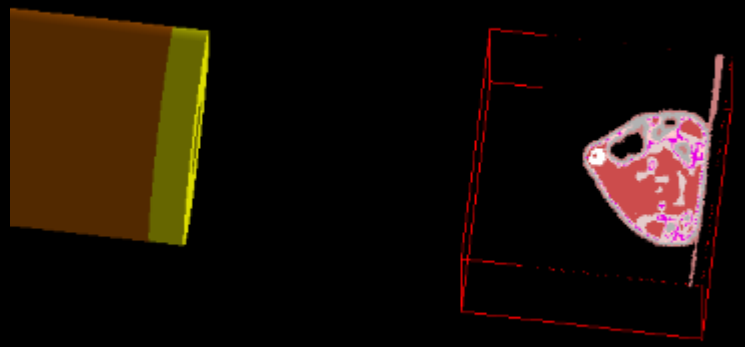
International Conference on Monte Carlo Techniques for Medical Applications (MCMA2017)

15th - 18th October 2017 Napoli, Italy



Monte Carlo dosimetric study for preclinical small animal hadrontherapy using Geant4 toolkit

P Pisciotta, G Russo, GAP Cirrone, F Romano, FP Cammarata, V Marchese, G Petringa, GI Forte, D Lamia, R Acquaviva, MC Gilardi and G Cuttone

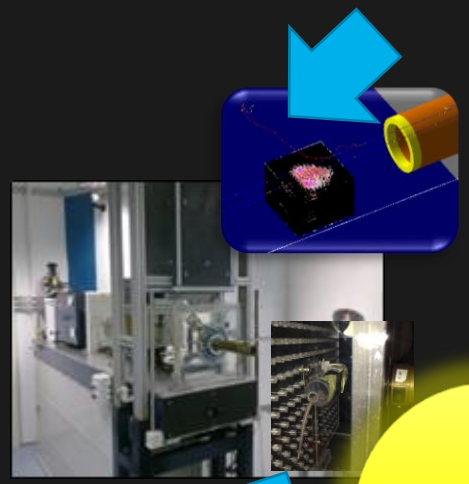
Motivations

"**CATANA**" Centro di AdroTerapia e Applicazioni Nucleari Avanzate

Proton irradiation of **small animals**

Laboratory Animal Science **FELASA** cat.**C**

Quantification and elaboration of **diagnostics imaging**



"CAPIR" Center for Advanced Preclinical in vivo Research PET facility
Optical Imaging and Ultrasound Imaging facility

New research platform
and Radiopharmaceutical production

RadioBiological Laboratory

Cyclotron and Radiopharmaceuticals production
Development of innovative radiopharmaceuticals

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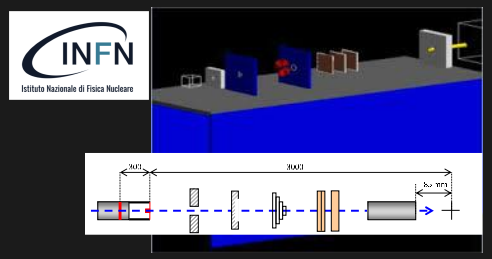
Geant 4 in medical physics

DICOM images in *hadrontherapy* application to performe preclinical studies

hadrontherapy

Linear Energy Transfer &
Relative Biological Effectiveness

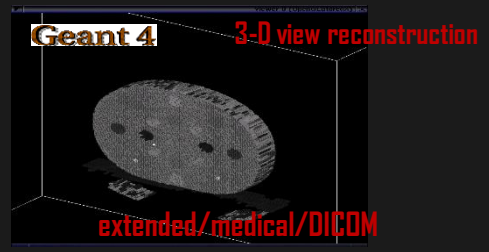


It permits reproduction of :
- geometry of CATANA beam line,
- hadronic physics process.

Therefore, all CATANA beam line features are fully simulated in the hadrontherapy application
(validated several times comparing experimental data).

DICOM

permits to handle DICOM medical images



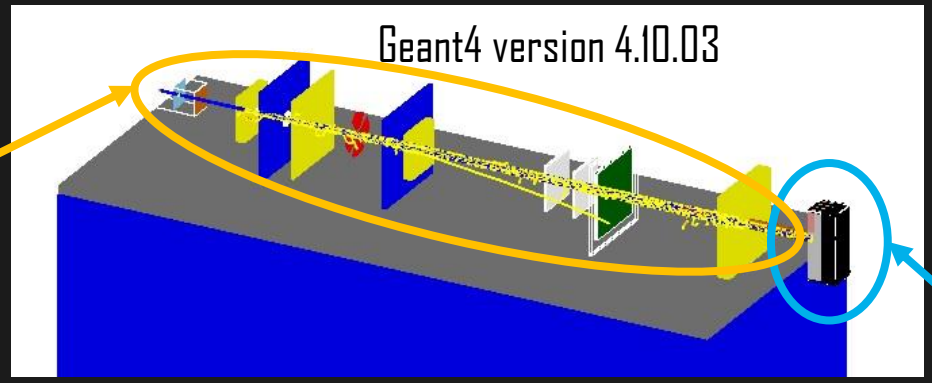
Each voxel value of DICOM CT images is transformed into a voxel of specific material within the simulation.

CIRS phantom is used to perform accurate calibration of Hounsfield Unit (HU) of microCT.

International Commission on Radiation Units & Measurements

Report 46 is used to assign material density.

hadrontherapy



DICOM

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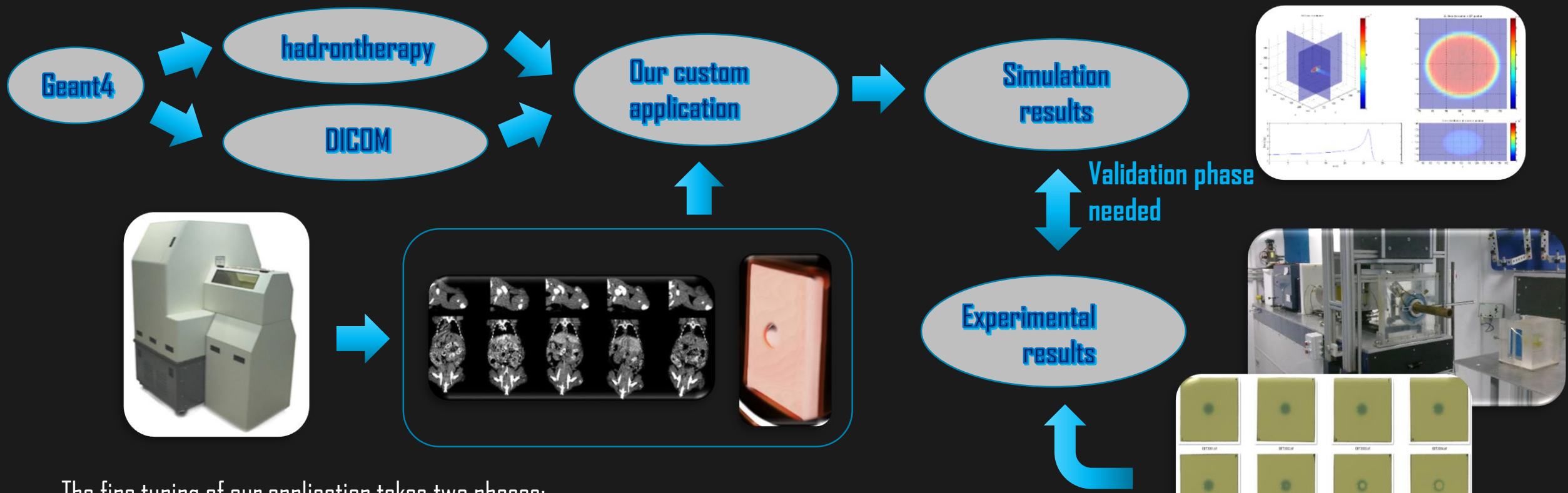
Application workflow and validation



The fine tuning of our application takes two phases:

validation

treatment simulation

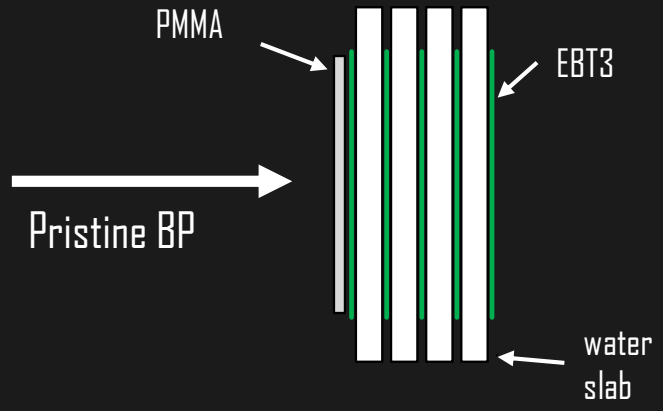
Validation

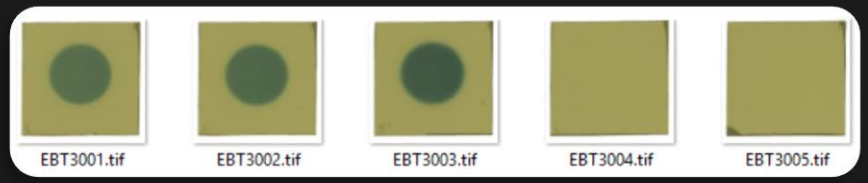
Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment

Volume 846, 21 February 2017, Pages 126–134

Preliminary study for small animal preclinical hadrontherapy facility

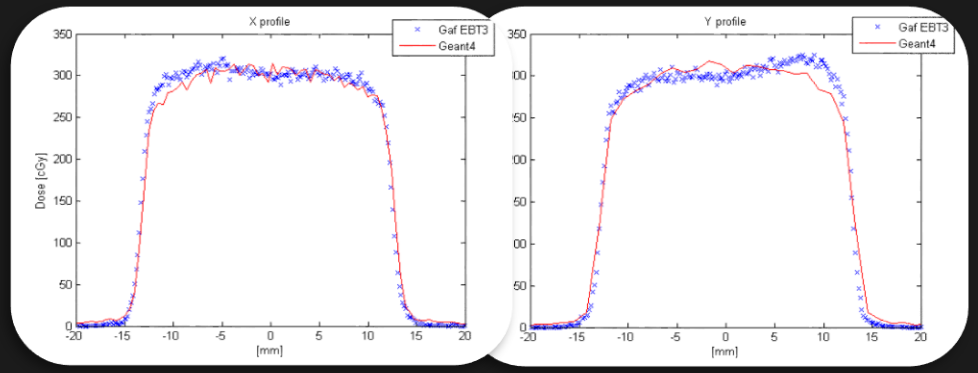
G. Russo[a], P. Pisciotta[a, b], G.A.P. Cirrone[b], F. Romano[b], F. Cammarata[a], V. Marchese[a], G.I. Forte[a], D. Lamia[a], L. Minafra[a], V. Bravatá[a], R. Acquaviva[c], M.C. Gilardi[a], G. Cuttone[b]



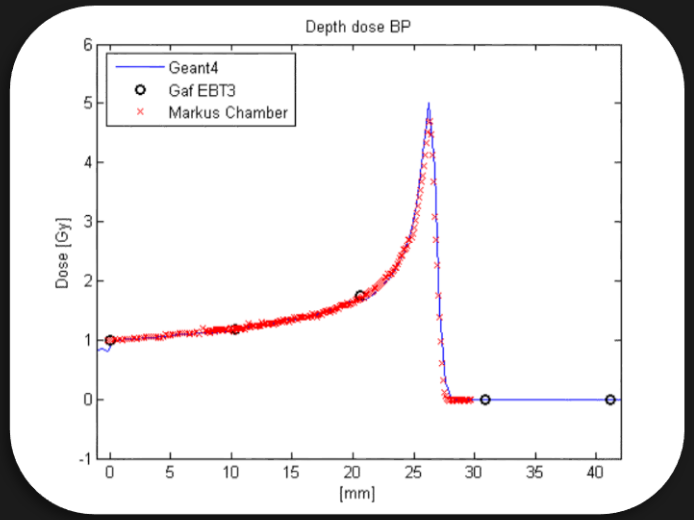


EBT3 vs Geant4 profile along horizontal (left) and vertical (right) direction

X-profile **Y-profile**



Geant4 vs EBT3 and vs Markus chamber depth dose distribution



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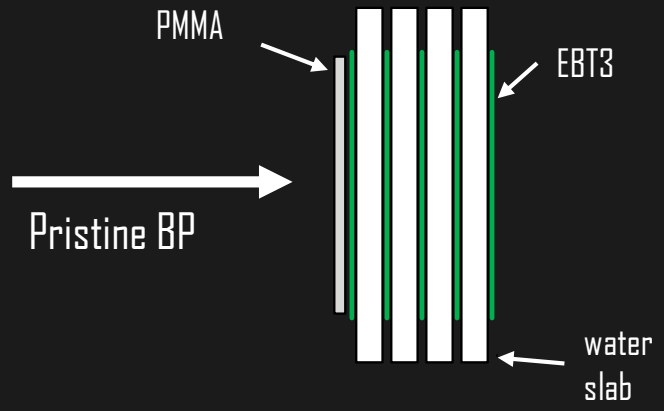
Validation

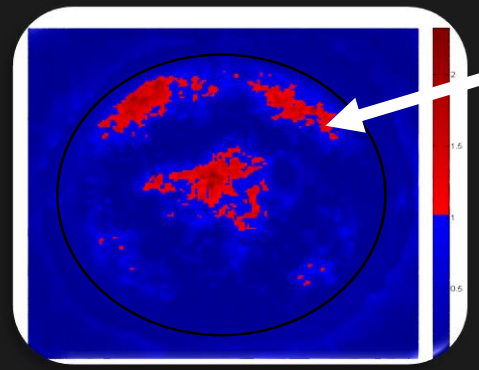


Gamma index test

- Criteria: 3% / 3 mm
- Comparison between 2D dose map obtained with:
  - Gafchromic films
  - Geant4 results

$$\gamma(\vec{r}_r) = min\{\Gamma(\vec{r}_e, \vec{r}_r)\} \ \forall \ \{\vec{r}_e\}$$

$$\Gamma(\vec{r}_e, \vec{r}_r) = \sqrt{\left(\frac{r^2(\vec{r}, \vec{r}_r)}{\Delta d^2}\right) + \left(\frac{\delta^2(\vec{r}, \vec{r}_r)}{\Delta D^2}\right)}$$



>94% points passed test

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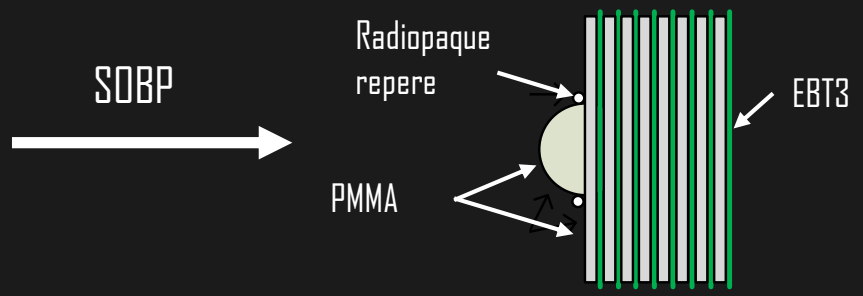
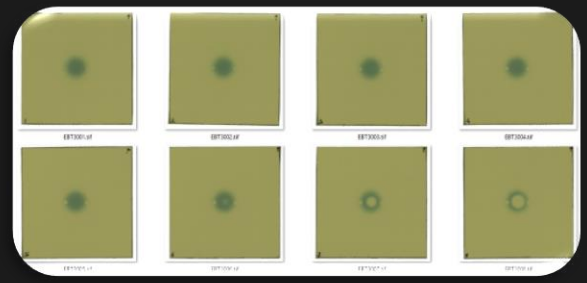
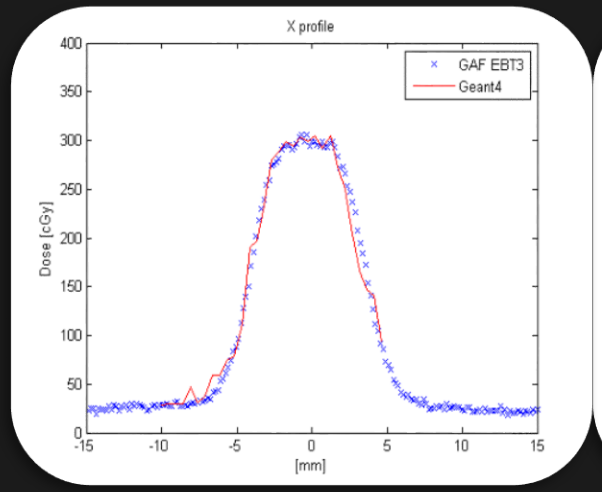
Treatment simulation

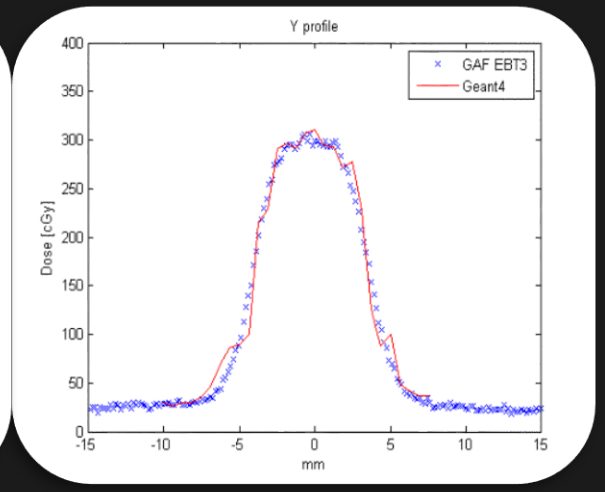




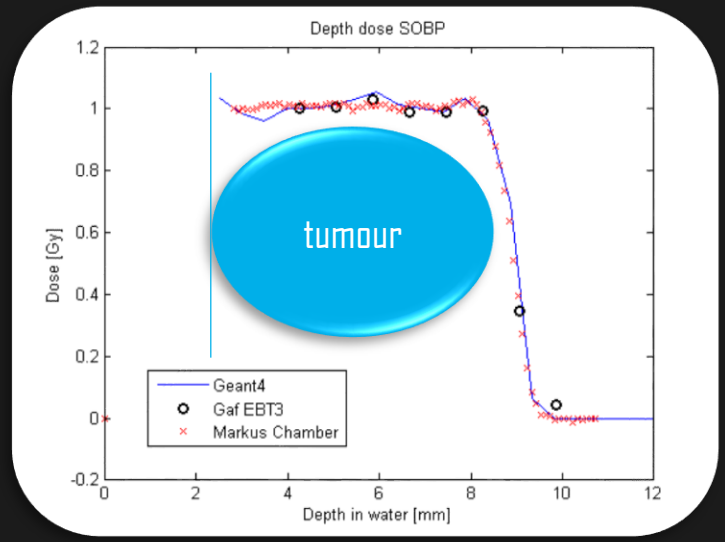
EBT3 vs Geant4 profile along:

- horizontal direction (left);
- vertical direction (right).





Geant4 vs EBT3 and vs Markus chamber spread-out Bragg peak



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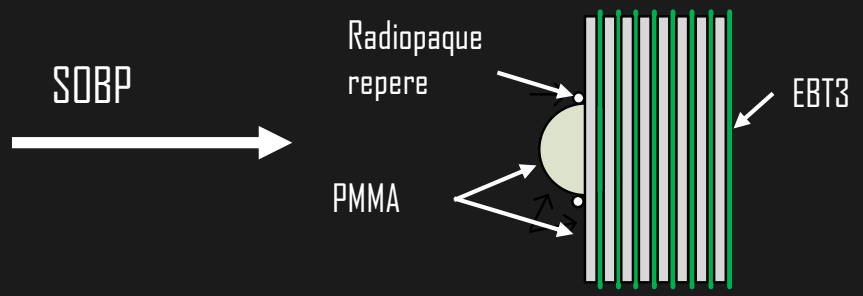
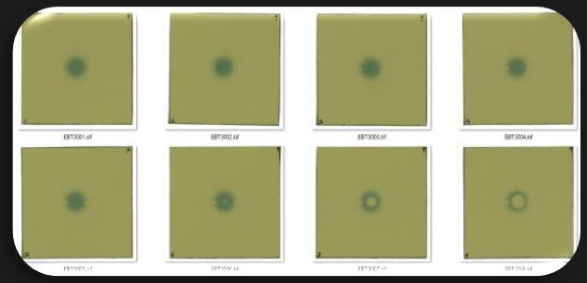
Treatment simulation





Gamma index test

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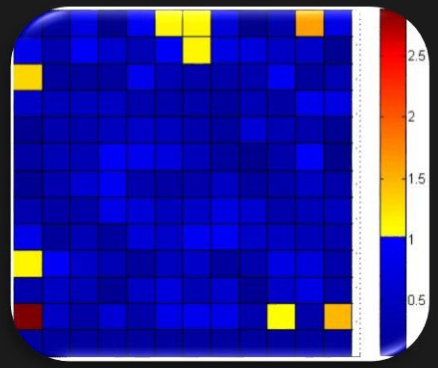
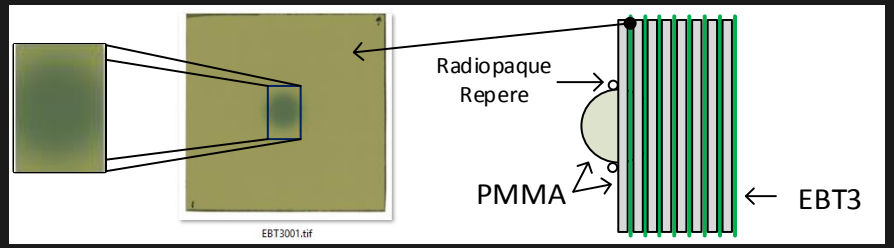


>93% points passed test



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MoVe-IT (INFN-project)

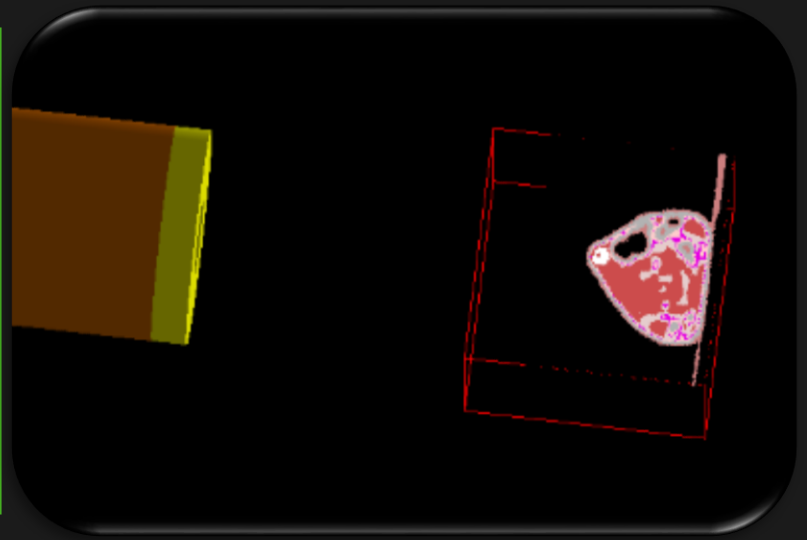
The aims of the project are:
- development of an innovative modelling for biologically optimized treatment planning;
- design of devices for the plan verification

Work Packages:
1) Radiobiological modelling for TPS (Leader: S Hild);
2) NTCP and TCP (Leader: MG Pugliese)
3) Biological Dosimetry (Leaders: W Tinganelli and G Russo)
4) Facilities and beamline simulation (Leaders: GAP Cirrone and F Romano)

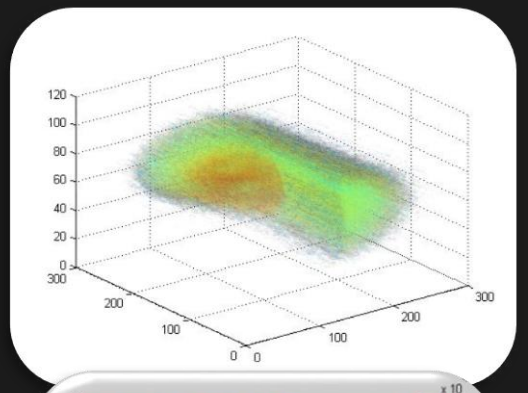
In details, Monte Carlo Geant4 toolkit inside MoVe-IT:

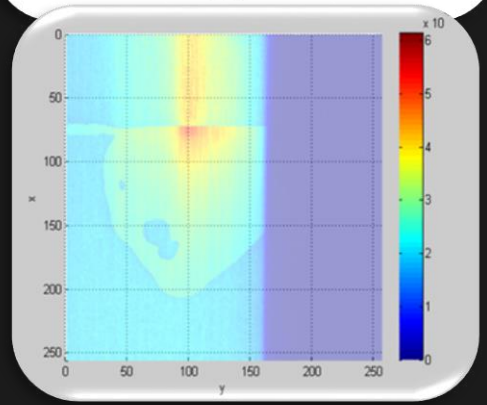
State of the art
- Experimental validation using gafchromic films and ionization chamber
- Preliminary in vivo test:
  - Small animal treatment plans;
  - Dose distribution and LET evaluation.

Future aims:
  - Implementation within hadrontherapy advanced example;
  - Implementation RBE calculation.



3D dose distribution





2D dose distribution

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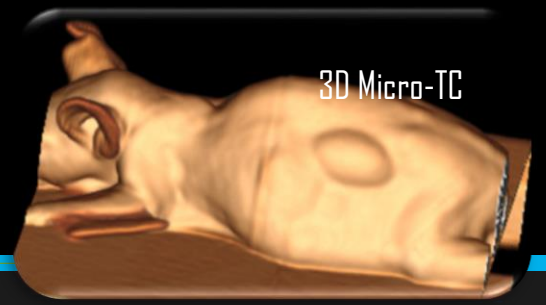
MoVe-IT: Myelopathy study

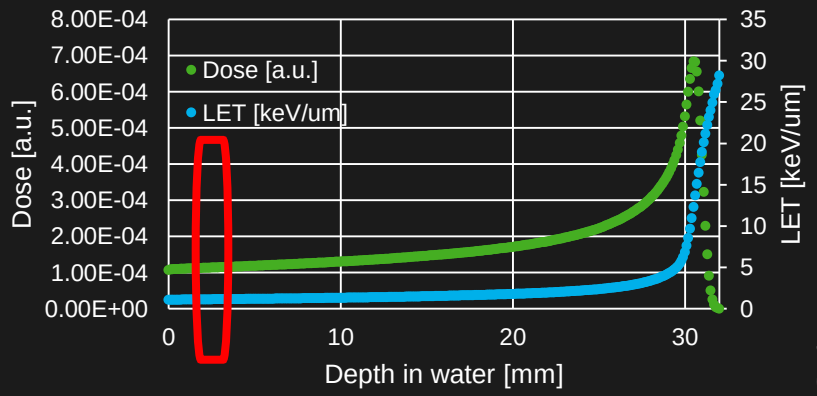


The aims of this project are:

- To study *in vivo* the RBE along the Bragg peak that shows high LET values differences;

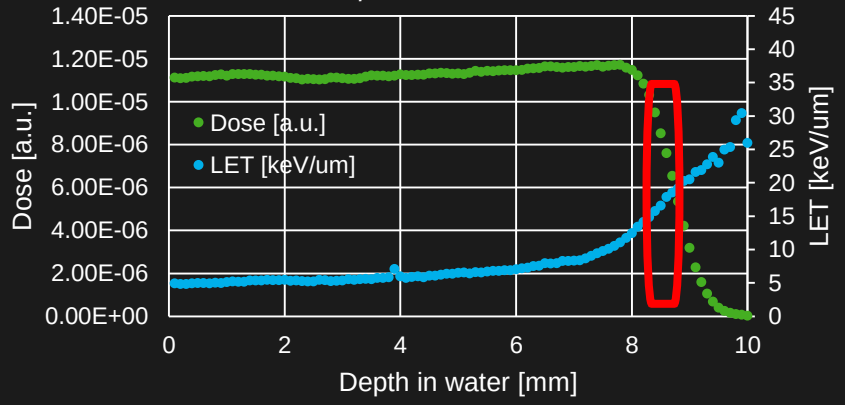
Preliminary dose distribution assessment

RBE ≈ 1,1

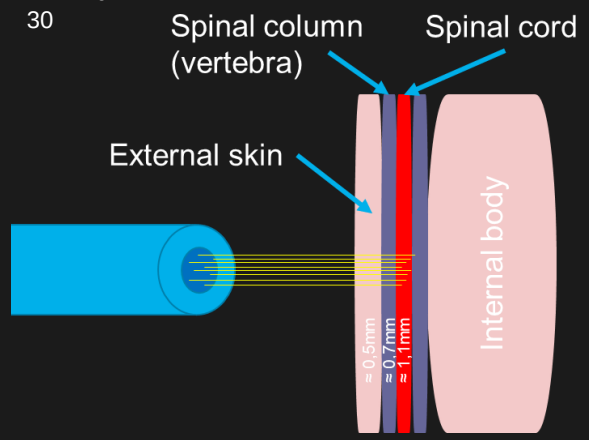


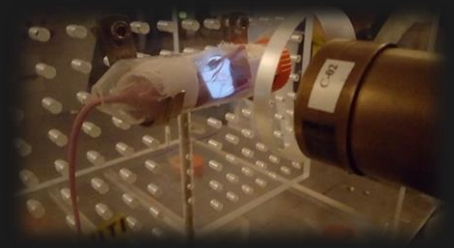
LET ≈ 1,10 keV/µm

RBE ≈ 1,5[*]



LET ≈ 16 – 18 keV/µm





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[*] Enhanced radiobiological effects at the distal end of a clinical proton beam: in vitro study. Journal of Radiation Research, 2014, 55, 816–822 Short Communication doi: 10.1093/jrr/rrt230 (2014)

Conclusions

In our work, it was prepared the ground to perform future proton therapy pre-clinical studies

All the dosimetric measurements obtained were useful to determine:

- the efficiency of our Geant4 application,
- to define the possibility to use it as a support to radiation treatment planning, and
- to define the best small animal irradiation conditions.

Our Geant4 application has proved to be a valid instrument to study the dose distribution in different type of phantoms with very variable geometry.

In the field of radiation oncology, the experimental design for mouse model may require specialized dosimetric techniques and innovative tool to ensure that lethal doses are delivered with sufficient accuracy.

That's all !!! Thank you for attention!

Cefalù (PA) – Rocca

Catania – Piazza Duomo

Catania – Piazza Teatro Massimo

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