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Monte Carlo simulation of the eye lens on the NIST X-Ray beam and Cs-137 with Geant4 simulation toolkit

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1. Introduction

On April 21th 2011, the International Commission on Radiological Protection (ICRP) has issued statement on tissue reactions [1] instead of ICRP 103 [2]. The Commission has reviewed recent epidemiological evidence suggesting that there are some tissue reaction effects. For the lens of the eye, the threshold in absorbed dose is considered to be 0.5 Gy and for occupational exposure in planned exposure situations, an equivalent dose limit for the lens of the eye of 20 mSv in a year, averaged over defined periods of 5 years, with no single year exceeding 50 mSv. The International Atomic Energy Agency (IAEA) followed ICRP new recommendation on their Safety Standards (Interim edition) [3] and Final report of the Fukushima Dai-ichi NPP [4] in 2011 also. In order to keep pace with international environment, we calculated absorbed dose for the eye of the lens to protect workers who work in Nuclear Power Plants with Geant4 simulation tool kit according to wearing lead-glasses or not.

2. Methods and Results

In this section, the size of the eye ball and the lens and materials in Geant4 simulation(2.1), the kinds of radiation source and initial condition(2.2), Geant4 configurations(2.3) and absorbed dose and radiation shielding rate with/without lead-glass for each beam are described(2.4).

2.1 Modeling of the eye ball and the lens

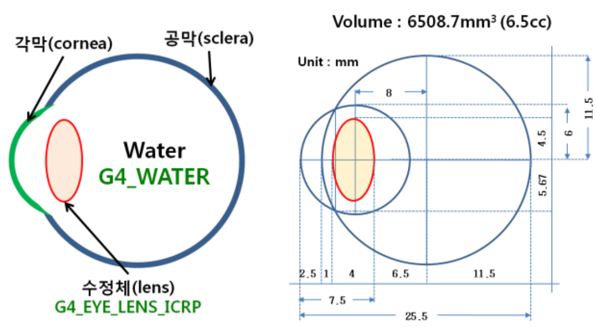

Figure 1. The dimension and materials of the eye and the lens

Total volume of an adult eye has approximately 6.5cc and 24mm axial length (cornea to the retinal lens). The general dimension of the lens of the eye is width 4mm and heights 9mm. More detail dimensions of the eye is Cornea to the center of the iris 1.6mm, cornea to in front of the lens 3.7mm, cornea to the lens directly on the back 7.3mm and the cornea, sclera, choroid, retina, and iris which have thickness of tens to hundreds of μm or less [6] are very thin. The front side of the lens is filled with aqueous humor and back side is vitreous which is made of water almost. For this reasons, we use water for all of eye ball except the lens of the eye and the material which is describe in ICRP 89[7] used for the lens. The membranes are not realized such as cornea, etc. Figure 1 shows what we used.

2.2 Radiation sources and initial conditions

X-Ray and γ-Ray are used to the test. X-Ray includes M30, M60, M100, M150, M250, and M300. Cs-137 and Co-60 are used as the γ-Ray sources. The sources are from the center of the eye ball 500mm away and they are generated at 20mm*20mm area with $2.5x10^3$/s·mm^2 flounce rate for 1 second. The beam goes to the center of the eye parallel to main axis of the eye ball. It is described in figure 2 with the Cartesian coordinate system and the beam direction is X axis.

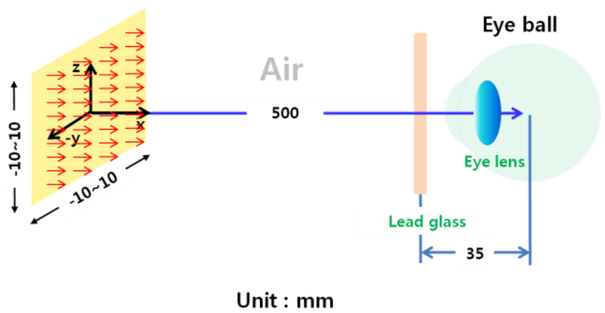

Figure 2. Spatial distribution and direction of the beam and position of the lens of the eye

2.3 Geant4 configurations

The Gean4 has been developed to calculate between mater and particle using by computational simulation with Monte Carlo Method in high energy physics. It can be applied to various fields depending on choice of proper physics model. We use emstandard_opt3 , as a physics model, which designed for any applications required higher accuracy of electrons, hadrons and ion tracking without magnetic field [9]. The calculation to find out absorbed dose according to presence of lead glasses and absence carried out with 2mm thickness of the lead glasses and the lead glasses is 35mm away from the center of the eye ball by considering glasses position(typically they are 2~2.5 cm cornea away). See the figure 2.

2.3 Absorbed dose and radiation shielding rate

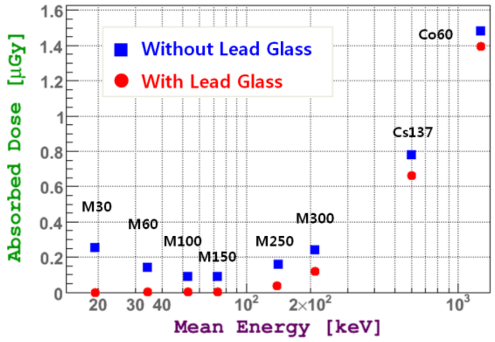

Figure 3. Absorbed dose of the lens according to the lead glasses

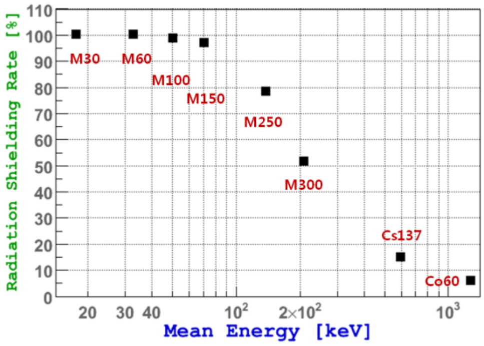

Figure 4. Radiation shielding rate for sources

Figure 3 shows absorbed dose for the sources which are represented by mean energy of energy distribution and depending on the lead glasses or not. Results of the geant4 simulation give more absorbed dose to Gamma-Ray than X-Ray. The radiation shielding rate, ($E_{\_with\ glasses}$ – $E_{\_without\ glasses}$ /$E_{\_with\ glasses}$)*100, was excellent at the X-Ray sources but Gamma-Ray was about 15% and 6%.

3. Conclusions

For rapid response to enhanced dose limit, we simulated absorbed dose of the lens of the eye with Geant4 simulation tool kit based on presence of lead glasses or absence. The Results of shielding effect is good in the low-energy X-Ray which used in a medical environment, but Nuclear Power Plant which have high energy gamma such Co-60 mainly was poor effect for the lead glasses. Considering the situation of Nuclear Power Plant, careful protection plan will be established by reducing the exposure time rather than wearing the uncomfortable lead glassed.

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