BJRS

BRAZILIAN JOURNAL
OF
RADIATION SCIENCES
11-01A (2023) | 01-10 | e2177

Enhancing radiation protection at Sirius: methodology and results of beamline training

Vieira A. L. C., Moura F.N.

Centro Nacional de Pesquisa em Energia e Materiais, R. Giuseppe Máximo Scolfaro, 10000 – Bosque das Palmeiras, Campinas - SP - ana.vieira@cnpem.br

ABSTRACT

This work is about radiation protection training at Sirius, a unique radiation facility in Brazil for being a synchrotron-type particle accelerator. Research in several areas takes place at the facility, attracting researchers from all over the world. The radiological protection group at Sirius works continuously to ensure everyone's safety, in addition to shielding and monitoring, there are several security elements and one of them is the application of radiological safety training, where the researcher is presented the "Search" procedure. At the end of the training, the researcher answers a feedback form, which is used as a satisfaction survey. In the first semester for 2022, 46 people were trained of which 43.47% responded to the feedback form. Of the total responses, 95% were satisfied. Due to the large number of people attending Sirius, the radiation safety training is in the process of moving to an online format, which brings new challenges.

Keywords: **Training, radioprotection, synchrotron.**

ISSN: 2319-0612
DOI: https://doi.org/10.15392/2319-0612.2023.2177
Submitted: 2022-11-28
Accepted: 2023-11-10

1. INTRODUCTION

The synchrotron Sirius, figure 1, is an unique machine in Brazil, installed at The National Center for Energy and Materials Research (CNPEM). The synchrotron is a particle accelerator, which reaches 99% of the speed of light, capable of generating a broad-spectrum radiation called synchrotron radiation. With it, it is possible to analyze and understand the structure of various materials, from rocks to proteins. [1].

Figure 1: *Sirius building*

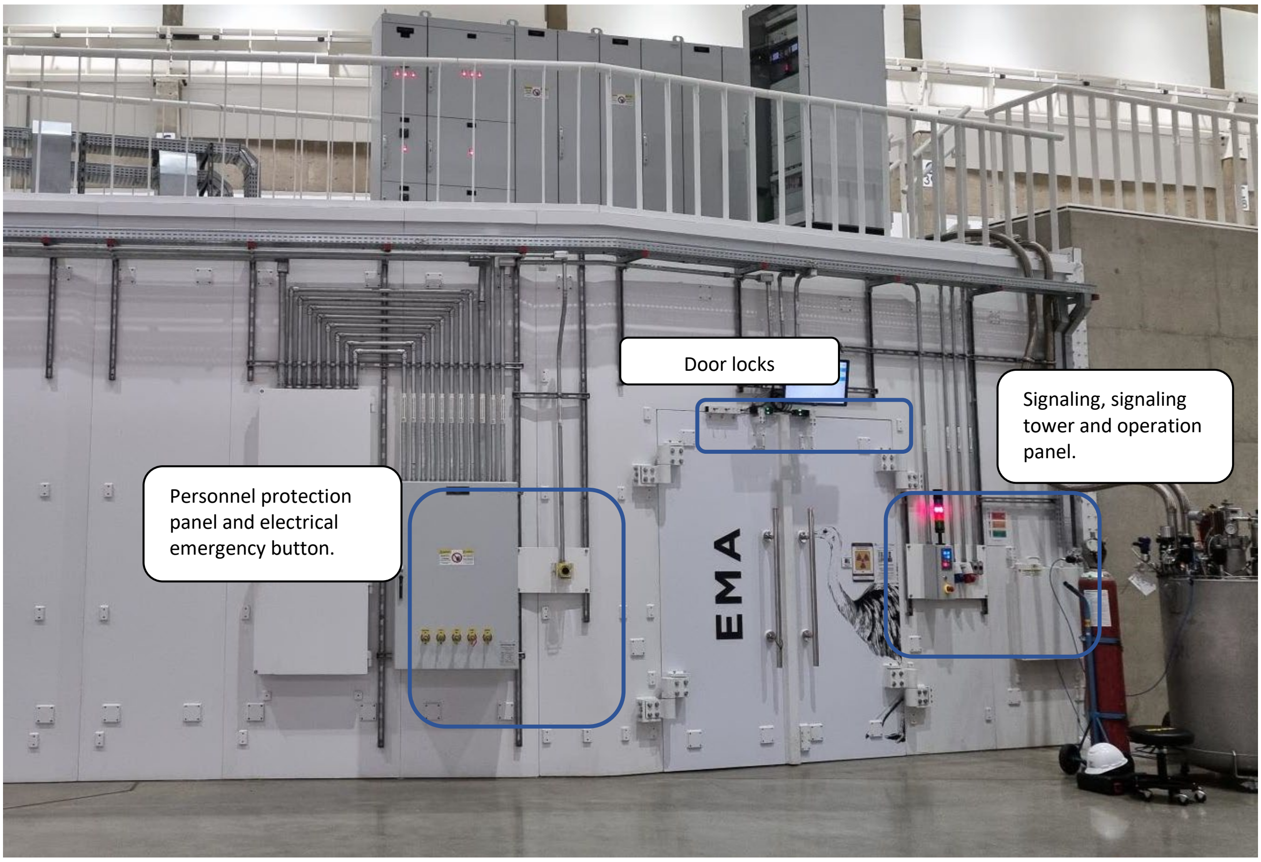
From an electron gun, by thermionic effect, the electrons are accelerated in a linear accelerator until they reach an energy of 150 MeV. For the final energy of the machine, which is 3 GeV, there is a second accelerator called an injector ring. The electron beam goes to the storage ring where it will remain in a circling orbit. At each turn, a portion of electron energy is lost tangentially to the magnetic lattice, due to the output of synchrotron radiation to the experimental stations called beamlines [1].

The beamlines are composed of hutches, designed to accommodate the sample analysis instruments where the synchrotron radiation will focus; and to ensure that the radiation generated is contained within its shielding [2]. In addition, there are several security elements involving its operation, such as security locks and keys, light curtains, signaling towers, emergency system, and the “Search” procedure. Figure 2 depicts the elements of the PPS (Personnel Protection System) on the EMA (Extreme Condition Methods of Analysis) beamline.

The “Search” procedure is the way to enable a beamline hutch for operation, only trained people should carry out this procedure, which consists of confirming whether the safety conditions inside the hutch are in place based on a sequential inspection of the control elements interlocking and ensuring that no person remains on-site during operation [3].

Sirius was designed to serve the entire scientific community in the world; therefore, thousands of researchers are expected to use the beamlines for their experiments. Thus, it is essential to implement Radiological Safety training for the beamlines, enabling researchers to perform the “Search” procedure and simulate emergency conditions and beamline failures, instructing individuals on the appropriate course of action in such situations.

Figure 2 : *Hutch of a beamline with security elements*



2. MATERIALS AND METHODS

The training applied by the Radiological Protection Group on Sirius takes as reference the training of other synchrotrons such as Diamond (Oxfordshire, England) [4] and MAX IV (Lund, Sweden) [5].

The “radiological safety on the beamlines” training at Sirius is carried out periodically with groups of researchers and is valid for one year. It is split into a theoretical and a practical part.

The theoretical material, shown in the figure 3 below, is divided into the following topics:

- Atomic structure: constituents of the atom, atomic number, mass number, and isotopes;
- What is radiation?: Origin of radiation, devices generating radiation and radioactive elements, ionizing and non-ionizing radiation;
- Physics of radiation: decay modes, modes of interaction of radiation with matter;
- Radiation protection: what radiation protection is, assumptions in radiation protection, radiation protection philosophy;
- Radiological protection on Sirius: Shielding, radiological monitoring systems on Sirius
- Search the beamlines: elements of the personnel protection system, signaling, emergency, and search procedure;
- Final questionnaire.

Figure 3: *Visual of the theoretical material*

With the theoretical part completed, the researchers can go to the practical part with the Radiological Protection Group. Currently, training is in person at the beamline chosen for the research, with the following topics:

- Radiological protection at Sirius: shielding, interlock, radiological monitoring system;
- Search the beamlines: elements of the personnel protection system, signaling, emergency procedure;
- Carrying out the “search” procedure.

The training begins with an explanation of each interlocking element, such as the signaling tower, safety switches, light curtain, access to cable passage doors (chicanes), and safety locks. Subsequently, the researcher performs the “Search” procedure, dealing with adversities caused by the Radiological Protection Group, simulating operating situations, and demanding a better understanding of the signals arising from failures generated by the safety system.

With the annual retraining of researchers, it is possible to keep them updated on the procedure, enabling a dialogue between collaborators and the Radiological Protection Group. Upon completing the training, the researcher is authorized to continue with the work on the beamline and invited to answer a feedback questionnaire to indicate the strengths and weaknesses of the training.

The form was created using Microsoft Forms, a tool developed by Microsoft that allows you to create personalized questionnaires, polls, and surveys with multiple choice, short or long answer questions, classification, and other options. The form developed to collect feedback on this training consisted of questions shown in the table 1 below.

Table 1 : Feedback form questions and answer field

Questions forms	**Answer**
Regarding the theoretical content, do you consider that:	Met expectations/ Partially met expectations /Did not meet expectations
Comment on what you thought of the theoretical content**:**	Discursive answer
Based on the practical training, do you consider that:	Met expectations/ Partially met expectations /Did not meet expectations
Regarding the communication and didactics (instructors), express your opinion about.	Discursive answer
Is there any procedure that was not completely clear?	Yes/No
Comment on this procedure that raised doubts	Discursive answer
Is there an emergency or failure that is not entirely clear?	Yes/No
Comment on the situation that raised doubts	Discursive answer
Is there another question that was not addressed previously or in the training?	Yes/No
Comment your question so we can answer	Discursive answer
From 0 to 10, with 0 being unsatisfactory and 10 being completely satisfactory, what did you think of the radiological safety training on the beamlines?	0 to 10

The "Discursive answer" are open fields, and the others are alternative answers. The estimated time to complete the form is 2 minutes.

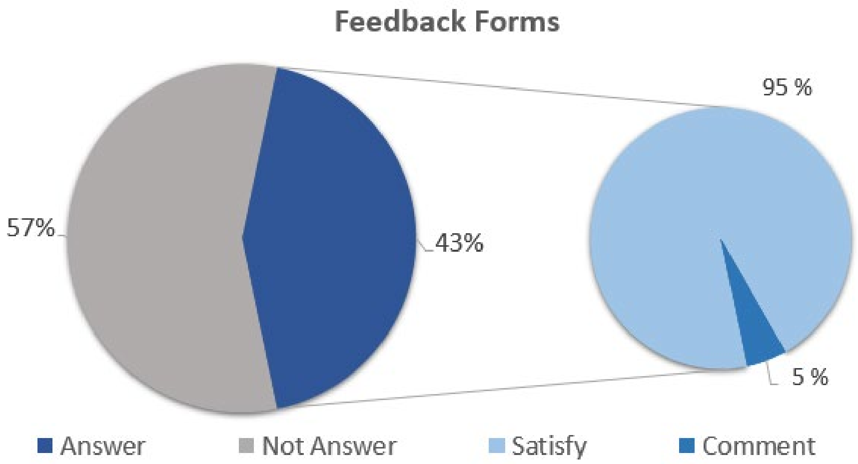
3. RESULTS AND DISCUSSION

The training described in the previous section went through a structuring period during 2021 and in 2022 the standard training procedure was consolidated.

During the first half of 2022, a total of 46 people were trained, of which 20 (43.47%) responded to the feedback form. Of these, 19 people (95%) were satisfied with the theoretical content and all with the practical content, figure 4. These results were obtained using the form developed in Microsoft Forms considering the total number of people trained and the number of people who responded to the feedback forms.

Of the people who answered the questionnaire, it was possible to carry out a satisfaction analysis based on the answers to the questions presented in Table 1. If the answers indicated any remaining doubts or suggestions for improvement, it was considered that the user was not completely satisfied with the training, if there were no doubts or suggestions, it was considered that the user was satisfied.

Figure 4 : *Results of the feedback forms*



There were comments and suggestions regarding the theoretical training, where the material was praised for its didactics and for being able to fully present the subjects addressed. It was pointed out that the material was extensive, with an estimated reading time of 45 minutes, and that it could bring more information about synchrotron radiation. It was also suggested to insert videos demonstrating the "Search" procedure in the first part of the training so that researchers would arrive at Sirius already familiar with how to perform it. Regarding practical training, 15 people praised the didactics and the team's attention in answering questions about the procedure, in addition to the fact that the content was transmitted clearly and objectively. The low response rate indicates a need for improvement in the feedback acquisition system. As solutions, the use of physical forms or tablet devices to collect responses at the training site, as well as providing users with QR Codes to the form page are possible solutions currently in analysis by the Radiological Protection Group.

But even with the low response rate, there were improvements in training due to feedback such as identifying doubts and adapting the material to become more accurate. Comparing Sirius to similar facilities around the world on which radiation protection training was based Diamond is a 3rd generation synchrotron with over 15 years of experience. From March 2021 to April 2022, they received more than 1,106 proposals, which surpassed 2,000 users in that period. On their website, in Training and Workshops, you can access the "Health Physics: Radiation Safety Training" page. The local rules for accelerators and beamlines are available, included a training video on safety elements and the procedure for searching the beamlines with an instructor indicating the steps to be taken. At the end, the researcher must answer a multiple-choice questionnaire with eleven practical questions related to the video. The training is valid for 2 years.

The MAX IV, on the other hand, is a 4th generation synchrotron, which started its activities in 2016; however, it has more than 30 years of experience since the MAX I-III. On its main page, under User access, Safety part, it is possible to download a file with general safety guidelines including radiological protection. After reading the file, the researcher must access the site with login and password provided by the facility to complete a safety questionnaire with multiple choice questions about safety, including radiological information about signs and procedure. The training is valid annually. In 2022, MAX IV hosted 1399 user visits.

Sirius training must follow in the footsteps of these consolidated synchrotrons, aiming at increasing the number of users and the demand for training.

4. CONCLUSIONS

The training materials were developed by Sirius's Radiological Protection Group to clarify and demystify the use of radiation and explain the system of personnel protection in the beamlines. Practical training proves to be an effective method to enable people regarding safety procedures and the measures that must be taken in radiological emergencies. Proximity to the public enabled revisions in the material to make it clearer about the area of radioprotection and safety systems in the installation.

Sirius was designed to attend national and international users and researchers, in the first quarter of 2023, 50 users were served, distributed across 6 different beamlines. Considering this value as a basis for calculating the annual flow of users, we can consider around 200 users per year with the machine in its current state, but Sirius is still in the commissioning stage, having the capacity to operate 38 beamlines in its final configuration, significantly increasing the number of users.

As a result, training in radiological protection must rely on a constant review of the didactic material, to ensure that the human step (a person carrying out the necessary procedures) is kept up to date. All persons trained for such a procedure are members of the public, as described in the CNEN NN 3.01 standard [5].

As a general result, there are positive indicators of satisfaction and efficiency (without recurrences) in the radiological safety training applied by the Radiological Protection Group. Another perspective that can be pointed out is that in the future, due to the large flow of people, this training will be updated to an online format exclusively for the practical part. Based on a recording, the instructor will explain about the safety components of the beamline and how to correctly perform the search procedure. The adoption of recording for radiological protection training is common in other synchrotrons around the world, allowing the researcher to watch the procedure repeatedly before arriving at the facility. The Radiological Protection Group's contact with the researchers is maintained based on the sharing of theoretical material and continuous assistance.

REFERENCES

[1] PROJETO SIRIUS, **A nova fonte de luz brasileira**. Available at < http://www.lnls.cnpem.br/wpcontent/uploads/2016/08/Livro-do-Projeto-Sirius-2014.pdf >. Acesso em: 10th june, 2022.

[2] DE MORAES¹, Isabela Castro et al. **Análise para cálculo de blindagem de cabana óptica para linha de luz do Sirius.**

[3] LIN, T. F.; WANG, J. P. **The Safety Interlock System of Synchrotron Radiation Research Center.** In: Proceedings Particle Accelerator Conference. IEEE, 1995. p. 2108-2110.

[4] Diamond**. Health Physics: Radiation Safety Training**, 2022. Available at. < https://ionactive.co.uk/training/rps-training?gclid=Cj0KCQiA-JacBhC0ARIsAIxybyN5xDGWX8dijniQ9K0IjpegdKa1s8EpkJykIfOLmmaAQRZG_QVAvcwaAqzREALw_wcB > Last acessed : 11th june, 2022.

[5] MAX IV. **Safety requirements for users, 2023.** Available at < https://www.maxiv.lu.se/user-access/safety/safety-requirements-for-users/ > Last acessed : 09th july, 2023.

[6] CNEN - Comissão Nacional de Energia Nuclear, CNEN-NN-3.01, **Diretrizes básicas de proteção radiológica**, 2014