Summary - The ratio of photon dose rate due to induced activity between SmCo5 and SrFe12O19 targets was estimated to be a factor of 13 using the RESNUCLE feature of FLUKA code.

NLC plans to use permanent magnet in its Damping Ring beamline and it is desired to know the photon dose rate from the induced activities of the magnets from future NLC operation. Since it is rather difficult to calculate such photon dose rate directly, in this work we calculated instead the induced activities of the SmCo5 and SrFe12O19 materials in a large cylinder geometry using the RESNUCLE feature of the FLUKA code. With the activities and radioisotopes known, the photon dose rate may be estimated.

In the FLUKA calculation, the electron beam hitting the center of the front face of the target cylinder was 2 GeV. The target was 5 cm in diameter and 30 cm long. The density is 8.5 g cm⁻³ for SmCo5 and 4.98 g cm⁻³ for SrFe12O19. Electrons, positrons and photons were transported down to 5 MeV, while neutrons were transported down to thermal energy. The induced activity was calculated for a single-material target that has been irradiated for one year and has cooled down for 1 hour.

There are hundreds of radioisotopes produced in both materials. However, it was found that there are a few radioisotopes that dominate the induced activity and, thus the radiation levels, because of their long half-lives and high photon yields. For SrFe12O19, the radioisotopes of ⁵⁴Mn (half-life 312 days), ⁵²Mn (5.6 days) and ⁴⁸V (16 days) contribute to 70% of total photon energy yield (defined as AxYxE, where A is the activity, Y is the yield of photon per decay, and E is the energy of the photon). For SmCo5, the ⁵⁸Co (71 days) radioisotope contributes to 89% of total photon energy yield. Note that the photon energies of these major radioisotopes are all around 800-1500 keV. Therefore, the photon dose rate external to a target is approximately proportional to the total photon energy yield. From the FLUKA-calculated ratio of total photon energy yield, the photon dose rate for SmCo5 is shown to be a factor of 13 higher than that for SrFe12O19.

The major radioisotopes are produced by bremsstrahlung’s photonuclear reactions in the targets, e.g., (gamma, n) for ⁵⁸Co, (gamma, np) for ⁵⁴Mn and ⁵²Mn. Note that the (gamma, n) reaction on iron, the main isotope of SrFe12O19, produces ⁵⁵Fe, whose activity is comparable with ⁵⁸Co, as expected. However, ⁵⁵Fe emits only weakly penetrating 5.5 keV photons and does not contribute much to total photon energy yield and, thus, the external dose rate.

The above-mentioned factor of 13 can be applied to a single-material target of other smaller sizes. However, for a magnet consisting of both materials of SmCo5 and SrFe12O19, the actual dose rate ratio when compared with a single material strongly
depends on how the beam is lost and bremsstrahlung photons are absorbed in different components. Note that the dose rate from a SrFe$_{12}$O$_{19}$ magnet should be close to that of an electro magnet made mainly of iron.

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