OrthoCT for assisting external-beam radiotherapy: 2D morphological image obtained experimentally without X-ray source rotation

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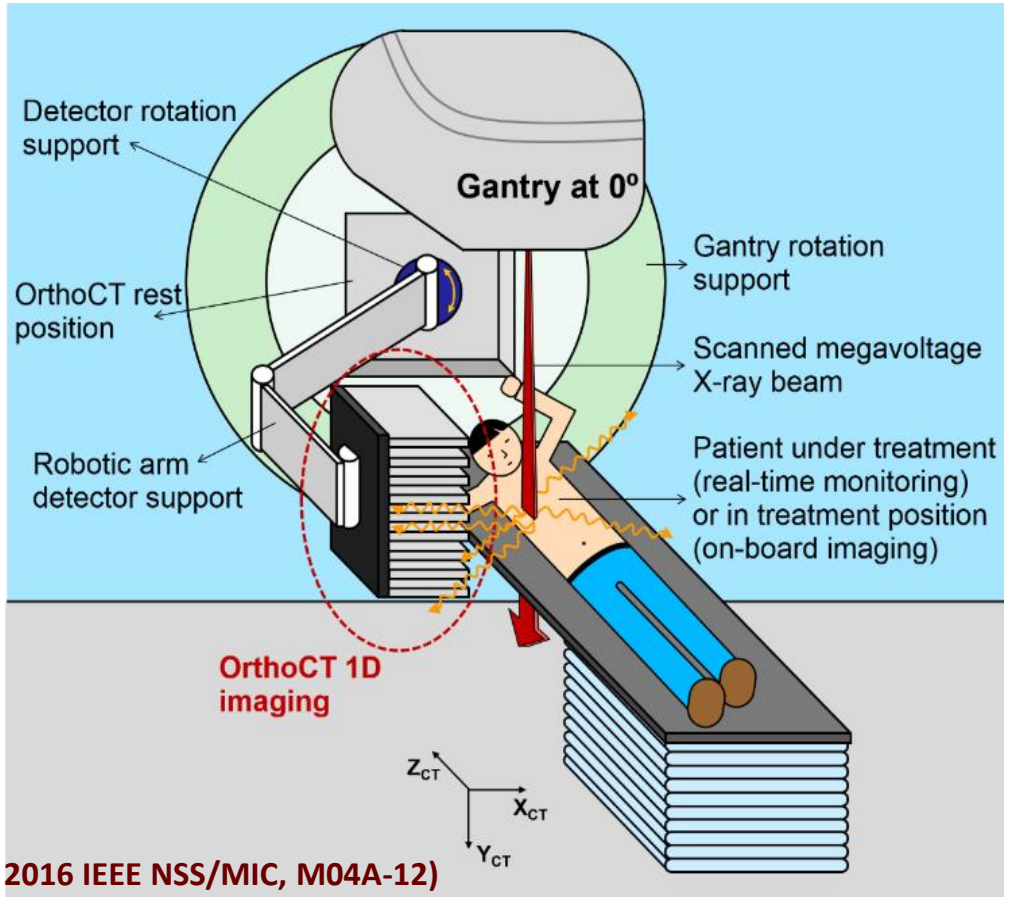
Outline

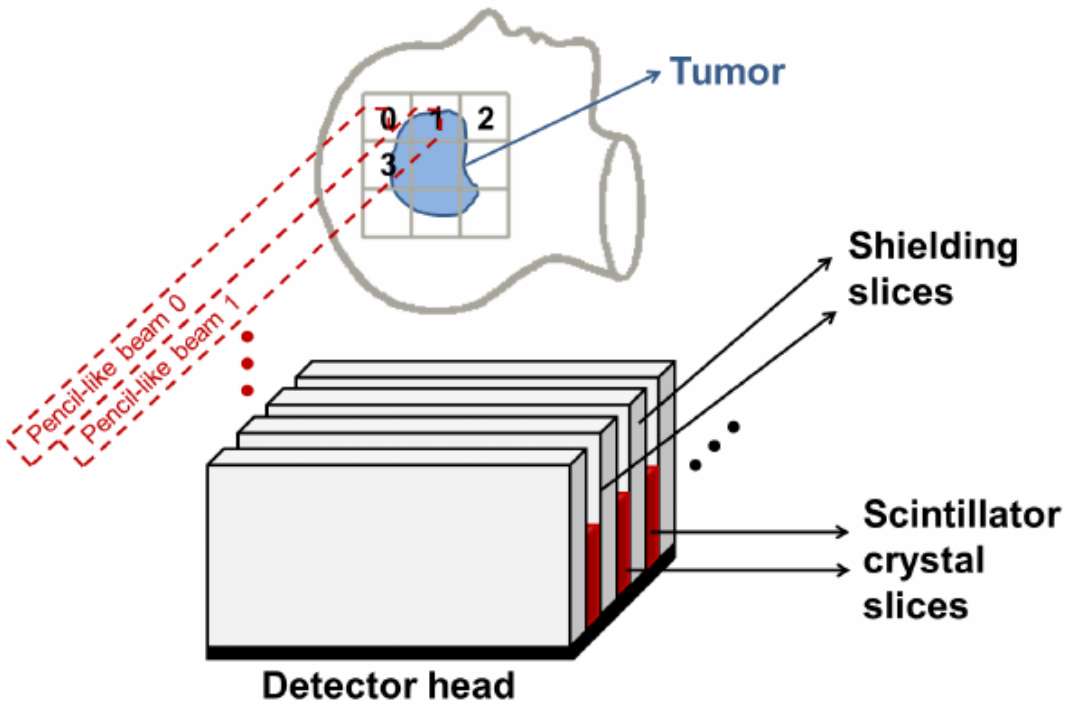
1. OrthoCT: remembering the concept
2. OrthoCT for monitoring lung irradiation
3. OrthoCT for monitoring head irradiation
4. 2D OrthoCT prototype construction
5. Experimental setup
6. Background reduction by means of shielding
7. Experimental results

1. OrthoCT: remembering the concept



(Simões *et al.* 2016 IEEE NSS/MIC, M04A-12)
(Simões *et al.* IEEE TRPMS, 1(5):452-459, 2017)

Provides 3D images of selected region without X-ray source rotation.

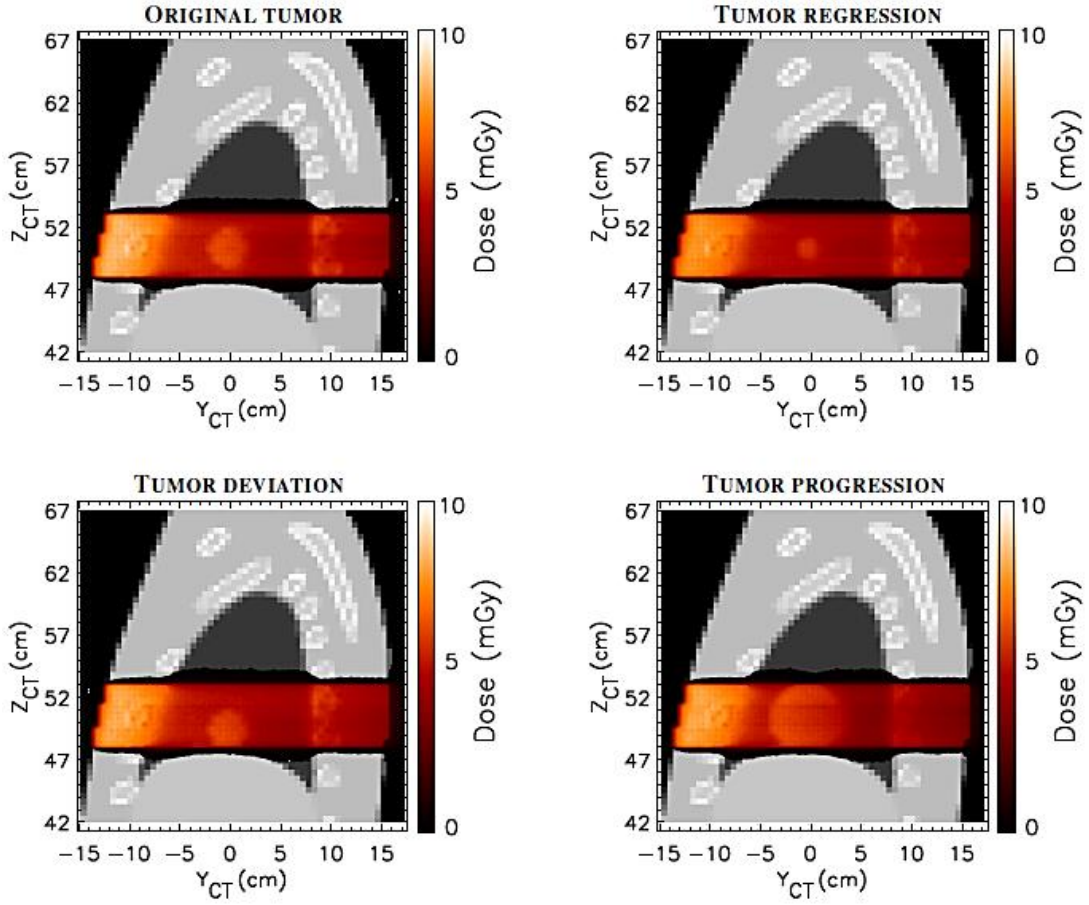


(Simões *et al.* 2016 IEEE NSS/MIC, M10C-5)
(Simões *et al.* Physica Medica: 42(1):32, 2017)

In addition, OrthoCT can be used to image other anatomical locations.

2. OrthoCT for monitoring lung irradiation

- **Simulated dose distributions**



(Simões *et al.* 2016 IEEE NSS/MIC, M04A-12)
(Simões *et al.* IEEE TRPMS, 1(5):452-459, 2017)

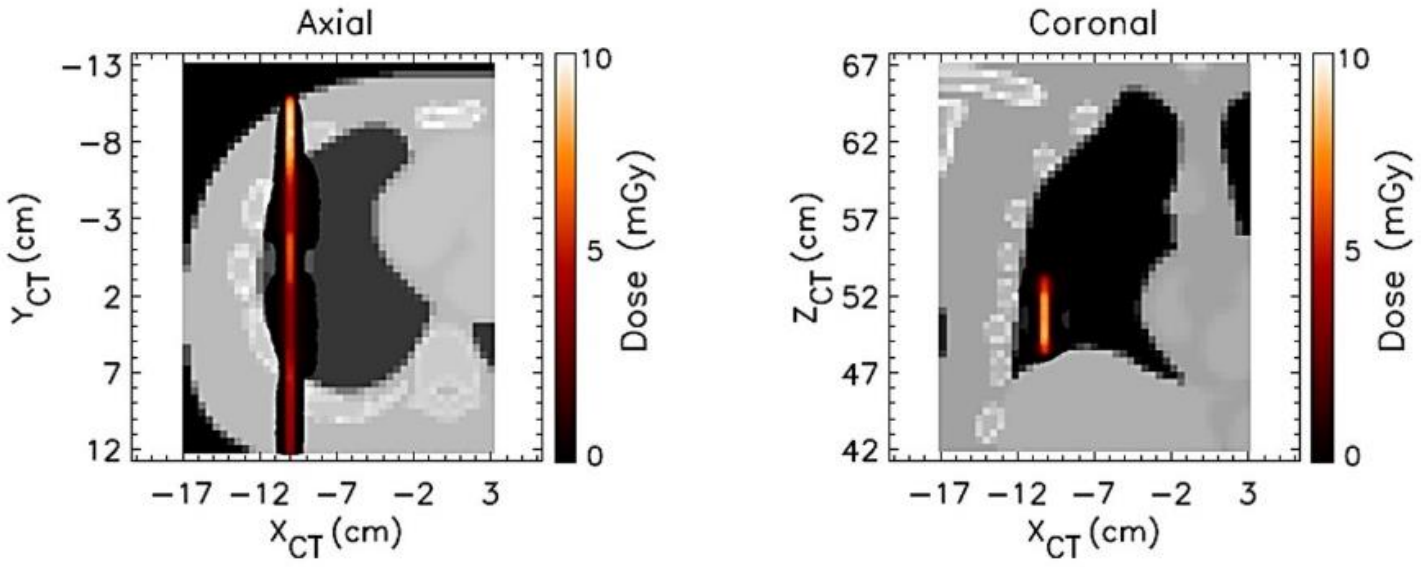
- The **tumor regression (top right)** leads to a significant portion of healthy lung tissue being irradiated unnecessarily;

- The **tumor deviation (bottom left) or progression (bottom right)** implies that a significant portion of the tumor does not receive the prescribed dose.

D_{max} : 10 mGy (in the ribs)

2. OrthoCT for monitoring lung irradiation

- **Simulated dose distributions**



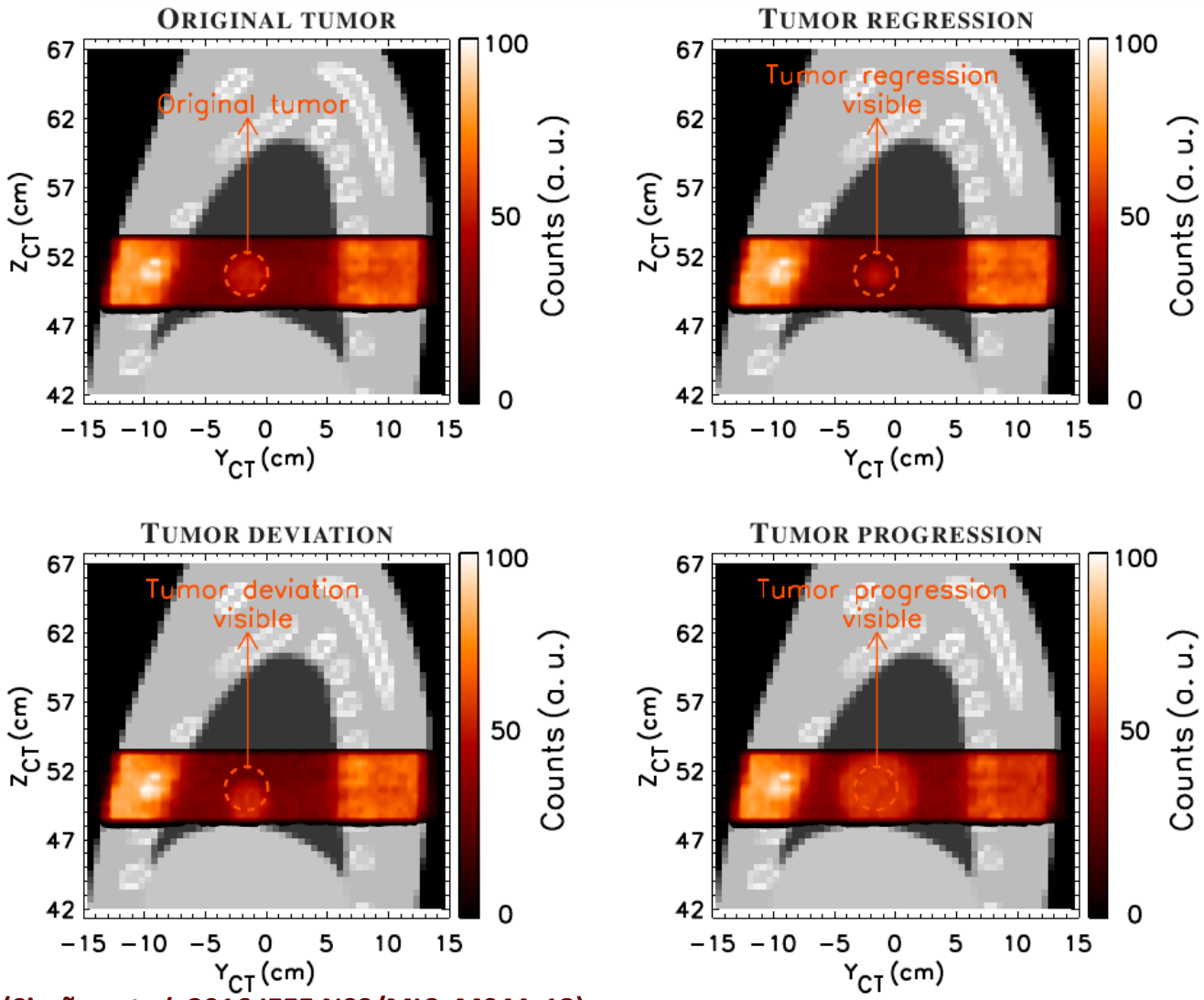
- Standard chest CBCT ≈ 67 mGy in the heart (M. Kan *et al.*, 2008)

- OrthoCT 3D image of lung tumor ≈ 0 mGy in the heart

- The irradiated area can be restricted to the tumor region, allowing to reduce very strongly extra dose to healthy tissues and organs at risk (e.g. heart, major vessels and bronchi).

(Simões *et al.* 2016 IEEE NSS/MIC, M04A-12)
(Simões *et al.* IEEE TRPMS, 1(5):452-459, 2017)

2. OrthoCT for monitoring lung irradiation



(Simões *et al.* 2016 IEEE NSS/MIC, M04A-12)
(Simões *et al.* IEEE TRPMS, 1(5):452-459, 2017)

- **OrthoCT images**

- Good visual agreement with simulated dose distributions and phantom bone structures;

- Clear detection of tumor deviations and tumor size variations.

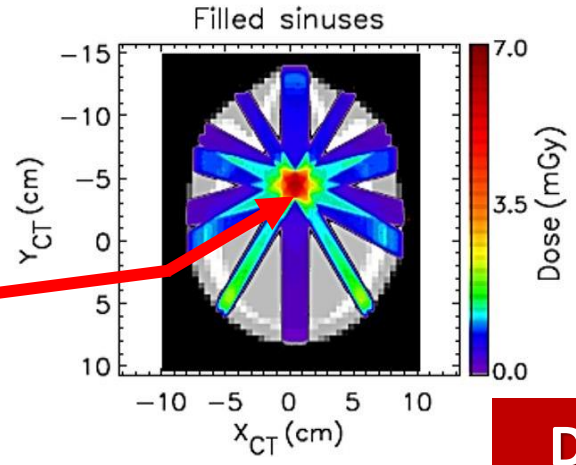
3. OrthoCT for monitoring head irradiation

- **Aim:** to study the potential use of this technique to monitor radiotherapy treatments in real-time.

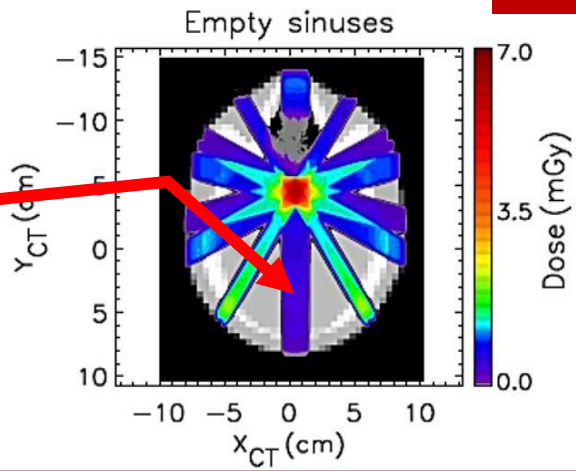
- **Simulated dose distributions**

  - Filled sinuses: underdosage at the periphery of the target of about 9.3%.

  - Empty sinuses: overdose of about 20% in the healthy tissues located distally to the target.



D_{target} : 7 mGy



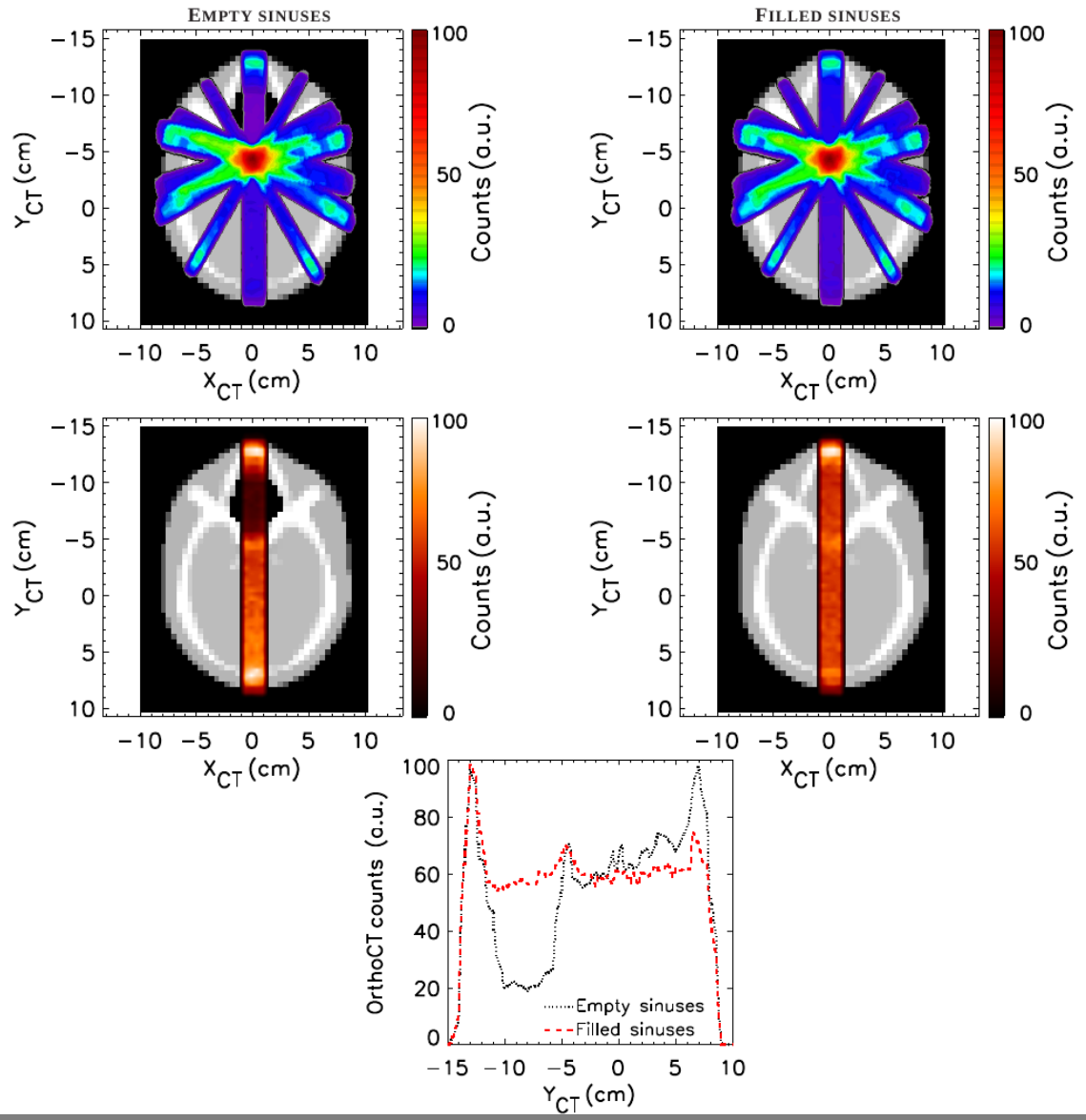
IMRT-like treatment: the pituitary gland was crossed by 7 beamlets with different angles

(Simões *et al.* 2016 IEEE NSS/MIC, M10C-5)
(Simões *et al.* Physica Medica: 42(1):32, 2017)

3. OrthoCT for monitoring head irradiation

- **OrthoCT images**

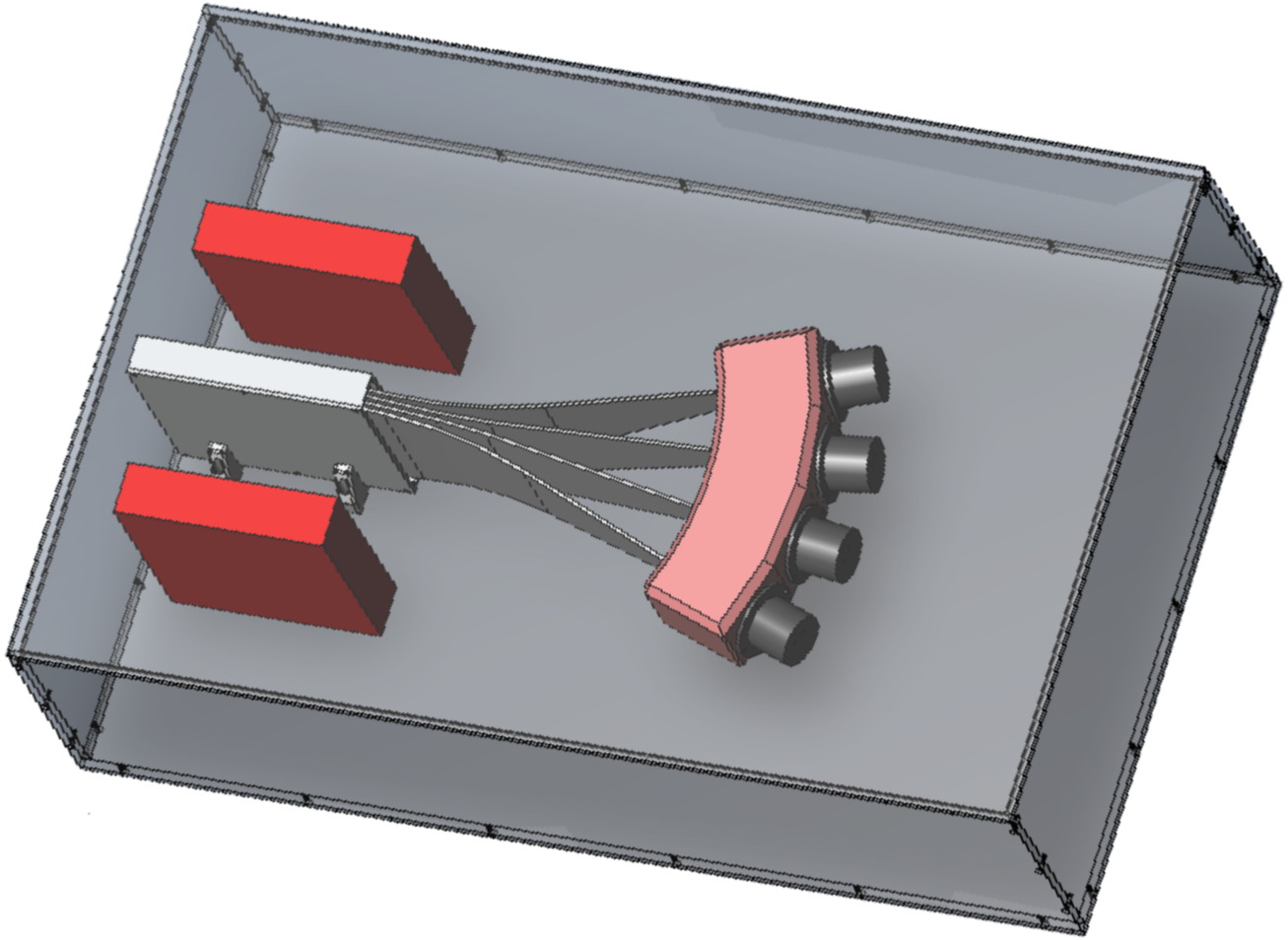
- The filling (or not) of the sinuses is clearly detectable;
- Good visualization of skull bones positioning;
- Good visual agreement with the simulated dose distribution;
- Potentially useful for real-time EBRT monitoring.



(Simões *et al.* 2016 IEEE NSS/MIC, M10C-5)
(Simões *et al.* Physica Medica: 42(1):32, 2017)

4. 2D OrthoCT prototype construction

A small 2D prototype with four channels was developed and built.
The area covered by the detector is 200 mm x 35 mm



- Each channel is composed by around 47 GSO crystals, resulting in a total length of 200 mm
- The scintillation ligth is driven to the PMT (XP5602) by an acrylic ligth-guide
- A lead collimator is used to select the orthogonal X-rays
- A CAMAC-based acquisition system is used to read the PMT signals (kindly provided by HZDR, Germany)

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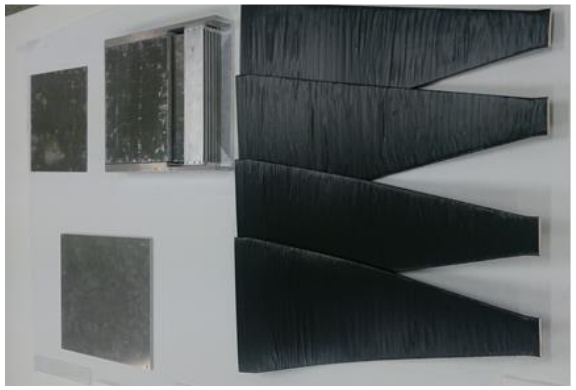
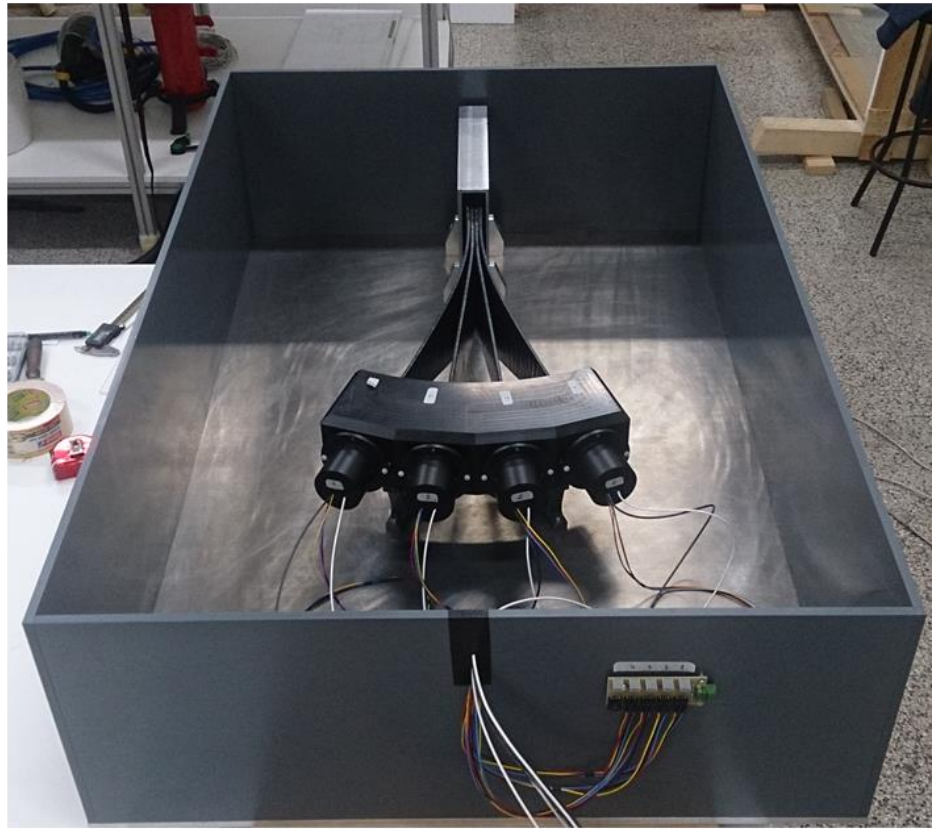
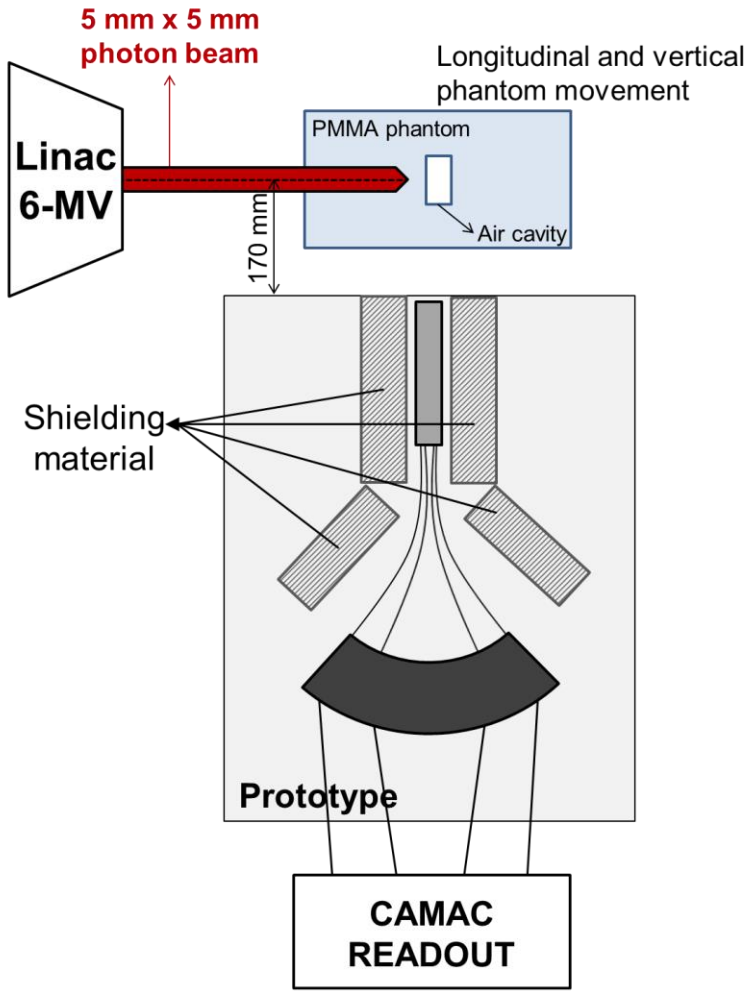
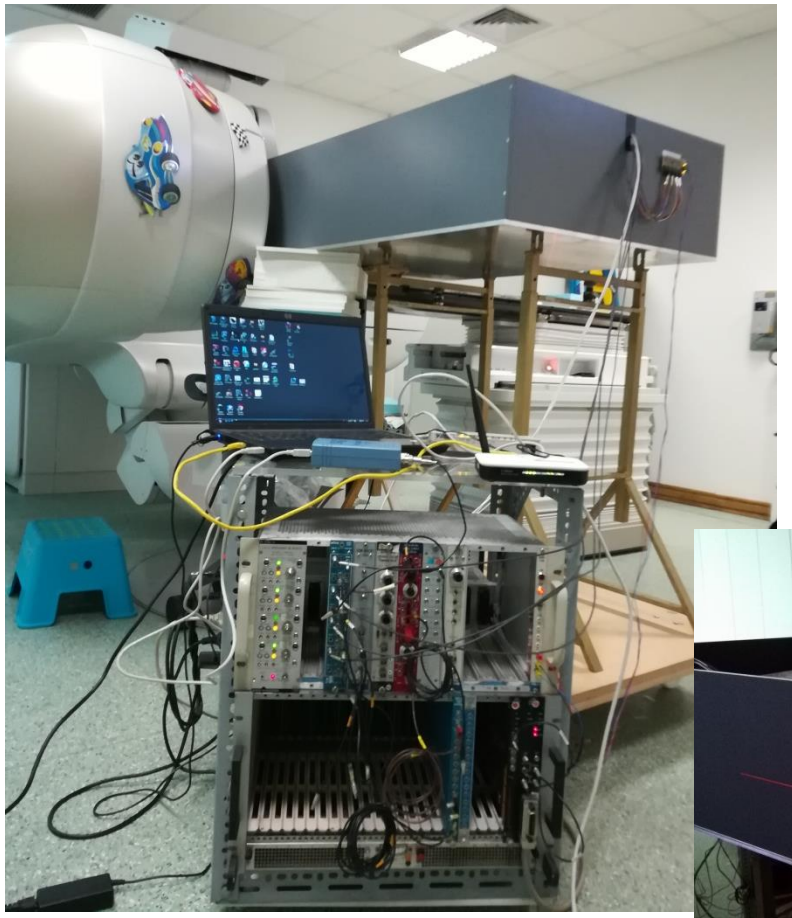
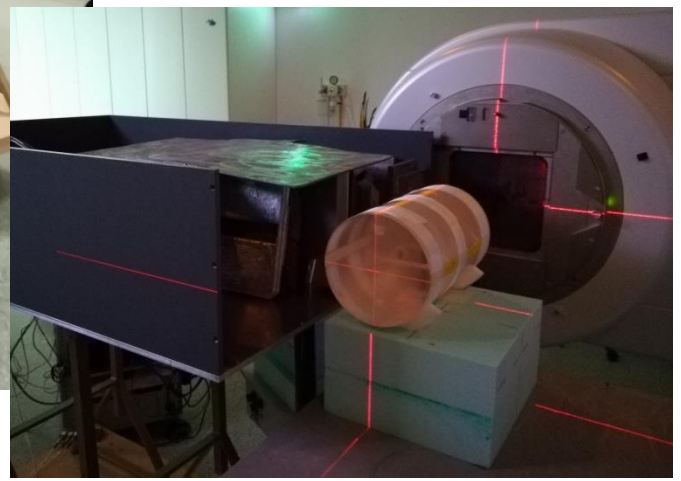



5. Experimental setup

The prototype was tested in the Varian TrueBeam Linac installed at the Radiotherapy Department of CHUC, operated at 6 MV and in the flattening filter free modality



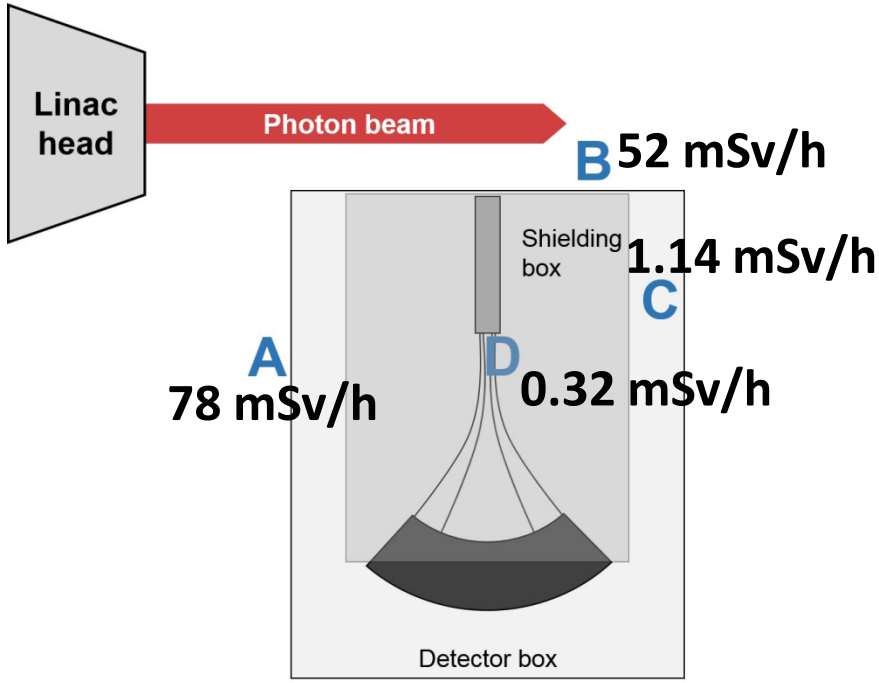




6. Background reduction by means of shielding

After many hours of testing several shielding configurations...

More than 300 kg of shielding material

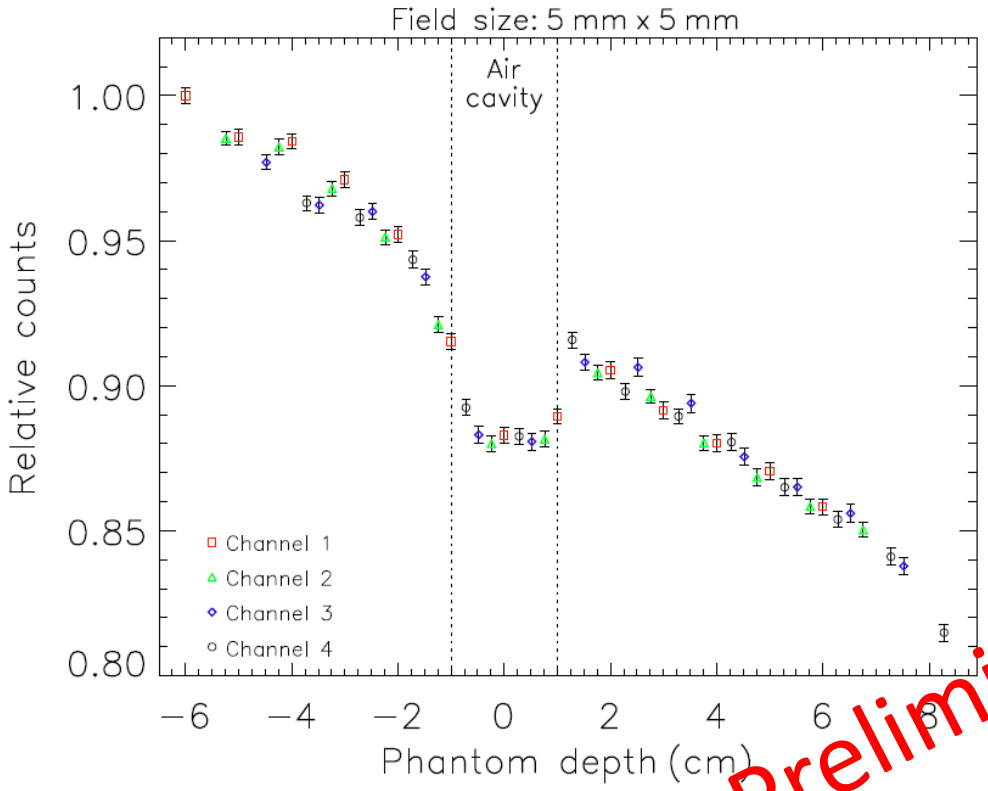


Background influence reduced by a factor of about 250

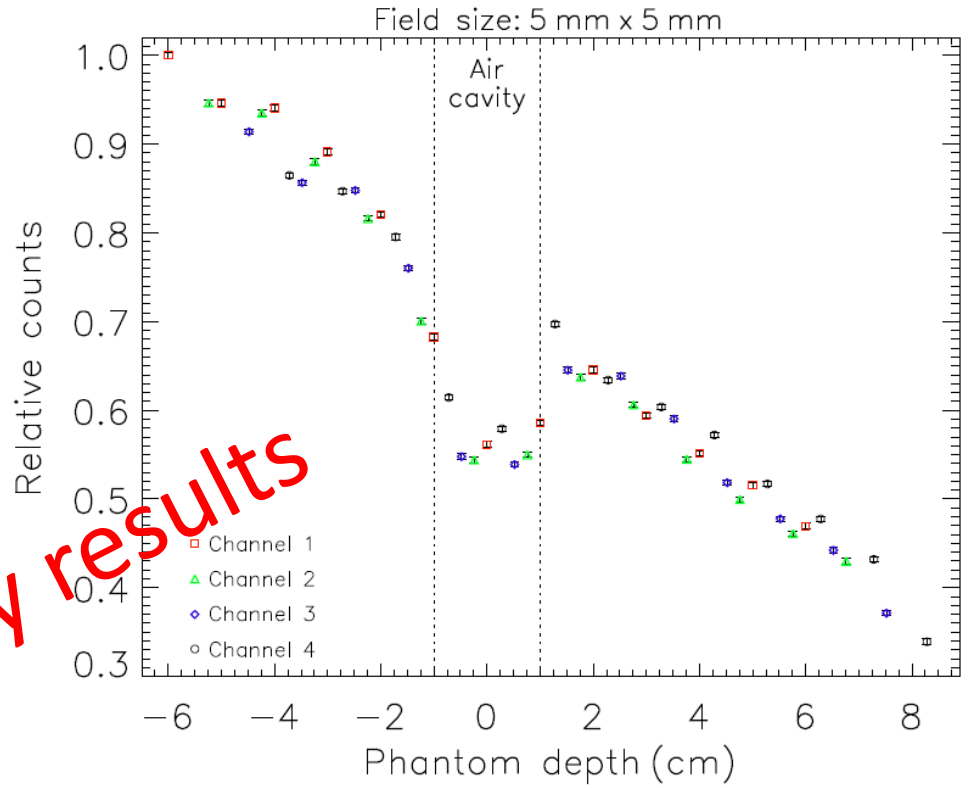
7. Experimental results

Longitudinal scan along the phantom

Steps of 1 mm (longitudinal direction)



Background subtraction allows to increase the detectability of the air cavity

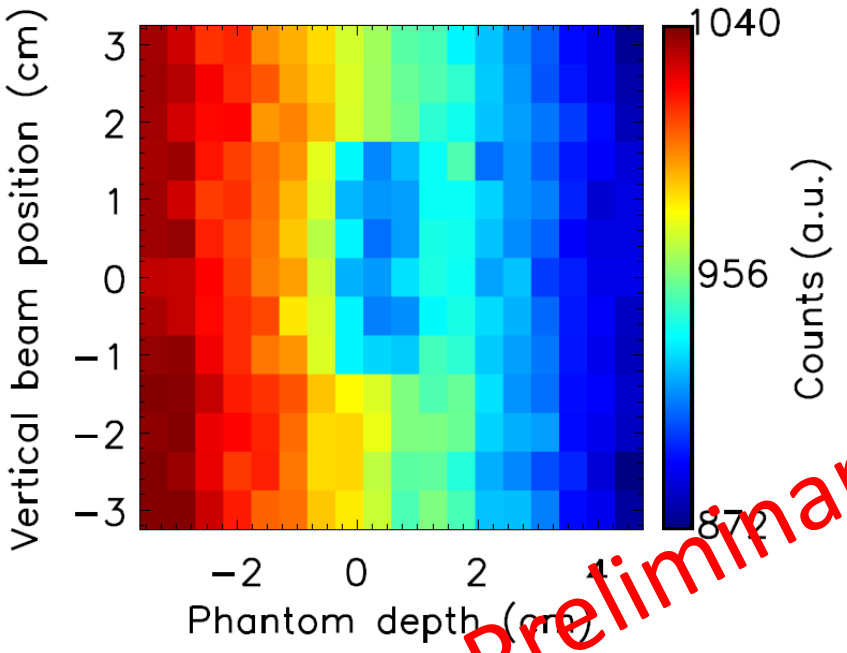


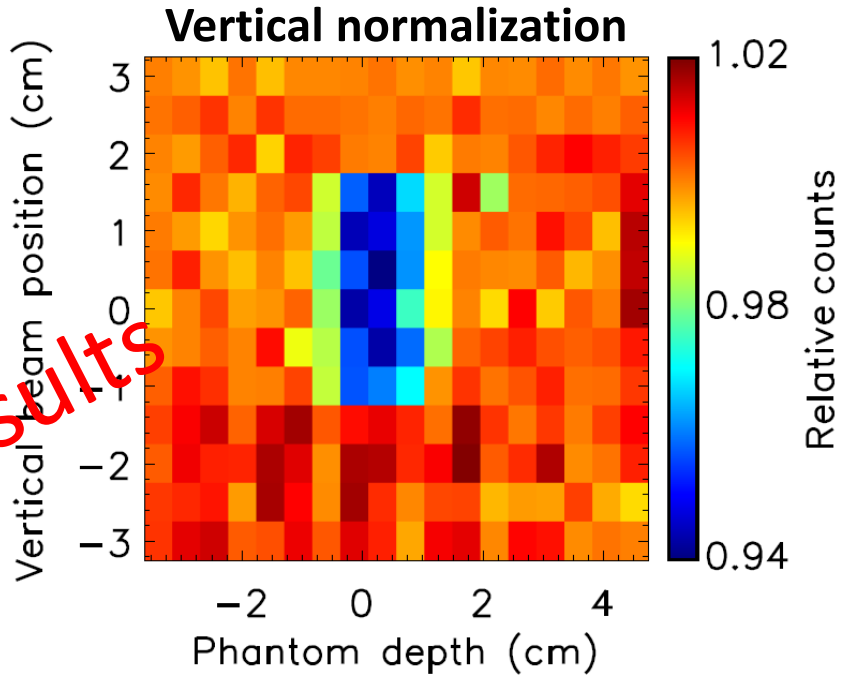
Preliminary results

7. Experimental results

2D morphological image obtained experimentally without X-ray source rotation

Steps of 22.8 mm in the longitudinal direction and 5 mm in the vertical direction





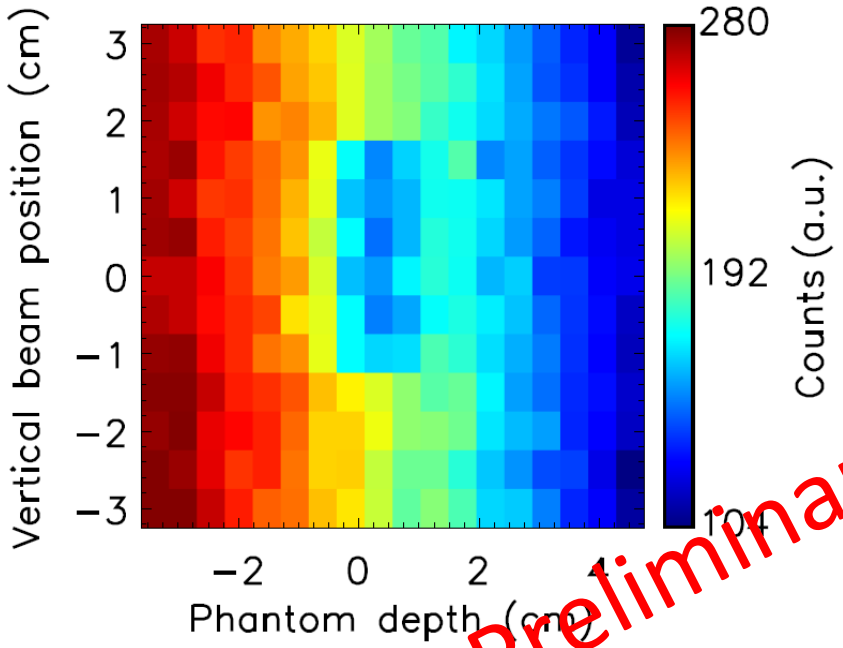
Preliminary results

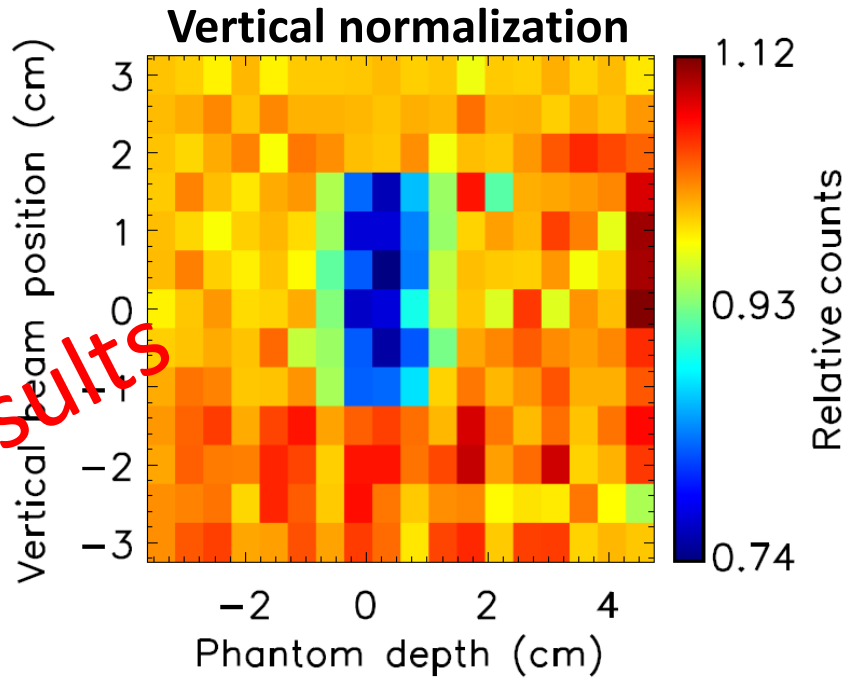
Air cavity is clearly distinguishable

7. Experimental results

2D morphological image obtained experimentally without X-ray source rotation

Background subtraction: the capability to detect the air cavity increases





Preliminary results

Practical implementation of OrthoCT is possible, but it requires a large amount of shielding material

Thank you for your attention

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