ACTIVATION AND RESIDUAL EQUIVALENT DOSE RATE STUDIES FOR AN ILC BETATRON SPOILER PROTOTYPE*

J. L. Fernandez-Hernando#, STFC, Daresbury Laboratory, Warrington, U.K.

Abstract

After different wakefield test beams and radiation damage studies a prototype design for the International Linear Collider (ILC) spoilers of the betatron collimation system in the Beam Delivery System (BDS) is under development. Studies of activation and residual equivalent dose rate are needed in order to achieve an optimum design as well as to assess the radiation shielding requirements.

INTRODUCTION

At the ILC, the removal of halo particles having large amplitudes relative to the ideal orbit is mandatory to both minimise damage to beam line elements and particle detectors and to achieve tolerable background levels in the latter. In the high energy, high intensity environment of the linear collider the low background levels will largely be ensured by placing a set of mechanical spoilers/absorbers very close to the beam. This presents two significant problems: (i) short-range transverse wakefields excited by these collimators may perturb beam motion and lead to both emittance dilution and amplification of position jitter at the IP, and (ii) impact of even a small number of bunches at the expected energy densities can damage the spoilers.

The required spoiler design must have a surface resistivity and geometry which reduces wakefield effects to an acceptable level, and must achieve this using materials and construction which resists damage due to rapid shock heating where such damage would degrade the operation of the spoilers, see e.g. [1]. The wakefield aspects of the design are being addressed by both experimental work centered around the T480 project [2] at SLAC ESA and modeling with GdfidL and ECHO [3]. The result of the T480 test beams and accident simulations lead to a geometry with a varying taper angle using 0.5 radiation lengths of titanium alloy as spoiling body and beryllium tapers. Figure 1 shows a scheme of the initial version for the prototype which was presented in [5].

BEAM HALO SIMULATIONS

For the simulations a halo with a 1/R distribution along the beam radius containing a fraction 10^{-4} of the total beam particles [6], which is $2{\bullet}10^{10}$, was considered. The simulations were done using FLUKA [7,8] and a primary beam made out of electrons with an energy of 250 GeV. To simplify the beam modeling in FLUKA a ring shaped beam was used containing a homogeneous distribution of particles which would correspond to the integrated amount of particles found in the halo for that region of space, from a radius of 0.5 cm up to 1 cm, being the former the spoiler half gap. Figure 2 shows the FLUKA geometry model of the spoiler prototype used in the simulations.

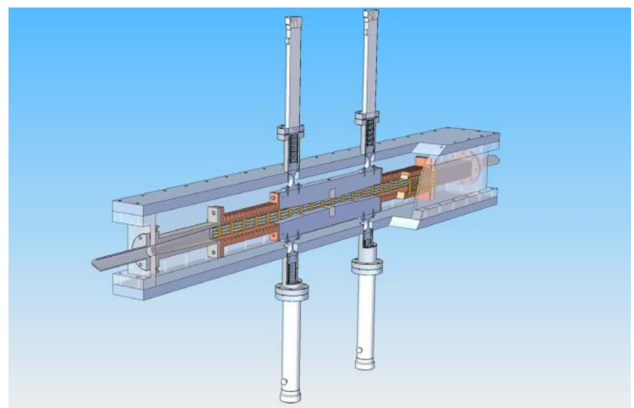

Figure 1: Spoiler mechanical design [5].

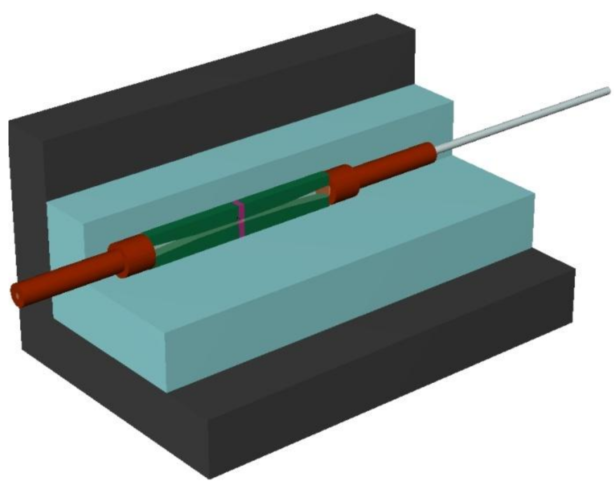

Figure 2: Spoiler model for FLUKA sitting on its shielding, borated paraffin and lead for this case.

Three different models were compared: the spoiler prototype without shielding, the spoiler with shields made out of concrete and lead, and the spoiler with shields made out of borated paraffin and lead. Concrete and borated paraffin are materials with high neutron stopping capabilities and lead is mainly used to shield from

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#juan.fernandez-hernando@stfc.ac.uk

generated photons and charged particles. The simulations were performed for a period of 1 month and another of 6 months of constant beam halo irradiation. The halo was only made out of electrons although a real halo would also contain a fraction of photons. Simulations with a photon halo demonstrated that the contribution to the overall activation and ambient dose was one to two orders of magnitude below the electrons contribution. Therefore for these simulations only electrons were used. Figures 3 and 4 compare the residual equivalent dose rate for the spoiler prototype without any shielding.

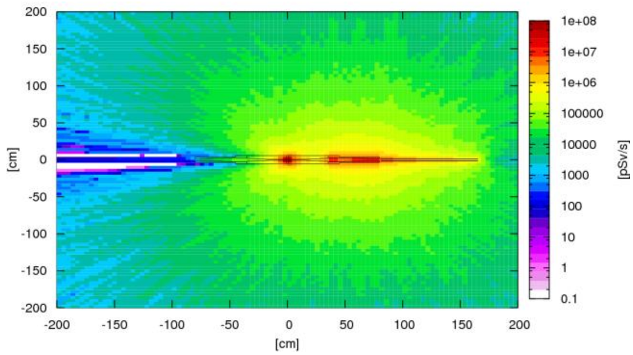

Figure 3: Residual equivalent dose rate after 1 month of constant irradiation by the halo and after 1 day of cooling time for the option without shields.

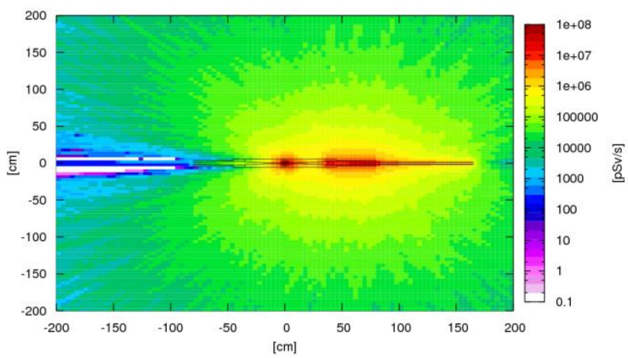

Figure 4: Residual equivalent dose rate after 6 month of constant irradiation by the halo and after 1 day of cooling time for the option without shields.

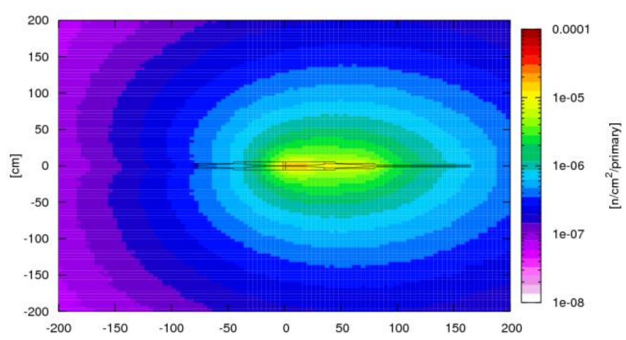

Figure 5: Neutron fluence per primary beam particle due to the halo hitting the spoiler prototype. No shielding.

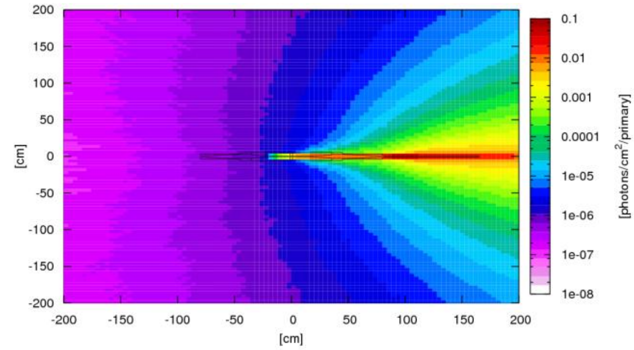

Figure 6: Photon fluence per primary beam particle due to the halo hitting the spoiler prototype. No shielding.

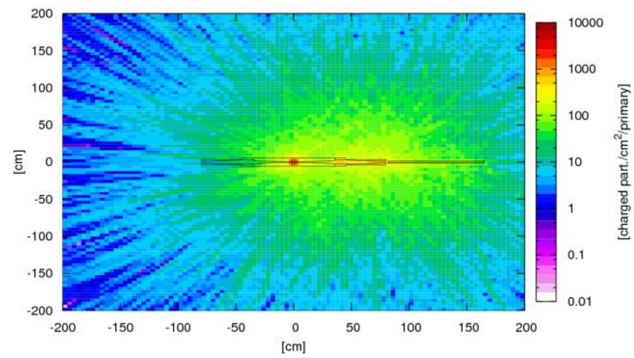

Figure 7: Charged particle fluence per primary beam particle due to the halo hitting the spoiler prototype. No shielding.

Figures 5 to 7 show the neutron, photon and charged particle fluence respectively per primary halo particle. It can be seen that the major source of residual equivalent (or ambient) dose rate comes from the generated charged particles while the generated photons play a secondary role. A rather negligible amount of neutrons is generated barely contributing to any amount of ambient dose.

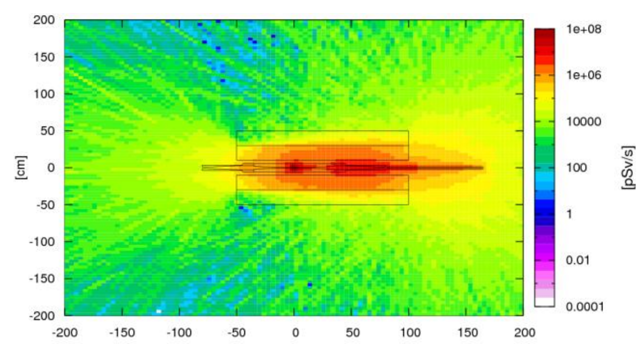

Figure 8: Residual equivalent dose rate after 1 month of constant irradiation by the halo and after 1 day of cooling time for the shielding option of concrete covered by lead.

Figures 8 and 9 show the residual equivalent dose rate after 1 month of constant halo exposure for the shielding configurations of concrete covered by lead and borated paraffin covered by lead, respectively. Figures 10 and 11 show the photon and charged particle fluences respectively for the spoiler with concrete covered by lead shields. The charged particle fluence is highly reduced by the shielding whereas the same cannot be said about the photons which flew downstream of the spoiler. Results are very similar for the option using borated paraffin instead of concrete.

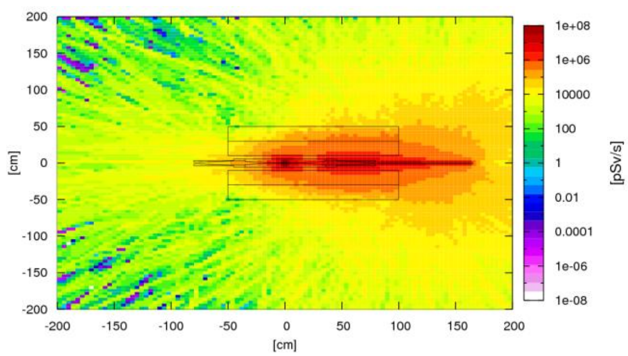

Figure 9: Residual equivalent dose rate after 1 month of constant irradiation by the halo and 1 day of cooling time for the option of borated paraffin and lead shields.

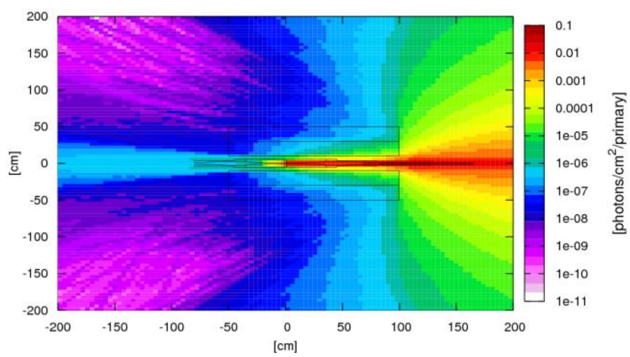

Figure 10: Photon fluence per primary beam particle due to the halo hitting the spoiler prototype with concrete covered by lead shields.

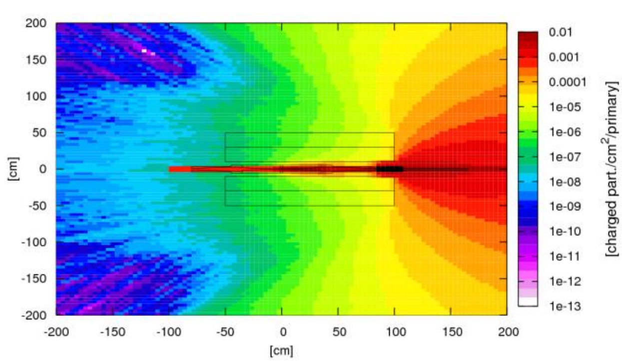

Figure 11: Charged particle fluence per primary beam particle due to the halo hitting the spoiler prototype with concrete covered by lead shields.

CONCLUSIONS

There is little difference between the concrete plus lead combination and the borated paraffin plus lead one, probably due to the negligible contribution to the dose of the few generated neutrons. Therefore increasing the lead length would be the best option to reduce fluence background and residual equivalent dose. The length and thickness of the shielding will have to be decided taking into account the threshold levels of acceptable ambient dose.

Shielding greatly helps in reducing the charged particle background around the spoilers but not as much with the generated photons which flow downstream of them. Most of them will be absorbed by the collimator absorber but maybe further studies could be done to acknowledge the danger that these photons may represent for the radiation background in the detector.

Simulations of six months exposure to the halo showed around a factor 2 greater residual equivalent dose rate than the ones performed with just one month of exposure in some positions but barely any difference in other areas.

Heating in the spoilers due to the halo exposure and a possible cooling system is under study.

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