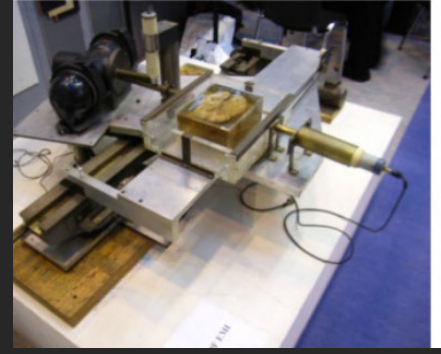
JMI Journal of Medical Imaging

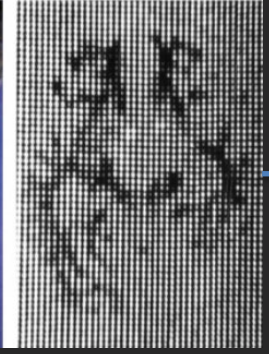
▸ J Med Imaging (Bellingham). 2021 Oct 29;8(5):052110. doi: 10.1117/1.JMI.8.5.052110

How CT happened: the early development of medical computed tomography

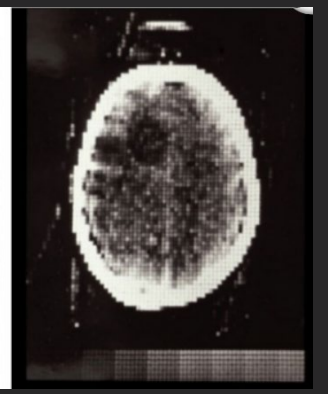
Raymond A Schulz [a,*], Jay A Stein [b], Norbert J Pelc [c,✉]

On Friday, October 1, 1971, a new procedure was performed to image a live patient's brain. After a (lengthy) computer processing reconstruction delay, a remarkable image appeared on the screen of a monitor, sparking a revolution in medical imaging. Image "200.2A" was of a middle-aged female patient of Dr. James Ambrose at Atkinson Morley Hospital with a suspected tumor in the left frontal lobe, which was successfully excised and confirmed as a cystic astrocytoma.[1] The scanning process was painfully slow. But since each new image was



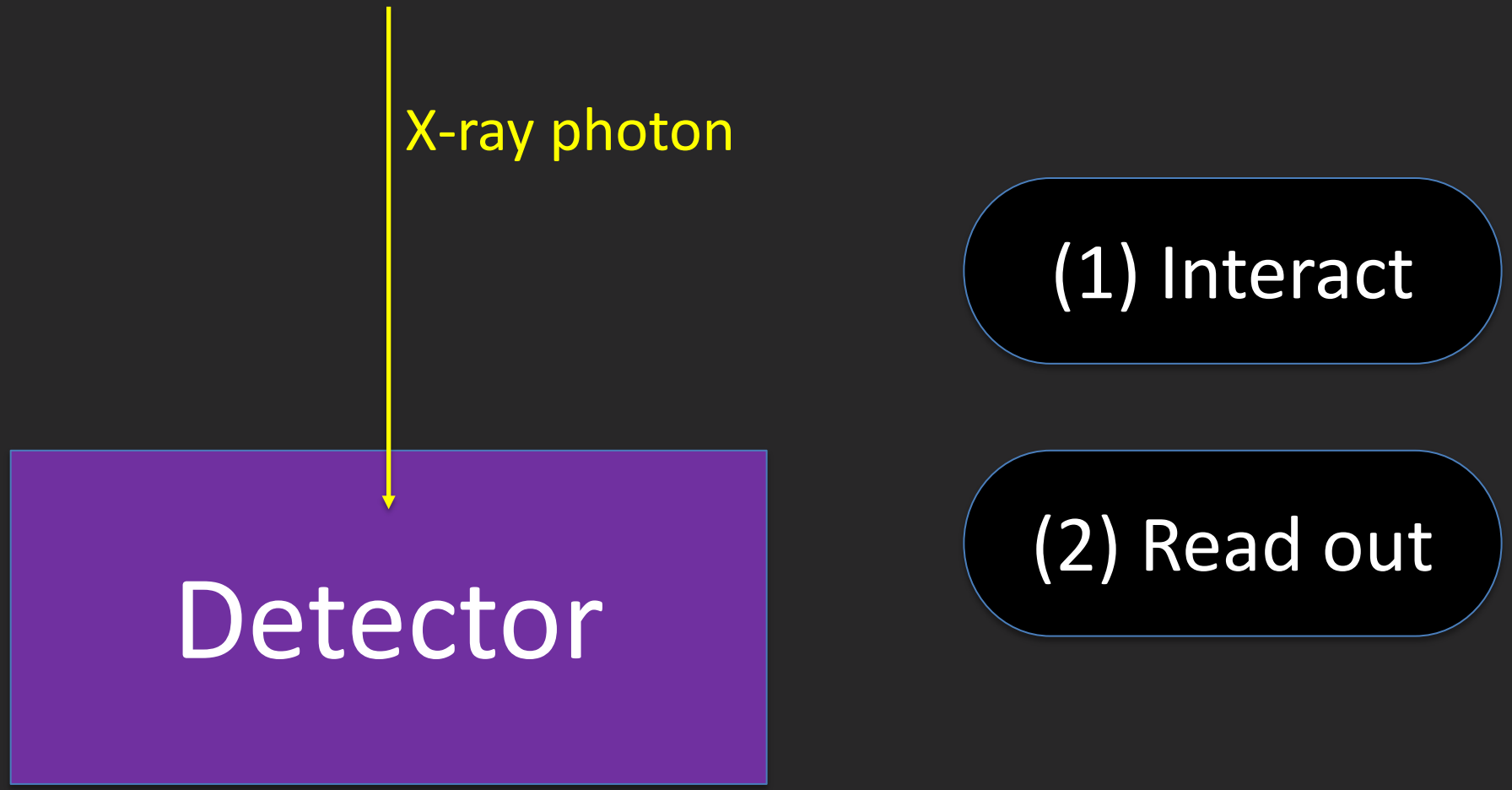


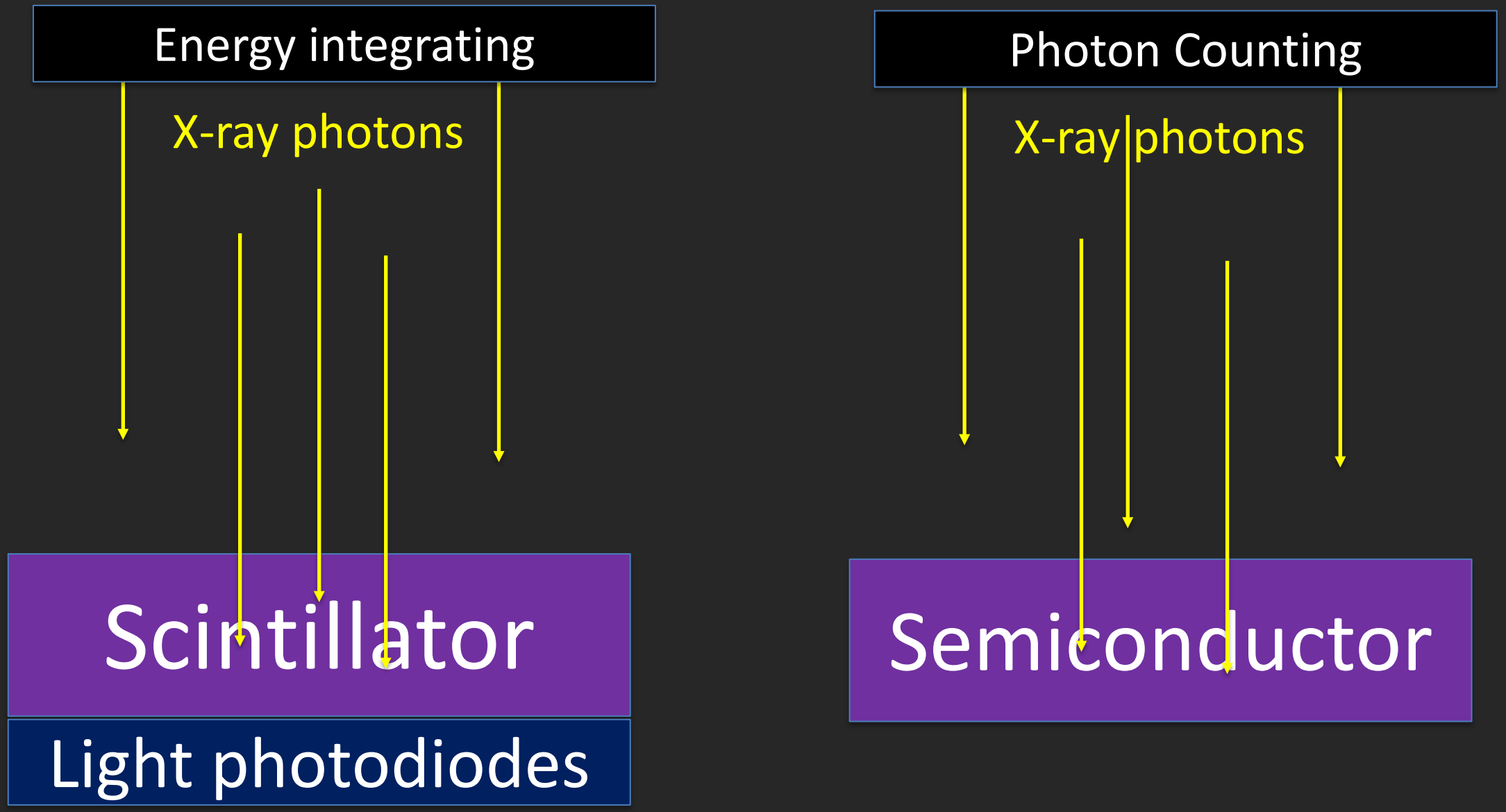
Look at the amazing progress from their benchtop system to their clinical system!

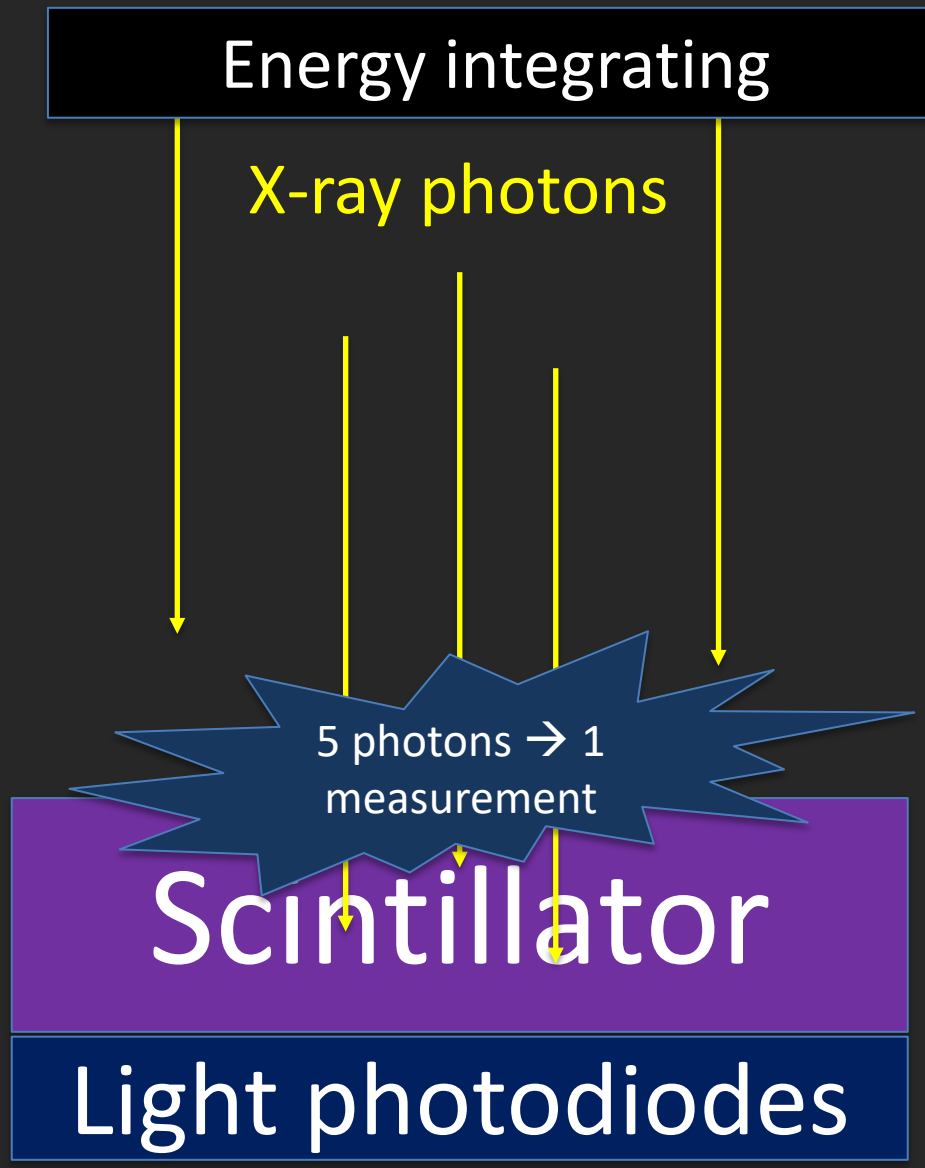


The first presentation of this early clinical data was held at the British Institute of Radiology conference in April 20, 1972,[13,25] by which time some 70 patients had been scanned. This

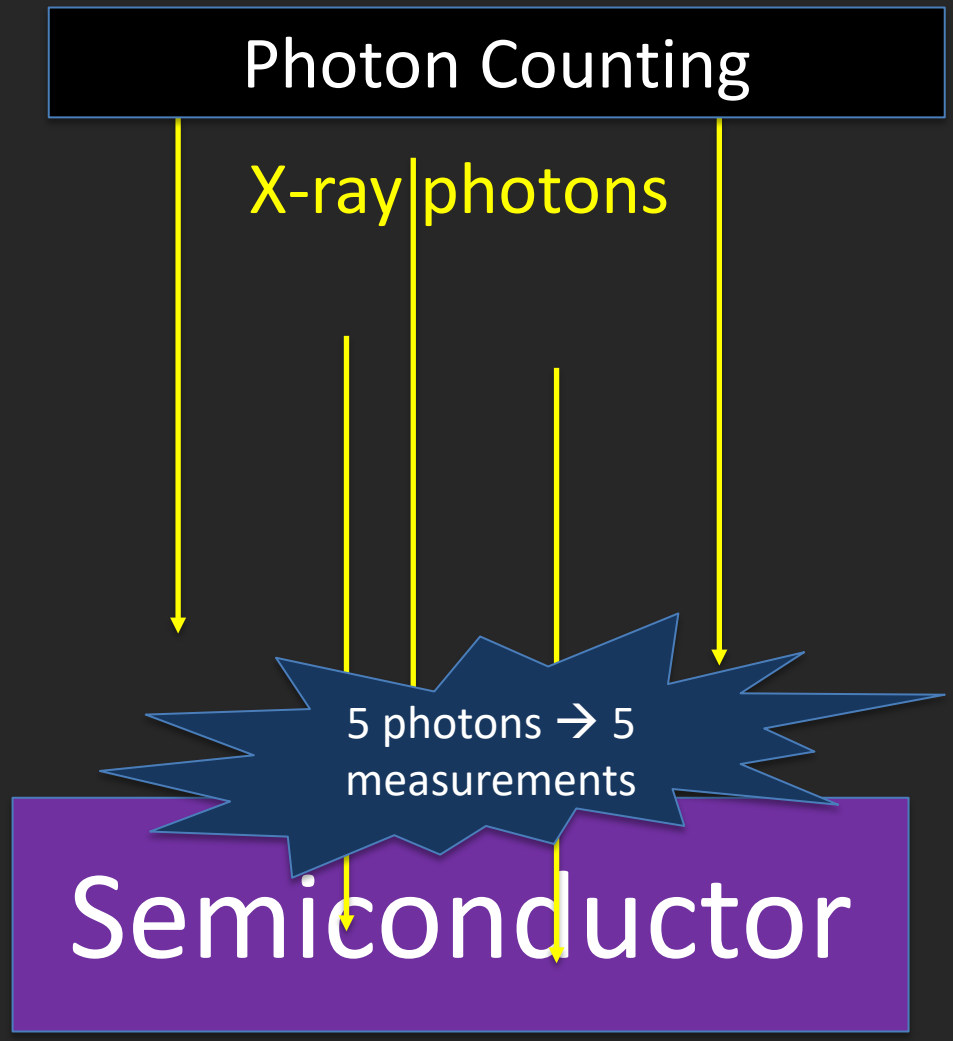
By RSNA 1973, five scanners had been installed beyond Atkinson-Morley, three in the UK (Manchester, London's Queen Square and Glasgow), and two in the United States. The Mayo Clinic EMI Mark-I system, delivered in early 1973, imaged the first patient outside the UK on June 18, 1973. About a month later, the MGH scanner was installed and operating. The first 10 EMI-scanners were partly hand built while manufacturing was ramping up.


X-ray photon
Detector
(1) Interact
(2) Read out


Energy integrating
X-ray photons
Scintillator
Light photodiodes
All photons interacting over milliseconds are recorded
Photon Counting
X-ray photons
Semiconductor
All photons interacting over nanoseconds are recorded

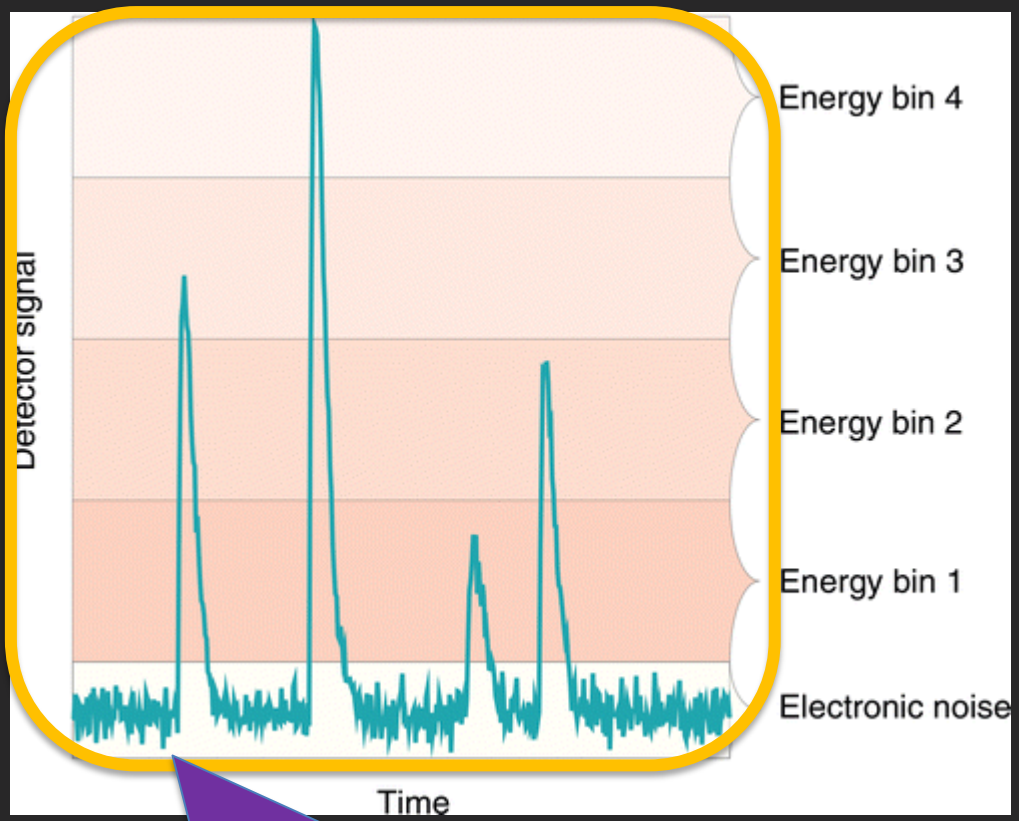


All photons interacting over milliseconds are recorded



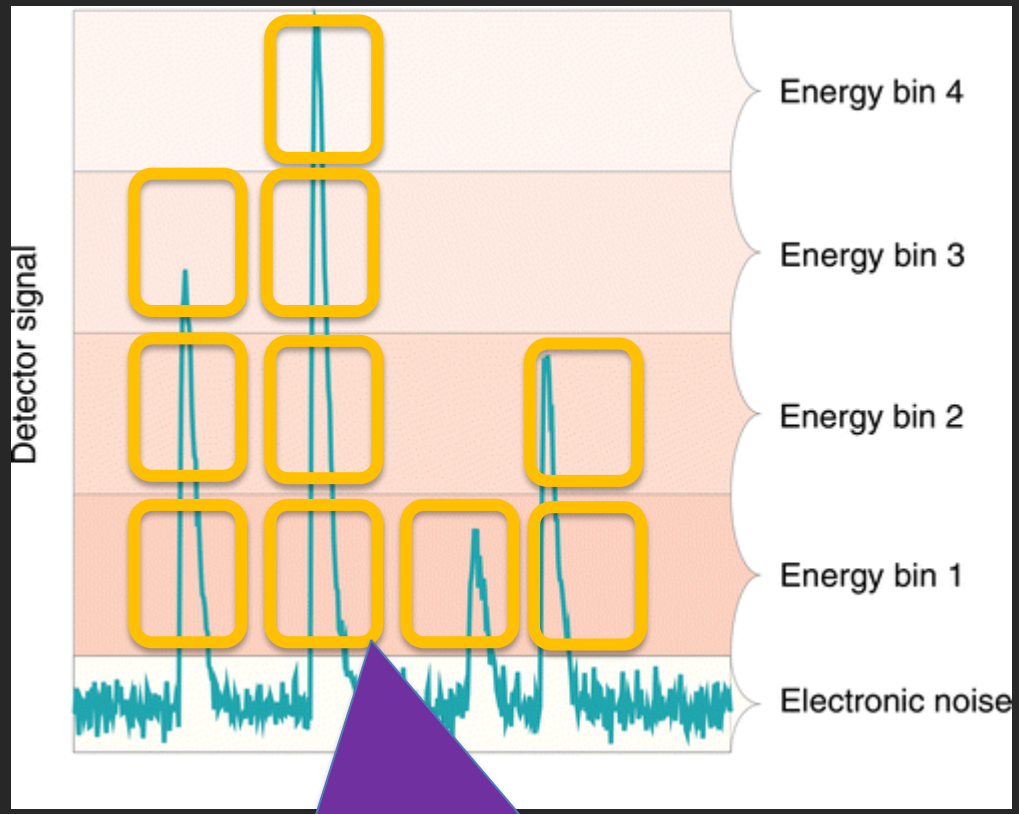
All photons interacting over nanoseconds are recorded

Energy integrating



1 measurement sums everything!

Photon Counting



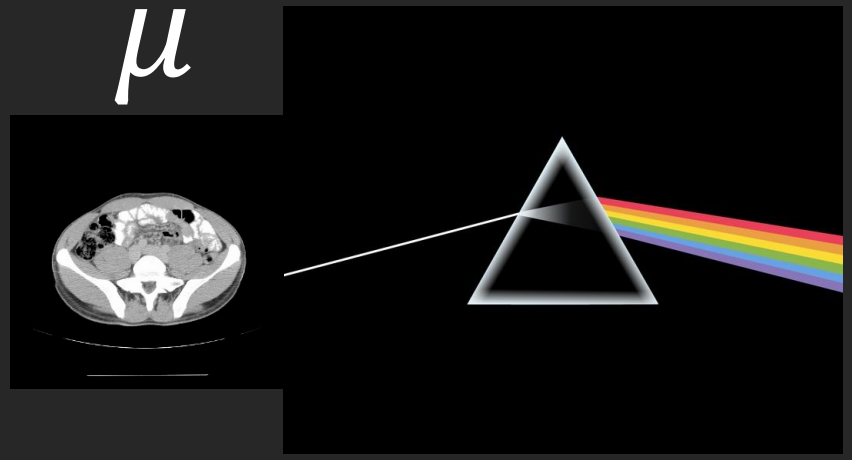
10 measurements let you define energy of each photon and reject noise!!!

Plots adapted from Willemink et al. 2018 https://doi.org/10.1148/radiol.2018172656

	(1) Interact		(2) Read out
Energy integrating	Photoelectric effect Compton Scattering	Produces light	Light signal recorded over milliseconds time range
Photon Counting	Photoelectric effect Compton Scattering	Produces charge	Electric charge recorded over nanoseconds

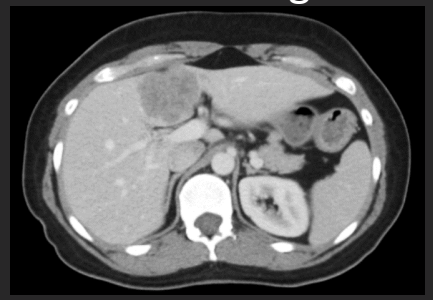
Single energy scanning (CT prior ~2006)

μ

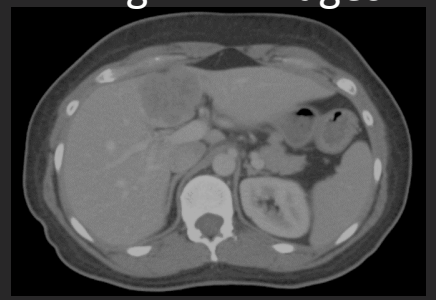


Dual energy/Spectral scanning

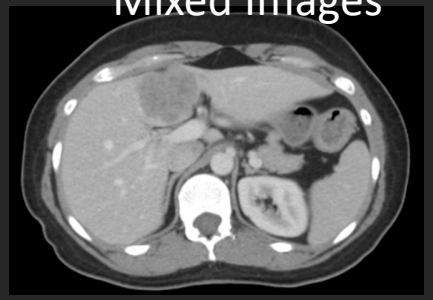
Low kV Images



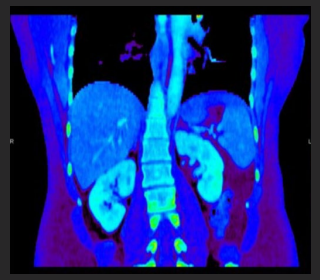
High kV Images



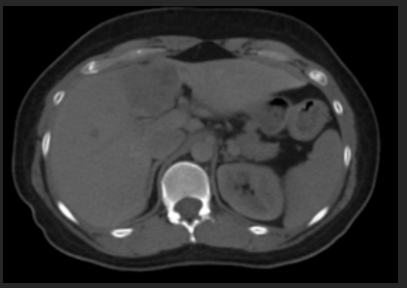
Mixed Images



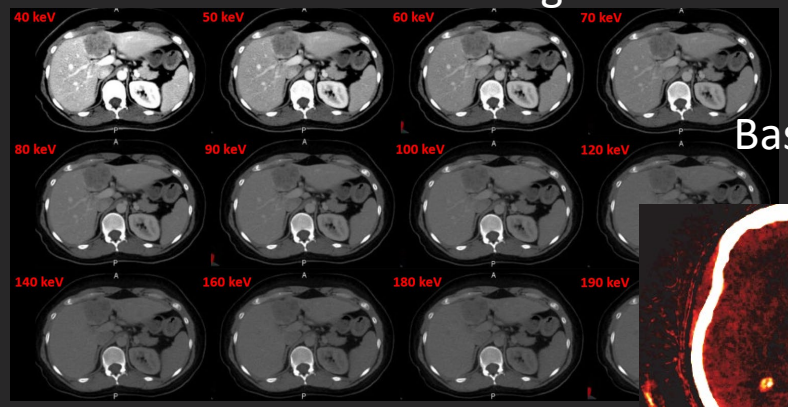
Effective atomic number images



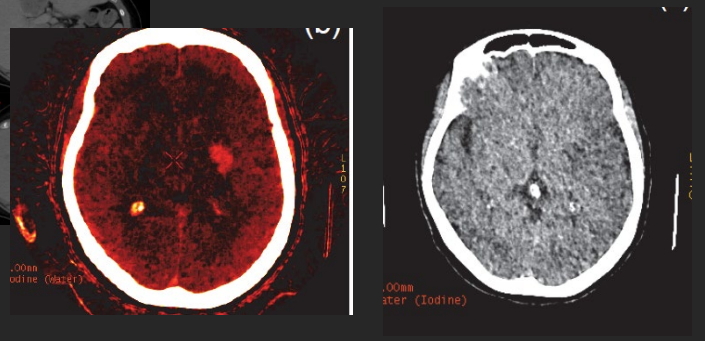
Virtual non contrast Images



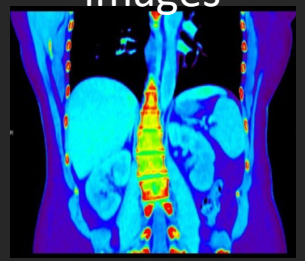
Monochromatic images

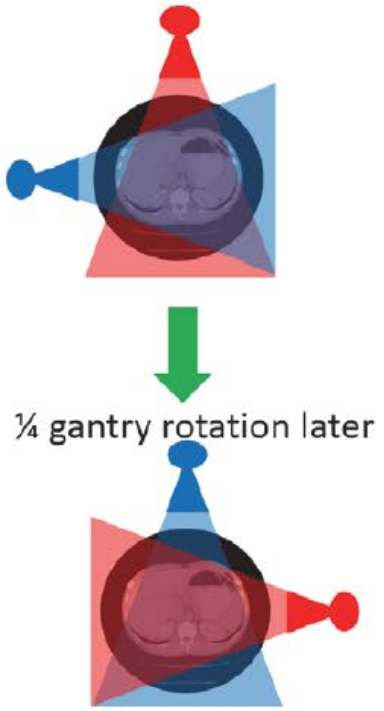
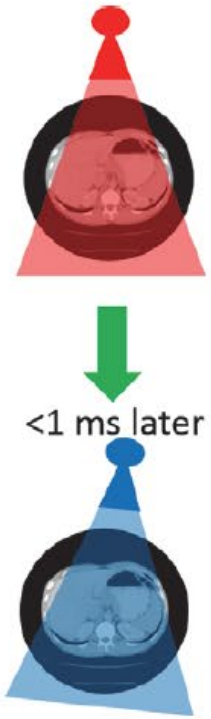
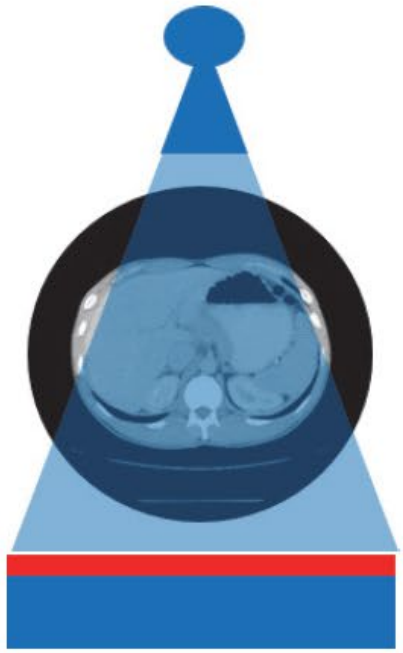
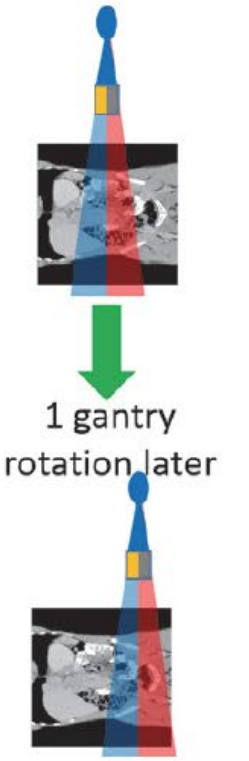
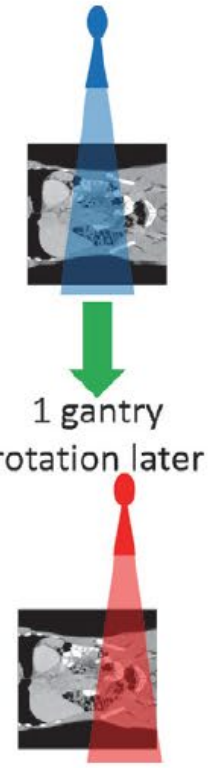
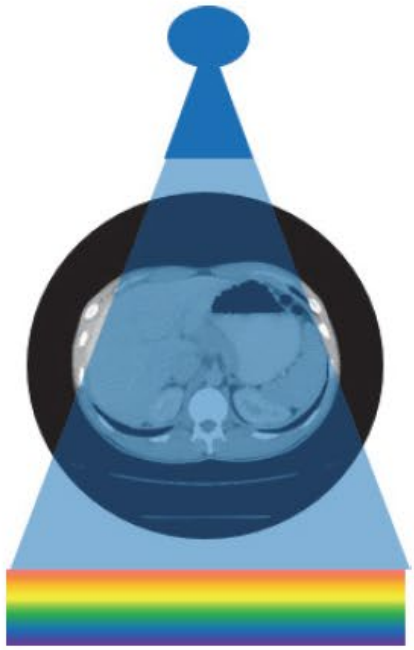


Basis Material Images

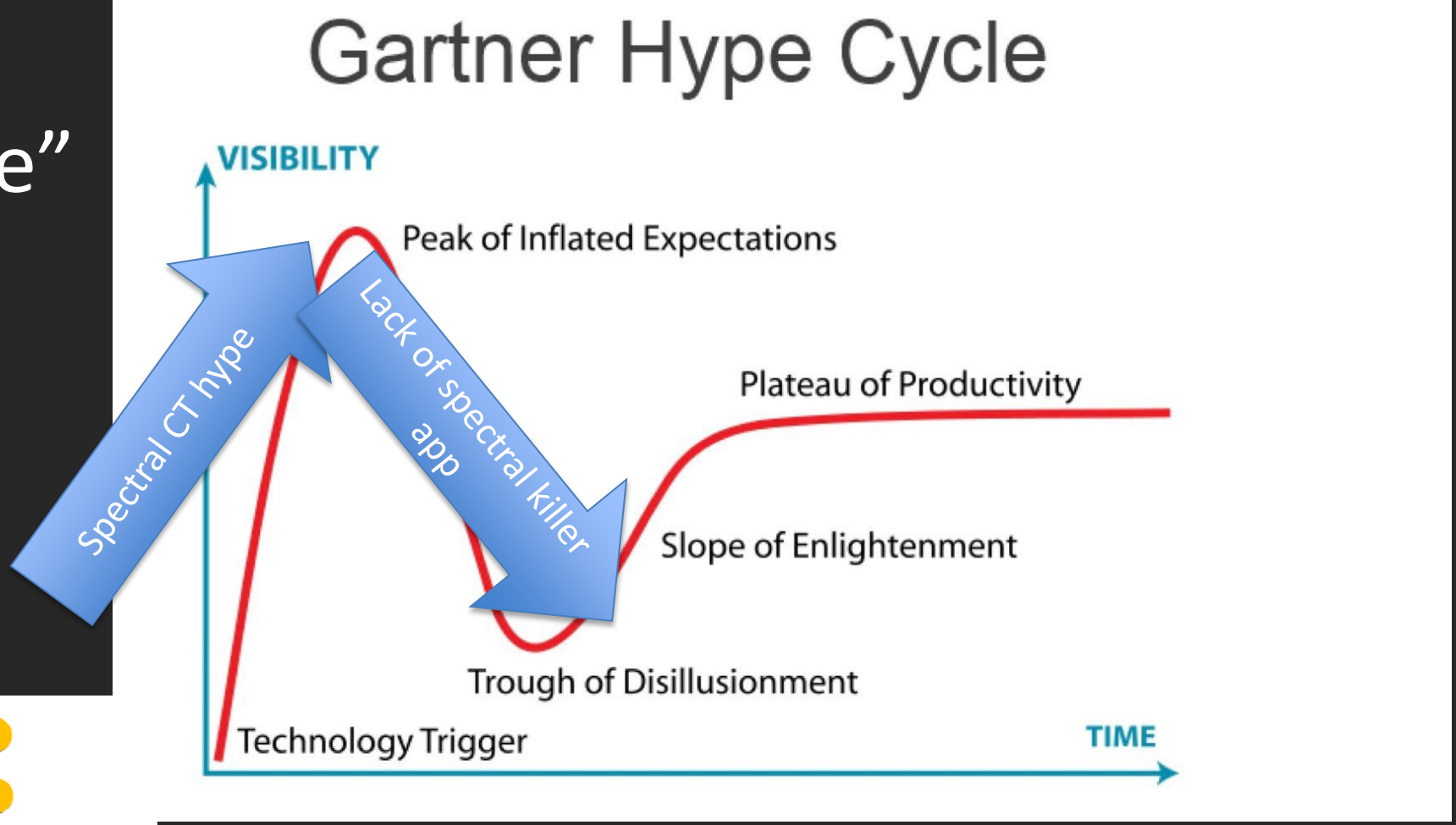


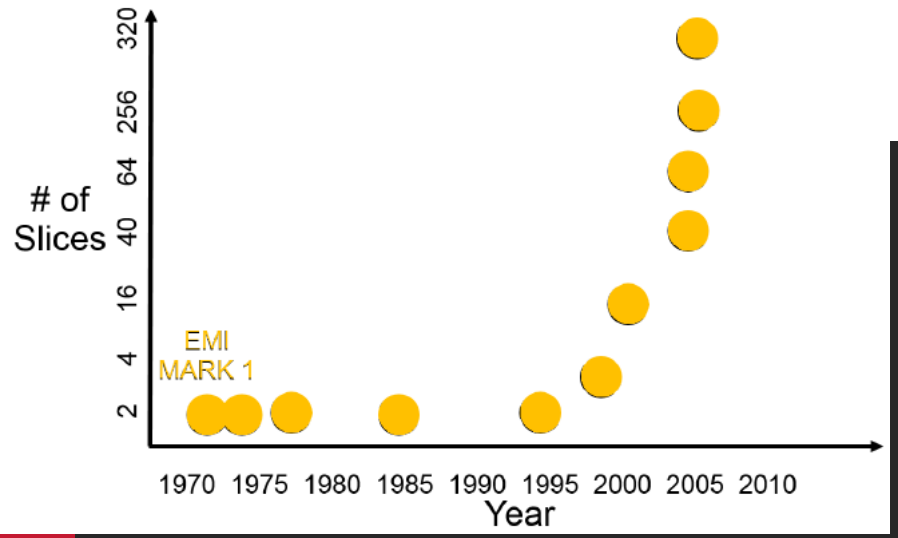
Electron density images



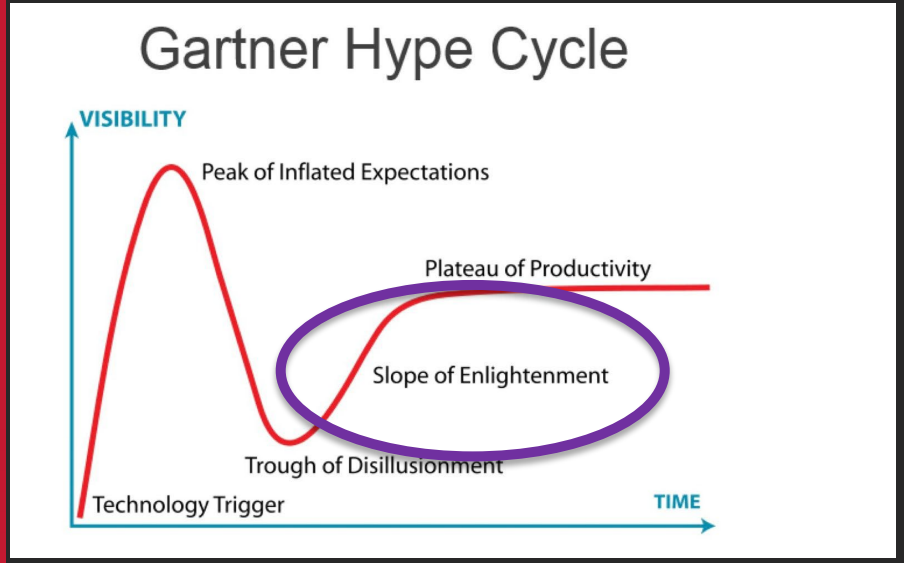
Dual source	kV switching	Dual layer “sandwich”	Filtration based	Rotate-rotate	Photon Counting
					
Siemens	GE and Canon	Philips	Siemens “twinbeam”	Any CT scanner	Photon Counting (Siemens ALPHA)

“Spectral Hype”





2010→ ~2020



Present day

REVIEW ARTICLE | VOLUME 61, ISSUE 6, P963-971, NOVEMBER 2023

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Dual-Energy Computed Tomography: Integration Into Clinical Practice and Cost Considerations

Lakshmi Ananthakrishnan, MD • Naveen Kulkarni, MD • Aran Toshav, MD

Published: June 18, 2023 • DOI: https://doi.org/10.1016/j.rcl.2023.05.003 • Check for updates

Practice | Published: 02 January 2020

Cost-effectiveness of dual-energy CT versus multiphasic single-energy CT and MRI for characterization of incidental indeterminate renal lesions

Bhavik N. Patel, Artem T. Boltyenkov, Maria G. Martinez, Domenico Mastrodicasa, Daniele Marin, R. Brooke Jeffrey, Benjamin Chung, Pari Pandharipande & Avinash Kambadakone

Abdominal Radiology **45**, 1896–1906 (2020) | Cite this article

Impact of spectral body imaging in patients suspected for occult cancer: a prospective study of 503 patients

Oncology | Open Access | Published: 04 May 2020 | **30**, 5539–5550 (2020)

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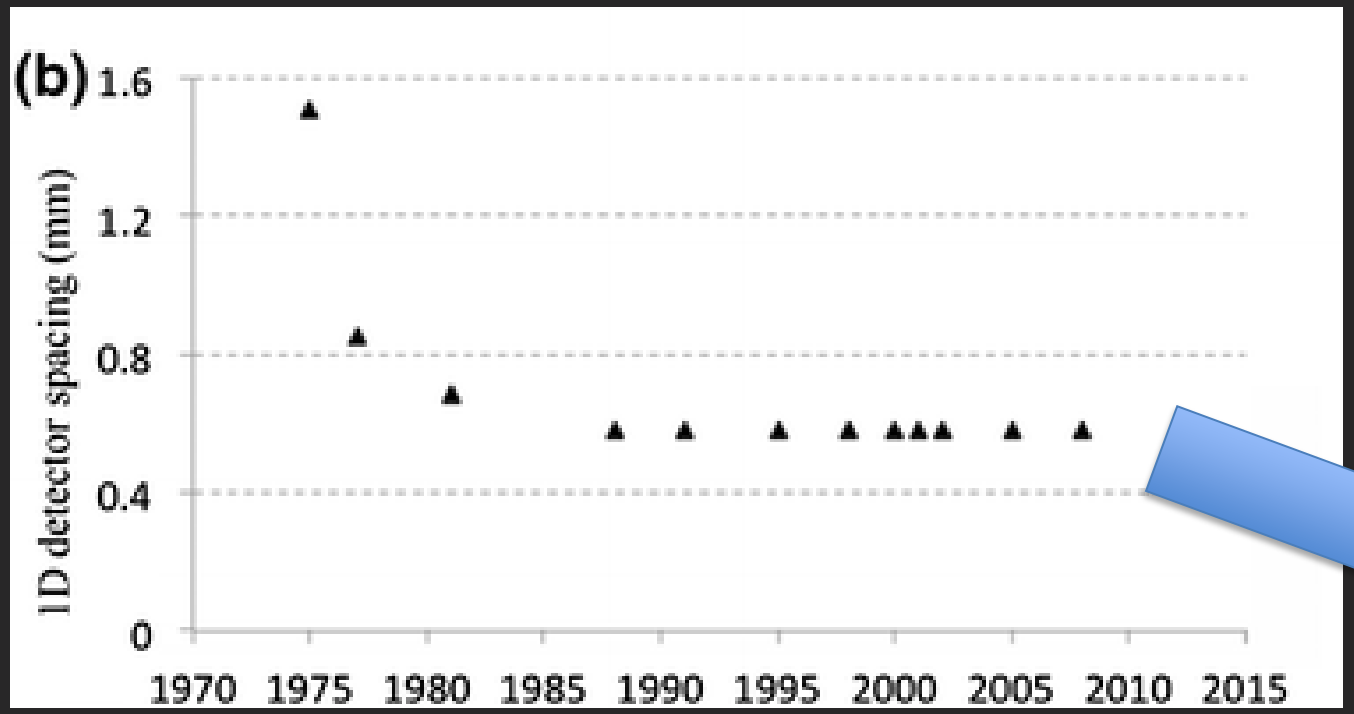
I think as a community, we are learning when spectral makes sense and what spectral image type adds value. And more importantly, limiting our “sending so many series to PACS that people think they are reading an MR”

EMI's first CT scanner was 3 mm!

Spatial resolution surrogate



Pressurized Xenon gas

Solid state

Photon Counting

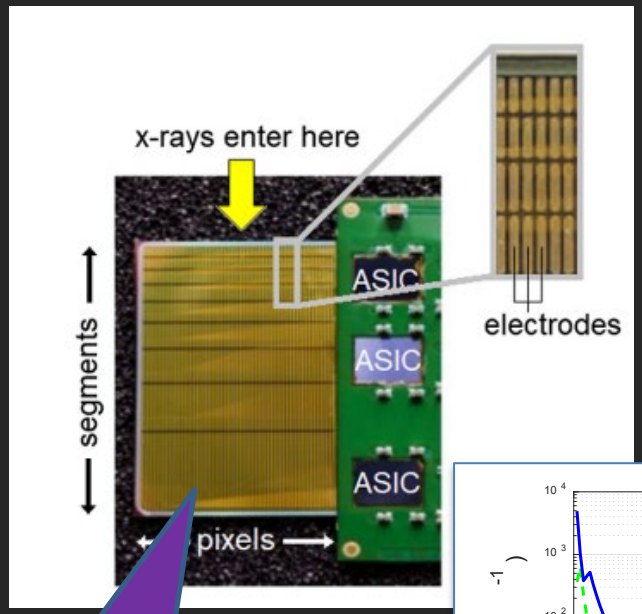
Pelc, N. J. (2014). Recent and future directions in CT imaging. *Annals of biomedical engineering*, *42*(2), 260-268.

A comparison between detector materials

14
Si
28.09

Silicon photon-counting detector for full-field CT using an ASIC with adjustable shaping time

Christel Sundberg,[a,*] Mats Persson,[a] Martin Sjölin,[a] J. Jacob Wikner,[b] and Mats Danielsson[a]
[a]KTH Royal Institute of Technology, Physics of Medical Imaging, Stockholm, Sweden
[b]Linköping University, Department of Electrical Engineering, Linköping, Sweden



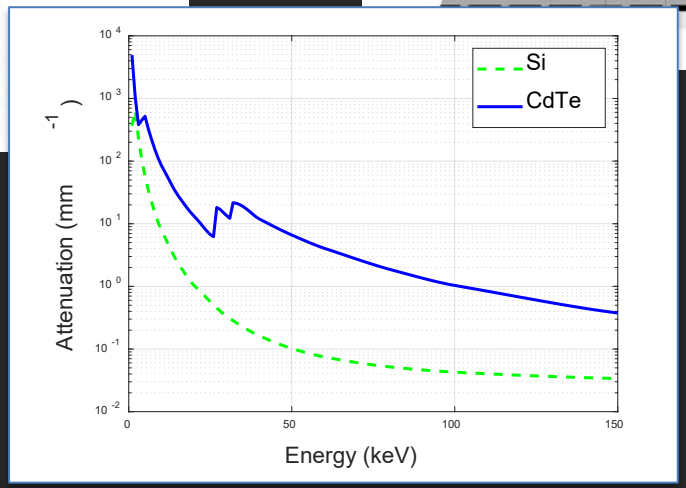
~ centimeters thick

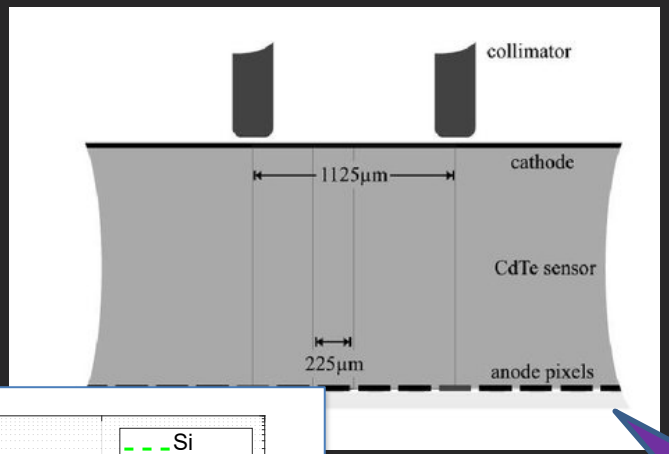
19 March 2014

Photon counting CT at elevated X-ray tube currents: contrast stability, image noise and multi-energy performance

S. Kappler, A. Henning, B. Kreisler, F. Schoeck, K. Stierstorfer, T. Flohr
Author Affiliations +

Proceedings Volume 9033, Medical Imaging 2014: Physics of Medical Imaging; 90331C (2014)
https://doi.org/10.1117/12.2043511
Event: SPIE Medical Imaging, 2014, San Diego, California, United States

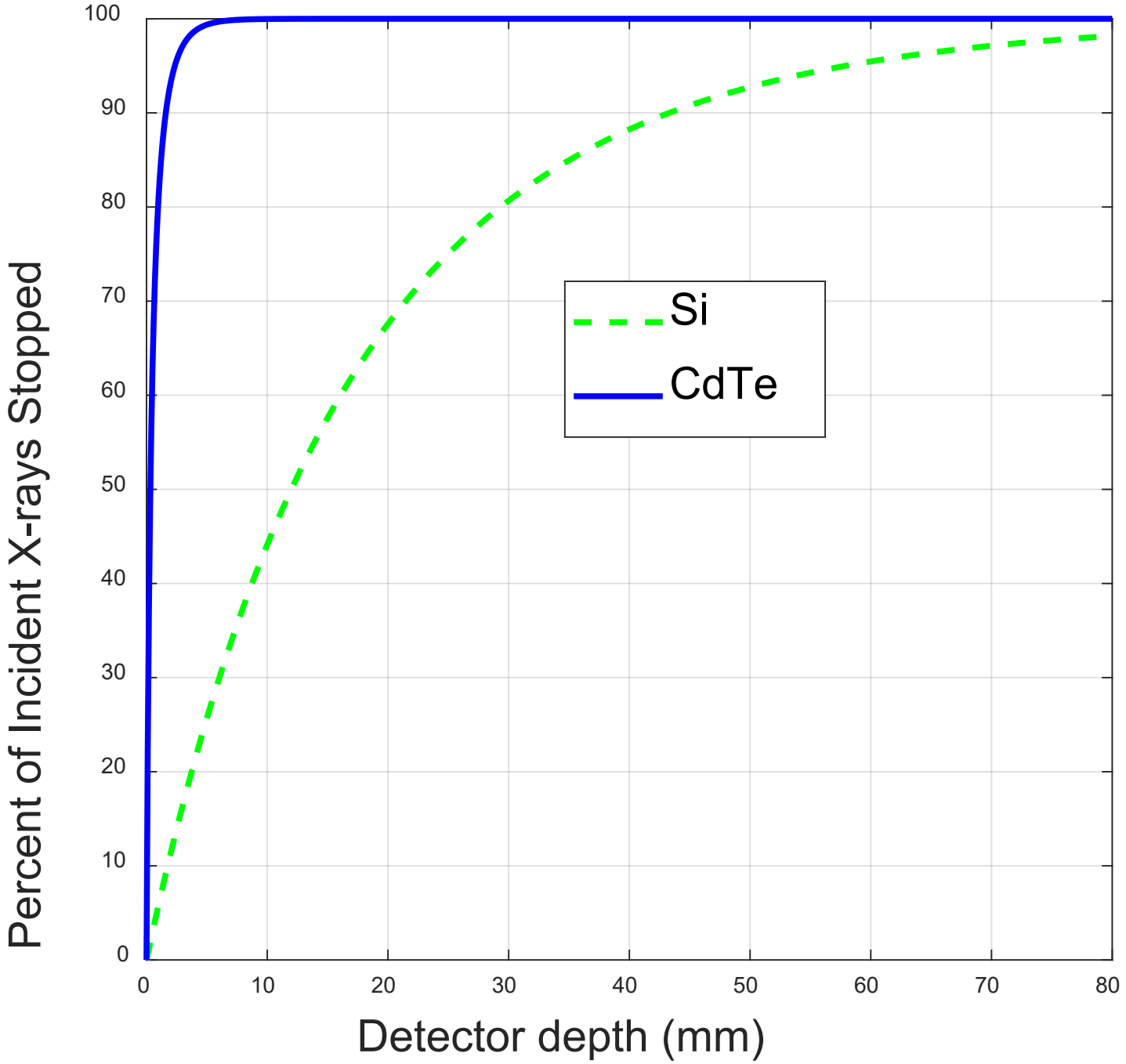


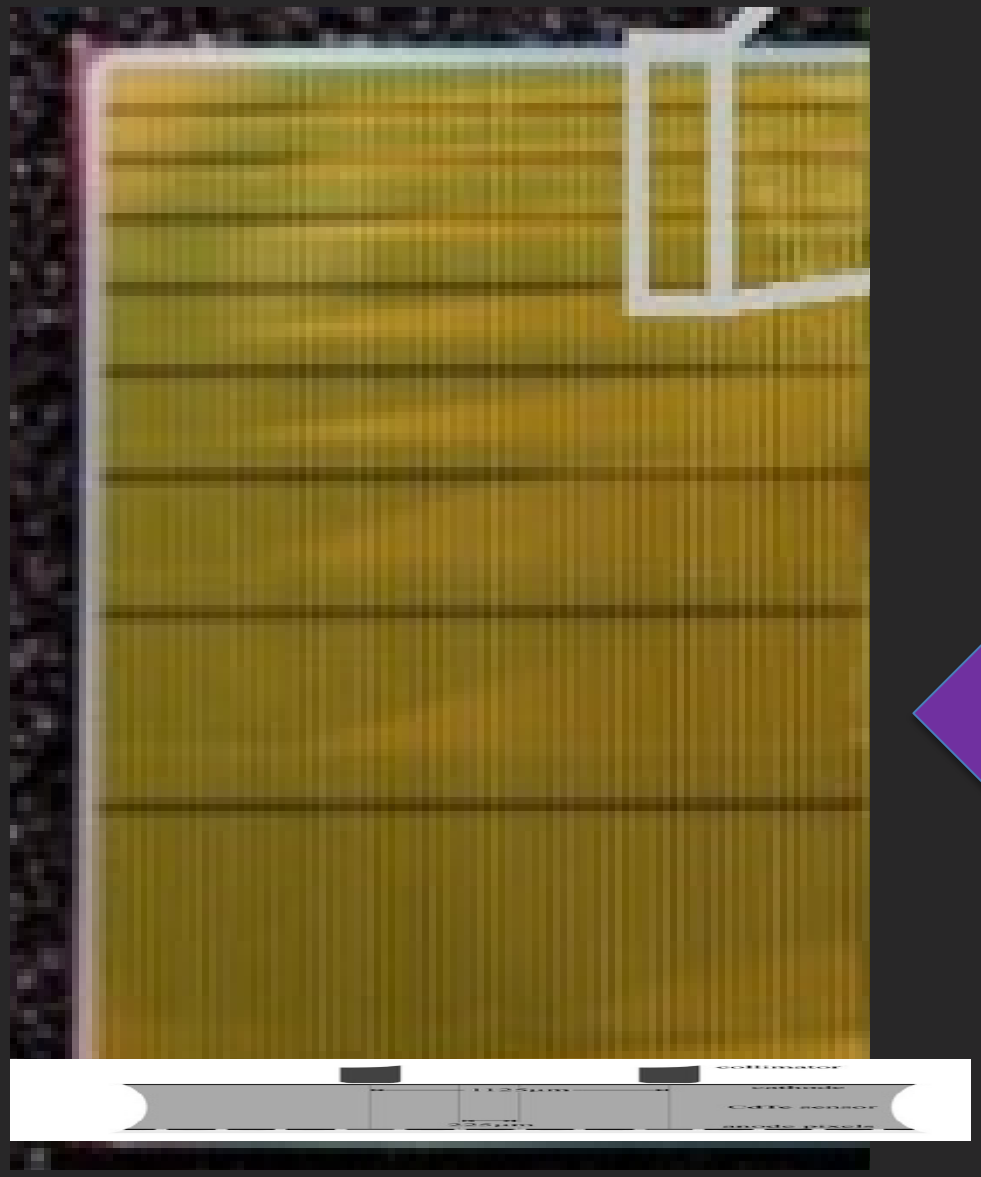


~ 1-2 mm thick

48
Cd
112.41

52
Te
127.60

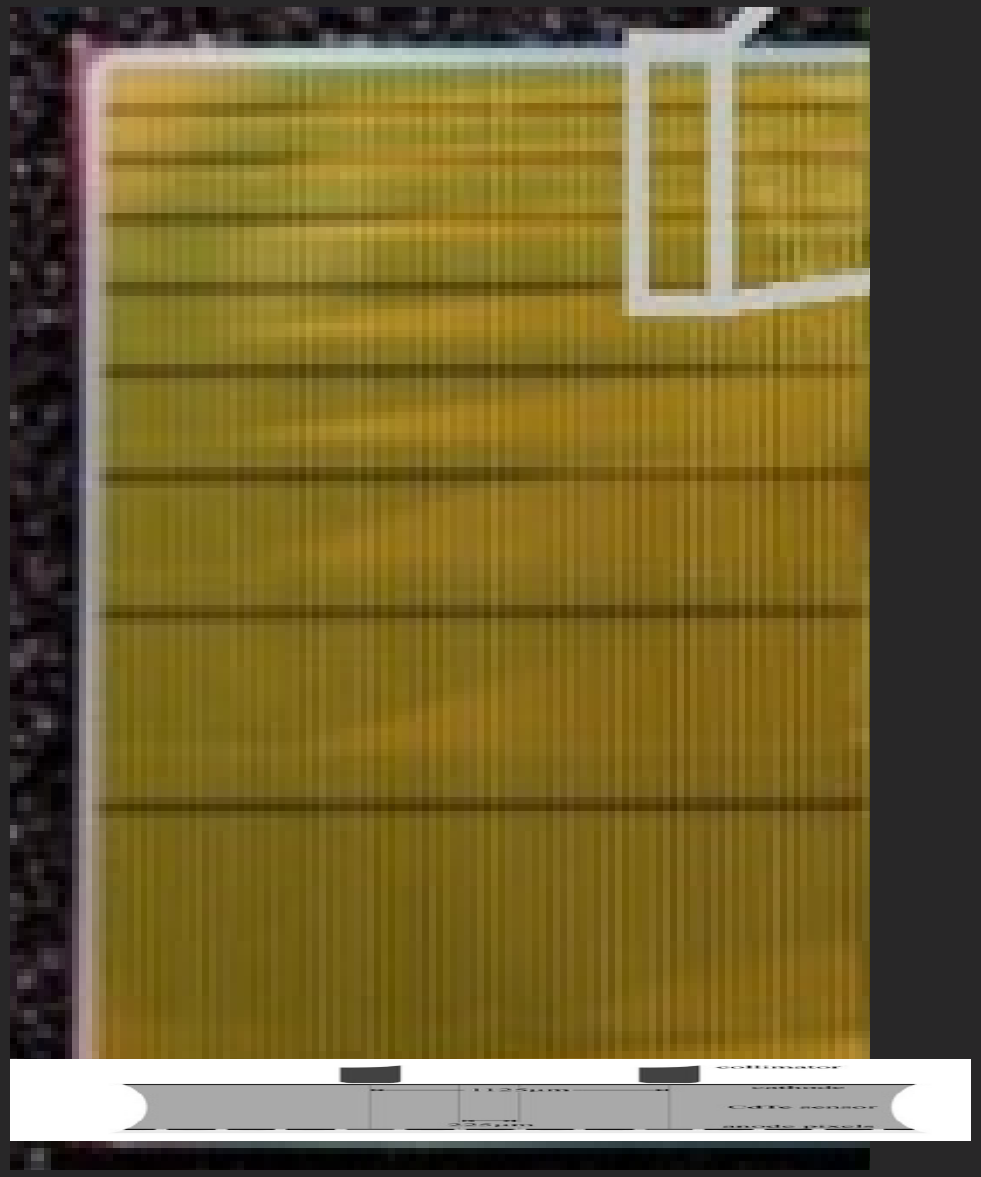

Percent of Incident X-rays Stopped
Detector depth (mm)
Si
CdTe
0
10
20
30
40
50
60
70
80
90
100



Deep Silicon to cadmium based is a factor of ~26x difference in thickness

Deep Silicon multiple cm

Cadmium ~1.6 mm



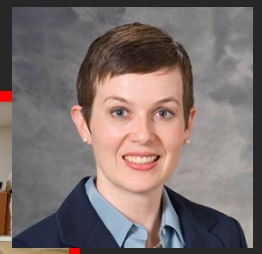
It is like 1.3x lengths of an iPhone height to thickness



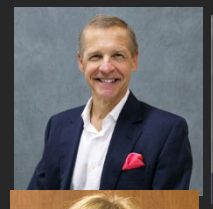




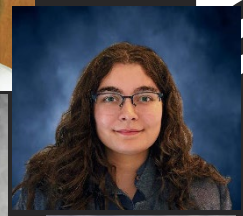
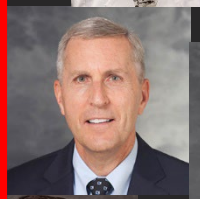
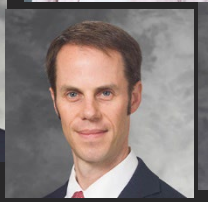
Human subject IRB protocol and UW-GE Research agreement in place

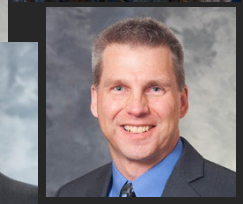






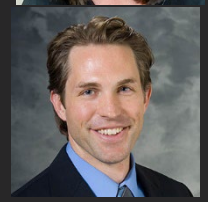


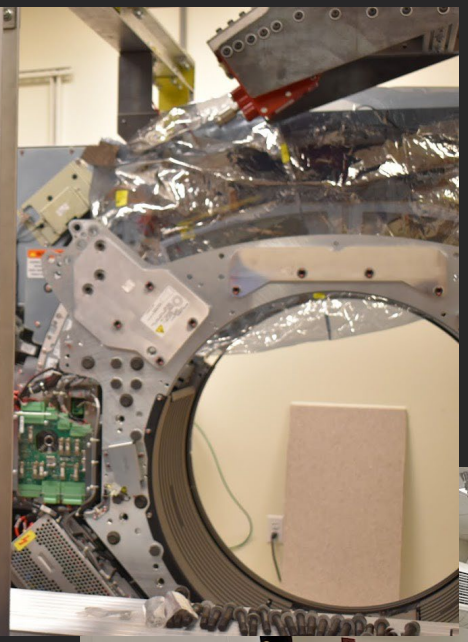


UW is the first site in the USA to perform human subject scanning on a Deep Silicon based Photon counting scanner.

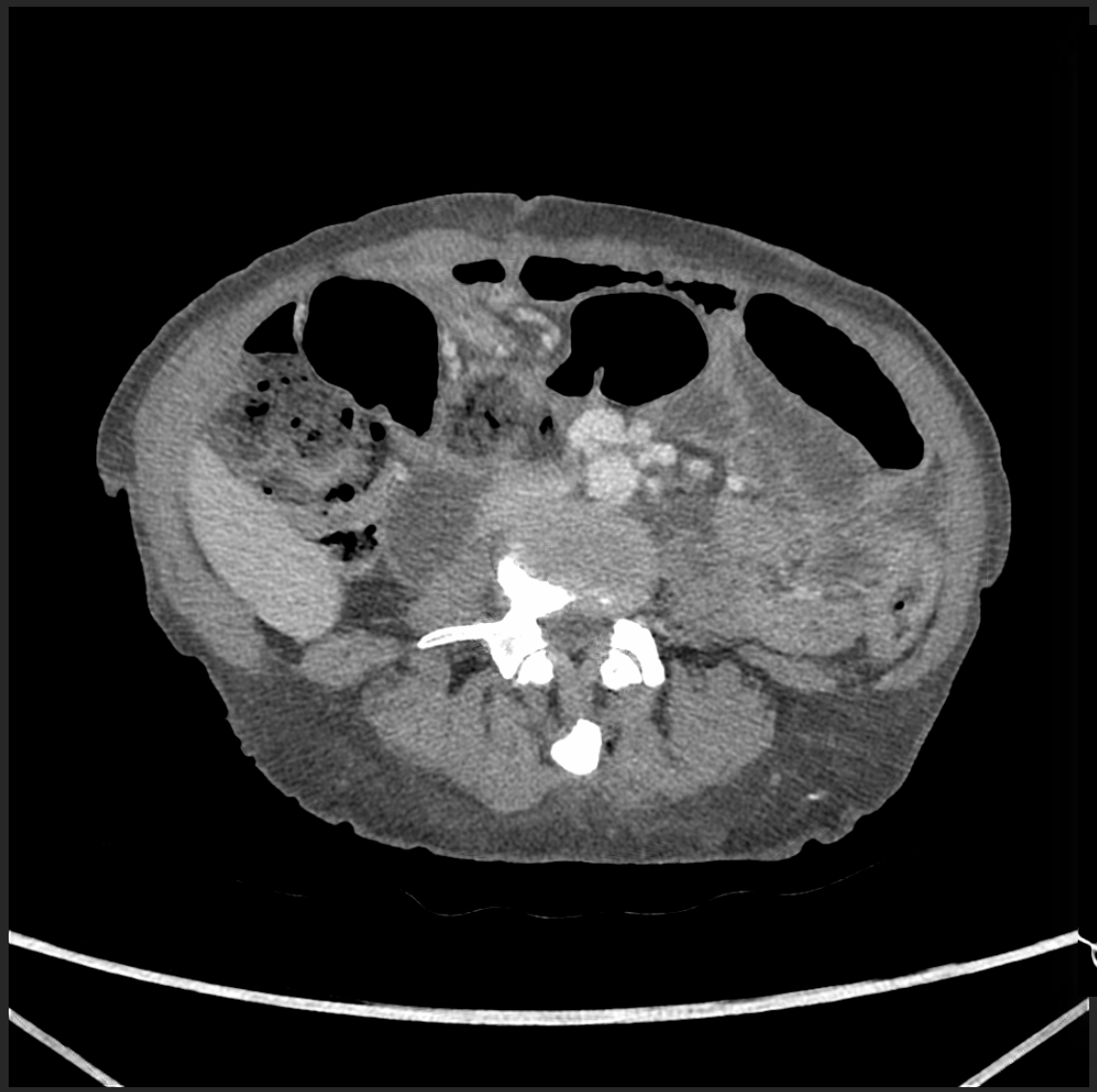
- 40 mm Deep Silicon detector coverage
- Scan modes: axial, helical, bolus tracking, scout, cardiac, cine
- 0.28 second rotation

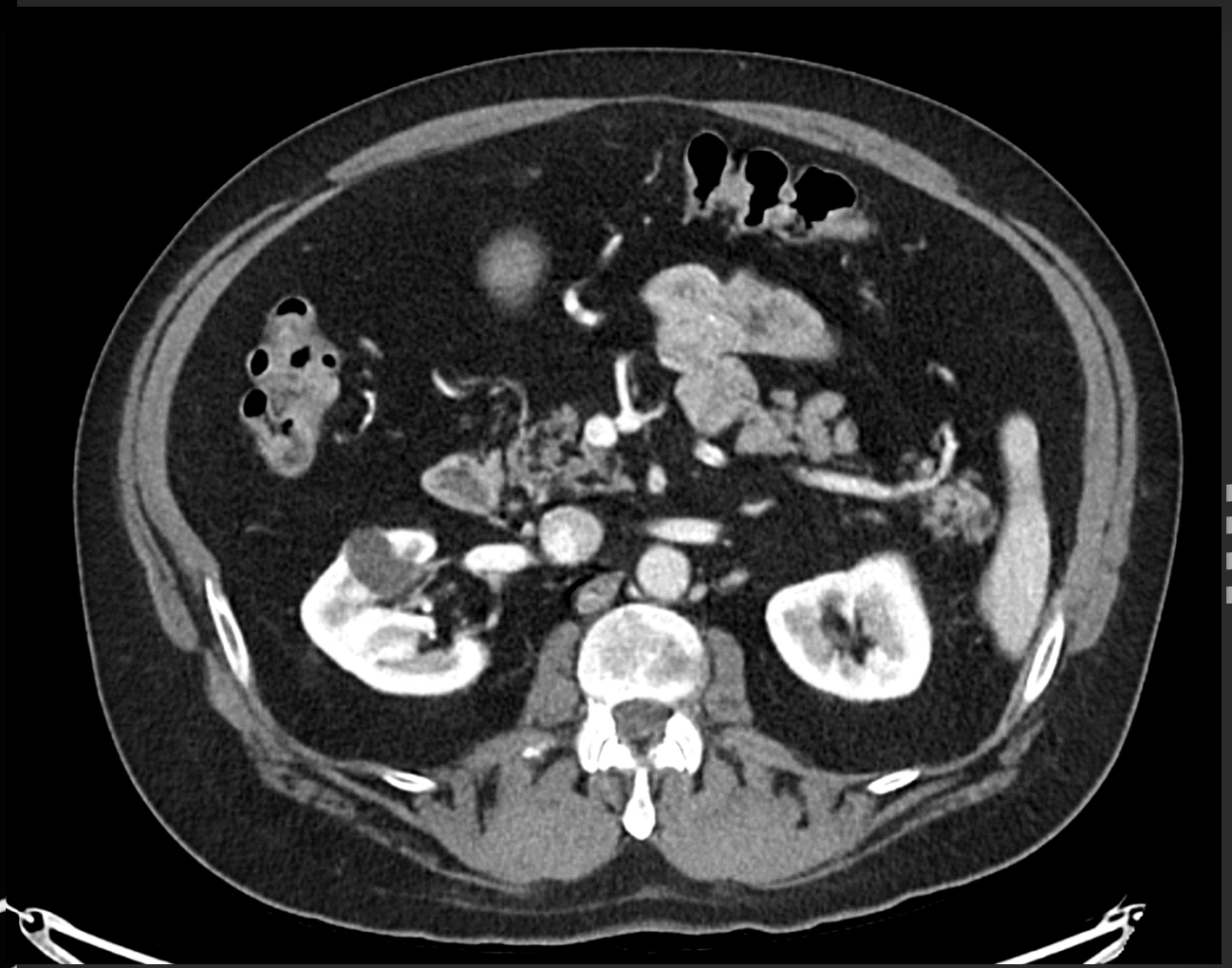




First human subject Generation 3 Deep Silicon Images were acquired the week before RSNA 2022 at University of Wisconsin Madison!



The prototype at UW just got upgraded, new and wider detector, new calibration process, new data corrections, new reconstruction algorithms!
(spring 2025)





All at 70 keV
Left was fall 2022, Right is spring 2024