AAPN2017 Scientific Symposium: Emerging and New Generation PET: Instrumentation, Technology, Characteristics and Clinical Practice
Aug 2 Wednesday 10:45am – 11:15pm

Solid State Digital Photon Counting PET/CT Instrumentation and Technology

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Disclosure

Philips Healthcare (Cleveland, OH) provided the precommercial investigational PET/CT system (Vereos).

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DPC PET/CT (Vereos, Philips Healthcare) at OSU





Pre-commercial release unit of digital photon counting PET/CT system (Vereos, Philips Healthcare) operational at The Ohio State University (<u>PL: Michael V Knopp, MQ, PhD</u>) inso October 2014. PET detector technology moving from PMT to solid state DPC is a technology leap.

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From PMT to Solid State DPC



Vereos PET Detector Geometry



DPC Data Acquisition Sequence





Energy Resolution







TOF Timing Resolution





NEMA NU 2 2012 Spatial Resolution



NEMA NU 2 2012 Spatial Resolution

at 1cm at 10cm at 20cm Axial 4.31 4.79 6.17
Axial 4.31 4.79 6.17
Transverse (Radial) 4.01 4.64 5.86
Transverse (Tangential) 4.01 4.41 4.99

where R is the overall spatial resolution, K_r – a scale factor, R_r the intrinsic resolution determined by crystal width, R_p the error due to positron range, R_r the error from noncollinearity, and R_r is the decoding error (anger logic positioning localization). For DPC FL R_r is zero due to that 11: coupling eliminates need for positron decoding.

WW Moses. Nucl Instrum Methods Phys Res A. 2011; 648 (Supplement 1): 5236–5240
 Jun Zhang, Michael V Knopp. J Nucl Med 2017; 58 (supplement 1): 1322

SAM Question

Compared to conventional photo-multiplier PET systems, spatial resolution of the SiPM digital photon counting PET system is NOT affected by

- A. Crystal size
- B. Positron Range
- C. Noncollinearity / Acollinearity D. Localization decoding

Answer: (D)

1:1 coupling eliminates need for position decoding



NEMA NU 2 2012 Sensitivity



NEMA NU 2 2012 NECR and Scatter



SAM Question

For a <u>48cm</u> diameter object, an estimated sensitivity gain and the SNR improvement of the digital photon counting TOF PET (320ps, <u>4.8cm</u> uncertainty) compared to nonTOF PET are about

- A. 5.0 and 5.0
- B. 10.0 and 10.0
- C. 10.0 and 3.2
- D. 10.0 and 5.0

Answer: (C) $G_{\text{TOF}} = \frac{2D}{c_{\text{At}}} = \frac{D}{\Delta x} = \text{time-of-flight gain}$ $G_{\text{SNR}} = \sqrt{\frac{D}{\Delta x}}$

NEMA NU 2 2012 Image Quality





Phantoms IQ



	🔳 Sp	here Contrast (%) Backgroun	d Variability (%)
				2
	*	33		
		5		
				82
		10		37
			nene size (min)	
	Alpha-Bra F18 @ 8:4 10:41	rvo Uniformity SUV Axi Sam on 09/19/2014, pi 9am, SUVmax=0.98, SU	al Profile - Brain 256F hantom on the table, Vmin=0.89, SUVmear	OV 2.26 mCi acq started at =0.97
.100				
.100				
. 100 . 900 . 900 . 900				
1.100 1.900 0.900 0.900 0.900 0.900				
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1.100 1.000 0.900 0.900 0.900 0.900 0.900 0.200 0.200 0.100 0.000				



System Specifications: DPC vs PMT

Specifications	Vereos	Gemini TF 64
Detector Design	Direct Photon Counting	PMT Anger Logic
Ring Diameter (mm)	764	764
Crystal	LYSO	LYSO
Crystal Size (mm ³)	4 x 4 x 19	4 x 4 x 22
# of Detector Elements	23,040	420 PMT
Crystal-Detector Coupling	1:1	multi : multi
Transaxial FOV (mm)	256 / 576 / 676	256 / 576 / 676
Axial FOV (mm)	164	180
Overlap in Axial FOV	39%	53%
Energy resolution (%)	11	12.3
Energy calibration	1:1	multi : multi
Timing Resolution (ps)	320	550
Timing Calibration	1:1	multi : multi
Coincidence window (ns)	2.0 / 4.0 / 4.6	2.0 / 4.0 / 4.6
Reconstruction Algorithm	3D OSEM TOF	3D OSEM TOF, 3D Ramla
Reconstruction Matrix (pixel)	up to 676 x 676	up to 338 x 338
Reconstruction Voxel (mm ³)	64 / 8 / 1	64 / 8
# Voxels per slice	up to 456,976	up to 107,584
Resolution Recovery	PSF	No PSF

PMT PET vs DPC PET



Gemini



Vereos

PMT PET vs DPC PET



550ps 4mm PET

325ps 4mm PET

PET Image Resolution (Recon)



Small Lesion Detectability with Less PVE



Lesion Detectability with Less PVE



Gemini (64mm³)



Vereos (1mm³)

Brain PET



ution	2mm	2mm
ness	2mm	2mm
ected	4.3mCi	5.0mCi
e time	45min	45min
Time	10min	10min
	С	D
	Vend	lor B
	1mm	1mm
	3mm	3mm
	10.0mCi	12.0mCi
	50min	49min
	10min	10min
1	E	F
	Vereos	Vereos
	2mm	1mm
	2mm	1mm
	13.9mCi	13.9mCi
	118min	118min
	90sec	90sec

Brain PET Redefinition – Speed, Convenience, Dose, IQ



90s/bed FDG

8/2/2017

WB PET Redefinition



WB NaF PET



12s/bed 12s/bed

12s/bed





90s/bed 15min



30s/bed 5min



9s/bed 1.5min

Low Dose FDG PET



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NIH R01 PIs: Knopp, Zhang

Clinical Post ⁹⁰Y Microsphere Radioembolization



Bremsstrahlung SPECT/CT



DPC PET



A – 10min/bed; B - 7min/bed



2.5mCi; NaF; 90s/bed; 110cm





Highlights

- 1:1 coupling eliminates need for position decoding
- Timing and energy calibrations per crystal
- Improved timing resolution
- Reduced dead time
- Increased count rate performance
- Early digitization eliminates as much as possible analog noise and distortion.

8/2/2017

How much SiPM DPC Detector Coverage Do We Really Need?





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Thank You



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