Collider-Accelerator Department

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Memo

date: *February 25, 2014*

to: *Collider-Accelerator Department Radiation Safety Committee and J. Skaritka*

from: *D. Beavis, Chair C-AD RSC*

subject: *Radiation Calculation for Gatling Gun Test and Controls*

The experiment would like to conduct a low power test of the Gatlin gun up to a current of 17 nano-Amps, which corresponds to $2.93*10^{16}$ e/hr. The dose rates at 130cm would be approximately 0.5 mrad/hr in the forward direction and 3-4 times smaller in the transverse direction. Scaling the potential dose rates at greater distances can be calculated with $1/r^2$ scaling where r is the distance. The dose scales linearly with the beam current. The details of how the estimate was conducted and the controls that are in place to limit the radiation are discussed below.

A calculation was conducted to estimate the dose rates for a Gatling gun test which will be conducted off-site. The Monte Carlo program MCNPX[1] was used to estimate the photon dose rates. A simplified geometry was used to provide to provide a conservative estimate of the radiation external to the device. The geometry of the dump area was approximated with a Al target with thickness 0.1 cm and radius 1mm at z=0. An Al can was placed around the target with the ends at z= -20 cm and z= +20 cm and an inner radius of 1cm. The wall thickness was 0.3 cm. Outside the Al can was a layer of Ti with a thickness of 0.15 cm. Point detectors were used to measure the photon dose at four locations. The dose per electron is given in Table 1 below:

Table 1: Dose per electron at 220 keV

Z (cm)	**Radius (cm)**	**Dose/electron (rad/e)**
-20	32	$3.7*10^{-18}$
0	32	$7.2*10^{-18}$
20	32	$6.1*10^{-18}$
25	0.5	$2.45*10^{-17}$

At a distance of 1.3 meters the 90 degree dose is $4.4*10^{-19}$ rad/e. The forward result is $1.48*10^{-18}$ rad/e. The 1.5 mm Al shield at 1.3 meters is not expected to reduce the dose much further, approximately 10%.

[1] MCNPX version 2.7C was used for the analysis. D. PELOWITZ (ed.), "MCNPX User's Manual", Version 2.7.0, Los Alamos National Laboratory, LA-CP-11-00438 (2011).

The power supply can deliver 8mA of current. It is important to the limit the current to the gun since the maximum power supply current is 8 mA, which could result in dose rates of 50- 200 rad/hr. These dose rates are sufficiently high that dual interlocks/protection would be required if the device was operated for substantial time at this current. There is no information to determine if the device would self limit at high current (i.e. break in a short time). A circuit to limit the power supply current to 83 micro-Amps has been designed and reviewed[2]. The circuit is being constructed and the gun will not be operated without the circuit installed. This limits the durations of a sparks to a short time duration. The sustained voltage of the cathode will be a decreasing linear function of current with the resistor in place. At a constant cathode voltage of -220 kV the maximum current would be 10 micro-Amperes. The maximum possible dose rate at 10 micro-Amperes is 60 to 250 mrads/hr at 130 cm. This control is very robust but an additional control to limit the electron current has been added.

The electron current from the gun is also dependant on the quantum efficiency and the laser power that excites the cathode. A procedure describes[3] how the laser coupled with the expected cathode quantum efficiency will limit the cathode current to less than 20 nano-Amperes. The dose rate at 130 cm will be less than 0.5 mrads/hr.

The electron beams can scrape on other materials before reaching the Faraday Cup at the end. There is sufficient material outside of the beam transport to keep radiation levels low.

CC:

R. Lambiase

[2] E-mail communication from J. Sandberg to D. Beavis, Feb. 20, 2014. A copy of the circuit diagram has been e-mailed to the RSC Chair.

[3] E-mail communication from J. Skaritka to D. Beavis, Feb. 30, 2014. A copy of the procedure has been given to the RSC Chair.