Simulation of 99Mo production from 30 MeV electron linear accelerator - Monte Carlo calculations

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Introduction
The most widely used isotope for medical imaging is 99mTc. This radionuclide is produced via 99Mo beta minus decay. A relatively new option is linac-based production of 99Mo through the photonuclear reaction 100Mo(γ,n)99Mo with bremsstrahlung irradiation. The purpose of this study was to simulate the process of 99Mo production using a 30 MeV electron linear accelerator with 100 µA average beam current. The Monte Carlo calculations were used for this purpose. The main goal of presented work was to optimize the process of irradiation the 100Mo target with electron beam in order to produce 99Mo with the highest efficiency.

Methodology
The simulation of irradiation of photon converter and photon-neutron targets depending on their geometry and thickness were performed. Tungsten and tantalum were investigated as photon converter targets. The Full Width Half Maximum (FWHM) of the beam dependance on bremsstrahlung photons energy was studied. The simulations were carried out using Monte Carlo method with FLUKA 2011.2x.4 program. The program code interface was: Flair_2.3-0. As the MC method requires high efficiency processors, the Swierk Computing Centre (CIS) software was applied for this purpose.

It was found that the FWHM of the beam parameter did not affect photons energy spectrum, therefore 4 mm FWHM beam parameter was chosen. The assumed geometry and scheme of targets system is presented in Fig. 1. An important issue was selection and optimization of the thickness of conversion target. Comparison of two converters is shown in Fig. 3. Tungsten is slightly more effective in generating bremsstrahlung photons when compare with tantalum. The highest number of photons was obtained for 3 mm tungsten target. This was confirmed by the measurement of photons number with energy above 30 MeV - Fig. 2 (threshold energy for 100Mo(y,n)99Mo nuclear reaction is 9.8 MeV). Performed simulation included studies on energy deposition in molybdenum target. It was found that during irradiation with photons the most exposed is first 2 mm of the molybdenum target (Fig. 4). Energy deposition is isentric (Fig.5) and amounts about 500 J/s in the middle of the target. This indicates that in the real experiment a target cooling system will be needed. Activity of 99Mo produced with 30 MeV electron beam depending on 100Mo target irradiation time is shown in Fig. 6. It can be seen that as results of 72 hours irradiation of 30 mm in diameter and 5 mm thick 100Mo target about 300 GBq (8.14 Ci) of 99Mo will be produced.

Conclusions
The performed calculation showed that 3 mm thick tungsten disc is the most optimal conversion target used in production of 99Mo according to nuclear reaction 100Mo(γ,n)99Mo. By the use of this conversion target it is possible to obtain 8.14 Ci of 99Mo after 3 days of irradiation of 100Mo target (φ=30 mm and 5mm thickness) with 30 MeV electron beam of 100 pA average beam current. The obtained results will be verified by experimental method in the near future.