Assessment of automatic exposure control systems on CT scanners using a custom made phantom

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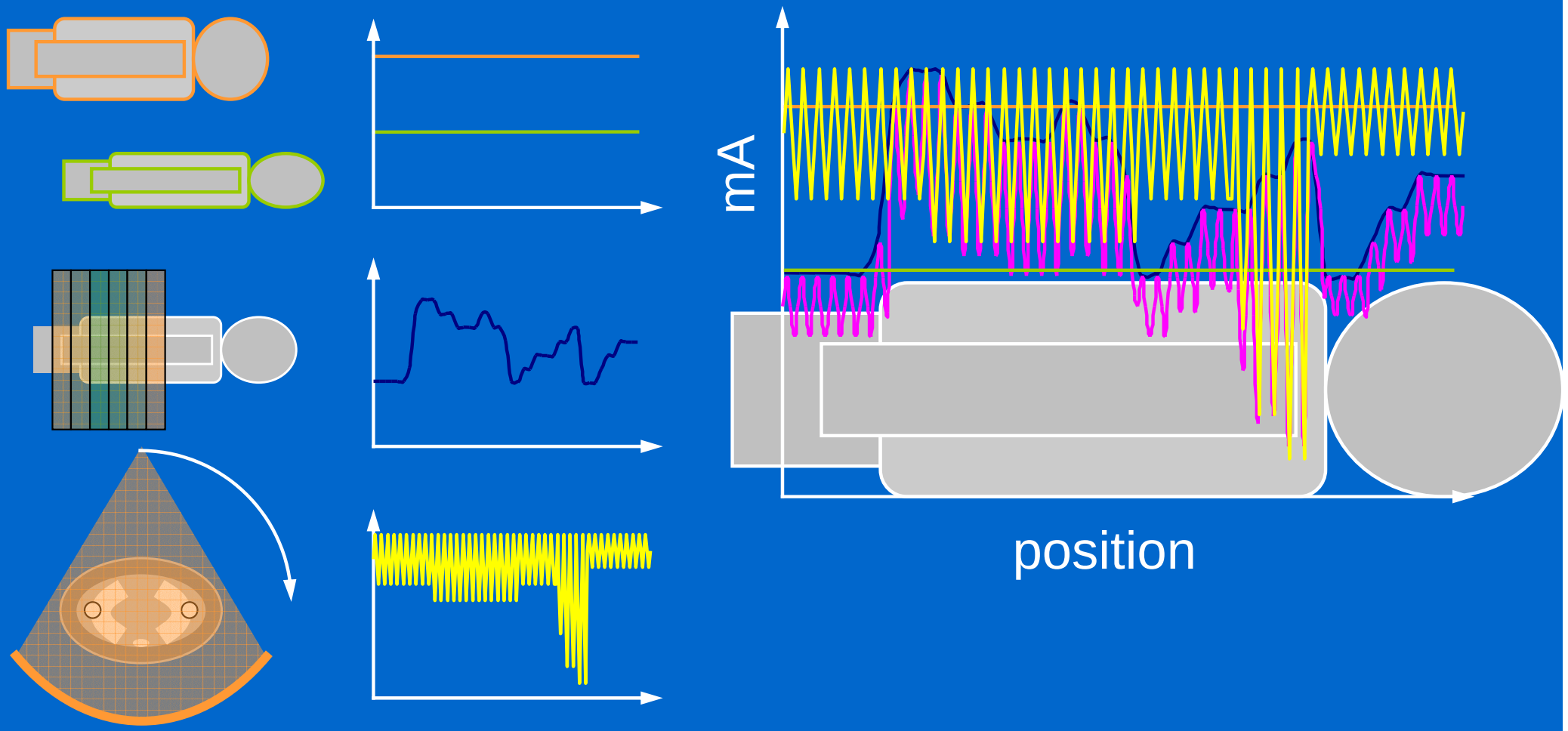
AEC systems

- Problem in defining CT protocols: Attenuation of x-rays is different
  - From patient to patient
  - Along patient length – z-axis
  - In AP and lateral directions – rotational
- All manufacturers have introduced or updated their 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

AEC systems

- mA adjusted to compensate for attenuation differences
  - dose applied to patient only where needed, avoiding dose where it isn't needed

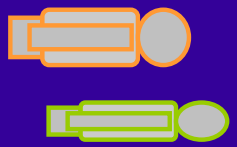
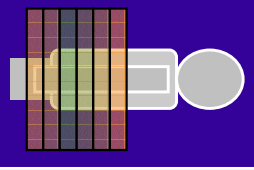
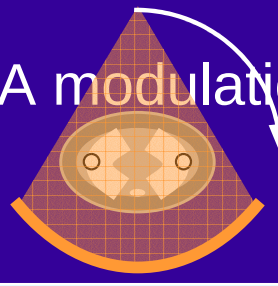


Advantages of AEC

- 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

Current 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 DOM
Siemens	CAREDose 4D**		CareDose
Toshiba	SUREExposure / Real EC		

*GE LightSpeed Pro16 only

**Siemens Sensation 10/16 upwards only

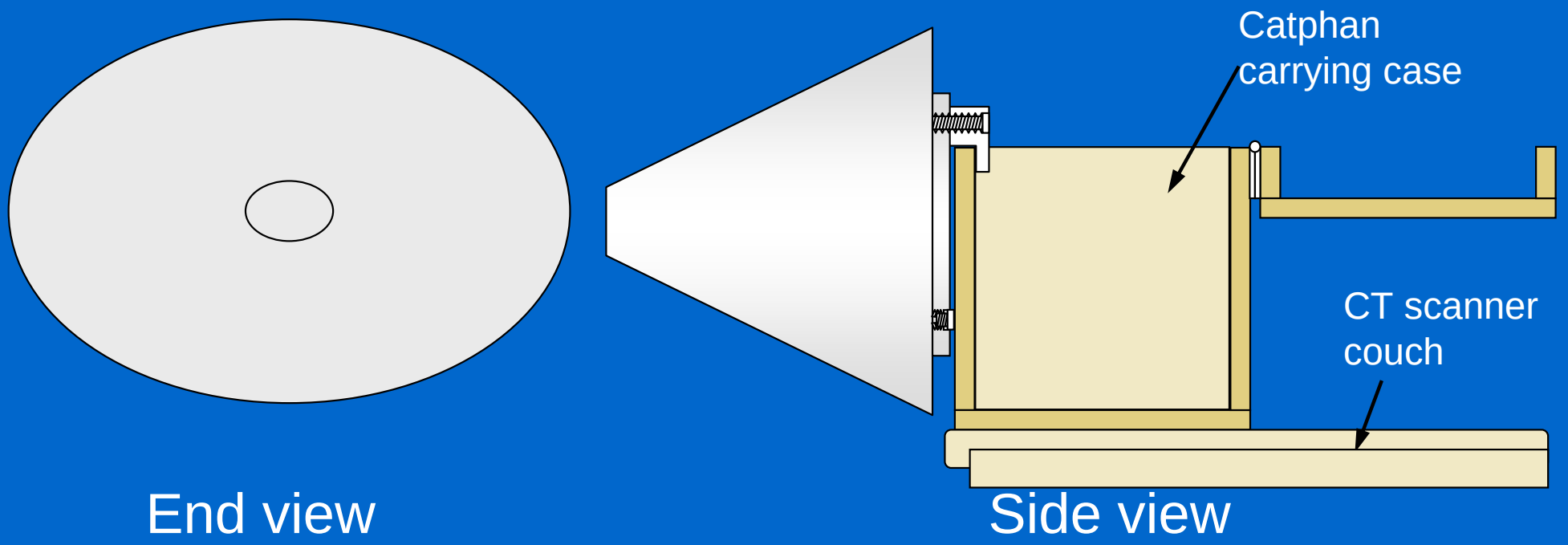
Methods to set AEC exposure level

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

Manufacturer	Method for setting exposure level
GE	‘Noise Index’ sets required image noise level
Philips	System attempts to give same level of image noise as a ‘Reference Image’ acquired earlier
Siemens	‘Equivalent mA’ set for standard sized patient
Toshiba	Set required standard deviation (noise)

ImPACT phantom

- Based on ‘Apollo’ phantom developed by Muramatsu, National Cancer Centre, Tokyo
  - Has ellipse, not circle cross section
  - Ellipse diameters in ratio 3:2

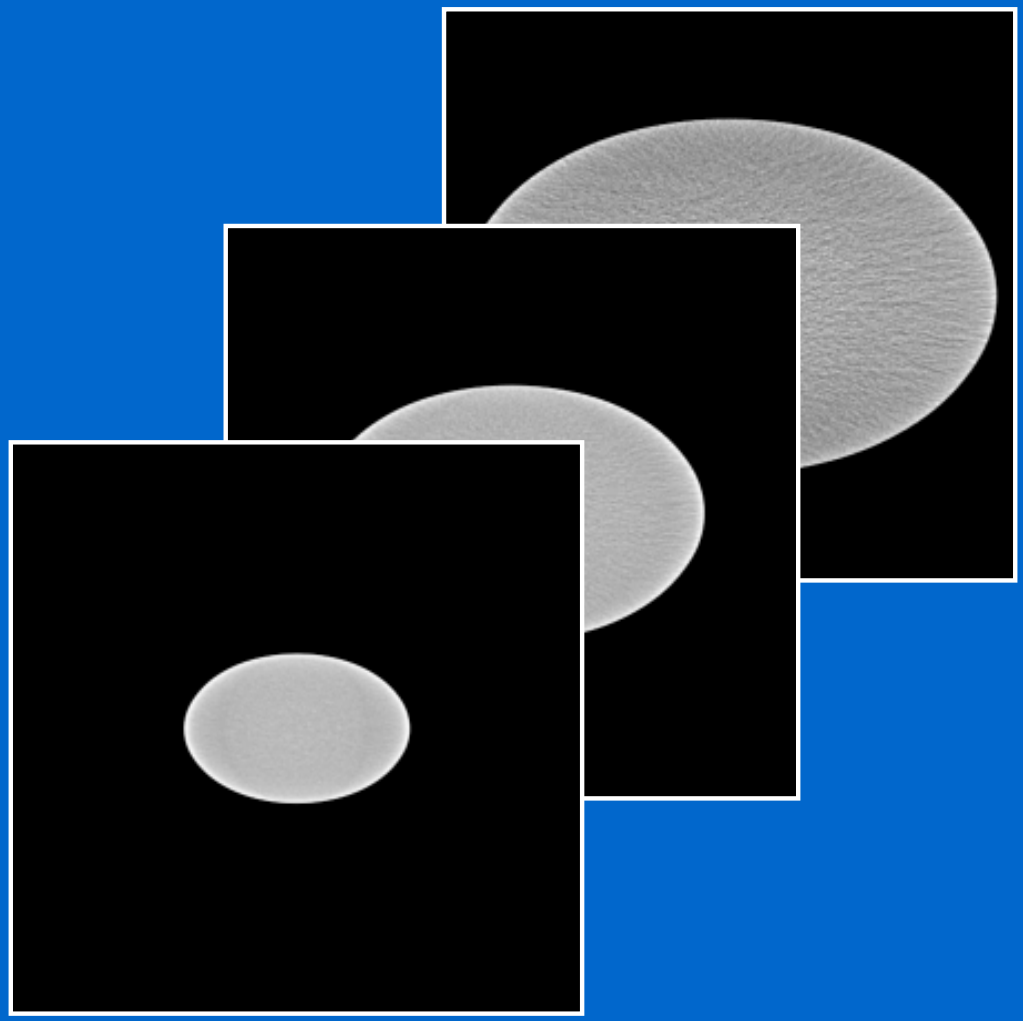


End view

Side view

ImPACT phantom

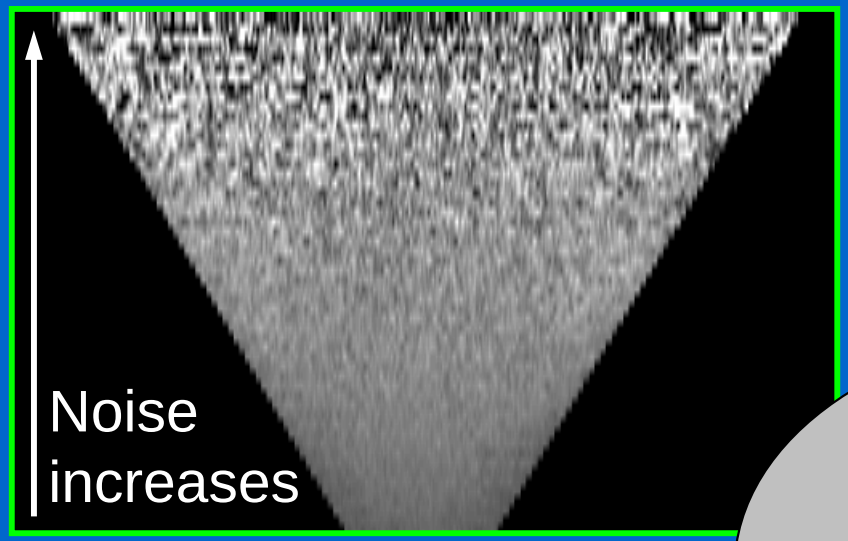
- Images along length of phantom (AEC off)

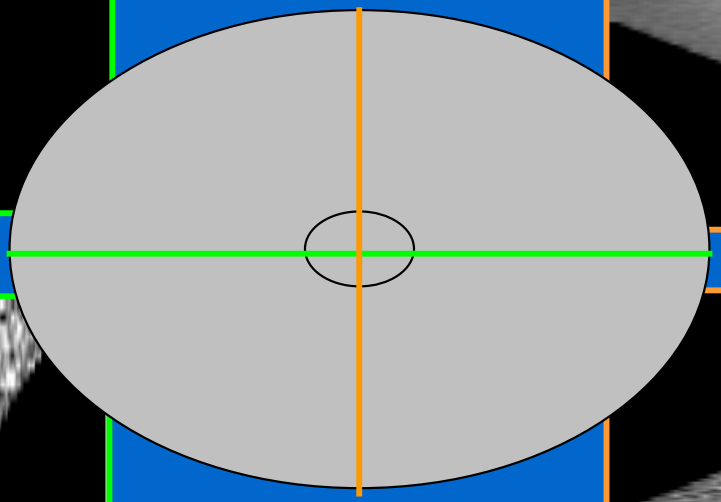


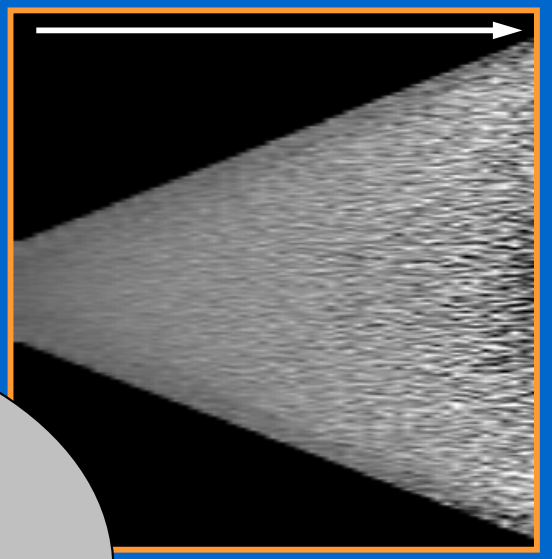
ImPACT phantom

Coronal view

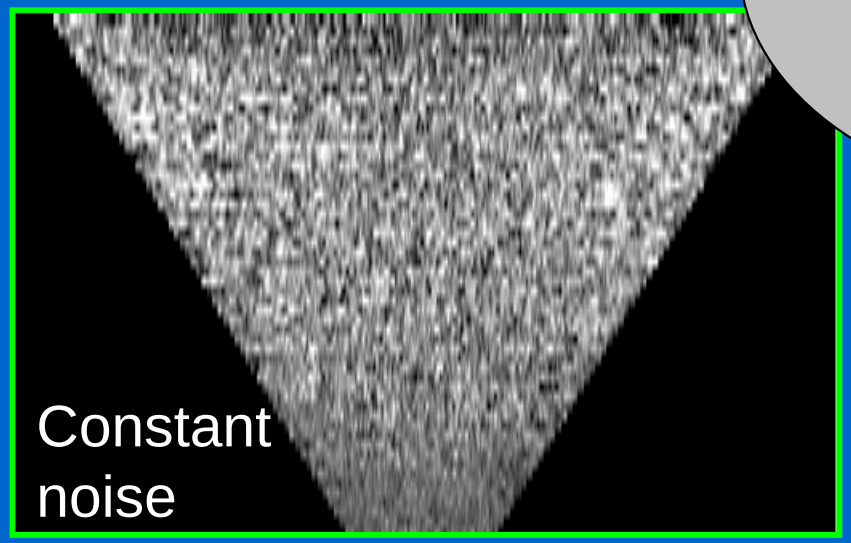
Sagittal view



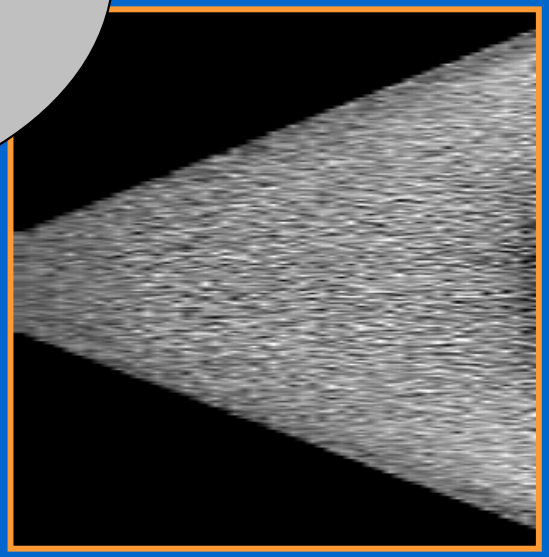




z-axis
AEC off



z-axis
AEC on

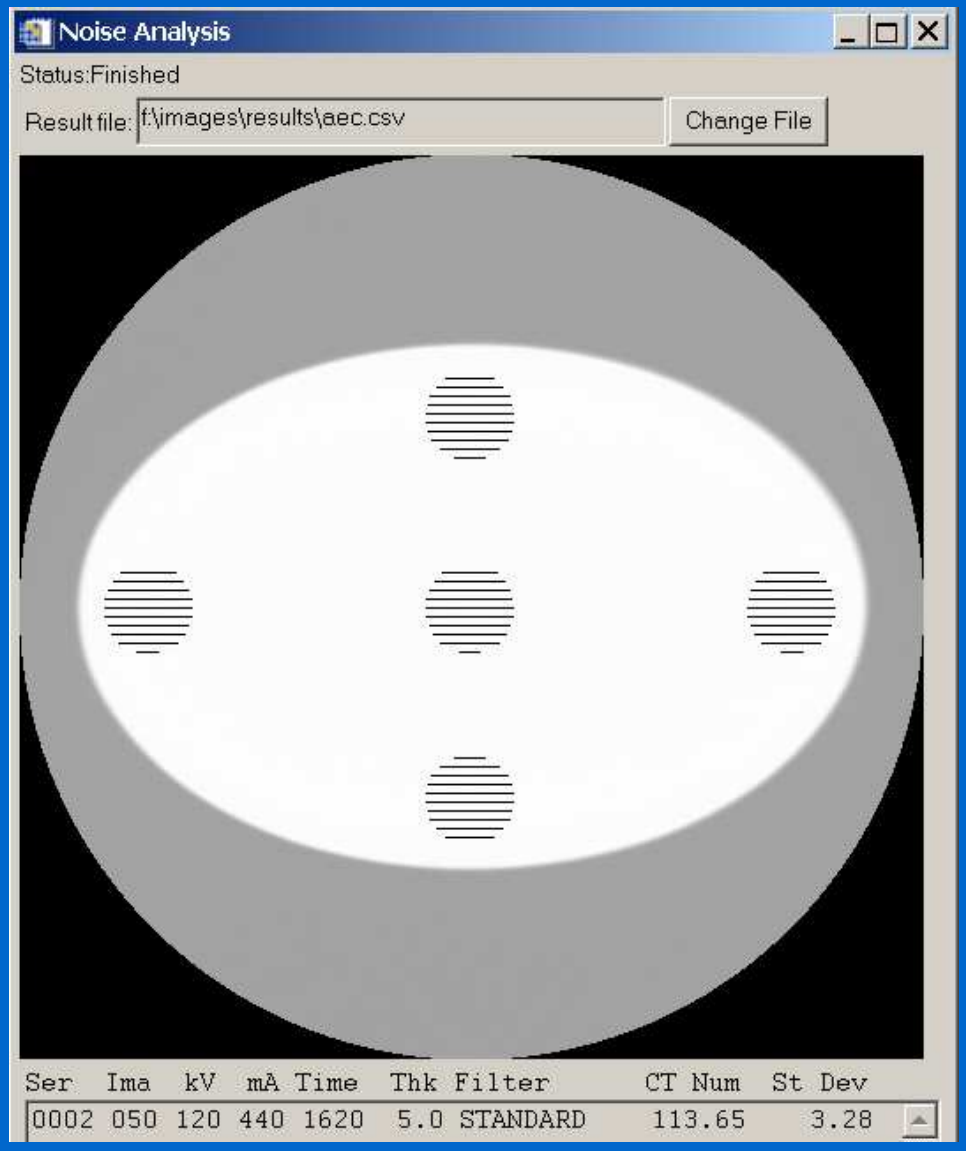


Scan protocol

- 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
- Look at effect of:
  - Exposure level – change desired standard deviation or reference mA
  - kV
  - Axial and helical scanning
  - Helical pitch and direction of couch 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

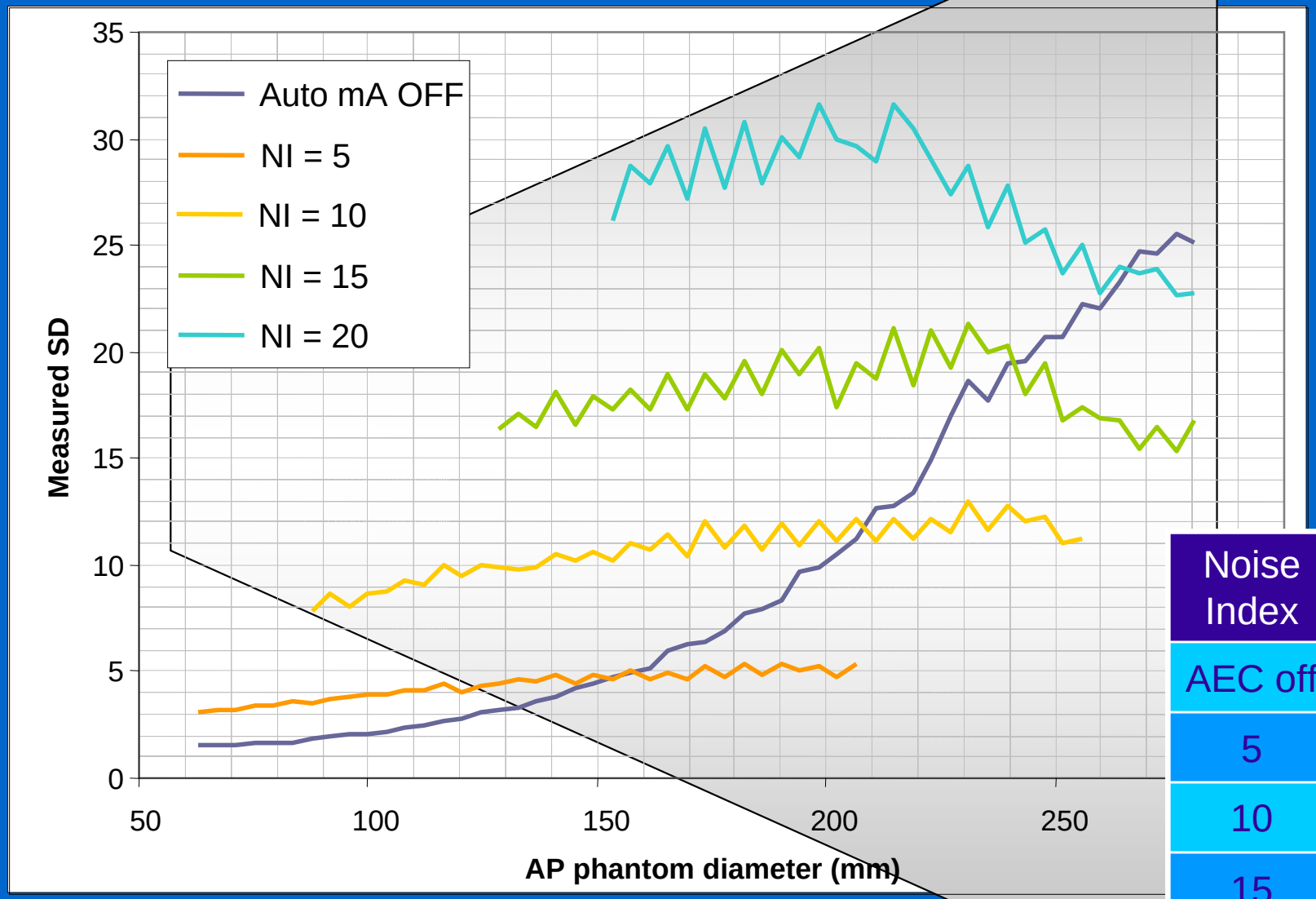


Results from testing

- Testing takes 1-2 hours.
  - Delays for tube cooling can be long
- 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 so far, much more data has been gathered

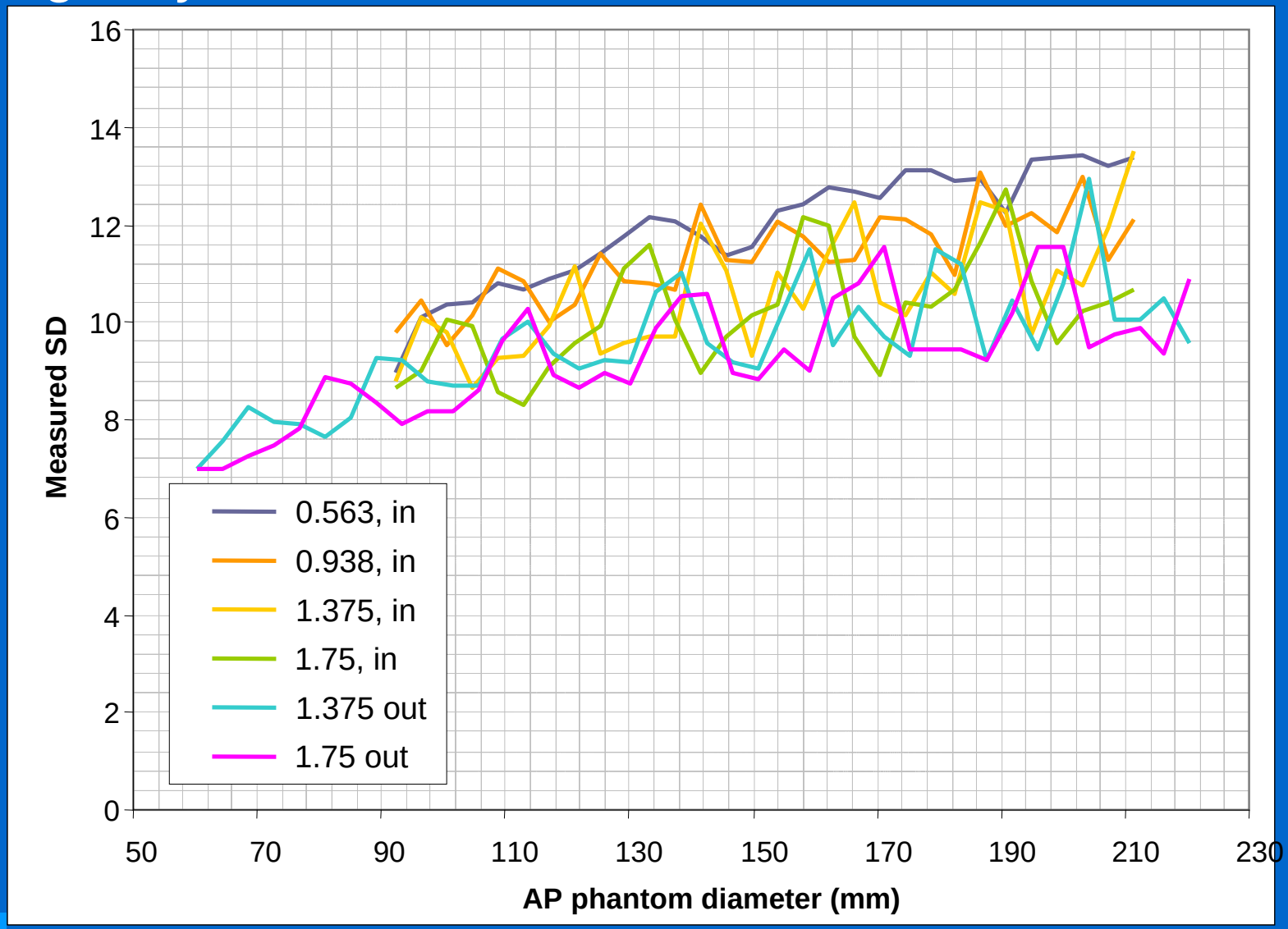
Results: GE



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

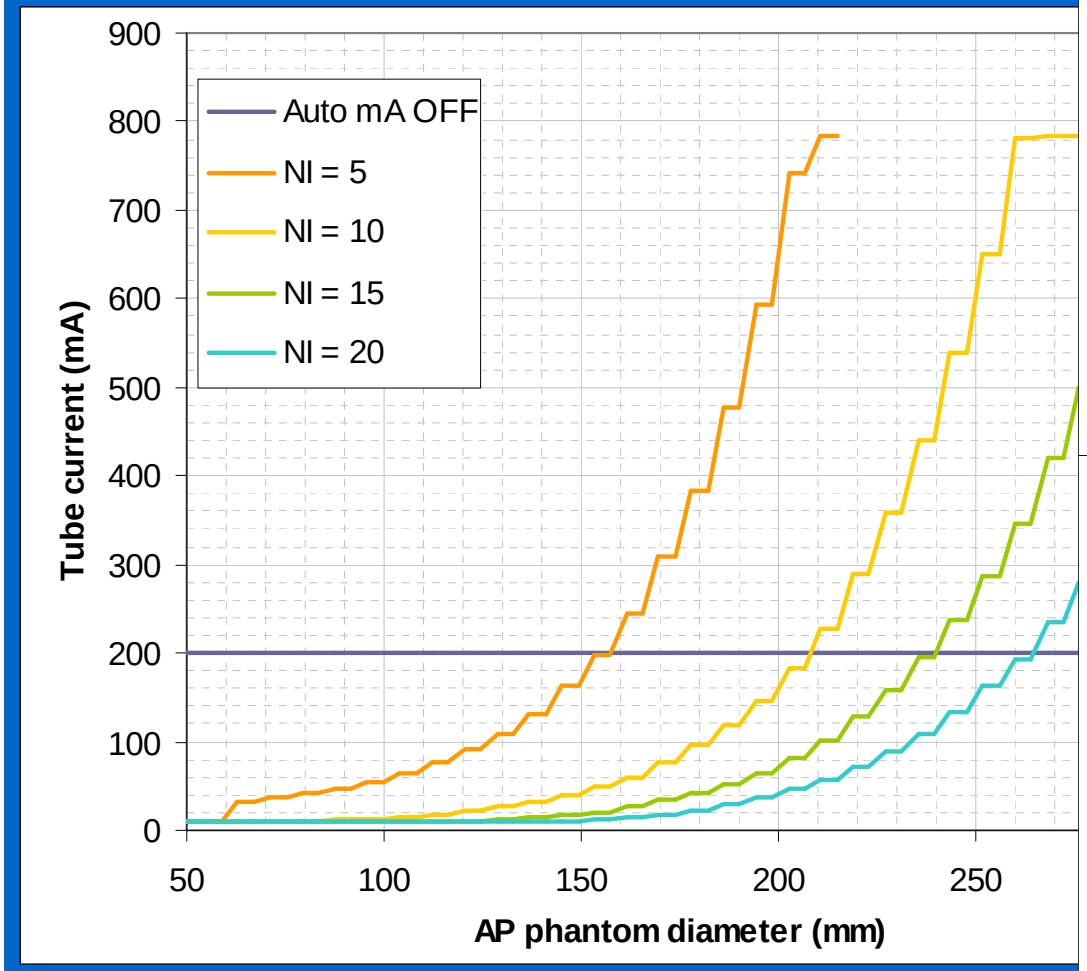
Results: GE

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

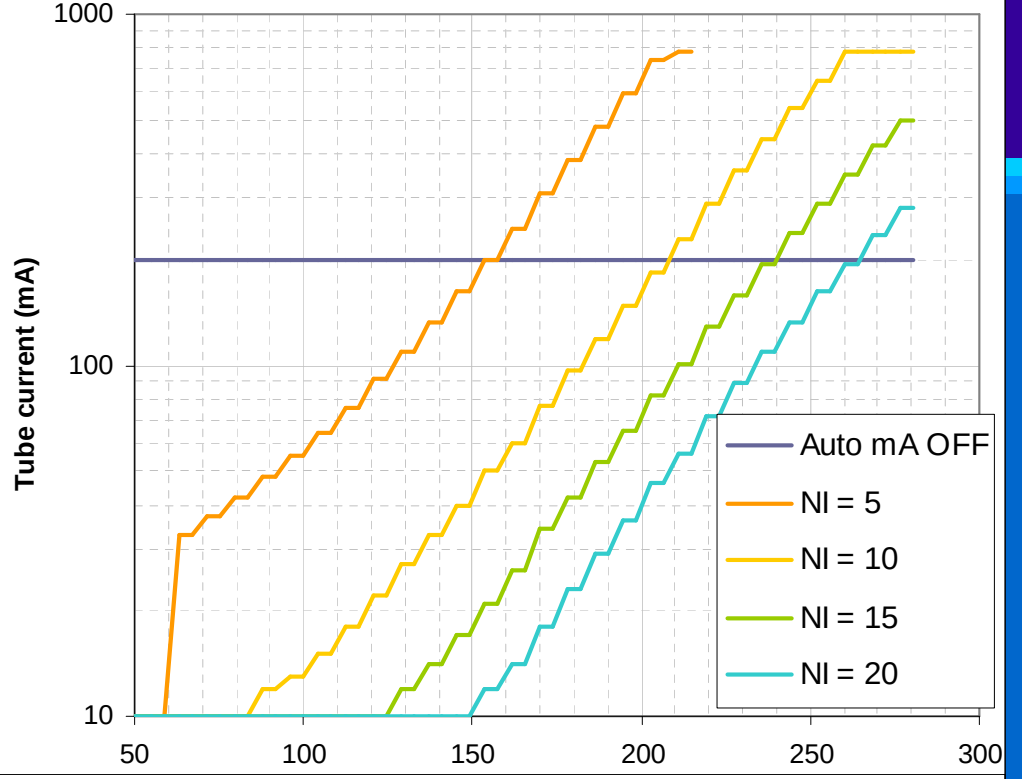


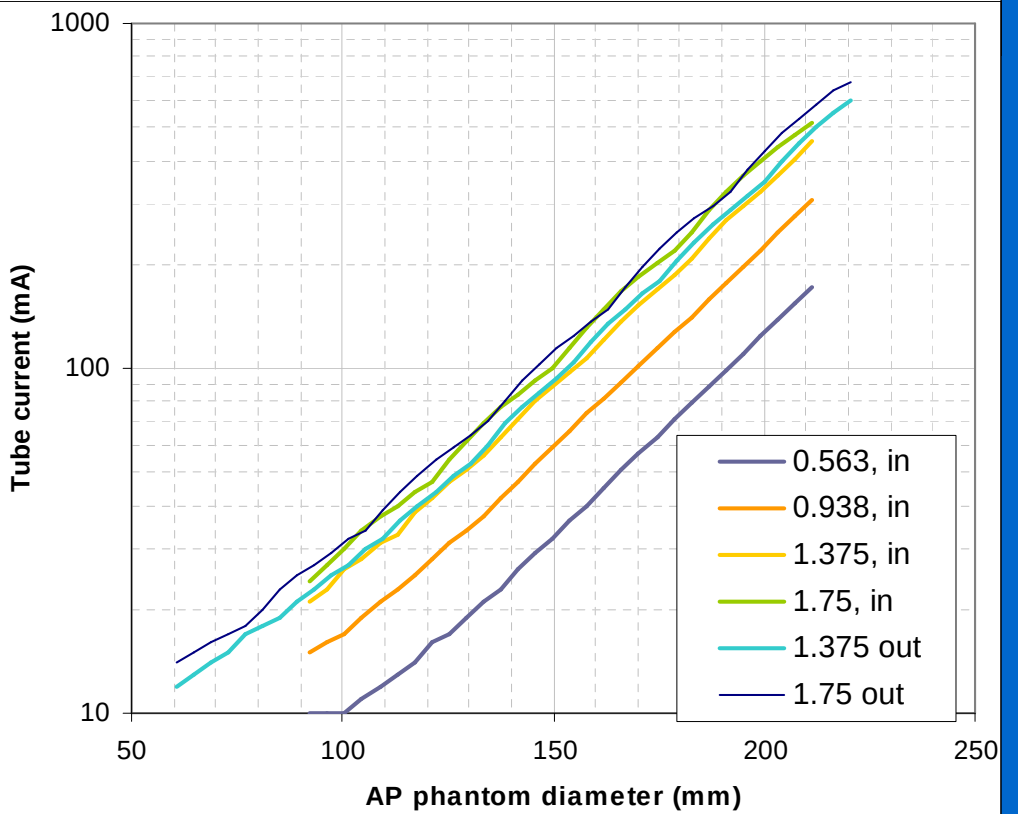
Results: GE

Axial



Axial





Helical

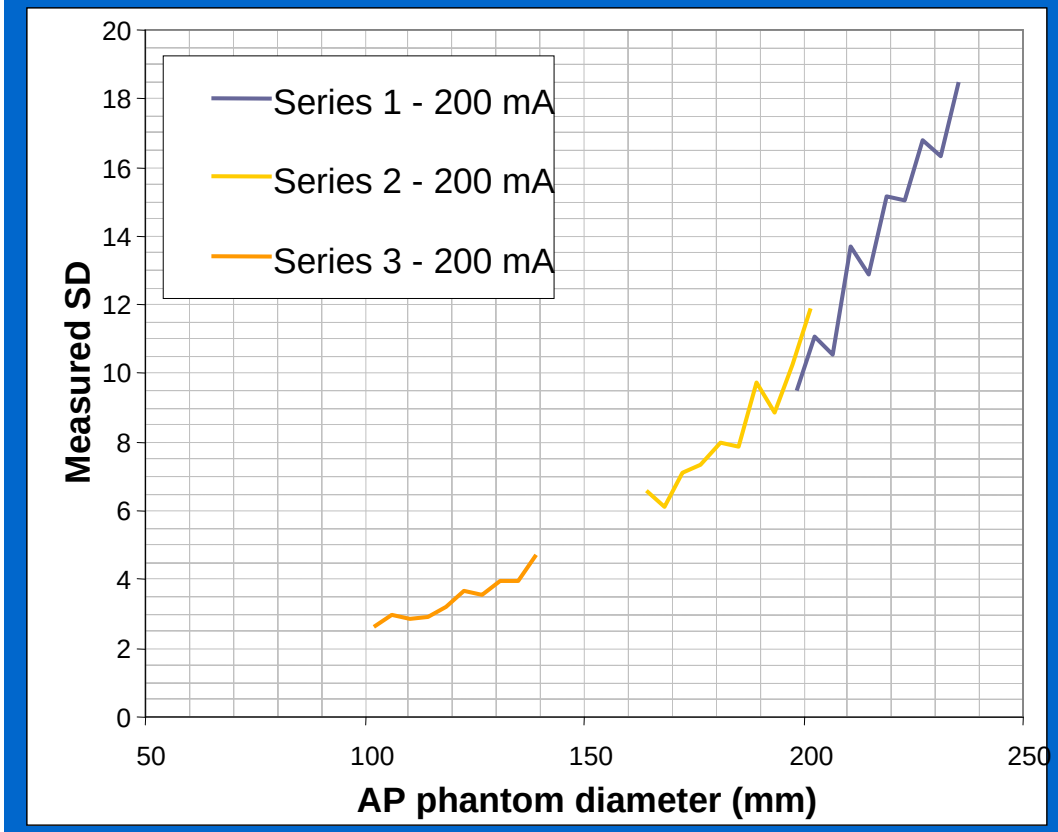
Results: GE

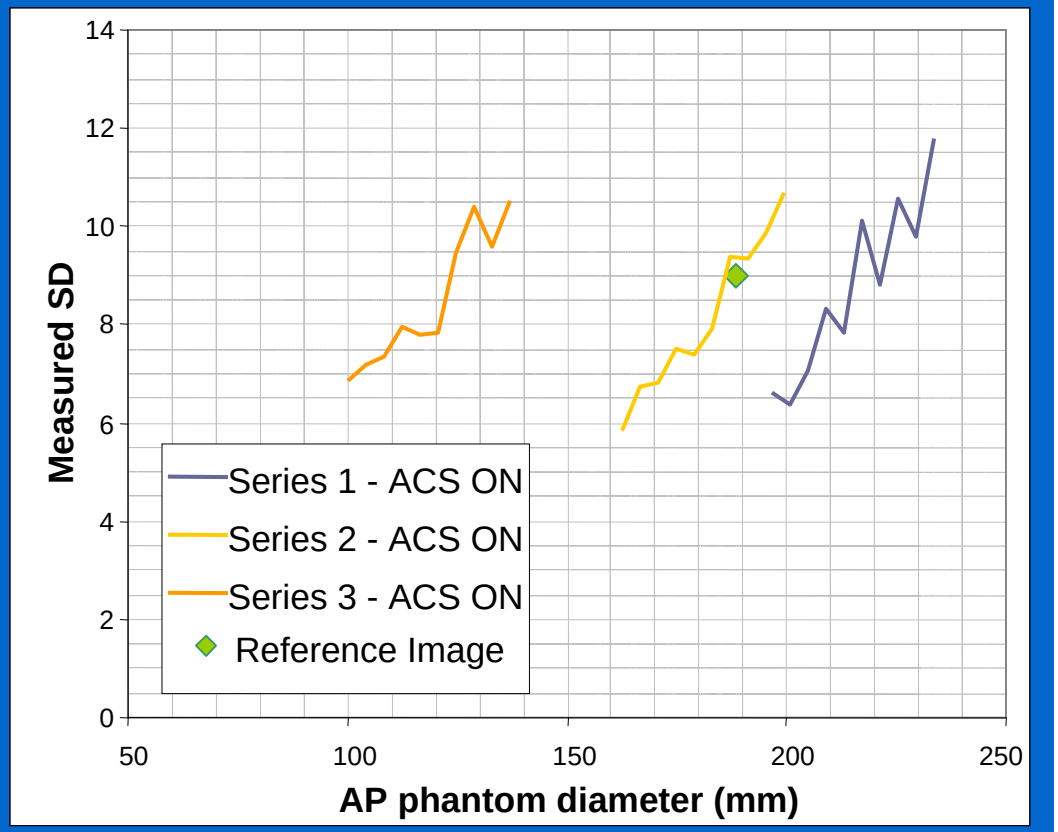
- Different kVs, Noise Index 10

kV	mA (Smart mA off)	Measured SD
80	451	10.6
100	179	10.9
120	105	10.5
140	73	10.7

Results: Philips

- Mx8000 IDT has patient size AEC, and mA modulation



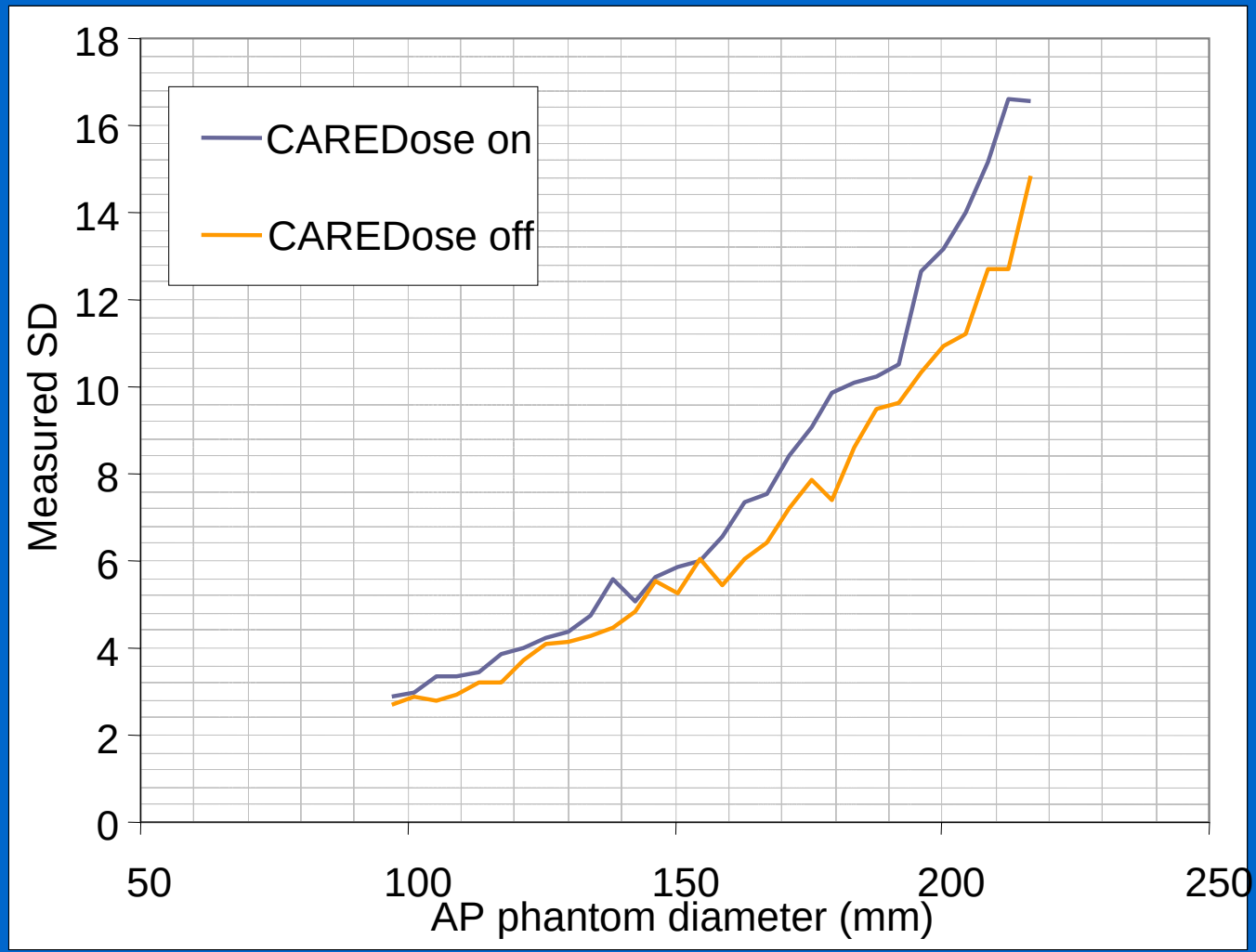


3 scans planned,
at different z-axis positions,
patient AEC off

3 scans,
patient AEC on

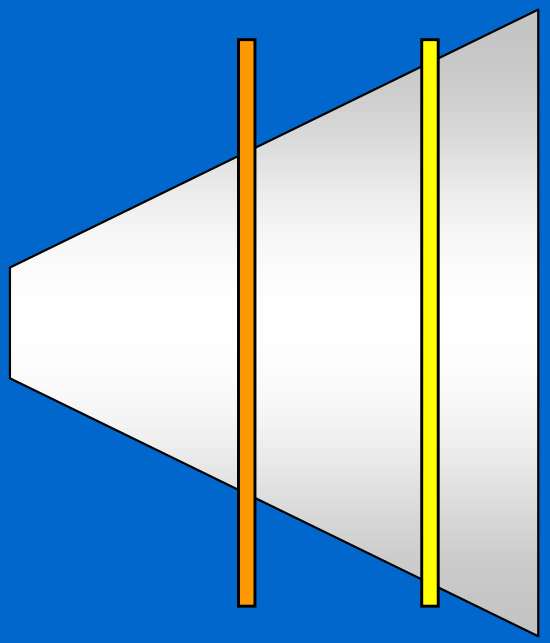
Results: Siemens

- CAREDose – only mA modulation tested
- With CAREDose on, effective mA, and therefore dose decreases (noise increases)



Results: Siemens

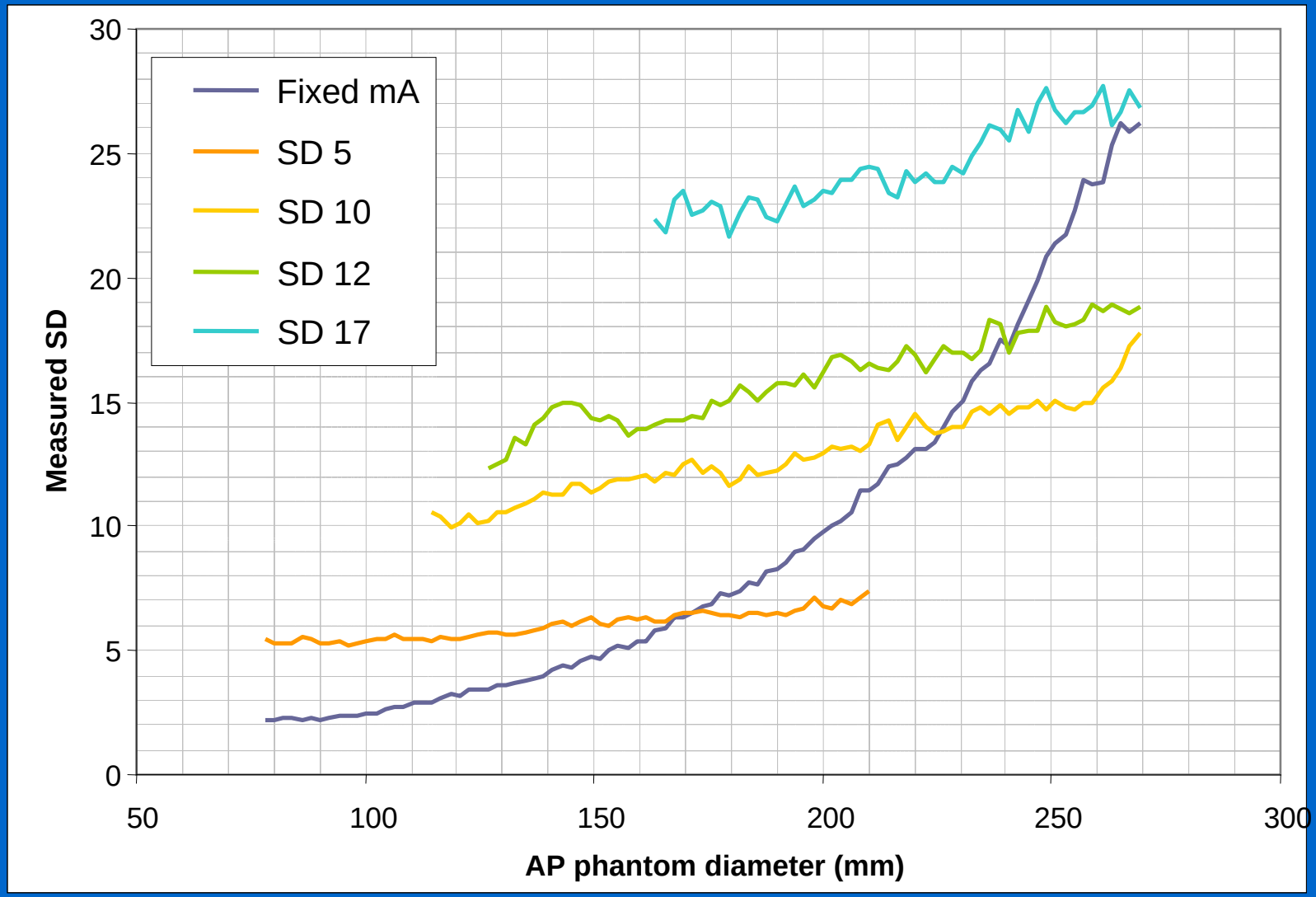
- Set mA = 200
- mA modulation is greatest at wide end of phantom – lower mean mA at wide end
- Improvements of up to 9% in noise and dose (9% lower noise for same dose).
- Greater improvements would be seen in a shoulder shaped phantom



mean mA / mA	SD - CAREDose	SD constant mA	Relative SD
134	12.2	13.0	0.93
120	47.2	50.0	0.91

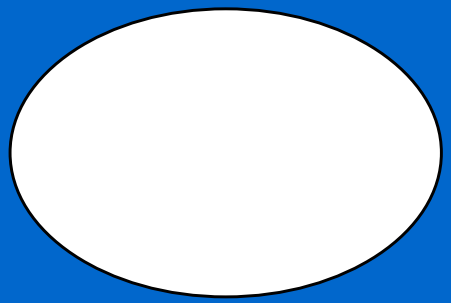
Results: Toshiba

- Data from RealEC on Aquilion 16

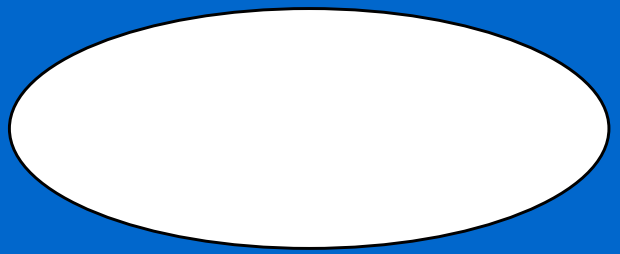


Future work plans

- Need to incorporate CAREDose 4D data:
  - Scanned last week, not yet fully analysed
- Could look at mA modulation systems in greater depth
  - Would require a less symmetrical phantom: our abdomen phantom diameter is in ratio 3:2, shoulders are closer to 5:2



Abdomen



Shoulder

Challenges for manufacturers and users

- Optimisation of scan protocols
  - AEC systems provide a method to define protocols in terms of image quality, rather than dose level
  - Work required to ensure that radiologists are getting good image quality, and patient doses are under control
- Standardisation of method to set exposure level
  - Currently, the user can choose noise index, reference mA, reference image, required SD
  - A single method would aid comparison of scan protocols from many scanners or scanning centres
- Education of users
  - AEC systems do not automatically lead to dose reduction – correct definition of required IQ is important

Conclusions

- AEC systems offer potential benefits for everyone!
  - Radiologists: image quality consistent from patient to patient
  - Radiographers: setting image quality for different sized patients is now much easier
  - 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 to improve them further
  - A common method for defining exposure would be useful
  - Potential to vary scan times and kV automatically