

2nd Divonne Brainstorming meeting on CERN Medical Applications

Future perspective in the coming 10 years

Terry Jones

University of California Davis

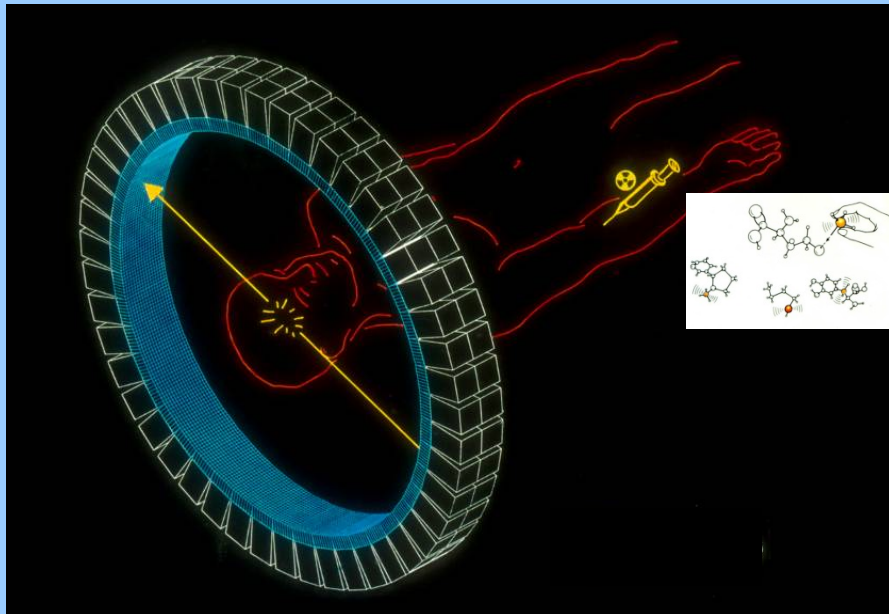


“Positron Emission Tomography (PET)

Is the most specific and sensitive means

for imaging molecular pathways

and molecular interactions in humans”.



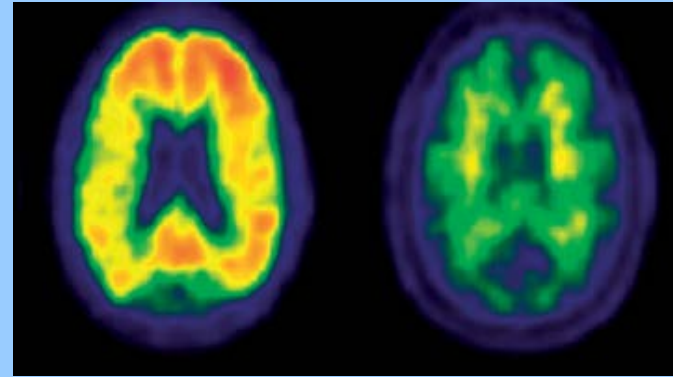
Cyclotron produced positron emitting radio nuclides:

←	Oxygen-15	2.1 min T1/2
	Nitrogen-13	10 min T1/2
	Carbon-11	20.1 min T1/2
←	Fluorine-18	1.7 hr T1/2

[¹⁸F] Fluorodopa Parkinson's



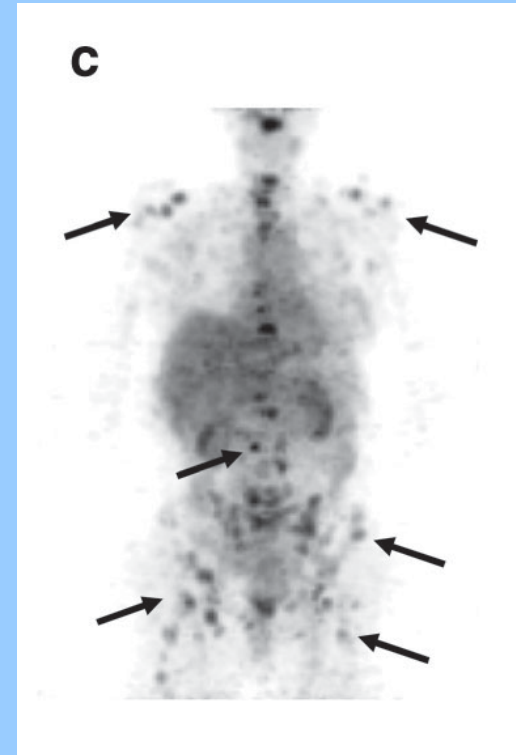
[¹¹C/¹⁸F] Beta Amyloid-Dementia



Brain PET

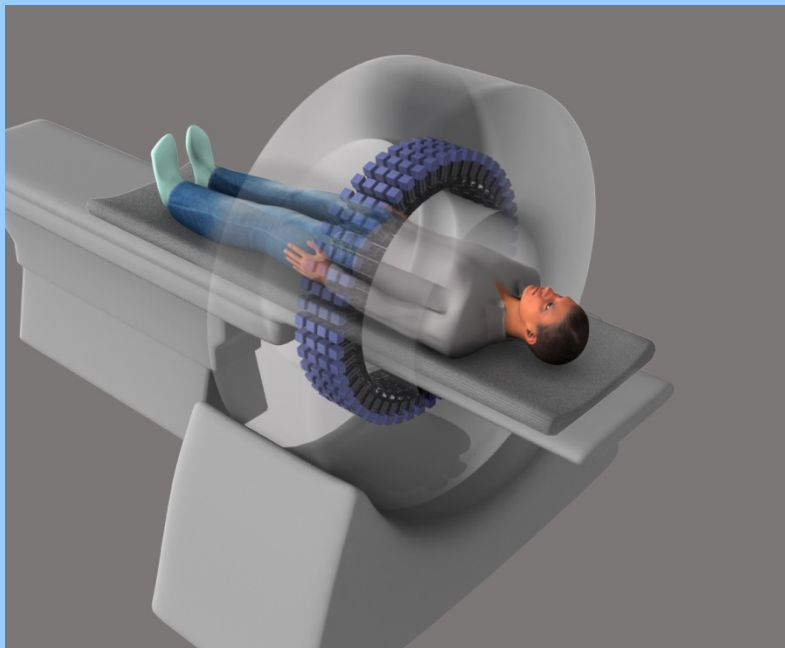


Cancer PET

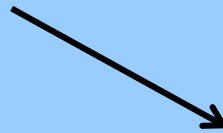


Whole Body ¹⁸FDG

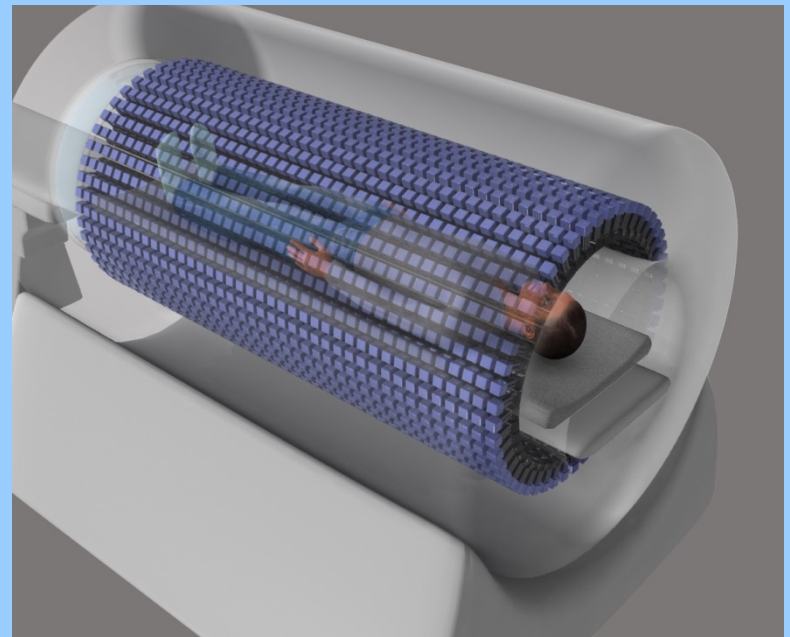
A HER2 Antibody labelled with ⁸⁹Zr (78.4 hour half life)




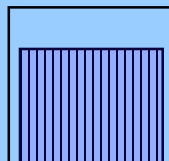
**Conventional
PET Scanner
(2016)**



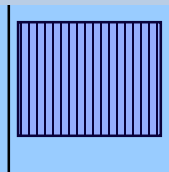
**EXPLORER
Total Body PET Scanner
(2018)**

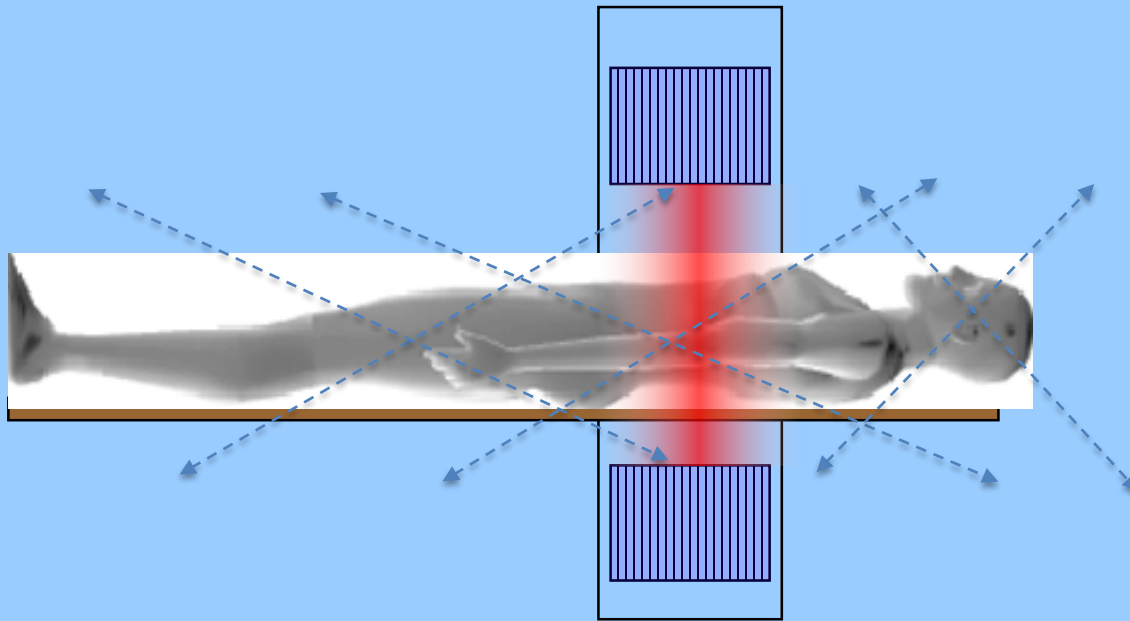


All PET studies are limited by statistics, radiation dose, or both



Current scanners do not maximize the sensitivity for whole-body imaging (<1% of the available signal collected)

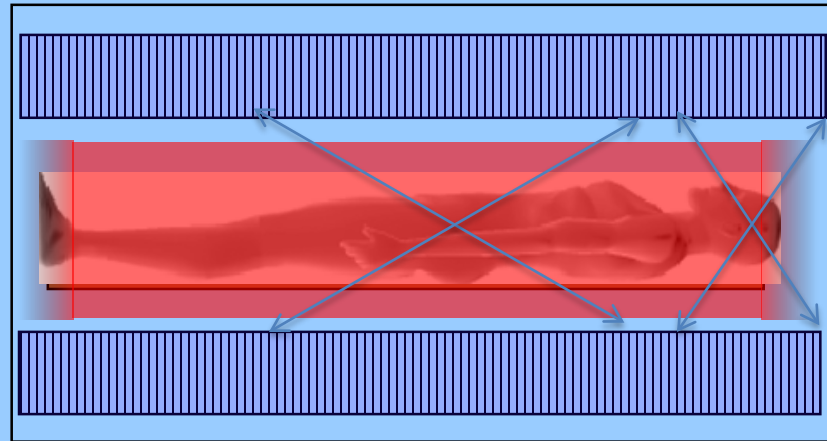




<1% of the potential return on the investment in:

- Cyclotron operation
- Labelled tracer production
- PET scanning facilities and resources
- The radiation dose to the patient

Total-Body PET: Maximizing sensitivity and simultaneously imaging the whole body



Needed to realise the potential of PET
In biomedical research and healthcare

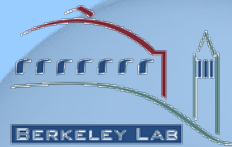


EXPLORER Team



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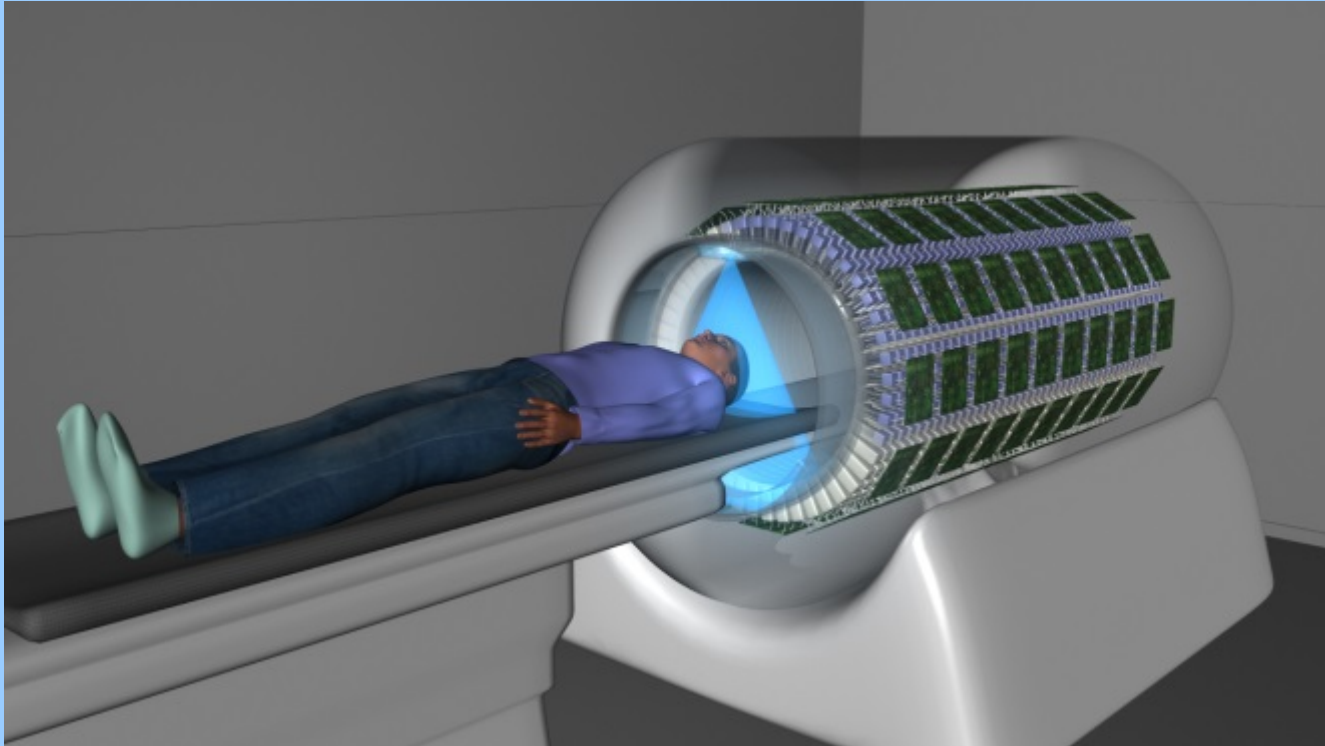


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Senior Advisors:
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Ten conventional PET scanners side by side



Total-Body PET: Maximizing Sensitivity

- 40x gain in effective sensitivity for total-body imaging!
- 4-5x gain in sensitivity for single organ imaging

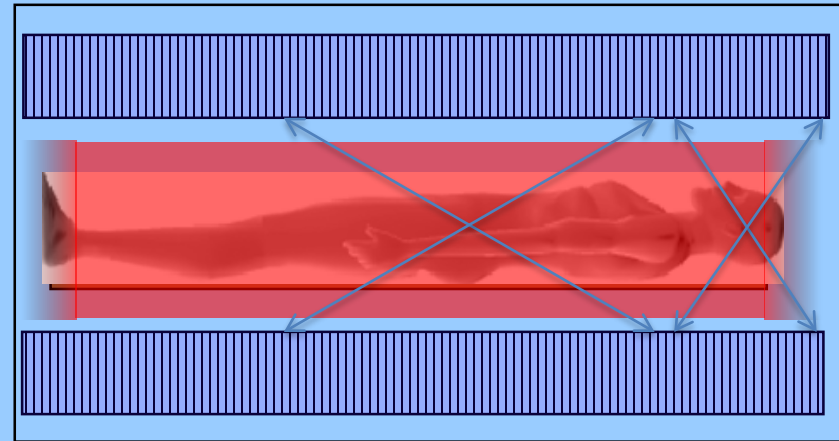
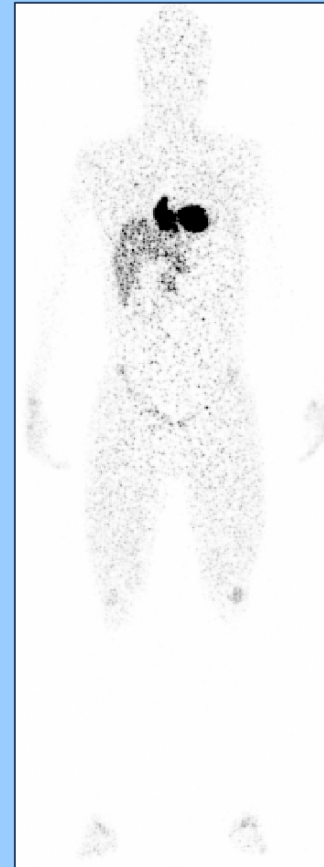
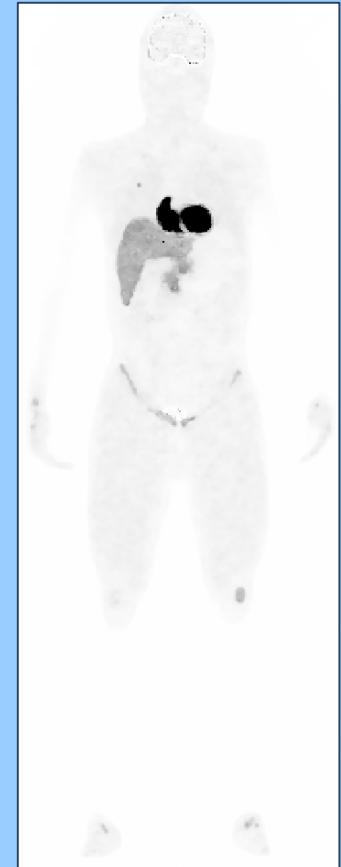


Image Better

- **> 6-fold improvement in SNR-simulations**
 - Reconstruct at higher spatial resolution
 - Detect smaller lesions
 - Detect low-grade disease
 - Better statistics for kinetic modeling

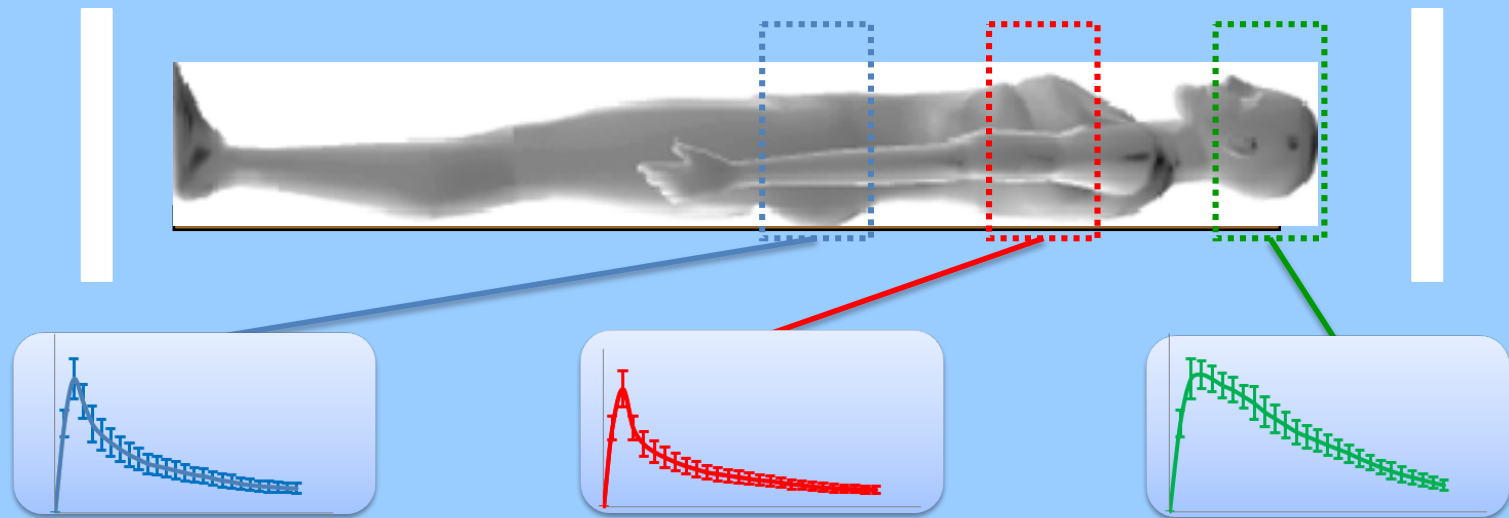


Conventional PET



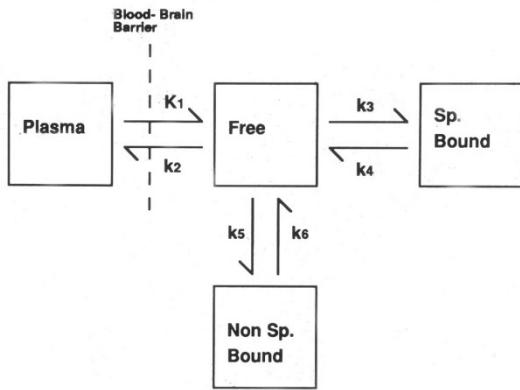
EXPLORER

Kinetic Data from the whole Body Field of View



*Regional tissue kinetics & arterial blood input functions
with high statistical quality*

Image Kinetics

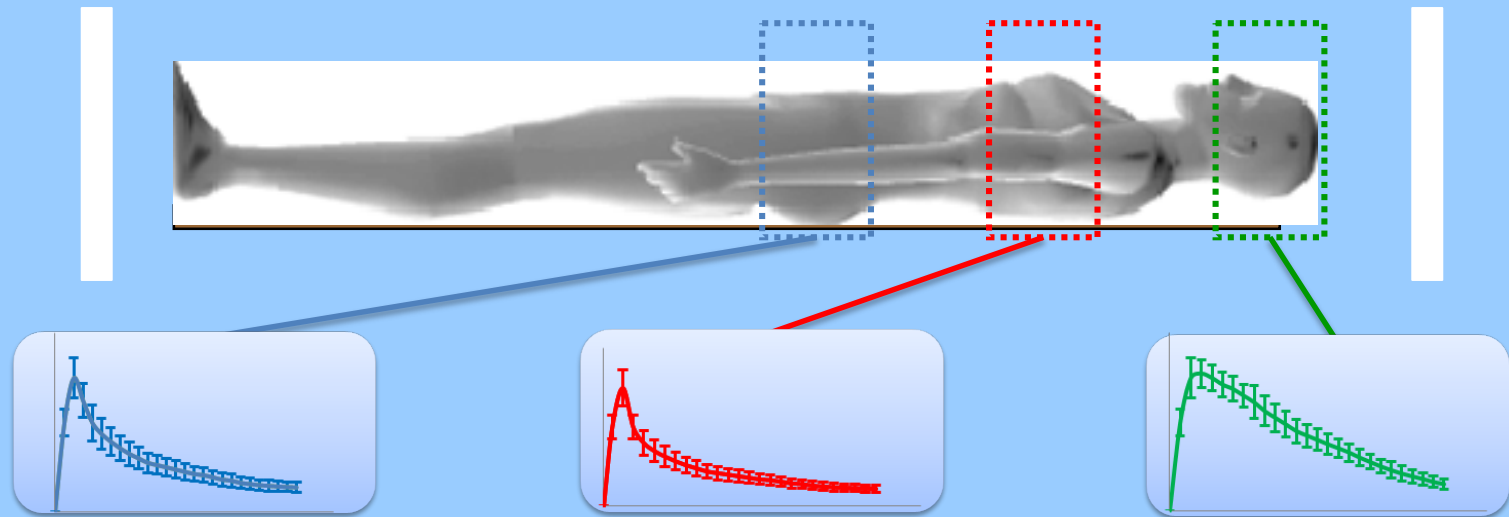


K_1 = flow x extraction ($\text{mls min}^{-1} \text{ml}^{-1}$),

k_2 = functional efflux (min^{-1}),

k_3 = combined forward rate constant ($K_{\text{ass}} \times B_{\text{max}}$) (min^{-1}),

k_4 = dissociation constant = k_{off} (min^{-1})



*Regional tissue kinetics & arterial blood input functions
with high statistical quality*

Image Longer

- **40-fold greater dynamic range**
can image for 5 more half lives

- ^{11}C
> 3 hours

- ^{18}F
> 18 hours

- ^{89}Zr
> 30 days



Conventional PET

time →



EXPLORER

Image Gently (Low Dose)

- **40-fold reduction in dose**

- Whole-body PET at ~0.15 mSv
- Annual natural background is ~2.4 mSv
- Return flight (SFO-LHR) is ~0.11 mSv
- PET can be used with minimal risk – new populations



Conventional PET



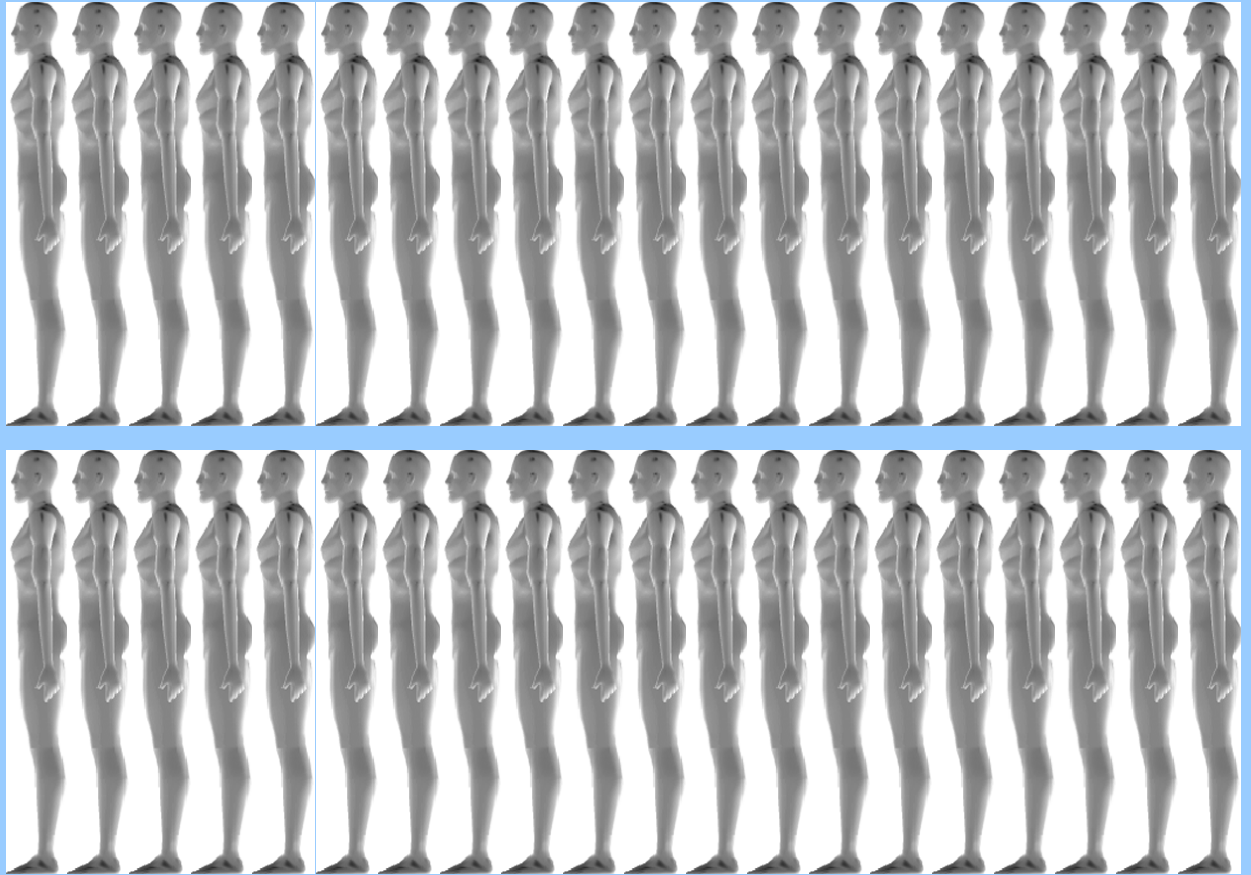
EXPLORER



Image More Often



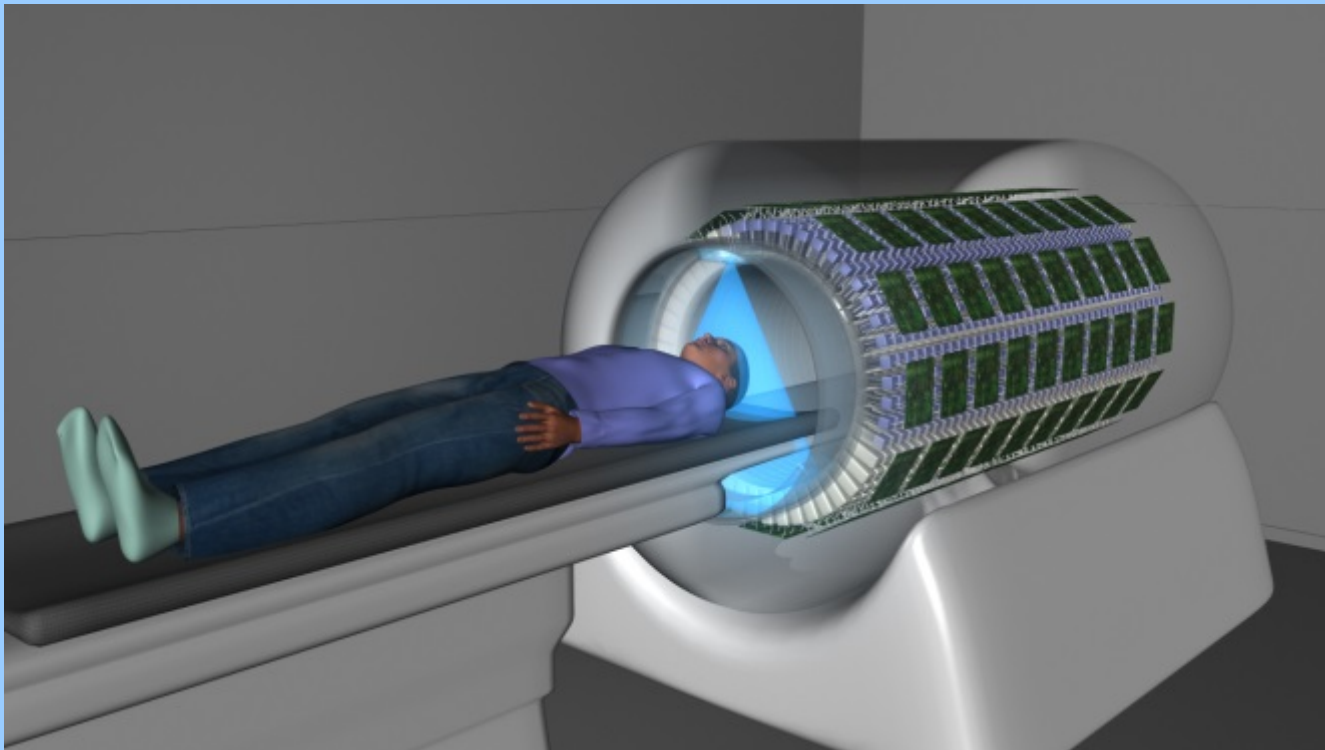
Conventional PET



EXPLORER

How to fund the construction of the World's first total body PET?

Need a lot of money but have no proof of
concept data





High-Risk Research

- The High-Risk, High-Reward Research program, has four unique funding opportunities for exceptionally creative scientists who propose highly innovative approaches to major challenges in biomedical research



- **The Transformative Research Award** supports exceptionally **innovative, unconventional, paradigm-shifting research projects that are inherently risky and untested**
- Applicants are instructed to focus their research strategies on significance and innovation **without the expectation of providing preliminary data**



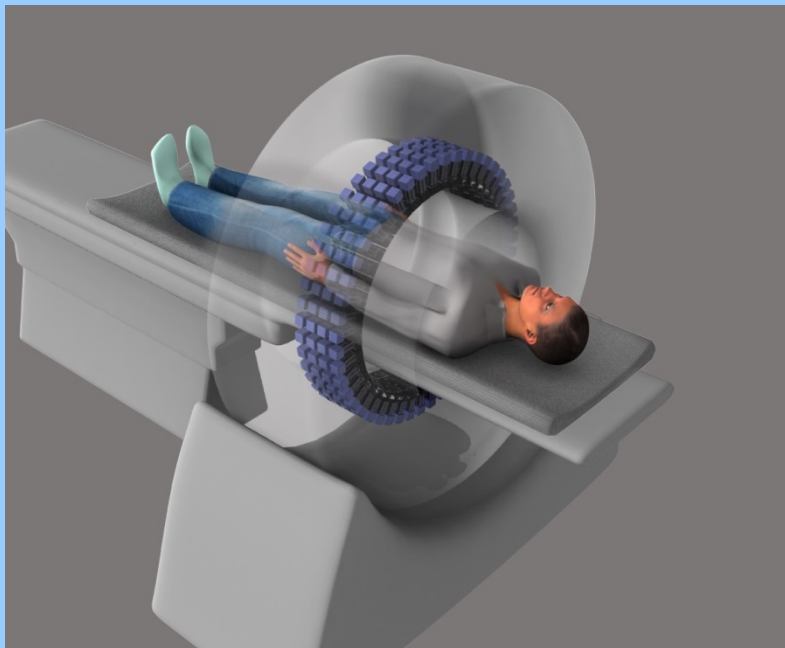
Simon Cherry



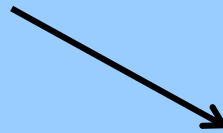
Ramsey Badawi



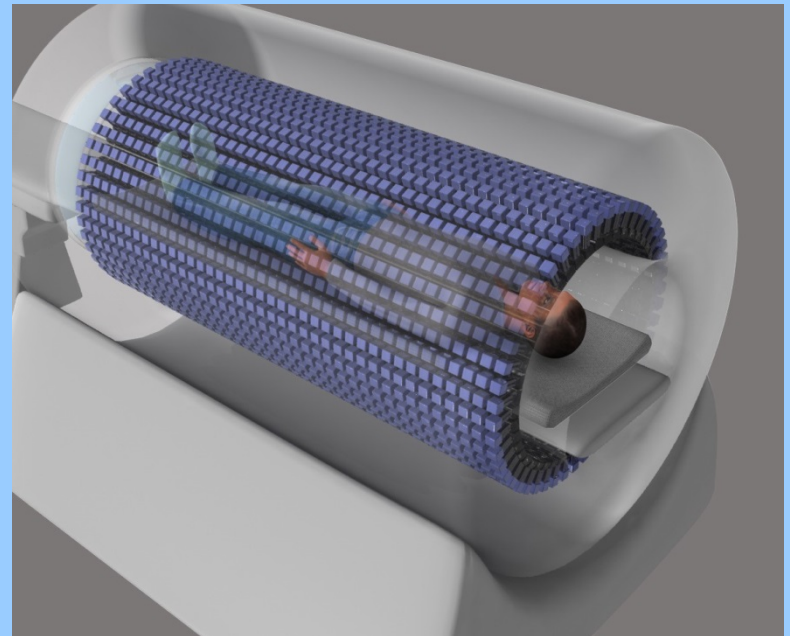
At UC Davis, who head the EXPLORER program, have been granted a **Transformative Research Award** of \$15.5M to build the World's first Total Body PET Scanner



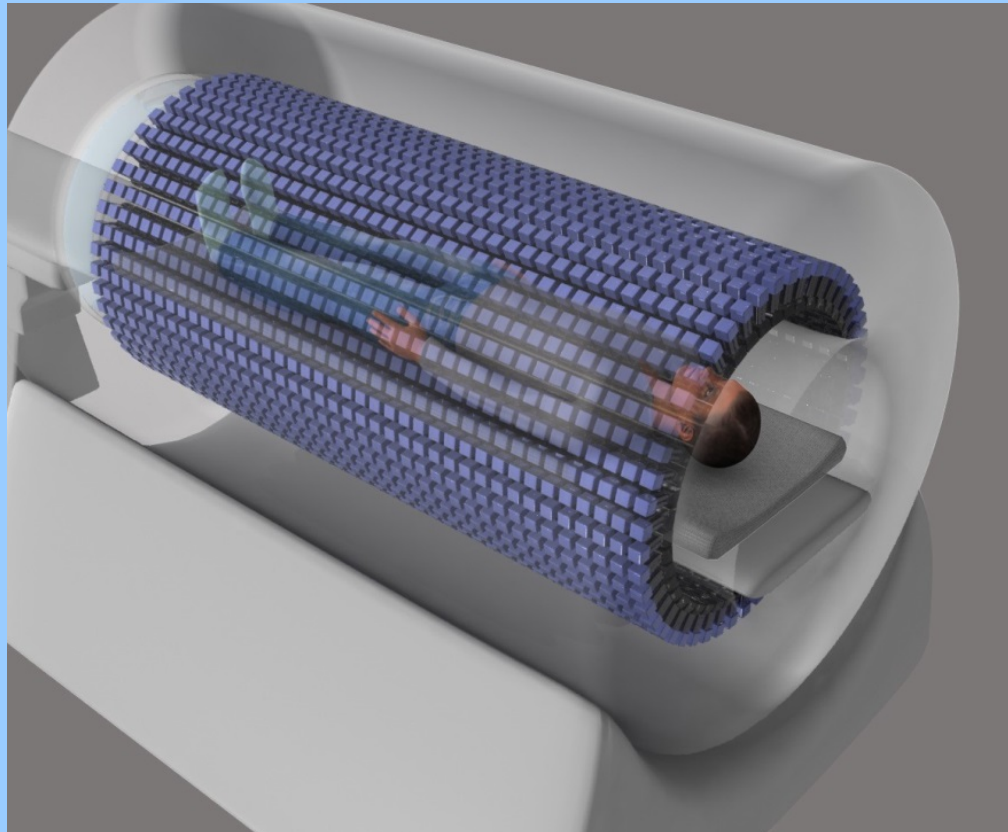
**Conventional
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(2016)**



**EXPLORER
Total Body PET Scanner
(2018)**



How could CERN and its associates contribute to the future development of Total Body PET?



Future Technical Developments

Low cost detectors (CERN active*)



Faster detectors (CERN active**)



<40pico second coincidence resolving time



Avoids reconstructions



Further increases in signal to noise: sensitivity

* Crystal Clear **Fast Advanced Scintillator Timing

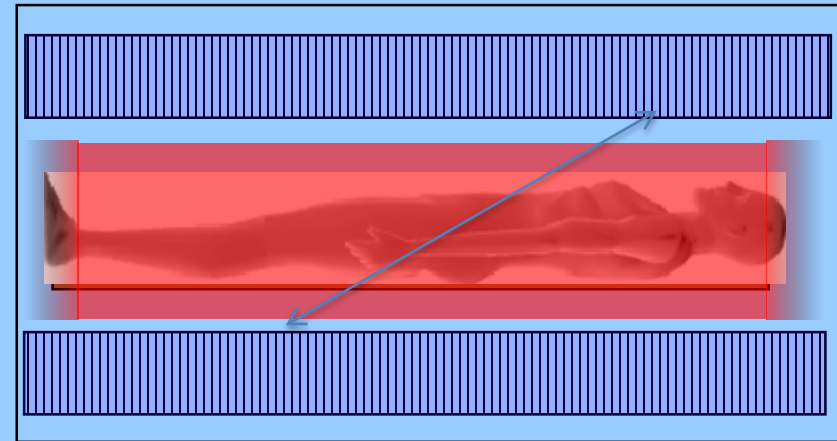
Optimizing event information through fast ASIC electronics to derive the most information from each event

- Digitize entire waveforms from 0.5-1 million crystals
- Real time processing to extract timing, energy, and position, and identify inter-crystal scatter
- Using maximum likelihood approaches to determine point of interaction in the detector

Total-Body PET: Maximizing Sensitivity

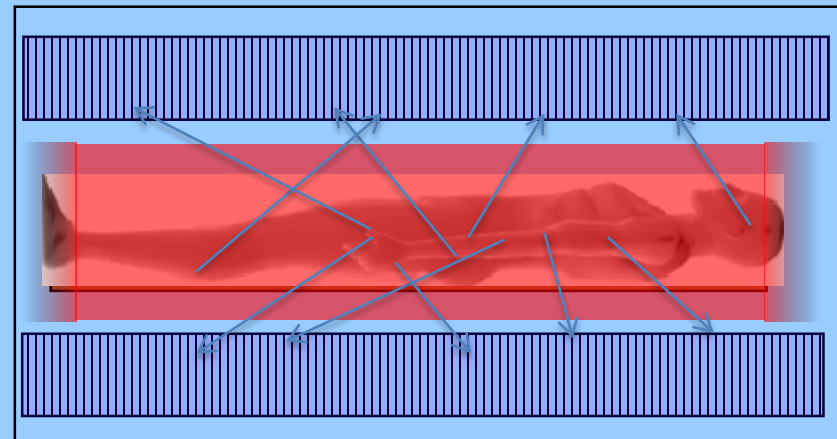
Coincident Events

1



Non-Coincident Events

10



Handling Big Data

- **ATLAS detector at CERN**
 - 1000 terabytes/second of raw data reducing to:
 - 100 megabytes of disk space per second
 - 1000 terabytes of data to analyse per year
- **Total Body PET (10 mCi in FOV):**
 - 1500 megabytes of raw data to disk space per second
 - ~10-40 terabytes stored per day

10 year vision for advanced technology of Total Body PET Scanning

- Maximising sensitivity
- Maximising spatial resolution
- Affordable

**Low dose radio tracer studies will
need compact low output cyclotrons**

CERN and associates expertise in
particle acceleration

Simple to Operate

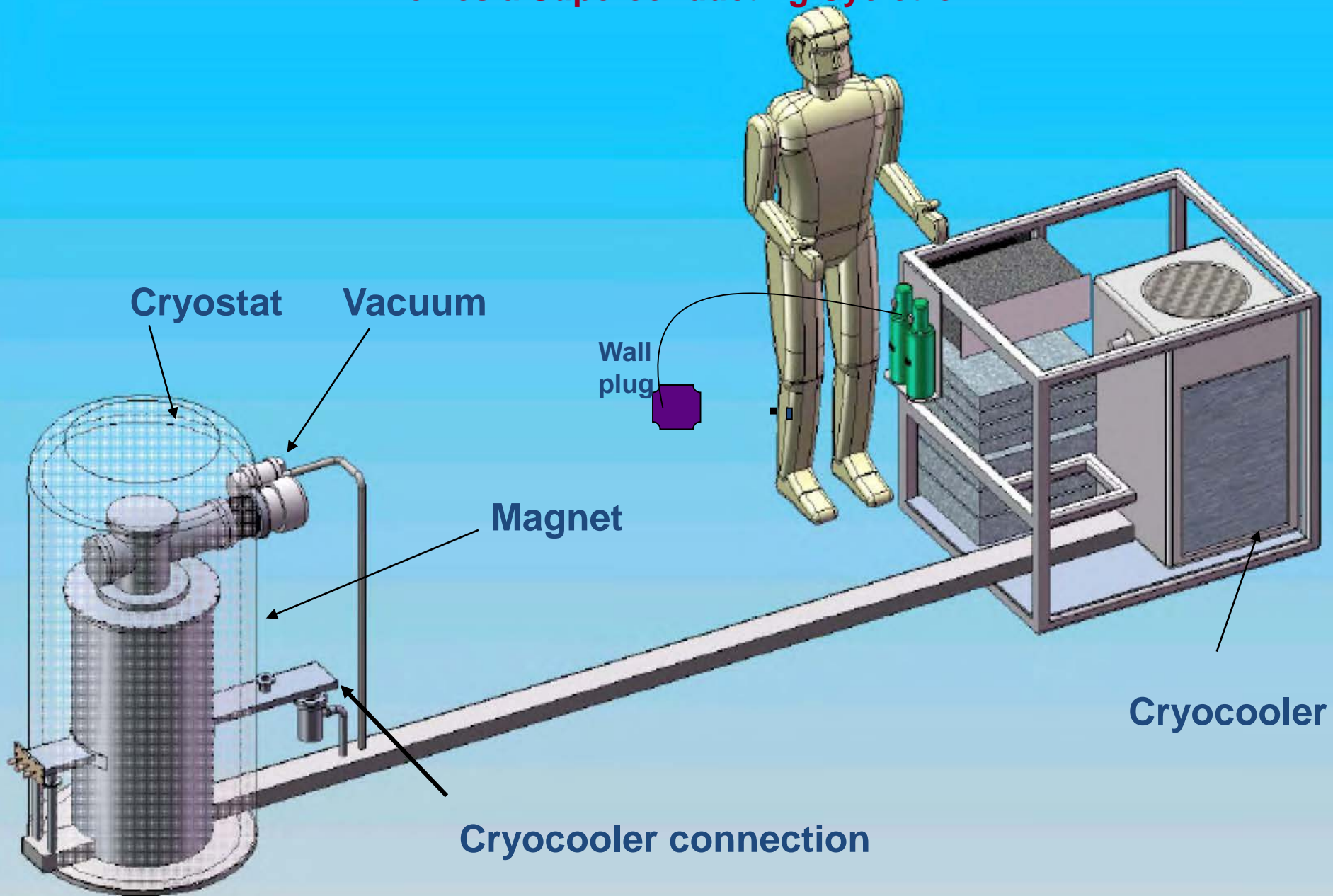
Low Radiation Emitter



Low Cost

Low Levels of Radioactivity

Five Tesla Superconducting Cyclotron



Fm. Timothy Antaya, MIT

That is the technological case

Thank you