The INFN Accelerator-Based NCT Project

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on behalf of NCT collaboration

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Introduction

The neutron-capture therapy (NCT) with ^{10}B (BNCT) has been proven to be an effective therapy for head-neck recurrent tumours, recurrent glioblastoma tumours, Malignant Melanoma (MM) of skin and mucosa. Studies about efficacy of this cellular therapy on other pathologies are in progress. BNCT has been so far performed only with research nuclear reactors. The INFN has launched some time ago the accelerator-based neutron capture therapy (ABNCT) project, which aims to construct a high intensity proton accelerator to produce thermal and epithermal neutrons at the Legnaro laboratories. Neutrons will be used to perform clinical studies on MM tumours, lung metastasis and other pathologies. The project involves the following different disciplines: i) physics of accelerators for producing high-intensity neutron beams; ii) chemistry and pharmacokinetics for new boron and gadolinium carriers; iii) physics of detectors for the development of microdosimetric radiation detectors for beam quality characterisation; iv) IT research for developing new simulation codes for an advanced NCT treatment planning.

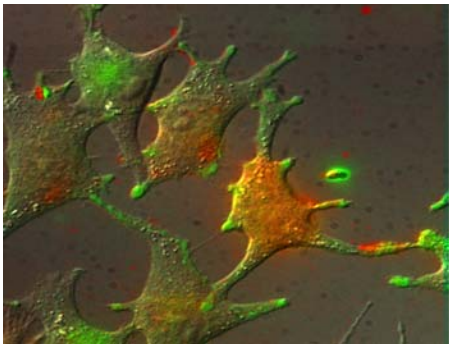

Fig. 1 Micrographs of melanoma cells showing the cell membranes (green) and the Boron Phtalocianine (red), which has been up taken inside them.

NCT is a binary therapy. First, a nuclide like ^{10}B or ^{157}Gd is injected in the patient body, then the patient is irradiated with thermal or epithermal neutrons. Only those cells containing ^{10}B will be damaged by ^{11}B nuclear fragments or Auger electrons from ^{158}Gd de-excitation, while the healthy surrounding ones remaining undamaged or lightly damaged by photon and neutrons. Such a peculiar behaviour of energy releasing allows of conceiving a cellular radiation therapy.

In figure 1, ^{10}B is conveyed inside the cells by boronated phtalocyanine, which is traced by fluorescence. Both neutrons and ^{11}B fragments are high LET particles. Therefore, their relative biological effectiveness (RBE) is bigger than 1. A mini counter made of two TEPCs (see figure 2) can assess the radiation field RBE of both in ordinary cells and in boronated cells.

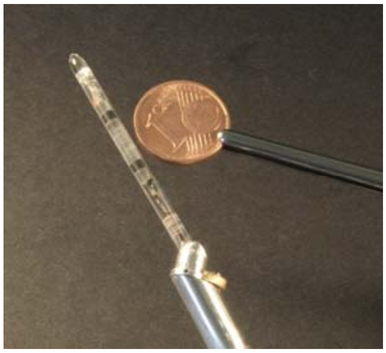

Fig. 2 Mini counter with two Tissue-Equivalent Proportional Counters,TEPC (the two black cylinders) inside the plastic sleeve.

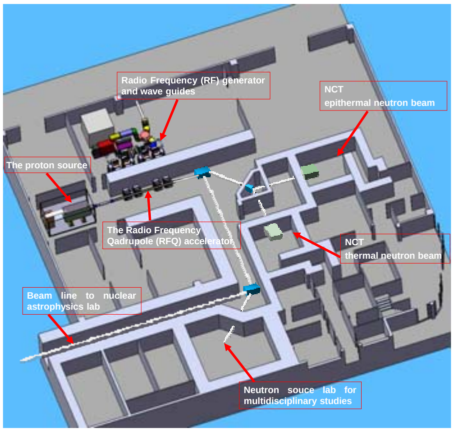

Fig. 3 Preliminary layout of the ABNCT facility at the Legnaro laboratories.

The accelerator-based neutron source will be made of an ion source, which supplies up to 50 mA of protons at 80 keV of energy, a Radio Frequency Quadrupole (RFQ) accelerator, which increases the proton energy up to 5 MeV, and a high-power beryllium target, which acts as proton-neutron converter. The neutron source will have an intensity of approximately 10^{14} s^{-1}. A neutron moderator will slow neutrons down to the required thermal or epithermal energy.

The facility layout is shown in figure 3. In the figure the thermal and epithermal neutron halls for medical use are visible, as well as the halls for physics research. The same proton beam is in fact useful to produce neutrons for radiation damage studies, 3D elemental analysis studies and other applied neutron studies, as well as nuclear astrophysical studies.

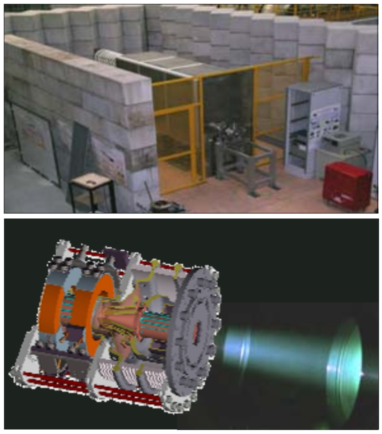

Fig. 4 The 50 mA proton source (bottom) showing the first beam extracted and the installation for commissioning (top).

The proton source has been already constructed (top of figure 4). A picture of the intense proton beam emerging from the source is visible in the bottom of figure 4, together with a 3D drawing of the source itself. The 3 accelerator units of the RFQ are visible in figure 5 placed on their supports. In figure 6 a detail showing the internal structure of a RFQ unit. The four copper electrodes both accelerate and focalize the proton beam. Half of the beryllium proton-neutron converter is shown in figure 7. It has been used for thermo-mechanical and radiation damage studies. The final converter is made of two halves, identical to that one of figure 7, positioned to form a duck beak that is opened towards the proton beam.

Fig. 5 The 3 modules of RFQ accelerator ready for RF test

Fig. 6 Close view of the RFQ accelerating electrodes

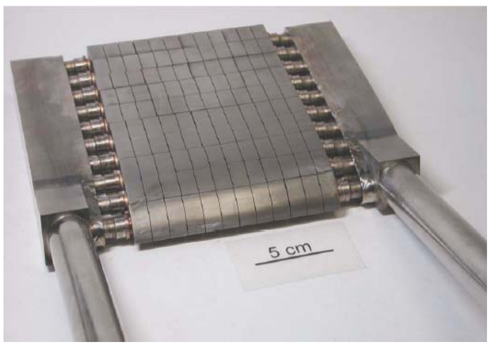

Fig. 7 The high power beryllium proton-neutron converter