Dedicated Imaging of the Breast with a Clinical Photon-Counting CT System: A Phantom Study

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Motivation and Aim

- **Modern clinical photon-counting CT (PCCT) systems provide a spatial resolution that is much higher compared to previous generations of systems.**

- **This high spatial resolution might allow for the development of applications that were previously restricted to other modalities.**

- **We want to investigate from a physics point-of-view if such a system, the SOMATOM Naeotom Alpha (Siemens Healthineers, Germany), allows for breast imaging.**

- **We further aim at comparing the result to a dedicated cone-beam breast CT (BCT) system (Koning Corp., USA).**

Diagnostic PCCT Systems
(as of November 2022)

	Sensor material	Detector pixel size at iso	FOM	Bins	FDA	Pubs	Installations
Canon	CdZnTe	?	50 cm	5	no	?	1 prototype (Japan)
GE	Si, edge on	?	?	?	no	?	2 experimental setups (Sweden, USA)
Philips	CdZnTe	275 × 275 μm	50 cm	5	no	≈22	1 experimental setup (France)
Siemens CounT	GOS/CdTe (dual source)	700 × 600 μm /250 × 250 μm	50 / 27.5 cm	4	no	≈50	3 experimental systems (Germany, USA)
Siemens CounT+	CdTe	150 × 176 μm	50 cm	4	no	≈11	3 prototypes (Czech Republic, Sweden, USA)
Siemens Alpha	CdTe/CdTe (dual source)	2· 150 × 176 μm	50 / 36 cm	4	Yes	≈40	About 100 worldwide

The additional factor 2 in the detector pixel size column indicates that some scan modes may use binning.

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Imaging Systems

Dedicated Breast CT[1] (BCT)

Photon-Counting CT (PCCT)

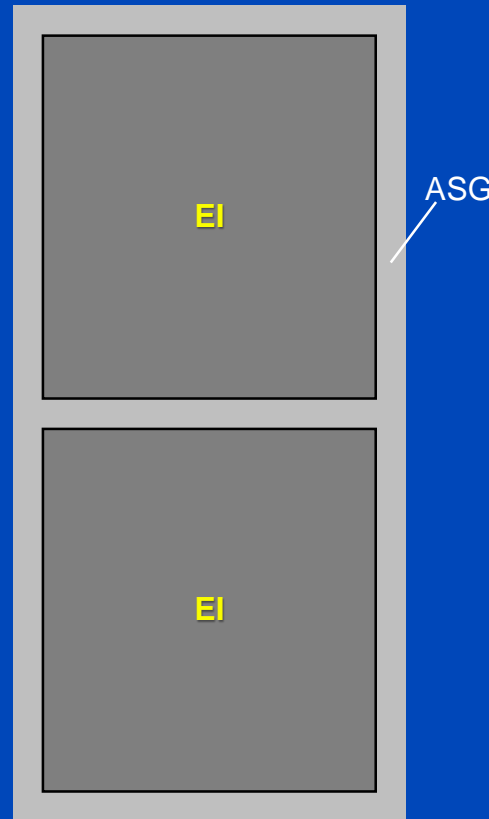**dkfz.**

Detector Pixel BCT[1], EICT, PCCT[2]

BCT[1]
2048 × 1536 pixels
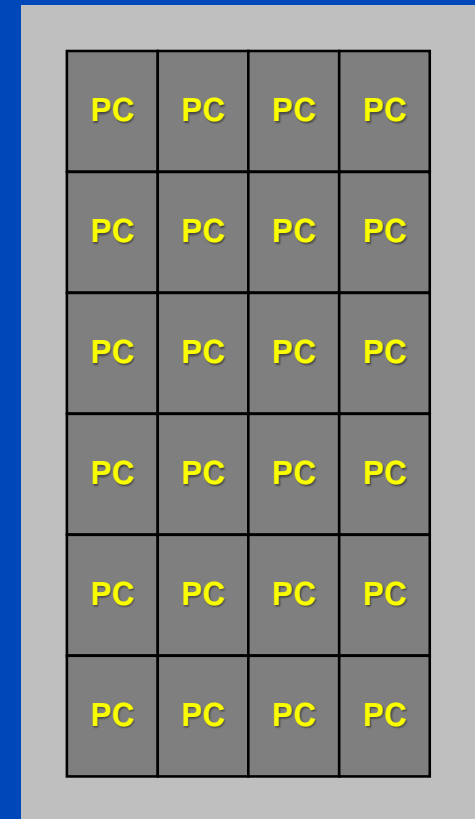pixel size 0.273 × 0.273 mm at iso
209 mm z-coverage

Force
920 × 96 detector pixels
pixel size 0.52 × 0.56 mm at iso
57.6 mm z-coverage

Alpha (UHR)[2]
2752 × 120 pixels
pixel size 0.15 × 0.176 mm at iso
24 mm z-coverage

ASG

z
β

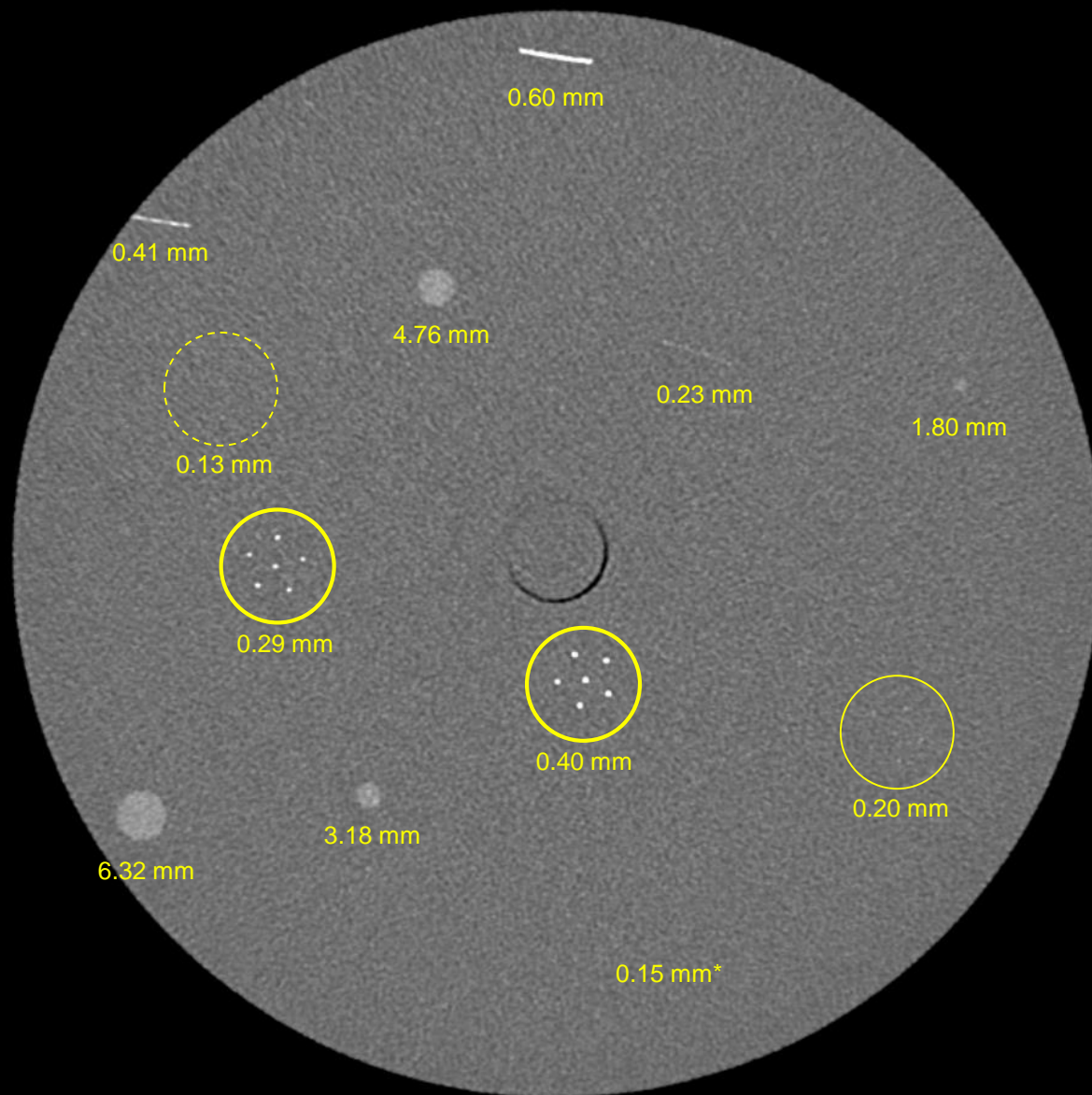**Focus sizes of Vectron tube:**
0.4×0.5 mm, 0.6×0.7 mm, 0.8×1.1 mm

[1]L. Brombal et al. Image quality comparison between a phase-contrast synchrotron radiation breast CT and a clinical breast CT: a phantom based study. Scientific Reports 9(1):17778, 2019.
[2]J. Ferda et al. Computed tomography with a full FOV photon-counting detector in a clinical setting, the first experience. European Journal of Radiology 137:109614, 2021.

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Breast Phantom

- **14 slabs of adipose tissue-equivalent material**

- **Structures of interest:**
  - **Calcifications**
  - **Fibers**
  - **Masses**

0.60 mm

0.41 mm

4.76 mm

0.23 mm

1.80 mm

0.13 mm

0.29 mm

0.40 mm

0.20 mm

3.18 mm

6.32 mm

0.15 mm*

*barely visible only when
 scrolling through slices and knowing where to look

Phantom Orientation

- **In case of the dedicated BCT system, the breast phantom can be imaged by itself.**

- **In case of the PCCT, two phantom positions are used:**

  - **The phantom is placed on the table and oriented in longitudinal direction. I.e., the trajectory of the source is similar to the BCT.**

  - **The breast phantom is combined with a thorax phantom to simulate an actual patient in the clinical scanner.**

**BCT
(circle)**

**PCCT
(breast only, spiral)**
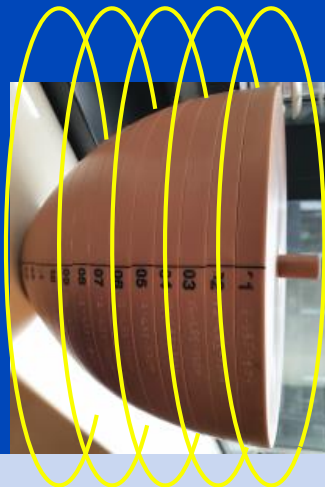
**PCCT
(breast+thorax, spiral)**

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Acquisition and Reconstruction

- **BCT:**
  - Images using the BCT system were acquired using a tube current of **50 mA** and a tube voltage of **49 kV**.
  - BCT data were reconstructed onto a grid of 960×1008 isotropic voxels with a size of 0.19 mm using the **FDK**.
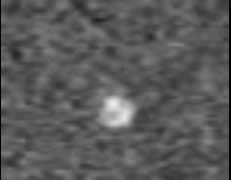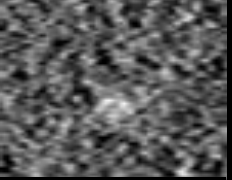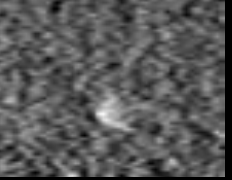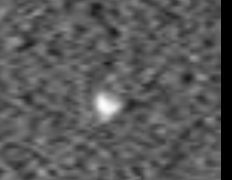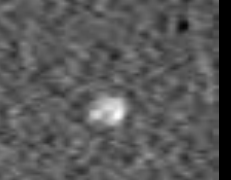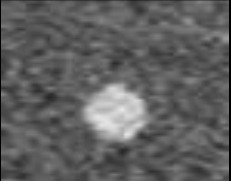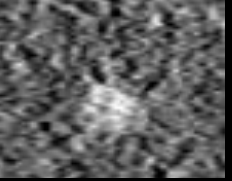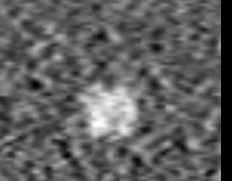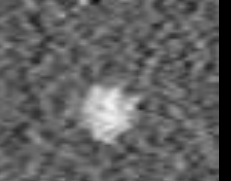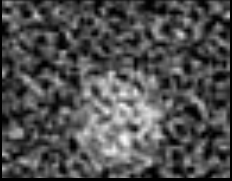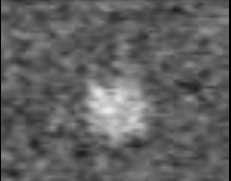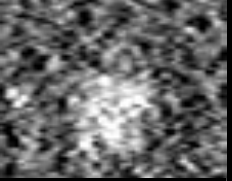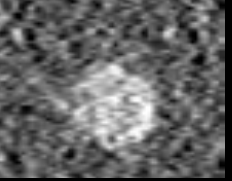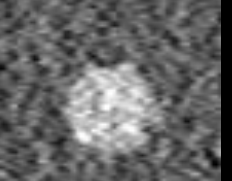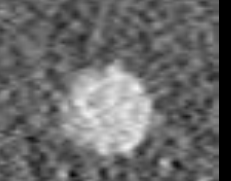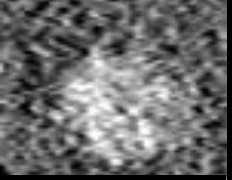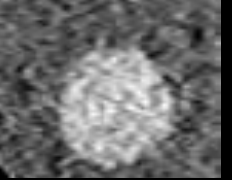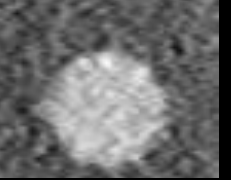
- **PCCT:**
  - Images using the PCCT were acquired in UHR mode using tube currents of **41 mA to 350 mA**, respectively, and a tube voltage of **120 kV**.
  - No dose modulation was used in any of the experiments.
  - Photon-counting data were reconstructed onto slices with 1024×1024 voxels with a size of 0.195 mm, a slice thickness of 0.3 mm and a slice increment of 0.15 mm.
  - All data were reconstructed using a B72u-kernel.
  - Image reconstruction was performed using Quantum Iterative Reconstruction (**QIR**), strength 3.

BCT

PCCT

7.0 mGy (CTDI$_{16\ cm}$)   7.0 mGy (CTDI$_{16\ cm}$)   1.3 mGy (CTDI$_{32\ cm}$)   3.5 mGy (CTDI$_{32\ cm}$)   7.1 mGy (CTDI$_{32\ cm}$)   12.5 mGy (CTDI$_{32\ cm}$)

0.13 mm

0.20 mm

0.29 mm

0.40 mm

Breast Phantom Only

Breast and Thorax Phantom
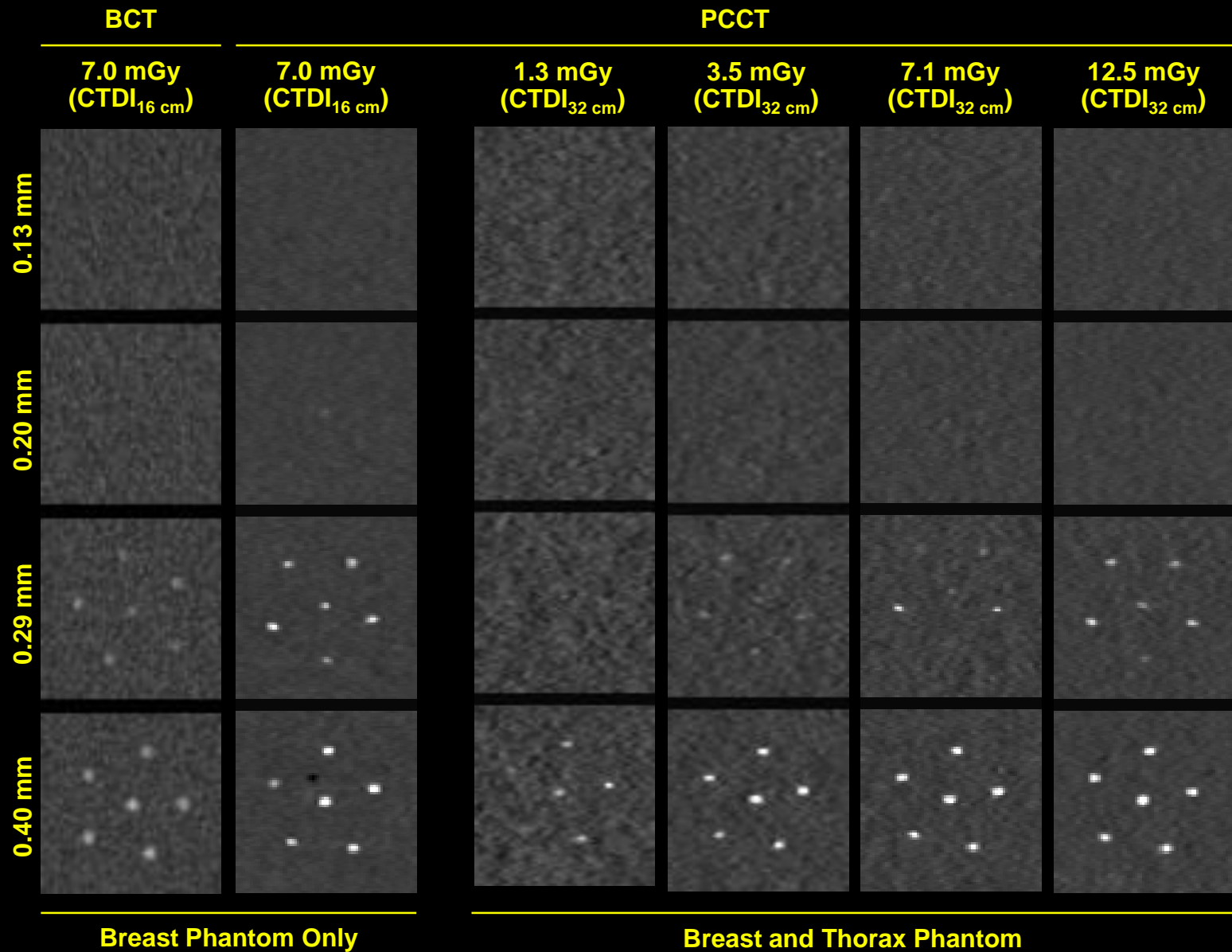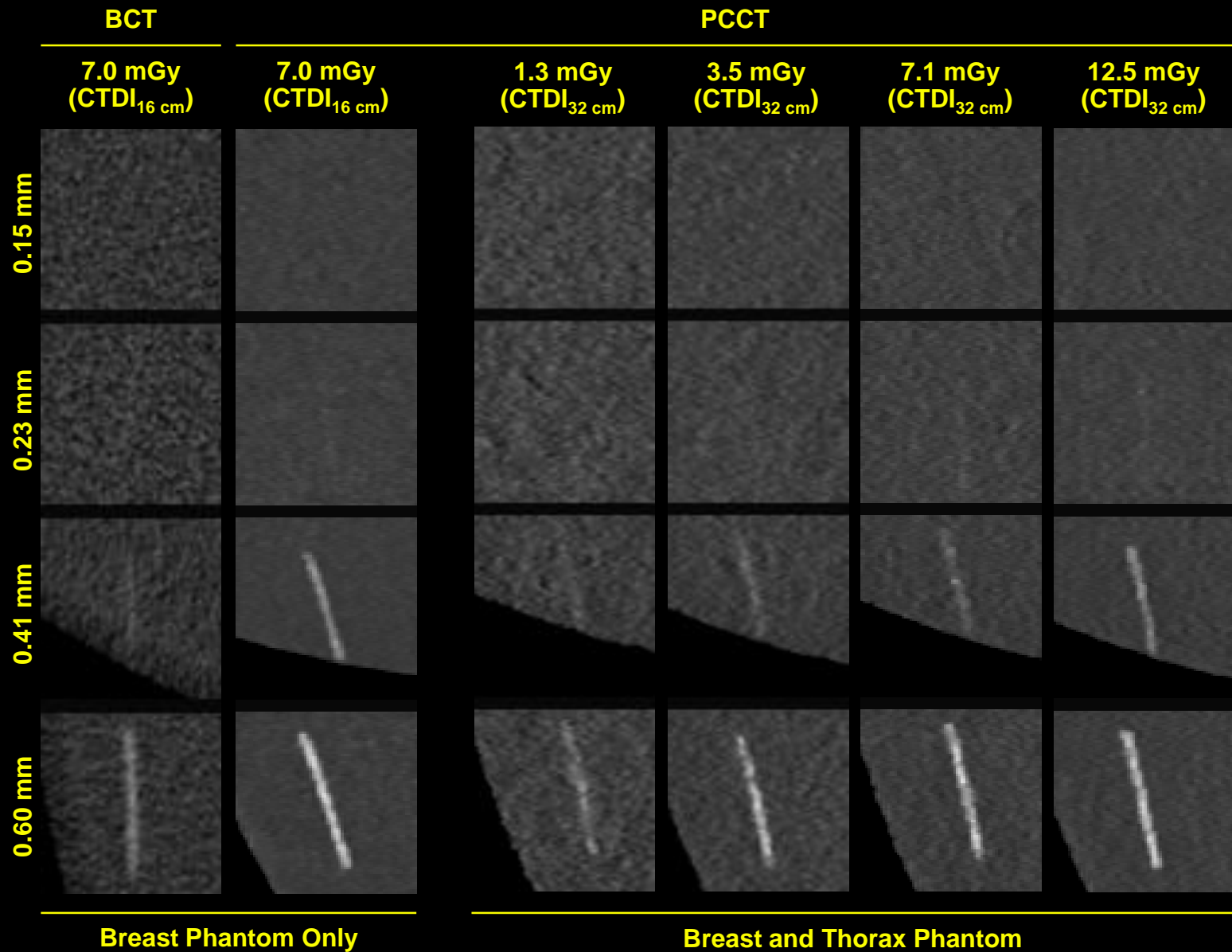
0.6 mm MIP, C = 300 HU, W = 1500 HU

BCT		PCCT			
7.0 mGy $(\text{CTDI}_{16\,\text{cm}})$	**7.0 mGy** $(\text{CTDI}_{16\,\text{cm}})$	**1.3 mGy** $(\text{CTDI}_{32\,\text{cm}})$	**3.5 mGy** $(\text{CTDI}_{32\,\text{cm}})$	**7.1 mGy** $(\text{CTDI}_{32\,\text{cm}})$	**12.5 mGy** $(\text{CTDI}_{32\,\text{cm}})$

Breast Phantom Only

Breast and Thorax Phantom

0.15 mm, 0.23 mm, 0.41 mm, 0.60 mm

0.6 mm MIP, C = 300 HU, W = 1500 HU

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BCT

PCCT

	7.0 mGy $(CTDI_{16\,cm})$	**7.0 mGy** $(CTDI_{16\,cm})$	**1.3 mGy** $(CTDI_{32\,cm})$	**3.5 mGy** $(CTDI_{32\,cm})$	**7.1 mGy** $(CTDI_{32\,cm})$	**12.5 mGy** $(CTDI_{32\,cm})$
1.80 mm	CNR=1.14	CNR=4.91	CNR=1.62	CNR=2.10	CNR=3.35	CNR=3.51
3.18 mm	CNR=1.26	CNR=5.47	CNR=2.12	CNR=2.25	CNR=3.34	CNR=3.37
4.76 mm	CNR=1.46	CNR=4.34	CNR=1.42	CNR=2.18	CNR=2.79	CNR=4.09
6.32 mm	CNR=2.11	CNR=4.24	CNR=1.49	CNR=2.32	CNR=2.58	CNR=3.99

Breast Phantom Only

Breast and Thorax Phantom

C = -50 HU, W = 400 HU

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Summary & Conclusions

- If only the breast phantom is imaged, the BCT and the PCCT show comparable image quality.

- In particular, the CNR in case of the PCCT is better.

- If the breast phantom is combined with the thorax phantom, the PCCT allows for the identification of fibers similar to BCT.

- It also allows for the identification of the larger calcifications.

- Clinical photon-counting CT might be an interesting modality for breast imaging in the future.

- Dedicated scan modes and reconstruction algorithms might further improve image quality.

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Thank You!