FACULTY OF ENGINEERING AND ARCHITECTURE

Innovative Molecular Imaging and Therapy

PSMR- TOTAL BODY PET

Prof. Stefaan Vandenberghe

Research professor, Innovative Molecular Imaging and Therapy

MEDISIP -Infinity lab, UGent Belgium

Stefaan.Vandenberghe@ugent.be

☏ 0032 93325854

GHENT UNIVERSITY

Penn
University of Pennsylvania

University of Pisa

- First Total body PET conference in Gent in 2018
- In 2021 digital TB-PET workshop (Edinburgh)

- Small animal PET seems to have many Total body mouse imagers (Bruker, Molecubes)

- A great number **(>20)** of systems installed and up and running:
  - United imaging Explorer: UCDavis, Sydney, 13 sites in China
  - Siemens Quadra: Bern, Groningen, Amsterdam, Tuebingen, Copenhagen, Sydney, Heidelberg, coming in Turku…

- Large interest from the nuclear medicine-radiopharmacy community, several MD's dream to have a TB-PET one day

- Several instrumentation projects ongoing
  - Valencia, Aachen, Ghent, Krakow, …

uEXPLORER

- Highest sensitivity
- 400-500 ps TOF
- 2m long
- United imaging Healthcare technology platform

PennPET EXPLORER

- High TOF resolution (close to 200 ps)
- 70cm-1m40 long
- Philips technology platform
- **Not commercialized**

Siemens Quadra

- High TOF resolution (close to 200 ps)
- 1m06 long
- Siemens Vision technology

GHENT UNIVERSITY

Pictures courtesy of Joel Karp, UPENN

TOTAL BODY PET: QUO VADIS

Research only system

High end system
for tracer development and studies

Clinical system of future

High cost of system
(2.5-7 times higher)
Technical complexity

Low dose of expensive tracers
Total body distribution
Drug development
Dynamic imaging

Majority of PET studies are body scans
Much higher sensitivity for body imaging
Trend towards low dose imaging
One system can replace 2-3 other PET scanners

GHENT UNIVERSITY

HOW MUCH FASTER AND/OR LOWER DOSE ?

- 10-20 fold reduction in dose for body imaging
  - Whole-body PET at ~0.5 mSv
  - Annual natural background: 2.4 mSv
  - PET can be used with minimal risk – new populations
  - Exact number depends on object and acceptance angle of scanner
  - CT is also becoming very low dose (Iterative recon + AI)
  - TB-PET-CT can become very low dose (and still quite fast)

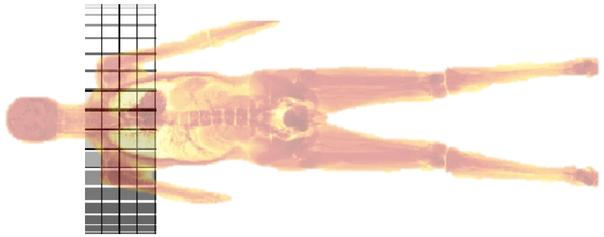
Conventional PET

TBPET

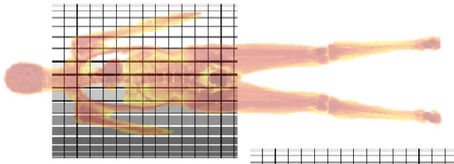
GHENT UNIVERSITY

Based on slides of Riemer Slart Groningen

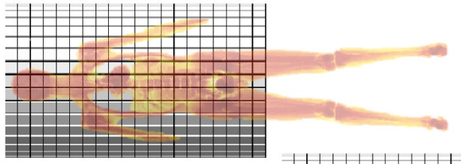
COST EFFECTIVE TOTAL BODY PET



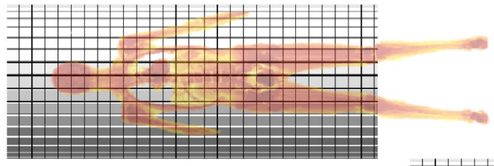
20 cm



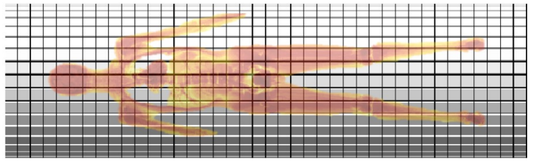
70 cm



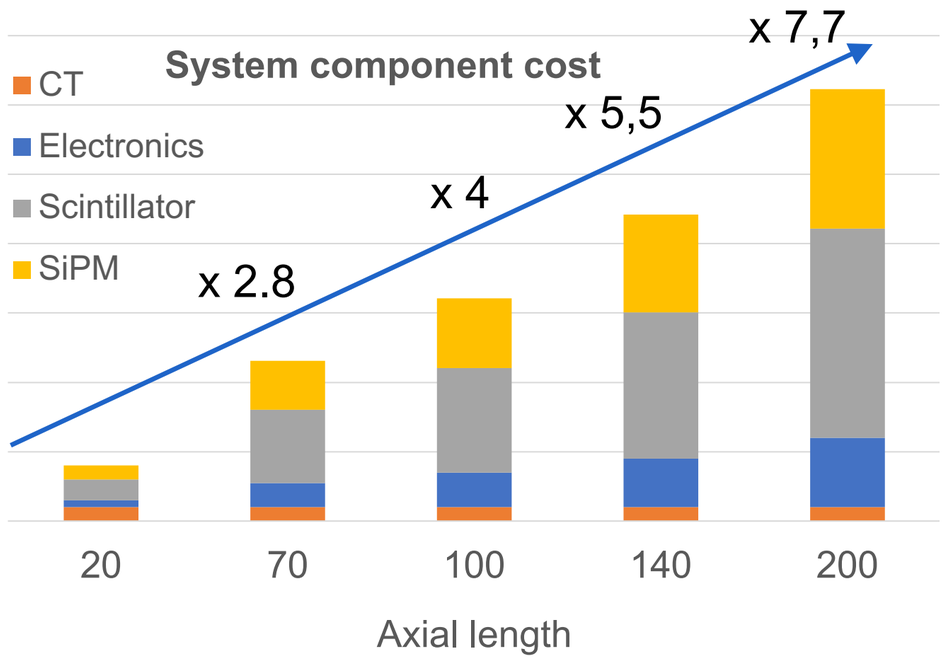
100 cm



140 cm



200 cm



Total body PET is very sensitive (and expensive) but clinical practice seems to limit the throughput to 4-6 patients per hour

Standard PET-CT: 2-3 Meuro

TB PET: 8-12 Meuro

Even with a 2x - 3x higher throughput financially difficult for most centers

State of the art in total body PET

Stefaan Vandenberghe ✉, Pawel Moskal & Joel S. Karp

EJNMMI Physics **7**, Article number: 35 (2020) | Cite this article

5986 Accesses | **6** Citations | Metrics

Top speed of 350 km/h
Avg speed in city 40 km/h
Brussels-Rome: 12 hrs
Cost >200kEuro

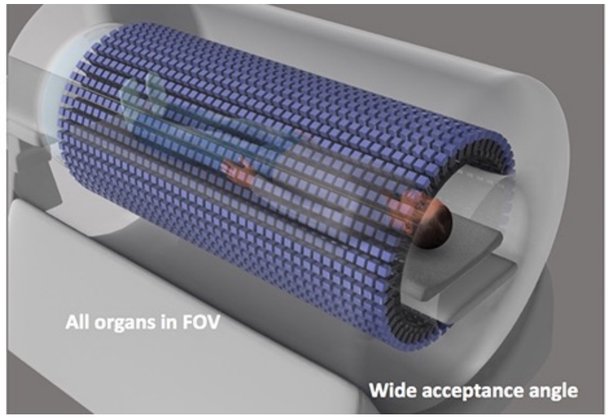
Top speed of 150 km/h
Avg speed in city 45 km/h
Brussels-Rome: 15 hrs
Cost around 20 kEuro

CAN WE FURTHER IMPROVE TB-PET?

Improve effective sensitivity
by better TOF

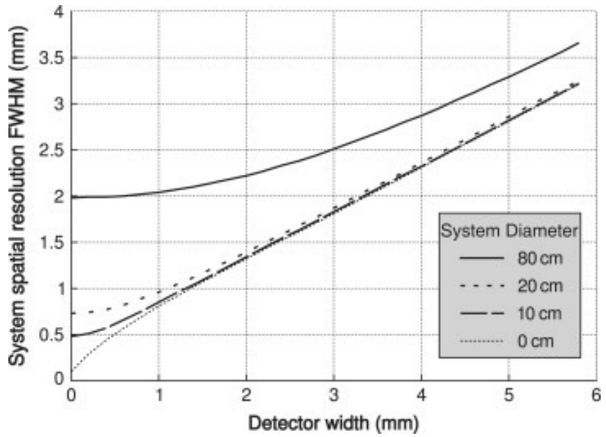
PennPET Explorer
250 ps

Siemens Biograph
Vision
214 ps



Full body coverage → geometric
sensitivity maximal
About 400 ps TOF
2.8 mm crystals
no DOI

Towards the 2mm limit of
spatial resolution in
clinical PET



Physics in Medicine & Biology

ROADMAP

Roadmap toward the 10 ps time-of-flight PET challenge

Paul Lecoq[1], Christian Morel[2], John O Prior[3], Dimitris Visvikis[4], Stefan Gundacker[1,5], Etiennette Auffray[1], Peter Križan[6], Rosana Martinez Turtos[1,21], Dominique Thers[7], Edoardo Charbon[8], Joao Varela[9], Christophe de La Taille[10], Angelo Rivetti[11], Dominique Breton[12], Jean-François Pratte[13], Johan Nuyts[14], Suleman Surti[15], Stefaan Vandenberghe[16], Paul Marsden[17], Katia Parodi[18], Jose Maria Benlloch[19] and Mathieu Benoit[20] – Hide full author list

Published 20 October 2020 • © 2020 Institute of Physics and Engineering in Medicine
Physics in Medicine & Biology, Volume 65, Number 21
Citation Paul Lecoq et al 2020 Phys. Med. Biol. 65 21RM01

Transverse and axial DOI in TB-PET

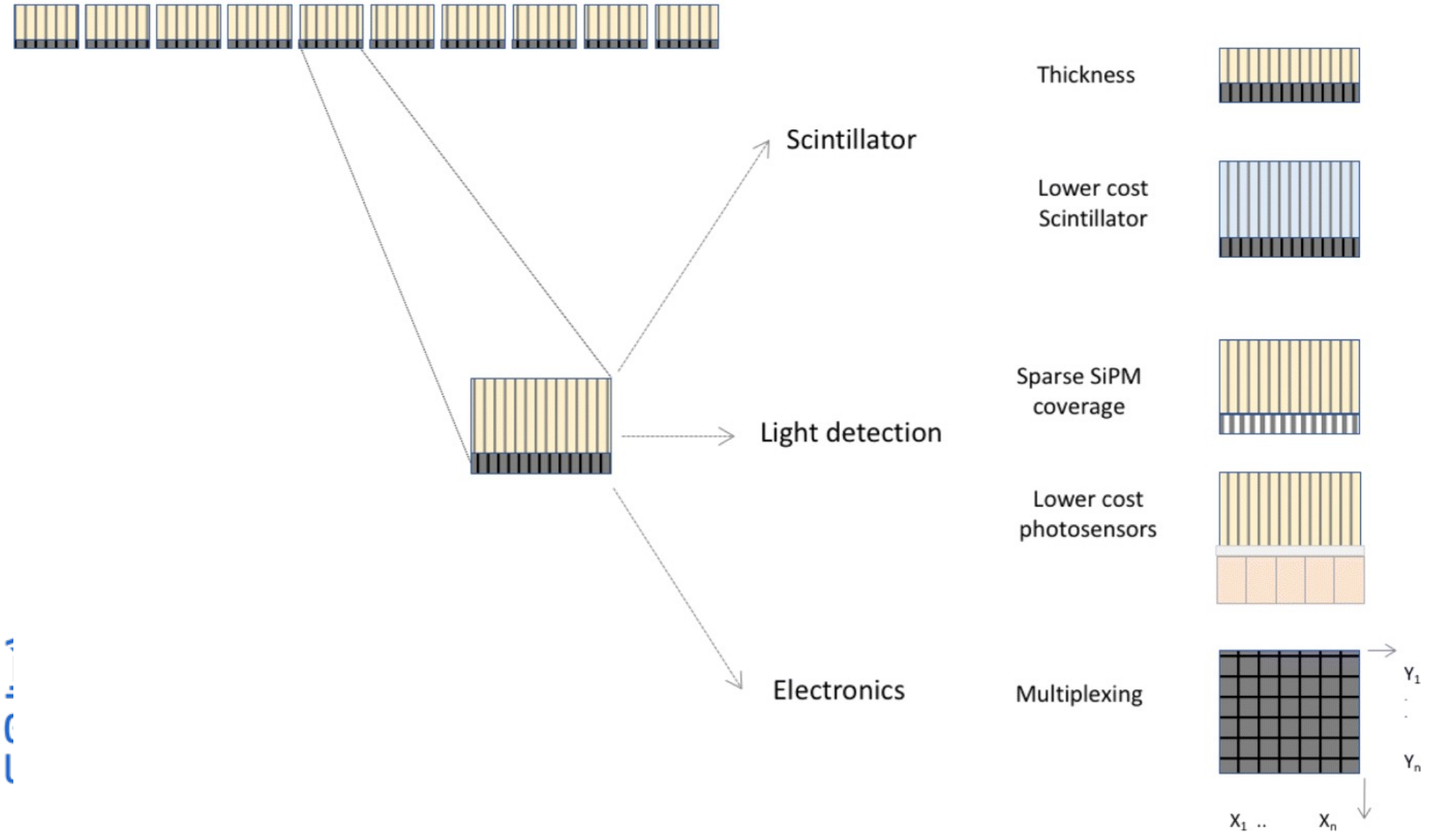
The promise of nuclear medicine technology: Status and future perspective of high-resolution whole-body PET,Physica Medica, Klaus P.Schäfers

- Very good systems available but quite expensive
- Systems are already quite fast (5-20 min per scan in CT, PET,MRI)
- We may not need directly novel and better detectors/systems as they may further increase the price

- Real world challenges (indicated by NM and radiologists)
  - Cost reduction of the systems without loss of quality
  - Improve reliability of systems
  - Enhance the workflow
  - Aid the physician in handling all the data

CAN WE LOWER THE COST OF PET DETECTORS?

Total body PET



Different options to reduce the cost of the detectors (scintillator, sensor, electronics) in total body PET systems

Review | Open Access | Published: 25 May 2020

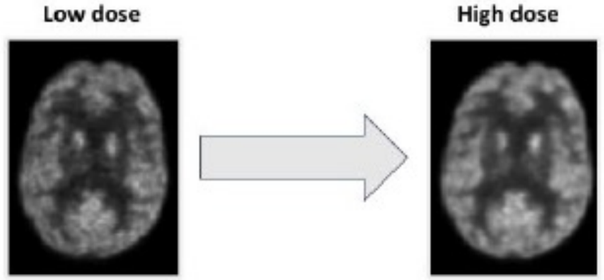
State of the art in total body PET

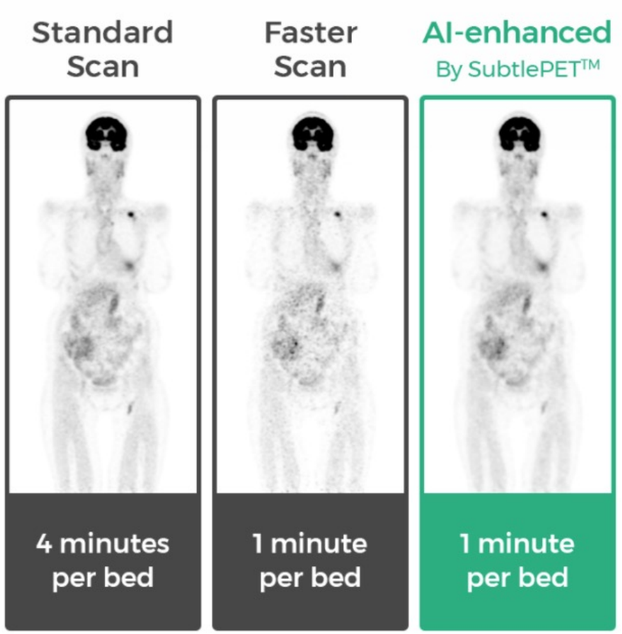
Stefaan Vandenberghe, Pawel Moskal & Joel S. Karp

EJNMMI Physics **7**, Article number: 35 (2020) | Cite this article

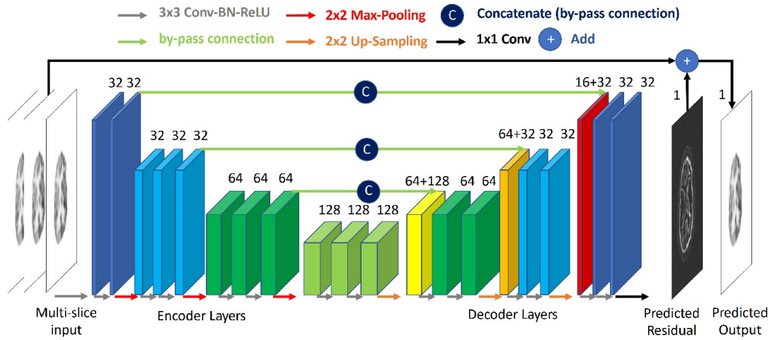
LOW NOISE ‘RECONSTRUCTION’ USING DEEP LEARNING

Train low dose-high dose pairs



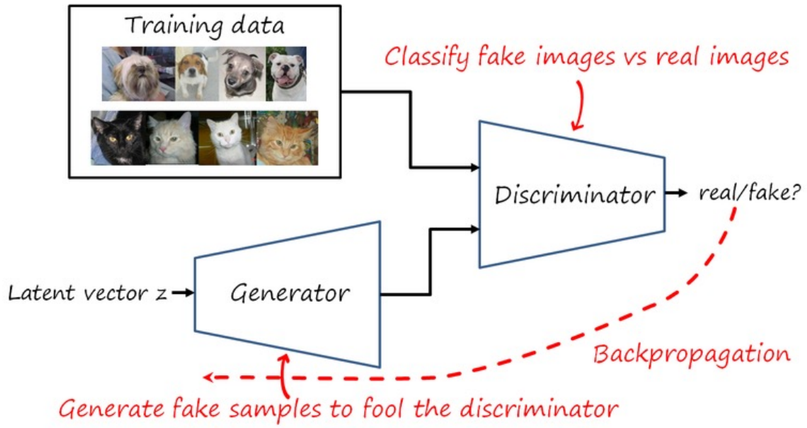


Convolutional Neural networks

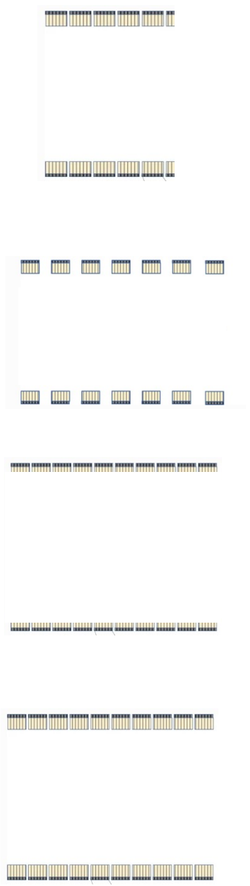


Why AI now ?

Generalized Adversial Networks



→ Results by several authors in DL-denoising indicate a 2-10x gain in counts



Configuration	Detector	Expected performance	Pro/Contra
Medium axial FOV PET (50-60 cm, 100 % detectors)	L(Y)SO + SiPM	200-400 ps 4-6 x more sensitive	Easy extension of current PET Limited part of body
Split axial ring PET (100-120 cm, 50% detectors)	L(Y)SO + SiPM	200-400 ps 4-6 x more sensitive	Easy extension of current PET Full torso Limited sensitivity gain
Thin crystal 100-120 cm, 50 % thickness	L(Y)SO + SiPM	150-300 ps 4-6 x more sensitive	Better TOF (thin crystal) More SiPMs + electronics
Thick crystal 100-120 cm 100 % thickness No axial gaps	BGO + PMT/SiPM	No or limited TOF 8-20 x more sensitive	Higher sensitivity Cheap Scintillation crystal No intrinsic Lu background Non-standard detector More SiPMs + electronics
….			

Scintillator: ~ 50 % of detector cost
SiPM + electronics: ~ 50 % of detector cost

L(Y)SO: ~ 30kEuro/liter
BGO: ~ 10kEuro/liter

GHENT UNIVERSITY

The potential of a Medium cost Total Body PET for nuclear medicine departments, S.Vandenberghe, N.Karakatsanis, S.Nemeh, R.A.Dierckx, JS. Karp, letter to be submitted to EJNMMI

R

Real world challenges (indicated by NM and radiologists)

- Cost reduction of the systems without loss of quality
- Improve reliability of systems
- Enhance the workflow
- Aid the physician in handling all the data

Reduce cost and/or improve performance of Total body PET system

- Better and/or cheaper detectors
- Use deep learning in detectors and image reconstruction/denoising
- Data reduction (histoprojections/sinograms)
- Faster and more accurate reconstruction (deep learning)