Dosimetric study of photon dose distribution in lungs under different respiratory phases: comparison with GEANT4 simulations

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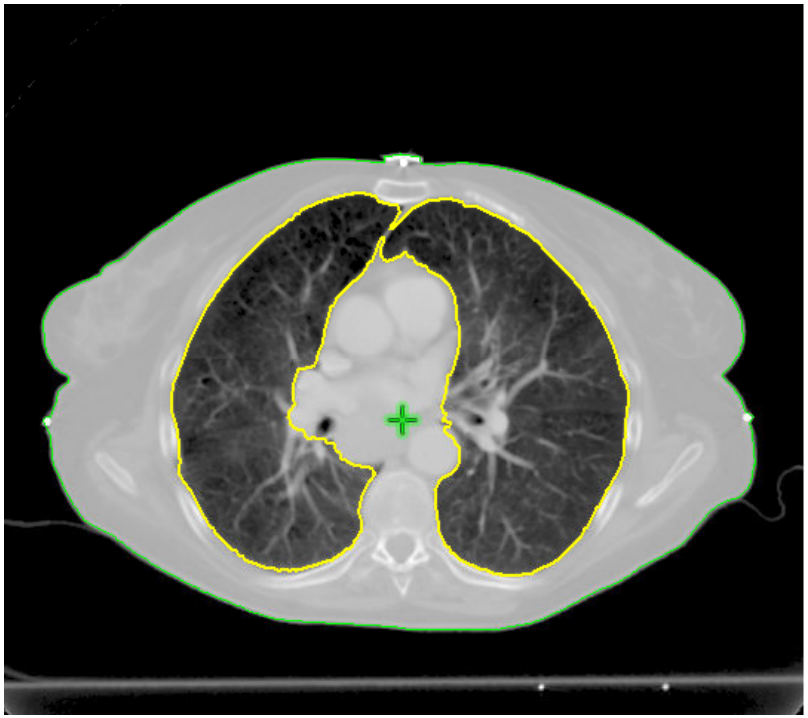
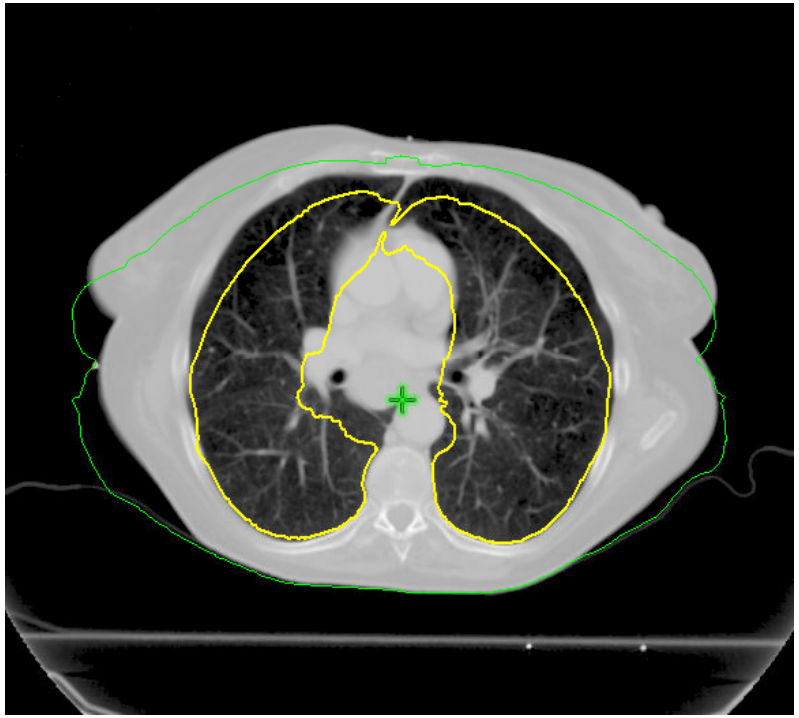
Objective

- The aim of the work is to evaluate the capability of GEANT4 respect to some commercial treatment planning systems to provide dose calculation maps with high level of accuracy also when lung densities are changing

Different breathing phases show different lung densities





volume = 3786 cm^3

density = 0.24 g/cm^3

volume = 5552 cm^3

density = 0.17g/cm^3

Computing setup

The Geant4 Group at INFN - Sanità

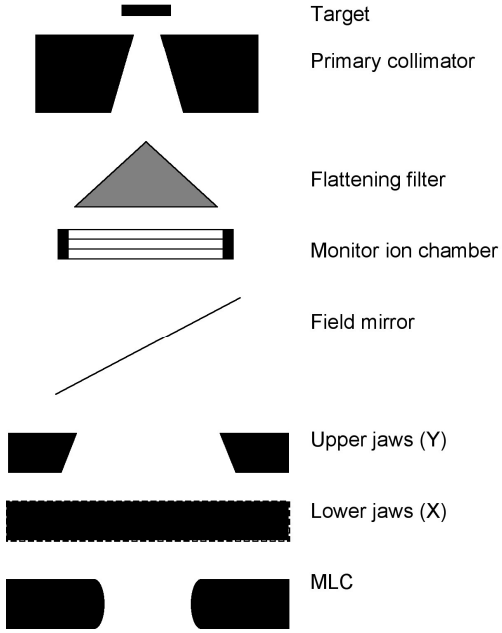
Commercial TPS

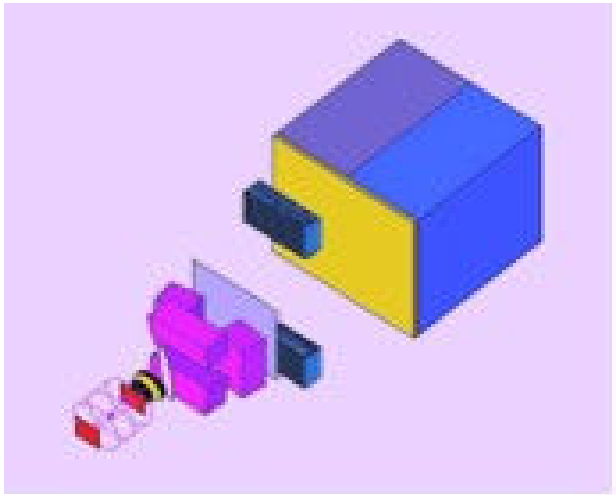
Varian Eclipse TPS (PB-EqTAR pencil beam with EqTAR algorithm for heterogeneities correction)

Philips Pinnacle TPS (CCC Collapsed Cone Convolution).

Geant 4

A 2100 Clinac Varian was modeled with a GEANT4 MC code based on a modified version of the GEANT4 Advanced Example MedLinac





Computing setup

- Used a phase space calculated before the jaws (about 60 MH)
- Dose computed in voxels located in correspondence of the measurements zones:
  - Voxel size: 10x10x1 mm^3 for PDD and 10x1x1 mm^3 for sections
  - 100-50 / 10-4 M of events in all voxels of each curve (30k - 300k in each voxel)
- Cut values and user limits: 10 μm
- Used a Beowulf type PC cluster with a homemade launch procedure
- Computing time: 6 nodes x 3 days

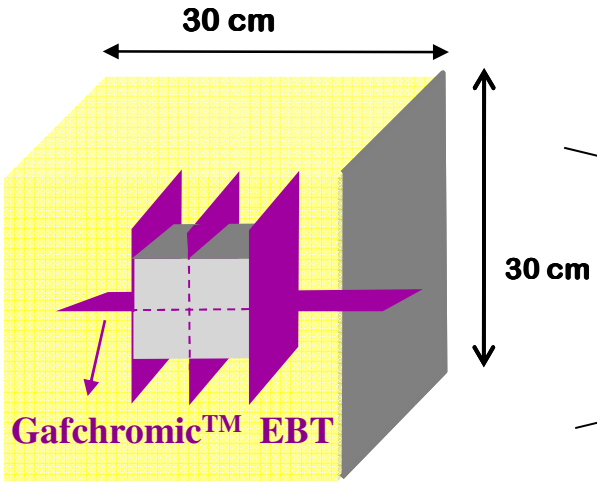
Experimental setup

Three phantoms (cubes of 30 cm side), simulating different lung densities (0.03-0.08-0.40 g/cm^3) with an in-homogeneities at the centre (a cube of PMMA of 6 cm side), were built.

Measurements were performed with radiochromic films (GafchromicTM EBT), calibrated with a 6MV beam in the range 0-6 Gy.

Images were acquired with a Epson Expression 10000 XL flatbed scanner and analyzed with Picodose X PRO software.

Dose in the phantom centre : 3 Gy



radiation 92°

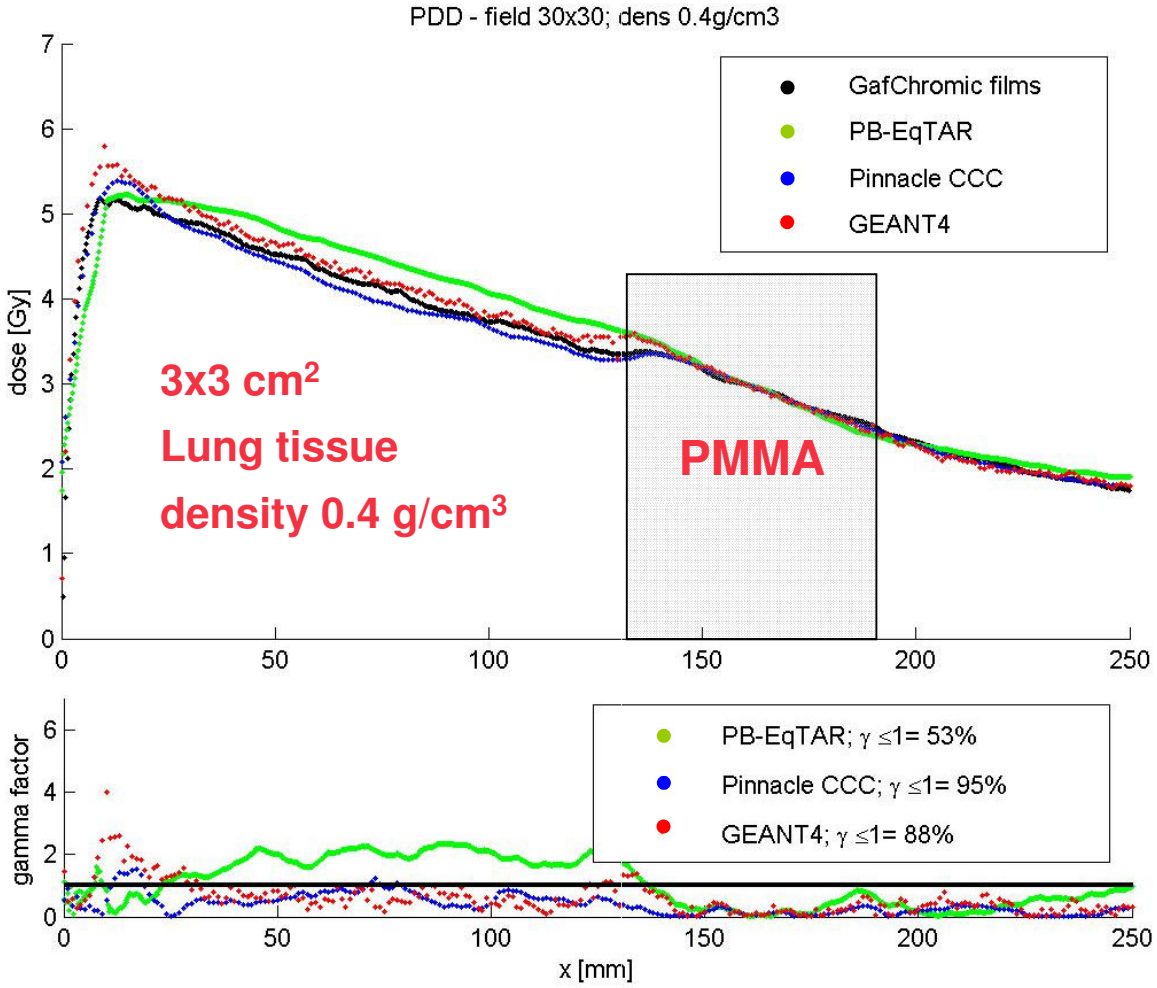
	Density 1 0.030 g/cm^3	Density 2 0.080 g/cm^3	Density 3 0.40 g/cm^3
Field 1 3x3 cm^2			
Field 2 7.5x7.5 cm^2			
Field 3 20x20 cm^2			

normal lung

"light lung"

GEANT4 MC simulations, gafchromic measurements and Pencil Beam Eclipse and Collapsed Cone Convolution Pinnacle TPS

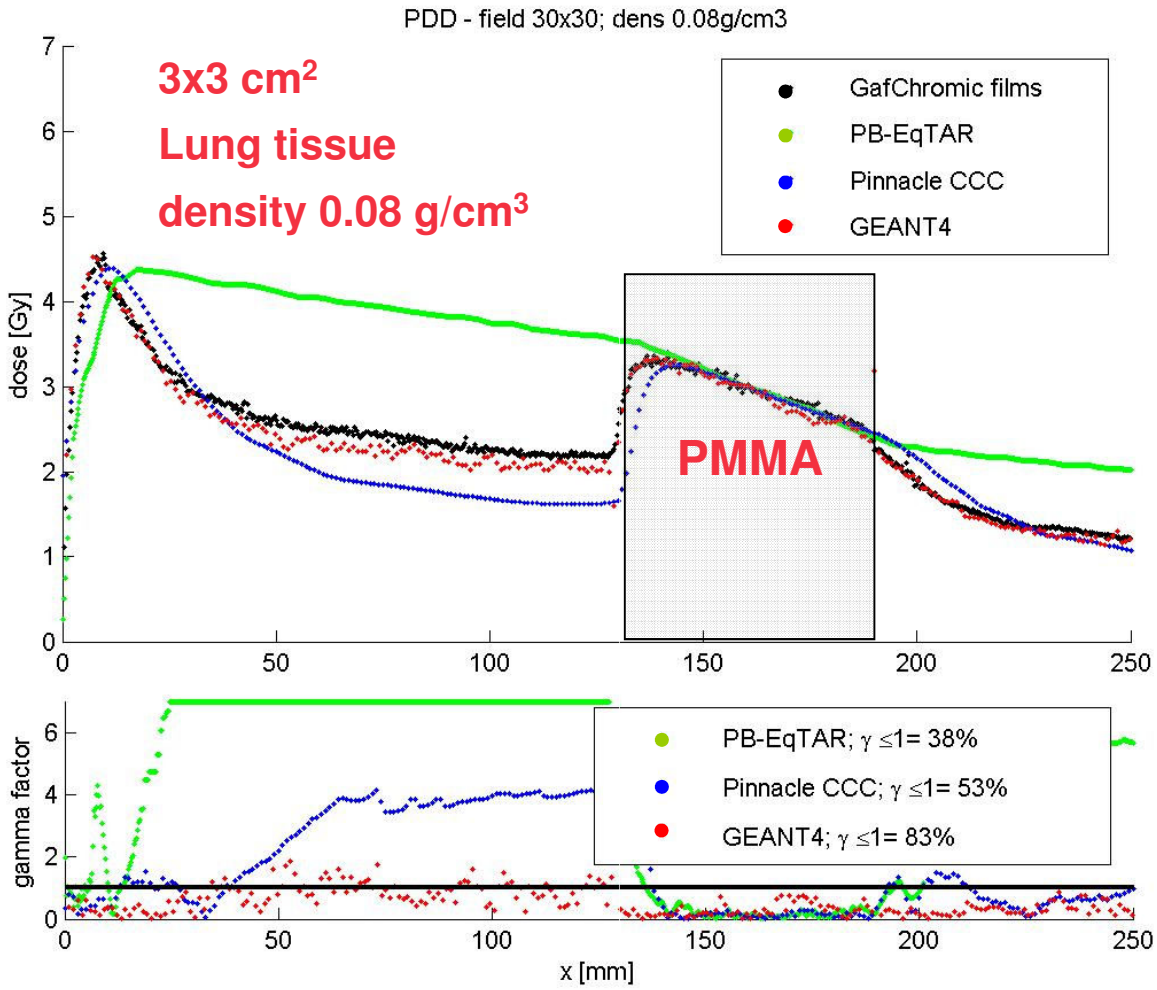
Results



DTA = 3 mm
DD = 3%

Decreasing lung density

Results



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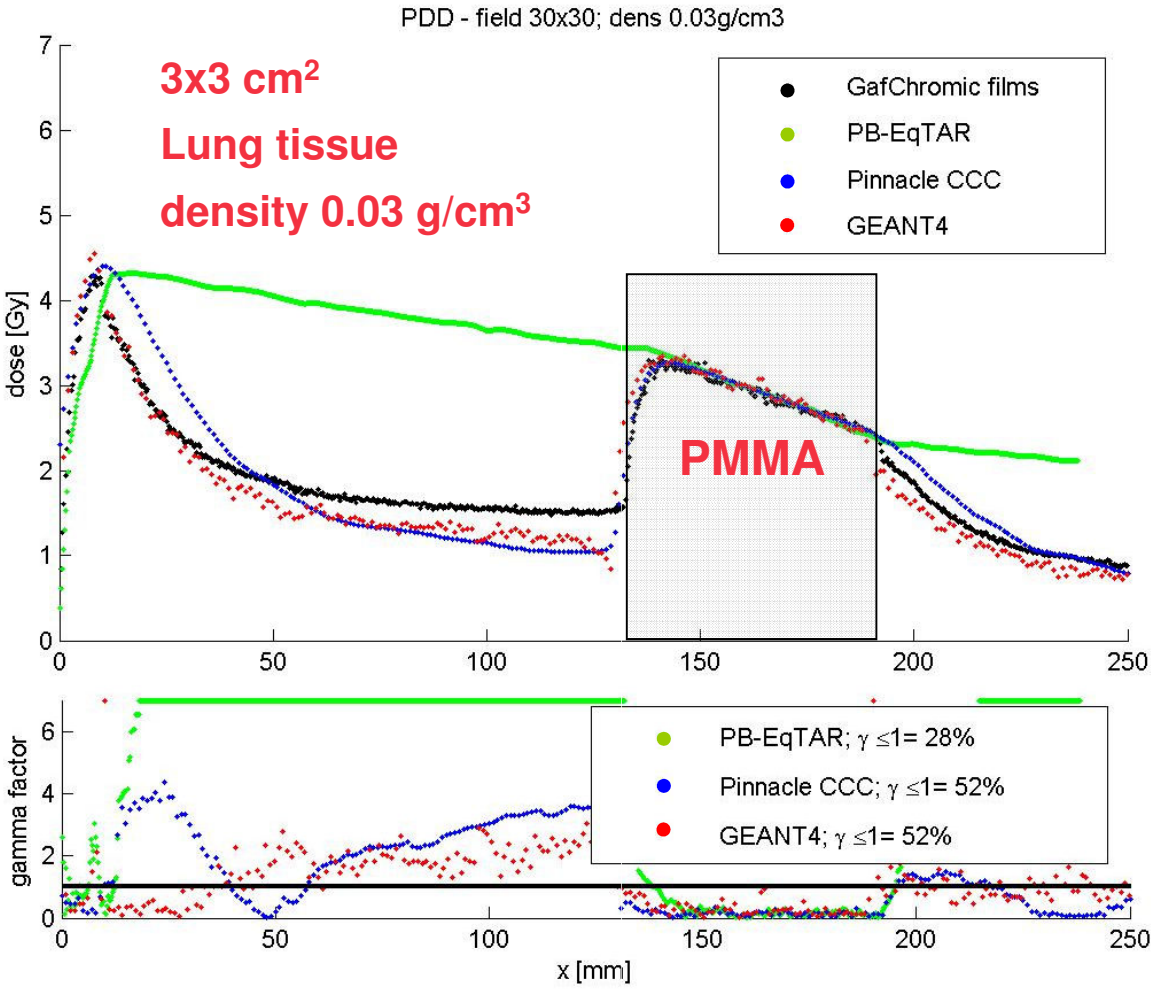
Decreasing lung density

Results



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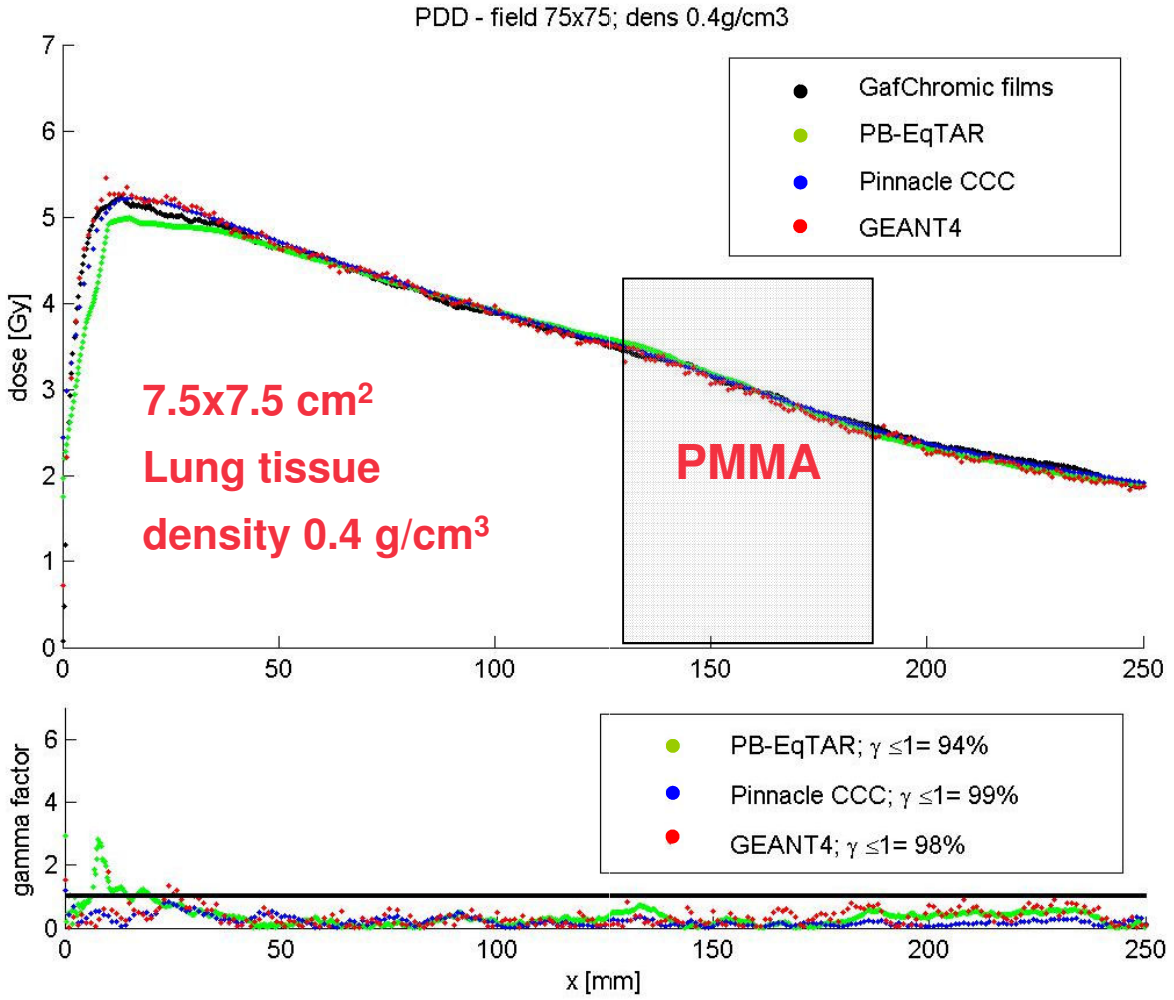

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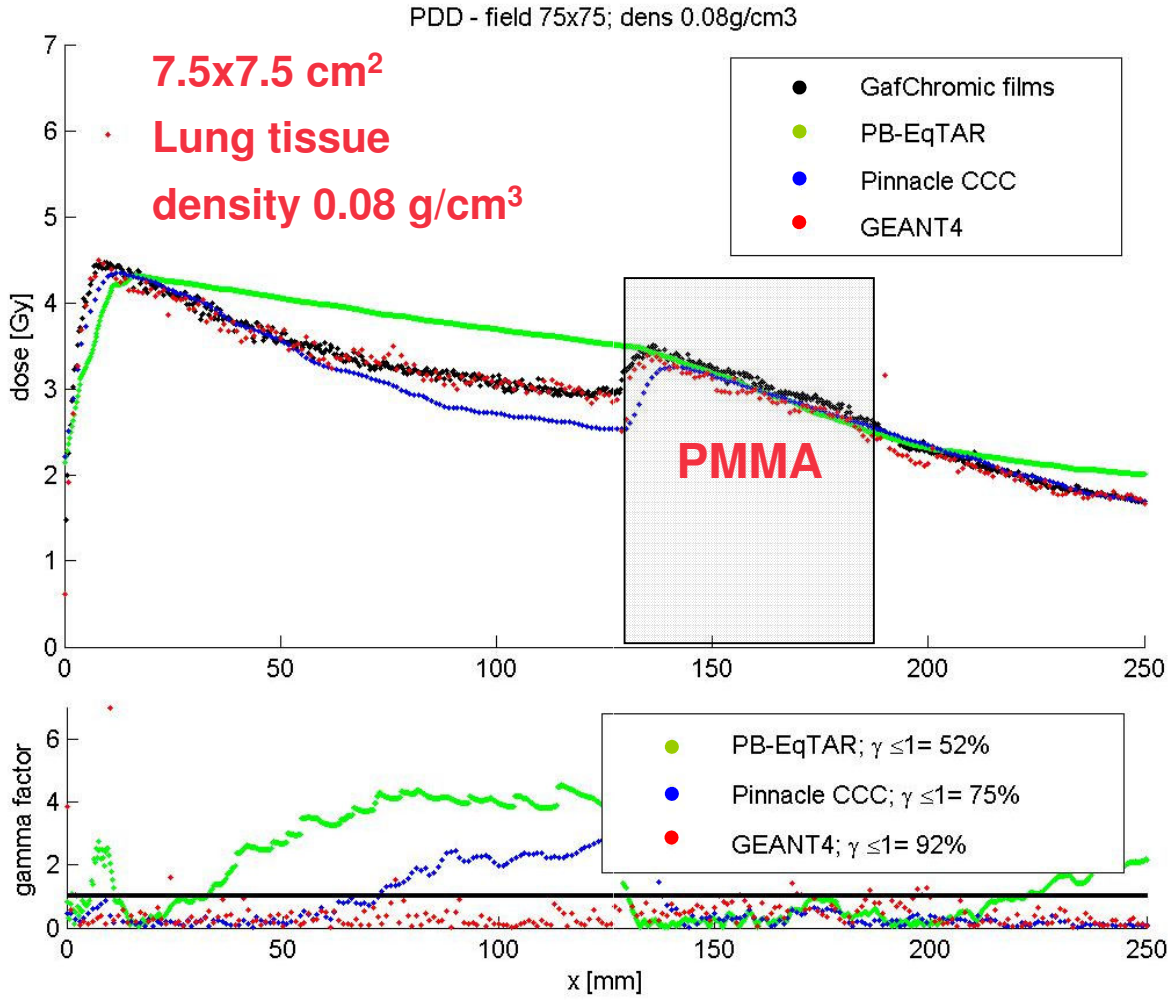

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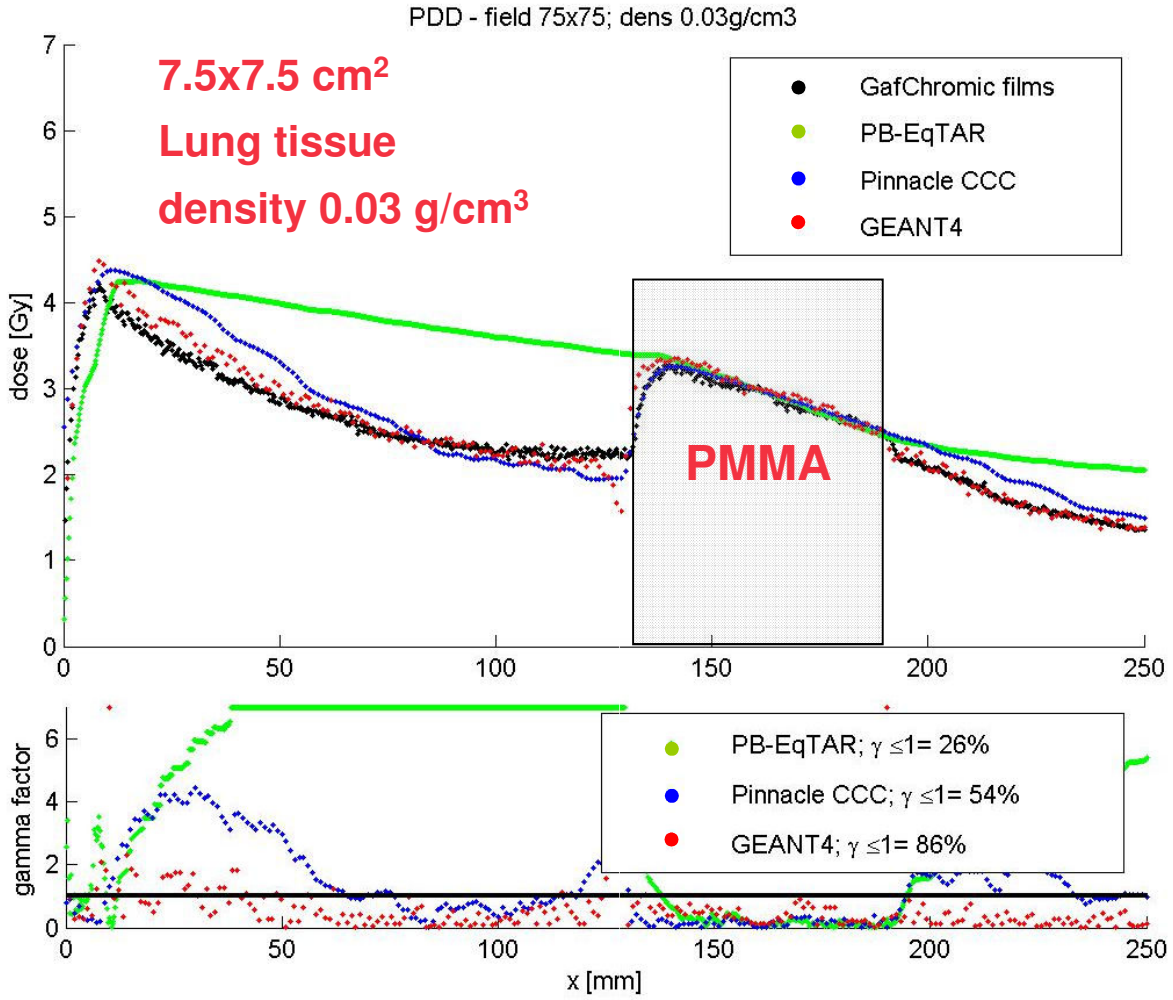

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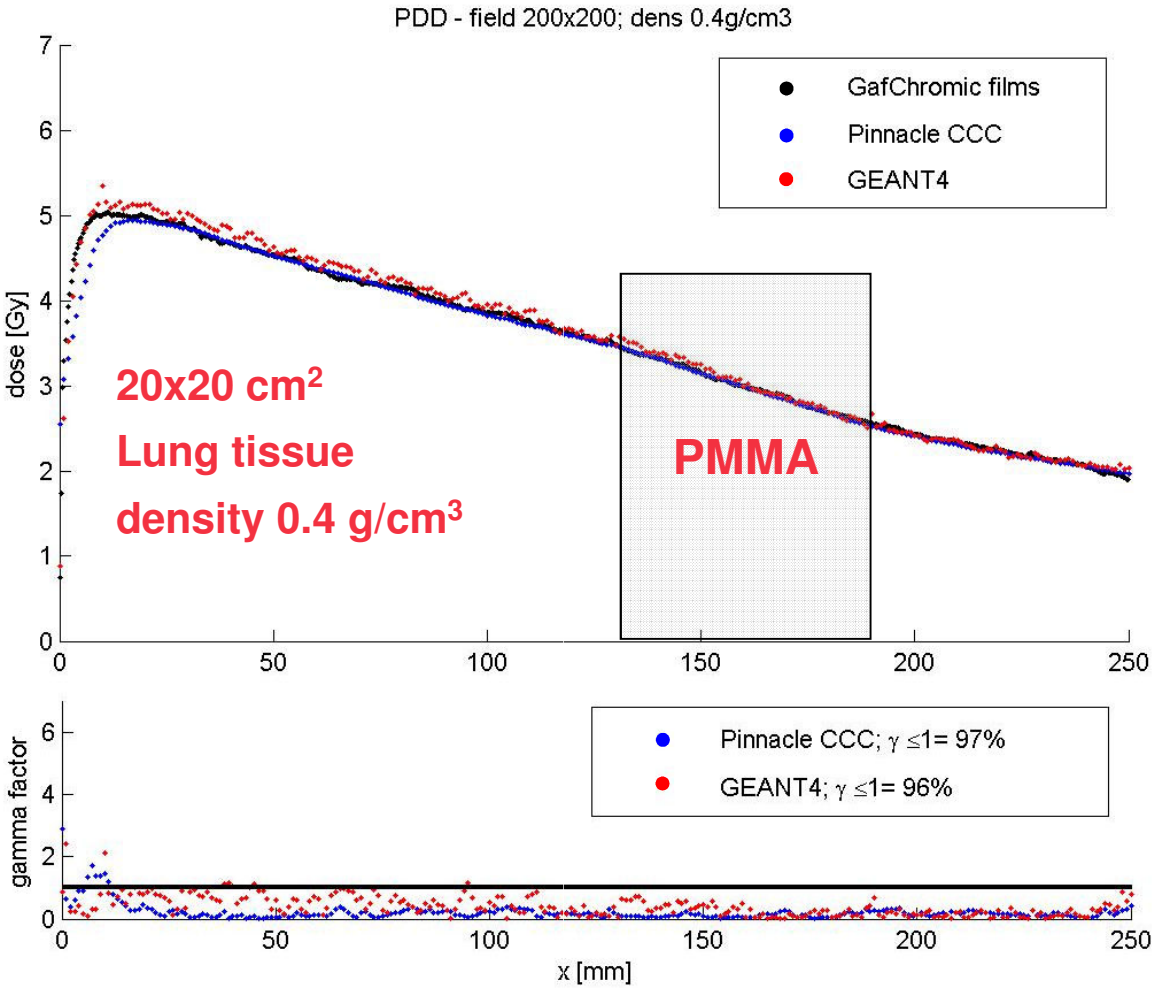

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Decreasing lung density

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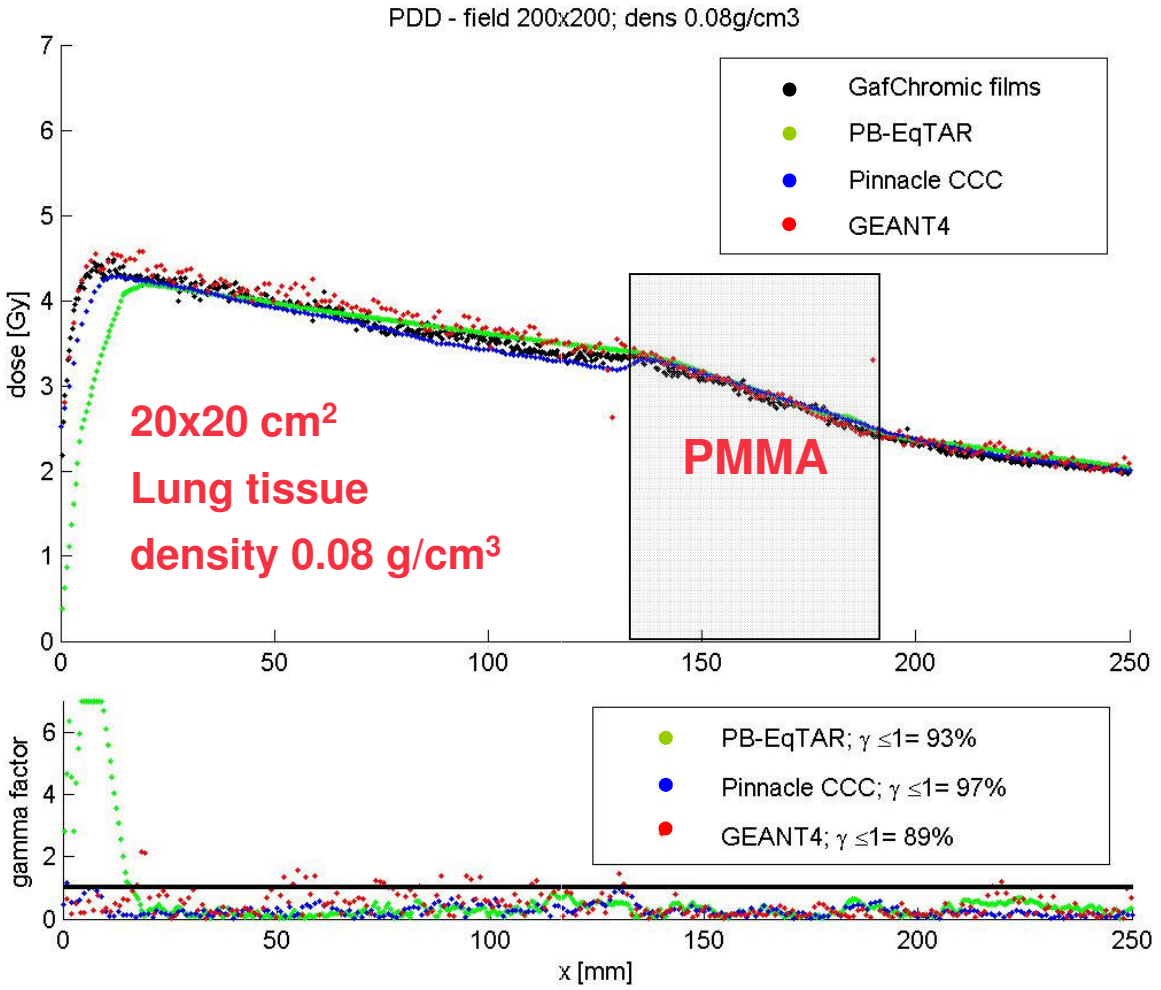

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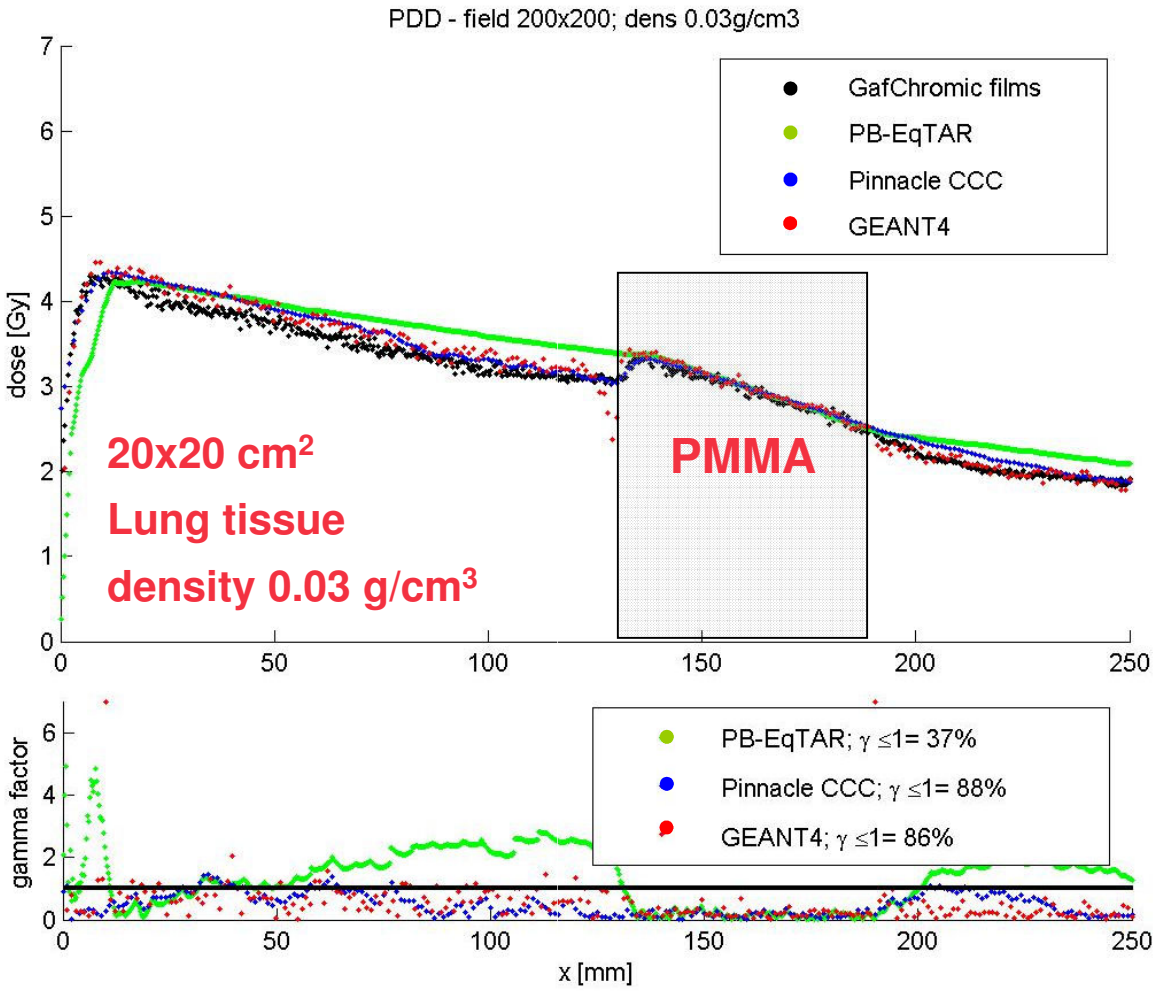

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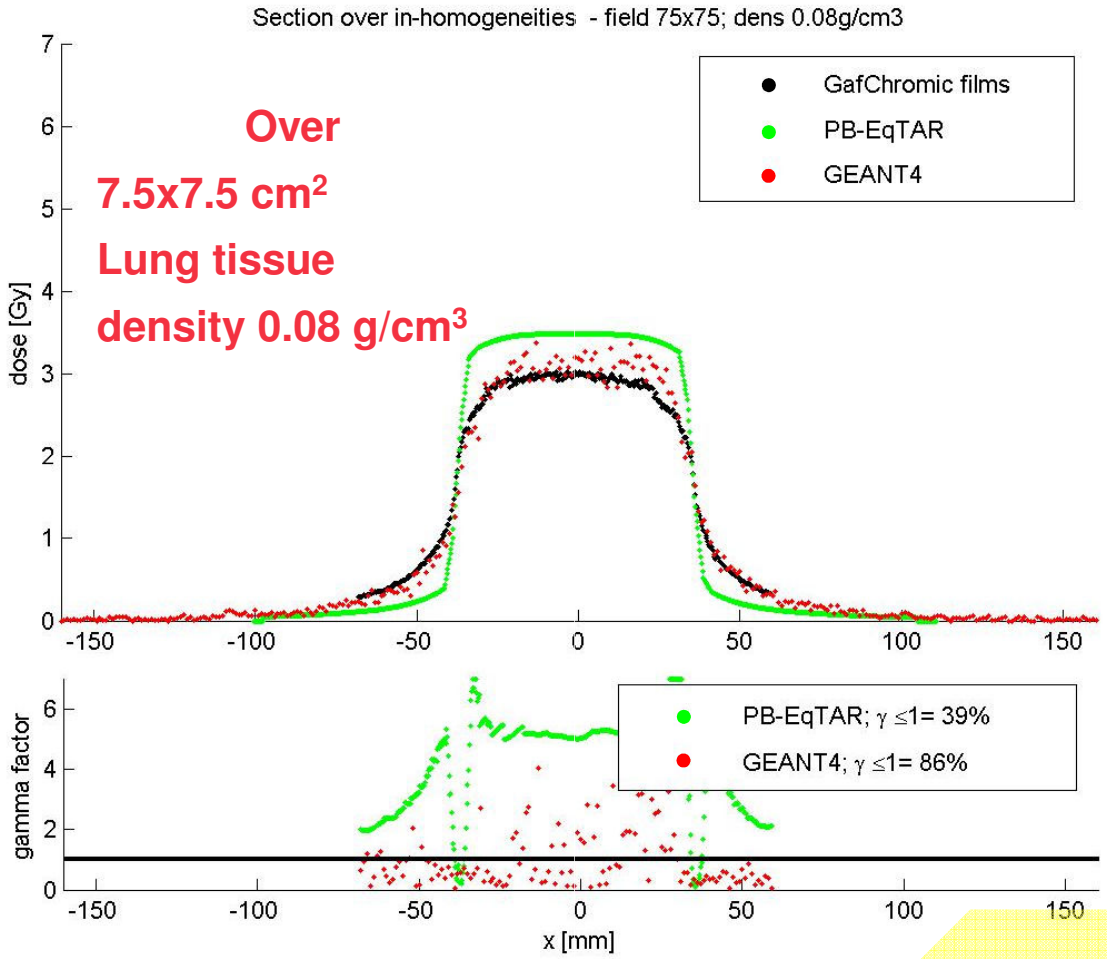

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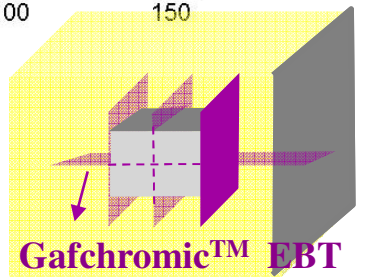

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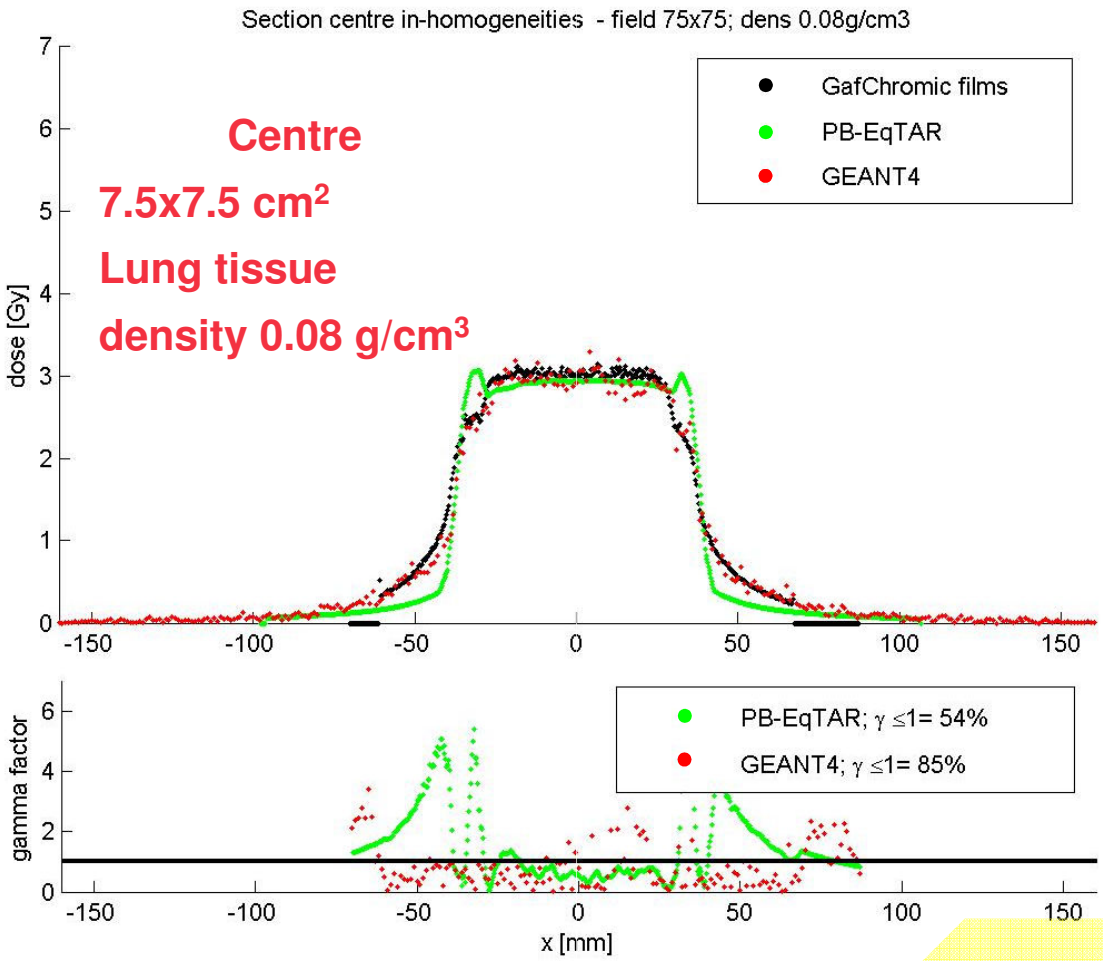

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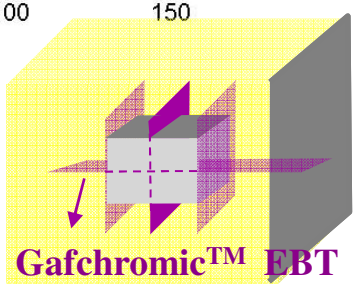
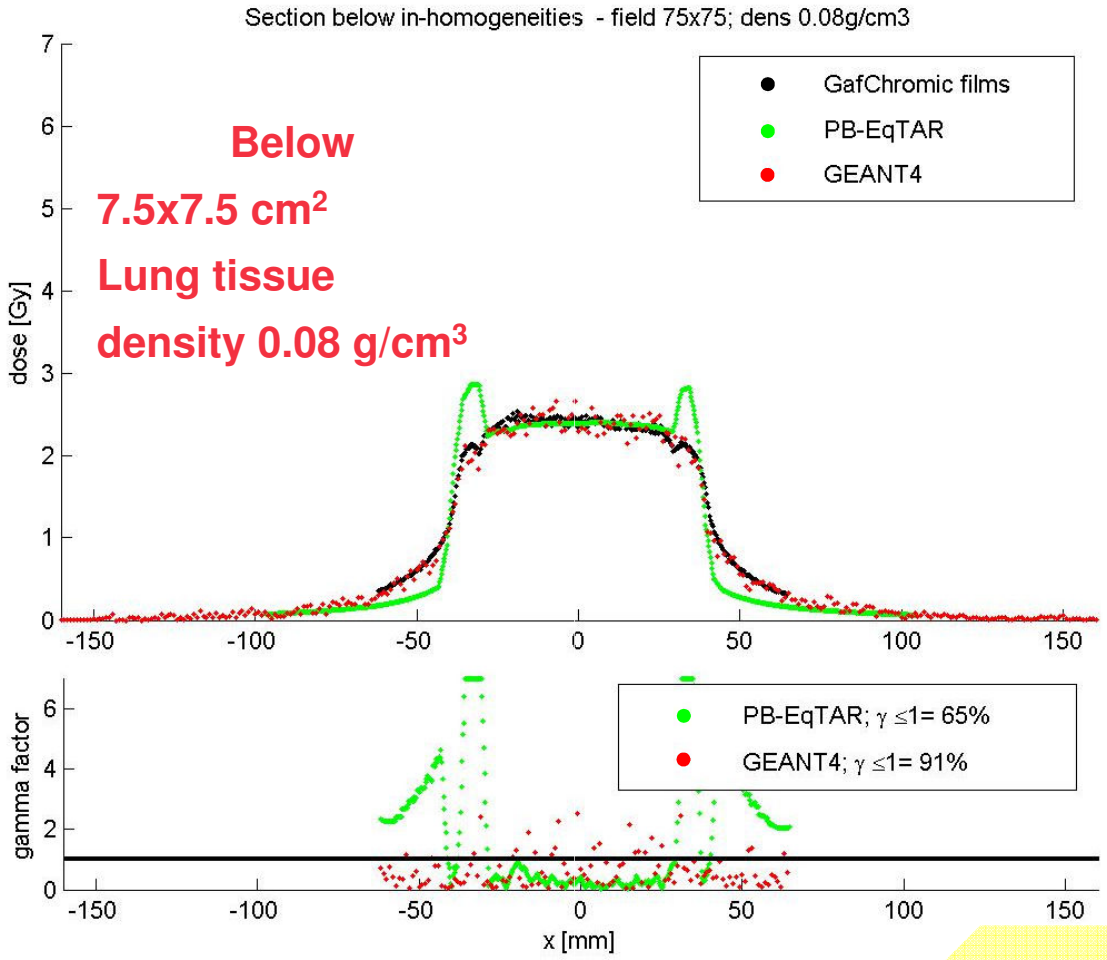


Results



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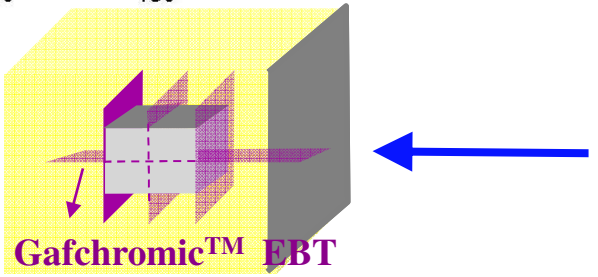

Results

Comparison among γ factors

Field [cmxcm]	Density [g/cm3]	GEANT4	PB-EqTAR	Pinnacle-CCC
	0.03	52	28	52
3x3	0.08	83	38	53
	0.40	88	53	95
	0.03	86	26	54
7.5x7.5	0.08	92	52	75
	0.40	98	94	99
	0.03	86	37	88
20x20	0.08	89	93	97
	0.40	96	/	97

Conclusions

- A GEANT4 based MC simulation of a 2100 Clinac Varian has been used to investigate the effect of different lung densities (simulating the breathing) as well as different field dimensions

- The results have been compared against GafchromicTM EBT measurements and two commercial TPS.

- A rather good agreement of the MC simulation with the measurements have been observed while TPS results appear to be less accurate especially when small fields and densities are taken into account. Between the two TPS adopted the Pinnacle gave a better agreement with respect to the Eclipse.

THANK YOU

Computing setup

Geant 4

- **gamma**
  - *Photo-electric*
  - *Rayleigh scattering*
  - *Compton scattering*
  - *Pair production (Gamma conversion)*
- **electron**
  - *Ionisation and delta ray production*
  - *Bremsstrahlung*
  - *MultipleScattering*
- **positron**
  - *Ionisation and delta ray production*
  - *Bremsstrahlung*
  - *MultipleScattering*
  - *Annihilation*

Computing setup

Geant 4

```
//gamma
this->lowePhot = new  G4LowEnergyPhotoElectric("LowEnPhotoElec");
pmanager->AddDiscreteProcess(new G4LowEnergyRayleigh);
pmanager->AddDiscreteProcess(lowePhot);
pmanager->AddDiscreteProcess(new G4LowEnergyCompton);
pmanager->AddDiscreteProcess(new G4LowEnergyGammaConversion);
//electron
this->loweIon  = new G4LowEnergyIonisation("LowEnergyIoni");
this->loweBrem = new G4LowEnergyBremsstrahlung("LowEnBrem");
pmanager->AddProcess(new G4MultipleScattering, -1, 1,1);
pmanager->AddProcess(loweIon,     -1, 2,2);
pmanager->AddProcess(loweBrem,    -1,-1,3);
//positron
pmanager->AddProcess(new G4MultipleScattering,-1, 1,1);
pmanager->AddProcess(new G4eIonisation,       -1, 2,2);
pmanager->AddProcess(new G4eBremsstrahlung,   -1,-1,3);
pmanager->AddProcess(new G4eplusAnnihilation,  0,-1,4);
```