OBJECTIVE EVALUATION OF IMAGE QUALITY IN PROPAGATION-BASED PHASE-CONTRAST BREAST CT

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PRESENTATION CONTENT

- Overview on main parameters influencing image quality
  - What is image quality?
  - How to get it?
  - How to measure it?

- Overview on previous works
  - Full reference indexes
  - Radiological assessment
  - FoM + Edge quality (IQ)

Overview on main parameters influencing image quality

What is High Quality?

- Good contrast
- Edge sharpness
- Low level of noise
- No artefacts
- Visibility of spiculations

How to get it?

- Sample-to-detector distance
- Energy
- Pixel size (DETECTOR)
- Photon statistics (DOSE)
- Reconstruction method

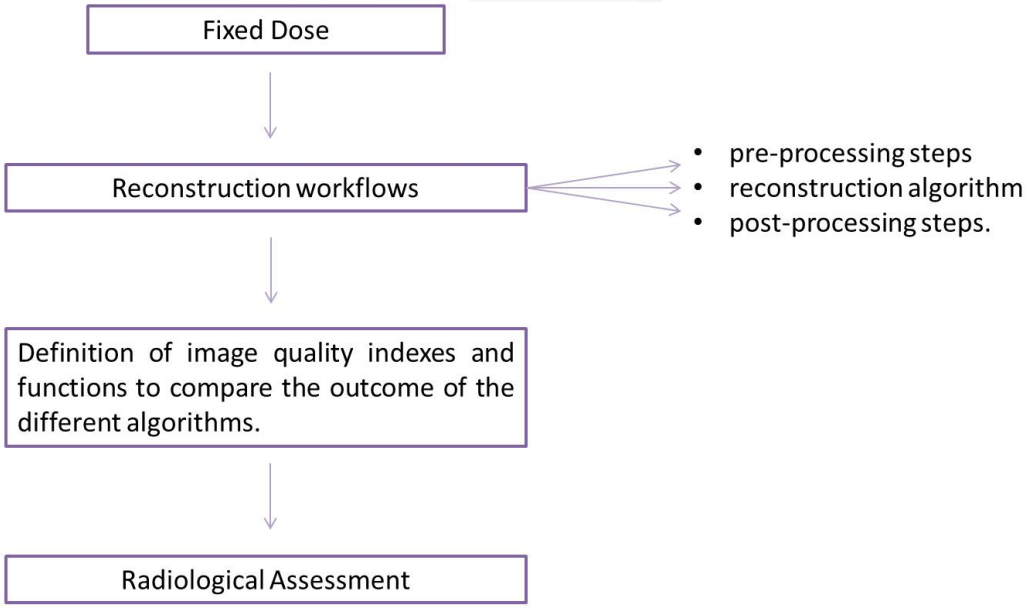
How to measure it?

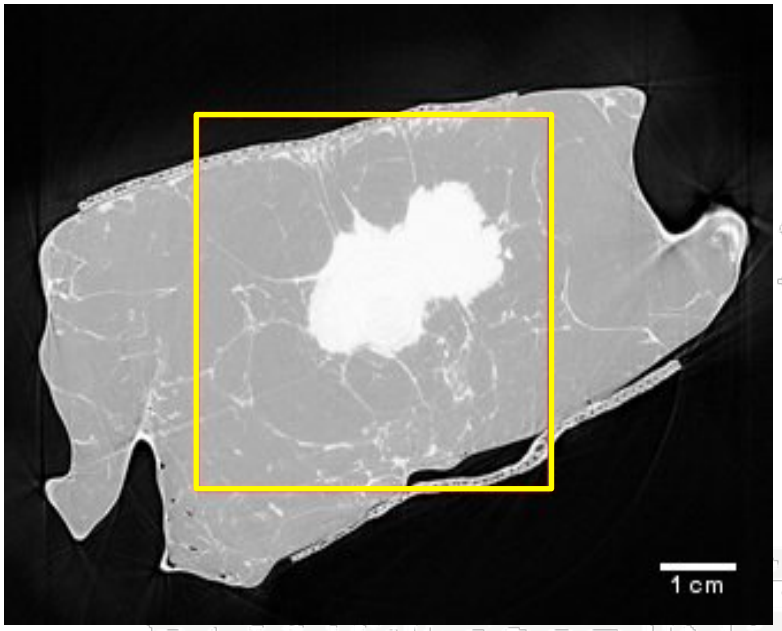
- Full reference quality indexes
  (Pacilè, S. et al, 2015. Clinical application of low-dose phase contrast breast CT: methods for the optimization of the reconstruction workflow. Biomed. Opt. Express 6, 3099–3112)
- Radiological assessment
  (Baran, P. et al, 2017. Optimization of propagation-based x-ray phase-contrast tomography for breast cancer imaging. Phys. Med. Biol. 62, 2315–2332)
- CNR + FWHM (IQ)
  (Pacilè, S. et al, 2017. Parameters affecting image quality in in propagation-based phase-contrast breast CT. - *Submitted to Medical Image Analysis*)

Full Reference Quality Indexes

Aim of the Work

Carry on a comparison between different reconstructions workflows and, at the same time, validate the proposed comparison method.





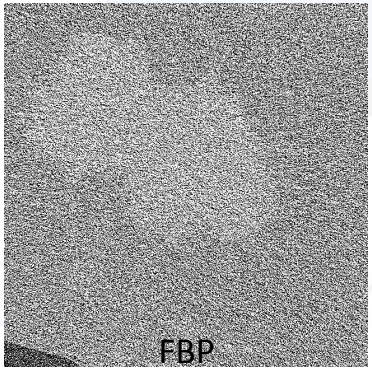
Full-reference indexes

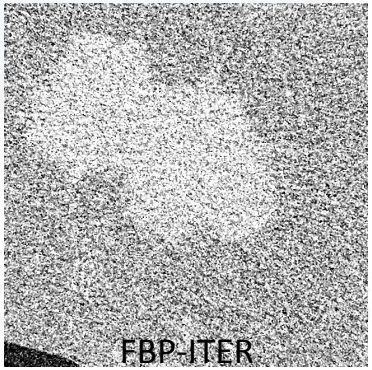
MSE – Mean Squared Error
SNR – Signal-to-Noise Ratio
UQI – Universal Quality Index
NQM – Noise Quality Measure
SSIM – Structural Similarity Index

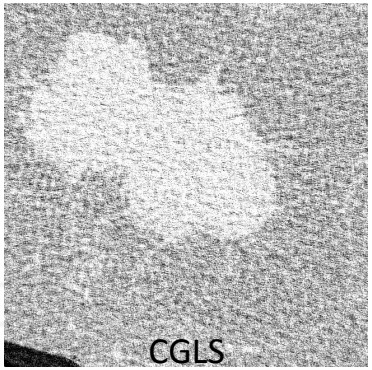
Radiological Assessment

From 0 (worst case) to 4 (best image)
No-diagnostic power (0 – 2)
Poor diagnostic power (2 – 3)
Full diagnostic power (> 3)

Full Reference Quality Indexes

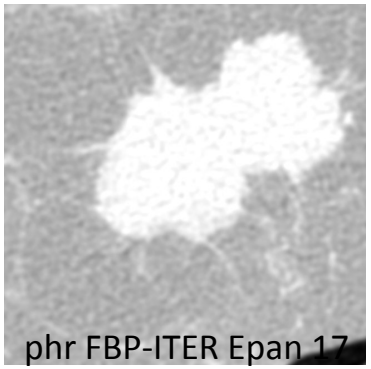


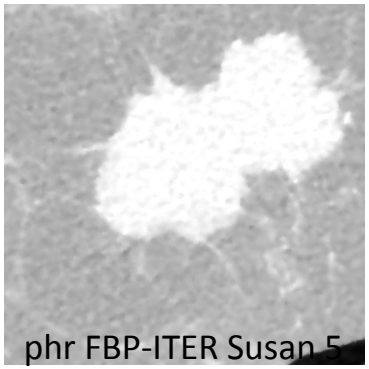


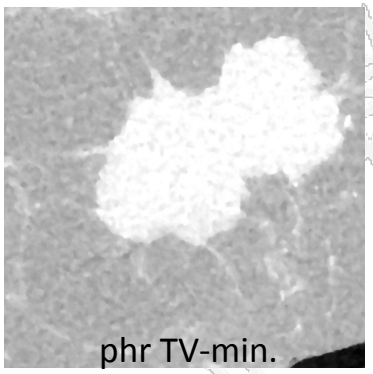


Radiological Assessment

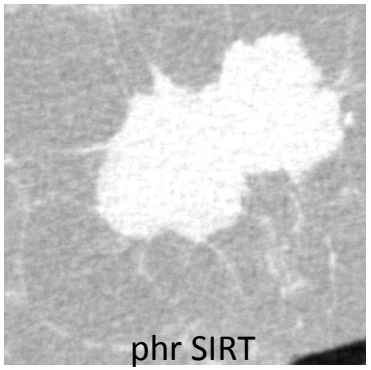
No-diagnostic power

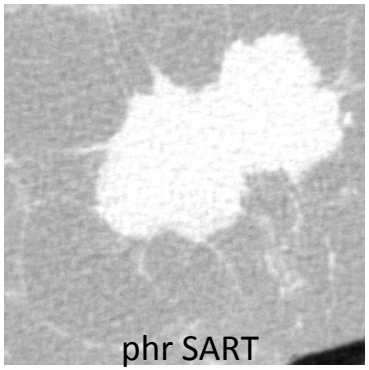


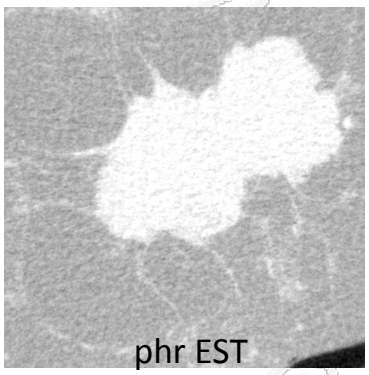




Poor-diagnostic power

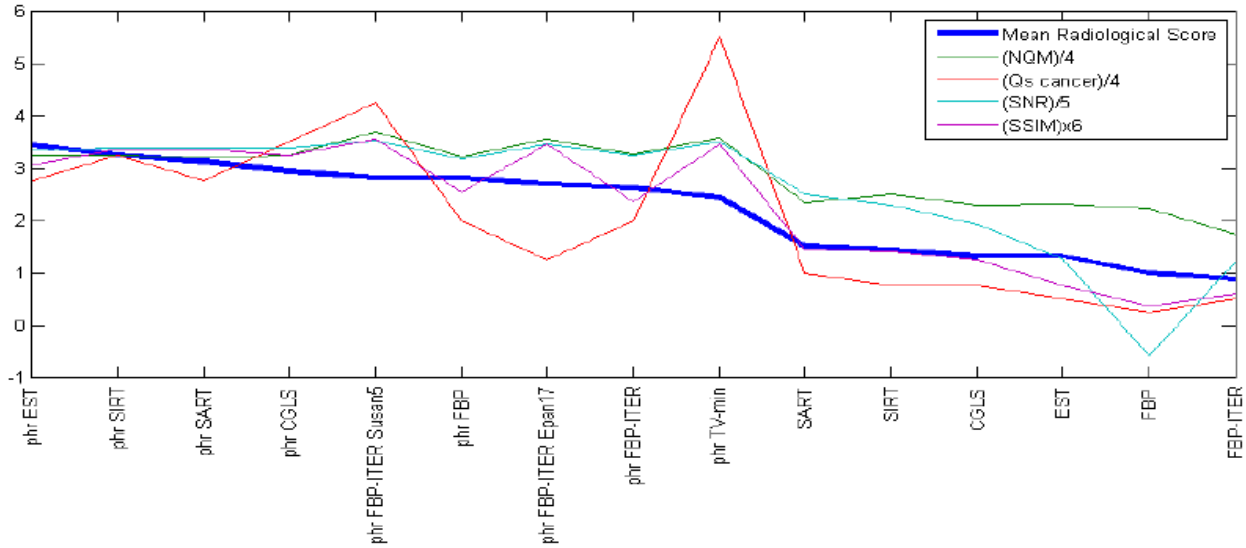






Full-diagnostic power

Full Reference Quality Indexes



Correlation between the radiological score and various image quality indexes.

Conclusions:

- Phase retrieval techniques significantly improve the image quality.
- With a dose comparable to conventional 2D planar radiography, it was possible to produce CT images with a high diagnostic value.
- Some of the proposed indexes are well suited for this kind of study.

Next step:

- Apply the proposed methodology to other experimental setups, such as e.g. different sample-to-detector distances and X-ray energies.

RADIOLOGICAL AND OBJECTIVE ASSESSMENT

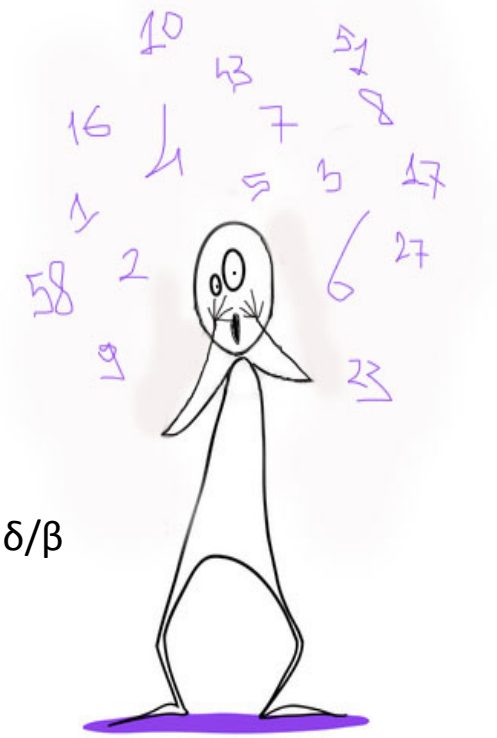
Sample-to-detector Distance
- 0.16 m
- 1.85 m
- 9.31 m

Energy
- 32 keV
- 35 keV
- 38 keV

Dose
- 473.74 mGy
- 10.3 mGy
- 5.05 mGy
- 2.17 mGy

Phase retrieval
- No phase retrieval
- Half nominal value of δ/β
- Nominal value of δ/β

Reconstruction Algorithm
- FBP
- SIRT
- SART
- MR-FBP
- CGLS



Radiological and Objective assessment

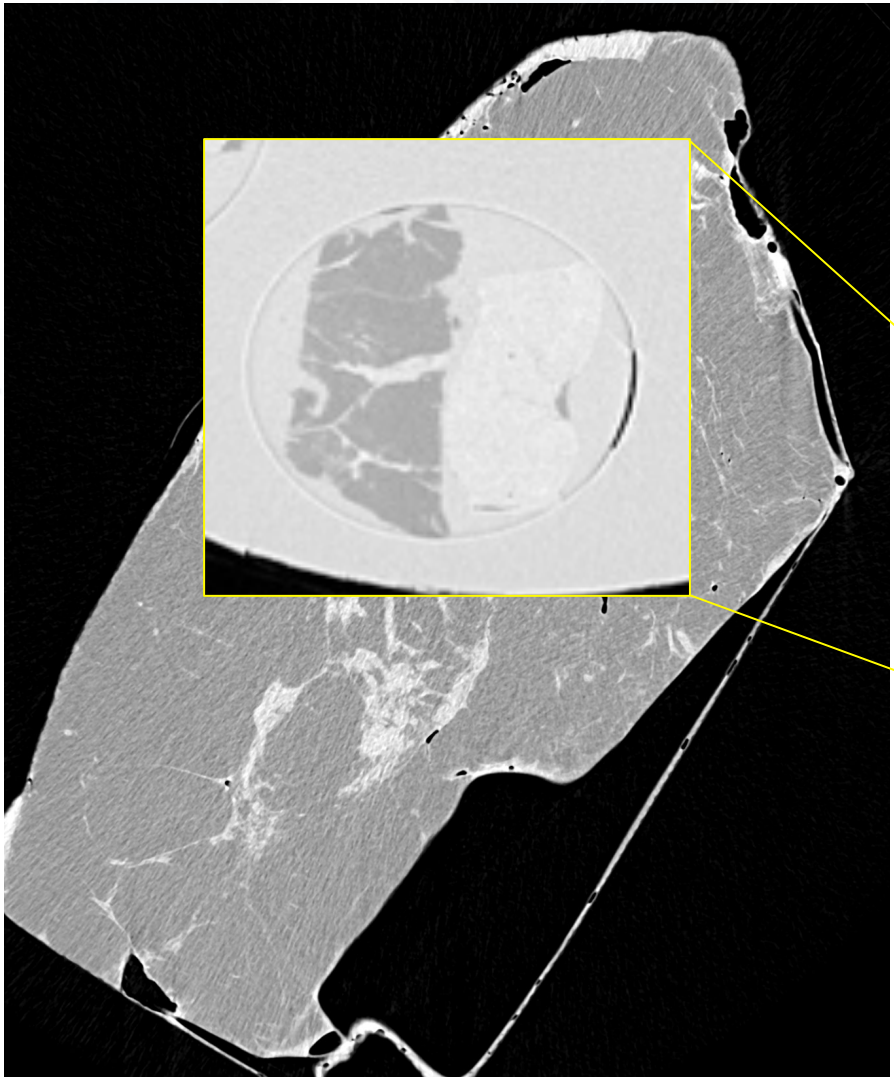
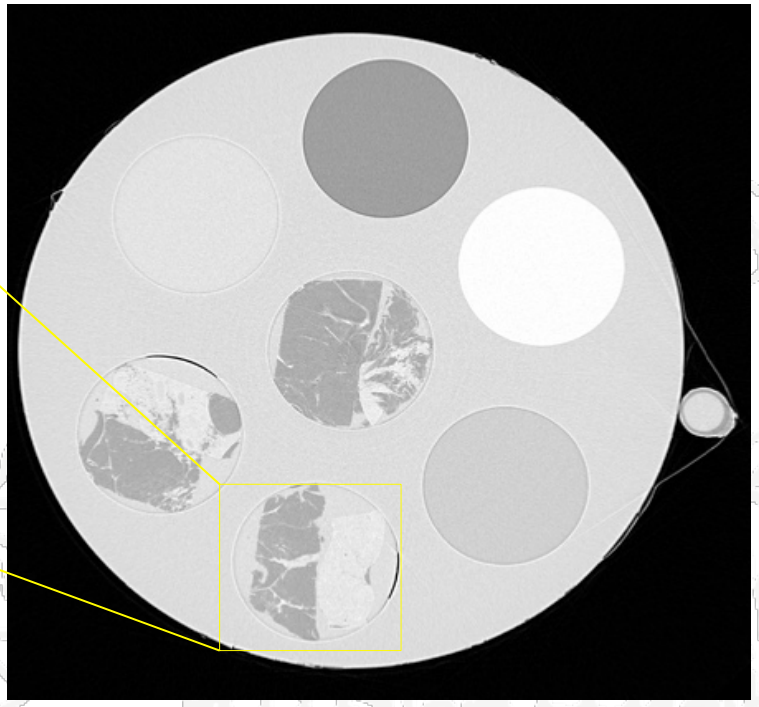


Image of breast tissue sample used in the radiological assessment (SIRT reconstruction from 1000 projections with 1000 iterations, *R*2 = 0.16 m, *E*=32keV, Dose=2 mGy). This image represents an approximation for the conventional (absorption-based or 'contact') mammographic image, with the best overall image quality achieved by the use of different reconstruction methods from the data collected at the shortest propagation distance at a given radiation dose.



Polycarbonate phantom with a diameter of 8 cm containing 7 holes. Four holes were filled with formalin 10%, paraffin, glycerol and EtOH and three additional holes with human breast tissue specimens fixed in formalin.

OBJECTIVE ASSESSMENT

$$CNR=|<\beta\downarrow fibrous>-<\beta\downarrow adipose>|/[(\sigma\downarrow fibrous\uparrow 2+\sigma\downarrow adipose\uparrow 2)/2]\uparrow 1/2$$

Edge Sharpness (*FWHM*)

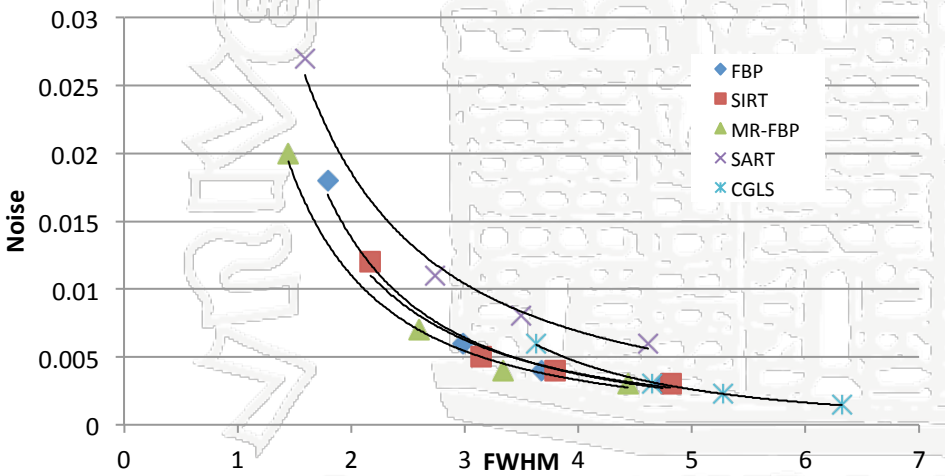
Noise (σ^2)

$$\sigma\uparrow 2 \propto 1/N$$

$$FoM=CNR/\sqrt{D\downarrow abs}$$

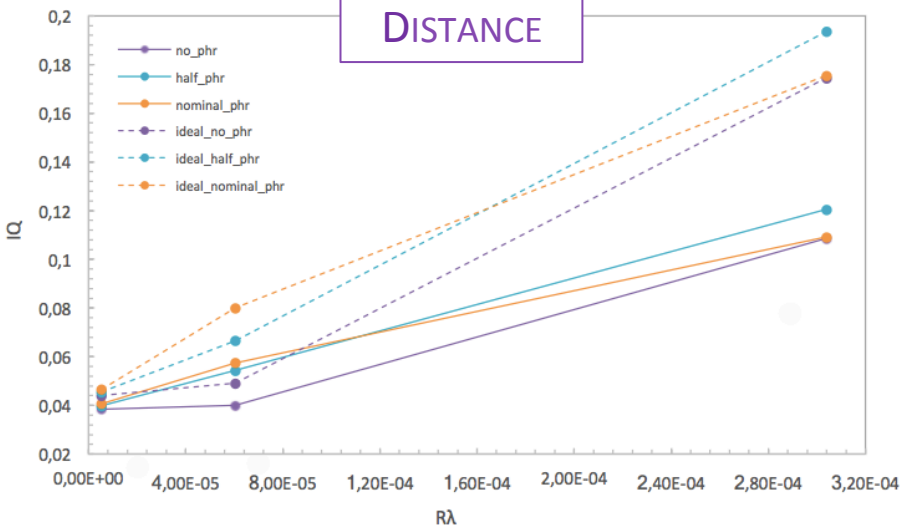
$$\sigma\uparrow 2 \propto f\uparrow 3$$

$$IQ=FoM/FWHM\uparrow n$$

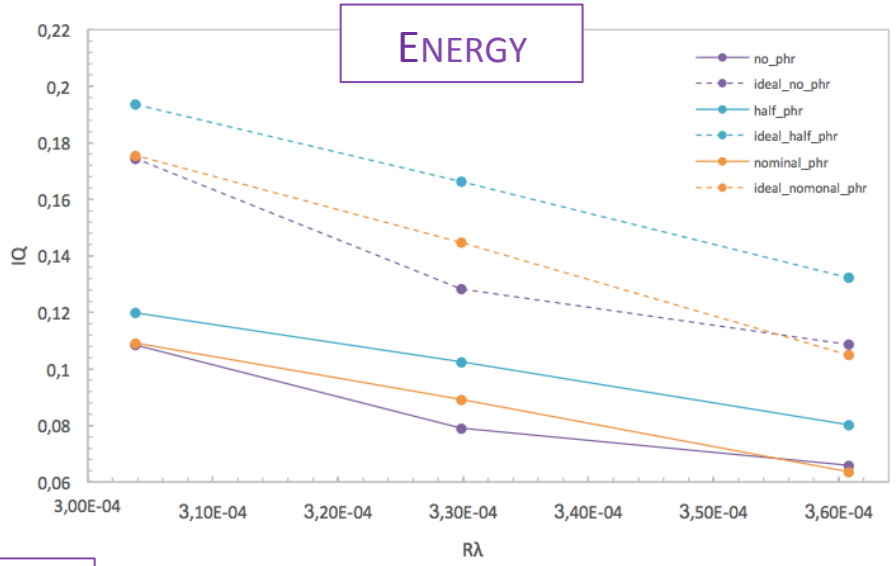


OBJECTIVE ASSESSMENT

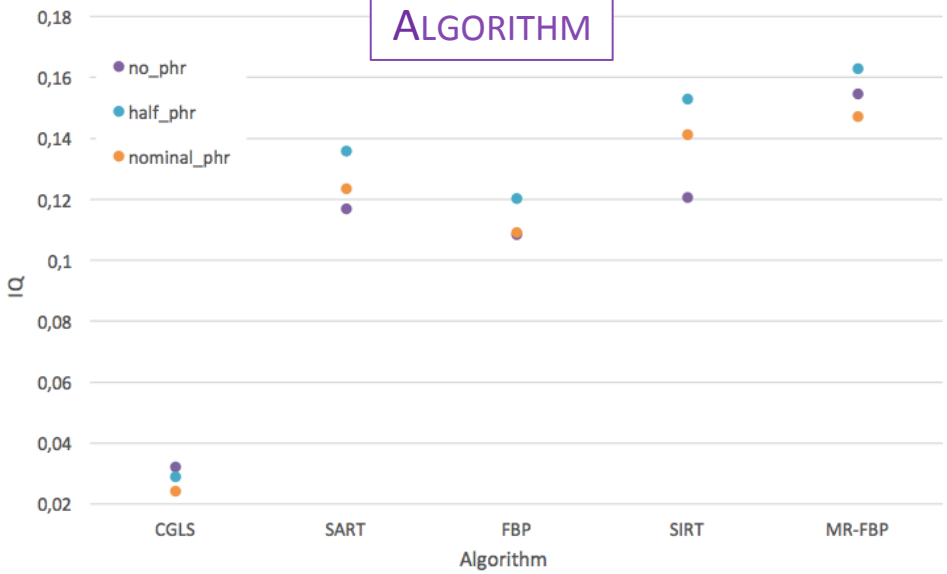
DISTANCE



ENERGY



ALGORITHM



CONCLUSIONS

- Image quality increases:
  - with longer sample-to-detector distances
  - for energies between 35 and 38 keV (in the considered range and experimental conditions)
  - processing images with Tie-Hom phase retieval algorithm
  - using MR-FBP and SIRT (among the considered reconstruction methods)
- It is possible to keep a sufficient level of image quality even at a very low dose, but it is essential to lower the x-ray attenuation in air by using an evacuated pipe to transfer the x-ray to the detector.

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[5]Commonwealth Scientific and Industrial Research Organisation, Melbourne Australia
[6]University of New England School of Science and Technology, Armidale Australia
[7]TissuPath Specialist Pathology Services, Melbourne Australia
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[13]ARC Centre of Excellence in Advanced Molecular Imaging, Melbourne Australia

GRAZIE!