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SHORT-TERM SCIENTIFIC MISSION - Scientific report

I have spent 5 days from November 15th, 2004 till November 19th, 2004 with my colleagues Dr G. Montarou and Z. Francis from LPC Clermont, France, at the Institute of Radiation Protection (ISS) - German GSF National Center for Environment and Health in Neuherberg, Germany - in the framework of the COST P9 working group 5 (study of track structure in cells, Chair: H Paretzke). During this stay, I have benefited from the expertise of Dr Werner Friedland and his colleagues to discover and learn the PARTRAC Monte Carlo simulation tool. This tool represents today the state of the art in computer simulation of DNA damage after cellular irradiation. Our laboratory in Bordeaux is equipped with a microbeam line allowing us to irradiate individual living cells with MeV protons and alpha particles. Simulations performed on our microbeam line using the GEANT4 Monte Carlo software developed at CERN allow us to predict the beam characteristics when it reaches the targeted cells. The characteristics of the beam like energy, position distribution, divergence can be entered into the PARTRAC simulation code. Using a reasonable cell geometry – our live cells are grown from the keratinocyte HaCat cellular line –, the PARTRAC software allows us to predict the consequent damages. For example, most our irradiation experiments are performed at CENBG using a 3 MeV incident alpha beam. GEANT4 predicts a beam energy on target close to 2.37 MeV corresponding to a linear energy transfer of 150 keV/µm in water, taking into account all the Physics process that may occur during the transport of the alpha particles along the microbeam line elements (energy loss, scattering, etc…). The cell is simulated using a spherical cytoplasm geometry of radius 12 µm and a concentric cylindrical nucleus of height 5 µm and radius 7.5 µm. The nucleus is divided into 46 regions with volumes equal to the corresponding chromosome volumes. The chromatine is modelised by 333000 linear elements of 18 kbp length. All the details about the nucleus geometry may be found in [1]. For an irradiation rate of 5 alpha particles per cell, which represent typical irradiation conditions at CENBG, PARTRAC predicts a total number of single strand breaks equal to 214 ± 28 and a total number of double strand breaks of 40 ± 5. These numbers have been averaged on 10 trials. The total number of hits along the structure reaches 2338 ± 206. We have measured in Bordeaux a corresponding survival rate of the order 10-15%. Our experimental microbeam line will soon provide estimation of damage in terms of yields of single and double strand breaks as well as yields of fragments. We will compare these measurements to PARTRAC predictions. Next year, the CENBG will be equipped with a new generation Singletron accelerator facility with a high energy stability allowing the development of a nanobeam line. This new line will reach a resolution on target of a few tens of nanometers, allowing a very precise targeting in proton and alpha irradiation. This new experimental facility will provide new and precise data that will be used to validate more precisely PARTRAC predictions. We also expect to be able to interface the GEANT4 software with PARTRAC in the framework of the GEANT4 DNA project (http://www.ge.infn.it/geant4/dna/index.html) in order to propose a full simulation tool, able to simulate experimental irradiation facilities and allowing us to predict the mechanisms of damage following a targeted irradiation. The COST P9 program provides thus an ideal framework enabling collaboration between CENBG and GSF on both experimental and theoretical aspects of cellular irradiation.

[1] W. Friedland *et al.*, Calculated DNA double-strand break and fragmentation yields after irradition with He ions, to appear in Radiation Physics and Chemistry (2004)

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