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#09-17 Evaluation of different detector designs for nanodosimetry

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Nanodosimetry is a relatively young research field which could help provide a more thorough understanding of how radiation interacts with cells. The nanodosimeters currently available are unfit for clinical use, due to their large size. The aim of this project is the development and characterization of a portable nanodosimeter.

It is known that how radiation interacts with cells is dependent on the type of radiation. This can be characterized by the Linear Energy Transfer (LET) of the radiation. Alpha radiation passing through tissue will leave a densely ionized path due to its high LET, whereas photons with a low LET will only ionize the tissue sparsely. From different cell experiments it is also known that radiation damages cells which can lead to cell death. Radiation can cause damage to DNA through ionizations in two ways: Indirect damage happens when radiation ionizes water molecules, resulting in free radicals which can then damage the DNA helix. The other form of damage is called direct damage and results from the radiation directly ionizing and damaging part of the DNA. The type of radiation also influences how many cells are inactivated by radiation. Alpha radiation causes more cells to be inactivated than photon radiation, due to its different LET and how it damages the DNA. In order to fully understand the processes on the DNA level a measuring device with a resolution of nanometres would be required. This technology is currently not feasible, but nanodosimetry offers an elegant solution to this problem.

The idea of nanodosimetry is to measure the number of ionizations happening within a small volume. Because DNA is the radiosensitive target of a cell, we are interested in a volume approximating the DNA double helix, for example a cylinder with a diameter of some nanometres. The number of ionizations produced within such a volume is repeatedly measured and called the ionisation cluster size. This is a stochastic quantity, it can therefore be characterized by a probability distribution, the ionisation cluster size distribution (ICSD). The ICSD describes how the radiation interacts with the DNA on a nanometre scale. The problem of observing such events on a nanometric scale can be solved by the equivalence principle, which states that the spatial distribution of ionization events scales linearly with density. This means that instead of measuring microscopic volumes directly, macroscopic volumes of low-pressure gas can be used instead. Different types of low-pressure gas were analysed and compared to liquid water by simulations and measurements by Grosswendt et al. in 2001. Propane gas was shown to be a good approximation of liquid water due to its similar behaviour regarding mean cluster size. In summary: Nanodosimetry measures ionisation cluster size distributions formed in macroscopic volumes of low-pressure gas.

There are different nanodosimeters which have shown this principle to work and which have measured ICSD. However, the Jet Counter from the Soltan Institute for Nuclear Studies, the Ion Counting Nanodosimeter from the Weizmann Institute and the Track-nanodosimetric Counter from Laboratori Nazionali di Lenaro all have one thing in common: They are functioning nanodosimeters, but very complex and bulky. This makes the devices impossible to use in a clinical setting for beam evaluation, where such a device would need to be portable and relatively small. This created the starting point for the development of a novel nanodosimeter at Loma Linda University. This new nanodosimeter was initially developed by Schulte, Bashkirov et al. over the last years.

The working principle of this detector is the detection of ionizations by use of a thick gas electron (THGEM) multiplier of a thickness of 1 cm. An alpha source is placed within a vacuum chamber, filled with low pressure propane gas. An alpha particle will ionize gas molecules along its way from the source to the alpha particle detector. The ions created by this will follow an electric field and drift towards the THGEM hole. Inside the THGEM hole a stronger electric field will cause the ion to be accelerated towards the cathode. During this acceleration electrons will be produced, but they will experience an acceleration away from the cathode and create an electron avalanche. This avalanche is then measured by a read-out pads, resulting in a signal.

For each alpha particle a measurement window of a few milliseconds is opened, within which all signals are counted.

The detector can successfully detect individual ionizations caused by alpha particles along their way, however its efficiency remains relatively low, with only few ionizations being counted per alpha particle. The aim of this project is to systematically analyse and characterize the detector for different pressures, THGEM hole diameters, drift voltages, high voltages and many other parameters, thus giving insight in how different parameters influence the efficiency and behaviour of a compact nanodosimeter. Initial results of this first extensive analysis will be presented.

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