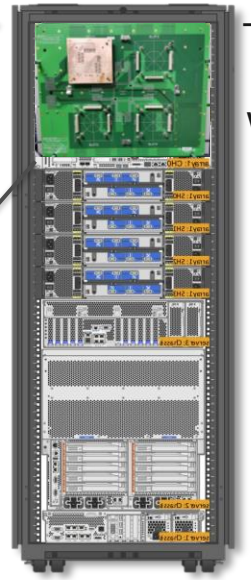
Irradiation area

EPR Test Board

4x Standardized Test slots



Test rack



Test rack permanently mounted

We just exchange the board on the slot and the test is ready!

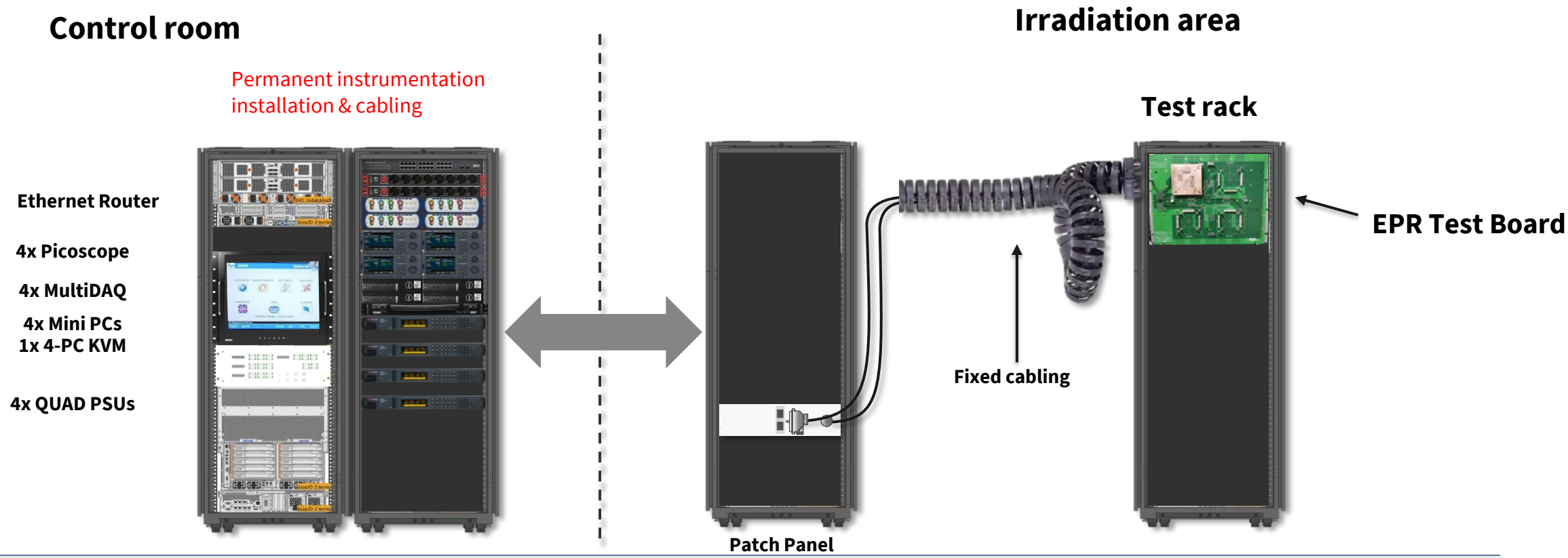
Zero effort required for installation

Connectivity per slot:

- 5 Power Channel
- 21 Single-ended DAQ Channels
- 20 Differential DAQ Channels
- 4 high-speed channels
- 38 Digital IOs

Feedbacks from the CERN Radiation Test Service

- **How do we test at the CHARM facility?**
- The control room provides a permanent rack with all the necessary instruments and fixed connections
- All the instruments are connected to PC, which is accessed remotely

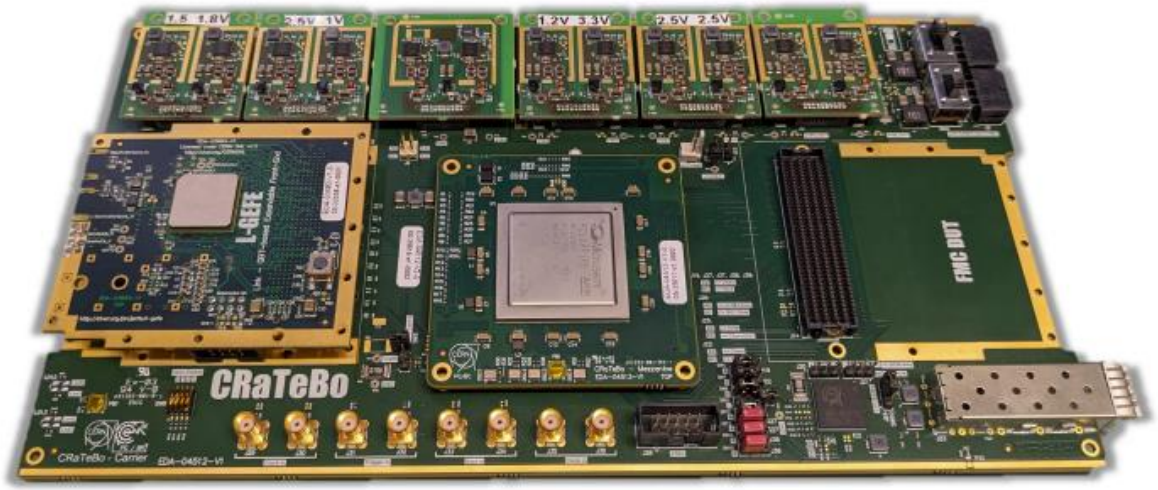


Feedbacks from the CERN Radiation Test Service

- **C**HARM **Ra**diation Tolerant FPGA **Te**ster **Bo**ard **(CRaTeBo)**

- A Rad-tolerant board where the FPGA is hosted on a custom SoM socket
- Fixed connection with the control room for communication and power
- Allows test of FPGAs and other complex FPGA-based systems

Permanent installation in CHARM



Example of developed FPGA Modules:

PolarFire SoM

GateMate SoM

- **Objective**

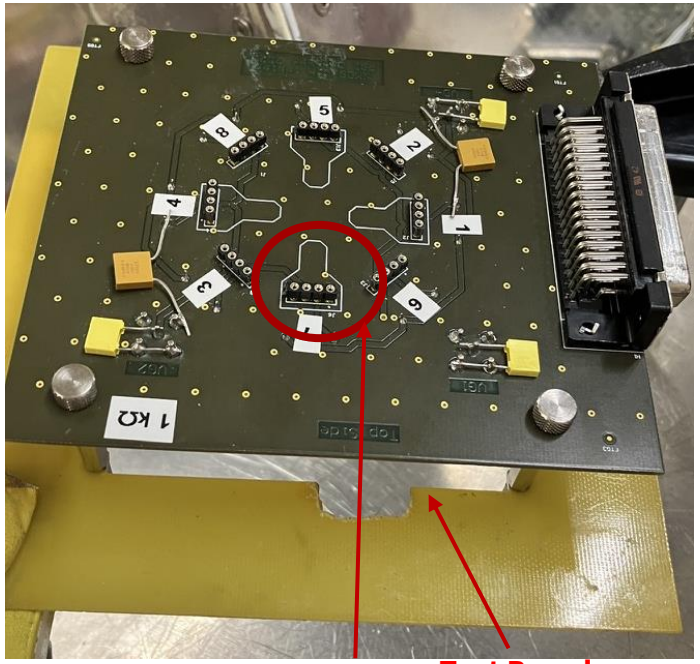
- Allow regular FPGA design testing through this permanent installation

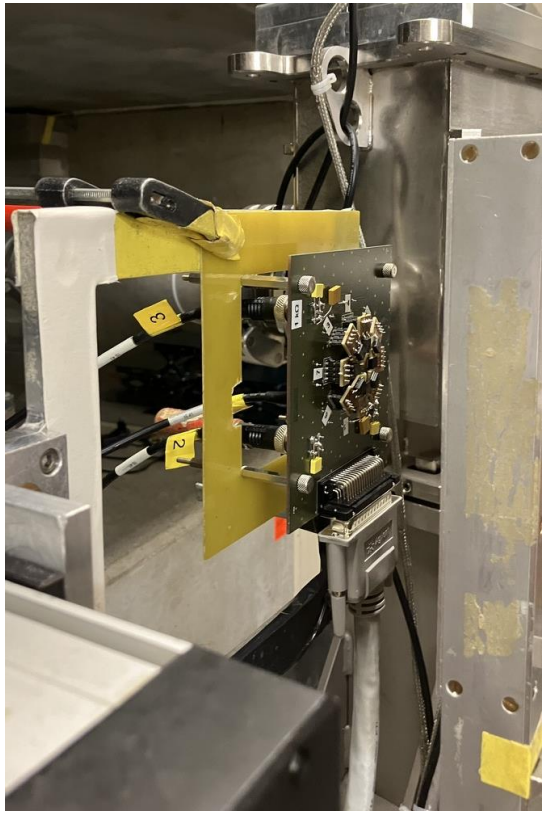
- One SoM can be developed for the FPGA of interest (Ex: Xilinx SoC, Lattice etc) and everyone can **reuse** it

- User could upload their design remotely and assess the sensitivity of their application on a new FPGA without having to develop a custom radiation-tolerant card for the FPGA

Feedbacks from the CERN Radiation Test Service

- **Test at the PSI facility**
- Examples of generic test board developed for MOSFET characterization
- MOSFET are just plugged into the sockets, and the board is installed in beam
- Minimum effort for installation
- An automated Python Framework acquires data during irradiation
- It could be easily converted to REMOTE TESTING





Summary

- Radiation qualification of a component/system may require several irradiations at different facilities

- Organization, preparation and execution of a radiation test campaign is not easy
  - Limited availabilities of facilities
  - A different test setup must be prepared for each facility
  - Problems encountered at the facility could make the campaign fail, with loss of money and time

- Remote testing could bring many advantages, however there are many challenges to face
  - Grant external access to the control of radiation source
  - Establish a set of common connections/cabling that could allow reusability of test setup
  - Put in place standardized tester board that could allow easy installation of the DUT from the facility staff
  - Grant external access to instrumentation and laptop for operating the test remotely

Points of discussions

- P1: How important is remote control of beam settings during an irradiation run? Already now in different facilities we have to "call" the operators for changing setting
- P2: How to grant external access to irradiation control from remote? Any attempt already done?
- P3: Which are the common needs for users? In terms of cabling length, connections
- P4: Do you make use of custom cards, or mainly development kits for your radiation test campaigns?
- P5: If you use devkit, would you develop a test card to comply with the "standardized" test support?
- P6: Can facility provide a wide set of instruments, and their remote access for user's test?
- P7: How likely is for users to adopt custom testers, cables (in addition of traditional ones) for their campaigns?