The GEANT4 toolkit capability in the hadron-therapy field: simulation of a transport beam line

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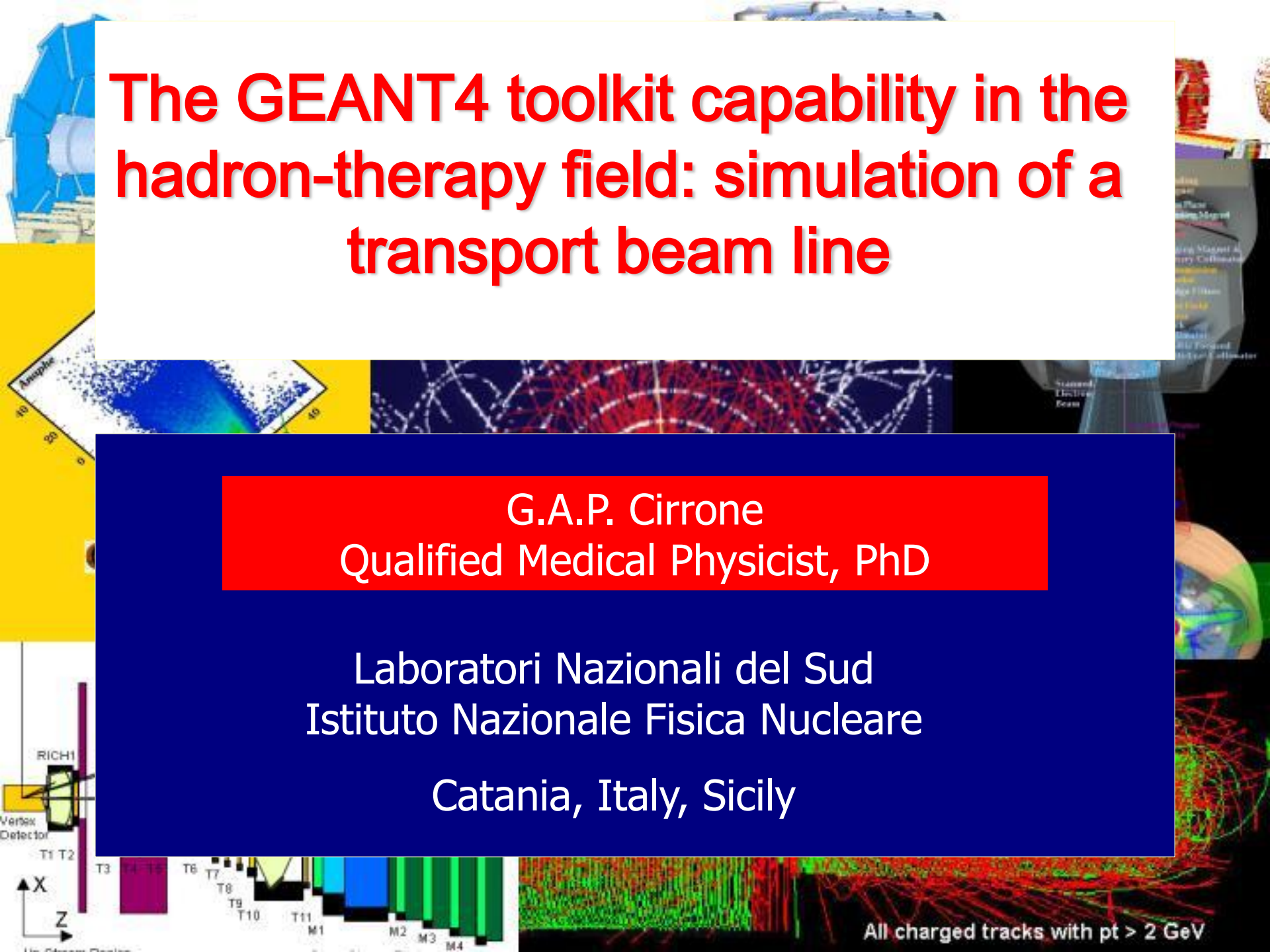
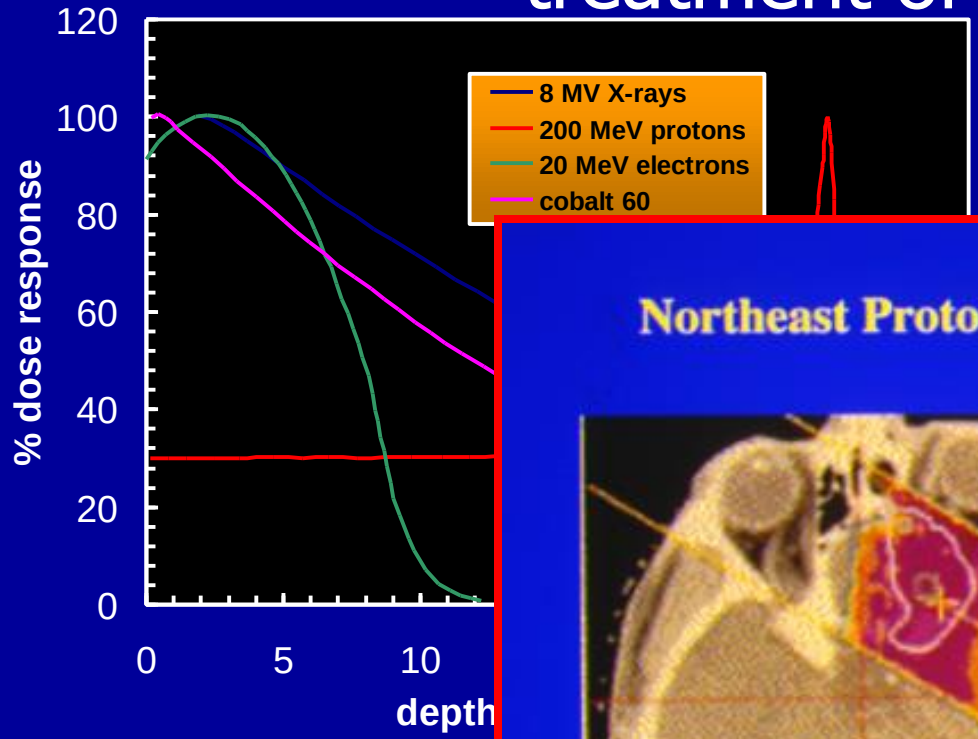
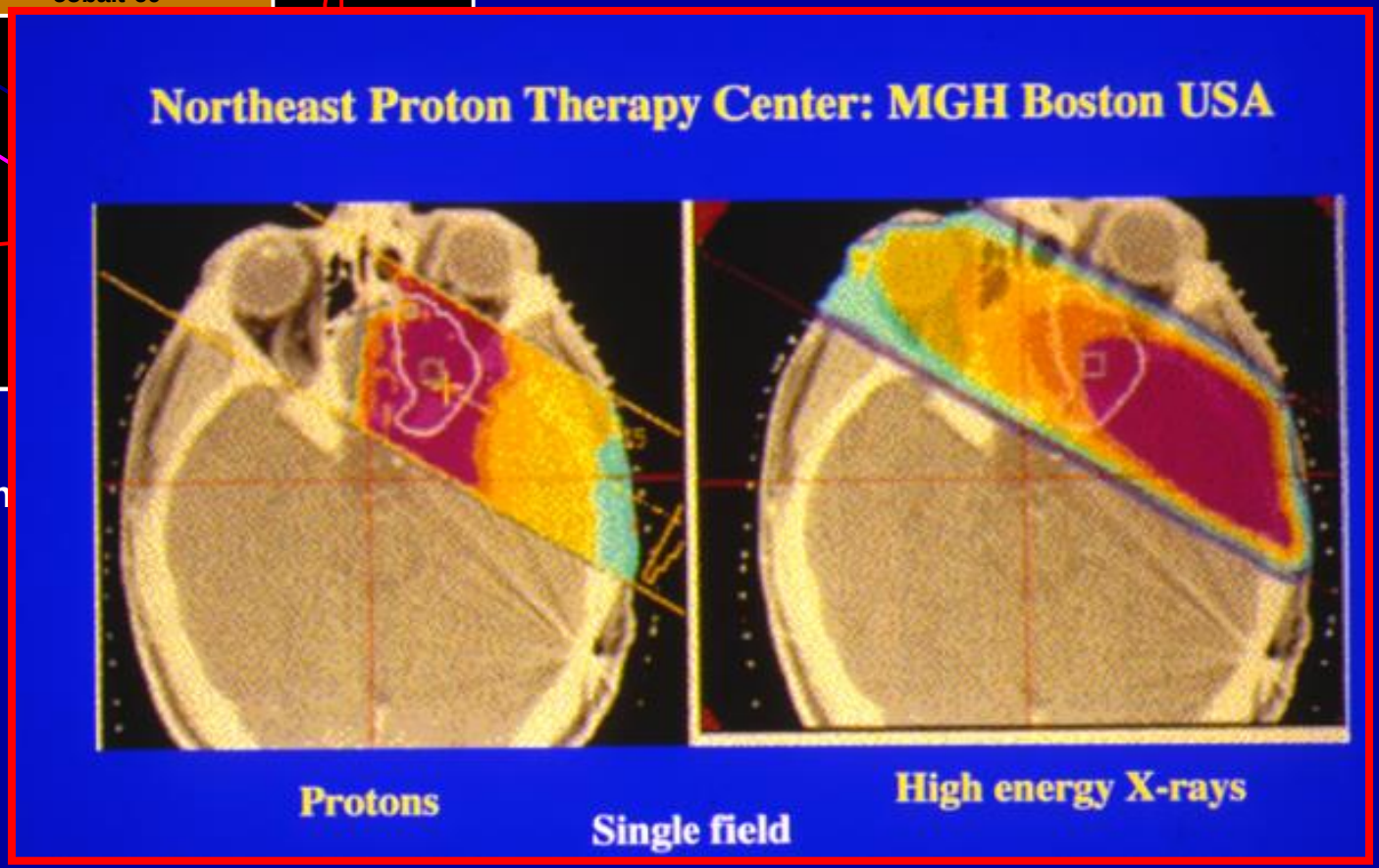


What is the hadron-therapy?

Use of ions for the radiotherapeutic treatment of tumours





So we can answare to the question: Why clinical proton beams?

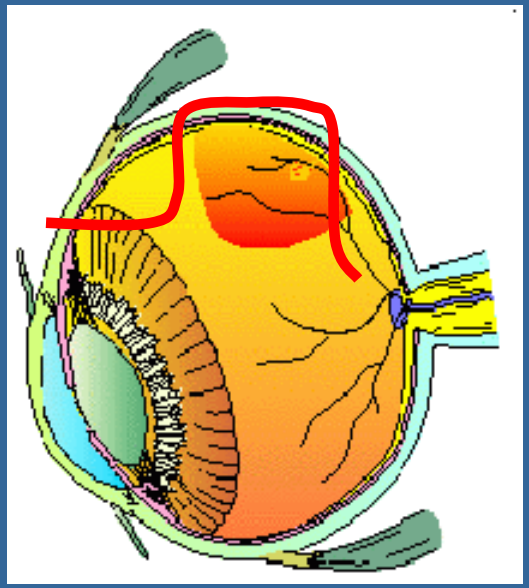
- penetration depth is ***well-defined*** and ***adjustable***
- most energy at ***end-of -range***
- protons travel in ***straight lines***
- dose to ***normal tissue*** minimised
- **no dose** beyond target

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

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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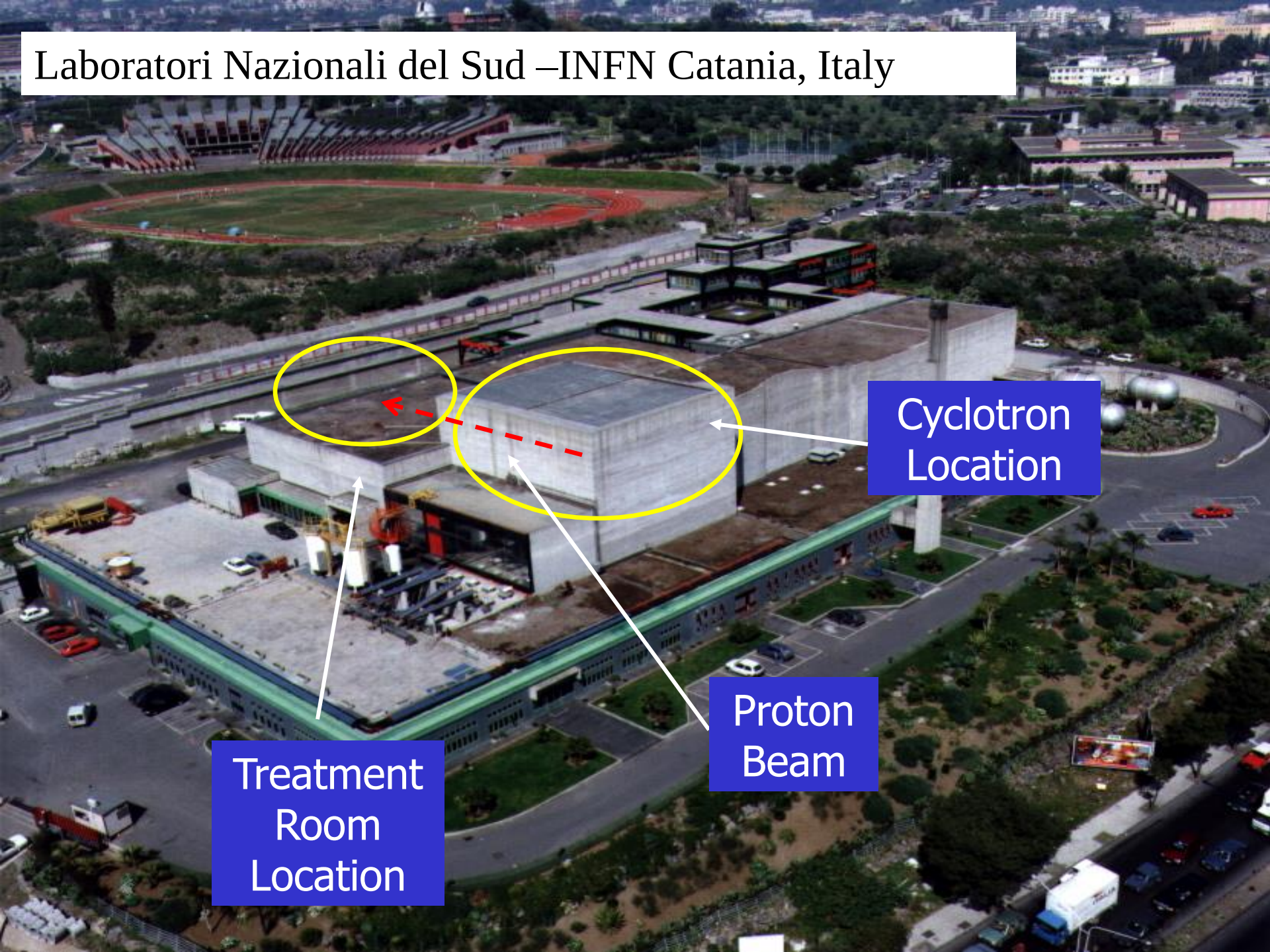
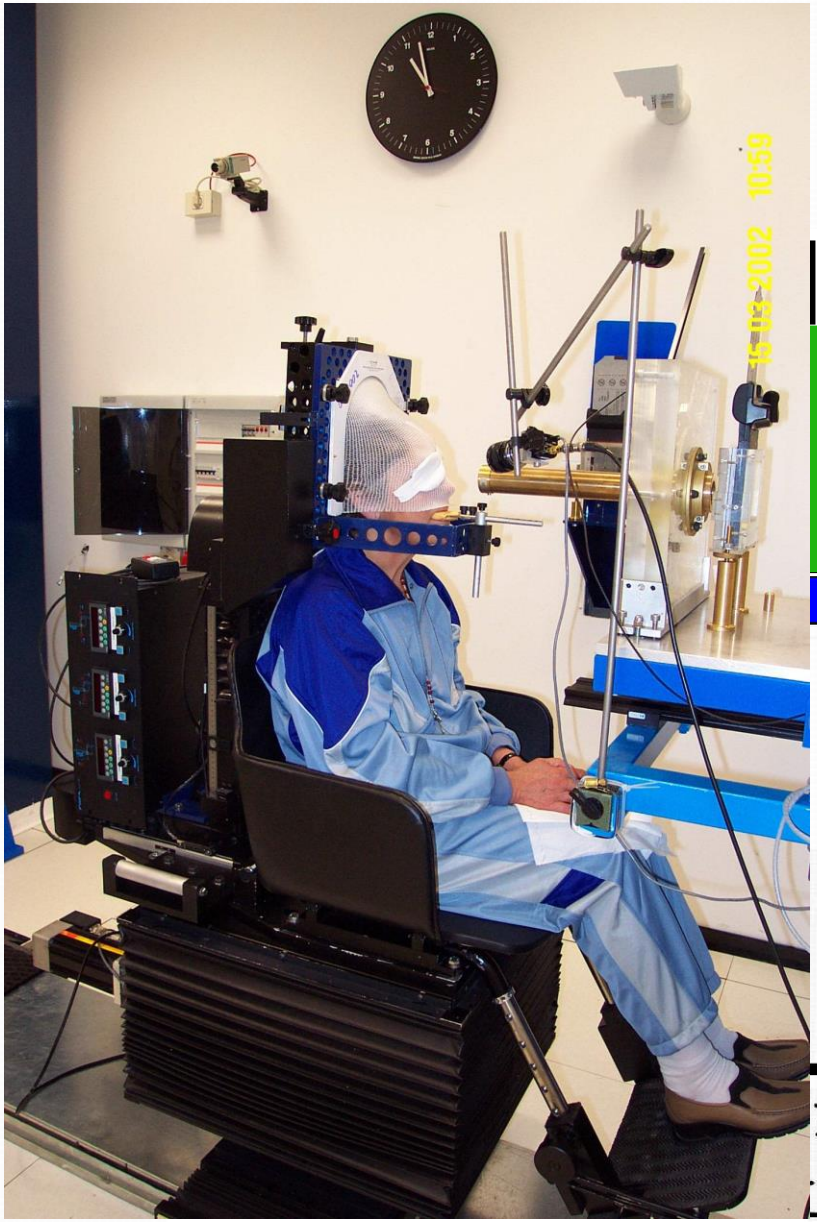
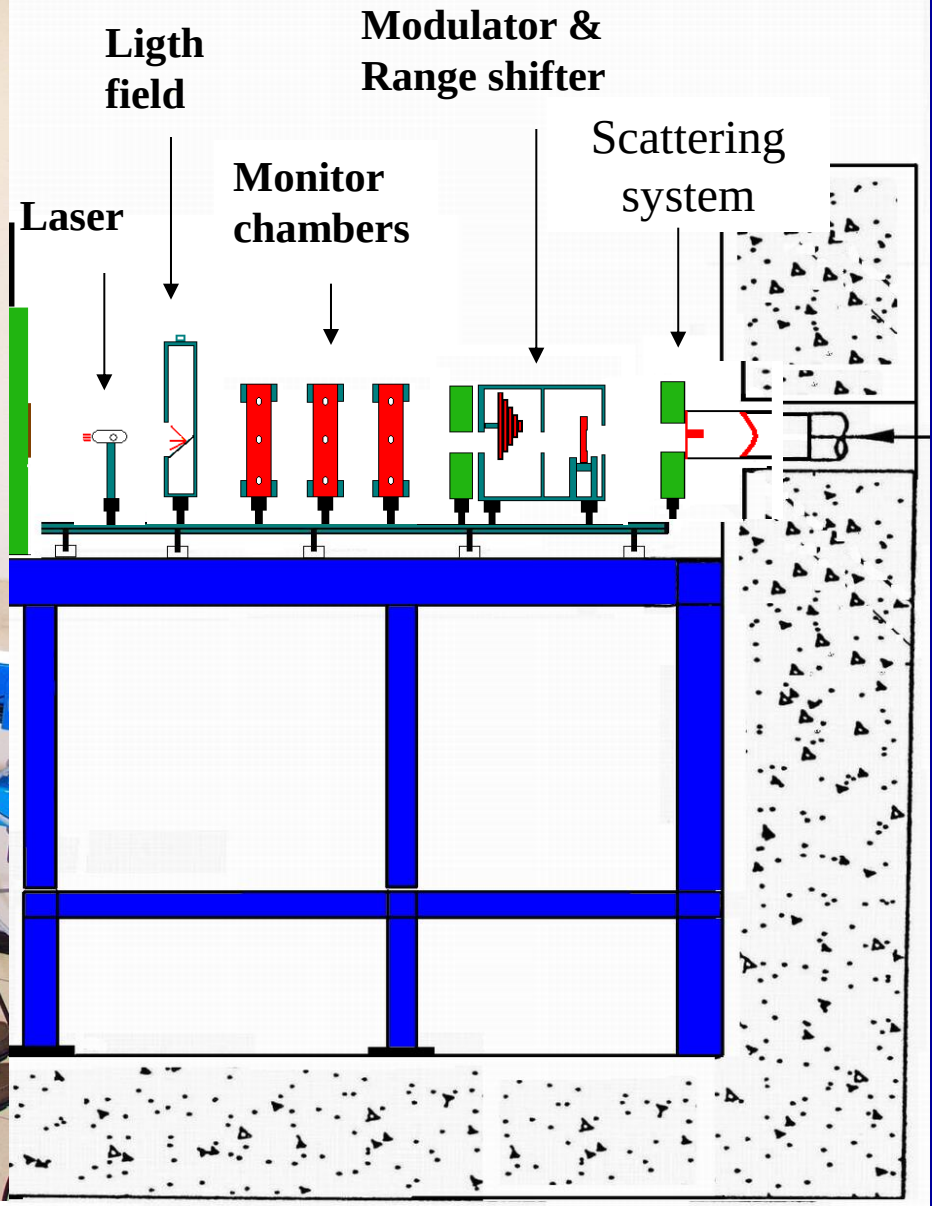
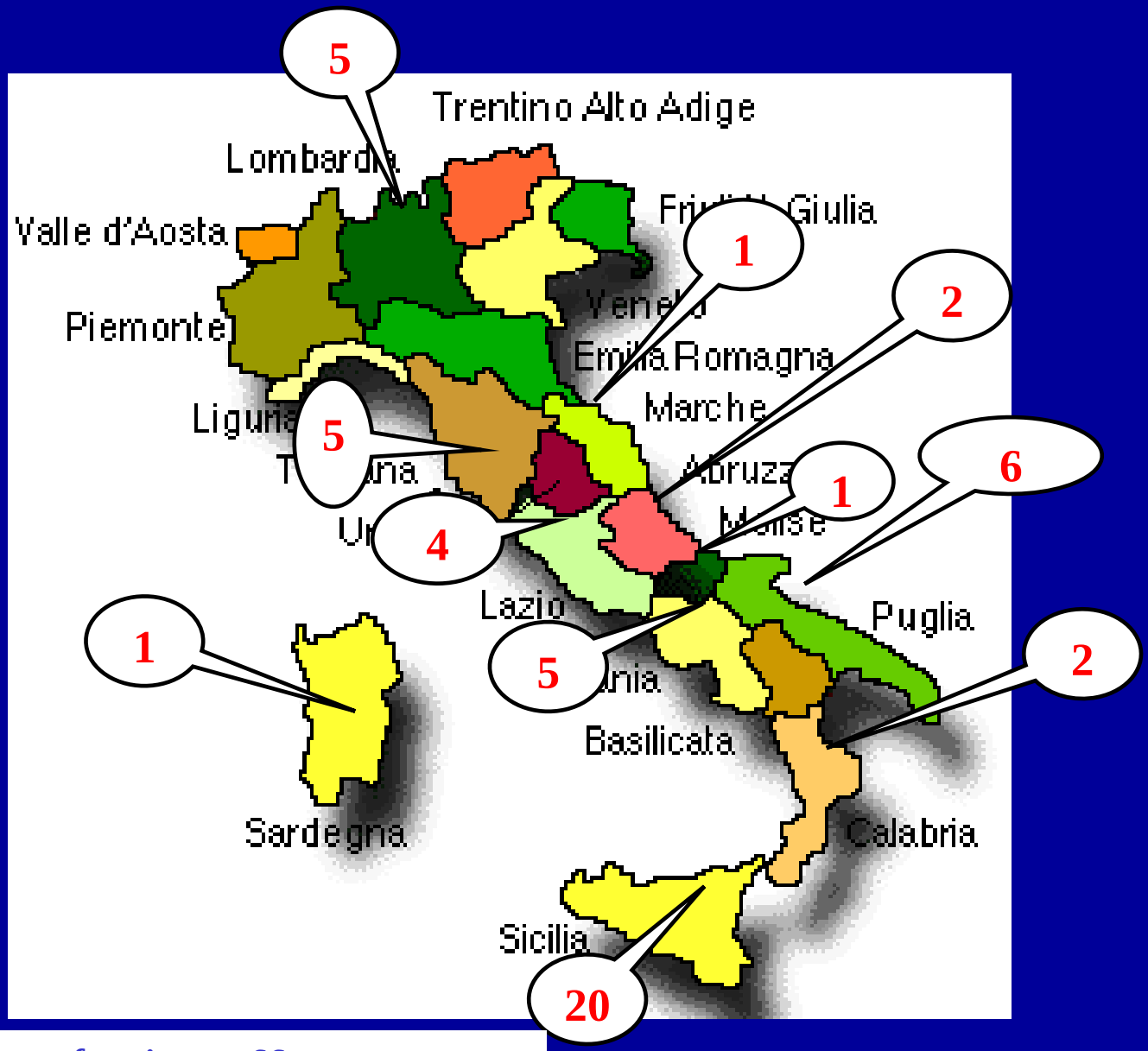





Ligth field
Modulator & Range shifter
Laser
Monitor chambers
Scattering system


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

Patient Distribution by Origin Region



N.B Total number of patients : 66

Why to start a Simulation Work ?

Therapy with hadrons still represents a pioneering technique

Today the development of a hadron-therapy facility requires a long experimental work due to the lack of SIMULATION TOOLS

Our work is inserted in the more general **medical-physics GEANT4 activity** and represents just a different application of a more general approach in the medical-physics field

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:

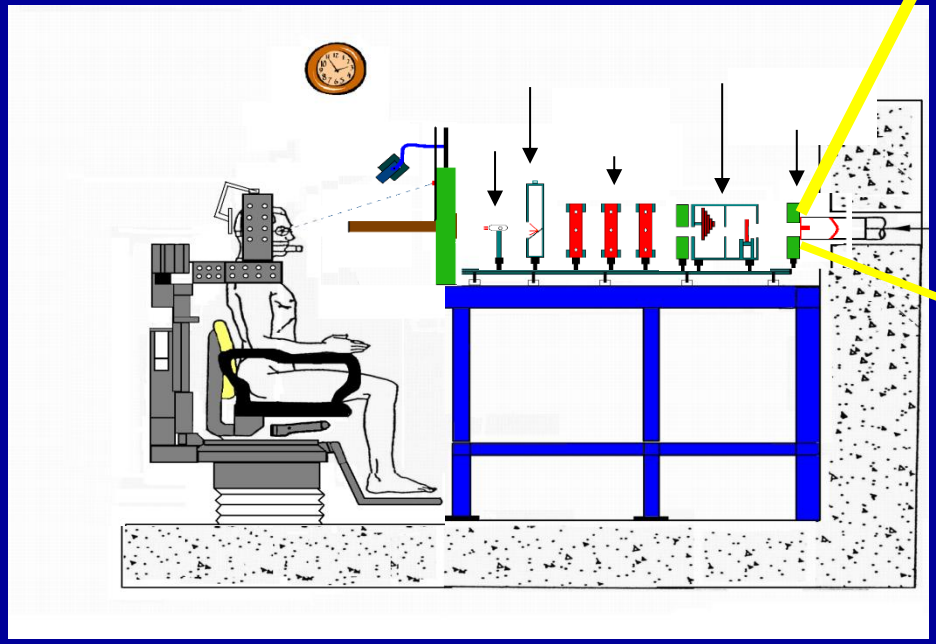
hadronTherapy.cc

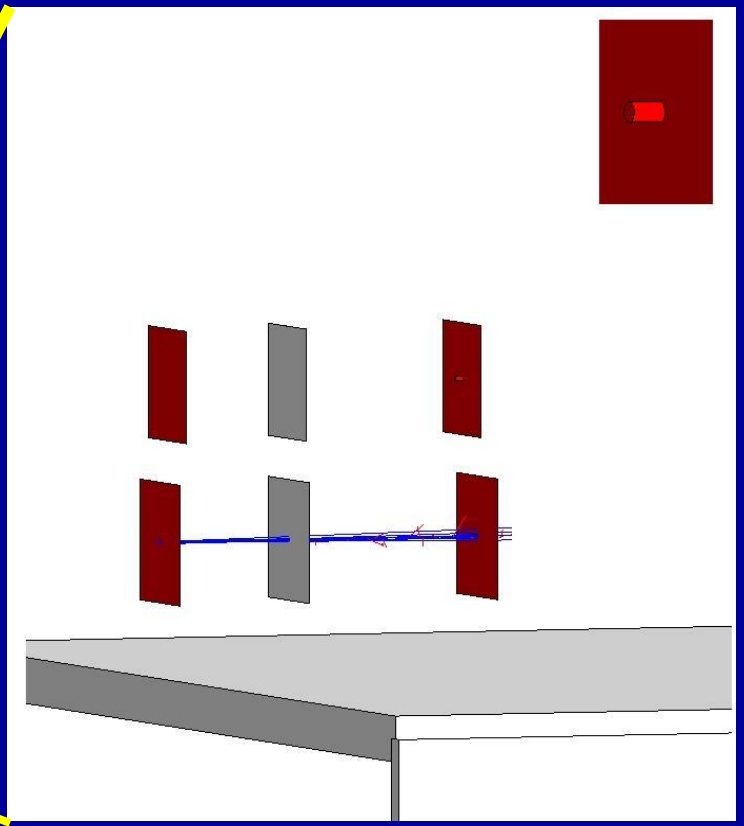
Complete simulation of CATANA hadron-therapy beam line with two dosemeters

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

BEAM LINE SIMULATION

Beam Line Simulation: Scattering system



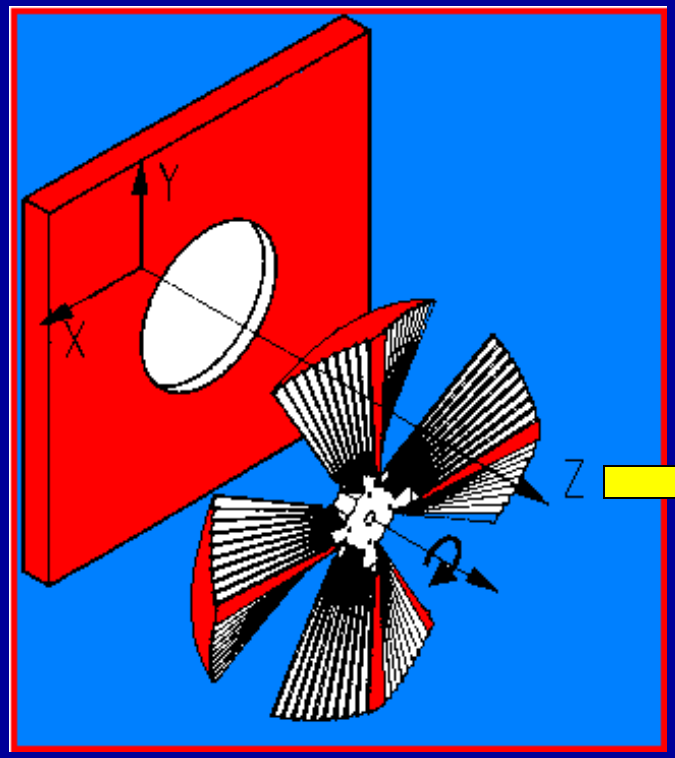


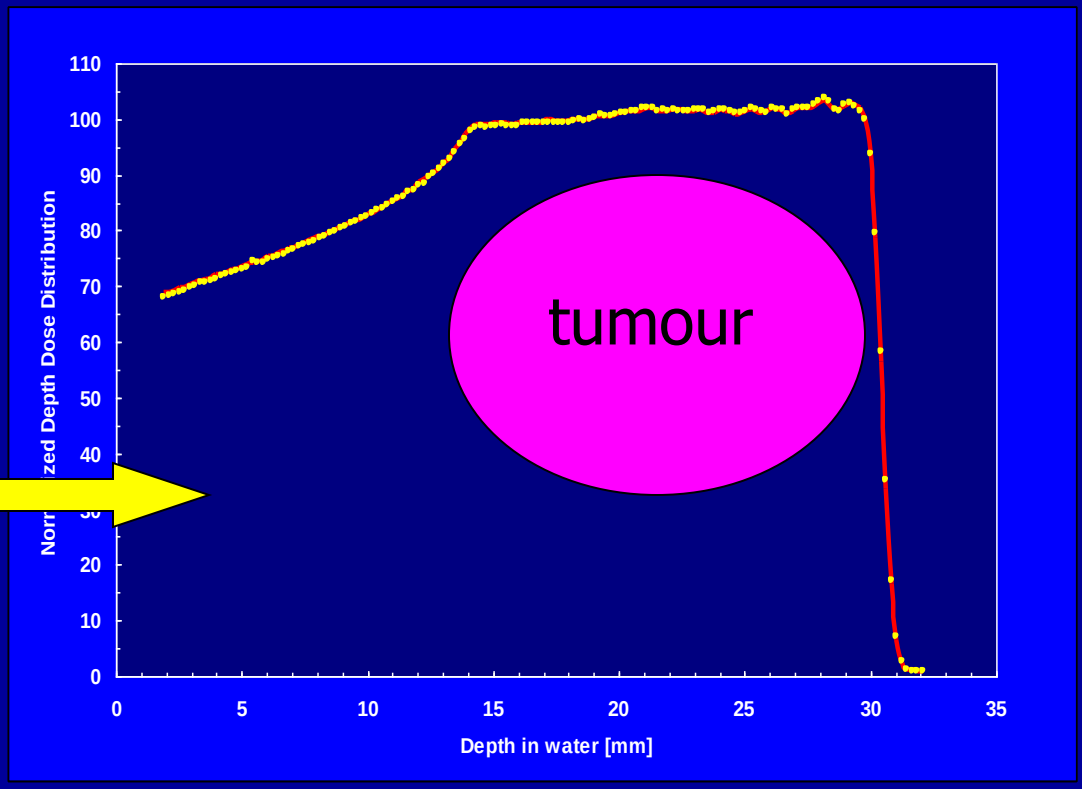
DOUBLE SCATTERER FOIL WITH CENTRAL STOPPER

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

Modulator Wheel: time dependent simulation

Modulator simulation for the SOBP reconstruction

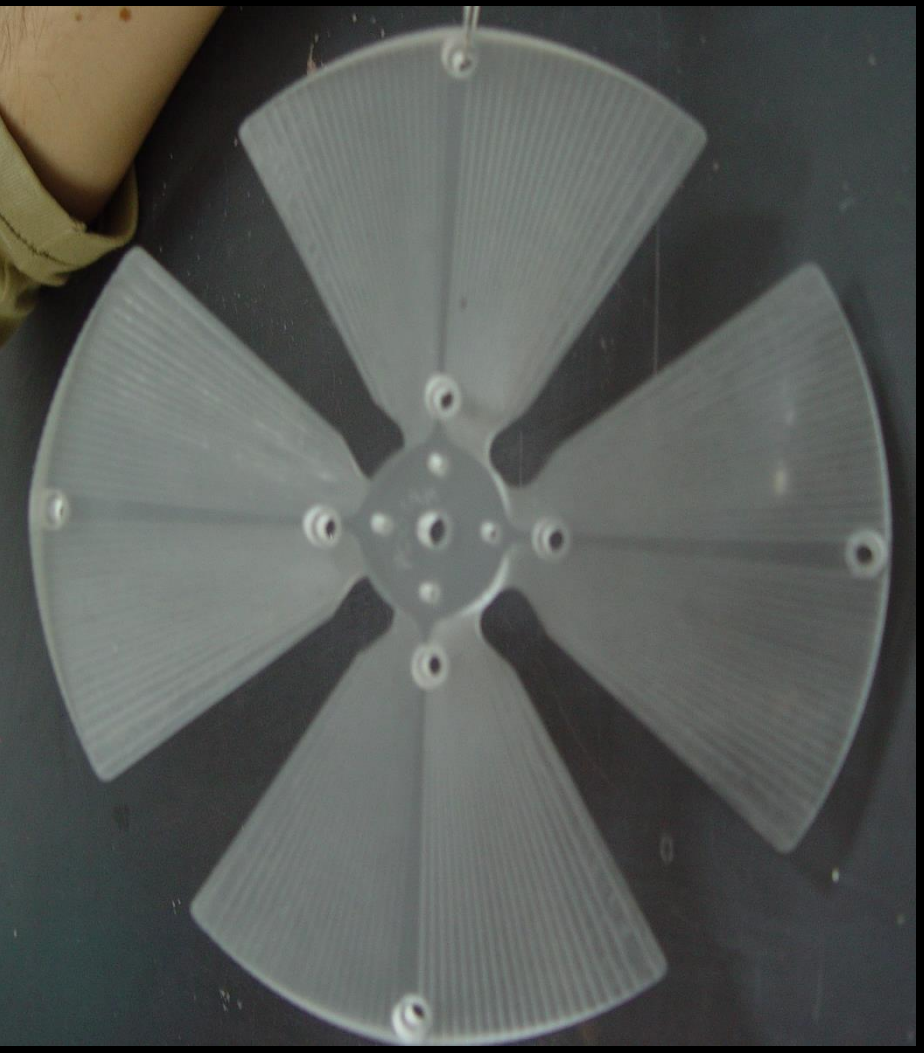




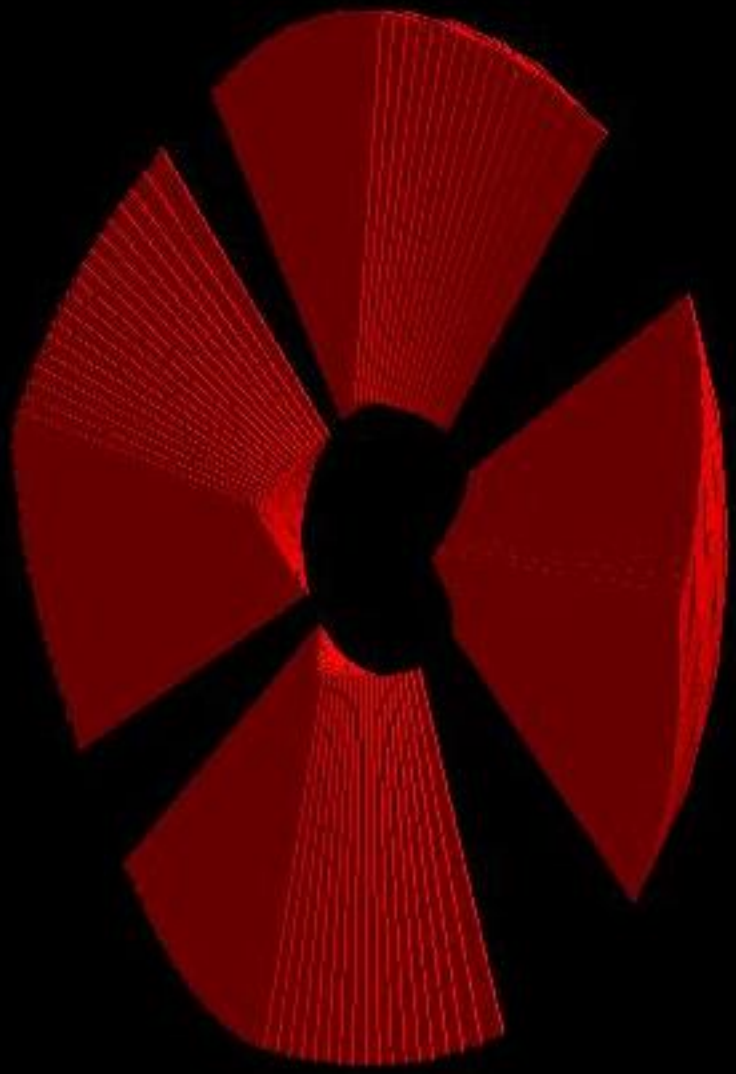
During the simulation the wheel rotates producing the flat dose distribution

Modulator wheel: time dependent simulation

Real Modulator



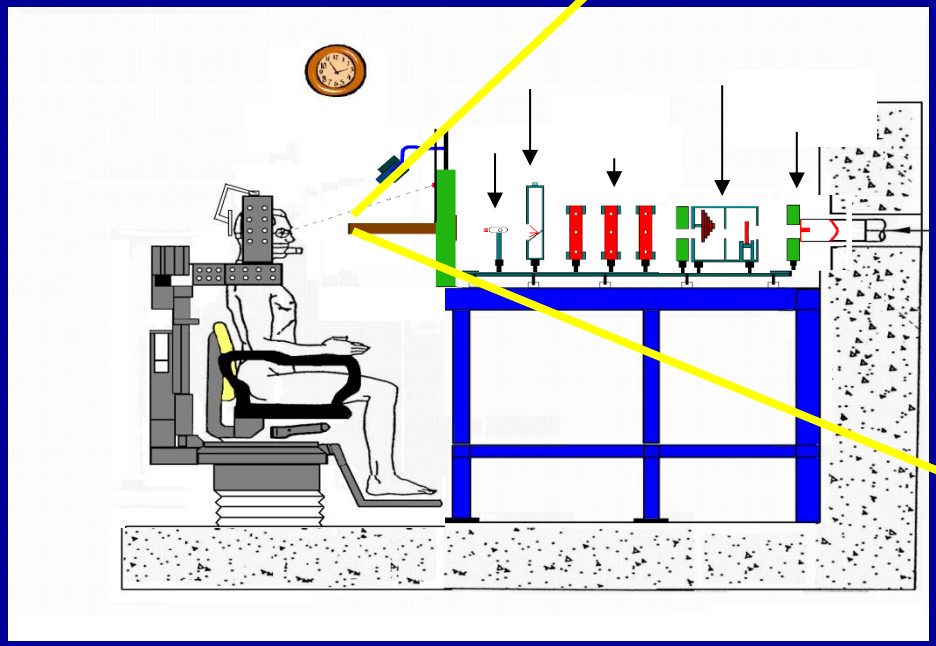
Geant4 Modulator

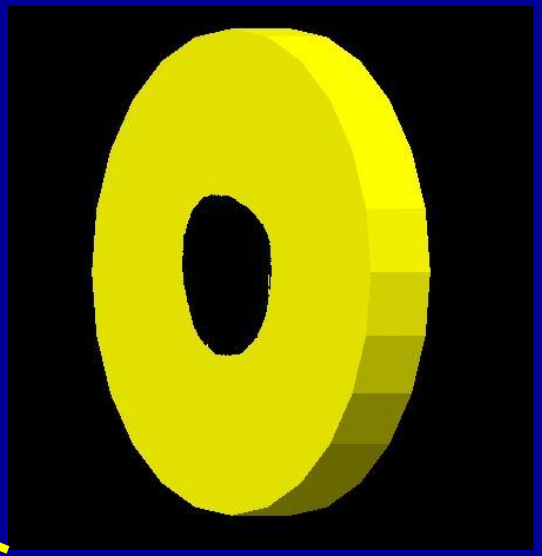


Beam Line Simulation: The Final Collimator

Simply using the G4Tubs class

This collimator has a shape dependents by the particular tumour





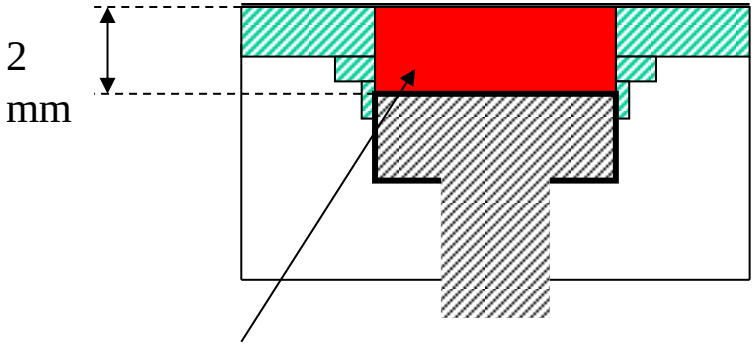
DETECTORS SIMULATION

Simulation of the dosemeters: ionisation chamber and radiographic film

DEPTH DOSE DISTRIBUTION

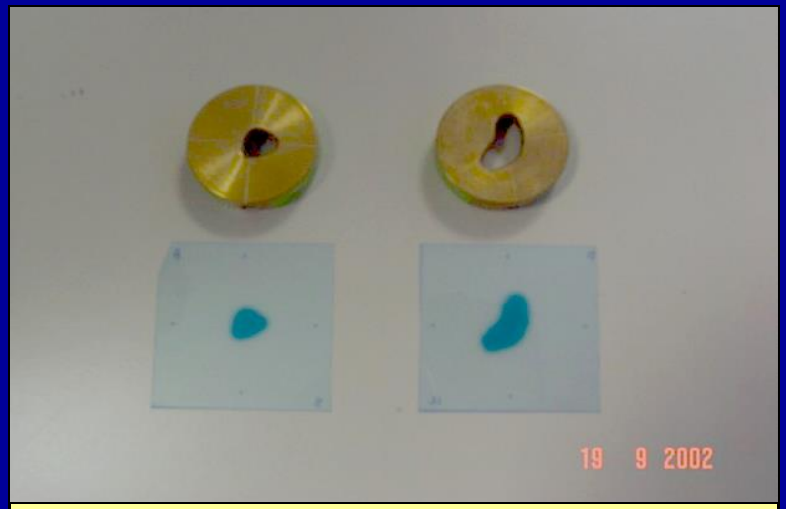
LATERAL DOSE DISTRIBUTION

- Markus Ionization chamber



Markus Chamber layout

- GAF Chromic Film

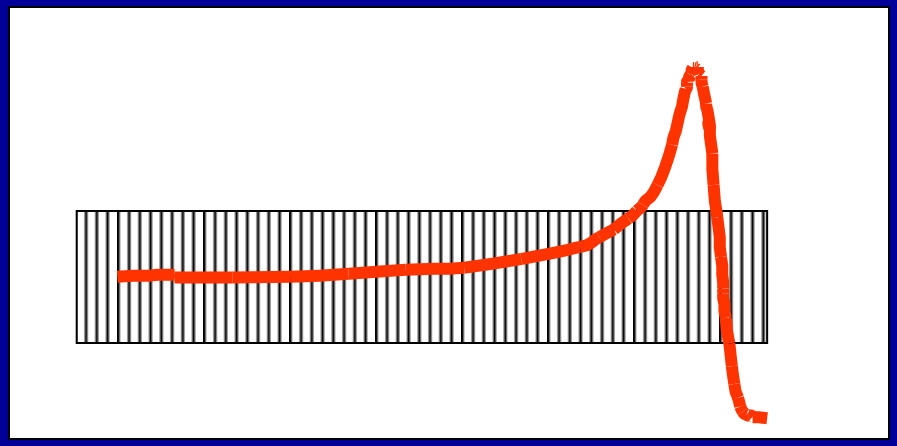


Irradiated GAF Chromic

Resolution 100 μm for DDP and 200 μm for LDP

Bragg Curve Reconstruction with the Markus ionisation chamber

Detector is simulated with
20 K air cylindrical slices, 200 μm thick
to reproduce experimental Markus chamber responce



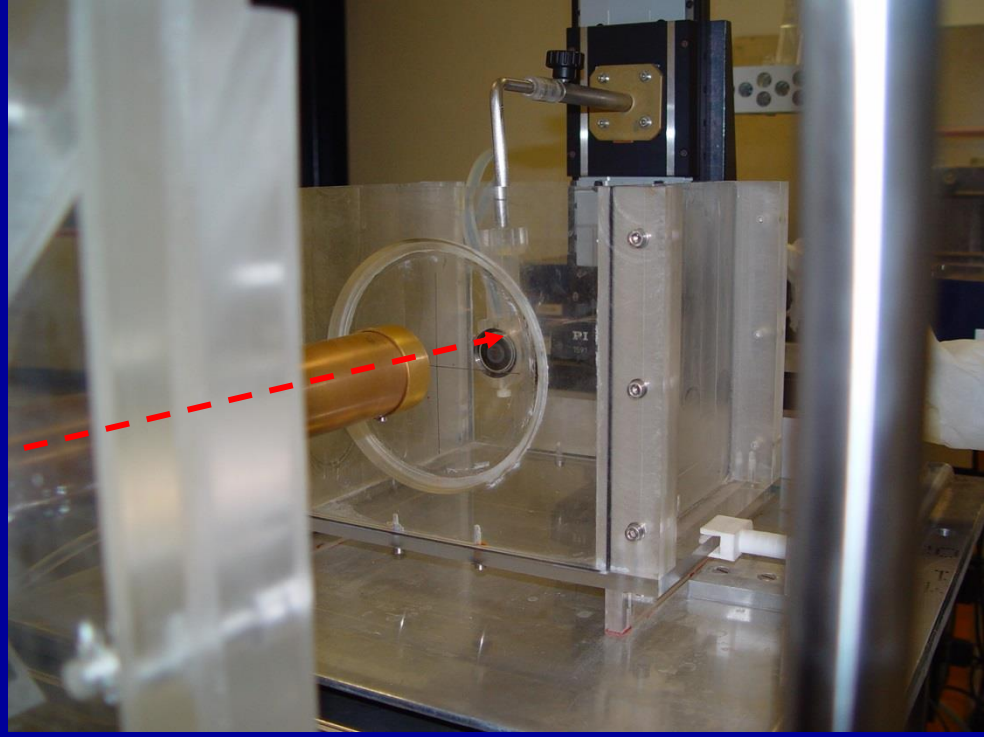
Energy deposited in each slice is collected

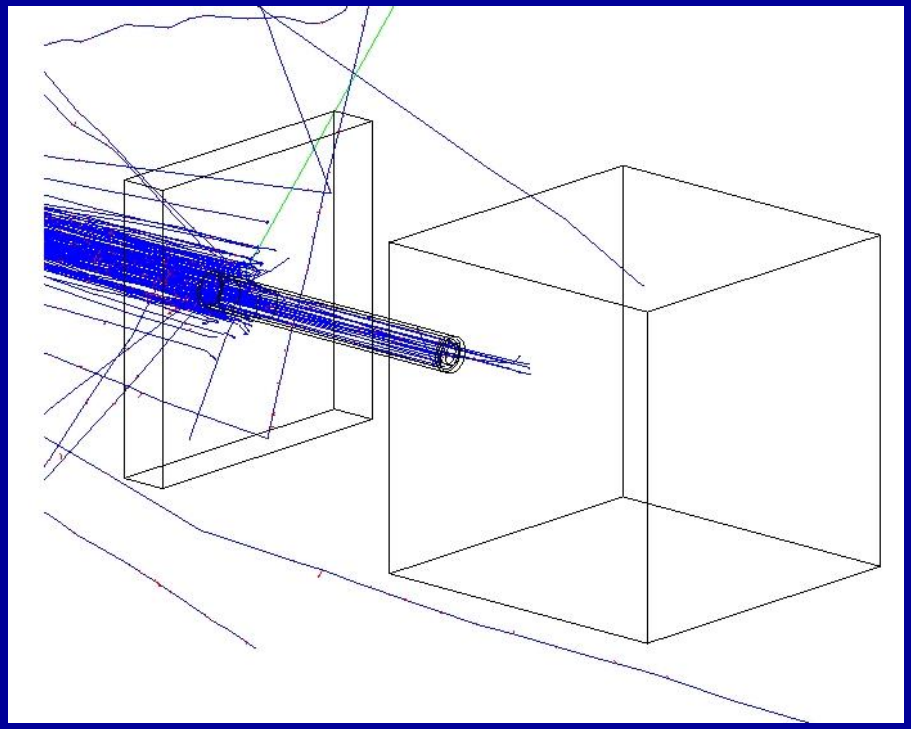
In progress implementation: ROGeometry

We calculated range values for the detector simulation validation from Bragg curve

Bragg Curve Reconstruction

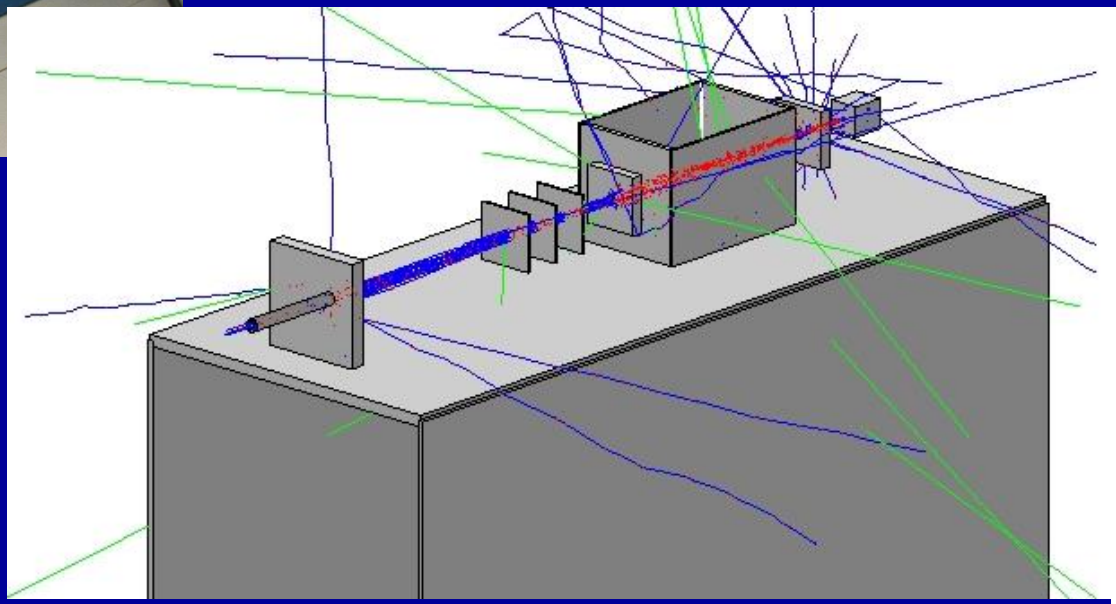
Water box with ionisation chamber





Water box + detector for Bragg curve as simulated

Real hadron-therapy beam line



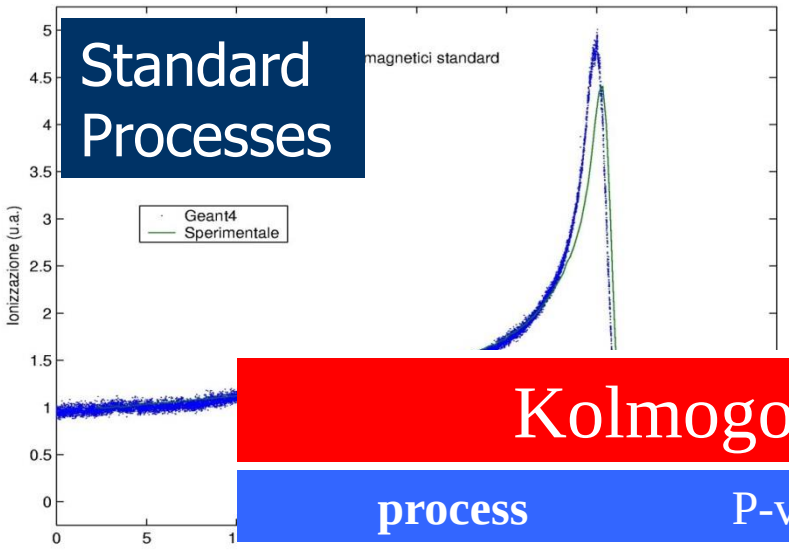
GEANT4 simulation

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

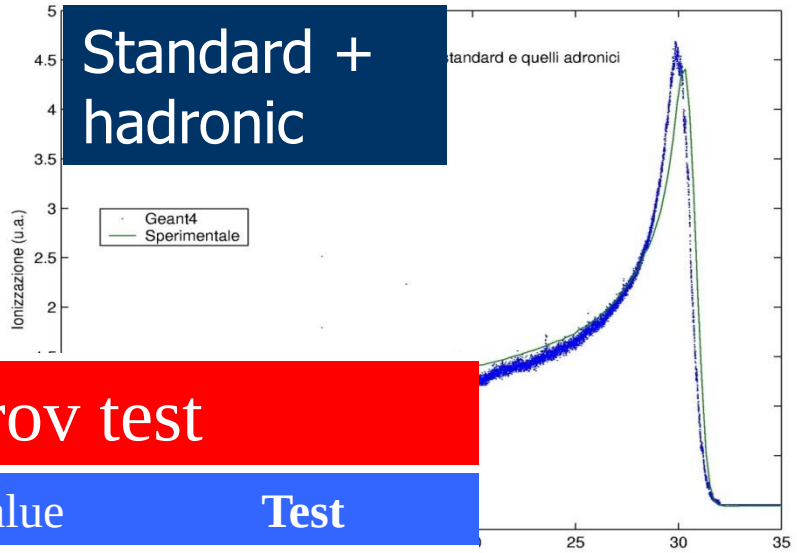
RESULTS AND VALIDATION

Physics models: comparison with experimental data

Standard Processes



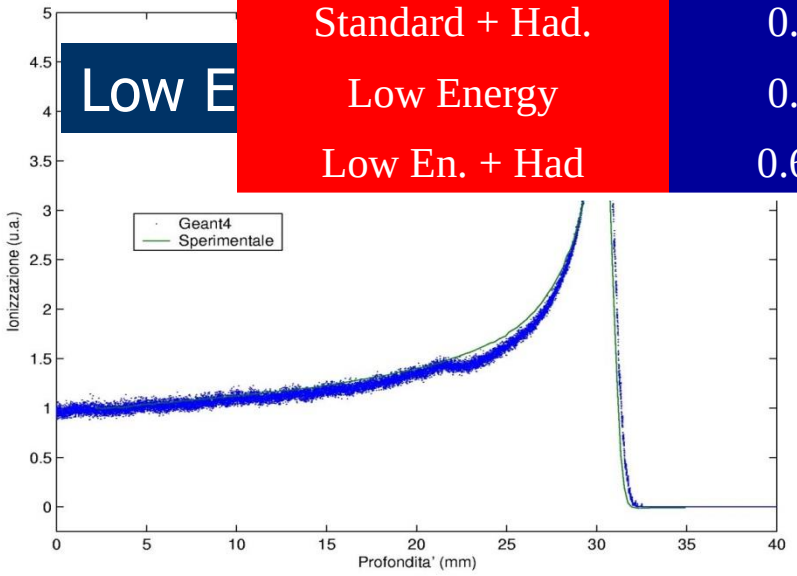
Standard + hadronic

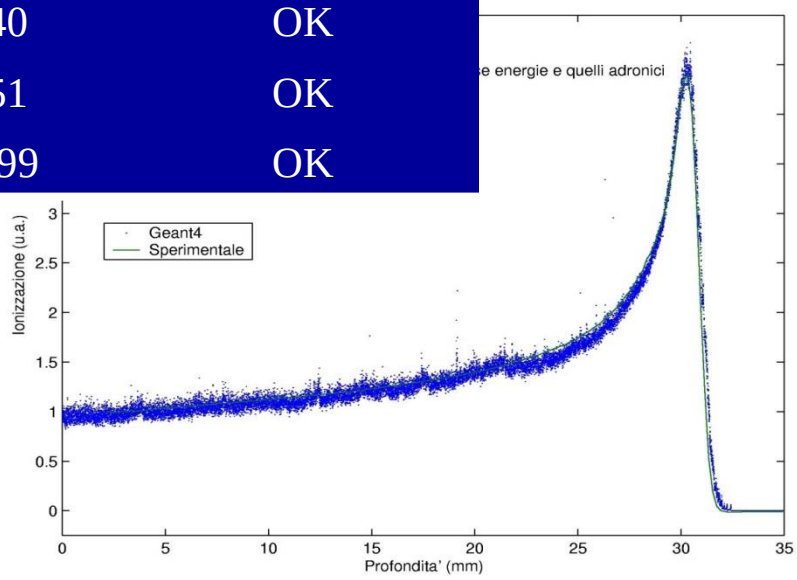


Kolmogorov test

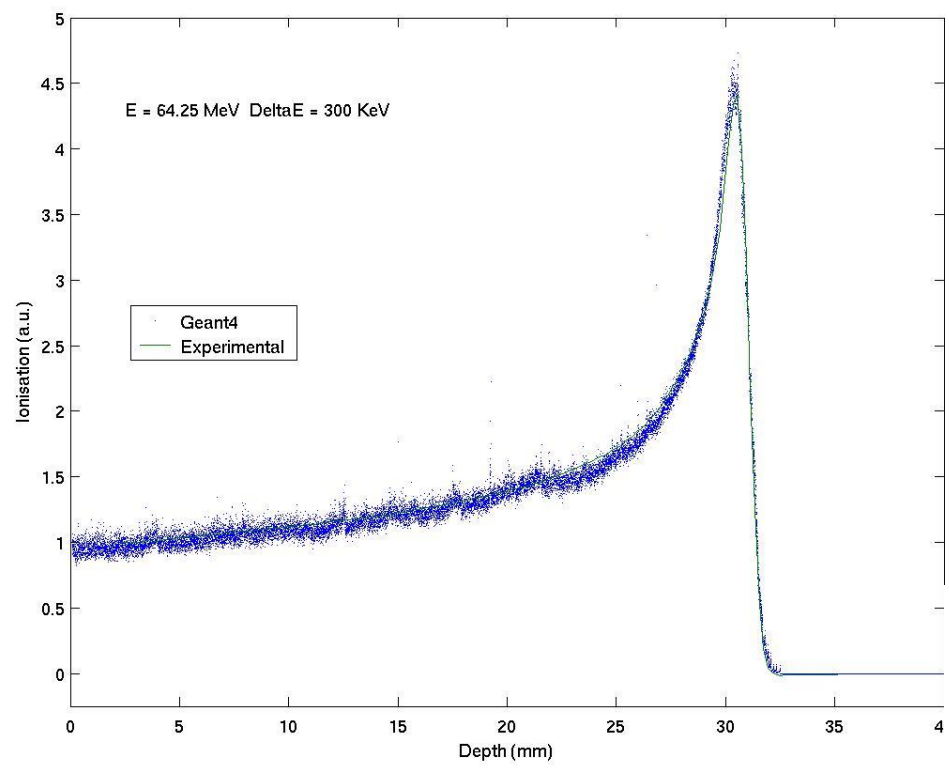
process	P-value	Test
Standard.	0.069	OK
Standard + Had.	0.40	OK
Low Energy	0.51	OK
Low En. + Had	0.699	OK

Low E



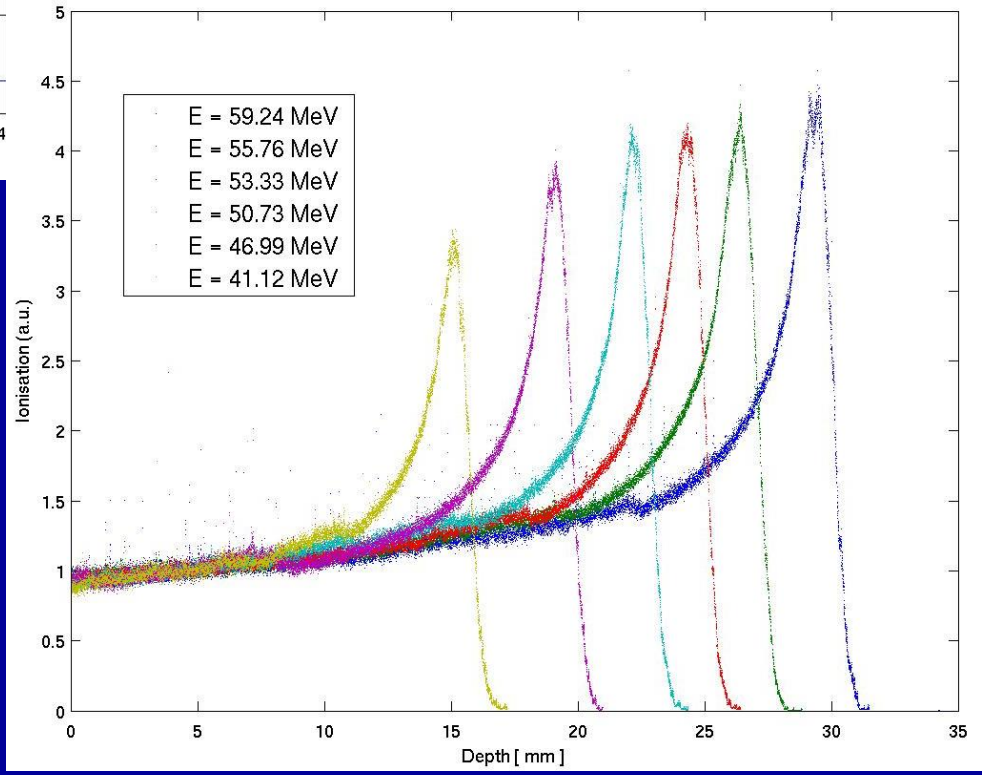


Experimental data comparison

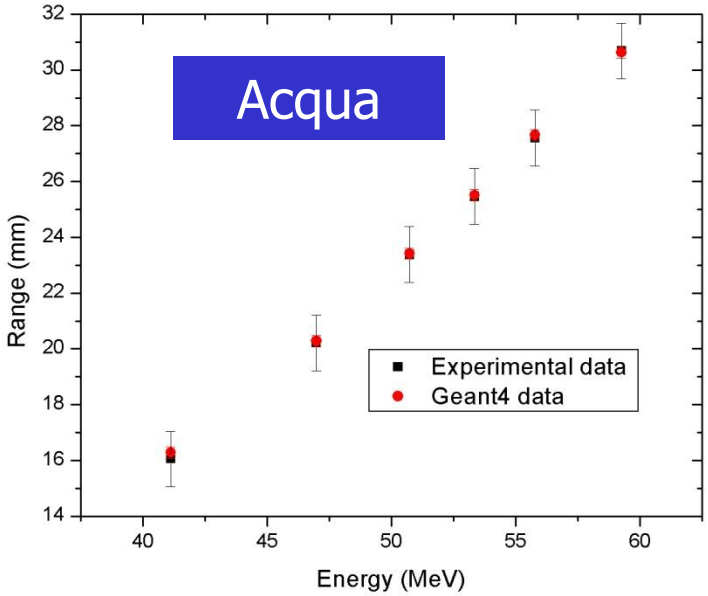


Low energy libraries and hadronic physics

Bragg peaks at diferent energies

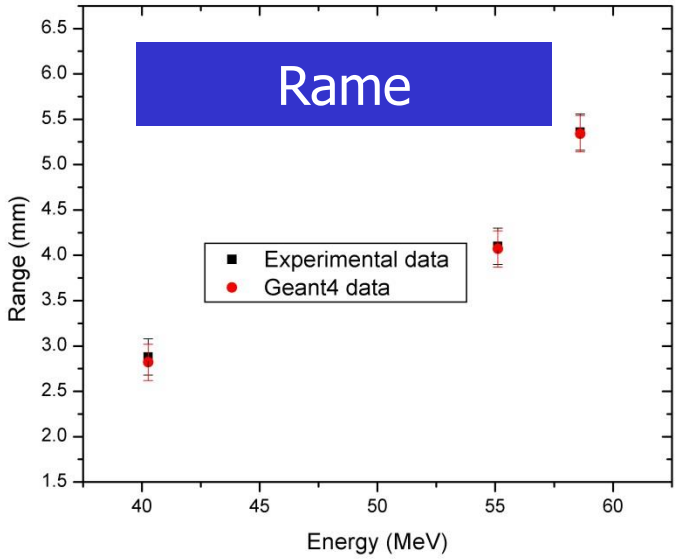


Experimental Data Comparison

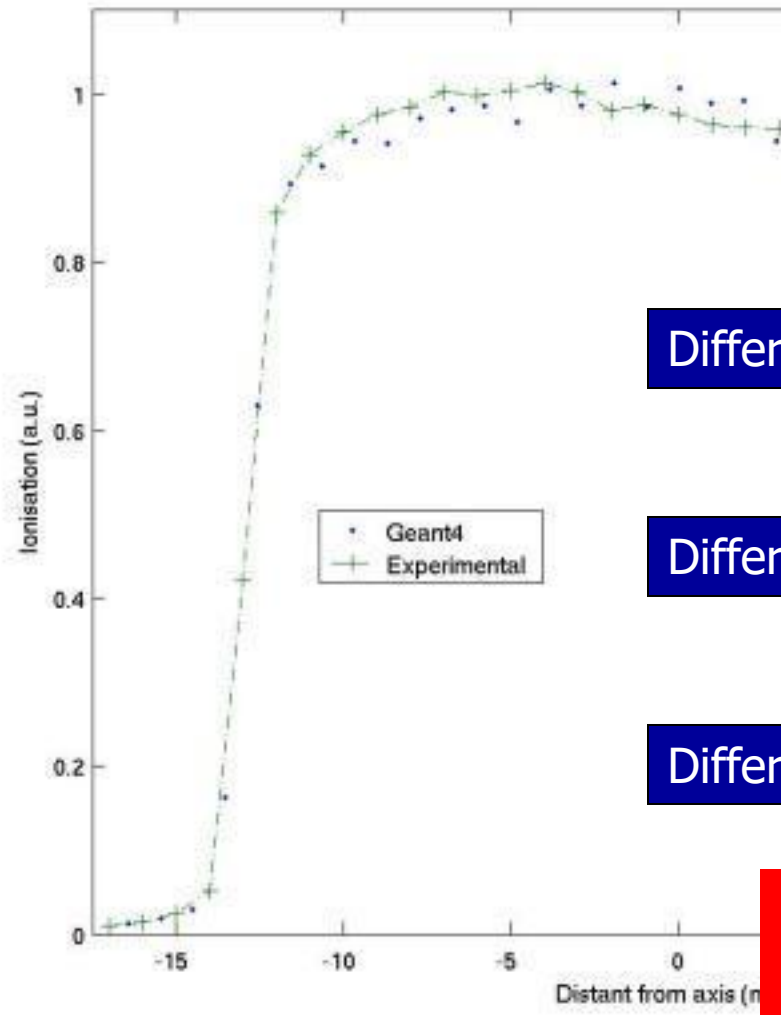


Kolmogorov test		
materiale	P-value	**test**
Acqua	0.9876	Accettato
Rame	0.999	Accettato

Simulated and experimental range in water and copper



Lateral Distribution: comparison with experimental data



Difference in penumbra = 0.5 %

Difference in FWHM = 0.5 %

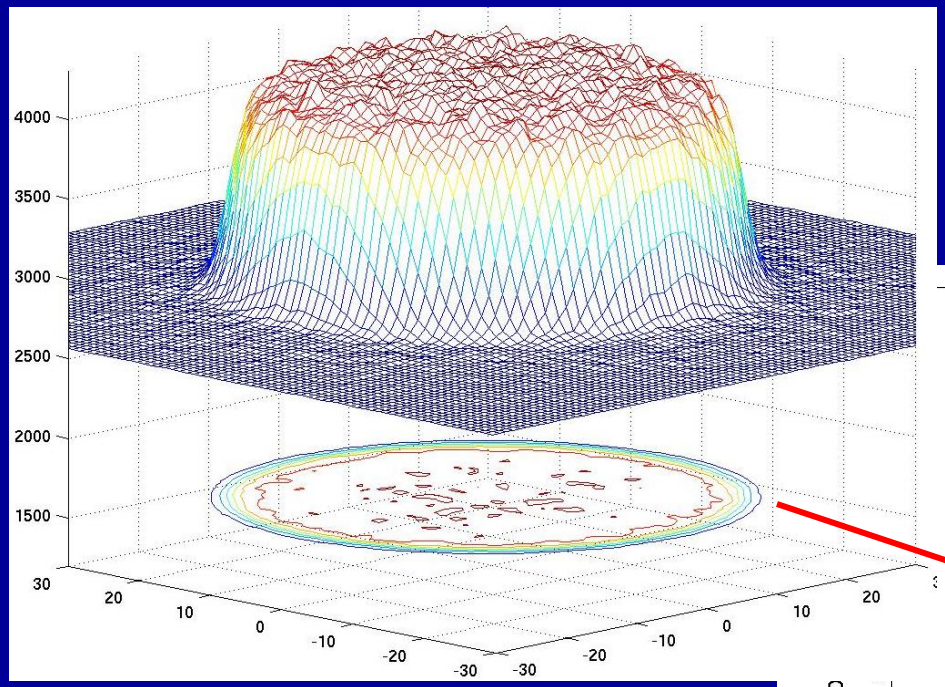
Difference Max in the homogeneity region = 2 %

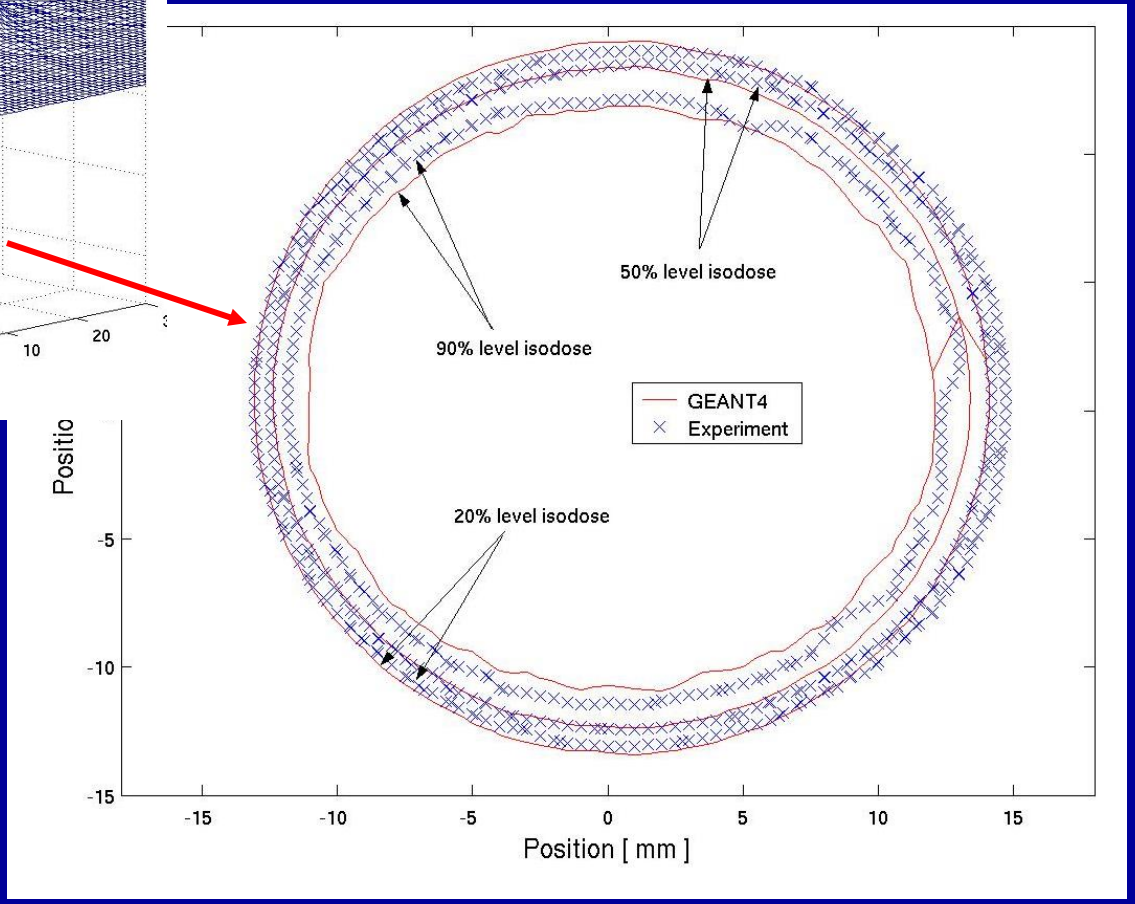
Kolmogorov test:

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

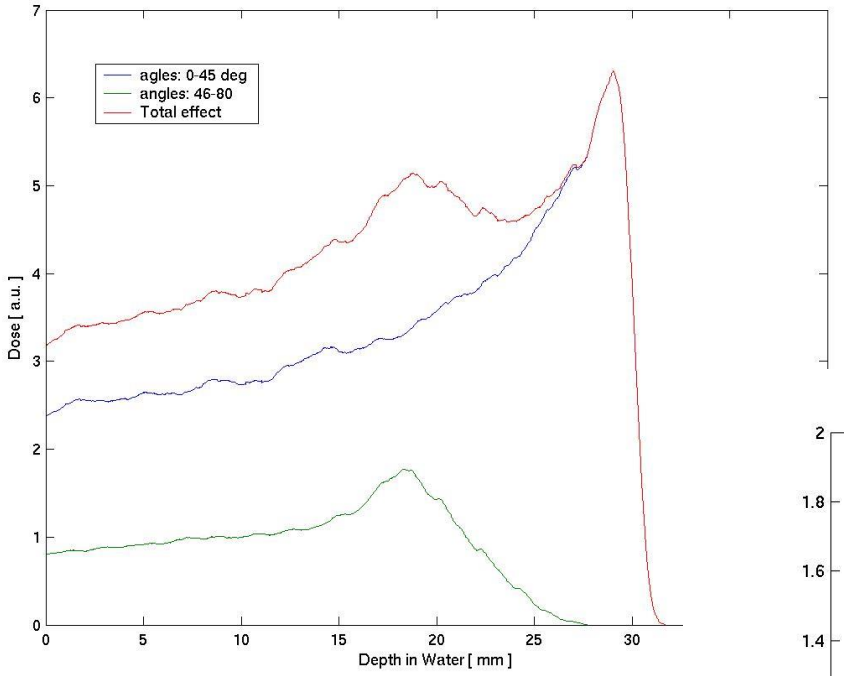
Lateral Distribution: comparison with experimental data

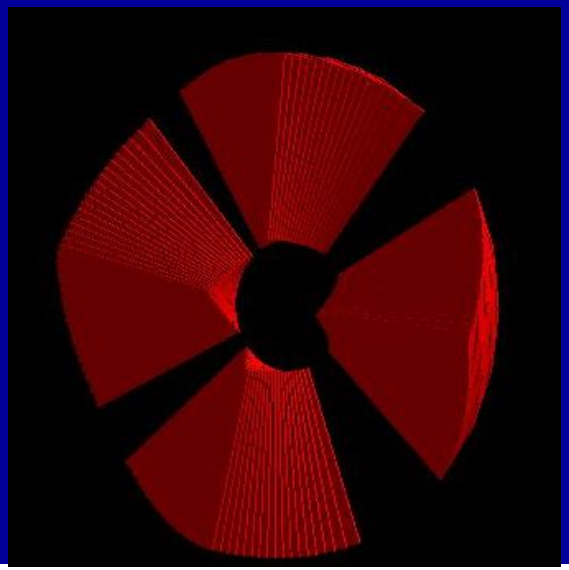
Isodose curves comparison in a qualitative way

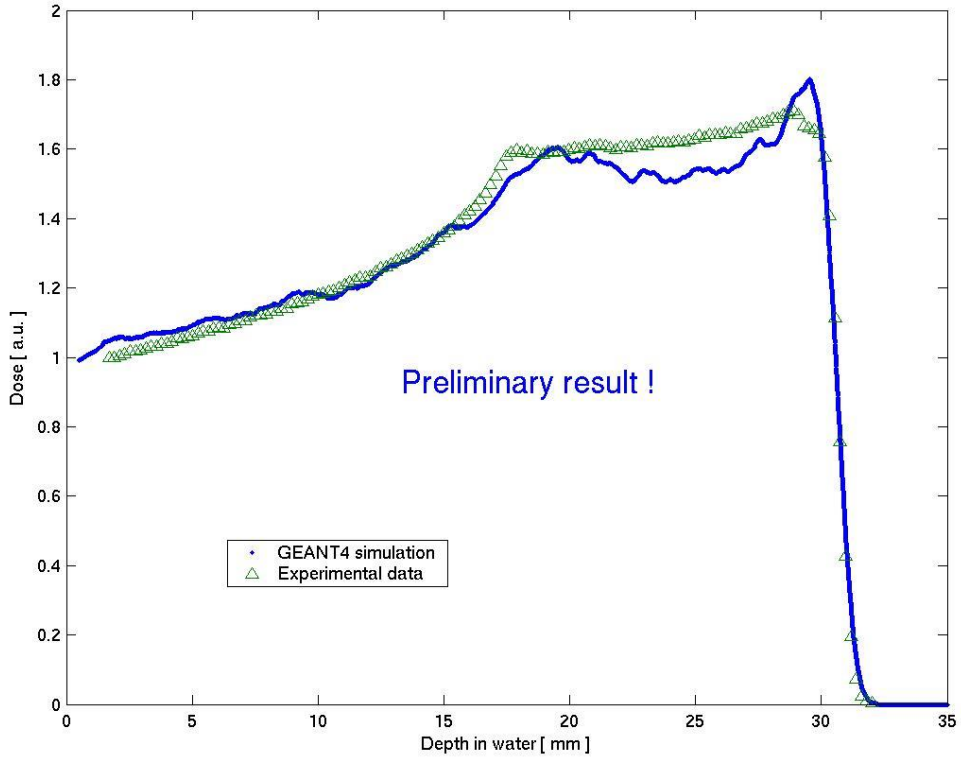




Modulator wheel: time dependent simulation







GRID implementation

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

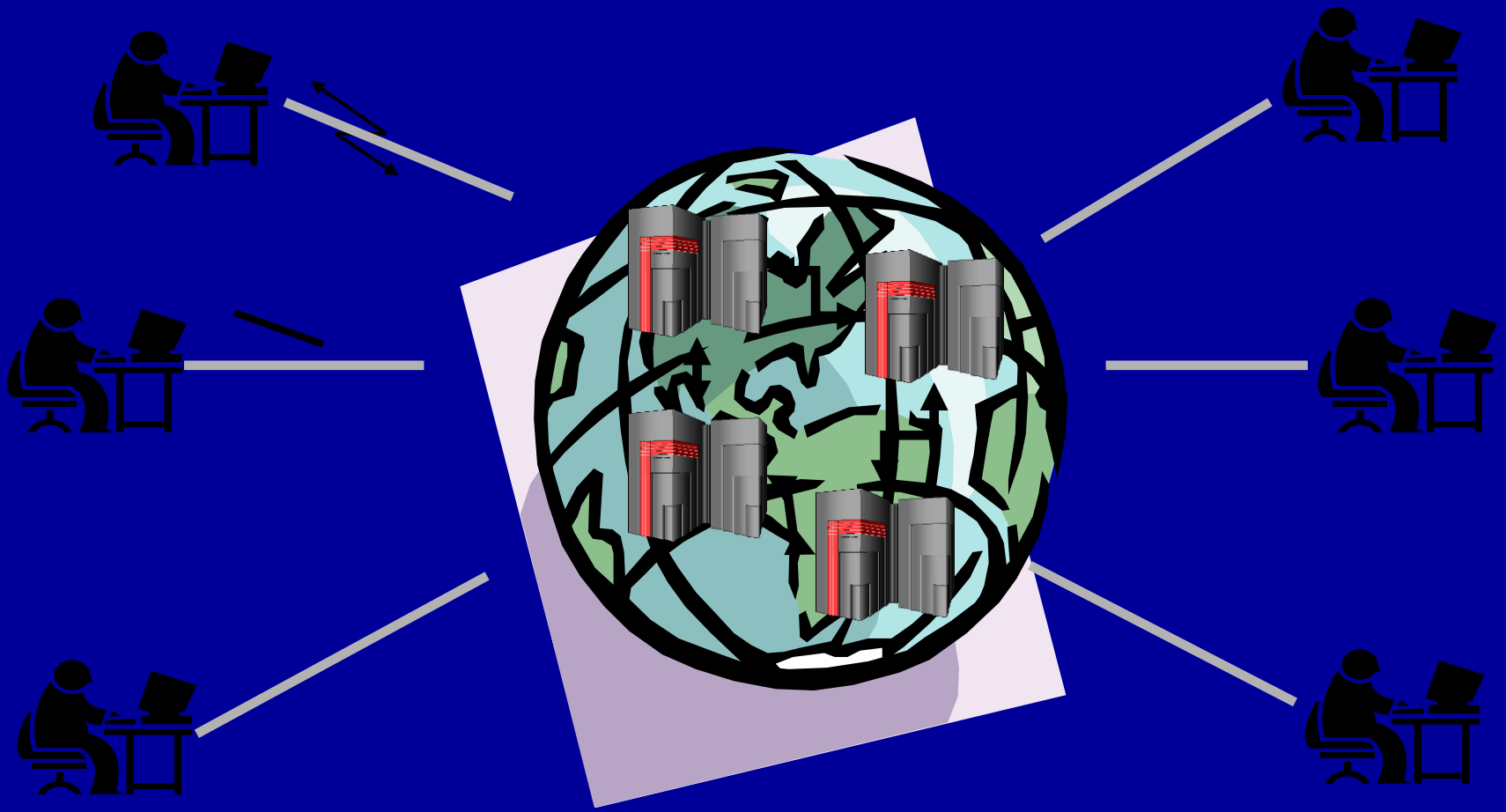
On the other hand *velocity* is mandatory for a medical physicis and a medical doctor when they are to plan a treatment

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

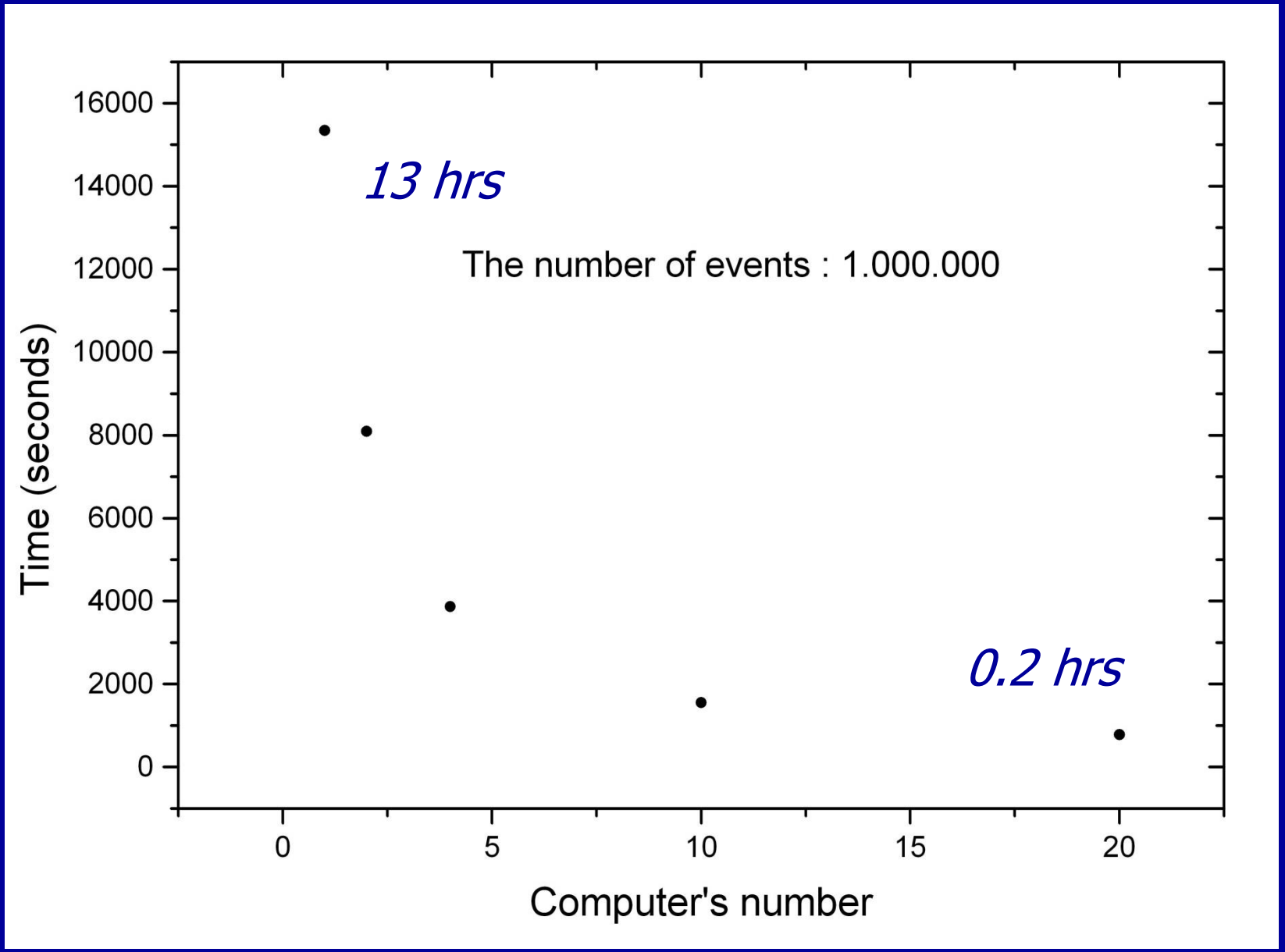
(Pentium 3 800 Mhz, 3 Mega protons simulated)

GRID implementation

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



First results on the GRID



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

BEAM ENERGY

Bragg Peak Submit Reset DISTRIBUTION CHOSEN

THICKNESS DEGRADER

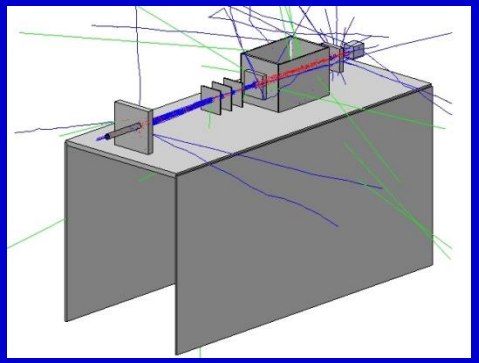
Bragg Peak
Spread Out Bragg Peak
Lateral Distribution

bmit Reset NUMBER OF EVENTS

Submit Reset NUMBER OF JOBS

Submit Reset VISUALIZATION

GRAPHICS OUTPUT



Modulation region button will be soon inserted

Operazione completata

Risorse del computer

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

Summary

- *Development of a Monte Carlo application for a generic hadron therapy beam line*
- *Simulation of all its elements*
- *….and of the detectors*
- *Comparison with experimental data*
- *Time dependent simulation for the modulator*
- *Grid for simulation time reduction*

THE NEAR FUTURE

- *Comparison respect analitical treatment planning systems*