SPECT:
Current Status, Future Directions

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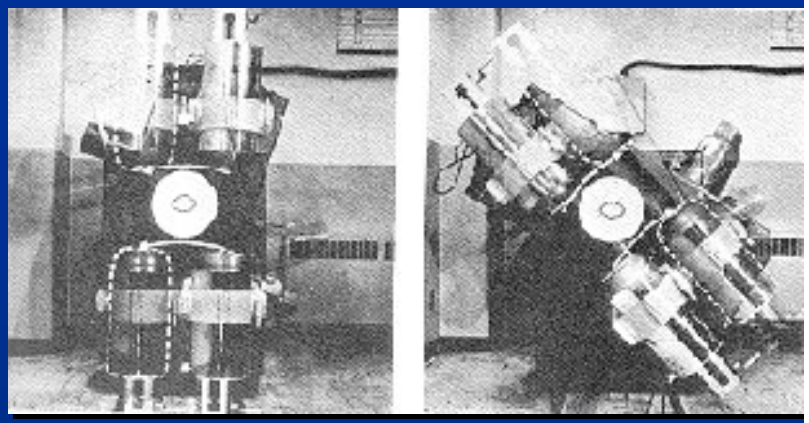
Outline

- instrumentation
- reconstruction
- quantitative corrections
- opportunities for development

SPECT: historical background



1959 - The world's first transverse section emission tomographic image was obtained by David Kuhl and Roy Edwards

1963 - Kuhl and Edwards developed an emission tomography system which became the precursor to SPECT

1973 - publication on Aberdeen section scanner

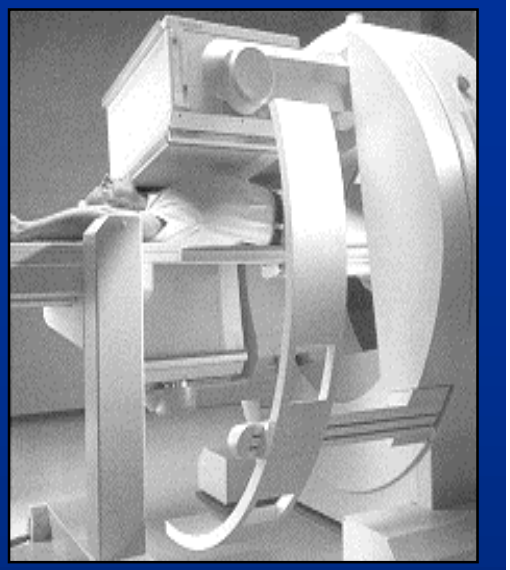
1976 - first gamma camera SPECT system introduced by Keyes

1983 - commercial gamma camera SPECT introduced

……

2003 - attenuation corrected SPECT using iterative reconstruction

SPECT:
current standard practice (basic!)

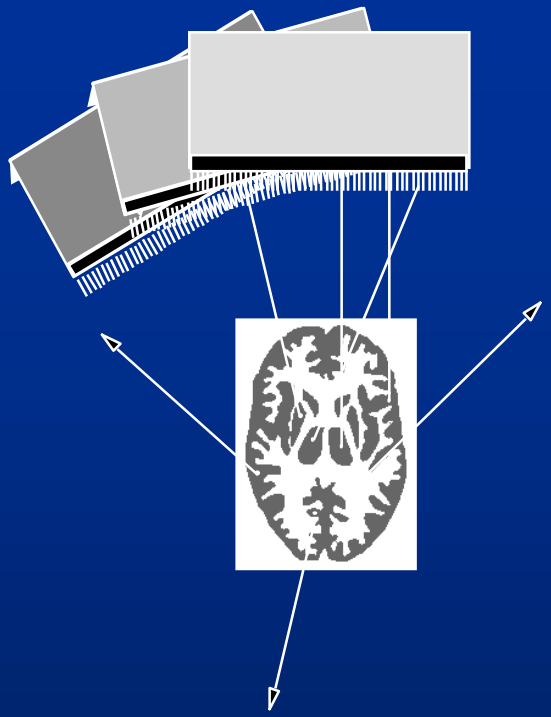


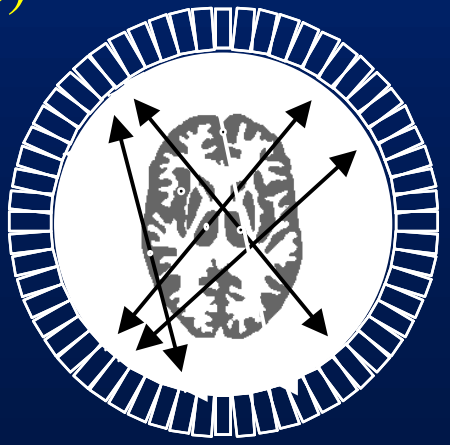
- dual head acquisition
- filtered back projection
- gated cardiac acquisition
- dynamic acquisition (never)
- Chang attenuation correction (sometimes)
- measured transmission (available at few sites)
- iterative reconstruction (available but underutilised)
- scatter correction (limited use)
- motion correction (available but crude!)
- resolution compensation (not usually available)
- partial volume correction (what's this?)

SPECT:
how different is it from PET?

- similar resolution possible
- lower attenuation
- less attenuation correction artefacts
- less scatter (compared to 3D PET)
- lower radiation dose
- more convenient radionuclides (longer half life)
- less expensive
- similar reconstruction methods
- LOWER SENSITIVITY
- more noise, longer acquisition... etc.

see: Bailey, Eur J nucl Med, 2003; 30: 1046-1049.





Instrumentation

old ideas being brought to reality

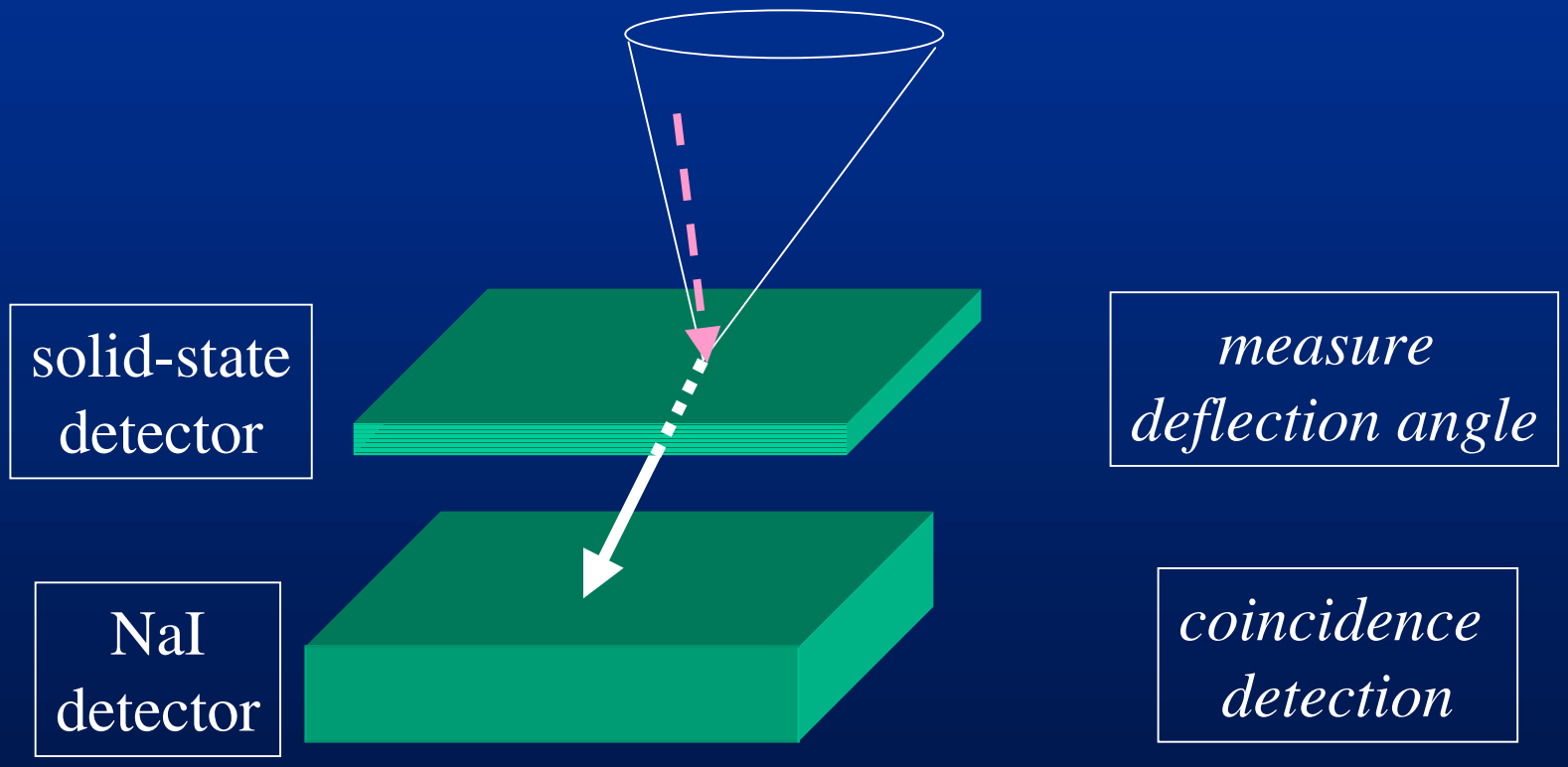
High resolution small animal systems
- dedicated systems with small detectors
- pinhole tomography
- coded aperture imaging

Application specific systems
- dedicated breast imaging
- high resolution brain SPECT

High sensitivity systems
- rotating slat collimator
- Compton camera

Instrumentation: Compton camera

replaces collimator with solid state detector (high energy resn)



potential sensitivity gain of 20 (Univ of Michigan)

Instrumentation:

Limitations in what the suppliers provide

- transmission measurement (reliability)
- dynamic SPECT (some capability)
- multiple energy windows (supplier dependent)
- dynamic projections
- listmode acquisition
- respiratory gating
- alternative collimators (e.g. pinhole)
- hybrid systems (i.e. CT)

- variation in implementation
- lack of verification tools
- concern regarding cross-comparison

Reconstruction

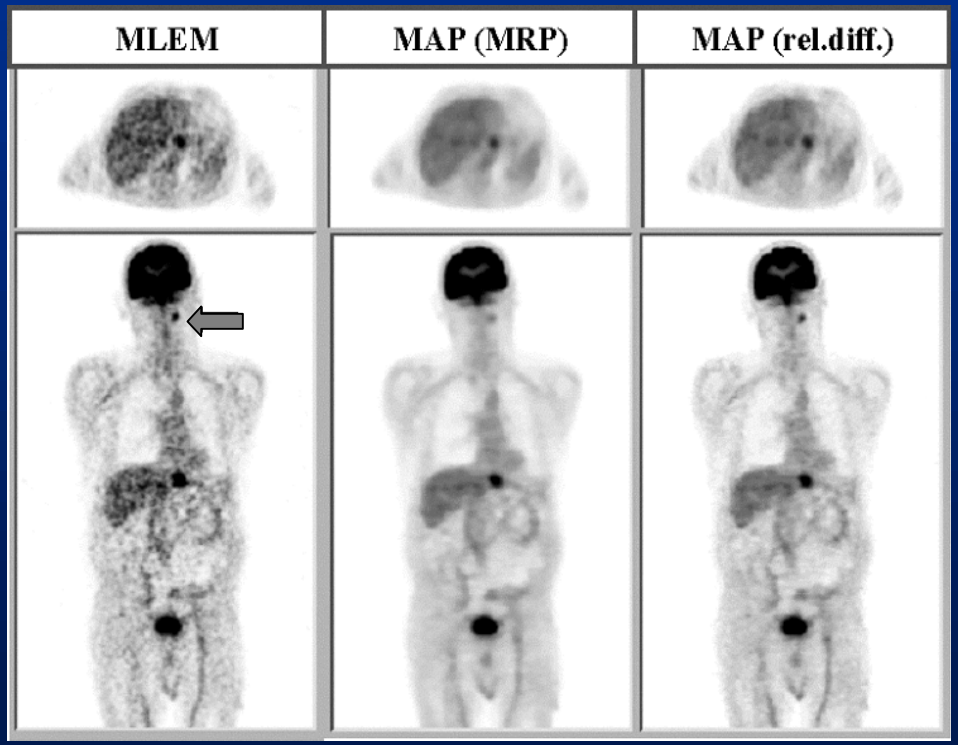
Poor understanding of when to use iterative methods

what is effect?

- contrast
- noise appearance
- lesion detectability
- quantitative accuracy

new initiatives

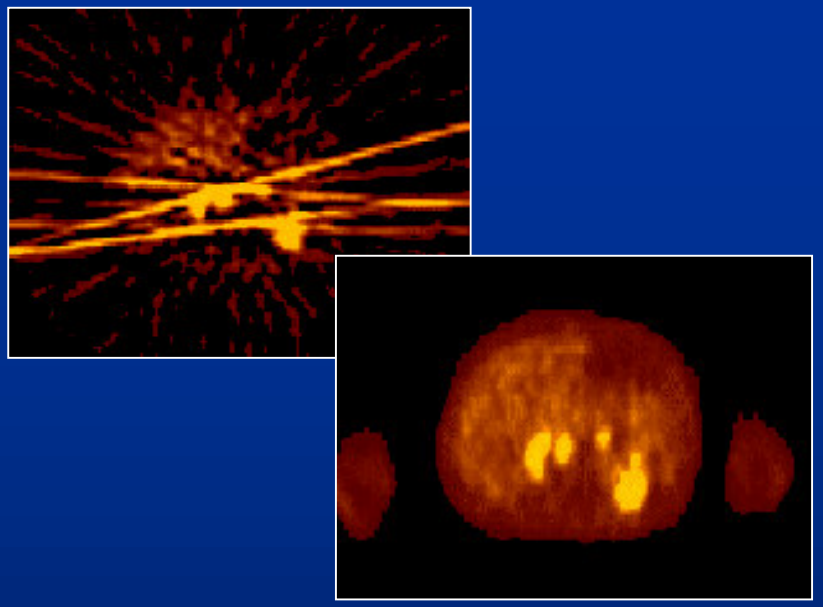
- novel geometry
- approaches to noise
- 3D and 4D models
- Monte Carlo



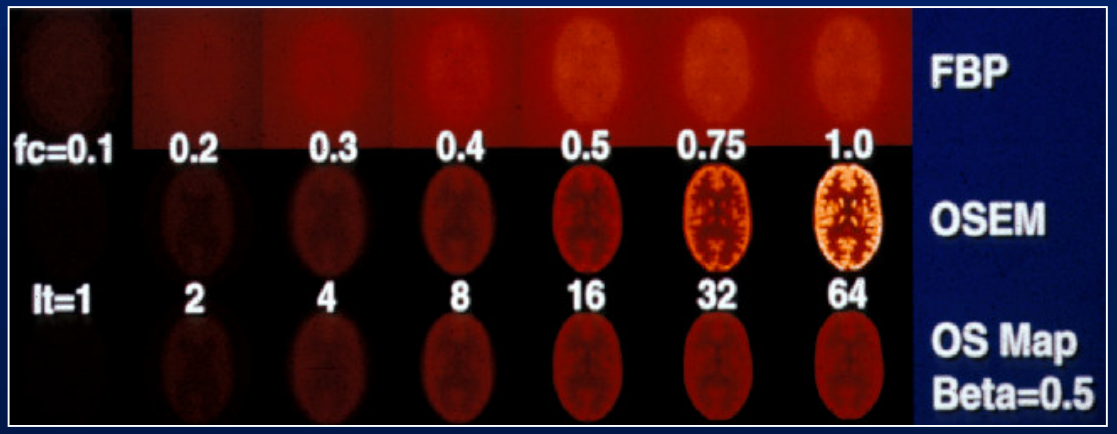
Hutton, Nuyts, Zaidi: 2003

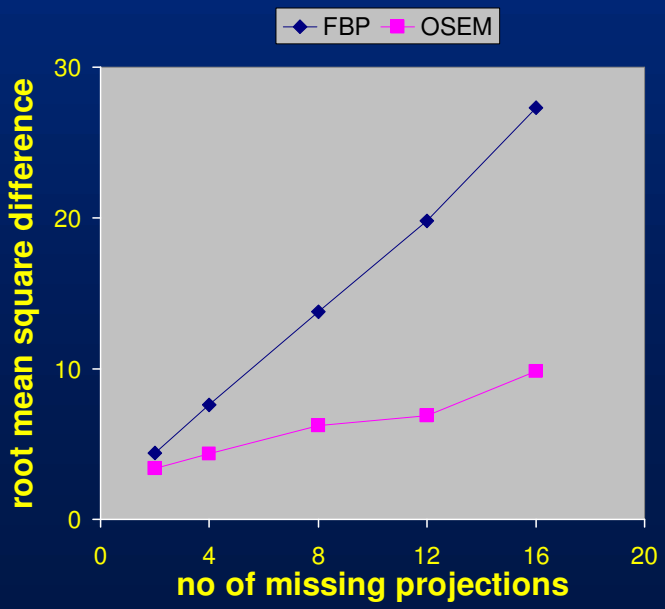
Reconstruction: OSEM

Available, fast and useful



- attenuation correction
- noise reduction (background)
- streak removal
- handles missing data
- flexible (attenuation, motion etc)

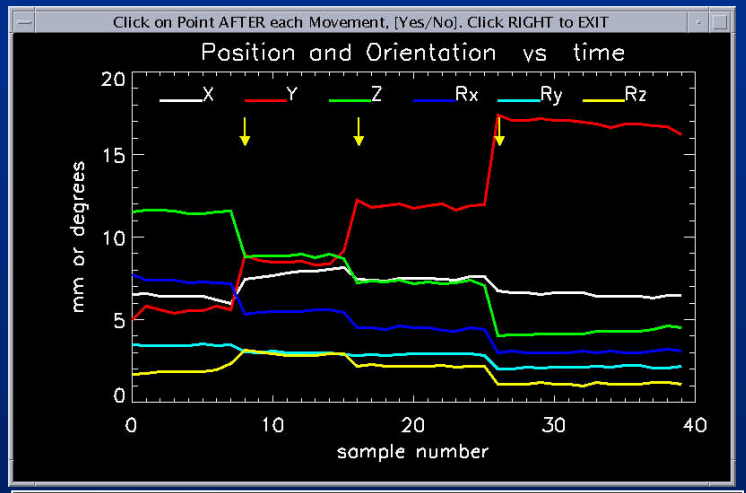


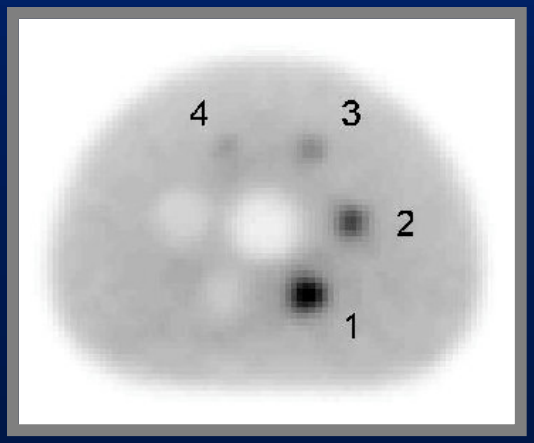


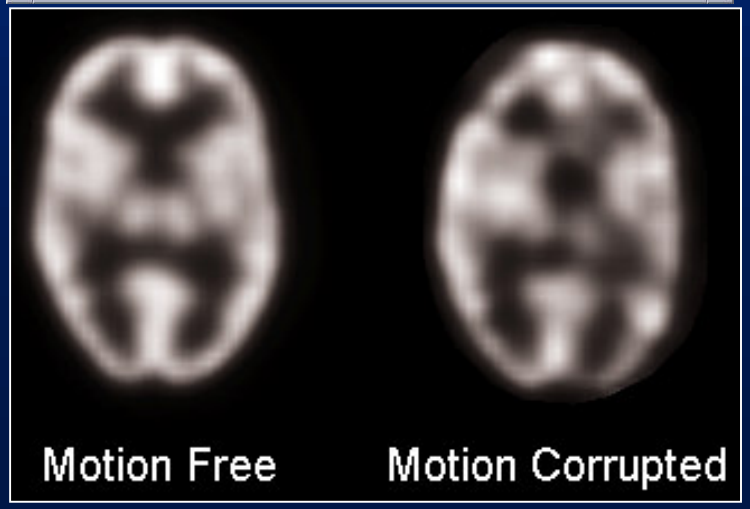
Corrections

Need better understanding of importance

- attenuation correction
- scatter correction
- resolution compensation
- partial volume correction
- motion correction

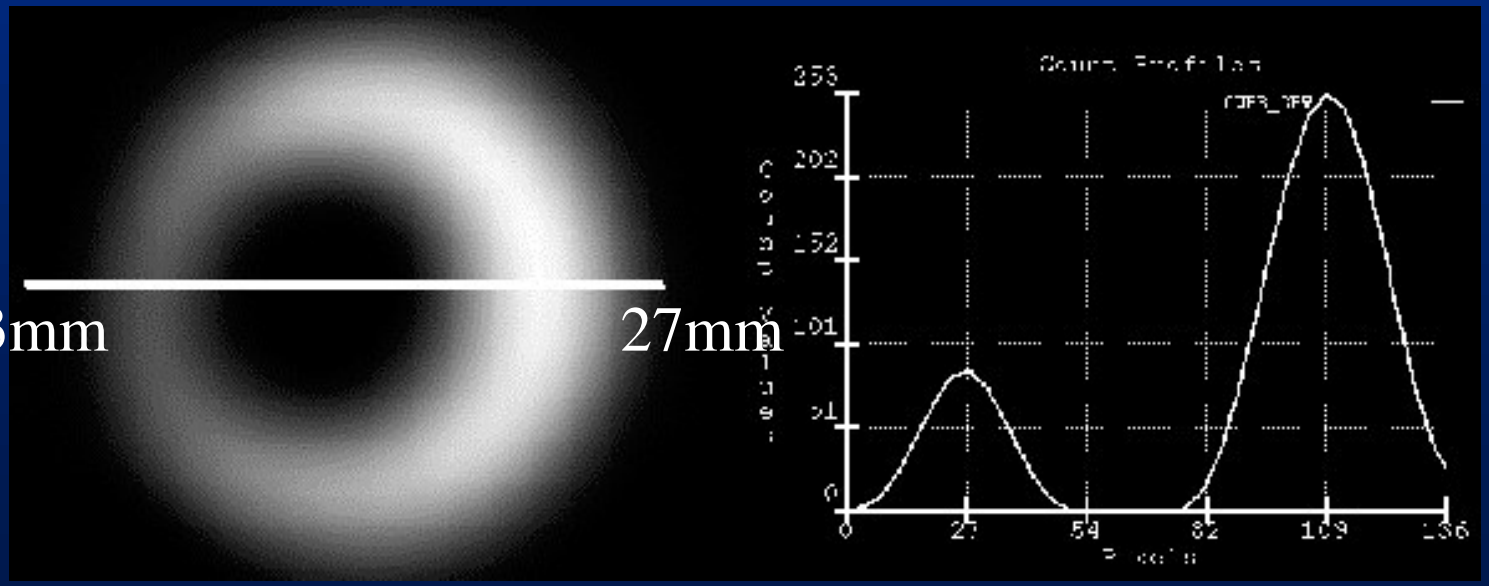


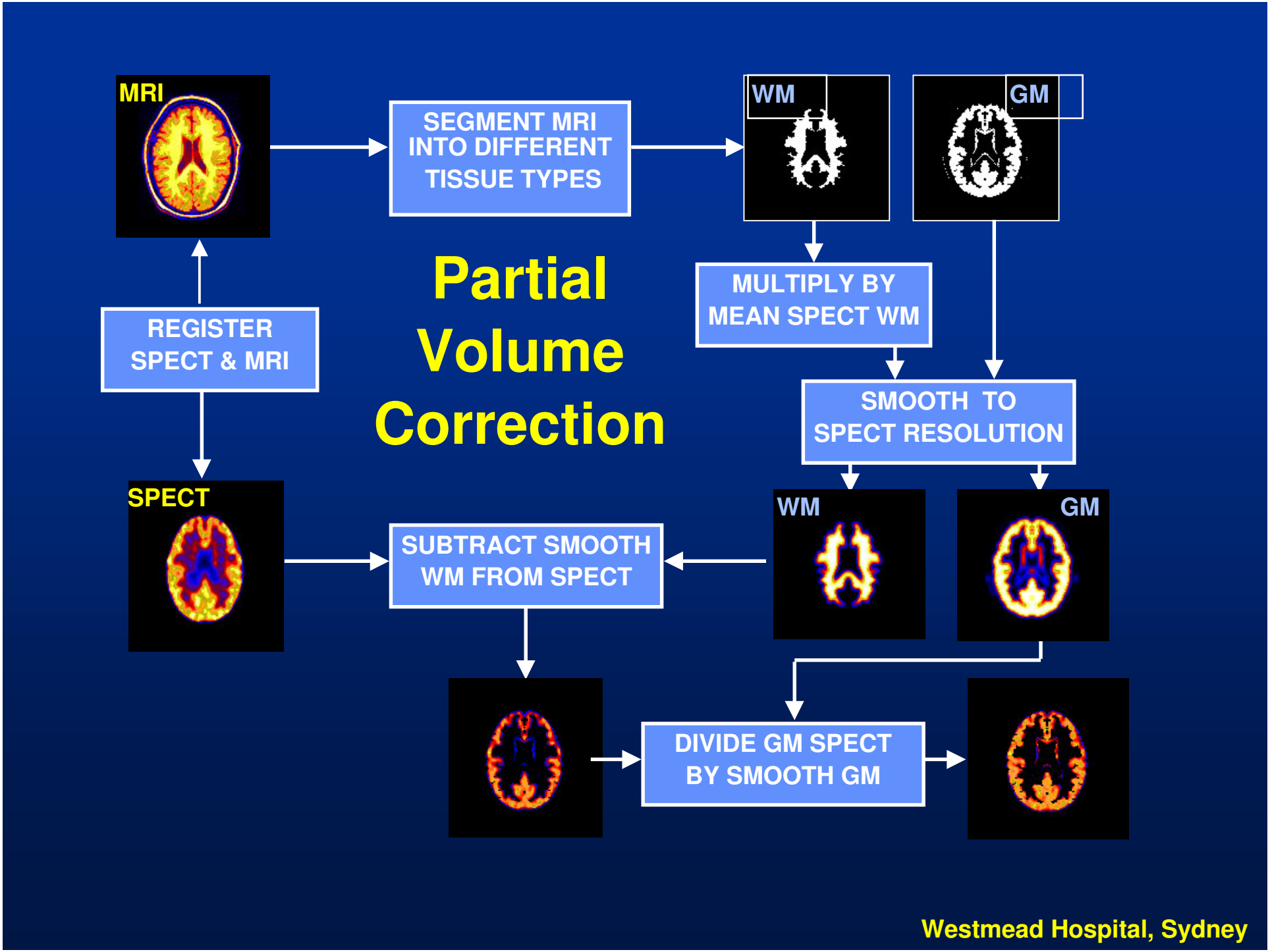




‘Partial volume’ effect

- difficult to identify
- usually not possible to distinguish count reduction from change in wall thickness

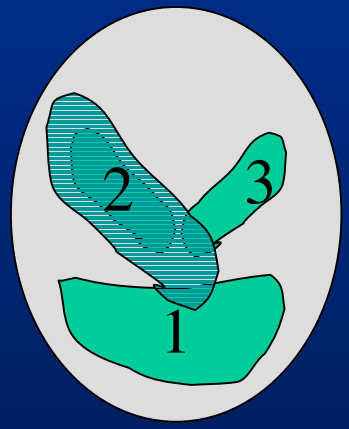



MRI
SEGMENT MRI INTO DIFFERENT TISSUE TYPES
WM
GM
Partial Volume Correction
MULTIPLY BY MEAN SPECT WM
REGISTER SPECT & MRI
SMOOTH TO SPECT RESOLUTION
SPECT
WM
GM
SUBTRACT SMOOTH WM FROM SPECT
DIVIDE GM SPECT BY SMOOTH GM
Westmead Hospital, Sydney

Region-based 'geometric transfer matrix'

(Rousset 1998)

- segment anatomical regions for structures or tissues
- smooth regions to match emission resolution
- define contribution of activities in structures to each region (geometric transfer matrix: w_{ij})
- solve for activity in each region (T_i), given measurement (t_j)



$$t_j = \sum_i w_{ij} T_i$$

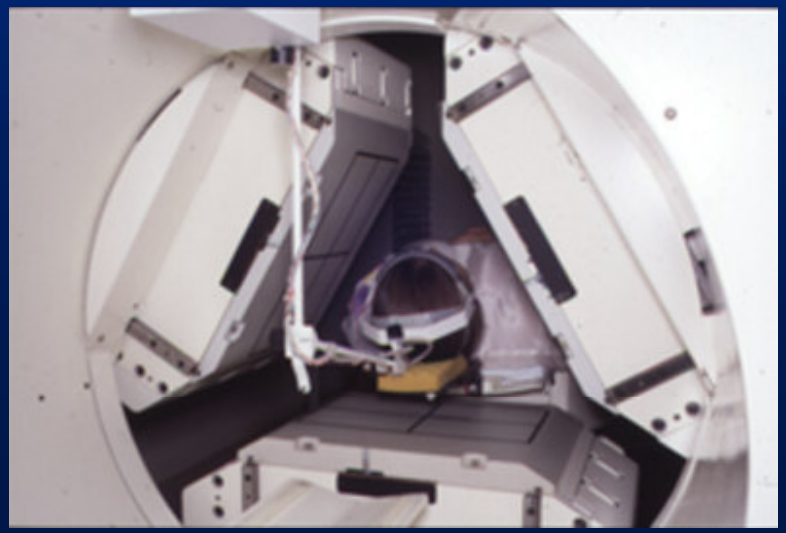
w_{ij}

region (j) \ structure (i)		
0.8	0.1	0.1
0.05	***0.65***	0.1
0.05	0.1	***0.65***

diagonal: RC; other: spillover

Motion measurement

- external markers
- video camera
- electro-mechanical device
- electro-magnetic device
- opto-electronic device (polaris)
- data-driven



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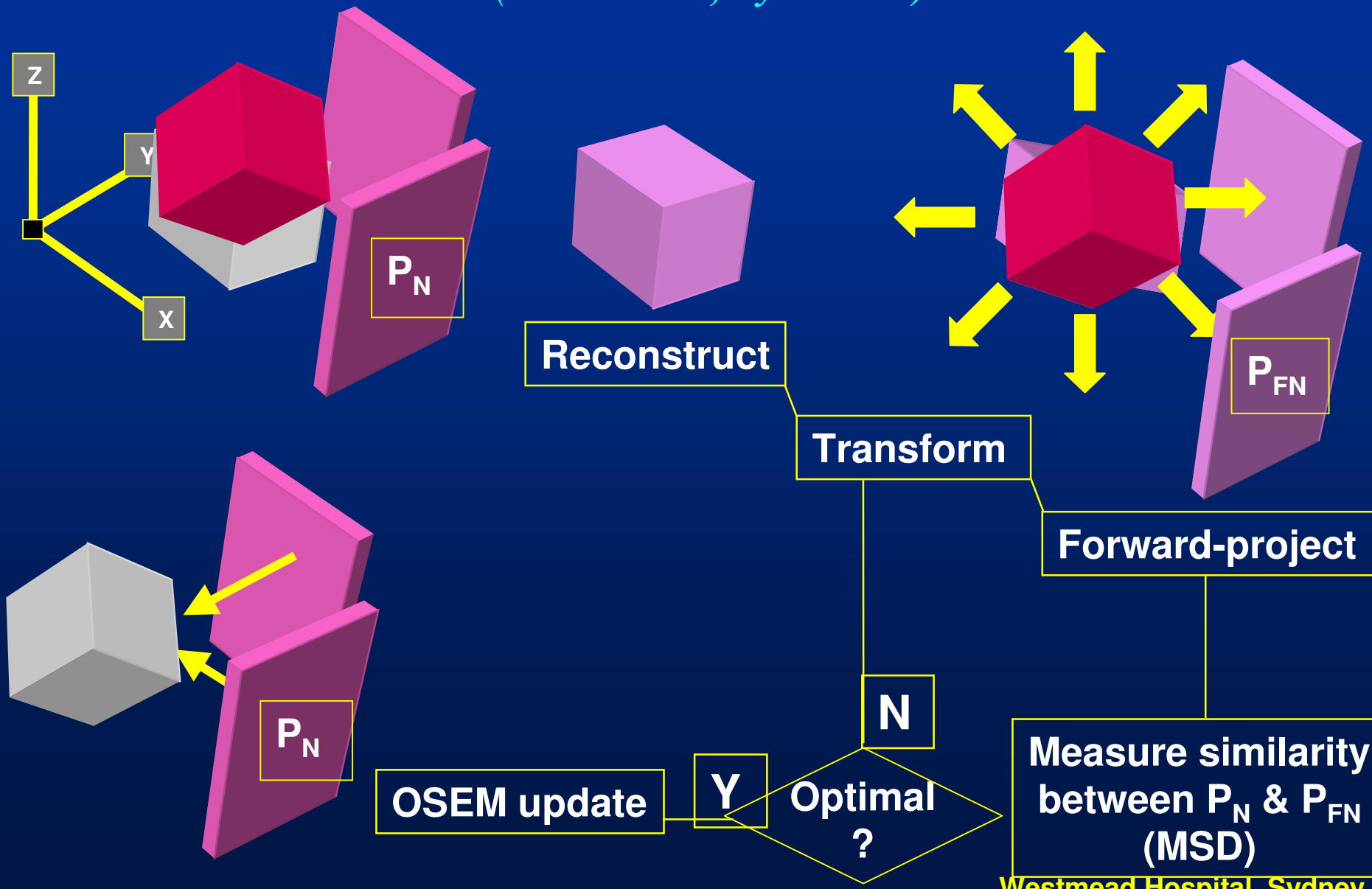
Data-Driven Motion Correction

(Hutton 2002, Kyme 2003)



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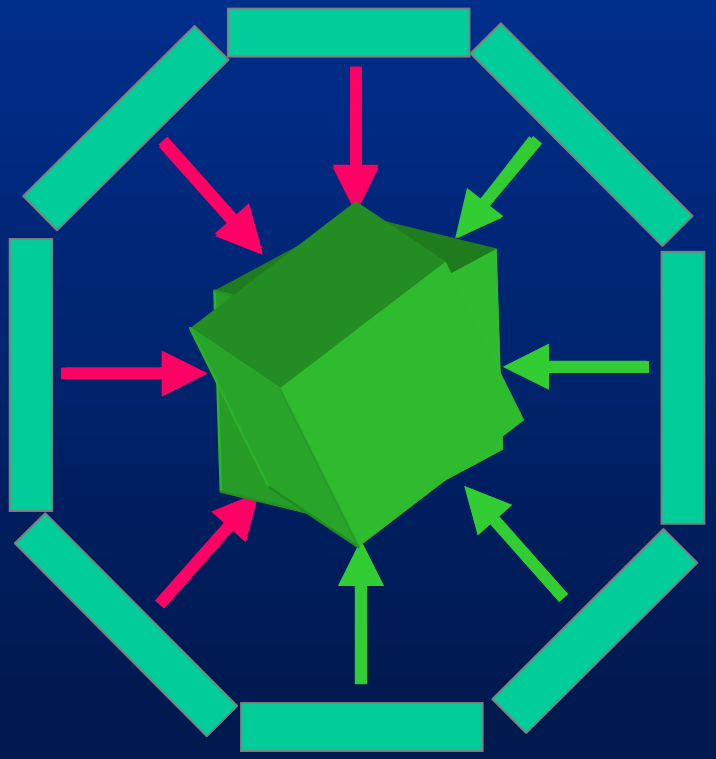
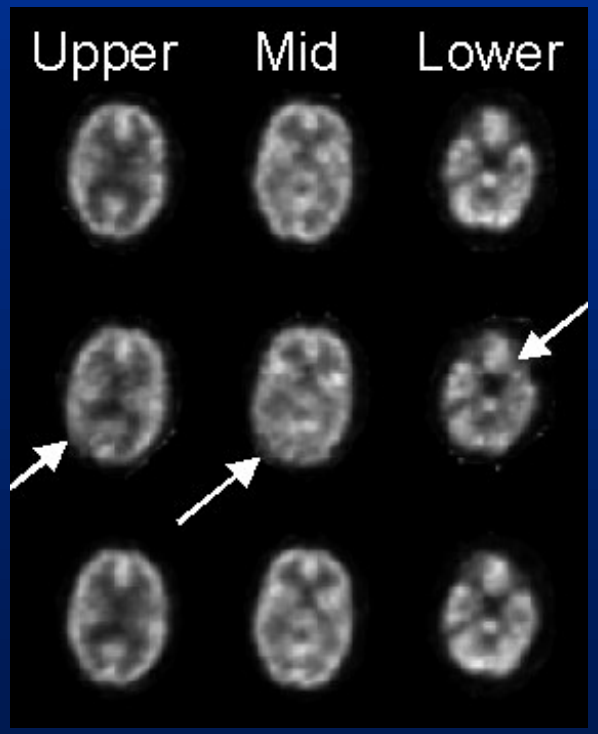
OSEM reconstruction given measured or estimated motion



Subset 1

Subset 2

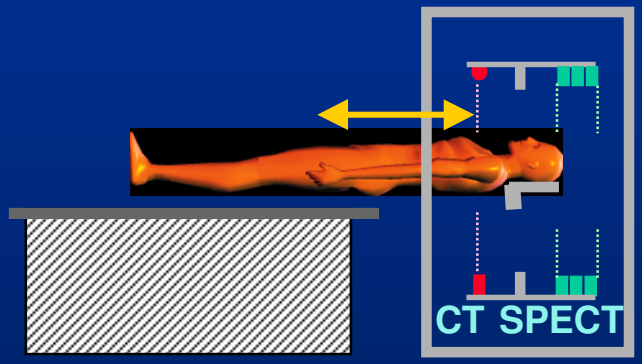


three discrete positions

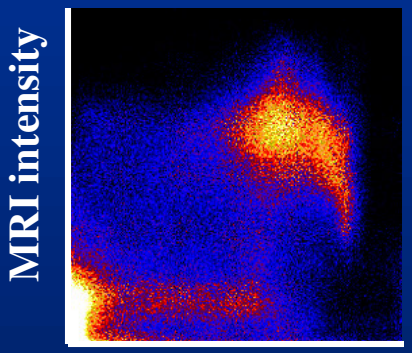
Opportunities for development

Multi-modality imaging as a precursor for advanced analysis

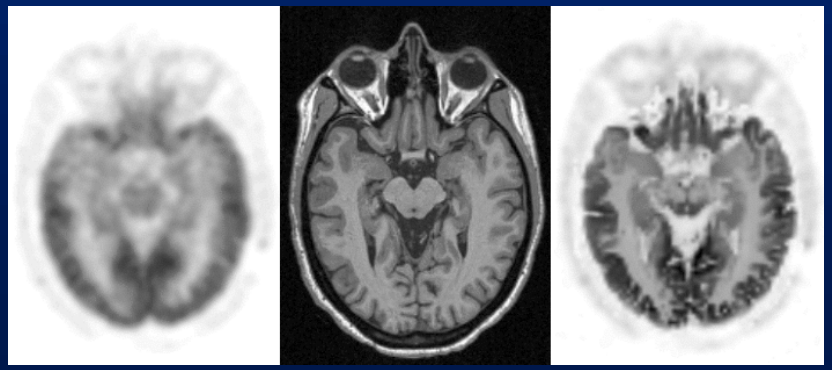
hardware



software

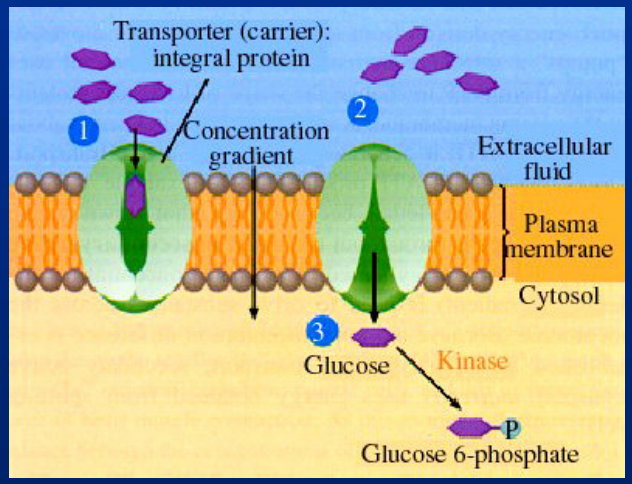


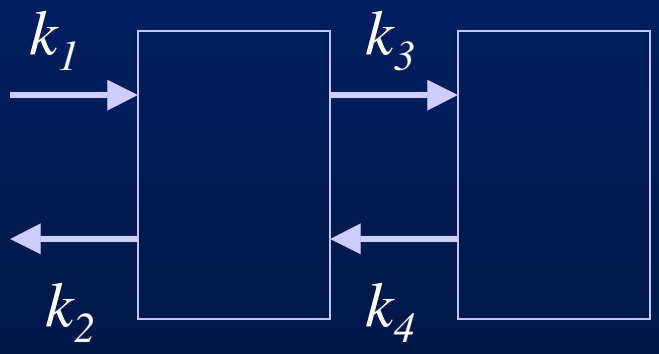
- functional parameter fusion
- partial volume correction
- motion correction
- segmentation and shape analysis
- resolution enhancement



Opportunities for development

Quantification of functional parameters: single photon tracers



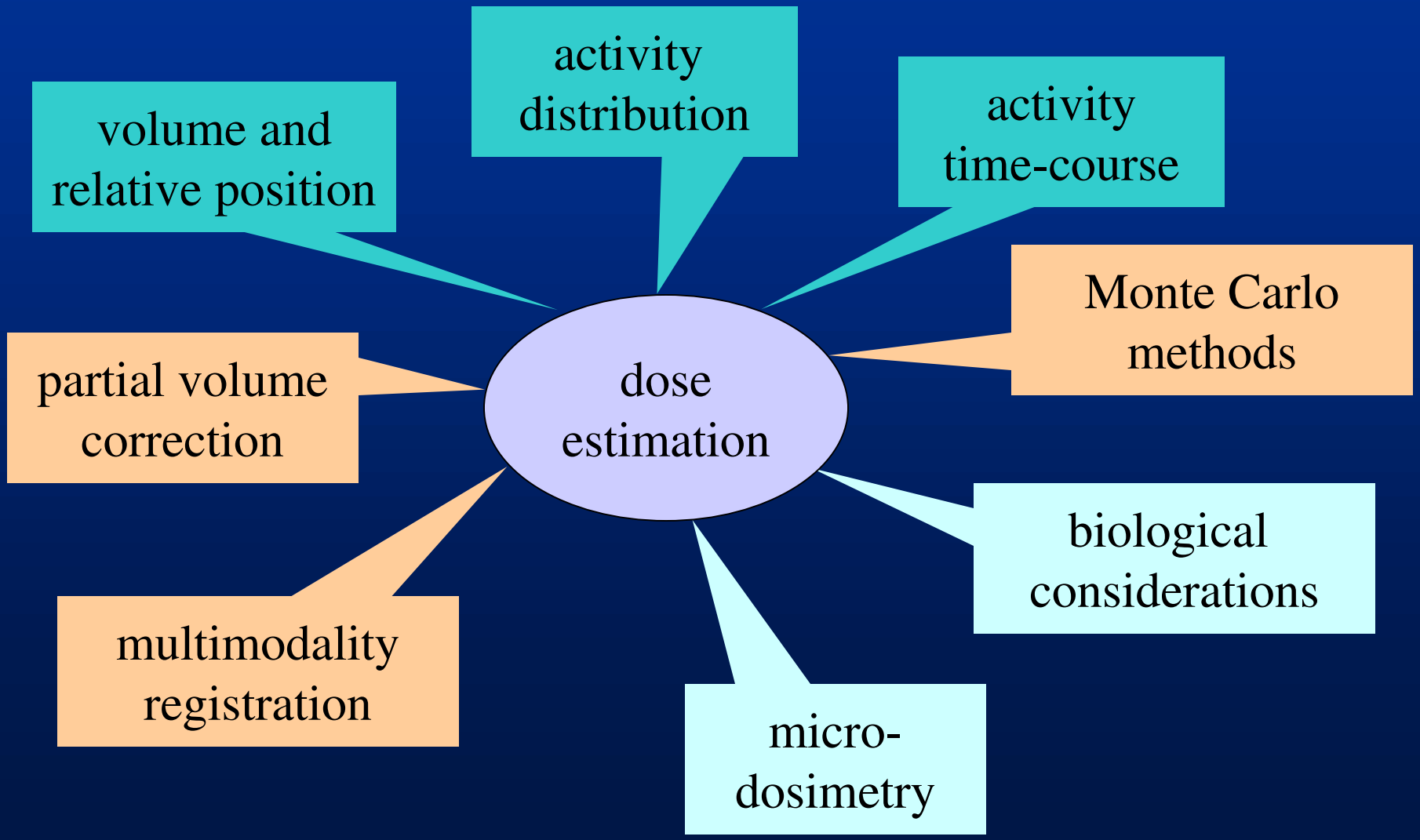


Tracer kinetic models

- simplified ROI parameters
- graphical analysis (e.g. Patlak)
- study decomposition
- compartmental models
- mixture models
- spectral analysis
- dynamic models
- interventional models
- microscopic models

Opportunities for development

Patient specific dosimetry using unsealed sources



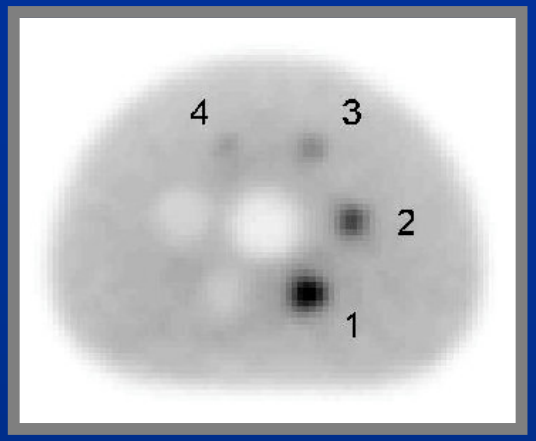
SPECT

Current status: the backbone of Nuclear Medicine
Future directions: quantitative molecular studies

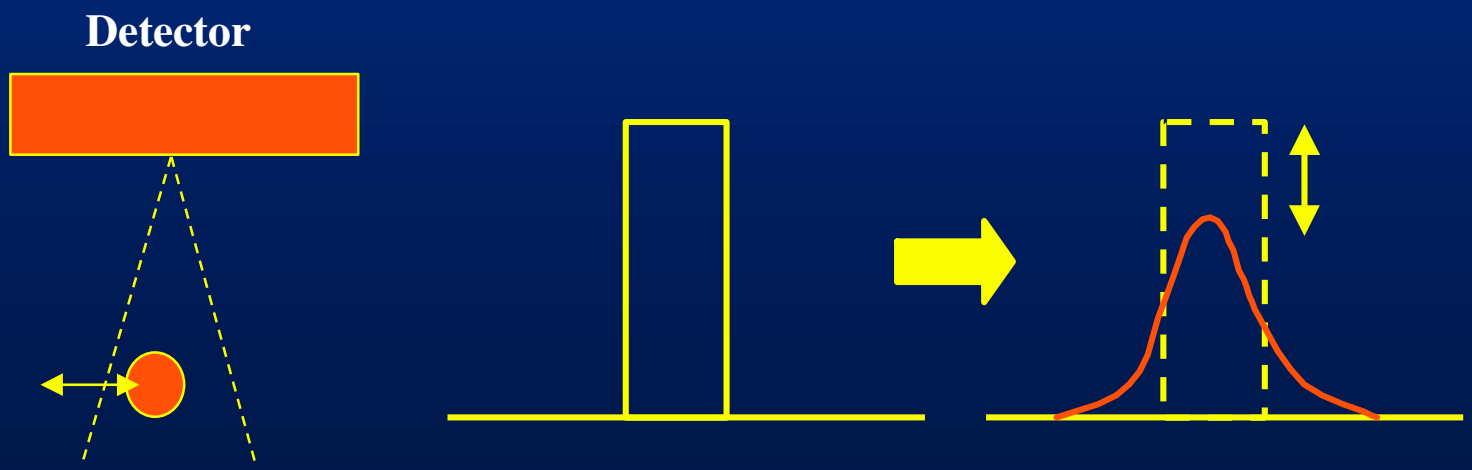
A program of relevant topics

- dynamics and tracer kinetics
- transmission scanning
- industry developments
- new tracers
- small animal systems
- radionuclide therapy planning
- clinical perspective

‘Partial volume’ effect
(limited resolution effect)



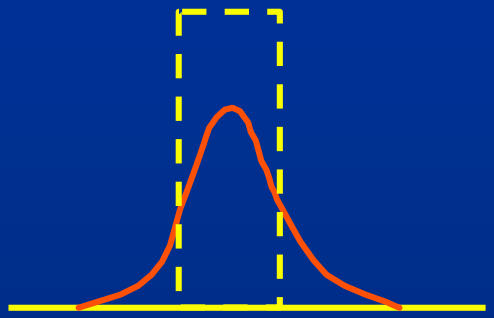
When an object partially occupies the sensitive volume of an imaging instrument (in space or time) the measured signal is reduced in amplitude.



Activity concentration: counts / volume

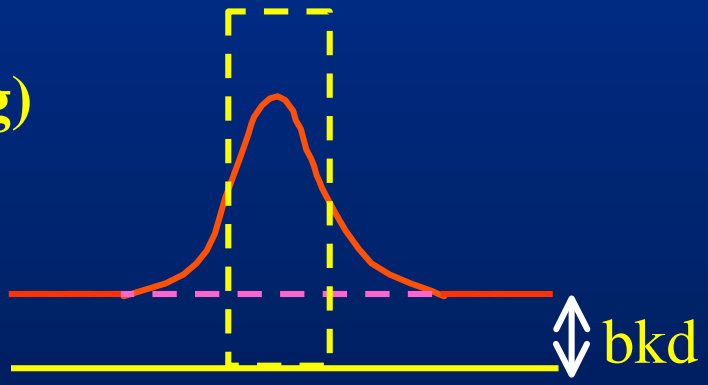
- **no background or adjacent activity**

$$\frac{\text{total counts}}{\text{actual volume}}$$



- **background (e.g. non-specific binding)**

$$\frac{\text{total counts - bkd}}{\text{actual volume}}$$



- **spillover correction (adjacent activity)**

$$\frac{\text{total counts - estimated bkd}}{\text{actual volume}}$$