

MR-based Attenuation Correction for PET

IDP Final Presentation

Loren Schwarz

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Chair for Computer Aided Medical Procedures & Augmented Reality

Department of Computer Science | Technische Universität München

Agenda



**Non-Attenuation
Corrected (NAC)
Emission Scan**

- Introduction
- Previous Work at CAMP
- Objectives for this Project
- Work done in this Project
- Results
- Faced Issues
- Future Work



**Attenuation
Corrected
PET Emission Scan**

Image Source: www.med.harvard.edu/JPNM/chetan/petct/petct_scroll.html

Introduction: PET attenuation correction

CT, MRT: anatomical imaging ↔ PET: functional imaging

- PET Principle:
 - Inject radioactive marker into patient
 - Marker is metabolized by body, e.g. accumulates in cancer tissue
 - Radioactive decay of marker emitting positrons
 - Positron annihilates with electron, resulting in two photons sent out in 180°
 - Detect coincident photons in circular detector ring around patient

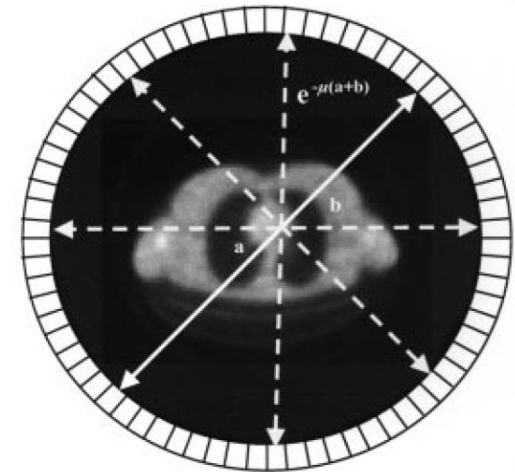


Image Source: [2]

Introduction: PET attenuation correction (II)

Problem: Photons are attenuated and scattered

- Detection of coincident photons at opposite positions is disturbed
- Possible artifacts:
 - One of two photons attenuated:
→ no detection of decay event
 - One of two photons scattered:
→ noise added to image
 - Two photons scattered:
→ possibly added noise

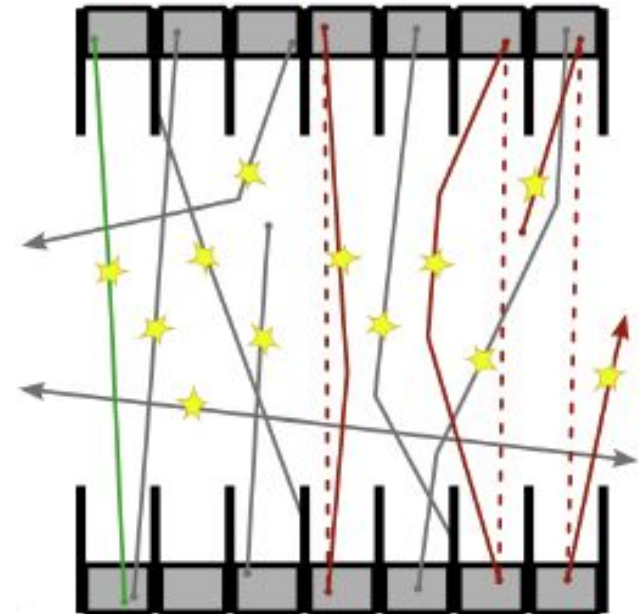


Image Source: IDP Report, Michael Riedel, CAMP 2006

Attenuation effect depends on **tissue types!**

Previous work at CAMP

- **Phantom Experiments**
 - ➔ Getting started with imaging modalities and registration
- **Registration**
 - ➔ Mutual Information most general and powerful
- **Application Development**
 - ➔ “MAPFusion”: framework for PET-MR registration
- **Small Animal Experiments**
 - ➔ Issues with positioning and image quality





Objectives for this Project

- **Acquire small animal data sets:**
 - Quality improvement through new PET and MR scanners?
- **Evaluate different segmentation approaches:**
 - Joint Histogram approach
 - More advanced approaches (e.g. Atlas-based)
- **Implement segmentation-based μ map generation**

Do we really need to distinguish > 2 classes for small animals?

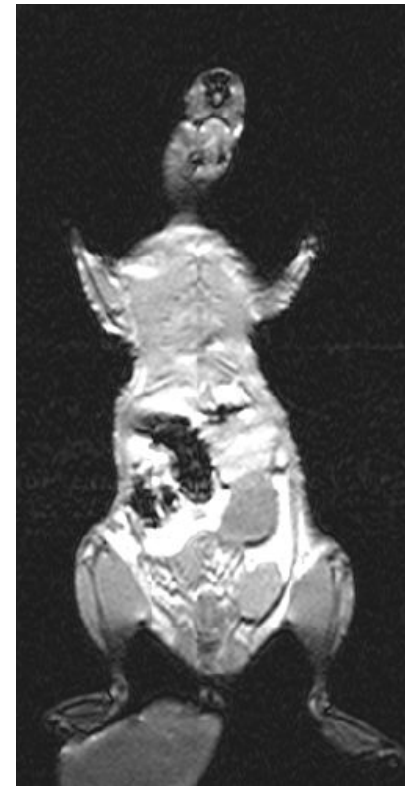
Is a μ map based on just 2 classes really much worse in practice than a more sophisticated one?

Work done in this Project

- **MR scans of mice in several sequences**
 - Evaluation of segmentation approaches 
- **Acquisition of whole mouse PET-CT-MR data set**
 - Uncompleted due to technical issues 
- **Implementation of software module**
 - Binary segmentation and μ map generation for small animal imaging 
- **Work on human clinical data**
 - Comparison of CT-based, MR-based μ maps and transmission scan μ maps 

Results: Small Animal Imaging

- Resolution: 0.2 x 0.2 x 0.2 cm
- T1: Best soft tissue contrast, bone hardly visible
- T2*: Bone structures visible as tiny dark structures
- Small Animal coil vs. Human hand coil:
Hardly any quality difference
- Duration per scan: 25-30 min



T1



T2*

Results: μ map Generation

Segmentation of 3 classes (air, tissue, bone):

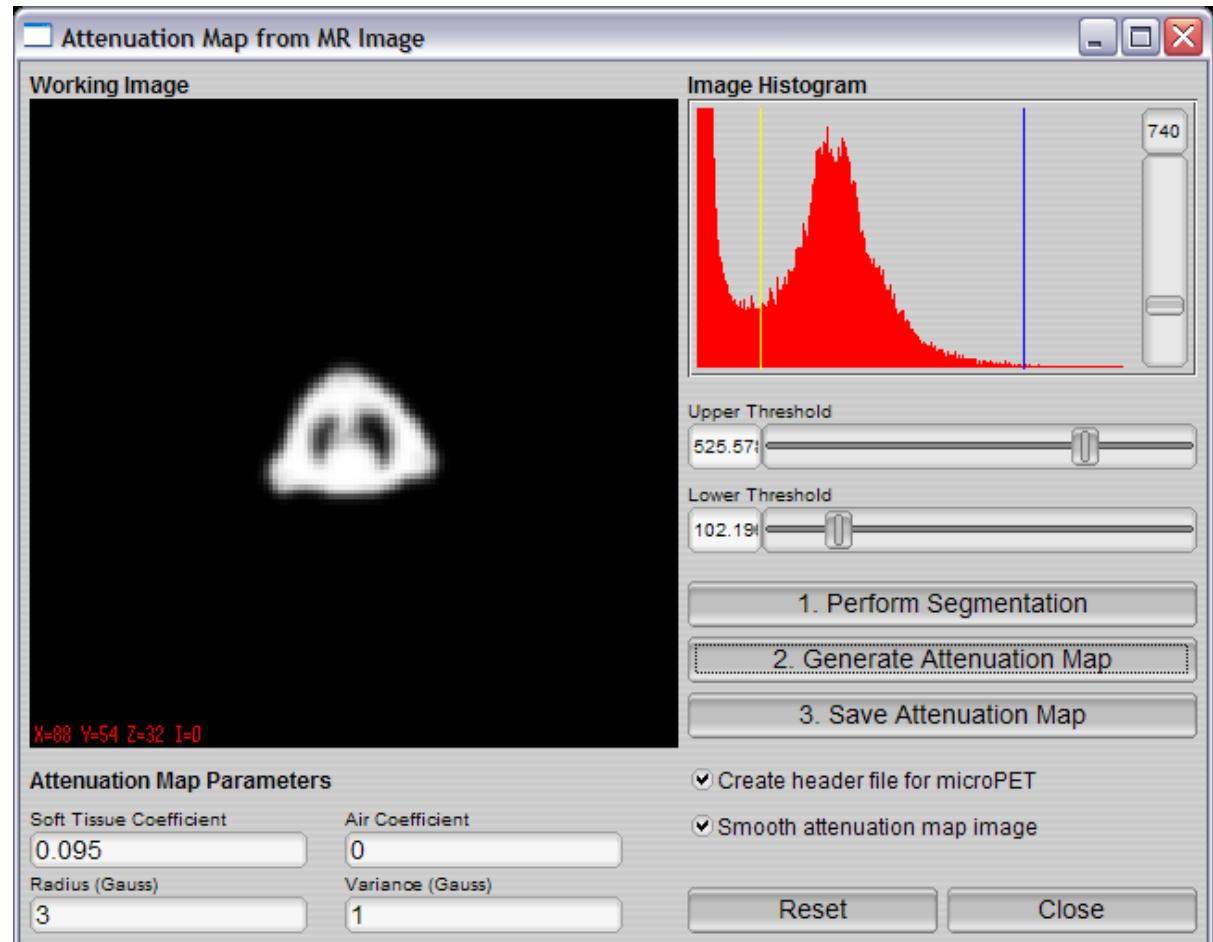
- Structures too tiny for automatic segmentation, e.g. region growing
- Intensity variation between different MR sequences too large
- Joint Histogram approach:
hardly feasible to scan multiple sequences
at necessary resolution due to time constraints

Segmentation of 2 classes (air, mouse):

- Simple binary thresholding
- Assign pre-defined attenuation coefficients to air, tissue
- Sufficient for small animal imaging

Results: Software Module

- Integrated into „MAPFusion“
- Applied to MR image after registration to PET
- Allows parameter adjustment
- Attenuation map export for microPET



Results: Human clinical data

2 existing human data sets:

- Whole-body MR (T2)
- PET-CT (thorax, abdomen)

Objective:

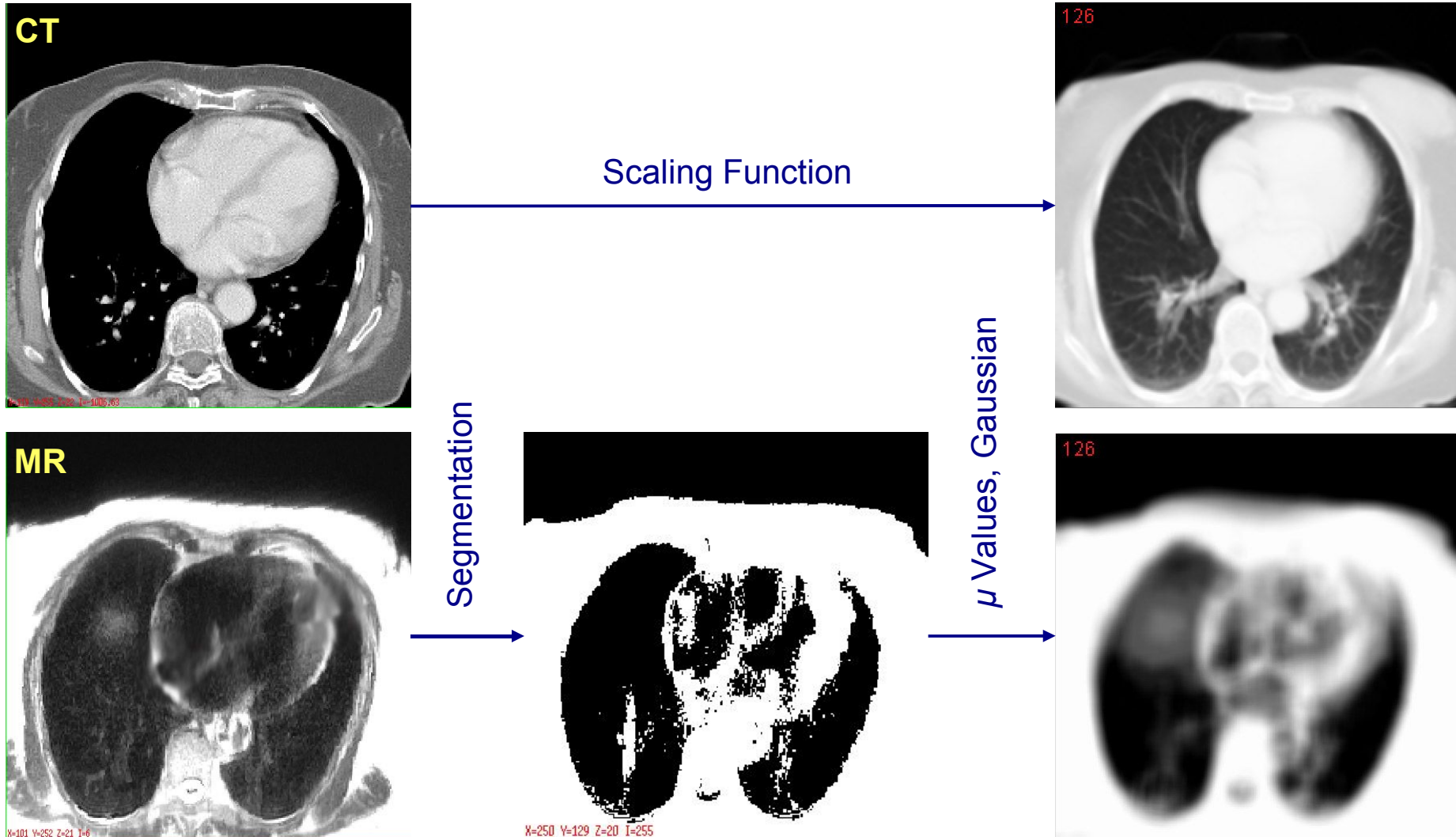
- Generate and compare μ maps from CT (scaling) and MR (thresholding)

Problems:

- Few regions of overlap (MR / CT)
- Patient position different (MR / CT)
- MR with only 27 coronal slices

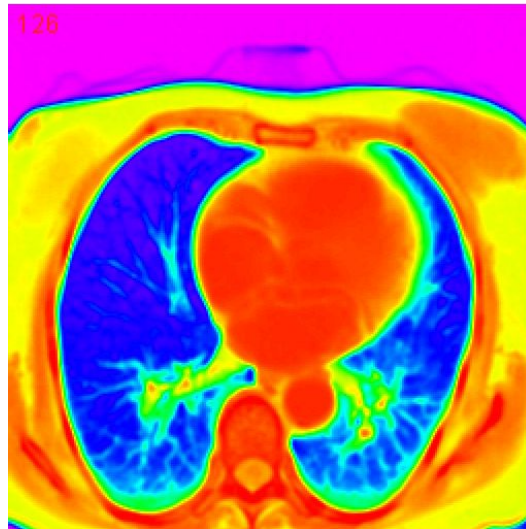


Results: Comparison of μ maps



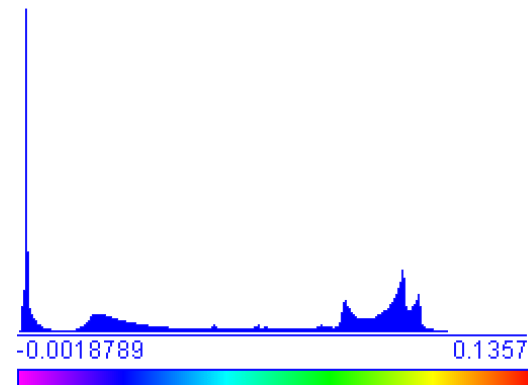
Results: Comparison of μ maps (II)

CT-based

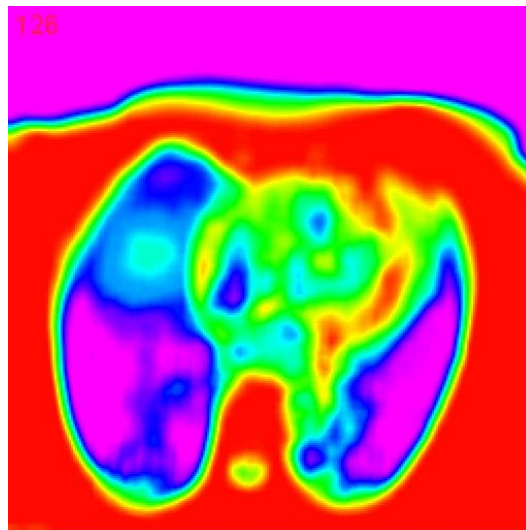


thorax-ct-map

Median: 0.060166 Mean: -0.0018482
 Mode: 0.00028017 Threshold Mn: -0.0018397

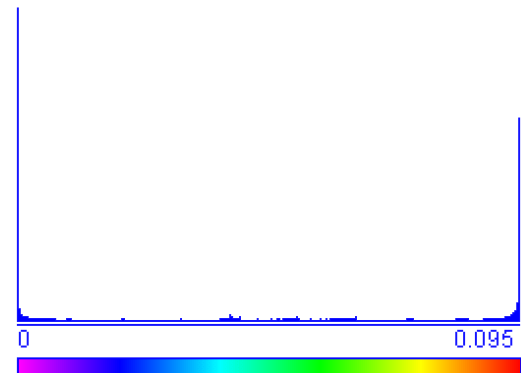


MR-based



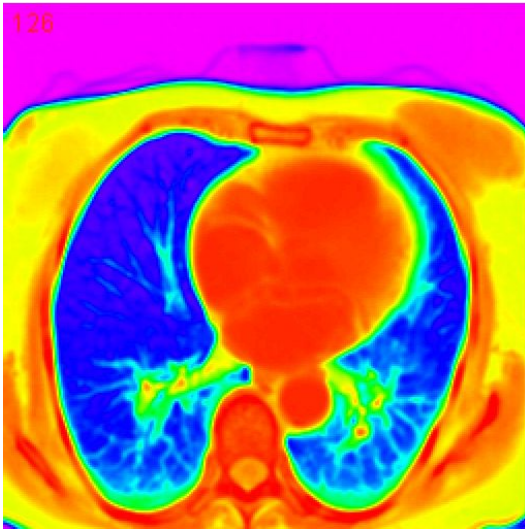
thorax-mr-reg-map

Median: 0.04247 Mean: 1.6623E-5
 Mode: 0 Threshold Mn: 2.3321E-5

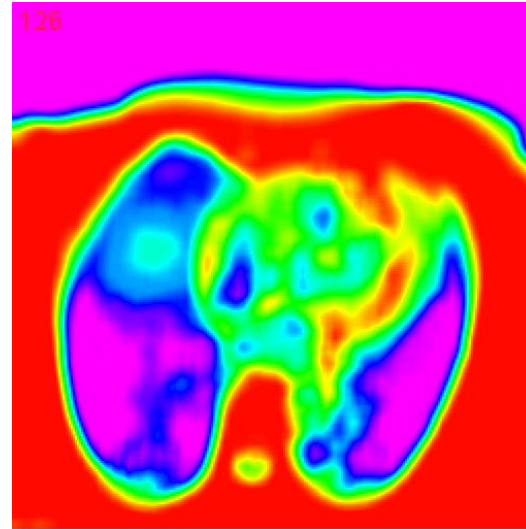


Results: Comparison of μ maps (III)

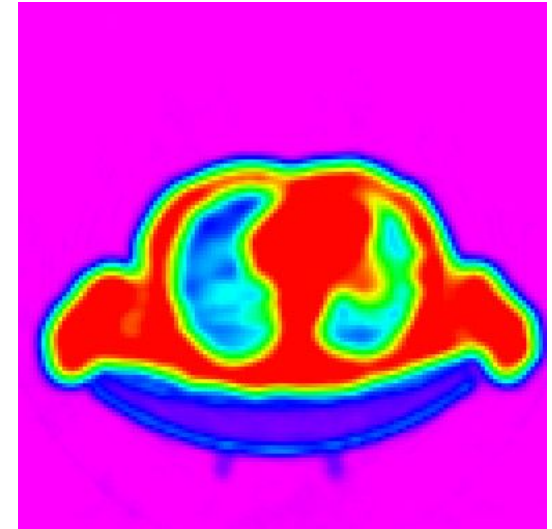
CT-based



MR-based



PET Transmission Scan



Conclusion:

- Most detail in CT-based μ map, least detail in Transmission Scan
- Quality of MR-based μ map comparable to Transmission Scan
- Segmentation difficulties in MR (e.g. heart not segmented)

Faced Issues

Animal placement: How do I keep my mouse at the same spot?
What type of mouse holder do I use?

Anaesthesia: How do I keep my mouse asleep?
How to schedule different modality scans?
How do I prevent my mouse from dying?

Scanner Issues: Broken PET scanner at scheduled date...
Unexpected metal artifacts in CT scans...

Future Work

- Find out what other research groups (Siemens) are doing
 - Avoid parallel and possibly duplicate work...
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- Assess whether more sophisticated approaches for segmentation (e.g. atlas-based) are worth the effort
 - Evaluate simple MR-based μ maps in practice
 - ➔ Use for correcting sample PET images
 - ➔ Compare correction results to results using CT-based map

References

- [1] Zaidi, H., Montandon, M.-L., Slosman, D.: Magnetic Resonance Imaging-guided Attenuation and Scatter Corrections in Three-dimensional Brain Positron Emission Tomography, *Med. Phys.*, Volume 30, pp. 937-948; 2003
- [2] Zaidi, H. and Hsegawa, B.: Determination of the Attenuation Map in Emission Tomography, *J. Nucl. Med.*, Volume 44, pp. 291-315; 2003
- [3] Chow, P. L. and Rannou, F. R.: Attenuation Correction for Small Animal PET tomographs, *Phys. Med. Biol.*, Volume 50, pp. 1837-1850; 2005
- [4] Rappoport, V., Carney, J. P., Townsend, D. W.: CT Tube-voltage Dependent Attenuation Correction Scheme for PET/CT Scanners, *IEEE*; 2004
- [5] Burger, C. Goerres, G. et al.: PET Attenuation Coefficients from CT Images: Experimental Evaluation of the Transformation of CT into PET 511-keV Attenuation Coefficients, *European Journal of Nuclear Medicine*, Volume 29, pp. 923-927; 2002

Discussion!