Effect of Voxel Size on Monte Carlo Dose Calculations for Clinical Radiotherapy Photon Beams

G. Mora and A. Maio
CFNUL, Universidade de Lisboa

T. Pawlicki, and C.-M. Ma
Stanford University, Stanford, USA

The use of CT in Radiotherapy

CT
(Computer Tomography)
IMAGE DATA

3D information
of the
Anatomical
Structures

Monte Carlo Dose
Calculation
Treatment Planning

Higher Accuracy
Treatment
Planning Systems

CT data Conversion

CT **IMAGE** DATA

CT NUMBER

$$\text{CT number (HU)} = 1000 \times \frac{\mu_{material} - \mu_{water}}{\mu_{water}}$$

Hounsfield Units

Material and Density Information of the patient simulation geometry

Monte Carlo Dose Calculation Code

CT Number Conversion Scheme

Material	CT number range	Density range
Air	0-100	0.001-0.1
Tissue	100-1125	0.1-1.125
Bone	1125-3500	1.125-2.65

Voxel (volume element)

An ideal conversion scheme

CT Voxel Size
(about 1mm)

Phantom Simulation geometry
Voxel Size (1mm)

CPU time and Computer Memory Size
increases rapidly with decreasing v.s.

More Practical conversion scheme

Resizing
CT voxels

Phantom Simulation geometry
Voxel Size (1-10mm)

Change the material types
and
density distributions

Affect the dose distributions

Materials and Method

Head patient CT data

Using the same
conversion algorithm

Patient simulation
phantoms
Voxel Sizes (2-10 mm)

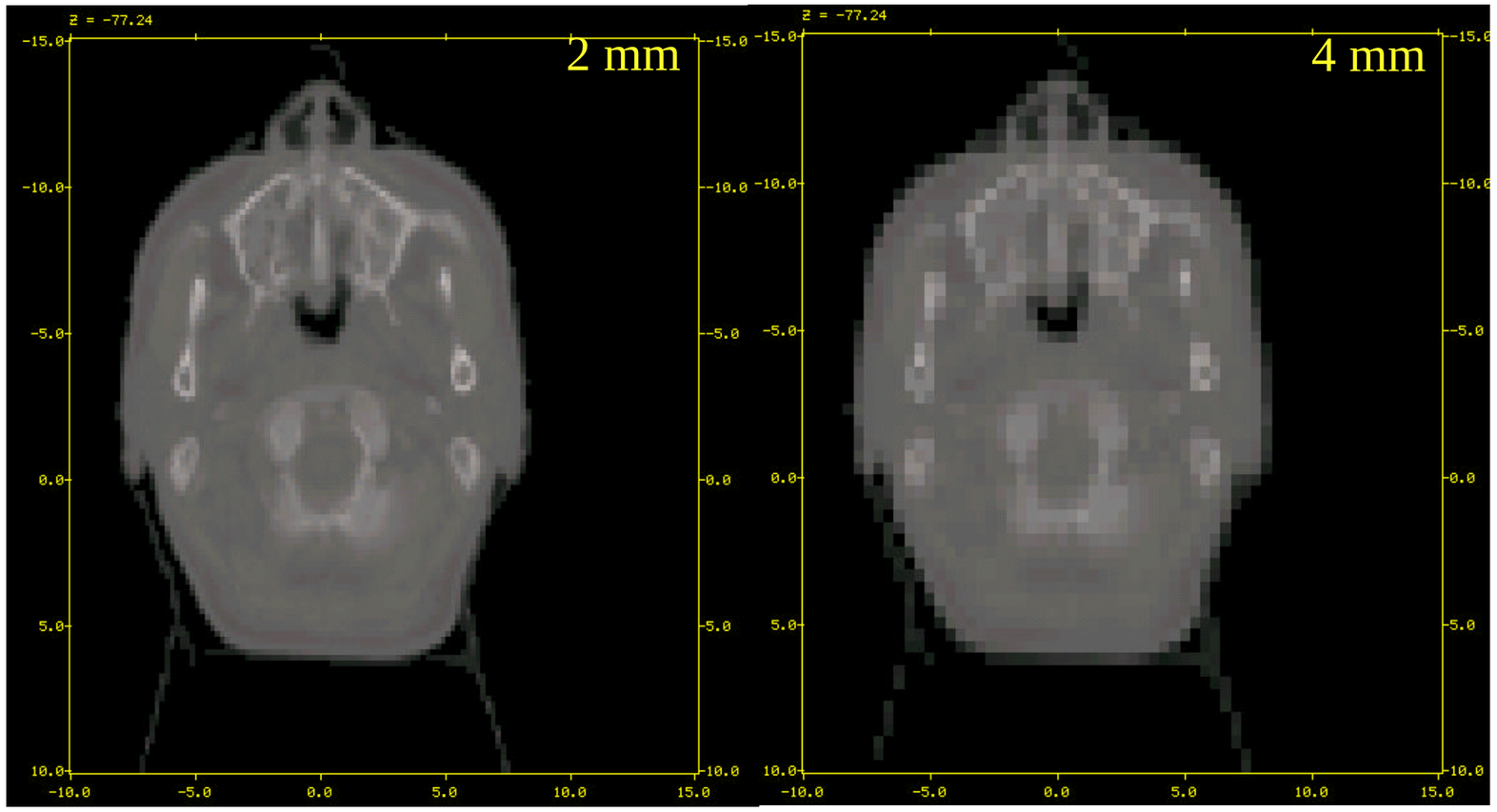
Materials and Method

- The Monte Carlo simulation

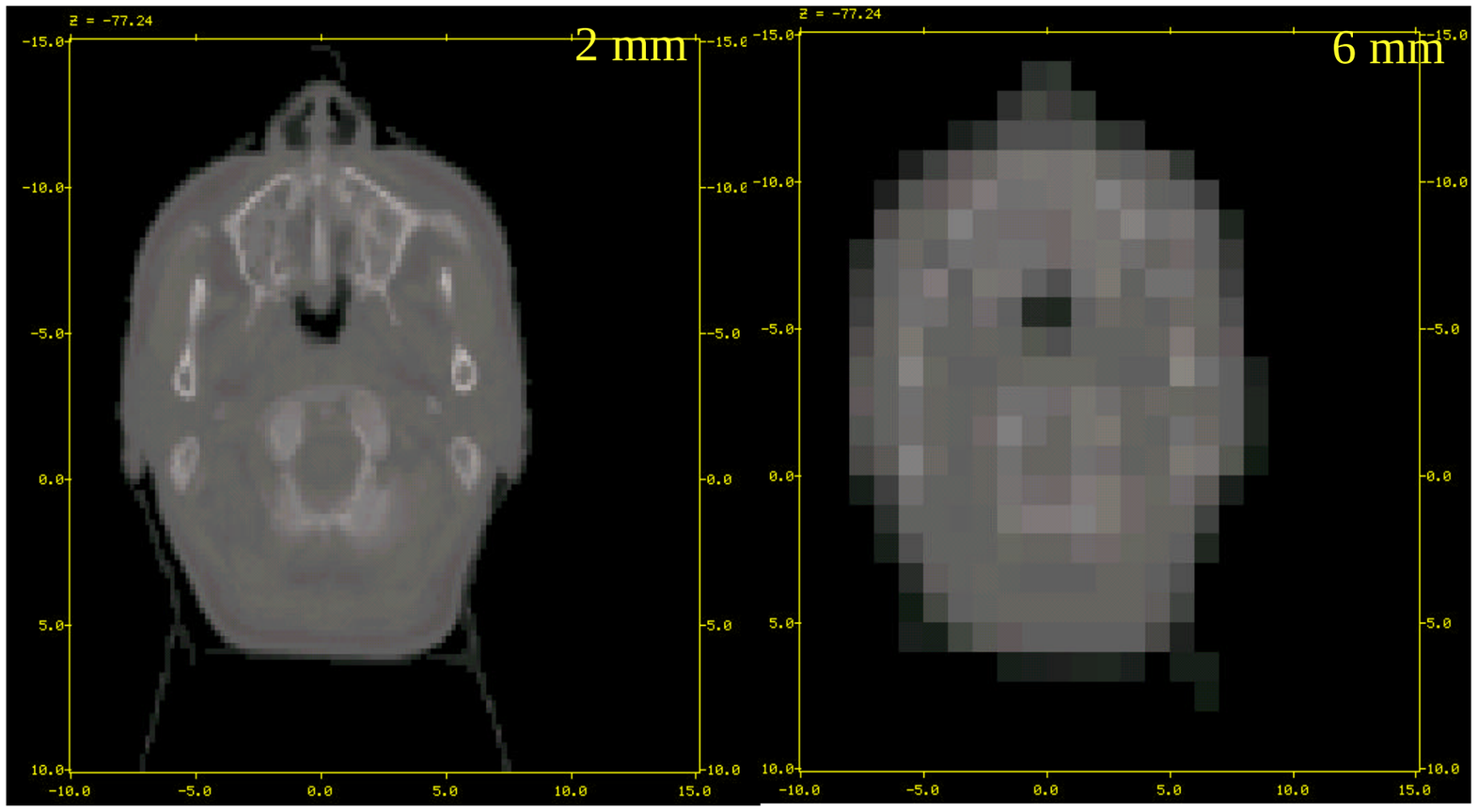
- 4 and 15 MV photon beams from medical accelerator

- EGS4/DOSXYZ - a Monte Carlo code to simulate dose distributions in a phantom or a patient geometry built from CT data

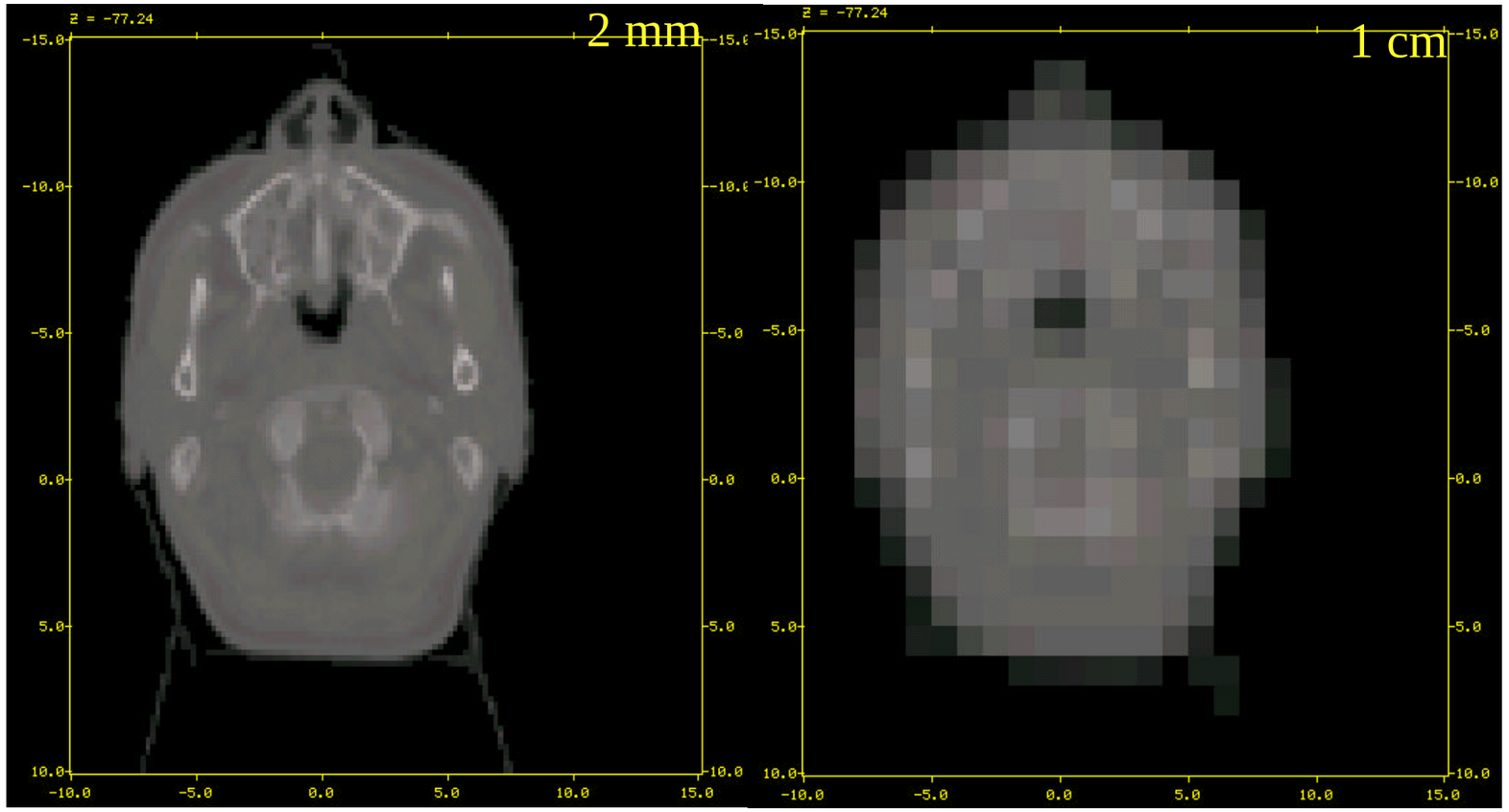
Patient Simulation Phantoms

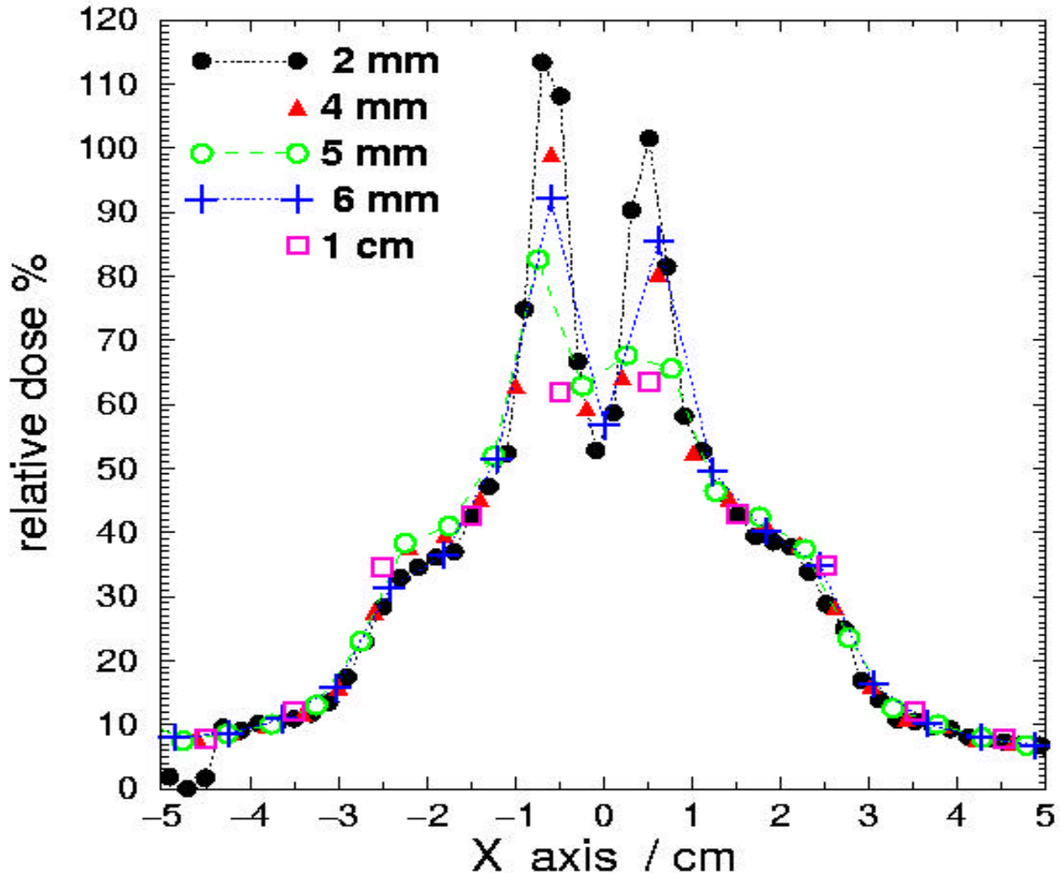


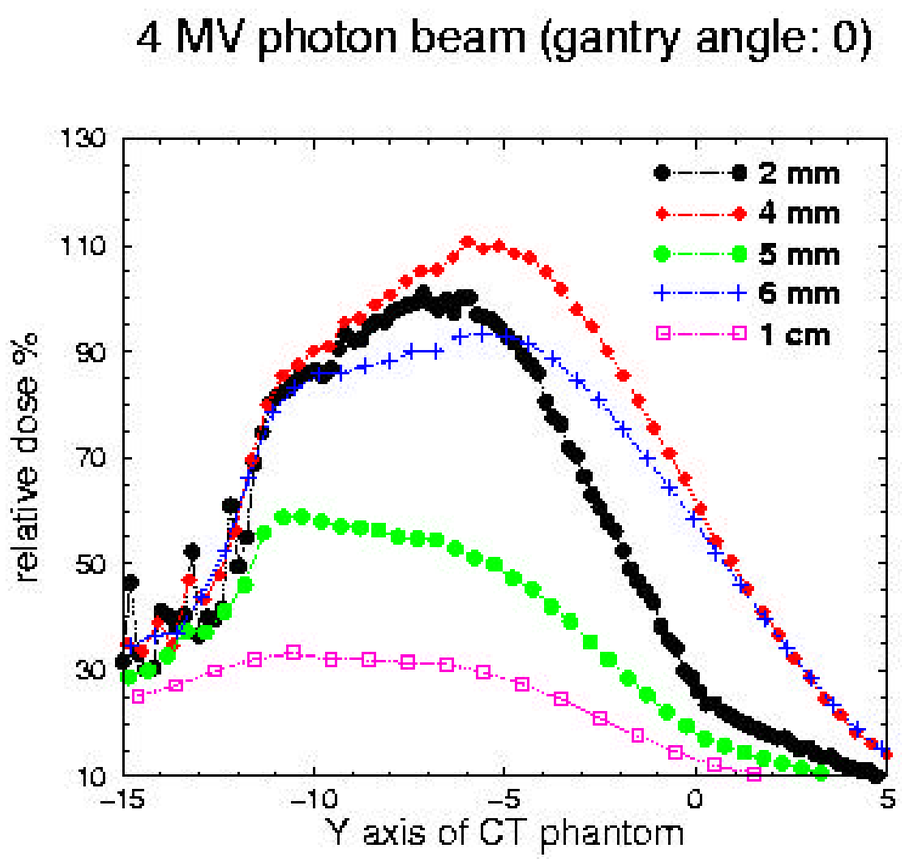
Patient Simulation Phantoms



Patient Simulation Phantoms

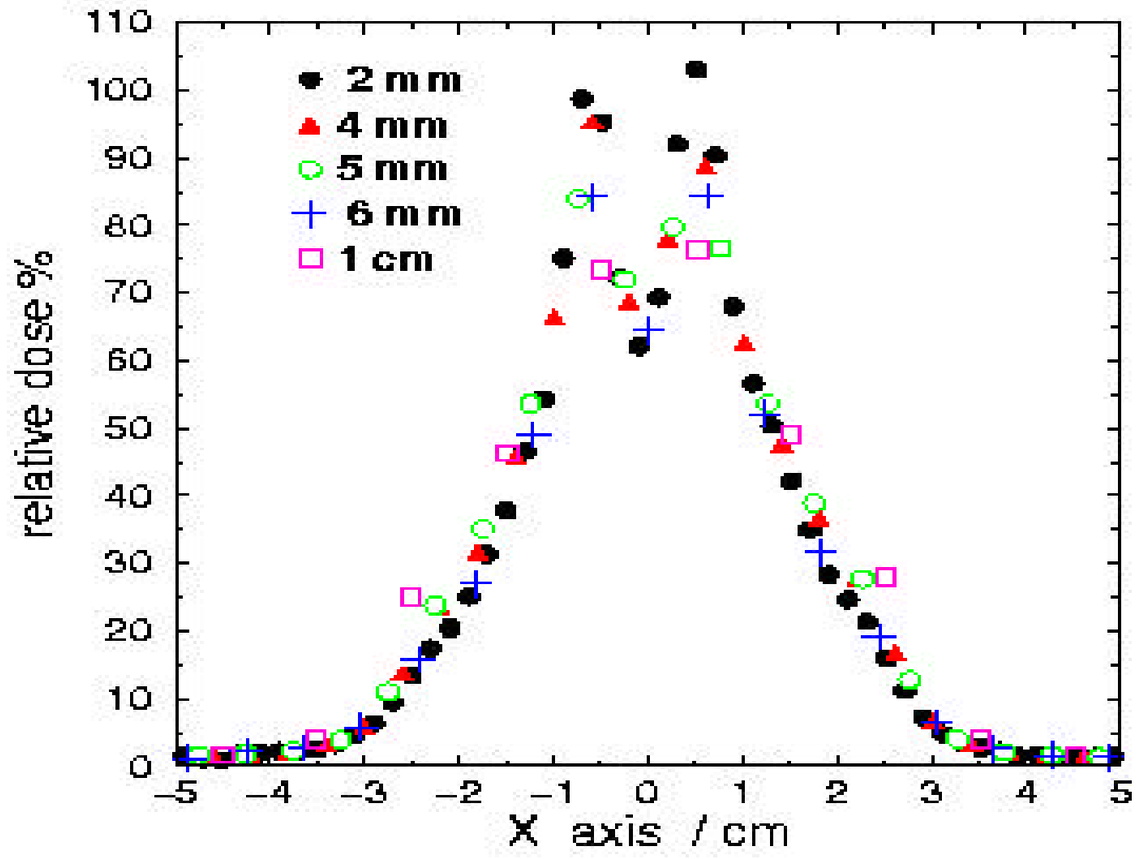



2 mm
4 mm
5 mm
6 mm
1 cm
relative dose %
X axis / cm
120
110
100
90
80
70
60
50
40
30
20
10
0
−5
−4
−3
−2
−1
0
1
2
3
4
5


4 MV photon beam (gantry angle: 0)
2 mm
4 mm
5 mm
6 mm
1 cm
relative dose %
130
110
90
70
50
30
10
−15
−10
−5
0
5
Y axis of CT phantom

CPU Time vs Voxel Size

Voxel Size (cm)	Number of events	CPU time ratio
0.2	$60x10^6$	1.00
0.4	$60x10^6$	0.70
0.5	$60x10^6$	0.64
0.6	$60x10^6$	0.59
1.0	$60x10^6$	0.52


2 mm
4 mm
5 mm
6 mm
1 cm
relative dose %
X axis / cm
110
100
90
80
70
60
50
40
30
20
10
0
−5
−4
−3
−2
−1
0
1
2
3
4
5

Conclusions

- Significant Voxel Size effect is observed on the dose distributions calculated in the nasal cavity region for 4 and 15 MV photon beams
- The effect decreases with beam energy.
- 3 mm or smaller voxels should be used for the nasal cavity region.