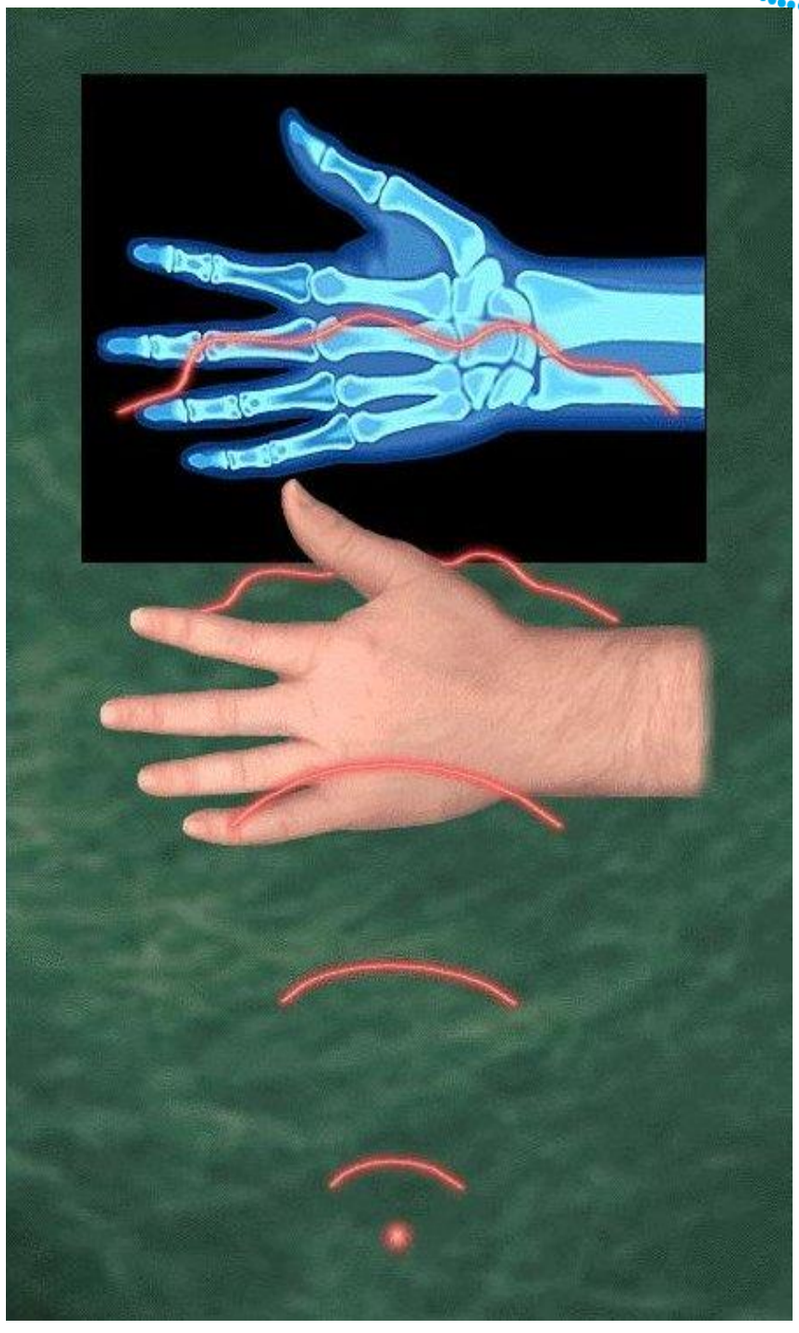
IMBL: X-ray characteristics & general imaging

Andrew Stevenson
MCT, Australian Synchrotron
& CSIRO Future Industries

CT@IMBL workshop – 28th May, 2018

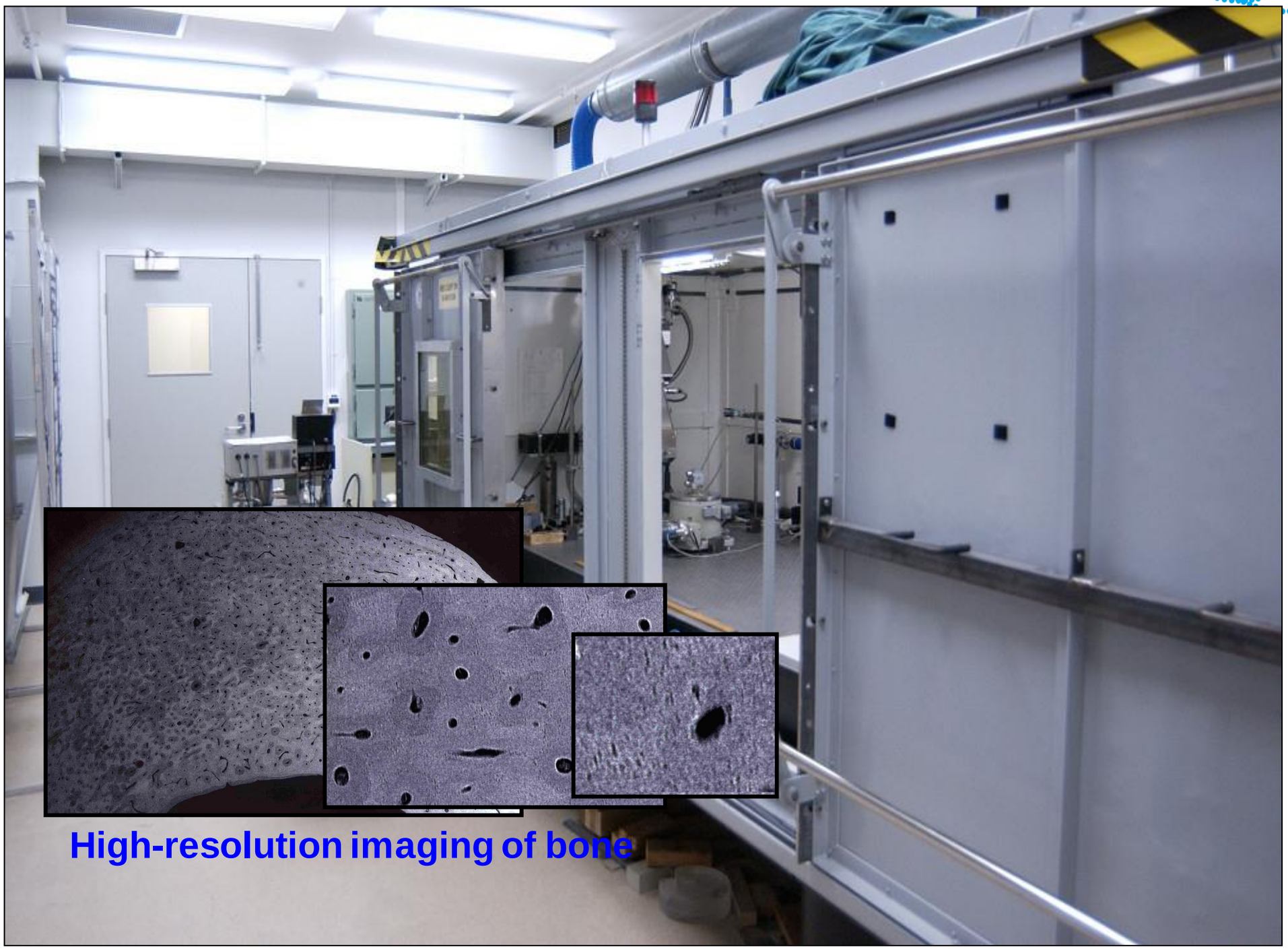
The “first” X-ray image



basic assumptions of conventional radiography

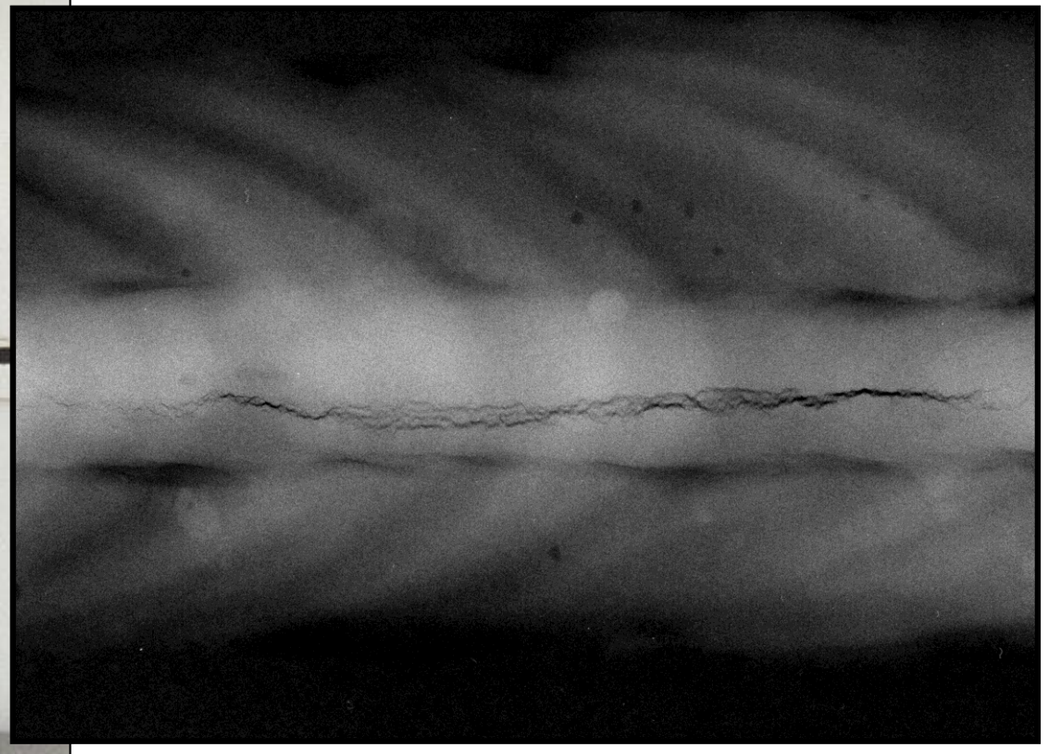
1. Contrast is produced purely by absorption in the object.
2. Ray (or geometrical) optics is sufficient to describe image structure.
3. It is not (usually) necessary to attempt to extract quantitative information from images.

laboratory-based PCX imaging system

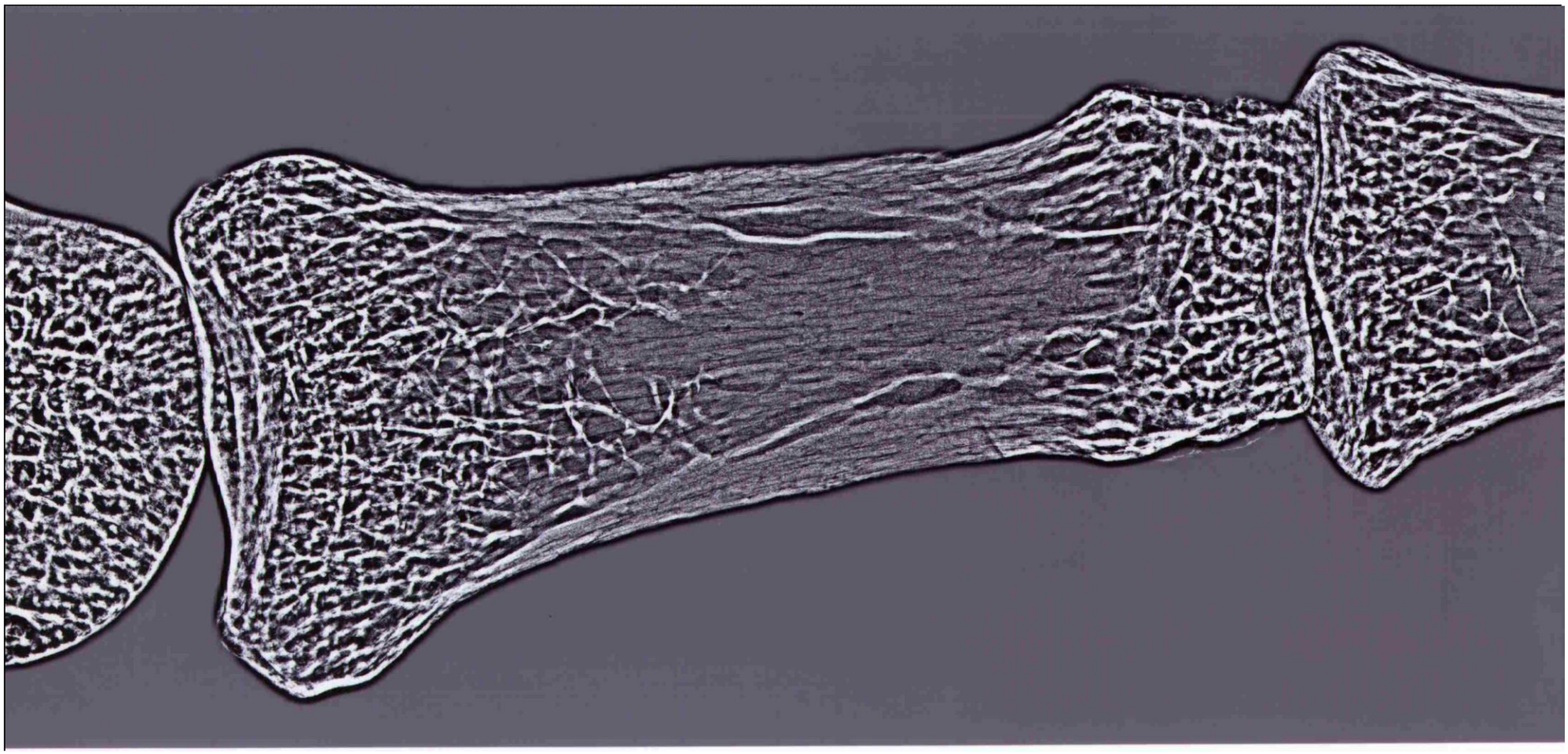


Feinfocus microfocus X-ray source - imaging and microtomography

hot tear in girth weld for 9mm steel pressure pipe

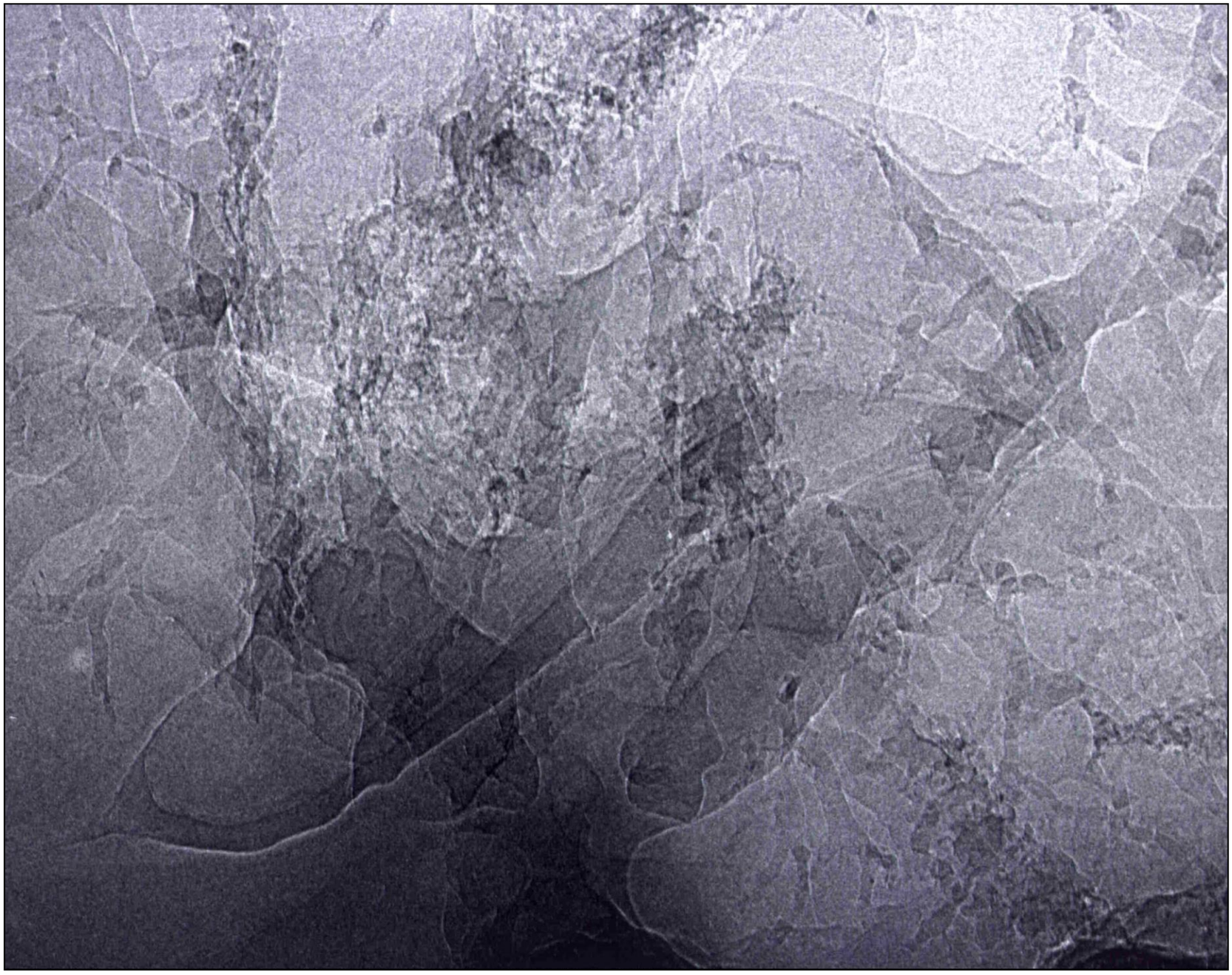


human finger (proximal phalanx)

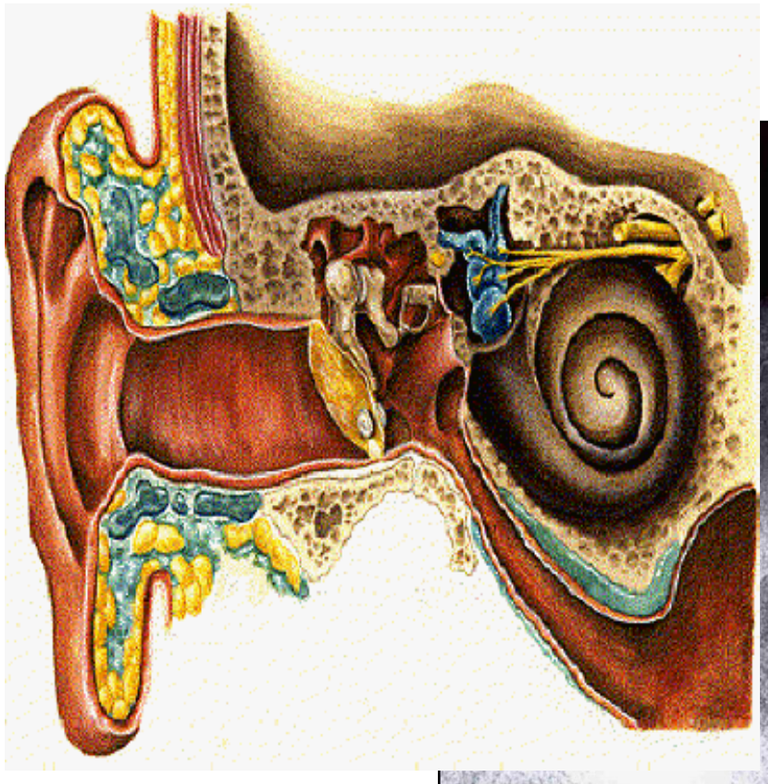


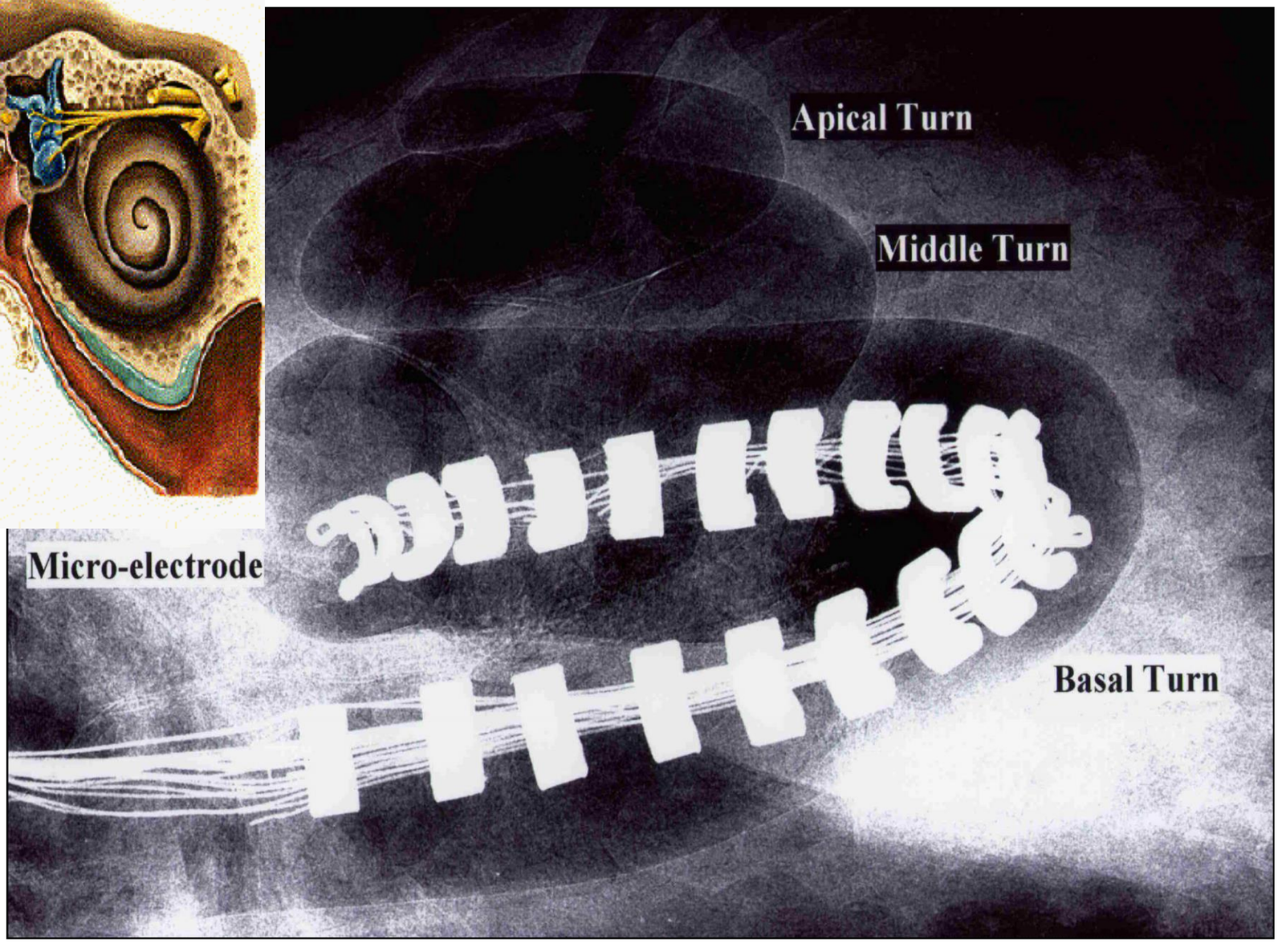
“unsharp masking”

excised mouse kidney

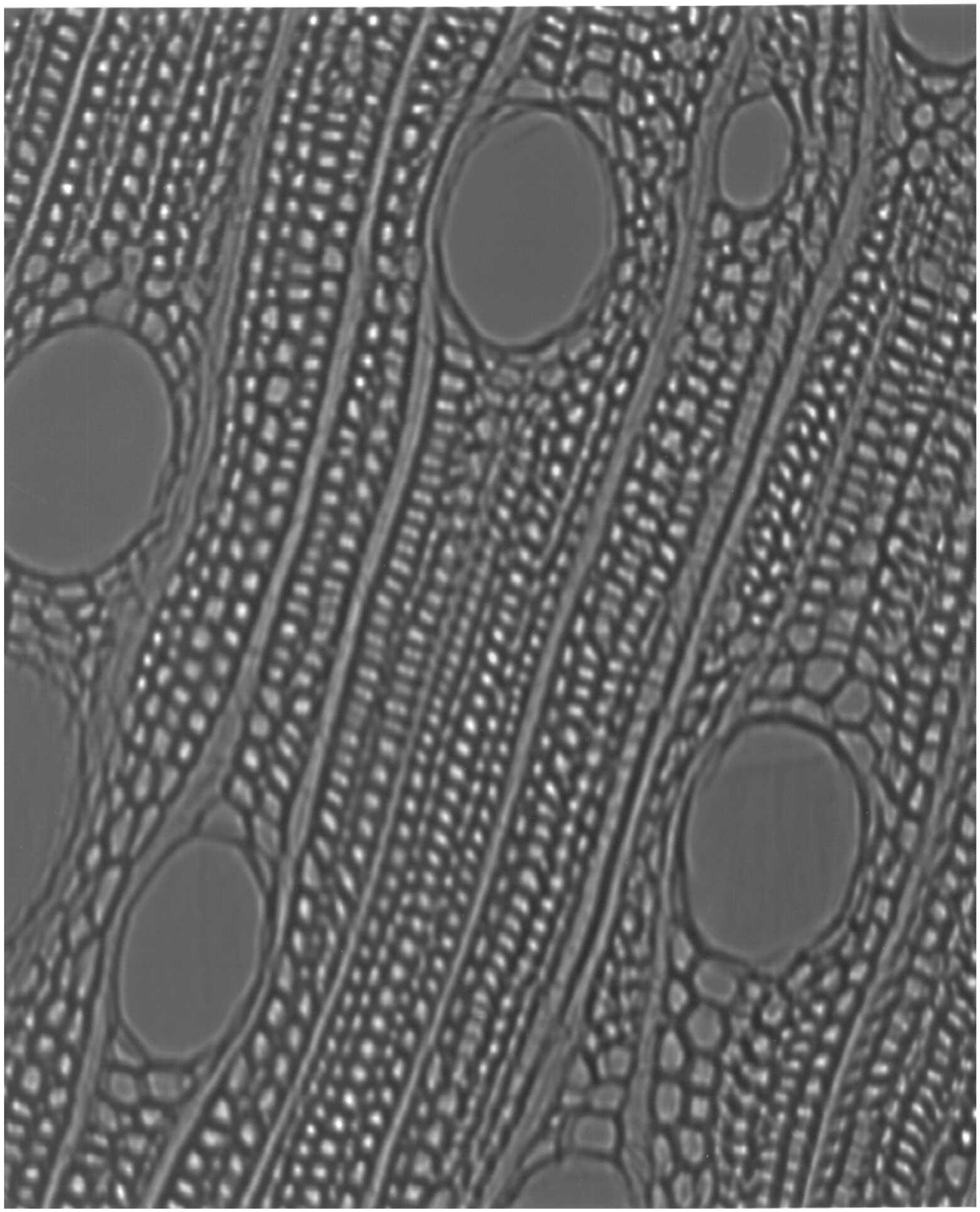


cochlear implant

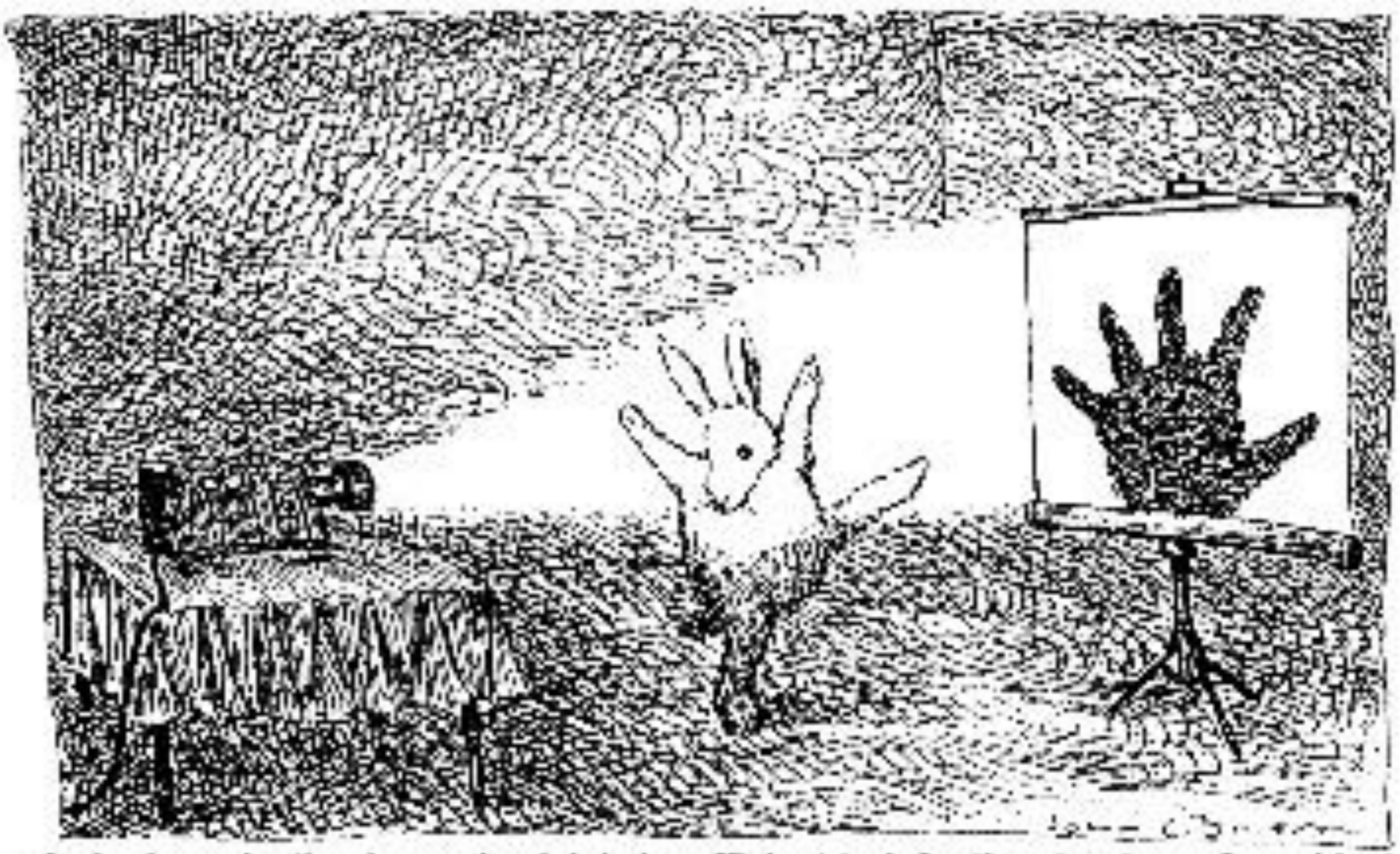




thin wood cross-section



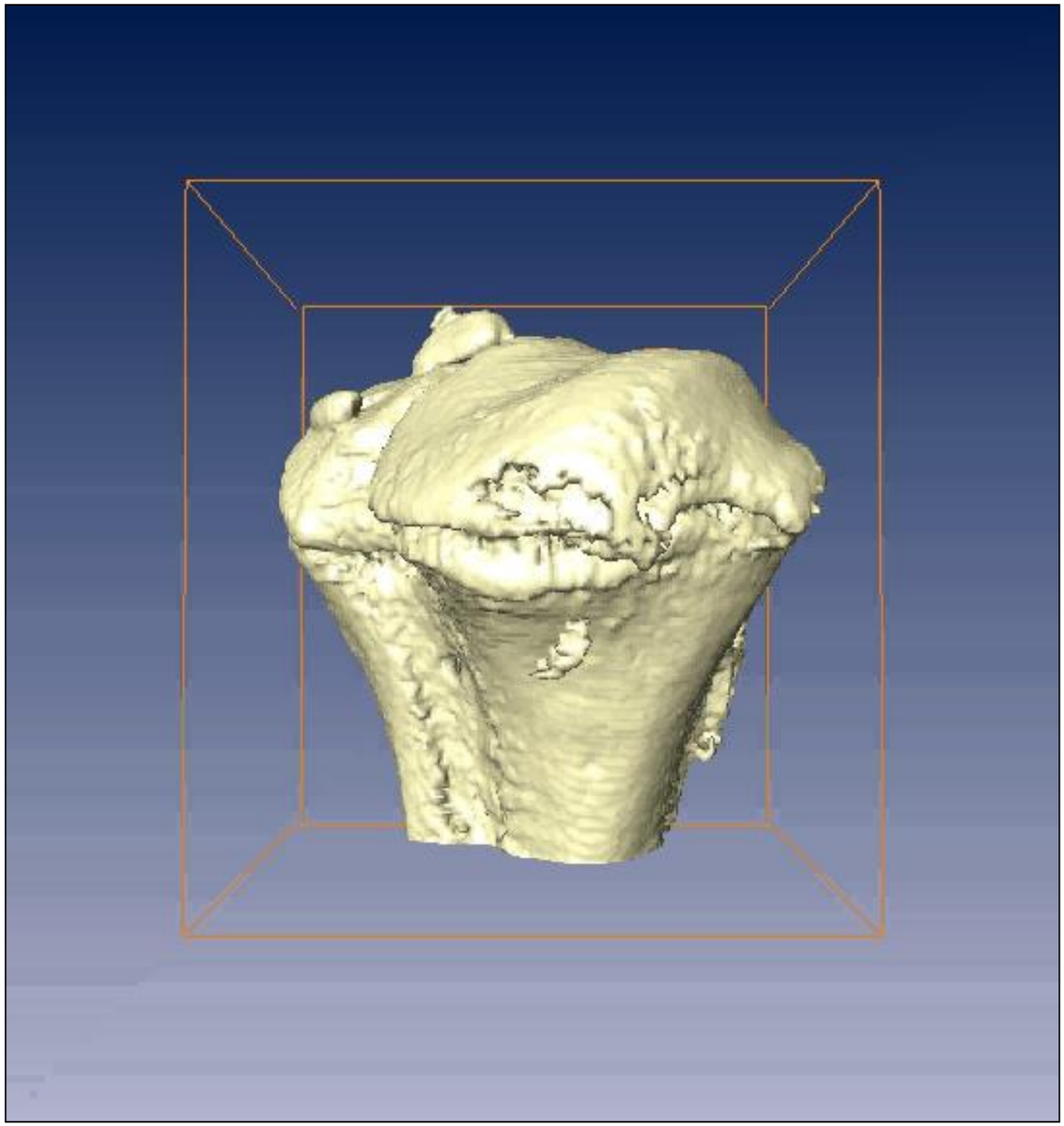
CT - motivation



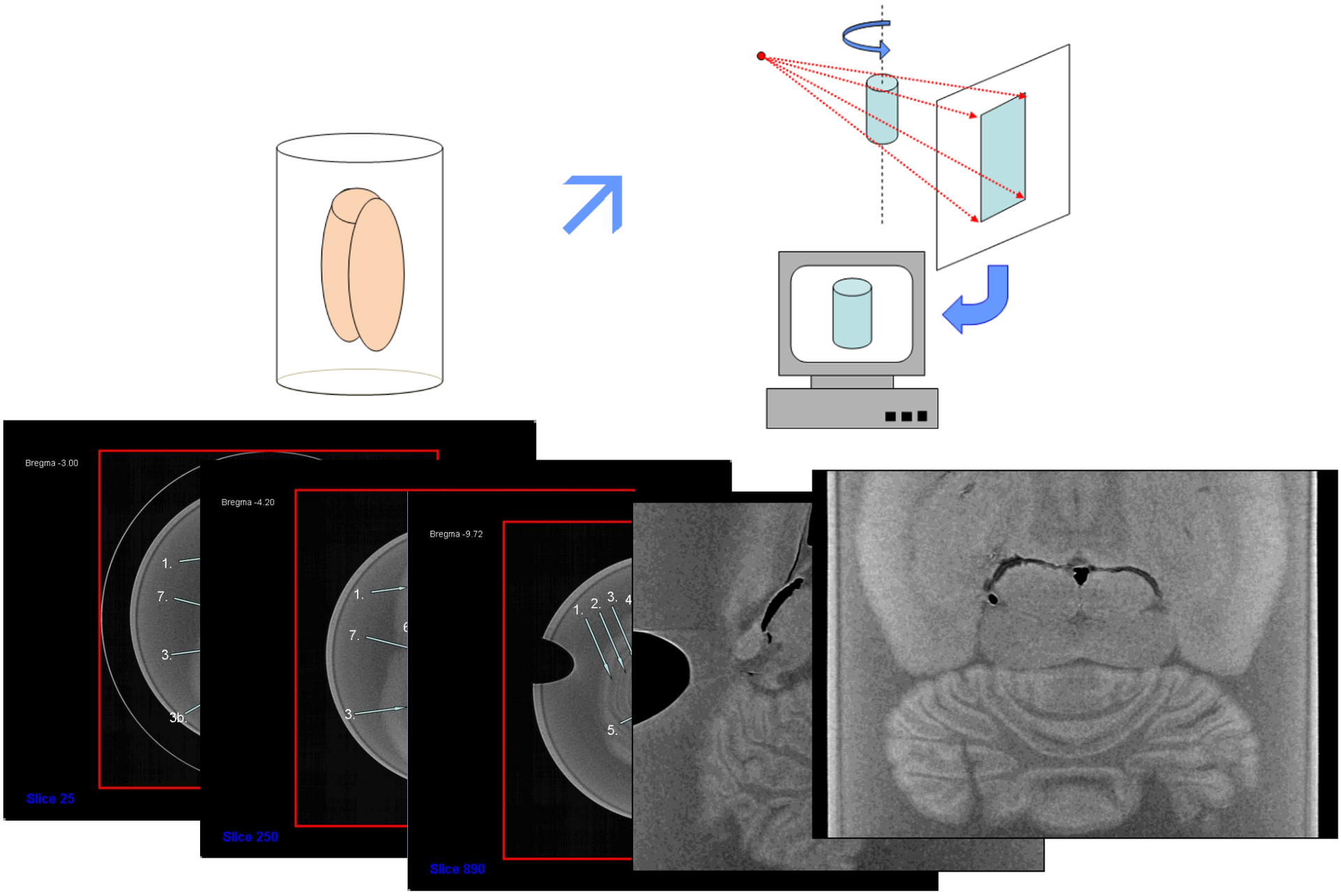
A single projection image is plainly insufficient to infer the structure of an object.

John O'Brien; © 1991 The New Yorker Magazine

mouse tibia - X-ray tomography



X-ray tomography on fixed & embedded rat brains



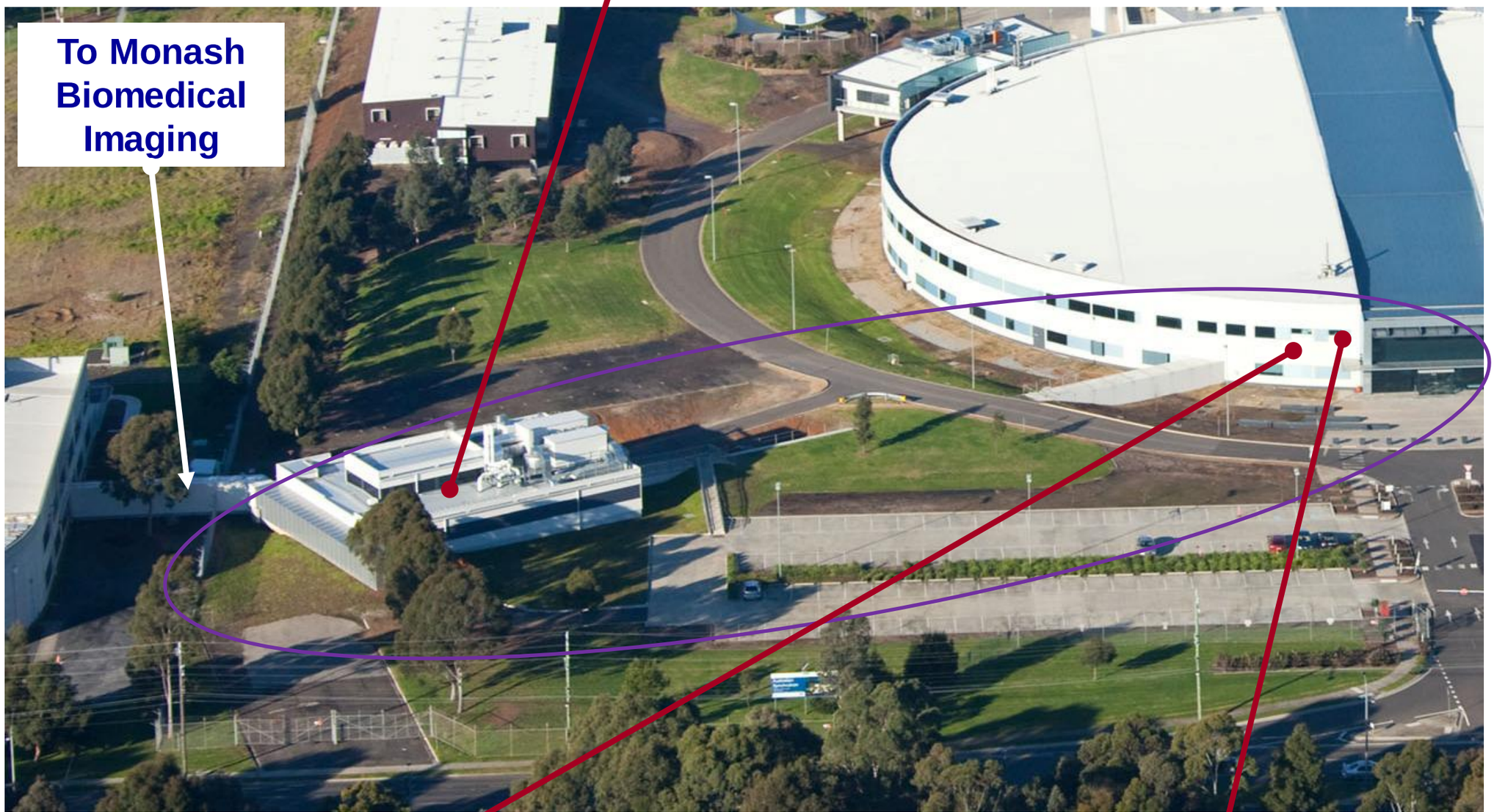
Imaging and Medical Beamline (IMBL)

Monash Biomedical Imaging (MBI)
– Monash/CSIRO

IMBL end station at 140m

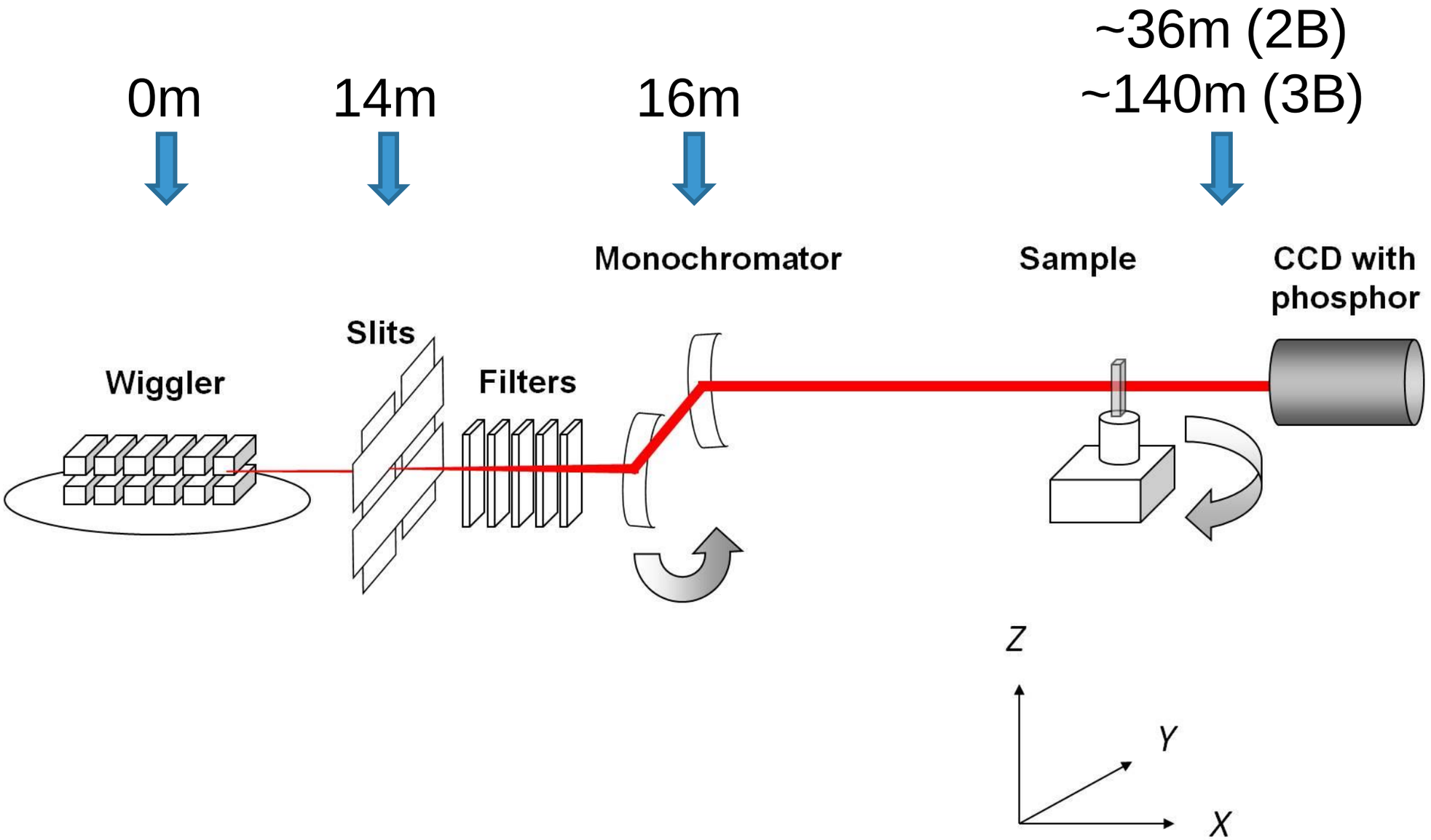
transfer tunnel

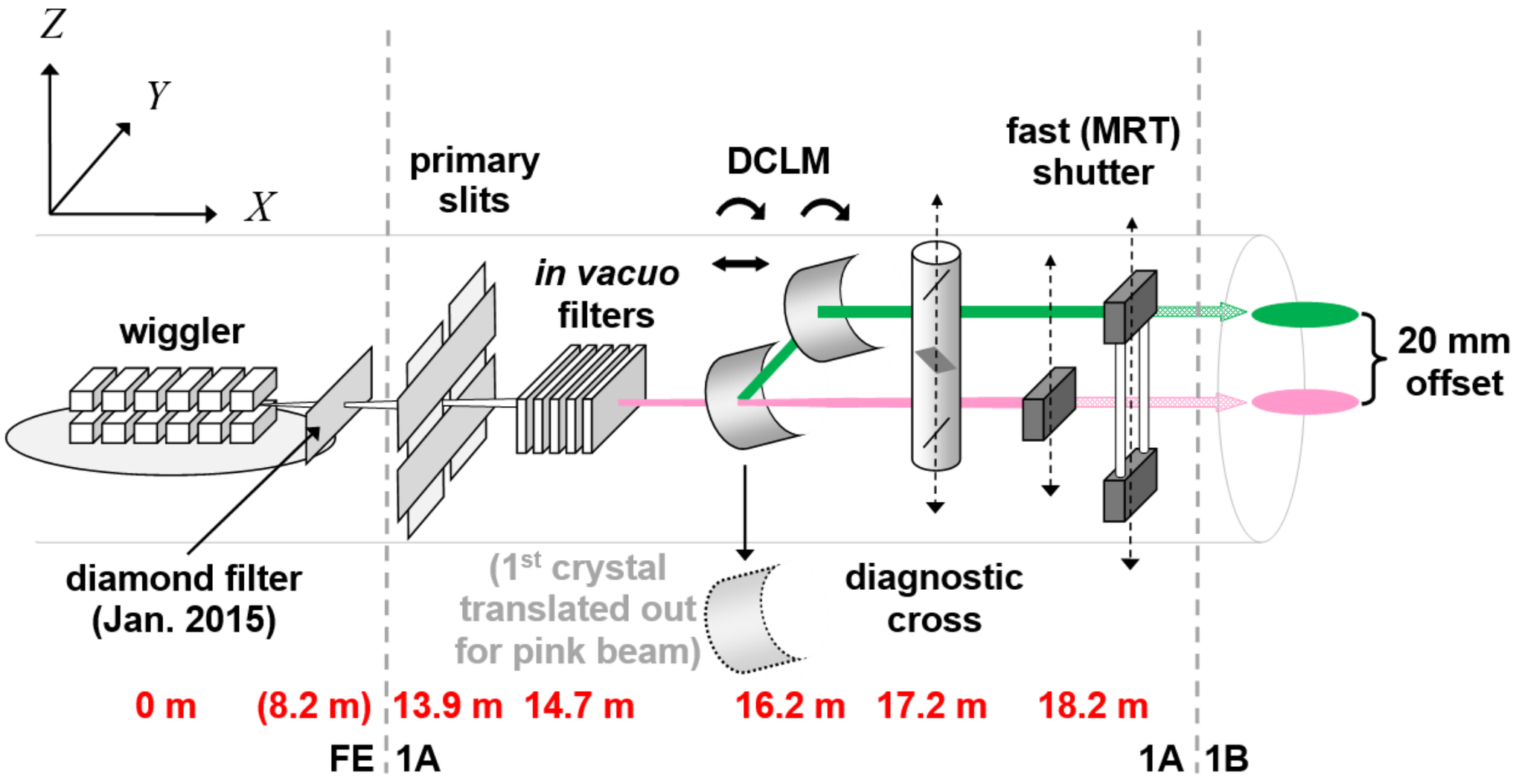
~140m - mode 3: high-resolution imaging (incl PCI) & (slower) CT

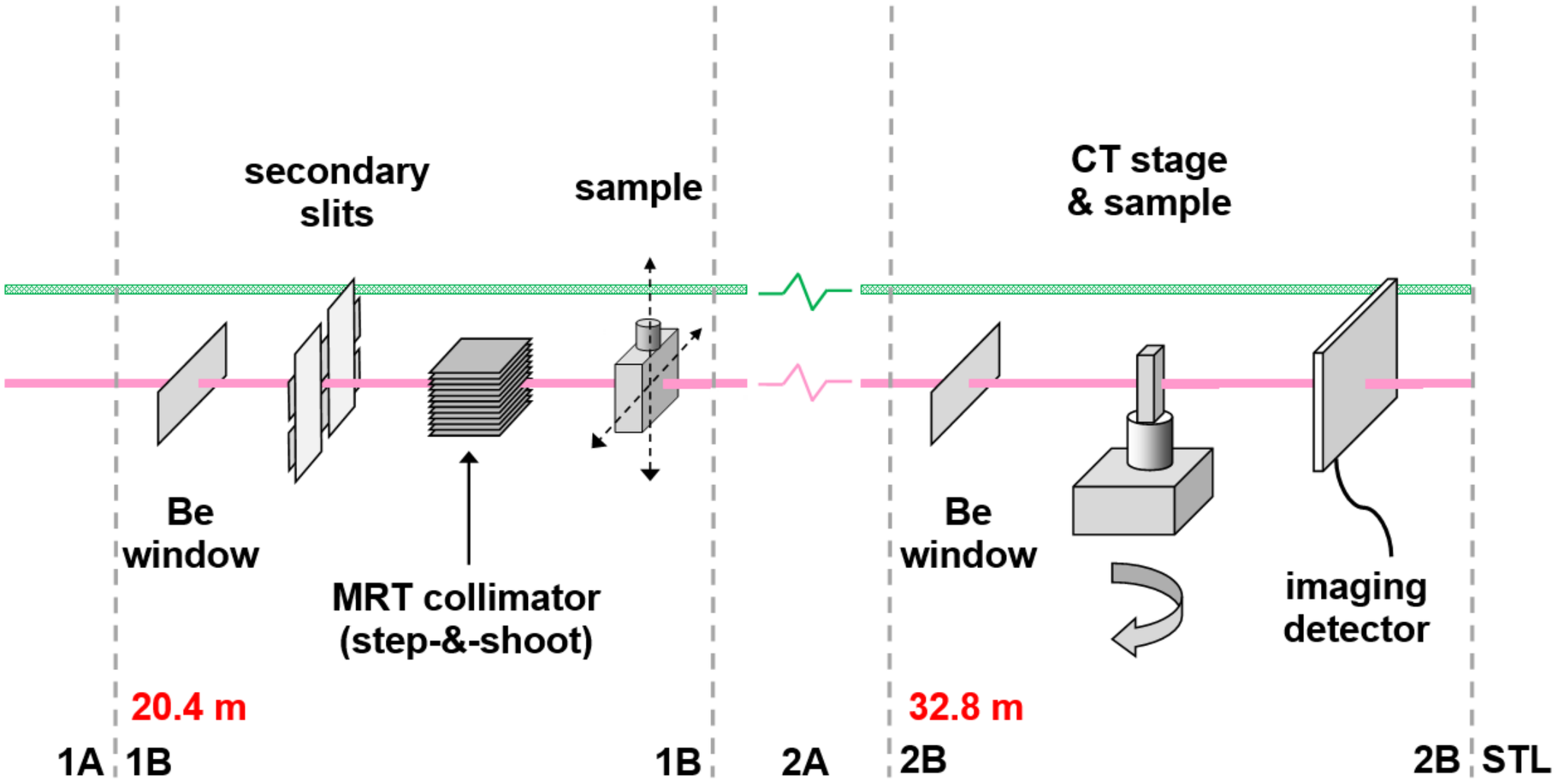


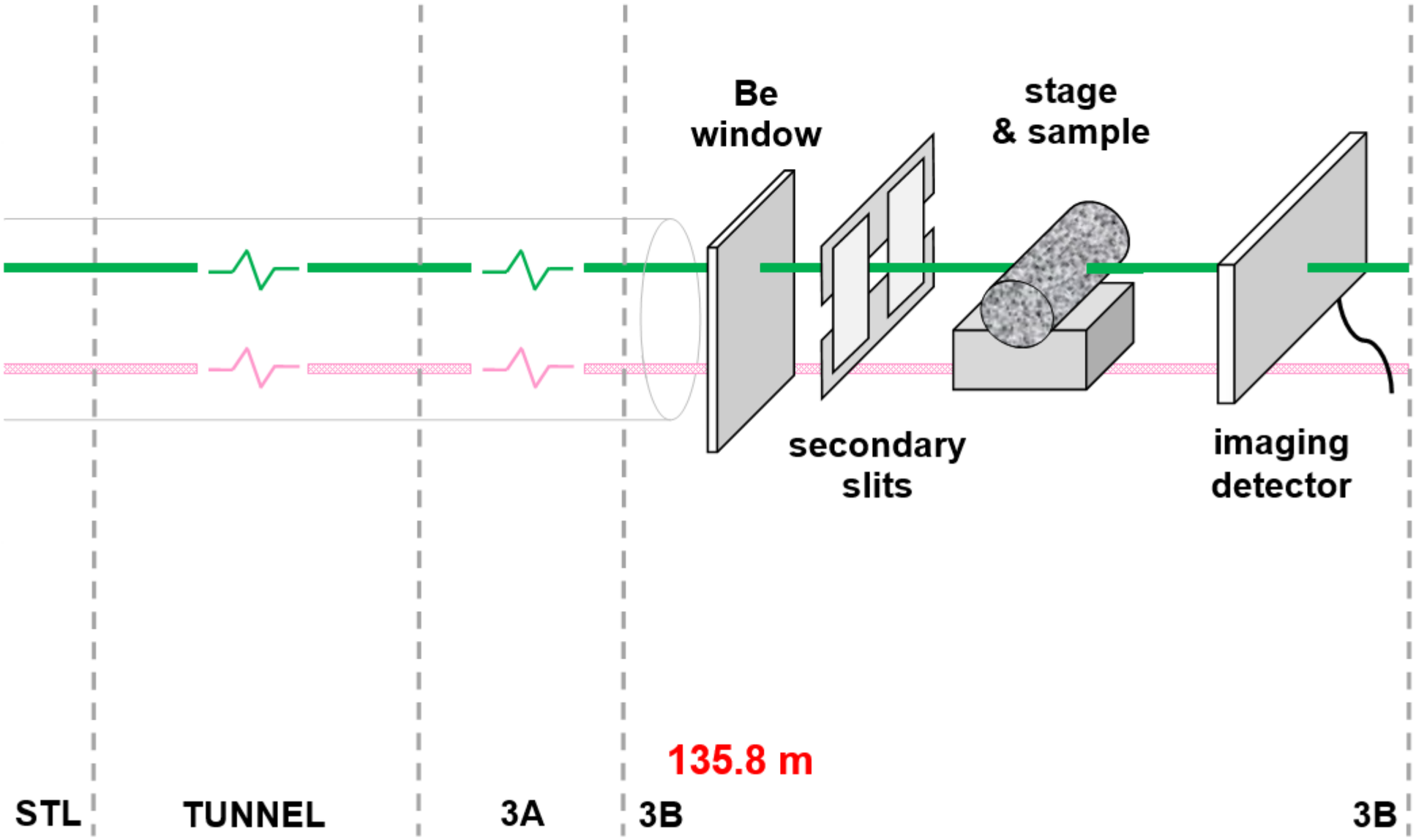
~36m – mode 2: fast imaging & CT, lower-dose radiotherapy

~22m - mode 1: high-dose radiotherapy


0m
14m
16m
~36m (2B)
~140m (3B)
Monochromator
Sample
CCD with phosphor
Slits
Wiggler
Filters
Z
Y
X

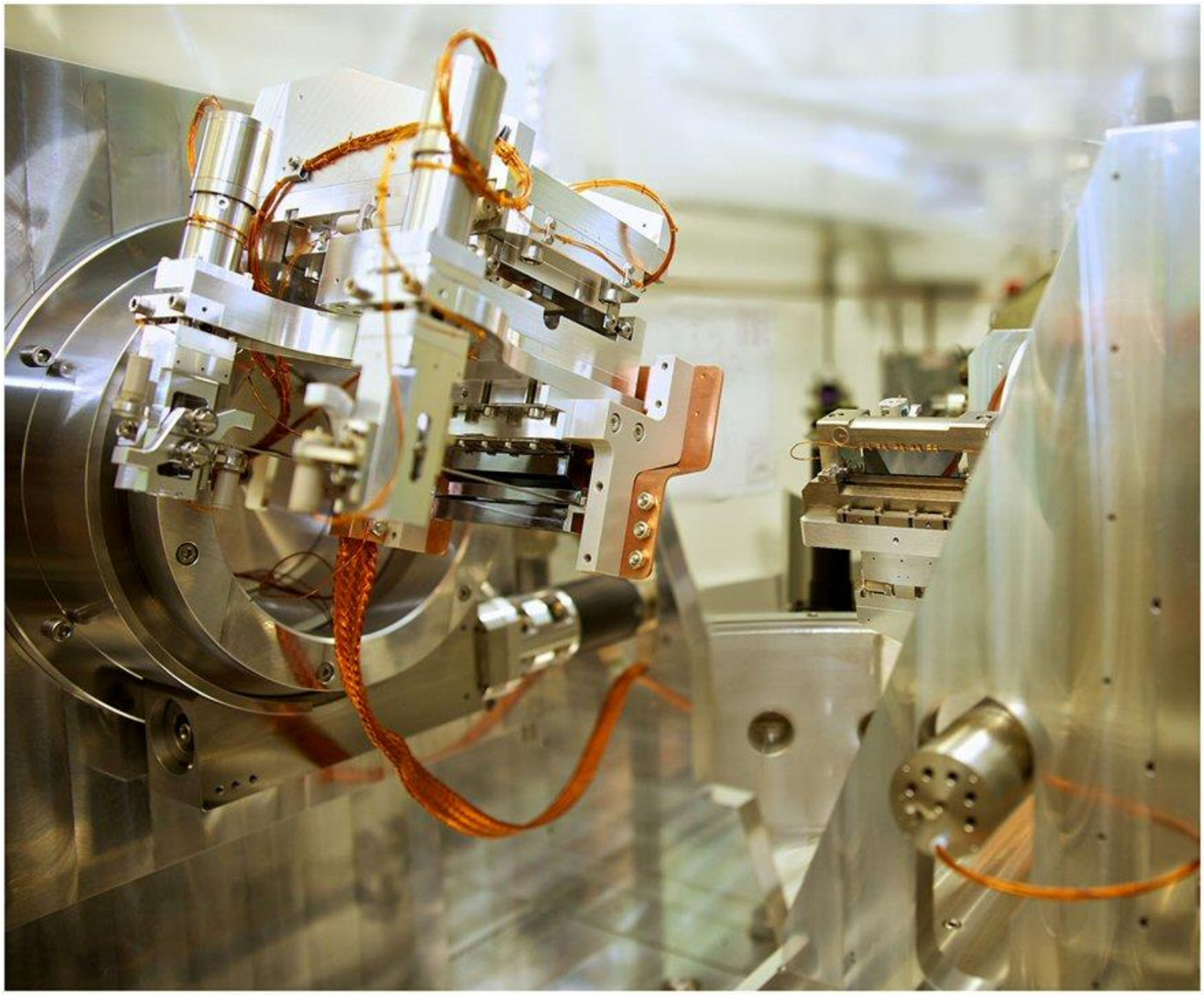

Z
Y
X
primary slits
DCLM
fast (MRT) shutter
in vacuo filters
wiggler
20 mm offset
diamond filter (Jan. 2015)
(1st crystal translated out for pink beam)
diagnostic cross
0 m
(8.2 m)
13.9 m
14.7 m
16.2 m
17.2 m
18.2 m
FE
1A
1A
1B

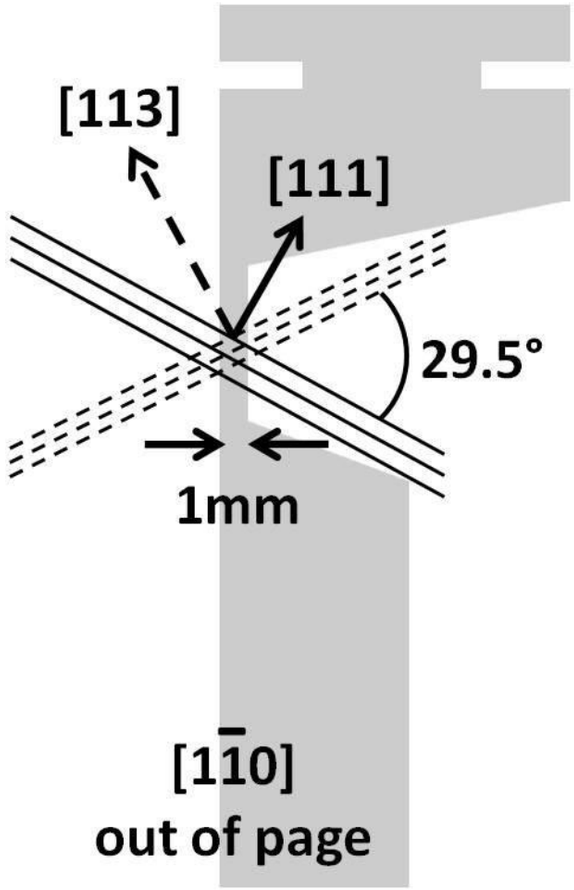

secondary
slits
sample
CT stage
& sample
Be
window
MRT collimator
(step-&-shoot)
Be
window
imaging
detector
20.4 m
32.8 m
1A
1B
1B
2A
2B
2B
STL

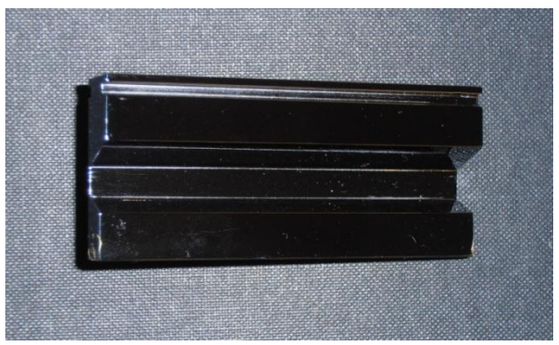

Be
window
stage
& sample
secondary
slits
imaging
detector
135.8 m
STL
TUNNEL
3A
3B
3B

SCMPW

DCLM



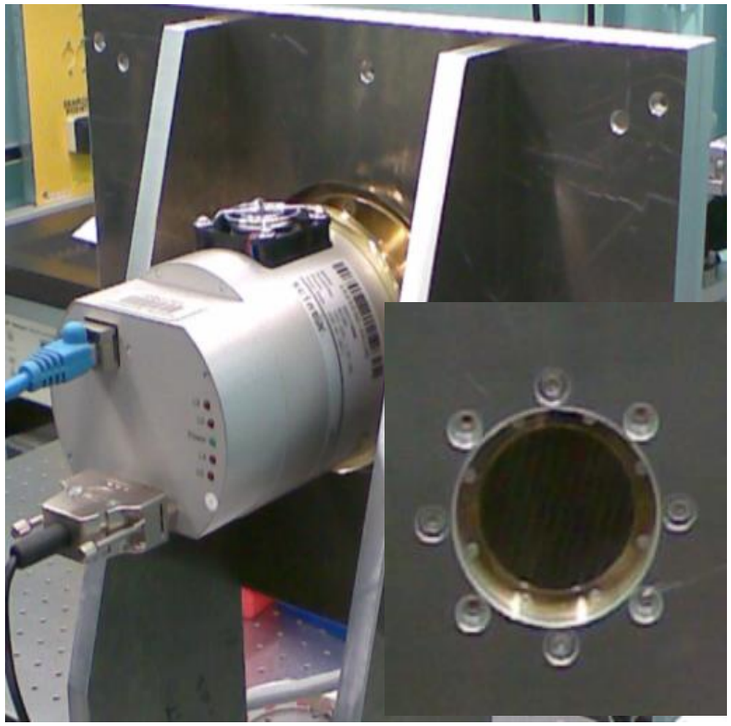




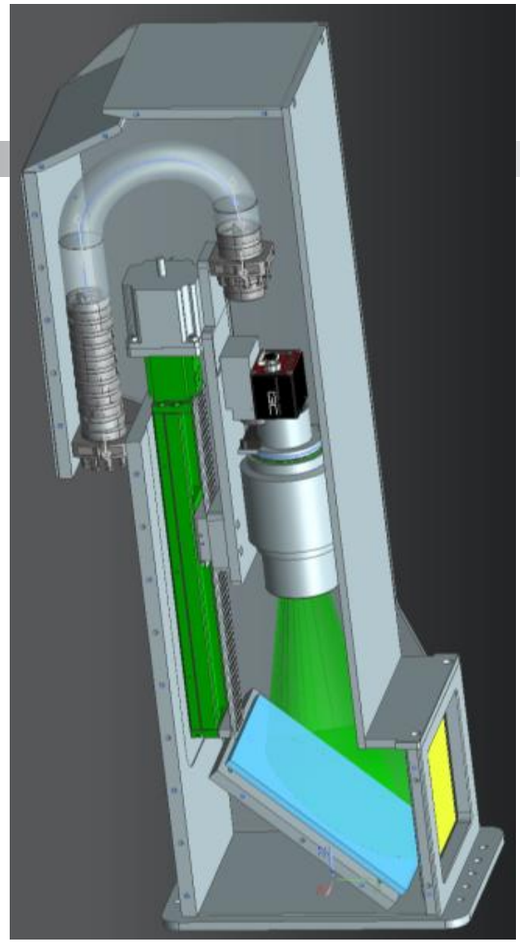
imaging detector details

detector	FOV (mm^2)	no. of pixels	pixel size (μm)	max. full fps	likely use
Diamond Optique Peter X-ray microscope with PCO.edge sensor	min: 1.66 x 1.40	2560 x 2160	0.64	50	high resolution imaging & CT of small objects
	max: 13.46 x 11.36	2560 x 2160	5.3	50	
Amethyst Scint-X DXI-11000	36.18 x 24.12	4024 x 2680	9	3	medium resolution imaging at higher energies
Ruby Single PCO.edge sensor, lens coupled to scintillator	min: 16.25 x 13.72	2560 x 2160	6.35	50	medium resolution imaging & CT at fast frame rates
	max: 57.1 x 48.2	2560 x 2160	22.3	50	
Amber Photonic Science Dual VHR Imager	100.14 x 33.48	8769 x 2923	11.4	1.2	medium resolution, large area imaging
Quartz Hamamatsu C9252DK-14 flat panel imager	min: 243.2 x 100	2432 x 100	100	146	therapy sample positioning, fast frame imaging & CT
	max: 243.2 x 123.2	1216 x 616	200	30	
Opal Teledyne Dalsa, Argus Pan	current: 220 x 6.9	8160 x 256	27	7.8	wide, medium resolution, for high energy imaging
	future: 440 x 6.9	16320 x 256	27	7.8	
Mica modular version of Ruby (In development)	min: 380 x 32.4	25600 x 2160	15	50	very large area, medium resolution imaging & CT
	max: 760 x 64.8	25600 x 2160	30	50	

detectors



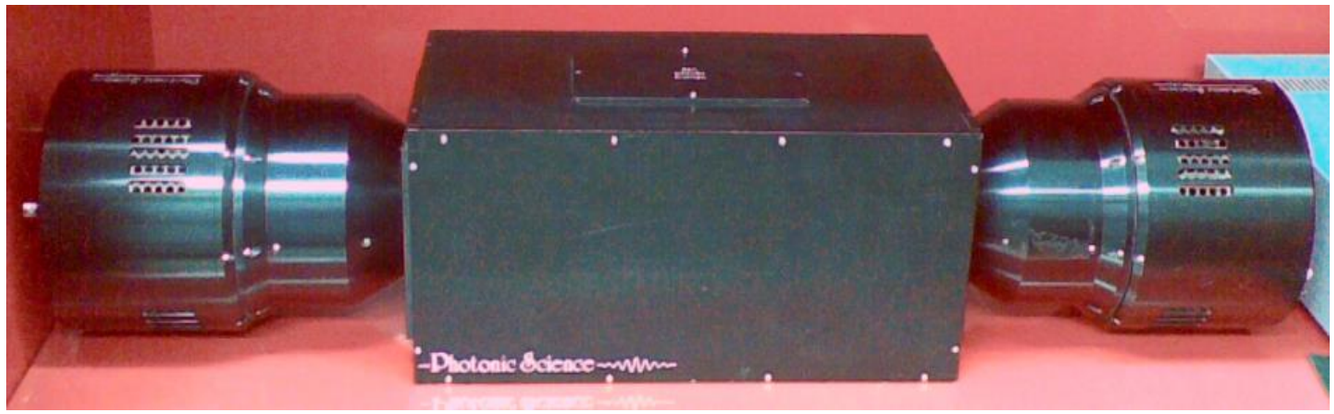
Amethyst – CsI



Ruby

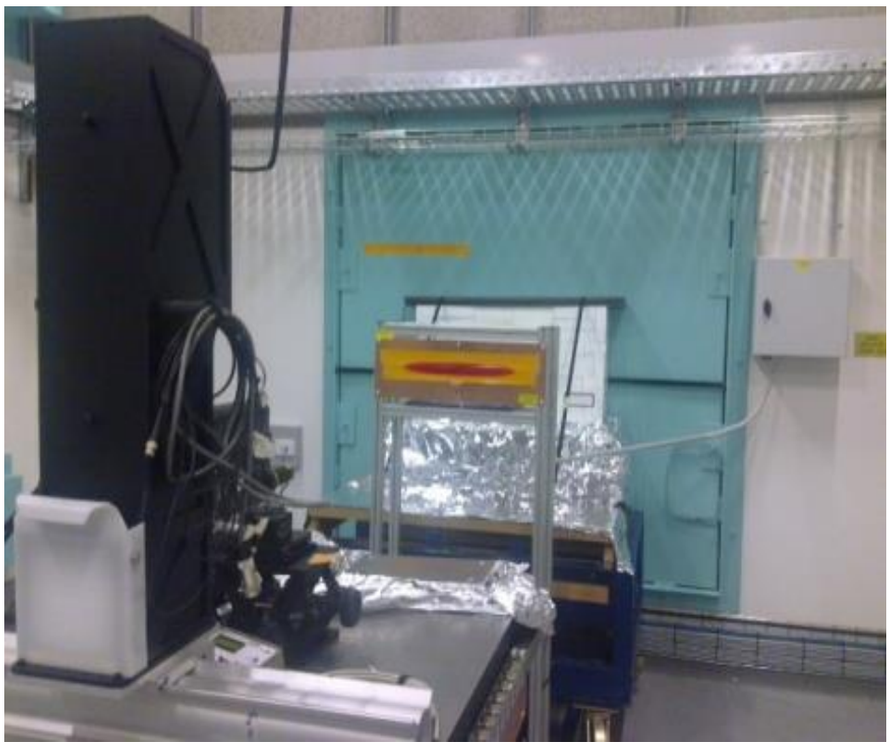
Diamond

Amber – Dual CCD Gadox

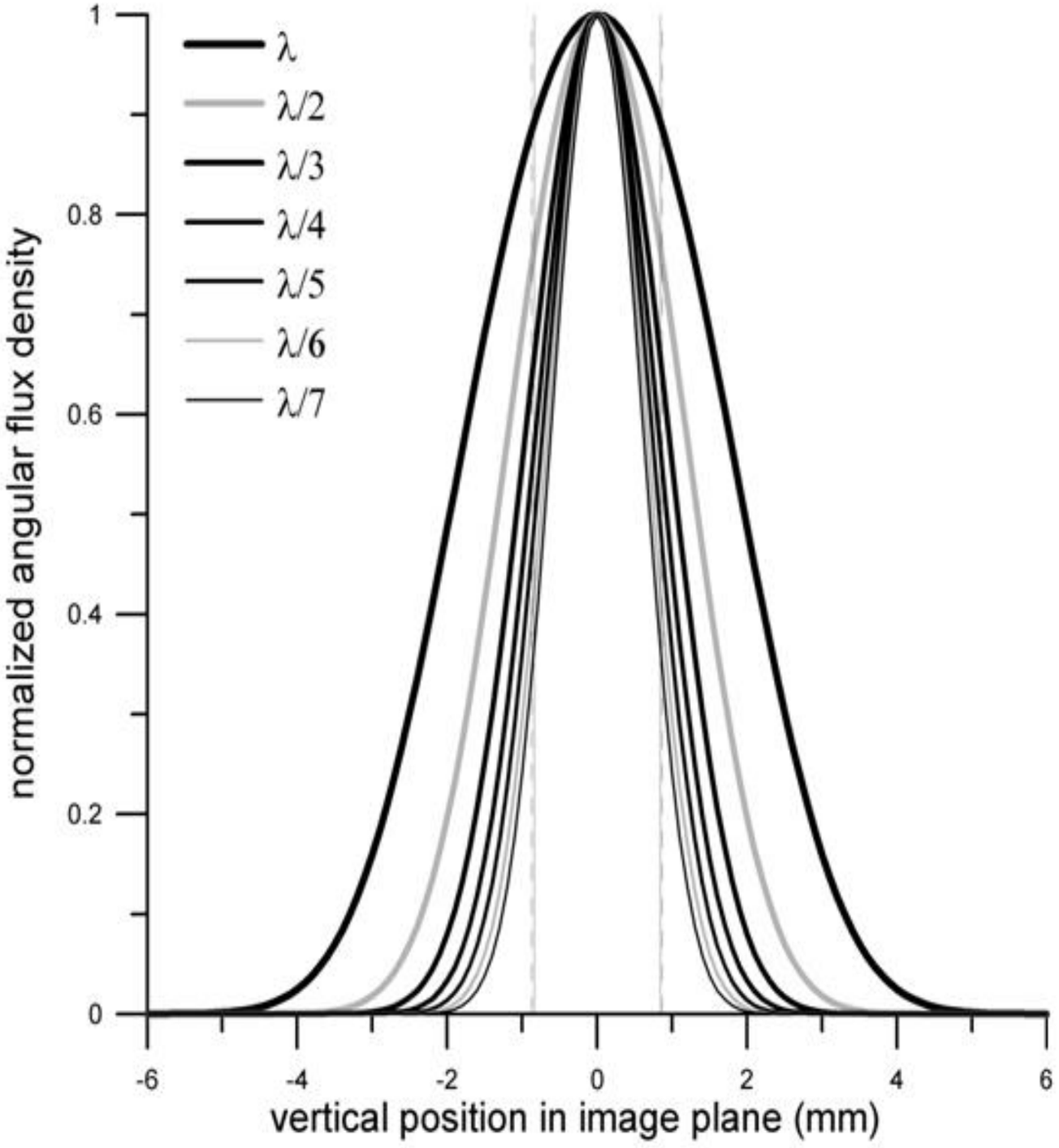


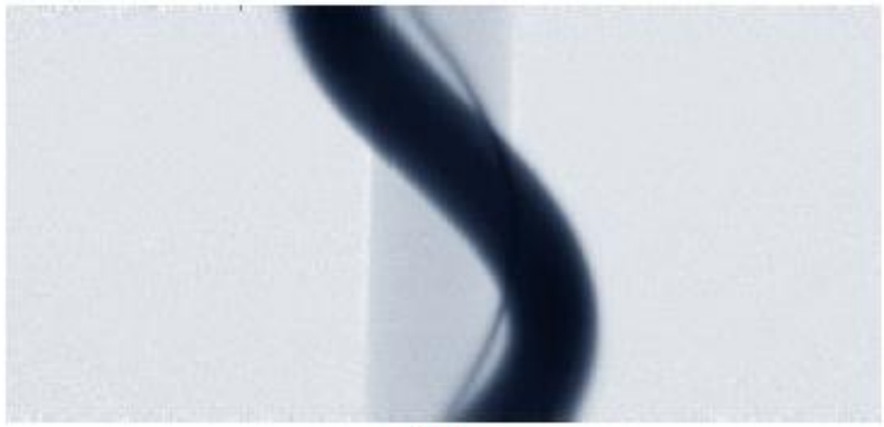
Flat-panel CMOS imager – CsI

3B for imaging/ tomography users



“roll-off” – vertical direction





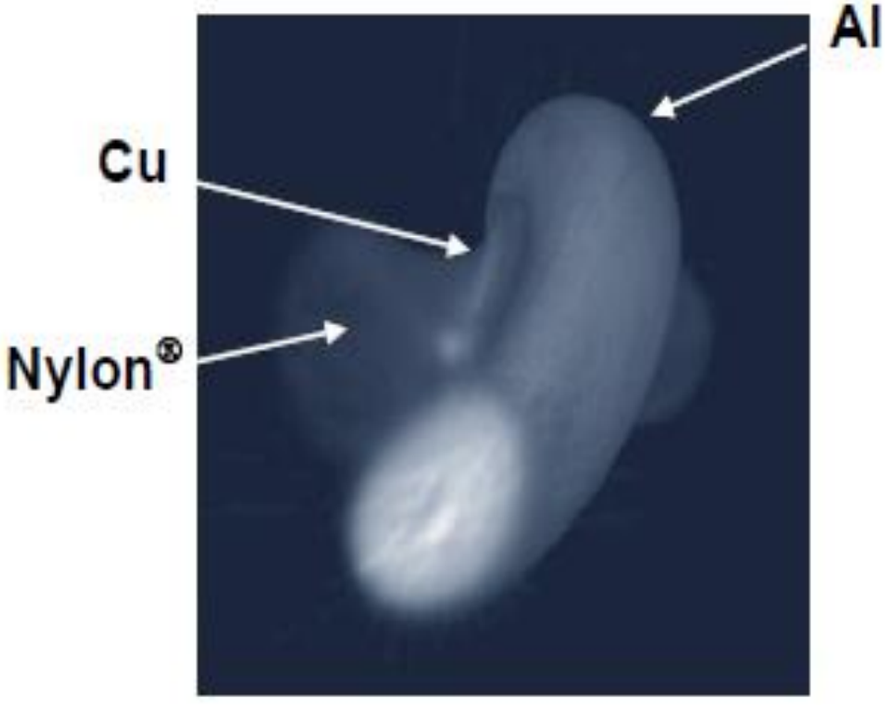
(a)

(b)

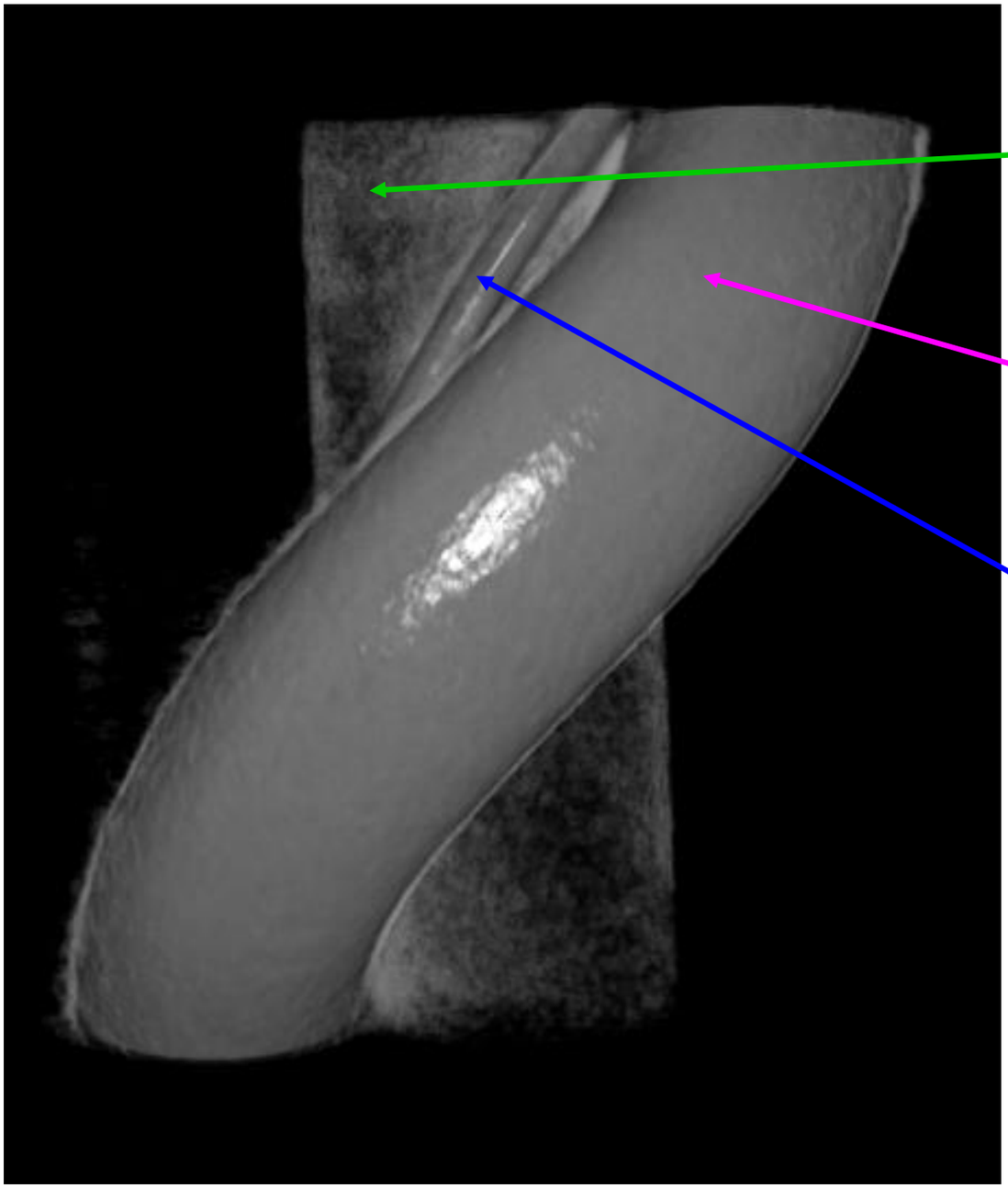
(c)

(d)

(a) 12.66 keV
(b) 18.00 keV
(c) 25.52 keV
(d) 30.49 keV

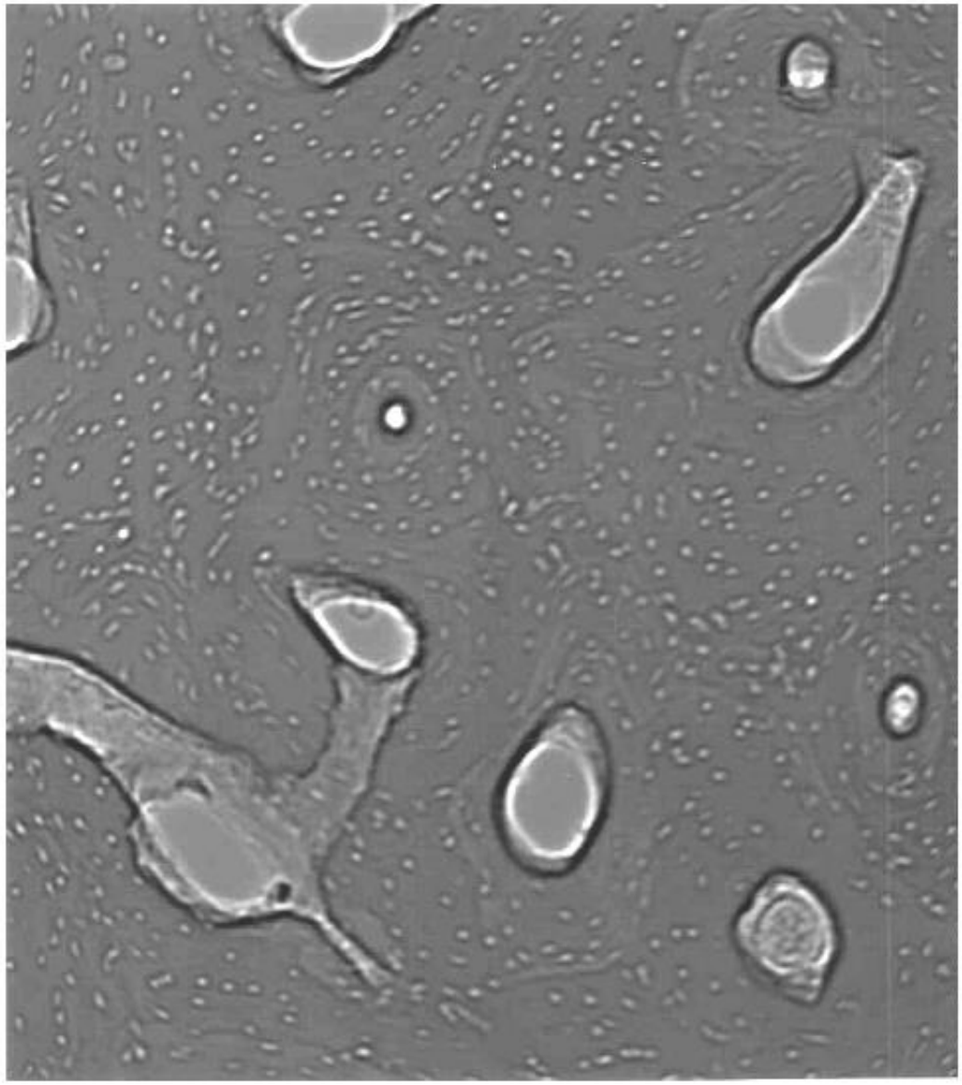


volume-rendered 12.66keV data

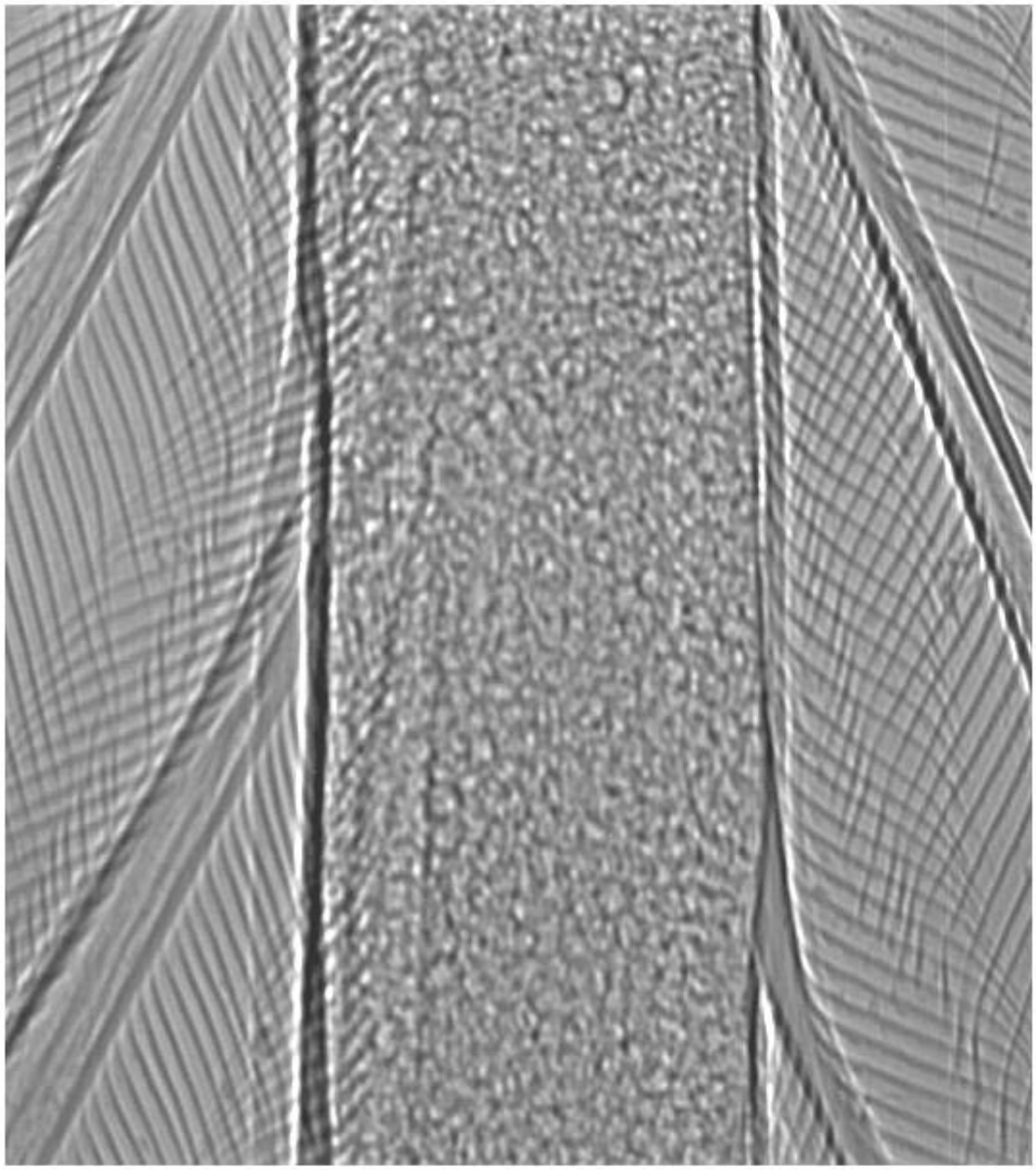


cross-section of human femur - data collected at ESRF in Grenoble, France

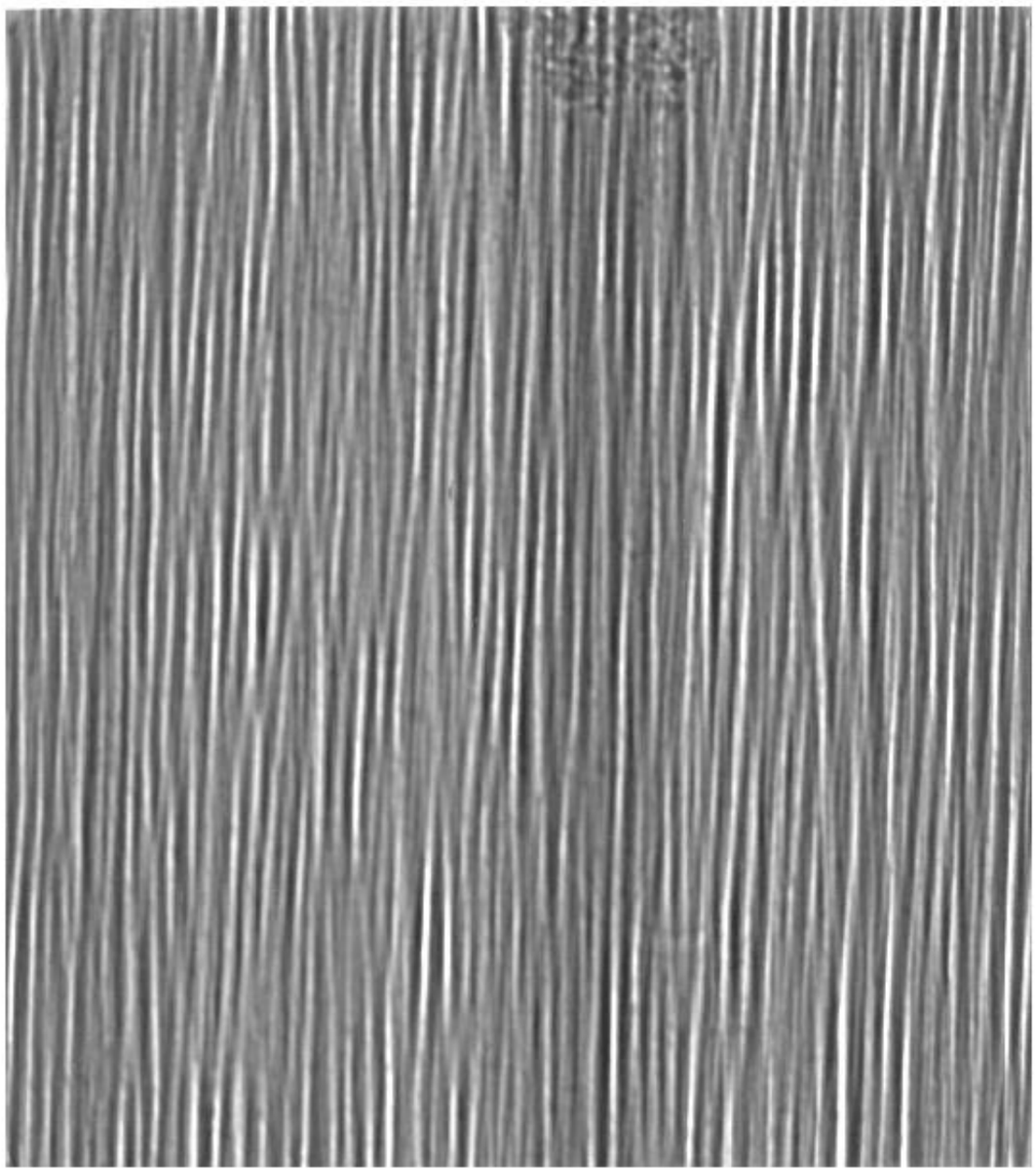
smallest features are osteocytes (of order 5µm)



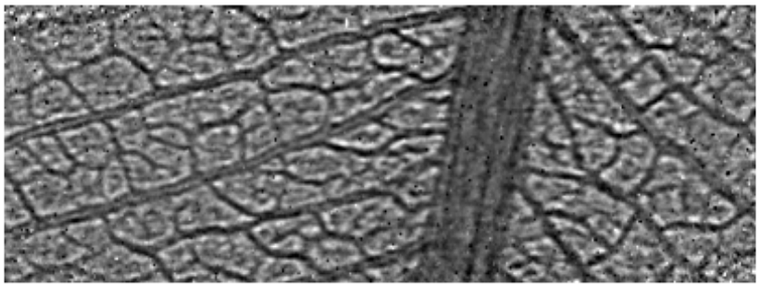
central section of a feather



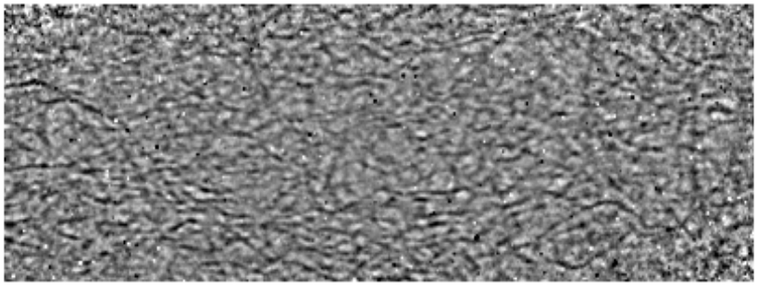
Graphite fibres (~10μm) in Aluminium - data collected at ESRF



first X-ray images from IMBL (polychromatic) - December, 2008

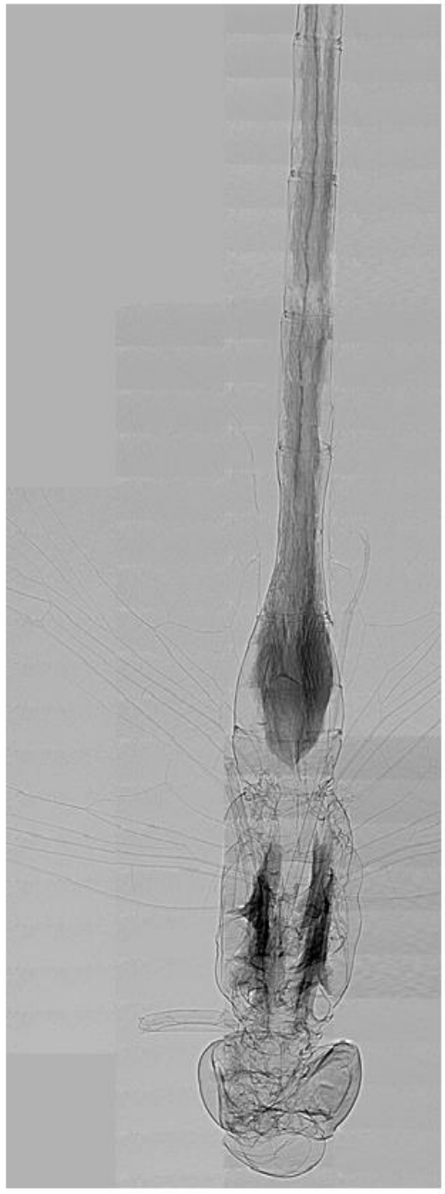


(a)

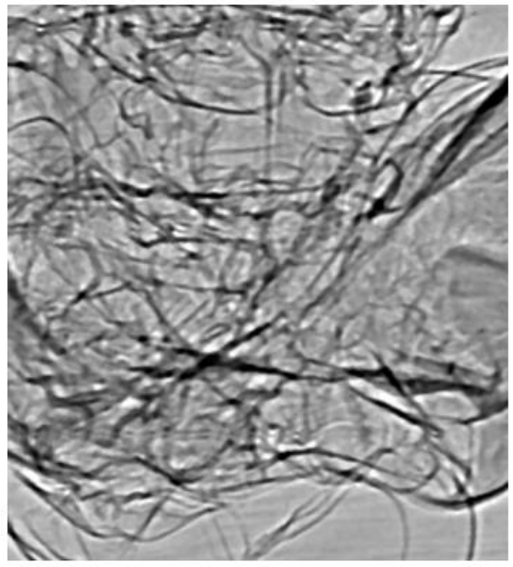


(b)

← ~6.2 mm →

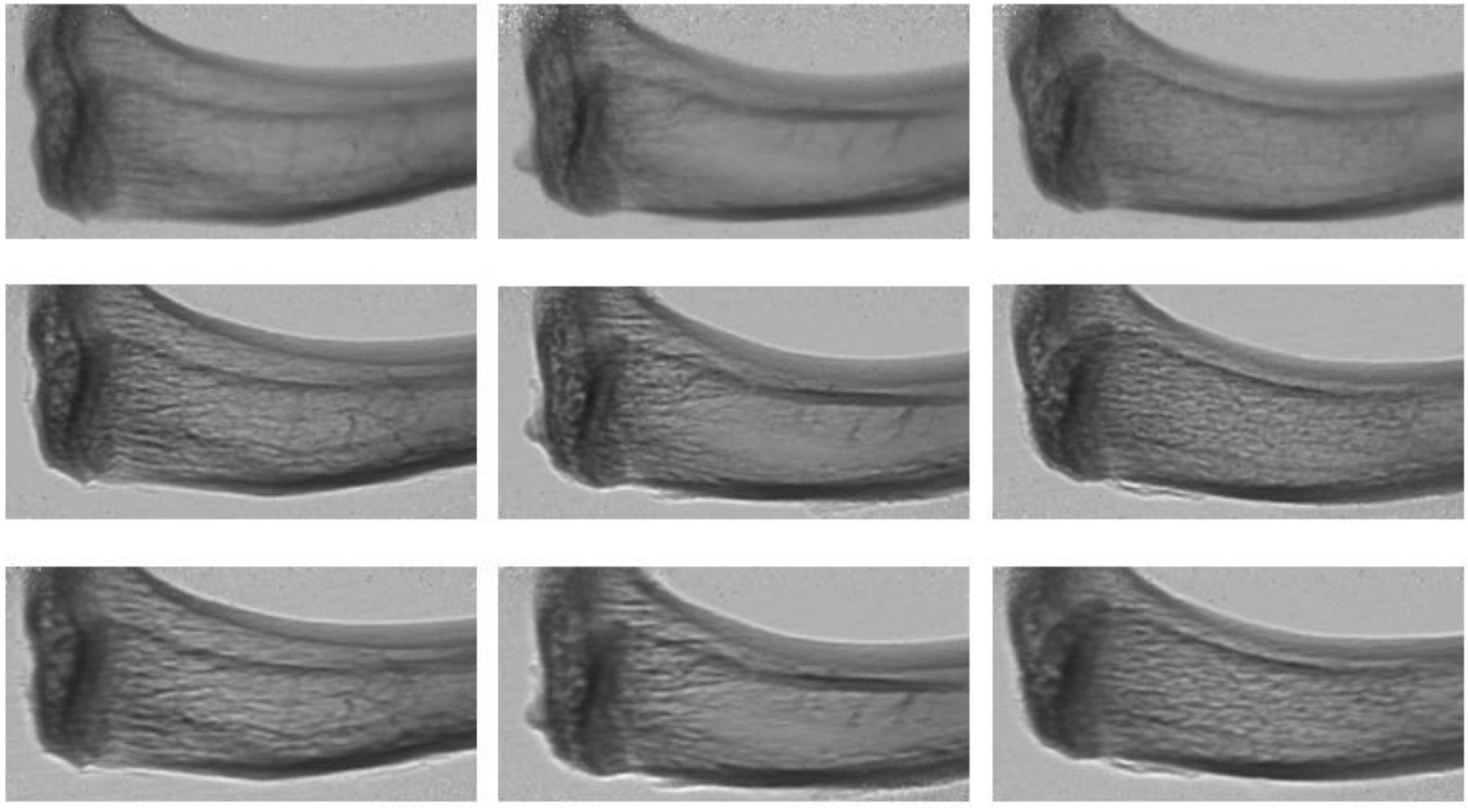


← ~26.5 mm→



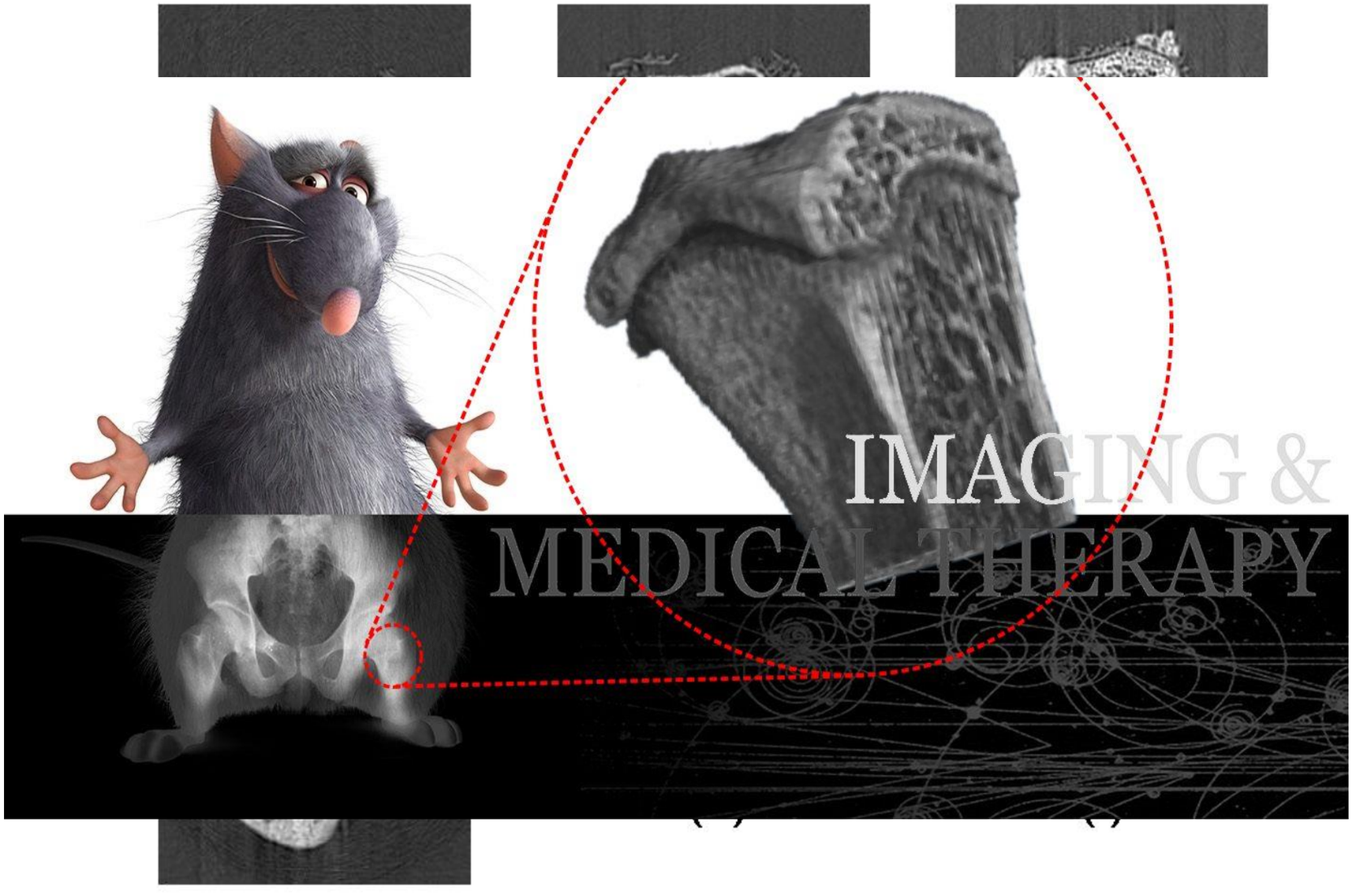
← ~6.5 mm →

first X-ray images from IMBL - mouse tibiae (different treatments & distances)



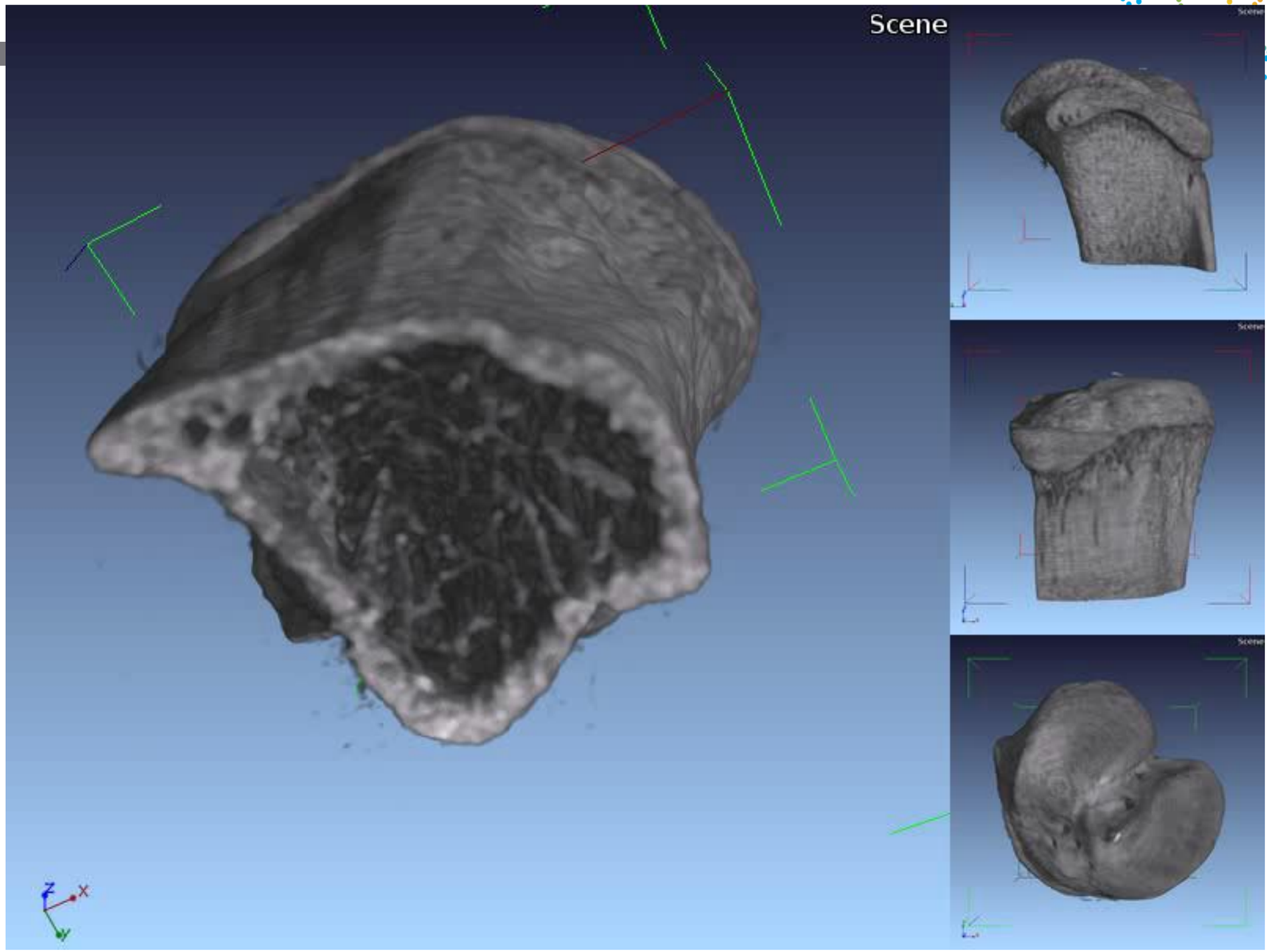
←~6.3 mm→

reconstructed tomography slices for leptin-treated mouse tibia



(d)

←~3.8mm→


Scene
Scene
Scene
Scene
Z
X
Y

CSIRO Future Industries/ MCT, Australian Synchrotron
Dr Andrew Stevenson

Phone: +61 3 9518 5945
Email: andrew.stevenson@csiro.au
or andrew.stevenson@synchrotron.org.au

Thank you for your attention

Australian Synchrotron

CSIRO

“25keV.avi”, “50keV.avi” & “100keV.avi”

- **1024 μm × 1024 μm**
- **Cu**
- **R_1 = 21 m & R_2 = 1 cm**
- **σ_d = 6.3 μm**

“detector_resolution.avi”

- 1024 μm × 1024 μm
- Ge 0.5 mm
- R_1 = 21 m & R_2 = 1 cm
- 50 keV

“signal_to_noise.avi”

- 1024 μm × 1024 μm
- Ge 0.5 mm
- R_1 = 21 m & R_2 = 1 cm
- σ_d = 5 μm
- 50 keV

“Z.avi”

- 1024 μm × 1024 μm
- 0.5 mm
- R_1 = 21 m & R_2 = 1 cm
- σ_d = 6.3 μm
- 50 keV

“K_abs_edge.avi”

- 1024 μm × 1024 μm
- I (“IM”) & Ba (“BL”) 0.1 mm
- R_1 = 21 m & R_2 = 1 cm
- σ_d = 6.3 μm

“1B_PC.avi”, “2B_PC.avi” & “3B_PC.avi”

- **1024 µm × 1024 µm**
- **Al 0.1 mm**
- **R_1 = 20 m (1B), 34 m (2B) & 138 m (3B)**
- **σ_d = 5 µm, $\sigma_{s,h}$ = 320 µm & $\sigma_{s,v}$ = 16 µm**
- **25 keV**