Radiation due to 3.5 MeV electron beam

October 1, 2012

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This document is written to report on the radiation dose due to the possibility of electron beam in the Energy Recovery LINAC (ERL) facility hitting concrete wall. The tool used here is the simulation software "MCNPX" with the newest available version 2.7.0 at the time of this work.

1. Simulation Setup

The maximum kinetic energy of the electron beam considered here is 3.5 MeV (even though it may be higher than what can be achieved realistically). The shielding setup is just simply a block of 4 foot normal/light concrete (with a density of 2.35 g/cm^3), which is the case for the roof of ERL. In the simulation, electrons hit straight (90^o) into the concrete wall. We examine the radiation dose at 1 foot and 20 foot (as if it is the ceiling) above (or behind, as the gravitational force is ignored anyway) the concrete. The initial input file for the simulation is attached in the Section 3 at the end of this document.

2. Results

Initial attempt was to use 2-D mesh tally (a tabulation in MCNPX) to find the doses. But very quickly, it has become obvious that this method would not yield enough statistics. Therefore, F5 point/ring detectors (a variational method for tabulation) have been employed to find the doses behind the 4 ft concrete. The results of dose are shown in rem per incident-electron.

Figure 1 and Figure 2 show the doses in the unit of rem per incident-electron versus the radial distances from the original transverse beam center (x=0, y=0) at 1 ft and 20 ft above/behind the concrete respectively.

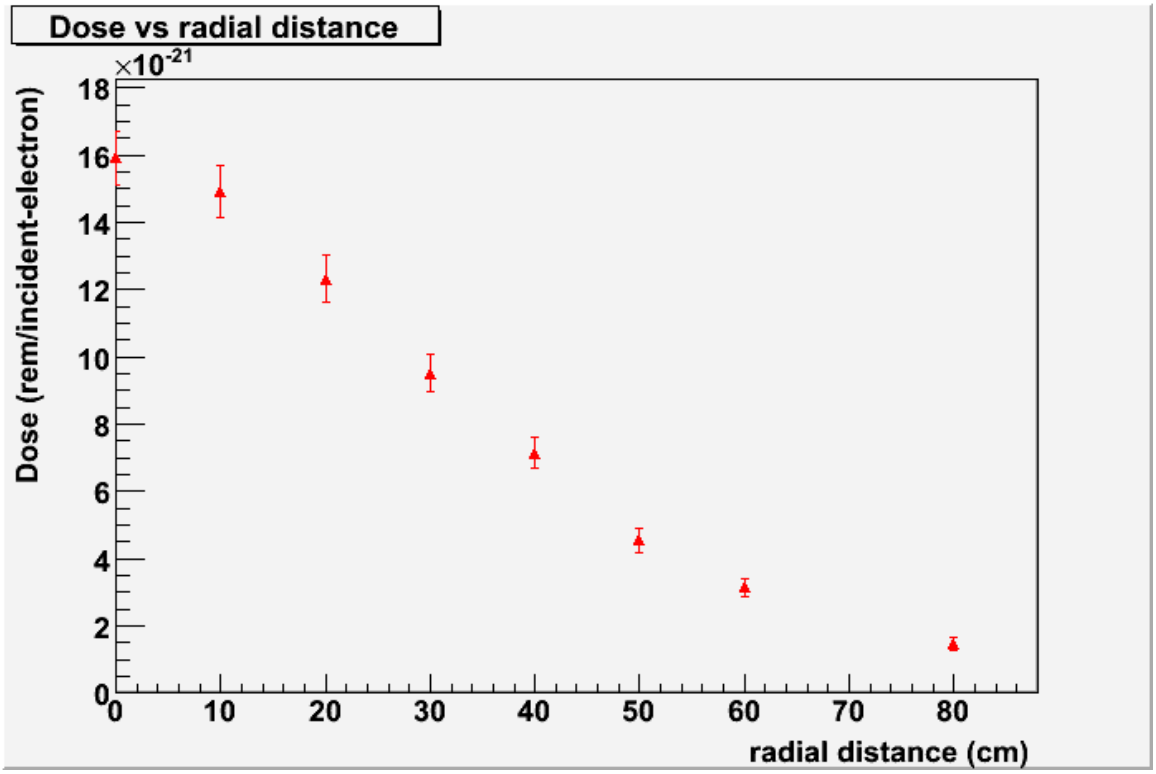

Figure 1: The doses (rem per electron) at one foot above/behind the concrete versus the radial distance from the original transverse center (x=0,y=0) of the beam.

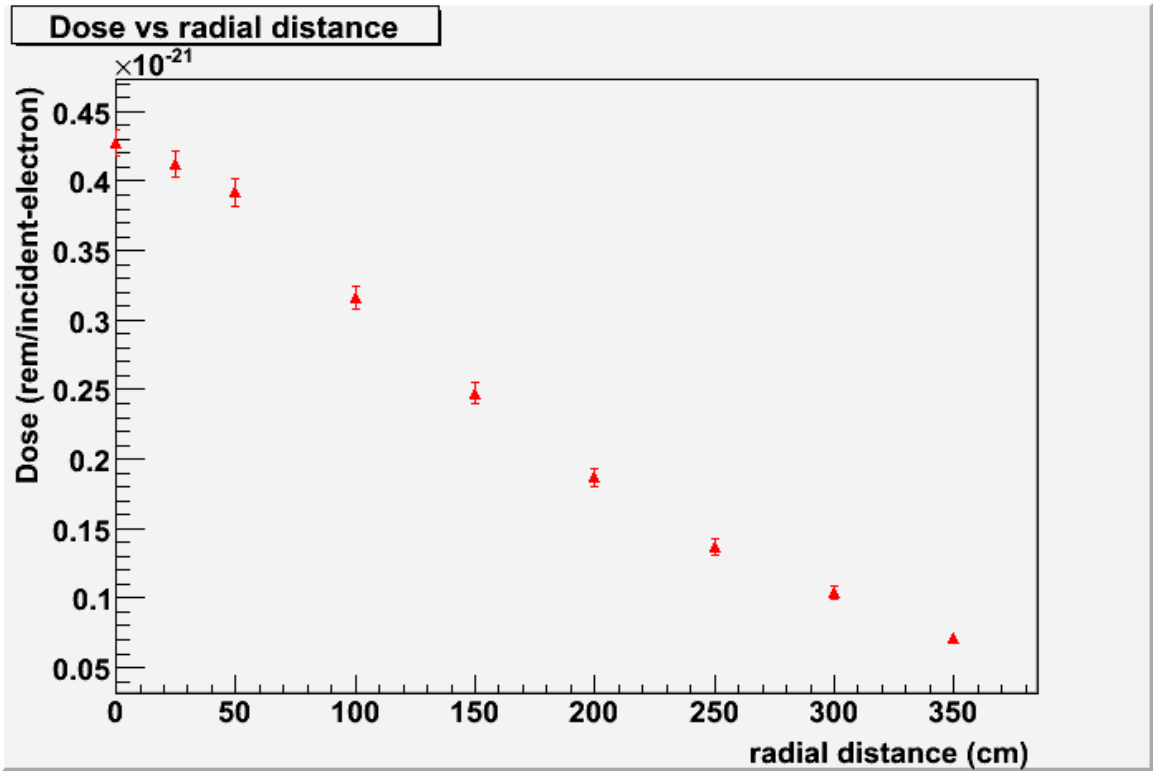

Figure 2: The doses (rem per electron) at 20 feet above/behind the concrete versus the radial distance from the original transverse center (x=0,y=0) of the electron beam.

For illustration, at 1 ft and 20 ft above the concrete, the highest doses are 1.591×10^{-20} and 4.272×10^{-22} per electron; and if the peak current is 2 μA, the doses would be 0.715 mrem/hour and 0.0192 mrem/hour.

All the doses here are due to photons as the energy is too low (ie. below the photonuclear for the materials in question) to produce neutrons. The plots shown above are the results of repeated runs with an accumulated statistics of 500 million events.

3. Appendix: MCNPX input code

```
ERL radiation behind 4 ft concrete --- Sept. 24, 2012
c
c Concrete walls
c
  1 1 -2.35 -1       imp:n,p,e,h=1
c
c vacuum
c
  2 0 -2           imp:n,p,e,h=1
  3 0 -3           imp:n,p,e,h=1
c
c
c -- don't care region
c
   999 0 1 2 3      imp:n,p,e,h=0
c ====================================

c ====================================
c
c z=0 is where the concrete starts
c x=y=0 is the center of the beam
c
c 4' concrete
c
   1 rcc   0. 0. 0.  0. 0. 121.92   100
c
   2 rcc   0. 0. 0.  0. 0. -0.2     100
c
c
c this is exactly 20'
c
c   3 rcc   0. 0. 121.92  0. 0. 609.6 400.
c
c Give it a bit more space
```

```
  3 rcc   0. 0. 121.92  0. 0. 616.0  400.
c
c
c -----------------------------------------------------

c -----------------------------------------------------
c
c
c Materials
c
c            Concrete
m1   1001 .1686 8016 .5762 13027 .0219 14028 .19350 14029 .00980 14030 .00650 &
     20000 .0191 26056 .0044
mx1:h  j        j          j          j          j          j 20040 j
mx1:p  j        j          j          j          j          j 20040 j
c
SDEF erg = 3.5  par=3  dir=1.0  vec = 0. 0. 1.0   x=0. y=0. z=-0.1  wgt=1
c
c
DBCN   52734873
c
phys:n 3.6
phys:h 3.6
c
c biased (hoping for better statistics)
c
phys:p 3.6  2j 1
phys:e 3.6
c
mode n e p h
c
c
c
nps   50000000
prdmp  5000000   5000000  1 10   5000000
c prdmp   2j 1
c
print
c
c Energy Bins (upper limits)
e0 1.0e-7 1.e-5 1.e-3 0.01 0.1 1. 2. 3.5 10.
c
c
F5:p 0. 0. 152.4 0
F15z:p 152.4 10. 0
F25z:p 152.4 20. 0
```

```
F35z:p 152.4 30. 0
F45z:p 152.4 40. 0
F55z:p 152.4 50. 0
F65z:p 152.4 60. 0
F75z:p 152.4 80. 0
c
F95:p  0. 0. 731.52  0
F105z:p 731.52  25. 0
F115z:p 731.52  50. 0
F125z:p 731.52 100. 0
F135z:p 731.52 150. 0
F145z:p 731.52 200. 0
F155z:p 731.52 250. 0
F165z:p 731.52 300. 0
F175z:p 731.52 350. 0
c
df0 iu=1 fac=2.77777777778E-4  log ic=10
c
c
c tmesh
c rmesh1:p dose 10 1 1 2.77777777778E-4
c CORA1 -60. 99i 60.
c CORB1 -60. 99i 60.
c CORC1  116.92 126.92
c rmesh11:p dose 10 1 1 2.77777777778E-4
c CORA11 -400. 99i 400.
c CORB11 -400. 99i 400.
c CORC11  726.52 736.52
c cmesh21:p dose 10 1 1 2.77777777778E-4
c CORA21   0. 99i 60.
c CORB21 116.92 126.92
c CORC21      360.
c cmesh31:p dose 10 1 1 2.77777777778E-4
c CORA31    0. 99i 400.
c CORB31  726.52 736.52
c CORC31      360.
c endmd
```