WS101-4: ELIMED beamline at ELIMAIA: current status, absolute dosimetry and preparation for the first radiobiological experiment

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The ELIMED (ELI MEDical and multisciplinary applications) beamline for transport and dosimetry of laser-accelerated ion beams has been completed by LNS-INFN (Catania, I) and installed as a part of the ELIMAIA (ELI Multidisciplinary Applications of laser-Ion Acceleration) beamline at ELI-Beamlines (Dolnì Brexany, CZ).

The beamline will be able to focus, select and transport proton and carbon beams up to 250 MeV and 70 AMeV, respectively, down to the sample irradiation point, which is located in air about 9 meters far from the laser-target interaction point. A picture of ELIMED after its installation in July 2018 is shown in Figure 1.

In order to deal with peculiarities of non-conventional, laser-accelerated ion beams, such as ultrahigh dose-rates (up to 10^9 Gy/min), non-monochromatic spectra (up to 100% bandwidth) and large angular divergence (tens of degrees), innovative transport and dosimetric solutions have been designed, realized and preliminary tested with laser driven proton beams. Such devices are based on permanent quadrupoles and electromagnetic dipoles (for focusing and energy selection, respectively) and by a dual-gap ionization chamber coupled with a Faraday cup, ad-hoc designed to minimize recombination effects coming from the high dose rates which are crucial for an accurate determination of the absorbed dose by the irradiated sample.

Cancer treatment with particle beams (hadrontherapy) arguably represents an appealing prospective for future applications of ELIMED beamline [1, 2]. To validate the feasibility of clinically sound laser-driven beams, preliminary in-vitro radiobiology experiments are necessary. This is because cellular response to ionizing radiation is profoundly influenced by the spatio-temporal distribution of DNA lesions along radiation tracks. Hence, the unprecedented physical regimes that can be achieved by such beams warrant verification that biological effectiveness at tumour cell killing is at least the same as that offered by conventionally accelerated beams, as most recent literature seem to confirm. Furthermore, the recent findings [3] that conventionally accelerated short-pulsed, ultra-high dose rate (exceeding 40 Gy/s) photon and electron irradiation may lead to an increased sparing of normal tissue (paving the way to the so-called FLASH radiotherapy), adds interest to test such a behavior also with optically accelerated particles, where such physical features are greatly magnified. The first radiobiology experiment at ELIMED is expected at the beginning of 2020, after a preliminary phase where all dosimetric devices will be characterized and the absolute dosimetry protocol defined.

We shall investigate the biological response along the ELIMED beamline using two cell lines, both from human breast tissue: highly metastatic MDA-MB-231 cells and the normal epithelial MCF-10A cells. The use of a breast model system stems from the growing interest in treating breast cancer by protontherapy. Reduction of normal-tissue damage, e.g.. radiation-induced cardiovascular disease in light of a confirmed ballistic precision at conforming dose to the tumor, represent the main rationale. Cell survival by clonogenic assay, the golden standard to measure cellular radioresponse in terms of loss of proliferative ability will be studied, together with cytogenetic and biomolecular assays such as cellular premature senescence, chromosome aberrations, γ-H2AX foci induction and gene expression profiling. Our group has a consolidated expertise in working with cell lines, and in particular with those from breast tumor, exposed to photons, electrons and particle radiation at conventional accelerating facilities, which would enable us to compare previously obtained results for such endpoints [4, 5] with those obtained at ELIMAIA. Moreover, our group has investigated the radiobiological effectiveness of both ultrashort laser-driven electron bunches at the Intense Laser Irradiation Laboratory (ILIL) of the National Institute of Optics of the CNR (Pisa, Italy) as well as laser-driven protons accelerated at the Laboratoire pour l'Utilisation des Lasers Intenses (LULI, Palaiseau cedex, France) [6, 7, 8].

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Figure 1: Photo of the ELIMAIA accelerator section (left) and of the ELIMED beam transport (collection, energy selection, transport and focusing and dosimetry) in November 2018, just after the installation in the RP3 hall at ELI-Beamlines (CZ)