Spiral CT:
Single and Multiple Detector Systems

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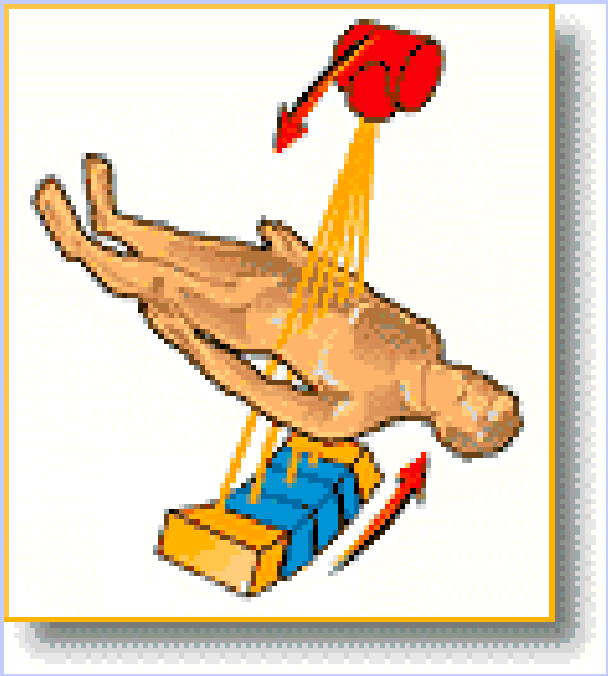
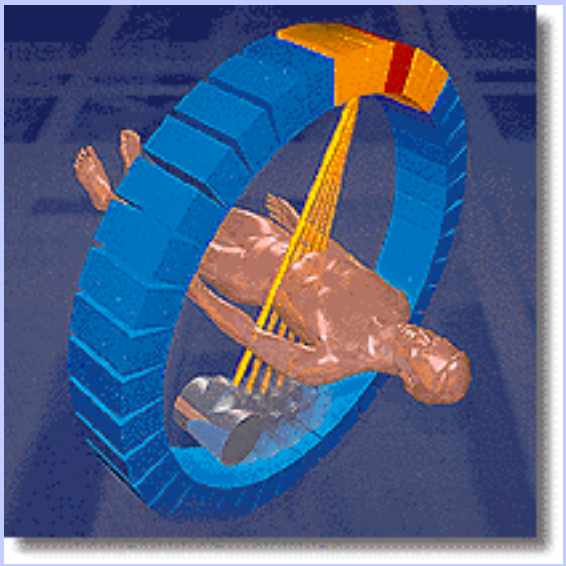
X-Ray CT Systems All Use:

- **Thinly Collimated X-Ray Beam**
- **Multiple Views**
- **Detectors to Collect X-Ray Photons**
- **Data Acquisition System**
- **Image Reconstruction Algorithm (Filtered Back Projection)**
- **Film/Monitors To Display Axial Slices**





3rd generation
rotate-rotate

4th generation
rotate-stationary

Conventional CT Systems (GE Hi-Lite Advantage) :

- **Tube Rotates Around Stationary Patient (Table is Incremented Between Acquisitions)**
- **All Views in a Slice are at Same Table Position**
- **Power to X-Ray Tube via Cord**
- **Scan CW and CCW to Wind/Unwind Cord**
- **Interscan Delays:**

  3.5 Seconds Between Slices

Spiral (Helical) CT Systems

Kalender's 1990 article was titled : "Spiral volumetric CT with single-breath-hold technique, continuous transport, and continuous scanner rotation."

Differences from Conventional:

- **Continuous Tube Rotation - No Interscan Delays (Power to X-ray Tube via Slip Ring)**
- **Continuous Table Motion as Tube Rotates**
- **Each View is at a DIFFERENT Table Position**

➡ **Form Images by Synthesizing Projection Data via Interpolation**

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Data Acquisition and Image Formation

- **Some Data Acquisition Parameters Behave as Always (kVp, mAs, Recon. Filter)**
- **Others (Collimation, Table Speed/Pitch, and Interpolation Algorithm) Interact to Influence Image Formation and Image Quality**
- **However, Image Formation has its own independent parameter- reconstruction interval**

Data Acquisition

$$\text{Pitch} = \frac{\text{Table Movement per Rotation}}{\text{Slice Collimation}}$$

(Essentially a measure of Relative Speed)

- **Contiguous Spiral**

  Pitch = 1 (10 mm / 10 mm)

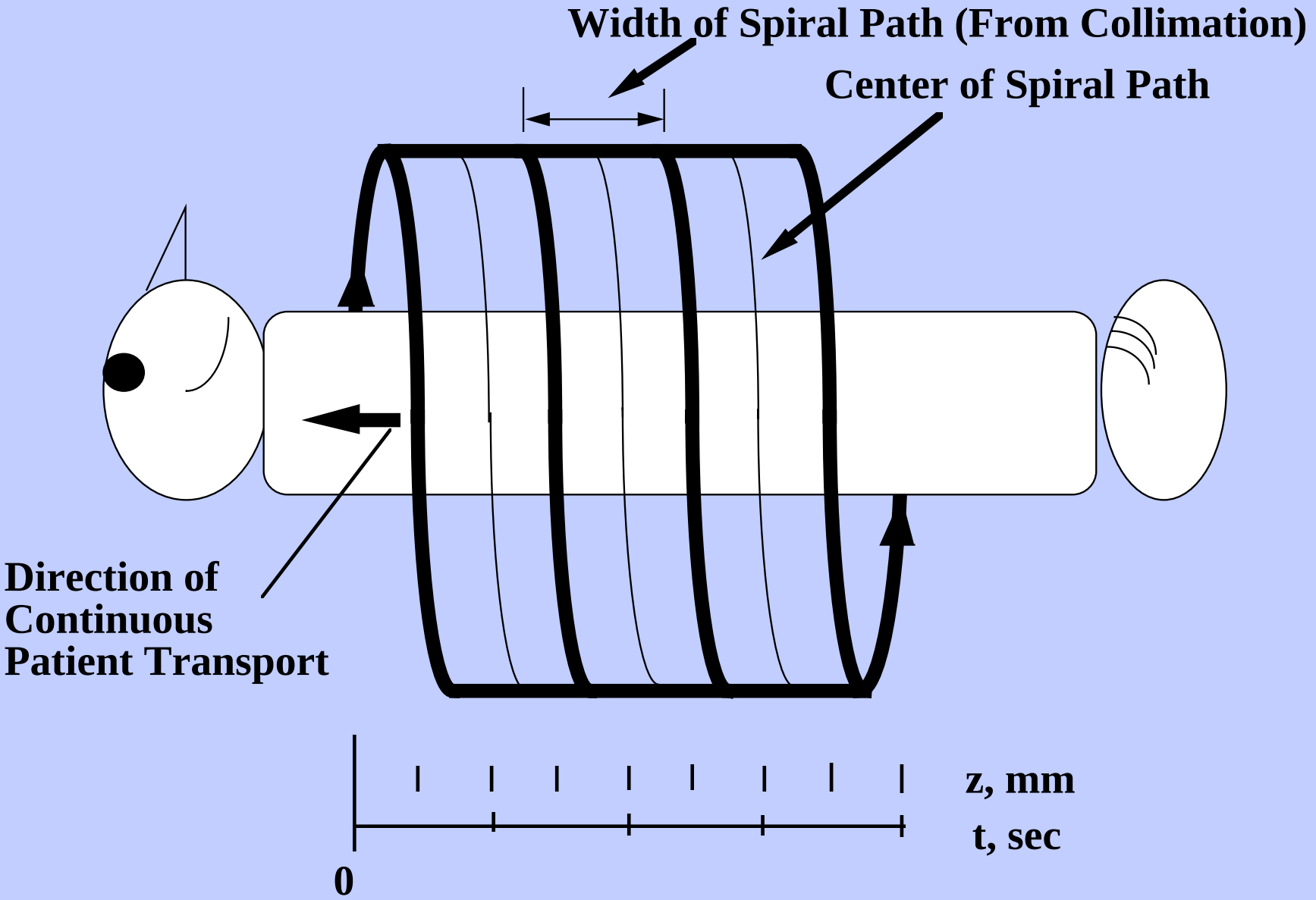
- **Extended (Non-Contiguous) Spiral**

  Pitch = 2 (20 mm/ 10 mm)

- **Overlapping Spiral**

  Pitch = 1/2 (5 mm / 10 mm)

Pitch=1; Contiguous Spiral



Pitch=2; Extended Spiral

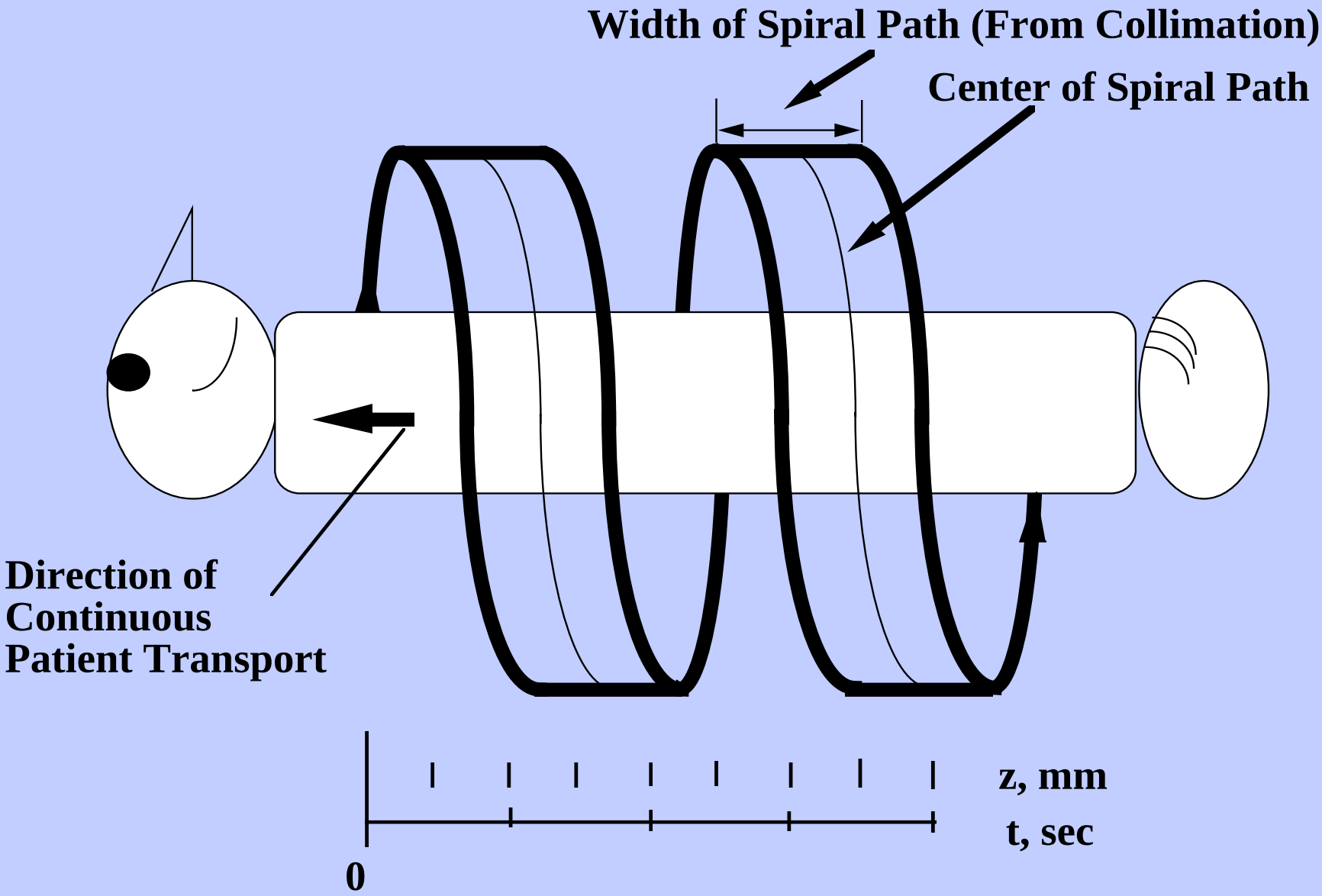
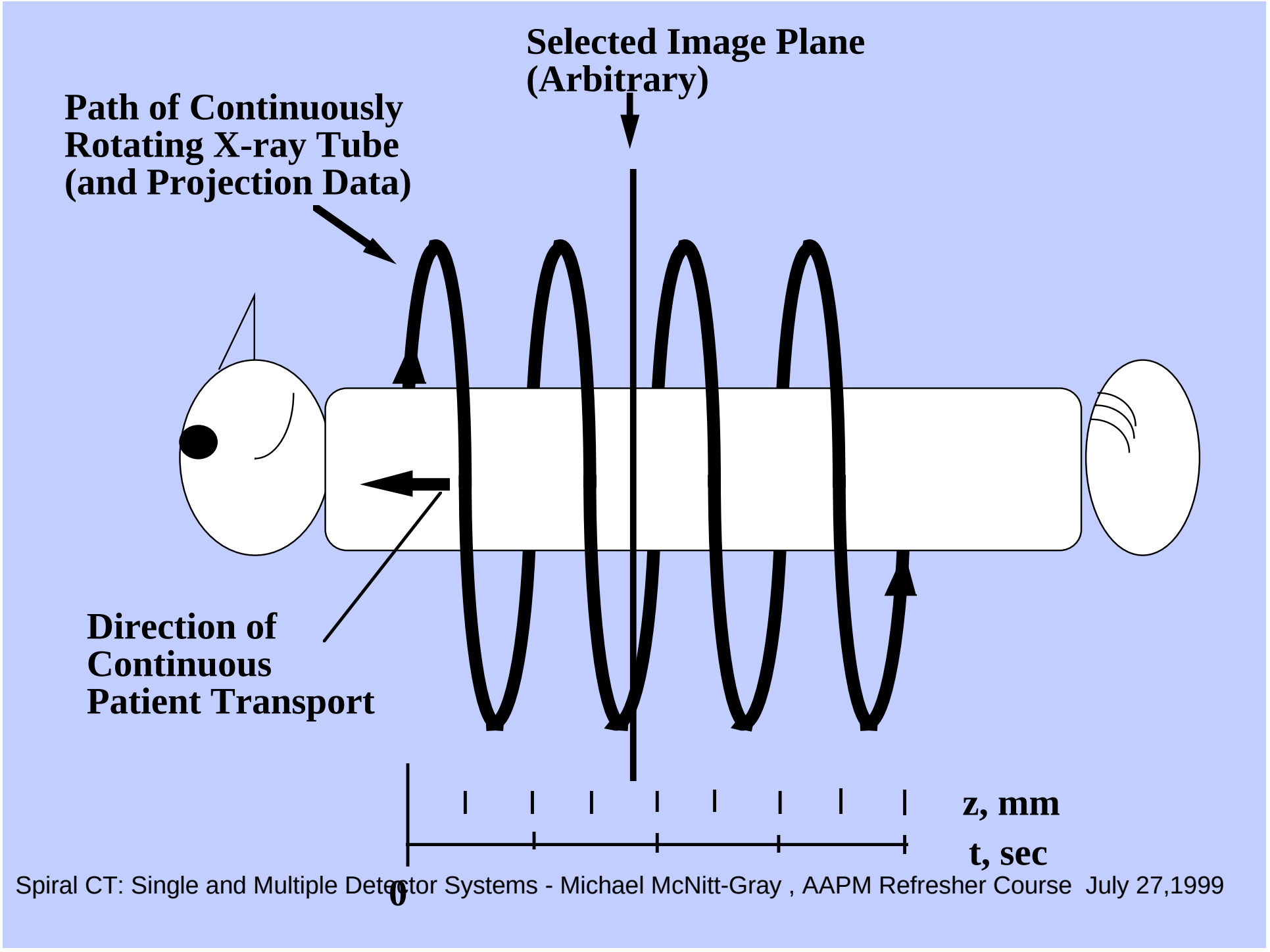
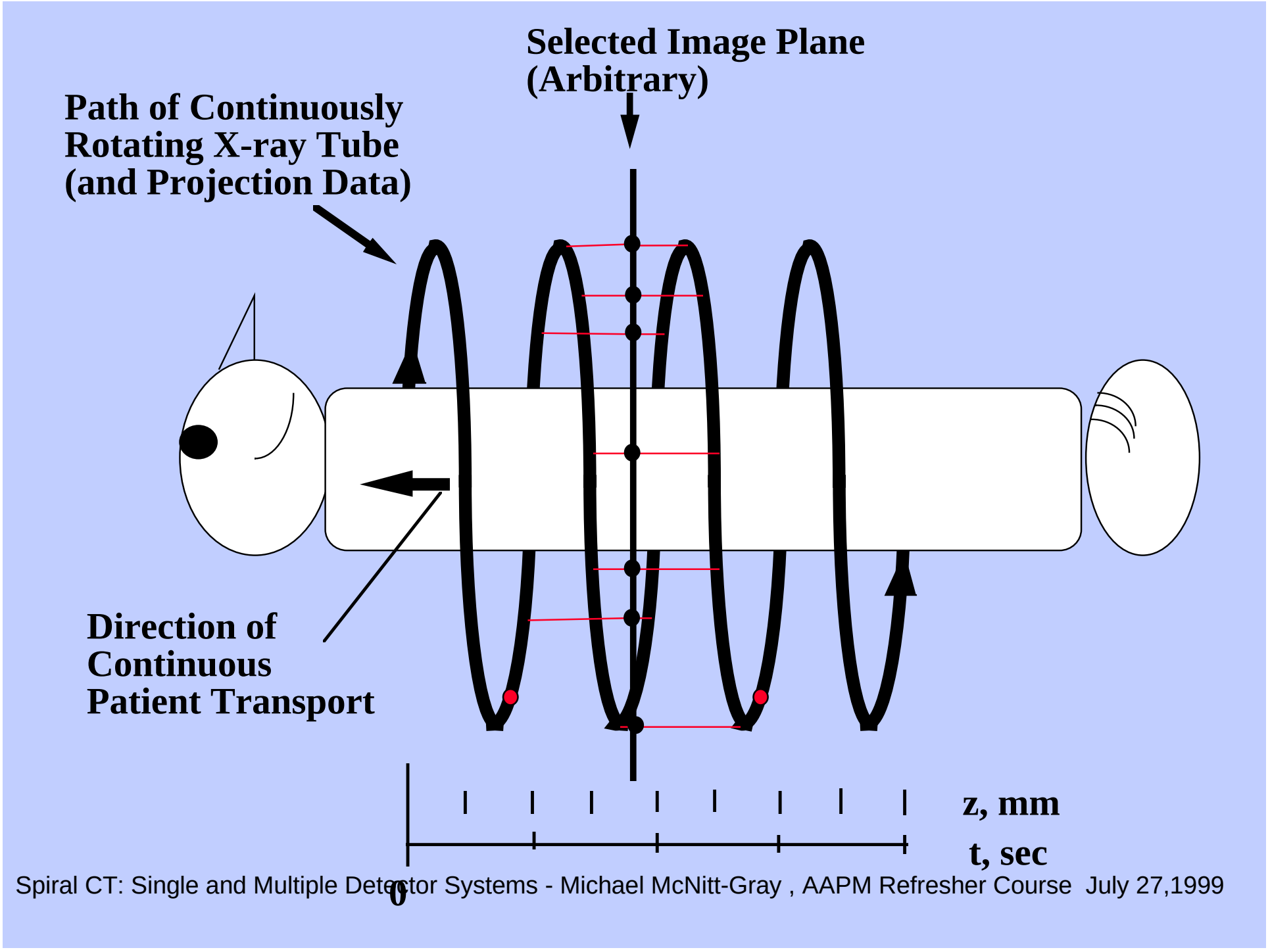


Image Formation

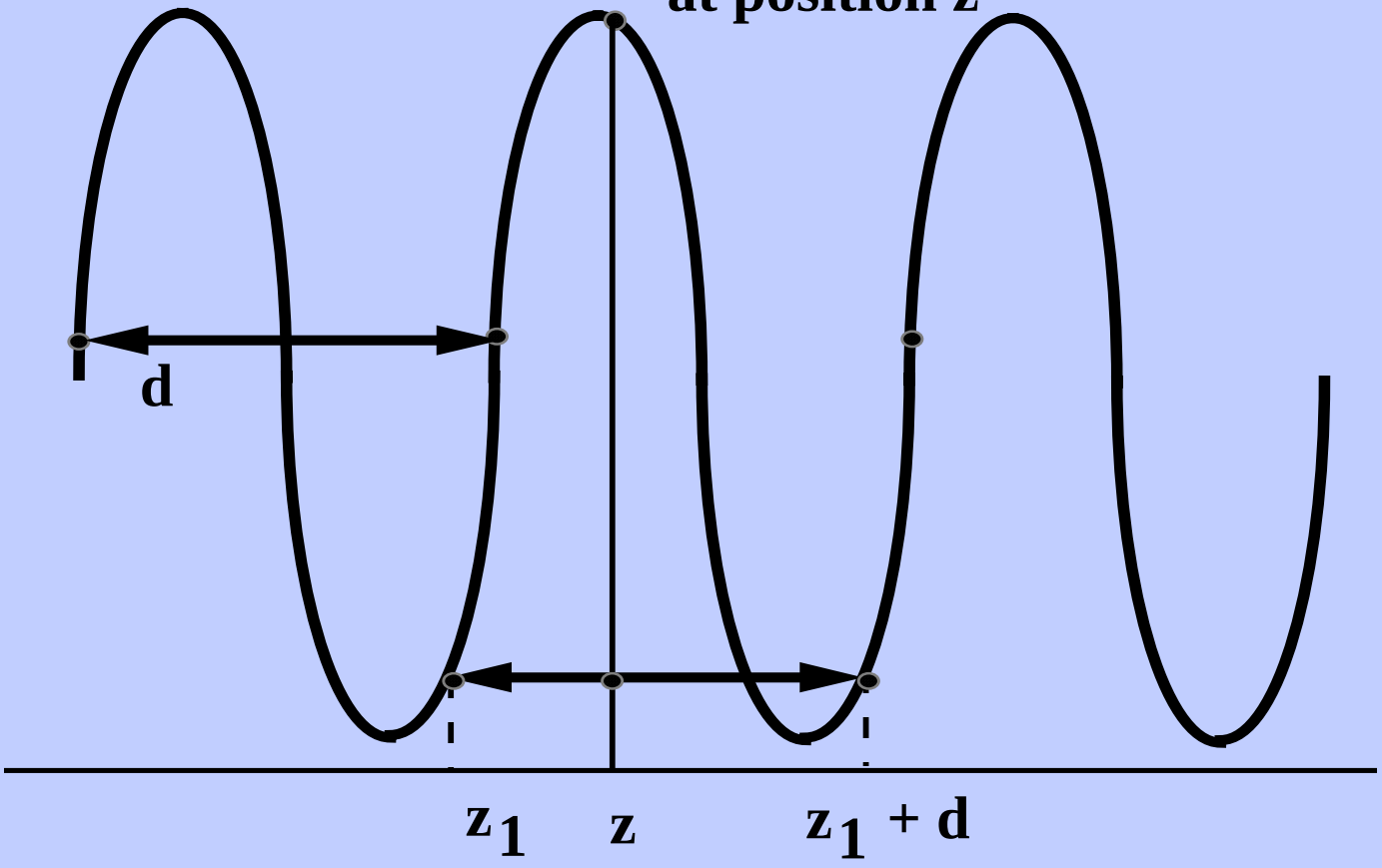
- **Collect Projection Data**
- **These Data are NOT all at same table position, so:**
- **Synthesize a set of Planar Projection Data via Interpolation (interpolate between views taken at same projection angle, but different table positions), then**
- **Use Filtered Back Projection on Synthesized Planar Data**
- **Because a VOLUME of data has been acquired, *IMAGE LOCATION IS ARBITRARY***


Selected Image Plane
(Arbitrary)
Path of Continuously
Rotating X-ray Tube
(and Projection Data)
Direction of
Continuous
Patient Transport
z, mm
t, sec
0


Selected Image Plane
(Arbitrary)
Path of Continuously
Rotating X-ray Tube
(and Projection Data)
Direction of
Continuous
Patient Transport
z, mm
t, sec
0

360 degree algorithm

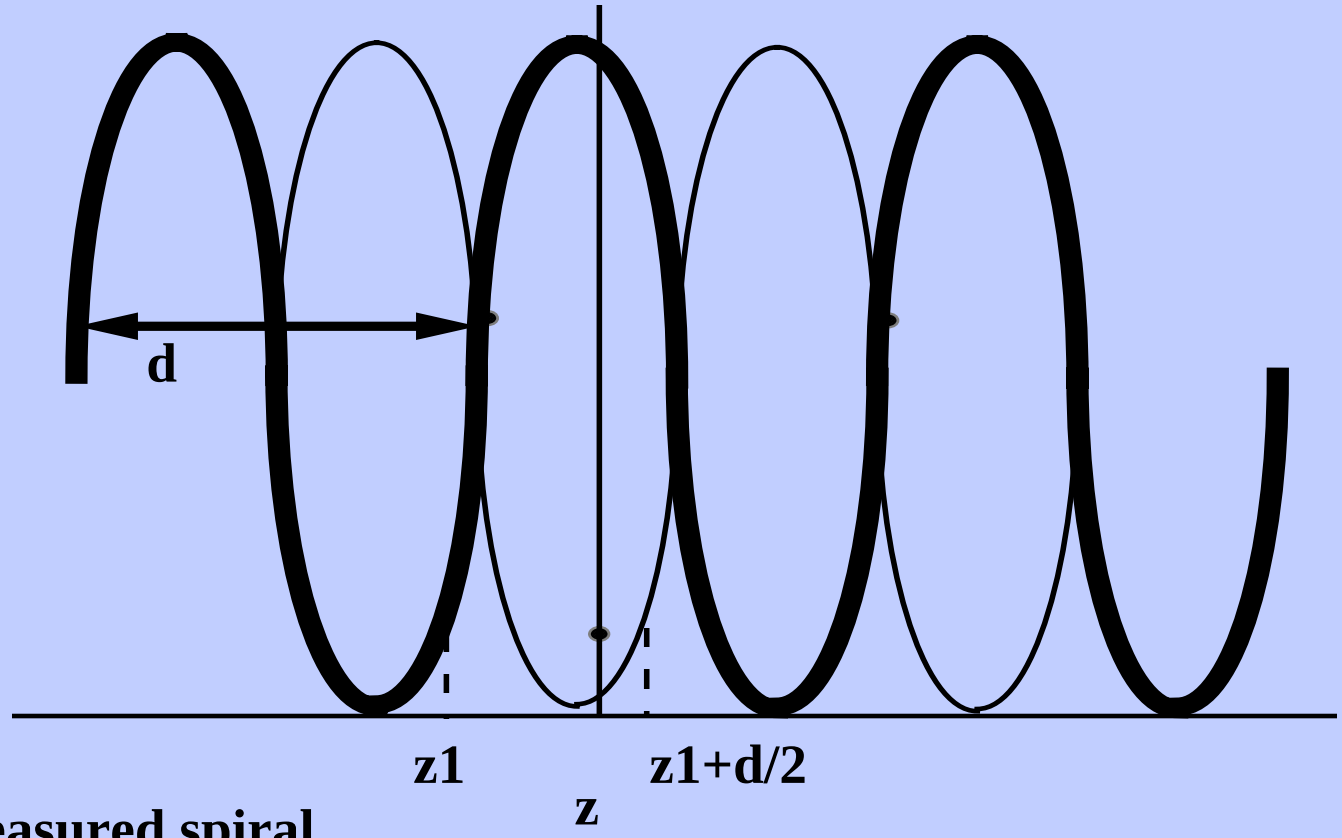
Arbitrarily selected planar section at position z



Planar data for arbitrary positions are calculated from spiral data by interpolation

180 Degree Algorithm

Arbitrarily selected planar section at position z



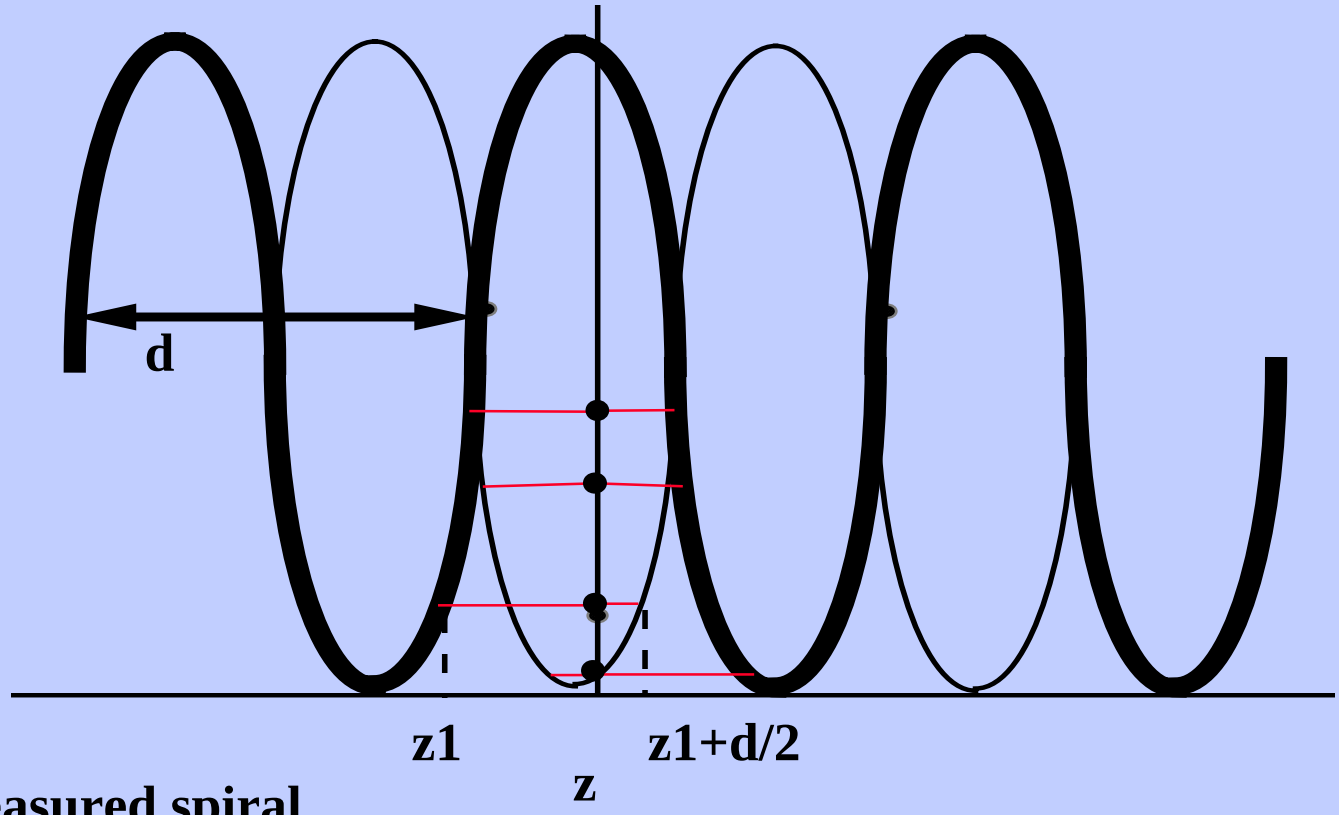
measured spiral

calculated spiral

Planar data for arbitrary positions are calculated from spiral data by interpolation

180 Degree Algorithm

Arbitrarily selected planar section at position z



measured spiral

calculated spiral

Planar data for arbitrary positions are calculated from spiral data by interpolation

Image Formation

- **Independent of IMAGE ACQUISITION PARAMETERS (Because a VOLUME of Data is Acquired and Interpolation is used)**

  Images can be formed ANYWHERE -->

  Slice Location is Arbitrary

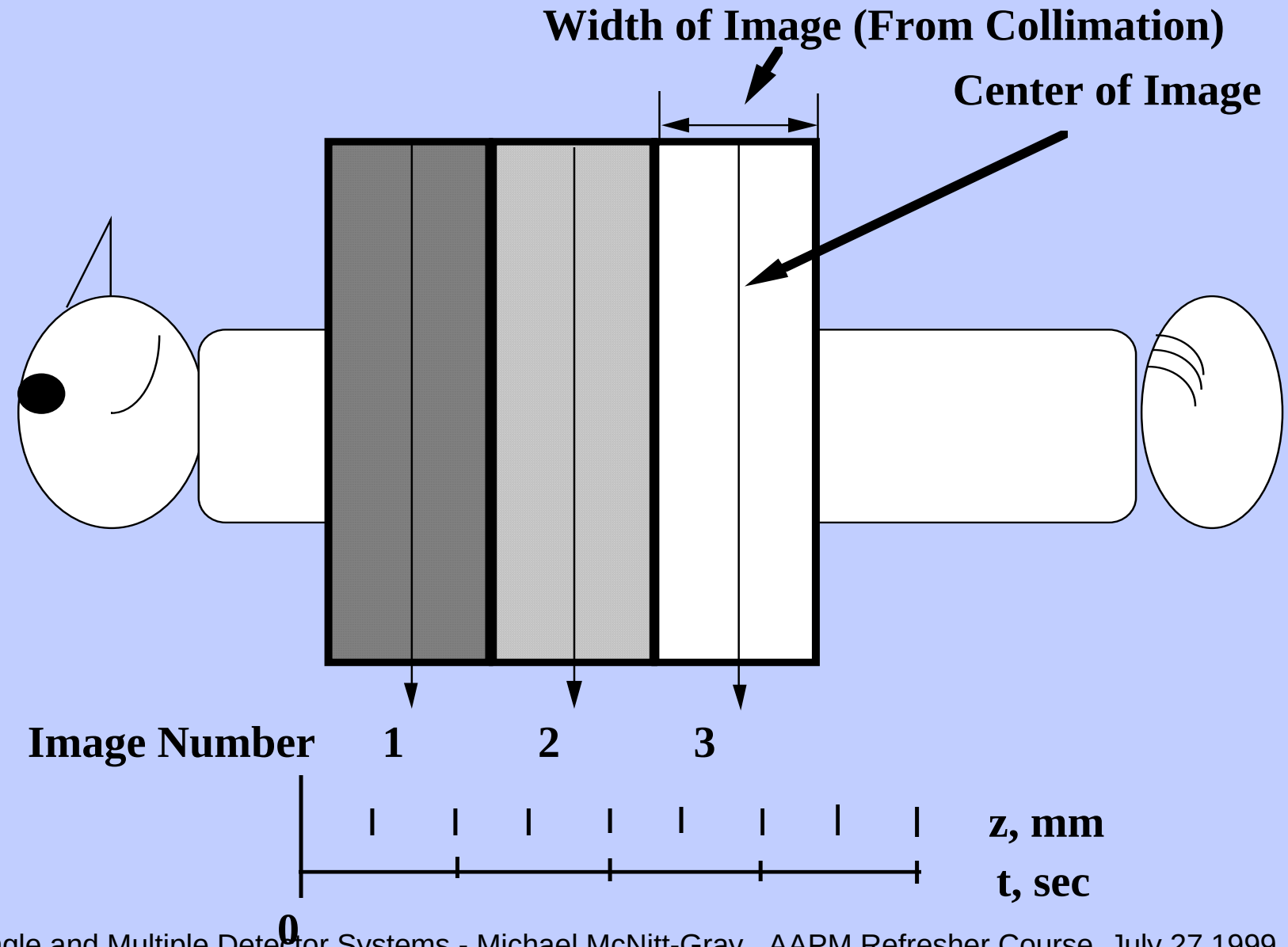
- **Overlapping Images can be created**

  FROM A SINGLE VOLUMETRIC SCAN

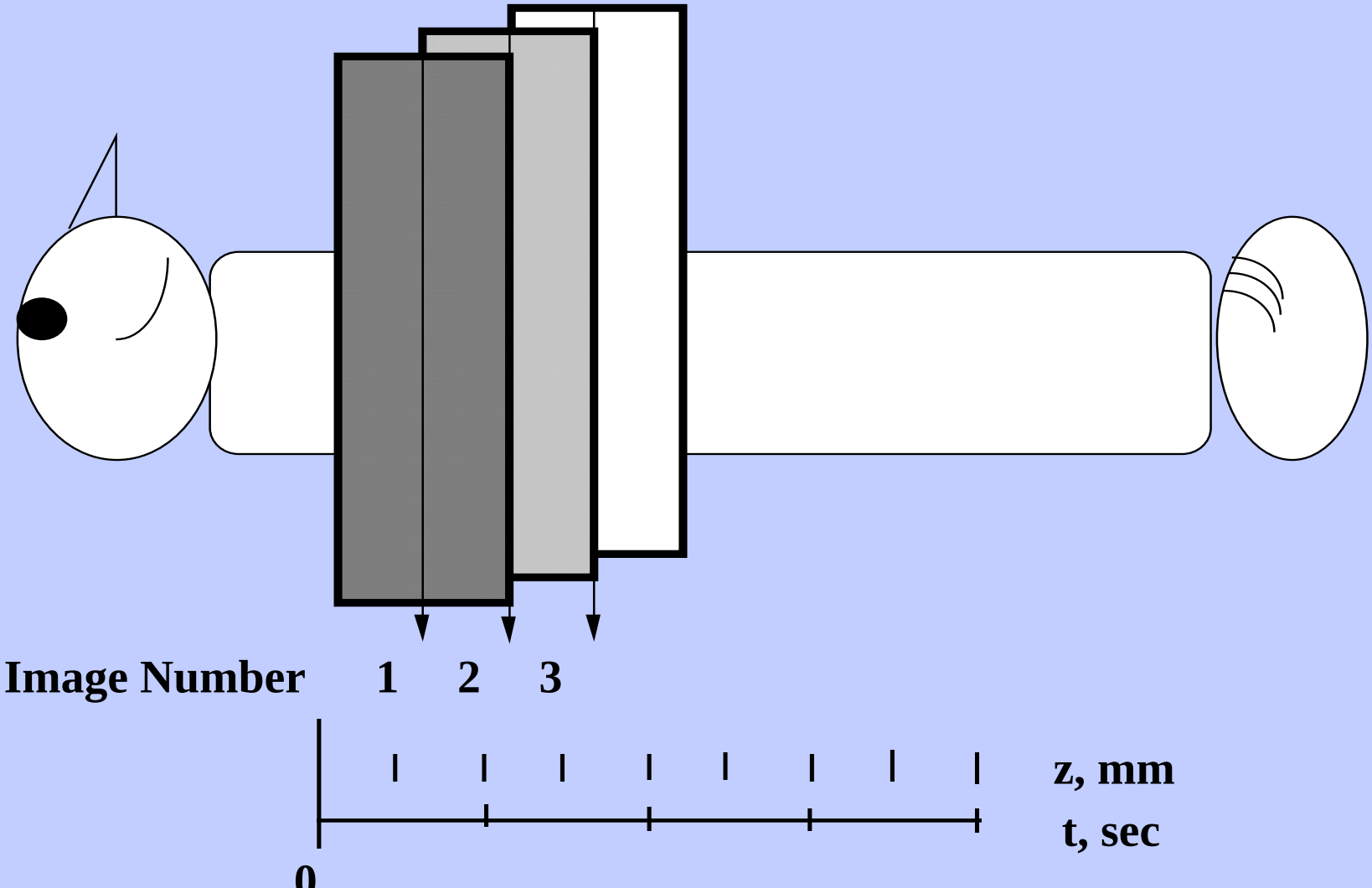
  - **(e.g. 10 mm thick, 5 mm apart).**

- **Effective Slice Thickness Is Determined by Acquisition Parameters (Collimation, Pitch) and Interpolation**

Contiguous Reconstruction - No Overlap



Overlapping Reconstruction - 50% Overlap



Contiguous reconstruction - object aligned with slices

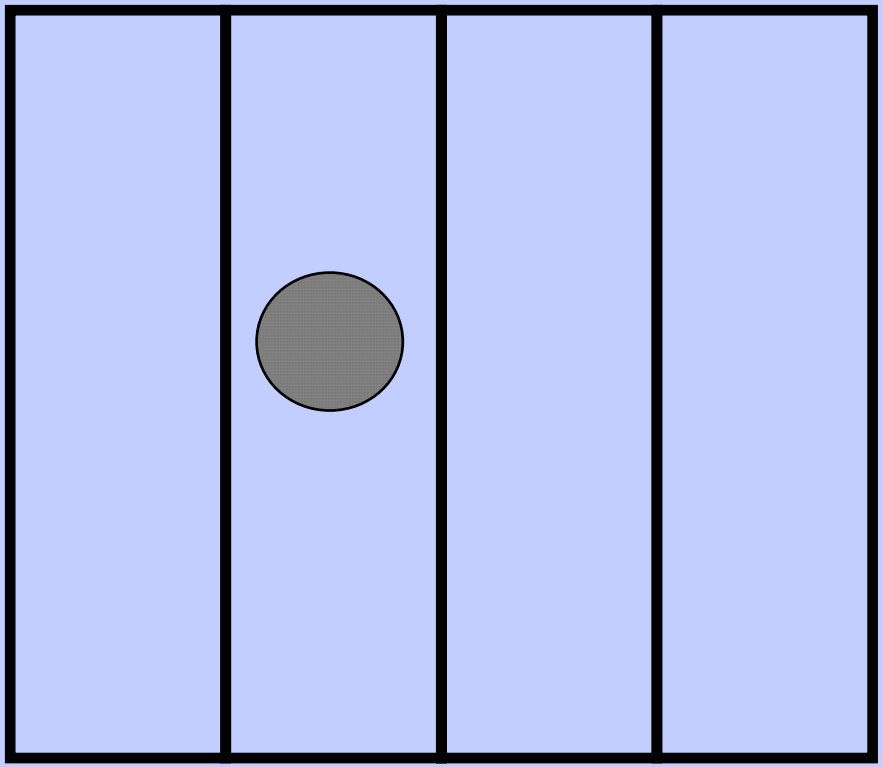


Image Number 1 2 3 4

Contiguous reconstruction - object aligned in between slices

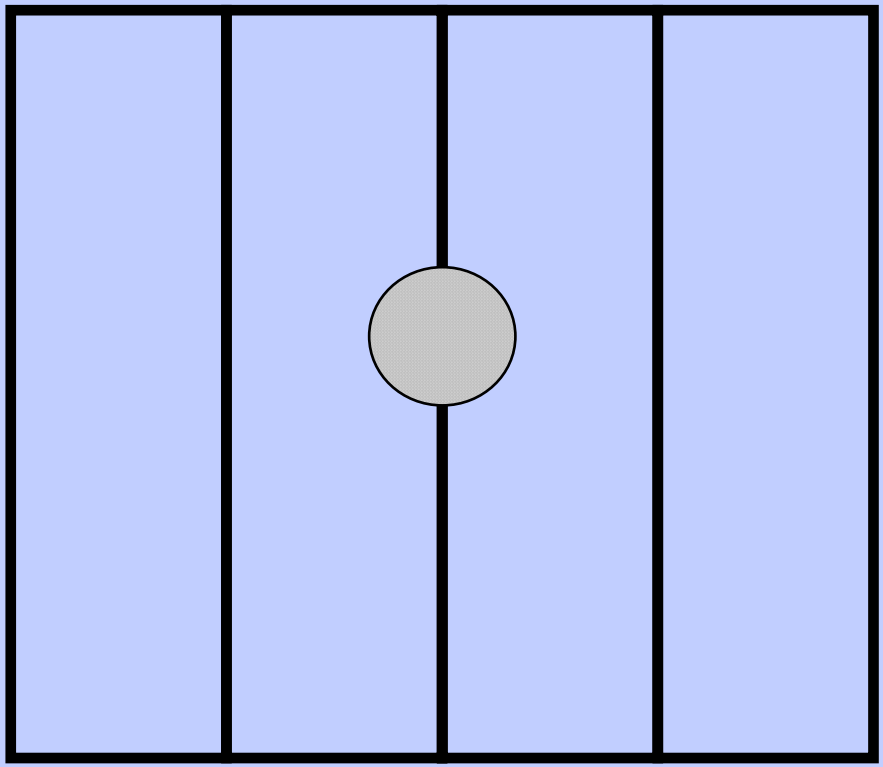
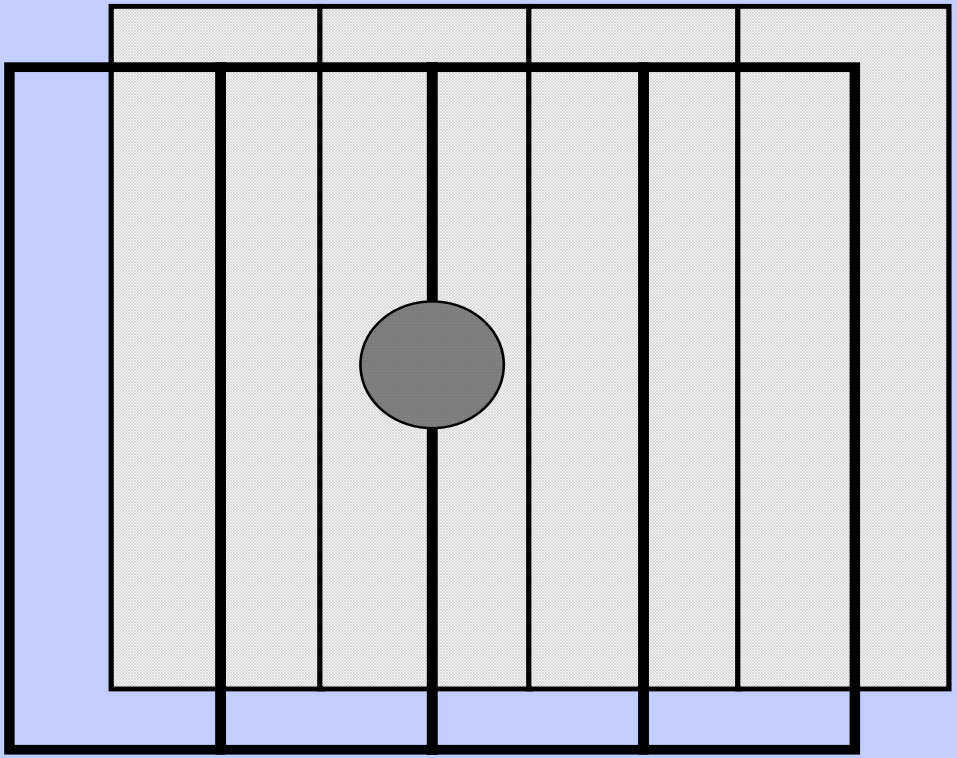


Image Number 1 2 3 4

Overlapping reconstruction - object aligned in between slices



2 4 6 8

Image Number 1 3 5 7

Note: Object is Volume Averaged in Slices 3 and 5, but contained completely within slice 4

Spiral CT - Differences From Axial

Image Quality (Assuming 180 interp. algorithm):

- **Effective Slice Thickness Increases with Pitch**
  (~10% increase for pitch 1; ~ 30% for pitch 2;
  ~ 70% for pitch 3)
- **Hence volume averaging increases with pitch**
- **Noise is > Conventional Axial under identical acquisition conditions, but does not change w/ pitch**

Spiral CT - Differences From Axial

Radiation Dose:

For Pitch of 1 ~ Same as Comparable Contiguous Conventional Scans

For Pitch 1.5 - Approximately 2/3 that of Contiguous Scans

For Pitch 2 - Approximately 1/2 of Contiguous Scans

- **Radiation Dose Proportional to 1/pitch**

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What's Next ?

Faster, Thinner Spirals with LOTS of Images

- **Faster Tube Rotation Times**
- **Greater Heat Capacity Tubes**
- **More Detector Planes**
- **Faster Image Reconstruction**

Faster Tube Rotation Times

Most Major CT Mfrs now offer subsecond scanners between .5 - .8 s for a full rotation

However, to get same photon statistics with shorter exposure time means tube current must increase

➡ **need higher kW generators and higher Heat Capacity Tubes to sustain tube currents.**

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Tubes with Greater Heat Capacity

Current Tubes are Typically 2-3 MHU
(Axial Scanners used < 1 MHU)

Top of Line NOW are > 6 MHU

This allows longer spirals
(less tube cooling delays)

Also allows increase in tube current to offset reduced scan times

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More Detector Planes

Elscint CT-Twin in 1994 had two adjacent detectors

This allowed simultaneous acquisition of 2 images - 2 X coverage for same scan time

Now GE, Siemens, Picker and Toshiba have, or have announced, Multidetector systems

Collect Multiple Slices Simultaneously to:

Cover More Patient in the Same Time

Cover Same Amount of Patient, but w/ Thinner Slices

Scan a Volume at Arterial Phase, Venous Phase, Parenchymal Phase after Contrast Injection

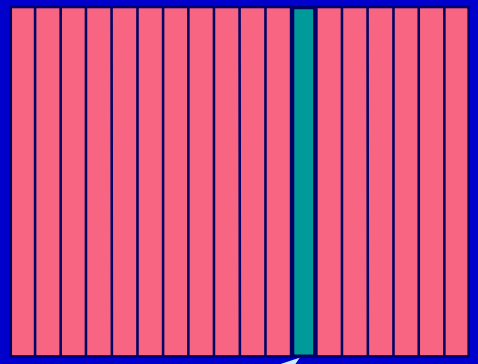
GE- 4 Row Detector

- **16 rows of detectors, use 4 at a time**
- **Allows collection of 4x1.25 mm slices (or 4x2.5, or 4x5) SIMULTANEOUSLY**
- **Will go to 16 rows simultaneous when data transfer is quick enough**

LightSpeed Matrix Detector

HiLight Detector

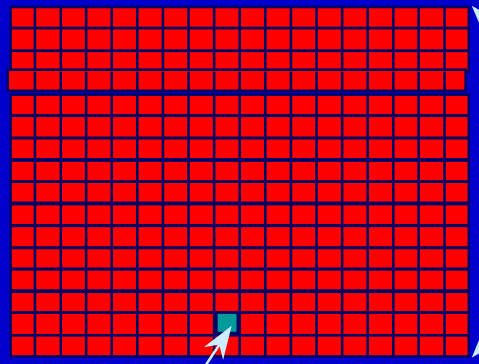
852 channels in 49^{o} degree arc



Each channel is 1 mm wide by 20 mm tall

LightSpeed Matrix Detector

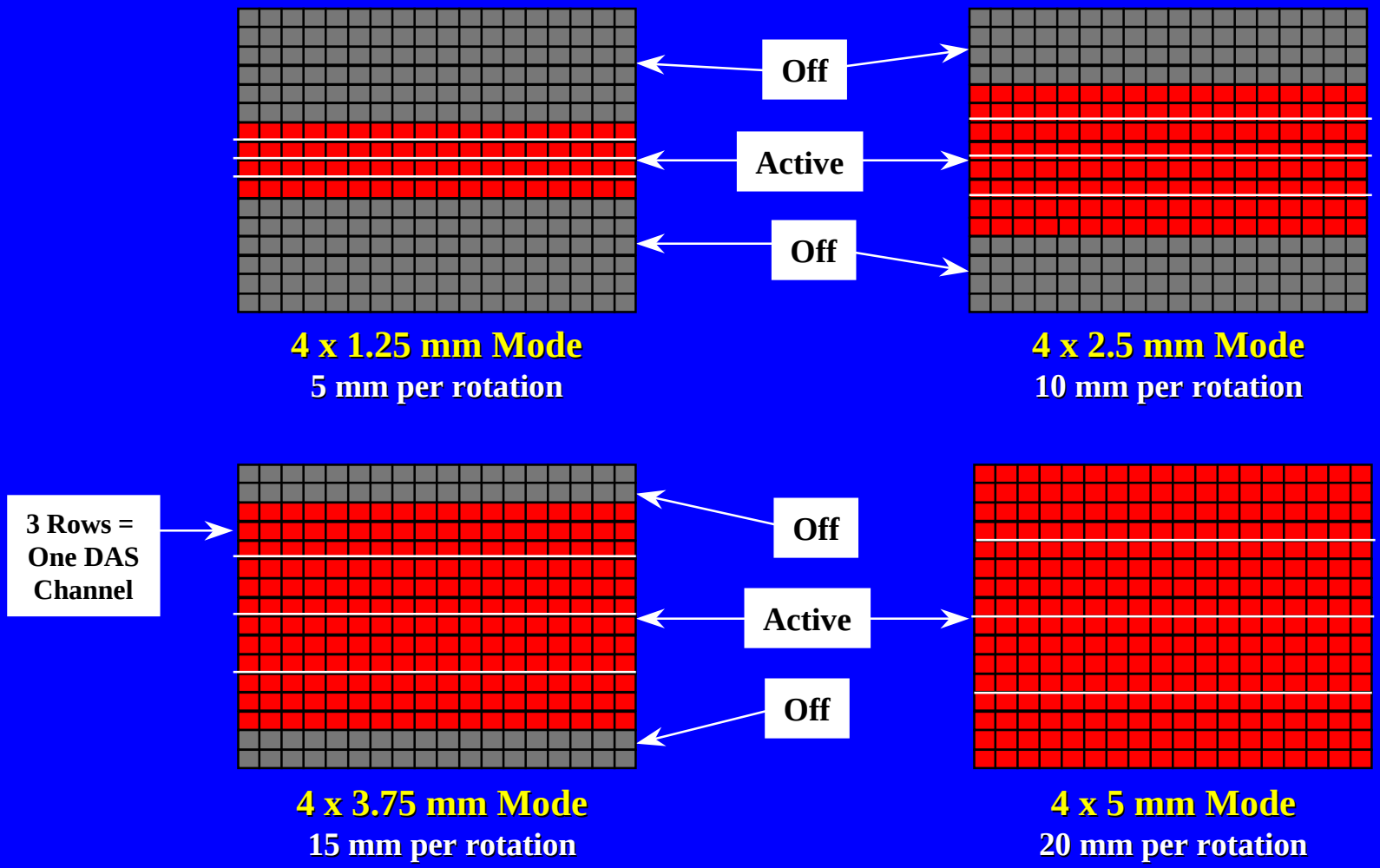
14,592 elements in 55^{o} degree arc



16 Rows x 912 Channels

Each ELEMENT is 1 mm wide by 1.25 mm tall

How Is It Used?

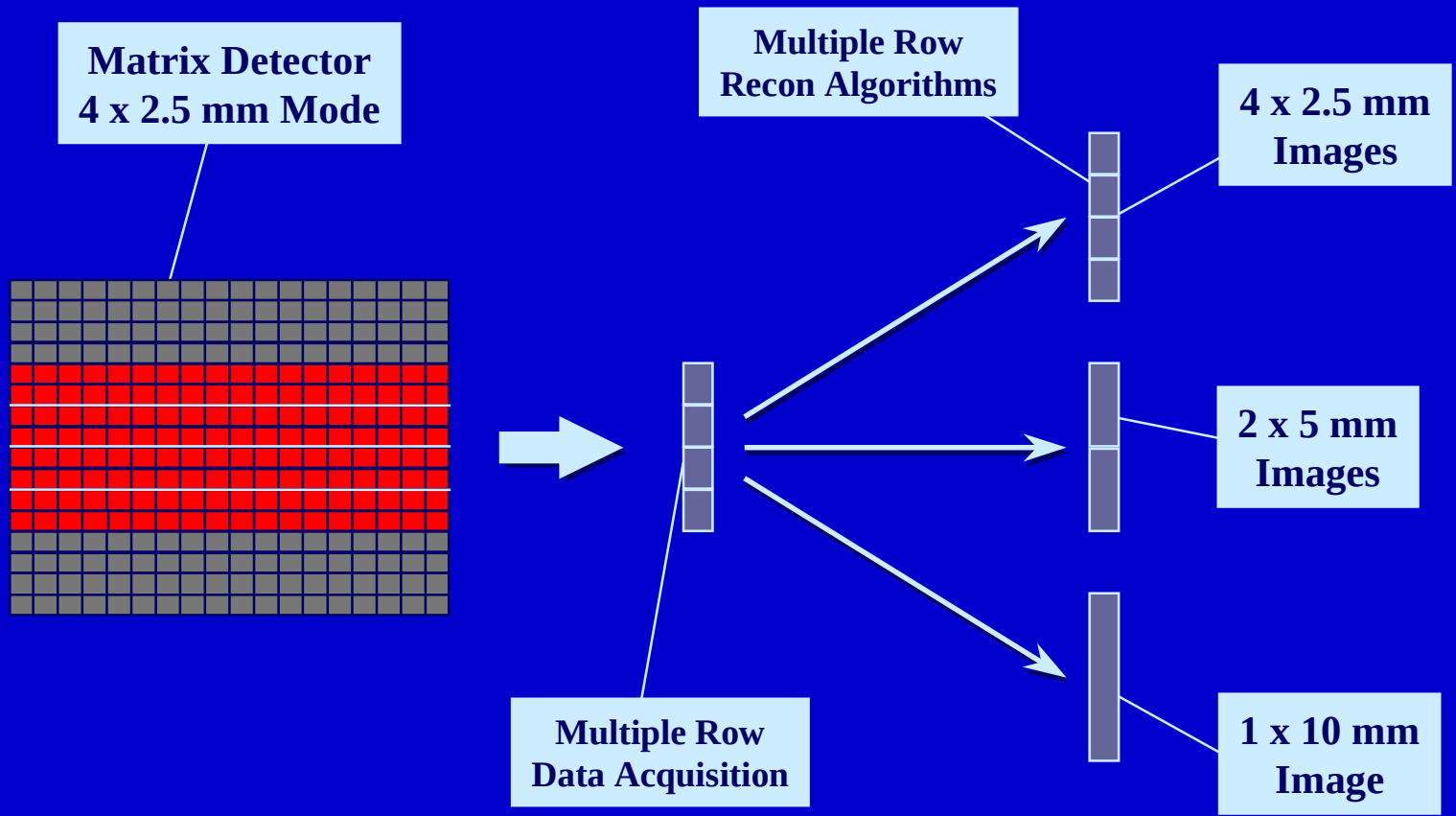


Helical Imaging Modes

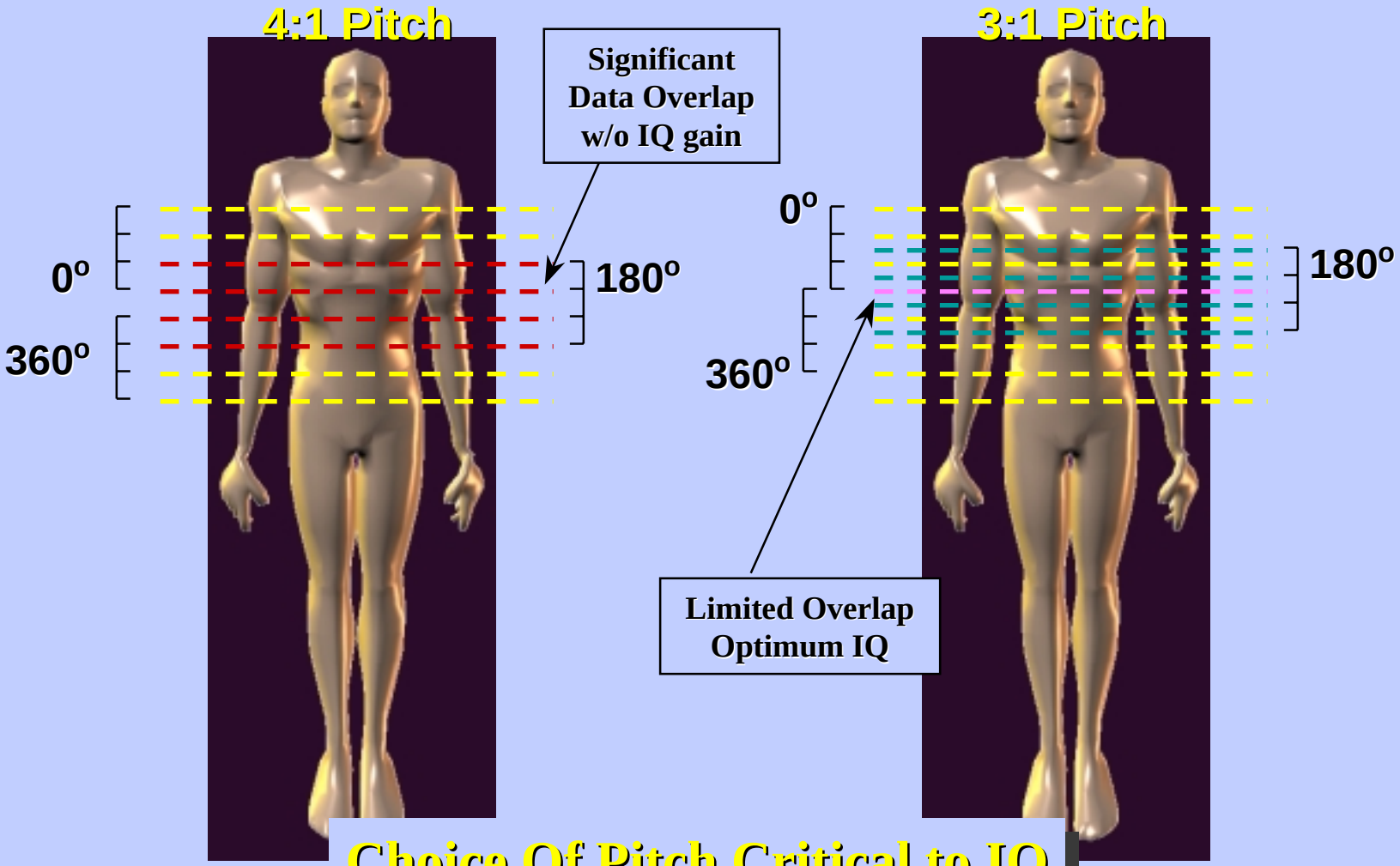
Detector Configurations	Image Thicknesses	Table Travel Per Rotation	
		HQ	HS
4 x 1.25 mm	1.25, 2.5 mm	3.75 mm	7.5 mm
4 x 2.5 mm	2.5, 3.75, 5.0 mm	7.5 mm	15 mm
4 x 3.75 mm	3.75*, 5.0, 7.5 mm	11.25 mm	22.5 mm
4 x 5 mm	5.0, 7.5, 10.0 mm	15 mm	30 mm

Note: * 3.75 mm thickness not available at 22.5 mm/rot

Acquisition & Reconstruction



More Complex Than Single-Slice



Choice Of Pitch Critical to IQ

Faster Reconstructions

Currently about 2-3 seconds per image

In some commercial packages (options)

~ 1 second

Faster Computers and Dedicated Processors will reduce this < 1 sec/image

What will the Current/Near Future System Look Like?

Fast Tube/Gantry Rotation (☯ .5 second)

Tube Heat Capacity > 6 MHU

MultiDetector System (4 now with pathways to 16 and up to 34 depending on manufacturer)

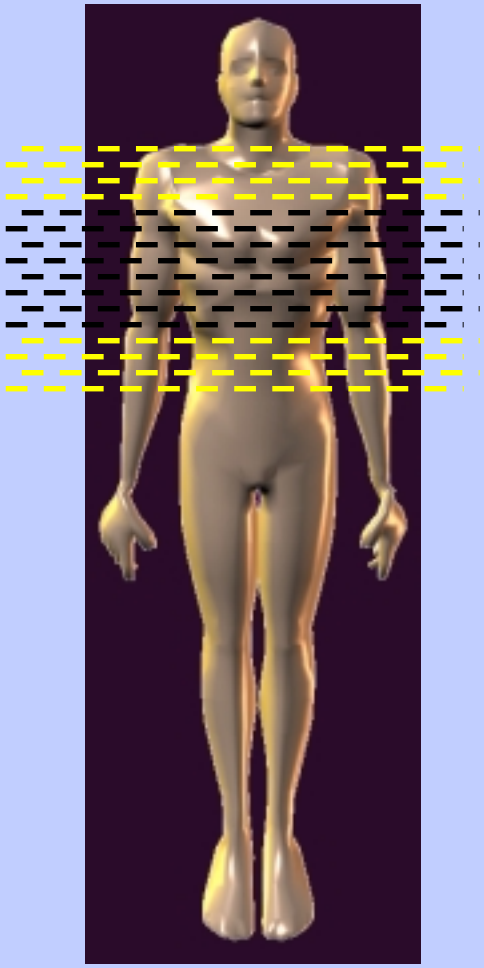
Faster Reconstruction Times (subsecond)

Hundreds (Thousands?) of Images Possible

How to review all these?

What Will You Be Able to Do?

Single Breath Thoracic Scan -
Cover 35 cm w/ 1.25 mm slices <10 s



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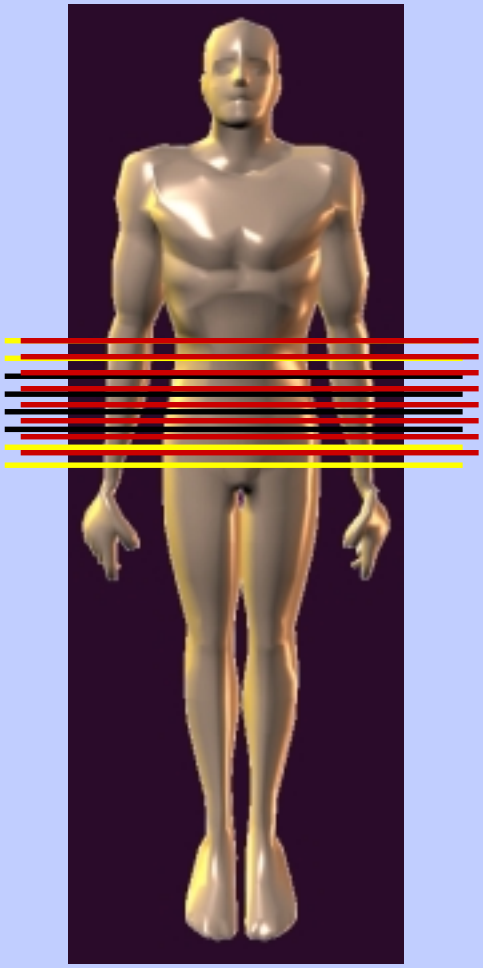
What Will You Be Able to Do?

Two Phase Liver with Contrast -
Cover 12 cm w/1.25 mm slices 2X
(up and back) in <(8s + scan delay of ~5s)



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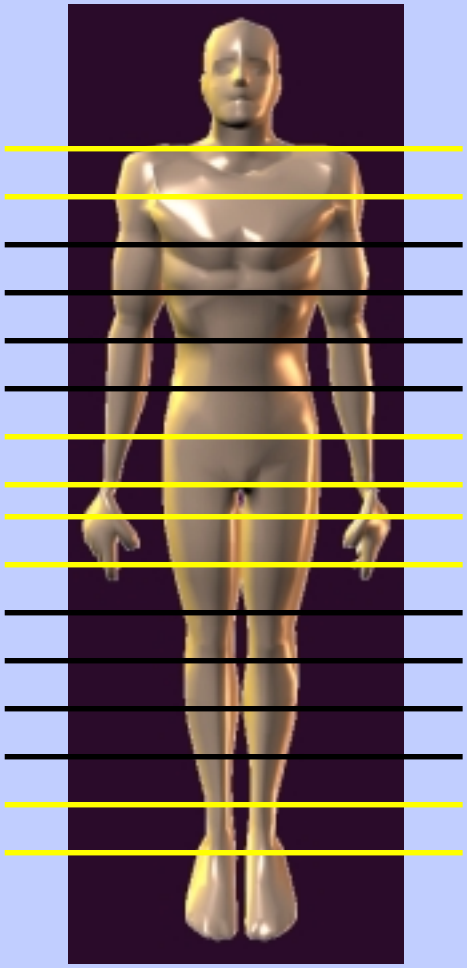
What Will You Be Able to Do?

ER Trauma Case
Cover 180 cm (head to toe) in a single
48 s scan with 5mm (soon with 1.25mm)



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