G-RAD Workshop - Grenoble Radiation Testing of semiconductor devices and systems

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on-line

Book of Abstracts

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The IRT Nanoelec

Corresponding Author: hughes.metras@cea.fr

This Pitch-presentation will present the French Technological Research Institute Nanoelec and its technoloical programs.

Welcome session / **3**

The PAC-G and the Large-Scale Instruments Characterisation Program

This pitch-presentation will focus on the large-scale instruement characterisation program of the IRT Nanoelec. It will introduce the idea of a center of expertise in radiation hardness testing based in Grenoble. It will also briefly mention de PAC-G, service platform of the program.

Welcome session / **4**

Overview of the RADNEXT project

Corresponding Author: ruben.garcia.alia@cern.ch

The RADNEXT H2020 project, recently approved for funding by the European Commission, will enable access to worldwide radiation effects scientist and engineers to a broad network of facilities, aiming also at improving the quality of the related user support and making progress on the irradiation procedures covering emerging needs.

Session 1 - Space environment and corresponding facilities / **5**

Irradiation facilities used by CNES for electronic component testing: Selection, limitations and possible evolutions

Corresponding Author: francoise.bezerra@cnes.fr

“Standard Radiation test methods recommend specific sources and beams in order to emulate space radiation environment for testing electronic components. Such facilities are quite rare and generally dedicated to other activities as research in medical or physics. The following points will be presented:
- Main characteristics of standard facilities
- Introduction to irradiation facilities used by CNES
- Possible issues when preparing a test
- Recent evolution due to COTS and New Space
- Limitations of existing facilities and suitable evolutions.”

Session 1 - Space environment and corresponding facilities / **6**

Irradiation facilities to test EEE components for ESA space missions

Corresponding Author: veronique.ferlet-cavrois@esa.int

- ESCC Test Guidelines, single event effects, Total Ionising Dose, Displacement Damage
- Facilities (type, species, energies) for assessment or qualification, commonly used facilities, identified facility needs
- Evolution in space industry wrt EEE components, increasing utilisation of COTS
- Classification of space missions, results of the COTS initiative working group at ESA

Session 1 - Space environment and corresponding facilities / **7**

Testing complex and highly-integrated RFIC devices under radiation conditions

Author: Jan Budroweit[1]

[1] *Deutsches Zentrum für Luft- und Raumfahrt - DLR*

Corresponding Author: jan.budroweit@dlr.de

According to Moore's law, technologies sizes decreases rapidly and allows the integration of multiple functions of integrated circuits into a single component. State-of-the-art radio frequency integrated circuits (RFIC), for instance the AD9361, integrates analog-to-digital converters , digital-to-analog converters , synthesizers, filters, amplifiers, mixers as well as several logics and interfaces. Usually, each individual function needs to be tested discretely as for single devices, which is impossible in case of RFICs, since probing the die is not feasible. In this talk, the developed test methodology, setup and the test results of various test campaigns for an RFIC are presented.

Session 4 - Alternative Testing Methods / **8**

Laser testing as an optimized complement of Heavy Ion for SEE testing - experiences from Airbus DS

Author: Cécile Weulersse[1]

[1] *Airbus Defense and Space*

Pulsed-laser approaches have demonstrated to be a very interesting tool for SEE testing and offers a great complementarity to heavy ions. This talk will address the basic mechanisms for laser charge generation in semiconductor materials and review the various SEE analyses for which laser testing can have an interest. Several applications performed at Airbus Defence and Space are detailed.

Session 1 - Space environment and corresponding facilities / **9**

Heavy Ions at the Grand Accélérateur National d'Ions Lourds (Ganil)

Author: Marie-Helène Moscatello[1]

[1] *Grand Accélérateur National d'Ions Lourds (Ganil)*

Corresponding Author: marie-helene.moscatello@ganil.fr

GANIL/SPIRAL2 is one of the major nuclear physics facilities in the world with SPIRAL2 selected in the ESFRI list. The accelerator complex can deliver high-intensity light- and heavy-ion beams, ranging from protons up to 238U in the energy range between a few keV to 95 MeV/u, and a wide range of high intensity exotic beams produced either in flight with the LISE fragment separators or with the ISOL method at the SPIRAL-1 facility.
A dedicated beam line is devoted to industrial applications, including a sample carrier system that has been adapted to industrial needs with CNES support.
The SPIRAL2 facility is composed of a superconducting LINAC accelerating beams from protons to heavy-ions with A/Q=3 in the energy range from 0.75 MeV/u to 14.5 MeV/u (up to 33 MeV for protons and 20 MeV/u for deuterons). The LINAC is used for the production of neutron beams as well. Continuous (up to 40 MeV) and quasi-monoenergetic spectra (up to 31 MeV) will be available for users in 2021. NFS will be a very powerful tool for physics and fundamental research as well as applications like the transmutation of nuclear waste, design of future fission and fusion reactors, nuclear medicine or test and development of new detectors and components.
GANIL-SPIRAL2 facilities and their performances will be presented, as well as the dedicated beam-lines for radiation effect research activities.

Session 1 - Space environment and corresponding facilities / **10**

Short overview of the irradiation facilities at UCLouvain

Corresponding Author: nancy.postiau@uclouvain.be

The Cyclotron Resources Centre of UCLouvain has 3 beam lines dedicated to radiation hardness tests (heavy ions, protons and neutrons). The heavy ion and proton facilities are recognized and supported by ESA. The presentation will focus mainly on these two facilities. The beam parameters and equipment will be described. Some new projects for the future will be presented

Session 1 - Space environment and corresponding facilities / **11**

Proton and heavy ion irradiations at the AGOR cyclotron facility

Author: Marc Jan van Goethem[1]

[1] *RUG*

The AGOR cyclotron (K=600) is capable of producing proton and heavy ion beams for radiation hardness testing. The experimental setup for proton irradiations (10-190 MeV) and the in-air experimental setup for heavy ion irradiations with O, Ne, Ar, Kr and Xe beams at 30 MeV/u will be presented.

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Irradiation facilities at CNA for electronics testing

Author: Yolanda Morilla Garcia[1]

[1] *Centro Nacional de Aceleradores - CNA*

Corresponding Author: ymorilla@us.es

The National Centre for Accelerators (CNA - US/CSIC/JA) is one of the Unique Scientific and Technical Infrastructures, declared in Spain. Nowadays, the irradiation testing is one of the strategic lines of this research center and the facility is open to other institutions and private companies.
The progress of different national research projects has contributed significantly to consolidate the CNA irradiation unit, with especial emphasis on the testing of electronic components and devices to be used in aerospace projects. Recently, it has been also developed a new system to allow low and high temperature irradiation testing. We will present three of the CNA laboratories available to carry out different irradiation tests; which are based on two low LET accelerators and one gamma irradiation system.

Session 1 - Space environment and corresponding facilities / **13**

Co-60 total dose testing – Old and new challenges

Author: Jochen Kuhnhenn[1]

[1] *Fraunhofer INT*

Corresponding Author: jochen.kuhnhenn@int.fraunhofer.de

TID testing is fundamental for nearly all components or systems that operate in radiation environments. Successful TID testing is based on the combination of suitability of the test approach, selection of facility, understanding of radiation effects and test procedure and sophisticated analysis of the results. While much of that seems well established for typical scenarios, new approaches, e.g. with implementation of COTS, demand more flexibility from users, facilities, and operators. This presentation will give an overview of typical and not so typical ways to perform TID testing at Co-60 facilities. Also test methods besides Co-60 gamma will be mentioned. Challenges and problems to be avoided will be discussed. Finally a subjective outlook to future developments will be given.

Session 1 - Space environment and corresponding facilities / **14**

Q&A Session Identification of the requirements of the Space Industry with regards to radiation testing, emerging needs and limitations of the current offer.

Corresponding Authors: letiche@ill.fr, capria@esrf.fr

Session 2 - Atmospheric and terrestrial applications / **15**

Radiation concerns in the automotive industry mechanisms, standards, typical measurements

Author: Dan Alexandrescu[1]

[1] *IROC Technologies*

Corresponding Author: dan.alexandrescu@iroctech.com

Current and future automotive and autonomous applications are complex, forward-looking systems, involving large quantities of silicon, machine computing power and human brains and tears.
Their quality is prescribed, described and expected by demanding standards. These benevolent dictators set requirements for functional safety and reliability targets and development and manufacturing processes.
Transient faults, including Single Events are one of the key concerns and the system's FIT rate and ability to manage faults are the principal metrics to demonstrate.
This presentation will highlight current and future topics dealing with the evaluation, certification and testing of automotive circuits and systems and will show how testing is the decisive, ultimate proof of design's worthiness.

Session 2 - Atmospheric and terrestrial applications / **16**

Ensuring the reliability of power electronic devices with regard to terrestrial cosmic radiation

Author: Gerald Soelkner[1]

[1] *Infineon*

Corresponding Author: gerald.soelkner@infineon.com

Terrestrial cosmic radiation (CR) is a significant factor for the reliability of power electronic devices, for all voltage classes from 150V to 6500V, for all device types and irrespective of the base material. Exact failure rate data are required to balance CR hardness and electrical performance for an optimum system design. Accelerated irradiation testing methods depend on the availability of high-energy/high-flux particle beams to model the terrestrial CR radiation environment and a quick & easy access for industrial users.
This talk will briefly explain basic CR-induced failure mechanisms. Options and limits of predictive device simulations will be discussed. Accelerated CR testing methods, most of which have already been laid down in a JEDEC specification (JEP151), will be described, with an emphasis on requirements for beam quality, infrastructure and access for industrial testing.

Session 2 - Atmospheric and terrestrial applications / **17**

Radiation effects in avionic equipment

Author: Maria Mazurek[1]

[1] *Airbus Operations*

Corresponding Author: maria.mazurek@airbus.com

This talk will detail the aeronautic industry needs in radiation testing of avionic equipment and the applicable standards. It will also explore new foreseeable needs and constraints.

Session 2 - Atmospheric and terrestrial applications / **18**

Radiation Effects in terrestrial environments: servers, telecommunications and automotive

Author: Jyotika Athavale[1]

[1] *Intel*

Corresponding Author: jyotika.a.athavale@intel.com

This talk will cover Single event effects terminology, mechanisms and trends for terrestrial environments including server, networking and AV systems. Single event effects modeling methodologies will be discussed, including modeling of Soft Error Rate (SER) vulnerability factors for intelligent dependable systems, and the needed mitigations at the technology, IP, SOC and system level. The impact of SOC soft error rate performance on functional safety metrics will be also be covered, with a focus on automotive safety critical systems that need to comply with ISO26262 requirements.

Session 2 - Atmospheric and terrestrial applications / **19**

Chipir: A Fast Neutron Beamline for Single-Event-Effect Tesing / Thermal and mono-energetic neutron beams at the ISIS Neutron and Muon Source

Author: Carlo Cazzaniga[1]

[1] *ISIS Neutron and Muon Source*

Corresponding Author: carlo.cazzaniga@stfc.ac.uk

Chipir: A Fast Neutron Beamline for Single-Event-Effect Testing
Chris Frost

Neutron single-event-effects are an increasing problem in modern electronic devices and systems, causing a range of substantial reliability issues and failures. To address this problem the UK's ISIS Neutron and Muon Source designed and now operates ChipIr, a fast-neutron beamline that mimics the atmospheric-like neutron spectrum in the 1-800MeV regime, but with a highly enhanced neutron flux, >10^6 n/cm2/s. Using this instrument, industrial and academic researchers perform accelerated fast-neutron testing on a wide variety of electronics to understand the detrimental effects of the natural atmospheric cosmic-ray neutrons on their device and systems and to mitigate their effects. In this talk we will discuss some of the design consideration of the beamline, how it was incorporated onto an existing spallation target station at ISIS and finally how it has been addressing industrial problems in the electronics' industrial sector.

Thermal and mono-energetic neutron beams at the ISIS Neutron and Muon Source
Carlo Cazzaniga

The ISIS Neutron and Muon source in the UK is expanding its irradiation capabilities of microelectronics to meet increasing demand of academia and industry.
Two thermal neutron beamlines, EMMA and Rotax, firstly designed for other applications, have been characterised and used for single event effects testing. Thermal neutrons are produced by the moderation of fast neutrons in materials, and can be a concern for microelectronics when boron is present. Recent studies have shown that in some cases the Failure In Time due to thermal neutrons can be comparable to the FIT due to fast neutrons in terrestrial applications. EMMA and Rotax have thermal fluxes in the order of 10^6 n/cm2/s, and different moderator temperatures (300 K vs. 100 K). A new facility with DT (14 MeV neutrons) and DD (2.5 MeV neutrons) compact generators is under construction and will start commissioning within the year. We will discuss how the use of this facility will be complementary to ChipIr and how it is designed to meet the requirements of users.

Session 2 - Atmospheric and terrestrial applications / **20**

TENIS thermal neutron irradiation facility at the ILL

Author: Manon Letiche[1]

[1] *Institut Laue-Langevin - ILL*

Corresponding Author: letiche@ill.fr

TENIS the new irradiation station at ILL will be introduced to the community. The station is under construction and is foreseen to be operational at the beginning of 2021. Details about the project will be given concerning beam characteristics, dosimetry control, mechanical options and beamtime available.

Session 2 - Atmospheric and terrestrial applications / **21**

CHARM Radiation Facility at CERN

Corresponding Author: ruben.garcia.alia@cern.ch

Since 2014, the CHARM facility at CERN is used to qualify electronic components and systems, mainly for accelerator applications. Its radiation environment and mechanical and electrical infrastructure make it a unique facility for testing radiation-tolerant systems for the LHC accelerator and its injector chain. Moreover, CHARM is also of potential interest for ground-level and space applications.

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LNL- The NEPIR Facility - Fast neutrons

Author: Jeffery Wyss[1]

[1] *INFN Legnaro National Laboratory*

Corresponding Author: wyss@pd.infn.it

We describe NEPIR, the fast-neutron irradiation facility under development at the 70 MeV cyclotron SPES facility of the INFN laboratory of Legnaro (LNL). The facility will be used to investigate neutron-induced Single Event Effects (SEE) in microelectronic devices and systems. It will be constructed in stages, according to the available funds. The initial funded configuration, based on a novel thick Be neutron production target, will be operational in 2023. In its final configuration NEPIR will have two target systems: one will deliver a Quasi Mono-energetic Neutron (QMN) beam, of multidisciplinary interest, with an adjustable energy peak in the 20–70 MeV range; the second target will deliver a specialized neutron beam with a continuous energy spectrum resembling that of neutrons at sea-level produced in cosmic ray air-showers in the 1-70 MeV energy range. In closing we describe ways, presently under preparation at LNL, to use the 6 MeV Van der Graaf and the15 MV XTU Tandem of LNL to produce nearly monochromatic fast neutrons that would complement the QMN system of NEPIR allowing one to probe for SEE below 20 MeV.

Session 2 - Atmospheric and terrestrial applications / **23**

Q&A Session on emergent needs and limitations of the current offer for radiation testing facilities

Corresponding Authors: capria@esrf.fr, boudou@ill.fr

Session 3 - Harsh Environments and specific needs / 24

Approach to Radiation, its Effects and its Testing in Fusion Reactors Experimental Areas

Author: Jean-Luc Leray[1]

[1] *Consultant*

Corresponding Author: jl.leray@anaxagoras2k.fr

The main scope of this presentation is the test of SEEs induced by neutrons on electronics intended to be operated in a neutron flux in a fusion reactor (DT plasma neutrons).
Regardless of the intensity of the gamma and neutron fluxes, this presentation focuses on the energy spectra of neutrons, whose energy degradation can vary from one place to another in the reactor building depending on the elastic and inelastic interactions of neutrons with the surrounding structures, such as shields and walls.
Although the neutron fluxes depend on the design of the machine and the building as well as the operation of the reactor, the energy spectra of the neutrons should be quite similar for all fusion reactors. This property very specific to fusion experiments, whatever the scale of the machine, prompts the development of a common methodology for the measurement of SEEs induced by neutrons on the electronics of fusion machines. Analogies with the natural atmospheric spectrum can be evoked.

Session 3 - Harsh Environments and specific needs / 25

Radiation effects and testing in CERN experiments

Author: Federico Faccio[1]

[1] *CERN*

Corresponding Author: federico.faccio@cern.ch

The estimated radiation field in the central particle detectors at the CERN High-Luminosity Large Hadron Collider will extend to ultra-high TID levels (1Grad). The radiation hardness specifications for the ASICs developed to read-out signals from these detectors will be presented, together with the technology and design choices enabling to meet them. Qualification procedures as well as irradiation facilities typically used for radiation testing will be discussed.

Session 3 - Harsh Environments and specific needs / 26

Radiation effects and testing for CERN accelerators

Corresponding Author: ruben.garcia.alia@cern.ch

The CERN accelerator complex and notably the Large Hadron Collider (LHC) host vast quantities of electronic components and systems exposed to radiation, which therefore need to be tolerant enough against radiation effects in order not to negatively impact the performance of the accelerator. This presentation will cover the related challenges and solutions in terms of radiation environment, effects on the accelerator systems, and related Radiation Hardness Assurance procedure.

Session 3 - Harsh Environments and specific needs / **27**

Q&A Session on limitations of current offer for radiation testing facilities

Corresponding Authors: boudou@ill.fr, capria@esrf.fr

Session 4 - Alternative Testing Methods / **28**

Pulsed Synchrotron focalised X-rays and XFEL

Corresponding Author: capria@esrf.fr

Session 4 - Alternative Testing Methods / **29**

Fast neutron GENESIS platform

Corresponding Author: baylac@lpsc.in2p3.fr

The GEnerator of NEutrons for Science and IrradiationS (GENESIS) produces a flux of fast neutrons at an energy of 14 MeV (or 2.5 MeV). The neutron source is provided by an electrostatic accelerator delivering 220 keV deuterons onto a tritiated (or deutered) target. It is used both for academic research (nuclear physics experiments, detector tests) and irradiations. Lately it was widely used to irradiate micro-electronics components in order to investigate their resistance to neutron flux. The facility is operated by the Laboratory of Subatomic Physics and Cosmology (CNRS, G-INP, UGA) located on the scientific polygon of Grenoble, next to ILL and ESRF.

Over the last few years, the facility was upgraded mainly to boost the neutron flux and improve the reliability of the machine. A compact ECR ion source was installed to produce a continuous and intense deuteron beam. Significant shielding was also added to the existing infrastructure in order to support the neutron flux increase. Presently, the maximum 14 MeV neutron flux reaches 5.10^7 n.s^-1.cm^-2 at the location of the sample.

The facility and its performances will be presented, as well as different types of applications.

Session 4 - Alternative Testing Methods / **30**

Neutron Irradiation Capabilities at the PTB Ion Accelerator Facility PIAF

Author: Ralf Nolte[1]

[1] *Physikalisch-Technische Bundesanstalt (PTB)*

Corresponding Author: ralf.nolte@ptb.de

At the accelerator facility PIAF of Physikalisch-Technische Bundesanstalt (PTB), proton and deuteron beams are used to produce monoenergetic neutron fields in open geometry (full solid angle) in a low scatter hall using various nuclear reactions. The energy range of the monoenergetic neutron fields ranges from 140 keV to 19 MeV with a gap between 8 MeV and 14 MeV where no monoenergetic neutron source exists. The flux densities range between 5·10^4 cm^-2s^-1 and 2·10^6 cm^-2s^-1 at 10

cm from the production target which makes these fields suitable for testing the energy dependence of radiation effects in microelectronic components. The monoenergetic fields are complemented by 'white' collimated high-intensity beams with a maximum neutron energy of about 17 MeV and flux densities up to 1·10^8 cm^-2s^-1 are achieved. Other radiation sources available at the PTB comprise an ion microprobe with proton and alpha beams and a 50 MeV electron linac with bremsstrahlung and electron beams. Access to neutron beams up to 200 MeV is possible via a collaboration with iThemba LABS in Cape Town.

Session 4 - Alternative Testing Methods / **32**

Pulsed-Laser Testing for Single-Event Effects Investigations

Laser testing offers an exciting opportunity for the impact of the natural space radiation environment on electronic components to be assessed in your own lab or workshop, without waiting for beam time and travelling to a remote facility. The value of laser testing for radiation tolerant product development and the screening of COTS parts is becoming appreciated ever more widely. When developing new products, the possibility of immediately testing the effect of a design change, mapping the single-event effects response across a die and correlating physical and virtual memory locations shorten the time to market and help you obtain results that are not possible with conventional radiation testing methods. When screening for part selection, laser testing can eliminate those types of component that are vulnerable to single-event effects so that you can use scarce heavy ion beam time on those you have confidence will pass. This approach is starting to make radiation testing available to even the lowest budget missions, something that was not attainable for CubeSats until now.

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Q&A Session on the limits of current radiation testing offer and emerging needs

Session 5 - Facility and user relationship - Expert Panel / **34**

The Dissimilar Dyad: Radiation Facility and Industrial Customer. Opportunities and perspectives for creating a successful cooperation

Author: Gerd Datzmann[1]

[1] *Datzmann interact and innovate Gmbh*

Corresponding Author: gerd@datzmann.eu

Radiation hardness assurance procedures nowadays often require tests with high-energetic protons, heavy ions or neutron for simulating the harsh radiation environment close to reality. These particles are generated by nuclear physics facilities – like particle accelerator or research reactors – which are located exclusively at universities or national research institutions. Thus, industry inevitably has to purchase a service from a publicly funded organization. This may potentially lead to "cultural" barriers in collaboration of the dissimilar dyad. On the other hand, such a cooperation is creating an opportunity to foster knowledge and technology transfer from science to industry and back.

An in-depth case study has been performed focusing on the relationship between radiation facility and its customer. The factors influencing this relationship including the mechanisms of interaction have been explored with a set of more than 30 expert interviews with stakeholders from industry, agencies and irradiation facilities. The findings confirm that influencing factors derived from the social capital dimensions play an important role for the success of the relationship. The keynote will address and discuss issues like availability, accessibility, offering and demand, policy of the facility, motivation and mutual trust. On the basis of the acquired and distilled information, recommendations will be presented enabling and fostering successful cooperation. A set of best practices are highlighted that support facilities who intend to start a service provision in this field with the aim of creating win-win situations for both sides.

Session 5 - Facility and user relationship - Expert Panel / **35**

Facility and user relationship - Expert Panel

Author: Jerome Beaucour (animator)[1]

Co-authors: Christian Chatry [2]; Dan Alexandrescu [3]; Ennio Capria [4]; Françoise Bezerra [5]; Gerald Soelkner [6]; Jochen Kuhnhenn [7]; Ruben Garcia Alia [8]

[1] *Institut Laue-Langevin*

[2] *TRAD*

[3] *IROC Technologies*

[4] *IRT Nanoelec PAC-G*

[5] *CNES*

[6] *Infineon*

[7] *Fraunhofer INT*

[8] *CERN*

This expert panel will focus on the access modes and organisational aspects of facilities. The convergence between industrial and academic needs in the use of these large-scale facilities will be addressed.
Recommendations for facilitating and strengthening successful cooperation between industry (radiation testing) users and research facilities will be drawn from these discussions.

Session 3 - Harsh Environments and specific needs / **36**

Radiation testing of measuring technology used in medical radiology

This contribution aims at presenting the challenges and requirements associated with radiation testing of measuring technology used in the field of medical radiology. The focus lies on radiation testing workflows of devices used for medical LINAC QA, one major market of PTW Dosimetry. Needs related to testing facilities as well as test standardization approaches will be discussed.

Welcome session / **38**

Welcome

Session 4 - Alternative Testing Methods / **39**

Recent advances in pulsed X-ray single-event testing

Pulsed x-rays have been demonstrated as a powerful tool that is complementary and supplementary to energetic particle and pulsed laser SEE testing. This talk will address the application of pulsed x-rays for SEE testing of microelectronic devices. Advantages and limitations of x-ray SEE testing will be discussed. The current test setup at the Advanced Photon Source at Argonne National Laboratory will be described in detail and several examples from recent work will be presented.

Visits / **40**

Visit of TENIS at ILL

Corresponding Author: letiche@ill.fr

Thermal and Epithermal Neutron Irradiation Sattion

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Visit of ID09 at ESRF

Corresponding Author: capria@esrf.fr

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Visit of GENESIS at the LPSC/CNRS

Corresponding Author: cheymol@lpsc.in2p3.fr

Session 5 - Facility and user relationship - Expert Panel / **43**

Closing