European Novel Imaging Systems for Ion therapy

http://cern.ch/ENVISION

Hadrontherapy is a highly advanced technique of cancer radiotherapy that uses beams of charged particles (ions) to destroy tumour cells.

While conventional X-rays traverse the human body depositing radiation as they pass through, ions deliver most of their energy at one point. Hadrontherapy is most advantageous once the position of the tumour is accurately known, so that healthy tissues can be protected.

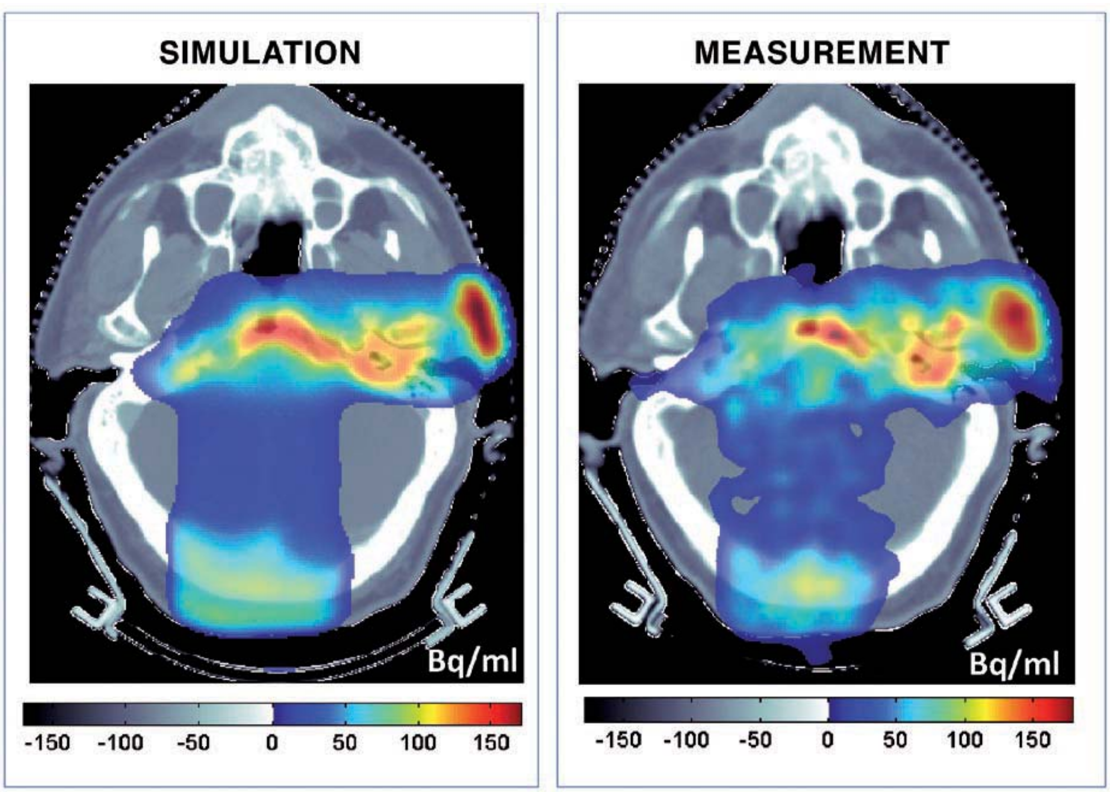
Accurate positioning is a crucial challenge for targeting moving organs, as in lung cancer, and for adapting the irradiation as the tumour shrinks with treatment. Therefore, quality assurance becomes one of the most relevant issues for an effective outcome of the cancer treatment.

In order to improve the quality assurance tools for hadrontherapy, the European Commission is funding ENVISION, a 4-year project that aims at developing solutions for:

- real-time non invasive monitoring
- quantitative imaging
- precise determination of delivered dose
- fast feedback for optimal treatment planning
- real-time response to moving organs
- simulation studies

Launched in February 2010, ENVISION is a collaboration of sixteen leading European research centres and industrial partners, coordinated by CERN.

Fast, reliable and precise monitoring of the dose deposition during the exposure to therapeutic ion beams is the key objective of ENVISION.



Comparison between the Monte Carlo simulated and measured activity distribution after proton irradiation at Massachusetts General Hospital, Boston, USA (adapted from Parodi et al, IJROBP 68 (2007) 920-34)

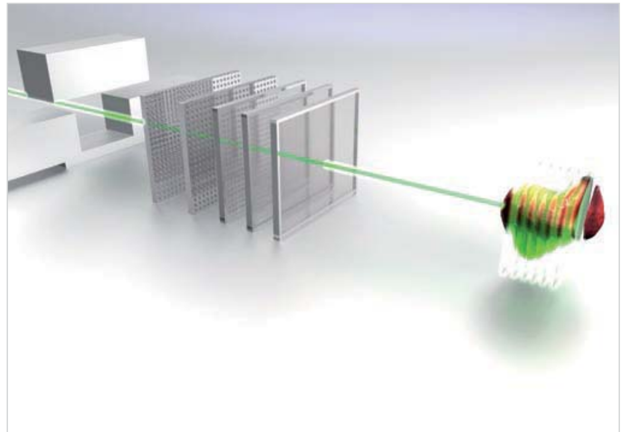
Striving for precision

Positron Emission Tomography (PET) is the only physiological real-time non-invasive monitoring tool available. During charged particle therapy, radioactive isotopes do not have to be injected, as is the case for normal PET imaging, since they are naturally generated in the irradiated tissues. The radioactive isotopes emit positrons that interact with tissues producing a pair of photons. The PET detector looks for two almost simultaneous photons to identify the origin of the positron.

Each photon needs a certain time, called Time-Of-Flight, to travel from the emission point to the detector. A fast and accurate measurement of the TOF difference between the two photons allows to better pinpoint the origin of the initial radiation, and therefore to improve the quality of the image.

A second promising way to better monitor the dose in real time is the detection of single photons and charged particles emitted almost instantaneously in the irradiated tumour.

These methods require the development of innovative detectors and dedicated recording electronics, both tackled by ENVISION.



Precise irradiation of tumour using with beams of hadrons using the raster scanning technique (courtesy GSI/HIT/Siemens)

Moving targets

In the field of cancer diagnostics, a major advance over still imaging is represented by PET coupled with a new technique called Four-Dimensional Computer Tomography (4DCT): this cutting edge technology allows to capture the movement of organs as well as the changes in position and shape of the tumour. 4D PET/CT has a huge potential to improve the current tools used to compensate for organ motion during irradiation. ENVISION explores the feasibility and the clinical relevance of 4D PET/CT application for hadrontherapy, and develops innovative technologies and methods for optimizing the quality of the images acquired.

Towards a global treatment planning

ENVISION's ultimate goal is to use the wealth of information provided by these novel imaging techniques to optimise treatment planning. This is an essential step to bring the technology out of the research environment and into the clinical world. ENVISION will develop tools to automatically analyse real-time monitoring images and use the information gathered to give feedback on how to continue the treatment. Since different treatment sites have different set-ups, ENVISION will also develop and build portable devices to measure the specific characteristics of each site and use them to fine-tune the therapy.

Models needed

Accurate numerical simulations are needed by all ENVISION tasks to optimise the design of the detectors, to develop software that can reconstruct the dose map from the images collected, and to assess the accuracy of real-time dose monitoring. ENVISION will implement full simulations of the detailed physics processes that lead from the dose deposition to the recorded image. A fast dedicated simulation tool suitable for use in treatment planning will also be implemented.

Hadrontherapy treatment room (courtesy IBA)

ENLIGHT

COOPERATION

The ENVISION project is cofunded by the European Commission under FP7 Grant Agreement No 241851

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