First high-energy proton tomography of a mouse

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Relativistic protons have been proposed as an alternative to low-energy ions in the treatment of cancer and non cancer diseases [1]. The increase of the primary beam energy to the GeV region will overcome several limitations of Bragg-Peak therapy with protons, such as the broadening of the primary beam due to multiple scattering and uncertainties on the particle range and Relative Biological Effectiveness (RBE). These processes lead to a reduced dose gradient between the tumor volume and the surrounding tissue and thus to an increase of side effects. The main advantage of relativistic protons is that the beam crossing the patient can be exploited for imaging purposes. Proton radiography was investigated for many years because of its low radiation dose and high density resolution, but until recently the image blurring caused by scattering was limiting its practical applications in medicine. In the past years, the Los Alamos National Laboratory (LANL) system based on a magnetic lens after the object for imaging and chromatic aberration corrections pushed the technique to unprecedented time and spatial resolution [2]. This technique exploits differences in the lateral scattering of the primary ions due to the material thickness and density they encounter. The application of this methodology to medical imagining has been tested at the pRad facility (LANL) in December 2012. The experiment was performed within the framework of the PANTERA (Proton Therapy and Radiography) project. Radiographies of simple (plastic tissue-equivalent targets) and complex (antropomorphic phantom, zebra fishes) geometries were acquired using 800 MeV protons. Furthermore, the first proton tomography of a formalin-preserved mouse was obtained. First preliminary results of the latter target are shown in this report.

The experiment

The mouse was placed with its main axis perpendicular to the beam direction. A rotational stage was used to allow a 360 degrees movement of the sample with a 0.5 degrees step. Examples of the mouse profile acquired in the orthogonal and parallel direction with respect to the beam axis are reported in Figs. 1 and 2. The former has been obtained from a direct acquisition of the target radiography while the latter was achieved through a more advanced data analysis. Using filtered backprojection (employing a ramp filter), tomographic slices were reconstructed from transmission images, of which Fig. 2 is an example. The shape of the mouse can be clearly distinguished in the full picture (Fig. 1). Furthermore, internal bony structures are well visible especially in the parallel reconstruction (Fig. 2).

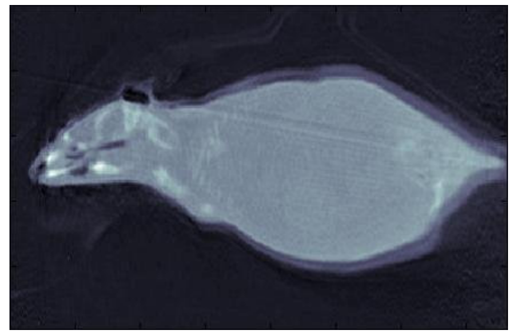

Figure 1: Profile of the mouse acquired in the direction orthogonal to the beam axis.

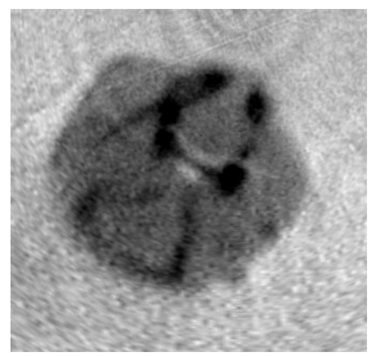

Figure 2: Tomographic reconstruction of a mouse slice acquired in the direction parallel to the beam axis. The image contains a section of the head, where the skull bones (dark areas) and nasal cavities (light areas) are visible.

Conclusions

The application of relativistic protons to diagnostic has shown promising results. Further tests on live animals are planned at pRad in 2013 and at the proton microscope PRIOR located in the FAIR facility, where energies above 1 GeV will be available. The experiments will focus on optimizing the technique for the image of lesions implanted in the animals and couple the irradiation with standard radiotherapy.

References

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