I-SEE
Internet
Simulation
Evaluation
Envision

Technology transfer: web apps on the cloud with I-SEE

Felix Mas Milian Ph.D **on behalf of Faiza Bourhaleb** Ph.D

- Monte Carlo simulations are the most accurate tool in the field of medical radiation physics.
- The main handicaps are the required computing resources and a full customization of those simulations.
- To respond to this need ISEE provide some on demand web applications, implemented specifically for different final users.

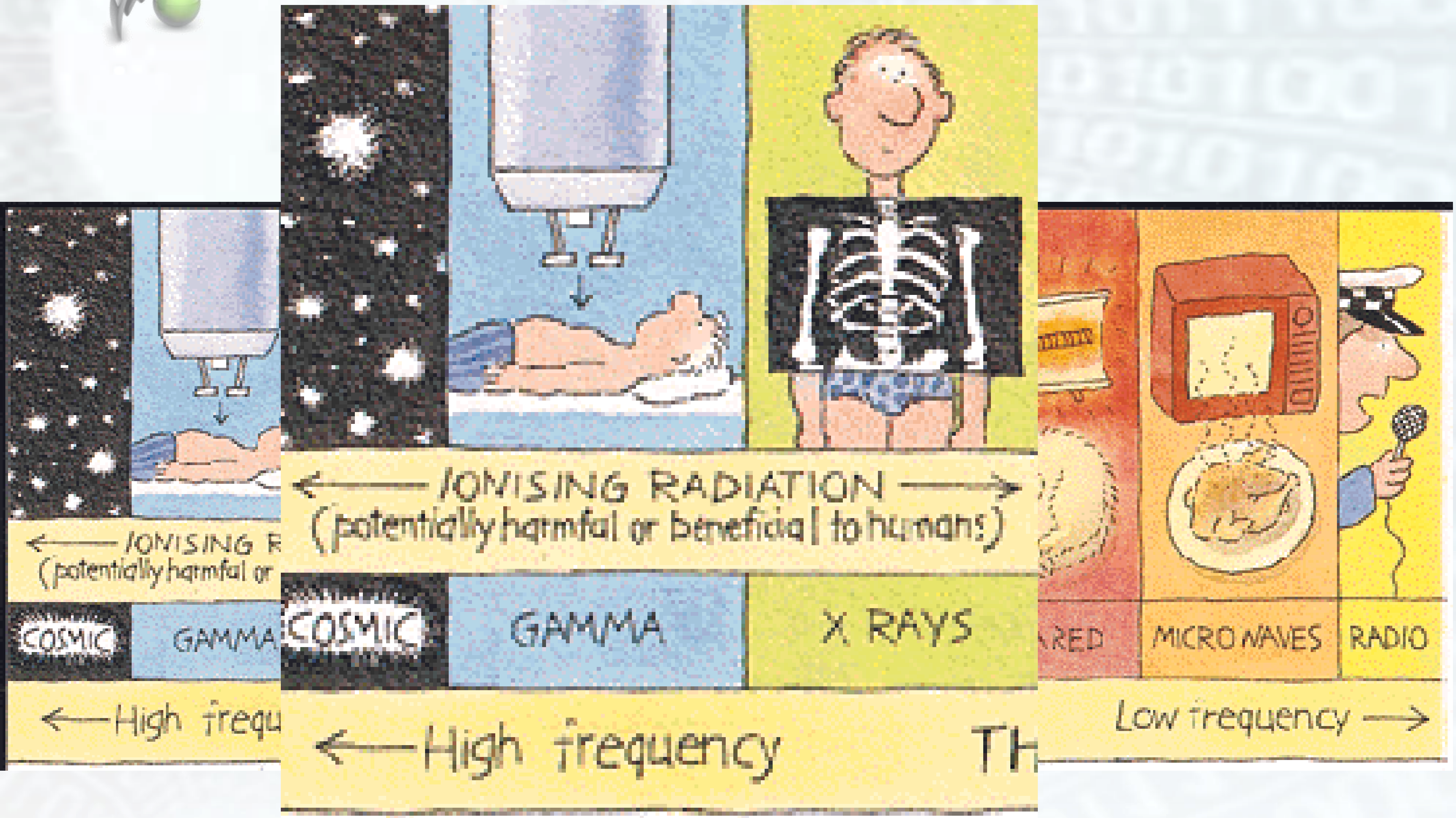
Summary

- Context
- Who and Where
- What and why: cloud
- How: web apps
- On going works
- So…
- Next

Introduction

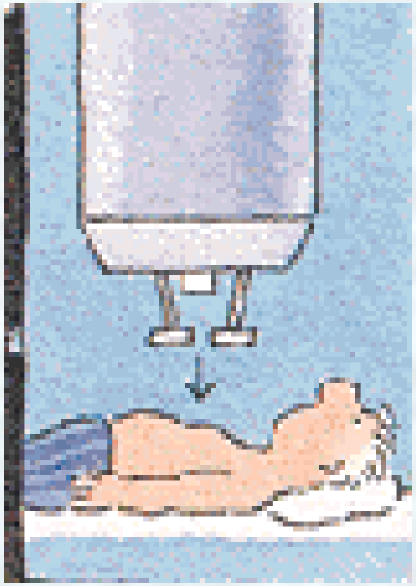
Context

The context


IONISING RADIATION
(potentially harmful or beneficial to humans)
COSMIC
GAMMA
X RAYS
High frequency
MICRO WAVES
RADIO
Low frequency

The context

Radiation therapy, also known as radiotherapy or radiation oncology, refers to the medical use of ionizing radiation for cancer therapy by controlling malignant cells.

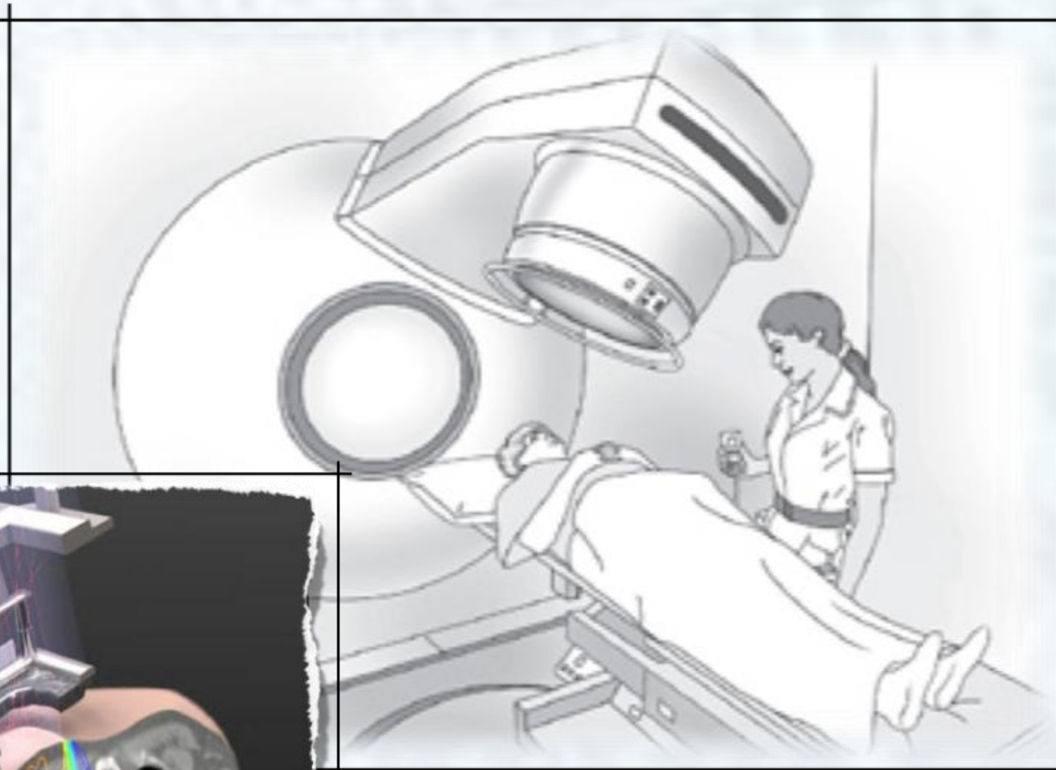


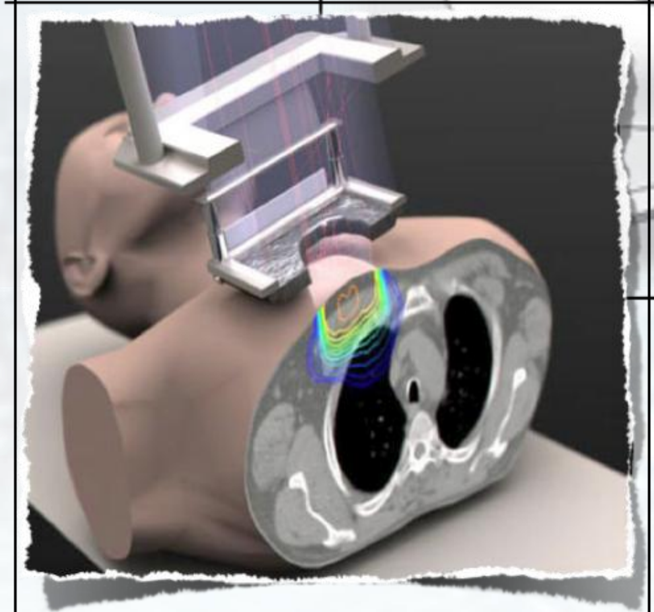
There are three main divisions of radiation therapy:
- brachytherapy where a sealed source is used in the area under treatment;
- unsealed source therapy given by infusion or oral ingestion,
- and external beam therapy where the radiation source is outside the body.

The context

Conventional Radiotherapy

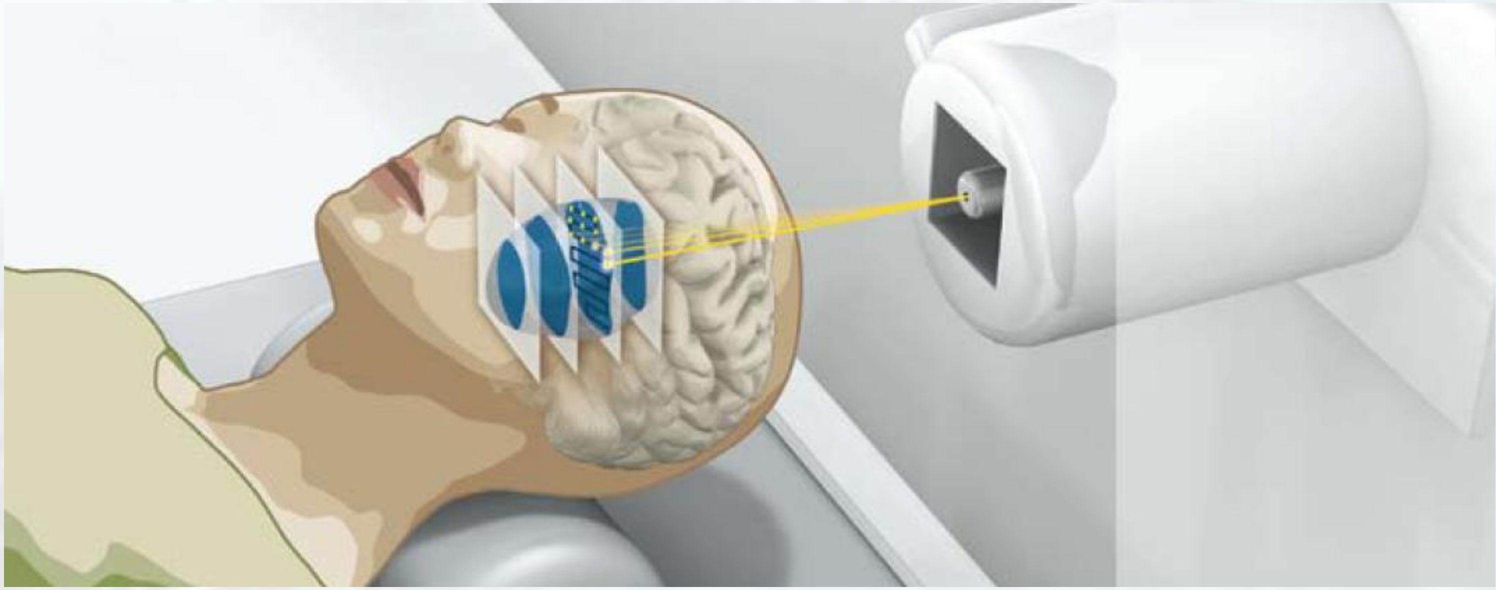
Conventional external beam radiotherapy is based on the use of photons for treatment.





The context

Hadrontherapy



Particle therapy (also known as hadron therapy) is a special case of external beam radiotherapy where the particles are protons or heavy ions.

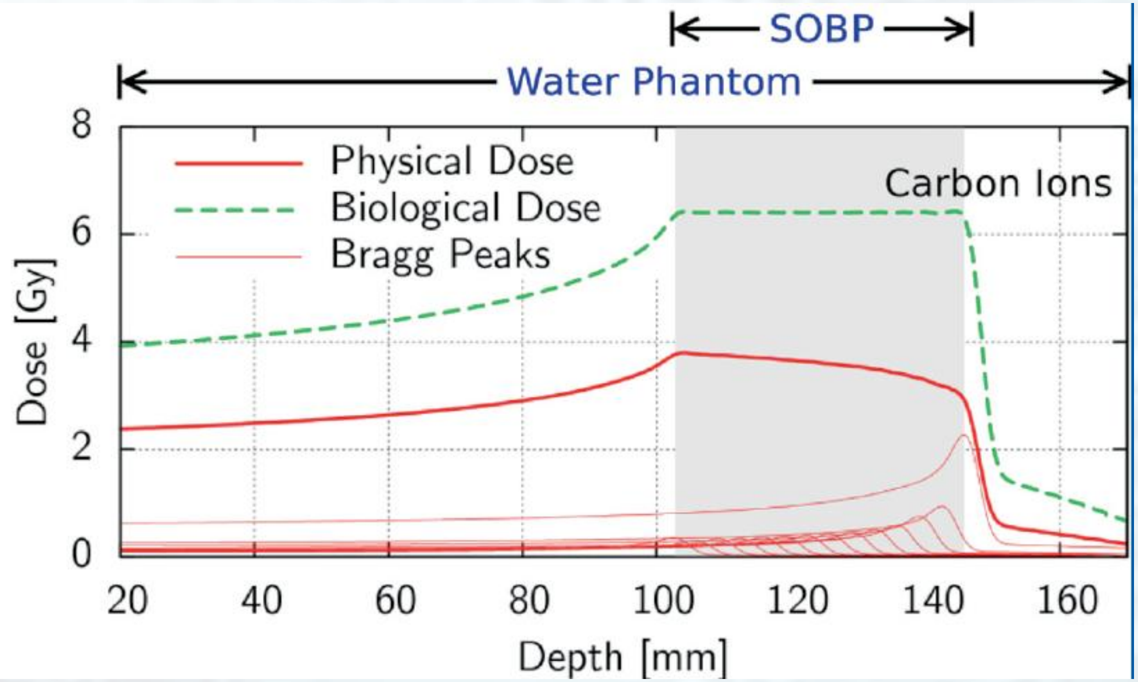
The context

Pictures Courtesy of CNAO
Italian National Center for Hadrontherapy

With CNAO center construction was open a new lines of opportunities and demands for Monte Carlo users.

The context

Simulations of radiation effects needs in Hadrontherapy



•Simulation of energy loss in 3D for protons and carbon ions beams in materials and tissues.
• Determination the spread out using different Bragg peak (SOBP) .
• Evaluation of ripple filters efficiency.
•Determination the production of secondary particles (it means the precise estimation of the fragments created and their distribution in the target volume.)
•Estimation of the radiobiological effect (biological dose) when using heavy ions.

I-SEE

INTERNET SIMULATION EVALUATION ENVISION

VISION

Within the cloud concept, we propose custom Web Apps for all simulations needing huge computing resources specially in advanced radiation oncology field.

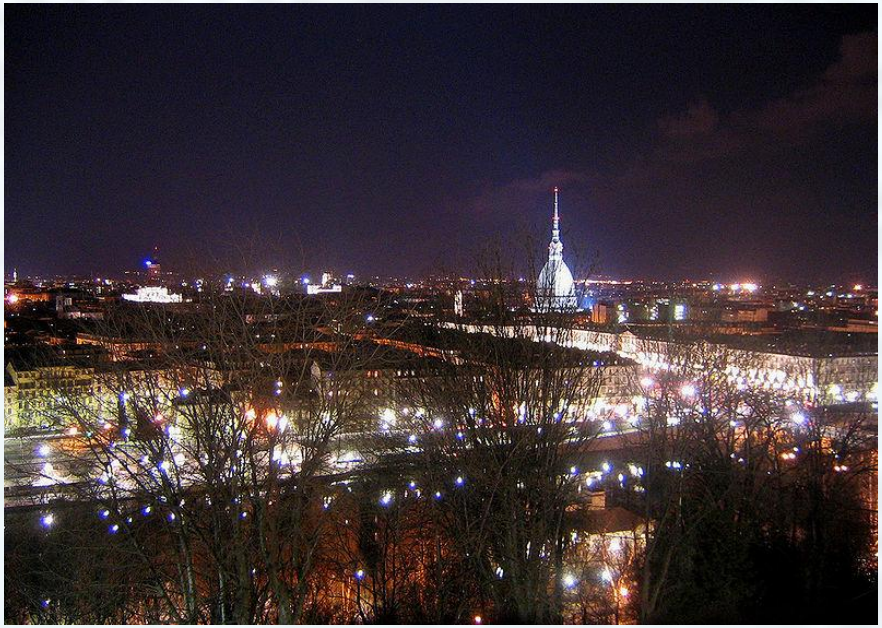
MISSION

We provide user friendly and accessible simulations for radiation effects on devices, different materials and biological tissues.

Team and Infrastructure

Who and Where

Who and Where



ISEE is spin-off company of the Turin University which also have a partnership with the INFN, collaborating and making use of its infrastructure

The ISEE idea begins in 2009 when a group of young researchers decided to make a product with all the know-how accumulated about Monte Carlo simulations for Hadrontherapy, using grid computing and web interfaces for the final user.

PATNERSHIP AND SUPPORT

I-SEE

INCUBATORE 2i3T IMPRESE
UNIVERSITÀ DI TORINO

bioPmed
PIEMONTE INNOVATION CLUSTER

INFN

UNIVERSITÀ DEGLI STUDI DI TORINO
ALMA UNIVERSITAS TAURINENSIS

reseauentreprendre piemonte
Réseau Entreprendre International

fondazioneCNAO
Centro Nazionale di Adroterapia Oncologica

nucleonica

➔Parnership with two other spinoff from Torino: Dixit (Medical Data exchange) & Detetector (Monitoring in dosimetry)

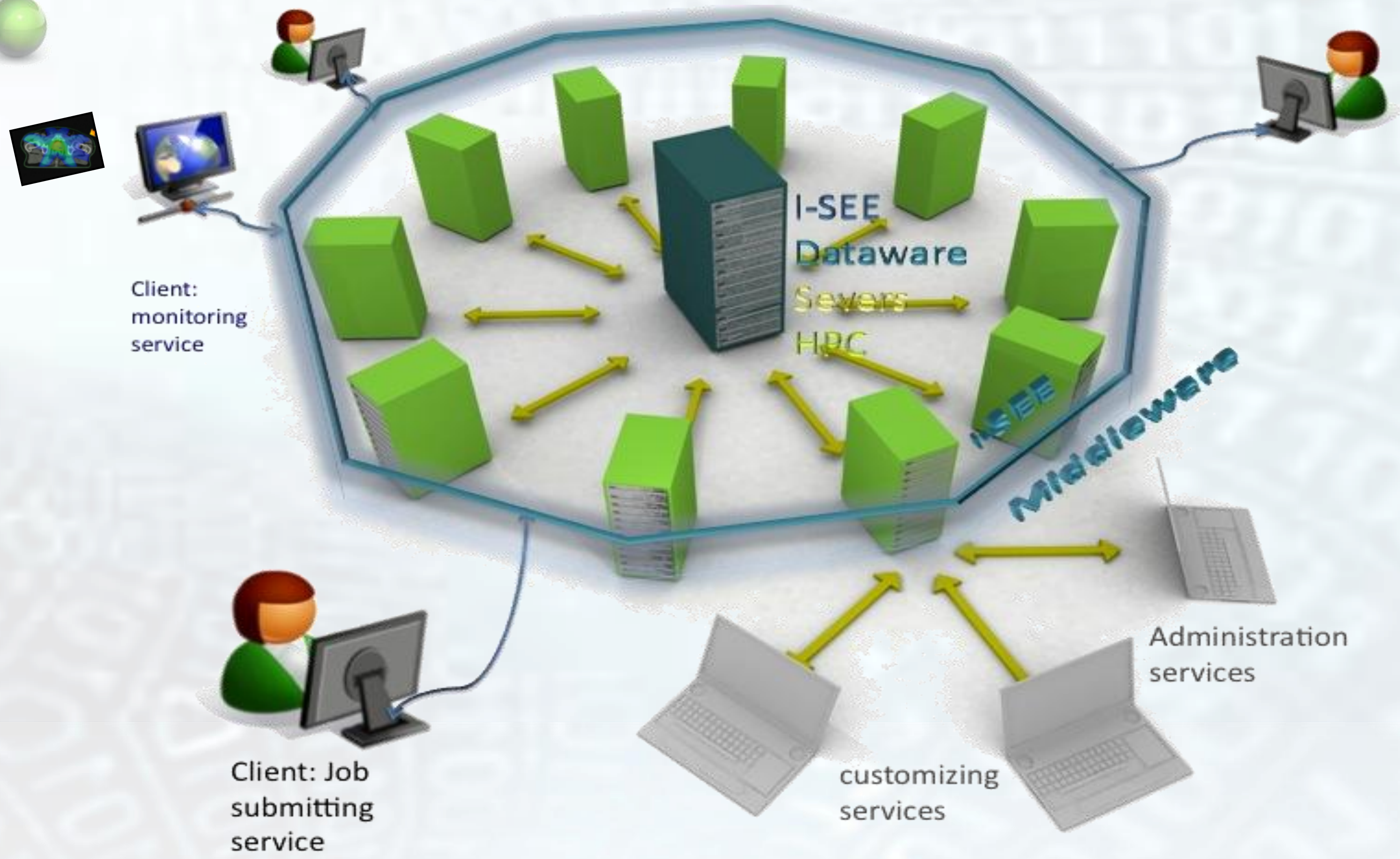
TEAM

- FaizaBourhaleb Ph.D, **CEO and general Manager**
- Andrea Attili Ph.D, **Chief Science Officer**
- Roberto Cirio Prof., **Segretario and external relation**
- Germano Russo Ph.D, **Development**
- Felix MasMilian Ph.D, **Developement**
- Federico Dalmasso M.Sc **Developement**
- Felipe Operti. **Student.**

The cloud and MC Simulations

What and Why

I-SEECLOUD CONCEPT



Since full Monte Carlo method is very CPU consuming ISEE implemented a platform called MainWall, to distribute simulations on a dedicated clusters

Technology transfer: web apps

How

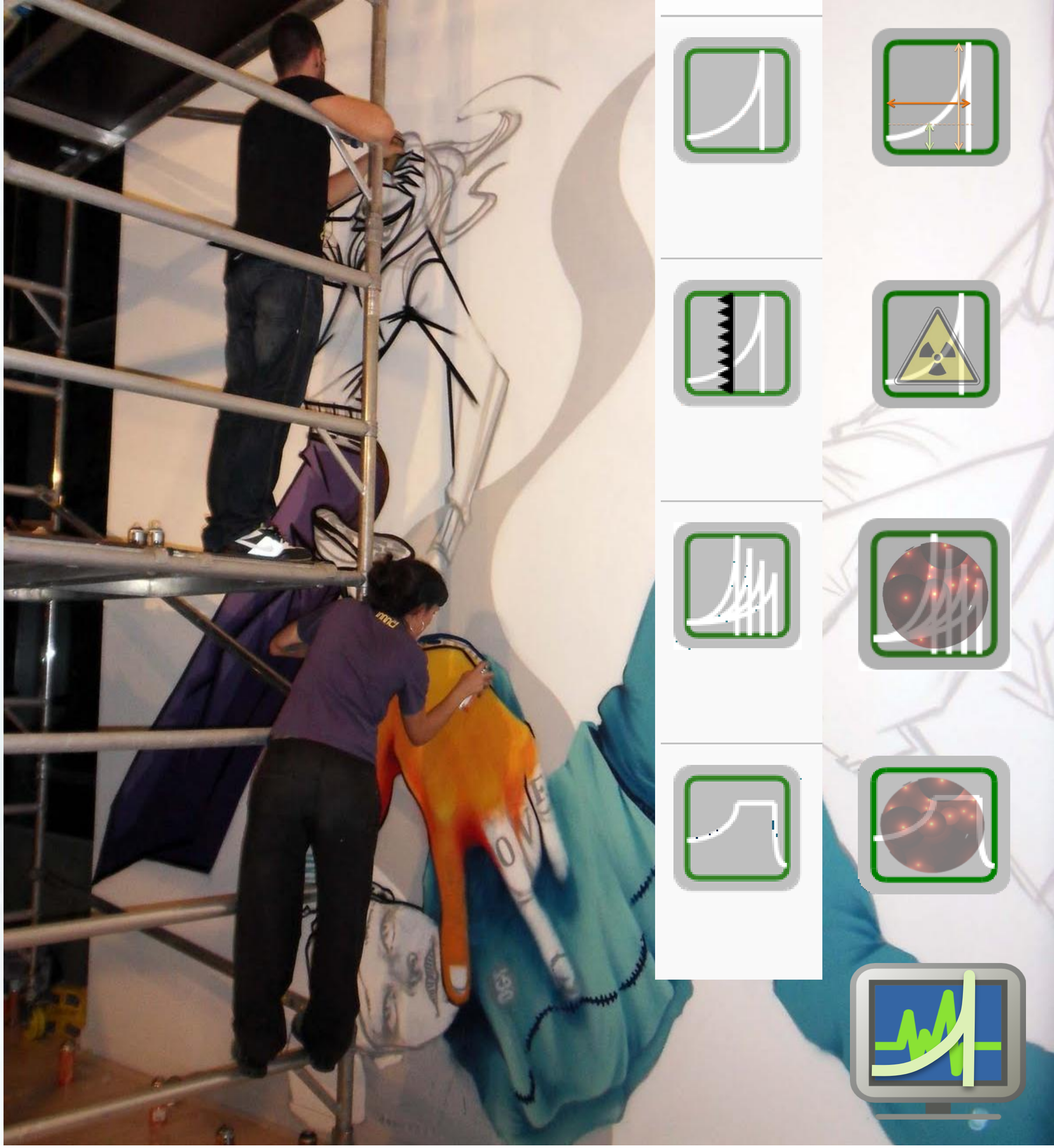
WEB APPLICATIONS ON MainWall

IN SILICO Dosimetry SUITE

Alghero school 30 May

I-SEE

IN SILICO Dosimetry SUITE



In Silico Dosimetry suite is a web application implemented for specific oncologic facilities trying to cover all the needs matter of Monte Carlo simulation

Web Apps

Bragg Peak

SOBP

Energy List

RippleFilters/
RidgeFilters

SYSTEM SPECIFIC
APPS

Radiation Protection
and Shielding

RADIOBIOAPP

Bio4Dose APPS

EXPERIMENTAL DATA

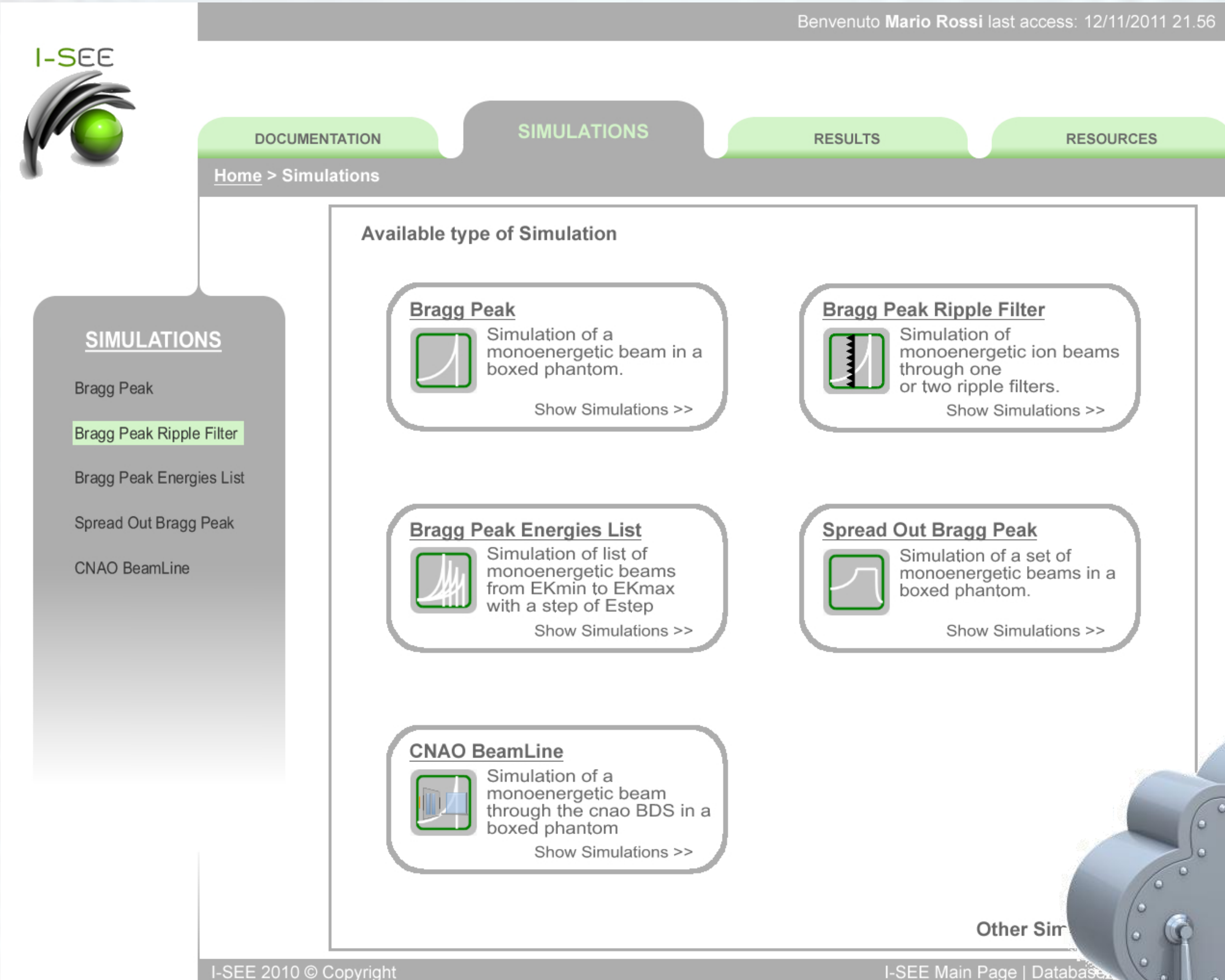
Web Apps

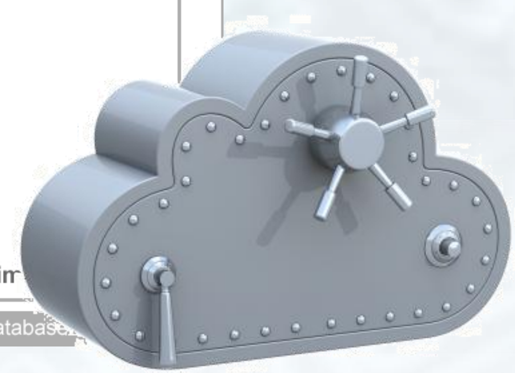
Physical aspects of radiation effects on materials are based mainly on Geant 4 Monte Carlo simulation package.

Simulations concerning radiation biology and cell survival evaluation are based on models needed especially in the field of particle therapy.
-LEM (Local Effects Model)
- MKM (Microdosimentric Kinetic Model)

Each simulation is in loco benchmarked. Free parameters in each apps are chosen to characterize the best possible the requirement of the final users.

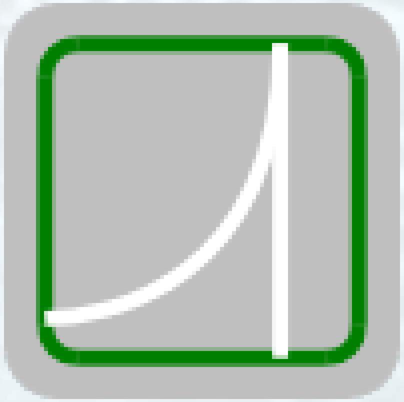
Analysis and results export are customized to the need of the facility from the dosimetric and radiation protection point of view.


I-SEE
Benvenuto Mario Rossi last access: 12/11/2011 21.56
DOCUMENTATION
SIMULATIONS
RESULTS
RESOURCES
Home > Simulations
SIMULATIONS
Bragg Peak
Bragg Peak Ripple Filter
Bragg Peak Energies List
Spread Out Bragg Peak
CNAO BeamLine
Available type of Simulation
Bragg Peak
Simulation of a monoenergetic beam in a boxed phantom.
Show Simulations >>
Bragg Peak Ripple Filter
Simulation of monoenergetic ion beams through one or two ripple filters.
Show Simulations >>
Bragg Peak Energies List
Simulation of list of monoenergetic beams from EKmin to EKmax with a step of Estep
Show Simulations >>
Spread Out Bragg Peak
Simulation of a set of monoenergetic beams in a boxed phantom.
Show Simulations >>
CNAO BeamLine
Simulation of a monoenergetic beam through the cnao BDS in a boxed phantom
Show Simulations >>
Other Sim
I-SEE 2010 © Copyright
I-SEE Main Page | Database



Bragg Peak

- Phantom parameters:
  - Geometry and slices
  - Material
- Source parameters:
  - Source position
  - Source Energy
  - Primary particle type
- Output:
  - Energy loss in the phantom for all generated particles.
  - Format: Graphic, ASCII data Files
  - Characterizing parameters (Peak FWHM, Bragg Peak Position, range, Falloff, etc …)



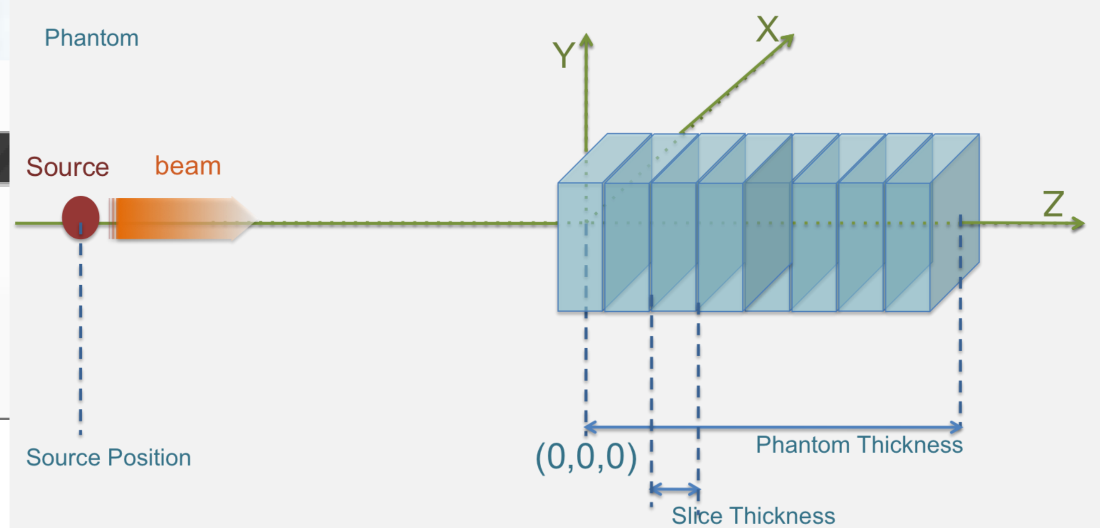
Bragg Peak user interface

Parameter for New Simulation of Type: Bragg Peak

General Information

Name of the simulation	
Author	
Number of events	

Description/Comment:



Parameters of the Simulation

particle type	proton
virtual source position x [mm]	0
virtual source position y [mm]	0
virtual source position z [mm]	0
beam sigma x [mm]	0
beam sigma y [mm]	0
energy [MeV]	100
sigma energy [MeV]	0.001
phantom z dimension [mm]	120
slice thickness [mm]	0.1
material	Water

Parameters description:

- **particle type**: type of particle ("proton" or "carbon");
- **virtual source position x**: *x* coordinate of the virtual source [mm];
- **virtual source position y**: *y* coordinate of the virtual source [mm];
- **virtual source position z**: *z* coordinate of the virtual source [mm];
- **beam sigma x**: standard deviation for *x* coordinate position of the beam [mm];
- **beam sigma y**: standard deviation for *y* coordinate position of the beam [mm];
- **energy**: mean energy of primary particles [MeV];
- **sigma energy**: standard deviation of energy distribution for primary particles [MeV];
- **phantom z dimension**: size of the phantom along the direction of the beam (*z*-axis) [mm];
- **slice thickness**: thickness of the sampling slices in the phantom;
- **material**: phantom material ("Water", "PMMA", "Mylar", "Kapton", "Fiber", "Alluminium", "Air".)

Submit New Simulation | Reset to Defaults

Bragg Peak user interface

General Information

Name of the simulation	
Author	
Number of events	

Description/Comment:

Parameters of the Simulation

particle type	proton
virtual source position x [mm]	0
virtual source position y [mm]	0
virtual source position z [mm]	0
beam sigma x [mm]	0
beam sigma y [mm]	0
energy [MeV]	100
sigma energy [MeV]	0.001
phantom z dimension [mm]	120
slice thickness [mm]	0.1
material	Water

Parameters description:

- **particle type**: type of particle ("proton" or "carbon");
- **virtual source position x**: *x* coordinate of the virtual source [mm];
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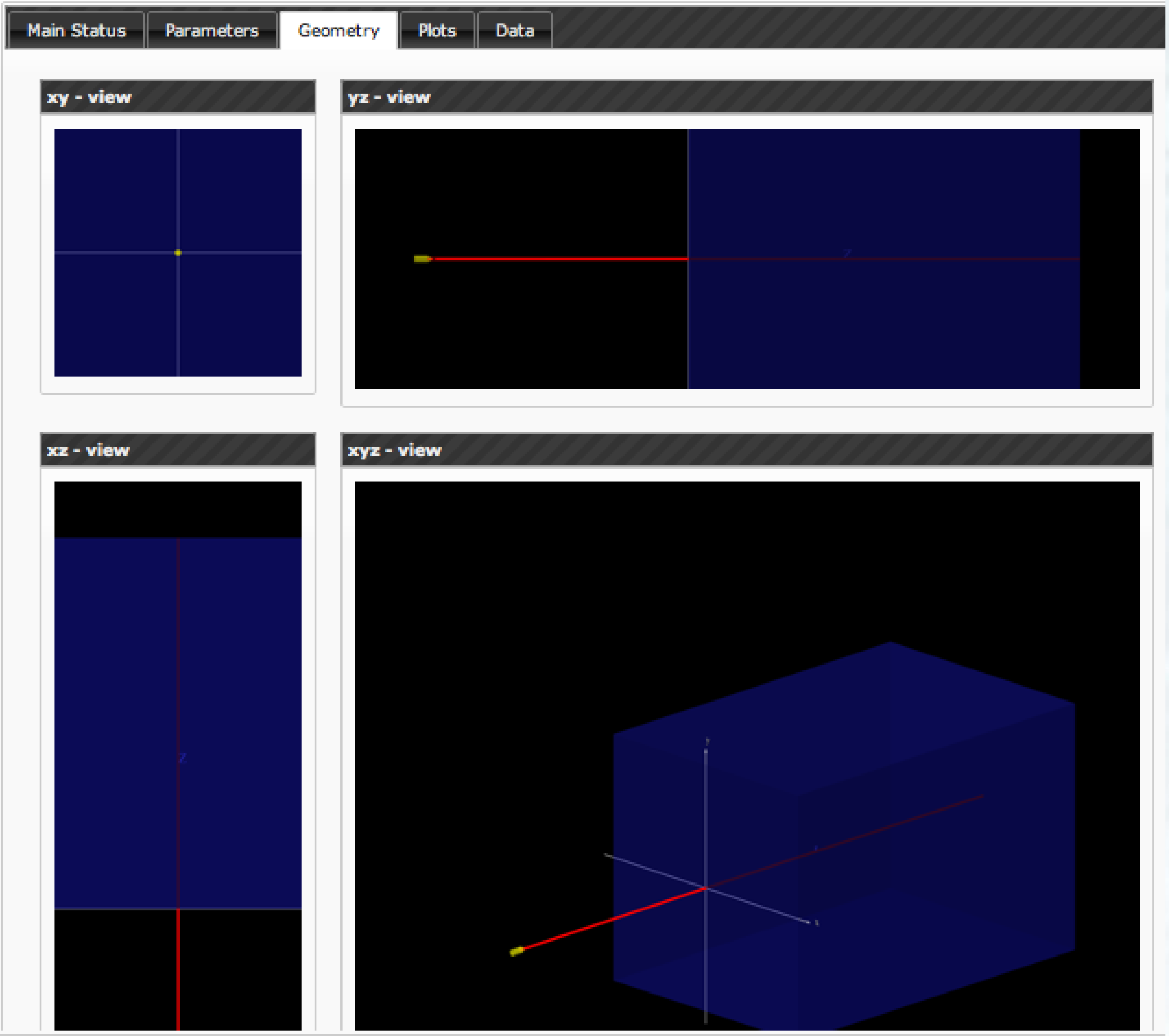
- **virtual source position z**: *z* coordinate of the virtual source [mm];
- **beam sigma x**: standard deviation for *x* coordinate position of the beam [mm];
- **beam sigma y**: standard deviation for *y* coordinate position of the beam [mm];
- **energy**: mean energy of primary particles [MeV];
- **sigma energy**: standard deviation of energy distribution for primary particles [MeV];
- **phantom z dimension**: size of the phantom along the direction of the beam (*z*-axis) [mm];
- **slice thickness**: thickness of the sampling slices in the phantom;
- **material**: phantom material ("Water", "PMMA", "Mylar", "Kapton", "Fiber", "Alluminium", "Air".)

Submit New Simulation | Reset to Defaults

Material: Actually It is possible to select between air, water or other materials usually used in the beam path before the patient as a component of devices for beam monitoring or for dosimetric purposes (Mylar)

Bragg Peak – Geom. Visual.



Bragg Peak - Runs

Details of Simulation: ProvaDemo

Simulation: ProvaDemo (id: 110)
Simulation Type: Bragg Peak
Submitted by: Faiza
Datetime: 2011-04-11 15:11:29
Number of Events: 30000
Tool: Geant4 (v9.3)

Main Status | Parameters | Geometry | Plots | Data

Global Status

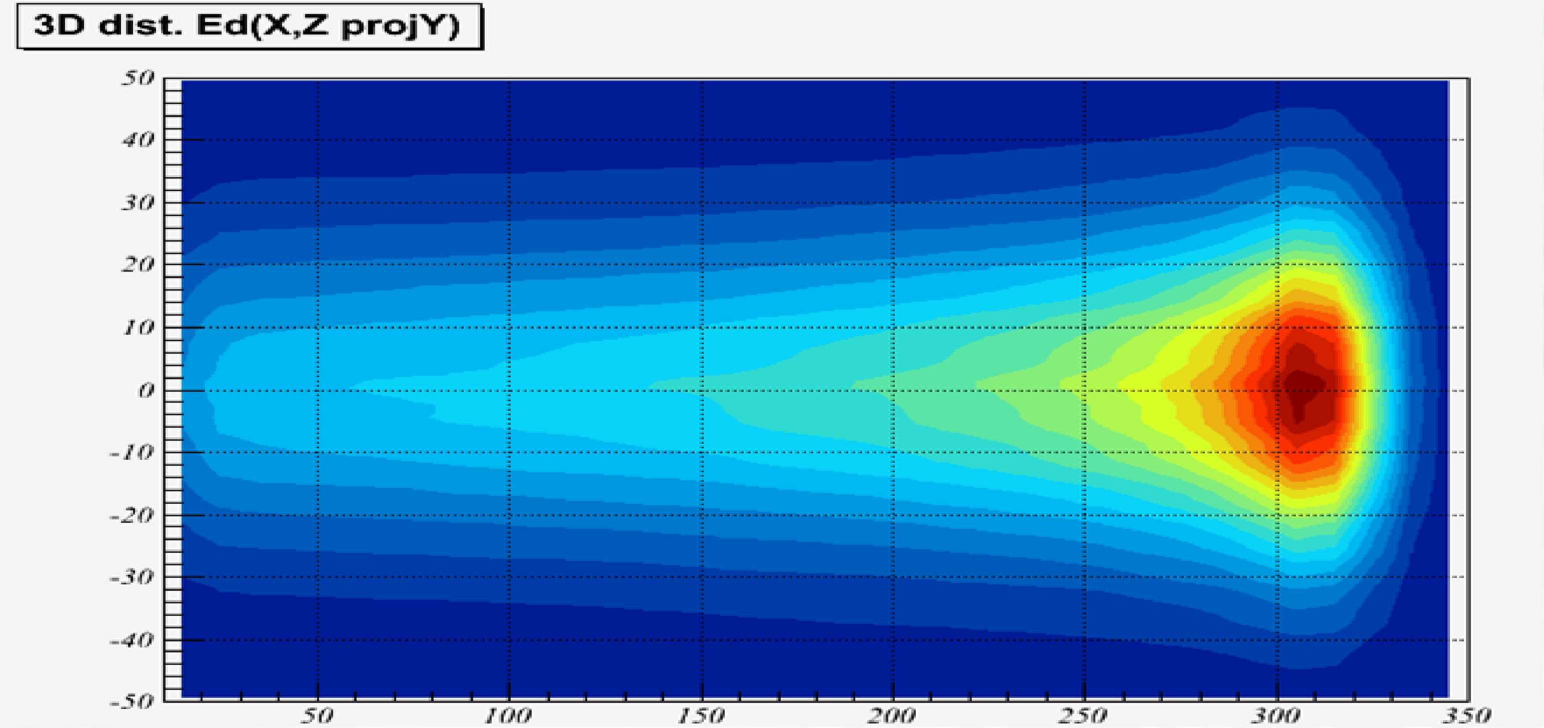
Simulation Status	completed	*Plots and Data available*
Total Simulated Events	100%	30000/30000
Total Runs	6 (Running: 0, Completed: 6, Paused: 0, Errors: 0)	

Runs of the Simulation

Run#	% of simulated events	Submission time	Start time	End time	Node	Status
0	100% (5000/5000)	2011-04-11 15:11:29	2011-04-11 15:11:30	2011-04-11 15:20:40	1	completed
1	100% (5000/5000)	2011-04-11 15:11:29	2011-04-11 15:11:30	2011-04-11 15:20:19	1	completed
2	100% (5000/5000)	2011-04-11 15:11:29	2011-04-11 15:11:33	2011-04-11 15:18:55	1	completed
3	100% (5000/5000)	2011-04-11 15:11:29	2011-04-11 15:11:37	2011-04-11 15:18:53	1	completed
4	100% (5000/5000)	2011-04-11 15:11:29	2011-04-11 15:11:37	2011-04-11 15:18:48	1	completed
5	100% (5000/5000)	2011-04-11 15:11:29	2011-04-11 15:11:39	2011-04-11 15:19:28	1	completed

Bragg Peak Results

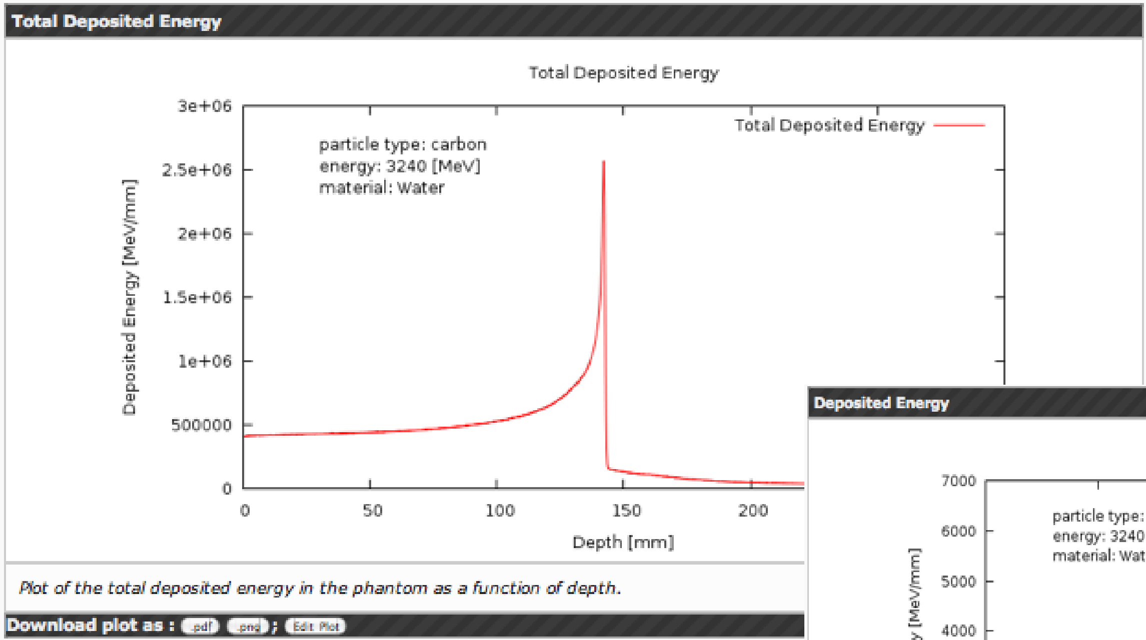
Total deposited Energy(X,Z).
Energy distribution in depth (Z axis) and along the lateral direction X, integrating on Y direction (isodose representation).



Bragg Peak Results

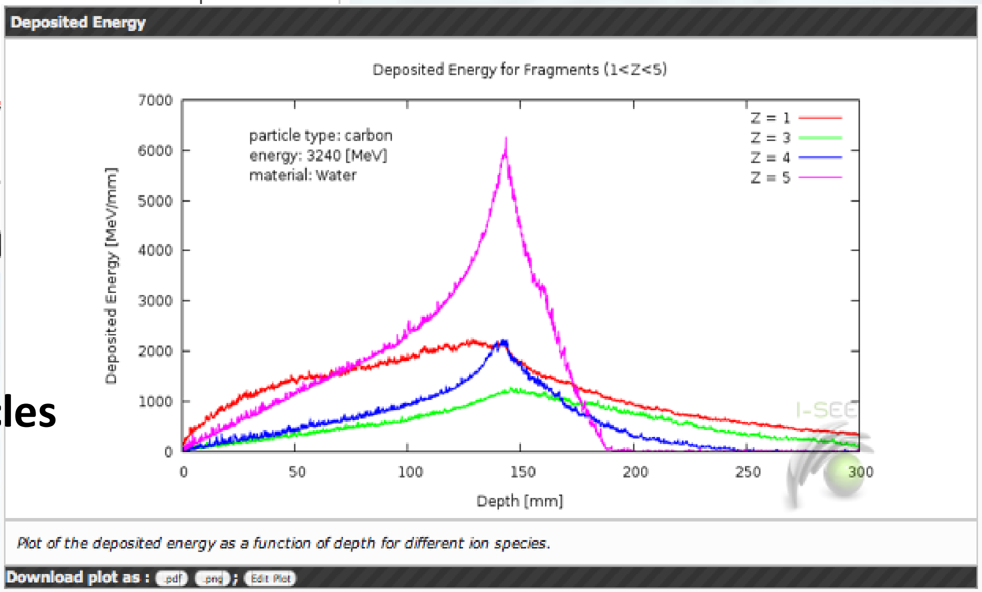
Total Energy loss in depth

Total energy deposition in depth considered in a slice of thickness dZ (free parameter of the simulation), and is reported in [MeV/mm].



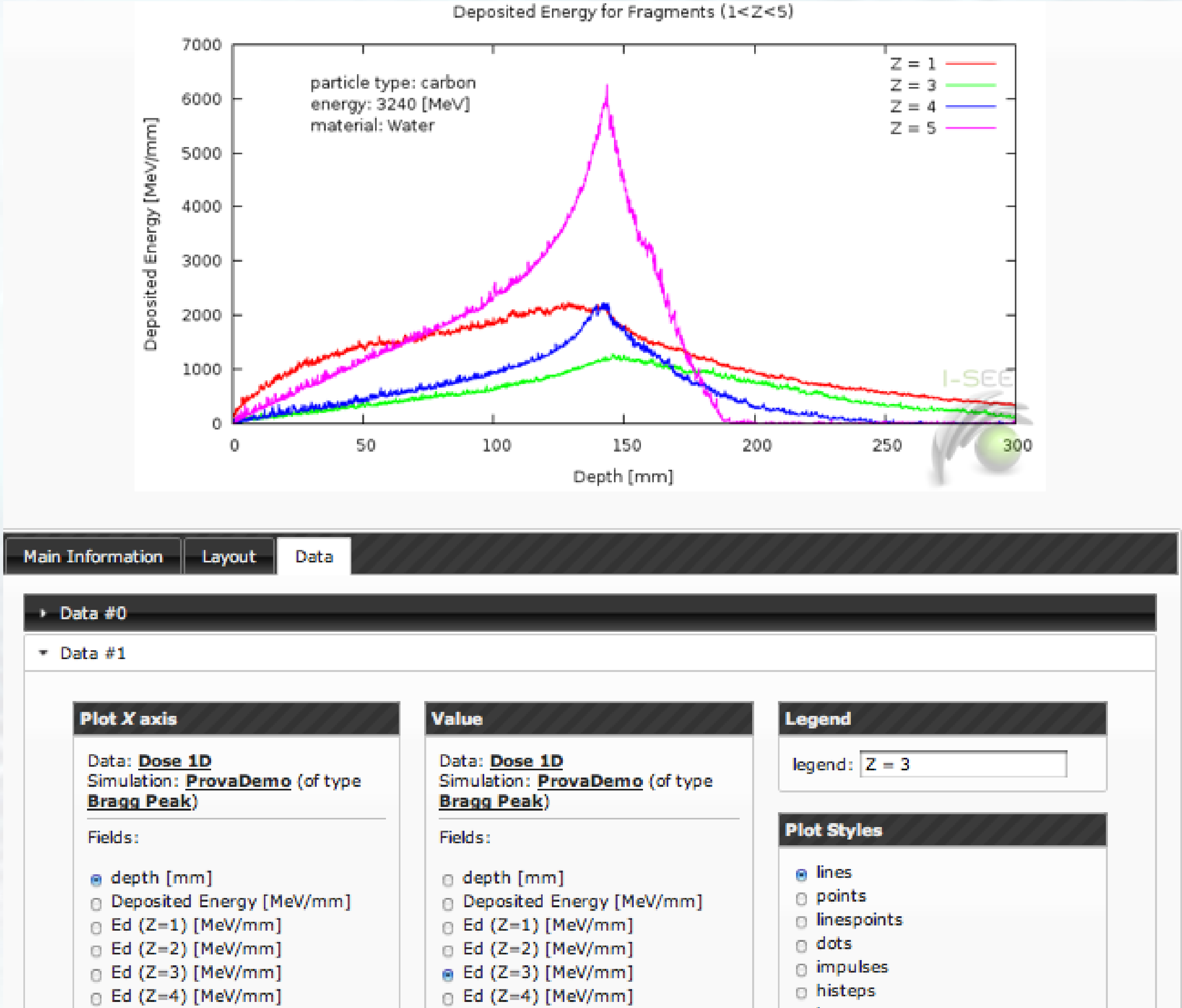
Plot of the total deposited energy in the phantom as a function of depth.

Energy loss in depth for different particles (Z=1,….,Z=8).



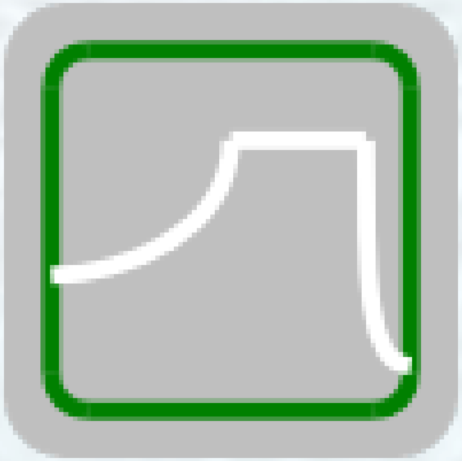
Plot of the deposited energy as a function of depth for different ion species.

Plots Edit


Deposited Energy for Fragments (1<Z<5)
particle type: carbon
energy: 3240 [MeV]
material: Water
Z = 1
Z = 3
Z = 4
Z = 5
Deposited Energy [MeV/mm]
Depth [mm]
0
1000
2000
3000
4000
5000
6000
7000
0
50
100
150
200
250
300
I-SEE
Main Information
Layout
Data
Data #0
Data #1
Plot X axis
Data: Dose 1D
Simulation: ProvaDemo (of type Bragg Peak)
Fields:
depth [mm]
Deposited Energy [MeV/mm]
Ed (Z=1) [MeV/mm]
Ed (Z=2) [MeV/mm]
Ed (Z=3) [MeV/mm]
Ed (Z=4) [MeV/mm]
Value
Data: Dose 1D
Simulation: ProvaDemo (of type Bragg Peak)
Fields:
depth [mm]
Deposited Energy [MeV/mm]
Ed (Z=1) [MeV/mm]
Ed (Z=2) [MeV/mm]
Ed (Z=3) [MeV/mm]
Ed (Z=4) [MeV/mm]
Legend
legend: Z = 3
Plot Styles
lines
points
linespoints
dots
impulses
histeps

SOBP

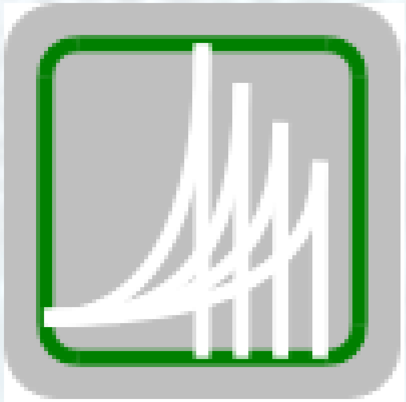
- Geometry
  - Phantom /slices
- Parameters
  - Source
  - Beams file.
  - Phantom/ slices
- Output
  - Energy loss/dose.
  - Format: Graphic, ASCII Data Files
  - Characterizing parameters



Simulation of a SOBP in a homogeneous medium. The Input are a file with the kinetic energies of each beam and the respective number of particles.

Energy List

- Geometry
- Parameters
  - Beam Ekmin, Ekmax, Ekstep
  - Other beam parameters
  - Source parameters
  - Phantom material
- Output
  - Plots
  - Data Files

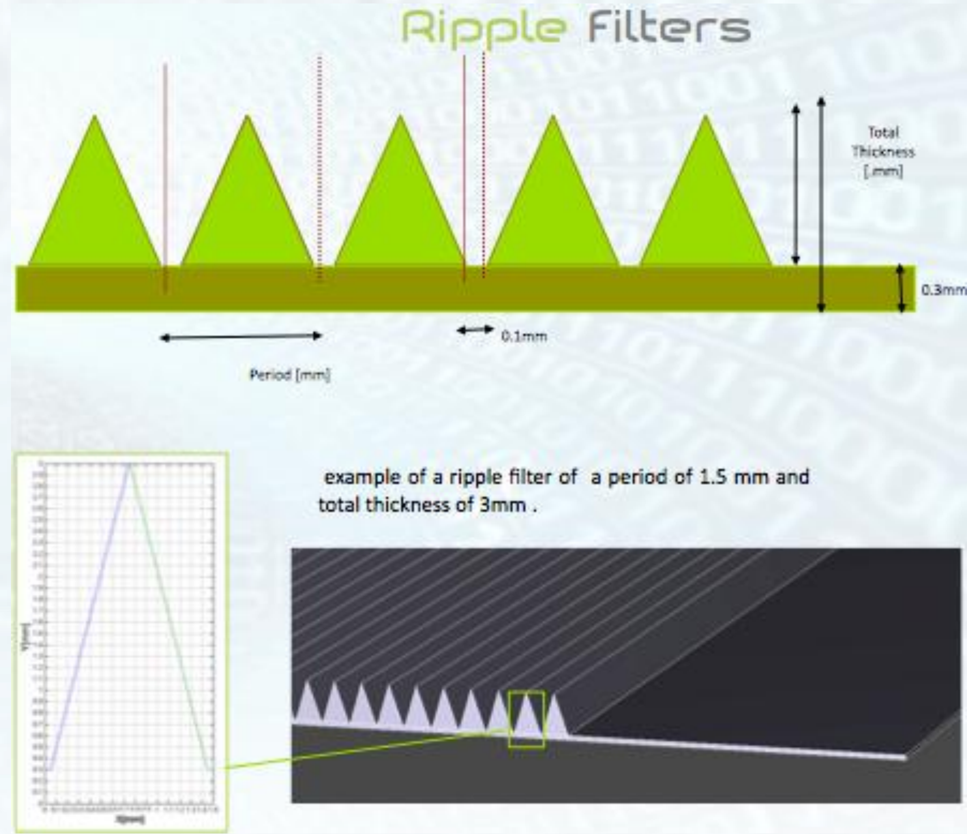


Simulation of Bragg curves in a homogeneous medium for a set of initial kinetic energies in a specific range with a specific step in energy.

RippleFilters/RidgeFilters

I-SEE

- Phantom Parameters
  - Geometry/slices
  - Material
- Ripple filters Parameters
  - Number and position
  - Geometry of the filters
- Source Parameters
  - Kinetic energy
  - Beam lateral dispersion
  - Source position



- Output
  - Energy loss in the phantom for all generated particles.
  - Format: graphic (pdf, png), ASCII data Files
  - Characterizing parameters (Peak FWHM, Bragg Peak Position, range, Falloff, etc …)

General Information

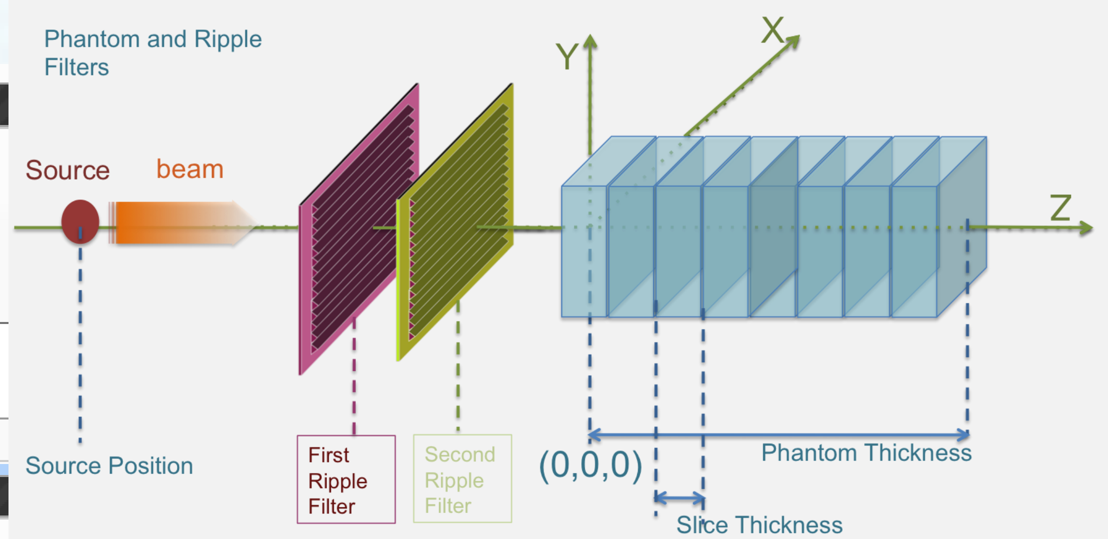
Name of the simulation	
Author	
Number of events	

Description/Comment:

Parameters of the Simulation

particle type	proton
virtual source position x [mm]	0
virtual source position y [mm]	0
virtual source position z [mm]	-500
beam sigma x [mm]	0
beam sigma y [mm]	0
energy [MeV]	100
sigma energy [MeV]	0.001
phantom z dimension [mm]	120
slice thickness [mm]	0.1
material	Water
ripple filter 1 active	false
ripple filter 1 x position [mm]	0
ripple filter 1 y position [mm]	0
ripple filter 1 z position [mm]	-250
ripple filter 1 tickness [mm]	1.5
ripple filter 1 period	1.5
ripple filter 2 active [mm]	false
ripple filter 2 x position [mm]	0
ripple filter 2 y position [mm]	0
ripple filter 2 z position [mm]	-150
ripple filter 2 tickness	1.5
ripple filter 2 period	1.5

Submit New Simulation | Reset to Defaults

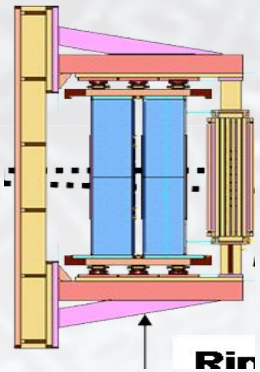


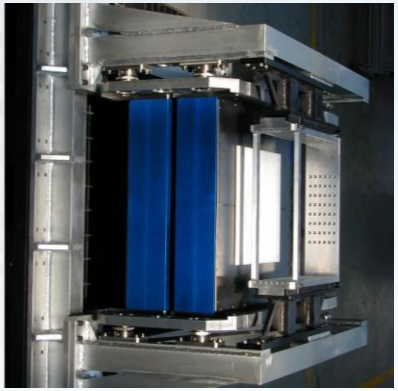
Parameters description:

- **particle type**: type of particle ("proton" or "carbon");
- **virtual source position x**: *x* coordinate of the virtual source [mm];
- **virtual source position y**: *y* coordinate of the virtual source [mm];
- **virtual source position z**: *z* coordinate of the virtual source [mm];
- **beam sigma x**: standard deviation for *x* coordinate position of the beam [mm];
- **beam sigma y**: standard deviation for *y* coordinate position of the beam [mm];
- **energy**: mean energy of primary particles [MeV];
- **sigma energy**: standard deviation of energy distribution for primary particles [MeV];
- **phantom z dimension**: size of the phantom along the direction of the beam (*z*-axis) [mm];
- **slice thickness**: thickness of the sampling slices in the phantom;
- **material**: phantom material ("Water", "PMMA", "Mylar", "Kapton", "Fiber", "Alluminium", "Air");
- **ripple filter 1 active**: Set ripple filter #1 active ("true", "false");
- **ripple filter 1 x position**: ripple filter 1 x position [mm];
- **ripple filter 1 thickness**: ripple filter 1 thickness [mm];
- **ripple filter 2 active**: Set ripple filter #1 active ("true", "false");
- **ripple filter 2 x position**: ripple filter 1 x position [mm];
- **ripple filter 2 thickness**: ripple filter 1 thickness [mm];

SYSTEM SPECIFIC APPS

- Device Apps
  - Beam Monitoring
  - Beam Diagnostic
  - Dosimetry device
    - (ion chambers,…)



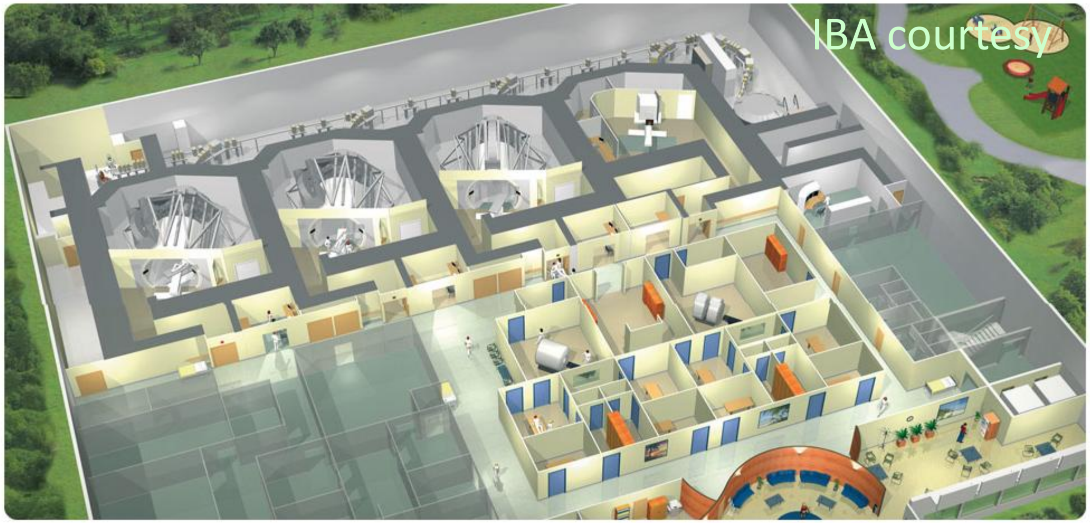


Simulation of the therapeutic beam through a specific devices used along the beam line for beam monitoring, beam diagnostic and dosimetry.

I-SEE

Radiation Protection and Shielding

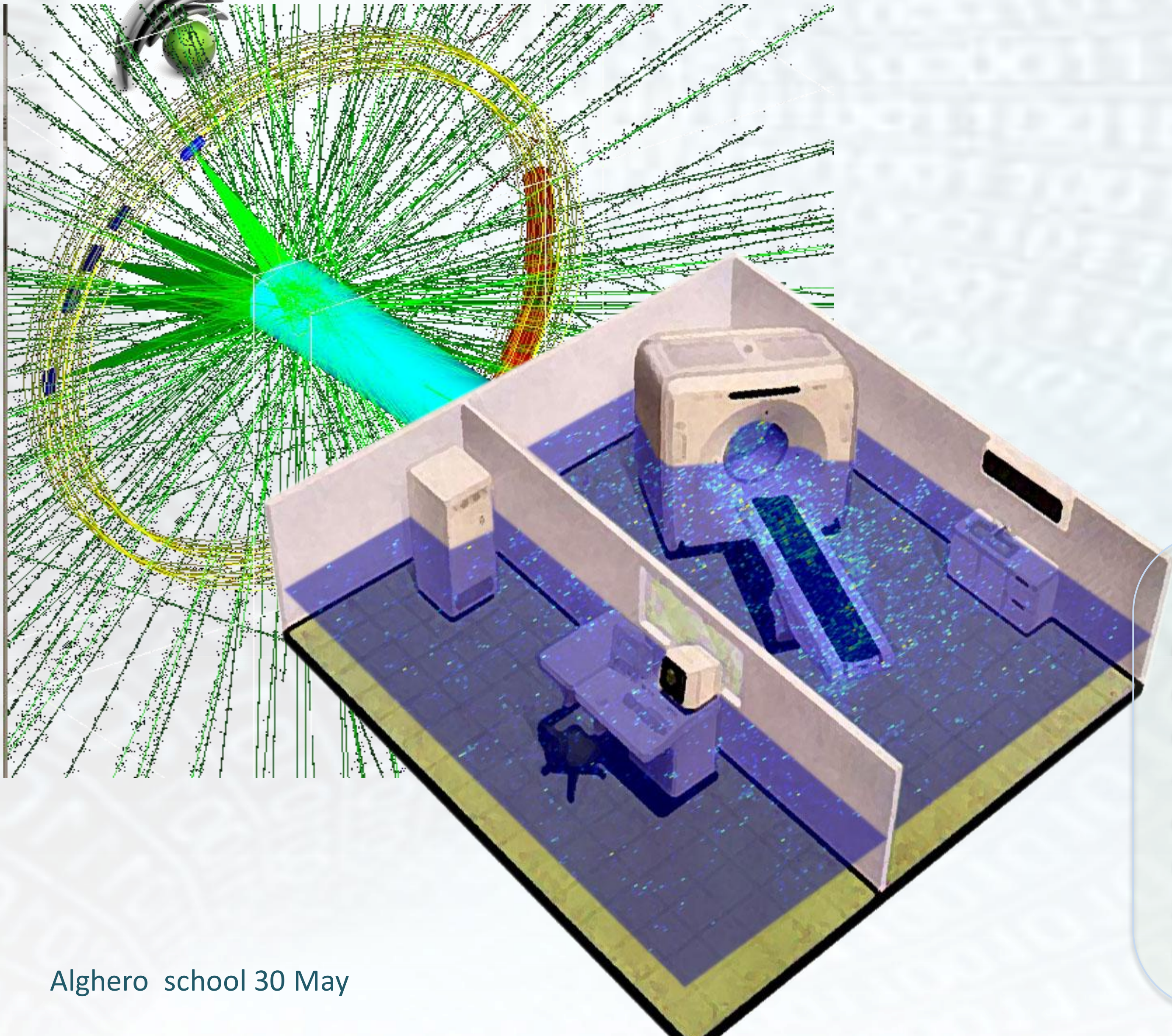
- Geometry
  - Treatment/Imaging room
- Parameters
  - Energy spectrum
  - Or a single beam
- Output
  - Plots
  - Data Files

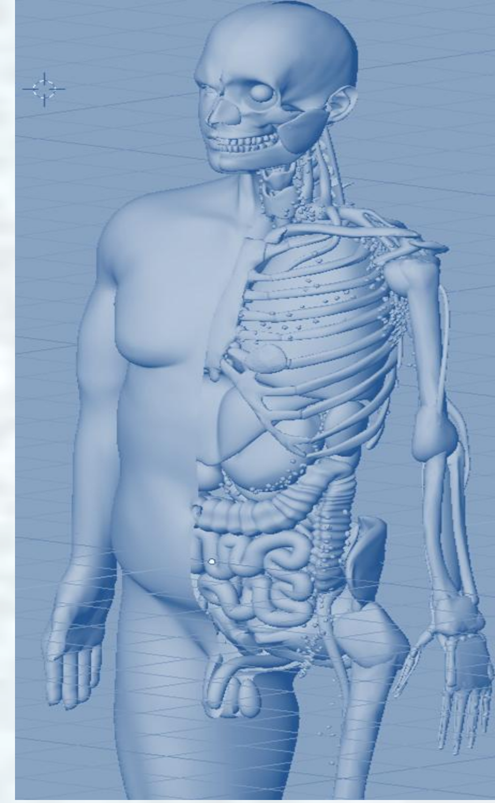


Simulation of the beam and secondary created in the treatment/imaging room.

Radiation Protection

I-SEE





- Simulation of the 3-dimensional dose distribution in radiology examination rooms.
- Simulation of delivered dose for exposed personal using last generation of anthropomorphic models (will talk later).

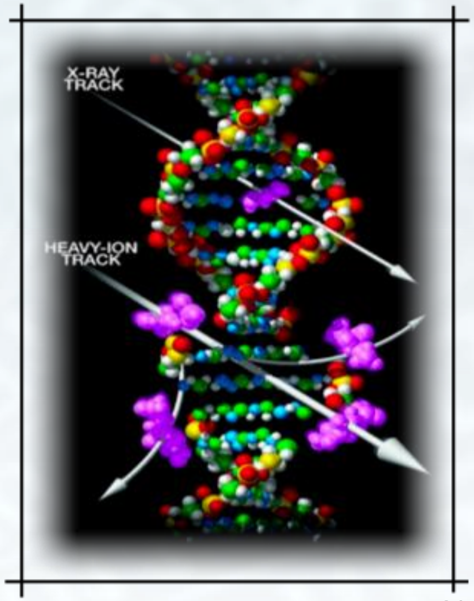
RADIOBIOAPP

When using heavy ion beams for radiation therapy, it is mandatory to estimate well the radiobiological effect in patients before treatment.

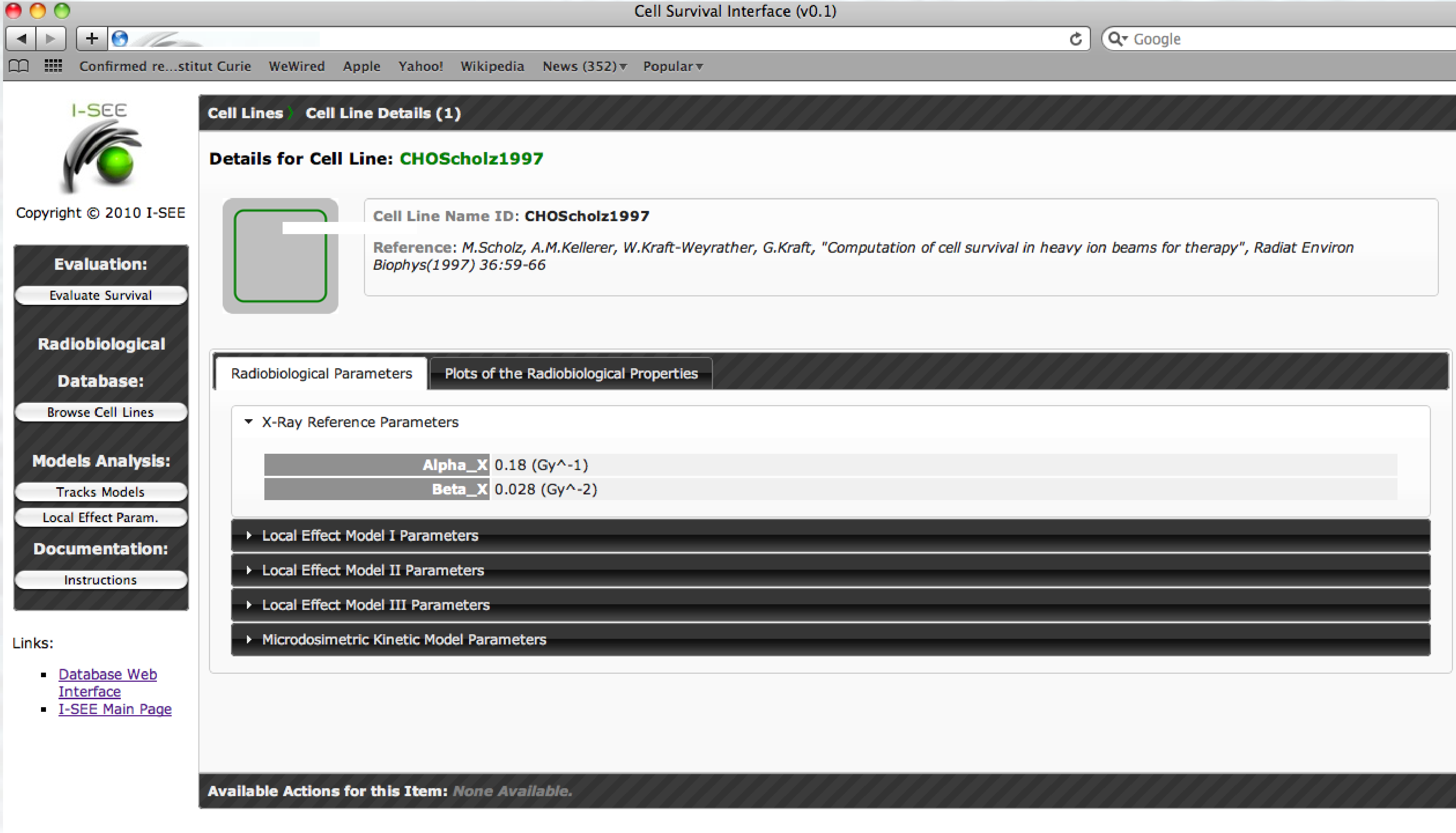
Using the Monte Carlo algorithms, one can estimate the tissue responses to radiation and cell survival when irradiated with specific beams.

RADIOBIOAPP

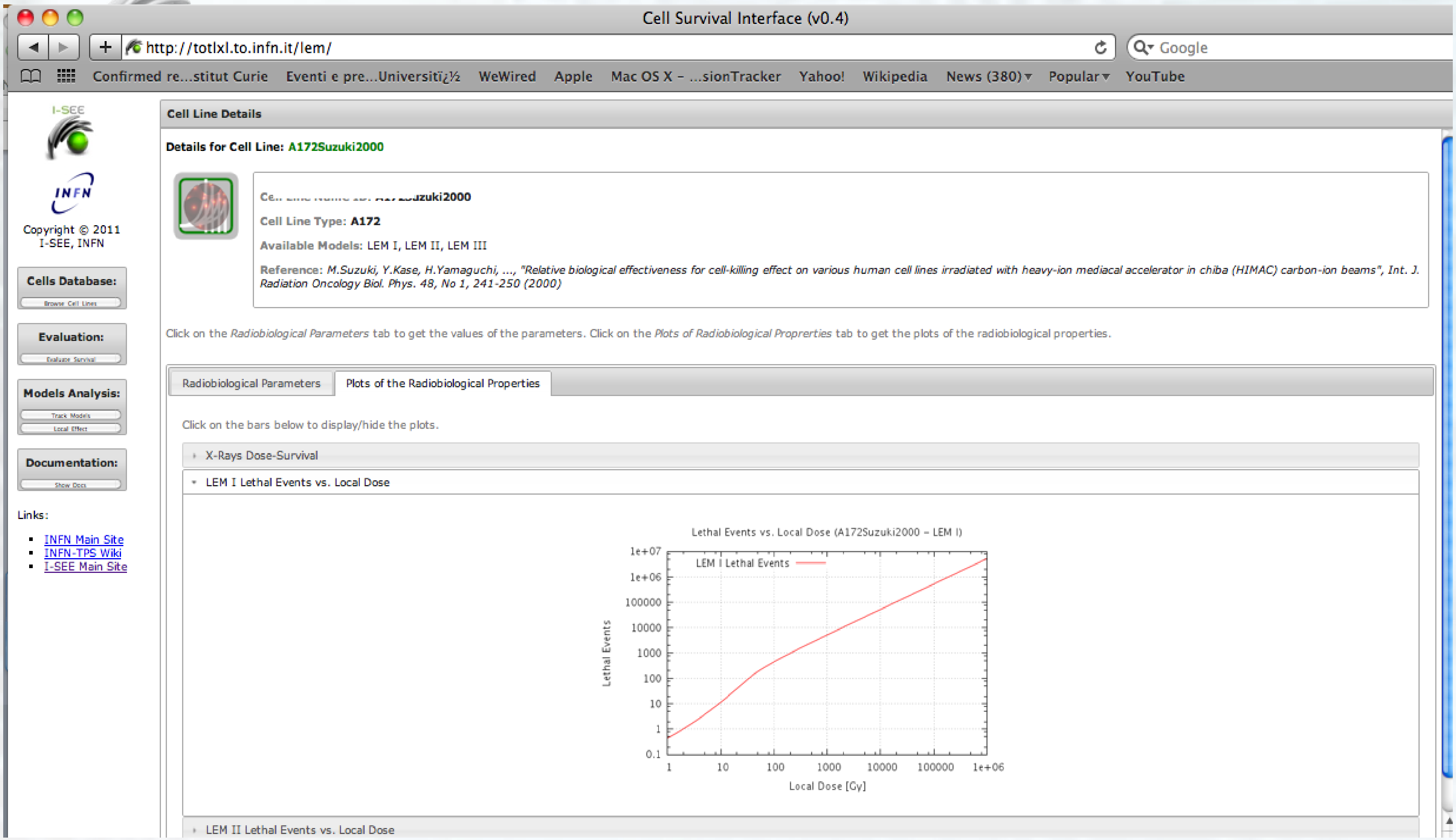
- Radiobiological models implemented:
  - LEM (M.Scholz, T.Elsasser et al)
  - MKM (Y.Kase et al.)
- Possible parameters:
  - Cell lines from database
    - Cell dimension
    - Alpha/beta
  - Dose level
  - Beam particle type
    (protonm Helium, Boron, Carbon ion, etc.)
- Output
  - Cell survival, LQ parameter alpha and beta, RBE.
  - Format: Graphs, ASCII data Files



RADIOBIOAPP



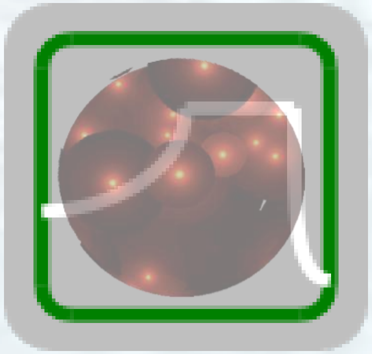
RADIOBIOAPP



Bio4Dose APPS

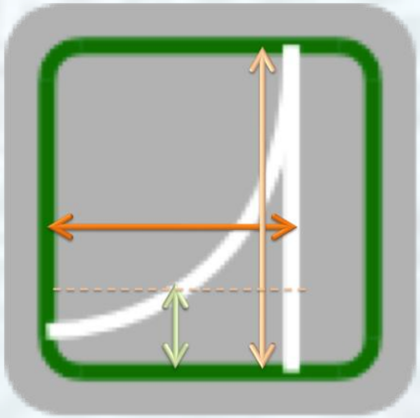
- Possible parameters:
  - Cell lines from database
    - Alpha/beta data file
  - Dose level
  - Beam type

    (x-ray, proton, Helium, Boron, Carbon ion, etc.)
- Output
  - Radiobiological equivalent dose
  - Format: Graphs, ASCII data Files



Web interface work in progress….

EXPERIMENTAL DATA



- Collection and storing data:
  - Physical (profiles,… treatment plans)
  - Radiobiological (α,β)….(radiobiological dose equivalent)
- **Output**
  - **Plots**

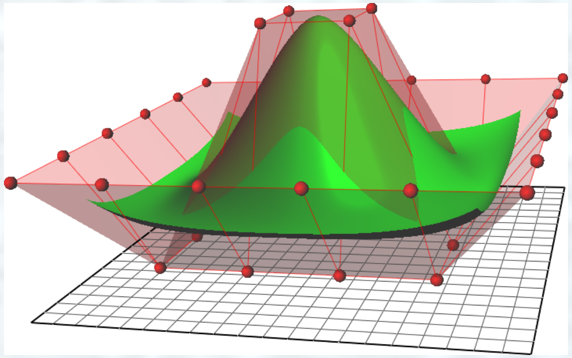
The database generated from the calculations needed by different users and measured data for innovative radiation facilities is an important source of information and an instrument to make the specifications for the new needs.

ON GOING WORK

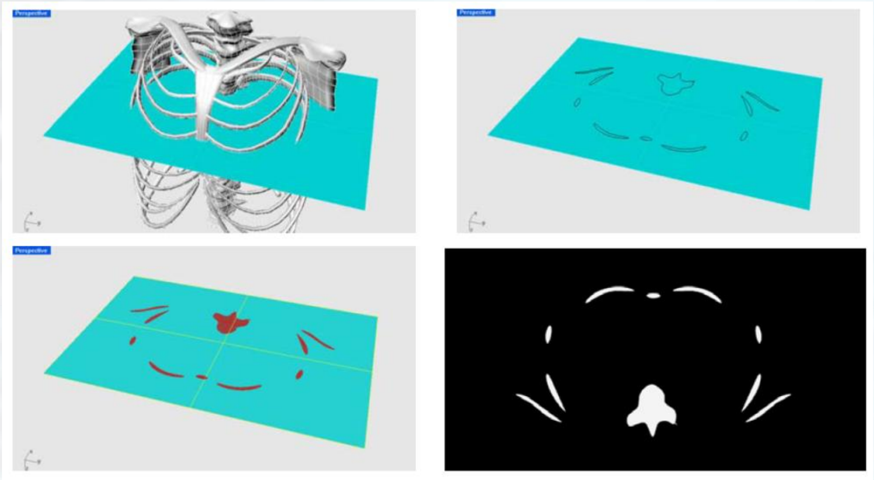
Patient phantoms based on BREP models for TPS and Monte Carlo benchmarking

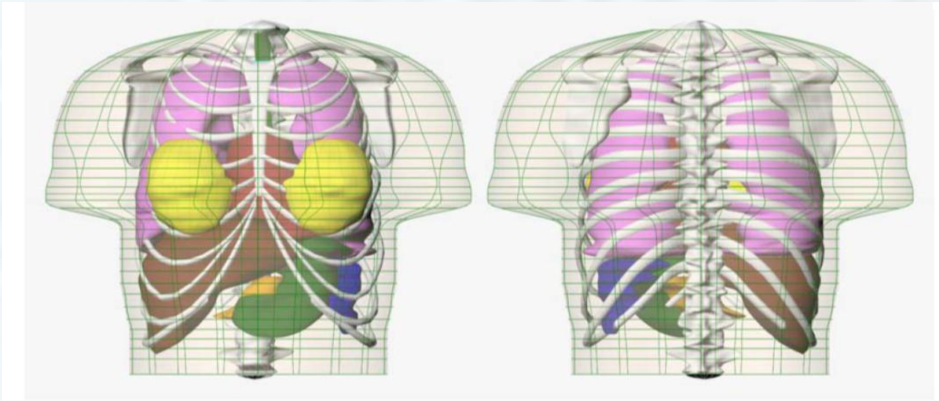
Patient phantoms based on BREP

New kind of anthropomorphic models named BREP (Boundary Representation) use 3D NURBS or MESH surfaces and created using CAD programs.

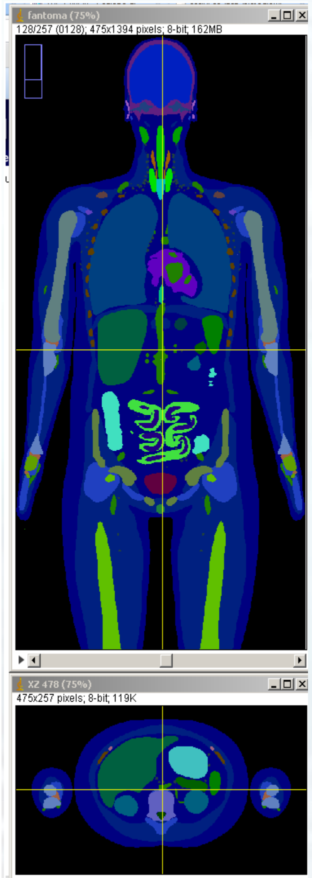


Advantages:
Possibility of changing easily the organs shape, size, posture or the inclusion of time-dependent animations





Patient phantoms based on BREP



Creation of an artificial CT images database of head, neck and sacral region cases.

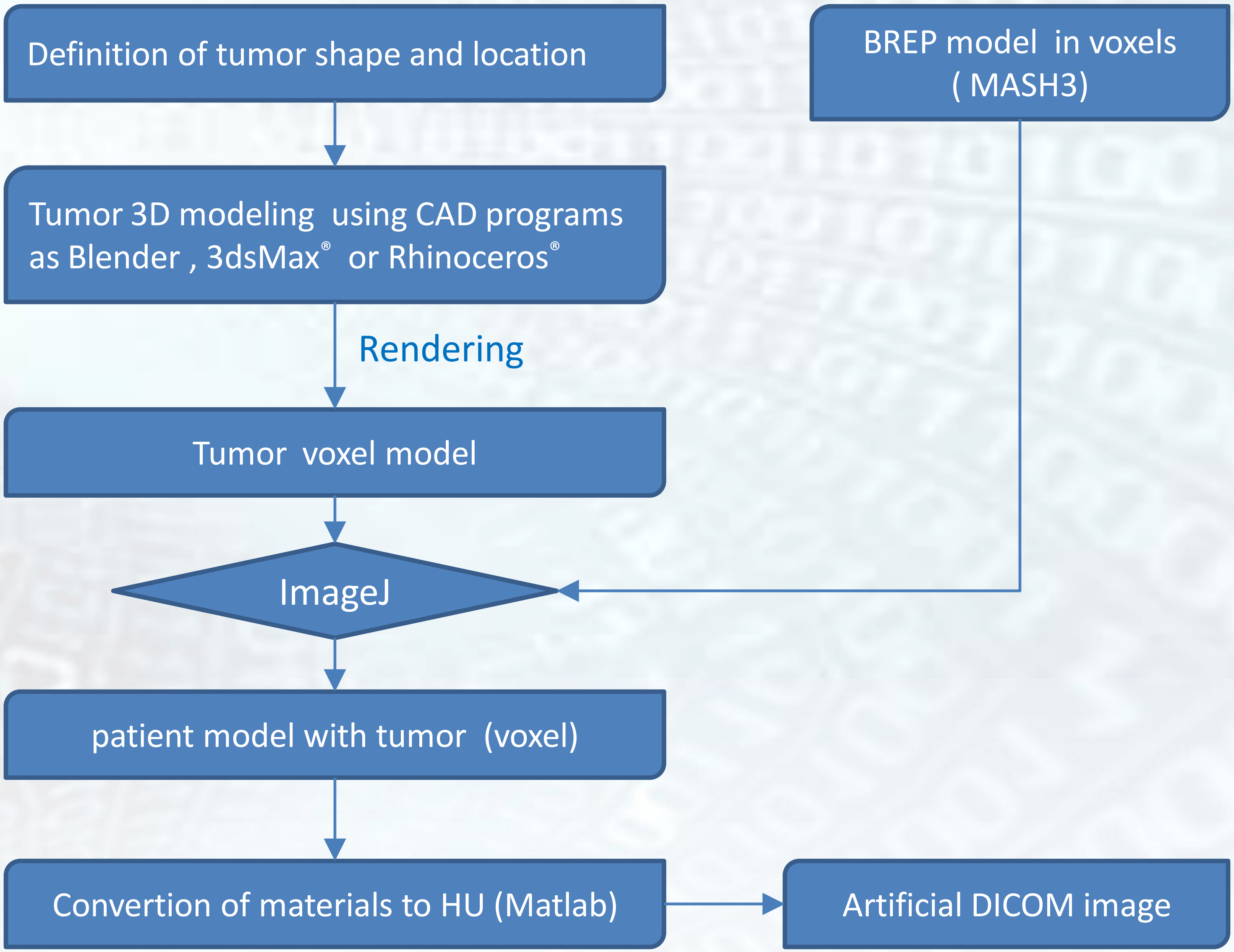
The selected BREP base model was MASH3 (Cassola 2010).

All its organs are segmented in volumes following ICRP89 recommendations.

478 x 258 x 1468 voxels (1.2 x 1.2x 1.2) mm^3 size.

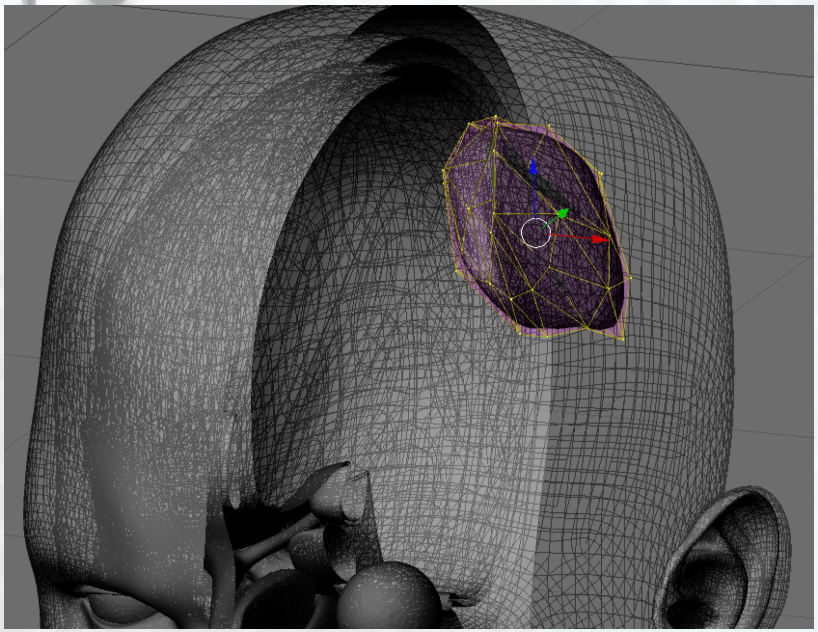
Cassola V F, Kramer R, C Brayner C and Khoury H J 2010. Posture-specific phantoms representing female and male adults in Monte Carlo-based simulations for radiological protection. *Phys. Med. Biol.* **55** 4399–4430.

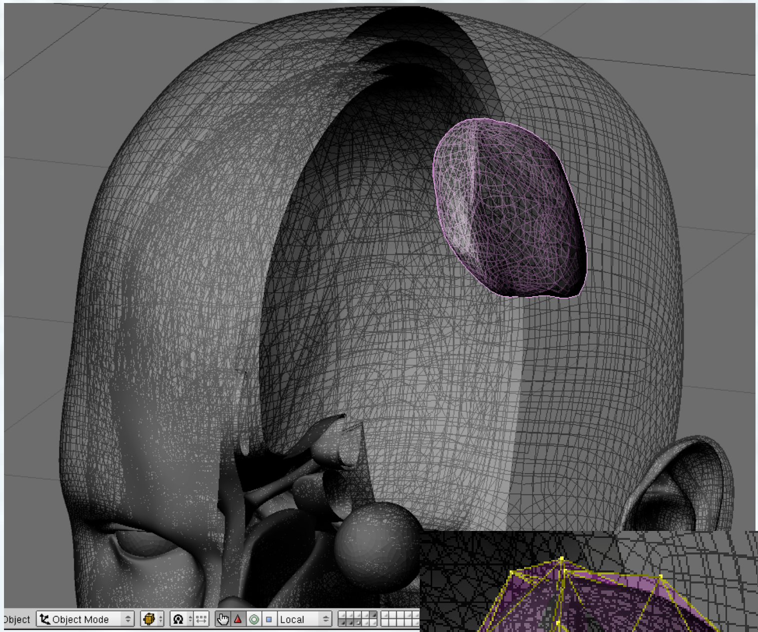
Patient phantoms based on BREP



Patient phantoms based on BREP

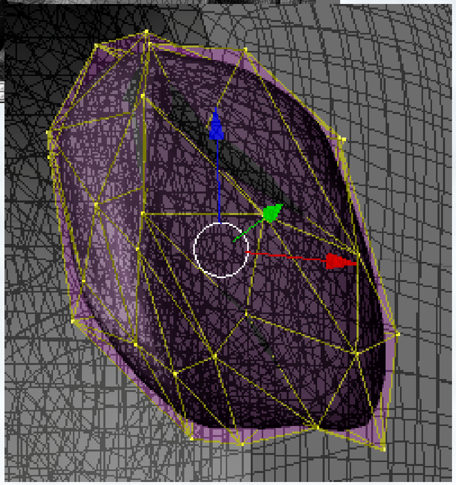
We started developing a brain tumor case. The first step is the definition of the tumors shapes and locations inside the model .





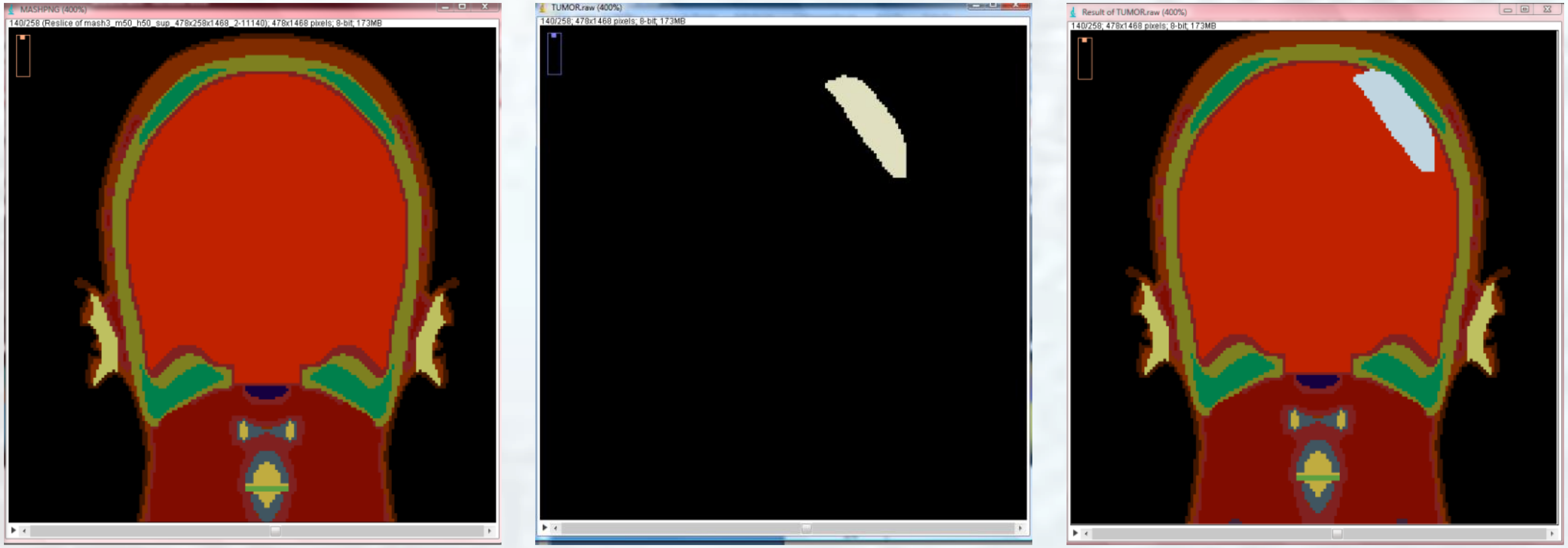
As CAD program was used Blender.

The tumor region was modeled using a sphere MESH surface and changing its vertices positions until reached the desired shape .



Patient phantoms based on BREP

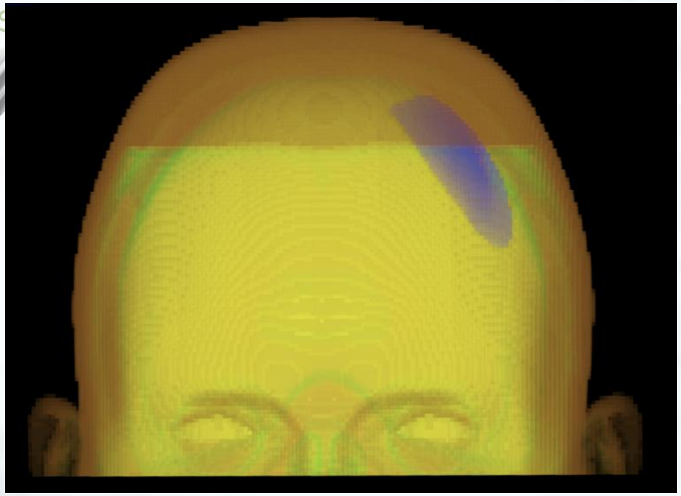
Next, the surface was converted into a voxel model with the same resolution as that of the MASH3 model (PNG sequence).

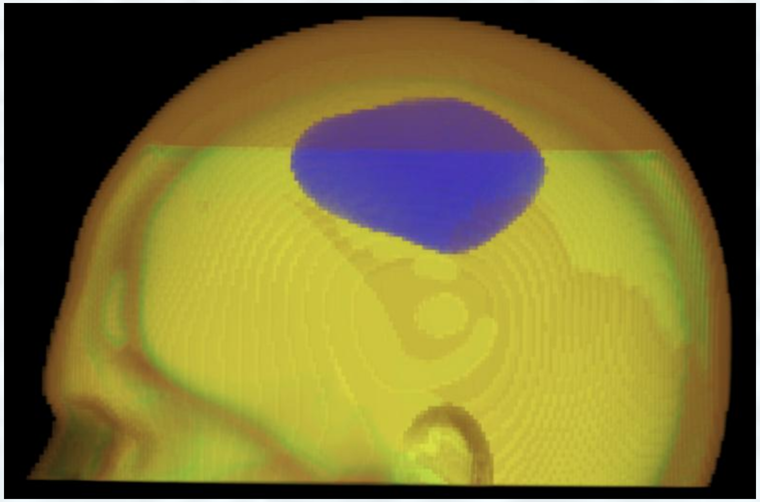


Using the ImageJ “image calculation” tools the tumor image sequence was added to the MASH3 voxel model, resulting in a new model with a brain tumor

The same program could be used for automatic detection of the PTV and sensitive organs contours.

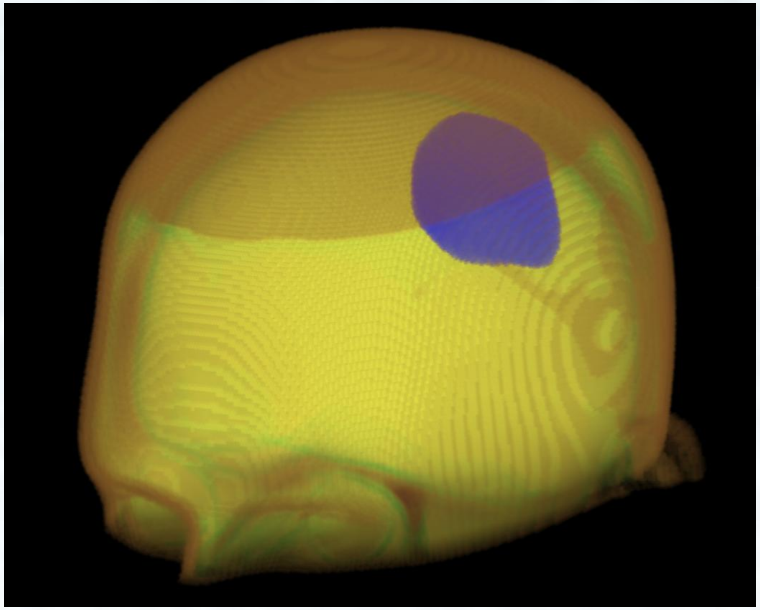
Patient phantoms based on BREP





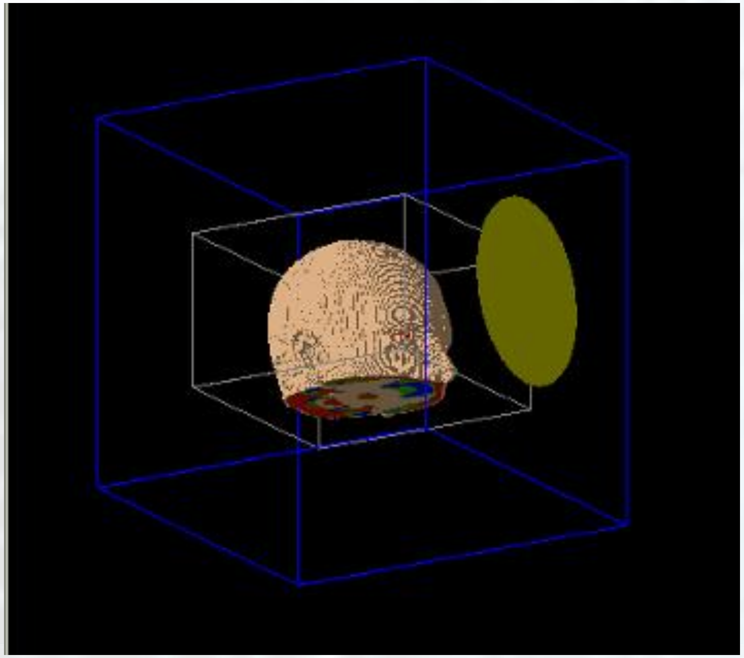
The ID of the tumor was set different to the rest of the organs, making it possible the allocation of the desired material and density.

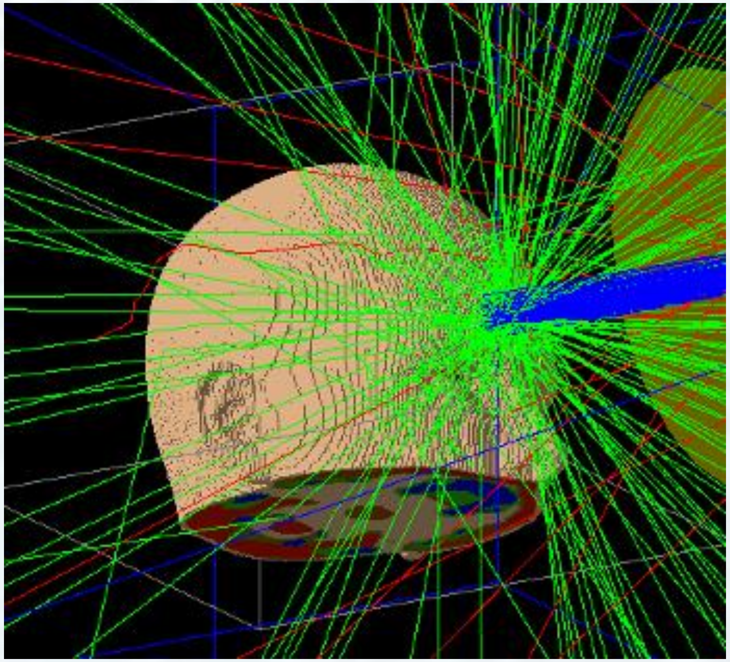
The final model was saved as a RAW format of 8 bit resolution



Patient phantoms based on BREP

To test the model within GATE package we conducted a simulation using a 100 MeV mono-energetic proton beam with a 7 mm spot size

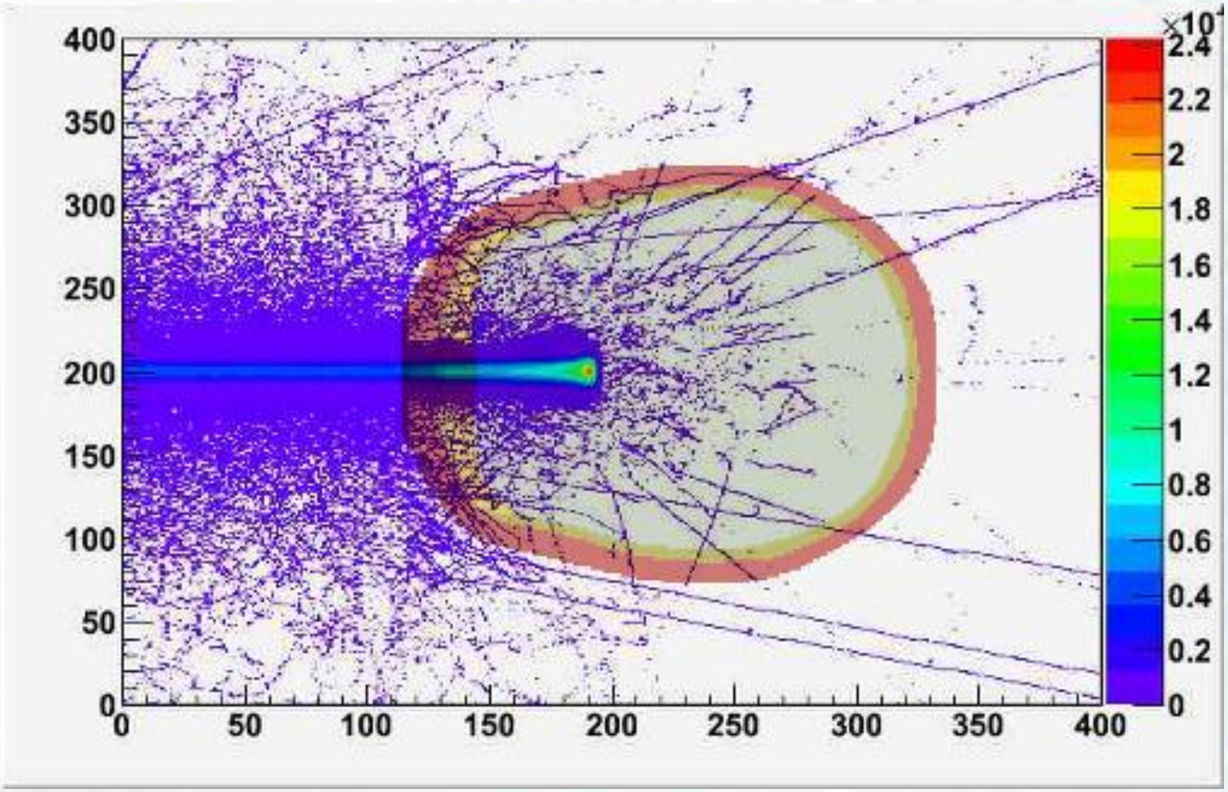




The patient model was loaded as a voxel phantom and each material was defined following the ICRP103 recommendations

Patient phantoms based on BREP

The dose deposition was registered using a "DoseActor" detector of 400 x 1 x 400 elements with 0.5 x 200 x 0.5 mm^3, around the head center



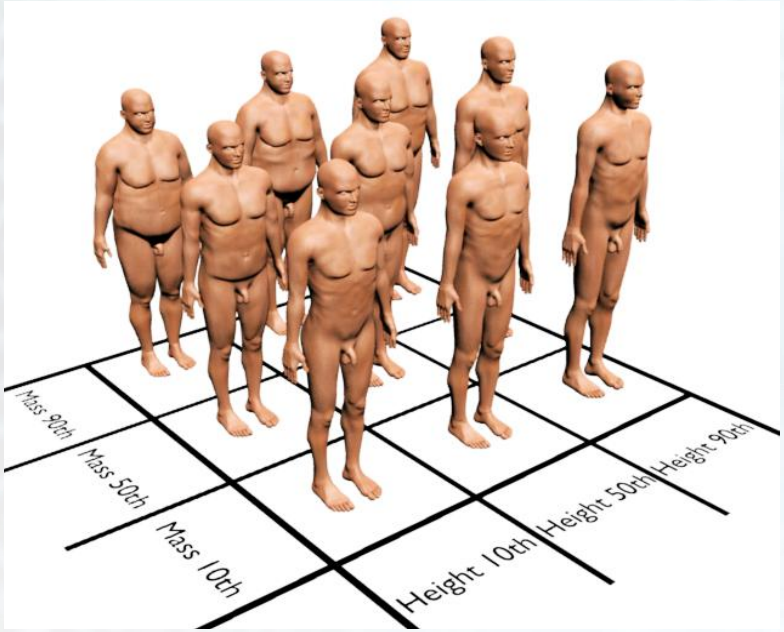
The simulation with GATE was successfully implemented and the results were in agreement to expectations

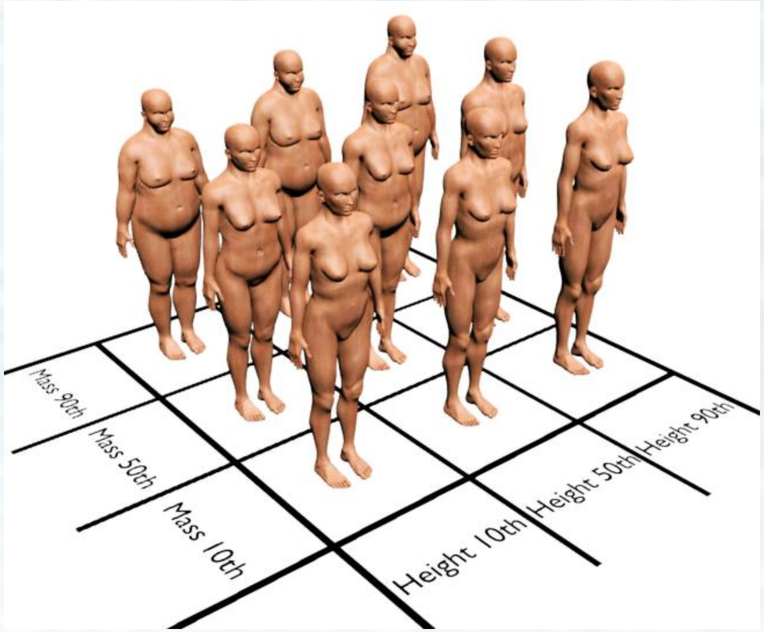
Patient phantoms based on BREP

I-SEE

Next steps

-Conversion in CT DICOM images.
- Forward planning using the INFN-TPS.
-Monte Carlo simulations of the TPS forward planning for benchmarking.
- Construction of the patient database with different tumors.
- Extend for others kind of BREP based models (Cassola et al 2011)





Reference: CassolaV, Milian F M, Kramer R, Oliveira Lira C.A. B., Khoury H. 2011 Standing adult human phantoms based on 10th, 50th and 90th mass and height percentiles of male and female Caucasian populations. *Physics in Medicine and Biology*, v.56, p. 3749 – 3772.

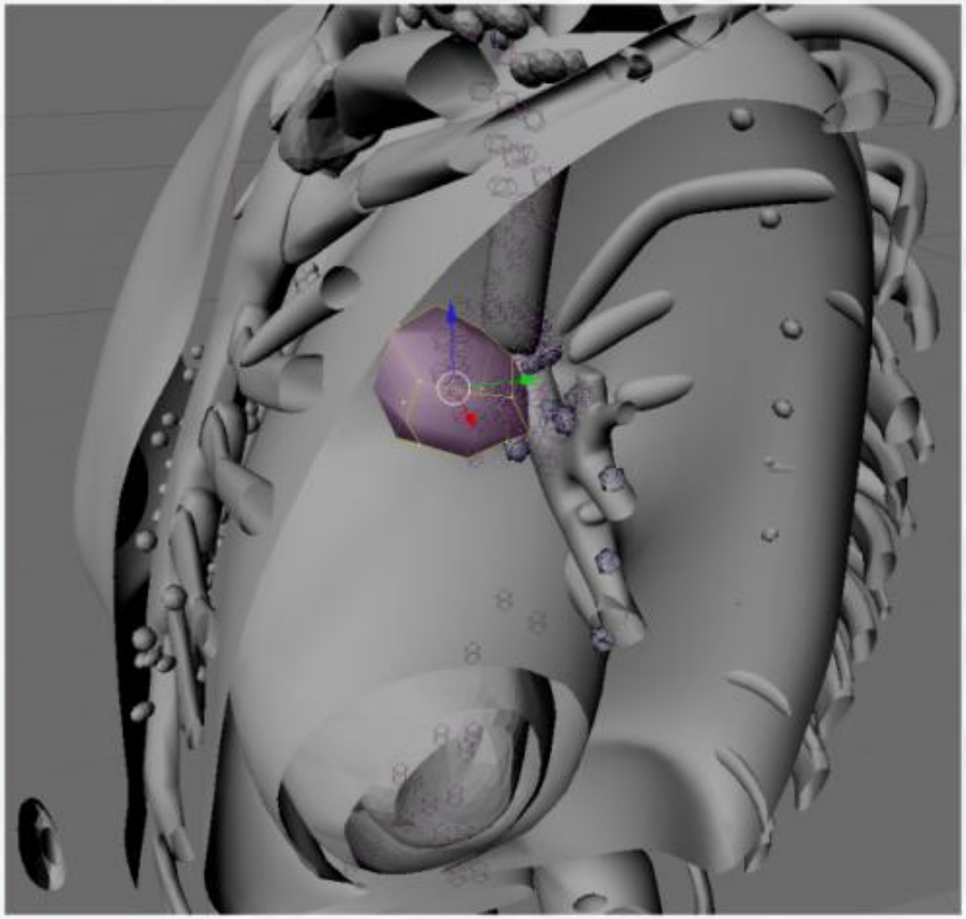
Patient phantoms based on BREP

I-SEE

Remarks

With the presented procedure will be possible to create a virtual patient database.

The phantoms will be available for free, allowing the comparison and benchmarking of the Monte Carlo simulation results between users.



So….

Now…

- Promotion
  - B2B
  - B2C
  - B2G
- Partnering
  - R. Therapy facilities.
  - Companies working in RT.
  - ICT Companies

Now…

- Web 3.0
- Cloud
- Augmented Reality
- Social net

- Web 2.0
- Grid
- Virtual Reality
- Email/chat

NEXT ?

PlanIT

MOM

MontecarloOptimized Mainframe

Pipeline + Timeline

I-SEE

Prototype → Products ready → Clients contact → I-SEE TEAM → sales

2009 · 2010 · 2011 · 2012

New Products → B2B ↗ → I-SEE TEAM ↗

2012 · 2013 · 2014

Final Remark

- The key innovation of ISEE the use of a distributed Monte Carlo computing environment (based on the delocalization of resources and adopting a parallelized architecture, to minimize calculation times).

- Also the use of web browser interface for running, checking and displaying results.

Thank you for your attention

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