Digital Mammography and Dedicated Breast CT

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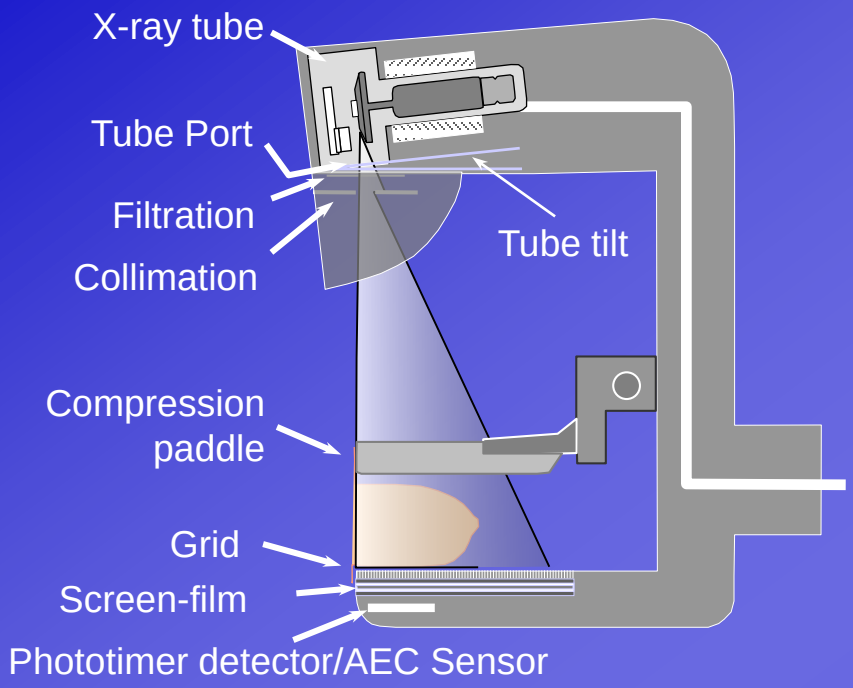
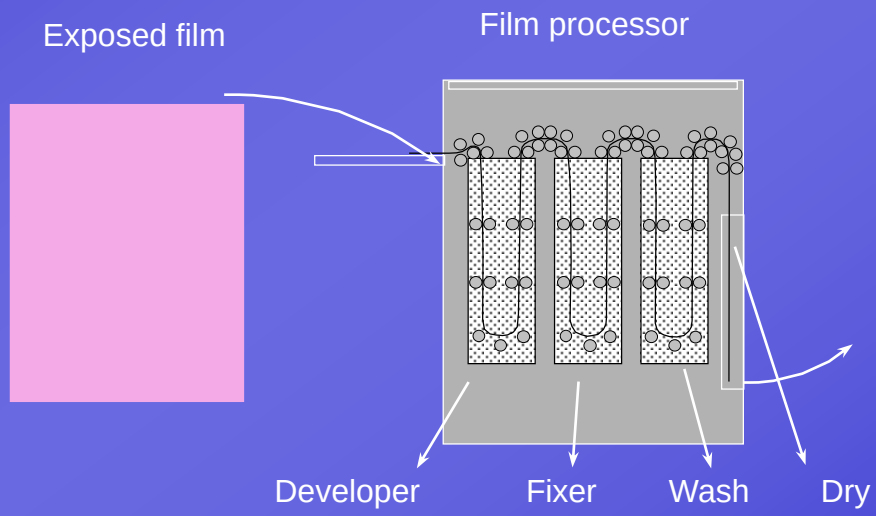
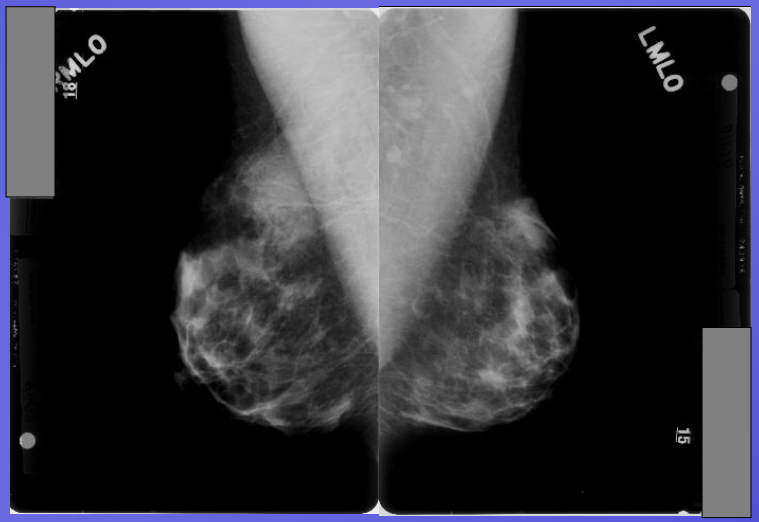
Why *Digital* Mammography?

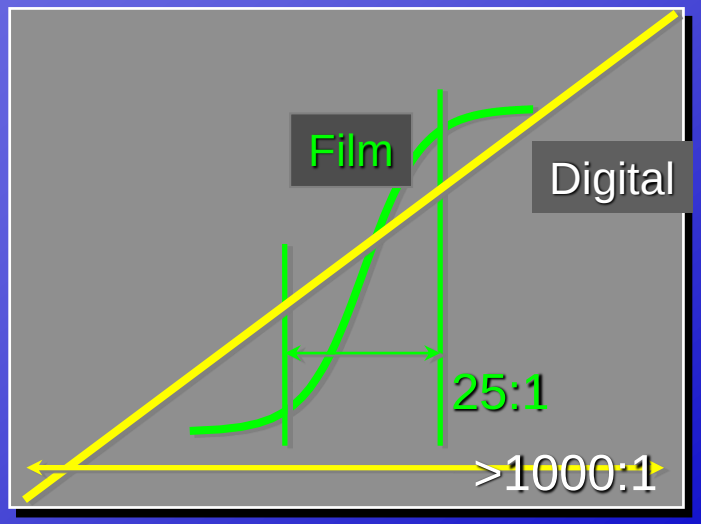
- Overcome limitations of screen-film
- PACS requires digital images
- ↑ efficiency, ↓ image handling
- Enhance image quality
- Provide “second opinion” (e.g., CAD)

Conventional Screen-Film Mammography

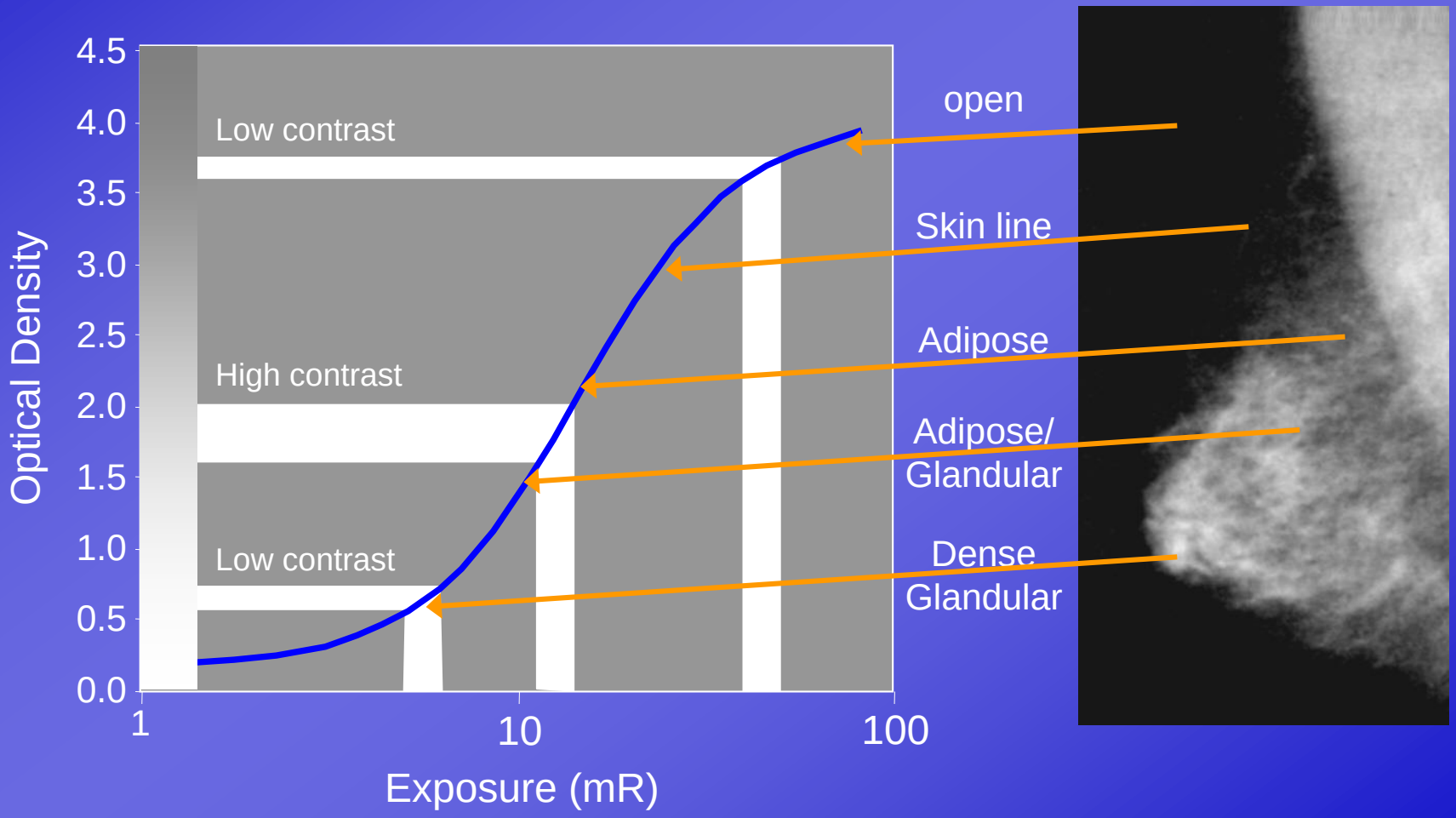








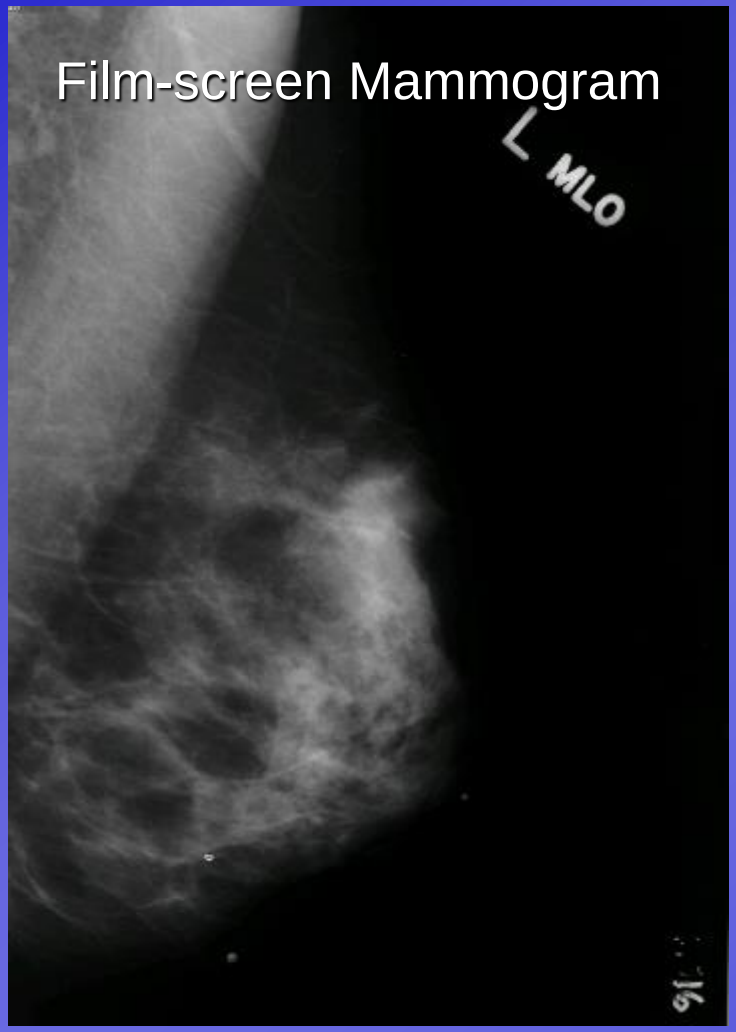
Mammography Film Response

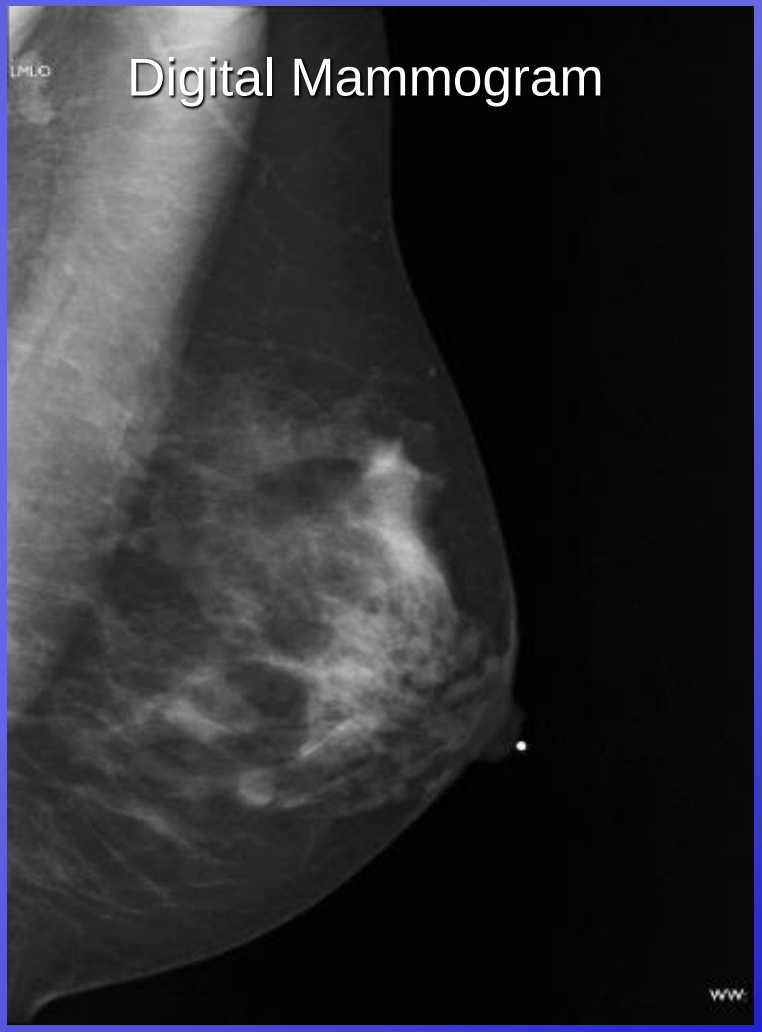


Large FOV Digital Mammography Systems

- Computed radiography (CR)
- Scanning slot acquisition (CCD array)
- Thin Film Transistor indirect detection
- Thin Film Transistor direct detection

Image Quality: Screen-film vs Digital





Digital has more uniform contrast from chest wall to skin line

Breast CT: Design, Performance and Clinical Feasibility

Kayseri, Turkey, September 2005

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J. Anthony Seibert, Ph.D.

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The Breast Tomography Project

University of California, Davis

California BCRP 7EB-0075
NCI CA89260
NIBIB EB002138-03 (BRP)
Susan G. Komen Foundation

John M. Boone, Ph.D.

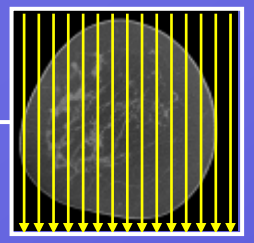
Principal Investigator

The Breast Tomography Project

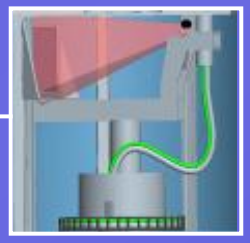
University of California, Davis

The Breast Tomography Project

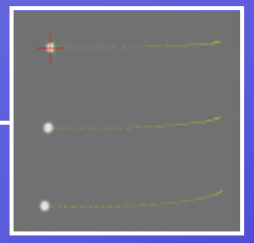
- Introduction



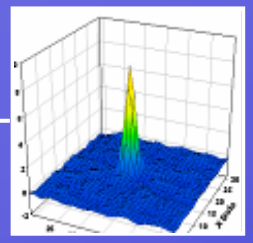
- Design and Fabrication



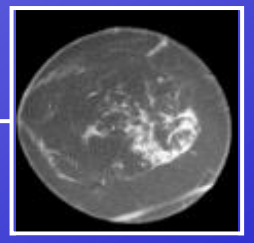
- Calibration & Reconstruction



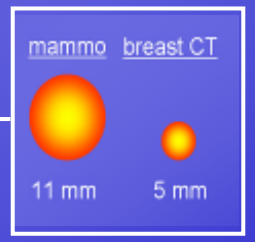
- Image Quality & Dose



- Patient Imaging



- Conclusions



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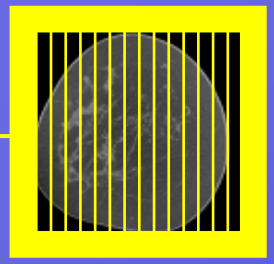
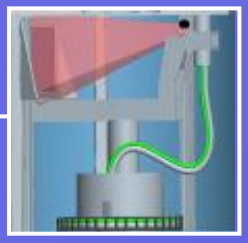
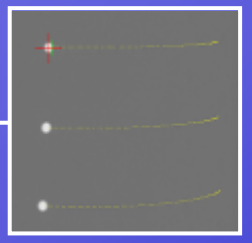
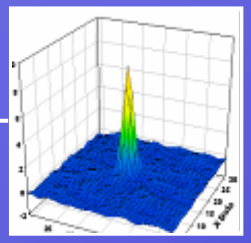
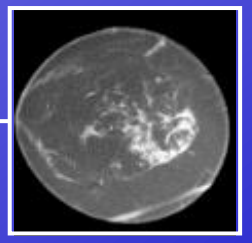
- Calibration & Reconstruction
- Image Quality & Dose
- Patient Imaging
- Conclusions

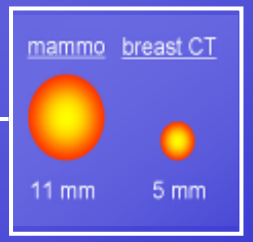




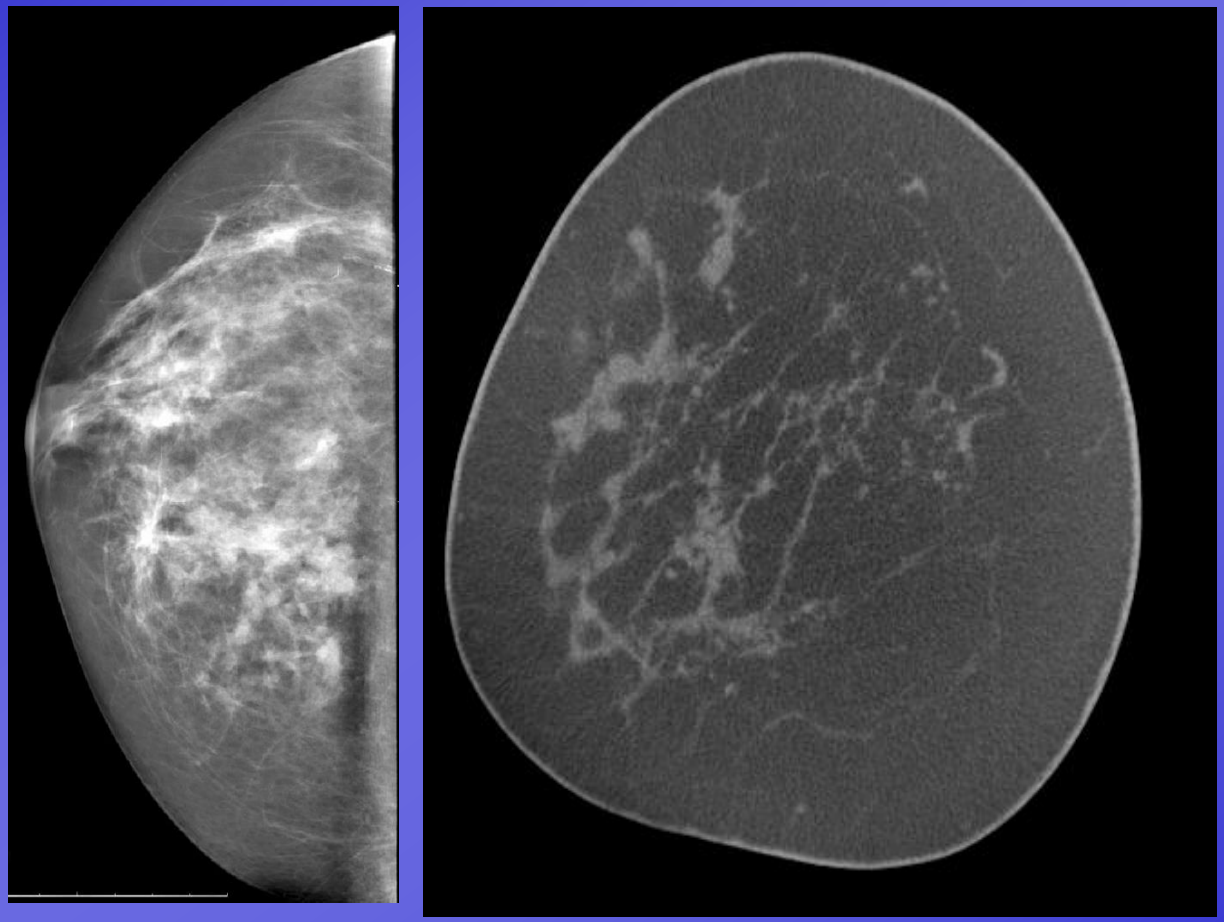




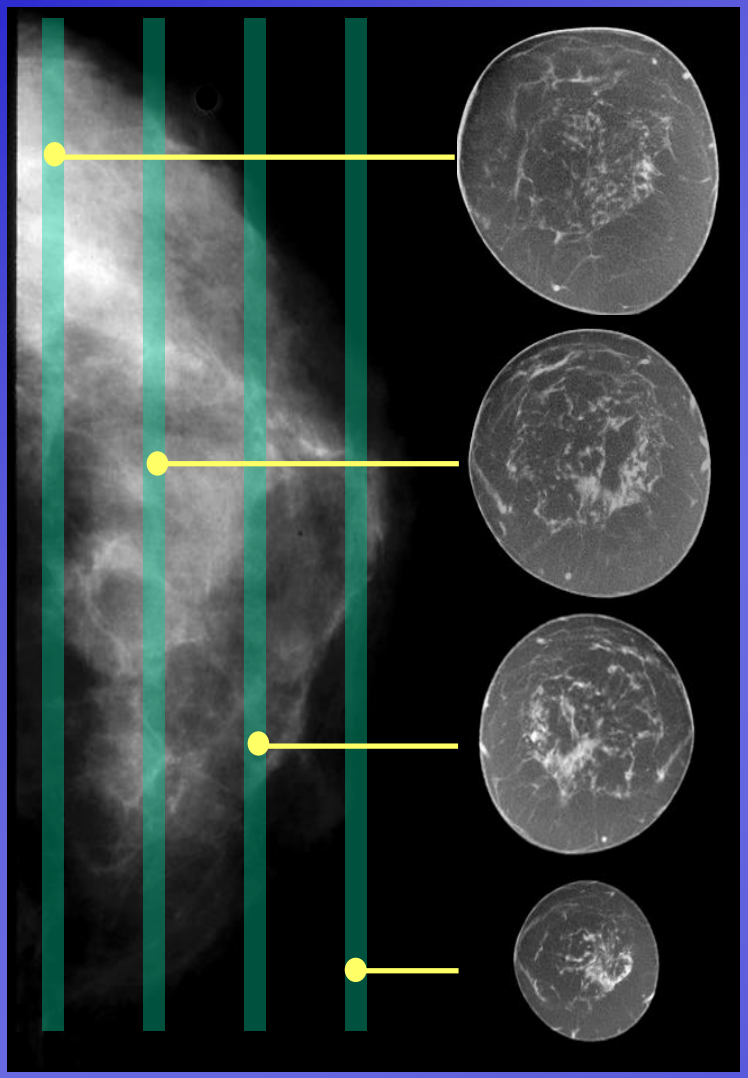


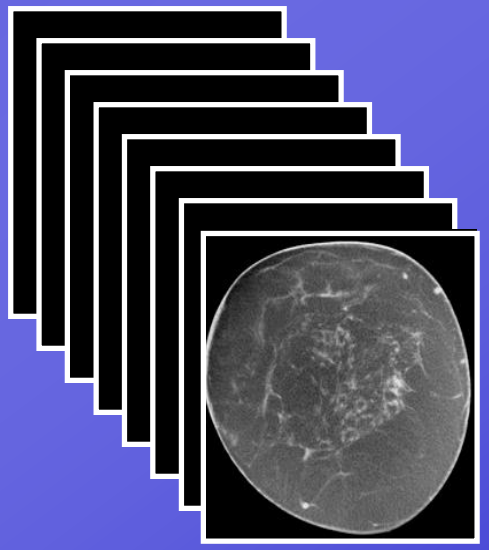


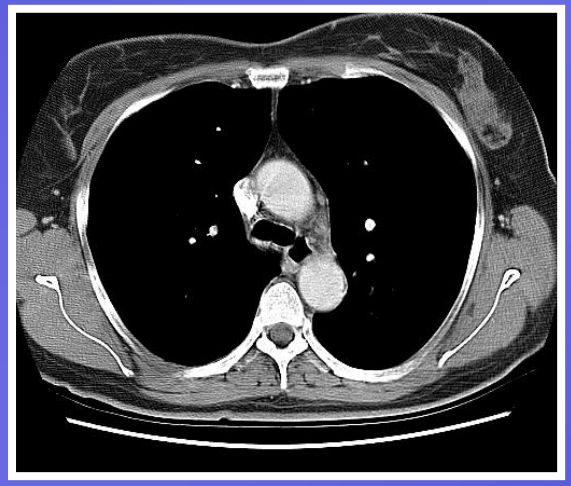
The Superposition Problem



The Power of Tomography

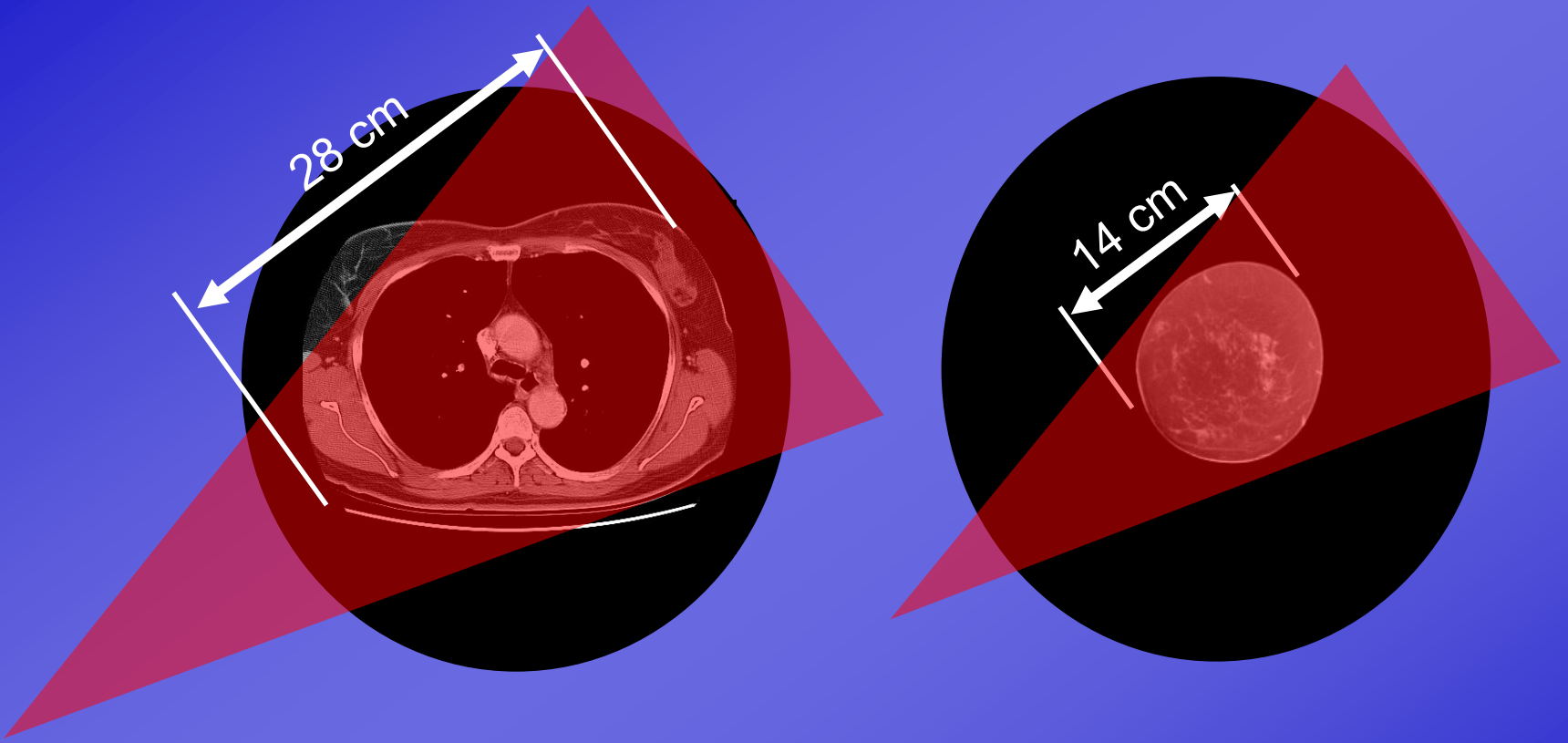






commercial CT: axial imaging

Scan the breast with an alternate geometry



Consequences:

Lower dose

Better image quality

pendant geometry breast CT scanner

The Breast Tomography Project

University of California, Davis

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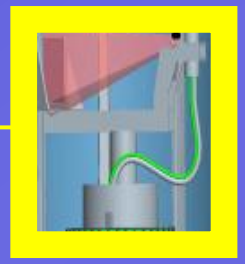
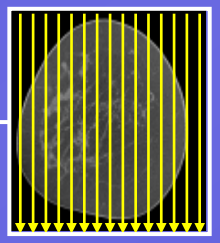
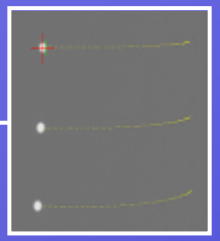
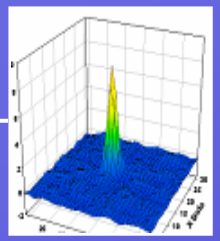
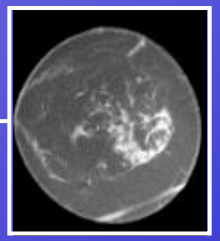
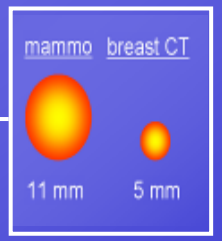


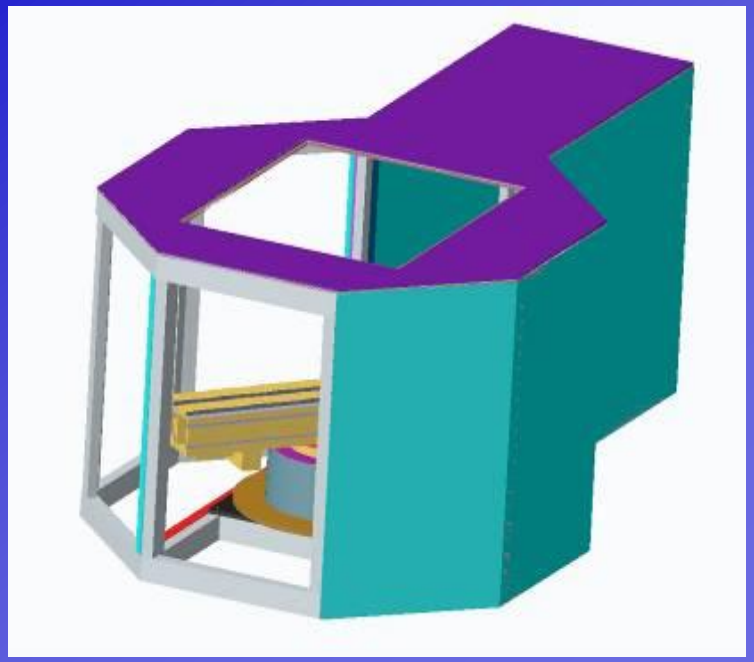






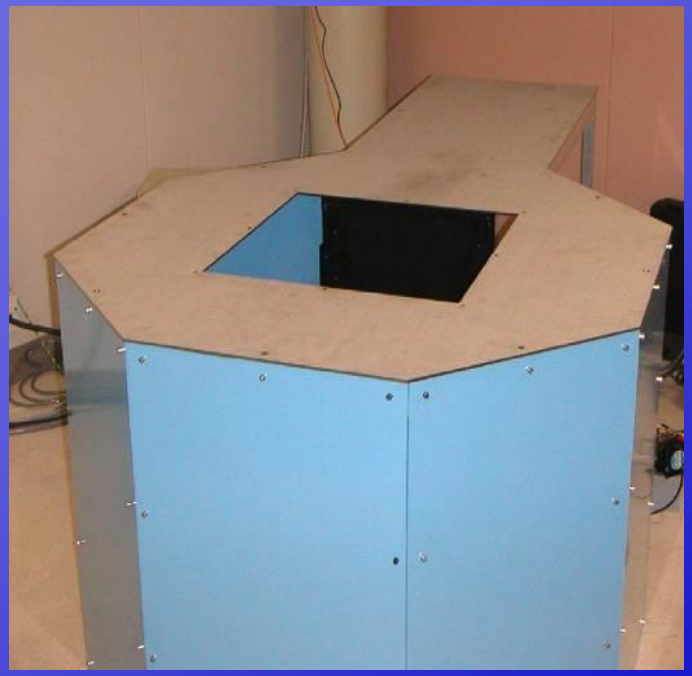






computer aided design

computer aided manufacture



Three main commercial components

Comet x-ray tube

Pantak HF generator
0.4 mm x 0.4 mm focus
W anode / Be window
water cooled 640 Watt
100 kVp / 6.4 mA

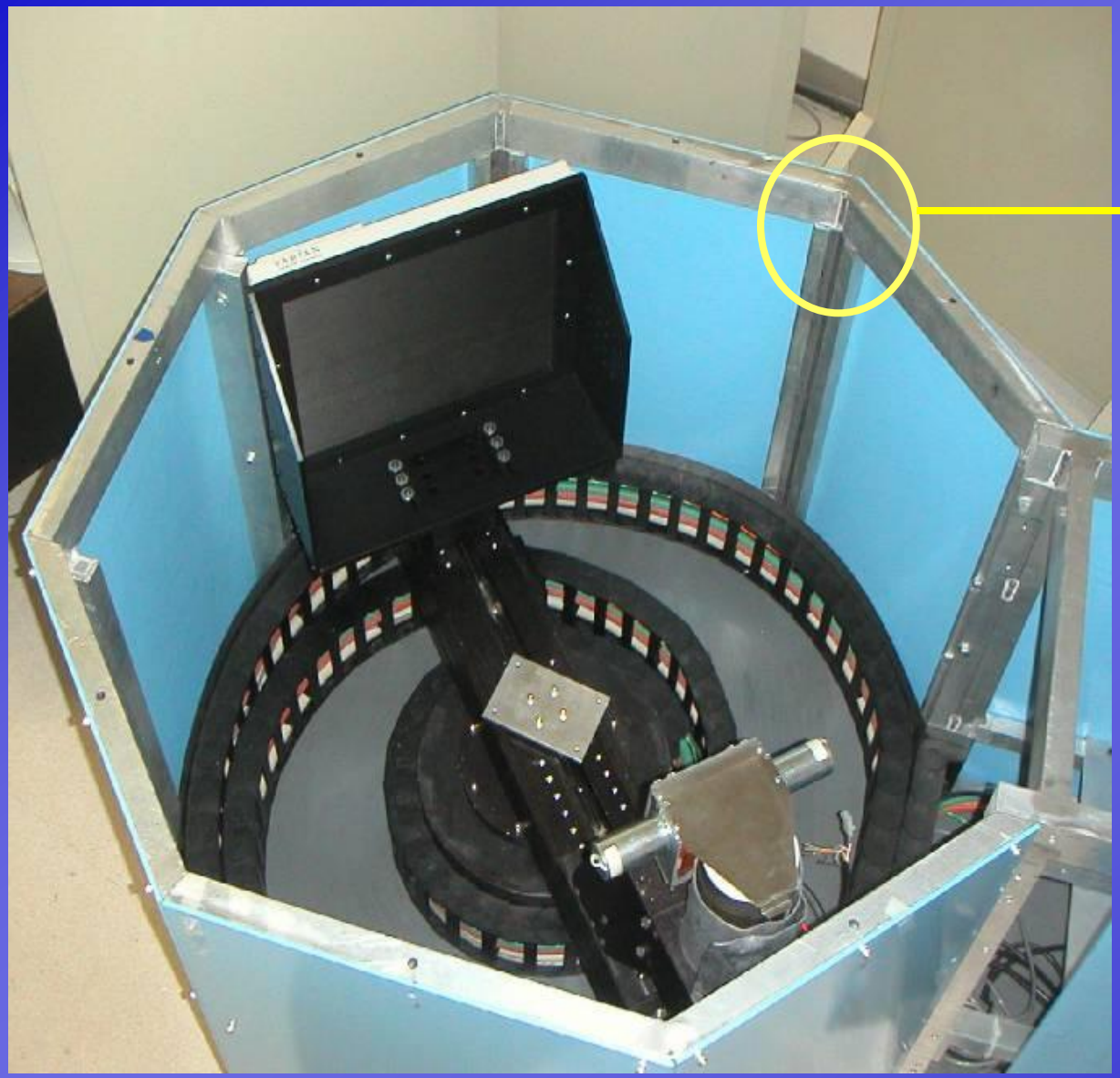
Varian PAXSCAN 4030CB

CsI Thin Film Transistor Detector
1x1: 2048 x 1536 194 μm pixels
2x2: 1024 x 768 388 μm pixels
30 frames per second
2x4: 1024 x 384 Dual Gain Mode
30 frames per second

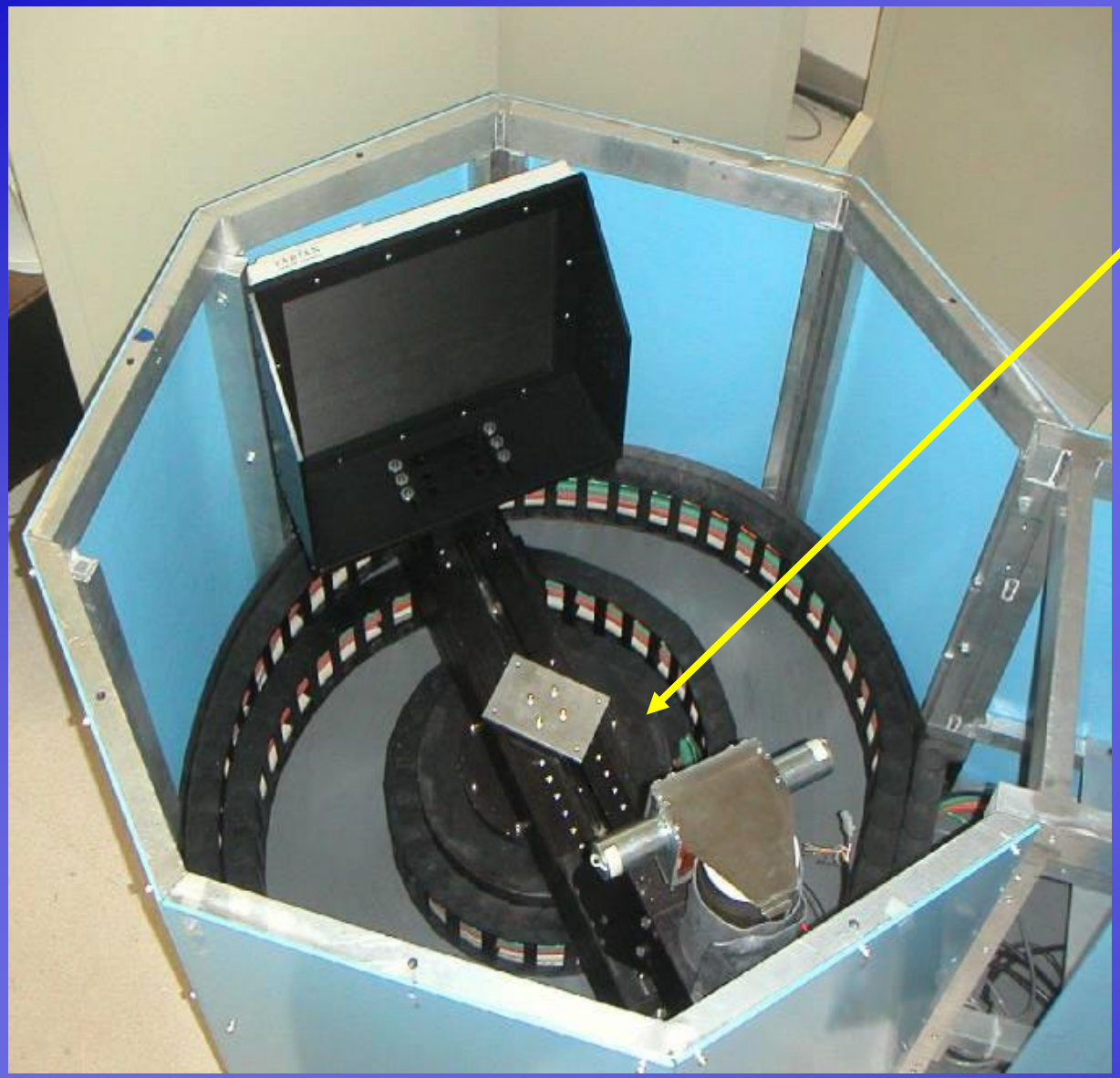
Kollmorgen Servo Motor

DDR DDR D081M
13.0 ft-lb continuous torque
32.0 ft-lb peak torque

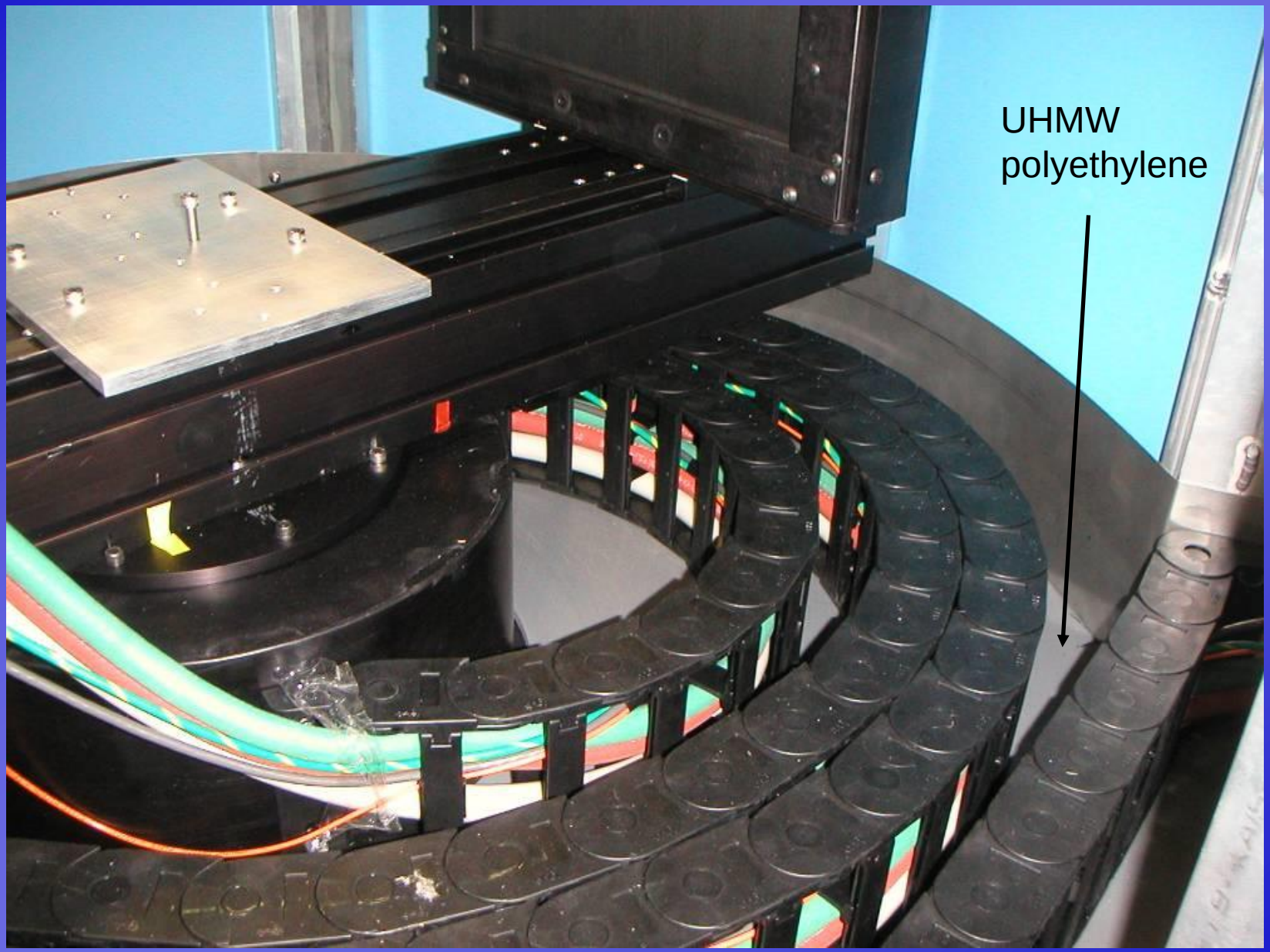
welded aluminum frame with Pb / Al laminated side panels



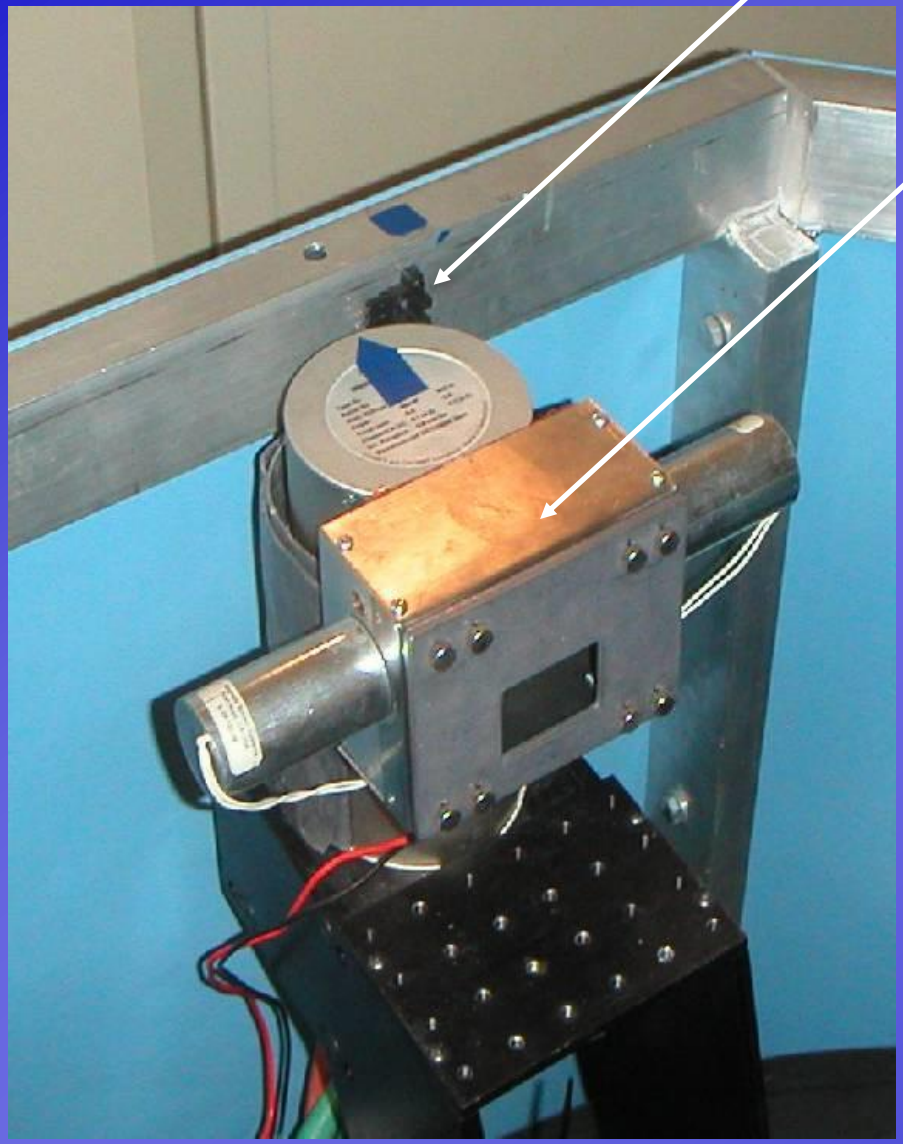
bearing, motion, and angle encoder in central hub



UHMW polyethylene surface & chain-link cable conduit system



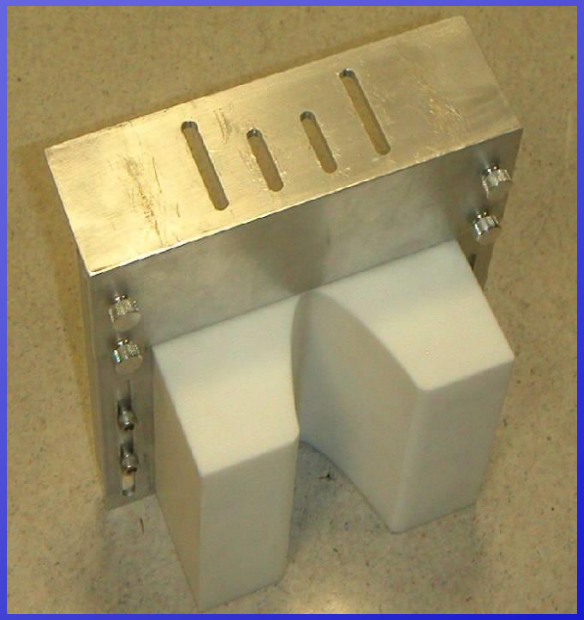
x-ray tube assembly

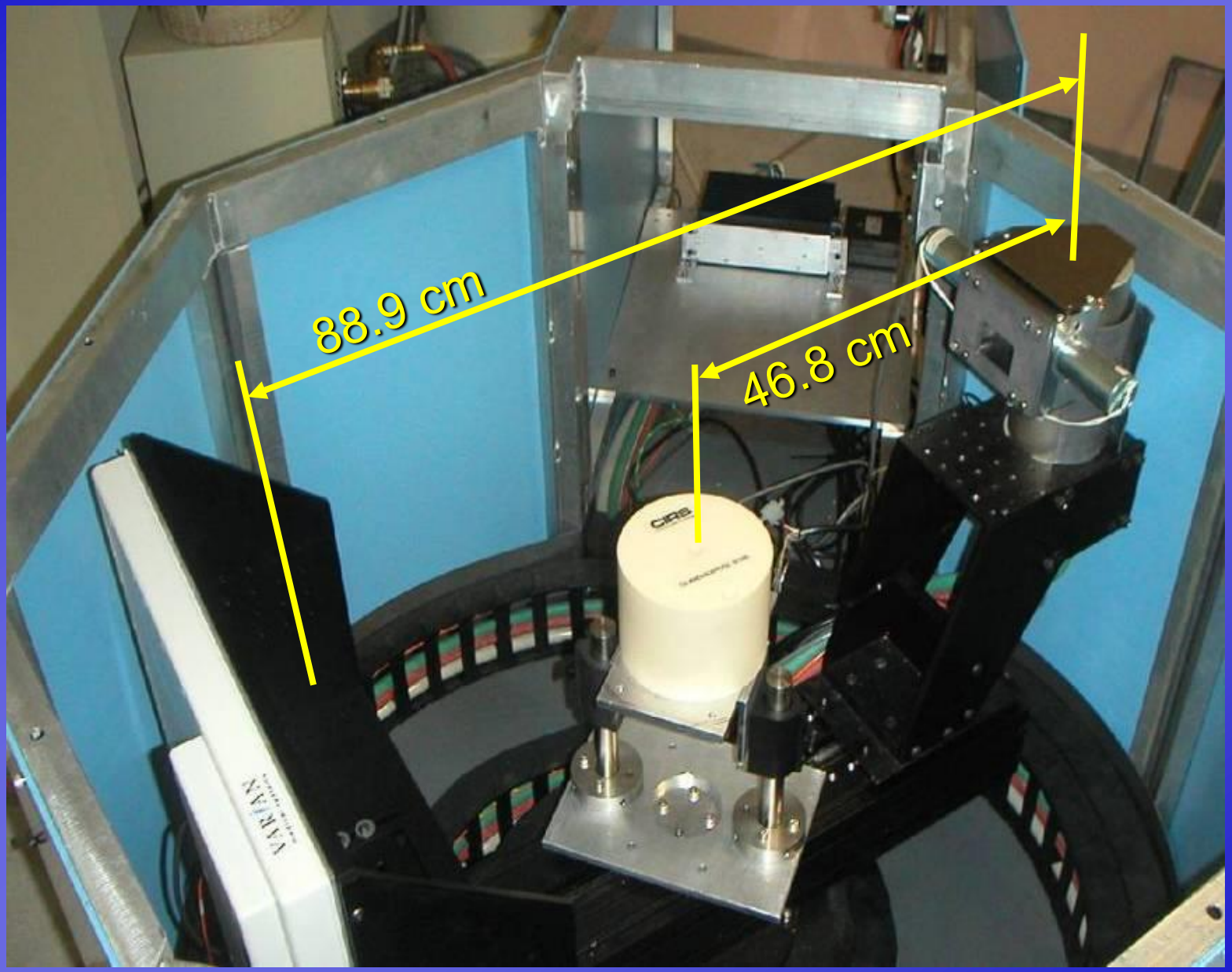


TDC sensor

lead x-ray shutter
using 2 solenoids
(normally closed)

teflon bow-tie filter




88.9 cm
46.8 cm

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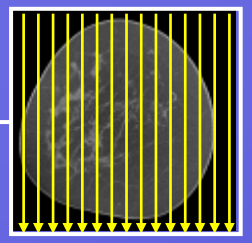
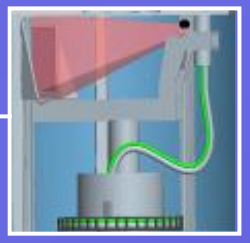
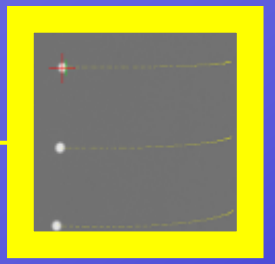
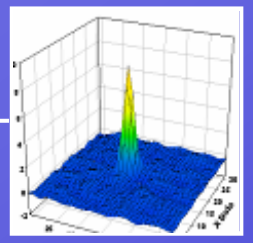
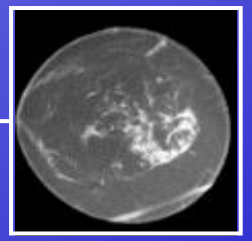
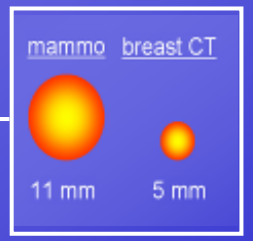






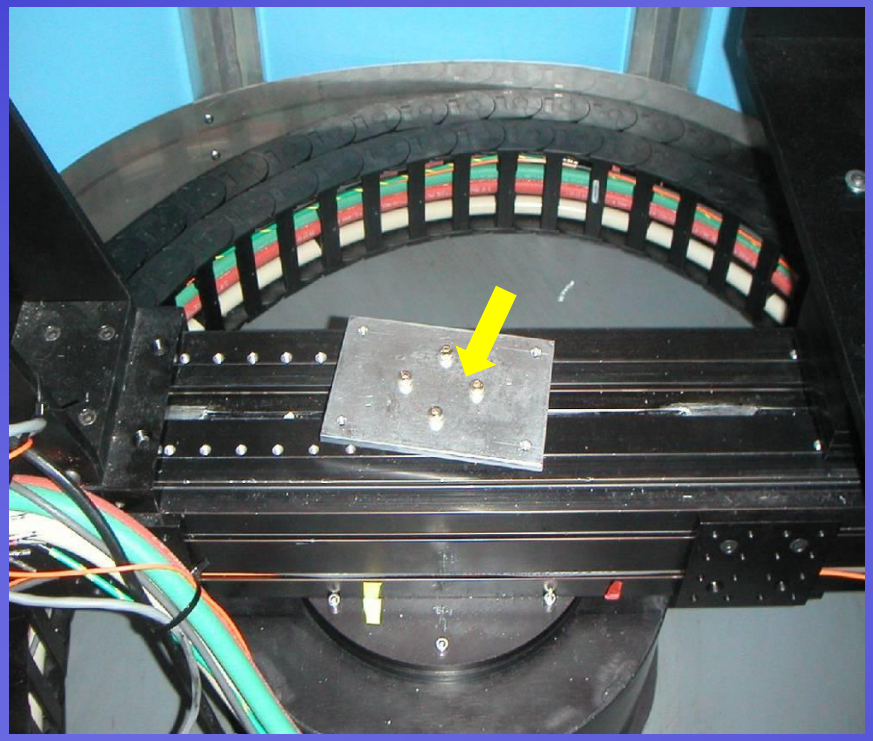




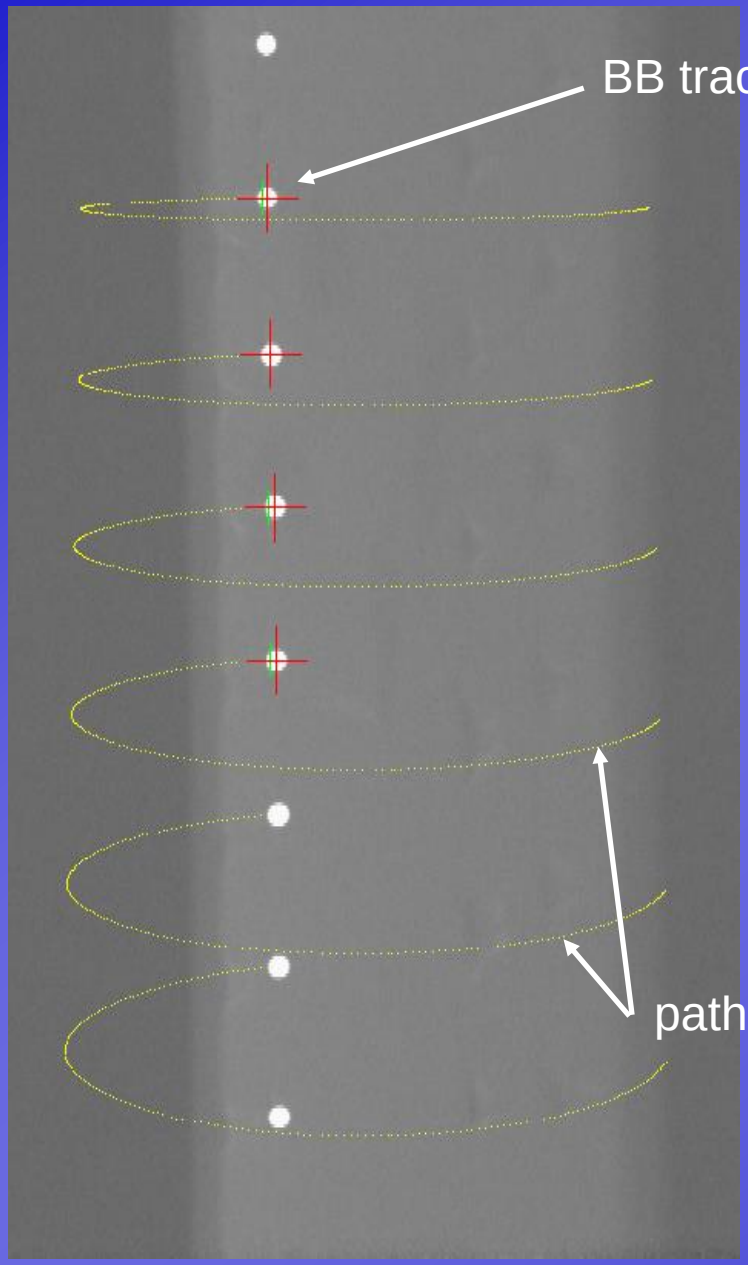


Geometric Calibration

stationary stand

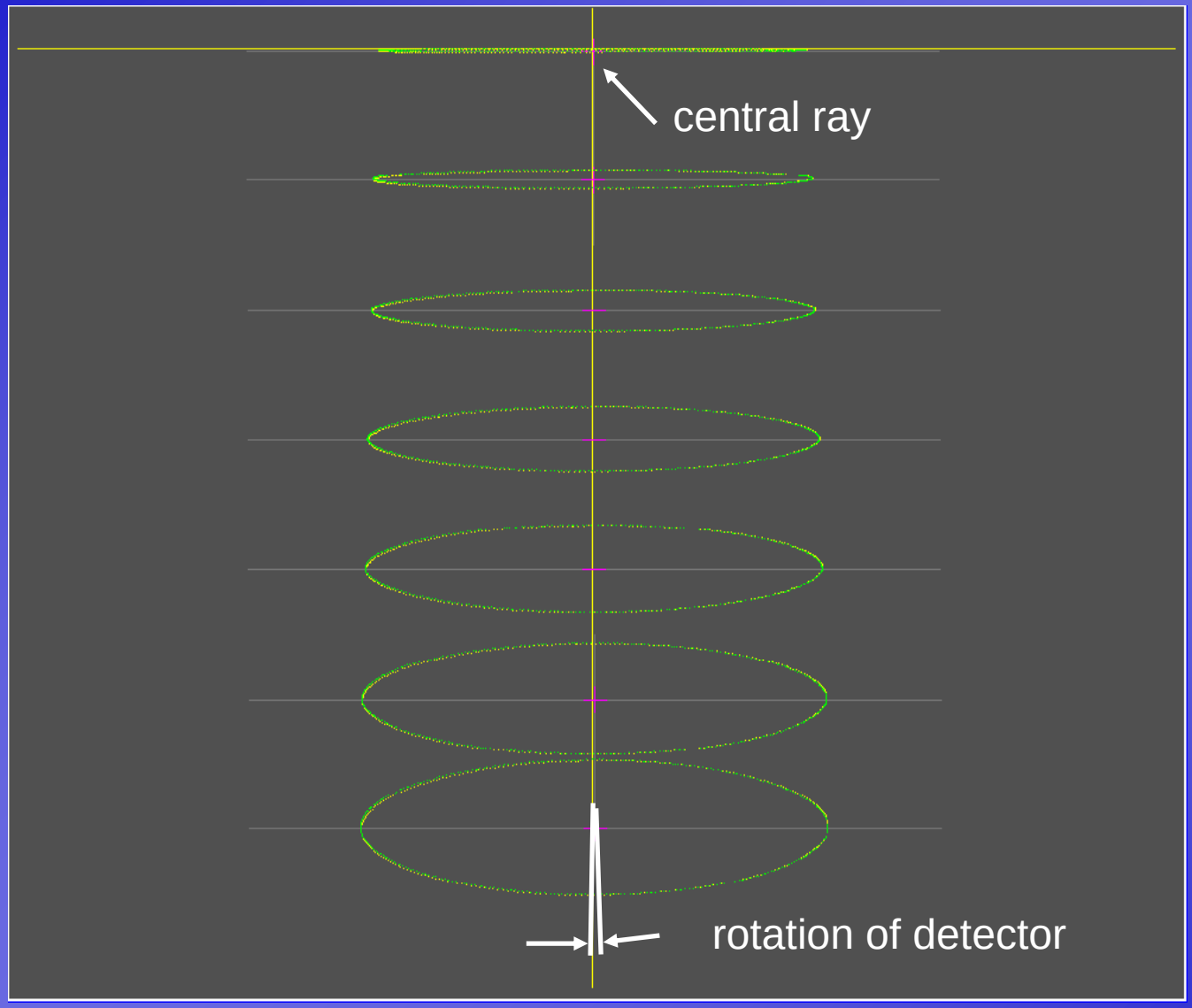


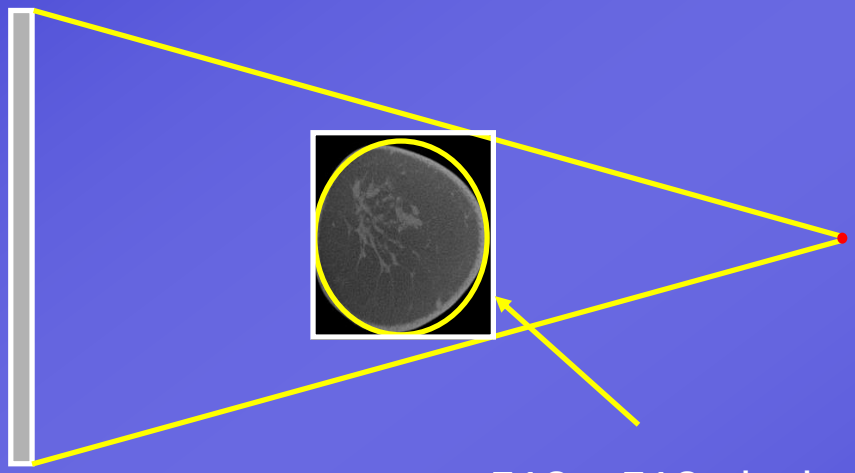
Pb shot in foam board



BB tracking software

BB paths are fit to analytical functions which define CT geometry





768 x 1024 pixels
500 views

512 x 512 pixels
300 slices ~(0.5 mm)

Reconstruction Algorithm

Feldkamp-like cone-beam
…written in C

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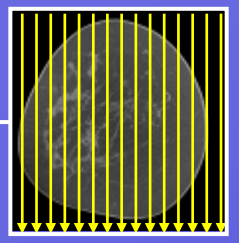
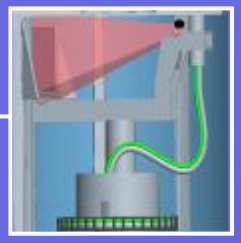
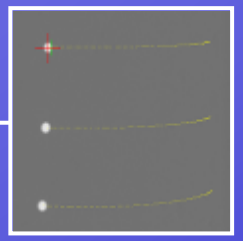
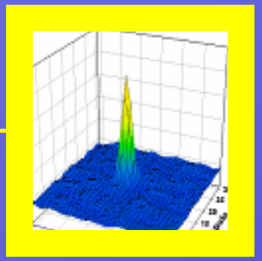
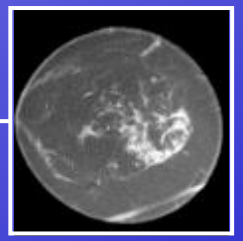
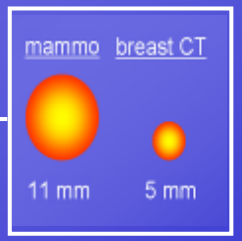








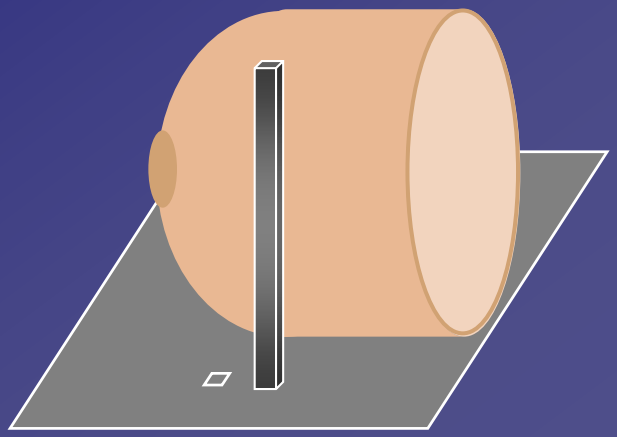




cancer detection potential

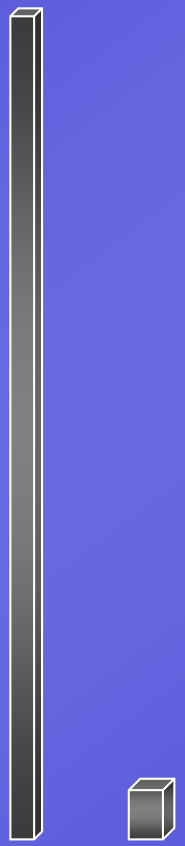
spatial resolution

mammography



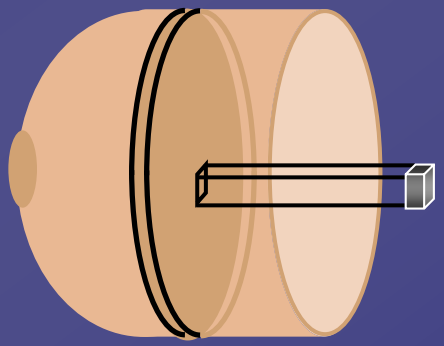
0.10 mm x 0.10 mm x 50 mm

= 0.50 mm^3



16x

breast CT



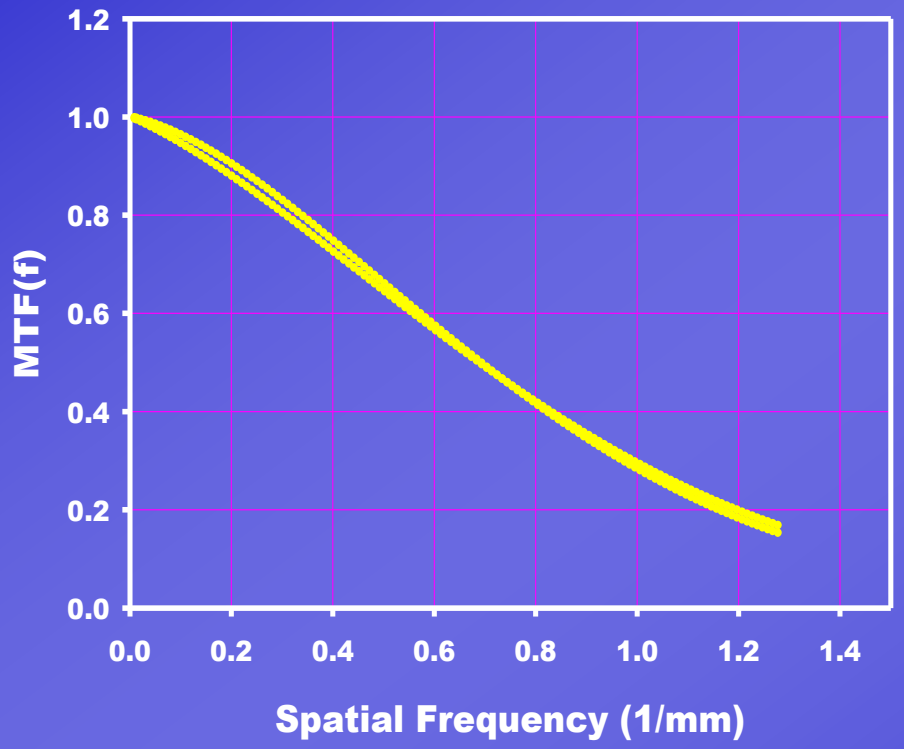
0.25 mm x 0.25 mm x 0.50 mm

= 0.03 mm^3

image quality

intrinsic detector performance

detector MTF



detector DQE

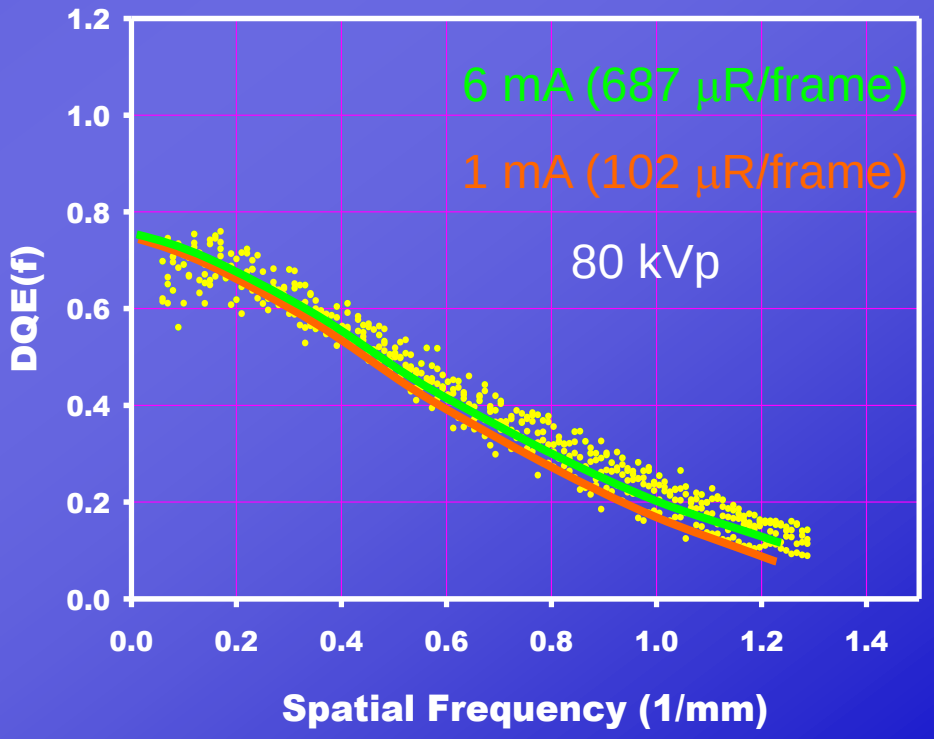
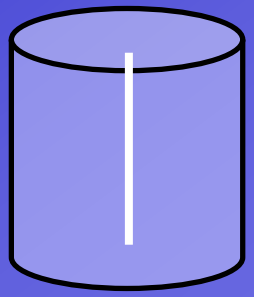
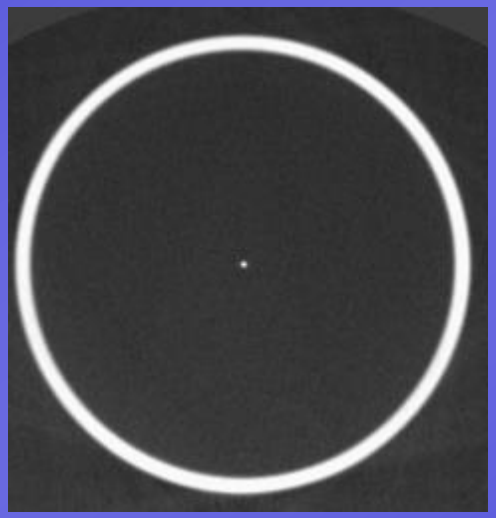


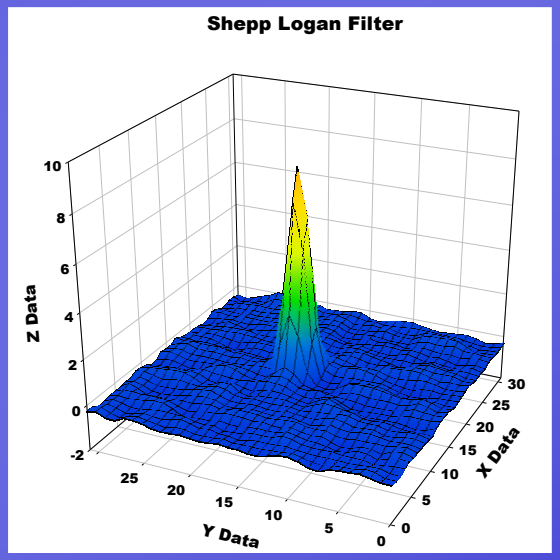
image quality

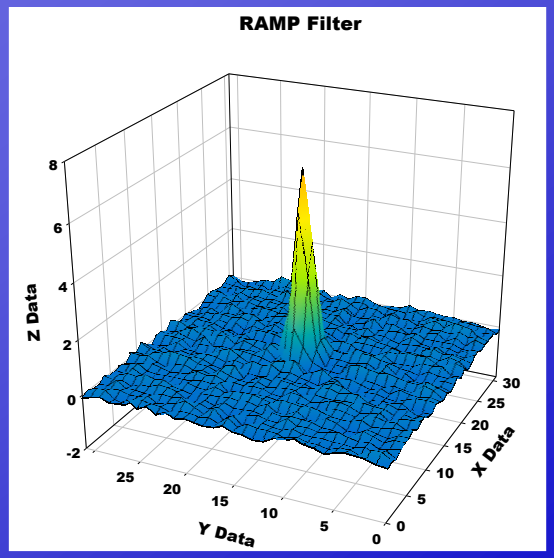
spatial resolution



70 μm nickel-chromium wire

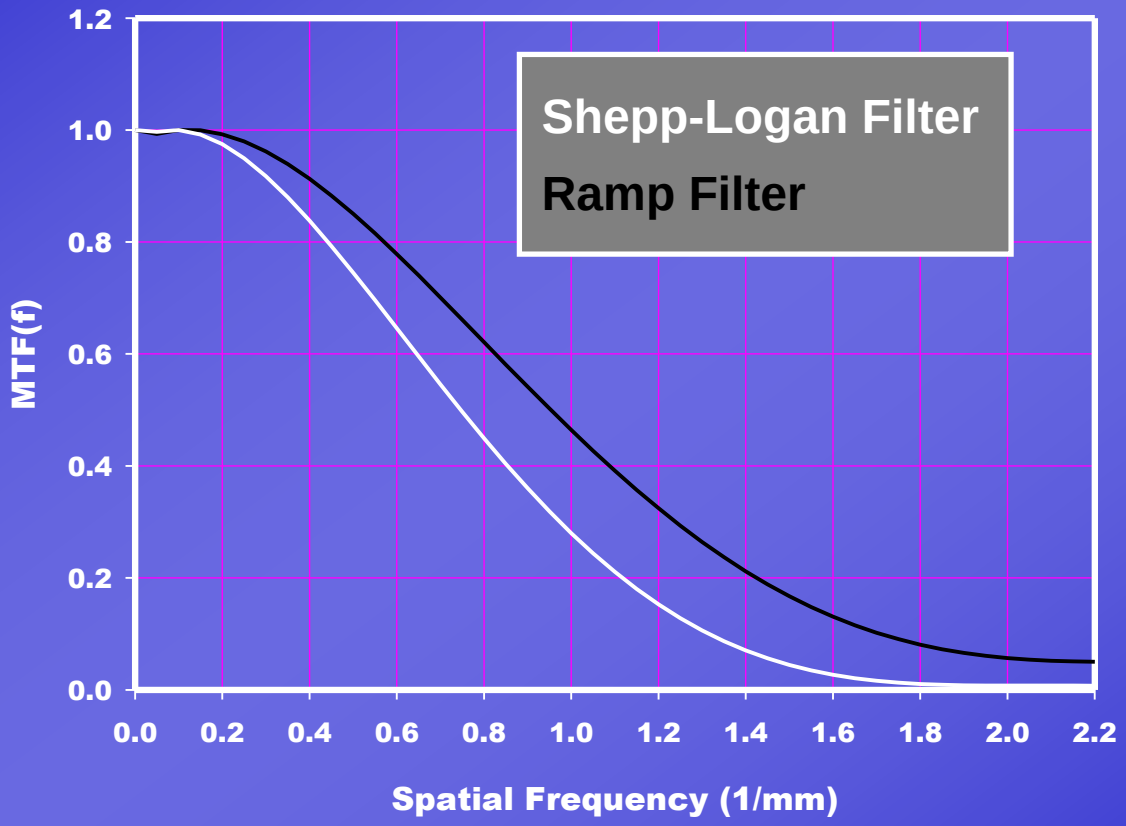






Spatial Resolution

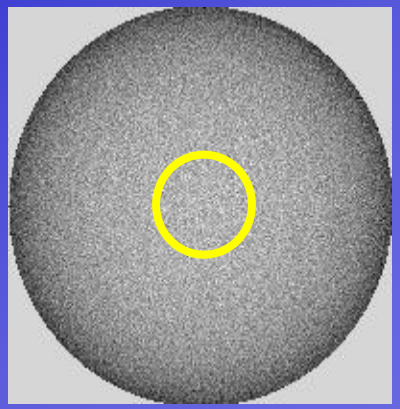
influence on reconstruction filter



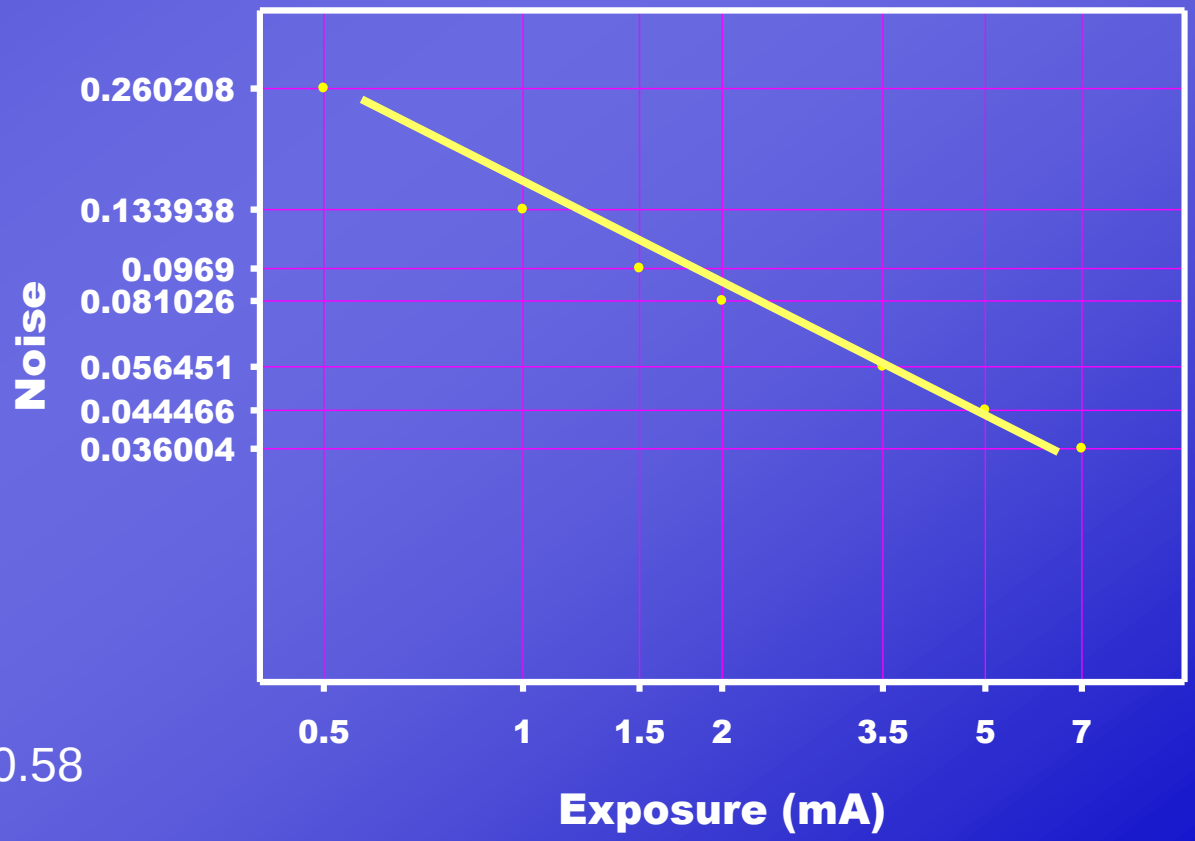
1000 views

image quality

noise assessment



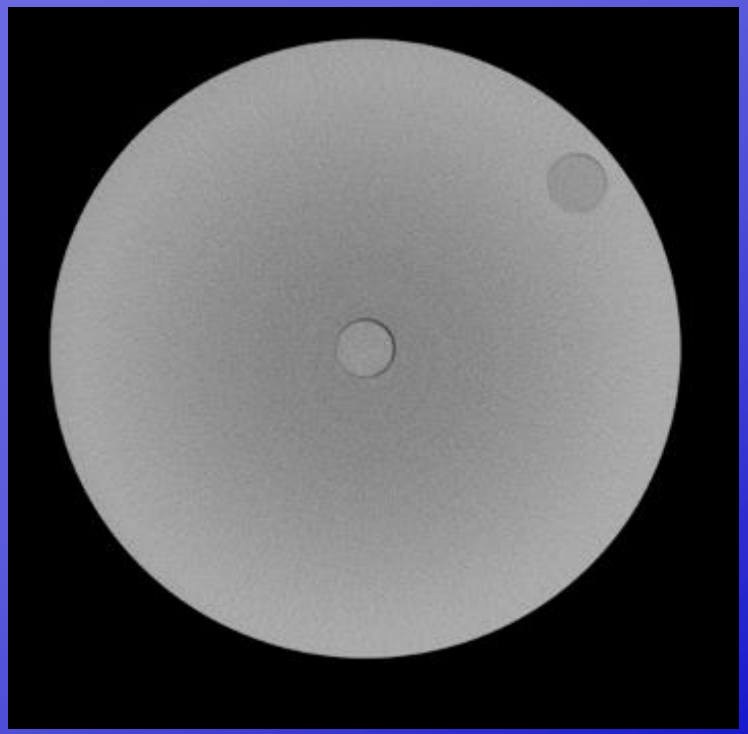
Air Scans

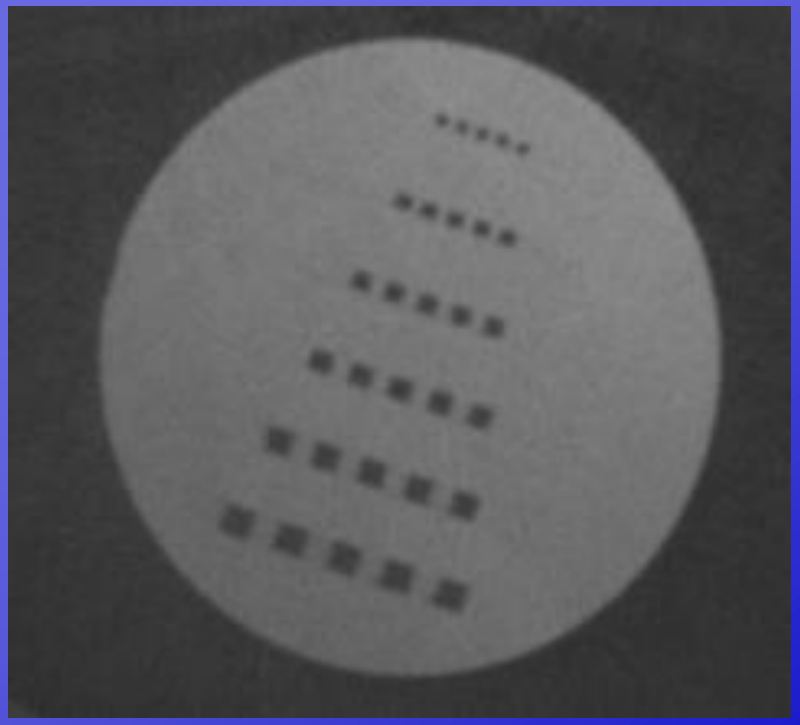


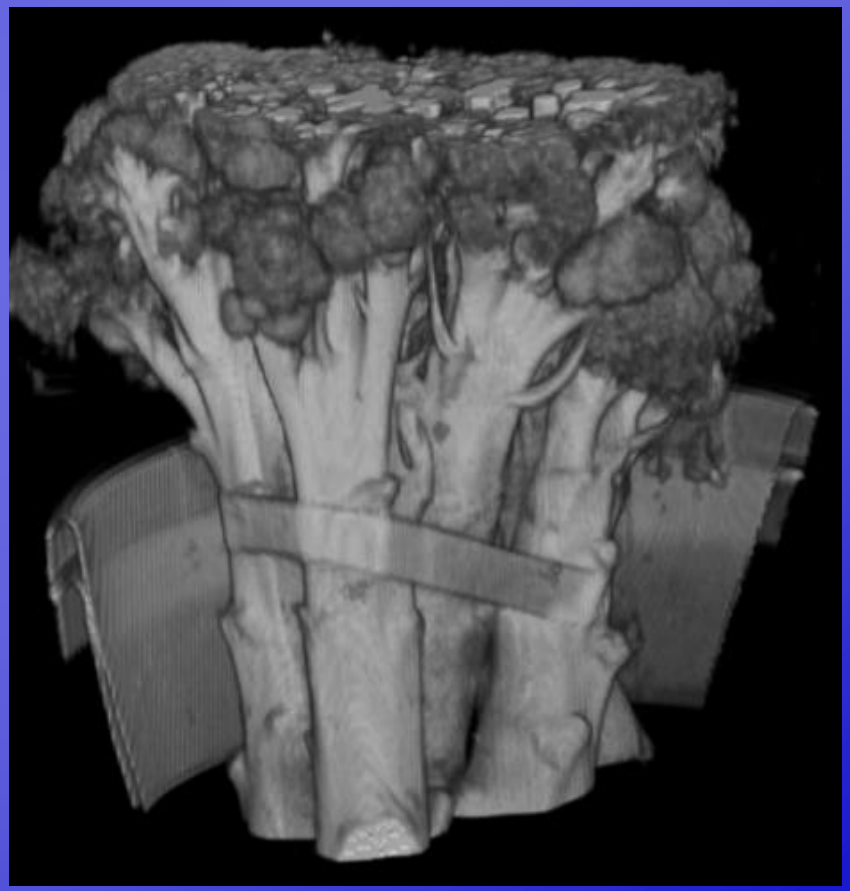
Slope ~-0.58

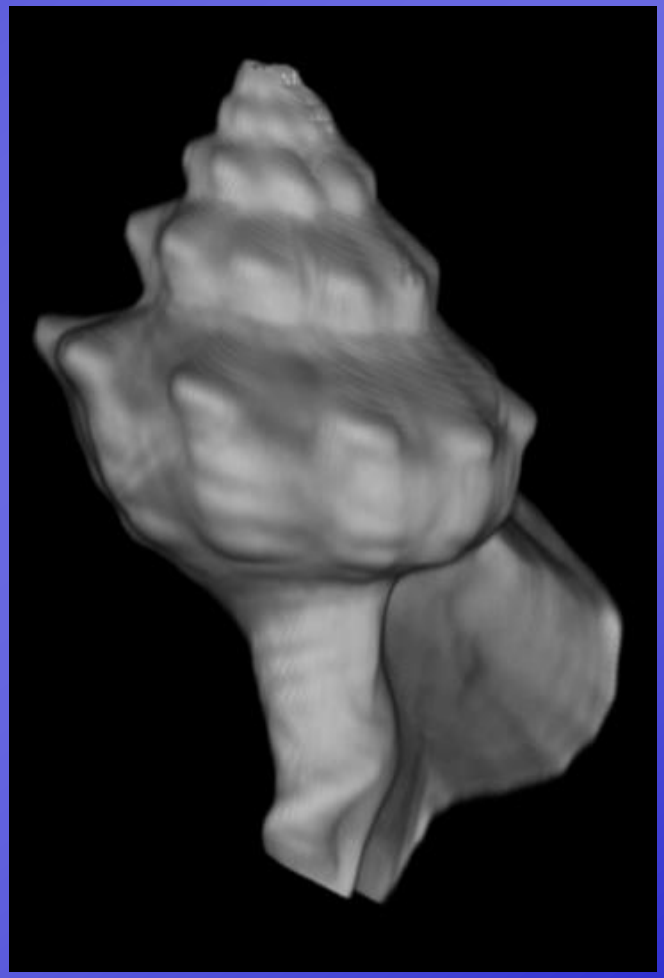
image quality

subjective assessment





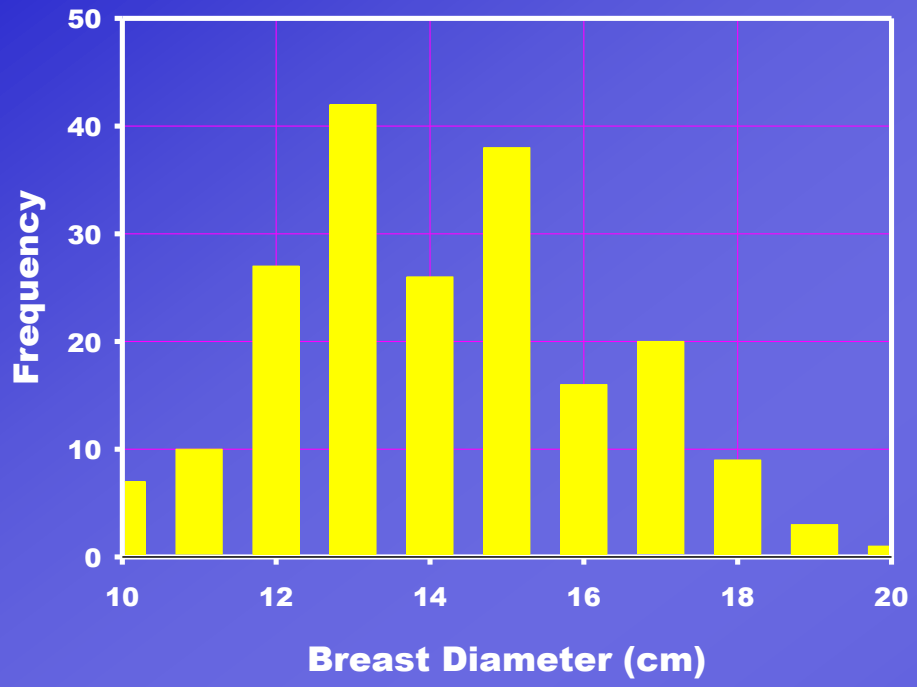




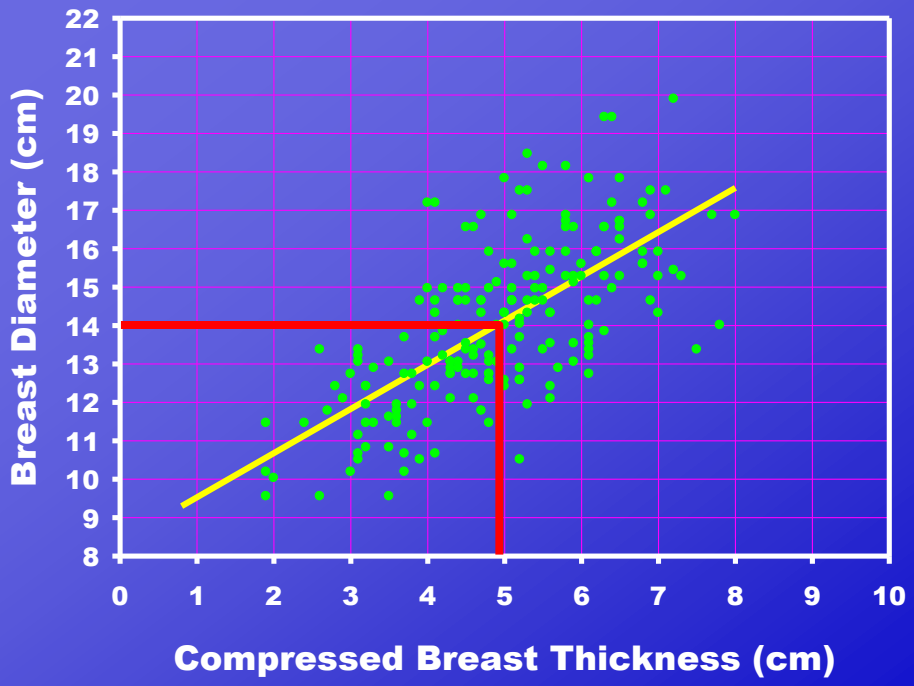
Radiation Dose

Breast Dimensions

distribution of breast diameters in 200 women

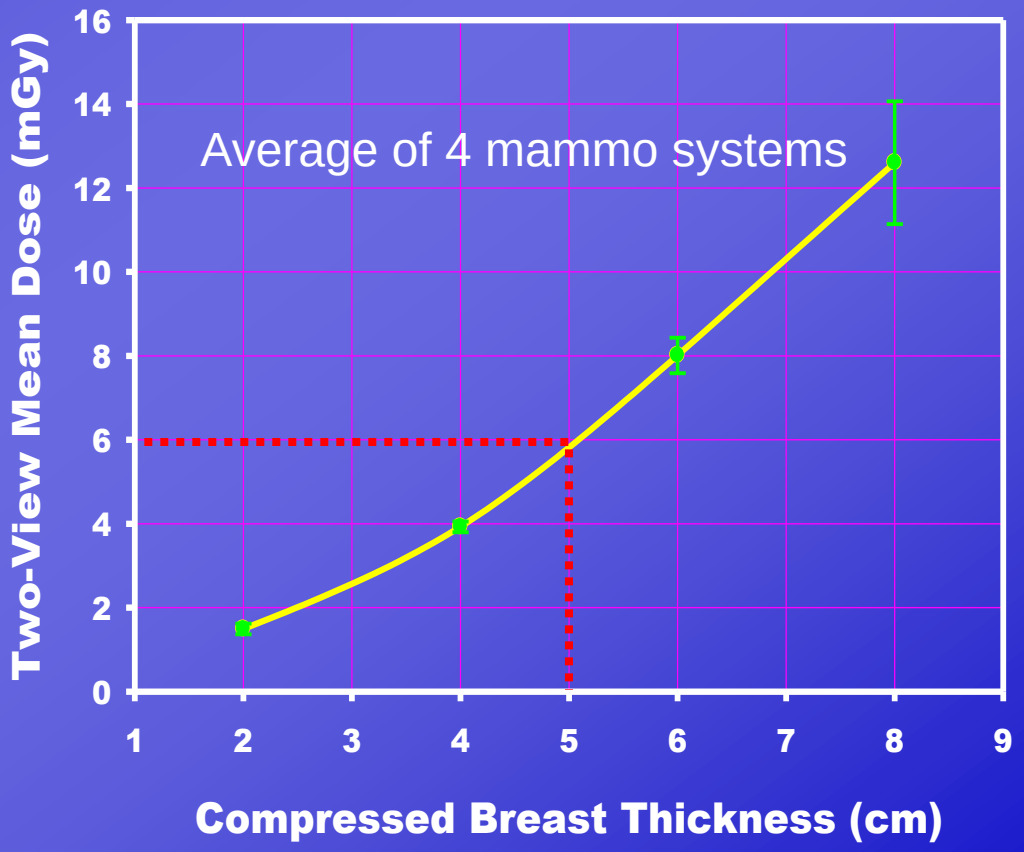


relationship between diameter
& compressed breast thickness

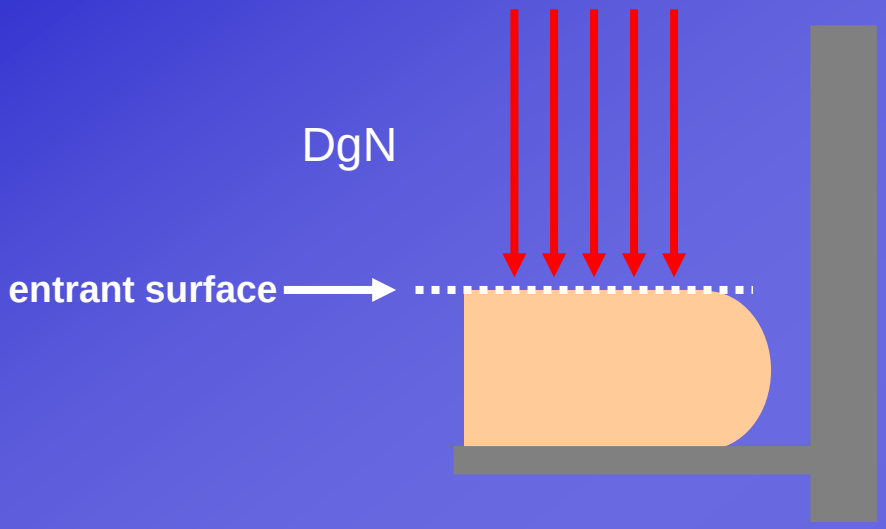


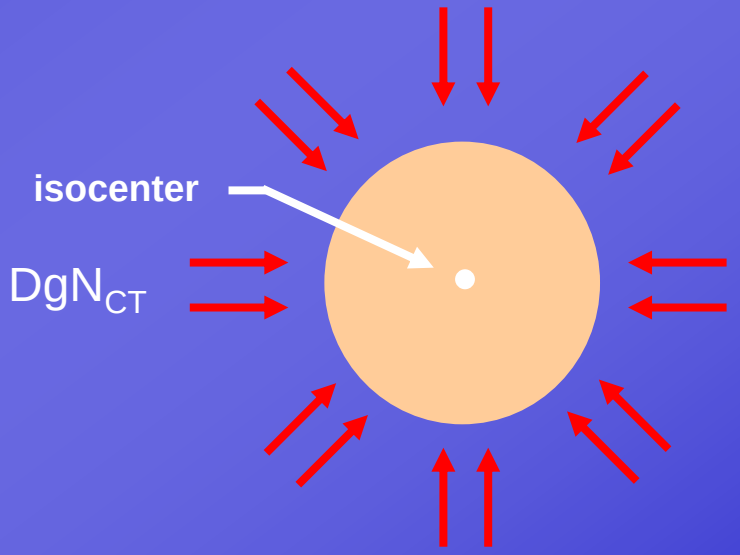
Mean Glandular Dose in Mammography

two-view mammography dose versus CB thickness



radiation dose

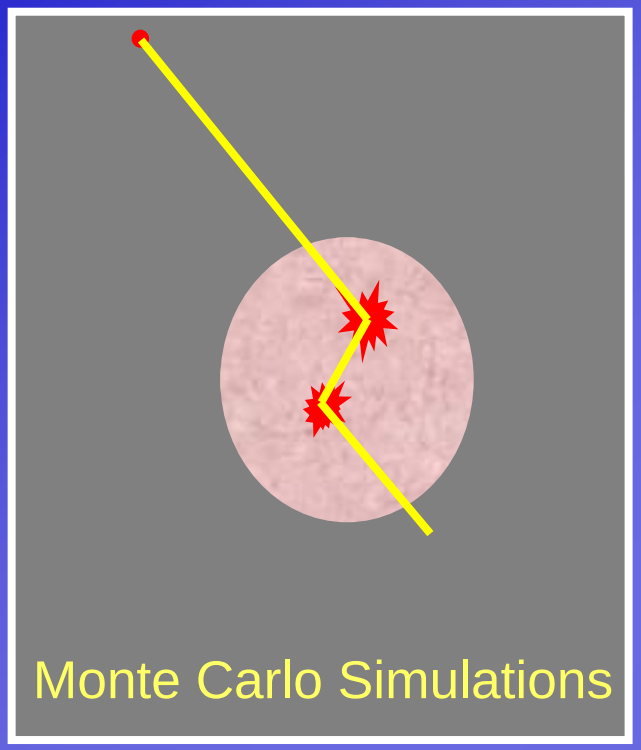




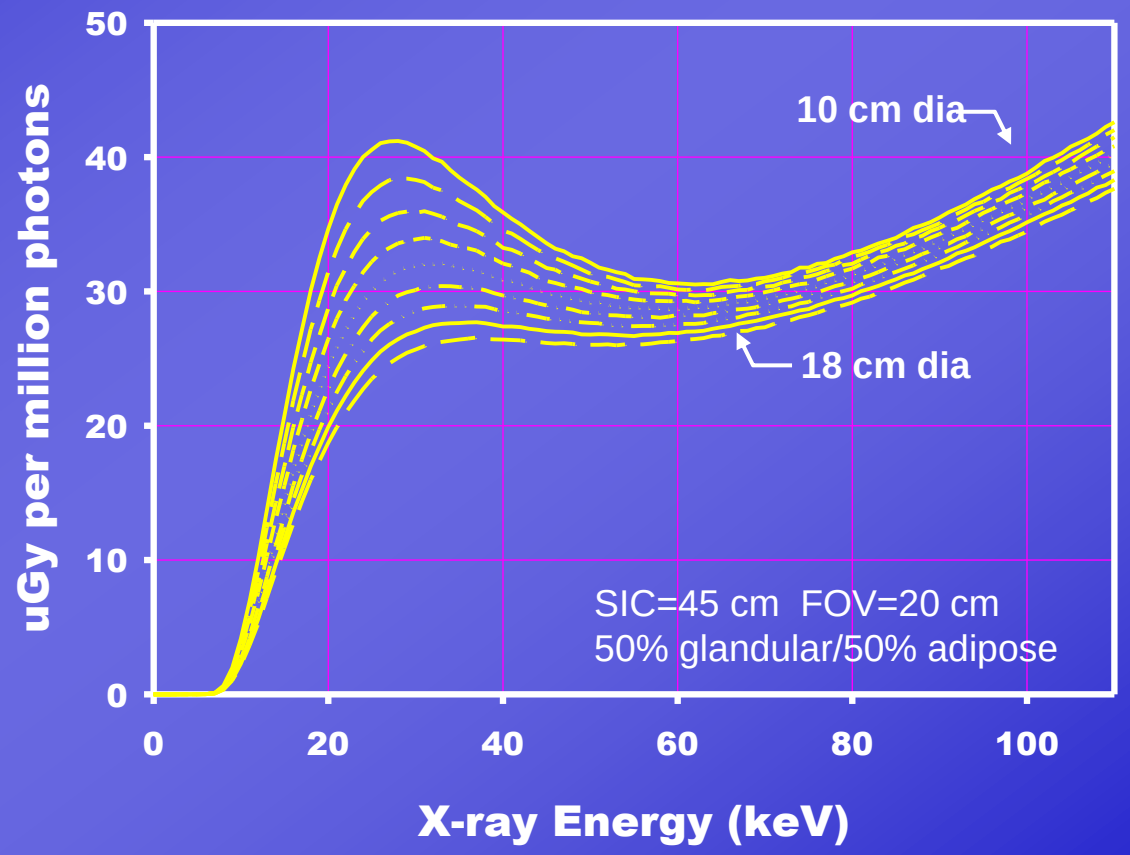
mammography

breast CT

m-DgN_{CT}

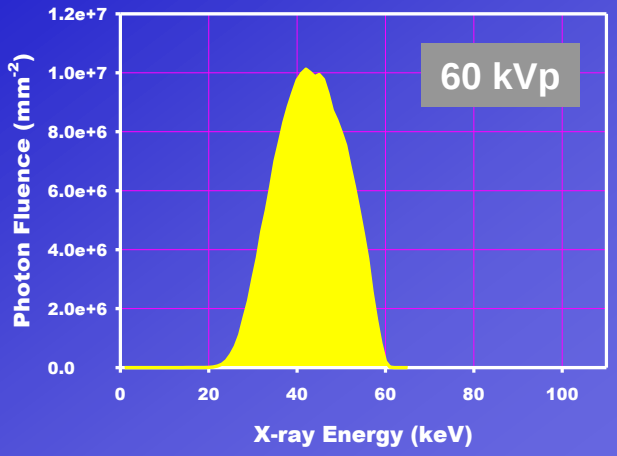


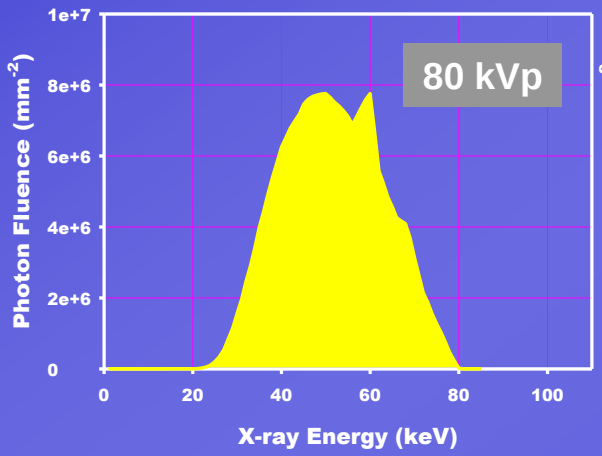
monoenergetic functions

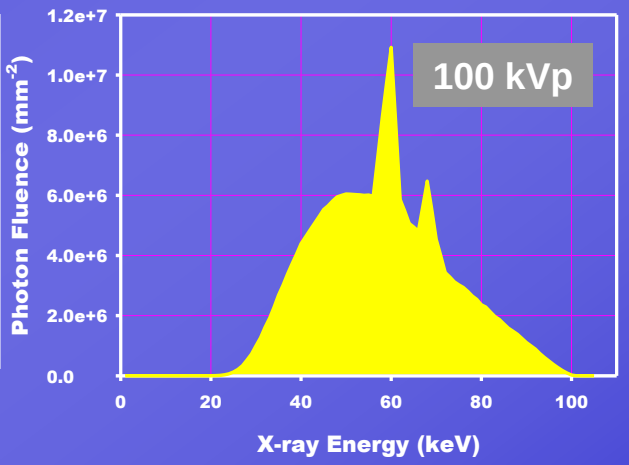


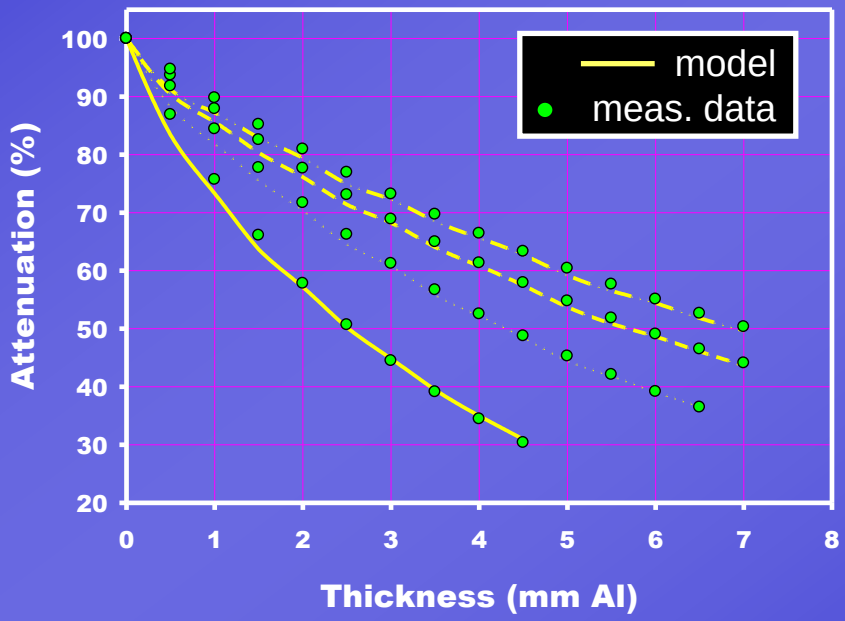
JM Boone, N. Shah, and T.R. Nelson, "A Comprehensive Analysis of DgN_{CT} Coefficients for Pendant-Geometry Cone-Beam Breast Computed Tomography", Medical Physics 31: 226-235 (2004)

Spectral Model



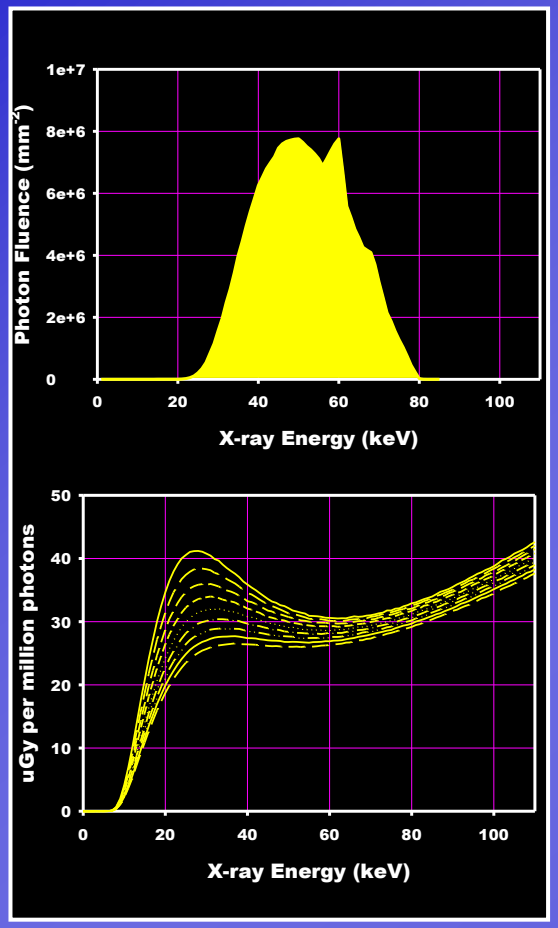




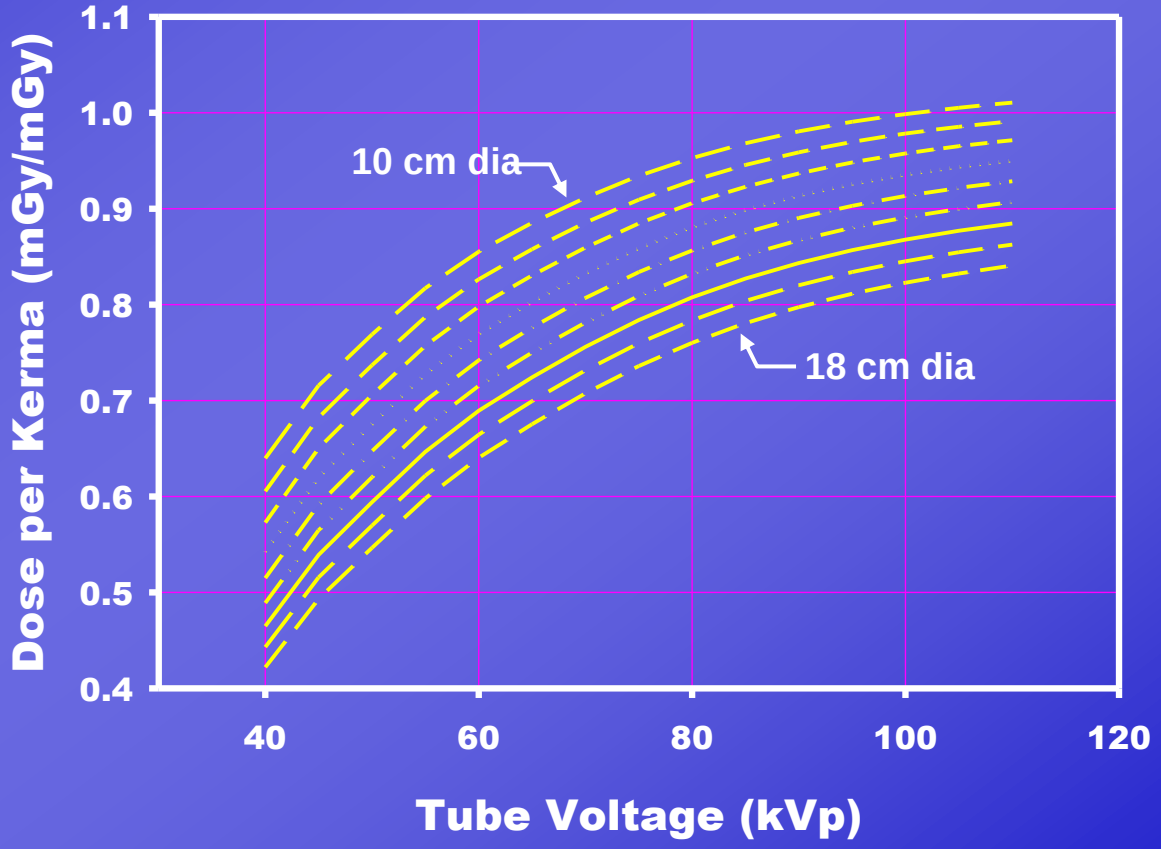


JM Boone and JA Seibert, *An accurate method for computer-generating tungsten anode x-ray spectra from 30 kV to 140 kV*, Medical Physics **24**;1661-670, 1997.

p-DgN_{CT}



polyenergetic functions



JM Boone, N. Shah, and T.R. Nelson, "A Comprehensive Analysis of DgN_{CT} Coefficients for Pendant-Geometry Cone-Beam Breast Computed Tomography", Medical Physics 31: 226-235 (2004)

Technique chart

mAs to use

Bra Cup Size

Peak Kilovolts (0.3 mm Cu added)	AA	A	B	C	D	DD
Breast Diameter	10.19	11.74	12.93	14.81	15.46	17.17
40	247	696	1198	2321	2807	4308
45	120	336	574	1099	1326	2021
50	70	195	331	630	758	1150
55	45	125	211	399	479	723
60	32	86	146	274	328	493
65	23	63	106	199	238	356
70	18	48	81	150	179	268
75	14	38	63	117	140	208
80	11	30	51	94	112	166
85	9	25	42	77	91	136
90	8	21	35	64	76	113
95	7	18	30	54	65	96

Technique chart

mAs to use

Bra Cup Size

Breast Diameter	AA 10.19	A 11.74	B 12.93	C 14.81	D 15.46	DD 17.17
40	247	696	1198	2321	2807	4308
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70	18	48	81	150	179	268
75	14	38	63	117	140	208
80	11	30	51	73	94	112	166
85	9	25	42	77	91	136
90	8	21	35	64	76	113
95	7	18	30	54	65	96

Peak Kilovolts
0.3 mm Cu added

14 cm dia breast
total exposure:
773 mR
6.75 mGy
dose calculation:
6.75 x 0.88 = 5.9 mGy

10.6 mR/mAs ← 73 mAs for 14 cm diameter breast

The Breast Tomography Project

University of California, Davis

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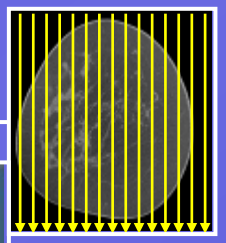

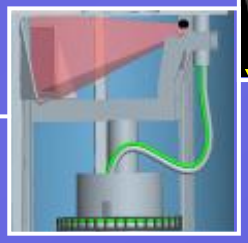

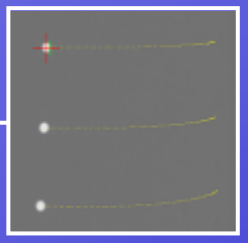

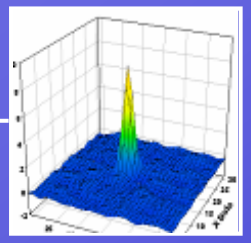

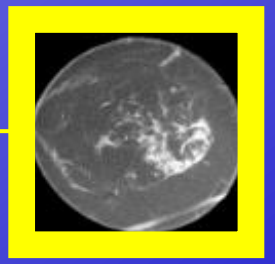

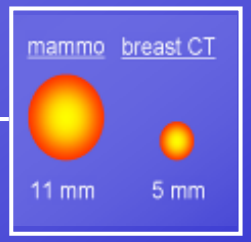

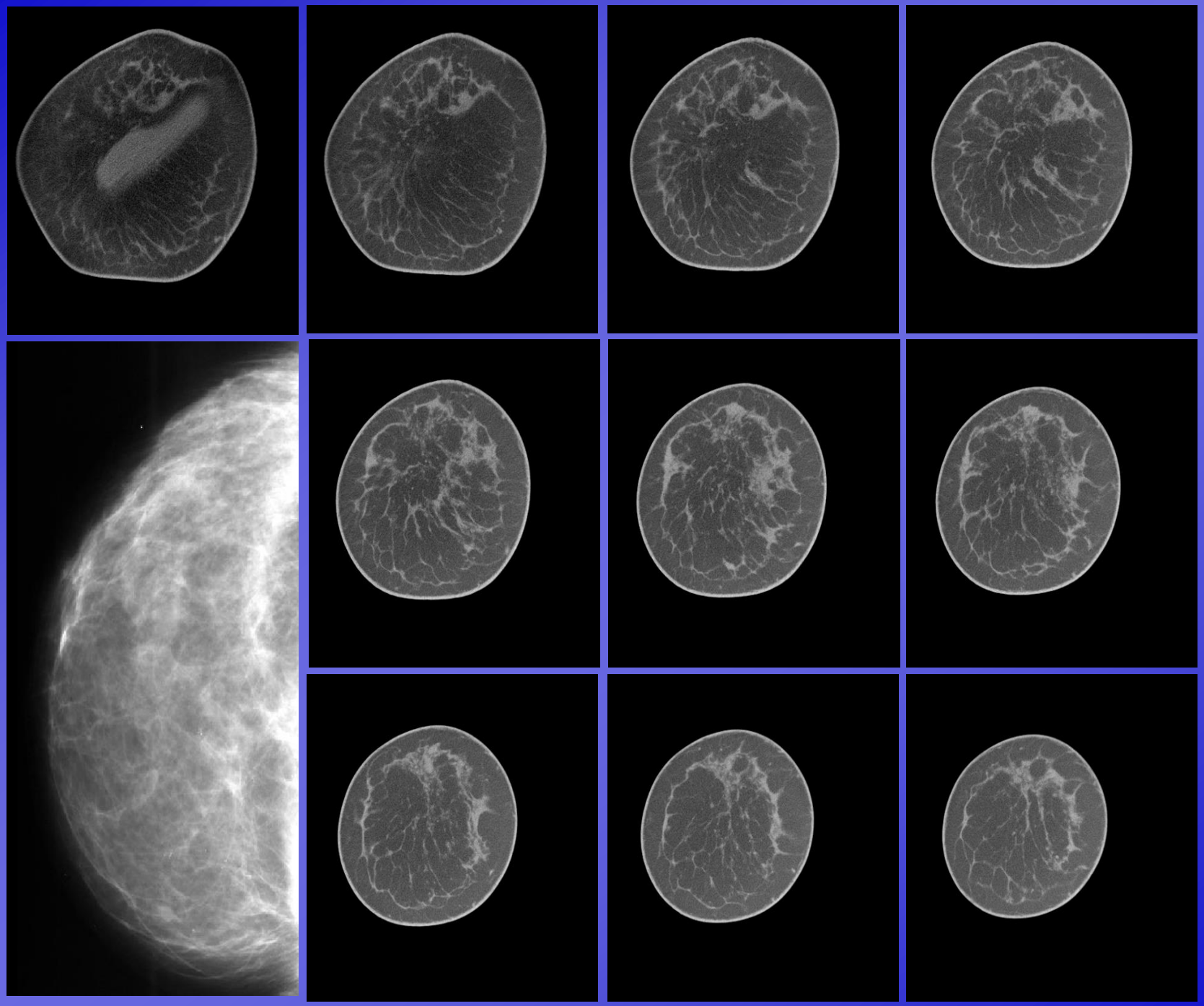

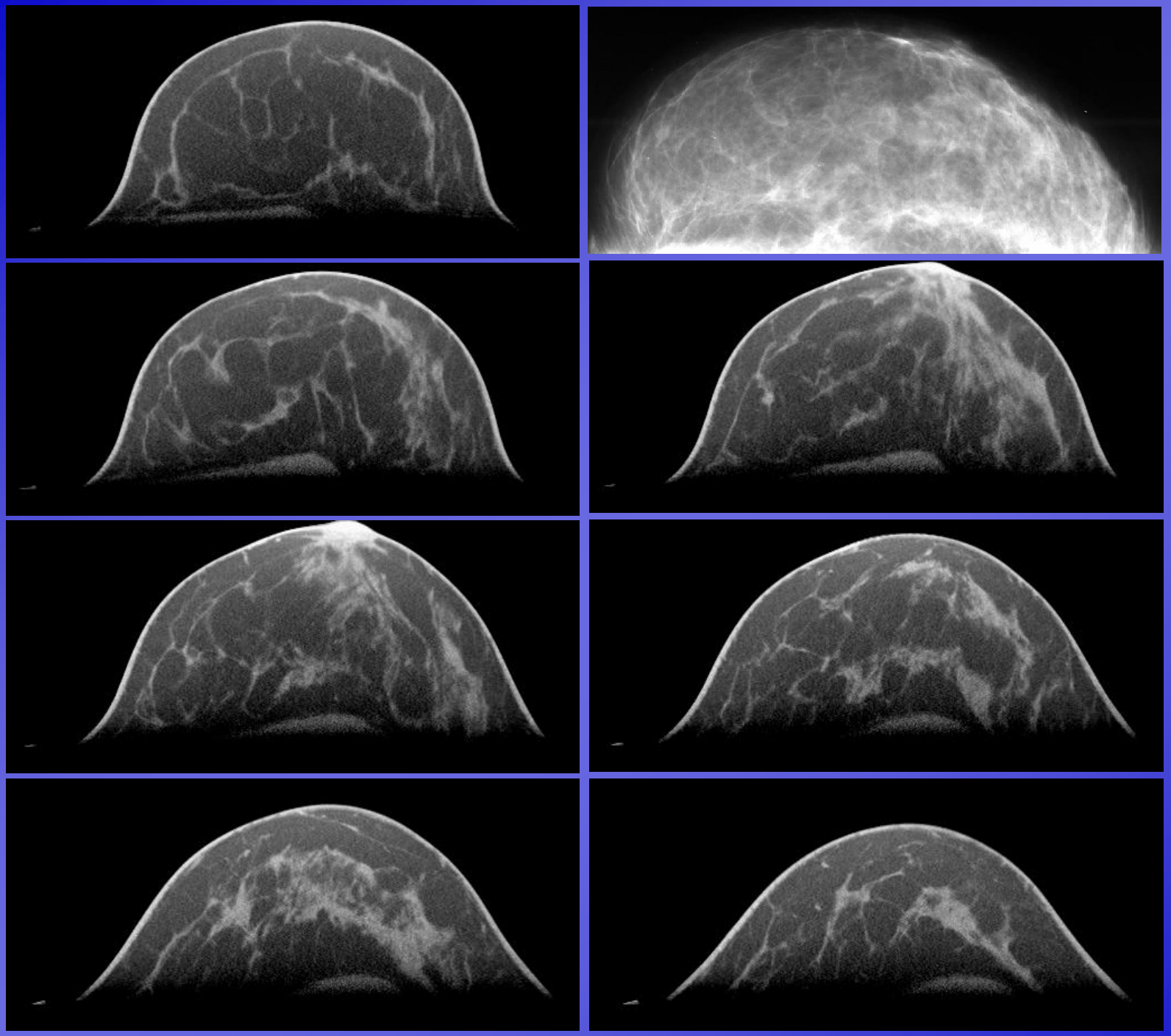

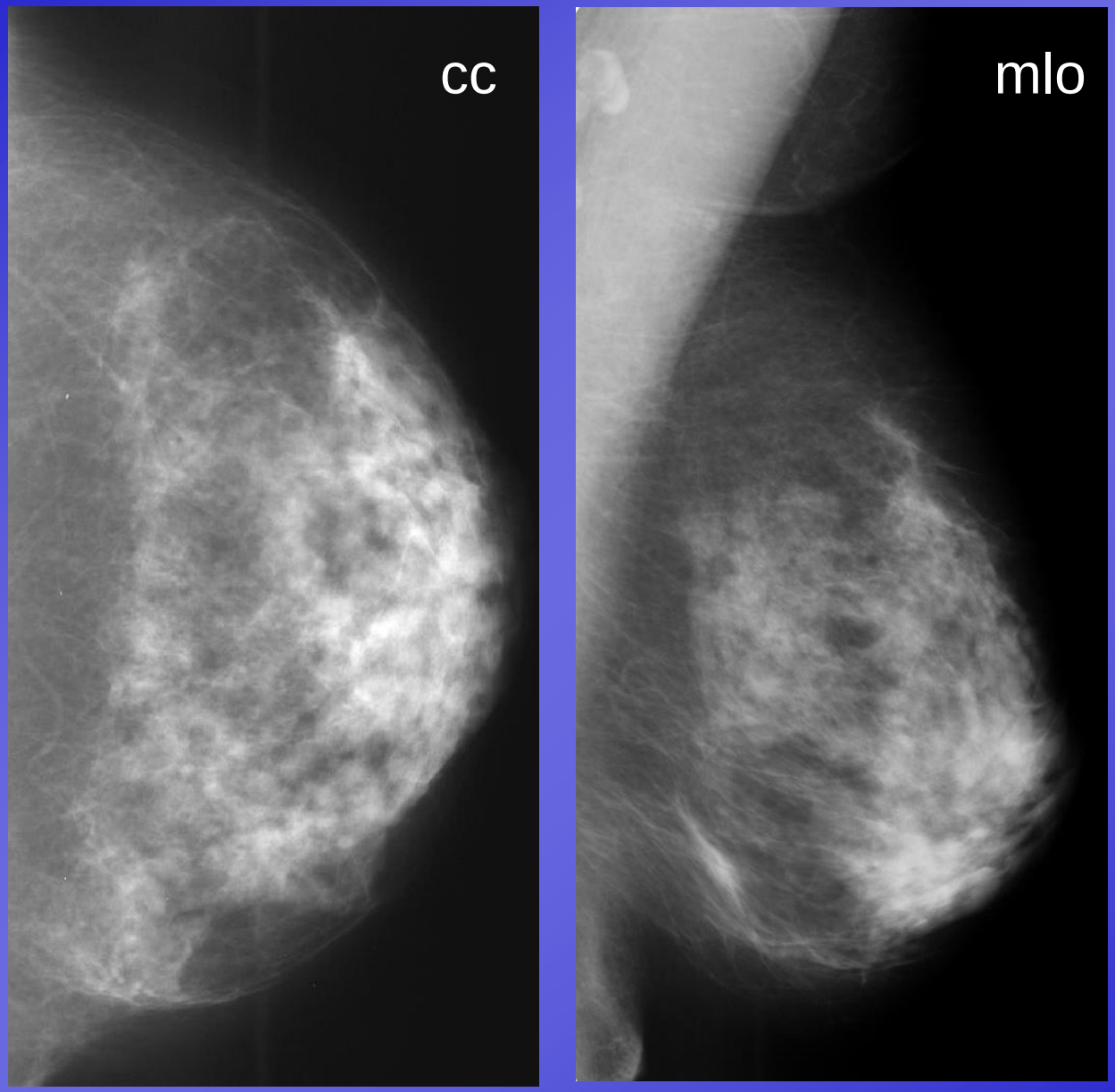
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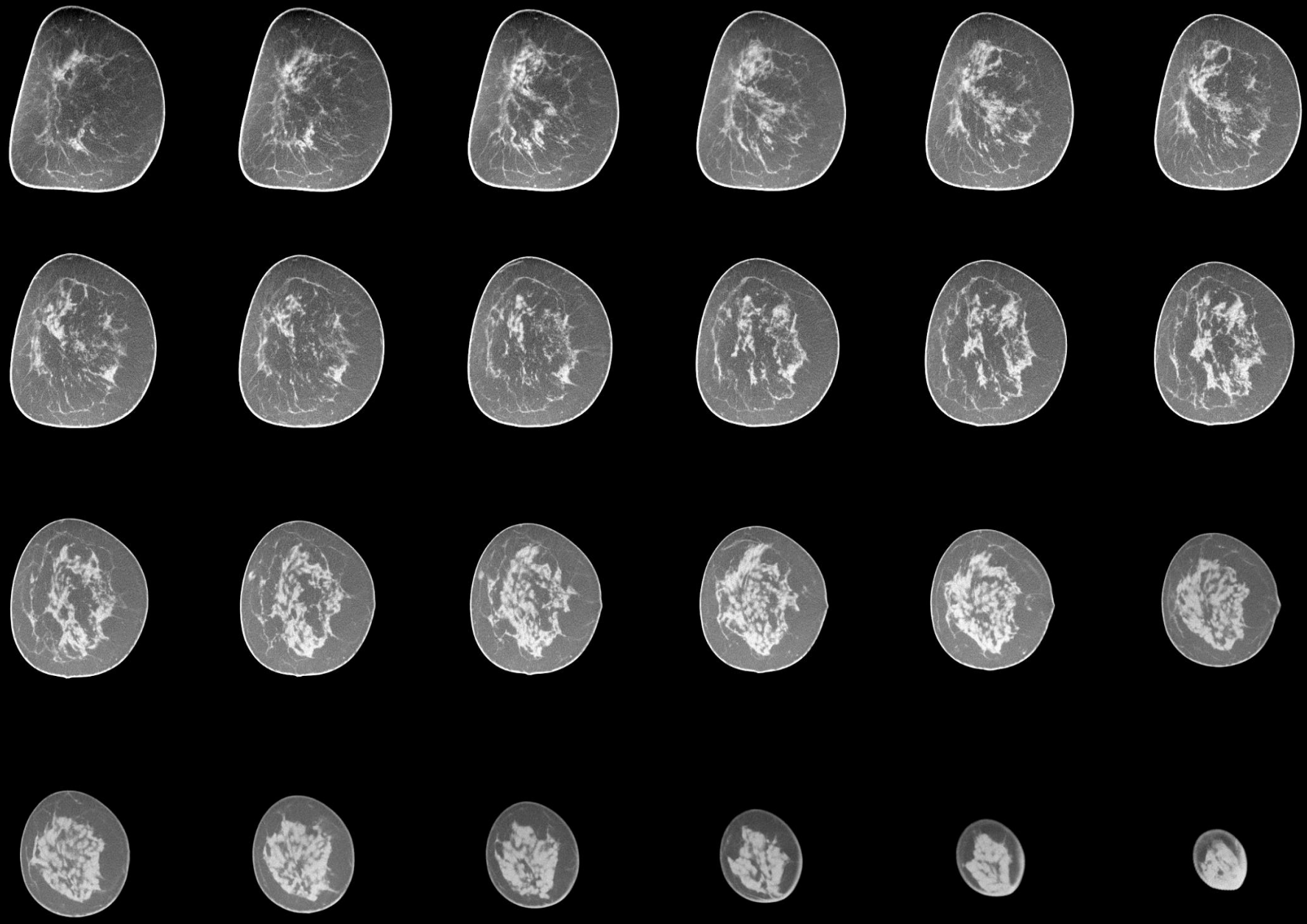

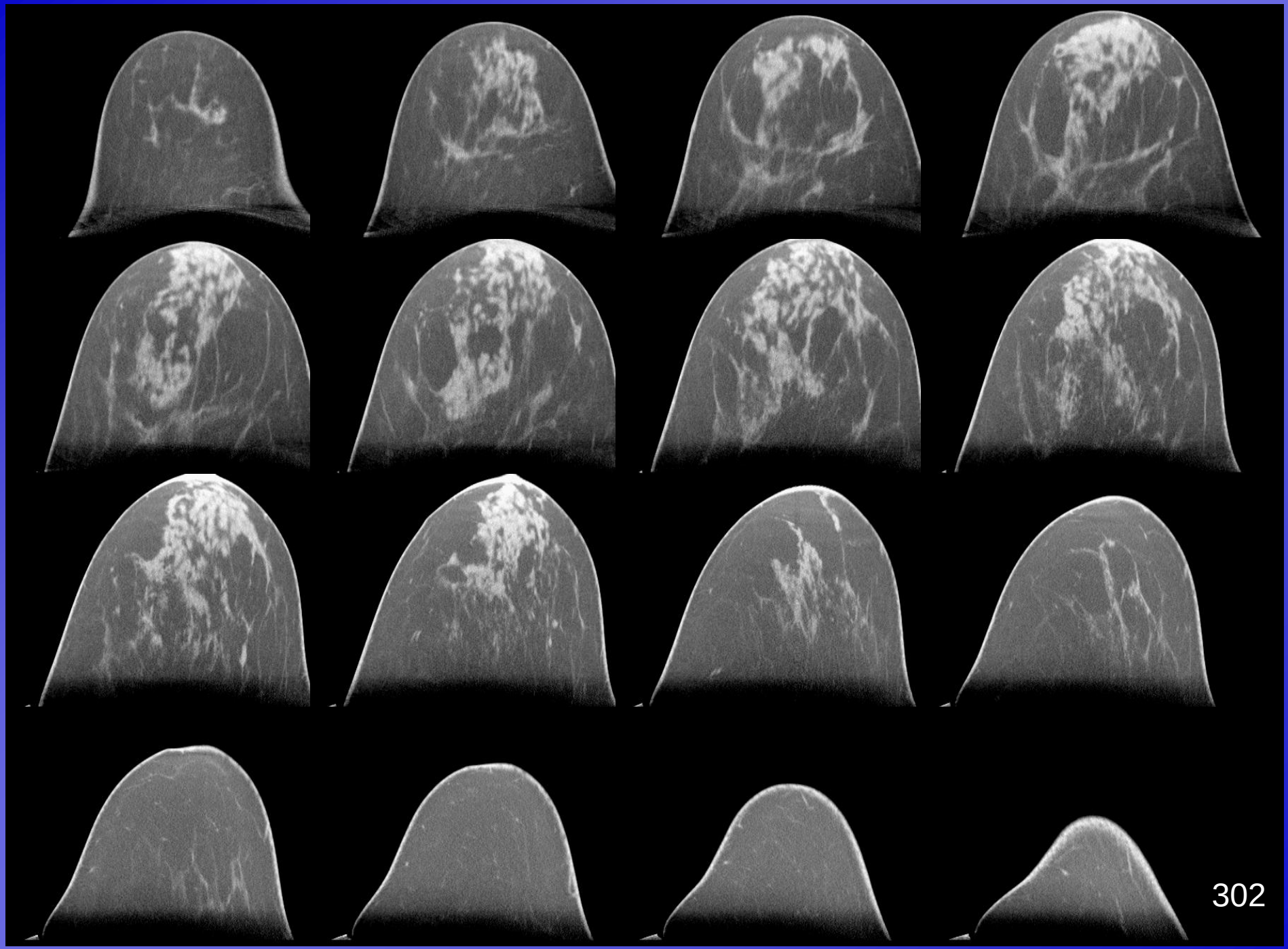
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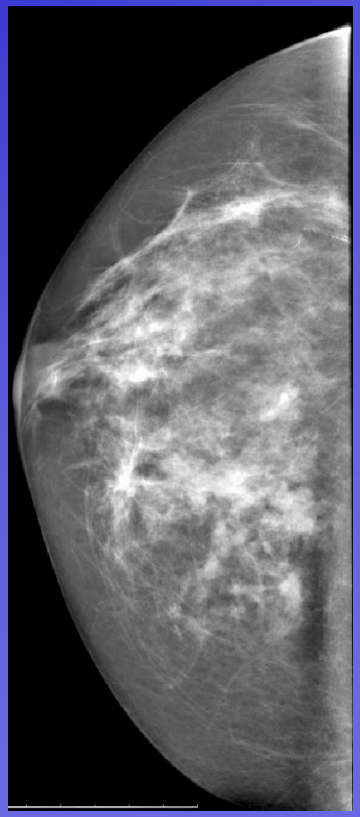

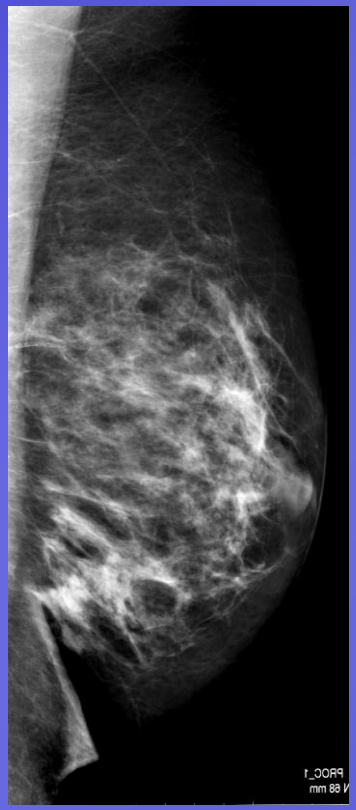

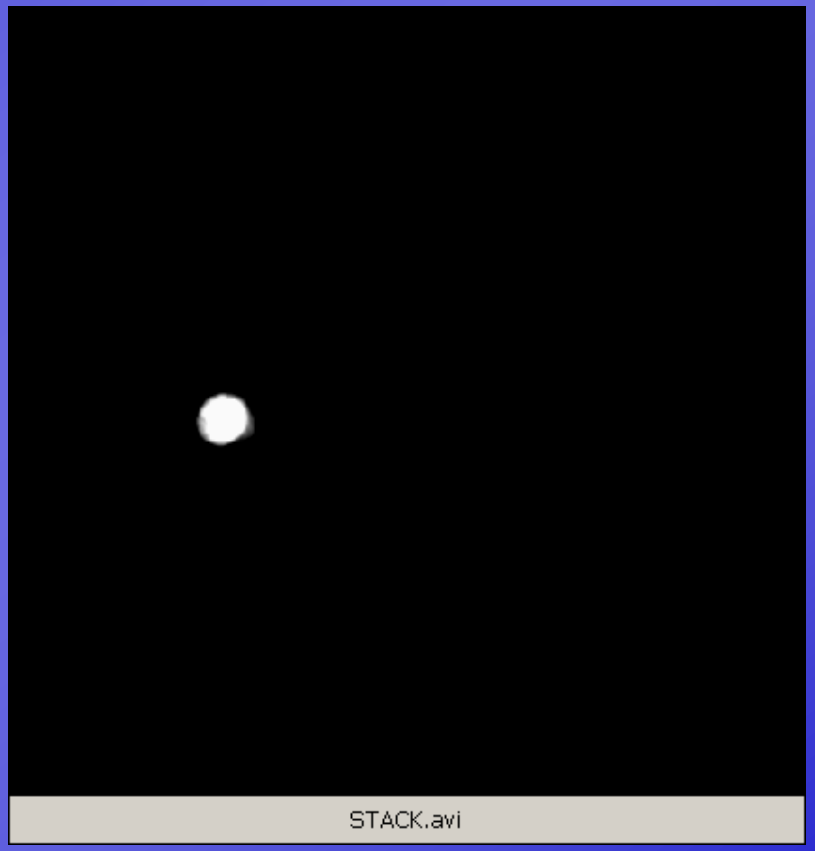
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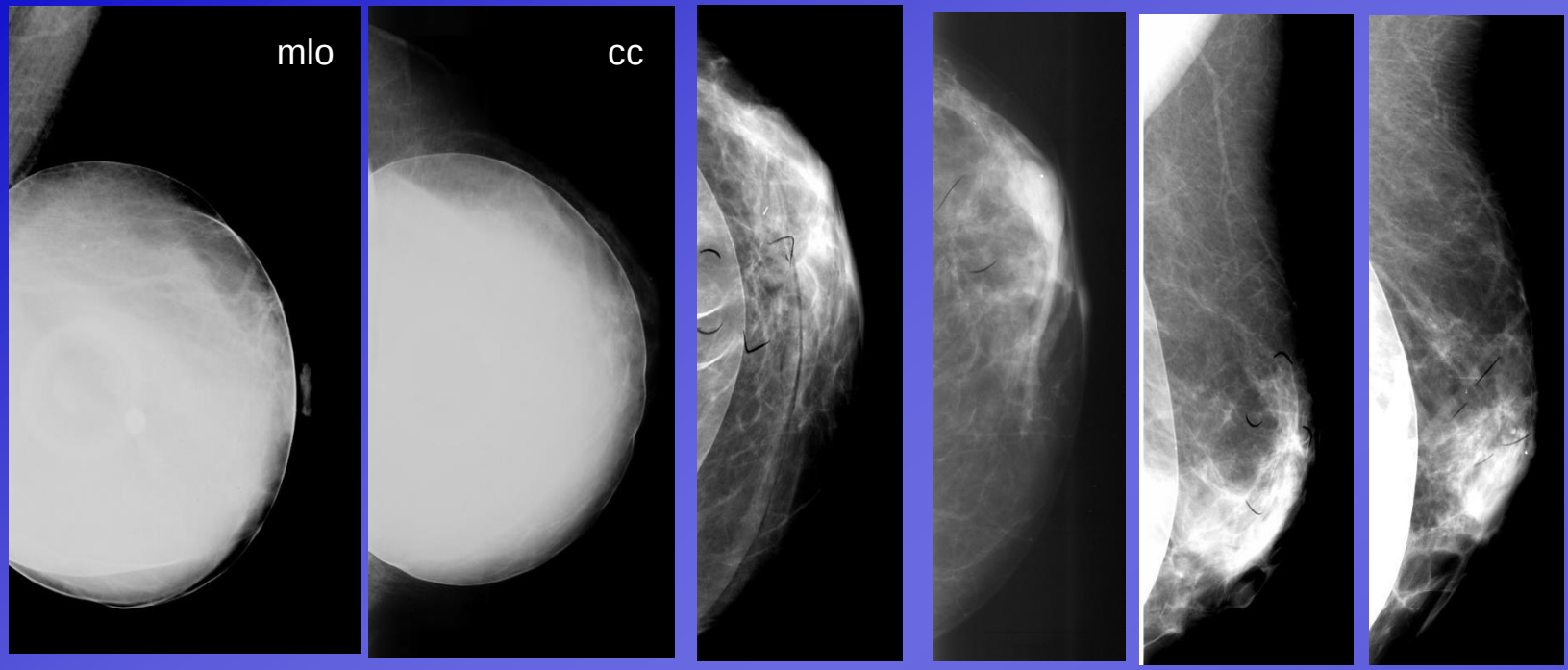
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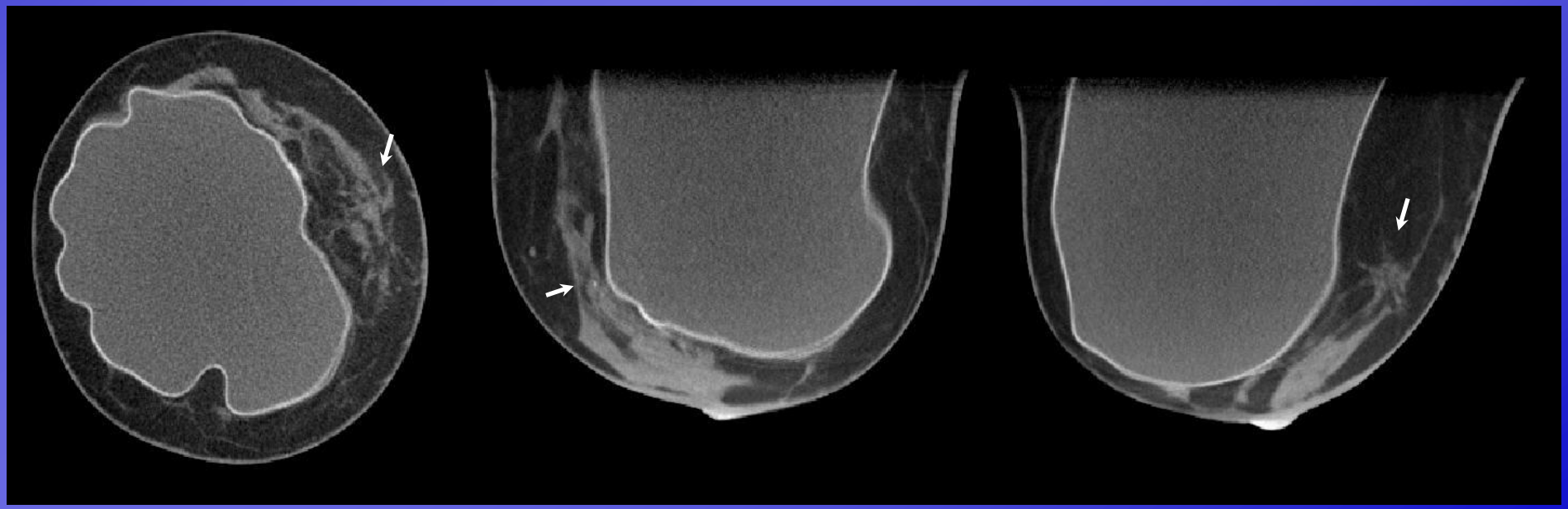

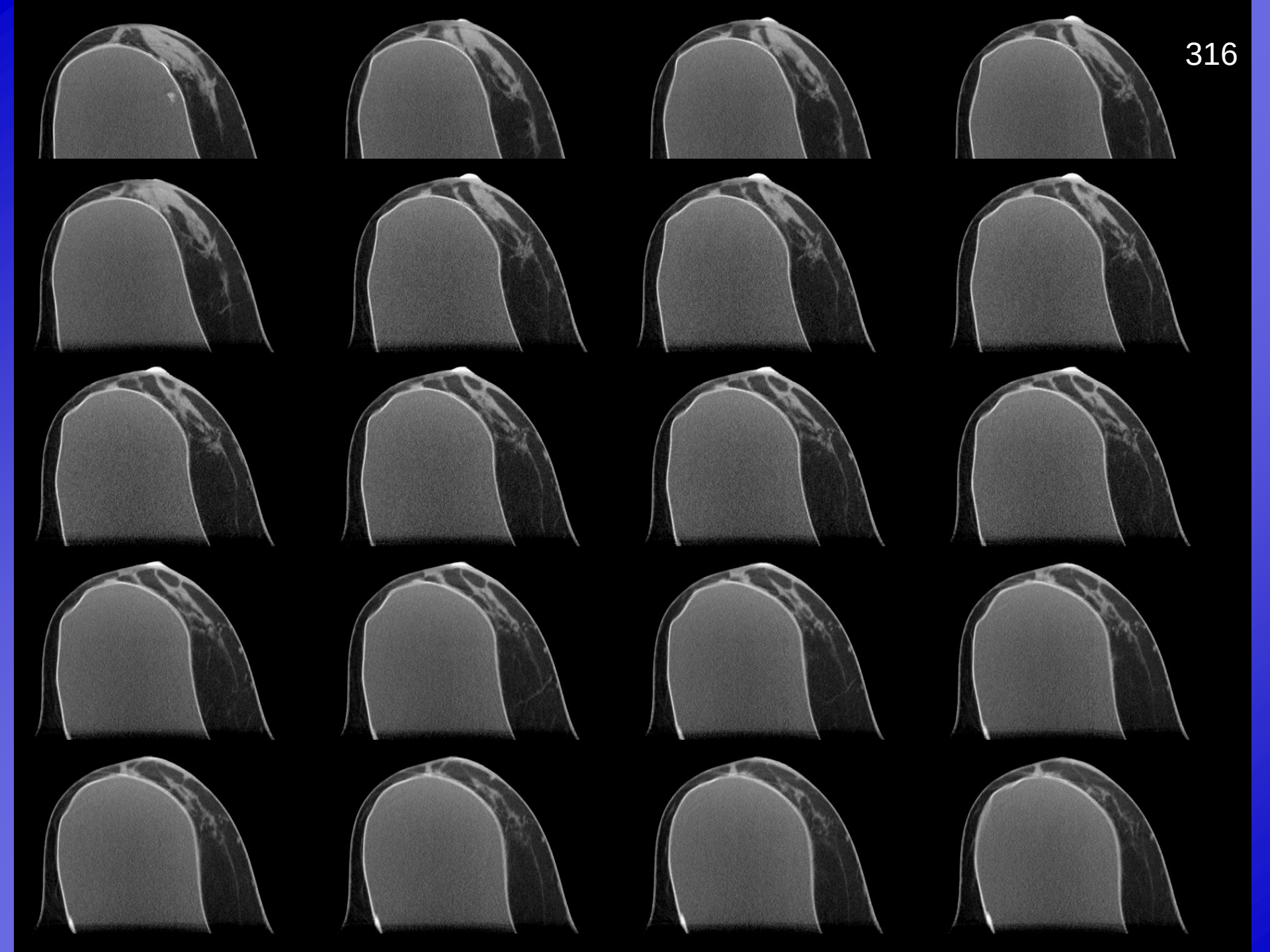
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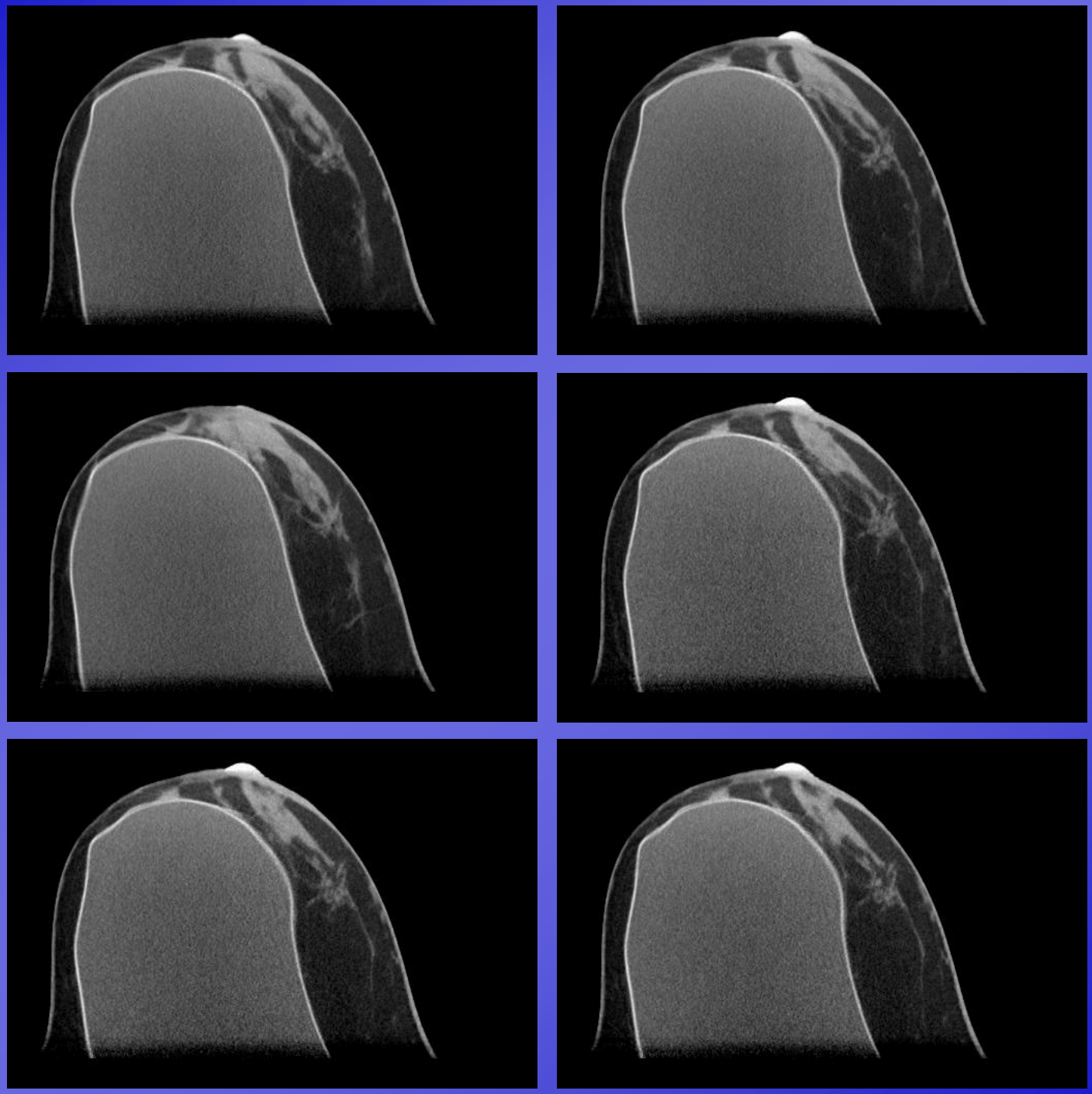
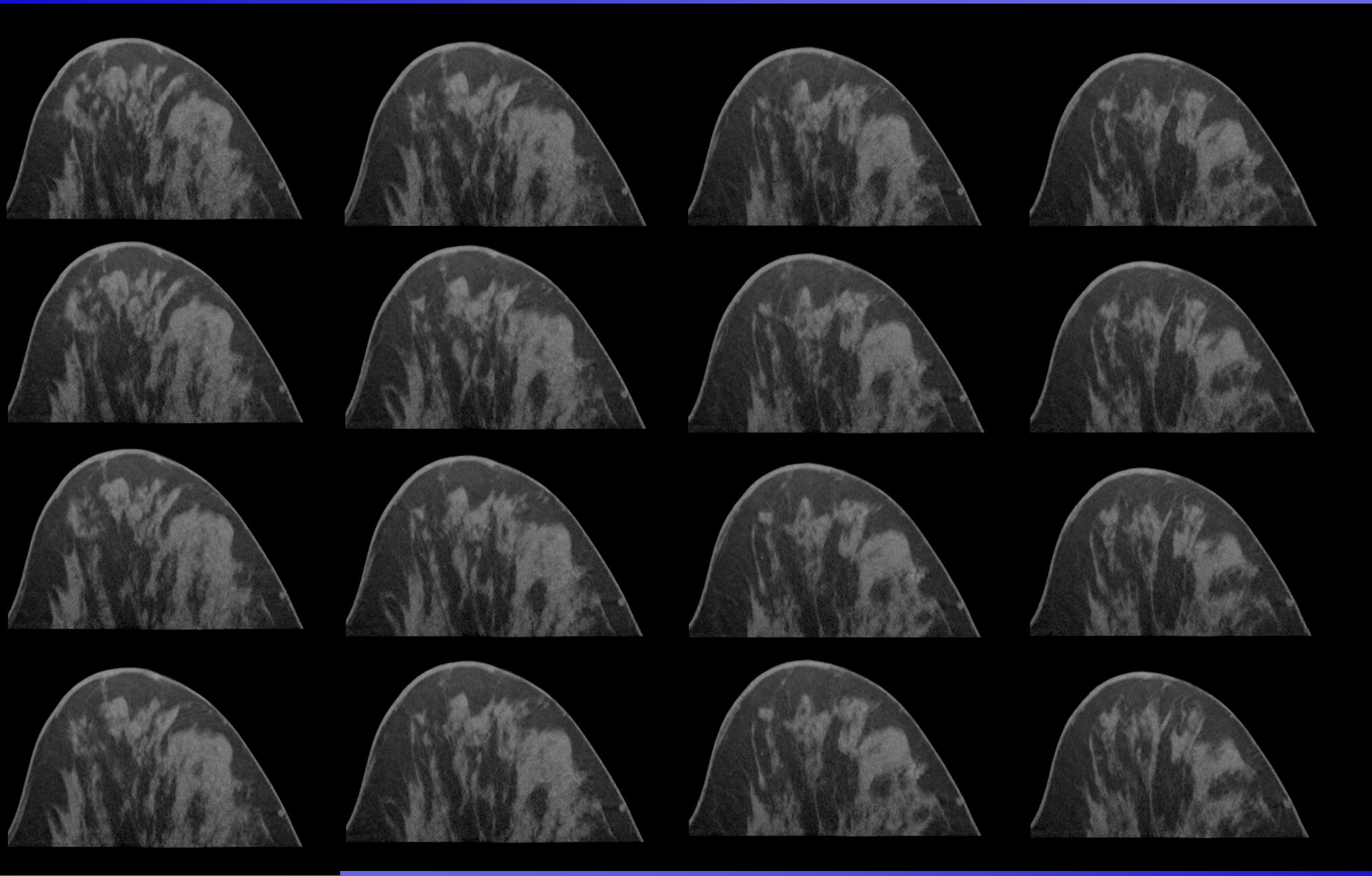
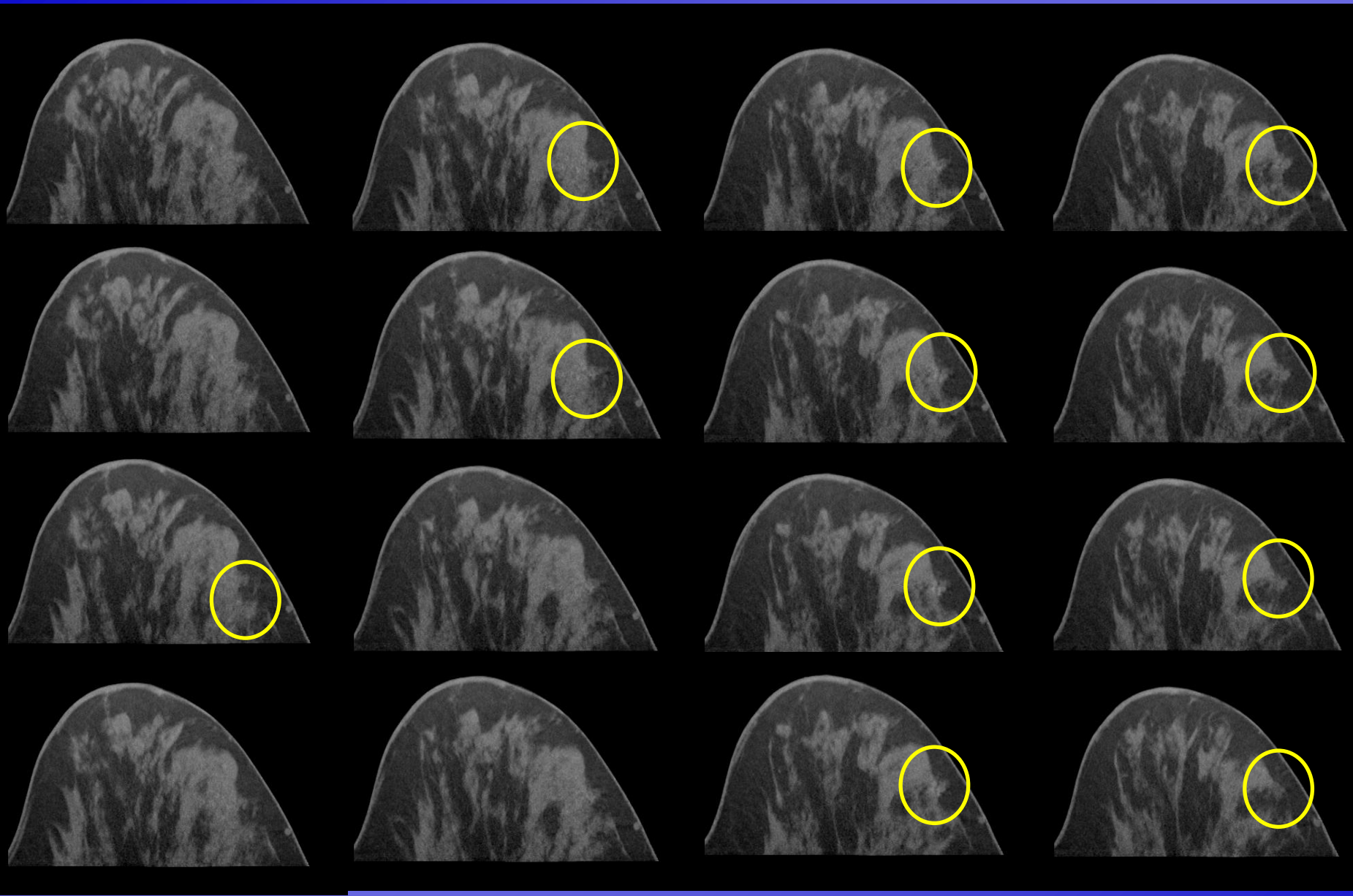


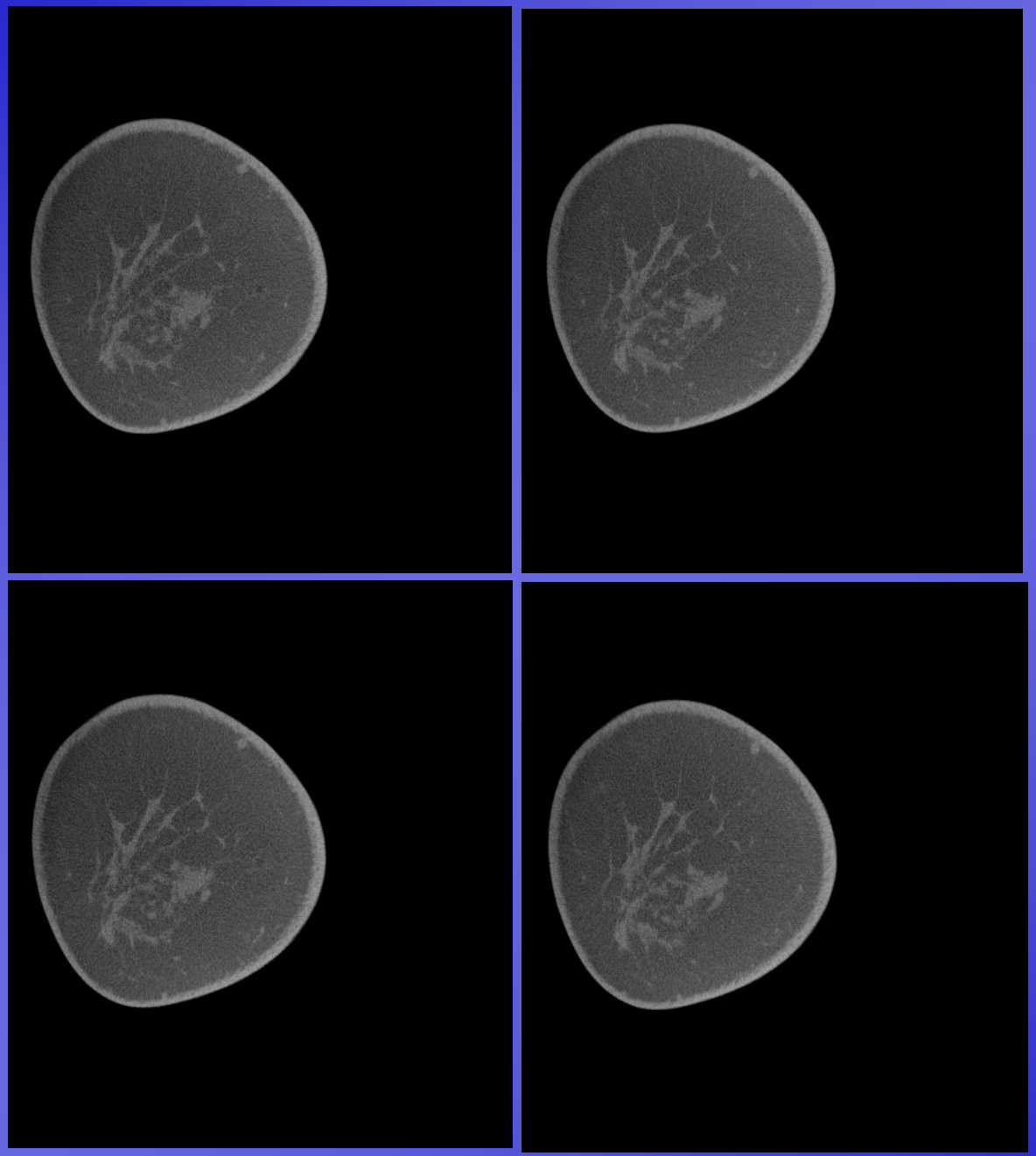


DCIS (415)



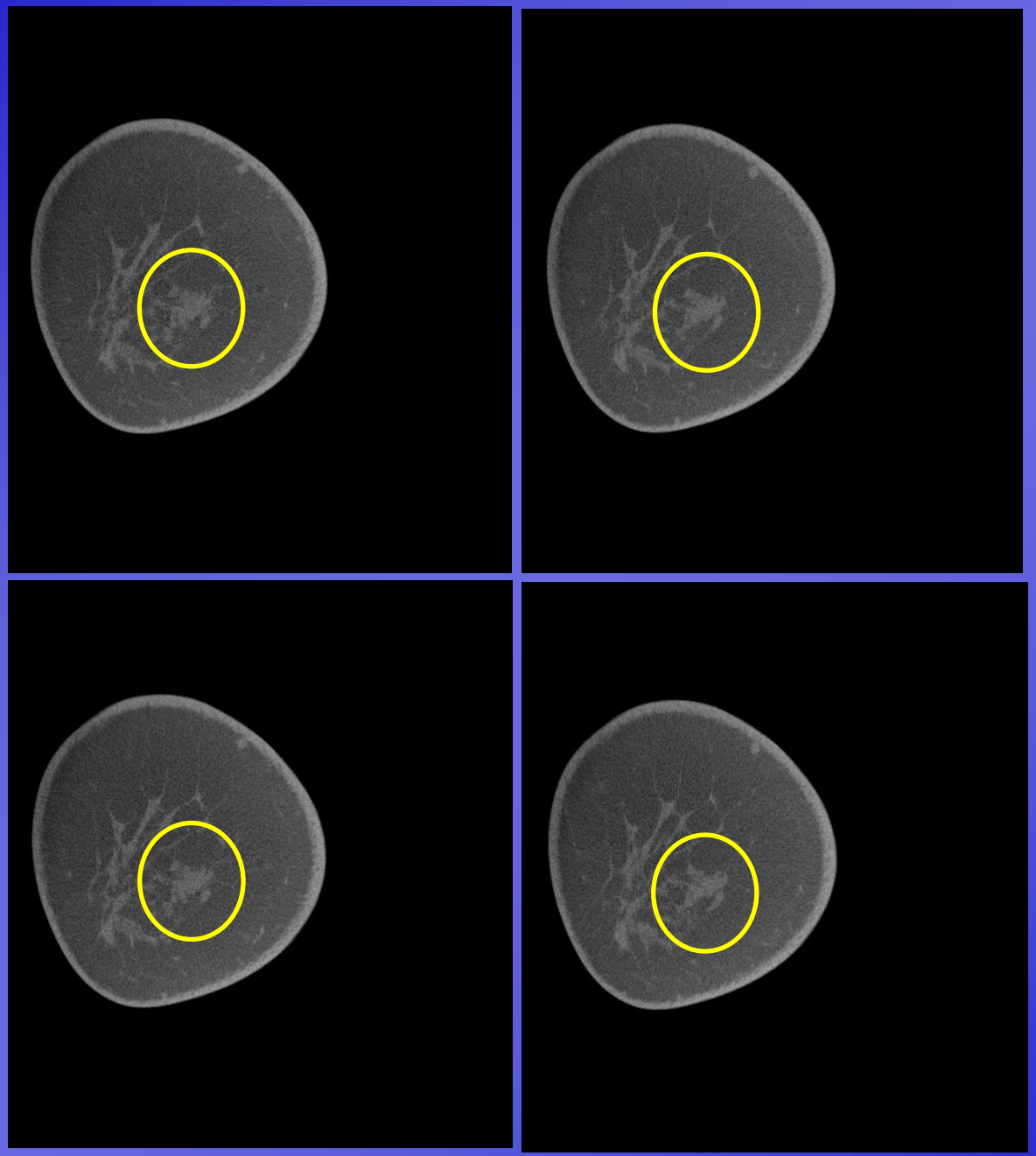
DCIS (415)

387

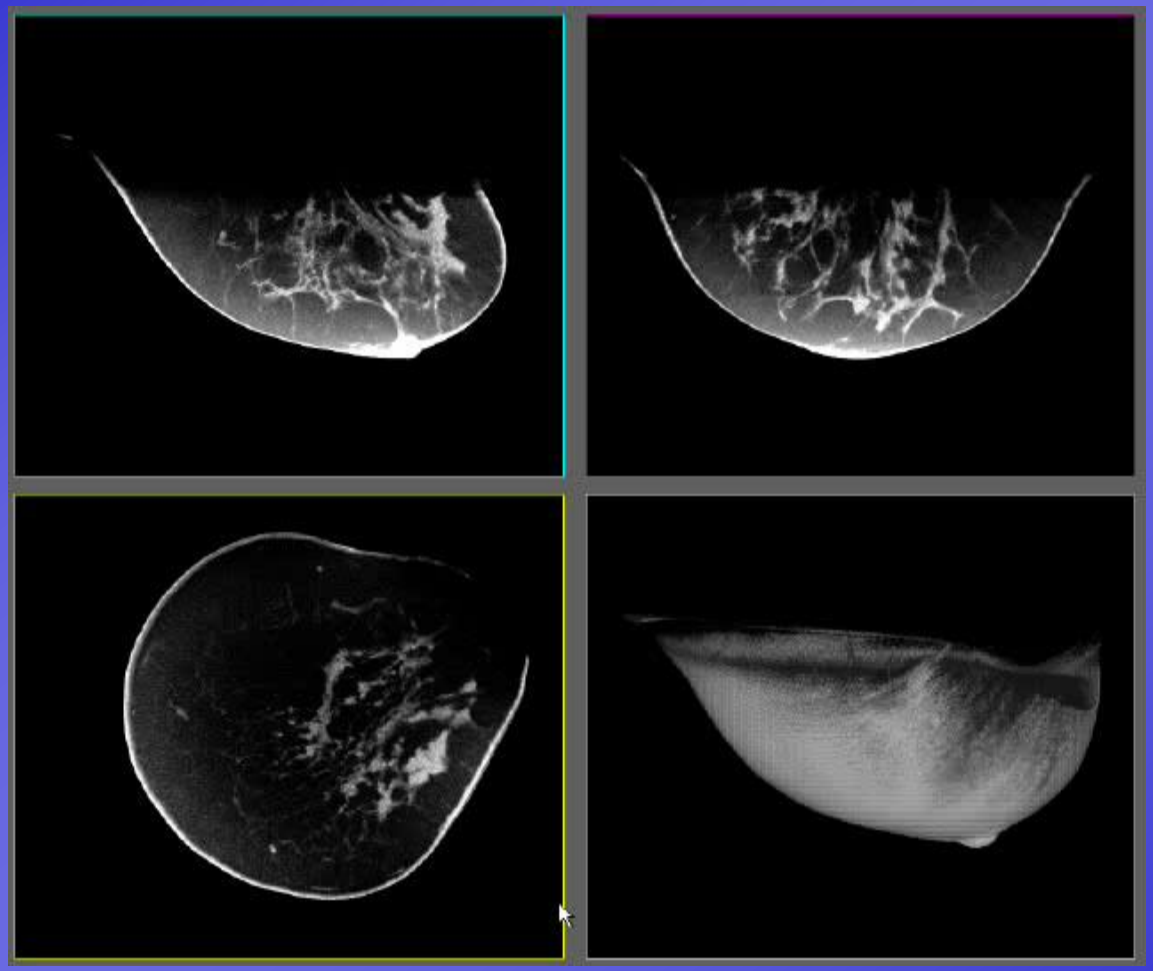


invasive ductal carcinoma

387



invasive ductal carcinoma



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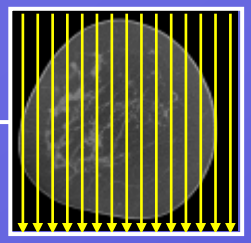
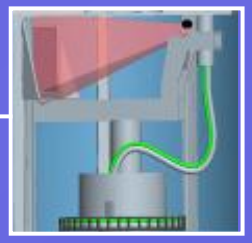
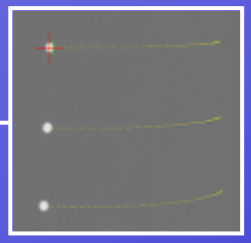
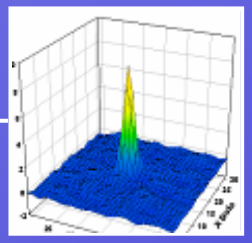
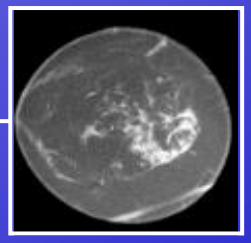
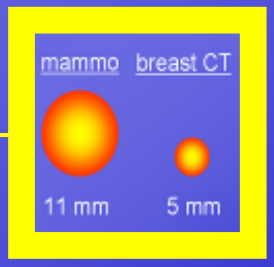




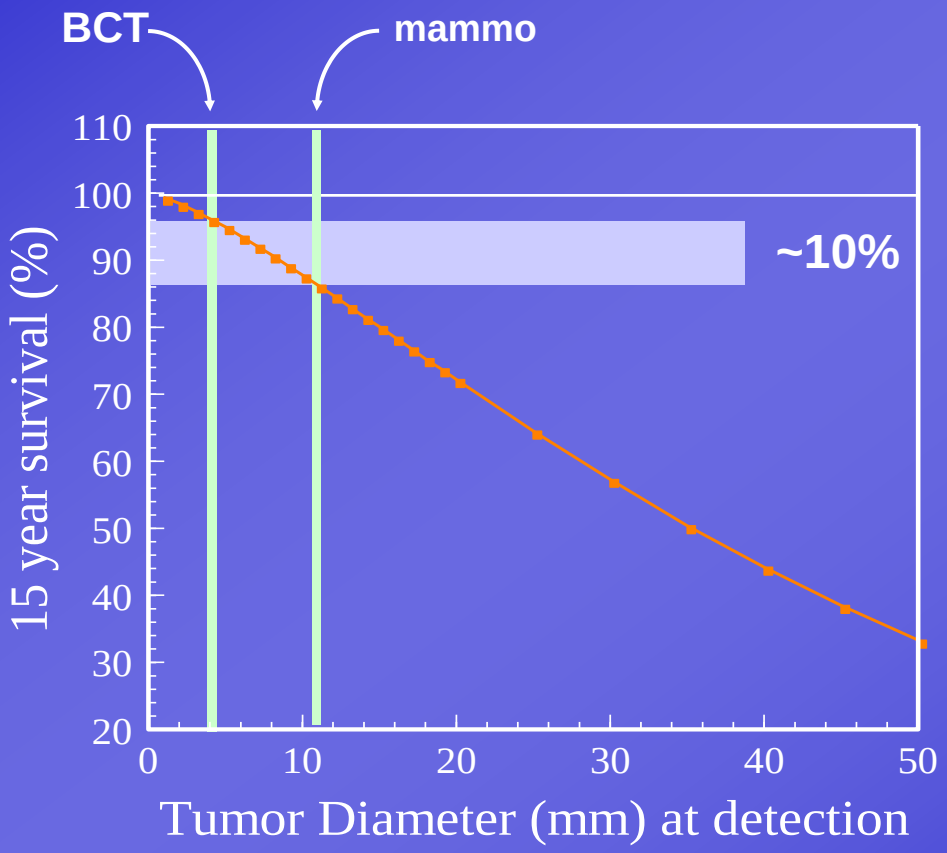


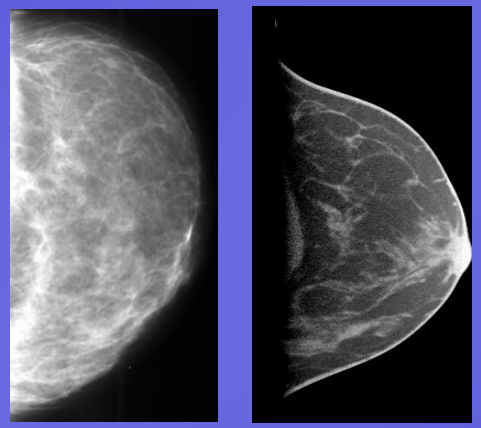




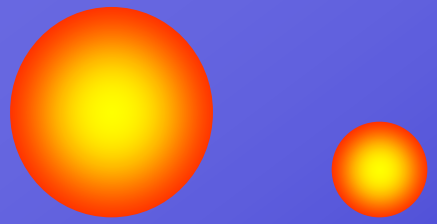


Potential Benefits?





mammo breast CT



11 mm 5 mm

9.4% of volume (cells)

0.93 year earlier detection

(100 day in vivo doubling time)

Predicting the survival of patients with breast carcinoma Using tumor size, JS Michaelson, M Silverstein, J Wyatt, et. Al. *Cancer* 2002; 95: 713-723

Breast CT at the University of California Davis

Introduction

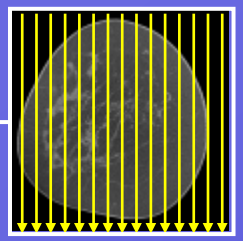
Design and Fabrication

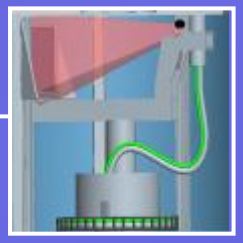
Calibration & Reconstruction

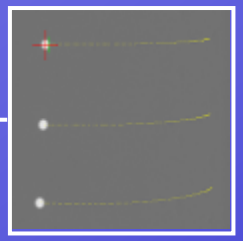
Image Quality & Dose

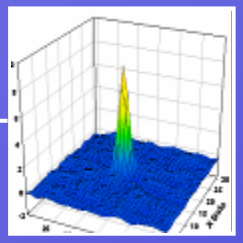
Patient Imaging

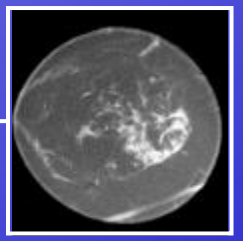
Conclusions

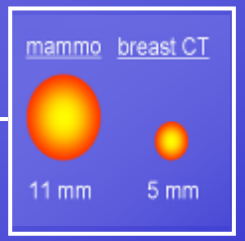












The Breast Tomography Project

University of California, Davis

The End