BASICS of

COMPUTED TOMOGRAPHY IMAGING IN ONCOLOGY

FOR THE STUDENTS OF
HIGH INSTITUTE OF HEALTH APPLICATORY SCIENCES

By

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1ST EDITION

22025

LECTURE 2

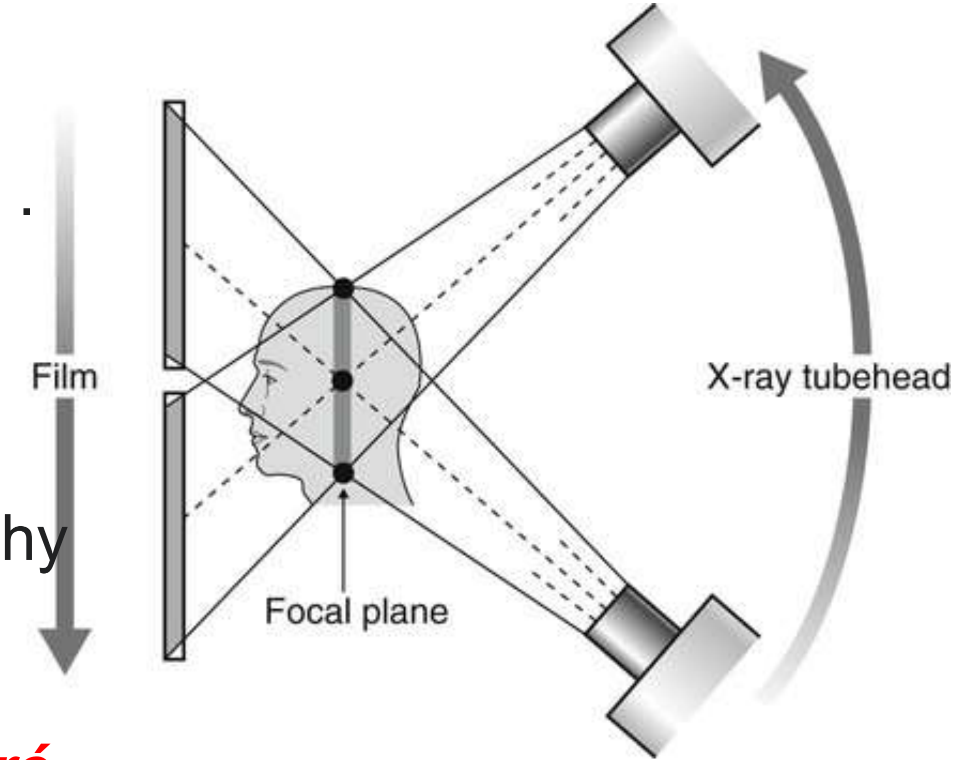
HISTORY OF CT

Year	Development
1924	Johann Radon formulated the mathematical theory of tomographic image reconstruction.
1930	A. Vallebona constructed equipment and published 1st clinical body section imaging material.
1963	A. McLeod Cormack developed the theoretical underpinnings of CT scanning.
1971	1st generation CT: commercial CT introduced by Sir Godfrey Hounsfield.
1972	EMI scanner was introduced as clinical system of cranial examination.
1974	2nd generation CT.
1975	3rd generation CT.
1976	4th generation CT.
1979	Cormack & Hounsfield shared the noble prize in physiology or medicine.
1980	5th generation cardiac CT.
1989	Single-row CT.
1991	Spiral CT was introduced.
1994	Double row spiral CT.
1998	Multidetector CT.
2004	16 row spiral CT.
2006	Dual source CT introduced.
2007	320 row spiral CT.

- -**1960S:** HISTORY OF CT SCAN BEGAN WITH **GODFREY HOUNSFIELD**
  - **1971**: THE FIRST PATIENT WAS SCANNED IN OCTOBER,
  - **BY 1972**, THE COMMERCIAL VERSION WAS RELEASED,
  - **1979**: HOUNSFIELD AND CORMACK EARNED THE NOBEL PRIZE

Focal Plane Tomography

- X-ray source and the detecting film moved simultaneously along specific trajectories → . Early attempts to overcome the superimposition of structures
- This approach became known as planography or focal plane tomography.
- Key contributors: the French physician ***André Bocage***, Italian radiologist ***Alessandro Vallebona***, and Dutch radiologist ***Bernard George***



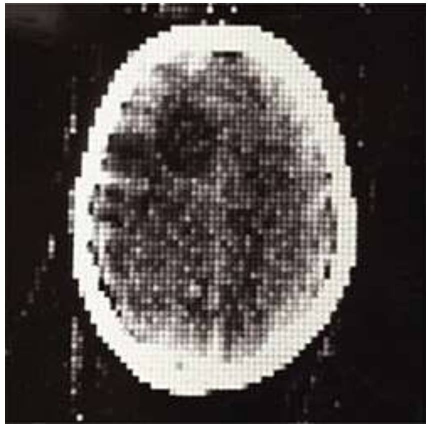
- **In 1961**, neurologist William Oldendorf → approach to imaging structures inside the skull.
- He developed an experimental trial → record variations in radiodensity within a **test sample** (containing aluminum and iron nails) arranged around the center, mimicking the structure of a skull.
- Throughout the mid-20th century, continued to evolve, → **sharper images** and allowing for **greater control** over the thickness of the examined cross-section.
- This progress was driven by the development of **more complex, multidirectional devices** capable of moving in multiple planes and achieving more effective blurring of out-of-focus structures.
- However, despite these advancements in focal plane tomography, its ability to image soft tissue remained highly limited due to poor contrast.

Godfrey Hounsfield

The British electrical engineer Godfrey N. Hounsfield

- **1967**, The british electrical engineer **Godfrey N. Hounsfield**,, work on his own project and proposed tackling the tomographic problem, drawing inspiration from his earlier radar research.
- Instead of detecting patterns in the periphery using radar, he wondered whether it would be possible to detect objects **inside a structure** by sending beams through it from different angles.

- **On October 1, 1971**, the first patient—a woman with a suspected brain tumor—was successfully examined.



The first clinical CT scan, in October 1971 at **Atkinson Morley's Hospital in London** with Hounsfield's scanner

- Hounsfield described the method, scanner design, and operation in his landmark **1973 paper**.

Hounsfield, G. N. (December 1973). "Computerized transverse axial scanning (tomography). 1. Description of system". *The British Journal of Radiology*. **46** (552): 1016–1022. doi:10.1259/0007-1285-46-552-1016. ISSN 0007-1285. PMID 4757352.

FIG. 5.
Illustration of the patient in position.

FIG. 6.
X-ray control console.

- **After 1972**, several companies around the world began developing their own CT systems.
- **In 1977**, at least 17 companies were already active on the global market, offering commercial CT scanners.
- Progress was driven by innovations in various fields, including :

• X-ray tube optimization,
• detector development,
• faster data processing, and
• advanced reconstruction algorithms.

These technological advancements defined the different "**generations**" of CT scanners, ranging from the **first** to the **fifth** generation.

- **Fan-beam CT devices**—known as third-generation scanners—have proven to be the most practical.

1973, *British Journal of Radiology*, *46*, 1016–1022

Computerized transverse axial scanning (tomography): Part I. Description of system

G. N. Hounsfield

Central Research Laboratories of EMI Limited, Hayes, Middlesex

(*Received February, 1973 and in revised form July, 1973*)

ABSTRACT

This article describes a technique in which X-ray transmission readings are taken through the head at a multitude of angles: from these data, absorption values of the material contained within the head are calculated on a computer and presented as a series of pictures of slices of the cranium. The system is approximately 100 times more sensitive than conventional X-ray systems to such an extent that variations in soft tissues of nearly similar density can be displayed.

For many years past, X-ray techniques have been developed along the same lines, namely the recording on photographic film of the shadow of the object to be viewed. Recently, it has been realized that this is not the most efficient method of utilizing all the information that can be obtained from the X-ray beam. Oldendorf (1961) carried out experiments based on principles similar to those described here, but it was not then fully realized that very high efficiencies could be achieved and so, picture reconstruction techniques were not fully developed.

As the exposure of the patient to X rays must be restricted, there is an upper limit to the number of

Radiology (Ambrose and Hounsfield, 1973). A short account has also appeared in the *New Scientist* (*Technology Review*), 1972.

PRINCIPLES OF THE METHOD

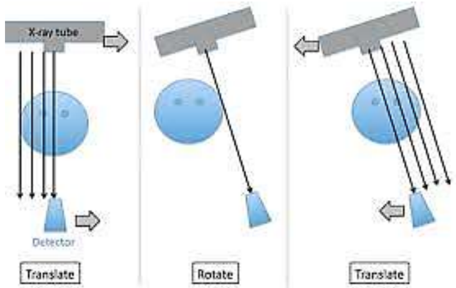
The aim of the system is to produce a series of images by a tomographic method as illustrated in Fig. 1. Each image shown at the bottom of the figure is derived from a particular slice.

In the actual equipment, the patient is scanned by a narrow beam of X rays. The X-ray tube, detectors, and collimators are fixed to a common frame, as shown in Fig. 2, those rays which pass through the head being detected by two collimated sensing devices (scintillation detectors) which always point towards the X-ray source. Both X-ray source and detectors scan across the patient's head linearly taking 160 readings of transmissions through the head as shown in scan 1 on the scanning sequence diagram (Fig. 3). At the end of the scan the scanning

Hounsfield, G. N. (December 1973). "Computerized transverse axial scanning (tomography). 1. Description of system". *The British Journal of Radiology*. **46** (552): 1016–1022. doi:10.1259/0007-1285-46-552-1016. ISSN 0007-1285. PMID 4757352.

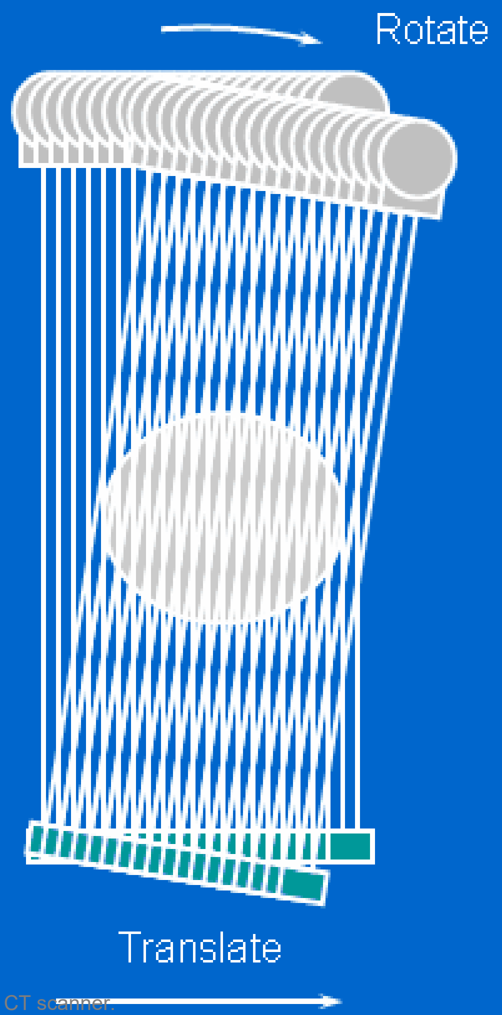
First generation scanners

- First-generation CT scanners—such as Hounsfield's *EMI Mark I* design
- The X-ray tube, typically operated at 120 kVp and 32 mA,
- emitted a **narrow pencil beam** aimed at a two-element detector (acquiring two 13 mm slices simultaneously),
- Detector consisted of sodium iodide (NaI) scintillators coupled to photomultiplier tubes.
- Both the **tube** and the **detector** moved linearly across the patient at a fixed gantry angle.
- After each traverse, during which 160 data points (two rows of 80 measurements at 1.5 mm intervals) were collected,
- the system rotated by 1° around the center of the bore and repeated the process,
- ultimately acquiring **180 projections** within **five minutes**.
- The detector required gain and offset calibration at the beginning of each linear pass.

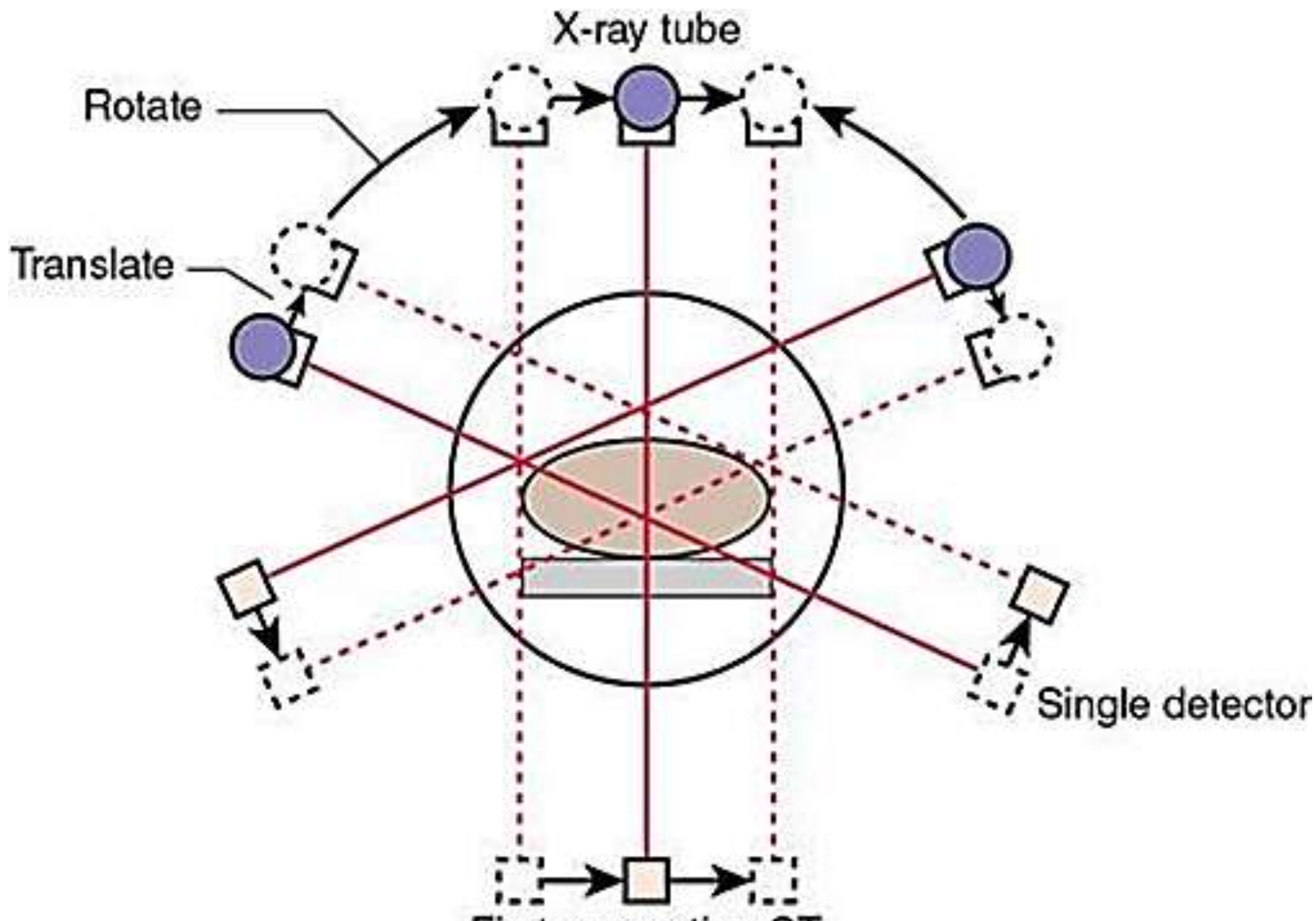


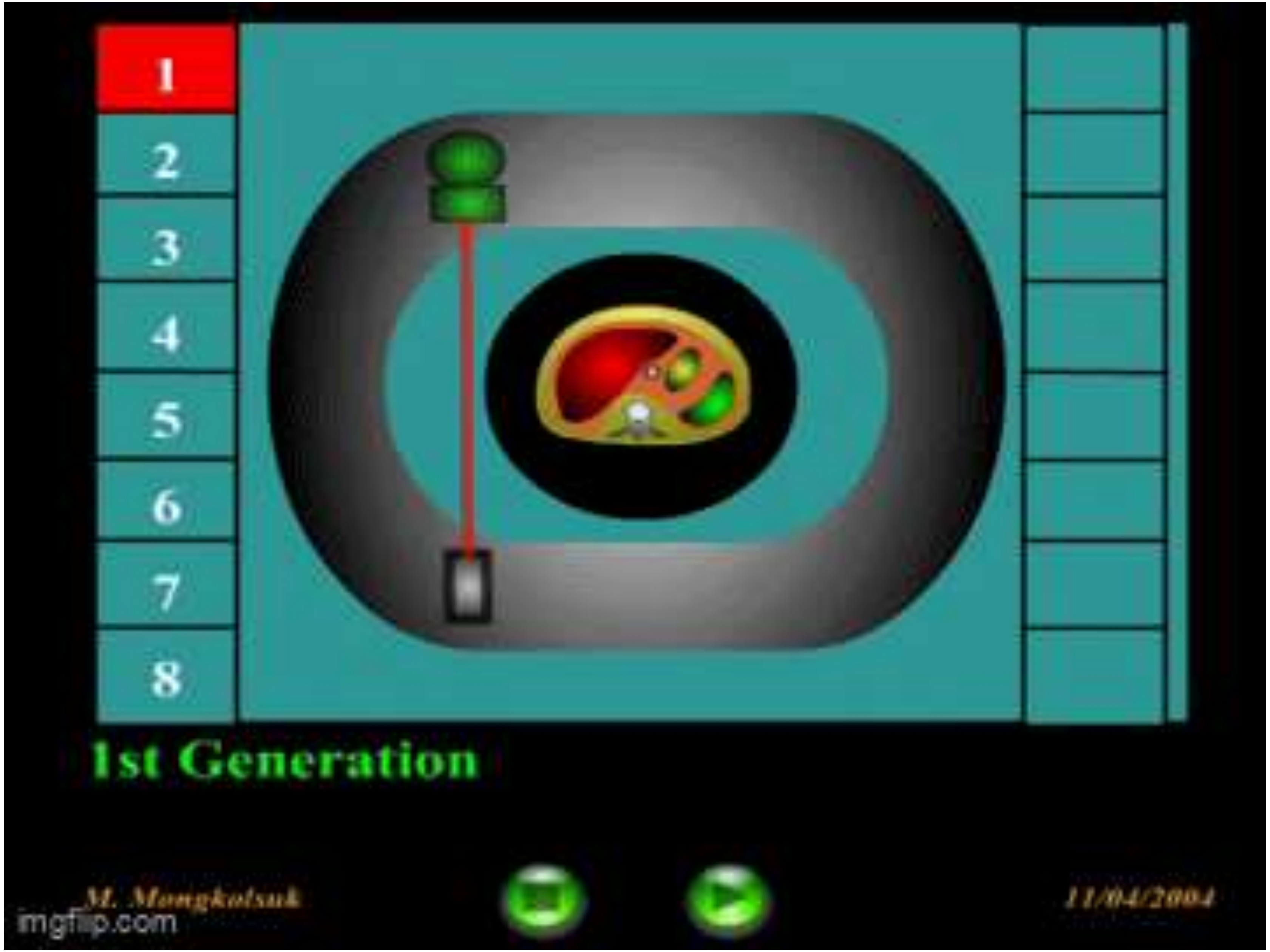
First generation CT scanner

- Single detector
- Translate - rotate acquisition
  - Translates across patient
  - Rotates around patient
- Very slow
  - minutes per slice



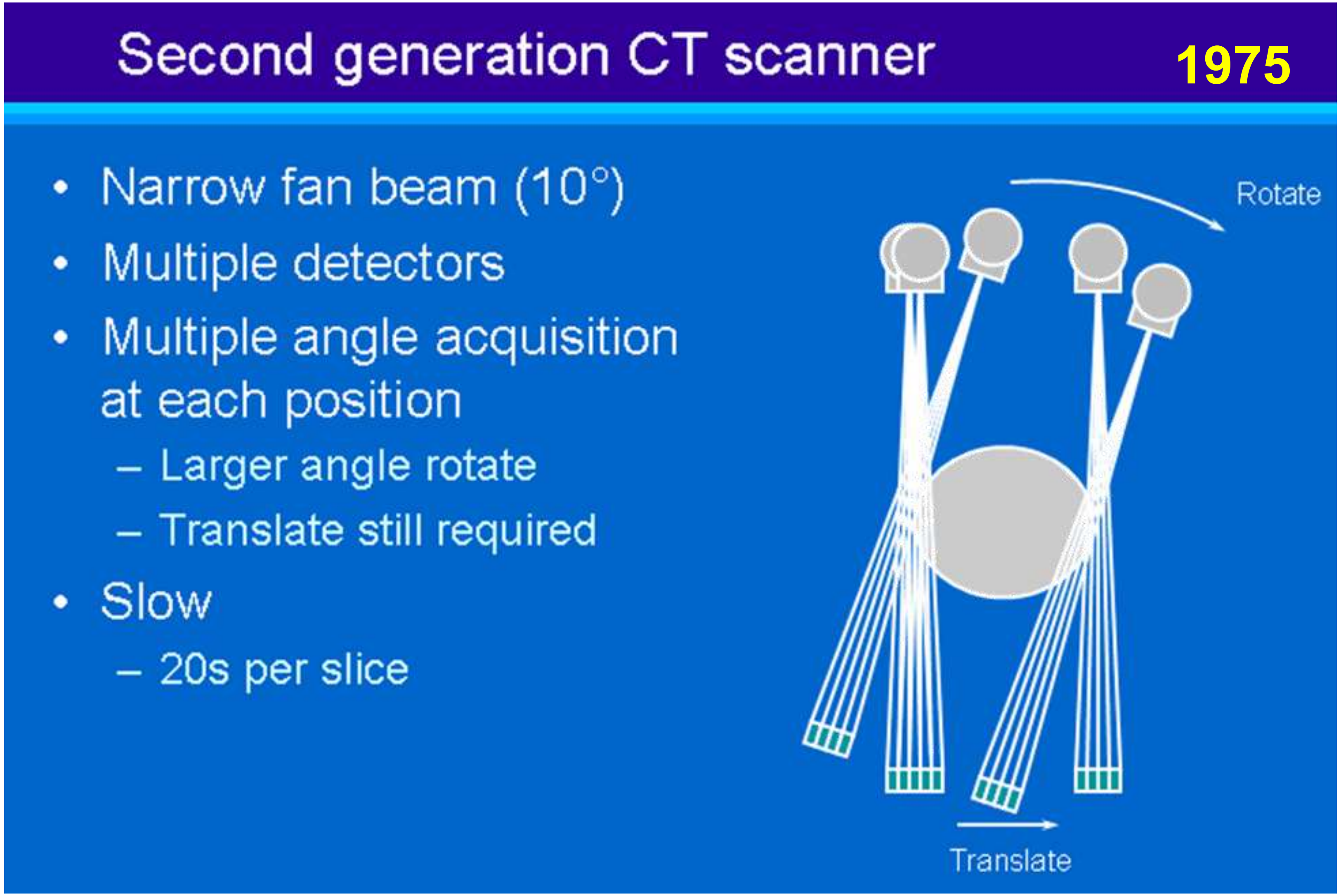
Outline of a first-generation CT scanner.


X-ray tube
Rotate
Translate
Single detector
First generation CT


1
2
3
4
5
6
7
8
1st Generation
M. Mongkolsuk
imgflip.com
11/04/2004

First-generation EMI CT unit: dedicated head scanner.

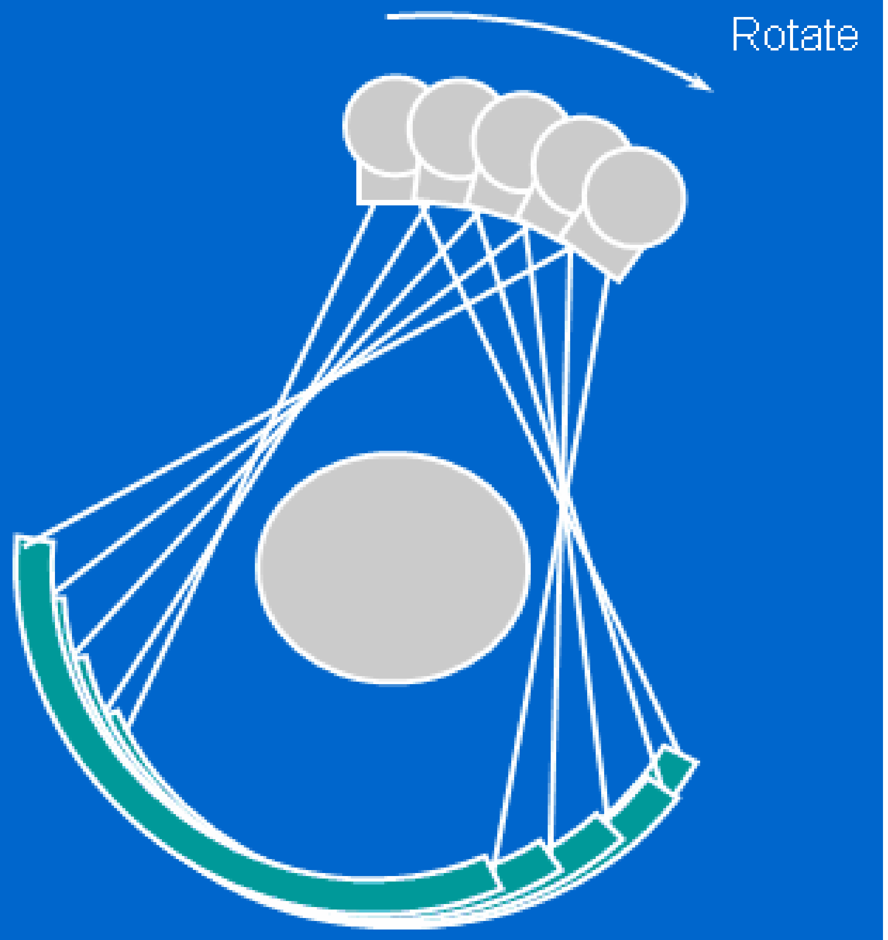
(Photograph taken at Reöntgen Museum, Lennep, Germany.)



- **introduced in 1975 , with** Faster scan speeds, ← the **narrow pencil X-ray beam** was expanded into a **fan-shaped beam** & paired with multiple detectors—often more than ten.

Third generation CT scanner

- Fan beam
- Multiple (500 - 1000) rotating detectors
- Rotation only
  - no translation required
- Much faster
  - as fast as 0.5 s per rotation
- Most common modern scanner design

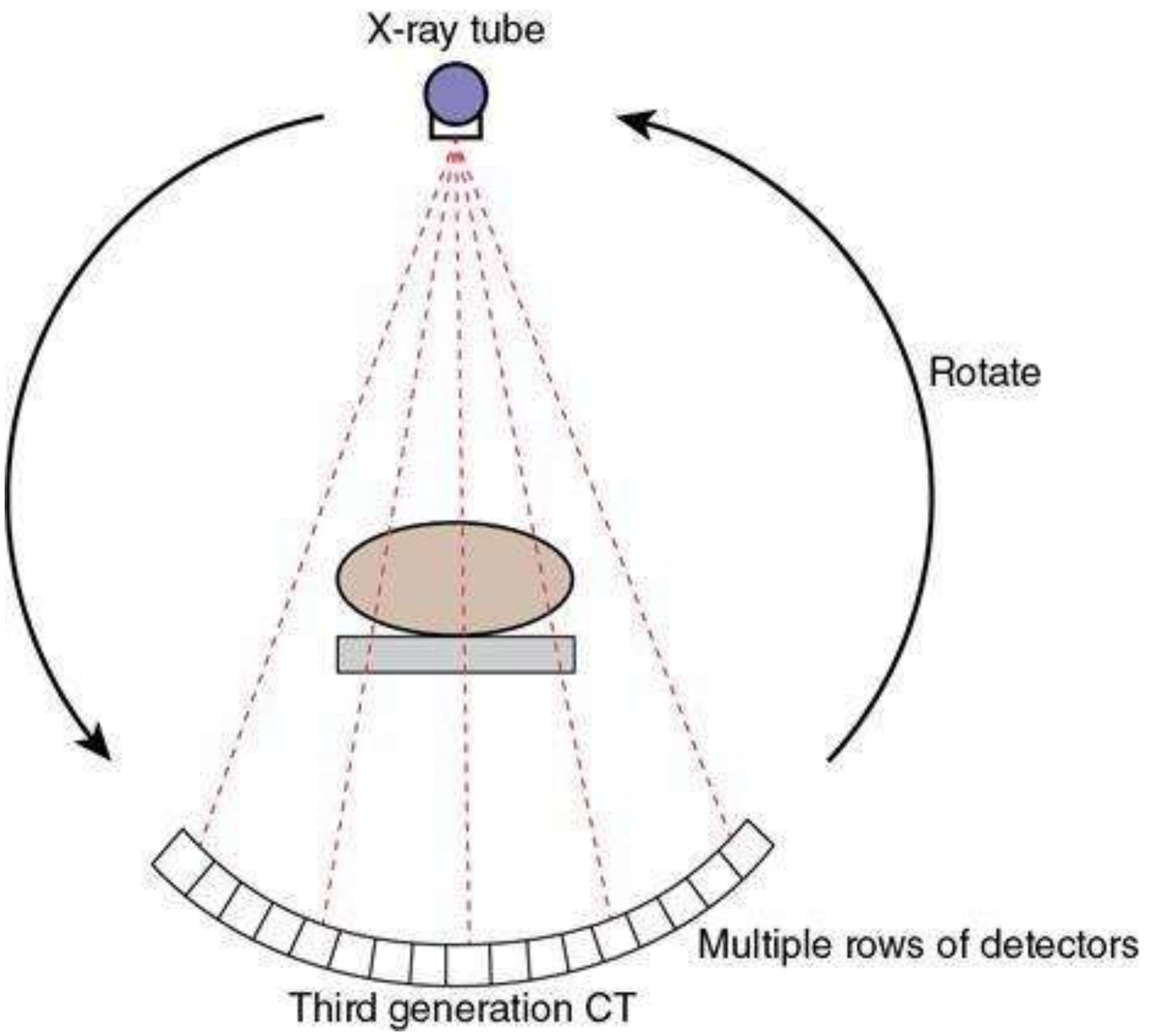


Number of detectors and projections

Typically, for 3rd generation scanners:

650 - 900 detectors (per row)

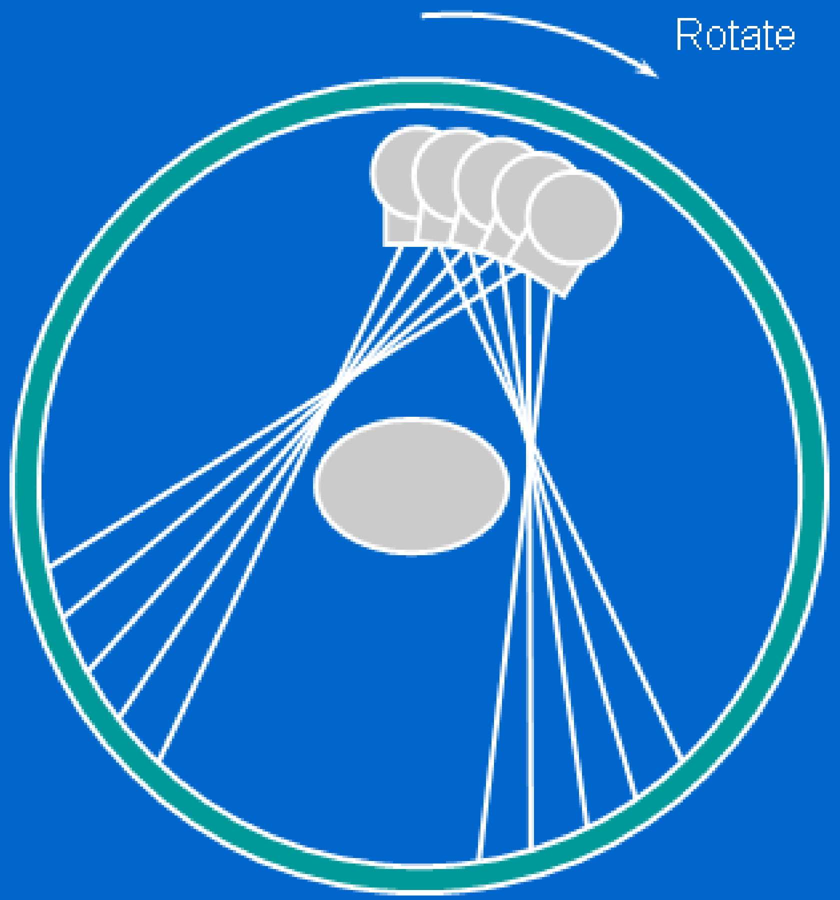
1000 - 2000 projections per rotation

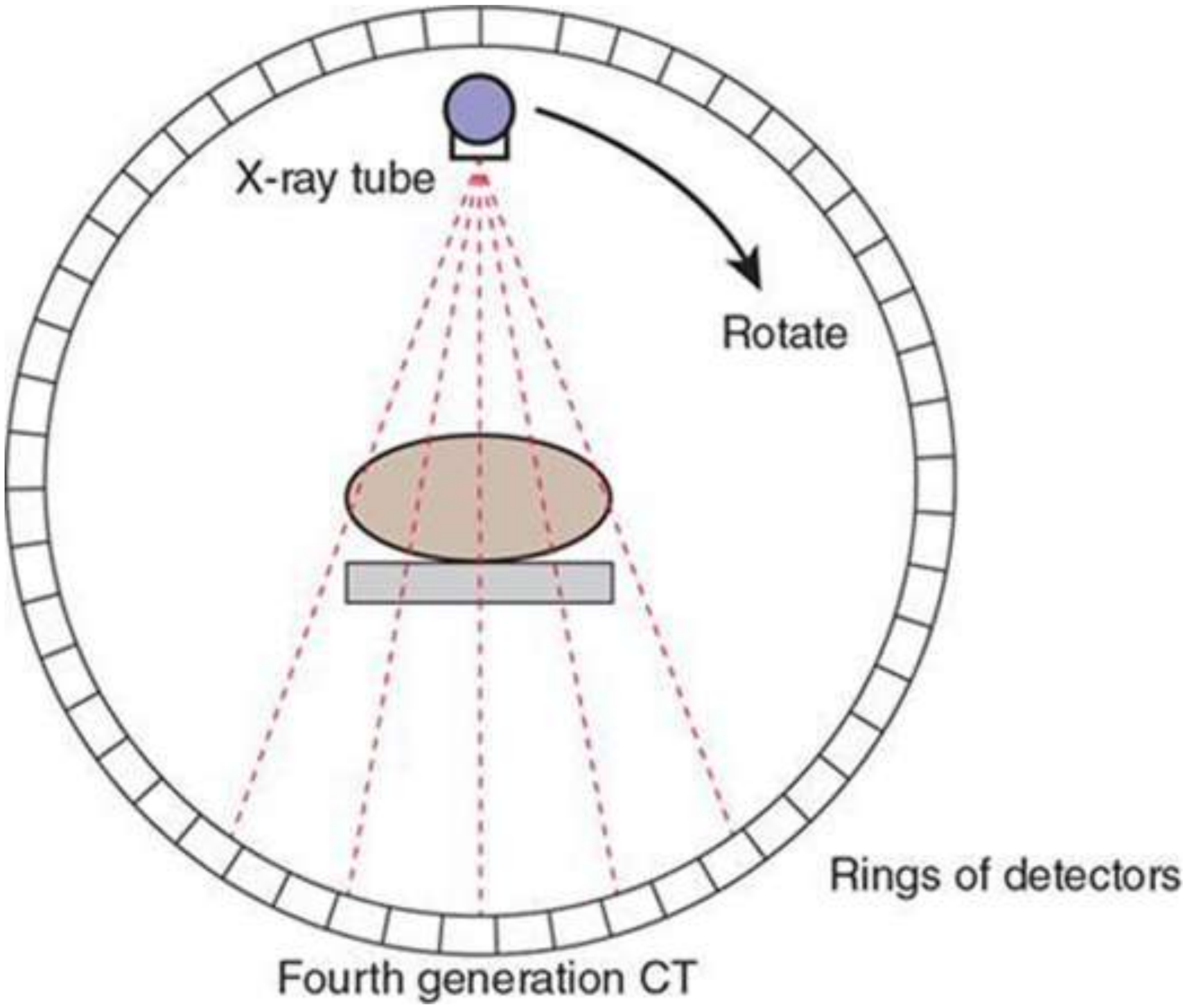

X-ray tube
Rotate
Multiple rows of detectors
Third generation CT

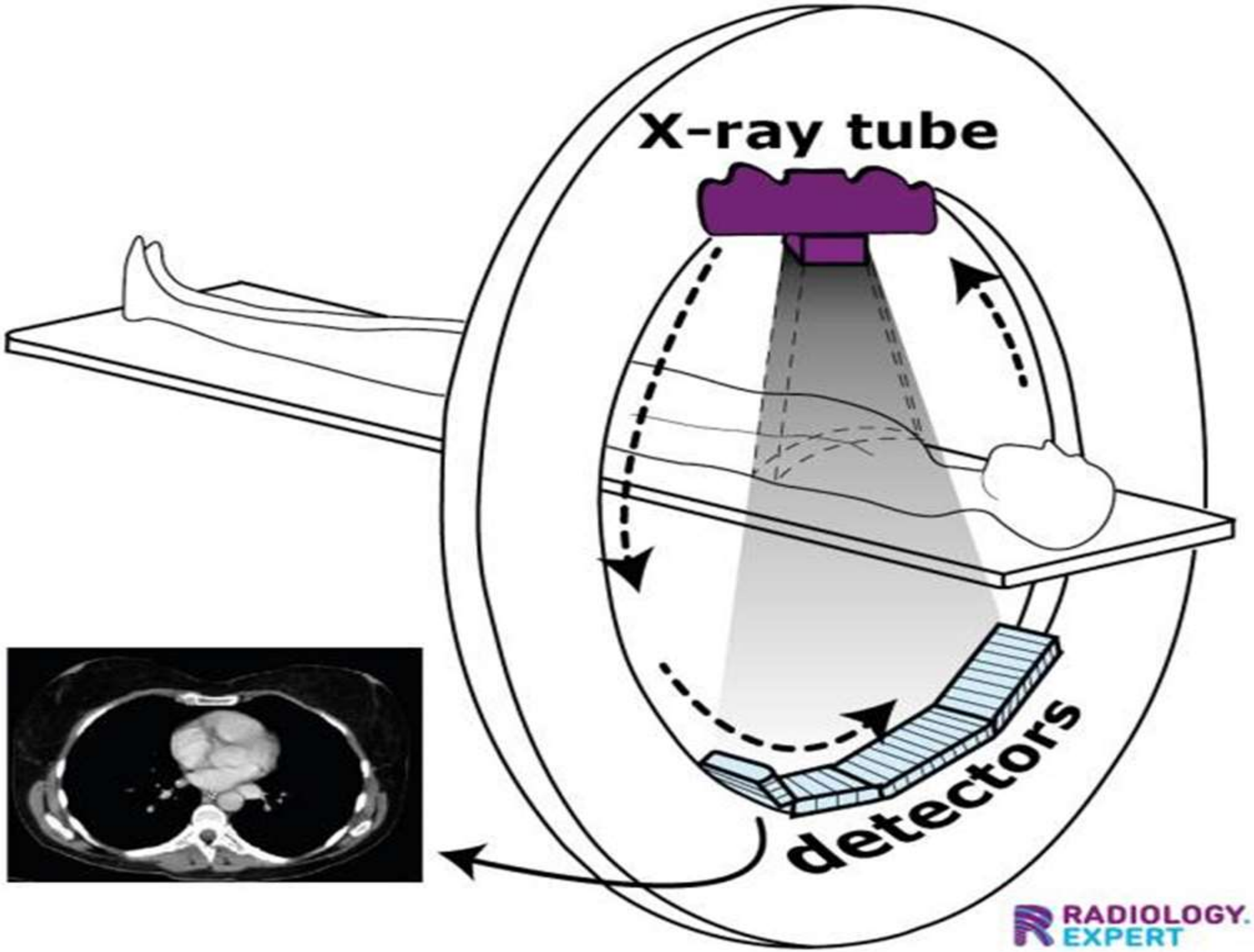
4th generation scanners

Fourth generation CT scanners

- Fan beam
- Static detectors all round gantry
- Only tube rotates
- Avoids ring artefact problems of 3rd generation scanners




X-ray tube
Rotate
Rings of detectors
Fourth generation CT

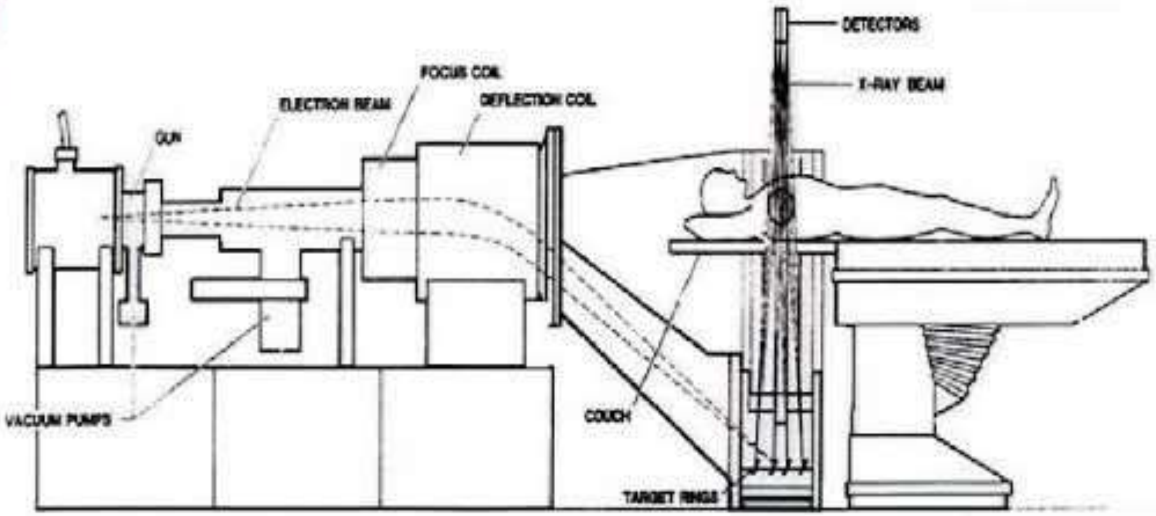

X-ray tube
detectors
RADIOLOGY.
EXPERT

2025

5th generation CT scanners 1981

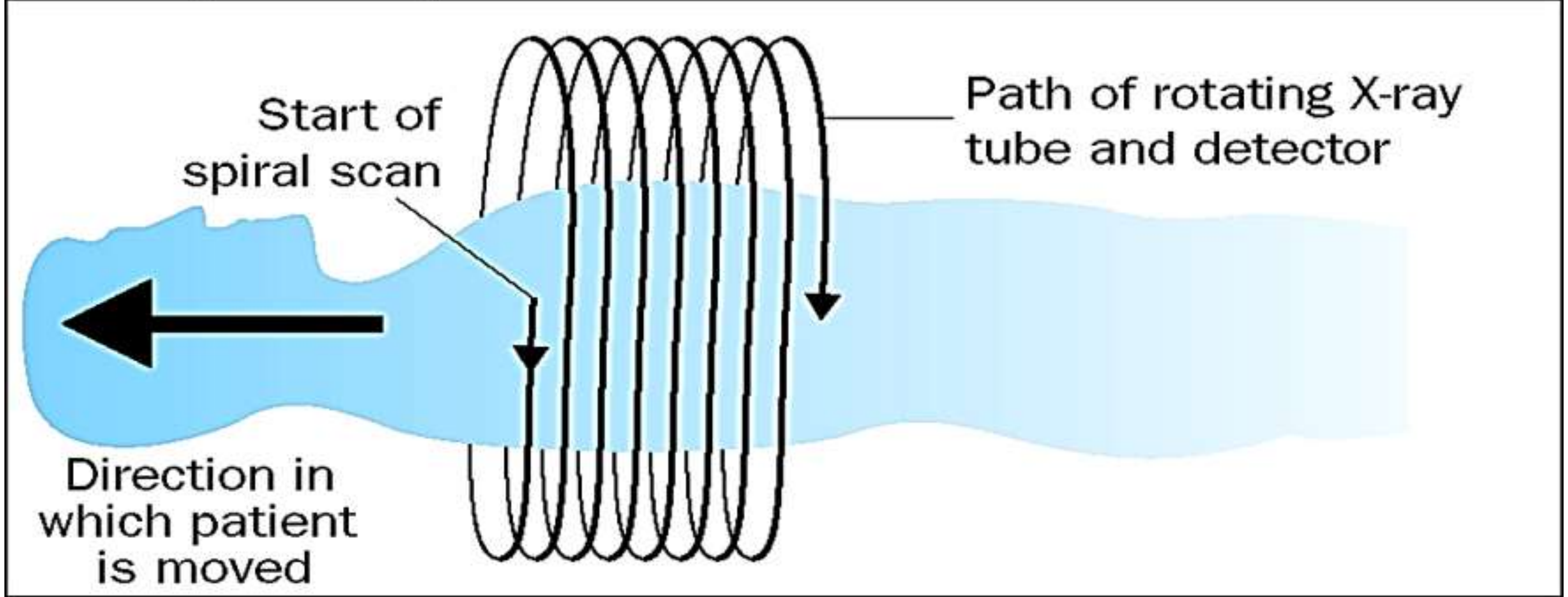
5th generation: Electron Beam CT (EBCT)

- x-ray source is not x-ray tube but a focused, steered, microwave-accelerated EB incident on a tungsten target.
- It has no moving parts .
- Target covers one-half of the imaging circle; detector array covers the other half.
- Images in
- less than
- 50ms.

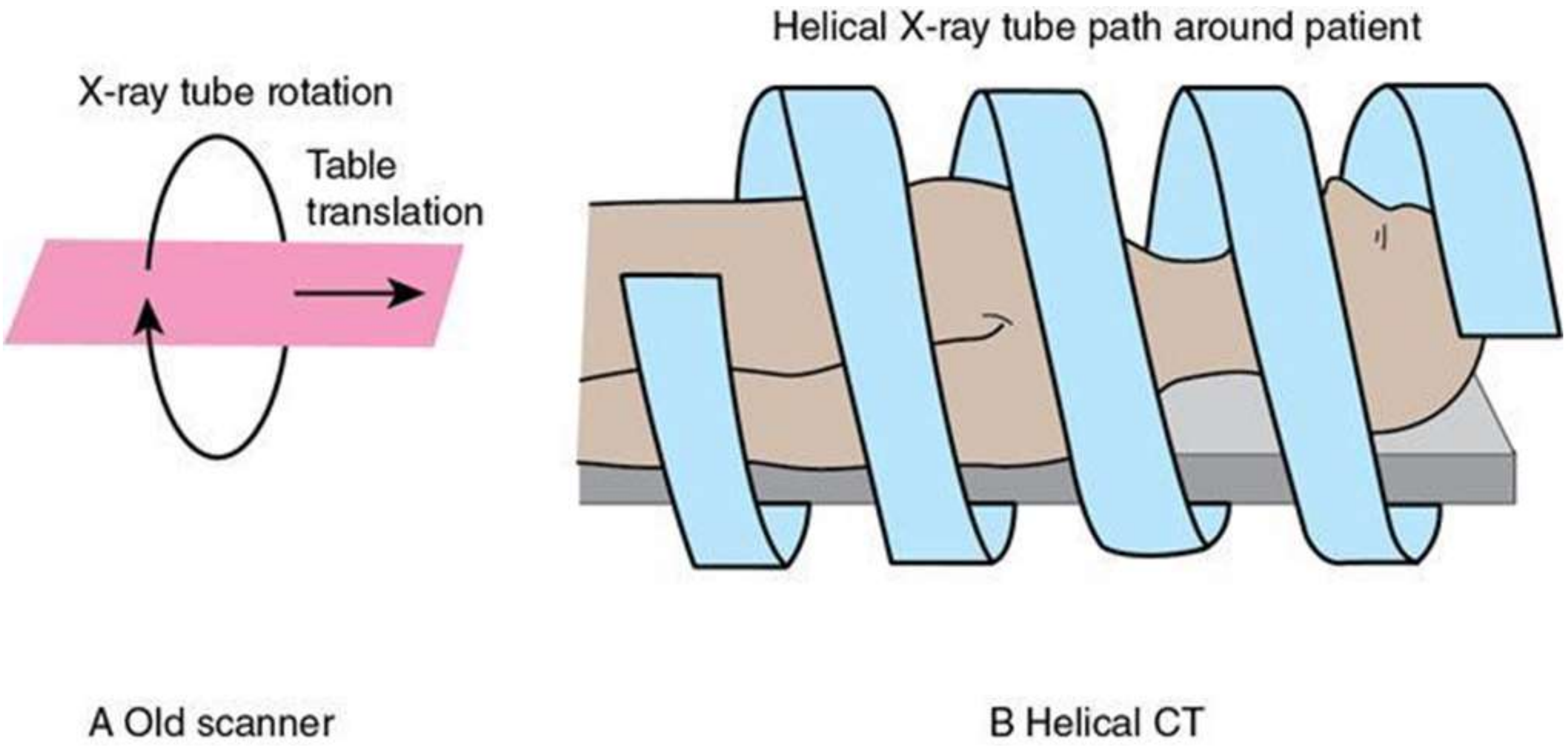


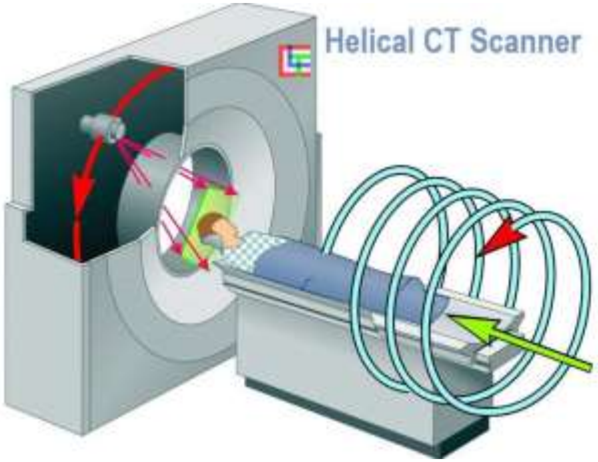
Helical / Spiral CT 1990

Principles of spiral CT



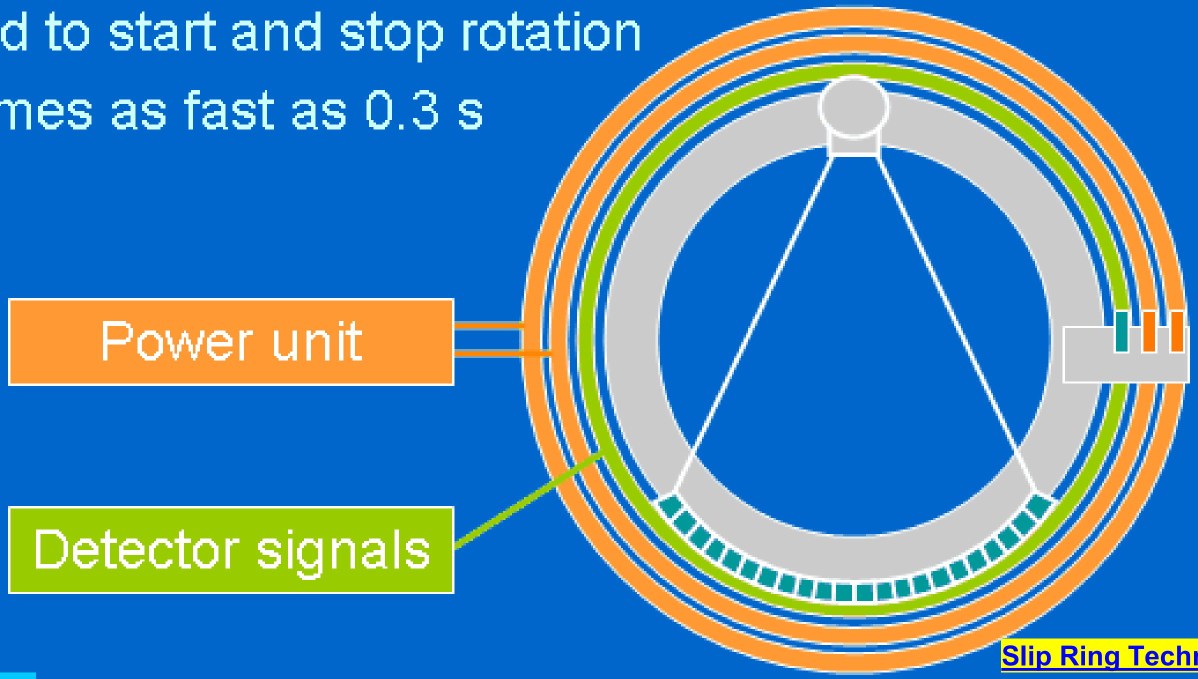
The patient is moved slowly through the gantry during continuous rotation of the X-ray tube. The pitch is the longitudinal distance the patient travels per tube rotation divided by the chosen thickness. For a table movement of 10 mm/s, a tube rotation of 1/s, and a slice thickness of 10 mm, the pitch is 1·0.


Helical X-ray tube path around patient
X-ray tube rotation
Table
translation
A Old scanner
B Helical CT

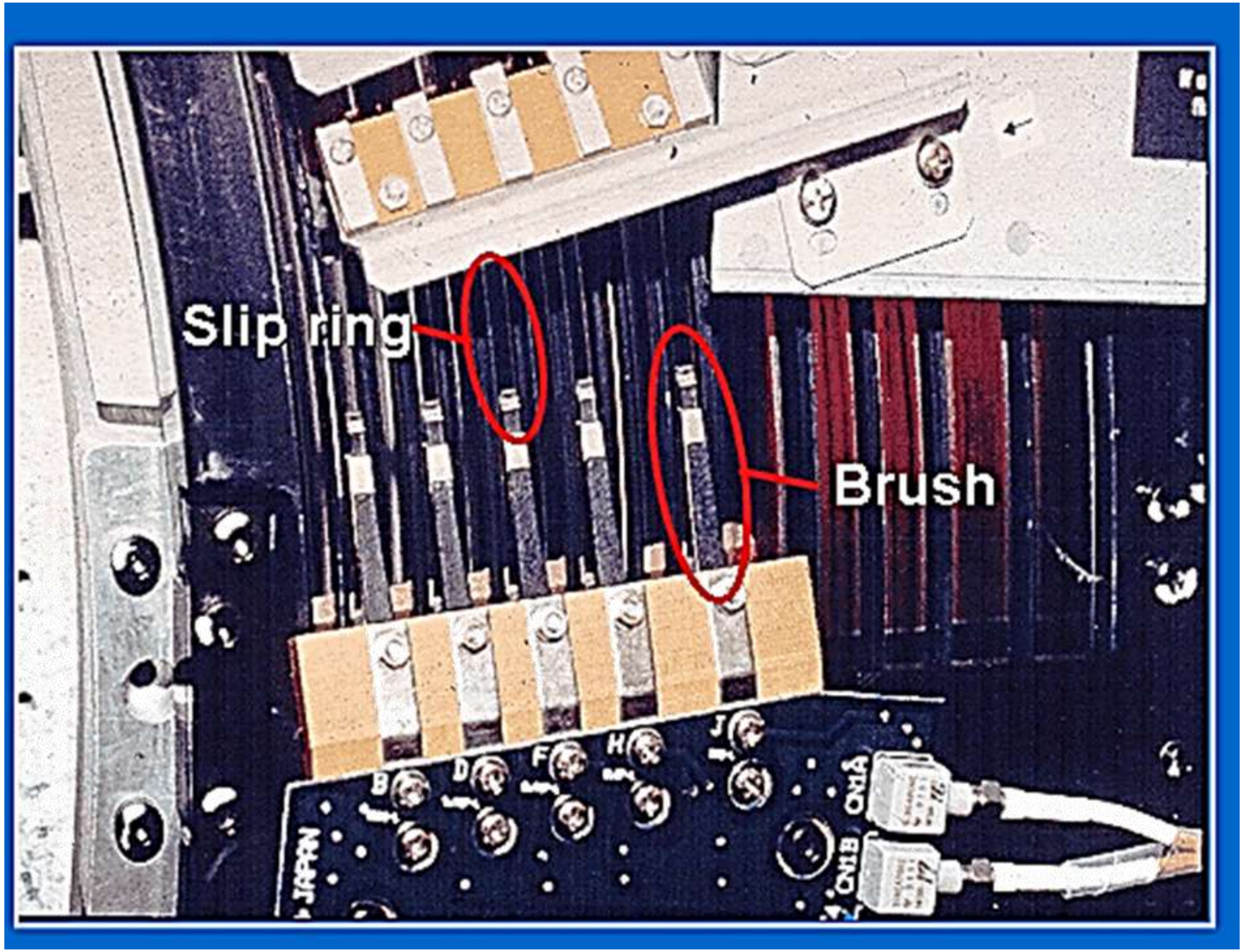

Helical CT Scanner

Slip rings

- Slip rings introduced in 1990 allowed continuous rotation
  - Power and signals transmitted to rotating gantry using ‘brushes’ on static rings
  - no need to start and stop rotation
  - scan times as fast as 0.3 s



Slip Ring Technology



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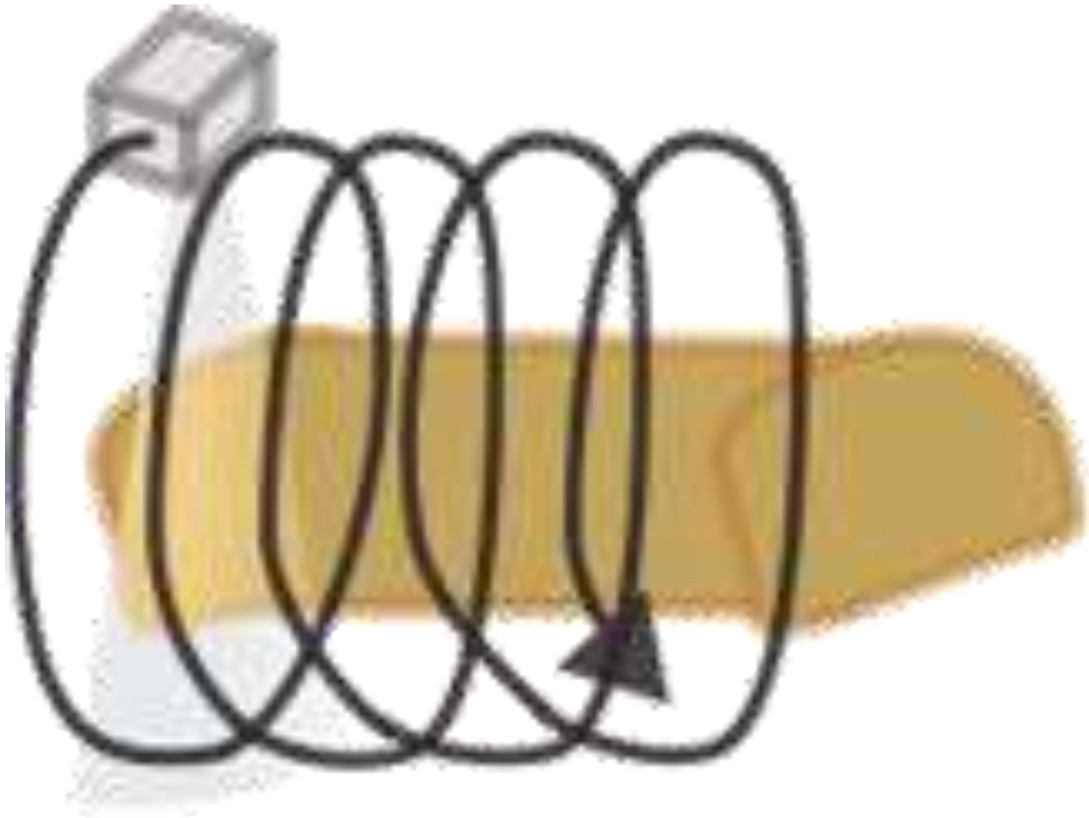
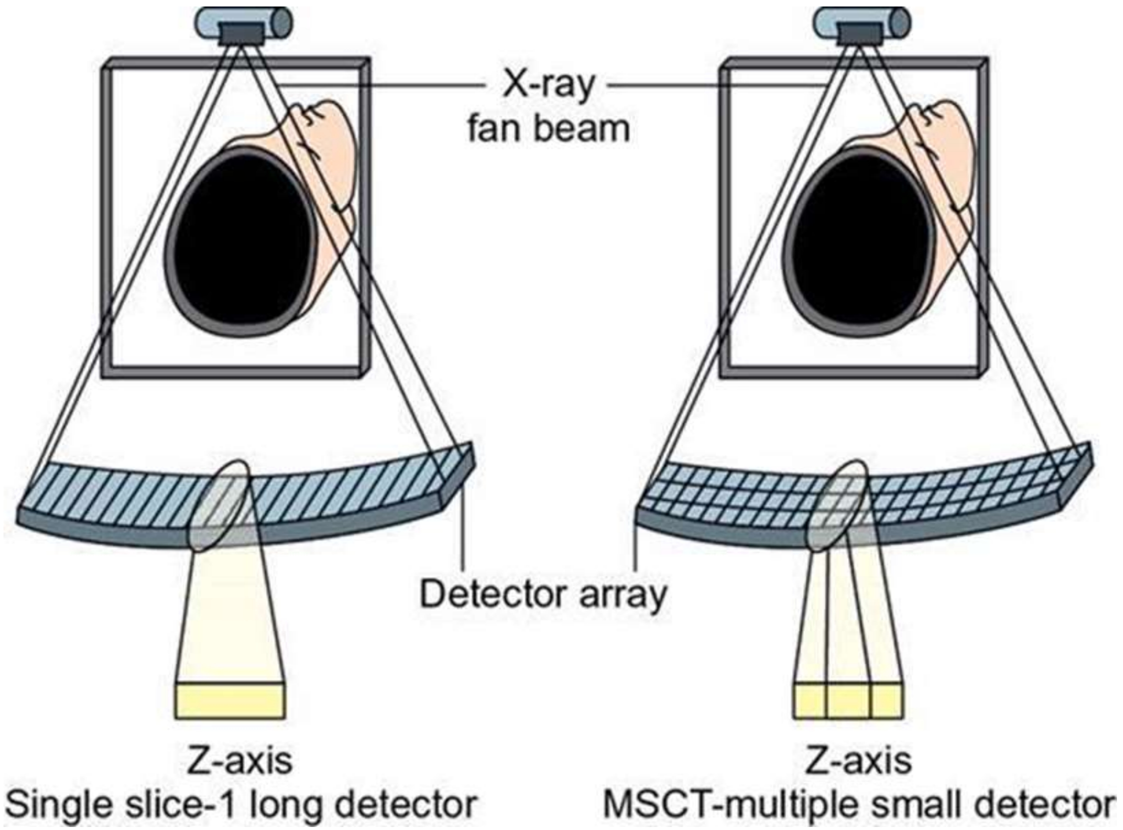
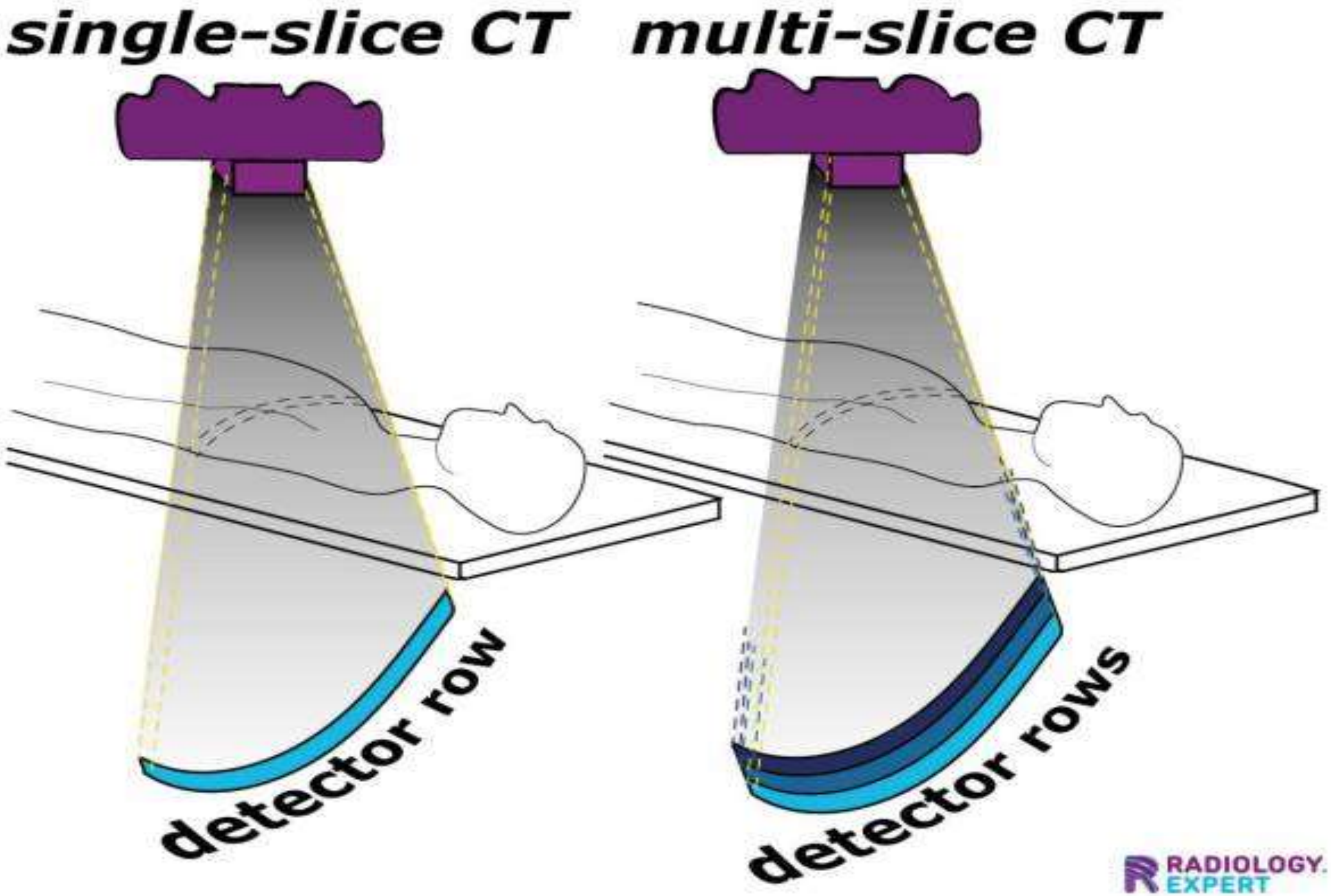
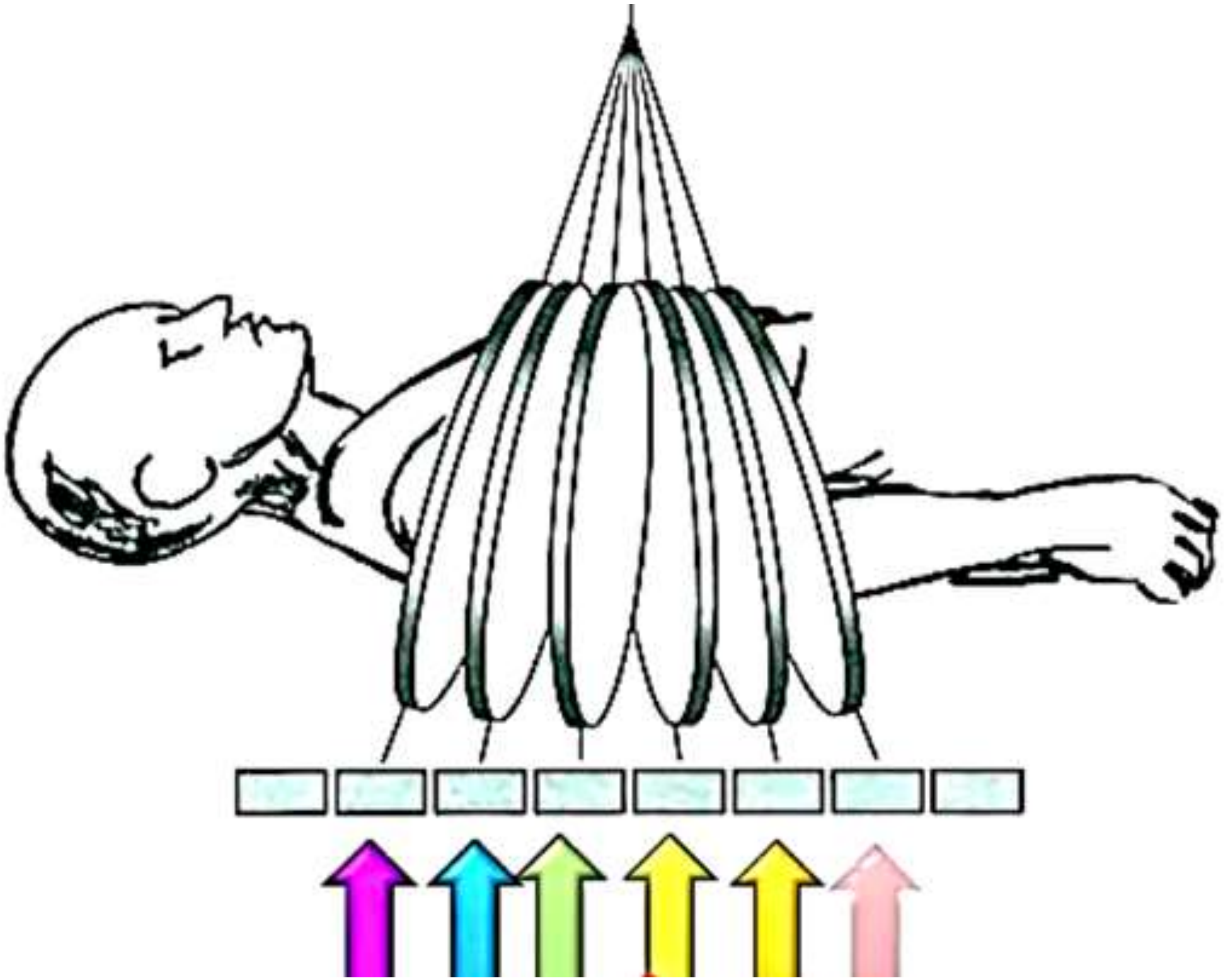


1990s, Multi Slice CT

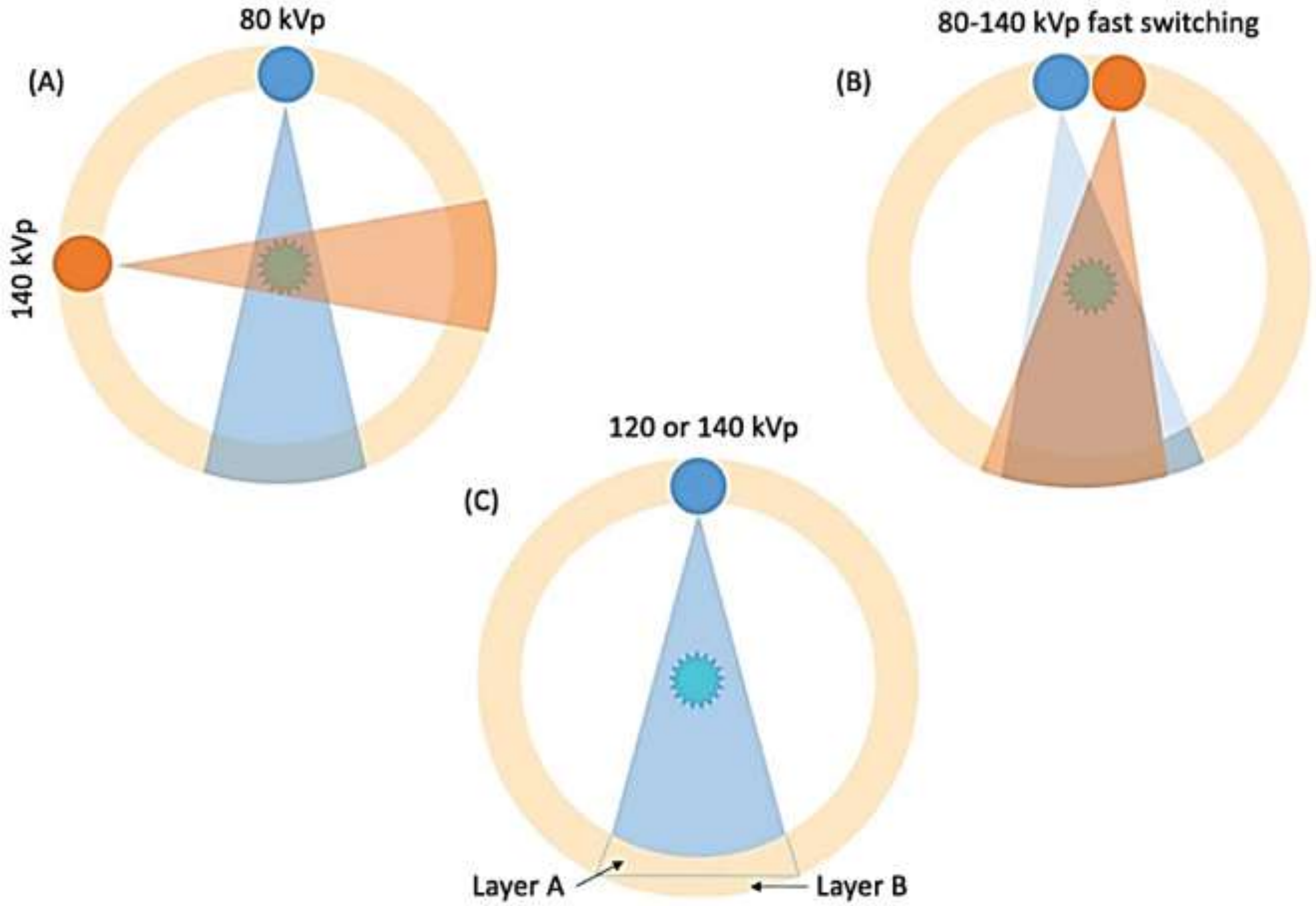


The combination of **Helical scanning** and **Multi-slice technology** → acquisition of very thin slices, → makes isotropic voxel reconstruction possible.
This means that anatomical data can now be viewed from any angle without distortion (multiplanar reconstruction), → allowing the extraction, analysis, and visualization of accurate **3D models** of the scanned structures.


single-slice CT
multi-slice CT
detector row
detector rows
RADIOLOGY EXPERT



Dual-Source & Dual-Energy CT



In **2005**, Siemens introduced the *SOMATOM Definition*, a scanner equipped with **two X-ray tubes** and **two detectors mounted** 90° apart on the gantry, each operating at different energies.

Photon-Counting CT 2021

- Advanced CT technology
- uses specialized semiconductor detectors → directly count individual X-ray photons and measure their energy, → providing clearer images with reduced noise and artifacts.

- In 2021 by Siemens Healthineers
- Ddetector arrays acquiring 144 slices
- The latest advancement in CT detector technology is the development of photon-counting detectors.
- These systems use semiconductor materials such as cadmium telluride (CdTe) to directly convert absorbed X-ray photons into electrical charges, with the signal strength proportional to the energy of the photon.
- CdTe is composed of high atomic number elements, making it highly effective at absorbing X-rays and offering excellent detection efficiency.
- Its relatively large bandgap of 1.5 eV also allows operation at room temperature with minimal thermal noise.

Lung imaging Photon-counting CT allows visualization of detailed structures (centre) with simultaneous functional imaging (right). For comparison, a conventional CT image is shown on the left.

Technique:

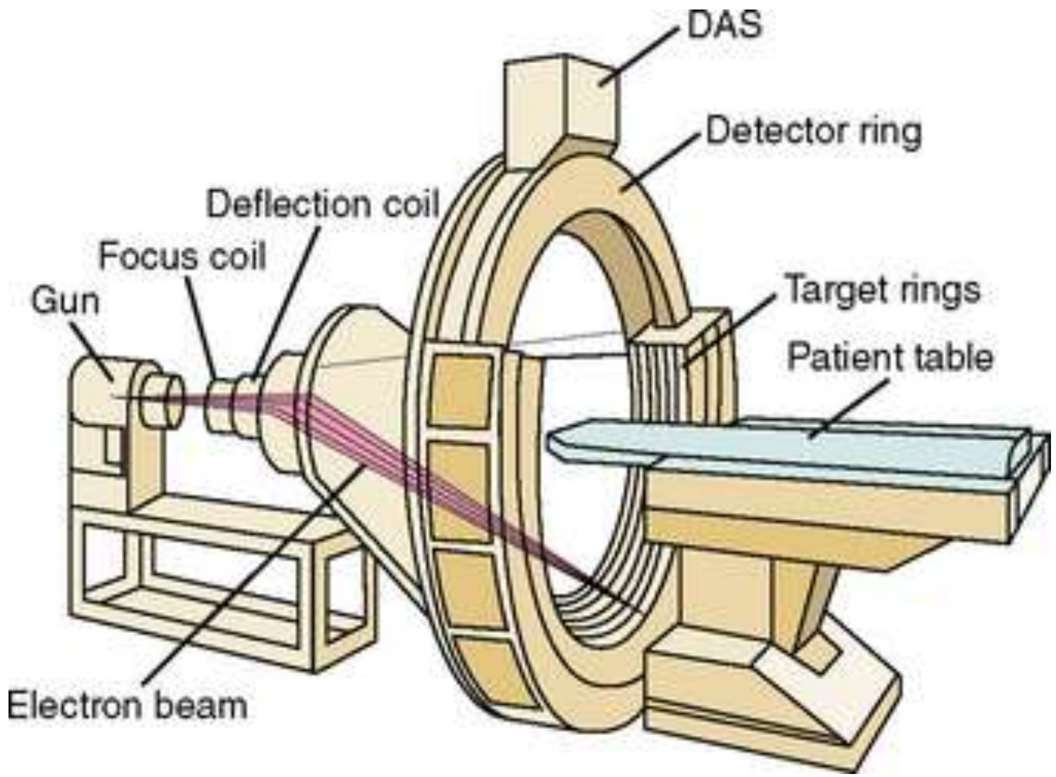
- X-ray photon → absorbed in the CdTe crystal via the photoelectric effect—energy→ is transferred to an electron, → ionizes atoms and generates electron-hole pairs.

- Charge collection electrodes separate these charges, and after amplification, the resulting signal is sorted into energy bins based on pulse height. → This enables ***every photon*** to be individually counted and classified by energy at ***each pixel***. As a result, photon-counting

- CT reaches an even **better performance** than dual-energy CT at material decomposition, and improves overall signal-to-noise ratio and dose efficiency.

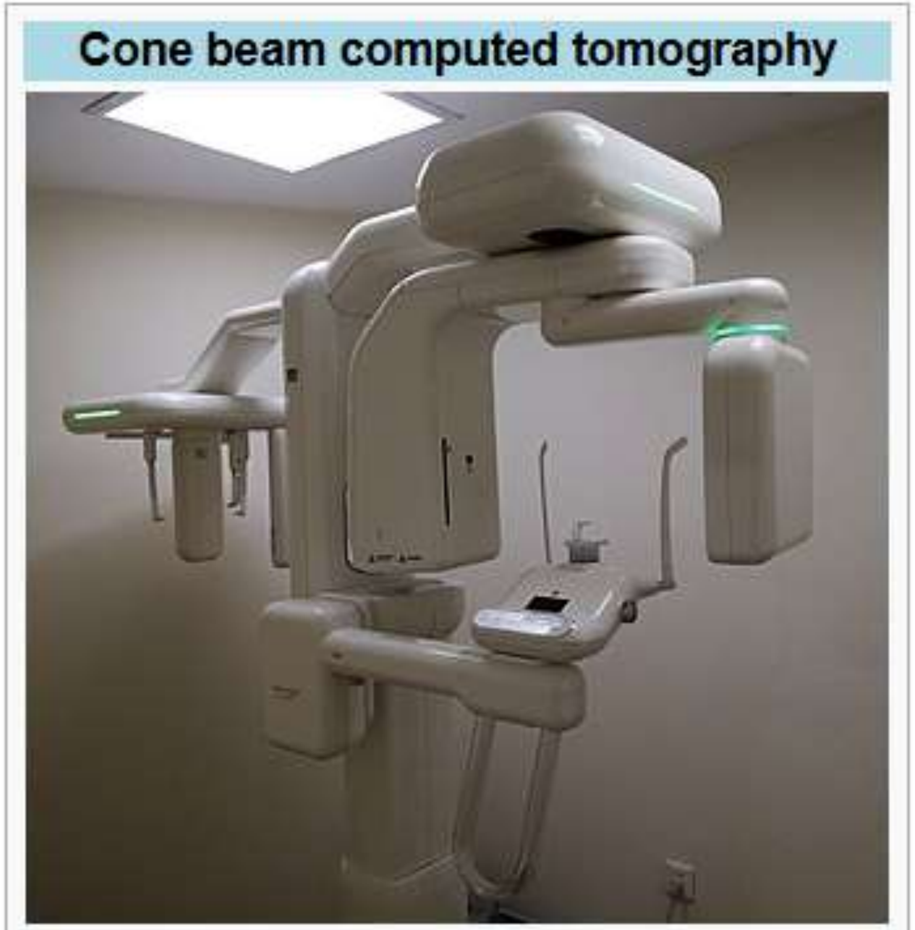
Parameters:

- (6cm collimation width)
- Gantry rotation time down to **0.25s**



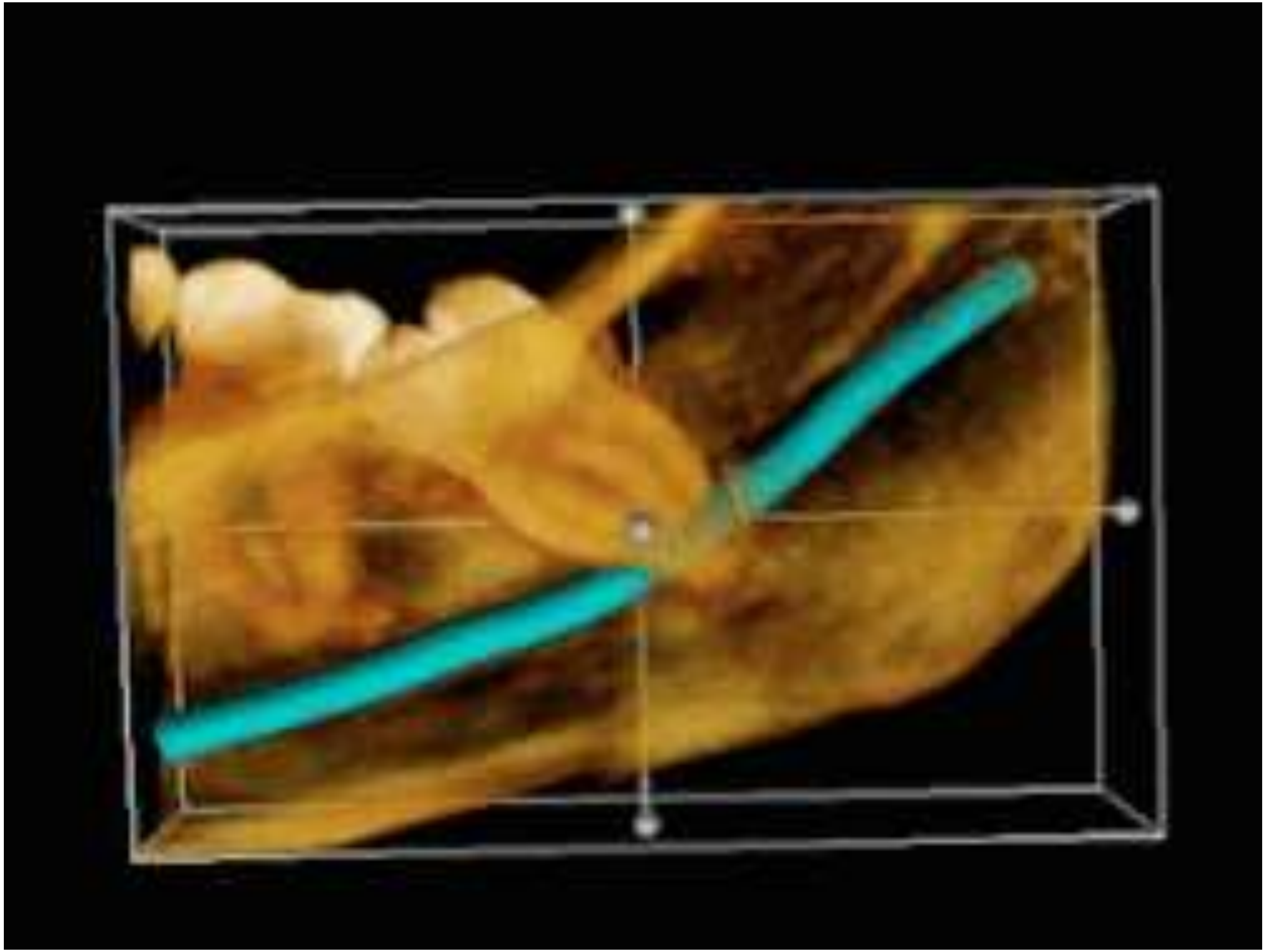
Cone-Beam CT 1998

- **Cone beam computed tomography** (or **CBCT**, also referred to as **C-arm CT**, **cone beam volume CT**, **flat panel CT** or **Digital Volume Tomography** (DVT))
- is a medical imaging technique consisting of X-ray computed tomography where the X-rays are divergent, forming a cone **used in dental imaging.**



Cone Beam CT scanner

- CBCT has become increasingly important in treatment planning and diagnosis in :
  - implant dentistry,
  - ENT,
  - orthopedics,
  - and interventional radiology (IR),



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GOOD LUCK

NEXT .... BASICS OF CT WORK