Monte Carlo Study of photoneutrons from flattened filter free medical linear accelerator for BNCT applications

M.A. Halato[1], G. Giannini[2], F. Longo[2], A.M. Artoli[1], Abdulaziz S. Alaamer[3], and I.I. Suliman[3,4,*]

[1]Medical Physics, Faculty of Science and Technology, Al Neelain University, P.O. Box 12702 Khartoum, Sudan.
[2]University of Trieste, Via Valerio, 2 - 34127 Trieste, Italy
[3]Department of Physics, College of Science, Al-Imam Mohammad Ibn Saud Islamic University, Riyadh, Saudi Arabia
[4]Institute of Radiation and Nuclear Safety, Sudan Atomic Energy Commission, P.O. Box 3001, Khartoum, Sudan

Introduction

Background:

- Boron neutron capture therapy (BNCT) involves the selective, radiation-based destruction of malignant tumours, mainly cancers of the head and neck.
- Malignant cells are loaded with the non-toxic 10B isotope after which the site containing the boron loaded cells is exposed with neutrons , and as a result excited ^{11}B is formed. This is followed by a nuclear fission that releases alpha particle (^4He) and lithium ion (7Li). Both alpha and ^7Li nuclei particles travel short range in tissue and have high probability to selectively kill cancer cells.
- Although, nuclear reactors and ion accelerators are the most efficient neutron sources, they are not practical for establishing clinical Boron Neutron Capture Therapy (BNCT).
- Thus, Studies have investigated the possibility of using photo-neutrons from Medical linear accelerator as an alternate in-Hospital neutron source for BNCT [1].
- the Flattening Filter Free (FFF) medical Linac can gives more directed photons beam in comparison with conventional linac thus more photonutrons

Aims

- The aim of this project was to study the photoneutron production from medical linear accelerators for BNCT purposes by investigating the effect of different convertor thickness on overall neutron flux

Materials & Methods:

Materials :

- Initially, a conventional Varian medical linac has been modeled using beamnrc Monte Carlo Code., which provides better modeling for photon beam
- Unfortunately, beamnrc Monte Carlo Code can not model neutrons. For MC calculation of neutron transport Geant 4 MC code has to be used
- Geant 4 MC calculated beam profile and percentage depth dose data were benchmarked against Beamnrc MC
- MC simulations were carried out on PC computers: Intel Core (i7), 2.2 GHz processor, 8.0 G byte RAM & 320 GB hard disk.

Methods:

MC calculations of photoneutrons production from FFF linac

- photoneutrons generation by using different photon beam energies ranged from 10 to 30 MeV produced from FFF medical linear accelerator.
- Photoneutrons produces through giant dipole resonance phenomena, when high energetic bremsstrahlung photons hits a target material

Photoneutron convertor thickness

- The thickness and the energy dependence of photoneutrons converters were calculated using 18 MV unflattened photon beam. The convertor was designed as lead or tungsten slap with a volume of $(30 \times 30 \times z\ cm^3)$.
- The optimum convertor thickness (z) was calculated by means of shooting a convertor of different thickness by the unflattened photon beam.

Effect of photon energy on emitted photoneutrons yield

- The effect of photon energy on the emitted photoneutrons yield was studied by exposing the optimum converters (7.0 cm of lead and 6.0 cm of tungsten) by different energies unflattened photon beams.
- These photon beams were produced by initial electrons energy ranged from 10 to 30 MeV by means of MC simulations.

Simulated Linac head

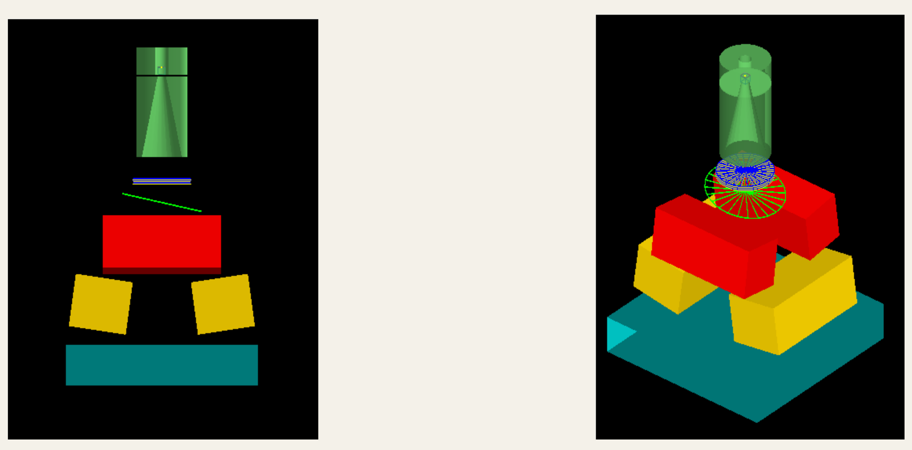

Figure 1. Screen shoots of the Linac head simulated with geant4 for photoneutrons production including; target, primary collimator ion chamber, mirror, X- jaws, Y-jaws and neutron.

Results

Geant 4 MC results vs Beamnrc MC

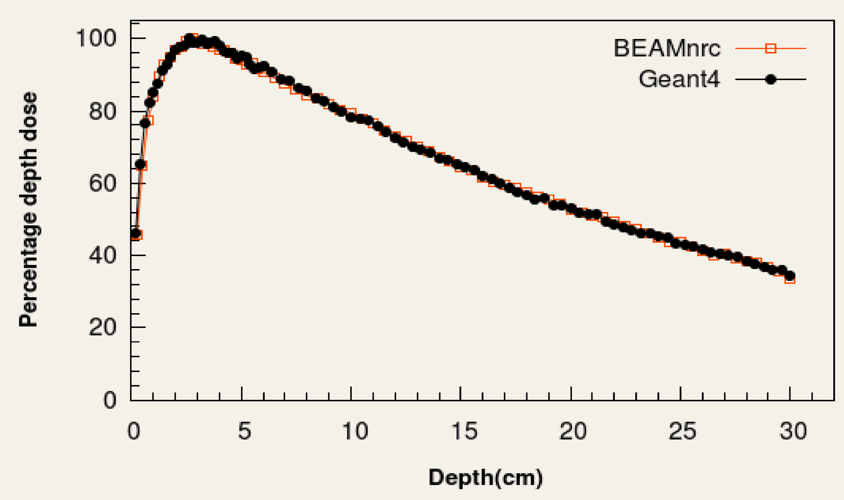

Fig. 2.

- Percentage depth dose (PDD) curves for 18 MV flattened beam $FS(20\ cm \times 20\ cm)$ at the isocenter (SSD=100)
- good agreements less than 2% between the beamnrc and geant4

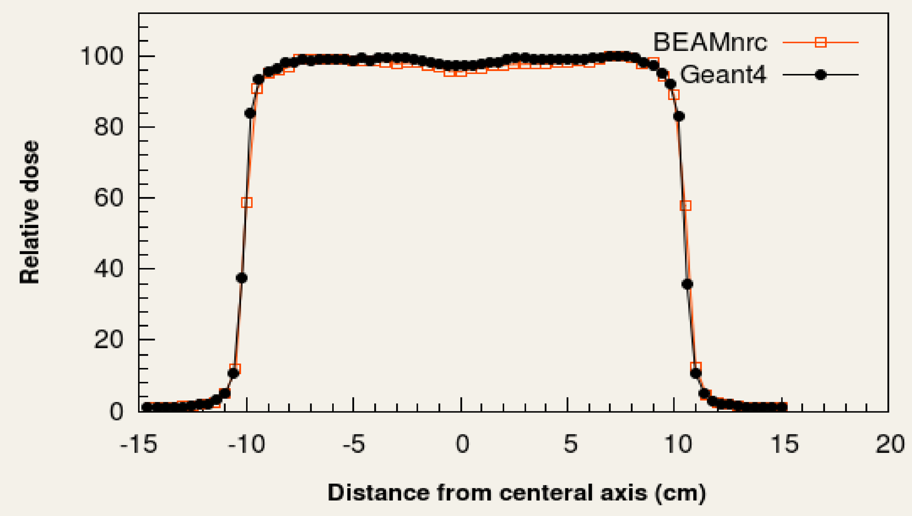

Fig. 3

- The dose profile curves are completely overlapped which confirms that the geant4 simulated beam dose profiles had symmetry and homogeneity characteristics similar to the beamnrc calculated photon beam.
- the overlapping of the PDD curves and the beam dose profiles confirmed that the geant4 simulated radiotherapy linac produced a photon beams having the characteristics similar to the photon beams previously produced by beamnrc simulations.

Photoneutrons production from FFF linac

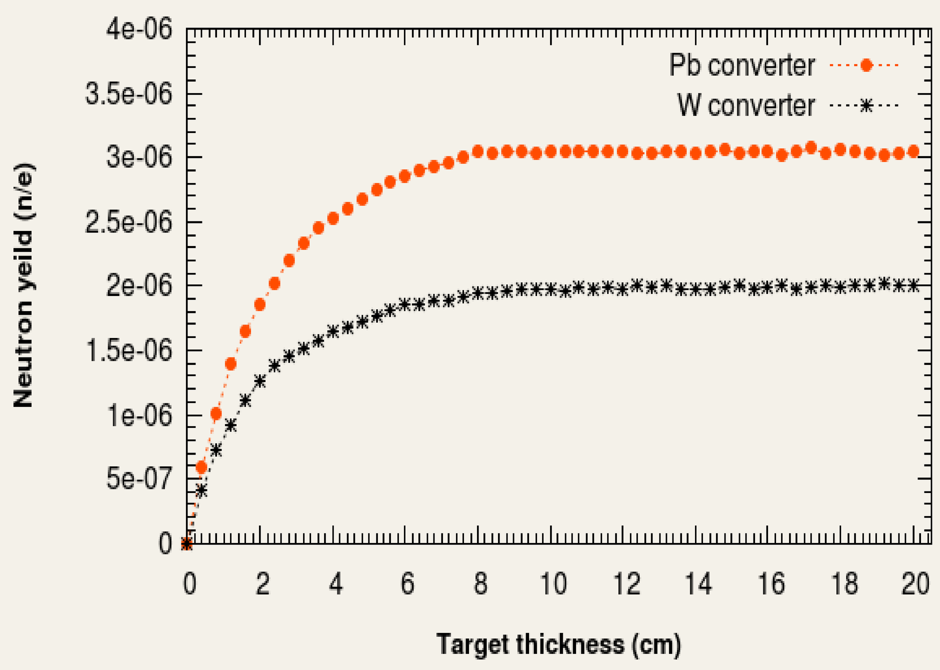

Fig. 4

- 18 MV FFF beam has been used for photoneutrons' productions and several simulations were performed by changing the convertor thickness (z) each time and the optimum thickness for the neutron convertor was determined.
- Photoneutron yield increases with converter thickness increasing until saturated
- In this study, the saturation thickness was found to be 7 cm for lead target and 6 cm for tungsten target.

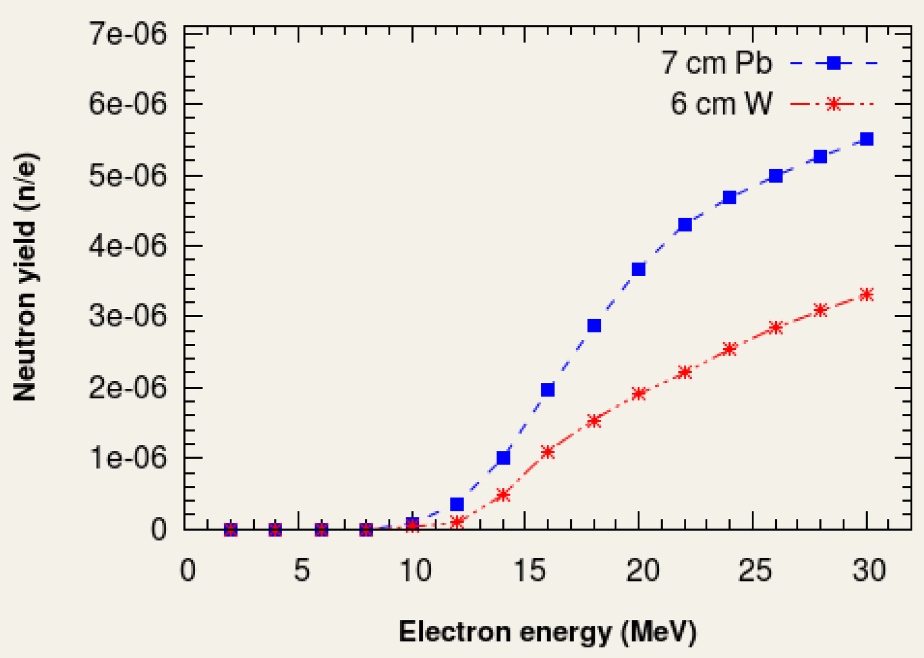

Fig. 5

- The effect of photon energy on the emitted photoneutrons yield was studied by exposing the optimum converters (7.0 cm of lead and 6.0 cm of tungsten) by different energies unflattened photon beams.
- Photoneutron yield increases with increasing photon energy. It is observed that more photoneutrons were emitted from lead convertor compared with tungsten.
- the atomic number of lead is relatively higher than tungsten, thus more bremsstrahlung interaction are expected for lead.

Results

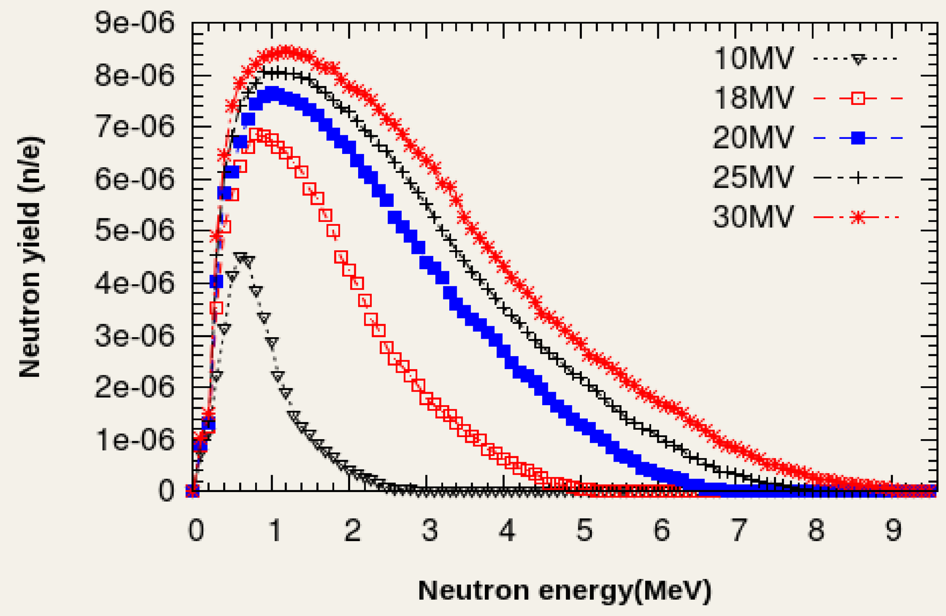

Fig. 6.

Neutron fluxes from 7 cm thickness lead target for 10, 18, 20, 25 and 30 MV photon beam from Linac

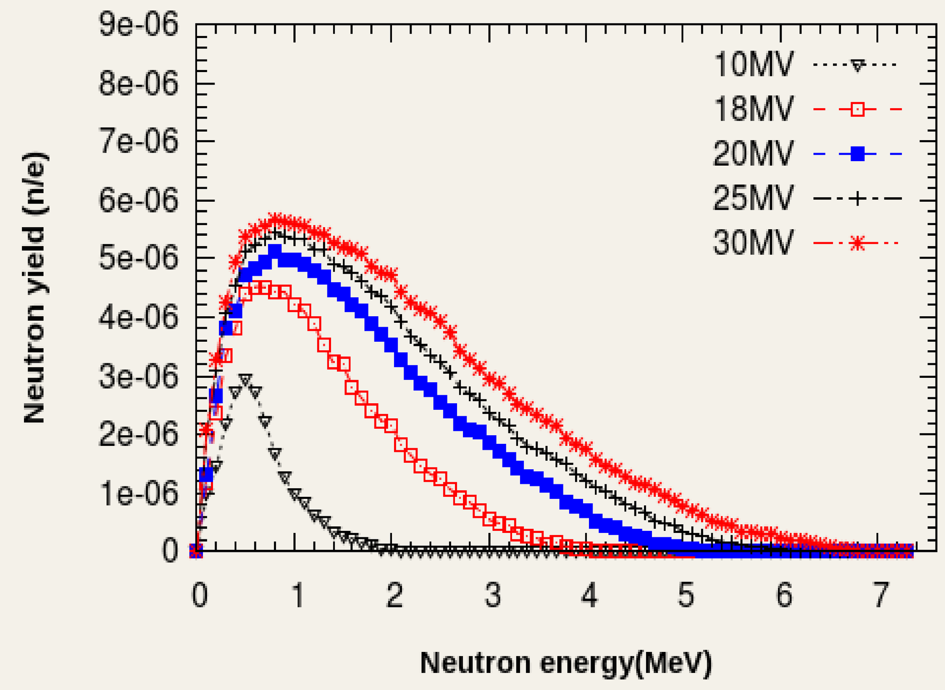

Fig. 7.

Neutron fluxes from 6 cm thickness tungsten for 10, 18, 20, 25 and 30 MV photon beam from Linac

electron Energy (MeV)	Neutron flux ($10^8 n/cm^2.s$)	Average N energy (MeV)	Neutron convertor Thickness(cm)	Material
30	3.971	1.214	7	Pb
30	2.929	0.863	6	W
25	3.263	0.877	7	Pb
25	2.585	0.709	6	W
20	3.101	0.673	7	Pb
20	2.068	0.582	6	W
18	1.896	0.601	7	Pb
18	1.206	0.564	6	W
10	0.529	0.586	7	Pb
10	0.459	0.480	6	W

Conclusion

- Our results showed that photo-neutrons flux and yield increase with both photon energy and convertor thickness, saturating at 7 cm (lead) and 6 cm (tungsten) convertors. The average photoneutrons energy produced ranged from 0.480 to 0.863 MeV for the tungsten convertor and from 0.586 to 1.214 MeV for the lead convertor.
- A photoneutrons flux of 3.971×10^8 n/cm²s and 2.585×10^8 n/cm²s were calculated for a 25 MeV medical linac equipped with 7 cm lead convertor and 6 cm tungsten convertor; respectively.
- In conclusion the FFF linac presented a considerable feasibility toward having it as an alternative neutron source for BNCT with lead and tungsten as a suitable photo-neutron converters.
- by using a suitable optimized convertor including moderator, collimator and neutrons reflectors and a high energy photon beam of 30 MV, the recommended BNCT neutrons fluxes could be achieved.

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Contact Information

Ibrahim I. Suliman , PhD
Institute of Radiation and Nuclear Safety, Sudan Atomic Energy Commission, P.O. Box 3001, Khartoum, Sudan
i.i.suliman@gmail.com