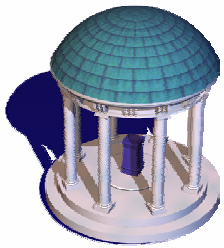


# Breast Tissue Imaging with DEI

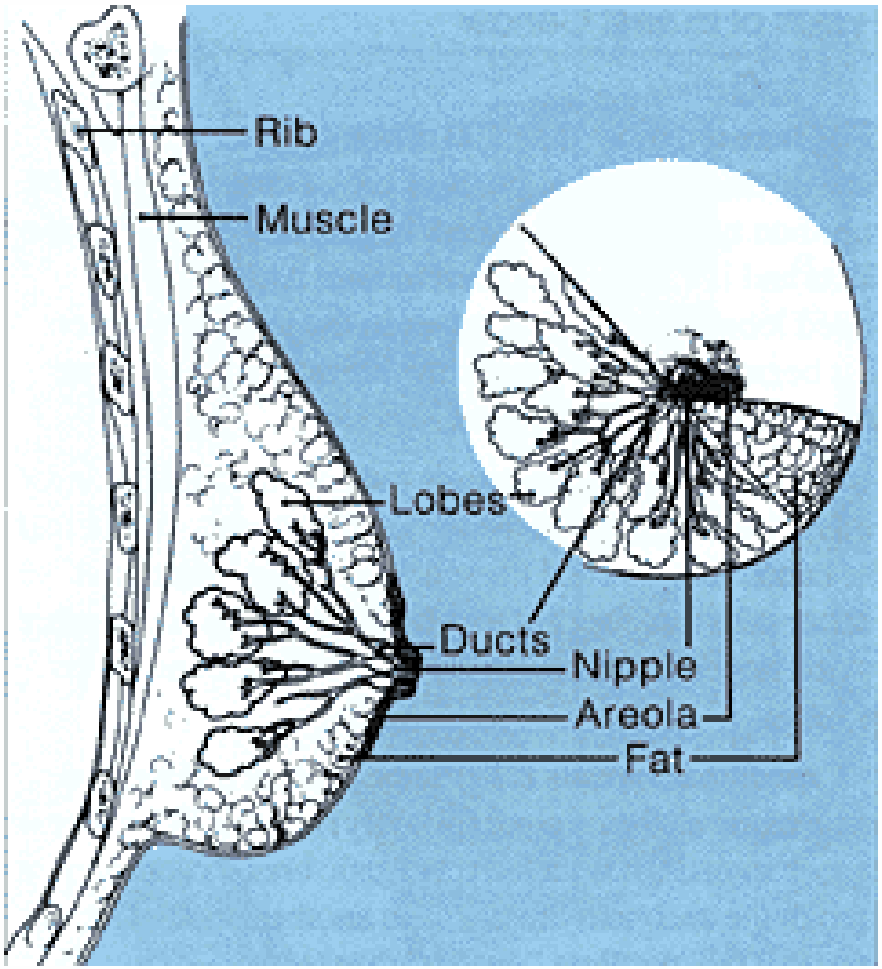
**Christopher Parham**

**UNC School of Medicine and Department of Biomedical Engineering**

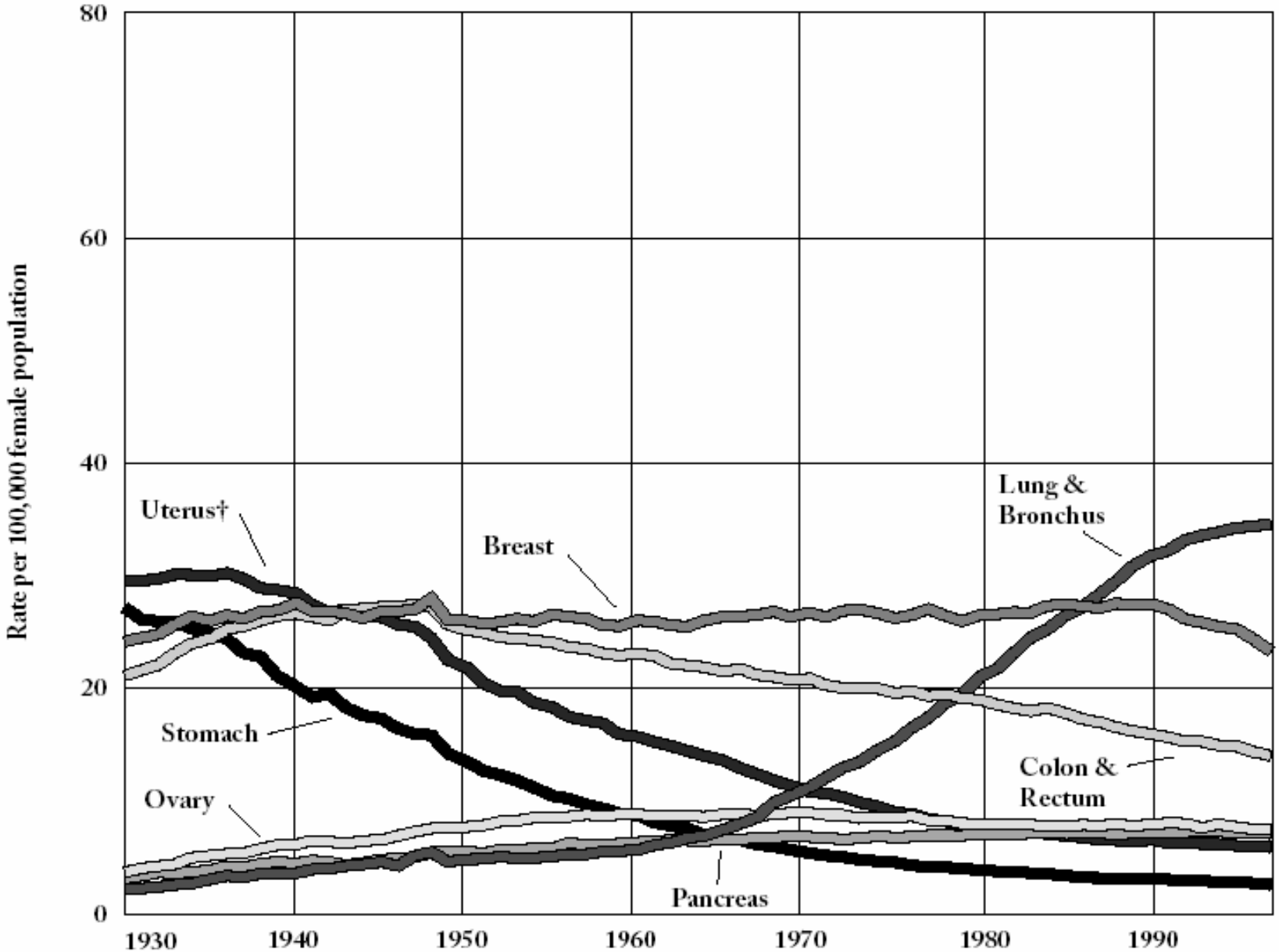
**NSLS-II Biomedical Imaging Workshop**

**September 22, 2003**

# Structure of the Breast



# Age-Adjusted Cancer Death Rates,* for Females by Site, US, 1930–1997




*Per 100,000, age-adjusted to the 1970 US standard population. †Uterus cancer death rates are for uterine cervix and uterine corpus combined. **Note:** Due to changes in ICD coding, numerator information has changed over time. Rates for cancers of the uterus, ovary, lung & bronchus, and colon & rectum are affected by these coding changes.

**Source:** US Mortality Public Use Data Tapes 1960–1997, US Mortality Volumes 1930–1959,
National Center for Health Statistics, Centers for Disease Control and Prevention, 2000.

American Cancer Society, Surveillance Research, 2001

# New Cancer Cases and Deaths

**Leading Sites of New Cancer Cases* and Deaths—2001 Estimates**

**Cancer Cases by Site and Sex**

| Male | Female |
|---|---|
| Prostate<br>198,100 (31%) | Breast<br>192,200 (31%) |
| Lung & bronchus<br>90,700 (14%) | Lung & bronchus<br>78,800 (13%) |
| Colon & rectum<br>67,300 (10%) | Colon & rectum<br>68,100 (11%) |
| Urinary bladder<br>39,200 (6%) | Uterine corpus<br>38,300 (6%) |
| Non-Hodgkin's lymphoma<br>31,100 (5%) | Non-Hodgkin's lymphoma<br>25,100 (4%) |
| Melanoma of the skin<br>29,000 (5%) | Ovary<br>23,400 (4%) |
| Oral cavity<br>20,200 (3%) | Melanoma of the skin<br>22,400 (4%) |
| Kidney<br>18,700 (3%) | Urinary bladder<br>15,100 (2%) |
| Leukemia<br>17,700 (3%) | Pancreas<br>15,000 (2%) |
| Pancreas<br>14,200 (2%) | Thyroid<br>14,900 (2%) |
| All Sites<br>643,000 (100%) | All Sites<br>625,000 (100%) |

**Cancer Deaths by Site and Sex**

| Male | Female |
|---|---|
| Lung & bronchus<br>90,100 (31%) | Lung & bronchus<br>67,300 (25%) |
| Prostate<br>31,500 (11%) | Breast<br>40,200 (15%) |
| Colon & rectum<br>27,700 (10%) | Colon & rectum<br>29,000 (11%) |
| Pancreas<br>14,100 (5%) | Pancreas<br>14,800 (6%) |
| Non-Hodgkin's lymphoma<br>13,800 (5%) | Ovary<br>13,900 (5%) |
| Leukemia<br>12,000 (4%) | Non-Hodgkin's lymphoma<br>12,500 (5%) |
| Esophagus<br>9,500 (3%) | Leukemia<br>9,500 (4%) |
| Liver<br>8,900 (3%) | Uterine corpus<br>6,600 (2%) |
| Urinary bladder<br>8,300 (3%) | Brain<br>5,900 (2%) |
| Kidney<br>7,500(3%) | Stomach<br>5,400 (2%) |
| All Sites<br>286,100 (100%) | All Sites<br>267,300 (100%) |

*Excludes basal and squamous cell skin cancers and in situ carcinomas except urinary bladder.

# Medical Terminology

## *What does "in situ" mean?*

The term "in situ" is used to indicate an early stage of cancer in which a tumor is confined to the immediate area where it began. Specifically in breast cancer, in situ means that the cancer remains confined to ducts or lobules, and it has neither invaded the surrounding tissue in the breast nor spread to other organs in the body. Ductal Carcinoma In-Situ (DCIS) is the most common type of non-invasive breast cancer.

## *What are Metastases?*

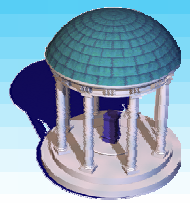
Metastases are satellite tumors that indicate a breast cancer has spread from the site where it began (referred to as the primary cancer) to a lymph node or a distant organ, such as the lung, liver, or brain

# Medical Terminology

***What are Calcifications?***

Calcifications are mineral deposits in the breast that may be caused by trauma to the breast, resorbed blood, or dead tissue cells.

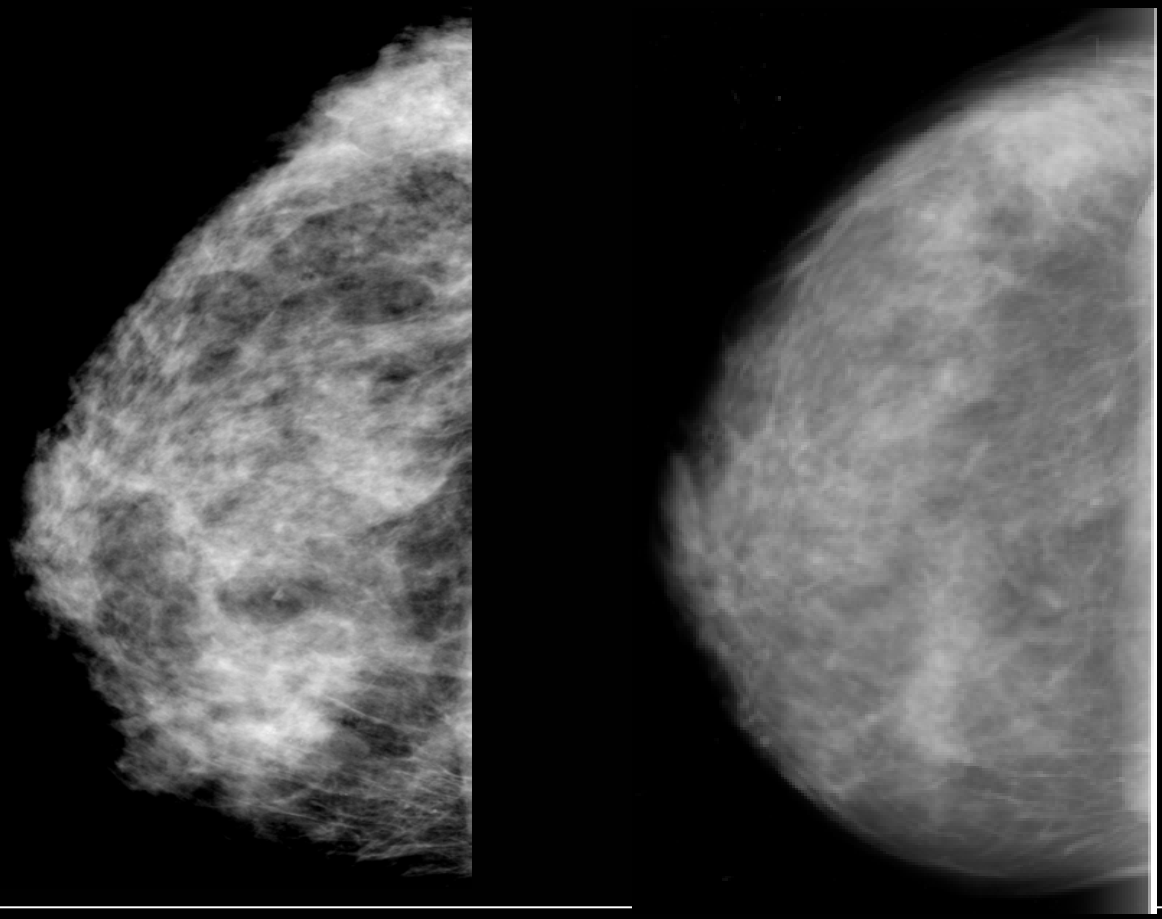
Calcifications are not equivalent to cancer. But they are signs of changes within the breast, and certain patterns of calcifications can be associated with cancer or benign breast disease.



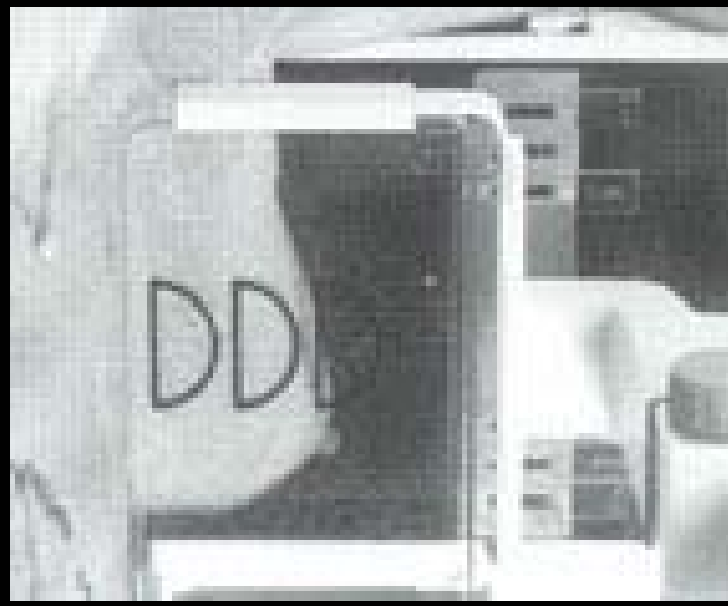
# Breast Cancer Types

| Breast Cancer Type | Comments |
|---|---|
| Ductal Carcinoma In-Situ | Mild malignant potential |
| Lobular Carcinoma In-Situ | Mild malignant potential |
| Infiltrating Ductal Carcinoma | The most common breast cancer by far |
| Infiltrating Lobular Carcinoma | 5 to 10 percent of all breast cancers |
| Inflammatory Breast Cancer | Very serious, uncommon |
| Medullary Breast Cancer | Uncommon |
| Cystosarcoma Phalloides | Very Rare |

# Examples of Screen-Film and Digital Mammography



# Conventional Mammography Breast Compression



Pictures provided by Imaginis

www.imaginis.com

The TNM staging classification for Breast Cancer can be illustrated as follows:

| Stage of Tumor | Size of the Cancer | Cancer in Lymph Nodes? | Metastasis |
|---|---|---|---|
| I | < 2 cm | None | None |
| II | 2 - 5 cm | No, or yes on same side of breast | None |
| III | > 5 cm | yes, on same side of breast | None |
| IV | doesn't matter | doesn't matter | Yes |

**Prognosis of Breast Cancer as a Function of TNM Stage**

**Stage I. Approximately 90% will be alive 5 years after diagnosis.**

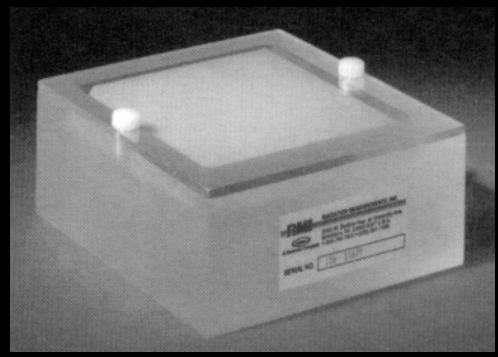
**Stage II. About 65% of patients with Stage II disease will be alive after 5 years.**

**Stage III. 45% of Stage III patients will be alive after 5 years**

**Stage IV. Women with Stage IV disease have a five-year survival of less than 10%.**

# Discovery of DEI

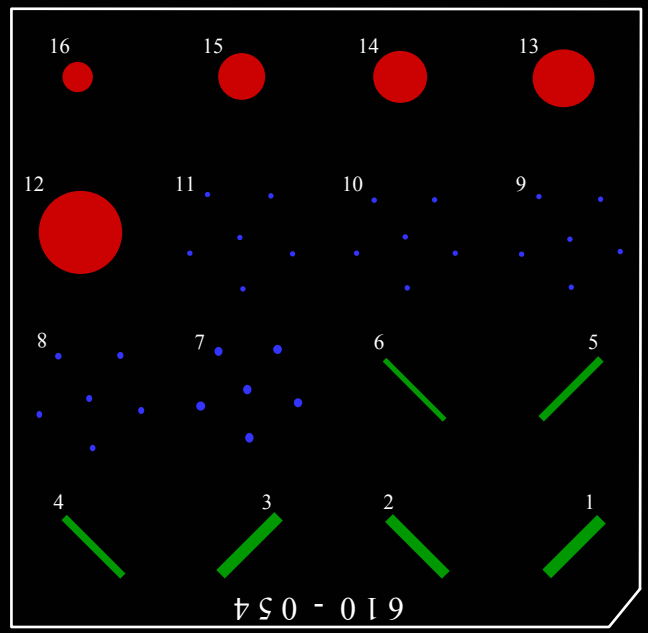
- Mammography Quality Assurance Object
  - **American College of Radiology Mammography Phantom**
  - **This phantom contains objects which simulate features presented by lesions in breast tissue (masses, fibrils and specks). Images are scored according to the number of targets detected in a category (i.e. masses, fibrils and specks).**



- Manufactured by Gammex RMI: Model 156.
- Sketch at right shows objects imbedded in phantom
- Phantom is approximately 3 in x 3 in x 2 in

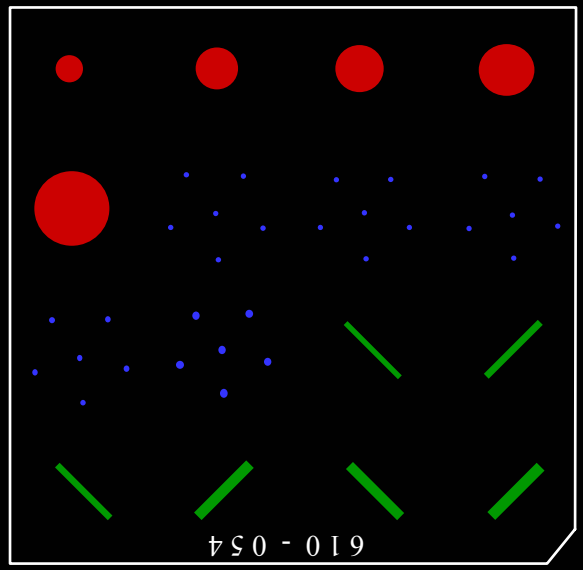
**Region Materials**

1. 1.56 mm nylon fiber
2. 1.12 mm nylon fiber
3. 0.89 mm nylon fiber
4. 0.75 mm nylon fiber
5. 0.54 mm nylon fiber
6. 0.40 mm nylon fiber
7. 0.54 mm simulation micro-calcification
8. 0.40 mm simulated micro-calcification
9. 0.32 mm simulated micro-calcification
10. 0.24 mm simulated micro-calcification
11. 0.16 mm simulated micro-calcification
12. 2.00 mm tumor-like mass
13. 1.00 mm tumor-like mass
14. 0.75 mm tumor-like mass
15. 0.50 mm tumor-like mass
16. 0.25 mm tumor-like mass

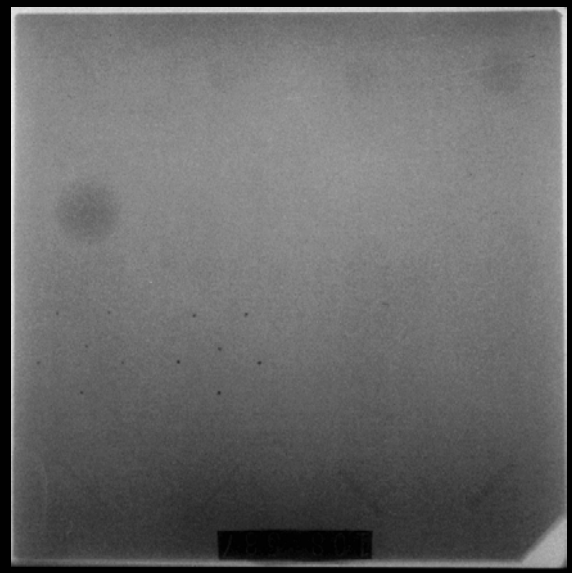



Slide Provided Courtesy of Dean Chapman, PhD, IIT

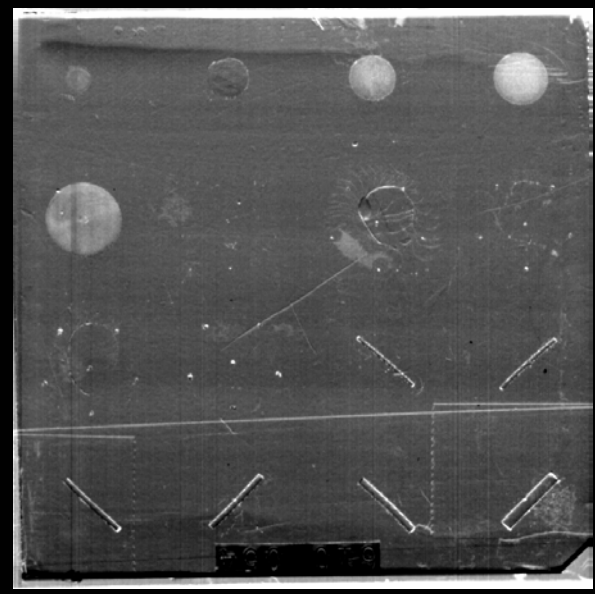
# Comparison - Conventional and DEI




Map



Conventional

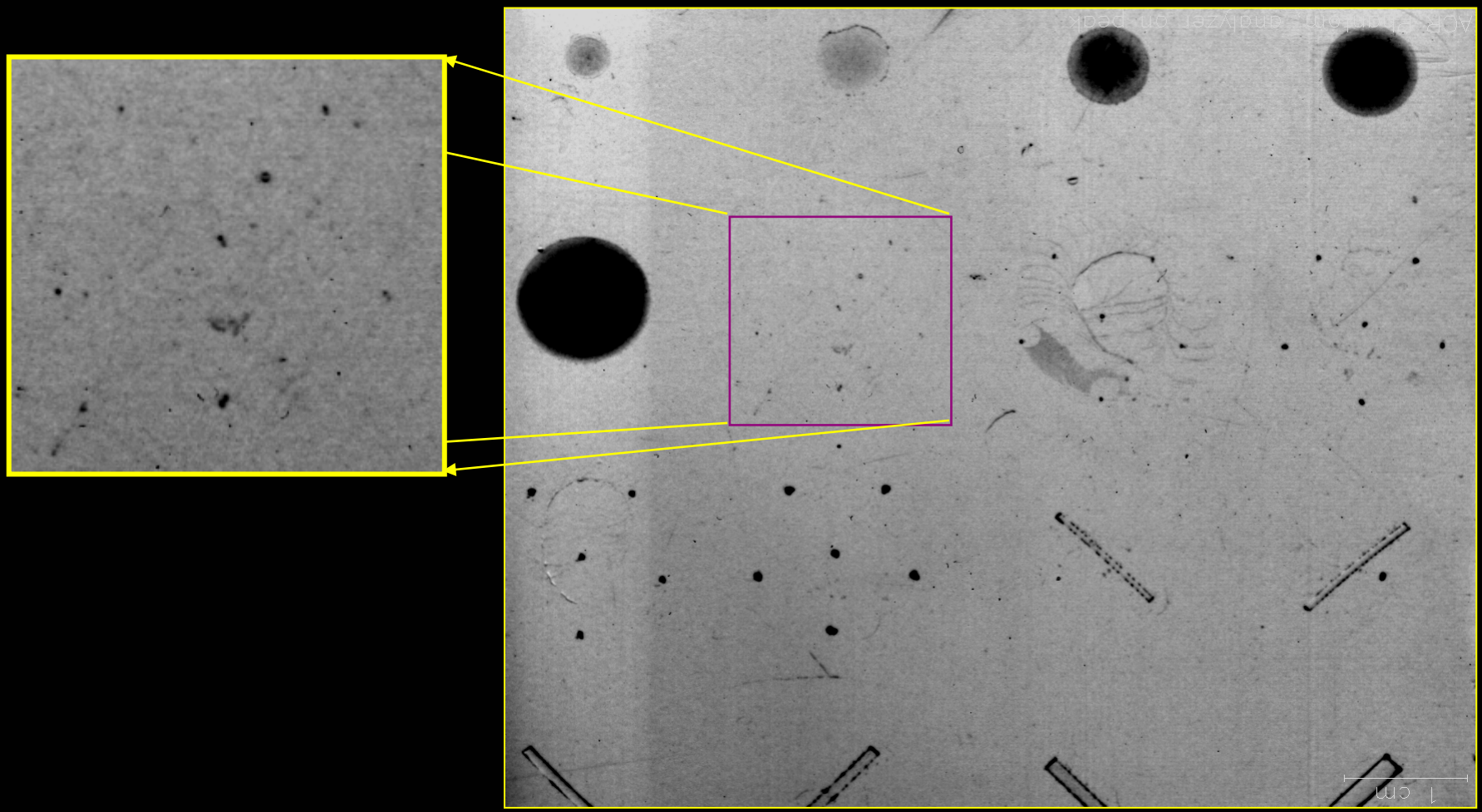


DEI

Slide Provided Courtesy of Dean Chapman, PhD

Illinois Institute of Technology

# DEI image of ACR phantom
## - smallest calcifications



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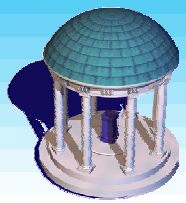
Illinois Institute of Technology

**Data from NSLS X27**



**DEI Parameter Study**
**Funding Agency:**
**U.S. Army Medical Research and Materiel Command**
**DAMD17-99-1-9330**
**Principal Investigator: Etta D. Pisano, M.D.**

**Purpose:**

**To determine the optimal imaging parameters for DEI in regards to beam energy, analyzer crystal configuration, and for different points on the rocking curve.**

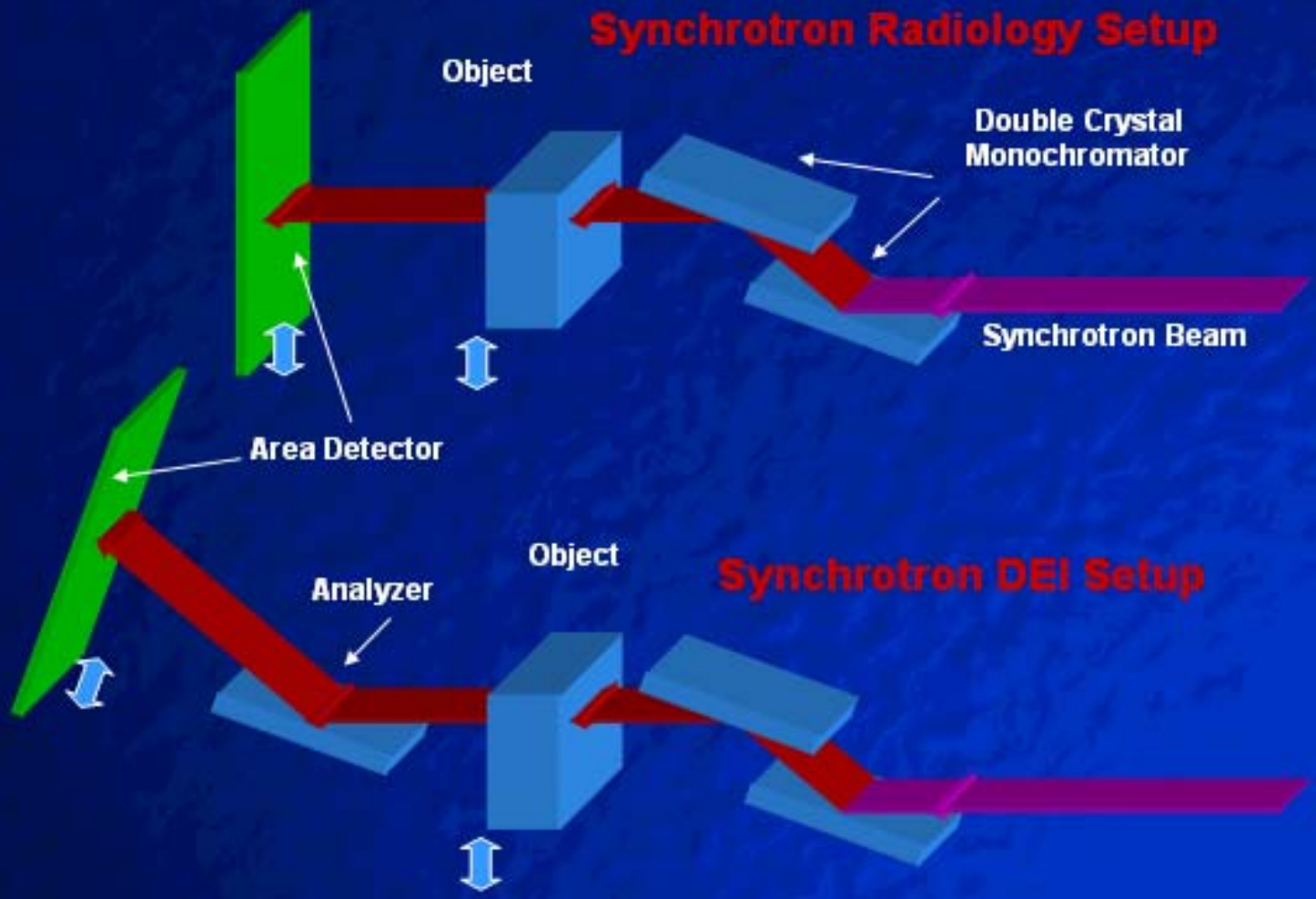
**Imaging Parameters:**

**Beam Energy:** 18 keV, 25 keV, 30keV, and 40 keV

**Analyzer Crystal Configuration:** Bragg[111] and Bragg[333]

**Rocking Curve Positions:** Peak, +1/2 DW, -1/2 DW

# Synchrotron Radiography and DEI




Graphics Provided Courtesy of Dean Chapman, PhD
Illinois Institute of Technology

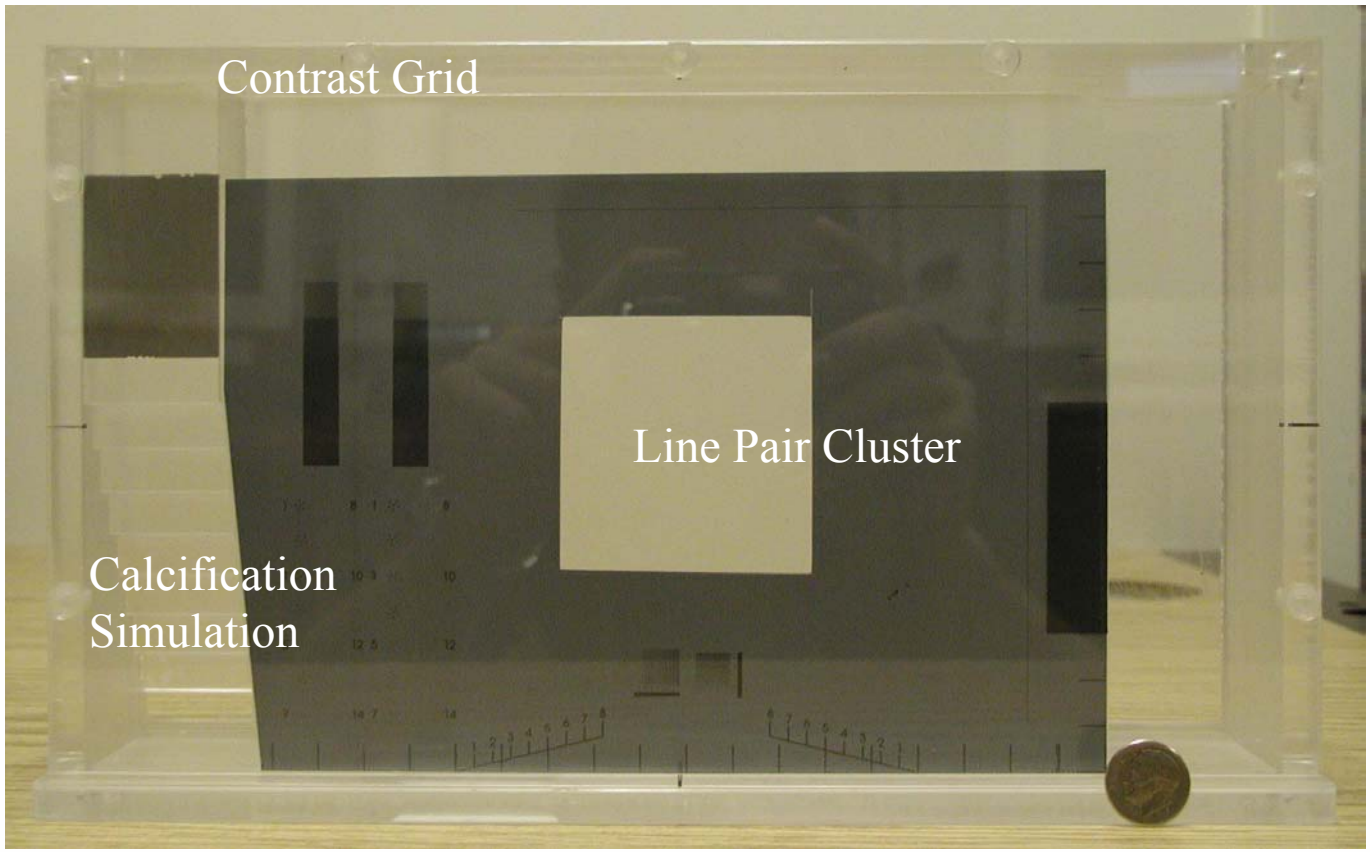
# DEI Parameter Study

Contrast-Detail (CD) Phantom

The level of contrast will decrease as you move from the upper right corner to the lower left corner.

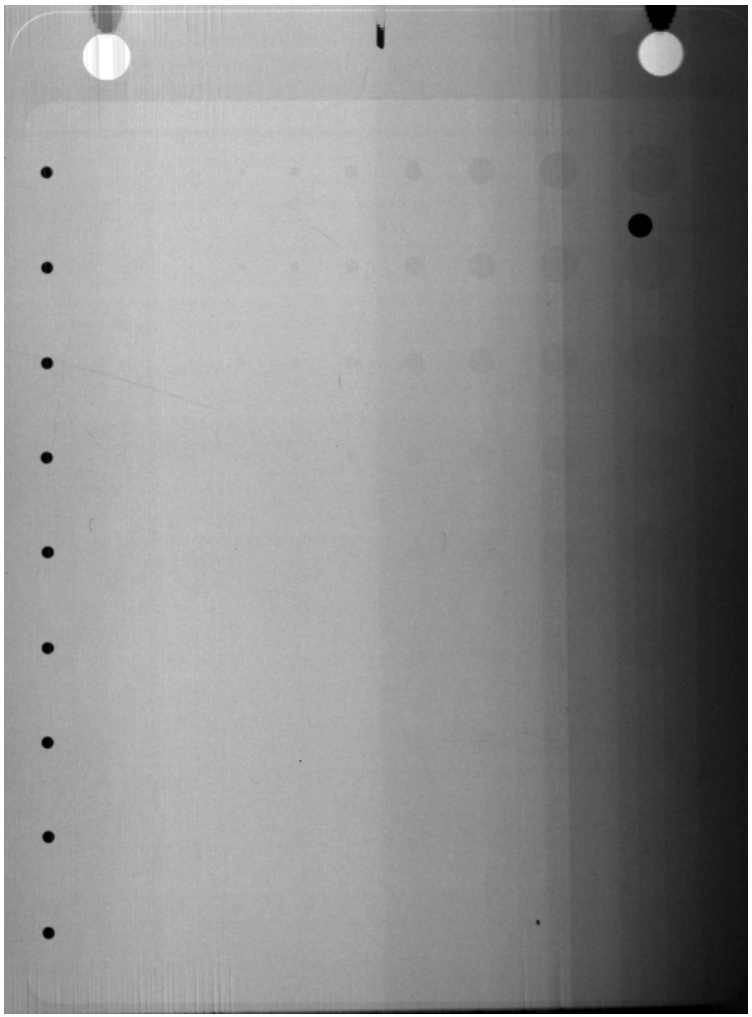
The size of each circle will decrease as you move from right to left.

# DEI Parameter Study




International Digital Mammography Development Group (IDMDG) Test Phantom

# DEI Parameter Study

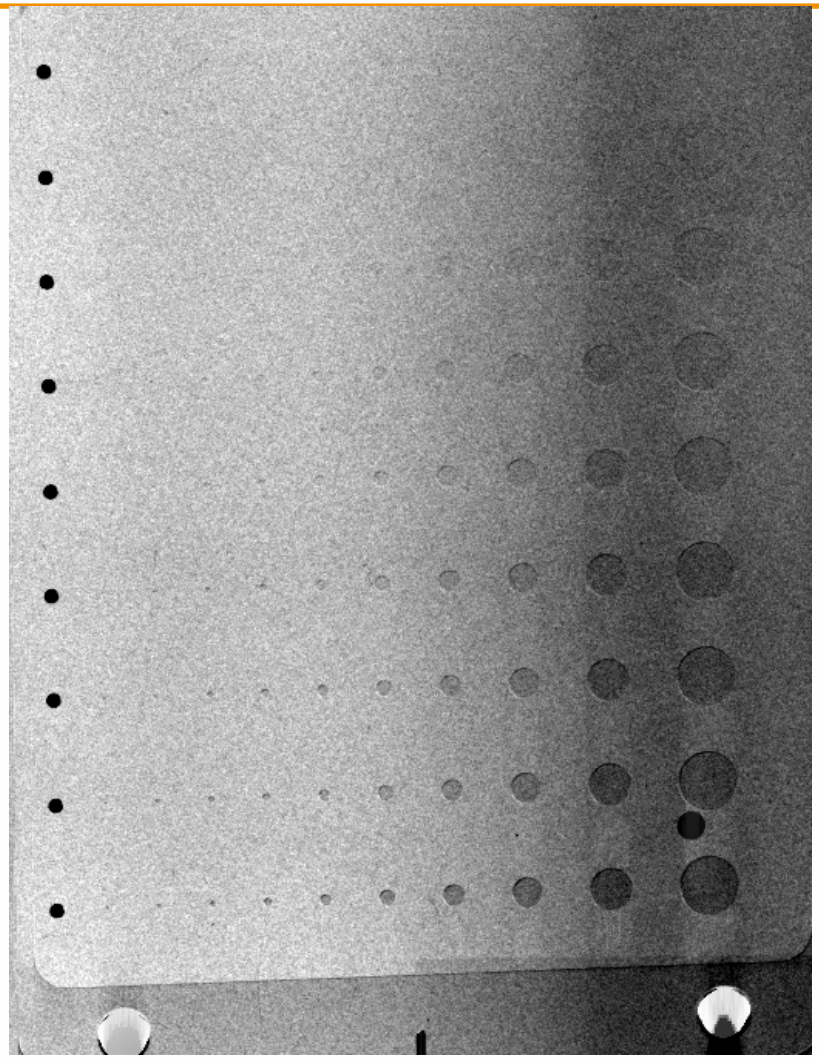


**Radiograph**

**CD Phantom**

**18 keV**

# DEI Parameter Study



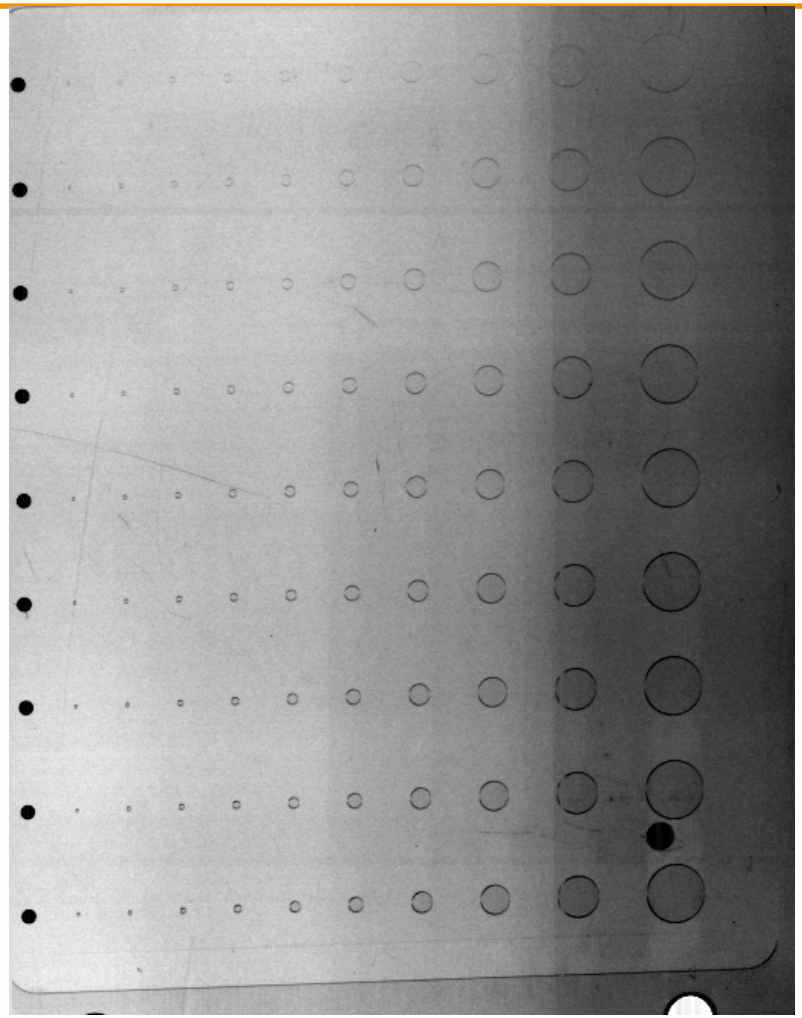
**DEI Image**

**CD Phantom**

**18 keV**

**Bragg [111] Configuration**

# DEI Parameter Study

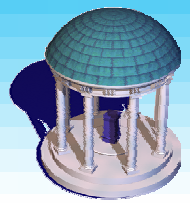


**DEI Image**

**CD Phantom**

**30 keV**

**Bragg [333] Configuration**



# Results of DEI Parameter Study

- The reader study performed using images obtained from combinations of these system configurations indicate that optimal visualization for DEI will be:

  **25 or 30 keV**

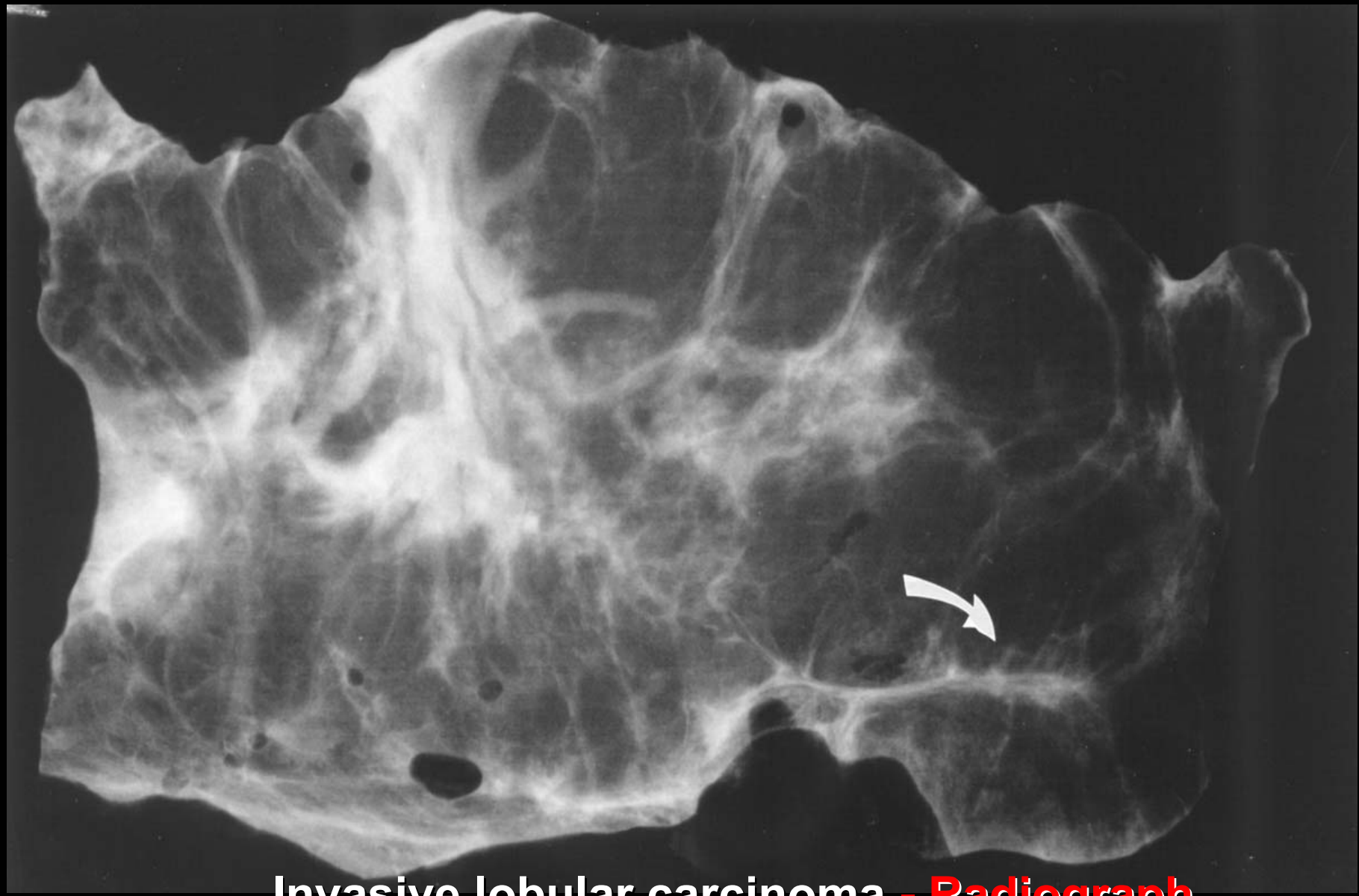
  **Bragg [333]**

  **Analyzer crystal position at peak**

# Initial Results of Tissue Imaging

"Seven breast cancer specimens examined at 18 keV with the use of the silicon 333 reflection in Bragg mode. Images were compared with with digital radiographs of the specimen, and regions of increased interest were identified. Six of the seven cases (86%) showed enhanced visibility of surface spiculations that correlated with histopathologic information, including extension of tumor into surrounding tissue."

Pisano ED, Johnston, RE, Chapman D, Geradts J, Sayers D, Tomlinson W. Diffraction Enhanced Imaging of Human Breast Cancer Specimens: Improved Conspicuity of Lesion Detail with Histologic Correlation. Radiology 241(3); 895-901, 2000



Invasive lobular carcinoma - Radiograph

Invasive lobular carcinoma - DEI

# DEI Compression Study

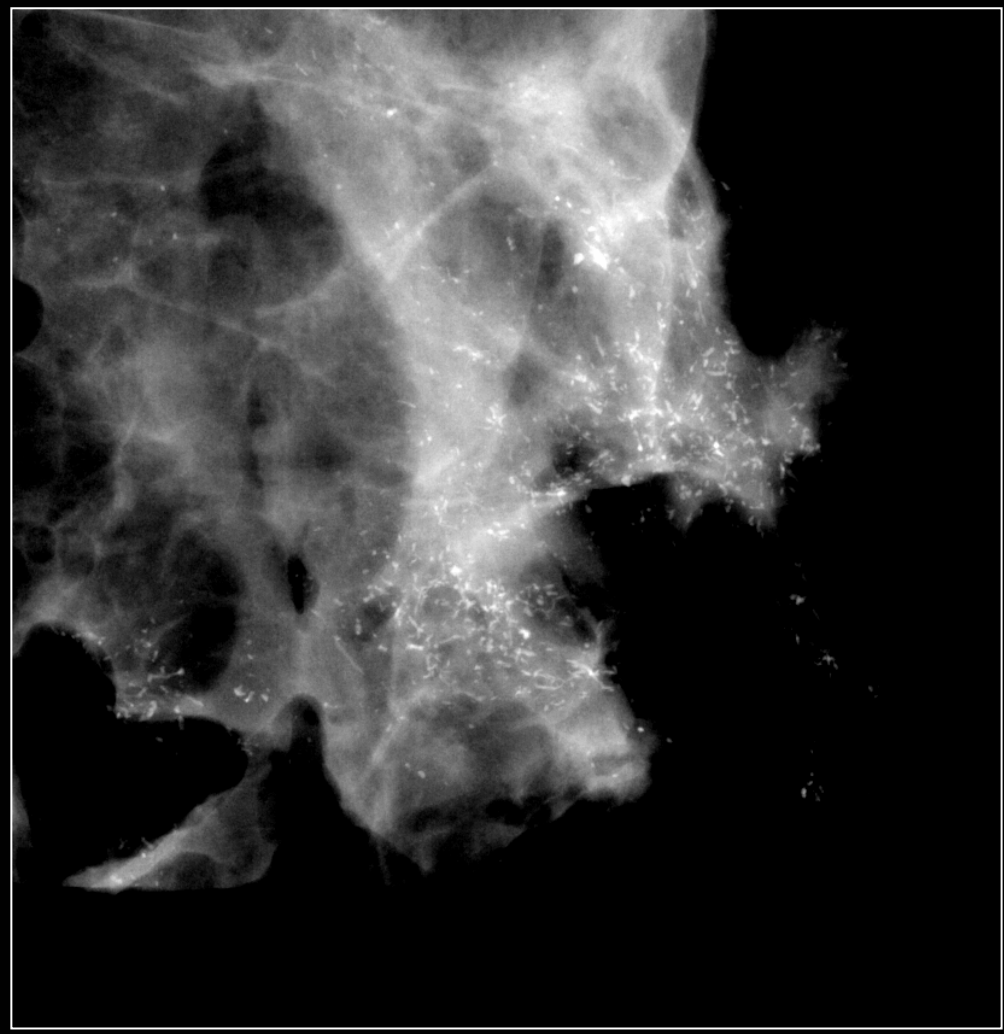
**Funding Agency:**
**Department of Defense**
**U.S. Army Medical Research and Materiel Command**
**DAMD17-02-0523**

**Purpose: To examine the effects of tissue compression on visualization of fine structural detail in breast tissue using DEI.**

**Our hypothesis is that tissue compression will not have a significant effect on visualizing fine structural detail and that one might be able to use reduced or no breast compression for DEI.**

# DEI Compression Study: Initial Results

- Digital mammogram
- Full compression to 50% of resting thickness
- Pathology: mixed invasive ductal and lobular carcinoma with admixed comedo-type DCIS
- 3.9 cm uncompressed thickness



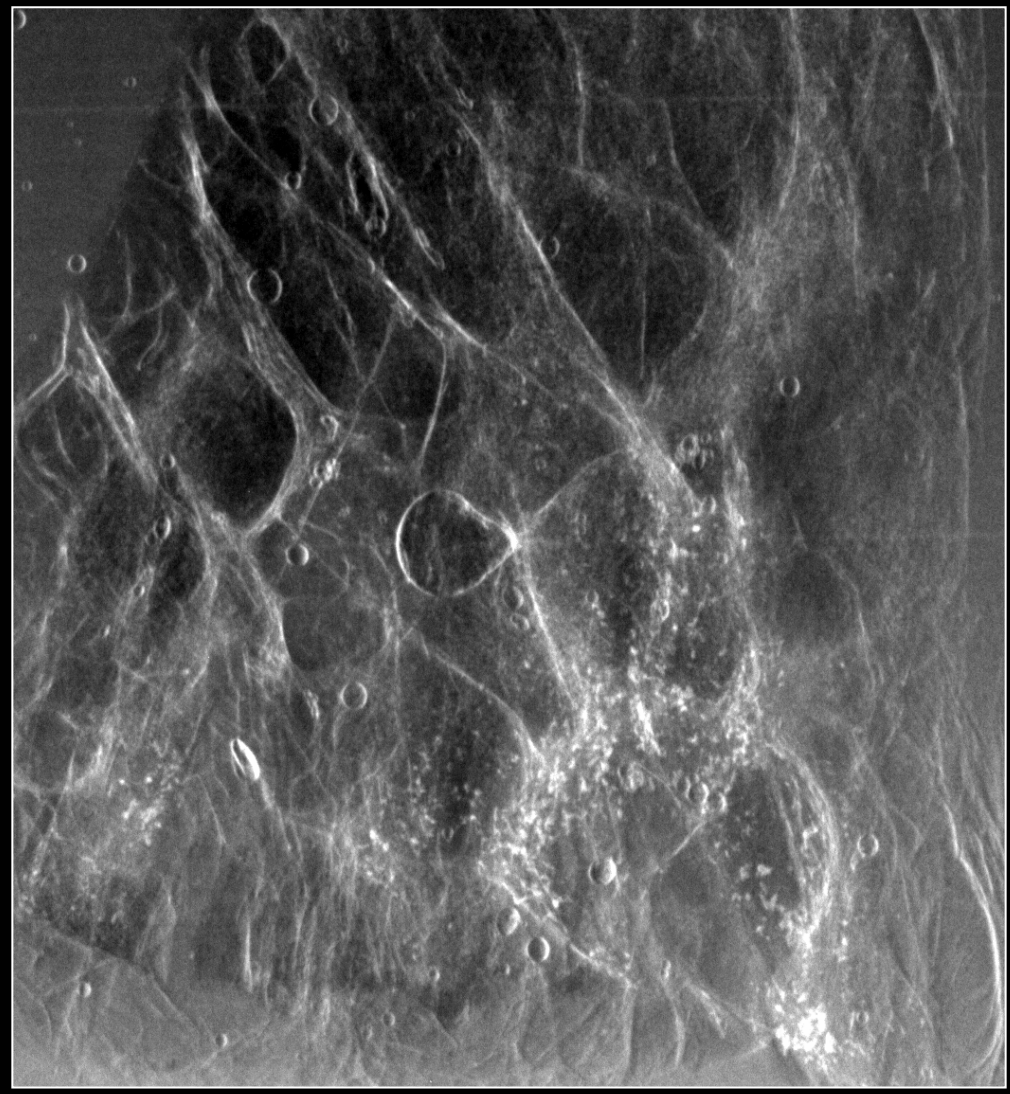
# DEI Compression Study Initial Results

Diffraction Enhanced Image - Peak

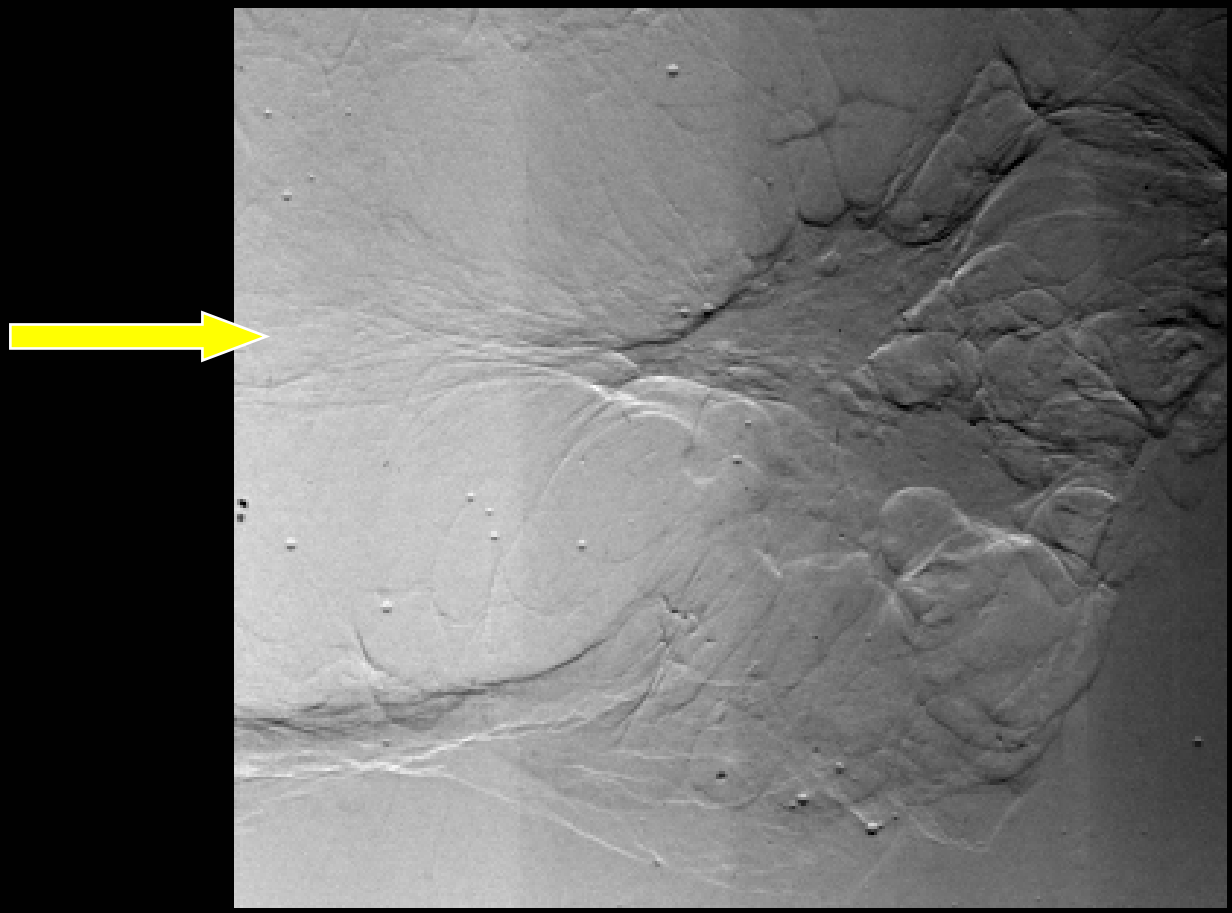
**NO TISSUE COMPRESSION**

Immersed in water

Pathology: mixed invasive ductal and lobular carcinoma with admixed comedo-type DCIS

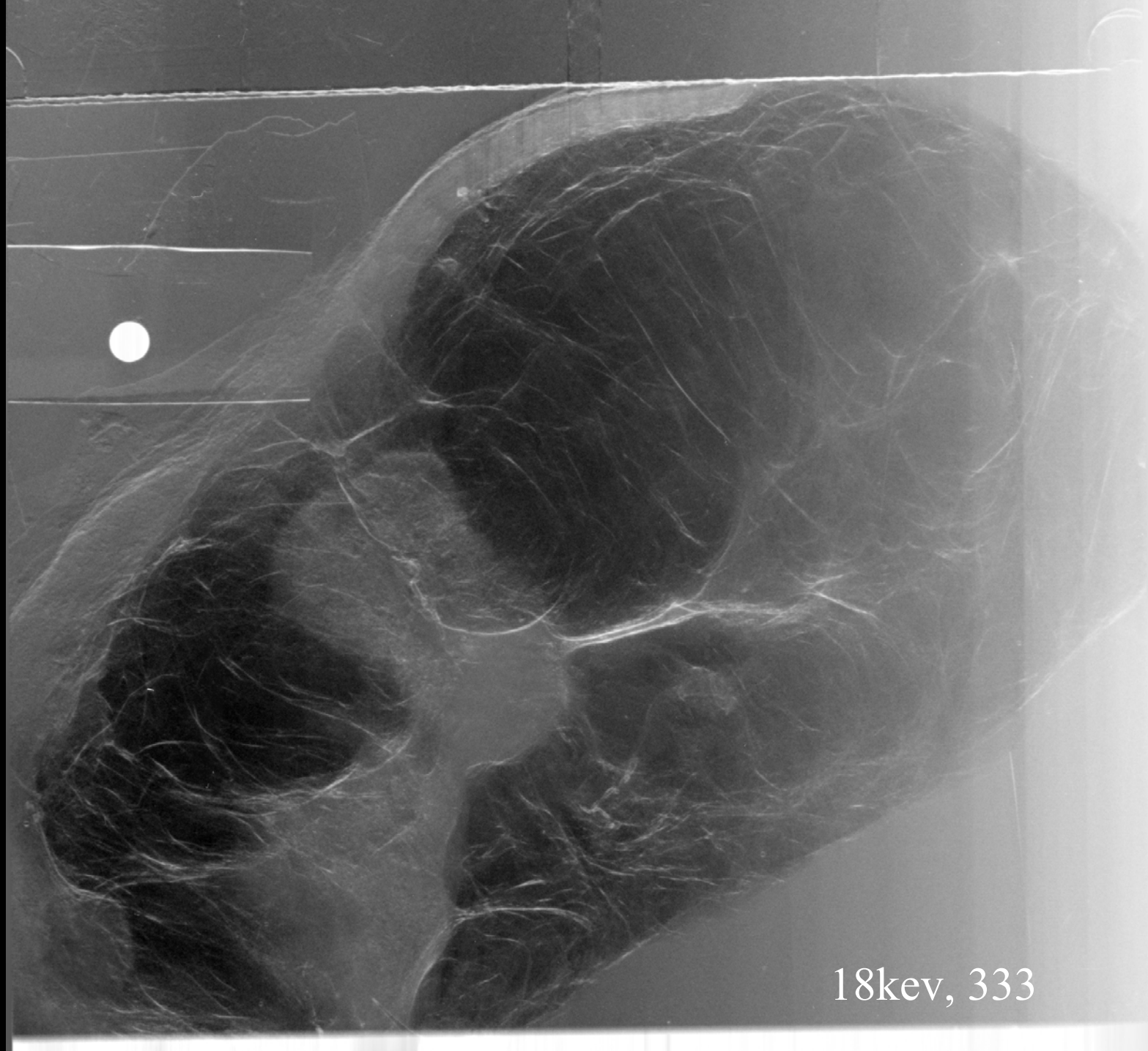


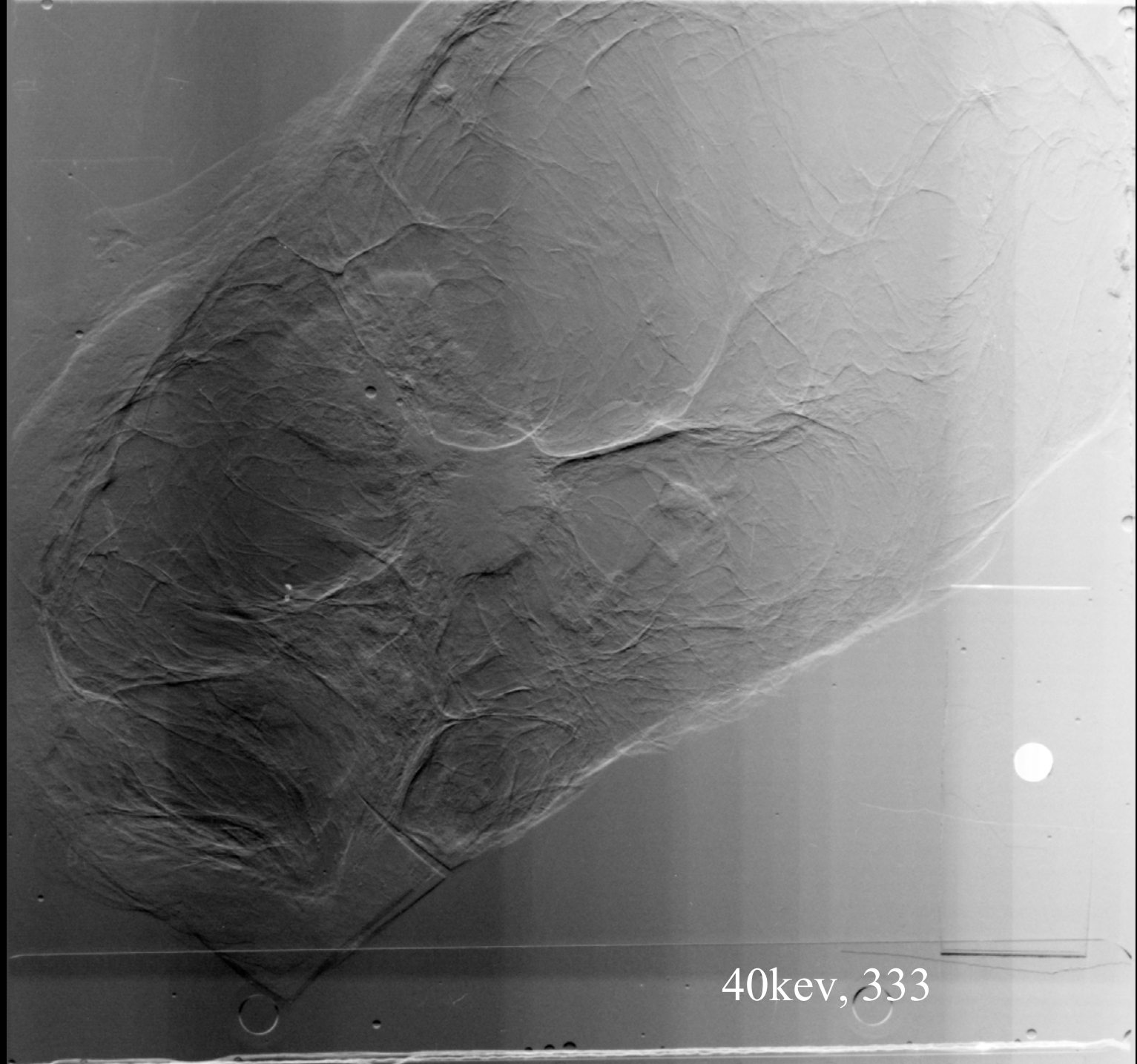
# DEI Characterization Study



Invasive Ductal Carcinoma

DEI 40 keV, Bragg [333]


18kev, 333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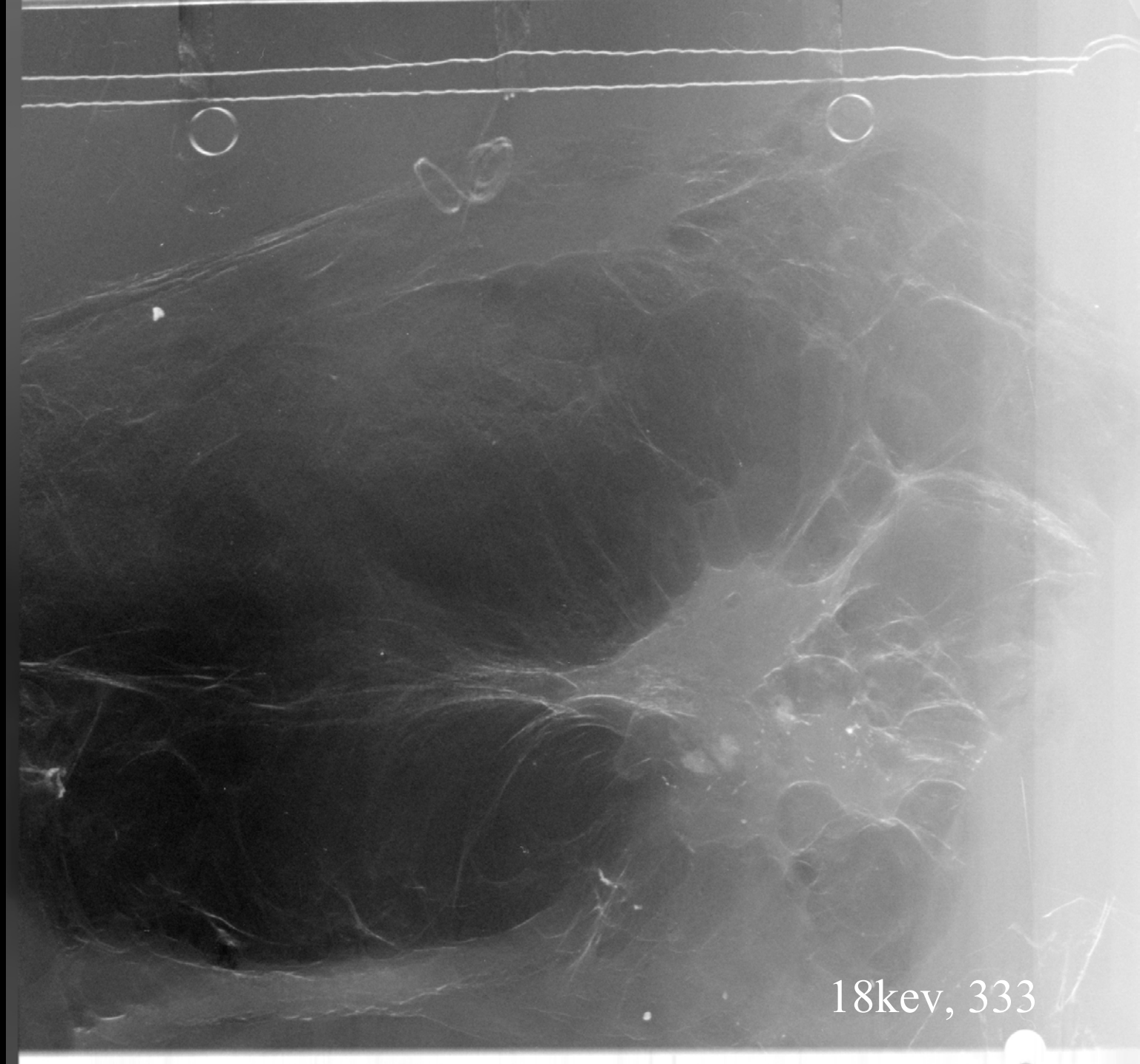
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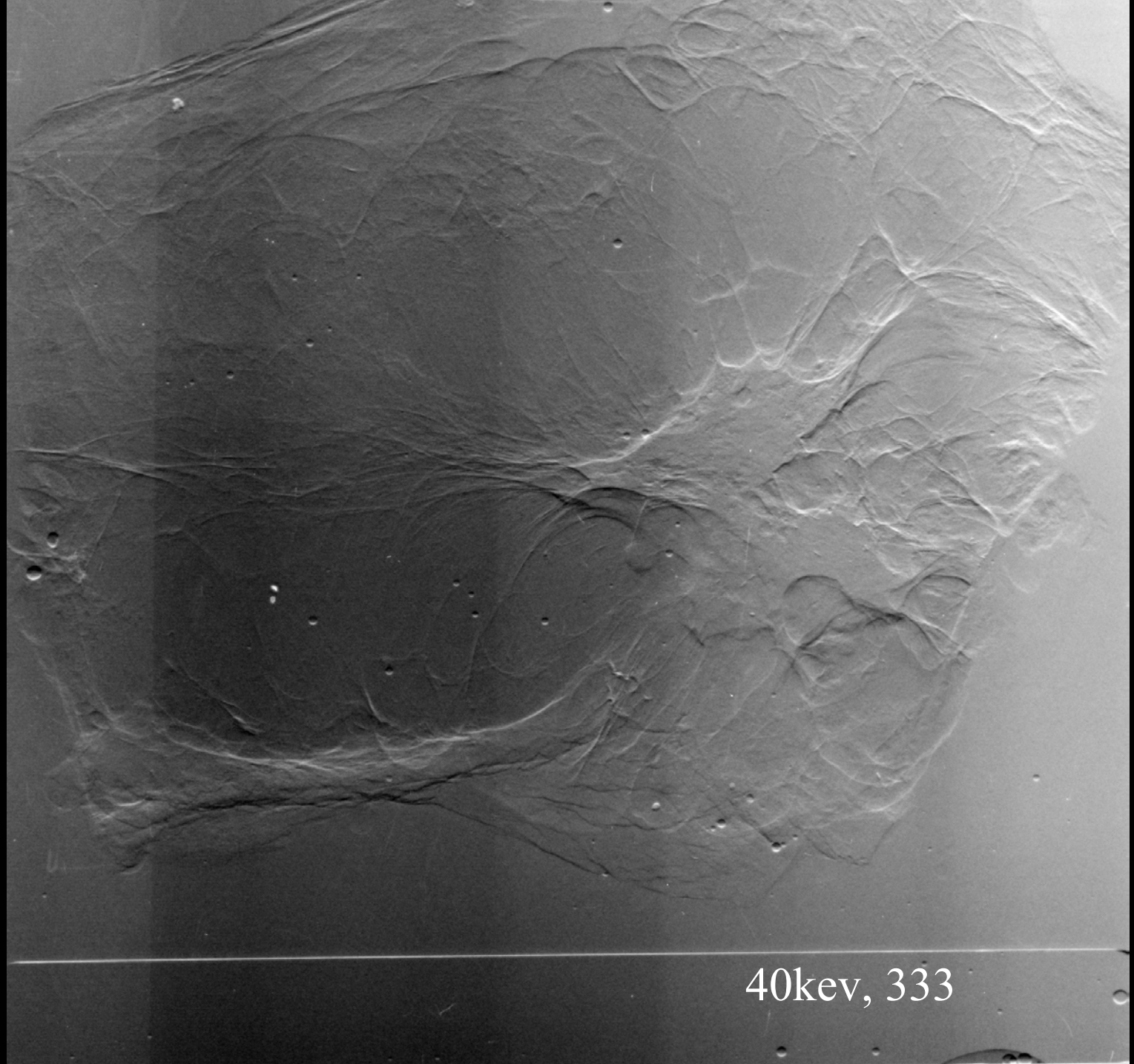
40kev, 333

# Current Limitations

- **Current non-synchrotron x-ray sources are not adequate for imaging in a realistic time window. Strides are being made by many groups to develop a system capable of delivering enough photon flux to make a clinical system plausible.**

- **The current setup on X-15A is effective but complex and requires an experienced operator for calibration and image acquisition. A more user friendly DEI system would significantly enhance applications research.**

- **There is only one Dr. Zhong Zhong in the world!**

# Future Projects

- Detailed analysis and characterization of breast tissue structures (benign and malignant) and the physical aspects of DEI providing an increased level of visualization.

- Detailed comparisons of images and data acquired at the National Synchrotron Light Source with non-synchrotron based prototype imaging systems. The point to determine if the imaging characteristics at the NSLS are conserved on a more conventional system.

- Applications of new image acquisition and reconstruction methods to DEI. (*Multiple Image Radiography*)

- Application of research towards the development of a prototype clinical imaging system.

# DEI RESEARCH AND DEVELOPMENT TEAM

ILLINOIS INSTITUTE OF TECHNOLOGY

*Transforming Lives. Inventing the Future.* www.iit.edu

Rush University

Rush-Presbyterian-St. Luke's Medical Center, Chicago IL

NC STATE UNIVERSITY

UNC SCHOOL OF MEDICINE

BROOKHAVEN NATIONAL LABORATORY

UNIVERSITY OF TORONTO 175 YEARS

NSLS

NATIONAL SYNCHROTRON LIGHT SOURCE