

Photon Counting CT

Technical Benefits



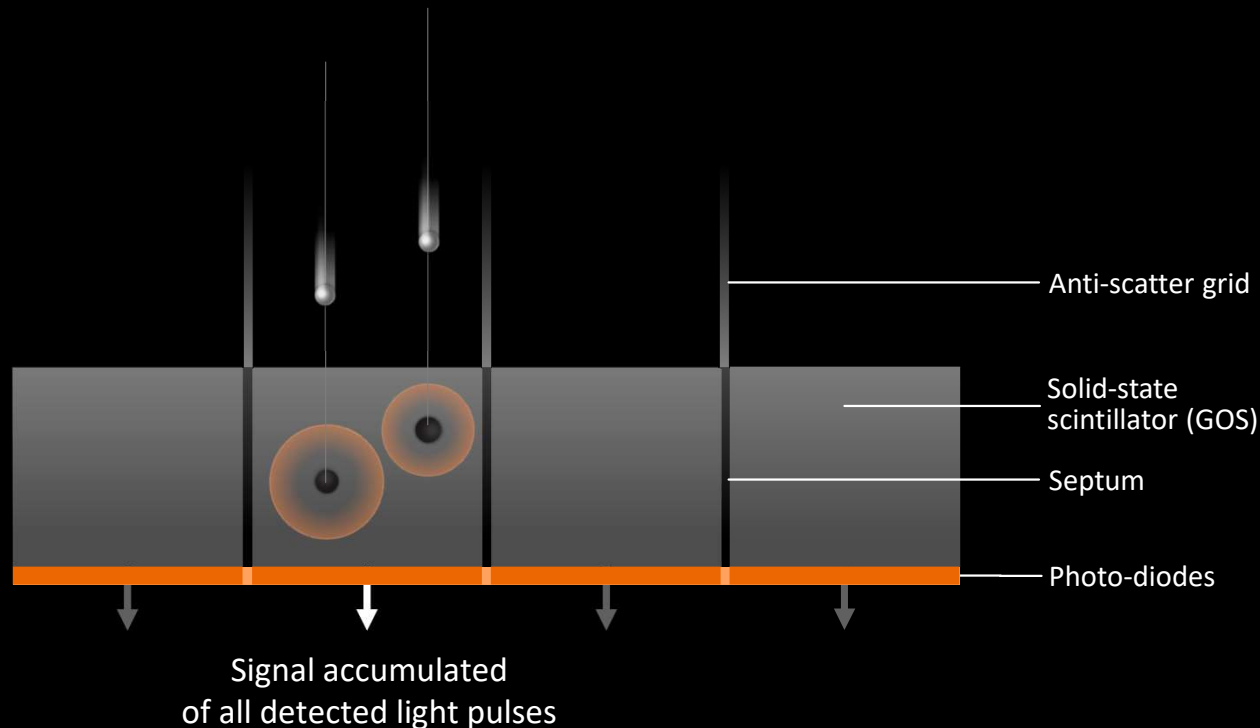
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Operation Principle – CT Detectors

Conventional Energy Integrating (EID)



Two-step conversion: X-rays → light → current

• Scintillator

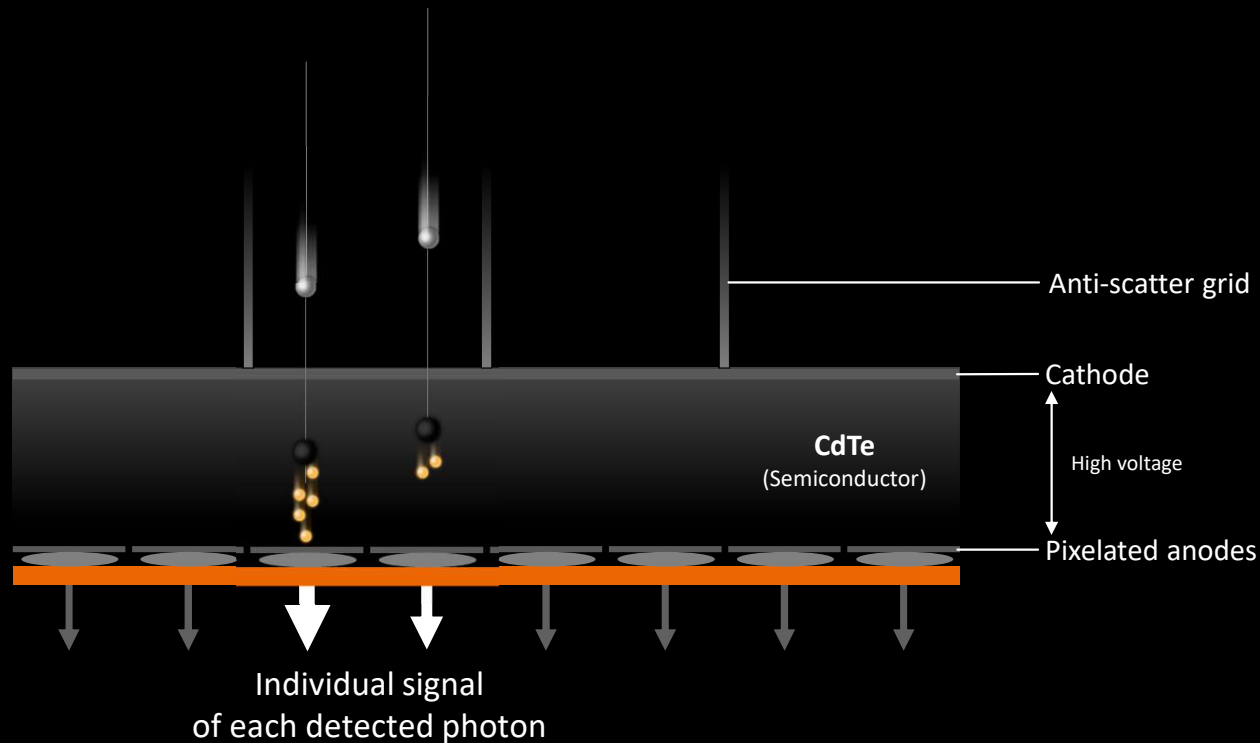
as indirect X-ray converter (GOS)

- Impacts produces **scintillation-light** proportional to X-ray energy
- Light is collected by photo-diodes and converted into electrical current
- Photo-current is integrated during the measurement time of one view (projection)
- Energy information is lost as the signals are combined in each projection

→ **Energy-weighted cumulated signal**

Operation Principle – CT Detectors

Photon-counting (PCD)



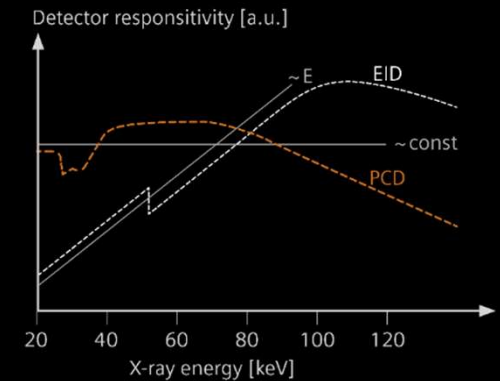
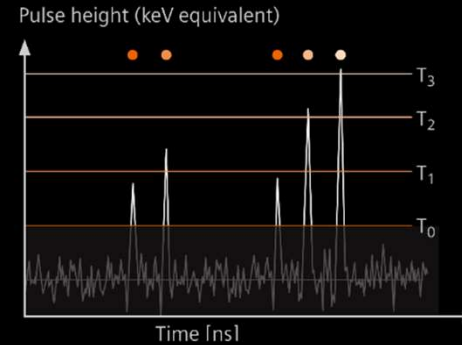
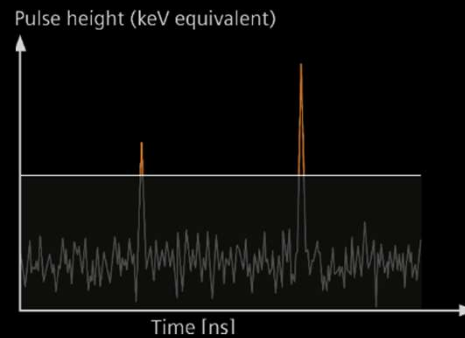
Single-step direct conversion: X-rays → current

- **Semiconductor**

- as direct X-ray converter (CdTe)

- Impacts produce a **charge** proportional to X-ray energy
- Individual impacts are measured allowing for measurement of energy information
- **Energy-selective counter signal**
- **Threshold-based counting of individual pulses**

PCD Technological Advantages



Smaller detector pixels

- 'large' pixel of 0.4 x 0.4 mm can be subdivided down to 0.2 x 0.2 mm. In-plane resolution of 44.3 lp/cm



Elimination of electronic noise

Threshold applied digitally to the pulse height. Baseline electronic noise can be removed from detection process



Intrinsic spectral sensitivity

- Pulses sorted in 1 or 4 energy bins according to pulse height. Detector always acquires a spectrally resolved signal regardless of scan speed or temporal resolution



Equal energy contribution

- Detector response is consistent over energy. PCCT weights photons equally, leading to enhanced iodine signal

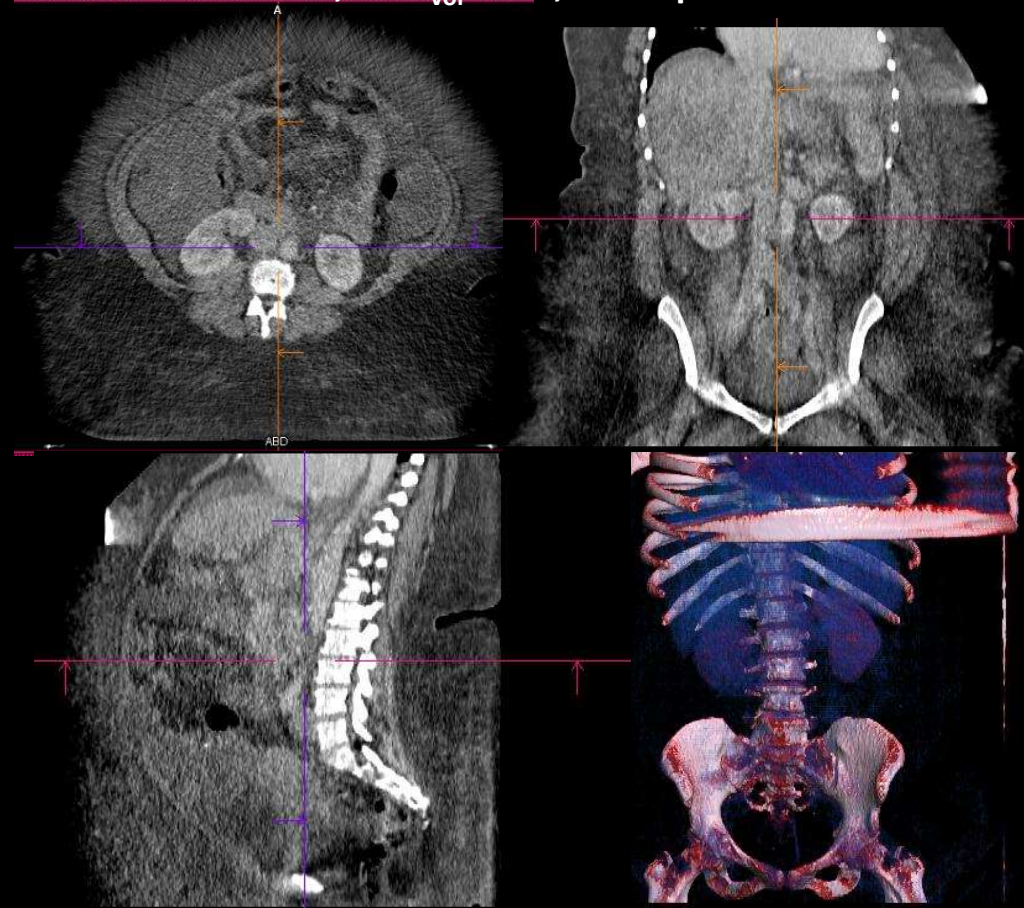
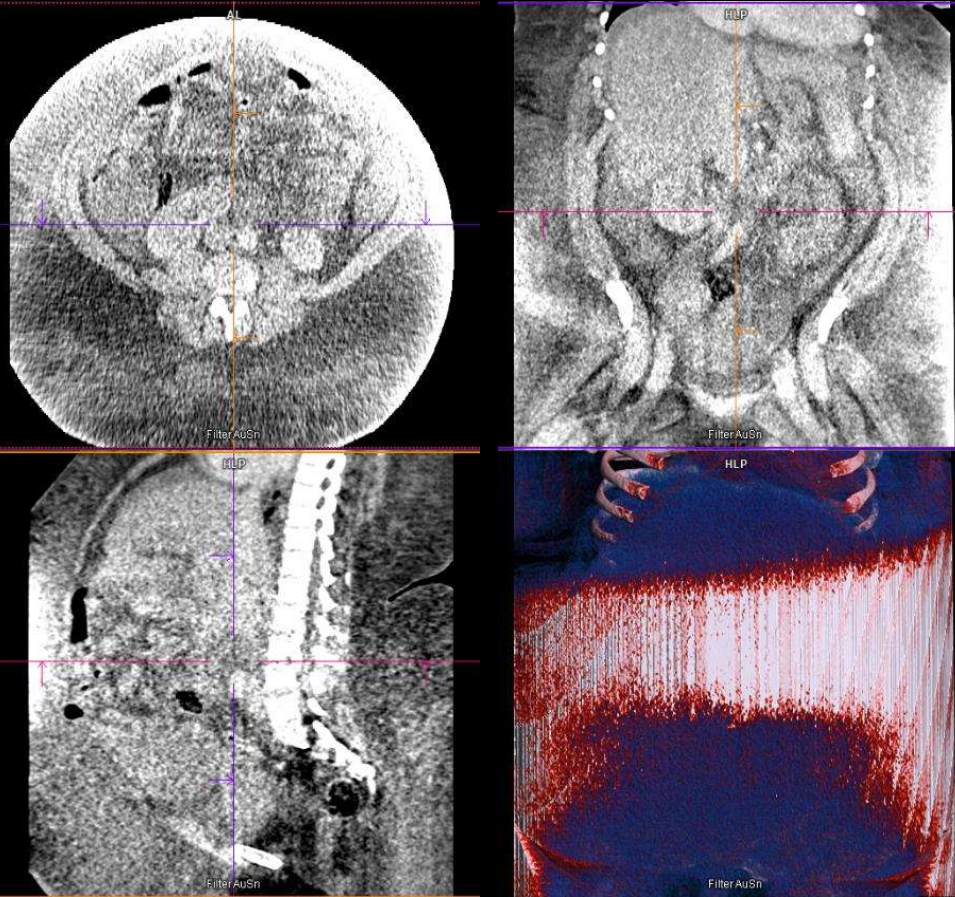
PCD Technological advantages (1/4)

No electronics noise

Case study comparing large patient (410 lbs, BMI=63) scanned over a period of 3 months (Ovarian mass)

SOMATOM go.Top, CTDI_{vol}: 23.98, AuSn140

SOMATOM FORCE, CTDI_{vol}: 31.7, 120kVp



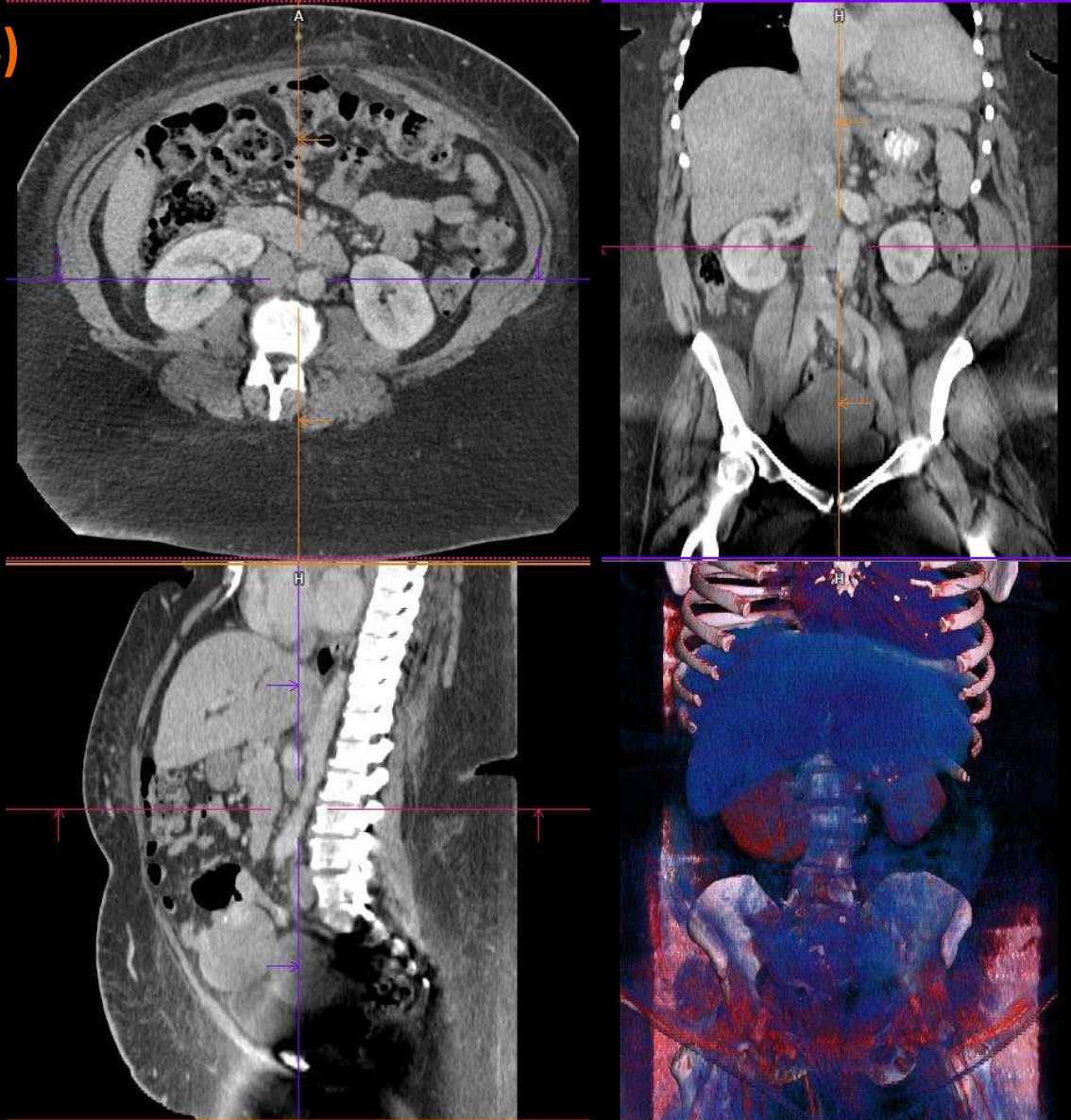
PCD Technological advantages (1/4)

No electronics noise

NAEOTOM Alpha

CTDI_{vol}: 37.20

140 kV Q+

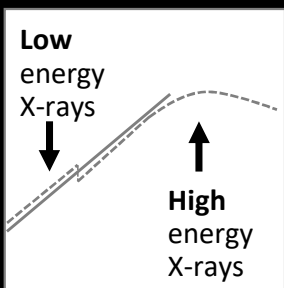


Courtesy of MUSC, Charleston, South Carolina

PCD Technological advantages 2/4

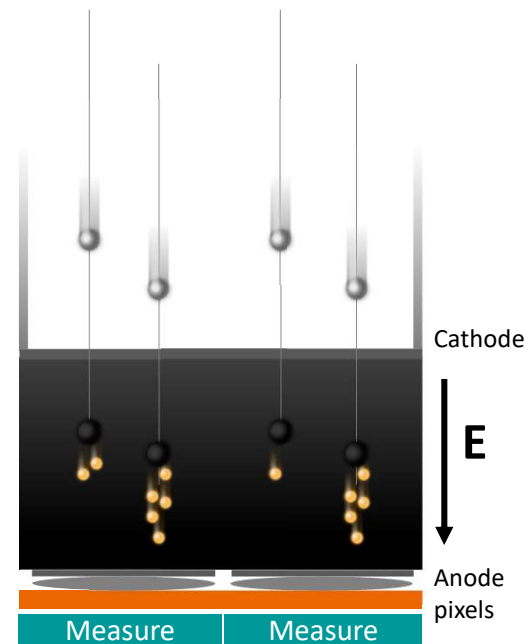
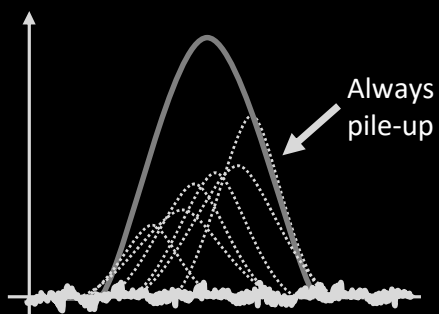
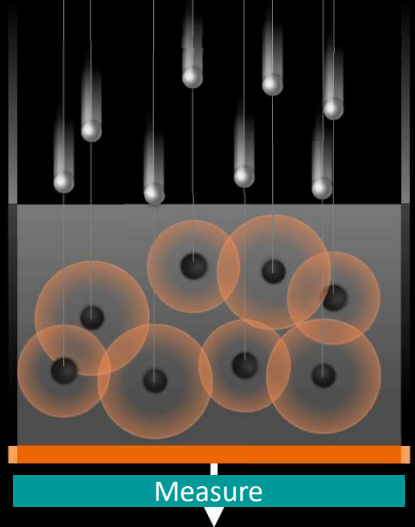
Equal contribution

Energy Integrating

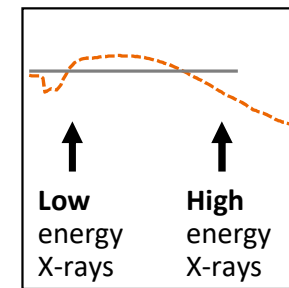


- Down-weighting of low energy X-rays reduces CNR
- Low kV required to boost Iodine signal

→ Time for a signal measurement ~250 μ s

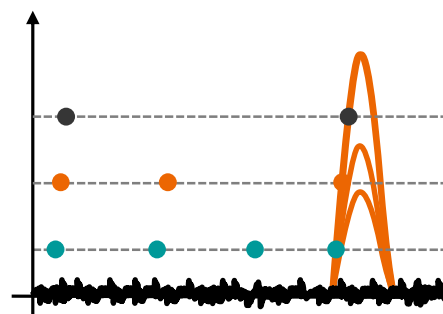


Photon-counting



- No down-weighting of low energy X-rays
- Use the full spectrum of X-ray information on equal level

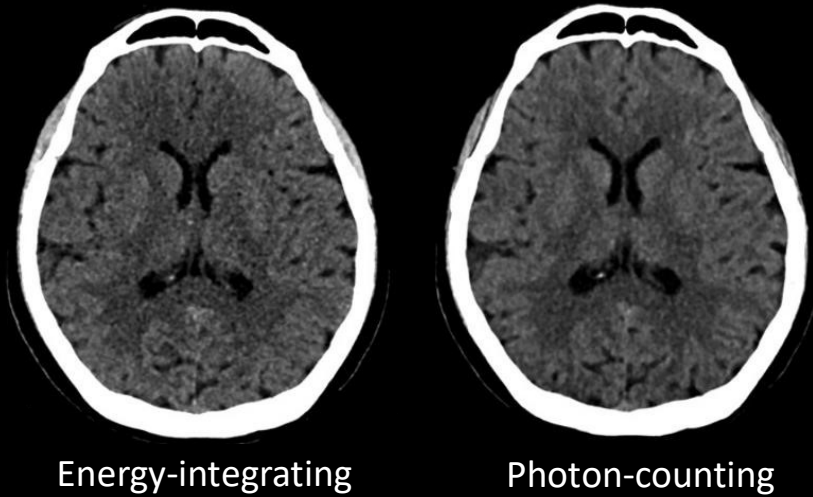
→ Time for a signal measurement ~15 ns



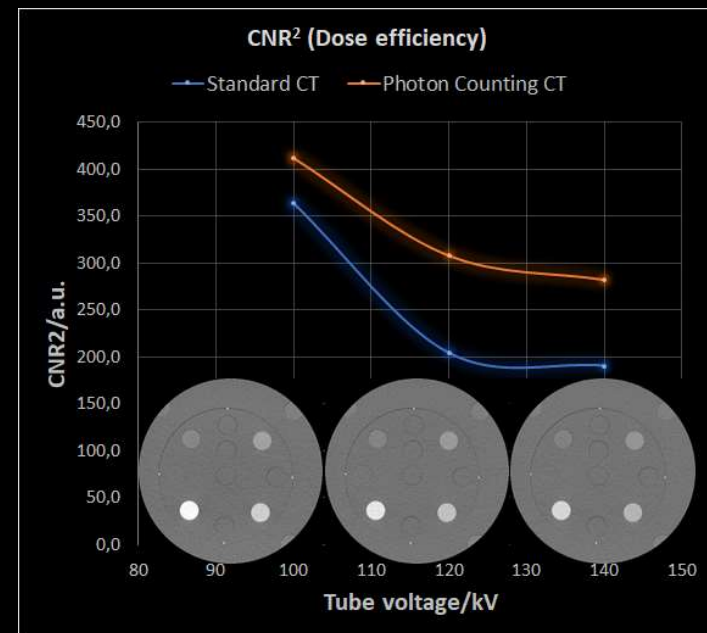
PCD Technological advantages 2/4

Equal contribution

(Slightly) increased tissue contrasts



Higher iodine CNR



- Improved iodine CNR, in particular at high kVp (120/140 kVp)
- **Potential for 10 – 35% less radiation dose or less contrast agent**
- Less change of CNR with kVp than with integrating detector

References: A. Pourmorteza et al, Photon-Counting CT of the Brain: In Vivo Human Results and Image-Quality Assessment, AJNR 38:2257–63, 2017
Internal measurements

PCD Technological advantages (3/4)

Increased spatial resolution

Conventional CT

- Optically opaque separation layers between individual detector elements to avoid optical cross-talk
 → (much) smaller detectors are not dose-efficient

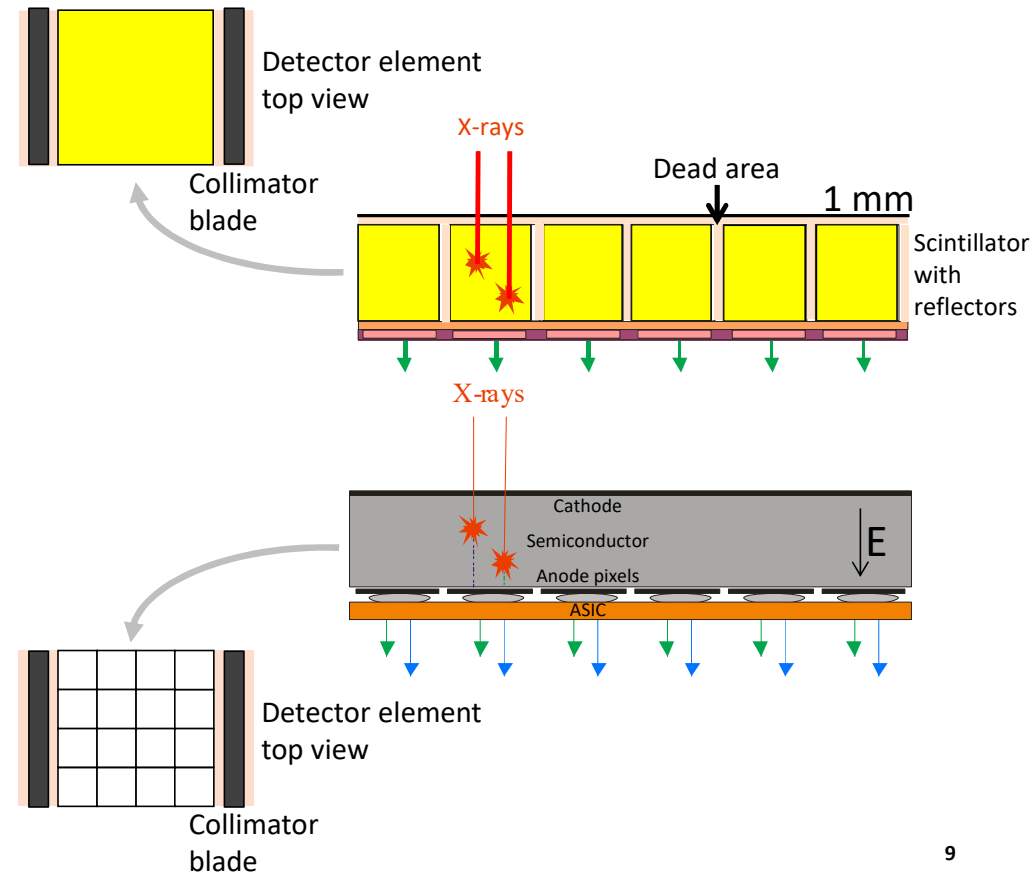
Photon Counting CT

No dead areas caused by optical reflectors – detector pixels are defined by the strong electric field between cathode and anode pixels

- Allows for sub-division of detector elements

Enables very high spatial resolution

- Standard energy integrating detector: size $\sim 1 \text{ mm}^2 \rightarrow 18 - 20 \text{ lp/cm}$
- Photon counting detector: depending on pixel size up to 40 lp/cm

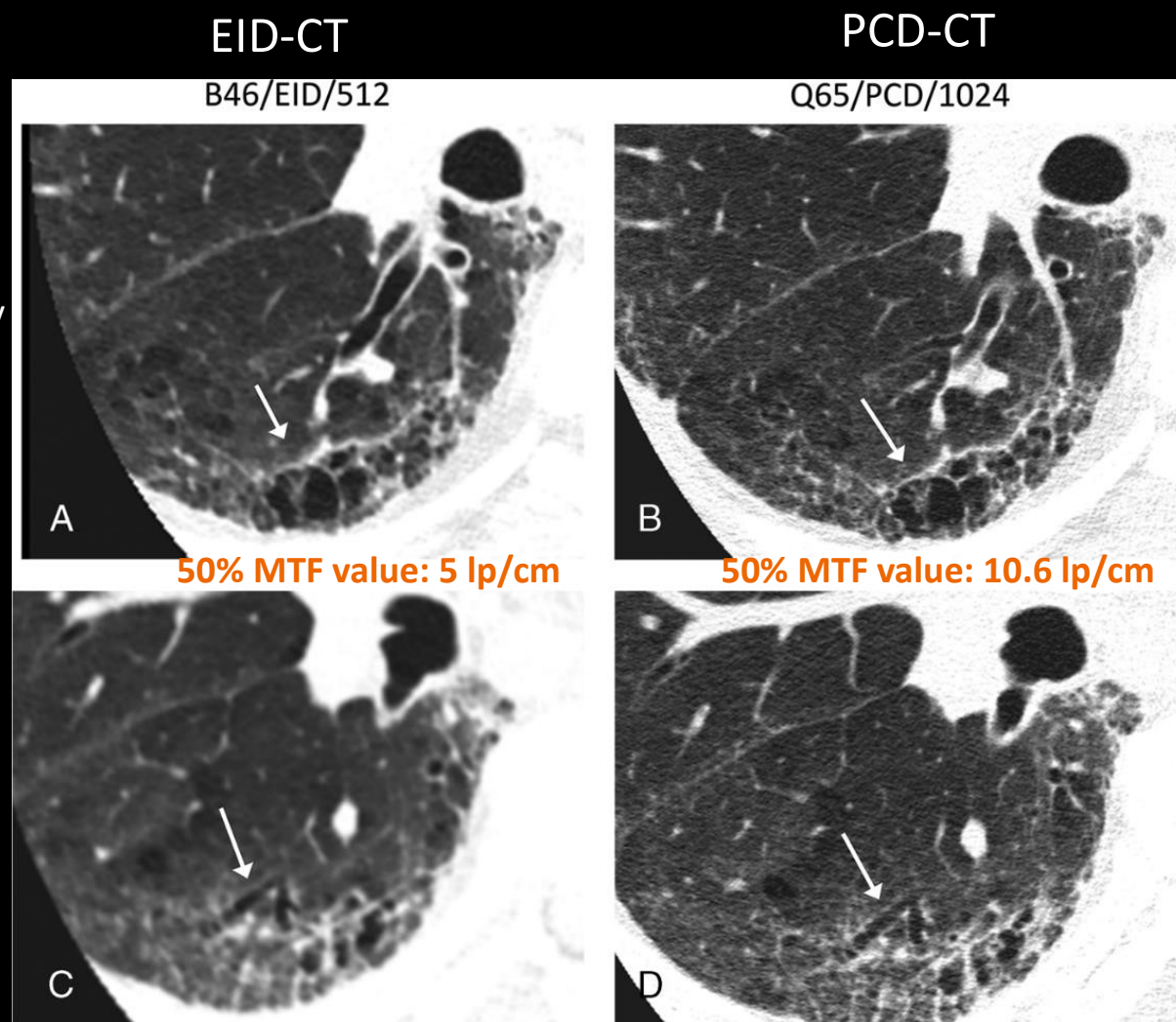


PCD Technological advantages (3/4)

Increased spatial resolution

Bartlett DJ et al, High-Resolution Chest Computed Tomography Imaging of the Lungs Impact of 1024 Matrix Reconstruction and Photon-Counting Detector Computed Tomography Invest Radiol. 2019 Mar;54(3):129-137

“High-resolution lung PCD-CT with 1024 image matrix reconstruction increased radiologists’ ability to visualize higher-order bronchi and bronchial walls without compromising nodule evaluation compared with current chest CT”



PCD Technological advantages (3/4)

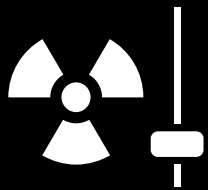
Increased spatial resolution

74-year-old male clinically diagnosed with ILD consistent with idiopathic non-specific interstitial pneumonia

SOMATOM Definition Flash (EID-CT)



NAEOTOM Alpha (PCD-CT)



**Dose
Matched
Comparison**

- ✓ Reticulation
- ✓ GGO

- ✓ Reticulation
- ✗ GGO

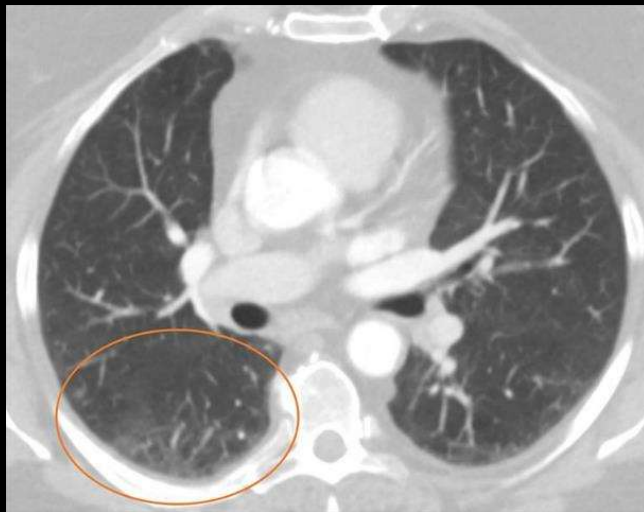
The confidence of reticulation was increased in 2 readers on PCD-CT.

PCD Technological advantages (3/4)

Increased spatial resolution

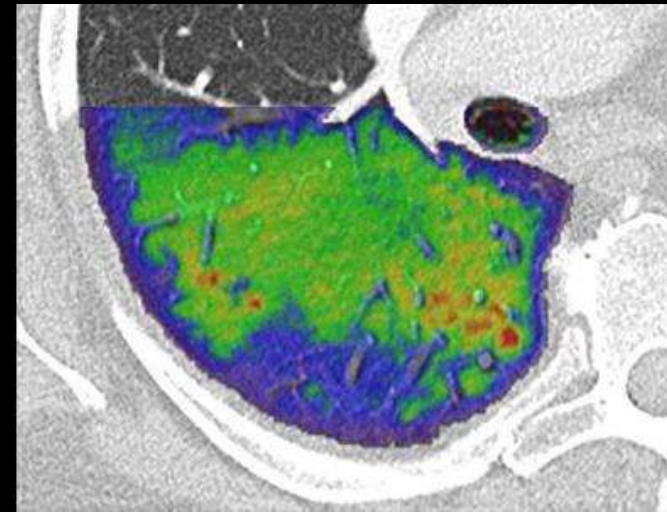
Lung images of a post-COVID patient with photon-counting CT

Conventional Energy Integrating



Standard Resolution

Conventional Energy Integrating



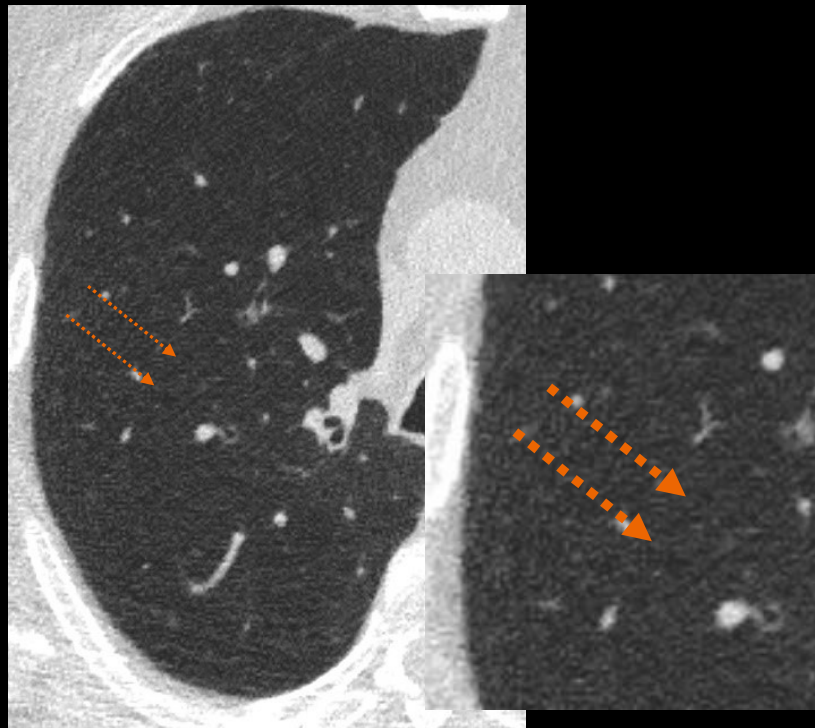
High-Resolution Standard Resolution Information

Photon-counting technology allows for simultaneous acquisition and visualization of **detailed structures** (center image) combined with **functional information** (image on the right).

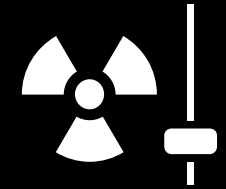
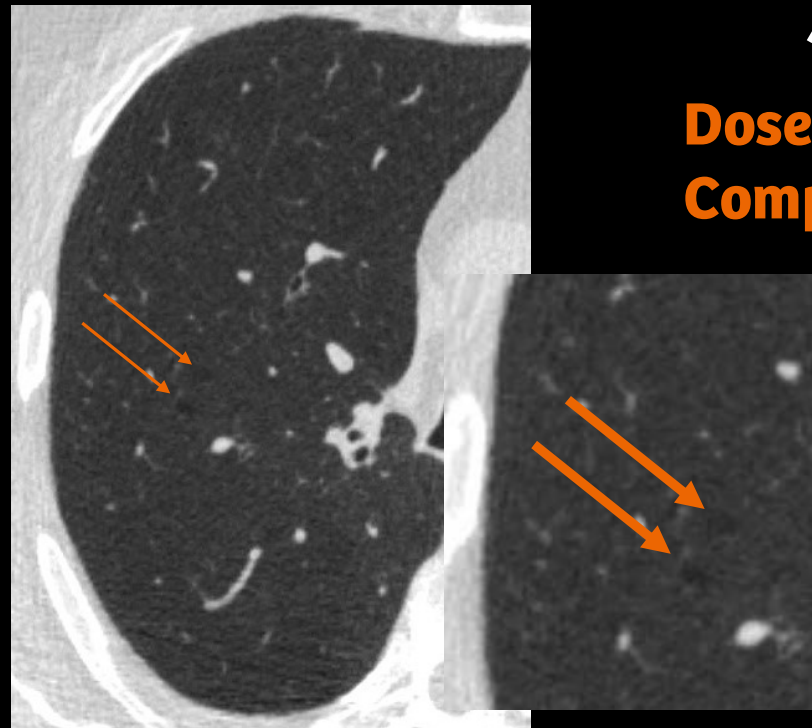
Centrilobular emphysema only seen on PCD

Comparison with matched $CTDI_{vol}$

Conventional CT (EID-CT)

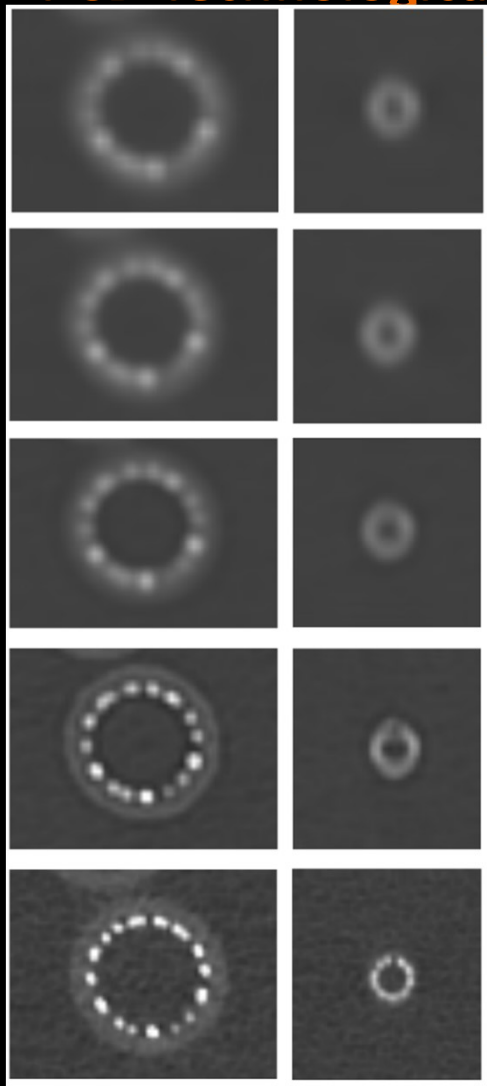


NAEOTOM Alpha (PCD-CT)



**Dose Matched
Comparison**

PCD Technological advantages (3/4)



Resolution
Qr40_c(0.6mm)

Qr40_c(0.4mm)

Bv44_m(0.4mm)

Bv60_m(0.4mm)

Qr72_c(0.2mm)



EID



PCD

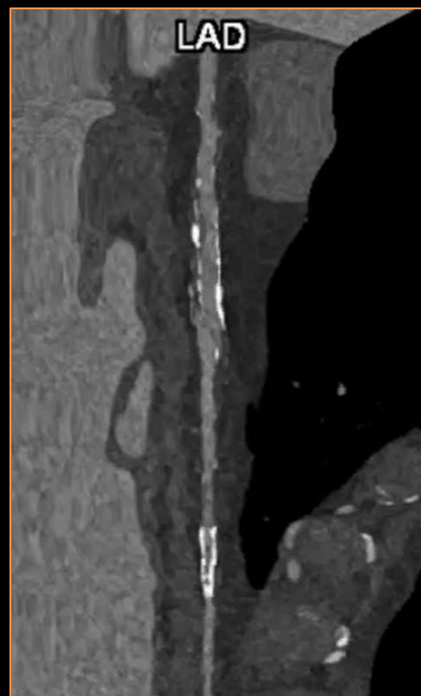
Decker & O' Doherty, European Radiology, In Press, Oct 2022

PCD Technological advantages (3/4)

Increased spatial resolution



Standard Resolution



Ultra-High Resolution

1024 x 1024 matrix

\sim v72, QIR 4, 0.2 mm slice thickness



Stents with intima hyperplasia



Stress testing: no ischemia

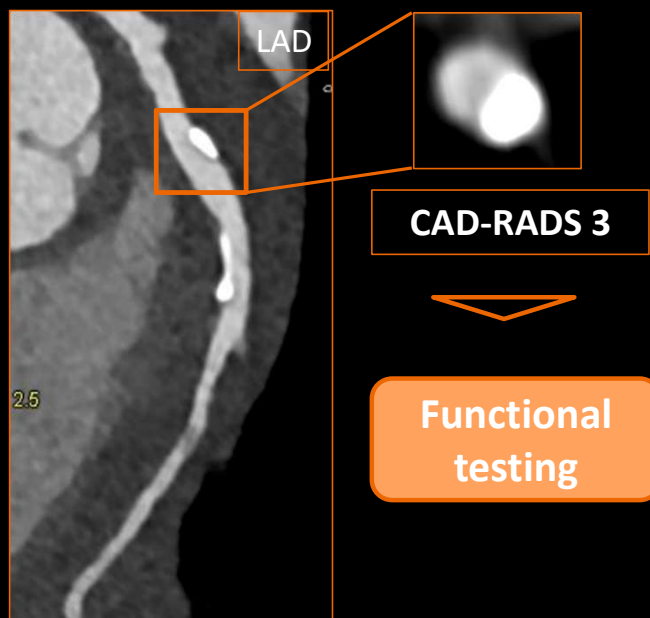


Follow-Up in one year

PCD Technological advantages (3/4)

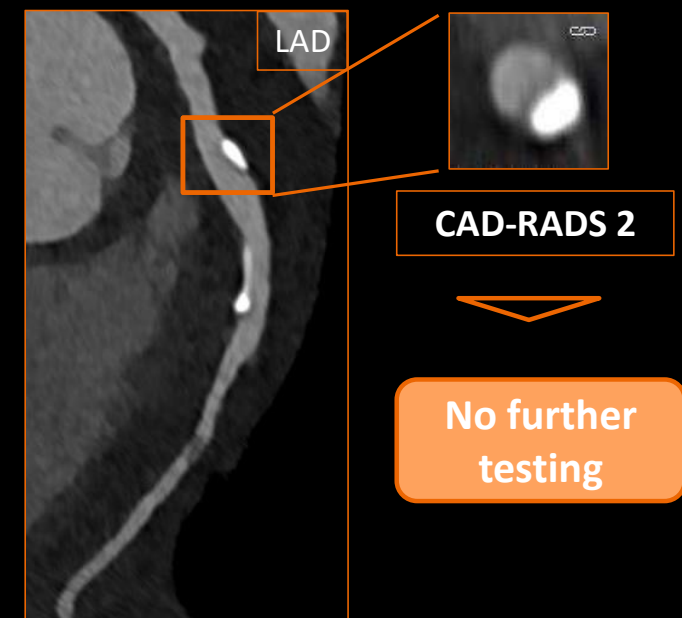
Increased spatial resolution

EID



Bv44, QIR 3
Slice thickness 0.6 mm

PCCT



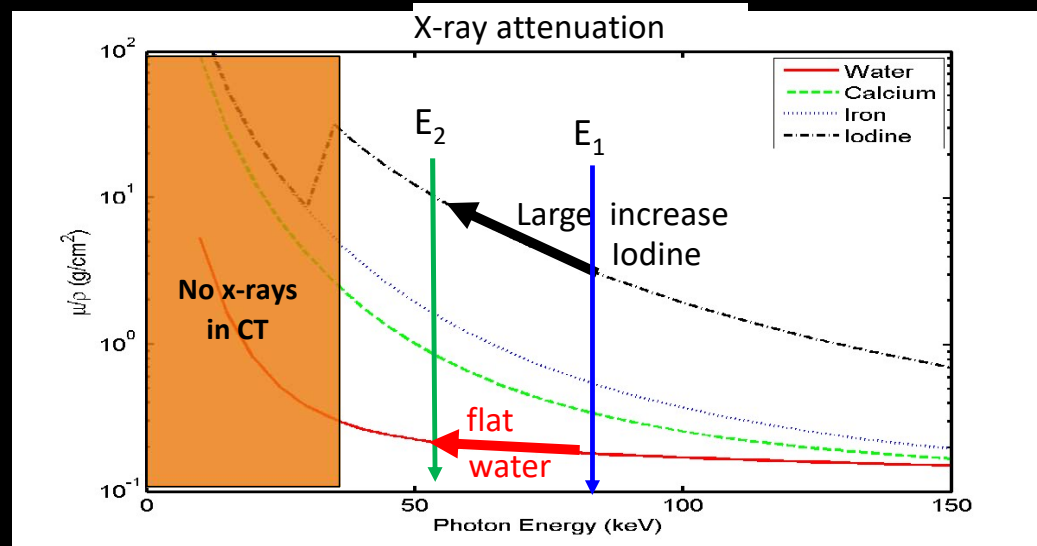
Bv44, QIR 3
Slice thickness 0.2 mm

PCD Technological advantages (4/4)

Intrinsic spectral sensitivity

Principle of spectral CT

- Scan at two energies E_1 and E_2 („dual-energy CT“)
→ *Change* of x-ray absorption characterizes the material



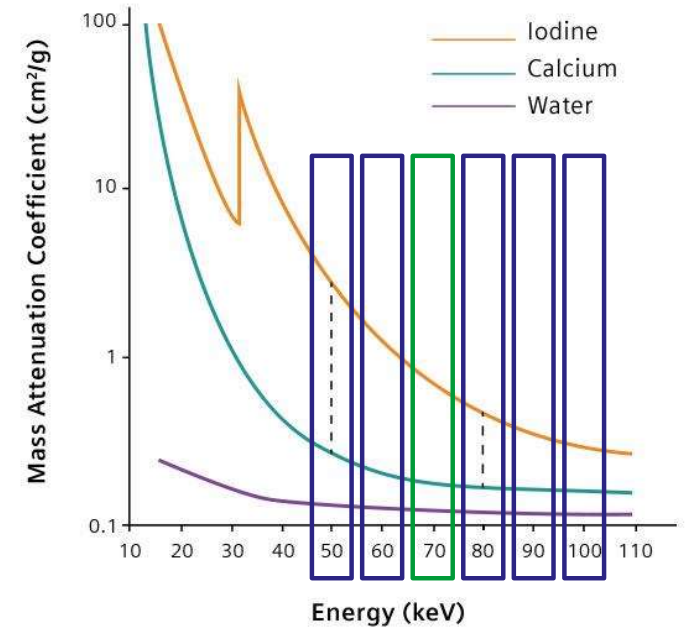
The "standard" Counting Image Result Type Virtual Monoenergetic keV Reconstruction



ME 50 keV

ME 70 keV
(≈ 120 kV)

ME 80 keV



PCD Technological advantages (4/4)

Advanced spectral processing algorithms PureLumen (calcium removal)

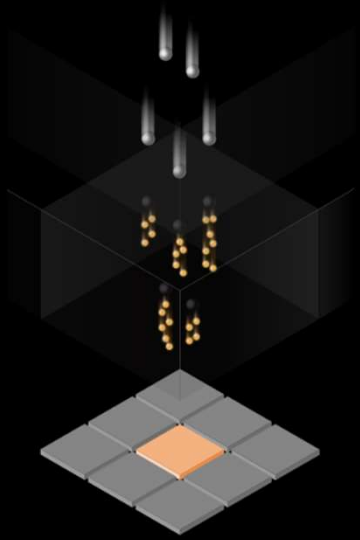
Dedicated recon free of calcifications or blooming, helping better coronary CTA even in patients with a high CaScore



Courtesy of MUSC, Charleston, South Carolina

Frei verwendbar © Siemens Healthcare GmbH, 2017

PCD Technological Advantages (4)

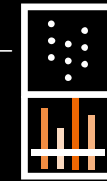
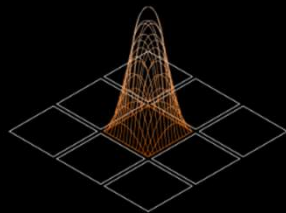


Equal energy contribution
Contrast-rich images

Smaller detector pixels
Higher spatial resolution at the same dose

Intrinsic spectral sensitivity
Multi-spectral information in every scan

Elimination of electronic noise
Lower dose



Quantum Technology



Thank you for
your attention

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