## *- WP9 - Construction of irradiation facilities at CERN*

The high radiation levels expected in LHC and future SLHC detectors require extensive R&D to study detector performance and optimization under such conditions, as well as finding suitable materials, testing control sensors and innovative approaches for detector assembly. The ability to investigate neutron, proton, X-ray, and gamma radiation effects in an experimental setting allows anticipation of component failure and development of new systems that can withstand these radiation exposures. At CERN, the existing Gamma Irradiation Facility (GIF), which permits irradiation of large area detectors, and the high fluence proton and neutron irradiation facilities in the PS T7 and T8 beam lines have been used at 100% of their capacity. Both facilities are unique in the world, as they allow testing the radiation tolerance of detectors and detector components in high-intensity, high-energy beams in a high quality setting offering centralized services around the irradiation experiments. To cope with the demanding detector R&D for SLHC these facilities need to be significantly upgraded especially in terms of radiation dose. Due to the overlap between LHC running and SLHC R&D work carried out by detector, accelerator and radioprotection communities, it is also important to improve user interfaces and accessibility to the new facilities such that setting up procedures and test time are minimized and more users can use them, even at very short notice if needed.

Another major issue facing the design teams of the LHC detectors was that the required assembly materials performance data was not available or not sufficient, therefore their performance could not be accurately predicted. The SLHC detector community requires a compilation effort to understand what has worked well in LHC and to establish the parameters and test procedures that are needed to validate and fully characterize new materials and fluids for the particle detectors foreseen for SLHC.

All these facilities can be regarded as indispensable qualification and development tools for understanding and mitigating possible failure effects in LHC, and starting an efficient LHC upgrade programme.

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| **Work package number** | WP9 | | **Start date or starting event:** | | | | M1 | |
| **Work Package title** | Construction of irradiation facilities at CERN | | | | | | | |
| **Activity type** | RTD | | | | | | | |
| **Participant number** | | | | | | | | |
| **Participant short name** | CERN | UNIGLA | Uni Karlsruhe | ULIV | RAL | USFD | VU | WEIZMANN |
| **Person-months per participant** | 62 | 18 | 10 | 18 | 18 | 12 | 8 | 24 |
| **Participant number** | | | | | | | | |
| **Participant short name** | INRNE | | | | | | | |
| **Person-months per participant** | 6 | | | | | | | |

**Objectives:**

**Task1: Construction of the GIF++.**

- Elaboration and evaluation of different scenarios to construct a new CERN gamma irradiation facility (GIF++), optimized for an effective SLHC R&D program. GIF++ will be used to probe efficiently LHC test detectors, establish recovery plans and validate SLHC detector prototypes.
- Produce the design specifications for the optimal gamma irradiation facility: freeze the technical requirements for the new source and coexisting particle beam - if any, the area layout, and general and peripheral infrastructure.
- Set-up the common infrastructure for the optimal and efficient use of the GIF++ facility by the different user communities (detector, accelerator, radioprotection).

- Build and operate the facility.

**Task 2: Upgrade of proton and neutron irradiation facilities**

- Elaboration and evaluation of different scenarios to upgrade and adapt the neutron and proton irradiation facilities at CERN in view of the upcoming SLHC irradiation programs.
- Design of new proton and neutron irradiation facilities according to the outcome of the evaluation study.
- Construction and commissioning of the upgraded proton and neutron irradiation facilities.
- Design and set up of common infrastructure for the facility, such as an offline radiation monitoring system based on the microwave absorption technique, and including specific equipment for the characterization of silicon sensors for SLHC:
    - Scanning table with >10cm$^2$ reach with local dose monitor and self-calibrating scanning software.
    - Temperature controlled cold box suitable for the scanning table.
    - System for monitoring and biasing a large number of Silicon detectors during irradiation.

**Task 3 Qualification of materials and common database**

- Publish a report with the history of materials used in LHC and defining the most important characteristics identified for SLHC detectors (trackers, muon detectors) and their services.
- Find optimal procedures for testing and report on results of selected materials for SLHC.
- Set-up and publish a WEB database compiling the information above.

**Description of work:**

**<u>Task 1. Construction of GIF++.</u>**

The CERN GIF set-up has permitted, in an accelerated manner, the extensive characterization of LHC detectors in presence of background radiation and the optimization of their system services, such as the complex re-circulating gas systems for the LHC muon gas detectors. The combination of high rate background radiation and coexisting muon beam has made it unique in the world. Following the dismounting of the SPS West Area beams, simultaneous beam tests are no longer possible, and the facility is scheduled to be shutdown in 2009. However, detector communities express the strong need of having access to a similar facility, modernized to cope with the needs imposed by the planned R&D for SLHC. The starting point for the construction of GIF++ is the collection of user requirements to perform the design studies and to freeze the technical specifications for the construction of the optimal facility. The requirements will be collected by CERN via questionnaires sent to user-communities in particle physics and in-depth discussions with the LHC upgrade programme teams. A dedicated task force including experts from several departments in the Organization will create and analyze the data and produce a report including:

- Technical specifications for the gamma source(s), linked to a high-energy particle beam if most users would request it.
- Optimized choice to condition the area for efficient use (heavy work needs, mechanics, attenuating filters and their remote control), design of the control room, optimized layout of common peripheral services (gas systems, cooling, slow controls, dose monitoring, common trigger and readout) and all the studies related to safety and radiation protection aspects (interlocks, log procedures).
- Operation plan for the facility and its inclusion in the CERN irradiation and beam tests programme.

The lead of CERN and involvement of Weizmann Institute in this task will trigger the construction of the new facility GIF++ in time to improve and find solutions for failure modes of detectors in LHC, and to coordinate prototyping work for SLHC detectors in a set-up that permits a fruitful interchange of experiences by all user groups involved. The Weizmann Institute and INRNE will play an important role defining and providing common infrastructure for the users, with special emphasis on the Slow Control Systems. This is of special importance as tests carried out to ascertain the long-term behaviour of detectors would run unattended for long periods of time.

**<u>Task 2 Upgrade of proton and neutron irradiation facilities</u>**

CERN will lead the process to evaluate the requirements of the High Energy Physics community for

irradiation facilities based on the very high energy and intense proton beams available at CERN. The resulting requirement list will be taken as an input to develop upgrade scenarios for the presently existing facilities. For the most feasible options, operation scenarios and cost estimates will be worked out and presented to the CERN management. Upon selection and approval of a specific facility proposal a detailed construction plan will be worked out and finally this work package will serve to contribute to the construction and commissioning of the new facilities. In detail the CERN contribution will be the area conditioning (heavy work, mechanics, beam lines, safety and radioprotection aspects, control room) and the optimized layout of common services (electrical and gas systems, cooling, slow control, common trigger and readout) as well as the installation of shuttle systems (remote sample positioning systems) and their control.
The UK groups Glasgow, Liverpool and Sheffield will design and deliver a cold box that can be scanned through the proton beam to achieve uniform fluences across an area of about 10x10 $cm^2$ surface. The system will be monitored in terms of stage position and movement, temperature and humidity inside the box and fluence. Its main purpose will be the irradiation of Silicon detectors and modules. Therefore, the system will be capable of biasing the detectors and monitoring their current to reproduce realistic operating conditions. A beam monitoring system that can monitor the relative fluence remotely will be developed. This will monitor the relative fluence across the box as a function of time to ensure that the devices are uniformly irradiated. The monitor will consist of a pixellated detector based on a rad-hard technology. The final deliverable will be a cold box system with a stage and monitoring commissioned in the CERN proton irradiation facility. Operation of the cold box system will then be taken over by the CERN group with the UK groups providing maintenance and expert support. An independent absolute fluence monitoring system based on carrier lifetime measurements in silicon as measured by microwave absorption will be provided by the Vilnius group. The system will allow for an absolute fluence calibration of the online monitor data after the irradiation experiment.

**Task 3 Qualification of materials and common database**

The construction of the particle detectors in consideration for the LHC upgrade demands an exhaustive and systematic search for new yet commercially available materials, with attractive properties in terms of density, expansion coefficient, elasticity modulus, radiation hardness, electrical and chemical properties, etc. This task will establish the shortfall in data for the LHC upgrade experiments, establish a set of procedures for obtaining the data, stress those procedures by making some tests, and publish the results and the procedures on the web for the benefit of the whole community. The guiding principle will be that materials successfully used and well characterized for LHC should remain suitable and be used again for SLHC. However it is possible that LHC will show that some materials do not perform as expected (e.g. adhesive did not always adhere), some others will be no longer available, performance of other ones will not match SLHC (e.g. radiation tolerance) or new required parameters have not been measured in a reliable way, or possibly a significantly better material is available (cheaper, lighter, stronger, etc.) whose performance in key areas has been demonstrated by trustworthy methods.
The task, led by the Advanced Materials Group of RAL, is divided in three sequential sub-tasks:
Subtask 1 requires establishment of the critical performance parameters for the materials, to document what materials were used or rejected before, and what promising alternative candidate materials there are. This will be carried out by all participants in this task working in close collaboration with the LHC and SLHC communities, performing a survey of literature about the original detectors, and by eliciting knowledge from the relevant members of the teams. From this exercise the list of materials requiring further tests will be established. The involvement of the UK groups is especially relevant as they hold important knowledge from the construction of silicon detectors for LHC. CERN will also play an important role opening up this activity to other detector communities, such as groups working on LHC muon gas detectors and their possible upgrades.
Subtask 2 requires establishing procedures to fill in the missing data items identified at the end of subtask 1 where radiation testing is involved. For this, the participants will give access to mechanical, electrical and thermal testing equipment and to suitable irradiation facilities. CERN and Karlsruhe will therefore play an important role in this subtask, facilitating the use of their irradiation facilities on a suitable time scale. Uni Karlsruhe, in collaboration with the Institut of Material Science at the Forschungszentrum, offers cutting-edge methods to investigate material properties.
Subtask 3 requires database expertise, as well as a full set of results from subtasks 1 and 2 and a

specification of the required functionality of the database. CERN will actively contribute to the development and maintenance of the database using in-house know-how.

| **Deliverables of tasks** | **Description/title** | **Nature**[1] | **Delivery month**[2] |
|---|---|---|---|
| 9.1.1 | Design study for a new GIF++ facility published | R | M12 |
| 9.1.2 | Technical specifications for the GIF++ with peripheral services and user infrastructure approved | R | M18 |
| 9.1.3 | Construction of the GIF++ facility completed | O | M36 |
| 9.1.4 | First Performance and operation report of the new GIF facility published | R | M48 |
| 9.2.1 | Design for upgraded proton and neutron facilities approved | R | M24 |
| 9.2.2 | Upgraded facilities constructed and operational, together with their peripheral detector-test systems | O | M42 |
| 9.2.3 | Performance and operation reports of upgraded proton and neutron facilities published | R | M48 |
| 9.3.1 | Description of materials used in LHC, indication of required properties for SLHC and missing items identified | R | M12 |
| 9.3.2 | Set of test procedures published | R | M28 |
| 9.3.3 | Material Database filled with results on Web | O | M48 |

| **Mile-stone** | **task** | **Description/title** | **Nature**[1] | **Delivery month**[2] | **Comment** |
|---|---|---|---|---|---|
| 1 | 9.1<br>9.2 | GIFF++ and proton and neutron facilities user requirements collected | R | M6 | Publication on web |
| 2 | 9.1 | Implementation plan for the construction of the GIF++ agreed by stakeholders | R | M22 | Publication on web |
| 3 | 9.1 | Commissioning of GIF++ completed | O | M42 | Declare infrastructure 'Ready for users' |
| 4 | 9.2 | Outline design of proton and neutron irradiation facilities | R | M18 | Publication on web |
| 5 | 9.2 | Open proton and neutron facilities to users | O | M45 | Declare infrastructure 'Ready for users' |
| 6 | | Compile the list of materials used successfully in LHC trackers and indication of required properties for SLHC agreed | R | M8 | Publication on web |
| 7 | 9.3 | Identify suitable testing procedures and radiation sources for characterization of new materials | R | M18 | Publication on web |
| 8 | 9.3 | Post-irradiation tests of materials completed | R | M36 | Publication on web |
| 9 | 9.3 | Materials database specification produced | R | M39 | Publication on web |