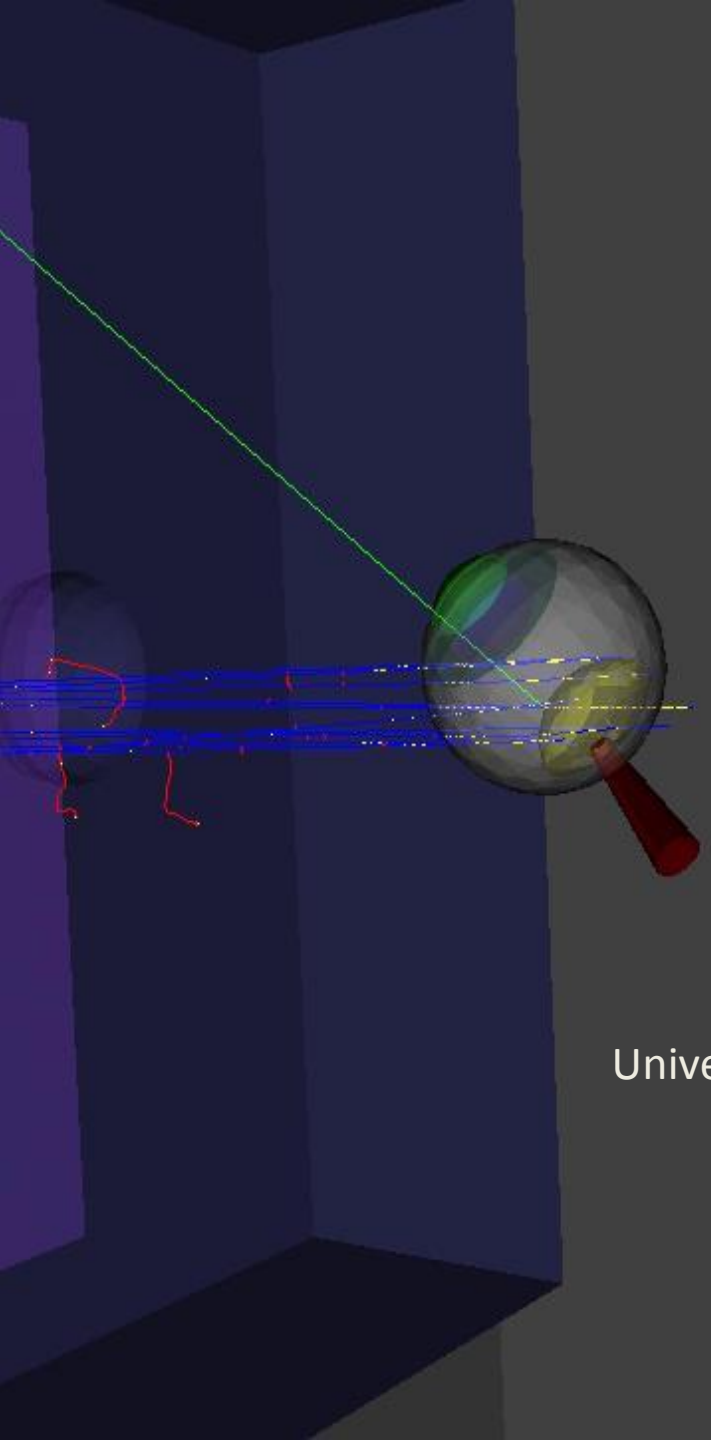

Geant4 simulation of a dedicated beam line at the CNAO facility for the study of uveal melanomas

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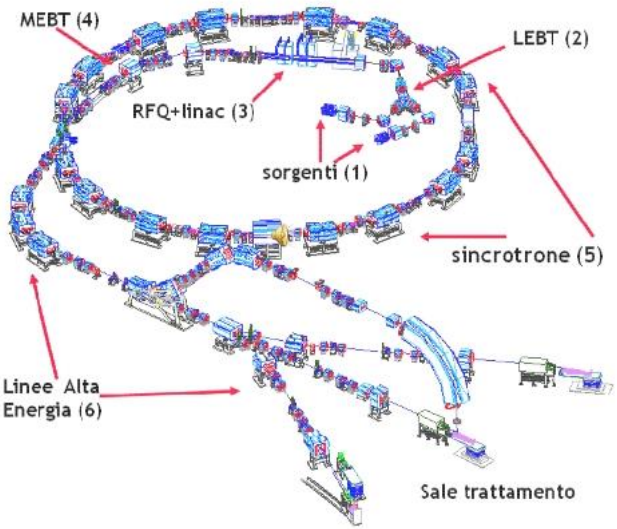
University of Pavia & INFN in Collaboration with CNAO Foundation
MC-INFN project

ICTR-PHE 2014 - 13 February 2014 - Genève (CH)

The CNAO facility

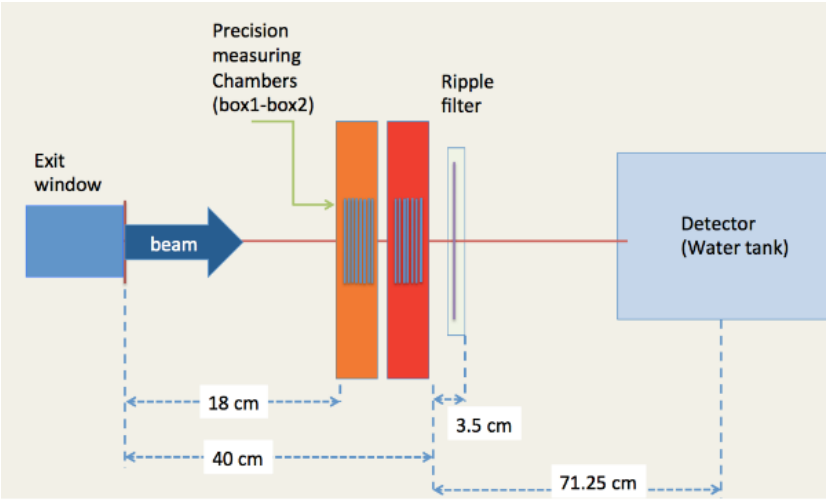


CNAO Parameters:

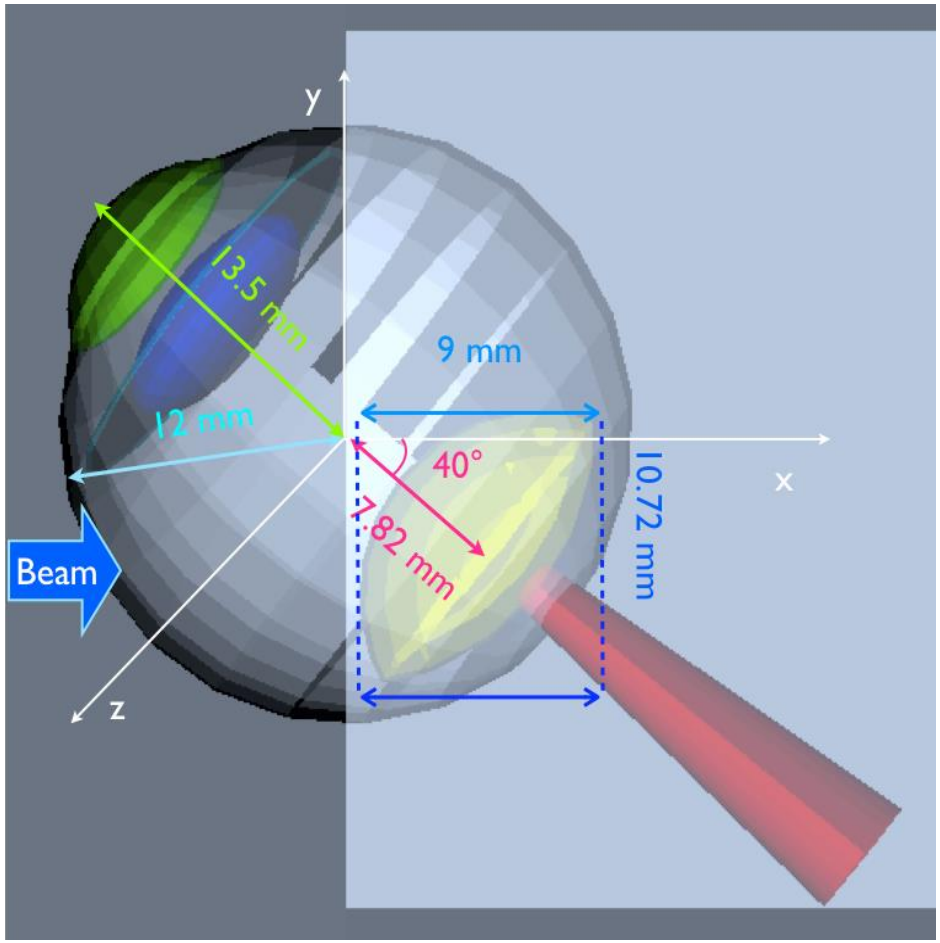
- 60 - 250 MeV protons
- 120 - 400 MeV carbon ions
- Beam FWHM 4-10 mm
- Energy step 0.02 MeV

Elements of existing *delivery line:*

- 6 m long vacuum tube
- Control chambers
- Passive components (optional)
- Detector



The eye detector



High detailed geometry implementation:

- Primary volumes implemented by Geant4 (CSG solids)
- More complex structures from unions and intersections of primary solids (G4UnionSolid and G4IntersectionSolid classes)
- Correct spatial placement of each component

Eye component	Primary CSG solids
Sclera	G4Orb, G4Sphere
Cornea	G4Sphere
Crystalline	G4Ellipsoid
Nerve	G4Tubs, G4Orb
Retina	G4Sphere
Tumor	G4Orb

Materials and tissues

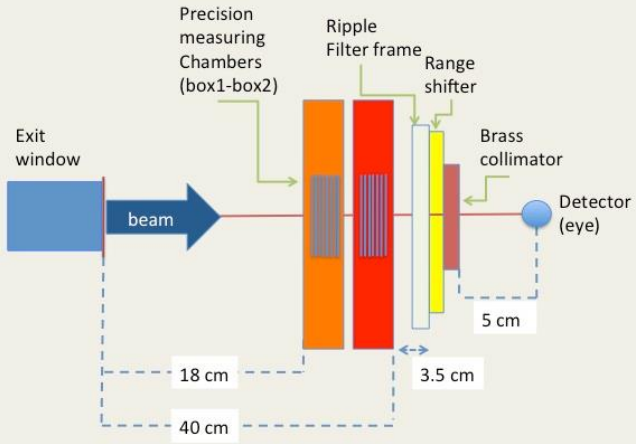
Definition of new materials:

- G4VElement class for elements implementation by atomic number
- G4VMaterial class for new materials from chemical structure and composition

Molecule	Composition
Proline	$H_9C_5O_2N$
Idrossiproline	$H_9C_5O_3N$
Collagen	Proline (86%) +Idrossiproline (14%)
Lipids	$H_{48}C_{24}O_6PN_2$
Lactate	$H_5C_3O_2$
Sugar	H_2CO
N-AcetilAspartate (NAA)	$H_9C_6O_5N$
Choline	$H_{14}C_5ON$
Creatine	$H_9C_4O_2N_3$
Proteins	H(50%) + C(28%) + O(13%) + N(8%) + S(1%)

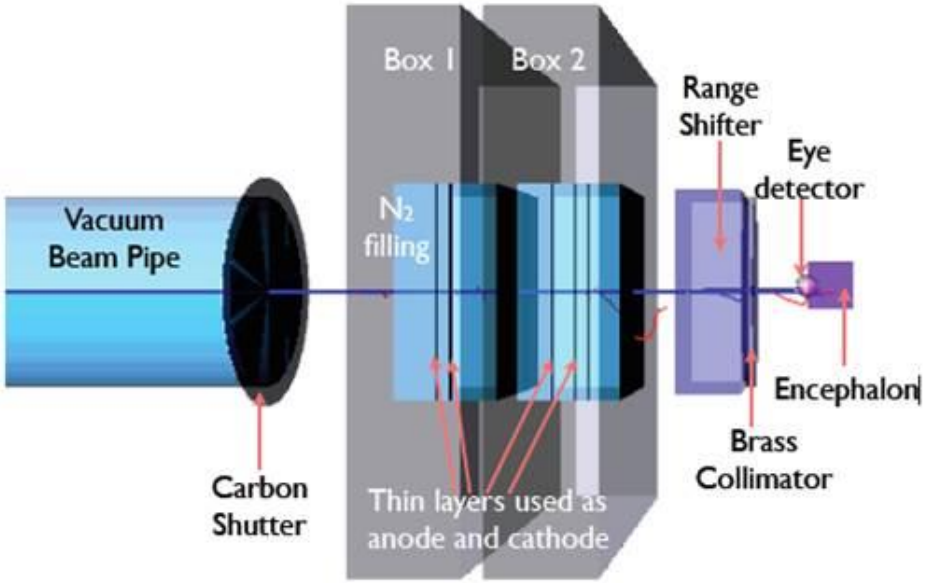
Eye component	Material	Density (g/cm^3)
Aqueous Humour	H_2O (98.5%) + NaCl (1.5%)	1.0080
Vitreous Humour	H_2O (98.5%) + Protein (1.5%)	1.0050
Sclera, Cornea, Ciliary Body	Collagen (50%) + Protein (25%) + Sugar (25%)	1.0710
Crystalline Lens	H2O (60%) + Protein (40%)	1.0670
Retina	H_2O(80%) + NAA (10%) + Choline (5%) + Creatine (5%)	1.0174
Tumour	H_2O (80%) + NAA (3%) + Choline (12%) + Creatine (3%) + Lipids (1%) + Lactate (1%)	1.0174

Simulated beam line



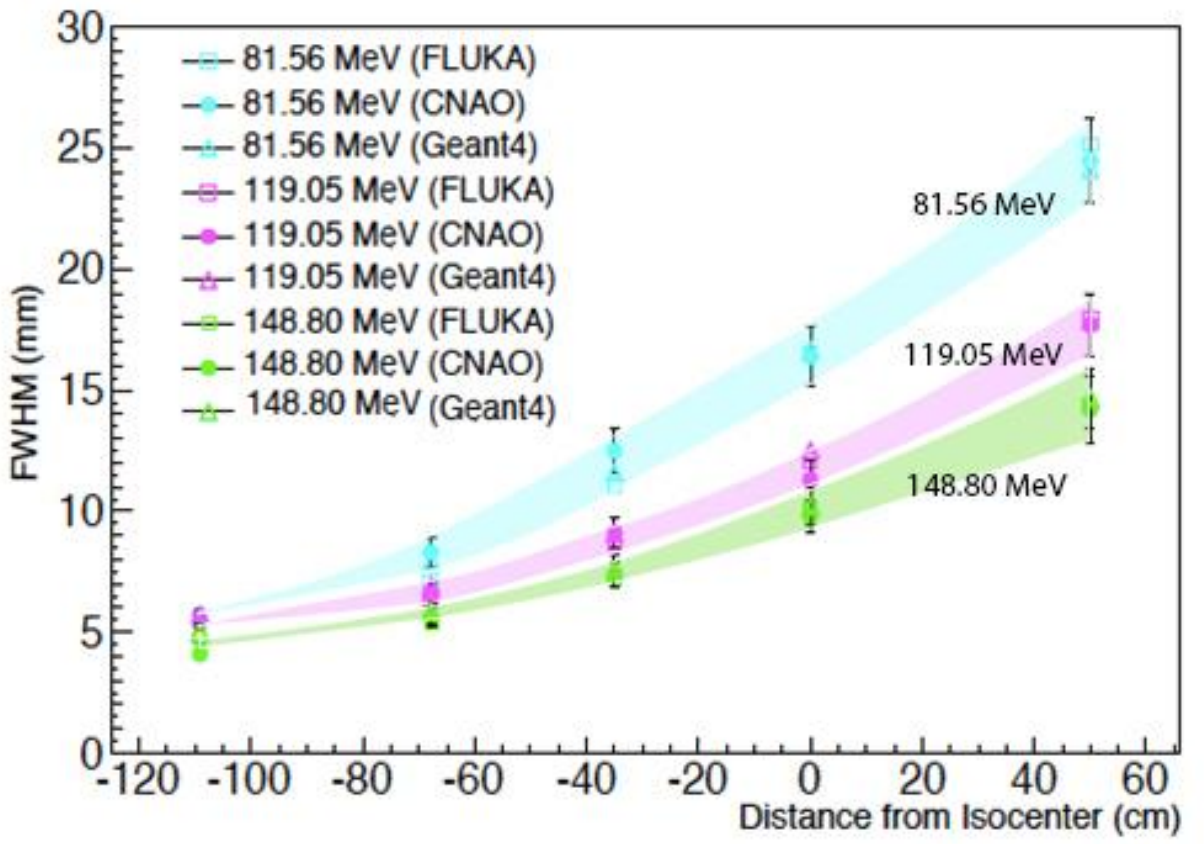
Optimization of the existing beam line:

- Approach the eye to the last component of the beam line
- Introduction of a 43 mm thin *range shifter* (for a nominal energy of 100.51 MeV)
- Introduction of a brass collimator to focus the beam



Data comparison

Experimental data from the interactions of particles with Gafchromic® films



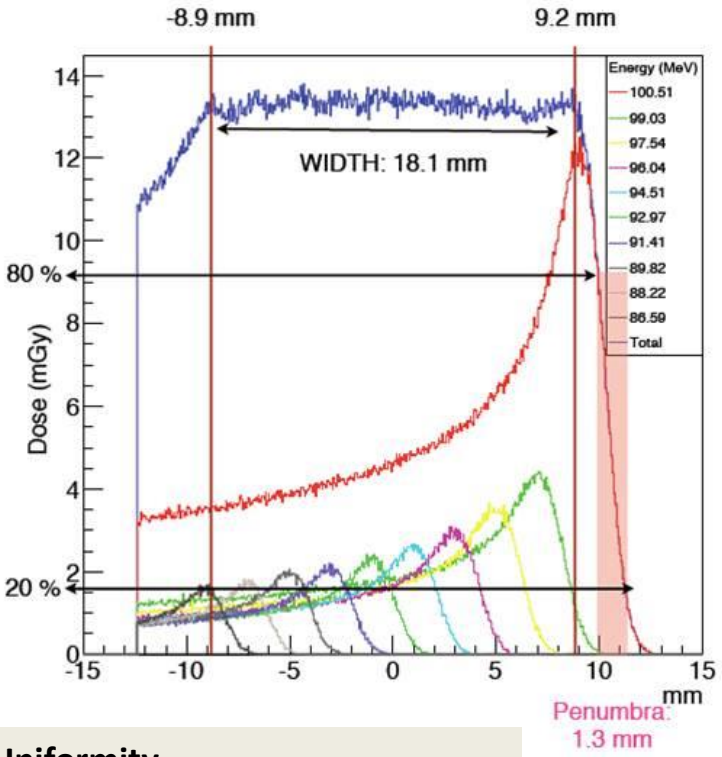
Excellent agreement between experimental data and simulation

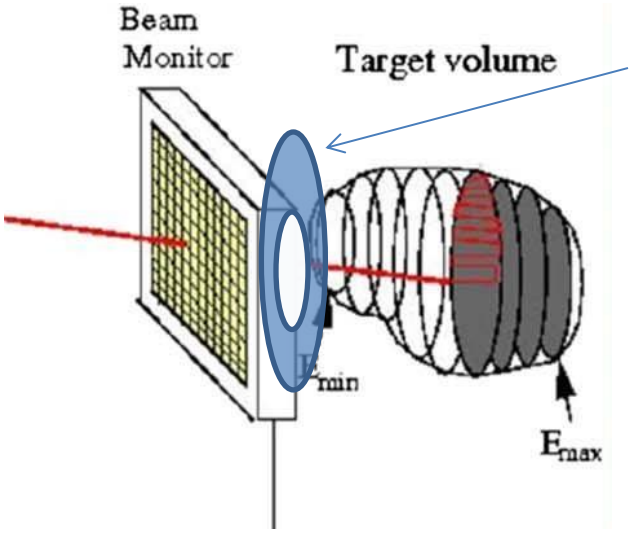
Irradiation uniformity

Longitudinal Uniformity

A Spread Out Bragg Peak (SOBP) has been developed

- Energies from 86.59 MeV to 100.51 MeV
- SOBP width: 18 mm





Tranverse Uniformity

- Grid dimensions: 40*40 mm^2
- Step: 3 mm

Features of the collimator:

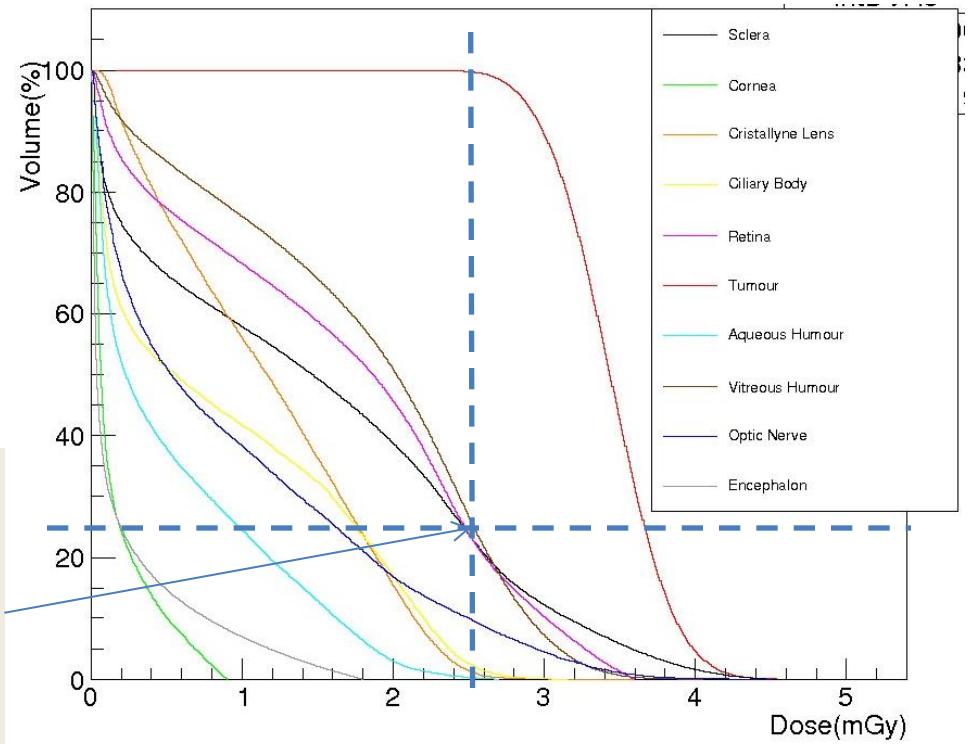
- Thickness: 10 mm
- Hole dimensions: 20*22 mm^2

Simulation results

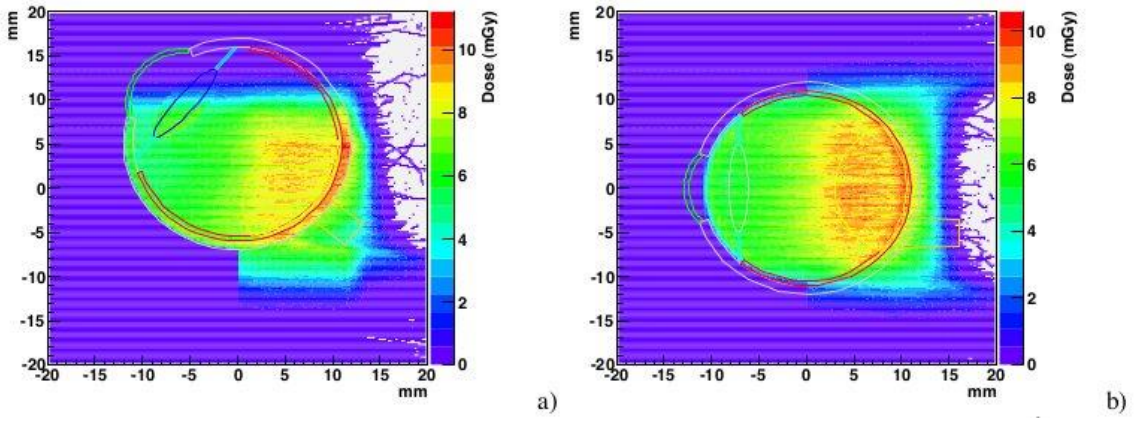
- $4*10^6$ simulated events
- Energies from 92.57MeV to 100.51Mev
- *Range shifter* depth: 43mm

Percentage of tissue absorbing 2.5 mGy or more:

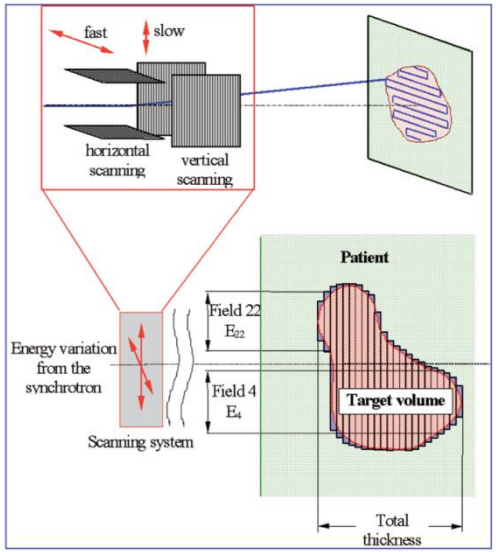
- 100% of the Tumor volume
- 20% of the Vitreous Humour volume
- Few percents of other radiosensitive components volumes



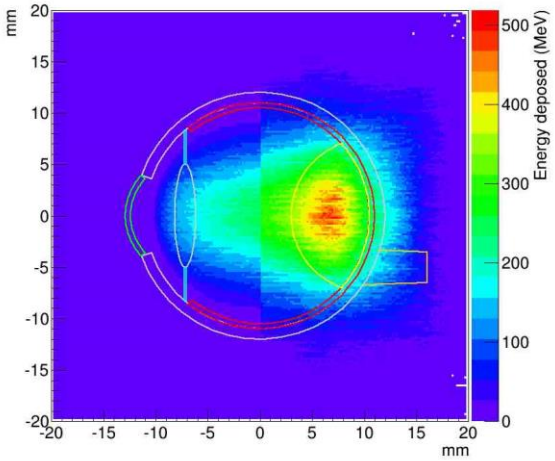
Beam



Active scan - Latest development

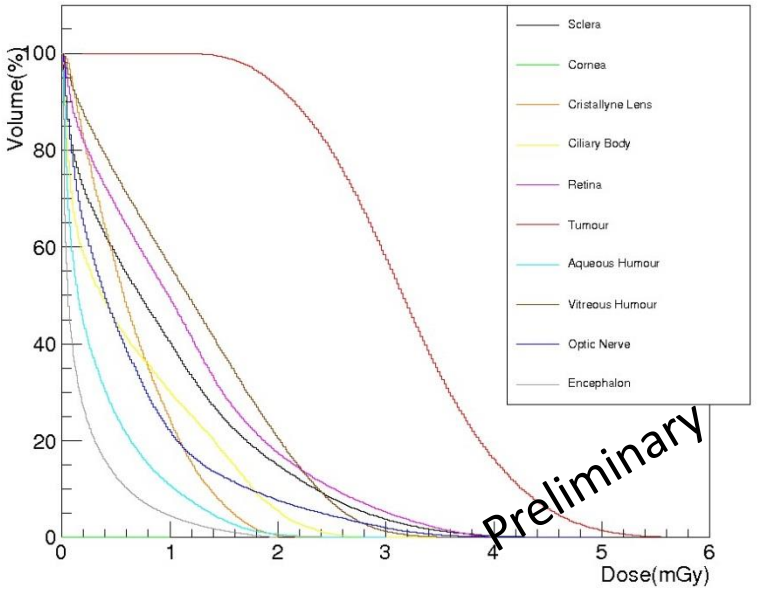


Top view

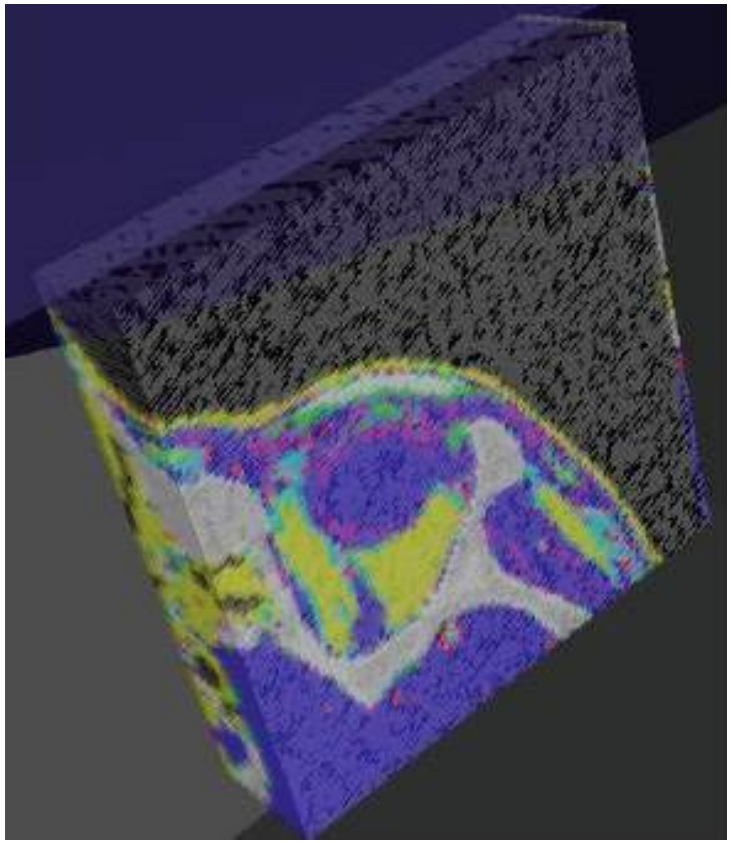


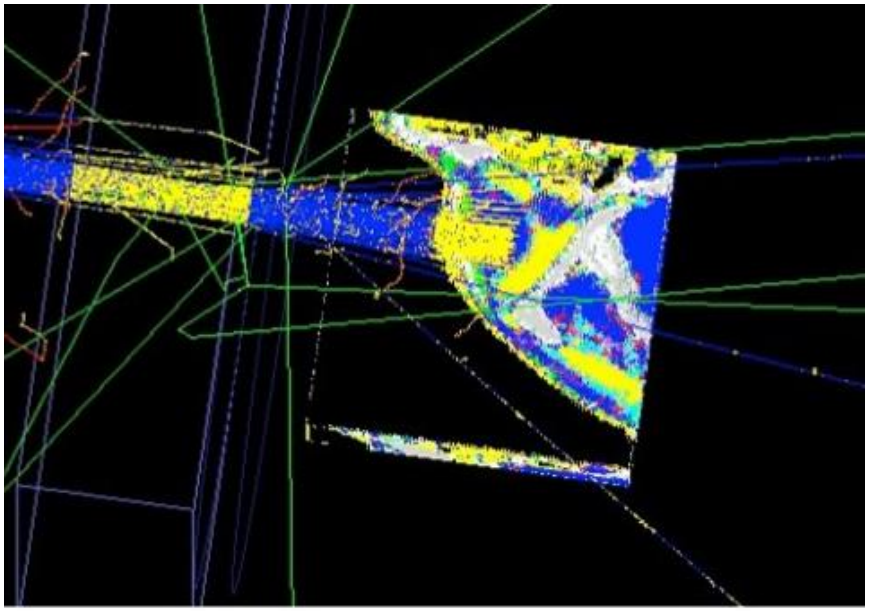
New method of particles generation:

- Identification of the target volume
- Recognition of the position
- Selective generation of the particles



DICOM *(Digital Imaging and Communications in Medicine)*





Dicom images:

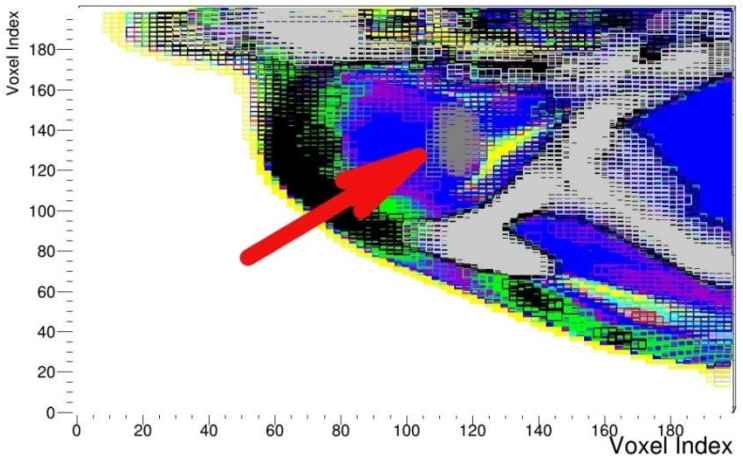
- Data from CT
- 10 Slices
- Slice depth: 1 mm
- Image dimensions: 86*86 pixels
- Pixel dimensions: 0.97*0.97 mm^2

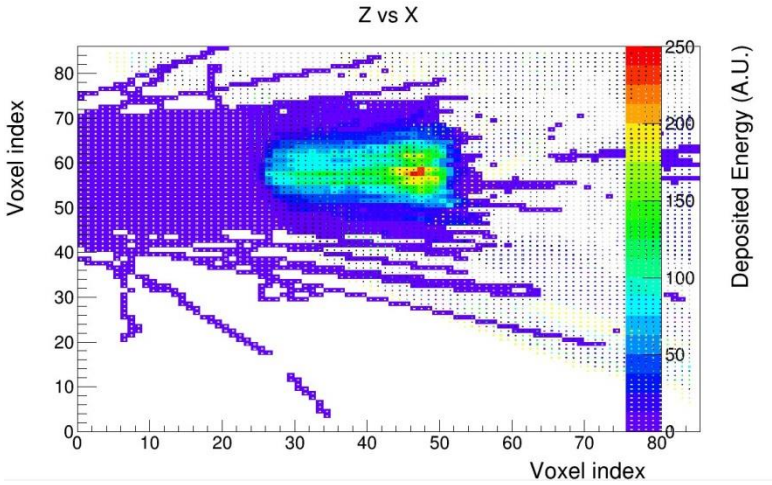
DICOM – Latest development

Insertion and identification of the tumor

Features of the tumor:

- Density: 1 g/cm^3
- Depth: 3 mm
- Transverse width: 10 mm





Example of DICOM geometry irradiation

Simulation parameters:

- 1*10^5 simulated events
- Energies from 97.54 to 100.51 MeV
- Tumor width from 6 to 9 mm (from isocenter)

CONCLUSIONS

- The CNAO transport beam line was simulated in detail
- Geant4-FLUKA/data comparisons for transverse FWHM were performed
- The Eye detector geometry has been implemented in detail
- The beam setup for ocular treatments has been optimized
- Uniform 3D dose deposition in the tumor volume was studied
- Active scan was implemented
- DICOM images have been used as target detectors