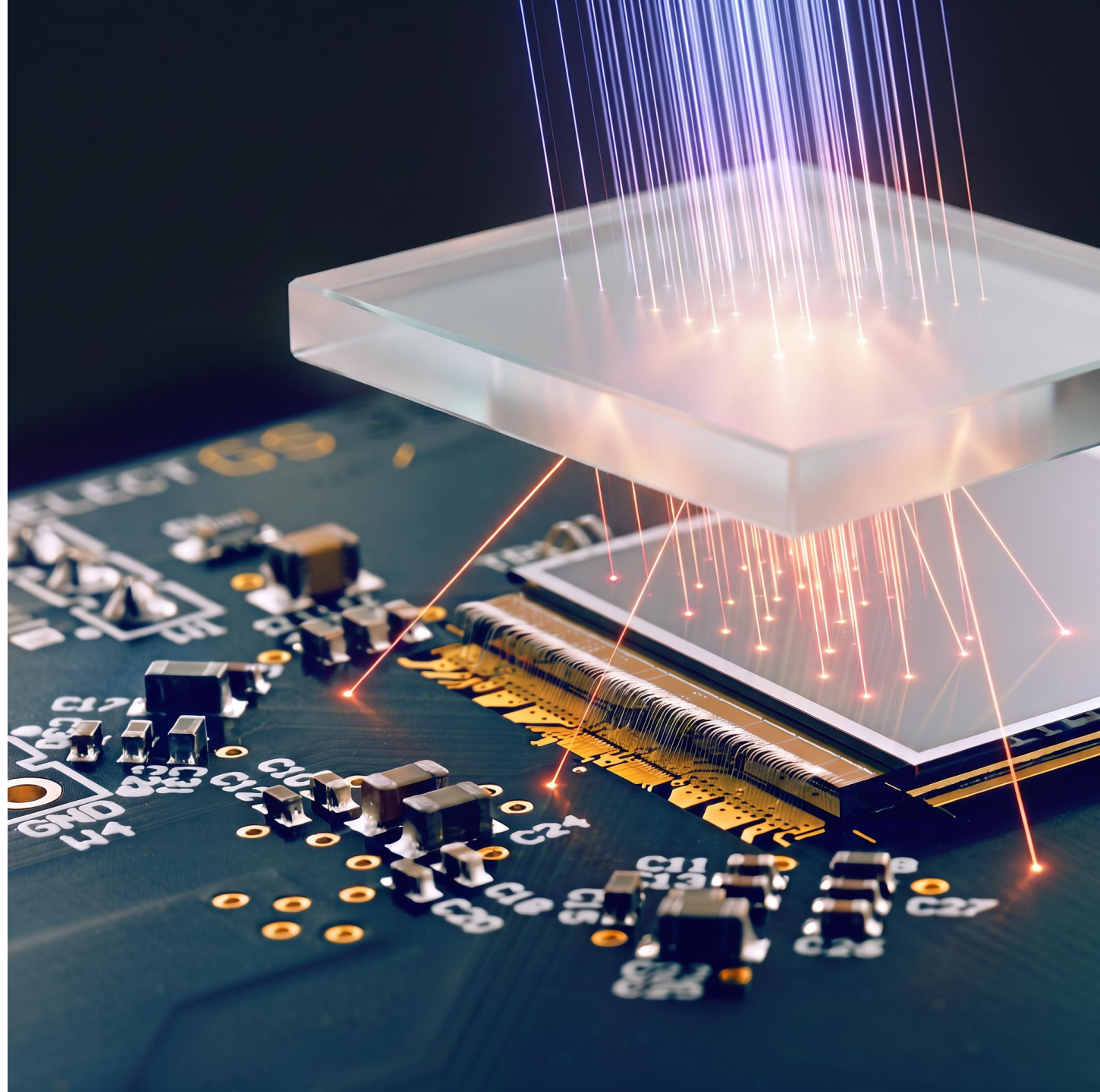




Spectral imaging with photon-counting computed tomography (PCCT)

Background and featured research
using spectral imaging



Background

Origins and fundamentals of MARS Bioimaging's photon-counting computed tomography technology.

ABOUT MARS

One company, one purpose; two key markets

We promote human healing by revealing hidden truth.

Biomolecular research

> Translation >

Medical imaging

Important note: Functionality and capability is different between the Microlab Imaging System (Biomolecular research) and the Extremity CT Imaging System (Medical imaging). **MARS makes no material differentiation claims for the Extremity CT Imaging System.**



Origins

MARS Bioimaging is a New Zealand-based medical imaging company specialising in photon-counting CT. Developed through the Medipix Collaboration at CERN, MARS built the world's first commercially available spectral photon-counting CT system for research — making simultaneous multi-material identification, once impossible with conventional CT, an affordable reality for the lab.

15+

Years of R&D

in photon-counting CT
development

CERN

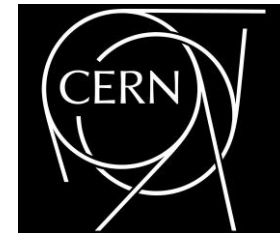
Technology origin

via the Medipix Collaboration

Global

Research partners

universities & institutes worldwide



Medipix3RX used under license. CERN does not endorse companies or products



CERN — Large Hadron Collider, Geneva

- Medipix3RX ASIC detector — the same particle-physics technology used at the Large Hadron Collider
- Fully self-shielded — plug-and-play installation in standard lab facilities
- MDSAP-audited quality management system



CERN-born technology



Medipix3RX ASIC detector chip

- **Medipix3RX ASIC Detector**

The same particle-detection chip used at CERN's LHC, adapted for X-ray photon detection in CT imaging.

- **CdTe Semiconductor Sensor**

Cadmium Telluride crystal directly converts incident X-ray photons to a charge cloud — each photon's energy measured individually.

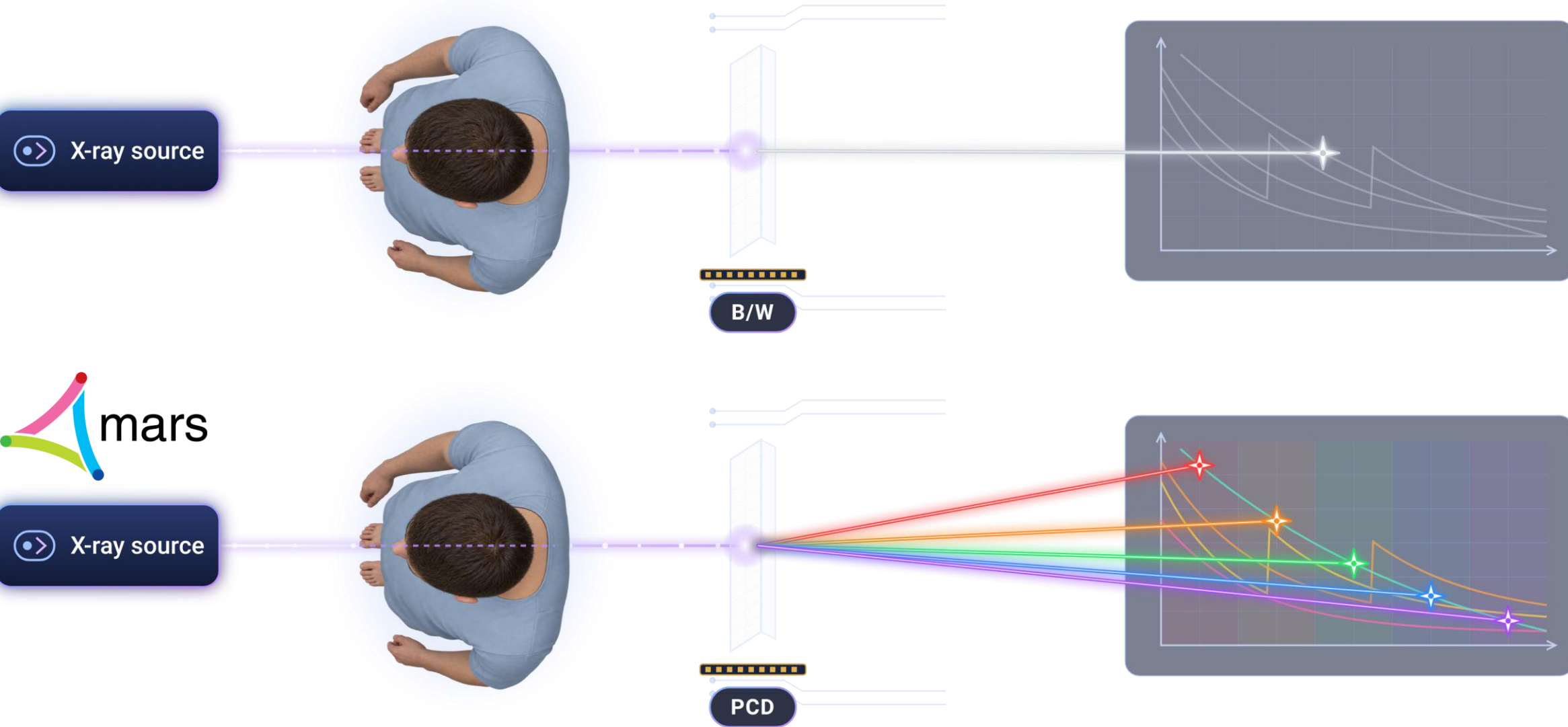
- **110 × 110 μm Pixel Pitch**

128 × 128 pixel array per detector module, 12 modules total. Patented Charge Summing Mode (CSM) manages cross-talk between pixels.

- **5 Energy Channels Simultaneously**

Unlike energy-integrating detectors, the Medipix3RX bins photons by energy — enabling spectral material decomposition in a single pass.

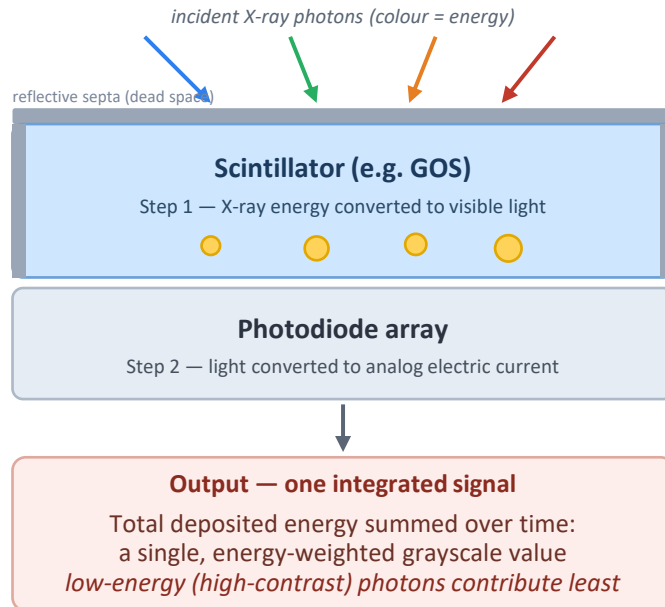
Photon counting detectors (PCD) provide spectral resolution



Conventional vs. Photon counting detectors

Conventional Detector

Energy-Integrating Detector (EID) · indirect conversion

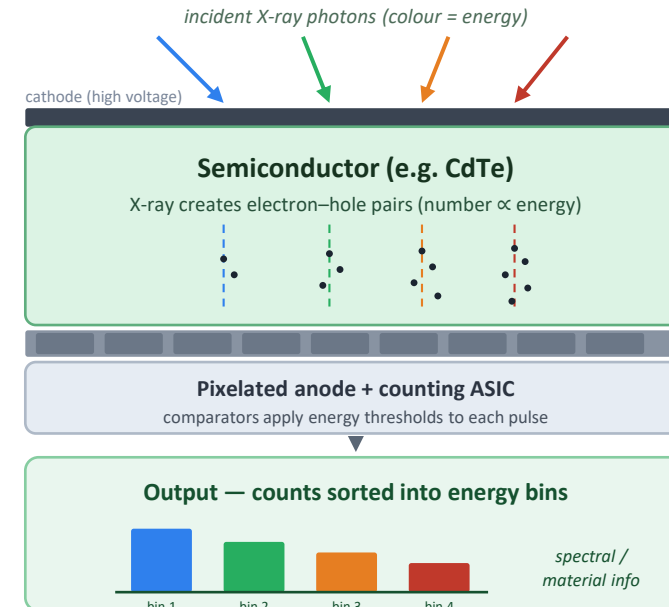


Characteristics

- Two-step indirect conversion (light intermediate)
- No energy discrimination — spectral data is lost
- Electronic noise can be integrated as signal
- Reflective septa reduce geometric dose efficiency
- Larger elements limit spatial resolution

Photon-Counting Detector

PCD · direct-conversion semiconductor



Characteristics

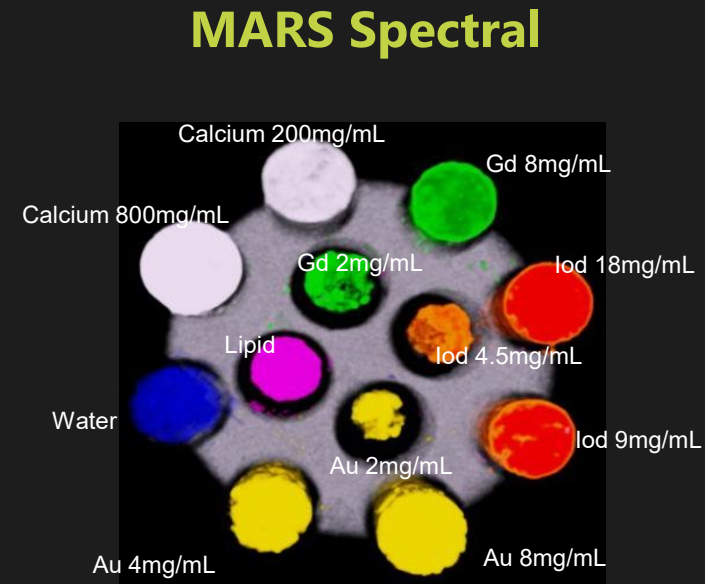
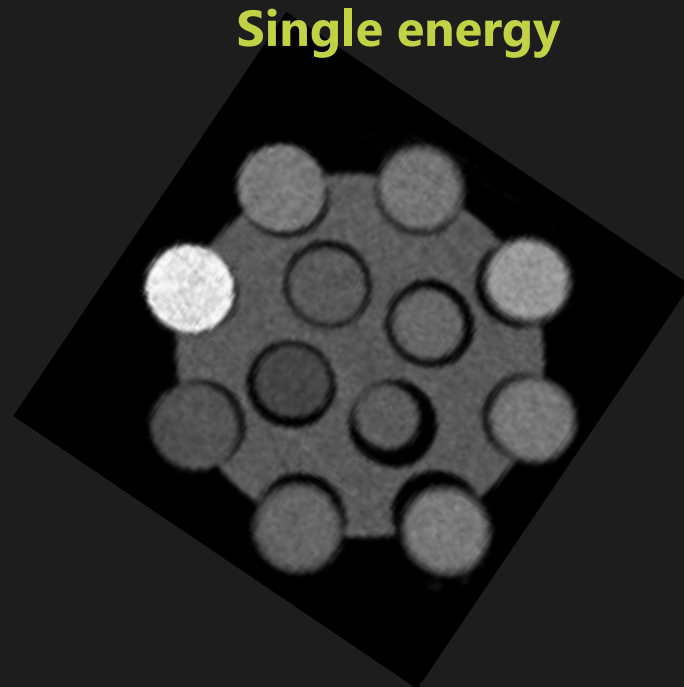
- One-step direct conversion (no light intermediate)
- Counts each photon and resolves its energy
- Energy threshold rejects electronic noise
- No reflective septa — higher dose efficiency
- Small intrinsic pixels — higher spatial resolution



From greyscale to coloured material imaging

Spectral imaging allows you to identify and quantify different materials

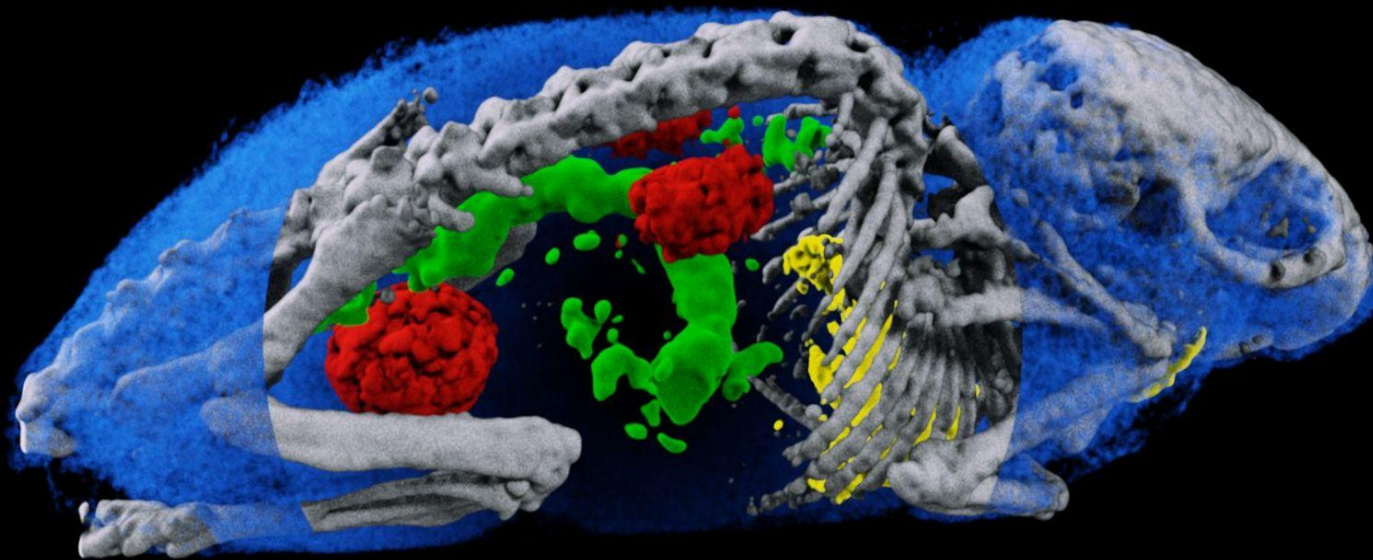
- a separate map (data channel) is made for each material
- each map gives the partial density (g/cm^3) for the material
- each material is then assigned a colour for easy visualisation



Data available in:
Moghiseh et al, JSM Biomed
Imaging Data Pap 3(1): 1007.
(2016)

Coloured material imaging

A mouse containing, gold, gadolinium, and iodine

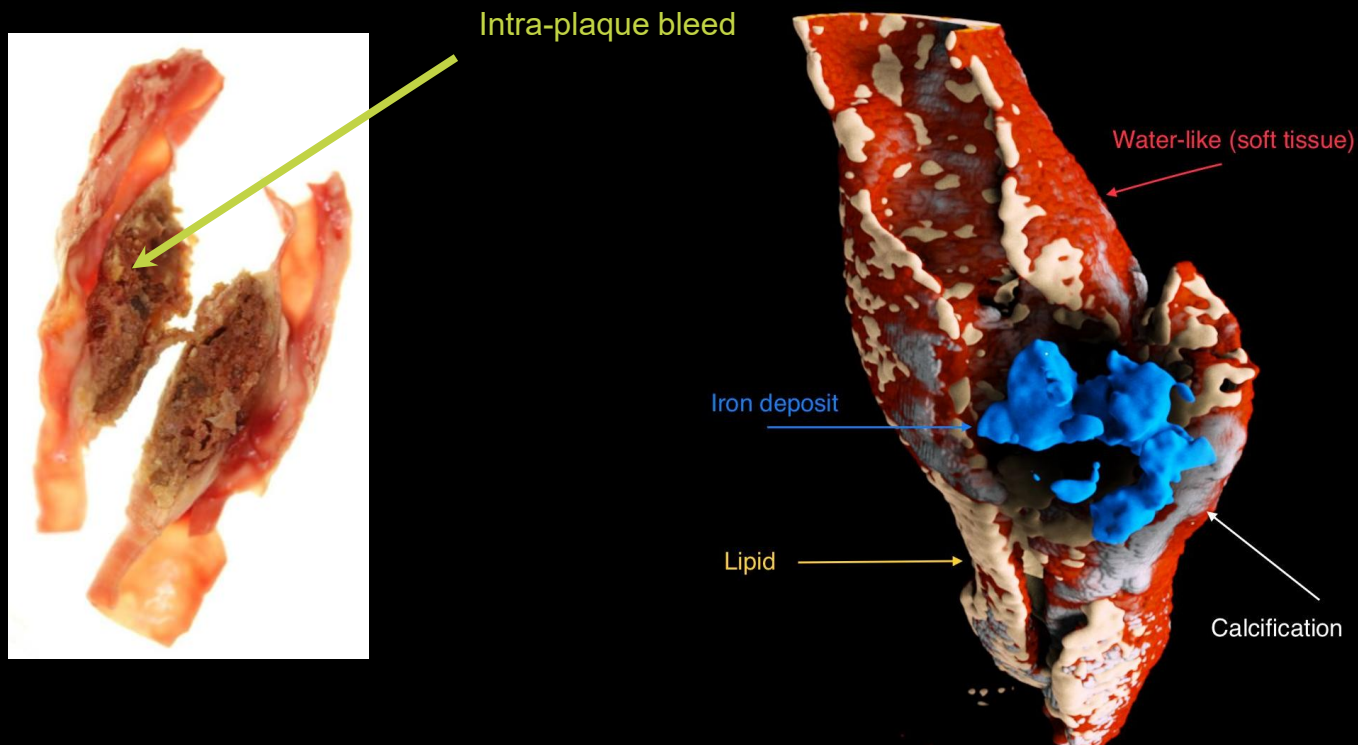


Images presented at the European Congress of Radiology, Vienna, March 2017.

Atheroma imaging

The cause of heart disease and stroke

Research only – Extremity CT Imaging System is not cleared for material differentiation



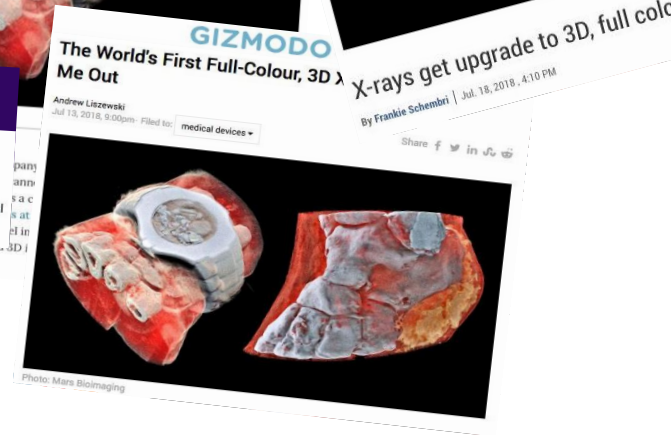
First human images, 2018



Founding Director, Prof Phil Butler, having his ankle imaged in early development of MARS PCCT scanning



Timepix3, one of the read-out chips of Medipix. ccs





Featured spectral imaging research

A selection of independent and collaborative research that has used MARS Bioimaging's spectral imaging to capture data and help provide clearer insights into biological or biomaterials characteristics and behaviour.

MARS separated lipid, water and calcium in lamb tissue at ~100 μm without any contrast agent.

R. Aamir et al., 2014 · MARS-CT4 · Medipix3RX

RESULTS

- Lipid-, water- and bone-like components clearly separated
- Composite RGB image showed fat marbling and tissue distribution
- Some cross-talk remained between fat and soft-tissue channels

“We have shown that lipid-like, water-like and calcium-like components of tissue can be distinguished from each other at high spatial resolution (~100 micron).”

STUDY DETAILS

Design Experimental demonstration of spectral molecular imaging

Sample Lamb tissue specimen: muscle, fat and bone

Performance ~100 μm spatial resolution without high-Z contrast

Limitation Narrow range of biological materials; demonstration only

R. Aamir et al. (2014). MARS spectral molecular imaging of lamb tissue: data collection and image analysis. DOI: 10.1088/1748-0221/9/02/P02005

Microlab only - MARS Bioimaging makes no material identification or quantification claims for its Extremity CT Imaging System

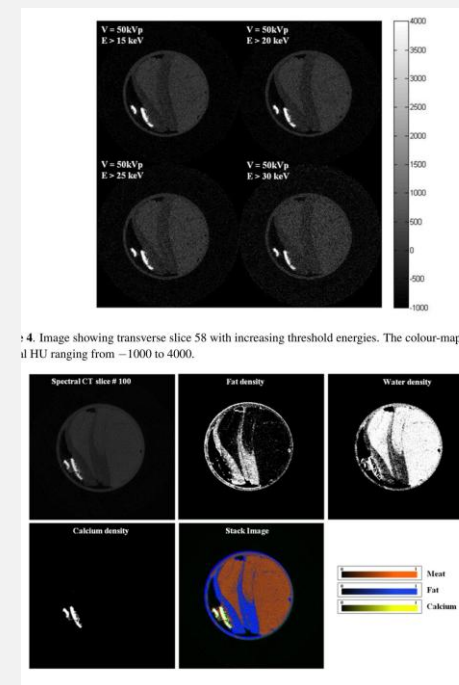


Figure 5, Aamir_2014_J._Inst._9_P02005.pdf (p. 9)

Material decomposition shown — not within the current 510(k) clearance.

Spectral CT distinguished calcium, iodine and barium simultaneously in a single mouse dataset.

N. G. Anderson et al., 2010 · Desktop spectral CT · Medipix2

RESULTS

- Calcium, iodine and barium separated in a single dataset
- Bone conspicuity fell with rising keV; iodine and barium rose to ~30–35 keV
- PCA processing completed in under five minutes

“We have been able to distinguish calcium, iodine and barium on the same dataset in mice and display this as 3D colour images at <55 μm effective pixel size.”

STUDY DETAILS

Design Experimental animal study on desktop spectral CT

Sample Six C57BL/6 mice; iodine and barium contrast

Performance <55 μm effective pixel size

Limitation Imaging time 20–90 minutes per animal

N. G. Anderson et al. (2010). Spectroscopic (multi-energy) CT distinguishes iodine and barium contrast material in mice. DOI: 10.1007/s00330-010-1768-9

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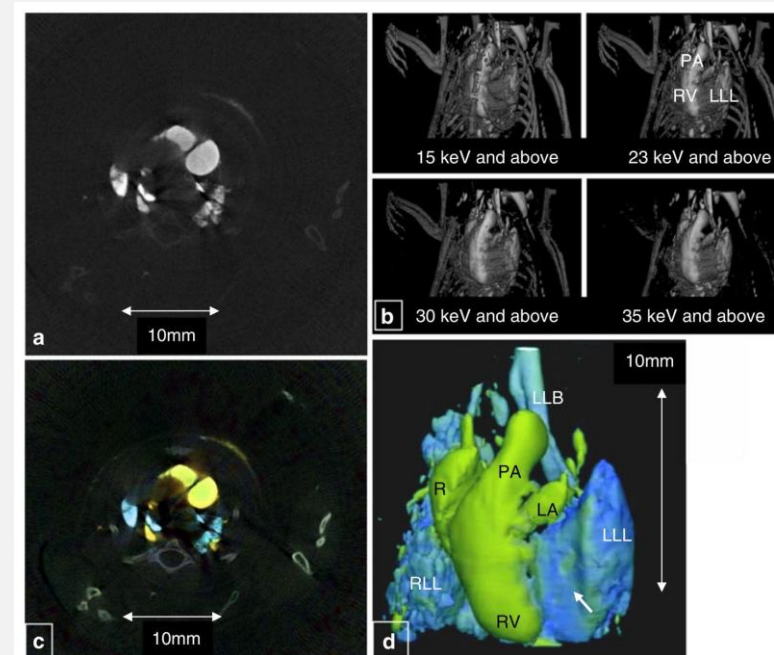


Fig. 5, anderson2010.pdf (p. 7)

Material decomposition shown — not within the current 510(k) clearance.

The MARS-MD rejection algorithm produces sparse material maps that reduce signal crossover between materials.

C. J. Bateman et al., 2018 · MARS v5 · Medipix3RX CZT

RESULTS

- Sparse material-domain solutions reduced crossover and noise fitting
- Both algorithm variants identified materials in the multi-contrast phantom
- Differences limited to boundaries and gadolinium distribution

“...the result of this process is that solutions will be sparse in the material domain, which reduces crossover of signal between material images.”

STUDY DETAILS

Design Technical report with phantom demonstrations

Sample Three multi-material phantoms: Au, Gd, I, Ca

Performance Good separation in multi-contrast phantom

Limitation Degrades where more than two materials share a voxel

C. J. Bateman et al. (2018). MARS-MD: rejection based image domain material decomposition. DOI: 10.1088/1748-0221/13/05/P05020

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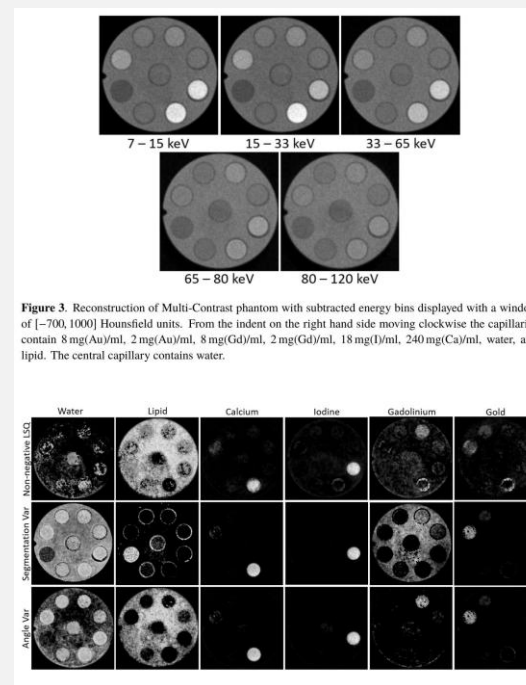


Figure 3, bateman2018.pdf (p. 11)

Material decomposition shown — not within the current 510(k) clearance.

Photon-counting CT as a potential advance over current imaging for articular calcium crystals.

Ilaria Bernabei et al., 2021 · MARS-based system; details not reported

RESULTS

- Highly sensitive for detecting articular cartilage mineralisation
- Only technique able to distinguish CPP from HA crystal deposits
- Excellent correlation with ultrahigh-resolution micro-CT

“Emerging PCD-CT outperformed other clinical imaging techniques for the identification of articular calcium crystal deposition.”

STUDY DETAILS

Design Letter to the Editor; ex vivo

Sample Articular calcium crystal deposition

Performance Not reported

Limitation Brief communication with minimal methodological detail

Ilaria Bernabei et al. (2021). Multi-energy photon-counting CT versus other clinical imaging techniques for the identification of articular calcium crystal deposition. DOI: <https://doi.org/10.1093/rheumatology/keab125>

Microlab only - MARS Bioimaging makes no material identification or quantification claims for its Extremity CT Imaging System

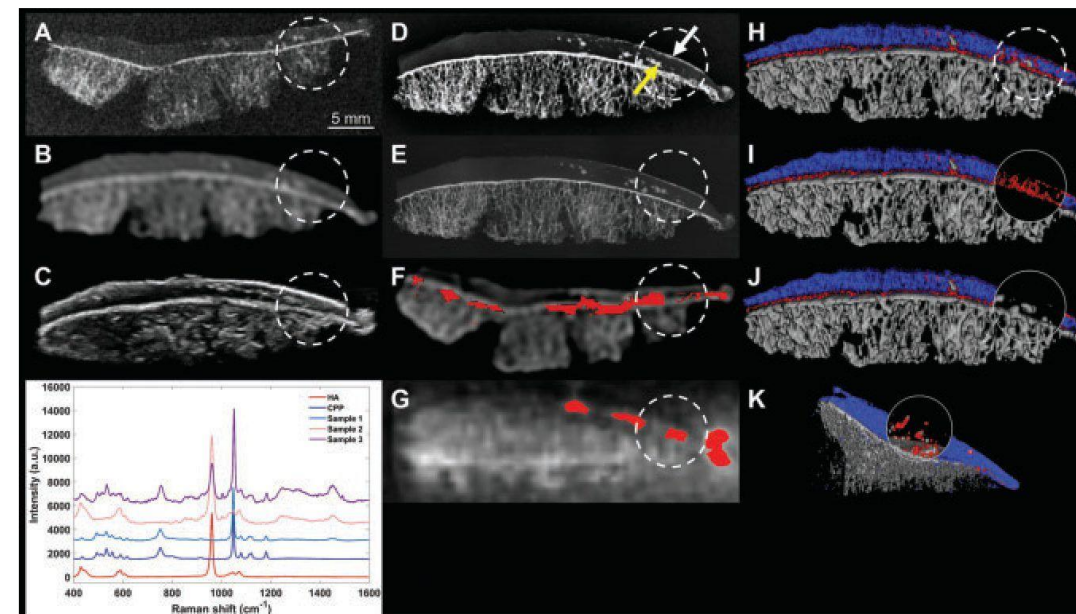


FIG. 1, Bernabei.pdf (p. 2)

Medipix-2 images of excised breast specimens retained all radiologically important detail seen on mammographic film.

A. P. H. Butler et al., 2008 · Medipix-2 detector

RESULTS

- Retained all radiologically important detail of mammographic film
- Fine internal structure including trabeculae clearly visible

“Detectors currently in development, such as Medipix-3, will have multiple energy thresholds allowing for routine use of spectroscopic bio-medical imaging in the future.”

STUDY DETAILS

Design Review with imaging of excised human specimens

Sample Excised human breast specimens with known lesions

Performance Fine internal structure clearly visible

Limitation Early Medipix-2; single-threshold acquisition

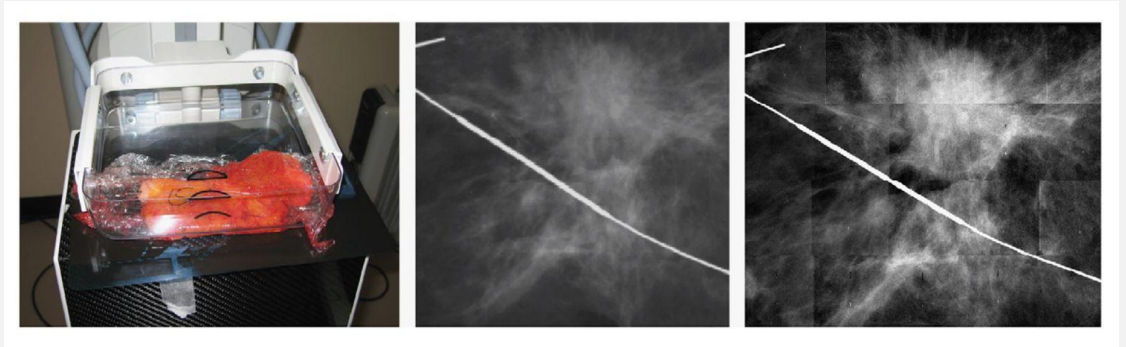


Fig. 2, butler2008.pdf (p. 4)

A. P. H. Butler et al. (2008). Bio-medical X-ray imaging with spectroscopic pixel detectors. DOI: doi:10.1016/j.nima.2008.03.039

SPCCT measured fibrous cap thickness and area in excised carotid plaque with no significant difference from histology.

Shishir Dahal et al., 2022 · Small-bore MARS-11 v5

RESULTS

- Fibrous cap thickness and area not significantly different from histology
- p 0.15–0.51 for cap thickness; 0.053–0.30 for cap area
- Intra-rater reliability for necrotic core ICC 0.92 ($p < 0.001$)

“The result demonstrated a viable technique for quantifying FC thickness, FC area, and LRNC area due to the combined effect of high spatial and energy resolution of SPCCT.”

STUDY DETAILS

Design Single-centre ex vivo cross-sectional observational study

Sample Excised carotid plaques from 20 patients (71±6 years)

Performance 90 μ m isotropic voxels; five energy thresholds

Limitation Ex vivo only; in vivo translation unresolved

Shishir Dahal et al. (2022). Components of carotid atherosclerotic plaque in spectral photon-counting CT with histopathologic comparison. DOI: 10.1007/s00330-022-09155-x

Microlab only - MARS Bioimaging makes no material identification or quantification claims for its Extremity CT Imaging System

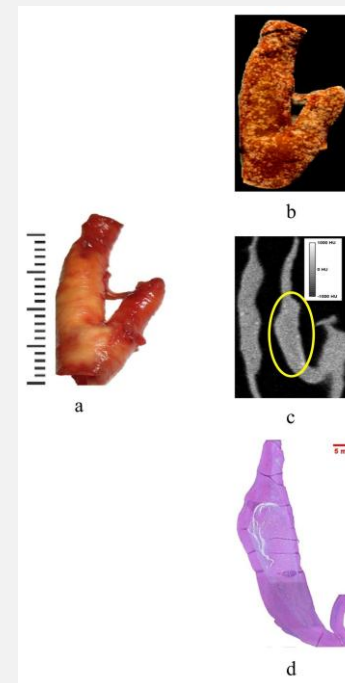


Fig. 1, dahal2022.pdf (p. 3)

Material decomposition shown — not within the current 510(k) clearance.

Applying measured geometric alignment corrections lifted MARS reconstruction quality to just above 30 μm resolution.

A. Gongadze et al., 2015 · MARS scanner · Medipix3.1 GaAs

RESULTS

- Alignment corrections markedly improved reconstruction quality
- Spatial resolution estimated slightly greater than 30 μm
- Independent estimation methods gave consistent results

“The results of different methods are consistent and give an estimation for the tomograph spatial resolution of slightly greater than 30 microns.”

STUDY DETAILS

Design Experimental alignment study at JINR, Dubna

Sample QRM bar-pattern resolution phantom

Performance Final spatial resolution slightly above 30 μm

Limitation Bench study; no biological samples imaged

A. Gongadze et al. (2015). Alignment and Resolution Studies of a MARS CT Scanner. DOI: <https://doi.org/10.1134/S1547477115050064>

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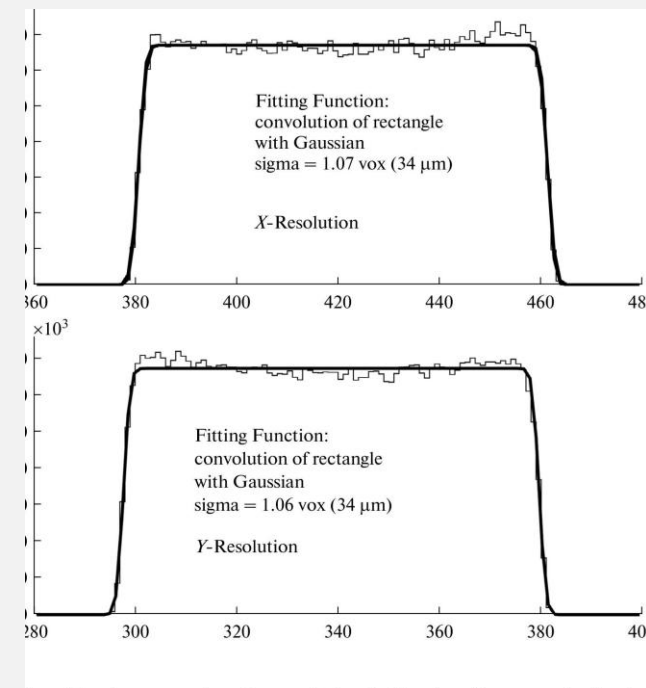


Fig. 20, gongadze2015.pdf (p. 9)

Energy-resolved attenuation on the MARS Micro-CT differentiated materials that conventional CT cannot separate.

Peng He et al., 2012 · MARS Micro-CT · Medipix MXR

RESULTS

- Energy-resolved attenuation enabled material differentiation
- K-edge plots for iodine and barium consistent with theory
- PCA produced three eigenimages and a true-colour composite

“The MARS micro-CT system provides significant attenuation information at different energy windows for the imaged materials, which can help to distinguish different material components in a way that is impossible using conventional x-ray CT systems.”

STUDY DETAILS

Design Preliminary experimental study, Virginia Tech–Wake Forest

Sample Multi-material phantom with iodine and barium

Performance 12 energy windows between 25 and 40 keV

Limitation K-edges broadened by finite energy windows

Peng He et al. (2012). Preliminary experimental results from a MARS Micro-CT system. DOI: 10.3233/XST-2012-0329

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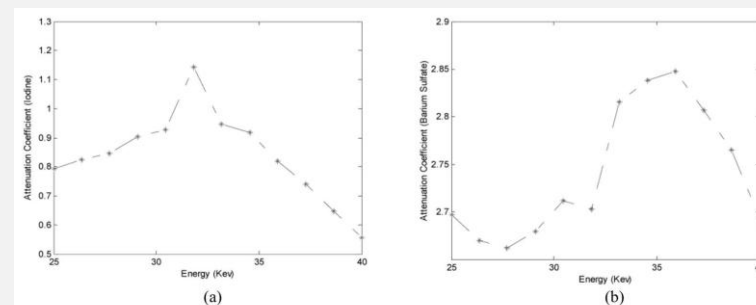


Fig. 4. (a) and (b) are the attenuation-versus- energy plots of iodine and barium sulfate sample, respectively.

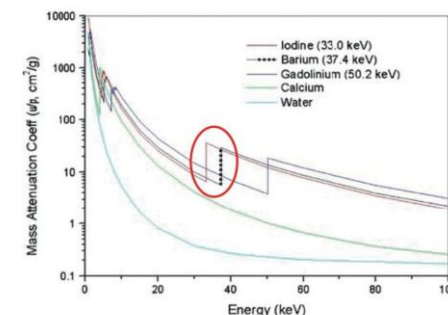


Fig. 4, he2012.pdf (p. 7)

Material decomposition shown — not within the current 510(k) clearance.

In vitro measurement confirmed that Hounsfield units vary with energy, motivating a spectral HU notation.

M. A. Hurrell et al., 2012 · MARS spectral CT · Medipix3 silicon

RESULTS

- Theoretical HU–energy variation confirmed by in vitro measurement
- Proposed HU_keV format stating the mean energy of the image

“Because radiologists are already familiar with the Hounsfield Unit (HU), it is proposed that a modified HU be used that includes the mean energy used to obtain the image, as a conceptual bridge between conventional CT and SCT.”

STUDY DETAILS

Design Experimental in vitro study on prototype spectral CT

Sample 9.5 mm phantom containing several substances

Performance Thresholds at ~5 keV intervals, 75 kVp

Limitation Silicon sensor restricted thresholds to low energies

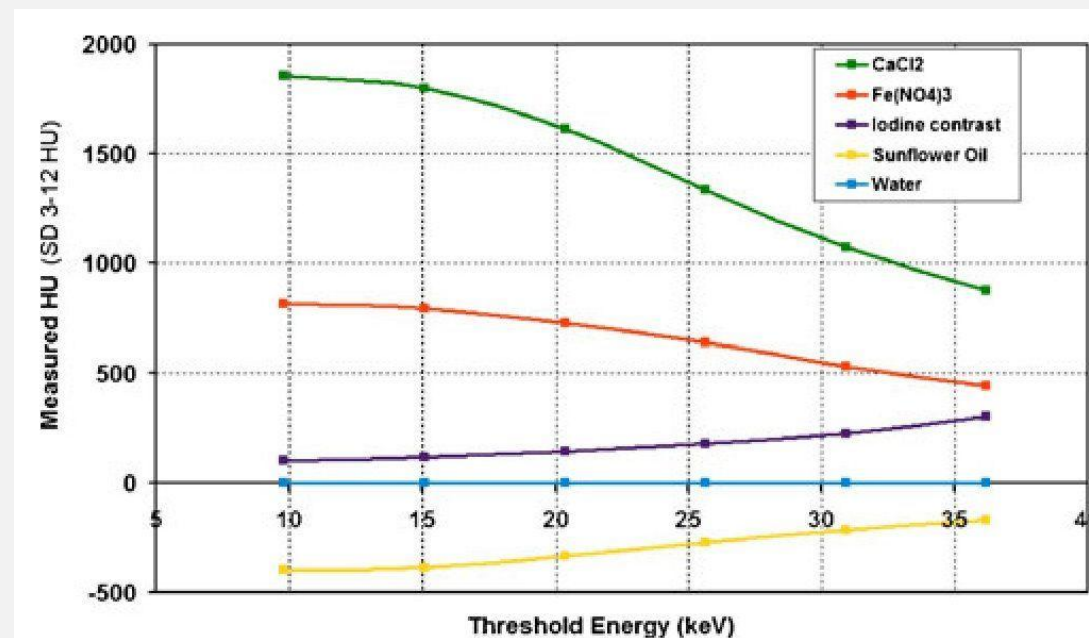


Fig. 6, hurrell2011.pdf (p. 5)

M. A. Hurrell et al. (2012). Spectral Hounsfield units: a new radiological concept. DOI: <https://doi.org/10.1007/s00330-011-2348-3>

Microlab only - MARS Bioimaging makes no material identification or quantification claims for its Extremity CT Imaging System

MARS CT revealed the polyethylene and tibial tray wear behind a failed knee implant that four standard modalities missed.

Lawrence C. M. Lau et al., 2021 · Preclinical MARS · five Medipix3RX

RESULTS

- Posteromedial polyethylene and tibial tray wear clearly shown
- Wear not seen on radiograph, fluoroscopy, ultrasound or MRI
- Material maps separated bone, cement, metal and polyethylene

“MARS can identify polyethylene insert and metallic tibial tray wear as a cause of TKA failure, that could not be identified with... standard pre-operative imaging.”

STUDY DETAILS

Design Case review against routine pre-operative imaging

Sample Extracted total knee arthroplasty prosthesis

Performance 0.09 mm isotropic voxels; five energy thresholds

Limitation Single case; clinical system under development

Lawrence C. M. Lau et al. (2021). Multi-energy spectral photon-counting computed tomography (MARS) for detection of arthroplasty implant failure. DOI: doi.org/10.1038/s41598-020-80463-2

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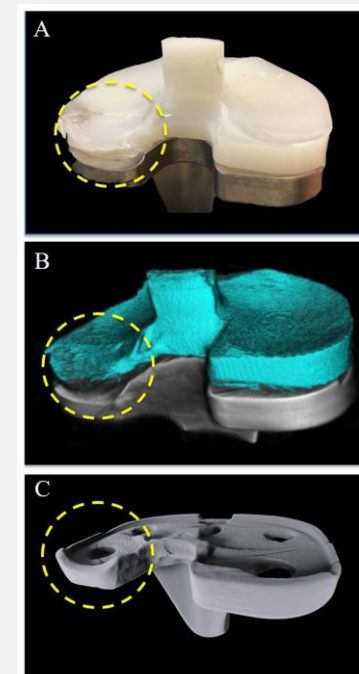


Figure 3, lau2021.pdf (p. 4)

Material decomposition shown — not within the current 510(k) clearance.

Raising tube current by 160% increased dose sharply while improving image quality by under 10%, favouring low-dose protocols.

Emmanuel Marfo et al., 2021 · MARS-11 v5 small-bore

RESULTS

- Tube current 24→54 μA increased dose by more than 160%
- SNR and resolution improved by under 10%; Gd identification under 20%
- HA identification above 80% correct at all tube currents
- Mouse images free of streak and beam-hardening artefact

“The results suggest that the energy resolving capability of photon-counting CT maintains diagnostically relevant image quality with high levels of material discrimination at reduced radiation dose.”

STUDY DETAILS

Design Phantom study with in vivo mouse dosimetry

Sample Gd/HA phantoms plus one gadolinium-injected mouse

Performance Mean absorbed dose 27.3 ± 2.4 mGy, below typical micro-CT

Limitation Single contrast agent; older scanner generation

Emmanuel Marfo et al. (2021). Assessment of material identification errors, image quality and radiation doses using small animal spectral photon-counting CT. DOI: 10.1109/TRPMS.2020.3003260

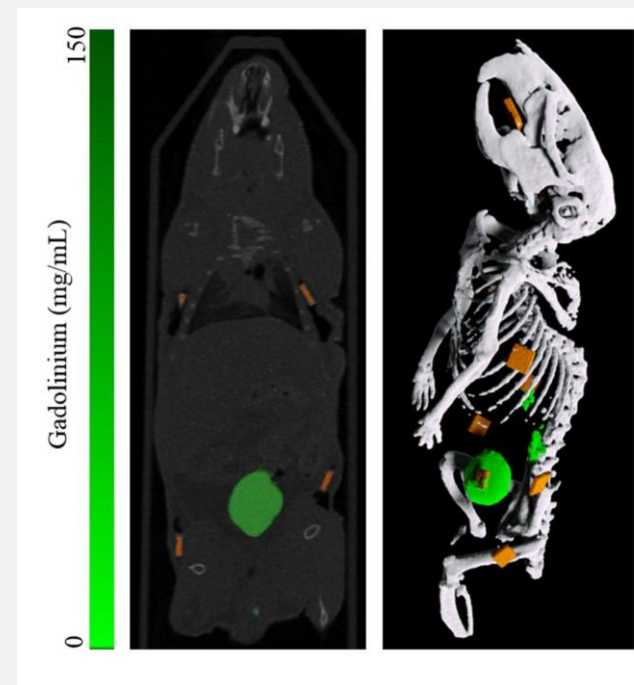


Fig. 9, marfo2021.pdf (p. 16)

Material decomposition shown — not within the current 510(k) clearance.

The CZT Medipix3RX delivered 98.8% working pixels and 2.5 keV energy resolution, making it suitable for spectral micro-CT.

Jeffrey F. Marsh et al., 2018 · Prototype MARS-1 · CZT Medipix3RX

RESULTS

- 98.8% of pixels functioning (16,193 of 16,384)
- Whole-chip response linear over one hour with low variation
- Energy resolution 2.5 keV FWHM single pixel, 3.7 keV full image

“The high yield of properly functioning pixels (98.8%), long-term stability... and energy resolution ... make this device suitable for spectral micro-CT.”

STUDY DETAILS

Design Systematic detector evaluation at Mayo Clinic

Sample CZT Medipix3RX with 30.5 mm Plexiglas phantom

Performance Four simultaneous threshold counters

Limitation Pile-up risk above 10 counts per ms per pixel

Jeffrey F. Marsh et al. (2018). Evaluation of a photon counting Medipix3RX cadmium zinc telluride spectral X-ray detector. DOI: 10.1117/1.JMI.5.4.043503

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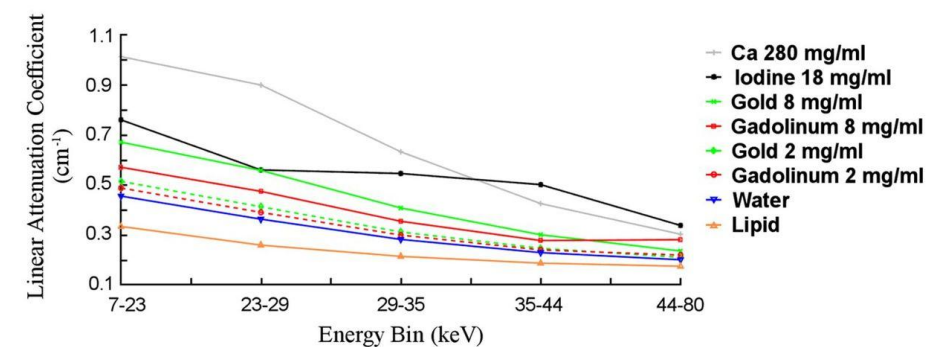


Fig. 13, JMI-005-043503.pdf (p. 10)

Targeted hafnia nanodots bound bone microdamage and were quantified separately from bone and soft tissue.

F. Ostadhossein et al., 2019 · Small-bore preclinical MARS

RESULTS

- Targeted nanodots accumulated at bone microdamage sites
- Hafnium clearly separated from bone and soft tissue
- R^2 above 0.97 for Hf and HA calibration curves
- $\sim 2.5\times$ higher total Hf at damage sites versus contralateral limb

“These HfO_2 based nanoparticles could potentially be used for the anatomical evaluations in the future.”

STUDY DETAILS

Design Phantom, ex vivo human bone and in vivo rat study

Sample Rat tibial microdamage model and human bone

Performance Energy resolution ~ 2.5 keV; four bins to 118 keV

Limitation Preclinical, small n; surgically induced microdamage

F. Ostadhossein et al. (2019). Multi-“color” delineation of bone microdamages using ligand-directed sub-5 nm hafnia nanodots and photon-counting CT imaging. DOI: 10.1002/adfm.201904936

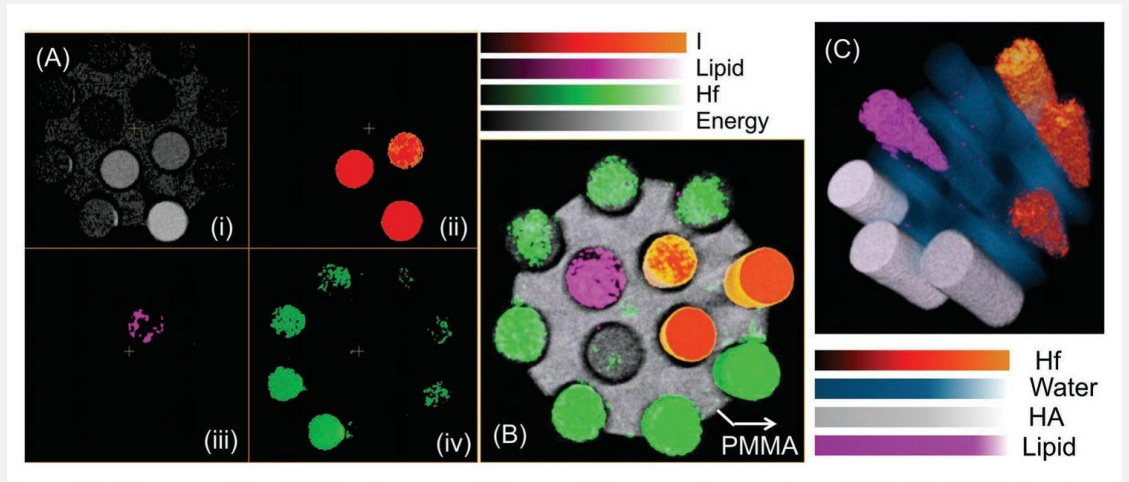


Figure 6, ostadhossein2019.pdf (p. 7)

Material decomposition shown — not within the current 510(k) clearance.

Optimised energy thresholds let MARS discriminate iodine, gadolinium and gold simultaneously in one scan.

R. K. Panta et al., 2018 · Preclinical MARS · CdTe-Medipix3RX

RESULTS

- Iodine, gadolinium and gold discriminated in a single scan
- Ranking method optimised thresholds for high-Z discrimination
- Maximum K-factor for iodine approximately 668%

“A photon-counting spectral CT using four energy thresholds of 27, 33, 49 and 81 keV at 118 kVp simultaneously discriminated three contrast agents... in a single scan.”

STUDY DETAILS

Design Experimental phantom study of multi-contrast discrimination

Sample 33 mm phantom: iodine, gadolinium, gold and calcium

Performance Thresholds 27, 33, 49 and 81 keV at 118 kVp

Limitation Sensitive to noise, scatter and sample size

R. K. Panta et al. (2018). Element-specific spectral imaging of multiple contrast agents: a phantom study. DOI: 10.1088/1748-0221/13/02/T02001

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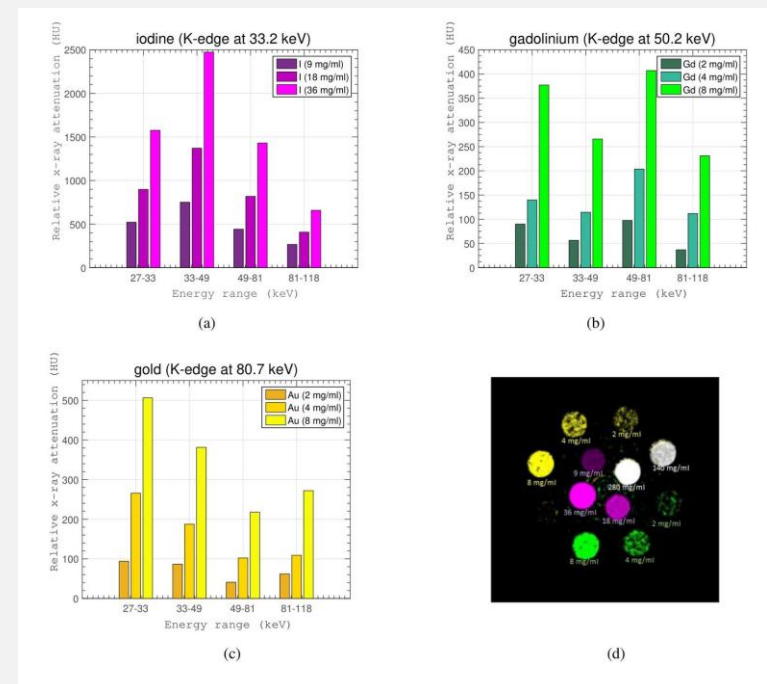


Figure 5, panta2018.pdf (p. 13)

Material decomposition shown — not within the current 510(k) clearance.

Two automated calibration techniques agreed within 1 keV, giving a practical daily QC method for spectral detectors.

Raj Kumar Panta et al., 2015 · Pre-clinical scanner · CdTe-Medipix3RX

RESULTS

- Both kVp-stepping and XRF practical as daily QC tools
- Methods agreed within 1 keV at 59.5 keV
- XRF faster and more efficient than radioisotope methods

“The comparison of these two techniques shows the energy difference of 1 keV at 59.5 keV which is less than the spectral resolution of the detector (full-width at half-maximum of 8 keV at 59.5 keV).”

STUDY DETAILS

Design Experimental validation of two calibration techniques

Sample CdTe-Medipix3RX detector; Mo, Pd, In, Ta, Pb targets

Performance Spectral resolution 8 keV FWHM at 59.5 keV

Limitation XRF technique requires metallic foil targets

Raj Kumar Panta et al. (2015). Energy Calibration of the Pixels of Spectral X-ray Detectors. DOI: 10.1109/TMI.2014.2337881

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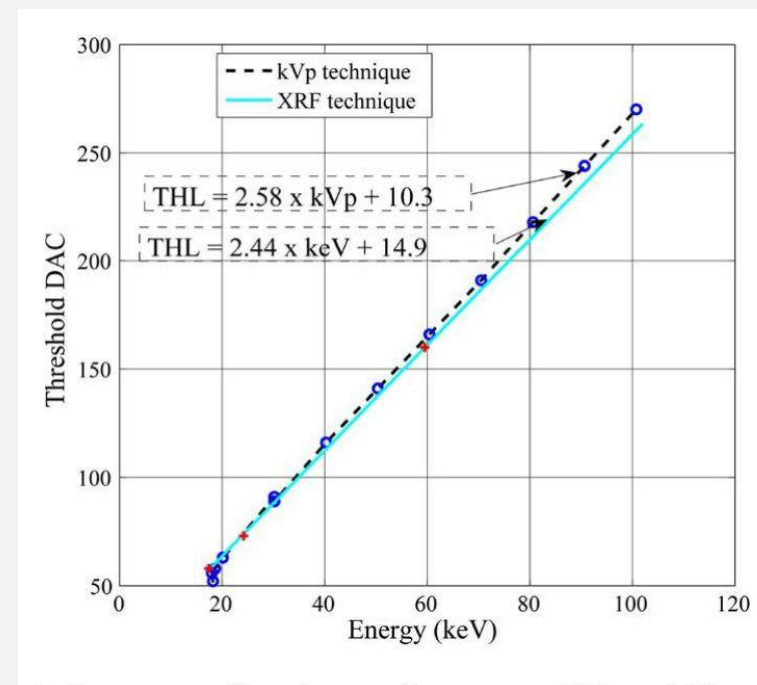


Fig. 12, panta2015.pdf (p. 8)

Filtered and unfiltered protocols produced markedly different material identification errors, 38% versus 58% for gadolinium.

Aamir Younis Raja et al., 2018 · MARS spectral scanner · CdTe Medipix3RX

RESULTS

- Large identification differences between filtered and unfiltered protocols
- Gd at 8 mg/mL underestimated by over 50% when unfiltered
- Misidentification at 1 mg/mL Gd: 38% filtered versus 58% unfiltered
- Hydroxyapatite also mis-quantified in unfiltered scans

“The advantage of spectral imaging... is to differentiate and quantify multiple biomarkers and drug penetration into the target tissue at the same scan.”

STUDY DETAILS

Design Comparison of filtered and unfiltered scanning protocols

Sample Gd/HA calibration phantom and bovine knee plugs

Performance Sensitivity and specificity used to capture errors

Limitation Sparse decomposition fails with mixed-material voxels

Aamir Younis Raja et al. (2018). Measuring Identification and Quantification Errors in Spectral CT Material Decomposition. DOI: <https://doi.org/10.3390/app8030467>

Microlab only - MARS Bioimaging makes no material identification or quantification claims for its Extremity CT Imaging System

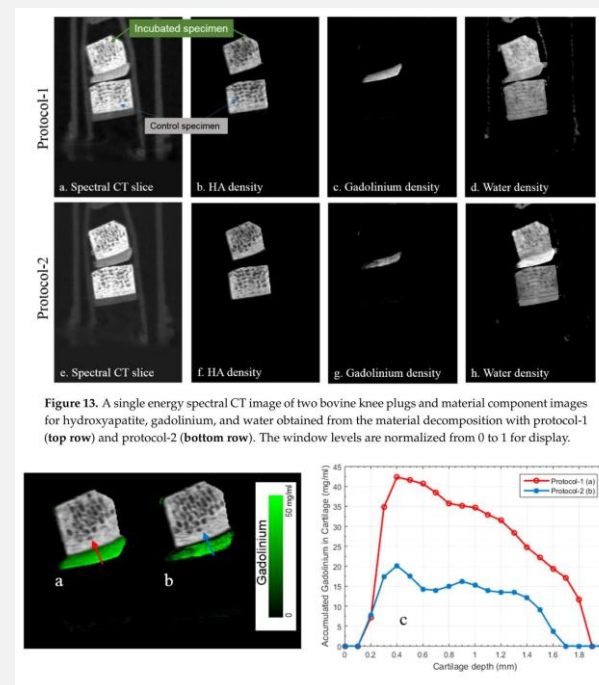


Figure 13, raja2018.pdf (p. 14)

Material decomposition shown — not within the current 510(k) clearance.

Acquiring in narrow high-energy bins with CdTe-Medipix3RX reduced both beam hardening and metal streak artefact.

K. Rajendran et al., 2014 · MARS · CdTe Medipix3RX, charge summing

RESULTS

- Beam hardening and metal artefact reduced in narrow high-energy bins
- CdTe charge-summing outperformed silicon Medipix3.1
- Clear reduction in cupping and metal streak artefact

“The results show reduction in beam hardening effects and metal artefacts in the narrow high energy range acquired using the spectroscopic detector.”

STUDY DETAILS

Design Experimental study on metal and biomaterial samples

Sample Titanium phantom, Ti and Mg scaffolds, Ti mesh

Performance Charge summing mode with 2 mm CdTe at 80 kVp

Limitation Bench samples only; no clinical validation

K. Rajendran et al. (2014). Reducing beam hardening effects and metal artefacts in spectral CT using Medipix3RX. DOI: 10.1088/1748-0221/9/03/P03015

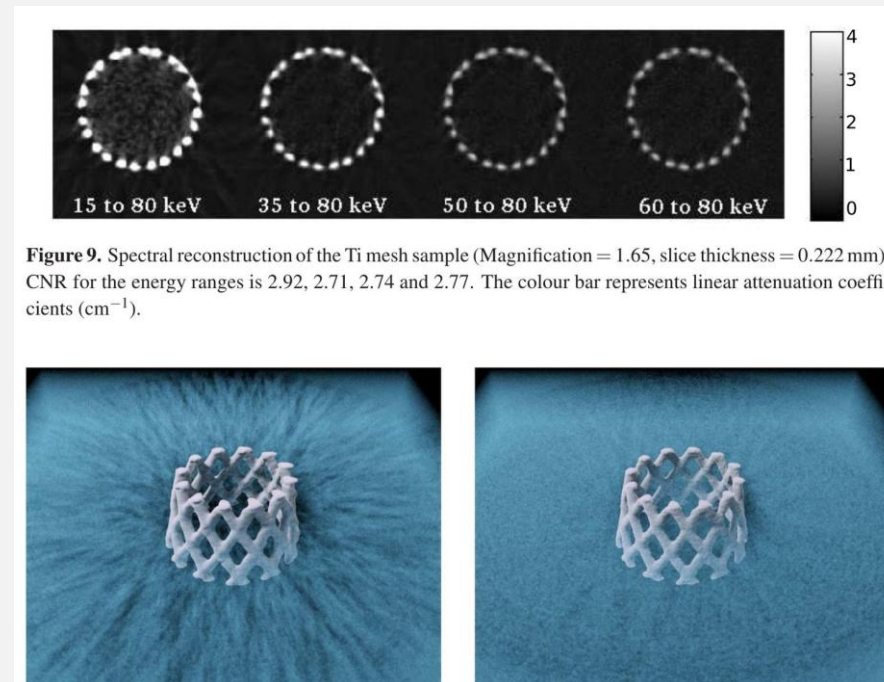


Figure 9, rajendran2014.pdf (p. 12)

Constrained least-squares decomposition quantified calcium and fat in soft tissue with R^2 above 0.99.

J. P. Ronaldson et al., 2012 · MARS-CT micro-CT · Medipix3 silicon

RESULTS

- Up to three materials quantified by constrained least squares
- R^2 above 0.99 for calcium and fat quantification
- Plaque and mouse decompositions consistent with expected composition

“The information content of spectral CT measurements... indicates that Fe and Ca are practically indistinguishable when present together in soft tissues.”

STUDY DETAILS

Design Experimental study on phantoms and biological specimens

Sample Phantoms plus excised human plaque and mouse

Performance Constrained least squares with volume constraints

Limitation Calcium and iron indistinguishable when co-located

J. P. Ronaldson et al. (2012). Toward quantifying the composition of soft tissues by spectral CT with Medipix3. DOI: <https://doi.org/10.1118/1.4760773>

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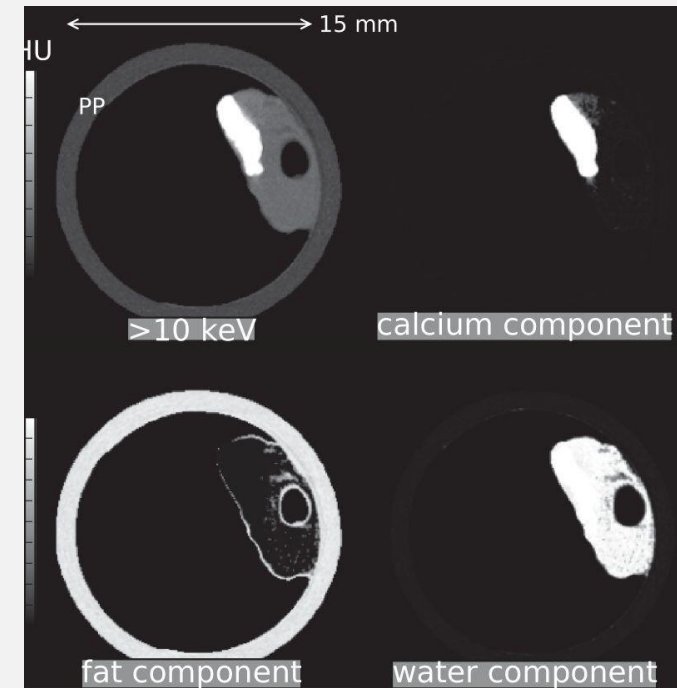


FIG. 8, ronaldson2012.pdf (p. 9)

Material decomposition shown — not within the current 510(k) clearance.

MARS SPCCT estimated electron density and proton stopping power more accurately than a clinical dual-energy CT.

Mikaël Simard et al., 2020 · MARS photon-counting scanner

RESULTS

- Electron density RMSE 0.89% versus 1.09% for dual-energy CT
- Proton stopping power RMSE reduced from 1.92% to 0.89%
- Iodine RMSE 0.12 versus 0.27 mg/mL; gadolinium RMSE ~0.23 mg/mL
- Bone accuracy comparable between the two modalities

“A MARS photon-counting scanner provides superior accuracy compared to a Siemens SOMATOM Definition Flash DECT scanner to quantify physical parameters relevant to radiotherapy.”

STUDY DETAILS

Design Phantom study benchmarked against clinical dual-energy CT

Sample Gammex 467 and 472 tissue-equivalent phantoms

Performance Four energy channels; MAP eigentissue decomposition

Limitation Gammex inserts differ chemically from real tissue

Mikaël Simard et al. (2020). Quantitative imaging performance of MARS spectral photon-counting CT for radiotherapy. DOI: 10.1002/mp.14204

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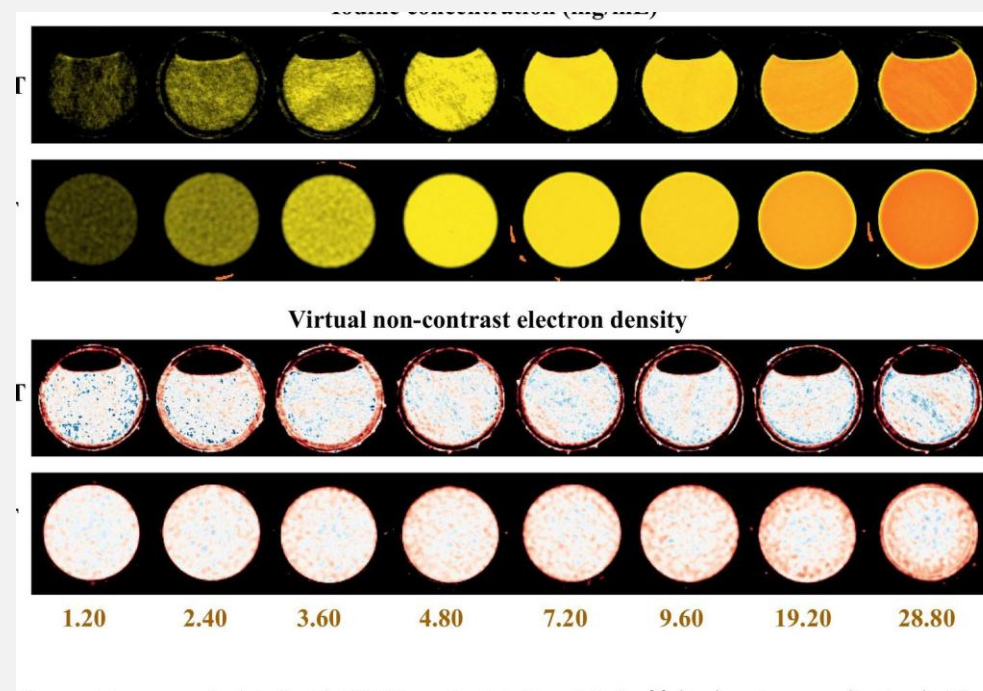


FIG. 6, Simrad.pdf (p. 25)

Material decomposition shown — not within the current 510(k) clearance.

Multi-energy SPCCT detected monosodium urate crystals with AUC above 0.99, exceeding published dual-energy CT accuracy.

Lisa K. Stamp et al., 2019 · MARS spectral scanner

RESULTS

- AUC above 0.99 for monosodium urate detection
- Exceeds the 0.96 AUC reported for DECT in meta-analysis
- Energy bins 20–30 and 30–40 keV used for urate analysis

“Overall, the differentiation of MSU from both calcium crystals was excellent (area under the receiver operating characteristic curve (AUC) > 0.99 for the 20-30 keV energy bin).”

STUDY DETAILS

Design Brief ex vivo report on crystal detection

Sample Monosodium urate crystal deposits

Performance Very high diagnostic accuracy (AUC > 0.99)

Limitation Lower detection limits not yet established

Lisa K. Stamp et al. (2019). Clinical utility of multi-energy spectral photon-counting CT in crystal arthritis. DOI: 10.1002/art.40848

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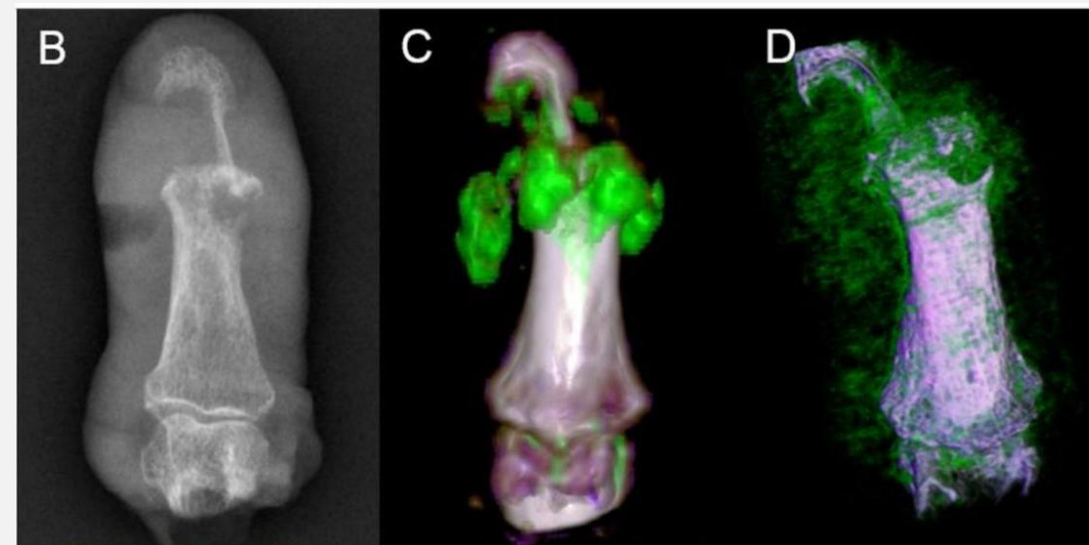


Figure 1, Stamp2019.pdf (p. 15)

Higher energy bins cut metal artefact and improved SNR by up to 25% while keeping quantification accuracy above 85%.

Briya Tariq et al., 2024 · MARS SPCCT Microlab 5×120

RESULTS

- Metal artefact decreased in higher energy bins
- Signal-to-noise ratio improved by up to 25%
- Iodine accuracy 86% with steel present (AUC 74%)
- Hydroxyapatite RMSE 0.11 mg/cm³ with steel insert

“Results show decreased metal artefacts and a better signal-to-noise ratio (up to 25%) with increased energy bins as compared to reference data.”

STUDY DETAILS

Design Experimental phantom and ex vivo study with metal inserts

Sample HA/iodine phantom; bovine femur with steel plate

Performance Five energy bins from 7 to 118 keV

Limitation Limited metal types; single bovine specimen

Briya Tariq et al. (2024). Assessment of material identification and quantification in the presence of metals using spectral photon counting CT. DOI: 10.1371/journal.pone.0308658

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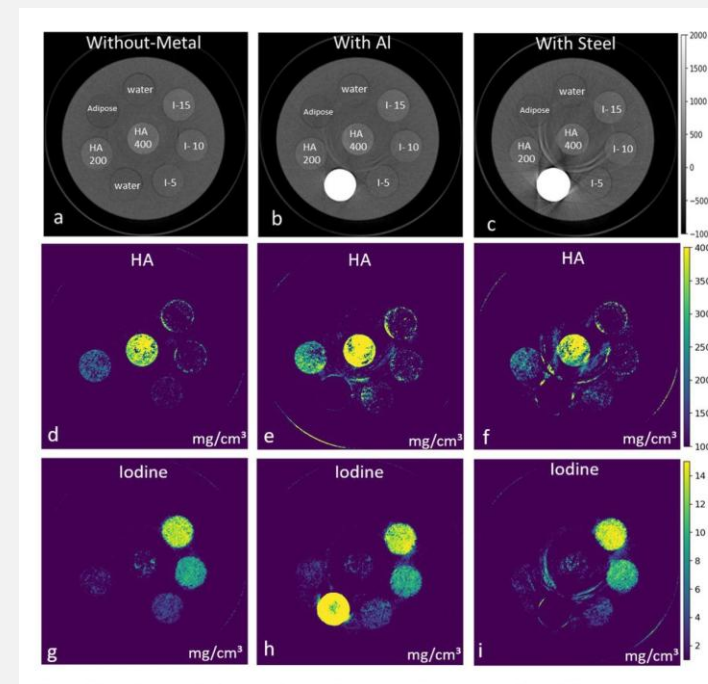


Fig 6, Tariq2024.pdf (p. 10)

Material decomposition shown — not within the current 510(k) clearance.

Eight simultaneous thresholds on Medipix3.1 separated iodine, calcium, fat and water in phantom and mouse.

M. F. Walsh et al., 2013 · MARS-CT · quad Medipix3.1 silicon

RESULTS

- Iodine, calcium, fat and water separated by material decomposition
- Gold nanoparticles separated from tissue and bone in the mouse
- Medipix3.1 more stable than Medipix3.0 in temperature and equalisation

“Using this spectroscopic data, we have been able to separate iodine, calcium, fat and water using an in-house material decomposition algorithm.”

STUDY DETAILS

Design Experimental animal and phantom validation study

Sample Mouse with gold nanoparticles; multi-contrast phantom

Performance Eight simultaneous thresholds between 15 and 29 keV

Limitation High-Z K-edges outside the usable energy range

M. F. Walsh et al. (2013). Spectral CT data acquisition with Medipix3.1. DOI: 10.1088/1748-0221/8/10/P10012

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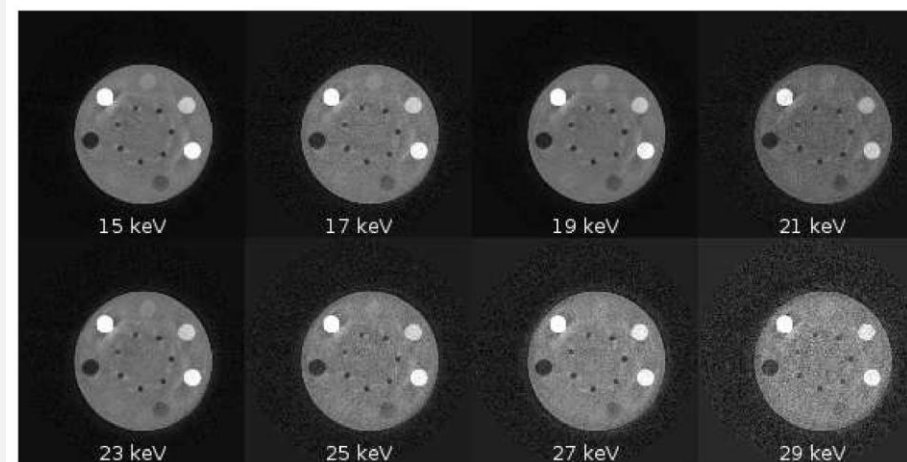


Figure 5. 8 energy CT reconstructions of the spectral phantom, taken with the Medipix3.1. The energy counters were all taken in a single acquisition per rotation step. The capillaries contain (from the top position and going clockwise) a gadolinium complex, an iodine complex, calcium chloride, canola oil, water, air and a contrast agent containing gold nano-particles, respectively. The decomposed image of this phantom is shown in figure 7.

Figure 5, walsh2013.pdf (p. 8)

Material decomposition shown — not within the current 510(k) clearance.

Vulnerable carotid plaque components proved spectrally distinguishable at 38 μm and consistent with histology.

R. Zainon et al., 2012 · MARS-CT · quad Medipix3.0 silicon

RESULTS

- Plaque components spectrally distinguishable within the same voxel
- Lipid distinguished from water-like components in plaque
- Decomposed images matched complex plaque morphology on histology

“The components of vulnerable plaque... have identifiably different attenuation curves across the energies, making them spectrally distinguishable in the same voxel in phantoms.”

STUDY DETAILS

Design Experimental ex vivo study with histological comparison

Sample Excised human carotid plaques

Performance 38 μm voxel size; dose 1 mGy/s

Limitation Iron-like images not cleanly recoverable

R. Zainon et al. (2012). Spectral CT of carotid atherosclerotic plaque: comparison with histology. DOI: <https://doi.org/10.1007/s00330-012-2538-7>

Microlab only - MARS Bioimaging makes no material identification or quantification claims for its Extremity CT Imaging System

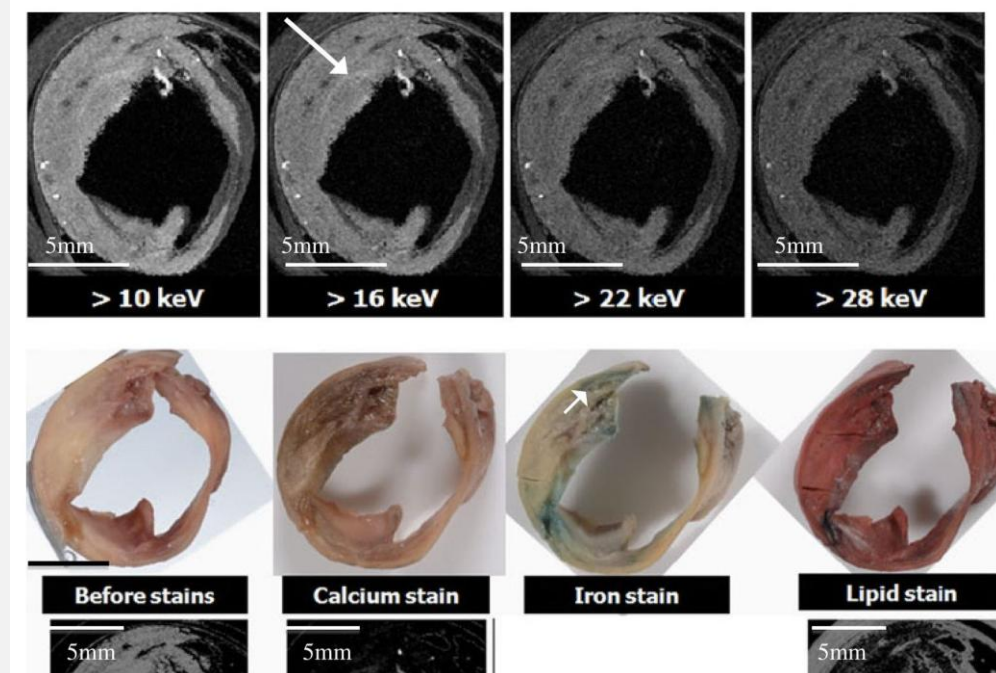


Fig. 3, zainon2012.pdf (p. 5)

Material decomposition shown — not within the current 510(k) clearance.

Abbreviations

SPCCT Spectral photon-counting computed tomography

PCD-CT Photon-counting detector CT

MDCT Multi-detector computed tomography

DECT Dual-energy computed tomography

MD Material decomposition

HU Hounsfield unit

keV / kVp Kiloelectronvolt (photon energy) / peak kilovoltage (tube setting)

CSM Charge summing mode

CZT / CdTe Cadmium zinc telluride / cadmium telluride sensor

SNR / CNR Signal-to-noise ratio / contrast-to-noise ratio

MTF Modulation transfer function

AUC Area under the receiver operating characteristic curve

ICC Intraclass correlation coefficient

RMSE Root mean square error

CI Confidence interval

MSU Monosodium urate (gout crystal)

CPP Calcium pyrophosphate crystal

HA Hydroxyapatite

TKA Total knee arthroplasty

FC / LRNC Fibrous cap / lipid-rich necrotic core

SPR Proton stopping power ratio

PCA Principal component analysis

OSEM / ART / FBP Iterative and analytic reconstruction algorithms

XRF X-ray fluorescence

Contact

www.marsbioimaging.com