

One-Dimensional Anti-Scatter Grids for Static CT

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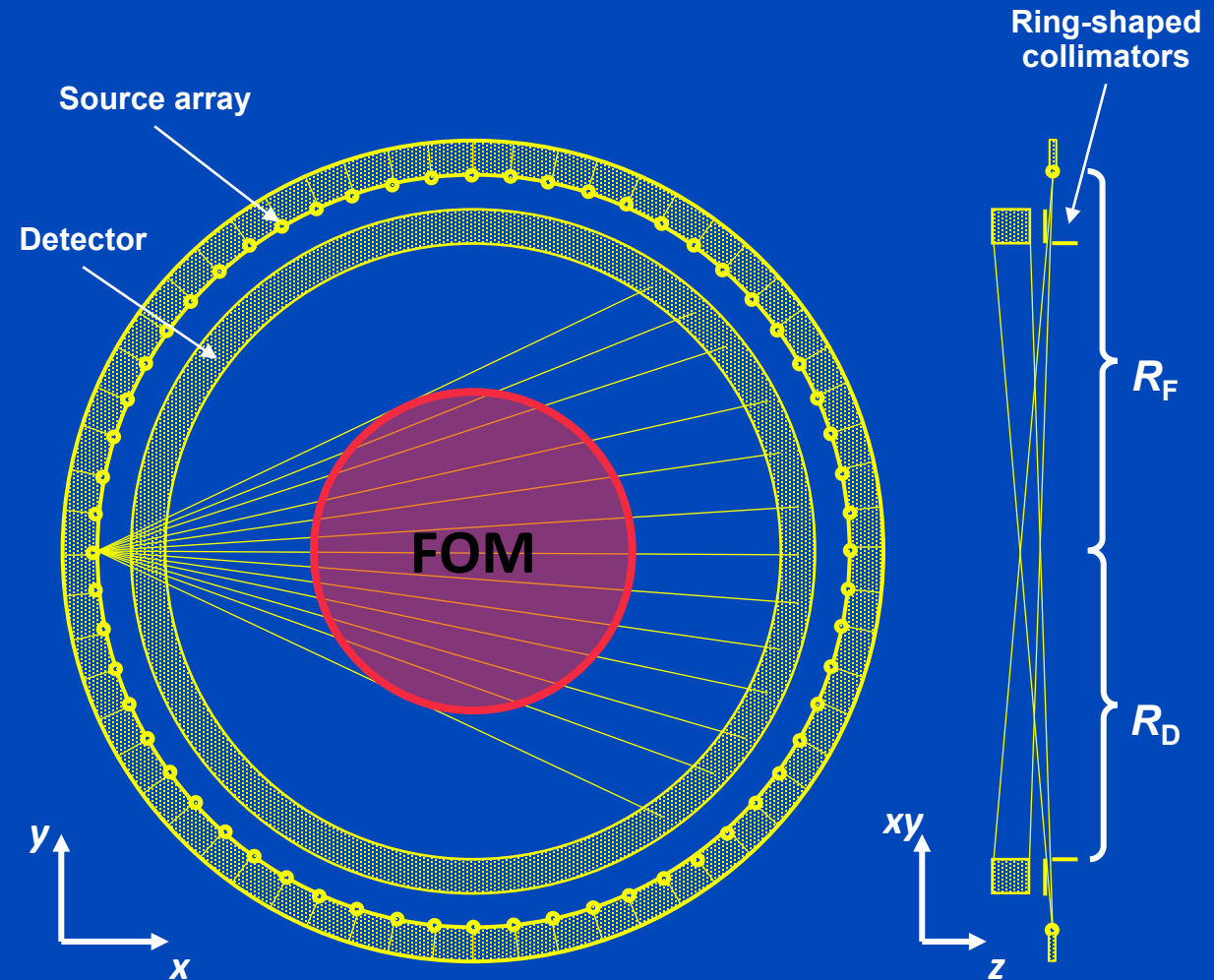
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Static CT: Construction and Motivation

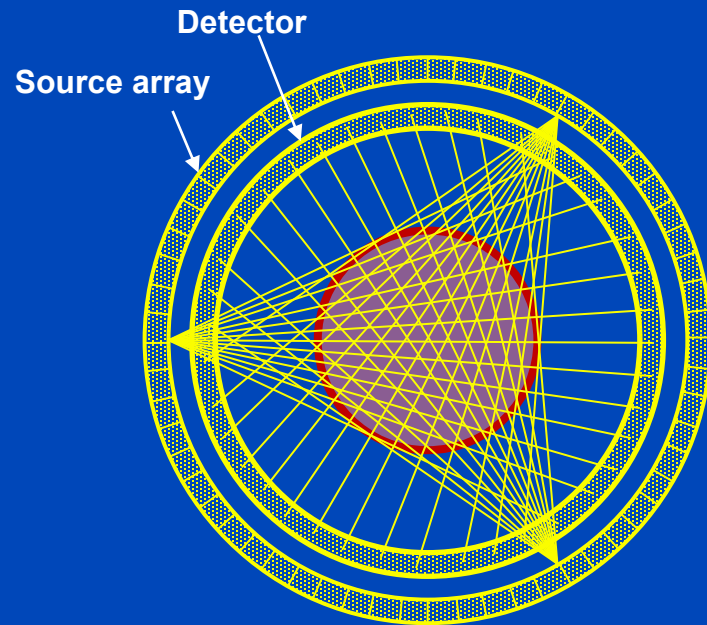
- 4th generation CT geometry
- No rotating components
- Ring source array
 - Composed of many individual sources
 - Field emission technology possible → more efficient
 - Ability of acquisition with varying tube voltage
 - Ability of shooting multiple sources simultaneously
- Ring detector
 - 16 detector rows
 - 12 mm z-coverage in the isocenter
 - Slice thickness ≈ 0.75 mm

→ Mechanical simplification, potentially more compact design
→ Inherently avoids ring artifacts
→ Acquisition time is not limited by rotation speed but rather by electronic switching time between sources and by source power

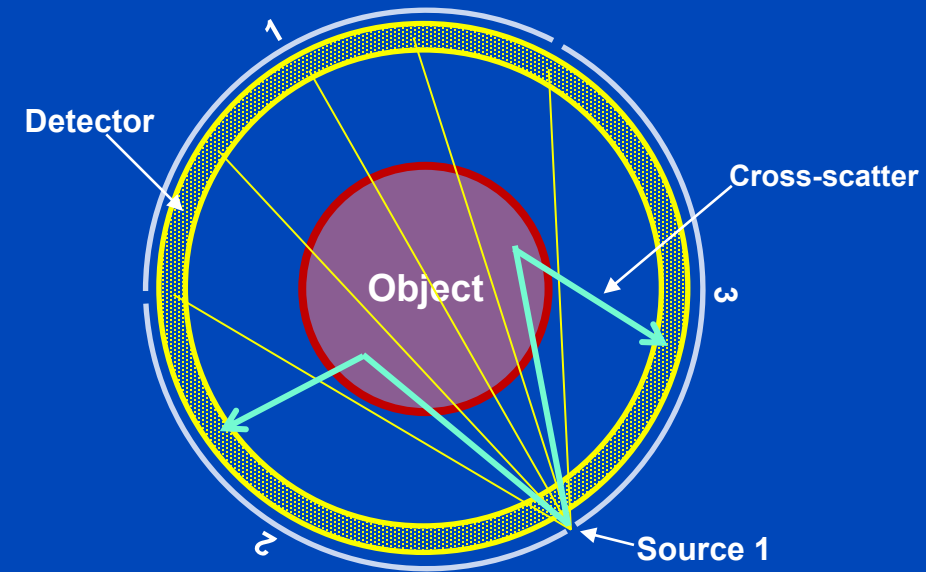


Multi-Source Operation?

- Respiratory and cardiac motion may cause artifacts in reconstructed images.
- Multi-source operation increases temporal resolution^{1,2} or available source power.
- However: Cross-scatter degrades image quality by causing scatter artifacts and increased image noise.



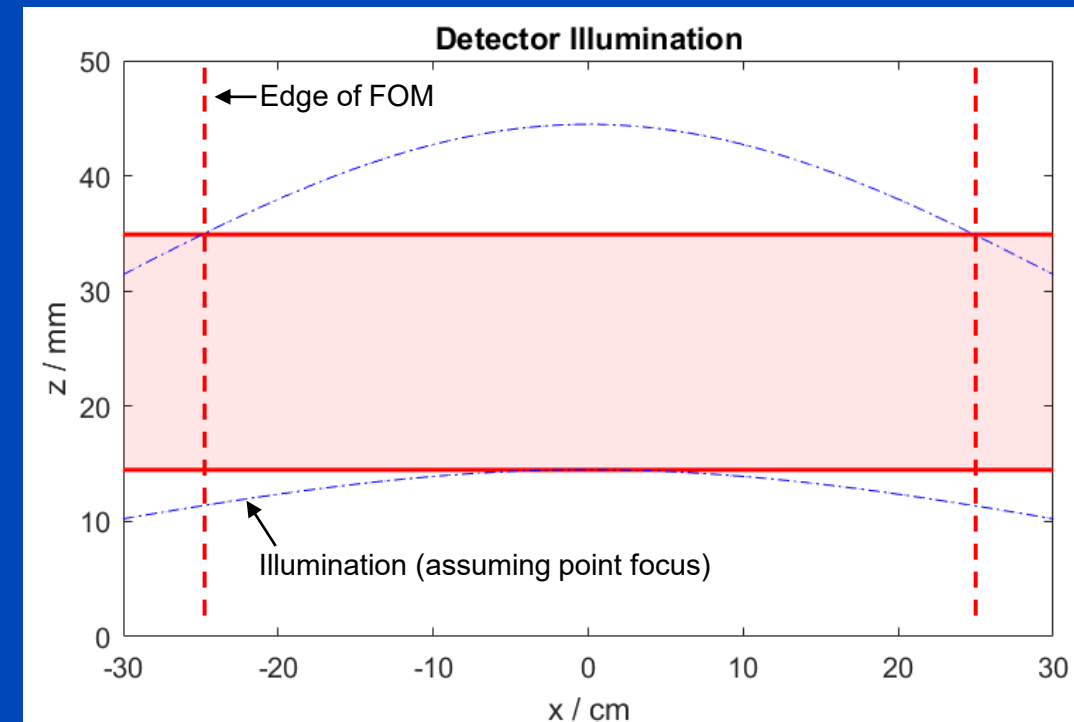
Triple-source operation



Cross-scatter degrades image quality

Challenges in Static CT

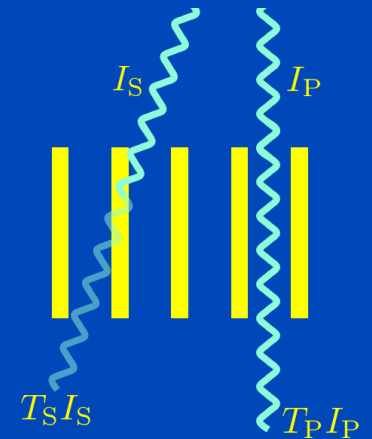
- **Ring-shaped collimators are easy to build, but:**
 - They cause banana-curved detector illumination.
 - Patient dose is wasted (depending on the collimation).
 - Sophisticated collimators, one for each source, would be required.
 - Similarly, each source would need its own bowtie filter.
- **Z-offset between source array and detector needed**
 - No exact image reconstruction possible
- **X-ray power demands grow with temporal resolution**
 - 240 kW at 63 ms temporal resolution are routinely available, today.
 - 10 ms temporal resolution would require 1500 kW power.
- **Source and detector rings are expensive**
- **Conventional anti-scatter grids (ASGs) cannot be deployed**
 - Impairment of image quality due to scatter artifacts
 - Increased image noise due to scatter



To Grid or not to Grid?

- A common misbelief is that a good scatter reduction software can be used instead of an ASG.
- This is wrong, since

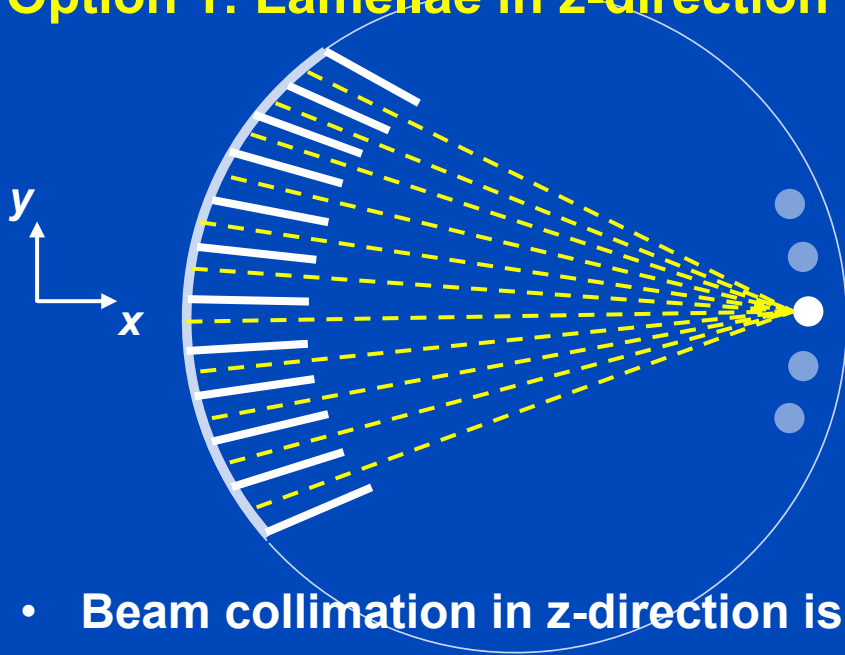
$$\text{SNR} = \frac{T_P I_P}{\sqrt{T_P I_P + T_S I_S}}$$



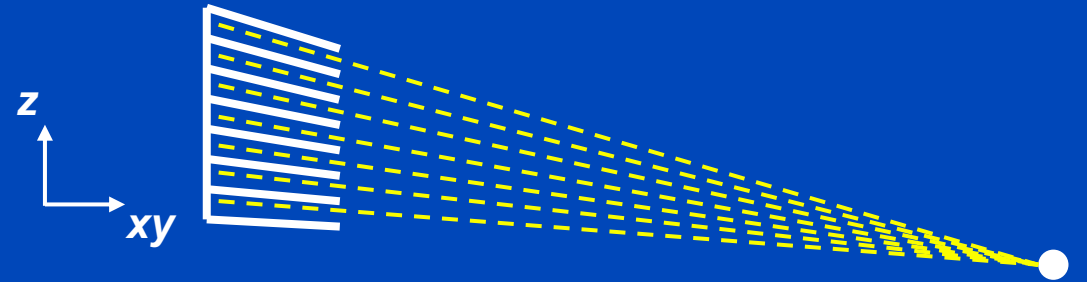
- **Facts:**
 - ASGs are beneficial if the scatter-to-primary ratio (SPR) exceeds a certain threshold.
 - Scatter reduction software is always beneficial, with or without ASG.
 - Noise reduction software is always beneficial, with or without ASG.

Arranging a One-Dimensional ASG

Option 1: Lamellae in z-direction



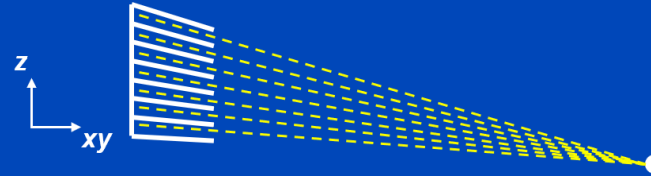
Option 2: Lamellae in fan-direction



- Beam collimation in z-direction is small compared to collimation in fan-angle direction.
- Therefore, ASGs with lamellae in z-direction (option 1) would generally be preferred.
- However, ASGs in fan-angle direction are not suitable for static CT since a slight change of the source position in the xy-plane would lead to the absorption of the primary signal.
- Thus, we need to choose option 2.

Aims

- Simulate ASGs in fan-direction and determine their suitability.



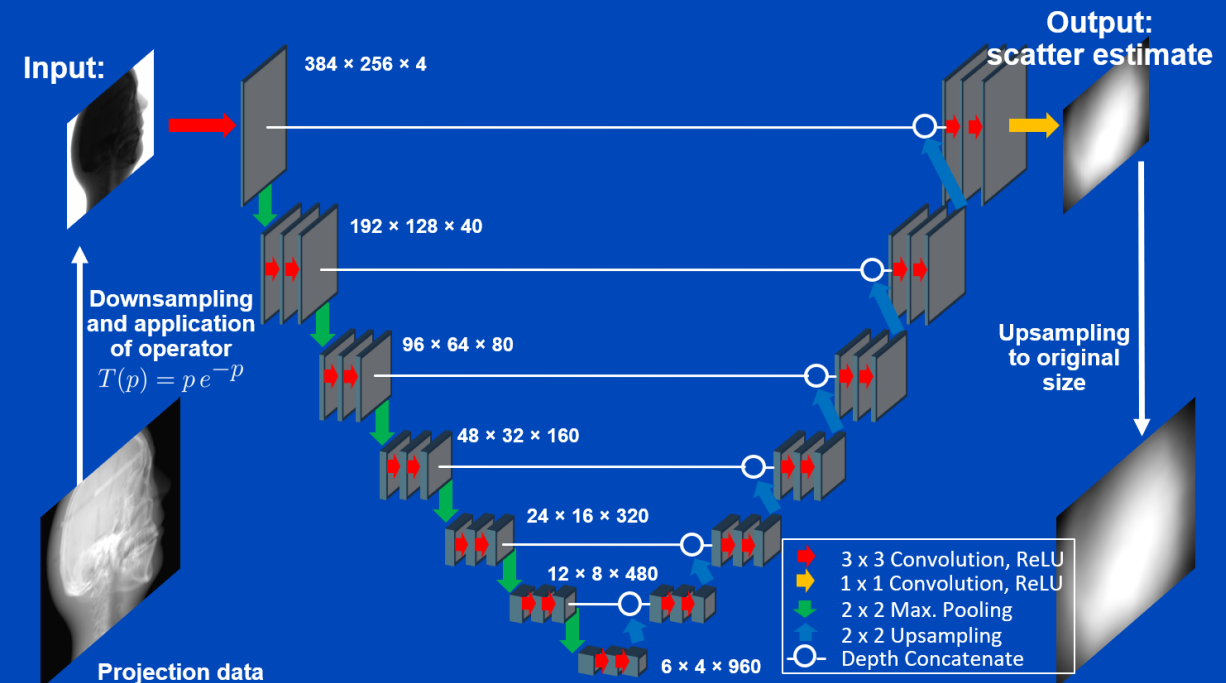
- Use a software-based scatter correction, e.g. the deep scatter estimation DSE^{1,2,3}, to reduce remaining scatter artifacts.

- **Simulate**

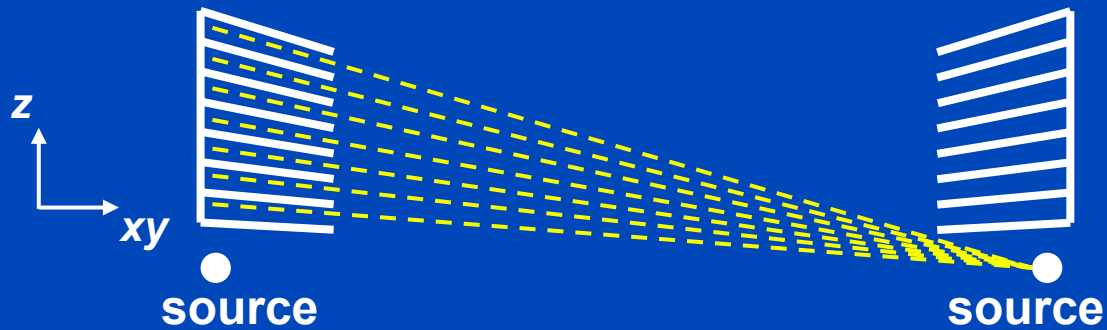
- ASG heights 5 mm, 20 mm, 40 mm
- Single and triple source operation

- **Evaluate**

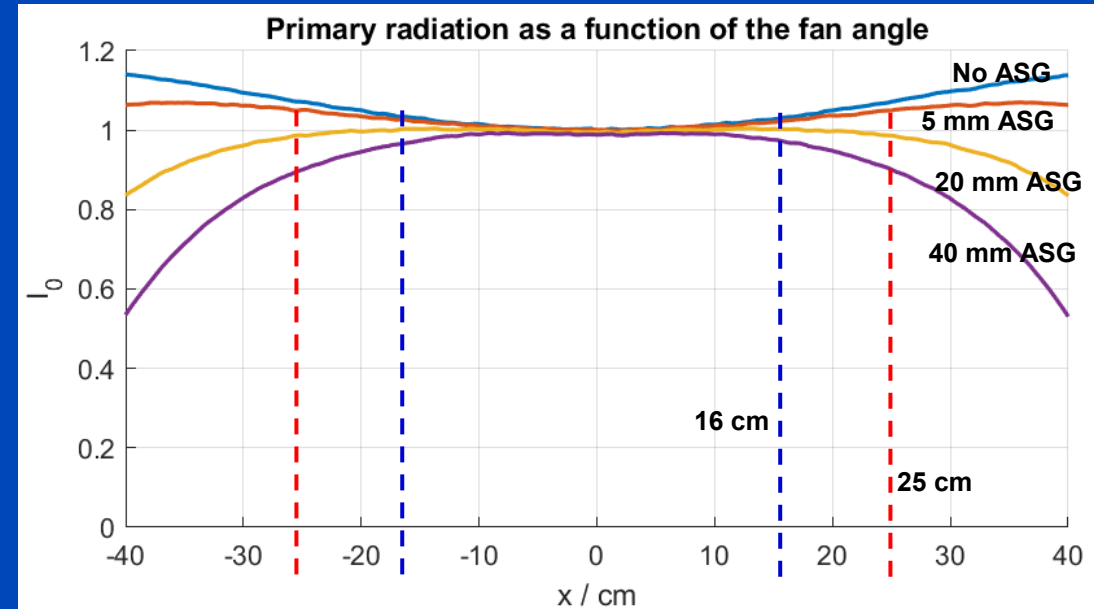
- Scatter artifact reduction
- SNR improvement
- Dose savings



ASG Simulations



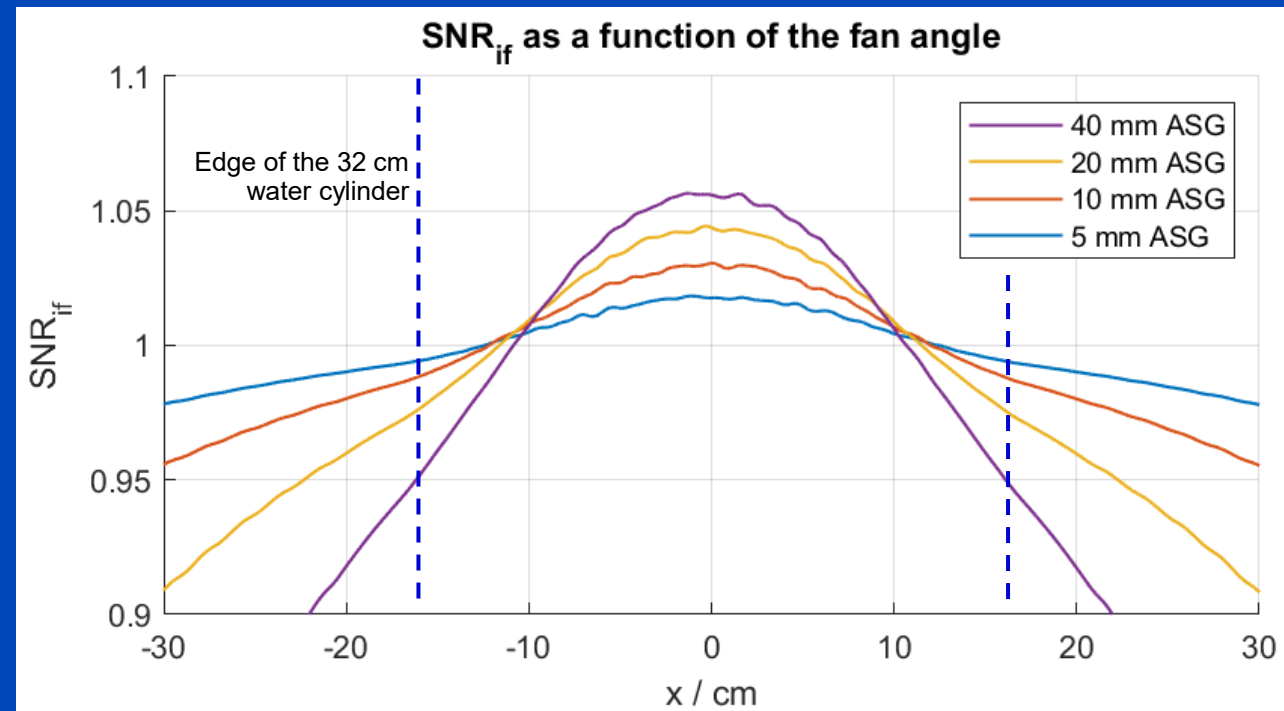
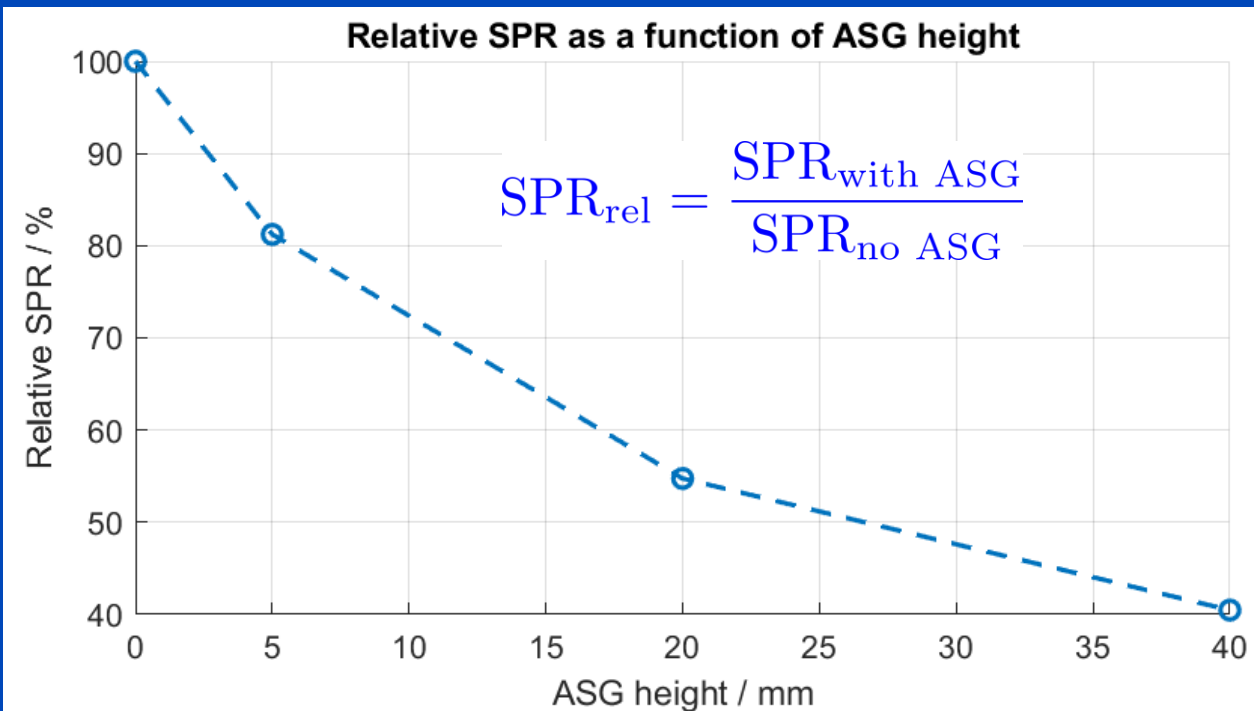
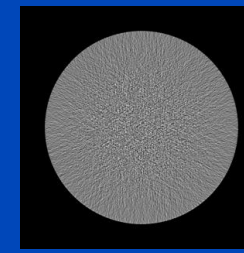
- ASG is focused towards the source exactly opposite of the detector element.
- For increasing angle within the fan, the alignment becomes worse: The lamellae attenuate the primary signal.
- Nevertheless, static CT may still benefit from an ASG if it improves the SNR.
- Simplifications in our simulation:
 - The lamellae overlap perfectly with the optical separators of the detector.
 - The ASG was implemented as an angle-dependent detection probability of the incident photons and not as a specific material.



	5 mm ASG	20 mm ASG	40 mm ASG
16 cm off-center	0.8 %	2.9 %	6.1 %
25 cm off-center	2.1 %	8.0 %	16.1 %

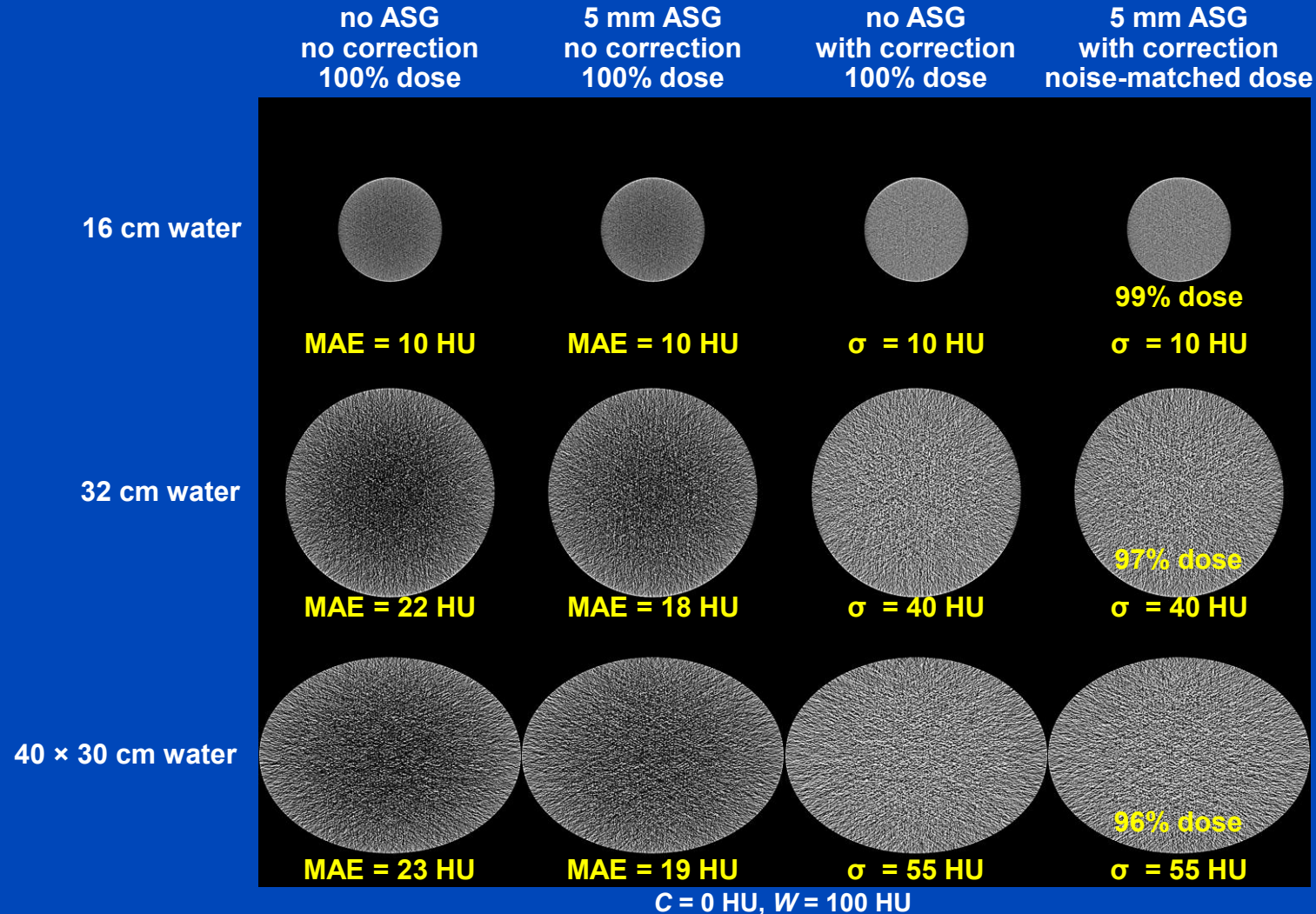
Fraction of primary that is attenuated by the ASG.

SPR and SNR_{if} (for a 32 cm Water Cylinder)

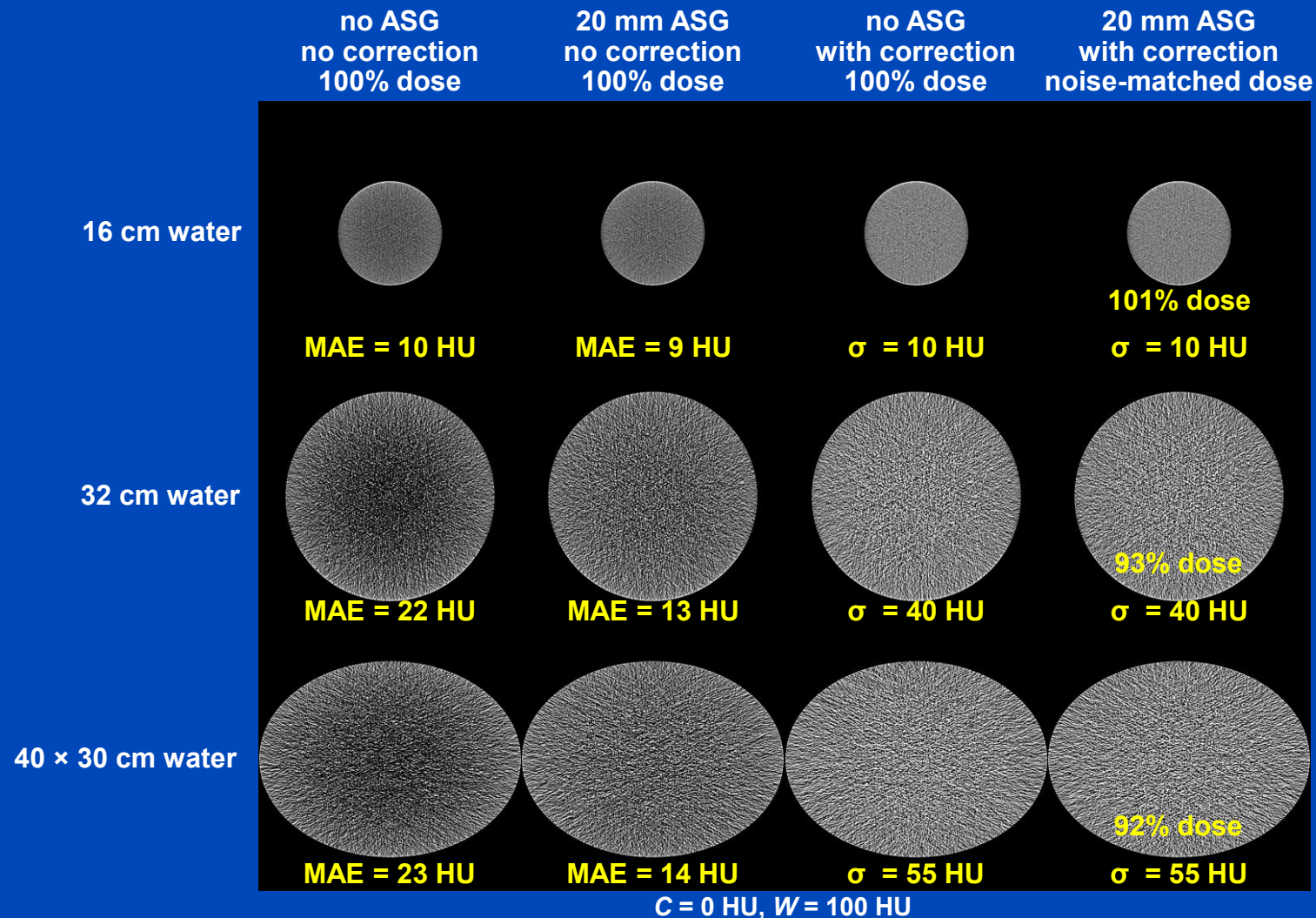


- SNR_{if} drops below 1 within the limits of the 32 cm water cylinder.
- Reconstructions may still benefit from the ASG since central rays contribute the most noise.

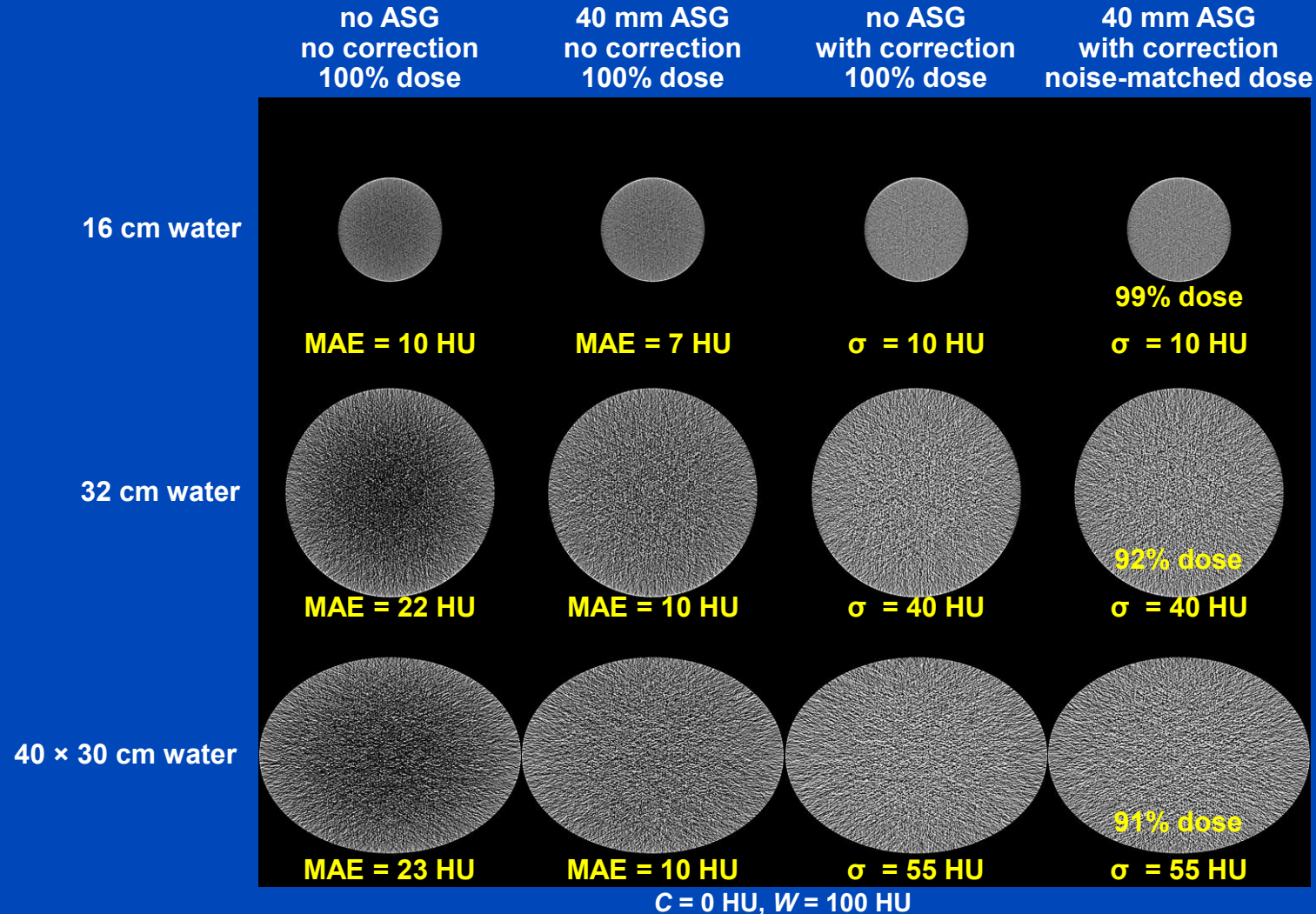
5 mm ASG, Single-Source



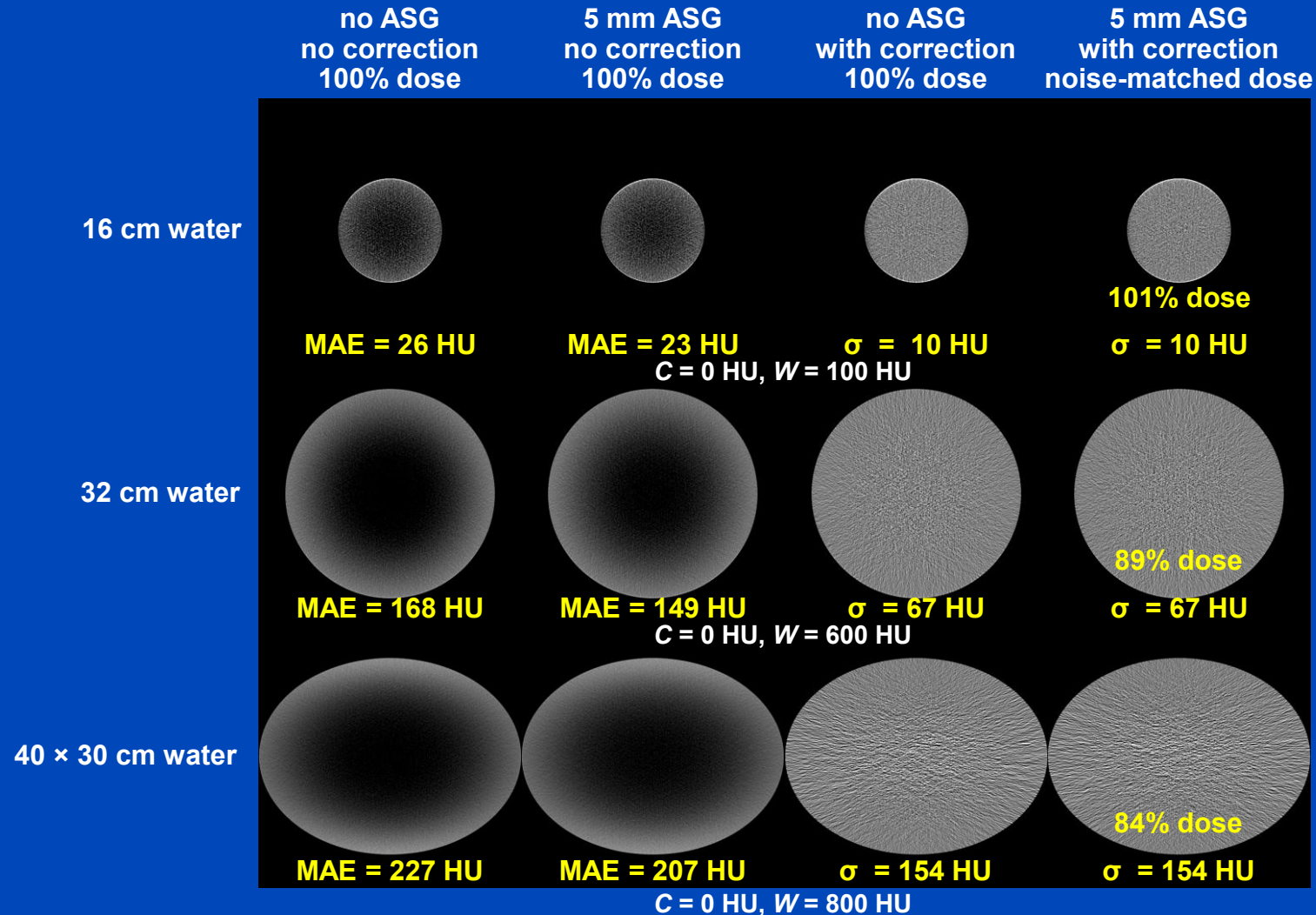
20 mm ASG, Single-Source



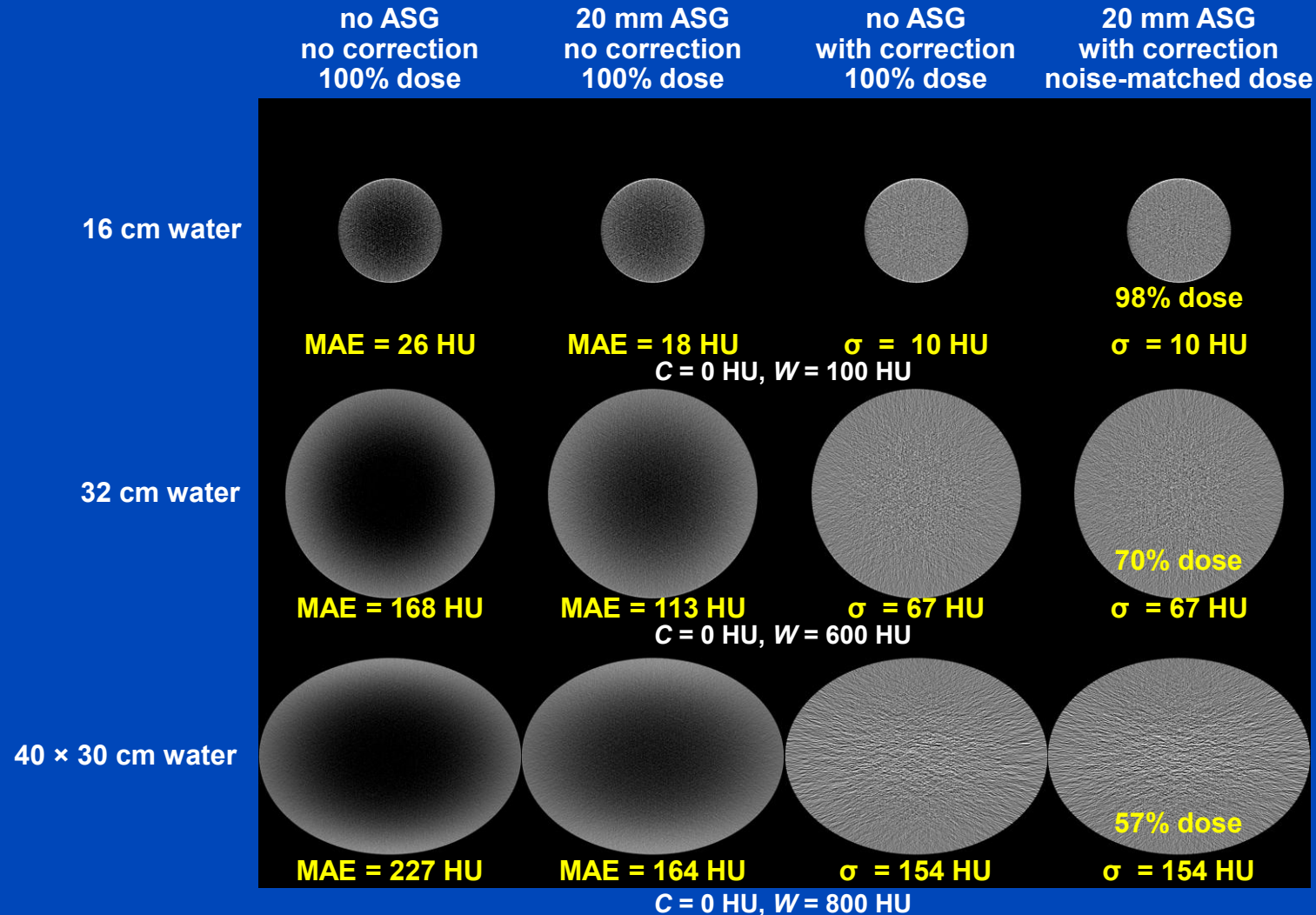
40 mm ASG, Single-Source



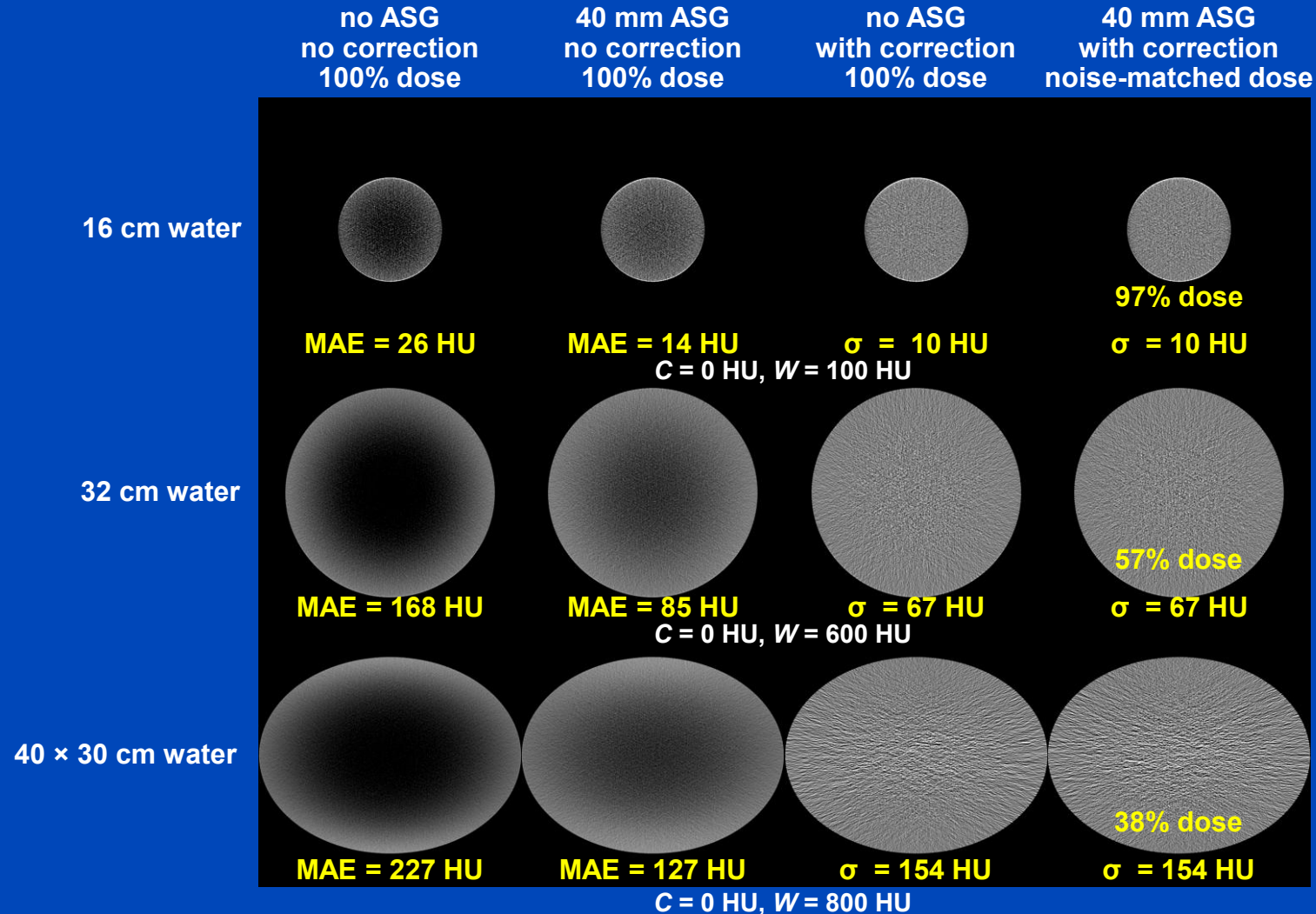
5 mm ASG, Triple-Source



20 mm ASG, Triple-Source



40 mm ASG, Triple-Source



Conclusions

- The ASG reduces the scatter artifacts and the image noise.
- However, remaining scatter artifacts are still severe.
- Software-based correction is mandatory in addition to the ASG.
- The best performance was observed for the 40 mm ASG.
- In terms of dose savings, ASGs are more efficient for larger phantoms and in multi-source mode.

Thank You!

- This presentation will soon be available at www.dkfz.de/ct.
- Job opportunities through DKFZ's international PhD or Postdoctoral Fellowship programs (marc.kachelriess@dkfz.de).