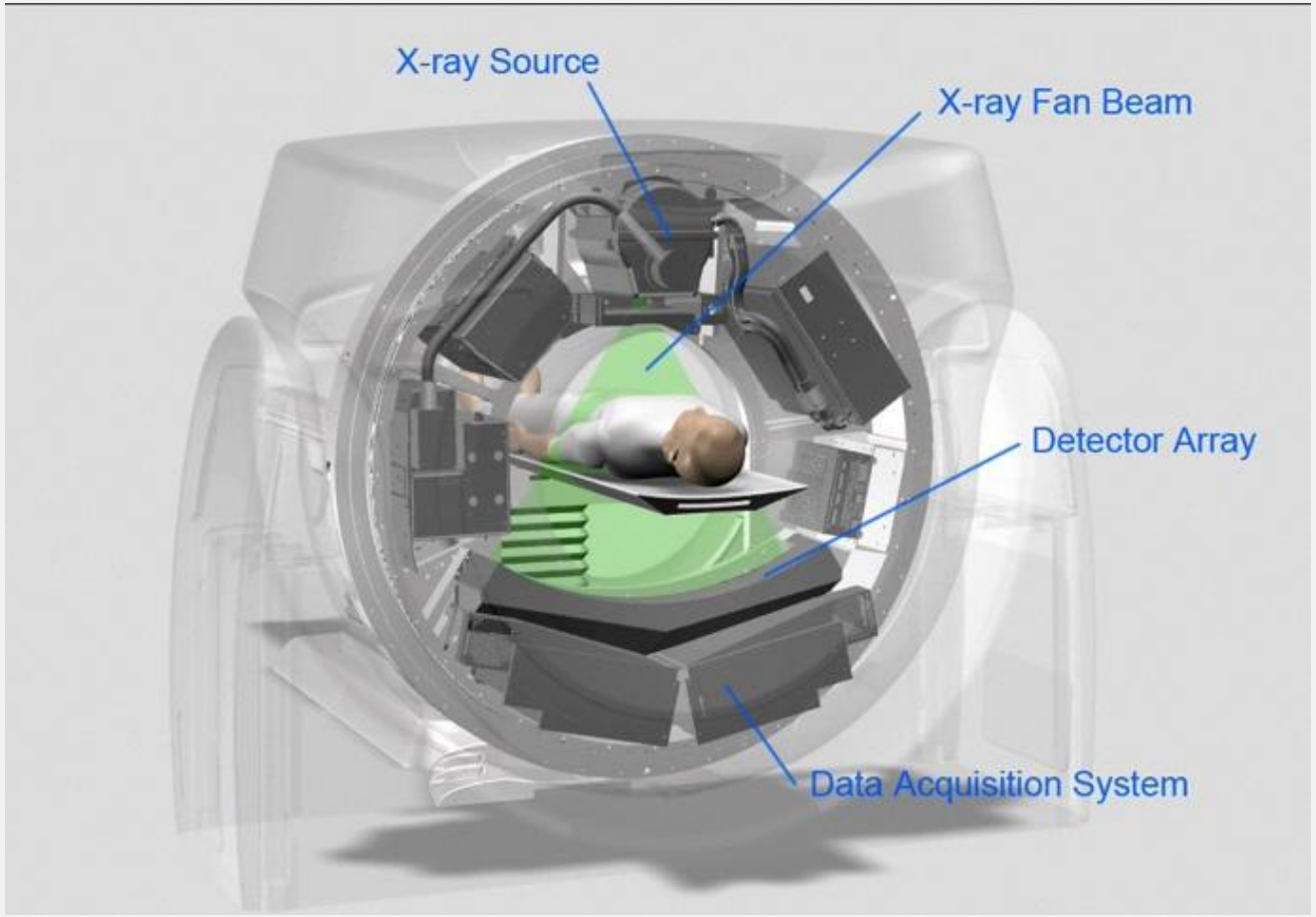
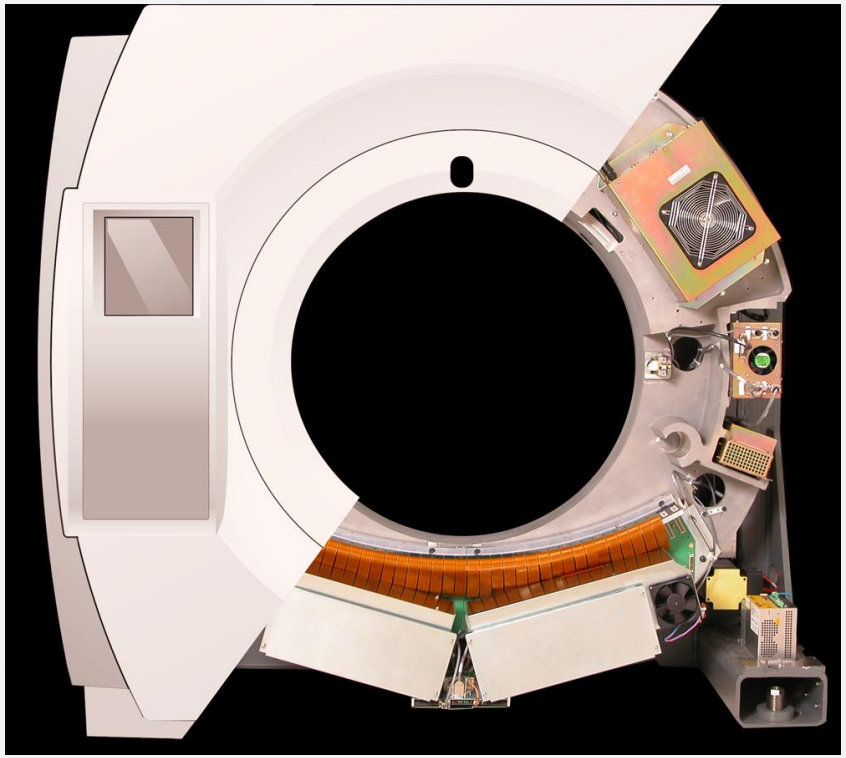
# Scanner Components and Operation – 3



# Major Component -- Gantry

- Ring-shaped part of the CT scanner
  - 70-90 cm
  - 15 - 30 degree forward or backward tilt

- Houses:
  - Slip rings
  - Generator
  - Cooling system
  - X-ray Tube
  - Filters
  - Collimators
  - Detectors

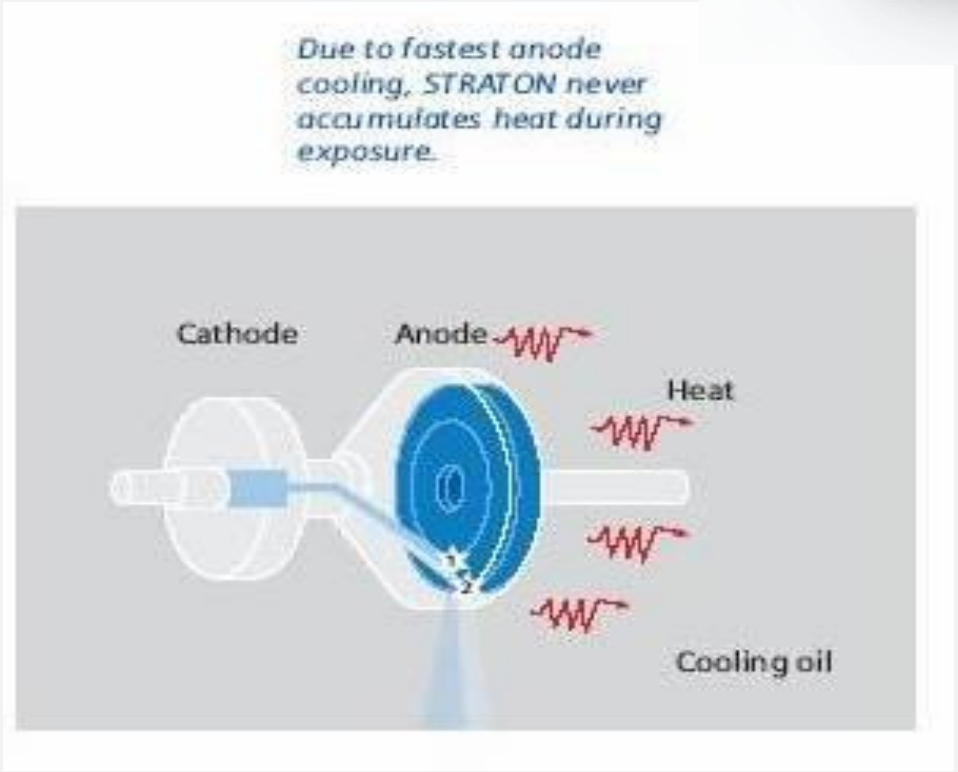


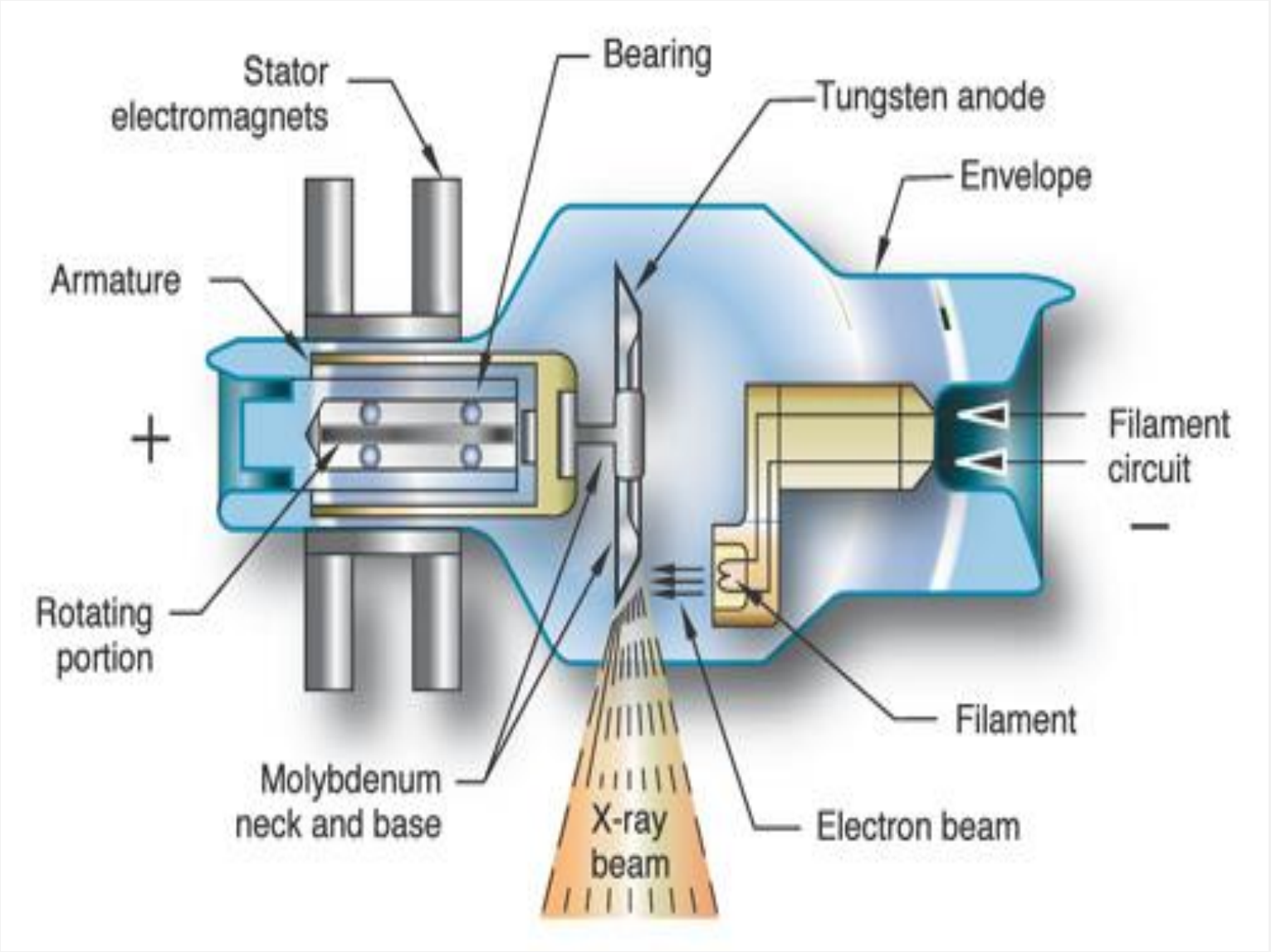
# X-Ray Tubes

- First and second generation scanners used
  - fixed anode
  - oil-cooled x-ray tubes
- Modern CT uses
  - rotating anode tubes for better tube cooling
  - Focal spot of .5 and 1 mm
  - Small focal spot - better detail
- Helical scanner tubes rotate for a longer period, thus the tube must be able to sustain high power levels
- Many technical and design advances have been made.

# Straton X-ray Tube

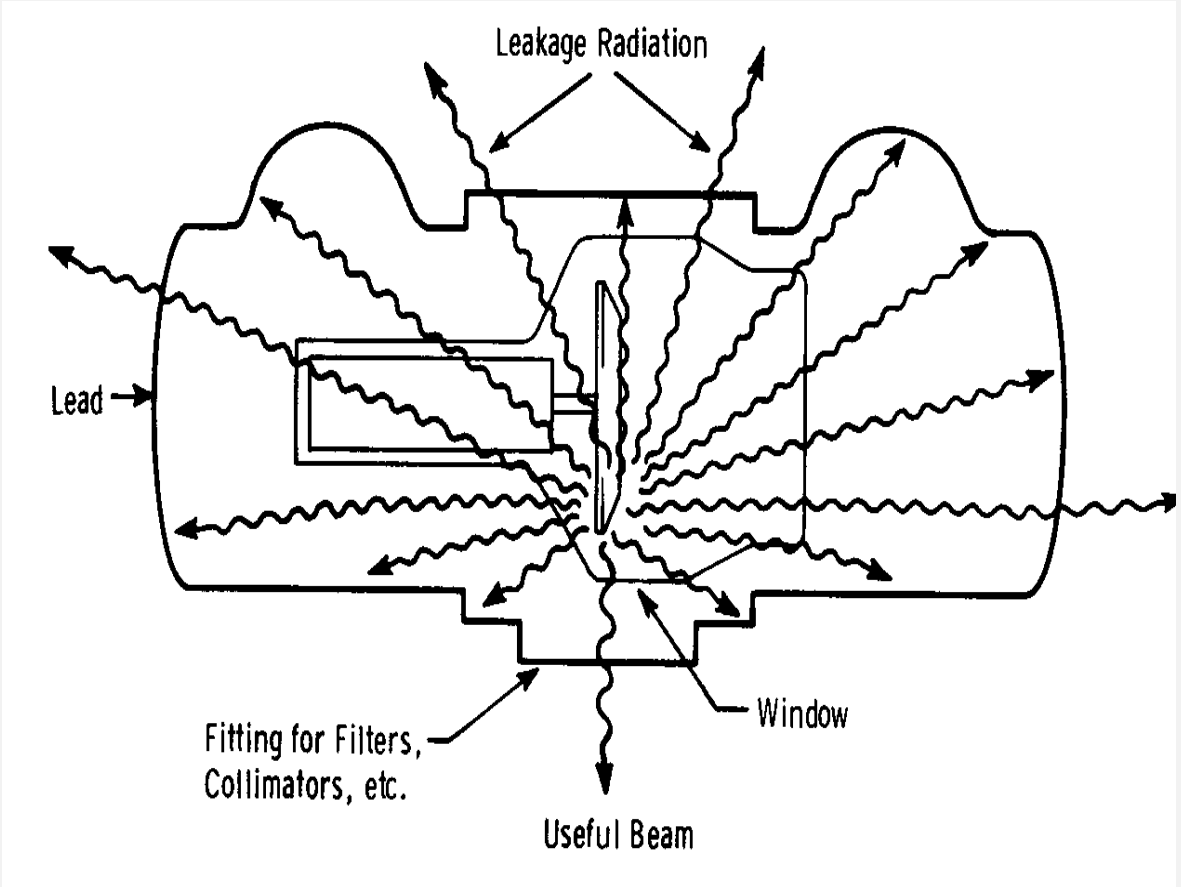
- For Multi slice (MSCT)
- Differences from Traditional
  - Entire tube rotates
  - Entire tube immersed in oil
  - Oil is circulated for cooling
  - Deflected Electron beam to 2 focal spots




Stator
electromagnets
Bearing
Tungsten anode
Envelope
Armature
+
Filament
circuit
−
Rotating
portion
Filament
Molybdenum
neck and base
X-ray
beam
Electron beam

# Protective Housing

- X-rays are emitted isotropically, with equal intensity in all directions
- The tube window is the section of tube designed to let x-rays pass through
- These x-rays are called the useful beam
- All others are termed Leakage Radiation



# Glass Envelope

- Tube is evacuated and contains two electrodes: cathode and anode
- Most tubes are made of pyrex, some newer tubes have metal construction
- As tungsten filament vaporizes in glass tube arcing can be a problem



# Cathode

- Cathode is the negative side of tube
  - Contains: Filament & Focusing Cup.
  - Filament: coil of thoriated tungsten wire and is a source of electrons
  - Tungsten has high melting point 3410$^{o}$c
  - Focusing cup: filament is embedded in metal focusing cup.
  - Negatively charged focusing cup directs electrons to specific area of anode



# Filament

- Dual Filamnets: most x-ray tubes have a small and large filament

- Filament provides resistance to flow of electrons and the heat produced causes thermonic emissions to occur.

- These are the electrons that strike the target of the Anode

# Anode

Anode is the  positive side of x-ray tube

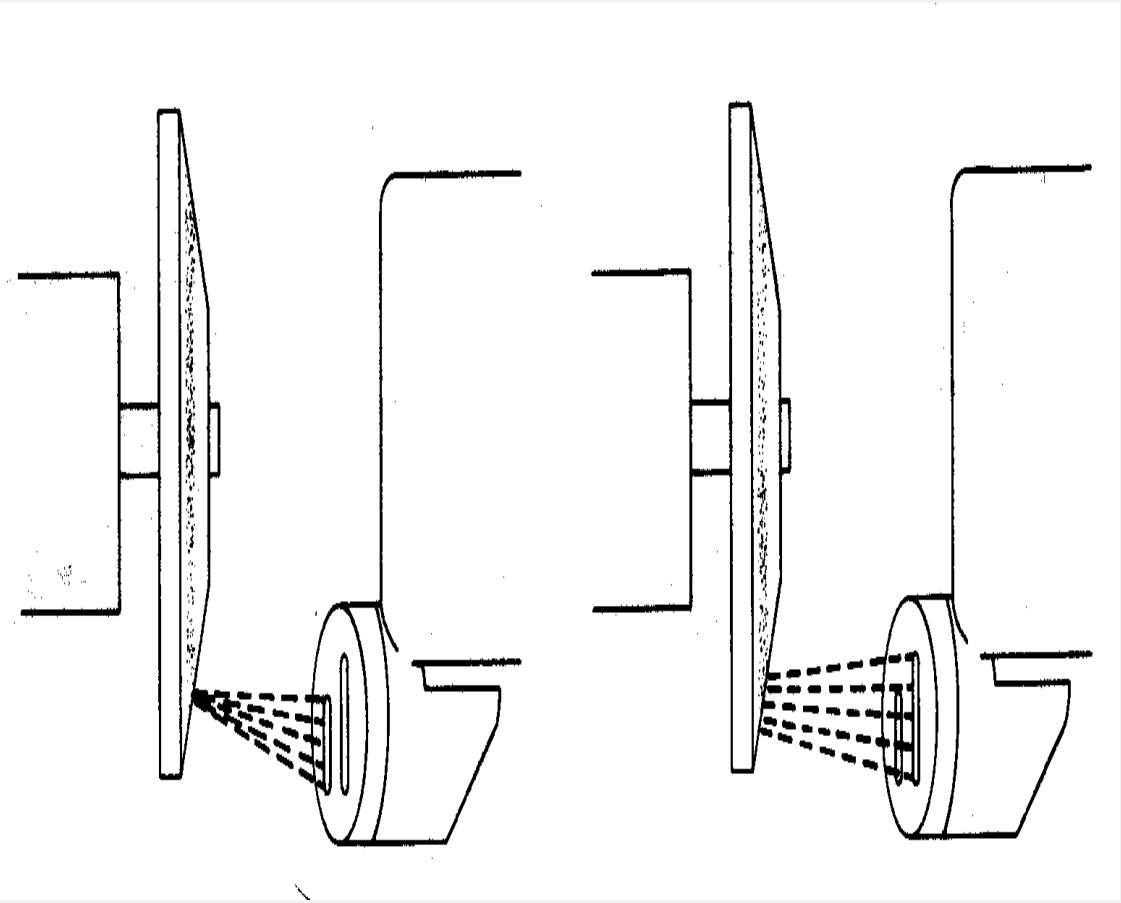
- Two types of anode:
  - stationary (no longer used)
  - Rotating

- Functions of anode
  - Anode target surface is where the high-speed electrons from the filament are suddenly stopped, resulting in the production of X-rays



# Focal Spot of Anode

- Small focal spot is associated with small filament.
- Large focal spot is associated with a large filament



# Anode Construction

- Anode construction:
  - copper for shaft
  - graphite and molybdenum light weight and dissipate heat.

- Target:
  - area of anode struck by electrons
  - usually constructed of tungsten/rhenium alloy.

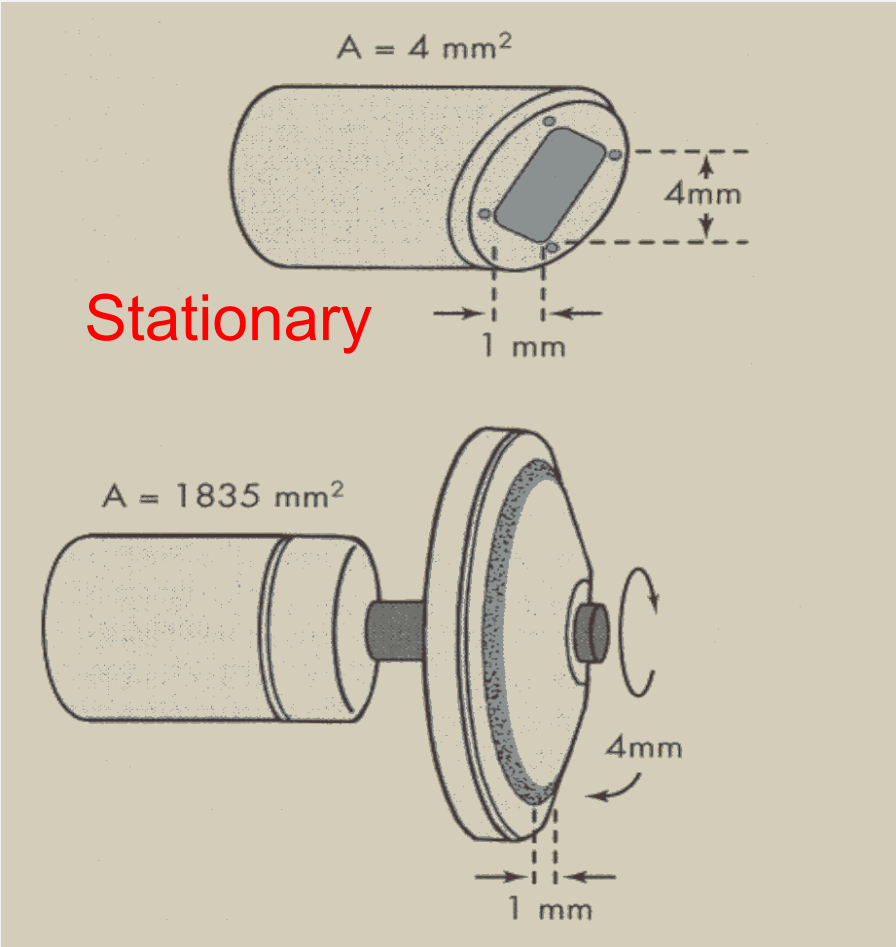
- Tungsten's high atomic # (74) results in high efficiency x-ray production.



# Target of Anode

- Rotating anode provides approximately 1000 times more area for electron beam to interact than a stationary anode

- Rotating Anode is driven by an electromagnetic induction motor



# Rotating Disk/Anode

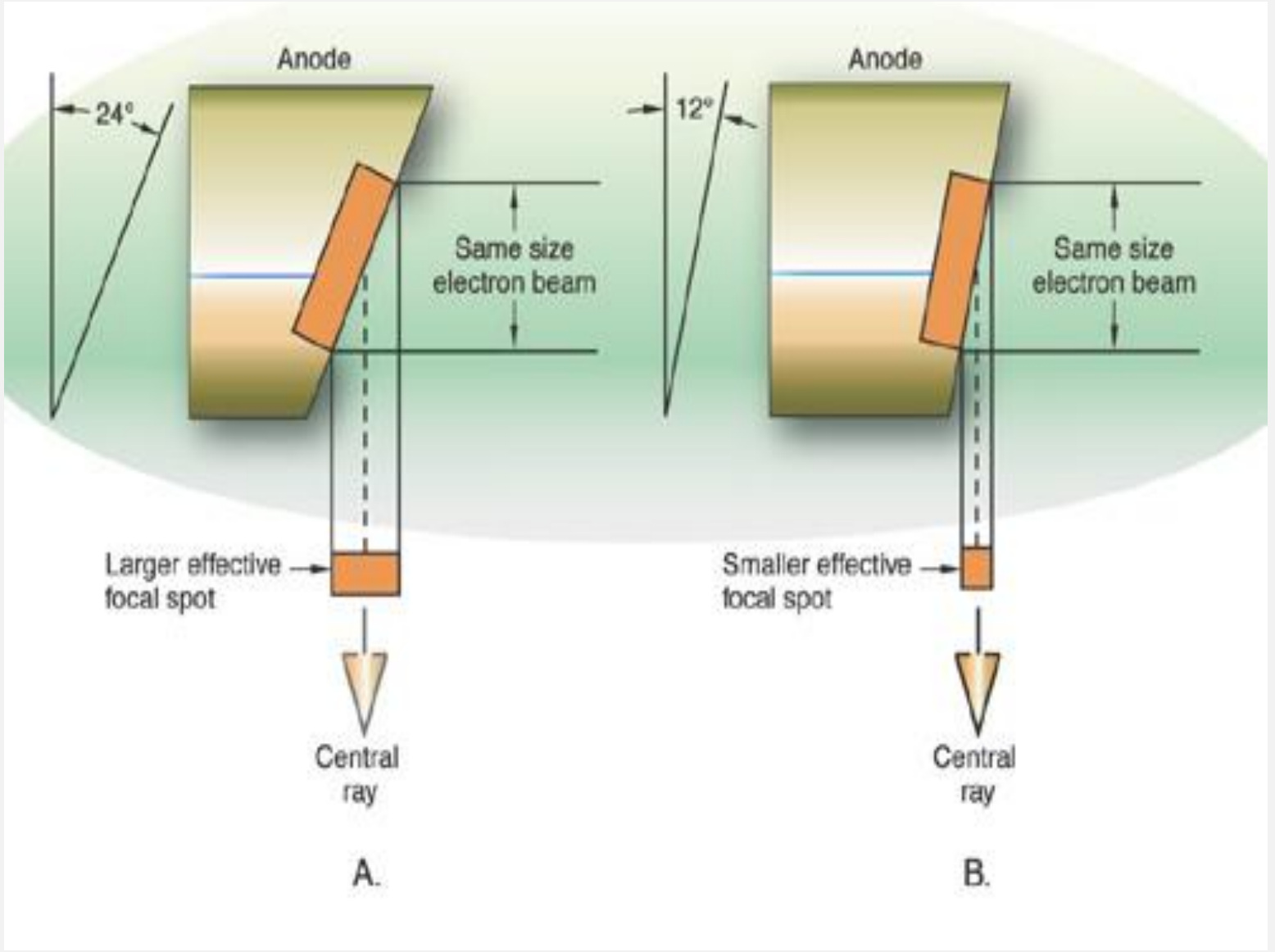
- Made of an RTM alloy:
  - Rhenium
  - Tungsten
  - Molybdenum
- Small target angle (usually 12 degrees)
- Rotation speed of 10,000 rpm



# Line Focus Principle

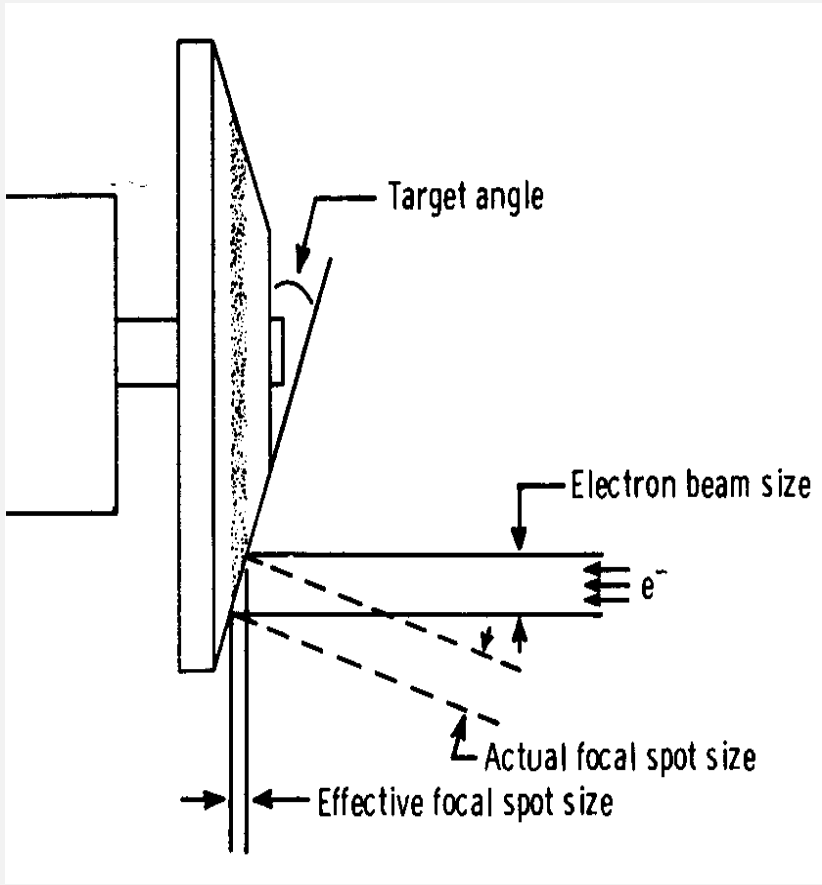
- Line-focus principle: by angling the target an effective focal spot can be created that is smaller than the actual focal spot.
- When target angle is made smaller, effective focal spot will be smaller.
- X-ray tube target angles vary from between $5^0$ - $15^0$




Anode
24°
Same size
electron beam
Larger effective
focal spot
Central
ray
A.
Anode
12°
Same size
electron beam
Smaller effective
focal spot
Central
ray
B.

# X-RAY TUBE

- Line-focus principle simultaneously:
- Improves spatial resolution of the x-ray beam
- As well as the heat capacity of the anode

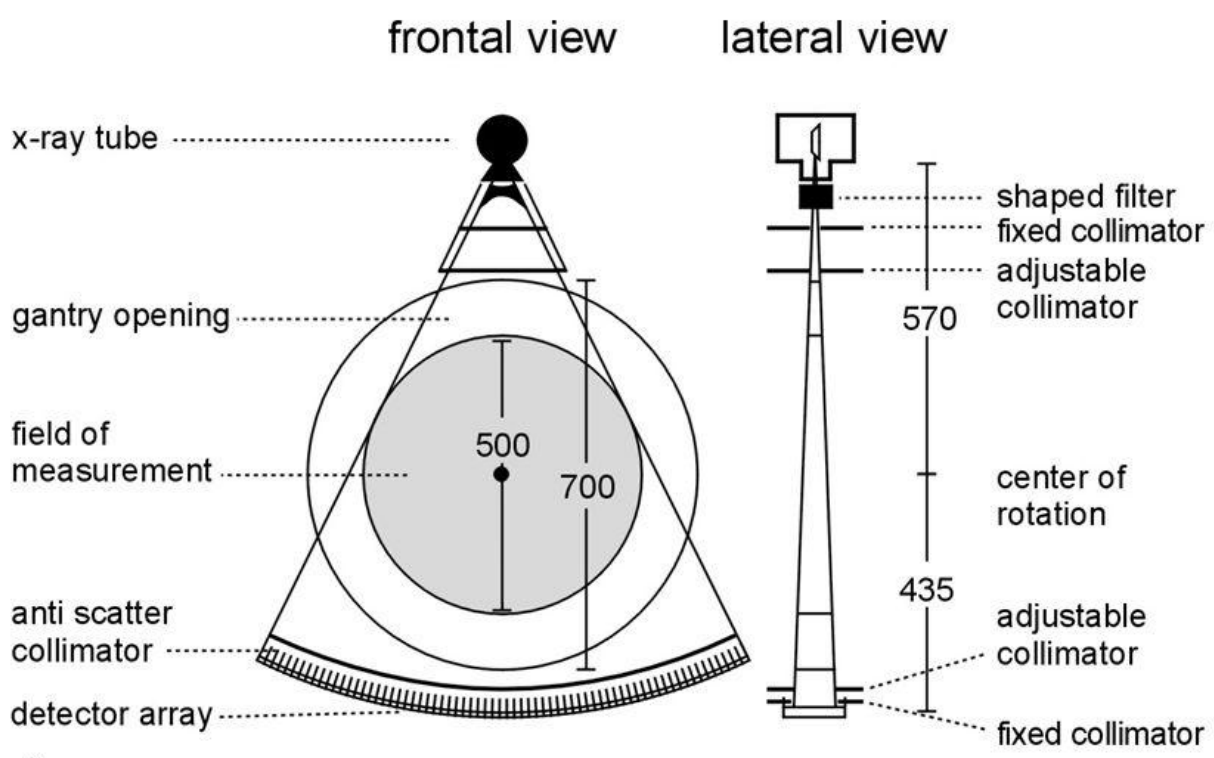


# X-Ray Tube Failure

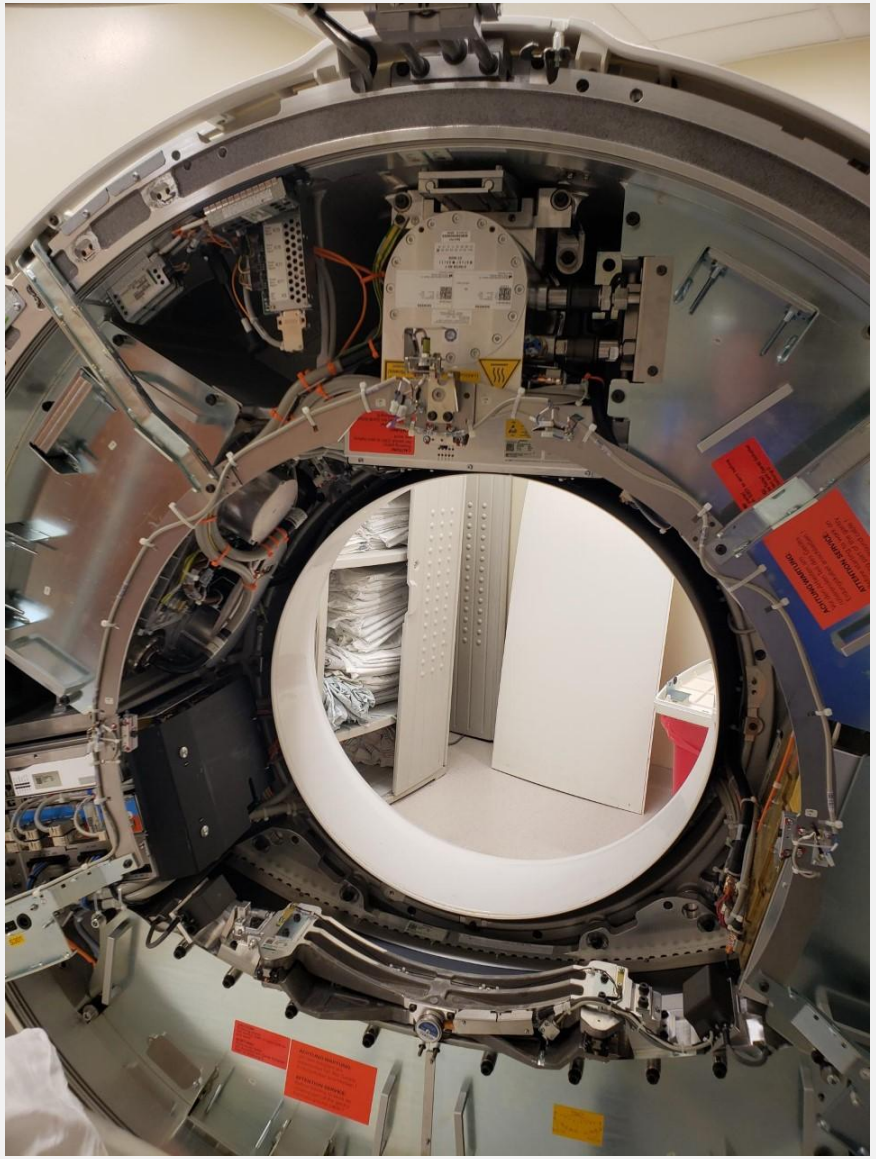
- Tube failure: tube life is extended by using appropriate radiographic factors of mA, kVp and time.
- Almost all tube failure is related to thermal characteristics of x-ray tube.
- Tube heat must be dissipated through radiation, conduction and convection.
- Tube warm-up procedures must be followed per manufacturers instructions

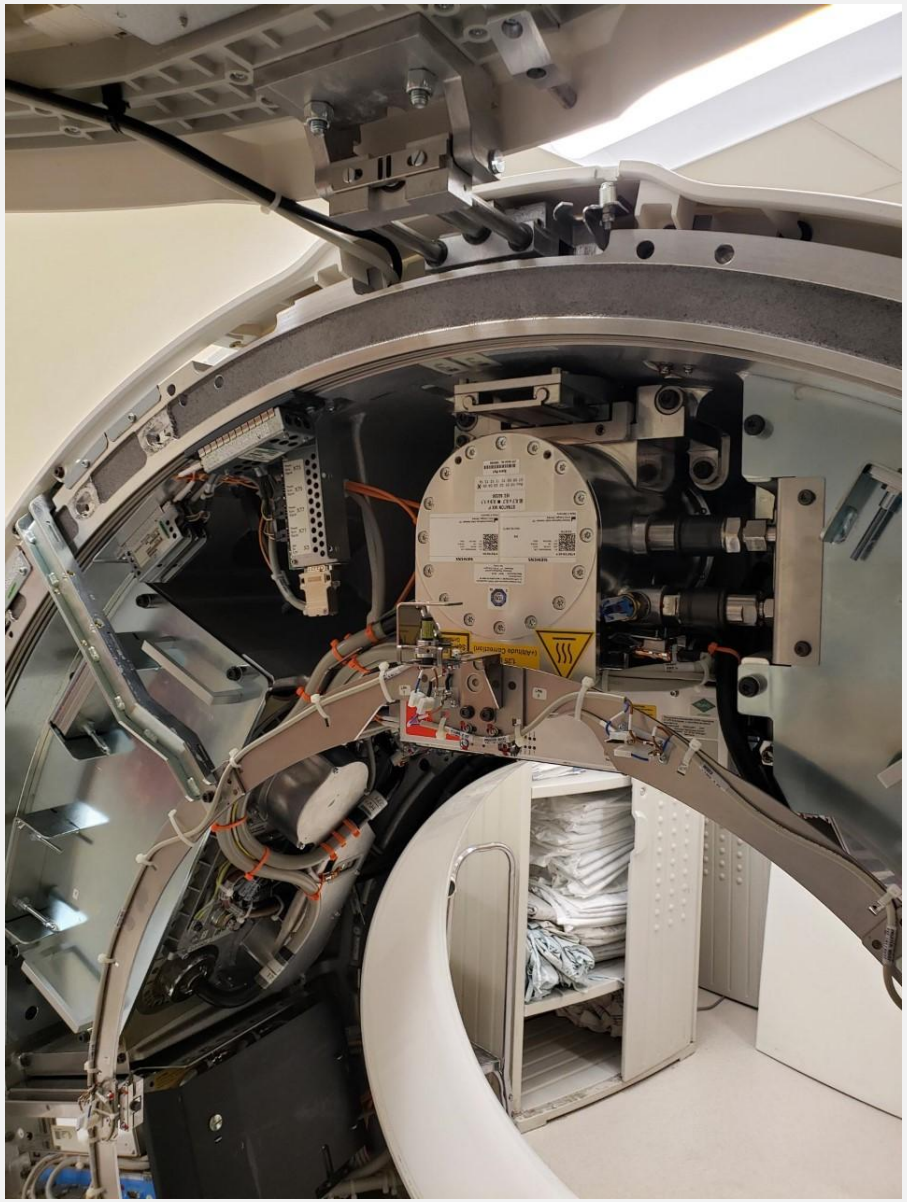
# Gantry Components

**What are inside the gantry?**




**Schematic Representation o f the Scanning Geometry of a CT System**





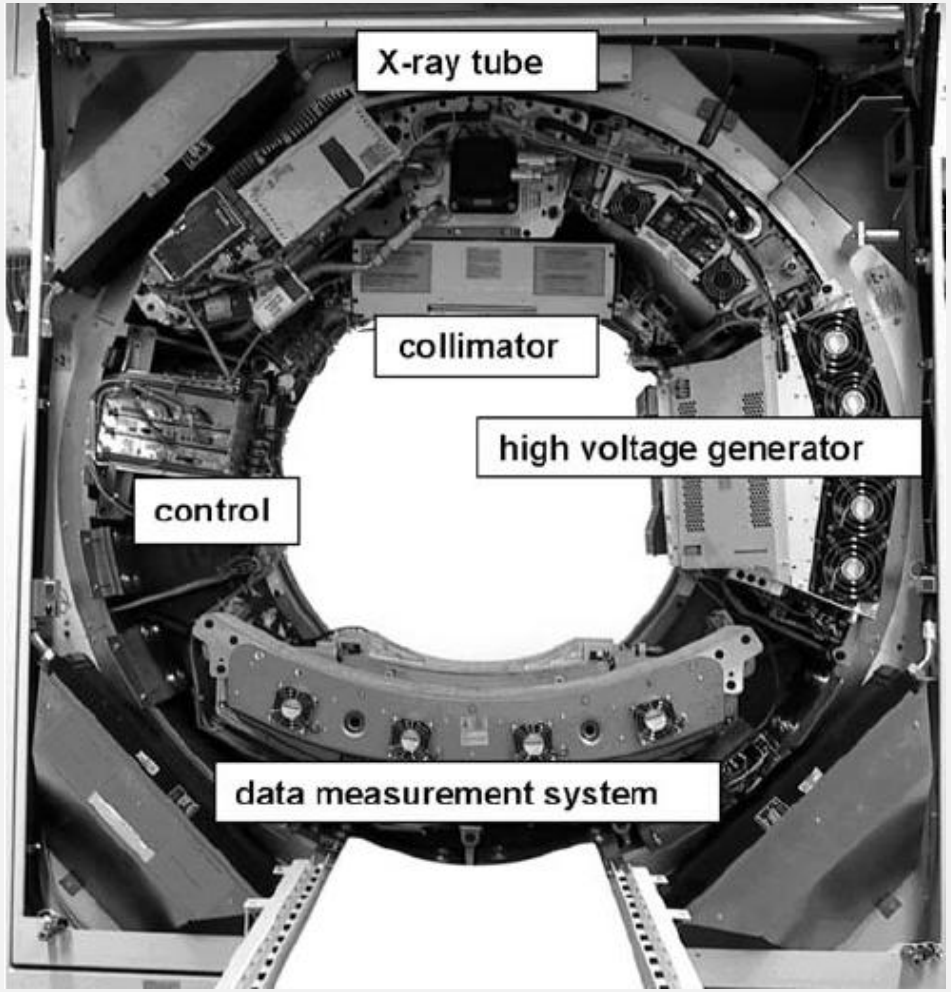
# Slip-Ring Technology

- Allows for continuous gantry rotation-faster scan times/no interscan delay
- Referred to as continuous rotation, Volumetric or Helical scanning
- Fast data collection- required for angiography and continuous acquisition protocols
- No high tension cables of the start/stop scanners



# Generator

- **Produce high voltage for the creation of x-ray photons**
  - **Increasing the voltage (i.e., kV) will increase the intensity of the x-ray beam. (quality or Hardness of beam)**



# Generator

- Early scanners used high-voltage stand alone transformer that were bulky with high tension cable from the generator to the x-ray tube

- Now high frequency generator are used
  - Smaller and more efficient at x-ray production
  - Located inside the gantry

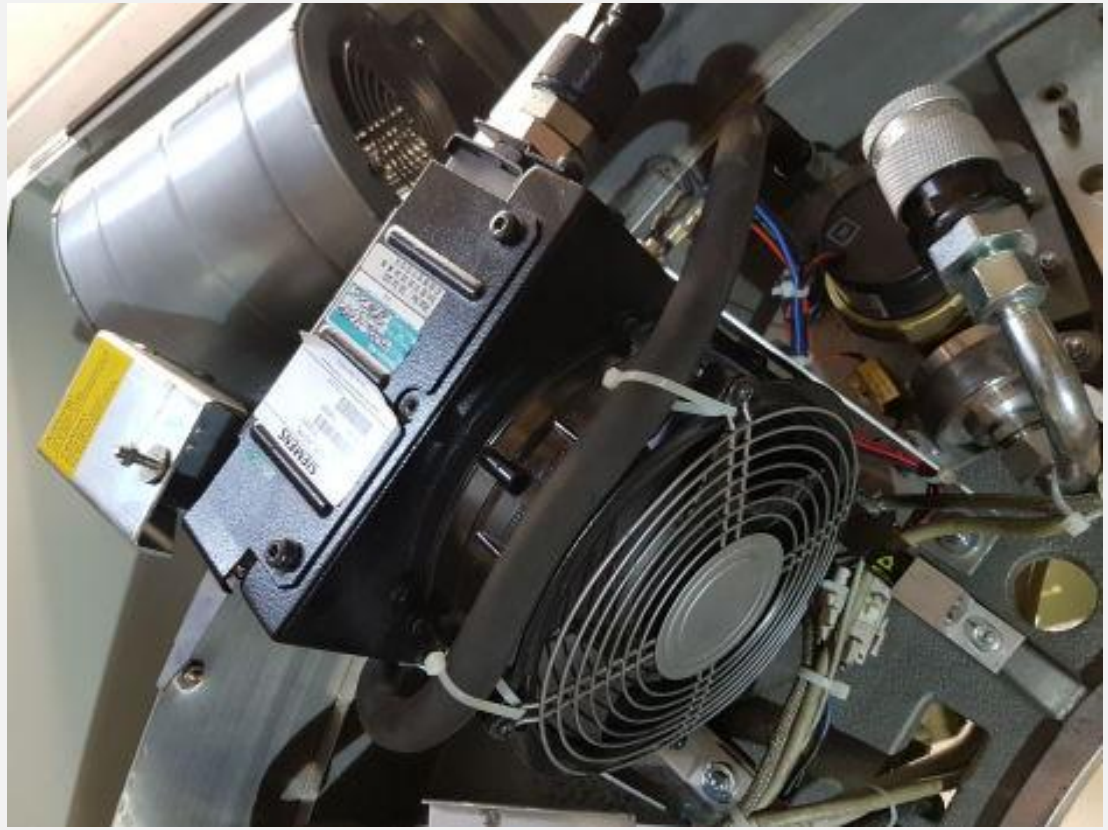
- kVp range settings 80, 120 & 140
  - High kVp reduces patient dose by allowing a lower mAs
  - Reduces heat load by using lower mA setting

- mA range settings 20-500



# Cooling Systems

- The production of x-ray energy results in a large amount of by-product heat
- Blowers, filters, or other devices help to dissipate the excess heat

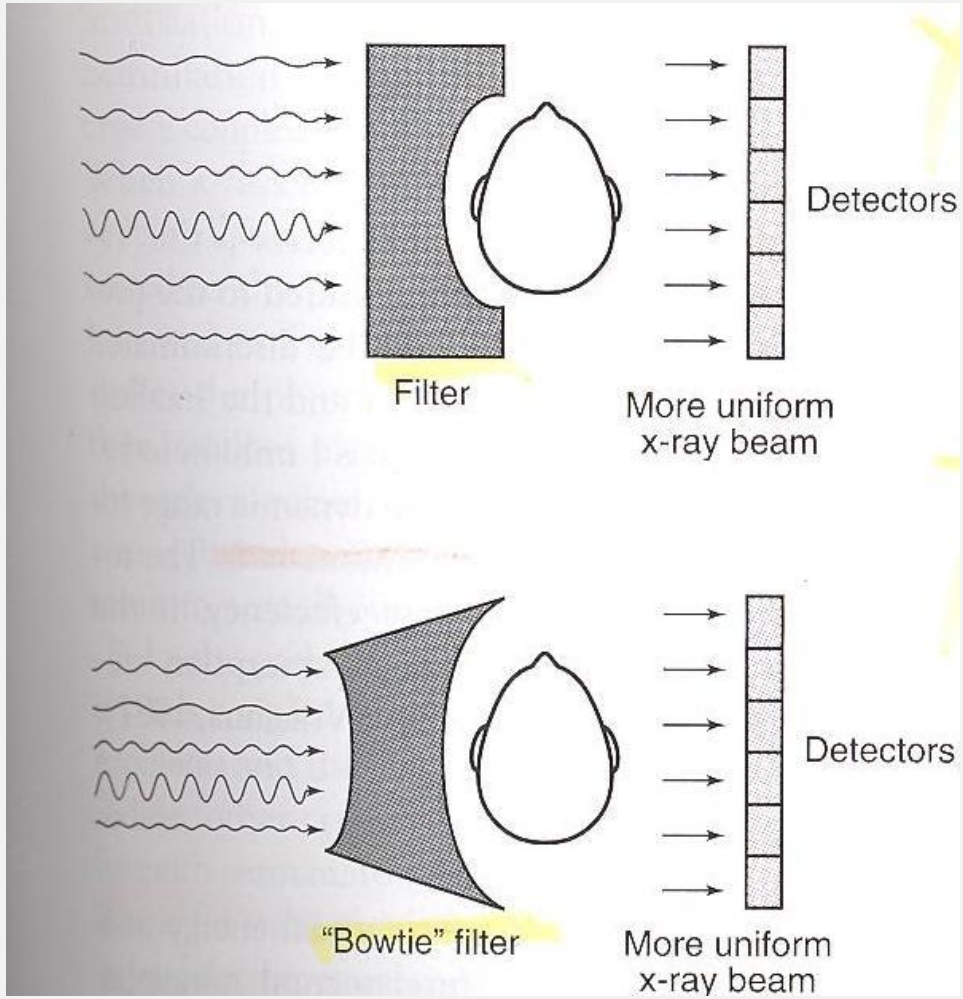


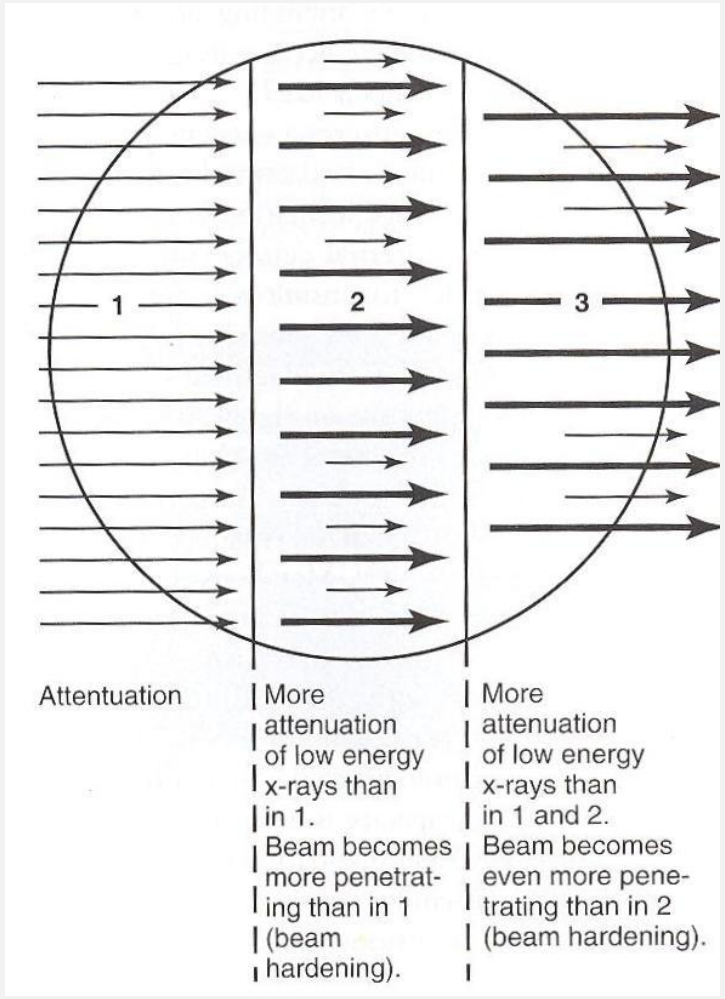
# Filters

- CT X-ray beams have long and short wavelengths – polychromatic.
  - Original scanner had monochromatic beam that satisfied the Lambert-Beer exponential attention law
  - Beam needs to be monochromatic on nearly monochromatic for reconstruction purposes. (Lambert-Beer exponential attenuation law)
- CT Filter has dual Purpose
  - Removes long wavelengths (low energy) x-rays that contribute to patient dose but DO NOT help form the image
  - This is called beam hardening
  - Filtration shapes the energy distribution across the radiation beam to produce uniform beam hardening . This reduces beam hardening artifacts



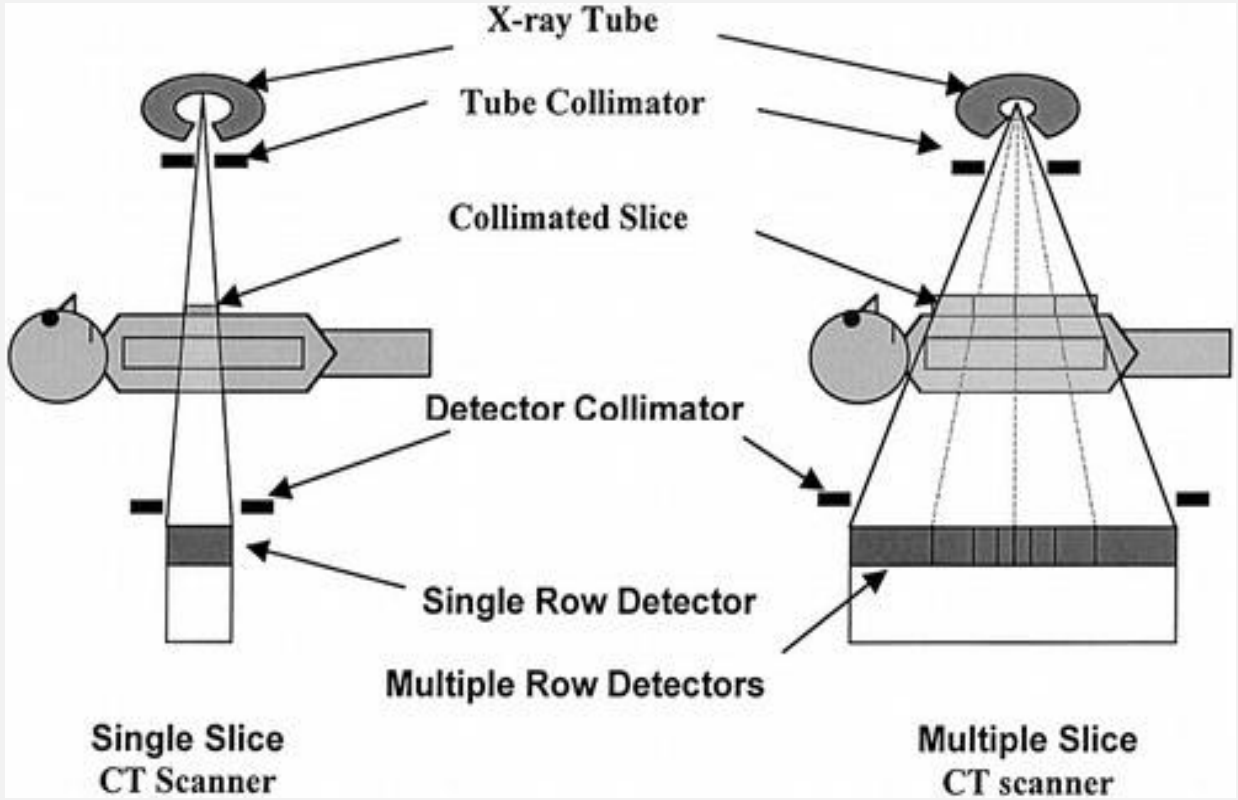
# Bowtie Filters and Beam Hardening



# Collimation

- Restricts the x-ray beam to a specific area
- Reduces scatter radiation
- Improves contrast resolution
- Decreases patient dose



# Collimation

- Two collimators in CT:
  - Pre-patient
  - Post patient or Pre-detector

- Pre-patient collimator
  - positioned near the x-ray source
  - Controls the patient dose

- Post Patient Collimator
  - Removes scatter and improves image quality



# Collimators

- Both sets of collimators insure a constant beam width

- Improves Contrast Resolution
  - Contrast Resolution is the ability to differentiate small density differences on the image
  - Reducing scatter always improves contrast resolution

- Post patient collimators control the slice thickness by widening or narrowing the x-ray beam.

- As the slice thickness changes so does voxel size.



# Detector - Scintillation (solid state)

- Converts x-ray energy into light, and then the light is converted into electrical energy

- Consist of scintillation crystals coupled to a photomultiplier (PM) tube

- Early scanners used sodium iodide crystals couple to PM tubes
- Today most scintillators are cadmium tungstate or high-purity rare earth oxides
- The detector efficiency rate of solid state detectors is 99%.
- Automatically recalibrated between scans.



# Detector Gas - Ionization Detectors

- Based on the principle of ionization
- Gas-filled detector array uses small ion chambers filled with high-pressure xenon or other gas
- Each ion chamber is about 1mm wide with essentially no inter-space
- Has excellent stability and fast response times but detector efficiency is only 50%.



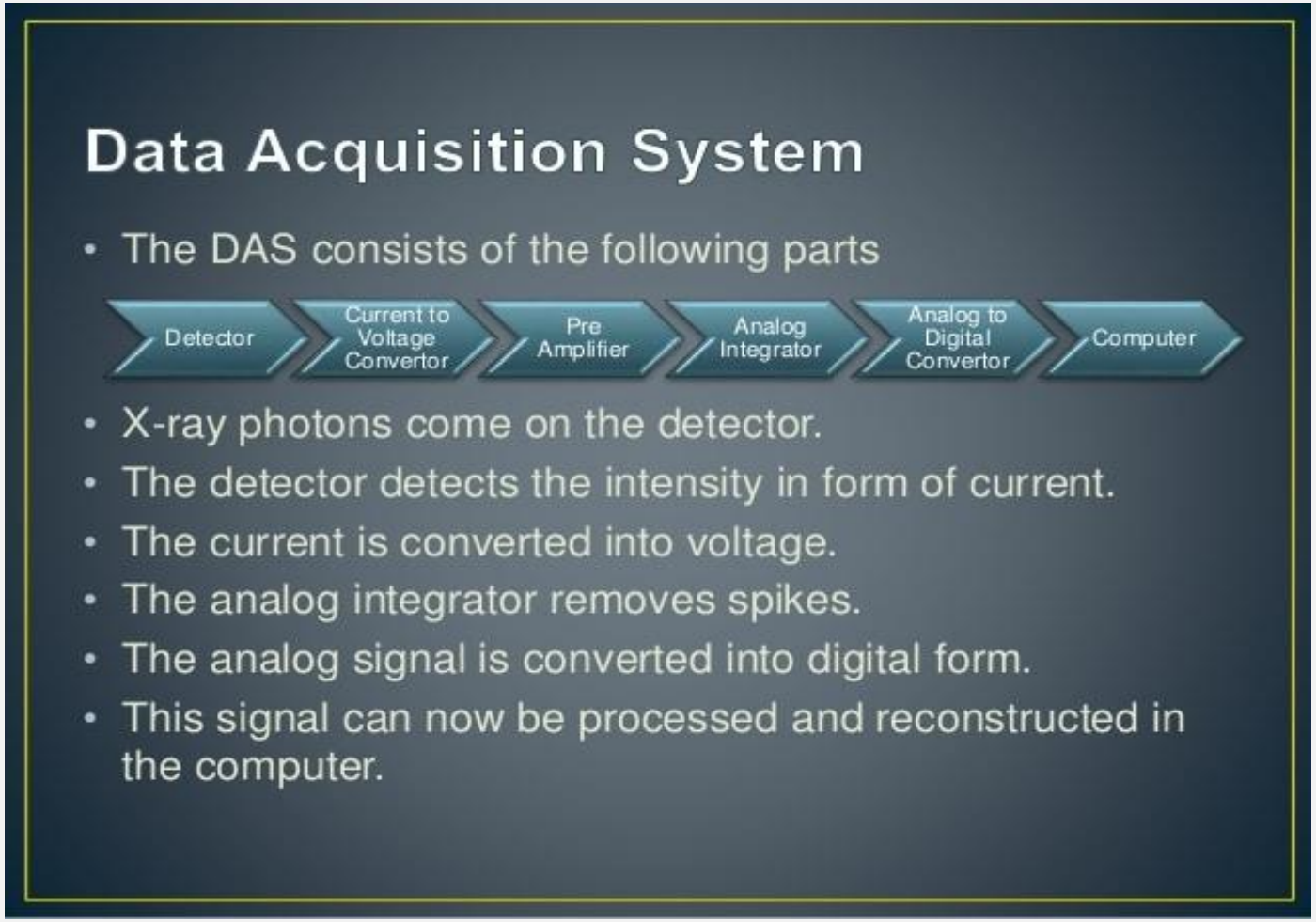
# Detector Characteristics

- **Efficiency :**
  - **The ability to capture, absorb, and convert x-ray photons to electrical signals.**
  - **Capture efficiency:**
    - **The efficiency with which the detectors can obtain photons transmitted thru the patient**
      - **Size of detector face**
      - **Spacing of detectors**
  - **Absorption efficiency:**
    - **the number of photons absorbed by the detector**
- **Stability**
  - **Steadiness or ability to stay in calibration**
- **Response Time**
  - **Speed of detecting and recovering to capture a new photon**



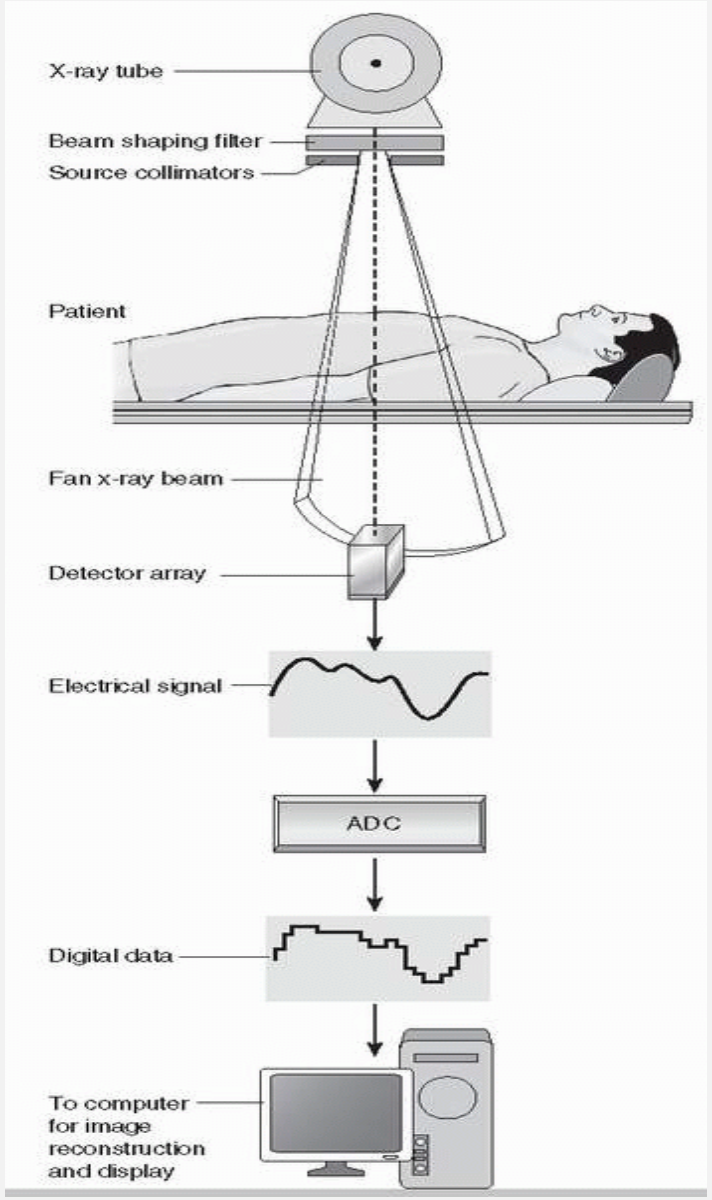
# Data Acquisition System (DAS)

- **Positioned Between**
  - **Detector array and Computer**
- **3 functions:**
  - **Measures the photons that pass through the patient and strike the detectors**
  - **Converts data from analog to digital**
  - **Transmits binary data to computer**



# Summary of Process

- Tube
- Filter
- Collimators
- Patient
- Post patient collimators (not shown)
- Detector
- DAS
- Computer to make image



# Patient Table

- The process of moving the table within the gantry by a specified measure is called incrementation, feed, step, or index

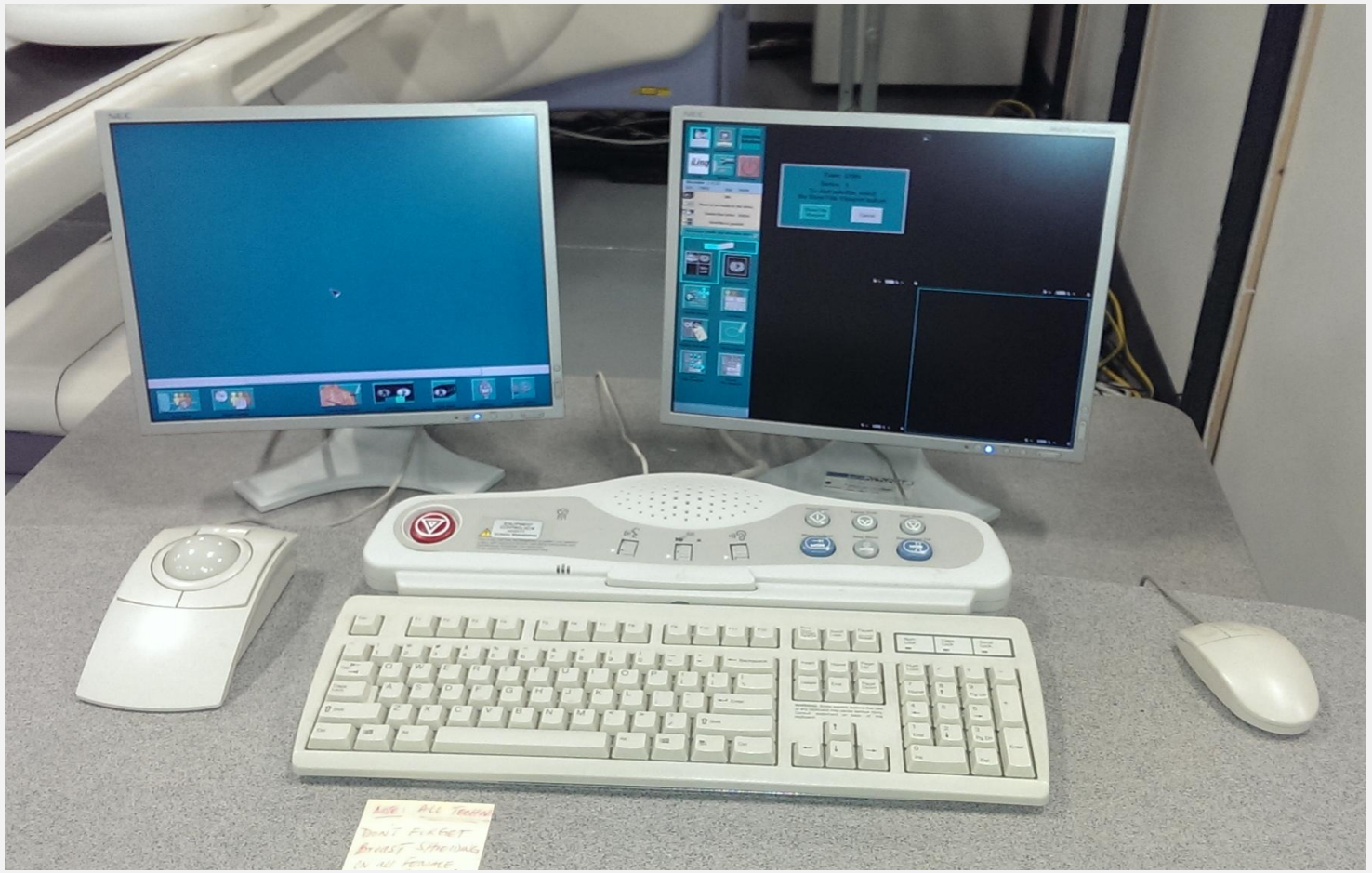
- The degree to which a table can move horizontally is called the scanable range
  - This determines the extent a patient can be scanned without repositioning



# Consoles

**CT Consoles - 2 types**

- **Operating**
  - Key Boards
  - Mouse
  - Flats Screens for viewing and programing
- **Viewing**

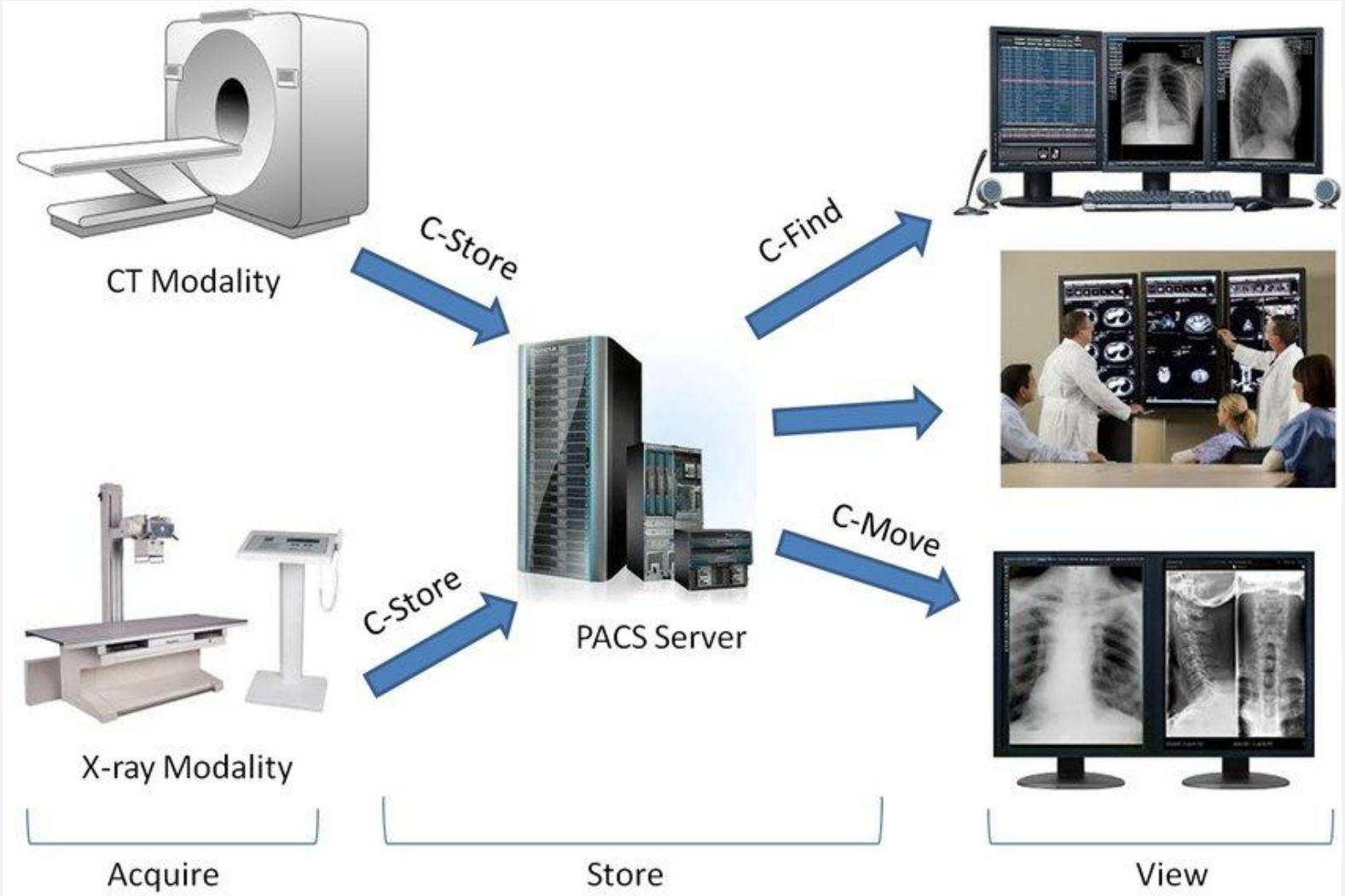


# Archival Devices

- Old Systems
  - Magnetic Tapes
  - Magnetic
    - Floppy and Hard
  - Film
- New Systems
  - CDs
  - PACS  (Picture Archiving and Communicating System)



# PACS


CT Modality
C-Store
C-Find
PACS Server
C-Move
C-Store
X-ray Modality
Acquire
Store
View