RADIATION PROTECTION ASPECTS

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Abstract

The paper describes CERN's approach to radiation protection during LS1. It addresses the regulatory and operational landscape before and during LS1. The lessons learnt from LS1 will be used to define the roadmap towards LS2. Despite the large amount of maintenance and repair work in all radiation areas, CERN succeeded in keeping the collective dose to personnel at a reasonable level. Moreover, CERN's objective of keeping individual doses below 3 mSv in 2013 was largely achieved; only two experts slightly exceeded the dose objective. In addition, no radiological incident or accident had to be reported.

INTRODUCTION

The long shutdown LS1 proved a challenge to CERN's Radiation Protection Group. It was the first time that the Radiation Protection Group had been faced with such an amount of maintenance and repair work in CERN's radiation areas. They represent about 45 km of accelerator tunnels; several target areas, experimental areas including the specific LHC experiments and facilities like ISOLDE and n-TOF. Moreover, changes in the radiation protection regulations had to be communicated and implemented – just before the beginning of LS1. Overall, the experience from LS1 was largely positive and the lessons learnt will be applied to LS2.

REGULATORY LANDSCAPE OF CERN'S RADIATION PROTECTION

As an intergovernmental organisation, CERN has the right to establish its own internal legislation as necessary for its functioning. CERN's Safety rules, including radiation protection rules, are based on International and European Standards and Directives as well as on the relevant legislation in CERN's Host States, France and Switzerland.

On an international level, the International Commission of Radiation Protection (ICRP) issues recommendations, which are then converted into Safety Standards and Guidelines by the International Atomic Energy Agency (IAEA). Although the IAEA recommendations are normally not binding, the European Union considers them as binding with respect to the European regulations. The European Union issues legally binding Directives in matters of radiation protection, which define the minimum requirements in the field and which then have to be introduced into national laws by all EU Member States. Although Switzerland is not a member State of the EU it normally follows EU Directives. EU member States can define stricter requirements than the European Directives concerned.

CERN's legislation in matters of radiation protection is currently laid down in Safety Code F "Radiation Protection" and its underlying rules and guidelines. All is tailored to the needs of a large, international High Energy Accelerator Laboratory.

Safety Code F mainly follows the Swiss Radiation Protection Ordinance, which has the international reputation of being one of the most pragmatic radiation protection regulations. Furthermore, Switzerland was the first European country to transpose the ICRP recommendation from 1990 into national law. Indeed, in 1994, Switzerland lowered the annual exposure limit for radiation workers from 50 mSv to 20 mSv and the limit for the public from 5 mSv to 1 mSv – as recommended by the ICRP. CERN's Safety Code F issued in 1996 followed the ICRP and the Swiss Ordinance. The EU adopted the ICRP recommendation from 1990 only in 1996 with the European Council Directive 96/29/EURATOM and it took the EU member States still some years to implement the Directive (e.g. Germany in 2002 and France in 2003). However, when the Safety Code F was revised in 2006 the concept of type A and B workers* defined in the 96/29/EURATOM Directive was introduced at CERN.

As it is a political sensitive subject, radiation protection has also been the subject of several agreements between CERN and its Host States. In the past, radiation protection was covered by several bilateral agreements between CERN and each Host State. This implied different rules and procedures applying to the French and the Swiss part of the CERN site, in particular when the so-called "INB convention" between France and CERN, signed in 2000, was in effect. On 15th November 2010, France, Switzerland and CERN signed a tripartite agreement on radiation protection and radiation safety that replaced all previous bilateral agreements. This agreement defines a framework for CERN and its two Host States to discuss matters of radiation protection and radiation safety in a collaborative way and on equal footing.

CERN further participated in a working group where the Host States' Safety Authorities, ASN and OFSP, but also the French work inspectorate, the French unions and employers, as well as the Swiss SUVA (accident insurance) were represented. The aim of the working group was to reassure the French unions, in particular as to CERN's compliance with French radiation protection standards. The result of the discussions was that CERN does indeed comply with French standards but that the French contractors did not comply with their obligations

* A worker: annual dose limit is 20 mSv
B worker: annual dose limit is 6 mSv

regarding the dose monitoring of their personnel. CERN thus clarified the contractors' responsibilities in this respect, imposing independent dose monitoring for all contractors. CERN further agreed to support its contractors by designing a radiation protection course adapted to the risks at CERN.

Naturally, the communication and implementation of these measures shortly before the beginning of LS1 was quite challenging.

As was the case for LS1, LS2 will also have to adapt to regulatory changes, namely to Council Directive 2013/59/Euratom that should be implemented by all EU member States by 6th February 2018. Once again, Switzerland will most probably be the first European country to follow this EU Directive with its new Ordinance in matters of radiation protection foreseen to enter into force in 2016. As a consequence, the exemption limits for radioactive material will be lowered by a factor of 10 to 100 for common radionuclides produced in CERN's radioactive material.

Table 1: Exemption limits applicable in LS1 and LS2 for selected isotopes typical at CERN

Isotope	**LS1**	**LS2**
22Na	3 Bq/g	0.1 Bq/g
54Mn	10 Bq/g	0.1 Bq/g
60Co	1 Bq/g	0.1 Bq/g

The Operational Landscape of LS1 and LS2

CERN's radiation areas comprise of about 45 km of accelerator tunnels, the LHC experiments and five fixed target facilities for the production of secondary beams to be sent to several big experimental areas. The fixed target facilities include the radioactive ion beam facility ISOLDE and the neutron beam facility n-TOF. Both ISOLDE and n-TOF are equipped with type A and C laboratories.

LHC in LS1: the LHC and its experiments are areas of relatively low radiation risk, the major part of the LHC and the experiments are classified as Supervised Radiation Areas. The collimator region in Point 3 and the injection areas of CMS and ATLAS are Simple Controlled Radiation Areas, the collimator region in Point 7 and the beam dump caverns are Limited Stay Areas.

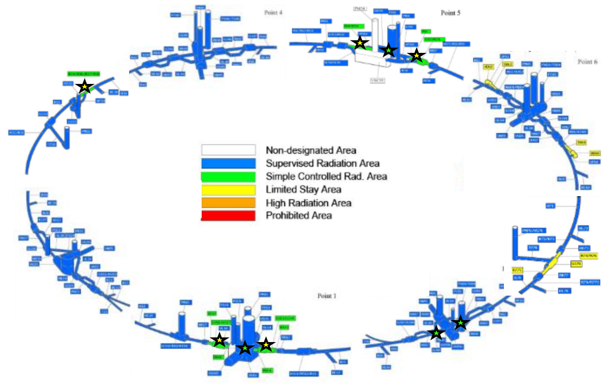


Figure 1: Radiological classification of LHC in LS1.

LHC in LS2: the radiation levels in LHC will increase due to increased beam intensity, beam energy and luminosity. FLUKA calculations based on the presently known scenarios for LHC operation until LS2 predict a dose rate increase by a factor of 3 to 4 in the collimator regions, the injection regions of CMS and ATLAS and the beam dumps. All these areas will have to be classified as Limited Stay Areas; whereas the rest of the accelerator remains quite clean meaning it should be possible to classify it as a Supervised Radiation Area.

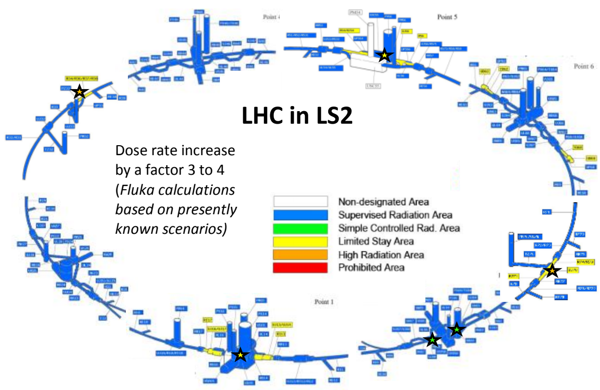
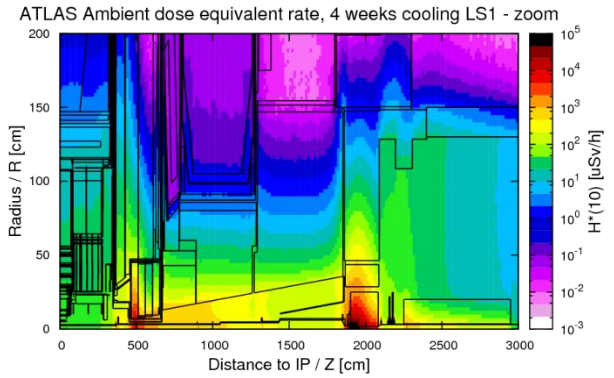


Figure 2: Radiological classification of LHC in LS2

Whereas for LHCb and ALICE no change in the radiological area classification is expected for LS2, the dose rates in CMS and ATLAS will increase by a factor of two to three. However, in some areas the dose rate will decrease as during LS1 the experiments replaced steel components by aluminium components. The major part of the CMS and ATLAS cavern will remain a Supervised Radiation Area, whereas the Forward Shielding and the Inner Detector will be classified as a Limited Stay Area.

ATLAS in LS1



ATLAS in LS2

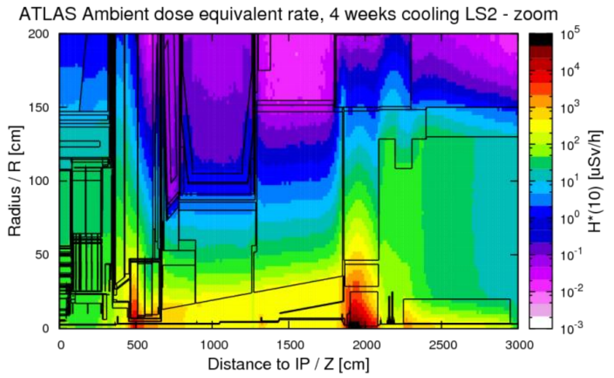


Figure 3: Radiological situation of ATLAS in LS1 and LS2

The dose rate levels in the LHC injectors and the target areas for the fixed target program will not change much from LS1 to LS2 as the activation of these facilities is already more or less in saturation. The LINACs are mainly Simple Controlled Radiation Areas whereas the rest of the injector chain is classified as a Limited Stay Area or High Radiation Area. The target areas are High Radiation Areas.

The experimental areas like the East or North Area are classified as Supervised Radiation Areas. In LS2 irradiation facilities like CHARM might need to be classified as Simple Controlled Radiation Areas or Limited Stay Radiation Areas.

The Preparatory Phase of LS1

During the preparatory phase of LS1, CERN's Radiation Protection Group faced the considerable challenge to provide high quality, sustainable and efficient radiation protection training without knowing either the exact number or the arrival dates of the participants.

CERN's Radiation Protection Group developed a new, radiation risk based training concept that fulfilled these requirements and that was endorsed by the Host States' authorities competent in matters of radiation protection and radiation safety. Whereas in the past all radiation workers had to follow a half-day, face-to-face theoretical training course, the new scheme introduced an e-learning based radiation protection course for all workers intervening in Supervised Radiation Areas and a full day face-to-face radiation protection training course for all workers intervening in Controlled Radiation Areas. The course for workers in Controlled Radiation Areas consists of half a day theoretical training and half a day practical training. A dedicated training room was acquired and installed close to the LHC mock-up on CERN's premises in Prévessin to allow for an integral radiation protection and radiation safety training. The training content for both types of RP courses is subject to continuous updates, integrating relevant changes in radiation protection procedures as soon as they become applicable. Due to this approach, no additional resources are required to prepare the content of the LS2 radiation protection training.

In total 4,767 persons successfully passed the e-learning course for Supervised Radiation Areas and 2,224 persons were trained in the one day face-to-face RP training course for Controlled Radiation Areas (1401 workers by the company SOFRANEXT since September 2012, 823 workers by CERN since March 2013).

With respect to operational radiation protection in LS1, several preparatory actions had been taken:

1) in his New Year's Speech 2013, the Director General announced an annual CERN dose objective of 3 mSv for radiation workers
2) in collaboration with the computer specialists of the HSE unit, CERN's Radiation Protection Group developed the data base RAISIN which lists all CERN's radiation areas (about 1000) and the corresponding radiological classifications. All persons with a NICE password have access to this database to find out the type of RP training required and to gain prior knowledge of the radiological situation of the workplace
3) CERN's Radiation Protection Group implemented a new operational dosimetry system which allows the immediate follow-up of operational doses. The system has been operational since March 2013
4) the new operational dosimetry system was integrated into the IMPACT work planning tool, a tool which now provides outstanding efficiency with respect to assigning doses to jobs and to dose follow-up
5) integration of RP's Work and Dose Planning (WDP) tool into the IMPACT tool which allowed the immediate comparison of the measured operational dose with the estimated dose.

The first ALARA committees for jobs costly in individual and collective doses or with increased radiological risks had already been held before the beginning of LS1. About 10 ALARA committees approved 11 jobs, with a total estimated collective dose of 423 man·mSv.

Radiation Protection during LS1 – Some Key Figures (status July/August 2014)

During the period from 1st March 2013 until 31st July 2014 the individual doses added up to a collective dose of 1,129 man.mSv. Two workers received an individual dose of more than 3 mSv/12 months (3.1 mSv and 3.4 mSv) and one worker received 4.2 mSv during the entire period mentioned above. In total, the CERN dosimetry service performed 13345 assignments of an individual dosimeter (DIS) to a radiation worker. The Associated Members of Personnel (MPA) represented the largest group, receiving 47% of the collective dose. CERN staff received about 22% and contractors' personnel 31% of the collective dose. In total 1,500 operational dosimeters were distributed for specific jobs in Supervised and Simple Controlled Radiation Areas (e.g. PS ventilation refurbishment) and for all jobs in Limited Stay and High Radiation Areas.

The Radiation Protection Group performed radiation surveys at several stages of the LS1, the first one at the very beginning of the shut-down. The resources for all surveys accumulated to 34 man·weeks, 2 for the PS complex and 16 each for the SPS complex and the LHC. The Radiation Protection Group validated 3,597 IMPACTs in total, including those with job and dose planning. More than 34,000 radiological checks of components had been performed and in total more than 2,982 tons of material measured. 2,302 tons had been found to be radioactive and 680 tons of the radioactive material were declared as radioactive waste.

In total 2,410 separate internal radioactive transports were performed by CERN's transport service. 1,145 transports departed from CERN/Meyrin, 527 from Prévessin and 738 from the various SPS and LHC points.

Radioactive goods were imported (36 packages) and exported (50 packages). The analytic laboratory performed 2,729 γ-spectrometry measurements and 7,318 measurements of alpha- and beta-contamination.

The calibration service calibrated 420 monitors from the ARCON/RAMSES system and 12,734 DIS dosimeters. Additionally, 163 new monitoring channels were added to RAMSES during LS1.

The Radiation Protection Group received 680 tons or 1,677 m^3 of radioactive waste in total. Unfortunately, the numerous non-conformities of the radioactive waste received caused additional costs in terms of resources (personnel, time and space). For example, about 1,800 bags of so-called burnable waste were received but 600 needed to be re-sorted as they contained metal pieces – which is not in compliance with the procedure for waste sorting at the source.

During checks on conventional waste, 56 radioactive items had been found in conventional waste bins, 8 in the recuperation centre for conventional waste and 16 were found during radiological checks on trucks by the gate monitor in Prévessin.

The GS Department, which manages the storage of radioactive material, could accommodate all requests during LS1 (2,450 m^3 for TE, 13 m^3 for EN, 30 m^3 for CMS, 12 euro palettes for BE). Even highly radioactive material like 7 septas, 16 magnets and 4 quadrupoles could be stored. However, today there is no more storage space available for heavy material and rack space is available for only a few euro palettes. GS Department proposes the extension of building 954 to overcome this critical space shortage.

Roadmap Towards LS2

The storage of both radioactive material and radioactive waste requires decent planning to ensure the availability of space, in particular in view of the LS2. Whilst a forecast for the production of radioactive waste for the next years including LS2 already exists in the form of the waste study, a similar survey has to be conducted for the storage of radioactive material. These forecasts have to be updated on a regular basis, preferably annually or at least bi-annually. As a lesson learnt from LS1: the forecast for radioactive waste for LS1 was performed at the beginning of 2013 and concurred with the amount delivered until the end of 2013. However, in 2014 about 2.5 times more than forecast was received. Finding a solution for the missing storage space should be considered as high priority – not only for LS2 but already for the shut-downs during the second LHC physics run.

Some regulatory changes have to be taken into account for LS2. CERN inter-site radioactive transports will have to be performed according to the international transport rules (ADR). Although the EN Department and the HSE Unit already acquired the necessary transport containers, some practical issues still need to be solved as loading and unloading the containers does not always conform to the ALARA principle. In addition, administrative issues still need to be discussed within the Tripartite to keep the "paperwork" at a reasonable level.

As already mentioned earlier, the exemption limits for some CERN specific radionuclides will decrease by a factor 10 to 100, representing a challenge to the measurement techniques applied by the Radiation Protection Group.

The responsibility of employers in matters of radiation protection has been clarified unambiguously for contractors, but not yet for associated members of the personnel (MPA). This subject is presently under discussion.

The lessons learnt from LS1 for LS2 are:

1. Communication throughout the preparatory phase and the entire shut-down period is essential. Well defined communication channels between the Departments and the Radiation Protection Group need to be established to avoid misunderstandings, frictions and delays.
2. Departments and the Radiation Protection Group need to ensure collaboration at an early stage for

all relevant technical specifications to avoid frictions, delays and extra costs.

3. The RP training for LS2 is continuously updated and does not require any specific modification for LS2.
4. The Dosimetry Service demonstrated its capacity to handle large amounts of radiation workers and to follow-up individual doses.
5. The operational dosimetry system is adequate for LS2; however the use of pool dosimeters will be promoted. A group of workers who are not frequently in radiation areas are asked to share dosimeters.
6. Forecasts for dose rates in LS2 are available, for LHC by Monte Carlo calculations, for injectors and auxiliaries via long-standing experience.
7. CERN's approach to ALARA is adequate; today it is an essential and natural part of CERN's culture.
8. Worksite planning and management needs further improvement. Excellent examples of planning and coordination from a radiation protection point of view had been the AD strip line repair, the Booster Beam Dump exchange and SMACC. Other worksites gave rise to concerns such as, for example:
    a. language problems between radiation protection personnel and contractors
    b. inadequate information flow between contractors' foremen and workers
    c. technically unskilled workers causing additional doses
    d. unsatisfying cleaning of the worksite
    e. end of shut-down cleaning was left to the Technical Coordinator and the Radiation Protection team.
9. The radiological characterization of potentially radioactive material and waste represents a challenge for the Radiation Protection Group.
10. Transport rules and procedures need to be finalized by RP and EN and agreed by the competent Host States authorities.
11. The needs for radioactive workshops need to be identified for LS2. In LS1 all requests were fulfilled.
12. The forecast for storage needs for radioactive material and waste has to be done for accelerators and experiments. First actions have already been taken by RSOs, RP and GS.
13. The forecast for radioactive waste exists, but the capacity for waste storage depends on the operation of the Radioactive Waste Treatment Centre:
    a. CMS still occupies space in ISR3 and building 184 but is ready to move out
    b. the agreement on project support by GS-SE is still pending.

CONCLUSIONS

Although LS1 was the first experience of a long shut-down in all CERN's radiation areas (including LHC), the results in terms of radiation protection were satisfactory. The new radiation protection training scheme allowed all radiation workers to be trained in time and according to the risks present. Thanks to an efficient shut-down planning by the EN planning team and the implementation of organizational and technical means such as IMPACT and the operational dosimetry system, the strong commitment of CERN's management to the ALARA approach finally resulted in a satisfying dose record. There were no radiological accidents to report and the collective dose was 1,129 man.mSv since 1st March 2013. Only two workers slightly exceeded the CERN dose objective of 3 mSv in 2013.

All radioactive material and waste is stored by GS and RP, respectively. However, additional storage space for the future has to be identified.

The roadmap towards LS2 has been identified - thanks to the "dry-run" LS1. However, it has to be followed rigorously to face and overcome the challenges of the next long shut-down.

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