Simulation of Photon and Electron dose distributions by MCNP5 code for the treatment area using the linear electron accelerator (LINAC) in Dongnai General Hospital, Vietnam

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ABSTRACT:
Nowadays, radiotherapy by linear electron accelerators (LINAC) has became popular and given high effects for cancer treatment in hospitals of Vietnam. The paper presents simulation for distribution of radiation dose fields by MCNP5 code for electron and photon radiations inside and outside the treatment room in Dongnai General Hospital. From that, it could carry out comparision between the results of calculation and those of experimental measurements at Dongnai General Hospital.

The calculation results described the distributions of radiation dose fields at some positions of inside and outside the treatment room. This is one of the important basises for calculating radiation safety in radiotherapy as well as construction and setup of rooms.

Keywords: *Radiotherapy, Linear electron accelerator (LINAC), Radiation safety, Dose field, MCNP5 code*

I. INTRODUCTION

The LINACs can emit one of two types of radiation which are photons, electrons with high dose, so the dose distribution in the treatment area is relatively complex. From receiving the dose distribution results fully and accurately, we will to have recommendations about radiation safety for healthcare facilities using the LINACs. MCNP5 code is used to calculate the simulated distribution of photon and electron doses inside and outside the treatment room. Subject of simulations in this report is available at Primus machines Cancer Center, Dongnai General Hospital, Vietnam.

II. EXPERIMENTAL

Radiation therapy in a hospital room built is set up according to the general regulations of production [1] with machine room dimensions shown in Figure 1.

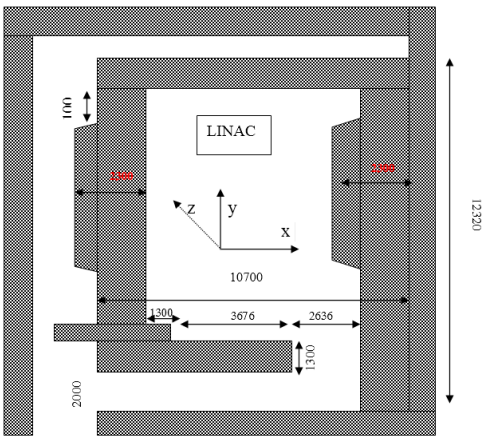

Figure 1. Radiation model room at Dongnai General Hospital.

The internal and external walls were made by concrete with density of 2.5 g/cm^3. Radiation therapy room door was made by lead together on / off semi-automatic control system.

Configuration and parameters of LINAC:

Configuration and specifications of the LINAC [2] are as follows:

Brand: Primus; Manufacturer: Simien (Germany); radiation type: single-energy electrons with energies of 5, 7, 8, 10, 12, 14 MeV; photons with energies of 6 and 15 MeV.

The probability distribution of the corresponding photons is outlined in Table 1 and 2.

Table 1. Distribution of photon beam with energy of 6 MeV.

Energy (MeV)	Relative probabilities (%)	Energy (MeV)	Relative probabilities (%)	Energy (MeV)	Relative probabilities (%)	Energy (MeV)	Relative probabilities (%)
0.10	0.05	0.40	0.80	1.00	11.80	3.00	9.60
0.15	0.10	0.50	1.60	1.25	14.40	4.00	8.10
0.20	0.20	0.60	3.20	1.50	12.80	5.00	6.40
0.30	0.60	0.80	9.00	2.00	14.40	6.00	0.80

Table 2. Distribution of photon beam with energy of 15 MeV.

Energy (MeV)	Relative probabilities (%)	Energy (MeV)	Relative probabilities (%)	Energy (MeV)	Relative probabilities (%)	Energy (MeV)	Relative probabilities (%)
0.10	0.06	0.50	2.28	1.50	4.86	6.00	7.17
0.15	0.73	0.60	2.35	2.00	10.18	8.00	0.72
0.20	0.89	0.80	4.69	3.00	16.98	10.00	4.19
0.30	1.98	1.00	4.65	4.00	13.48	15.00	1.00
0.40	2.19	1.25	5.42	5.00	9.08	20.00	0.00

Note: Refer to this values when performing QA at Dongnai General Hospital.

Set the input file:

File input is a description of all the parameters of the problem, including materials, resources, computational requirements [3].

The geometry of the problem consists of two components: fixed and radiotherapy room accelerator can shoot many different angles around the axis of the machine.

- Radiotherapy room consists of 4 walls around the room, inner room walls, hallways, patient bed and doors lead.

- Accelerator consists of body, locomotives, cones, waveguides, beer Tungstens, sad ion, the collimator and jaws with aperture of 1.83x83 cm^2 (corresponding to the projection 40x40 cm^2).

Source with disc-shape, isotropic toward the patient's bed with a distance of 224 cm from the ground. Photon and electron energy levels listed above.

Requirements are calculated dose rate in air and concrete blocks shaped 1.5 cm diameter, 5 cm length at the following locations:

+Direction -$\vec{y}$: the cell with coordinates of (0,-5,120), (0,-10,120)... (0,-400,120), respectively.

+ Direction -$\vec{x}$: the cell with coordinates of (-5,0,120), (-10,0,120) ... (-590,0,120), respectively; co-ordinate origin is from the ground, and the central axis of the source.

III. RESULTS AND DISCUSSION

After using the software simulation mode and calculated by the Visual Editor executable (command form), the results are as follows:

Structure radiation therapy room

Observed system accomodations in 3-dimensional space with multiple viewing angles and different sizes are presented in Figure 2.

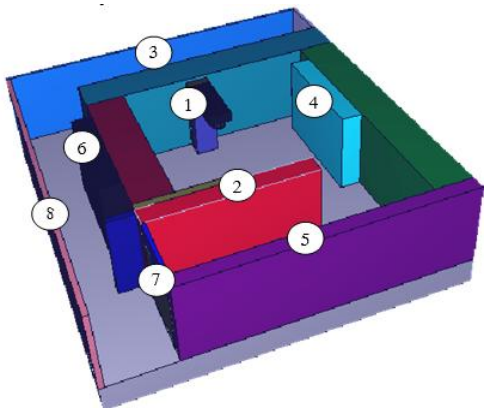

Figure 2. Radiotherapy Department in Dongnai General Hospital (1: Accelerator; 2: inside walls; 3, 4, 5, 6: concrete walls; 7: doors lead; 8: corridor).

Scattering of photons and electrons in the room

Implementation of particle display functions of the software requirements for a simulation, scattering processes of photons and electrons in the treatment room are presented in Figures 3, 4 and 5.

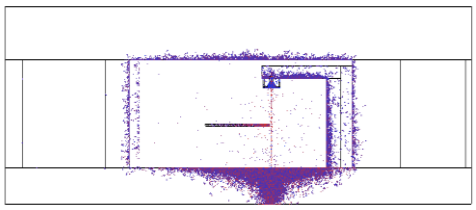

Figure 3. Scattering of 15 MeV energy photons (plane y, z).

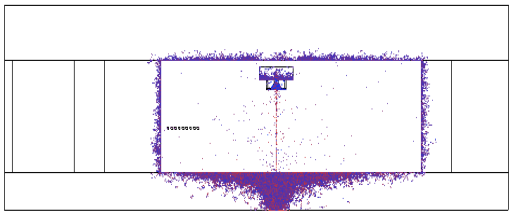

Figure 4. Scattering of 15 MeV energy photons (plane x, z).

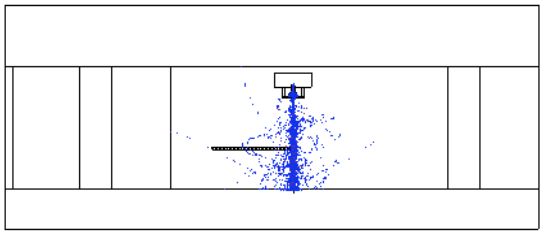

Figure 5. Scattering of 10 MeV energy electrons (plane x, z).

From the scattering images, they are shown: range of photon scattering is very large and complex distribution in the case of large particles made with range spread throughout the room, including locomotives. In the case of plant at 0^o location, primarily scattering direction is toward the patient's bed. For the case of plant at 90^o location, the scattering direction is toward the operators with relatively high quantity, and the range of electron scattering has tendency for concentrating in the direction from the source to the patient's bed.

Results of calculating dose rate

From calculating the dose rate for each position, we obtain the dose distribution with distances from the source (and compared with experimental results measured by the portable photon dose-rate meter of Inspector, USA).

Table 3. The dose distribution of 15 MeV energy photon in the direction of -$\vec{y}$.

Distance from source (cm)	Dose rate calculated by MCNP (μSv/h)	Experimentally measured dose rate (μSv/h)	Relative error in MCNP (%)	Distance from source (cm)	Dose rate calculated by MCNP (μSv/h)	Experimentally measured dose rate (μSv/h)	Relative error in MCNP (%)
5	110,343.21	110,344.00	0.37	90	1,410.20	1,413.41	1.97
10	56,315.60	56,315.89	0.52	95	1,237.54	1,240.13	2.03
15	37,842.31	37,845.24	0.63	100	944.82	945.81	2.27
20	27,793.53	27,794.47	0.71	105	860.35	864.17	2.35
25	21,688,57	21,691.88	0.79	110	795.35	797.90	2.41
30	17,070,34	17,073.75	0.86	115	640.53	641.63	2.58
35	13,876.84	13,877.02	0.92	120	568.07	570.43	2.67
40	11,231.65	11,232.15	0.99	125	520.31	522.81	2.79
45	9,372.82	9,375.81	1.05	130	455.17	456.79	2.87
50	7,717.94	7,718.87	1.11	135	397.94	398.64	3.02
55	6,527.46	6,528.24	1.18	140	373.94	377.40	3.15
60	5,527.14	5,,528.20	1.26	145	377.38	378.99	3.14
65	4,547.03	4,549.12	1.32	150	355.54	356.46	3.20
70	3,937.05	3,940.90	1.44	155	318.78	321.93	3.34
75	3,375.22	3,378.23	1.47	160	286.74	287.32	3.48
80	2,466.32	2,466.40	1.63	165	263.33	266.98	3.57
85	1,820.14	1,821.40	1.83	170	260.43	261.37	3.63

Calculation and simulation results showed consistent ones with experimental values. The measured experimentally values are negligible higher due to environmental background.

Table 4. The dose distribution of 15 MeV enery photon in the direction of -$\vec{x}$.

Distance from source (cm)	Dose rate calculated by MCNP (μSv/h)	Experimentally measured dose rate (μSv/h)	Relative error in MCNP (%)	Distance from source (cm)	Dose rate calculated by MCNP (μSv/h)	Experimentally measured dose rate (μSv/h)	Relative error in MCNP (%)
5	112,343.21	112,389.92	0.37	135	468.60	469.73	2.79
10	56,473.80	56,474.19	0.52	140	390.10	462.55	2.87
15	37,921.36	37,622.24	0.63	145	373.43	474.00	3.02
20	27,806.78	27,809.45	0.71	150	367.18	368.33	3.15
25	21,762.22	21,765.35	0.79	155	345.35	365.67	3.14
30	17,454.36	17,554.47	0.86	160	318.42	350.07	3.20
35	13,910.33	14,113.49	0.92	165	302.98	305.77	3.34
40	11,371.63	11,375.34	0.99	170	271.12	273.91	3.48
50	7,856.20	8,257.71	1.05	175	205.08	205.32	3.57
55	6,641.05	6,743.94	1.11	180	178.19	179.46	3.63
60	5,,805.07	6,307.25	1.18	185	179.83	179.88	3.80
65	5,906.42	6,008.09	1.26	190	135.90	137.90	6.96
75	3,677.65	3,681.49	1.32	195	106.56	106.67	3.81

Distance from source (cm)	Dose rate calculated by MCNP (μSv/h)	Experimentally measured dose rate (μSv/h)	Relative error in MCNP (%)	Distance from source (cm)	Dose rate calculated by MCNP (μSv/h)	Experimentally measured dose rate (μSv/h)	Relative error in MCNP (%)
80	2,918.09	3,021.71	1.40	200	113.50	113.58	3.81
85	2,033.92	2,335.25	1.47	205	112.95	112.02	3.80
90	1,873.05	1,673.97	1.63	210	108.36	108.37	4.00
95	1,532.98	1,533.65	1.83	220	106.79	106.90	4.10
100	1,184.36	1,187.53	1.97	230	98.22	98.29	4.13
105	899.28	972.56	2.03	240	90.28	90.42	4.15
110	821.45	825.15	2.27	250	81.56	81.60	4.16
115	726.86	728.32	2.35	260	69.63	69.73	5.00
120	677.42	698.95	2.41	270	53.09	53.19	5.00
125	603.71	618.96	2.58	280	43.52	43.53	5.00
130	540.37	581.54	2.67	290	26.85	26.91	5.00

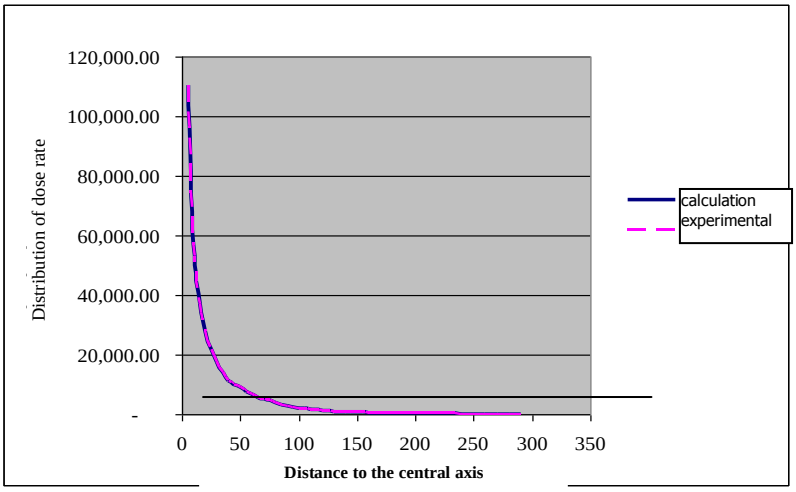

Figure 8. Graph comparison between the calculated results and experimental measurements (interpolation from Table 4).

Table 5. The dose distribution of 15 MeV energy photon in the direction of $-\vec{x}$ (in concrete).

Distances from the source (cm)	Dose rate calculations MCNP (μSv/h)	Distances from the source (cm)	Dose rate calculations MCNP (μSv/h)
300	17.3910	360	0.0094
310	12.0100	370	0.0033
320	1.0190	380	0.0021
330	0.7180	390	0.0010
340	0.0528	400	0.0007
350	0.0187	410	0.0003

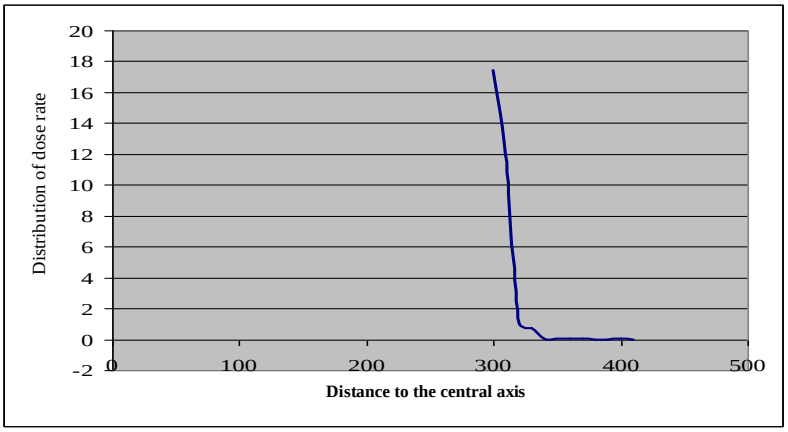

Figure 8. Graph comparison between the calculated results and experimental measurements (interpolation from Table 5).

Radiation is decreased rapidly in the concrete wall, so that the concrete shielding is in a match. The simulation of radiation and dose rate measurements can help for getting optimal shielding.

Table 6. The dose distribution of 10 MeV enery electron in the direction of $-\vec{x}$ (in concrete).

Distance from source (cm)	Dose rate calculated by MCNP (μSv/h)	Relative error in MCNP (%)	Distance from source (cm)	Dose rate calculated by MCNP (μSv/h)	Relative error in MCNP (%)	Distance from source (cm)	Dose rate calculated by MCNP (μSv/h)	Relative error in MCNP (%)
5	110,343.21	0.54	70	315.30	3.75	135	50.51	4.46
10	10,584.36	0.65	75	238.65	3.81	140	45.13	4.51
15	4,301.56	0.95	80	226.22	3.97	145	36.60	4.53
20	2,428.68	1.12	85	196.75	3.99	150	45.79	4.57
25	1,713.48	2.12	90	152.66	4.10	155	45.14	4.58
30	1,247.11	2.90	95	169.23	4.16	169	42.98	4.61
35	858.82	2.95	100	135.26	4.19	165	33.64	4.64
40	793.20	2.99	105	110.87	4.23	170	21.83	4.72
45	637.62	3.12	110	71.10	4.25	175	19.50	4.79
50	650.96	3.13	115	78.93	4.27	180	19.42	4.81
55	506.20	3.41	120	74.60	4.28	185	18.41	4.82
60	458.73	3.52	125	56.88	4.30	190	14.26	4.83
65	302.26	3.67	130	53.41	4.42	195	11.53	4.87

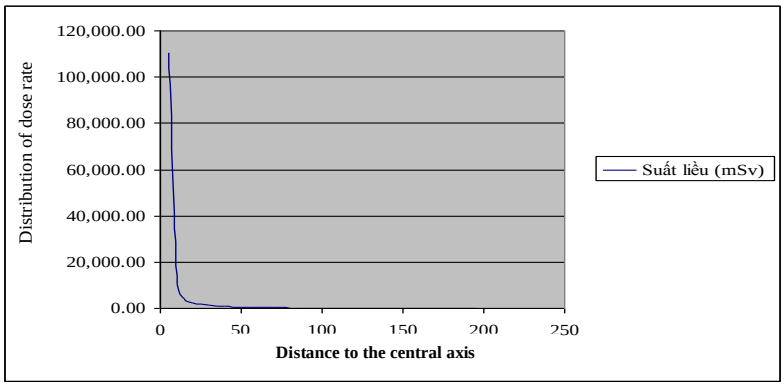

Figure 9. Graph comparison between the calculated results and experimental measurements (interpolation from Table 6).

From Figure 9 it is shown that electron dose rates are decreased rapidly with distance, due to the stronger absorption of photons..

IV. CONCLUSION

From independently simulation by the MCNP software, we obtained the results that are quite consistent with experimental measurements. This allows the user to confirm that the simulation method of calculating dose distribution for all radiation at different energy levels in all positions of inside and outside the radiation room. From that, it could establish a 3-dimension map on dose field distribution inside and outside the treatment room.

One of the important goals of our research is directed toward safety shielding calculations for radiation treatment room just to ensure radiation safety and efficiency in the highest stage of economic development, by changing thicknesses of the concrete as well as the size and structure of the room.

REFERENCES

[1]. MED AID, Inc Vietnam (2010), *Requirement of preparing Siemens Primus machine room*, 12-BT1-X2 Bac Linh Dam, Hoang Mai, Hanoi, Vietnam.
[2]. Siemens Medical Solutions USA (2003), *PRIMUS Linear Accelerator*, Ins., Siemens AG.
[3]. Los Alamos National Laboratory (2006), *MCNP/MCNPX*, Los Alamos, New Mexico.