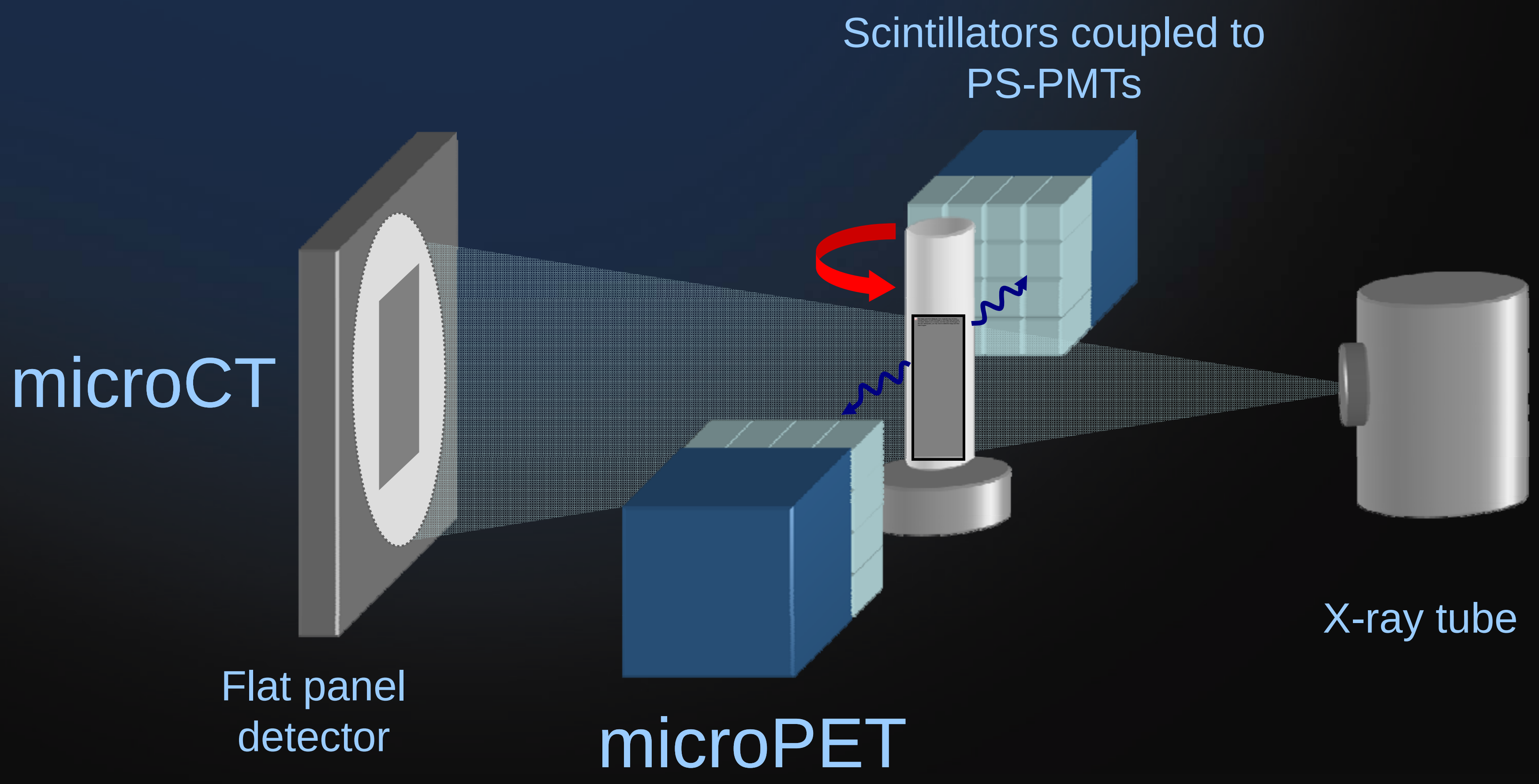
Image-transfer properties of a microCT system based on a flat panel detector

Arnulfo Martínez-Dávalos
Instituto de Física, UNAM
arnulfo@fisica.unam.mx

Sistema Bimodal de Imágenes (SIBI)



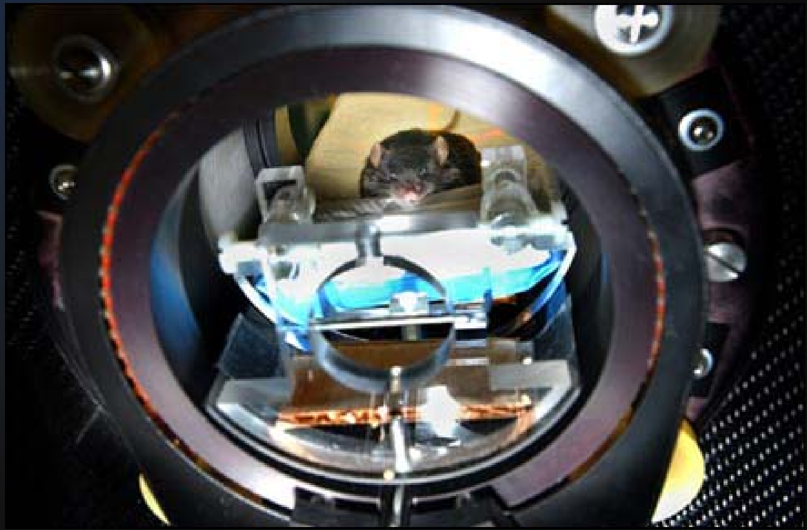
SIBI

Aims

- To develop radiological imaging systems for small rodents using state of the art technologies
- To integrate different imaging techniques in order to provide both anatomical and functional information
- To provide advanced training in all related areas (radiation detection, nuclear techniques, imaging, preclinical studies, etc.)
- To collaborate in basic biomedical research using *in vivo* molecular imaging techniques

Why study mice?

- Biological model *par excellence*
- Genetically modified strains
- Animal models of neoplasic or neurological diseases
- Non invasive *in-vivo* studies
  - Neurochemistry
  - Disease development
- Longitudinal studies



The dose problem in microCT

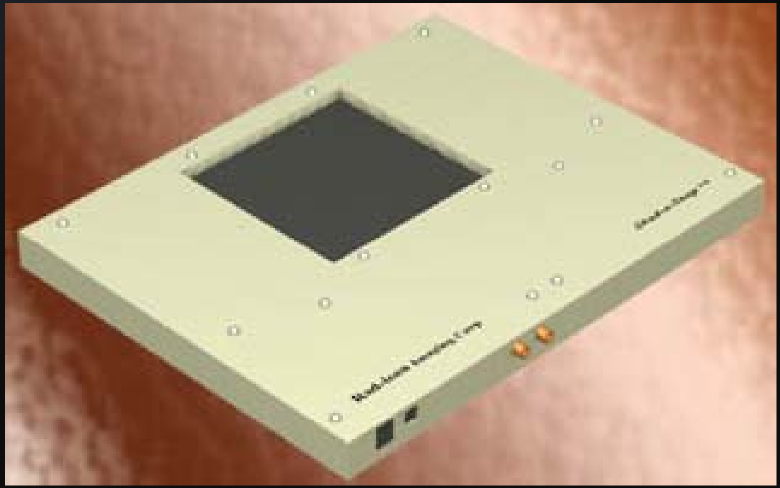
- In-vivo imaging allows longitudinal studies, but …
  - only meaningful if the subject is not altered!
- Excessive dose can alter physiological functions:
  - 200 mGy *in-vivo* elevates gene expression level [Amundson et al. 2001]
  - 20-50 mGy *in-vitro* induces stress-response gene expression [Fornace et al. 2002]

Oxford Instruments X-ray tubes

	Ultrabright	Apogee
Target	W	W / Mo
Current interval (mA)	0.1 - 2	0.1 - 1
Voltage (kV)	10 - 90	20 - 50
Focal spot (µm)	13 - 40	35
Beam angular aperture	33º	22º

Flat panel detector

- Rad-icon Shad-o-Snap 4k
- 8 CMOS photodiode panels
- Gd_2O_2S scintillator screen
  (Kodak Lanex fine, ~80 µm thickness)
- 2000×2048, 48 μm^2 pixels
- 96.1 mm h × 98.6 mm w
- 12 bits per pixel
- 4000:1 dynamic range
- USB data interface
- 540 ms readout period

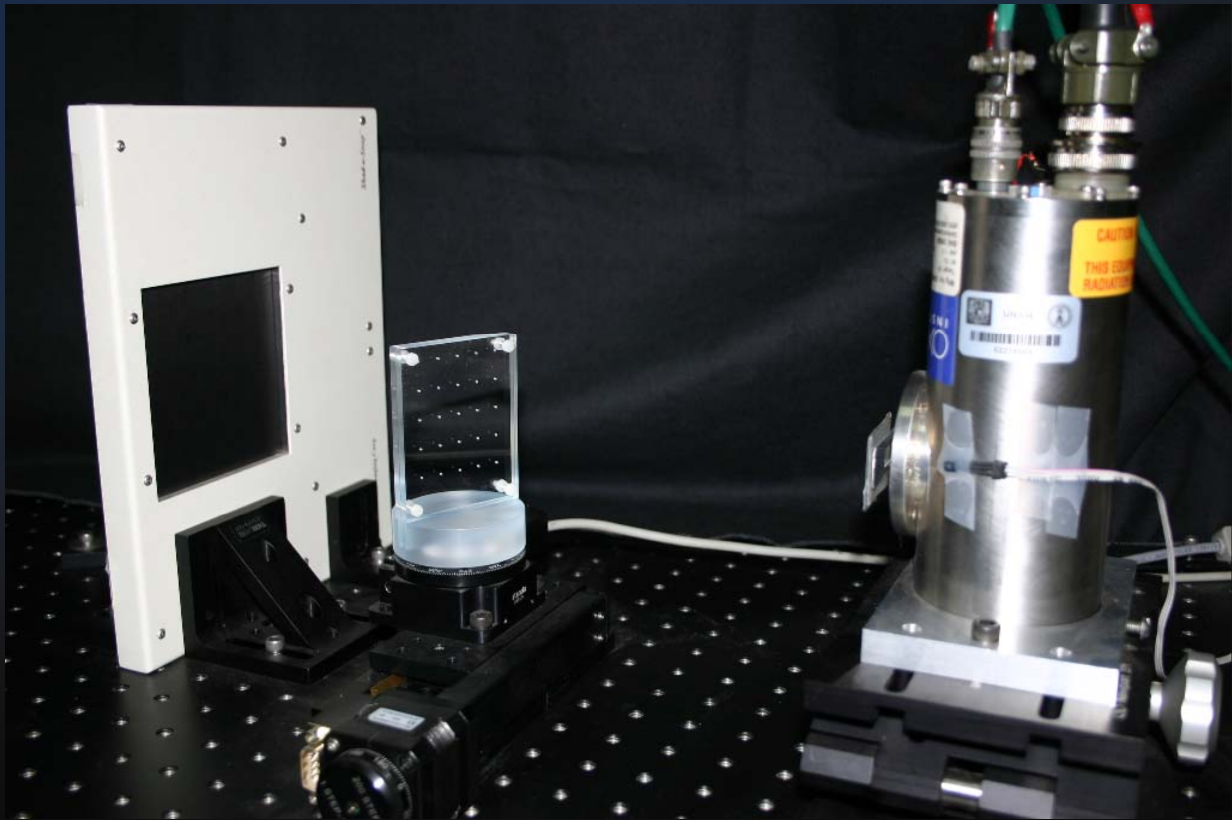


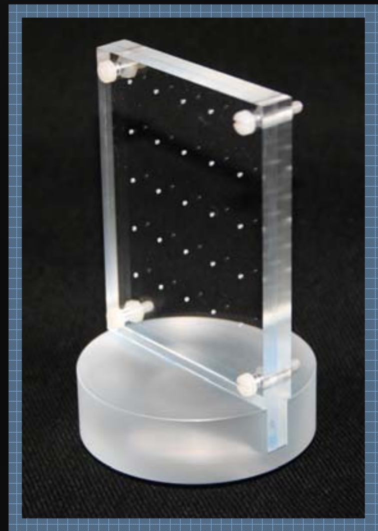
Rad-icon Imaging Corp · 3193 Belick Street, Unit 1 · Santa Clara, CA 95054

Basic setup

Detector

X-ray tube





X-θ stage

Olinca Galván, MSc Thesis, Graduate Program in Medical Physics, UNAM, 2008

mCT control panel

LabVIEW v8.5, modular VI library.

Methods

- X-ray spectra: Amptek CZT detector
- FPN (flat field correction)
- MTF : Slanted edge technique
- NPS : 2D FT of relative noise distribution
- DQE : $MTF^2 / (X\ \Phi_x\ NPS)$
- Dose performance : TLD & MC
- CT rec. : Feldkamp

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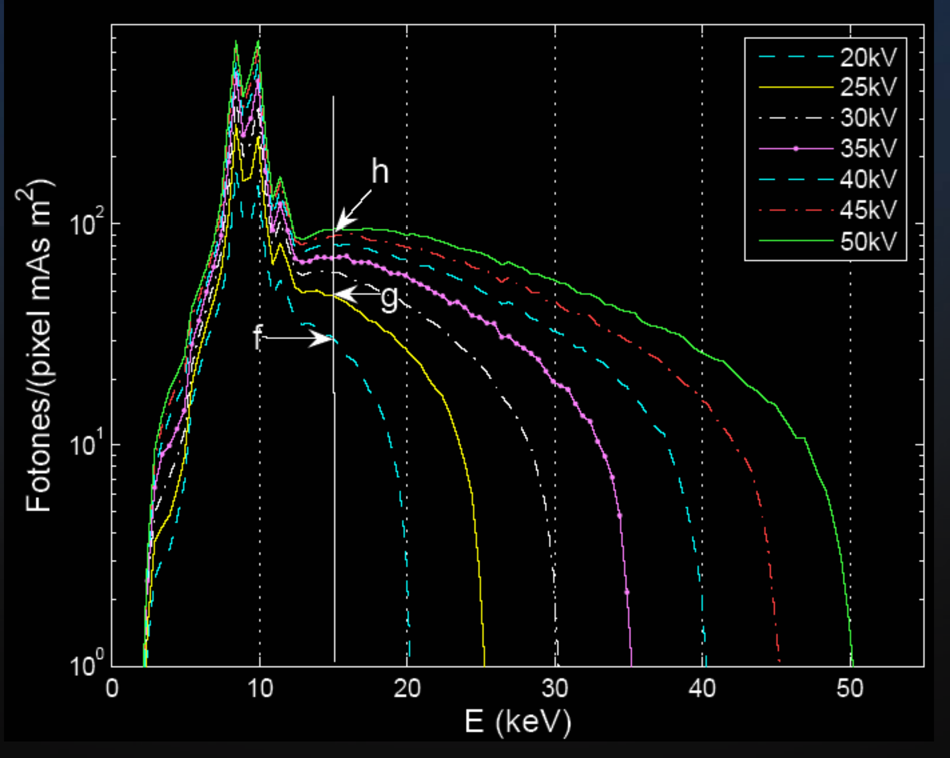
X-ray spectra

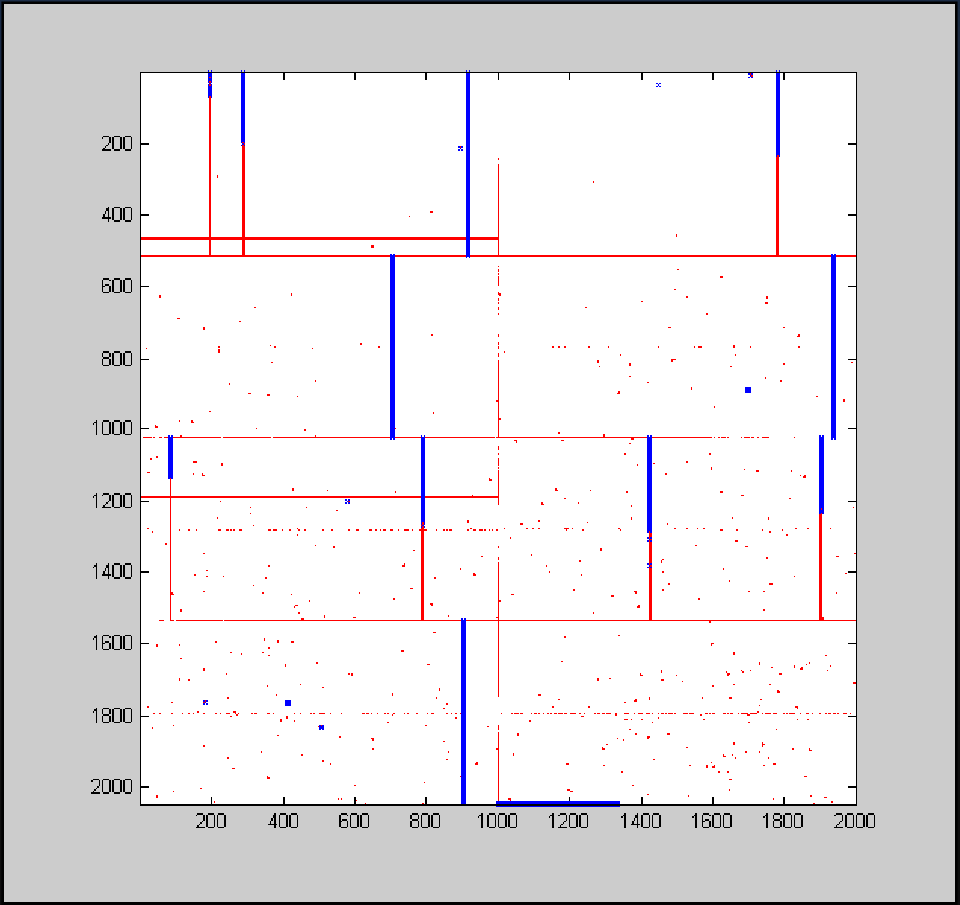
$$\Phi(E,V)=a(E)kV^3+b(E)kV^2+c(E)kV+d(E)$$



- Spectra
- Angular distributions
- Backscatter factors
- Output factors
- Half-value layers
- Parameterization

Ulises Moya, MSc thesis, Graduate Program in Medical Physics, UNAM, 2008

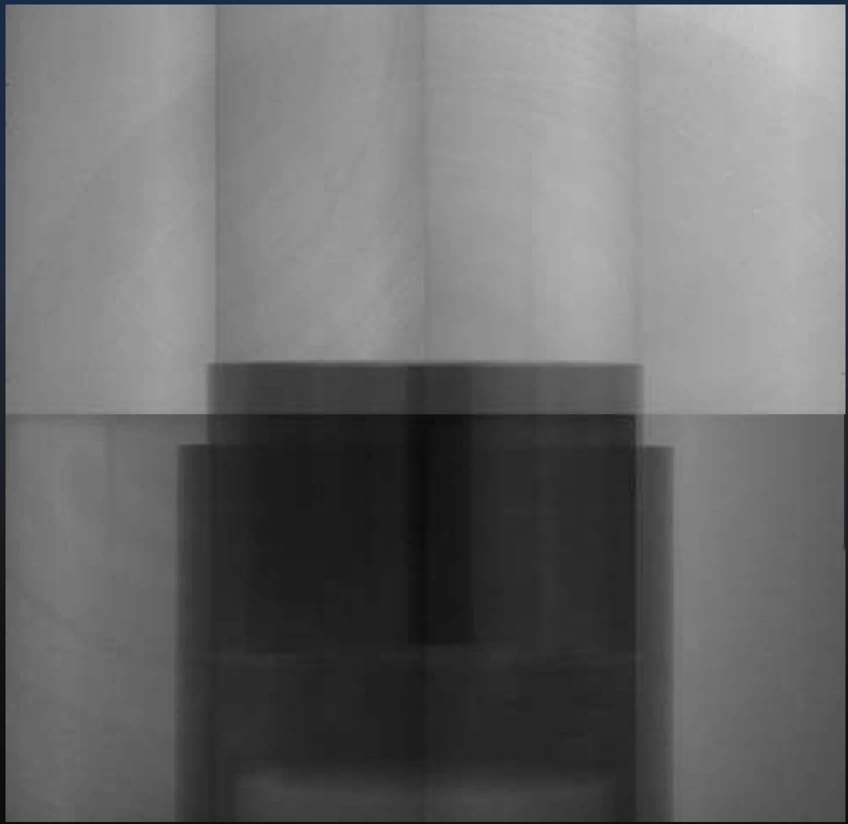
Fixed Pattern Noise



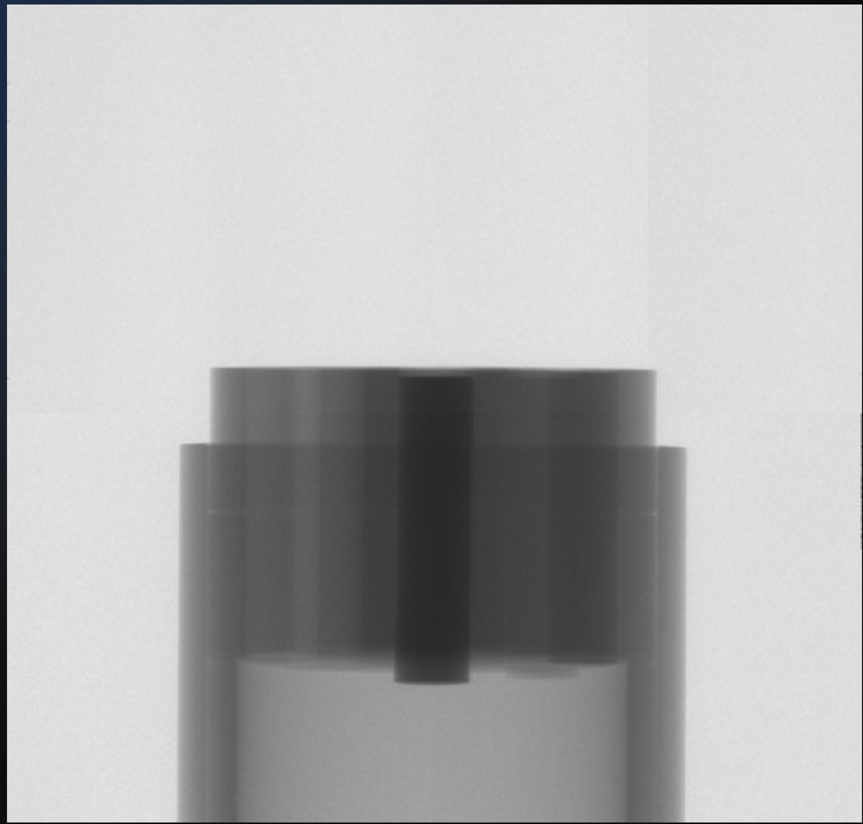
- x : dead pixels
  aprox. 0.1%
- o : outliers
  aprox. 1.0%

Flat field correction

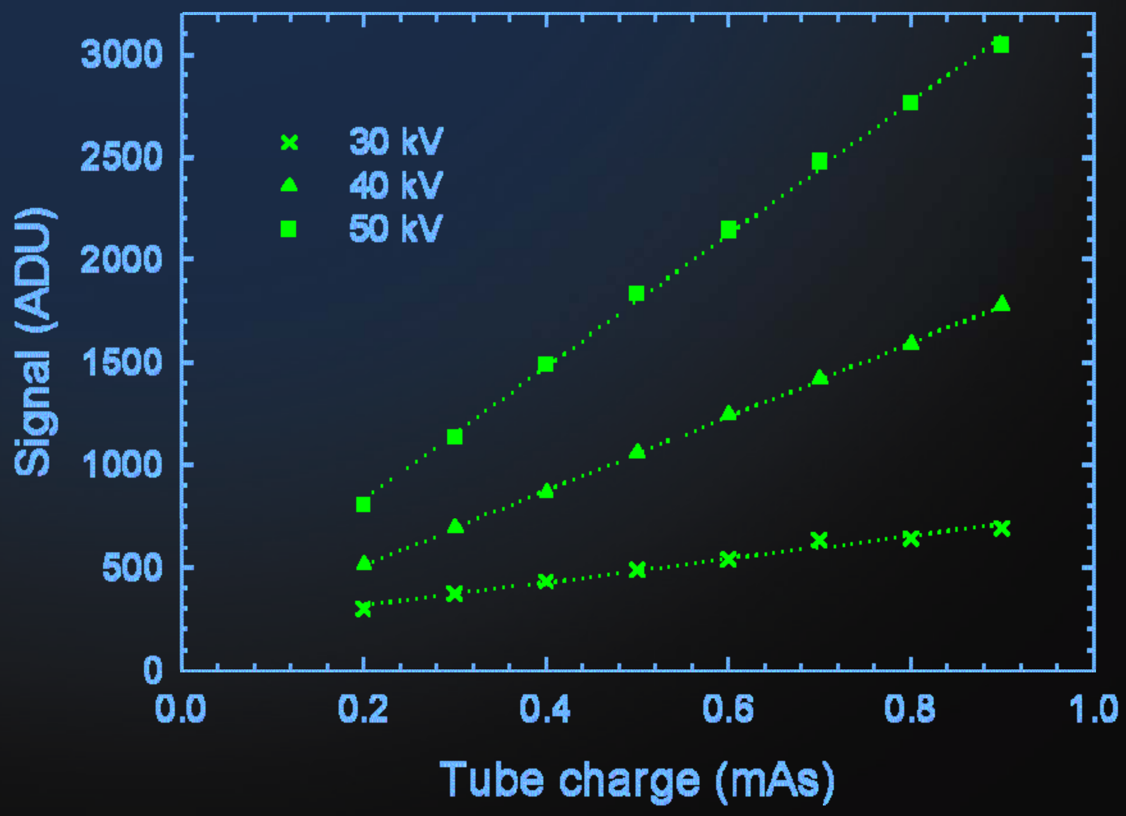
Non-uniform response



Corrected

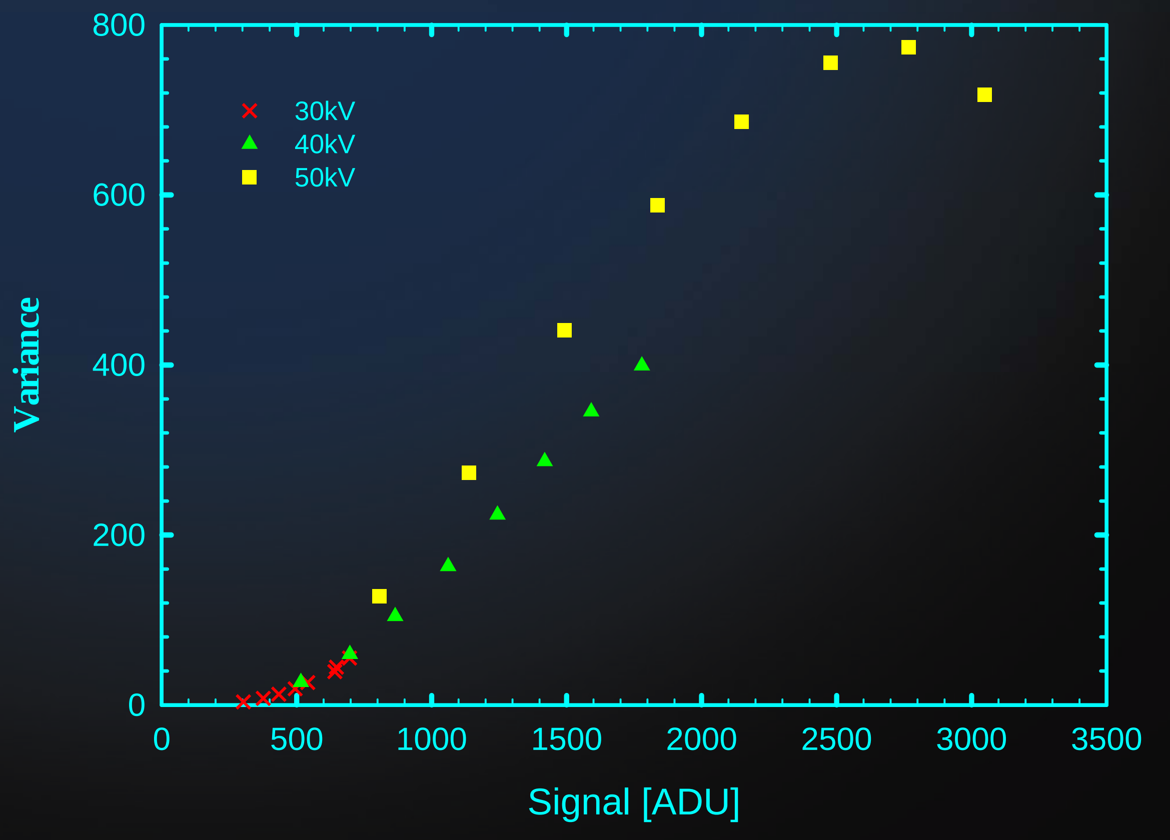


Linearity of response



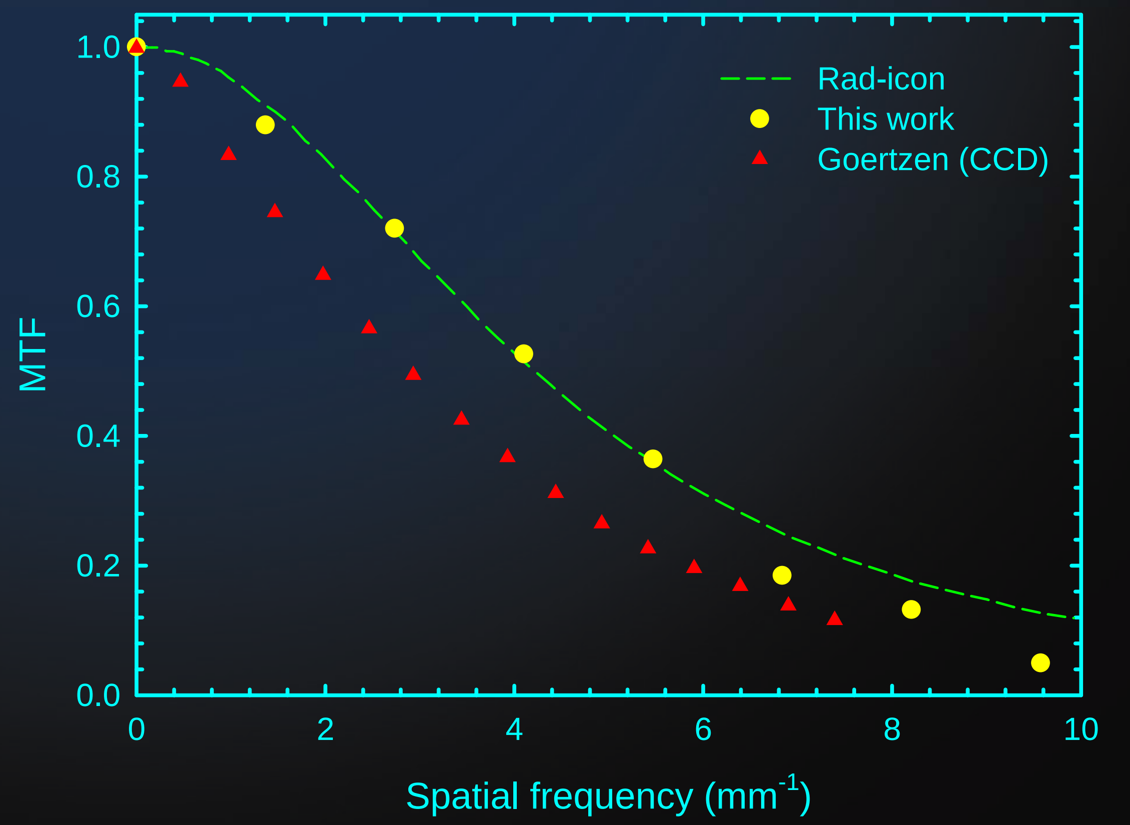
Oxford Instruments Apogee W, 1 mm Al, 1 mAs

Noise



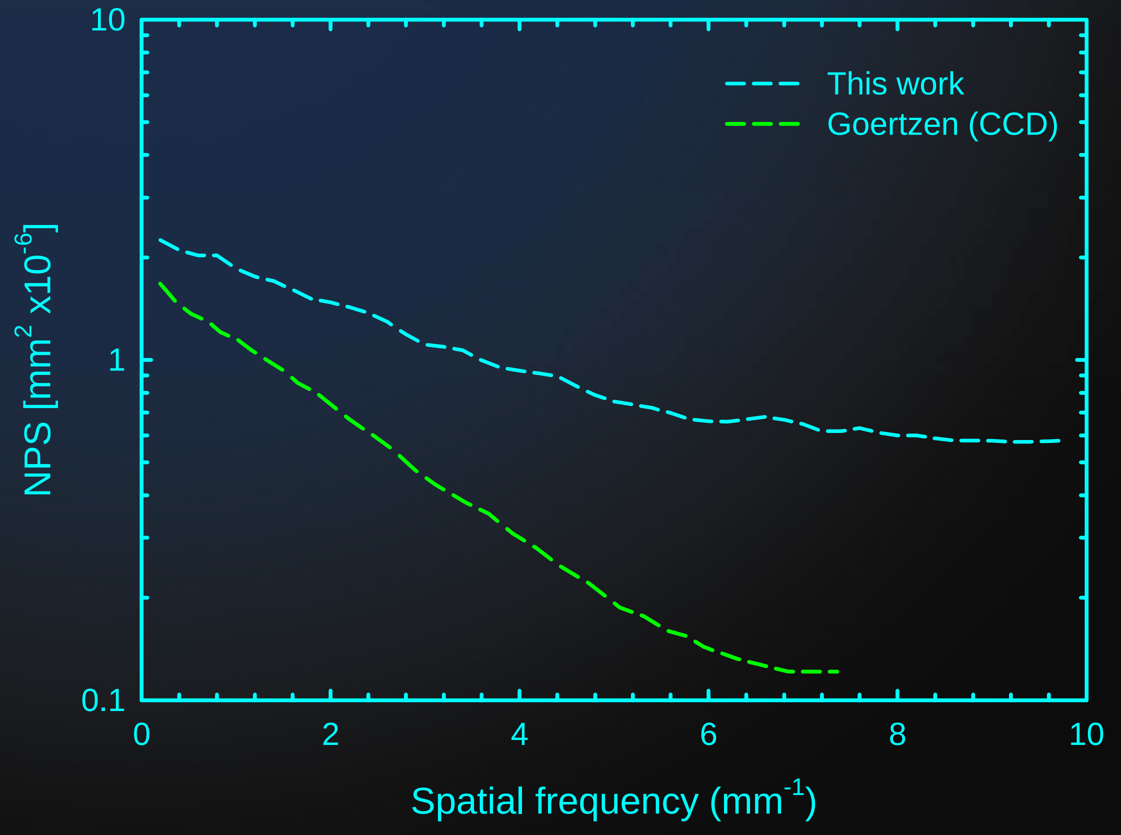
Oxford Instruments Apogee W, 1 mm Al, 1 mAs

Presampling MTF



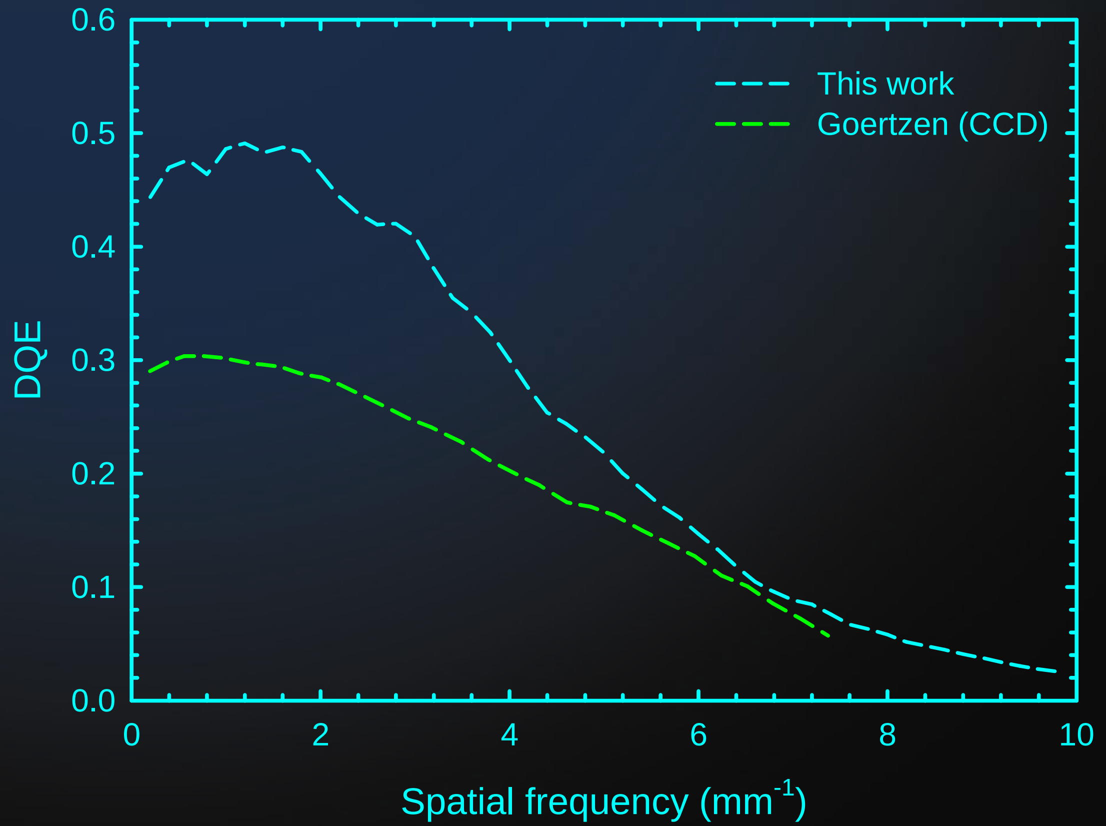
Spatial resolution at 10% MTF ~ 10 lp/mm

NPS



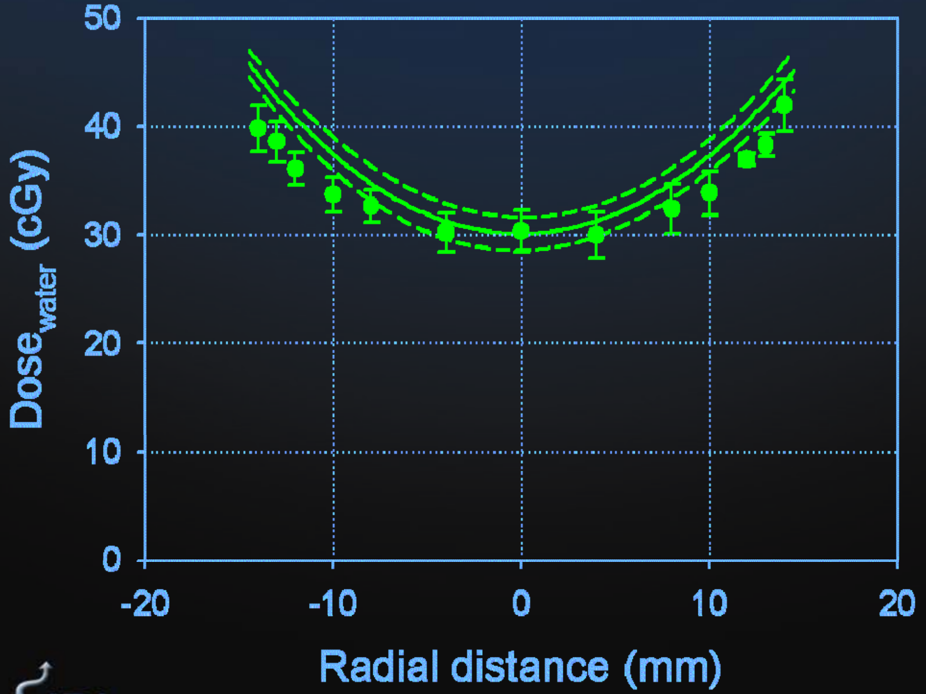
W 40 kVp, 0.5 mm Al, 30 mR

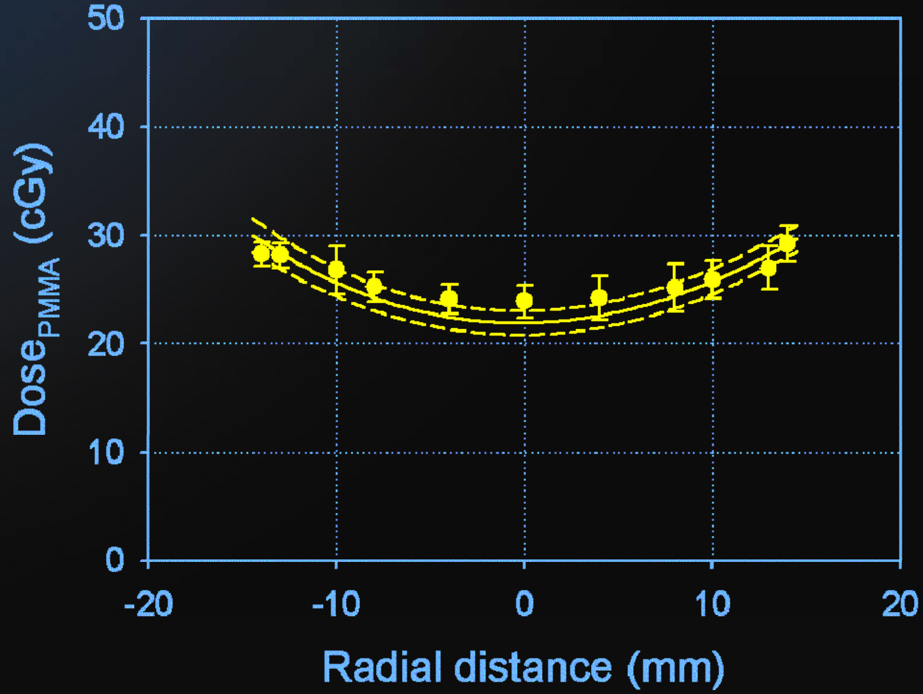
DQE



$$DQE = MTF^2 / (X\ \Phi_x\ NPS)$$

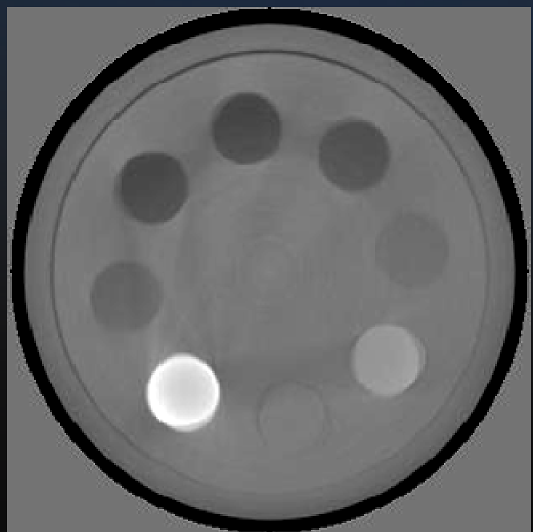
Dose measurements & simulations

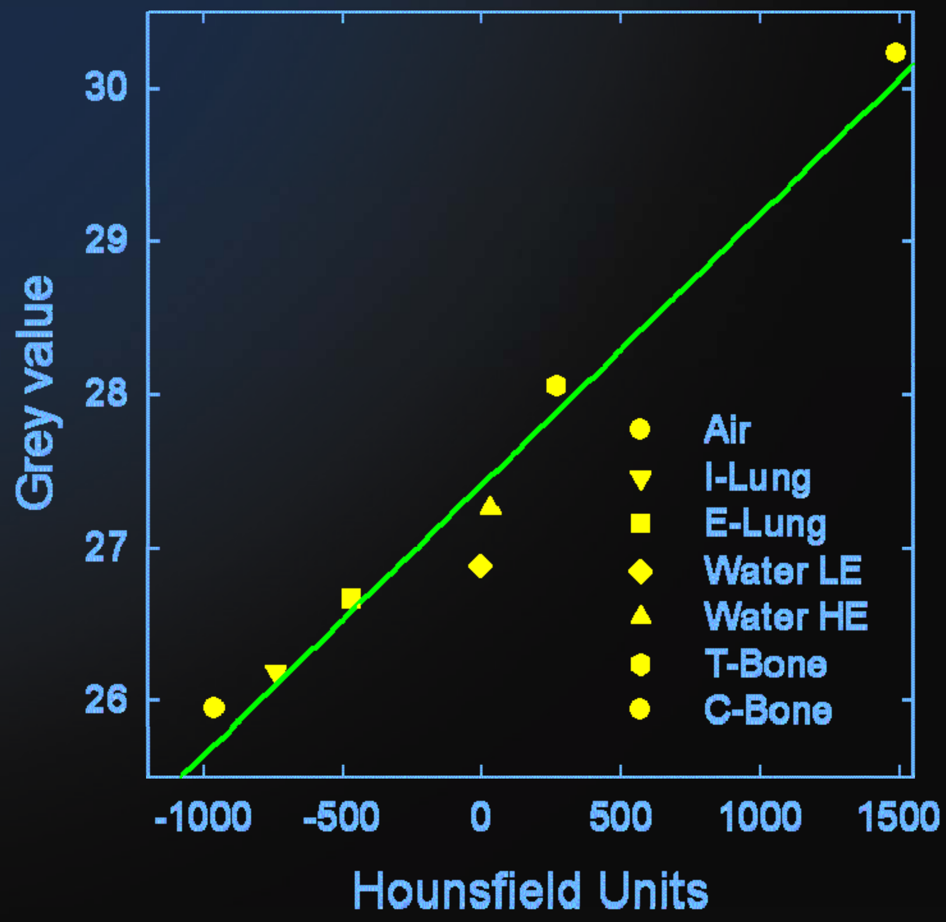




Carla Montaño, MSc thesis, Graduate Program in Medical Physics, UNAM, 2007

Calibration in HU



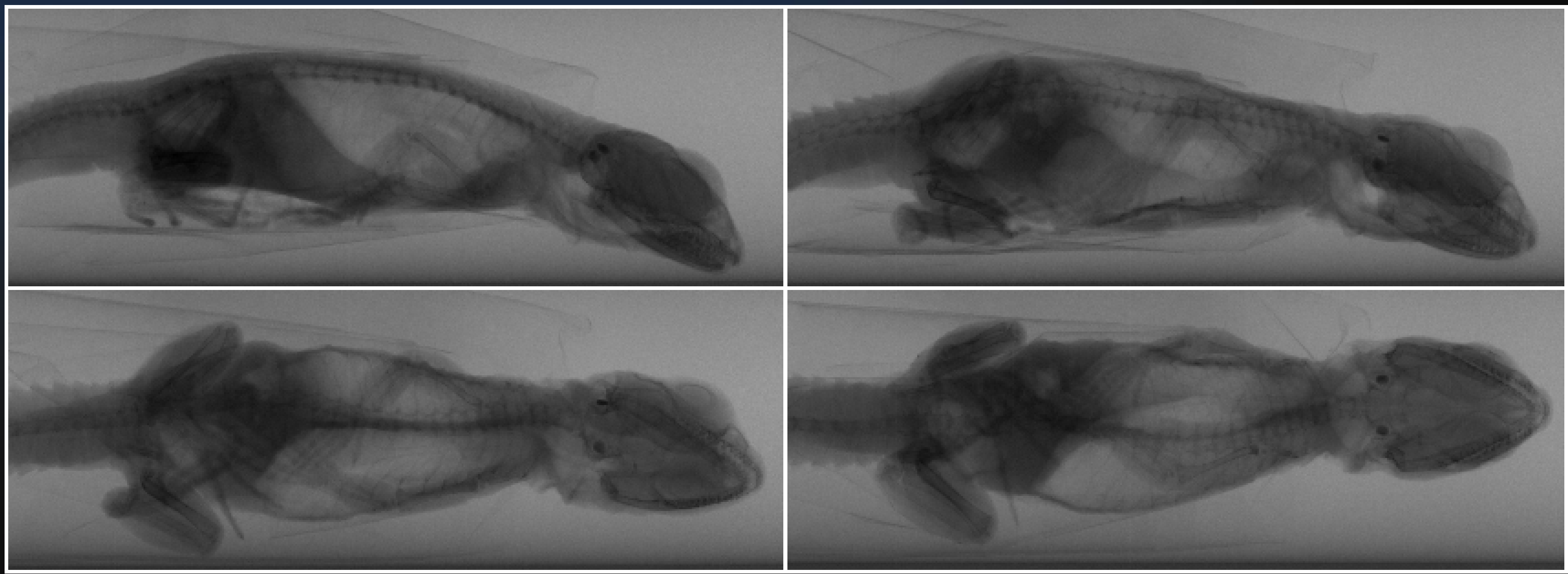


Orlando Soberanis, MSc Thesis, Graduate Program in Medical Physics, UNAM, 2008

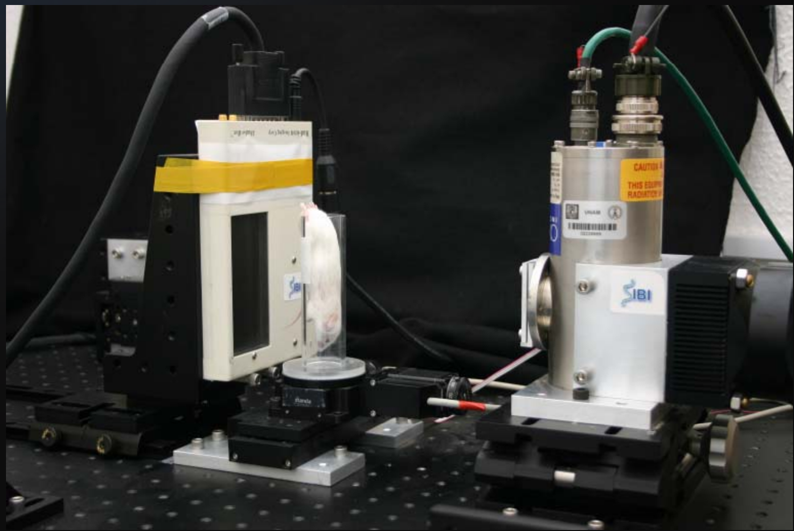
Mexican Iguana

W target, 1.0 mm Al, 30 kVp, 0.5 mAs

Body length ~ 4 cm



First mCT of a mouse (*ex-vivo*)



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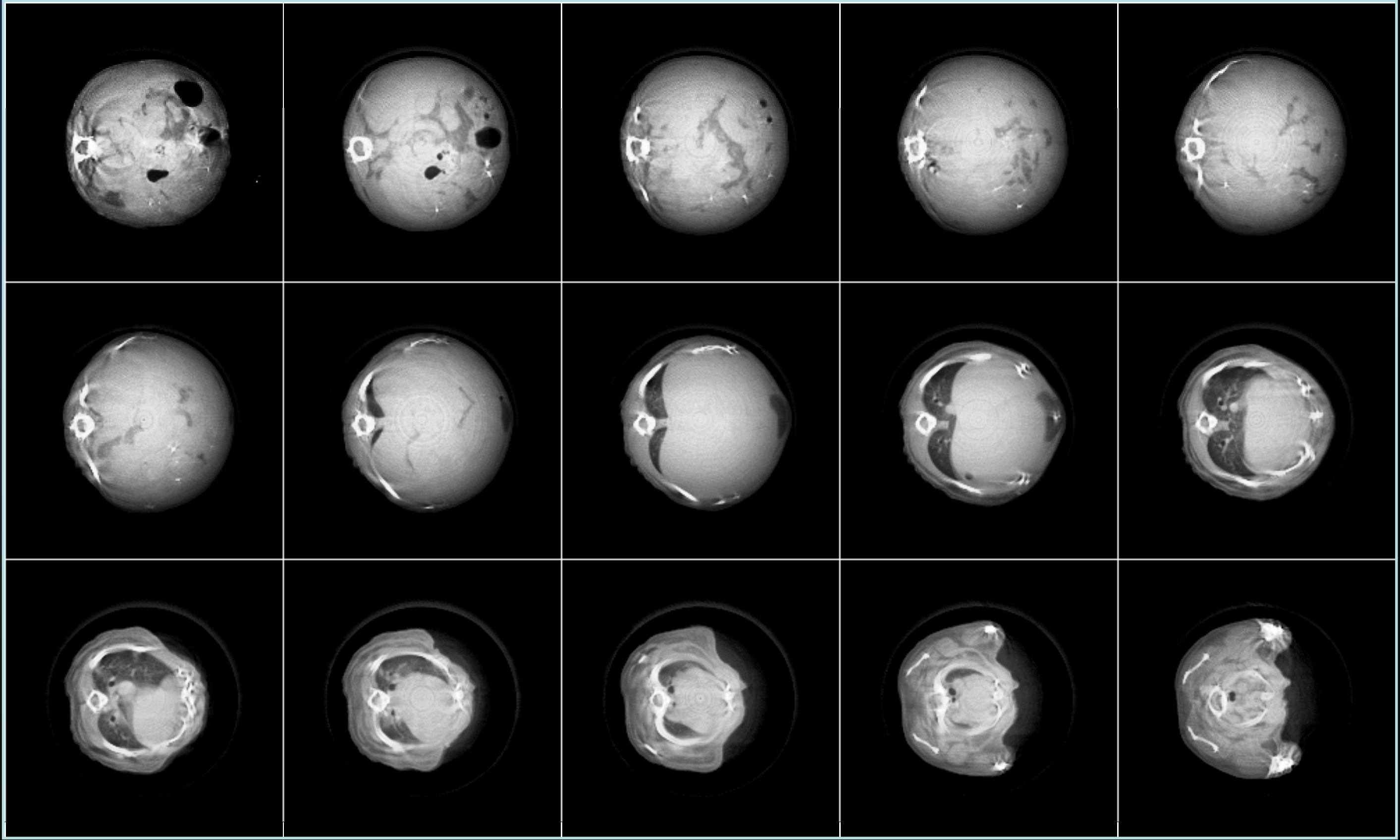
CT reconstruction, axial slices

W 50 kVp, 0.5 mAs, 1 mm Al, 360º orbit, 1º steps

Feldkamp, Hann filter, 0.7 cutoff frequency



Conclusions

- We have built and characterized a benchtop microCT prototype
- Detector performance:
  - Excellent spatial resolution (~10 lp/mm @ 10% MTF)
  - Good noise performance
  - Very good DQE (40-50% at low spatial frequencies)
- Successful image acquisitions and tomographic reconstructions

To do:

- New detector, faster data transfer
- Use of contrast media and/or dual energy techniques
- Integration of microCT with microPET

Participants

Faculty






Students









Human vs. mouse

Human – 70 kg

CT

- 100-120 kVp
- Spatial resolution ~0.4 mm
- Ring geometry
- Dose ~2-20 mGy

PET

- Spatial resolution 2-3 mm
- Activity ~ 10-15 mCi
- Sensitivity ~ 2-4%

Mouse – 30 g

microCT

- 30-80 kVp
- Spatial resolution ~50 µm
- Flat panel detectors
- Dose ~30-300 mGy

microPET

- Spatial resolution 1-2 mm
- Activity ~ 0.5 mCi
- Sensitivity ~ 3.5%

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Reconstruction parameters

	Ramp	Shepp-Logan	Cosine	Hann	Hamming
SNR	24.7	22.9	25.8	25.2	26.7
CNR	3.5	3.9	4.8	5.2	5.1