Simplifying CT annual quality assurance tests

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Aims

- To reduce the likelihood of accidents arising from the use of heavy test objects
- To reduce the amount of time required on the scanner
- To reduce the weight of required test equipment
- Streamline and introduce more modern image quality tests

Background

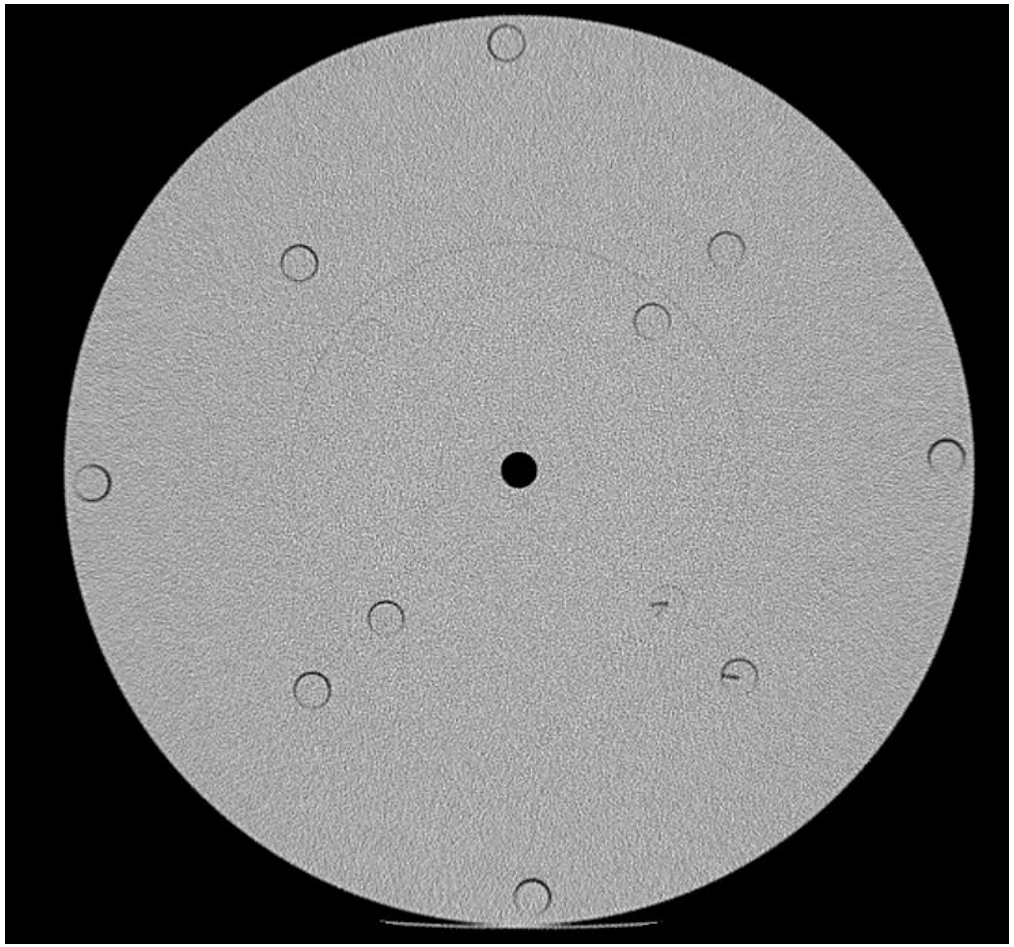
- Currently the annual CT QA requires heavy equipment to be used
  - Recently had a few accidents with heavy test objects 😱
  - Can we reduce the weight or number of test objects needed?
- Can we reduce the time taken on the scanner?
  - Full set of tests can take over 2 hours: lost patient scanning time
  - Physicist / technologist time: not enough staff, too many scanners

- Could we use alternative forms of transport (e.g. metro or train) to access remote sites?

Shine
Sustainable Healthcare in Newcastle

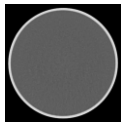
Current QA procedures

- Dose related tests:
  - CTDI in air
  - CTDI(w) – commissioning and new tube or every 3 years
  - Radiation slice width – CR cassette: commissioning and new tube
  - Tube alignment – CR cassette: commissioning and new tube

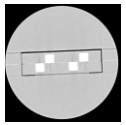


Current QA procedures

- Image quality tests:

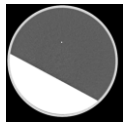


- SNR and CT number uniformity in water



- Reconstructed slice width: slice width phantom

- CT number accuracy: CT number phantom



- Modulation transfer function (straight edge method

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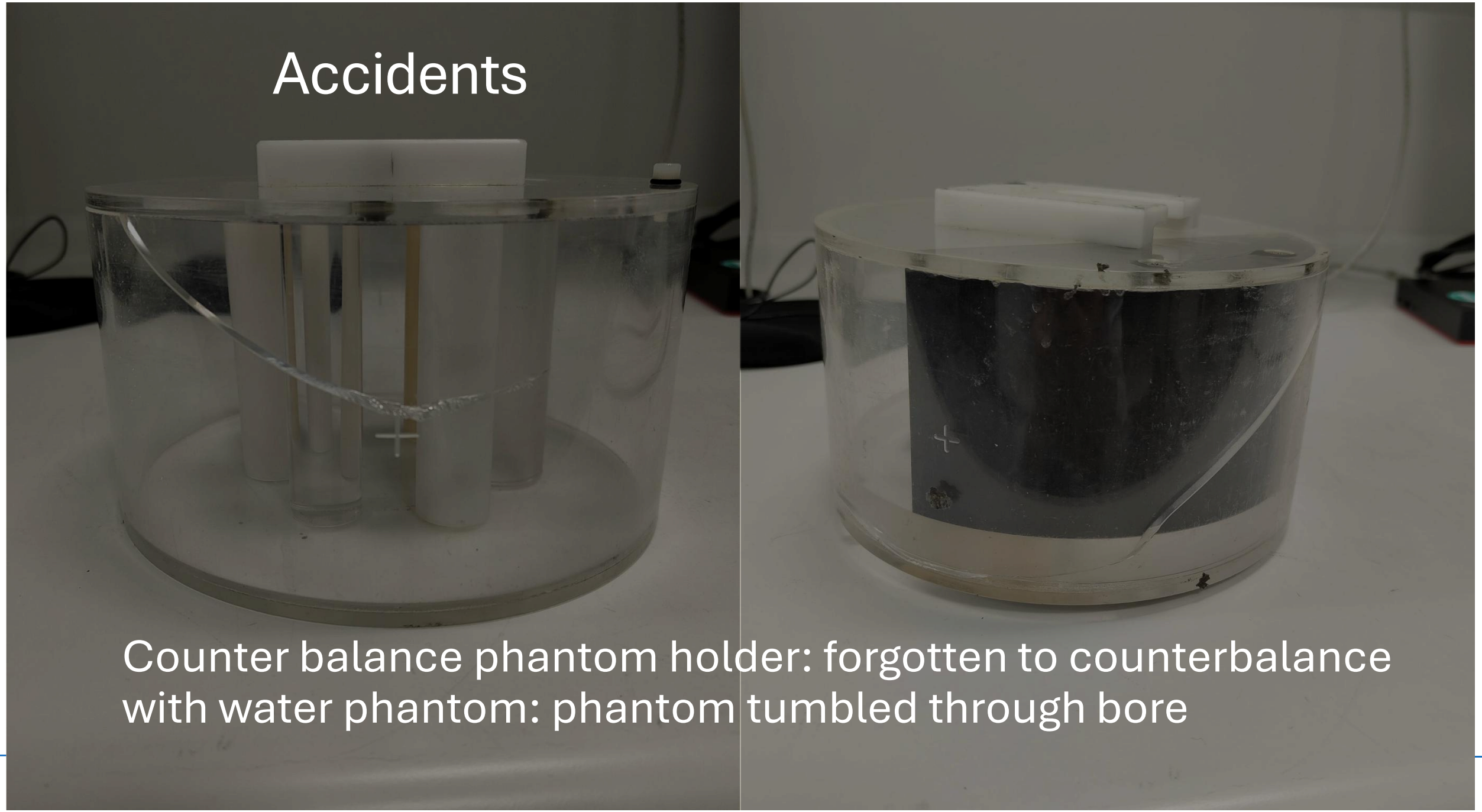
Heavy equipment

- CR Cassette
- Counter balance phantom holder
- Dose meter’s
- CTDI(w) phantom (3x sections)
- 4X IQ phantoms
- >70kg weight

Accidents



Counter balance phantom holder: forgotten to counterbalance with water phantom: phantom tumbled through bore

Consequences

- Broken test object
  - Bespoke phantoms: Can't do further tests until replacement made
- Damage to scanner
  - Fortunately the scanner was unharmed in all cases, but potential for:
    - Water damage
    - Damage to bed
    - Damage to scanner bore
- Damage to room
  - Cleanup of phantom fluid – just water for CT
  - Floor damage
    - This did happen – infection control risk

Changes to dose measurements

- Drop CTDI(w) – commissioning only
- CTDI(air) sufficient by itself: compare CTDI(air) annually with commissioning per kV
  - No need to carry heavy phantoms for annual QA
  - Saves time

- Calibration of console CTDI:
  - “air cal factor” : console/CTDI(air)
    - measure at commissioning and annual QA
    - Depends on kV: use average of most commonly tested kV (120kV)

Changes to image quality tests

- Replace with a single water filled phantom test

- Can use manufacturers phantom:
  - No need to carry heavy water filled phantoms about
  - Less chance of accidents – manufacturer phantom designed to properly fit to scanner table
  - Can be scanned remotely by radiographers and images transferred to Newcastle PACS for analysis by the medical physics QA team

Image quality tests

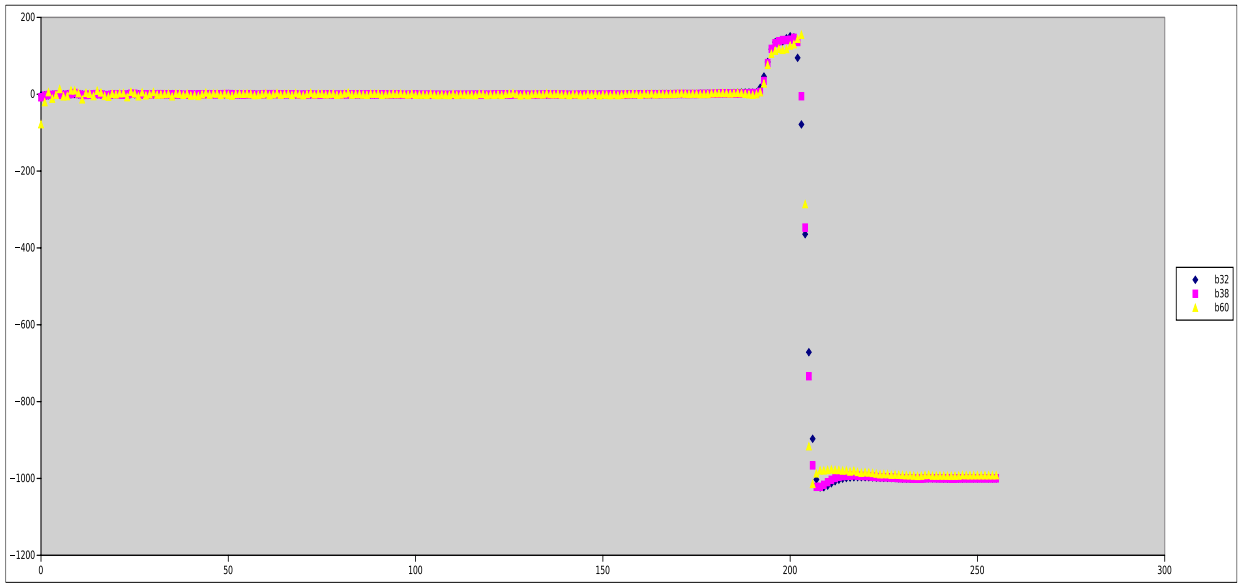
- SNR & image uniformity: same as before
- NPS: noise power spectrum – supplement SNR, characterises kernel and reconstructed slice width
- Check CT Number: air – water – Perspex phantom body: 3 points enough to define linear relationship: mu vs CT number
- MTF: MTF derived from the test object body

MTF derived from the test object edge

- Use a radial average 1-D profile:
  - Each pixel in the image placed in 1D array according to its distance from the centre of the test object
  - The circular nature of the test object means that each pixel at the edge is sampled in a slightly different location depending on radial angle
  - Circular-edge MTF technique has been described before, usually using a contrast disc, for example see
    - Simulation Analysis on the Performance of a Circular-Edge Technique in Measurements of the Modulation Transfer Function (Maruyama S. *J Med Phys* 2023 **48** 90-7

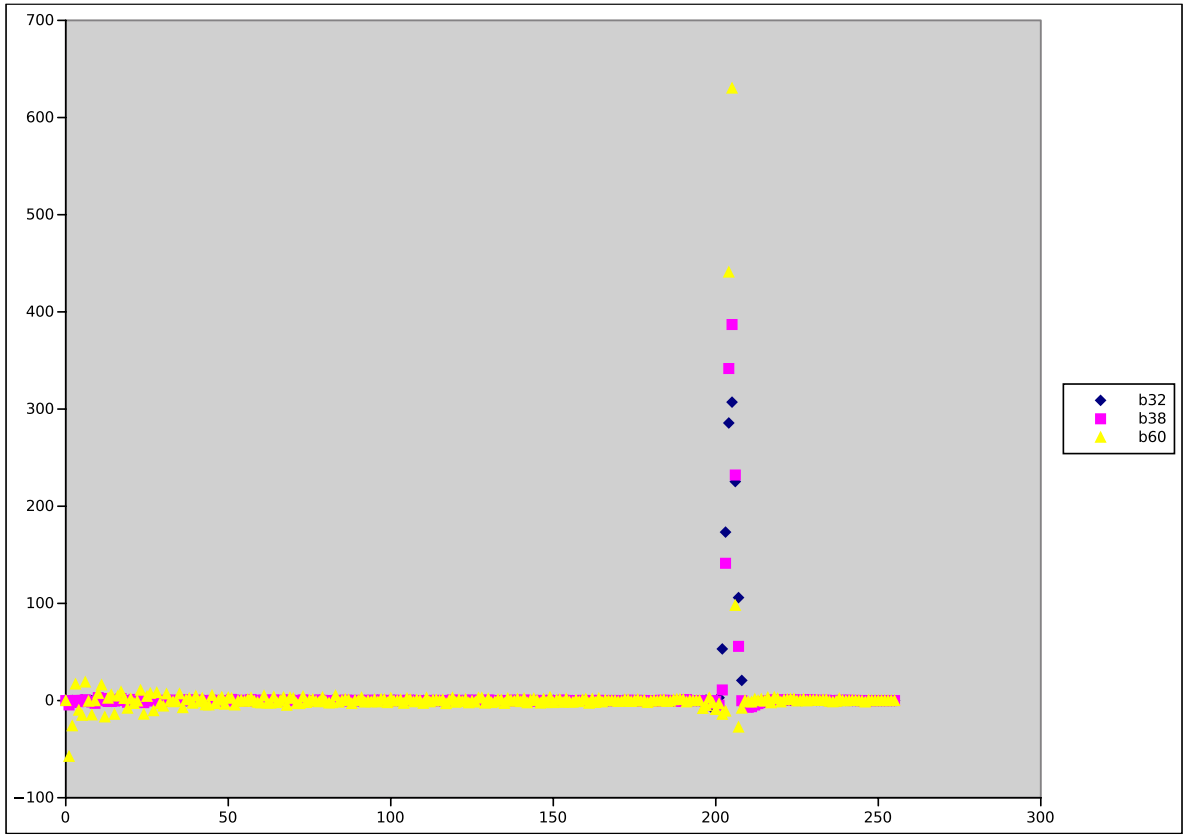
MTF derived from the test object edge

- Example 1D radial profiles for 3 kernels:
  - Blue – low resolution (b32)
  - Pink – medium resolution (b38)
  - Yellow – high resolution (b60)
- From this the following can be obtained:
  - Average water CT number
  - Average Perspex CT number
  - Average air CT number
  - Edge spread function for MTF, using the Perspex/air interface

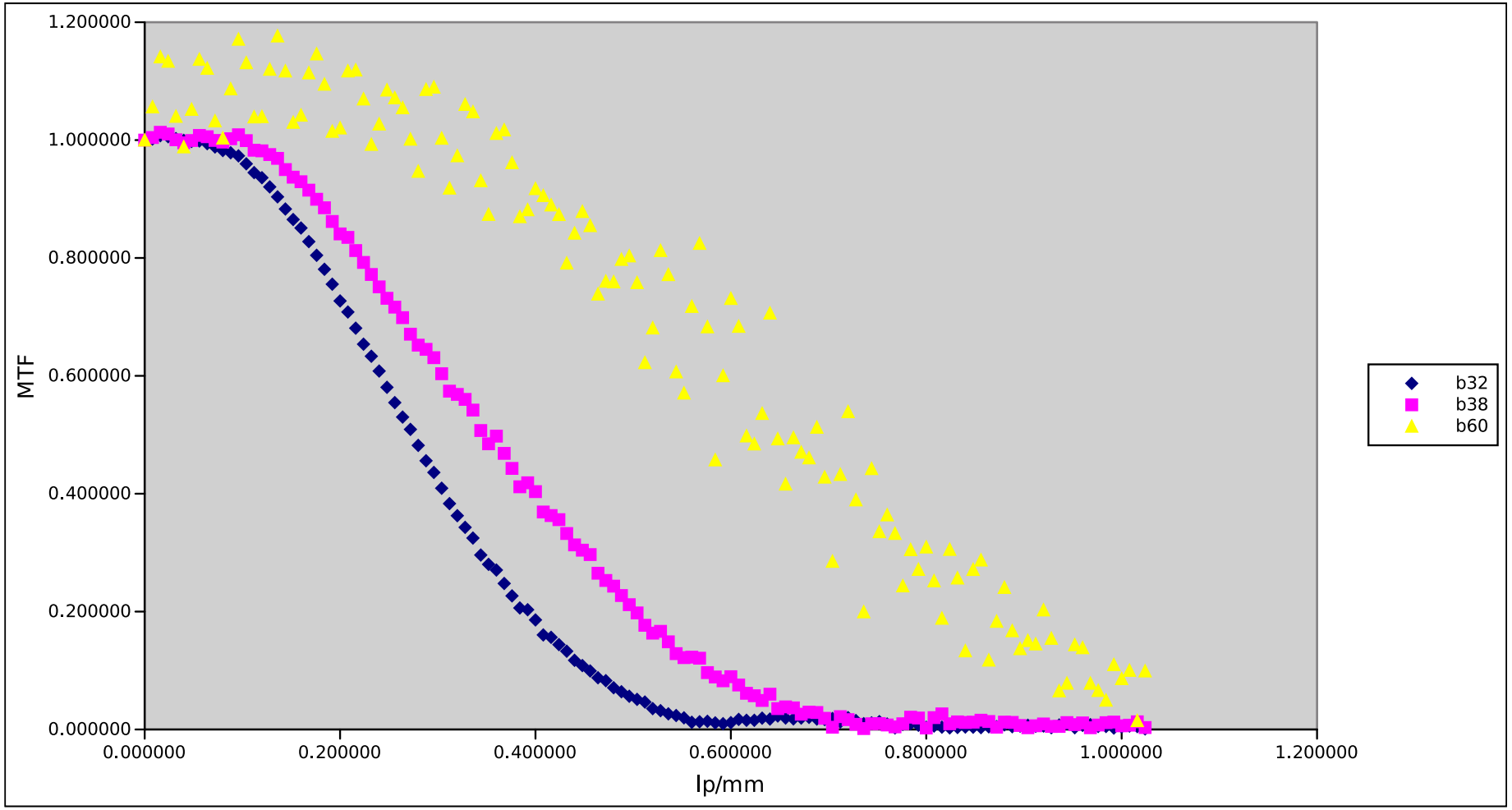


MTF derived from the test object edge

- Derive the MTF
  - The edge spread function from the previous slide can be differentiated to produce a line spread function (LSF).
  - This will produce two LSFs:
    - Water / Perspex interface (wp)
    - Perspex / Air interface (pa)
  - These two LSFs will be of opposite polarity (absolute values for LSF should not be used!)
  - Can easily remove the wp LSF, being careful to retain the ‘tails’ of the pa LSF



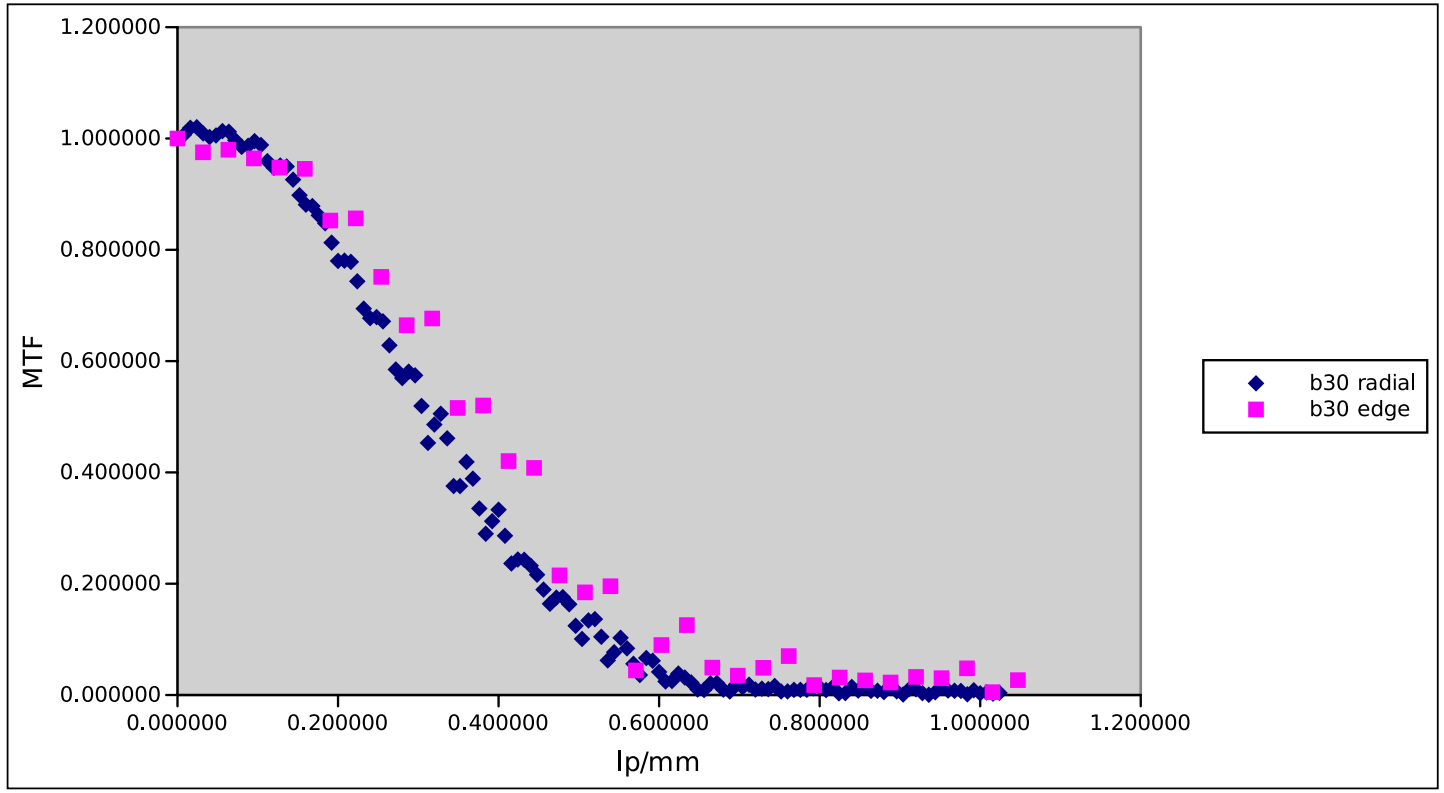
MTF derived from the test object edge



- Final values of the MTF
- Single slice
- Reconstructed slice width 0.6mm

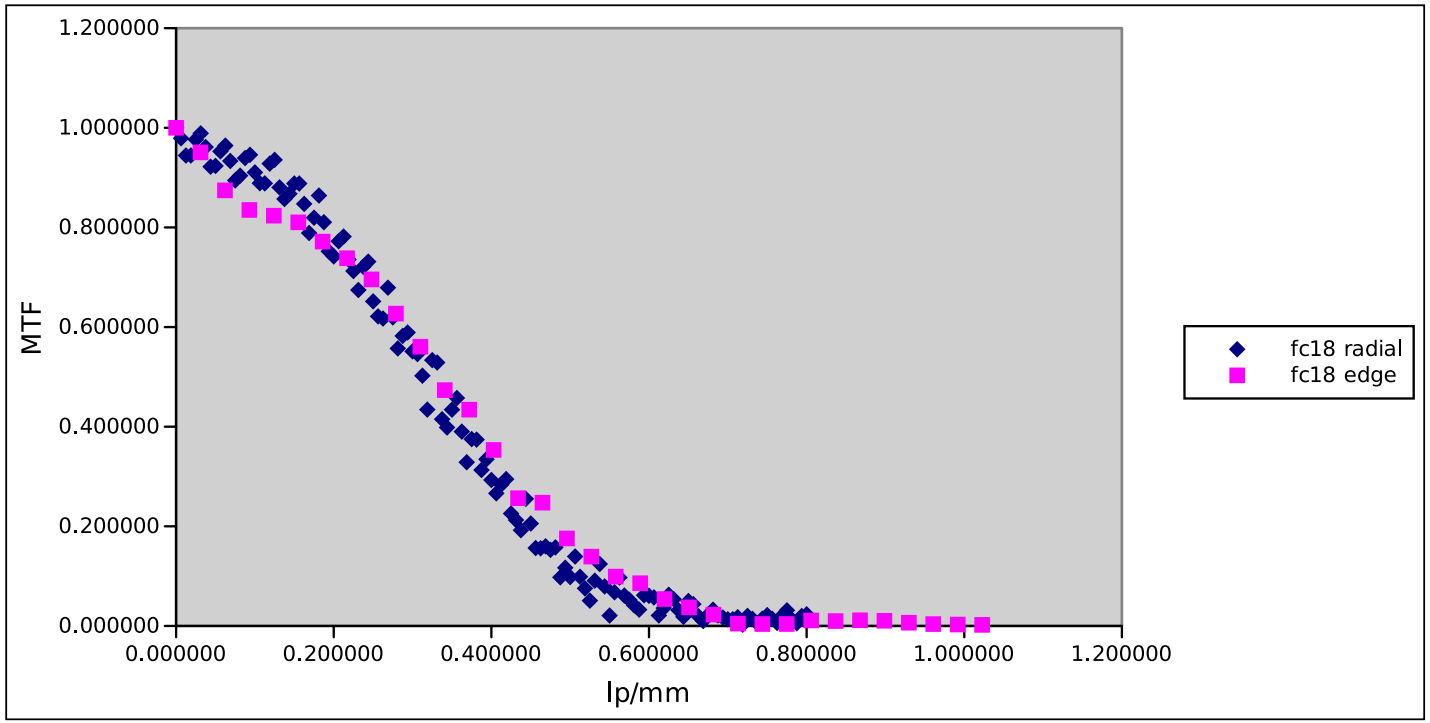
Comparison of MTF methods

- Siemens AS plus
- Radial method possibly slightly under estimates MTF
- There is a small low frequency drop on the edge method.



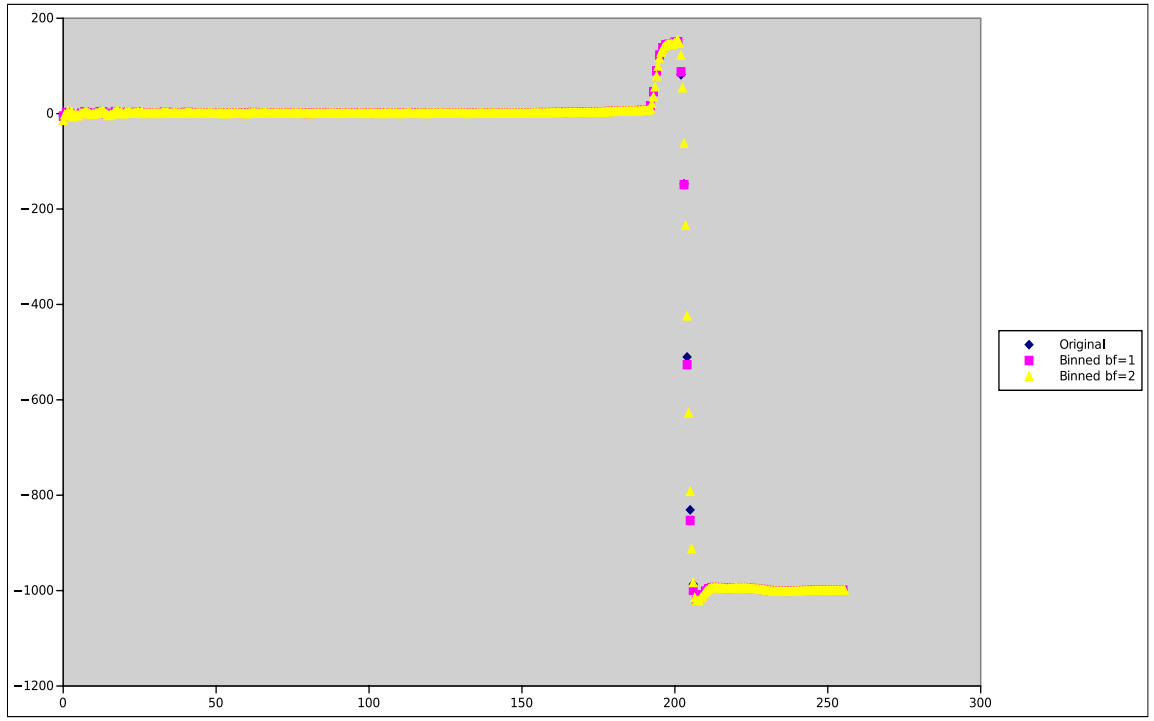
Comparison of MTF methods

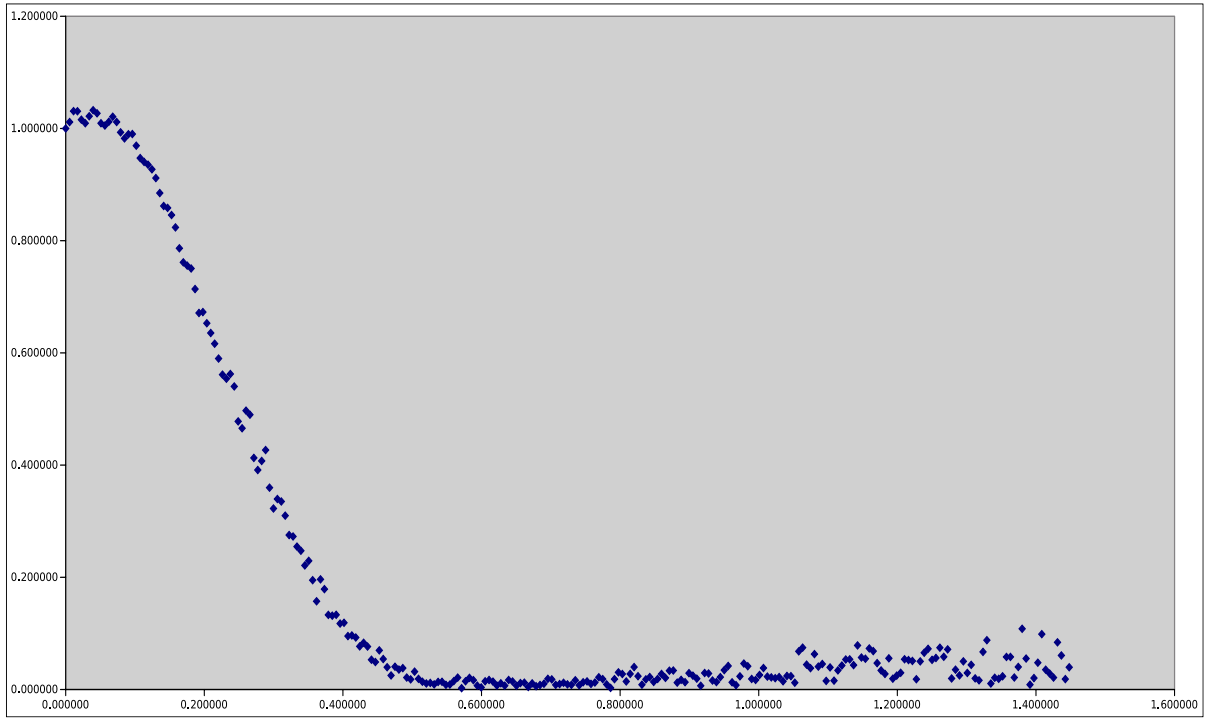
- Toshiba Aquillion one
- The edge MTF was obtained in air (after the TO was broken!)
- The edge method has a more pronounced low frequency drop



Breaking news…

- Previous images based on existing code using an integer algorithm
- Rewritten in double precision – more accurate pixel distances from centre
- Can re-bin, e.g. double number of pixels defining the ESF (b30 kernel):
- Trade-off: less averaging / increase in noise in the MTF as number of bins is increased

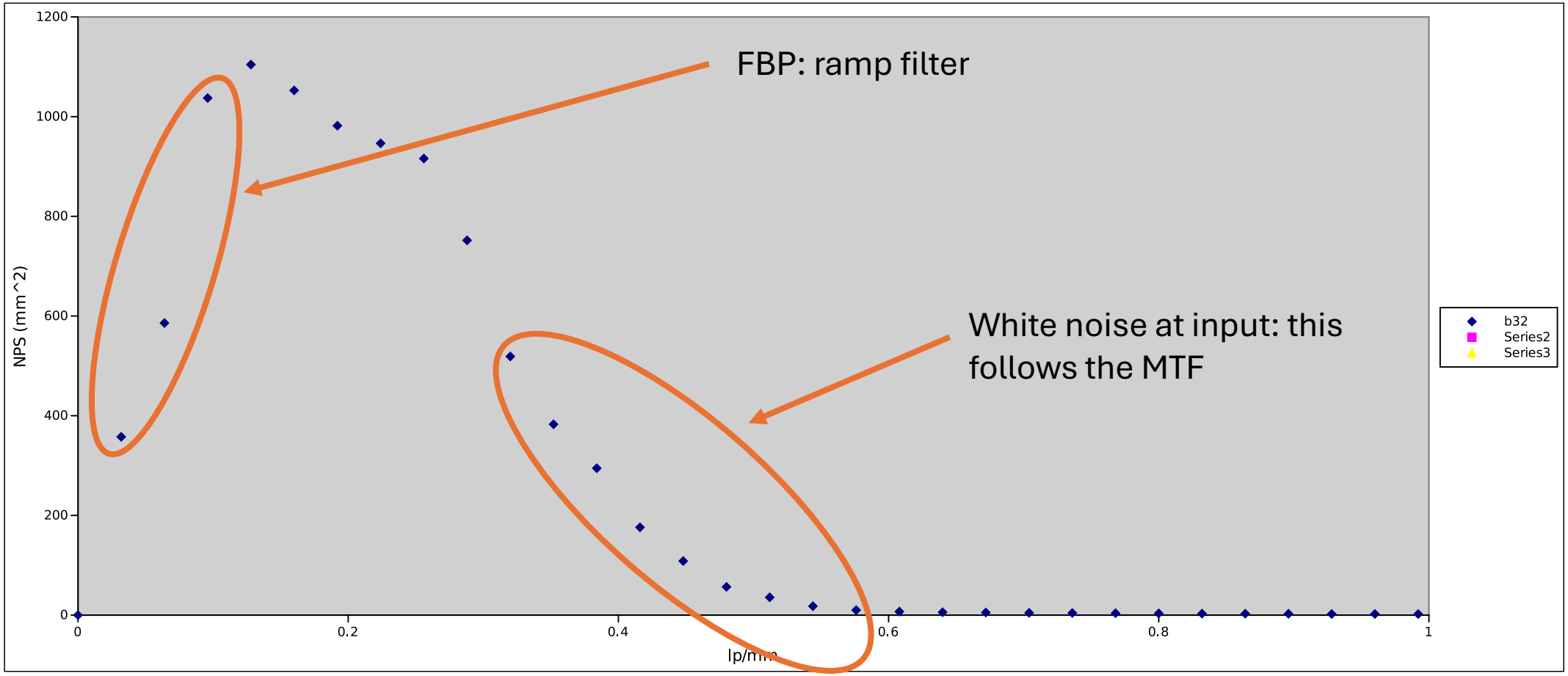




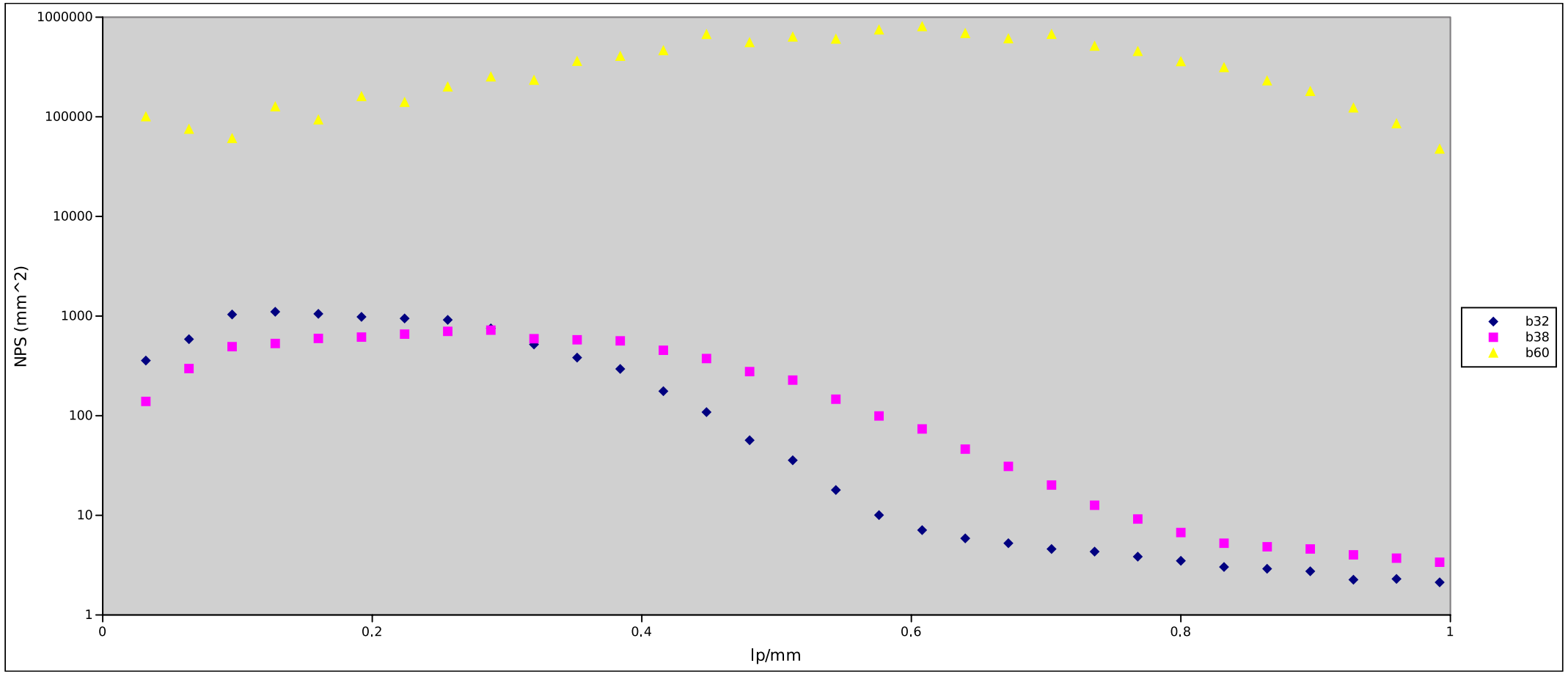
Limitations to MTF from TO edge

- Quality of the edge – results imply edge is good enough to cover sharpness range normally used in old style QA: e.g. Siemens b30 – b60 kernels. Poor circular uniformity of the test object will cause the MTF to be underestimated.
- Accuracy of detecting the centre of the test object: this is critical, and depending on the binning used needs sub pixel accuracy
- Removal of the water/Perspex LSF and other unwanted ‘edges’ – affects the mtf, introduces a modulation on top of the mtf curve if not completely removed.

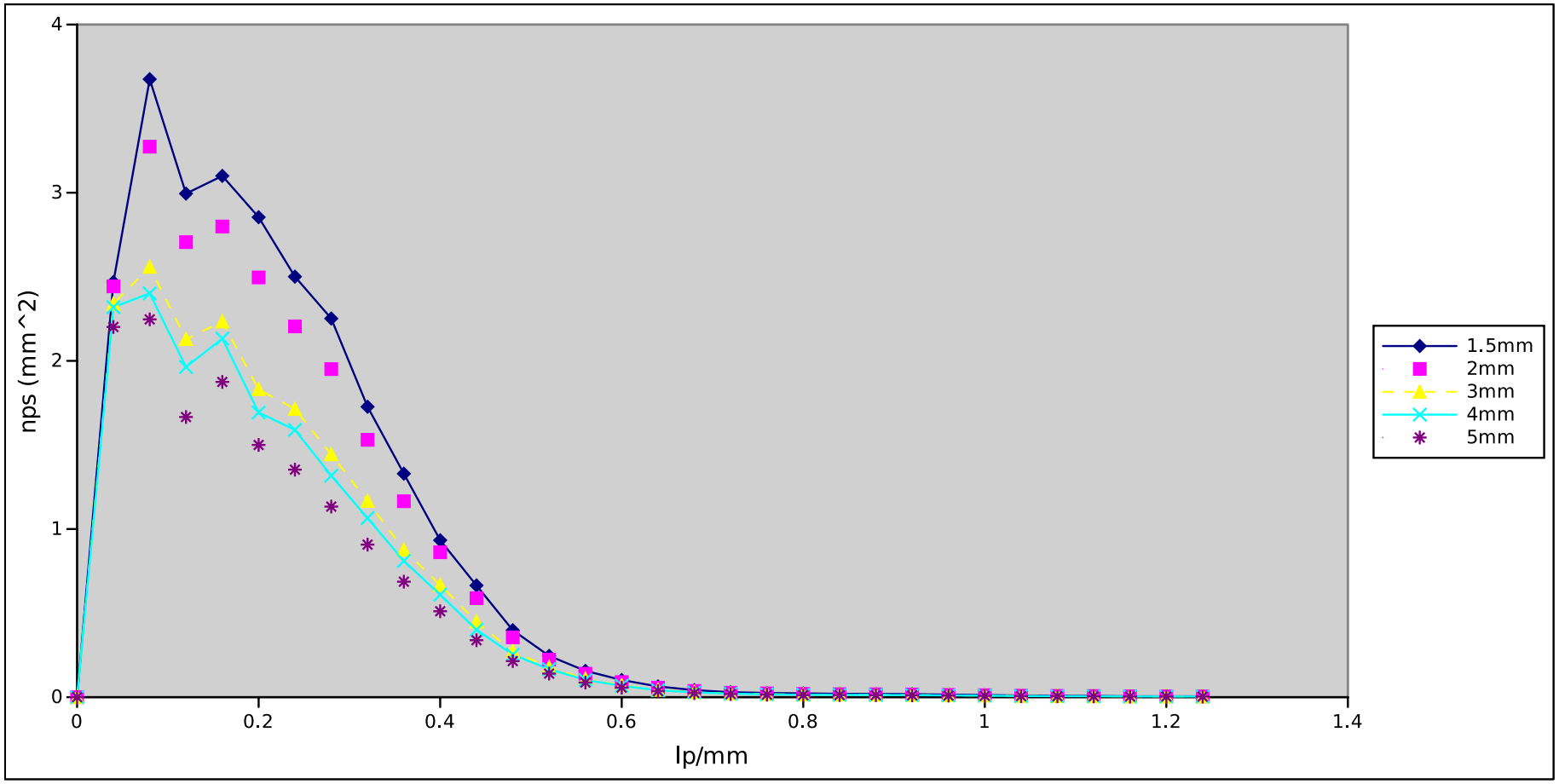
WIP: nps – linear plot of Siemens b30 kernel



WIP: nps: log plot of low, medium, high resolution kernels



WIP: nps: reconstructed slice width



Conclusion

- Annual QA tests can be done with just dosemeter and manufacturer phantom
  - Only need to carry a dosemeter: phantom available onsite
  - Less chance of accidents
  - Can use public transport: environmentally friendly
  - Can obtain images for comparison with baseline without visiting the site if quality problems occur: radiographer can scan the test objects and send via PACS