Vereos PET/CT

La Tecnologia PET Full Digital

una reale innovazione a garanzia dei PDTA in Oncologia

L'INNOVAZIONE TECNOLOGICA NEL SETTORE DELLA
MEDICINA NUCLEARE E *DELL'IMAGING MOLECOLARE*

Pisa 21 Febbraio 2018

innovation you

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Today

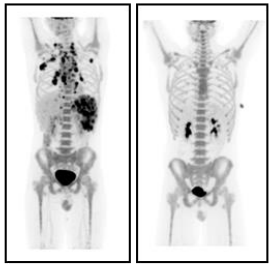
PET

Research - era of discovery
The "basement" era

PET/CT

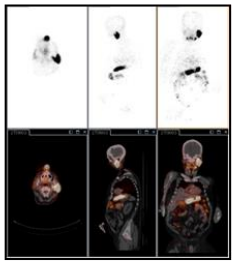
Era of image quality,
and integration with CT
Era of lesion detection and localization
Image "Beautification"

PET/CT



Era of quantitative accuracy and integration with MRI

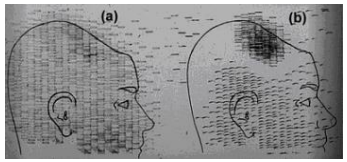
Personalized Diagnosis & Treatment



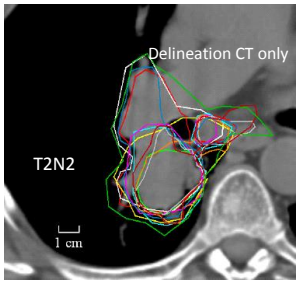
Era of targeted therapy and imaging
Individual patient management

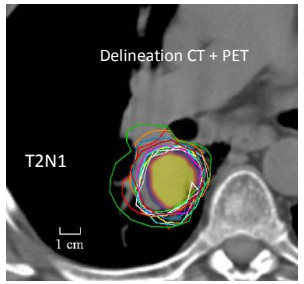
Era of precision medicine

MGH 1811



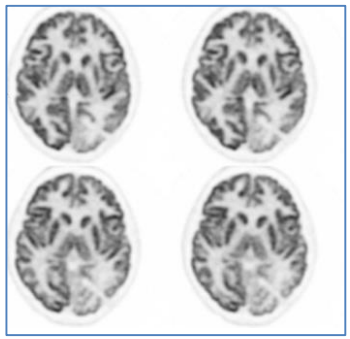
NKI-AVL

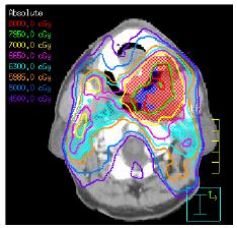


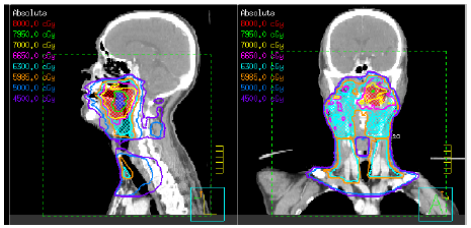


University Hospitals
Case Medical Center

SCHOOL OF MEDICINE
CASE WESTERN RESERVE UNIVERSITY







Precision medicine enabled by clinically proven:

Improved detectability & characterization **of small lesions** [1]

Uncompromised lesion detectability & quantification **at 1/2 the PET dose** [2]

Uncompromised lesion detectability **at 1/10 the time** [3]

[1] Nguyen NC, Image Quality and Diagnostic Performance of a Digital PET Prototype in Patients with Oncologic Diseases: Initial Experience and Comparison with Analog PET, J Nucl Med 2015; 56:1378–1385
[2] Liu X et al, Impact of FDG Dose Reduction on Lesion Quantification in Dynamic PET: A Simulation Study Based on Clinical Trial Data, SNMMI 2016
[3] Zhang J., Evaluation of speed of PET acquisition: How fast can we go? - A validation of list mode PET simulation approach with true acquisitions, SNMMI 2017

Visualization of small lesions is essential for clinicians to diagnose, stage and monitor therapy in oncology patients. The challenge is being able to detect these small lesions reliably[1].

Vereos, the world's first and only fully digital PET/CT, provides improved detectability and characterization of small lesions[2].

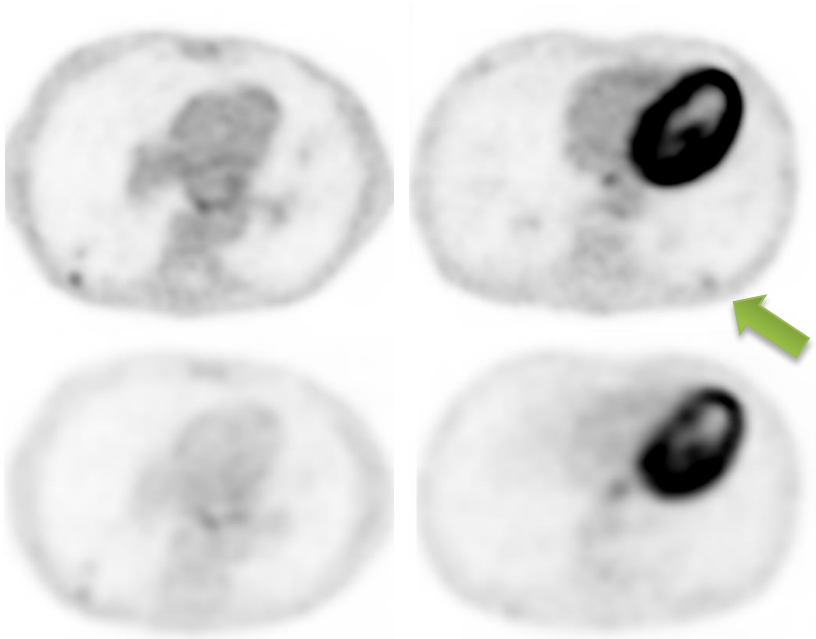
* "Optimization" refers to the use of strategies and techniques that facilitate the management and control of both image quality and dose.

[1] Liu X et al, Impact of FDG Dose Reduction on Lesion Quantification in Dynamic PET: A Simulation Study Based on Clinical Trial Data, SNMMI 2016

[2] Nguyen NC, Image Quality and Diagnostic Performance of a Digital PET Prototype in Patients with Oncologic Diseases: Initial Experience and Comparison with Analog PET, J Nucl Med 2015; 56:1378–1385

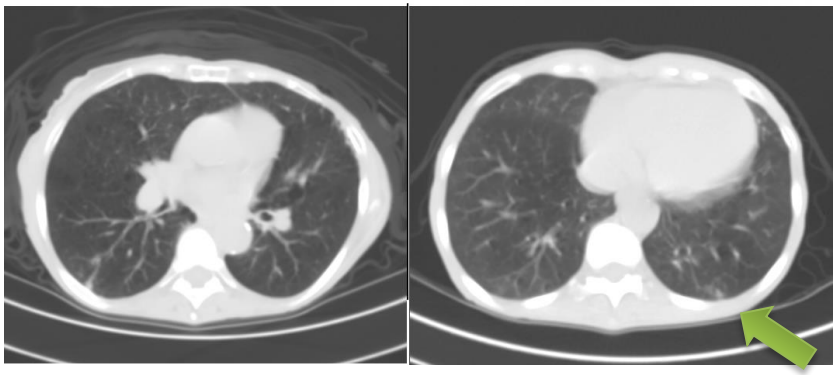
Improved detectability & characterization of small lesions[1]

Improved detectability of small lesions with digital PET/CT, relative to the same patient acquired on analog PET/CT.



Vereos DPC

Analog*



Slice 1 *Slice 2*

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Wright Center of Innovation in Biomedical Imaging

[1] Nguyen NC, Image Quality and Diagnostic Performance of a Digital PET Prototype in Patients with Oncologic Diseases: Initial Experience and Comparison with Analog PET, J Nucl Med 2015; 56:1378–1385

Sample images acquired in a clinical study of the Vereos PET/CT system at The Ohio State University. Investigational device limited by law to investigational use.

*GEMINI TF 64

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Long acquisition time with molecular imaging may result in patient discomfort[1], and also associated motion artifacts.

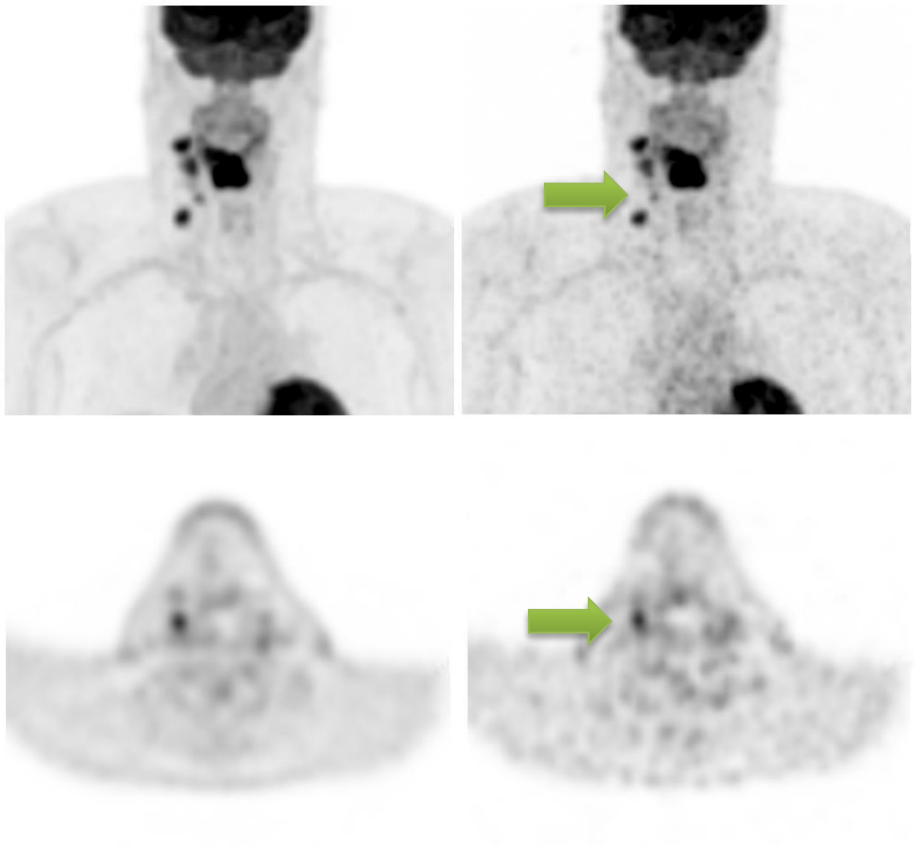
Vereos, the world's first and only fully digital PET/CT, provides uncompromised detectability at 1/10th of the time[2]

[1] Gückel B et al, Patient comfort during positron emission tomography/magnetic resonance and positron emission tomography/computed tomography examinations: subjective assessments with visual analog scales. Investigative Radiology, 2015 Oct;50(10):726-32

[2] Zhang J. et al, Evaluation of speed of PET acquisition: How fast can we go? - A validation of list mode PET simulation approach with true acquisitions, SNMMI 2017

Uncompromised lesion detectability at 1/10 the time[3]

Equivalent detectability of neck lesion at 9 sec/bed, relative to a 90 sec/bed acquisition.



Vereos DPC 90 sec/bed **Vereos DPC 9 sec/bed**

89 kg, 1.79 m
12.9 mCi / 477 MBq
F-18 FDG

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[3] Zhang J., Evaluation of speed of PET acquisition: How fast can we go? - A validation of list mode PET simulation approach with true acquisitions, SNMMI 2017

Sample images acquired in a clinical study of the Vereos PET/CT system at The Ohio State University. Investigational device limited by law to investigational use.

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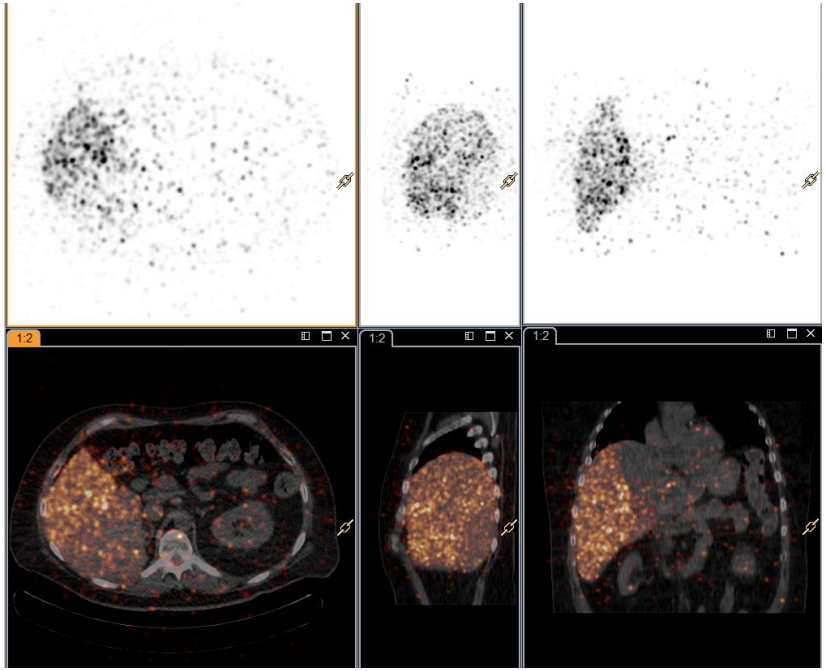
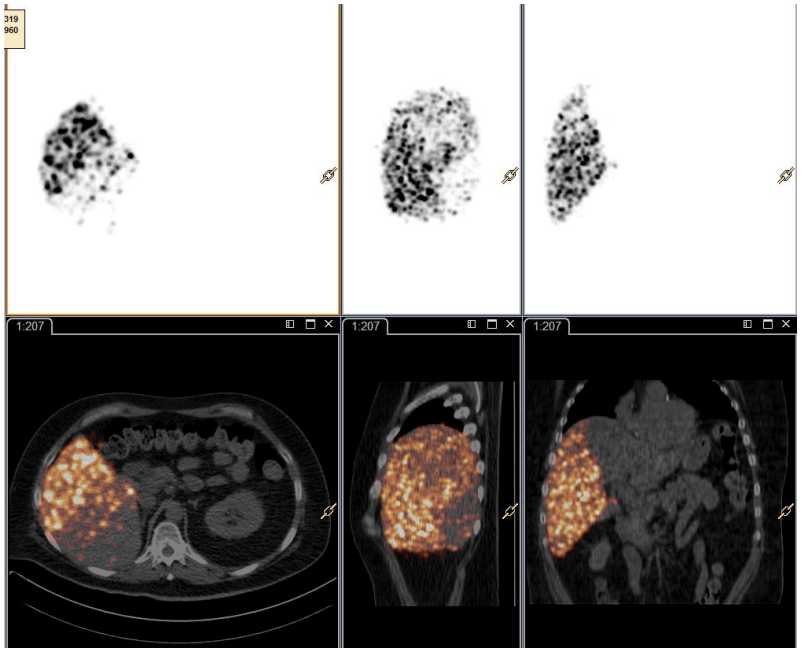
Era of Theranostics

Theranostics uses specific biological pathways in the human body, to acquire diagnostic images and also to deliver a therapeutic dose of radiation to the patient.

Vereos, the world's first and only fully digital PET/CT, provides uncompromised image quality with all tracers

Yttrium-90 SIRT Therapy





Analog (Gemini TF)

Digital (Vereos)

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Your Online Knowledge Base

Personalised medicine will require a patient-specific picture of the functional processes associated with disease," added Pablo Ros, M.D. "**Accurate quantification of processes is therefore an important requirement for functional imaging** in diagnosis, therapy and research.

The quantitative accuracy and remarkably clear images that the **new digital PET/CT system delivers are a key step forward**."

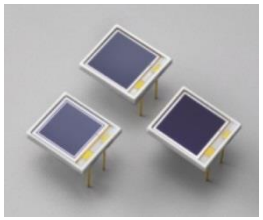
Digital innovation

Digital Innovation

PMT

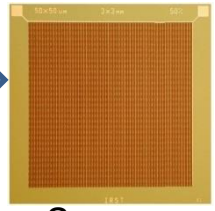
70 years

APD(analog)



30 years

SiPM(Analog)



8 years

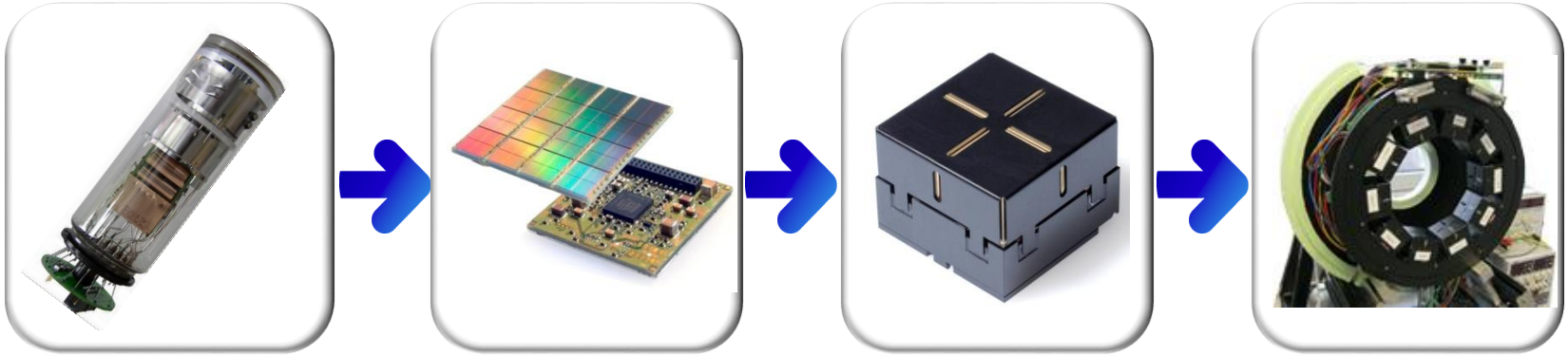
dSiPM(Digital)

New technology

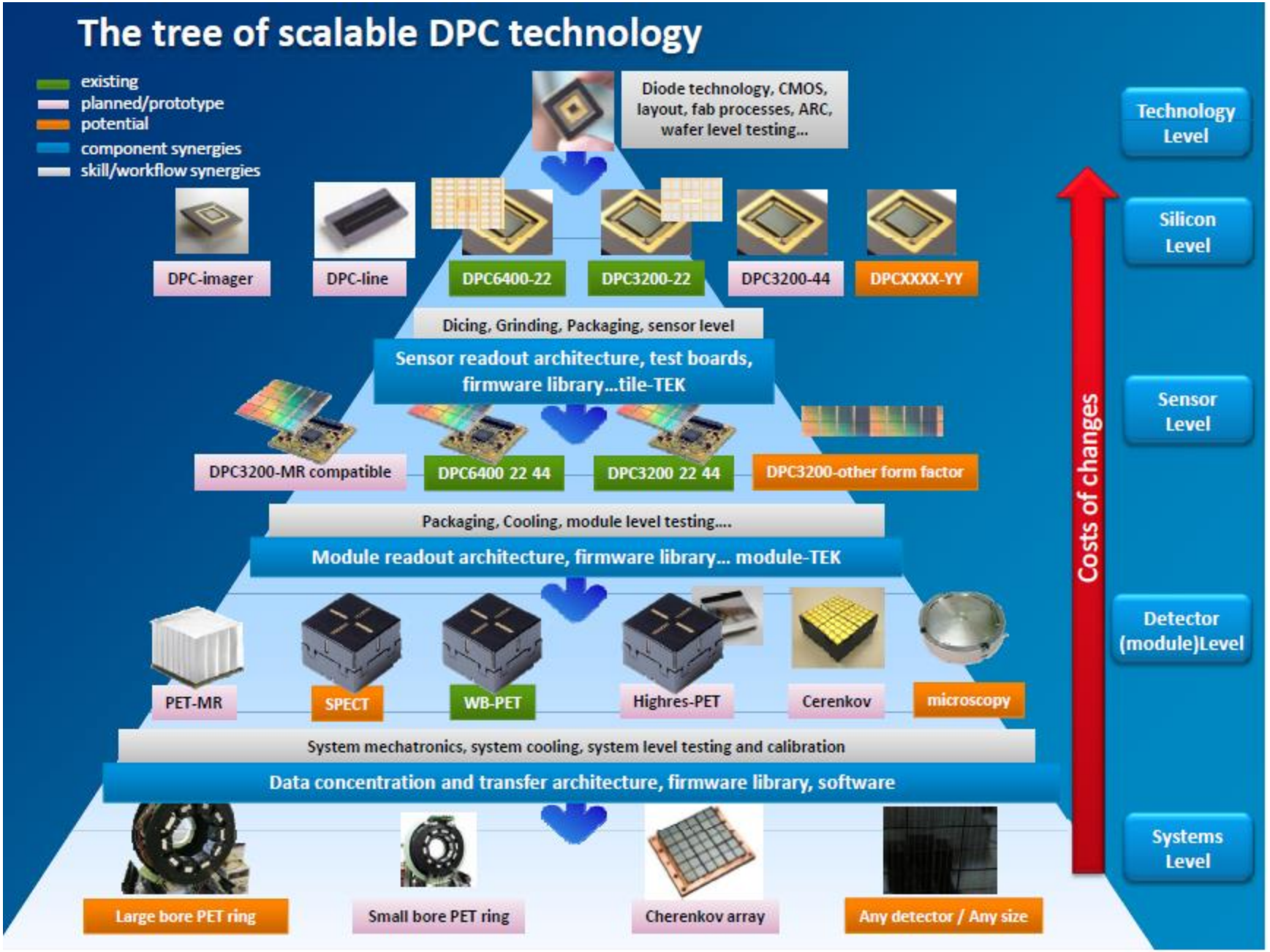
Solid state

Fully digital SiPM (**dSiPM ©**)

invented within Philips Research

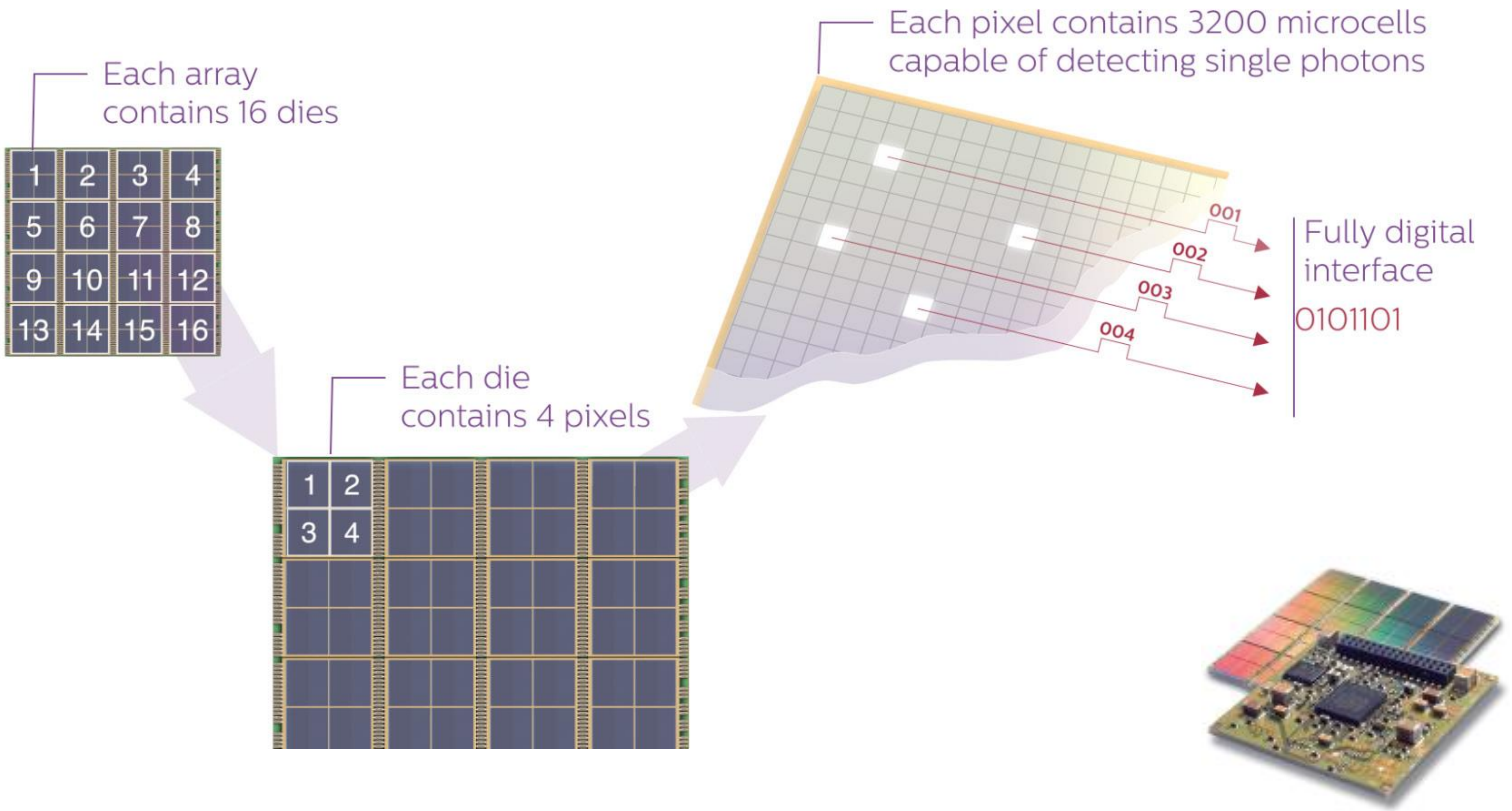


The tree of scalable DPC technology



How Digital Photon Counting works

The Digital Photon Counter converts scintillating light directly to a digital signal



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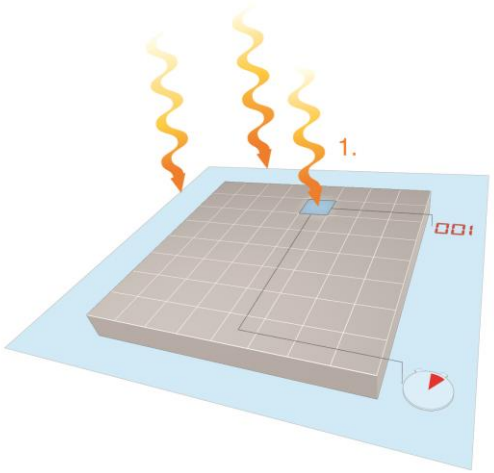
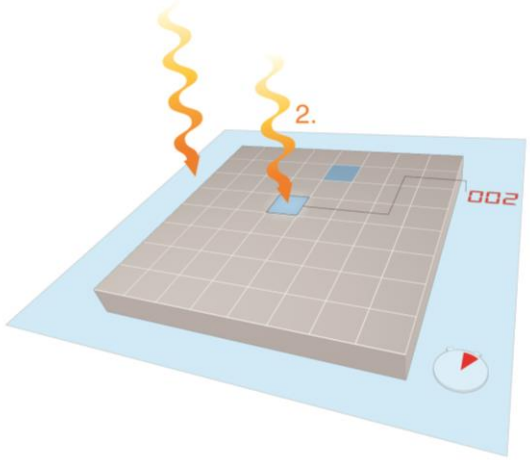
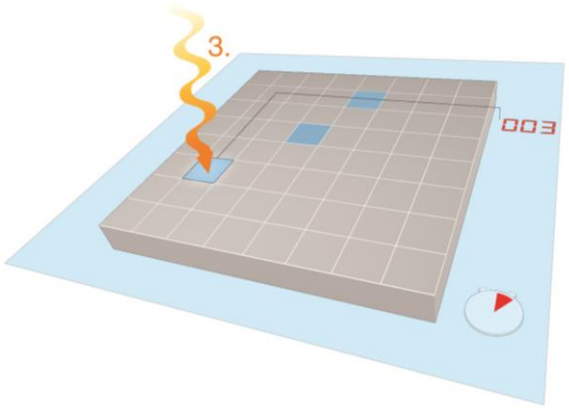
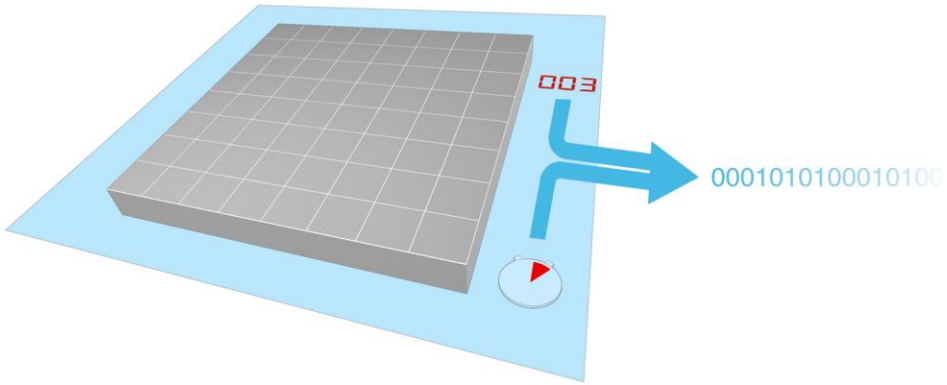
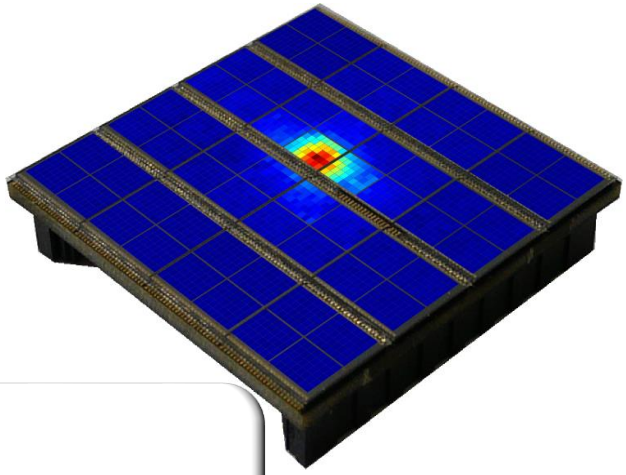
Now Photons are Counted Directly

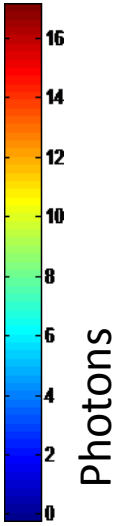












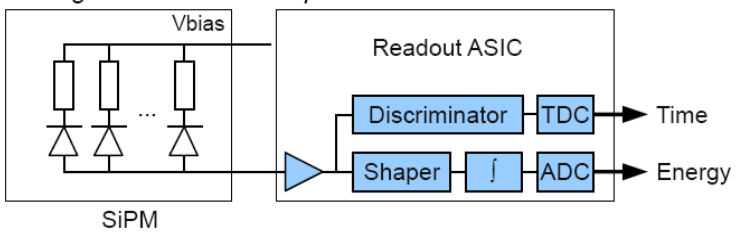
Output: > no. of photons
> time stamp(s)

No analog post-processing necessary!

The dSiPM is an Integrated, Scalable Solution

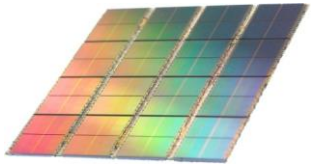
Analog SiPM

Analog Silicon Photomultiplier Detector

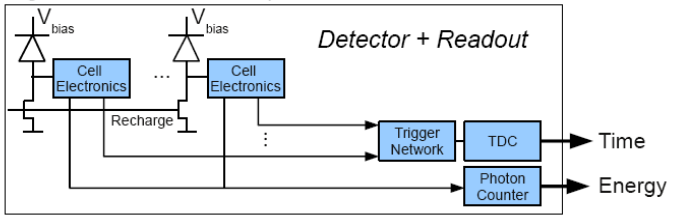


- discrete, limited integration
- analog signals to be digitized
- Dedicated ASIC needed
- not scalable

Digital SiPM



Digital Silicon Photomultiplier Detector



- fully integrated
- fully digital signals
- no ASIC needed
- fully scalable

ASIC: Application-Specific Integrated Circuit

Philips Digital Photon Counting

Digital that's really digital

Redefine light detectors with digital SiPMs

Digital SiPMs create a new class of light detectors for ultra-low light levels down to single photons, by integrating both the sensor and the data processing into a single silicon chip.

When it comes to scintillation light detectors, **how does technology compare?**

	PMT	APD	Analog SiPM	Digital photon counting Digital SiPMs
*TOF capability**	*analog, time-of-flight*	*N/A*	*analog, time-of-flight*	*digital, time-of-flight*
Operational stability	*medium*	*low*	*medium*	*high*
Signal amplification	*10^6*	*10^{2-3}*	*10^6*	*not needed*
Level of Integration	*low*	*medium*	*medium*	*high*
Signal readout	*analog*	*analog*	*analog*	*digital*

** Assumes the use of LYSO as the scintillator*

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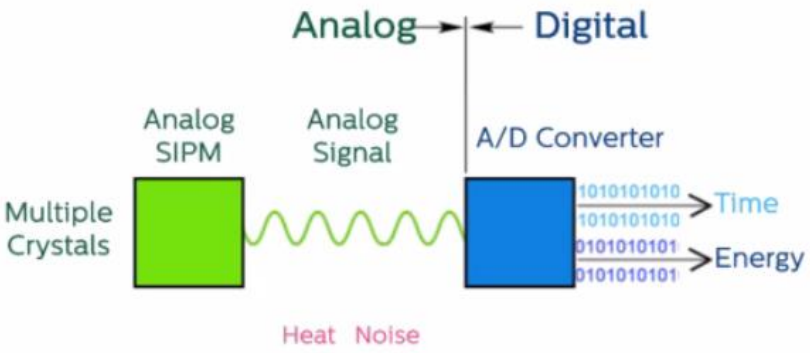
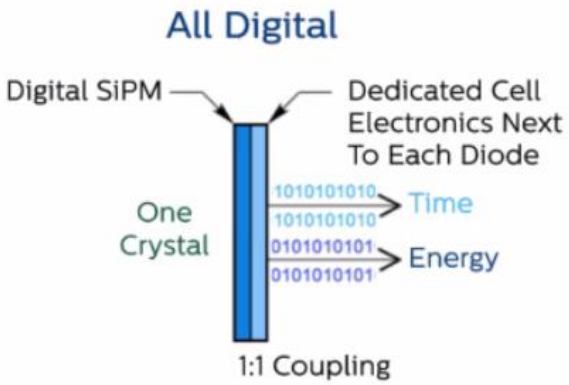
Philips Digital Photon Counting

Digital that's really digital





Analog SiPM
Limited Integration
Analog Signals To Be Digitized
A/D converter needed

Digital photon counting Digital SiPMs
Fully Integrated
Fully Digital Signals
No A/D converter

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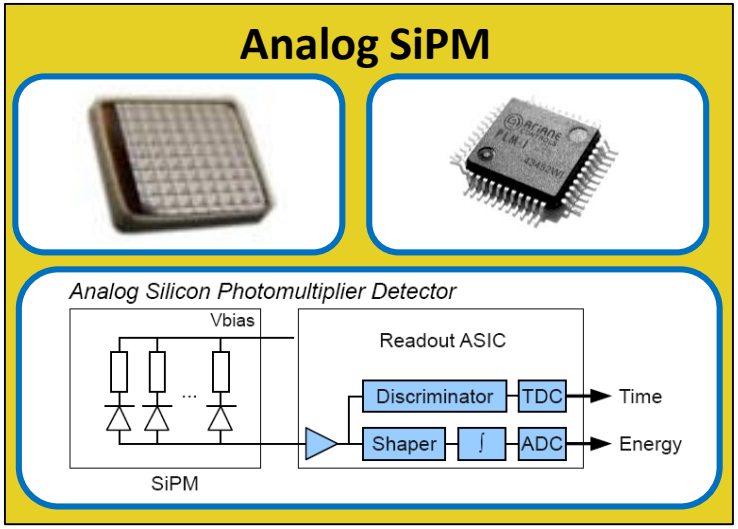
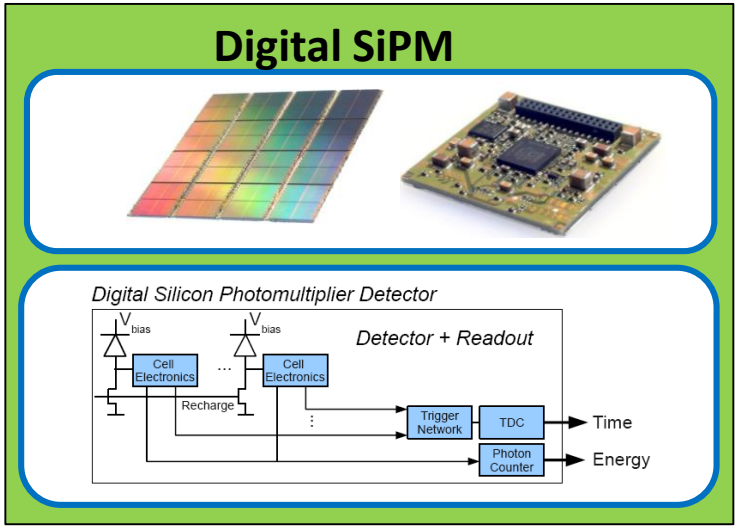
The dSiPM Takes Advantage of the Binary Nature

Unwanted collateral effect of SiPM that generate noise:

- Dark count
- Afterpulsing
- Crosstalk



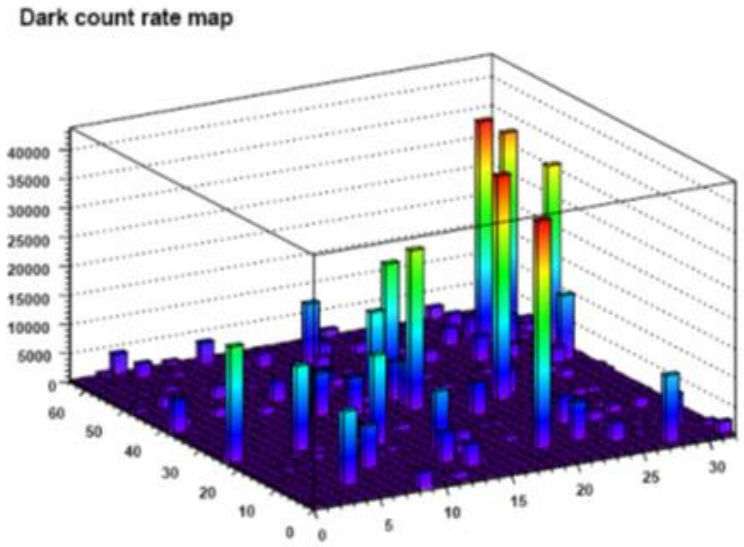


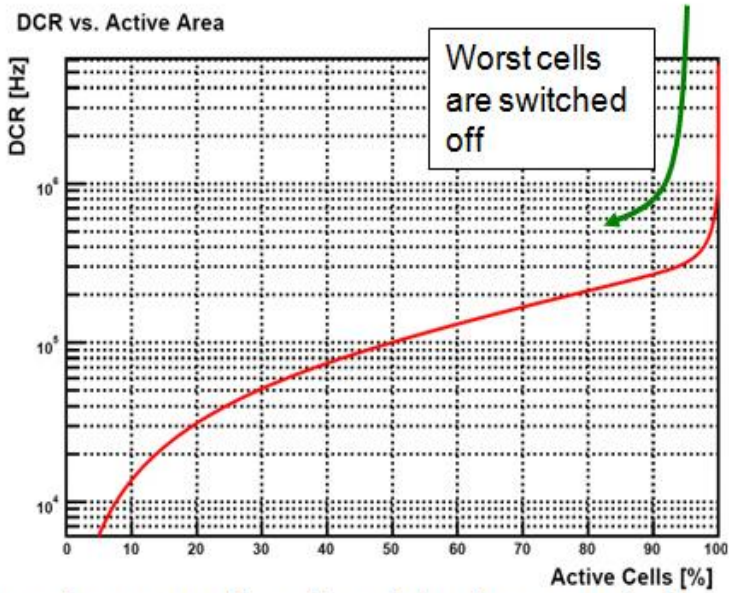
No chance to eliminate this noise

Noise reduced thanks to digitalization

DPC: dark count management by digitization

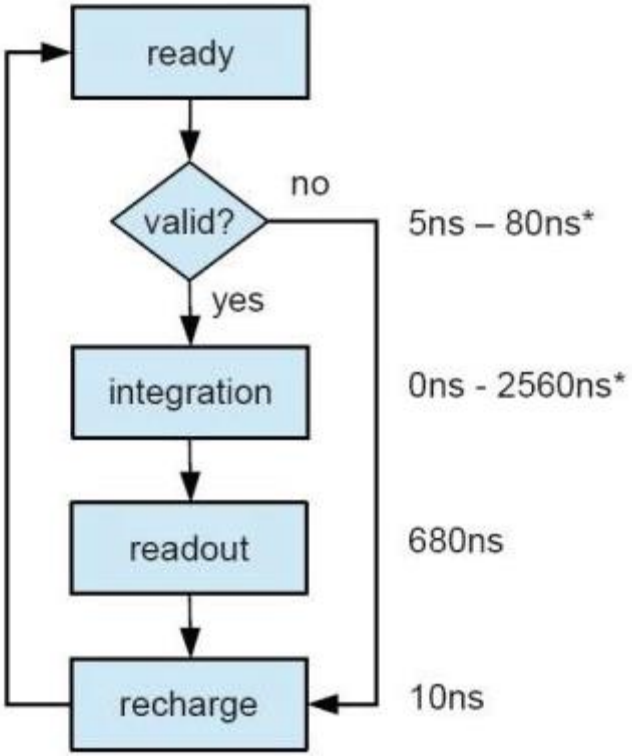
Within one pixel you have 3200 micro cell





- Silicon based light sensors have background noise (dark counts), varying with temperature.
- In digital SiPMs every cell can be addressed individually.
- Cells with high dark counts can be switched off.
- A few cells switched off (1-5%) reduces dark count levels by orders of magnitude.

DPC: dark count management by digitization

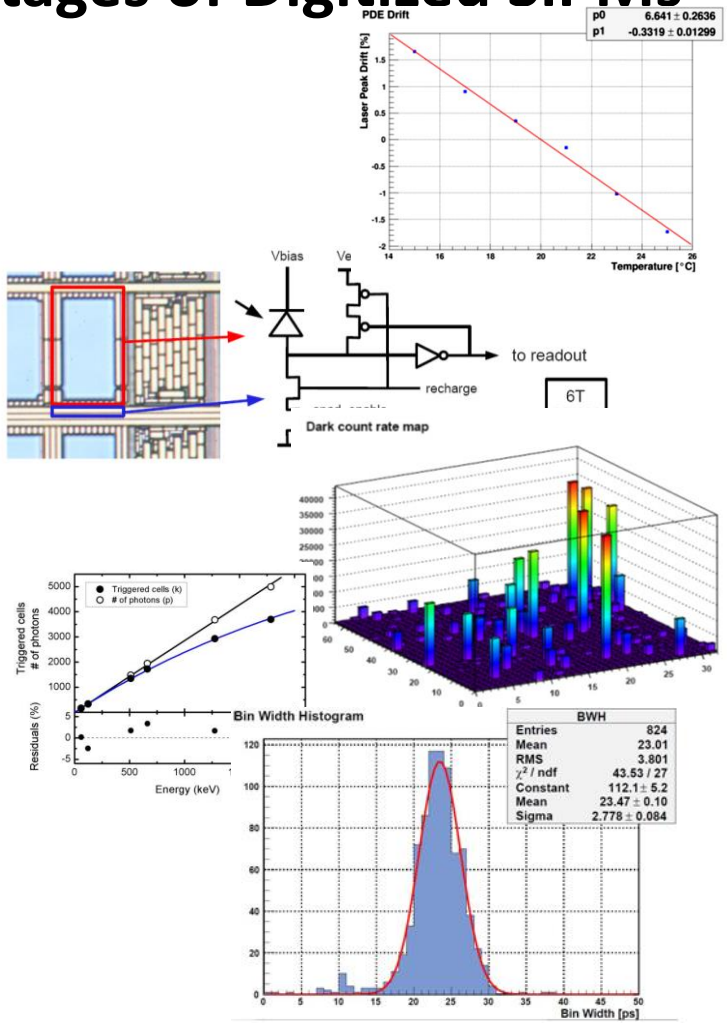


- 200 MHz (5ns) system clock
- Variable light collection time up to 20 µs
- Dark count recovery
- Data output parallel to acquisition

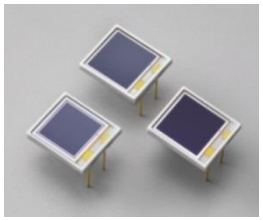
* Programmable

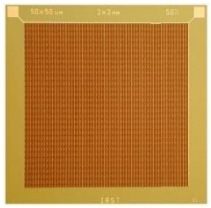
Sub-Summary: Advantages of Digitized SiPMs

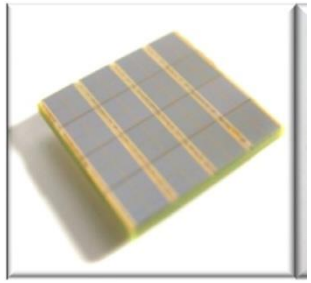
- significantly reduced temperature sensitivity
- active quenching reduces afterpulsing &crosstalk
- individually addressable cells enable DC control
- better linearity (&correction)
- better intrinsic timing resolution due to integrated TDCs
- no analog electronics, no ADCs, no ASICs



Scintillation light detectors – what is out there?





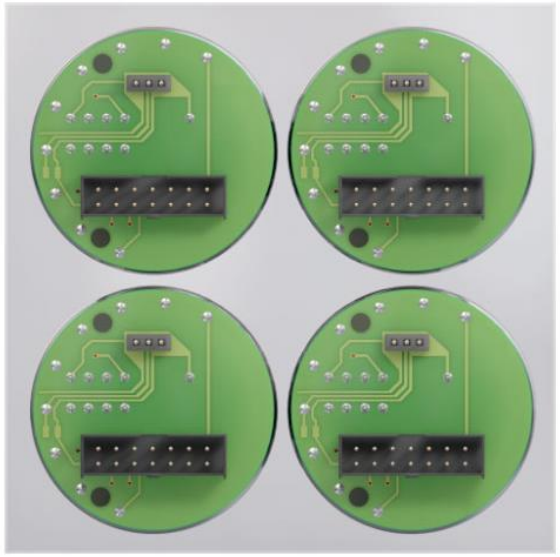


Type	PMT	APD	analog SiPM	dSiPM
MR compliance	**No**	**Yes**	**Yes**	**Yes**
ToF compliance	limited	No	Yes	Yes
operational stability	medium	low	low	high
amplification	High (10^6)	Low (10^{2-3})	High (10^6)	meaningless
compactness	bulky	compact	very compact	very compact
power/readout	HV, complex, analog	HV, complex, analog	complex, analog	simple, digital

Analog vs. Digital Photon Counting

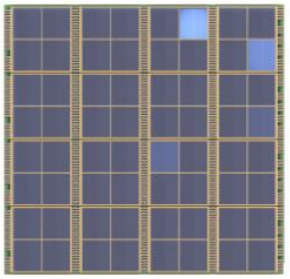
Over 50 times more detectors than analog detection systems.

Analog



420 detectors

Digital Photon Counter



23.040 detectors
73.728.000 photon counter

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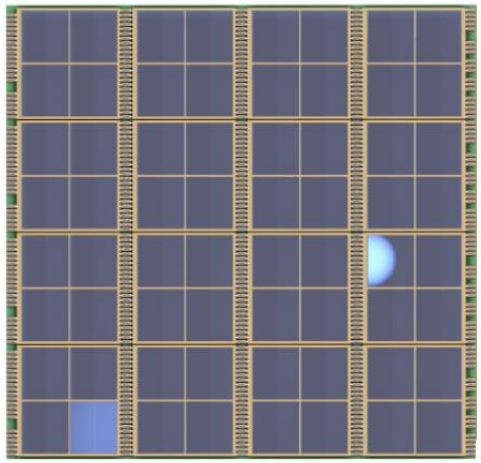
The advantages of Digital Photon Counting

DPC Scintillator

Digital Photon Counter



- 1:1 coupling
- Dramatically higher count rate
- Excellent timing resolution
- Faster Time of Flight performance
- Superb SUV quantification
- Improved contrast resolution

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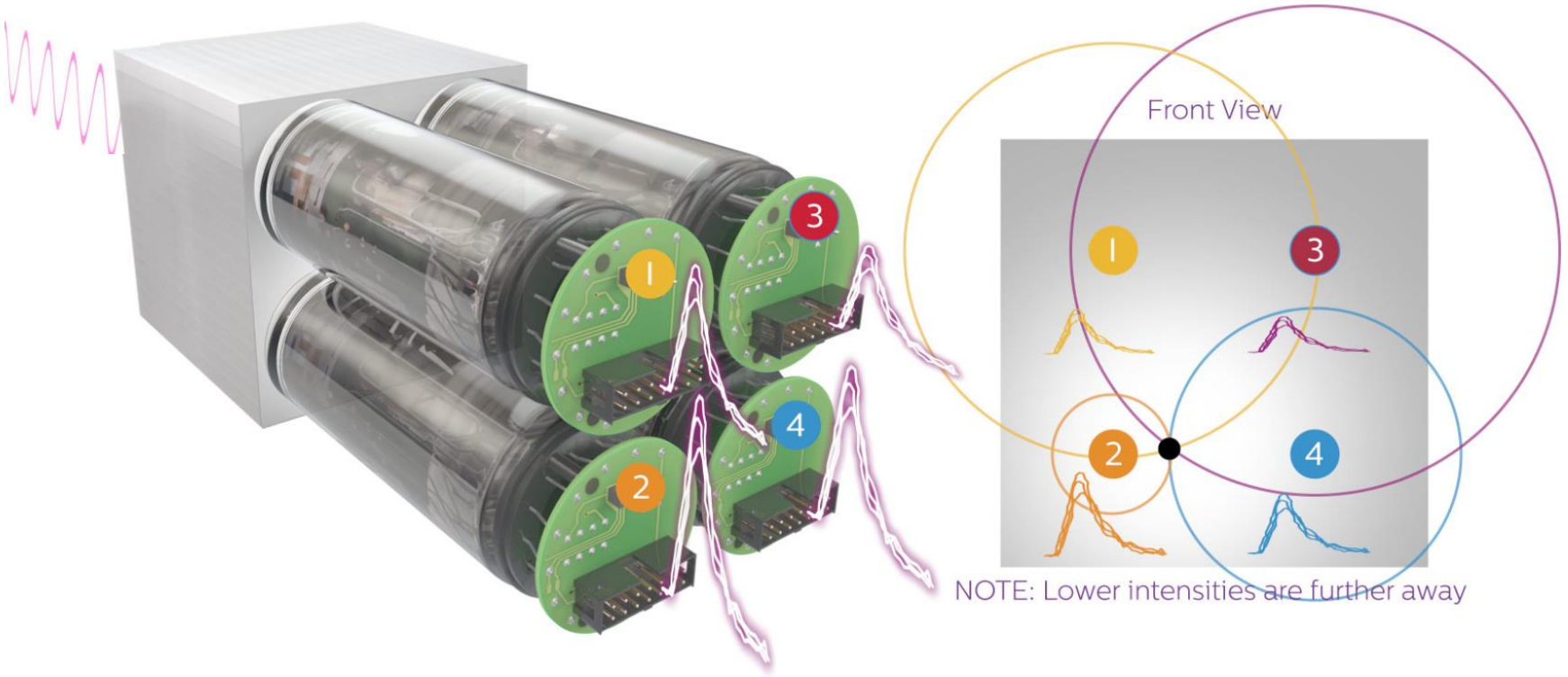
How today's analog detection works

Photomultiplier tubes approximate the location of an event.



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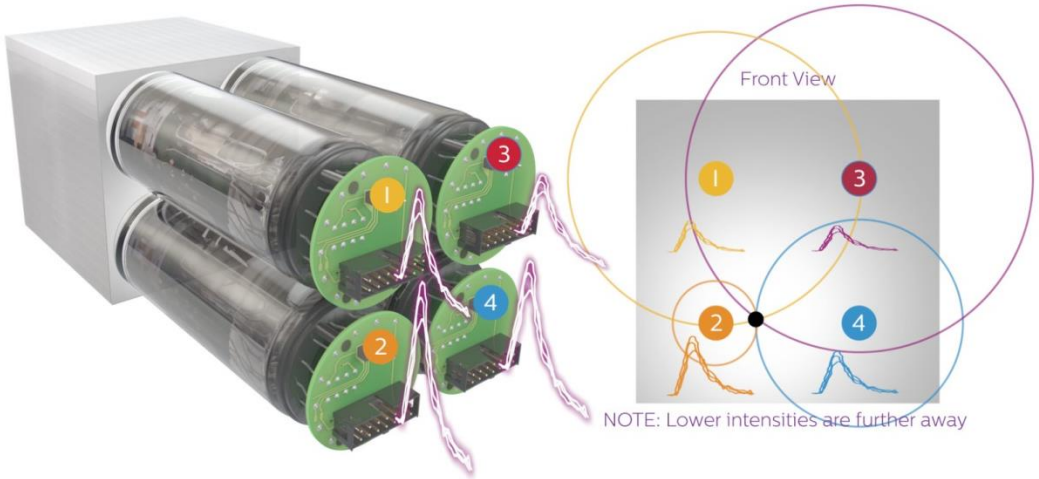


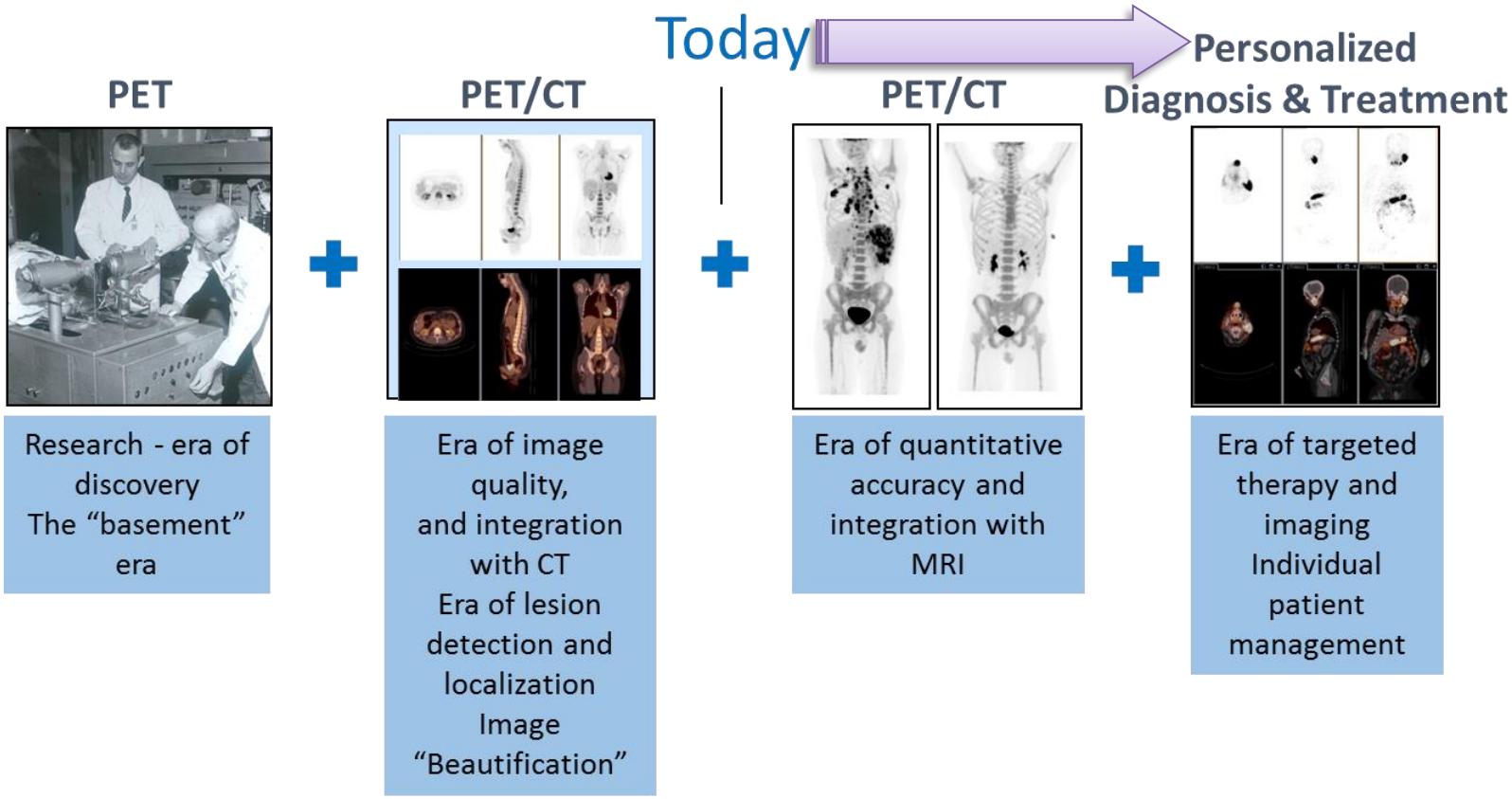
As the signal is amplified, the electrical noise is also amplified causing a noisy output signal

The intensity of the signals are averaged in order to estimate the origin of the signal.

With a **noisy signal** and **an inaccurate localization** of the signal,
the output of the PMT-based system is extremely inaccurate.

Technology
to Clinical
Performance.

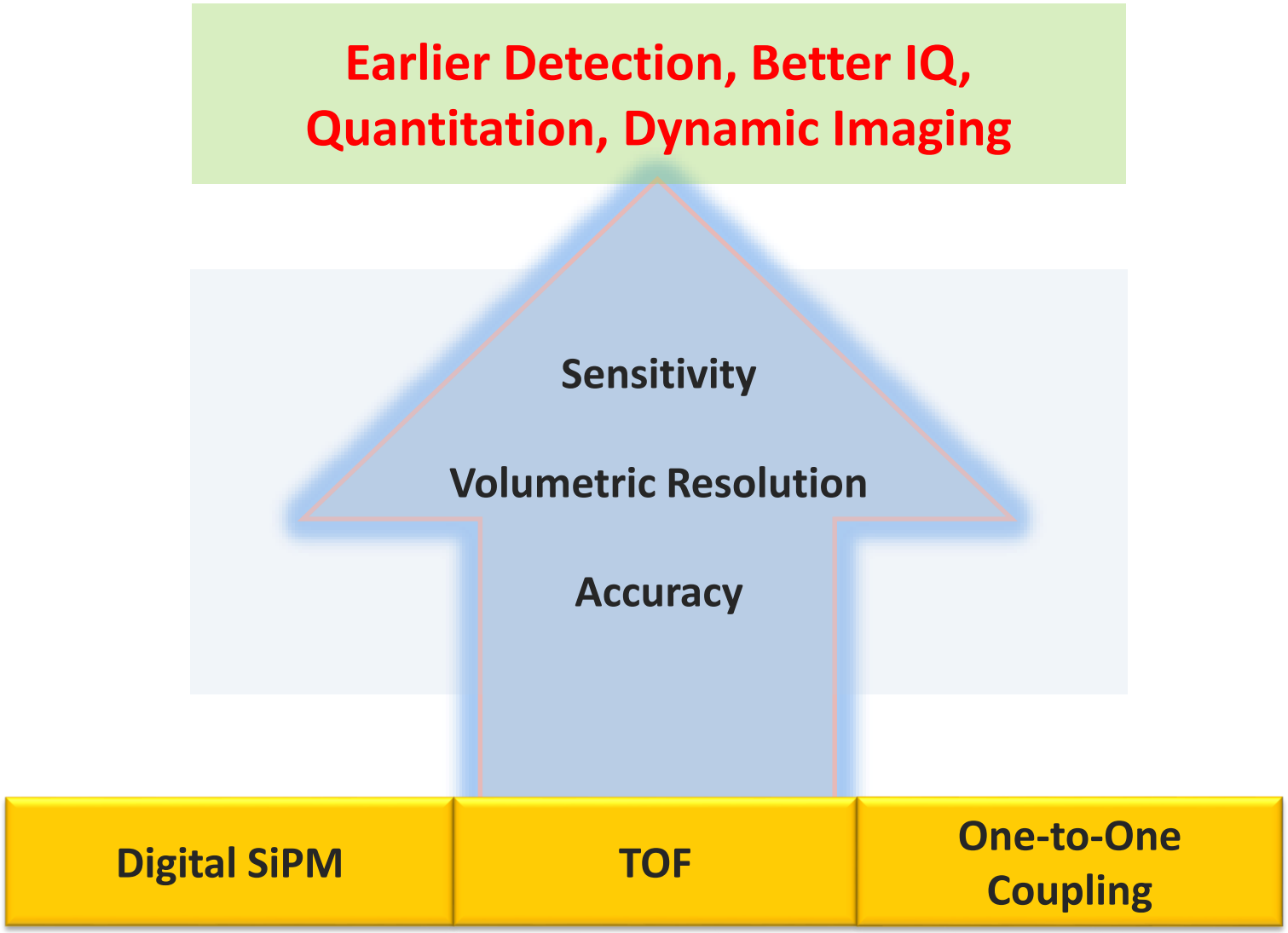
Evolution of PET



PHILIPS

Vereos PET/CT

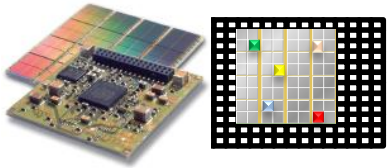
A Breakthrough Technology



PHILIPS

Vereos PET/CT

A Breakthrough Technology



Earlier Detection, Better IQ, Quantitation, Dynamic Imaging

Sensitivity

Volumetric Resolution

Accuracy

Better Resolution Shape- No dead time

Better Detector Resolution

Uniform Detector Resolution

Digital SiPM

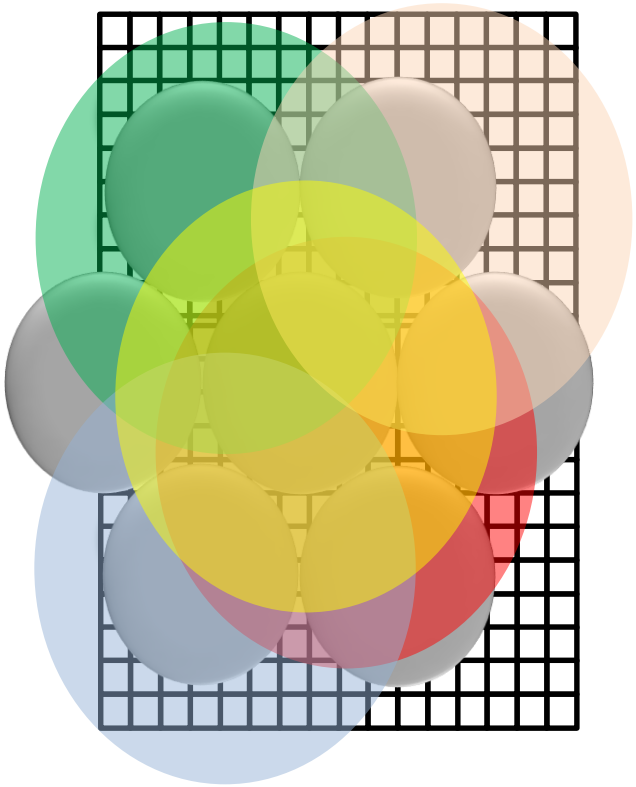
TOF

One-to-One Coupling

PHILIPS

Digital Photon Counting

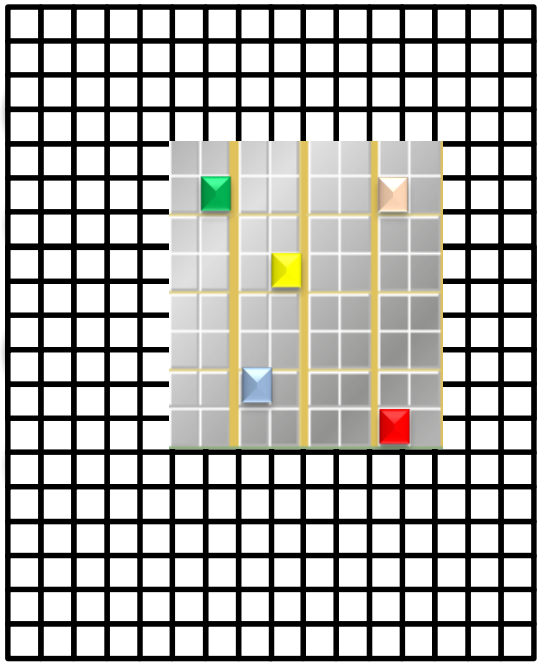
1:1 coupling.



DPC reduces the traditional tradeoffs between sensitivity gains and resolution gains.

Conventional block detector limitations

- Optically isolated for surrounding blocks
- PMTs are used to localize
- Light collection dropoff at edges of blocks
- Light collection variability with position



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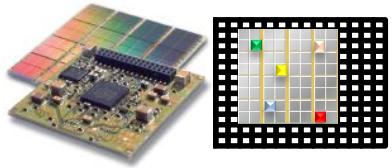
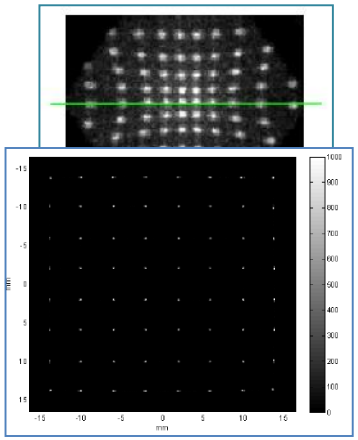
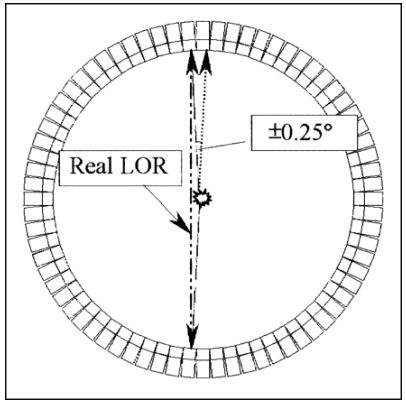
1:1 Coupling: Spatial Resolution



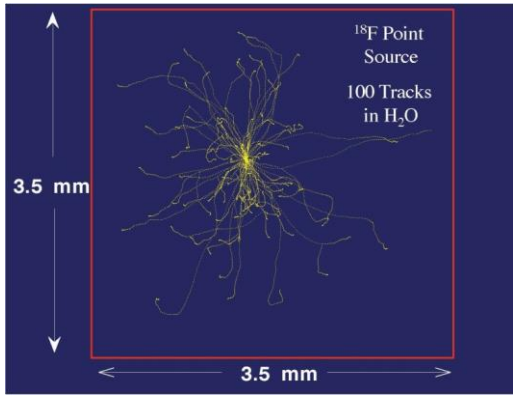
$$FWHM = a\sqrt{\left(d/2\right)^2 + b^2 + (0.0022D)^2 + r^2}$$

Crystal Size





Noncolinearity

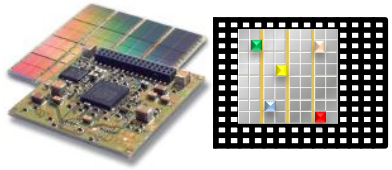


Positron range

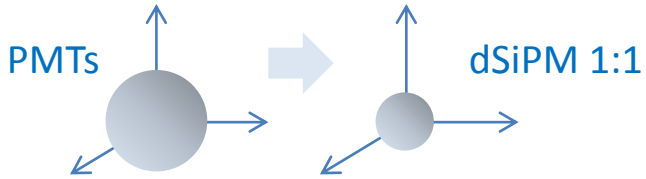
The final spatial resolution of the PET image results from various factors, some intrinsically related to the β^+-annihilation interaction, noncolinearity of annihilation photons and positron range) and some related to the detection system, such as the scintillation crystal performance and electronics used.

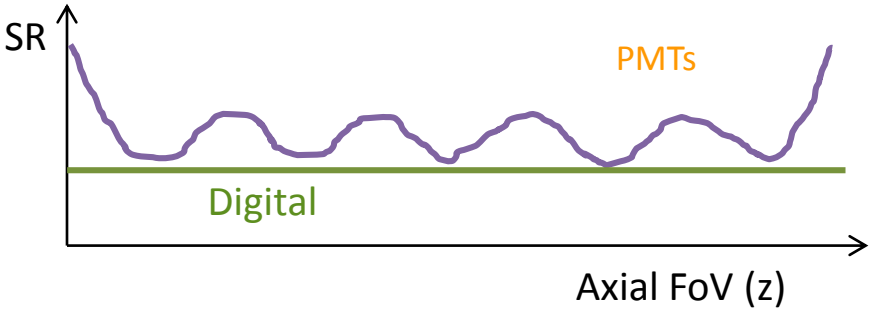
PET Instrumentation and Reconstruction Algorithms in Whole-Body Applications, Gabriele Tarantola et al, J Nucl Med May 1, 2003 vol. 44 no. 5 756-769

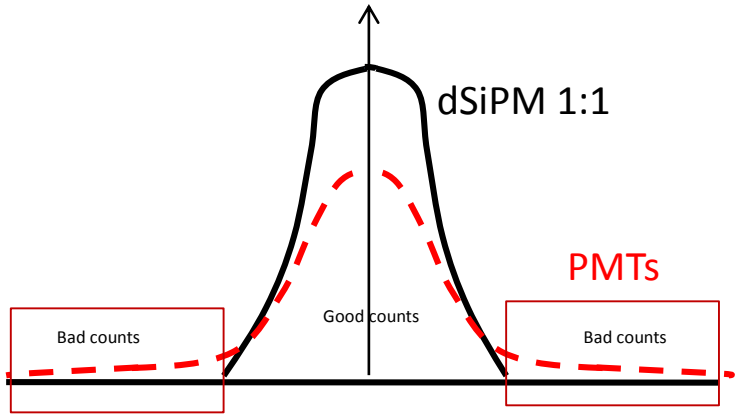
1:1 Coupling – Resolution



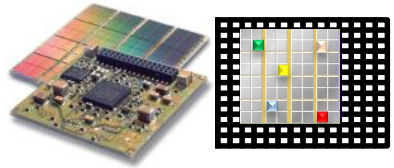
- **Factor of 2 volumetric resolution gain**
  - 3D, (axial*radial*tangential)
    61 mm^3
- **Uniform detector resolution across all detector surface**
  - Digital: Constant in axial direction
  - PMT Tubes: worse resolution under the tubes and at the edges
- **Bad counts vs. good counts**
  - No “bad tail”; all are good counts for Vereos







1:1 Coupling – Resolution

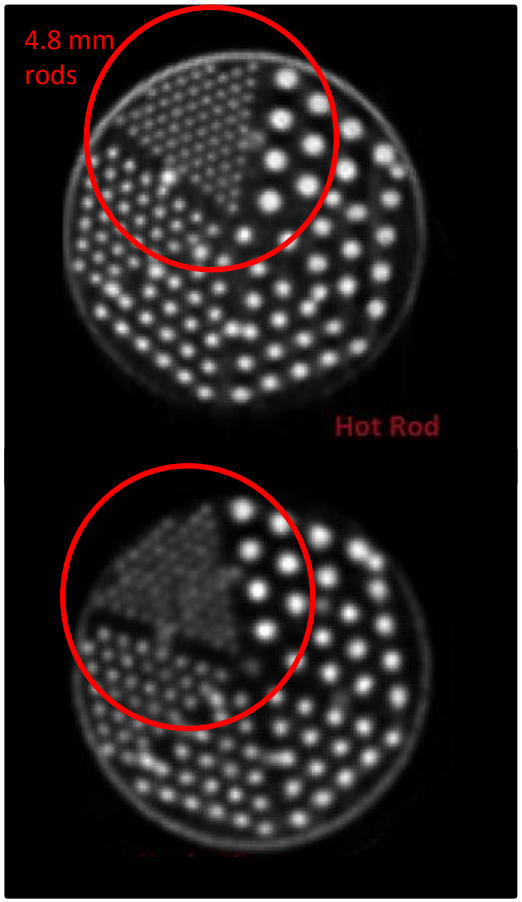


Improved spatial resolution seen with conventional clinical phantoms.

Digital

Analog*

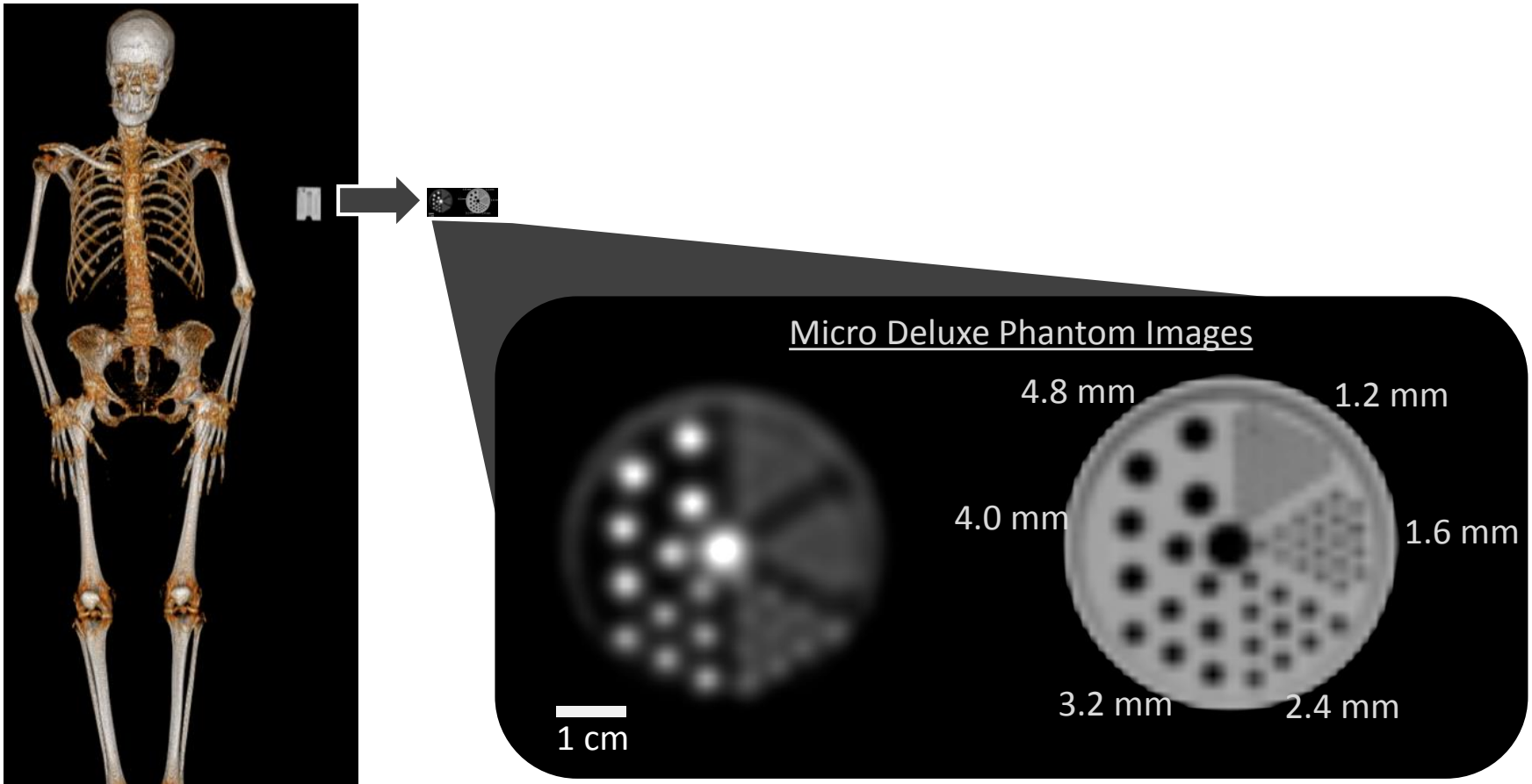
**GEMINI TF 16*



Deluxe Jaszczak Phantom

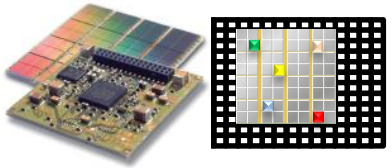
PHILIPS

Spatial Resolution



Standard brain imaging protocol (10 min acq) with TOF reconstruction with resolution recovery

1:1 Coupling – Sensitivity



Improved quantitative performance.

Very minimal to none dead-time → Increased sensitivity

- Typical whole body scans with analog technology operate at 10-20% dead time,
- Typical dynamic studies with analog technology operates at 30-50% dead time

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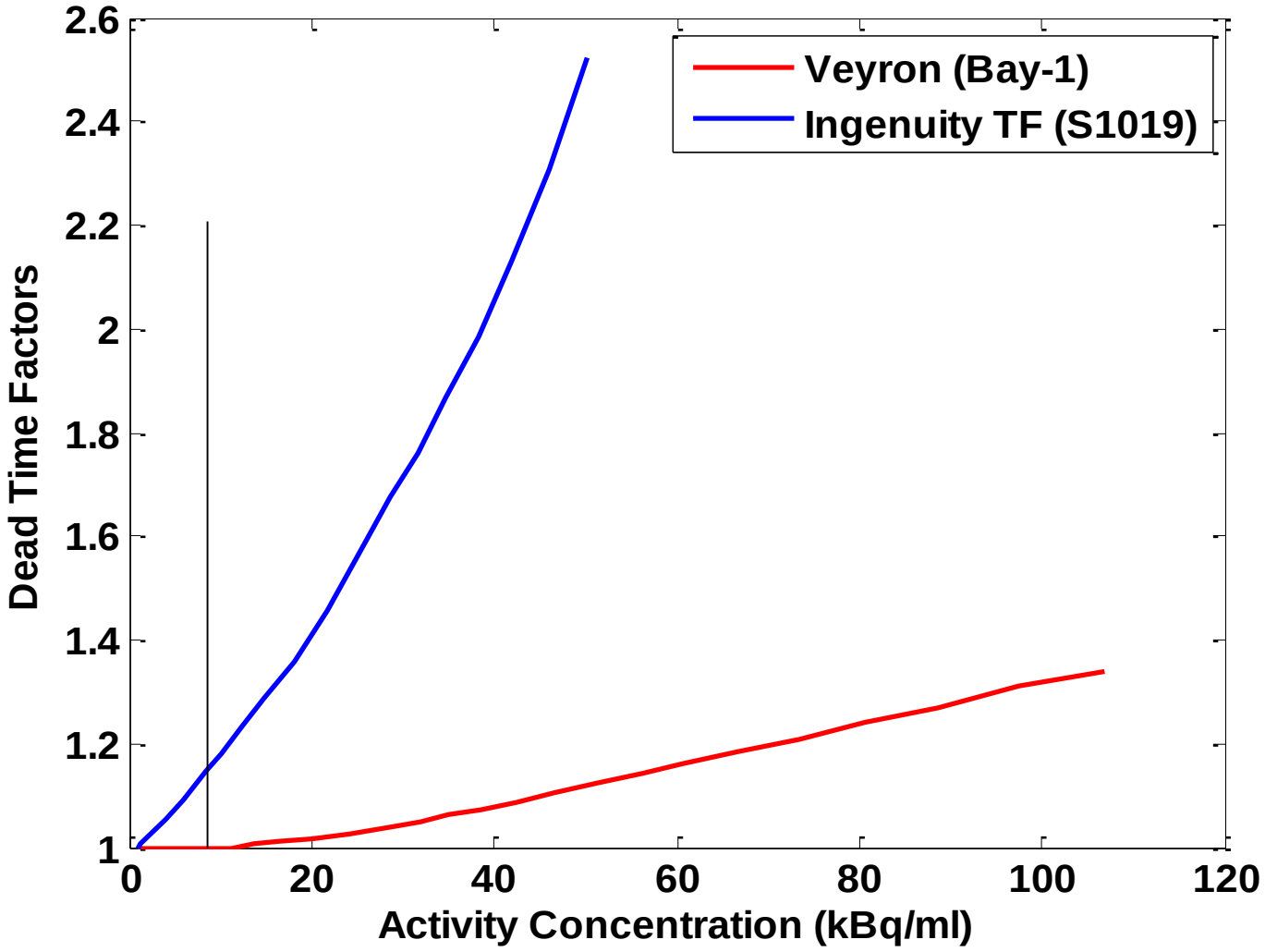
One-to-one Coupling – Benefits

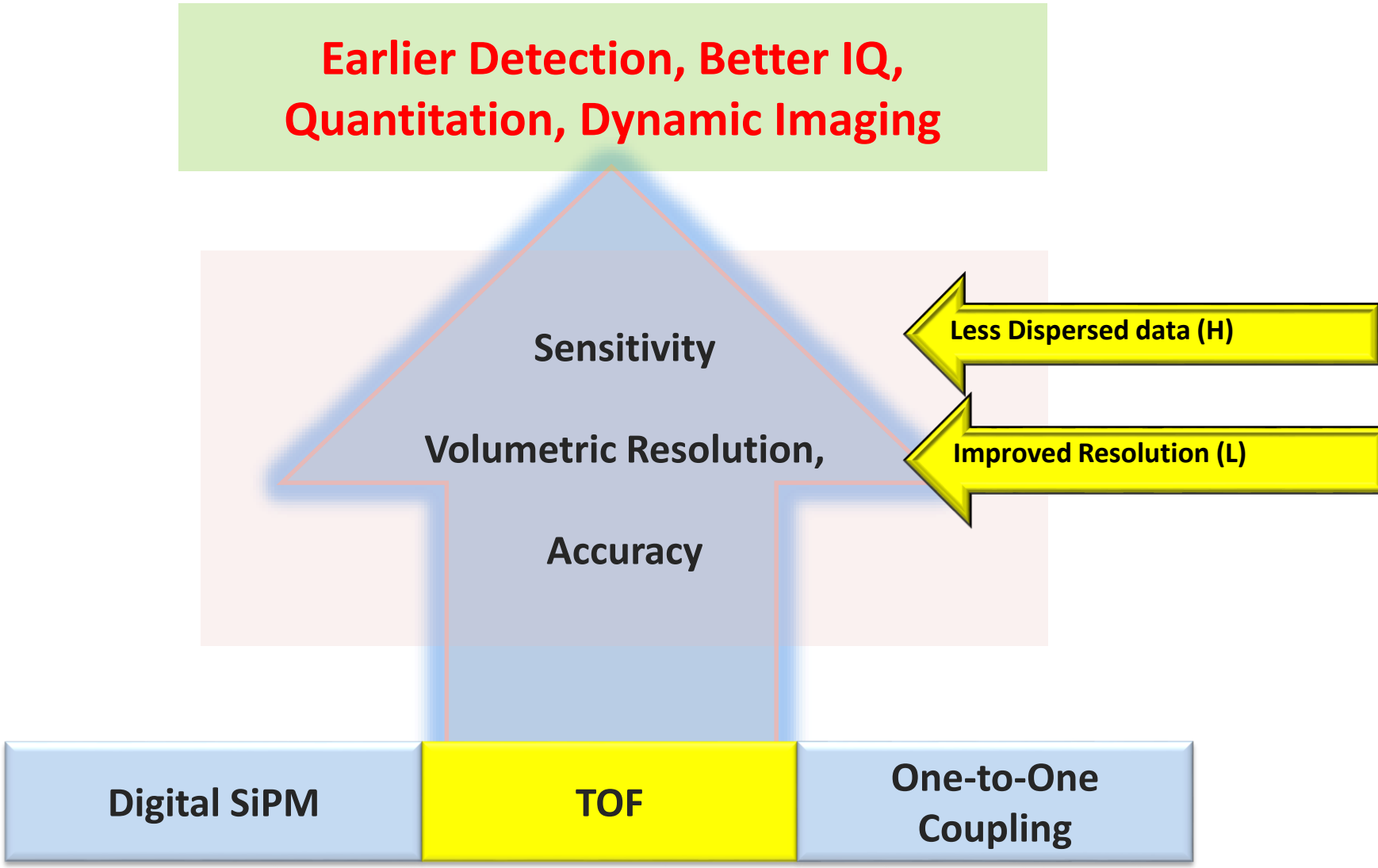
Preliminary: Deadtime Comparison



Most whole body studies are below 10kBq/ml

Vereos PET/CT

A Breakthrough Technology

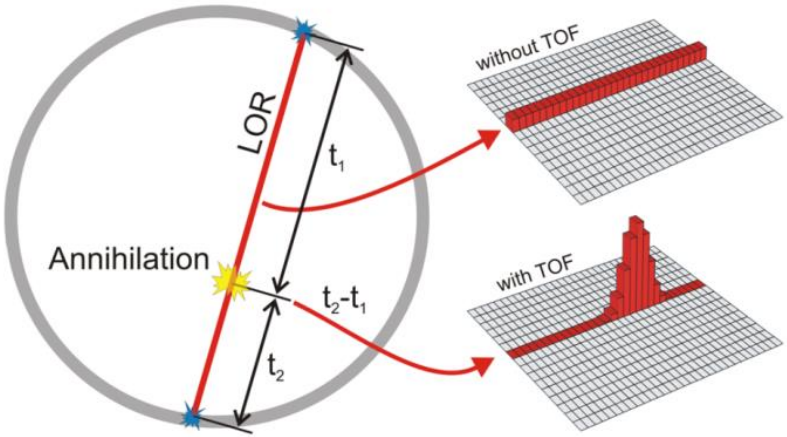


Time of Flight

Δx = position uncertainty along LOR = $c \cdot \Delta t/2$

Effective Sensitivity gain = $D/\Delta x$

Δt – Time Resolution, D – Diameter of Object;
c – light speed; Δx - position uncertainty



Time Resoltuion (ps)	Non-ToF	1000	550	495	310	300	100
Spatial Unceternity (cm)		15.0	8.3	7.4	4.4	4.5	1.5
Sensitivty Gain for 20 cm	1	1.3	2.4*	2.7*	4,3	4.4	13.3
Sensitivty Gain for 30 cm	1	2.0	3.6*	4.0*	6,5	6.7	20.0
Sensitivty Gain for 40 cm	1	2.7	4.8*	5.4*	8,7	8.9	26.7

*Sensitivity gains for analog technology need to be corrected for dead times

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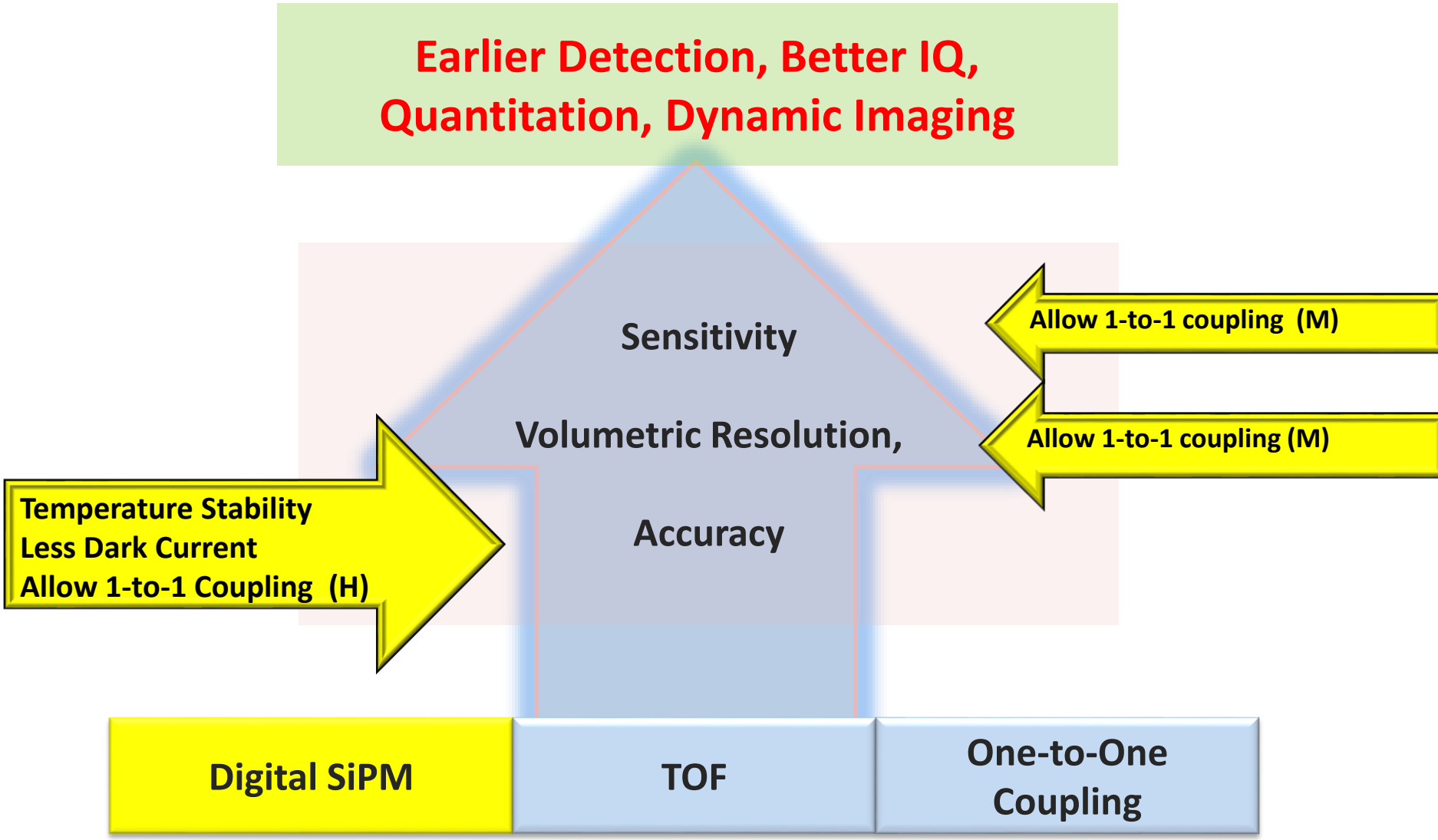
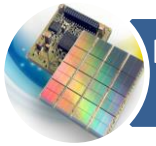
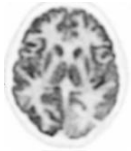
Vereos PET/CT

A Breakthrough Technology

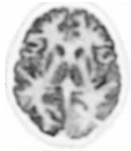




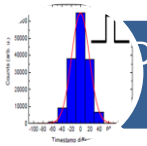
Digital Photon Counting



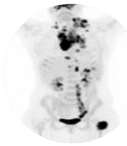
≈ 2x improved volumetric resolution*



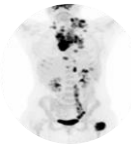
? Earlier detection



Digital Time of Flight

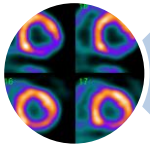


≈ 2x sensitivity gain*

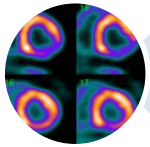


? Lower dose

1:1 Coupling



≈ 2x improved quantitative accuracy*

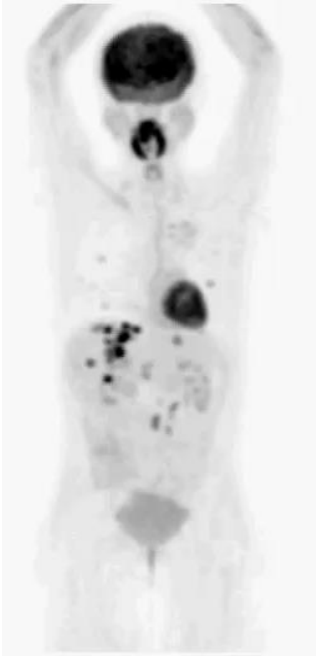


? Responders vs non-responders

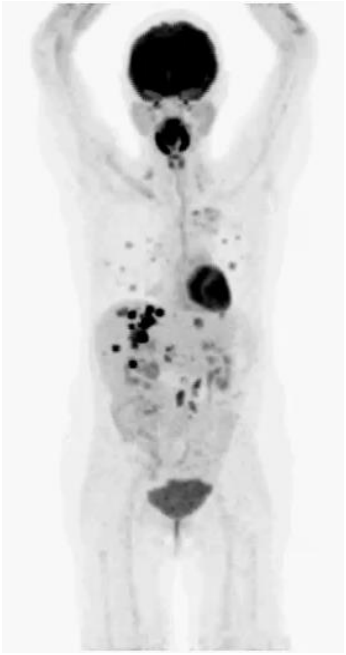
* Analog (*GEMINI TF)* to digital comparison

Clinical Performance.

Analog *
Time of Flight



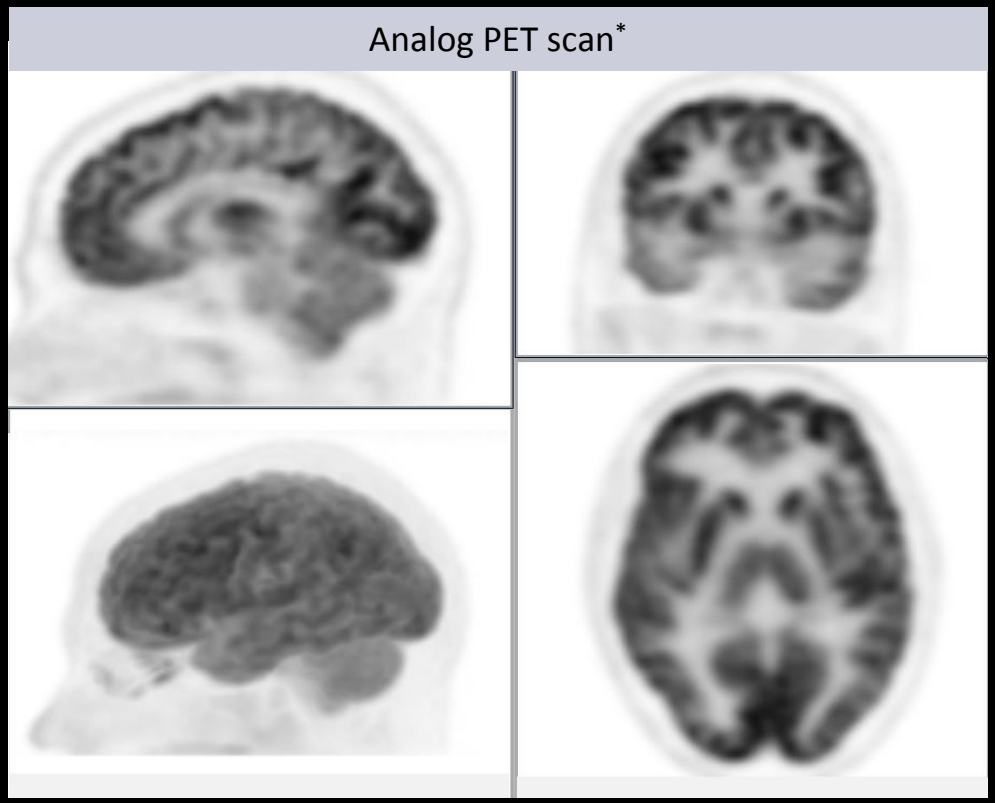
Digital
Time of Flight



THE OHIO STATE UNIVERSITY
WEXNER MEDICAL CENTER
Wright Center of Innovation in Biomedical Imaging

Patient data courtesy of Dr. M. Knopp
"Results from case studies are not predictive of results in other cases. Results in other cases may vary."

See further



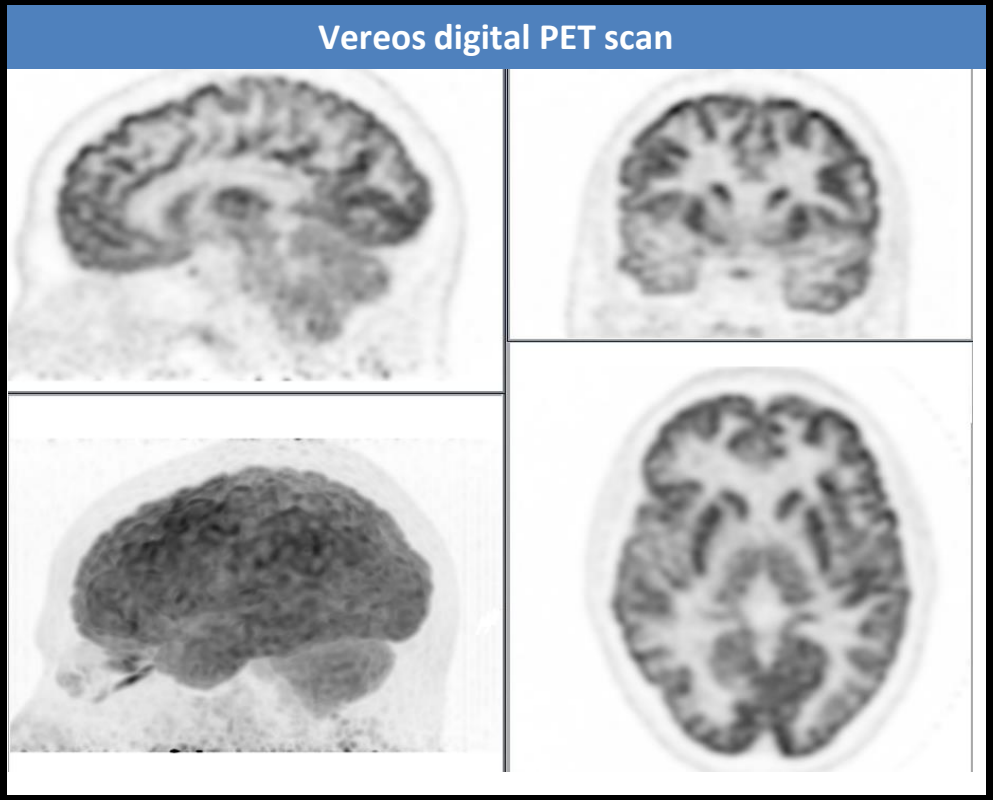
**GEMINI TF 16*

Images courtesy of University Hospitals Cleveland

PHILIPS

See further

Superb spatial resolution provides exceptional detail in brain images.



Images courtesy of University Hospitals Cleveland

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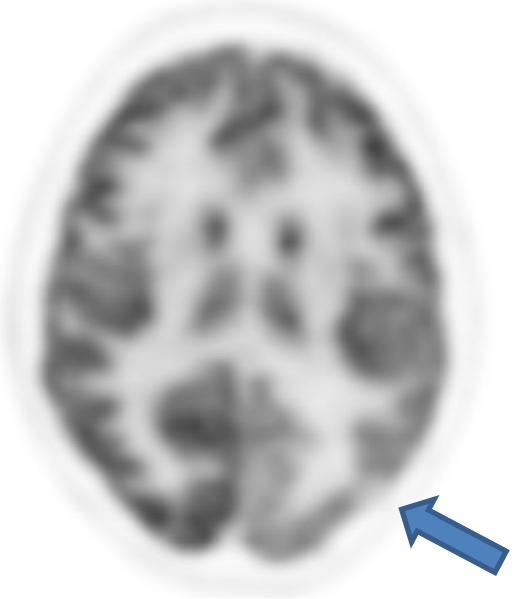
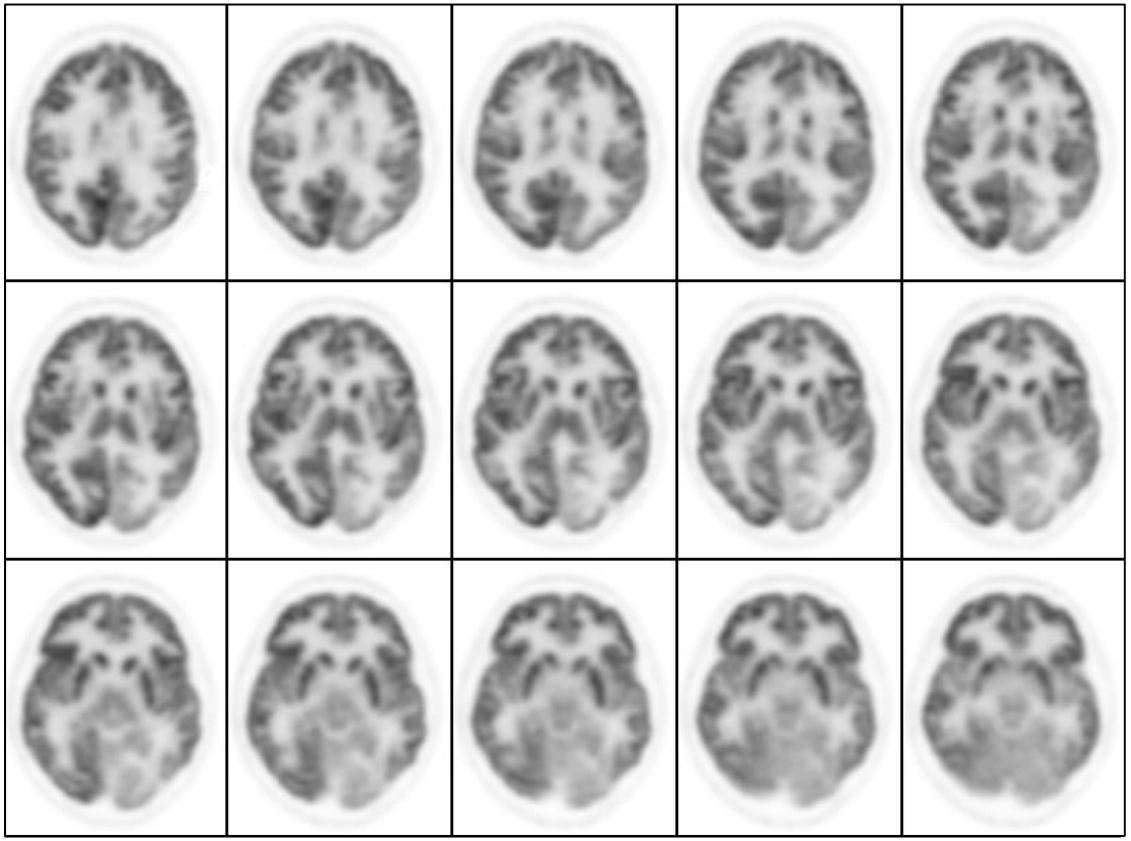
See further

Improved image contrast in evaluation of post-operative changes.

Analog PET scan*



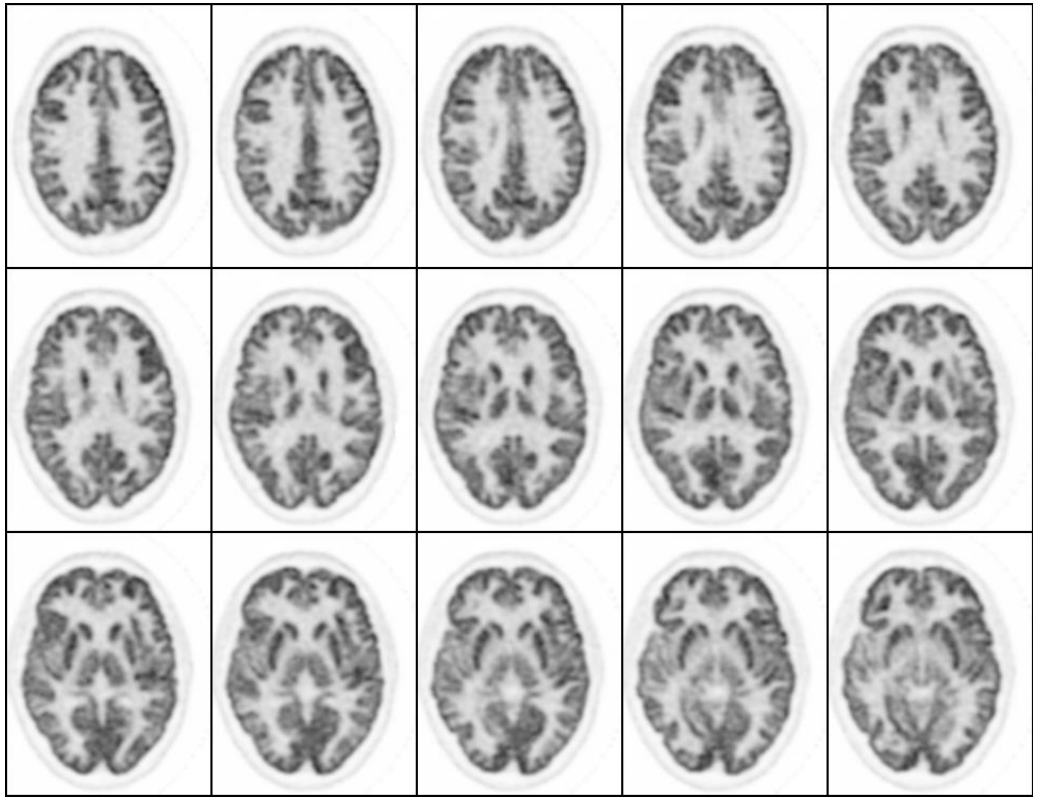


Images courtesy of University Hospitals Cleveland

PHILIPS

See further

Superb spatial resolution provides improved detail in brain images.



Images courtesy of University Hospitals Cleveland

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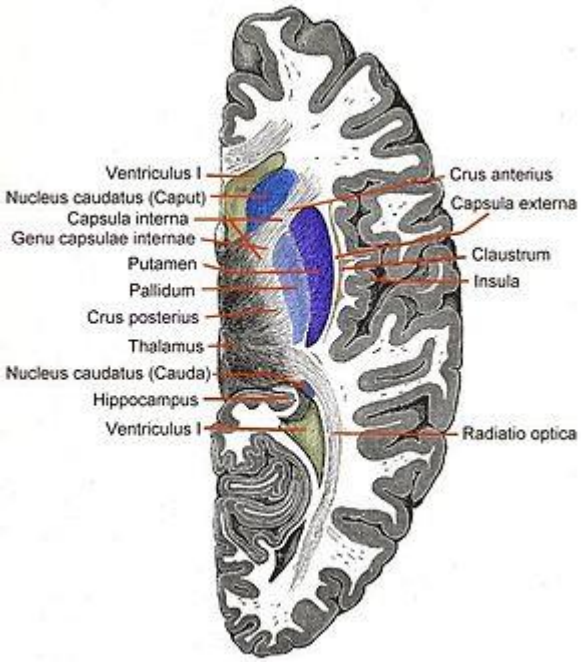
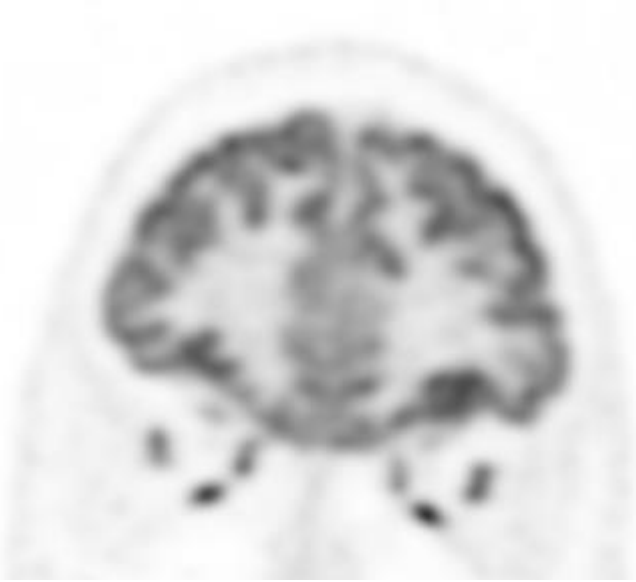
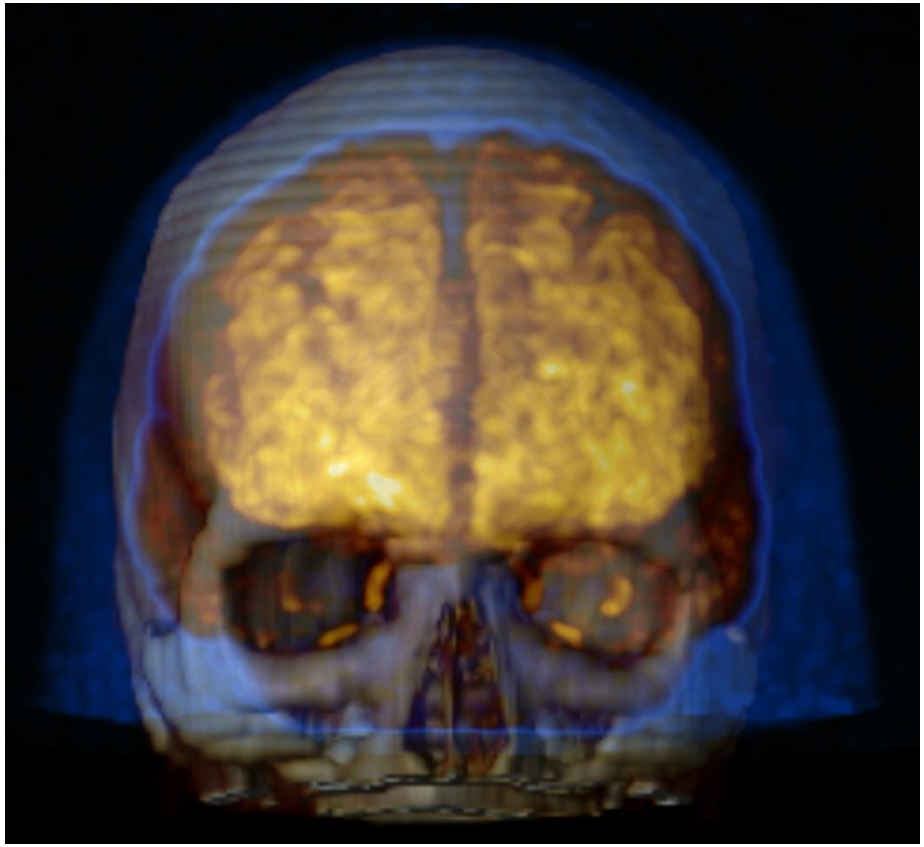
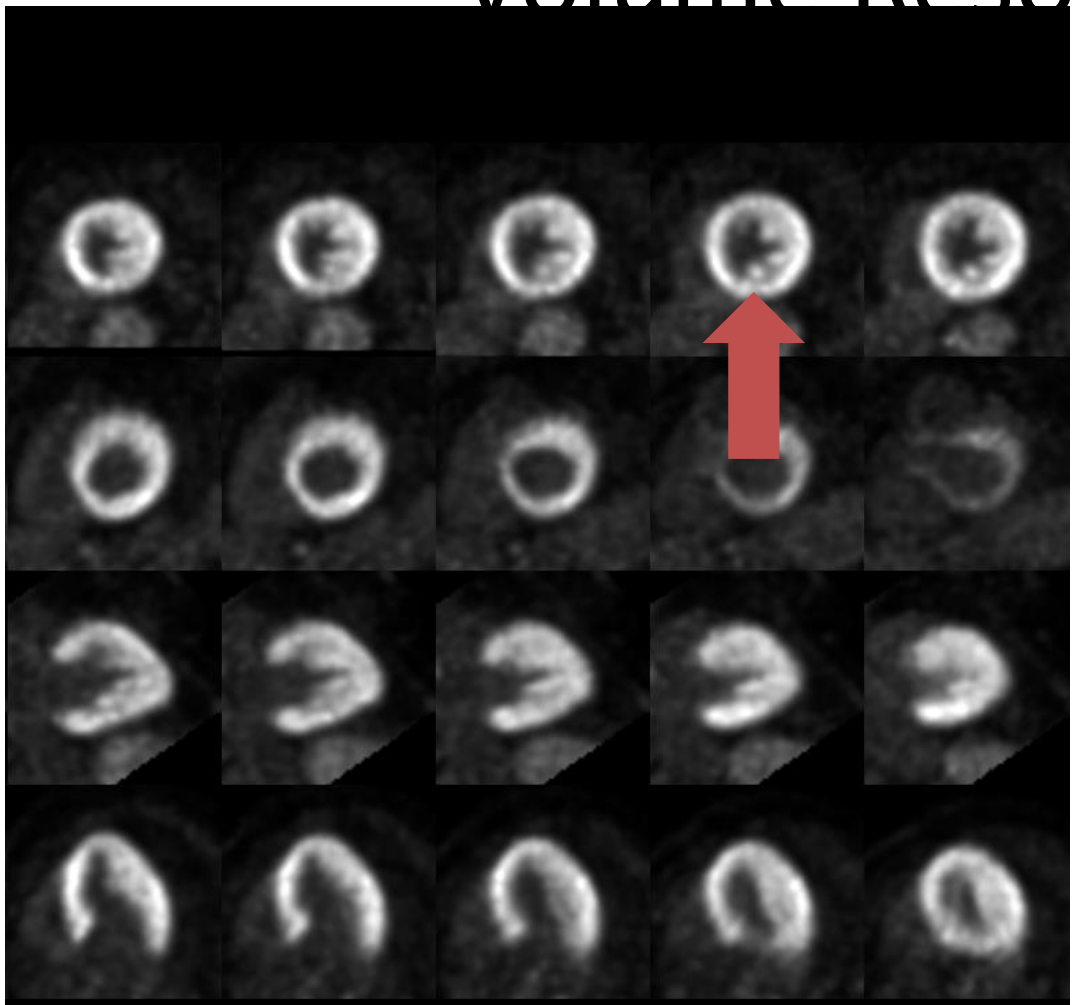
Volumetric Resolution

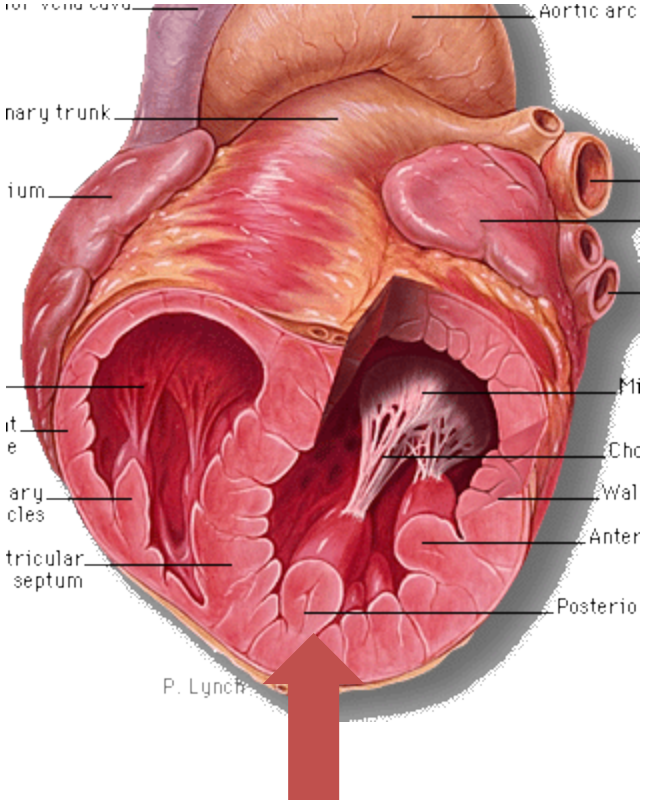




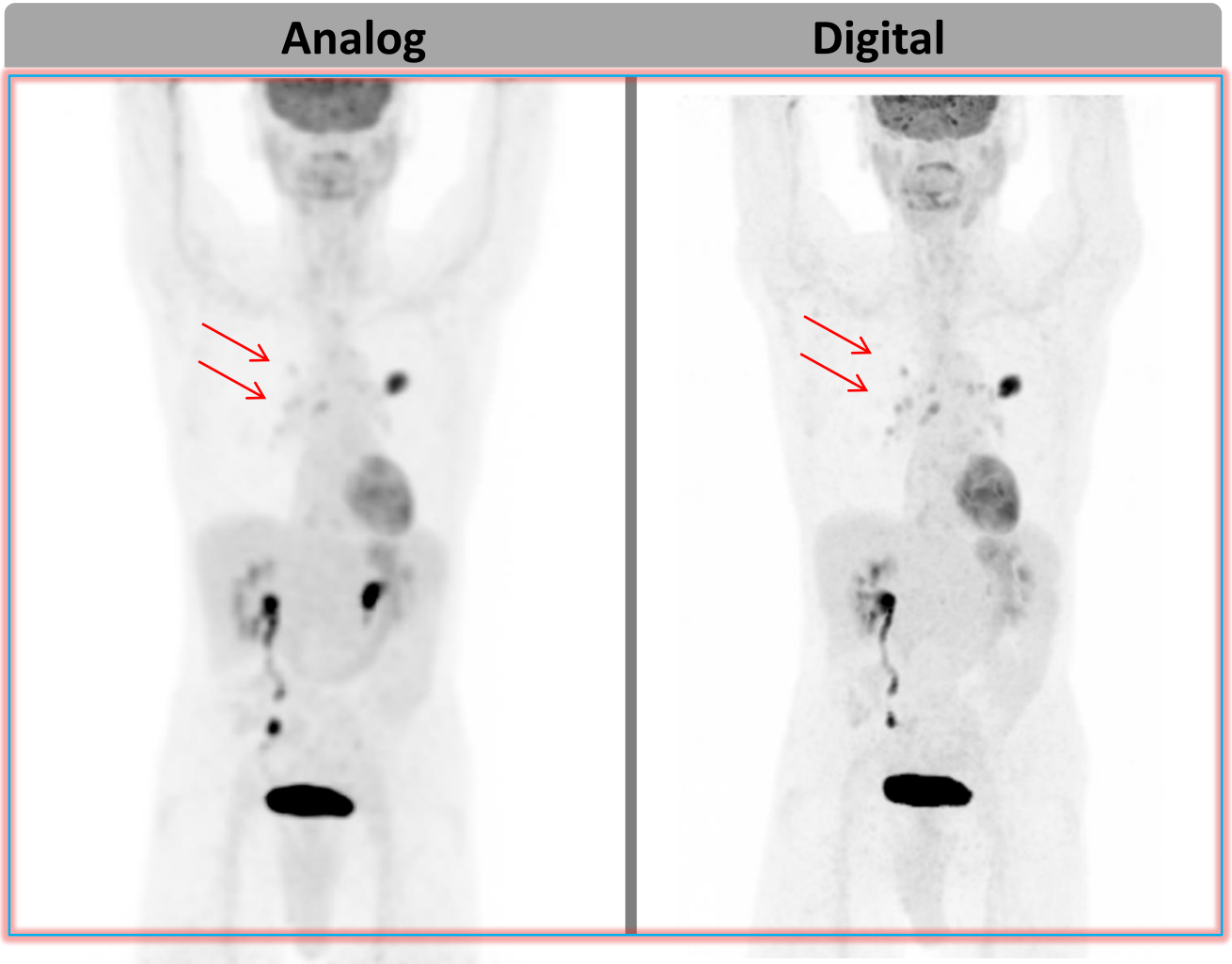


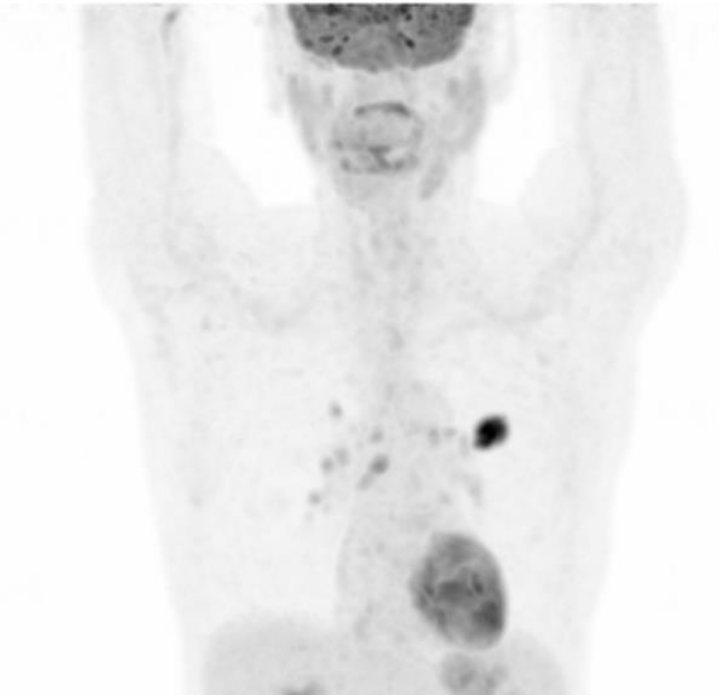
Volume Resolution

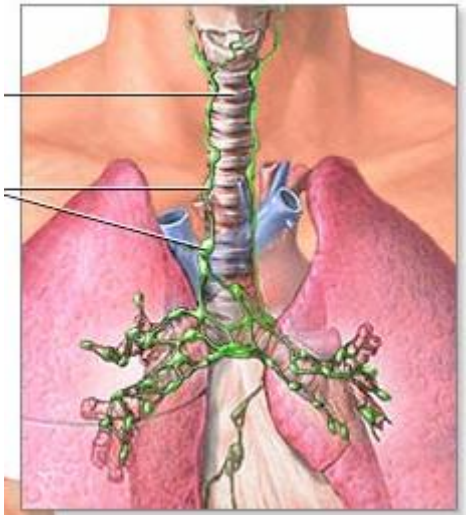




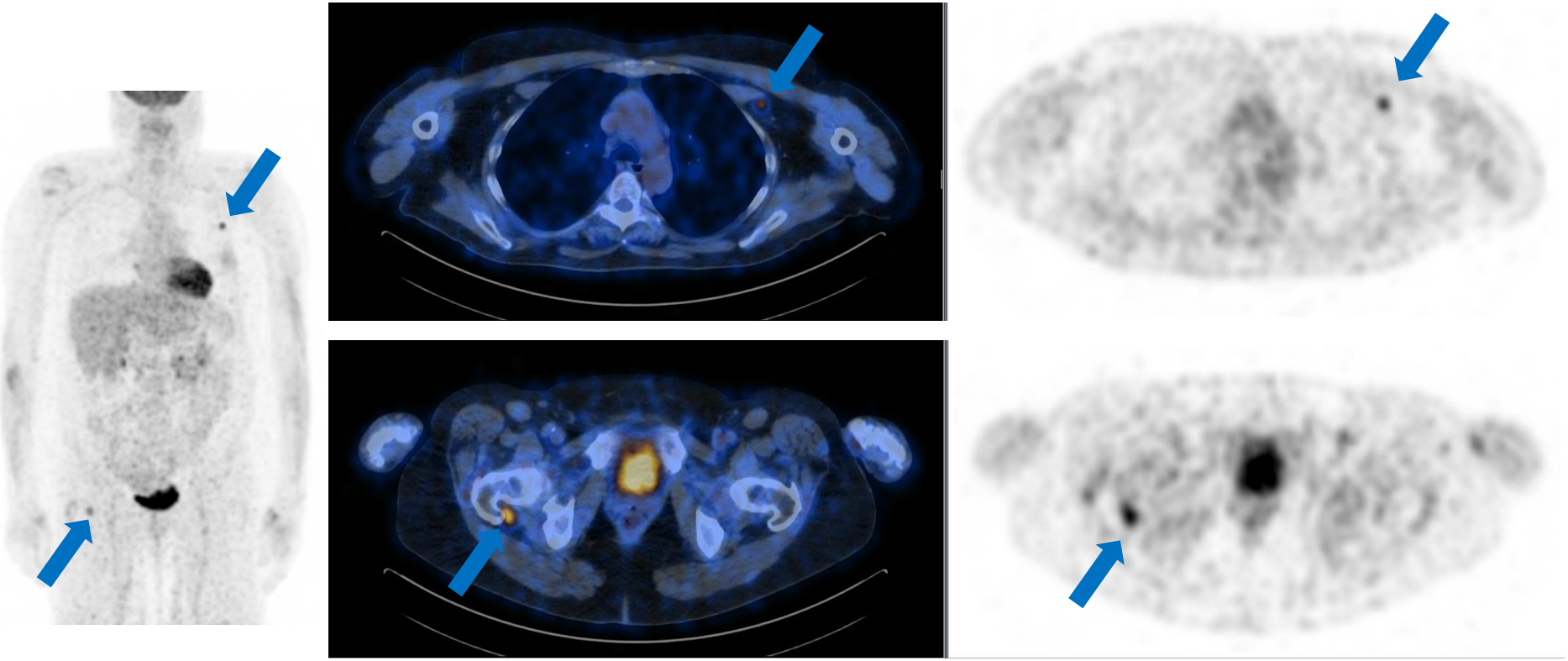
Digital Photon Counting







Oncology case 418

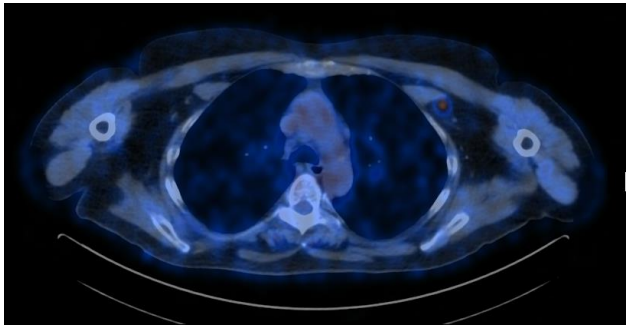


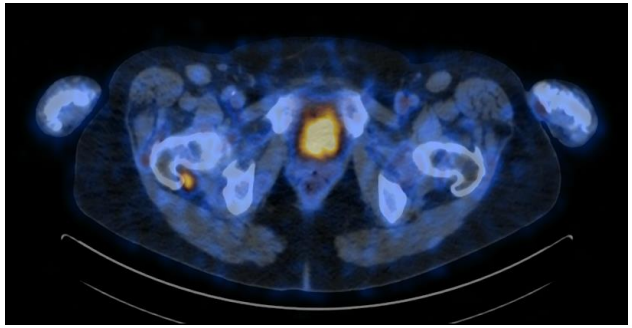
Total Body PET acquisition time: <u>81 seconds</u>

Oncology case 418

Acquisition time

- 81kg, 1.73m
- 13 mCi / 481 MBq
- F-18 FDG
- 61 min delay
- 9 sec/bed, 9 beds
- 81 sec acquisition time

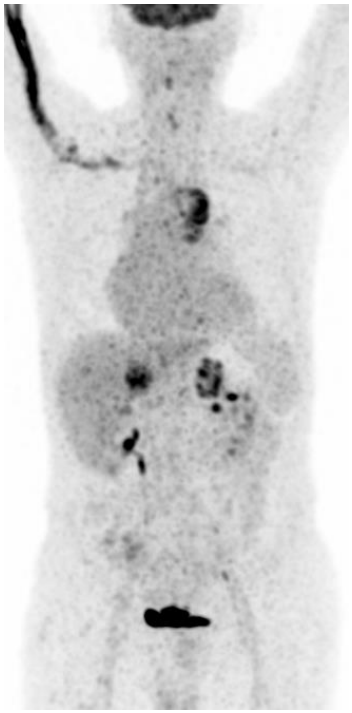


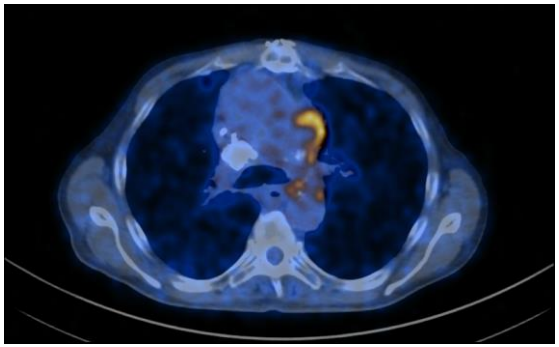


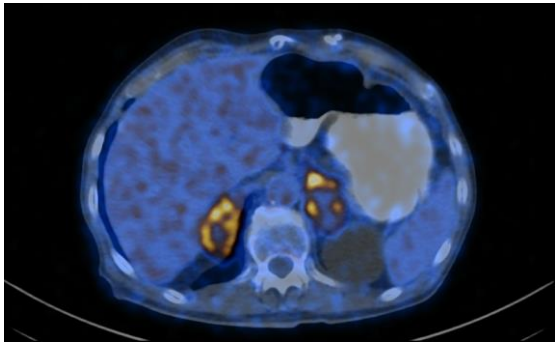
Oncology case 416

Acquisition time

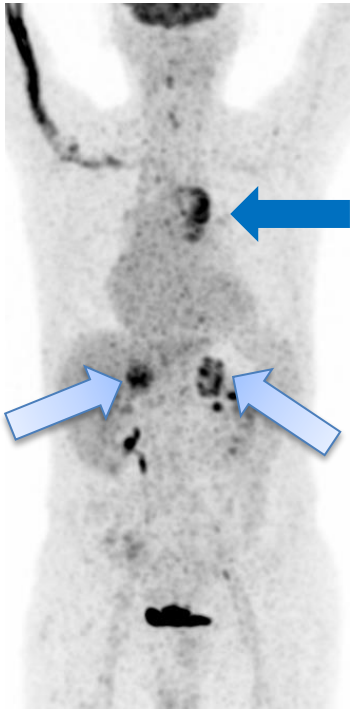
- 75 yo M
- 58 kg, 1.7 m
- 13.8 mCi / 510 MBq
- F-18 FDG
- 50 min delay
- 9 sec/bed, 9 beds
- 81 sec acquisition time

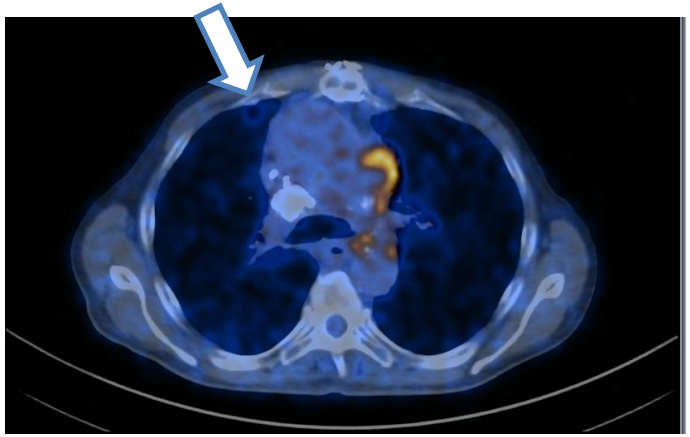


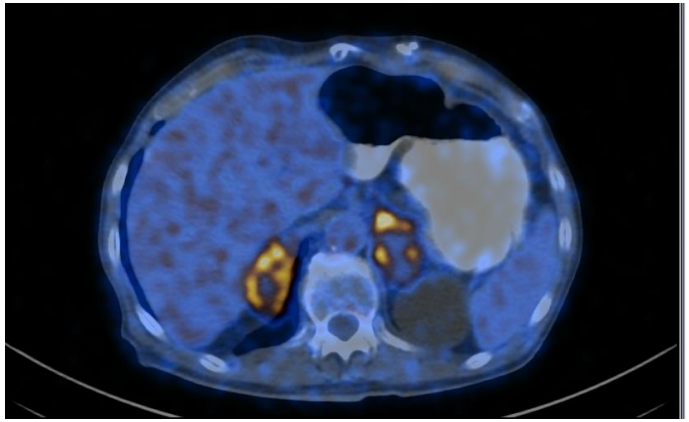


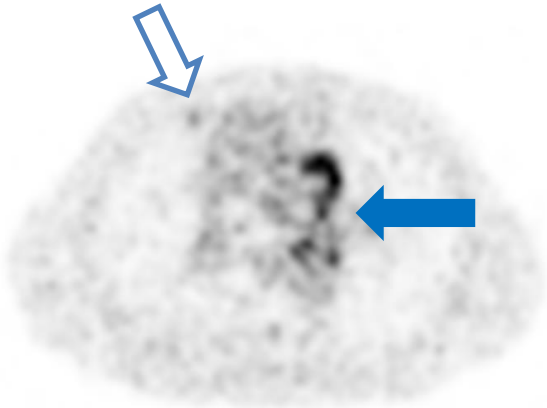


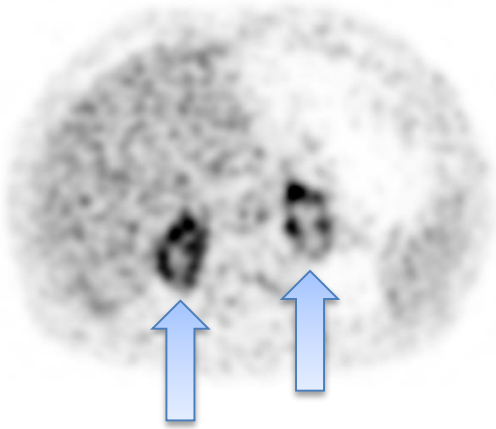
Oncology case 416





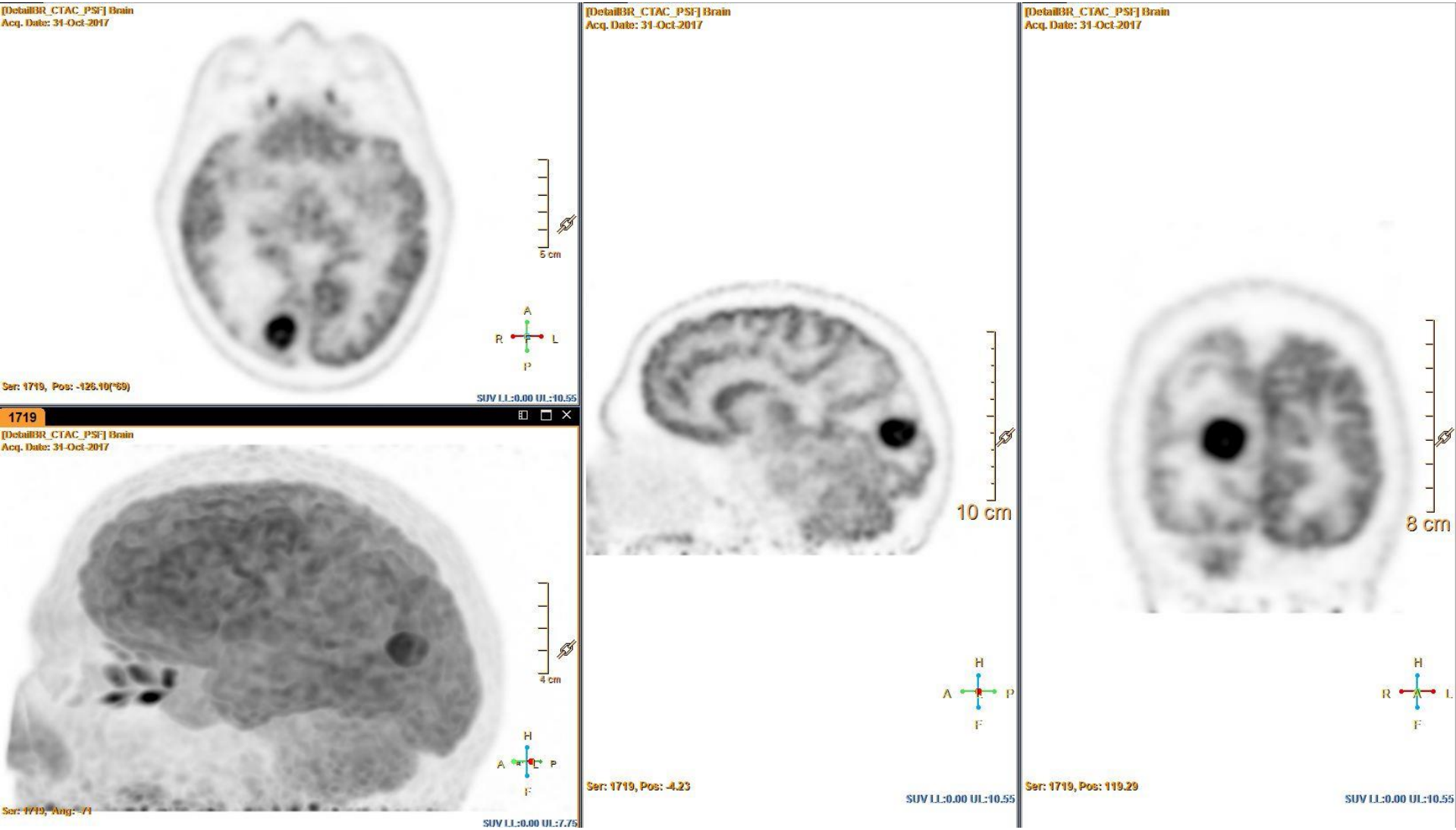






Total Body PET acquisition time: 81 seconds

2mm PET voxel reconstruction



65kg 179cm 186MBq cerveau 8min Nancy

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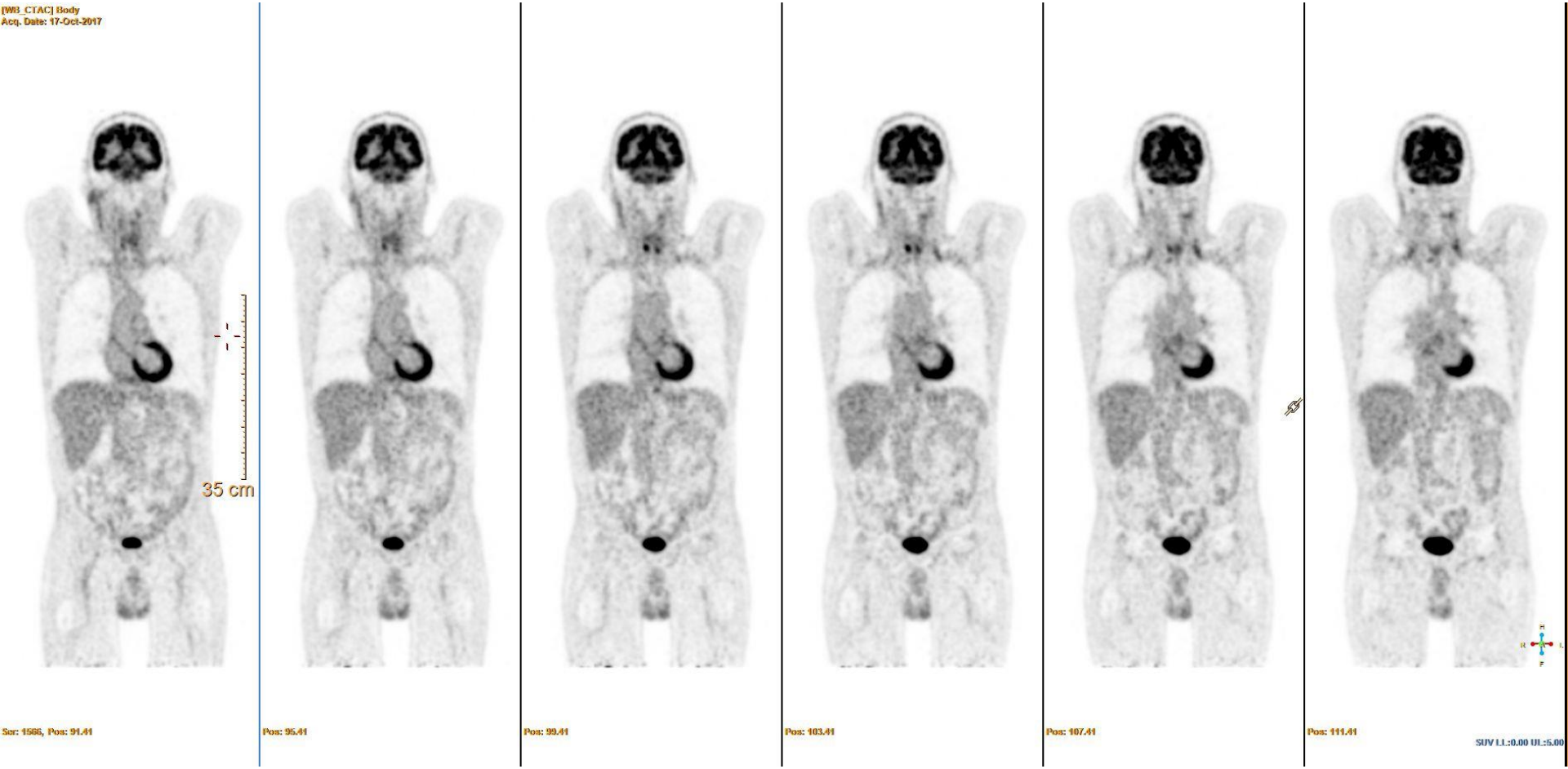

102MBq 120s-pas 4mm 65kg 173cm Genolier

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Vereos… the dawn of a new truth

State-of-the-art analog PET

Philips Vereos Digital PET

- What if you could **double your diagnostic confidence** and **detect cancer six months earlier**?
- Vereos **Digital PET** with DPC[1] completely redefines performance point for PET with
  - **2x volumetric resolution**
  - **2x sensitivity gain**
  - **2x quantification accuracy**

1 Digital Photon Counting

Designed for patient comfort

PHILIPS

Vereos PET/CT Wins Global Design Award

Praise for digital PET continues…

Vereos PET/CT wins iF product design award 2014!

Fondly nicknamed in the industry as the "Design Oscars," the iF Product Design is awarded annually by the iF International Forum Design after reviewing more than 2,000 applications. In its 61st year, the iF seal of good design is independently awarded to outstanding achievements in product, communication, and packaging design.

Philips Design was instrumental in the new industrial product design of Vereos PET/CT. The design team utilized a whiter, fresher palette in order to create a new identity. Vereos PET/CT stands apart from the crowd with its patient-focused design elements such as the light ring around the system parameter, table elements including arm rests, and a rear zone where clinical staff can store and attach accessories. This project took almost two years to complete. The result is a simplified design that improves patient comfort and increases clinical staff pride.


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Precision medicine enabled by clinically proven:

Improved detectability & characterization **of small lesions** [1]

Uncompromised lesion detectability & quantification **at 1/2 the PET dose** [2]

Uncompromised lesion detectability **at 1/10 the time**[3]

[1] Nguyen NC, Image Quality and Diagnostic Performance of a Digital PET Prototype in Patients with Oncologic Diseases: Initial Experience and Comparison with Analog PET, J Nucl Med 2015; 56:1378–1385
[2] Liu X et al, Impact of FDG Dose Reduction on Lesion Quantification in Dynamic PET: A Simulation Study Based on Clinical Trial Data, SNMMI 2016
[3] Zhang J., Evaluation of speed of PET acquisition: How fast can we go? - A validation of list mode PET simulation approach with true acquisitions, SNMMI 2017


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