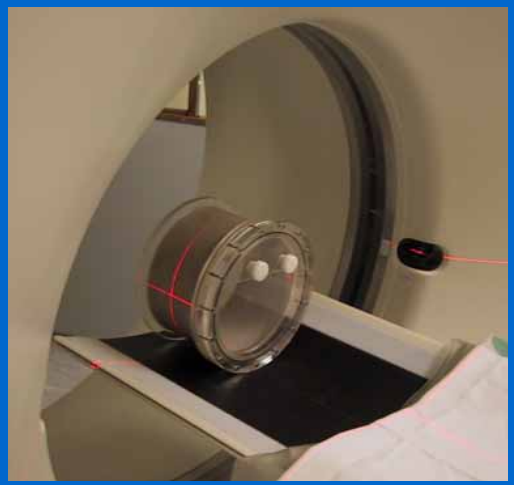
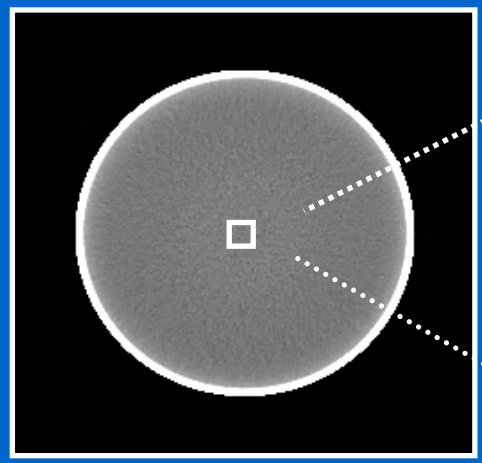
# Effect of ROI Size on Image Noise

Sue Edyvean
ImPACT (Imaging Performance assessment of CT Scanners)

# Image noise

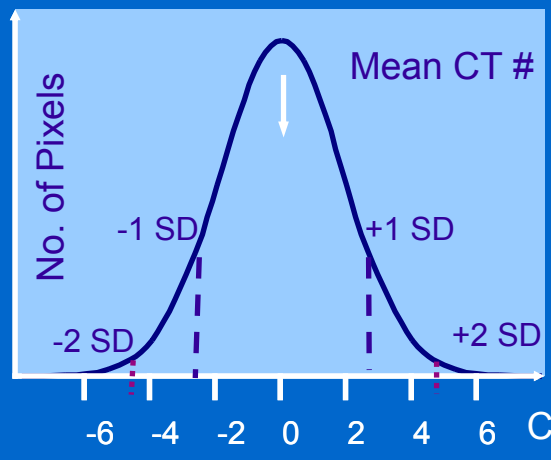
- Noise describes the extent of the variation in CT number in an image of a uniform medium





| | | | |
|---|---|---|---|
| 4 | 0 | -1 | 2 |
| 0 | 0 | 1 | 0 |
| -2 | 0 | 4 | 0 |
| 0 | 2 | 3 | -4 |

- ROI: mean CT number, standard deviation ‘noise’
  - 95% of values within +/- 2 SD

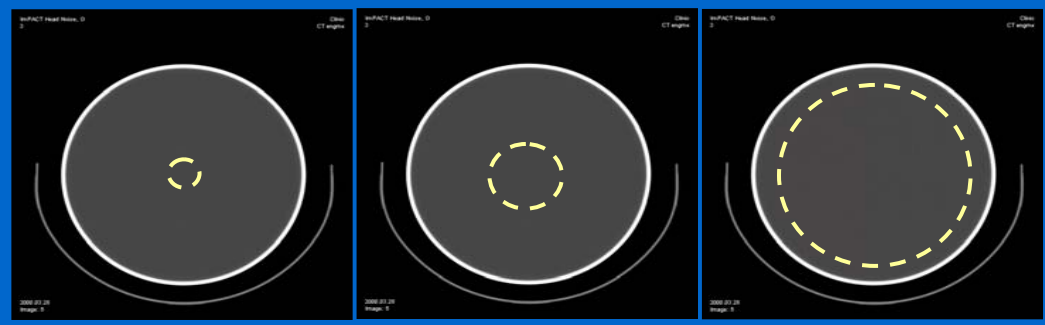


# What ROI size to use ?

- Report 32 Edition 1, 1980: 100 pixels
- ImPACT:
  - area 500 $mm^2$
  - average from > 10 rotations

500 $mm^2$ ≡ ROI diameter 25 mm,
= 14% of 185 mm diam., 2k pixels (250 mmfov),
= 7% of 340 mm diam., 900 pixels (380 mmfov),

- Report 32 Edition 2
  - ~ 10% - 20% diameter of phantom, average of > 10 images
- RSNA Refresher Course 2000
  - Philip Judy > 10 mm diameter
- Comments (Sweden) on IEC acceptance standard:
  - suggested 40% of phantom diameter (20k-30k pixels)



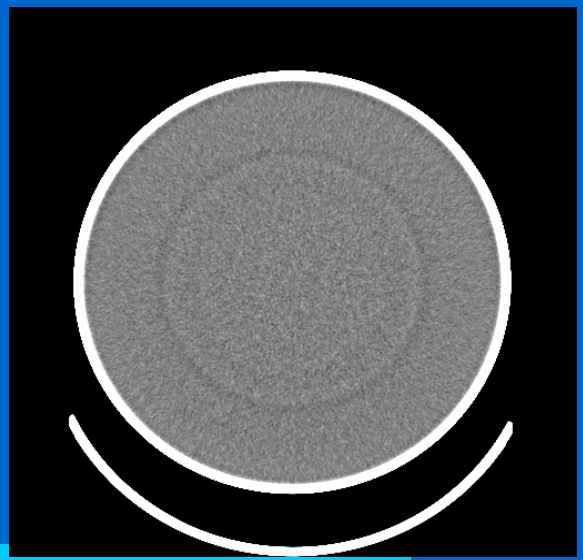
# Outline

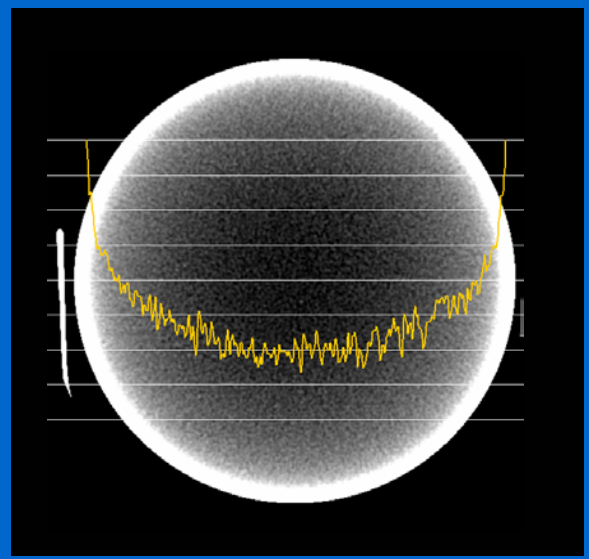
- ROI size and error in noise value
- ROI size and noise value
- FOV and noise value
- Conclusions

# Contributions to image noise

- Stochastic or quantum noise
  - determined by the number of photons detected
- Electronic – small compared to stochastic noise
- Structured noise – from reconstruction process
  - CT number non-uniformity (eg.ring artefacts, beam hardening effects)
  - pixel correlation, ‘blobs’, correlation over a few mm

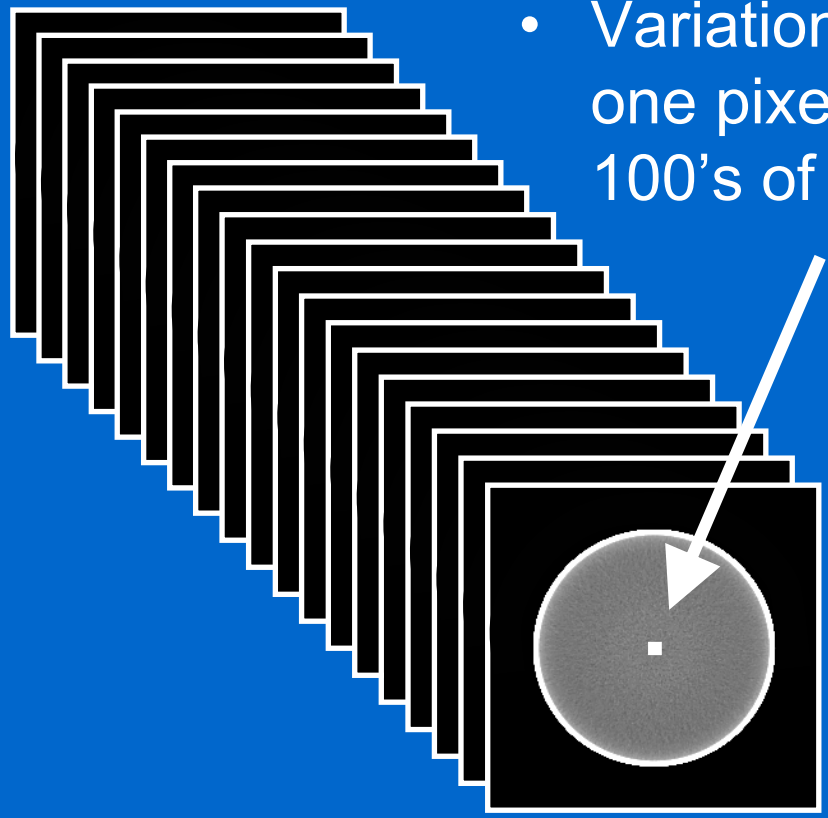
| | | | |
|---|---|---|---|
| 4 | 0 | -1 | 2 |
| 0 | 0 | 1 | 0 |
| -2 | 0 | 4 | 0 |
| 0 | 2 | 3 | -4 |





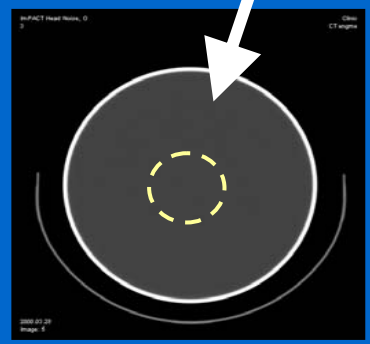
| | | | |
|---|---|---|---|
| 3 | 2 | 3 | 2 |
| 2 | 2 | 1 | 0 |
| 1 | 0 | 0 | 0 |
| 0 | 1 | -1 | 1 |

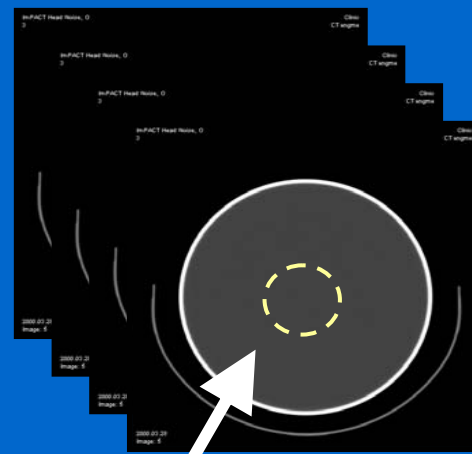
# Measuring stochastic noise



- Variation of value of one pixel from many 100's of images

- Variation of value of many pixels in one image





- Variation of value of many pixels from a small no. of images

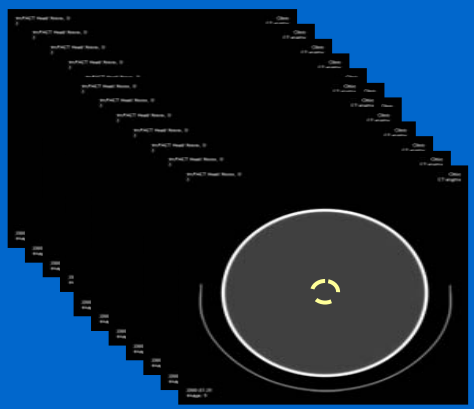
# Outline

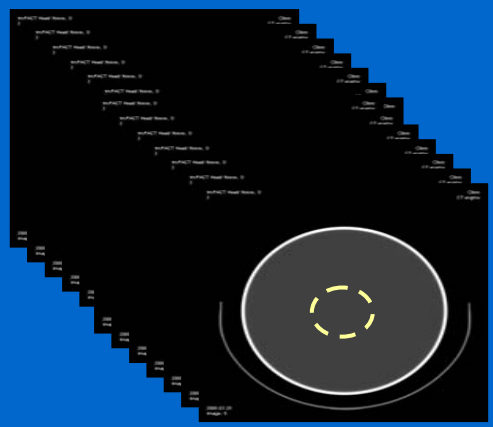
- ROI size and error in noise measurement
  - How repeatable is the noise value ?
  - Can we just use one image ?
- ROI size and noise value
- FOV and noise value
- Conclusions

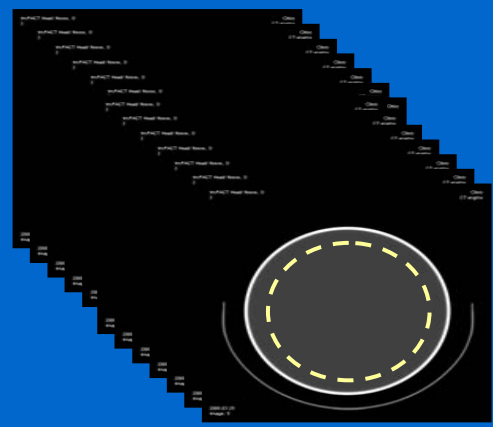
# Noise and ROI size

- Data from four current 16 slice scanners
- Ten rotations, two or four slice ⇒ 20-40 images each scanner
- Used 8 ROI sizes (head); 11, 16, 25, 36, 50, 80, 113, 160 mm
- Plus two more for body phantom; 252, 319 mm diameter

- $ROI_1$ ……..  $ROI_4$ ……..  $ROI_8$

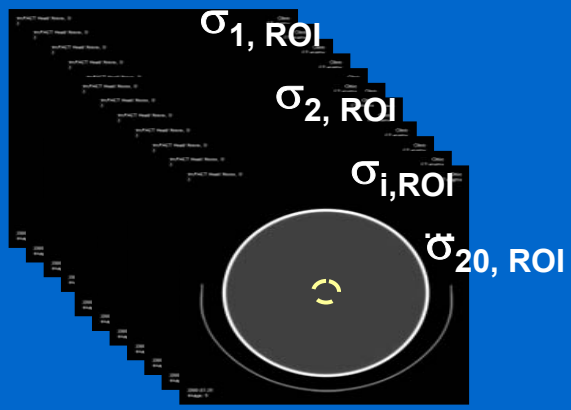




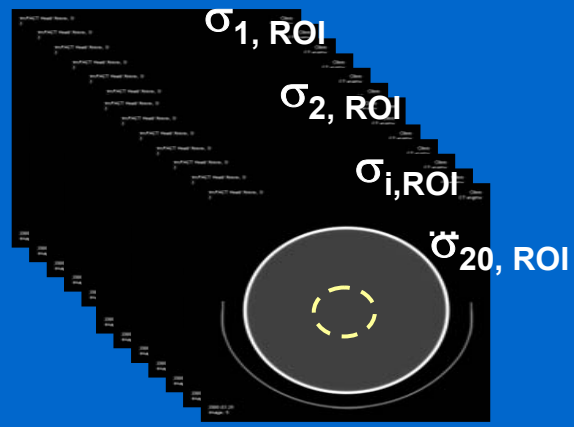


# Noise and ROI size

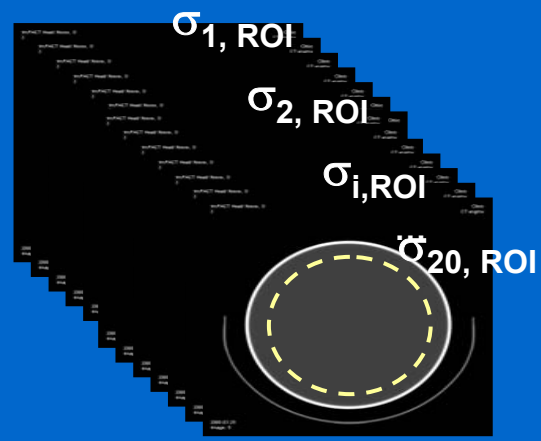
- For each ROI size, and each image, noise ($\sigma_{i,ROI}$) obtained
- The average noise ($\sigma_{mean,ROI}$) was calculated for the ROI set
- This average noise has its own range and SD.




range = 33 %



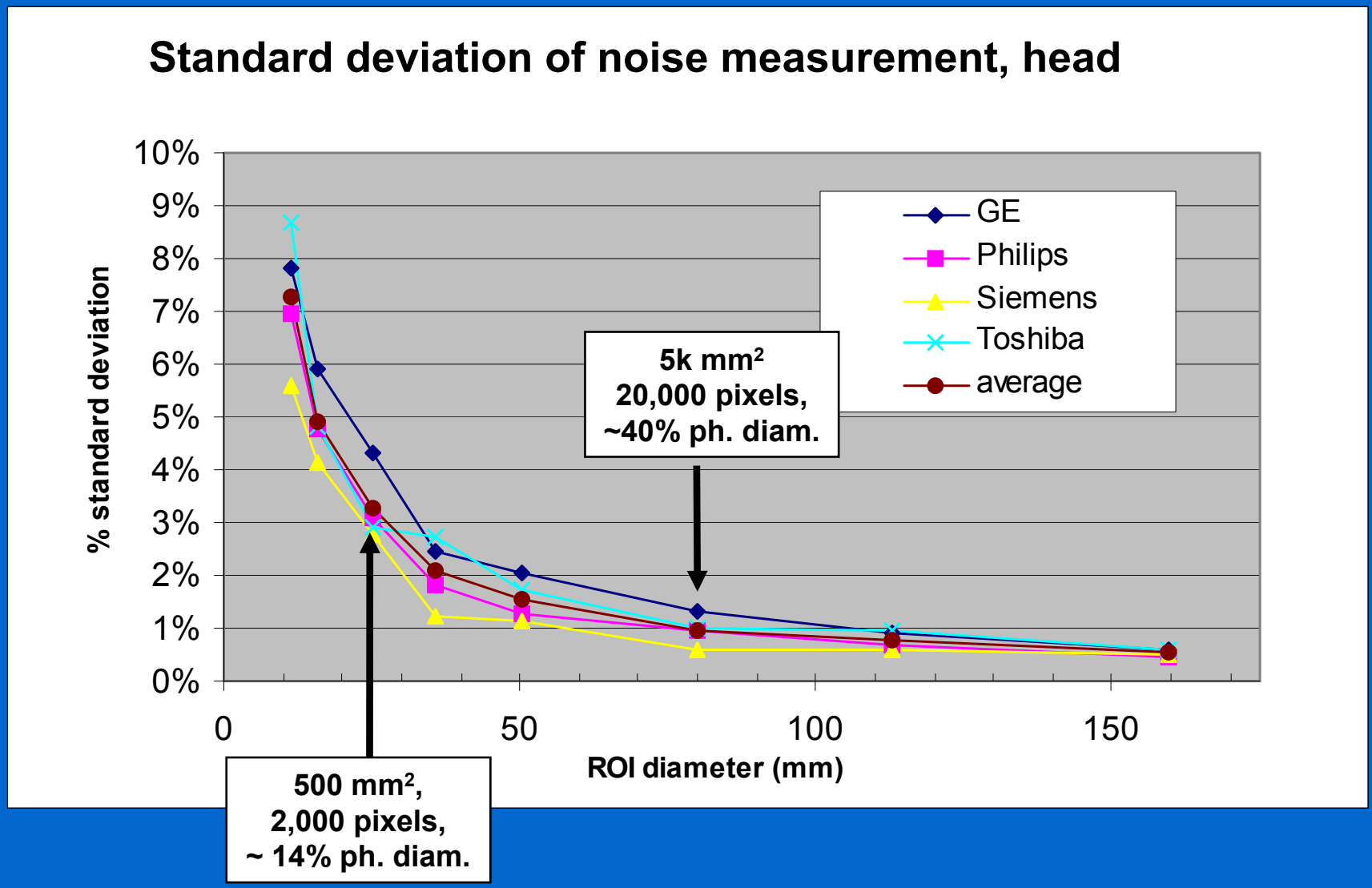

$\sigma_{meanROI}$ = 3.1
range 2.8 - 3.3 = 15%
SD 0.13 = 4%
+/- 2 SD (95%) = 16%



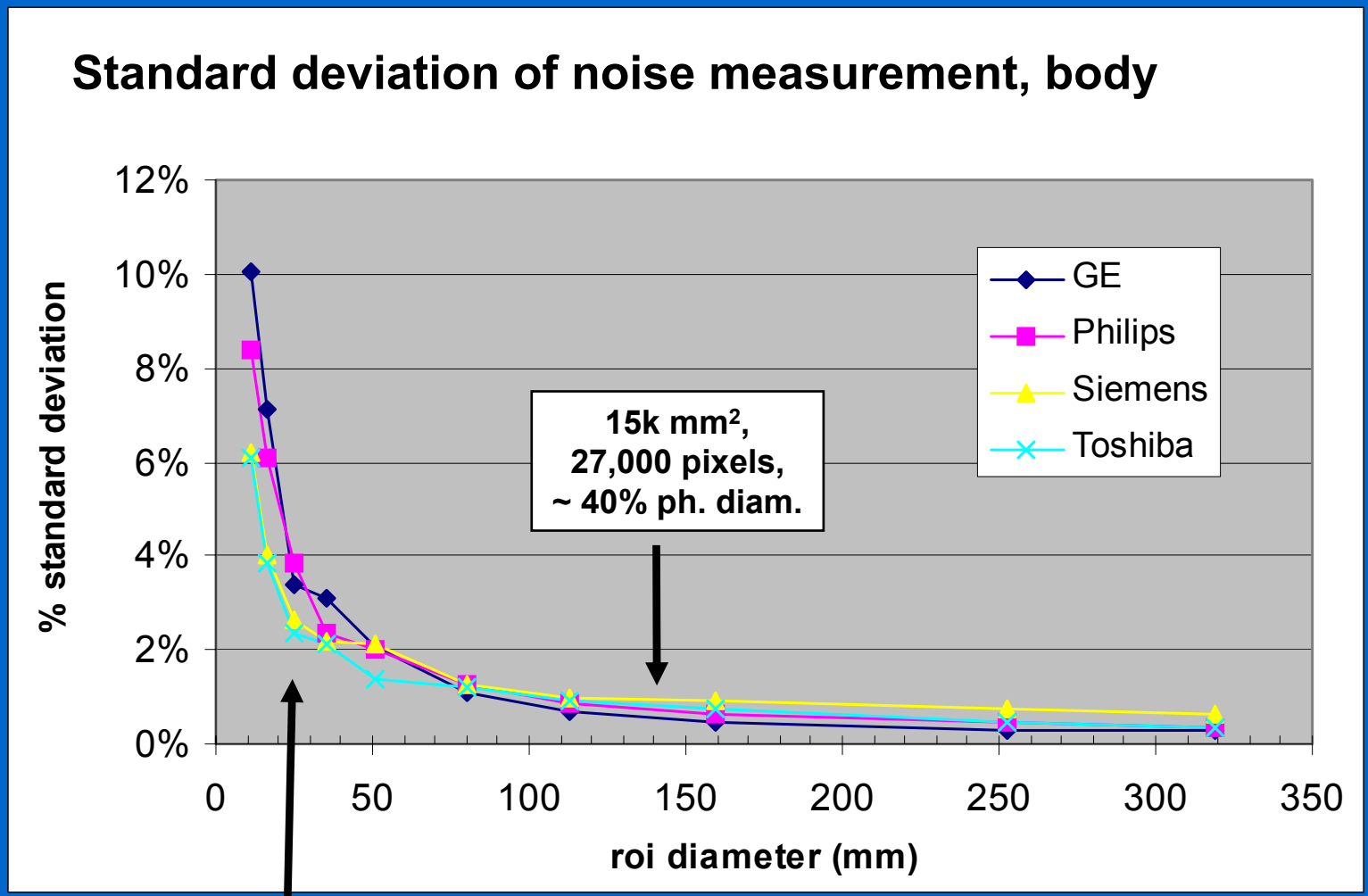

range = 2 %

GE LightSpeed16

# Std. dev. of measured noise versus ROI size



# Std. dev. of measured noise versus ROI size



# Range and SD of measured noise versus ROI size

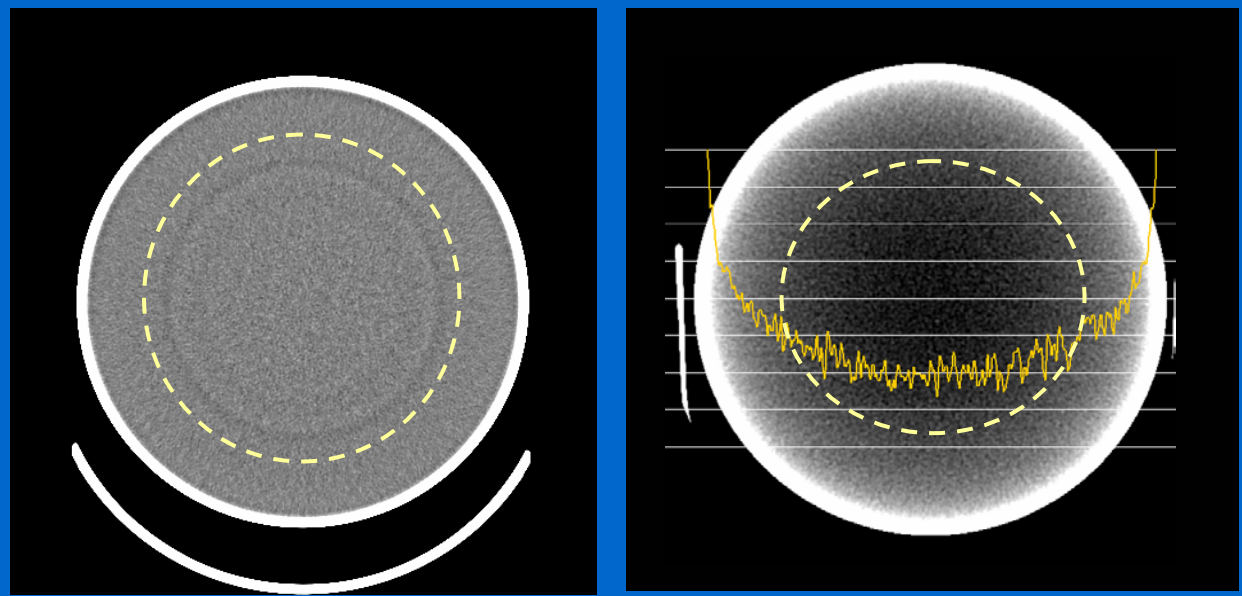
| | | head (ph.185 mm) 250 mmfov | | | | body (ph. 340 mm) 380 mm fov | | | |
|---|---|---|---|---|---|---|---|---|---|
| area $mm^2$ | ROI diam | | %diam.of | average | average | | %diam.of | average | average |
| | mm | no.pixels | phantm | sd% | range% | no. pixels | phantm | sd% | range% |
| 100 | 11 | 419 | 6% | 7% | 25% | 182 | 3% | 8% | 34% |
| 500 | 25 | 2,097 | 14% | 3% | 11% | 908 | 7% | 3% | 12% |
| 1k | 36 | 4,194 | 19% | 2% | 7% | 1,815 | 10% | 2% | 12% |
| 5k | 80 | 20,972 | 43% | 1% | 3% | 9,077 | 23% | 1% | 6% |
| 10k | 113 | 41,943 | 61% | 1% | 3% | 18,154 | 33% | 1% | 4% |
| 20k | 160 | 83,886 | 86% | 0.5% | 2% | 36,308 | 47% | 1% | 4% |
| 80k | 319 | - | - | - | - | 145,232 | 94% | 0% | 3% |

# Outline

- ROI size and error in noise value
- ROI size and noise value
- FOV and noise value
- Conclusions

# Potential pitfalls: large region of interest

- CT number may not be uniform across field
  - eg ring artefacts and ct number shading
  - Increase measured ‘noise’ value

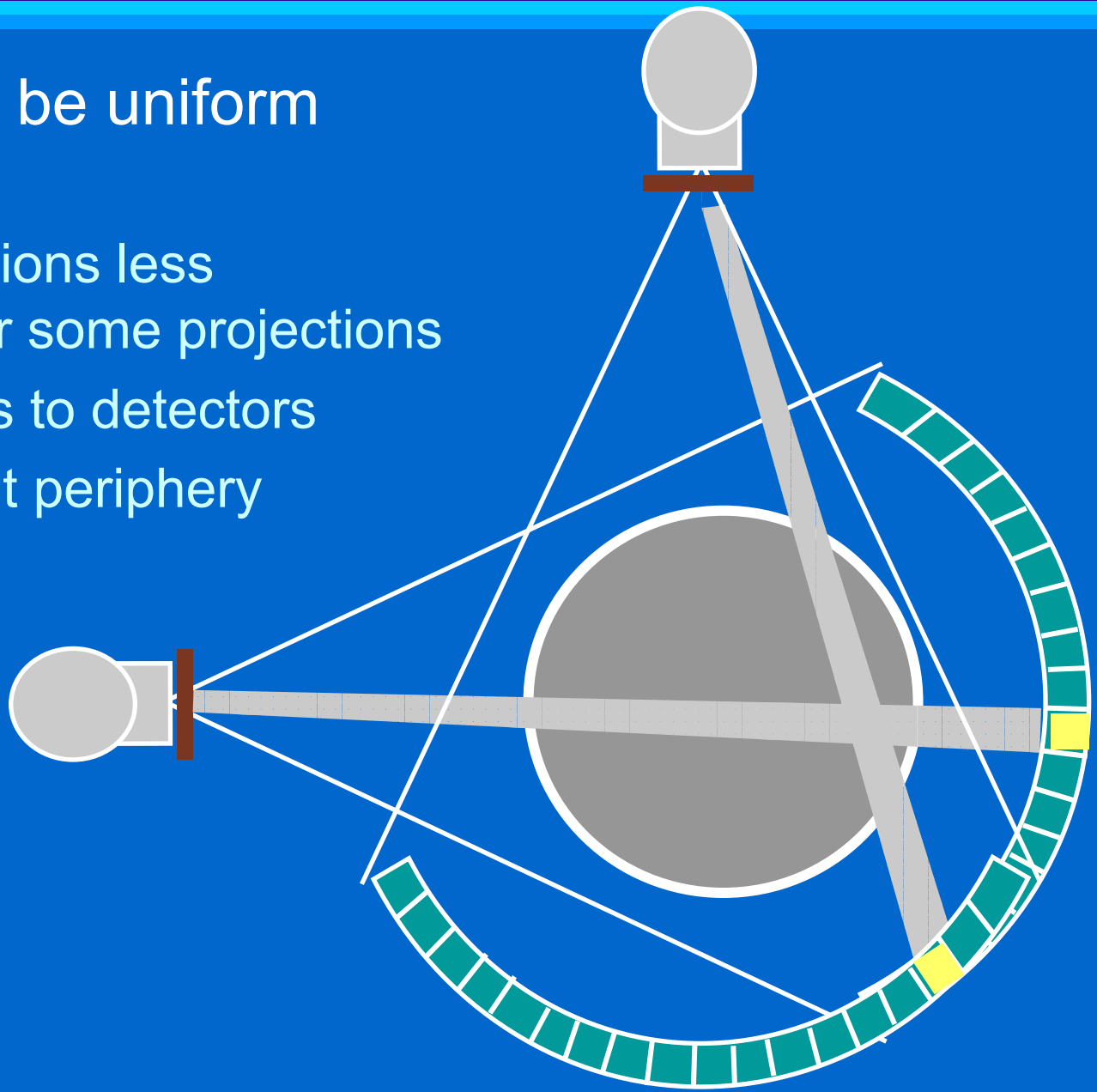


# Potential pitfalls: large region of interest

- Noise may not be uniform across field
  - peripheral regions less attenuating for some projections

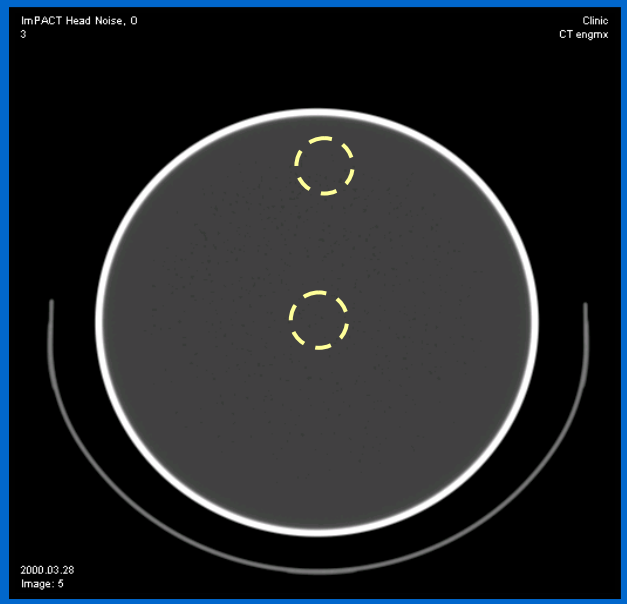
  → more photons to detectors

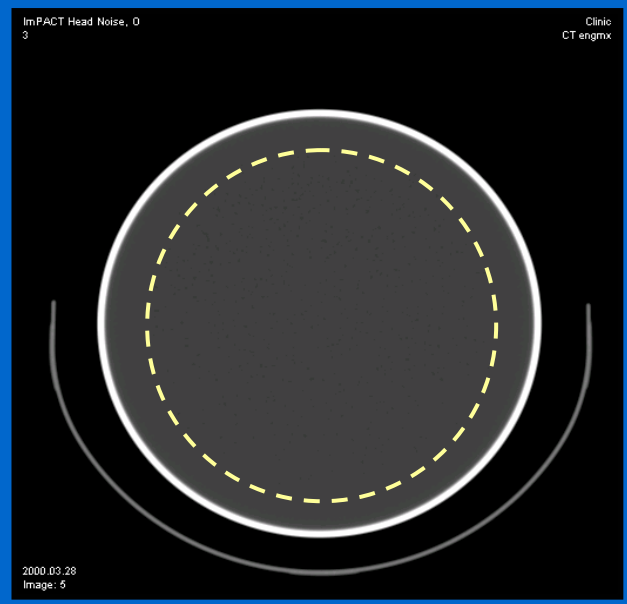
  → lower noise at periphery



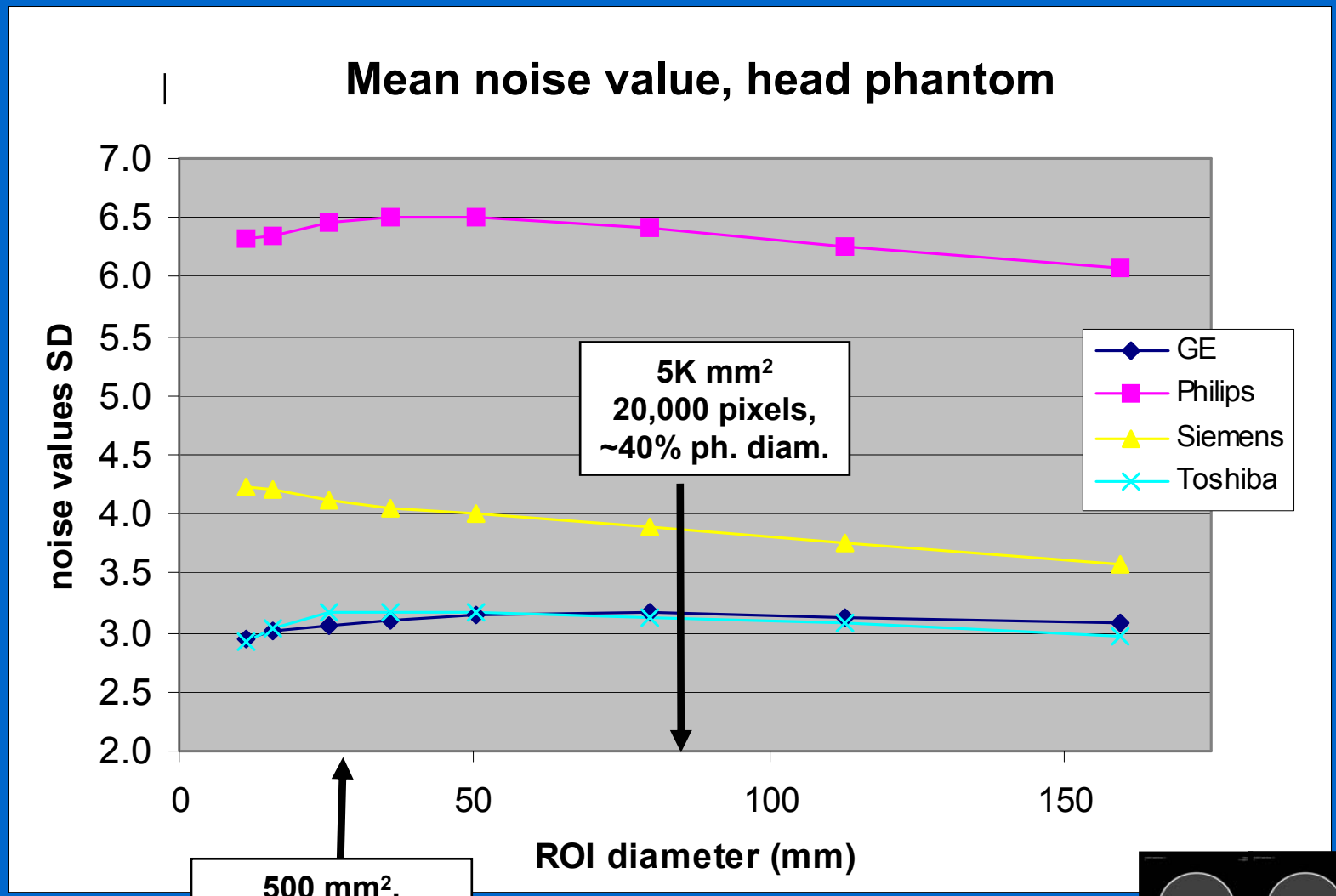
# Potential pitfalls: large region of interest

- If noise decreases at periphery
  - Lower average value of noise in larger ROI

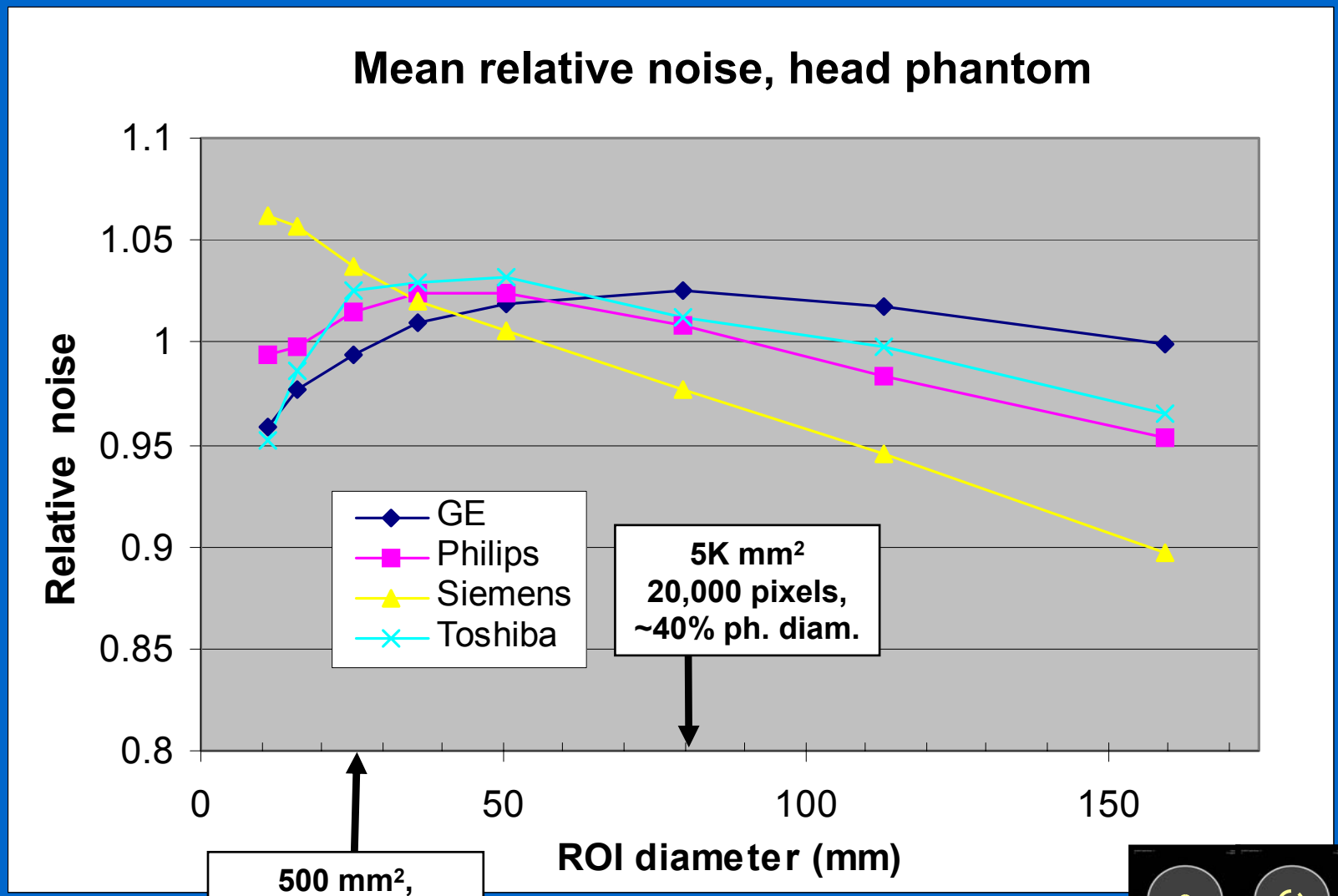


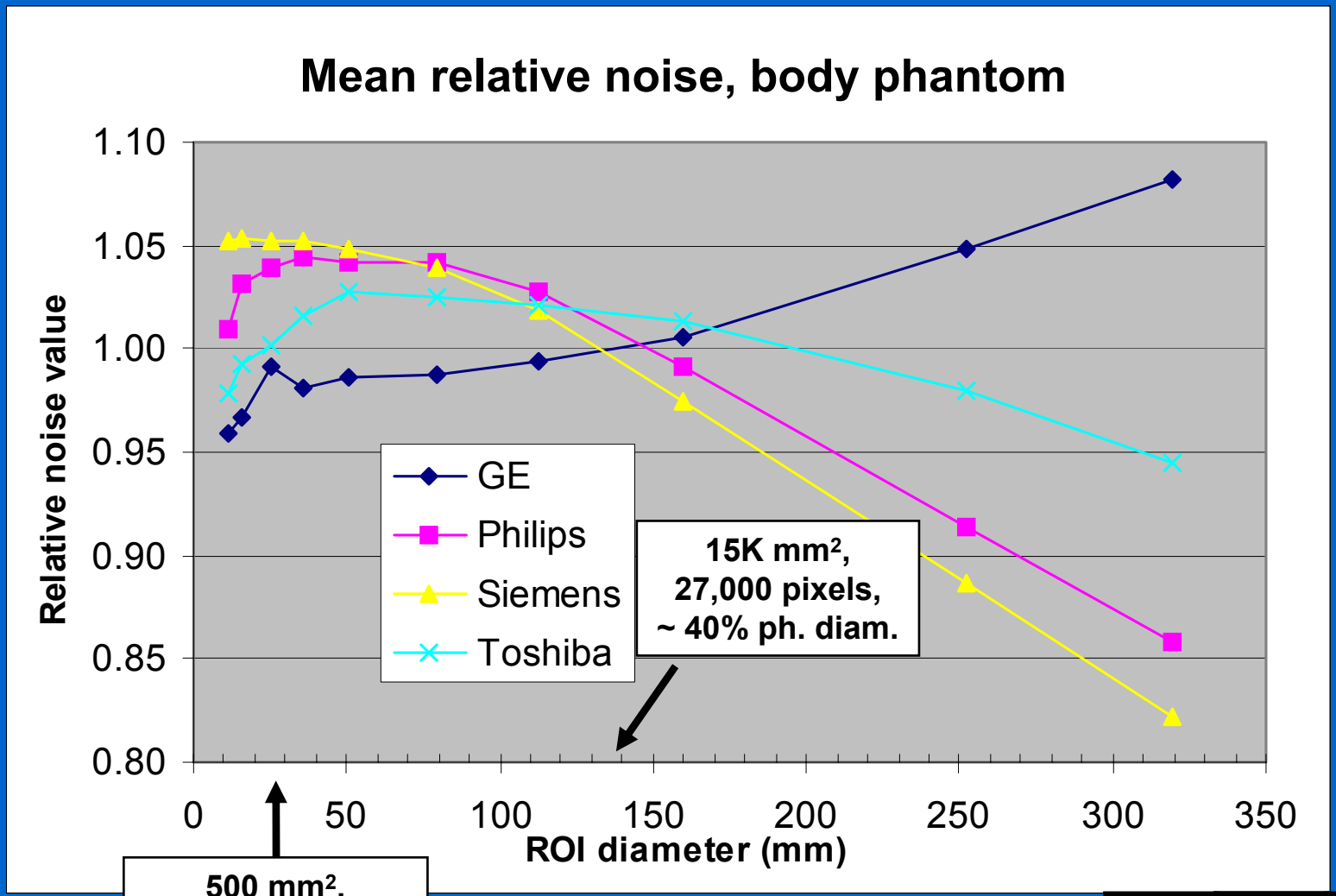
# Noise and ROI size, head phantom

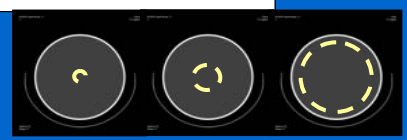



# Noise and ROI size, head phantom



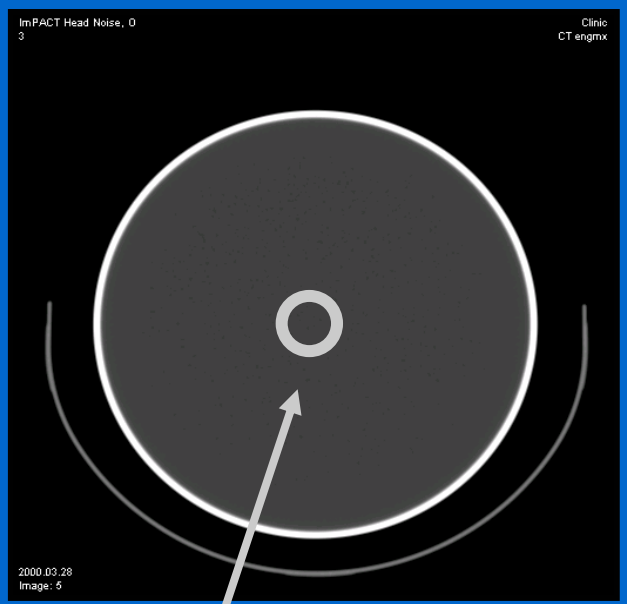

# Noise and ROI size, body phantom

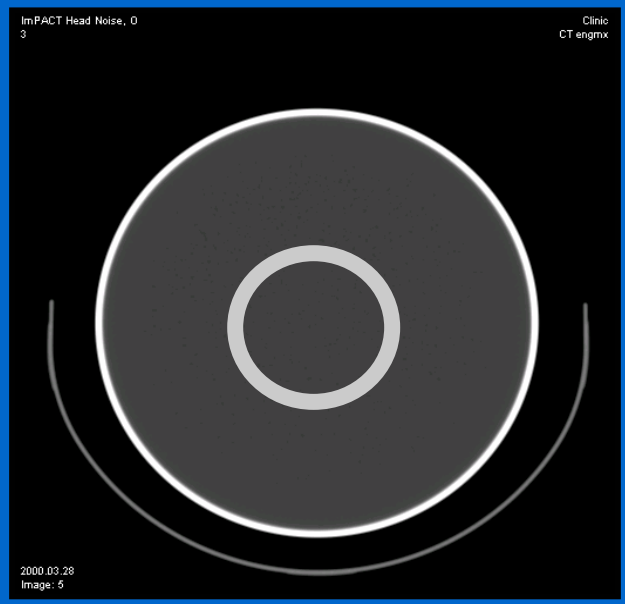


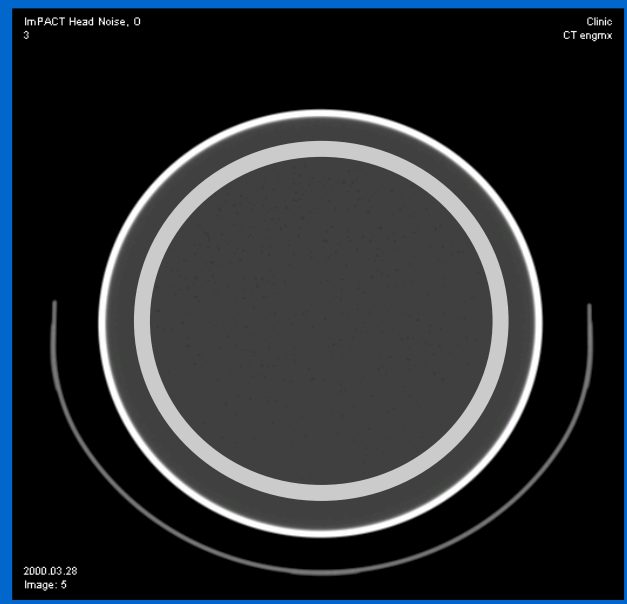



# CT number and noise uniformity

- CT number and noise evaluated from a ROI annulus
- To investigate CT number and noise uniformity

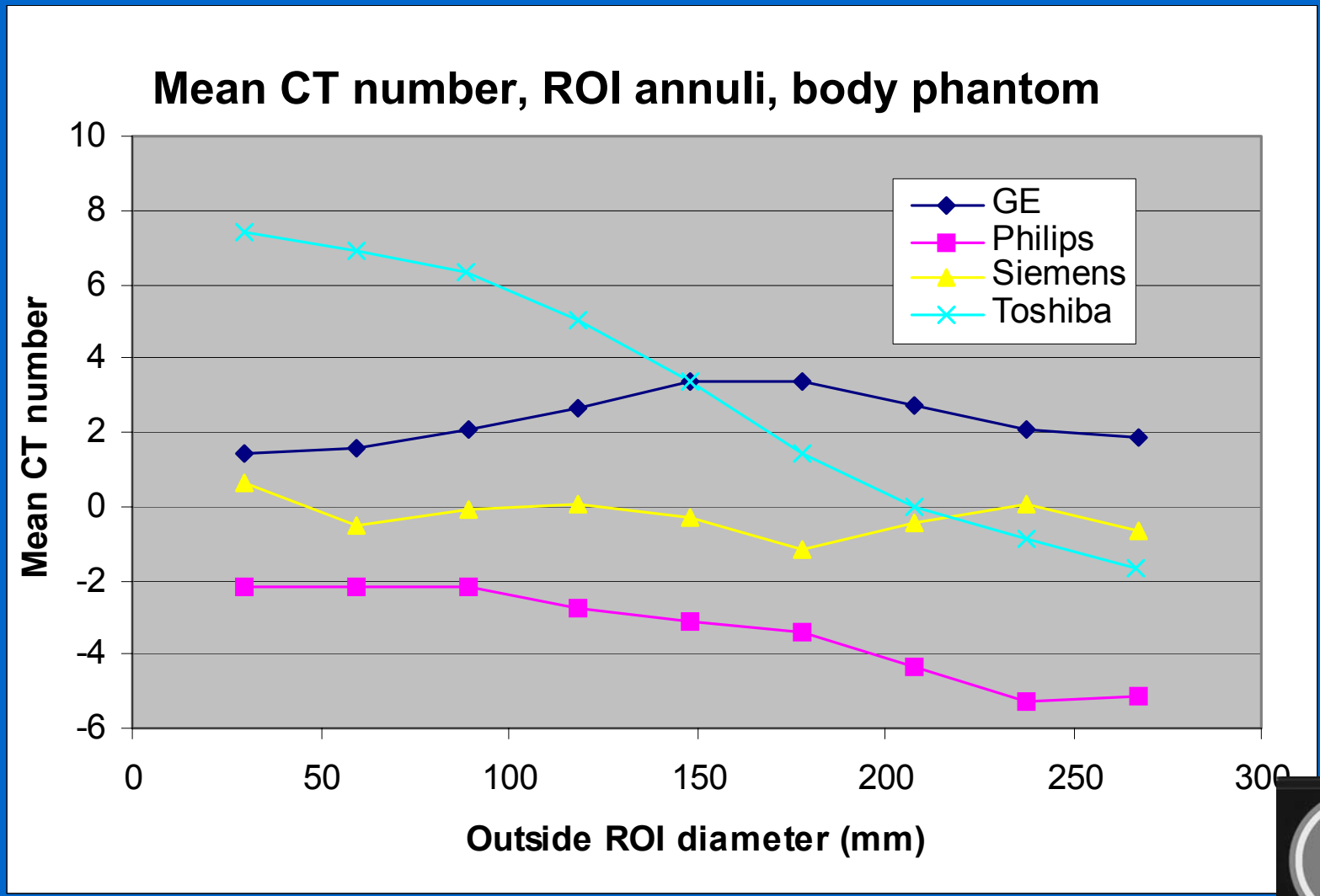


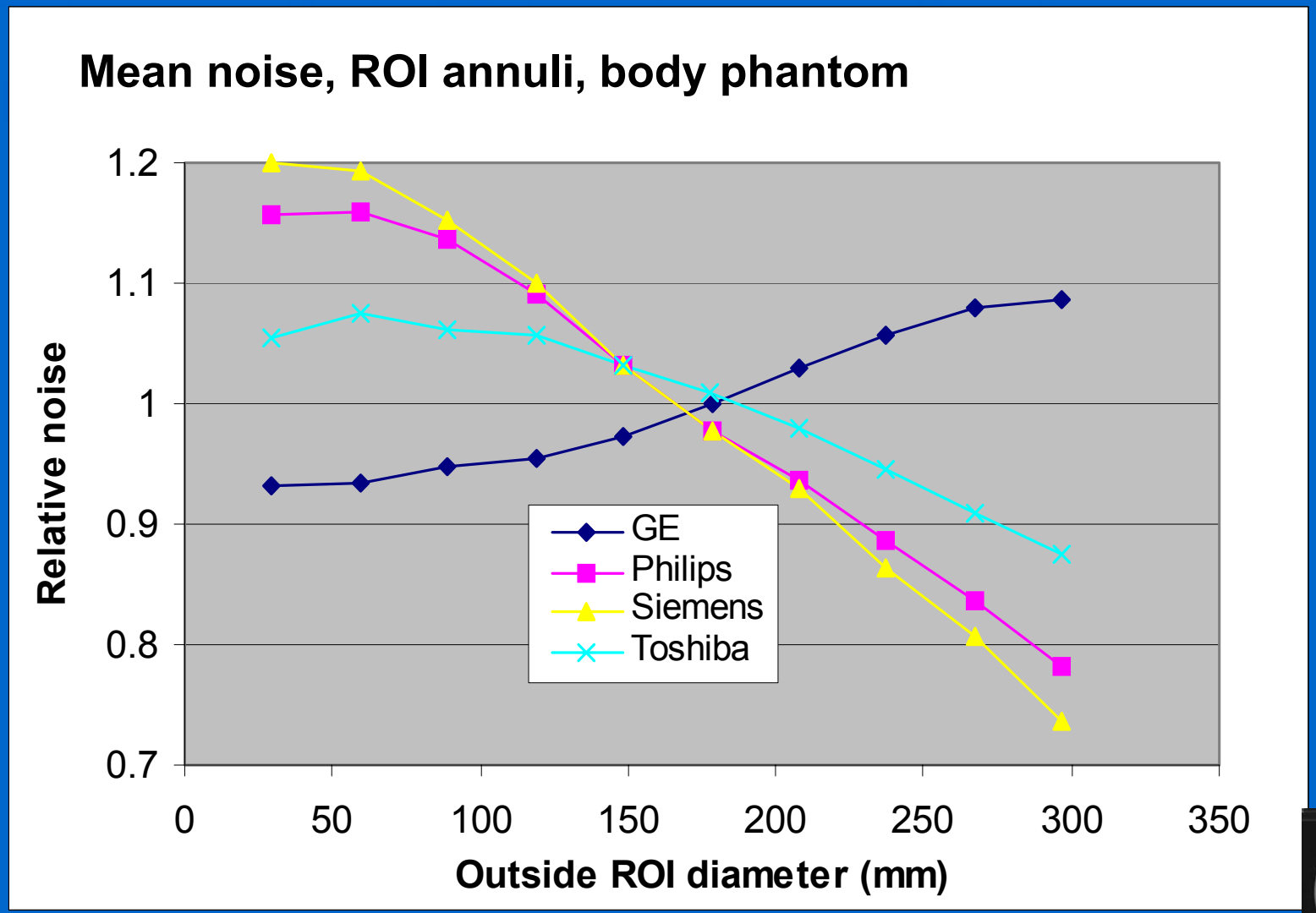




region of interest annulus

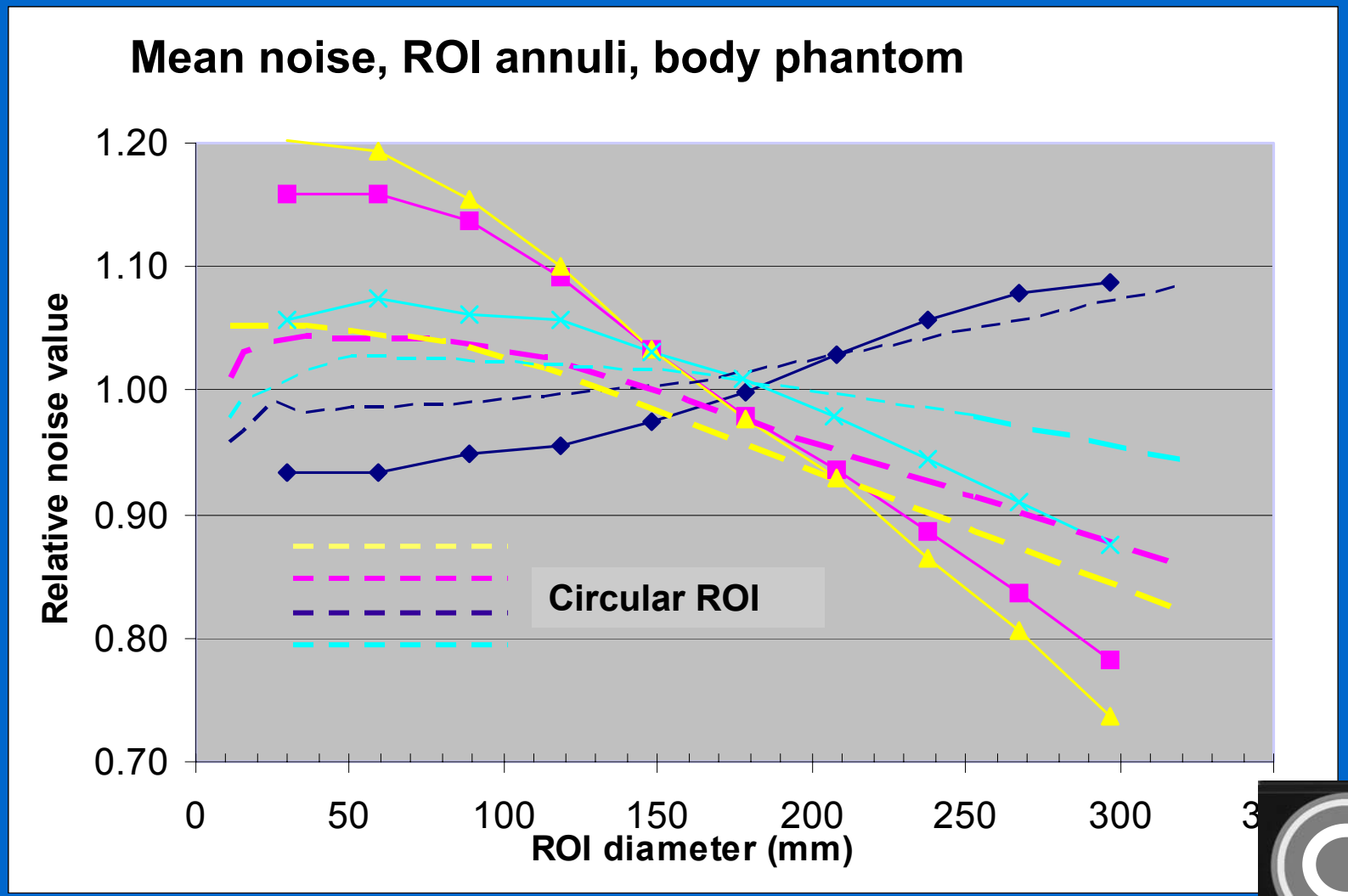
# CT number uniformity: body phantom



# CT noise uniformity: body phantom



# CT noise uniformity: body phantom

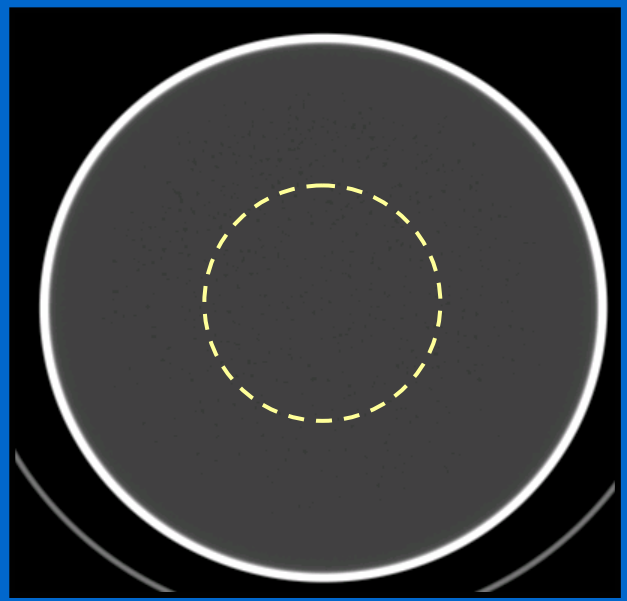


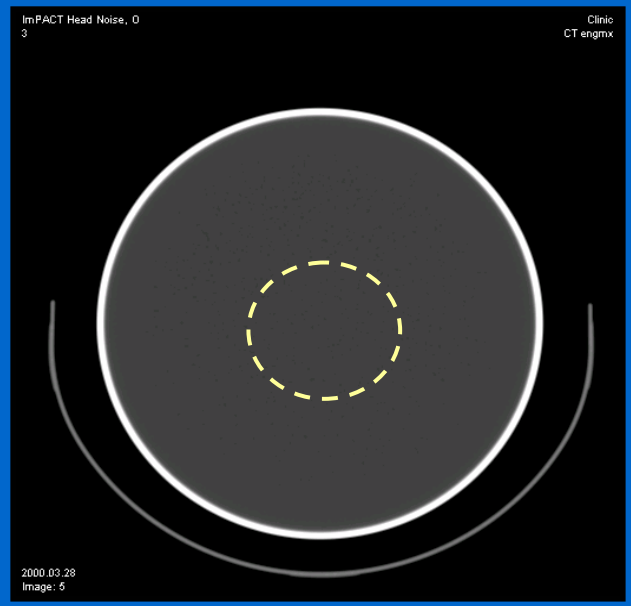
# Outline

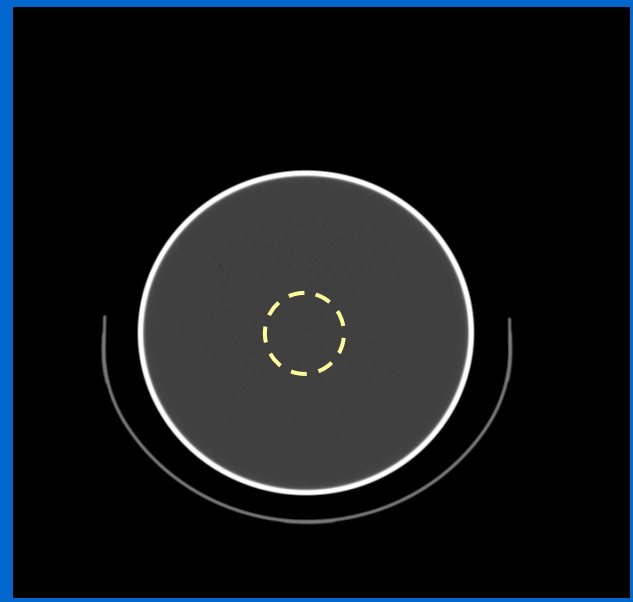
- ROI size and noise value
- ROI size and error in noise measurement
- FOV and noise value
- Conclusions

# Image noise

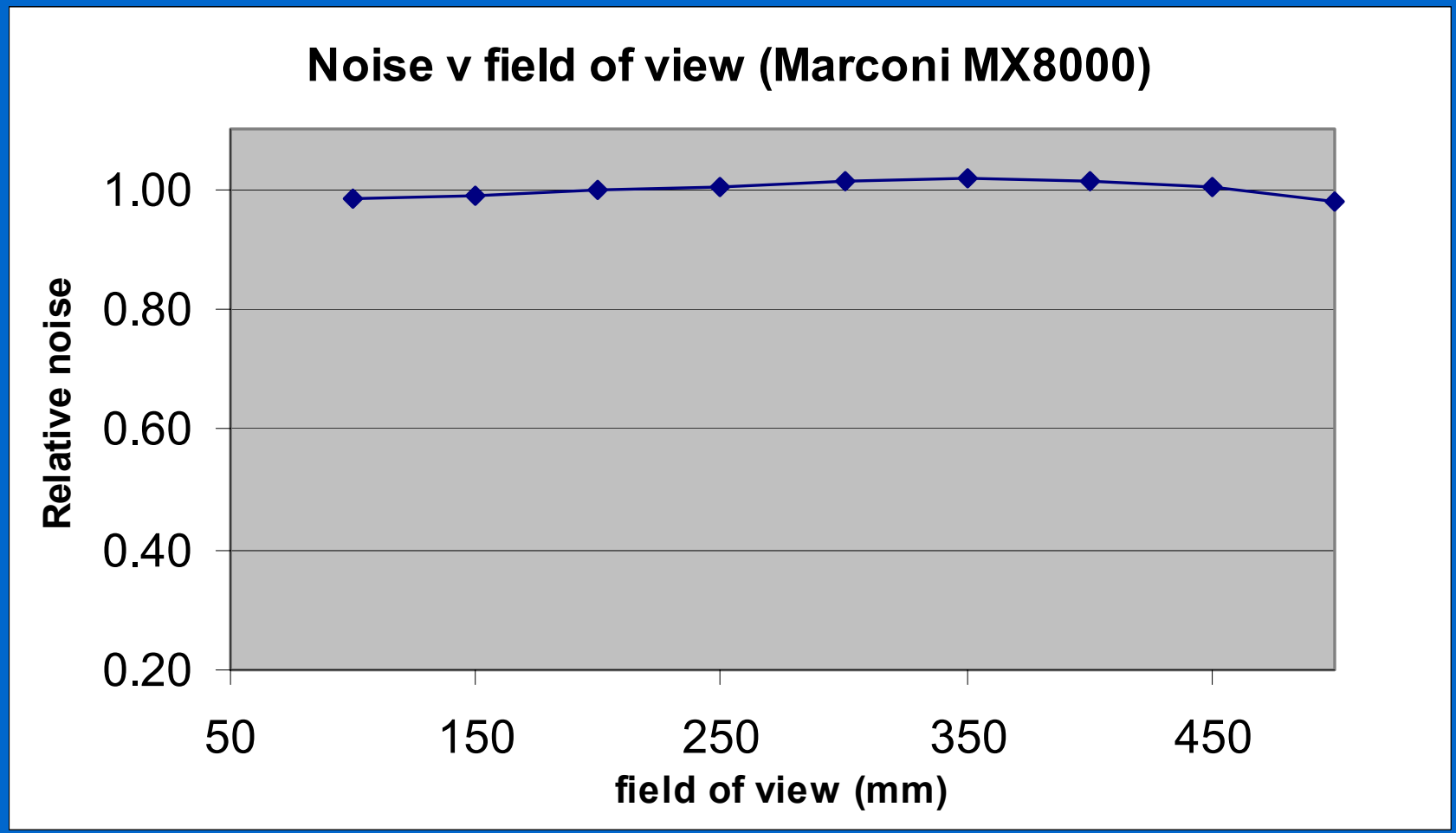
- Does the noise change with field of view ?



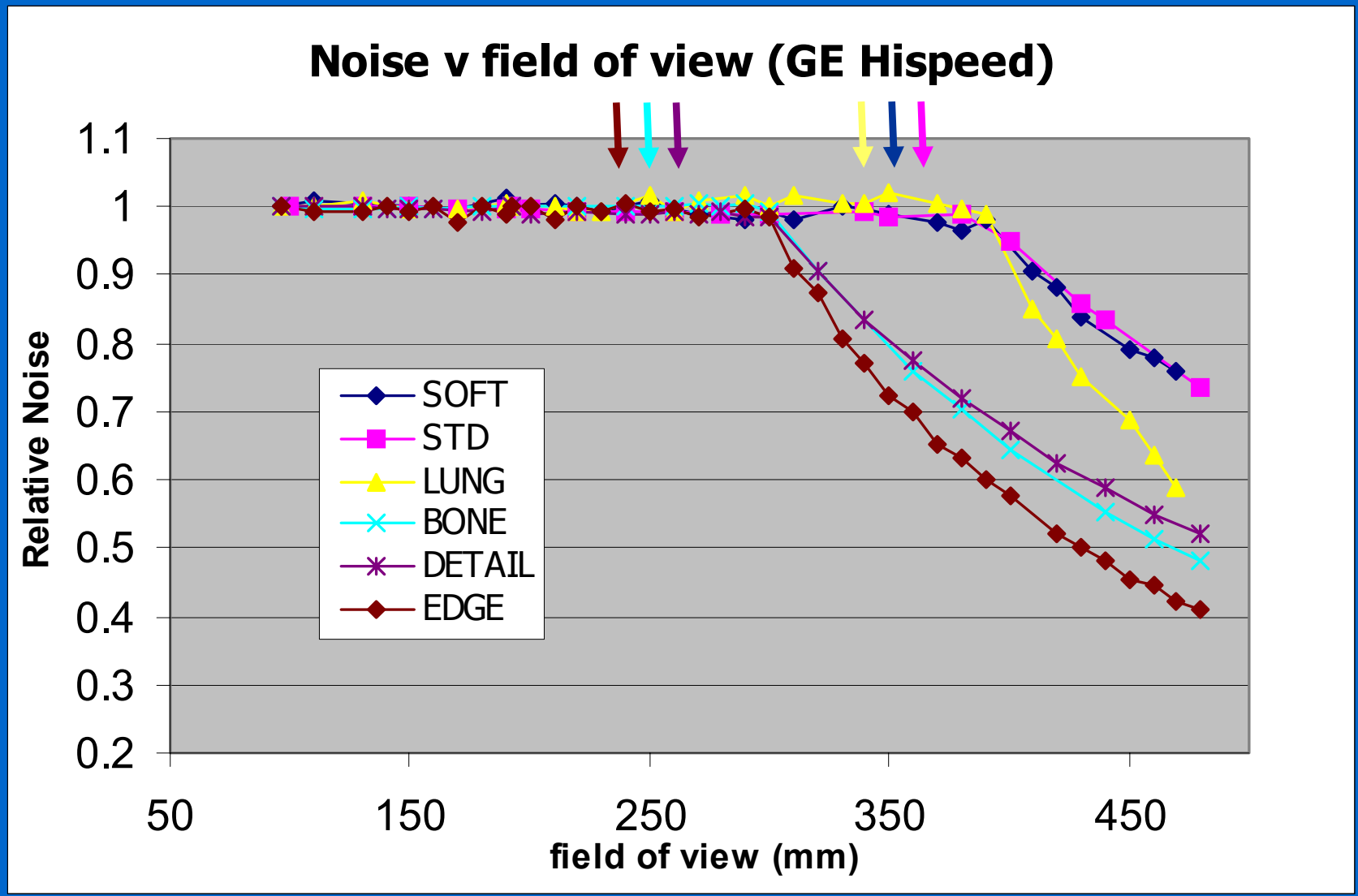


# Noise and fov



# Noise and fov



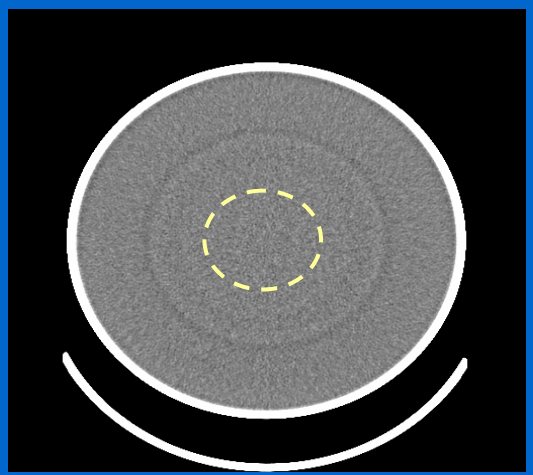
# Outline

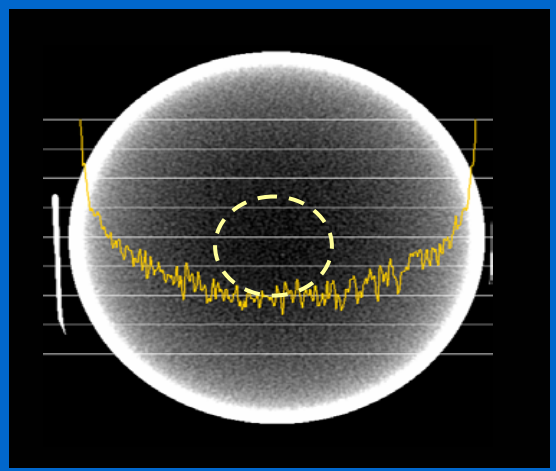
- ROI size and error in noise measurement
- ROI size and noise value
- FOV and noise value
- Conclusions

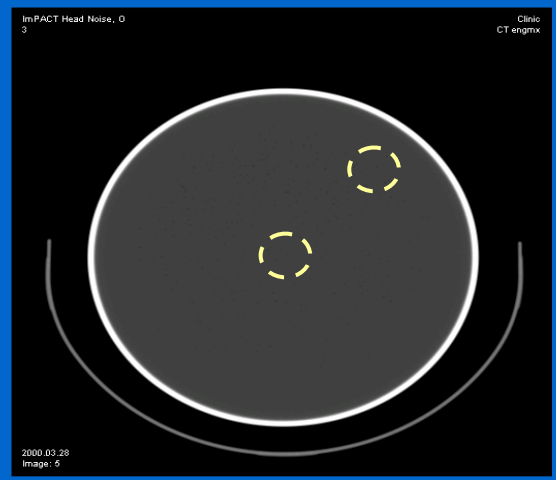
# Measuring stochastic noise with a ROI

- ROI large enough…
  - for good statistics
  - to avoid smoothing due to correlated pixels
- ROI small enough…
  - to minimise effects of non-uniformity in CT number (eg ring artefacts or beam hardening)
  - to minimise any noise non-uniformity
- Consistent

| | | | |
|---|---|---|---|
| 3 | 2 | 3 | 2 |
| 2 | 2 | 1 | 0 |
| 1 | 0 | 0 | 0 |
| 0 | 1 | -1 | 1 |







# Practical comments

- ROI size for errors

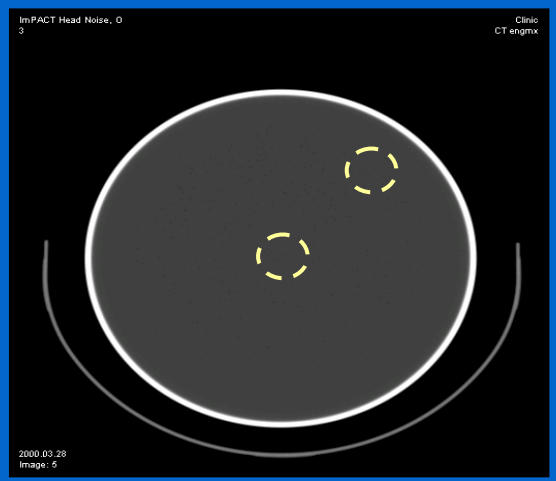
  500 $mm^2$, 25 mm diameter,

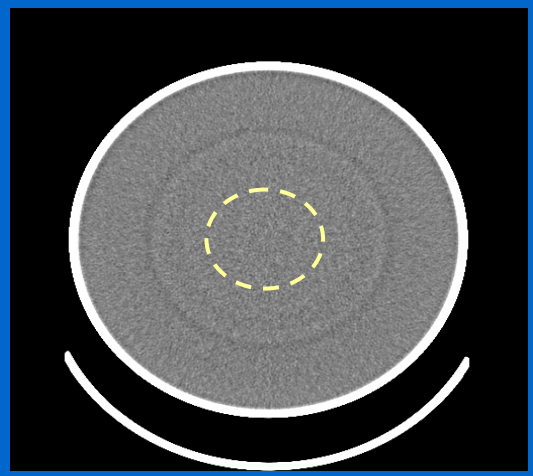
  stdev = 3 %, range ~11%, use at least 10 images

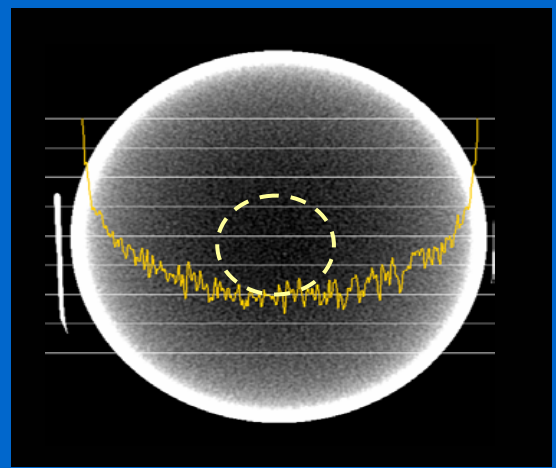
  40% of phantom diameter (80 mm on head, 140 mm on body),

  stdev = 1%, range ~3-4%

- Keep everything constant in quality control
  - As value depends on both ROI and FOV size





# Effect of ROI Size on Image Noise

Sue Edyvean
ImPACT (Imaging Performance assessment of CT Scanners)