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UNIVERSITÀ DEGLI STUDI DI SALERNO

Dipartimento di Fisica E.R. Caianiello

Innovative cone beam computed tomography orbit toward quantitative imaging

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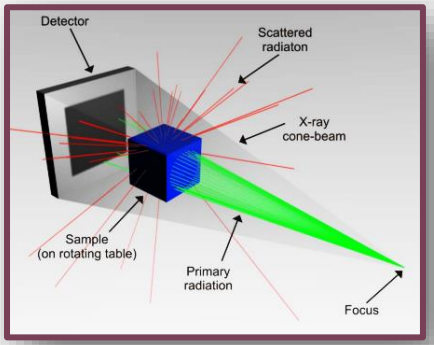
INFN

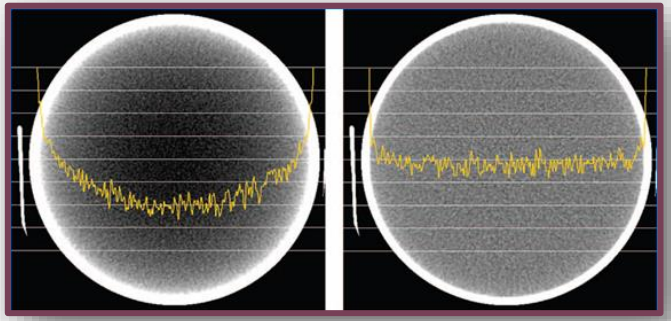
Main CBCT shortcomings



Detected scattered radiation

Leads to low and high frequency noise, reducing accuracy and precision in quantitative evaluation and hiding small details.

Cupping artifact

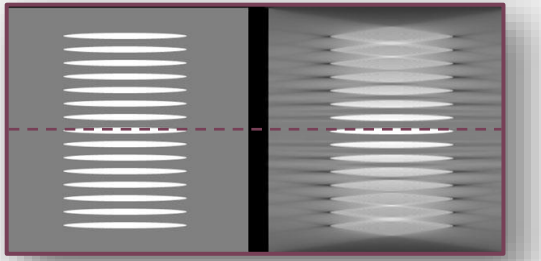


Uniform phantom **with** cupping

Uniform phantom **without** cupping

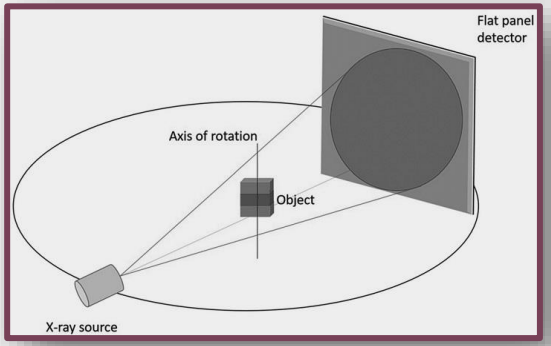
Main CBCT shortcomings

Cone beam artifacts



Ideal Real

reconstructed slice



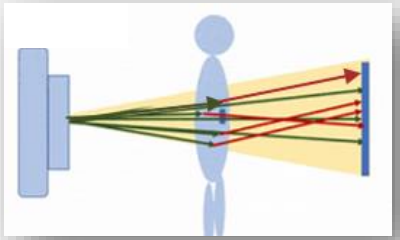
Volumetric beam in a circular orbit

The conventional circular orbit does not satisfy the data sufficiency condition as the distance from the plane containing the source increases.

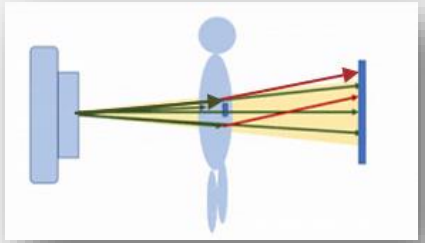
ExoCT scanning protocol

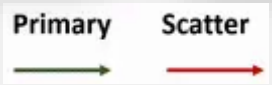
This protocol aims at experimentally study advantages of using a collimated beam and an oscillating scanning geometry for enhancement of quantitative evaluations and visualization of small details in CBCT.

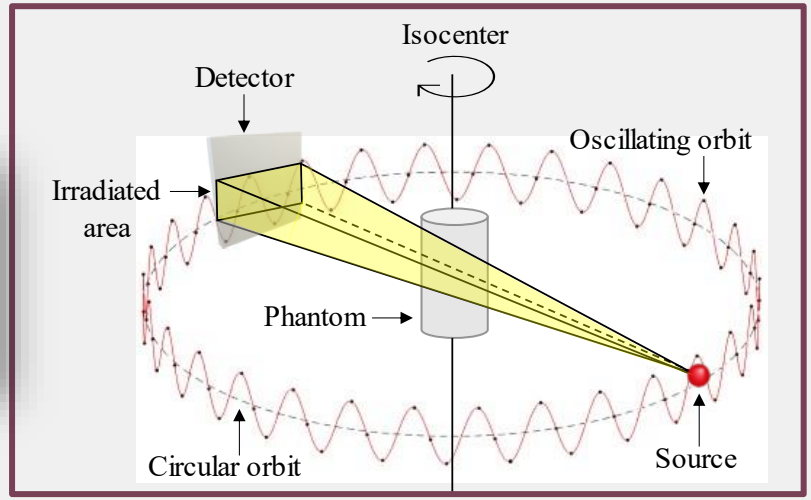
without beam collimation



with beam collimation



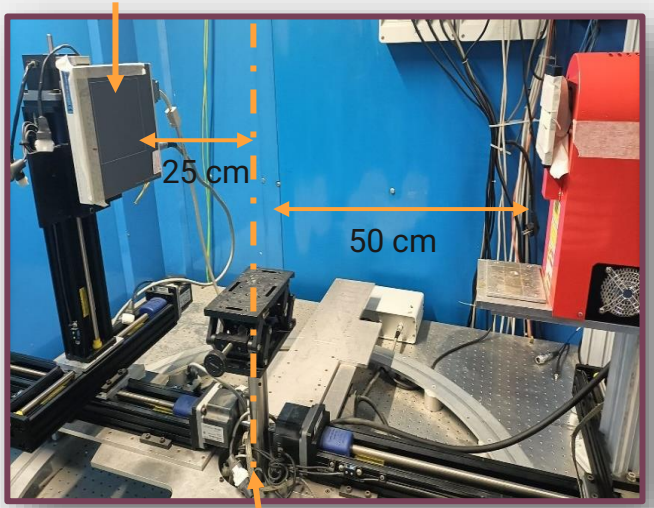




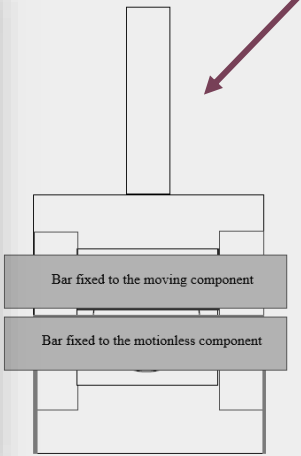
ExoCT scanning protocol

Scatter reduction

Hamamatsu detector C7942CA-02
100 µm pixel pitch

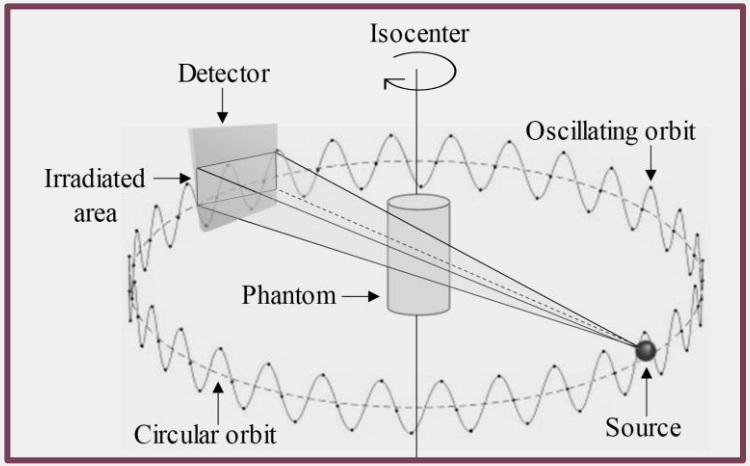


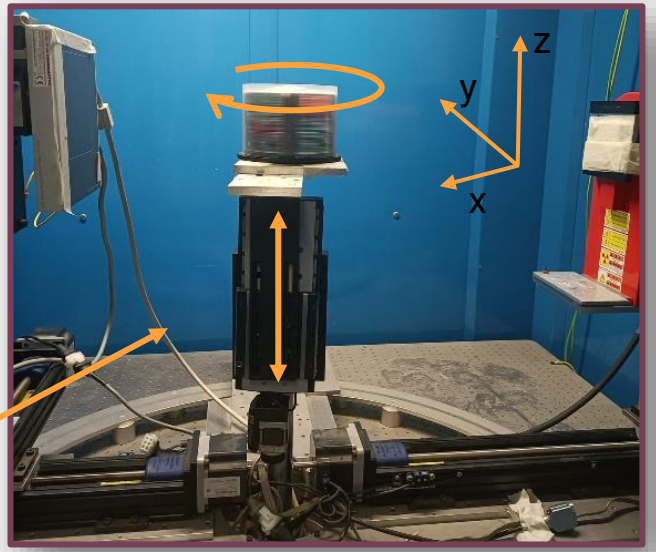
Variable aperture collimator



Oscillating orbit

The oscillating orbit is achieved through the relative motion between the sample and the source/detector system.

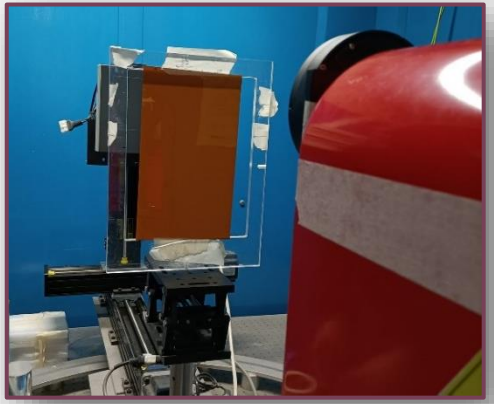




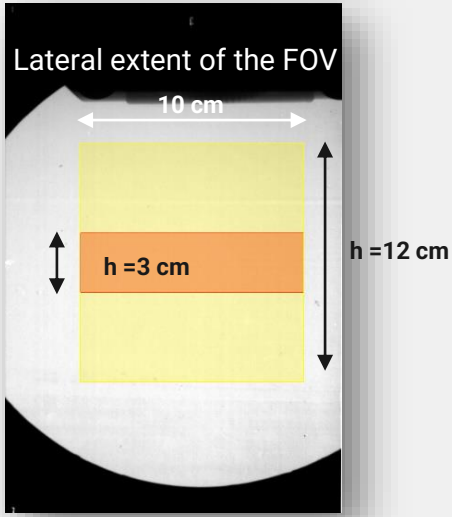
Gantry circular rotation and phantom motion along the axial direction.

Dosimetric assessment

In order to keep constant the dose in ExoCT with respect to conventional CBCT, a protocol which considers the Kerma Area Product (KAP) as CBCT dosimetric index is applied.



GafChromic™ XR-QA2 film calibrated at 80 kV

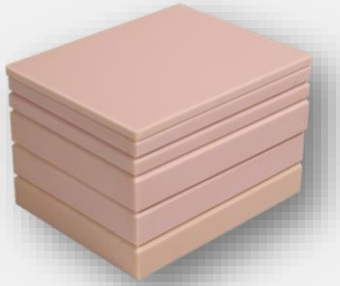


$$I(h) = I(H) \cdot \frac{KAP(H)}{m \cdot KAP\ (h)}$$

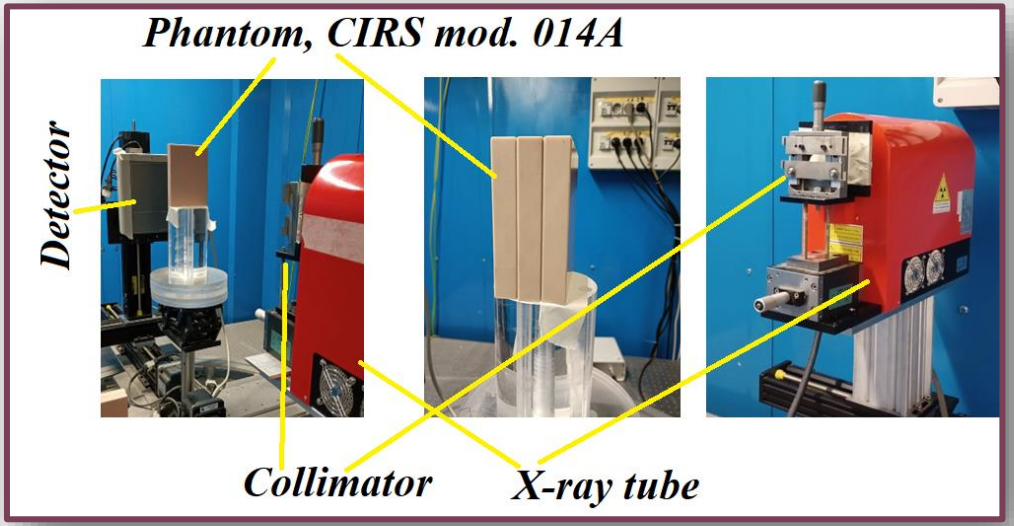
with $m \cdot h = H$

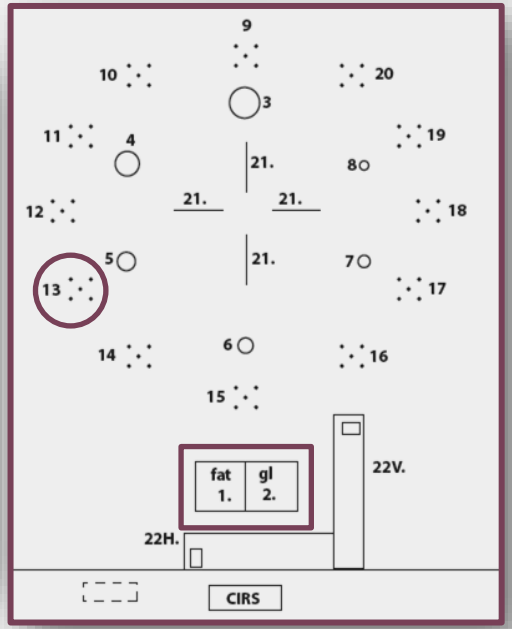
h (cm)	Current (μA)
12	500
6	498
4	496
3	494
2	490
1	478

2D acquisitions

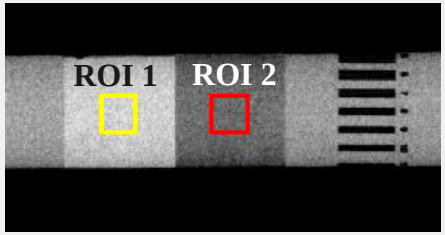


Enhancements on image quality indexes and on microcalcification visibility were evaluated.

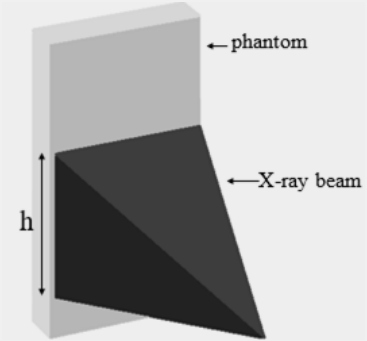




2D acquisitions – Scatter influence

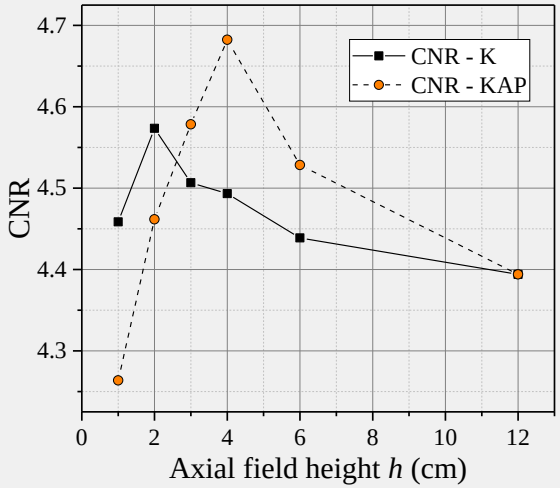


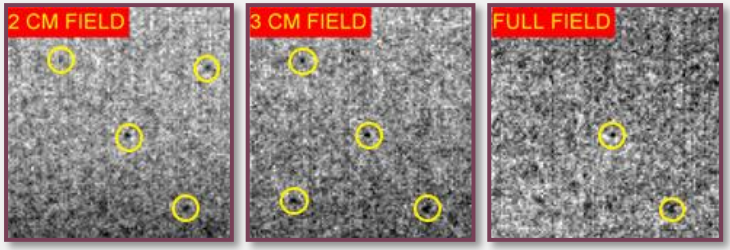
Phantom thickness: 6 cm
Tube voltage: 80 kV
Tube current: 500 µA
Incident Air Kerma **(K)**: 0.5 mGy



Contrast to Noise Ratio

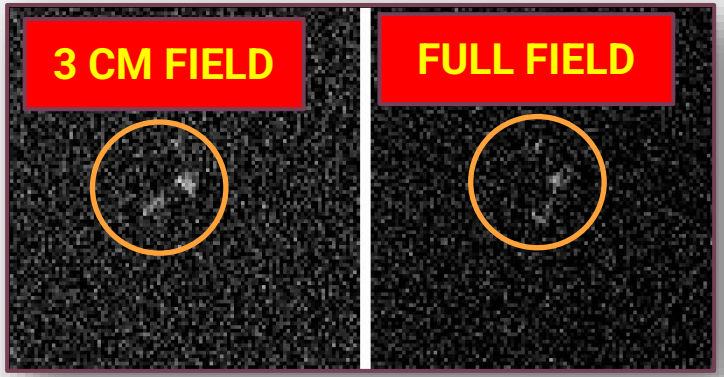
$$CNR = \frac{\mu_1 - \mu_2}{\sqrt{\frac{\sigma_1^2 + \sigma_2^2}{2}}}$$



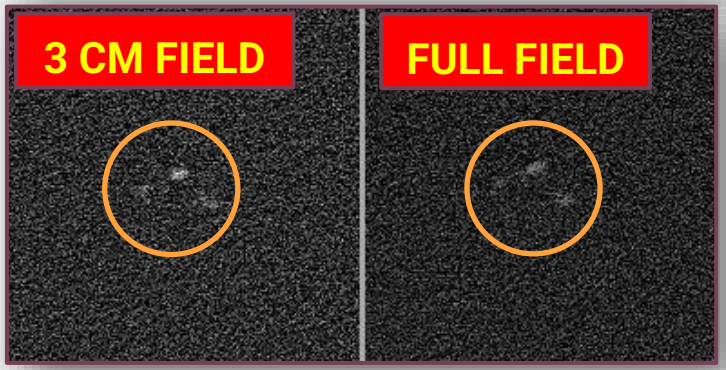


Microcalc. dimension: 160 µm
Tube voltage: 80 kV
Tube current: 200 µA
IAK: 5 mGy

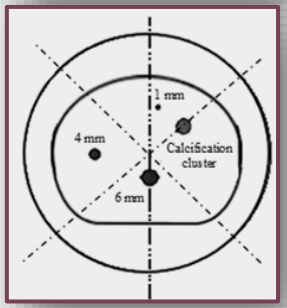
3D acquisitions – Microcalcification visibilty



Microcalc. dimension: 300-350 µm
Tube voltage: 80 kV
Tube current: 200 µA
IAK: 10 mGy



Microcalc. dimension: 300-350 µm
Tube voltage: 60 kV
Tube current: 400 µA
IAK: 12 mGy

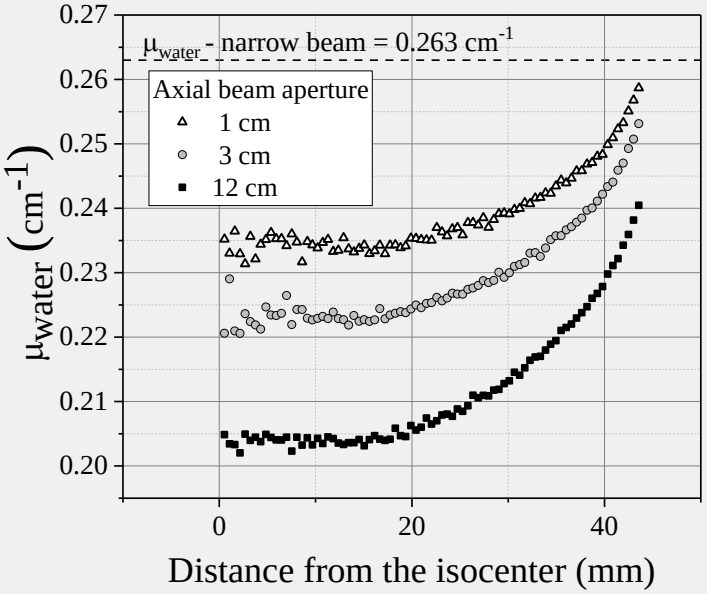


Phantom, CIRS mod. 1272-00-00

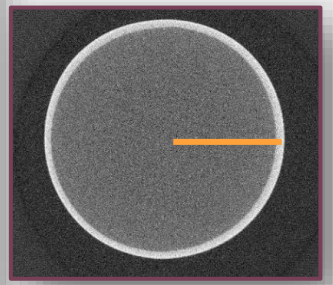
3D acquisitions – Cupping artifact

Collimation leads to more uniform attenuation profile of homogeneous objects.

Tube voltage: 80 kV
Tube current: 500 µA



Water phantom



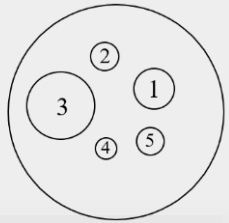
Reconstructed axial slice

3D acquisitions – μ evaluations

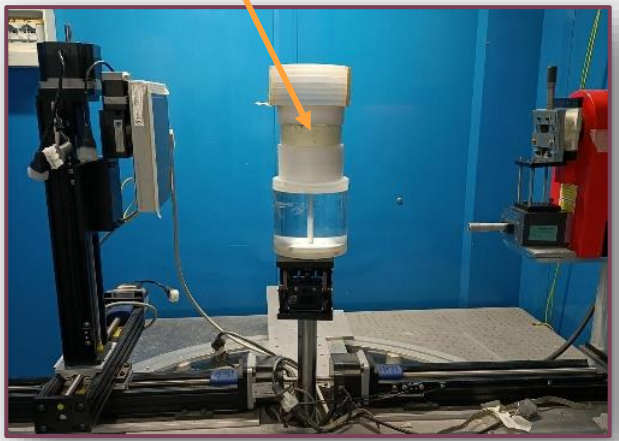
Scatter reduction allows to increase the accuracy in the evaluation of attenuation coefficients μ.

	Difference from expected (%) h = 12 cm	Difference from expected (%) h = 3 cm
1. PVC	48.3	33.3
2. PET-P	25.3	14.3
3. TEFLON	42.5	28.7
4. NYLON	20.5	14.3
5. PMMA	26.5	15.0

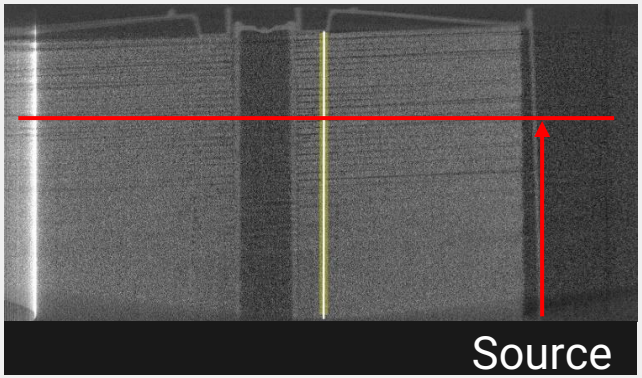
Tube voltage: 80 kV
Tube current: 500 μA



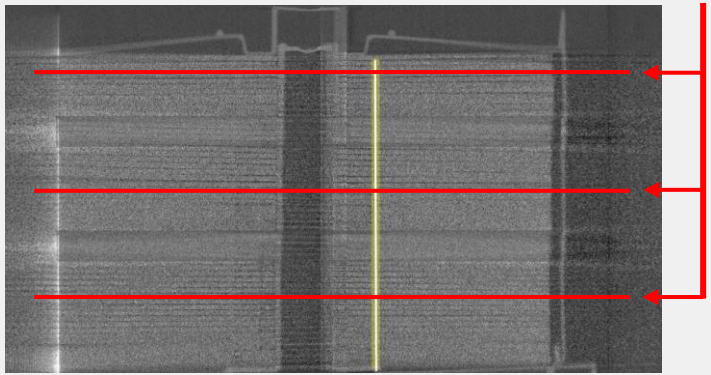
Wax phantom



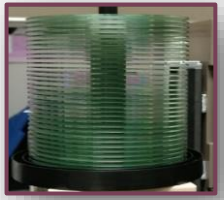
3D acquisitions – CD Defrise phantom



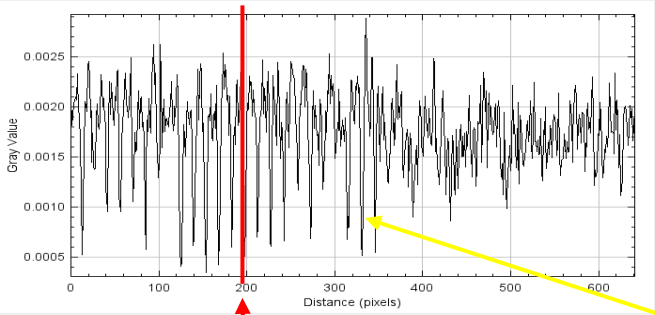
Conventional CBCT

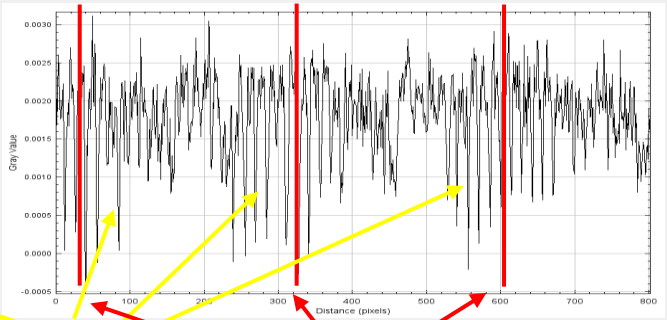


ExoCT



CD Defrise phantom

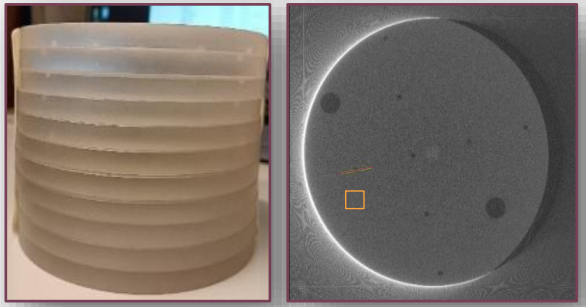




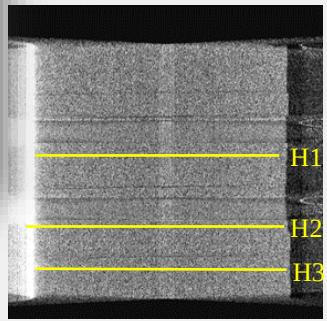
Tube voltage: 80 kV
Tube current: 500 µA
Axial field height: 33 mm

3D acquisitions – PMMA Defrise phantom

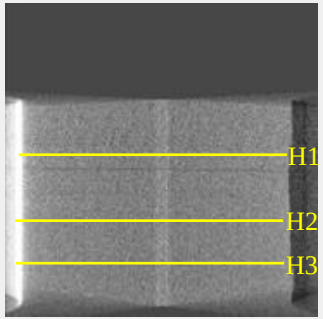
Tube voltage: 80 kV
Tube current: 500 µA
Axial field height: 33 mm



PMMA Defrise phantom



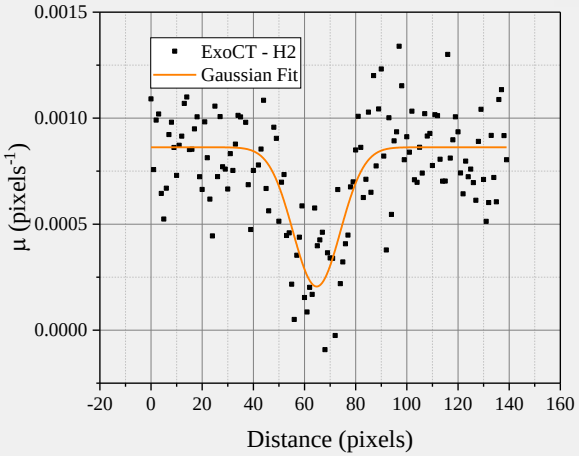
ExoCT



CBCT

Signal Difference to Noise Ratio

$$SDNR = \frac{\mu_s - \mu_{bgnd}}{\sigma_{bgnd}}$$



	Distance from the midplane of CBCT (mm)	SDNR ExoCT	SDNR CBCT
H1	7.1	2.1±0.2	2.3±0.2
H2	23.5	2.2±0.2	1.8±0.2
H3	38.6	3.2±0.2	1.7±0.2

Conclusions

Beam collimation in the axial direction and oscillating scanning geometry result in image quality enhancement with respect to conventional CBCT in terms of:

- Improved visibility of small details both in 2D projections and 3D images;
- Reduced cupping artifacts in 3D reconstructed images;
- Improved accuracy in the evaluation of materials attenuation coefficients in 3D images;
- Improved image conspicuity for field of view portion distant from the plane containing the rotating source.

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Thank you for the attention