SHIELDING CALCULATIONS FOR THE COMMISSIONING BEAM DUMP DURING THE FIRST STAGE BEAM COMMISSIONING OF THE ESS WARM LINAC

K. Batkov*, L. Tchelidze, European Spallation Source, Lund, Sweden

Abstract

Starting operations in 2019, the European Spallation Source will be a long pulsed neutron source powered by a 5 MW proton beam impinging on a rotating tungsten target. This study describes the results of shielding calculations performed to determine necessary shielding configuration during various steps of first stage beam commissioning of the ESS Linac. The first stage commissioning is divided in four steps with different beam energy, up to maximum 74 MeV. The commissioning beam dump shielding assessment is presented for each step of first stage commissioning and different beam parameters (energies, repetition rates, pulse lengths and currents).

INTRODUCTION

The European Spallation Source facility is hosted in Lund, Sweden. It consists of a linear proton accelerator, target for neutron production and a number of neutron instruments. The ESS project is in a construction phase. Currently, the accelerator design is close to be finalised. The procurement phase for many of the accelerator components has started. The structural part of the infrastructure hosting the accelerator is built.

ESS accelerator consists of a normal-conducting and superconducting parts. The proton beam is created in an ion source, which is then transported through a low energy beam transport (LEBT). After that the beam is injected in a radio-frequency quadrupole (RFQ), which accelerates the beam to 3.6 MeV. Medium energy beam transport (MEBT) follows, which transports and matches the beam to a first tank of a drift tube linac (DTL). The normal conducting part of the accelerator ends with the 5th DTL tank, after which a superconducting linac (SCL) follows. In 2018, a beam commissioning of an ESS normal conducting accelerator (excluding the 5th DTL tank) is planned. This corresponds to a proton beam up to 74 MeV. The beam will be commissioned on a temporary beam stop.

In order to gain flexibility and time for project schedule, the accelerator tunnel, which is approximately 600 m long, will be divided into two parts. In the first ~60 m of the tunnel, the normal conducting linac will be installed and commissioned, while in the second part of the tunnel, superconducting linac and support structures will be installed. The two parts of the tunnel will be separated by two concrete walls, which will form a chicane as shown in Fig. 1a. Shielding of a temporary beam stop will be designed in a way that allows installation activities in the superconducting part of the linac even when the beam is on in the first part of the tunnel.

This paper presents the results of preliminary prompt dose rate calculations for 4 proton beam energies: 22, 40, 57, and 74 MeV and for a beam on a Linac4 [1] beam dump. These energies correspond to the ends of individual DTL tanks.

GEOMETRY

A Monte Carlo model of the ESS linac tunnel was created, where the beam dump and temporary shielding walls were inserted as described below.

Beam Dump

A temporary beam stop needs to be considered for the ESS linac 1st stage beam commissioning. Initially, it was planned to use a beam dump, similar to that used at Linac4 [1]. Shielding for the Linac4 beam dump assessment was performed and the results are presented below. However, later it was decided to use a Faraday cup instead and its shielding optimisation calculations are currently on-going.

The Linac4 beam dump consists of a graphite core, sitting on a copper base (Fig. 1 and [1, page 22]). The dump is actively cooled with water and is surrounded with steel and concrete shielding.

Temporary Shielding Walls

Two temporary shielding walls (TSW) made of concrete are installed behind the beam dump. The thickness of each wall is 1 m, the distance between the walls is 1.2 m.

CALCULATIONS

The CombLayer tool [2] was used to build the MCNP(X) [3] model of the beam dump and the linac tunnel walls. The CEM model [4] coupled with the ENDF/B-VII neutron libraries [5] were used for particle transport. The ICRP-116 [6, 7] flux-to-dose conversion factors were used for the prompt dose estimation.

For each incident proton energy, the beam dump was moved at the end of the corresponding DTL tank. Since the considered proton energies are low, only the neutron and gamma contributions into the total dose rate were considered. They are shown individually in the corresponding figures.

RESULTS

Figure 2 and 3 show the dose rate maps two extreme proton beam energies, 22 and 74 MeV. Figure 4 and 5 show the corresponding maximal dose rates along the proton beam direction, where the locations of the beam dump and the temporary shielding walls are shown by grey rectangles.

* konstantin.batkov@esss.se

04 Hadron Accelerators

A17 High Intensity Accelerators

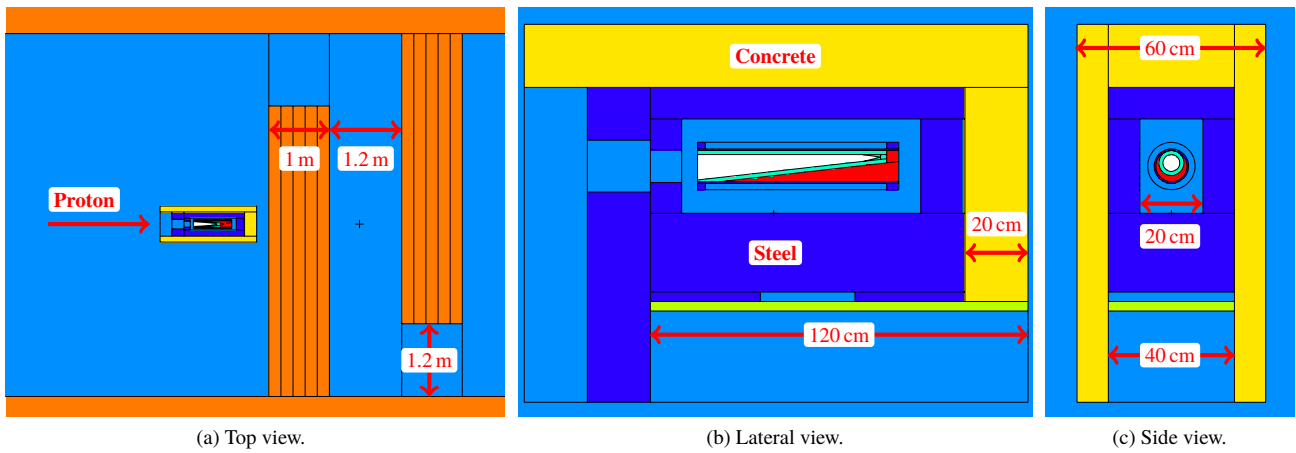(a) Top view.   (b) Lateral view.   (c) Side view.
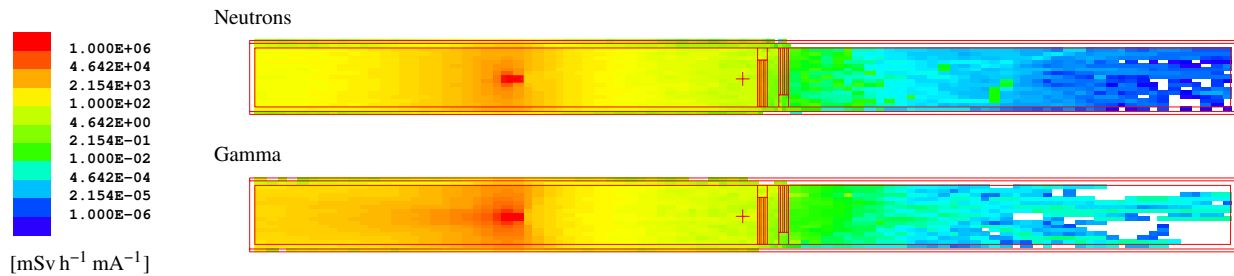
Figure 1: Beam dump geometry.

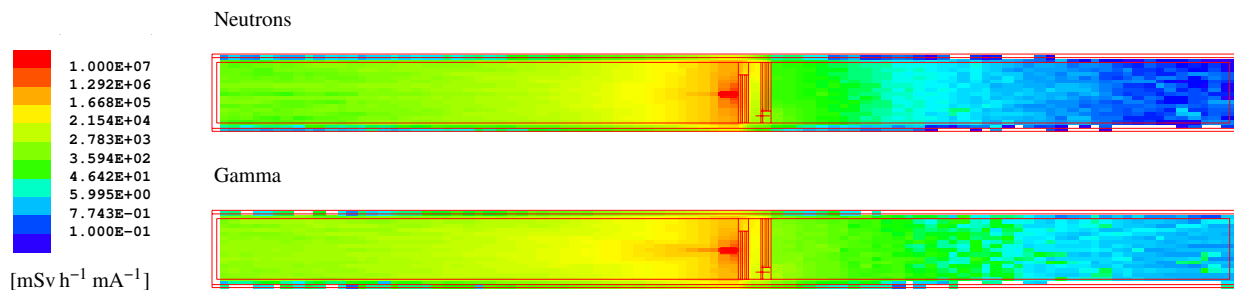Figure 2: Dose rate maps at $E_0 = 22$ MeV.
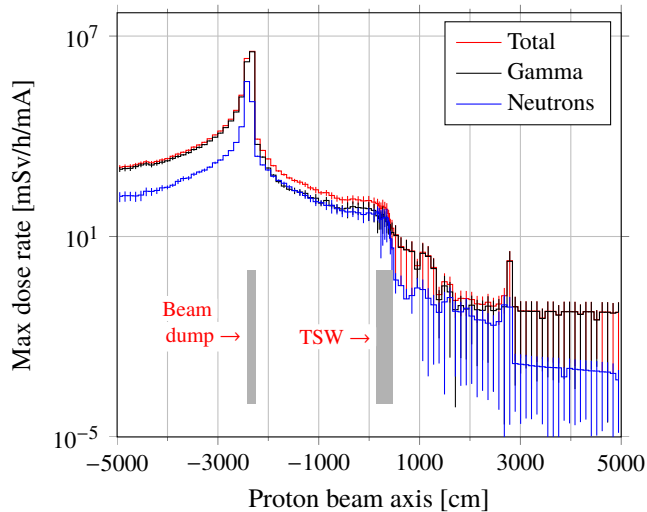

Figure 3: Dose rate maps at $E_0 = 74$ MeV.

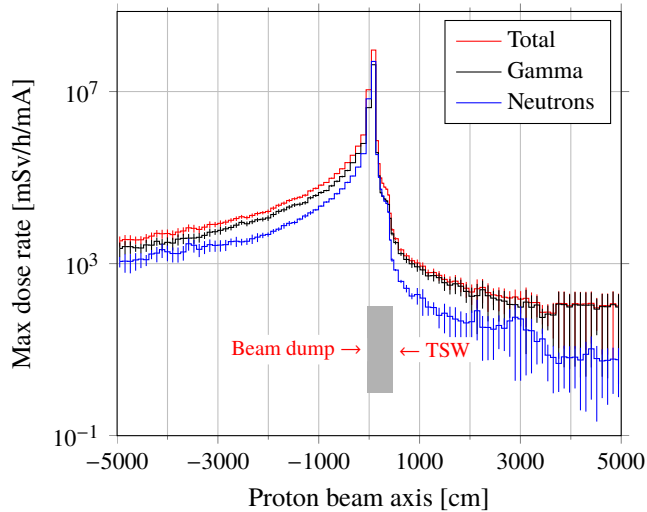Figure 4: Maximal dose rates along the proton beam axis at $E_0 = 22\,\text{MeV}$.

Figure 5: Maximal dose rates along the proton beam axis at $E_0 = 74\,\text{MeV}$.

CONCLUSIONS

Figure 6 shows maximal dose rate behind the second temporary shielding wall as a function of proton energy. The dose rate is normalised per 1 mA.

Average beam current limit for each step of beam commissioning (energies 22 MeV to 74 MeV) will be derived from the shielding calculations. The limit will be determined such
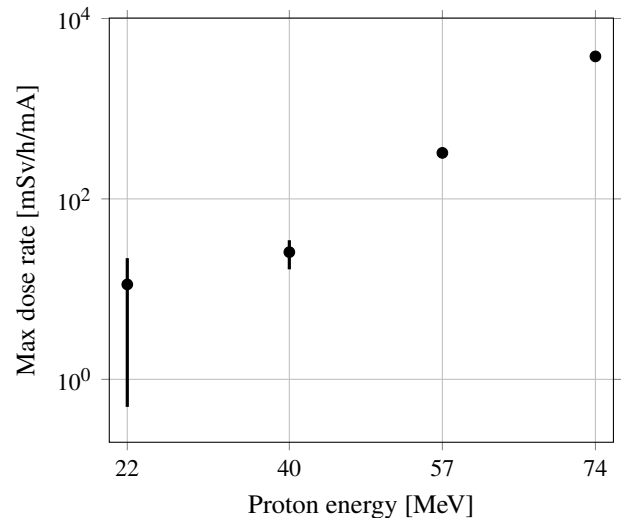

Figure 6: Maximal dose rate behind two temporary shielding walls . The data for this plot are the bin contents of the *Total* histograms on the figures like Fig. 4 at $x = 500\,\text{cm}$ for the corresponding energies.

that it allows for a supervised green radiation area ($<3\,\mu\text{Sv/h}$) outside of the temporary shielding chicane.

REFERENCES

[1] Cesare Maglioni. The Linac4 commissioning dump, June 2013. EDMS-1182648.

[2] Stuart Ansell. CombLayer: A fast parametric MCNP(X) model constructor. In *ICANS XXI*, pages 148–154, Mito, Japan, September 2014. DOI:10.11484/jaea-conf-2015-002, JAEA, https://github.com/SAnsell/CombLayer.

[3] Denise B. Pelowitz. MCNPX 2.7.0 User's Manual. LA-CP-11-00438, April 2011.

[4] K.K. Gudima, S.G. Mashnik, and V.D. Toneev. Cascade-exciton model of nuclear reactions. *Nuclear Physics A*, 401(2):329 – 361, 1983.

[5] M.B. Chadwick et al. ENDF/B-VII.0. *Nucl. Data Sheets*, 102:2931, 2006.

[6] C.H. Clement, editor. *Annals of ICRP. ICRP Publication 116: Conversion Coefficients for Radiological Protection Quantities for External Radiation Exposures*, number 40 (2–5). ICRP, 2010.

[7] Günter Muhrer and François Javier. ESS procedure for designing shielding for safety. ESS-0019931, March 2015.