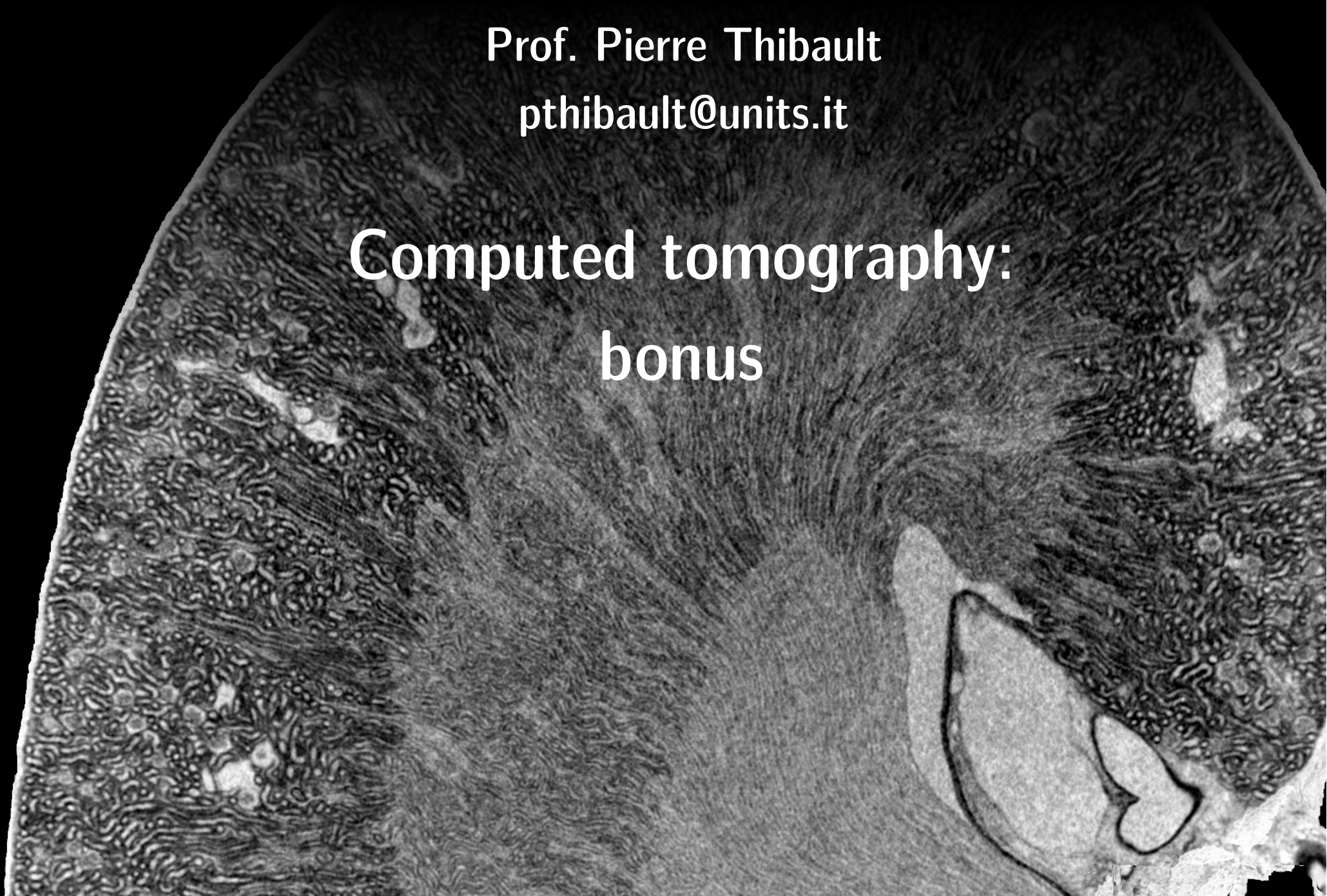


Image Processing for Physicists

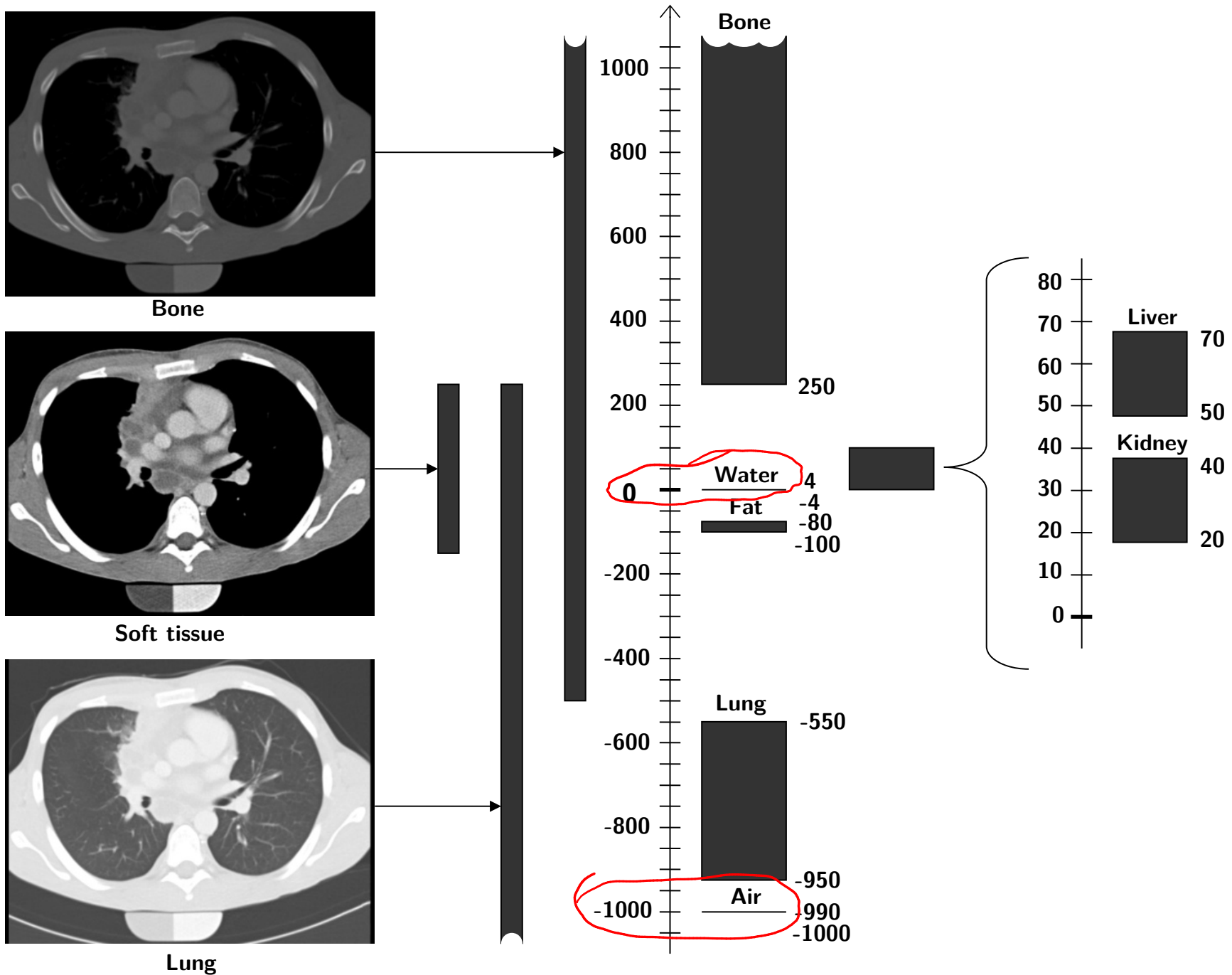
Prof. Pierre Thibault

pthibault@units.it

Computed tomography:
bonus



Hounsfield units



Medical CT

- Mathematical methods developed by Allan M. Cormack in the early 60s.
- First clinically useful CT instrument developed by Godfrey Hounsfield in the early 70s.
- Cormack & Hounsfield were awarded the Nobel prize in 1979 “for the development of computer assisted tomography”.

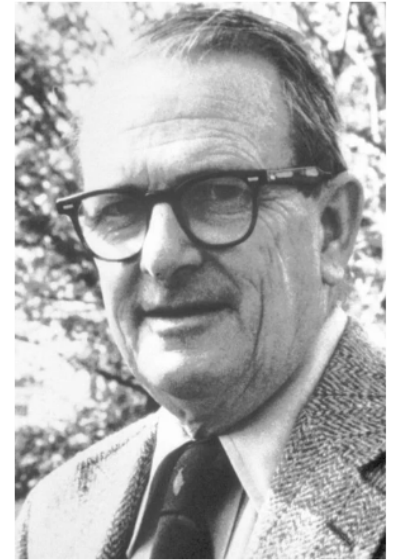


Photo from the Nobel Foundation archive.
Allan M. Cormack



Photo from the Nobel Foundation archive.
Godfrey N. Hounsfield

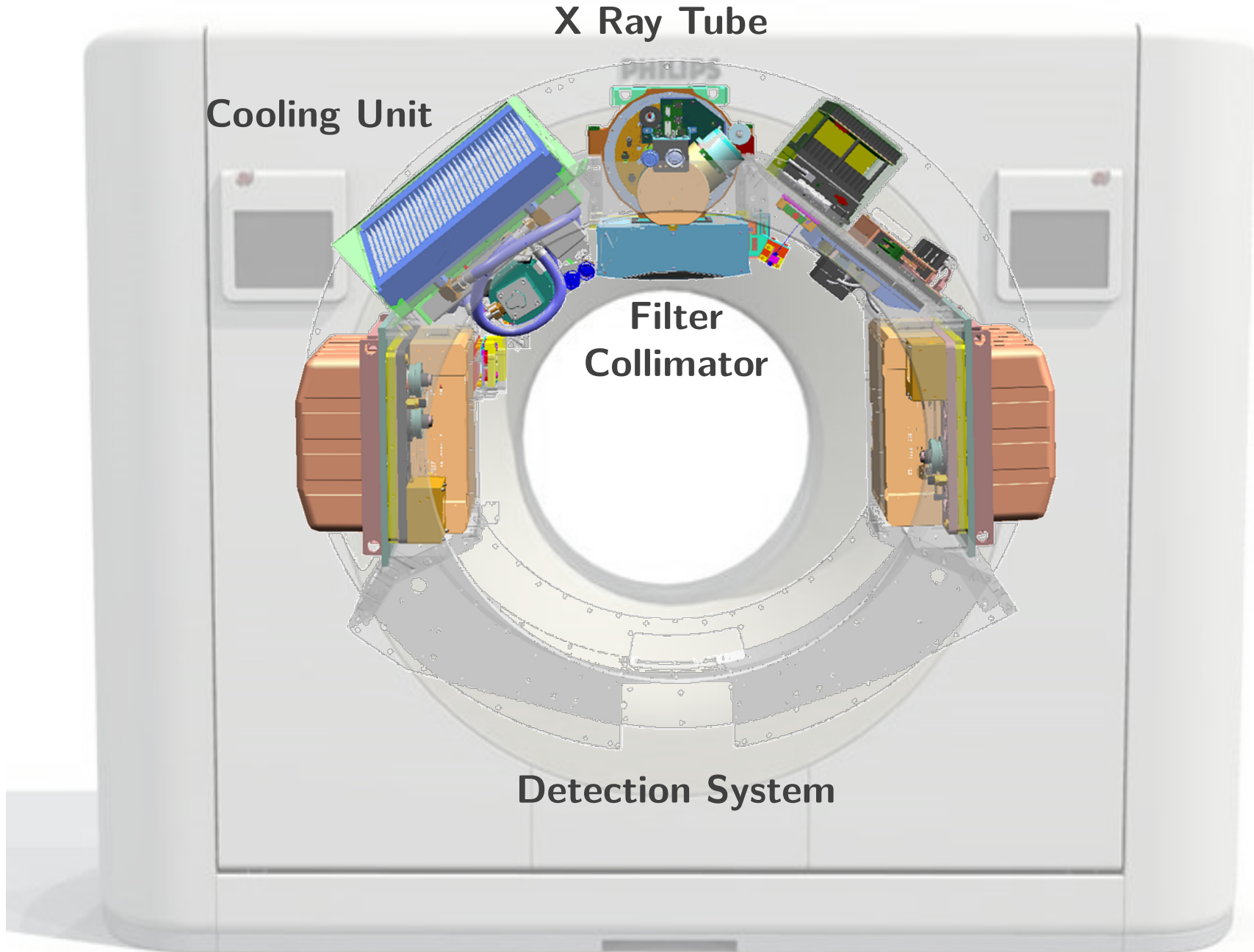
CT systems

Gantry



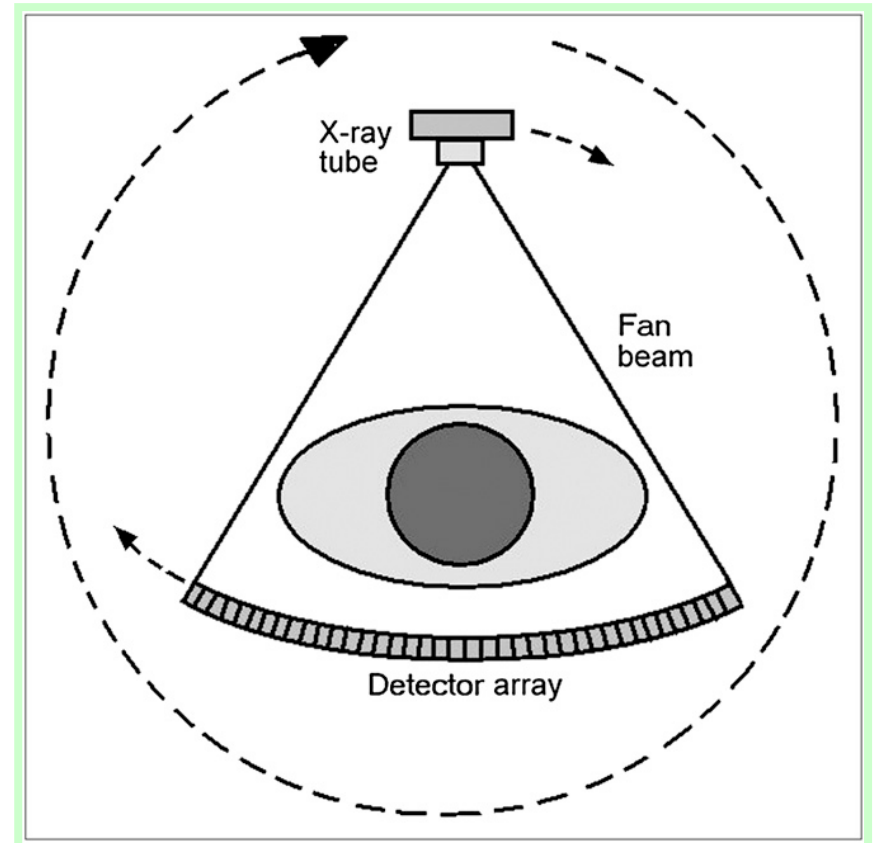
Bed

CT systems



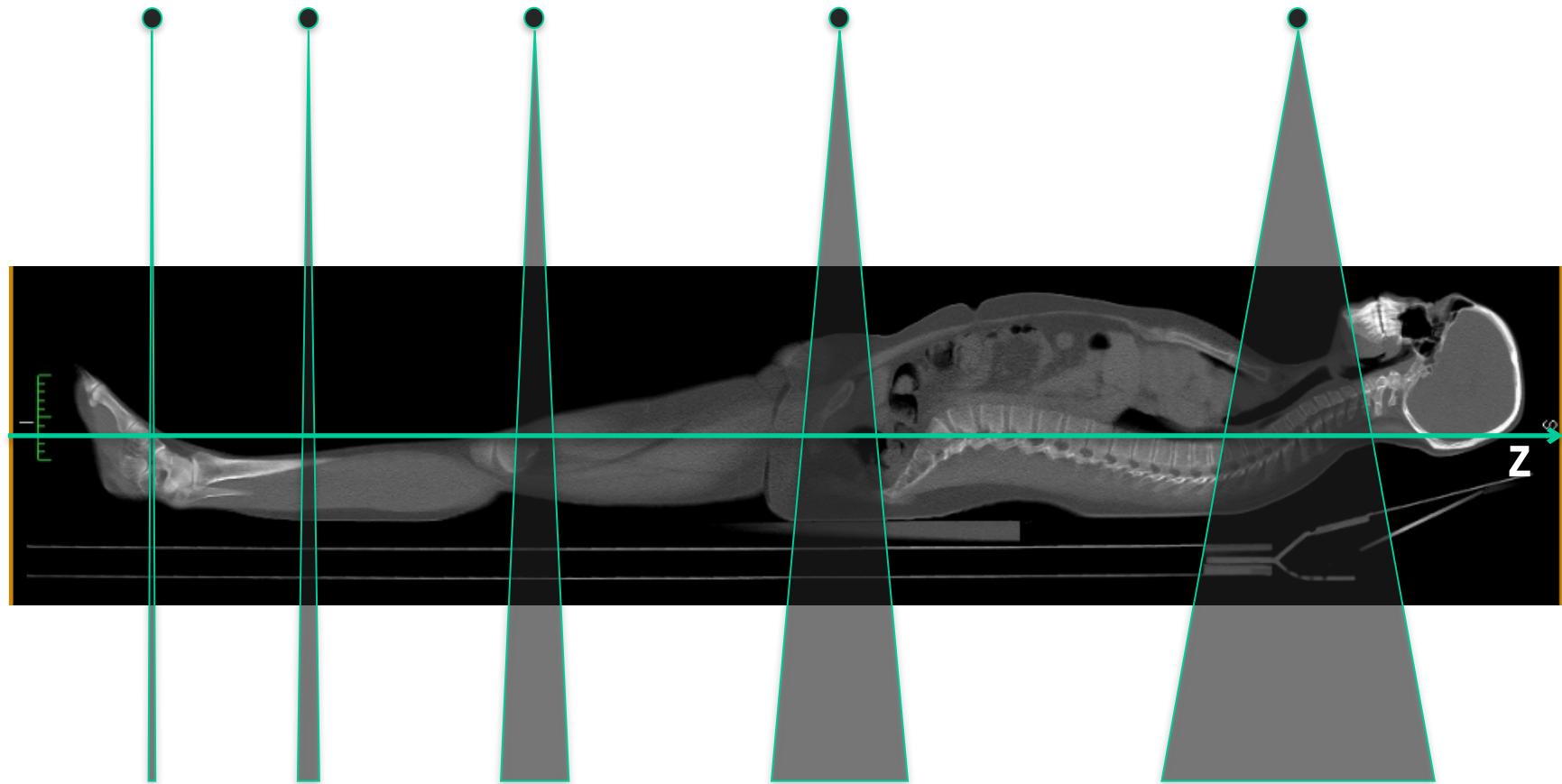
CT systems

- 3rd generation scanners:
 - 1 X-ray source
 - 1D detector
 - *Fan beam* geometry
 - Total scan time less than 5 second.



CT systems

- Recent scanners: 2D detectors (cone beam)



NxT	1x5mm	4x1mm	16x0.75mm	64x0.6mm	320x0.5mm
t_{rot}	0.75s	0.5s	0.42s	0.33s	0.27s
year	1995	1998	2001	2004	2008

CT systems

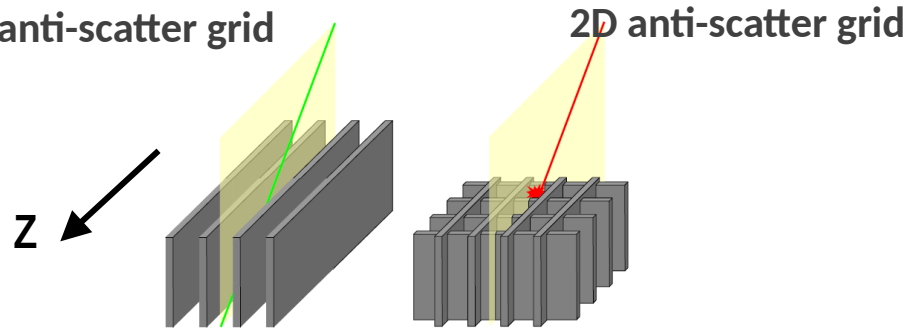
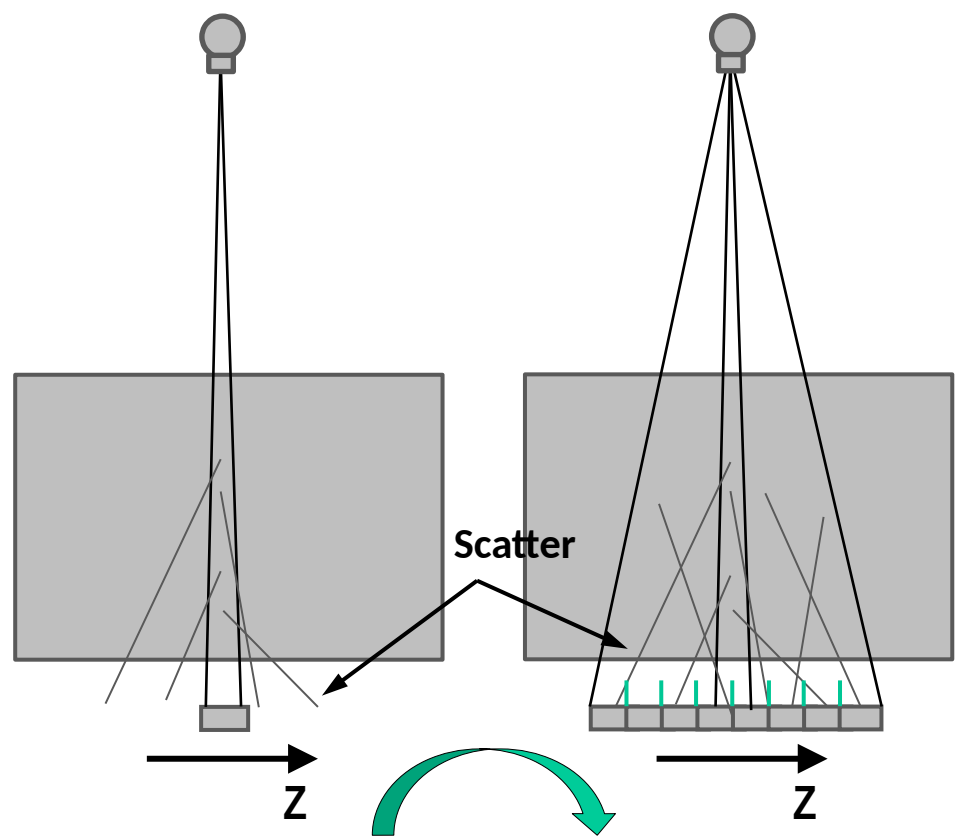
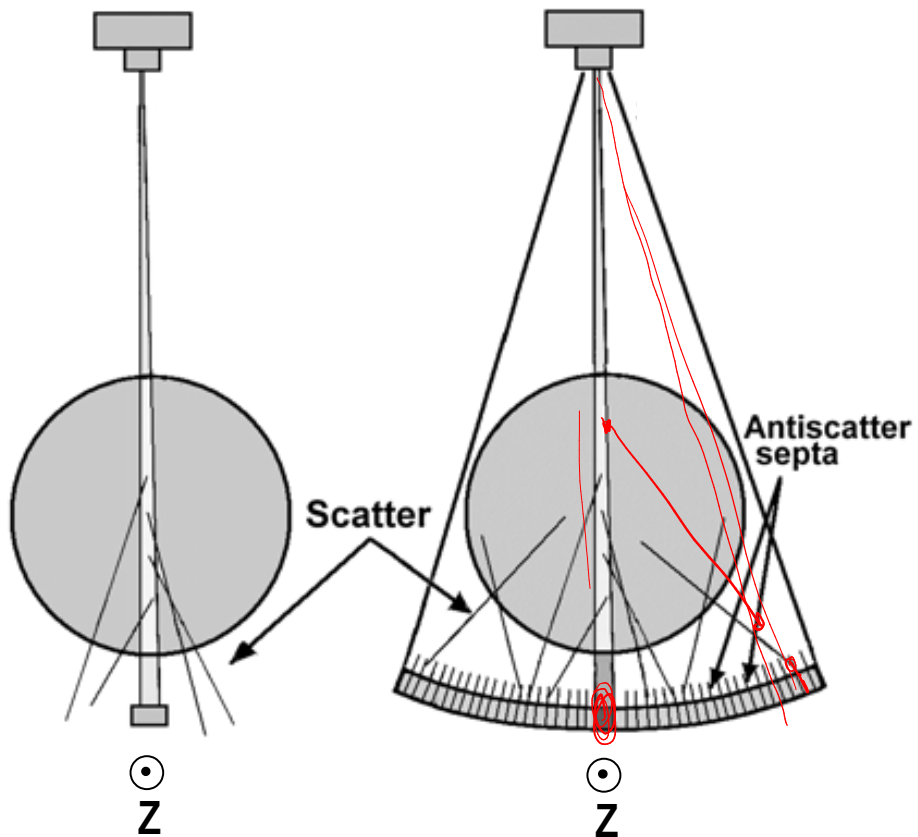
Anti-scatter

1st Generation

3rd Generation

Small Z coverage

Large Z coverage



CT systems

Spiral CT

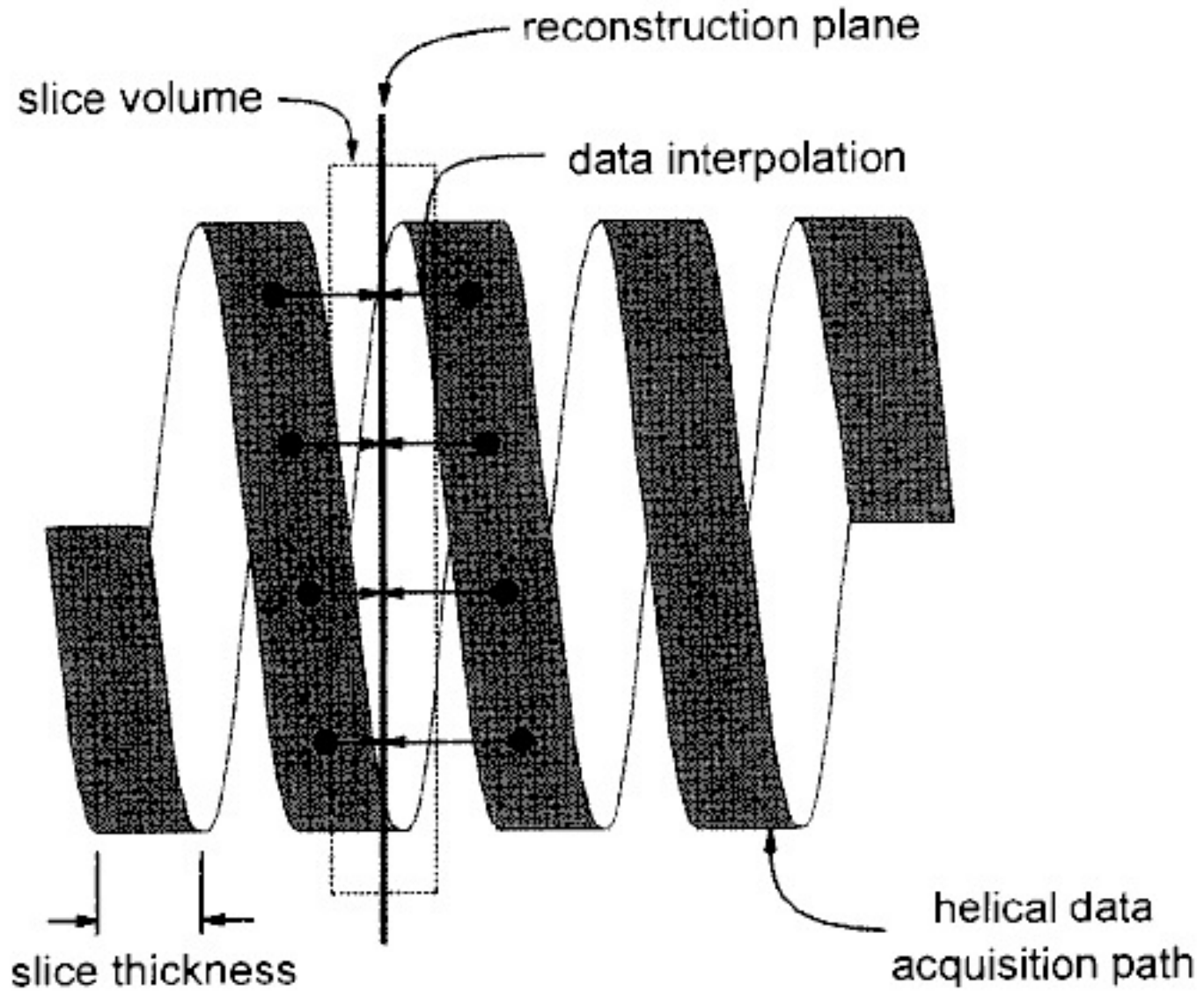
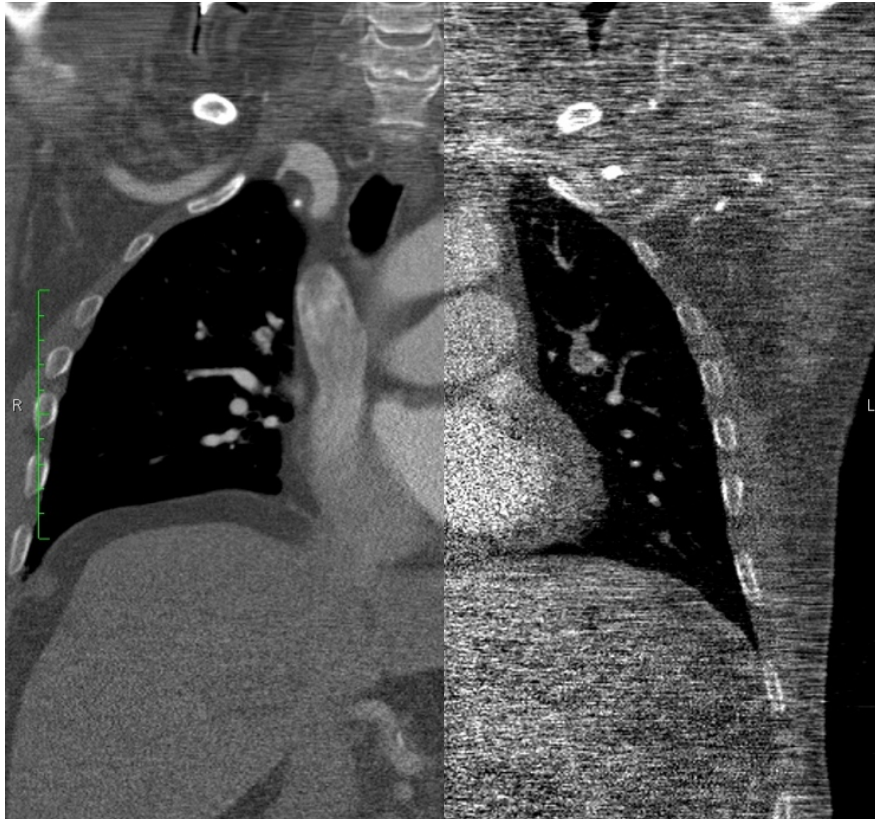


Image quality

Signal to noise

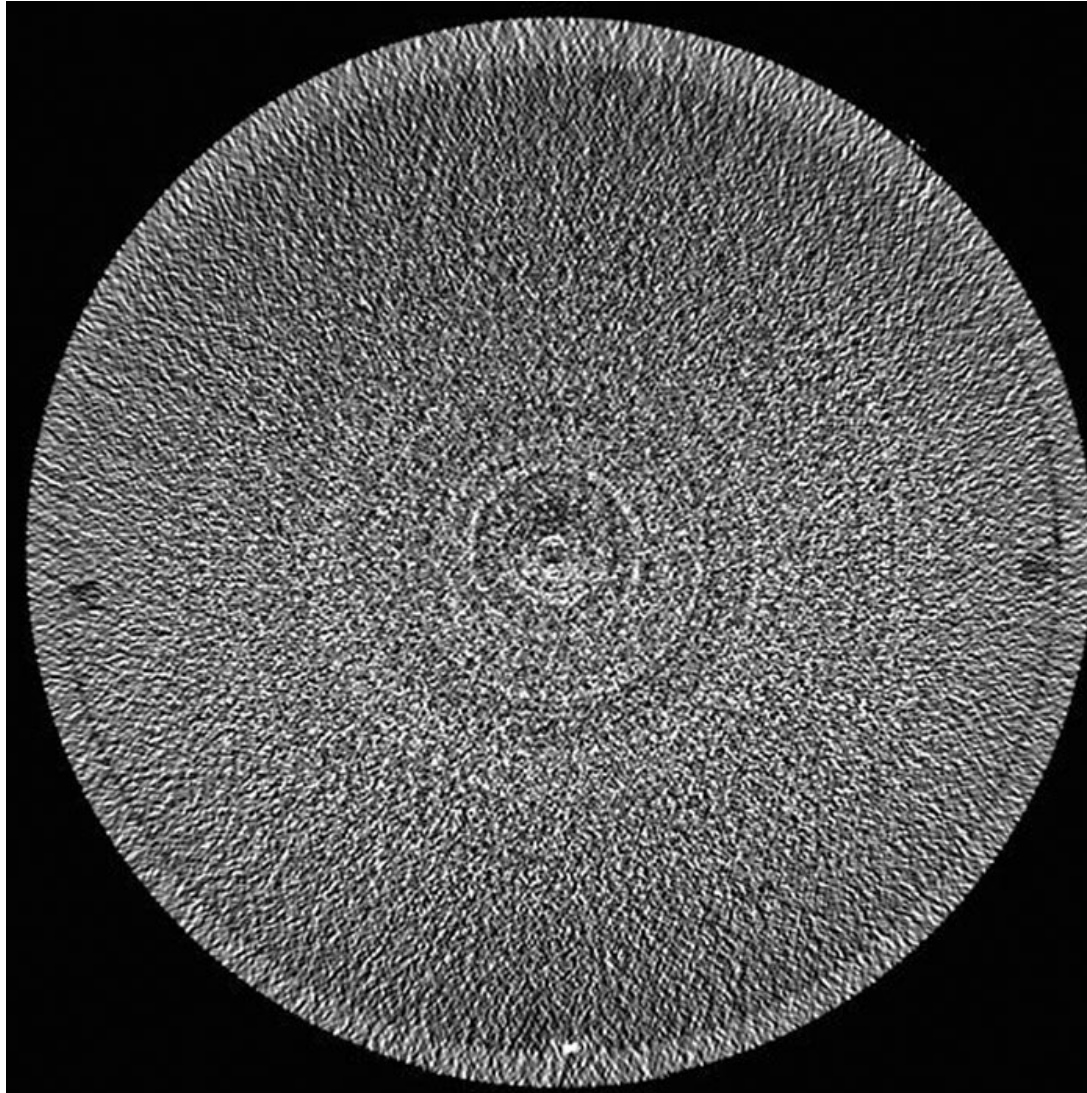


Artifacts



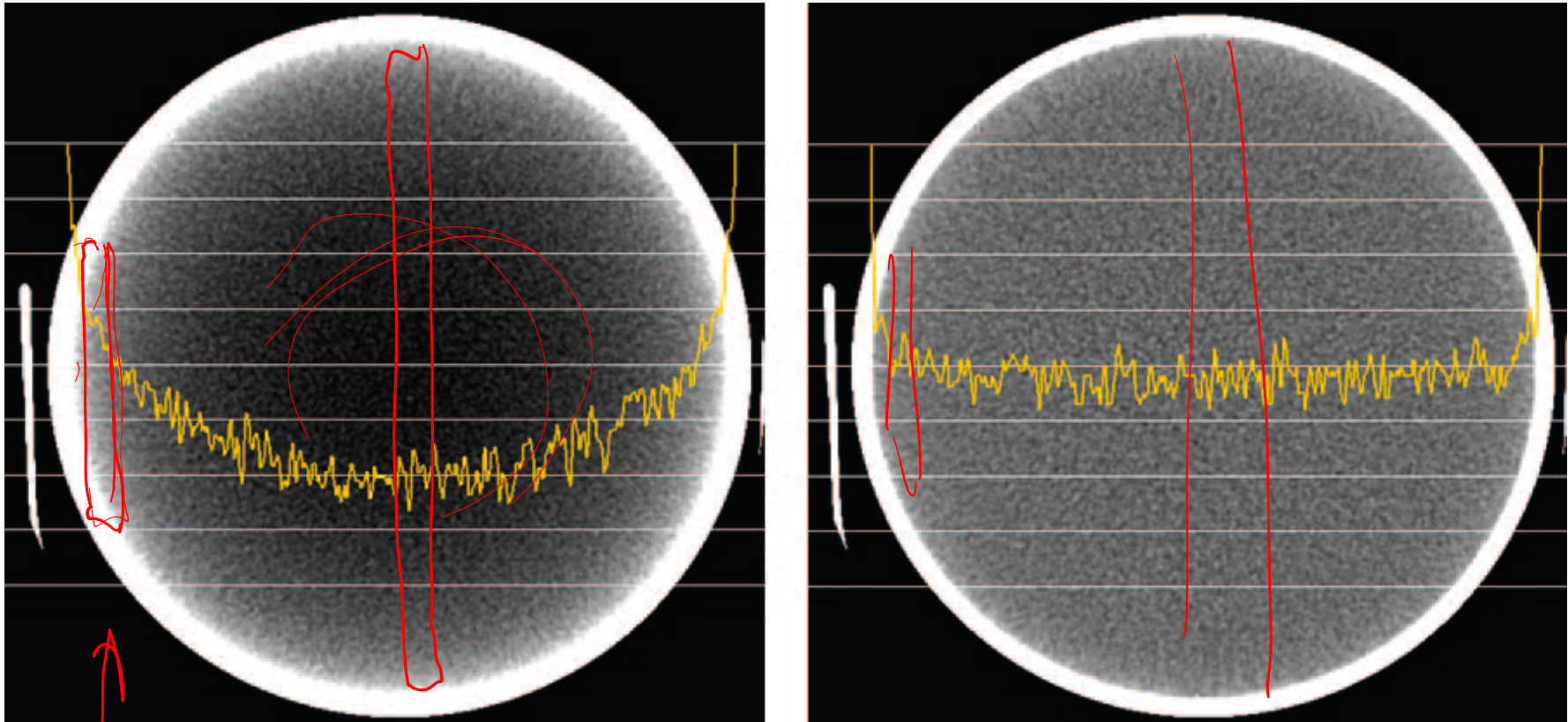
Artifacts

Ring artifacts: caused by damaged or miscalibrated detector pixels.



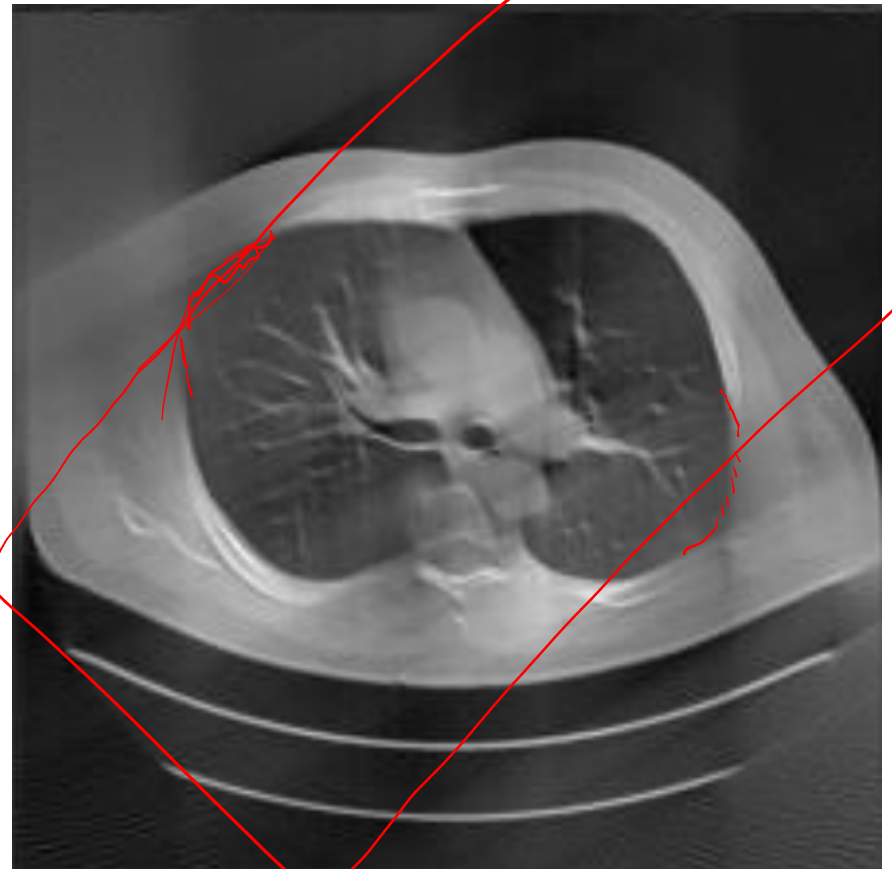
Artifacts

Beam hardening: deviation from the exponential law caused by the attenuation of a broad spectrum (thicker objects seem more transmissive than they should)



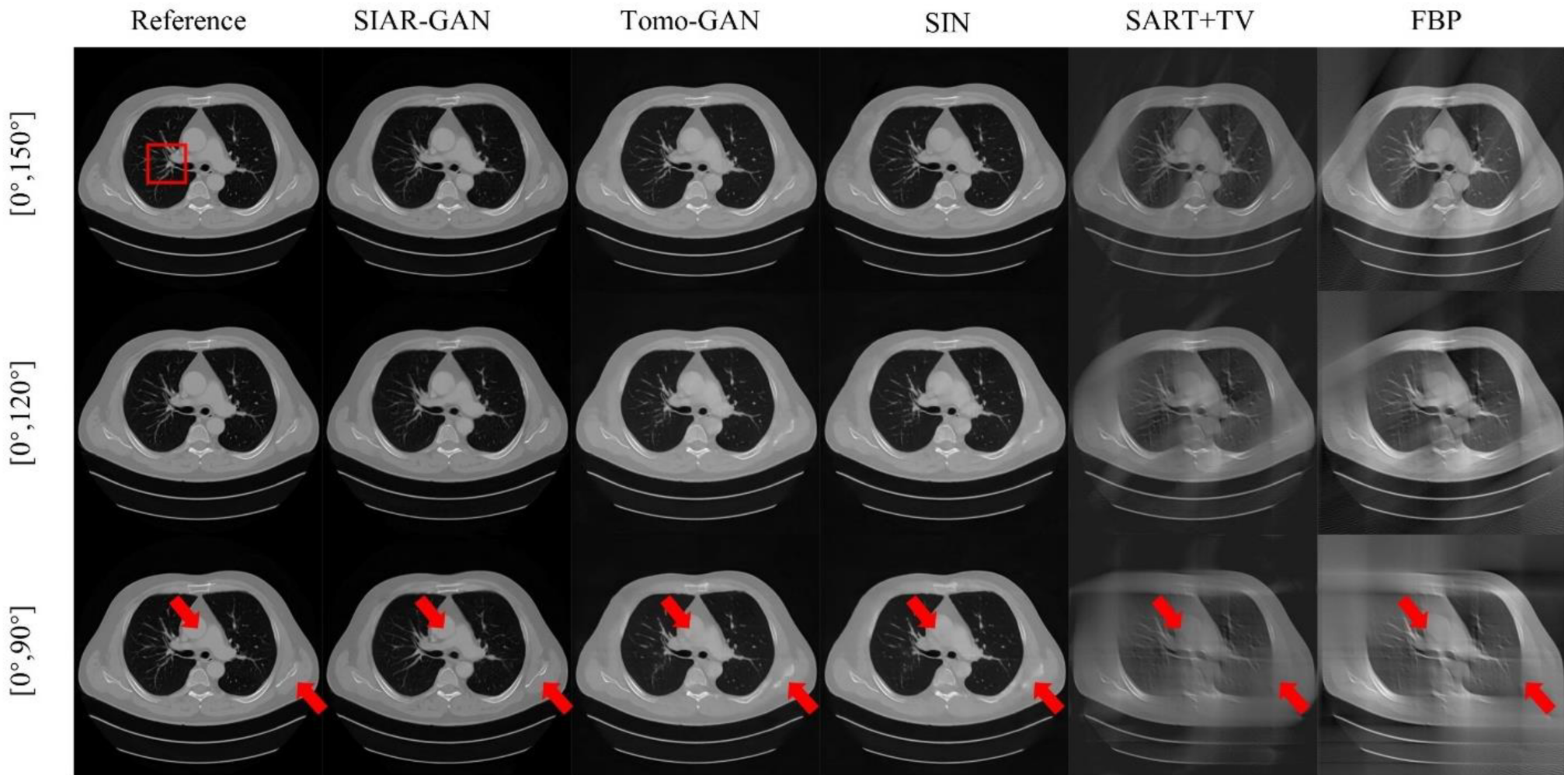
Artifacts

“Missing wedge”: caused by an incomplete sinogram
(also called limited angle tomography)



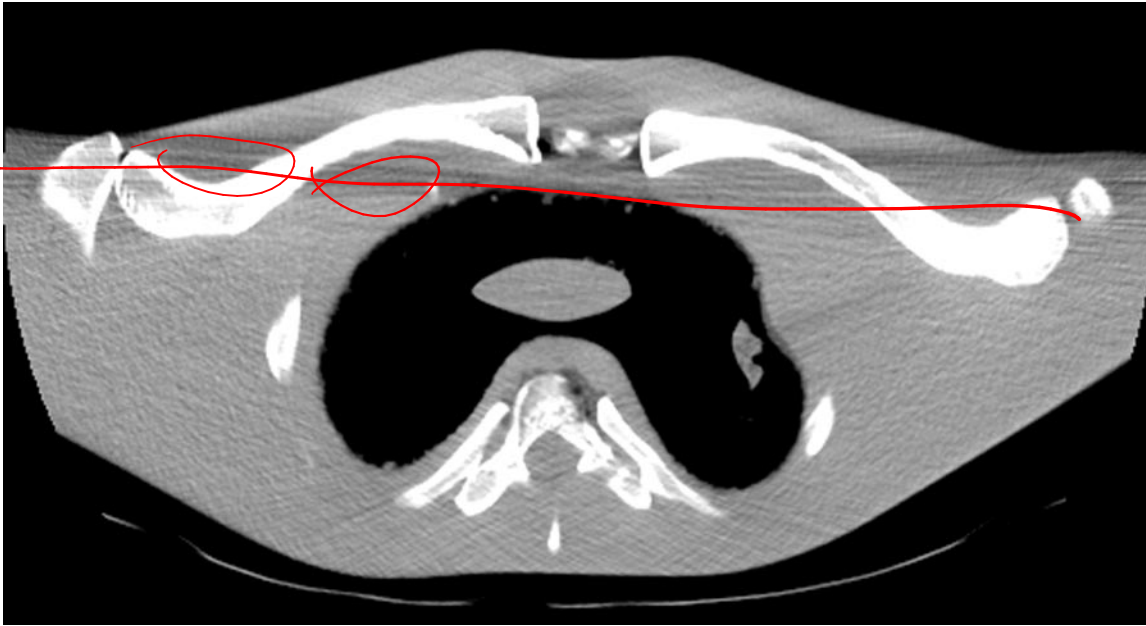
Artifacts

“Missing wedge”: promising results using machine learning



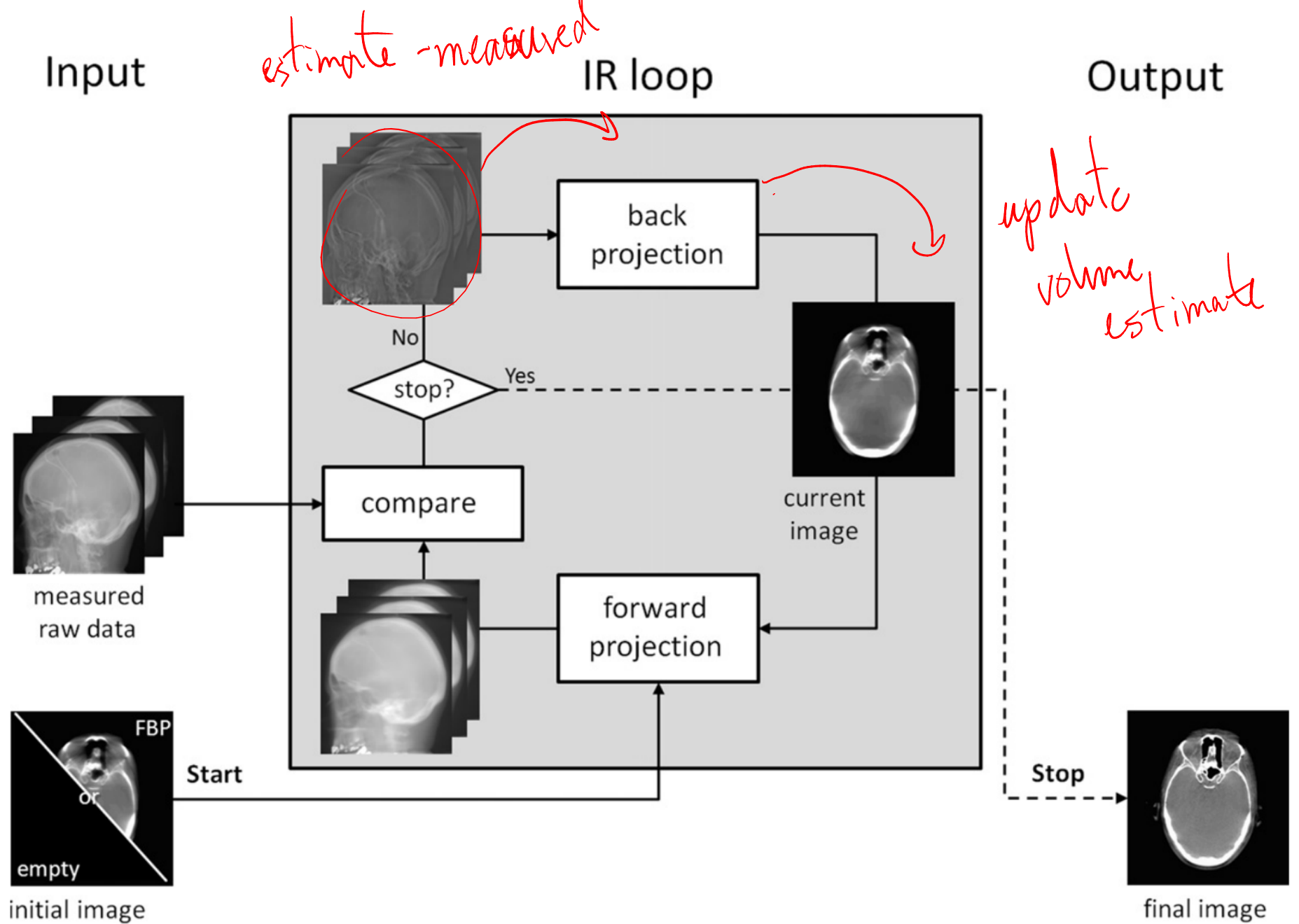
Artifacts

Photon starvation: strongly absorbing features discard useful signal for the reconstruction of nearby areas



metal implant

Iterative methods



Iterative methods

Abbreviation	Meaning	
ART	Algebraic reconstruction technique	Gordon et al. 1970
SART	Simultaneous ART	Anderson & Kak, 1984
SIRT	Simultaneous iterative reconstruction technique	Gilbert 1972
OS-SIRT	Ordered subset SIRT	Gordon et al. 1970
MART	Multiplicative algebraic reconstruction technique	
ML-EM	Maximum likelihood expectation-maximization	Lange & Carson 1984
OS-EM	Ordered subset expectation-maximization	Manglos et al 1995
OSC	Ordered subset convex algorithm	Kamphuis & Beekman 1998 Erdogan & Fessler 1999
ICD	Iterative coordinate descent	...
OS-ICD	Ordered subset ICD	
MBIR	Model-based iterative reconstruction	