Automated dose control in multi-slice CT

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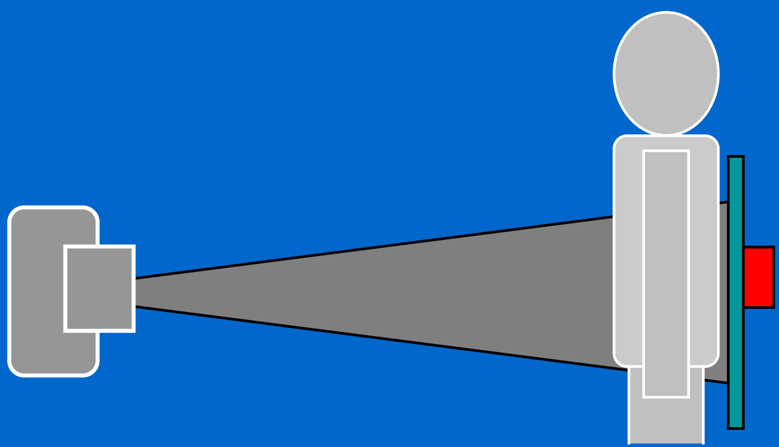
Introduction to presentation

- CT contributes ~50+ % of all medical radiation dose
- Ideally all patients would receive ‘just enough’ radiation to produce a diagnostic image
  - Extra radiation provides no clinical benefit, but extra dose
- Controlling exposure usually achieved with ‘standard’ protocols
  - These usually err on the side of over-exposure
- Automatic exposure controls (AECs) introduced on CT scanners to address these issues

X-ray exposure

- X-ray film needs correct exposure to get the best image
- Phototimers used since ~1940 to set x-ray exposure time

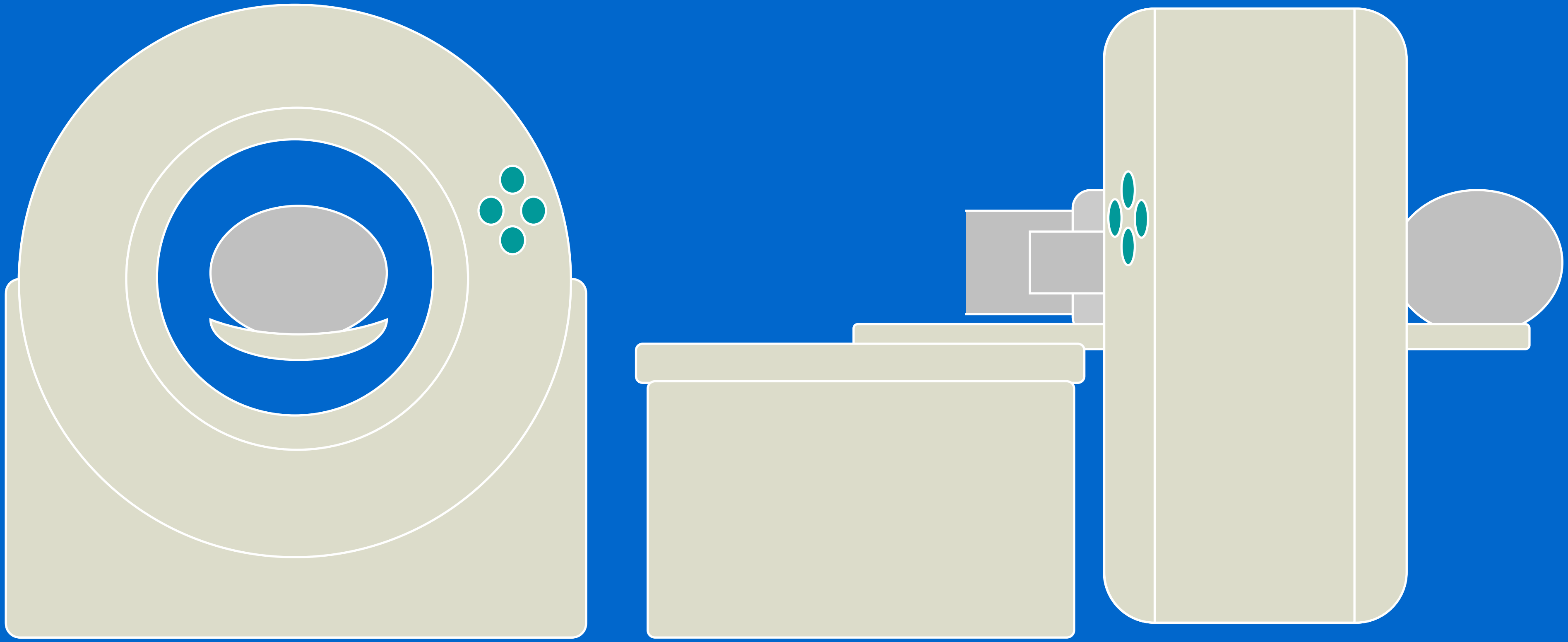


AEC systems in CT

- CT uses digital detectors, not easily under or over-exposed
- Over-exposure leads to better image quality!
  - Under-exposure gives noisy or streaky images
- Manufacturers have introduced CT AEC systems in last three years
- CT has caught up with general x-ray, 60 years after introduction of the phototimer
  - In CT, tube current, not exposure time is being controlled

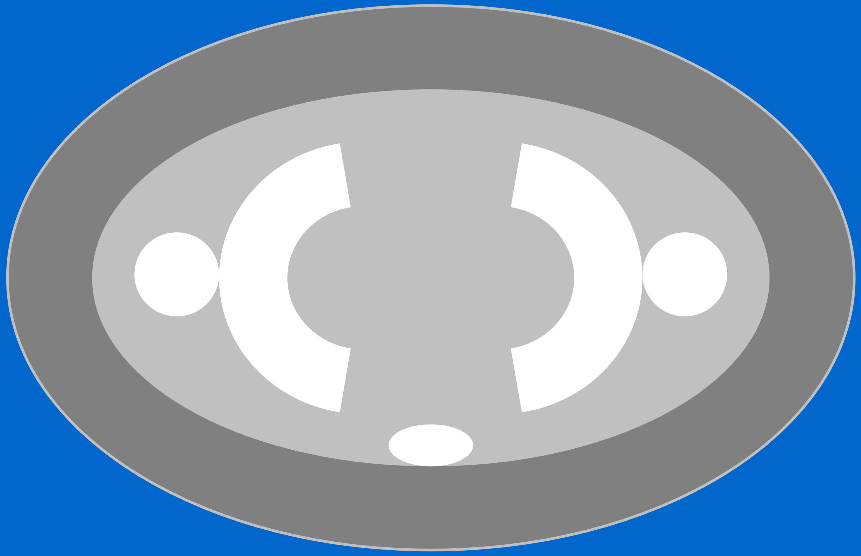
CT scanner exposure pattern

- CT scanner exposure is highly localised
  - Good opportunity for AEC optimisation

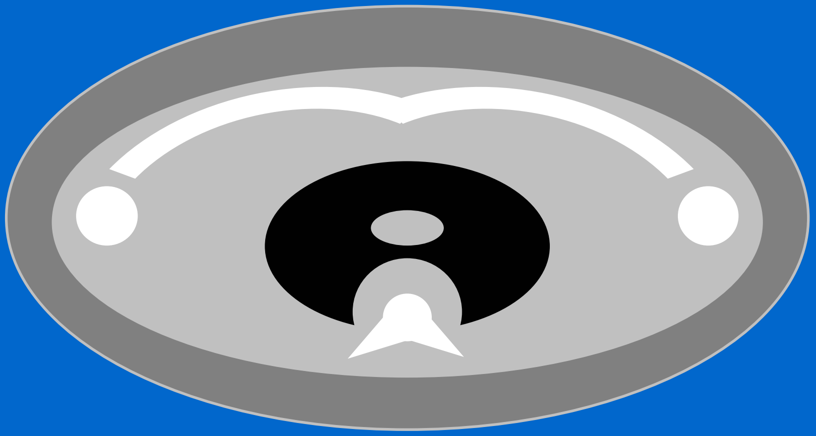


Variable patient attenuation

- Attenuation of x-rays varies according to patient density and thickness
  - Each patient is a different size
  - Cross sectional diameters change along patient length
  - Bones highly attenuating, lungs low attenuation
- Signal to detectors varies inversely to attenuation



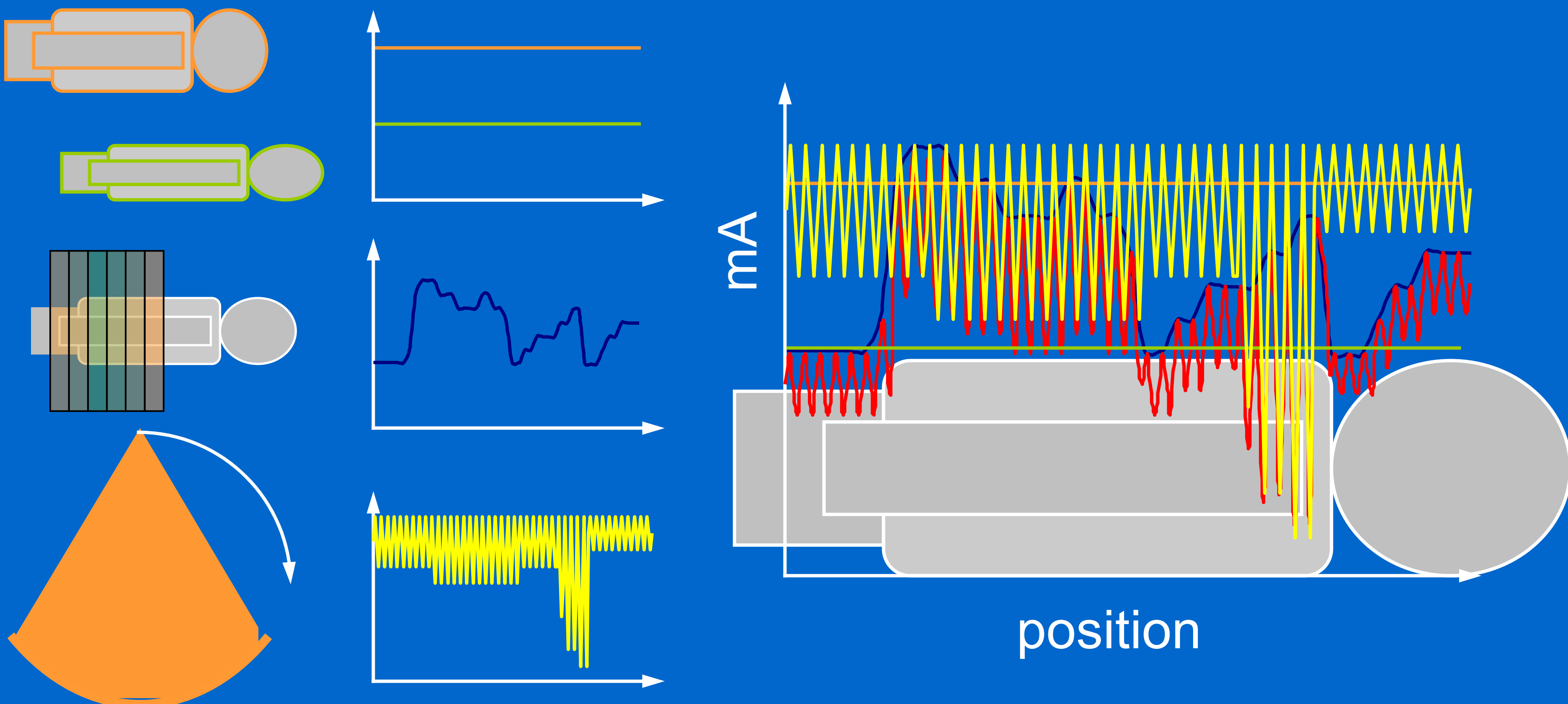
Pelvis



Shoulder

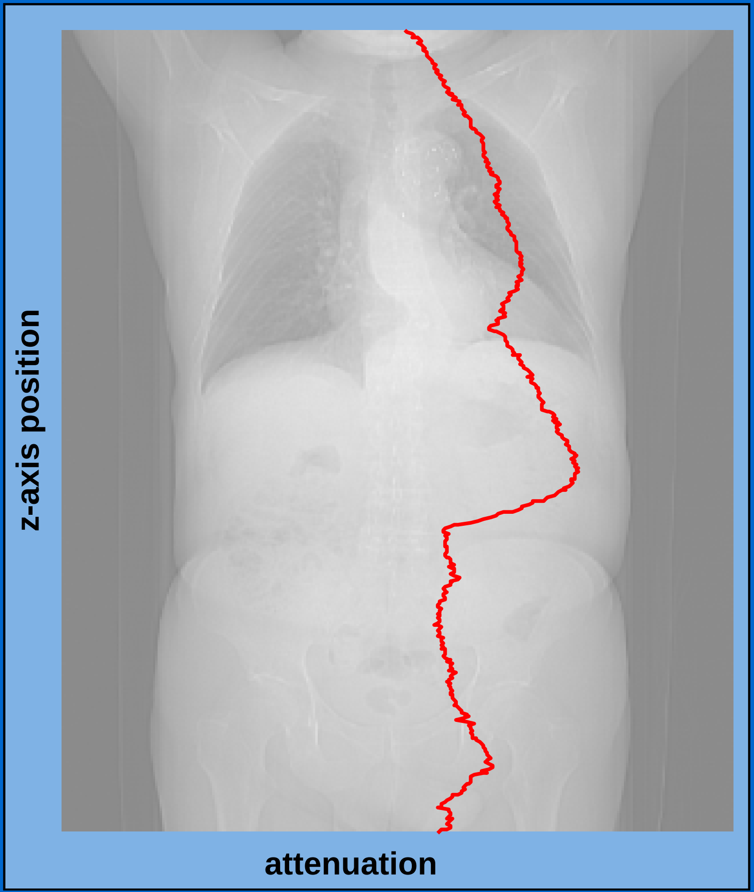
CT AEC principles

- mA adjusted to compensate for attenuation differences
  - dose applied to patient only where needed
  - image quality less variable



Patient attenuation

- Assessed from SPR (plan) view, or from feedback from previous rotations
- Tube current adjusted accordingly



Advantages of AEC

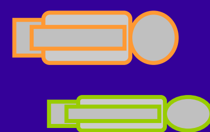
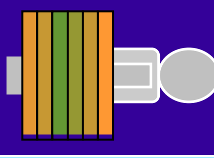
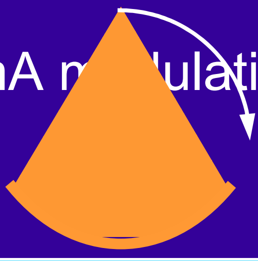
- More constant level of x-ray signal to detectors
  - Avoids under- and over-exposing detectors
- Image quality is kept at a constant level
  - From patient to patient, and during single study
- Tube heat capacity is conserved
  - Avoids tube cooling delays
- Reduction in ‘photon starvation’ streak artefact
  - Caused by under exposure of detectors
- Dose optimisation becomes easier
  - CT scan setup is based on image quality, not tube current

Dose and image quality

- Dose and image quality are opposite sides of the same coin
  - Good image quality ‘costs’ x-ray exposure
- AEC systems operate by varying tube current (mA)
  - Patient dose proportional to mA
  - Image noise proportional to $1/\sqrt{mA}$
- AECs are generally operated by specifying image noise characteristics
- Specifying patient protocols using image noise levels has implications for patient dose

Present AEC systems

- AEC systems available on multi-slice systems are applied at one or more levels:

	Patient size AEC 	Z-axis AEC 	mA modulation 
GE	Auto mA		SmartmA*
Philips	DoseRight ACS	DoseRight ZDOM	DoseRight DOM
Siemens	CAREDose 4D		
Toshiba	SUREExposure		**

*GE LightSpeed Pro scanners only

** Work in progress

Methods to set AEC exposure level

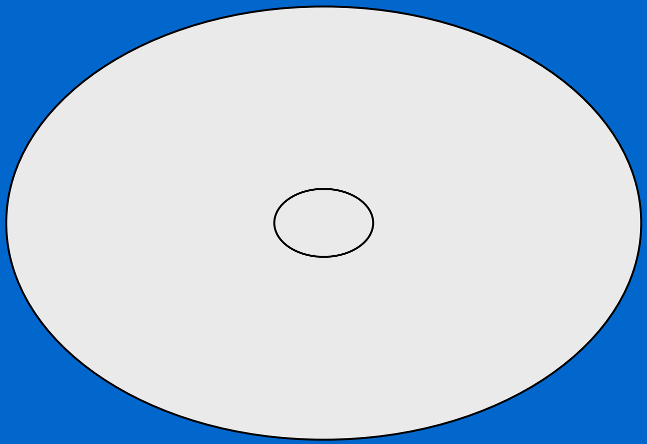
- Different methods exist to define the exposure level using AEC systems

Manufacturer	Method for setting exposure level
GE	‘Noise Index’ sets required image noise level
Philips	A ‘Reference Image’ is used, which has the desired level of image noise.*
Siemens	‘Equivalent mA’ set for standard sized patient
Toshiba	Set required standard deviation (noise)

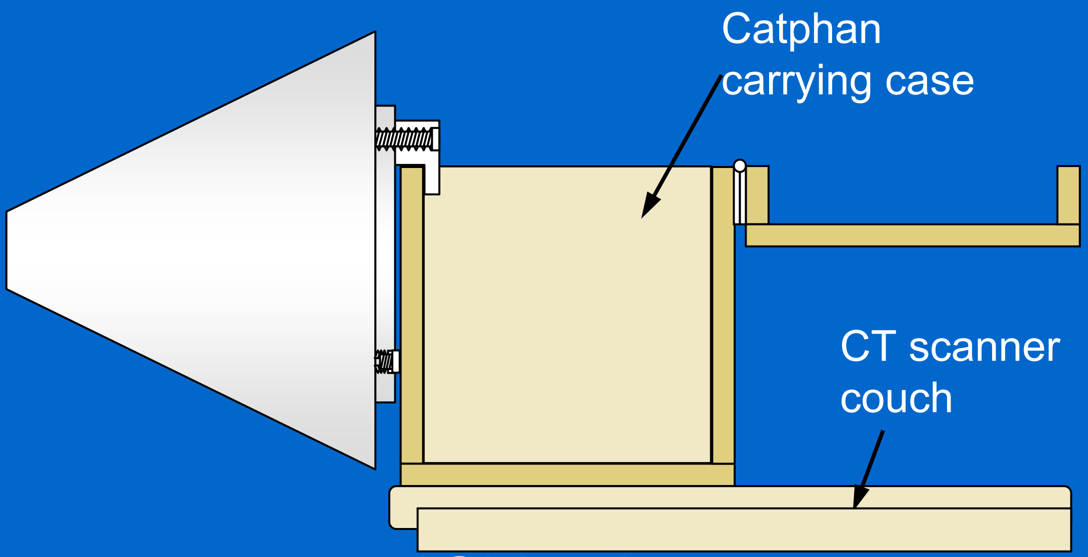
* new method based on reference mAs forthcoming

ImPACT cone phantom

- Conical Perspex phantom with elliptical cross section
- Based on ‘Apollo’ phantom developed by Muramatsu, National Cancer Centre, Tokyo



End view

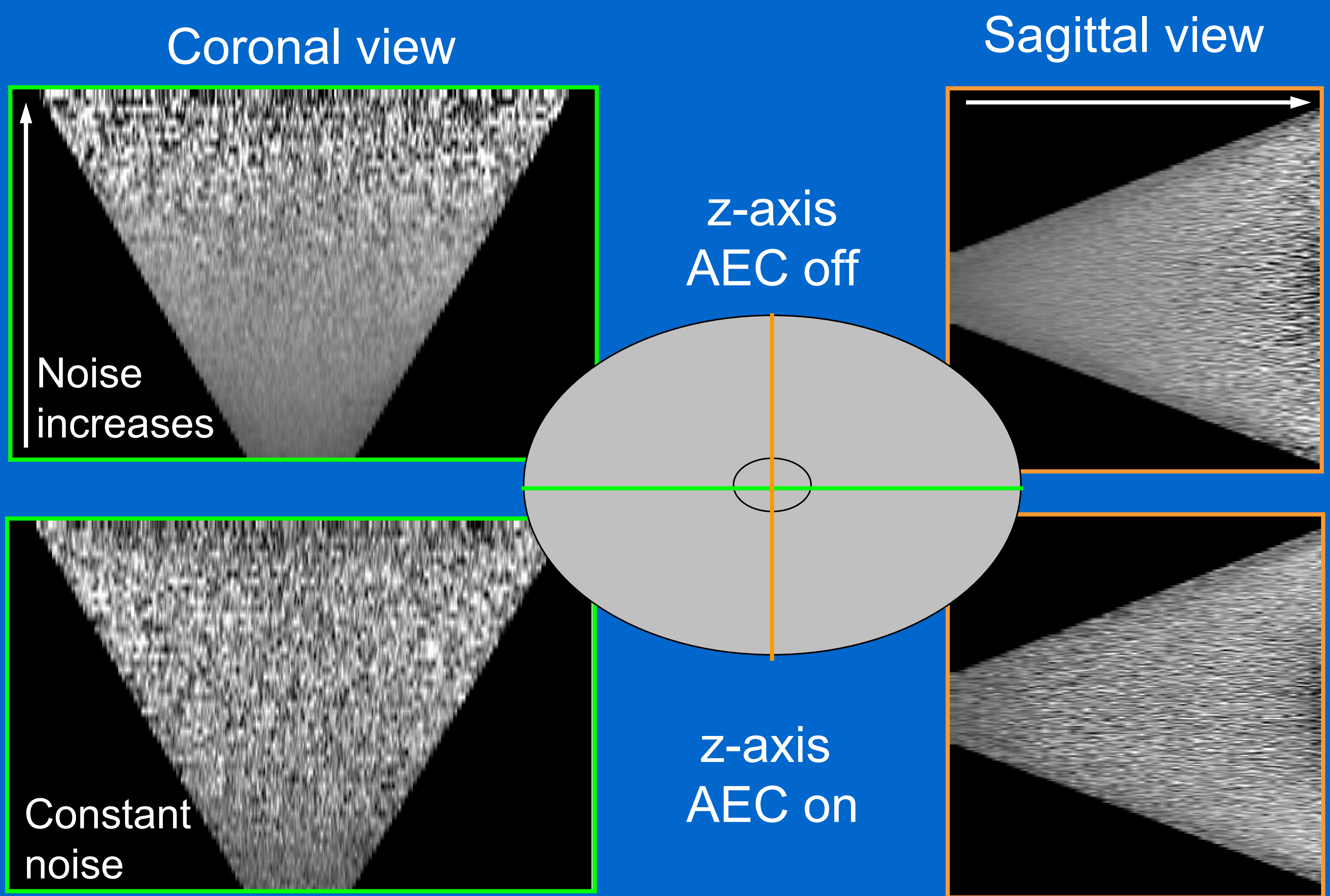


Side view

Cone phantom

- Images along length of phantom (AEC off)

Cone phantom

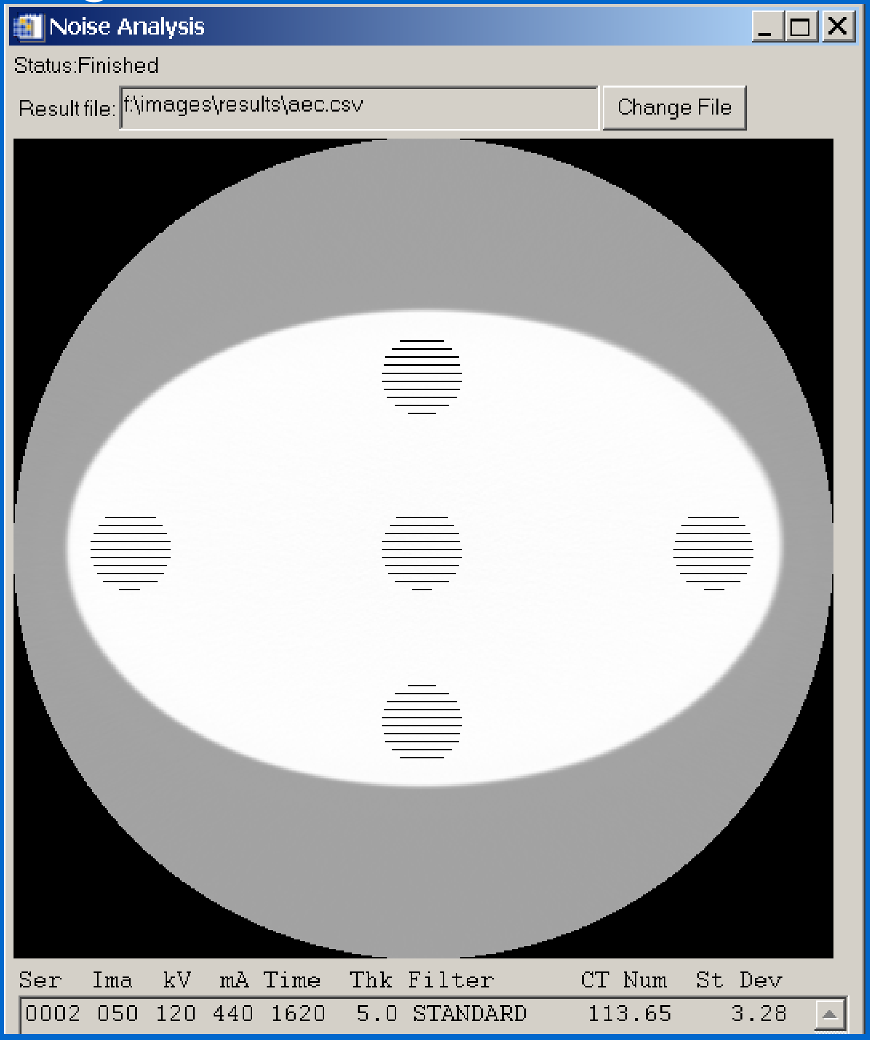


Scan protocol

- Standard conditions:
  - 120 kV, approx 200 mA, 1 s or less rotation time,
  - wide collimation e.g. 20 mm, 5 mm slice, 45 cm reconstruction field of view
- Scan along phantom with AEC off and on
  - If possible select different features of AEC separately
- Change exposure level – increase desired standard deviation or reference mA
- Look at effect of different kVs
- Change helical pitch and direction of tube movement
- Store DICOM images on CD

Image analysis

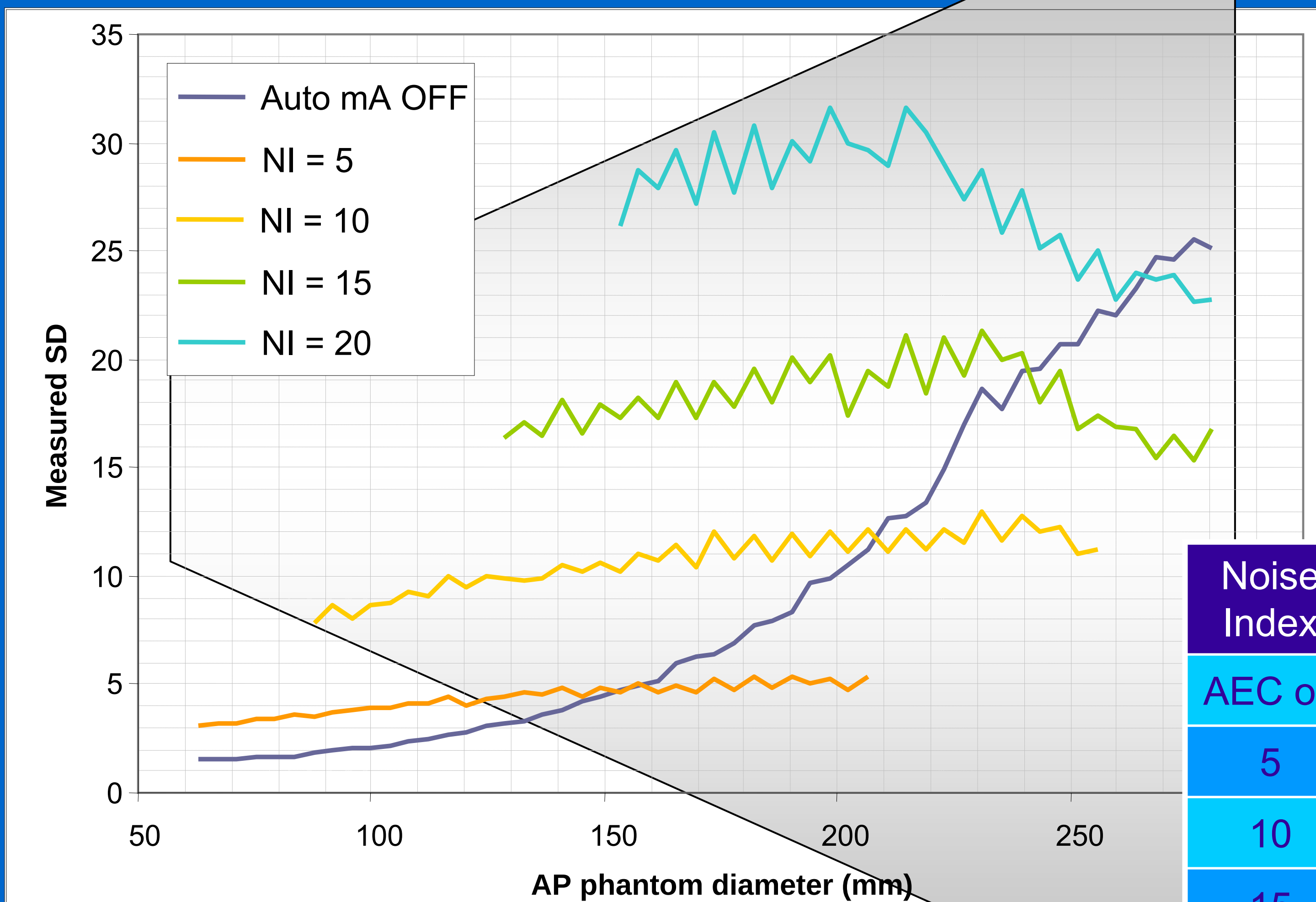
- mA information retrieved from DICOM files
- Standard deviation (SD) and average CT number calculated at centre and edge of image using automatic analysis tool
- Region of Interest (ROI) size 2000 mm^2
- Results analysed using Excel



Results from testing

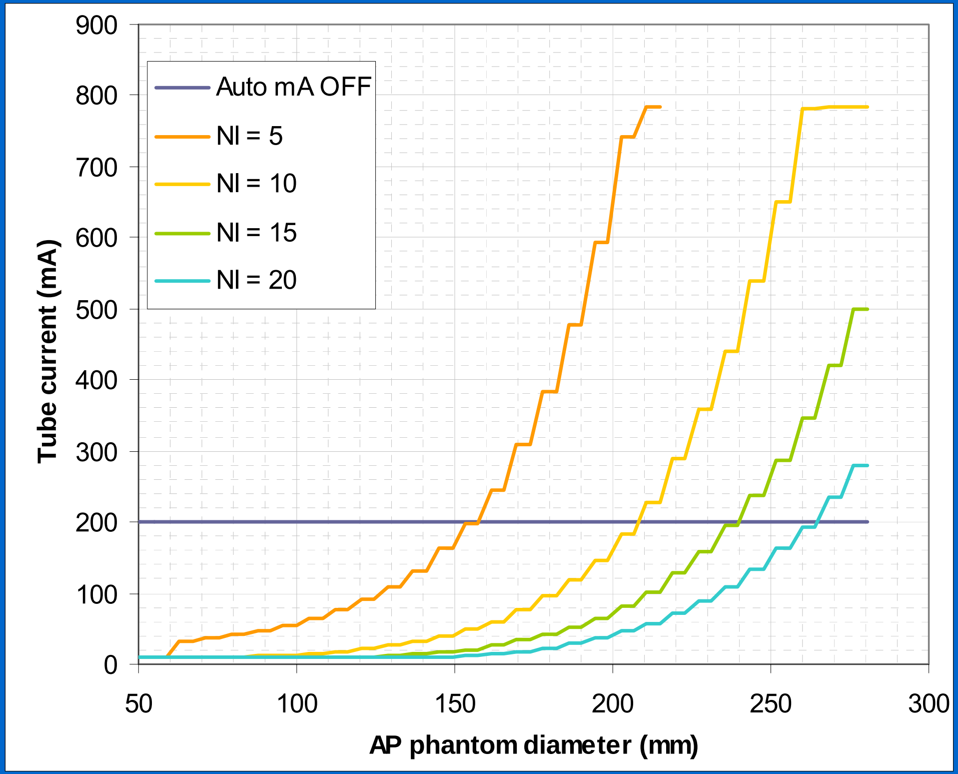
- Aims of each AEC system are slightly different, so it is difficult to compare results
- In general, all systems successfully achieved their aims
- Following slides show a selection of the results, much more data has been gathered

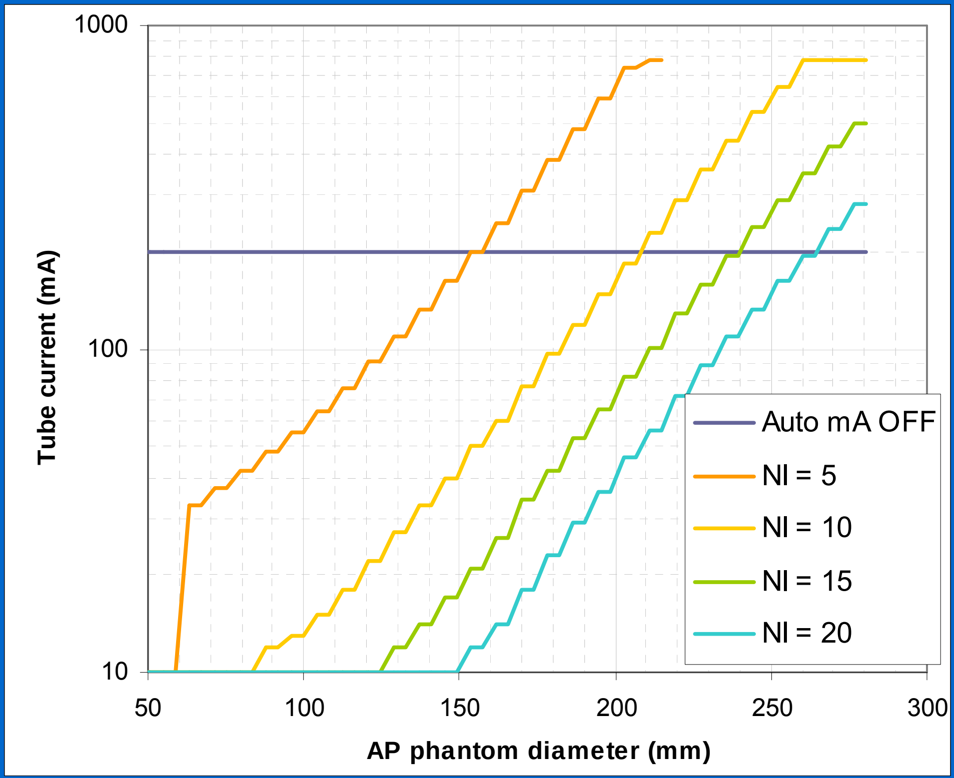
Results: GE - axial



Noise Index	mA	Mean SD
AEC off	200	-
5	10-783	4.4
10	10-783	11.0
15	10-500	18.0
20	10-280	27.3

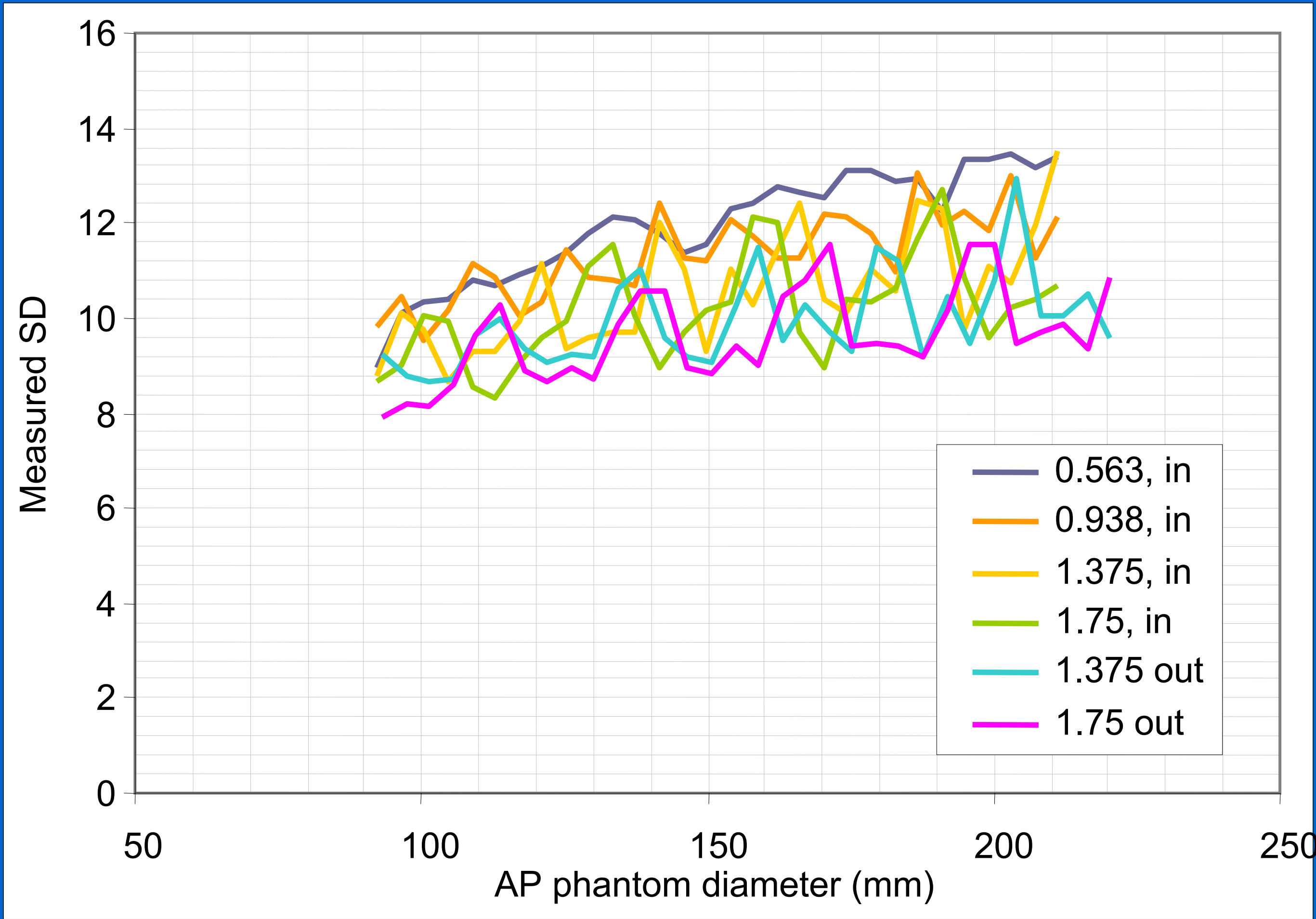
Results: GE - axial





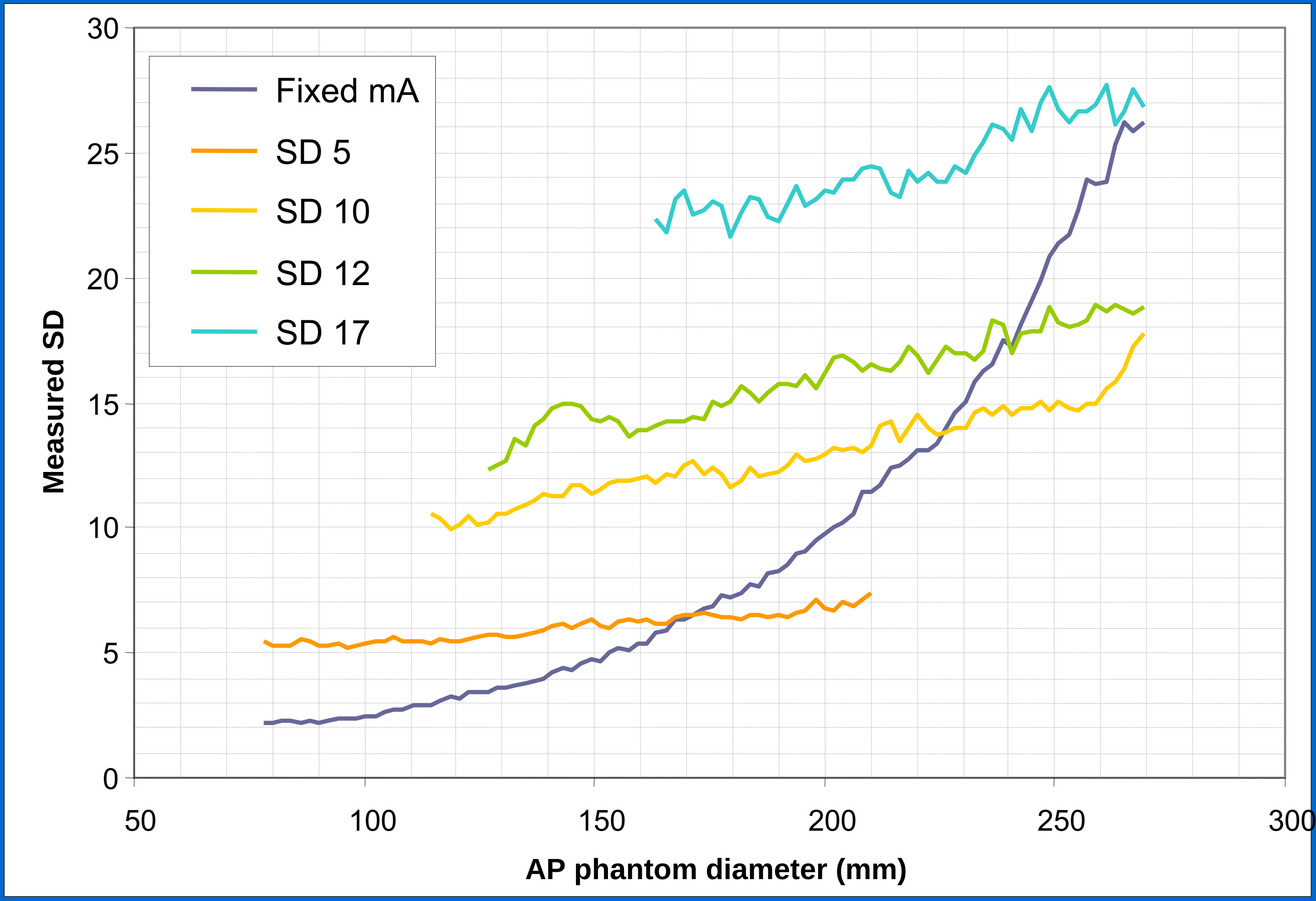
Results: GE - helical

- Noise index 12, different helical pitch, table movement in and out of gantry



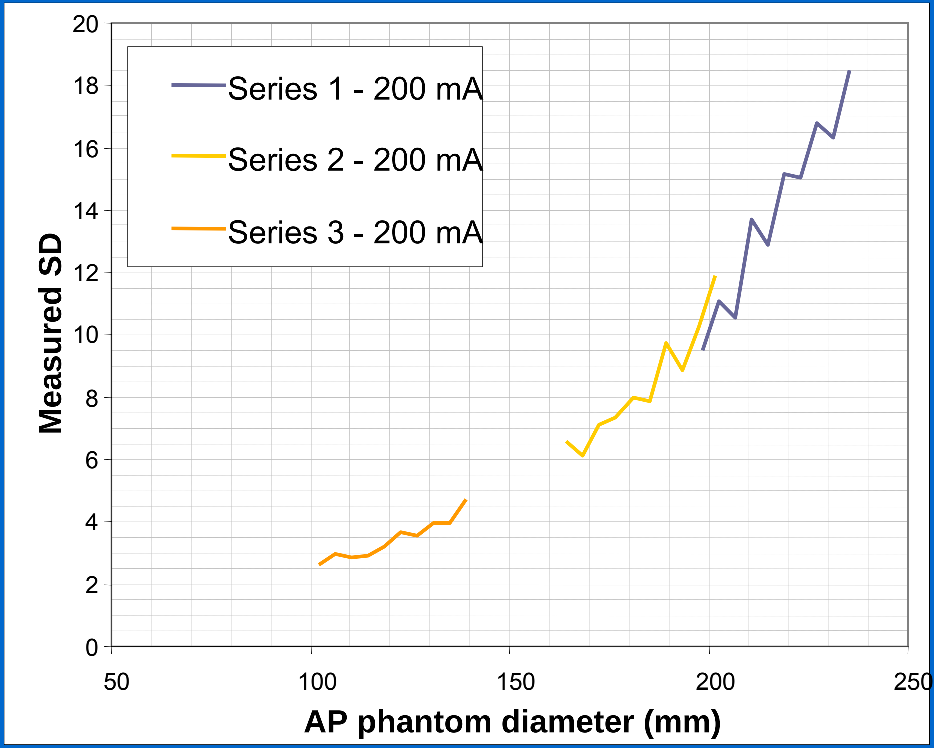
Results: Toshiba

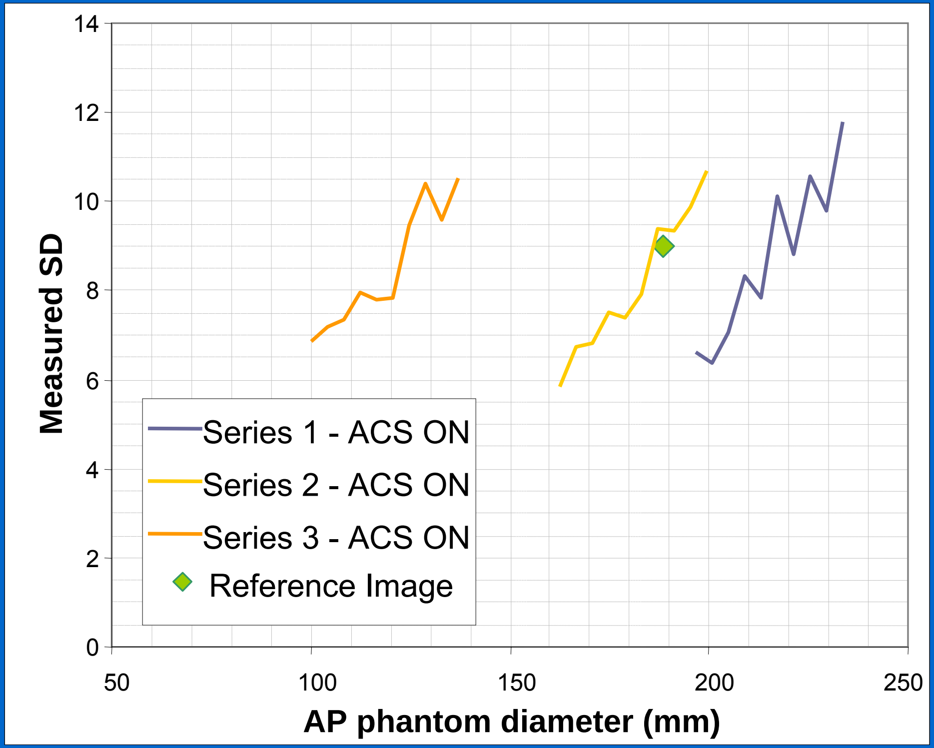
- Data from RealEC on Aquilion 16



Results: Philips

- Mx8000 IDT has patient size AEC, and mA modulation



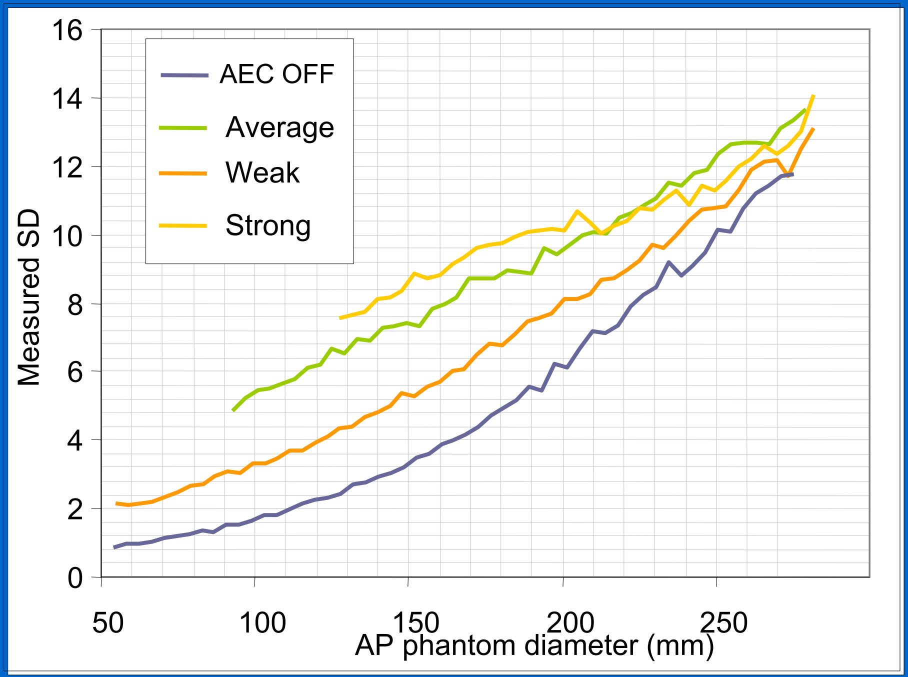


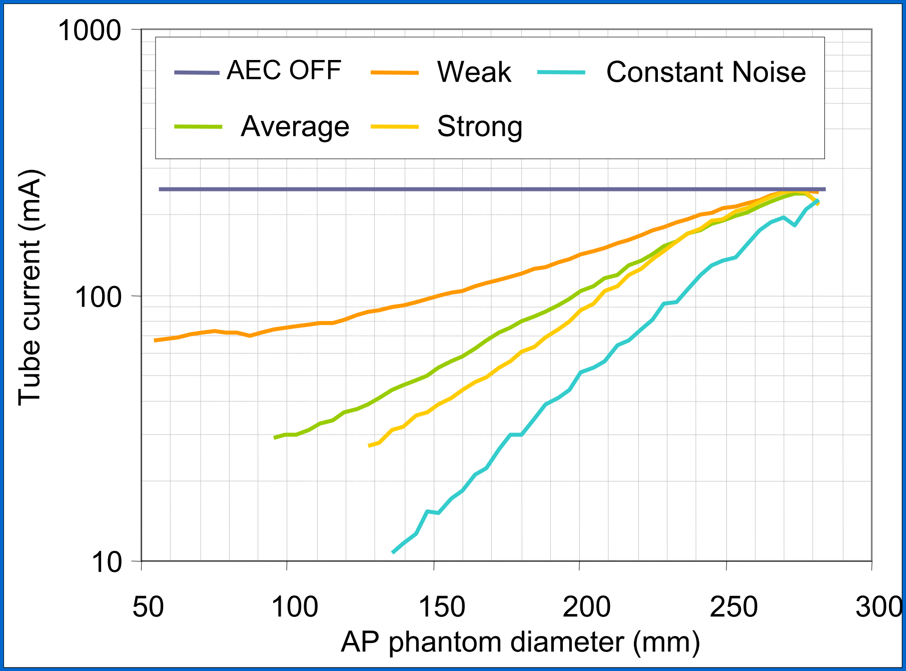
3 scans planned,
at different z-axis positions,
patient AEC off

3 scans,
patient AEC on

Results: Siemens

- System does not aim to keep noise constant
  - Smaller patients may need better quality images
- Three ‘strengths’ of AEC





Know your AEC!

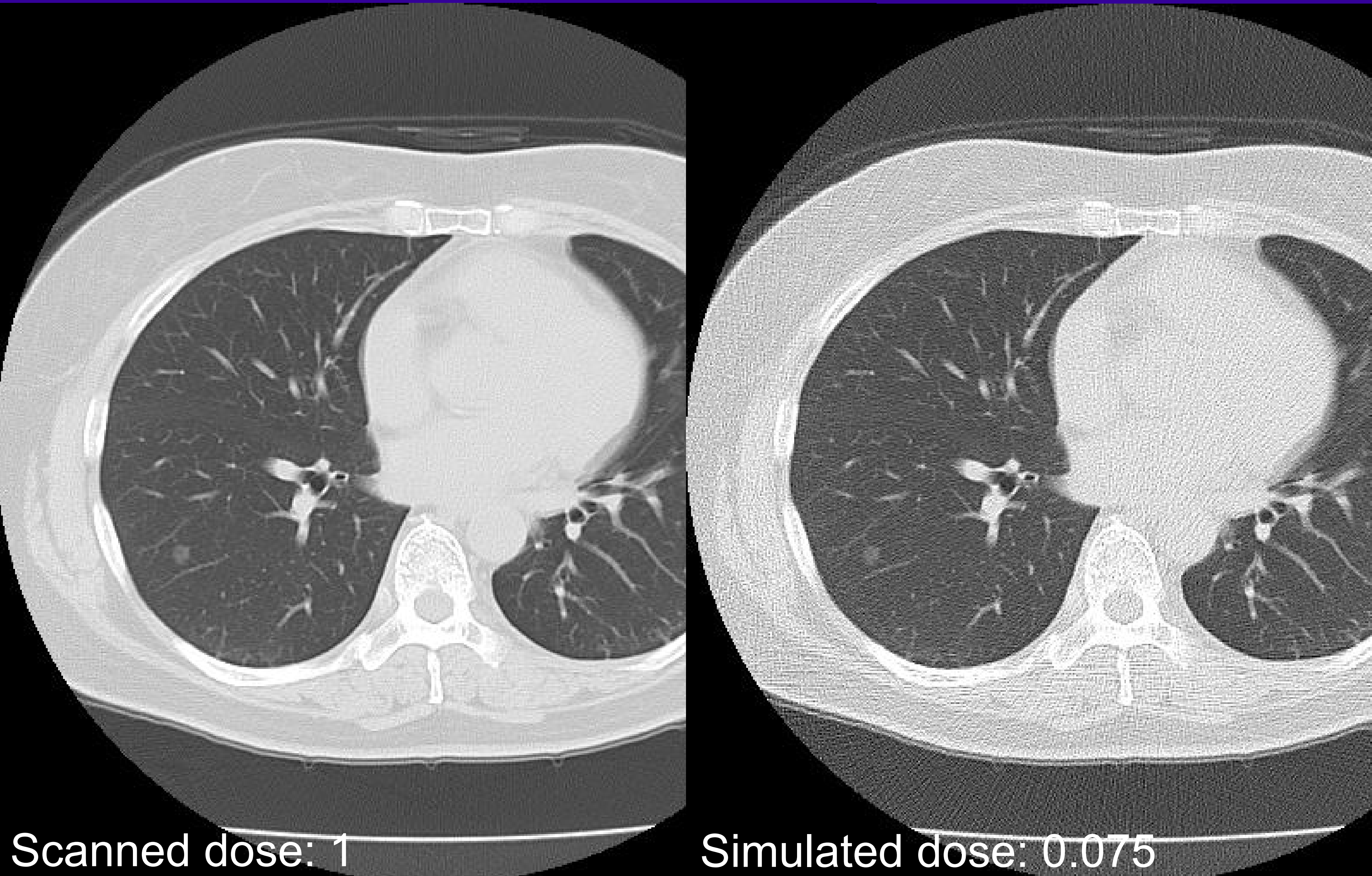
- Each AEC responds differently to changes in scan and recon parameters
  - Important to know how **your** system will react!

Manufacturer	Tube voltage	Rotation time	Helical pitch	Image thickness	Recon kernel
GE	✓	✓	✓	✓	
Philips	✓	✓	✓	✓	
Siemens		✓	✓		
Toshiba	✓	✓	✓	✓	✓

What is the is optimum AEC setting?

- Depends on the application
  - One body part may require different IQ levels depending upon clinical requirements
- How do we find this out?
  - Critical evaluation of image quality, feedback
  - Simulation studies
- Responsibility for manufacturer to develop good default protocol settings

What IQ or dose is needed?



Images courtesy Y. Muramatsu, NCC Tokyo

What do AECs give us?

- Lower patient doses than before?
  - Possibly, but this is by no means a foregone conclusion
  - It is possible to use AEC and give higher dose than previously
  - Keep monitoring $CTDI_{vol}$ and DLP – expect larger variations
- More consistent image quality?
  - Yes…
- The optimum image quality?
  - If they are used well

Conclusions

- AEC systems offer potential benefits for everyone
  - Radiologists: image quality consistent from patient to patient
  - Radiographers: consistent IQ for different sizes is now simple
  - Patients: potential for dose reduction, repeat exams less likely
  - Physicists: protocol optimisation is easier
- Users need to understand the systems
  - How does mA vary when changing slice thickness or kernel?
- The current systems work as intended, but there is opportunity for manufacturers to improve them further
  - Optimisation of scan protocols with AEC
  - A common method for defining image quality would be useful
  - Potential for AEC to control scan times and kV too
- ImPACT AEC report: www.impactscan.org/bluecover.htm

Challenges for manufacturers and users

- Optimisation of scan protocols
  - Work required to ensure that radiologists are getting good image quality, and patient doses are under control
- Standardisation of method to set exposure/IQ
  - A single method would aid comparison of scan protocols from many scanners or scanning centres
- Education of users
  - AEC users need to know the details of their system, how it differs from others