13th UK Monte Carlo User Group Meeting
March 28-29, 2007
NPL, Teddington, UK

Hadrontherapy GEANT4 application: How Monte Carlo Helps Hadrontherapy

G.A.P. Cirrone, PhD
on behalf of
G. Cuttone, F. Di Rosa and G. Russo
the Geant4 Medical Group of

Laboratori Nazionali del Sud – INFN, Catania (I)

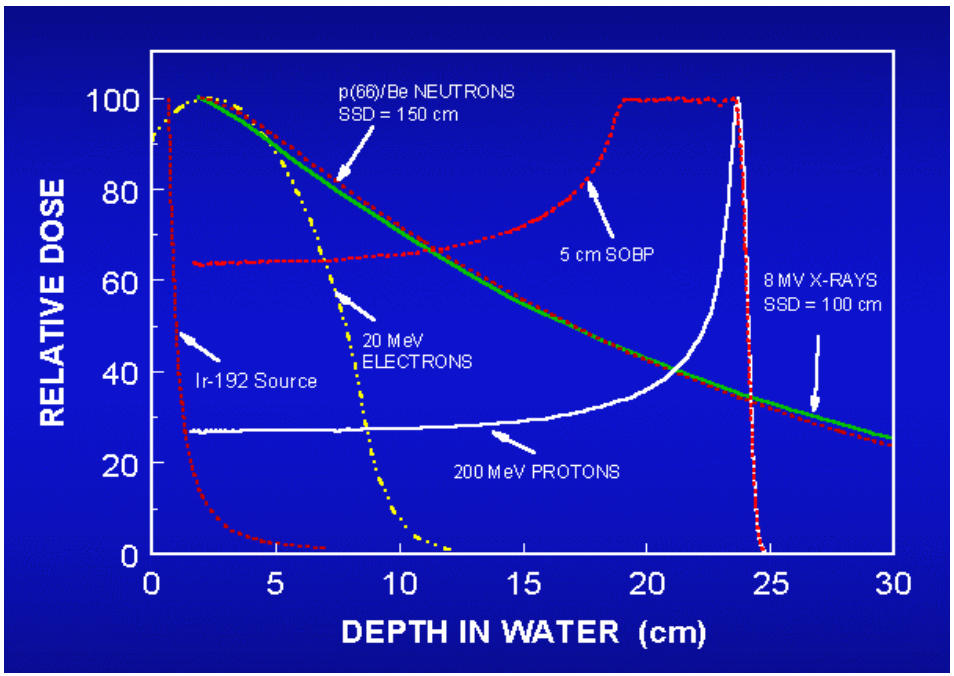
S.Guatelli. B.Mascialino and M.G.Pia
INFN Section of Genova (I)

TALK OUTLINE

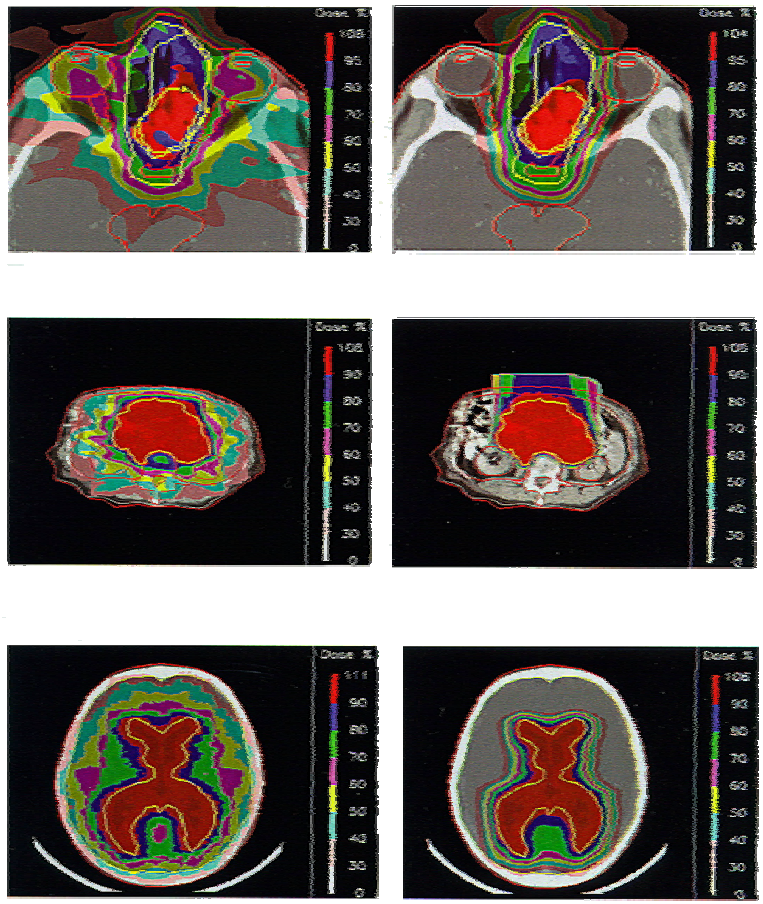
1. WHY PROTON BEAM FOR RADIATION TREATMENT?
2. THE ITALIAN PROTON THERAPY FACILITY
3. THE USE OF MONTE CARLO IN PROTON THERAPY
    1. Experimetal data comparison
    2. Limitation
4. GRID approach

WHY PROTON BEAM FOR RADIATION TREATMENT?

Proton therapy is a growing radiation treatment technique (more 35 centers today)



IMRT PT



WHY PROTON BEAM FOR RADIATION TREATMENT?

- penetration depth is ***well-defined*** and ***adjustable***
- most energy at ***end-of -range***
- protons travel in ***straight lines***
- dose to ***normal tissue*** minimized
- ***dose*** beyond target

PROTONS PERMIT TO DELIVER AN HIGH DOSE TO THE TUMOUR SPARING THE SOURRONDING TISSUES

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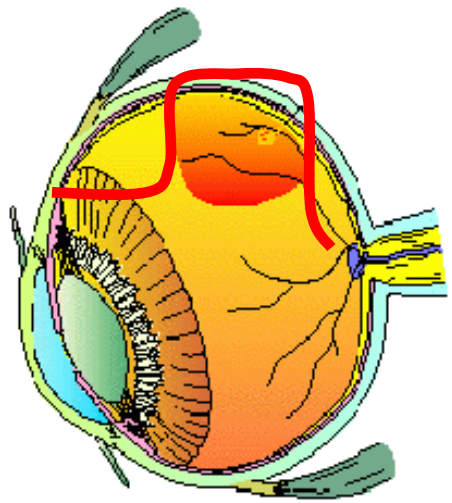
THE ITALIAN PROTON THERAPY FACILITY

LNS Superconducting Cyclotron is the unique machine in in Italy and South Europe used for protontherapy

Treatment of the choroidal and iris melanoma

In Italy about 300 new cases for year



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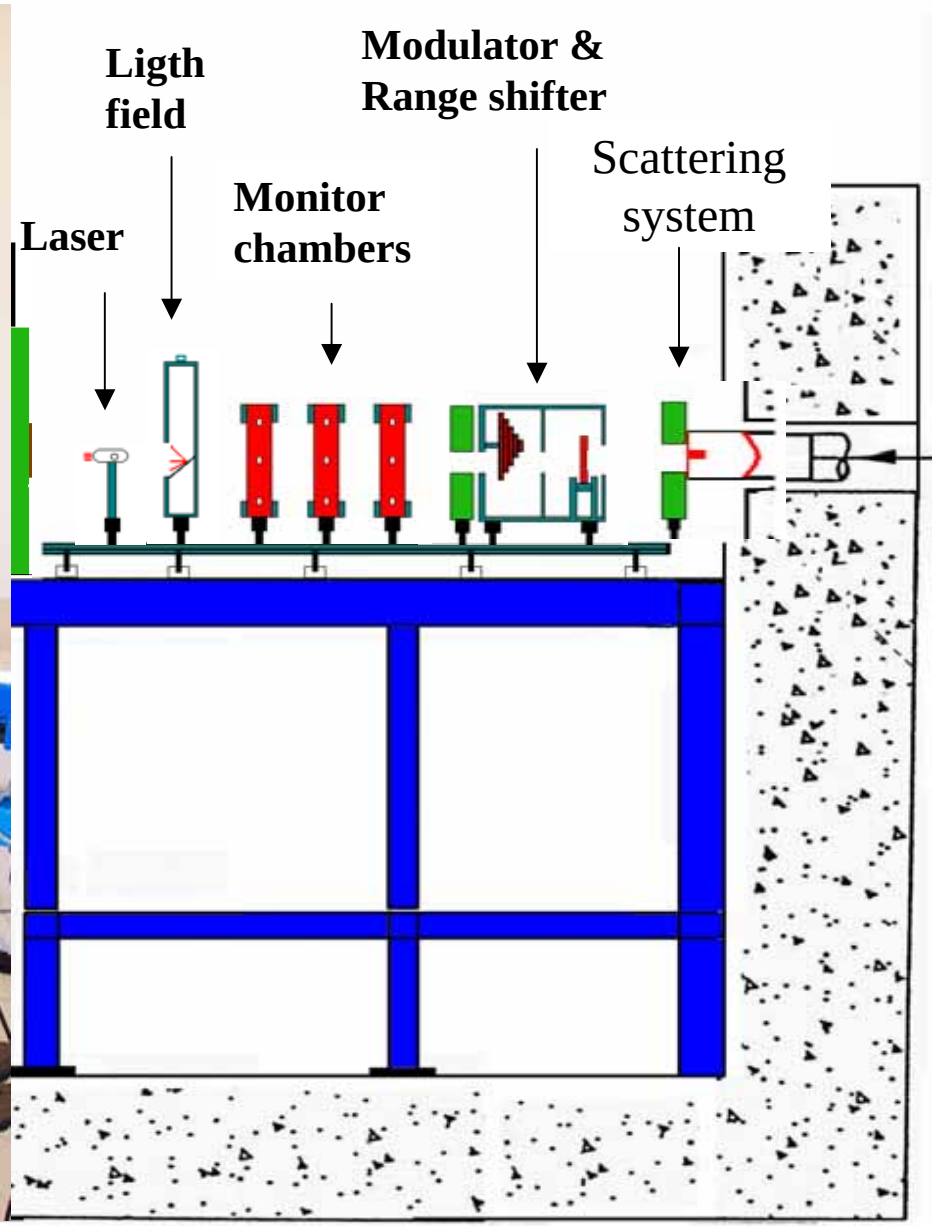
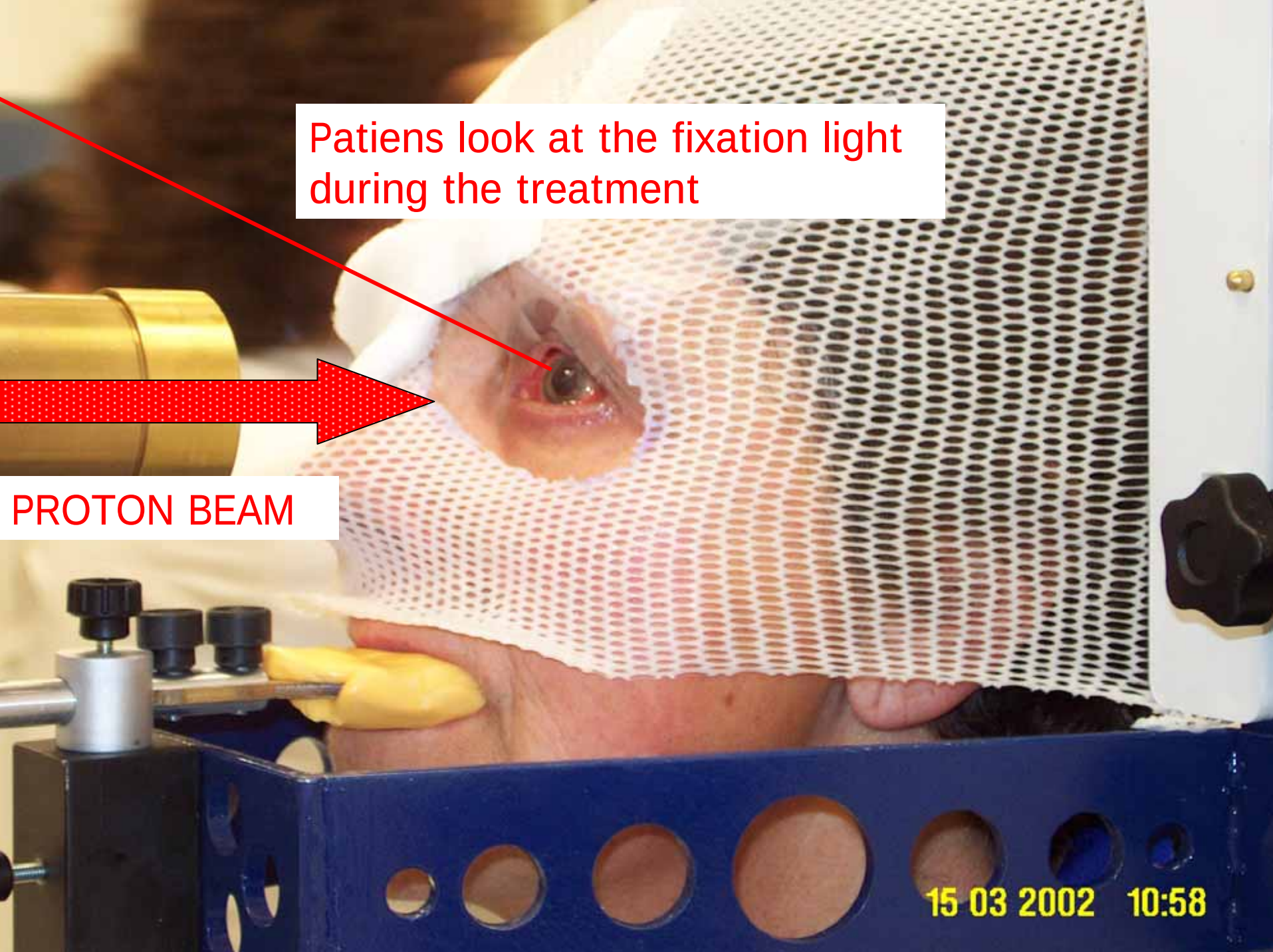
Cyclotron Location

Treatment Room Location


Ligth field
Modulator & Range shifter
Laser
Monitor chambers
Scattering system


Patiens look at the fixation light during the treatment
PROTON BEAM
15 03 2002 10:58

Patient Distribution by Region

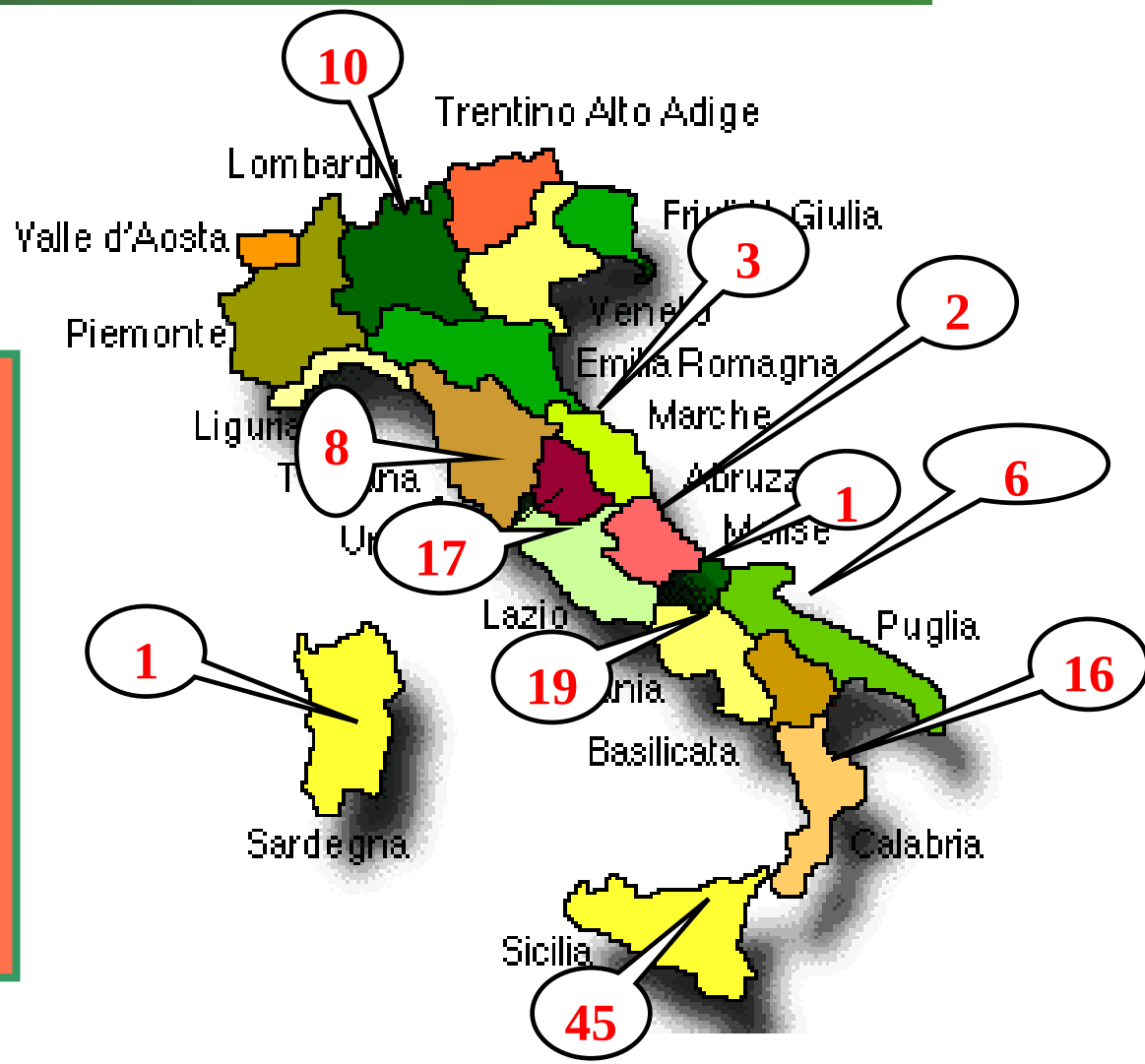
First patient:
March 2001

Total patients number
(February 2007) : 130

Employers: Radiologist 3

Oculists 3

Med. Physicist 3



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Patient Follow-Up (March 2002 – May 2006)

PatientsTotal Number (April 2006)	130
Patients with Follow up	100

TUMORAL THICKNESS		ECOGRAPHIC REFLECTIVITY	
Reduced	70 %	Increased	77 %
Stable	24 %	Stable	18 %
Increased	2 %	Not evaluable	5 %
Not evaluable	2 %		

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Why to start a Simulation Work ?

So we start our simulation work using GEANT4:

- To simulate a generic hadron therapy beam line with all its elements and
- To riproduce all the dose distributions and
- To investigate the Monte Carlo capability for Treatment Planning

It's impossible to conceive a modern detector w/o simulation

Rossi and Greisen 1941, Rev. Mod. Phys. 13:240

Our GEANT4 Application: hadronTherapy.

HADRONTHERAPY: AN OFFICIALLY GEANT4 ADVANCED EXAMPLE FREELY AVAILABLE INSIDE THE DISTRIBUTION

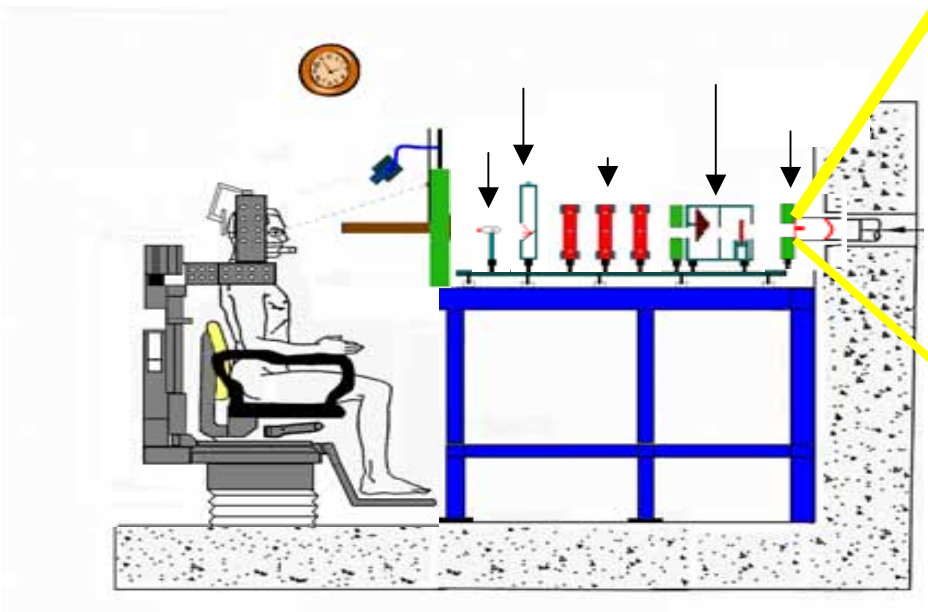
www.cern.ch/GEANT4

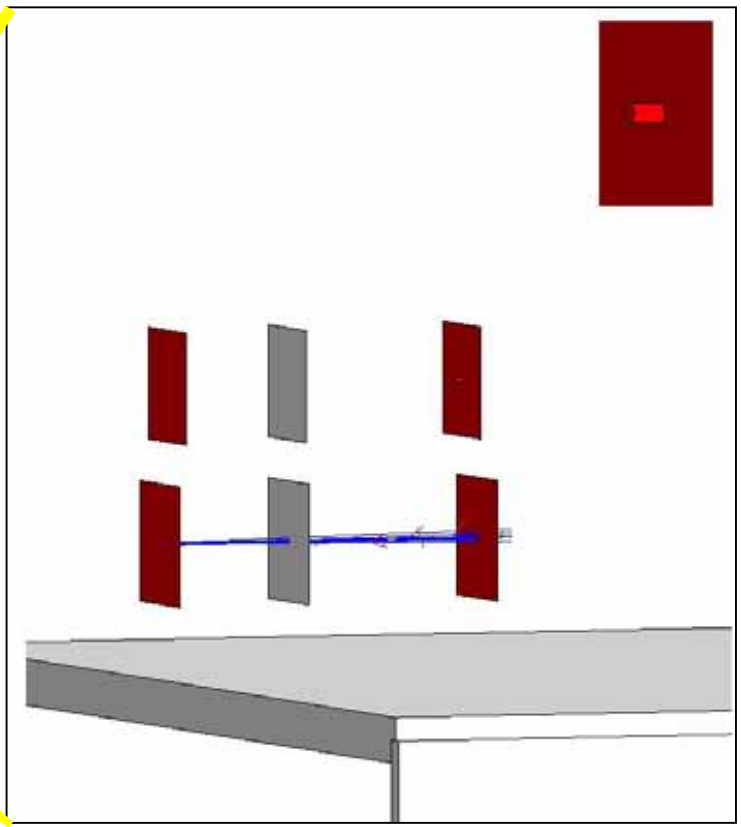
Complete simulation of CATANA hadron-therapy beam line with two dosemeters

- **Depth Dose Distribution in Water** (Bragg curve): Markus type ionization chamber;
- **Lateral Dose Distribution:** Radiochromic film;

DOUBLE SCATTERER FOIL WITH CENTRAL STOPPER

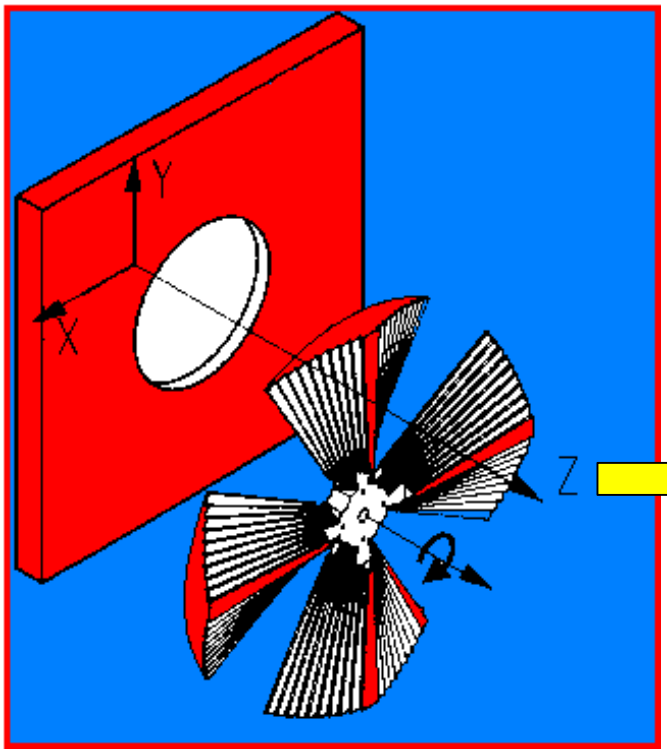
15 μm + 25 μm + 7 mm thick copper beam stopper

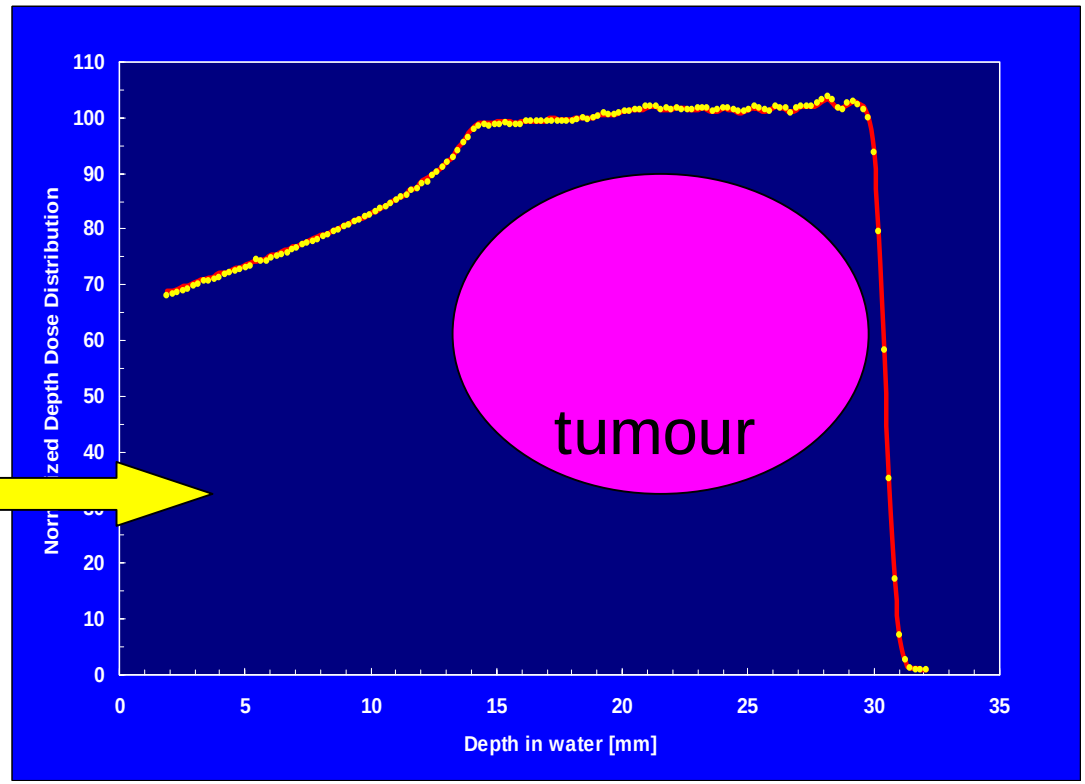




The modulator wheel: time dependent simulation

Modulator simulation for the SOBP reconstruction





During the simulation the wheel rotates producing the flat dose distribution

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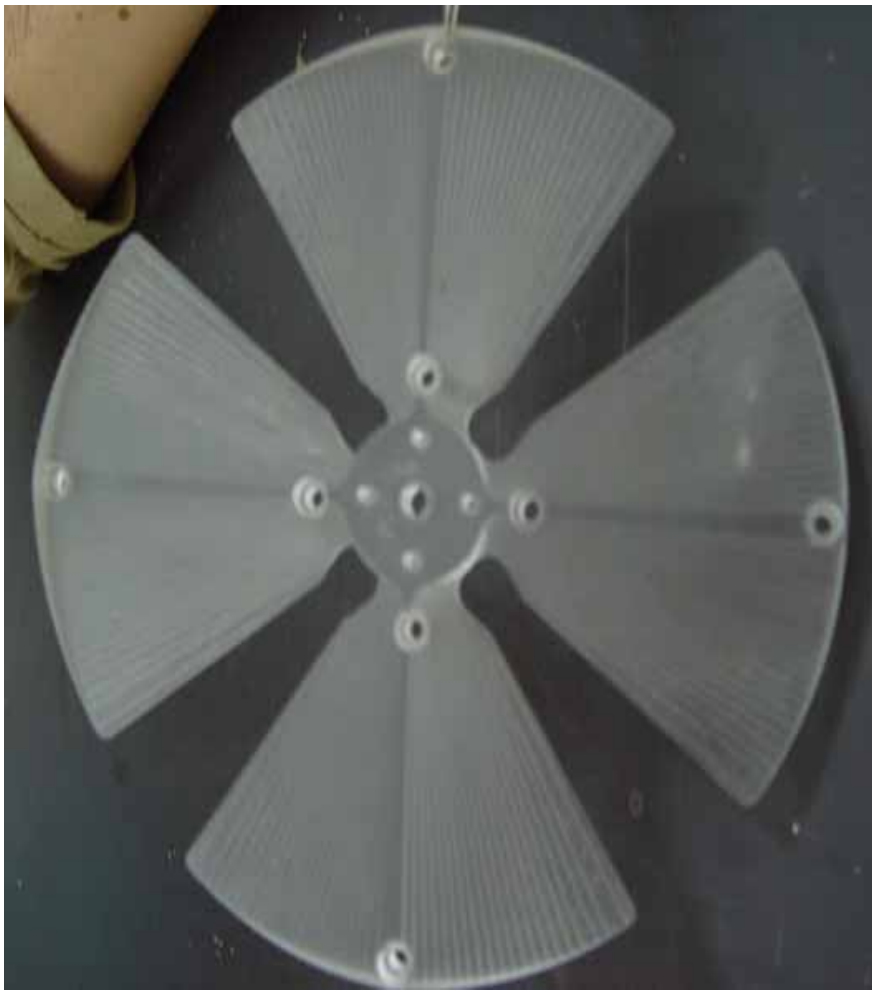
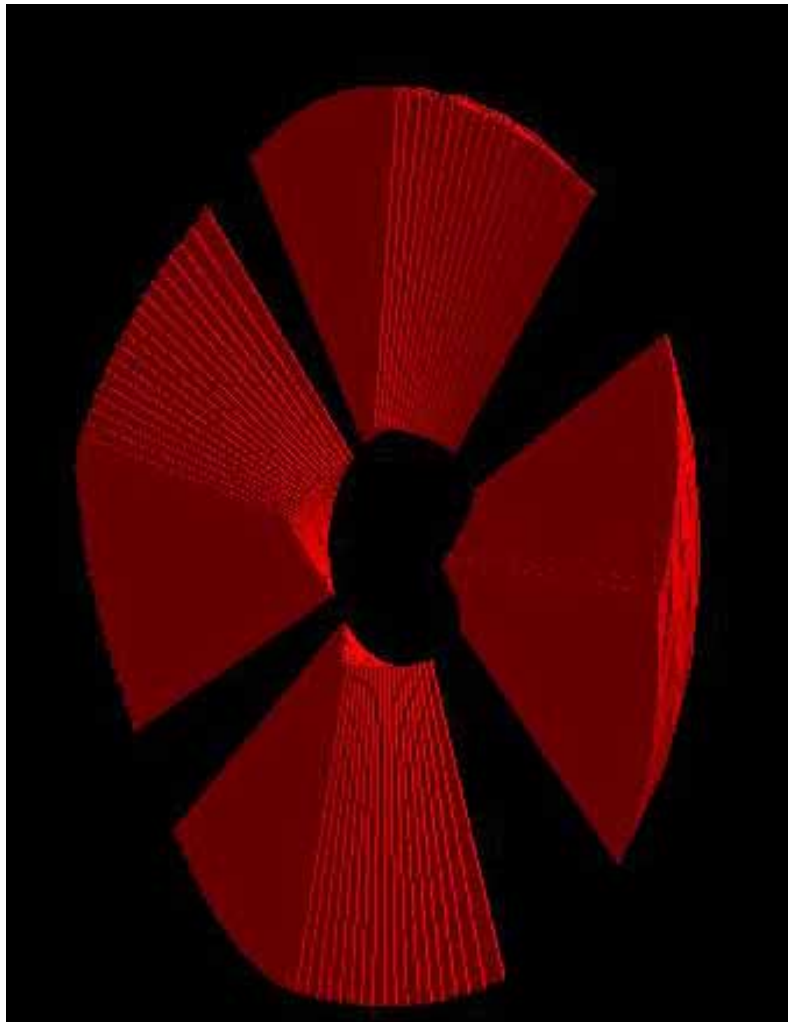
The modulator wheel: time dependent simu

Real Modulator



Geant4 Modulator



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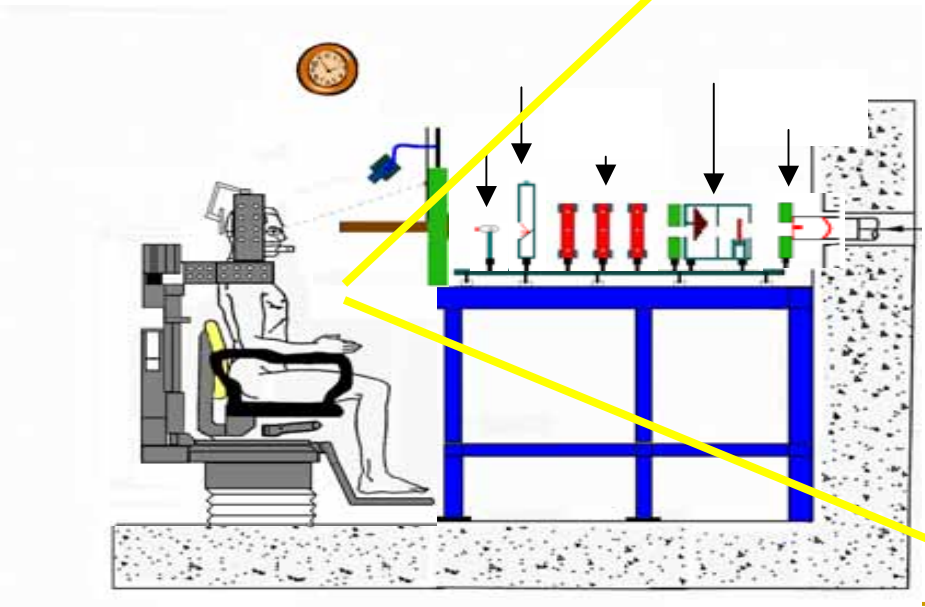
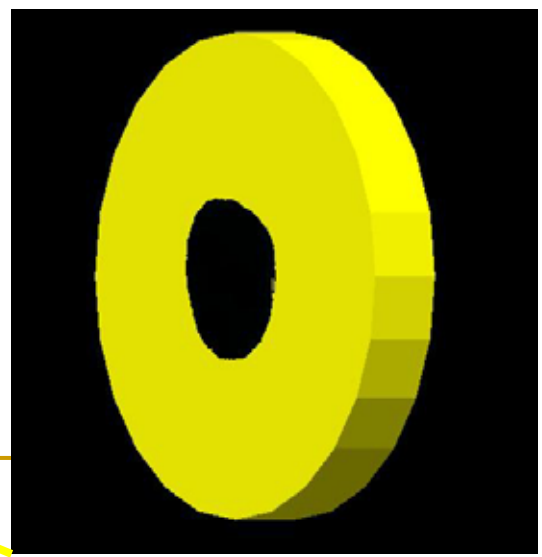
The beam line simulation: the final collimator

Collimator with a shape dependents on the particular tumour





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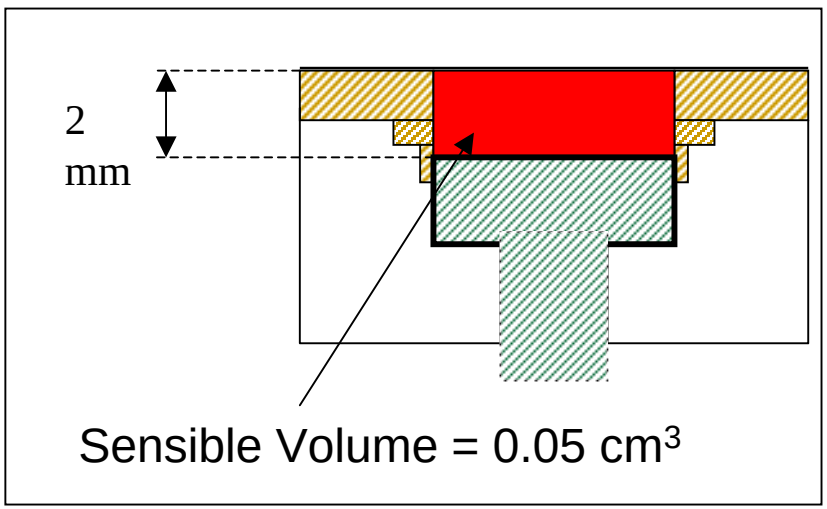
Simulation of the dosemeters: ionisation chamber and radiographic films

DEPTH DOSE DISTRIBUTION

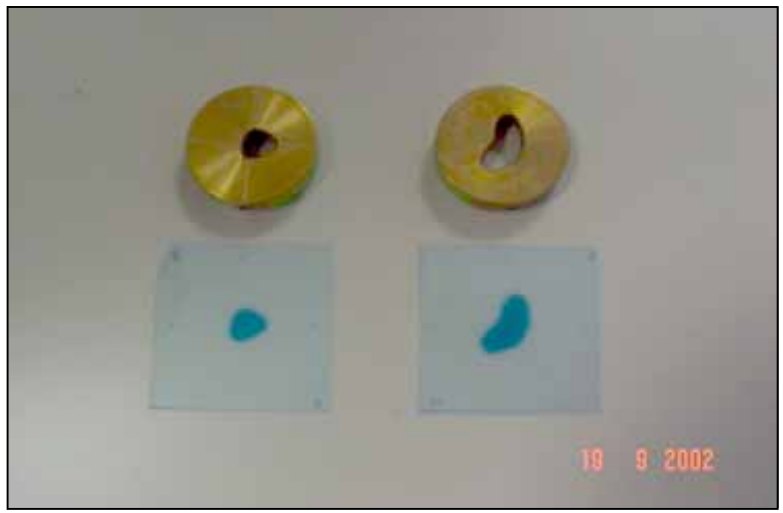
- Markus Ionization chamber



Markus Chamber layout

LATERAL DOSE DISTRIBUTION

- GAF Chromic Film



Irradiated GAF Chromic

Resolution 100 μm for DDP and 200 μm for LDP

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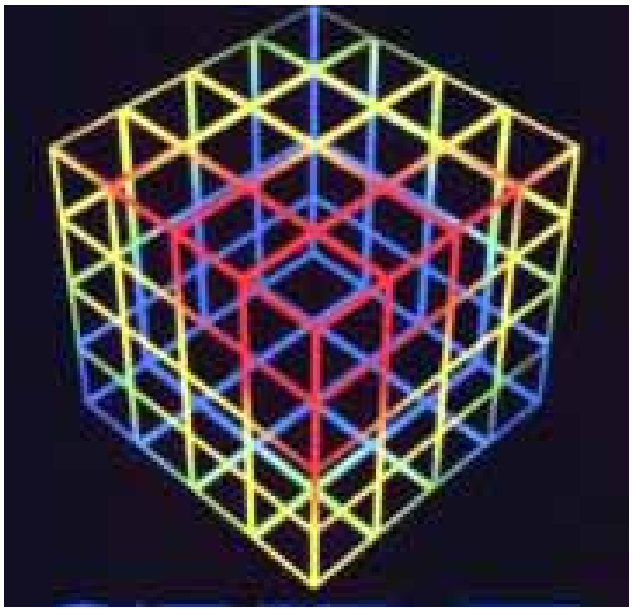
Bragg curve reconstruction

Detector simulated as a 3D cube (RO Geometry Class)

Energy collected in each voxel at the end of a run



The cube shape can be changed:

- The whole cube if all the informations are needed
- A plane for the GAF simulation
- A small cylinder for the Markus simulation

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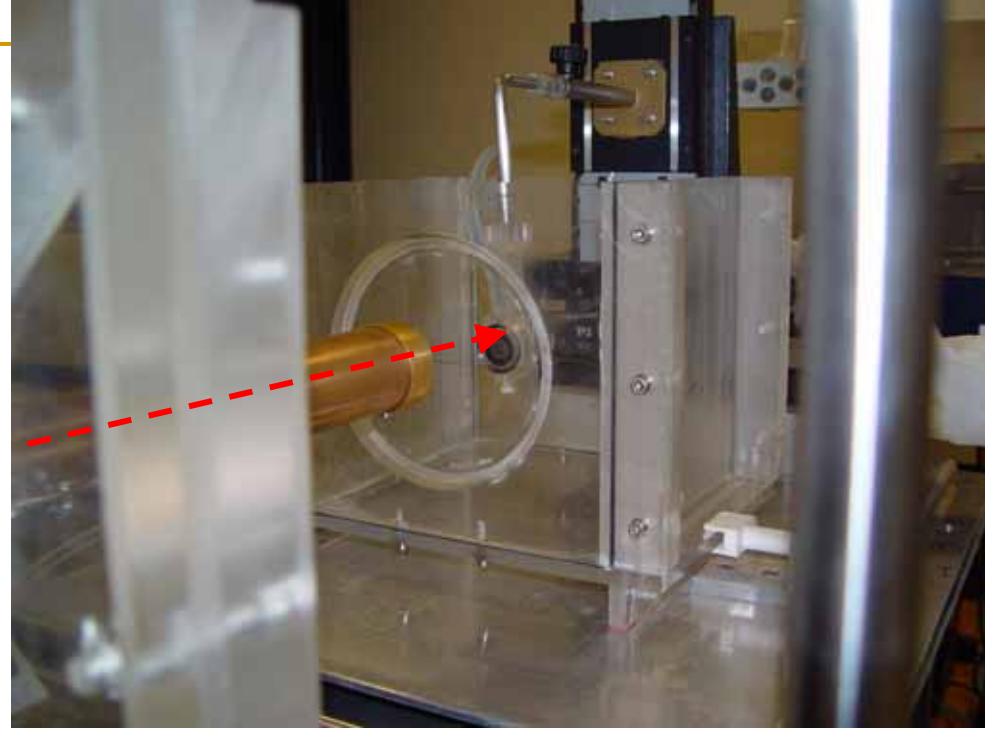
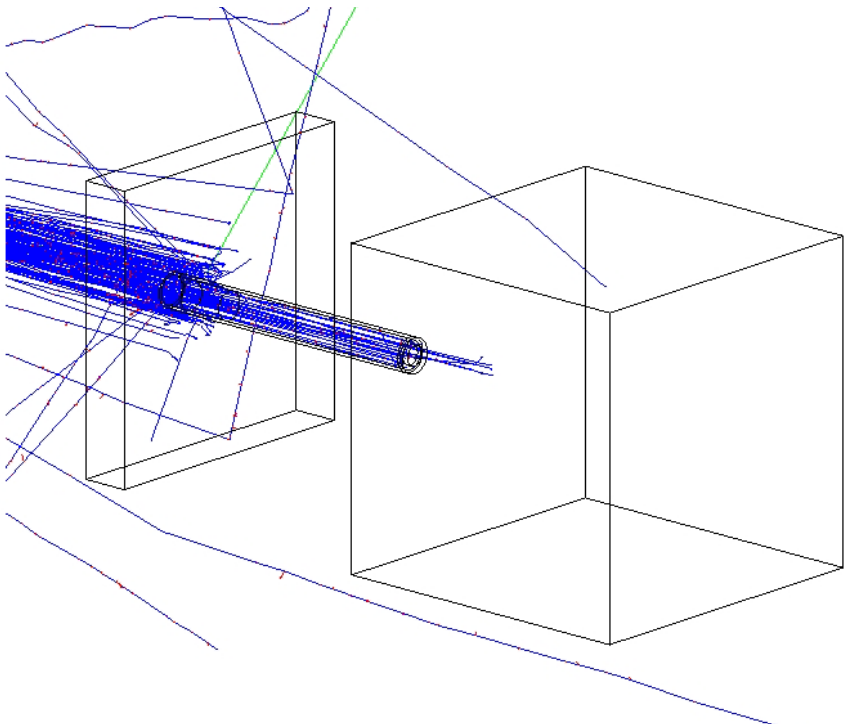
Bragg curve reconstruction

Water box with ionisation chamber

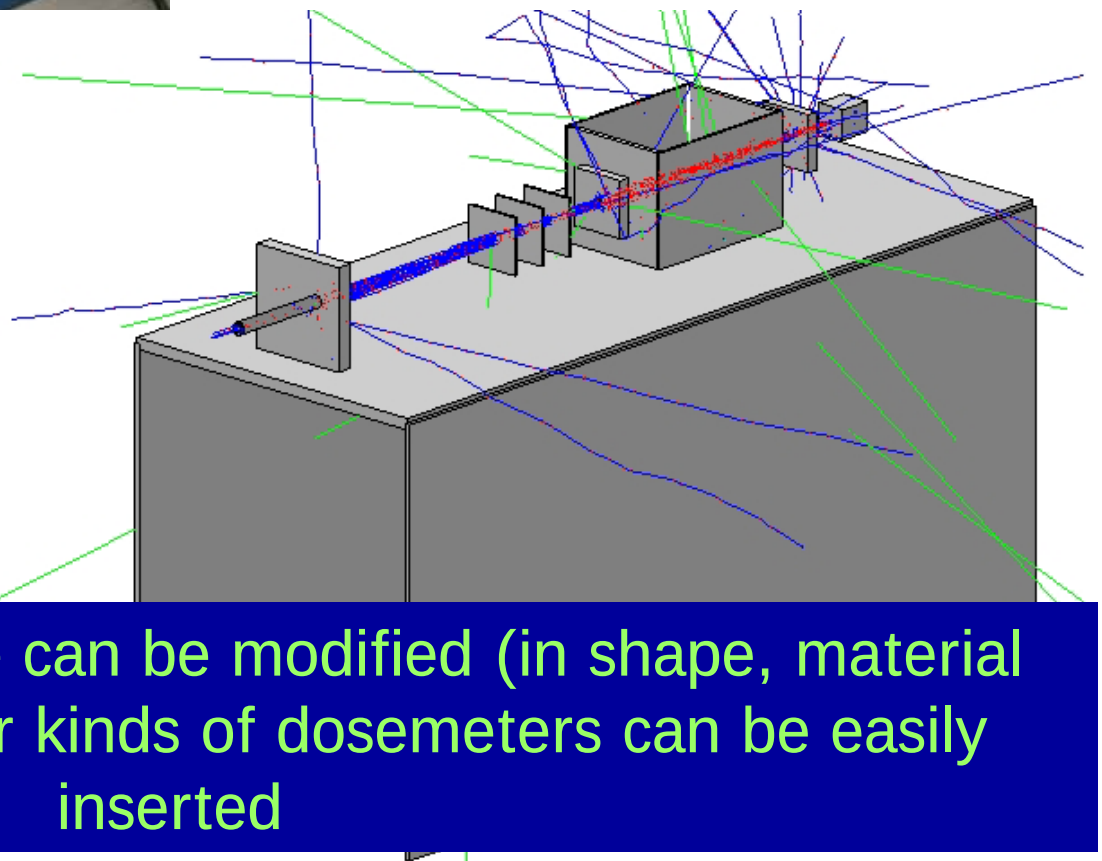




Water box + detector for Bragg curve as simulated

Real hadron-therapy beam line

GEANT4 simulation

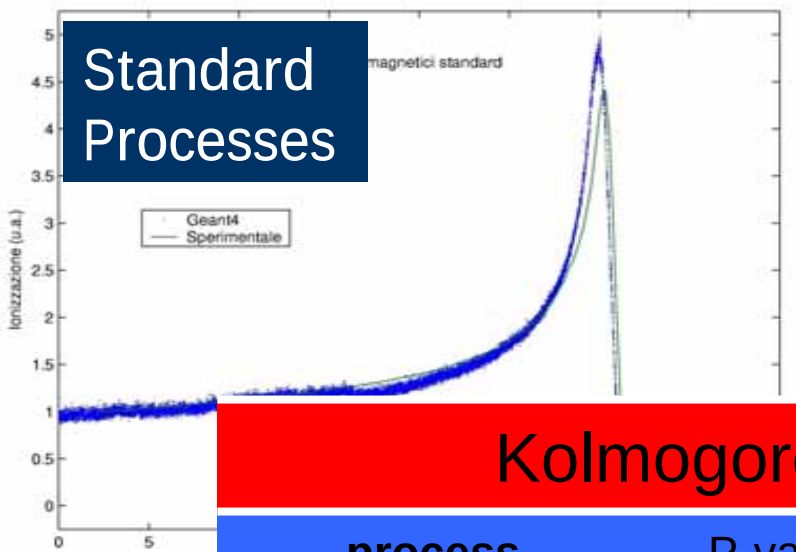


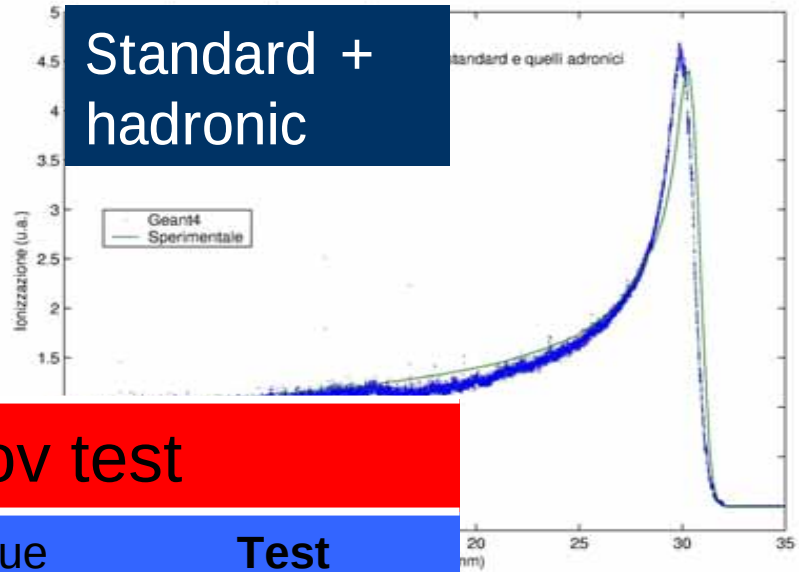
OUR COMP

- GEANT4 MC t
- Electromagnet
- Elastic nucrea

Each element of the line can be modified (in shape, material and position) and other kinds of dosemeters can be easily inserted

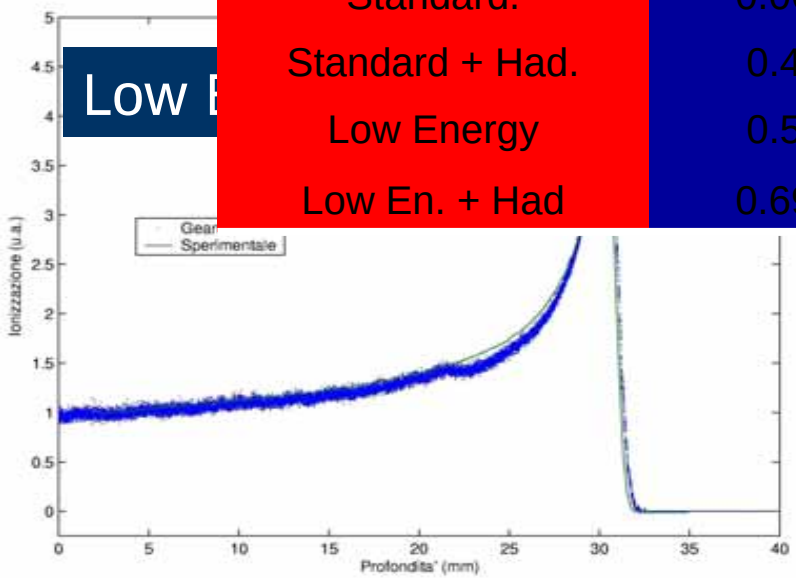
Physic models: comparison vs experimental data

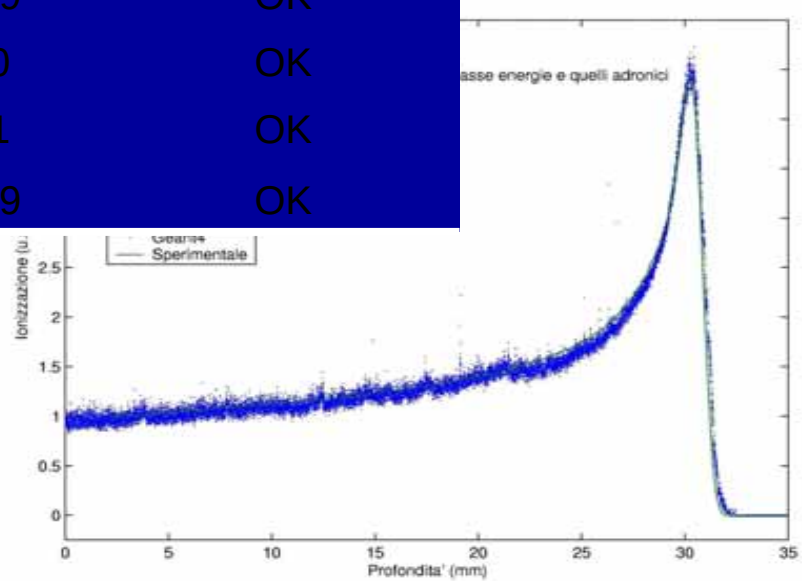




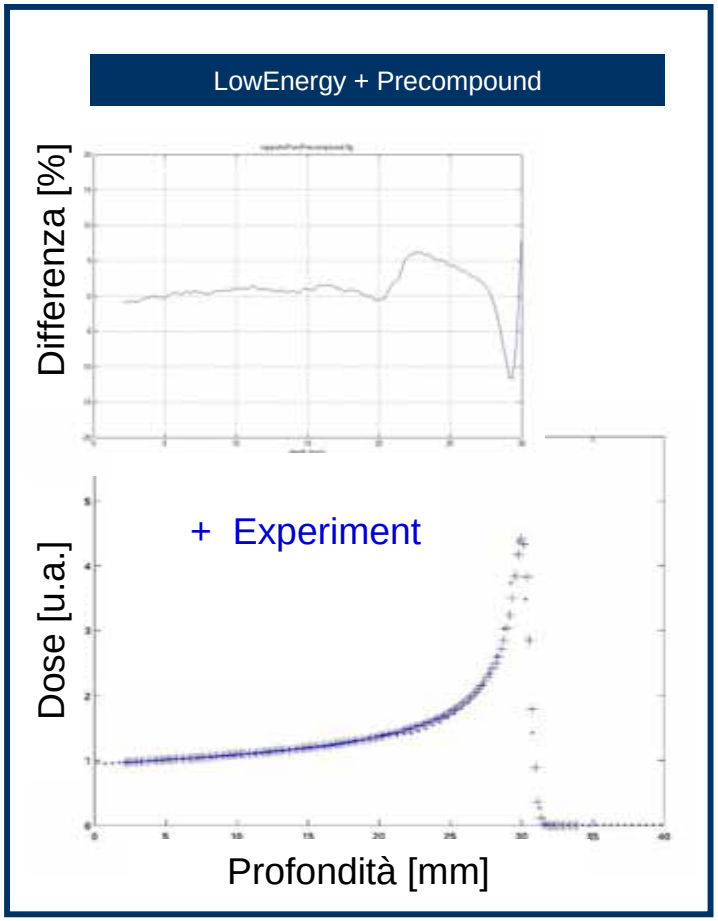
Kolmogorov test

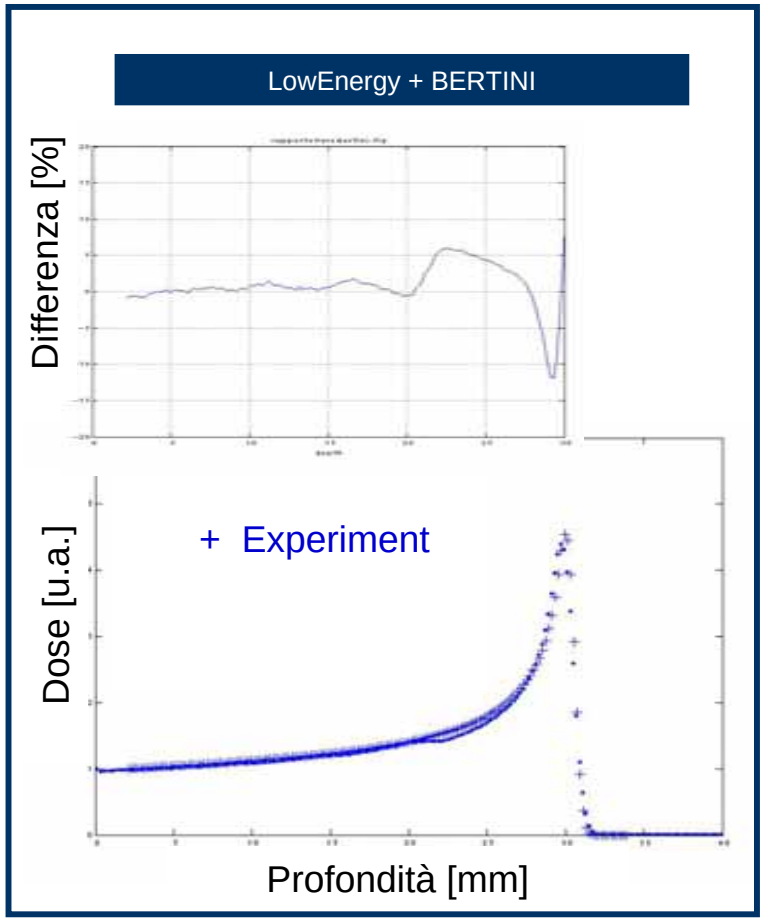
process	P-value	Test
Standard.	0.069	OK
Standard + Had.	0.40	OK
Low Energy	0.51	OK
Low En. + Had	0.699	OK





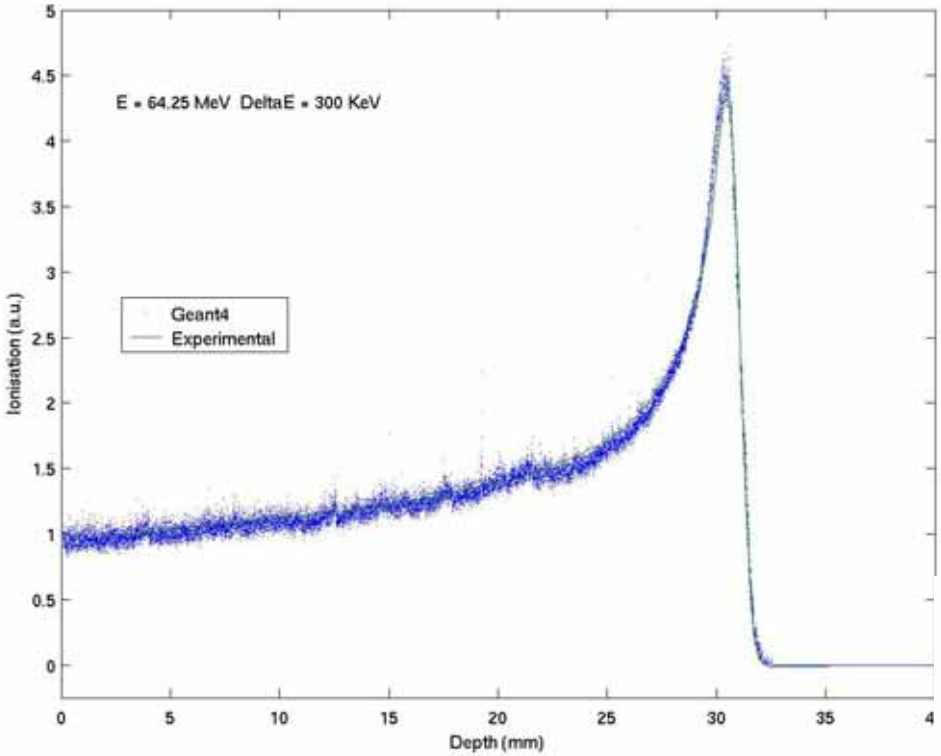
Physic models: comparison vs experimental data



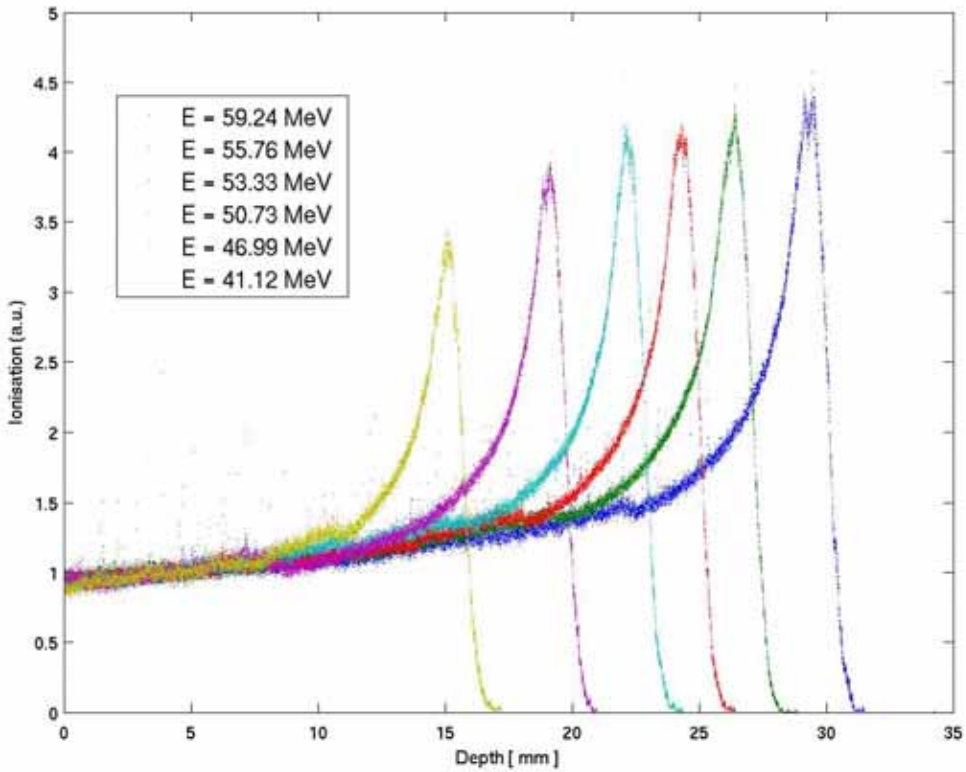


Parametri	Rapporto Picco-Plateau	FWHM [mm]	Range Pratico [mm]	Penombra90/10 [mm]
LowEn+Bertini	4.39	3.34	31.21	1.10
LowEn+Precompound	4.54	3.35	31.12	1.05
Sperimentale	4.54	3.59	31.09	0.8

Physic models: comparison vs experimental data

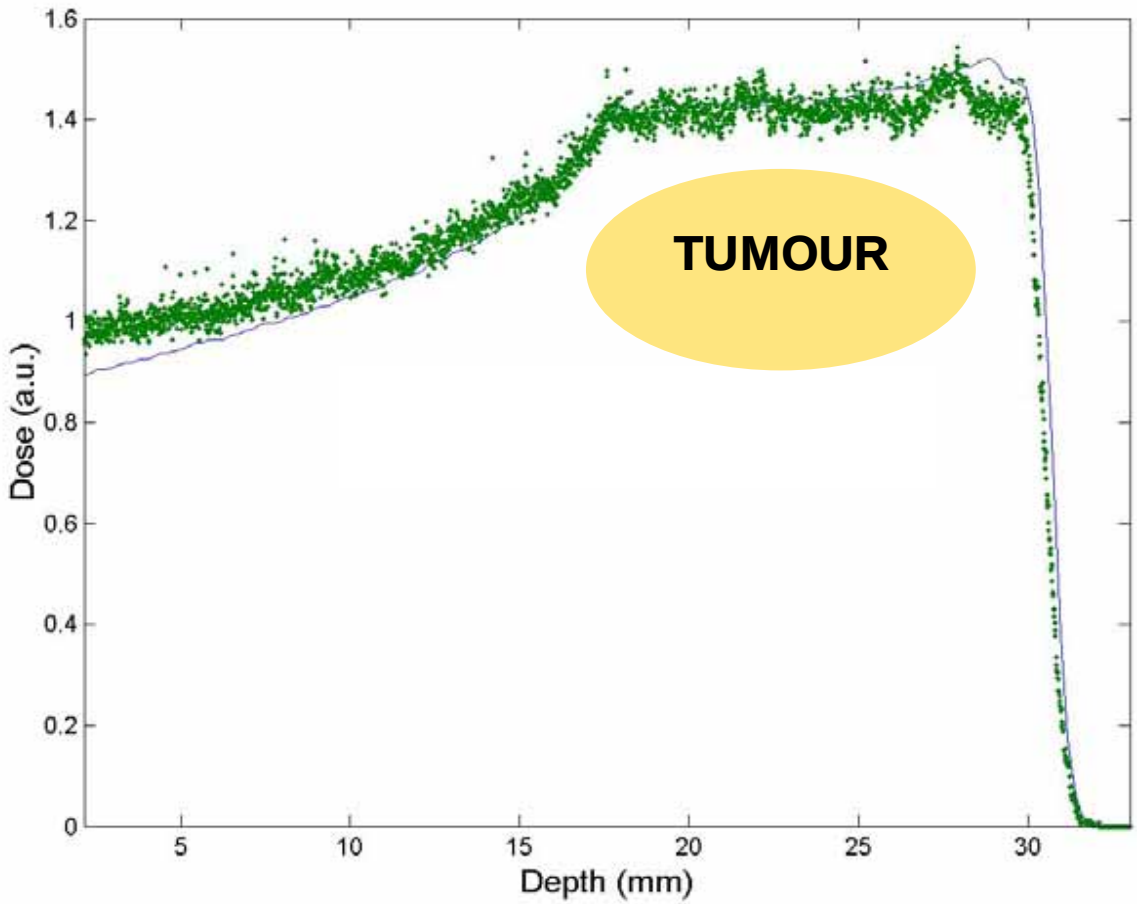


Low energy libraries and hadronic physics



Bragg peaks at diferent energies

Spread Out Bragg Peak: simulation vs experiment



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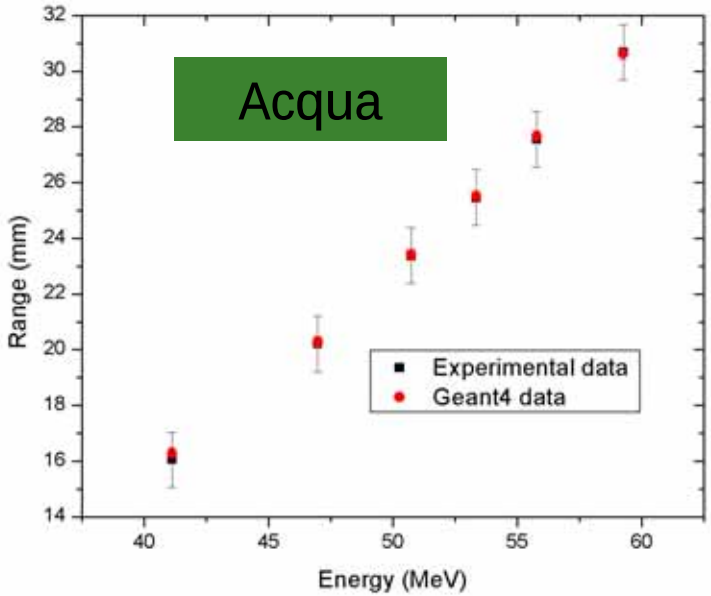
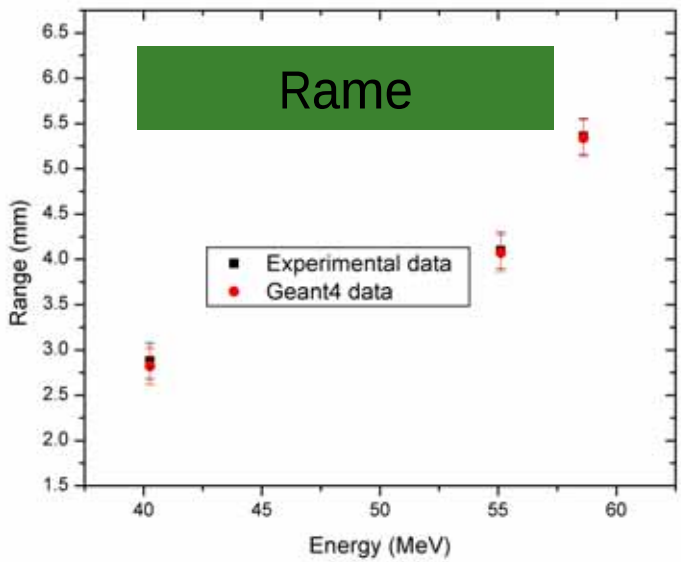


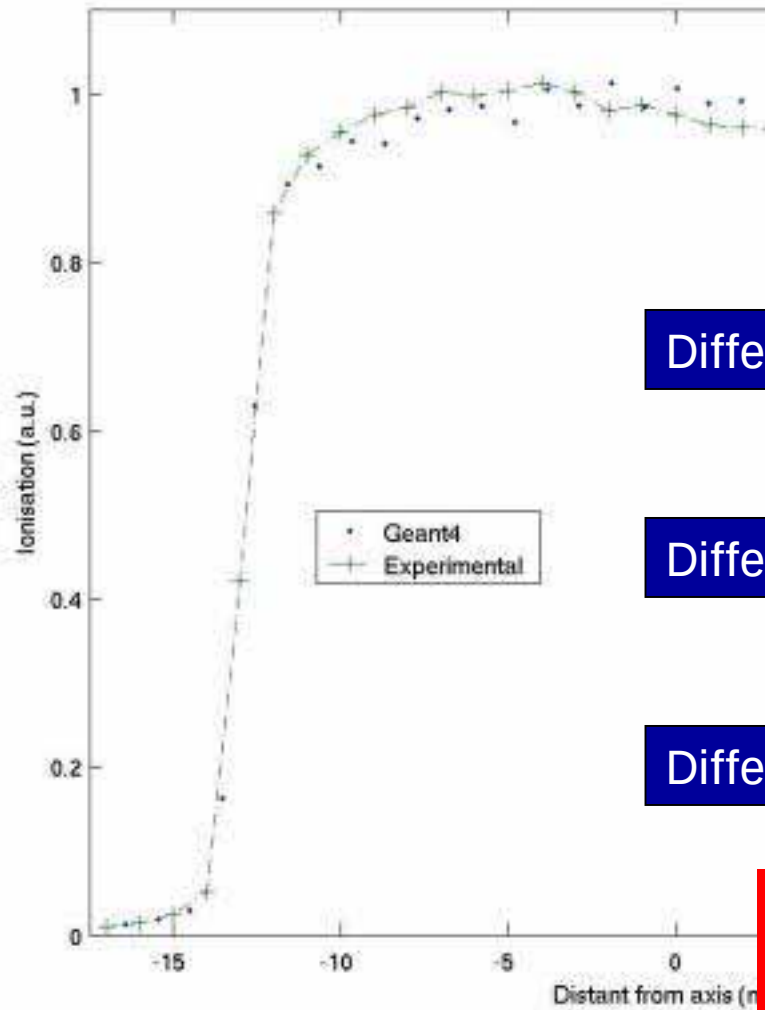
Physic models: comparison vs experimental data

Kolmogorov test		
materiale	P-value	**test**
Acqua	0.9876	Accettato
Rame	0.999	Accettato

Simulated and experimental range in water and copper



Lateral distributions: comparison vs experimental data



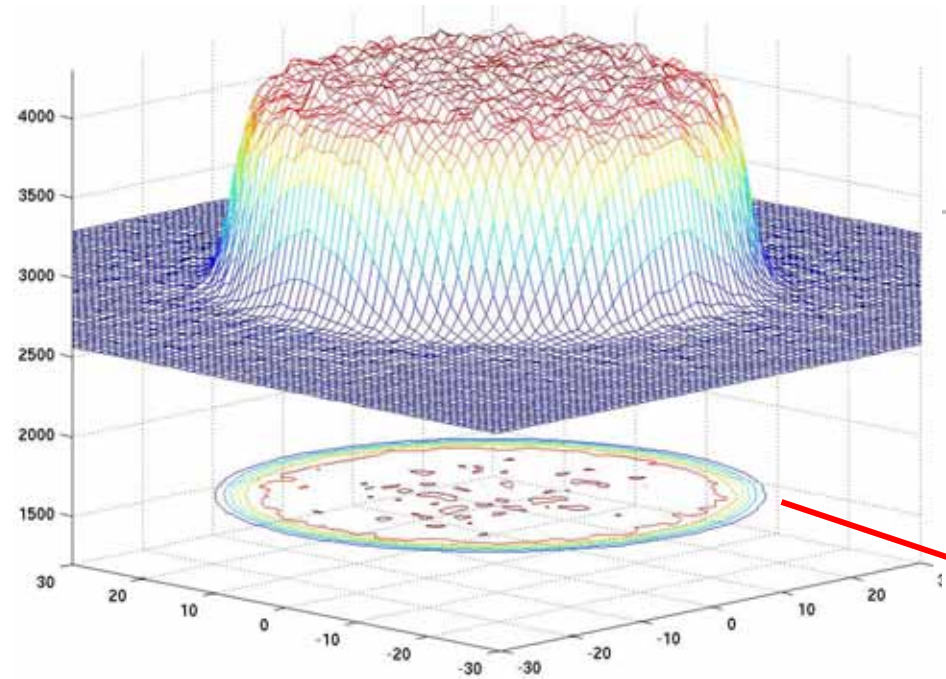
Difference in penumbra = 0.5 %

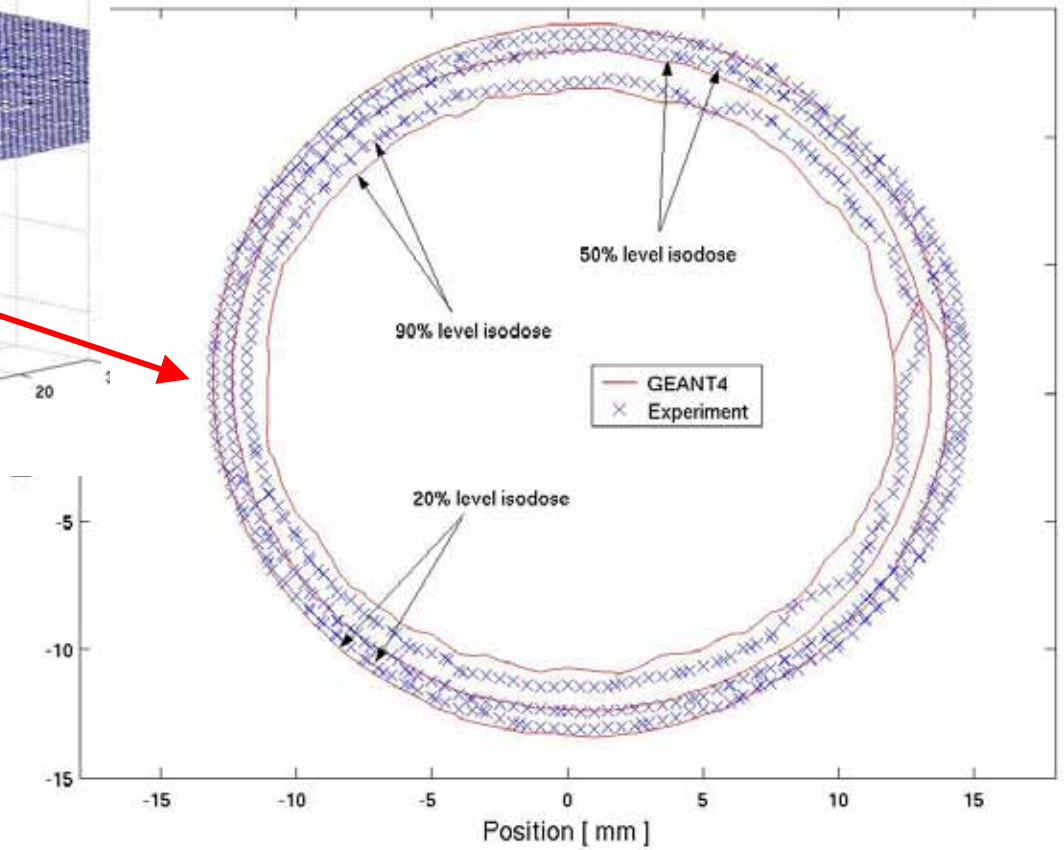
Difference in FWHM = 0.5 %

Difference Max in the homogeneity region = 2 %

Kolmogorov test:

$\chi^2 = 0.011$, p= 0.97, $\nu = 2$


4000
3500
3000
2500
2000
1500
30
20
10
0
-10
-20
-30


50% level isodose
90% level isodose
20% level isodose
GEANT4
Experiment
-5
-10
-15
-15
-10
-5
0
5
10
15
Position [mm]

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Monte Carlo in the clinical practice can be limited by the long calculation times

On the other hand *velocity* is mandatory for a medical physicis and a medical doctor when they are to plan a treatment

Now our application needs 12 hours to obtain a good information about dose distributions.

(Pentium 3 800 Mhz, 3 Mega protons simulated)

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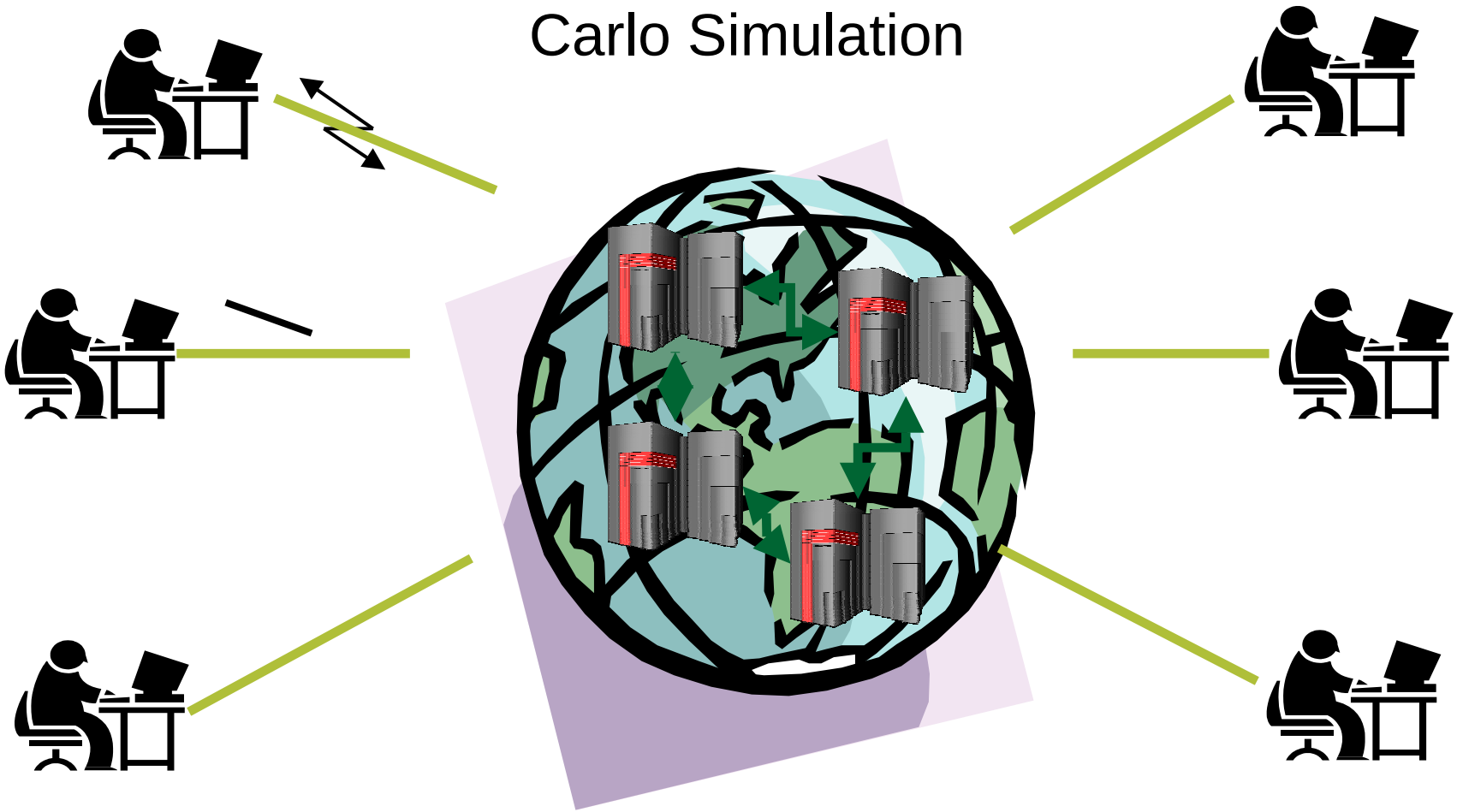
GRID should be a solution for time problem of a Monte Carlo Simulation



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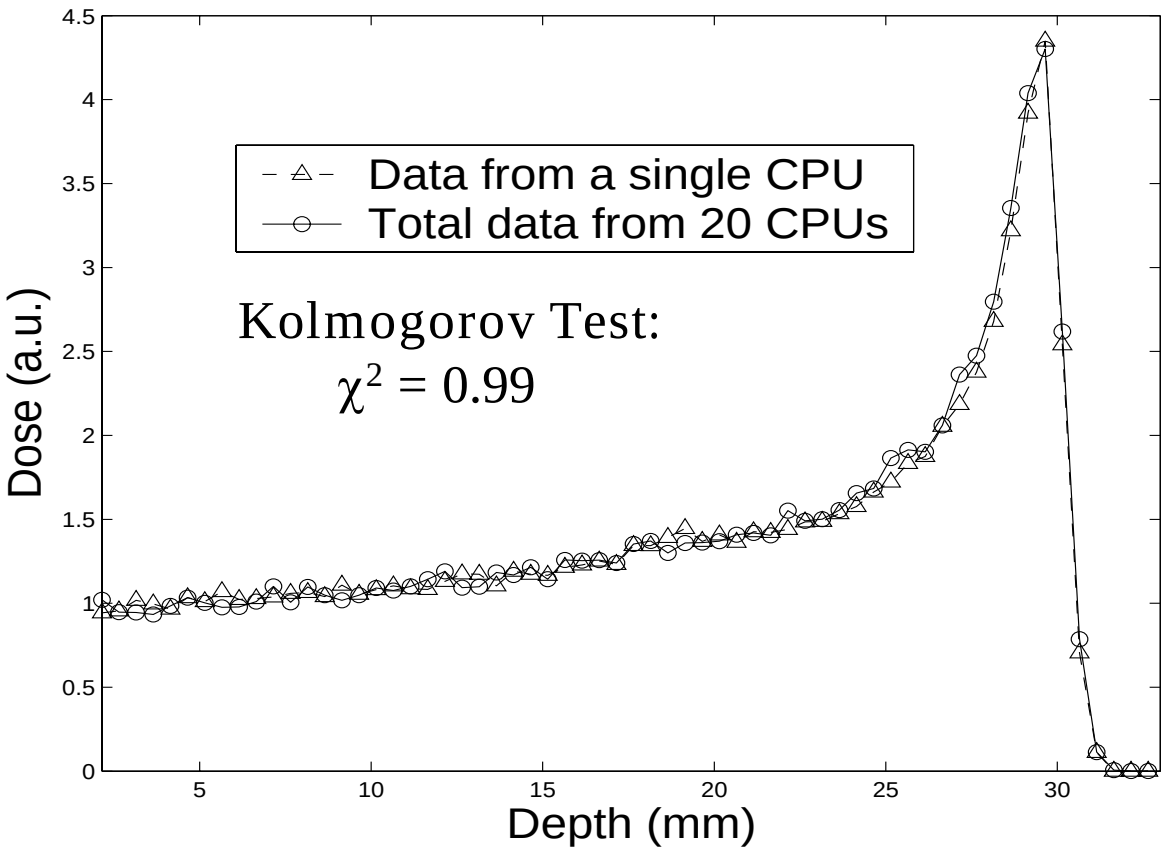
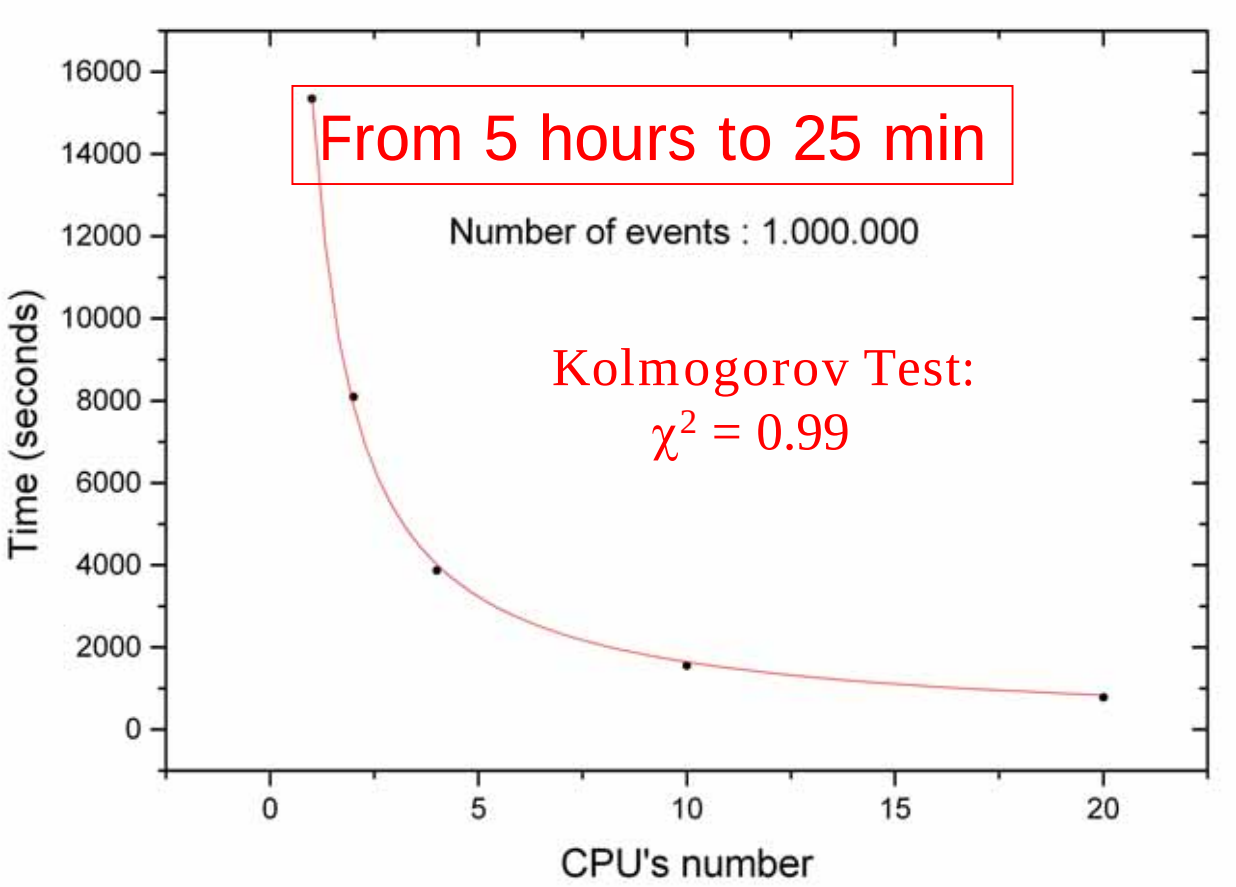
GRID implementation

- RPM for a simpler installation on the GRID;
- No change of the specific application C++ code;
- FUTURE: investigation for the use of GEANT4 for a MC treatment planning system



Any GEANT4 application can run on the GRID in the same manner

GRID implementation



Any GEANT4 application can run on the GRID in the same manner

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HADRON THERAPY - Microsoft Internet Explorer

File Modifica Visualizza Preferiti Strumenti ?

Indietro Cerca Preferiti Multimedia

Indirizzo C:\temp\hadron_therapy.htm Vai Collegamenti

HADRON THERAPY

CONFIGURATION PANEL

Submit Reset FILE NAME

Submit Reset BEAM ENERGY

Bragg Peak Submit Reset DISTRIBUTION CHOSEN

Bragg Peak
Spread Out Bragg Peak
Lateral Distribution

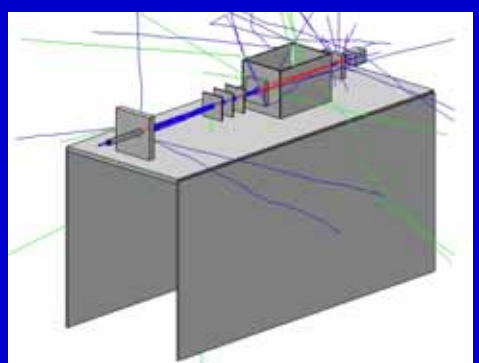
Submit Reset THICKNESS DEGRADER

bmit Reset NUMBER OF EVENTS

Submit Reset NUMBER OF JOBS

Submit Reset VISUALIZATION

GRAPHICS OUTPUT



Operazione completata

Risorse del computer

Start conferenz... Microsoft ... Calcolatrice temp HADRON ... Microsoft ... IT 22.06

G4EMU

The Geant4 European Medical User Organization

http://g4emu.wikispaces.com/

We are planning to launch the group for the rapidly growing Geant4 medical user community of Europe.
The purpose of G4EMU is to bring Geant4 medical users together to share issues and practical advice, and to develop collaboration in Europe.

12th Geant4 Collaboration Workshop

from **Thursday 13 September 2007 (09:00)**
to **Wednesday 19 September 2007 (18:00)**
The first days open to the users

Supported by


Thank you for your attention