# *Calculation of neutron contamination from medical linear accelerator in treatment room*

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**abstract:**

The electron linear accelerators (linac) which are used in radiography and radiotherapy applications with photon energy over 8 MeV. These photons are produced by bremsstrahlung, generated undesired neutron contamination in the therapeutic beam. This study is concerned with the measurement of photoneutron contamination emitted from a Neptun 10PC medical linear accelerator, with the Mont Carlo code MCNPX. This code is used to simulate the transport of these photoneutrons across the linac and the treatment room, giving the neutron spectra and neutron dose equivalent around the accelerator.

The results for two size of fields, 20×20 and 30×30, show that the production of photoneutrons are reduced by distance from isocenter and increased with the size of field. Furthermore, the photoneutron dose equivalent is decreased by increasing the size of field.

**keywords:**

*Medical accelerator , Photoneutron , Neutron contamination , Radiotherapy, MCNPX.*

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## 1)Introduction

The electron linear accelerator, which produces bremsstrahlung by electron bombarding the target is a good X-ray source for medical systems.

Photoneutrons exist in and out of high energy X-ray beams of medical linear accelerators. Whenever the photon energy exceeds the energy thresholds of the photonuclear reactions of the target ,collimator and beam flattening filter materials such as $w^{184}$ , $E_{th}$ =7.41 MeV [1] which are produced in giant dipole resonance (GDR) process by exciting high Z materials ( mainly tungsten and lead )[2] .

These photoneutrons are causing many problems such as image resolution deterioration and radiation protection concerns[1].

Also the gamma rays produced by the while interactions with the body deposit a dose that is not negligible, and in order to estimate this dose, it is necessary to know the energy spectrum of the photoneutrons that produced this dose ( NCRP-79) [3]

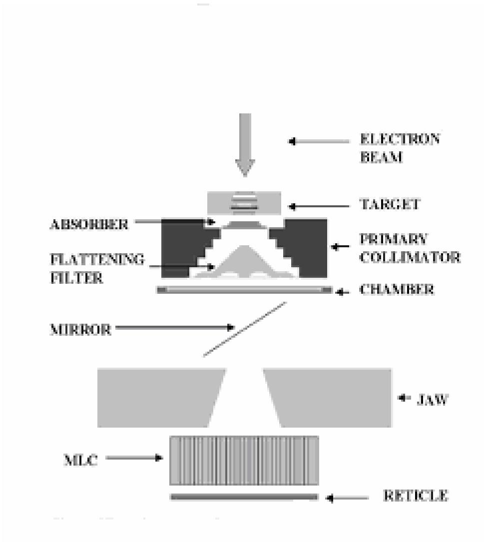
And consequently it is important to know the neutron spectrum, which contaminates the therapeutic beam, both to project the room shielding as well as to evaluate the increase to the patient dose [4].

## 2)Materials and Methods:

The physics model used in early studies of neutron spectra , mentioned in NCRP Rep.No.79 considered only the production of neutrons. But in the whole accelerator facility, neutrons are transported through the materials, and scattered by light nuclei. These processes are so complex , that simulations with an effective Mont Carlo code are very helpful to get information on bremsstrahlung production , electron leakage and neutron spectra .

Mont Carlo simulations with MCNPX codes were carried out to study the photoneutron spectra and the neutron dose equivalent at the isocenter of a linear accelerator.

The photon mode mechanical structure of the head of the medical linear accelerator is illustrated in Fig. 1. Pulsed electron beams are well selected by the bending magnet and then hit on the target. The main material of the target is *w* and this is cooled by water. High-energy bremsstrahlung is produced after electrons pass through the target and its intensity is modified by absorbers and flattening filters to flatten for clinical purposes. The absorber and flattening filter are located at the opening of the shielding structure, and are made of tungsten. The flattened high-energy X-ray beam then passes through the monitor chamber and mirror, and is collimated and shaped by upper jaw and multileaves collimator (MLC) to fit the treatment target in the patient. For electron mode, there are two foils and one chamber in the structure; however, no absorber, flattening filter and mirror are needed. A cone which serves as an additional collimator is mounted under the MLC for collimation. The structure of the electron mode of our linac head is illustrated in Fig. 2.



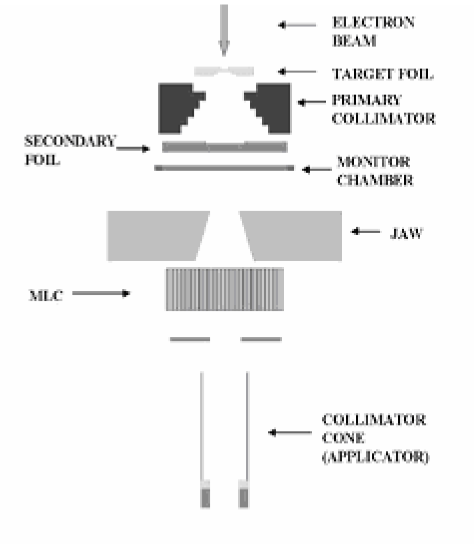


**Fig**.1.The photon mode mechanical structure of linac **Fig**.2. The electron mode mechanical structure of linac[8]

Since the threshold energy of neutron emitted from the device materials, such as Al, Fe, Au and W, are13.06, 13.38, 8.06 and 8.41 MeV, respectively, (NCRP No. 79, 1984), neutrons will be produced by (e, Xn) and (g, n), (g, 2n) and (g, pn) reactions while high-energy bremsstrahlung reacts with those beam modified devices and shielding structure [8].

The treatment room structure has been shown in Fig.3. and neutron spectra were measured at marked points. The simulation was performed in two steps, first the electron source with Gaussian distribution was determined above the target and then the bremsstrahlung X-Ray spectra ,after target, was used as the photon source. So the flux of photoneutrons during the $(\gamma,n)$ process was calculated.

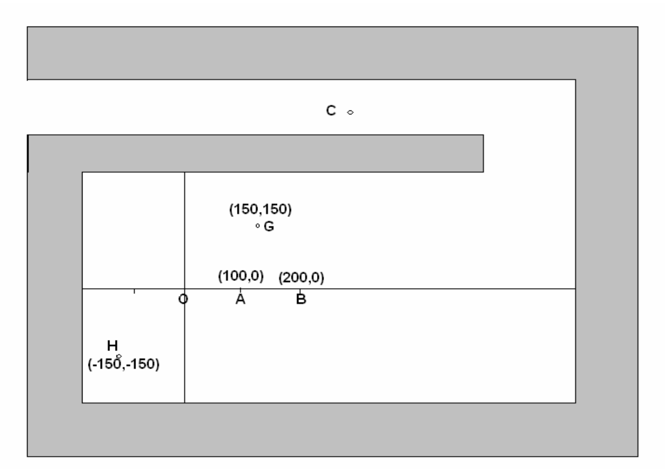


Fig. 3.The structure of treatment room.

## 3)Results and discussion:

We have worked with a photon source. The reason for doing that is the photons produce the photoneutrons. To achieve this we are putting an electron source with a Gaussian spectra before the target. By doing this, we obtain the photon spectra after the target, which is used as a source. Figure4. shows the photon spectra after the target.

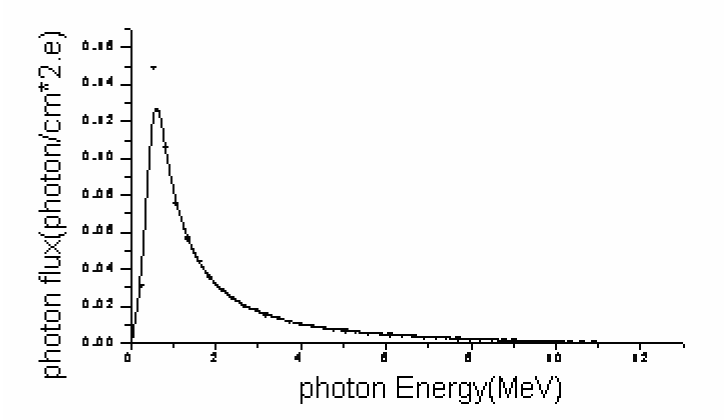
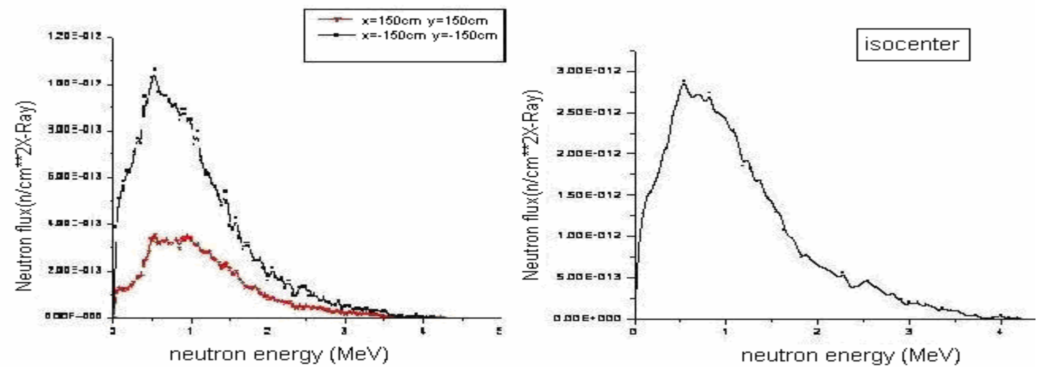


Fig.4. photon spectra produced in 10Mev linear accelerator after the target.

Then by using the **phys** card from the MCNPX code in the simulation, the neutron production will be obtained. Figure.5 shows the neutron spectra at the marked points of Fig.3 around the isocenter. We have compared all spectra together in the Fig.6



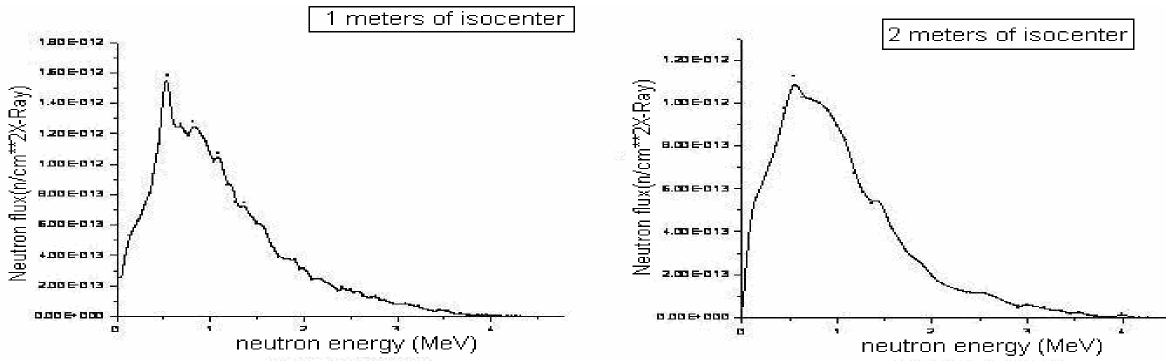


Fig.5. photoneutron spectra produced in the labeled points in Fig.3.

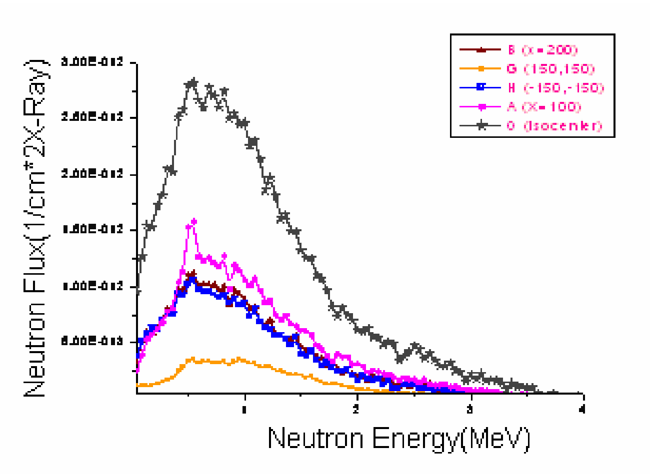


Fig.6. ptotoneutron spectra produced in 10Mev linear accelerator and treatment room

The Figure indicates that the production of photoneutrons is decreased with distance from isocenter, except near the walls because of backscattering from walls.

The dose-equivalent was calculated by using the fluence to dose-equivalent conversion factors reported in NCRP Report 79 [5].:

$$cf = \frac{\overline{E}^{0.735}}{4.4 \times 10^{6}}$$

The average photoneutron energy, $\overline{E}$, for each spectra was calculated as follows [7]:

$$\overline{E} = \frac{\sum_{i=1}^{N} E_i \Phi(E_i)}{\sum_{i=1}^{N} \Phi(E_i)}$$

Where $E_i$ is the transmitted neutron energy of the *ith* energy interval; $\Phi(E_i)$ corresponds to its flux obtained by MCNPX calculations and the sum is run over all N energy intervals of each spectra [7].

However we obtain the neutron dose, but the experimental measured dose of our accelerator is an equivalent dose (msv/Gy), in fact it is the ratio of the neutron dose to the measured photon dose around the accelerator. Figure7. shows the photon spectra in the isocenter and in the 100 and 200 centimeters from the isocenter.

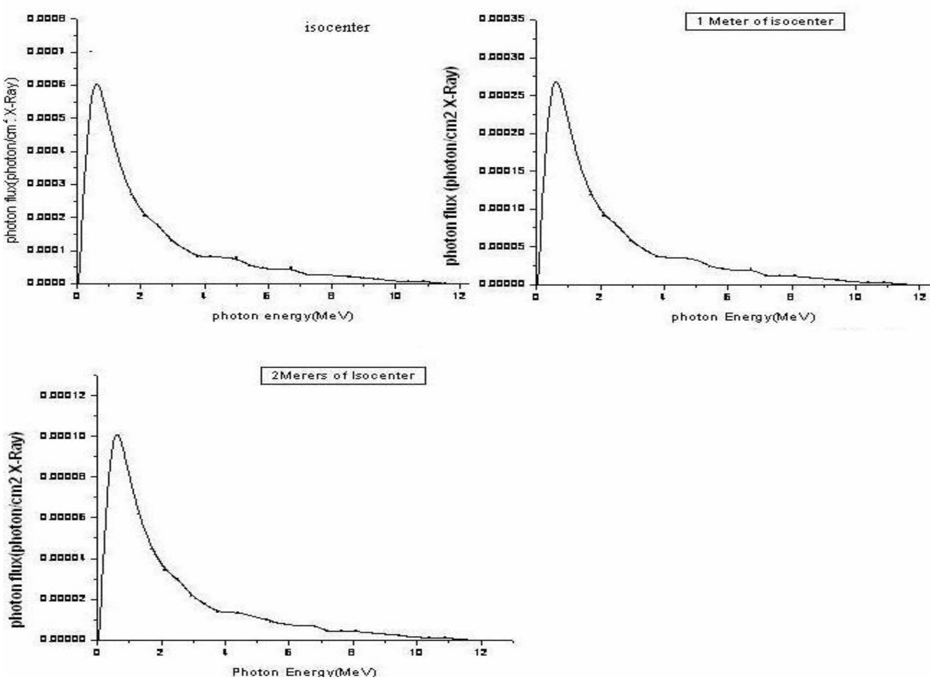


Fig.7. Photon spectra produced in the labeled points of Fig.3.

Now we have access to the photon dose by using the fluence to equivalent dose conversion factors, then by dividing the neutron dose to the photon dose, we have the neutron equivalent dose in the unit of msv/Gy.The results are shown in table1. and table2. for two different sizes of field.

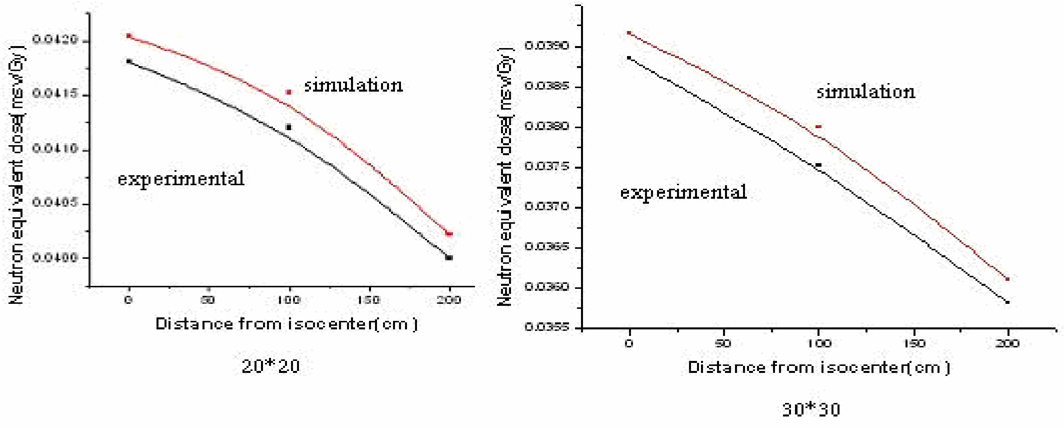
Table 1.comparison of neutron dose equivalent between simulation and experimental for 20×20 field

| *Dosimeter position* | *Neutron dose (mSv/e)* | *Photon dose (Gy/e)* | *Neutron dose equivalent (mSv/Gy) (simulation)* | *Neutron dose equivalent (mSv/Gy) (experimental)* |
|---|---|---|---|---|
| *Isocenter(O)* | $2.212\times10^{-17}$ | $5.26\times10^{-16}$ | *0.042036* | *0.041803* |
| *1meter from isocenter(A)* | $0.966984\times10^{-17}$ | $2.32890\times10^{-16}$ | *0.041521* | *0.0412* |
| *2meters from isocenter(B)* | $0.349929\times10^{-17}$ | $0.869974\times10^{-16}$ | *0.040223* | *0.0400* |
| *In maze(C)* | ٠ | ٠ | ٠ | ٠ |

Table 2.comparison of neutron dose equivalent between simulation and experimental for 30×30 field

| *Dosimeter position* | *Neutron dose (mSv/e)* | *Photon dose (Gy/e)* | *Neutron dose equivalent (mSv/Gy) (simulation)* | *Neutron dose equivalent (mSv/Gy) (experimental)* |
|---|---|---|---|---|
| *Isocenter(O)* | $2.42111\times10^{-17}$ | $6.184\times10^{-16}$ | *0.039152* | *0.038841* |
| *1meter from isocenter(A)* | $1.106608\times10^{-17}$ | $2.912816\times10^{-16}$ | *0.037991* | *0.037523* |
| *2meters from isocenter(B)* | $0.374918\times10^{-17}$ | $1.038266\times10^{-16}$ | *0.036110* | *0.035810* |
| *In maze(C)* | ٠ | ٠ | ٠ | ٠ |

In Figure.8 we compared the experimental and the simulation results. As the Figure shows the result are consistent with each other.



20*20

30*30

Fig .8. A comparison between experimental measurement and simulation with the MCNPX code.

Figure.9 also shows that our results are in a good agreement with the simulation by FLUKA code in the Tsinghua University in China.

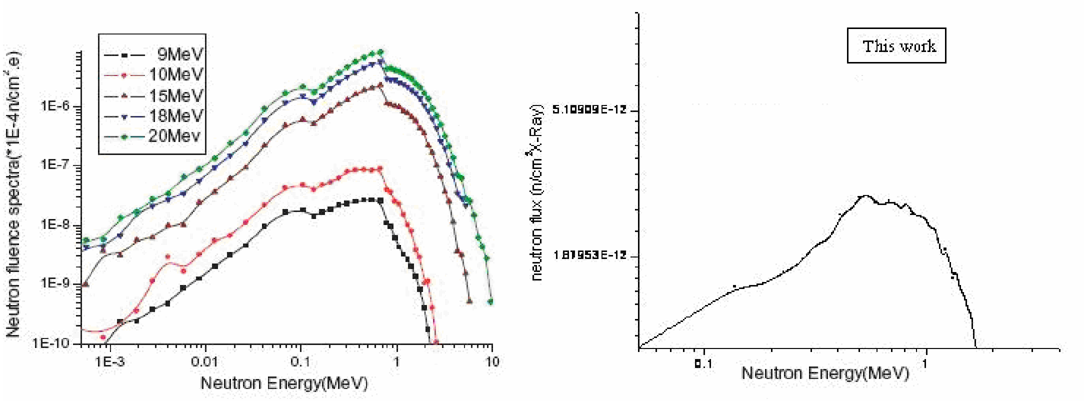


Fig.9. A comparison with simulation by another code,FLUKA [2].

## 4)Conclusion:

We conclude that the production of photoneutrons is increased with field size and is decreased by distance from isocenter. The calculations of simulation show that there is no photoneutron in maze. It has found that the neutron dose equivalent is reduced by increasing the field size.

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