11th International Workshop on Radiation Safety at Synchrotron Radiation Sources (RadSynch23)

ESRF, Grenoble, France

30 May-2 June 2023

Book of Abstracts

Session 1 – Facility Upgrades / New Projects

The ESRF Extremely Brilliant Source (EBS)

Berkvens P., Colomp P.

ESRF, 71, avenue des Martyrs, 38000 Grenoble, France

On 10 December 2018, after 25 years of User Service Mode Operation, the ESRF X-ray source was shut down for an upgrade to a brand-new storage ring, the Extremely Brilliant Source (EBS). Less than 12 months later, on 2 December 2019, the first electrons were injected in the new storage ring and 4 days later, on 6 December, the first beam was stored. On 28 February 2020, the design value of 200 mA stored beam in the new EBS storage ring was reached for the first time. User Service Mode resumed on 25 August 2020, essentially six months ahead of schedule.

The presentation briefly recalls the radiation protection challenges of the new storage ring with respect to the old one and will give an overview of the results from radiation measurements during the new storage ring commissioning, the beamlines commissioning and the now almost three years of User Service Mode. The results of these radiation measurements are compared with the results of the radiation shielding study for the EBS storage ring.

Radiation Shielding Calculations for the ALS Upgrade Project

Trovati S., Liang T.*

Lawrence Berkeley National Laboratory, 1 Cyclotron Road, Berkeley CA-94720, USA
*Deutsches Elektronen-Synchrotron, Notkestraße 85, 22607 Hamburg, Germany

The Advanced Light Source (ALS) at the Lawrence Berkeley National Laboratory is undergoing an upgrade (ALS-U), which will result in the production of much brighter and highly focused X-ray beams. The storage ring will be completely replaced by a new 9-bend achromat ring and an accumulator ring will be added to the accelerator chain. The increase in stored-beam losses due to the substantial decrease in beam lifetime, and the addition of the accumulator ring and new transfer lines, will change the dose intensity and distribution outside the shielding. Beam collimators will be installed in the more heavily shielded sectors of the storage ring to intercept most of the losses. ALS-U has planned to retrofit all the ratchet walls with floor-to-ceiling lead panels and to increase the thickenss of the roof blocks above the injection sectors during the so-called dark time, when the storage ring will be decommissioned and replaced with the new one. Shielding retrofit at the ALS is challenging, due to existing space constraints and the additional infrastructure needed for the accumulator ring and the new storage ring.
This study deals with the radiological impact of the upgrade. Methods and results of the analysis performed to assess existing and planned accelerator shielding against the new electron beam parameters and losses, and to provide new requirements, are presented.
Source terms and attenuation lengths have been calculated for several targets, scattering angles and shielding materials, using Monte Carlo simulations and analytical models. Both pure and combined materials have been considered. The shielding data, validated with measurements at the ALS, can be used to quickly and reliably calculate shielding requirements for a large number of source and shielding combinations, without the need for a Monte Carlo simulation when beam parameters or layout change. Several safety factors have been included in the analysis, for instance by increasing the beam loss assumptions, maximizing the radiation yield from a target, and increasing occupancy factors.
The results show that, in general, the planned retrofit of all ratchet walls is adequate to attenuate the dose below the legal requirements and the design goals set in the ALS-U shielding policy. Only the collimation sectors will require additional shielding to mitigate the dose outside the walls and on the roof. Additional controls will be needed to limit the access to the roof in those sectors where a retrofit is not planned.

Acknowledgments
This work was supported by the Director, Office of Science, Office of Basic Energy Sciences, of the U.S. Department of Energy under Contract No. DE-AC02-05CH11231

Shielding assessments for Diamond II machine upgrade

Faruk S, Doull R.E.

Diamond Light Sources Ltd, Harwell Science & Innovation Campus, Didcot, Oxfordshire, UK, OX11 0DE

The Diamond II machine will be upgraded to increase the brightness and coherence of the emitting synchrotron light [1]. The Linac will operate at 150 MeV, and the Booster and storage ring will be operated at 3.5 GeV with 300-mA current. The initial shielding calculation for Diamond was done at 100 MeV for the Linac and 3.0 GeV at 500 mA for the Booster and Storage Ring. An empirical and semi-empirical analysis, the SHIELD11 code, and the FLUKA [2, 3] particle transport code were used to evaluate potential radiation hazards. Under normal and abnormal loss conditions, the dose rate outside the Storage ring was below 1 mSv/y. Doses >1 mSv/y doses were calculated in the following areas: In Booster zone 1, we observed a possible high radiation dose rate of 90 μSv/h between the Linac and Booster inner walls under normal loss conditions. Abnormal loss conditions due to beam miss-steering in a quadrupole corrector magnet can lead to a dose rate of 90 μSv/h around the Linac rear entrance and 30 μSv/h on the primary entrance side. The Linac to Booster (LTB) dipole beam miss-steering could lead to a dose rate of 90 mSv/h in the Booster on the other side of the Linac back wall. Abnormal loss in the Faraday cup in the Linac enclosure could, in principle, lead to a dose rate of up to 30 μSv/h around the Linac rear entrance and 1 μSv/h on the main entrance. Additional local lead shielding will be used to reduce the local dose limit to 0.5 μSv/h (1mSv/y for 2000 hrs working year). Personal Safety System Controls will also be used to exclude people from areas.

References

[1] – R. P. Walker *et al* Diamond-II: Technical Design Report, (2022)

[2] - "The FLUKA Code: Developments and Challenges for High Energy and Medical Applications" T.T. Böhlen, F. Cerutti, M.P.W. Chin, A. Fassò, A. Ferrari, P.G. Ortega, A. Mairani, P.R. Sala, G. Smirnov and V. Vlachoudis, Nuclear Data Sheets 120, 211-214 (2014)

[3] - "FLUKA: a multi-particle transport code" A. Ferrari, P.R. Sala, A. Fasso`, and J. Ranft, CERN-2005-10 (2005), INFN/TC_05/11, SLAC-R-773.

Radiation Shielding Evaluation of 4th Generation Storage Ring in Korea

JUNG Nam-Suk

Pohang Accelerator Laboratory / POSTECH

The ultra-low emittance storage ring light sources, called 4th Generation Storage Ring (4GSR), are being planned or under construction worldwide. The construction project of the 4GSR in Korea, called 'Multipurpose Synchrotron Radiation Construction Project', was launched in July 2021. The emittance of the storage ring is 61 pm-rad with 799.2 m circumference multi-bend achromat (MBA) lattice. The stored electron beam energy and current are 4 GeV, 400 mA. The injector of the storage ring (SR) is composed by 200 MeV linac and booster ring. SR and booster ring share the same tunnel. Detailed designs for the accelerator, beamlines and infrastructures are in progress.
In this presentation, the current results of radiation shielding evaluation is introduced based on the present design conditions. The appropriate shielding criteria were established based on Nuclear Safety Act in Korea and ALARA principle. As the beam loss scenario, the injection efficiency was assumed as 90% with the consideration of the recent trend of SR shielding design. The two injection points, BTS (booster-to-SR) and LTB (linac-to-booster), are located nearby in the SR-booster tunnel. Accordingly, different tunnel thicknesses were applied by classifying the area into injection area and non-injection area.

This research were supported in part by the Korean Government MSIT(Multipurpose Synchrotron Radiation Construction Project).

Shielding design for NanoTerasu: Gas bremsstrahlung and induced radiations

Akihiro Takeuchi[1], Masayuki Hagiwara[1], Hiroki Matsuda[1], Toshiro Itoga[2], Hiroyuki Konishi[1]

[1] National Institute for Quantum Science and Technology, 6-6-11-901, Aza Aoba, Aramaki, Aoba-ku, Sendai-shi, Miyagi, 980-8579, Japan
[2] Japan Synchrotron Radiation Research Institute, 1-1-1, Kouto, Sayo-cho, Hyogo, 679-5198, Japan

A compact 3-GeV synchrotron light source (NanoTerasu) is under construction at Tohoku University's new Aobayama campus in Japan and is expected to be operational in April 2024. This facility provides highly brilliant soft X-rays with energies ranging from 50 eV to 2 keV. The storage ring can be equipped with 28 beamlines, with the first 10, which will be installed in April 2024. This facility was designed to keep the experimental hall from the radiation-controlled area under a policy that "users can participate in synchrotron radiation experiments as much as possible without the license of the radiation workers."

Gas bremsstrahlung, generated by the electromagnetic interaction between stored electrons and residual gas in the storage ring, is an important radiation source in the shielding of synchrotron radiation facilities. So far, air has been conventionally assumed as a bremsstrahlung target in the storage ring for the shielding design [1]. On the other hand, hydrogen was dominant in the residual gas of the storage rings in recent synchrotron radiation facilities. The major residual gas in the electron storage ring is estimated to be hydrogen with the atomic ratio of 50.9% in NanoTerasu [2]. To study the effect of residual gas composition on the dose rate outside the shield, we calculated the intensity of gas bremsstrahlung with the gas composition in the storage ring for not only air, but also residual gas expected under realistic vacuum conditions using an analytical formula and a general-purpose Monte-Carlo code for particle transport calculations. The analytical shielding design with a realistic gas composition well reproduced the energy spectra of gas bremsstrahlung simulated by the Monte-Carlo code which were validated by experimental data. Comparing air and residual gas compositions, the intensity of gas bremsstrahlung in the residual gas is 0.43 times lower than that of air.

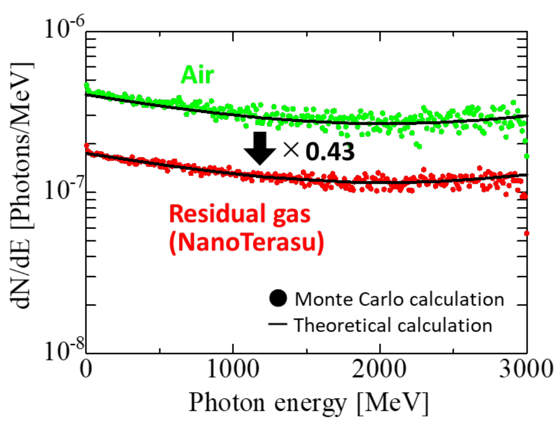


Figure.1 Comparison of Monte Carlo and theoretical calculations of gas bremsstrahlung energy spectrum

References

[1] Y. ASANO and N. SASAMOTO, "Characteristics of shielding design calculation for the SPring-8 synchrotron radiation beamlines," Radiat. Prot. Dosim., 82, 3, 167 (1999).
[2] Accelerator design report for 3-GeV Next-Generation Synchrotron Radiation Facility, https://www.qst.go.jp/uploaded/attachment/18596.pdf

Shielding Design and Current Status of New Compact Synchrotron Facility

Hee-Seock Lee[1,2], Mahdi Bakhtiari[2], Ukjae Lee[1]

[1]Pohang Accelerator Laboratory, POSTECH, Pohang, 37673, South Korea
[2]Div. of Advanced Nuclear Engineering, POSTECH, Pohang, 37673, South Korea

Pohang Accelerator Laboratory has constructed new compact synchrotron facility for developing EUV (Extreme Ultra-Violet) light source, PAL-EUV. In February 2023, its commissioning started. The PAL-EUV consists of 20 MeV s-band linac, 400 MeV booster synchrotron and 400 MeV storage ring (140 mA of stored current, 36 m of circumference). At initial step, one EUV beamline is ready for a semiconductor industry. Three accelerators are located in one box-style ordinary concrete tunnel.
The PHITS code was used for the shielding analysis. Several assumptions of beam loss were introduced for normal operation conditions and accidental operation conditions. The injection efficiency is also critical factor to determine the shielding structure and to estimate the expose dose to workers. The literature information or operation experience of PLS-II were applied to assume an injection or extraction efficiency. Two near dipole magnets are energized using one current supply unit, which is a different concept to the dipole of PLS-II storage ring by increasing the probability of electron beam path to EUV beamline. The safety magnet is set up at the risky beamline. In this presentation, the philosophy of beam loss in shielding design and the operation status of the PAL-EUV in commissioning step are introduced. The photography is overall view of accelerator complex in the accelerator tunnel before closing lid concrete plates.

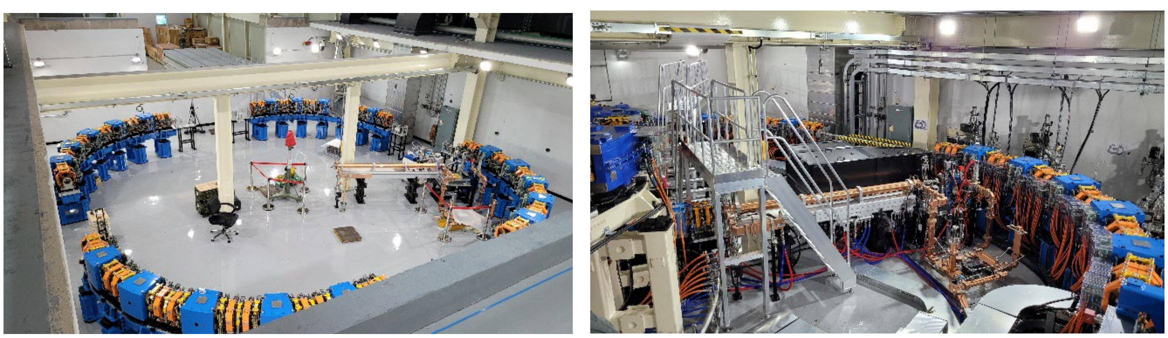


Figure 1: PAL-EUV on construction (left) and on commissioning period (right).

Building new personnel safety systems for the PETRA IV complex.

Michael Dressel

Deutsches Elektronen Synchrotron DESY, Notkestr. 85, 22607 Hamburg, Germany

In the planed DESY project PETRA IV the PSSs for the whole accelerator chain Linac 4, Booster, PETRA 4 storage ring and the 31 beamlines with a total of about 100 experiments and optics hutches will be replaced or newly built using PLC technology. In this talk the necessities for the replacements and some of the methods envisioned for the requirements assessment, design and development will be outlined.

Shielding Considerations for BEATS beamline (SESAME)

Zahran I.Y*, Hamad A.M*, García-Fusté M.J.[1]

* SESAME (Synchrotron-Light for Experimental Science and Applications in the Middle East), Allan 19252, Jordan, [1]ALBA Synchrotron Light Source, Barcelona, Spain.

BEATS (BEAmline for Tomography at SESAME) beamline will have a 3T 3-pole-wiggler as insertion device located on a short straight section of the SESAME storage ring. The beamline aims at producing synchrotron beams in the range of hard X-ray for tomography techniques.
This work gives the recommendation for the shielding of BEATS hutches: material and thickness for the different walls. Those requirements have been checked by FLUKA Monte Carlo simulation to ensure that the outside contact radiation levels are below the guideline of 0.5 μSv/h limit when considering a vacuum chamber pressure of 5×10^{-9} mbar. All the calculations were done under the supervision of Radiation Protection Service of ALBA synchrotron.

Elettra 2.0 project: radiation protection issues for the new and upgraded beamlines

Tromba G.[1], Casarin K.[1], Alikaniotis K.[1], Scian G.[1], Berkvens P.[2]

[1]Elettra-Sincrotrone Trieste S.C.p.A. S.S. 14 - km 163,5 in Area Science Park, 34149 Basovizza, Trieste (I)
[2]ESRF, 71, avenue des Martyrs, 38000 Grenoble (FR)

In the next years Elettra synchrotron will undertake a major upgrade program by enabling new science and the development of new technologies.
The main features of the Elettra 2.0 machine are an important increase of the brilliance and coherence fraction of the source as compared to today's configuration. This objective should be reached without compromising the stability and reliability of Elettra and without increasing the operational and electricity costs.

The driving concept for the new machine is the substantial reduction of the emittance of the stored electron beam, targeting emittance levels capable of providing a diffraction limited X-ray source also in the horizontal plane, while such a limit is already achieved at Elettra for the vertical plane. Therefore, the new machine will provide intense nano-beams in the range of VUV to X-rays for the study of matter with very high spatial resolution.
The project will also take on board the demands of the X-ray users' community, increasing the offers for applications in the fields of X-ray imaging, X-ray Fluorescence, Diffraction and Small Angle Scattering.

The new storage ring will be installed in the same tunnel of the existing one. Therefore, severe space constraints are posed for the new components. The new machine lattice will be completely different: the existing double-bend achromat will be replaced by a special symmetric six-bend achromat configuration. Several existing insertion devices (IDs) will be kept in the upgraded machine, some new ones, such as three in-vacuum undulators, will be realized exploiting the new machine characteristics. In addition, three super-conducting bending magnets will be installed to serve high energy X-ray beamlines.
From the radiation protection point of view, it is important to assess the impact of the new machine parameters and the new lattice, on the existing beamlines hutches layout and to understand whether it is necessary to increase their shielding barriers. At the same time, it is necessary to evaluate the design and radiation challenges posed by the new beamlines both from IDs and, above all, from superconducting magnets.

Indeed, the hard X-ray imaging beamline (SYRMEP_LS) fed by a 6 T superconducting bending magnet, capable to provide X-rays in the range 30-150 keV, is the first of the new beamlines under construction. The needed shielding thickness of the three foreseen hutches has been evaluated using Monte Carlo simulation studies using FLUKA code.
Specific MC simulations have been also carried out for the upgrade of the existing ID beamlines that will keep their position on the new machine.
The main characteristics of the new machine and the most recent outcomes of these evaluations will be presented and discussed.

Radiation Shielding of Beamlines at APS-U

Sunil Chitra

Argonne National Laboratory, Lemont, USA, 60439

The Advanced Photon Source Upgrade (APS-U) will have a Multi Bend Achromatic (MBA) lattice that can produce intense X-rays with very small vertical and horizontal emittances, with 6 GeV electrons and stored beam of 200 mA. APS philosophy on beamline radiation shielding is to bring all the beam lines within a bounding envelope that consists of the source, configurations and scenarios. This gives the facility the freedom to operate beamlines with changes to source, mirror parameters, etc. if they fall within the envelope. There is very limited scope to augment the existing shielding that was or is being built. Dose rates from Synchrotron Radiation (SR) from the various Insertion Devices (ID), Bending Magnet (BM) and Gas Bremsstrahlung (GB) were estimated under the existing configuration using XOP [1], STAC8 [2], FLUKA [3] and PHITS [4] codes. The SR source terms calculated using XOP were used as inputs in the other codes for dose estimation. Among the scenarios considered were SR and GB on solid targets in enclosures and beam transport sections, and various beam stops and shutters. These sources were also used on an air column to simulate vacuum loss scenarios. Overall, SR spectrum from STAC8 and the Wiggler approximation of XOP gave similar source results. FLUKA and PHITS results were similar while STAC8 results were about 1.5-2 times higher. Based on the simulations, it was found that the strongest SCU (1.85 cm period length) could not be used as a bounding case because the dose rates outside enclosures were more than what is stipulated by the ANL shielding policy for full occupancy. Using a low powered planar undulator and by incorporating additional radiation safety components as credited controls, the dose rates were brought within the limits to allow full occupancy. Beamlines that will use the SCU will be treated as special cases and analysed separately. Also kept out of the bounding envelope were special beamlines such as the ISN with a concrete enclosure and the CSSI beamline with steel flight station that also acts as the radiation shield. While most of the simulations were carried out using empty enclosures, a few scenarios also used full geometries of the beamlines. When the full geometry was used for calculations, the dose rates were largely within the limits. Figure 1 shows the 2D plot of dose rates due to the GB in a high heat load beamline and the projection outside of the First Optical Enclosure at the upstream end.

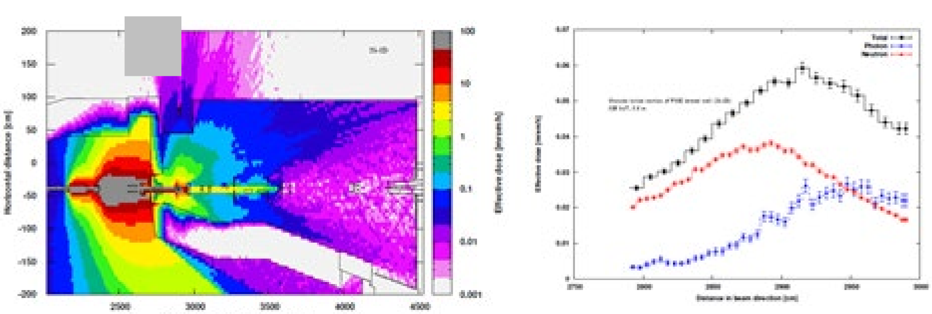


Figure 1: Dose rates from GB source in a high heat load ID beamline.

Acknowledgements
The work at Argonne National Laboratory was supported by U.S. Department of Energy, Office of Basic Energy Sciences under contract no. DE-AC02-06CH11357.

References

[1]. M. S. del Rio et al., International Society for Optics and Photonics, vol. 8141, SPIE, 2011, pp. 368–372.
[2]. Y. Asano, Radiation Physics and Chemistry, vol. 44, no. 1, pp. 133–137, 1994
[3]. T. Bohlen et al., Nuclear data sheets, vol. 120, pp. 211–214, 2014
[4]. T. Sato et al., Journal of Nuclear Science and Technology, vol. 55, no. 6, pp. 684–690, 2018.

Assessment of shielding for Diamond-II beamlines

Doull R.E., Faruk S.

Diamond Light Source Ltd, Harwell Science and Innovation Campus, Didcot, Oxfordshire, UK, OX11 0DE.

In common with many synchrotron light sources around the world which are carrying out or planning upgrades, the Diamond machine upgrade involves replacing the current Double Bend Achromat lattice structure with a Multi-Bend Achromat in order to reduce the emittance of the electron beam and so increase the brightness and coherence of the emitted synchrotron light [1], the energy will also be increased from 3 GeV to 3.5 GeV, the current will remain at 300 mA.

In addition to the upgrades to the accelerators, some beamlines will upgrade insertion devices (ID) and optics; other beamlines will move from bending magnet sources to insertion device sources on the new mid-straights created by the multi-bend lattice structure. This requires that the shielding requirements of all existing beamlines be reassessed.

Using STAC8, we calculated the dose rates outside of the shielding using a constraint of 0.5 μSv/h (1mSv/y for 2000 hrs working year). Diamond was shielded to operate at 500 mA; therefore, in most cases, the existing shielding is sufficient for the increased radiation output of Diamond-II. STAC8 calculated that increased shielding is required for some beamlines. Due to the expense and technical difficulties of increasing entire walls or sections, we are using FLUKA models to confirm if additional shielding is needed and identify precisely where additional shielding is required.

References

[1] – R. P. Walker *et al* Diamond-II: Technical Design Report, (2022)

Session 2 – XFELs

Commissioning of the Radiation Safety Systems for the LCLS-II Accelerator Facility*

Rokni S.H., Bauer J., Blaha J., Liu J.C., Nicolas L., Santana M., Xiao S.

SLAC National Accelerator Laboratory, 2575 Sand Hill Road, Menlo Park, CA 94025, USA

The Linac Coherent Light Source II (LCLS-II) at SLAC is currently being commissioned. LCLS-II is a Super-Conducting (SC) RF Linac capable of delivering a 4 GeV, 1 MW electron beam with a pulse rate of up to 1 MHz to two adjustable gap undulators. The generated Free Electron Laser covers an energy range from 0.2 to 1.3 keV for Soft X-Rays and 1 to 5 keV for Hard X-Rays (HXR). X-rays from the undulators are transported to the Front-End Enclosure (FEE) where they are directed to instruments housed in experimental hutches.

The existing Normal Conducting LCLS-I Linac continues to operate at 120 Hz, up to 5 kW and 17 GeV. With both LCLS-I and LCLS-II, the X-ray energy ranges available at SLAC extend from 0.2 to 8 keV for soft X-ray lines and 0.2 to 30 keV for hard X-ray lines.

SLAC's Radiation Safety System (RSS), which is comprised of shielding, Access Control System and Beam Containment System (BCS), assures safe transport and operation of the high-power electron beams and very intense FEL beam through the entire facility.

This presentation gives an overview of the key RSS elements for LCLS-II electron and FEL beams, and discusses the plan, status, and preliminary results from radiation surveys as well as from commissioning of BCS devices that limit beam energy, beam current and beam losses.

*This work is supported by the Department of Energy Contract DE-AC02-76SF00515.

Radiation Safety Analyses and Tests for the FEL Beam from LCLS-II Superconducting Linac

Xiao S., Liu J., and Rokni S.

SLAC National Accelerator Laboratory, 2575 Sand Hill Road, Menlo Park, California, USA

The Linac Coherent Light Source II (LCLS-II) at SLAC will commission electron beams from the superconducting Linac through both soft and hard x-ray undulators in the middle of 2023. The electron beams will be 4 GeV nominal and are expected to generate high repetition rate (up to 929 kHz) Free Electron Laser (FEL) to experimental hutches. Based on Start-to-End simulations, FEL beams can be up to 8.8 mJ, 880 W to soft x-ray lines and 5 mJ, 500 W to hard x-ray lines, which have much higher average power than FEL beams from the normal conducting Linac and thus bring very different challenges to safely contain the FEL beams.

This presentation shows the analyses performed by the SLAC Radiation Physics group as well as LCLS scientists and engineers on the radiation hazards from high repetition rate FEL beams and the mitigations, including new FEL stopper and dump design, new burn-through monitor design, vacuum interlock analysis, air attenuation estimates, and so on. Several tests have been performed using the FEL from the normal conducting Linac to support some of the analyses. More tests have been planned during the commissioning and power ramp-up of high repetition rate FEL beams.

*This work is supported by the Department of Energy Contract DE-AC02-76SF00515

Operation of a Fluorescence Light Based Burn Through Monitor System at the European XFEL

Clement W.[*], Leuschner A.[*], Zander S. [*], Gerdt S.-L. [*], Liang T.[*], Voige M.[*], Stein O.[*], Ansari Z.[1]

[*]Deutsches Elektronen Synchrotron DESY, Notkestr. 85, 22607 Hamburg, Germany
[1]European X-ray Free-Electron Laser Facility GmbH, Holzkoppel 4, 22869 Schenefeld, Germany

Focused FEL pulses produced by the European X-ray Free-Electron Laser are capable to drill through any solid material. This property poses enormous challenges for a beam confinement system.

Absorbers and beam shutters block the FEL beam between different accelerator and experimental areas, and at the end of experimental hutches the beam is finally stopped by a graphite absorber. Although it is not intended to focus onto these safety components, this cannot be completely ruled out. Should this unlikely event occur and the beam drill through a safety absorber, the FEL beam would be detected by a so-called Burn Through Monitor (BTM) system and the accelerator safely switched off immediately. The BTM detectors are based on two different light-sensitive sensors that detect the fluorescence light excited by the FEL beam in a volume of air.

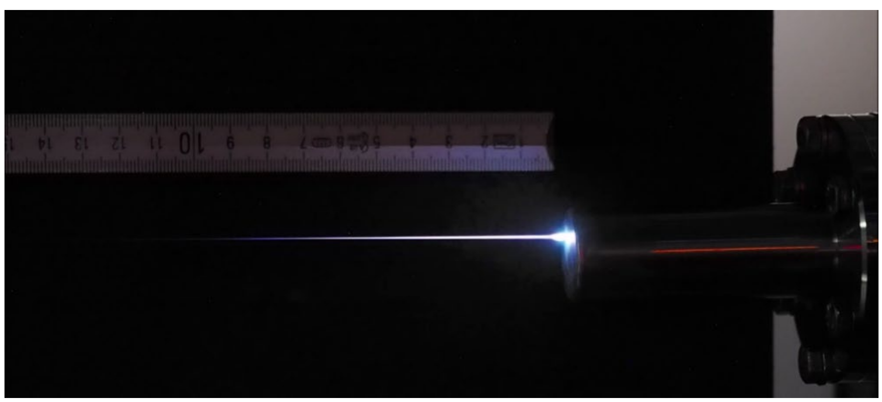


Figure 1 : Visible air fluorescence generated by an XFEL photon beam of 0.7 keV burning through a steel cap of the vacuum chamber and entering the air.

The BTM system was installed in 2020 at the European XFEL. The in-house developed detection system comprises a safety related self-diagnostic to meet the high demands for reliability [1]. The talk describes the BTM system and the self-diagnostic principle. Results of test measurements of the BTM detectors with FEL beam will be presented and lessons learned from the system's three years of operation will be described.

References

[1] – W. Clement, A. Leuschner, S. Zander, T. Liang, S.-L Gerdt, N. Tesch: "XFEL Burn-Through Monitor System", internal Technical Report, unpublished

A beam containment scheme to protect radiation protection components for the world's most powerful x-ray laser beam

Ansari Z. *, Boyd E.*, Sinn H. *, Zander S. [1], Leuschner A. [1], Gerdt S-L.[1], Liang T[1], Clement W.[1]

*European X-ray Free-Electron Laser Facility GmbH, Holzkoppel 4, D22869 Schenefeld. Germany

[1] Deutsches Elektronen Synchrotron DESY, Notkestr. 85, D22607 Hamburg. Germany

The European X-ray Free-Electron Laser Facility GmbH (European XFEL) is the world's most powerful x-ray laser machine. The design parameters are listed in table 1 [1], [2]. For radiation protection such parameters pose a challenge on how to stop or block such a powerful beam to protect human life.

Beam lines at XFEL are separated from the accelerator with beam shutters that contain ceramics, metal and an active detector. The beam shutters are connected to the radiation interlock system and protect life by switching off the XFEL beam if these are drilled through. Material testing performed on metals, ceramics, rock, concrete and water has shown that a focussed XFEL beam can drill through several centimetres of material within seconds, or less. The question is how to protect radiation protection components that protect life to ensure smooth facility operation.

This talk focusses on a beam containment interlock scheme called the safety equipment protection system (SEPS interlock) that relies on the position of focussing optics (mirrors or compound refractive lenses) and the state of the beam shutters (open/close) to switch off photon pulses to the beam lines if the optics focus the x-ray beam on to the beam shutter.

	Photon energy range (keV)	**Pulse Energy (mJ)**	**Average Power (Watts)**
SASE1 & 2	4.7 - 30	3.3	89
SASE3	0.25 – 3	10.7	290
The pulse duration is 8 – 20 femtoseconds.			

Table 1: Design parameters of photon pulses produced by the European XFEL accelerator

References

[1] - R. Abela et al: " The European X-ray Free-Electron Laser Technical Design Report", ISBN 978-3-935702-17-1.

[2] - E.A. Schneidmiller and M.V. Yukarov: " Photon beam properties at the European XFEL Saturation Tables (December 2018 revision)", unpublished.

[3] - Decking and Scholz: " Lasing performance of the European XFEL", unpublished.

Material Burn-through Tests at the European XFEL

Liang T.*, Ansari Z.[1], Clement W.*, Gerdt S.L.*, Leuschner A.*, Tesch N.*, Zander S.*

* Deutsches Elektronen-Synchrotron DESY, Notkestraße 85, 22607 Hamburg, Germany
[1] European X-ray Free-Electron Laser Facility GmbH, Holzkoppel 4, D22869 Schenefeld. Germany

The radiation protection group at DESY in collaboration with staff at the European XFEL conducted burn-through monitor (BTM) and material tests at the XFEL's beamlines. The experiments utilized XFEL photon beam at various energies in the keV-range. The high-power density deliverable by the XFEL's photon beamlines have the unique ability to burn-through centimeters of material, such as the 1 cm tungsten alloy plate as seen in Figure 1, even after traversing an air gap. The burn-through holes are on the order of tens of microns in diameter, and burn-through times have dependence on both the target thickness and XFEL beam parameters, such as photon energy, bunch energy, and pulse spacing. Figure 3 shows a collection of material burn-through data with the number of XFEL pulses required to burn-through different thicknesses of materials. These material tests at the XFEL seek to characterize this burn-through phenomenon in order to determine proper shielding and protections for personnel and equipment at the facility.

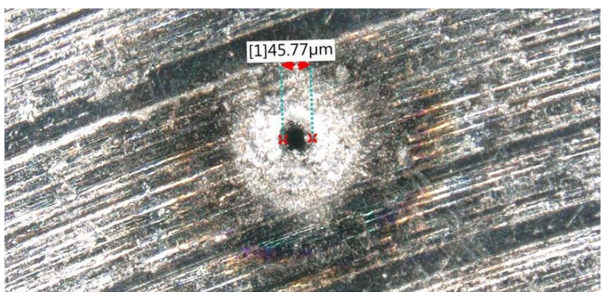


Figure 2 : Microscope image of a burn-through hole in a 1 cm tungsten alloy plate drilled by the XFEL.

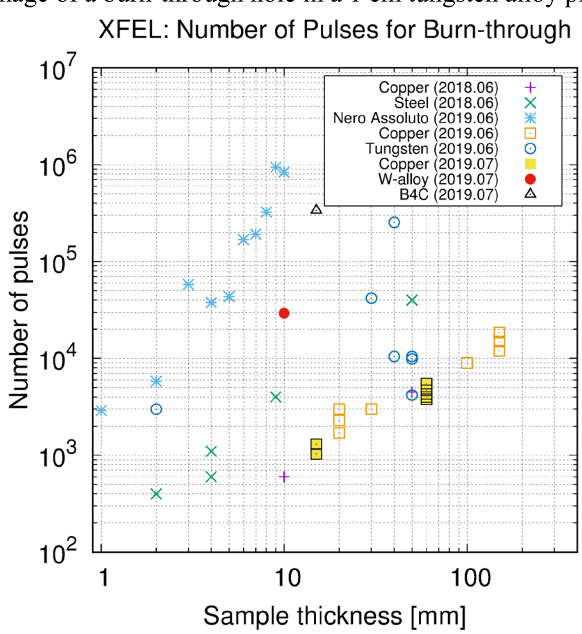


Figure 3 : Number of XFEL pulses needed to burn-through different materials at the XFEL with photon beam energies of 9.3 keV.

Radiation Field Studies around the 130 m long SASE 3 Undulators at the European XFEL by a modified LB 6419 probe mounted on the MARWIN4 robot

Leuschner A.[*], Gerdt S.-L. [*], Karabekyan S.[1], Dehne A.[2]

[*]Deutsches Elektronen Synchrotron DESY, Notkestr. 85, 22607 Hamburg, Germany
[1]European X-ray Free-Electron Laser Facility GmbH, Holzkoppel 4, 22869 Schenefeld, Germany
[2]ASPERON GmbH, Rosentwiete 1, 25355 Groß Offenseth-Aspern

At the European X-ray Free-Electron Laser (EU.XFEL) the SASE3 soft X-ray undulator system produces sub-picosecond X-ray pulses from 0.25 keV up to 3 keV. Their energy content ranges up to 10 mJ. A new project for the generation of circular polarization was realized a year ago [1,2]. For this purpose, the system of planar undulators was extended by four helical APPLE-X undulators, which were installed directly behind the planar undulators. Recently, the APPLE-X undulators suffered from radiation damage. Particularly, the encoders used for positioning of the magnetic structures got damaged.

During beam operation a modified neutron probe LB 6419 was carried by the MARWIN4 robot along the undulator beam line in the tunnel in order to measure dose rate profiles. From the point of view of dose rate measurement two challenges have to be mastered: Firstly, stray radiation of primary beam losses must be distinguished from X-rays generated by the SASE3 undulators. And secondly, any radiation occurs within sub-picosecond bursts. This leads to the pile up of many photons to a single response of high energy absorbed in the detector. Saturation can easily be reached here. Particularly, photon pulses with dose increments up to 1 µSv must properly be detected. Here, the detection principle of an active fluorescence dosimeter [3] was used. Therefore, the detector consists of a photomultiplier, which monitors an air volume covered by a black plastic tube. Ionizing radiation excites molecular states of the nitrogen molecule N_2 in air. The excited N_2 molecules emit violet light in the wavelength range from 300 nm to 450 nm with life times at about 1 ns at atmospheric pressure.

Figure 4 : MARWIN4 in its docking station in the tunnel downstream of SASE3. The modified LB 6419 is mounted on the right side.

References

[1] – S. Karabekyan et al., “SASE3 Variable Polarization Project at the European XFEL”, in Proc. IPAC'21, Campinas, Brazil, May 2021, pp. 1678-1680. doi:10.18429/JACoWIPAC2021-TUPAB122

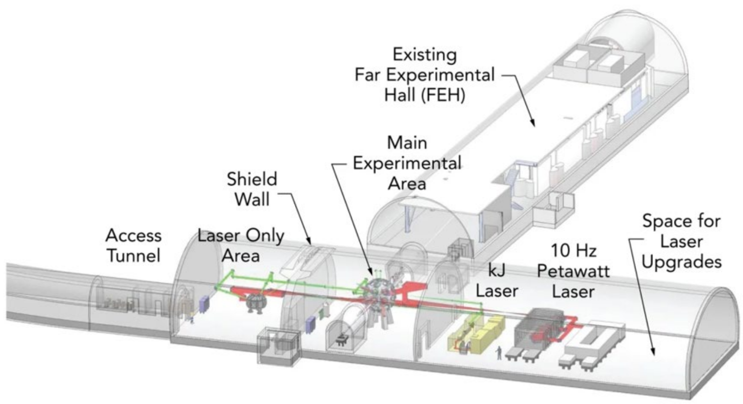
[2] – S. Karabekyan et al., “The Status of the SASE3 Variable Polarization Project at the European XFEL”, in Proc. IPAC'22, Bangkok, Thailand, June 2022, pp. 1029-1032. doi:10.18429/JACoW-IPAC2022-TUPOPT014
[3] – A. Leuschner, S. Zander, T. Liang: “A New Active Fluorescence Dosimeter for Pulsed Photon Radiation”, *doi.org/10.13182/ICRSRPSD22-394*

Radiation Protection at SLAC's Future MEC-U Laser Facility

<u>Bauer</u> J.[1], Rosenstrom A.[1,2], Connolly P.[1,2], Liu J.C.[1], Rokni S.H.[1]

[1]Radiation Protection Department, SLAC National Accelerator Laboratory, 2575 Sand Hill Road, Menlo Park, CA 94025, USA

[2]Department of Nuclear and Radiological Engineering, Georgia Institute of Technology, North Ave NW, Atlanta, GA 30332, USA



The Matter in Extreme Conditions Upgrade (MEC-U) is a flagship laser facility for plasma physics and fusion science that will combine high energy kilojoule (kJ) and high rep rate (10 Hz) lasers with the Linac Coherent Light Source (LCLS) at the SLAC National Accelerator Laboratory. The project is currently in the design phase with first operation estimated in as early as 2028.

With MEC-U's high-intensity optical laser systems, laser-target interactions will accelerate electrons and protons that will become a source of prompt dose from ionizing radiation. These electrons and protons will also be able to activate material inside target chamber, in the hutch and the environment.

The talk will introduce the MEC-U project, present the electron and proton source terms used in the FLUKA-based radiation protection analyses, discuss the estimated number and type of laser shots, and will show how personnel and environment will be protected from prompt and residual radiation. Shield walls will protect the personnel from prompt radiation while laser and utility pipes cross the walls. The expected residual radiation in devices in and around the target chamber, in the target chamber itself and in support structures is being studied, and the radiation doses to staff and users who will be working in and around the hutch are being estimated. Potential impact on the environment (groundwater and air) are also being studied.

This work was supported by Department of Energy contract DE-AC02-76SF00515.

Session 3 – Facility Reports

Radiation Protection on Sirius, the new Brazilian synchrotron

Moura F.N. [1], Lima L.P[1], Vieira A.L.C[1], Neto F.A.B[1]

[1] Brazilian Center for Research in Energy and Materials (CNPEM), Campinas, Sao Paulo, Brazil

The Brazilian Synchrotron Light Laboratory (LNLS) accommodates the new Brazilian synchrotron Sirius. In 2018, the linear accelerator was installed and commissioned, acquired from TPS, with a final energy of 150 MeV; in 2019, the booster reaches the final energy of 3 GeV, and the storage ring was validated with the first image in the beamline. Currently, Sirius operates in decay mode, with three injections per day to maintain 100 mA. In May 2023, the machine will work in top-up mode and, in 2024, the goal is to reach the final current of 350 mA with the installation of the superconducting cavity.

All accessible areas of Sirius respect the annual dose of 1 mSv. However, inside the tunnel, there is a change in the classification of the area, from a controlled area to a free area after waiting 06h for the controlled loss of the beam, known as the cooling time due to localized activations. The Sirius shield was elaborated using a Monte Carlo simulation [1] and was built in a unique way, with ten openings for the passage of equipment on the roof and people through eleven chicanes. Radiometric surveys are made at each increase in current or change in operating mode. There are no records of irregularities regarding shielding, doses above the limits allowed in the operation or radiological emergencies at the facility.

Currently, the installation has a monitoring system with 18 pairs of detectors (gamma radiation and neutrons) around the accelerators and 17 in the installation phase on the beamlines; 435 dosimeters (thermoluminescent, LiF, and optically stimulated, CaSO4 dosimeter pairs) spread around the shielding and external area of the installation. Inside the accelerators, there are 100 scintillator detectors for Bremsstrhalung gas developed in-house and high-dose dosimeters (alanine).

Due to the lack of radioprotection standard for synchrotrons, the safety assumptions and procedures adopted at Sirius are based on experience, acquired with UVX, and other synchrotrons around the world. The radiation protection group seeks to consolidate shared experience and theoretical knowledge in periodic machine studies. Mainly, the activation of components inside the tunnel and the integral dose value at that location are evaluated. So far, it has been possible to trace beam loss points, which are confirmed with external detectors.

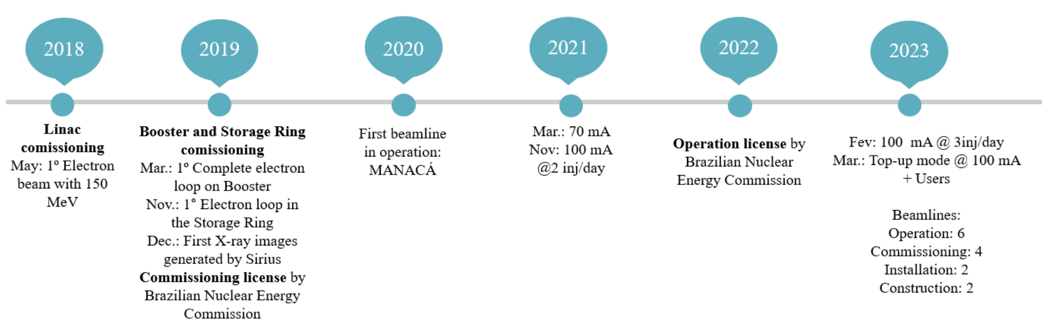


Figure 1: Timeline with Sirius milestones.

References

[1] Netto, F.A.B. Radiation Protection Status of Sirius Project. 10th International Workshop on Radiation Safety at Synchrotron Radiation Sources. Sweden, 2019.

Planned service and maintenance of the MAX IV personnel safety system

Rosborg A., Malmqvist J., Jönsson N.

MAX IV Laboratory, Lund University, PO Box 118, SE-221 00 Lund, Sweden

The radiation safety-related personnel safety system (PSS) at MAX IV is based on safety PLCs and cover all accelerator areas and beamlines at the facility. An overview of the design and functionality of the PSS was presented at RadSynch17 [1]. The focus of this presentation is the planned service and maintenance of the radiation safety-related PSS. It can be divided into the annual check of the PSS and the replacement of critical PSS equipment before the mission time of 20 years has passed.

Each year an annual check of the MAX IV PSS is performed. As long as the safe part of the PLC code is locked and equipped with a safety signature no significant changes can be done to the functionality of the PSS. There is thus no need to regularly verify the functionality of the PSS. Functional tests are only performed when a new or updated version of a PSS is deployed. The annual check of the PSS is therefore limited to a check that all individual PSS components work as intended. This is verified by performing an I/O test of every single PSS signal every calendar year. The annual check was envisaged from the start of the design process and the design of the PSS was done with it in mind. The annual check is typically performed during the summer shutdown and takes about one week for two persons using specially developed test GUIs.

For the performance level calculations for the critical safety functions of the MAX IV PSS a mission time of 20 years was used. It is thus necessary to start replacing the PSS equipment before it is 20 years old. The equipment that should be replaced is the equipment that is included in the performance level calculations, such as input devices (limit switches, door switches, emergency stops etc.), I/O nodes and cards, PLC controllers and output devices (contactors etc.). Special care should be given to the question if and to what extent the validation of the PSS should be redone, particularly with respect to the PLC controller and the logic, since a complete re-validation can take a significant amount of time. The oldest part of the MAX IV PSS was deployed almost 10 years ago. The initial work to prepare for the equipment replacement has recently started and the first replacement tests are planned to occur within the coming year or two.

References

[1] – A. Rosborg, The MAX IV personnel safety system, Proceedings of the 9th International Workshop on Radiation Safety at Synchrotron Radiation Sources, NSRRC, Hsinchu, Taiwan, pp. 219--254 (2017).

Shielding design for the installation of Non-linear collimator at SuperKEK

Yasuhito Sakaki

KEK Radiation Science Center

SuperKEKB broke the world record for instantaneous luminosity in June 2022, achieving a luminosity of 4.7×10^34/cm^2/s. Reducing the background near the beam collision point is essential to improve the luminosity further. Therefore, a new collimator (non-linear collimator) has been installed in the Oho area of SuperKEKB, which will be a new radiation source. The Oho area is located near the Oho experimental building and the D5 power supply room, where people enter during accelerator operation.

We evaluated the effective dose in the Oho area after the installation of the collimator using the PHITS code. According to the calculation, it was found that a new shield is necessary to ensure radiation safety in the Oho area. Therefore, we optimized the shield shape that can be realistically installed using PHITS.

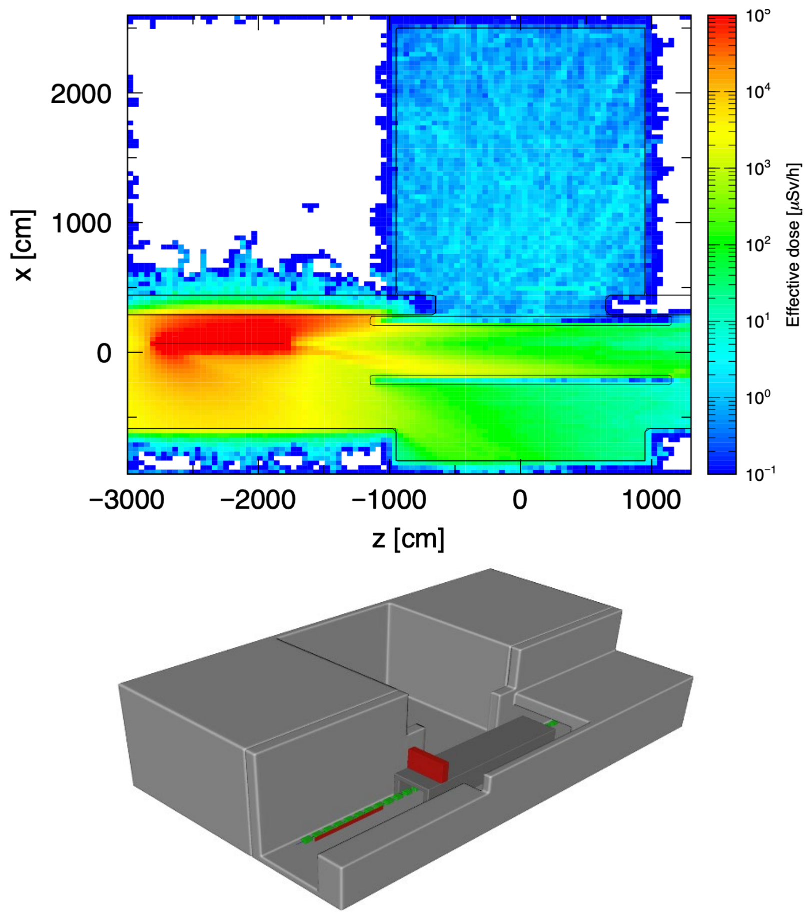


Figure 1: [top] effective dose in the Oho area of SuperKEKB after installation of the non-linear collimator, [bottom] 3D model of Super KEKB Oho area.

Top-up Operation Safety Features at the Canadian Light Source

Cubbon, G*., Street, D*., Bewer, B.*

*Canadian Light Source Inc., 44 Innovation Boulevard, Saskatoon, Saskatchewan, Canada S7N 2V3

The Canadian Light Source, located in the prairie province of Saskatchewan, is a third-generation facility operating with a 2.9 GeV electron beam. User operation began in 2005, and was limited to decay mode where beam was injected once every 12 hours to refill the storage ring. In decay mode the front end safety shutters were kept closed to protect personnel on the experimental floor from potential radiation produced during the injection process. Making the transition to beam injection with safety shutters open required a defence in depth approach to ensure the risk of radiation exposure to personnel during beam injection was mitigated. The safety features were designed and implemented, including safety interlocks to inhibit top-up operation when safety conditions were not met, will be discussed. The CLSI Top-Up mode of operation was reviewed and approved by the Canadian federal regulator in 2018, and CLS first operated in Top-Up in 2019.

ELI Beamlines facility: heading towards operations

Cimmino A., Horváth D., Lefebvre B., Olšovcová V., Šesták M., Truneček R., Versaci R.

ELI Beamlines, ELI ERIC, Za Radnici 835, Dolni Brezany

In 2021, the Extreme Light Infrastructure European Research Infrastructure Consortium, ELI ERIC, was established. The consortium is an international European project aiming at building and operating the next generation of high power lasers for fundamental research and industrial applications in Europe. The ELI Beamlines laboratory, in the Czech Republic, became an integral part of the Consortium on 1.1.2023.

ELI Beamlines aims at the development of ultra-short high brilliance X-rays sources and acceleration of electron and proton beams. After the RadSynch19 conference, and despite the delay caused by the worldwide Covid pandemic, a large amount of work has been carried out in the laboratory. Different beamlines and workstations have been commissioned, a new workstation has been built, and several experiments have been performed. This contribution will provide an update, summarizing all the work done in the past years, lessons learnt, and presenting the plans for the near future.

Radiation Protection and Personal Safety System at SOLARIS National Synchrotron Radiation Centre

Magdalena B. Jaglarz, Dagmara Michoń, Barbara Zdrodowska- Pawluś, Krzysztof Wawrzyniak, Mateusz Augustyn, Adriana I. Wawrzyniak

National Synchrotron Radiation Centre SOLARIS Jagiellonian University,
Czerwone Maki 98, 30-392 Kraków

All the activities undertaken at National Synchrotron Radiation Centre SOLARIS concerning radiation protection comply with requirements described in Atomic Law. In accordance with applicable law the National Atomic Energy Agency (PAA) oversees SOLARIS operations in this area. At SOLARIS, the radiation measurements using radiation monitor stations (RMS), thermoluminescence dosimeters (TLDs) and portable radiometers have been carried out since 2015 [1]. Furthermore, radiological safety of employees exposure is controlled through individual thermoluminescent dosimeters (TLDs) and, if necessary, also electronic dosimeters [2].

Moreover, SOLARIS research infrastructure was equipped with Personal Safety System (PSS) to protect facility personnel and users from ionization radiation by controlling access to designated areas and stopping synchrotron operations in the event of the hazardous situation. PSS is based on programmable logic controllers (PLCs) which are reliable, fail-safe, redundant and diverse (especially the most critical parts). RMS are measure radiation level at the facility 24/7 and in some cases provide beam stopping when preset dose rate or accumulated dose threshold is exceeded.

The first users started doing their experiments on the SOLARIS beamlines in 2018 [3]. Since then, the synchrotron has been under continuous development and several improvements to the radiation shielding have been implemented that enabled it to fulfill the ALARA principle.

Solaris research infrastructure will be presented through the prism of radiological protection in particular with the effective use of the PSS system.

References

[1] – J. Wikłacz, Magdalena Jaglarz, Adriana Wawrzyniak „Radiation levels around SOLARIS 1.5 GeV storage ring after the machine commissioning" Radsynch19, 10th International Workshop, MAX IV Laboratory, Sweden May 2019

[2] – Magdalena B. Jaglarz, Justyna Wikłacz, Adriana I. Wawrzyniak, "Radiation safety at Solaris 1.5 GeV storage ring" IPAC2019, Melbourne, Australia, JACoW Publishing doi:10.18429/JACoW-IPAC2019-THPRB059

[3] – A.I. Wawrzyniak, P. Andryszczak, G.Cioś, K.Guła, G.W.Kowalski, A.M. Marendziak, A. Maximenko, R. Panaś, T. Sobol, M. Szczepaniak, J. Wiechecki, M. Wiśniowski, M. Zając, A. Curcio "Recent developments at SOLARIS National Synchrotron Radiation Centre" IPAC2022, Bangkok, Thailand JACoW Publishing doi:10.18429/JACoW-IPAC2022-TUPOPT024d

Measurements of Bremsstrahlung by Field Emission from the BESSY HOM Cavities

Huck H., Bergmann Y., Bundels A., Pichl L.

Helmholtz-Zentrum Berlin für Materialien und Energie
Hahn-Meitner-Platz 1
14109 Berlin

Since 2015, the BESSY II storage ring runs on four HOM damped normal conducting single cell BESSY type cavities, which are also in operation at several other European synchrotron light sources. While the usual input power per cavity is 40 kW, it is possible to operate them with up to 80 kW. Recently, the corresponding cavity test stand has been upgraded with an 80 kW solid-state amplifier as well, enabling easy measurements of ambient radiation dose rates due to field emission at highest power without electron beam. We present first results of these measurements, indicating a sharp exponential rise of Bremsstrahlung after a certain power threshold, up to values of 1 mSv/h at 1 m distance.

Radiation safety at KARA, FLUTE and its future upgrades

P. Wesolowski, E. Bründermann, M. Hagelstein, E. Huttel, R. Ruprecht, M. Schuh, O. Zwernemann

KIT, Germany

The circular accelerator KARA (Karlsruhe Research Accelerator) is in opeartion since more than two decades. FLUTE (Ferninfrarot Linac- und Test-Experiment) commenced operation and is presently upgraded; further major expansions are planned. General radiation safety issues of KARA and FLUTE are covered in this paper. Radiation safety of future extensions of FLUTE will also be discussed.

High Energy Scattered Synchrotron Radiation at the KARA Visible Light Diagnostic Port

Batchelor D.R.[1], Blomley E.[2], Huttel E.[2], Hagelstein M.[2], Mochihashi A.[2], Schuh M.[2], Simon R.[1]
.
Karlsruhe Institute of Technology,
[1] Institute for Photon Science and Synchrotron Radiation (IPS),
[2] Institute for Beam Physics and Technology (IBPT),
KIT Campus North, Hermann-von-Helmholtz-Platz 1, D-76344 Eggenstein-Leopoldshafen

In a recent publication [1] measurements of radiation entering the visible light Diagnostics port were presented. The geometry of the simple optics employed for the extraction is similar to that used in a variety of Infra-Red beamlines. Nevertheless, a higher than allowable dose was measured at the exit hole in the ring wall. Fortunately, it was easily shielded with 2mm Pyrex glass to an acceptable level; however, its origin was not entirely clear. Further measurements and also calculations will be presented supporting the above publication and also extending the scenarios to other ports/beamlines.

References

[1] - D. R. Batchelor, E. Blomley, E. Huttel, M. Hagelstein, A. Mochihashi, M. Schuh, R. Simon, Journal of Physics: Conference Series 2380 (2022) 012087 doi:10.1088/1742-6596/2380/1/012087

Session 4 – Activation and Decommissioning

Predicting 3D Radioactivity Distribution in Large-scale Structures Using Machine Learning Techniques

UkJae Lee, Phillip Chang, Nam-Suk Jung, Hee-Seock Lee.

Pohang Accelerator Laboratory, POSTECH, Pohang, 37673, Republic of Korea

A new method has been developed to evaluate the three-dimensional (3D) radioactivity distribution within large-scale radioactive structures by utilizing machine learning techniques [1]. Traditional evaluation of radioactivity distribution in large radioactive structures involves destructive analysis and sample collection, which is a time-consuming and labour-intensive process. However, using this proposed technique, it will be possible to evaluate the radiation distribution in large radioactive structures more conveniently and with reasonable accuracy through a non-destructive analysis. A number of irradiation scenarios that are possible in nuclear facilities, were derived to define various radioactive sources for making prediction model of machine learning. The internal 3D distribution of radioactivity could be estimated using machine learning by supplying the gamma-ray spectra measured at the surface of the radioactive structure. In this work, a random radioactivity distribution inside a cubic concrete structure with a side length of 1 m was defined. The radioactivity distribution is assumed as Gaussian distribution on the X, Y plane and an exponentially decreasing form in the Z axis direction. Using the FLUKA 4-3 code [2], 16 detectors were defined on each side of the concrete structure, and the gamma-ray spectra were scored and fed to the machine learning for the radioactivity evaluation. A distribution prediction model was constructed using a Convolutional Neural Network (CNN) 3D method. The CNN 3D method is suitable for predicting radioactivity distribution because this method operates based on 3D kernel which can learn gamma-ray spectra data with position information. The 3D radioactivity distribution inside the concrete structure were evaluated and is illustrated in Figure 1. The left side of Figure 1 is label data which is simulated distribution data and right side of Figure 1 is predicted data with machine learning model. It is confirmed that the predicted result and label data show similar distributions.

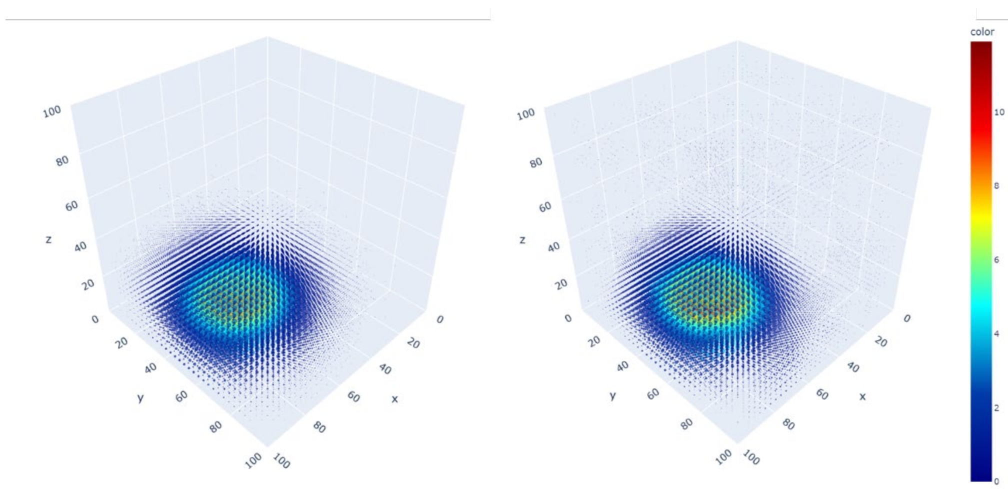


Figure 1: The label data (left) and predicted data (right) of radioactivity distribution.

References

[1] Moroney, L. AI and Machine Learning for coders. O'Reilly Media. (2020)
[2] G. Battistoni, et al, "Overview of the FLUKA code", Annals of Nuclear Energy 82, 10-18 (2015).

Induced Radioactivity in the Elettra Storage Ring

Alikaniotis K. *,1, Casarin K.[1], Scian G. [1], Tromba G. [1], Ferrari A.[2]

[1]Elettra-Sincrotrone Trieste S.C.p.A.
S.S. 14 - km 163,5 in Area Science Park, 34149 Basovizza, Trieste, Italy
[2]Institute of Experimental Particle Physics, Karlsruhe Institute of Technology, Germany

The Elettra storage ring will be upgraded to a new generation machine in the near future. The installation of the new storage ring in the existing tunnel will require the dismantling of almost all components of the present accelerator.
Article 54 of the Italian radiation protection legislation in the framework of D.Lgs 101/2020 [1] regulates the release of radioactive material, in which the release levels follow the radiological non-relevance criterion (the 10 uSv/y concept). As a consequence, an accurate prediction of induced radioactivity is essential for the decommissioning.
Simulations have been performed by means of the FLUKA [2] Monte Carlo particle transport code. For this purpose, a detailed FLUKA model of the Elettra storage ring was built, based on the manufacturing drawing of the different accelerator components both for geometry and elemental composition.
In collaboration with the machine physicists, beam losses scenario occurred during the 30 years of laboratory activity has been investigated, and activation maps have been calculated for the different storage ring components, such as magnets, vacuum vessel, supports. Preliminary results show that, in general, most of the elements inside the Elettra storage ring will be below the release levels, but further investigations are necessary, especially in the most critical parts of the machine.
By way of example, Figure 1 shows the activation map expected for a quadrupole magnet, in which the highest specific activation is located on the pole tips and coils.
Moreover, experimental studies by using radiochromic films have been carried out in order to locate the major machine hotspots, and *in-situ* gamma spectrometry measurements are in progress to fix the nuclide vector, matching the experimental results with the simulation ones.

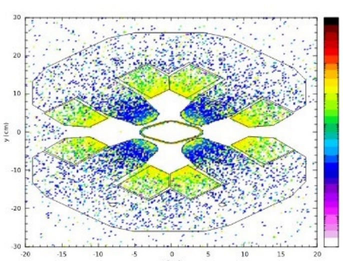


Figure 1: Activation map for the quadrupole Q3.1 Total specific activity (all isotopes) integrated overall z axis, for a conservative beam losses scenario.

References
[1] - Legislative Decree 31st of July 2020, n. 101. Implementation of council directive 2013/59/Euratom
[2] - A. Fassò et al, CERN-2005-**10**, INFN/TC_05/11, SLAC-R-**773** (2005)

Decommissioning of UVX, the first Brazilian synchrotron

Moura F.N. [1], Lima L.P[1], Neto F.A.B[1], Szabo T.V[1], Moraes IC[1], Madacki R[1].

[1] Brazilian Center for Research in Energy and Materials (CNPEM), Campinas, Sao Paulo, Brazil

In 1997, the Brazilian Synchrotron Light Laboratory (LNLS) started a second-generation synchrotron light source, called UVX, which operated with electron beams at an energy of 1.37 GeV and 250 mA. The injection system included a 120 MeV linear accelerator and a 500 MeV Booster. The machine operated in decay-mode, with two injections per day and most of the beamlines were based on dipole magnets. On August 2019, the UVX synchrotron light source ceased operation for user research activities.

In Brazil, the Brazilian Nuclear Energy Commission defines radiation protection standards for all radioactive installations. For the decommissioning of the UVX, the general recommendation was followed with the writing of the decommissioning plan, practical actions for monitoring the machine components and storage the individual dose history.

Simulations with FLUKA.CERN [1] were performed to evaluate possible activation points after 22 years of operation. In absence of the record of the electron losses tracks through the years, some conservative assumptions were adopted to increase the radiation levels calculated, such as the incident beam profile and the target geometry.

The analysis of electron beam losses considered the transfer lines between the linac, booster, and storage ring, as well as the normal beam lifetime. The study also included an evaluation of the activation due to high energy photons from Gas Bremsstrahlung. The beam incidences in simulation were concentrated on a single location, perpendicular to the surface, without any significant divergence to maximize the activation. However, during the operation, the beam losses occurred at a grazing incidence, distributed across the accelerator component. The scenarios with the highest activation potential found were due to losses in the linac transfer line and per lifetime in the storage ring. The worst-case material was steel.

in active monitoring Geiger muller (GM), ionization chamber and gamma spectrometer were used in active monitoring. The UVX magnetic lattice was monitored before being disassembly and only the final dipole of the linac to booster showed counts above 20 cps and 0.2 uSv/h. A detailed monitoring procedure was defined in parts with dose potential by literature [2] and simulation results. All points remained within the natural background radiation (0.1 uSv/h) whose result agrees with calculations.

In conclusion, the recommendations of the Brazilian radioprotection standards were followed and there were no complications during the disassembly of the machine, which took place two years after the end of its operation. Even with the enormous conservatism employed, due to the absence of records with defined parameters, the results obtained in the simulations showed activation levels comfortably below the limits. As a lesson learned, it is recommended to draw up a decommissioning plan detailing frequent beam loss locations, recorded values, and machine parameters that can be used in analytical calculations or simulations for future generations.

References

[1] Cerutti, F., et al. “New Capabilities of the FLUKA Multi-Purpose Code", Frontiers in Physics 9, 788253 (2022).
[2] IAEA. Decommissioning of particle accelerators. International Atomic Energy Agency, 2020.

Decommissioning of the ESRF storage ring

Berkvens P., Colomp P.

ESRF, 71, avenue des Martyrs, 38000 Grenoble, France

On 10 December 2018, after 25 years of User Service Mode Operation, the ESRF X-ray source was shut down for an upgrade to a brand-new storage ring, the Extremely Brilliant Source (EBS). The entire old storage ring was decommissioned, except for the straight section vacuum vessels, the insertion devices and parts of the front ends.

After several years of discussion, the proposal from the ESRF for the classification of the dismantled storage ring components as non-activated waste was accepted by the French Nuclear Safety Authority. As a consequence, the valorization of these components as non-activated waste is possible after detailed radiation measurements of all individual elements.

By the end of 2022, all components taken out of the tunnel during the long shutdown had been measured. None of the scanned components showed any measurable level of activation. As such, more than 1000 tons of metal have been evacuated with a corresponding cumulative net income from the valorisation of this waste of the order of 1 M€.

Throughout the lifetime of the old storage ring, a large number of components were taken out of the tunnel and were stored on site. All these components have now also been measured, using the same protocols, and they also have been disposed of as non-activated waste.

Following the start of the EBS, the French Nuclear Safety Authority has asked the ESRF to provide activation calculations for all the accelerators to update the ESRF waste management plan. The results of these calculations must be used to define waste management zoning in the tunnels and define the corresponding procedures to be followed for the verification of the non-activation of accelerator components taken out of the tunnel (simple measurements using hand-held monitors or robotized measurements similar as the ones used for the old storage ring decommissioning).

The presentation gives an overview of the old storage ring decommissioning and a give a status of the activation calculations of the present accelerators.

Session 5 – Calculation Methods

Combining Alanine Dosimeters and Monte Carlo Simulations: A method for demagnetization forecast by high dose exposure

Moura F.N. [1], Moraes I.C. [1], Estevão D.M.M.[1], Neto F.A.B[1], Rodrigues Jr. O.[2]

[1]Brazilian Center for Research in Energy and Materials, [2]Nuclear and Energy Research Institute

Sirius, the new Brazilian synchrotron, was designed to operate with 3 GeV, 350 mA in top-up mode and 0.25 nmrad of emittance, which represents a photon flux per second of the order of 6.5×10^{16} for bending device. According to the literature [1], high-dose deposition by photons and neutron generation represents a long-term risk of demagnetization of magnetic lattice components. This work presents the results of experiments carried out with alanine/EPR [2] dosimeters and Monte Carlo simulations with the FLUKA.CERN [3] code to investigate photon and neutron dosimetry. The use of high-dose dosimeters composed of alanine and read by Electron Paramagnetic Resonance (EPR) appears as a viable and robust dosimetric method for monitoring throughout the useful life of the machine. In this study, at each measurement point, three alanine pellets purchased from Bruker BioSpin Corporation were placed in a PLA holder.

In the first experiment, with 12 months of exposure, the dosimeters were positioned on central permanent magnetic dipoles, called BC, made of NdFeB during the machine commissioning phase. The current increased from 5 to 40 mA, and the main objective was to confirm which region of the BC (begin, middle or end) would present the highest dose. As a result, the middle region of BC (BC01) showed a maximum measured value of 386±10Gy. For the simulations, a segment of the ring was modelled, including a BC and the alanine dosimeters (Figure 1a). Due to the absence of the electron losses tracks, the dose maps around the dosimeter's region were evaluated for various beam losses profiles (Fig. 1b) for different types of particles, indicating a neutron contribution for dose lower than 1%.

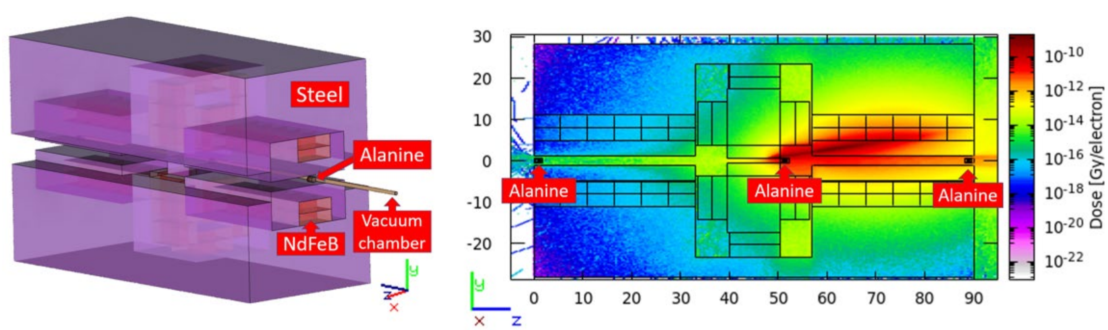


Figure 1: (a) Simplified BC geometry in FLUKA (b) Vertical dose distribution for an arbitrary beam loss.

The work represents a promising validation methodology between experimental dosimetry and simulation. Furthermore, new measurement points will be considered due to the installation of new beamlines, beam current increase, operation in top-up mode, and experimental evaluation of the contribution of neutrons.

References

[1] Samin, Adib J. "A review of radiation-induced demagnetization of permanent magnets." Journal of Nuclear Materials 503 (2018): 42-55.
[2] "Numerical analysis of the alanine response using Monte Carlo: Correlation with experimental results." Radiation Physics and Chemistry 190 (2022): 109824.
[3] Cerutti, F., et al. “New Capabilities of the FLUKA Multi-Purpose Code", Frontiers in Physics 9, 788253 (2022).

Estimation of thick target effect using multi-point kernel method in synchrotron radiation shielding calculations

Asano, Y.

ASA Radiation Engineering Research Laboratory
6-19 Johoku-cho Toyama 930-0854, Japan e-mail:asarel.4416@gmail.com
High Energy Accelerator Research Organization KEK
1-1 Oho Tukuba Ibaragi 305-0801, Japan
Research Centre for Nuclear Physics Osaka University
10-1 Mihogaoka Ibaraki Osaka 567-0047, Japan

A point kernel method with scattering process is employed generally in shielding calculations of synchrotron radiation beamlines because of the huge intensities and the strong attenuation. The components and the sources of the beamlines are variable easily so that Monte Carlo codes are unsuitable, and some techniques are necessary to use for the shielding design of synchrotron radiation beamlines. Monte Carlo codes are used exclusively for the evaluation. In shielding design calculations, the conservative results are one of the most important requirements and the calculations using point kernel methods with photon scattering indicate conservative results in genal. However, some cases that are the thick target including inclined target in comparison with the distance from the target to the estimation point are too conservative as indicated in figure 1 using STAC8(1) , EGS4(2) and FLUKA(3) In this presentation, the improvements for such shortcomings will be discussed by using multi- point kernel method that is the adding up the results with point kernel method for each segmented target.

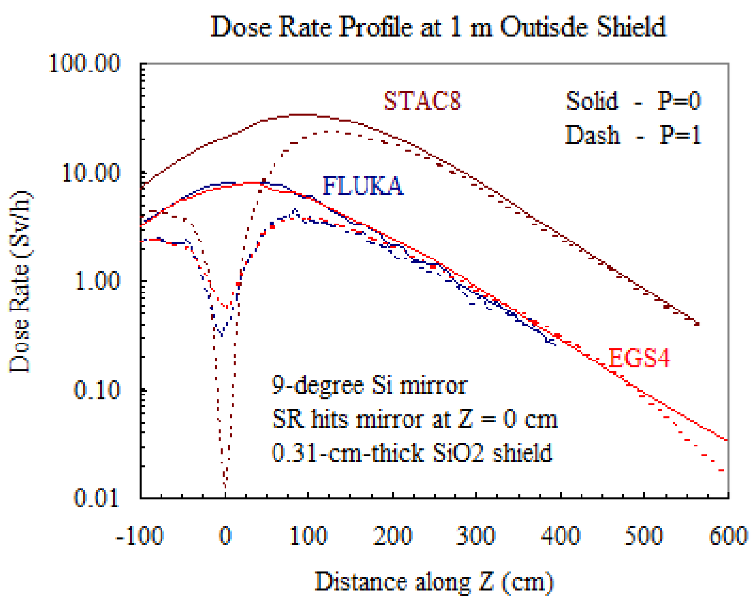


Figure 1: Comparison of photon dose equivalent rate profile at **1 m** away, parallel to Z-axis, outside the SiO_2 shields. Calculations using STAC8 (ICRP51 ambient dose equivalent), FLUKA (ICRP74 Effective Dose, worst geometry) and EGS4 (ICRP74 Effective Dose, AP geometry) with and without linear polarization (P=1 and P=0, respectively) are indicated. (4)

References

[1] Y.Asano JAERI Report 2001-006 (2001).
[2] Nelson, W. R., Hirayama, H. and Rogers, D. W. O., SLAC-265 (1985)
[3] Fasso, A., Ferrari, A. and Sala., Monte Carlo 2000 Conference, Lisbon, October 23-26, 2000,
[4] J.Liu, A.Prinz, S.Rokni and Y.Asano, SLAC-PUB-10427 (April 26, 2004)

Shielding calculations with Markov chains and genetic algorithms

Batkov, K.[1], Ansell, S.[1], Bentley, P.[2], Kurakhtenkov, L.[3]

[1] MAX IV Laboratory, Fotongatan 2, 22484, Lund, Sweden
[2] European Spallation Source ERIC, Box 176, 22100, Lund, Sweden
[3] Independent expert

Traditionally, shielding calculations are performed using either an analytical approach or Monte Carlo simulations. Analytical methods are less accurate than Monte Carlo, but the latter can be very computationally expensive, even with the use of variance reduction techniques. In this paper, we propose a one-dimensional particle transport method that is almost as accurate as Monte Carlo simulations but orders of magnitude faster. This method is applicable to an arbitrary number of transported particle types and enables the estimation of double differential spectra of all transported particles beyond the shielding. It also allows the user to define the physics settings of transport processes, making it adjustable for specific applications. We provide a user-friendly, open-source tool that can be used for quick design of shielding components that can be further optimized using detailed Monte Carlo simulations. This methodology is demonstrated through its application in the design of the electron beam dumps for the transverse deflecting cavity line at the MAX IV laboratory.

CombLayer: A High-Efficiency System for Modeling Complex Accelerator Systems in Radiation Shielding Calculations

Stuart Ansell and Konstantin Batkov

MAX IV Laboratory, Fontongatan 2, 22484 Lund, Sweden

CombLayer is a powerful code designed to quickly and easily build complex geometric models that run efficiently in FLUKA and similar Monte Carlo codes. Essentially, it is a high-level language used to describe geometry that can be compiled into the low-level Constructive Solid Geometry (CSG) used in Monte-Carlo inputs.

By utilizing CombLayer, users can create comprehensive models with ease and speed, eliminating the need for time-consuming manual construction. The high-level language approach streamlines the process, allowing users to generate models significantly quicker. Additionally, CombLayer models are optimized for fast and accurate Monte-Carlo calculations, making them ideal for a wide range of applications.

CombLayer enables users to create models using pre-defined components such as pipes, screens, gate valves, mirror chambers, monochromators, bellows, and undulators. Users can also build new bespoke components as needed. Each component is highly parametric, allowing for complete freedom to modify all dimensions, or apply rotations and translations to the component (or groups of components). These components can be linked together in any direction and on any outer surface(s), creating common external surfaces or by directly overlapping them, much like a rotatable LEGO system.

CombLayer can automatically construct a complete and valid FLUKA, MCNP, or PHITS input file, including estimators (tallies), sources, materials, physics cards, automatic variance reduction, and the typical inclusion of a large number of magnetic and R.F. fields which FLUKA supports with simple downloadable modules.

To demonstrate CombLayer's capabilities, we simulated radiation losses due to a 3 GeV electron beam along the transverse deflecting cavity (TDC) line, recently installed at the end of the MAX IV facility's linac. The TDC line is over 130 meters long and consists of over 50 magnetic components, multiple screens, gate valves, shielding blocks, and two R.F. cavities and several changes in beam direction. These were placed within the short pulse facility hall.

The model allows electrons to be transported through the complete model from start to beamdump in one simulation, including all the magnetic lattice, including the acromat bends. 1 The model's programmability was used to construct several hundred different beamloss scenarios, which could be rapidly re-run as the shielding design was improved, both locally and non-locally.