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Complementary shielding calculations for Linac 4 in the South Hall

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Abstract

This note discusses Monte Carlo simulations performed to assess the possibility of reducing the thickness of the top shield at the high-energy end of Linac 4 by replacing concrete by a concrete/iron structure, in order to allow for sufficient clearing for the crane traveling across the South Hall. The note also reports on some improved estimates of the ambient dose equivalent rate $H^*(10)$ in building 354 located at approximately 20 m distance from the linac.

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1. Introduction

A new proton linac, called Linac 4, is being designed at CERN to replace the present Linac 2 injecting protons at 50 MeV into the PS booster (PSB). Linac 4 will accelerate H^- ions at a kinetic energy of 160 MeV (see, for example, ref. [1]) to be injected into the PSB by charge-exchange. The linac is also conceived as the first section (the so-called front-end) of a future multi-GeV, multi-MW Superconducting Proton Linac (SPL) [2, 3]. Until now the project has primarily considered the installation of Linac 4 in the South Hall of the PS complex.

The shielding design for Linac 4 in the South Hall has been discussed in a number of technical notes [4 – 6] and published in the Technical Design Report [7]. The study has shown that the minimum thickness of the roof shielding at the high-energy end of the linac tunnel is 160 cm concrete. Such thickness poses a problem for the clearing of the crane traveling across the South Hall. The present note discusses the possibility of reducing this maximum thickness of the top shield. The note also reports on some improved estimates of the ambient dose equivalent rate $H^*(10)$ in building 354 located at approximately 20 m distance from the linac.

2. Top shielding at the high-energy end of the linac

A routine loss of 1 W/m has been assumed as guideline value in the shielding calculations. In a real scenario, beam losses will most likely not be equally distributed along the machine, but rather concentrated in a number of “hot spots”. As in the previous calculations, in this study it was assumed that constant losses of 10 W occur at selected points along the machine. It has been shown previously that for the shielding requirements this loss pattern is approximately equivalent to a uniform loss of 1 W/m.

In order to reduce the thickness of the top shield at the high-energy end of the linac tunnel, an alternative shielding design based on a composite iron/concrete structure was considered. Simulations with the FLUKA radiation transport code [8, 9] were run with the same simplified model of the South Hall used in the previous calculations, including the roof, the linac tunnel and the adjacent PS wall (figure 1). As in the previous studies a 10 W, 160 MeV proton beam hits a 5 x 5 x 5 cm^3 copper target, to simulate a point loss in a quadrupole or in a drift tube. Copper was chosen as an element representative of other materials with similar density (e.g., iron and stainless steel). The roof of the South Hall was represented by a 1 cm thick layer of iron 17 m above the floor (the actual height of the hall). The ambient dose equivalent rate $H^*(10)$ was scored at height between 4 m and 5 m above the floor level. This height corresponds to the gangway running on the first floor of the hall, adjacent to building 354, at about 20 m distance (left in figure 1) from Linac 4.

Three different configurations of the top shielding were investigated: 40 cm of iron + 40 cm of concrete, 40 cm of iron + 60 cm of concrete, and 40 cm of iron + 80 cm of concrete. Figures 2, 3 and 4 show the dose equivalent rate $H^*(10)$ expected between 4 m and 5 m above the hall floor for these configurations (it should be noted that the scale used for the plots is not always the same)

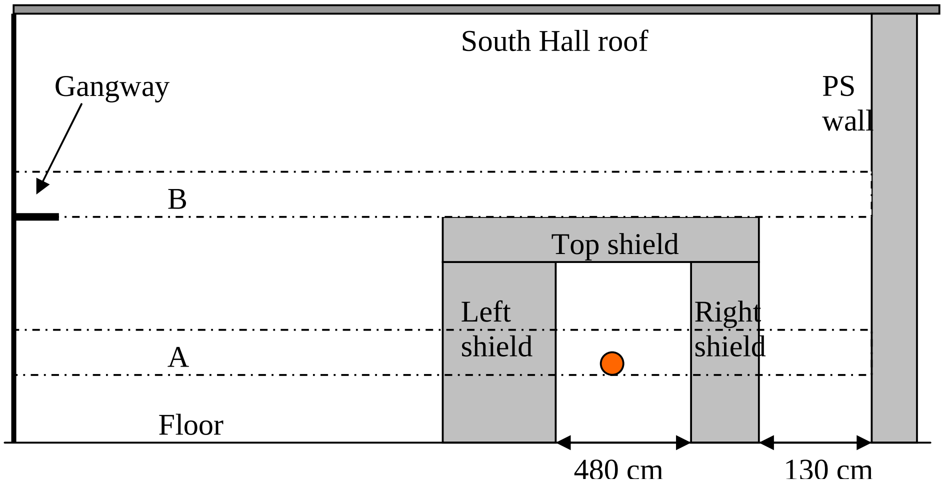

Figure 1: Front cross-sectional view of the linac tunnel inside the South Hall. The spot inside the tunnel represents the linac [6].

With a top shielding made of 40 cm of iron + 40 cm of concrete the dose equivalent rate on the gangway would be around 0.9 μSv/h. This is not acceptable due to the approximations and uncertainties in the calculations and because the gangway is frequently used by the personnel and is not classified as controlled area (that is, wearing of a film badge is not required). The dose equivalent rate in the adjacent building 354 will be similar to the one on the gangway.

The 40 cm of iron + 60 cm of concrete composition would keep the maximum dose equivalent rate at around 0.3 μSv/h, while the 40 cm of iron + 80 cm of concrete structure would keep the maximum dose equivalent rate at around 0.2 μSv/h. In the last two configurations the dose equivalent rate is below 0.5 μSv/h, the limit for non-designated areas according to the new version of Safety Code F (Radiation Protection) recently released [10], with a reasonable safety margin. These areas are monitored by installed detectors and/or passive dosimeters, but wearing of a personal dosimeter is not required. The latter solution appears to guarantee maintaining the same amount of stray radiation as the 160 cm concrete roof, at the same time reducing the total thickness of the roof shield down to 120 cm. The 40 cm reduction in the overall thickness of the top shield seems sufficient to allow the necessary clearing for the crane.

3. Stray radiation in building 354 adjacent to the South Hall

As has been addressed in a previous note [11], one of the critical issues with the installation of Linac 4 in the South Hall is its proximity with office buildings, specifically building 354 (the former MCR, presently occupied by a drawing office and a meeting room), building 6 and building 8. In addition, its proximity with the weakest point of the Proton Synchrotron shielding (the so-called PS bridge) means that stray radiation from Linac 4 would add to stray radiation from the PS. For these reasons the shielding design aimed at a maximum dose equivalent rate in the South Hall below 3 μSv/h.

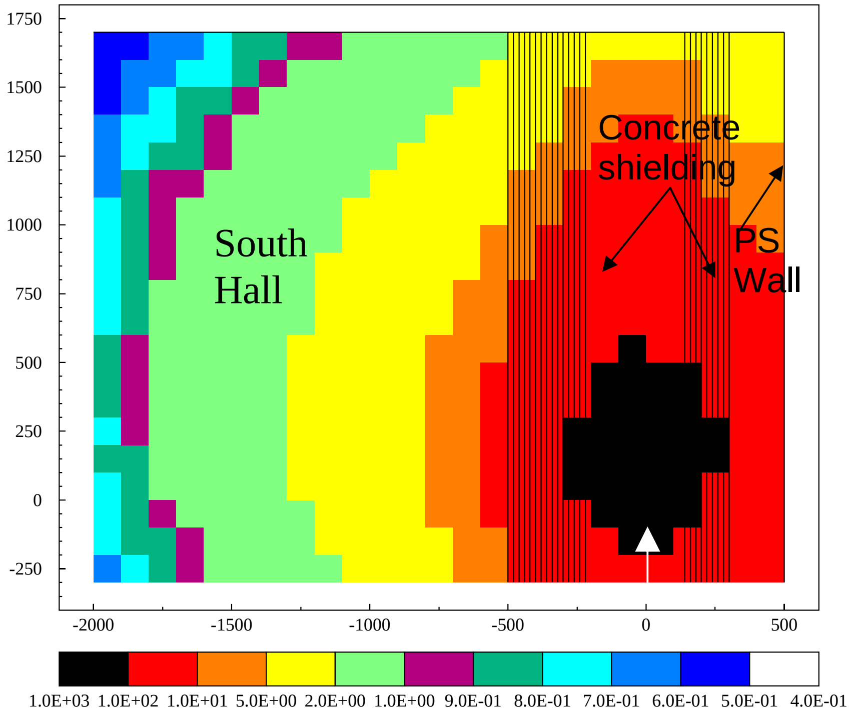

Figure 2: Beam loss in a 5 x 5 x 5 cm³ copper target, 10 W, 160 MeV, top shielding 40 cm iron + 40 cm concrete. Top cross-sectional view of the South Hall with the linac tunnel. H(10) in µSv/h at 4 m above the hall floor.*

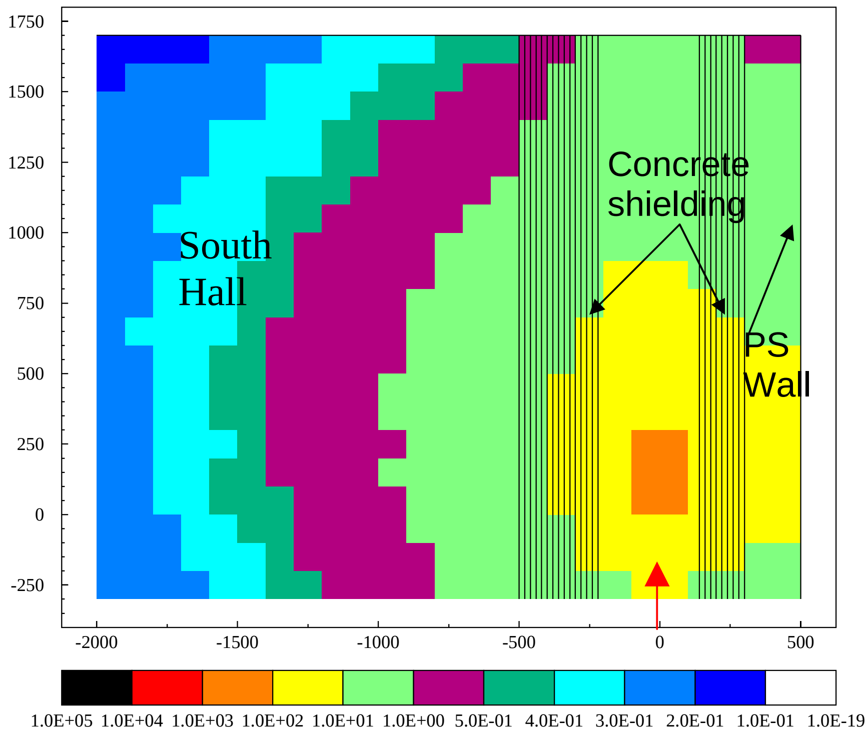

Figure 3: Beam loss in a 5 x 5 x 5 cm³ copper target, 10 W, 160 MeV, top shielding 40 cm iron + 60 cm concrete. Top cross-sectional view of the South Hall with the linac tunnel. H(10) in µSv/h at 4 m above the hall floor.*

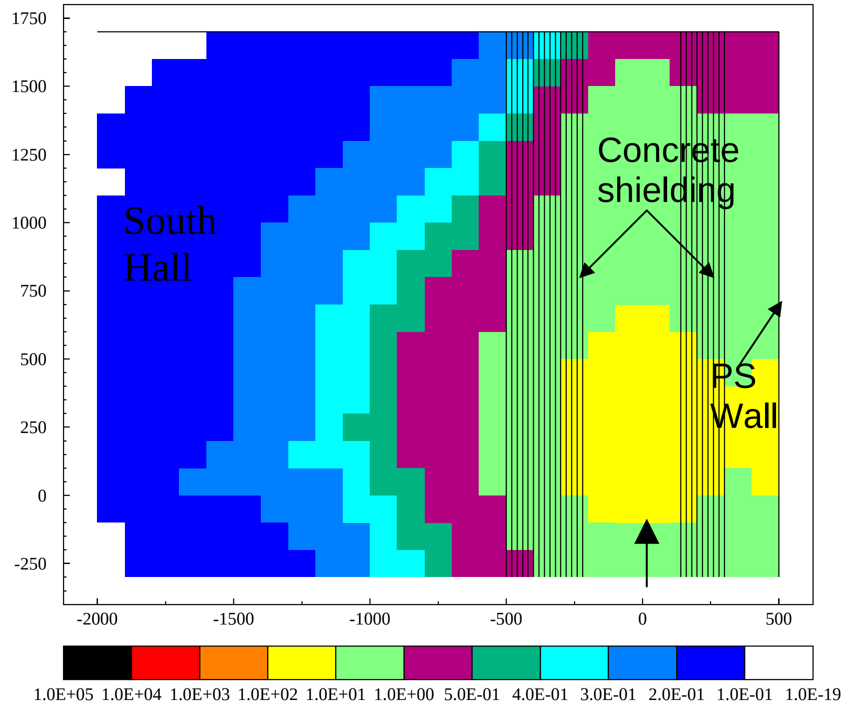

Figure 4: Beam loss in a 5 x 5 x 5 cm^3 copper target, 10 W, 160 MeV, top shielding 40 cm iron + 80 cm concrete. Top cross-sectional view of the South Hall with the linac tunnel. H(10) in µSv/h at 4 m above the hall floor.*

The section of Linac 4 closest to the above mentioned office buildings is where the beam energy varies from 40 MeV to 90 MeV. Some additional FLUKA simulations were thus performed for these two selected energies, scoring the ambient dose equivalent rate $H^*(10)$ on a finer grid at distances of up to 25 m from the linac tunnel (unlike the previous simulations for which scoring was limited to distances of up to 20 m), to include building 354. The model used for the previous simulations was modified considering the proper dimensions of the shielding at those two energies and adding a 5 cm thick concrete wall at the separation between the South Hall and building 354.

Figures 5 and 6 plot the dose equivalent rate $H^*(10)$ expected at 4 m above the floor in the south Hall and in the building 354 for a beam loss of 10 W in a 5 x 5 x 5 cm^3 copper target, for energies of 40 and 90 MeV. In both cases the maximum dose equivalent rate in the adjacent building is around 0.2 µSv/h. It should again be stressed that stray radiation from the PS will add to the contribution from Linac 4.

4. Conclusions

Monte Carlo simulations were performed to optimize the roof thickness of the tunnel designed to house the future Linac 4 in the South Hall, and to improve the dose rate estimates in the nearby building 354.

A 160 cm thick roof made of concrete [6] could be replaced by a roof made of 40 cm iron and 80 cm concrete, which has the same shielding efficiency and allows for sufficient clearing for the crane traveling across the South Hall.

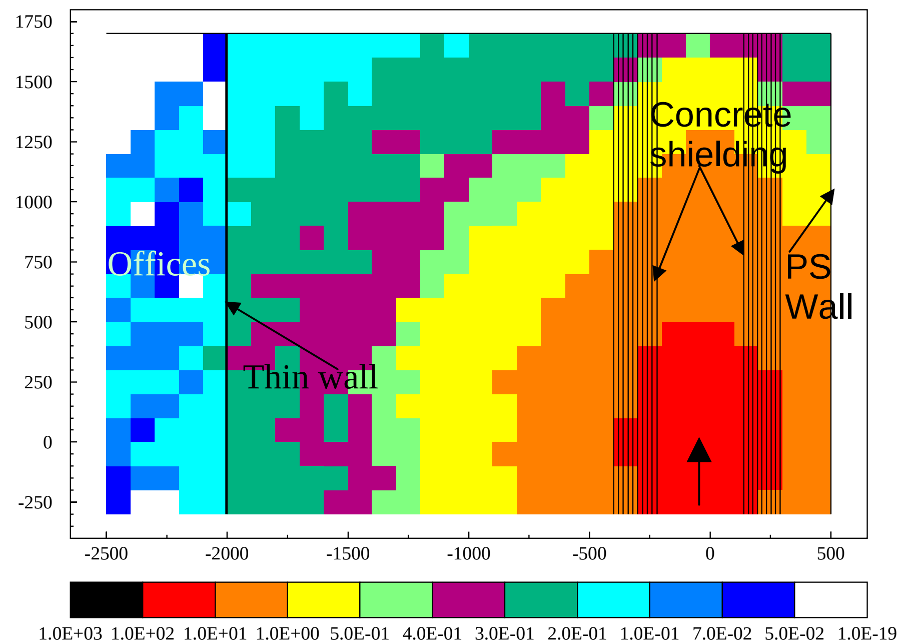

Figure 5: Beam loss in a 5 x 5 x 5 cm³ copper target, 10 W, 40 MeV. Top cross-sectional view of the building 354 and the South Hall. H(10) in µSv/h at 4 m above the hall floor.*

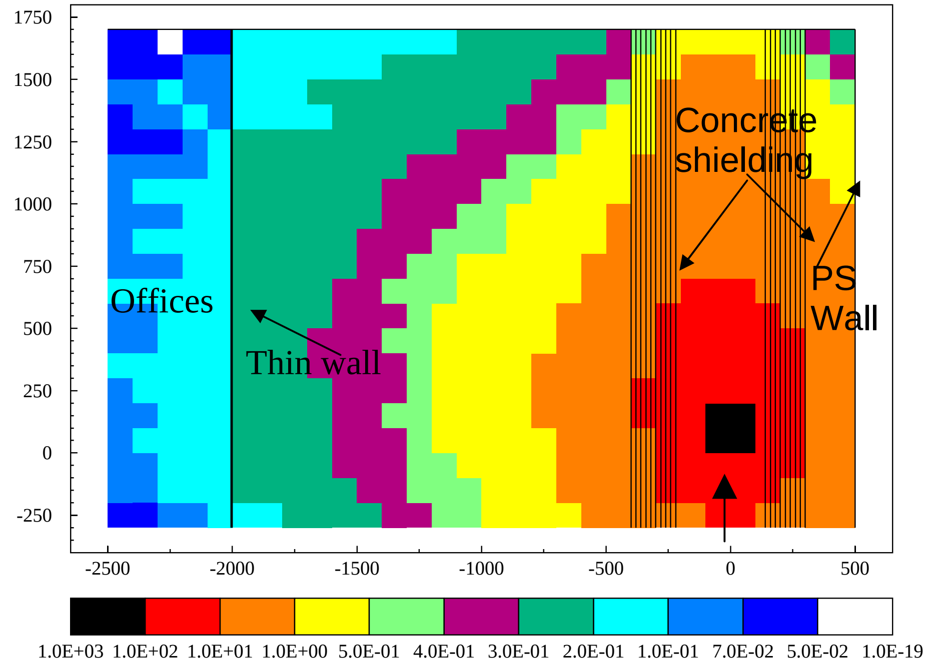

Figure 6: Beam loss in a 5 x 5 x 5 cm³ copper target, 10 W, 90 MeV. Top cross-sectional view of the building 354 and the South Hall. H(10) in µSv/h at 4 m above the hall floor.*

The dose rate in building 354 is expected to be around 0.2 µSv h^{-1}. Unless the contribution of stray radiation from the PS turns out to be more important than the one from Linac 4, this building is a “non-designated area” (i.e., an area where the dose rate is less than 1 mSv per year for annual occupation of 2000 hours, or 0.5 µSv h^{-1}). However, a permanent occupation would lead to an annual dose of about 400 µSv, which is unjustified according to Safety Code F [10]. The building should then be used for occupation on a non-permanent basis.

References

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