The State of the Art in CT
or
I can diagnose that case in 1 mSv!

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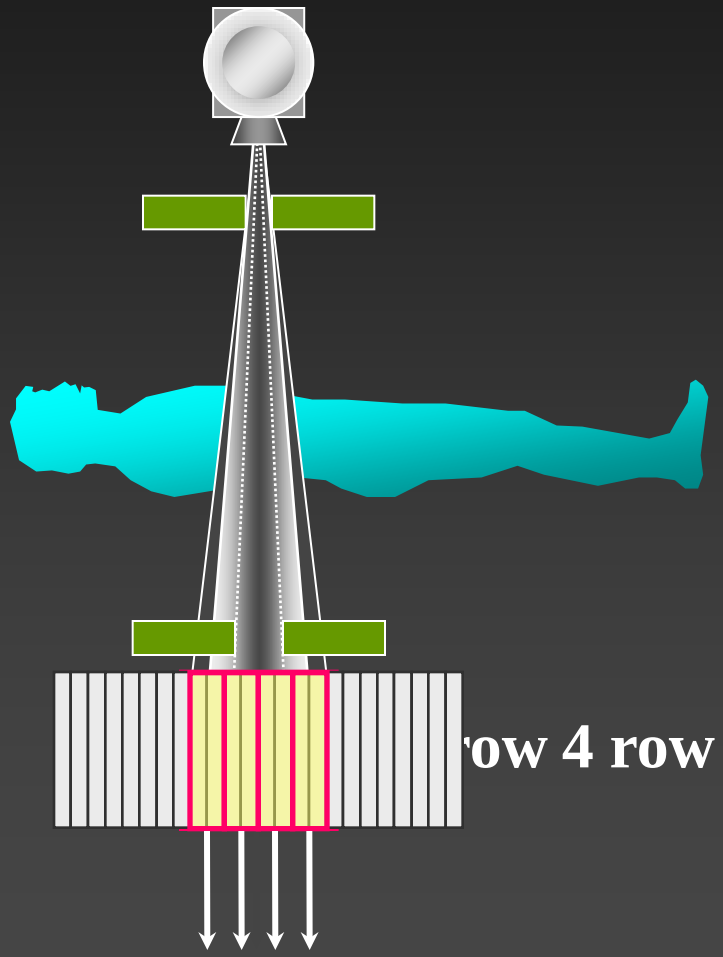
Where have we come (read “outline”)

- CT evolution from single to multi, slow to fast
- Hardware dose reduction
- Software dose reduction
- Conclusions

- Notes
  - I will call out vendor unique technologies, otherwise they are common. I received slides from all vendors.
  - Focus is on dose reduction. There are many other advanced technologies that can’t be covered in 20 minutes!

CT Evolution

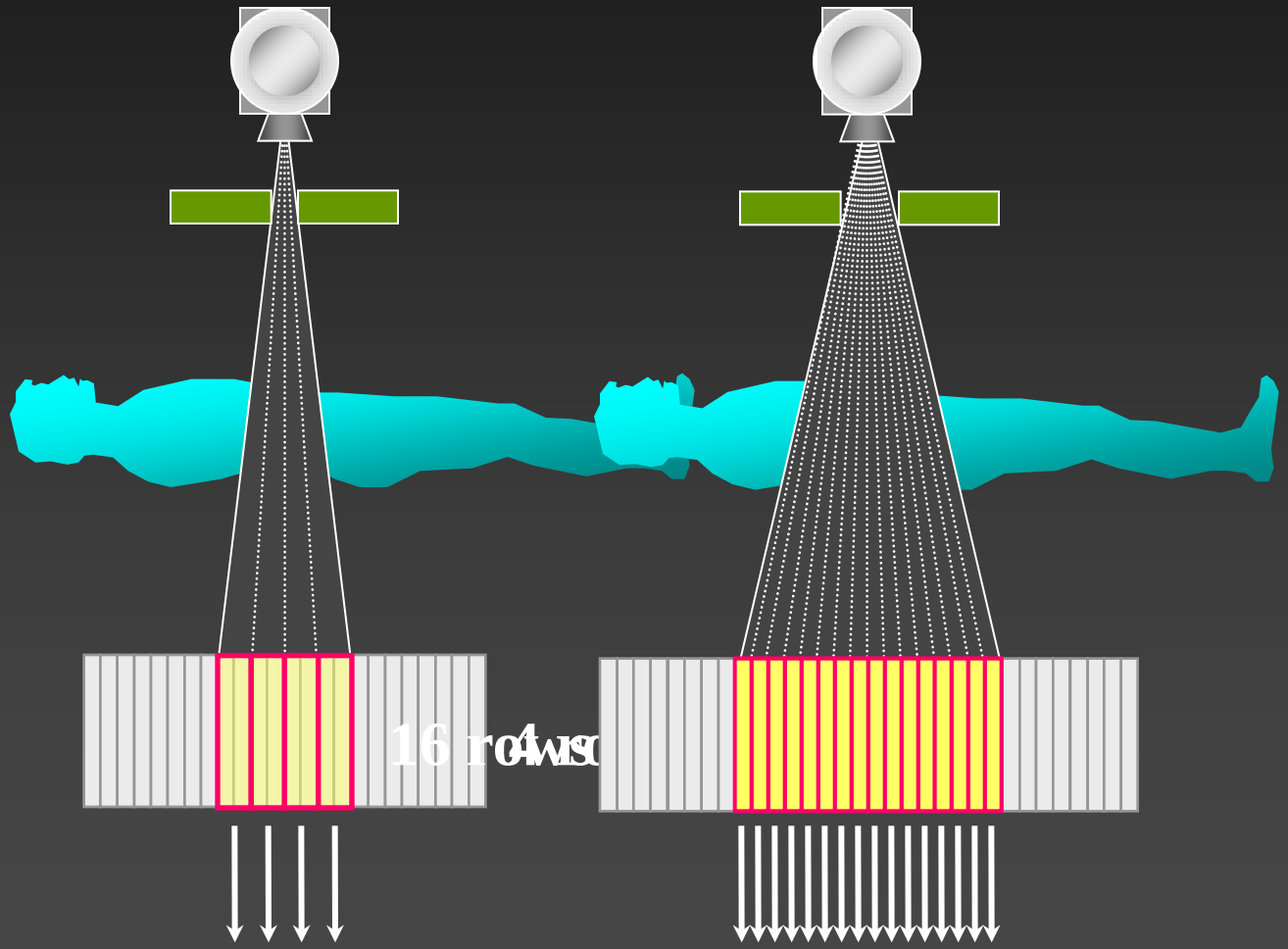


Multi Slice

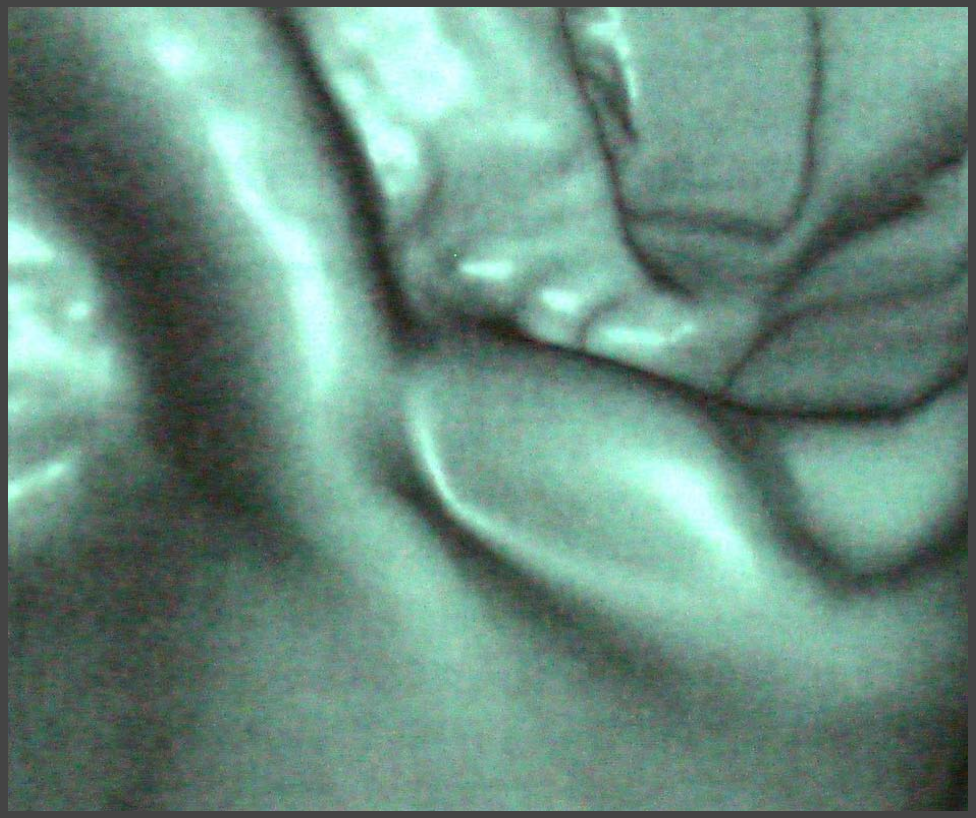
4-Row Scanner

- Quantum leap over single slice
- Enabled true volume coverage
- Limitations
  - Tradeoff between coverage and slice thickness (resolution)
  - Not enough coverage for cardiac scanning
  - Dose penalty for thin slices

CT Evolution

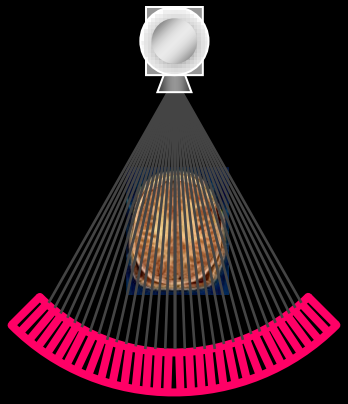


3 mm. Polyp

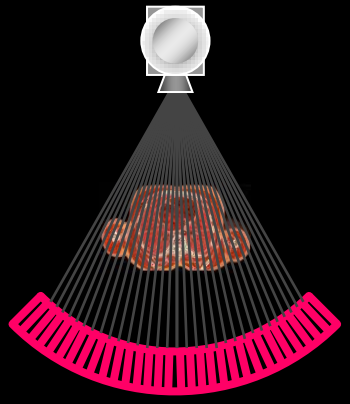


3 mm. Slices

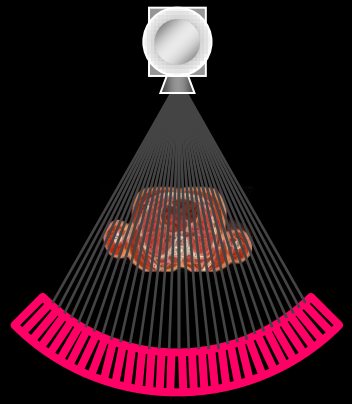
Rotation Speed



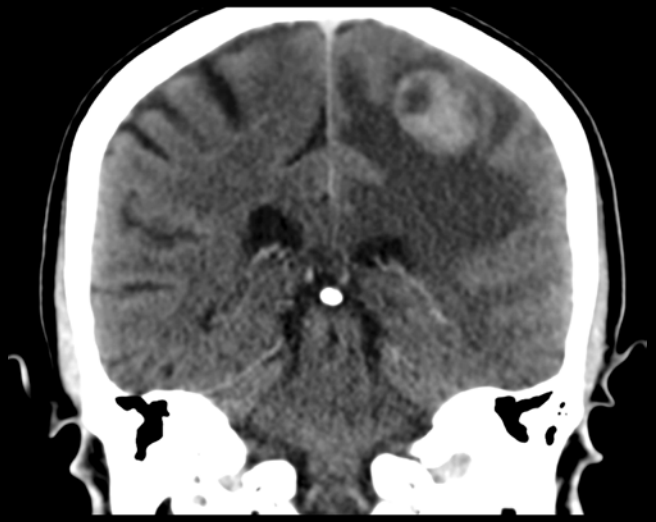
1 sec rotation



0.5 sec rotation

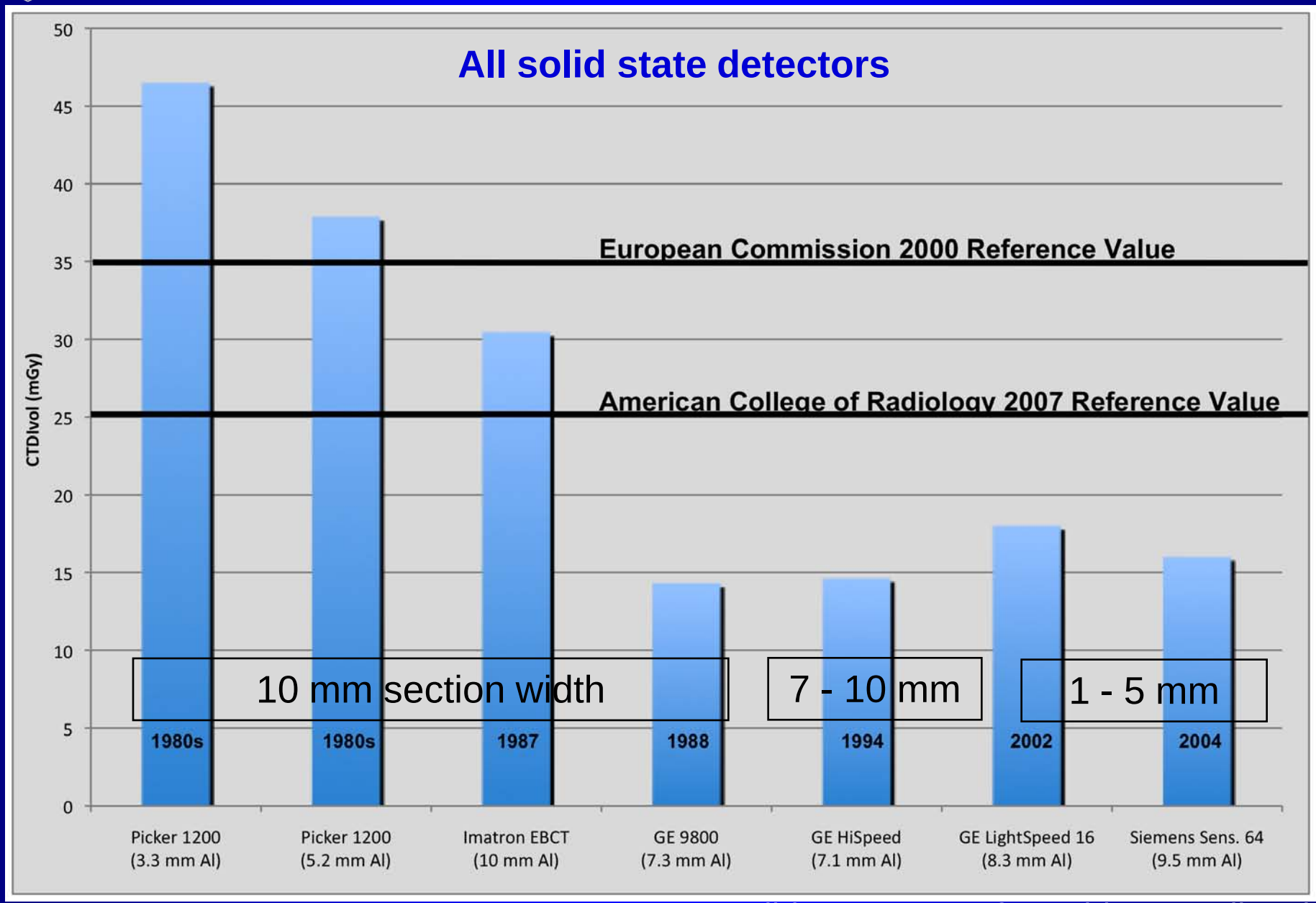


0.3 sec rotation



MAYO CLINIC

Routine Body CT Doses over 2 Decades



Slide Courtesy of Cynthia McCollough

Dose Reduction

- Not just about the scanner
- Many players
  - Radiologist, technologist, medical physicist
  - Applications specialist, development engineer
  - Academic researcher, industry researcher
- Ultimate goal
  - Right scan on the right patient with the right dose

Top-of-the-Line Scanners

GE Discovery CT750 HD

- Fast kV switching
- HD mode
- Gemstone Detector
- ASiR

Philips Brilliance iCT

- 256 slices
- iDose^4
- 8 cm volume
- 0.27s rotation

Siemens Flash

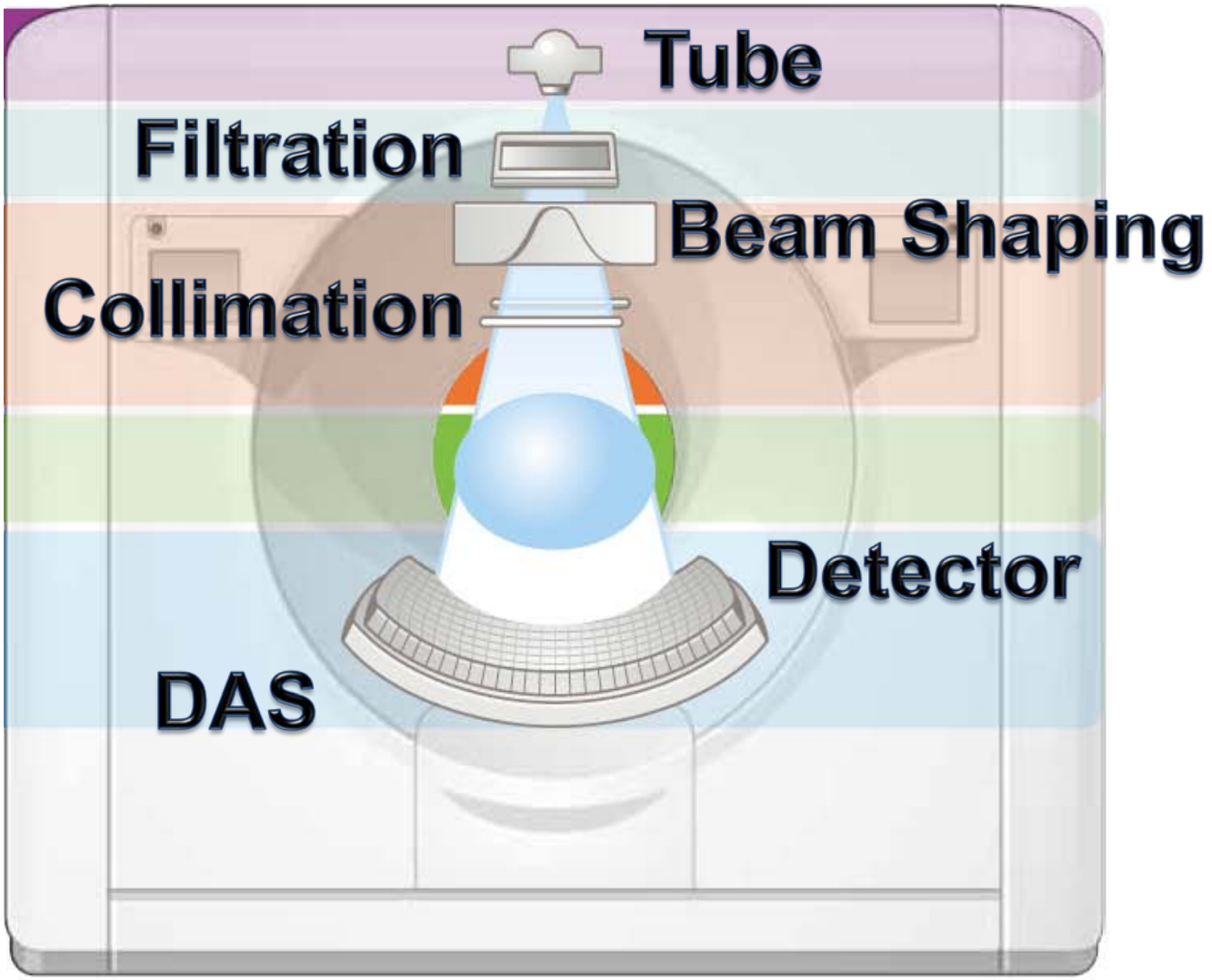
- 2 x 128 slice
- High pitch helical
- IRIS
- 75 ms temp res

Toshiba Aquilion ONE

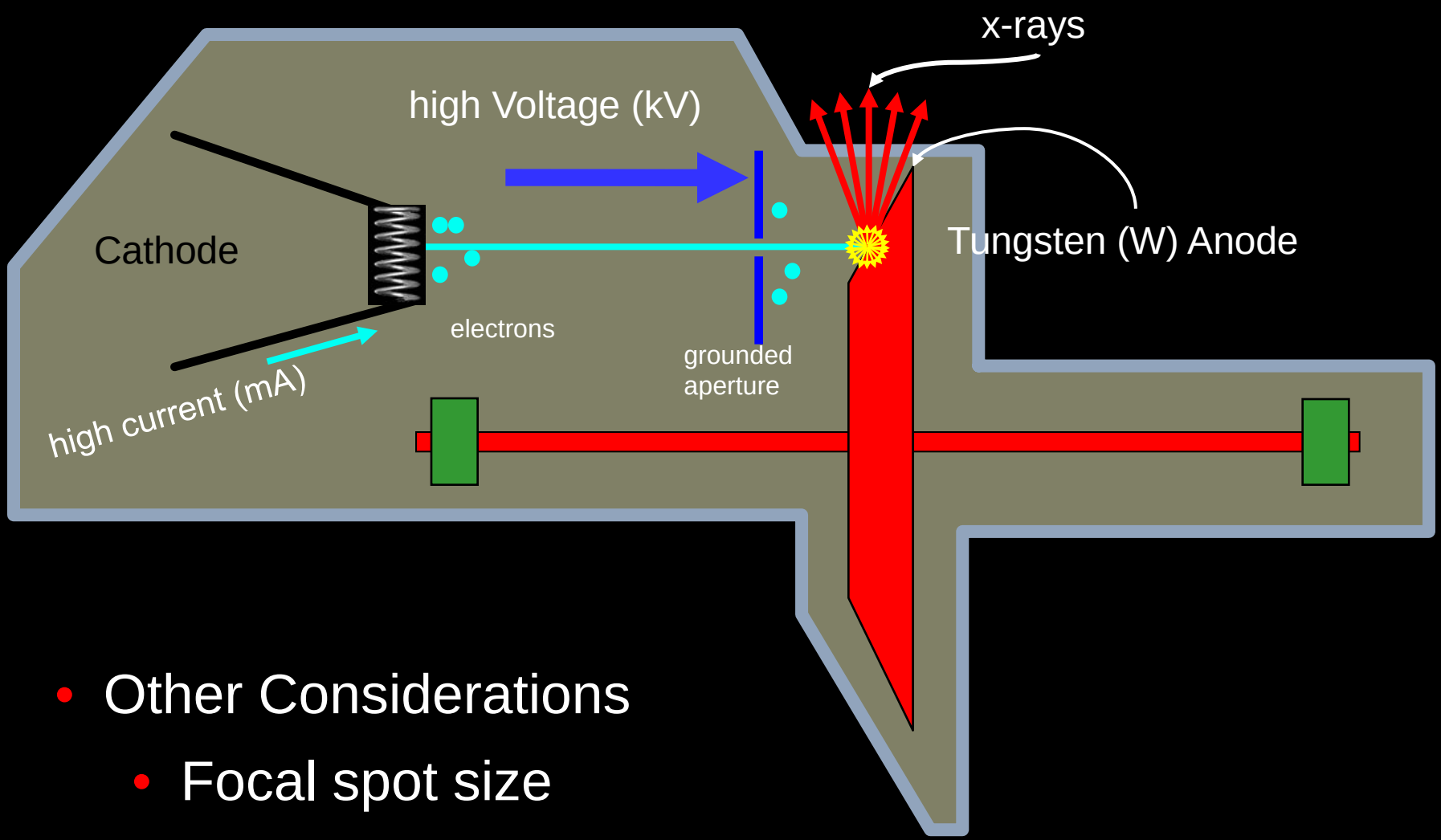
- 320 detector rows
- 16 cm volume
- AIDR
- Dynamic volumes

Why it's cool

Imaging Chain Hardware



Slide Courtesy of **PHILIPS**



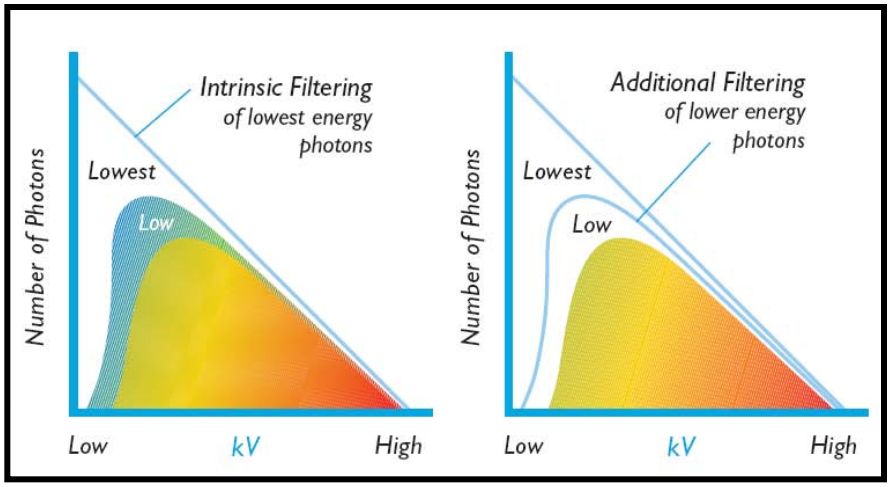
- Other Considerations
  - Focal spot size
  - “flying” focal spots

Additional Beam Filtration

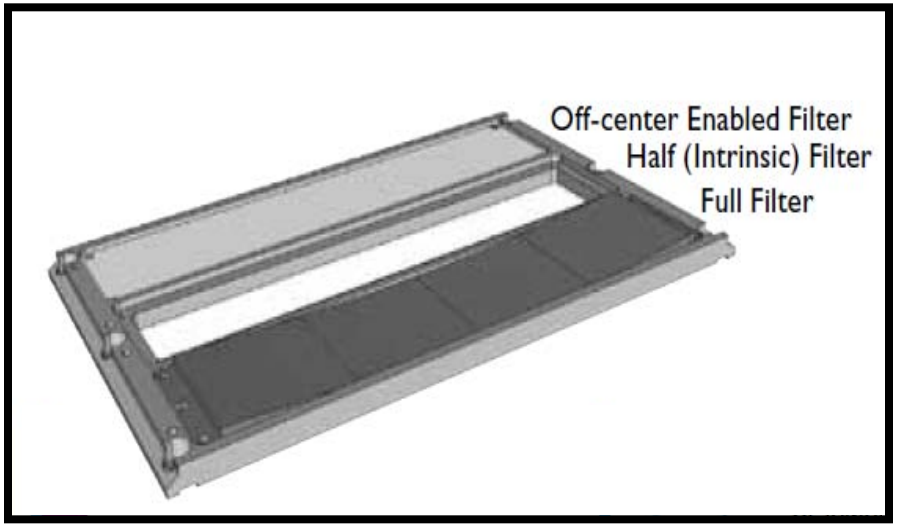
Quality *of Dose Needed*

Increase beam hardness and reduce soft radiation when possible

- 120 kVp
  - 30% dose reduction
- 80 kVp
  - 46% dose reduction



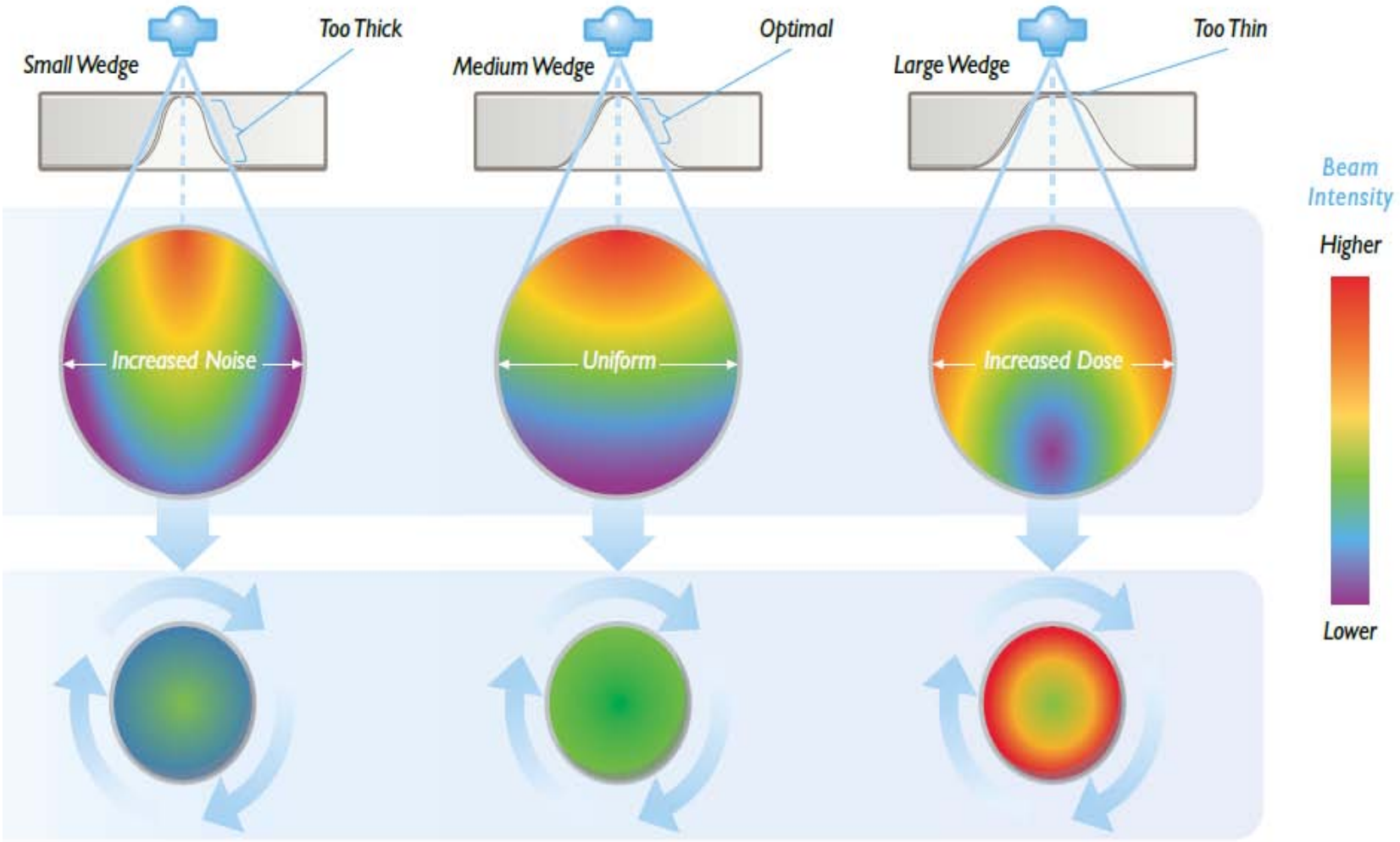
* relative to half-filter (softer beam)



Slide Courtesy of **PHILIPS**

Beam Shaping Filters

*Dose Only **Where** Needed: Wedge/Bowtie Filters*

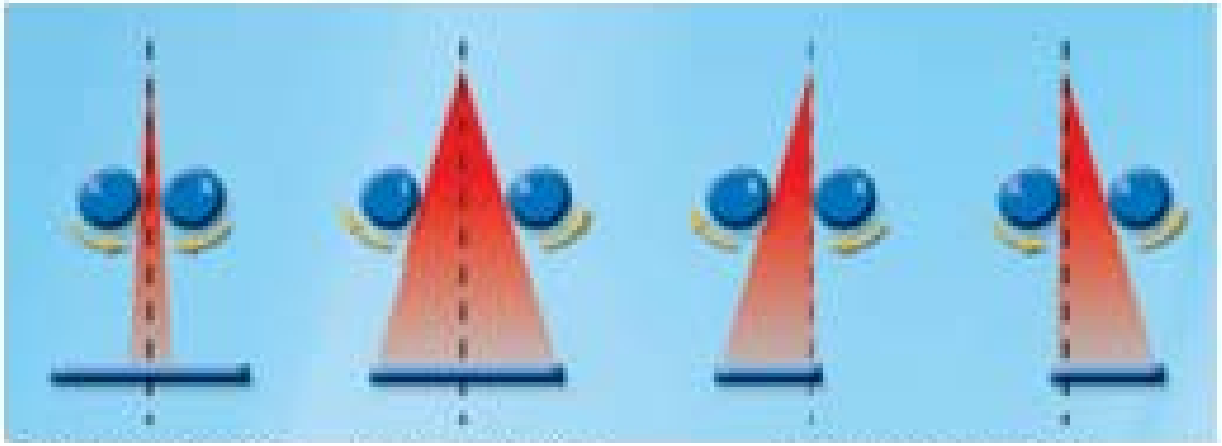


Slide Courtesy of **PHILIPS**

Collimation

Lower dose, same IQ for helical scans

- Enhanced Z-axis tracking for additional dose reduction
- Automatically opens and closes cams at the beginning and end of helical scans to reduce unused dose
- Applied for all body and neuro helical acquisitions
- Can reduce total exam dose up to 6% for typical chest protocol*



Closed cams for narrow beam

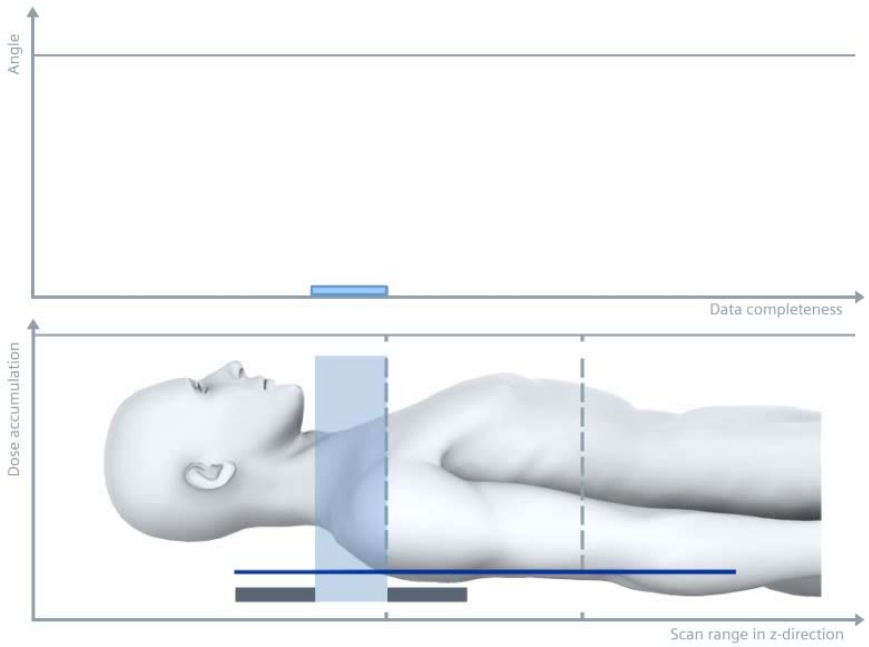
Open cams for wide beam

Counter rotate cams to position beams

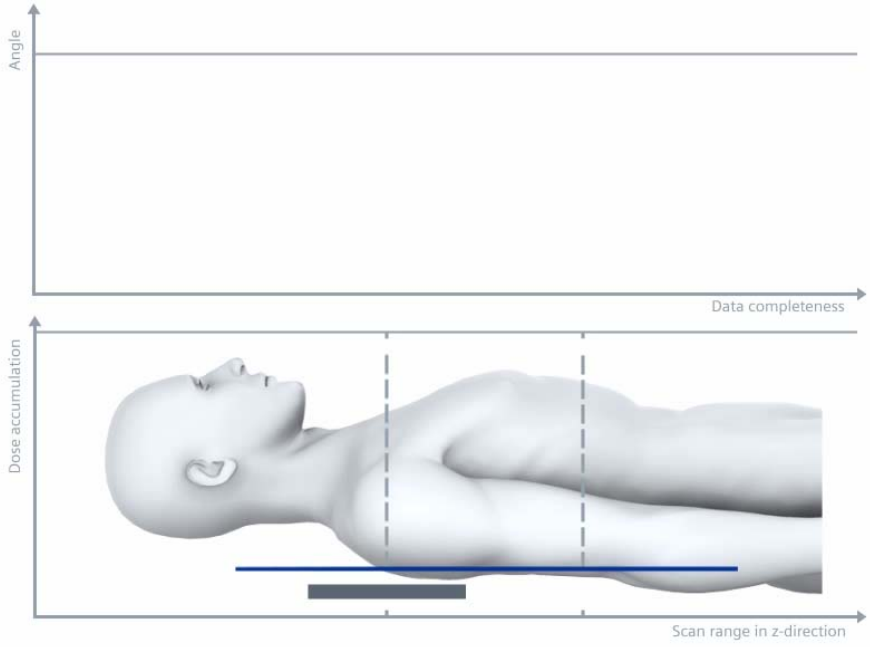
*Routine chest protocol = 200mm coverage, 40mm aperture, and 1.375 pitch

Slide Courtesy of **GE**

Blocking unnecessary radiation
Independent Collimators



Conventional technology without independent collimators



New technology with adaptive independent collimators

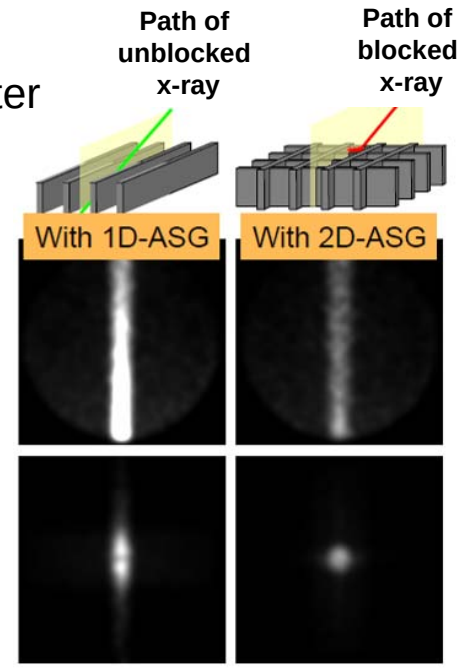
 Slide Courtesy of **SIEMENS**

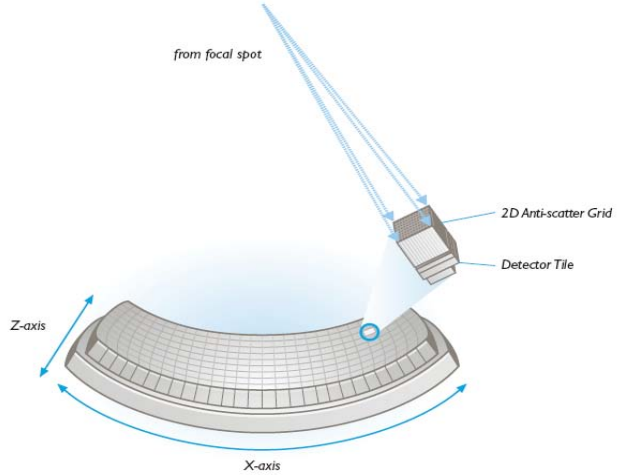
Detectors and DAS

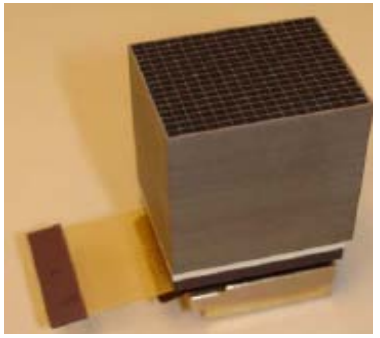
- Ceramic or garnet detectors
  - Fast decay
  - Short afterglow
  - Good stopping power
  - High light output
- Data acquisition system
  - High frequency readout (1 – 3 kHz)
  - Low electronic noise

2D Antiscatter Collimator

- Improves scatter to primary ratio (SPR): 3x reduction in scatter
- With a higher SNR, radiation dose may then be reduced
  - Up to **10%** for 12" phantoms
  - Up to **16%** for 16" phantoms
- Reduces scatter artifact and nonuniformity
- Increases low contrast for larger patients
- Spherical geometry for true cone-beam focus







Vogtmeier, G.; Dorscheid, R.; Engel, K. J.; Luhta, R.; Mattson, R.; Harwood, B.; Appleby, M.; Randolph, B. & Klinger, J. (2008), Two-dimensional Anti-Scatter-Grids for Computed Tomography Detectors, *in* Jiang Hsieh & Ehsan Samei, ed.,'Medical Imaging 2008: Physics of Medical Imaging', SPIE Press, pp. 69159R.

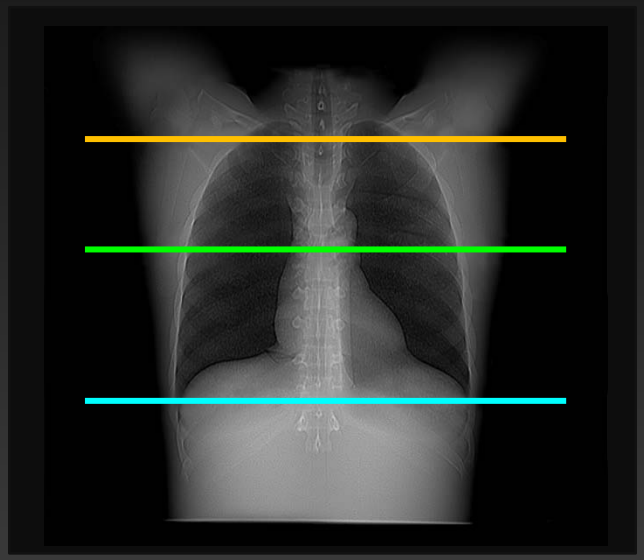
Slide Courtesy of **PHILIPS**

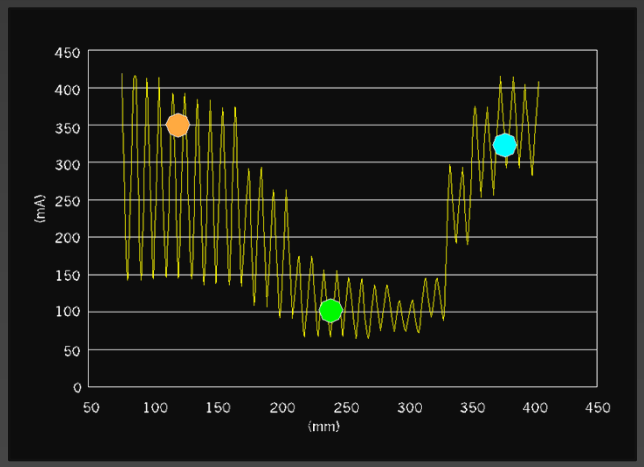
Software Dose Reduction

- Automatic exposure control
  - XY and Z
  - ECG
- Prospective cardiac
  - Helical
  - Axial
  - Volume
- Right patient, right protocol, right dose
  - Pediatric protocols
  - Dose Check
- Advanced Reconstruction

Automatic Exposure Control

- XYZ mA modulation
- Scan projection radiograph based
- Optimized dose for image quality
  - Current selection
  - Modulation

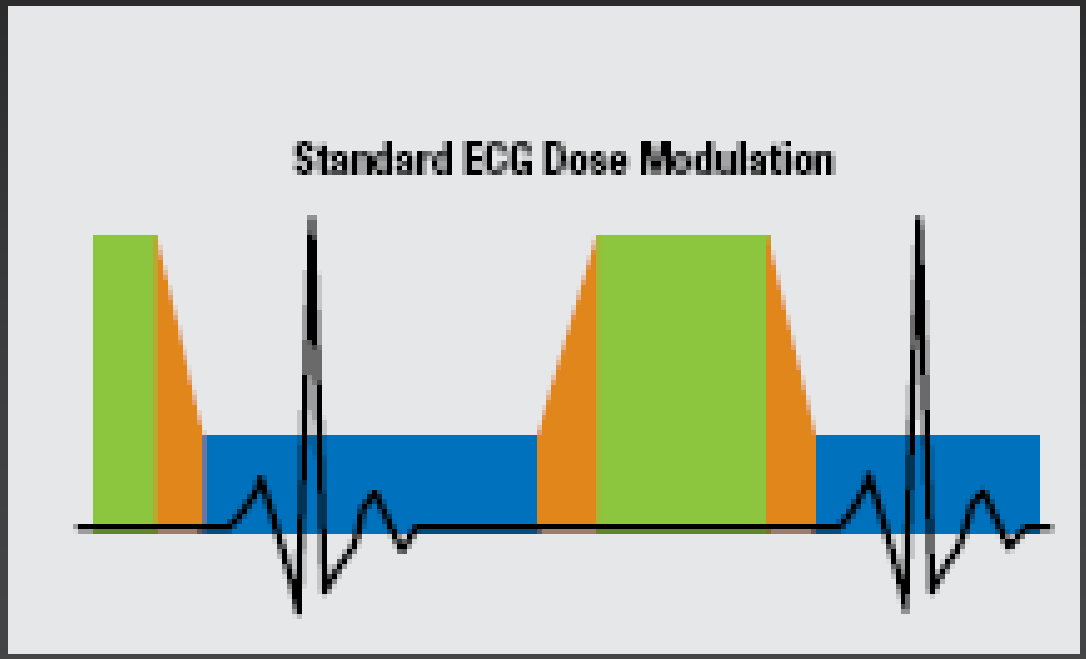




Slide Courtesy of **TOSHIBA**

ECG Modulation

- Low dose cardiac CTA acquired in helical mode



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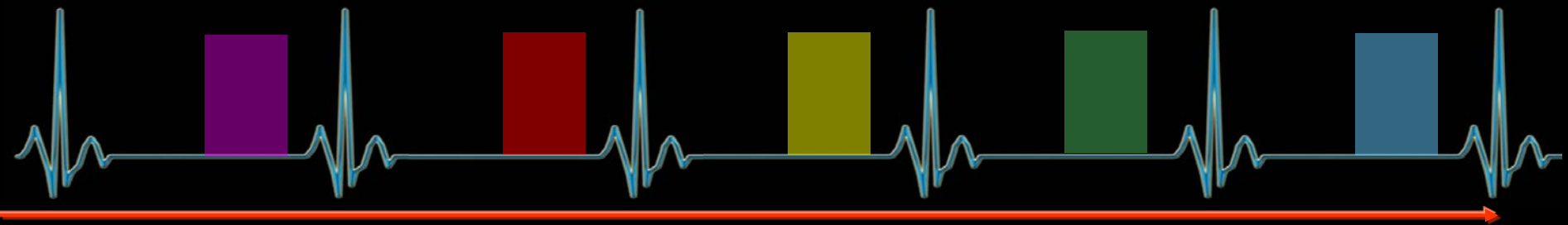
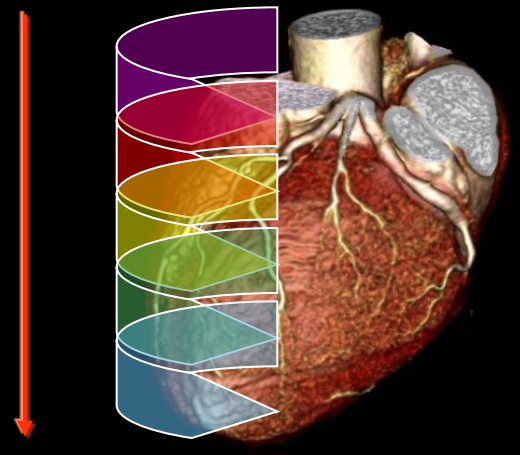
Helical prospective





- Exposure is pulsed on/off for the same % R-R for each heart beat.

Slide Courtesy of **TOSHIBA**

Axial cardiac

~80% Less Dose & Improved IQ

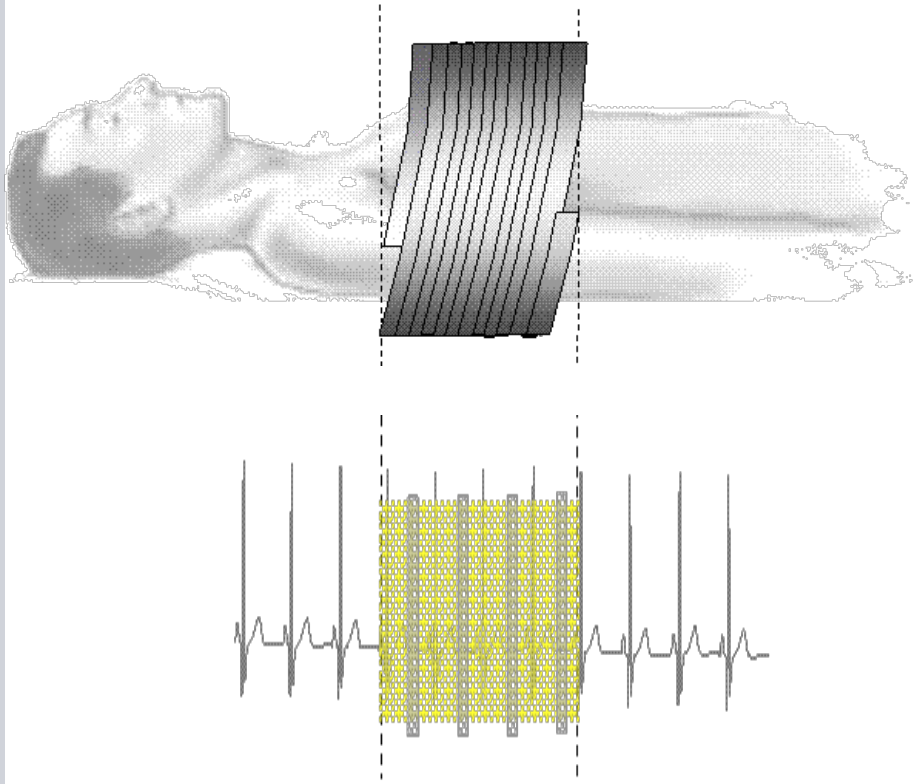
- Prospective ECG gating axial scanning
- Real-time heart rate monitoring and gating
- Not a *single* phase; it is a phase *range*
- Dose and exposure time are heart rate independent
- Real-time adaptive scanning avoids unanticipated premature beat arrhythmias, improving overall scan reliability
- Improves image quality during Axial cardiac scanning

Slide Courtesy of **GE**

2nd generation Dual Source CT

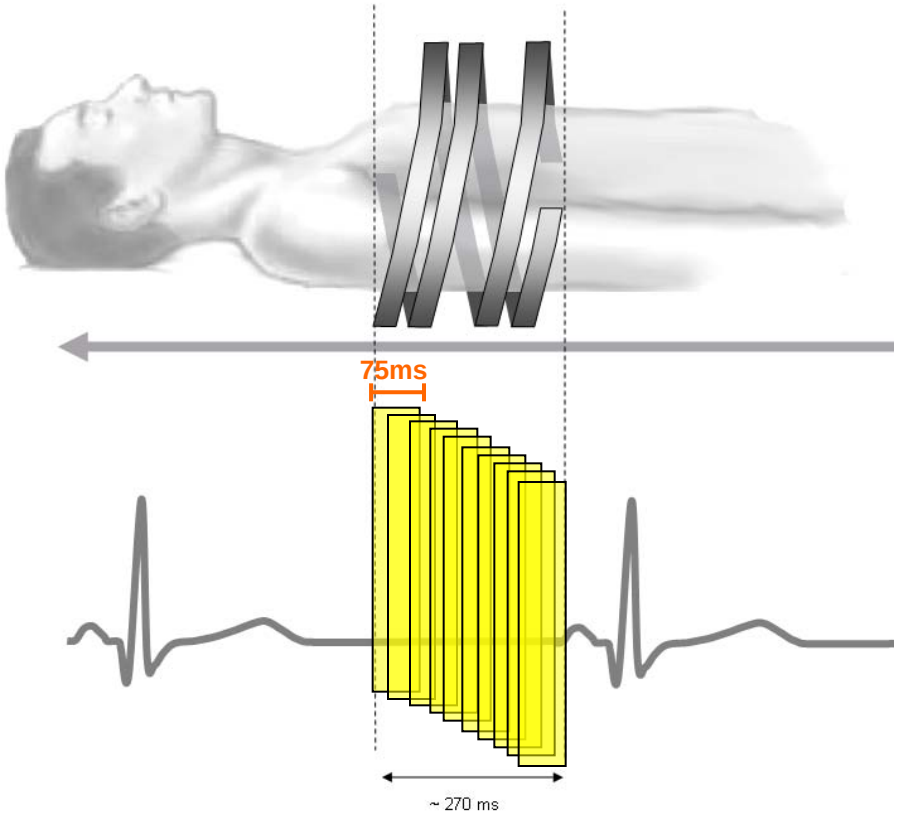
Image the heart in one beat at low dose

Conventional ECG-Gated Spiral



- **Low pitch, slow scan speed**
- **Scan time 5 – 10 s heart,**
  10 – 20 s chest
- **Redundant data → High dose**

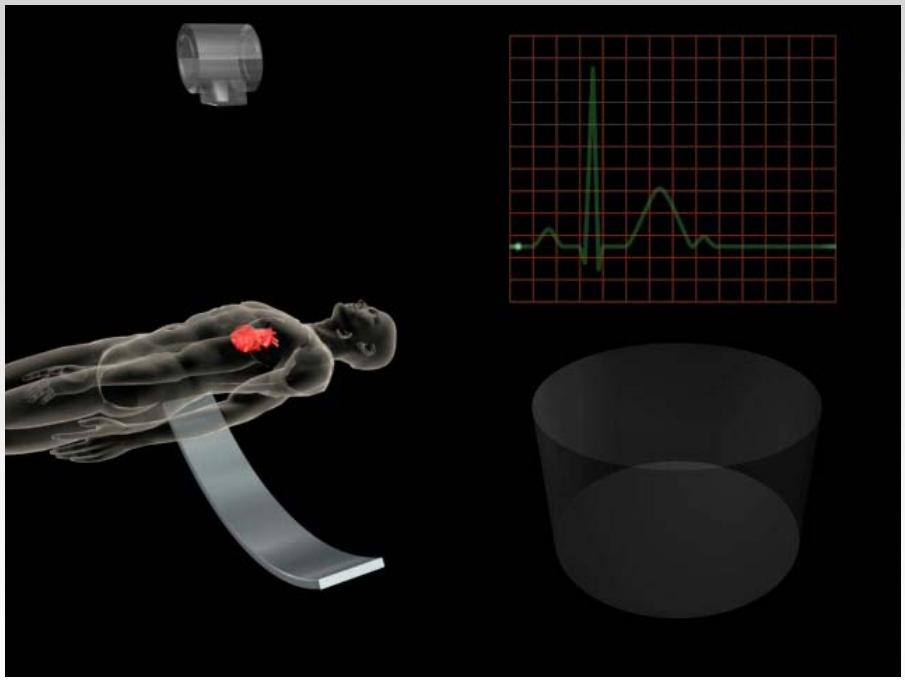
ECG-Triggered Flash Spiral



- **High pitch, high scan speed**
- **Scan time 0.25 – 0.27 s heart**
  0.6 – 0.7 s chest
- **No redundant data → Low dose!**

 Slide Courtesy of **SIEMENS**

Dynamic Volume CT – Temporal Uniformity



Up to 16 cm coverage in one rotation

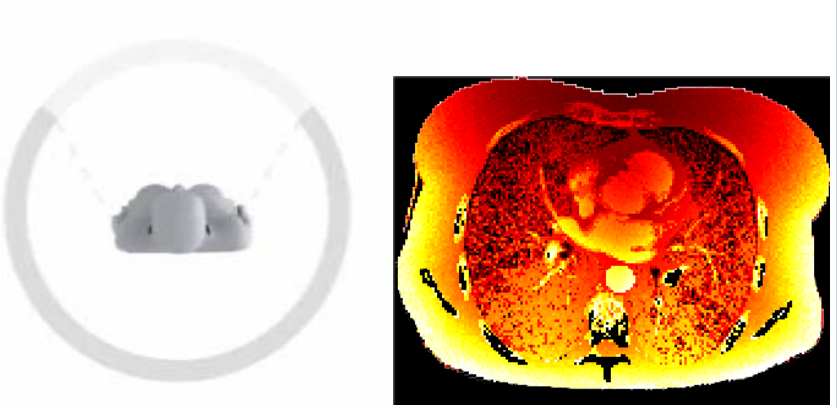
Slide Courtesy of **TOSHIBA**

Targeted organ dose reduction
Dose reduction with X-CARE

Conventional Technology

- **Full radiation of breast**
- Breast is always included in any diagnostic thoracic scan, but almost never organ of interest

with X-CARE



- **Up to 30 - 40% dose reduction**
- No compromise in image quality
- For dose sensitive organs:
  e.g. **breast and eye lens**

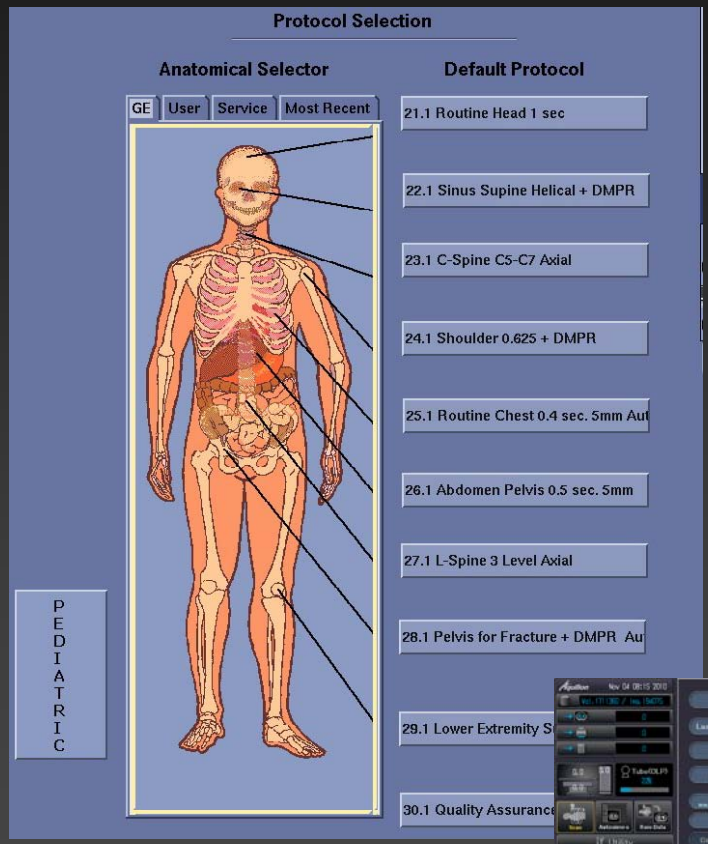
 Slide Courtesy of **SIEMENS**

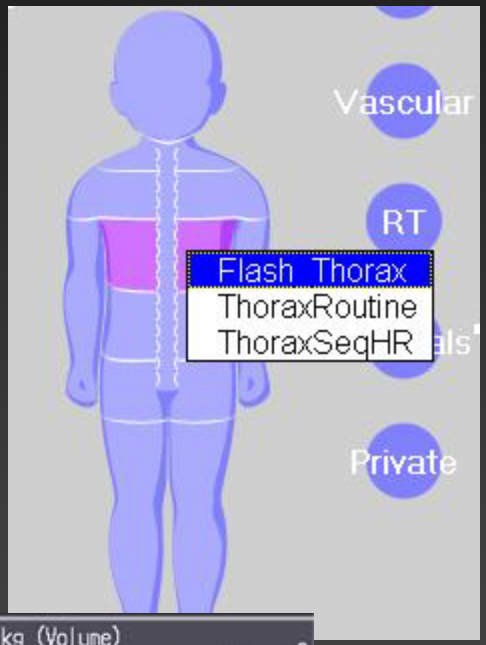
Variable Helical Pitch vHp

- Changing table speeds within the same exam saves time, dose and cost
- Combining ECG and non ECG gated scans into one makes excellent use of contrast media with up to 40% dose reduction

Slide Courtesy of **TOSHIBA**

Dedicated Protocol Selection





Notification vs Alert

	Notification	Alert
Values Checked	$CTDI_{vol}$ and/or DLP	Cumulative $CTDI_{vol}$ per PT location and/or Cumulative DLP
Context	Current scan	Current patient
Required before proceeding	Confirmation Comments (optional)	Confirmation Operator's name Password (if configured) Comments (optional)
Audit trail recorded	Date/Time Unique Study ID Values exceeded Corresponding dose index value Comments	Date/Time Operator's name Unique Study ID Values exceeded Corresponding dose index value Comments

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MEDICAL IMAGING
& TECHNOLOGY ALLIANCE
A DIVISION OF NEMA

! DOSE ALERT
A dose alert value will be exceeded !

Proceeding with this exam will exceed
the dose alert level that has been set.

	Predicted Dose	Alert Level
Cumulative CTDIvol	1263.7 mGy	1000.0 mGy
Patient total DLP	6643.0 mGy.cm	6500.0 mGy.cm

Edit OK

Dose Alert

Seq.No.	CTDIvol[mGy]	DLP[mGy·cm]	Notification Value(DLP)[mGy·cm
7	88.5	1327.1	150.0

Sum DLP[mGy·cm] : 1769.4
Alert Value(DLP)[mGy·cm] : 1000.0

A Dose Alert Value will be exceeded.

Please input a password and click the "Confirm" button to scan.

Password

Confirm Cancel

Dose Alert

A dose value will be exceeded!

The accumulated CTDIvol (767.47 mGy) will locally exceed the alert value (700 mGy for Adult).
Please reconsider the current examination procedure.

Hint: The currently used scan protocol can not be saved!

User name (mandatory)

Diagnostic reason

Load Cancel

Dose Alert

Dose Alert - Alert value will be exceeded!

The scan has a $CTDI_{vol}$ of 1255.6 mGy. This exceeds the Alert Value of 1000 mGy.
This may result in an excessive level of radiation exposure

Enter user name: *

Enter diagnostic reason:

Enter password: *

Confirm and proceed Go back and adjust scanning parameters

DoseAlert

The prescribed scan parameters result in a projected exam dose exceeding the user configured Alert Value. Select Cancel to go back to Viewedit and adjust scan parameters if clinically appropriate to set below the Alert Value. An authorized user name and password must be entered to select Confirm. Selecting Confirm will proceed to scan and log user confirmation of scan parameters exceeding the Alert Value.

	AV	Projected/Accumulated	Start	End
CTDIvol (mGy)	1000	2281.00	12.5	537.5

Logon Name:

Password:

Diagnostic Reason

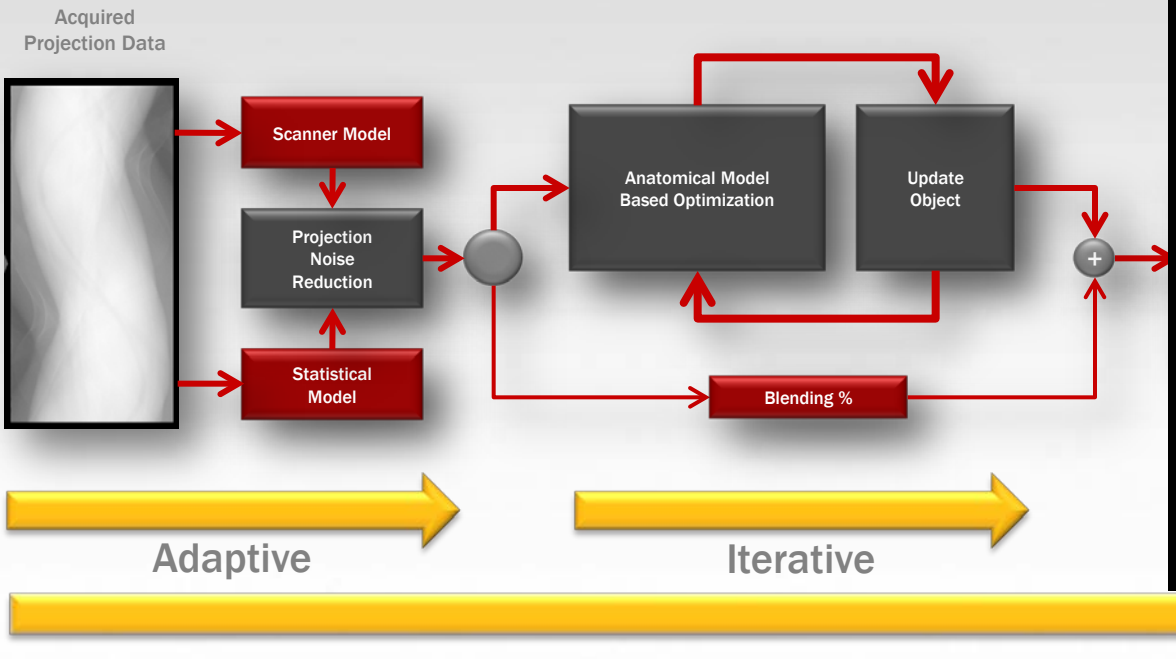
Confirm Cancel

Advanced Reconstruction

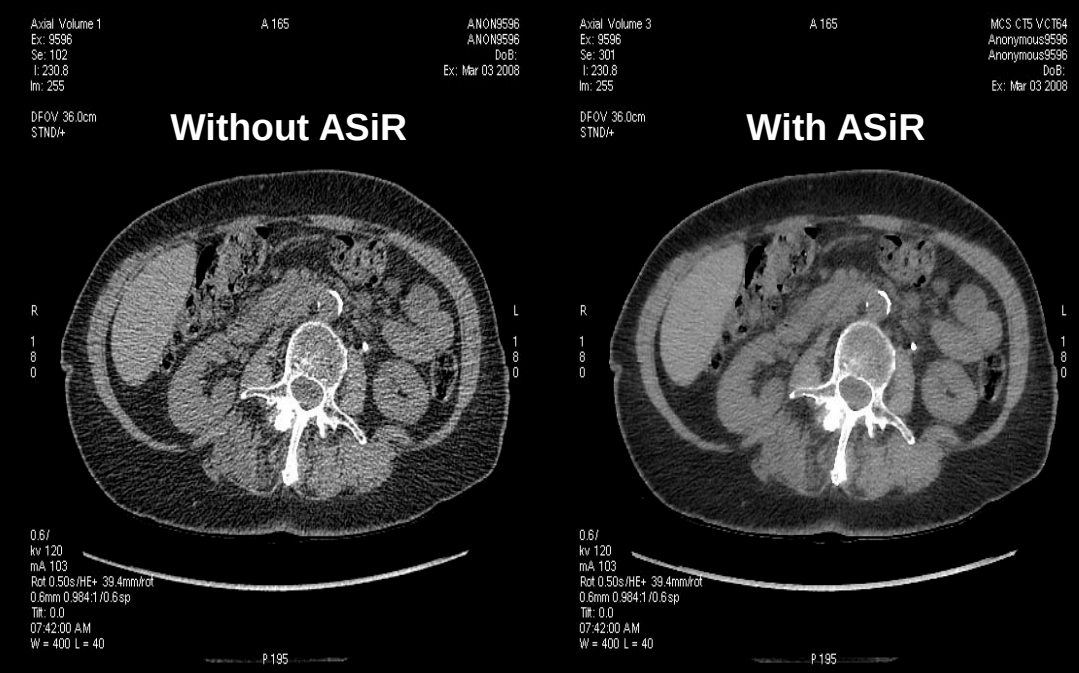
- AIDR
- ASiR
- iDose^4
- IRIS

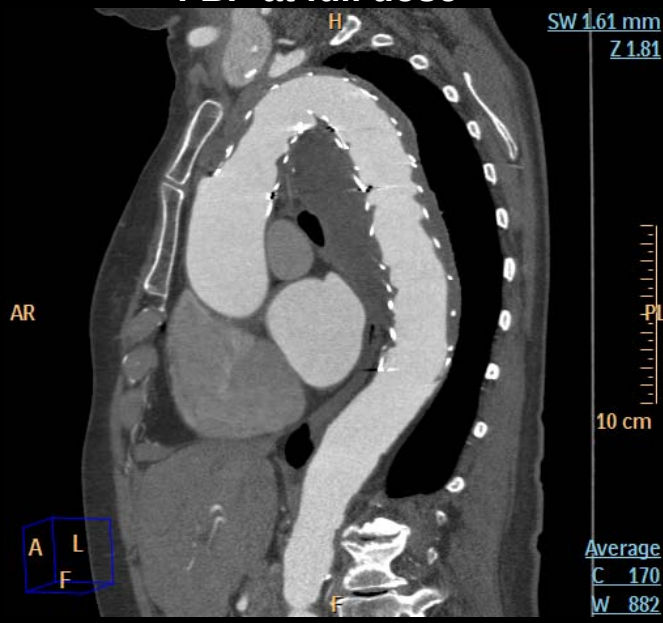
AIDR Algorithm

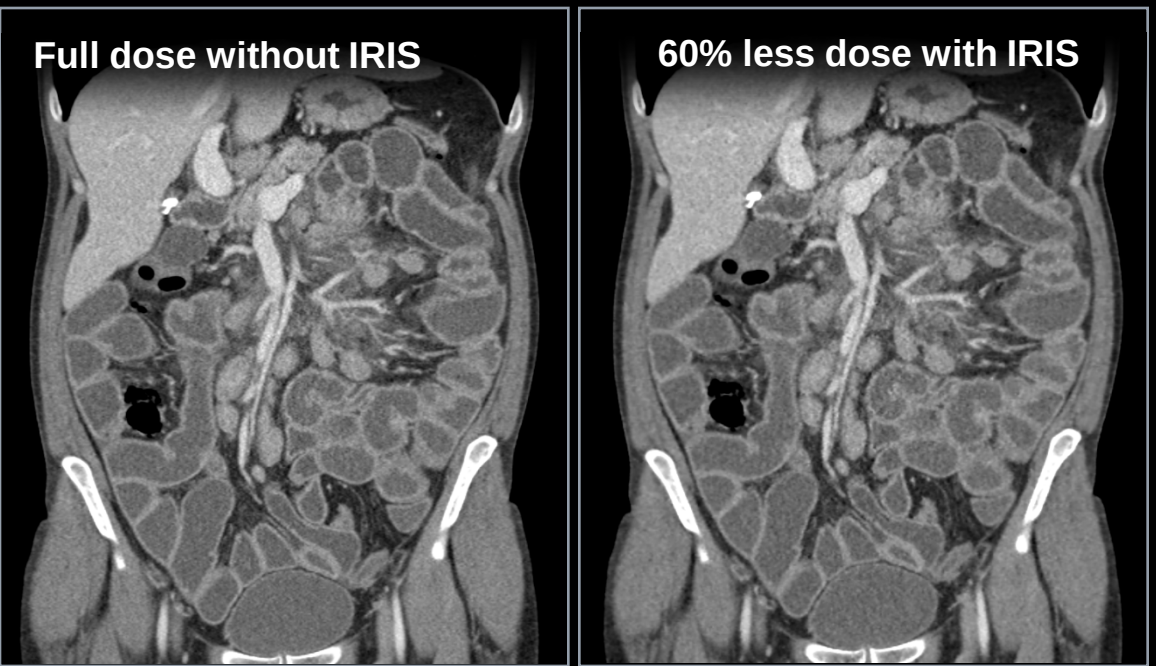
- Iterative Noise Reduction
- Reduces image noise by up to 50%
- Reduces dose by up to 75%

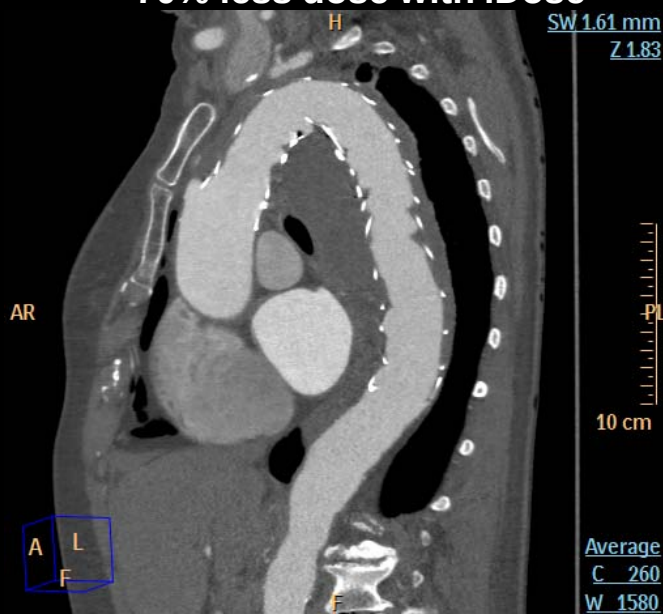


Slide Courtesy of **TOSHIBA**


Without ASiR
With ASiR


FBP at full dose
SW 1.61 mm
Z 1.81
10 cm
Average
C 170
W 882

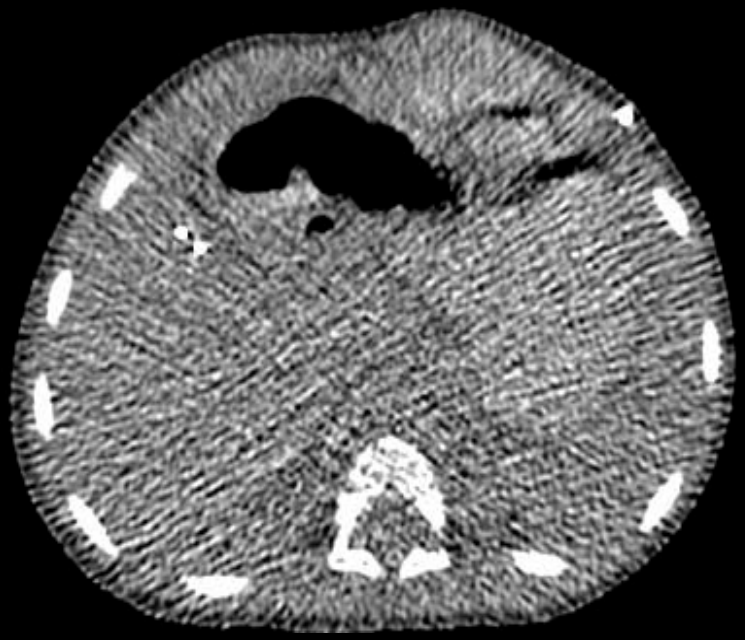

Full dose without IRIS
60% less dose with IRIS

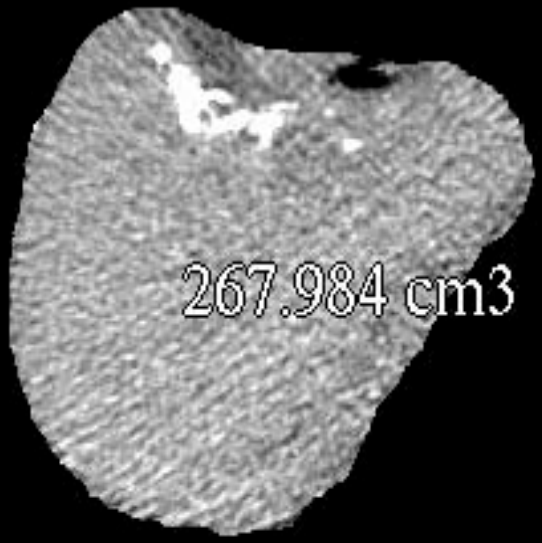

70% less dose with iDose4
SW 1.61 mm
Z 1.83
10 cm
Average
C 260
W 1580

Dose Reduction- a multifaceted challenge

- **Optimize the protocols**
  - **Size based-**
    - » **Peds vs Adults**
    - » **Obese vs thin**
  - **Task based**
    - » **Limit to a single phase whenever possible**
    - » **Tailor dose to the clinical question**

Liver Volume





DLP = 1.5; Effective Dose = .097 mSv

About 5 chest x rays; *less than 1 abd series!*

Slide Courtesy of **Don Frush, Duke**

Dose Reduction- a multifaceted challenge

- Review the protocols
  - Clinician, technologist, physicist
  - Periodic reviews for consistency, dose
- Lock down the protocols
  - Once they have been reviewed and blessed
  - Password protection on scanners
- Dose reporting
  - IHE REM profile
  - Dose reviews

Dose Reduction- a multifaceted challenge

- **Training of operators**
  - **Scanners are increasingly complex**
  - **Make sure all dose reduction features are understood and used**
- **Scanner Hardware**
- **Scanner Software**

- **Right exam on the**
- **Right patient with the**
- **Right dose**

The Good News

- **Cardiac (2009) = 15 mSv**
- **Cardiac (2011) = < 1 to 3 mSv**