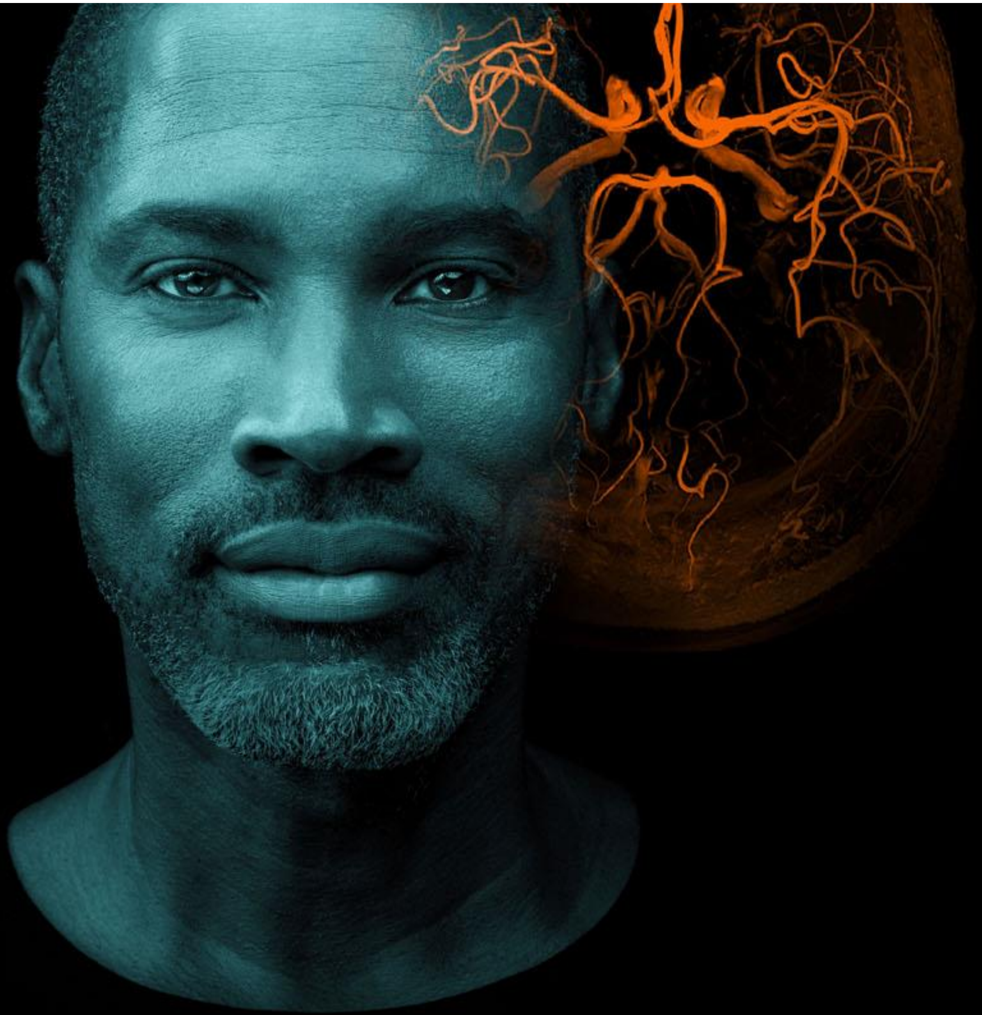
SIEMENS Healthineers

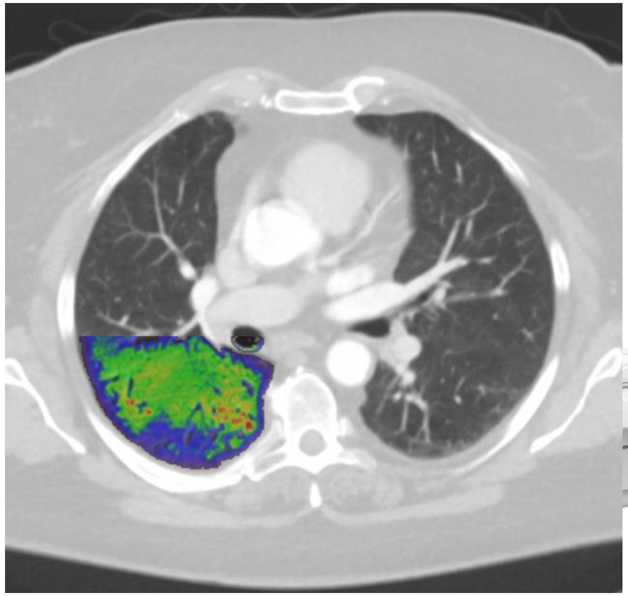
Electronics Integration Challenges in Computed Tomography Scanners

ESTC 2024

Dr. Michael Hosemann
Siemens Healthineers AG



World's 1st Photon-counting Computed Tomography Scanner – NAEOTOM Alpha



- Emergencies
- Heart conditions
- Lung
- Stroke
- Cancer

The products/features (mentioned herein) are not commercially available in all countries. Due to regulatory reasons their future availability cannot be guaranteed. Please contact your local Siemens Healthineers organization for further details.

Photon-counting CT – sharper images for a new level of detail
Pushing the boundaries of what is visible in CT

SOMATOM Force
15.6 mGy

NAEOTOM Alpha
8.14 mGy

Courtesy of Medical University Hospital Würzburg, Germany

Photon-counting CT – sharper images for a new level of detail
Ultra-high resolution may overcome limitations of coronary CTA

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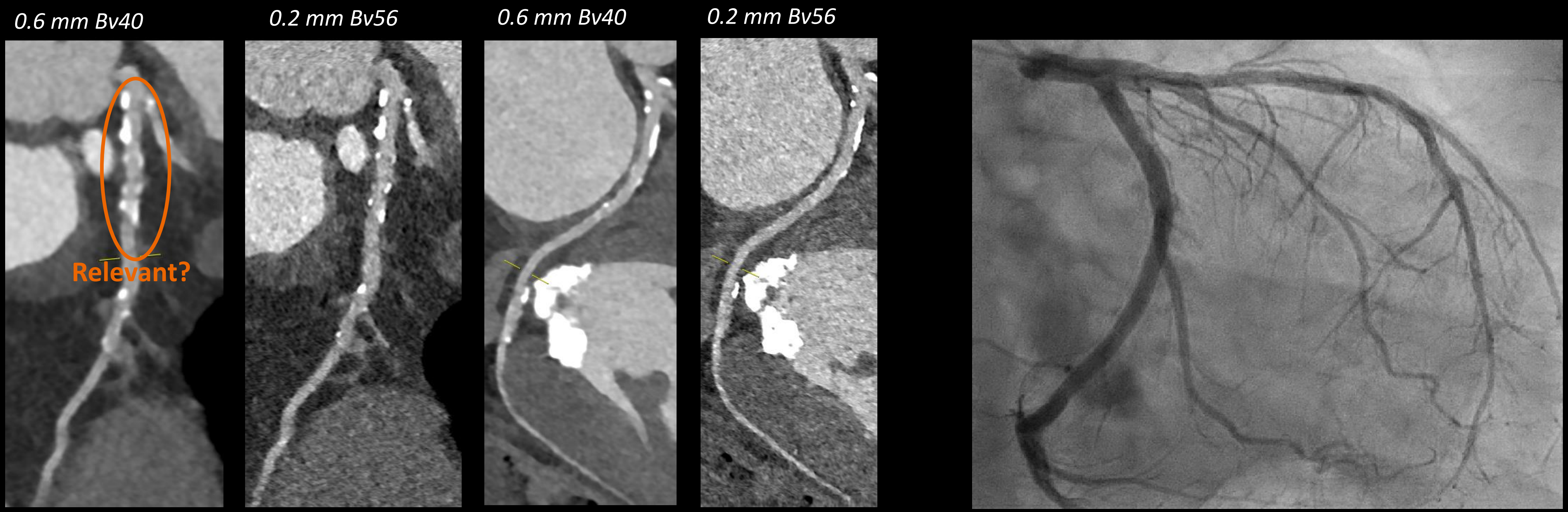
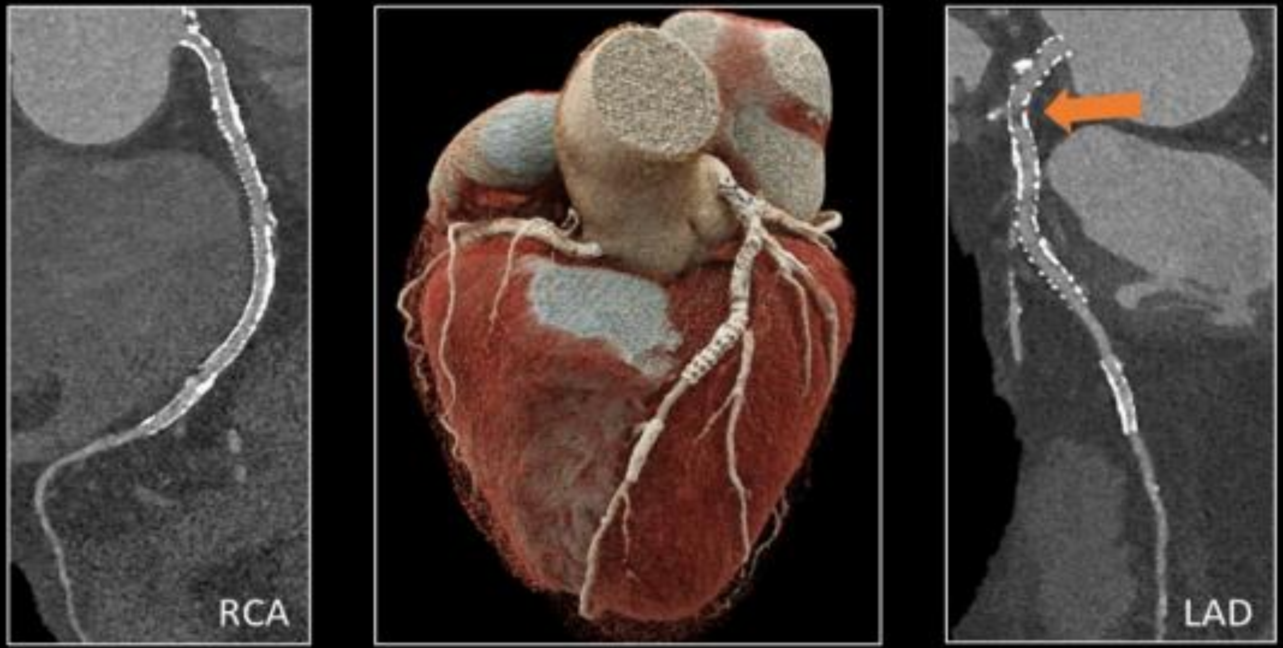
PCD-CT addresses the challenge of Ca blooming

- 80-year-old female patient pre-TAVR planning, dual source PCD-CT, 2 x 120 x 0.2 mm



Courtesy of R. Budde, Erasmus Medical Center, Rotterdam, The Netherlands

Photon-counting CT – sharper images for a new level of detail
Clinical advantages using PCCT for stent evaluation



The figure shows PCCT images (Bv60, 0.2 mm, 512x512, QIR 3) of long, partially overlapping stents in the left anterior descending artery (LAD) and the right coronary artery (RCA). Orange arrow indicate in-stent restenosis of the stent in the proximal LAD

Amnestic Data

81-year old male referred for stent patency evaluation after multiplex PCI (6 stents) due to recurrent angina.

Heart rate was 55/beats during scan

Imaging parameters and contrast protocol

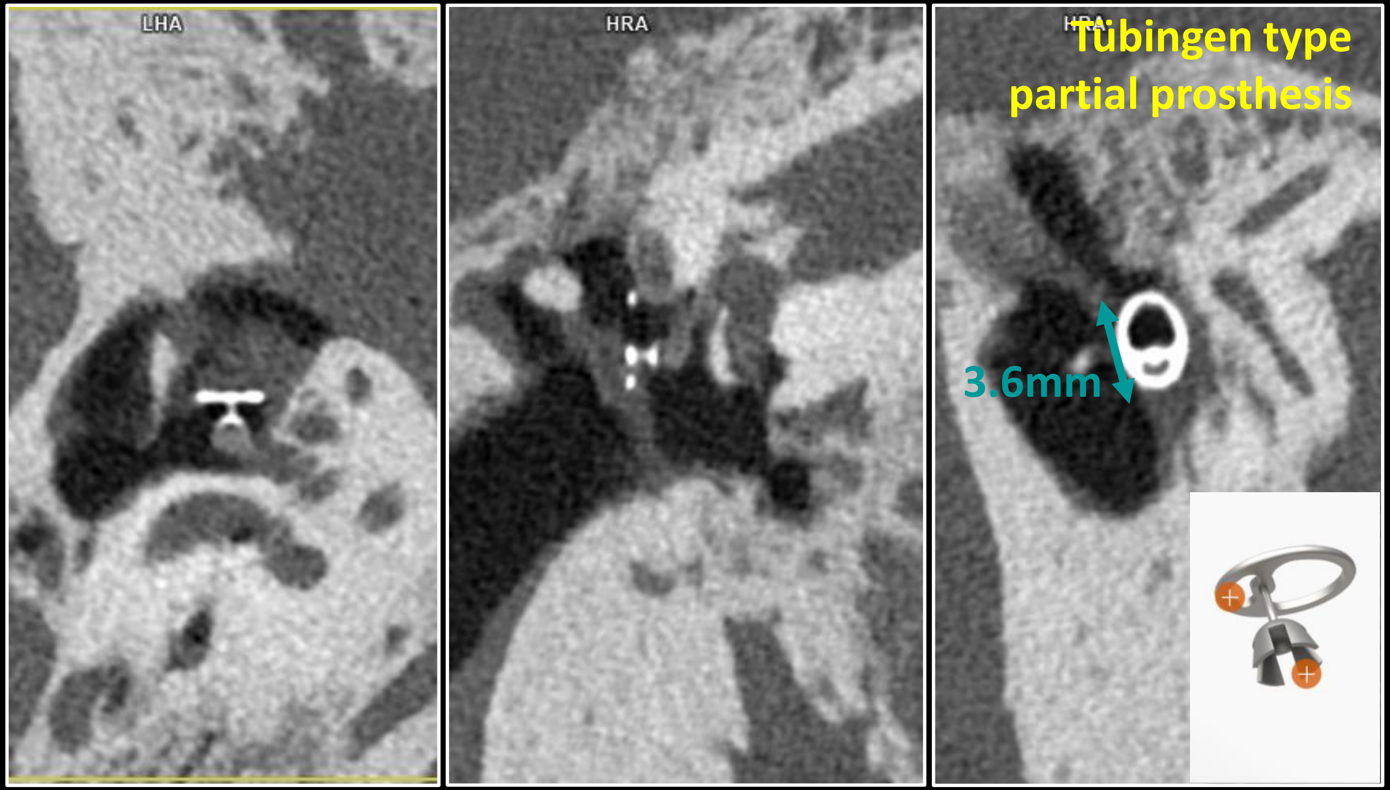
UHR: 0.2 mm, BV 60
IQ 64, QIR 3, 512x512 matrix
72 ml Iomeron 370
120kV, CCTA DLP= 290 mGycm
Sequential scan mode

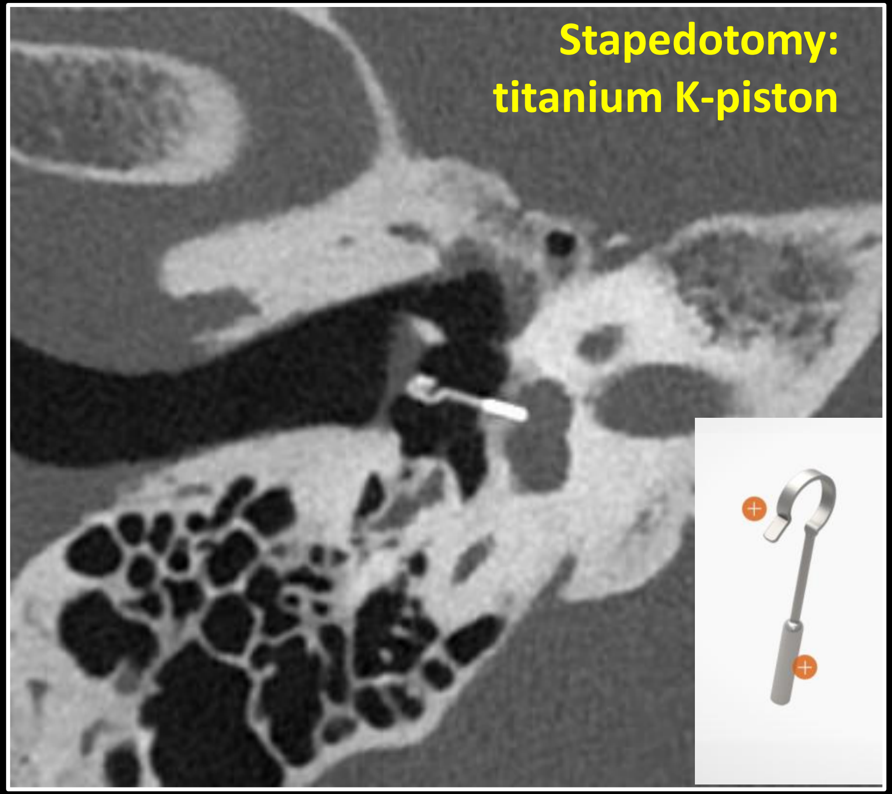
Significance and novelty

Accurate visualization of in-stent restenosis is challenging using conventional energy-integrating detector CT due to the blooming artifacts by metal struts. High-resolution PCD-CT imaging provides superior spatial resolution and reduced blooming for the evaluation of stent patency.

Courtesy of Semmelweis University, Budapest, Hungary.
Source: https://journals.lww.com/investigativeradiology/abstract/2023/07000/characterizing_the_heart_and_the_myocardium_with.9.aspx
The statements by Siemens Healthineers' customers described herein are based on results that were achieved in the customer's unique setting. Because there is no "typical" hospital or laboratory and many variables exist (e.g., hospital size, samples mix, case mix, level of IT and/or automation adoption) there can be no guarantee that other customers will achieve the same results.

Photon-counting CT – sharper images for a new level of detail
Superior visualization of inner ear structures





Courtesy of A. van der Lugt, Erasmus Medical Center, Rotterdam, The Netherlands
Source: https://www.symposiumparkstad.nl/upload/documents/CT_2022/handout/1_PhotonCounting_2022_PCCT_RBooij.pdf
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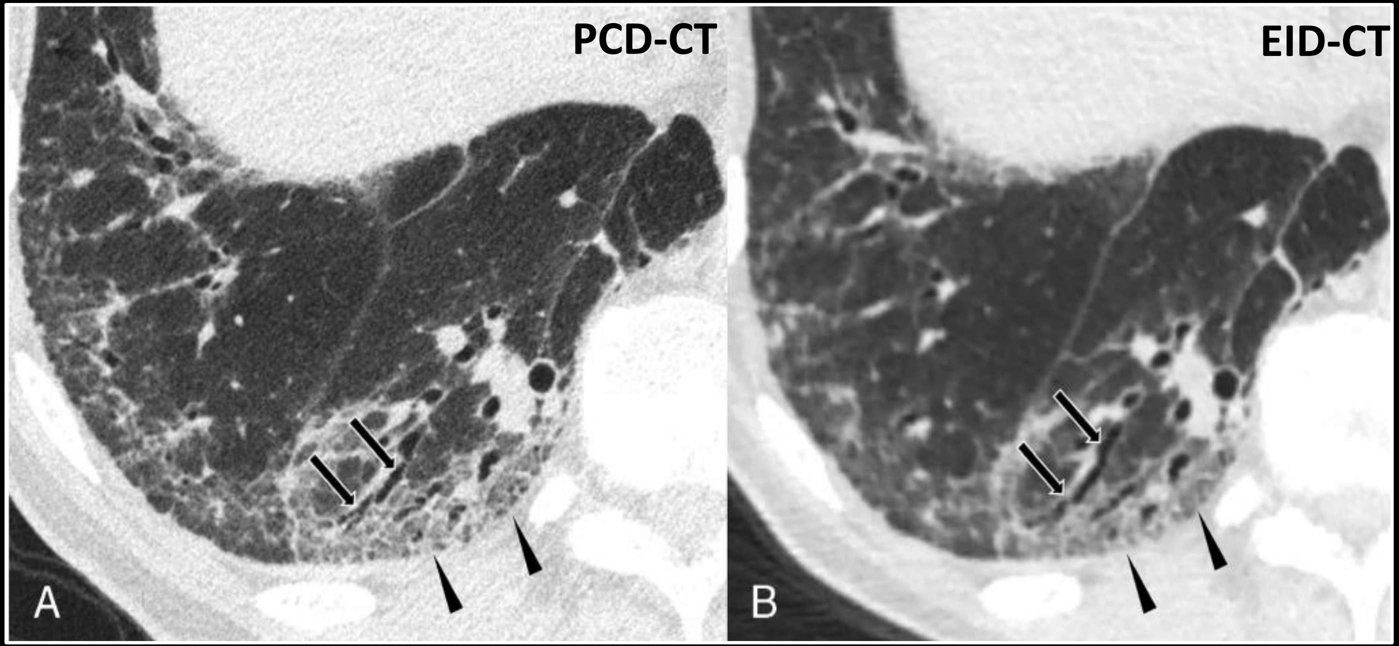
Photon-counting CT – sharper images for a new level of detail
Increased reader confidence in diagnosis of interstitial lung disease

Chest CT of patients suspected of interstitial lung disease*

- EID-CT 128 x 0.6 mm or 192 x 0.6 mm
  mean DLP = 219.8 mGy cm

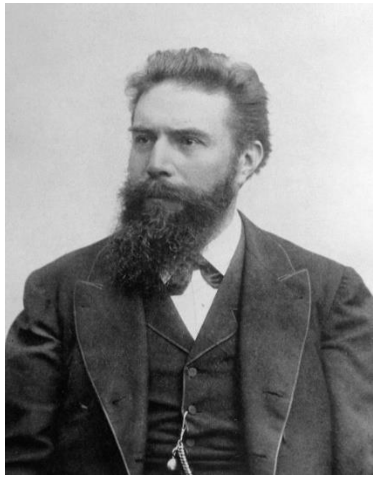
- PCD-CT UHR 120 x 0.2 mm
  mean DLP = 193.8 mGy cm



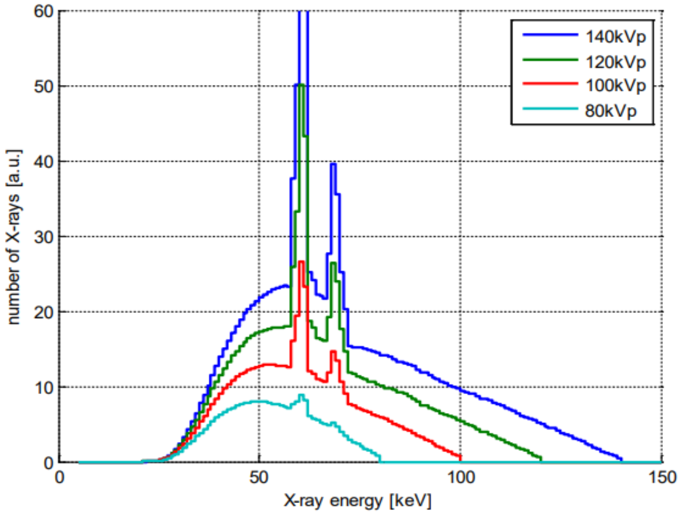
Conclusions: Photon-counting detector CT provided better image quality and improved the reader confidence for presence or absence of imaging findings of reticulation, GGO, and mosaic pattern with idiosyncratic improvement in confidence in UIP presence.

* Inoue A et al, Estimating the Clinical Impact of PCD-CT in Diagnosing Usual Interstitial Pneumonia, Invest Radiol 2022

Functional principle of a CT system

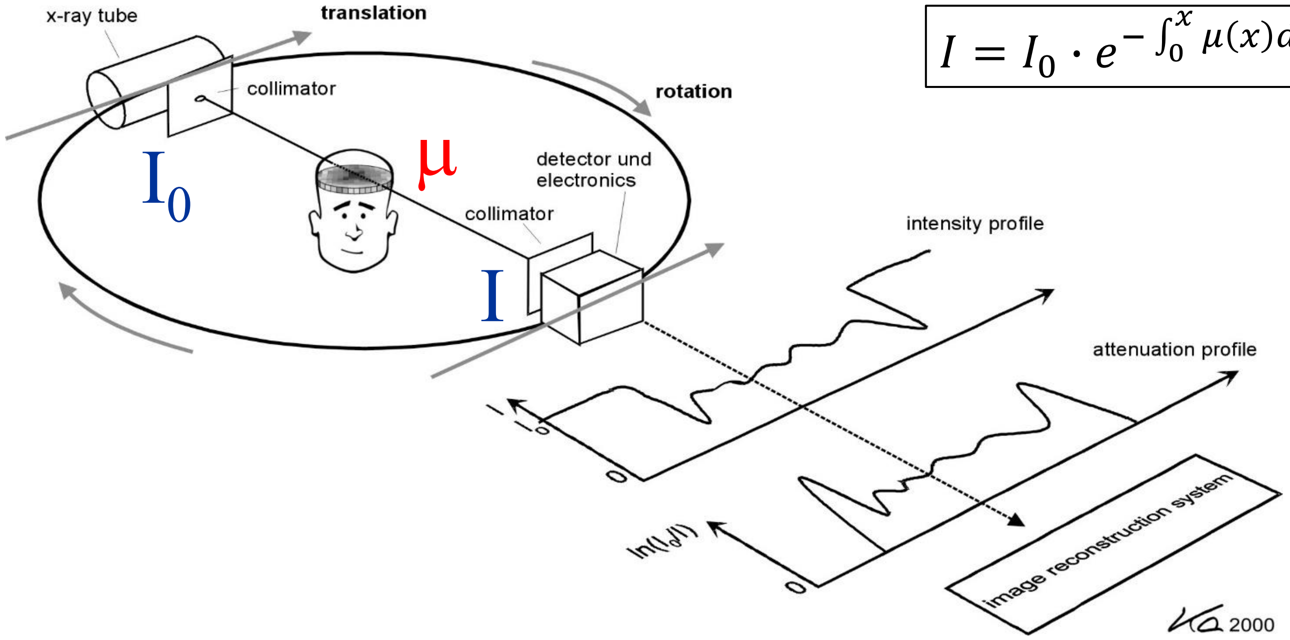


Wilhelm Conrad Röntgen, ca. 1900



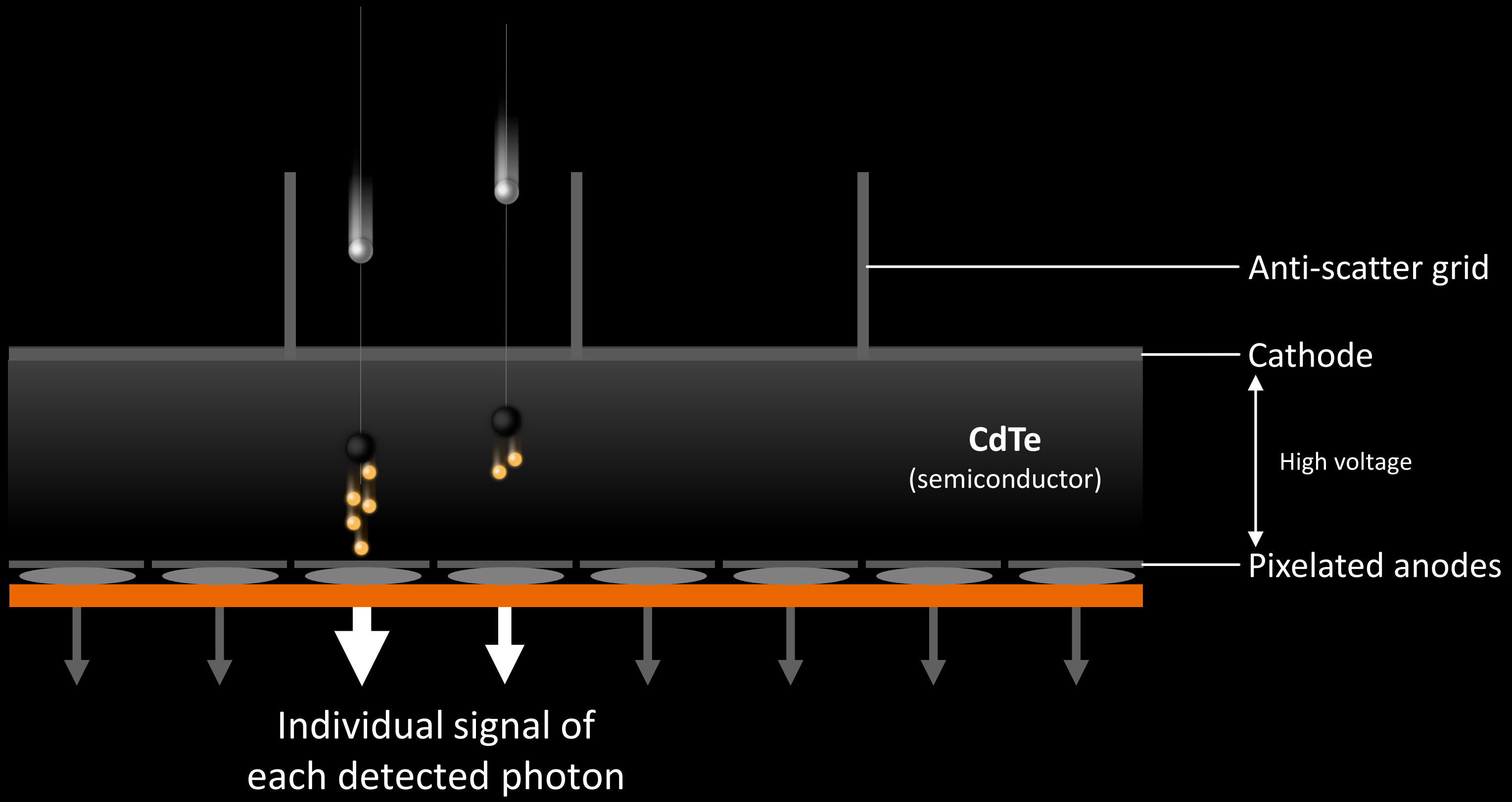
Typical spectrum used in a CT x-ray tube

$$I = I_0 \cdot e^{-\int_0^x \mu(x)dx}$$



Functional principle of a CT system, adapted from:
Kalender, Willi A:. Computed tomography: fundamentals, system technology, image quality, applications. John Wiley & Sons: 2000.

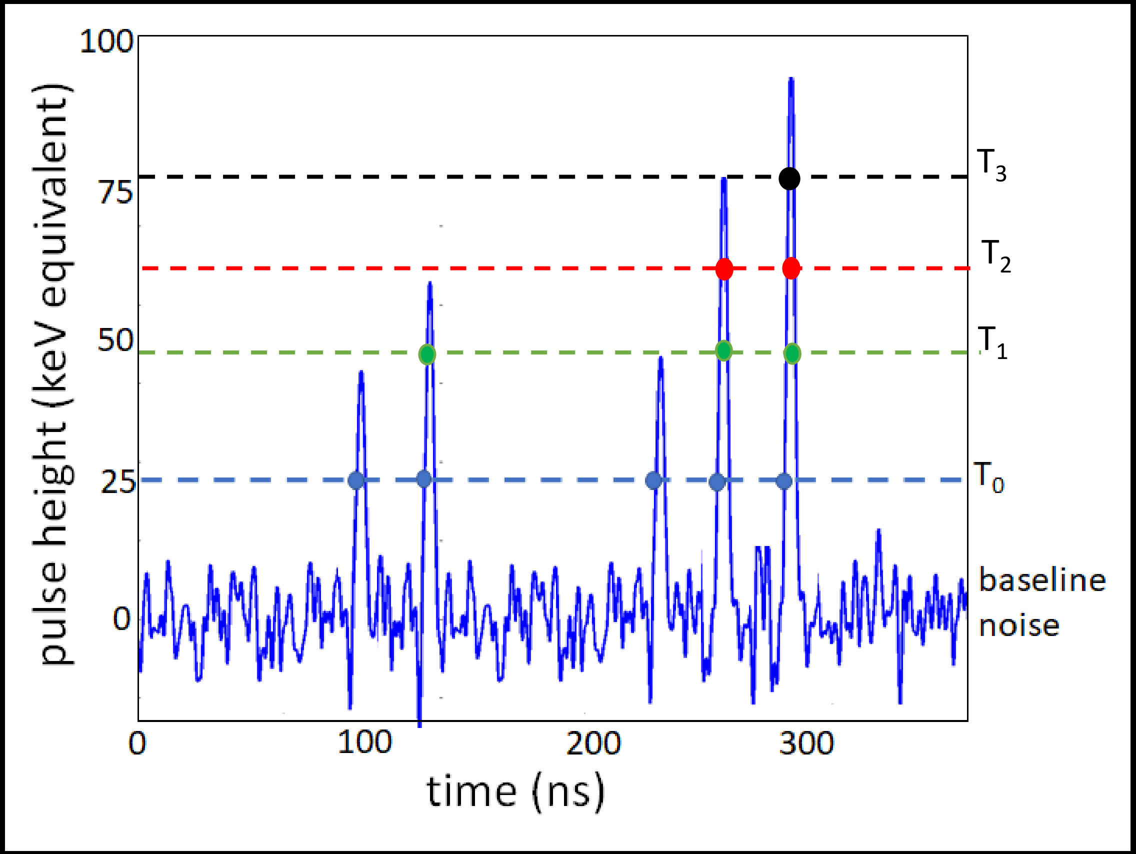
Operation principle – Photon-counting CT detectors



- **Semiconductor** as direct X-ray converter (cadmium telluride)
- Photoelectron creates **electron hole pairs**
- Number of pairs proportional to X-ray energy (100keV photon -> 3.64fC)
- Electric field causes fast drift of charges toward anode pixels
- Electrons induce short charge pulses when approaching the pixelated anode pads

→ Each photon is counted separately and measured by its energy level

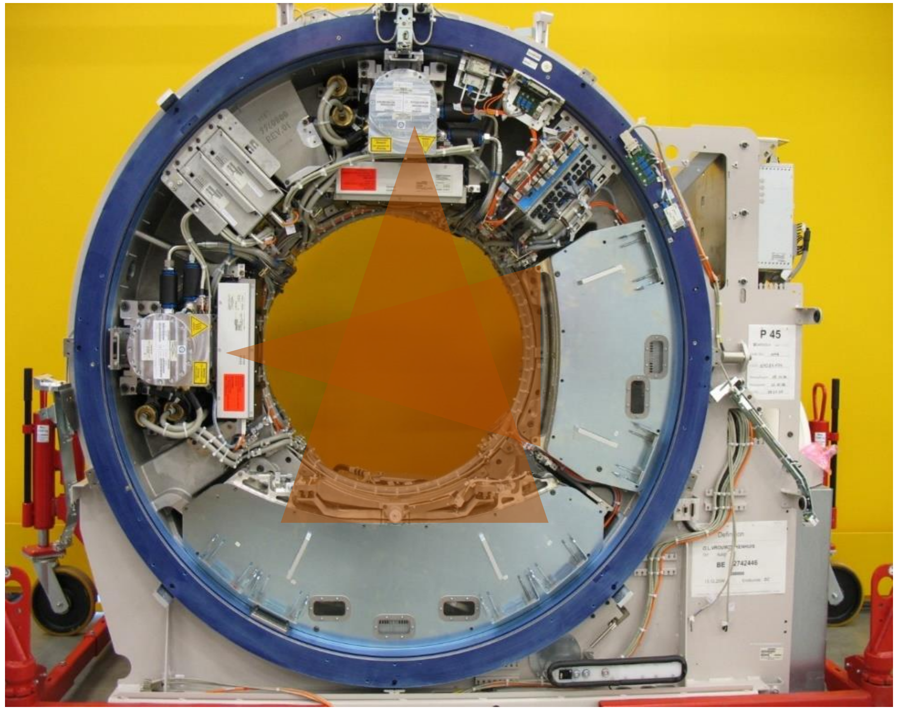
Operation principle – Photon-counting CT detectors

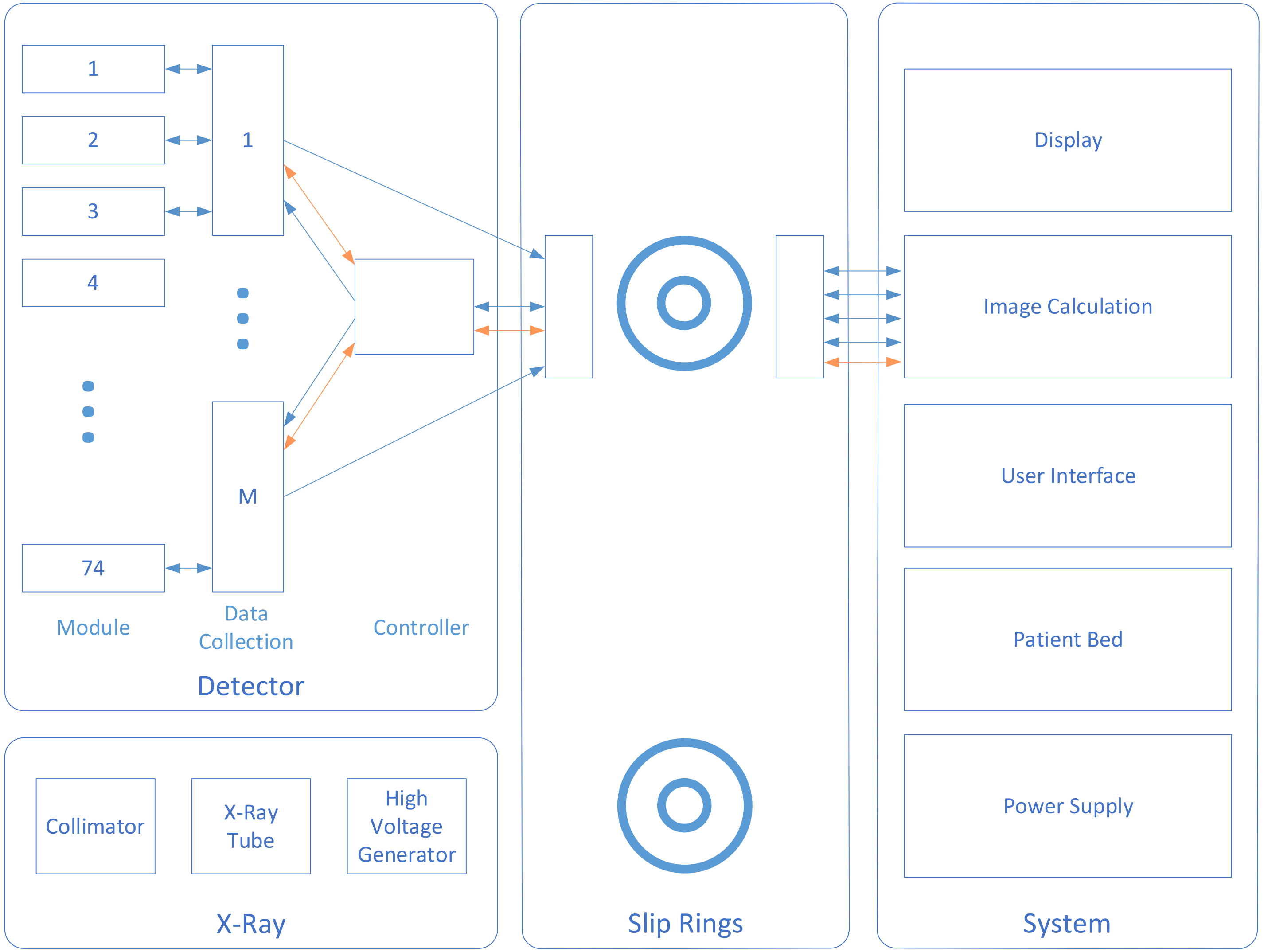


- Charge pulses at ASIC input
- Typ. <10ns duration (~1GHz Bandwidth)
- Input capacitance affects conversion to input voltage
- Electronics noise converts to threshold noise
- Pulses are counted over typ. 100..200µs

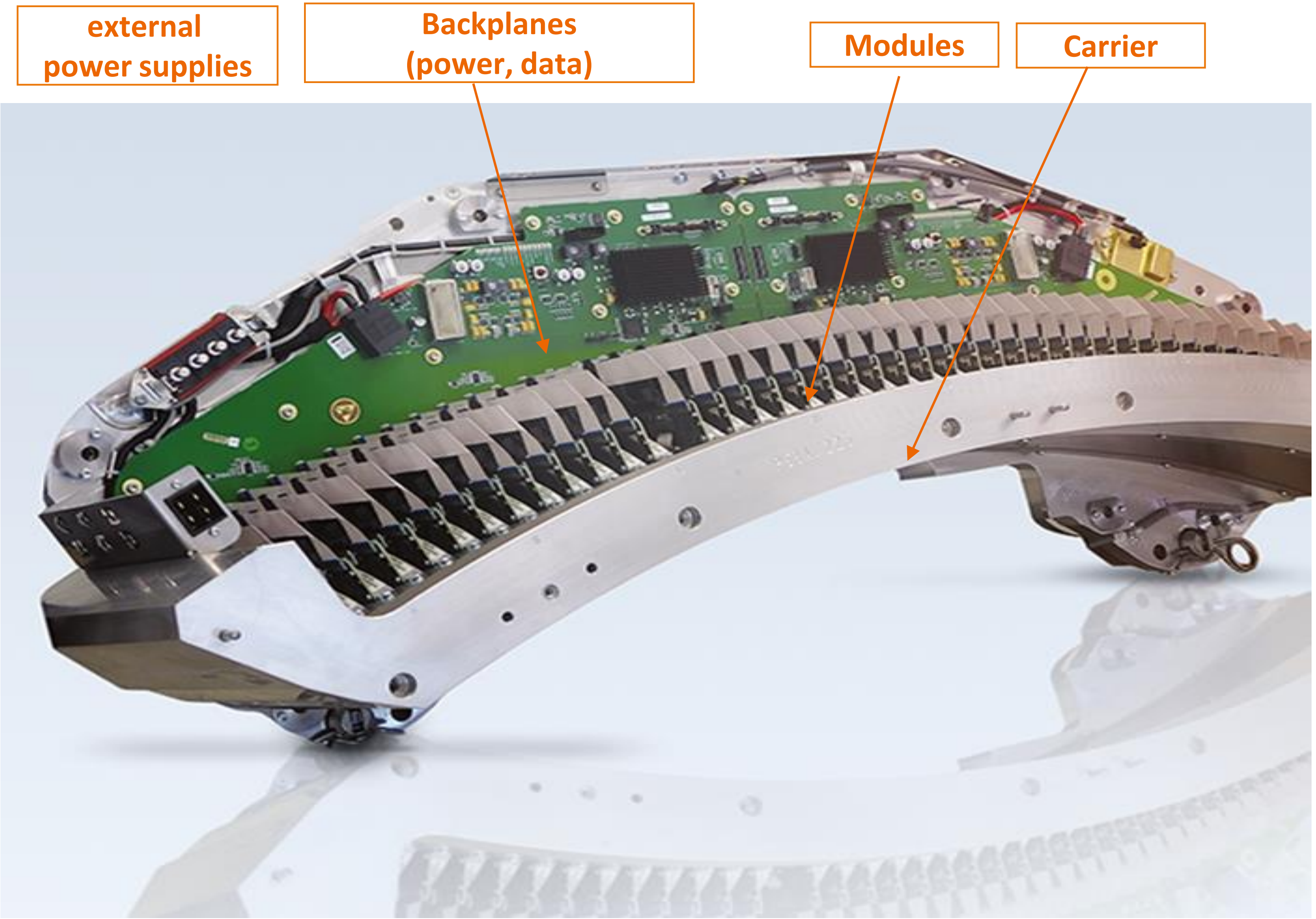
→ Keeping input capacitance low is key to low noise

Inside NAEOTOM Alpha

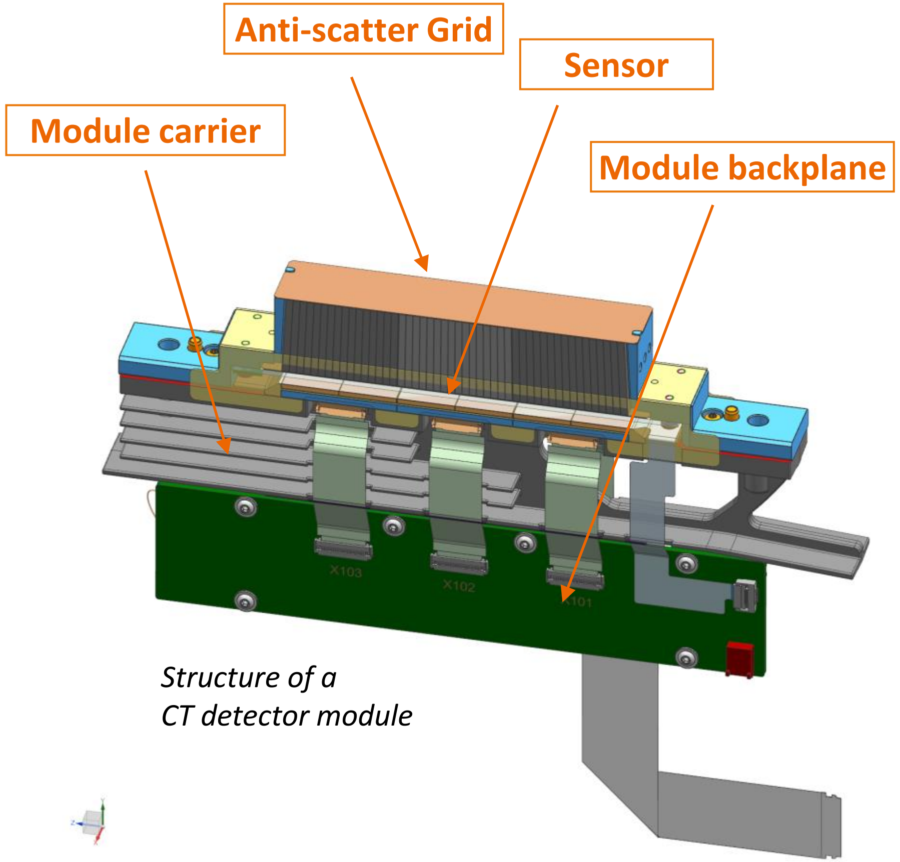




Inside NAEOTOM Alpha
The Detector



Structure of a CT detector

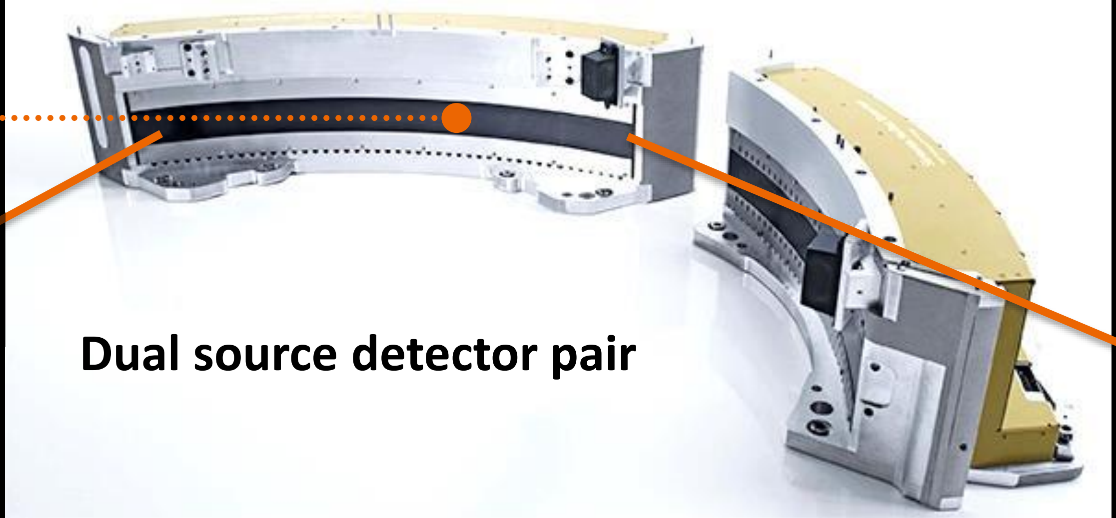


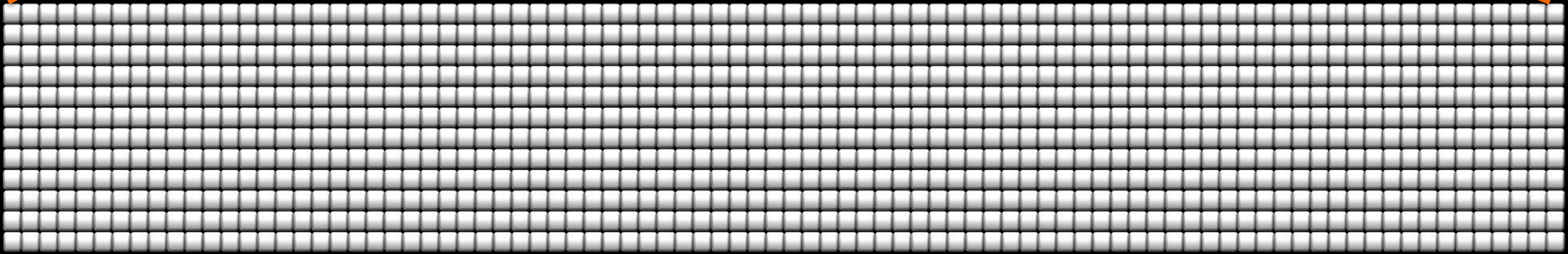
Structure of a CT detector module

Inside NAEOTOM Alpha
The Detector

X-ray entrance window

Typical detector area: $90 \times 60 cm^2$
Realistic die size: $1\ cm^2$





ASIC die tiling requires four-side buttable assembly

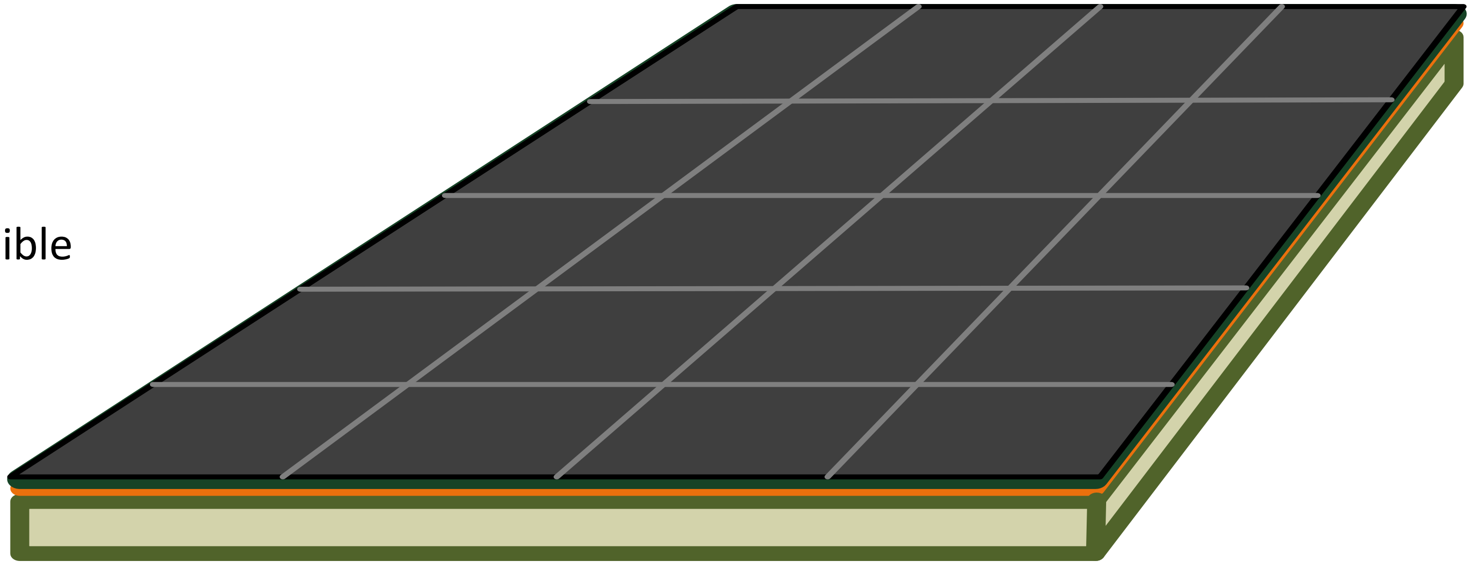
E. Goederer, K. Stadlthanner, S. Chaudhury, A. Gabiger-Rose, M. Hosemann, B. Kreisler
6th Workshop on Medical Applications of Spectroscopic X-ray Detectors, CERN, September 2022

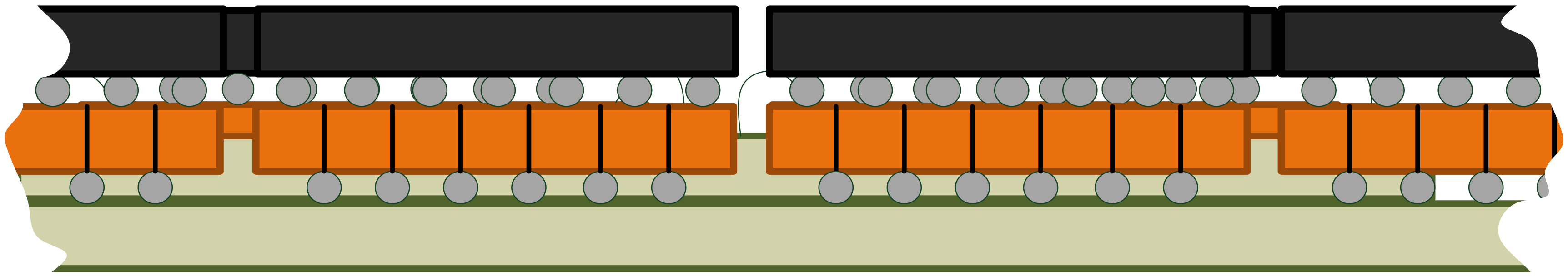
Inside NAEOTOM Alpha
The Detector

- Detect almost all radiation!

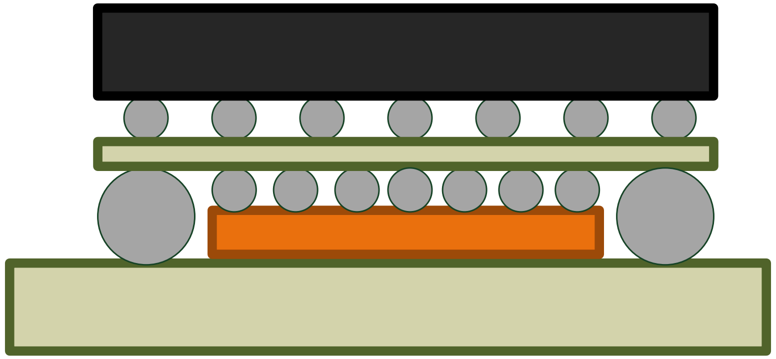
  -> As few and narrow dead spaces as possible
- Make components four-side buttable

  -> Enable efficient mass production



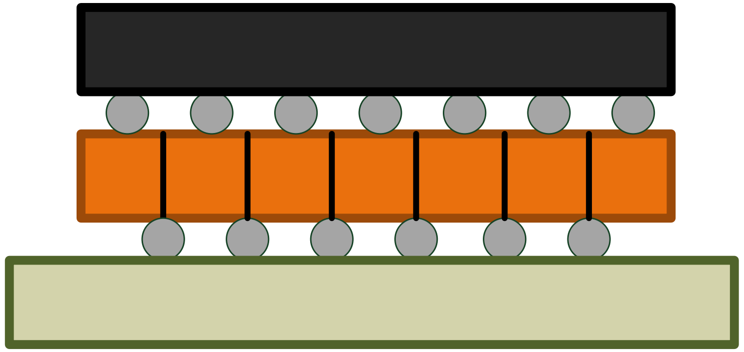


ASIC & Sensor Integration Options



Interposer between Sensor and ASIC

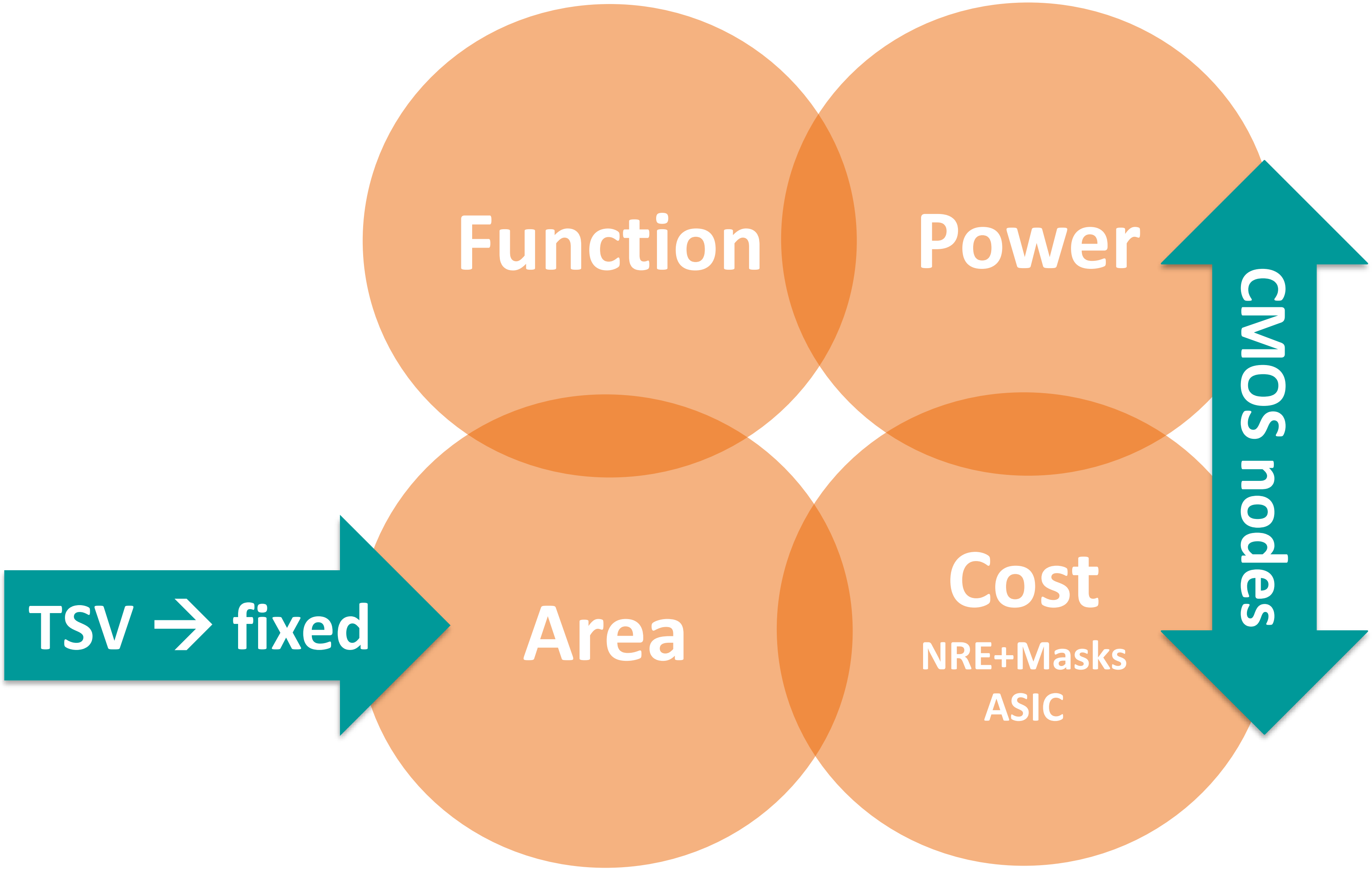
- **Geometry uncoupled**
  Smaller ASIC die than sensor
  Flexible pixel geometry
- **Parasitic capacitance**
  Noise
  Cross-coupling
  Regular patterns



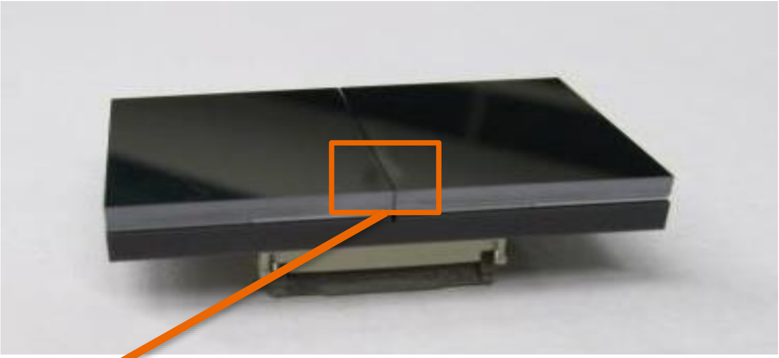
Through-Silicon Vias in ASIC

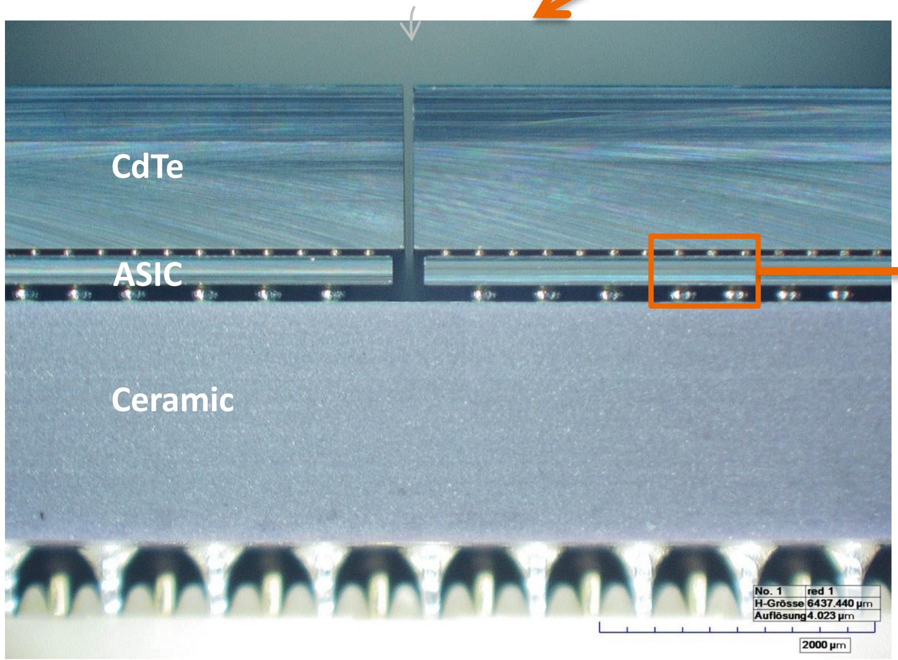
- **ASIC geometry determined by sensor**
  Costly re-designs
- **Shortest possible connection between sensor and ASIC**
  Lowest noise
  No cross-coupling

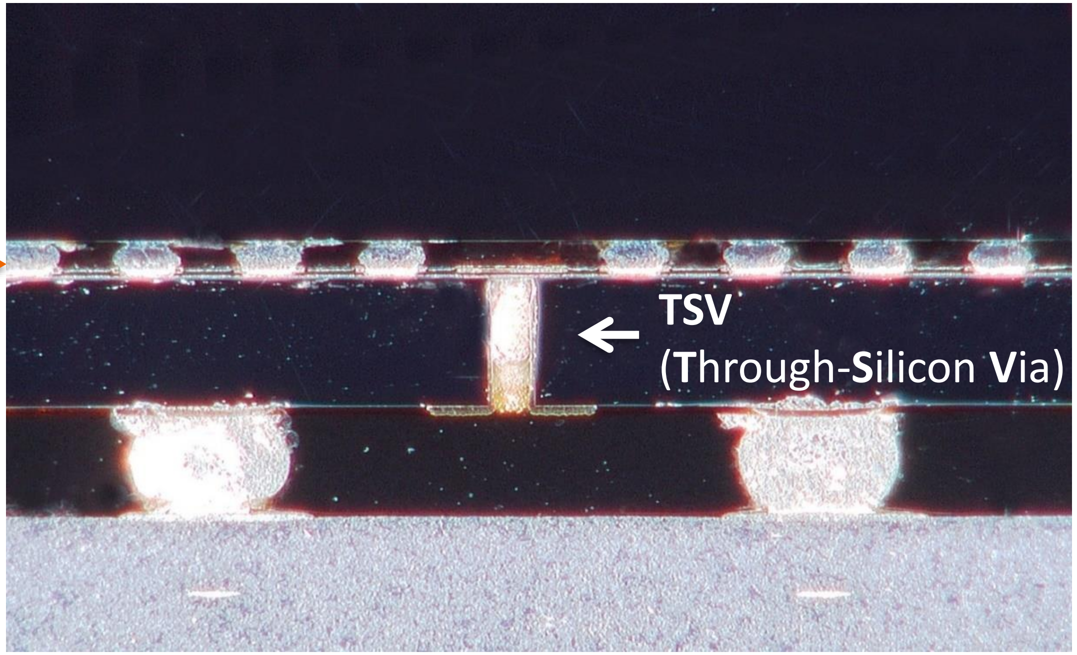
ASIC Design & Integration



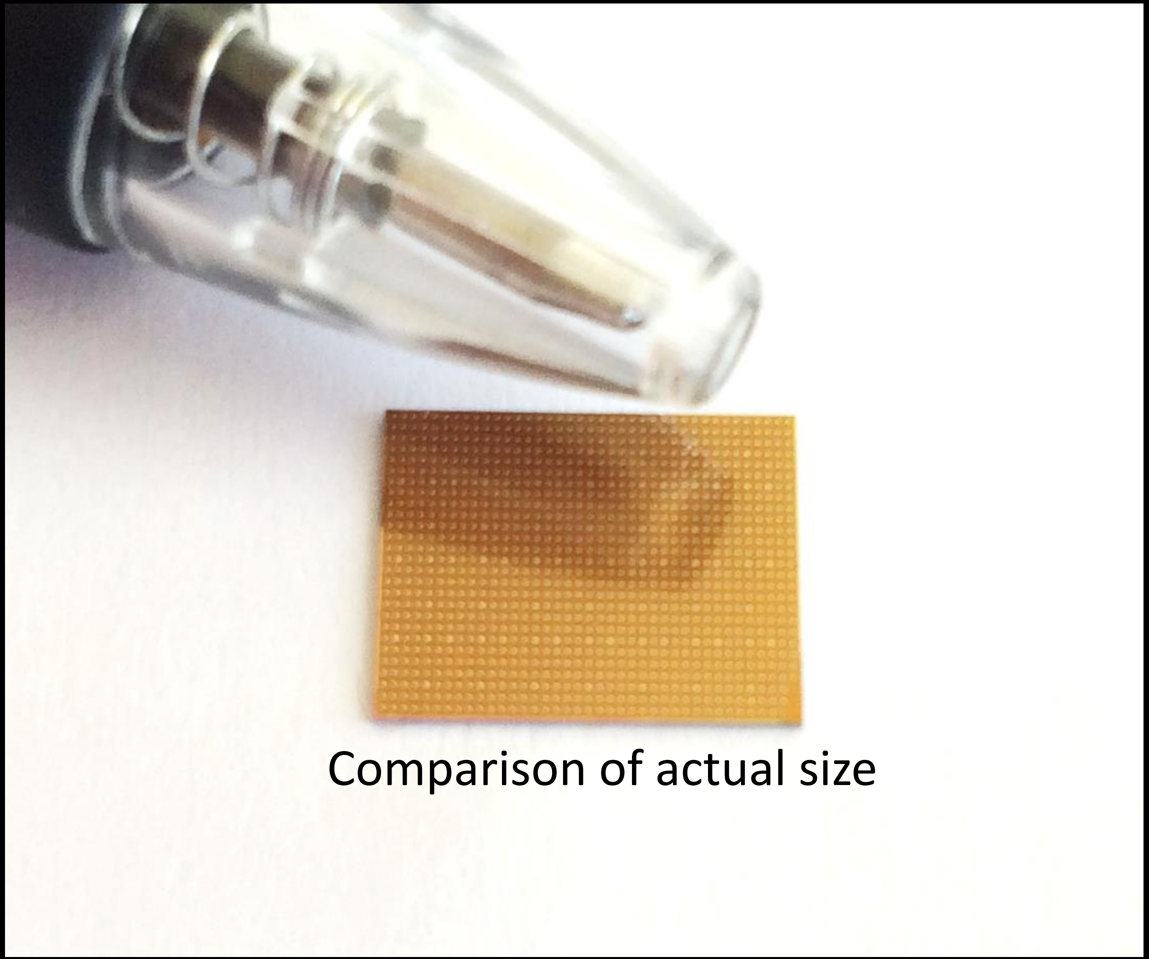
Inside NAEOTOM Alpha – ASIC & Sensor Integration

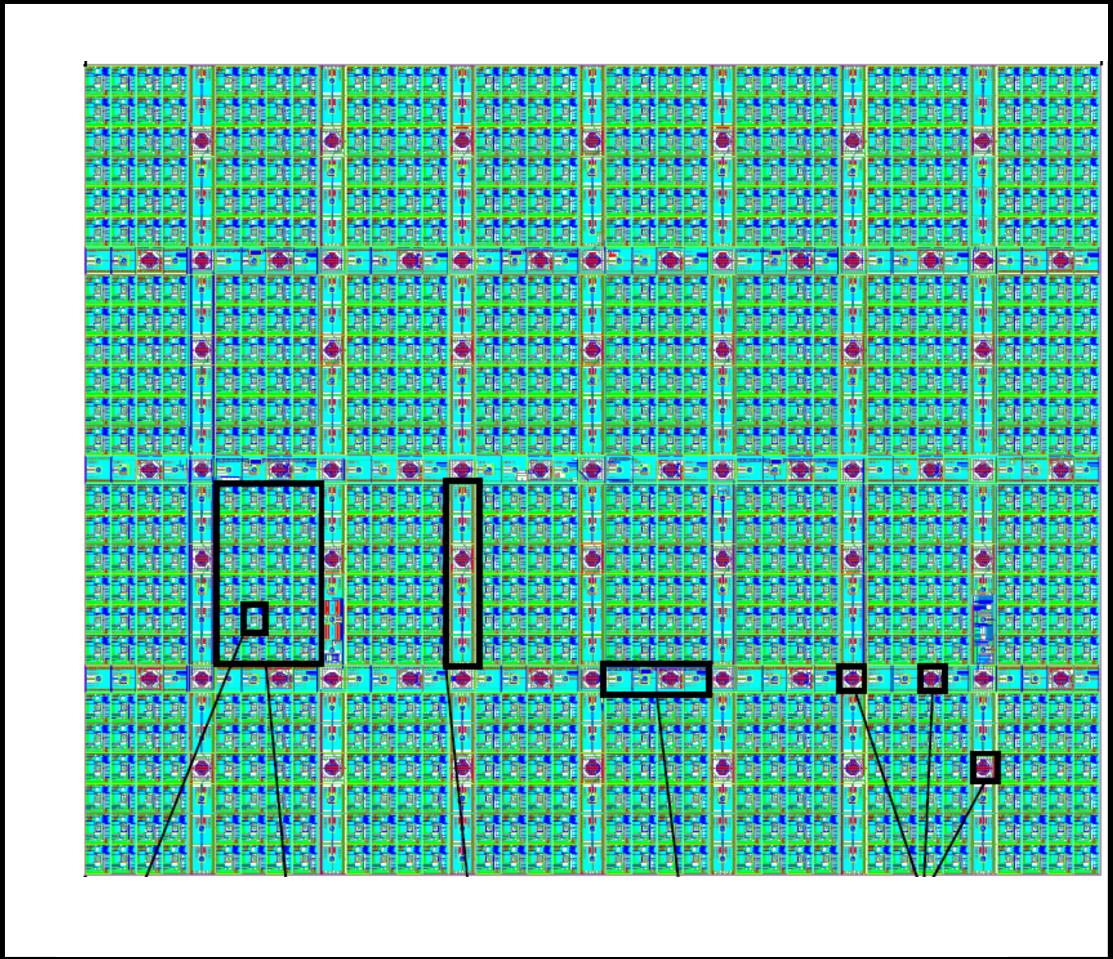






Inside NAEOTOM Alpha
MC3 ASIC





Inside NAEOTOM Alpha
MC3 ASIC

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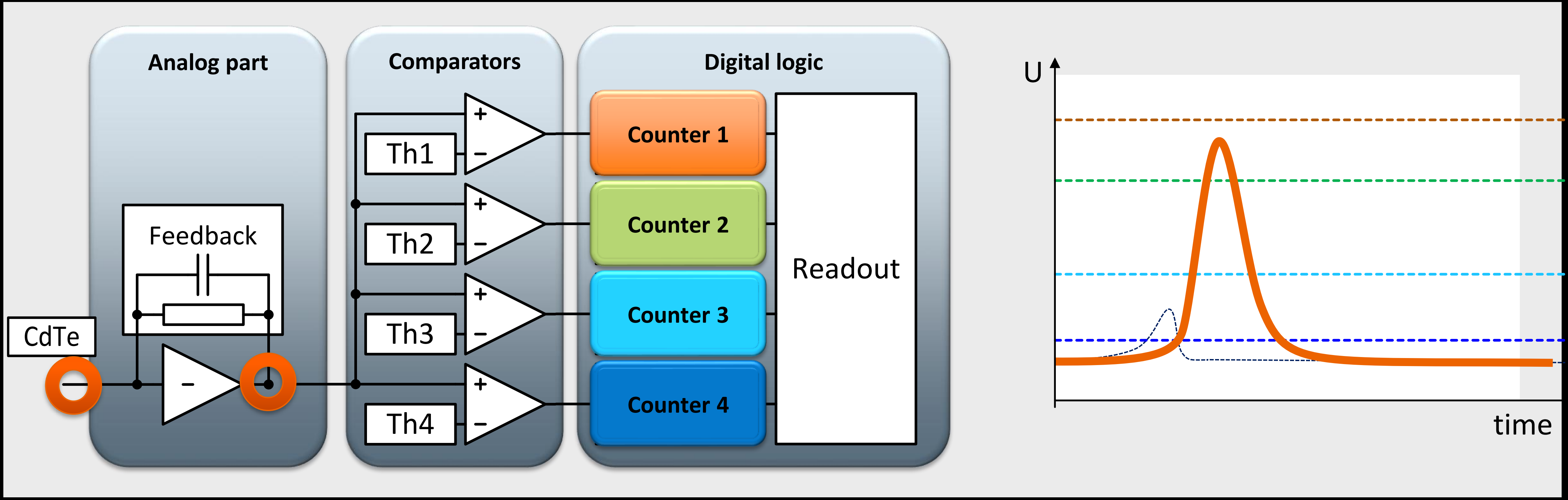
charge signal → (spectral) count rate



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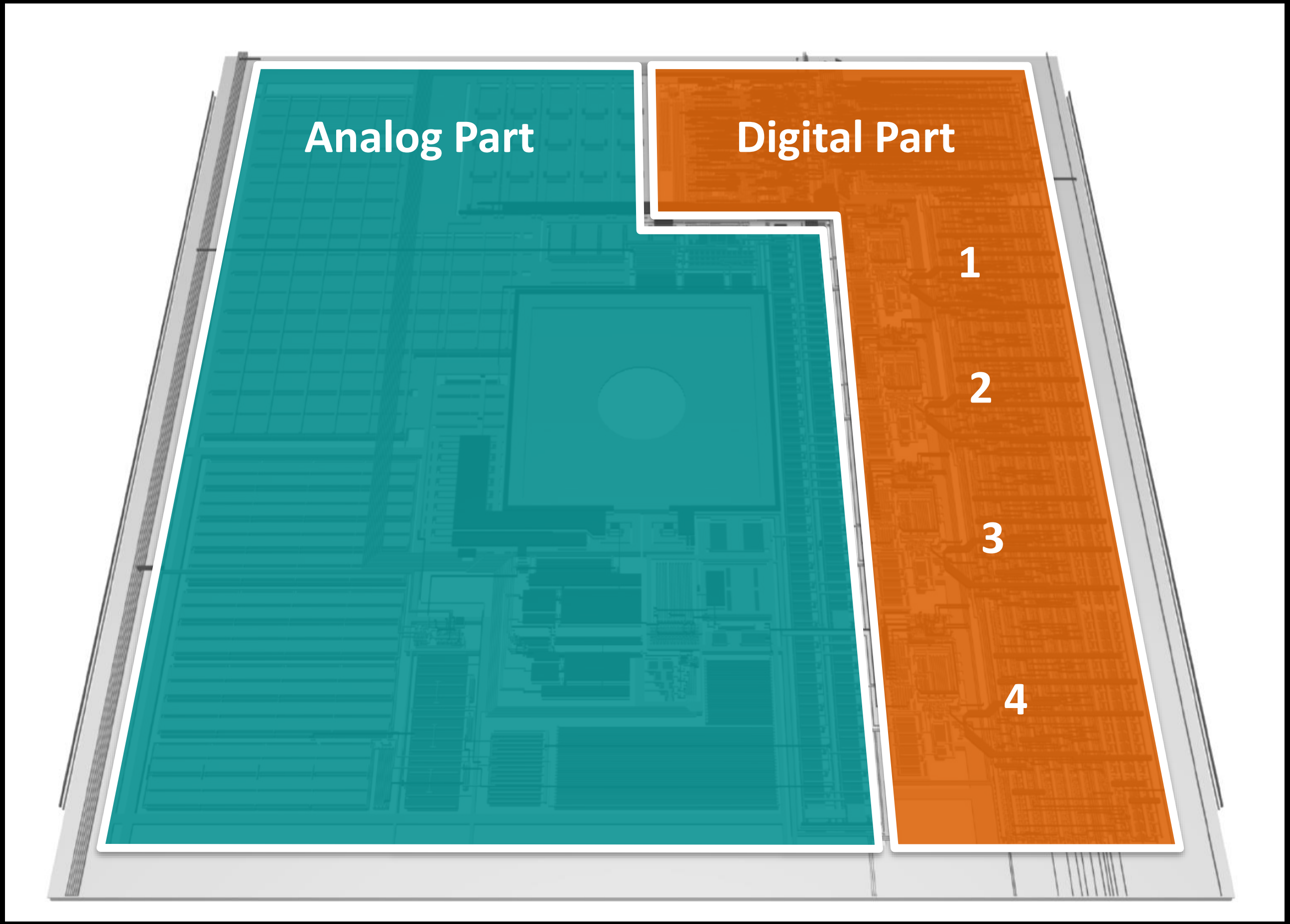
6th Workshop on Medical Applications of Spectroscopic X-ray Detectors, CERN, September 2022

Inside NAEOTOM Alpha
MC3 ASIC

Die size:	89 mm² (~10 * 9 mm)
Pixel matrix:	32 x 24
Thresholds:	4
Counter depth:	16 bit
Readout speed:	300 Mbit/s
	<200 µs per full frame
Threshold range:	0 - 195 keV
Pulse width:	12.5 ns (FWHM)
Counter type:	non paralyzable



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Thank You!

Thank you
for your enthusiasm!

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