5th Workshop on Medical Applications of Spectroscopic X-ray Detectors

Workshop Summary

29 Aug 2022, 10:00 → 1 Sept 2022, 18:00 Europe/Zurich

503/1-001 - Council Chamber (CERN)

Anthony Butler
Radiologist and Physicist

CERN

University of Otago

mars
Medipix All Resolution System

Disclaimer

My job is as a clinician; My hobbies are physics and engineering

My apologies about terrible pronunciation of names

Listening, understanding, and writing simultaneously is hard

Since 2005 I’ve been associated with CERN, CMS, and Medipix

I am a founder of MARS Bioimaging Ltd

Overview

- Participants and submissions
- Context
- Review of talks
- Conclusions

CERN

- Participants
- Context
- Review of talks
- Conclusions

CERN

Scientific committee

Michael Campbell, CERN

Anthony Butler, Univ. of Otago & MARS Bioimaging

Steffen Kappler, Siemens Healthcare

Yoad Yagil, Philips Research Laboratories

Katsuyuki (Ken) Taguchi, Johns Hopkins University

Richard Thompson, Canon Medical Research

Brian Yanoff, GE Global Research

Initiation only for several reasons

... with lots of assistance from **Patricia Mage-Granados**

Participants

113 registrants

2019 => 119

2017 => 130

2015 => 112

2013 => 102

2011 => 76

58 Industry; 23 Scientists; 32 Medical

most are returning guests

- Participants and submissions
- Context
- Review of talks
- Conclusions

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Context

The beginning…

Erik Heijne, Robert Klanner, Gehard Lutz

2017 High Energy and Particle Physics Prize of EPS

"for their pioneering contributions to the development of silicon microstrip detectors that revolutionised high-precision tracking and vertexing in high energy physics experiments"

Context

The beginning…

It is photon processing

Erik Heijne, Robert Klanner, Gehard Lutz

2017 High Energy and Particle Physics Prize of EPS

"for their pioneering contributions to the development of silicon microstrip detectors that revolutionised high-precision tracking and vertexing in high energy physics experiments"

Context

Before SpecXray

Early ’80s, direct Si detectors

– Erik Heijne, Robert Klanner, Gehard Lutz

Their role is recognized by the 2017 High Energy and Particle Physics Prize of EPS

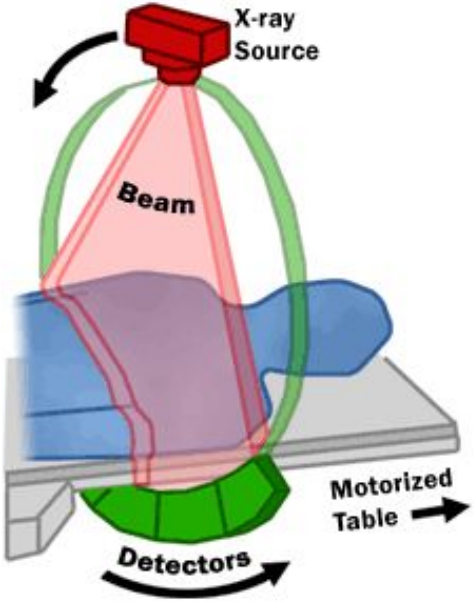
Mid ’90s, Medipix – Michael Campbell

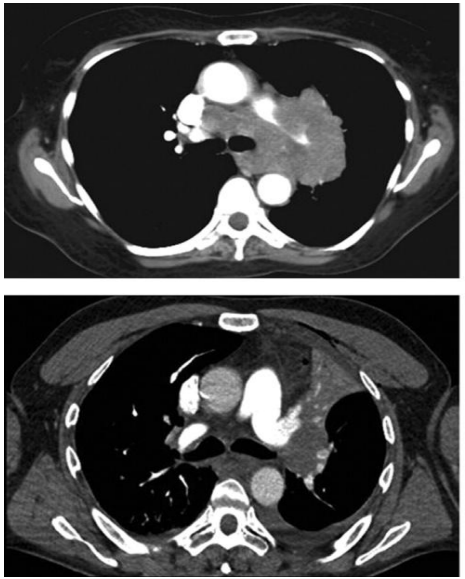
“Various applications like Medical Imaging should profit”

CERN

Context

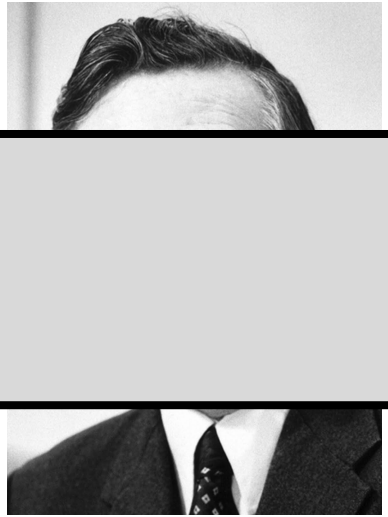
Hounsfield,
Nobel Prize 1979



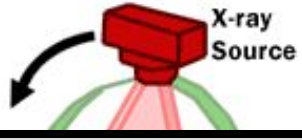


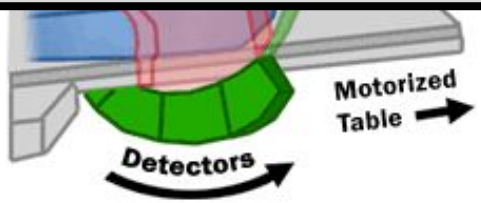
Computed Tomography is 3D X-rays

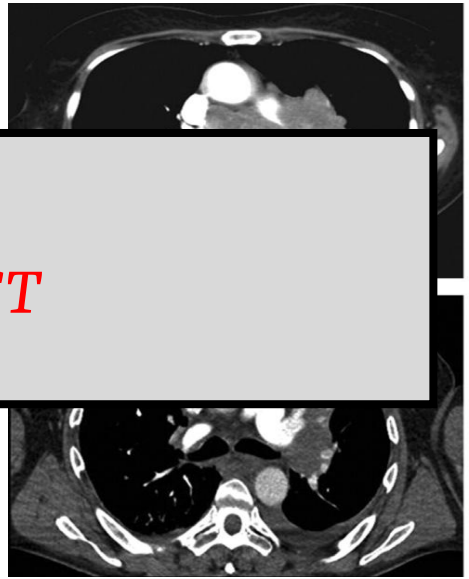
Context



Hounsfield,
Nobel Prize 1979



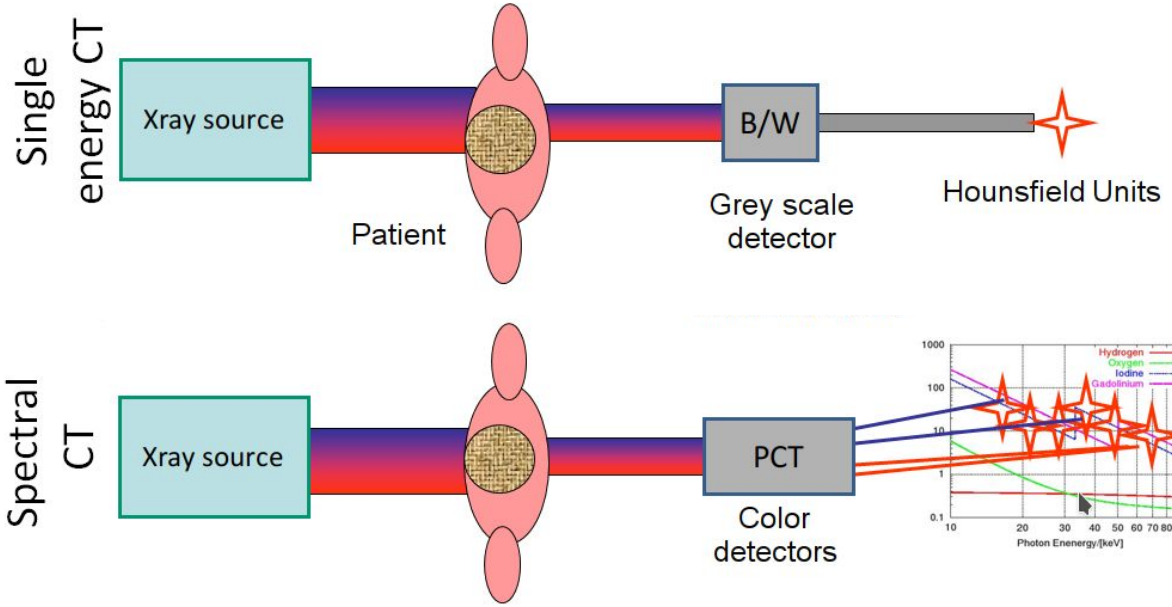




300,000,000 people per year get a CT

Computed Tomography is 3D X-rays

Context



Spectral CT is true colour x-ray imaging

Context

SpecXray 2011

Outside our community
there was a lot of skepticism

- ***It can not be done***

- ***It is not worth doing***

CERN

Context

SpecXray 2011

Outside our community
there was a lot of skepticism

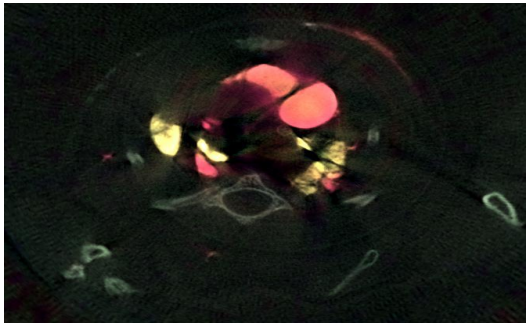
- ***It can not be done*** ← *I don't know how to do it*

- ***It is not worth doing*** ← *Uses are beyond my imagination*

CERN

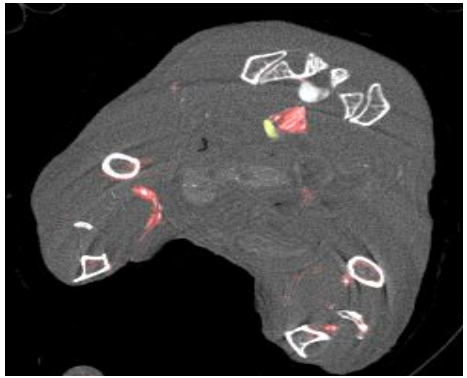
Context

SpecXray 2011



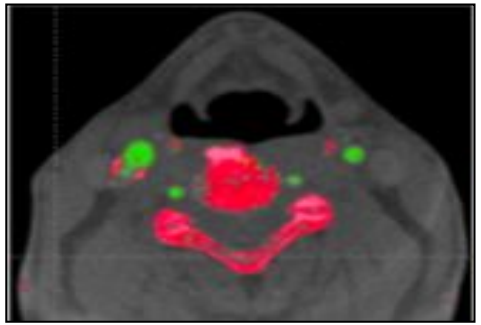
Mouse, 2 contrast agents

Anthony Butler



Mouse, functional agents

Ewald Roessel



First Human Photon counting CT,

Jerry Arenson

MARS, Philips, and GE Healthcare

Context

SpecXray 2011

Outside our community there was a lot of skepticism

- ***It can not be done***
- ***It is not worth doing***

"This may even be real"

Jerry Arenson

- Clinician want more information
- The technology is almost there
- Many people see widespread benefit

CERN

Context

It was nice to reconnect after 3 years !!!

Context - clinical use is here

Siemens Naeotom scanner
… many more systems coming

Feature | Computed Tomography (CT) | October 04, 2021 | By Dave Fornell, DAIC Editor

First Photon-counting CT System Cleared by the FDA

FDA and CT experts say this is the start of a paradigm shift in CT technology

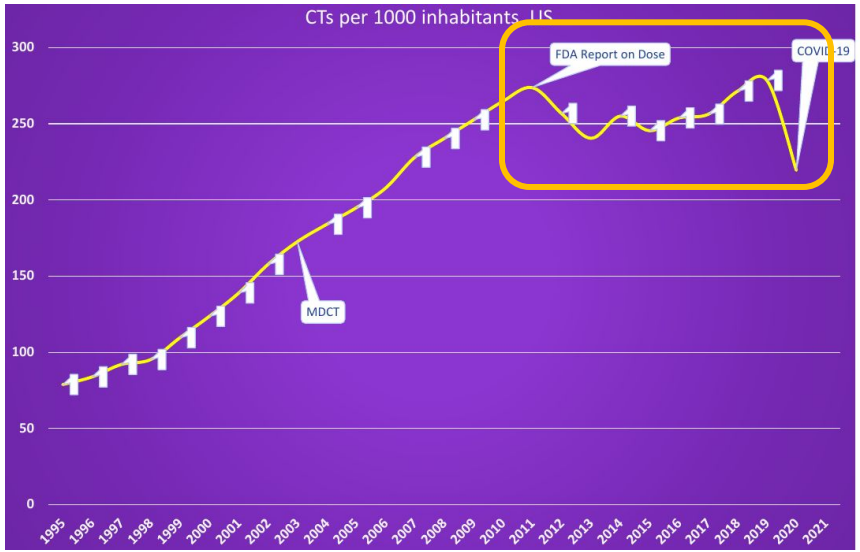
NeuroLogica Announces FDA 510(k) Clearance for Photon Counting Computed Tomography Using OmniTom Elite

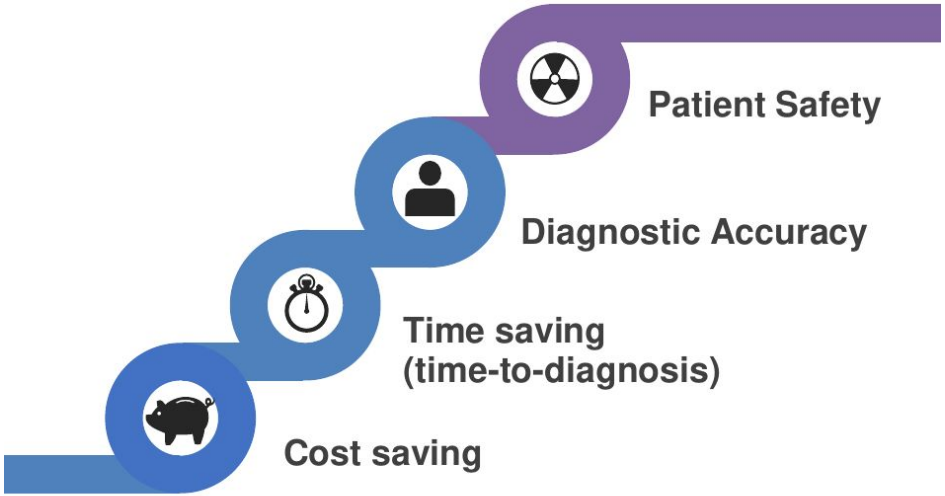
USA on March 11, 2022 Audio Share

I'm lucky if I can learn one thing per talk

- Participants
- Context
- Review of talks
- Conclusions

Invited talk



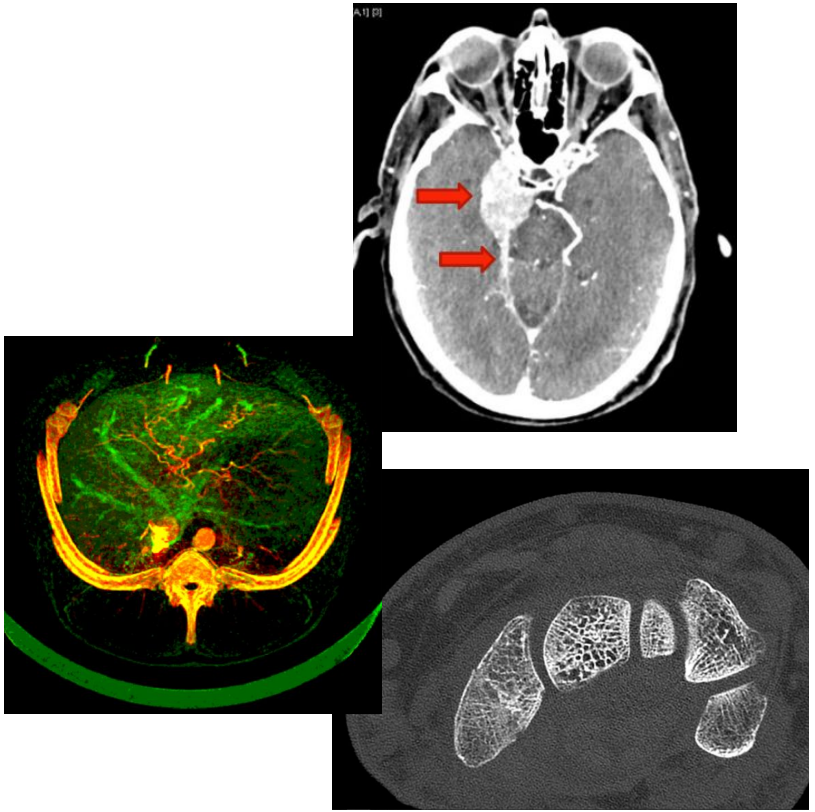


Talked about the different types of benefit from imaging

Dushyant Sahani

Clinical

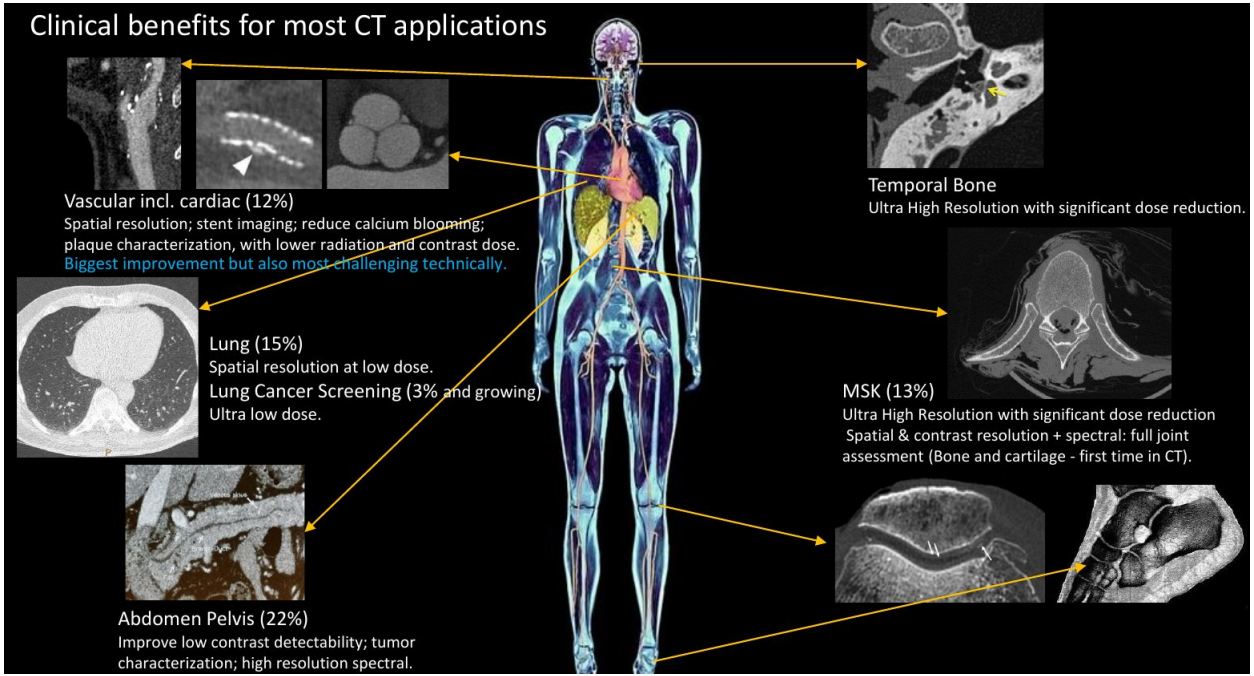
- Rejection of electronic noise
- Improved quantitative performance
- Increased iodine CNR/dose efficiency
- Increased iodine signal at high kV
- Reduced beam hardening and metal artifacts
- Improved spatial resolution
- Lower radiation dose
- Simultaneous, single kV, multi-energy CT
- Multi-contrast, image new contrast agent
- New Applications



> 700 patients with Siemens' FDA cleared device

Cynthia McCollough

Clinical



Clinical benefit for most CT applications, Philips scanner

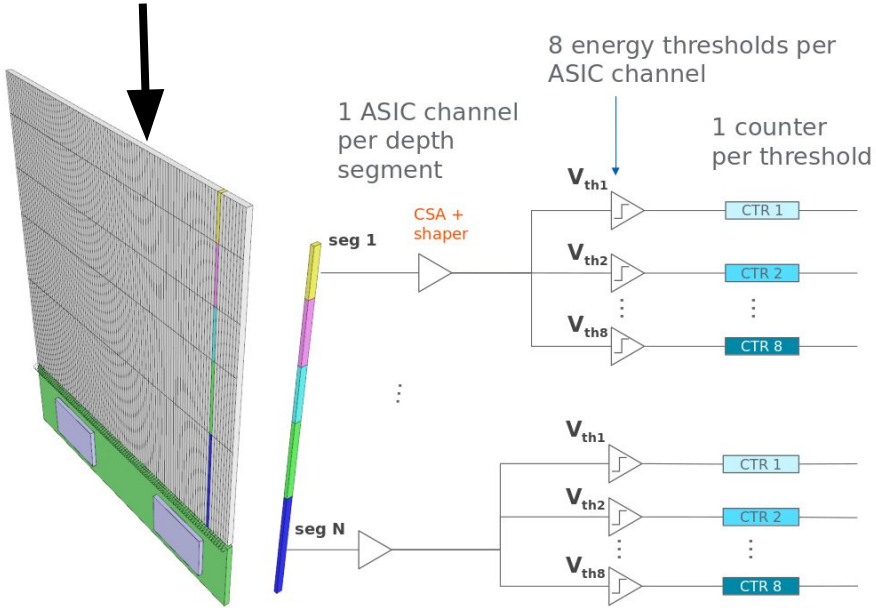
Philippe Douek

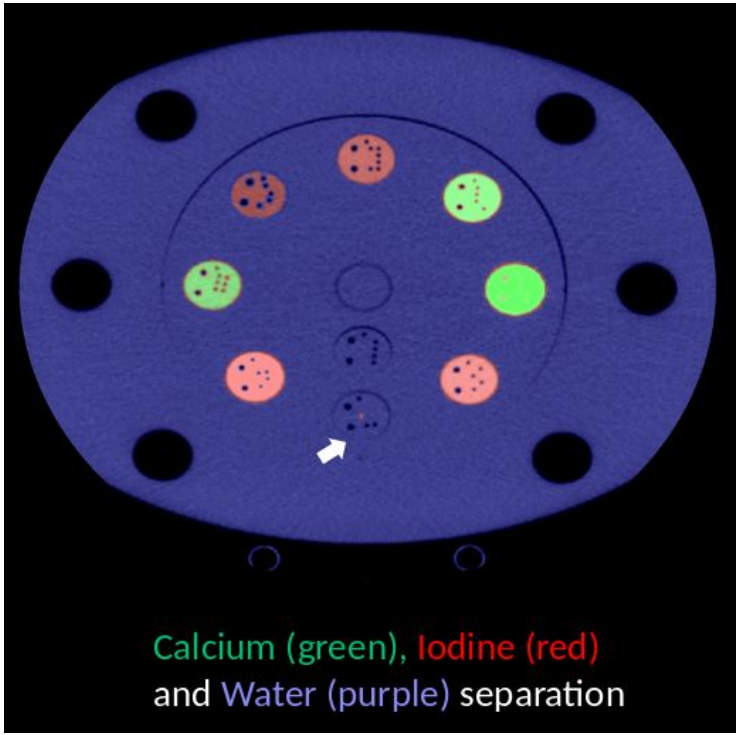
Clinical

MARS Point-of-care takes technology to the patients

Anthony Butler

Clinical

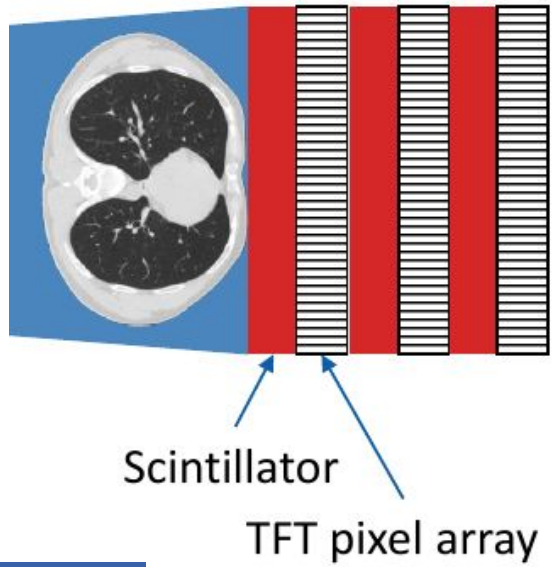


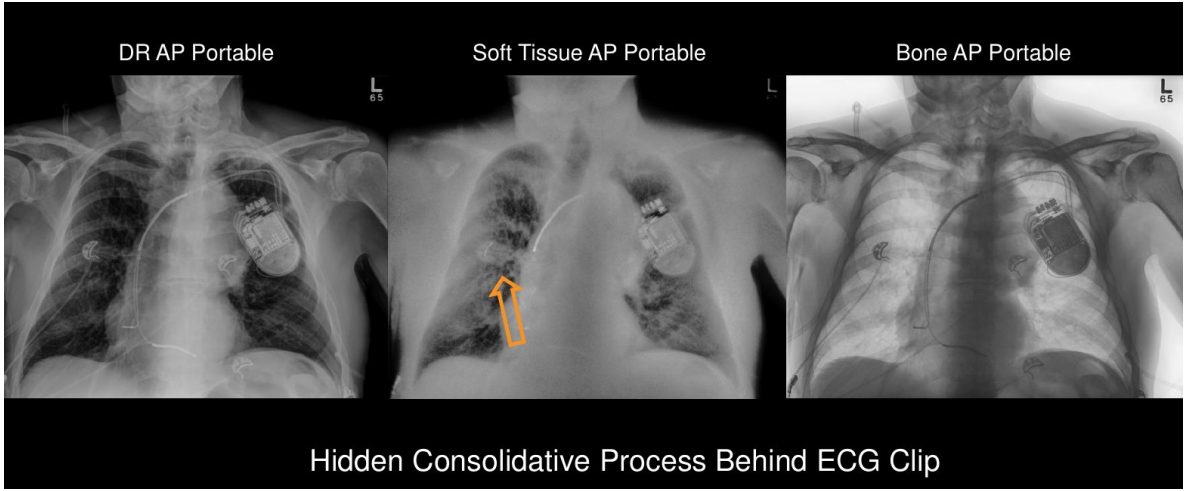


Edge on silicon, from GE

Brian Yanoff

Clinical



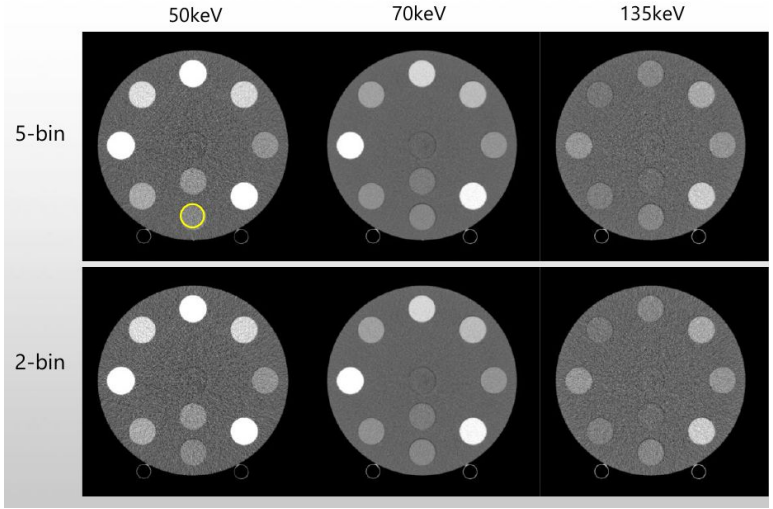


Three layer flat panel for 2D spectral, KA Imaging

Karim Karim

Clinical

Canon CZT clinical prototype

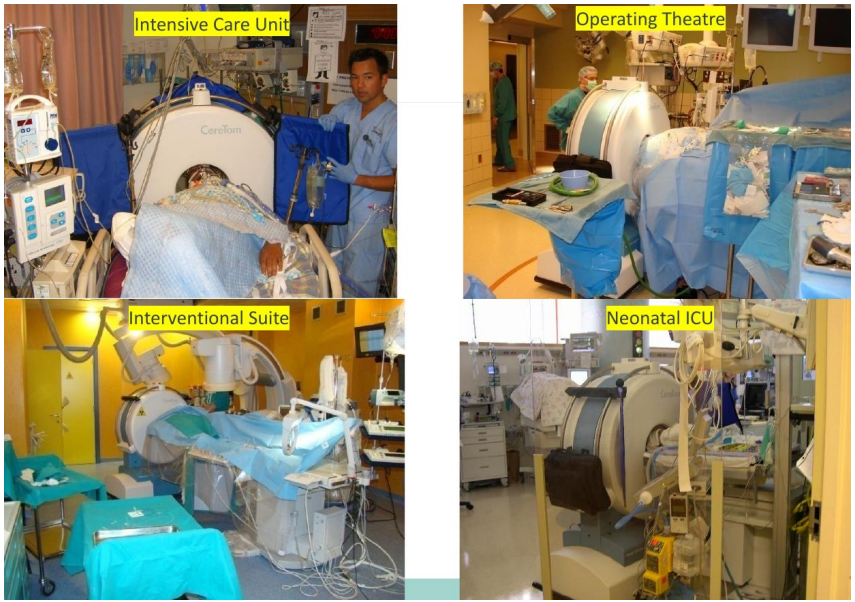


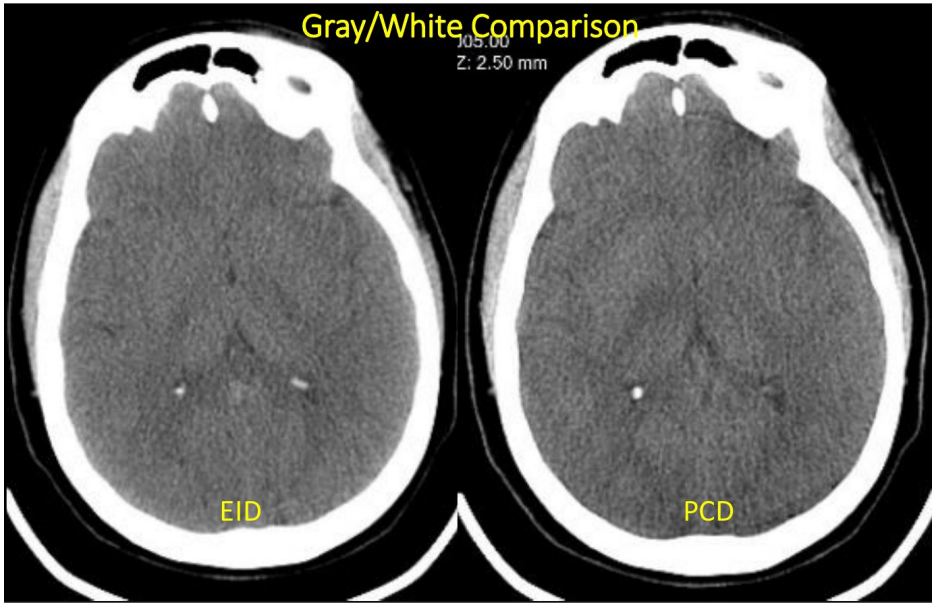
Material decomp. input	50keV SD	70keV SD	135keV SD
5-bin (30/45/55/65/80)	33.1	11.2	28.0
2-bin (30/65)	41.2	13.5	34.2
Noise increased in 2-bin decomp	24.5%	20.5%	22.0%

5 energies better than 2 - but also lots of other useful knowledge

Xiaohui Zhau

Clinical





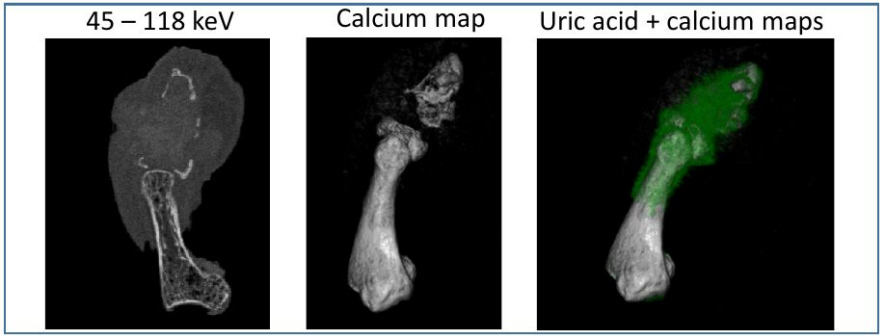
Portable head scanner, developed by Neurologica / Samsung

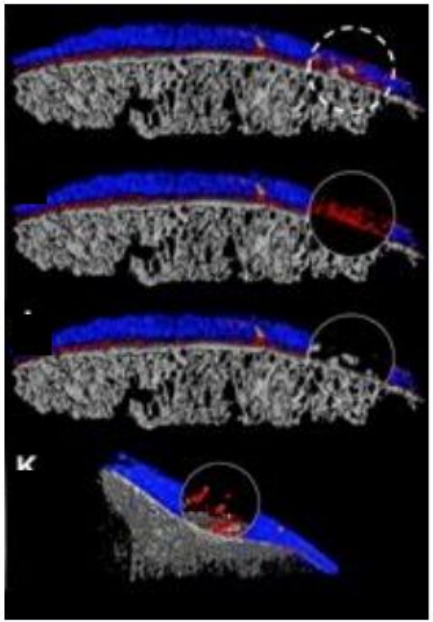
Rajiv Gupta

Clinical

MARS Extremity 5X120 is a perfect example of the evolution of CT systems

- Dedicated CT – upper extremities
- Single-photon counting detector with small voxel sizes
- Multi-energy images and material images





Calcium (HA and CPP) and water maps

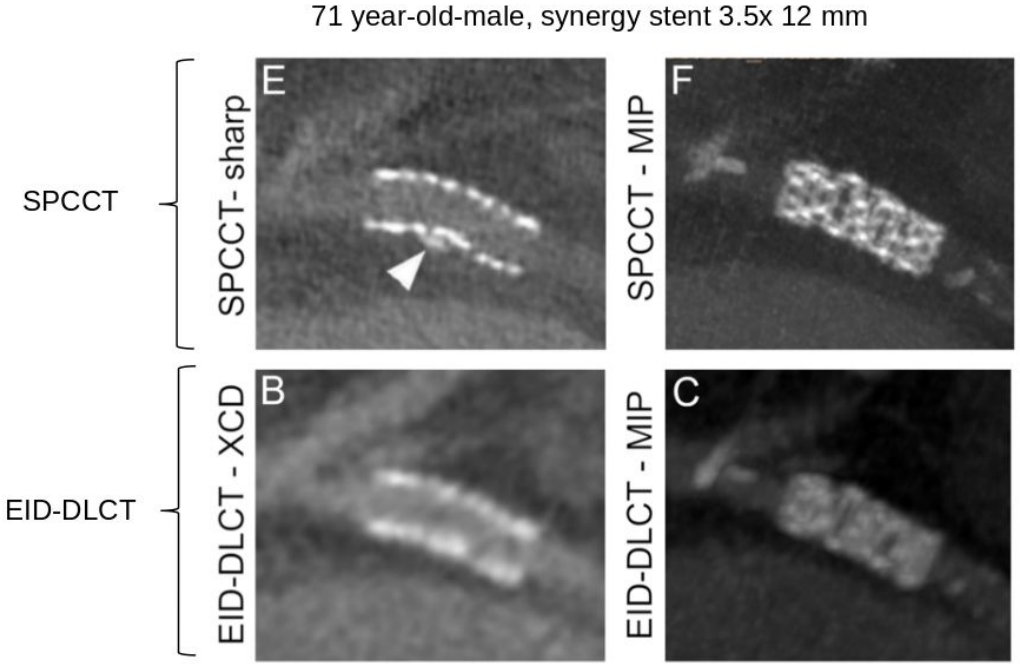
Traditional commissioning need to evolve

Lucia Gallego

Clinical

You can see the important parts !!!

Such as inside a coronary stent



Coronary imaging using Philips system

Salim Si-Mohamed

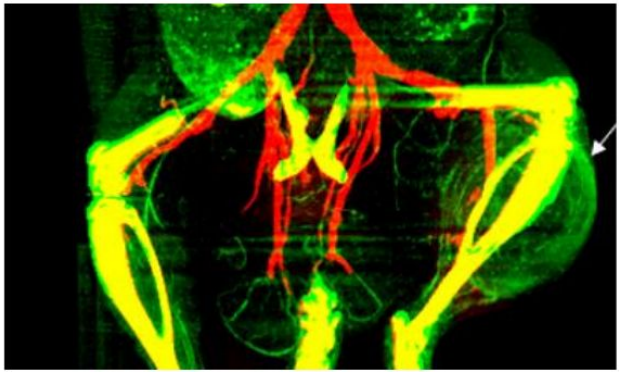
Chateau de Chillon

Opportunity to talk - stressed health systems

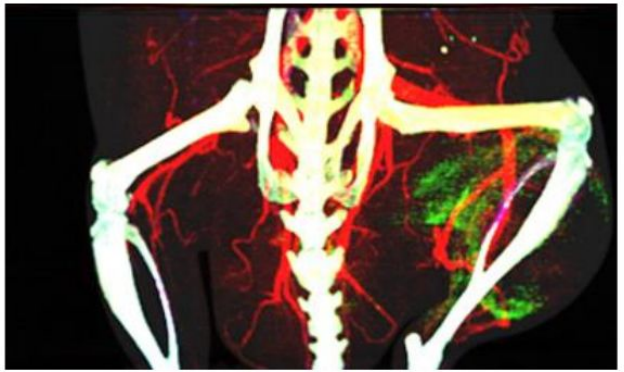
1835 -New Zealand's oldest stone building =>

Detector systems

2x EID detectors (dual energy)



PCD detector (multi-energy)



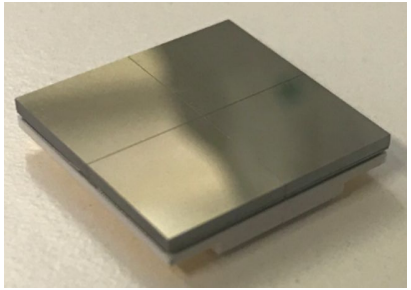
Dual source EID + PCD system

- 2x X-ray sources, Varian, max. 150kVp
- Flatpanel Detector: Dexela 1512, 75um pixel
- PCD: SANTIS, 16x4 cm^2, 1mm CdTe, 150um pixel, 4 thresholds
- Vertical stage for helical scanning

Detectors for pre-clinical and clinical imaging, Dectris

Tomas Thuering

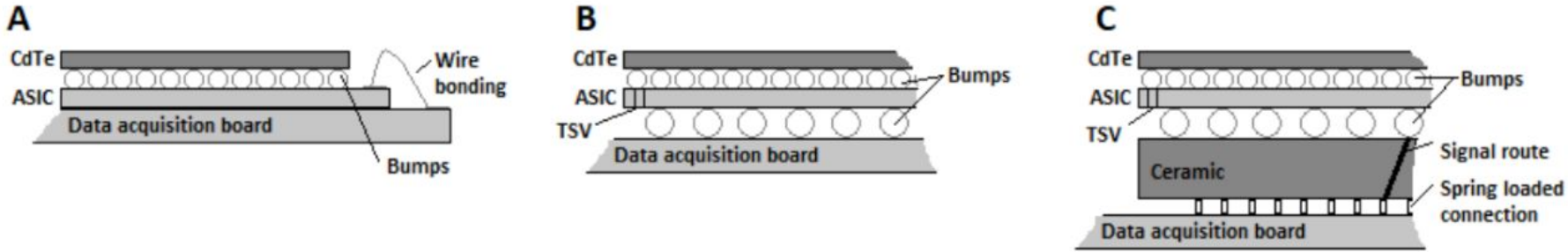
Detector systems



A: 3-side tileable structure

B: 4 side tilable TSV-based structure

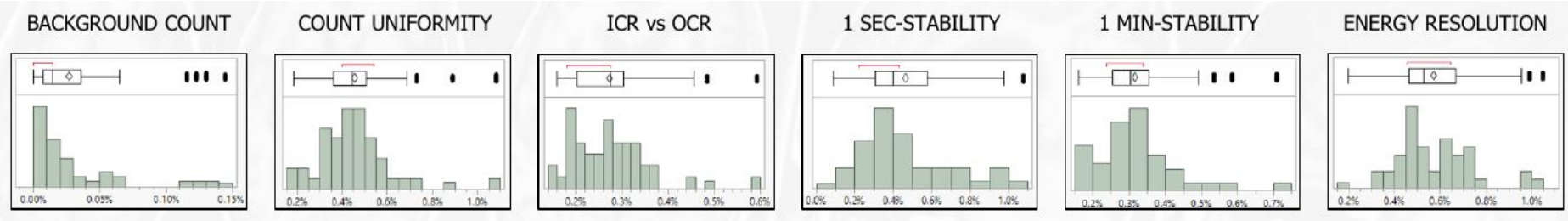
C: Developed tile

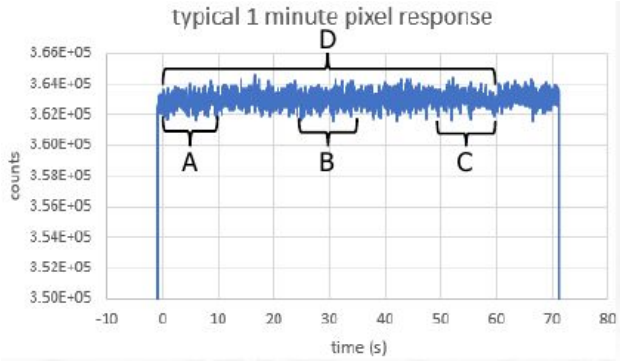


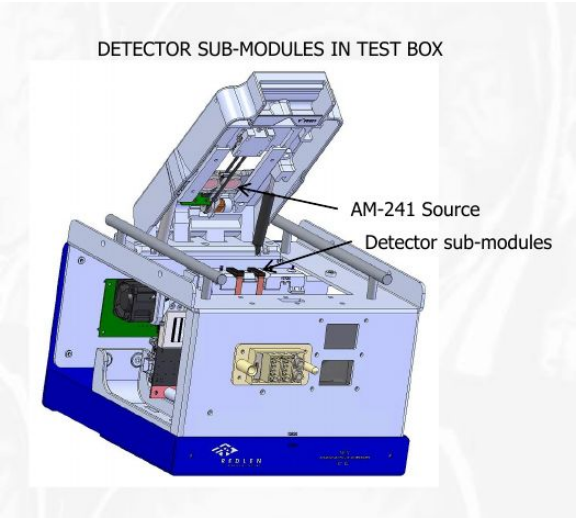
Seamless CdTe to expand applications beyond CT

Matti Kauppinen

Detector systems





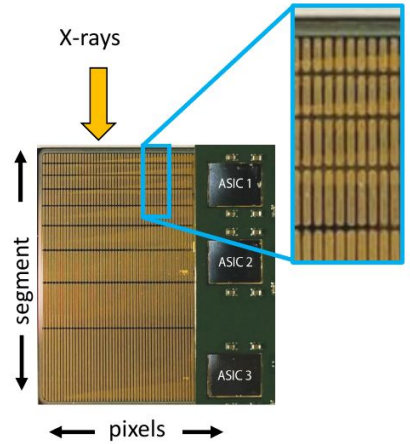


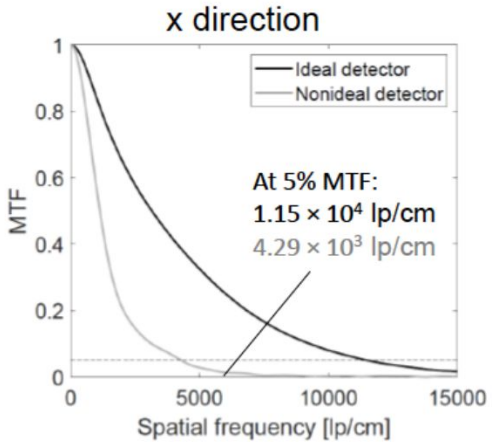
Acceptance testing for CT use, Redlen

Oliver Tousignant

Detector systems

Potential 1um spatial resolution => Could enable phase contrast





1 um Detector

- Increased segmentation
- ASIC approximately matching the sensor area
- Flip-chip ASIC mounting or integrated in the sensor Silicon

REVIEW ARTICLE OPEN

Ultra-thin chips for high-performance flexible electronics

Shoubhik Gupta[1], William Taube Navaraj[1], Leandro Lorenzelli[2] and Ravinder Dahiya[1]

npj Flexible Electronics (2018)2:8 ; doi:10.1038/s41528-018-0021-5

Edge on silicon for hi-res CT

Mats Danielsson

Detector modelling

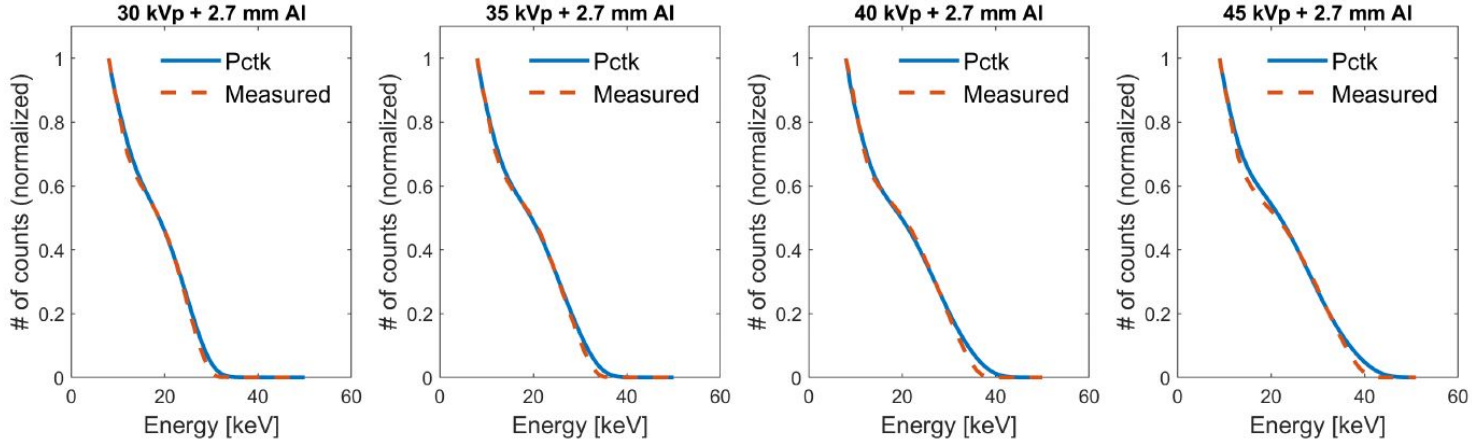


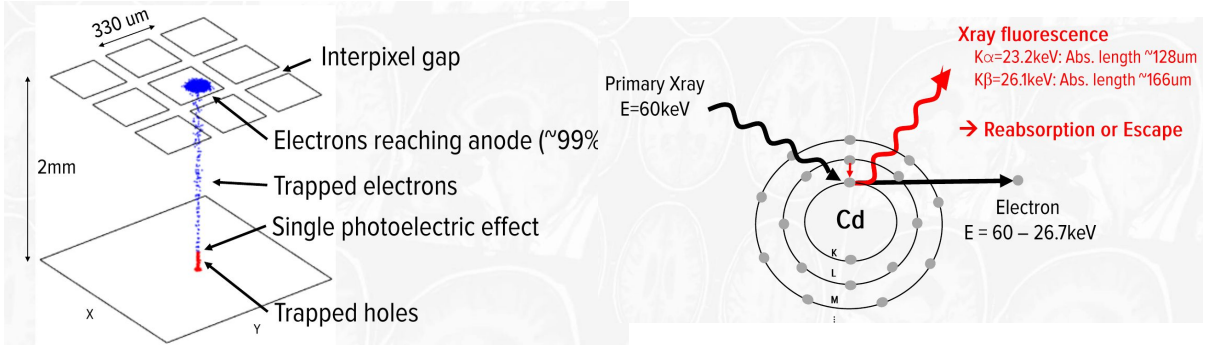
Figure: Comparisons between simulated and measured spectra with incident tungsten target X-ray spectra.

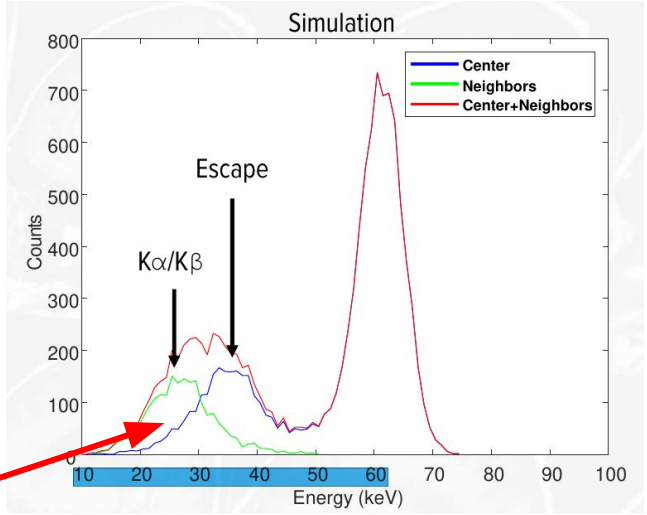
https://pctk.jhu.edu/

Added GaAs to Matlab modelling toolkit for photon counting

Bahaa Ghammraoi

Detector modelling





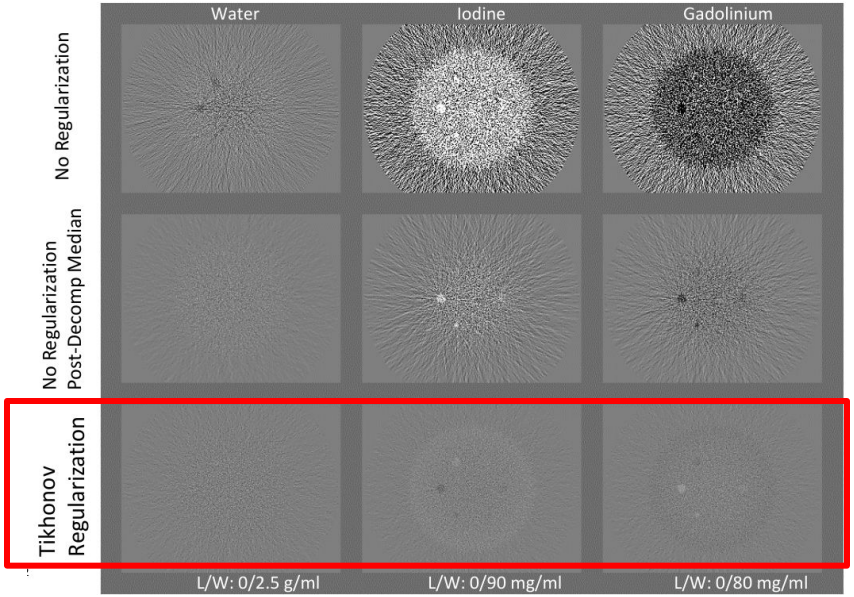
Lots of fluorescence into neighbours @ 330um (see later discussion in ASICS)

Intrinsic spatial resolution of CZT, Redlen

Xavier Defay

Simulation and reconstruction of

- Polynomial approximation (Alvarez & Macovski, 1976) of or its inverse (Lehmann et al., 1981)
- Maximum-likelihood (Roessl & Proksa, 2007)
- Penalized-likelihood decomposition (Brendel et al., 2016) using a Huber regularization on difference in neighbors
- Regularized weighted-least squares (Abascal et al., 2018) and different regularization terms (Huber, quadratic, …)



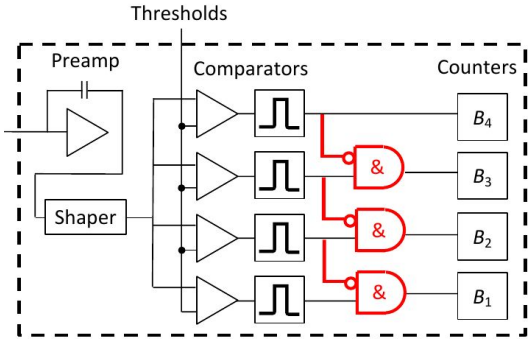
Improving the ill-posed material identification problem

Klaus Erhard

Simulation and reconstruction of

Current technology is like '90s dial-up

Broadband is the future



Idea #1: Direct binning to reduce pileup

Idea #2: Retrigger-driven secondary counters for pileup

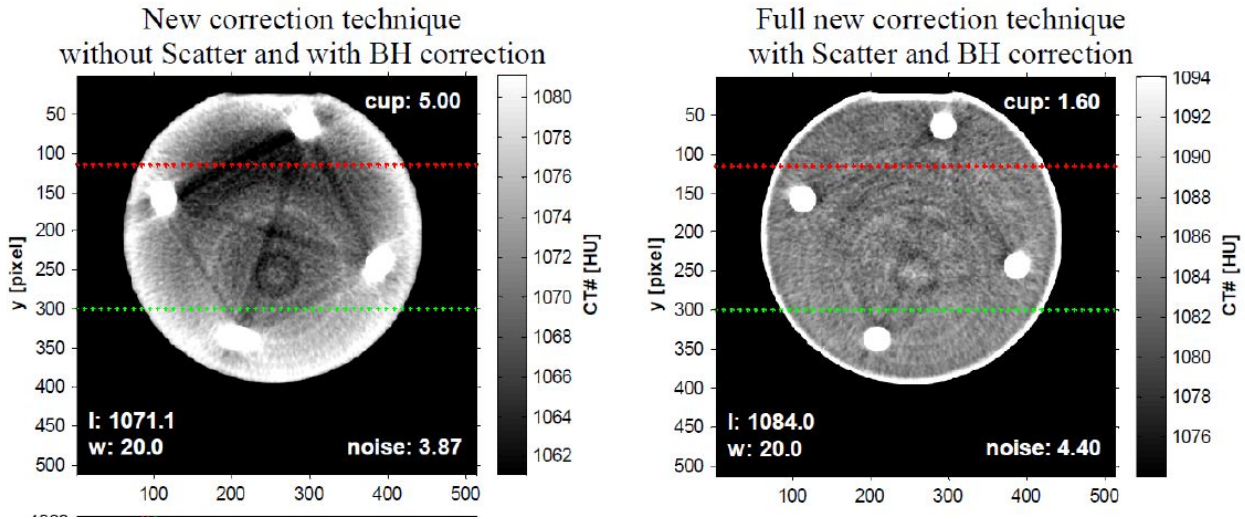
Idea #3: Coincidence counting for charge sharing

Ideas for photon processing for the next generation ASICs

Scott Hsieh

Simulation and reconstruction of

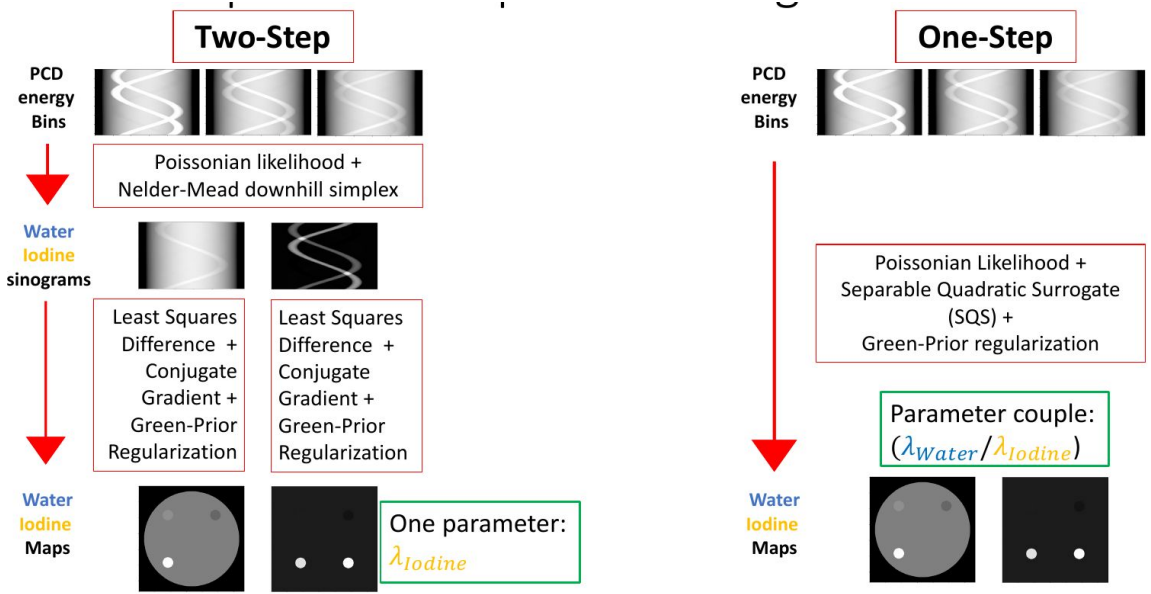
One person's noise, is another person's signal



Use the better signal measurements to correct for scatter

Yoad Yagil

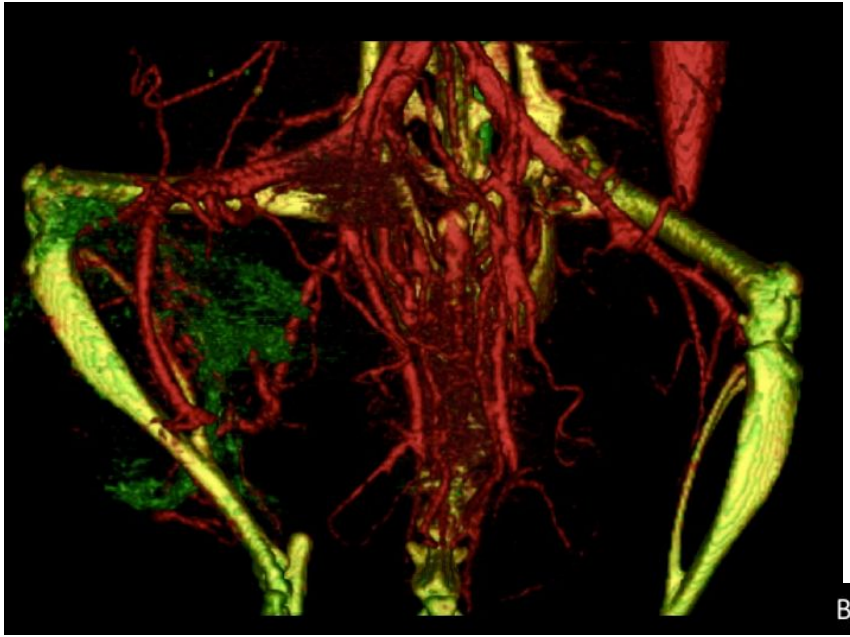
Simulation and reconstruction of

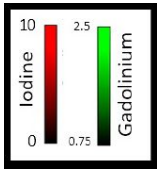


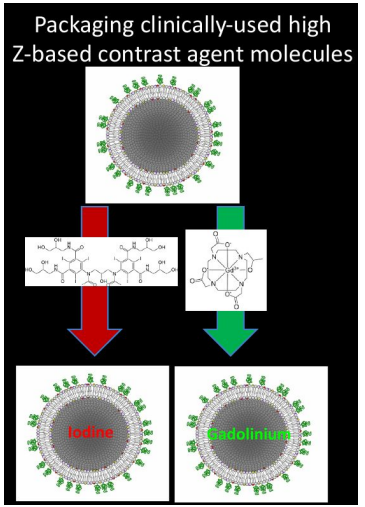
Correct physics - One step MD and spatial reconstruction

Pierre-Antoine Rodesch

Contrast agents and Molecular imaging





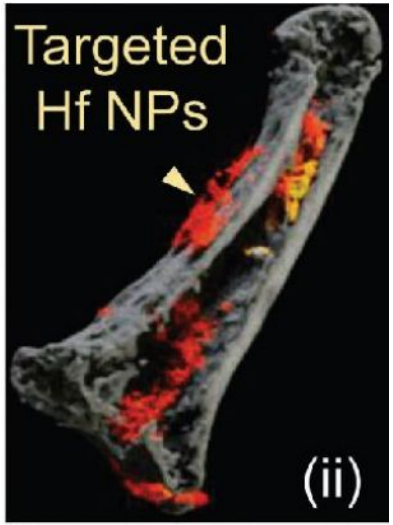


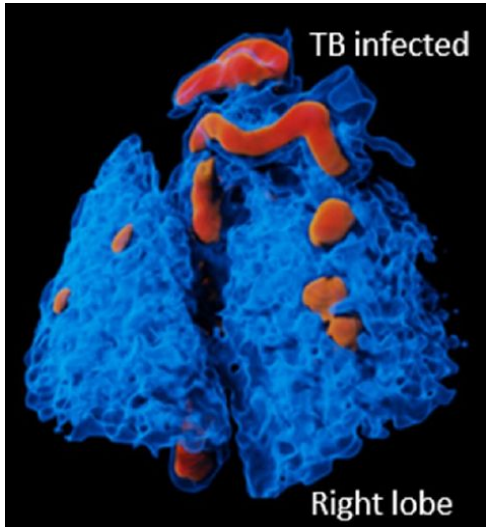
Badea et al. *Phys Med Biol. 2019*

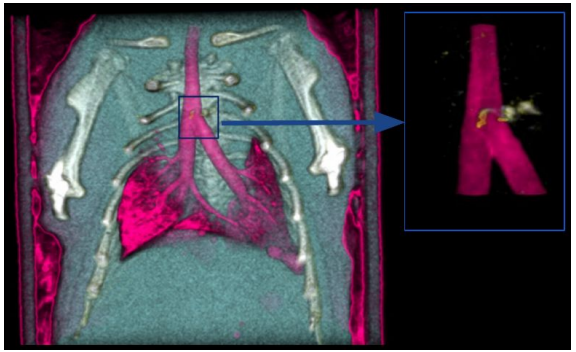
Spectral allow functional imaging of cancers (sarcoma)

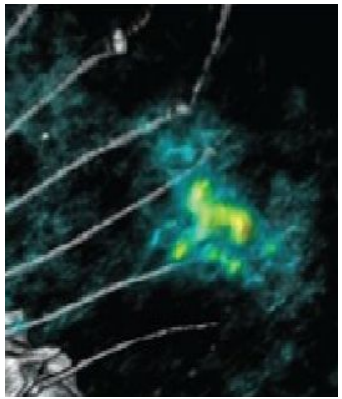
Ketan Ghaghada, Bayler School of Medicine

Contrast agents and Molecular imaging







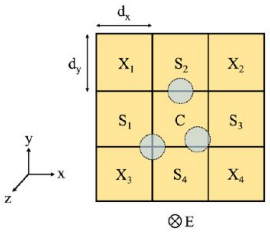


Wide range of new applications

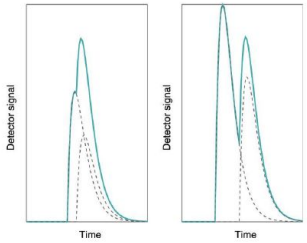
Anthony Butler

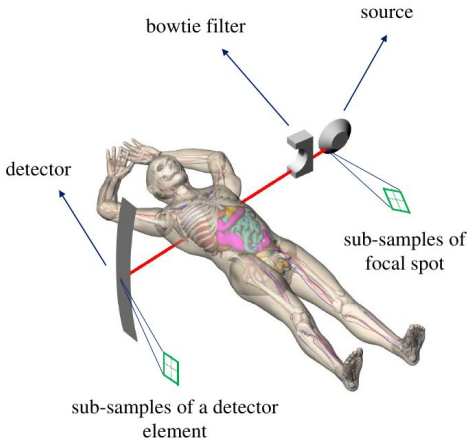
Material separation

Modeling noise and charge sharing

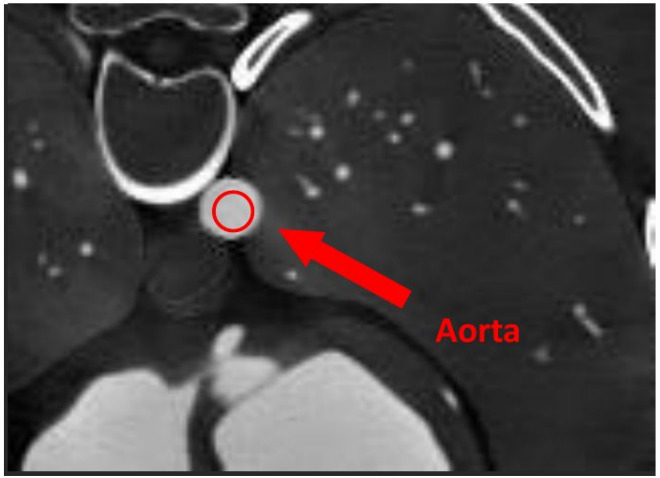


Modeling pulse pile-up





Iodine image

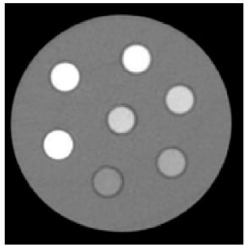


Simulations of pile-up and charge sharing

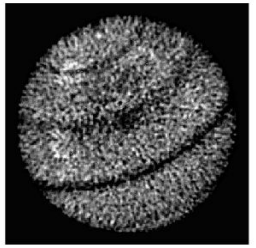
Stevan Vrbaski

Material separation

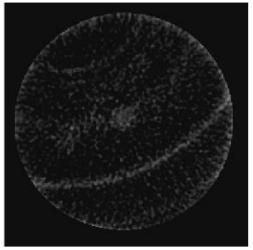
Uncorrected



CT-image

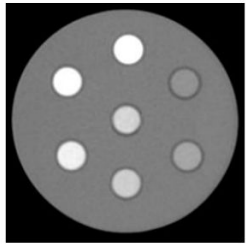


VNC-image

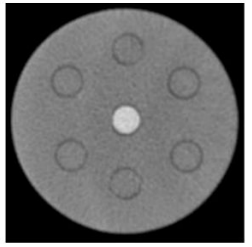


Iodine map

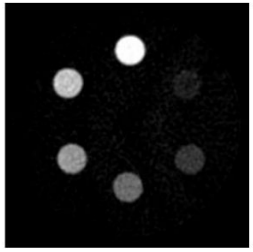
Corrected



CT-image



VNC-image



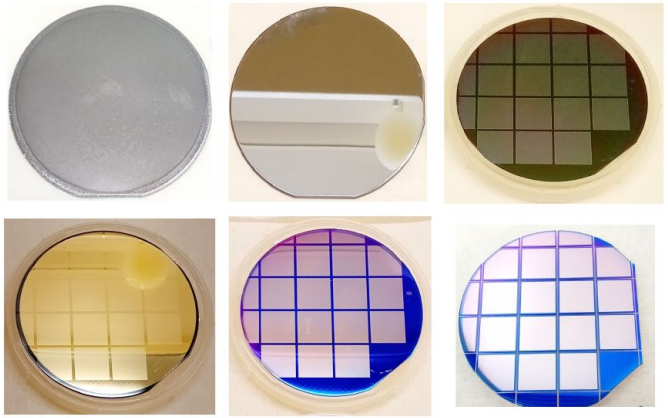
Iodine map

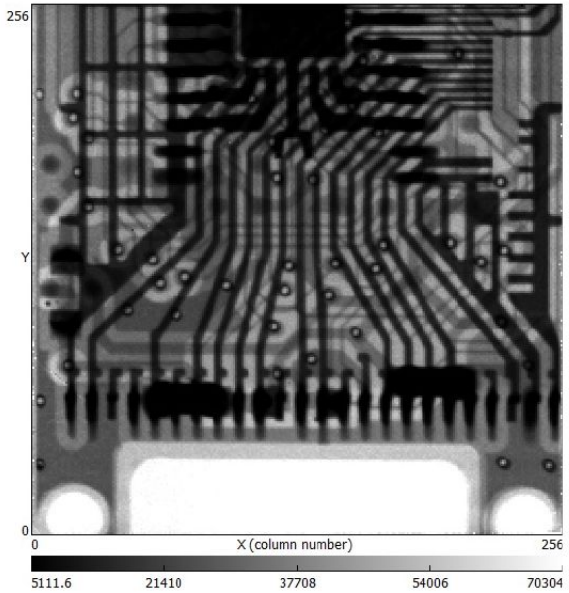
Charge sharing in 100um pixels - does it affect breast CT?

Veikko Ruth

High-Z semiconductors

Locally developed Cr compensated GaAs

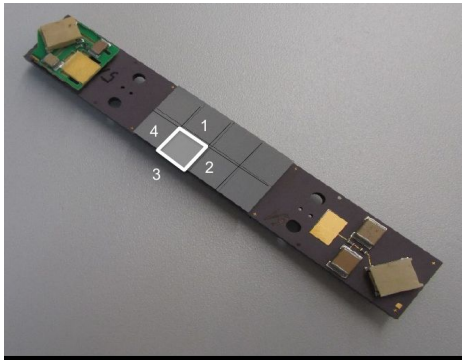




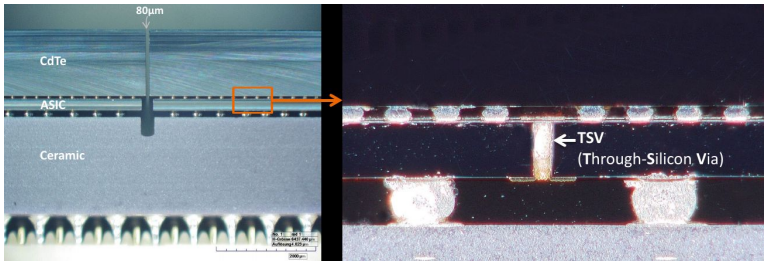
GaAs – there are many room temperature semiconductors

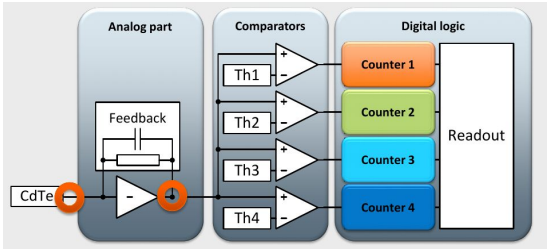
Juha Kalliopuska

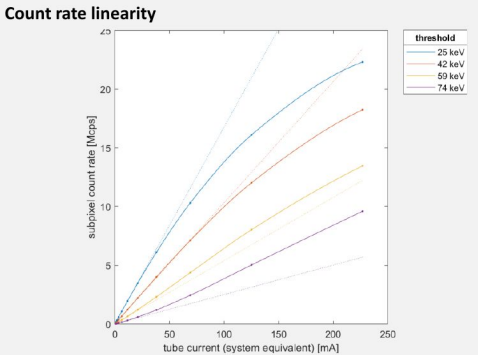
ASICs

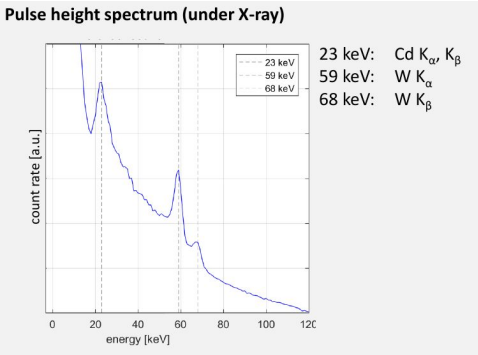


4 side buttable ASICs
(on 3 side buttable sensor board…)







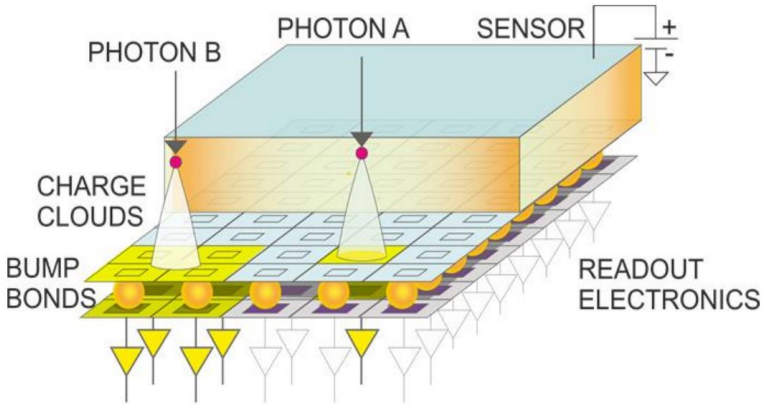


Naeotom Alpha ASIC, Siemens

Edgar Goederer

ASICs

Important problem – charge sharing



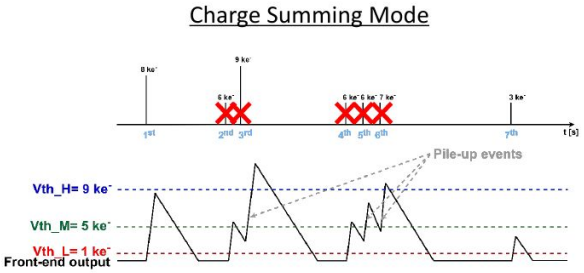
Charge sharing depends on: pixel size, detector thicknes, bias voltage, etc.

Example of ASICs with charge sharing compensation:
Medipix3RX, miniVIPIC, X-Counter, PIXIE-3, Chase Jr., ….

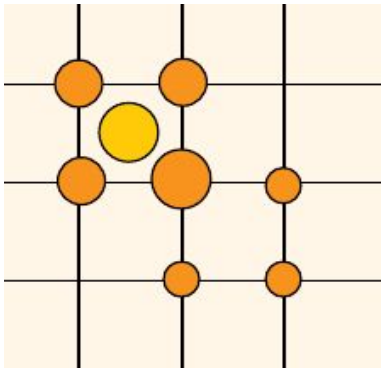
Charge sharing correction is now widely used

Piotr Kmon

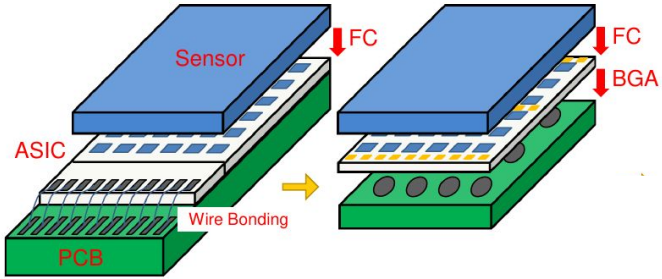
ASICs



Pile up correction



Charge sharing correction

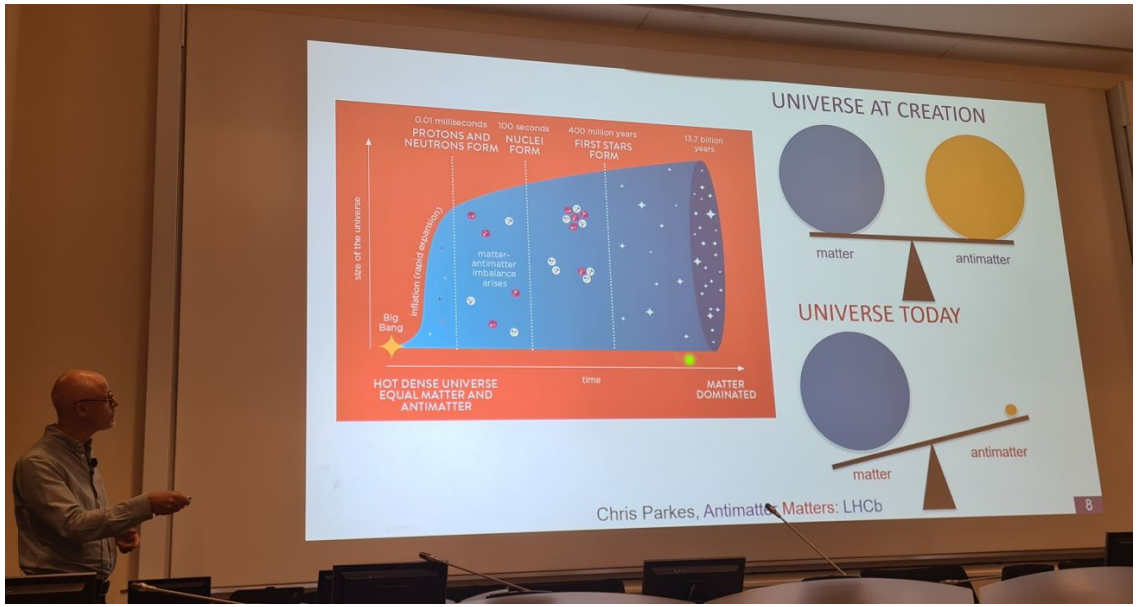


4 Side buttable

Medipix4: High flux; High energy resolution; Extendable active area

Viros Sriskaran

Invited HEP talk



Antimatter Matters: LHCb

Chris Parkes

- Participants
- Context
- Review of talks
- Conclusions

CERN

Conclusion

2011 – would any of this work?

Conclusion

2011 – would any of this work?

2022

- *Wide acceptance of technical feasibility*
- *Wide acceptance of clinical utility across a wide range of imaging problems*
- *Likely to dominate traditional CT in the future*

CERN

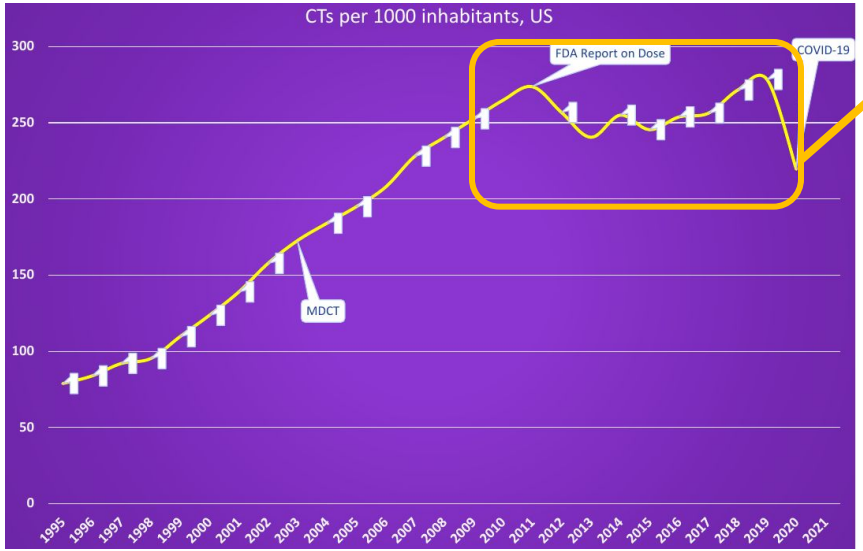
Conclusion

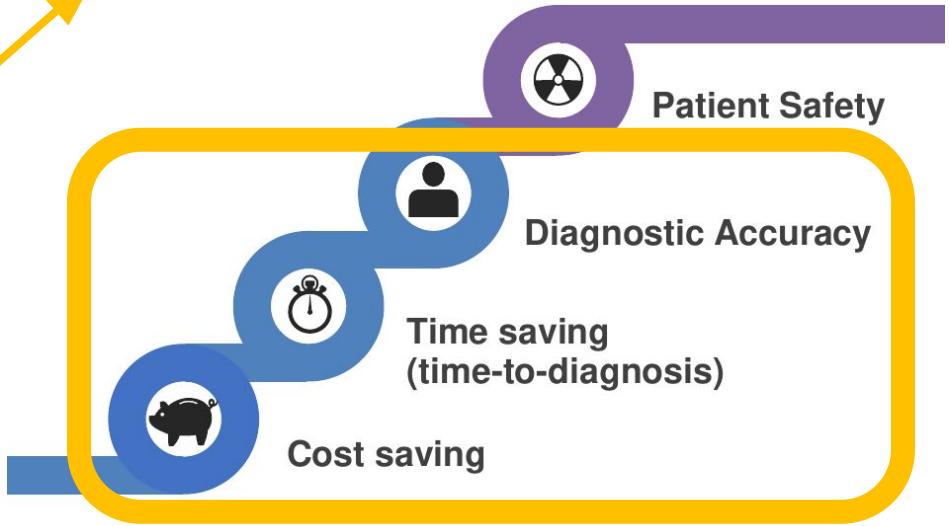
I am convinced, that institutions like CERN play an important role for continuous innovations in medical imaging. Communities like the Medipix Collaboration and the SpecXray Workshop are essential instruments of our society, connecting and affirming researchers in academia and industry during the maturation and commercialization processes of disruptive detector technologies for medicine.

Stephan Kappler, Scientific committee

Conclusion

The problems to address





How do we make a better future for our patients?

See you again in 2 years !!

Michael Campbell, CERN

Anthony Butler, Univ. of Otago & MARS Bioimaging

Steffen Kappler, Siemens Healthcare

Yoad Yagil, Philips Research Laboratories

Katsuyuki (Ken) Taguchi, Johns Hopkins University

Richard Thompson, Canon Medical Research

Brian Yanoff, GE Global Research