Belgrade, 12-14 March 2018

MediNet_Midterm Meeting

Research and networking activities @ INFN-Laboratori Nazionali del Sud

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Workflow

first

Introduction

second

Multidisciplinary beamlines

CATANA, ZERO DEGREE
beamlines @LNS
TIFPA beamlines

LET & RBE implementation

third

DICOM imaging

DICOM in preclinical studies:

Hypoxia project
RBE studies

last

IORT-therapy and LASER-driven app.

New geometry in iort-therapy
Laser-driven applcation
ELIMED project

Multidisciplinary beamlines

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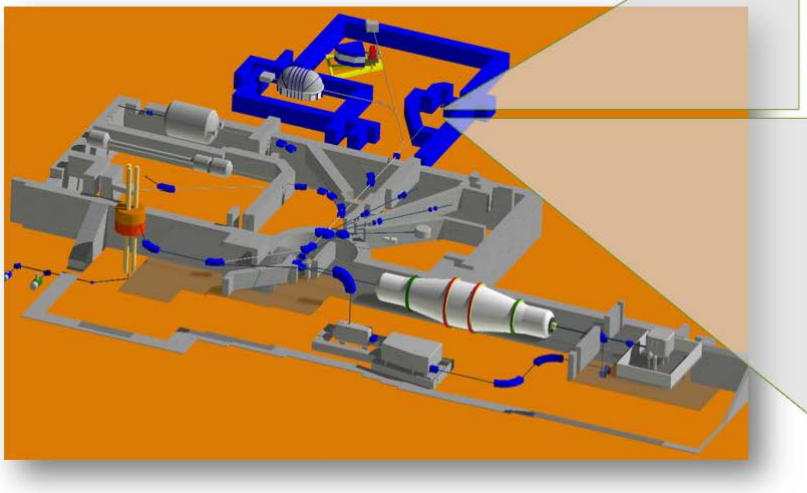
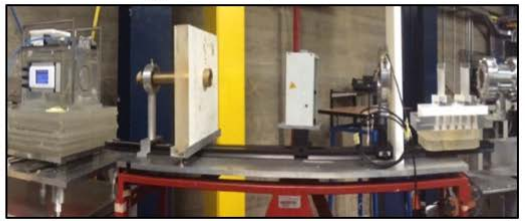
Laboratori Nazionali del Sud

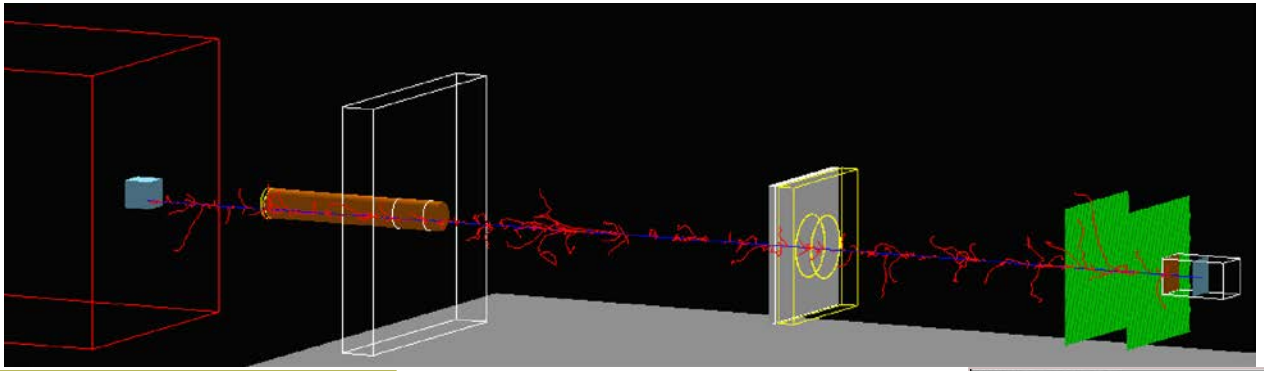


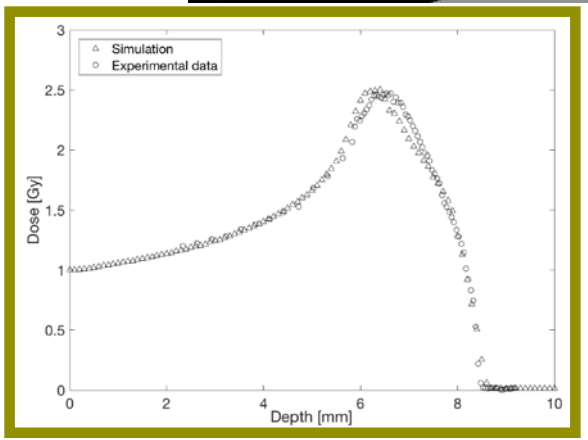
Zero degree experimental room



CATANA beam line

Zero Degree beamline simulation





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SEZIONE DI TORINO
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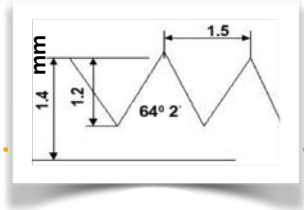
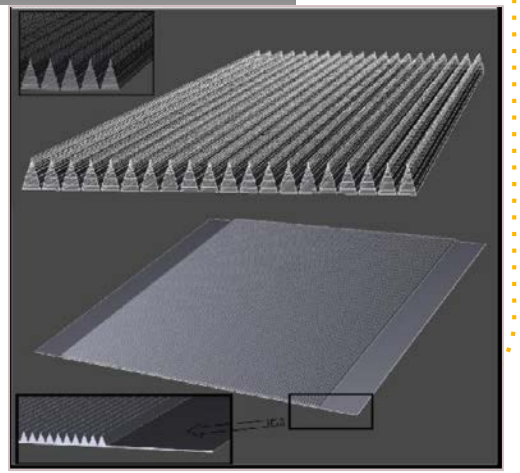
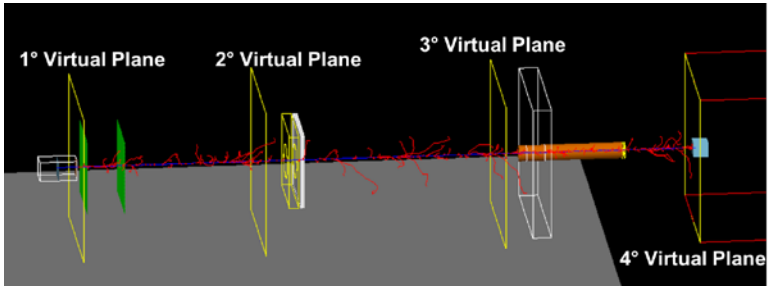


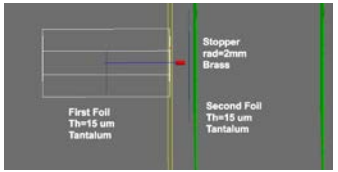


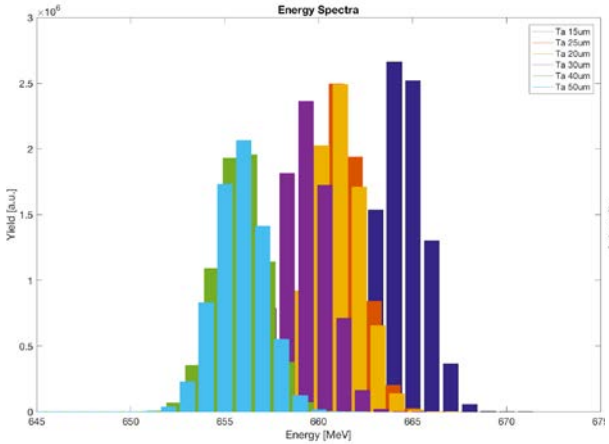
Scattering system for ion beams

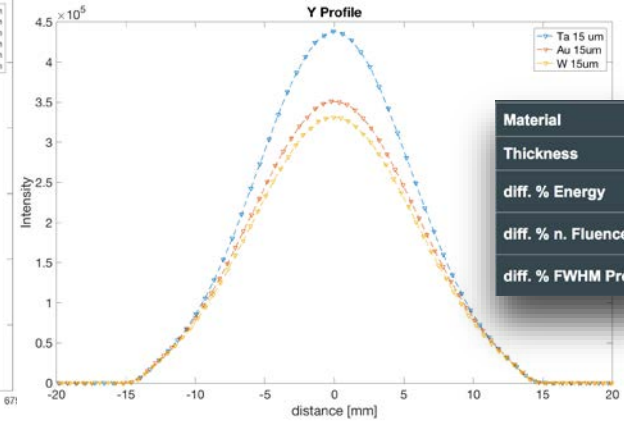
Feasibility study of two configurations:

1. a single scattering foil in vacuum
2. two scattering foils with a stopper



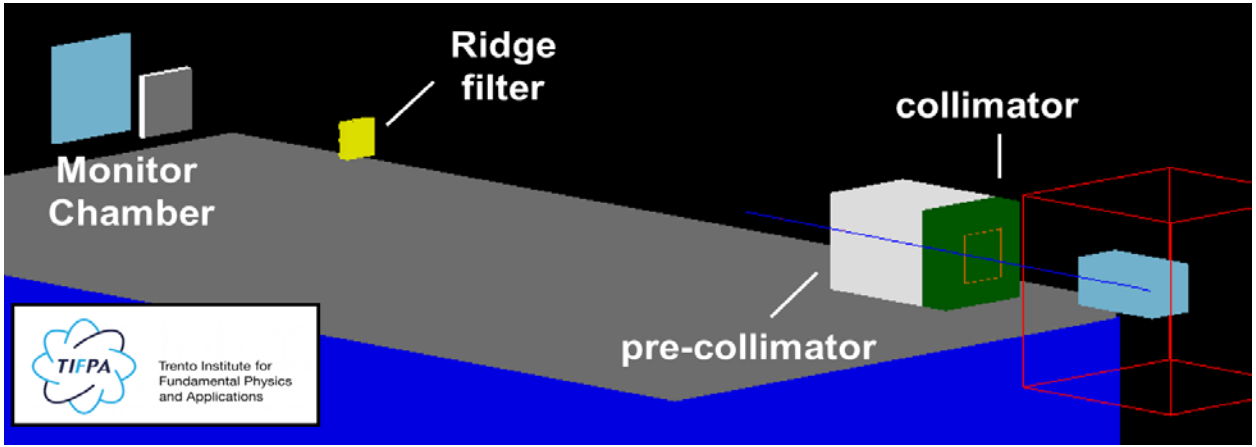






Material	Tantalum					Au	W
Thickness	20 um	25 um	30 um	40 um	50 um	15 um	15 um
diff. % Energy	0,37	0,40	0,70	1,20	1,21	0,075	0,22
diff. % n. Fluence	9,01	9,09	13,38	21,63	21,98	2,72	2,72
diff. % FWHM Profile	13,9	13,11	13,18	22,85	22,91	10,2	8,25

TIFPA beamline simulation



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Provincia Autonoma di Trento

iba

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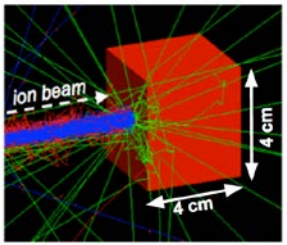
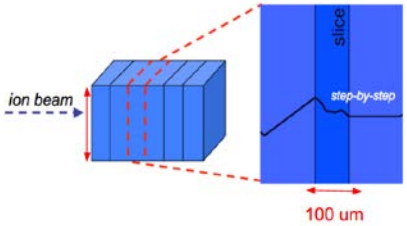
Passive proton beam line

- **Energy: from 70 MeV to 250 MeV**
- **Fluence: from 10^5 to 10^8 p/sec**

LET calculation: the approach





LET dose

substituted

$$\mathrm{LET}_d = \sum_{i=1}^{n}\left(\frac{\varepsilon_i}{l_i}\right) w_{i,d} = \frac{\sum_{i=1}^{n}\left(\frac{\varepsilon_i}{l_i}\right)\varepsilon_i}{\sum_{i=1}^{n}\varepsilon_i} = \frac{\sum_{i=1}^{n}\frac{\varepsilon_i^2}{l_i}}{\sum_{i=1}^{n}\varepsilon_i}$$

Higher dependence by transport parameters: cut, voxel size, step max

New implementation of the LET dose calculation

$$\mathrm{L}_d = \frac{\sum_{n=1}^{N}\left[\frac{(\sum_{s=1}^{S_n}\varepsilon_{sn})^2}{\sum_{s=1}^{S_n} l_{sn}}\right]}{\sum_{n=1}^{N}\sum_{s=1}^{S_n}\varepsilon_{sn}}$$

ε_{sn} is calculated as the energy deposited by the primary proton along the step **plus** the kinetic energy of the δ-rays released in the medium in that step

Goal: each term is created by grouping the energy losses and lengths of all the steps done within the voxel. Thus, the contributions of each particles are mediate into the voxel.

New implementation

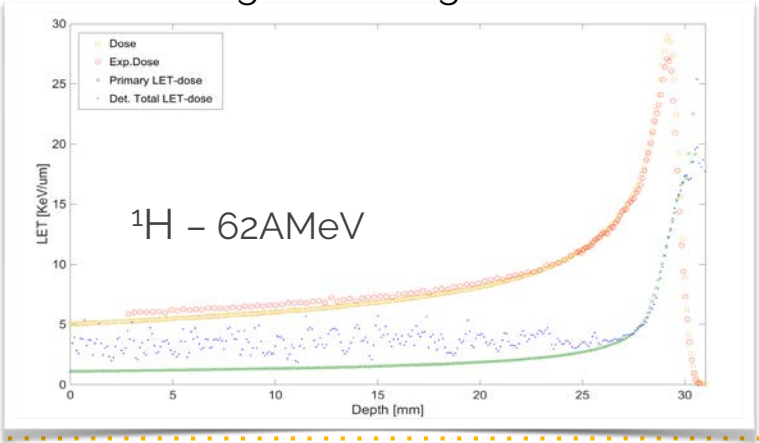
LET track

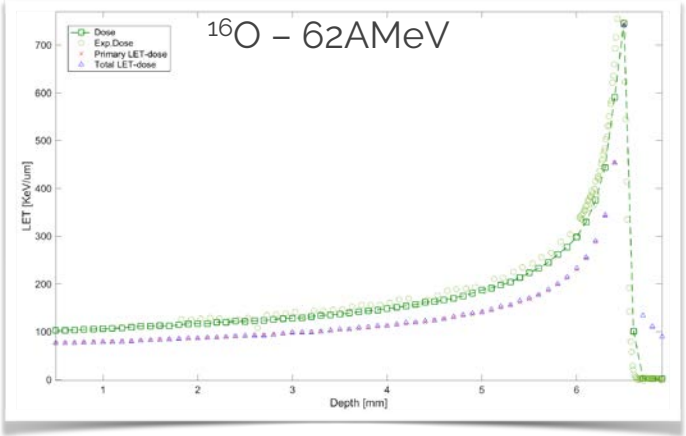
$$\mathrm{LET}_t = \sum_{i=1}^{n}\left(\frac{\varepsilon_i}{l_i}\right) w_{i,t} = \frac{\sum_{i=1}^{n}\left(\frac{\varepsilon_i}{l_i}\right) l_i}{\sum_{i=1}^{n} l_i} = \frac{\sum_{i=1}^{n}\varepsilon_i}{\sum_{i=1}^{n} l_i}$$

M.G. Cortes et al."A critical study of different Monte Carlo scoring methods of dose averaged linear-energy- transfer maps calculated in voxelized geometries irradiated with clinical proton beams",Phys. Med. Biol. 60 (2015) 2645-2669

LET calculation: studies

- Production cut dependence of dose averaged LET distributions
- Implementation of a new algorithm for total dose-average and track-average LET
- Validation of dose-average and track-average LET using ICRU tables





^{1}H, ^{4}He, ^{6}Li, ^{9}Be, ^{11}B, ^{12}C, ^{14}N and ^{16}O

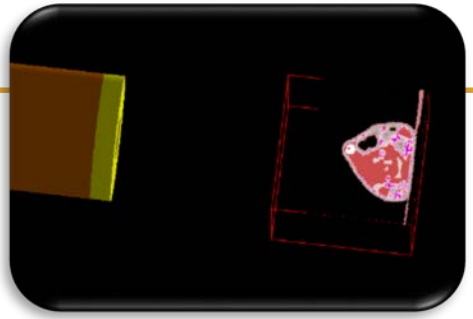
DICOM in *hadrontherapy*

State of the art

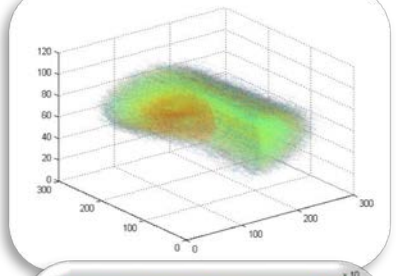
- Experimental validation using gafchromic films and ionization chamber
- Preliminary in vivo test:
  - Small animal treatment plans;
  - Dose distribution and LET evaluation.

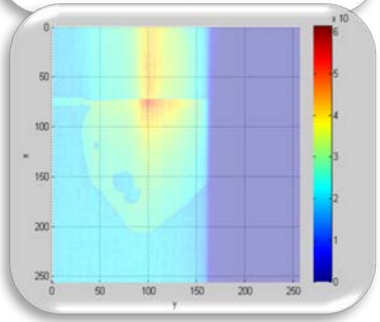
Future aims:

- Implementation within public hadrontherapy advanced example version;
- Implementation RBE calculation.



3D dose distribution





2D dose distribution

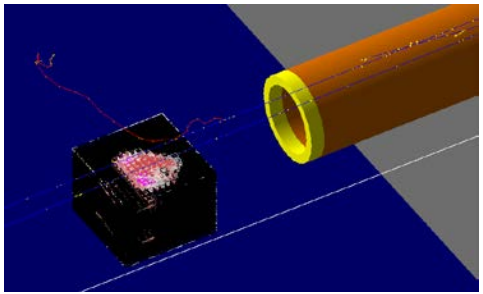
- Preliminary study for small animal preclinical hadrontherapy facility. Russo G. *et al.* NIM A. (2017)

Hypoxia study

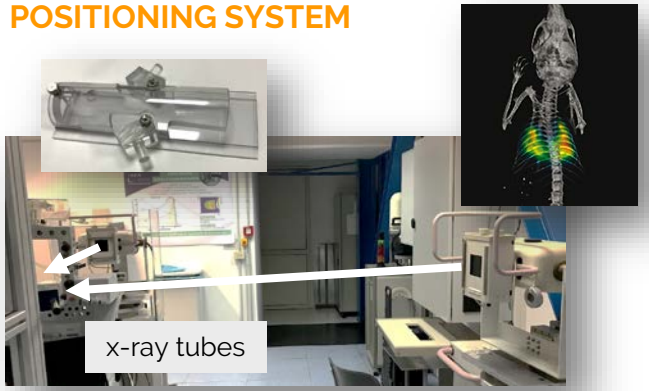
PET/CT

PRE-TREATMENT

Simulation using Geant4 app.
-> dose distributions



POSITIONING SYSTEM



DICOM PET AND CT: the images will be used to calculate the coordinates for each dose-shot

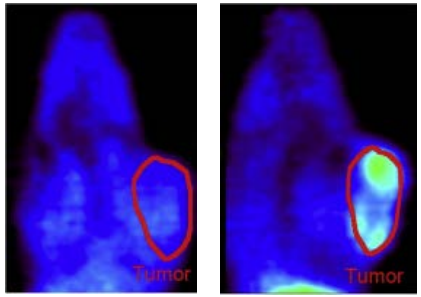
Holding SYSTEM will permit the animal positioning guaranteeing the possibility to use the PET/CT system of coordinates

X-RAY TUBES will permit to place the holding system at the origin of system of coordinates

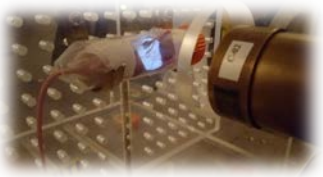
TREATMENT

Escalation dose on hypoxia region

HIGH O_2 **LOW O_2**



Myelopathy study



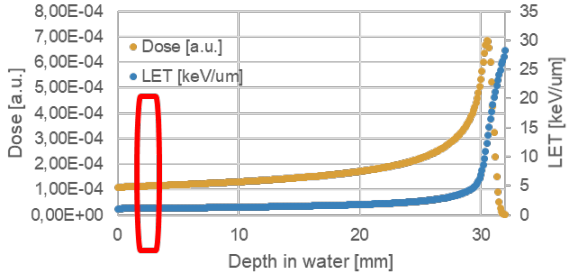
MoVe IT

The aims of this project are:

The aims of this project are:

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

LET ≈ 1,10 keV/µm RBE ≈ 1,1



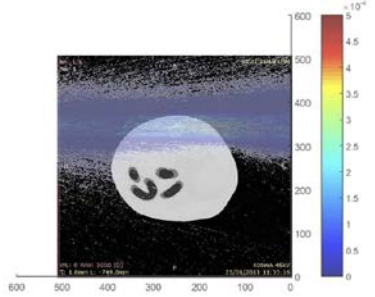


Figure 4: Pristine Bragg peak - One treatment field coming from left side

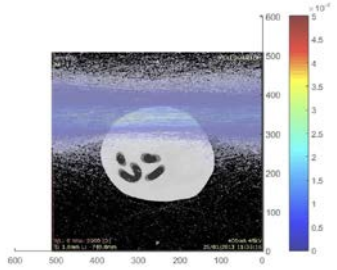
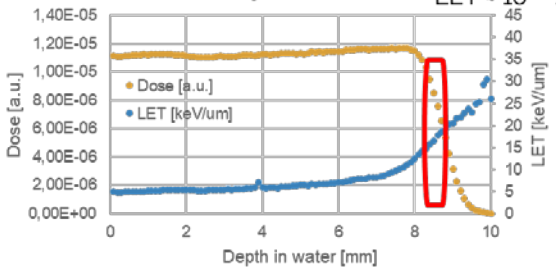


Figure 5: Pristine Bragg peak - Two opposite treatments beams coming from left and right sides

RBE ≈ 1,5[*] LET ≈ 16 – 18 keV/µm



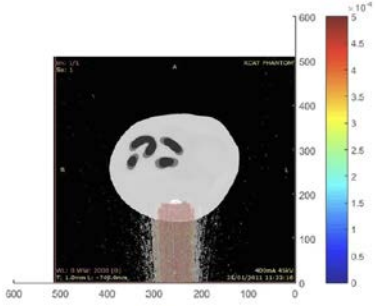


Figure 6: Spread-Out Bragg Peak - One treatment field

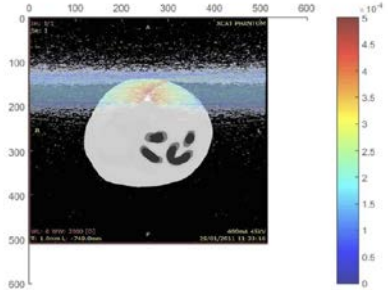


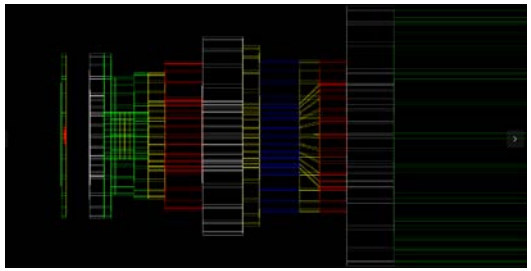
Figure 7: Spread-Out Bragg Peak - Two opposite treatments beams coming from left and right sides

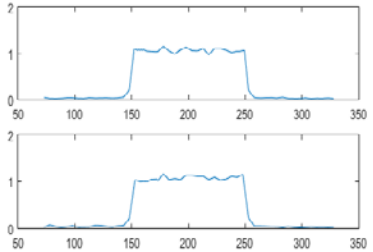
- Monte Carlo application for in vivo RBE study using small animals at LNS-INFN preclinical hadrontherapy facility. Pisciotta P. *et al.* submitted to EJMP (2018).

Iort-therapy advanced example

STATE-OF-ART:

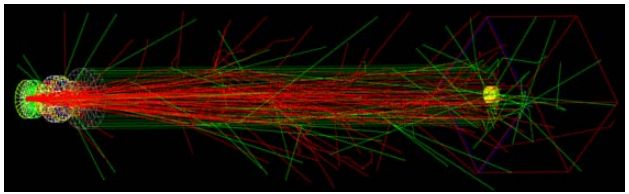
- Implementation of NOVAC7 and LIAC10 geometry;

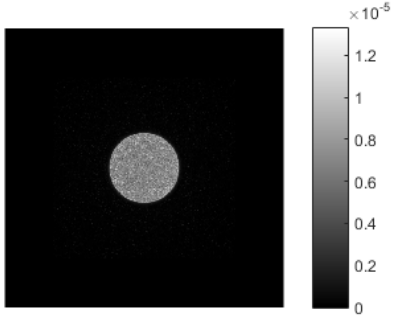




FUTURE AIMS:

- Goodness evaluation of Geant4 results (PDD, lateral profile @R100); beam;
- Output factor calculation;
- Radioprotection assessment.





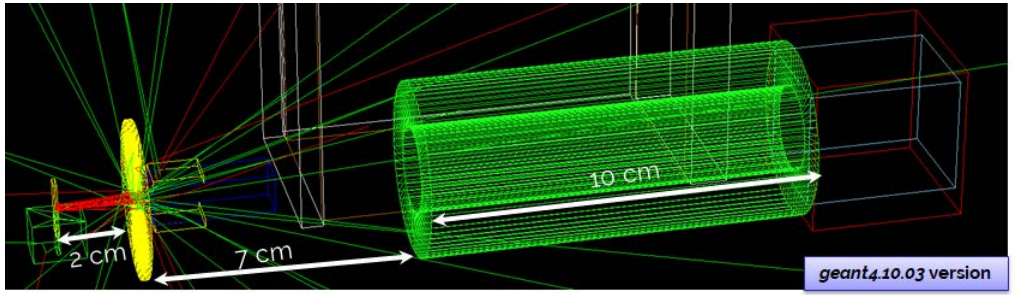
Laser-driven electron application

STATE-OF-ART:

- Implementation of a laser-driven electron spectrum;
- Production of bremsstrahlung X-ray source ;
- Collimation system;
- 3D dose distribution and profiles.

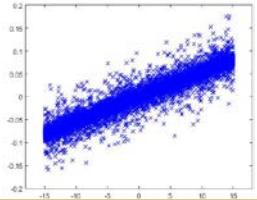
FUTURE AIMS:

- Image quality and dose assessment for diagnostic scopes;
- Radioprotection studies;
- Preclinical imaging.



X-ray spectrum

Emittance

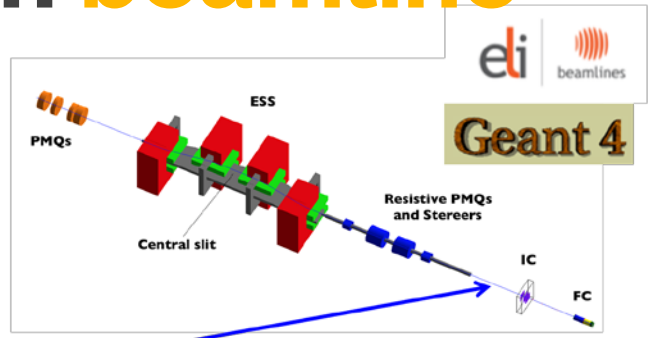


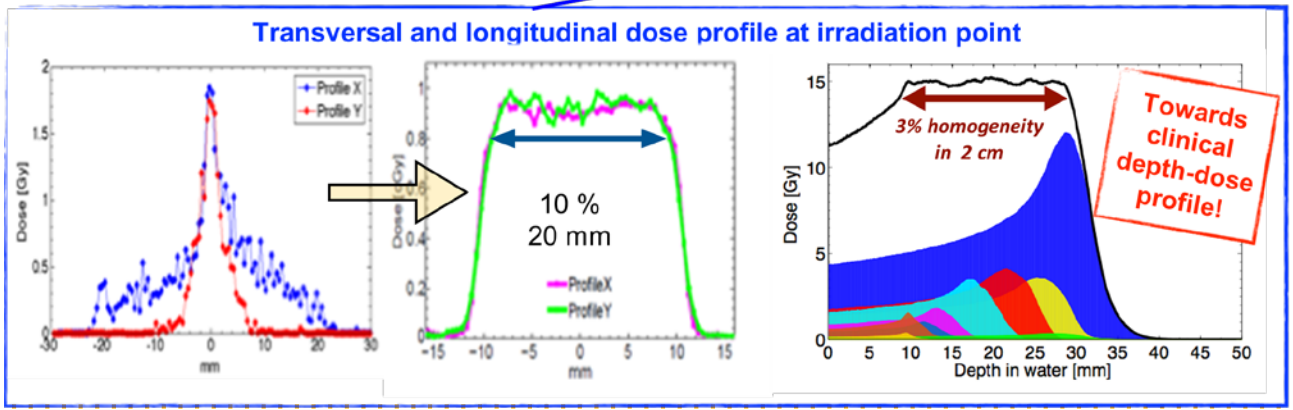
PRIN 2015: **Clinically Compatible Tool For Advanced Translational Research with Ultrashort and Ultraintense X-ray Pulses**

ELIMED laser-driven beamline

STATE-OF-ART:

- User beam line for future multidisciplinary applications @ELI Beamlines
- Monte Carlo simulation aimed at predict energy and dose distributions along the beam line and at the irradiation point
- Optimization of transversal and longitudinal dose distributions for clinical interests





- "Monte Carlo simulation of the ELIMED beamline using Geant4", Pipek J. et al., J. Instr. 12 (2017) C03027
- "Geant4 simulation of the ELIMED transport and dosimetry beam line for high-energy laser-driven ion beam multidisciplinary applications", Milluzzo G. et al., NIM A (2018)
- "Transversal dose distribution optimization with the Geant4 code for laser-accelerated proton beam multidisciplinary applications" Milluzzo G. et al., submitted in EJMP (2018).

Thanks!

Any questions?