AEC Calibration for a Samsung DR Imaging System

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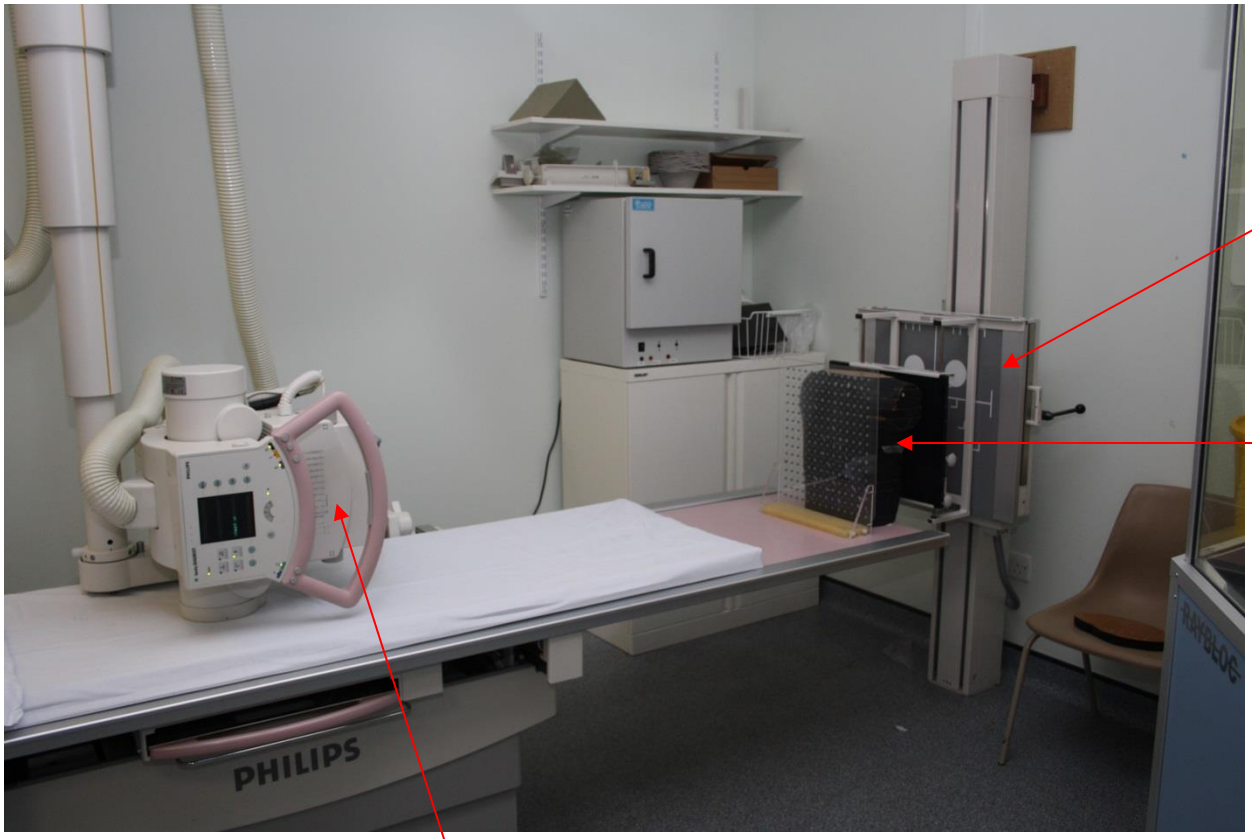
What is an AEC?

- **A**utomatic **E**xposure **C**ontrol
- These devices have been used by operators of radiological imaging systems for many years
- They are designed to maintain an appropriate level of image quality irrespective of:
  - Body region
  - Thickness of anatomy
  - Tube voltage
- Ion chambers inside the 'bucky' mechanism are calibrated to terminate the x-ray exposure at a pre-determined dose

What is an AEC?



AEC ion chambers here

patient

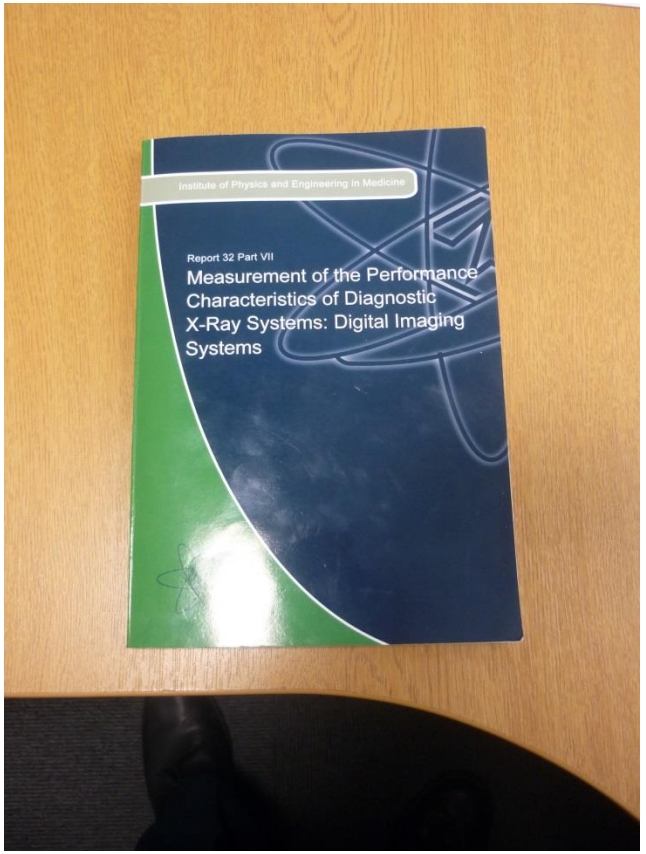
X-ray tube

What is an AEC?

- Traditional AEC devices, used in conjunction with film-screen detectors, were calibrated to maintain optical density (OD) at a target value (within acceptable limits).
- Digital image detectors, such as DR CsI phosphors, have a much greater dynamic range than film and grey levels in the resulting image are usually adjusted, irrespective of incident detector dose, to match the output of the display monitor
  - So we ***cannot*** use optical density to calibrate an AEC system with digital detectors

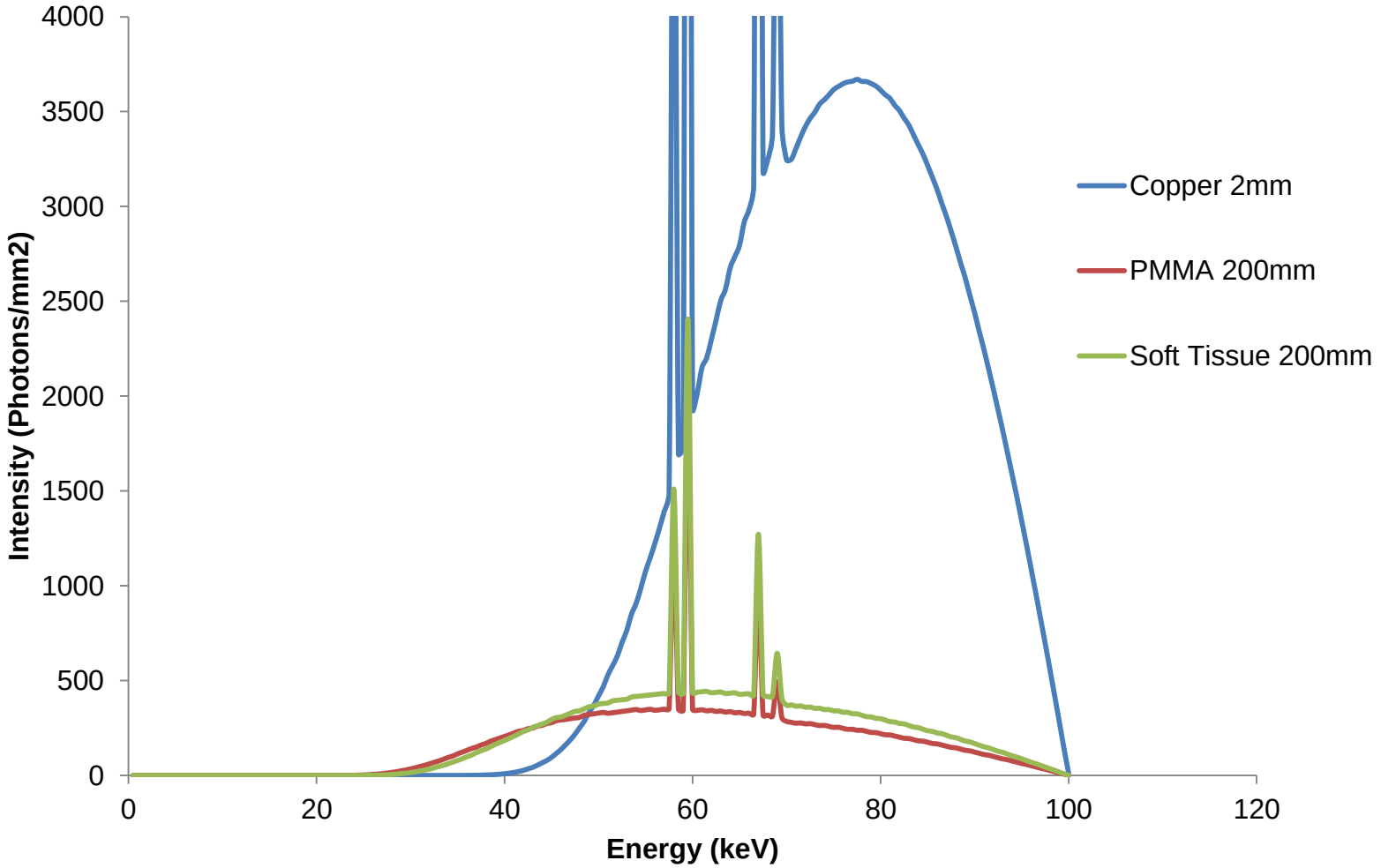
How to calibrate a DR AEC device?

- IPEM have published guidance for carrying out digital QA (IPEM 2010)
- This report makes it clear that there are no agreed metrics for AEC calibration, but they do suggest ones that can be used
- Across the tube voltage range, IPEM suggests we can hold constant:
  - Detector Dose Indicator (DDI)
  - Detector air kerma (DAK)
  - Signal to noise ratio (SNR)
  - Contrast to noise ratio (CNR)

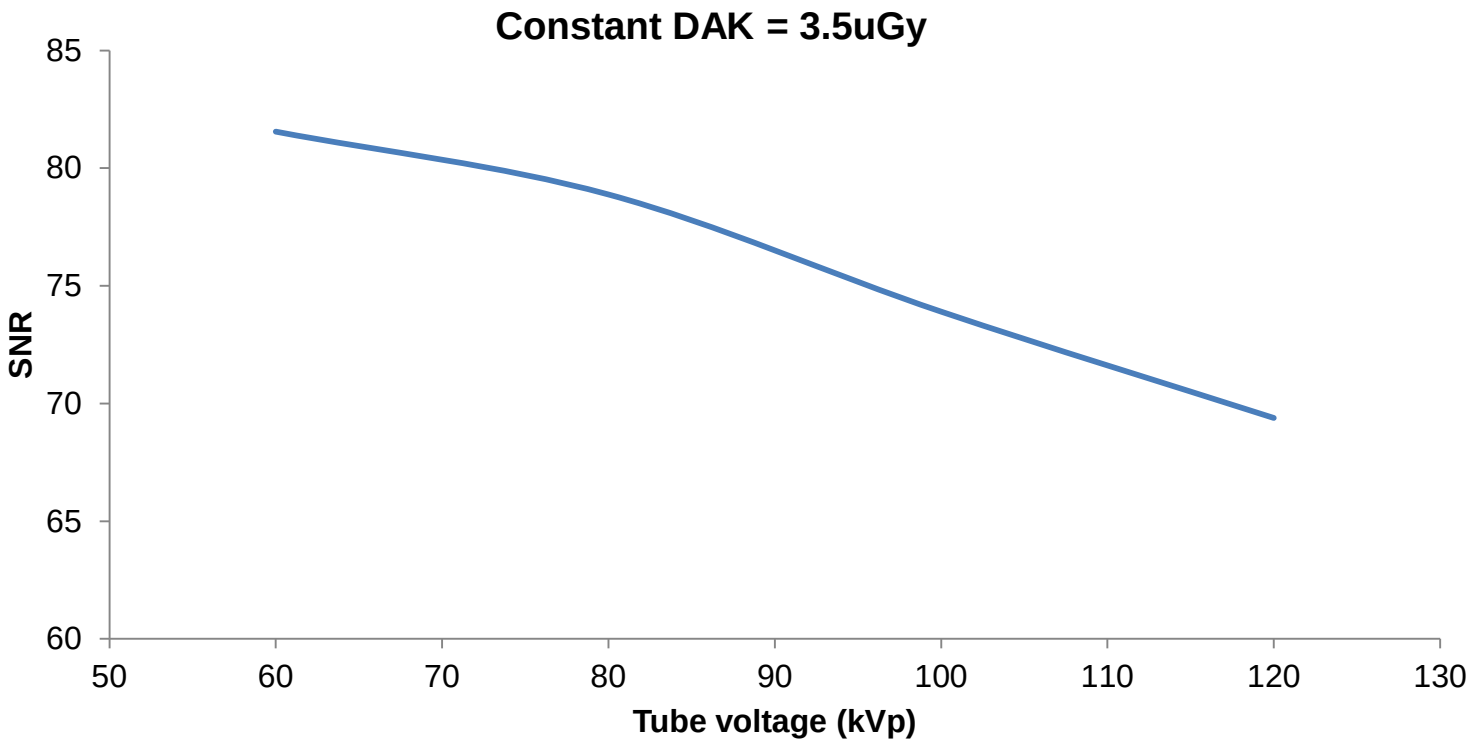


What the installers (MIS) wanted to do….

- 2mm Copper at the tube
- Hold the detector air kerma constant at 3.5 uGy across the tube voltage range
- Is this optimum??
- Probably not!!
  - Copper is not very tissue like
  - Not a clinically realistic setup i.e. Cu at tube
  - Constant DAK will ***not*** produce constant image quality across the tube voltage range


4000
3500
3000
2500
2000
1500
1000
500
0
Intensity (Photons/mm2)
0
20
40
60
80
100
120
Energy (keV)
Copper 2mm
PMMA 200mm
Soft Tissue 200mm

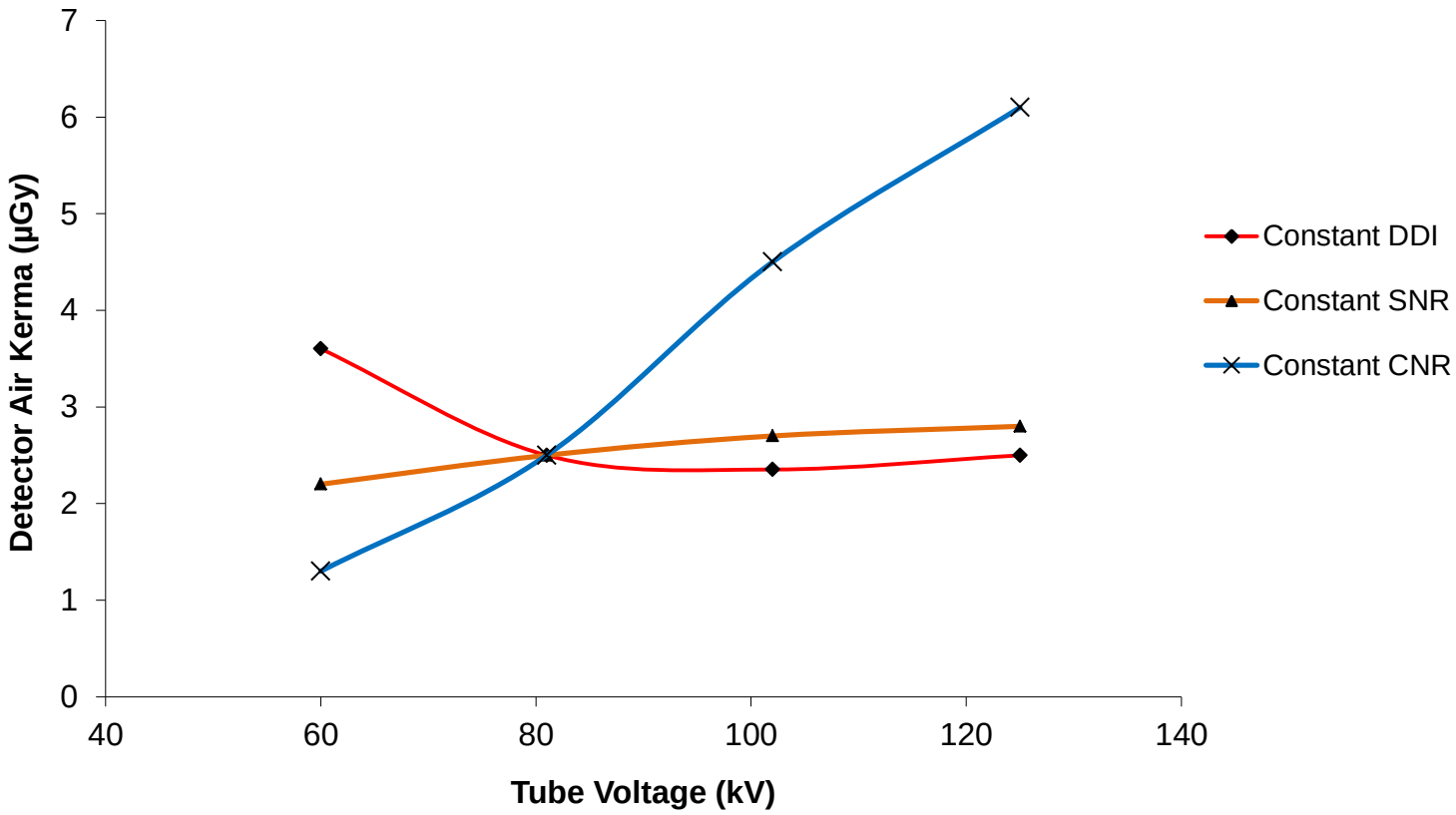
What the installers (MIS) wanted to do….



What have we done in the past?

- We have done lots of work on calibrating AECs for **CR** in recent years
- Investigated use of the following metrics:
  - SNR
  - CNR
  - DDI
- Used simple **PMMA** phantom to derive AEC calibration curves needed to hold SNR, CNR and DDI constant

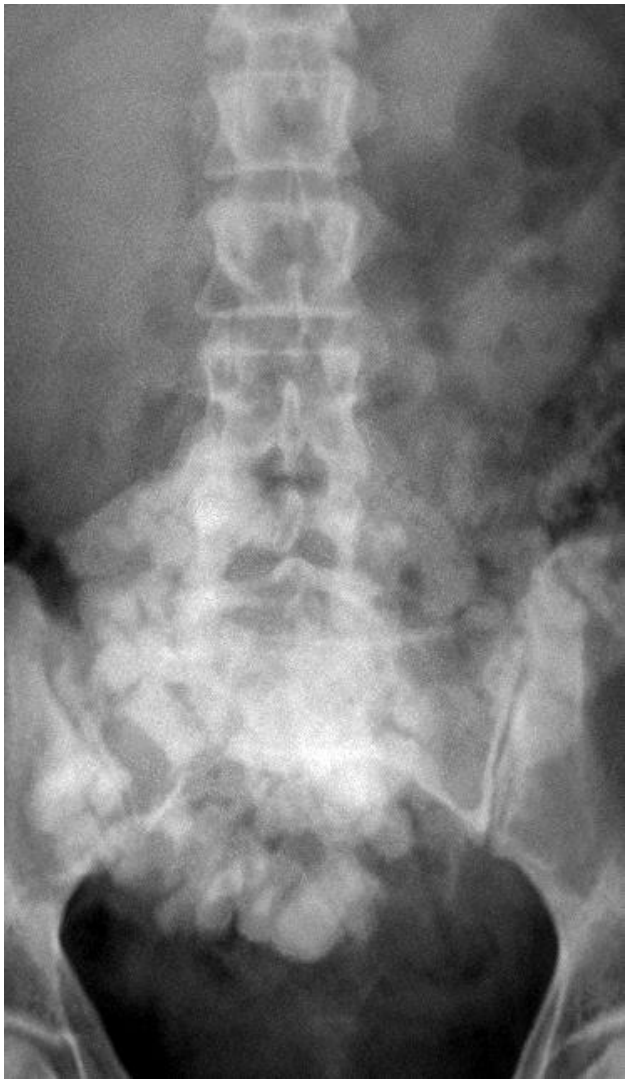
CR AEC calibration curves



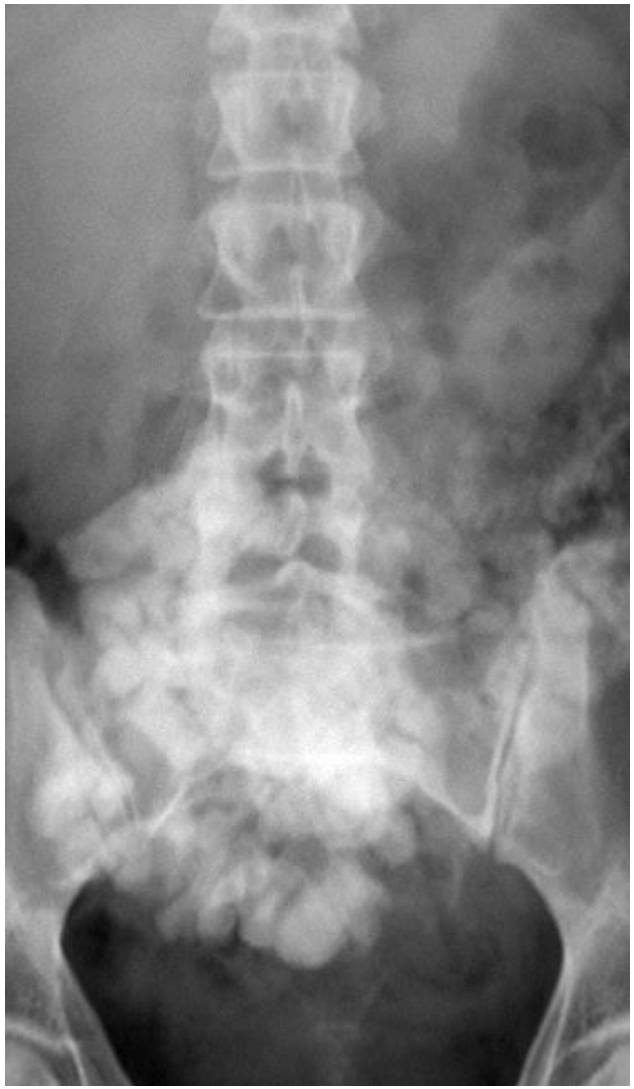
Validating the curves…for **CR**

- Used computer simulated abdo/pelvis/spine images (my PhD software)
  - Moore et al 2011
- Simulated images were reconstructed at each tube voltage of each curve, and these were scored against the corresponding (i.e. same tube voltage) image for the constant DDI curve.
- Four expert image evaluators
- 80 patients

Image Criteria
Overall quality of image compared to reference
Quality of iliac wings compared to reference
Quality of sacral foramina compared to reference
Quality of pubic and ishial rami compared to reference
Quality of sacroiliac joints compared to reference
Quality of femoral heads compared to reference



Low dose



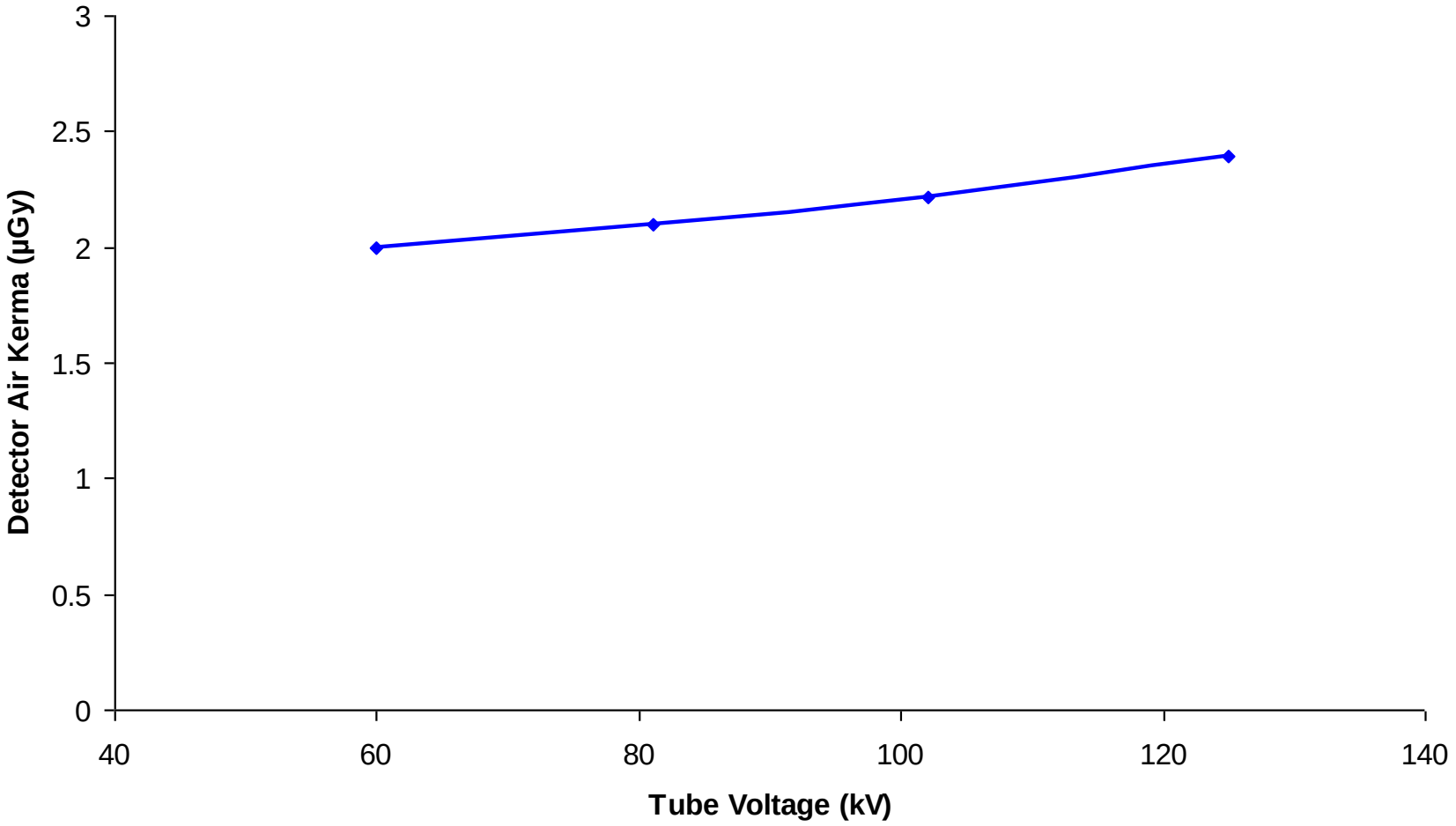
High dose

Optimally Shaped Curve for CR – Constant SNR

- The results demonstrated **constant SNR** was optimal
- We have recalibrated all of our AEC devices
- Image quality & patient dose acceptable
- Publications:
  - Moore C S, Wood T J, Avery G, Balcam S, Needler L, Beavis A W and Saunderson J R 2014. An investigation of automatic exposure control calibration for chest imaging with a computed radiography system. ***Phys. Med. Biol***. **59** 2307-2324.

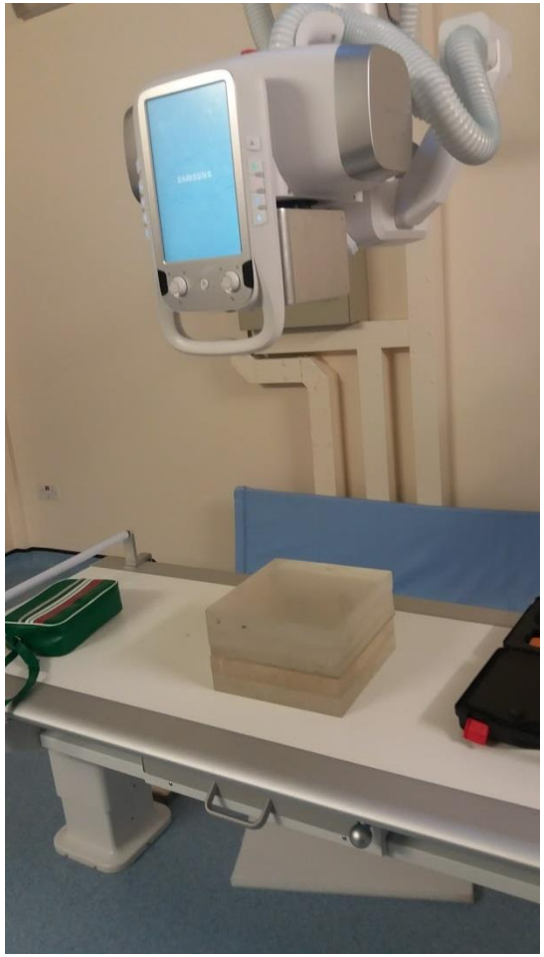
  - Moore C S, Wood T J, Avery G, Balcam S, Needler L, Joshi H, Saunderson J R and Beavis A W 2016. Automatic exposure control calibration and optimisation for abdomen, pelvis and lumbar spine imaging with an Agfa computed radiography system. ***Phys. Med. Biol***. **61** N551-N564.

Constant SNR for CR



Back to DR….

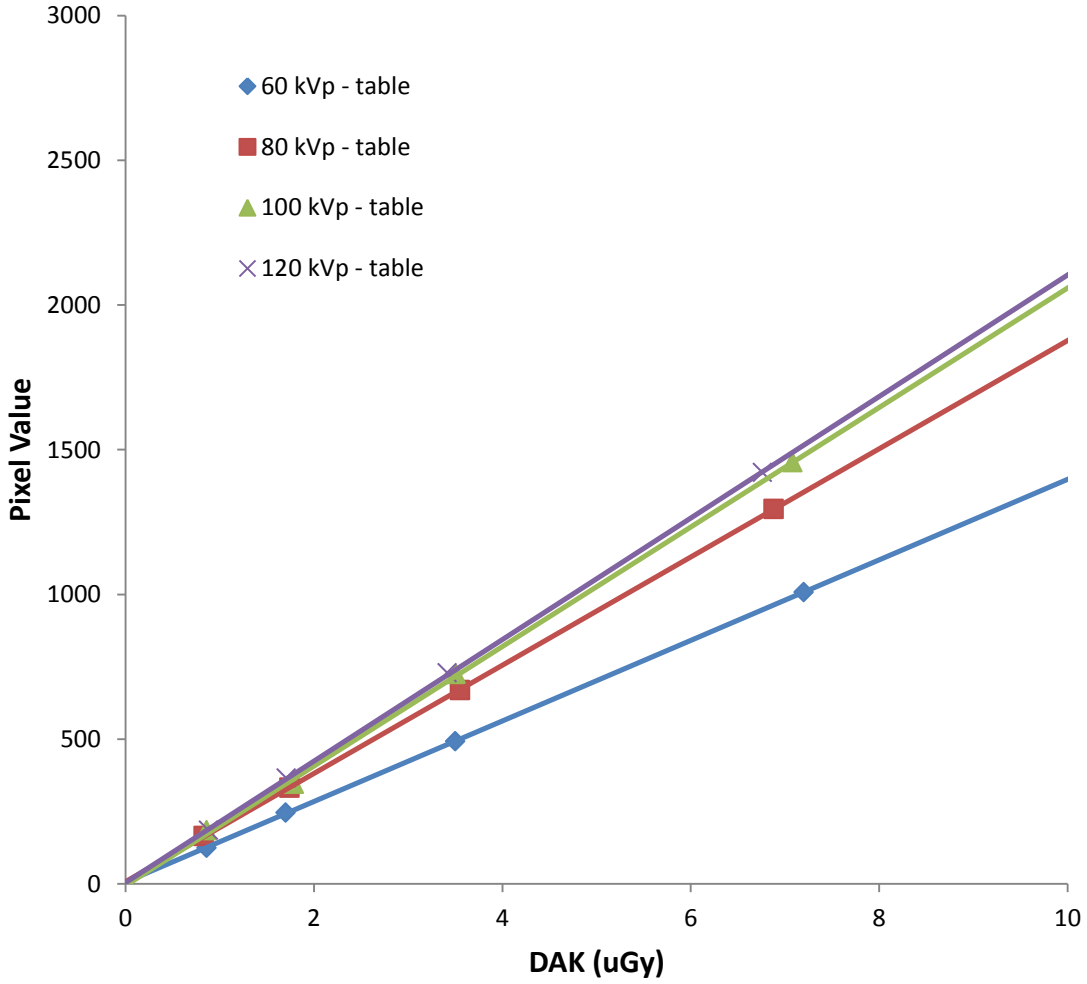
- In the absence of any concrete recommendations for DR we decided to follow the constant SNR approach
- We also decided to use PMMA positioned in the patient position
  - This is how we did it for CR
  - PMMA better matched to soft tissue than copper
  - Assume anti-scatter grid is doing its job so images taken off the system are not contaminated with scatter



System Transfer Properties (STP)

- First we need to measure the STP so that we can linearise all images used for analyses
- Measure STP for 60, 80, 100 & 120 kVp with 18.5 cm PMMA in the beam at the bucky with grid in and full field irradiation.
  - Remove flat panel detector
  - Unfors Xi inside bucky behind the grid
  - **Can only do this in service mode**

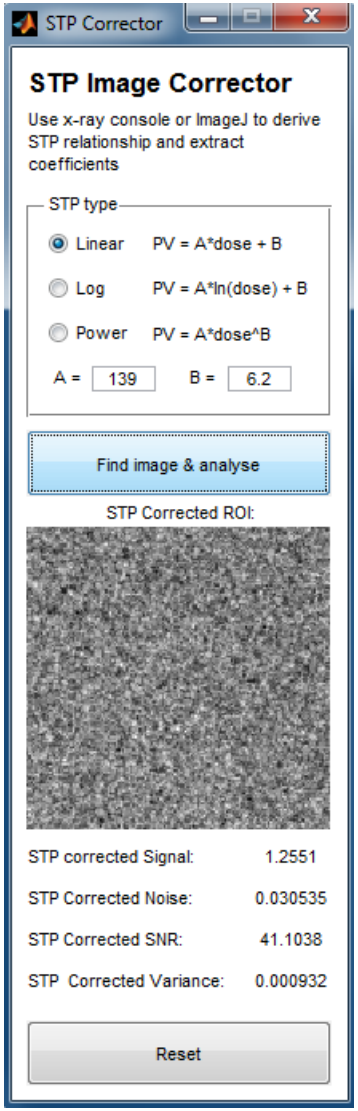
STP



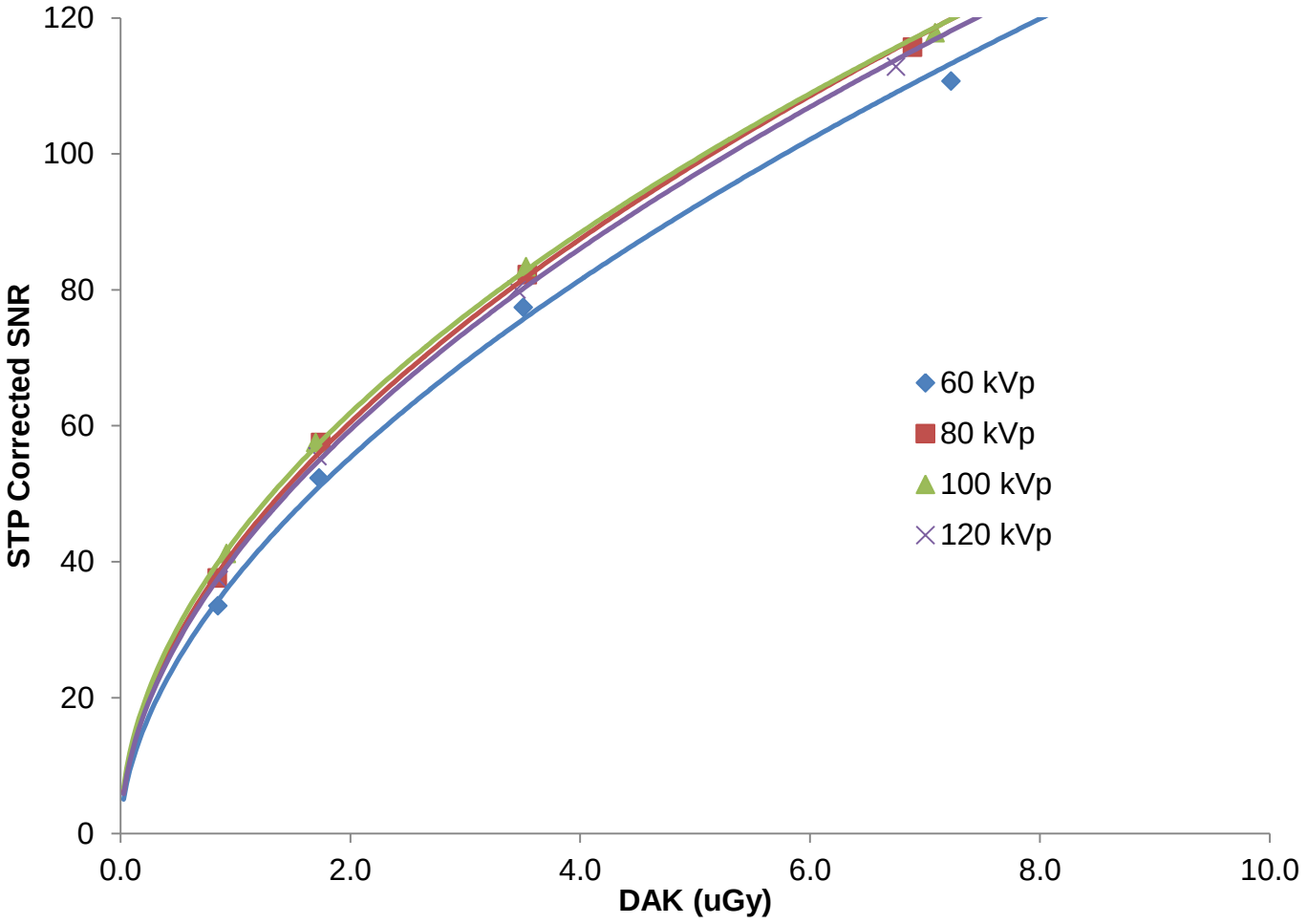
- Note: STP differed by less than 10% using narrow beam free in air method

Derive SNR v DAK

- Next step is to STP correct the resulting images, and calculate the SNR at each kV/DAK combination using MATLAB tool
  - ‘STP Corrector’
  - **Very important & extremely useful we can STP correct in real time**



SNR v DAK


120
100
80
60
40
20
0
STP Corrected SNR
0.0
2.0
4.0
6.0
8.0
10.0
DAK (uGy)
60 kVp
80 kVp
100 kVp
120 kVp

Fit parameters

SNR Fit parameters (SNR = A*DAK^B)			
kVp		A	B
60		37.6	0.56
80		41.9	0.53
100		43.3	0.51
120		41.0	0.54
		Target SNR	
80 kVp, 2 uGy	→	60.5	

We chose 2uGy as a starting point!!

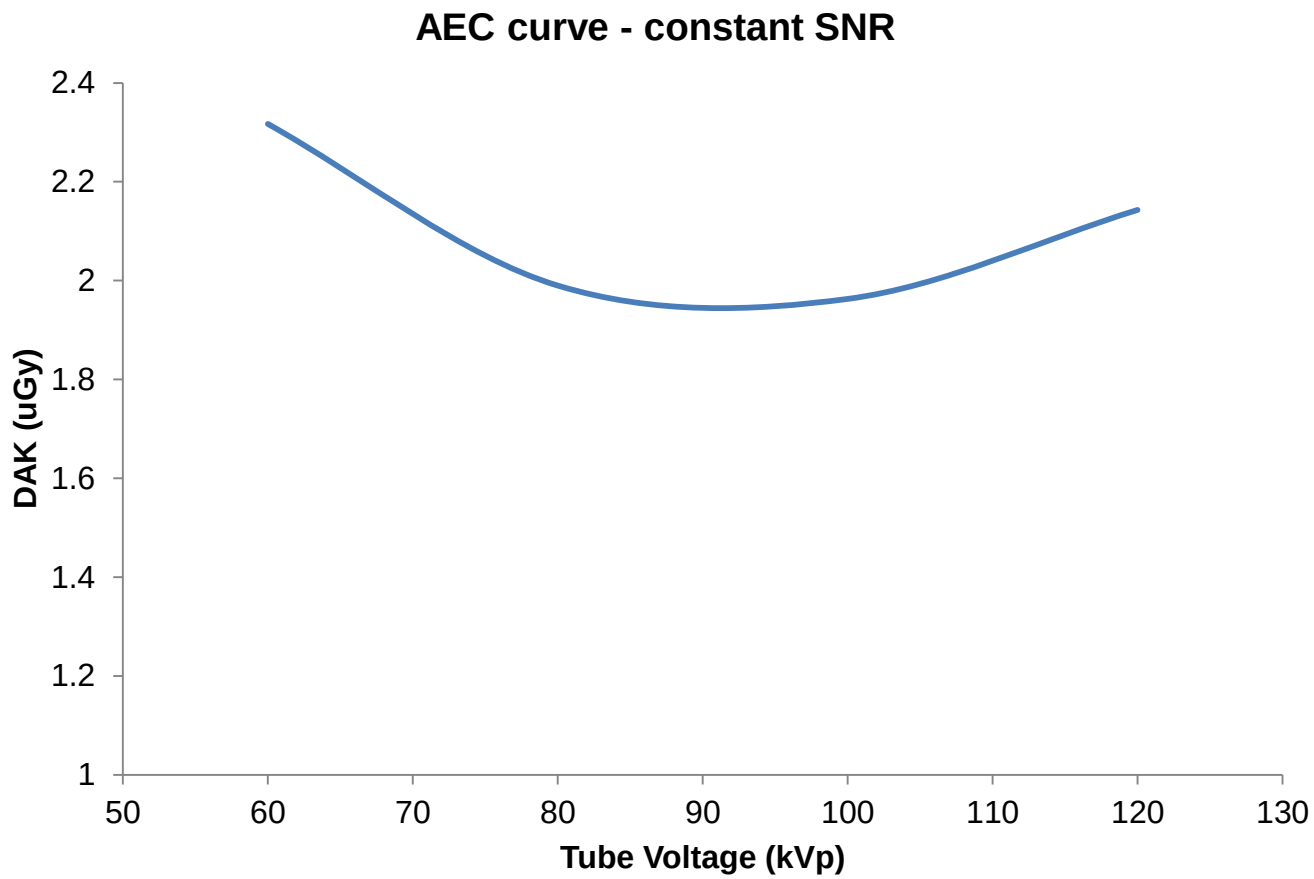
To hit target SNR…

To hit the target SNR value…			
	DAK_{PV}	PV	DAK @ setup
60 kVp	2.3	333	2.3
80 kVp	2.0	382	2.0
100 kVp	1.9	390	2.0
120 kVp	2.1	440	2.1

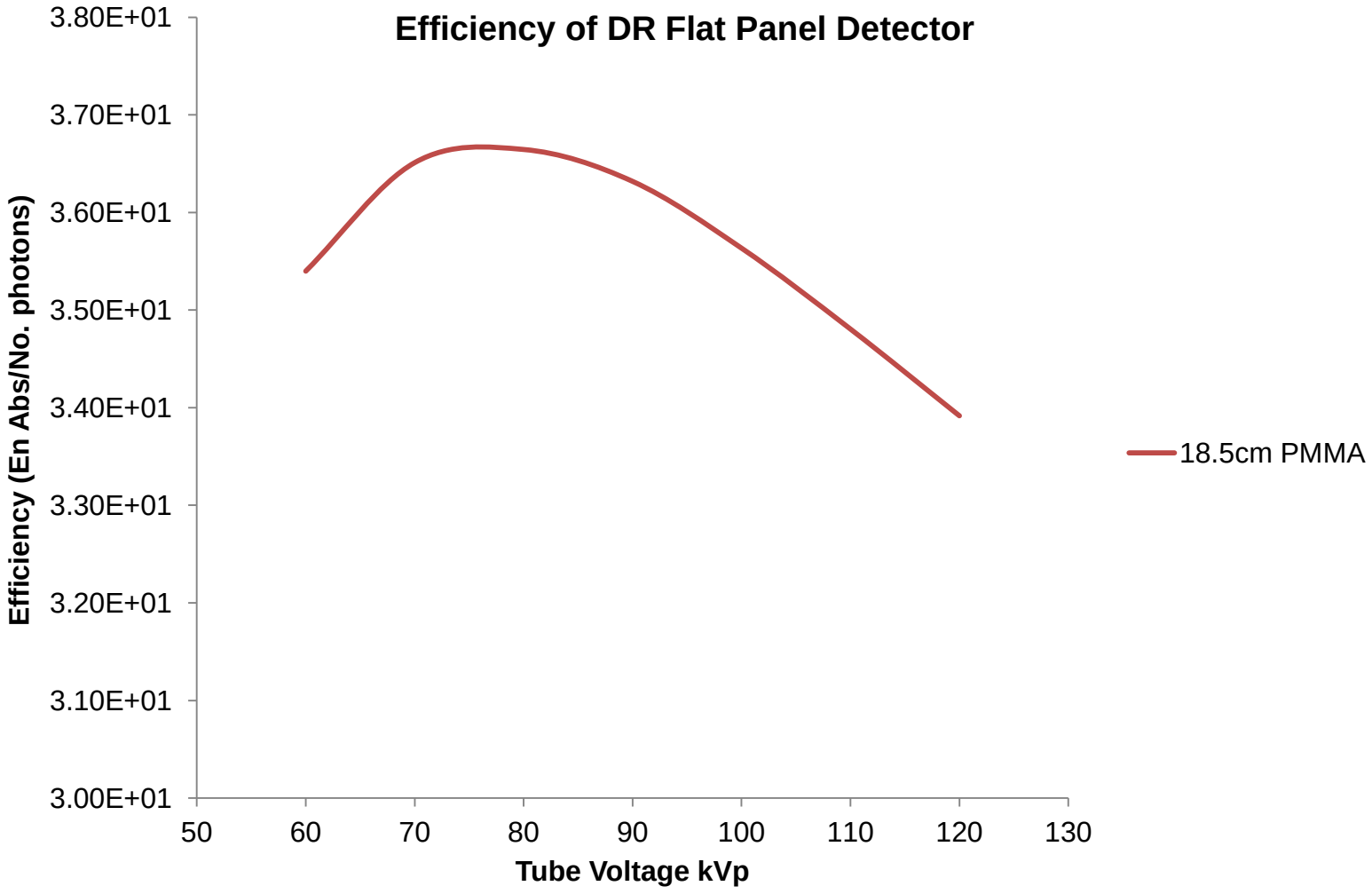
DAK calculated

DAK measured with Unfors Xi in bucky and service mode

DAK to give constant SNR…



Does this make sense??



Does this make sense??

- Yes we think it does!!
- The constant SNR curve is a mirror image of the efficiency curve
  - CsI is less efficient at low and high tube voltage
  - Constant SNR curve compensates for this
  - Exactly what an AEC device is designed for!!

Final test…

- Exit service mode
- In clinical mode measure the DAK across tube voltage range
  - Not possible to place Unfors Xi detector inside bucky
  - DAK is measured directly from the STP corrected images (DAK_{PV})

	PMMA at bucky. With grid. Full beam.			
Clinical mode	mAs	DAK_{PV}	SNR	% diff. from intended
60 kVp	81	2.1	58.6	-3.2
80 kVp	19	1.9	60.9	0.7
100 kVp	7.5	2.1	63.6	5.1
120 kVp	4.3	2.2	64.4	6.4

Something to beware

- Table and chest AEC will perform differently even with same calibration
- Always find that table AEC cuts out at a lower DAK
- Probably because of gravity!!
  - The AEC device is a thin ‘plate’
  - This droops in the table bucky and so is closer to flat panel detector
  - When we calibrate with Unfors Xi in bucky, backscatter to the AEC is ***not*** taken into account

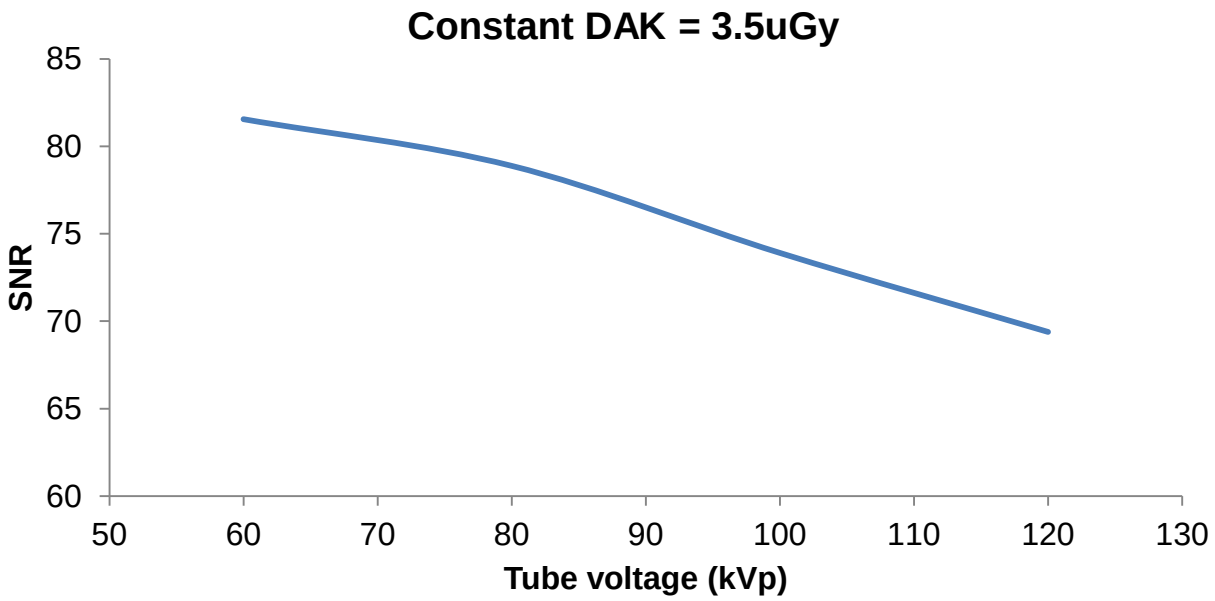
	Erect AEC	
Clinical mode	mAs	DAK_{PV}
60 kVp	81	2.1
80 kVp	19	1.9
100 kVp	7.5	2.1
120 kVp	4.3	2.2

	Table AEC	
Clinical mode	mAs	DAK_{PV}
60 kVp	29	2.1
80 kVp	6.1	1.7
100 kVp	2.5	1.8
120 kVp	1.3	1.7


Grid
AEC plate
Flat panel
SID180

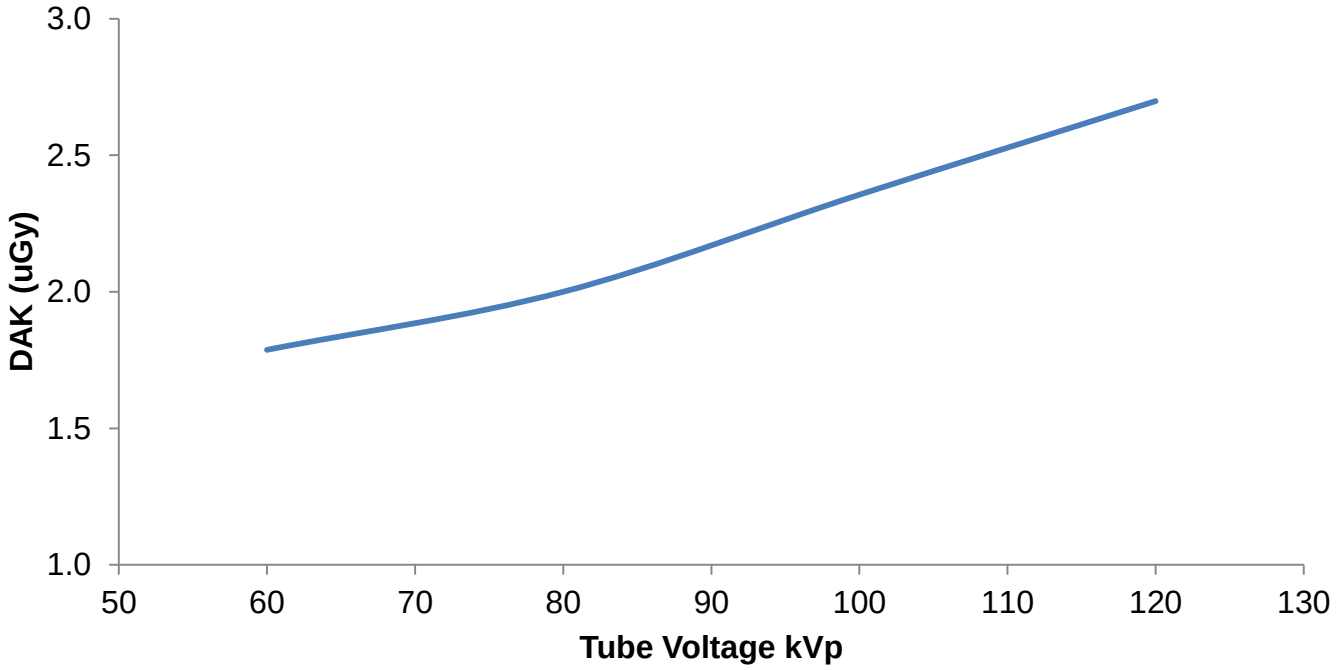
What if we have used MIS' approach?

- Constant DAK of 3.5 uGy
- Cu (2mm) at tube
  - Have already shown SNR is ***not*** constant

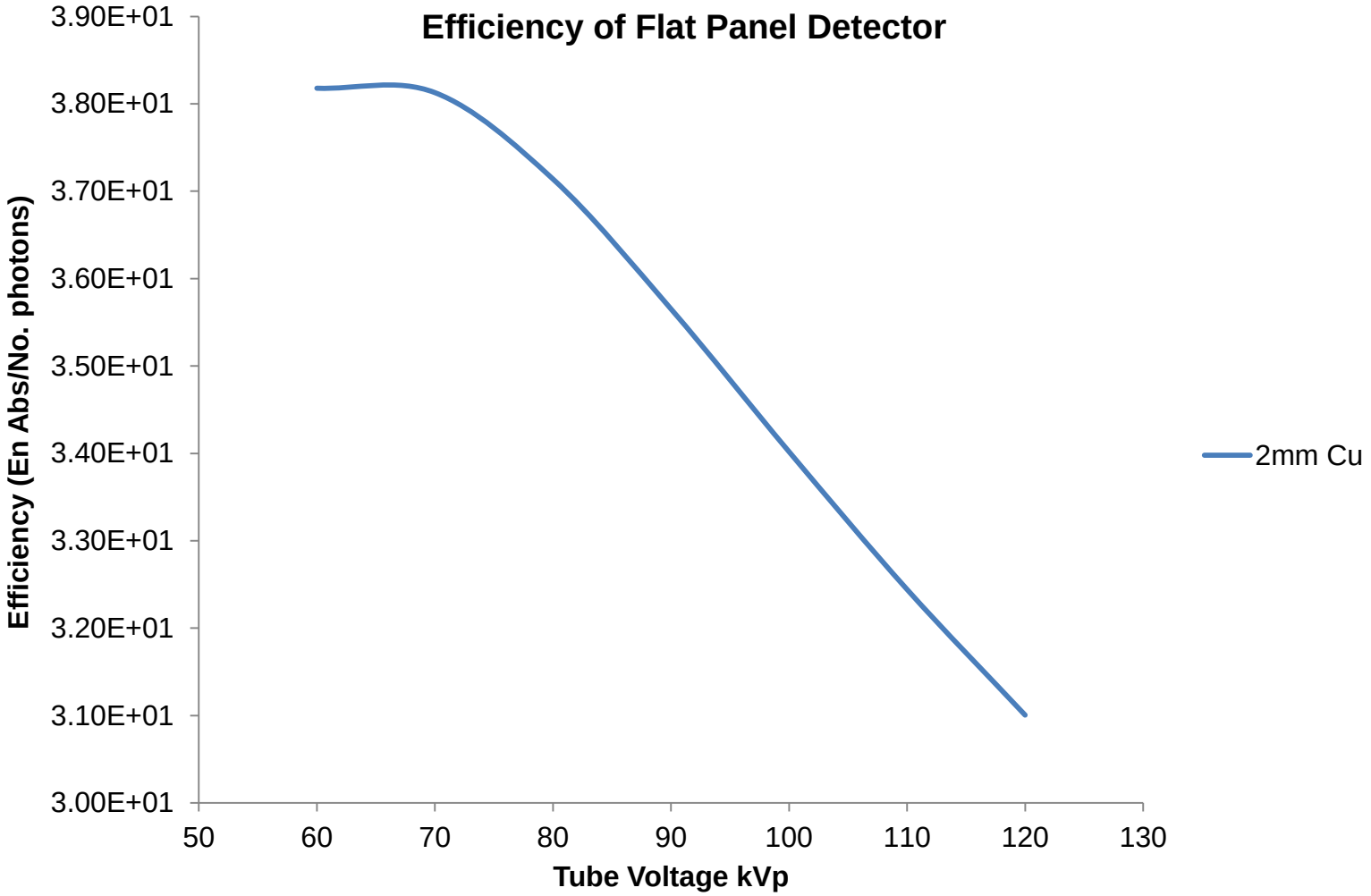


Constant SNR with MIS' setup

- Repeat what we have just shown with Cu at tube rather than PMMA at detector….



Compare with efficiency…



Constant SNR with MIS' setup

- Calibrate with constant SNR with 2mm copper at tube
- In clinical mode test with PMMA at flat panel

	SNR	% diff from expected
60	55.6	2.6
80	54.2	0.0
100	51.2	-5.6
120	48.3	-11.0

Drop in image quality at high kVp

Conclusions

- This work has investigated the calibration of a **Samsung AEC device for DR**
- A **constant SNR metric** was used and the AEC calibration curve was derived with a simple PMMA phantom
- A sensible **'U'** shaped curve has been implemented
  - **No concerns with image quality**
- STP correcting in real time is **very useful**
- Curve based on constant DAK and 2mm copper does ***not*** provide constant SNR
- However, it is vitally important the value of the calibration DAK (which will determine the position of the curve with respect to the DAK axis) is chosen carefully with close cooperation of the expert image evaluators; by its very nature this is a subjective process.
- We have calibrated ***three*** Samsung AEC devices in recent months
  - Consistent dose
  - Consistent image quality
  - Optimised patient care
- Science for Patient Benefit