Diffraction Enhanced Imaging

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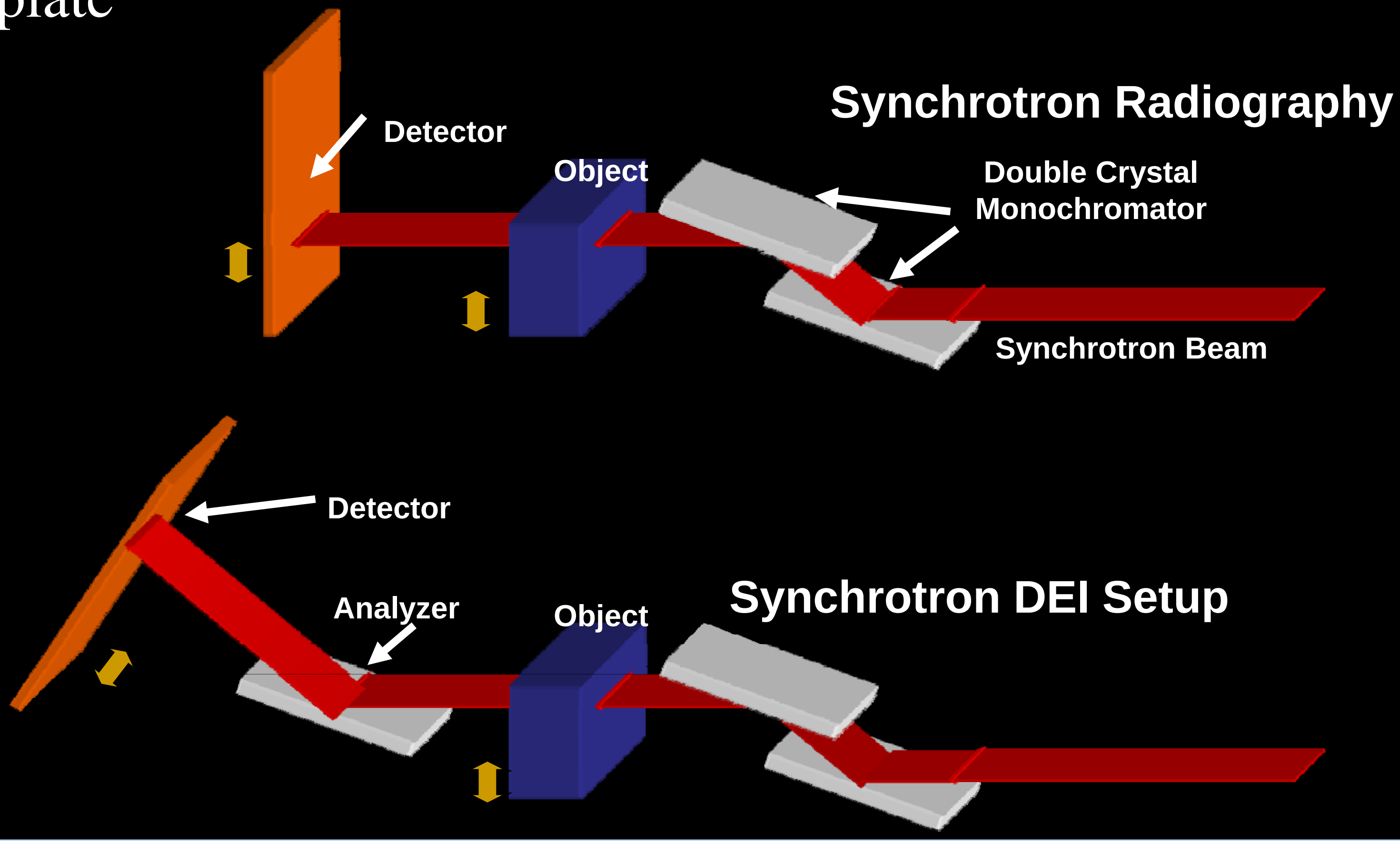
X15A - current resources

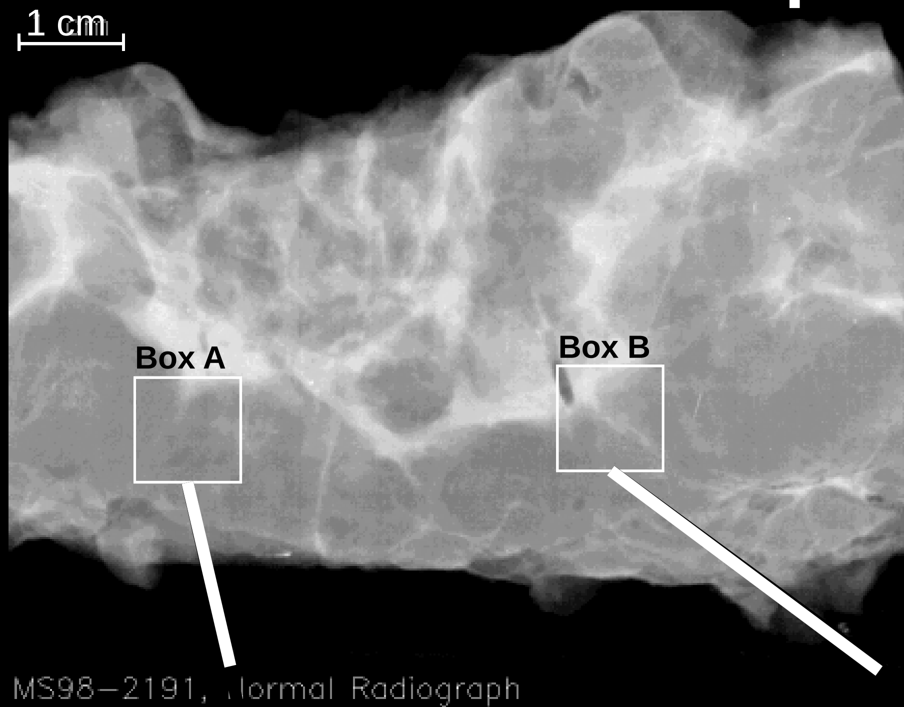
- Silicon 111 and 333 monochromator with matching analyzer
- 10 - 60 keV
- 3 detectors: 9 micron CCD, 30 micron CCD, 50 micron image plate



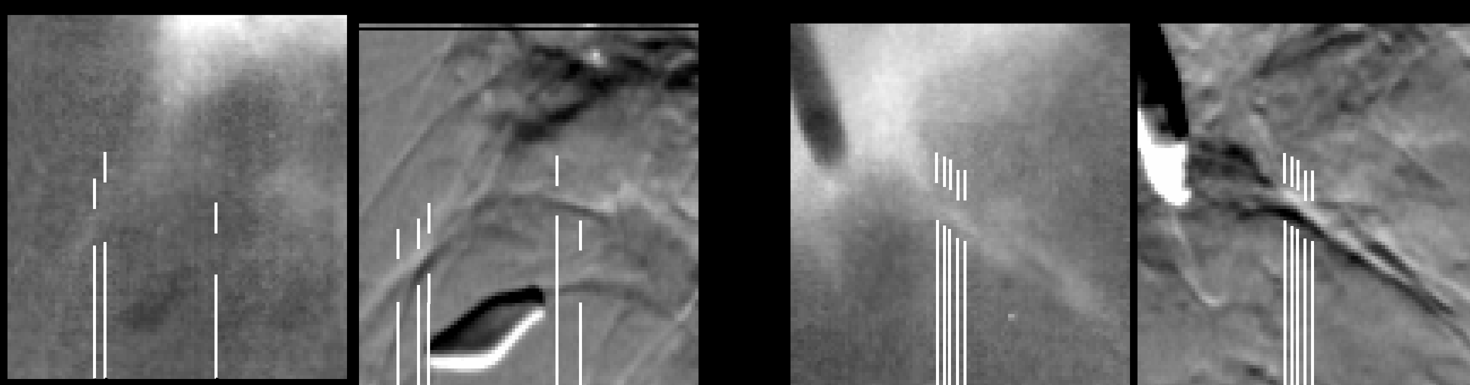
Scientific Need

- Breast cancer imaging
- Osteoarthritis and cartilage research
- Alzheimer’s Disease research
- Lung cancer imaging
- Small animal imaging

Science at X15A: Spiculations in Breast Cancer



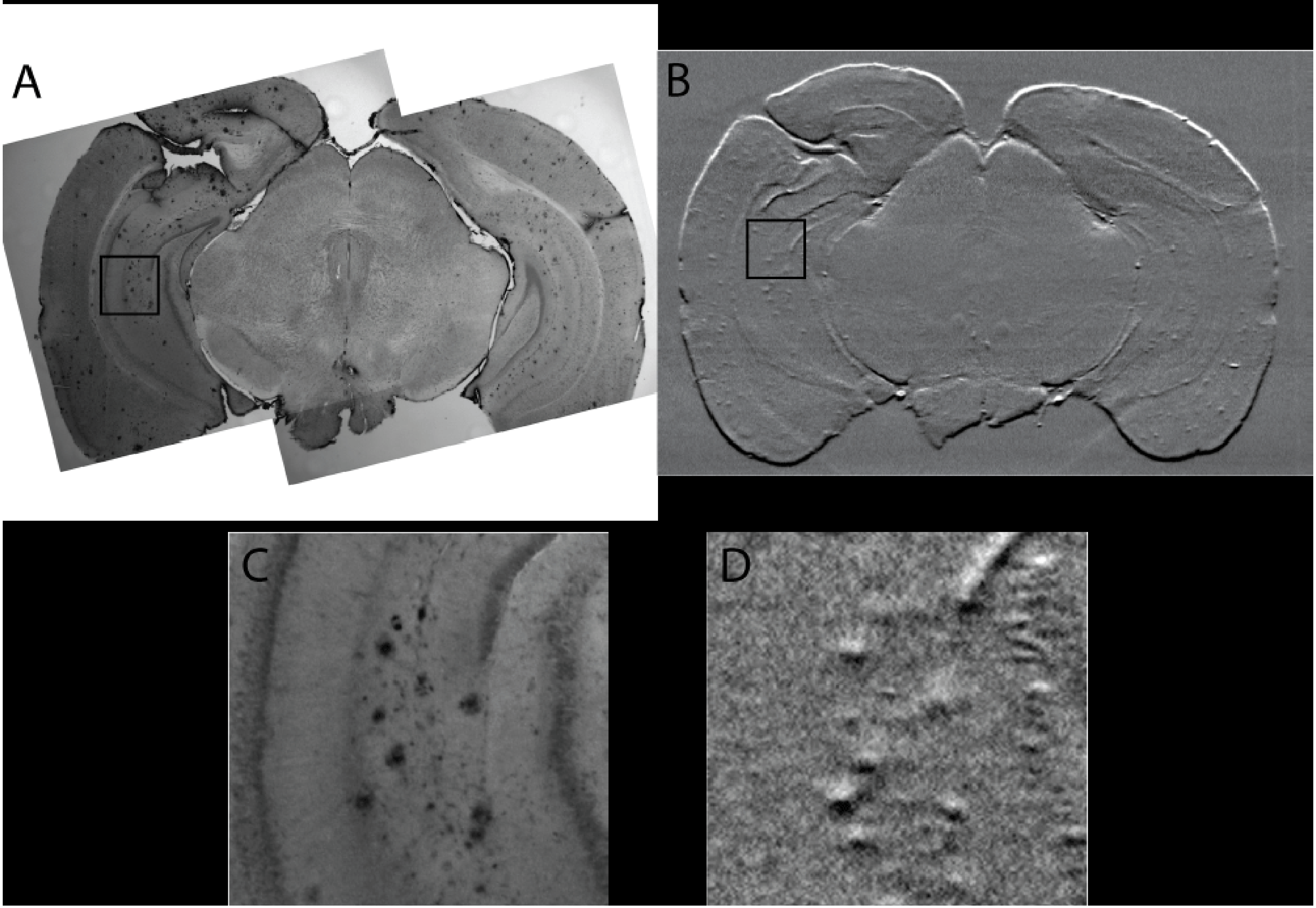
- Spiculations are due to cancer itself or the response of the host to the cancer
- Contrast quantified by measuring intensity change across spiculations
- DEI has 8 – 33 times greater contrast



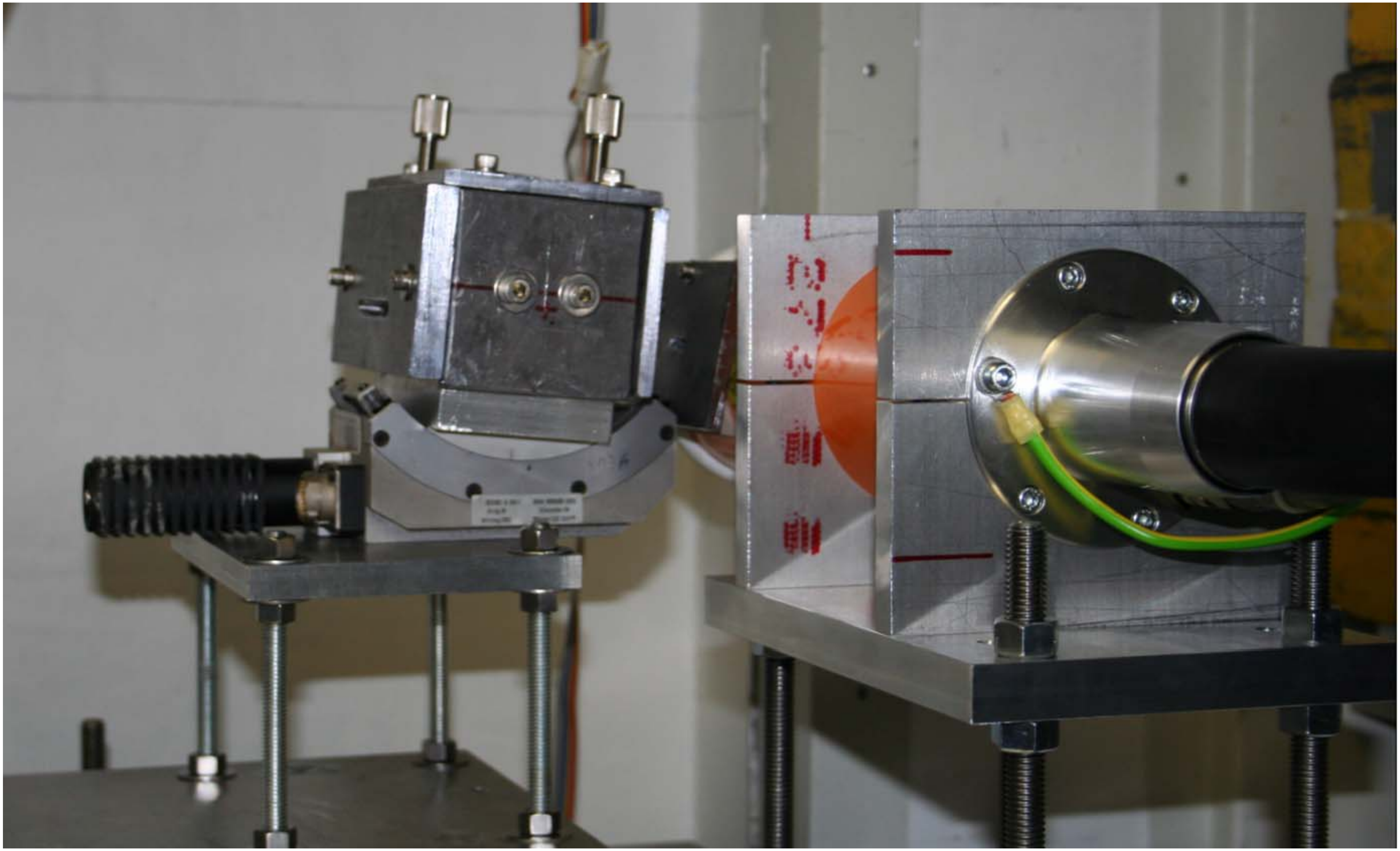
Rad **DEI** **Rad** **DEI**

Hasnah et. al., *Phys. Med. Bio.* 2006

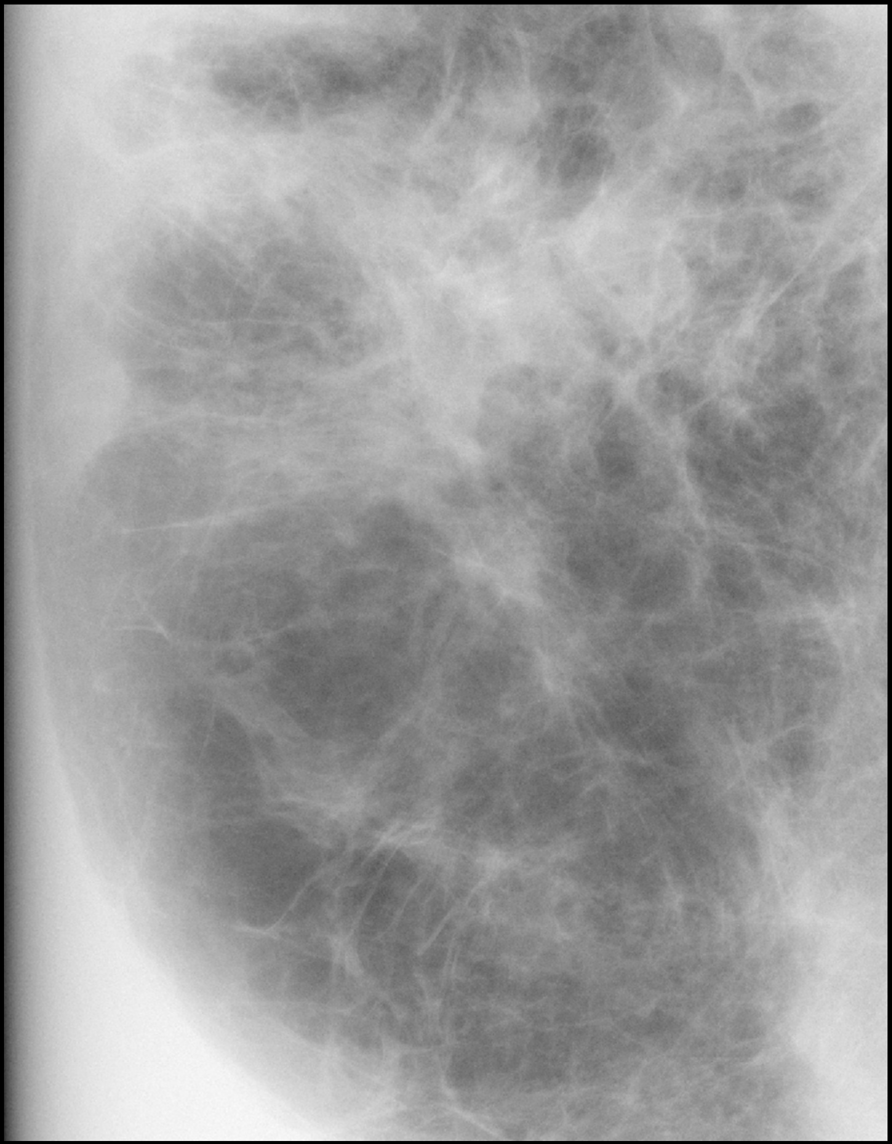
Imaging Alzheimer's Plaques in Mouse Brain



Prototype DEI with x-ray tube



Prototype DEI with x-ray tube



DEI (8 mrad) **GE Digital (400 mrad)**

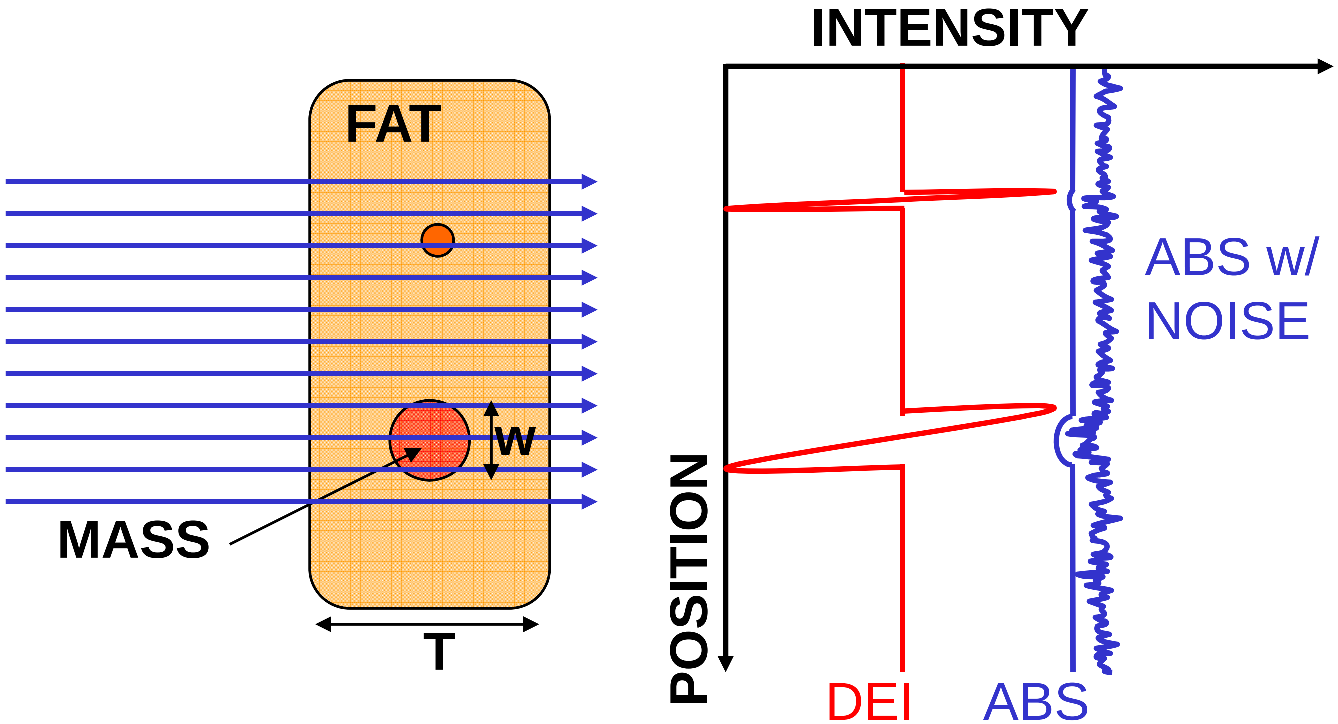
User Demand

• Dedicated core DEI group, including Dean Chapman (USASK), Avraham Dilmanian (BNL), Carol Muehleman (RUSH), Etta Pisano (UNC), Miles Wernick (IIT) and Zhong Zhong (NSLS)

• NIH funding to carry out DEI research and to contribute to upgrade and operation of X15A beamline

• The only DEI facility in USA, X15A has attracted numerous general users

Where is the limit? Dose and Resolution



Absorption: Contrast proportional to object size w

- Dose ~ $1/w^4$
- 1 mGy for w=100 microns, 10^5 Gy for w = 1 micron

DEI : Contrast independent of object size

- Dose ~ $1/w^2$
- 0.1 mGy for w=100 microns, 1 Gy for w = 1 micron

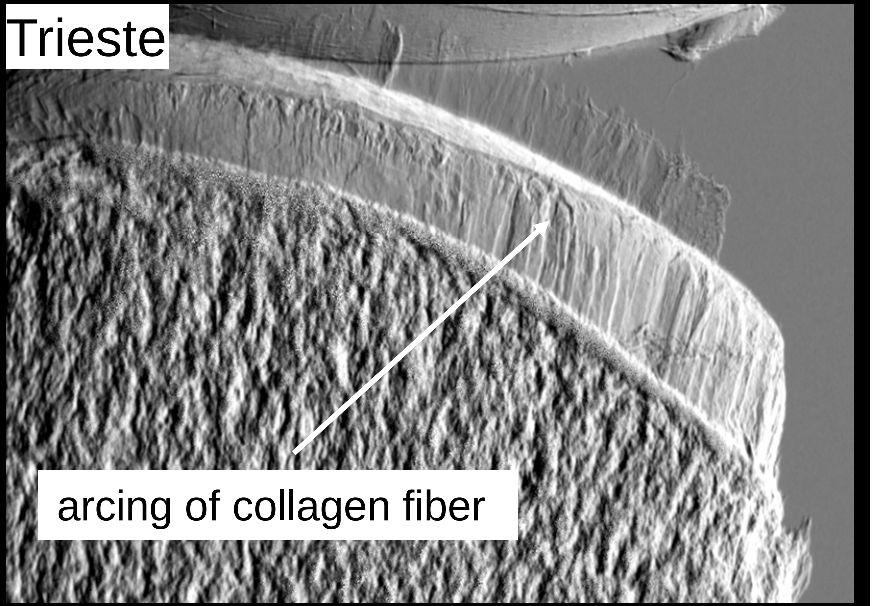
NISL-II, High-res DEI reveals micro-structure

Currently Limited by:

• Source size -> Spatial resolution ~ 50 microns

• Brightness -> Sensitivity ~ 0.1 micro-radians

• The advantages of DEI are not realized for small features

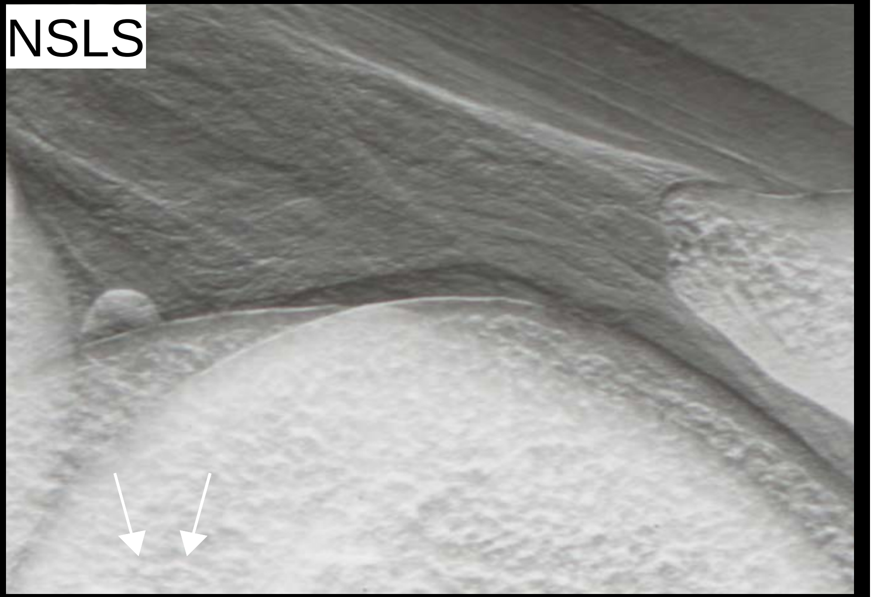


High brightness of NSLS-II will allow:

• 1 micron resolution

• 0.01 micro-radians sensitivity

• Micro-structure in animal models, e.g., amyloid plaques in Alzheimer's disease models



New NSLS-II DEI Beamline

- Superconducting wiggler to enable imaging above 60 keV
- Sample environment more appropriate for live animals (humans included)
- Part of biomedical research suite
- Incorporate:
    - Lessons learned at Trieste, ESRF, Spring8
    - Lessons that will be learned at CLS and Australian Light Source and Shanghai Light Source

Transition Timeline

Completion of Transition

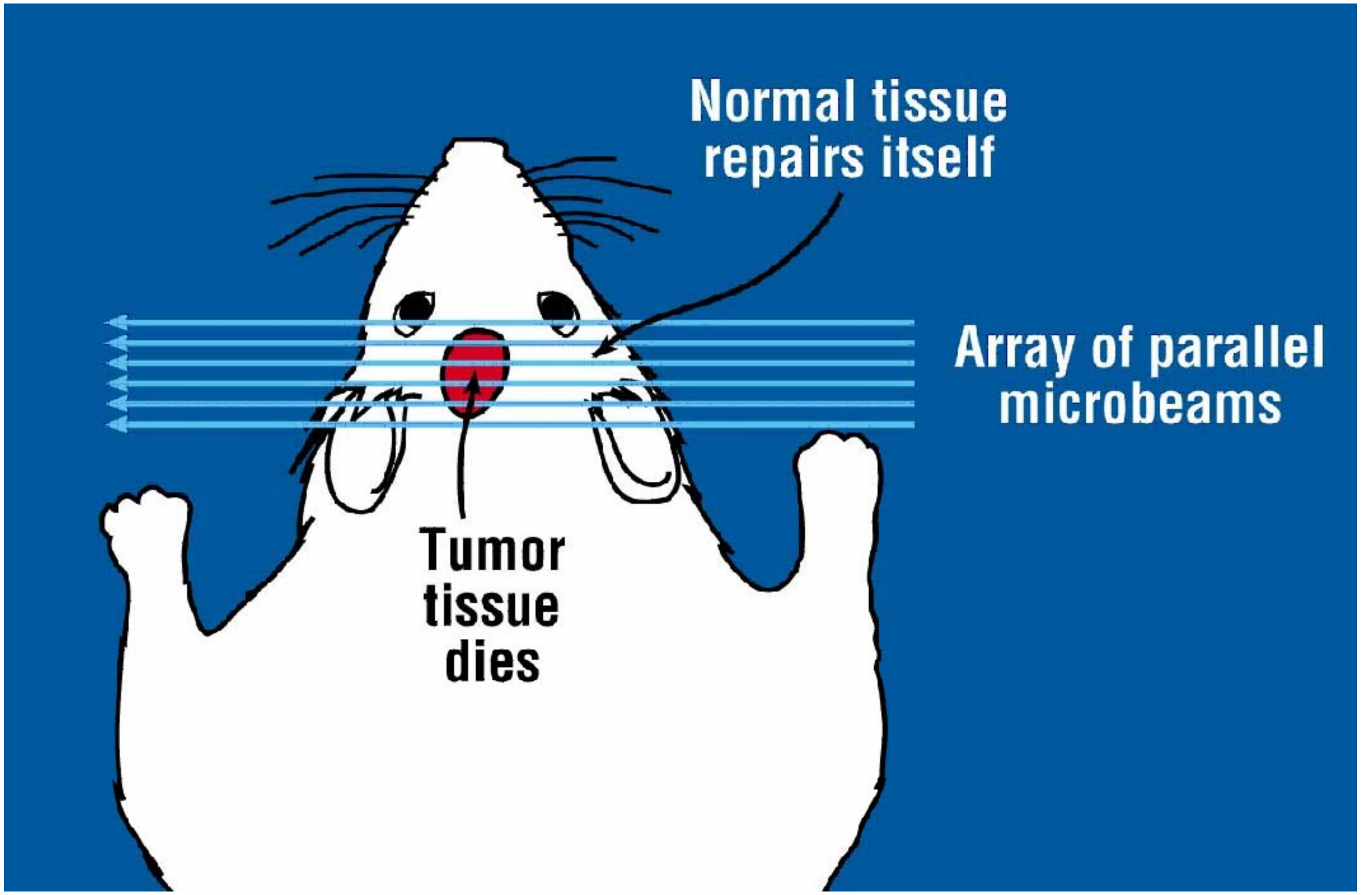
Construction of new
hutch, move optics to
NSLSII

-7 0 10

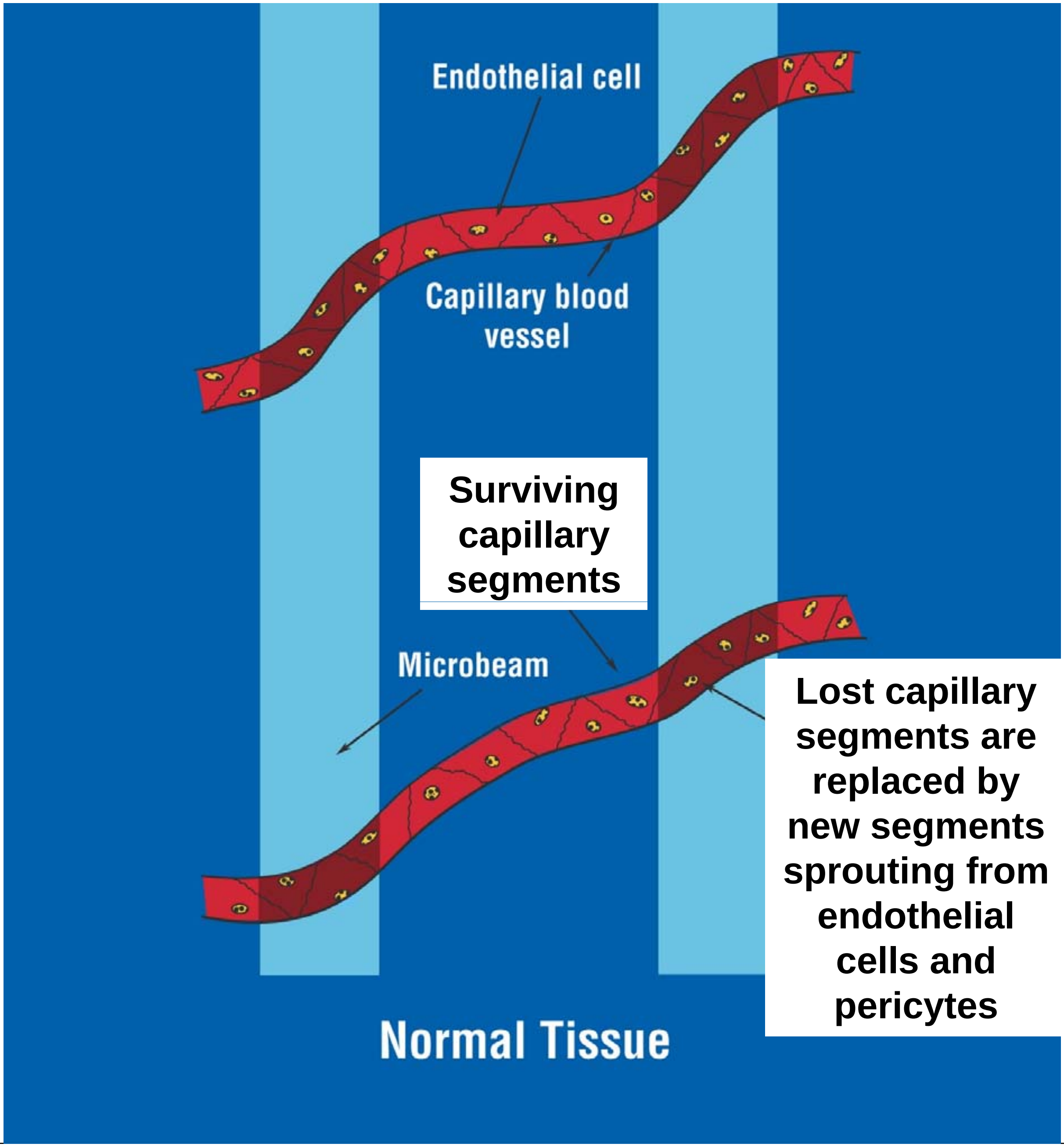
Detailed Design
of NSLSII DEI

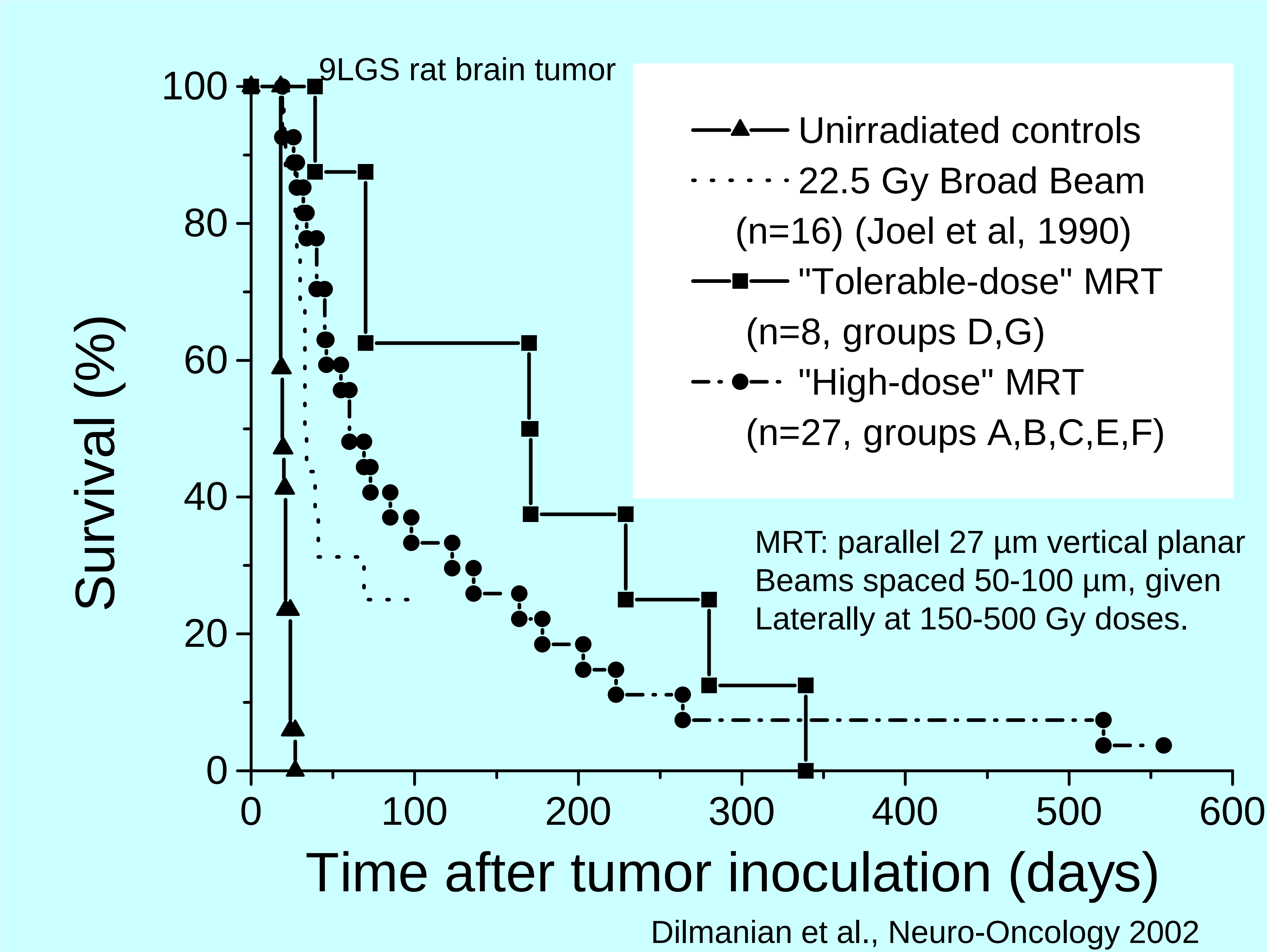
- Development of DEI science
- Improvement of instrumentation
- Plan of NSLSII DEI

Microbeam Radiation Therapy (MRT) - Concept for tumor therapy



Mechanisms of normal tissue sparing: Current hypothesis



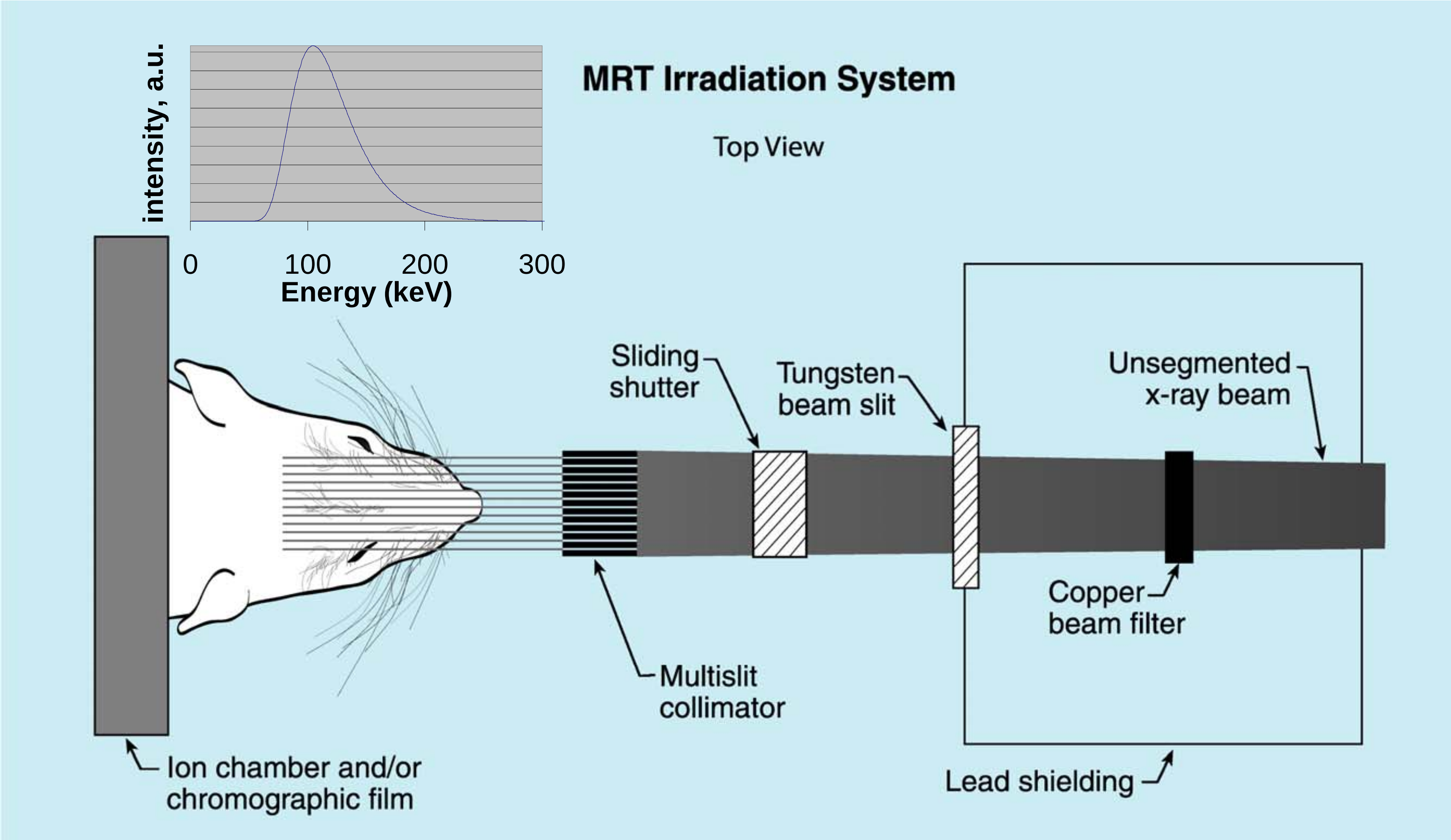

9LGS rat brain tumor
100
80
60
40
20
0
0
100
200
300
400
500
600
Survival (%)
Time after tumor inoculation (days)
Unirradiated controls
22.5 Gy Broad Beam
(n=16) (Joel et al, 1990)
"Tolerable-dose" MRT
(n=8, groups D,G)
"High-dose" MRT
(n=27, groups A,B,C,E,F)
MRT: parallel 27 µm vertical planar
Beams spaced 50-100 µm, given
Laterally at 150-500 Gy doses.
Dilmanian et al., Neuro-Oncology 2002

MRT: Physics

<u>The source</u>: The X17B1 superconducting wiggler beamline of the National Synchrotron Light Source.

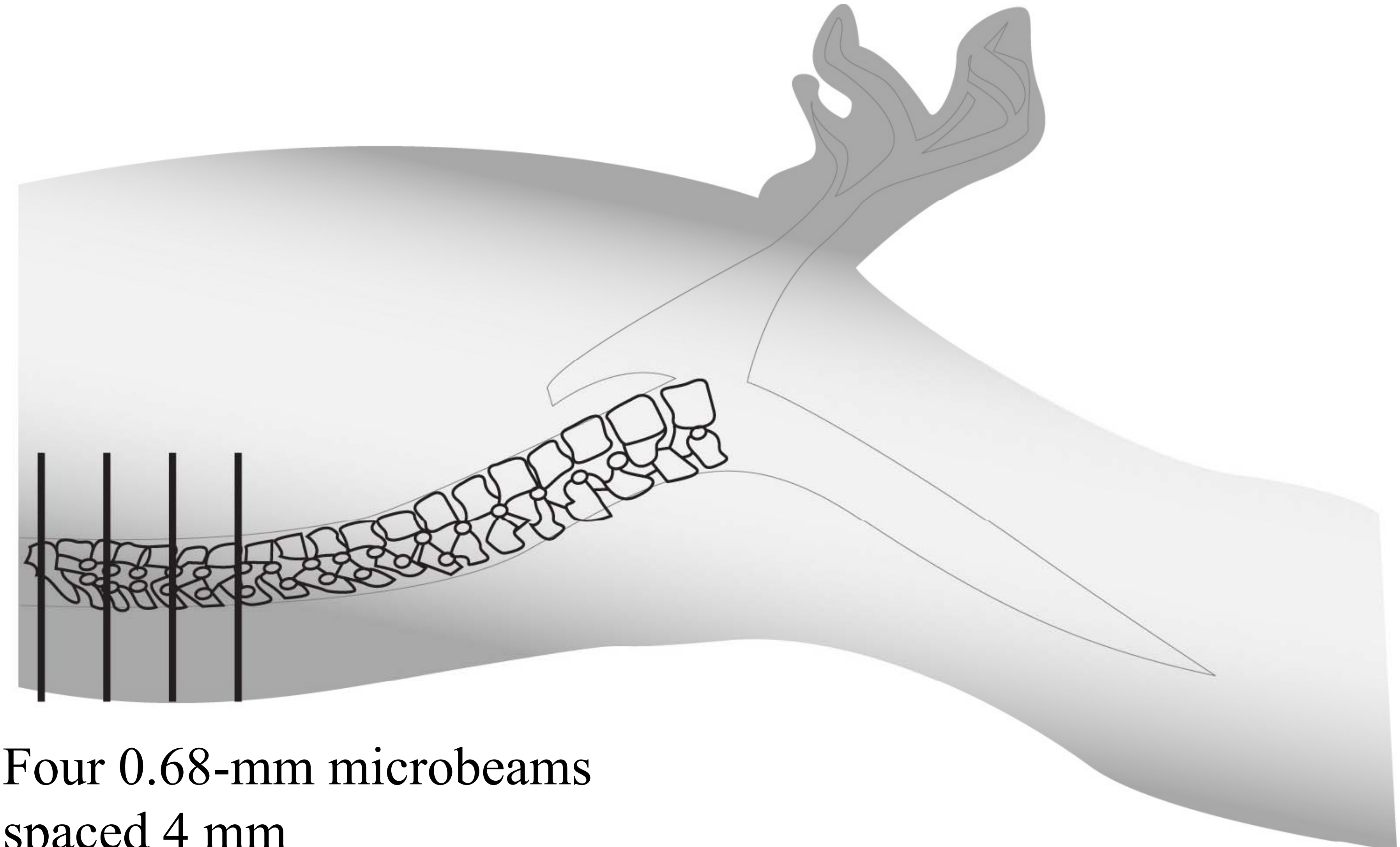
<u>Operating conditions</u>: 2.8 GeV ring energy; 4.3 T wiggler field; 200-300 mA ring current

<u>Beam with ¼" Cu filtration</u>: ~40 Gy/s dose rate and 120 keV median beam energy

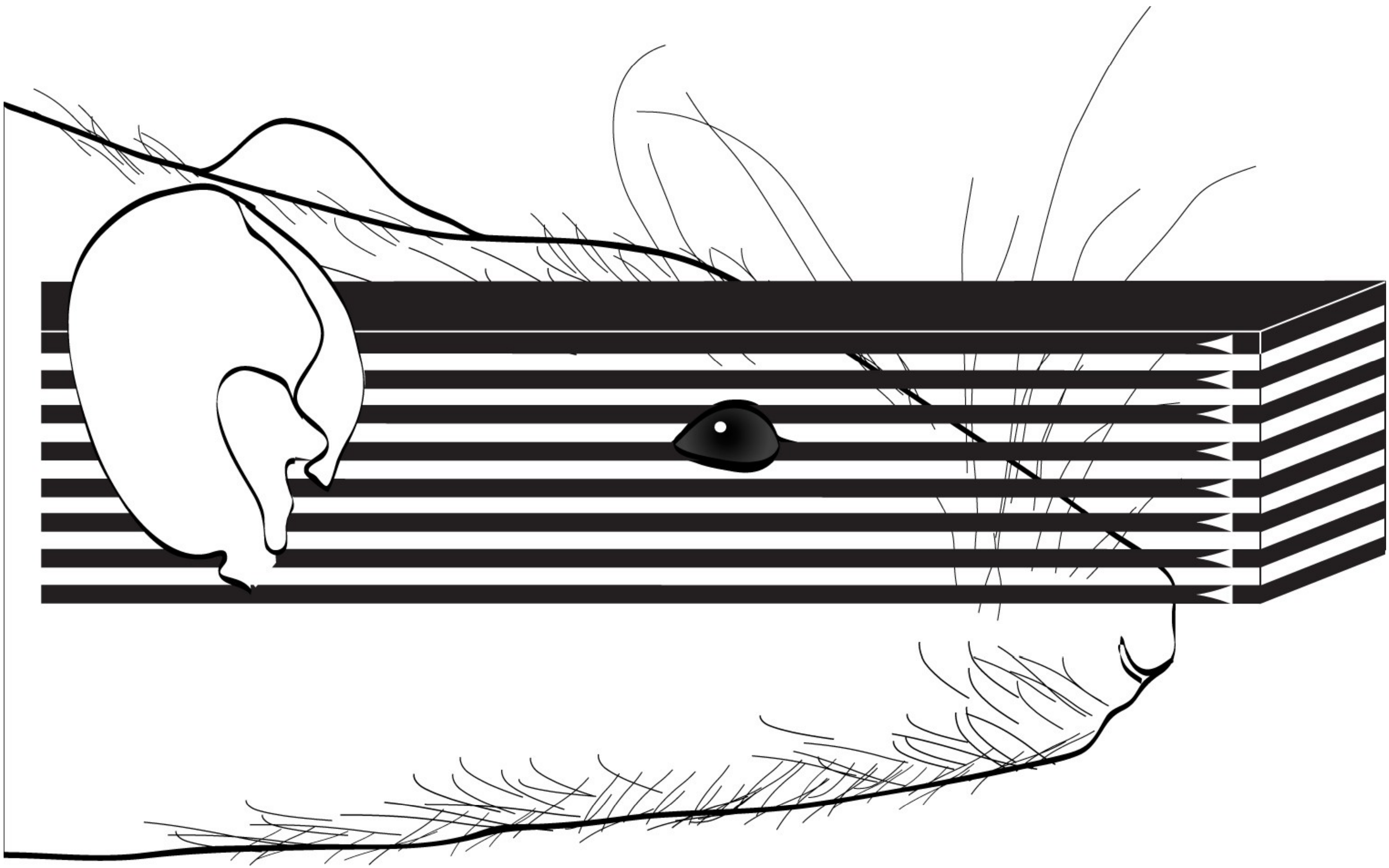


Switching to thicker microbeams

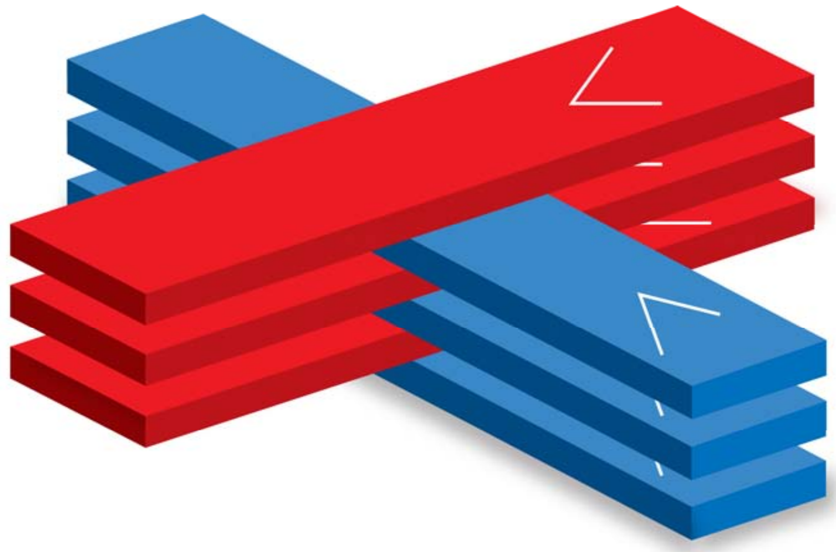
- Much of the early MRT work at the NSLS and ESRF was done with 25 μm beams.
- The goal: To establish the upper limit of beam width.
- Results: Normal rat spinal cord and brain tolerated beams as thick as 680 μm.



Four 0.68-mm microbeams
spaced 4 mm



A new administration method: Interlaced thick microbeams



- The microbeam-exposed normal issue surrounding the tumor is spared.
- The broad-beam-exposed tumor is damaged.

The dose falloff at the edge of the target is very sharp (80%-to-20% of about 30 μm).

Summary and Conclusions

1. The microbeam technique has great potential in treating tumors and neurological disorders.
2. The NSLS-II ring energy and current are ideal for pursuing microbeam research, using a superconducting wiggler.
3. An adequate beamline design could leave the door open for possible future human studies.