5th International Particle Accelerator Conference IPAC2014, Dresden, Germany JACoW Publishing
ISBN: 978-3-95450-132-8 doi:10.18429/JACoW-IPAC2014-TUPRI097

RADIATION PROTECTION CONCEPTS FOR THE BEAMLINE FOR DETECTOR TESTS AT ELSA

N. Heurich*, F. Frommberger, P. Hänisch, W. Hillert,
ELSA, University of Bonn, Physics Institute, Nussallee 12, D-53115 Bonn, Germany

Abstract

At the electron accelerator ELSA, a new external beamline is under construction, whose task is to provide a primary electron beam for detector tests. In the future the accelerator facility will not only be offering an electron beam to the currently implemented photoproduction experiments for hadron physics, but to the new “Research and Technology Center Detector Physics”, whose task is to develop detectors for particle and astroparticle physics.

To dump and simultaneously measure the current of the electron beam behind the detector components a Faraday cup consisting of depleted uranium is used. The residual radiation leaving the cup is absorbed in a concrete casing. The radiation protection concept for the entire area of the new beamline was designed with the help of the Monte Carlo simulation program FLUKA. In addition to the concrete casing, radiation protection walls were taken into account to allow a safe working environment in the room created by the shielding walls.

INTRODUCTION

At ELSA a primary electron test beam is under construction. The electron beam with a variable beam width from 1 mm to 8 mm at the test area is slowly extracted from the strechter ring via excitation of a third integer betatron resonance.

The extracted electrons are guided onto detector components in order to get information about their stability and ageing or if the concept is working. Moreover, components following the detectors like electronics and data processors can be checked.

As a part of a particle accelerator, the test laboratories are subjected to the radiation protection surveillance. This means, that the laboratories must not be accessed during operation and furthermore that no harmful radiation levels are to be measured outside the laboratories.

In order to fulfill these restrictions at the new test beamline at ELSA a concept has been worked out with the help of a simulation program, taking into account several constraints, especially resulting from the intended utilisation of the laboratories and the fire protection requirements.

THE RADIATION SAFETY CONCEPT

The new beamline is located in the former synchrotron light experiment laboratories in the basement of the physics institute at Bonn University. It is separated from the tunnel of the strechter ring (see Fig. 1).

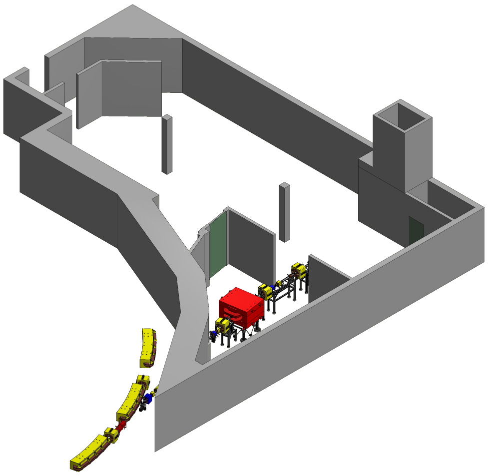

Figure 1: The laboratories with the new detector test beamline. On the left side at the bottom a part of the yellow dipole bending magnets of the strechter ring can be seen. Upstream the extraction septum (in red) is located with the test beamline branching off to the right side.

Constraints

The situation as displayed in Fig. 1 is not suitable for operation, since without dumping of the electron beam in an appropriate way, the radiation level in the laboratories, the surrounding soil and the overlying meadow would raise above limits. However, it is also the structural situation and consequential requirements that have to be respected:

- **a)** Next to the test area a control room as supervised area with an effective dose D_{eff} less than 6 mSv/a needs to be created (see Fig. 2 a)).
- **b)** The geometry of the beam dump casing has to take into account, that the existing emergency exit shaft must be preserved (see Fig. 2 b)).
- **c)** The test area should be as large as possible, so the dump casing should be placed as deep as possible in the emergency shaft (see Fig. 2 c)).
- **d)** The area above the laboratories is public area where the effective dose D_{eff} has to be below 1 mSv/a (see Fig. 2 d)).
- **e)** An existing Faraday cup should be used as beam dump.

Simulation Process

The aim of the simulations is to conceive a possible solution regarding a radiation safety concept, following the constraints mentioned above.

For this purpose FLUKA [1], a Monte Carlo simulation program was used, which simulates the transport of parti-

---

[*] heurich@physik.uni-bonn.de

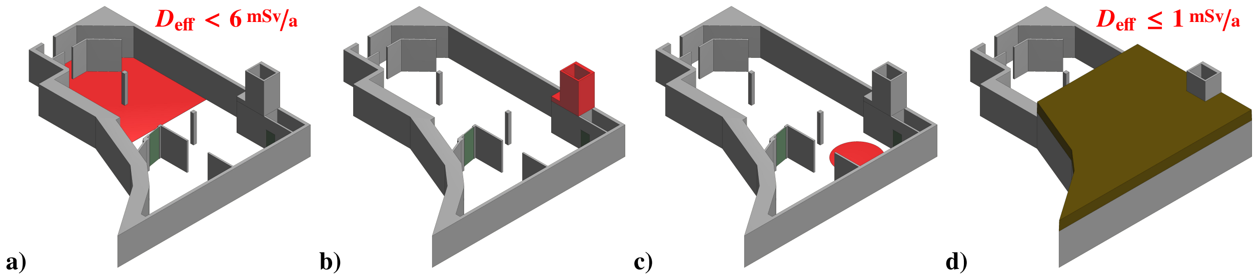

Figure 2: The laboratories with illustrations for the different constraints for the radiation protection concept.

cles in and their interaction with matter. The user defines an input file containing beam properties, output parameters and the geometry with corresponding materials. This input file is produced by the graphical user interface FLAIR, which also visualizes the output parameters of FLUKA. The occasionally complex geometry can be built using the interface SimpleGeo, which is a CSG (constructive solid geometry) based program. Objects—or regions as combinations of objects—can be created with the help of geometric primitives by using Boolean operators.

After the geometry is generated, materials need to be assigned for the geometry regions or objects. Some materials are predefined in FLAIR, others can be defined using the stochiometric composition in units of the mass percentage number. For example baryte or barium sulfate ($BaSO_4$) consists of 27.42 % oxygen, 13.74 % sulfur and 58.84 % barium.

Next, the output parameters of FLUKA are selected. Here, the equivalent dose of electrons and photons as well as of neutrons are quantities of interest to be optimized in regions defined by the constraints.

FLUKA does not give equivalent dose as output, but deposited energy in the case of electrons and photons plus fluence in the case of neutrons. To obtain the equivalent dose in both cases, two user routines are used. One routine converts the deposited energy E_{dep} from electrons and photons into absorbed dose D, which is in case of electrons and photons equal to the equivalent dose. The other routine converts the neutron fluence Φ into the equivalent dose via multiplication of Φ with an energy dependant factor from ICRP74 [2] and Pellicioni [3] data.

In the input file beam properties like particle type, beam energy and width as well as the position relative to the geometry are defined.

One simulation with user defined primaries consists in general of several cycles. After the simulation process the data files created are merged to create a file containing the average values and statistical errors.

Simulation Geometry

In course of the simulations a geometry fulfilling all demands **a)** – **e)** was developed; it is shown in Fig. 3. Based on the geometry of the laboratories and of the Faraday cup, heavy concrete elements were added.

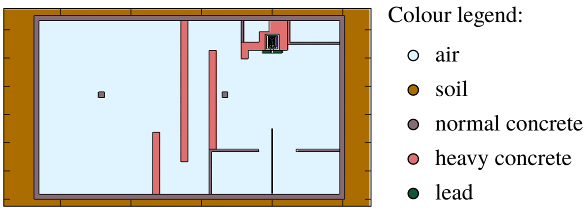

Figure 3: The simulation geometry created with SimpleGeo. A simplified model showing the soil sourounding the basement with its walls consisting of normal concrete. Heavy concrete elements are used for the radiation protection walls dividing the room into two areas, as well as for the beam dump casing.

To fulfill demand **a)**, a radiation shielding wall, consistinging of baryte concrete with a density of $3.5\,\text{t}\,/\,\text{m}^3$ is used. The remaining constraints can only be realized by using a beam dump casing with a customised form (see Fig. 4). This special form assures a further usage of the emergency exit. In this casing—which is also positioned as deep as possible into the emergency exit shaft area (Fig. 5)—a hole remains housing the Faraday cup.

The Faraday Cup

To be able to measure the external beam current, a Faraday cup is used as primary beam dump. This cup was used in the 1980s and consists of 81 kg depleted uranium and is sourrounded by a lead casing. The advantage of this uranium dump is its small dimension. Compared to a lead dump it must only be half as large in order to get the same shielding effect. A slight disadvantage is the higher backscattering of secondary radiation, which increases with heavier elements.

Simulation Results

The simulation results—thus equivalent doses—are displayed in Fig. 6 to Fig. 8, for electrons and photons on the one hand and neutrons on the other. In every simulation the electron beam had an energy of $E = 3.2\,\text{GeV}$ and an external beam current of $I_{\text{ext}} = 100\,\text{pA}$ was delivered to the experiments for the duration of $t = 1000\,\text{h}$, which corresponds to one operational year.

A further reduction of the neutron fluence in the test area could be achieved by using polyethylene as coating of the in-

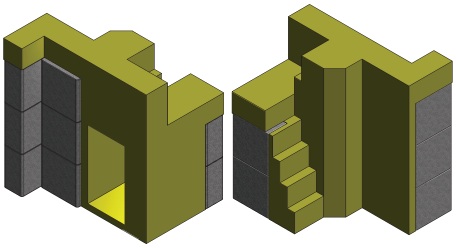

Figure 4: The beam dump casing viewed from front (left part) and back side. The electron beam would come from the lower left corner. A hole is left in the casing to house the Faraday cup. The back side view reveals the step-like form to match the form of the real stairs. The hole casing consists of baryte heavy concrete. Eight existing concrete blocks could be used, the rest is bricked and poured.

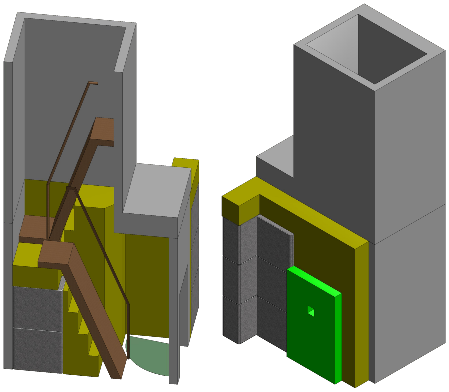

Figure 5: The emergency exit shaft with stairs and beam dump casing. Here, one can see that the special form for the casing is required to conserve the emergency exit shaft. To gain as much space as possible for the concrete shielding the first stairs are shifted towards the door. In front of the hole (visible in Fig. 4) a lead wall is installed to reduce radiation propagating towards the test area.

ner walls of the beam dump casing, which acts as moderator for neutrons. Secondary particles, produced in the moderation process will stay in the lead wall or in the concrete. This leads to a decrease of the neutron fluence of roughly a factor 10.

CONCLUSION

The radiation safety concept of the new beamline for detector test at ELSA was simulated with the particle transport code FLUKA. Starting with the geometry of the laboratories, heavy concrete walls and a casing for the primary beam dump were added to obtain radiation levels that remain under statutory limits in regions where it is required.

The beam dump casing was built. The shielding walls and the Faraday cup will be installed in the following weeks. The part of the beamline located in the laboratories is completed. The part in the tunnel will be set up within this year.

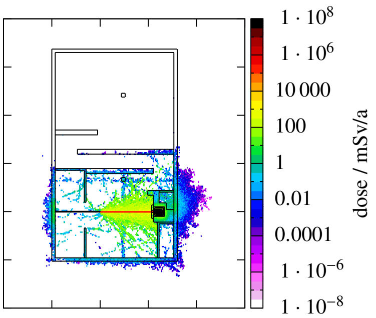

Figure 6: The dose in the basement generated from electrons and photons. In the control room there is no radiation level indicated.

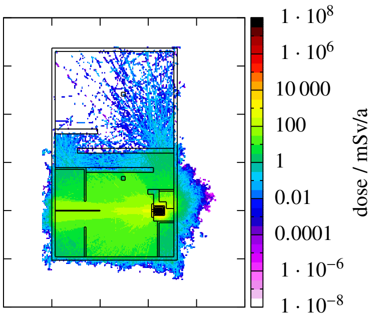

Figure 7: The neutron dose in the basement. Neutrons are present in the control room, but the dose is below the statutory limit.

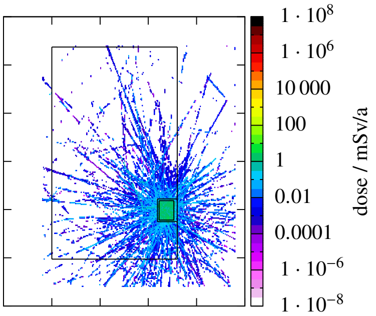

Figure 8: The neutron dose on the meadow remains under the value of 1 mSv/a. The exit shaft, where the dose is above this limit, cannot be accessed.

REFERENCES

[1] G. Battistoni, S. Muraro, P.R. Sala, F. Cerutti, A. Ferrari, S. Roesler, A. Fassò and J. Ranft, “The FLUKA code: Description and benchmarking”, Proceedings of the Hadronic Shower Simulation Workshop 2006, AIP Conference Proceeding 896, pp. 31–49 (2007).

[2] ICRP, 1996. “Conversion Coefficients for use in Radiological Protection against External Radiation”, ICRP Publication 74. Ann. ICRP 26 (3–4).

[3] M. Pelliccioni, “Overview of fluence-to-effective dose and fluence-to-ambient dose equivalent conversion coefficients for high energy radiation calculated using the FLUKA code”, Radiation Protection Dosimetry Vol. 88, No. 4, pp. 279–297 (2000).