

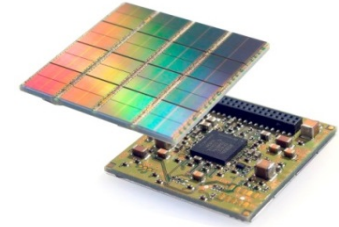
Philips Digital Photon Counting

PDPC



Date: 24.09.2015
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Business Unit: Advanced Molecular Imaging

Overview



- Technology: analog and digital SiPMs
- Unique features of digital SiPMs
- TEK: Technical Evaluation Kit
- Application for dSiPMs: VEREOS PET/CT
- Additional applications: pre-clinical, PET/MR, High energy physics...

Overview

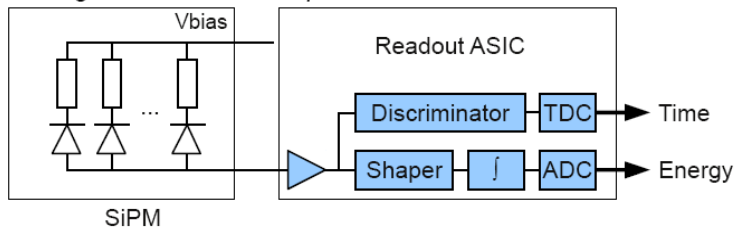
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Differences of analog and digital SiPMs

Analog SiPM

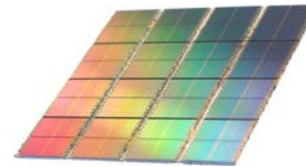


Analog Silicon Photomultiplier Detector

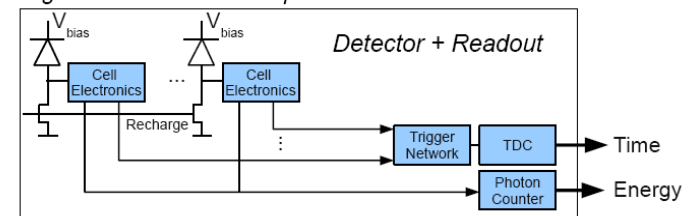


- discrete, limited integration
- analog signals to be digitized
- dedicated ASIC needed
- difficult to scale, high power cons.

Digital Photon Counter



Digital Silicon Photomultiplier Detector



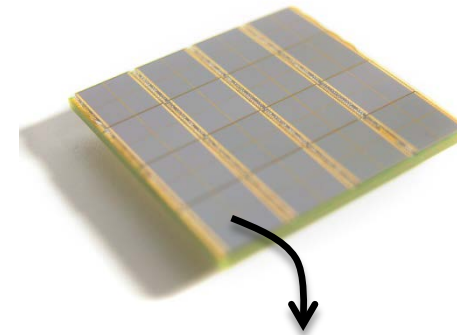
- fully integrated
- fully digital signals
- no ASIC needed
- fully scalable, low power

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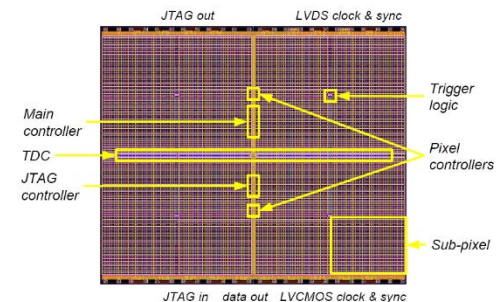
Sensor Tile

for a scalable detector



Geometry:

- Designed for crystal pitch 4.0mm
- Each SiPM has 3200 cells divided into 4 subpixel
- Die has 4 SiPMs, pitch 8mm
- Sensor tile has 4x4 dies, 32mm size



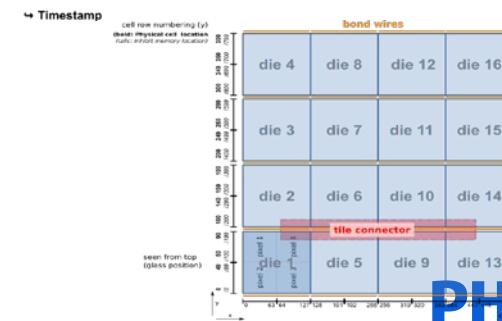
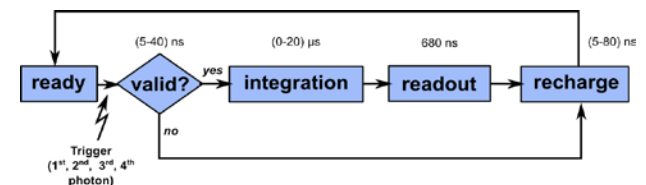
Programmable

- Enable/Disable of each SPAD
- Trigger setting: Trig 1, Trig 2, Trig 3 Trig 4

Performance:

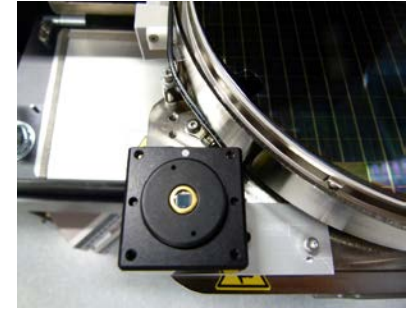
- Each die has one TDC with 20ps bins, $\sigma < 10ps$
- PDE, DCR, etc see next slides....

More infos at <http://www.digitalphotoncounting.com/>

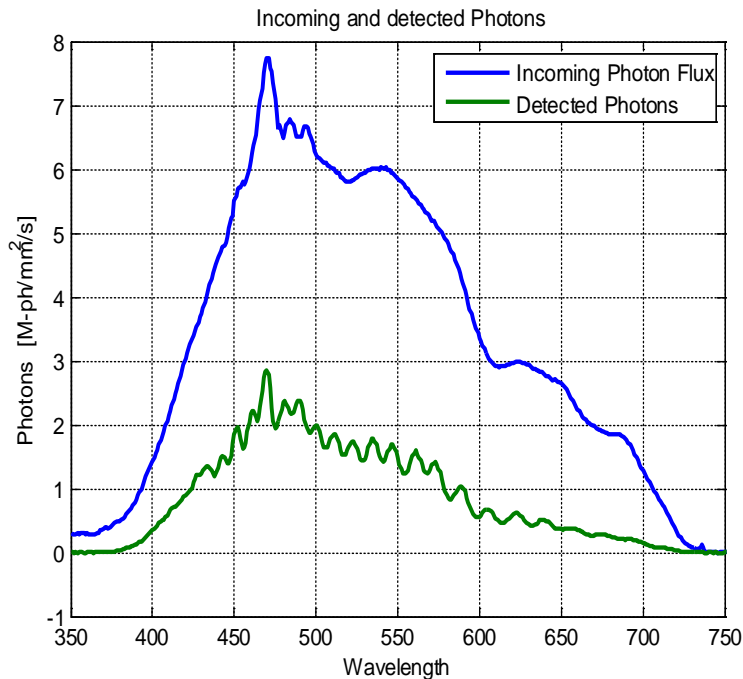


Signal

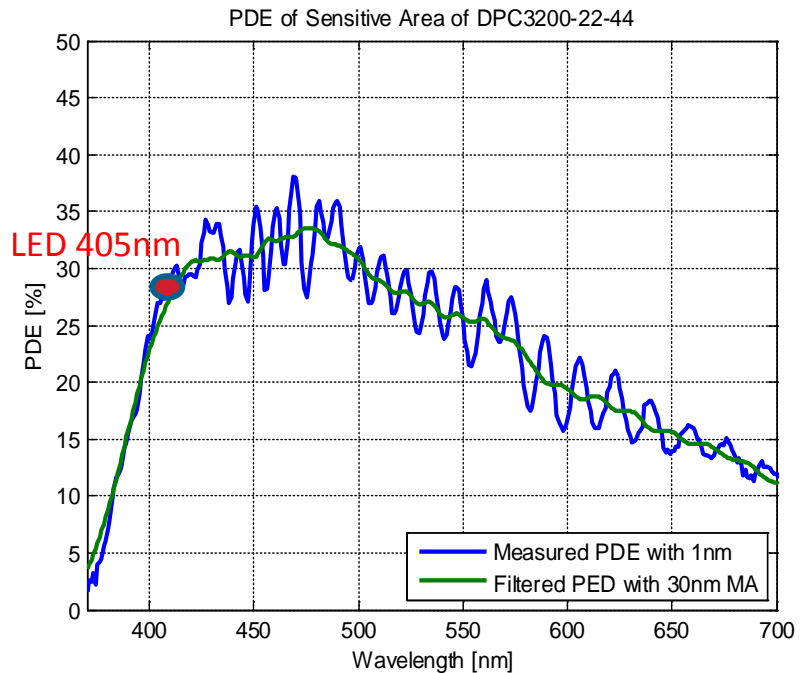
Absolute PDE Measurement with Spectrometer



Incoming and detected photon flux



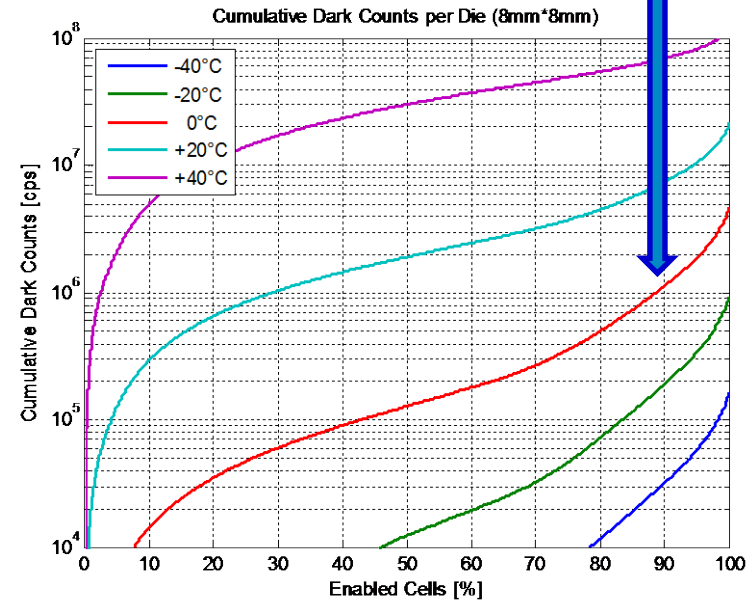
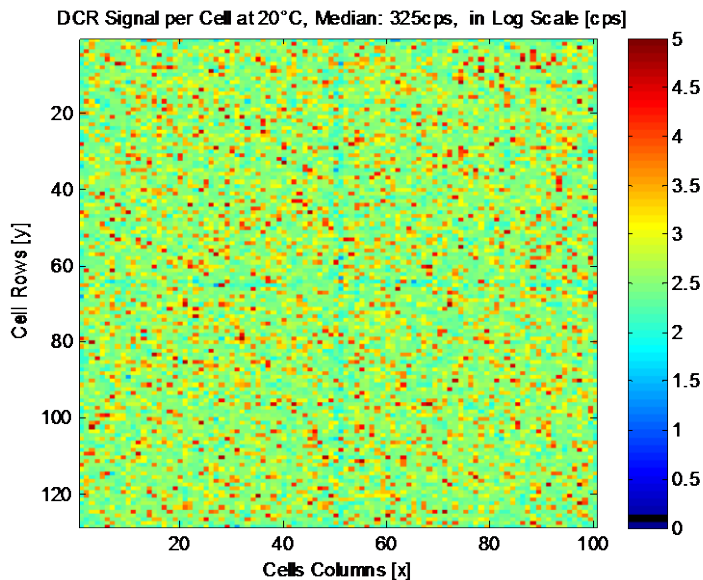
Absolute PDE



Noise

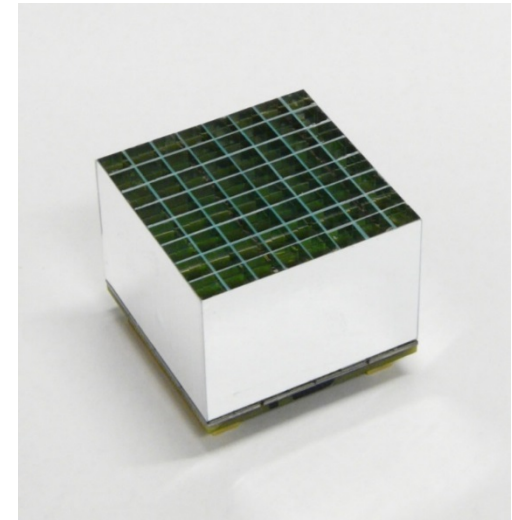
Full flexibility due to programmable SPAD array

90%

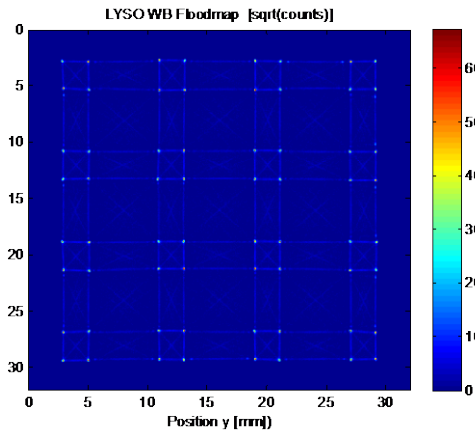


- Dark counts per second for 3.3V excess voltage
- Typical DCR at 20°C: 5Mcps/die = 100kcps/mm²
- Typical DCR at 0°C: 500kcps/die = 10kcps/mm²
- Dark count rate drops to ~1-2Hz per diode at -40°C

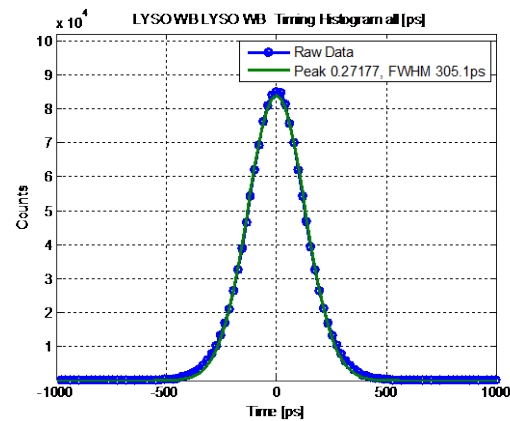
Typical PET Performance for 19mm LYSO Arrays in coincidence



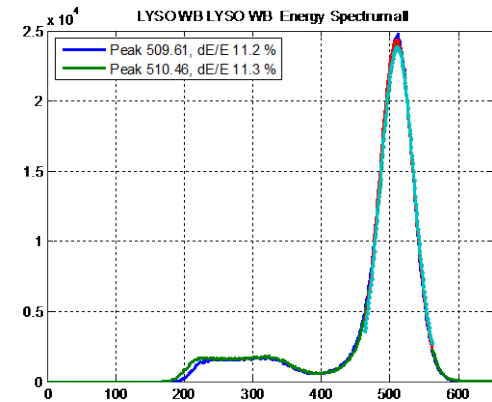
Floodmap



Timing Resolution for Trig 2



Energy Resolution with sat. corr.

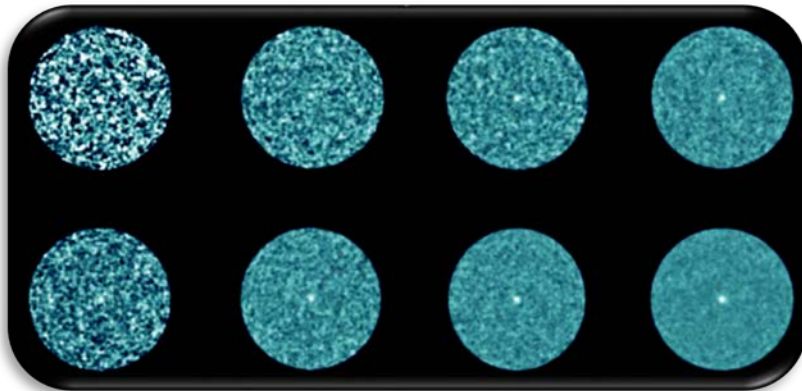
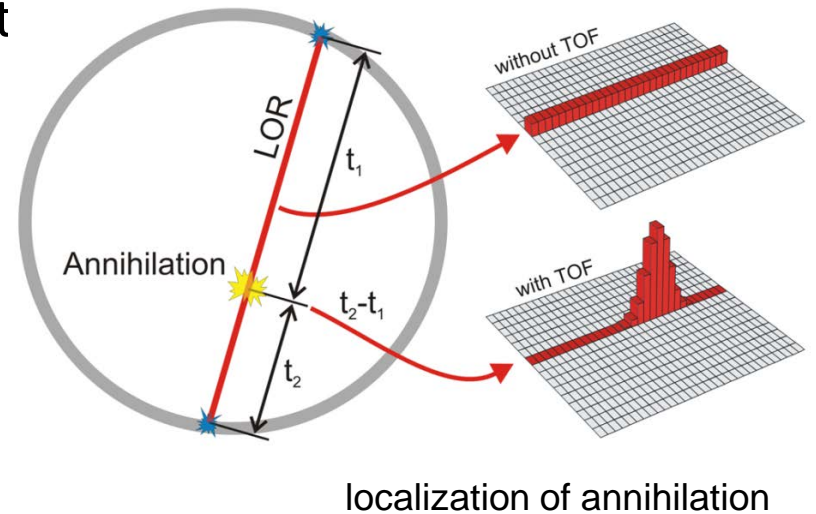


Benefits of Philips digital PET-Detector

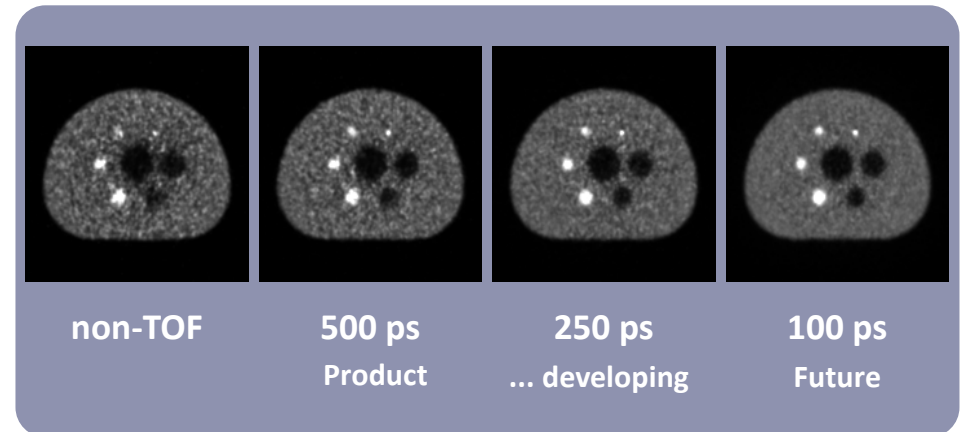
Pixelated readout with Time-of-Flight

- higher sensitivity
- shorter acquisition time
- no pile-up
- improved spatial resolution

$$NEC_{TOF} = \frac{2D}{ct_{CRT}} \frac{T^2}{(T + Sc + R)}$$



CRT >1ns 500 ps 250 ps 100 ps



non-TOF

500 ps
Product

250 ps
... developing

100 ps
Future

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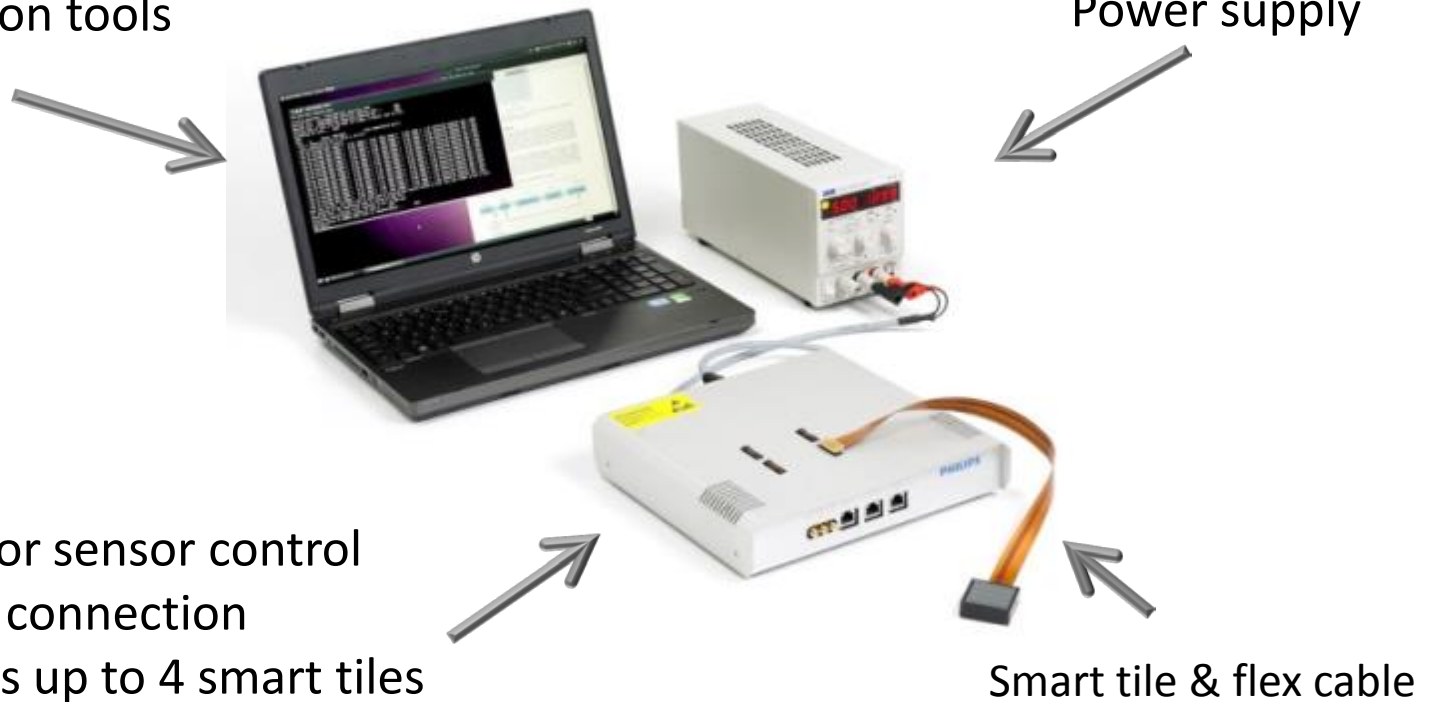
Technology Evaluation Kit (SensorTEK)

Smart way to proof-of-concepts



Preinstalled Linux laptop

- Control software
- Calibration tools



Base unit for sensor control

- USB 2.0 connection
- Supports up to 4 smart tiles

Smart tile & flex cable

Scalable DPC - From sensor to module



- 4 DPC sensor arrays (tiles)
- $\sim 6.6 \times 6.6 \text{ cm}^2$
- usable with or w/o scintillator crystals
- variable scintillator geometries
- Module board with FPGA, pre-processing capability & well defined interface
- local power supply
- experimentally cooled to -40°C

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True Digital DPC for VEREOS

Analog PET scan*

Vereos digital PET scan

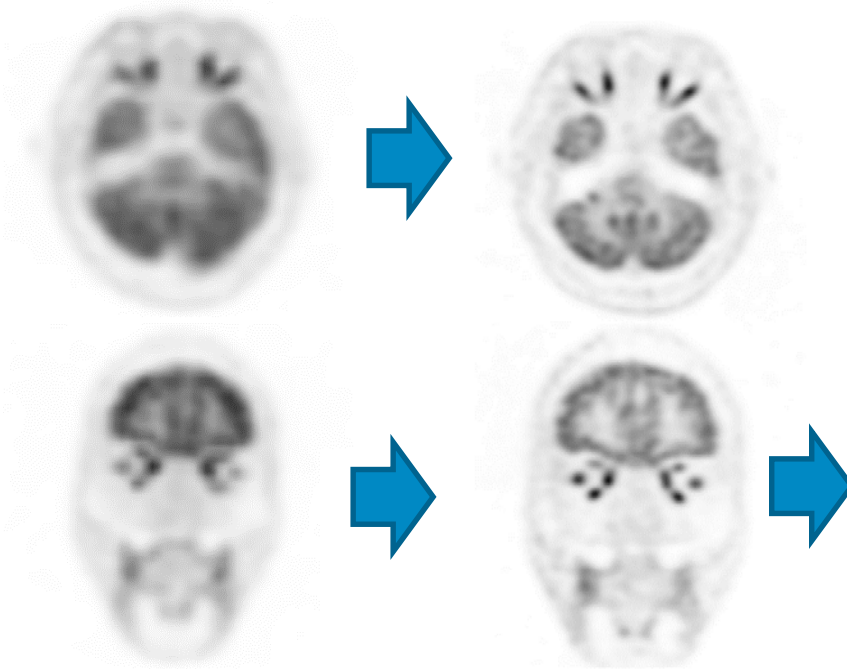


Image Quality

Improvements

- ≈ 2x volumetric resolution
- ≈ 2x sensitivity gain
- ≈ 2x quantitative accuracy

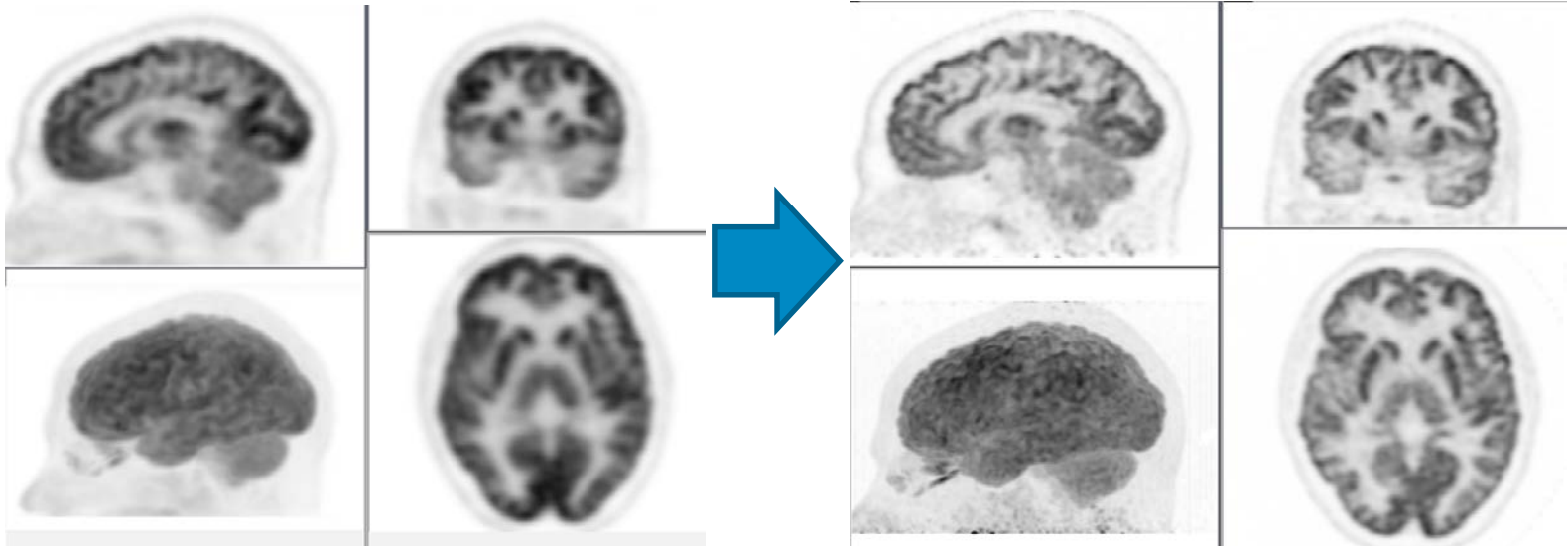
Images courtesy of University Hospitals Cleveland

Improved Image Quality and Sensitivity

...with digital SiPMs

Ingenuity TF

VEREOS



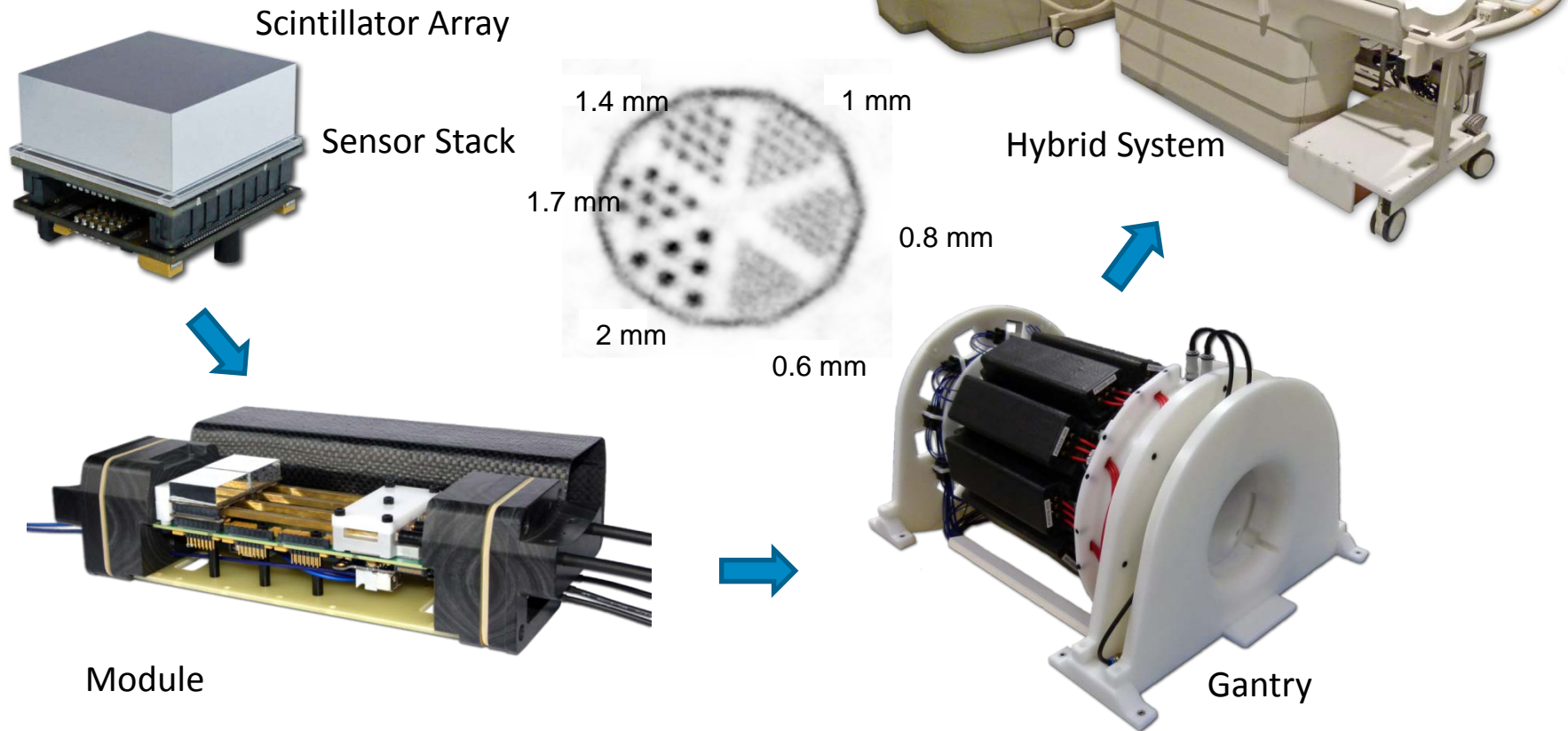
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SUBLIMA FP7 Health

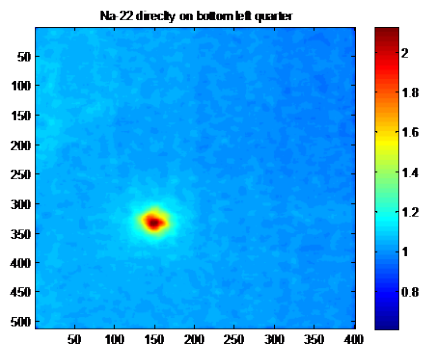
...push the limits for PET/MR



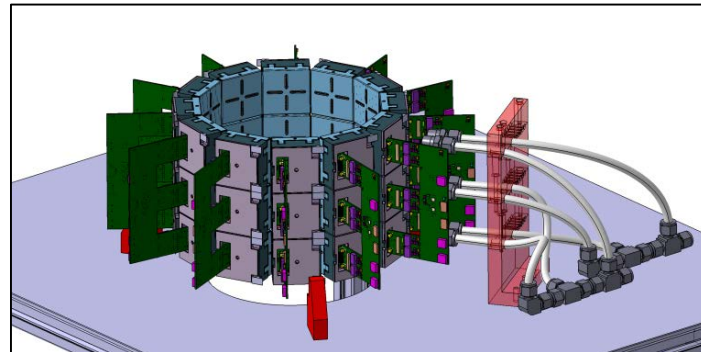
New Applications

TEK as stepping stone for new applications

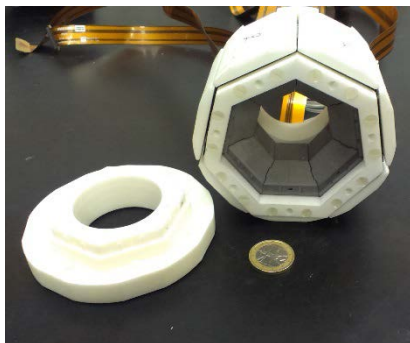
Cherenkov Detector (PDPC)



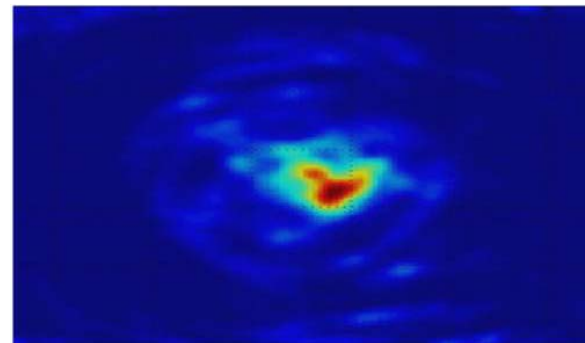
Pheno PET (Jülich)



SPECT/ MR (MEDISIP)



Compton Camera (Hanyang)



Summary

- Digital SiPMs have unique features like a switchable SPAD matrix
- Sensor is optimized for PET imaging
- Other applications can be built with this Lego-Type sensor
- Technology evaluation kit is available to simplify exploring new detector concepts

