Chicago PET Development and Recent Progress in Digital TOFPET

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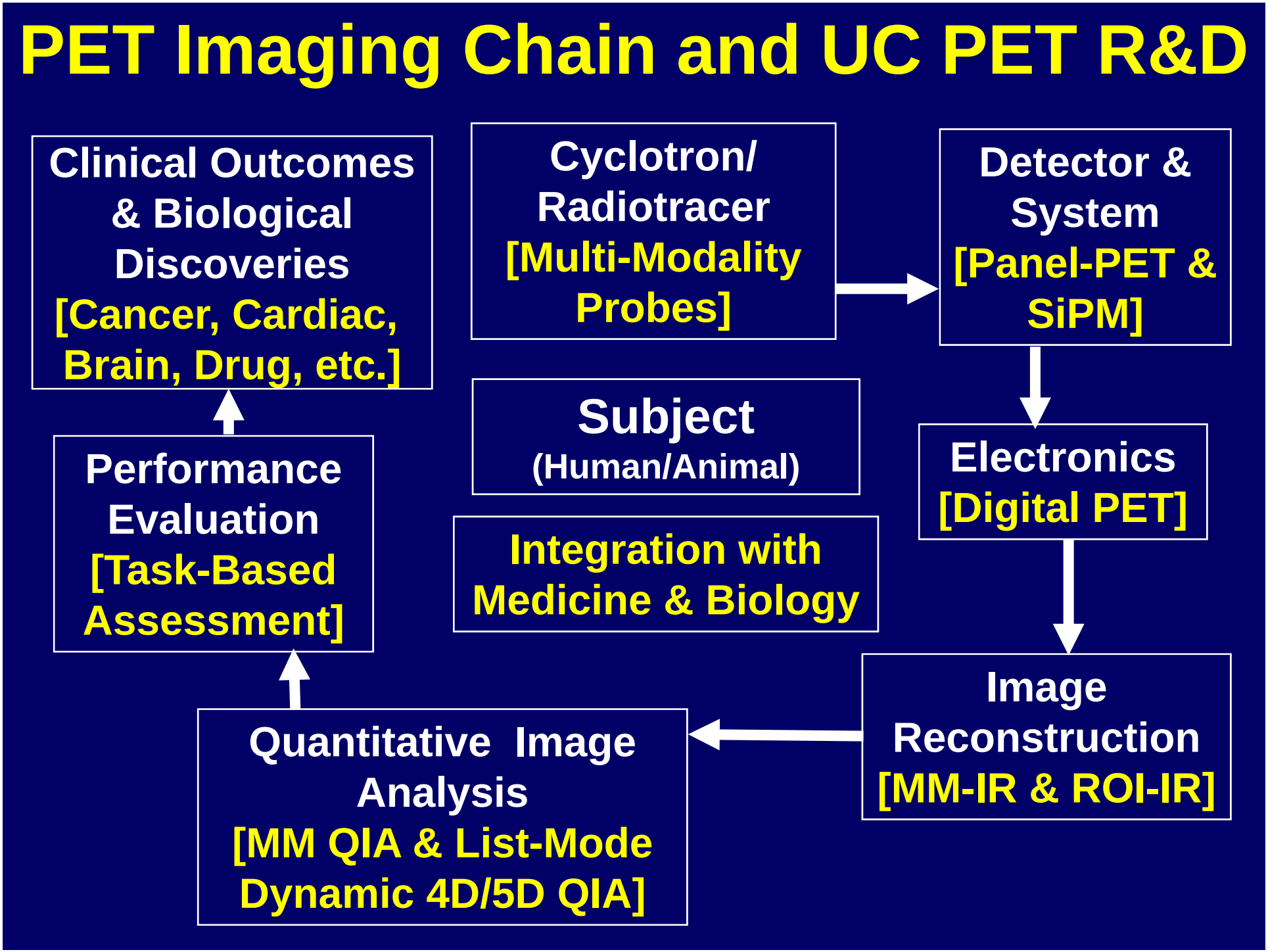
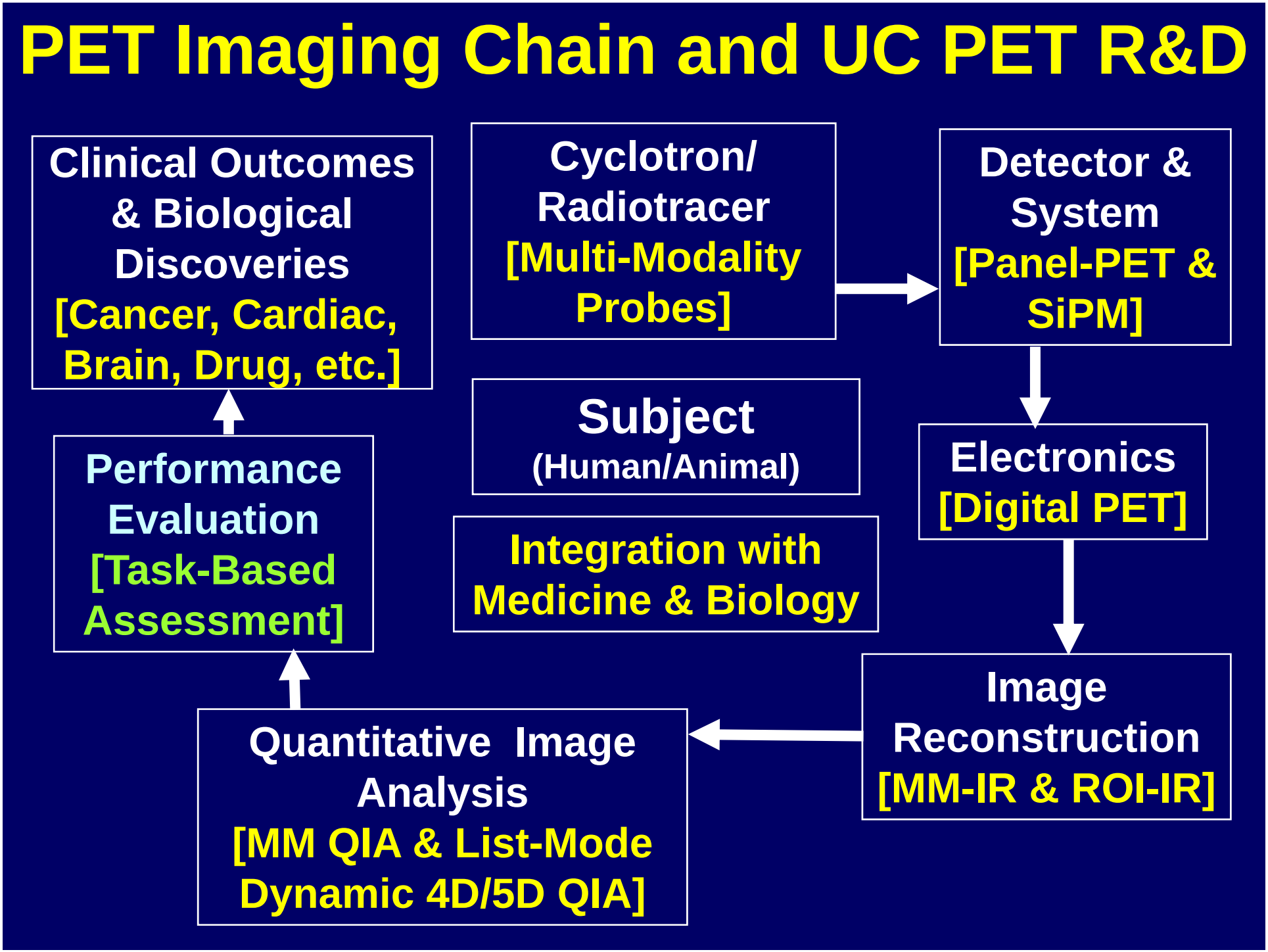
PET Imaging Chain and UC PET R&D



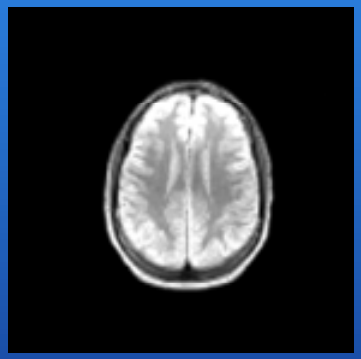
Quantitative Imaging
Multi-Modality Integration
High-Performance
Low-Cost
Broad-Access

PET Imaging Chain and UC PET R&D

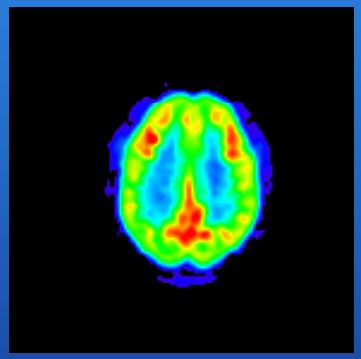


Imaging of Life and Life Processes

Live Brain

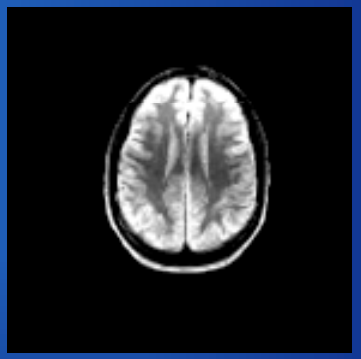


MR



PET

Dead Brain



MR

PET

Task-Based Image Quality Assessment
Tasks – Detection and Estimation

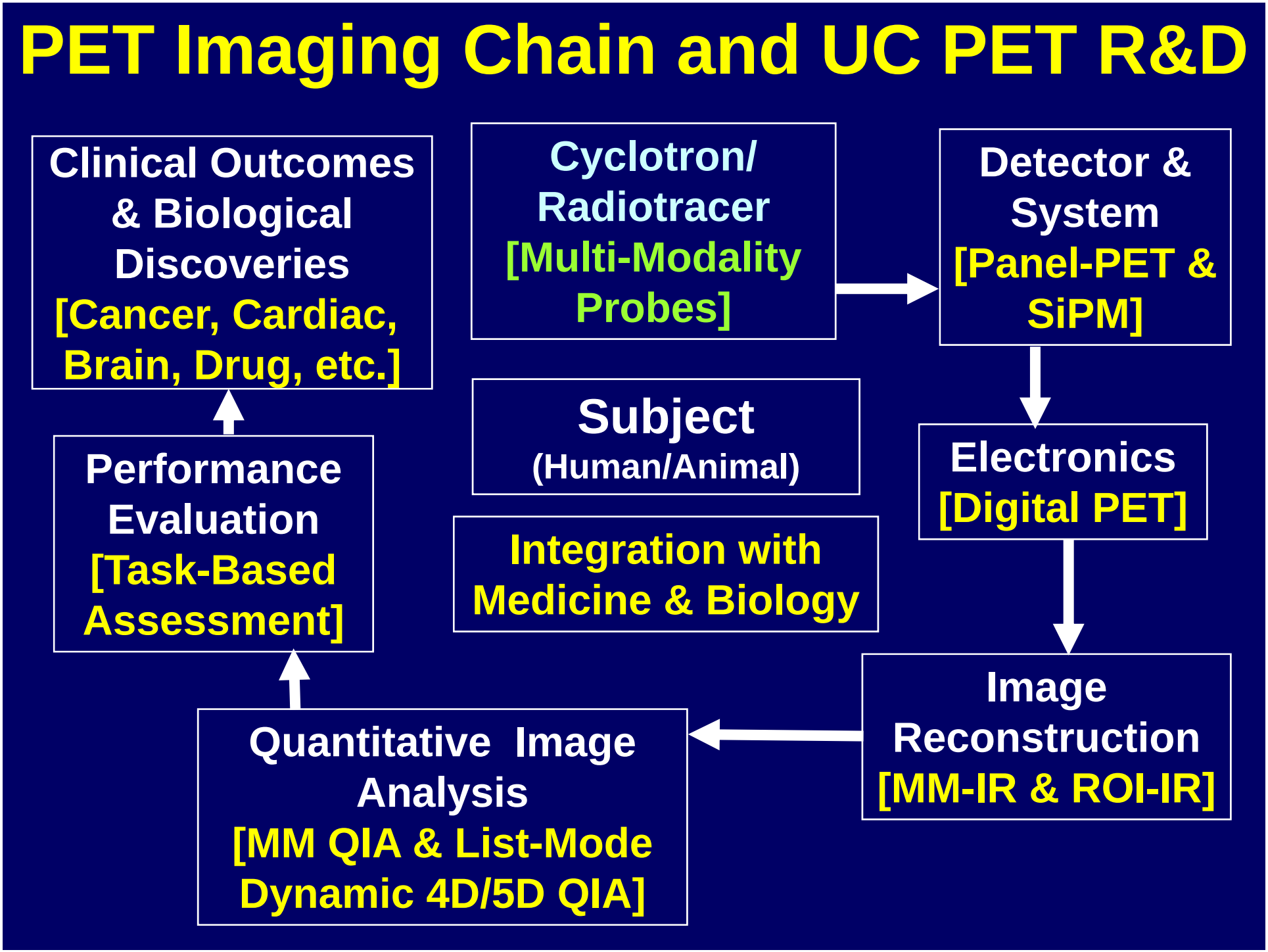
2008 IEEE NSS/MIC/RTSD
MIC Short Course
" Image Quality in Adaptive and Multimodality Imaging"

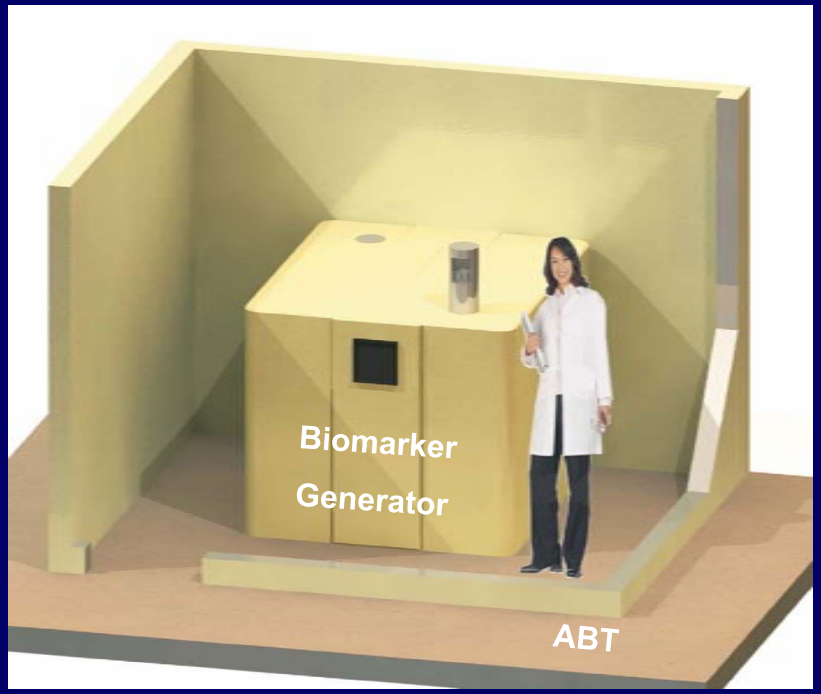
20 October 2008

Dresden, Germany

Organizer: Harrison Barrett,
Matthew A. Kupinski,
Lars R. Furenlid

PET Imaging Chain and UC PET R&D



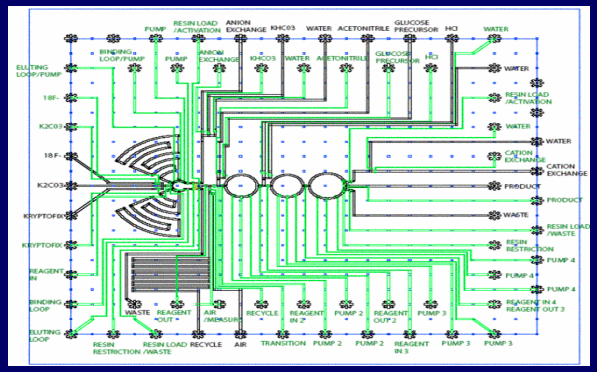


Micro Accelerator

Key Characteristics of Biomarker Generator

- **Lower cost & much smaller to be located at scanner**
- **To be an approved FDA medical device**
- **Produce dose of F-18 or C-11 biomarker in 20 minutes**
- **Base chemistry system for drug discovery**
- **Handling of micro to millicuries, not curies**

Microchemistry & Microfluidics

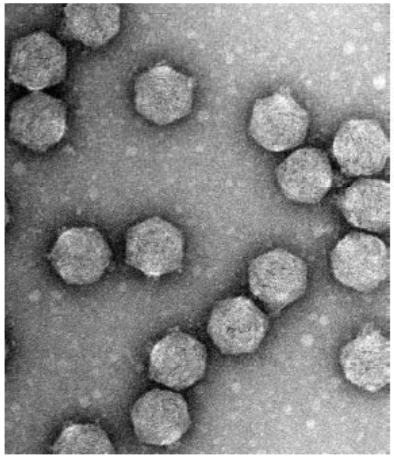


Courtesy of Nanotek & ABT

Multi-Modality Targeting Molecular Imaging & Therapeutic Probes (Phage and Micelle Nanosystem)

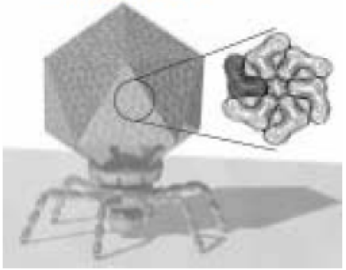
T7 bacterium virus (phage)

Size: ~50 nm in diameter



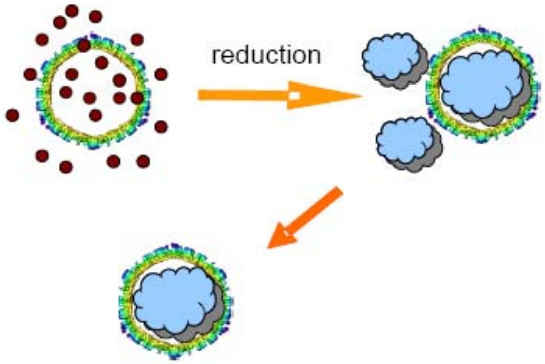
Components:

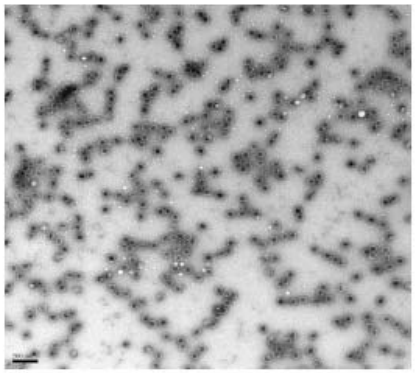
Capsid shell,
head-tail connector,
tail, tail fibers.



Fabrication of hybrid Tc-99m phage particle

Tc-99m reagent





Ultrasound, MRI, SPECT, PET,
X-Ray/CT, Fluorescence & Therapeutics

PET Imaging Chain and UC PET R&D

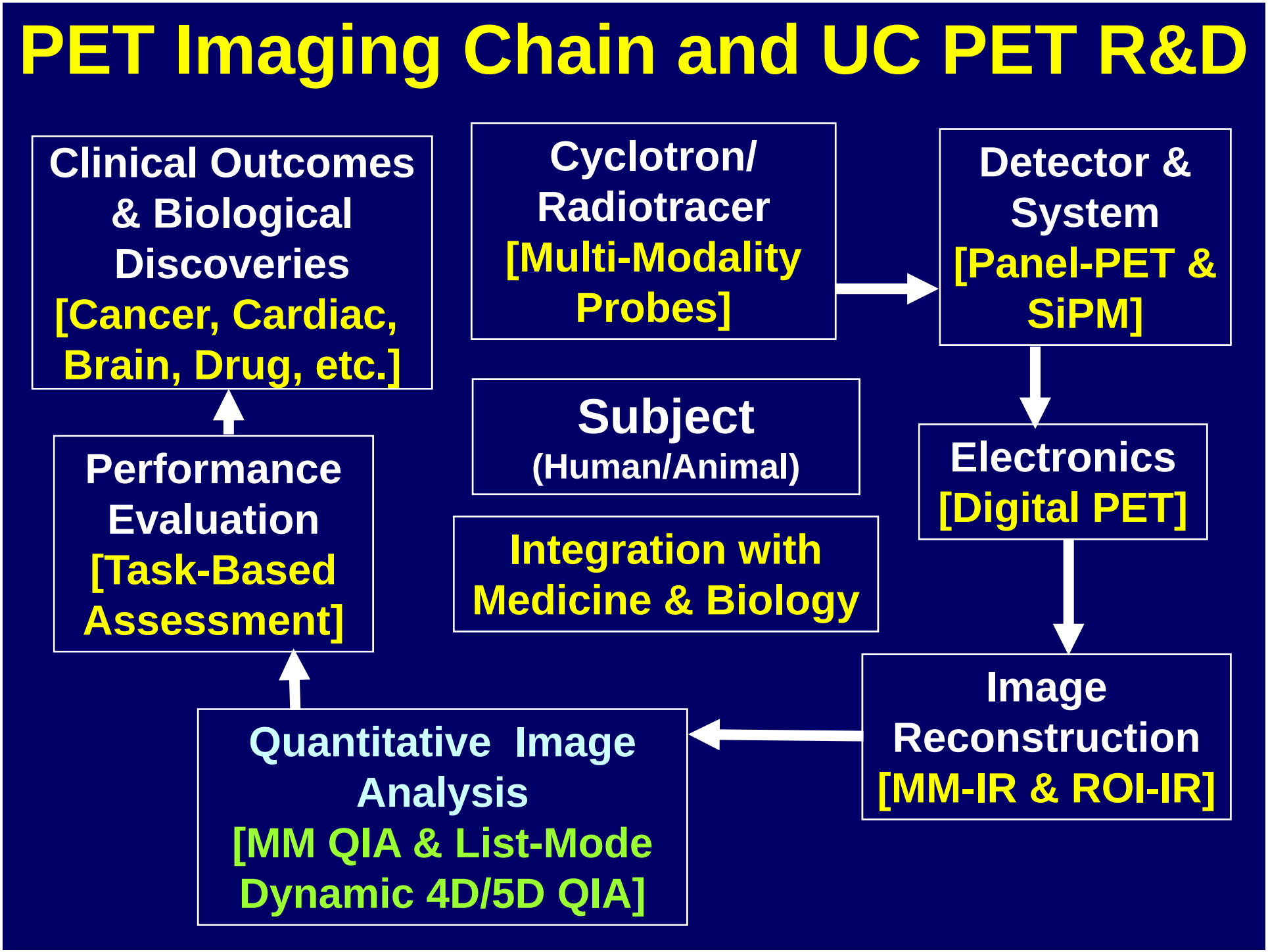
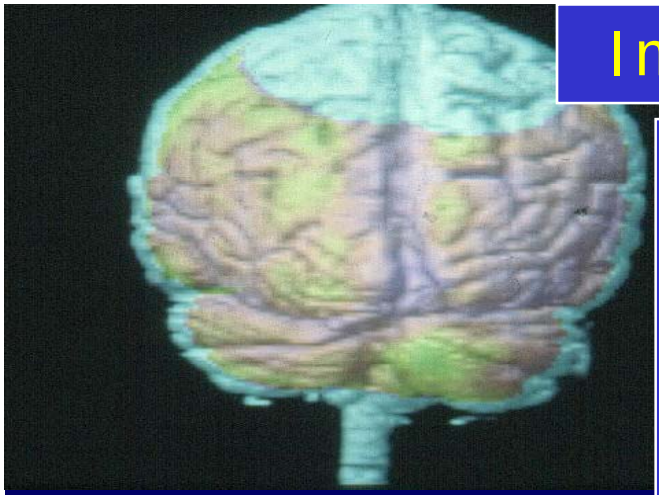
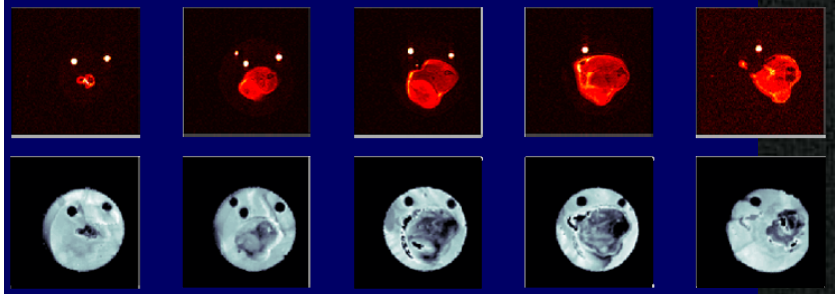
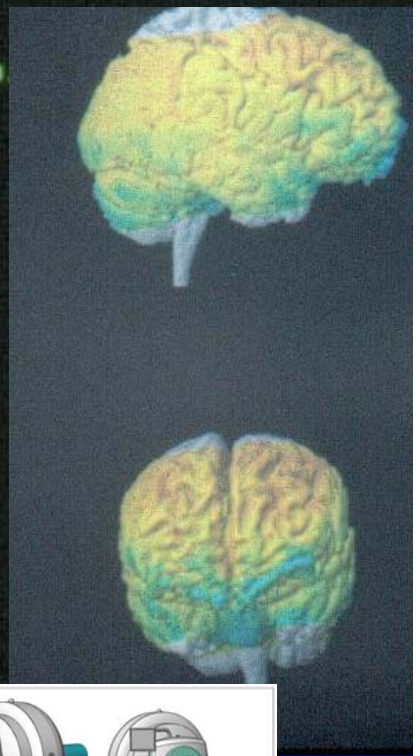


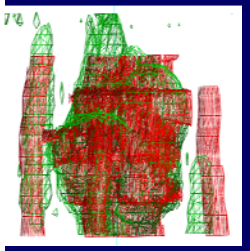
Image Co-Registration & Integration

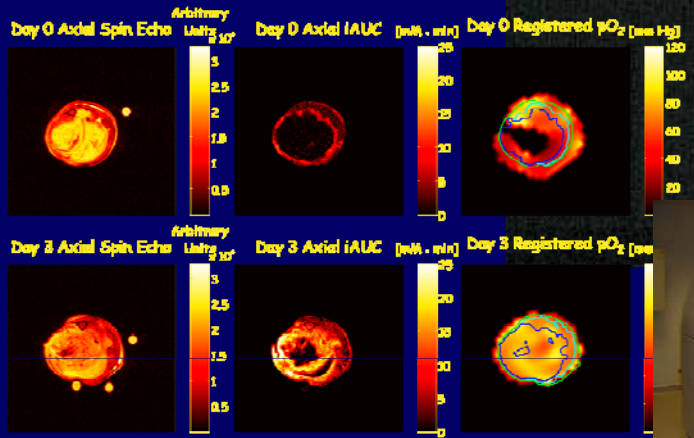


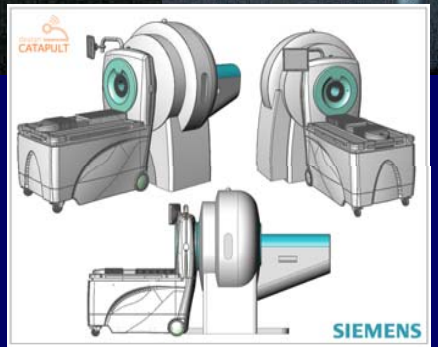
Fusion of PET, SPECT, MRI, CT, EPRI, Histology





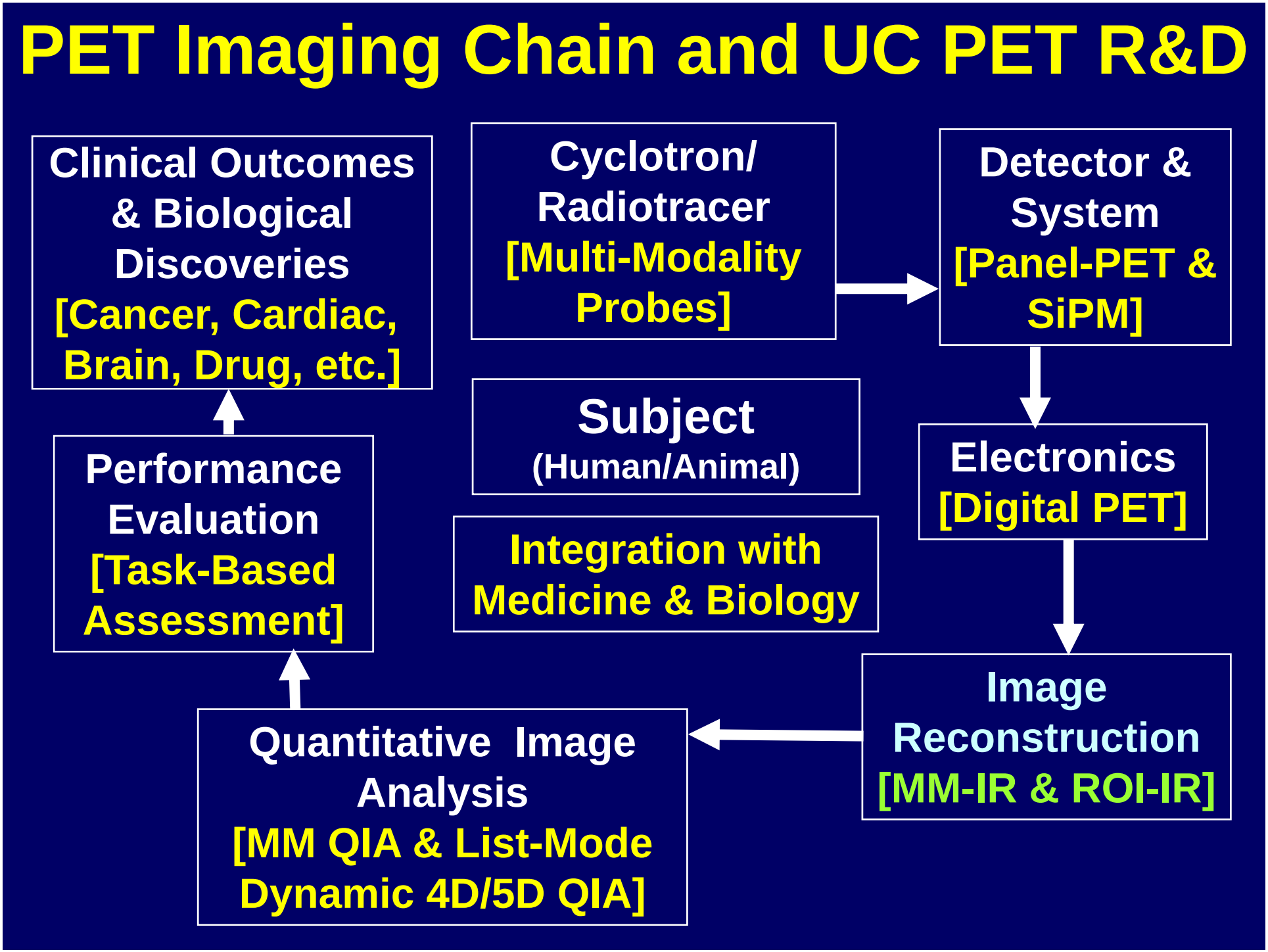






Halpern,
Pelizzari
Karczmar
Weichselbaum

PET Imaging Chain and UC PET R&D



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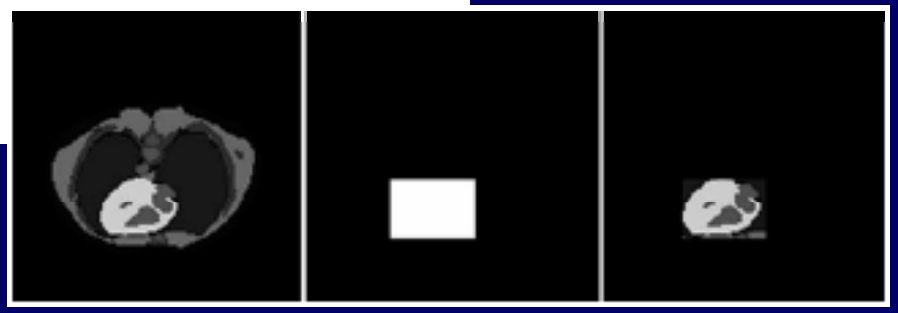
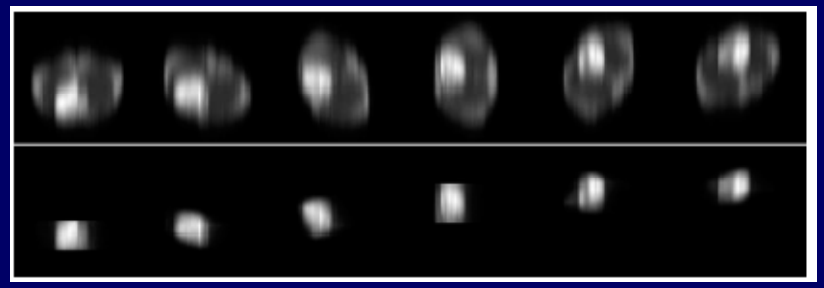
Phys. Med. Biol. 53 (2008) 3431–3445 doi:10.1088/0031-9155/53/13/002

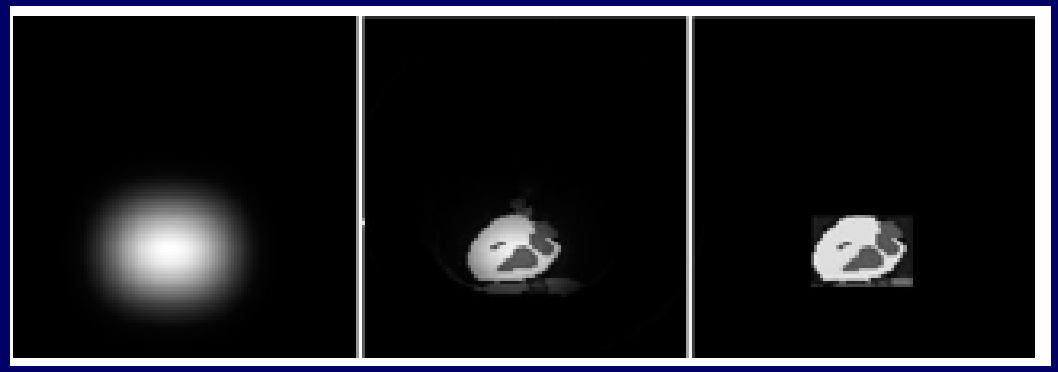
Windowed image reconstruction for time-of-flight positron emission tomography

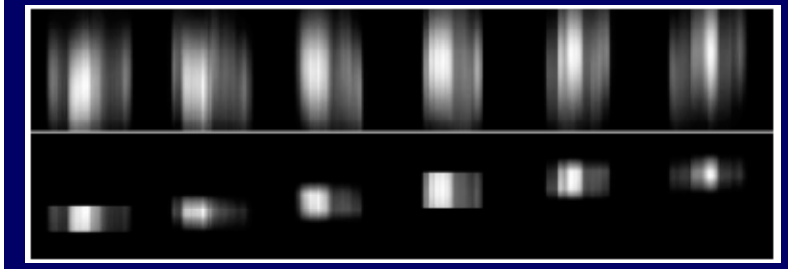
Chien-Min Kao



600 ps

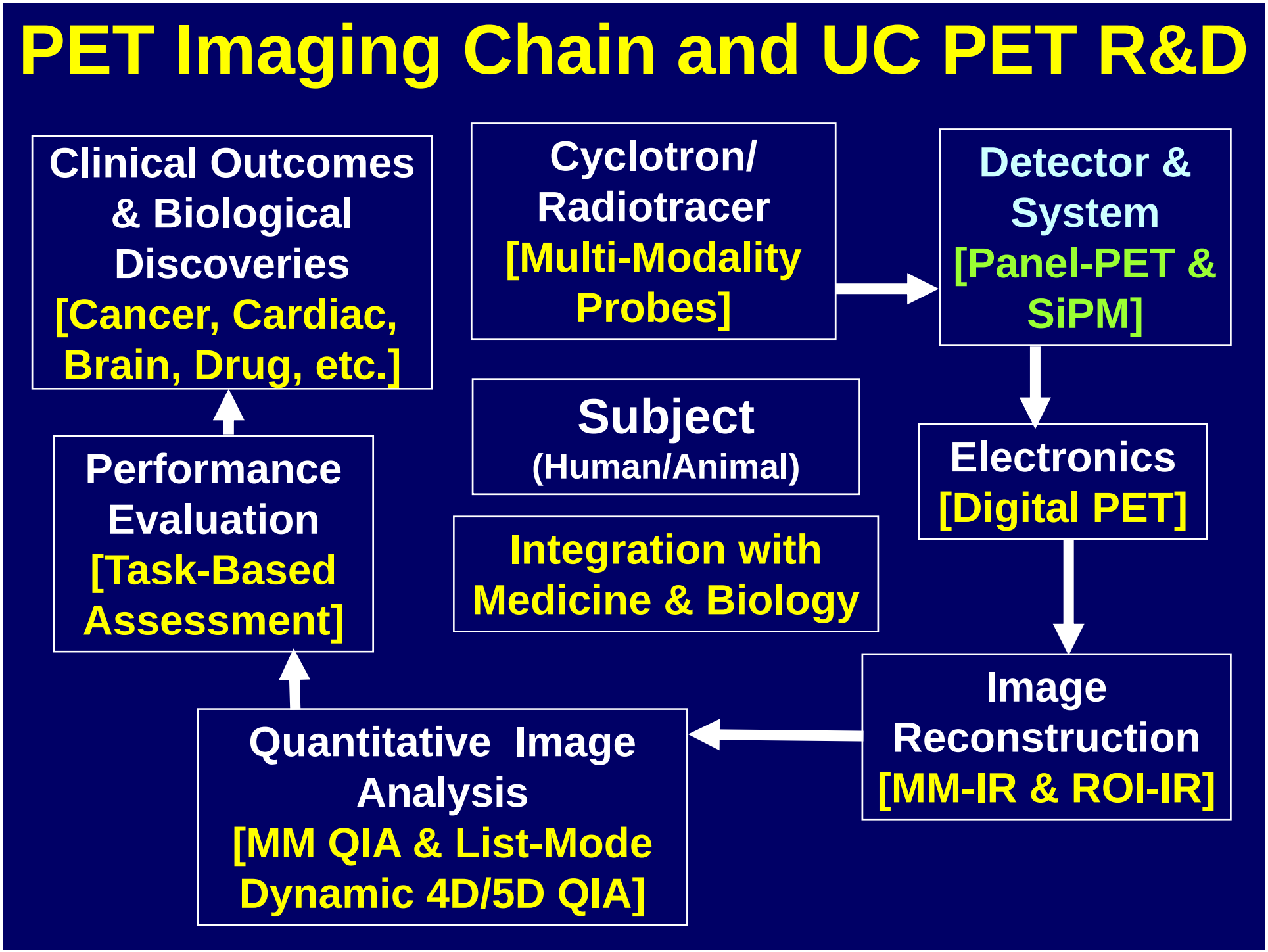






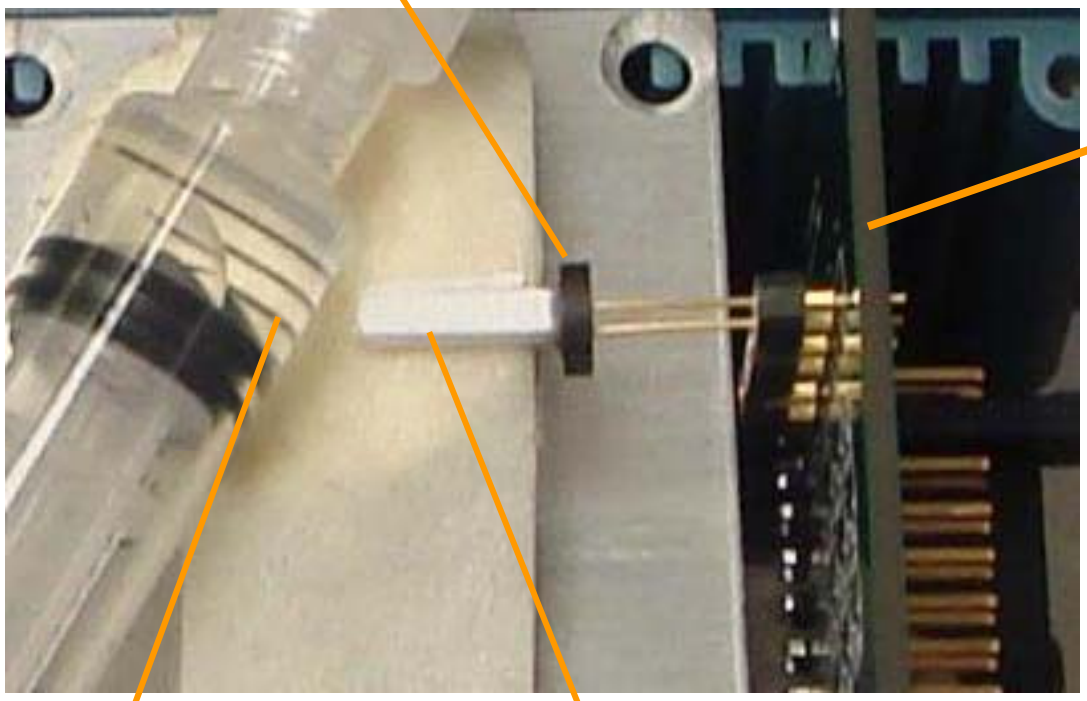
2 ns

PET Imaging Chain and UC PET R&D



Silicon PM Characterization

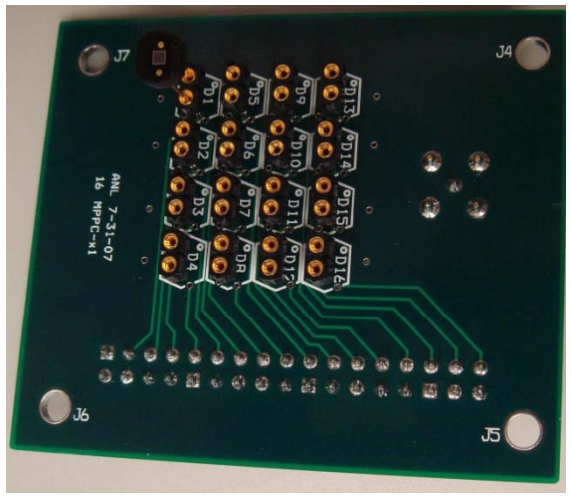
MPPC: 1x1mm^2
25-μm, 50-μm, or 100-μm



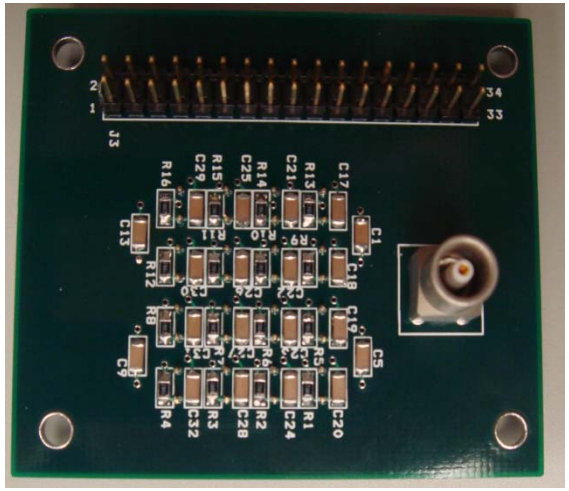
Source:
F-18

LYSO:
1x1x10mm^3, 2x2x10mm^3

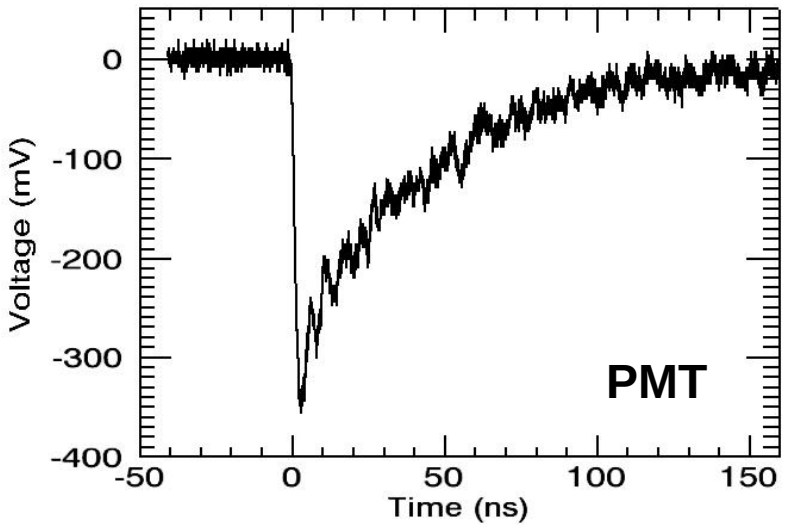
Front

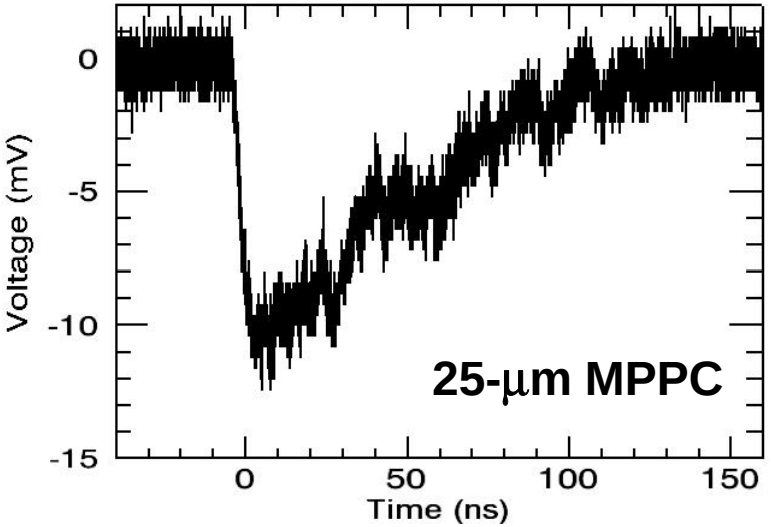


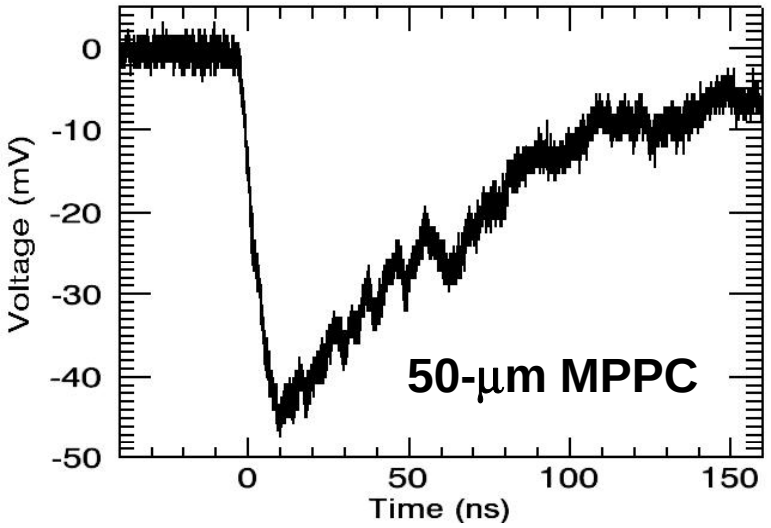
Back

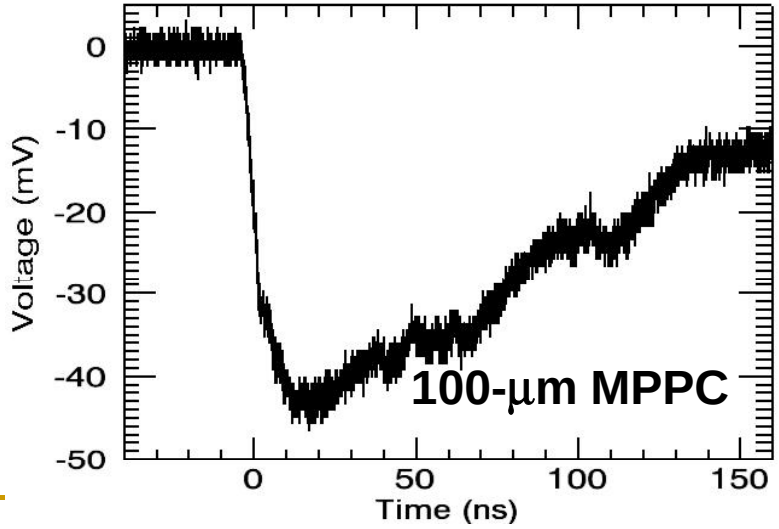


F-18/LYSO Sample Pulses

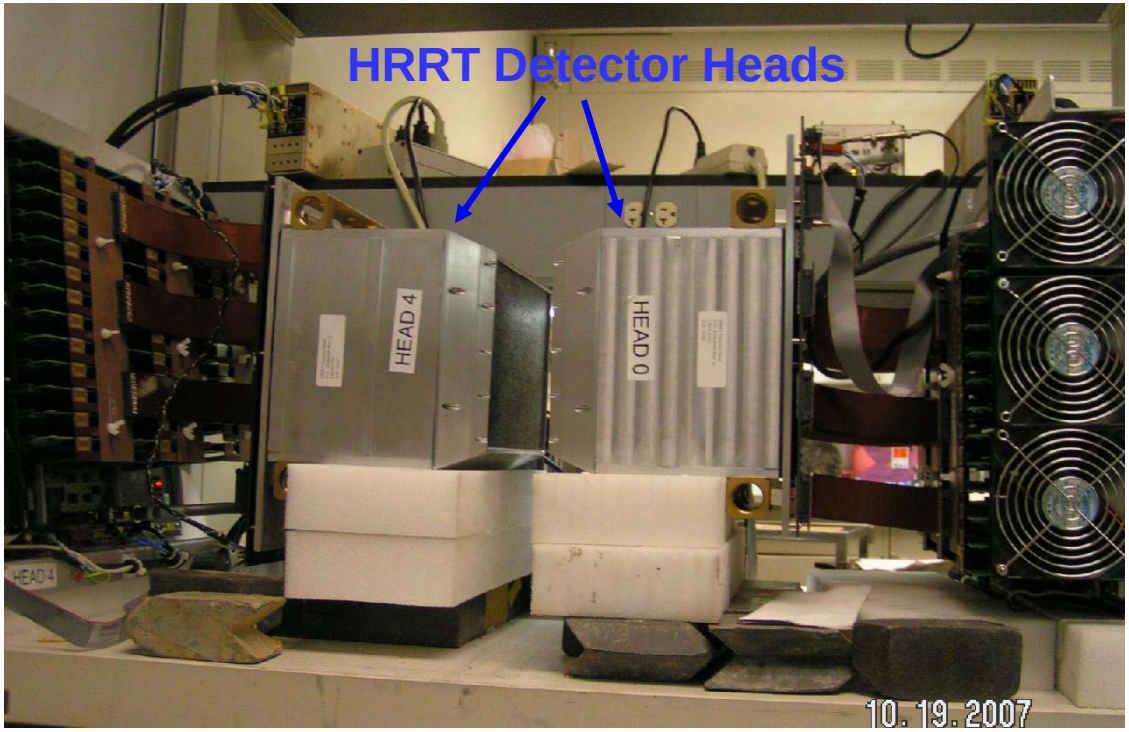








A Table-Top Prototype

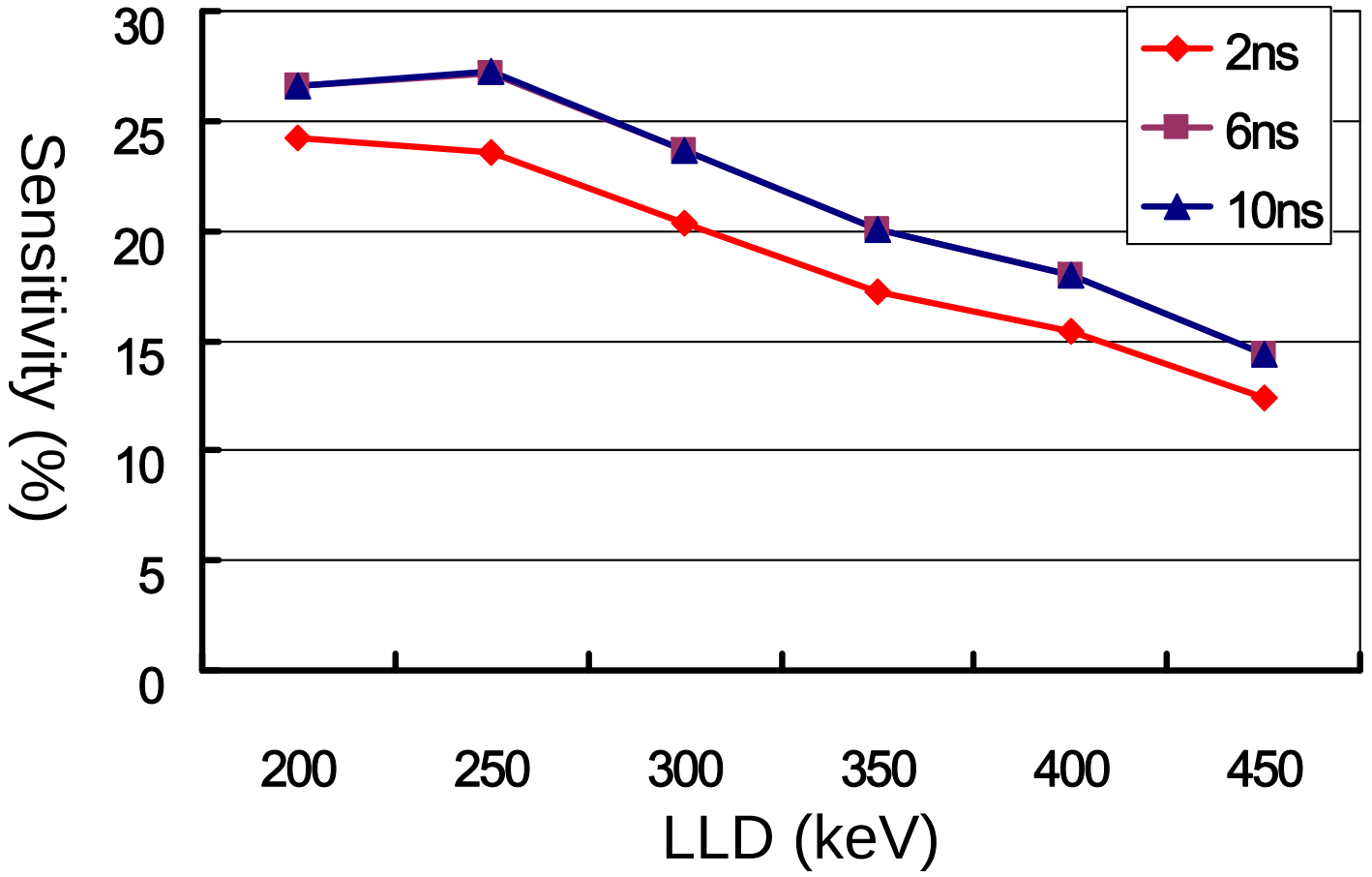


The prototype consists of two HRRT (High Resolution Research Tomograph) detector heads. The spacing between detectors shown is ~6 cm, which is adequate for imaging rodents.

A single double-layered, 8 x 8 LSO crystal block affixes onto 4 photomultiplier tubes in the quadrant-sharing configuration.

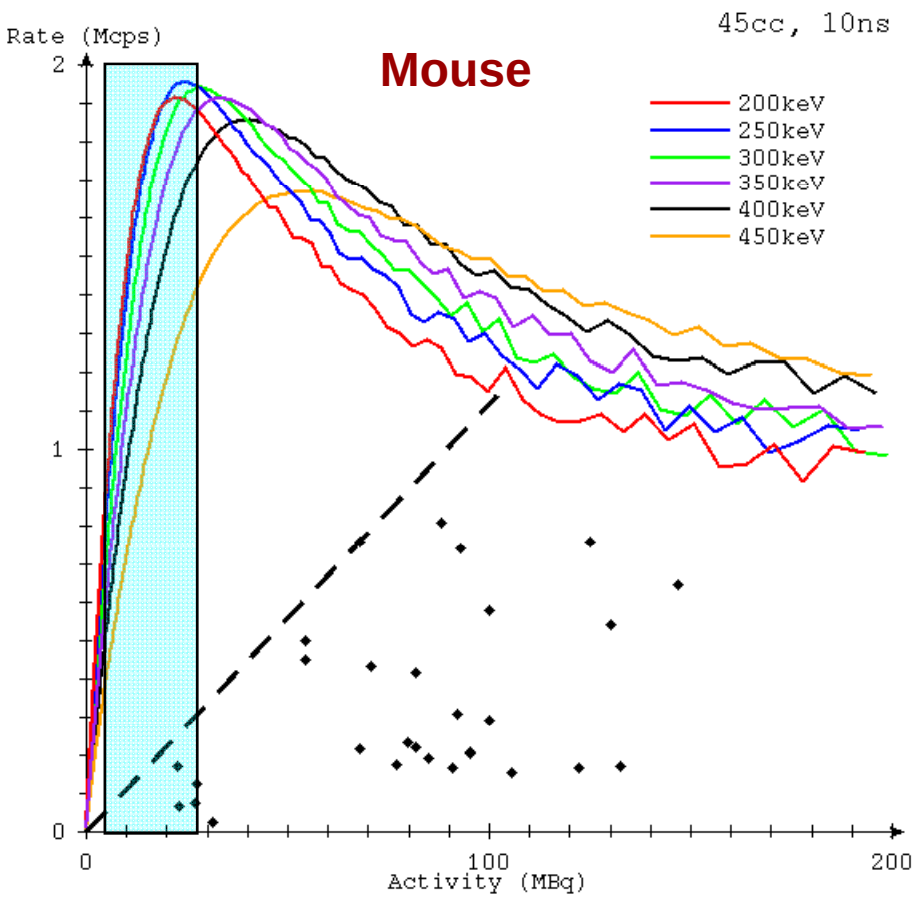
Central Sensitivity

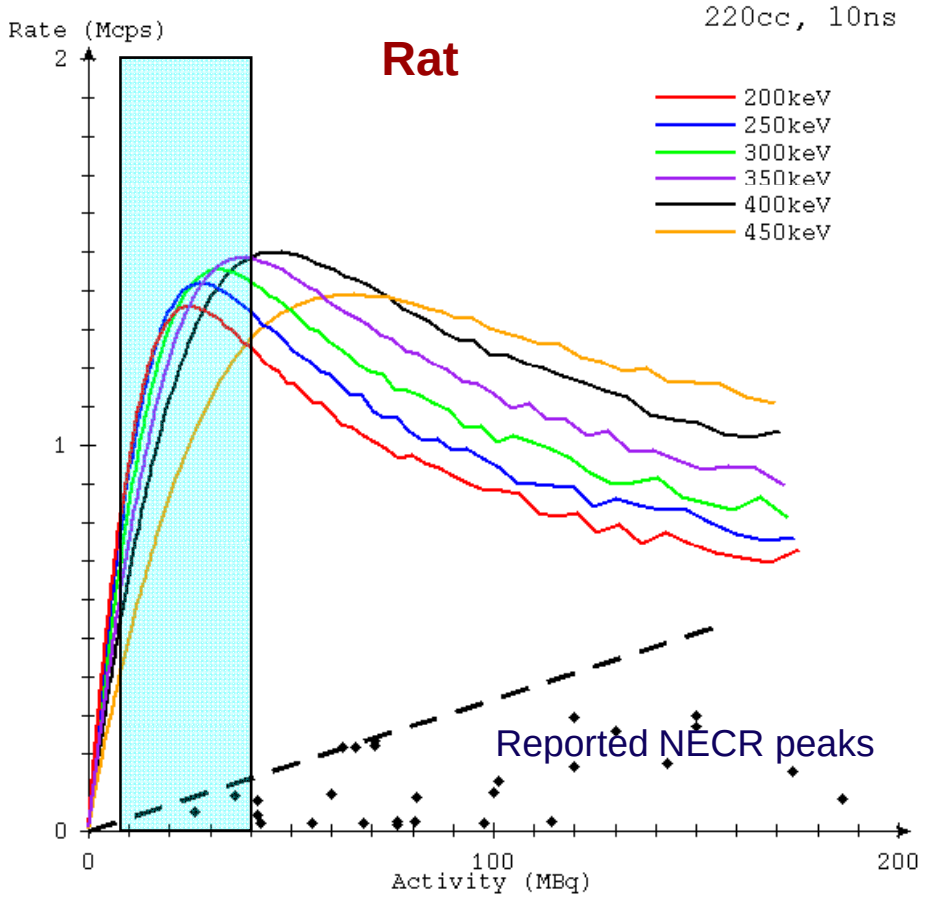
(GATE Simulation, 20% ER, 3ns TR)



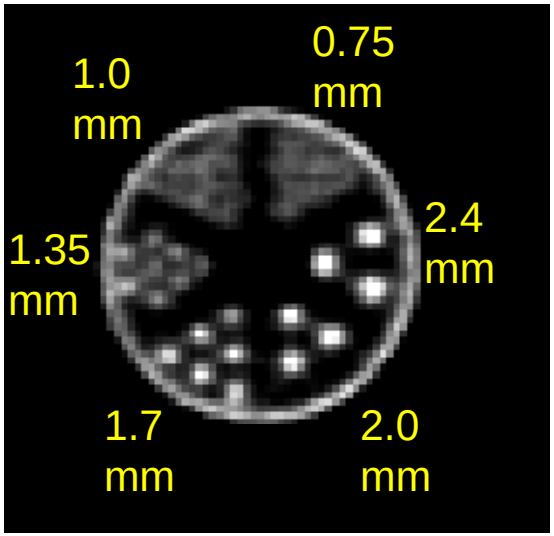
Noise-Equivalent Count Rate

Comparison with reported NECR peaks

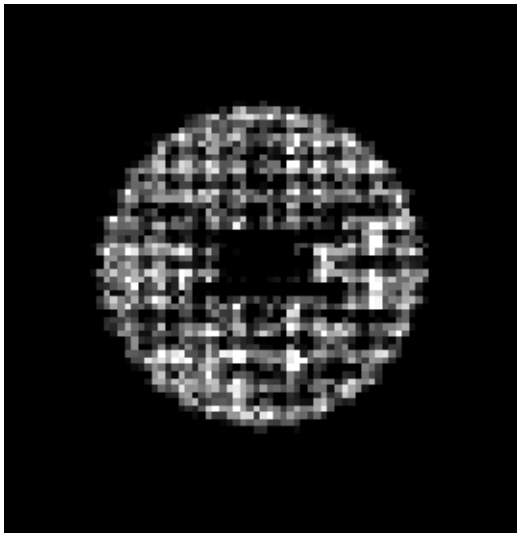




FDG Resolution phantom real data

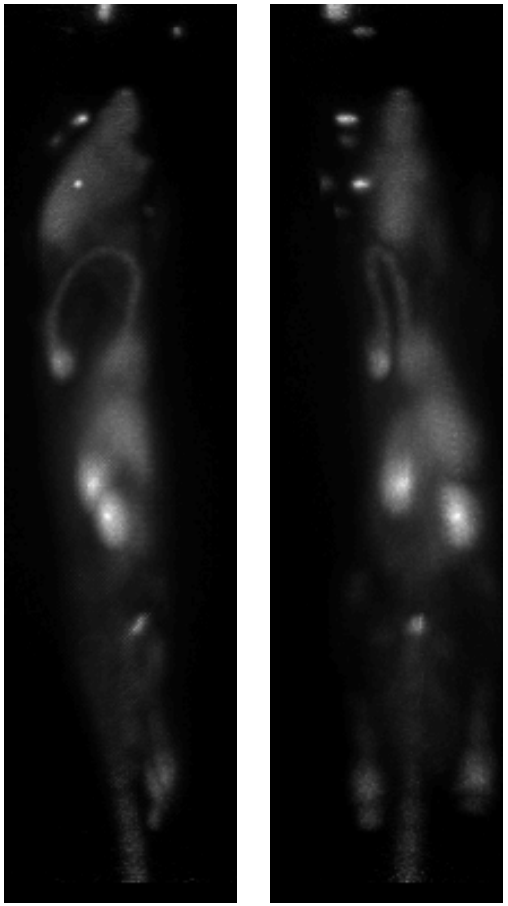


Modeling the responses by MC simulation

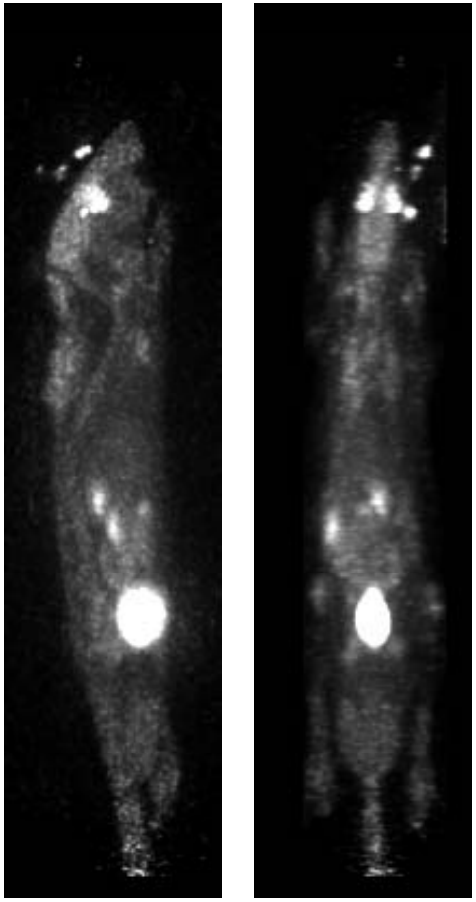


Ideal line integral

Sample Image
real FDG-Rat data

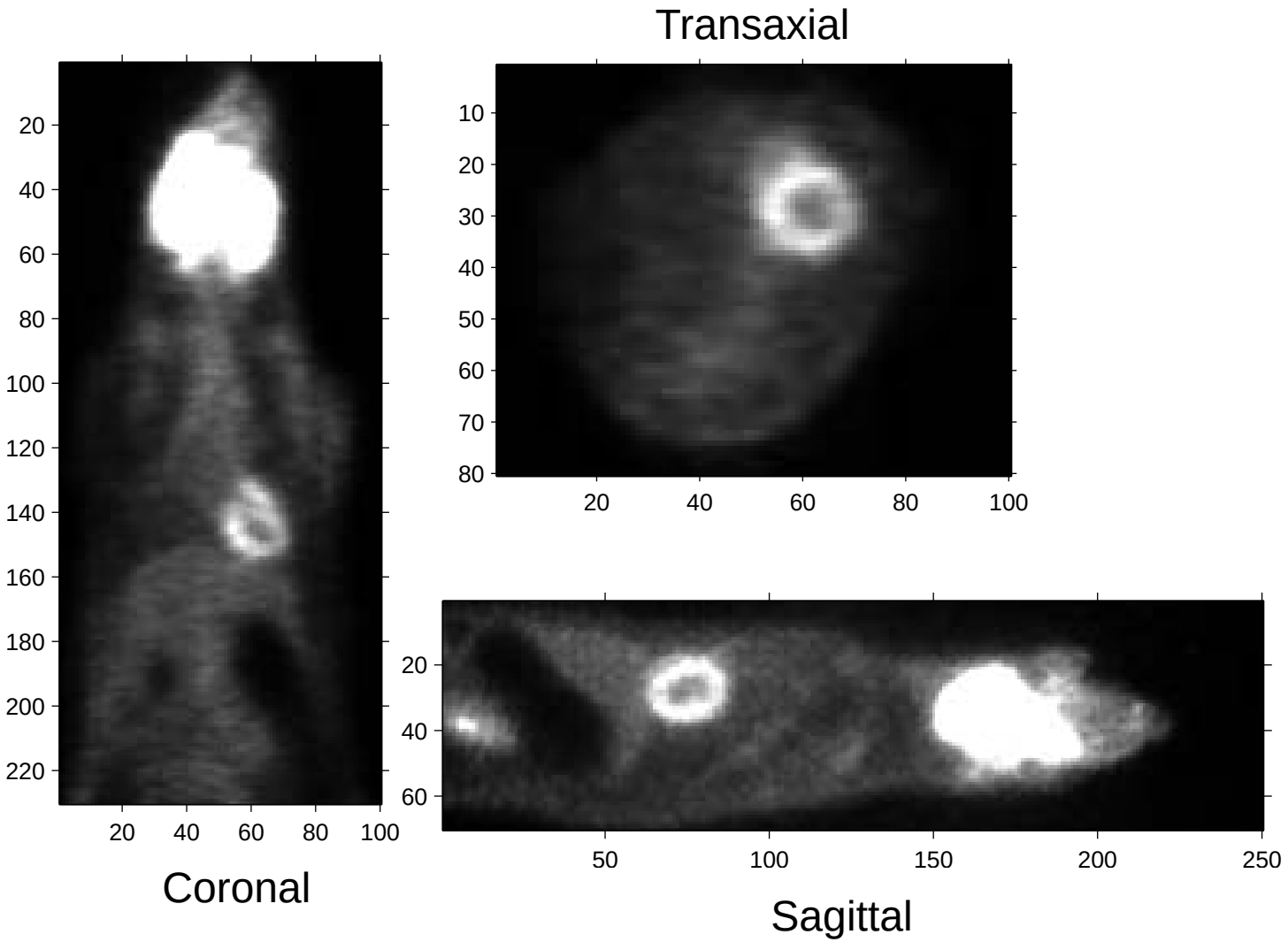


Ideal line integral

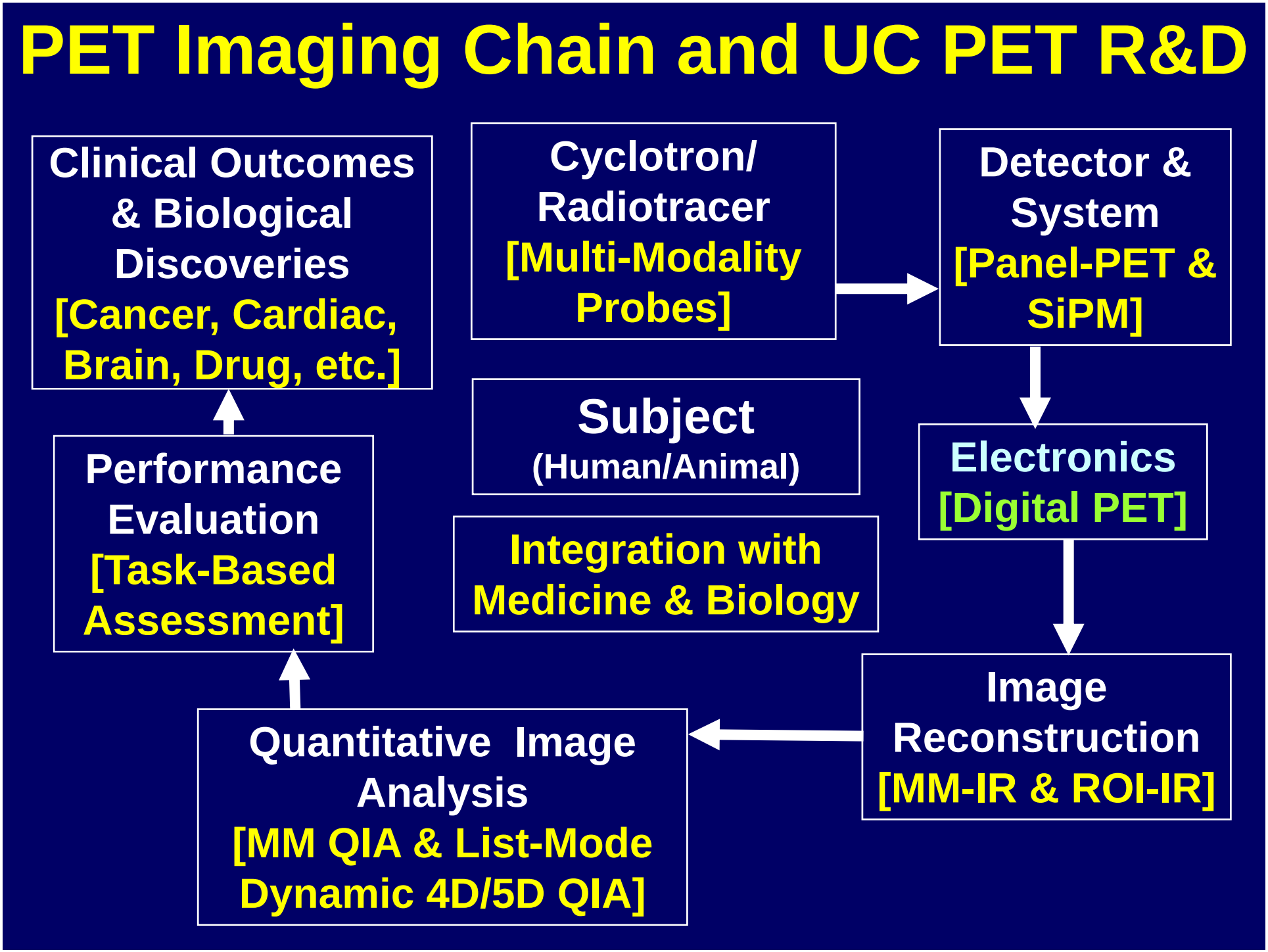


Modeling response

Initial FDG-Rat Images

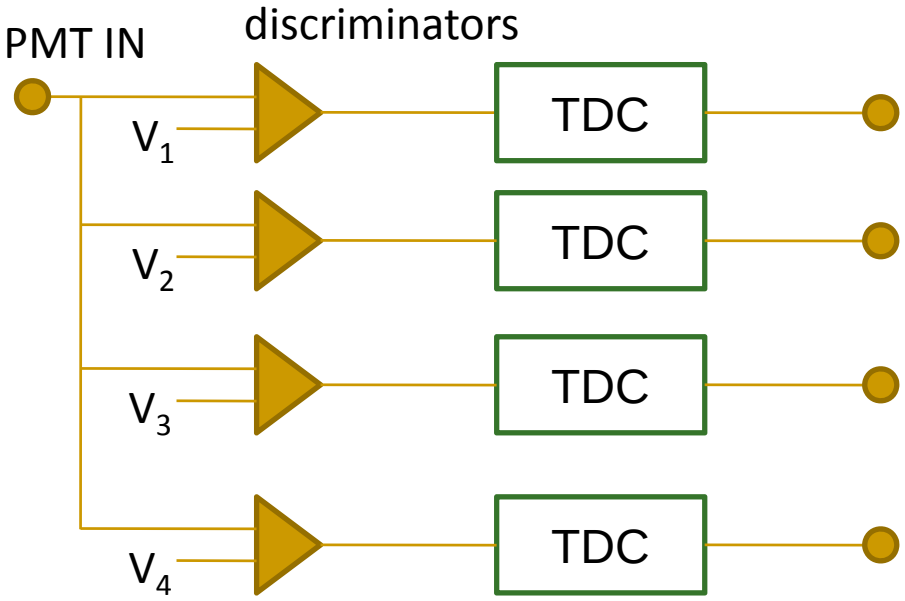


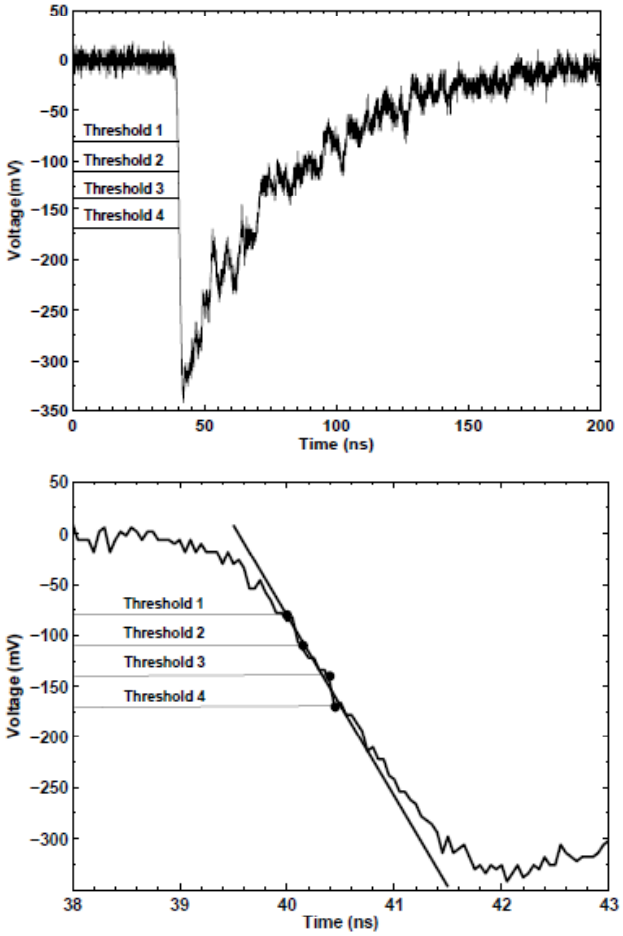
PET Imaging Chain and UC PET R&D



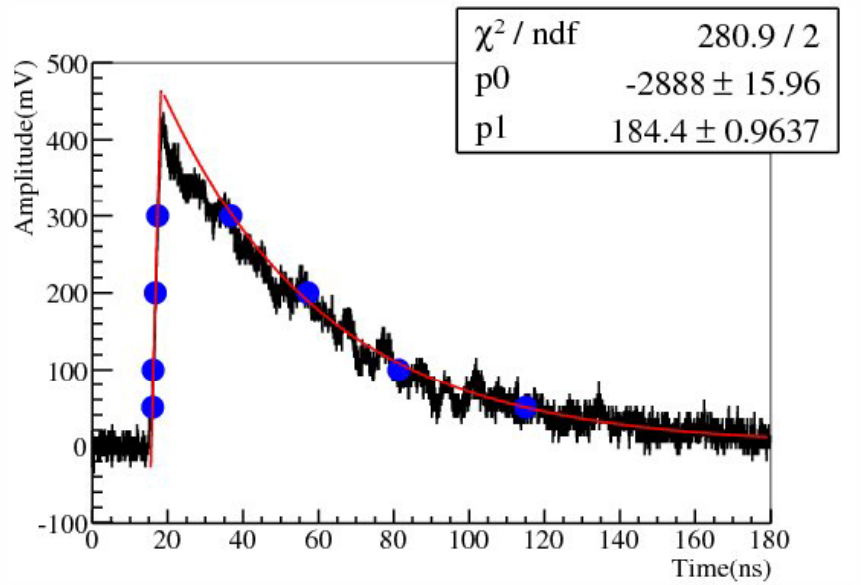
Digital PET Data Acquisition

A Multi-Threshold Approach





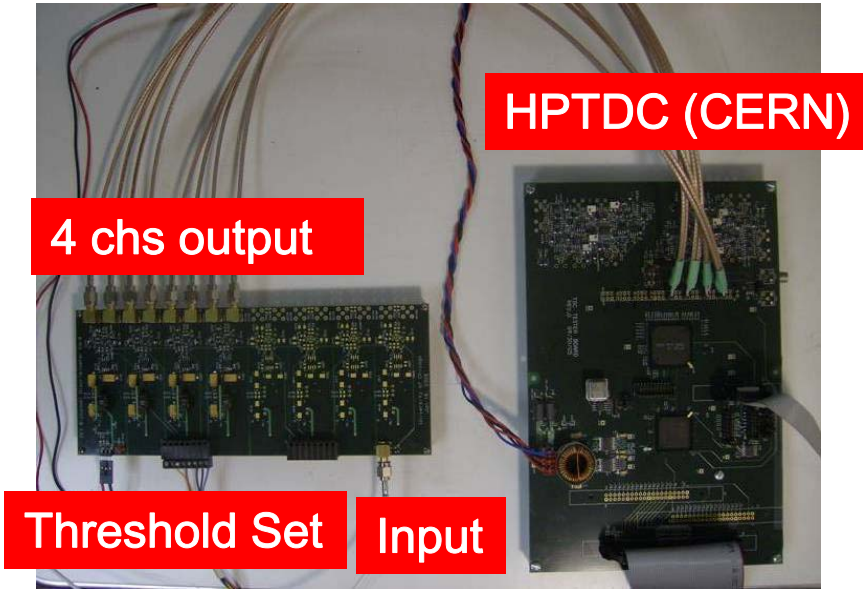
Multi-Threshold Approach



PMT waveform by 20GS/s oscilloscope superimposed with timing readouts by the multi-threshold board + HPTDC

- Sampling pulse at pre-defined voltage levels.
- Output : only digitized timings.
- Pulse reconstruction using digitized timings.
- Remove analog blocks. (Pre-Amp, ADC, CFD)
- Digital Signal Processing (DSP) technology can be utilized. (event time, energy)

Multi-Threshold Board + HPTDC



Multi-threshold board (left)
connected to HPTDC module (right).

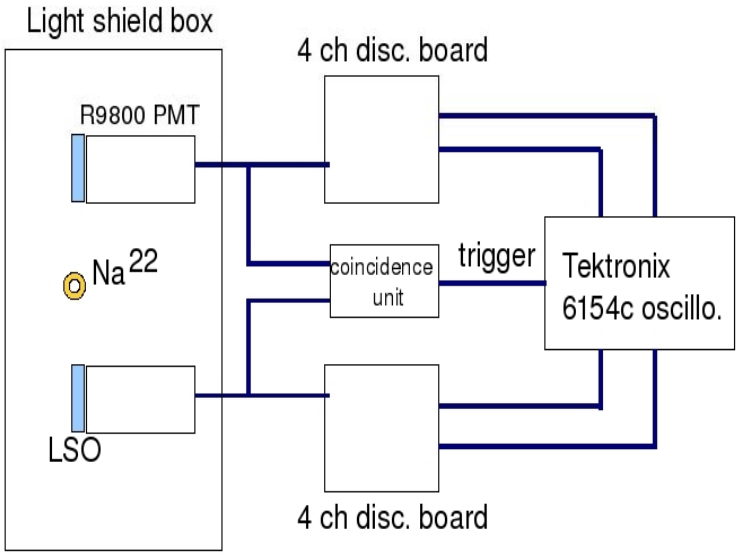
Multi-threshold discriminator board

- 2 boards with 4channels in each.
- 0-700mV of adjustable threshold level.
- Used ADCMP582 comparators.
- Timings at leading and falling edges.

High Performance TDC (HPTDC)

8/32 channels.
25 ps/bit.
developed at CERN.

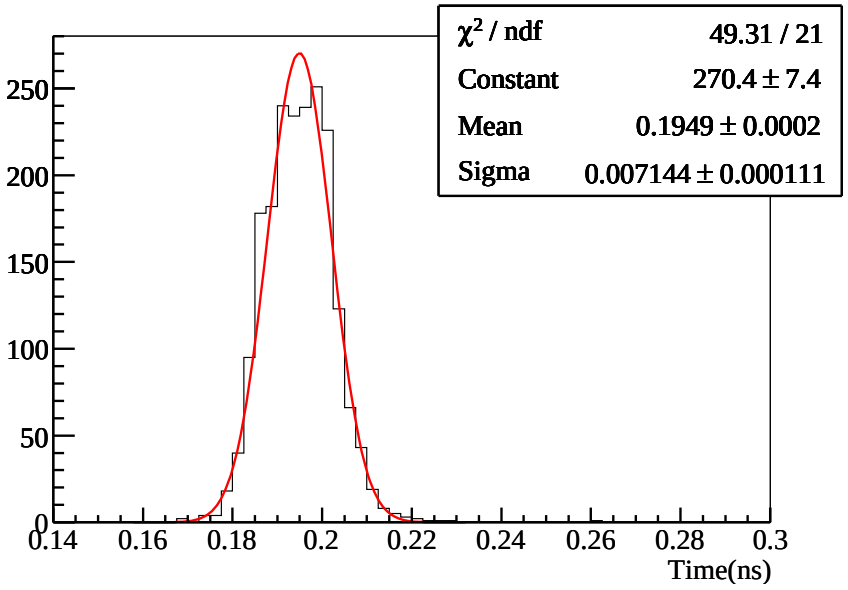
Experimental Setup



A Block diagram of the setup.

- Two Hamamatsu R9800 photomultiplier tubes (HV = -1,300V)
- Coupled with LSO crystals (6.25x6.25x25mm3).
- Separated 5cm apart.
- Na-22 used for positron source located at the center.
- Multi-threshold discriminator board setup:
  - Inputs from 2 PMT signals
  - Thresholds : 50, 100, 200, 300mV
- Timing Readout :
  - TDS6154 oscilloscope20GS/s. (Tektronix)
  - HPTDC. (8chs, 25 ps/bit, developed at CERN)

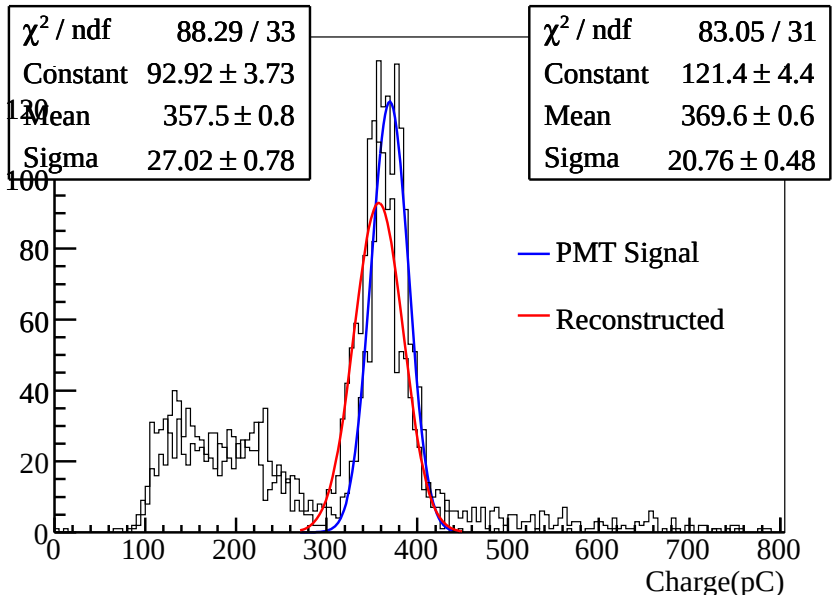
Time Resolution of Discriminator



Time offset between two channels of the Multi-threshold discriminator.

- Sent pulse generator signals to two channels.
- Measured time difference with the TDS6154 oscilloscope.
- Time resolution of single channel : ~13.3ps(FWHM)

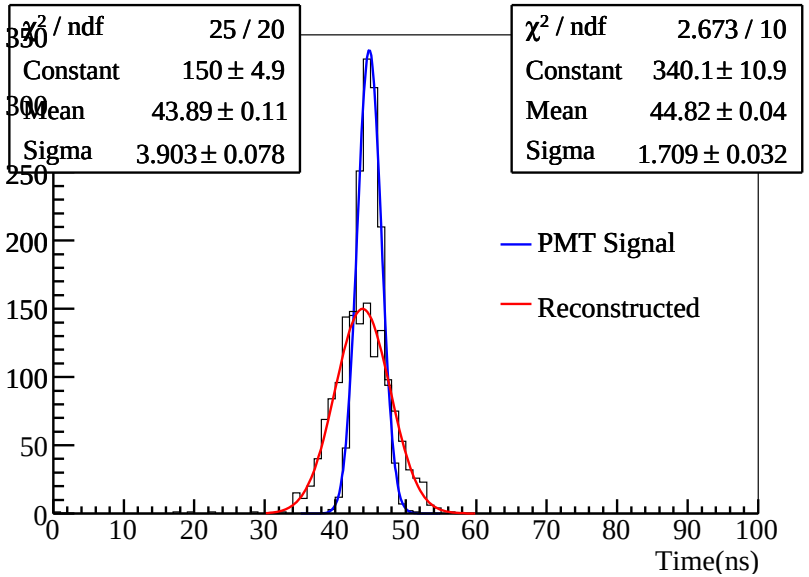
Pulse Reconstruction (HPTDC)



Energy distribution of 511keV gamma.

- Select the gamma coincidence events. events with 2, 3 and 4 hits from each board.
- Reconstructed pulse shape.
- Linear fit on the leading edge. (event time).
- Exponential fit on the falling edge. (energy, decay constant)

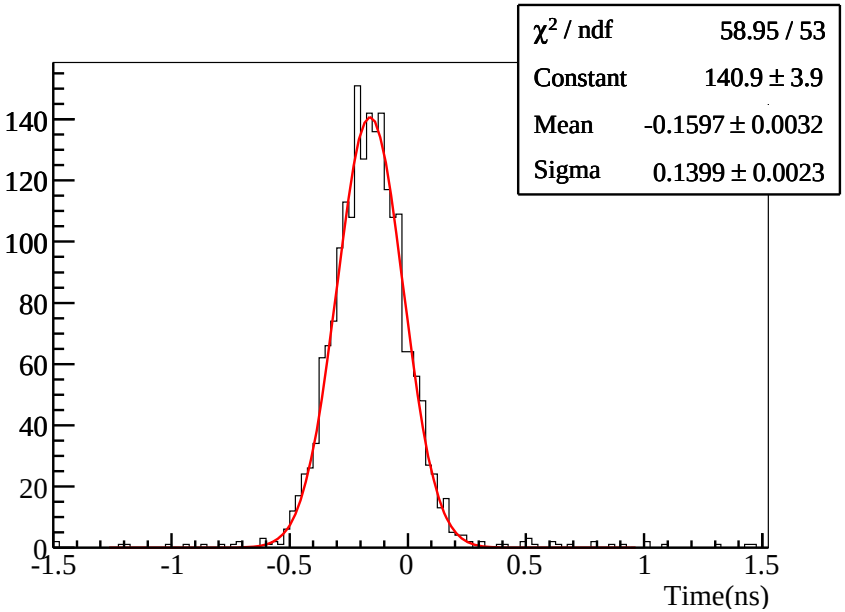
Pulse Recontstruction - 2



	20GS waveform	Multi-threshold
Energy resolution	13%(FWHM)	18%
Decay constant	45ns (4ns width)	44ns (9ns width)

The decay time constant.

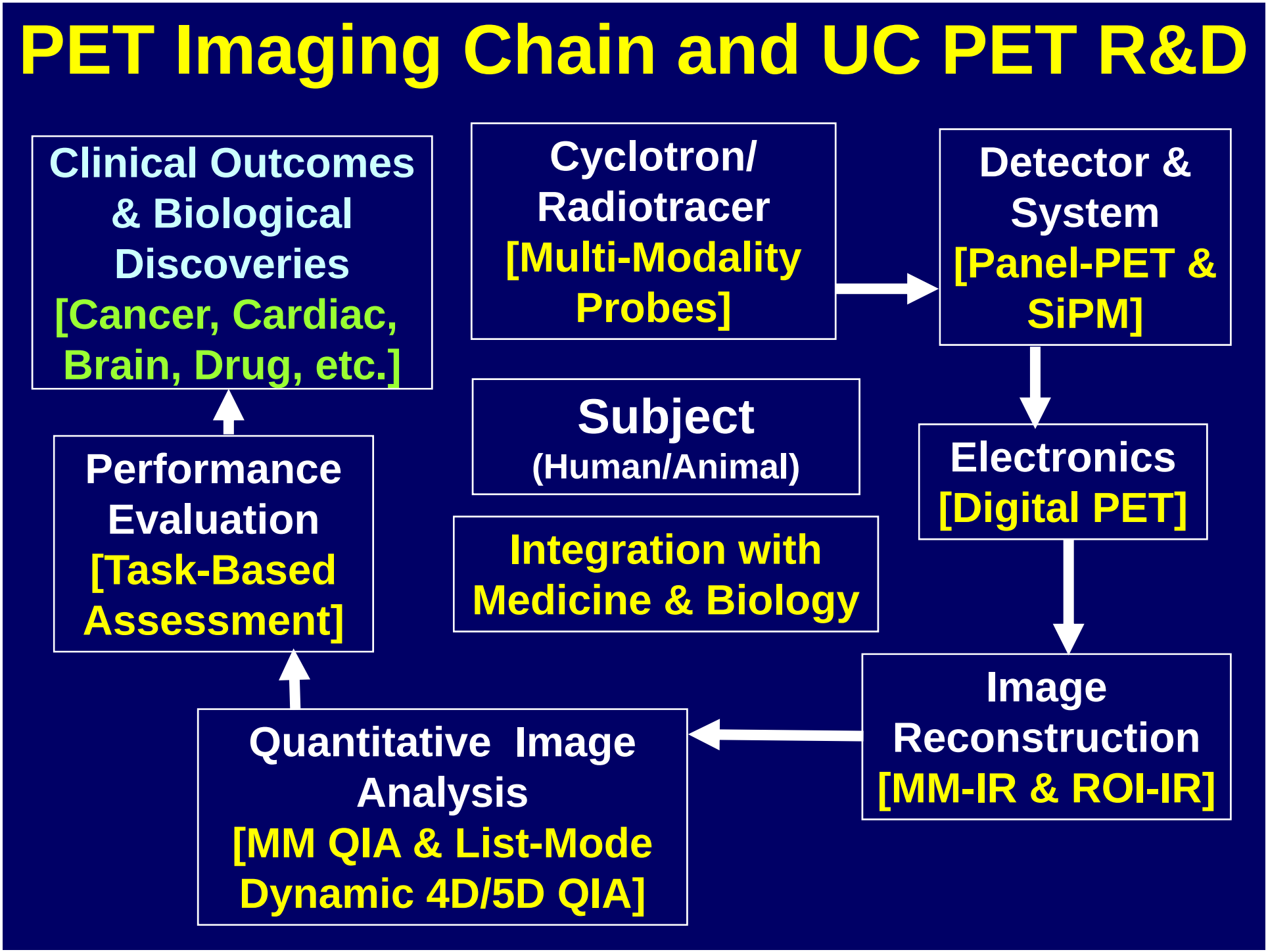
Coincidence Timing Resolution



Time difference of 511keV gamma coincidence events

- Select the coincidence events.
- Least square fit to the leading edge timings.
- Use two leading edges with100, 200mV thresholds.
- Extrapolated at 0mV.
- The time difference, t1-t2. (FWHM)
  Oscilloscope : 330ps
  HPTDC : 350ps

PET Imaging Chain and UC PET R&D



Motor Activity Study (Stroke)

Motor Activity Studies