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Modeling and experimental validation of radiation-cell interaction in radiotherapy by photon activation of gold nanoparticles

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Malignant brain tumours represent a few percents of adult cancers and are the most frequent for children. Because of the delicate location, the radio sensitivity of healthy brain and the presence of the blood brain barrier, the current treatments for some of these brain cancers are not efficient. An innovative approach using X-rays in addition with heavy elements, as iodine or gold nanoparticles, seems to open a promising way.

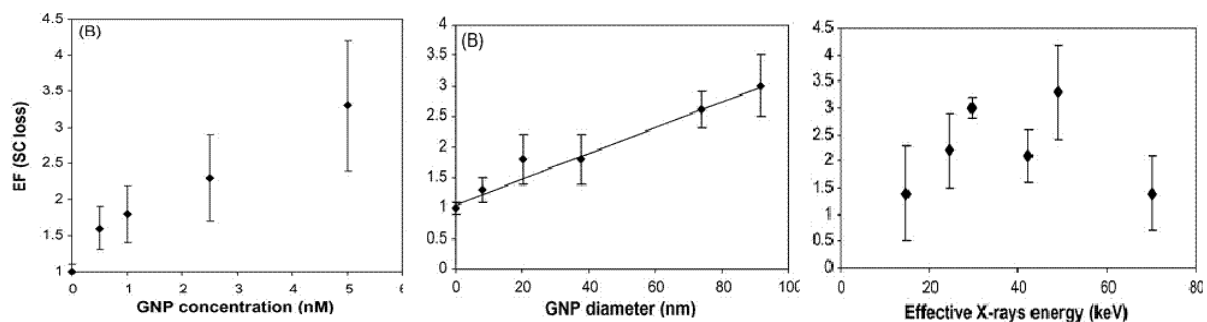


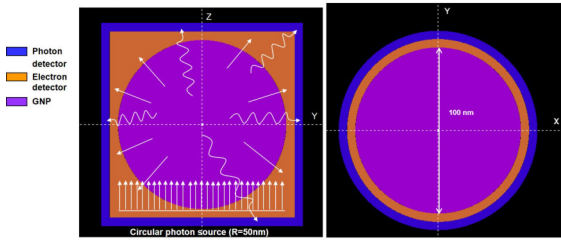
Figure 1 : Radiosensitization with gold nanoparticles (E. Brun et al., 2009)

Such technique is developed at the medical beam line of European Synchrotron Radiation Facility using monochromatic X-rays in the 50-100 keV range for the treatment of resistant solid tumours such as high-grade gliomas. With this approach, a localized dose enhancement can be obtained from photoelectric effect on heavy elements introduced in the target volume. However, the physical processes and biological impact of the photon activation of heavy elements are not well understood. The experimental results can not be explained from macroscopic dose calculations, the radio-induced damages at the cell level have to be considered.

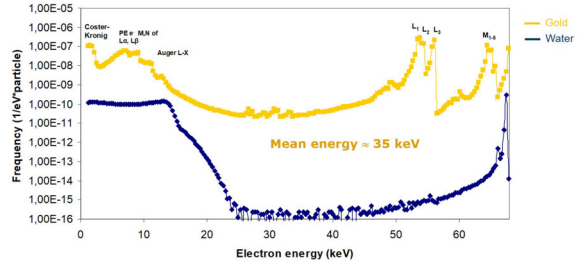
The aim of this work is to model and simulate, with a Monte Carlo transport code, the interaction between radiations and cells or DNA in presence of heavy elements and to compare the results with experimental measurements carried out in two partner laboratories: laboratoire des L esions des Acides Nucl eiques at CEA of Grenoble and the INSERM team of the beam line dedicated to medical studies at ESRF. To this end, we first started to study the characteristics of the gold nanoparticles under various conditions of irradiation, for instance looking at the spectra of secondary electrons created and the deposited dose at a micrometer level around a nanoparticle. In a second hand, we will look into a more realistic model close to the experimental conditions in order to see potential correlation between a physical process modelled and a radiobiological result obtained with the experiments made at ESRF.

Penelope code

- **Gold nanoparticle geometry, spectrum study:**
 - sphere of 100 nm diameter, full of water or gold.
 - Detectors are virtual tools which quantify the spectrum of outgoing particles.

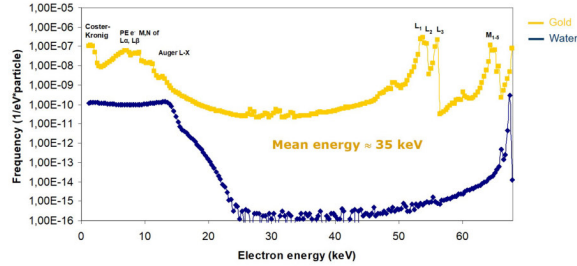


Electron spectrum for 68 keV monoenergetic beam



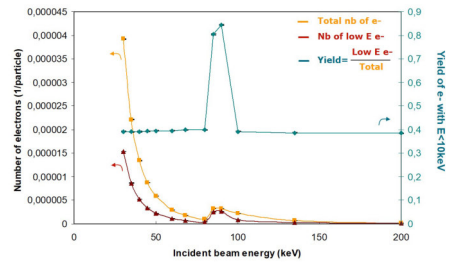
→ Modification of the spectra before and after the K-edge: influence on the mean energy and range of electrons created from the GNP.

Electron spectrum for 68 keV monoenergetic beam



→ Modification of the spectra before and after the K-edge: influence on the mean energy and range of electrons created from the GNP.

Study of total electrons emitted and the yield of low energy electrons (< 10 keV) produced in GNP as a function of beam energy



→ Strong enhancement of the yield of low energy electron (range of few μm) after the K-edge due to the photoelectric absorption.

Figure 2 : Study of the characteristics of the gold nanoparticles under various conditions of irradiation

Study of microdosimetry around the GNP

- **Dose study :**
 - Geometry: spherical GNP of 100 nm diameter in a water sphere of 1 μm .
 - Study of the deposited dose due to the GNP in the water sphere.

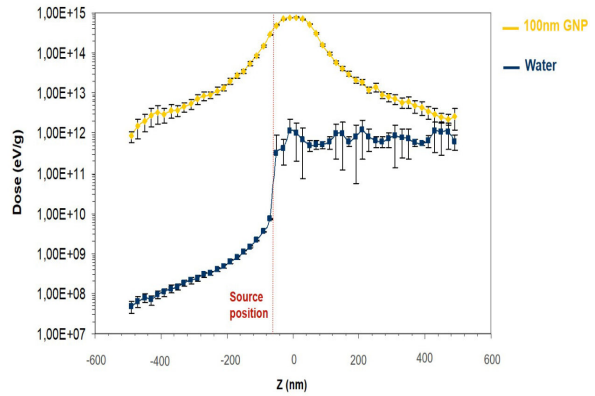
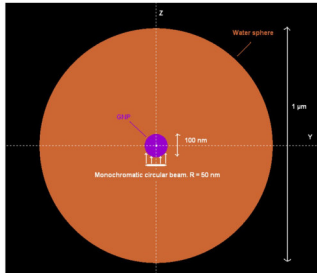


Figure 3 : Study of microdosimetry around the gold nanoparticles