

Dosimetric Verification of the Radiotherapy Treatment Planning System Based on the PENFAST Monte Carlo Code for Photon and Electron Dose Calculations

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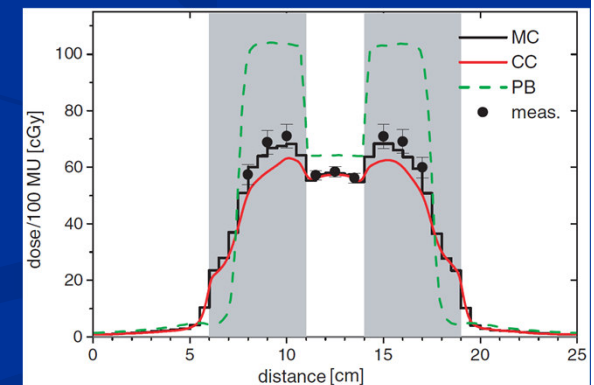
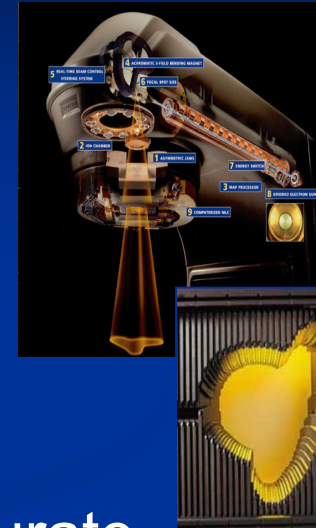
CEA, LIST, F-91191 Gif-Sur-Yvette, France.



Context

Dose calculation using advanced statistical methods for treating cancer with radiotherapy

- Radiotherapy
 - High dose to the tumour → chance of recovery
 - Lowest dose to sound tissues → avoid complications
- New technologies (IMRT, IGRT) require a very accurate dose calculation: heterogeneities, small beams
- Solution: Monte Carlo (MC) methods
 - ✓ Accurate results closer to reality
 - x Long computing time, normally not adapted to the clinical situation



Krieger T and Sauer OA.
Phys. Med. Biol. 2005 (50)

Objective

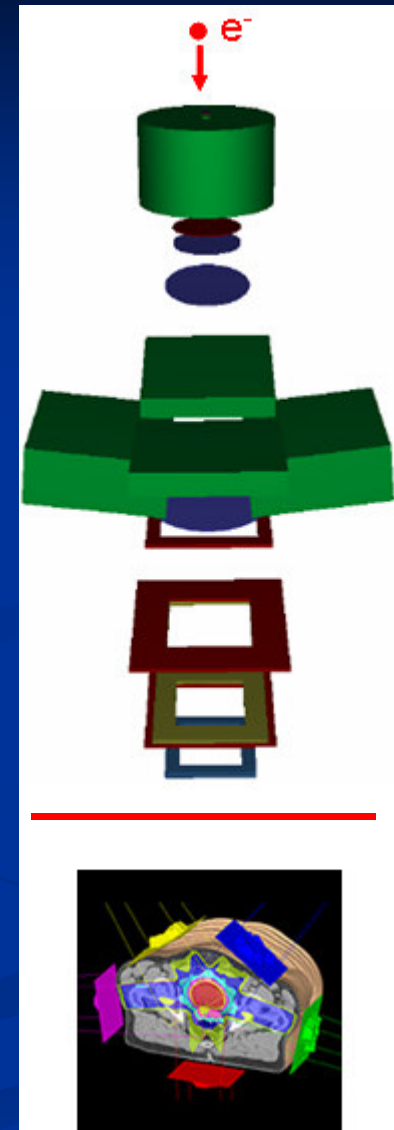
- MAESTRO & TELEDOS Projects → ISOgray TPS (MC)
 - Optimised physics
 - Variance reduction techniques
 - Parallelisation with MPI



Verification of the dose calculation accuracy ?

Monte Carlo dose calculation

- **PENELOPE** (PENetration and Energy LOSS of Positrons and Electrons) **code:**
 - Detailed simulation of particle transport through the accelerator head
 - A PSF is created for each beam
- **PENFAST code** (in the TPS):
 - Accelerated MC simulation of dose distributions in the voxelised geometry (CT scan)



Monte Carlo dose calculation

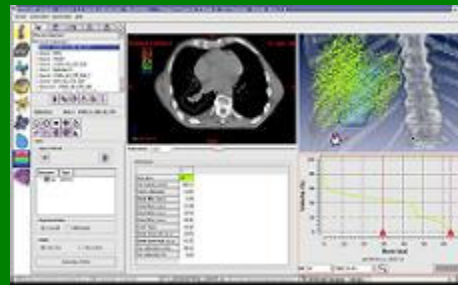
Pre-calculated
PSF
library



Patient CT data



ISOgray TPS

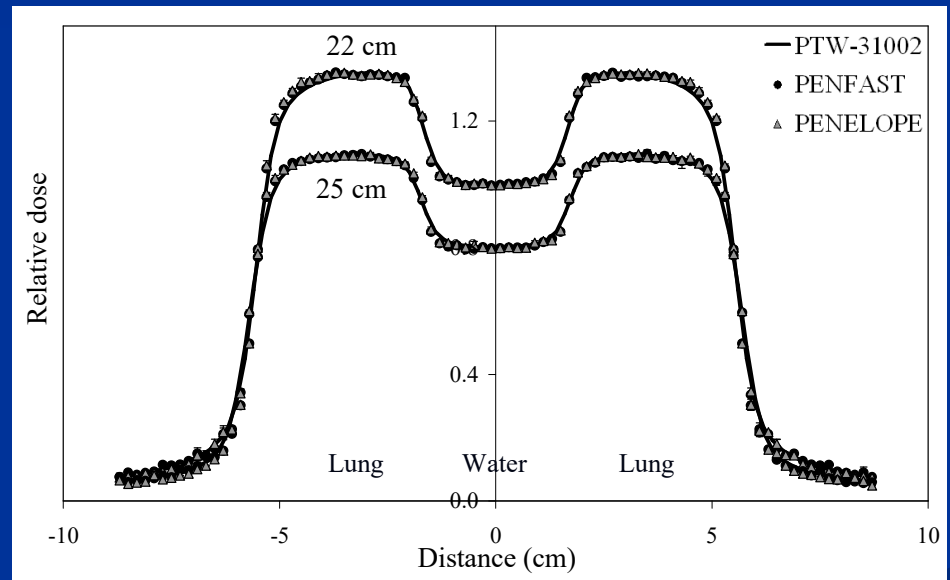
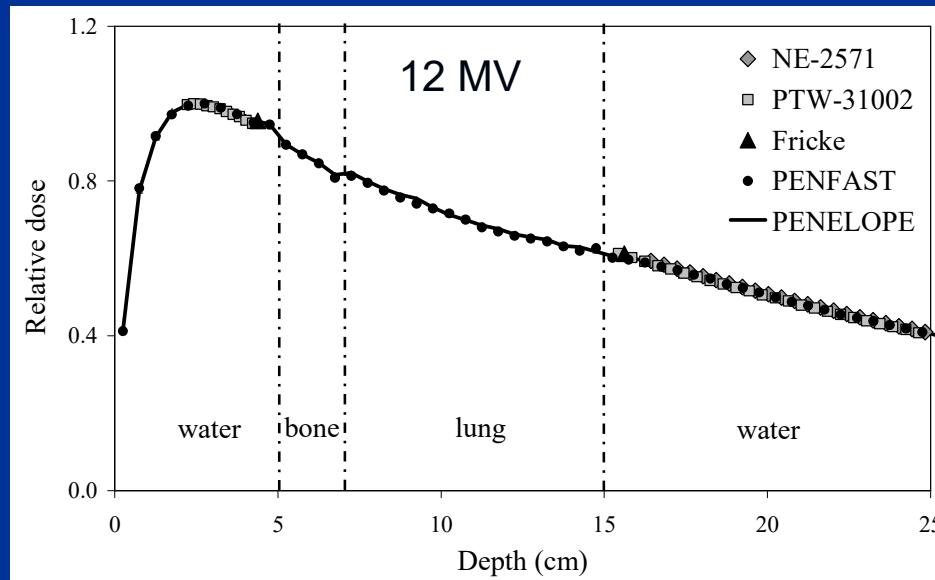


PENFAST dose
calculation &
Visualisation of dose

DOSI  soft

Verification of the dose calculation accuracy

Habib B et al. *Evaluation of PENFAST - a fast Monte Carlo code for dose calculations in photon and electron radiotherapy treatment planning.* Physica. Medica. Eur. J. Med. Phys. 2009

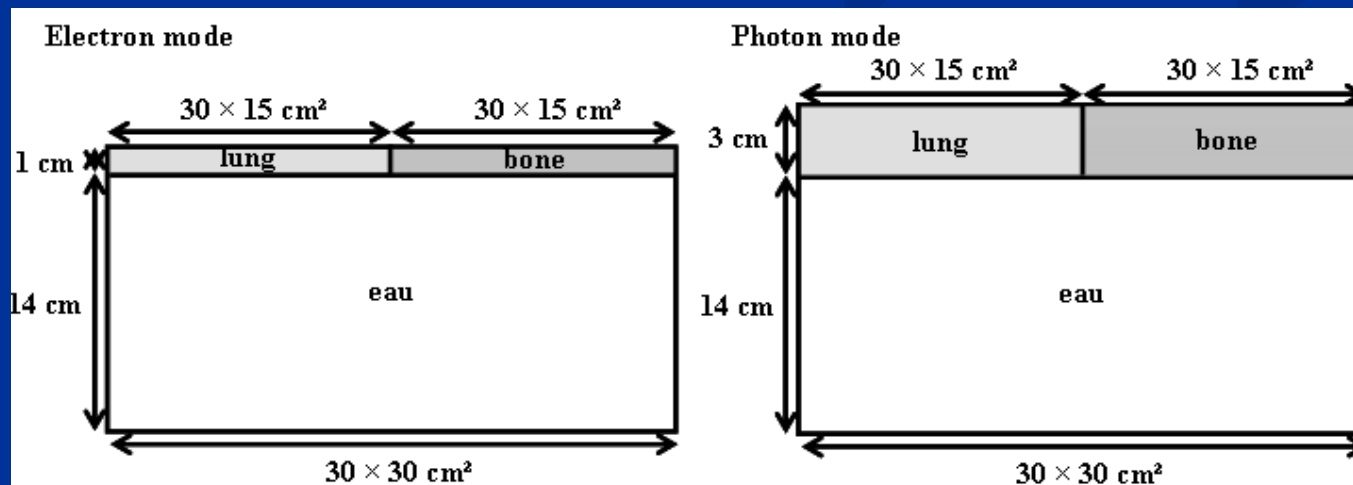


Difference < (2% - 2 mm)

4 min (e-), 15 min (Ph) for 1% stat. uncert. on 20 processors

Materials

- **Primus-Siemens Accelerator**
 - 25 MV photon and 9 MeV electron modes
 - Fields: 4x4 (6x6 for electrons), 10x10, and 20x20 cm²
- **Dosimeter**
 - IC Scanditronix Wellhöfer CC13 (0,13 cm³) in water
 - Radiographic film in heterogeneous phantoms
- **Phantoms**
 - Water phantom 50x50x50 cm³
 - Heterogeneous slab phantom (Lung and Bone)



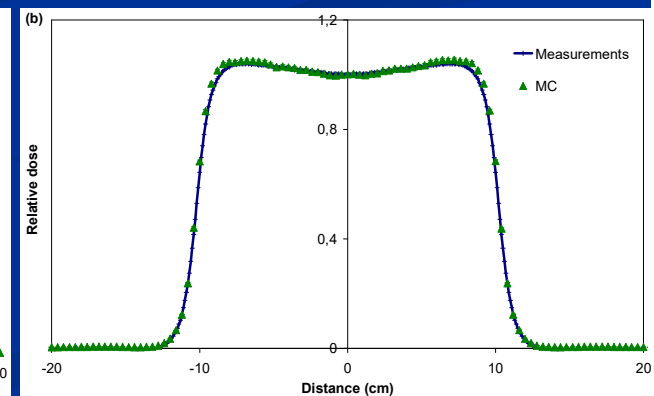
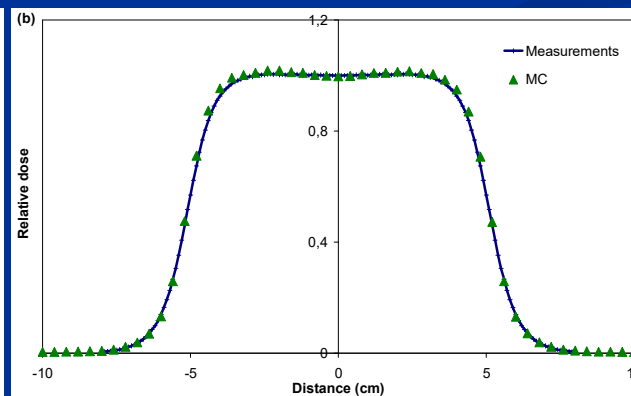
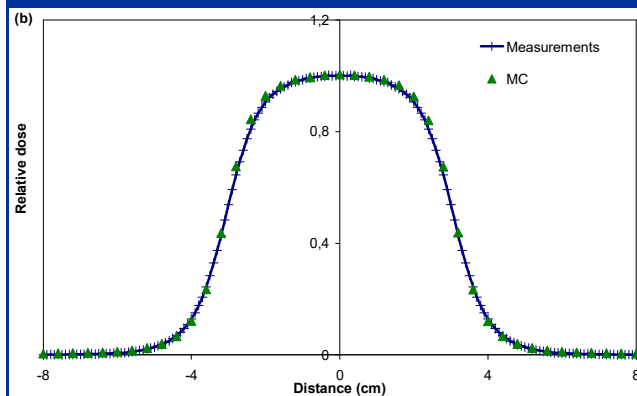
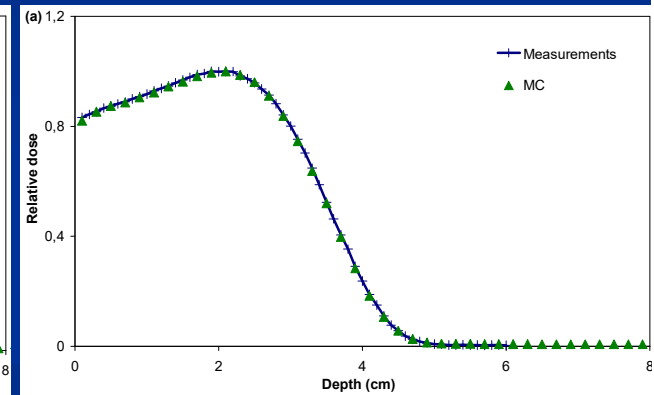
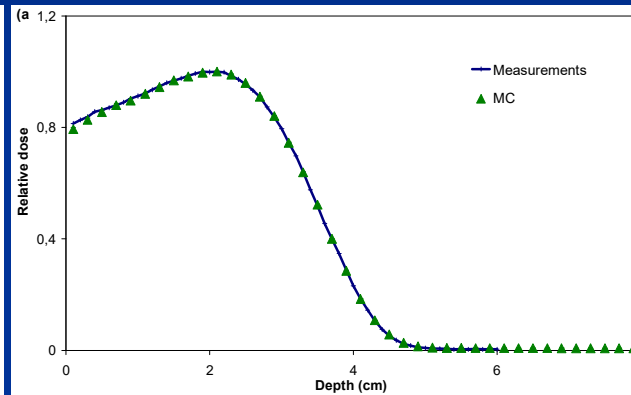
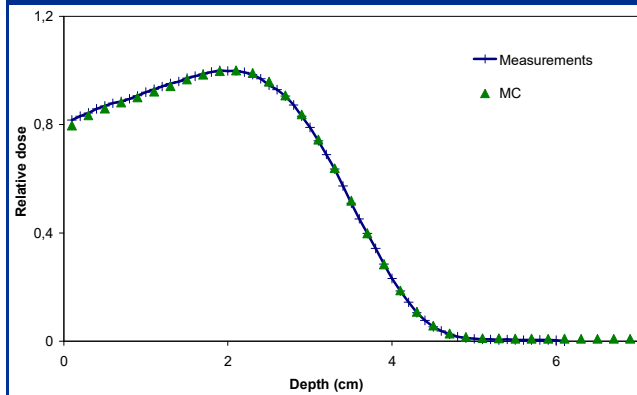
Results

9 MeV electron mode, water phantom Depth-dose and dose profiles at 2 cm depth

6x6 cm²

10x10 cm²

20x20 cm²



Difference < (2% - 1 mm)

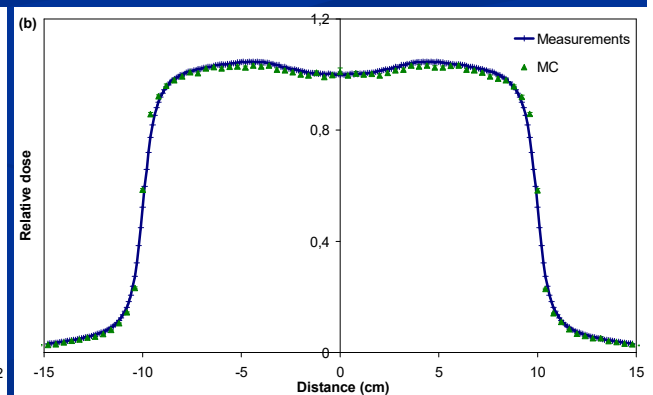
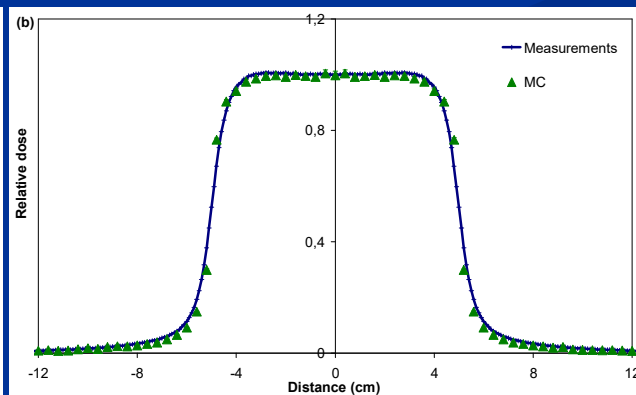
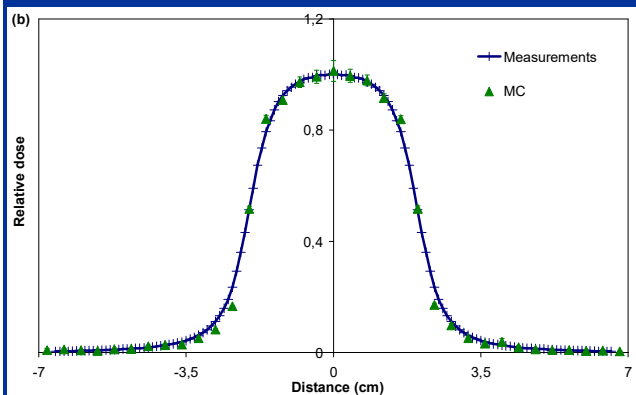
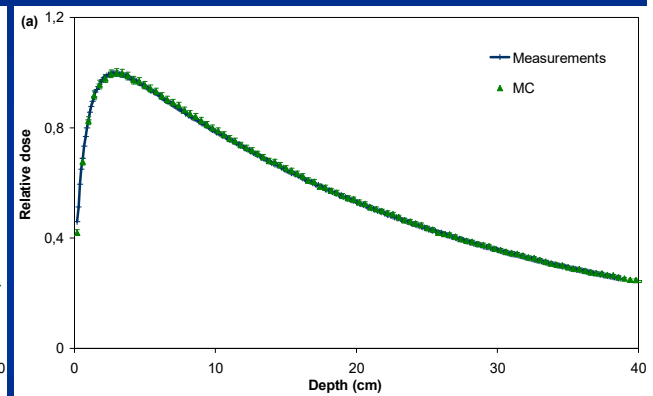
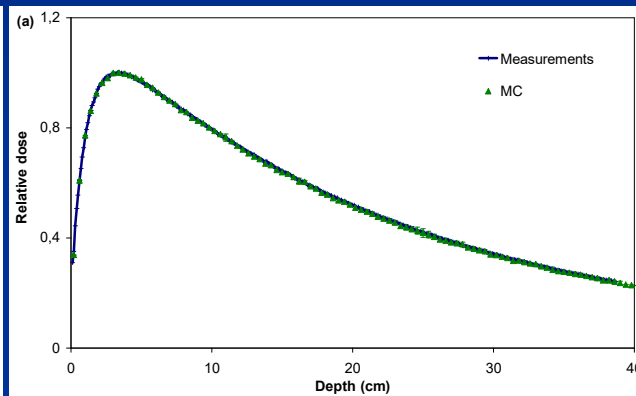
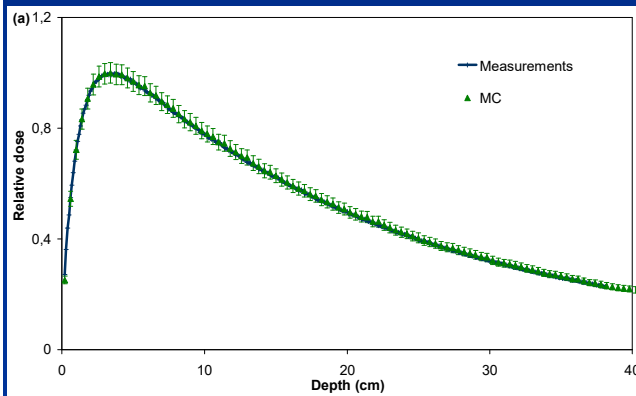
Results

25 MV photon mode, water phantom Depth-dose and dose profiles at 10 cm depth

4x4 cm²

10x10 cm²

20x20 cm²

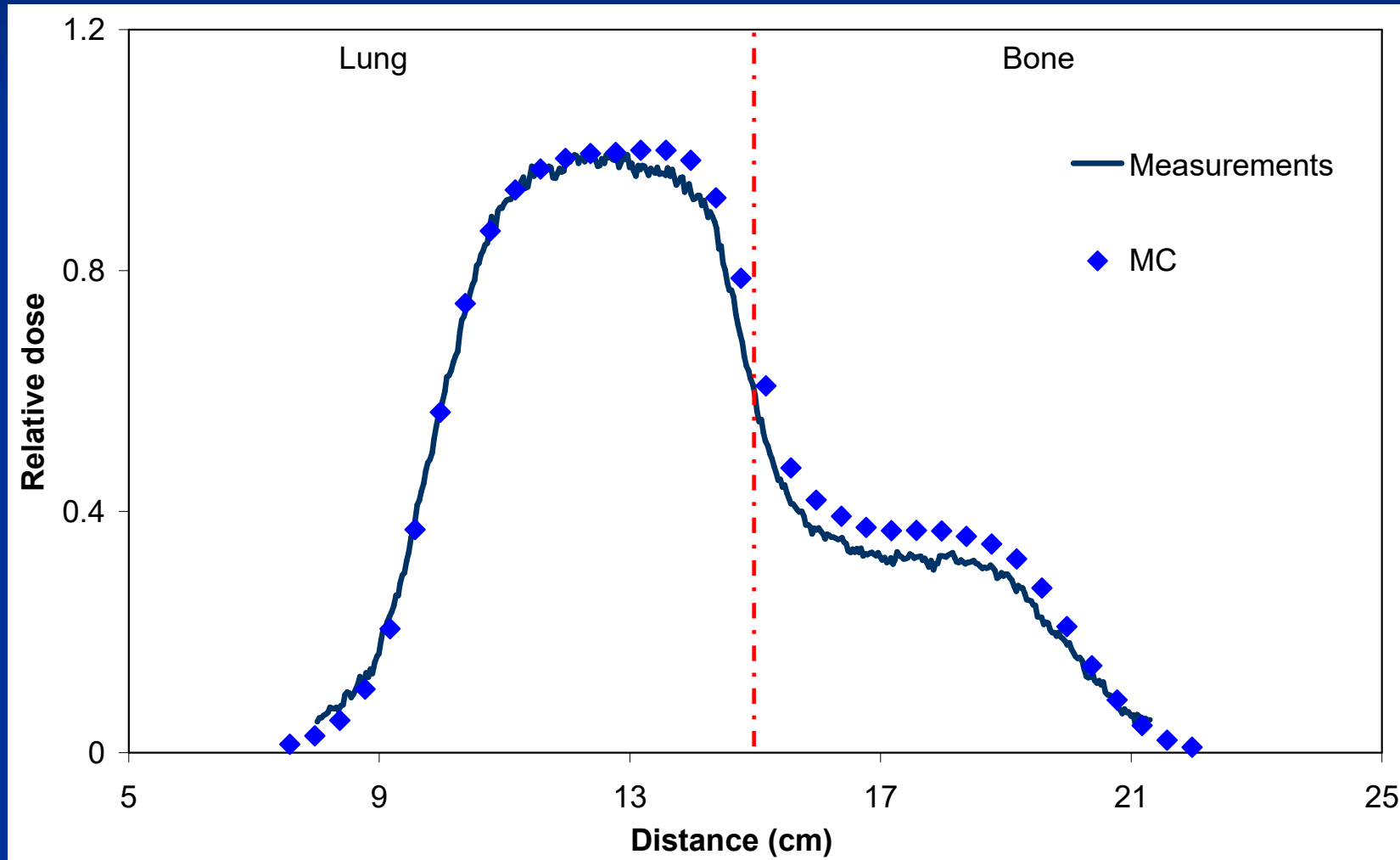


Difference < (2% - 1 mm)

Results

9 MeV electron mode, 10x10 cm²

Dose profiles at 3 cm depth in the heterogeneous phantom



Results

9 MeV electron mode, 10x10 cm²

Dose profiles at 3 cm depth in the heterogeneous phantom

Errors in the material and mass density assignment:

- Artefacts in the CT image due to the presence of a high density slab (bone)
- Unique HU-material and HU-density correspondences?

	Material	Color
1	Liquid water	Blue
2	Air	White
3	Compact bone	Yellow
4	Lung	Pink
5	Titanium	Light Green
6	Lead	Dark Red



Results

9 MeV electron mode, 10x10 cm²

Dose profiles at 3 cm depth in the heterogeneous phantom

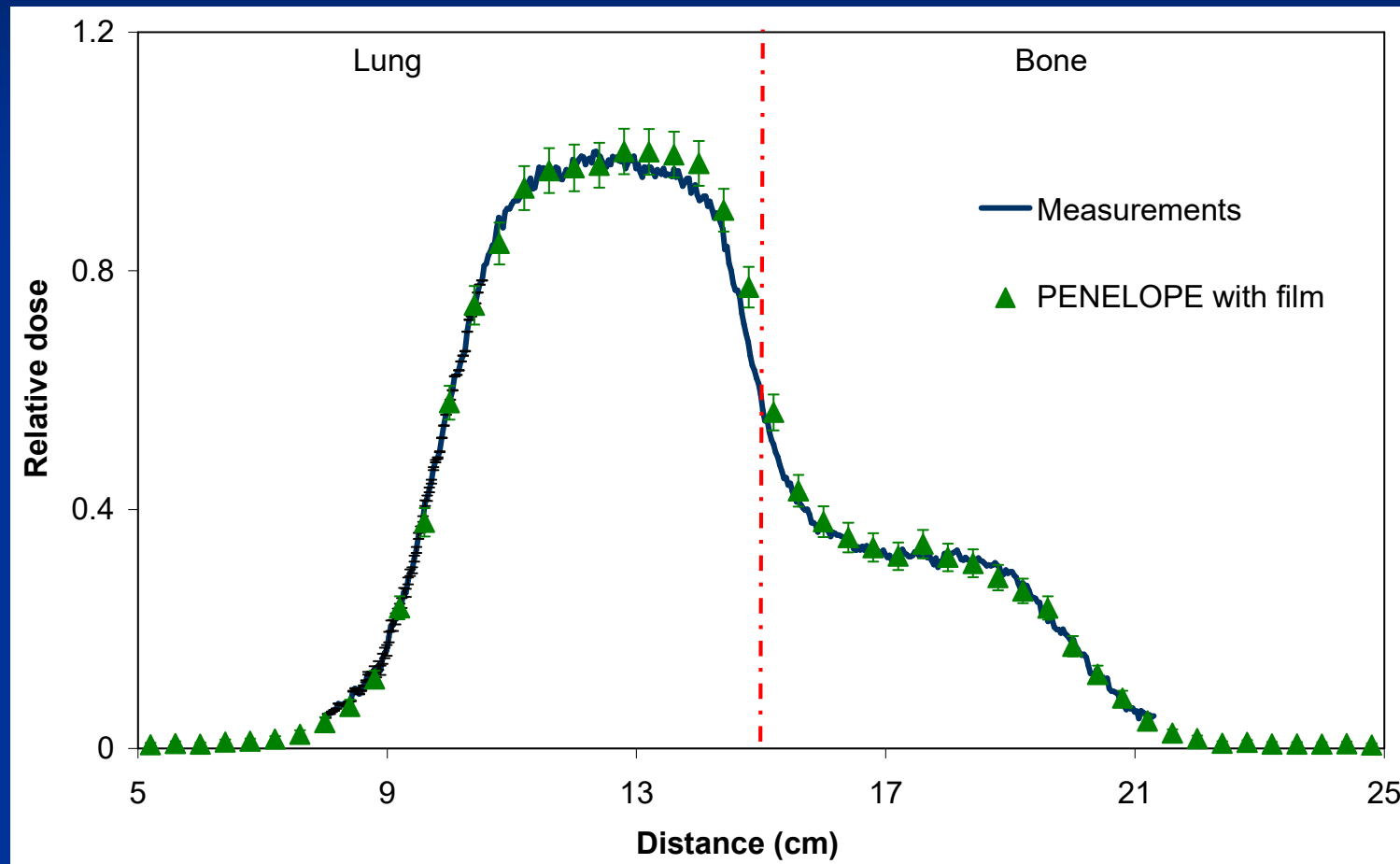
Radiographic film influence:

- Perturbation of the dose measurement by the presence of the film
- Overestimation of the dose because of the film sensibility for low energy radiation backscattered from the high density material

Results

9 MeV electron mode, 10x10 cm²

Dose profiles at 3 cm depth in the heterogeneous phantom

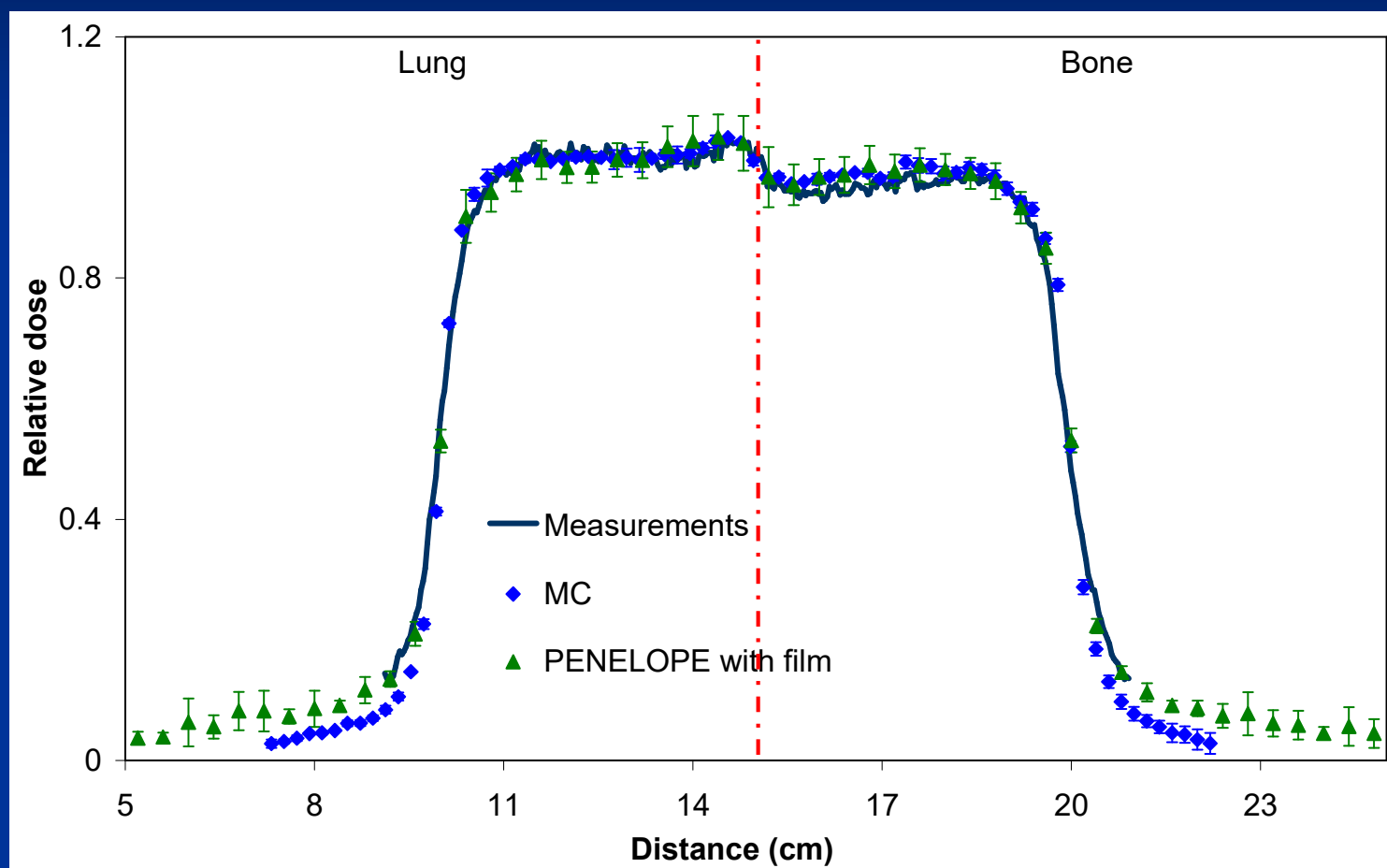


Difference (PENELOPE with film/Measurements) < (2% - 2 mm)

Results

25 MV photon mode, 10x10 cm²

Dose profiles at 5 cm depth in the heterogeneous phantom



Difference < (2% - 2 mm)

Conclusions and outlook

- TPS (MC) ables to calculate accurate dose distributions for photon and electron beams when materials are well defined and the dosimeter disturbance is taken into account
- Errors in HU-material and HU-density conversion (artefacts, image acquisition conditions, phantom characteristics)
- Sensibility problem with the radiographic film in presence of high density materials (bone)
- Evaluation of the material assignment process & testing complex configurations ... progressing

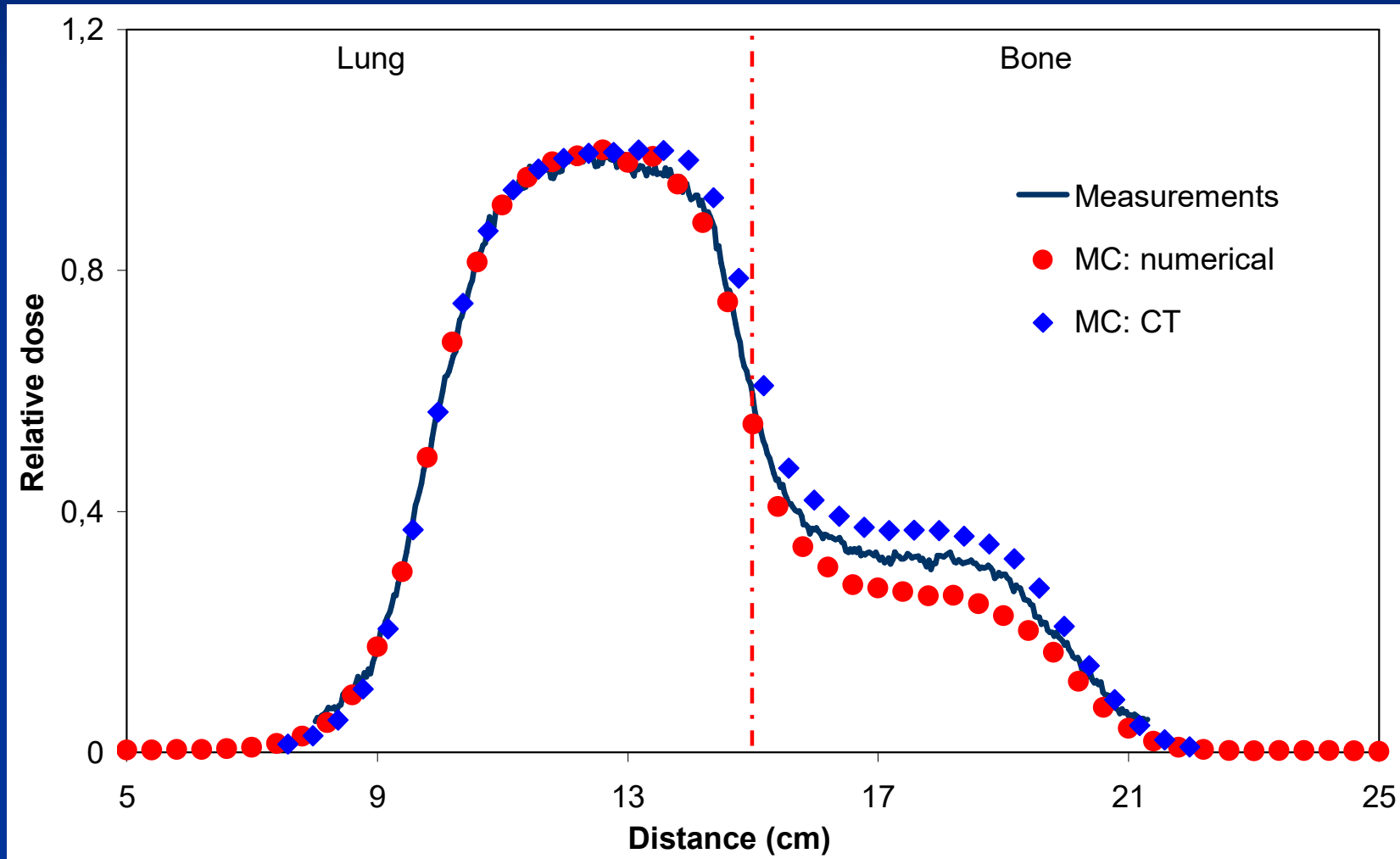


Thank you for your attention
bouchra.habib@cea.fr

Results

9 MeV electron mode, 10x10 cm²

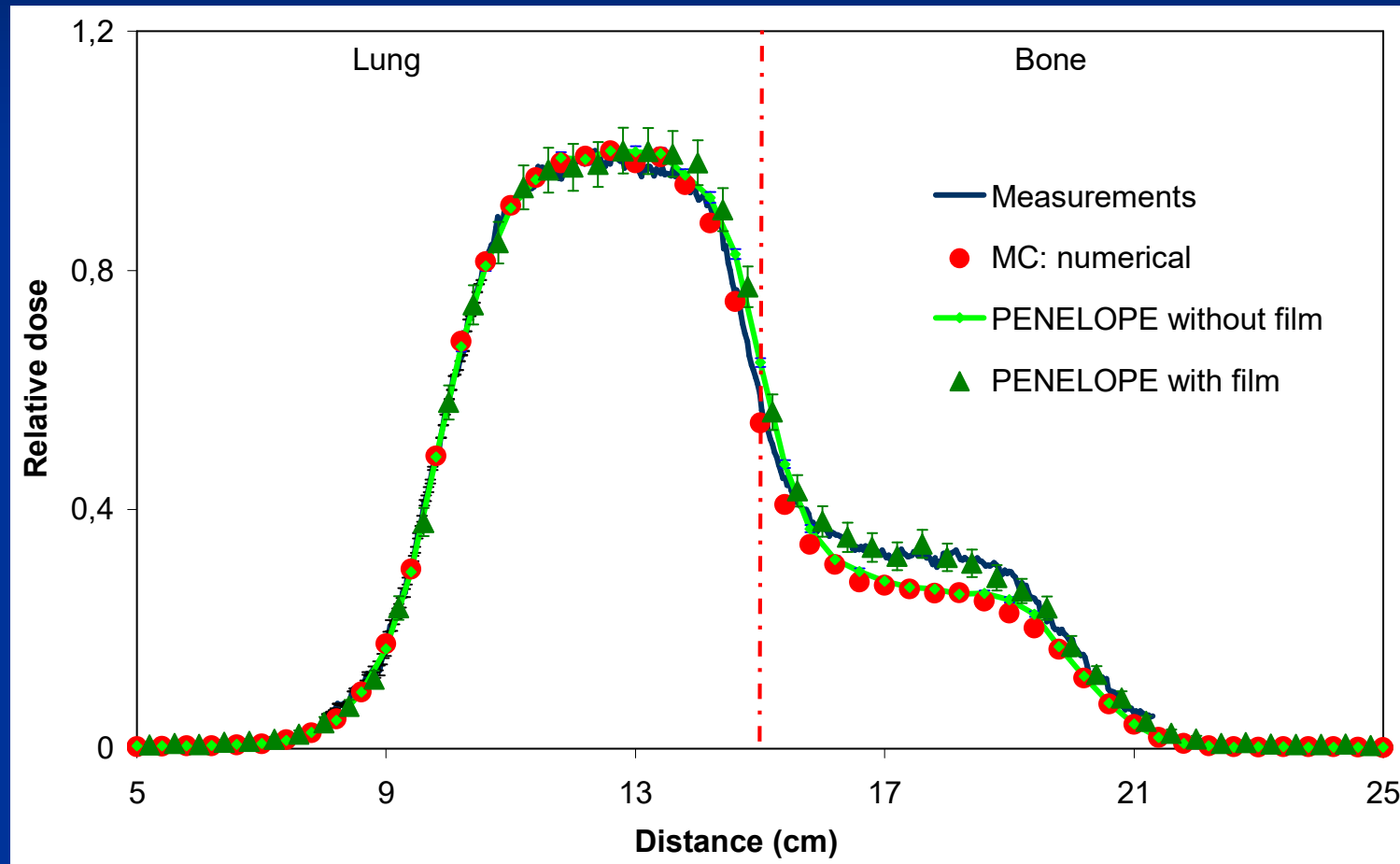
Dose profiles at 3 cm depth in the heterogeneous phantom



Results

9 MeV electron mode, 10x10 cm²

Dose profiles at 3 cm depth in the heterogeneous phantom

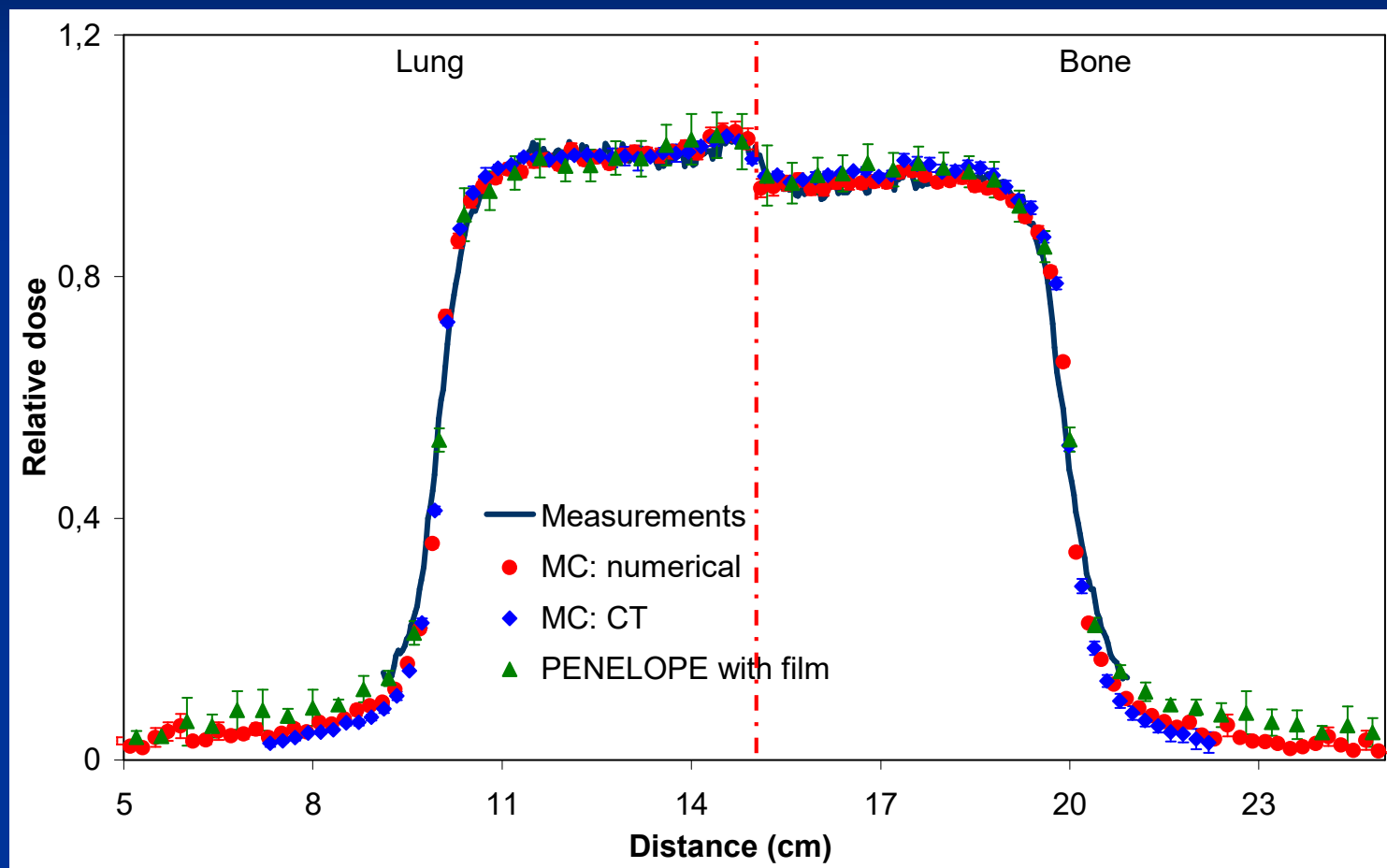


Difference (PENELOPE with film/Measurements) < (2% - 2 mm)

Results

25 MV photon mode, 10x10 cm²

Dose profiles at 5 cm depth in the heterogeneous phantom



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