Clinical Applications

- Flat Panel Detectors for Clinical Cone Beam CT
- CMOS Detectors for Breast CT

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Professor of Biomedical Engineering
University of California Davis

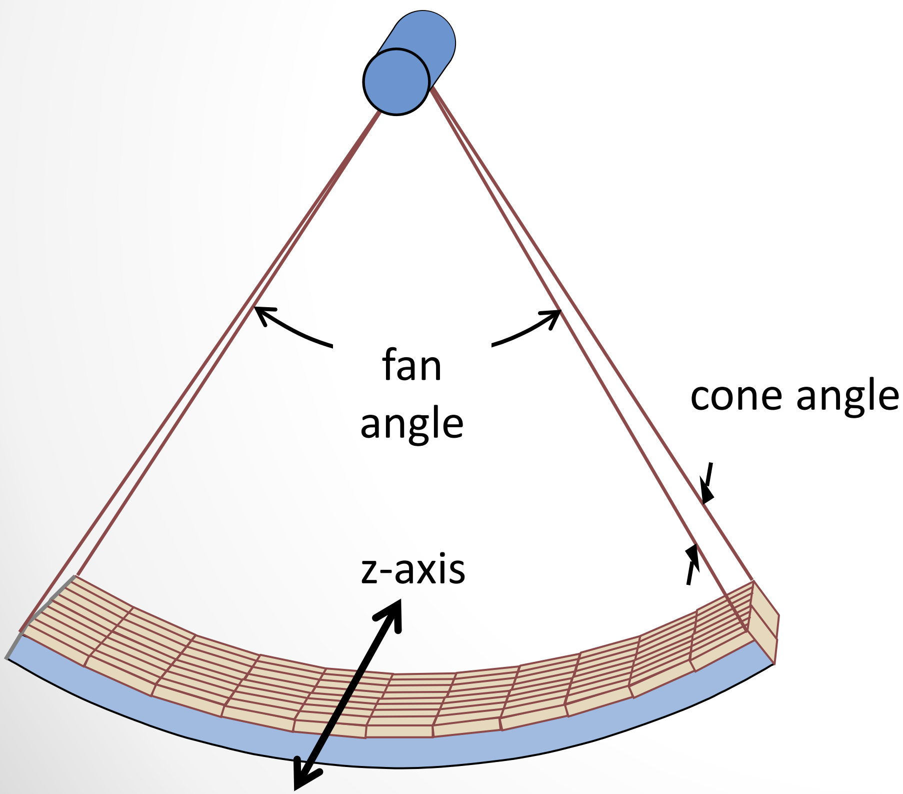
Clinical Applications

- Flat Panel Detectors for Clinical Cone Beam CT
    - Cone Beam CT: Benefits and Limitations
    - Applications
        - Dental / Head
        - SPECT / CT
        - C-arm CT
        - Extremity
        - Radiation Therapy
        - Breast CT
    - Summary

Cone Beam CT: Benefits and Limitations

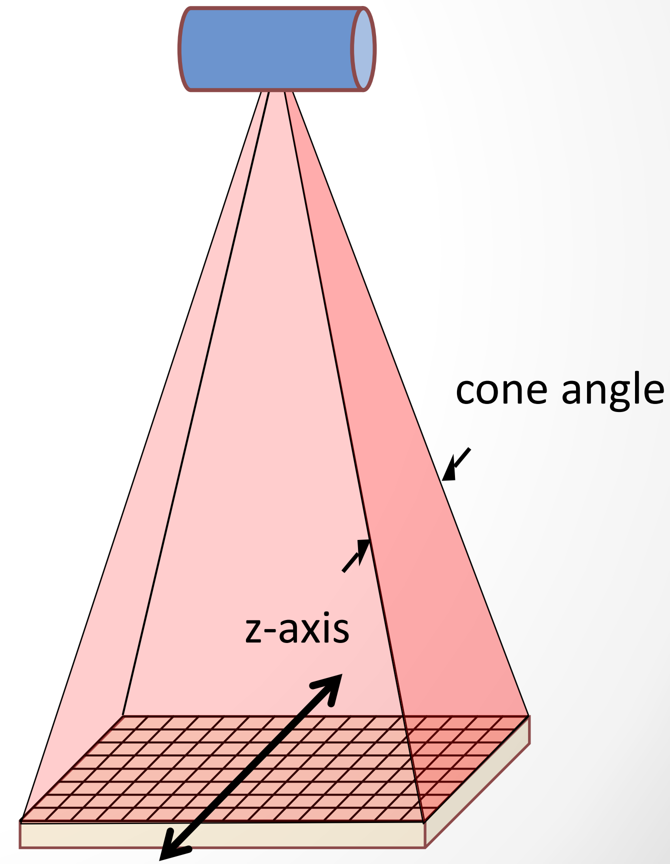
Multiple Detector CT

64 – 320 detector arrays along z



Flat Panel CT

e.g. 768 detector arrays along z

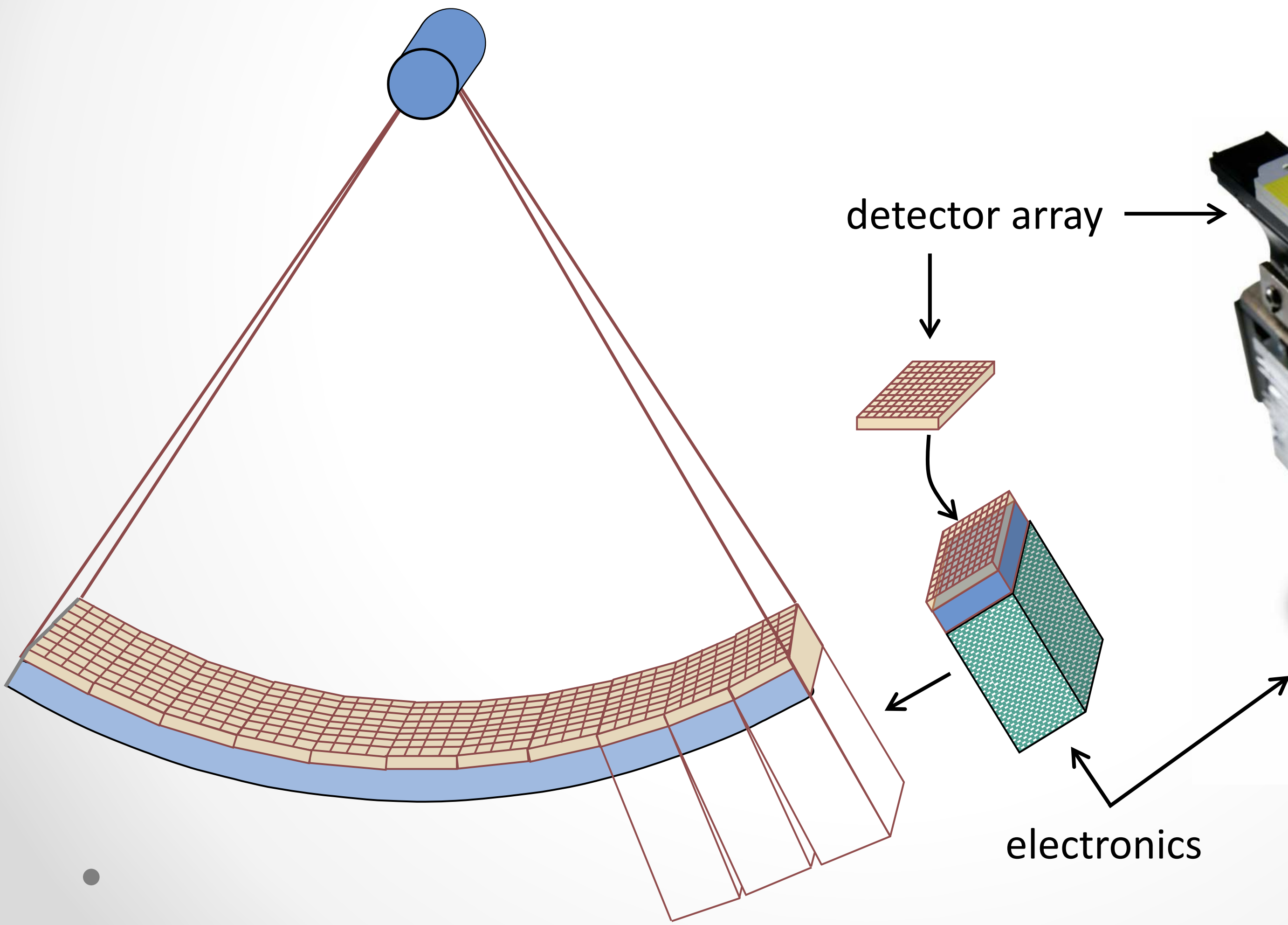


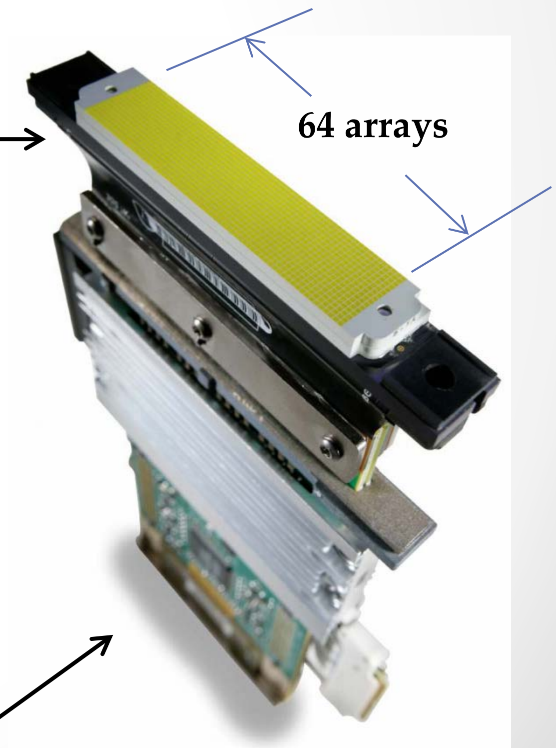
Cone Beam CT: Benefits and Limitations

Multiple Detector CT

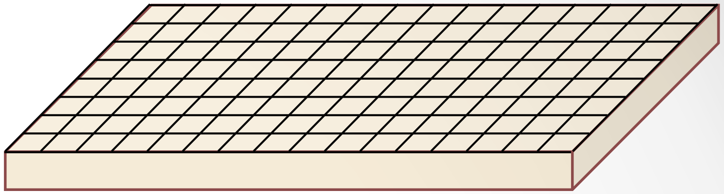
64 – 320 detector arrays along z

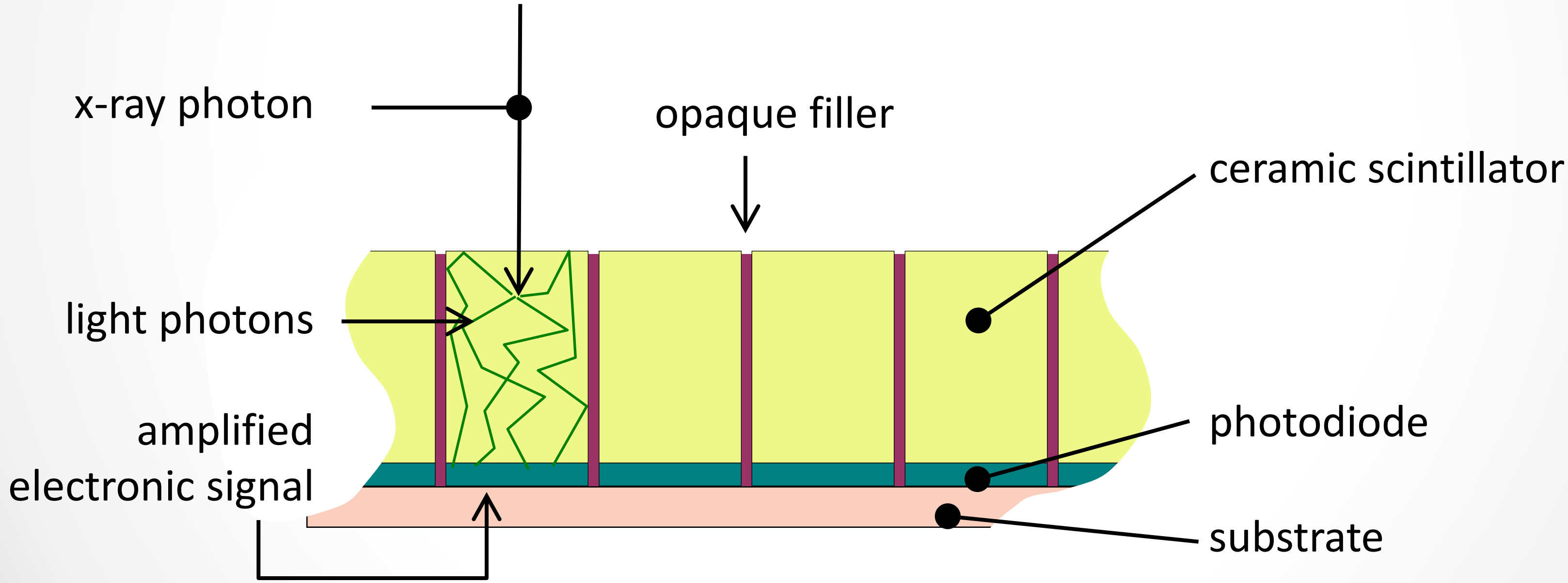
$N_{\text{modules}} = 60$
$N_{\text{detectors}} = 61{,}440$
$t_{\text{readout}} = 0.3$ ms





The solid state CT detector





Cone Beam CT: Benefits and Limitations

Flat Panel CT

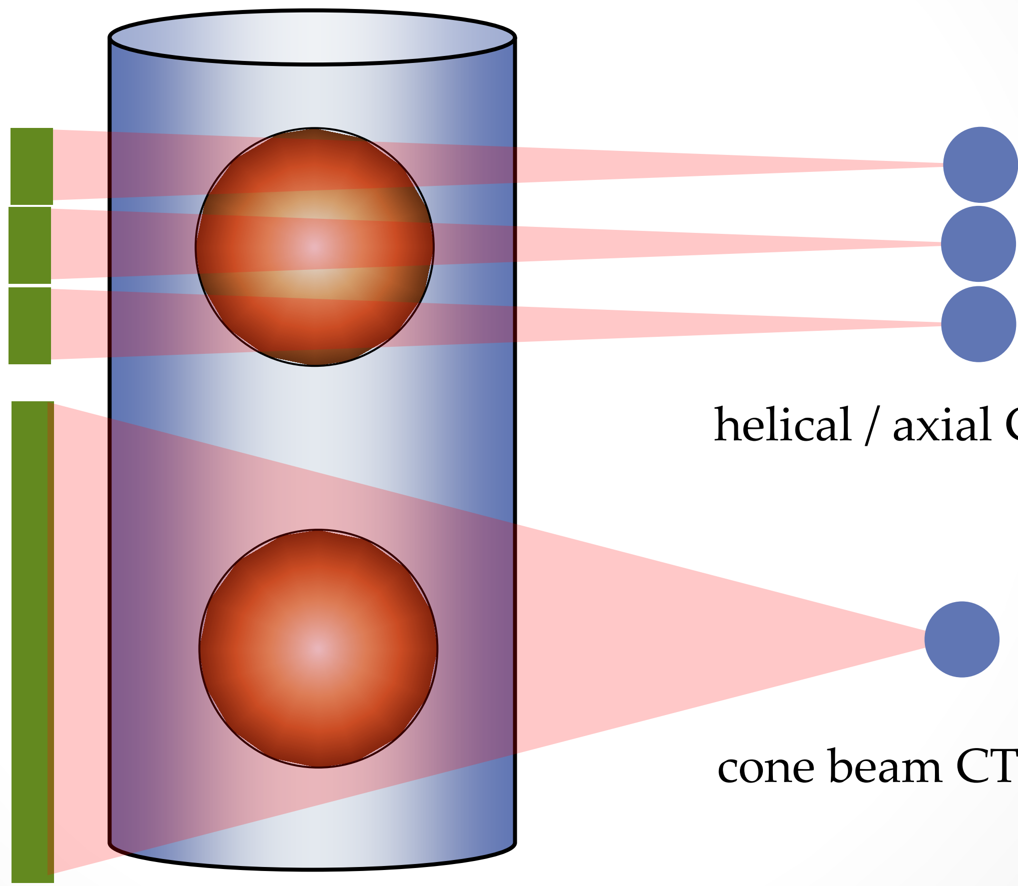
e.q. 768 detector arrays along z

$N_{modules} = 1$
$N_{detectors(1x1)} = 3{,}145{,}728$
$N_{detectors(2x2)} = 786{,}432$
$t_{readout} = 33$ ms

slow readout !

Breast CT scanner at UC Davis

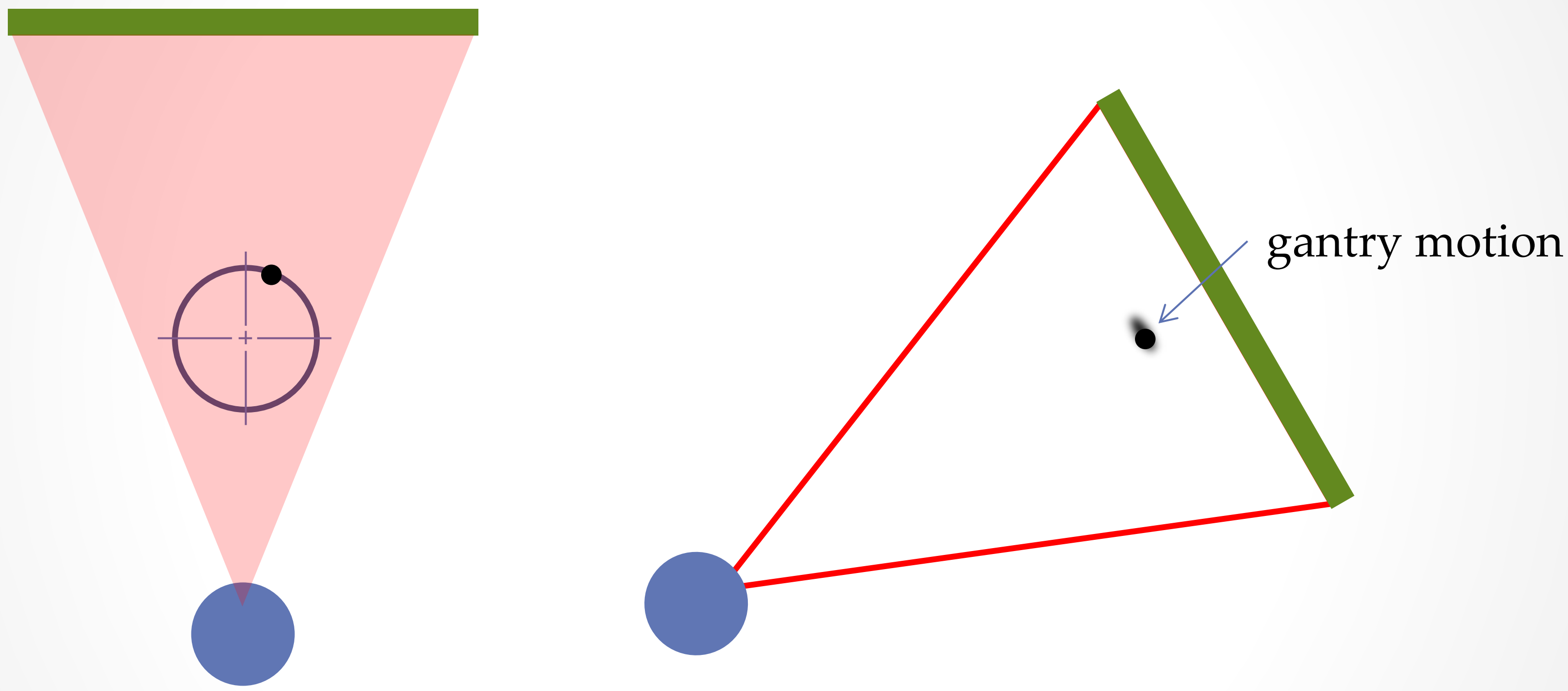
Cone Beam CT: Benefits and Limitations



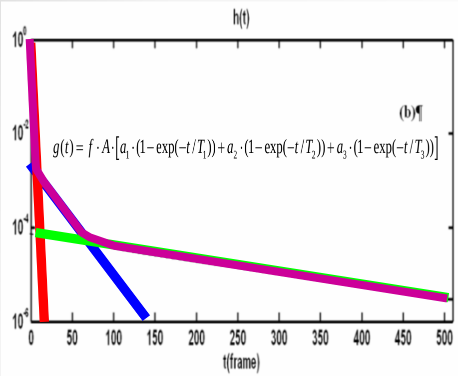
greater coverage with higher spatial resolution / single rotation of gantry

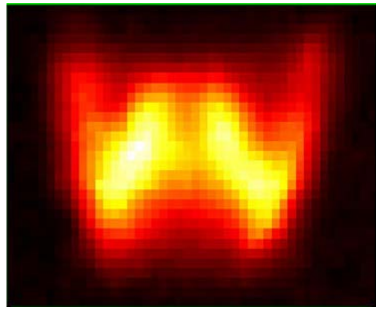
Cone Beam CT: Benefits and Limitations

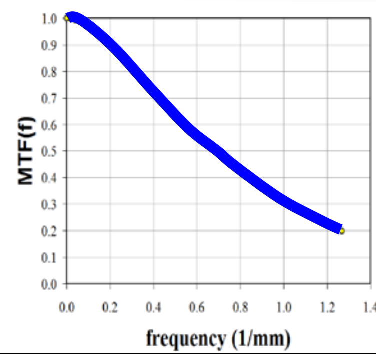
motion artifacts / requires pulsed x-ray source

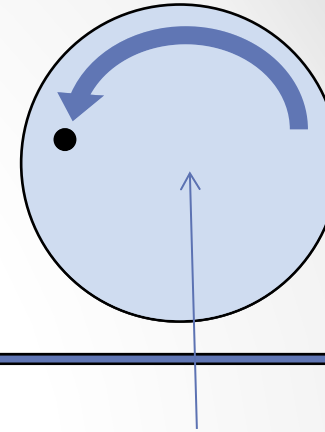


Spatial Resolution: Modeled & Measured MTF's

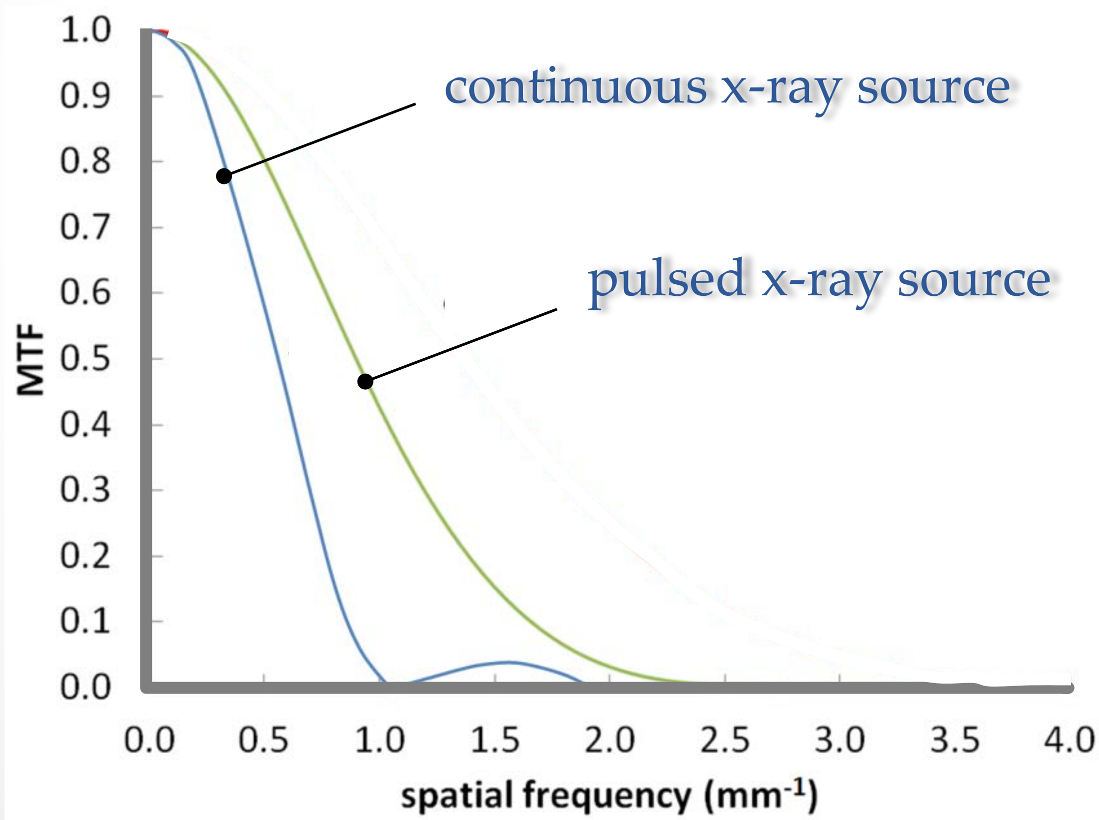






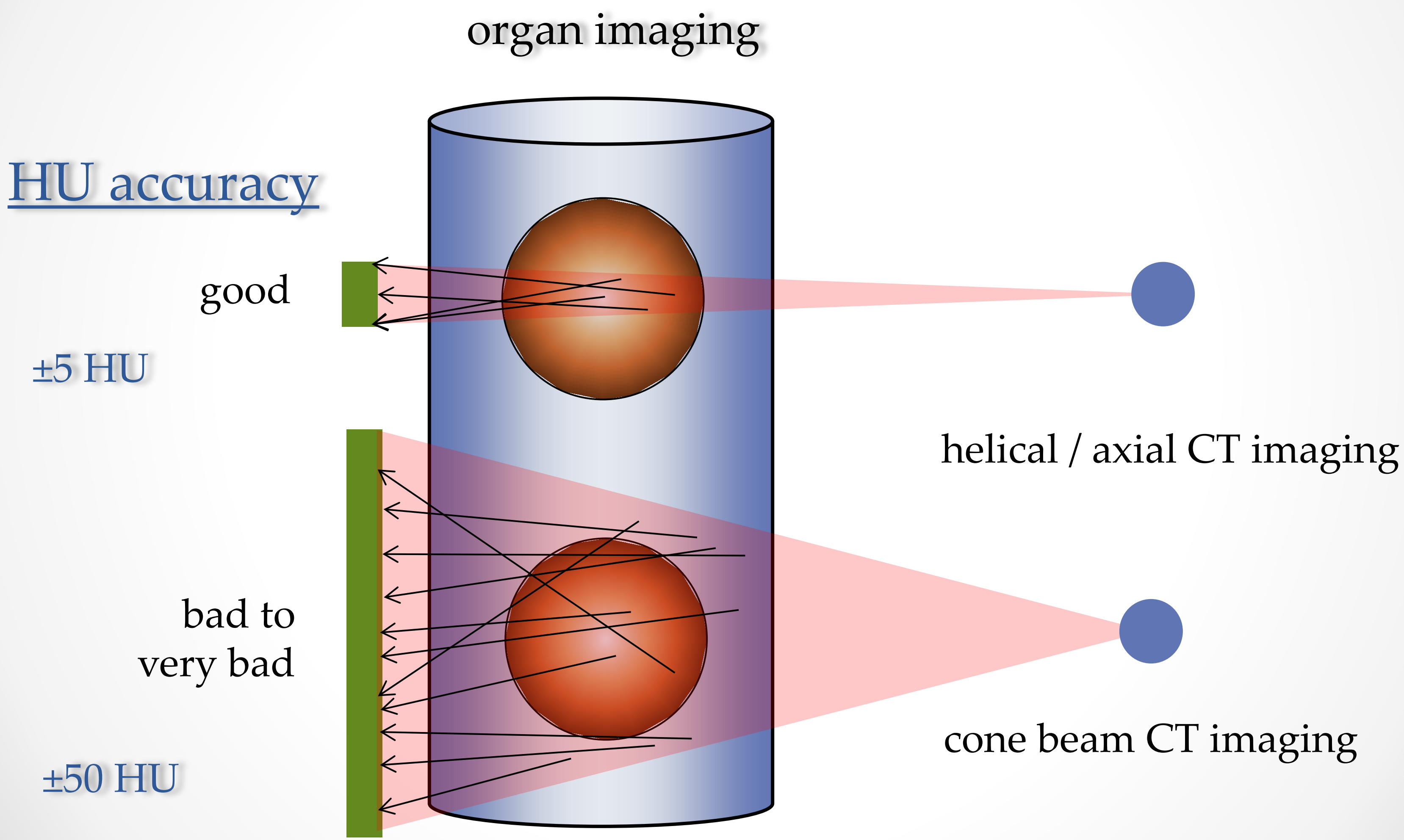


gantry motion



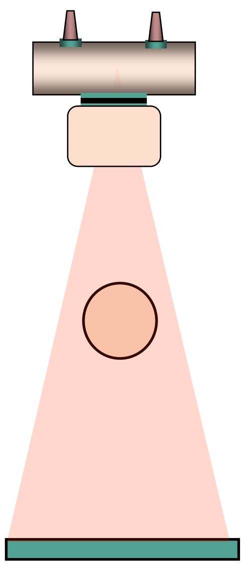
Cone Beam CT: Benefits and Limitations

cone beam ➡ more scattered radiation detection



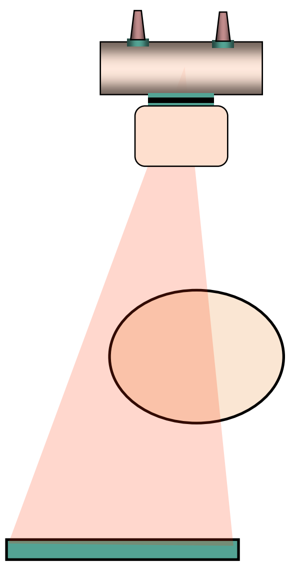
Clinical Application: Body imaging

Small FOV



Full cone beam scan (360°)

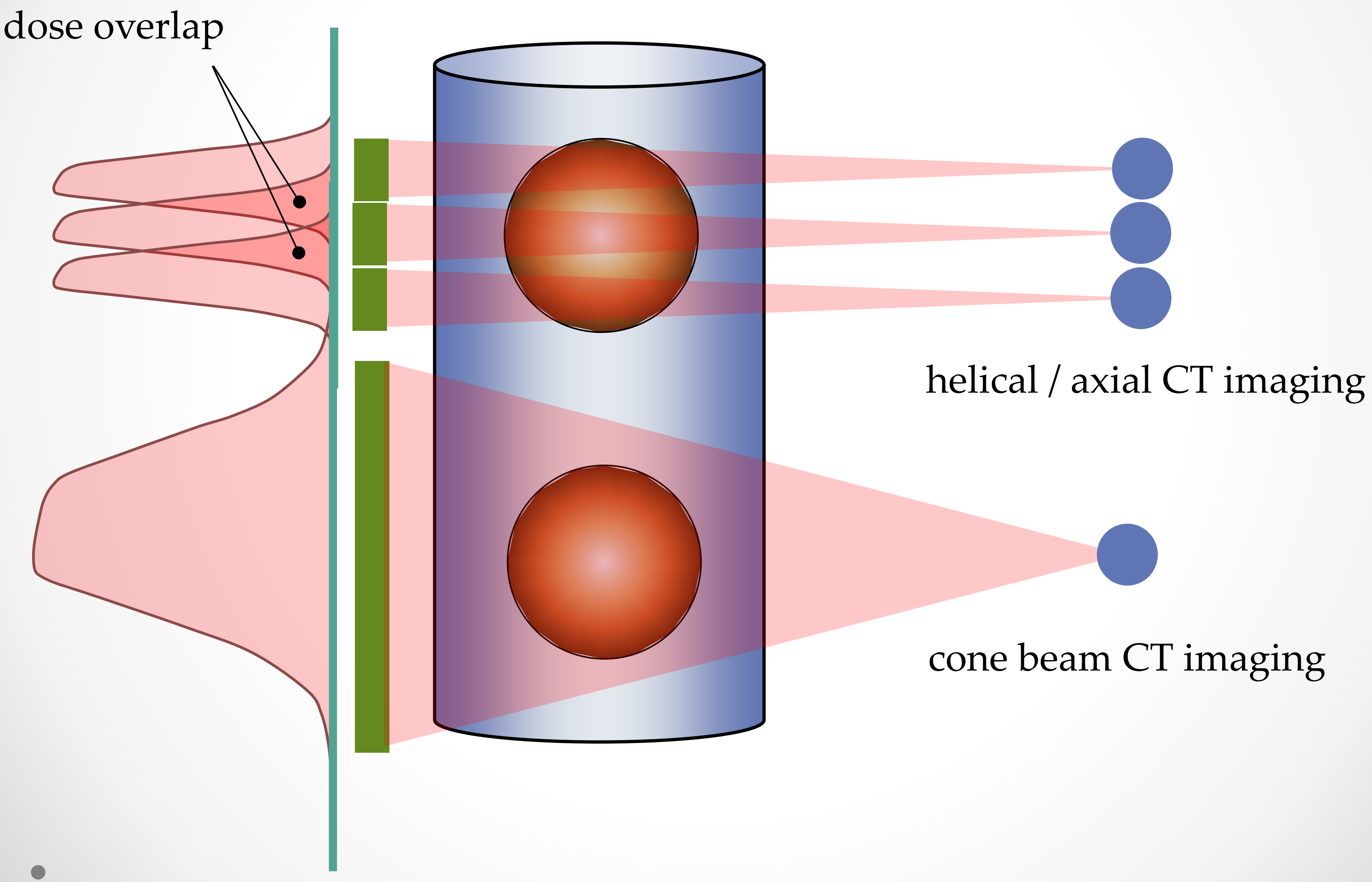
Large FOV



Detector-shifted scan
cone beam scan (>180°)

Cone Beam CT: Benefits and Limitations

radiation dose efficiency



Clinical Applications

- Flat Panel Detectors for Clinical Cone Beam CT

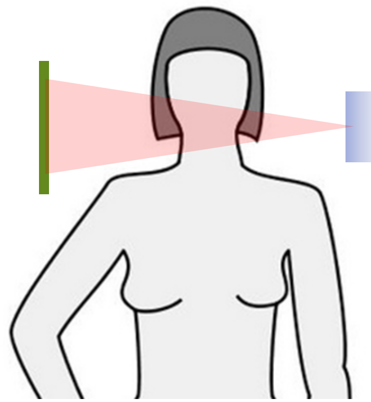
  Cone Beam CT: Benefits and Limitations

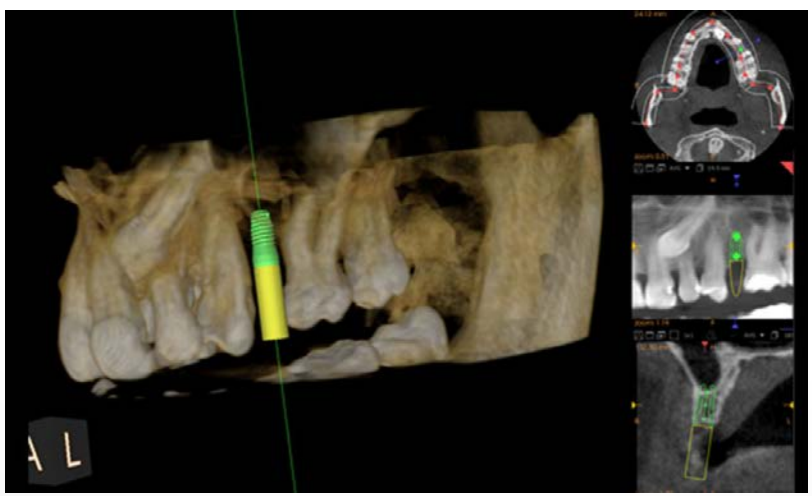
  Applications

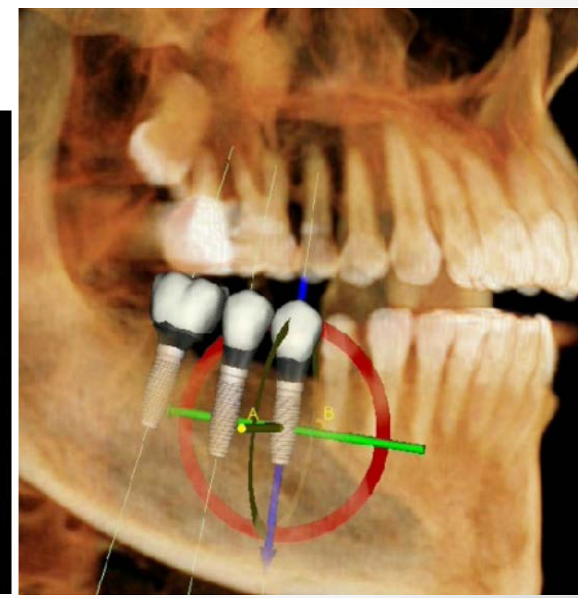
  - Dental
  - SPECT / CT
  - C-arm CT
  - Extremity
  - Radiation Therapy
  - Breast CT

  Summary

Clinical Application: Dental

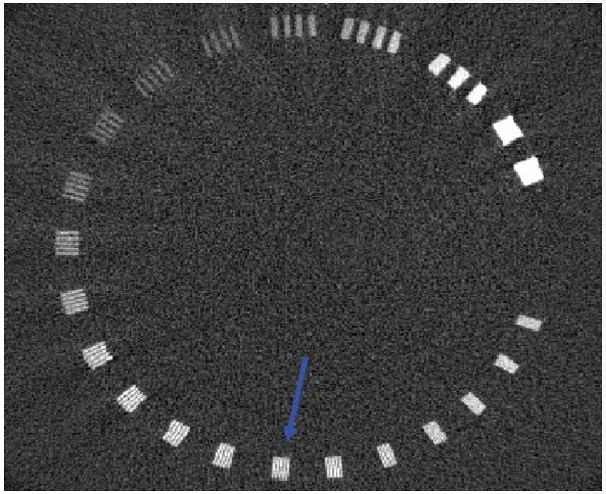


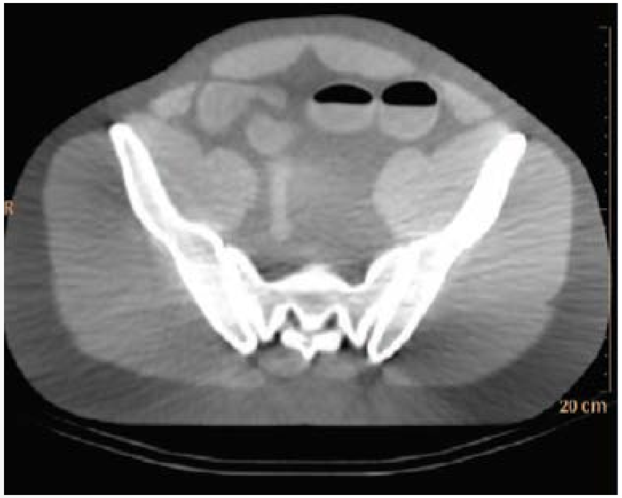


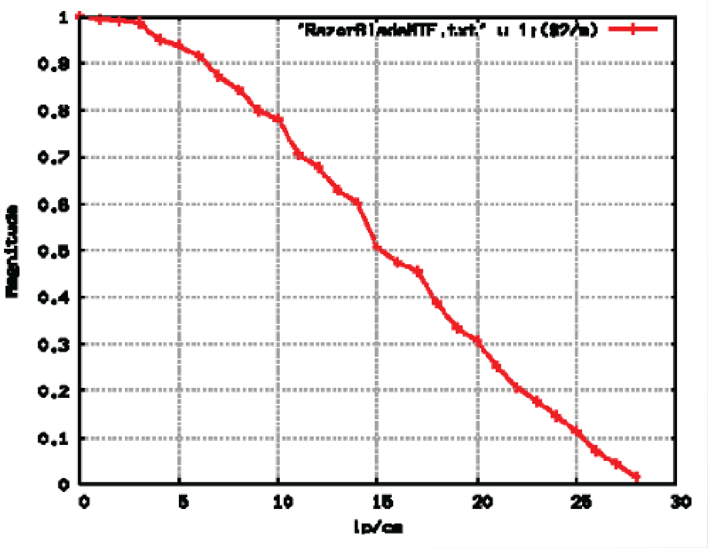


Clinical Application: Head (SPECT/CT) Imaging

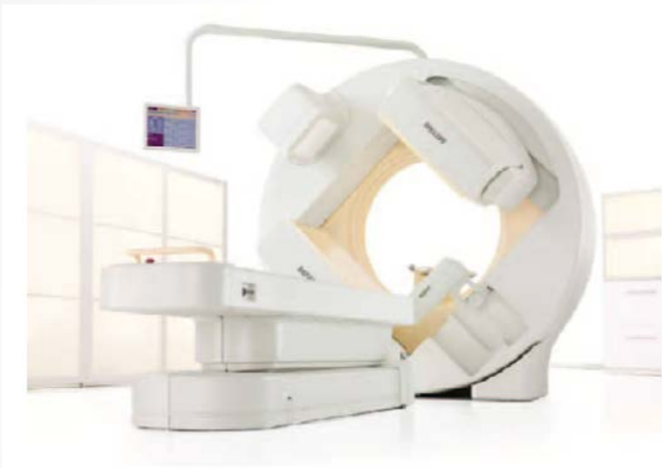
Clinical Application: SPECT / CT

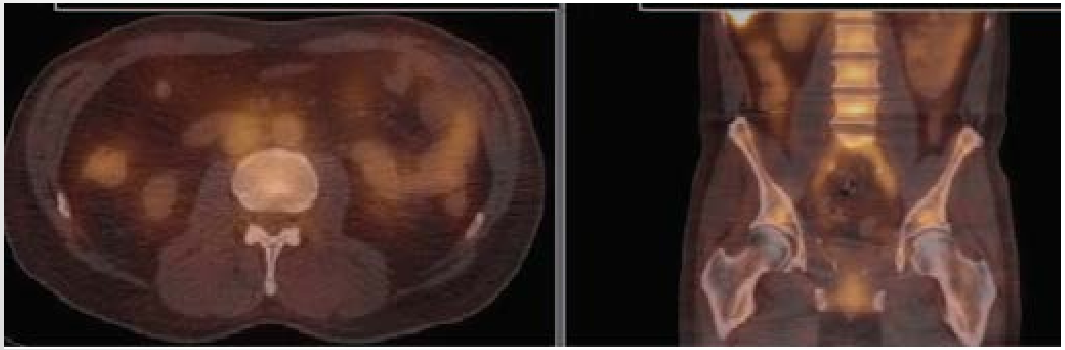


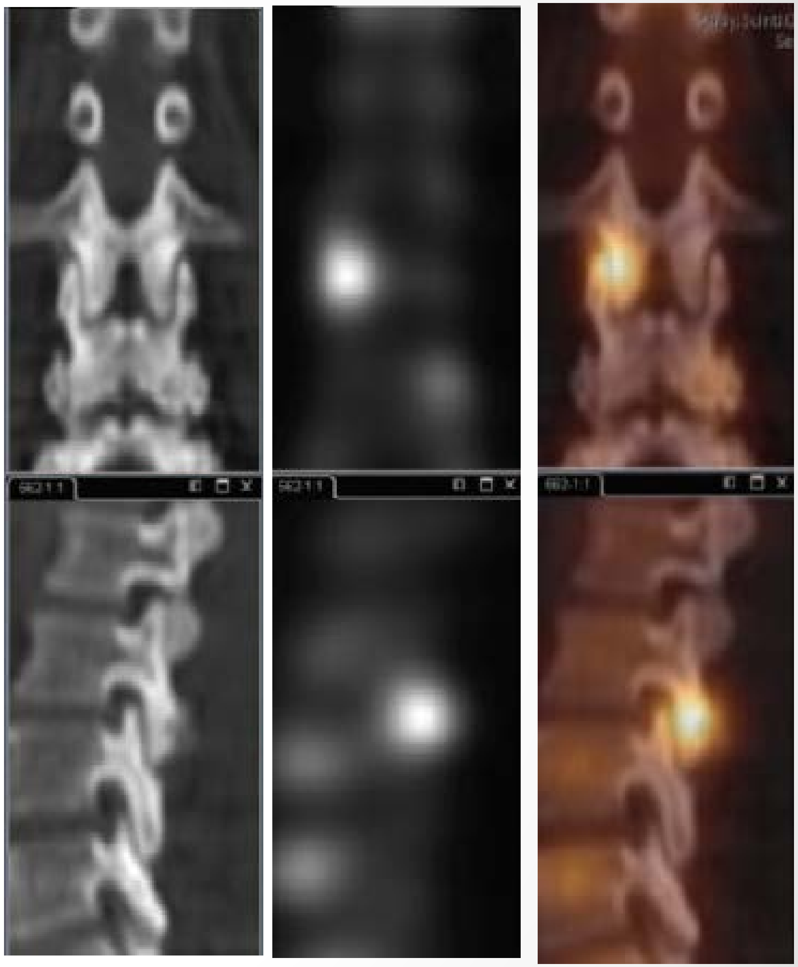




Clinical Application: SPECT / CT





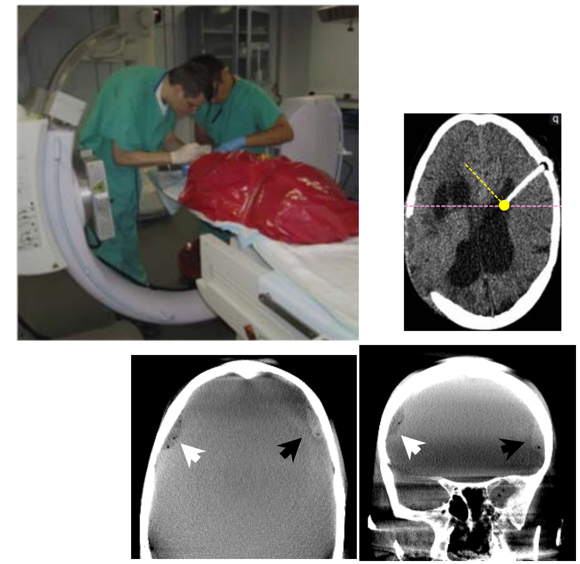


Clinical Application: C-arm / Head

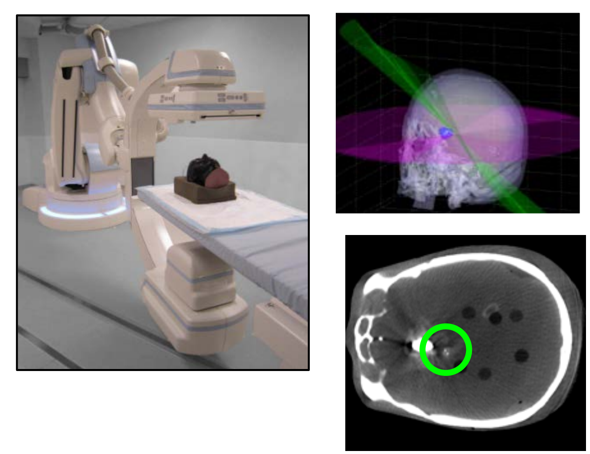
Head & Neck / Skull Base

Base of Tongue (TORS)

Neurosurgery

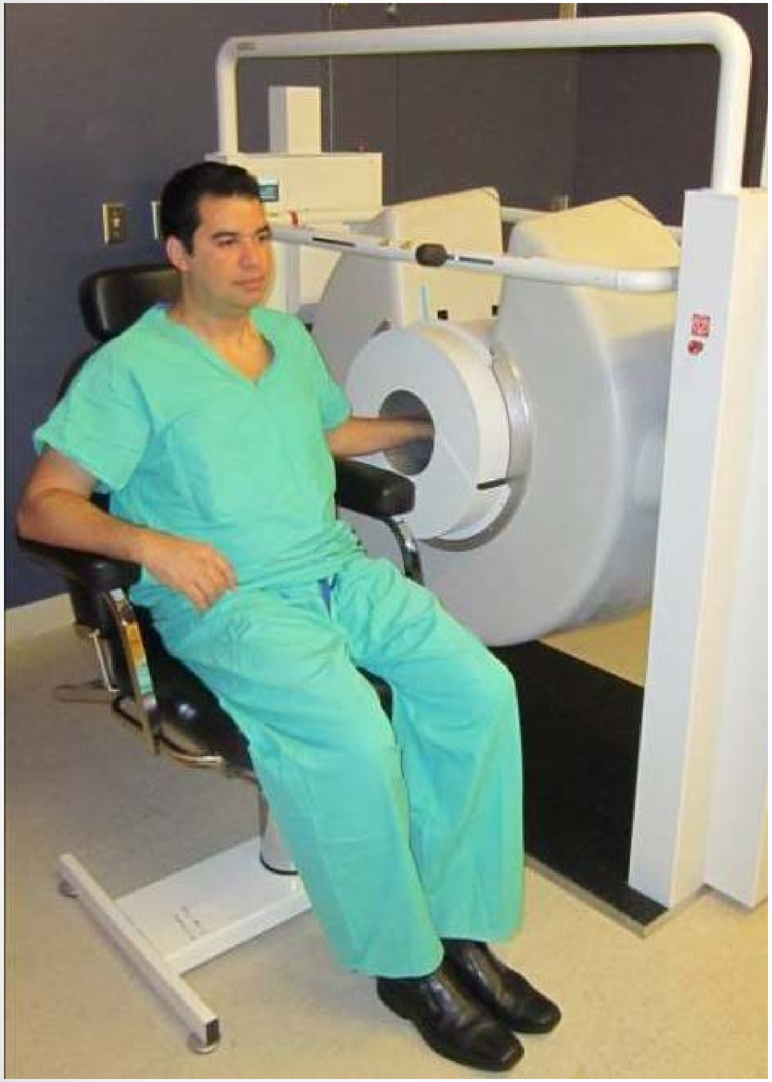


Interventional Radiology

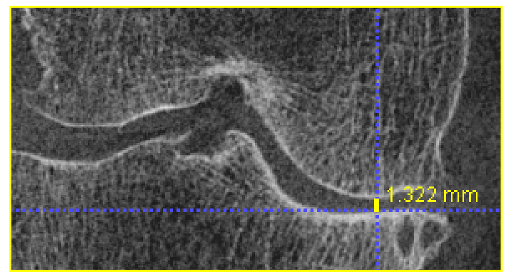


Courtesy: Jeff Siewerdsen (Johns Hopkins University)

Clinical Application: Extremity



Clinical Application: Extremity

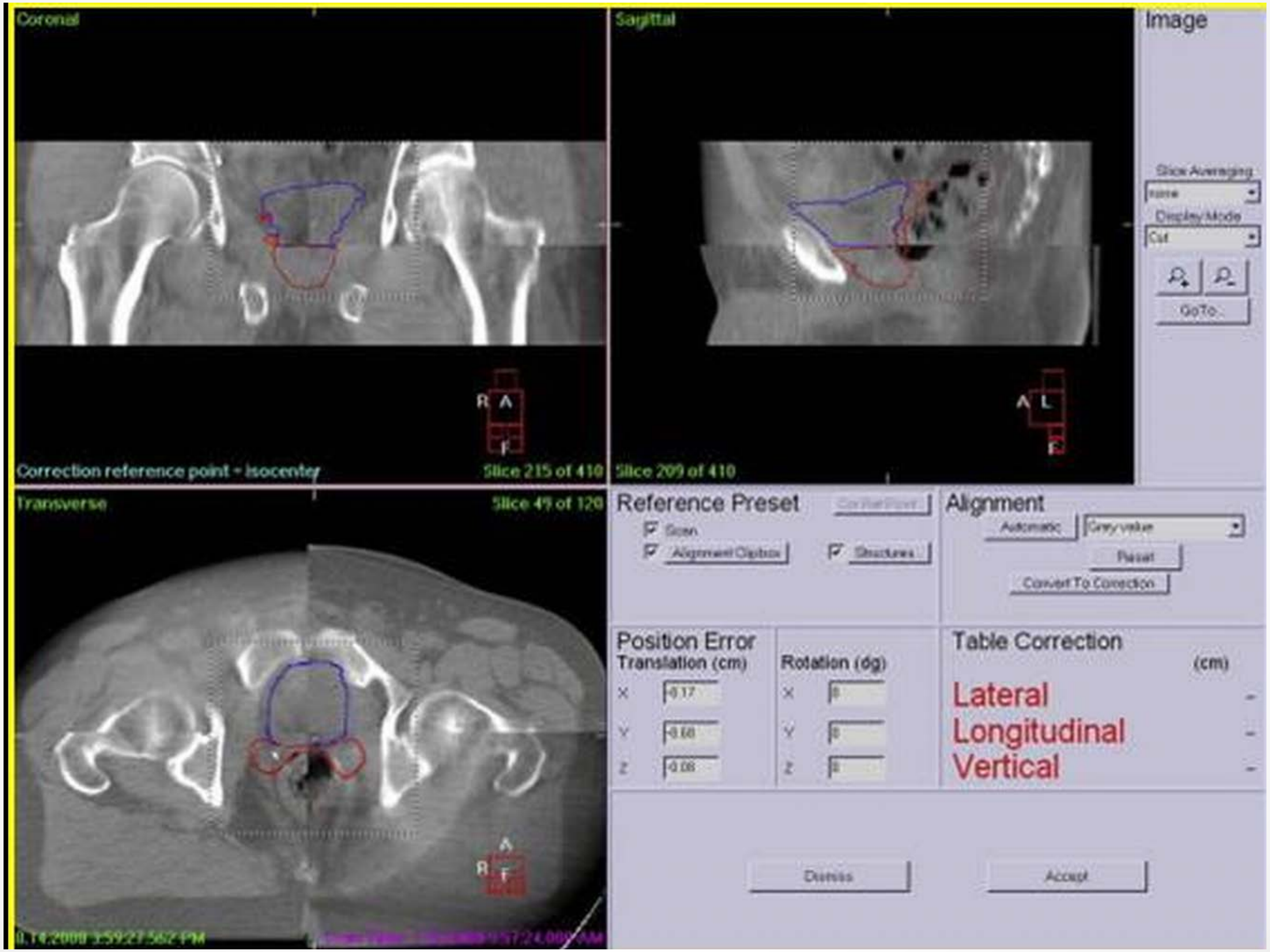


Clinical Application: Radiation Therapy

MV Treatment Beam

kV CT Imaging Beam

Clinical Application: Radiation Therapy
prostate RT positioning images



Clinical Application: Breast CT

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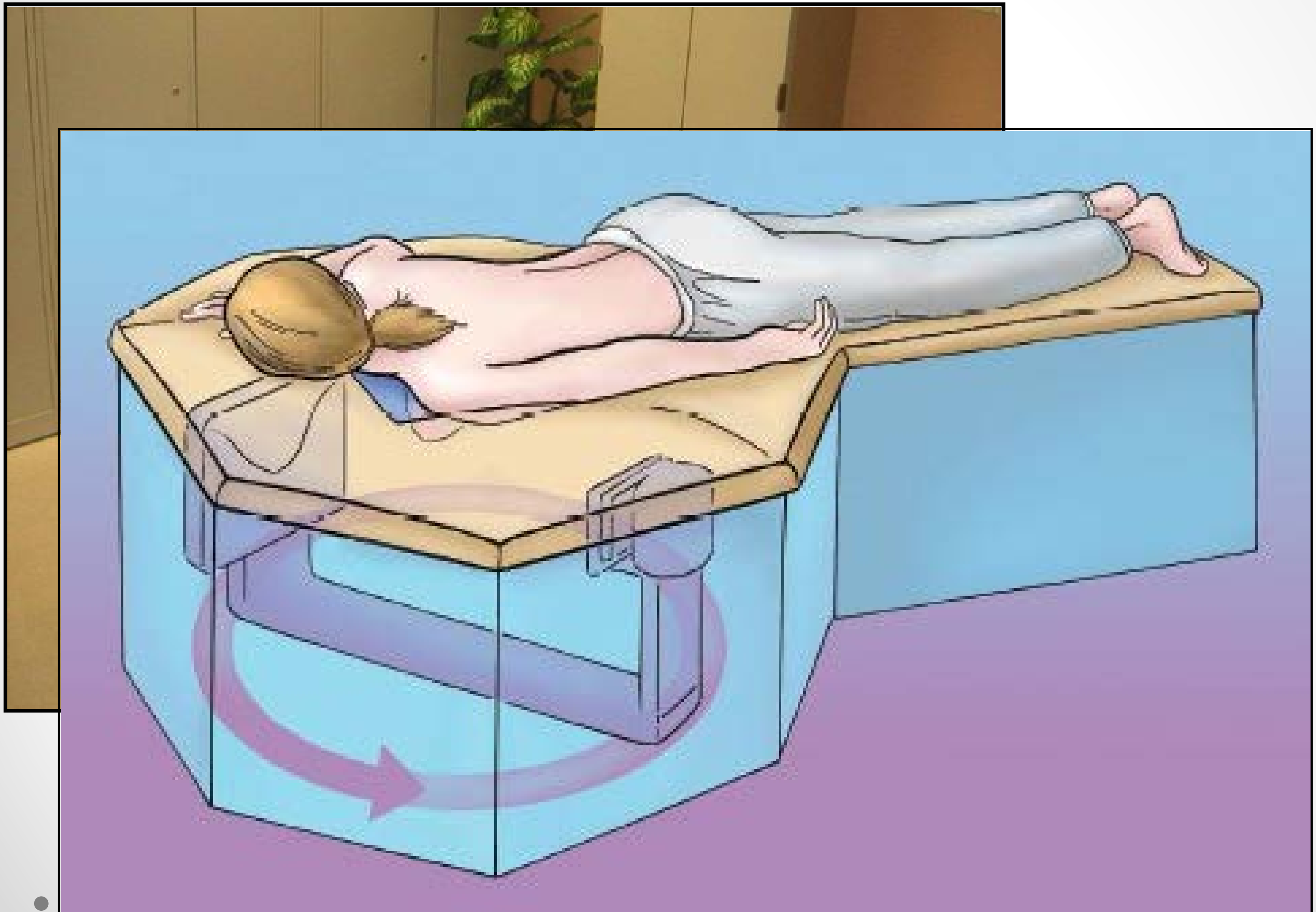
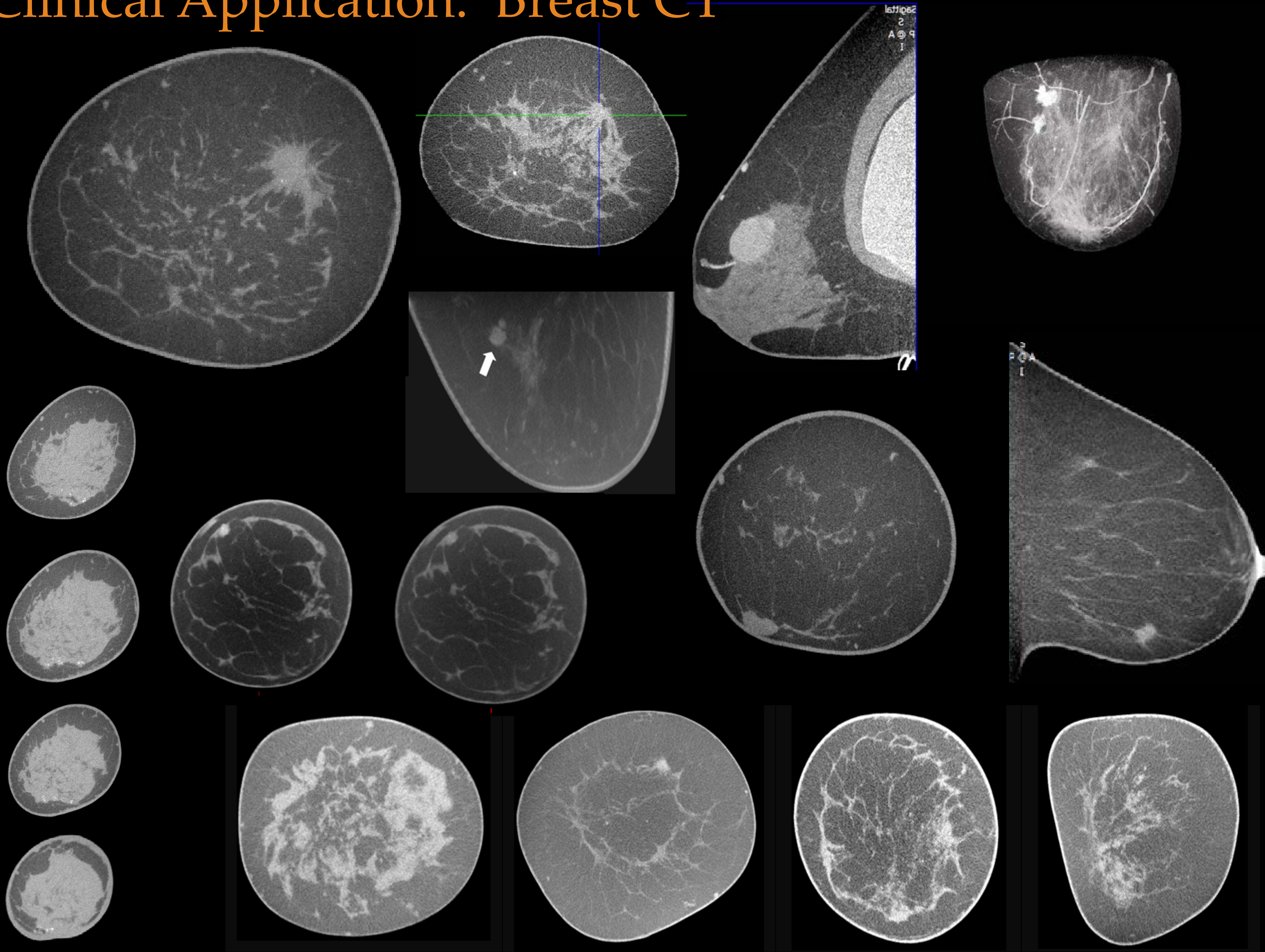


Clinical Application: Breast CT



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    ➡ Summary

Summary: Clinical Applications

Flat Panel Detectors for Clinical Cone Beam CT

CBCT has ~isotropic resolution for small FOV apps

Dose efficiency is high

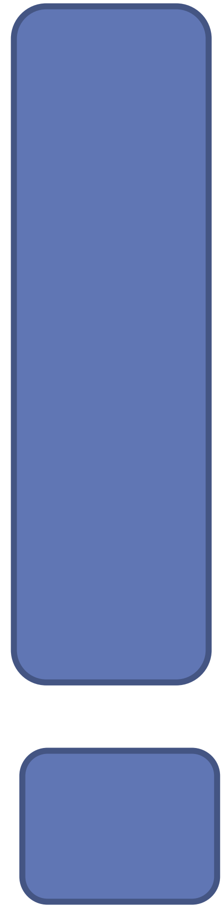
Scatter levels are higher

HU values are typically inaccurate

Cone Beam CT has several important niches

Special thanks to:

Cari Borras', Ph.D.
Jeff Siewerdsen, Ph.D.
Robin Stern, Ph.D.
J. Anthony Seibert, Ph.D.



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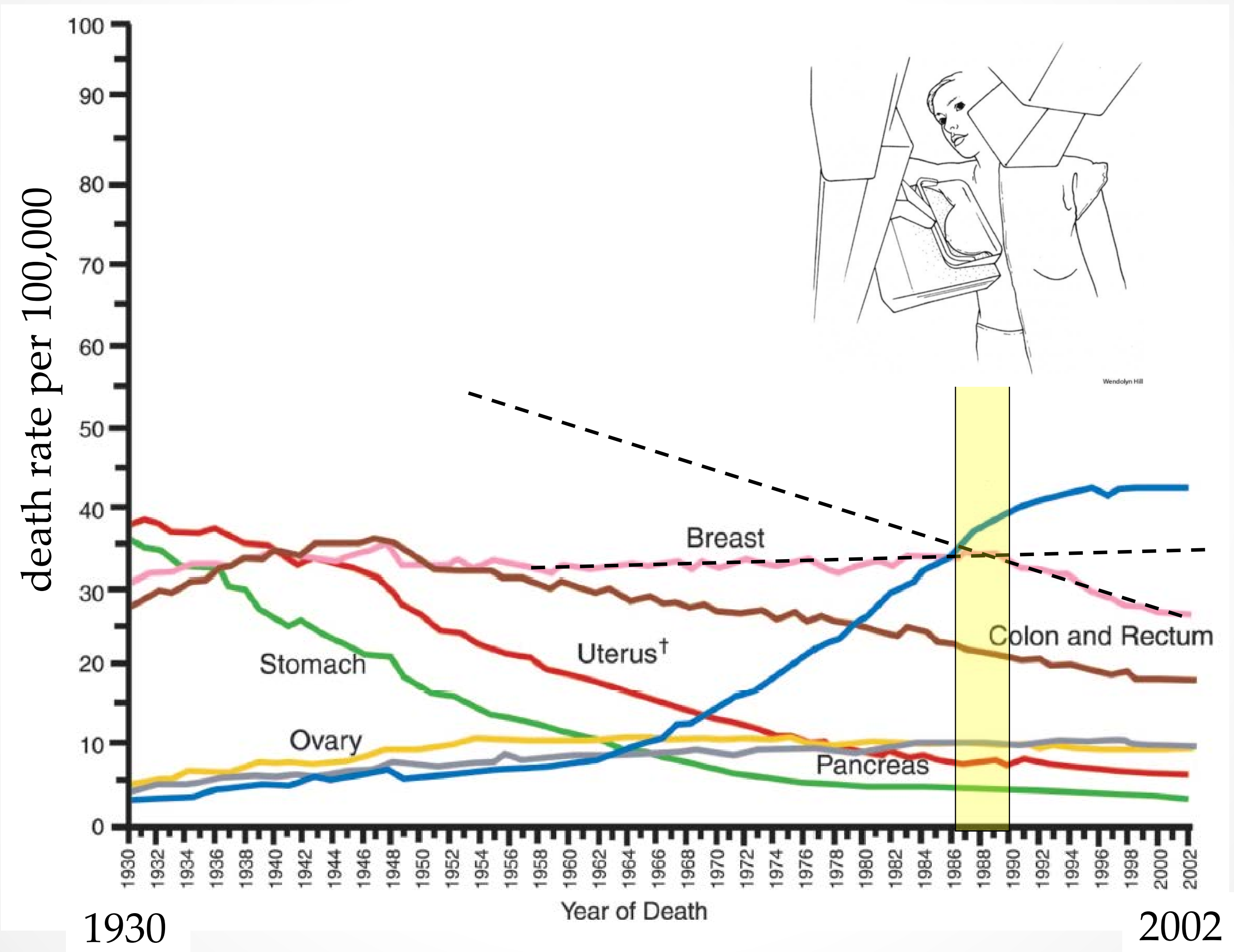
→ Breast CT: The basics

Breast CT: TFT versus CMOS specifications

Preclinical scanner data

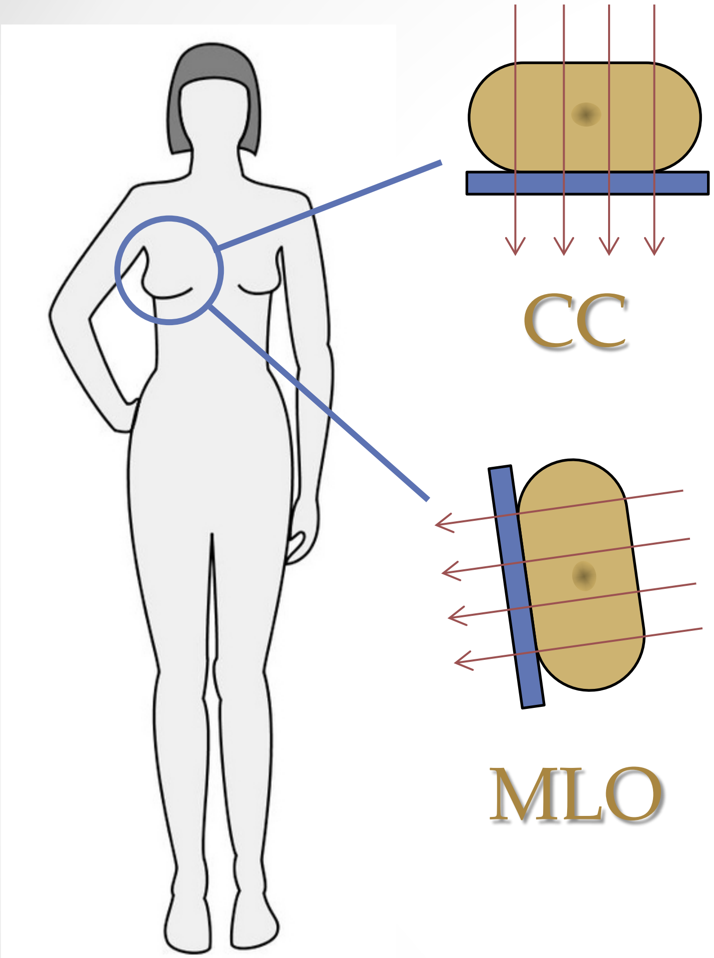
Summary

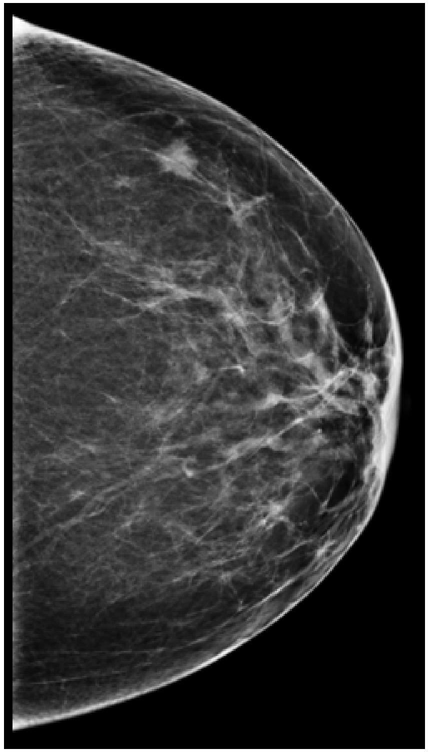
Cancer Incidence and Screening



Jemal A, *et al.*, Cancer Statistics 2006

Mammography: Standard of Care



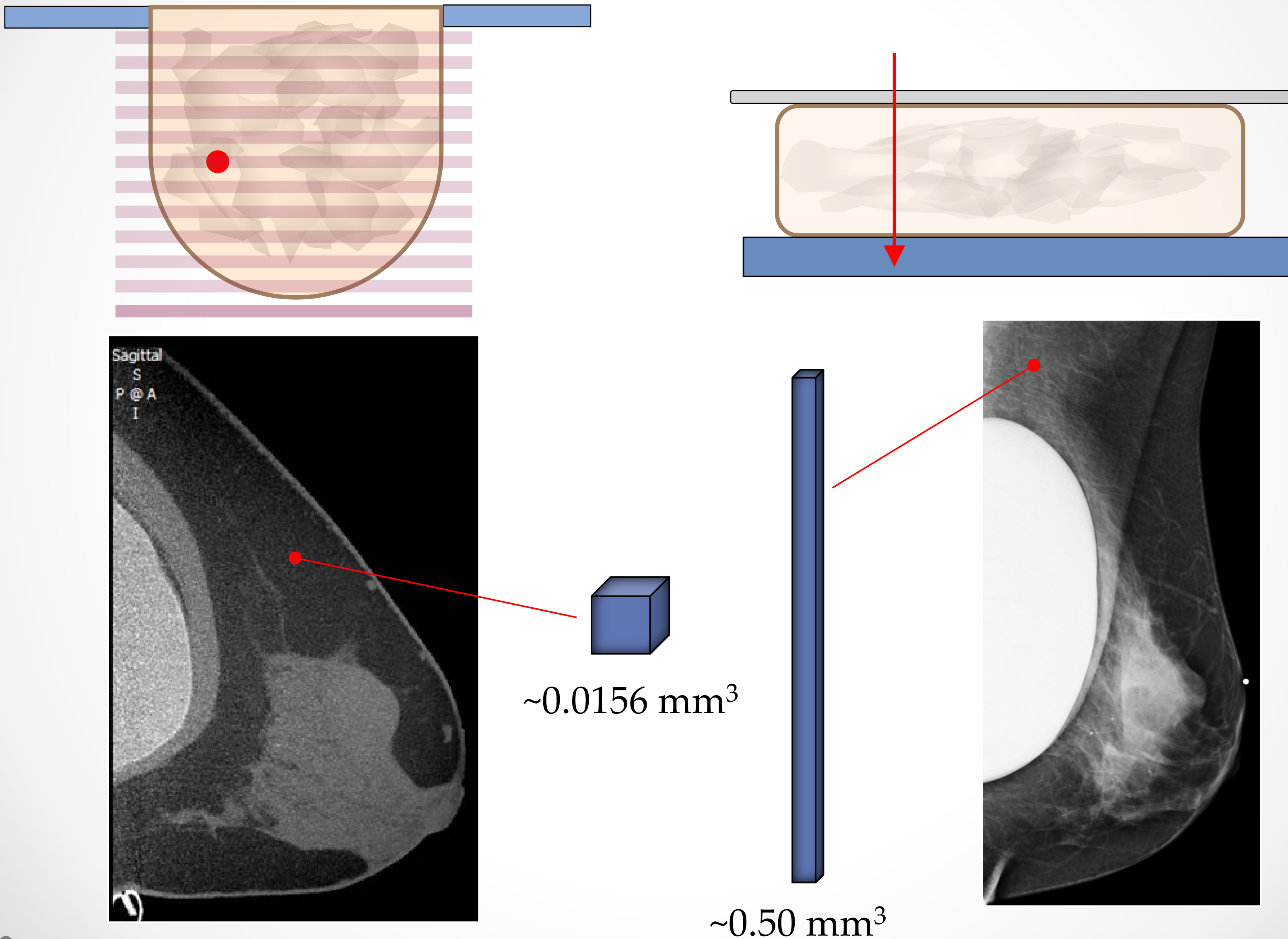


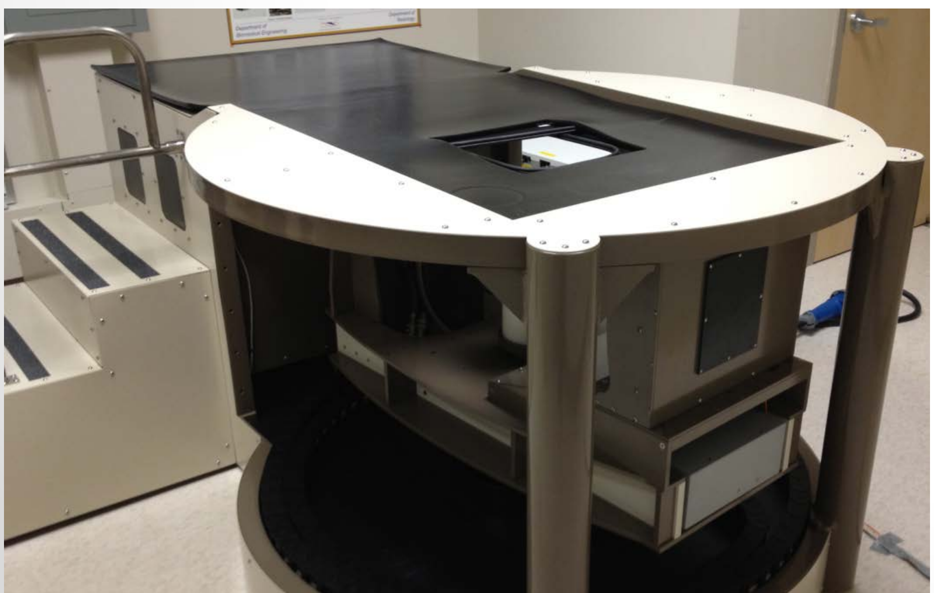
CC

MLO

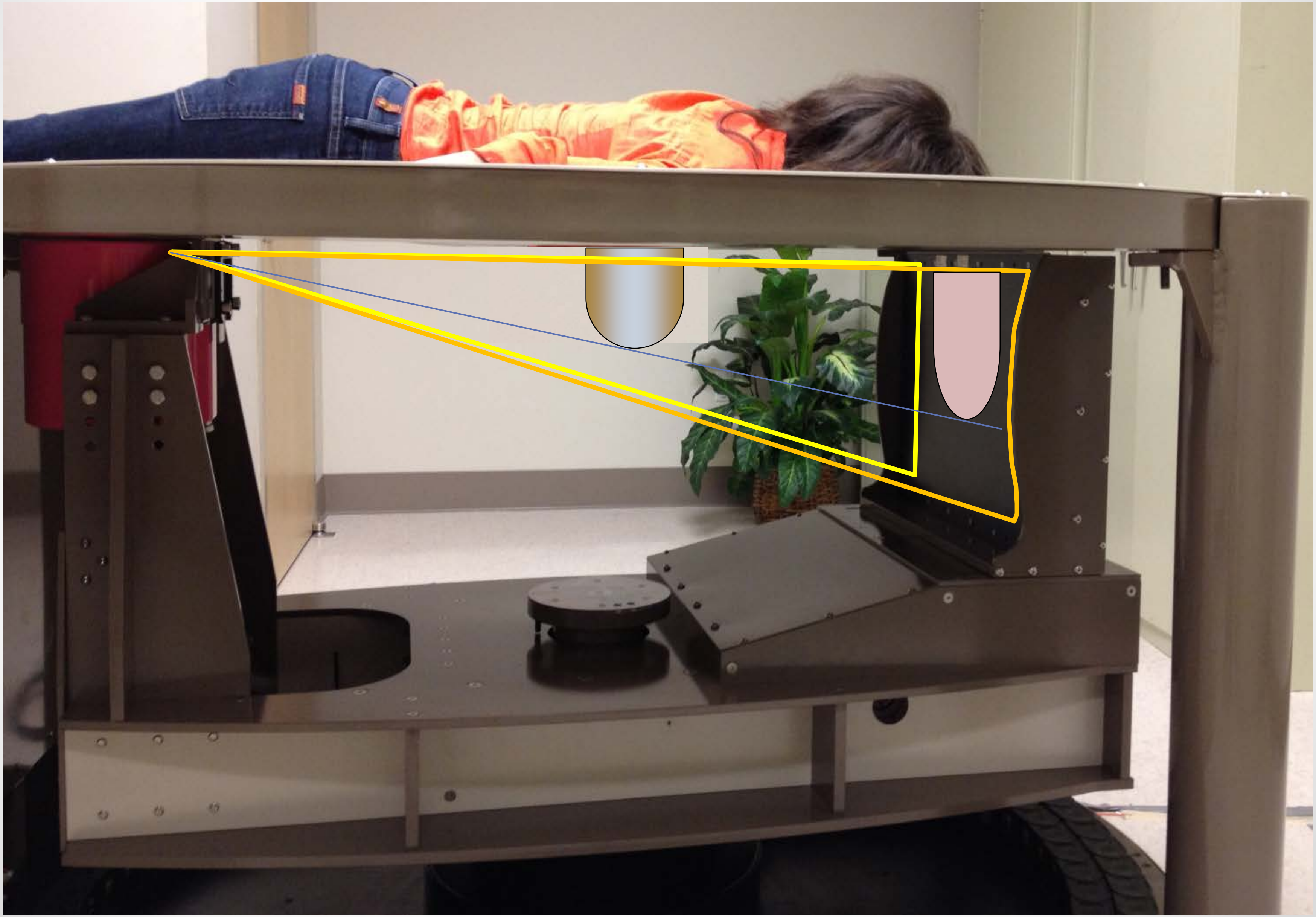
Breast CT

Mammography

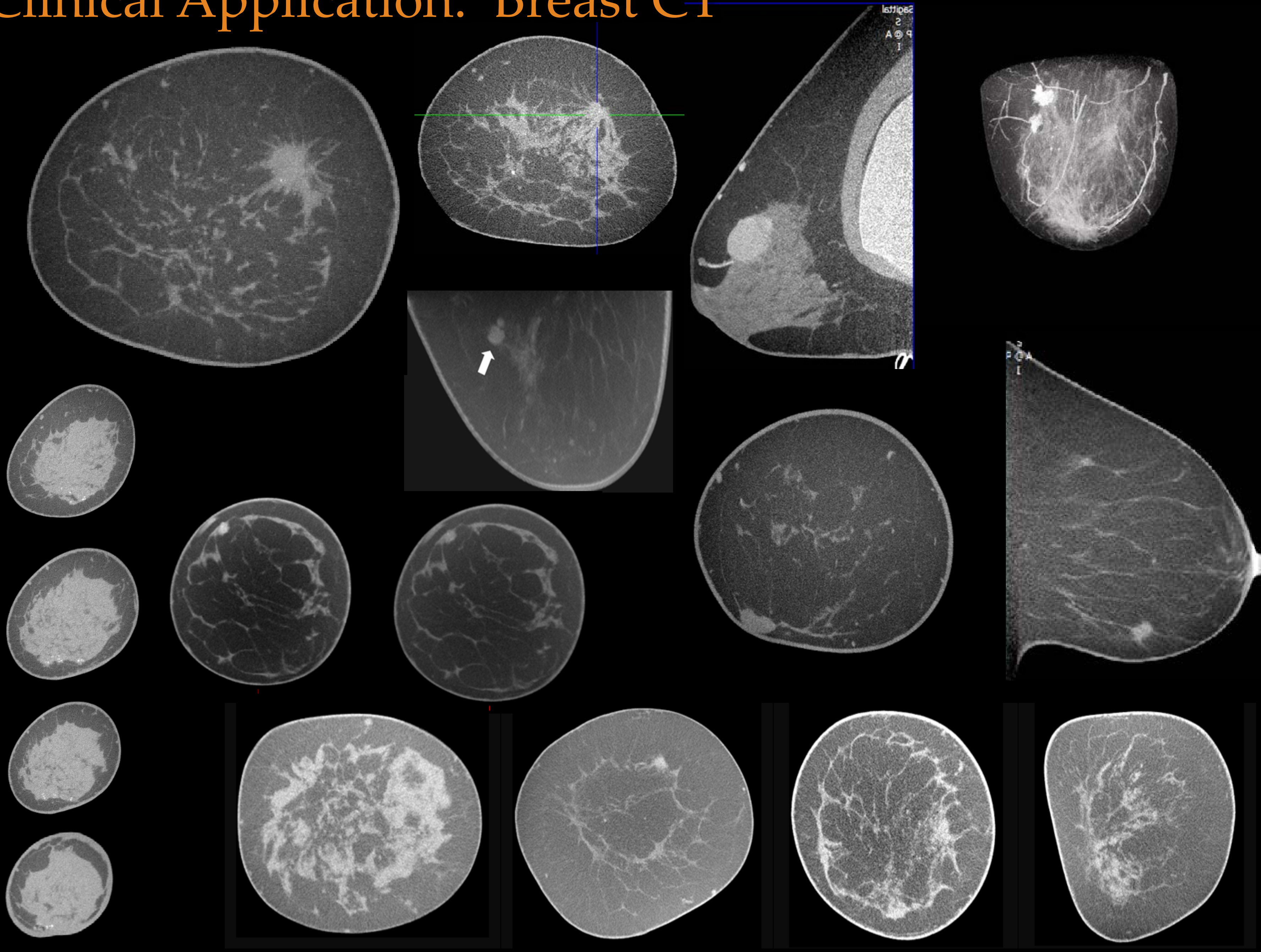




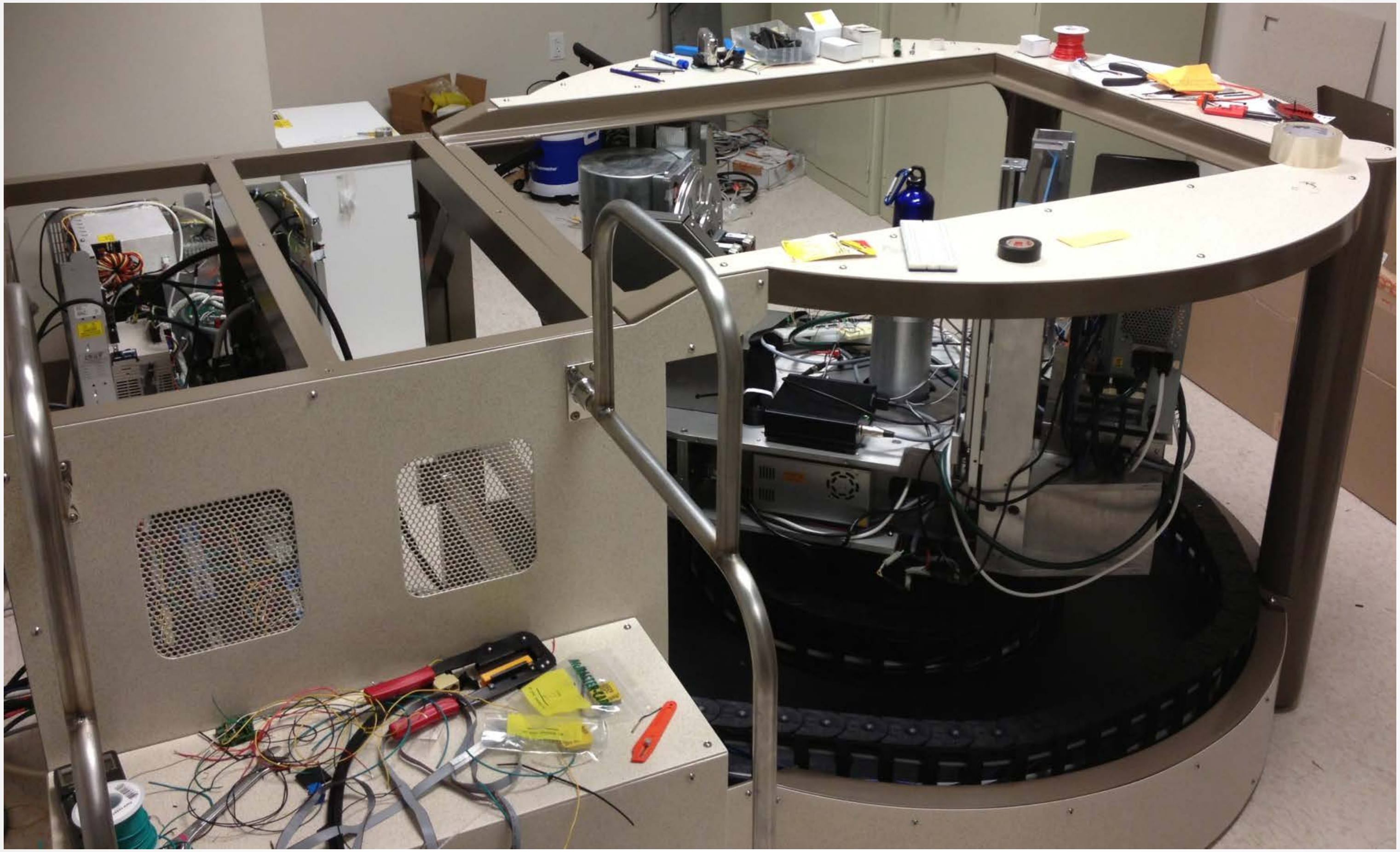
Half Cone Beam CT Geometry



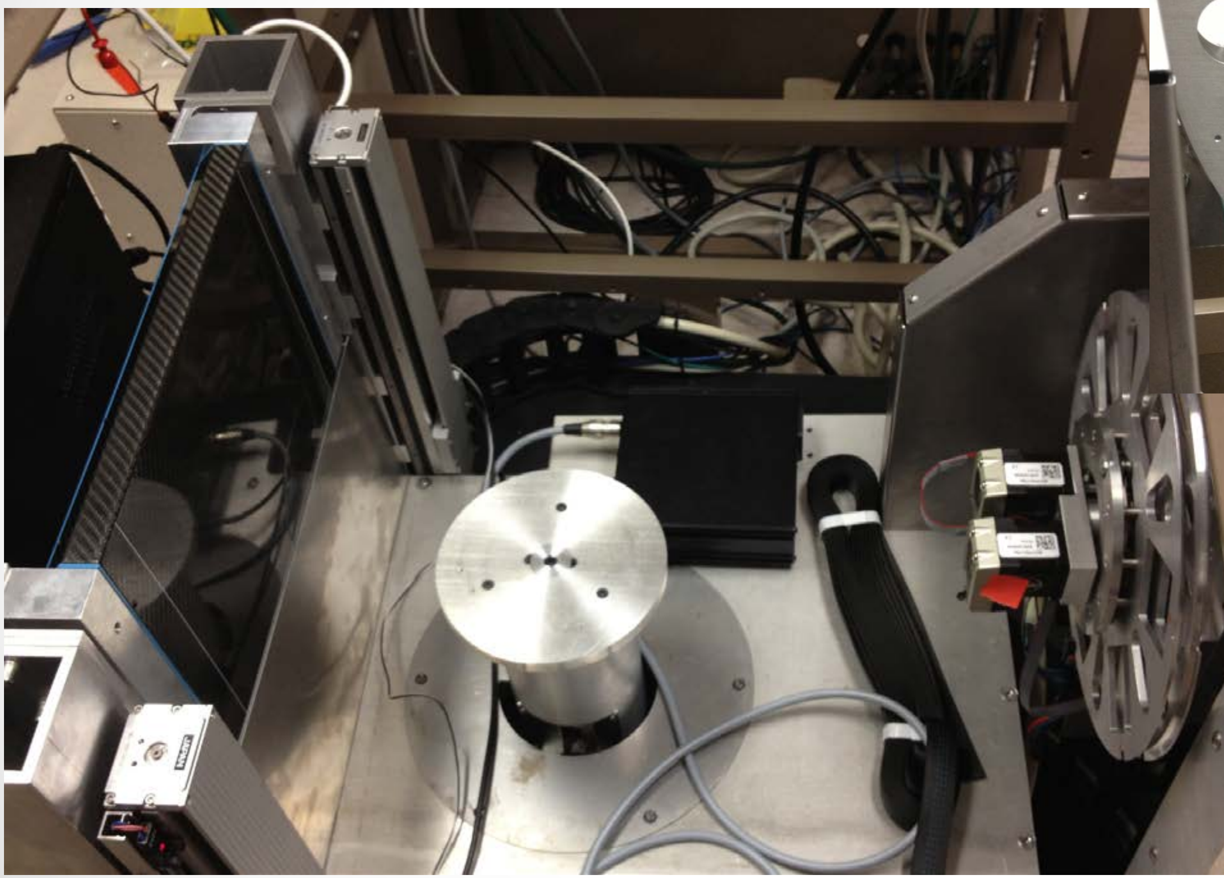
Clinical Application: Breast CT



Fabrication of "Doheny", 4th bCT system at UC Davis



CMOS detector mounted on Breast CT scanner (UC Davis)



filter and collimator wheels in front of x-ray source

Clinical Applications

- CMOS Detectors for Breast CT

Breast CT: The basics

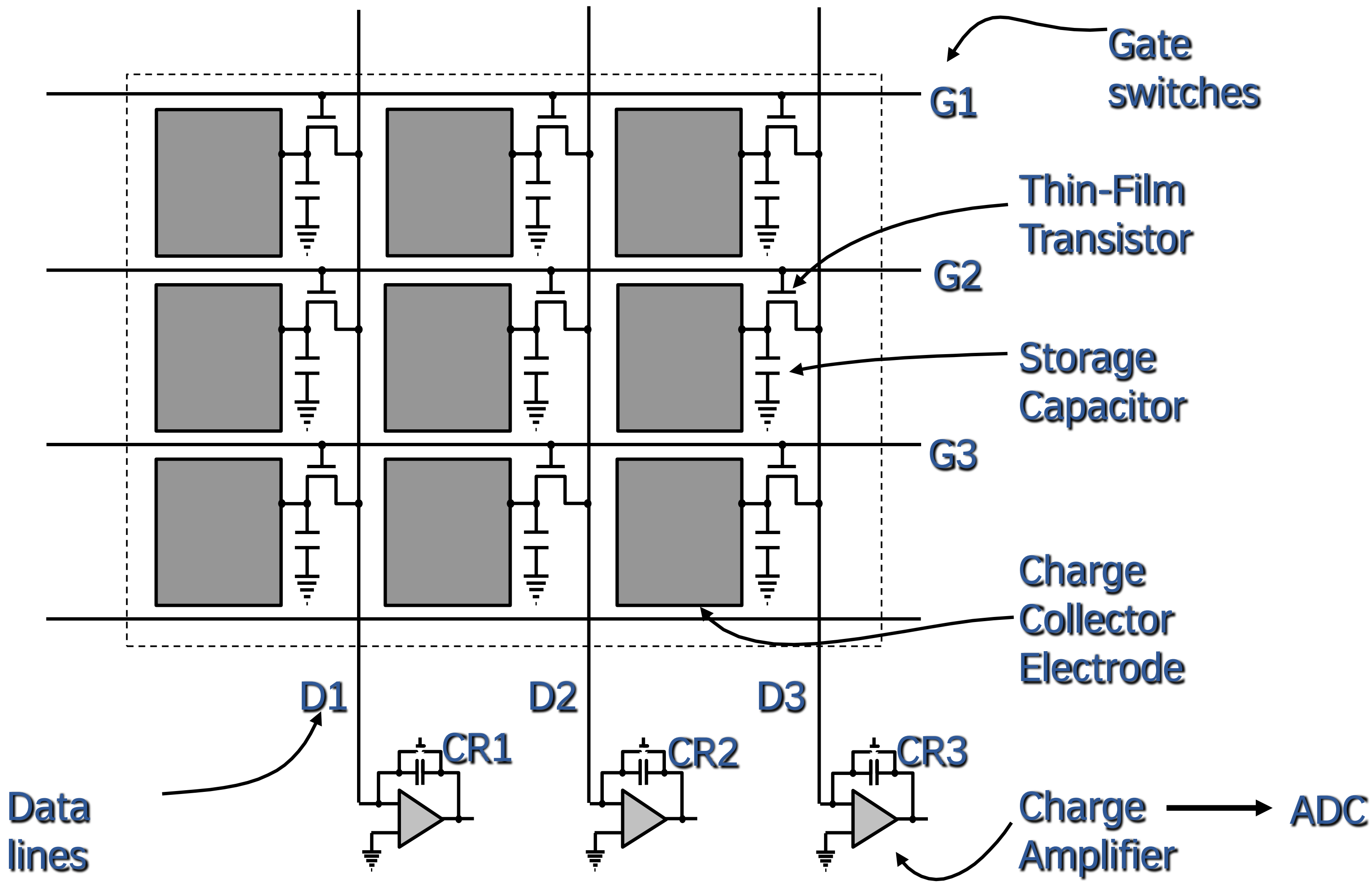
➡ Breast CT: TFT versus CMOS specifications

Preclinical scanner data

Summary

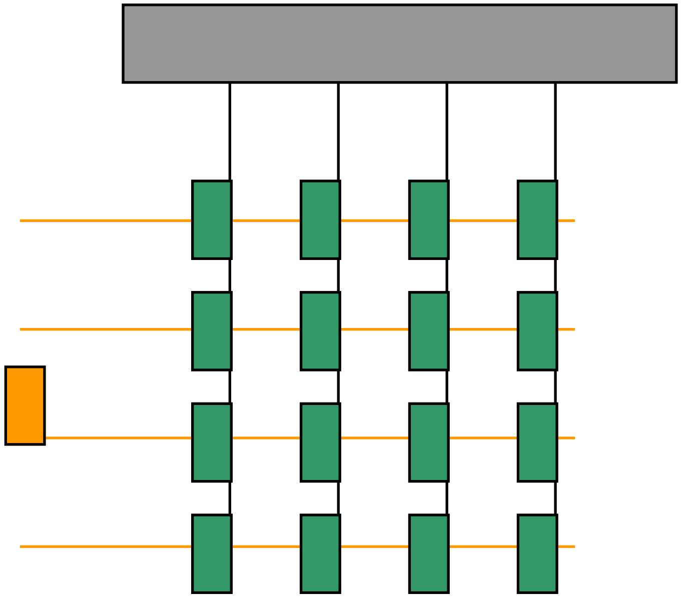
Breast CT: TFT versus CMOS

<u>TFT</u> Design and Operation



Breast CT: TFT versus CMOS

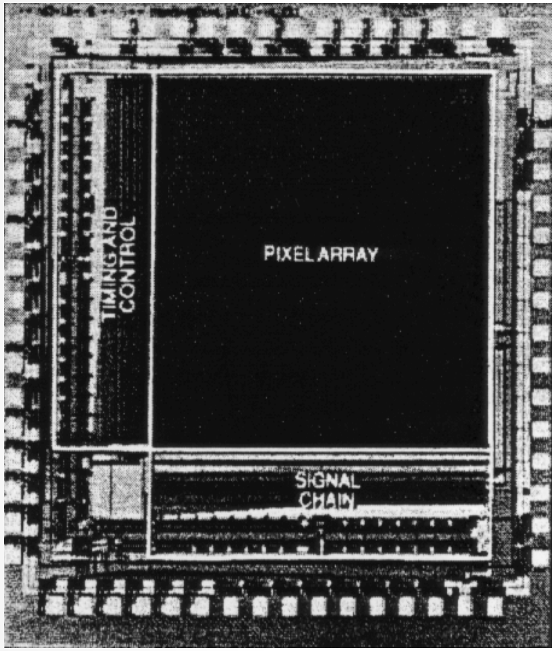
CMOS Design and Operation



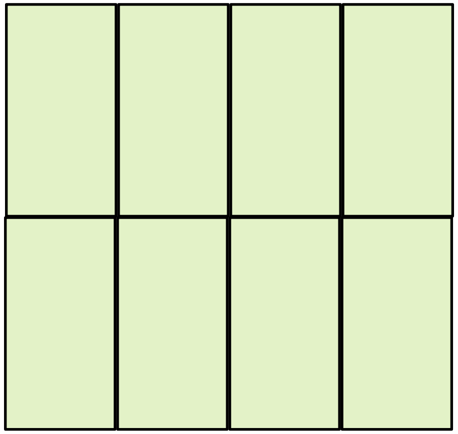
detector elements are individually addressable

Breast CT: TFT versus CMOS

CMOS Design and Operation



photomicrograph



29 cm x 23 cm CMOS
mosaic of several CMOS units

CMOS is essentially a computer chip

Breast CT: TFT versus CMOS

Fundamental Comparisons

Thin Film Transistor detector	CMOS detector
monolithic amorphous silicon	mosaic crystalline silicon chips
large field of view	small field of view
large dark current levels	low dark current levels
slower read-out rates	faster read-out rates
not directly addressable	directly addressable

Experimental CBCT system

PARAMETERS	Varian	Dexela
X-ray absorber	aSi/CsI	CMOS/CsI
Matrix size	2048 × 1536	3888 × 3072
Data depth	14 bit	14 bit
Intrinsic pixel size	194 μm	75 μm
Active image area	40 × 30 cm^2	29 × 23 cm^2
Frame rate at full resolution	7.5 fps	26 fps
Source-to center (SCD)	88 cm	88 cm
Source-to-detector (SID)	135 cm	108 cm
Magnification (SID/SCD)	1.53	1.23
Nominal focal spot size	0.3 mm	0.3 mm
kVp	80 kVp	80 kVp

Clinical Applications

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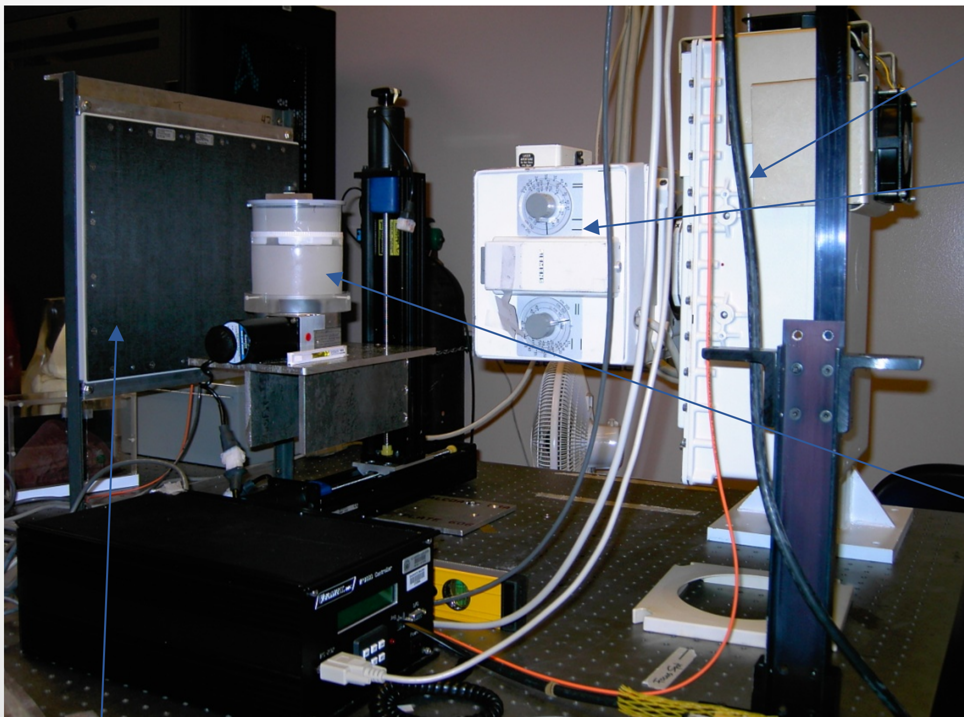
Breast CT: The basics

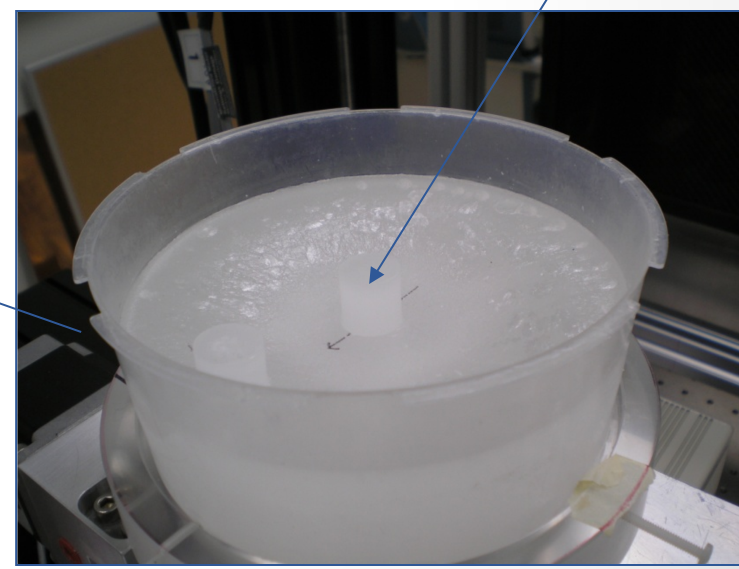
Breast CT: TFT versus CMOS specifications

➡ Preclinical scanner data (MD Anderson)

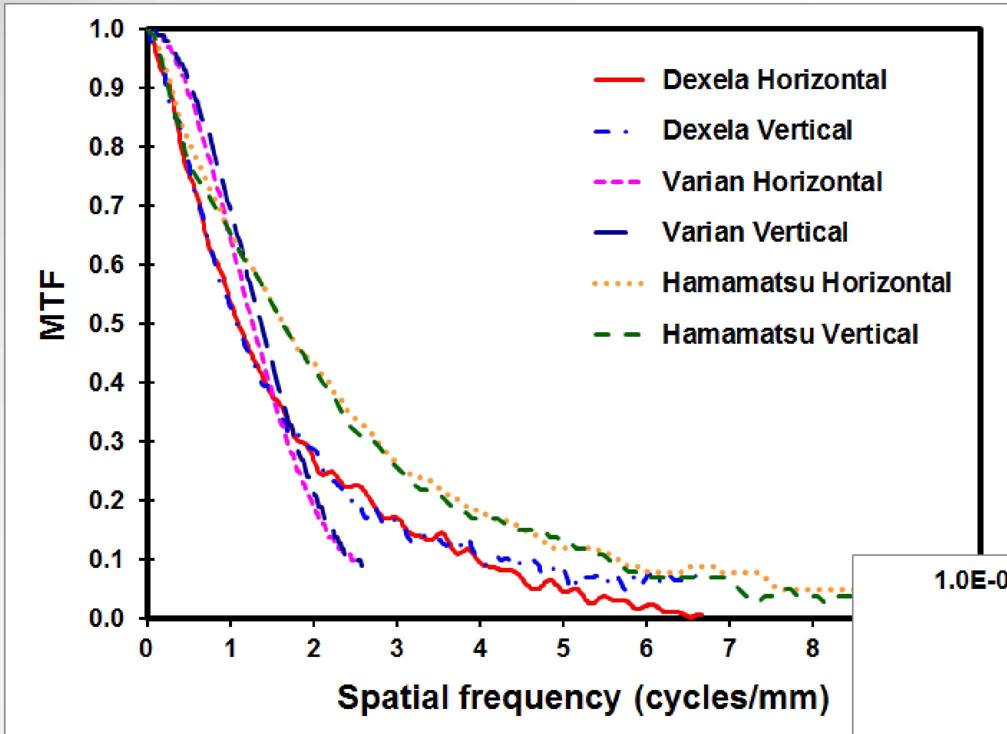
Summary

Experimental Setup

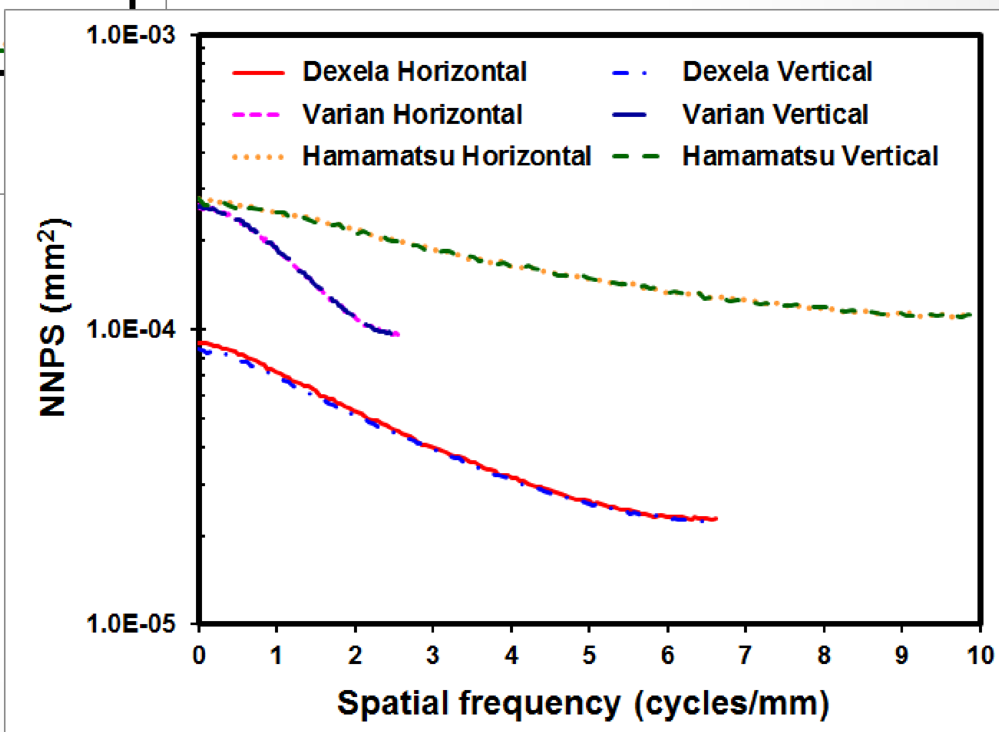




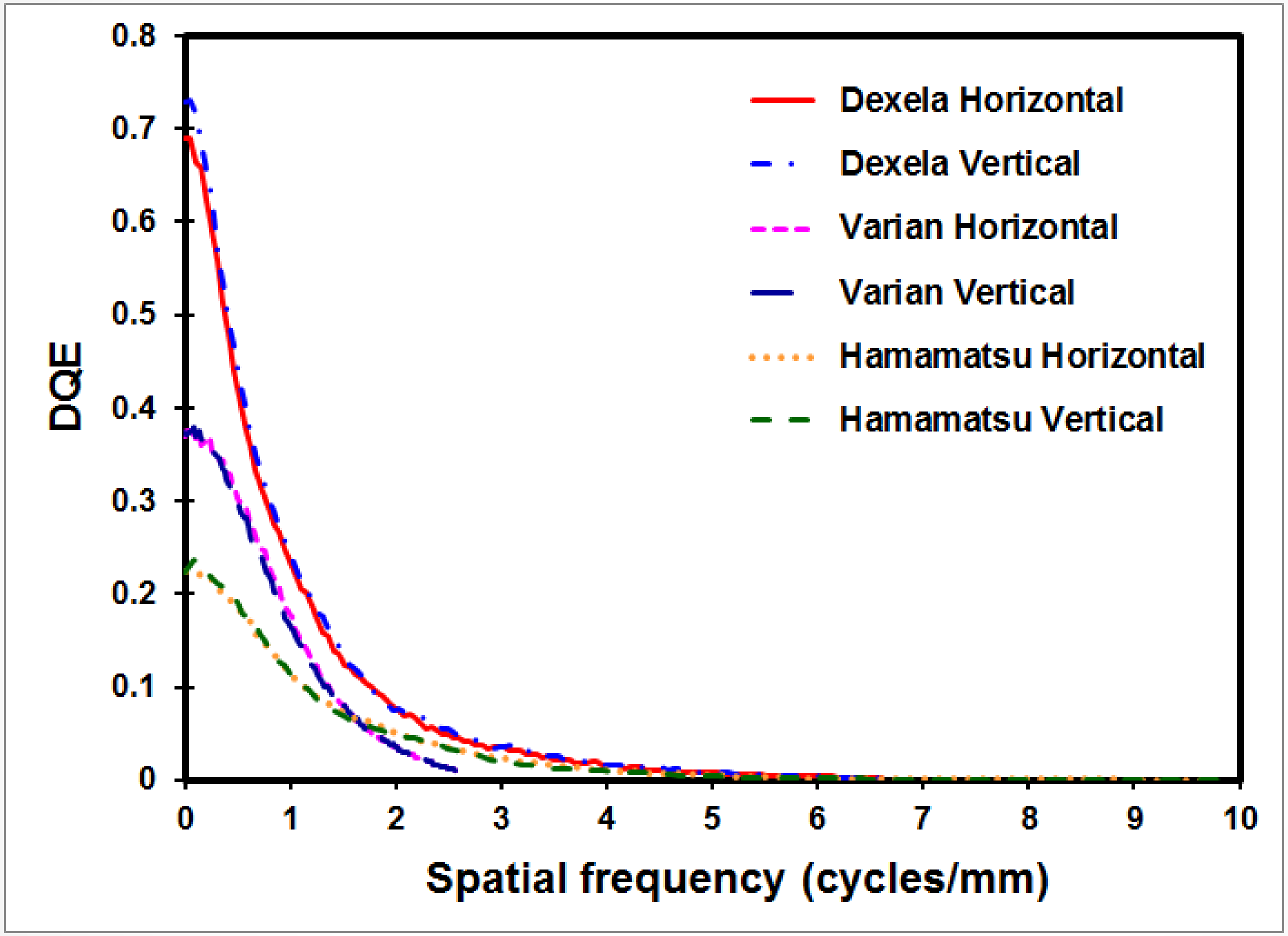
Modulation Transfer Function (MTF)



Normalized Noise Power Spectrum (NNPS)

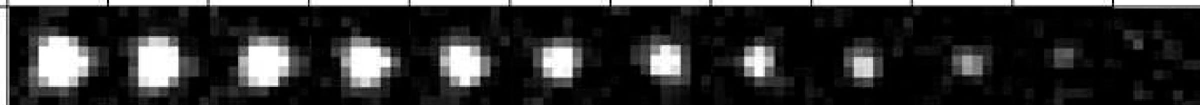
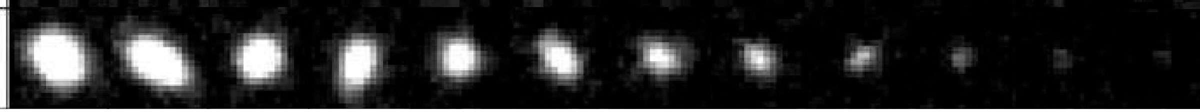


Detective Quantum Efficiency (DQE)

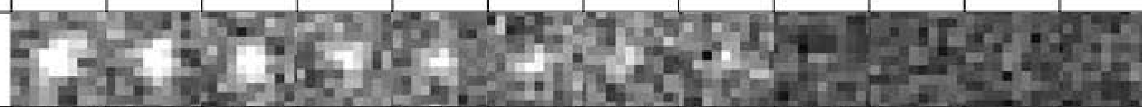
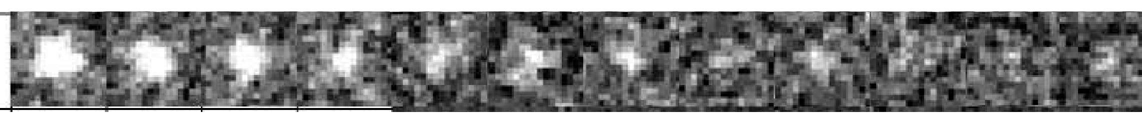


CBCT images of Al wires

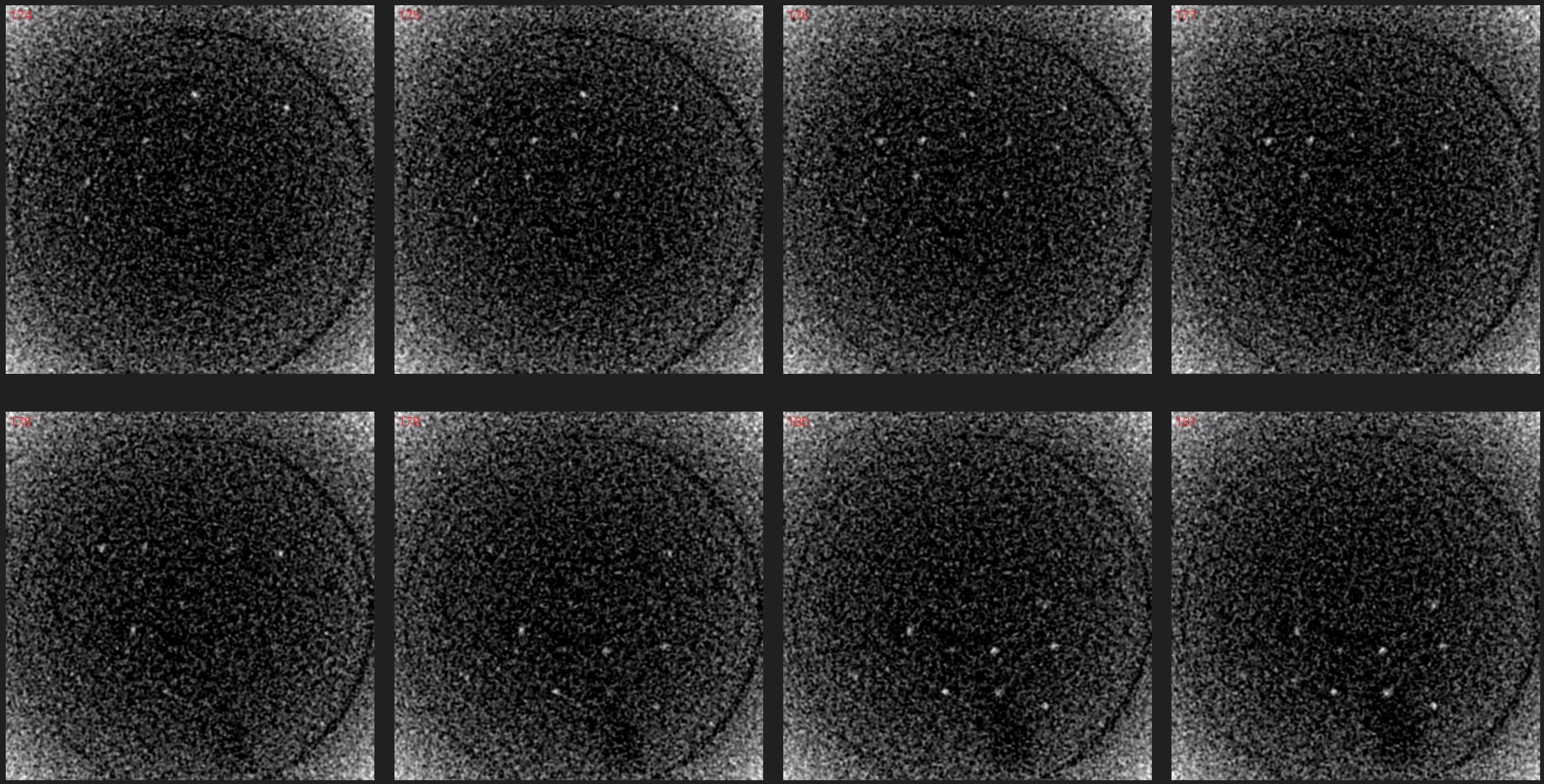
in air

Al wire diameter (µm)	356	305	279	254	229	203	178	152	127	102	76	51
TFT												
CMOS												

in wax

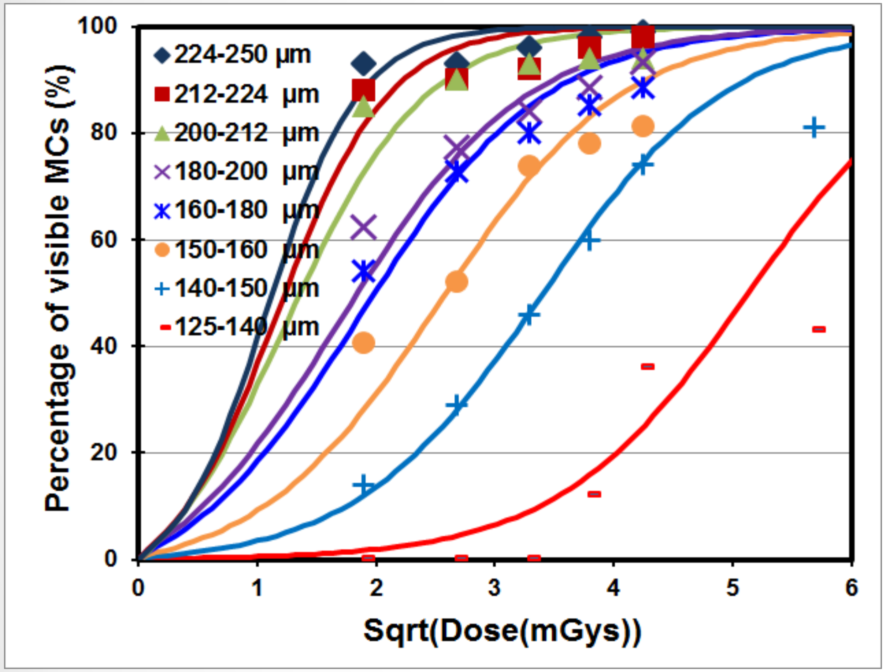
Al wire diameter (µm)		356	305	279	254	229	203	178	152	127	102	76	51
TFT	3.6mGys												
CMOS	3.6mGys												

microcalcification phantoms

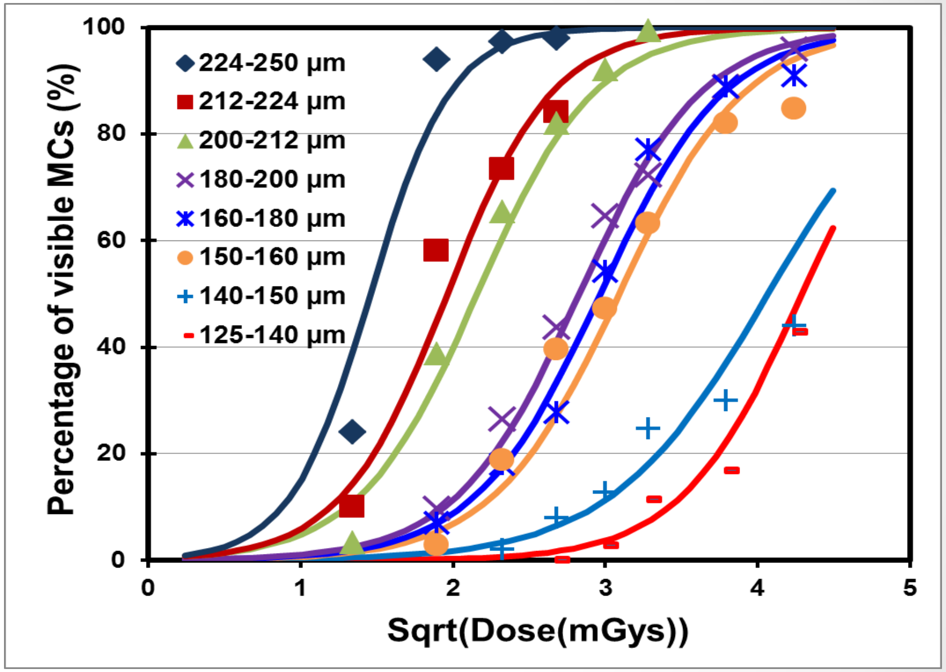


Microcalcification visibility vs MGD

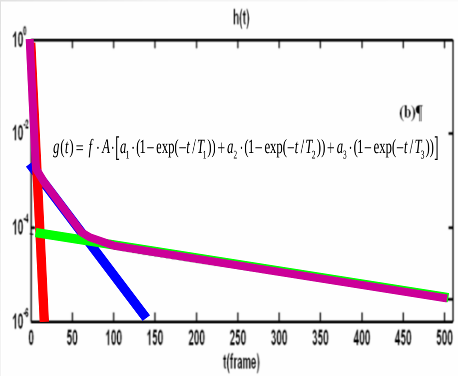
CMOS

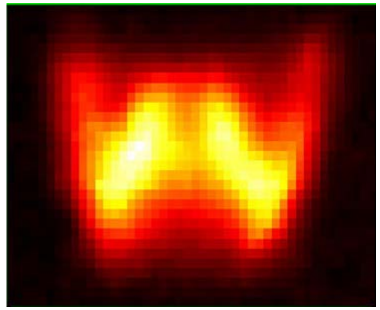


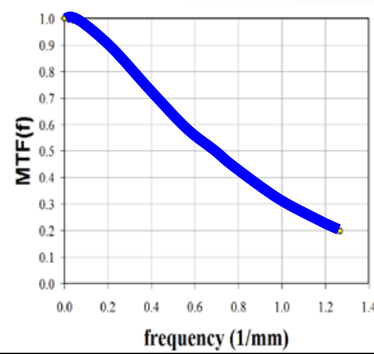
TFT

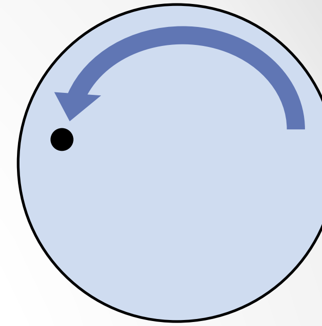


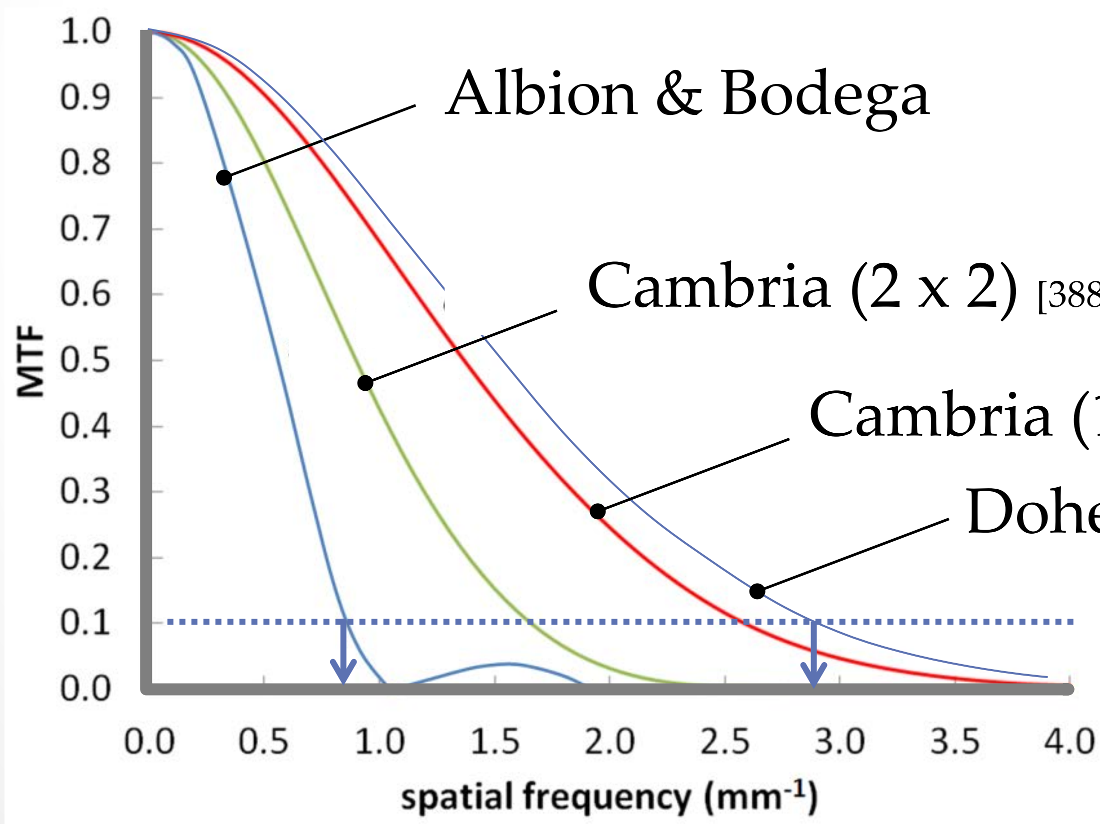
Spatial Resolution: Modeled & Measured











3X Spatial Resolutio n

Clinical Applications

- CMOS Detectors for Breast CT

Breast CT: The basics

Breast CT: TFT versus CMOS specifications

Preclinical scanner data

Summary

Clinical Applications: Summary

- CMOS Detectors for Breast CT

CMOS detectors outperform TFT detectors in terms of:

Spatial Resolution
Frame Rate
Electronic Noise

TFT Detectors are a proven technology in Breast CT

CMOS detectors are being integrated into a Breast CT Research Labs

MD Anderson Cancer Center (Chris Shaw) – table top system
UC Davis (John Boone) – patient imaging system

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Tianpeng Wang, Ph.D.

MD Anderson Cancer Center, Houston TX

Clinical Applications

- Flat Panel Detectors for Clinical Cone Beam CT
- CMOS Detectors for Breast CT

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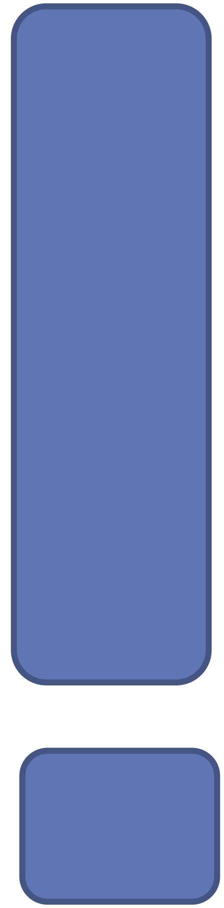
Professor and Vice Chair of Radiology
Professor of Biomedical Engineering
University of California Davis



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