Progress report on orthogonal ray imaging for assisting radiotherapy treatments

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2. U C
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A line of research of the project Rad4Life

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FCT Fundação para a Ciência e a Tecnologia
MINISTÉRIO DA CIÊNCIA, TECNOLOGIA E ENSINO SUPERIOR

QREN Quadro de Referência Estratégico Nacional Portugal 2007.2013

Ciência.Inovação 2010 Programa Operacional Ciência e Inovação 2010
MINISTÉRIO DA CIÊNCIA, TECNOLOGIA E ENSINO SUPERIOR

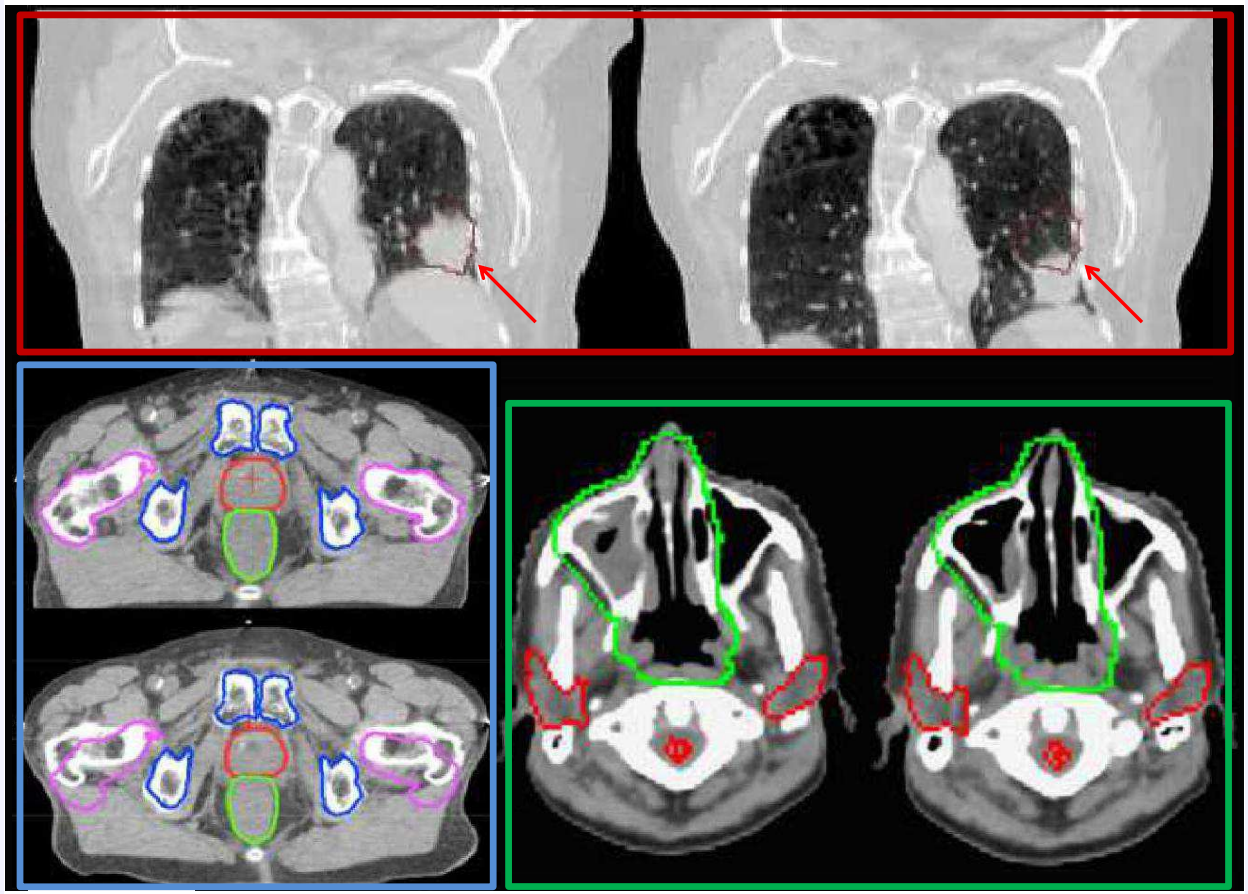
UNIÃO EUROPEIA
Fundo Europeu de Desenvolvimento Regional

Outline

1. Motivation

1.1 Need for image guided radiotherapy (IGRT) and adaptive radiotherapy (ART)

Patient morphologic alterations/mispositionings in RT



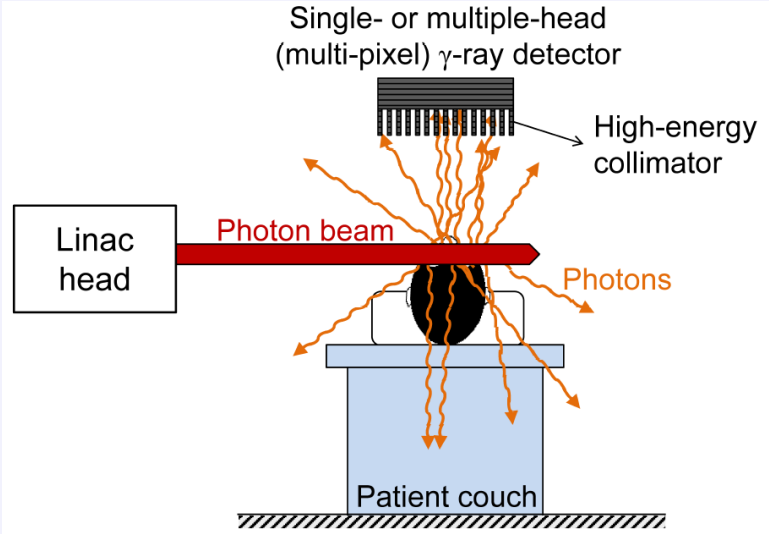
Engelsman and Bert 2011
Lüchtenborg PhD 2012

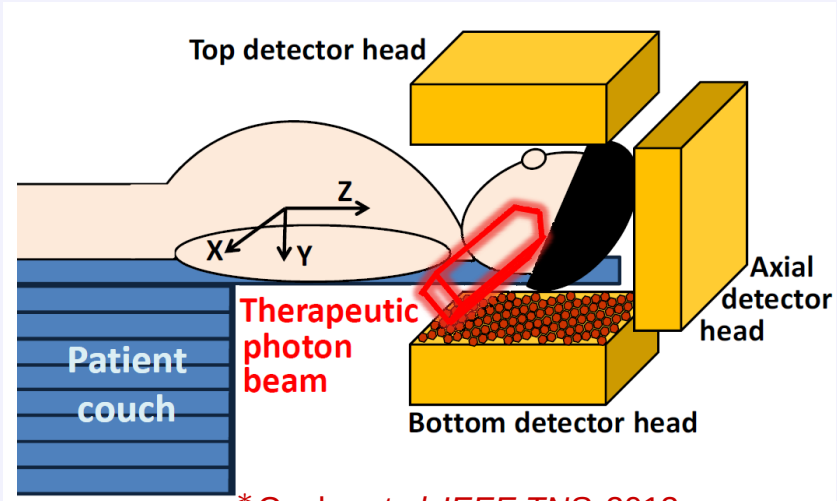
High conformality requires high precision and accuracy.
Hence, RT monitoring techniques are highly desirable

2. RTmonitor: RT treatment monitoring

2.1 Concept

- Detection of photons at approximately right angles
- Determination of positional deviations from the planning
- Real-time monitoring dose deviations*
- Allows for potential intervention whenever needed (ART), without additional dosage to the patient



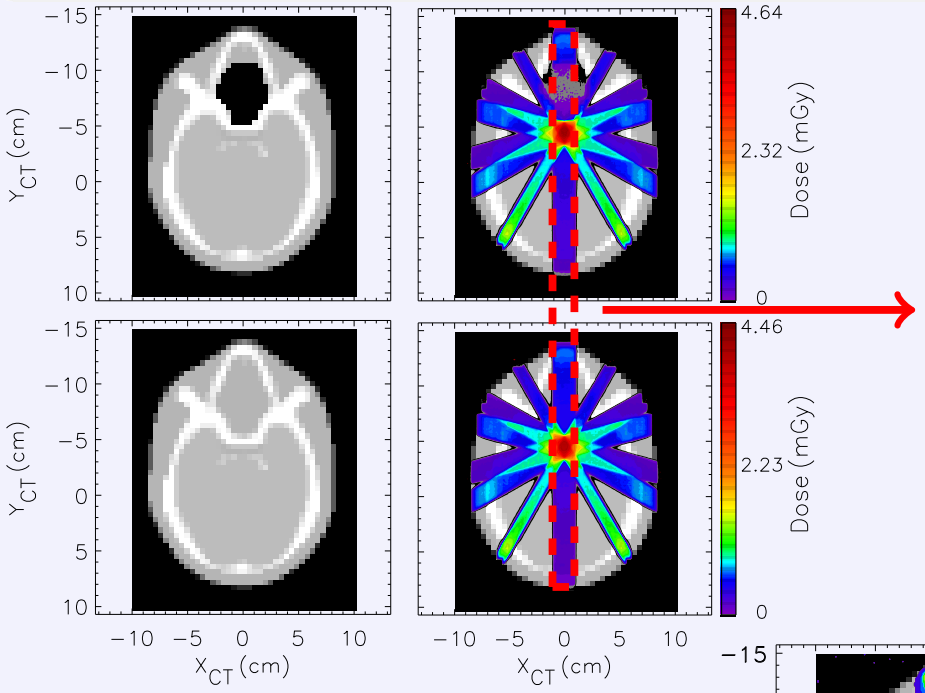


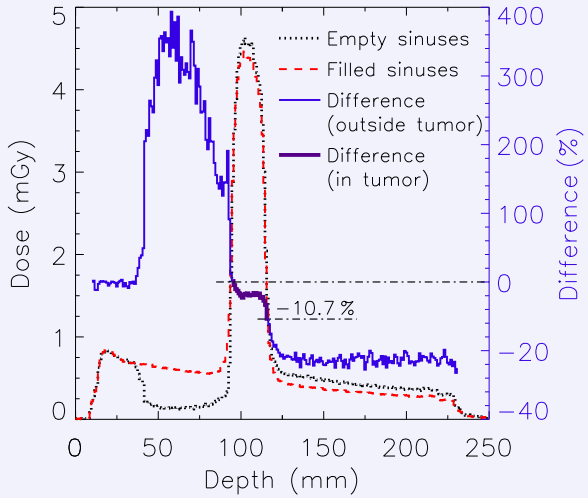
* Cunha *et al*, *IEEE TNS*, 2013
* Simões *et al* *IEEE TNS*, 2013
* Battaglia *et al*, *IEEE NSS & MIC*, 2012

2. RTmonitor: RT treatment monitoring

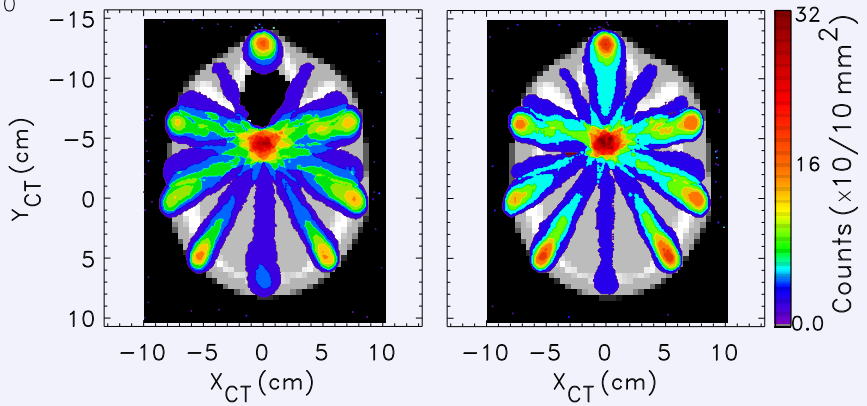
2.2 Simulated results: head

H. Simões *et al*, preliminary





RTMONITOR IMAGE

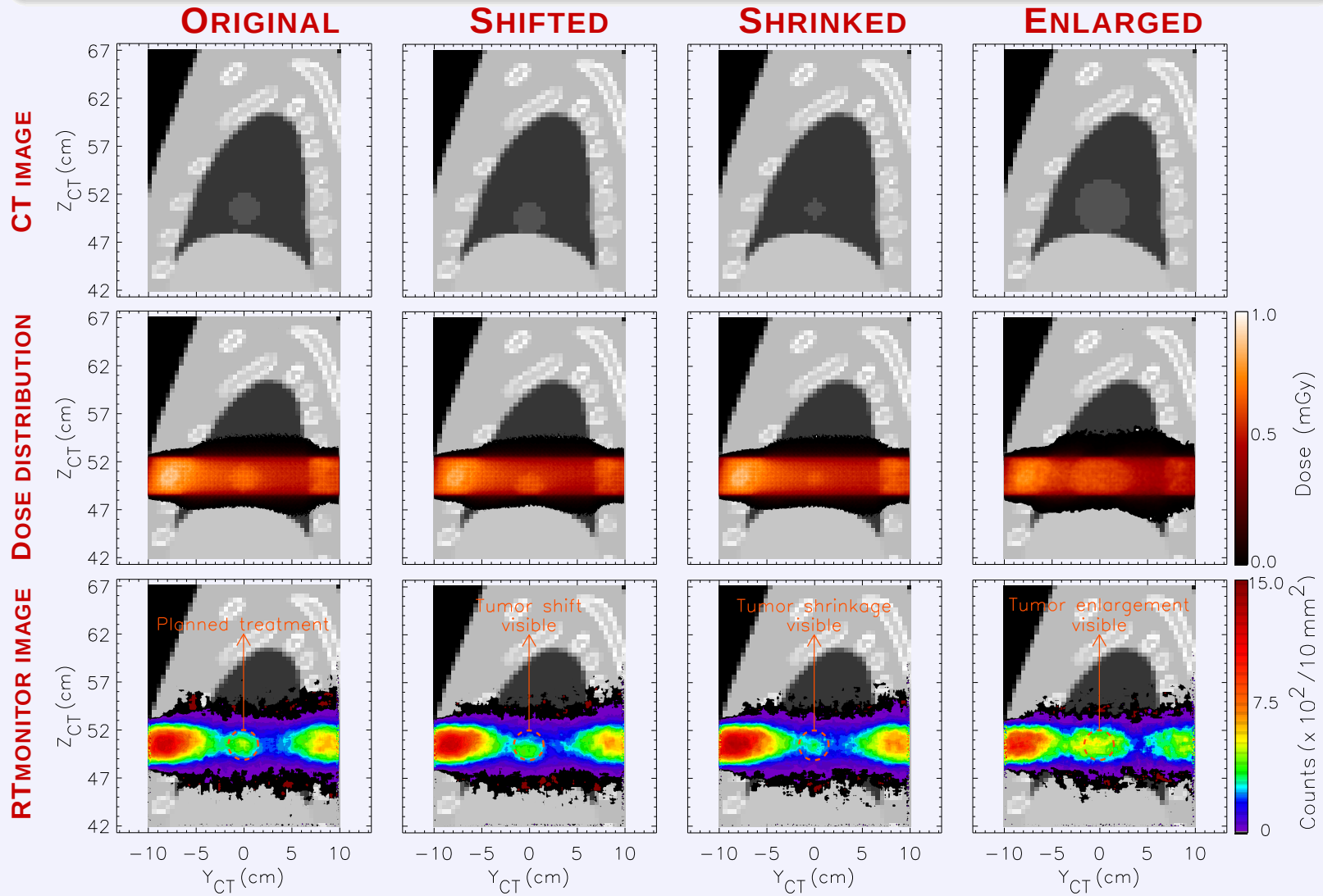


Morphologic change detectable with RTmonitor imaging

2. RTmonitor: RT treatment monitoring

2.3 Simulated results: lung

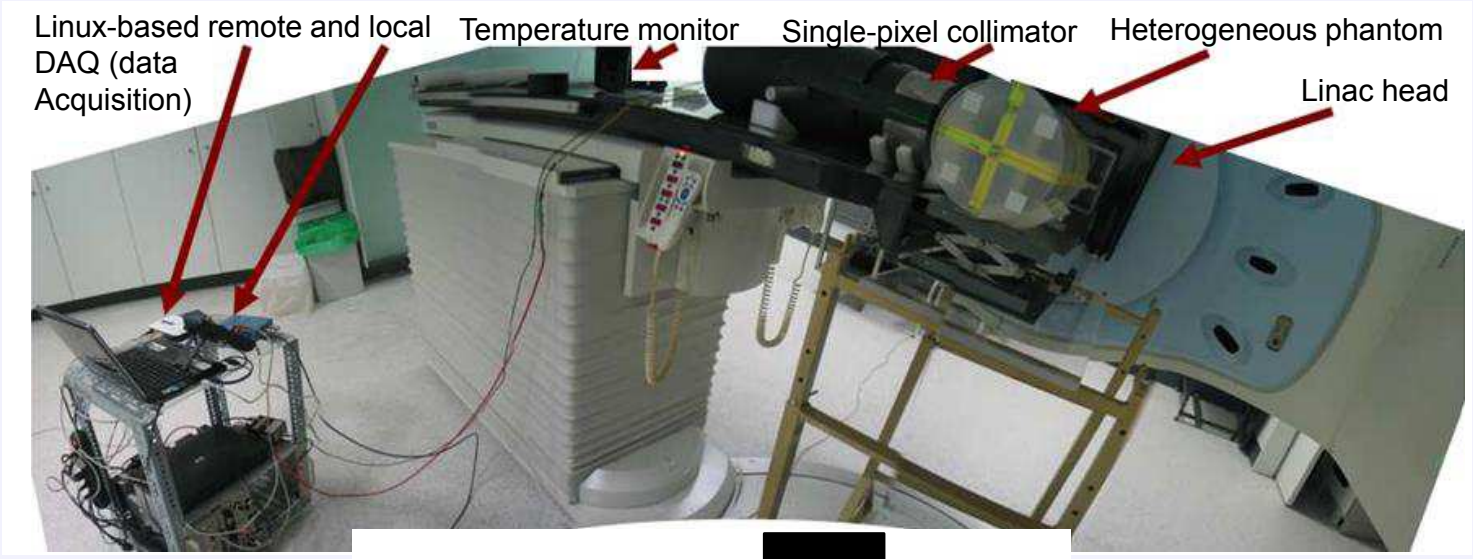
Simões *et al.*, *IEEE MIC* 2013

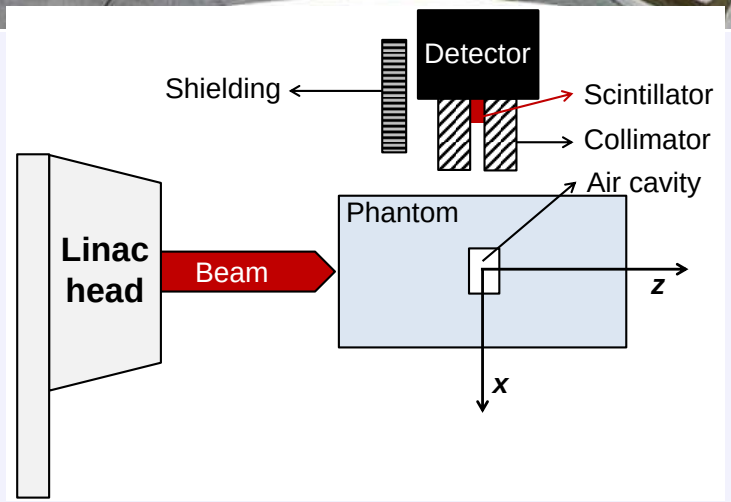


2. RTmonitor: RT treatment monitoring

2.4 Experimental results with a PMMA phantom

Setup implemented at IPOCFG, E.P.E. (IPO-Coimbra)



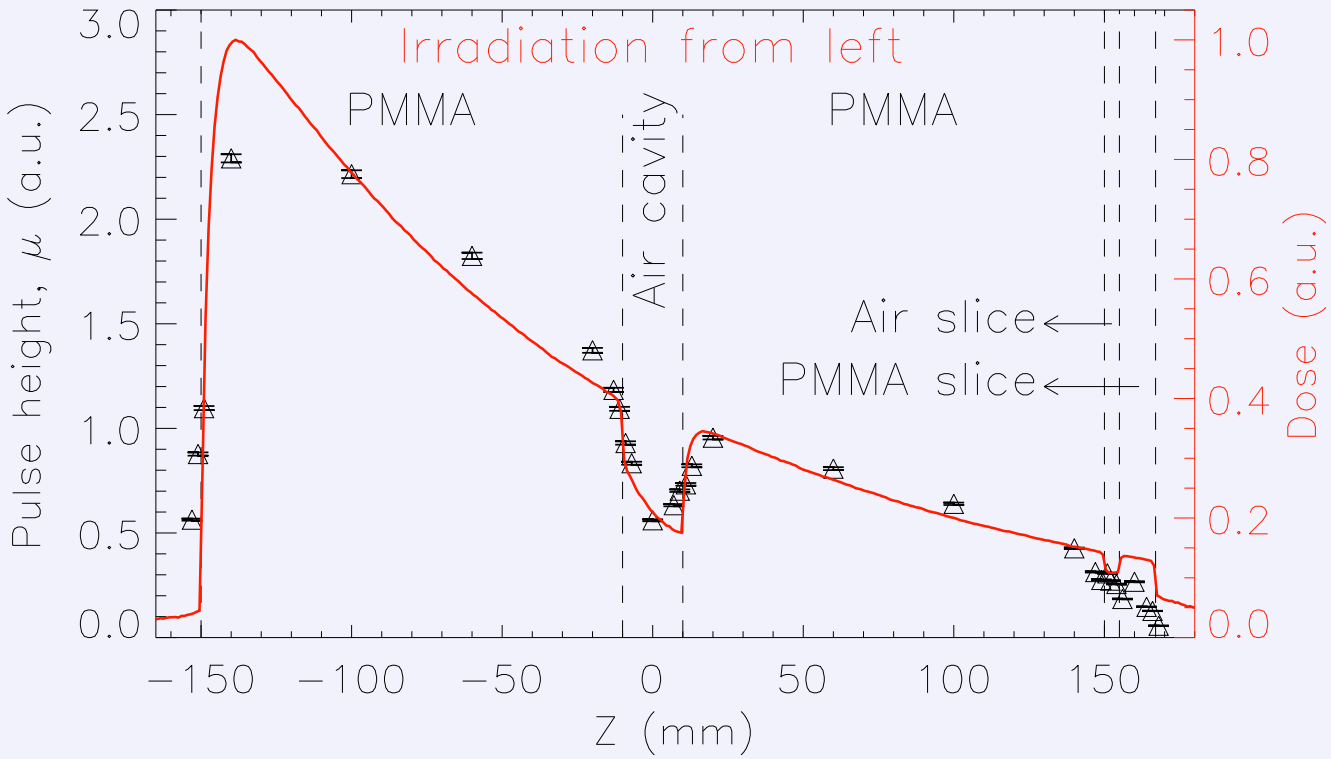


Simões *et al*, *IEEE TNS*, 2013

2. RTmonitor: RT treatment monitoring

2.4 Experimental results with a PMMA phantom

Good visual correlation between measured data and simulated dose profile

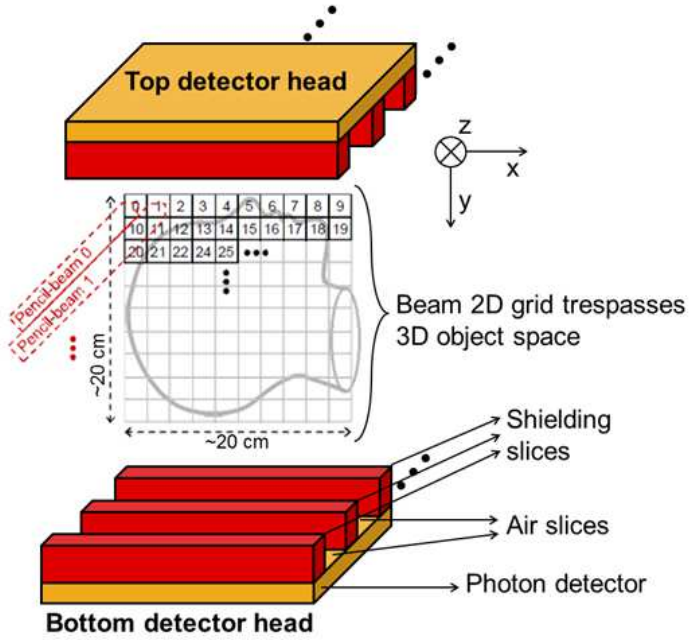


Simões *et al*, *IEEE TNS*, 2013

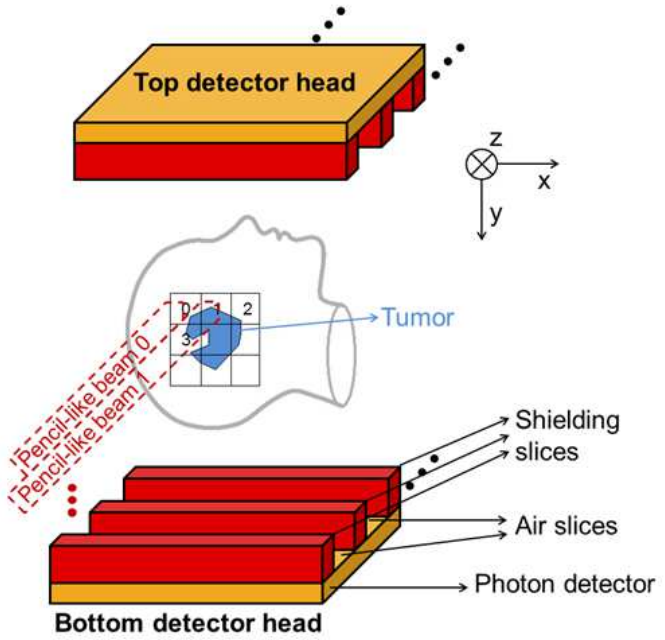
3. OrthoCT: low-dose morphologic imaging

3.1 Concept

- 3D imaging: a pencil-like photon beam traverses the patient at known coordinates (X, Y); the detector slice hit by an emerging photon yields the Z coordinate
- Scan area can be limited to the tumor only: organs at risk with minimal to null dose exposure
- Allows for targeted on-board imaging with low dose



Simões *et al*, *IEEE NSS & MIC*, 2012
Battaglia *et al*, *IEEE NSS & MIC*, 2012

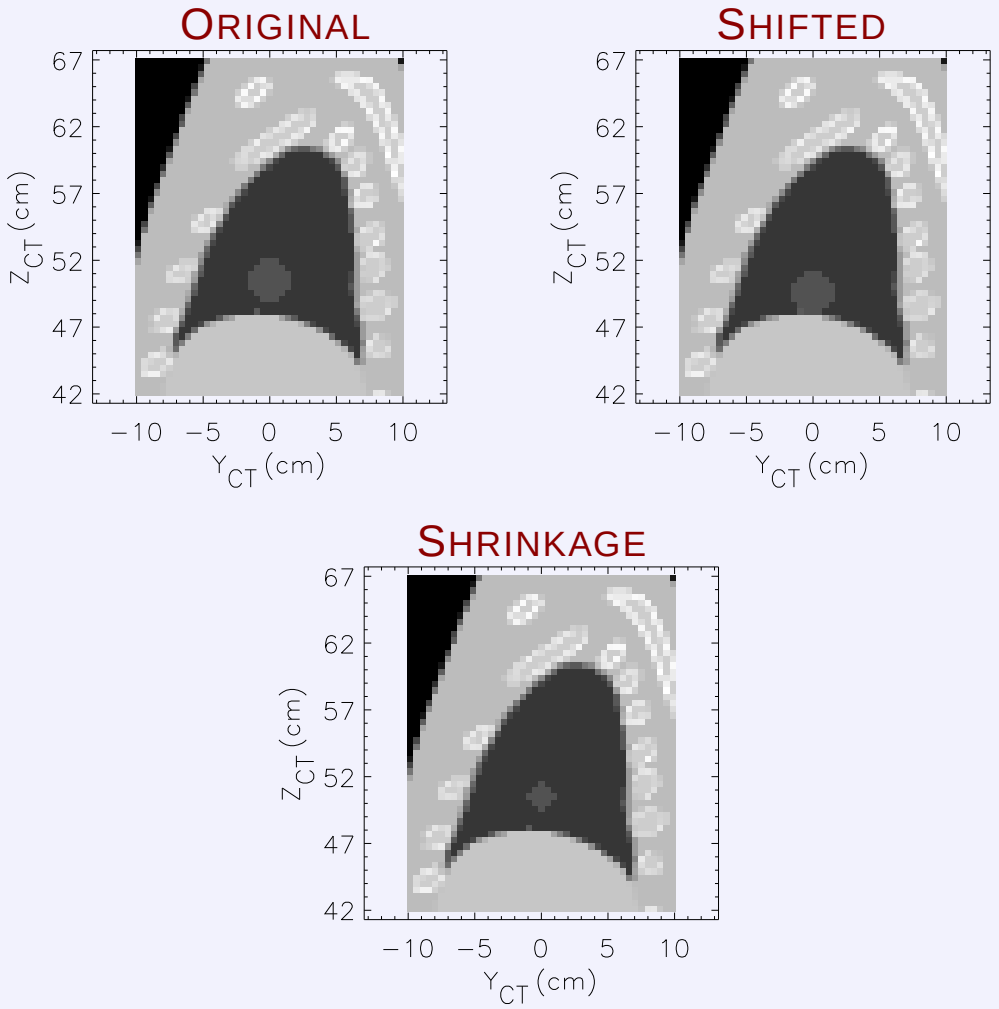


U. C. PATENT PENDING

3. OrthoCT: low-dose morphologic imaging

3.2 Simulated results: lung (Simões *et al.*, preliminary)

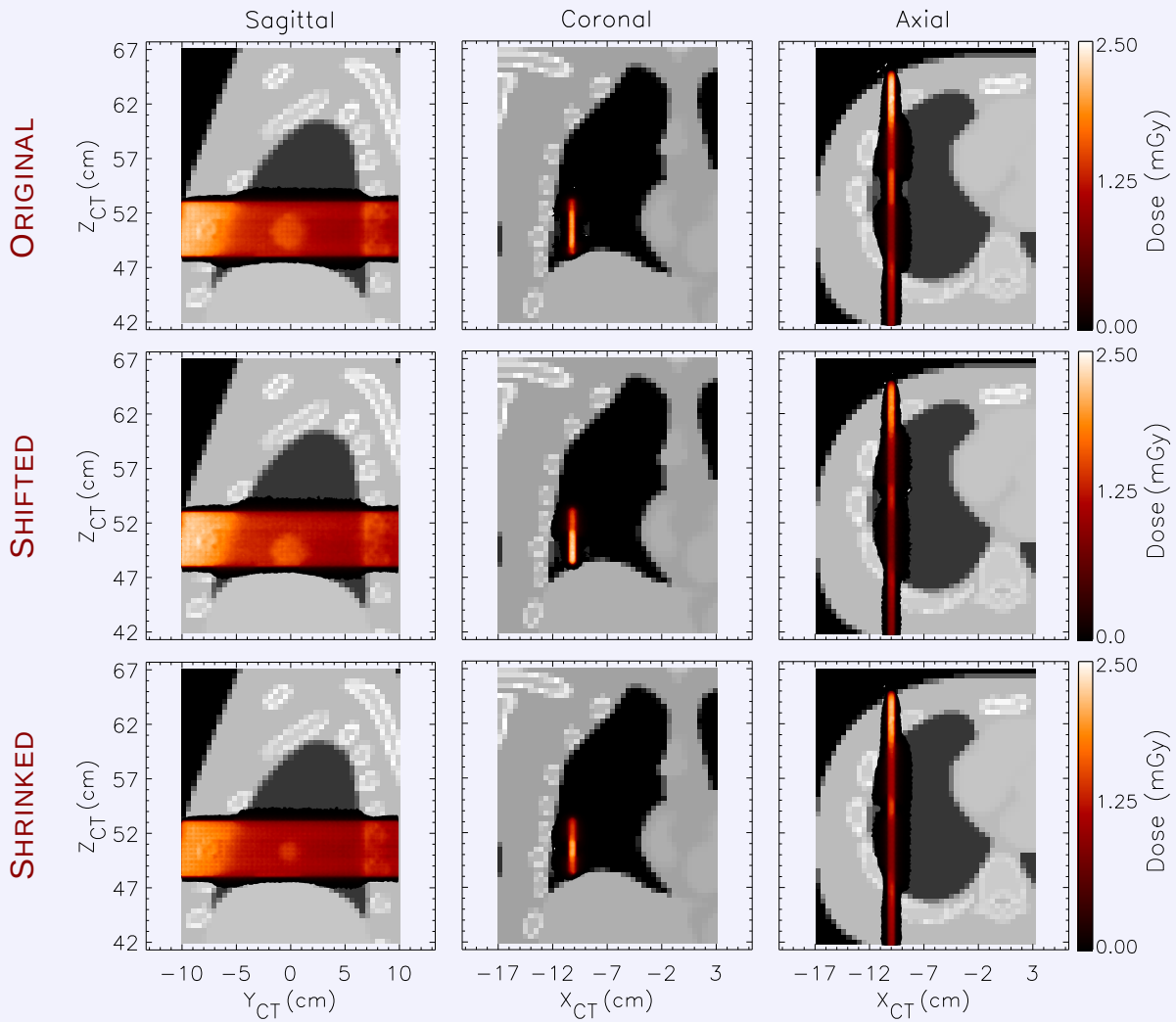
Tumor movement or tumor shrinkage



3. OrthoCT: low-dose morphologic imaging

3.2 Simulated results: lung (Simões *et al.*, preliminary)

Simulated dose distributions (tumor movement or tumor shrinkage)

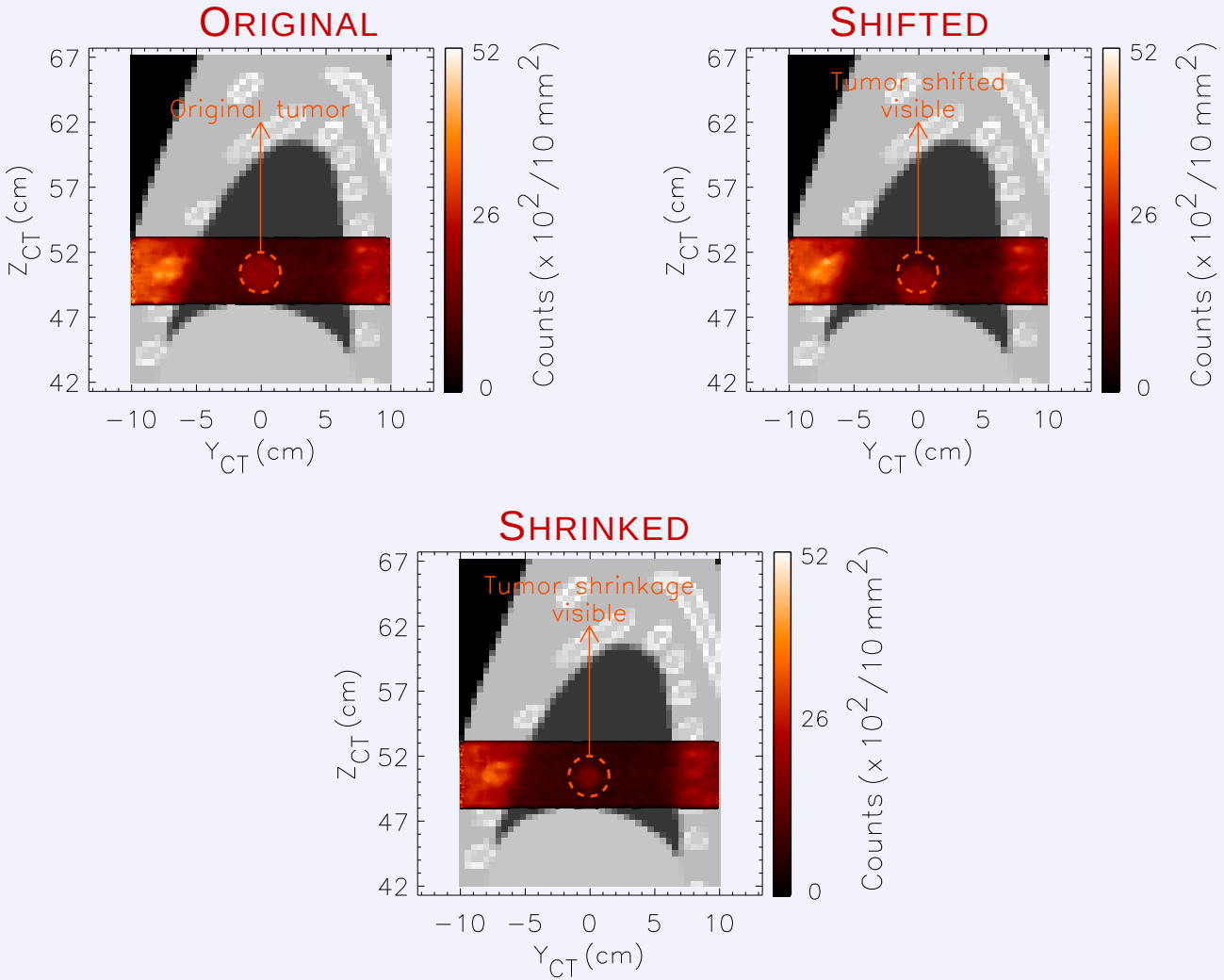


3. OrthoCT: low-dose morphologic imaging

3.2 Simulated results: lung (Simões *et al.*, preliminary)

OrthoCT images (mathematical collimation)

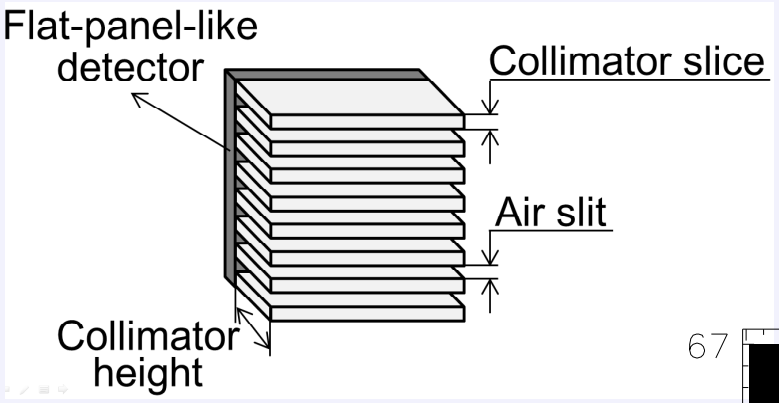
Gamma angle of acceptance $\theta_\gamma \leq 0.9°$
Photon energy threshold $E_\gamma \geq 250$ keV
Median filter with a voxel span of 6

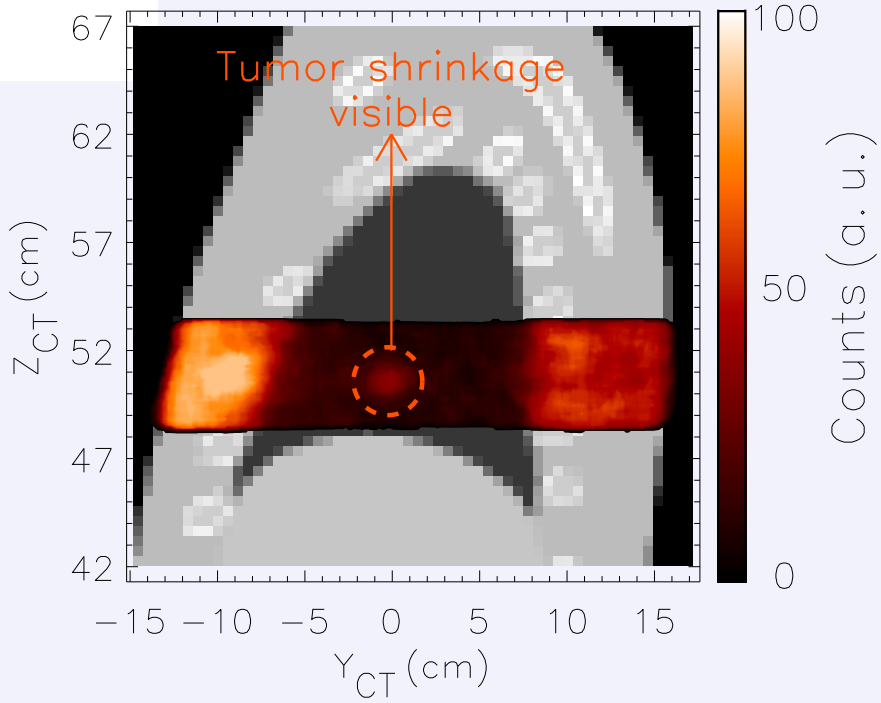


3. OrthoCT: low-dose morphologic imaging

3.2 Simulated results: lung (Simões *et al.*, preliminary)

OrthoCT images (real collimation + GSO crystals)

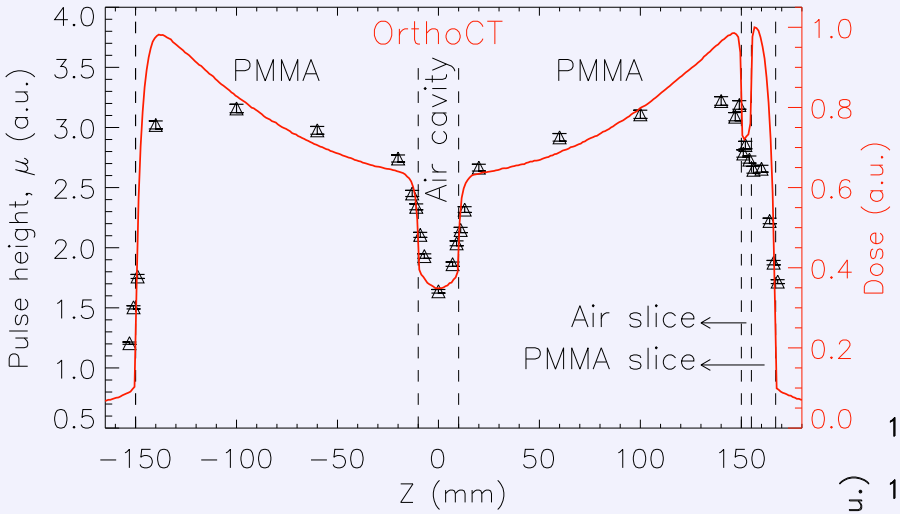




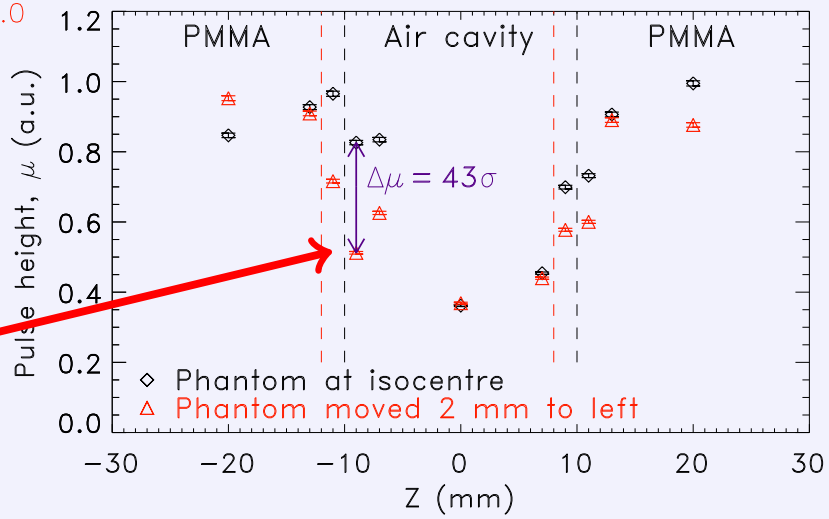
3. OrthoCT: low-dose morphologic imaging

3.3 Experimental results with a PMMA phantom

Good visual correlation between measured data and simulated dose profile



ZOOM IN CENTRAL AIR CAVITY



A 2-mm deviation is clearly distinguishable

Simões *et al*, *IEEE NSS & MIC*, 2012

4. Conclusions and ongoing work

Conclusions:

- RTmonitor images show high visual correlation with the prescribed dose and with patient structures, representing a high potential asset for image-guided RT, ART, and in-vivo dose verification.
- Scanned OrthoCT shows high visual correlation with (1) phantom anatomic structures and (2) tumor in lung region even at low doses.
- The experimental results are promising; a good correlation between the experimental profile and the simulated dose has been obtained.
- Working only with experimental raw data, a phantom deviation of 2 mm has already been detected.

Ongoing work:

- Investigate the usefulness of orthogonal ray imaging (RTmonitor & OrthoCT) techniques to assist other cancer modalities (e.g. prostate, breast).
- Parameterize and build two small multi-pixel prototypes (RTmonitor & OrthoCT) and test them in radiotherapy environment.

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